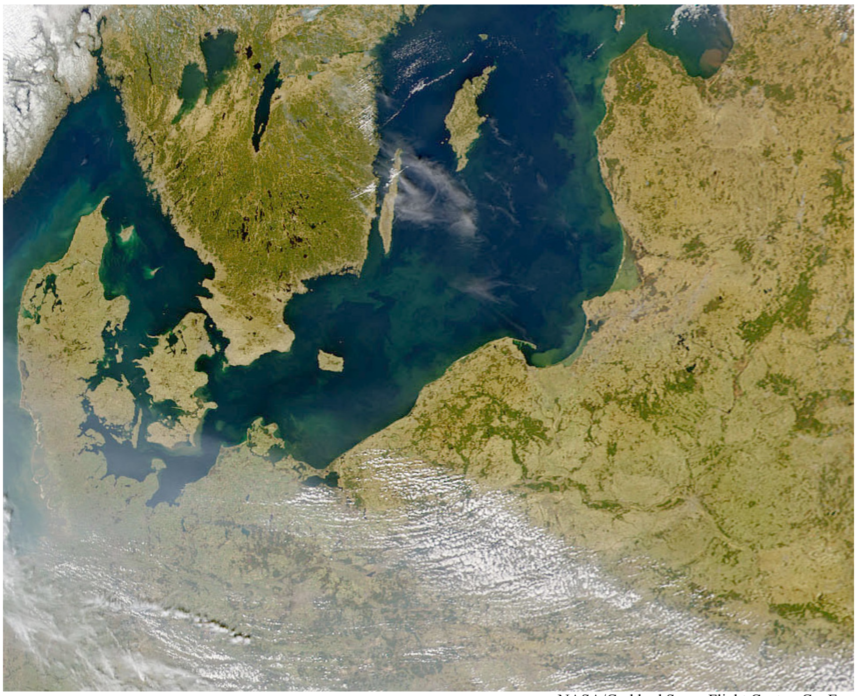
International Conference on

Climate Change
The environmental and socio-economic response
in the southern Baltic region



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and Hans-Jörg Isemer

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Preface

Climate change and its interrelation with human life are in the focus of scientific research and political debates. Remarkable progress in understanding the climate system has been achieved e.g. through analysing climate records and using numerical global models for future climate projections based on reliable socio-economic scenarios. Tailored downscaling of these global projections to the regional scale for impact studies and decision making in the context of mitigation and adaptation is urgently required. Due to both its complex geophysical structure and large regional variability the Baltic Sea basin is an ideal example to be studied with high spatial resolution. In addition, the densely populated basin is under stress by further activities, e.g. agriculture and industry. The southern part of the Baltic basin is of special interest: The Polish lowland hosts in numerous lakes unique records of Late Pleistocene to Holocene sediments. Together with sediments of the Baltic Proper these deposits can be used for the derivation of complex climate proxies for a high resolution reconstruction of the regional climate. At the same time, the adjustment of agriculture and water management to the changes in climate challenge stake holders and planning agencies. In addition, sea level rise superimposed on neotectonic land subsidence leads to a continuous retreat of the southern Baltic Sea coast line and requires increasingly activities in coastal protection at the southern Baltic Sea.

The conference is organised in the frame of the BALTEX program and brings together scientists, economists, engineers, politicians and managers.

The conference site has been selected thoughtfully: Regionally, Szczecin represents the Polish lowland – a zone of transition between the influence of air pressure systems of the North Atlantic and Eurasia. Politically, the town stands for the ongoing process of European unification – hospitably to scientist from all over Europe and beyond. Altogether, more than 120 participants from 23 countries (11 of which outside Europe) have registered for the Conference, and 93 papers – both oral and as posters – will be presented and discussed. In this volume the abstracts are ordered by Conference session and alphabetically according to first authors' name, where - on purpose - no distinction is made between poster and oral presentations:

Session A: Marine and terrestrial proxies for reconstructions of paleo-climate
Session B: Modelling of past climate change and future projections
Session C: Climate and anthroposphere interactions
Session D: Prehistoric communities and climate change
Session E: Climate variability and change impacts on Baltic Sea coasts

The numerous participants from overseas prove that the Baltic Sea basin is regarded a natural laboratory of general interest for the study of regional climate change processes.

The organisers wish to thank Mr Frithjof Sterrenburg for language editing of several abstracts and Ms Kheira Dashti-Hashtjin at the BALTEX Secretariat for invaluable logistic support during the Conference's preparation phase.

April 2009

Andrzej Witkowski, Jan Harff and Hans-Jörg Isemer

Editors

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Abstracts

Winter air temperatures in the Baltic Sea region during the past millennium

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In the central part of the Baltic Sea Region (being precise the data hereby cover its´ eastern coastal region) the key season causing the climate warming is winter. Significant positive mean air temperature trend could be followed from November to February. Decrease of snow cover in past decades results even greater positive trend in March, April and May where the leading factor is radiation balance with expressively smaller albedo of land surface.

In the region observed modern time air temperature on the level of monthly means is well correlated despite mesoscale impacts and unhomogeneties in time series. Proxy data, especially formation or disappearing ice cover on bodies of water (Table 1) the Baltic Sea included one can find in historical documents beginnig from the 11th century. The number of winter seasons with some description by proxy we have as follows: 11th – 10, 12th – 12,13th – 23, 14th – 39, 15th – 86, 16th – 90, 17th up to 20th – 100. However, the general rule of historical data is that with going back into history the less data we have and the less accurate they are.

List of ice-break series presented here includes parts of the Baltic Sea and inland rivers and lakes as well, which all have different hydrology. Deciding generally on the values of linear correlation one can sort out well correlated (coefficient over 0.7), satisfactoty correlated (coefficient 0,5 – 0,7) and badly correlated (coefficient less than 0.5) time series of ice-break.

It should be the main criterium in reconstruction of past climate, where gaps in time-series result the need of using method of average differences between different observation points. For excample from Table 1 you can implement all ice-break data of the rivers Daugava, Pärnu, Võsu or Neva or only one of them (e.g. Daugava) because of high correlation (0.7 to 0.85) between time-series. On the other hand, it is risky to fill gaps in these time-series with the data of rivers Aura or Kokemäki which have very good correlation between themselves but a bad one with first named group.

The best proxy of characterizing winter temperature in our region is the maximum ice area on the Baltic Sea. Trying to go further back in time the Tallinn and Riga time-series are available. Comparing these with maximum extent of ice one can find that ice-break on Tallinn road is much better correlated (0.84) than that of the River Daugava (0.54). It means that the factor of winter-severity is more expressed in Tallinn data and intensity of warming up in spring is more expressed in Riga data. The break-off on the opened Bay of Tallinn which is situated near to the average freezing line on the Gulf of Finland does not correlate well with break-off on the closed bays of Viipuri and Pärnu (coefficients 0.4 - 0.5).

Body of water	**Observed place**	**Observed period**[1]	**Observers and/ or publishers and collectors**[2]
Tallinn Bay	Port (road) of Tallinn	1339…1599 1600 - 2009	
Daugava River	Riga (sometimes Bulduri)	1530…1707 1709-1958	P. v. Schiefelbein (18th cent); P. Stalke 1931; V. Betin & J. Preobrazhensky 1962; H. Lamb 1977
Neva River	St. Petersburg	1706-1892	Russian Academy of Sciences
Baltic Sea : maximum ice area	Baltic Sea	1720-2009	R. Jurva 1940; M. Leppäranta & A.Seinä 1985
Aura River	Turku	1740…1839	H. Wild 1887
Võsu River	Palmse	1766…1809	G. Pahlen
Emajõgi River	Tartu	1800…1960	Tartu University
Kokemäki River	Kokemäki	1801-1849	J. Eklöf
Lestene Lake	Lestene	1805 - 1824	K.Watson
Narva River	Narva	1812…1888	
Pärnu Bay	Pärnu	1817…1980	
Pärnu River	Pärnu	1818…2009	
Viljandi Lake	Viljandi	1824…1847	G. Dumpf
Viipuri Bay	Viipuri	1833…1939	Holms` family
Paldiski Bay	Paldiski	1837 - 1987	C. Kalk
Kuremaa Lake	Close to Jõgeva	1861-1904	Oettingens´ family

Table 1. Icebreak time-series on the eastern coast of the Baltic Sea

Reconstructing the climate of the past for the whole region, it seems to be important to keep in mind:

1) Method of average differences never gives your exact results for every individual year or season but does give a characteristic of certain time period (e.g 30 years), which are comparable with each other.

2) Proxy indeces should be differenciated even in the case of melting ice (0 centigrades in laboratory) correspondig to the main factor having impact to the index value.

[1] 1399...1599 period with gaps; 1720-2007 period without gaps

[2] if not named, collected by author or by modern official observations

The BACC Strategy
(BALTEX Assessment of Climate Change for the Baltic Sea basin)

Hans von Storch[1], Hans Jörg Isemer[2], Marcus Reckermann[2] and the BACC Author Team

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The purpose of BACC (BALTEX Assessment of Climate Change for the Baltic Sea basin) is to provide the scientific community and the public with an assessment of ongoing and future climate change in the Baltic Sea region. This was done by reviewing published scientific knowledge about climate change in the Baltic Sea region. The book with the report and a comprehensive summary came out in January 2008:

The BACC Author Team, 2008: Assessment of Climate Change in the Baltic Sea Basin., Springer Verlag Berlin - Heidelberg; ISBN 978-3-540-72785, 473 pp

BACC offers an up-to-date overview over the most recent scientific findings in regional climate research in the Baltic Sea basin, including climate changes in the recent past, climate projections until 2100 using the most sophisticated regional climate models available, and an assessment of climate change impacts on terrestrial, freshwater and marine ecosystems. This overview was authored by a consortium of more than 80 scientists from 13 countries and was published as the comprehensive text book mentioned above.

A unique feature of BACC is the combination of evidence on climate change and related impacts on marine, freshwater and terrestrial ecosystems in the Baltic Sea basin (catchment and water body). It is the first systematic scientific effort for assessing climate change in the Baltic Sea region. Another unique feature is that BACC made sure that political and economic interests did not participate in the assessment activities.

The results are presented in four main chapters, two dealing with the geophysical (atmosphere, ocean, sea ice) side and two with the ecological (terrestrial and marine) dimension, and an extensive Annex, providing textbook background information.

In the past century here has been a marked increase of temperature of more than 0.7°C in the region, which is larger than the global mean temperature increase of 0.5°C. Consistent with this increase in mean and extreme temperatures, other variables show changes, such as increase of winter runoff, shorter ice seasons and reduced ice thickness on rivers and lakes in many areas. These trends are statistically significant but they have not been shown to be larger than what may be expected from natural variability. In addition, no robust link to anthropogenic warming, which on the hemispheric scale has been causally related to increased levels of greenhouse gases in the atmosphere in "detection and attribution" studies, has been established. However, the identified trends in temperature and related variables are consistent with regional climate change scenarios prepared with climate models. Therefore, it is plausible that at least part of the recent warming in the Baltic Sea basin is related to the steadily increasing atmospheric concentrations of greenhouse gases. Efforts are needed which systematically examine the inconsistency of recent trends with natural variability, circulation changes as well as the consistency with elevated greenhouse gas concentrations as a potential cause.

The situation is much less clear regarding precipitation: in the past, a spatially non-uniform pattern of upward and downward trend has been observed, which can hardly be related to anthropogenic climate change. For the future, intensified winter precipitation may emerge later in this century over the entire area, while summers may become drier in the southern part – but this expectation is uncertain for the time being. For the water body of the Baltic Sea, a tendency towards lower salinity is expected. Similarly, no clear signals, whether for the past or for the scenarios, are available with regard to wind conditions.

In view of the large uncertainty in our knowledge about the changing climatic conditions, it is not surprising that knowledge about ecological implications of ongoing and future climate change is far from complete and also very uncertain. The observed changes in temperature in the past have been associated with consistent changes in terrestrial ecosystems, such as earlier spring phenological phases, northward species shifts and increased growth and vigour of vegetation. In lakes, higher summer algal biomasses have been found. These trends are expected to continue into the future; induced species shifts may be slower than the warming which causes it. In the marine ecosystem of the Baltic Sea the assessment is particularly difficult because of the presence of strong non-climatic stressors (eutrophication, fishing, release of pollutants) related to human activities. Changing temperatures have been related to various effects, in particular to the composition of species. A lowering of salinity is thought to have a major influence on the distribution, growth and reproduction of the Baltic Sea fauna. Freshwater species are expected to enlarge their significance, and invaders from warmer seas (such as the zebra mussel Dreissena polymorpha or the North American jelly comb Mnemiopsis leidyi) are expected to enlarge their distribution area. The expected changes in precipitation (and thus river runoff) may have additional detrimental effects on the problem of eutrophication.

A second BACC report is presently in preparation, using the same philosophy of the first report. A new scientific Steering committee has been formed, and new lead authors are presently selected. The results are expected for 2012. For further information, refer to http://www.baltex-research.eu/organisation/bwg_bacc2.html.

Nuclear astrophysics versus global warming

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Nuclear astrophysics deals with nuclear processes taking place in the stellar interior and explains the occurrence of chemical elements in the universe as well as the energy production in stars. Can this fundamental science help us with global warming? There are at least two important reasons for which the answer should be positive. First of all, clean nuclear power plants applying nuclear fission and fusion reactions could reduce emission of green house gases. Moreover, nuclear processes known from dense astrophysical plasmas can revolutionize our future energy supply. Secondly, investigations of the solar wind confirm its large influence on recent climate change. Astrophysically, the study of cosmic rays primarily provides information about the evolution of the universe as a whole, fundamental interactions between elementary particles and contributes to our knowledge about the origin of so-called dark matter and dark energy, responsible for an accelerated expansion of the universe. Nevertheless, terrestrial astrophysical laboratories and satellite observatories also support investigations of the cosmic weather, correlated not only with the Earth's climate but also with short-term temperature changes. Both subjects above will be illustrated with some unexpected results of own research.

Dating of paleo-shoreline terraces of Lake Lisan high stands

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Lake Lisan was one of a series of lakes that occupied the Dead Sea depression during the last glacial period (70-14 ka BP) (e.g., Waldmann et al. 2007). It extended for 300 km from Lake Teberias in the north to more than 60 km south of the present Dead Sea. A series of shoreline terraces and finely laminated deposits were left behind by its regression The terraces on the Jordanian side of the valley were recorded for the first time using DGPS survey techniques. The levels of the terraces range between -370 m and -138 m, implying a total lake level drop of 232 m. Several terrace profiles were compared and their altitudes were correlated showing no evidences of tectonic subsidence and demonstrating that the lake level drop was due to climatic changes.

In-situ stromatolites were found on most of the terraces, reflecting a shallow water environment. U/Th dating of the terrace stromatolites allowed dating two events within the lake level history more precisely. The high level of -148 m occurred at 30.5 ± 0.22 ka BP, consistent with the Heinrich Event 3 and Dansgaard Oeschger Stadial 5, the coldest period in the NGRIP Greenland Ice Core record. The next lower terrace at -154 m was formed at 22.9 ± 0.29 ka BP and corresponds to the Stadial 2C, the final phase of the Last High Glacial. The good correlation between the Lisan high stands and climatic Stadials suggests that N-Hemispheric cold periods led to periods with a more positive water balance in the Near East. Moreover, our dates of the high Lisan levels correspond well with those reported from the western coast (i.e., Matmon et al. 2003, Bartov et al. 2002 and Hazan et al., 2005) and again suggest that there is no significant displacement along the Dead Sea Transform Fault.

OSL dating of Lisan sand in Wadi Dahel, south east of the Dead Sea, suggests that Lake Lisan experienced a sharp drop to -200 m at ~ 10 ka BP. The existence of deep water deposits overlying the sand layer up to -195 m suggests that the lake recovered to a high level of more than -195 m after 10 ± 0.8 ka BP.

U/Th dating courtesy of A. Mangini, Heidelberg.

Global warming in the perspective of 20,000 years

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1. Background

Since the Last Glacial Maximum (LGM), ca. 20.000 years ago, Earth has undergone profound changes: the large continental ice sheets in the Northern Hemisphere have vanished (with the exception of the Greenland ice sheet), the Antarctic ice sheet has diminished considerably, local mountain ice caps have disappeared (and partly reappeared) and sea level has risen 120-130 m. As a consequence of these changes Earth looks very different today compared with the LGM situation and with continuous changes throughout these 20.000 years. By combining proxies from marine, terrestrial and ice core records from different parts of the globe it is possible to examine the general climate development since then.

2. The Last Termination

One intriguing feature of the end of the last ice age, the Last Termination, is the step wise and oscillating warming scenario of most of the Northern Hemisphere, compared to the gradual and more or less continuous warming in most of the Southern Hemisphere, including large parts of the equatorial regions. While the complex climate trend of the north is well-mirrored by the development of e.g. the atmospheric CH_4 content, the atmospheric CO_2 content and southern temperature curve "go hand-in-hand". The onset of the first large deglacial warming in mid-high southern latitudes took place several millennia before it abruptly started in the corresponding latitudes of the north at ca. 14.600 cal yrs BP, and in general, the glacial climatic anti-phase relationship (with some phase lags) between the two hemispheres, the so-called bipolar seesaw mechanism, continued at least until ca. 12.000 cal yrs BP.

3. Early Holocene

At the distinct onset of the Holocene Series/Epoch, as defined by *Walker et al.* (2008), and warming in the north, large parts of the south had already been warming for at least 1000 years. During the subsequent deglaciations of the northern and Antarctic continental ice sheets huge amounts of freshwater was discharged into the ocean during a fairly short time; sea level rose 60 m in less than 6000 years (*Siddall et al.* 2003). These often periodic fresh water pulses had a "disturbing" effect on both the atmospheric and marine circulation pattern, which caused an almost chaotic behavior of the climate of the higher latitudes in the early Holocene. When marine, ice core and terrestrial records are compared from these regions it is not difficult to find consistent climate oscillations within each region, consistent trends within each hemisphere - possibly insolation forced – and even roughly synchronous interhemispheric oscillations (Fig. 1), but it is virtually impossible to find evidence for globally synchronous climate events with the same climate signature. However, in terms of a possible forcing mechanism many of the "events" have been assigned to still partly unknown climate related processes: decreased solar activity-irradiance/increased cosmogenic radiation (e.g. *Björck et al.*, 2001; *Bond et al*., 2001). Partly in contrast to this oscillating pattern, the high summer insolation to lower latitudes strengthened the monsoon effect in these regions, with a fairly stable climate and humid summers as a consequence during the first few millennia of the Holocene.

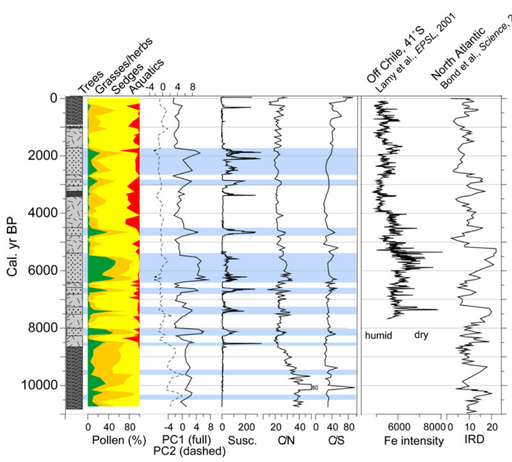

Figure 1. The pollen and geochemistry record from 2nd Pond on Nightingale Island, South Atlantic (after *Ljung & Björck*, 2007), correlated to the Fe intensity and IRD records of *Lamy et al.* (2001) and *Bond et al.* (2001), respectively.

4. Mid Holocene

Around 6000 cal yrs BP only two inland ice sheets remained, the Greenland and Antarctic ice caps, and many of the alpine glaciers had also melted as a consequence of the high summer insolation of the early Holocene. As a direct consequence, the sea level rise had more or less reached today's level and the world did not look very different from today's world. However, in spite of the absence of the large continental ice sheets climate variability continued. The frequency of this variability varies between regions, latitudes and time periods, and the spectral peaks are found in a spectral band between 100 and 2200 years, and no global consistency regarding the character of climate events can be found (*Wanner et al.*, 2008). Some events may be synchronous, e.g. IRD pulses in the North Atlantic (*Bond et al.*, 2001) and precipitation events in the South Atlantic (*Ljung & Björck*, 2007), see Figure 1, but their nature in terms of temperature, precipitation etc, never seems globally consistent. However, some general long-term trends can be seen in the records, which can be related to the gradual changes in the insolation related parameters.

5. Late Holocene

The last few thousand years have been studied in great detail by several research groups and in many projects, e.g. the EU Millennium project, and global consistency is difficult to find evidence for. The often cited climate pattern of the last 2000-3000 years with the Roman Warm Period, the Dark Cold ages, the Medieval Warm Period and the Little Ice Age seems to be restricted to the Northern Hemisphere, or only parts of it, and does not show up as a global pattern of warmings and coolings. In fact, these changes as well as the often more or less synchronous changes in the Southern Hemisphere, seem to be the result of a temporally variable atmospheric and marine circulation pattern and in part also changing solar variability.

6. Conclusions

In view of these long-term changes, the ongoing Global Warming seems to be an anomaly. Owing to often incomplete chronologies of the paleorecords, in relation to the last 150 years of instrumental records, such a statement may be difficult to find good enough evidence for. However, as long as there is no clear evidence for distinct, globally synchronous climate events (since LGM) with consistent climate signals, we have to consider the ongoing Global Warming as an anomalous climate event, possibly with a global forcing mechanism – CO_2 – altering the energy budget of the Earth. The consequences of such a standpoint can of course be discussed and will be further developed at the meeting.

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Sedimentation of a marine deposit in the „Szczecin Bay" during the Littorina transgression

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1. Introduction

During the Littorina transgression, ca. 6500 BP (Borówka et al. 2002, 2005), the present-day area of the Szczecin Lagoon and Świna Gate has been occupied by a marine bay (the "Szczecin Bay"). The aim of the geological investigations which has been executed in the last few years, was to specify the period of the marine bay presence and to define the character of the marine deposit.

The results presented in this paper are based on a detailed analysis of 12 cores collected with vibroprobe (10 cm in diameter). The research procedures included:

- radiocarbon dating (AMS ^{14}C) of *Cardium (Cerastoderma) glaucum* shells preserved in a life position in the marine deposit
- pollen analysis including non-pollen palynomorphs
- analysis of organic matter content (LOI) in the sediments
- analysis of granulometric composition of the marine deposit with the use of sieve method for sand component (test sieve produce by Retsch) and dispersion method for silty component (Malvern Mastersizer Micro Particle Sizer)

2. Results

The radiocarbon age of 61 shells of *C. glaucum* preserved in life position in the marine deposit have been determined. The CalPal-online program (http://www.calpal-online.de/) developed by the Radiocarbon Laboratory from the University of Cologne was used for calibration of the dates. The result of shells age determination was compared with the results of pollen analysis; both data are in good agreement.
The radiocarbon age of *C. glaucum* shells is from 6460 ± 40 to 3040 ± 35 years BP (7378 ± 41 to 3269 ± 53 cal years BP). It means that accumulation of the marine series in the "Szczecin Bay" continued for around 4100 years. The sedimentation rate of the marine deposit was between 0.1 to 4.2 mm/year and it varied in different parts of the basin. The highest values have been recorded for the northern part of the bay, in the area where a back delta deposits accumulated.
The marine series in the Szczecin Lagoon is built of different sediments. Fine-grained and very fine-grained sands as well as silty sand are the most important.
The distribution of the age of *C. glaucum* shells against the topography ordinates shows that the shells connected with the earlier phase of the Littorina transgression (6500-4000 years BP) originate from a layer located 4 m below the present-day sea level. At the same time, along the shoreline of the bay, on similar ordinate, swampy deposits have been accumulated. It suggests that in this phase of the Littorina transgression the ordinate of the sea level was not higher than -4 m a. s. l.

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Geomorphic evolution of small river-lake-systems in Northeast Germany during the Late Quaternary

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1. Introduction

The state of knowledge on the Late Quaternary evolution of drainage patterns in Central Europe varies substantially from region to region. A broad range of studies is available from the German uplands and Alpine forelands as well as from the Elsterian and Saalian glacial belts of northern Germany, the Netherlands and Poland, which have led to the formulation of generalised models that conceptualise the postglacial fluvial dynamics (e.g. *Hagedorn* 1995, *Starkel* 1997). By contrast, only very little geomorphological, palaeohydrological, and geochronological work has been completed on the fluvial system evolution in the Weichselian glacial belt of NE Germany (e.g. *Helbig and de Klerk* 2002, *Kaiser* 2004).

We present a summary of geomorphological, sedimentological, and geochronological investigations conducted in four valleys located in the Weichselian glacial belt of NE Germany. The study is based on geomorphological mapping and an extensive coring campaign. The work was carried out in the context of several research projects on the Late Quaternary landscape development of the German lowlands (*Terberger et al.* 2004). We attempt 1) to identify geomorphic structures and to elucidate landform genesis associated with the Late Quaternary evolution of small river valleys in NE Germany, and 2) to clarify the infilling history of basins present on valley floors. The results have implications for the testing and improvement of previous models on the Late Quaternary evolution of drainage patterns in the Weichselian glacial belt of northern Central Europe (e.g. *Marcinek and Brose* 1972, *Nitz* 1984, *Florek* 1996, *Niewiarowski* 2003, *Błaszkiewicz* 2005).

2. Methods

Selected segments of four river valleys were investigated using geomorphological mapping and lithostratigraphic logging of a total of 860 sediment cores and soil pits (depth: 1.5-15 m). Equipment used for coring comprised augers, percussion corers, Polish folding corers, and modified Livingstone corers, which yielded core diameters of 3-8 cm. More than 700 samples from 65 sediment cores and soil pits were analysed for grain-size distribution, loss-on-ignition and carbonate content. We obtained a total of 36 radiocarbon dates that provide age control for 21 profiles. Twelve sediment cores were analysed for their pollen content to obtain additional stratigraphical and palaeoenvironmental information.

3. Settings

The four studied valley stretches are located in different glacial landscape types (Rhin River: dominantly outwash plain; Mildenitz River: transition from terminal moraine to outwash plain; Nebel River: terminal moraine complex, Barthe River: predominantly flat to gently undulating ground moraine). In comparison to dominating glacial, fluvial-lacustrine and eustatic processes, the influence of (neo-) tectonic processes in the region plays an insignificant role in the geomorphic evolution of the regional drainage pattern. Of particular importance for the analysis presented in this study is the existence of several large (palaeo-) lake basins within the course of the valleys. The two largest basins cover an area of 10 to 16 km^2 (Endinger Bruch palaeolake, present Lake Krakower See) and contain sediments that are in excess of 20 m thickness.

4. Results and conclusions

Valleys in the Weichselian glacial belt of NE Germany are morphologically diverse systems. They are characterised by frequent and marked changes in direction, a succession of aggradational and degradational valley reaches, and the presence of numerous stagnant-ice depressions in the valley course occupied by lakes or peat bogs. The depressions vary widely in size (<1 to >10 km^2) and typically contain sedimentary sequences ranging in thickness between a few to more than 20 m. As these depressions frequently hold a long-term sedimentary record as well as dateable organic matter, they provided excellent archives from which the postglacial fluvial-lacustrine dynamics can be reconstructed.

Despite a significant south-north delay in regional deglaciation and consequently the initial establishment of Late Pleniglacial fluvial systems, the Late Quaternary valley genesis followed a broadly consistent pattern, which can be summarised as follows (*Kaiser et al.* 2007):

(1) Late Pleniglacial formation of subglacial meltwater channels, ice proximal glaciofluvial aggradation, and inclusion of stagnant ice;
(2) Late Pleniglacial ice retreat and (glacio-) fluvial incision;
(3) phased Lateglacial to Early Holocene melting of stagnant-ice, lake formation and unblocking of subglacial channel segments;
(4) flow reversals during Lateglacial-Early Holocene transition;
(5) Mid- to Late Holocene terrestrialisation of lakes by deposition of gyttja and peat;
(6) Late Holocene intensification of morphodynamics by human impact.

Study results indicate that the valleys re-use segments of former subglacial meltwater channels. During the Late Pleniglacial these channels carried meltwater streams. Stagnant-ice melting occurred in stages from the Oldest Dryas to the Early Holocene and was often followed by the formation of lakes in the valley course. Flow reversals occurred during the Lateglacial-Holocene transition and were in response to general base level lowering caused by stagnant-ice melting, headwater erosion and lake overspills. Lacustrine deposition typically started during the Early Lateglacial comprising mainly silicate gyttjas, whereas organic gyttjas and peats accumulated during the Allerød. The Younger Dryas is associated with a marked increase in fluvial and aeolian sedimentation, and lake-level high stands. This was followed by Early Holocene lake-level low stands and a subsequent stabilisation phase with decreasing silicate input and increasing organic lacustrine deposition. The evolution of fluvial systems during the Lateglacial-Early Holocene period was often associated with dramatic changes in sedimentation suggesting that small scale catastrophic events played a more important role in triggering geomorphic changes then previously recognised. Such events typically include lake overspills following intense lake-level fluctuations and relief instabilities in association with stagnant-ice melting. Infilling continued until peat accumulation and terrestrialisation of lake basins became widespread during the Mid- to Late Holocene. Beginning in the Late Holocene anthropogenic influences become important mainly involving an increase in sediment supply due to forest clearing and land use, followed by mill stowage, river course correction and anthropogenic lake-level manipulations.

The study also shows that the timing of these processes varies somewhat throughout the region. However, the general patterns inferred are consistent with earlier findings and hypotheses on the Late Quaternary evolution of drainage patterns in northern Central Europe.

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BONUS programme: INFLOW project – Providing information on forcing mechanisms of environmental changes of the Baltic Sea during the past 6000 years and future scenarios

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1. Introduction

Environmental conditions of the Baltic Sea's ecosystem depend strongly on meteorological forcing over the area and the adjacent North Atlantic region. It affects e.g. hydrological processes in the Baltic Sea catchment area, and the interaction between saline North Sea water inflow and freshwater discharge from river inflows. These changes are recorded in the Baltic Sea sediments. The INFLOW –project aims to identify forcing mechanisms of environmental changes of the Baltic Sea over the past 6000 years by studying these archives.

2. INFLOW Partners

INFLOW (2009-2011) is one of the BONUS research programme (http://www.bonusportal.org/) projects and it is funded by national funding agencies (e.g. Academy of Finland and Ministry of Science and Higher Education, Poland) and the EU Commission. Geologian tutkimuskeskus (GTK) coordinates the INFLOW project that has 9 partners in 7 countries of the Baltic Sea Region: Finland, Russia, Poland, Germany, Denmark, Sweden and Norway.

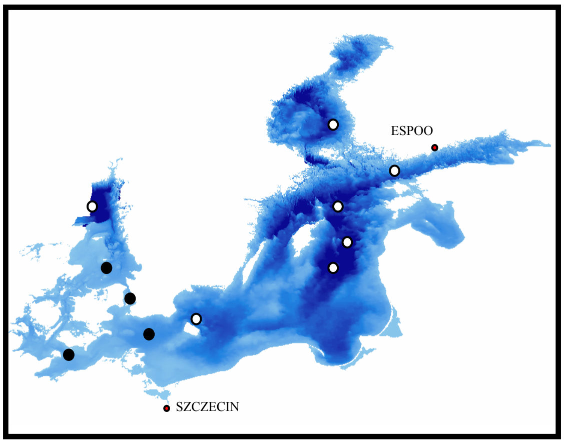

Figure 1. INFLOW key-sites. Black dots indicate sites that have been already recovered (existing sediment cores).

3. Methods

The INFLOW (Holocene saline water inflow changes into the Baltic Sea, ecosystem responses and future scenarios) –project studies ongoing and past changes in both surface and deep water conditions and their timing by means of multi-proxy studies combined with state-of-the-art modelling approaches. INFLOW uses sediment proxy data from key sites on a transect from the marine Skagerrak to the freshwater dominated northern Baltic Sea (Figure 1). The definition and selection of these key-sites is based on extensive new sets of multibeam, seismoacoustic and ecosystem modelling data and on the consortiums long-term experience in working with Baltic Sea sediments. The validated ecosystem models can provide simulated data for extreme natural climatic conditions over the past thousands of years (e.g. Medieval Warm Period, Little Ice Age). Proxy reconstructions will be compared to results from model simulations. These evaluated models will be used to provide predictions of the Baltic Sea ecosystem state at the end of the 21st century for selected IPCC climate change scenarios.

4. Expected results

Expected outcomes include information on the natural elasticity of the Baltic Seas' ecosystem and their forcing mechanisms, and on the degree of anthropogenic impact on the recent environmental changes observed. INFLOW will provide data on the link between climatic changes in the North Atlantic, saline water inflow changes into the Baltic Sea and redox stages in the Baltic Sea basins. Expected results include also scenarios of the future development of the Baltic Sea.

A deeper scientific knowledge and understanding of the factors affecting the long-term changes in the Baltic Sea and of possible future changes will provide basis for improved management and implementation of policy strategies (e.g. the proposed European Marine Strategy Directive) in the Baltic Sea environmental issues.

Lake Hańcza (northeast Poland) – A new multi-proxy record of Lateglacial and early Holocene climate and environmental change in the eastern Baltic

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1. Introduction

High-resolution oxygen isotope measurements on both endogenic and biogenic carbonates from lake sediments have been successfully used as a climate proxy for the Lateglacial and Holocene in Central Europe (e.g. *von Grafenstein et al.*, 1999; *Schwander et al.*, 2000). These studies demonstrated the strong similarity of the climatic development in Greenland and Europe during the Lateglacial and Holocene. Particularly the combination of stable isotope data with other climate-relevant proxies, e.g. vegetation and geochemical data, can provide additional information on past climate dynamics. Unfortunately, regional coverage of palaeoclimate records in Europe is rather heterogeneous with only few multi-proxy records in Central Eastern Europe (e.g. *Ralska-Jasiewiczowa et al.*, 1998; *Goslar et al.*, 1999). Indeed, the east-west gradient in continentality in Europe implies that past climate variability in this region might be driven by other mechanisms than in Central Europe as inferred from results from sites located farther east (*Subetto et al.*, 2002; *Wohlfarth et al.*, 2002; *Stančikaitė et al.*, 2008) which questioned the rapid early Holocene warming in Northeastern Europe. Therefore climate reconstructions from the Eastern Baltic could aid the understanding of the spatial-temporal pattern of past climate change in the circum-North Atlantic region.

2. Lake Hańcza and the DecLakes project

To cover the demand for new well-dated palaeoclimate records, the international project DecLakes (*Decadal Holocene and Lateglacial variability of the oxygen isotopic composition in precipitation over Europe reconstructed from deep-lake sediments*) has been initiated within the frame of the European Science Foundation (ESF) EuroCLIMATE programme. Within this project, the sediment record of Lake Hańcza (229 m a.s.l., 54°16'N, 22°49'E, Suwałki Lake District, Northeastern Poland) has been investigated in high resolution to identify major climatic and environmental fluctuations during the Lateglacial and early Holocene in this region. For this purpose, a multi-proxy approach focussed on stable isotope measurements but combined with sediment microfacies analysis, pollen analysis, µ-XRF element scanning and geochemical analyses as well as ostracod and diatom analyses has been applied.

3. The Lake Hańcza sediment record

Sedimentation in Lake Hańcza starts with a predominantly clastic-detrital facies indicating intensive catchment erosion during the Lateglacial. The initial chaotic layering of silty-clayey deposits with frequently intercalated sand and gravel layers is interpreted as the primary basin infill, deposited in the still ice-filled basin and subsequently re-deposited after final melting of dead ice. The shift in the depositional environment from gravel-dominated high-energy deposits towards mainly silty-clayey sediments around 12,700 cal. yr BP marks the onset of predominantly pelagic lacustrine sedimentation. The sedimentological change is coincident with a shift in the vegetational succession from open *Pinus-Betula* forests towards light-demanding shrub vegetation of the Younger Dryas period. The still scanty vegetation might have promoted continuous active catchment erosion as reflected by constantly high input of fine-grained siliciclastic minerogenic detritus. A significant environmental shift with increased biogenic productivity and rising temperatures occurs at the Lateglacial / Holocene transition at about 11,600 cal. yr BP. This is characterised by decreasing input of allochthonous siliciclastics, the onset of endogenic calcite precipitation, the decline of Lateglacial shrub vegetation (e.g. *Juniperus*) and a steeply increasing abundance of ostracods. Gradually decreasing siliciclastic fluxes until ca. 11,300 cal. yr BP might be related to a rather slow soil stabilisation. In contrast to vegetation and sedimentology, the oxygen isotope record does not reflect the Younger Dryas / Preboreal transition as the record is likely biased during this interval by either a substantial proportion of isotopically enriched melt water in the lake basin or continuing hydrological re-organisation of the catchment. The period of massive endogenic calcite precipitation is followed by a significant sedimentological shift with the increase of organic material at about 9,450 cal. yr BP. This falls into the period between 10,000 and 9,000 cal. yr BP where a major rise by about 1.7‰ in oxygen isotope ratios and also the establishment of temperate forests (e.g. *Corylus* and *Quercus*) can be observed. Interestingly, a similar rise in oxygen isotopes ratios has yet not been observed in Central European records during the early Holocene. A possible trigger mechanism for this isotope shift could be the combination of (1) increasing evaporation resulting from gradual warming / reduced precipitation, (2) a shift towards predominantly isotopic heavier summer rainfall or (3) a change in the moisture source.

4. Regional palaeoclimatic implications

Summarising these triggers implies that a cold and dry climate persisted in Northeastern Poland during the early Holocene, being likely the response to a specific East European circulation pattern. As a consequence of the still relatively large Scandinavian Ice Sheet, a high pressure cell could have established above Northern Europe. The associated anticyclonic circulation (*Yu & Harrison,* 1995; *Harrison et al.,* 1996) could have engendered strong easterly winds. On the one hand, these Easterlies could have brought δ^{18}O-depleted meteoric precipitation from the Arctic to the Lake Hańcza region, causing the comparatively low oxygen isotope values during the early Holocene. On the other, strong Easterlies would have substantially blocked the influence of warm and moist Westerlies in the Eastern Baltic and favoured the persistence of a pronounced continental climate with cold winters and warmer / drier summers than today south of the Scandinavian Ice Sheet. With the substantial retreat and final decay of the ice sheet after ca. 9,000 cal. yr BP, a more zonal circulation pattern established also in Eastern Poland (*Yu & Harrison,* 1995). In this context, warm and moist air brought by the Westerlies from the isotopically enriched Atlantic source advanced further east into the continental interior than before.

Acknowledgements

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Climatic changes reflected in high-resolution pollen diagram from Lake Hańcza, NE Poland

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1. Introduction

Pollen analysis of sediments from the Lake Hańcza was done as a part of the ESF funded project: "Decadal Holocene and Lateglacial variability of the oxygen isotopic composition in precipitation over Europe reconstructed from deep-lake sediments" (acronim DecLakes). The main aim was to reveal detailed climatic changes based on isotope analyses, however, in the course of the project it was decided to use palynological methods for easier and reliable correlation of all the results. We also wanted to obtain detailed description of vegetation succession changes during the late glacial and beginning of the Holocene. It was possible due to the high-resolution samples taking and an exact time scale according to the C 14 dating (Lauterbach et al). This presentation shows some results of pollen analysis and their interpretation at the paleoecological and biogeographical background of this part of Europe.

2. Location of the site and its biogeographical background

Lake Hańcza, 54°16'N, 22°49'E, surface - 3,1 km², 227 m a.s.l. (Choiński 1992), is the deepest lake in Poland and Central European Lowland. It is located in moraine upland of north-eastern part of the country, near the Polish – Lituania border. The region is called East Suwałki Lakeland (Kondracki 1994). There are a lot of geomorphological forms: drumlins, eskers, end moraines, kames and deep channels. Together with anthropogenic elements like: fields, meadows, bushes and single small buildings they create differentiated and attractive landscapes. Hańcza belongs to the Baltic Sea catchment through the river Czarna Hańcza, a tributary of Niemen.

Distinction of the Hańcza region is clearly seen looking at climatic, soils, vegetation and plants ranges maps. Main feature of climatic conditions in NE Poland is growing continentality (to the east) and the lowest winter temperatures of Polish Lowlands, the biggest numbers of days with the temperature below 0°C and relatively short vegetation period, ca 190 days, while a good part of Poland has 200-220 days.

Poland is located within Euro-Siberian Region of Holarctis, Central European Lowland-Upland Province. A good part of the country belongs to the Baltic Divide. However according to geobotanical divisions of Szafer (1959) the EN part of Poland states separate, item land divide: Northern Divide. Hańcza is located at the subpart called Region Suwalsko-Augustowski. Hańcza is located at the SW limit of transitional zone including features of temperate zone of deciduous forest and boreal plant communities. It shows clear distinction to the rest of Poland. Undoubted location in Central Europe is simultaneously marked with clear features of boreal influences and continentality.

3. Research methods

Field work for coring of sediments from Lake Hańcza was done in September 2005 (see Lauterbach et al., in press). Palinological samples of 1 cm^3 were taken every 1, 2 or 3 cm and prepared in a standard way for microscope analysis (Berglund, Ralska-Jasiewiczowa 1986). They were treated with cool HF and HCl to remove mineral matter and carbonates, 3 min. acetolysis. The samples were embedded in pure glycerine and stained with safranine only before the microscope preparation. All counts exceeded 500 of AP and NAP sum except some, mostly late glacial part were pollen frequency was lower. Pollen data were assembled with the Tilia program (Grimm 1992). The pollen diagram constructed with the Tilia-Graph program shows trees and shrubs as AP and herbs (except aquatic and wetland plants) as NAP. Their sum is basic for percentage calculations (AP+NAP=100%).

4. Results of pollen analysis

Pollen diagram reveals vegetation succession since ca 13 000 to 4 000 calendar years BP (Fig. 1). Nine local pollen assemblage zones were differentiated according to the course of curves of main components of vegetation: *Pinus, Betula, Juniperus*, NAP and selected deciduos trees. L PAZes allowed us to describe all the stages of vegetation succession. The bottom layers of sediments were accumulated during the late glacial. Pine was dominant during Allerod, but there were also some birch and relatively high amounts of NAP and Poaceae, *Artemisia* and Chenopodiaceae in it. L PAZ 2 shows the highest content *of Juniperus* pollen grains and these of other heliophytic plants. Next two pollen zones reveals growing curves of trees, mainly *Pinus* and then *Ulmus* and *Quercus* at the beginning of Holocene. *Betula* curve is high at the turn of late glacial/Holocene and then decreases its proportion. Starting with fifth zone *Corylus*-*Pinus* pollen grains of decidous trees show the bigger proportion while *Pinus, Betula* and heliophytic plants are of minor meaning. The uppermost part of the diagram is marked with growing curve of *Carpinus betulus*, the latest immigrant tree during the interglacial in Central Europe.

5. Main conclusions

According to C14 datings analysed sediments from Lake Hańcza were accumulated during the late glacial and in the older part of the Holocene, ca 13 000 to 4 000 cal. years BP. As seen at the time scale, rate of accumulation of sediments was not even in different periods. The highest rate of accumulation was found generally during the climatic optimum, 9600 – 5600 cal. years BP. The lowest one in Subboreal chronozone, since 5600 cal. BP to the uppermost part of the core.

Main stages of vegetation succession were differentiated: sparse pine forest during the Allerod, open plant communities with juniper and heliophytic plants dominating, birch-pine forest at the beginning of Holocene and the development of dense forest communities with succeeding pine, hazel, elm, oak and hornbeam as dominants during the later periods of Holocene. There are two main shifts observed in the sediments, vegetation succession and environment (comp. Lauterbach et al). First one within 300 years-time span, at the turn of the late glacial and Holocene, when clear climatic change – warming was observed. It is the time of disappearing of steppe-like plant communities and decrease of *Juniperus* and the beginning of development of forest in the present interglacial. The second shift found in ð18 curve is related to a longer time of 1000 of years, when deciduous forest developed.

Diagram from Hańcza showed a relatively late immigration of mediocratic elements of vegetation to the NE Poland in the past. It is confirmed by isopollen maps for Poland of such species like *Corylus avellana* or *Quercus*. So, i.e. spreading of elm and oak which is almost concurrent in boreal period in Wielkopolska, W Poland, at the area adjacent to Lake Hańcza was clearly different and *Ulmus* spread much earlier than *Quercus*.

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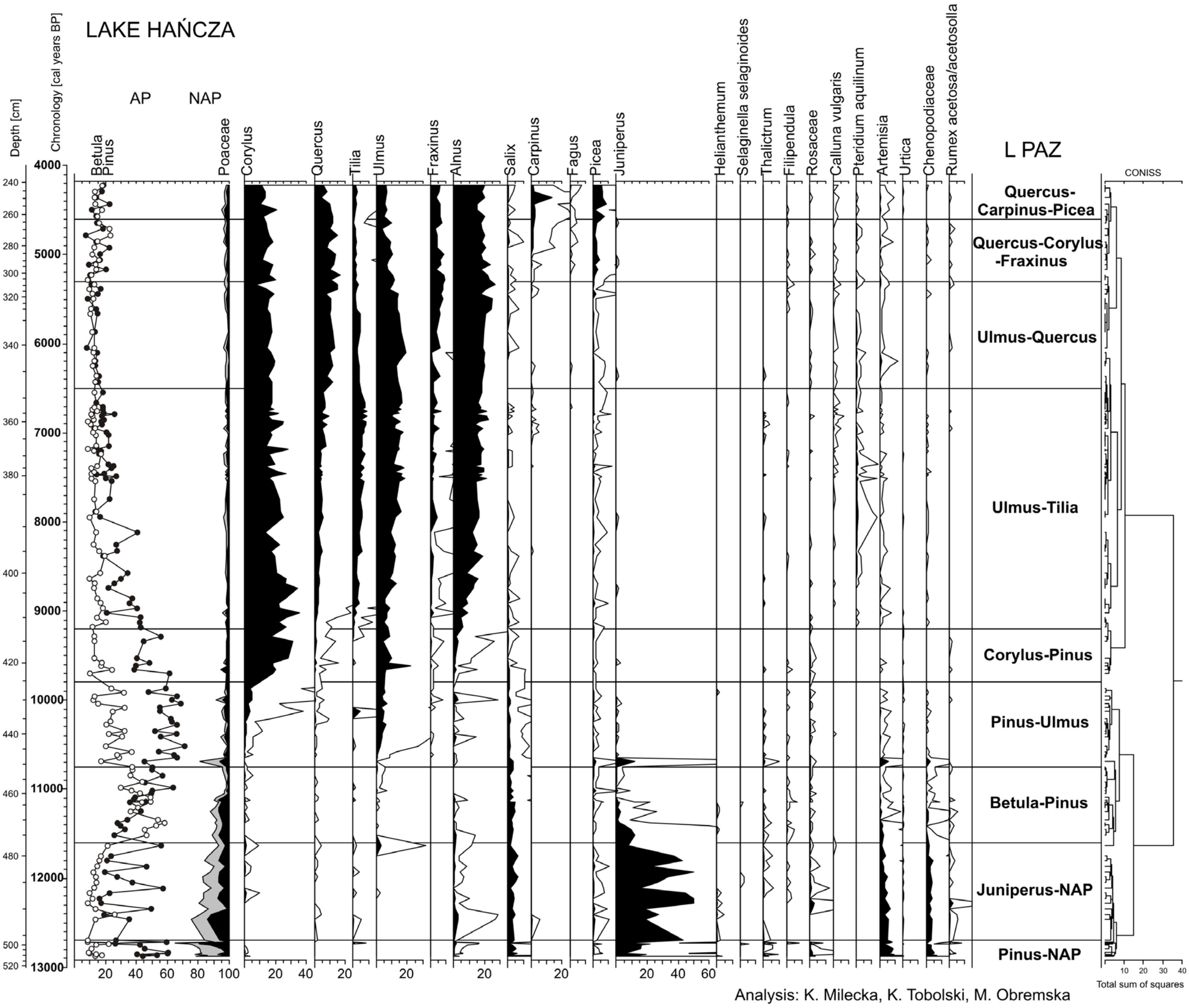

Figure 1. Percentage pollen diagram of Lake Hańcza

Sediments of the Gulf of Gdańsk as indicator of short term climatic oscillation

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1. Assumptions

Taking into consideration present climatic changes and their influence on sea level, climate research is of great importance in human's life. Prediction of climatic changes and knowledge about extreme weather events play fundamental role in e.g. costal management. Hence, recognition of factors, which cause these changes, is so crucial. The key to understanding future oscillation is comprehension of past climate fluctuation.

Analyses of ice cores from Greenland and sediments cores from ocean's bottom has proved occurrence of periodic climatic oscillation as a result of either the North Atlantic's termohaline circulation with cyclicity of 1500 years (Bond et al., 1997, Bianchi and McCave, 1999), or changes in solar radiation with cyclicity of 1000 and 550 years (Stuiver and Braziunas, 1993; Stuiver et al., 1995, Chapman and Shakleton, 2000) on the area of North Atlantic.

It is well known that changes in atmospheric and oceanic circulation, which cause climatic changes of the Atlantic Ocean's area, determine changes in hydrodynamic conditions of the Baltic Sea and also in rivers' inflows. It has a reflection in sedimentation processes declining in the Baltic's basins. There was slight Baltic Sea level rise after the Littorina transgression (Uścinowicz, 2003), therefore the sedimentation environment of the Baltic has been especially susceptible to any climatic fluctuations and related to them hydrodynamic changes. Data collected by Andrén et al. (2000) show that there also are records of Holocene climate's oscillation in sediments from the Baltic deeps.

In addition, Bond et al. (1997), comparing their results to Pleistocene research, state similarity in Holocene climatic oscillation to Dansgaard /Oeschger oscillation characteristic for the last glaciation. Therefore they advance thesis that there is pervasive millennial – scale cyclicity occurring independently of the glacial – interglacial shifts. However the presence of Dansgaard /Oeschger oscillation during Pleistocene on the area of Poland has already been suggested by Jary et al. (2004).

2. Aim

The aim of these studies is reconstruction of palaeoclimate conditions and hydrological changes in period of ca. 5000 years in the southern Baltic Sea. The investigations have in view identification of short period climate oscillation in sediments from the Gulf of Gdańsk. Special attention will be paid on recognition of sedimentation process and influence which inflow from Vistula river has on it.

3. Materials and methods

In order to achieve assumed purpose there are complex laboratory analyses planned: high - resolution granulation analysis, geochemical analyses (content and distribution of C, P, N), radiocarbon dating, pollen analyses.

The subject of intended research are two cores of muddy sediments collected within the framework of project of the Branch of Marine Geology of the Polish Geological Institute in Gdańsk. The 3 m long cores were taken from the bottom of the Gulf of Gdańsk using Kullenberg Core Sampler. One of the cores was situated in front of Vistula mouth, so there is probability that the impact of river inflow will be noticeable. There also were seismoacustic profiles made, but because of gas' presence they were unclear.

Cores were divided into 1 cm wide pieces. The research is going to be lead with this resolution.

4. Results

The initial results of granulation distribution analysis made for one of the cores present great variability in median value. Excluding the top 30 cm (sling of the core), where values of median are almost invariable, there are differences even up to 30 µm on interval equal 2 - 3 cm.

After smoothening the plot using trend line (movable mean) two clear cycles appeared with onsets and ends on c.a. 30 - 150 cm and 150 – 300. There is well – defined border in the middle of the core (c.a. 150 cm) where the smoothed plot of median reached the lowest values. Assuming mean sedimentation rate 1 – 1,5 mm/year (Pempkowiak, 1991, Szczepańska and Uścinowicz, 1994) the lifespan of these cycles comes to c.a. 1200 – 1800 and 1500 – 2250 years.

In addition, shorter variations can be observed in both distinguished cycles. Assuming 1 mm/year as sedimentation rate their period amounts to c.a. 450 ±150 years.

However time frames will be verified after ^{14}C dating.

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Multi-proxy record of climate and Holocene palaeohydrological events in SE Wolin Island (southern Baltic Sea)

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1. Introduction

Several hydrological events involving fluvial activity of the Odra River and marine episode due to the Littorina transgression in the area of the present-day Szczecin Lagoon resulted in bottom sediment disturbances. Therefore it has been assumed that complementary profile taken outside of the Lagoon, but in its immediate surroundings, should complement the data on particular palaeohydrological episodes in the area.

The Wolin II/00 site lies in the immediate vicinity of the Lagoon, in the starting point of the Dziwna River valley connecting the Lagoon with the Baltic Sea to the east. Lithological description of the profile, pollen analysis including non-pollen palynomorphs, analysis of plant and faunal macroscopic remains as well as geochemistry are the basis for the environmental reconstruction.

2. Results

The Wolin II/00 profile consists of mineral-organogenic sediments in the bottom-most part deposited during the Younger Dryas/Holocene transition. Fine detritus gyttja, calcareous gyttja and peat are the main components in different sections of the profile illustrating changing hydrological conditions. In the top-most part of the profile cultural layers of the early medieval settlement have been recognized.

Pollen analysis suggests that in the well developed section of the profile representing the Preboral period the widely discussed temporary climate cooling is reflected. The evident hiatus covers the whole Boreal and the earlier part of the Atlantic period. The water level lowering is confirmed by both pollen and macrofossil data. *Cladium mariscus* swamp is characteristic for this phase. The new water level rise is reflected by an appearance of large numbers of several plant and animal aquatic taxa remains. The beginning of this phase coincides well with the beginning of inundation in the neighbouring Wolin II site (Latałowa 1992, 1999) and the Littorina transgression into the area of the today's Szczecin Lagoon (Borówka et al. 2002, 2005; Witkowski et al. 2004). The subsequent lowering of a water-table on the site has started ca. 3000 BP. The upper part of the profile displays several consecutive phases of low and high water table, supplementing the data on the late Holocene palaeohydrological changes in the Lower Odra River valley.

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Palaeobiogeochemical data in the models of global and regional climate change

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The environment, flora and fauna changes expected in the South Baltic and North Black Sea regions are compared with spores, pollen, diatoms and some bivalve molluses as examples through Holocene-Pleistocene history in order to propose a most probable model-analogue of the future global and regional climate change. This approach is based on the species composition and δ13C- δ18O characteristics of so-called thermally anomalous changes found in different parts of the seas. The shell characteristics, trace-element contents and stable isotope ratios were used for comparison and correlation of palaeoclimatic events. The opportunity of use of palaeobiological and palaeobiogeochemical markers for implementation of simultaneous analysis is discussed in connection with evidence of pre- and postglacial warming stages.

Debatable questions of Holocene geological history of the Eastern Gulf of Finland

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1. Introduction

The Late Pleistocene and Holocene geological history of the Eastern Gulf of Finland still has some gaps in knowledge. The adjacent coastal areas (especially the Karelian Isthmus) are very well known as a “classic sample” of benchlands. The earliest studies of the Quaternary deposits were carried out at the end of XIX century by Kropotkin, De Geer and Berghell. The terraces marked the Baltic Ice Lake, Ancylus Lake and Litorina Sea shorelines had been described already by Yakovlev, Markov and Hyyppä in 1920-1930th. The first map of the postglacial basins was published by *Yakovlev* (1925). In 1960-1970th the significant investigations and dating of on-land postglacial sediments were undertaken by *Kvasov* (1979); *Dzinoridze, Kleimenova* (1965); *Znamenskaya, Cheremisinova* (1974) and others). The systematic geological surveys carried out by the VSEGEI in 1980-2000 have enabled the distribution, composition, structure and thickness of the Quaternary deposits of the Russian part of the Gulf of Finland *Spiridonov et al.* (1988; 2007).

In spite of significant amount of data there are lots of debatable questions and unsolved problems about postglacial and especially, the Holocene, geological history. Unlike the other parts of the Baltic Sea, the shoreline displacement curves for the Eastern Gulf of Finland have never been published. The first such attempt was presented in a recent study of *Miettinen et al.* (2007) based on the Holocene lakes sediments analysis. The sea-level curve for the central Karelian Isthmus is represented time period from 9500 to 5000 (calendar ^{14}C years BP). There is no clear conception of the Holocene shorelines location. The salinity of paleobasins as well as the time, frequency and intense of Holocene saline water inflows are still unknown. There is an urgent need in complex investigation with use of modern dating methods (OSL, ^{14}C etc.) and modeling approaches.

2. Holocene shorelines

The terraces and plains formed by postglacial basins are sharply defined in relief along the northern and southern coast of the Eastern Gulf of Finland. The benchland, which has been formed since the Middle Holocene, is from 150-200 m to 1 – 1.5 km wide along the northern and southern coasts of the Gulf (with the maximal width of 6 km within the ancient bay nears Privetnaya River). In the eastern coast of the Gulf (Lahta depression and Prinevskaya Lowland) it is up to 13 km wide. The maximal level of Litorina transgression is marked by a distinct scarp in the altitude from 18 to 35 m along the northern coast and from 10 to 23 m along the southern coast) *Znamenskaya, Cheremisinova* (1974). The eastern shoreline of the Litorina Sea during its maximal transgression is not observed in relief. Between the highest marine terrace and the modern shoreline there are up to four Litorina terraces. Besides during the VSEGEI investigation undertaken in 2005-2008 (800 km of side-scan sonar and echo-sounding, surface sediment sampling) the submarine terrace (about 18 km long, with the surface on the 4-5 m of water depth and foot on the 8-12 of water depth) was found along the northern coast of the Gulf *Ryabchyk et al.* (2007) (Fig.1).

A lot of ^{14}C dating analyses of the peat samples of Holocene sediments were done during the 1960’s and 1970’s. However due to rather complex recent tectonic movements of the different blocks, the sea level changes and shoreline displacement during Middle and Late Holocene is not yet fully understood.

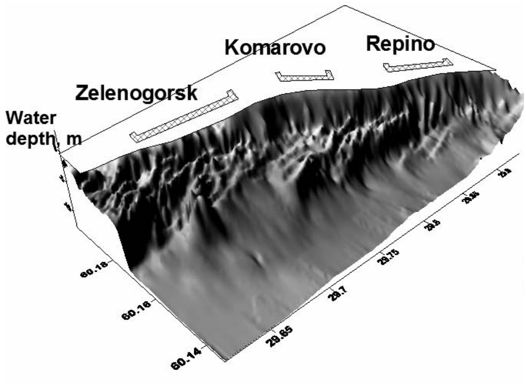

Figure 1. The submarine terrace along the northern coast of the Gulf of Finland.

In order to explain the morphology of the observed submarine terrace and to correlate it with the on-land data, the attempt was made to reconstruct the evolution of coast over period of late Holocene by using a mathematical modeling (*Leont'ev et al.*, in press). The key assumption of the concept suggested is that at earlier stage the tectonic processes played the main role, while at later stage the sea-level changes were of greatest importance. The tectonic block comprising the investigated area of the Gulf of Finland at first rapidly raised and then it stabilized and was influenced by sea level rise. This development excited the formation of series of terraces. The earlier of those are situated now on dry land, while the later terraces are observed on submarine slope. In frameworks of our concept, the coastal evolution during the late Holocene appears to be similar to the process of gradual erosion of the above-water terraces and formation of underwater ones (*Leont'ev et al.*, in press).

The developed model should be confirmed by the geological data.

3. Holocene saline water inflows

In 1960’s investigations of the on-land sequences with brackish water diatoms the Yoldia Sea existence in the areas around Eastern Gulf of Finland was suggested *Dzinoridze, Kleimenova*, (1965); *Znamenskaya, Cheremisinova* (1974). But later diatomic analysis of the cores taken by the VSEGEI from the open part of the Gulf has shown that the brackish-water diatoms are very rare within Late Holocene horizon *Dzinoridze* (1986; 1992). It permits to suggest that the saline water did not reach the eastern part of the Baltic Sea and the Gulf of Finland. There are 'brackish-water' diatoms in Yoldian sediments of the Baltic States and St. Petersburg area, probably due to redeposition processes *Raukas* (1995). On the other hand many scientists have opposite opinion *Heinsalu* (2001). As there are a lot of contradictions in the data available and the lack of knowledge about open part of the Gulf of Finland new research of the Holocene sequence should be undertaken with use of modern analytical methods. The Late Holocene saline water inflows have never been studied in described area. It is planned to do in the range of BONUS INFLOW project which has started this year.

4. Holocene accumulative relief forms development

Middle- and Late Holocene dunes are located mostly along the northern and eastern coasts, and locally (near Bolshaya Izhora village) along the southern coast of the Gulf. They were formed by aeolian processes from the ancient beach ridges and spits on the surface of Litorina and post Litorina terraces. The largest dunes complex is about 7 km long and 0.5 - 0.6 km wide and 10-15 m high and is situated in the northern coast of the Gulf near Sestroretsk town. In this dune massive there are some areas of migrating dunes. The other dune missives of the Eastern Gulf of Finland coasts are much lower – the major part of the dunes is 2-6 m high. Unfortunately the time of the dune forming is determined mostly by indirect methods (geomorphological observations) while the absolute age analysis are still rare.

In the southern coastal zone near Bolshaya Izhora village there is an area of long time sand accretion with complex sandy spit system consisted of "hooked spits" of different form, size and age. The distance between the shoreline, which was formed before the spits development began, and the modern shoreline is about 500 m. There are elongated shallow water lagoons between the spits. Nowadays the marine coast of the spit to the east of Tchernaya River is actively eroded. Under the eroded spit there is an outcrop of organic rich silty-clay. In 2008, the sediments sampling of lagoon mud were taken using a post-hole digger. The ^{14}C-dating of silty-clay mud from the shoreline (an interval 0 – 20 cm under the modern sandy spit) has shown the age 1800 $\pm$ 170 BP (calibrated years). The thickness of relict sand spit, which is located 100 m landward from the modern shoreline, is from 1 to 1.5 m. The ^{14}C-dating of the organic rich sandy-clay layer from the interval 1.3 – 1.5 m depth has shown the age 2060 $\pm$ 150 BP. These data allow to conclude that sand accretion and spit growing have taken place here at least during last two thousand years.

5. Conclusion and debatable questions

1. The Eastern Gulf of Finland is the easternmost part of the Baltic Sea so the phases of the Baltic Sea development have some special features here. The question of Yoldia Sea existence and Late Holocene saline water inflows is still debatable.
2. The structure of the coastal areas demonstrates inherited features in erosion and accretion areas with typical relief forms distributions (escarps, terraces, relict beach ridges, dunes, spits) during Holocene. In many cases the absolute time of their formation is unknown.
3. The complicated modern tectonic movements of different blocks, which have been changing during Holocene, the contradictions in available ^{14}C data and the lack of knowledge about paleosalinity of sediments cores from the open part of the Gulf do not allow developing the complete hypothesis of Holocene transgressions and regressions and saline water inflows. The contribution to these research, using the modern analytical methods and modeling approach, is planned to make during BONUS "INFLOW" project and the project 09-05-00303-a funded by Russian Fund of Basic Research.

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Non-stationarities in the circulation-climate-relationship over the Baltic Sea and its effects on reconstructions of climate indices

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1. Introduction

An important factor influencing the climate of the catchment area of the Baltic Sea is the North Atlantic Oscillation (NAO). The knowledge about this influence over the last centuries is of great importance reconstructing past terrestrial and oceanic climatic conditions. Bottom-up approaches are widely used to reconstruct the NAO from proxies reflecting the local near-surface climate. However, as we demonstrate in this study, localizations of proxies are partly inadequate for the large-scale influence distinct from the North Atlantic Ocean due to non-stationarities in the NAO-temperature relation.

In a first step of our approach we relate the NAO-index to the near-surface climate (i.e. temperature and sea-ice extent) of the Baltic region on monthly and seasonal basis. In a second and third step, we also use multi-proxy reconstructions and climate model simulations to investigate the NAO-climate relationship on longer time scales.

2. Characteristics of the climate of the Baltic sea

The Baltic Sea, including its coastal zone, covers a range of about 0.5 Mio. km² from 66° N to 53° N and 10°E to 30°E. In the winter half year (ONDJFM) the NAO explains more than one third of the monthly to seasonal interannual climate variability *Chen and Hellström* (1999) showed different spatial correlations between NAO and station temperature time series for Sweden. Although the whole Baltic region appears to be homogeneous with respect to changes in the strength of the NAO-influence during 20th century, our analysis yields that this is not the case previous to 1900.

3. Data

Because most recent reconstructions have already been subject of non-stationarities we concentrate our study mainly on long historical measurements and data from GCM simulations. The NAO-record is taken from *Jones et al.* (1997) for the period 1824 –2000. It is based on the normalized (1951–80) SLP of Gibraltar minus Stykkis-holmur/Iceland and updated until 2008 by *Osborn* (2006).

Station temperature data are taken from *Jones and Moberg* (2003) and from the KNMI Operational Data Center (KODAC: http://kodac.knmi.nl/kodac/). Data for the max. sea-ice extent of the Baltic Sea (MIB) stem from *Seinä and Palosuo* (1996) for the period 1720–1995. They are updated by the Finish Institute of Marine Research till 2008 (FIMR: www.fimr.fi).

For studies of the last 500 years we used the gridded data set from multi-proxy reconstructions by *Luterbacher et al.* (2002) for the period 1500–1999. For the MIB data based on model simulations from *Hansson and Omstedt* (2007) for the period 1500–2001 are used. Comparisons with observations show high degree of trustworthiness on decadal and multi-decadal time scales.

For investigations of the last 1000 years we used the output of a control simulation and two externally forced (solar, volcanic and greenhouse gases) simulations from the comprehensive coupled atmosphere-ocean model Echo-G.

4. Methods

In our approach non-stationarities in the climate-circulation-relationship are detected and analyzed by changes of running correlations (Pearson correlation). Prior to analysis all time series were tested for serial autocorrelation and potential trends were removed. Because the running correlation analysis is based on sub-periods with window length of 30 years these sub-periods were de-trended, too.

5. Results (observations)

Running correlations (RC) between NAO and station-based temperatures show a high degree of non-stationarities for the Baltic region. Noteworthy are comparisons of the RC values of the 20th century with those of the 19th century for winter months (DJF). Accordingly, synchronous alterations since 1900 for the whole area and decreasing values in the 19th century for stations far in the north and east are evident. The divergence in the RC supports findings of *Jacobeit et al.* (1998) and *Lamb* (1985).

A hypothesis potentially suited to explain the physical mechanism controlling changes in RC is related to increased continental conditions during the Little Ice Age. This would also explain the spatial divergence of the RC previous to 1900. This results therefore questions the quality of proxy-reconstructions of circulation indices like the NAO from peripheral regions for the Little Ice Age.

Periods of high or low levels in RC for both, the NAO-temperature as well as sea-ice correlations, do not appear to be systematically linked to the mean strength or variability of the NAO. This finding is in general agreement with results from *Slonosky* (1999) and with *Chen & Hellström* (1999). The authors also do not find any link between the degree in stationarity and anomalies of the NAO for Sweden.

6. Results (reconstructions)

The reconstructed SLP/NAO data sets by *Luterbacher et al.* (2002) include a high number of different proxies. In the following we used the historical MIB as representation of the near-surface winter climate of the Baltic Sea for RC with the NAO reconstructions.

Results indicate RC between winter-NAO (DJF) and MIB in the range of $0.3 < r < 0.8$ for the period 1720–1999. The non-stationarities of the reconstructed NAO with the modeled MIB of *Hansson and Omstedt* (2007) for the period 1500–2001 are in very good agreement with the historically observed MIB since 1720. Although the pattern of non-stationarities reflected by the reconstructed time series shows a similar amount of variability as the observations, interpretation is restricted by the question whether these non-stationarities are related to real climatic processes or to shortcomings in the reconstruction method. To analyze changes in the circulation-climate relationship on longer time scales we therefore used long simulations carried out with a coupled GCM.

7. Results (model studies)

Model studies with coupled GCMs for past climates are indispensable for our understanding of possible mechanisms of the climate system. This is because observations are not available and/or proxy-reconstructions are spatiotemporal too limited.

Results of RC for 1000 years show a high degree of non-stationarities between NAO and T-Baltic with correlation coefficients ranging between $0.0 < r < 0.8$ for winter (DJF). The amplitude of the RC and their temporal variability are similar in both, the control simulation and the two forced simulations (see fig. 1). In addition, non-stationarities in the simulations are in the same order like in observational studies of the last 175 years.

The agreement with respect to non-stationarities of the control/externally forced simulations and observations therefore suggest that non-stationarities are an internal climatic phenomenon. The results are in contradiction to findings by *Osborn et al.* (1999), who found lower variability in the RC in the control run compared to externally forced simulations with the GCM HadCM2.

8. Concluding remarks

Decadal running correlations between NAO and near-surface climate indices show a high degree of non-stationarities that are of the same order in observations, empirical reconstructions and in GCM simulations. The lack of link between clusters of high and low levels in RC with the strength or the variability of atmospheric circulation indicates on the one hand that non-stationarities are caused by internal chaotic variability.

On the other hand, in the case of decreasing values of RC during the 19th century in regions far to the north and east, also shifts to more continental conditions [associated to Little Ice Age type events] play an important role. The latter also points to a potential role of external forcing on the degree of stationarity.

Possible mechanisms causing these non-stationarities i.e. like the climatic shifts from the 19th to the 20th century are of great importance for future studies, because these episodes are shown to significantly lowering the level of RC over typical peripheral regions used for reconstructing the NAO.

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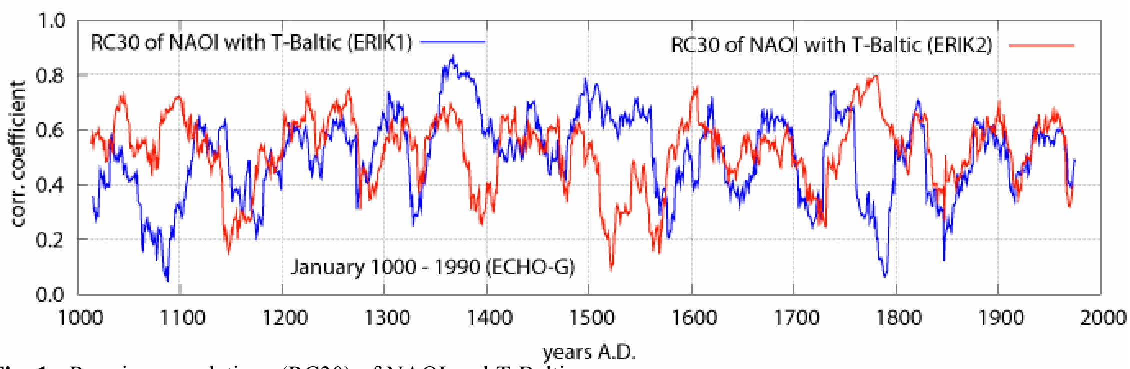

Fig. 1. Running correlations (RC30) of NAOI and T-Baltic calculated from two external forced simulations of the coupled GCM ECHO-G for January 1000-1990 A.D.

Paleo-environmental development of the Gdansk Basin in the Late Pleistocene – Holocene according to the data of investigations of the core-section #303700-7 sampled during the Poseidon cruise

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1. Introduction

Core-section #303700-7 was sampled using a gravity-corer during the cruise of the German research vessel Poseidon in June 2005 within the framework of the Russian-German GISEB Project (GIS for Time/Space Modeling of Sediment Distribution as a Function of Changing Environment in the Baltic Sea). The sediment site is located in the south-eastern part of the Gdansk Deep (54 ^{0}49,34 N; 19 ^{0}11,1 E; sea depth -105.4 m). The length of the core section sampled in? plastic tubes equalled 11.55 m (0.8-12.35 m – depth of sediment section). The upper part of the sediment section (0-0.57 m) was characterized by a core sampled using a multi-corer.

2. Materials and methods

The sediments of the section were examined for the following analyses: pollen, ^{14}C (the gravity-corer section) dating, ^{210}Pb dating (the multi-corer section), X-ray diffraction, grain-size, geochemical, radionuclides activity**.**
Isotopic analyses (14C, 210Pb) for dating were carried out in the Center of Isotopic Research of VSEGEI using an ultra-low level scintillation counter Quantulus 1220. The content of 210Pb was calculated by the β-spectrum of ^{210}Bi. The composition of clay mineral (<0.001 mm) was determined with a DRON-6 X-ray diffractometer. Grain-size analysis were carried out in the laboratory of the Atlantic Branch of the P.P.Shirshov Institute of Oceanology using a FRITSCH laser analyzer “Analizette-22” (<0.001-0.1 mm) and FRITSCH analytical sieve shaker “Analizette-3” (>0.1 mm). Gamma-radiating radionuclides (^{226}Ra, ^{232}Th, ^{40}K, ^{137}Cs, ^{60}Co) were determined with a gamma-ray scintillation spectrometer MKGB-01 and geochemical analysis used a field X-ray scanning crystal-diffractive spectrometer SPEKTROSKAN-005, in the laboratory of the VSEGEI Department of Regional Geo-ecology and Marine Geology.

3. Results

The main layers of sediments can be distinguished visually. The Late Holocene marine olive-grey muds are preliminarily fixed up to marks – 6.15 or 6.44 m (?). The muds are laminated, locally porous and contain numerous remnants of shells. The next layer up to sediment depth – 7.73 or 7.93 m (?)corresponds to the sediments accumulated during the Ancylus Lake and Yoldia Sea periods. These sediments are represented by grey muddy clays incorporating black micro-grains of sulphides. The lower part of the sediment section (7.93-11.35 m) is represented by grey clays containing rare microlenses and thin laminae enriched in silty particles. Possibly these sediments correspond to the Baltic Ice Lake period. At the interval 10.07-10.08 m the sandy laminae were fixed. From the mark 11.35 m – the density of the sediments increases markedly.

Pollen analysis permits distinction of 10 pollen assemblage zones, which correspond to climatic events from the Bolling-Middle Dryas to Subatlantic time and mostly coincide with lithologic contacts.
The sediments sampled by gravity-corer are characterized by a relatively low content (less than 1 wt%) of analyzed organic matter, especially deeper than 500 cm. Therefore the data of C^{14} analysis are characterized by an essential spread of recorded isotopic dates, but as a whole they allow distinction of the main stages of Baltic Sea development. After screeningof doubtful data it is possible to calculate the average rate of sedimentation as equalling 0.84 mm/yr and its fluctuations during the Late Pleistocene – Holocene from 0.37 to 1.62 mm/yr.
According to the calculation based upon Pb^{210} content determination the rate of recent accumulation of water-saturated sediments up to the sediment depth of 35 cm is about 1.7 mm/yr on the average.
Analysis of Br concentration in the sediments of the upper part of the core section showed significant fluctuations that allowed determination of the main tendencies of relative salinity variations of the bottom water during the Holocene. These data fix local fluctuations of water salinity within the Litorina and Post-Litorina seas and its marked decrease in sediments corresponding to the Ancylus Lake. It is also possible to confirm that formation of the Yoldia Sea did not lead to increasing salinity within the Gdansk Basin. The essential intrusion of salt marine water into the Gdansk Basin started about 8200 cal.years BP.
As an index of near-bottom hydrodynamic activity during Litorina and Post-Litorina times the modal value of sediment grain-size distribution has been used. The episodes of increasing near-bottom current activity in the Gdansk Basin coincide with the periods of increasing salinity (fixed by Br fluctuations). It is possible to assume that these episodes corresponded to the influence of intrusions of North Sea waters.

Environmental change during the Holocene in the Baltic Sea based on sediment core analysis of the eastern Gotland Basin

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1. Introduction

Within the Baltic Sea, the Eastern Gotland Basin hosts high resolution sedimentary records from the Late Pleistocene to the Holocene. A "Master Station" identified within the frame of an international study BASYS (Winterhalter 2001) have been selected for coring. Fig. 1 shows the coring site within the central Baltic Sea.

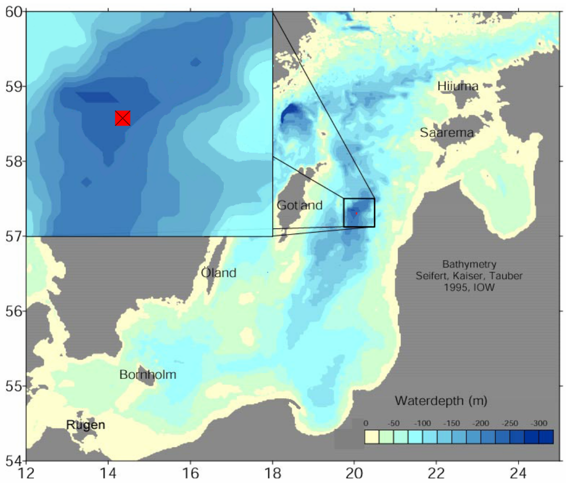

Fig. 1. Master-Coring site within the Eastern Gotland Basin, Baltic Sea.

Based on physical core-logging and geochemical data the fine grained sediments (silt/clay) within the master-core 211660-5 (20° 7.135'E; 57° 17.003'N), have been subdivided into physico-chemical stratigraphic units (zonation) and allocated to the time of formation using an age model developed by Kotilainen (2000), and Andrén et al (2000). The zonation coincides with the main stages in the evolution of the post-glacial Baltic Basin (Harff et al 2001). A-zones stand for pre-Littorina stages, and B-zones represent Littorina and Post-Littorina sediments. In particular the B-zones consists of homogeneous (zones B2 and B4) and clearly laminated sediments (zones B1, B3, B5). The lithological and geochemical facies analysis identified zones B1, B3, B5 to be deposited under anoxic and zones B2 and B4 under oxic condition. In order to reconstruct the change in salinity and the trophic state of the Holocene sediments a core 303610-12 (57°17.01' N, 20°07.10' E) taken at the Master-site in 2005 has been analysed diatomologically.

2. Data and results

The diatom analyses were carried out according to all principles and covered section between 20 – 520 cm of the core 303612-12 which includes 132 samples. The preservation state of the diatom flora was variable. A total of 219 diatom taxa were identified and analyzed. Based on the number of dominant taxa and changes in the distribution of ecological groups diatoms assemblage zones (DAZ) were distinguished which are correlated with several stages related to the development of the Baltic Sea. Additionally, taxa representing the salinity and the trophy have been pooled and plotted as a function of core-depth. The zonation boundaries (and age dates) have been correlated between cores 211660-5 and 303610-12 based on the lithofacies. Fig. 2 shows summarizing the abundance of salinity and trophy indicators superimposed with the zonation and the time of formation.

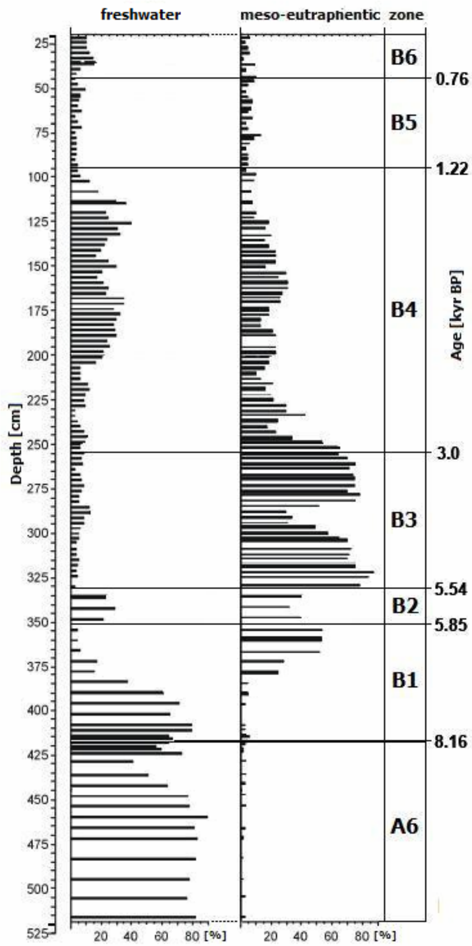

Fig. 2. Results from salinity and trophy indicating diatoms physico-chemical facies zones and age (in cal. kyr BP) for core 303610-12 from the Eastern Gotland Basin, Baltic Sea (core depth in cm).

3. Discussion and summary

Changes in the diatom flora species composition made it possible to reconstruct environmental condition prevailing when the sediment studied was deposited. The most notable environmental changes during the Holocene was the transition from the freshwater A6-zone (Ancylus Lake) to the brackish water Littorina Sea (zone B1). Diatom assemblages in sediments indicate on that time a slow rise in salinity of the surface water and primary production caused by the inflow of marine water enriched in nutrients. During the accumulation of zone B1, salinity and nutrient did rise up. The formation of a halocline prohibited vertical transport of surface water rich in oxygen to the bottom. Oxygen from inflowing saline water has been biologically consumed soon causing in anoxic conditions. These conditions served for the conservation of organic matter resulting in an relative increase in eutrophication. This environment determines the accumulation of laminated sediments of zones B1, B3, and B5. The accumulation of laminated sediments in a more brackish-marine environment relatively enriched in nutrients is interrupted by the deposition of more homogeneous sediments low brackish to freshwater conditions. This switch between fresh and brackish-marine environment of the Baltic Sea during the Holocene is interpreted as an expression of a change in the atmospheric circulation in the North Atlantic / European area. Anoxic depositional environment and laminated sediments within the central Baltic Sea represent prevailing westerly winds (Maritime NAO mode after Alheit and Hagen 1997), driving the inflow of saline water from the North Sea into the Baltic. Homogeneous sediments deposited under freshwater conditions point to an increasing influence of easterly winds (continental NAO mode after Alheit and Hagen 1997) causing reduced saline water inflow. A lack of inflowing saline water weakens the stratification of the water body and allows vertical ventilation of the bottom water.

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Holocene climate variability on a millenial time-scale based on palaeolimnological evidence (Great Poland Lowland)

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In the past several years, the changeability of the Holocene climate has been more frequently revealed, while recent research based on various proxies reveals the presence of climatic cycles on decadal- centennial- and millennial time scales. Multi-scale climatic cycles were discovered, for instance, in the record of the North Atlantic sediments, varved sediments from the Santa Barbara Basin, and are known from isotopic records of glacier cores of Greenland and Antarctica (a.o. *Barber et al. 2004*, *Dansgaard et al. 1993*, *Johnsen et al. 2001*, *Mayewski et al. 2004*).
Important evidence of the cyclic character of climatic changes was also provided by examination of sediments of the Kórnik-Zaniemysl lakes (Great Poland Lowland) based on lithological, geochemical and malacological records (*Wojciechowski 2000*). Spectral analysis of the organic matter content of those sediments, as a quantitative measure of lithological variability, enabled identification of two main climatic cycles: the ~1150 year cycle and the ~2300 year cycle in the radiocarbon time scale (*Wojciechowski, 2007, 2008*).
The distinctive cycles are so important that they allow their association with the course of the most important paleogeographic events, both in the Late Glacial and Holocene, and in the Upper Plenivistulian, and they also permit forecasting of future climatic changes.
Of both identified cycles, the ~1150 year cycle, which reflects the main climatic episodes of the Holocene connected with changes of solar activity, is of special importance for paleoclimatic reconstructions. Within the identified ~1150 year cycle, which refers to 1374 years in a calendar scale, warm climatic stages appear as culminations in the following years (all dates according to the conventional BP radiocarbon time scale and the BP calendar scale): 900 BP (790 cal. BP), 2050 (1995 cal. BP); 3200 (3420 cal. BP), 4350 (4870 cal. BP), 5500 (6290 cal. BP), 6650 (7530 cal. BP), 7800 (8590 cal. BP), 8950 (10160 cal. BP), 10100 (11650 cal. BP) and 11250 lat BP (13160 cal. lat BP) (Fig. 1).On the other hand, culminations of cool climatic phases appear in the following years: 325 BP (400 cal. BP), 1475 (1350 cal. BP), 2625 (2750 cal. BP), 3775 (4120 cal. BP), 4925 (5650 cal. BP), 6075 (6900 cal. BP), 7225 (8000 cal. BP), 8375 (9400 cal. BP), 9525 (10900 cal. BP), 10675 (12700 cal. BP) and 11825 lat BP (13830 cal. BP) (Fig. 1).

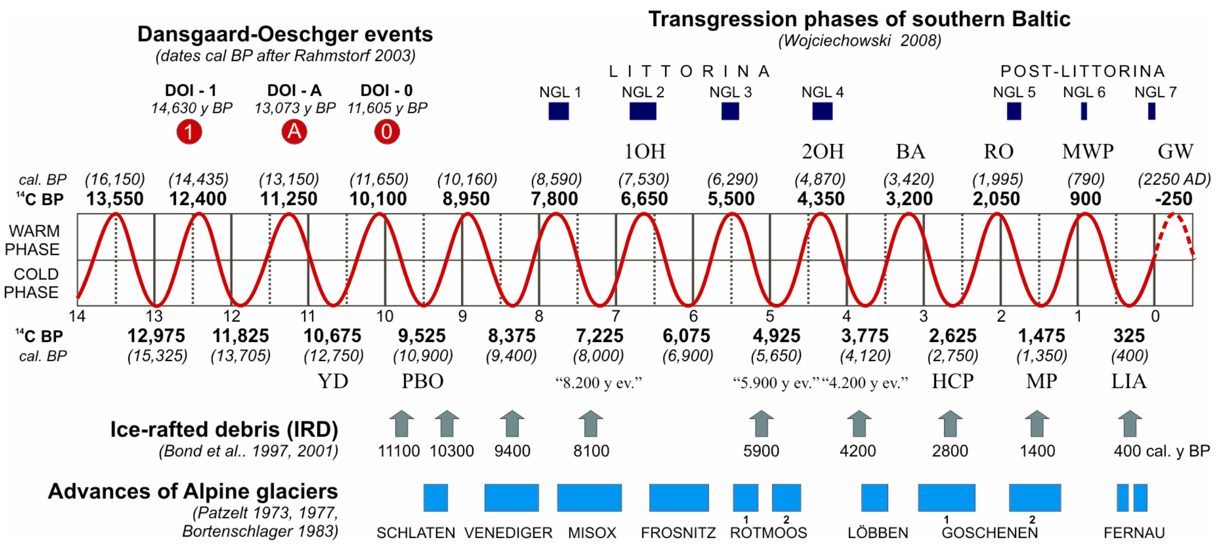

Figure 1. The Late-Glacial and Holocene course of the ~1150 yrs climatic cycle recognized in the lake sediment record from the Kórnik-Zaniemyśl trough, central Great Poland Lowland (after Wojciechowski 2000) and the comparison of selected warm/cold oscillations with the: D-O events (Rahmstorf 2003), marine transgressions of the southern Baltic Sea (Wojciechowski 2008), ice-rafted debris (IRD) record from the North Atlantic sediments (Bond et al. 1997, 2001) and the history of advances of Alpine glaciers (Patzelt 1973, 1977, Bortenschlager 1983). Dates of cold and warm peaks shown as conventional radiocarbon dates (BP) and the calendar years (in brackets). ^{14}C dates recalculated using OxCal v.3.10. Selected warm phases: 1OH, 2OH - first and second optimum of the Holocene, BA - Bronze Age optimum, RP - Roman period optimum, MWP - Medieval warm period, GW - contemporary "global warming"; selected cold phases: YD – Younger Dryas, PBO - Preboreal Oscillation, climatic events "8200 yr", "5900 yr" and "4200 yr", HCP - Hallstatt cold period, MP - Migration period, LIA - Little Ice Age.

Within the identified ~1150 year cycle in the Kórnik-Zaniemysl Lake deposits, all climatic optima of the Holocene known and recorded in the literature are mapped,including: Medieval Warm Period, Roman optimum, Bronze Age optimum, first and second optimum of the Holocene and the onset of the Holocene, divided by cooler periods Little Ice Age, Migration Period, Hallstatt Period, cold periods, so called "*4200 yr event*" and "*8200 yr event*", as well as the cold period of Preboreal Oscillation. Cyclically appearing warm and cold climatic phases of Holocene are especially connected with a) fluctuations of the range of the Alpine glaciers and changes in the forest-limit (*Patzelt 1973, 1977, Bortenschlager1983*), b) lake level changes in Central Europe (*Magny 1992, Wojciechowski 2000*), c) marine transgression and regression of the southern area of the Baltic Sea (*Wojciechowski 2008*), d) phases of increasing ice-rafted debris (*Bond et al. 1997, 2001*), e) changes in concentration of $\delta^{18}O$ in ice cores of Greenland and Antarctica (*Dansgaard et al. 1993, Johnsen et al. 2001*), f) recurrence surfaces in peatbogs (*Granlund 1932*).

Beside the above-mentioned paleogeographic events, the identified ~1150 year cycle also demonstrates the stage of contemporary warming of climate, emphasizing the important role of natural factors in monitored climatic changes.

The discovered and documented relation of diverse paleoclimatic events in the Upper Plenivistulan and Holocene, with the ~1150 year cyclicity focus on: (1) an important relation between the period of the cycle and the solar activity, (2) continuity of the course of the cycle for about 20000 years minimum, which permits relating the cyclic character of the events registered in the Upper Plenivistulan (the Dansgaard-Oeschger cycle, the Heinrich cycle) to the Holocene cycle (the Bond cycle); (3) the synchronic character of the record of climatic changes in various natural environments and (4) the global character of climatic changes.

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Past and future changes in Latvian river runoff: The cases of Bērze and Salaca river basins

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1. Introduction

Climate change is a worldwide observed phenomenon, also in the Baltic See drainage basin. Traditionally, climate change studies include identification of natural climate variability, attempt to detect climate signals in historical data and elaboration of possible scenarios for future (Hisdal et al., 2006). In 2006, the Research Programme *Climate change impact on water environment in Latvia* (2006-2009) was initiated (http://kalme.daba.lv). The generic goal of the Programme is to assess short, medium and long-term impact of climate change on the environment and ecosystems of the inner waters of Latvia and the Baltic Sea, and to create a scientific basis for adaptation of environmental and sectorial policies of Latvia to climate change. This study is a part of this program aiming to carry out a simulation of hydrological processes in different river basins and to forecast climate change impact on runoff and nutrient loading in the future.

Before running the water quality model, we have to simulate hydrological behaviour in river runoff, in particular for past and future changed climate conditions. In this study, the conceptual rainfall-runoff model METQ was applied, originally developed using Latvian catchments. In this paper, results are presented for two different river basins: the Bērze (agricultural river basin) and the Salaca (a part of the *North Vidzeme Biosphere Reserve*).

This paper addresses: (1) the results of the METQ model, the latest version METQ2007BDOPT, calibration and validation for two different river basins in Latvia, and (2) the analysis of meteorological and hydrological data series in projection of future climate, based on the control period (1961-1990) and the scenarios (2071-2100).

2. Materials and methods

In this study, the mathematical models on the basis of the conceptual rainfall-runoff METQ2007BDOPT were developed, calibrated and validated to two different river basins - the Bērze and the Salaca. The calibration period was selected from 1961 to 1990 (30-years as the control climate conditions) with an aim to simulate the scenario climate from 2071 to 2100 in the future, and validation period – next ten years from 1991 to 2000.

The river basin Bērze is located in the Central part of Latvia. A total drainage basin is 1180 km^2, and the runoff – 0.25 km^3 per year. The mean temperature is -5.0 ^{o}C in January and +17 ^{o}C in July. The average amount of precipitation is about 650 mm per year. The river basin is characterised as agricultural. For the water quantity modelling purpose, the river basin Bērze was divided into 15 sub-basins with different land-use and antropogenic impact. The river basin Salaca is located in the North-East of Latvia. Its total drainage area is 3220 km^2, 62% of which are occupied by the watershed of the lake Burtnieks. Major part of the river basin Salaca belongs to the biosphere reserve therefore an anthropogenic impact here is low comparing to the river basin Bērze. The total runoff is 1.06 km^3 per year. The mean temperature is -6.5 ^{o}C in January and +17 ^{o}C in July. The average amount of precipitation ranges from 650 to 810 mm per year. To perform the calibration procedure, the river basin was dived into six sub-catchments.

The METQ2007BDOPT model consists of different routines representing snow accumulation and ablation, water balance in the root zone, water balance in the groundwater and capillary water zone and runoff routing. Runoff routing can be simulated by simple hydrological methods, such as modifications of the unit hydrograph approach. However, if there is a lake (in the case of Salca) or water reservoir (in the case of Bērze) in the river basin which considerably influences the hydrological regime of the river, then there is a need for hydraulic runoff routing. The total runoff from each of HRU consists of three runoff components: Q_1 - surface runoff, Q_2 - subsurface runoff (runoff from the groundwater upper zone) and Q_3 - base flow (runoff from the groundwater lower zone). For more detailed description of this model find (Krams and Ziverts, 1993; Ziverts and Jauja, 1999, Apsite et al., 2008).

In the terms of data, the study was based on meteorological and hydrological observed data series provided by the *Latvian Environment, Geology and Meteorology Agency* and SIA *Melioprojekts* national data bases. Daily measurements of air temperature (^{o}C), precipitation (mm) and vapour pressure deficit (hPa) at six meteorological stations and daily river discharge (m^3 s^{-1}) of seven and water level (m) of two hydrological stations were applied as input data for the METQ2007BDOPT model calibration and validation. Statistical criterion R^2 (Nash and Sutcliffe, 1970), correlation coefficient r, mean values and graphical representation were used for the analysis of the model calibration results.

River runoff under the changed climate conditions, meteorological data series (daily air temperature, precipitation and vapour pressure deficit) provided by the National Research Programme *Climate change impact on water environment in Latvia* were used for the simulation and study. These data series were developed by the *Faculty of Physics and Mathematics* (FPM) of *University of Latvia*. FPM analyzed 21 regional climate models (RCM) from the EU project PRUDENCE and selected HCCTL model from SMHI (driving from GCM HadAM3H) as the best applicable for Latvian conditions. Description of the applied methodology can be found in Bethers et al. (2008). Therefore, in this study the calculated data series of HCCTL present the control period from 1961 to 1990, and HCA2 and HCB2 scenarios from 2071 to 2100.

3. Results and discussions

The results of the METQ2007BDOPT model calibration and validation show a good coincidence between the measured and simulated daily discharges. The river basin Bērze was calibrated and validated at the two river gauging stations – the Biksti and the Baloži. We found the following: the Nach-Sutcliffe (1970) efficiency R^2 varies from 0.80 to 0.72 and correlation coefficient r from 0.88 to 0.85 for the calibration period (1961-1990), and statistical efficiencies R^2 vary from 0.77 to 0.44 and correlation coefficient r from 0.87 to 0.80 for the validation period (1991-2000). The river basin Salaca was calibrated and validated at five river gauging stations – the Lagaste, the Masalaca, the Dravnieki, the Oleri and the Vilnīši. The river basin Bērze was calibrated and validated at two river gauging stations – the Baloži and the Biksti. One of the reasons for the difference between the simulated and observed runoff values is the quality of precipitation input data and location of the available meteorological stations characterising the spatial and temporal distribution of precipitation in the studied drainage area. Another explanation of the above mentioned calibration differences could be a broad palufied flood plain, a high percentage of wetlands in the sub-basins of the river Salaca and a lack of the channel measurements at the outlet of the lake Burtnieks. These reasons determine a specific hydrological regime and additional riverbed measurements for the better simulation of the hydrological processes within studied catchments.

After learning the results of several studies carried out in the Baltic region and Europe (Hisdal el al. 2006; Danker et al, 2007; Bolle et al, 2008; etc.), we can come to the conclusion that in this study we have identified similar tendencies of meteorological and hydrological trends in the forecast of future climate changes. Analysis of the climate change conditions metrological data in studied river basins shows an average increase in annual air temperature by 3.8-4.0 ^{o}C for the HCA2 scenario and by 2.5-2.7 for the HCB2 scenario in the period of 2071 to 2100 comparing to the control period of 1961-1990. Most considerable temperature increase is forecasted for the winter and autumn seasons: 4.1-4.9 ^{o}C HCA2 and 3.0-3.4 ^{o}C HCBA2 respectively. Atmospheric precipitation, at the same time, will increase by 10-12% according to the HCA2 scenario and by 6-9% according to the HCB2 scenario. The highest atmospheric precipitation increase is registered in winter, but the major decrease – in the summer and autumn seasons. Climate scenario data, particularly the HCB2 scenario, allows forecasting the eventual decrease of total annual river runoff in the future. The highest increase in the river runoff is registered in winter due to the increase of the mean atmospheric temperature and precipitation, while the decreased river runoff is forecasted for the second half of the year, particularly in autumn. The mentioned changes in the river runoff regimes can be explained by the higher air temperatures and particularly increased total evaporation as well as decreased amount of precipitation.

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Probable response of the Baltic Sea cold intermediate layer to climate warming: Field data analysis and numerical modelling

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1. Field data

Recent investigations (*Chubarenko, Demchenko*, 2008a,b) have suggested that the most cold waters of the Cold Intermediate Layer (CIL) of the Baltic are formed in shallow coastal regions during early-spring heating period. Data of field measurements in the Baltic sea coastal zone in March (2004 and 2005 years, 59 and 67 cruises of r/v "Professor Stokman", off the Curonean spit; courtesy Drs. V.Paka, N.Golenko), have revealed that conditions in shallow areas are favourable for the formation of denser water cascading down slopes: (i) water temperature is well below the temperature of maximum density (Tmd), (ii) upper mixed layer is homogeneous in temperature in vertical, (iii) whilst in horizontal there are large temperature gradients between shallow and deep regions (**Figure 1**). Under such conditions, when heating from the surface begins (either in day/night rhythm, or in synoptic or seasonal course), water with temperature below the Tmd becomes heavier and initiates cascading down-slope, much alike autumn-winter cascading from shelves. Indeed, profiles of **Figure 1** show warmer water near the bottom in shallow area. Important to note is that this water has a bit *higher* salinity, than the upper mixed layer in this location does: it results from mixing in intermediate layers (*Chubarenko, Demchenko*, 2008b). Overall salinity in the upper mixed layer is rather high 7.2-7.4 psu.

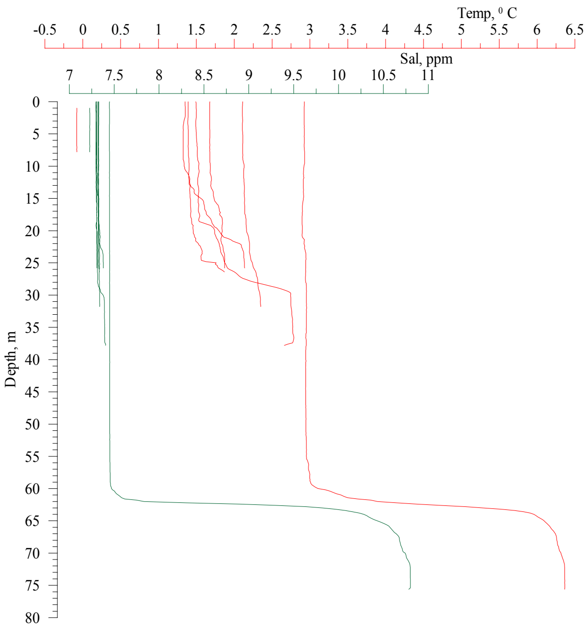

Figure 1. Vertical temperature (red lines) and salinity (dark-green lines) profiles at different depths on 2-7 March 2005 along the section from cape Taran northward. (67 cruise of r/v "Prof. Stokman"; courtesy Drs. V.Paka, N.Golenko).

Analysis of various published mean-annual data for the Baltic CIL was performed. Even though many seas have an intermediate layers (e.g., the Black sea, the Mediterranean sea) the Baltic CIL has some specific features: in typical years, (i) its waters have a temperature below that of maximum density till June-July; (ii) in many areas of the Baltic, minimum temperature within the CIL is 0.1-0.15°C below minimum surface water temperature in winter; (iii) it is more or less homogeneous; (iv) about 0.1-0.2 psu saltier than the surface layer; (v) from spring towards autumn the CIL deepens, and its salinity increases.

We suggest that horizontal exchange of a convective nature, supported by temperature differences between shallow and deep regions, is an important mechanisms contributing to the formation of the Baltic CIL. In autumn and spring, this means the formation of denser water cascades from slopes. Unique feature of the Baltic is that the coldest CIL waters have a temperature below the Tmd – and this fact can be used to trace the process. Indeed, such waters (T<Tmd and $T_{CIL}<T_{surface}$) can be produced intensely only by cascading from slopes during a very short time period: from the beginning of spring heating in March till end of April/May (for the central Baltic), when $T_{surface}$ becomes higher that Tmd.

2. Laboratory experiments

Set of laboratory experiments is presented, showing the formation of cold intermediate layer in a long basin (7.5 m) with sloping bottom under conditions of heating from the surface (laboratory of AO IO RAN, Kaliningrad). The basin contained two water layers: warm and salty (5-7°C / 8-12 psu in different experiments) lower layer and cold (1-2 C) and fresh upper layer. Bottom slope was 4.5°; water was heated via exchange with warmer air; bottom and walls of the tank were insolated.

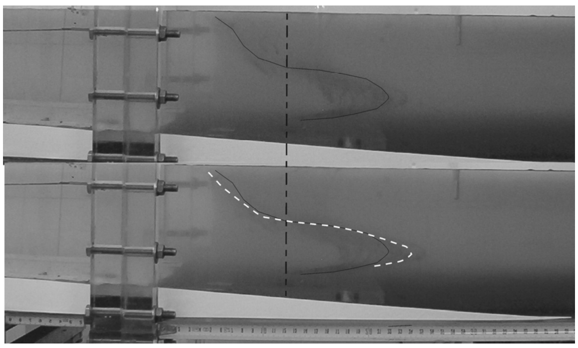

Figure 2. Laboratory experiment on heating from the surface of a laboratory tank, containing 2 water layers: upper one – fresh and cold (T<Tmd), and lower one (dark on the photos) – warm and salty. Laboratory of AO IO RAN, Kaliningrad.

Heating from the surface of waters in the upper layer, which has a temperature below Tmd (4°C for fresh water), leads to cascading from sloping bottom (**Figure 2**). Down-slope flow develops in the upper layer only, transporting waters from shallow part into the intermediate layer of the flume. Again, observations in the most shallow part did show, that the main mixing region, where waters of intermediate layer (intrusion on **Figure 2**) come from, is not the very top, but the lower half of sloping region within the upper fresh layer. It is in accord with field data, described above, and show the mechanism how coastal waters gain additional salinity and become able to sink below the upper mixed layer in deep part of the sea.

Figure 3 demonstrates variation with time of vertical temperature profile in deep part of the flume during the experiment. Salty layer is below 10 cm depth in this experiment. It is obvious that cold intermediate layer is formed. Analysis of time rate of temperature growth at different depths has revealed that it is maximum at the surface, less in the bottom layer and minimum – within the CIL, what suggests additional horizontal cold-water transport.

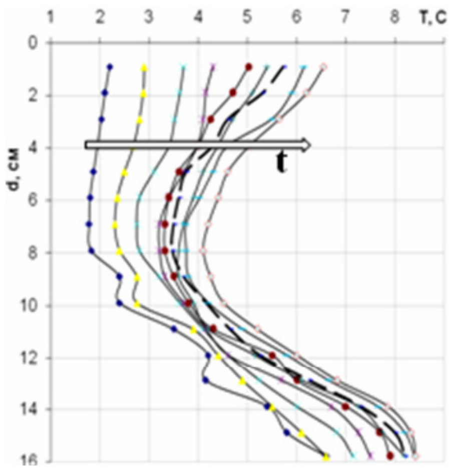

Figure 3. Vertical temperature profile variations with time in deep part of laboratory flume. Below 10 cm water is salty.

3. Numerical modelling

3D non-hydrostatic hydrodynamic numerical model (MIKE3-FlowModel, DHI Water & Environment; http://www.dhi.dk) was used to reproduce the process in the South-East Baltic (bathymetry field from http://www.io-warnemuende.de) and to reveal the response of the CIL characteristics to one particular feature: initial water temperature in the beginning of spring heating process. Simulations started in February, with the same structure of salinity field (7.3 psu upper mixed layer, halocline at the depth of 62 m), however water temperature in the upper layer in different runs was 1°C and 3°C. The CIL features were compared then in May-June. The rectangular grid of dimensions of 152 × 306 cells has a resolution of 5 km in horizontal and 92 levels (4 m each) in vertical was used for the entire Baltic; then the nested grid technology was applied to the Gdansk basin.

Comparison of different runs has demonstrated that in “warm year” the CIL has higher temperature and is less pronounced (vertical temperature gradients are smaller), whilst in “cold year” rather sharp temperature gradients are kept both below and above it. Surprisingly, the CIL is rather narrow after the “cold year”, what may be explained by lower mixing at sharper boundaries. Comparison with field data shows that this is in accord with the observed CIL features.

Projection of the discussed mechanisms and situations onto the expected climate changes suggests, that, under the global warming process, the CIL of the Baltic sea will become thicker, less pronounced and less oxygenated (being formed in November-December, and not refreshed in March). When Tmd is no longer observed within the CIL, it should lose its features of homogeneity, slight salt excess and deepening with time (*Chubarenko, Demchenko*, 2008a). Weaker vertical stratification makes wind mixing more efficient; thus, in autumn, the CIL should be mixed over at earlier times.

The investigation is supported by RFBR, grants № 07-05-00850, 09-05-00446.

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Seasonal structural front in the Baltic Sea under changing climate conditions: Field data analysis and numerical modelling results

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1. Introduction

Study of mixing mechanisms in lakes and inland seas is an important question of hydro physical research. Especial attention is paid to the features of frontal zones. The front, associated with the passing of water temperature in a basin across the temperature of maximum density (3.98°C for fresh waters), is well known in limnology as a ”thermal bar” It is formed in large water bodies in spring and autumn. It has been under wide investigation in Great Lakes of America (*Rodgers*, 1965; 1966) and many Russian lakes, such as Ladoga, Onega, Baykal, etc. (*Tikhomirov*, 1982; *Shimaraev*, 1977). In oceanographic terminology, this front belongs to wide class of structural fronts. There are only a few publications on the observation of such structural front in the Baltic sea (*Bychkova* et. al., 1987); any systematic investigation of this front in the Baltic was never published.
The main goal of this work is to reveal how the changing climate conditions may impact on the characteristics of the seasonal structural front.

2. Methods

The following field data were analyzed. (1) Mean-annual characteristics of thermo-haline fields (96 years; *Janssen et al.,* 1999) of the Baltic Sea along the section “Gdansk bay – Gotland sea”. (2) Data of field measurements, performing by the Leibniz Institute for Baltic Sea Research in frames of HELCOM program along a section in southern and central Baltic in spring period (21^{st}-31^{st} of March; 2-12^{th} of May, 2003). (3) Subsurface temperature, salinity and chlorophyll-*a* along the section Travemünde-Helsinki, performed by Finnish Institute of Marine Research (Ship of Opportunity program) for the mentioned above periods.

A 3D non-hydrostatic hydrodynamic numerical model MIKE3-FlowModel (DHI Water & Environment, www.dhi.dk) was used in order to reproduce thermo-haline structure of the Baltic sea, formation and propagation of the structural front during spring heating period. Model calibration and verification was performed using mean-annual characteristics of the thermo-haline fields of the Baltic sea, inter-basin water exchange data, general sketch of the water circulation in the Baltic sea (*Esuikova,* 2008). The dimensions of numerical grid are 152x306 horizontal cells (5x5 km) and 92 layers in vertical (4 m each); time step of integration – 90 s; heating is modelled as turbulent heat exchange with warmer air and solar radiation, corresponding to spring period at mid latitudes; the simulated period is 1.5 year, starting from February. Features of the structural front are analyzed for the next spring, i.e. after 1 year of the simulation.
Initial conditions were taken from mean-annual thermo-haline fields of (Jansen et al., 1999). For the boundary conditions, two kinds of data sets were used. First, mean-annual thermo-haline fields in accordance with (*Janssen et al*., 1999); air temperature (30 points; 96 years), wind variations from real data for Visby, Sweden (data from www.rp5.ru), year 2007-2008; seasonal course of 25 river discharges from (*Hydrometeorology and Hydrochemistry,* 1992); open boundary in Northern Kattegat (tidal water level variation). Second, boundary conditions for the particular period from February 2002 till July 2003: (i) every 6 days air temperature (35 points are specified for islands and Baltic coastal area) and (ii) wind (12 points) for the year of 2002-2003, which was the second severe in the two last decades. River discharges and exchange with the North Sea – as in previous simulation.

3. Results

Mean-annually, the thermo-haline structure of the Baltic Sea along the section “Gdansk bay – Gotland sea” under conditions of early-spring heating has some specific feature: under the same conditions of heating from the surface, shallow parts are stably thermally stratified, whilst waters in deeper regions are almost homogeneous, having temperature near the T_{md} throughout the upper layer of the thickness of about 30 m. The location of the T_{md} is specified. Mean-annual horizontal density gradient between these parts for April is about 10^{-8} kg/m^4. Depth of the halocline formation is about 45-60 m.

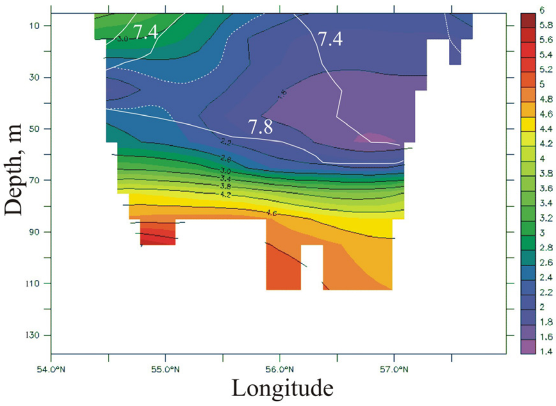

Figure 1. Mean-annual temperature field on the section “Gdansk bay – Gotland sea” in the April. Solid line marks salinity field, dotted line marks $T=T_{md}$. Data from www.io-warnemuende.de

Winter 2002/2003 was the most severe after the winter 1995/1996 and the second severe after 1986/1987 over last 30 years. As a result of the extreme cold December 2002, water temperature in central and northern Baltic Sea was in January well below the average, and below the T_{md}. However, all the following months after March were warmer than usual: for instance, air temperature in period from May to August was more than 2°C higher than normal (www.bsh.de).
Due to these conditions, very favorable for the structural front formation, it was well pronounced during spring period of 2003 in the southern and proper Baltic: at the beginning of spring heating, water temperature in one part

is close to the T_{md} (T_{md}=2.3°C; S=8 psu) down to the bottom; in another part, an inverse temperature stratification is still preserved. With the progressive heating, water temperature in one part becomes higher than temperature of maximum density, in another part is still around T_{md}. Important to note, that water salinity in the upper layer is homogeneous down to D=60-70 m.

Analysis of subsurface water temperature, salinity and chlorophyll-*a* along the section Travemünde-Helsinki, performed by FIMR in April 2003, showed an obvious surface temperature jump while passing the T_{md}; horizontal temperature gradient in this area was 10 - 100 times as large as mean-annual value; horizontal density gradient in this area was 10^{-6} – 10^{-5} kg/m^4; speed of propagation of frontal zone – about 11.4 km/day. Thus, the frontal zone associated with the T_{md} does exist in the Baltic Sea in spring period.

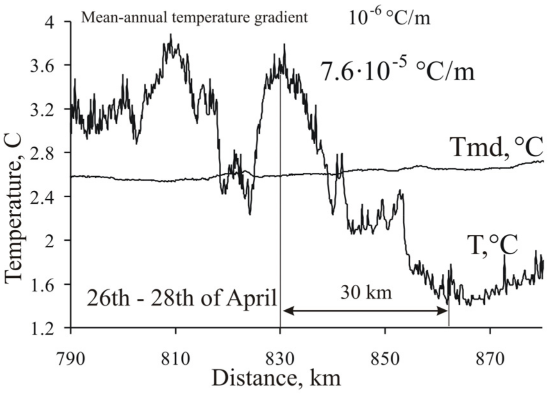

Figure 2. Temperature jump associated with the passing the T_{md} on the section Travemünde-Helsinki on 26-28 April 2003.

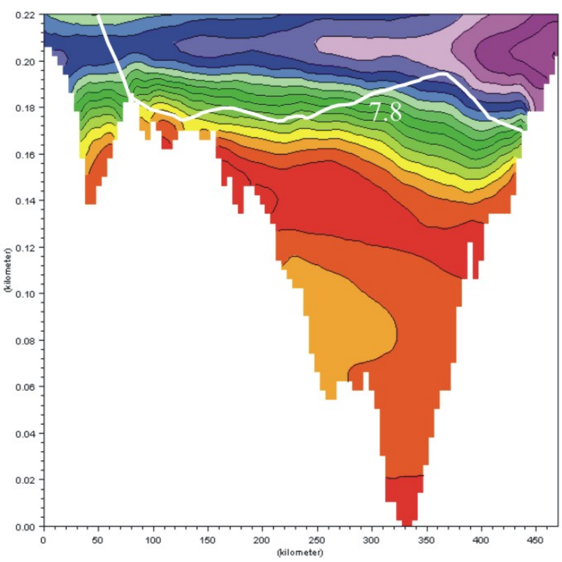

Figure 3. Vertical cross-section of simulated mean-annual temperature on the section "southern part of Baltic – Gotland sea" in April. Violet colour marks the region with temperature below 2°C; navy - blue colour marks T_{md} -line, whilst yellow & red – above 5°C. Isotherms are plotted every 0.2°C and are omitted above 5ºC (in the upper-most layer). Solid line shows salinity.

Simulated mean-annual temperature field of the Baltic Sea along the section "southern part of Baltic – Gotland sea" during spring heating is in a good agreement with the mean-annual field data: one of the areas is stably stratified; another one – unstably stratified. The location of the simulated T_{md} concurs with the location of T_{md} - isotherm. Simulated mean-annual horizontal density gradient between these parts for April is about 10^{-7} kg/m^4. Simulated depth of the halocline formation is around 40-45 m.

4. Acknowledgements

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www.dhi.dk

www.io-warnemuende.de

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Horizontal water exchange within the Baltic Sea: Results of numerical modelling

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General aim of the investigation is to estimate value and to reveal spatial structure and time variability of horizontal water exchange within the Baltic Sea during annual cycle under mean-annual external conditions. Calculation of volumetric flow-rates through 70 cross-sections (Fig. 1) was performed, which were placed both between the Baltic sub-basins and inside them.

1. Numerical model and the set-up

Three-dimensional non-hydrostatic hydrodynamic numerical model MIKE3-FlowModel (DHI Water & Environment, http://www.dhi.dk) was used for that. The bathymetry field was taken from http://www.io-warnemuende.de. The rectangular grid of dimensions of 152 × 306 cells has a resolution of 5 km in horizontal and 92 levels (4 m each) in vertical. Open boundary is in the North Kattegat. Time step of integration was 90 seconds, what kept the Courant number close to 1.

As initial conditions, mean-annual salinity and temperature fields *T, S (x,y,z)* were taken for the whole Baltic in February in accordance with (*Janssen* et al., 1999). Open boundary was placed in the Northern Kattegat, where mean-annual salinity and temperature profiles, taken from (*Janssen* et al., 1999), varied monthly. Water level variations due to tides for the given location were prescribed at the open boundary.

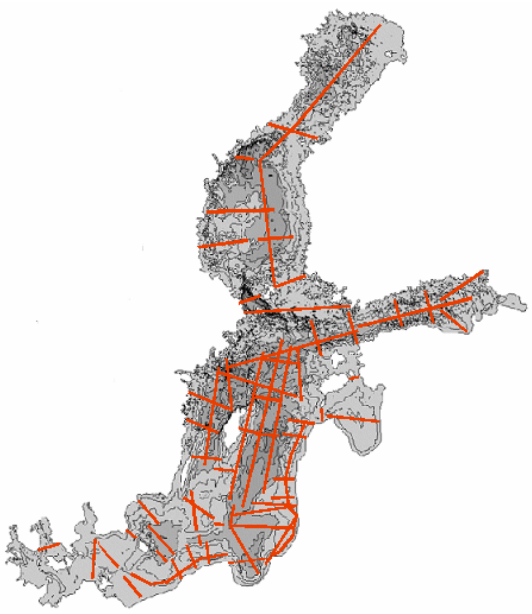

Figure 1. Cross-sections used for calculation of water-exchange. Bathymetry - http://www.io-warnemuende.de

External forcing included solar radiation, turbulent heat exchange with the atmosphere, wind, rivers and the Earth rotation. The conditions of solar radiation, including day/night variations, are calculated in the model automatically on the base of latitude/longitude of every particular place. Mean-monthly values for cloudiness are used, averaged over the Baltic area. Turbulent heat exchange with the atmosphere is calculated from air-water temperature difference and wind speed; evaporation/precipitation and ice coverage are not included. Air temperature (2 m above sea level), variable over the sea area, follows monthly mean-annual variations (*Hydrometeorology and hydrochemistry*…, 1992). Wind data is the only set taken from real measurements in Visby: 1/day, for the year 2007 (http://rp5.ru). The whole Baltic sea river runoff is distributed between 21 individual river and varies monthly. For turbulence closure, the Smagorinsky formulation has been used.

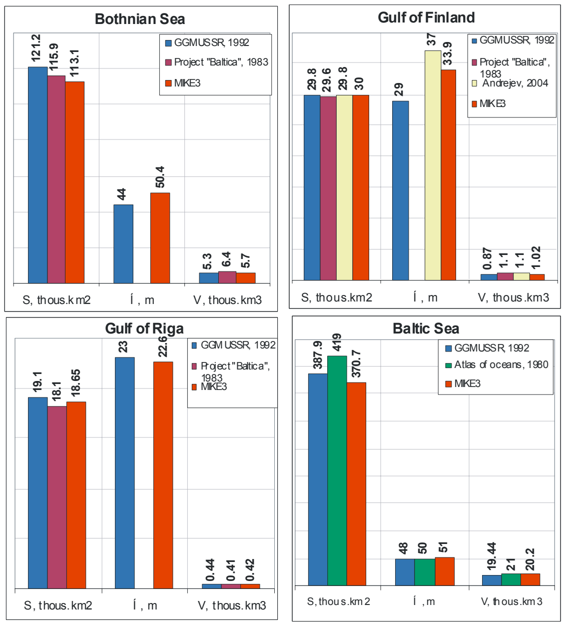

Figure 2. Comparison of model areas, depths and volumes of four particular sub-basins of the Baltic Sea with data from other publications.

The model calibration and verification has been carried out (*Esiukova*, 2008). Calibration parameters were horizontal and vertical coefficients of turbulent momentum exchange and the bottom roughness. Sensitivity tests for wind friction were carried out. It was demonstrated in verification procedure, that the main features of fields of water temperature and salinity are well reproduced by the model: horizontal variations, depth and inclination of the thermo-cline, location and thickness of the cold intermediate layer. General structure of surface currents agrees well with published schemes, e.g. (*Hydrometeorology and hydrochemistry*…, 1992). Figure 2 demonstrates, that volumes of particular basins in the model are very close to that reported in another published investigations. Warming-up period for the model is about 3-4 months, after which the mean-annual features of thermo-haline and current fields in the Baltic are reproduced by the model quite well.

2. Results

For one year period the values of horizontal water exchange through the large-scale sections (Fig. 1) were calculated. In an order of magnitude, mean-annual volumetric fluxes through these sections are several times as big as the total river runoff into the sea (~450 km^3/year). The most intense horizontal exchange is observed in areas with the largest depths (depressions, trenches). During a year, it is most active in April and in October-January.

Analysis of water exchange through the borders between exclusive economic zones of the Baltic states (Fig. 3) has revealed, that the most active mean annual volumetric flux is formed across the border between Polish and Russian (Kaliningrad region) economic zones – about $1.5 \cdot 10^6$ km^3/year. The Kaliningrad region is the most active transit zone in the Baltic Sea

Estimation of a renewal times for water in sub-basins of the Baltic Sea and in exclusive economic zones of all the Baltic states was carried out. Water renewal time for the economic zones is less than 2 years.

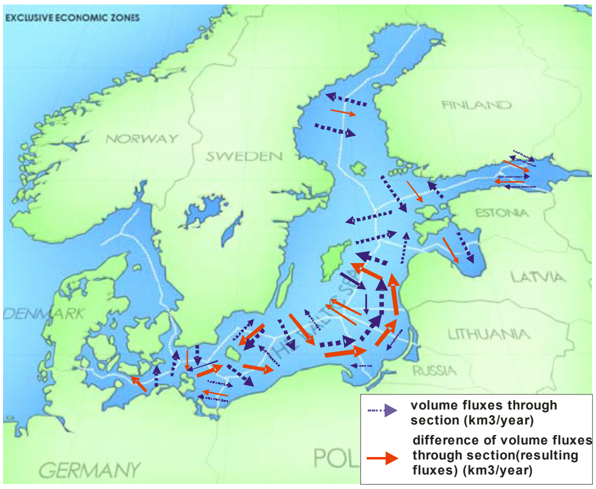

Figure 3. Water exchange across the borders between exclusive economic zones of the Baltic Sea states. The largest net flow (red arrows) is from Polish to Russian zone, the smallest – from Swedish to Estonian waters.

The investigation is supported by RFBR, grants № 07-05-00850, 09-05-00446.

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First-order estimation of climate change influence on the nutrient load from a small river system using a nutrient dynamics model

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1. Introduction

First-order estimation of climate change influence on the nutrient load from the Instruch River was done using nutrient dynamics model. The Instruch River sourced at the north-east of Kaliningrad Oblast (South-East Baltic) and together with the Angrapa River they form the Pregolia River that discharges in the Vistula Lagoon of the Baltic Sea. As river flow contributes the main portion of nutrients to the Vistula Lagoon, the Instruch River was chosen as model river basin for estimation of nutrient load variations due to climate change. The Instruch River is refereed to as a minor river according to hydrological classification of rivers, its catchment area is 1095 km^2 and the total stream length of river network is 1190 km.

2. Material and methods

The FyrisNP model (Swedish University of Agricultural Sciences) (*Kvarnas*, 1996) was used for modelling of the main nutrients (nitrogen, phosphorus) load from the Instruch River network and estimation of possible scenarios of climate change. The model accounts the catchment land use, nutrients runoff from different lands and point sources, stream characteristics. Retention, i.e. losses of nutrients in river stream is calculated as a function of water temperature, nutrients concentrations, water flow and stream surface area. The model is calibrated against time series of measured nitrogen and phosphorus concentrations by adjusting two parameters (*Hansson et al*, 2008).
GIS data for subcatchments areas, streams length, forested areas, wetlands, administrative division[1] and agricultural land-use statistical data[2] were used in the model. The nutrient pressure from population and stock-breeding were evaluated using the Federal State Statistics Service data (*The main indexes* …, 2006) and accounting the nutrients contents in waste (*Swedish Environmental Protection Agency*, 1995; *Maslennikova & Gorbunova*, 2007). Type specific nutrient concentrations in the runoff from different land uses was taken as for South-East of Sweden[3]. The time series of measured nutrients (nitrogen and phosphorus), river runoff and temperature were available from Kaliningrad Centre for Hydrometeorology and Environmental Monitoring for December 2005 – November 2006.

3. Results and Discussion

The FyrisNP model evaluates the gross nutrients load from a catchment as sum of load from point sources (wastewater treatment plants, industrial and agricultural facilities) and runoff from agricultural, forested, open lands, clear cuts and wetlands, accounting a retention of nutrients within the river stream (including a lake if exists). The agricultural lands that use as arable and pastures occupy the main part of the Instruch River basin. The forested areas are located mostly in the downstream subcatchment. There are no urban settles and waste water treatment plants in the Instruch River Basin. Nutrient load is diffuse and includes natural and agricultural components as well as contributions from population and stock-breeding.

The FyrisNP model evaluates the net nutrients load as gross load after retention. i.e. losses of nutrients in river stream through sedimentation, up-take by plants and denitrification. The relative removal is given by the retention coefficient, defined as production of the temperature adjustment factor and the flow rate adjustment factor (*Hansson* et al, 2008). The idea of first-order estimation of climate change influence on the nutrient load from the Instruch River system was in simulation (by FyrisNP model) of sceneries of hypothetic temperature increase by 0.5ºC and 1ºC for the whole year temperature series. The retention as only temperature dependent function within the FyrisNP model was studied under this conditions. The model shows that in general the temperature rise causes the nutrients decrease due to retention increase in river, but this decrease is very small and doesn't exceed one percent.
So, there is no chance that temperature rise due to climate change will increase the carrying capacity of the natural river stream ecosystem. Much more influence on the nutrient load from a catchment should be expected from the antropogenic factor as wastewater treatments and agricultural technologies.
The study was supported by RFBR grant 08-05-01023 and related to ECOSUPPORT Bonus+ project.

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[1] - GIS database of the Laboratory for Coastal Systems Study of the Atlantic Branch of P.P.Shirshov Institute of Oceanology of Russian Academy of Sciences

[2] - data set of Kaliningrad Institute of Agro-business Experts Retraining

[3] - lecture of Wallin M. (Swedish University of Agricultural Sciences)

Contribution of regional climate drivers to future winter Baltic Sea-level changes: An application of statistical downscaling to the output of global climate model simulations

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1. Introduction

Present estimations of future global sea-level change are based on simulations with coarse-resolution global climate models (GCMs). The simulated sea-level changes mostly depend on the heat-flux into the ocean, on changes in the ocean circulation and on the rate of possible Greenland ice-sheet melting. A global average of sea-level rise, however, ensconces considerable regional variations, that may be caused by other processes that operate on regional and local scales.

The Baltic Sea is one of the largest brackish seas in the world and, with its complex coastline and bathymetry, a clear example of a complex coupled ocean-atmosphere-land system. Baltic Sea level variations at inter-annual to decadal timescales are generally believed to be caused essentially by variations in wind forcing, in particular (although not exclusive) by the sea level pressure pattern of the North Atlantic Oscillation (NAO). However, the correlation between individual Baltic Sea level stations and SLP is heterogeneous in space (see Figure 1) and in time (range of 0.25 to 0.8 in wintertime for 1900 to 2000).

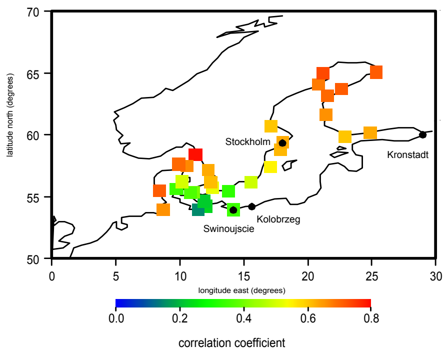

Figure 1 Correlation between winter mean (DJF) of NAO index and winter mean (linearly detrended) Baltic Sea level (obtained from PSMSL), 1900 to 1998. (adapted from Hünicke and Zorita, Tellus A, 2006). Sea level records for the 20th century are obtained from the Permanent Service for Mean Sea Level (PSMSL); the four longer time-series (up to 200 years; black dots) are obtained from Ekman (2003), Bogdanov et al. (2000) and TU Dresden.

In recent studies Hünicke and Zorita (2006, 2008) used several statistical approaches to investigate the influence of different atmospheric forcings on past and present Baltic Sea level with focus on multiyear to decadal timescales (in the context of anthropogenic climate change). Thereby, they restricted their study on those atmospheric forcing factors for which long term observations or reconstructions are available, and which are potentially well simulated by GCMs. Their results indicated that the influence of different large-scale forcing factors on sea-level vary geographically. While the decadal sea-level variations in the northern and eastern Baltic gauges are strongly influenced by the atmospheric circulation, decadal variations in the Southern Baltic Sea can be explained better by area-averaged precipitation. The establishment of these statistical relationships in the observational record allows an estimation of regional climate change by statistical means through the application of the statistical models to the corresponding output of GCM simulations.

2. Method

A statistical downscaling approach is applied to the output of different GCM simulations (Table 1; also see http://www-pcmdi.llnl.gov/ipcc/model_documentation/ ipcc_model_documentation.htm) driven by SRES A2 future scenarios of greenhouse gas concentrations to estimate the contribution of changes in atmospheric circulation and in precipitation to regional future winter (December-January-February) sea-level changes in four Baltic gauges (Figure 1, black dots). The method is based on linear regression models, which establish a statistical relationship between Sea level as predictand (regional scale dependent variable) and large scale climate fields as predictors (independent variables).

Table 1 List of Global Climate Models.

Trends mm/year (95% confidence interval)	**Kolobrzeg**	**Swinoujscie**	**Stockholm**	**Kronstadt**
Global climate models	predictor precipitation		predictor sea-level pressure	
NCAR CCSM 3.0 (POP OGCM)	0.24 (±0.05)	0.21 (±0.05)	-0.19 (±0.21)	0.01 (±0.38)
NASA GISS Model E-R (Russell OGCM)	0.17 (±0.04)	0.14 (±0.03)	0.14 (±0.09)	0.13 (±0.17)
UKMO HadCM3	0.30 (±0.05)	0.26 (±0.04)	0.32 (±0.13)	0.29 (±0.26)
MPI ECHAM5	0.60 (±0.04)	0.52 (±0.04)	0.88 (±0.13)	1.25 (±0.26)
NOAA GFDL CM 2.1	0.62 (±0.05)	0.54 (±0.04)	1.24 (±0.18)	2.53 (±0.34)

Before applying the sea-level records to regression equations, we eliminate the contained trend caused by post-glacial land uplift and possibly by eustatic sea-level change by subtracting the linear long-term trend from each sea-level record. As the interest lies in the variability at decadal and longer timescales, all time-series were smoothed with an 11-year running mean filter.

For the central (Stockholm) and eastern (Kronstadt) Baltic Sea level stations, SLP was used as predictor. Therefore, the SLP field was decomposed to its principal components (PCs) to avoid co-linearity. Once the regression coefficients had been estimated by Least Mean Square-Error, the respective climate model time series associated with the leading SLP PCs were determined for the whole time-period (around 1860 to 2100, with minor changes depending on the climate model run used) by projecting the simulated SLP anomalies (deviations from the model 1900-1998 mean) onto the observational spatial eigenvectors of loadings from the PC analysis. The regression coefficients were calibrated in 1900-1999 by using gridded climatic data sets of SLP (Trenberth and Paolino, 1980) and precipitation (Mitchell and Jones, 2005).

For the sea-level stations in the Southern Baltic Sea (Swinoujscie and Kolobrzeg) catchments area-averaged precipitation was applied as predictor. Thereby, the precipitation time-series is treated the same as a single PC of the SLP field.

3. Results

Figure 2 shows the results of the regression analysis for the different GCM simulations. The estimated linear trends of the contribution of SLP and precipitation changes to future winter sea-level change are also given in Table 2, together with their 95% confidence interval.

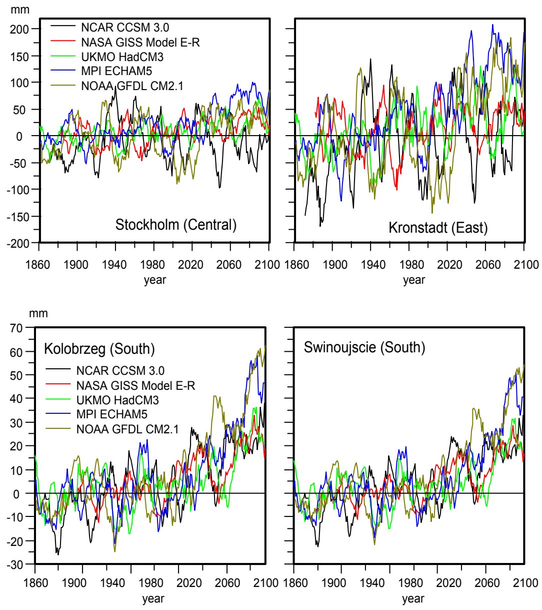

Figure 2 Estimations of the contribution of changes in atmospheric forcing to future winter sea-level change in the Baltic Sea based on regression between observed sea-level as predictand and SLP (upper panels) and area-averaged precipitation (lower panels) as predictor.

For the sea-level stations Stockholm and Kronstadt (predictand SLP PCs) the simulations with the UKMO HadCM3, MPI ECHAM5 and NOAA GFDL CM 2.1 climate models show a clear significant positive signal on sea-level rise. The strongest signal is obtained by applying the SLP output of the NOAA GFDL CM 2.1 simulation to the regression models (see Table 2 for more details). The ECHAM5 model also produces a much higher positive trend for Kronstadt than for Stockholm, but the values are lower. The HadCM3 model leads to positive trends, but much weaker and more similar between the two sea level stations. Whereas the NCAR model shows no significant trend for both sea level stations, the NASA model produces a minor upward trend for Stockholm. Considering all significant values, the mean estimate changes brought about by simulated changes in the SLP field are of the order of 1 mm/year for the investigated sea-level stations for the time period 2000 to 2100.
The estimation of the contribution of precipitation changes to future winter sea-level changes in the Southern Baltic Sea level stations Kolobrzeg and Swinoujscie (predictand area-averaged precipitation) shows a much more uniform result across the simulations. Similar to the findings using SLP as predictor, the strongest signal is reached by applying the precipitation output of the NOAA GFDL CM 2.1 simulation to the regression models. Thereby the 21st century trends reach values of 0.63 ±0.05 mm/year for Kolobrzeg and 0.54 ±0.04 mm/year (95% confidence interval) for Swinoujscie. Again, the ECHAM5 model delivers quite similar results. The lowest trends are estimated by using the precipitation output of the NASA GISS Model with values. The results for the NCAR and UKMO climate models are quite similar. For more details see Table 2.

Table 2 Estimated linear trends of the contribution of SLP and precipitation changes to future winter sea-level change (2000 to 2100), together with their 95% confidence interval.

Trends mm/year (95% confidence interval)	**Kolobrzeg**	**Swinoujscie**	**Stockholm**	**Kronstadt**
Global climate models	predictor precipitation		predictor sea-level pressure	
NCAR CCSM 3.0 (POP OGCM)	0.24 (±0.05)	0.21 (±0.05)	-0.19 (±0.21)	0.01 (±0.38)
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NOAA GFDL CM 2.1	0.62 (±0.05)	0.54 (±0.04)	1.24 (±0.18)	2.53 (±0.34)

4. Summary and Conclusions

A statistical downscaling approach is applied to the output of different global climate model simulations driven by SRES A2 future scenarios of greenhouse gas concentrations to estimate the contribution of changes in the atmospheric circulation and in precipitation to regional future winter sea-level changes. The method is based on observed statistical relationships between sea level as predictand and large-scale climate fields as predictors.
The results indicate that future trends in sea-level rise caused by these forcing are larger than the past variability. Using sea level pressure as predictor for the central and eastern Baltic Sea level stations, three climate models lead to 21st century future trends in the range of the order of 1 to 2 mm/year. Using precipitation as predictor for the stations in the Southern Baltic Coast all five models lead to significant trends with a range of the order of 0.4 mm/year. These numbers are smaller, but of the order of magnitude of the predicted future global sea level rise.
The findings qualitatively agree with the results of a dynamical downscaling approach by Meier et al. (2004).
Nevertheless, these estimations comprise only a partial contribution of selected large-scale regional predictors and an estimation of the total regional sea-level rise has to consider other regional factors such as the isostatic contribution to relative sea level changes or substantial changes in the sea-ice cover and global sea level rise.

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Contemporary and future changes of snow accumulation of the south-east Baltic region

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1. Contemporary condition of snow accumulation

Contemporary changes of snow storage show essential regional distinctions. The Northern part of North America and North Eurasia display different tendencies of snow accumulation. This process is connected to features of changes in atmospheric patterns and is illustrated in particular by changes of the indexes of North Atlantic Oscillation and Arctic Oscillation. The general warming does not affect snow accumulation in North Eurasia in connection with low air temperature of the winter period and the increase of precipitation causes an increase of snow storage here. The long-term increase of maximum snow storage in North Europe is defined first of all by changes in snow gains in January as the coldest month. Nevertheless, the process of snow storage increase cannot last indefinitely under conditions of warming. The limit of snow storage increase in Scandinavia, for instance, has already been reached, the snow depth is reduced there (trend in January - 0.35 cm / year for 1936-2004) and the duration of snow cover is also increased there. Cold winters over north and central parts of the East European plain still constrain a decrease of snow depth (trend in January +0.24 cm / year for 1936-2004). This process takes place against a background of warming: the regional trend of temperature amounts to +0.14 ^oC / year. (*Kitaev et al.,* 2006; BACC, 2008)

2. Future changes of snow accumulation

For an estimate of the future changes of snow storage in the East European plain we use the results of calculations of global climatic models. The forecast of the snow water equivalent was based on recalculation of a water equivalent from winter precipitation by means of a special algorithm: precipitation is calculated more reliably by models and seven models have been selected after comparison of the designed modeling and real values of the snow water equivalent for the base period 1961-1989: CCSM3, NCAR (USA), CGCM3.1(T47) (Canada), GFDL-CM2.0` (USA), GFDL-CM2.1 (USA), MRI-CGCM2.3.2 (Japan), PCM (USA), INM (Russia). Spatial changes of dependence of snow gains on rises in temperature for February have been determined? for contemporary conditions in the base period of 1961-1989, and for two forecast periods in the 21st century - 2047-2065 and 2083-2099. Thus, changes are revealed for borders between territories where the snow water equivalent continues to increase under conditions of warming and where it is already reduced (fig. 1). This border under conetmperary conditions is located along the 60th parallel of the East European plain and for 100 years of the modeling forecast is displaced by almost 1000 km to the northeast, to the Ural foothills.

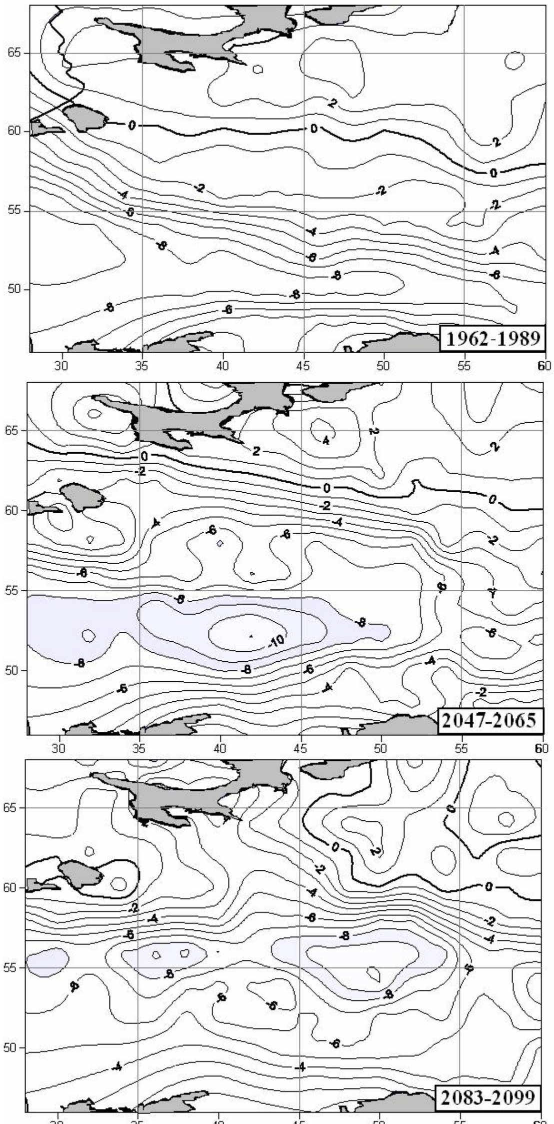

Figure 1. Dependence of long-term variability of gains of snow water equivalent on changes in gains of air temperature: coefficient of regression for contemporary conditions in the base period 1961-1989 and two forecast periods – 2047-2065 and 2083-2099.

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Variability of cool, hot and very hot days in the zone of the Polish coast of the Baltic Sea

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1. Introduction

Among the meteorological factors that shape the conditions of recreation at the seaside the following kinds of days are mentioned: cool (t_{max}<15°C), hot (t_{max} >25°C) and very hot (t_{max}>30°C). During the last few decades an increase in the number of hot and very hot days affecting biothermal conditions have been observed in various regions of Poland. A long-lasting period of very hot weather results in serious consequences for health and human life, especially as at the beginning of the 21st century the number of very hot days in Poland is still increasing and maximum temperatures even exceed 35°C (Cebulak, Limanówka 2007). In the zone of the Polish cost of the Baltic Sea a decrease in the number of cool days and an increase in the number of hours with sunshine are recorded, and that improves conditions for recreation in summer (Atlas… 2004, Filipiak 2004, Koźmiński, Michalska 2006). In the first half of the year, apart for June, there was a distinct increase in the daily temperature of air, statistically significant in January (3.3°C/50 years) and in April (4.1°C/50 years), and in autumn there was a slight decrease in this temperature – particularly in September (Koźmiński, Michalska 2008).

The aim of the study is to evaluate the frequency and direction of the changes in the number of cool, hot and very hot days and the intensity of these days in the warm half of the year on the Pollish coast of the Baltic Sea.

2. Material and methods

In the study, daily values of maximum temperature below 15°C (cool days) in the period from June to August and above 25°C (hot days) and above 30°C (very hot days) in the period from April to September gathered at six weather stations (Świnoujście, Kołobrzeg, Koszalin, Ustka, Łeba, Hel) over the years 1986-2007 were analysed. Besides basic statistical characteristics such as: mean, maximum, standard deviation, variability index, calculated for months and periods, the linear trends of the number of cool, hot and very hot days and mean temperature in these days were determined. Using correlation matrix, statistical relations between the number of the cool, hot and very hot days and the stations situated along the Polish coast of the Baltic Sea were analysed.

3. Results

During the discussed period of 1986-2007, a positive statistically significant trend of the number of hot days ($\alpha_{0.05}$), is recorded in the zone of the coast, except for Hel. As far as very hot days are concerned no trend of this kind was observed. A particular attention should be paid to very large variability of the number of days from year to year, especially over the years 2001-2007 (Fig. 1)

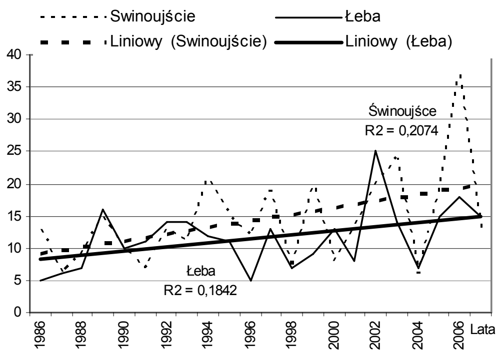

Fig.1 The distribution of the hot days along with with trend over 1986-2007

In the analysed 22 year period the largest number of hot days was recorded in 2002 - from 19 in Kołobrzeg to 25 in Łeba and in 2006 - from 18 in Łeba and Kołobrzeg to 37 in Świnoujście. The largest number of very hot days was observed in 1992 - from 2 in Hel to 8 in Kołobrzeg and Świnoujście, and in 1994 - from 4 in Hel to 9 in Łeba. The vicinity of the sea and periodical sea breezes cause that the maximum temperature in hot days does not constitute much inconvenience during the sunbathing. Only just very hot days, during which the maximum temperature reached 38°C (Kołobrzeg 10.08.1992), along with intense irradiation constitute a great discomfort and even a threat to health..

Multiannual maximum mean temperatures in hot days ranged from 30.8°C in Hel to 32.1°C in Kołobrzeg, showing no distinct direction of changes. Moving along the coast from the west to the south, the number of hot days decreases in the warm half of the year, on average, from 14.5 in Świnoujście to 10.7 in Hel and that of very hot days - from 3.0 to 0.5, respectively. The largest stabilization of the number of hot days is recorded in the region of Kołobrzeg (coefficient of variation 30.6%), and the smallest in Hel (56.8%). In the coastal zone large differences of mean number of hot days is noticed between the seashore line and the adjacent area, which is illustrated by the values in Kołobrzeg – 12.1 and in Koszalin (situated about 15 km from the shore) – 17.7 days.

In the analysed period of 1986-2007 there is, apart from Hel, a negative linear trend of the number of cool days, statistically significant only in Świnoujście and Ustka (Fig. 2).

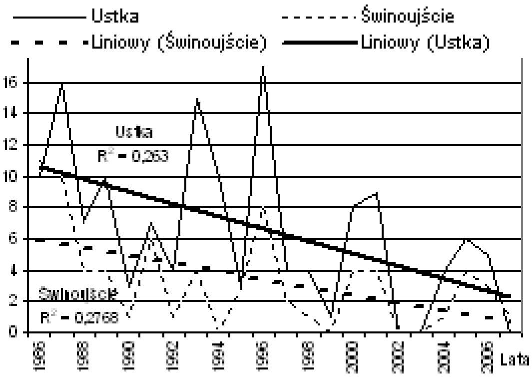

Fig. 2 The distribution of the cool days along with the trend over the years 1986-2007

Cool days (t_{max} <15°C) during summer (June - August) do not constitute much inconvenience for the recreation in the coastal zone as their share in the general number of days varies from 2.8% in Hel and 3.3% in Świnoujście to 5.6% in Łeba and 6.5% in Ustka. Nevertheless, the number of days in individual years may reach 20%, mainly in June. In comparison with hot days, variability of the number of cool days is much larger as it ranges from 68.7% in Łeba to 96.2% Świnoujście, decreasing in the coastal zone from the west to the east

4. Conclusions

- In the zone of the Polish coast of the Baltic Sea the number of hot days increased statistically significantly (t_{max} >25°C) in the warm half of the year over 1986 - 2007, and the number of very hot days (t_{max} >30°C) did not show any significant direction of changes.
- As far as cool days (t_{max} <15°C) during the Summer period (June - September) are considered, a negative trend, statistically significant (α = 0.05) was only recorded in Świnoujście and Ustka.
- Large variability is characteristic of biothermal conditions in the coastal zone, which may cause hindrance in planning various plans of recreation.
- Mainly very hot days decide about inconvenience of recreation conditions on the coast. They occur sporadically in the warm half of year.

The study carried out within the frame of the research project PZB-KBN-086/PO4/2003

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The weather generator: A tool for modelling agricultural and socio-economic responses to future climate

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1. Introduction

One of the key problems of future agriculture is the impact of climate change on crop production (Rabbinge and van Diepen, 2000). Particularly, a decision support systems for adaptation, including change of crops, cultivars, zonation, nutrient management, agricultural systems and irrigation strategy, are constructed in the form shown in schema below (Fischer et al., 2005; Reilly and Schimmelpfennig, 1999).

Climatology characteristics of region	**Climate change scenario**
↓	↓

Weather generator
↓
Synthetic meteorological data
↓
Weather-crop model
↓
Socio-Economical evaluation of crop production
↓
Decision support system for adaptation options

All of the considered support systems work based on mathematical, agricultural or economical models; and they use/implement, as a basic component, weather-crop relations and weather generators – tools which produce future climate data – requested as an input to crop models.
Weather data, particularly daily data of solar radiation, maximum and minimum temperature, and total precipitation are most often required (Richardson, 1985; Hunt et al., 1998) and use in agronomic simulation models. In case of future climate or new environmental conditions there are no required data and records of daily data are not available.

2. Methodology

Daily records of data are simulated by means of general climate information. Weather generators like many environmental statistical models, use Markov chains to determine occurrence of wet/dry days, and gamma or exponential probability distribution for amount of rainfall. Daily values of solar radiation, temperature maximum and minimum are considered as a weakly stationary process and generated by general linear model (GLM). Depending on location of future application more studies were related to choosing an appropriate probability distribution for each climate variable (Hayhoe, 2000; Wilks, 1992).

A WGENK model - modification of the well-known WGEN, weather generator of Richardson (1985) generates daily values of precipitation (P), solar radiation (SR), maximum (T_{max}) and minimum temperature (T_{min}). The occurrence of precipitation has an influence on the solar radiation and the temperature for a day by determining a status (wet or dry day) and independently generating solar radiation and temperature for a given status day. The model preserves the dependence in time, and the seasonal characteristics for locations (Richardson, 1985).
Precipitation is generated by means of the first-order Markov chain to determine occurrence of wet/dry days, and then two-parameter gamma distribution for the amount of rainfall (Bruhn et al., 1980; Larson and Pense, 1982). The transition probabilities and α parameter of Γ distribution are continuous during the year for a given location owing to the application a trigonometric polynomial function (Kuchar, 2004):

3. Data

Evaluation of WGENK model for the needs of decision support systems were obtained for five first order Institute of Meteorology and Water Resources (IMGW) stations located in Southwest of Poland. Stations were selected so that there would be no data gaps. Daily data of SR solar radiation ($MJm^{-2}day^{-1}$), maximum and minimum temperature (^{o}C), and total precipitation (mm) was collected for the twenty years period. In a few cases missing solar radiation data were estimated based on sunshine hours or cloudiness according to Hunt et al. (Hunt et al., 1988).

4. Results

The WGENK weather generator was examined by comparison of observed climatology vs. climatology computed based on generated data from WGENK model (Kuchar, 2004).
The above evaluation was made by means of the data from meteorological stations and generated by model 300-year data series for each station. For all data, the values of means, variances and correlations in different time period as annual, seasons and monthly were computed and evaluated by relative differences in form: abs(observed - estimated)·100% /observed as well as (for rainfall sum) absolute differences between observed and generated parameters.
Data generated by WGENK method has shown low errors for all means, and variances of solar radiation and both temperatures.
To obtain good fitting of rainfall sum and variance of rainfall by the model, WGENK procedure introduces annual courses of transition probabilities, α parameter of Γ distribution, variables correlation described by trigonometric polynomial approximation and β parameter calibration. Time series of transitions probability and α parameter are smoothed by moving average (five points on either side of the target) and fitted by trigonometric polynomial, and calibrated by w_t weights.
This approach give absolute errors of total precipitation from 1.8 to 3.0 mm depend on considered time period (for standard deviation up to 7.2 mm),
and relative error up to 3.8% for sums and up to 10.6% for standard deviations, depending on considered period. The best results were obtained for longer periods: as year and season while poorly for monthly periods.
The same technique (trigonometric approach) is used in WGENK model to fit a seasonal correlation (Kuchar, 2004). Each correlation are smoothed by 11-day moving window before function fitting. Approach used for annual

course of correlations were statistically examined (at 0.05 level) and accepted in 95% for all 240 computed tests. For the annual period, highest average error was observed for cross correlations (equal to 0.05). In these cases the number of significant different correlations between observed and generated data was 6.0%.

Low errors are also observed for the season periods. This fact is well shown by absolute model error, but first of all shown by percentage of statistically different (at alpha 0.05) tests. The highest percentage of significant different values of correlation is 2.5%.

The evidence of effectiveness of method is correlation fitting for monthly periods. For this period the biggest absolute error is observed for cross correlation (0.05). Percentage of significant different correlations are observed for lag-cross correlation (0.9), while 0% for cross correlation.

From the point of view of type of correlation the best estimation was obtained for cross, while most deficient for lag correlations.

5. Conclusion

A WGENK weather generator, tested for weather data from five Meteorological Station (Southwest Poland) showed low errors for means and variances of generated data and accepted errors for lag, cross, and cross-lag correlation. Computed tests have shown good fitting of annual seasonality of transition probability, and Gamma probability distribution of total precipitation.

The method proved good possible applicability in describing process: climate change – environment – economy. production – agricultural economy.

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Detailed assessment of climate variability of the Baltic Sea for the period 1950/70-2008

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1. Introduction

The warming trend for the entire globe (1861-2002) is 0.05°C/decade. A specific warming period started around 1980 and continued at least until 2006. The temperature increase of that period is about 1°C (0.4 °C/decade). This trend is equally well evident for many areas on the globe, especially on the northern hemisphere in observations and climate simulations (IPCC 2007: WG1 AR4). Consequently, this warming appeared also for the Baltic Sea catchment. From 1960 to 1980 the air temperature for the catchment was close or slightly below the long-term mean with respect to the period 1871-2004, only between 1965-1975 the temperature was slightly above the mean. Then with the beginning of the 1980s the annual mean temperature increased by about 1°C until 2004.

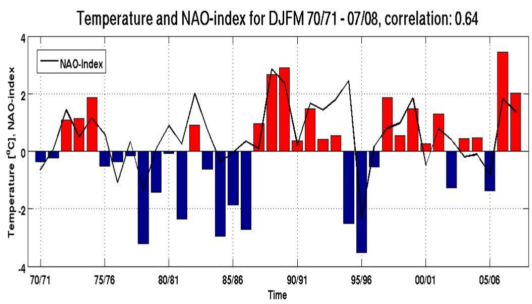


Figure 1. Winter air temperature anomaly (DJFM) at Kiel Lighthouse derived from SMHI-meteorological data base for the period 1970-2008 and winter NAO-index.

A similar warming trend could be observed for the SST of the Baltic Sea (Siegel et al. 2006; MacKenzie and Schiedek 2007). Since 1985, summer SSTs have increased at nearly triple the global warming trend, and for the period 1985-2002 summer SSTs have risen by 1.4°C, 2-5 times faster than in any other season. Even the annual mean water temperatures averaged spatially and vertically for the deep basins of the Baltic Sea show similar trends (Hinrichsen et al. 2007). Figure 1 shows the winter air temperature anomaly at Kiel Lighthouse for the period 1970-2008 based on the SMHI-meteorological data base. The number of anomalous warm winters has strongly increased for the period 1988-2008. The winter 2006/07 was about 3.5°C warmer than the seasonal mean over the period 1970-2008. The winters 2006/07 and 2007/08 were not only mild in the south-western Baltic area. The maximum sea ice extent in these years was extraordinarily small: for 2006/07 it was 139,000 km², and for 2007/08 a new low ice record was document, the ice cover being only about 49,000 km² which is the smallest since 1720 (Vainio and Isemer, 2008).

2. Methods and concepts

As climate, to a large extent, controls patterns of water circulation and biophysical aspects relevant for biological production, such as the vertical distribution of temperature and salinity, alterations in climate may severely impact the trophic structure and functioning of marine food webs. Since the mid-1980s an acceleration of climate warming has occurred which agrees remarkably well with a regime shift in the pelagic food webs (Hinrichsen, et al. 2007). To answer which are the processes linking changes in the marine environment and climate variability it is essential to investigate all components of the climate system. This will be performed by a detailed analysis of about 2 decades-periods before and after the regime shift.

Most of the studies of climate change in the Baltic Sea area have been restricted to the analysis of temperature records. The detailed analysis of changes in variability of atmospheric heat, radiation and momentum fluxes and their impact on the Baltic Sea has not been studied in detail. Her we will provide a detailed assessment of the variability of atmospheric variables and the corresponding response of the Baltic Sea including temperature, salinity and circulation for different time slices seasonally resolved within the period 1970-2008. NCEP/NCAR re-analysis data are available for the northern hemisphere for the period 1948-2008. However, NCEP/NCAR re-analysis data are only poorly resolved (2.5x2.5°, 6 hours) for the Baltic Sea area. Thus, the approach is to use additionally atmospheric data from the SMHI meteorological data base (1x1°, 3 hours, 1970-2008) together with COADS-data (at present 1949-2004), ICES Oceanographic data, IFM-GEOMAR atmospheric and oceanographic measurements (1987-2008) and BSH SSTs (1990-2008).

The main idea is to investigate in detail the climate variability of the Baltic Sea area as a whole and for the different sub-basins to assess the regional difference in response to the large scale atmospheric forcing.

3. Results

We used statistical analysis including basic and higher order statistics to discriminate the climatological conditions between different time slices and identify significant changes in atmospheric and oceanic variables.

As one example of our comprehensive analysis, Figure 2 shows the wavelet analysis of air temperature at the position of Kiel Lighthouse and NAO DJFM-winter indices (Figure 1). Interesting is the common structure of the wavelet analysis for temperature and NAO which reflects the high correlation between them. For the periods 1970-1987 and 1988-2008 there is also a change in the spectral characteristics of both temperature and NAO winter index. After 1985, higher variability occur at periods of about 2.5 and 5 years. Before 1985 highest variability was concentrated at a period of about eight years which slightly shifted to longer periods.

Additionally to the changes in temperature there is also a change in prevailing winds for the periods under

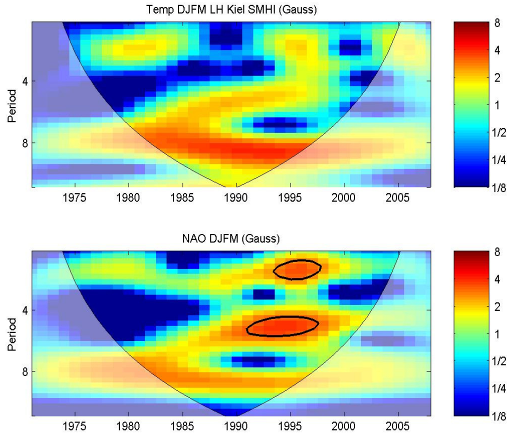


Figure 2. Wavelet analysis of air temperature at Kiel lighthouse and NAO DJFM winter indices. The thick black contour designates the 5% significance level against red noise and the cone of influence where edge effects might distort the picture is shown in lighter shade.

consideration. Figure 3 shows the decrease in frequency of wind from westerly directions for autumn (SON) and an increase for winter (DJF). This shift in wind directions is associated also with a decrease of strong wind events during autumn and a corresponding increase in winter.

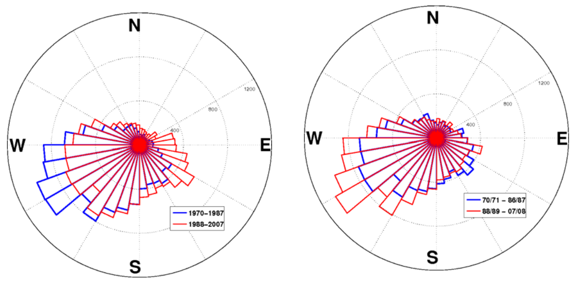
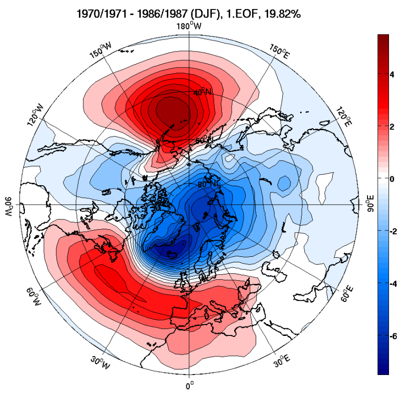


Figure 3. Frequency of wind events for autumn SON (left) and winter DJF (right) for the periods 1970-1987 (blue) and 1988-2008 (red).



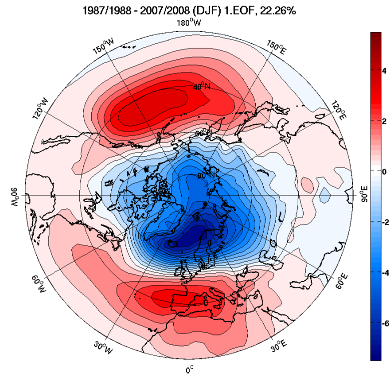


Figure 4. First EOF of MSLP data for DJF calculated from NCEP/NCAR reanalysis data for the period 1970-1987 and 1988-2008.

From NCEP/NCAR reanalysis MSLP data, we calculated the first EOF for DJF for both periods (Fig. 4). Comparing the first with the second period reveals an intensification of the NAO/AO pattern and a slight shift to the east of the centers of action.

Hilmer and Jung (2000) observed a similar shift of the NAO pattern to the east when comparing the periods 1958-1977 and 1978-1997. Cassou et al. (2004) explained the shift by the asymmetry of the NAO pattern. For positve phases the NAO is located more easterly than for negative phases.

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The Fahrenheit scale and three hundred years of thermometry over the Baltic Sea

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1. Three hundred years of thermometry

Year 2009 is the three hundredth anniversary of building the first commonly used thermometric scale by Daniel Gabriel Fahrenheit. Comparable thermometry started in the City of Gdańsk, at the southern Baltic Sea coast, in winter 1708-09, when Fahrenheit (1686-1736) conducted extended experimental investigations and finally successfully calibrated the first precise thermometric scale.

2. Challenge of thermometric calibration

The original instrument constructed by Fahrenheit used alcohol as the liquid medium expanding its volume with increasing temperature in a closed glass capillary tube, connected to a large container filed with alcohol (Middleton, 1966). Closing the system from outside conditions was a significant technical innovation since finally the atmospheric pressure changes did not affected the instrument and there was no evaporation of alcohol from the system. However, proper calibration of the instrument was very difficult and challenging since 300 years ago the documented knowledge and perception of temperature changes was very limited. To find a reasonable calibration procedure Fahrenheit used his own experimental approaches. These included measurements conducted during winter time in City of Gdańsk and systematic records of human body temperature. Based on the experiments, he used two distinctly different temperature readings; the lowest air temperature recorded in Gdańsk during winter 1708/09, and as the highest point, the human body temperature measured by a thermometer held in the mouth or under the armpit. Both readings were considered as stabile and useful marks, thus provided calibration points for the instrument's scale. As a result, the obtained distinct points were taken as the minimum and the maximum temperature for scaling the capillary tube into 96 intervals. From the time when Fahrenheit's calibration was completed, comparing temperature data became possible. One may for example compare the first air temperature recorded during the coolest day in winter 1708/09 in Gdańsk, which was 0 ^{o}F; that is -17.8 ^{o}C with the lowest air temperature recorded in Gdańsk in winter 2008/09, which showed 8.2 ^{o}F; that is -13.2 ^{o}C (the mentioned temperature for 2008/09 was recorded at the Measuring Station (ARMAAG, 2009) located in the centre of Gdańsk, in January 5 of 2009, at 2 AM. The comparison of both records indicate that the lowest temperature in Gdańsk of 2008/09 was 4.6 ^{o}C higher than that precisely measured for the first time in Gdańsk 300 years ago. Although the two compared records are not representative for long-term climate records, nevertheless it indicates the overall significant warming of the Gdańsk region. The same tendency is confirmed based on long-term air temperature records obtained in the area of Gdańsk as well as all other meteorology stations located along the southern Baltic Sea coast, e.g. Walczakiewicz et al., (2009).

3. Grounding new scientific disciplines

It is worth mentioning that the Fahrenheit scale as well as instruments that he produced provided a base for extended comparable investigation of temperature distribution in the Atmosphere, Ocean and Lithosphere. That is why year 1709 can be considered as important year in modern science, when comparable thermometry had its beginning. This event was the ground for a number of related scientific disciplines, which base on thermometry e.g. meteorology, climatology and oceanography. These disciplines accommodated thermometry as the most important tool providing knowledge about basic processes on the Earth.

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Precipitation changes on the Polish coast of the Baltic Sea (1954-2003) caused by the intensity of westerlies over Europe

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1. Introduction

The main aim of the study is an analysis of trends in pluvial conditions on the Polish sea coast. The study details the changes in total precipitation, frequency of days with precipitation and relations between precipitation in particular seasons described a pluvial continentalism on several weather stations. The atmospheric circulation is a major factor shaping both short- and long-term fluctuations of precipitation, therefore links of changes in pluvial conditions to trends in large-scale atmospheric circulation (especially the intensity of westerlies) were also analyzed .

2. Data and methods

Mean daily total precipitations from the period 1954-2003 were used. The data from the following weather stations were utilized: Szczecin, Świnoujście, Koszalin, Łeba, Hel, Gdynia and Elbląg, from published and unpublished materials of the Institute of Meteorology and Water Management. An analysis of linear trends of sums and the frequency of precipitation was carried out. The statistical significance of the coefficients obtained was determined at the 0,05 level.

Circulation conditions were defined by measures of zonal circulation intensity - Zonal Index (referred by Rossby as the difference of pressure between 35^o and 65^{o}N) and index of North Atlantic Oscillation.

The relationship between variability of precipitation and the circulation were determined by total precipitation, numbers of days with precipitation and annual courses of precipitation in particular circulation epochs, ie. periods of time when definite macroforms of the circulation (connected with the zonal flow) prevail over Europe and the entire Northern Hemisphere. Epochs were classified by Degirmendžić, Kożuchowski and Wibig (2000) for the period 1901- 1998. Testing of the significance of differences between total precipitation and the number of days with precipitation in particular circulation epochs was performed with the t Student test.

The variability of pluvial conditions and a link between precipitation and the intensity of westerlies (a large-scale circulation) were determined among others by difference-integral curves (Kożuchowski, 1985) - effects of cumulated of relative anomaly of the variable.

3. Trends in precipitation

In the period 1954-2003 a significant increase occurred in total precipitation for March in Szczecin, Koszalin, Łeba and Elbląg (Tab. 1). Over 50 years monthly precipitation sums increased there by about 20mm. The greatest positive trend occurred in Koszalin (above 30mm) which is connected with relatively high precipitations at this station. The high value of this increase is certain but on the other hand, the coefficient of determination attains a value of only 0,16. The significant upward trend of the monthly precipitation total (25mm during defined period) occurred in May in Gdynia,also. Table 1 shows linear trends of monthly total precipitation in March from weather stations where a significant trend was observed.

Table 1. Linear trends of total precipitation in March (1954-2003)

	a	r2	dR
Szczecin	0,43	0,10	21,39
Koszalin	0,63	0,16	31,49
Łeba	0,36	0,09	17,80
Elbląg	0,44	0,18	22,05

a - regression coefficient
r2 - coefficient of determination
dR - increase of prec. totals[mm] during 50 years

Analysis of ratios of total summer precipitation to winter totals and of spring to autumn totals showed significant changes in Elbląg only (Table 2).

Table 2. Linear trends of seasonal total precipitation and ratios of summer to winter total precipitation (s/w) and spring to autumn totals (s/a)(1954-2003)

		spring	summer	autumn	winter	year	s/w	s/a
Szczecin	a	0,22	-0,29	-0,06	0,50	-0,73	0,00	0,00
	r2	0,01	0,01	0,00	0,04	0,01	0,00	0,00
	dR	11,17	-14,38	-3,01	25,07	-36,45	-0,24	0,03
Swinoujście	a	0,09	-0,21	0,26	0,06	-0,84	0,00	0,00
	r2	0,00	0,00	0,00	0,00	0,01	0,00	0,02
	dR	4,37	-10,48	12,79	3,03	-41,97	0,05	-0,21
Koszalin	a	0,55	-0,25	0,02	0,30	-0,79	-0,01	0,00
	r2	0,04	0,00	0,00	0,01	0,00	0,02	0,01
	dR	27,28	-12,72	0,79	15,00	-39,31	-0,45	0,12
Łeba	a	0,26	0,00	1,22	0,48	1,59	-0,02	0,00
	r2	0,01	0,00	0,06	0,03	0,04	0,06	0,03
	dR	12,89	-0,07	60,89	23,94	79,45	-0,76	-0,17
Hel	a	0,48	-0,18	0,38	0,12	-0,69	-0,01	0,00
	r2	0,04	0,01	0,01	0,00	0,01	0,02	0,00
	dR	23,81	-9,21	19,17	6,20	-34,59	-0,42	0,07
Gdynia	a	0,61	0,58	0,46	-0,31	0,33	0,00	0,00
	r2	0,06	0,02	0,02	0,02	0,00	0,00	0,00
	dR	30,29	28,77	23,17	-15,70	16,26	0,21	0,06
Elbląg	a	0,48	-0,79	0,16	**<u>0,74</u>**	-0,38	**<u>-0,02</u>**	0,00
	r2	0,03	0,02	0,01	**<u>0,08</u>**	0,00	**<u>0,10</u>**	0,01
	dR	23,95	-39,68	8,02	36,91	-19,15	-1,04	0,07

a - regression coefficient
r2 - coefficient of determination
dR - increase of prec. totals [mm] or value of quotient during 50 years
bolded and underlined coefficients are those significant at p=0,05

A decreasing tendency of a ratio of total summer to winter precipitation in Elbląg is related to the relatively high upward trend of winter sums and the weak decrease that occurred in summer sums (not proved to be significant). A small increase of oceanic features of precipitation conditions of the eastern part of the Polish sea coast was shown.

Analysis of time series of the precipitation frequency led to the deduction of a decreasing yearly number of days with precipitation in the eastern part of the coast – in Hel, Gdynia and Elbląg (tab. 3), the highest rate of increase occurred in Elbląg (above 30 days during 50 years). The significant upward trend in almost all weather stations in June, in Elbląg in January, March and October and in Koszalin in February was also observed.

Table 3. Linear trends of the number of days with precipitation (1954-2003)

		I	II	III	VI	X	year
Szczecin	a	0,00	0,06	0,08	0,06	0,05	0,16
	r2	0,00	0,03	0,06	0,05	0,03	0,01
	dR	-0,10	2,85	4,05	3,14	2,49	7,76
Świnoujście	a	-0,01	0,04	0,06	0,08	0,03	0,10
	r2	0,00	0,02	0,04	0,07	0,01	0,01
	dR	-0,58	2,20	3,19	4,13	1,49	5,10
Koszalin	a	0,02	**0,09**	0,06	**0,09**	0,06	0,35
	r2	0,00	**0,08**	0,03	**0,08**	0,04	0,06
	dR	0,88	4,57	3,12	4,32	3,15	17,52
Łeba	a	-0,01	0,03	0,05	**0,10**	0,06	0,17
	r2	0,00	0,01	0,03	**0,12**	0,03	0,02
	dR	-0,66	1,64	2,54	4,89	2,87	8,74
Hel	a	0,03	0,02	0,07	**0,12**	0,08	**0,39**
	r2	0,01	0,00	0,06	**0,14**	0,06	**0,09**
	dR	1,47	0,93	3,73	5,75	4,14	19,47
Gdynia	a	0,03	0,04	0,08	**0,11**	0,08	**0,40**
	r2	0,01	0,01	0,07	**0,14**	0,06	**0,08**
	dR	1,54	1,78	3,89	5,47	4,14	20,00
Elbląg	a	**0,11**	0,05	**0,10**	**0,09**	**0,11**	**0,60**
	r2	**0,12**	0,03	**0,09**	**0,09**	**0,10**	**0,18**
	dR	5,34	2,73	5,11	4,30	5,61	30,24

a - regression coefficient
r2 - coefficient of determination
dR - increase of number of days with precipitation during 50 years
bolded and underlined coefficients are those significant at p=0,05

4. Circulation impact on precipitation

An example of a difference-integral of the number of precipitation days (Fig. 1) showed an evident relation to a variability of a large-scale circulation and is presented below. During the period of weak zonal circulation (1957-1970) the downward trend of cumulated of the relative anomaly of the number of precipitation days is observed and during the epoch of the strongest zonal circulation prevailed (1987-1998) the upward trend is observed.

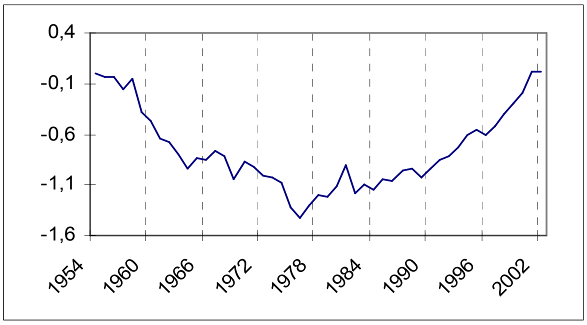

Figure 1. Difference–integral curve of the number of days with precipitation in Elbląg.

5. Discussion and concluding remarks

Räisänen and Joelsson (2001) demonstrated an increase of the wet-day frequency in northern and northeastern Europe and a decrease of its frequency in southern and southwestern parts of the continent. The southern Baltic region is situated between these two regions. The present paper has shown a similarity? of the eastern Polish sea-coast to the former (Tab. 3) but the changes are not major. Yearly, seasonal and monthly total precipitations have been almost invariable, except for a positive trend in March. The upward trend in March total precipitation on the Polish coast was shown also in the climate trends atlas by Schönwiese and Rapp (1997).

The analysis (not presented in this abstract) demonstrated a frequent occurrence of atmospheric precipitation on days with western circulation. The air mass advection from the east was accompanied by less frequent, but more intense precipitation. The relationship between pluvial conditions on the Polish sea-coast and the trend of intensity of westerlies is not too strong in contrast to a very strong positive influence in the northern part of Europe (Hurrell, 1995; Busuioc et al, 2001) or a negative one in the southern Europe (Tomozeiu et al, 2005; Türke, Erlat, 2005)

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Changes of elements of water balance and their forecast against global climate fluctuation

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1. Data and methods

Materials of stationary hydrological and climatic supervision by the hydro-meteorological centre of the Ministry of natural resources and the environment of the Republic of Belarus were used for an estimate of transformation of water parameters of the rivers caused by climatic fluctuations and anthropogenic influences.

Water-balance investigations of river basins are executed with a hydrology-climatic calculation method developed by V.S. Mezentsev (1980, 1986) based on the joint solution of the equations of water and heat-and-power balances.

The equation of water balance of a river basin for a certain time interval looks like:

$$Y_K(I) = H(I) - Z(I)\,, (1)$$

where Y_K (I) – a total climatic drain, mm; H (I) – total resources of humidifying, mm; Z (I) – total evaporation, mm; I – an averaging interval.

Total evaporation can be calculated:

$$Z(I) = Z_m(I)\left[1+\left(\frac{\dfrac{Z_m(I)}{W_{HB}}+V(I)^{1-r(I)}}{\dfrac{X(I)+g(I)}{W_{HB}}+V(I)}\right)^{n(I)}\right]^{-\frac{1}{n(I)}}, (2)$$

where $Z_m(I)$ – the greatest possible total evaporation, mm; W_{HB} – the least moisture capacity of soil, mm; $V(I)=\dfrac{W(I)}{W_{HB}}$ – relative soil humidity at the beginning of the reference period; X (I) – sum of an atmospheric precipitation, mm; g (I) – a soil component of water balance, mm; r (I) – parameter depending on water-physical properties and mechanical structure of the soil; n (I) – parameter considering physiographic conditions of a drain.

Relative humidity of soil at the end of the reference period is determined from relations:

$$V(I+1) = V(I)\cdot\left(\frac{V_{cp}(I)}{V(I)}\right)^{r(I)}, (3)$$

$$V_{cp}(I) = \left(\frac{\dfrac{X(I)+g(I)}{W_{HB}}+V(I)}{\dfrac{Z_m(I)}{W_{HB}}+V(I)^{1-r(I)}}\right)^{\frac{1}{r(I)}}, (4)$$

The greatest possible total evaporation can be estimated by the procedure described by Volchek A.A. (1986). Total resources of humidifying are defined as follows:

$$H(I) = X(I) + W_{HB}(V(I) - V(I+1))\,, (5)$$

The solution of combined equations (1) – (5) is carried out by iteration procedure until the value of relative soil humidity at the beginning of a reference interval is equal to the value of the relative humidity at the end of the last interval. The initial value of humidity is considered equal to the value of the lowest moisture capacity, i.e. $W(1) = W_{HB}$, from which $V(1) = 1$. Convergence of the outcome of the hydrology-climatic calculation method is reached already on the fourth step of calculation.

The climatic drain value is updated by means of coefficients considering the influence of various factors on formation of channel flow, i.e.

$$Y_P(I) = k(I)\cdot Y_K(I)\,, (6)$$

where Y_P (I) – total channel flow, mm; k (I) – the coefficient considering hydrographic characteristics of a river basin.

2. Analysis of the results

The hydrology-climatic calculations method is realized in the computer program "Balans". Modeling of water balance of the river in question is carried out in two stages: adjustment of the model and modeling.

In the first stage it is necessary to set co-ordinates of the centre of gravity of the basin of the investigated river and the basic hydrographic characteristics of the basin. Then the program selects the river-analogue from the built-in data bank of hydro-meteorological information taking into account similarity of formation of a water mode of the rivers. Further changing parameters W_{HB}, r and n and solution of combined equations (1) – (5) permits adjustment of the model for the river-analogue. The least moisture capacity of soil W_{HB} varying within the limits of 60 to 220 mm, parameter r – 1 to 2.5, parameter n – 2 to 3.4. When the model is adjusting the aim is to reach the greatest conformity of the calculated climatic drain and channel flow of a river-analogue. The first stage ends after the diagrams of climatic drain and channel flow are plotted and the error of modeling is estimated.

The second stage represents direct calculation of the water balance of the river investigated, using the parameters obtained when modeling a drain of the river-analogue. Calculation of elements of the water balance takes features of the river basin considered into account.

For construction of forecasting models on the basis of the hydrology-climatic calculations method the future values of changes of the basic climatic characteristics are necessary. For this purpose we will use earlier obtained values of changes in temperature, atmospheric precipitations and deficiencies of air humidity, resulting in Table 1.

Using these data and the computer program «Balans», the model of a climatic drain of the river Narev (station Nemerzha) is constructed. Possible changes of a climatic drain connected with changes of components of water balance for 2015 are calculated by the model. Figure 1 shows the diagrams of model adjustments to a natural drain of the river Narev (station Nemerzha).

The results of the forecast are present in Table 2, in which the values of a layer of a drain for the modern period and predicted drain layer for the basin of Narev are also resulted.

3. Conclusions

The results of the predicted changes of a layer of a drain on a river Narev basin clearly shows the periods of significant changes of annual distribution of a drain. During the winter period (February) a probable reduction to 25% of a drain is possible, and during the period of summer and autumn mean water redistribution of a drain up to 20% is possible (September →August). In turn, change of an average annual drain is insignificant (0,1 %). The result of possible changes of climatic parameters (warming) will not cause a change of size of annual drain, but there will be a seasonal redistribution of an annual drain.

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Table 1. The Basic climatic characteristics

Belovezhskaya Pushcha													
Month	1	2	3	4	5	6	7	8	9	10	11	12	Year
current values	Air temperature, C^0												
	-2,93	-2,15	1,48	8,07	13,75	16,54	18,67	17,87	12,58	7,67	1,98	-1,90	7,64
	Atmospheric precipitations, mm												
	30,43	33,09	33,02	37,58	54,53	64,13	75,60	70,54	52,47	36,15	39,84	38,70	566,17
	Deficiency of air humidity, mb												
	0,73	0,99	1,82	4,11	6,20	6,53	7,33	6,96	3,74	2,17	0,97	0,66	3,52
forecast values for 2015	Air temperature, C^0												
	-1,55	-0,41	1,98	8,86	13,90	16,93	19,88	18,67	13,49	8,07	2,72	-2,64	8,33
	Atmospheric precipitations, mm												
	26,26	40,93	27,99	34,73	58,98	54,11	85,75	83,61	36,73	41,78	38,71	33,24	562,97
	Deficiency of air humidity, mb												
	0,72	1,01	2,07	4,60	6,52	7,49	8,01	7,85	4,81	2,09	1,03	0,63	3,90

Table 2. Change of a climatic layer of a drain of river Narev (station Nemerzha)

Values	Months												Year
	1	2	3	4	5	6	7	8	9	10	11	12	
Modern, mm	4,38	5,82	21,5	32,9	9,25	4,96	3,25	2,78	1,72	2,78	5,2	3,92	98,5
Predicted (2015), mm	4,68	4,59	21,5	33,1	9,24	4,93	3,28	2,33	2,23	2,81	5,15	4,8	98,6
Relative change of a layer of a drain, %	6,41	-26,8	0,00	0,60	-0,11	-0,61	0,91	-19,3	22,8	1,07	-0,97	18,3	0,10

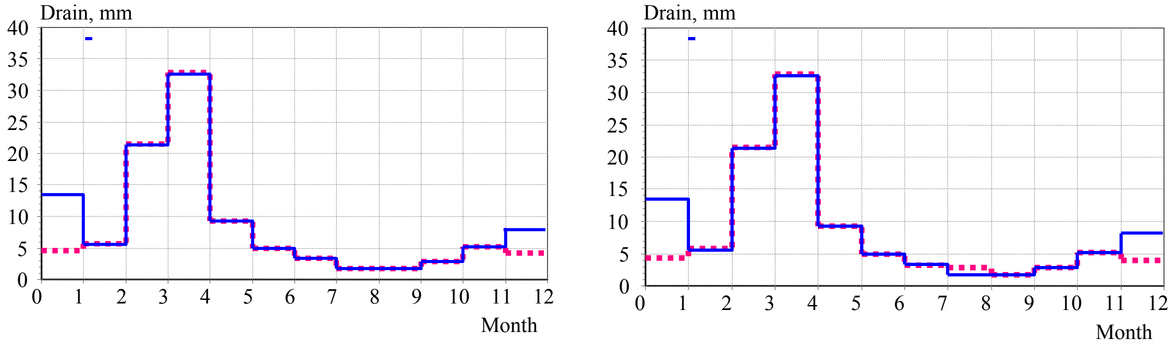

Figure 1. Analytical hydrographer of a layer of a drain of river Narev (station Nemerzha)
a) current values climatic drain; b) predicted values of climatic drain

Variability of droughts in Poland, 1951-2006

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1. Introduction

According to 4th IPCC Report (Christensen et al., 2007) in central Europe, precipitation is likely to increase in winter but decrease in summer. Because all models predict the increase in temperature it means that evaporation is likely to increase also. The decrease in summer precipitation together with increase in evaporation is very likely to lead to reduced summer soil moisture in parts of central Europe (Douville et al., 2002; Wang, 2005). Fifteen recent AOGCM runs indicate that in future warmer climate the summer drynes is likely in mid-latitudes (Bates et al., 2008).
Since the mid 1950s a large drying trend was found over much of Eurasia by Dai et al. (2004) on the basis of PDSI. Van Ulden and van Oldenborgh (2006) found for Germany that increases in winter precipitation were enhanced by increased westerly winds, with decreases in summer precipitation largely due to more easterly and anticyclonic flow. The precipitation in Poland reveals slight increasing tendency in annual total and decreasing trend in ratio of summer to winter precipitation amounts (Kożuchowski, 2004).The number of days with precipitation is increasing (Wibig, 2008). Any changes in heavy precipitation events are not observed (Wibig, 2008). Podstawczyńska (2008) has analyzed the index of dryness by Ped and has found an increasing tendency for dryness in Lodz in Poland for the period 1904-2000. The current paper concentrates on droughts in Poland in the period 1951-2006.

2. Data and methods

The term "drought" expresses a deficiency of fresh water resources from the climatological mean. The disastrous effect of drought is a consequence of precipitation deficit but also the soil moisture at the onset of dry period. Moreover any realistic definition of drought must be site specific. In this paper three drought indices were used: standardized effective precipitation (SEP) index and effective drought index both defined by Byun and Wilhite (1999) and a number of days with precipitation amount lower then 0.5 mm.
To calculate the SEP the effective precipitation (EP) on each day was firstly calculated as a weighted sum of precipitation on 365 preceding days. Weights are described by the series of equations

$$w(365) = 1/365,$$
$$w(n) = w(n+1) + 1/n$$

where n is a number of days before ($n=1,..,365$). Variation of the weights of precipitation to EP along the day pass is presented on Figure 1.
The EP has a strong annual variation, so to make it comparable between stations and within the year the mean (MEP) and standard deviation (ST(EP)) values of EP for each calendar day were calculated and then smoothed with 5-day running mean. In the next step the SEP was calculated as a standardized value of EP

$$SEP=(EP-MEP)/ST(EP).$$

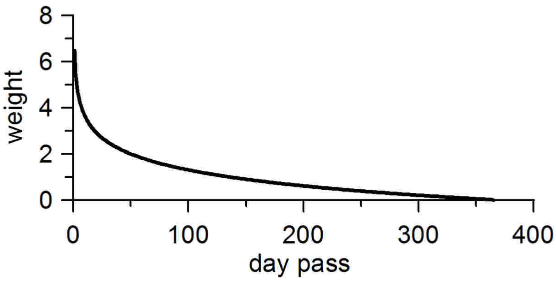

Figure 1. Variation of the weight of precipitation to EP along the day pass.

The EDI was defined as a (EP-MEP)/ST(EP-MEP). It can describe drought condition at specific location because it is independent of climatic characteristics of the location.
The last index is a number of consecutive preceding days with precipitation amount lower than 0.5 mm.
To calculate all these indices daily precipitation totals from 18 Polish meteorological stations located below 1000 m a.s.l. were used. Because the SEP and EDI indices on 1 January 1952 were calculated from the 365-day precipitation of 1951, the indices cover the period 1952-2006.

3. Results

At the beginning the climatology of EP index will be described on the basis of site and calendar day specific mean and standard deviations The annual course of mean effective precipitation for each calendar day show the evident annual cycle with minimum in early spring (April) and maximum in late summer (August). An example for Toruń is shown on Figure 2. Even stronger is the annual cycle of standard deviation of effective precipitation for each calendar day. Here the minimum occurs in late winter and early spring (from February to April) and the highest variability is characteristic for high summer (the second half of July). Figure 3 presents an example for Toruń.

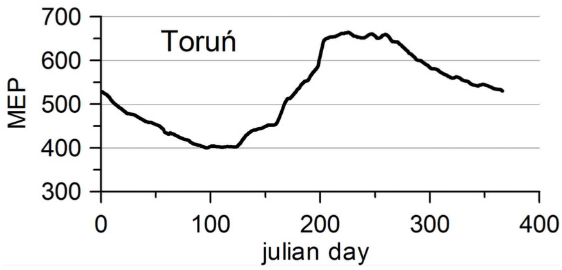

Figure 2. Annual course of mean effective precipitation smoothed by 5-day running mean

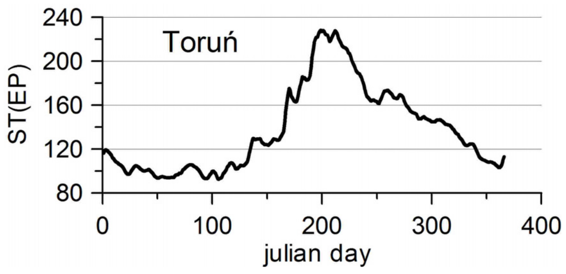

Figure 3. Annual course of standard deviation of effective precipitation smoothed by 5-day running mean

There is no trend in SEP and EDI indices but it is easy to distinguish prolonged periods with high (wetness) and low (dryness) values of both indices. In some cases they appear in the whole country in the other they have regional extent. On this basis it is possible to distinguish coherent regions with similar course of drought events.

4. Acknowledgements

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SST retrieval from MSG/SEVIRI data in the Baltic Sea area

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1. SEVIRI radiometer on MSG

SEVIRI radiometer with 15-minute time resolution is carried onboard Meteosat-8 and Meteosat-9. This time resolution is much better than that of the AVHRR radiometer. Using SEVIRI images enhances observation of some short-time variability of the SST.

2. Field of study

The research examined the Southern Baltic Sea (between 13° E 53° N and 21° E 58° N). The Sea Surface Temperature was calculated using the brightness temperature. Data were collected in 2007, for all seasons.

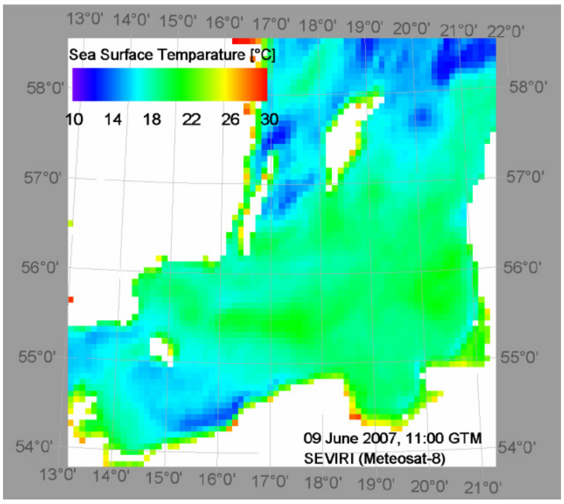

Figure 1. Sea surface temperature [°C] of the southern Baltic Sea, June, 9th ,2007, 11:00 GMT calculated on the basis of SEVIRI data

3. Algorithms

SST was calculated by using two algorithms: Multi-channel sea surface temperature (MCSST) and Non-linear sea surface temperature (NLSST).

$MCSST = aT11 + (b + cS_{\theta})(T11 - T12) + d$
$NLSST = aT11 + (bTclim + cS_{\theta})(T11 - T12) + d$

where: $T11$, $T12$ equals brightness temperature in AVHRR spectral channels 4 and 5 and SEVIRI 9 and 10 respectively; S_{θ} equals satellite zenith angle minus 1.

The coefficients were found by means of regression analysis. SST determined on the basis of AVHRR images was used in the regression analysis instead of *in situ* data. The comparison was performed on a set of paired AVHRR and SEVIRI images spaced no more than 8 minutes apart. The statistical error (standard deviation) is about 1,02°C during the day and 1,15°C at night with negligible overall bias over the field of study.

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Impact of climate change on the long-term variability of the ecological state of the Curonian Lagoon in the Baltic Sea

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1. Introduction

Coastal lagoons are most vulnerable to direct impacts of natural environmental and anthropogenic factors. Due to this sensitivity, the analysis of long-term changes of chemical and biological parameters in lagoons could help to demonstrate the actual relationship between global and local changes, discrimination what is "natural" from what is due to the human action. The Curonian Lagoon is the largest coastal lagoon (area 1584 km^2) of the Baltic Sea separated from the sea by narrow sand spits. The Curonian Lagoon and watershed area are located in density populated district with highly developed industry and agriculture. During the latest decades, significant anthropogenic changes have been observed in the lagoon and watershed area. Ongoing eutrophication is one of the most important problems. Until the late 1980s nutrients loading exceeded by many times the permissible nutrients loading leading to eutrophication of water body with such mean depths. Multiple reductions of nutrients loading from the watershed area in 1990s owing to the economic crisis in the industry and agriculture did not result in considerable improvement of the ecological situation. As compared to 1980s the concentration of total nitrogen and phosphorus in water of the Curonian Lagoon in summer even increased and considerably exceeded the level causing the water body eutrophication. Eutrophication of the Curonian Lagoon affects all trophic levels and primarily the intensity of phytoplankton development. The research of phytoplankton in 1980s-2000s showed that 7 from 10 "hyperblooms" of Cyanobacteria have been observed in the latest decade (Aleksandrov, Dmitrieva, 2006; Olenina, Olenin, 2002). Phytoplankton biomass during these years considerably exceeded the level at which the secondary eutrophication of the water body is observed.

The purpose of this article is to analyze temporal and spatial changes of biomass and production of phytoplankton, chlorophyll and nutrients concentrations and to evaluate the impact of abiotic factors on biological productivity and ecological conditions. In particular, the attempt is made to reveal a probable reason of ongoing eutrophication.

2. Material and methods

The researches were carried out seasonally (from 1991 to 1994) and monthly (from 1995 to 2008) from March to November at 12 standard stations in the Curonian Lagoon. The hydrological, chemical and hydrobiological parameters (water temperature, transparency, nutrients and chlorophyll concentration, species composition, biomass and production of phytoplankton) were assessed in water samples with standard methods (Edler, 1975; ICES, 2004). Long-term data on the water temperature were estimated on the basis of daily observations at standard hydrometeorological station in the Curonian Lagoon (v. Otkrytoye), which were submitted by the Kaliningrad Center for Hydrometeorology and Environment Monitoring.

3. Results and Discussion

In the current period, the Curonian Lagoon may be characterized as a highly eutrophicated water body on the basis of chemical and biological parameters. The species typically abundant in eutrophicated waters prevailed in the phytoplankton (*Aphanizomenon flos-aquae, Microcystis aeruginosa, Actinocyclus normanii, Stephanodiscus hantzchii,* etc) (Aleksandrov and Dmitrieva, 2006). In July-October intensive development of Cyanobacteria leading to the water "blooming" was observed in the Curonian Lagoon. The intensive development of Cyanobacteria was recorded during the entire 70-year period of phytoplankton research. However, in the latest decades phytoplankton biomass increased more than by the order of magnitude – from 34 g/m^3 in 1930s and 12 g/m^3 in 1950s to 120-240 g/m^3 in the mid-1990s (Olenina, 1998). The research of phytoplankton in 1980s-2000s showed that biomass of Cyanobacteria in summer was always at the level of intensive bloom (10-100 g/m^3) and during 10 seasons it reached the hyperbloom state (above 100 g/m^3). It is important to note that during 3 seasons the hyperbloom was observed in the period of the most intensive fertilizers usage in agriculture, while during the remaining blooms occurred during 7 seasons in the post-Soviet period when the input of nutrients from lagoon's watershed areas decreased considerably (Aleksandrov, Dmitrieva, 2006; Olenina, 1998; Olenina, Olenin, 2002).

The occurrence of cyanobacterial blooms resulted from intensive nutrients loading of the Lagoon which occurred up to 1991. During 1980s in the period of maximum fertilizers usage in agriculture and industrial development, the annual input of phosphorus were 3.7-8.5 g/m^2 and that of nitrogen – 60.8-109.6 g/m^2. Reduction of industrial production and fertilizers usage in 1990s resulted in a decrease of the external nutrients loading by 3-4 times to 0.75-2.3 g/m^2 of phosphorus and to 20.8-40.4 g/m^2 of nitrogen per year (Cetkauskaite et al., 2000). As a result it was expected that we would observe a reduction in nutrients concentration in the water and decrease of phytoplankton biomass since 1990s. However, the research showed that neither a decrease of the trophic status nor an improvement of the ecological situation occurred in the Curonian Lagoon. As compared to 1980s, the same high concentration of the total phosphorus and nitrogen are observed, which exceeded the level causing eutrophication of water bodies with such mean depths.

The eutrophication processes and water "blooming" were most pronounced in the southern and central parts of the Curonian Lagoon (75% of the area), where the environmental conditions (high concentrations of nutrients in silt, continuously resuspension into the water column due to shallow depths, absence of the sea water intrusion, slow water exchange, fresh water) were favored Cyanobacterial development. Of the hydrological and hydrochemical conditions, water temperature appears to be the key factor determining the seasonal and long-tern variability of the production and abundance of phytoplankton, and therefore, the level of biological production and the trophic status.

The years with "hyperblooming" of Cyanobacteria coincide with the years of the maximum water warming-up. *Aphanizomenon flos-aquae*, the typical species of highly eutrophicated water bodies, which produces water "blooming" in the Curonian Lagoon, may develop in the wide range of the water temperatures, however, the optimal temperature causing the reproduction "outburst", is observed at water warming-up to 20-22ºC and more (Whitton, 1973). The temperature optimum of nitrogen fixing for these algae is above 20ºC (Waughman, 1977). Consequently, abundance of *Aph. flos-aquae* permanently present in the Curonian Lagoon during year increases rapidly (by 100-1000 times), when the water temperature exceeds 20ºC during several weeks and the weather is warm and windless (Aleksandrov, Dmitrieva, 2006; Olenina, 1998). It is important to note that in the Curonian Lagoon the water temperature exceeds 20ºC only in some "warm" years. Therefore, in these "warm" years *Aph. flos-aquae* formed high biomass in summer and autumn owing to "outburst" reproduction pattern in combination with consumption of ammonia nitrogen and nitrogen fixation and high concentration of phosphorus in the water, which results in "hyperblooms". In the years when water temperature does not reach 20°C "hyper-blooming" of the Curonian Lagoon is not observed. As a consequence, this lagoon is characterized with high variability of the trophic status indices in different years. The mean concentration of total phosphorus for the growing season (April-October) in 1990s-2000s varied within 87-255 μg P/l, total nitrogen – 948-3148 μg N/l, chlorophyll *a* – 45-186 μg/l, phytoplankton biomass – 33-71 g/m^3 and total primary production – 360-620 gC/(m^2·year). The estimates obtained characterize as a hypertrophic water body for most years, according to *Hakanson, Boulion* (2002).

"Hyperblooming" of Cyanobacteria was observed at the mean water temperature above 14.5ºC for the growing season and mean water temperature above 19ºC for summer in the Curonian Lagoon. The mean water temperature during the growing season varied from 12.8 to 15.3 ºC in different years from 1970 to 2004. During the latest decades the trend towards increase number of "warm" years with intensive water warming-up has been observed. The water temperature above 14.5ºC, typical to "hyperblooming" was observed 3 times in 1970s, 4 times in 1980s, 6 times in 1990s, and 6 times in 2000s. The respective trend to increase the mean water warming-up during a decade (from 14.1ºC in 1970s to 14.6 ºC in 2000s) was recorded. The more intensive water warming and the increase in the number of "warm" years in 1990s-2000s created exceptionally favorable conditions for development of Cyanobacteria. Therefore, small fluctuations of the mean summer water warming-up (in 2-3 ºC) resulted in 2-4-fold variations of the trophic status indices and affected considerably the ecological state. The increase in the number of warm years due to the climate warming in the Baltic region is a probable reason of the ongoing eutrophication of the Curonian Lagoon despite of significant reduction of external nutrients loading due to decrease of applying fertilizers and industrial production.

In the years of "hyperblooming" of the Curonian Lagoon, phytoplankton biomass during the months July-October exceeded the level at which the secondary eutrophication of the water body is observed. On the average for the eight years' period (2001-2008) phytoplankton primary production exceeded mineralization of organic matter on 50% in Curonian Lagoon. Such ratio testifies to accumulation of organic matter. It conducts to further eutrophication of the Curonian Lagoon where on greater part of water area slow water exchange is observed. The concentration of ammonia nitrogen may attain 800-1000 μg N/l, BOD_5 – 10-19 mg O_2/l, and pH of water – 9.8-10.0, i.e. maximum permissible concentrations for fishing water bodies have been considerably exceeded. In the coastal zone concentration and decomposition of Cyanobacteria leads to the oxygen deficit (reaching anoxic conditions) and death of fish. These phenomena are of local nature and determined by direction of the wind during the "bloom" period. The years with persistent east winds in summer resulted in the wind-driven aggregation of Cyanobacteria near the western coast, which is the most inhabited and recreationally developed area (the resort city Zelenogradsk and the National Park of Curonian Spit) are most unfavorable. Therefore, the warming up of the water resulting from global climatic changes represents a risk for coastal water bodies, as this stimulates Cyanobacteria "hyperblooms".

4. Conclusions

According to the trophic classification, the Curonian Lagoon may be considered as hypertrophic water body. On the basis of comparison with hydrological and chemical parameters, the main abiotic factors which influence the level of biological production and the trophic state of the Curonian Lagoon are indicated. The water temperature appears the key environmental factor determining the seasonal and long-term variability of chlorophyll and nutrients concentration, phytoplankton biomass and primary production, and therefore, the level of biological production and the trophic status. More intensive summer warming-up of water in 1990s-2000s combined with freshwater conditions, slow-flow velocity and high concentrations of phosphorus creates conditions for "hyperblooms" of Cyanobacteria (*Aphanizomenon flos-aquae, Microcystis aeruginosa*). In the coastal zone periodical accumulation and decomposition of algae result in oxygen deficit and death of fish. Probably, the climate warming in 1990s-2000s causes ongoing eutrophication of the Curonian Lagoon despite of significant reduction of external nutrients loading due to decrease of applying fertilizers and industrial production. Therefore, the warming up of the water resulting from global climatic changes represents a risk for coastal water bodies, as this stimulates the "hyperblooms" of Cyanobacteria.

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Change of climate in the Baltic region for the last thousand years

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This paper is focused on the analysis of regional climate changes. Which are based on the studies different sources of information – from ancient chronicle, folklore, speed of lake sedimentation and rings of trees formation to the usage of instrumental measurement of the near land air temperature. The first stage is characterized as a small climate optimum (VIII – XII centuries). The second (XIII - XVIII centuries) as a small glacial period and third (from the middle of the XIX century to the recent time) as a modern warming time. The warming of the first state beginning in the Baltic Sea area resulted in some shifts of vegetation development. Thus the grape was cultivated in northern Germany and even in Latvia. The thaw on the early middle ages stimulated quite dense population of the ancient ethnoses.

In the small glacial epoch (XIII – XVIII centuries) water balance changed strongly, and it provoked unusual cold move over the ice-bound sea from Sweden to Denmark, and sledge across the Baltic Sea from Latvia to Sweden. There are a lot of stations, which keep long-lived regular meteorological observation.

The second half of the XVIII and the XIX centuries, are characterized by sharp oscillations and low values of annual air temperature. The lowest annual air temperature of air 5°C; in 1786 – 1790 in Vilnius even the lower temperature was registered. The same situation was registered in St.-Petersburg; the annual temperature within the period of 1781 – 1790 was 2.8°C. The lowest annual temperature of air 4.7°C in Warsaw in 1829, the same temperature is registered in 1871 in Koenigsberg-Kaliningrad. At the beginning of the XIX century the coldest annual temperature (1.2 – 1.3°C) was estimated in St.-Petersburg in 1809-1810.

New thaw of a climate began at the end of the XIX century and in the XX century the average annual temperature in Kaliningrad was 7.5°C, in Warsaw – 8.4°C and sometimes 0.7 – 0.8°C above, and the temperature is just the same for the rest of the XIX century. The period from 1988 to 1989 was the warmest as contrasted to the other sections of time series. The highest temperature of air for all the period of instrumental observations was registered in 1989 and 1990. The positive anomaly in Kaliningrad compounded 2°C in 1989, 2.2°C in 1990.

The positive trend of average annual air temperatures was typical also for the period 1990-2002. For example in the central part of Curonian Spit average annual temperature varied from 7.1°C (in 1996) until 10.0°C (in 2000). The absolute maximum in Kaliningrad air temperature 12.6°C, was observed in January 10 2007.

So, the analysis of the climate change history in Baltic Sea area will let us estimate the reasons and possible consequences of the modern thaw more precisely. Change of air temperature vawes of warm and could times this is a cause of instability of meteorological situations and increasing of dangerous atmospheric events.

Analysis of interactions between the level of economic development, industrial production and environmental pollution in Baltic Sea region

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1. The aim of the research

The main goal of the paper is an assessment of relationships between the level of development and the level of industrial production and environmental pollution in countries of the Baltic Sea Region.

2. Methodology, data and expected results

The analysis is conducted by means of some econometric methods i.e. regression models, time series analysis and classification algorithms. The data derive from Eurostat, EEA The Conference Board and Groningen Growth and Development Centre and also National Statistical Offices.

The main variables examined are different kinds of environmental pollution (with sectoral aspects), industrial production and level of economic development measured by GDP per capita.

3. Conclusions

Recommendations for policy-makers in the field of economic activities and environmental issues are formulated on the basis of the results.

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Synchronous regime shifts in Baltic Sea ecosystems: Similarities and dissimilarities in response to climate, nutrients and fisheries

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1. Introduction

Changes in marine ecosystems during the last decade led to severe changes in the community composition and overall ecosystem structure in marine systems (Daskalov et al. 2007, Cury & Shannon 2008, Möllmann et al. 2008). The changes are often induced by changes in environmental factors, such as climate. The Baltic Sea has been recently strongly affected by atmospheric and anthropogenic forcing: Increasing temperatures, a reduction of inflow events, eutrophication and high fishing pressure had severe impacts on ecosystem structure and functioning. The aim of this paper is first to test if the regime shifts which occurred in the Central Baltic (Möllmann et al 2008, Casini et al 2008) are also present in the other major basins of the Baltic Sea, i.e., the Sound, Gulf of Finland, Gulf of Riga, Bothnian Sea and Bay. Secondly, to test which abiotic drivers (climate, nutrients and overfishing) are linked to the regime shifts.

2. Methods

Analysis is based on long-term physical, chemical and biological data (1979-2006) from 7 basins of the Baltic Sea. The final dataset used for this analysis is based on the ICE/HELCOM workgroup on Integrated Assessments of the Baltic Sea (WGIAB, http://www.ices.dk/iceswork/wgdetail.asp?wg=WGIAB). Data have been log-transformed and a Principal Component Analysis (PCA) was performed for each basin. Based on the PC scores, the occurrence of regime shifts is determined using the Sequential Regime Shift Detection Method (STARS: Rodionov, 2004; Rodionov & Overland, 2005). Here a pre-whitening procedure has been used to remove the red noise component of the PC scores. Further, we applied a Generalized Additional Model (GAM) to test the relationship between the main drivers, i.e. salinity, spring and summer temperature, winter phosphorus and nitrogen and fishing pressure, and the PC 1 scores of the different basins. Only the models with the lowest AIC and significant factors are shown for each basin. We conducted an ecosystem assessment for the entire Baltic Sea and main basins, i.e. the Sound, Central Baltic Sea, Gulf of Finland, Gulf of Riga, Bothnian Sea and Bothnian Bay, covering the time period from 1979 to 2006. The assessment is part of the ICES/HELCOM working group of integrated assessments of the Baltic Sea (WGIAB).

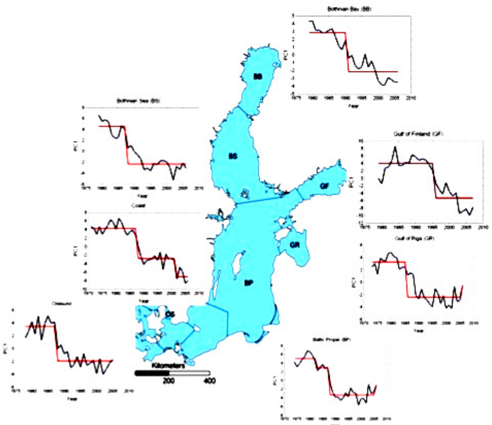

Figure 1. The regime shifts in the different basins in the Baltic Sea.

3. Results and Discussion

Integrated analyses of hydro-climatic, nutrient, phyto- and zooplankton as well as fisheries data covering a period from 1979-2006 showed that the observed' changes were not gradual but rather abrupt affecting multiple trophic levels: In the late eighties quasi-simultaneous regime shifts in various sub-systems of the Baltic Sea were observed (Figure 1, Table 1) due to the abrupt changes in the atmospheric forcing, i.e. North Atlantic Oscillation. Further, we extracted common trends in Baltic ecosystem state indices and identified an overall climate driver and basin-specific combinations of drivers. We found that ecosystem responses following the synchronous shift were considerably different: While in the Central Baltic Sea an alternative stable state was reached characterised by a change from a cod- to a sprat dominated system (Möllmann et al. 2008), other areas showed an increasing importance of top-predators and or nutrients. We thus suggest system-specific chains of mechanisms being important for stabilising or reversing ecosystem states. New statistical early warning methods, which are based on structural detectable changes in the food-web long before the regime shift occurs, i.e. increase in variance, autocorrelation etc., are developed (Carpenter & Brook 2006, Carpenter et al. 2008). Those methods could make an early warning of a coming regime shift possible. This could further prevent future regime shifts if the data are stored in one common database, statistically analysed as early as possible after the sampling, and form the basis for an adaptive and open-to-learning management structure. Only by this approach, we could cope with future changes in climate and unpredictable events to maintain a high resilience in marine ecosystems.

Table 1. Overview of the different regime shifts in the Baltic Sea based on the STARS test on PC1 and PC2.

System	Period covered	RS 1	RS 2	RS 3
Öresund (OS)	1979-2005		1988	1996
Baltic Proper (BP)	1974-2006.	1983	1988	
Gulf of Riga (GR)	1974-2006		1987	1995
G. of Finland (GF)	1979-2007		1991	1996
Bothnian Sea (BS)	1979-2006		1988	1996
Bothnian Bay (BB)	1979-2006		1991	2003
Coast	1971-2006		1988	2002

4. Key findings

a) All basins show clear regime shifts over the whole study period.
b) Coherent climate-induced regime shifts occur around 1988 even so the basins differ largely in their environmental characteristics
c) Other regime shifts are linked to basin-specific drivers, i.e., salinity, nutrients and overfishing.

5. Acknowledgements

The present study is mainly a result of the ICES/HELCOM Working Group on Integrated Assessments of the Baltic Sea (WGIAB). We thank all colleagues involved in the work of the group and those involved in the HELCOM monitoring and data acquisition. Without such continuous monitoring programme such study would not be possible. We further thank the ICES and HELCOM secretariats for their support.

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Quantitative inventory of exhaust gas emission from coastal fishing vessels in Poland

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1. Introduction

Air pollution is a significant environmental problem. Over the past decades, emission control programs, established at the national levels, helped to significantly reduce emissions from land-based sources, many of which now pollute at only a fraction of their prior rates. However, continued industrial growth and the proliferation of reciprocating engines in transport threaten to invalidate these achievements. A number of environmental programs has concentrated on reducing a selection of exhaust gas components. The Marpol 73/78 Convention, established by International Maritime Organization (IMO), regulates worldwide environmental protection of seas. In relation to shipping, the Baltic Sea has been designated as a special environmental area since 19 May 2006. Annex VI to Marpol 73/78 Convention (regulation 14) contains provisions for special "SO_x Emission Control Areas" (SECAs). Various inventory analysis suggests that marine diesel engines are a significant source of: NO_X and SO_x emissions. At the same time, it is believed that marine diesel engines are the most efficient combustion sources for transporting freight globally. Nonetheless, the latest inventories and experimental results identify shipping as a significant factor contributing to climate change *(Endresen et al., 2003)*. Emissions from marine diesel engines tend to be concentrated in specific areas of the country seaside (ports, coastal areas, and rivers), thus local levels of these pollutants can be very high. The tremendous size range of engines used in shipping, from small generators used on-board coastal vessels to large main propulsion engines used on-board ocean-going vessels, suggests a need to institute different emission inventories according to the size and function of the vessel.

2. Emission inventory methodology

The aim of this study is to provide selected information on the amount of current emissions from fishing fleet activity in coastal areas and inland waters in Poland.

Figure 1. Major fishing ports of Polish seacoast.

Figure 1 shows major fishing ports in Poland, while Table 1 contains numbers of small trawlers and fishing boats of Polish fleet. Our main goal was to investigate the proposed emission inventory for specific marine shipping segment. The rough contribution of different fishing vessels and boats to costal emissions were appraised and evaluated. The study concentrates on exhaust emissions from main propulsion diesel engines, which were computed from experimental data.

Table 1. Number of fishing boats in major polish ports *(Borkowski & Myskow, 2008)*

Port name	2004	2006	2007
Władysławowo	101	74	80
Kołobrzeg	101	62	65
Ustka	114	82	86
Hel	31	23	23
Darłowo	67	44	44
Gdynia	21	11	16
Dziwnów	57	27	28
Świnoujście	48	31	33
Łeba	47	35	36
Jastarnia	61	52	53
Others	595	436	448
Total	1243	877	912

Proposed, marine engine exhaust emission inventory, commonly referred to as 'vessel activity based' methodology *(Corbett et al., 2003)*, estimates total ship emissions by using its corresponding engines: exhaust emission, effective load and fuel oil consumed profiles. With this methodology, the fishing fleet is divided into two groups with related activity profiles, presented in Table 2.

Table 2. Number of fishing vessels according to an activity profile

Port name	Fishing boats[1]	Fishing vessels[2]
Władysławowo	19	61
Kołobrzeg	16	49
Ustka	37	49
Hel	11	12
Darłowo	21	23
Gdynia	1	15
Dziwnów	18	10
Świnoujście	24	9
Łeba	17	19
Jastarnia	37	16
Others	432	16

Each vessel group was assigned a representative time spent: trawling (higher engine load), cruising (higher engine load), maneuvering (lower engine load) while in the vicinity of the port. Air contaminant emission factors were determined for the group, reflecting the average engine type and fuel consumed. For the purpose of inventory, essential indirect assumptions were required

[1] Below 12m length
[2] Above 12m length

that ignored considerable variability of individual vessels. Rather than estimating ship and engine load, direct engine power, fuel consumption and exhaust emission measurement obtained, for each vessel studied – see Figure: 2 and 3. Essentially, engine emission calculation involved direct effective power (torque and rotational speed), fuel consumption and the complete exhaust gas composition analysis experimental results. Engine emissions tests were performed on chosen representative fishing vessels, following onboard measuring methods in accordance to IMO NO_x Technical Code (International Maritime Organization, 1998).

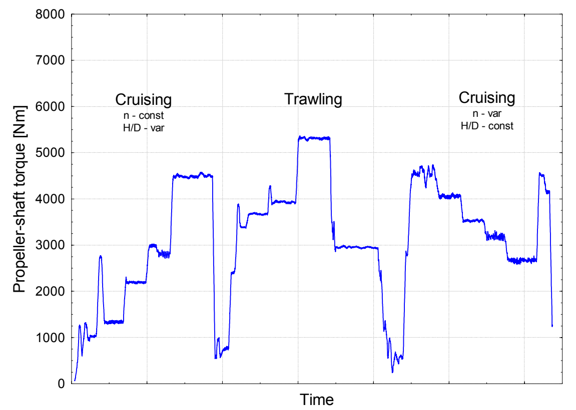

Figure 2. Main engine effective torque profile during operation.

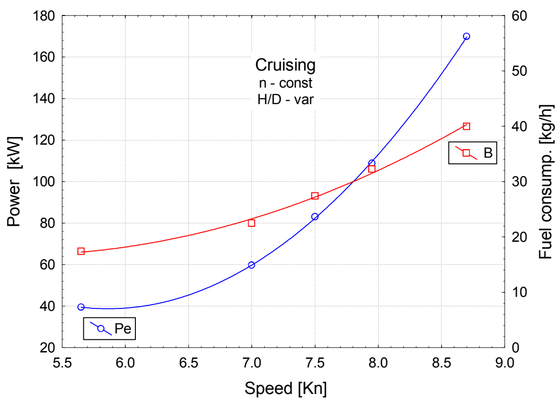

Figure 3. Main engine effective power and fuel oil consumption in cruising mode.

The comprehensive database, covering selected engines in both vessel ranges, provided a listing of all important test data parameters, including:

- raw concentration emission measurements for nitrogen oxide (NO), sulfur dioxide (SO_2), carbon monoxide (CO), carbon dioxide (CO_2), oxygen (O_2), and hydrocarbons (HC),
- test engine load, speed, and volumetric fuel consumption,
- test fuel density and carbon, hydrogen, nitrogen, and sulfur mass fractions,
- ambient test conditions.

Regression analysis of individual data points was utilized to relate emissions to engine load factor. Regression analysis indicates that specific fuel consumption is inversely related to fractional engine load. Based on this behavior, statistical regression structures based on emissions mass by fractional load were investigated as the most promising basis for emission factor algorithms.

3. Results and summary

The analysis presented in this paper shows emission factors for fishing vessels operating around Polish coastline, based on experimental data *(Borkowski & Myskow, 2008)*. The obtained emission factors are expressed in units of engine work (kW-hr) and are dependent on engine load factor – Fig. 4.

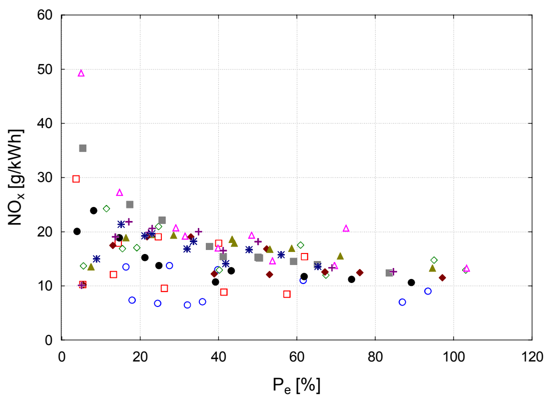

Figure 4. The aggregated NO_x emission factors of fishing vessels operating in coastal region.

The emissions calculations were performed according to chosen vessel types and required the following inputs:

- The number of calls to the port by vessel - type.
- The fishing activity time spent (Figure 4), by vessel - type, in each of characteristic operating modes.

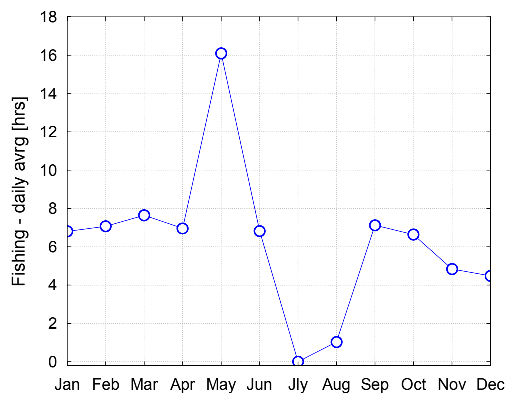

Figure 5. Fishing vessel average time spent at sea (example).

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On the influence of anthropogenic factors and regional climatic changes on the dynamics of the bottom sediments of the Vistula Lagoon

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For the last century the ecosystem of the Vistula Lagoon was subjected to significant transformation under the influence of anthropogenic factors. Regulating the rivers flow, building a new route of marine channel, intensive ship traffic and dredging measures in the channel could not have left uninfluenced the sedimentation and dynamics of the bottom sediments.

Through the comparison of two maps of the bottom sediments, in accordance with F. *Shepard's* classification (1954**),** long-term changes were exposed in the spatial distributing of basic types of sediments. One scheme was made based on materials of investigations during 1959-1965 *Wypych, Nieczaj* (1975), and the second - during 1992-1996 *Chechko* (2008).

After 35 years the most significant changes happened within clayey silt areas, i.e. fine-grained sediments. The area of clayey silt distribution was considerably reduced – from 29 to 20%. Territories, covered by sandy silt, generally reduced from 23 to 17%. Areas, covered by sand, increased from 21 to 29%. Hence, the modern sediment genesis of the Vistula Lagoon is characterized by processes of sediment material redistribution within the limits of the basin, accompanied by the flow of fine-grained materials to the sea *Chubarenko&Chubarenko* (2001).

Predictions of the evolution of sediment distribution for the period of time up until 2100 were based on the results of comparative lithological analysis, on the method of paleogeografical analogies, and have taken into account possible changes of the sea level and river discharges caused by climate fluctuations.

Presently there is no united opinion on the future ocean's level; however, dominating assessment predicts its increase by approximately 0.5 – 0.8 m by the end of the century. According to the mean statistical values of the extrapolations of the sea level increase obtained by MSU (Moscow State University) researchers, the level of the World's Ocean will be raised by 85 ± 47 cm by 2100. The work of Meier and colleagues *Meier et. al*. (2004) examines a scenario in which the level of the ocean rises by 88 cm by 2100. For the Gdansk basin this would mean the increase of the average seasonal value by up to 1 m. At the same time, as a result of possible climatic changes a river flow will diminish in the southern region of the Baltic Sea. *Chubarenko et. al.* (2008).

The predicted increase of the sea level and the reduction of river flow will result in strengthening of the marine influence on processes of sedimentation in the Vistula Lagoon. The possible (without the account of the coast protection measures) breaches of Vistula Spit (located in the village Kosa, northerly of capes Glawnyi and Vysokiy) and formation of additional connections of the lagoon with the sea will augment this influence. Rise in the water level of the lagoon will cause activation of processes leading to destruction of presently stable shore faces of marine mounds and to possible renewal of washing away of the dead waterside terraces. Potentially, the washing out of the bodies of the Vistula Spit and alluvium islands along the Kaliningrad Marine Navigation Canal will also increase. Such changes in lithodynamic processes will cause the deposition of considerable volumes of sandy material into the lagoon. On the other hand, fine-grained components of sediments will be more intensively removed by the currents into the sea. As a result, the increase of sand occupied areas and the reduction of areas with other types of sediments will occur. A region adjacent to the Baltiysk Strait, will suffer the most dramatic changes. A continuous field of sand will be formed at its bottom extending from the strait to the.Cape Severnyi. Moreover, sandy areas will broaden substantially along Vistula Spit, as well as in the Primorskaya Bight. At the same time, the regions of the bay occupied by sandy silt and silts will shrink considerably. In the eastern part of the lagoon silts will be preserved within the depressions of the axial zone, and also within bights, formed by possible submergence of the parts of coastal territory. The least changes will occur in the south-western part of the lagoon; and will be characterized by the reduction (by approximately 25-30%) of clayey silt area and the expansion of coastal sandy deposits.

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Substantiation for climate change at the Lithuanian coast in the south-eastern Baltic

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1. Introduction

Recently society in many countries is concerned about the effect of global climate change. A timely understanding of the possible essential changes not only in the natural environment, but also in human lifestyle and social-economic structures is developing. A detailed research is being made, the scenarios of possible changes, based on long term observations data are created. Recently the effect of global climate change on sea-level rise has drawn widespread interest, as a changing coastline has ecological, economical and social impact in coastal areas of the Europe, Baltic Sea, including the Lithuanian area.

The problem of global sea-level rise is closely linked with the problems to be solved when considering the development of the infrastructure of the sea-side towns, ecosystems, the security of waterfront installations, and seashore erosion.

2. Methods

Relevant observed time series for the Baltic Sea basin in the south-eastern part at the Lithuanian coast from the last centuries were used to investigate climate variations and trends. The analyses of climate variability are based on the Baltic Sea and the Curonian Lagoon meteorological and hydrological monitoring data measured in Lithuania for the past 45 years (1961-2005). The data have been gathered at the Center of Marine Research and from the archives of the Lithuanian Hydrometeorological Service. The study focuses on the long-term changes of the hydro-meteorological conditions in the Baltic Sea.

3. Results and discussion

The results indicate positive trends for air and sea temperature, sea level, and frequencies of westerly wind types since the middle of the 20th century. Negative trends were found for the duration of sea-ice cover, precipitation and frequency of south-easterly wind. The study indicates that the duration of the westerly winds during the winter time has increased. Air temperature has risen by 0.9 ºC, sea surface temperature in the Baltic Sea and in the Curonian Lagoon has risen by 0.6 ºC during the period 1961-2005. The length of the ice season has shortened by one month and wintershave become warmer. A west-to-east air mass transfer has become more frequent.

The results of this study clearly showed a rise of the sea-level on all time scales in the southeast Baltic along the coastal area of Lithuania (Fig. 1). The sea level in the Curonian lagoon has been rising by an average of 3 mm/year^{-1} since 1961. Therefore, statistical mean sea-levels, which are regarded as standard, should be corrected according to increasing trends. This would foster further studies of sea-level variability in the area given the important practical and economical consequences of the potential further rise.

The increased sea-level variation in the study region of the Baltic Sea can probably partly be explained by a global sea-level rise but also by the change in atmospheric circulation. The study results suggest that a rising sea-level, increase in the air and water temperature and a decrease in the ice cover duration are probably related to the changes in atmospheric circulation, and, more specifically, to the changes in wind climate. That is in good agreement with the increasing trends in local stormy weather and in higher intensity of westerly winds, and with the winter NAO index that indicates a change of the atmospheric circulation in the North Atlantic region, including the Baltic Sea area.

Coastal erosion is stimulated by sea level, more frequent cyclones induce storms and hurricanes. Due to more intensive cyclones movement between the 19th and 20th centuries on the Baltic coast, serious damage resulted from strong hurricane winds. A positive >25 m/s wind trend was estimated. During the past few years there were few strong storms and hurricanes that damaged natural, hydro-technical installations and destroyed south-eastern Baltic Sea coast. In the perspective of the sea-level rise the low and sandy seashores of Lithuania, the hydro-technical installations in the port as well as the lowlands of the Nemunas River including the delta region in the central part of the Curonian Lagoon will be strongly affected.

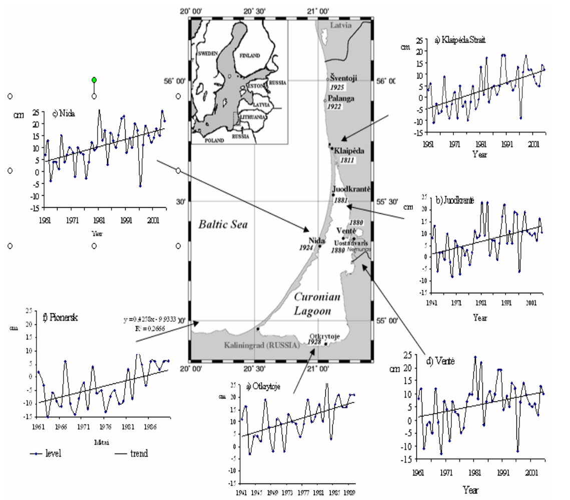

Figure 1. Sea level change in the South-Eastern Baltic along the coastal area (1961-2005).

Global environmental change and urban climate in central European cities

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1. Introduction

Cites are the places where about a half of human population lives. It is expected that this proportion will increase in the next future. Urbanization affects on local climate conditions in different ways and in consequence climate of towns differs from the climate of surrounding rural areas. On the other hand, cities belong to the main hot-spots of the emission of atmospheric pollution including greenhouse gasses and therefore play important role in global environmental change (*Grimmond*, 2007). *Svirejeva-Hopkins et al.* (2004) suggest that more than 90% of anthropogenic carbon emissions are generated in cities. The main purpose of this work is to characterize main feature of urban climate of Central European cites and put them in the perspective of the global environmental change.

2. Factors changing local climate at urban areas

There are many factors leading to alternation of the urban climate. The most important of them are:
- city metabolism – the most striking effect of it is an air pollution which alters radiation conditions by reduction of incoming solar radiation (especially direct solar beam), and intensifies downward longwave radiation (reduce net radiation losses by longwave emission). The air pollution is also a source for increased number of condensation nucleus in urban atmosphere. Other result of city metabolism is anthropogenic heat emission.
- urban geometry – influences of radiation by increasing urban albedo and decreasing longwave losses. In general it intensifies turbulence and turbulent transport but also reduce ventilation in narrow, wind perpendicular, urban street canyons.
- urban fabric and cover – changes thermal properties of the surface (heat conductivity, heat capacity) and alters albedo and emissivity. Impervious materials cause rapid water runoff.

The role of these factors in modification of weather/climate conditions by cites depends on:
- city location which determines large scale climate condition (climatic zone),
- rural surroundings of the city like degree and type of agricultural land use, type of natural vegetation and soil properties, presence of big river or water reservoirs,
- local topography
- actual weather conditions, especially wind speed, cloud cover and stability of the atmosphere,
- season and time of a day,
- city size and density.

3. Singularities of urban climate in the perspective of climatic changes

The best known (*Oke*, 1995) singularity of the urban climate is urban heat island (UHI). Under favor weather conditions the temperature in the city is much higher than at surrounding rural areas. It appears at the temperature file as a warm island in a sea of cold air. UHI is a dynamic phenomenon – the highest urban-rural temperature differences (UHI intensity, $\Delta T_{u\text{-}r}$) are observed at calm, cloudless night (Fig. 1). During the day or under the windy and/or cloudy weather UHI disappears. In fine weather UHI intensity at night can reach 8–10°C or even more – the highest values of urban-rural temperature differences in Polish cites are: >11°C in Łódź, >10°C in Warsaw, 9°C in in Wrocław, 8°C in Cracow. In general the highest $\Delta T_{u\text{-}r}$ is proportional to the logarithm of city population (*Oke*, 1973). This allows to expect even higher values of

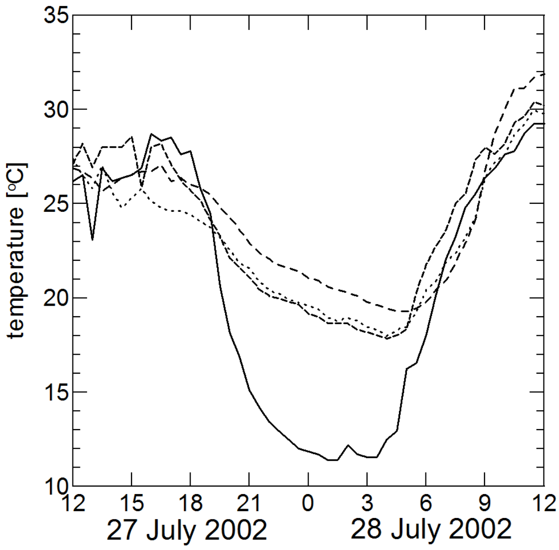

Figure 1. Strong urban heat island episode – nighttime temperature evolution at rural station (solid line) and at three urban station (dashed lines). Łódź, 27/28 July 2002 .

$\Delta T_{u\text{-}r}$ when cities population grown. However, climate change can reduce this effect. UHI is observed mainly in the antycyclonic situation. Wind speed and clouds related with atmospheric lows significantly reduce UHI. Some investigations suggest increase of cyclonic activity in Baltic region (see: *Bärring and Fortuniak*, 2009 for discussion). Thus number of situations with well developed UHI should decrease. On the other hand, even rare UHI episodes could cause significant consequences for a society. Heat waves are one of the potential consequences of global warming which directly affect human health. For example, the heat wave that affected Europe in 2003 claimed more than 35000 lives (*Schar et al.*, 2004). During heat wave episodes the city temperature at night stays a few degrees higher than rural one. As a result temperature in the city can remains above acceptable threshold for a few consecutive days and city population has now nighttime rest form hot temperature. Intensively operating air conditioning produce a large amount of anthropogenic heat and can additionally amplify UHI in such situations. A city influents on the humidity field too. The combined effect of UHI an urban modification of humidity field can cause even stronger total stress for human body during heat wave (*Diaz et al.*, 2002). Moreover, in city the health-damaging effects of high temperatures can be intensified by air pollution (notably ozone and total suspended particulates) further stressing the body's respiratory and circulatory systems (*Souch and Grimmond*, 2004). On the other hand, there are positive aspects of UHI. Increase of the city temperature in winter can reduce energy used for building heating, but opposite effect, increased energy consumption for air conditioning, can be observed in summer. Net influence of both effects on total energy consumption depends on the climatic zone and degree of economical development. Urban heat island reduces stability of the urban atmosphere at night. This can prevent urban atmosphere form high concentration of air pollution emitted by surface sources. But, increased instability of the urban atmosphere together with large amount of condensation nucleus can intensify growth of convective clouds (*Kłysik at al.*, 1990). In the perspective of increased events of heavy precipitations and thunderstorms the city population can be especially affected by these dangerous weather phenomena. It can increase economical losses caused by them and need extra costs for adaptation of urban storm-water drainage. Possible climatic changes which result in increase in convective precipitation and decrease in large scale precipitation alter surface water balance and can lead to water deficit. At urban areas this effect can be more pronounced. Large parts of the cities are covered by impervious materials and majority of rain water is taken off by urban drainage system. During drought periods deficit of soil water content at small lawns can be higher than at rural areas. Deep soil water used by single trees scattered between buildings can be also reduced by urbanization. In result urban green could be even more sensitive for increasing number of dry period than rural one (Fig. 2). En extra water supplied by irrigation system could be needed to mitigate this effect. Possible increased number of days with high wind speed (e.g. *Leckebusch et al.*, 2006) can also make more uncomfortable conditions for city population. In general urbanization reduces mean wind speed, but tunneling of wind between high buildings can generate local wind speed above critical value for human comfort or even for human stability. Moreover, sudden changes in wind speed and wind direction being a result of urban structure have a significant impact on the response of an individual to the strong wind. High gradients of wind speed and direction observed between urban structures can obviously cause danger situations for urban transport and constructions.

4. Conclusions

While predicting climate change and its impacts is still highly uncertain, its negative effects can be amplified at urban areas. Although high developed cites in Central Europe and Baltic region are less vulnerable to potential climate change than cities in low latitudes some effect could have severe socioeconomical consequences. These possible effects could be reduced by mitigation strategies which adopt urban environment to be less vulnerable to climate change. Some of them like increasing of building and road reflectivity by using high reflection paints for roads, buildings and vehicles; improved roof and walls insulations; application of district heating and cooling systems can be applied to the already existing city districts. Other ones like changes in building spacing and building heights, greenroofs and greenwalls or significant increase of greenspaces must be taken into consideration in planning of new parts of city. In the perspective of global environmental change mitigation of negative consequences for city-dwellers should be one of priority in urban planning.

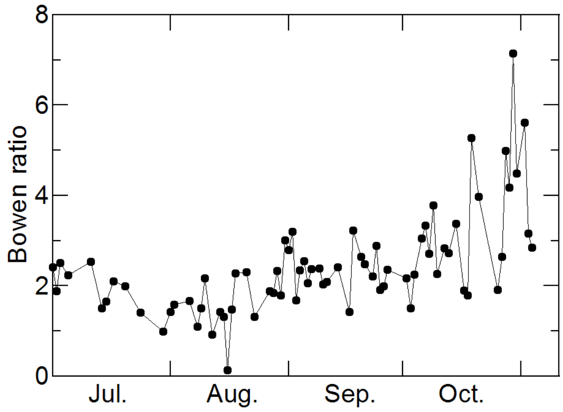

Figure 2. Increasing Bowen ratio during dry period from a typical value for urban site ($\beta \approx 2$) to extremely high one: $\beta > 7$ – values characteristic for semiarid areas (on the base of data from Łódź 2005).

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The application of the exploratory factor analysis in the study of heat power costs determinants in housing resources

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The aim of the paper is to prove the importance of heat insulation of buildings made of precast concrete slabs for the heat consumption in households, its costs and the emission of harmful gases to atmosphere.

In the paper the author will analyse operating the costs spent on supplying heat to households by the Housing Cooperative in Stargard Szczeciński. The Cooperative's housing resources amount to almost one third of the total city housing resources, so the costs incurred there are of great significance for the whole city and its environment.

The variables affecting heat consumption in households (thermoinsulation, the number of residents, the size of a dwelling) in different types of buildings as well as their spatial arrangement will be specified. The examined models will also include additional factors such as medium air temperature, the prices of energy carriers and the emission of pollutants in the area.

Multidimensional models will be used and the variables reduction will be carried out by means of the exploratory factor analysis.

Extreme weather event in the Baltic region in July 2006: Its causes and consequences

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1. Introduction

The Baltic region experienced a period of an extremely hot and dry weather in July 2006. Causes of this meteorological anomalies were examined in order to assess the status of this event. Few environmental consequences of this extreme weather were described too.
The meteorological data utilized in analyses are sets from Polish Institute of Meteorology and Water Management and from internet (*http://www.dwd.de, http://eca.knmi.nl, http://www.smhi,se*).

2. Description of meteorological conditions

Mean daily air temperatures in July varied from about 13,5°C in Swedish Lapland to over 24°C in western Poland (fig. 1). These values exceeded 1961-90 normal temperatures for July even up to 5°C. Maximum daily air temperatures reached 30°C and more in the southern part of the Baltic Sea drainage basin and 25°C in its northern part.
July monthly precipitation totals lower than 20% of 1960-90 normal appeared in souithern Finland, in Sweden in Gotland and Scania, in Denmark in Bornholm, in Pomerania (Poland and Germany) and in central and southwestern Poland. In the Święty Krzyż meteorological station (near Kielce) a precipitation total was 1,9 mm then – the lowest monthly value recorded since an activation of the station in 1955.

Figure 1. Mean daily temperatures and precipitation totals in Baltic Sea drainage basin in July 2006 (in brackets exceedance of 1961-90 normal temperatures and percentage of normal 1961-90 precipitations).

Preliminary results of analysis suggest that this hot and dry weather was caused by long-lasting blocking of the zonal-type flow dominating atmospheric circulation in the middle latitudes by the atmospheric high (*http://cdc.noaa.gov/data/reanalysis*).
It allows to state that mentioned above period of the hot and dry weather should be treated rather as an example of extreme weather event of very low frequency than an evidence of global warming.

3. Environmental consequences

The hot weather in July 2006 increased a threat of sunstrokes and heatstrokes. As it was described earlier maximum daily temperatures excceded 30°C in many regions which is a threshold value for heat waves distinguishing in Poland – *Kuchcik M.* (2006). There were two such heat waves in Kielce – 7-13.07. and 18-28.07.
High air temperatures were accompanied by high water temperatures of Baltic Sea. This caused frequent algal blooms (actually blooms of cyanobacteria) along the southern coast of Baltic Sea.
Low precipitations caused hydrological drought. Mean water level in Oder river in Słubice was over 1m lower than multiannual normal (*http://www.rzgw.szczecin.pl*). It worsened conditions of a navigation on Oder river.

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Course of phenological phases of potato and its determination by multiannual variability of air temperature in Poland

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1. Introduction

Air temperature is one of the most important meteorological elements determining the rate of growth and development of plants (*Sysoeva et al. 1997, Popov et al. 2003, Ahmed et al. 2004, Chmielewski et al. 2005*). Changes in the course of phenological appearance occurring under influence of climate changes, depending on a species and a region of the world may completely differ – from acceleration to retardation of the date of a phenophase (*Chmielewski et al. 2004, Lobell et al. 2007, Wang et al. 2008, Xiao et al. 2008*). Works describing the influence of climate changes on the course of phenophases of crop plants are relatively rare (*Ahas et al. 2000, Menzel 2000, Dalezios et al. 2002, Mazurczyk et al. 2003,Tao et al. 2006, Kalbarczyk 2009*); there are no studies concerning potato.
The aim of the work was to determine the influence of multiannual air temperature changes on the course of the dates of phenological phases and the duration of development periods of medium-early and medium-late potato cultivated in Poland.

2. Material

Results of experiments of the Research Centre for Cultivar Testing (COBORU) from 1973-2002 for a standard of medium-early and medium-late potato cultivated in 30 experimental stations in whole Poland constituted the material for research. Using in the research a collective model was based on an assumption that intra-species differences do not obscure general regularities that were sought after for the species. The results of field experiments concerning the dates of planting, emergence, flowering, haulm drying and harvesting were collected for a model which was the most common in cultivation medium-early and medium-late potato cultivars in a given year. Meteorological data, the average monthly air temperature in the vegetation season of potato, i.e. from April to October, were collected from all meteorological posts functioning at the experimental stations of COBORU or from the nearest IMGW (Institute of Meteorology and Water Management) stations. Because of a small number of the stations and, at the same time, high microclimatic variability of weather conditions, the study eliminated mountainous regions situated within the boundaries of 5 former provinces: Jeleniogórskie, Wałbrzyskie, Bielsko-bialskie, Nowosądeckie and Krośnieńskie.

3. Methods

The relation between the dates of phenophases and average air temperature, the temperature trend and the size of changes in the multiannual period was determined on the basis of the linear regression analysis.
Moreover, in grouping of years with similar air temperature shaping a similar course of potato phenophases, emergence and flowering, the method of the generalized cluster analysis was employed. The division of all the observations of the analysed variables into clusters was conducted by the non-hierarchical method of *k*-means, in which the Chebyshev distance was used. Grouping by the *k*-means method consisted in moving observations from cluster to cluster to maximise variance between particular clusters, simultaneously minimising variance within the examined clusters. To determine the optimal number of clusters the test of *v*-fold cross-validation was employed. The significance of differences between separated clusters was evaluated by means of variance analysis, using the Fisher test at the level of $P<0.05$ (*Dobosz 2001*).

4. Results

In 1973-2002 a positive trend of the average monthly air temperature in four months of potato vegetation was confirmed; the strongest for April (r=0.59, $P<0.01$) and August (r=0.47, $P<0.01$), and then July (r=0.41, $P<0.05$) and May (r=0.38, $P<0.05$). A positive trend, significant at $P<0.01$, was also shown for the average temperature of the whole vegetation season of potato (April-October, r=0.66). An increase in the average monthly air temperature in 1973-2002 amounted to from 0.54°C/10 years for the average temperature in the whole April-October period to 0.96°C/10 years for April.
On the other hand, all the examined phenophases of potato, and also agrotechnical dates, occurred on average increasingly early. Both for the dates of medium-early and medium-late potato the strongest negative trend was characteristic of flowering, for which it amounted to -3.6 days/10 years and -3.9 days/10 years, respectively, at $P<0.01$. Also the date of medium-early potato emergence underwent high acceleration, by -3.5 days/10 years, $P<0.01$. The lowest acceleration occurred in the case of both earliness groups of potato for the date of haulm drying; for medium-early potato the acceleration amounted to -1.4 days/10 years, $P<0.1$, and in the case of medium-late potato -0.9 day/10 years, $P<0.1$.
A consequence of the changes in the dates of phenophases was also the change in the duration of development periods, especially of the flowering-haulm drying period (lengthening by 2.2 days/10 years, $P<0.05$ for medium-early cultivars and 3.2 days/10 years, $P<0.01$, for medium-late ones), but also of the emergence-flowering period of medium-late potato (shortening by 1.7 days/10 years, $P<0.01$) and the haulm drying-harvesting period of medium-early potato (shortening by 0.8 day/10 years, $P<0.1$).
Strong correlation of the date of emergence of both earliness groups of potato with the average air temperature in April (r=-0.66 and r=-0.63) and the date of flowering with the average air temperature in May (r=-0.82 and r=-0.81) was statistically confirmed at $P<0.01$.

As a result of the used cluster analysis three clusters, differing significantly in values of the 4 considered variables, i.e. the date of emergence, the date of flowering, the average air temperature in April and the average air temperature in May, were separated. Cluster 1, grouping the latest dates of phenophases, encompassed 10 years in which the average date of emergence fell on 3 June, and the average date of flowering on 10-11 July. The average air temperature, in comparison with the other clusters, was the lowest and amounted to 6.5^{o}C in April and 10.7^{o}C in May. Cluster 3, encompassing results from 14 years, grouped the earliest dates, on average, 21-24 May for emergence and 28-29 June for flowering, which were accompanied by the highest air temperature – on average, 8.6^{o}C in April and 14.0^{o}C in May. Differences in average dates in particular clusters between the two earliness groups did not usually exceed 1 day, the exception was the date of emergence in cluster 3, which for medium-late potato occurred 3 days later than for medium-early potato.

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Role of air temperature in shaping variability of phenological dates of onion and cucumber in Poland

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1. Introduction

Growth, the rate of development and crop productivity of plants mainly depend on the course of air temperature in successive years *(Sysoeva et al. 1997, Popov et al. 2003, Ahmed et al. 2004, Chmielewski et al. 2005, Kalbarczyk 2008*). The observed increase in air temperature results in the acceleration of phenological phases of wild growing and crop plants contributing to a drop in yields or to their increase depending on a region of the world and a plant species (*Chmielewski et al. 2004, Tao 2006, Kalbarczyk 2006, Lobell et al. 2007, Wang et al. 2008, Xiao et al. 2008*). The aim of the work was to evaluate air temperature changes from 1966-2005 and their effect on the dates of phenological phases of onion and cucumber in Poland.

2. Material

The work used data coming from 50 stations of the Institute of Meteorology and Water Management (IMGW), including monthly air temperature (average, minimum and maximum) in Poland from the period from March to October and from the seasons: March-September and May-October, from 1966-2005. The work also used the results of phenological observations of onion and cucumber, field-cultivated vegetables, conducted in the whole country, respectively, in 17 and 28 experimental stations of the Research Centre for Cultivar Testing (COBORU) in the period of 1966-2005, excluding the year 2003 in the case of onion and cucumber and the year 2004 in the case of cucumber, in which the research was not carried out. Phenological observations of onion covered the dates of the end of emergence and the beginning of falling over of leaves, and for cucumber: the end of emergence, the beginning of flowering and fruit setting (Figure 1). The work also employed agrotechnical dates of both vegetables (sowing and harvesting); in the case of cucumber the first and the last harvesting.

Figure 1. Distribution of COBORU stations conducting experiments on onion (■) and cucumber (●) in years 1966-2005.

In order to standardize the terms of onion development, each development stage determined in accordance with COBORU was further described with the use of the BBCH numerical scale, binding in the states of the European Union, using the principle for determination of development stages of monocotyledonous and dicotyledonous plants (*Meier 2001*).
The initial data were collected for all the most common in cultivation medium-late varieties of onion and pickling varieties of cucumber examined in a given year which after averaging were accepted as a collective model of the described plants. The experiments from 1966-2005 were conducted on typical soils for onion and cucumber cultivation: wheat complexes, a very good and good one, and a very good rye complex.

3. Methods

The temporal structure of air temperature and phenological phases were statistically described with the use of: the average, the standard deviation, the minimum and maximum value, the deviation from the multi-year average and a linear trend. To determine the relation between the dates of phenophases of onion and cucumber and the average air temperature in the period preceding the earliest date of their occurrence and to determine the linear trend of phenological phases, agrotechnical dates and agrophenological periods of the characterized plants in 1966-2005 the study used single regression analysis. On the basis of the equations of linear regression, formed for the relation between the average, minimum and maximum air temperature (calculated on the basis of 50 IMGW stations) and successive years of the multi-year period of 1966-2005, ten-year changes of air temperature were calculated. The regression function parameters were determined with the use of the method of least squares. The hypothesis of the significance of the regression, i.e. the correlation coefficient, was examined with the F-Snedecor test, and the significance of regression coefficients with the t-Student test. The correllation coefficient served as a measure of fitting of the regression function to empirical data.
In order to group years similar in terms of the course of phenological phases of onion and cucumber and accompanying them thermal conditions of air the method of generalized cluster analysis was used. The division of all the analysed variables into clusters was conducted with the use of the non-hierarchical method of *k*-means, in which the squared Euclidean distance was used (*Jain et. al. 1999, Everitt et al. 2001*). Grouping of observations with the *k*-means method consisted in moving observations from cluster to cluster in order to maximise variance between particular clusters, simultaneously minimising variance within the examined clusters. To determine the number of clusters the test of *v*-fold cross-validation was used. The significance of

differences between separated clusters was evaluated with by means of variance analysis, using the Fisher test at the level of $P<0.05$ (*Dobosz 2001*).

4. Conclusions

In 1965-2005 the average air temperature analysed in vegetation seasons of onion and cucumber showed a significant increase in 4 months: April, May, July and August; the highest in April -0.49°C/10 years. The air temperature increase contributed to the acceleration of all phenological phases of the described vegetables. The bigger size of the changes was, the later phenophase it pertained to – for onion emergence the average acceleration of the date amounted to +0.6 day/10 years, for falling over of leaves +0.8 day/10 years, and for cucumber emergence the average acceleration of the date amounted to +1.2 days/10 years, for flowering +1.9 days/10 years and for fruit setting +2.1 days/10 years. Persistence of the same tendencies, i.e., the acceleration of the dates of phenophases of the discussed vegetables, will cause that the plants will develop in different light, thermal and moisture conditions. A consequence of the changes is shortening of successive development periods of both vegetables and probably deterioration of the conditions of obtaining good yields of onion and cucumber in Poland.

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Coastal communities and climate change: Discussing environmental risk and perspectives of tourism development in sociological terms

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"*climate is a key resource for tourism and the sector is highly sensitive to the impacts of climate change and global warming, many elements of which are already being felt. (...)Given tourism's importance in the global challenges of climate change and poverty reduction, there is a need to urgently adopt a range of policies which encourages truly sustainable tourism that reflects a "quadruple bottom line" of environmental, social, economic and responsiveness*"
Davos Declaration: Climate Change And Tourism Responding To Global Challenges. Davos, Switzerland, 3 October 2007

The aim of our project is to present the impact of climate changes on local tourism industry using sociological notions and methods. Researching the environemental risk and expected results of climate change for tourism based local community we focus on two issues:

1. Environmental risk and changes of tourist images of coastal regions

In this part ot the project our research goals focuses on how climate change affects on tourist images of Zachodniopomorskie region. We present tourism industry of Polish coastal regions referring to effects of climate change. Using visual sociology tools we examine tourist images of landscape, their symbolical and economical values,. The key issue of this part of the project is environemntal risk impact on adaptation strategies of stakeholders of tourist industry (local authorities, government, local economy, local community) for changing landscape.

2. Climate change and development of local communities

In this part ot the project we discuss toursim as the key factor of social development of local community, examining strategies for climate change in terms of local and global context of ecological rules. We see landscape as a cultural heritage and economical resource and we are examinig the ecological, economical and cultural aspects of local community social development in terms of climate change.

The use of geo-statistical methods in the analysis of changes in the erosive and accumulative systems of the southern Baltic Sea

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The subject of this article is the application of spatial statistics tools to explore erosive and accumulative systems in the southern Baltic Sea area. Attention was paid in particular to advantages of geo-statistical and interpolative methods such as the *inverse distance weighting method* (IDW), the *regularized spline with tension method* (RST), the *ordinary kriging method* (OK) and the *indicator kriging method* (IK). With these methods it is possible to forecast changes despite insufficient statistical data.

Sea erosion – Present state and simulation of coastal change in the southern Baltic Sea

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This article presents formation mechanisms of erosive and accumulative systems and their impacts on the socio-economic development of coastal regions.
In addition, simulations of coastal change in the southern Baltic Sea area were carried out using the database software called ALASKA (*The Supporting of Critical Responding System*), with additional components: *Operation Graphics Pack* and the *GIS software ArcGIS*. The use of computer graphics in the analysis of digital terrain models illustrates the increasing problem of sea erosion in the context of coastal use and ordinary living of the local population.

Theoretical foundation of a common programme of the insurance sector

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The analyses presented shows that it is possible to create guidelines for a common approach for the Insurance Sector. However, its execution depends on meeting several criteria. The European Commission mentions as important: political criteria, socio-economic criteria (co-operation with the private sector, insurers, re-insurers and farmers), and technical criteria. The notion of public aid has recently gained a huge popularity, particularly in the context of various kinds of support from EU Structural Funds for entrepreneurs, farmers and other social groups.
We can distinguish five types of insurance-risks, of which the production risk connected with specificity of production and market risk are considered the most significant:

- production risk (linked with natural uncertainty resulting from the universals of the land factor – e.g. weather);
- market risk results from the change of external economic conditions of production, i.e. for instance the loss of markets and, connected with this, excessive supply of products and fall of prices, or opening of new markets and increase of demand causing a rise in product prices;
- institutional risk;
- financial risk;
- risk connected with the human factor.

Some Member States of EU have already introduced national systems in order to encourage farmers to insure for such events. In many highly developed countries, systems aiming at insurance protection of agricultural production have been functioning for years. The principle of such systems is supporting private funds, i.e. an insurance taker's premiums, with funds from central budgets, or local budgets (communes, provinces), or co-financing costs of re-insurance.
The notion of state aid has not been precisely defined in the European Union documents. Art. 87(1) of the Treaty Establishing the European Community (EC Treaty) stipulates only that "save as otherwise provided in this Treaty, any aid granted by a Member State or through State resources in any form whatsoever which distorts or threatens to distort competition by favouring certain undertakings or the production of certain goods shall, in so far as it affects trade between Member States, be incompatible with the common market".

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Insurability of agricultural production in the region of Poland

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The increase of agriculture requires a wider insurance offer regarding protection of crops against numerous risks and also protection against price fluctuations. An analysis of existing agriculture insurance systems indicates great differences among individual European Union members. The greatest threats to agricultural production and production facilities in the European countries include external climatic and environmental conditions, such as: intensity of precipitation, unfavourable temperature distribution, humidity, and the frequency of plant diseases and pests. These factors cause hurricanes, hailstorms, droughts, fires, flooding and frosts, as well as other natural disasters.
In the policies for disaster aid and risk management it is essential to have clear definitions of risks, disaster, calamity, crisis, etc. Natural disasters are divided into three specific groups: hydrometeorological, geophysical and biological. However, the European Commission includes among the natural disasters only hydro-meteorological disasters and geophysical disasters, considering biological disasters (diseases, pests, contamination in the food chain as by dioxins) a separate group (EC, 2005b). A crisis may occur on a personal or societal level. In agriculture, a crisis may be caused by natural disasters, diseases and pests affecting animal or plant health or contamination of the food chain; economic factors having short-term but significant effects on farm income; or market shocks with high-intensity negative consequences.
The European Commission has identified the following three options of agriculture insurance systems: contributing to the payment of premiums farmers pay for the insurance, against natural disasters, extreme weather conditions or animal and plant diseases; encouraging the development of mutual funds for agriculture, by granting temporary and digressive support for the funds' administration and launching new instruments to protect farmers in different types of income crises. Analysing existing insurance systems in Europe, it is seen that well-developed one-risk insurance (mainly hail) is present in almost all European countries. A direct connection between government involvement and the development of insurance in agriculture is also noticeable. In the authors' opinion, the indicated threats require the creation of strong theoretical foundations of a common programme for agricultural sector insurance in Poland, taking into consideration joint principles for all European Union countries. The conditions described in the study, the results of numerous studies and analyses, may constitute one voice in the discussion about creating assumptions for agricultural sector insurance programme and creating hypothetical scenarios of all-Union insurance.

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Anthropogenic changes in the region of Gdańsk Żuławy (Vistula Delta) resulting from climatic effects.

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1. Introduction

Żuławy is the region (1703 km^2) situated at the mouth of Vistula, the largest Polish river. It consists of three parts: Gdańsk Żuławy situated on the left hand side of Vistula River, Malbork Żuławy situated between Vistula and Nogat Rivers, and Elbląg Żuławy on the east of Nogat River adjacent to the Vistula Lagoon (Fig. 1). Important part is the Gdańsk Żuławy, where in XVIII and XIX century important floods occurred. They appeared every 3 to 4 years and were caused by ice jams.

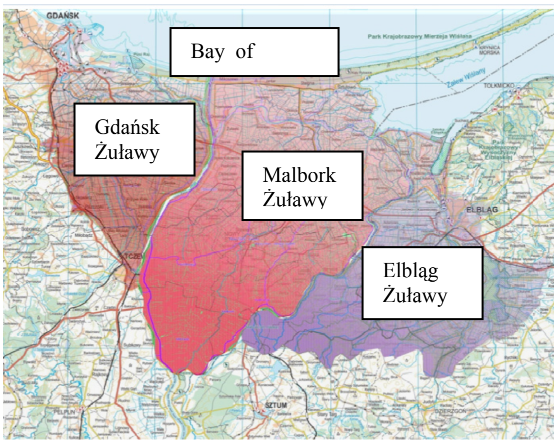

Figure1. Żuławy at the mouth of Vistula

Gdańsk Żuławy are a very important part of Vistula delta because here is located big city of Gdańsk with important sea harbour. The Gdańsk Żuławy has the area of 391 km^2 and includes complicated system of rivers and channels called Gdańsk Water Node (GWN). It is also the area of valuable agricultural land. Large part of Gdańsk Żuławy is in depression, which significantly complicates the situation in case of flood.

2. Flood hazard

Żuławy are the region which is most endangered by floods in Poland. The arrows indicate possible flood hazard directions (Fig.2). From the Martwa Vistula in case of storm surges, from the main channel of Vistula in case of high discharge or ice-jam flood, and from the moraine hills (in the south) in case of high precipitation.

In XVII and XVIII century the main channel of Vistula, called Gdańsk Vistula was directed to the west, parallel to sea coast. The main outlet was near the fortress Wisłoujście. In XVII and XVIII century there was no direct outlet to the sea, as shown in Fig.2.

The whole section of the Lower Vistula (300 km) was always prone to ice-jams and ice jam floods. The marks of high water on the walls of the cities along the Lover Vistula clearly indicate that most severe floods were in winter or spring.

The situation was even more dangerous over the GWN due to complicated layout of rivers (Majewski 2008). One of the actions to mitigate the influence of ice-jam floods was the construction of flood dykes.

In XVII and XVIII century winters in Poland were severe and all rivers were covered with ice. Vistula River (1047 km long) flows from the south to the north. There was significant difference in the beginning of spring in southern and northern areas. This time difference was about 2 weeks. When in the south there was ice break-up and increased discharge with ice, in the north rivers were still covered with ice. Its thickness on the Lower Vistula very often exceeded 0.5 m. Increased discharge and ice-run as well as water elevation in the sea, and wind direction were the reasons for ice jam formation.

In 1829 severe winter flood resulted in breaching of the left-hand dykes along the main channel of Vistula. This way predominant part of Gdańsk Żuławy was flooded. The city of Gdańsk was inundated up to the second floor, which resulted in considerable economic losses. Vistula channel changed its outlet direction to the sea (Fig.2).

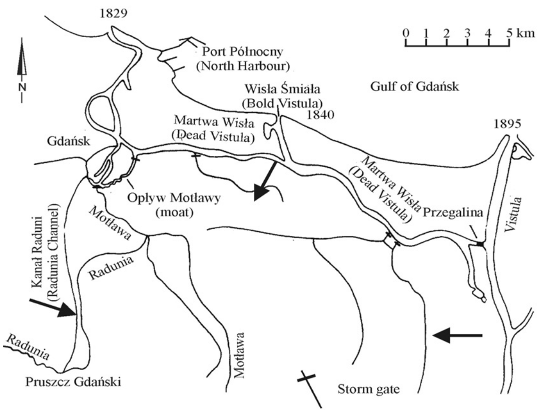

Figure 2. Layout of Vistula River

In 1840 large ice-jam formed near the place Wiślinka (Fig. 2), which resulted in the breach of sand dunes along the sea coast and a new outlet of Vistula to the sea was formed. It was called Wisła Śmiała (Bold Vistula).

3. Direct channel to the sea (Vistula Przekop)

Finally in 1895, due to the formation of ice-jams along the branch of Gdańsk Vistula, it was decided to form a new outlet of Vistula to the Baltic Sea. A direct channel 7 km long was formed from Przegalina. During short time flowing water widened the channel. Now the width of the channel is from 300 to 400 m. The old arm called Gdańsk Vistula was cut-off by means of navigation lock in Przegalina and thus Gdańsk Vistula became Martwa Vistula (Dead Vistula). This way the layout of main Vistula outlet was considerably simplified and no more ice-jams were observed. However, the assistance of ice-breakers is indispensable.

Till today (after 113 years) the original outlet of Vistula and the coastline moved about 3 km in the northern direction due to the formation of sedimentation cone. Extension of the channel was carried out by means of some kind of artificial piers (dykes) constructed on both sides of the river channel.

4. Problems at the mouth of Vistula

Although the hazard of ice-jam floods was significantly reduced by the formation of direct outlet channel i.e. anthropogenic (engineering) changes old and new problems were created.
The old problem is the formation of ice cover and possible ice-jam along the final section of Vistula. Ice cover during some winters achieves the thickness of 0.5 m. Formation of ice jams over his Vistula section depends on many factors. These are:

- thicknes of ice cover on Vistula River,
- amount of ice in the Bay of Gdańsk,
- water elevation and wind direction in the Bay of Gdańsk,
- discharge in Vistula.

The only solution is the fleet of ice breakers, prepared to crush ice cover. The view of final section of Vistula in winter is shown in Fig.3.

Figure 3. The view of final section of Vistula with ice.

Another problem is sediment transport in Vistula and its deposition at the river mouth. Deposited sediment forms sedimentation cone which decreases water depth and thus impedes navigation and facilitates the formation of ice-jam. During past 100 years since the formation of direct channel the original coastline moved seawards by about 3 km. The view of sedimentation cone is shown in Fig.4.

Figure 4 The view of Vistula sedimentation cone

5. Conclusions

Severe winters and unfavorable layout of the final section of Vistula River resulted in past centuries in frequent ice-jam floods which caused significant social and economic losses. Flood dykes mitigated results of these floods, however, could not prevent their devastating effects.
The formation of new outlet channel of Vistula to the sea (7 km long) solved this problem quite well, however, flood hazard due to ice-jams still exists. Solution to this problem is the fleet of icebreakers.
A very important problem is the formation of sedimentation cone due to the deposition of sediments. During past 100 years the original coastline moved by about 3 km. Extension of the channel is made by the construction of longitudinal dykes on both sides of the channel.
Engineering (anthropogenic) changes can solve some important problems caused by natural phenomena, however, they also cause new issues.

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Indicators for Integrated Coastal Zone Management in the south-eastern Baltic

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Europe has a large continental shelf and a there is a wide variety of types of coastal zone, with different natural, economic and social conditions. Scientists and society are concern about the impact of natural and anthropogenic facts to coast zone.

South-eastern Baltic Sea coast zone is defined as very unique, therefore the most of its territory are protected areas. Curonian Spit separates Baltic Sea and Curonian Lagoon and is a worldwide landscape park which was included into World heritage list. The international collaboration of the neighboring countries helps to complete the logical and unique circle of the management of Baltic Sea coastal zones despite political boarders among the participating countries. The unified system of indicators helps to compare different regions in terms of sustainable development of the coastal zone.

SDI-4-SEB (Sustainable Development Indicators for Integrated Coastal Zone Management of South-Eastern Baltic) project aims were to promote the integrated way of trance-border coastal zone management in the South-Eastern Baltic. The coasts of the Lithuania (Klaipeda County), Russia (Kaliningrad Oblast), and Poland (Pomorskie Voivodship) comprise unified coastal strip with identical geo-morphological and dynamic features. This part of the Baltic coast typologically belongs to open sandy coast with similar problems of erosion, sand dynamics and economical development.

The different set of indicators is used when assessing the tendencies of coastal zone's natural – social – economical environment development and dynamics. The group of indicators assessing coastal zone dynamics and possible risk helps to identify and recognize the threat to coastal zone posed by climate change and to ensure appropriate and responsible implementation of coastal protection measures. Such measurements as sea water level rise, extreme weather conditions, length of eroded and accreted coast, the position of coastline and protective fore-dune, length of coastline protected by hydro-technical structures are important for indicating the coastal dynamics tendencies. Indicators helping to evaluate the protection of natural and cultural values make another separate group of environmental parameters. These control the establishment and care of the protected areas in the sea and on land.

Recent research shows that the climate change could bring negative effects. The climate change affected a rise in sea level of several millimetres per year, and an increase in the frequency and intensity of coastal storms. The positive stronger then 25 m/s wind trend was estimated. Coastal erosion is stimulated by sea level; more frequent cyclones induce storms and hurricanes. The sand of accumulative type Curonian coast within thousand years is brought by south-western flows, mostly from Sambia peninsula.

However nowadays the coastal erosion process is more intensive, new dune's scour spots have appeared, the amount of sand offshore has decreased. Ordinarily on the human population and economical concentrations are in coast areas and therefore it is in are biggest risk areas.

During recent decades the effect of global climate change has attention broad interest, as changes of coastlines have ecological, economical and social impact in coast areas of the Baltic Sea. The applied sustainable development indicators approach allow to evaluate the climate changes in the most impartial way what leads towards responsible implementation of most efficient coastal zone management tools.

Climate Change: New challenges for State Geological Surveys of Germany

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1. Basics

Geologically, the earths evolution is a history of environmental changes. These include climate changes as permanent processes in different time scales. From this point of view "climate changes" use to be "normal" processes/events which are detected in the sedimentary record since > 2 Ga. For example, relics of Precambrian glaciations document climate changes at very early times of the earths history. Moreover, green house gases (GHG) made evolution of life only possible ! No doubt at all, the geological record worldwide presents "climate changes" as that what they really are, namely natural processes of a dynamical/mobile earths. The word "climate catastrophe" which is used at modern times not only by the "yellow press", but also by politicians, who should know it better, geoscientifically must be regarded as a wrong term concerning environmental information politics for the society. There is also no doubt, that since > 150 years in the course of the "industrial age" mankind increasingly act as a "global environmental architect" reconstructing the earth according to growing world population, to enormous energy requirements as well to huge waste volumes in every respect, to mention only a few fundamental aspects. Therefore, it is suggested by some geoscientists to introduce the stratigraphic epoch "Anthropocene" since the beginning of the industrial revolution in midth of 19th century in order to consider the modern human-being as a "geological force".

2. State Geological aspects of climate change

Despite the above-mentioned fundamental facts State Authorities have to take care for social development, safety and justice under the present (man-controlled) climate change, which, from an actualistic point of view, is characterized by fundamental geological principles/processes: Among others, increase in atmospheric temperature, worldwide glacier melting, sea level rise (i.e., transgression), disappearing of species. Therefore, State Geological Surveys worldwide, especially deal with new thematic challenges in georisk assessment, groundwater supply, use of geothermal energy and Carbon-dioxide sequestration (storage) in deep-lying sedimentary formations. The latter is regarded as a important geological contribution on the way to the so-called "CCS-Technology" (**C**arbon **C**apture and **S**torage) leading to "clean coal". There is much activity within the EU and the Member States regarding CCS. The EU expects to bring CCS as standard technology for modern coal-fired power plants to application by 2020.

In the following these new challenges are described which the State Geological Survey of Mecklenburg-Vorpommern is in face of . As a State at the German Baltic Sea coast bordering to the Polish region of Pomorze (Western Pomerania) there should be further cooperation on these different topics in cross-bordering projects.

3. Georisk assessment

German State Geological Surveys in 2006 have compiled a catalogue on relevant geohazards for the country. These include the following:

- Slope stability/mass movements
- Subrosion/Karst
- Coastal flooding/-protection
- Unstable building ground
- Dangers by mining activities
- Surface exit of groundwater
- Saline groundwater
- River floods
- Escape of gases (methane, radon, carbon dioxide)
- Earthquakes

For the State of Mecklenburg-Vorpommern (NE-Germany) in recent years river floods (Elbe-Flood in August 2002), cliff coast collapses and landslides on Rügen-Island (chalk cliff collapses and Lohme landslide in February/March 2005) and earthquakes with a magnitude up to 4.7/Richter-scale (December 2008) made georisk potentials aware for the public.

Especially, due to the global climate change (see above) the State Government has presented a status-report in 2008 on the expected regional consequences until the end of the 21th century. This report reflects data, trends and consequences on, among others, temperature increase, seasonal changes in rainfall, sea level rise and coastal retreat, changes in the species distribution of flora and fauna, spreading of infectious diseases and, moreover, suggests measures to adjust to the changing environmental conditions. For example, a sea level rise in the order of 20 to 35 cm until the end of the century is assumed by interpretation of eustatic and relative sea level data from the Holocene sedimentary record as well by historic gauge records along the southern Baltic Sea.

4. Geothermal energy potentials

Germany intends to increase the amount of renewable energy potentials from 14 % at present up to 30 % in 2020. This ambitious plan needs to consider the geothermal energy potentials for infrastructural developments, both from deep-lying (> 1,000 m) geothermal aquifers of the North-German Basin (especially of Mesozoic sandstones, thicknesses > 20 m) and from near-surface geothermal reservoirs of a depth up to 100 m. Recently, the latter get more and more important for private family houses. For this purpose, German State Geological Surveys publish maps and other information digitally and supply investors with relevant geological data. The Geological Survey of Mecklenburg-Vorpommern has published a "Manual on near-surface geothermal energy use" (2006). Furthermore, during the last years a German-wide "Geothermal Information System" (GeotIS) on deep-lying geothermal reservoir formations has been established and funded by the Federal

Ministry of Environment (BMU). In this project the State of Mecklenburg-Vorpommern participates by its Geological Survey and the Geothermy Neubrandenburg Enterprise (GTN). Most recently, the results have been published in "Journal for the Geological Sciences" (vol. 36, issue 4/5, 2008; Fig. 1).

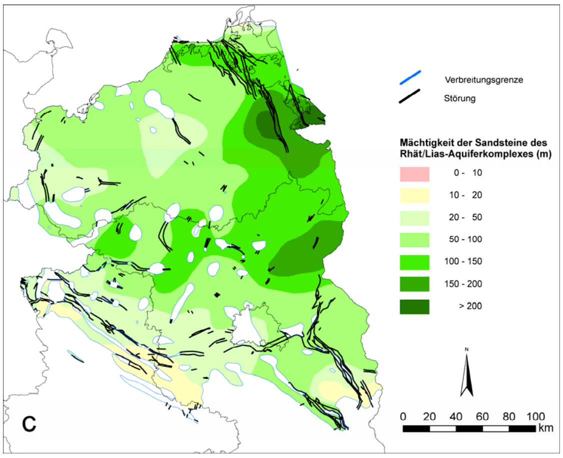

Figure 1: Distribution and thickness of the sandstones of the Rhaetian/Liassic geothermal aquifer complex (*Feldrappe et al*. 2008)

5. Sequestration of carbon dioxide in saline aquifers

There is no doubt that for long-term periods the "classical" world energy resources used in power plants (oil/gas, coal) have to be replaced by alternative (i.e., renewable/sustainable) energy sources, among others, besides geothermy (see above), solarthermy, wind, water, biomass. Of course, nuclear power as a carbon dioxide-free energy source cannot be neglected for the future. But, it is known that the world coal reserves are large enough to secure the energy requirements for hundreds of years. Moreover, the distribution of coal (both brown and hard coal) in Europe allows the use of this "classical" energy raw material for many decades under the pre-condition that climate-relevant gases, especially carbon dioxide, is captured technologically in modern coal-fired power plants by pre- or postcombustion or by the oxy-fuel-process. After that, carbon dioxide has to be stored in deep-lying porous sandstone formations. This system of capture, transport and storage of carbon dioxide in geological formations is known as CCS-Technology. A first pilot-study started in September 2008 in Germany (Spremberg/State Brandenburg) by Vattenfall. The captured carbon dioxide is transported to the Altmark-area and stored in former natural gas reservoirs of the Rotliegend.

Since 2008 there is an EU-directive on CCS which focuses on the widespread application of the technology by 2020. In a first step, 12-15 Europe-wide CCS-demonstration projects shall be erected. It may be assumed that up to 3 of these pilot projects could be built in Germany. Regarding this the State Geological Surveys in many European countries see one very important task in providing energy enterprises with reservoir-geological information on storage sites. In this respect the British Geological Survey (BGS) is ahead and acts for the EU as leading institution in CCS regarding geological storage. According to the great extension of the North-German Basin (see above) beneath the State of Mecklenburg-Vorpommern good opportunities for storage sites do exist (Fig. 2). At present, therefore, the State Geological Survey of Mecklenburg-Vorpommern deals with preparation, documentation and interpretation of relevant geological data for a planned new coal-fired power plant near Greifswald.

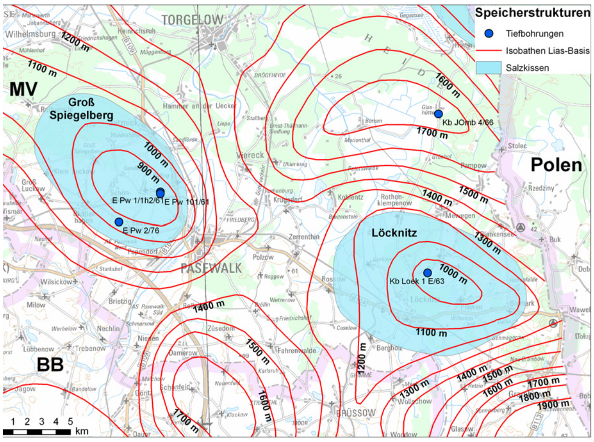

Figure 2: Two possible storage structures for carbon dioxide in the Southeast of Mecklenburg-Vorpommern close to the Polish border (*Obst* 2008)

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Climate change and the future of water sports around the Baltic Sea region

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1. Introduction

The coasts around the Baltic Sea are traditional destinations for water sport tourists, but also for domestic recreation. Water tourism replaces the conventional maritime sector more and more and reflects the current transforming processes of the national economies. Sea spas have their own rich history; the current boat stock in Scandinavian countries outdistances the number of inhabitant nearly, and trendy water sports (e.g. Kite-Surfing) have established successfully.

The expectations of tourism stakeholders on the benefits of climate change are still high: extended tourism seasons and the decline of traditionally contributing destinations (e.g. the Mediterranean) are only the most important of them. Admittedly, this generalized view does not cover the special demands of several water sports and their winter variants (e.g. ice-sailing). The following paragraphs analyze the detailed demands of several water sports on the natural background and the future development of the limiting factors altered by climate change.

2. Boating – the winner of climate change

Boating profits definitively from climate change: Seamen in sailing yachts and canoes can go in for their hobby in warmer conditions and for up to three additional months. It is worth to invest in a yacht, because it will be used significantly more than presently. A significant higher risk of storms will not be expected (but is discussed differently in the scientific community). The expected loss of ice coverage opens new horizons for the behavior during the cold season: The yachts can stay in water without risks; but that requires a re-thinking of the marina infrastructure (and its management), too.

3. Scuba diving – the negative example

Most of recreational scuba divers prefer warm water destinations due to the comfortable environmental conditions and the attractive biosphere. Scuba diving in the Baltic Sea (and lakes, too) demands conforming (and expensive) equipment (dry suit, cold-water tested regulators) and needs an extended education for the conditions (higher risks brought along by darkness and coldness in depth under the thermocline). What positive effects climate change brings along? No noteworthy ones: Recreational divers will not profit from the higher surface temperatures; algae blooms will downgrade the visibility and the lighting conditions in the water column. The decreasing salinity will reduce the biodiversity (and the attractiveness for recreational diving). For the (long-term) development of scuba diving artificial attractions like reef structures and intentionally submerged ships seem to be required.

4. Decline of ice variants – the loss of touristic diversity

Ice variants of several water sports reflect traditional economic sectors (ice fishing, transport over ice) and are attractive either for sportsmen and tourists or for tourism suppliers (additional income during the low season). In detail, winter variants without consolidated ice coverage (e.g. winter swimming) will hardly be influenced by climate change, but all the more ice-variants like ice-diving and ice-sailing. Both kinds of water sport have their own great history in middle European lake lands. The future of these sports with the special "thrill" seems to be open.

Figure 1. Only a fiction: Tropical biodiversity and attractiveness in the Baltic Sea offshore the chalkstone rocks of Rügen (photomontage: R. Scheibe).

5. Conclusions from the examples

Indeed, climate change will influence water sports in different manner. Independent from socio-economic trends, several water sports could be strengthened, but several water sports will disappear possibly. It is open, if artificial worlds of experience can avoid this loss of diversity. A long-term planning and monitoring of the demand on touristic service is necessary as a further research on the down-scaled changes of the environmental factors wind, ecological conditions and ice coverage.

Is the European blocking the precursor for the droughts in the southern Baltic region?

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1. Introduction

Well-established blocking type circulation always denotes abnormal temperature and precipitation anomalies across the Europe during all seasons of the year. Wintertime or cold season weather anomaly dependence on the blocked flow is already well cross-lighted in scientific literature. Most of the papers deal with abnormal circulation patterns related to the North Atlantic oscillation (NAO), Arctic oscillation (AO) or other regional or hemispheric prominent and persistent circulation patterns (eg. *Barriopedro et al*. (2006), *Croci-Maspoli et al.* (2007), *Scherrer et al.* (2006), *Shabbar et al.* (2001), etc). Some the authors argue about decreasing trend of blocking patterns over the Atlantic and Europe during last 50 years while others discuss about future increasing blocking frequency and their relation to European heat waves (*Meehl and Tibaldi,* 2004) or even increase in frequency of extreme cold-air outbreaks (*Vavrus et al. 2006*). The present study looks for possibility to relate the blocking flow patterns over Europe to the drought formation in the southern Baltic region during warm half of the year. The main task of the research is the determination of the drought initiation conditions regarding to the disturbed upper level flow indices.

2. Data and methods

Two different indices representing blocked flow were used in this study: that of proposed by *Molteni and Tibaldi* (1990) and recently used for monitoring purposes in NOAA (BI), and the European blocking index (EBI) as experimental product derived in the International Research institute. The later is based on 300 hPa zonal wind component over the region of 15W to 25E and 35N to 55N, while former is based on 500 hPa geopotential height gradients and could be calculated around the globe for the latitudes belt spanning between 35N and 85N. In present study BI index was calculated only for meridians from 30W to 30E.

Meteorological drought conditions could be described either by precipitation deficiency or by soil moisture content. The latter has a very high temporal and spatial variability and so can not be taken into account, while the former is expressed in two indices: the Effective Drought index (EDI) and the length of period without precipitation or less than 0.5 mm per day. Unlike many other drought indices, the EDI is the daily index and its calculation procedure is described in. Byun and Wilhite (1996) paper. This index uses only observed precipitation data and so has an advantage. Period without precipitation also is good indicator of aridity but only in summer and has no accumulation effect. These dryness indices were calculated for 19 meteorological stations in Poland. Avoiding misunderstandings of the ‘drought’ definition we used the term ‘dry spell’ because no soil moisture data were analysed.

At the first step the cluster analysis was used for identification of the consistence of the blocked flow (defined by appropriate index) relation to the beginning or continuation of dry spell. Than additional indices like NAO on the daily timescale as well as Objective Grosswetterlagen Catalogue daily patterns or regional atmosphere circulation types (according to J. Litynski) were used to identify the circulation processes favoring for dry spell maintenance.

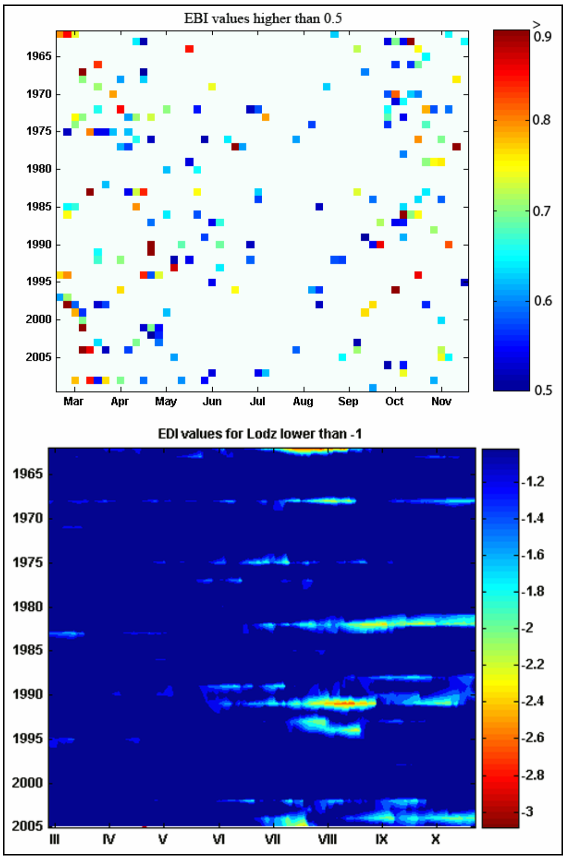

Figure 1. The interannual and intraannual variation of: (upper panel) European Blocking index (EBI), and (lower panel) Effective Drought index (EDI) for Lodz. Color bar in both panels adjusted for highlighting the ridging (upper panel) and the dryness (lower panel) with the reddish shading.

3. Results

All dry spells defined by EDI index in the interseasonal scale seem to be shifted to the autumn period because of the unavailability to assess the melting process impact on the dryness conditions. Although such spells are linked to resettle in the following warm season. From the other hand, the early spring dry spells have too little impact on the humidity conditions through the whole vegetation period.

Notwithstanding to such kind of issues the strength of the European blocking as well as the blocking at any other longitude strongly depends on pressure gradients which usually are the strongest during the cold part of the year (fig. 1, upper panel). So the most important thing here appears to be the persistence of the blocking.

Analysis showed that the warm season blocking only initiates dry conditions which after could be maintained by various weather regimes, eg. the stable surface anticyclone, which has no effect on the large scale westerly type flow. Blocking index (BI) defined on 13 different longitudes appears to be the better measure of the dryness: the Atlantic blocking cases seem to be much less responsible for the regional precipitation than the Eastern European counterpart even if they are climatologically less frequent.

The strong and persistent blocking events in autumn season show the close relation not only to the dryness during the same season but also to the following spring and summer.

Droughts in the southern Baltic region have weak or no connection to the Western European droughts (eg. 1976 or 2003), as well as Mediteranean or southeastern European droughts (eg 2007) but related to the Scandinavian droughts (1992, 1994, 2006, except 2002) which manifest through unusual frequency and persistence of anticyclonic conditions (HNA, HFA, HFNA, SEA large scale patterns), Eastern European droughts (SA, SZ, TRW, SWA patterns) or Central European droughts (HB, BM patterns). Only Scandinavian patterns are relevant to blocking flow and are responsible to the great spatial variability of dry spells, while Eastern European patterns rather show only stabilization of the planetary scale long wave ridge over that particular region than the blocking itself and invoke intensive temperature advection which accelerates the development of the dry spell. Finally, Central European patterns are only rarely related with blocked flow and are represented by semi permanent surface anticyclone producing more or less even distribution of dry spells across analysed area.

Further research is necessary to provide a better understanding of how and why droughts occur in this region as well as regional climate modeling studies to predict their strength and frequency in the future.

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Climate change influence on the human settlement in the region of the Dziwna river (NW Poland)

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1. Introduction

Much geological and archeological work has been done in the study area, e.g. many papers by Filipowiak W. (2005), Indruszewski G. (2000), Malinowski T. (1973), Piskorski J.M. (1987), Piskorski (1990), Ruszała M. 1977, Dworaczyk M. (2008), Latałowa M. (2007), Piotrowski A. (2007).

2. Description of the Study area and archeological background

The Dziwna River is located in the Szczecin Coast area, a part of the Southern Baltic Coast Area (Kondracki, 1981). It would be more proper to call it a strait, one of the three connecting Szczecin Bay with the Pomeranian Gulf, and in a way an extension of the course of the Odra River. It separates Wolin Island from the inland. The general shape of the Odra River mouth area was formed during the Littorina transgression. The topography of this region is undergoing constant changes from natural factors, and for the past several centuries from human activities.

The Dziwna River is undergoing constant and continous changes as well. They concern, first of all, the embankment line formation and its course. As an effect of the accumulation processes, Rów Peninsula, located at the Szczecin Bay exitto the river, is gradually enlarging (Malinowski, 1973). The Dziwna River outflow to the sea occurs also in a different location comparing with the initial situation. Besides, during the Early Middle Ages, the coast line has been artificially moved near the town of Wolin, as shown by the archeological investigations carried out there (Filipowiak et al., 2005). Recently an acoustic survey of the Dziwna River bottom has been carried out near Wisielców Hill (Hanged Men Hill), i.e. at the contact area of Szczecin Bay and the river. It has been established that during the past circa 1000 years, several regressions of the embankment lines have taken place there (Indruszewski, 1973).

Formation of the riverbed along the remaining river's course was probably also constantly changing during this time. The present short study intends to define and describe it. The development of the Dziwna River bank consolidation is presented, based on the archeological data, from the appearance of humans in the area until the medieval period. As far as possible on the basis of archeological site? location from particular periods, this may assist in preliminary reconstruction of the river embankment line changes. In this sketch, only sites? located within 1 km distance from both sides of the Dziwna river-bed have been taken into consideration.

The reconstruction of the Dziwna River embankment line requires, therefore, extensive and complex interdisciplinary studies, as shown by the above-mentioned archeological investigations in the town of Wolin, and the acoustic studies on the Dziwna riverbed near Wisielców Hill. The results would help in the reconstruction of the river course changes during the various timespans, and, therefore, in preparation of the techniques preventing changes in the present riverbed course.

3. Summary

Some of the early settlement archeological sites? show a correlation with other sites with similar natural and climate conditions. Evidently, there was an influence of human activity on the climate and vice versa. The condition of the environment was worsening under the influence of Łużycka Culture settlement. Subsequently the region in question was less attractive for the settlement of the German nations (before the Roman period and Roman influence period). Much more marked activity of human settlement started in the Middle Ages, with the appearance of Slavic tribes. A distinct settlement network developed and survived to recent times. In the study area sediments and geomorphologic forms developed during the past 14,5 thousand years. Humans were able to colonize this land only after the Ice sheet retreat. The sediments include glacial tilt and fluvioglacial sands. Only some parts of the area are covered with organic and mineral sediments accumulated during the last 7 thousand years, along with the rise of the Baltic Sea level. Changes in the water level influenced the volume of the river in the Dziwna River channel, thus causing the barrier for colonized land on Wolin Island.

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Palynological data on the Late Mesolithic and the transition to the Neolithic economy in Wolin Island, the southern Baltic coast

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1. Introduction

Pollen analysis from two sites – Wolin II and Wolin II/00 – situated in the south-eastern part of Wolin Island (NW Poland), supplemented by microcharcoal data and radiocarbon dates, reveals substantial anthropogenic environmental changes in the period preceding Neolithic settlement in this area. Already in the earlier paper (Latałowa 1992) it has been argued that it might be evidence for the activity of the Ertebølle-type culture. The new pollen data confirm earlier suggestion on the presence of the Late Mesolithic tribes in the areas adjacent to the basin of the present-day Szczecin Lagoon. Unfortunately, there is no direct archaeological data supporting the pollen record.

2. Results

The data from both sites reflect the discussed period in different detail, probably due to more local (Wolin II) or extra-local (Wolin II/00) pollen source area. In both sites, however, regularly repeated burning in forest is well documented for the period 6300-5800/5000 ^{14}C BP (5300-4700/3800 BC). It is suggested that, as in many other sites in NW Europe, also in this area the Mesolithic tribes used fire intentionally changing forest structure for hunting purposes and – maybe – to maintain better environment for herds of game. The long-lasting and intensive traces of this activity, as shown by the pollen data, hints that also in the Wolin area, the Late Mesolithic (Ertebølle ?) settlement could be used throughout the whole year and inhabited for centuries.

Both pollen profiles illustrate the beginnings and then development of agriculture in the area of SE Wolin. In this case the pollen data are supported by archaeological material (Cnotliwy 1961) including archaeobotanical record (Klichowska 1967). Archeologically, the first Neolithic settlement was that of the Funnel Beaker culture.

The pollen results suggest continuity of settlement from the Late Mesolithic to the Neolithic and similar type of woodland management, however, the economic pressure on the local environment was distinctly increasing due to rising agricultural activity. The first indicators of agriculture (*Plantago lanceolata* and Cerealia-type pollen) seem to appear earlier than the Funnel Beaker settlement. The meaning of these pollen records will be discussed.

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Hunters and fisher in a changing world - Preliminary results of the archaeological fieldwork 2003-2008 of the SINCOS research unit in Wismar Bay, Germany

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1. The SINCOS-Research unit

Submerged prehistoric sites in the south-western Baltic with well preserved organic finds contain a great potential for cultural and archaeo-/palaeoenvironmental studies to reconstruct archaeological settlement history and for marine geological research concerning the Litorina transgression in the Baltic basin. In Mecklenburg-Vorpommern a systematic research, excavation and management of submarine Stone Age sites started in 1998 in a close cooperation with marine geologists of the Baltic Sea Research Institute Warnemünde. The investigations were mainly supported by the German Research Council (DFG) as one part of the interdisciplinary DFG Research Unit "Sincos" (www.sincos.org), which founded in 2002 (Harff et al. 2007). Since 2007 the archaeological investigations of SINCOS were continued under the leadership of the Roman-Germanic Commission of the German Archaeological Institute.

2. Wismar Bay

The two main areas of investigation were the Wismar Bay west and the coastal waters of Rügen Island east of the Darss sill structure, which played a central role during the beginning of the Litorina transgression in the Baltic basin.
In Wismar Bay it was possible to reconstruct the cultural development from the beginning of the late Mesolithic around 6500 cal BC until the end of the terminal Mesolithic before the late hunter-fisher-gatherer societies were superseded by the early Neolithic Funnelbeaker Culture around 4100-4000 cal BC. The excavated sites were found between 11 m and 3m water depth depending on their age and the rapid sea level transgression in this region.

3. Jäckelberg-Huk

The first main region of investigations in Wismar Bay is the northern end of the "Jäckelberg", a moraine ridge 1,5 nautical miles off Poel Island. Several Stone Age sites were located here in 6 up to 11 m deep water (Lübke in press). The sites are belonging to different phases of the Late Mesolithic and the Early Terminal Mesolithic between 6.500 and 5000 BC – a time period which is up to now not really known in North Germany due to the lack of stratified sites.
The site Jäckelberg-Huk is situated at the edge of the Jäckelberg in 8.5 m below MSL. It is one of the oldest settlement sites known in the Wismar Bay so far dated to the early late Mesolithic between 6400-6000 BC. The sediments consist of a change of mud and reed peat layers indicating varying water levels. Marine molluscs could only be observed in higher sediment layers in the shore line dated shortly after 6000 cal BC, the fish remains of the site itself belong without exception to freshwater and katadrome species like pike (*Esox lucius*), perch (*Perca fluviatilis*) and eel (*Anguilla anguilla*) (Schmölcke et al. 2006). During the time of settlement the site had to be situated in immediate proximity to a fresh water lake, which extension in the today's Wismar Bay is still unknown.

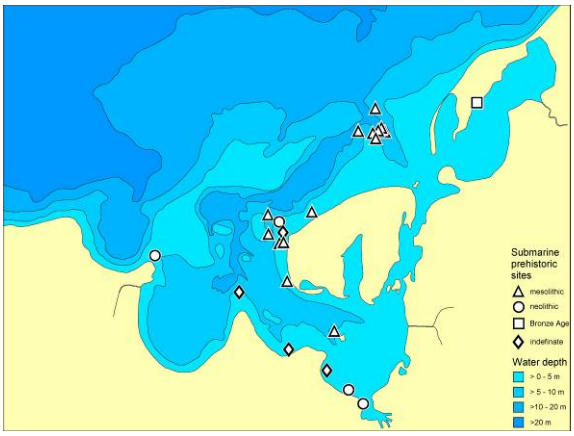

Figure 1. Bathymetric map of Wismar Bay with new discovered submerged prehistoric sites.

The main culture layer was detected in the strongly humic upper horizon of the mineral palaeosol under the peat-/mud-sediments. Exposed fireplaces and concentrations of fire-cracked boiling stones show, that a part of the settlement area had been recovered inside the excavation area. The appropriate shoreline could not be localized yet.
Among the archaeological objects the arrowheads and microliths have to be emphasized specially. Next to trapezes and oblique transverse arrowheads, also rhombic arrowheads and a few very small longish triangles belong to the finds. The inventory can be compared with Danish sites belonging to the first phase of the Kongemose culture dated to 6400 – 6000 BC. Therefore the archaeo-typological data refer to the same time period as the C-14 data so far. Thus the site has an extraordinary importance for the history of cultural evolution in the south-western Baltic Sea region, because for the first time the existence of the Kongemose culture could also be proven at the German Baltic coast.

4. Timmendorf-Nordmole I

In the second main region several sites of 5th and the 4th millennium BC were discovered in 2 m up to 5 m deep water off the small fishing village Timmendorf-Strand on the western Island Poel. The excellent preservation of organic material especially on the two sites Timmendorf-Nordmole I and II of a middle and a younger phase of the Ertebølle-Culture allows detailed archaeological and scientific studies about settlement structures, economy and ecology of the latest hunter-gatherer-societies at the German Baltic coast (Lübke 2006). Together with new results of investigations on the West Mecklenburgian Bay they gave proof of the existence of a younger phase of the Ertebølle Culture on the Northern German Baltic coast which was replaced by the Funnel Beaker culture not earlier than 4100 BC (Hartz and Lübke 2006; Hartz et al., 2006). During the investigations of the site Timmendorf-Nordmole I the find layer of a settlement of the late Ertebølle culture (4400 - 4100 BC) could be laid open in 2.5 to 3.5 m below MSL.

Large parts of the former settlement surface in 2.5 m deep water were destroyed by erosion, as an abraded marl layer appeared directly below a 20 cm thick surface layer consisting of gravel with numerous eroded stone artefacts. But entrenched settlement features are preserved in this area, as e.g. a pit, which had a pear-shaped outline with a narrow entry at one side and an extended utilization area at the other. The values of the 14C-dated samples indicate an age of the pit between 4200 – 4100 BC

In deeper water the former border of the contemporary settlement and the refuse area in the shore zone are preserved. which contain a large number of archaeological remains (Lübke in press). Countless pieces of sharpened sticks might be part of a fishing fence, which lower post fragments were found in a line in the trench. In front of the post line laid a row of large stones with a flat side up which served as stepping stones in the muddy ground.

According to the preliminary results of the zoo-archaeological material seals (Phocidae) and water fowl like ducks (Anatidae) or Merganser (Mérgus), were hunted besides land mammals such as red deer (*Cervus elaphus*), roe deer (*Capreolus capreolus*) and wild boar (*Sus scrofa*). Except for dogs the existence of domesticated animals could not be proven. The large amount of fish remains is remarkable. Most frequently represented is eel (*Anguilla anguilla*), followed by cod (*Gadus morhua*) and other species. (Schmölcke et al. 2006). Taking into account the analysed artefacts, the inhabitants primarily subsisted on marine resources. Hunting played a secondary role.

5. Summary of the investigation results

Summarizing the investigation results it is now possible to give a first preliminary description of the changing landscape of the Wismar Bay from a glacial shaped valley with lime-oak-forests and fresh water lakes to a semi-enclosed fjord and further to the modern bay. The geo-archaeological investigations could prove freshwater sediments between 11 m and 8 m MSL at the shore-lines of late Mesolithic archaeological sites dated between 6500 and 6000 BC. According to the investigation results on Jaeckelberg-Huk the Baltic reached a sea level around 10 m below modern MSL shortly after 6000 BC. Marine sediments dated to 5400 BC are proven in 7 m below MSL on the site Jaeckelberg-Nord. A further boundary between freshwater and marine sediments were found in 5 m below MSL on the site Timmendorf-Nordmole II dated around 5000 BC. Finally for the period between 4400 and 4100 BC a sea level of approx. 3 m below MSL was determined on the site Timmendorf-Nordmole I.

In addition extensive knowledge could be gathered for the cultural development of the late and terminal Mesolithic in the Wismar Bay area between 6400 and 4000 BC. The hunter and gatherer communities changed their economic system of the late Mesolithic based mainly on large terrestrial mammal hunting and freshwater fishing to a more and more intensive exploration of marine resources in the terminal Mesolithic. This development took place parallel to the Neolithisation of interior Middle Europe and led to a separate parallel economic system in the South-western Baltic for over 1000 years before the Neolithisation of this area happened around 4000 BC (Hartz et al. 2007).

Further it was possible to create in comparison with the investigation results achieved in Ostholstein a first chronostratigraphic division of the terminal Mesolithic Ertebølle culture and the oldest early Neolithic Funnel Beaker Culture in the Mecklenburgian Bay between 5400 and 3700 BC (Hartz et al. 2007).

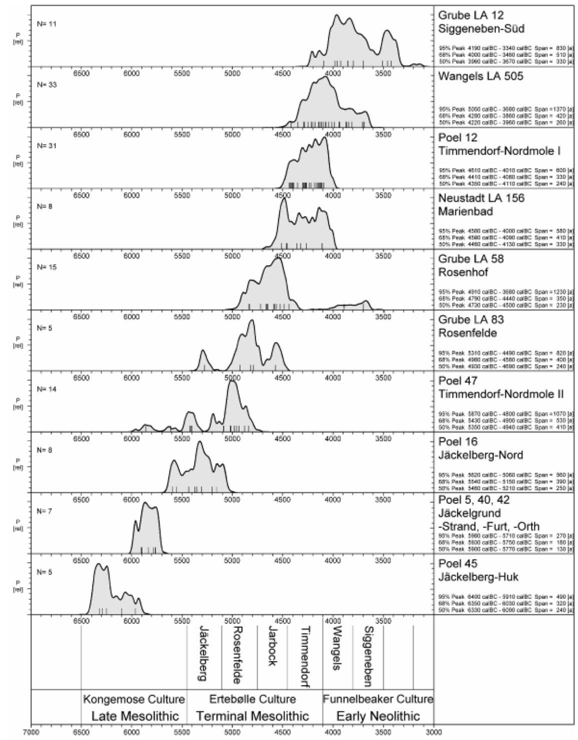

Figure 2. Group calibration of radiocarbon dates of Mesolithic and early Neolithic coastal settlements at the southern Mecklenburgian Bay..

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Climate change influence on the human settlement in the region of the Świna River Gate (NW Poland)

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1. Introduction

The area of Świna River Gate developed in three major stages, depending on climate changes and related sea level changes. Areas differing in time of deposition are divided into brown, yellow and white dunes and some of the young alluvial plains of the reverse delta of Świna River.

Changes in natural environment and climate are correlated with the response of humans as regards degree and stages of settlement.

2. Archeological backgroud of the study area

Archeological data on the study area are sparse and scattered around the region. There are 15 sites without detailed localisation. Staging of the land form accumulation allows distinction of these sites in the southern part of the area.

Identification of the recorded medieval settlement location is possible based on the dune embankment development. Assuming a location of such a settlement by the mouth of the Świna river, the most probable location is within the southern part of the yellow dunes zone.

The scarcity of archeological sites is an effect of water level rise of the Littorina Sea and accumulation of peat. Single sites and discoveries of artefacts in the area of the Pomeranian Bay indicate human presence since the end of the last glacation. The type of archeological finds (coins) indicates locations by the Old Świna river channel as a part of long-distance trade route and waterway.

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Climate change and the prehistoric exploitation of siliceous raw materials: Pomeranian and European perspectives

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Siliceous raw materials played basic role for the tool production during Stone Age. However, accessibility of the outcrops varied according to periodical climatic changes. The character and range of vegetation zones, the water erosion, and the extent of shorelines were among main factors changing ease of access to the outcrops. This contribution presents several prehistoric subsistence strategies, developed in response to the different environmental conditions. It is shown, how these limitations effects in cultural transformations. Also the location of several Pomeranian sources of siliceous rock is discussed, as well as their importance for the prehistoric societies.

Hunting-gathering communities on the Kashubian Shoreland

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The northern part of East Pomerania (known also as Gdansk Pomerania) is quite poor in archaeological sites connected with activity of hunters-gatherers communities. The results of recent research on the Żarnowiec Upland provides new data for investigating the earliest settlement on the territory north from Reda-Łeba ice-marginal streamway and south from the Baltic coast. The presentation deals both with the changes of settlement density and environmental conditions in the period from the Late Glacial to the Early Holocene. Especially, the questions of site condition, assemblage quality, lithic resources and settlement patterns are presented. Also, hypotheses concerning the origin of the first settler's communities and taxonomical affiliation of discovered assemblages are discussed.

Development of concepts of coastal sediment drift structure and coast defence strategy during rising sea levels

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In the middle of the 20th century, in the beginning of lithodynamic research, the concept of homogenic (continuous) coastal drift prevailed. According to this concept, West Baltic sediment drift (WBSD, 385 km) is formed near cape Taran of the Sambian peninsula, and unloads near cape Kolka in the Strait of Irben *Knaps, 1952*. To the south of cape Taran the Gdansk drift forms and reaches to the mouth of the Vistula (98 km). The leading scientists maintained this opininon until the 90's *Zenkovich, Boldyrev (1958), Boinagryan (1966), Beloshapkov (1988), Kirlis (1990), Subotovich (1992)*.

As measurement data accumulated, it became clear that drift direction depends on shore layout relative to the resulting wind and wave force vector. The more acute the angle between wind and wave force vector and coastline, the more stable and powerful is the drift. When the wave vector crosses the normal to the coastline, the drift turns around *Babakov (2003)*. Such a regularity may be observed on the whole southeast Baltic coast, including Gdansk Bay *Muselak* (1988), *Ceslak (*1992). It is also confirmed by calculations by the procedures of Knaps, Loginov, Popov-Sovershaev, Maximchuk, Pyshkin, and by the CERC and IBW PAS models *Beloshpkov* (1984), *Ryabkova* (1987), *Babakov (*2003), *Kaczmarek et. al.* (2008).

Thus, a system of contrary drifts is formed within coast arcs. In the convergence area a migrating type of transfer and accumulation of sediments start to prevail. At the same time transverse ejection of material into the sea becomes more intense. As a rule, flows diverge near capes, which are natural borders of separate lithodynamic systems.

The second important peculiarity of nearshore sediment drifts is a high activity of transverse drift, which is apparent from strong deformations of underwater slope at depths up to 10-15 m and more: 2 m near Yurmalciems, 2.5 m near Shventoy, 3 m near Klaipeda, 3,5-4 m near Nida, 4-5 m near Svetlogorsk, up to 5 m near Vladislavovo *Korobova* (1972), *Aibulatov et al* (1979), *Shuisky* (1986), *Boldyrev et al*. (1990), *Semrau* (1992), *Babakov* (2003, 2008).

The power of sediment drift on the whole Sambian coast is estimated by different authors to amount to 150-250 thousands m^3 per year *Boinagryan* (1966), *Boldyrev, et al* (1979), *Ryabkova* (1987), *Babakov* (2003). Yet deformation capacity within half-closed bays and at dumping spots near Yantarny and Baliysk varies from – 2.5 to + 3 millions m^3 per year. This clearly means that migrating drift type prevails, and transverse drift in the first place. It is important to note that most strong deformations occur in the period of extreme storm pileups, the coasts are eroded, and on underwater slopes of up to 15-20 m accumulation prevails *Babakov* (2003).

As is well known, during the 20th century a coast destruction process prevailed. Towards the end of the century it activated, extending to coasts that were stable before. Many scientists tend to relate this process to global warming of anthropogenic nature, others think it is due to non-uniform cyclicity of natural processes. Nevertheless, the effects of such a tendency can be seen in a rising sea level and in increasing cyclonic activity.

In Klaipeda, Baltyisk and Kaliningrad the sea level rose by 13.1, 20.1 and 16.5 cm respectively over 90 years (1901-1989), and for 9.2, 10.2 and 12.0 cm over the last 10 years (1981-1989). Over the period of 1951-1989 the regular occurrence of western winds increased from 39% to 61%, storm pileups –by 5 times, and to the end of that period there were 7 cases of absolute levels increasing by 126 cm *Sergeeva* (1991).

With rising levels coastal recession also increased: up to 0.5–1.5 m at the Sambian peninsula (Boldyrev et al, 1990), to 1 m at abrasion spots of Curonean Spit (Kasakavicus, 1990), and to a lesser degree at the stable coast of Vistula Spit *Kaczmarek et al. (*2008).

In the 21st century acceleration of rising sea levels and coast destruction is expected. In *Meier's et al.* (2004) paper three possible scenarios of rising levels by 2100 are considered: slow, to 9 cm, medium, to 48 cm, and fast, to 88 cm. For Gdansk Bay the maximum sea level rise may reach 1 m, which leads to coast recession by 50-100 m. All lower regions will be drowned.

In such circumstances it is only possible to protect single, most valuable regions. The peculiarities of sediment drift routine within lithodynamic systems are to be considered. The most active abrasion will take place in the area of drift saturation. Right there it is recommended to decrease wave loading, reducing transverse ejection of sand to deep water. For this to be attained, it is necessary to mount a series of emerged or submerged discrete breakwaters at the first break line of storm waves, possessing maximum energy. Limiting transverse ejection of sediments, they let excessive pileups pass along the shore, diminishing the risk of lower wash-out. Making and maintaining of such constructions does not cost much, and the beach keeps its natural look.

Similar breakwaters proved their efficiency and are widespread in the west *Peshkov,* (2003). They are used at the Polish coast of Gdansk bay. In Russia their wide adoption is planned at Azov and Black seas *Shahin et al*., (2007), *Krylenko, Kosyan,* (2007).

It is important to precisely calculate parameters of breakwater series in specific spots, which requires special field observations and theoretical research.

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Present sea coast condition of the south-eastern Baltic Sea according to remote sensing and monitoring data

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In the light of the indisputable facts of global climate changes taking place everywhere in the world, it is interesting to follow the response of the condition of coastal zones to these changes. In the past 25 years the south-eastern Baltic coast has experienced 25 storms of extreme power.

Research on this problem has been carried out at the Atlantic Branch of the Institute of Oceanology, using the results of aerial photography of the Baltic coasts in 1960 together with annual south-eastern coast monitoring since 2000. While comparing the aerial photography data with numerous photographs taking in recent years for monitoring, a clear insight was reached into the developments of the past 45 years.

The most powerful storm of 1962 has been recurring regularly once in 50 years. When comparing the aerial photographs of 1961 and of 1962, the year when this storm calmed down, it is possible to follow its effect along a considerable stretch of the sea coast.

Analysis of the recent 5-years monitoring data shows varying tendencies and speed dynamics, depending on the genesis and orientation of the sea coast. Most vividly these differences can be observed at the sea coasts of the Vistula and Curonian Spits, and on the western and northern shores of the Sambian peninsula.

Development over time of the Pleistocene outcrops at the steep coast of the Stoltera west of the harbour Rostock-Warnemünde

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1. Motivation

In the last years the spectacular cliff slides at the steep coast of Rügen sensibilised layman and scientist for the problems of coastal changes in Mecklenburg-Vorpommern. Also the cliff of the Stoltera situated 3 km west of the harbour Rostock-Warnemünde suffers from coastal erosion by the water of the Baltic Sea, especially by the storm event 'Kyrill' in 2007. This event generated fresh outcrops of Pleistocene sediments after a longer period with less erosional effects, in which vegetation has covered most of the cliff. However, in the past there were also similar exposure conditions like today. This factor had early aroused the interest of geologists. The first author, who investigated this section since 1884, was *Eugen Geinitz* (therefore the landmark 'Geinitzort' is named after him). The last geological survey of the cliff was done by *Schütze & Strahl* (1988/89) and dates back 20 years ago. Landslide inventories by the State Geological Survey led to new subscription of the steep coasts. Thus, the cliff of the Stoltera was recently mapped (*Brumme* 2008). Besides determination of the geological situation, the cliff exposures were also documented by photographs.

2. Investigation area

The cliff of the Stoltera has a length of c. 1,100 m between 'Wilhelmshöhe' in the east and 'Geinitzort' in the west. It represent the northern end of a shallow, in part undulating ground moraine of the youngest ice advance of the Weichselian glaciation. The altitude of this NNE-SSW striking hill reaches nearly 18 m NN at the cliff, but only 10 m landwards. Remarkable are the NE-SW striking synclines and anticlines well exposed at the cliff face. In the area of synclines, the cliff is made of sandy to silty deposits, while in the anticlines till is truncated.

There are five different till units in the investigation area named as m_1- m_5 till. Between this units there are sediments called i_1 to i_3. The oldest stratigraphic unit is the m_1-till which was deposited during the Saalian glaciation. The following tills (m_2 to m_5) belong to the Weichselian glaciation. With the exception of the i_1-sediments, which are probably a Eemian deposition, all other intercalations (i_2 and i_3) are remnants of different Weichselian thermomeres. The complete succession is intensely disordered by glacial tectonics (*Ludwig* 1964).

3. Methods

At the beginning of the investigations, the cliff was calibrated in equal segments of 50 meters starting at Wilhelmshöhe. Important locations were marked with capitals from E to O. After that the profile was mapped in detail. The composition and thickness of the different lithologic units was described. Additional a photographic documentation was made for every 10 meter profile. These photos were located with GPS to include them into the geohazard database. Changes of the

To show the changes of the appearance of the steep coast of the Stoltera over the time, results of prior mappings (*Köster* 1947, *Ludwig* 1964, *Cepek* 1973, *Schütze & Strahl* 1988/89) were used. For that reason profiles were brought to an uniform scale and compared with each other.

Figure 1. Example for the eroding effects of the sea water at the cliff of the Stoltera at section meter 740, scale = 2,5 meters, view from the north

4. Results

Because of the incompetence of the sandy to silty sediments in the exposed synclines the erosion of the seawater had especially here a high effect (Figure 1). These parts of the cliff are niche-liked developed. The till areas had a higher competence, thus they stick out like a pillar.

Furthermore, the situation of outcrops at the Stoltera has changed over time. The eroding effects from the seewater generated new outcrops respectively "cuts" of the pleistocene deposits. Stratigraphic members appear and fade away, thickness as well as strike and fall trends vary. Because of this circumstances the interpretations of the genesis of the Stoltera from different authors also vary.

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Is the 8200 cal y BP climatic event recorded in the southern Baltic Sea lagoon deposits? Microfossil - based (diatoms, cladocera) study on the Rega River valley

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Ideas on postglacial development of the southern Baltic Sea coast have been subject to significant changes over the past decades. This particularly concerns the spatial and vertical extent of consecutive stages of the Holocene transgression, which are known as Littorina and Postlittorina, respectively (e.g. Rosa, 1964; Tobolski, 1989; Rotnicki, 2001; Uścinowicz, 2006).

The geological structure of the lower Rega river valley was explored by means of a number of drillings in the area of the Rega river mouth (Fig. 1). The material from the cores was retrieved with an intact sediment samples for analysis. In total, 29 cores varying in length from 7 to 13 m were drilled. In addition to lithological analyses, the sediment samples from several cores were studied by microfossil analyses and these included diatoms and cladocerans and to a lesser extent pollen. The major aim of the study was to establish palaeoinferences of environmental variables including salinity, trophy and pH. The results of the lithological and microfossil analyses permitted compilation of a meridional geologic cross-section (cf. Fig. 1). Interpretation of this cross-section revealed several lithological units (D-I). To a certain extent, these units correspond to changes in diatom assemblages and in cladocerans.

Our analyses revealed that the biogenic sedimentation filling in the bed of the Urstromtahl and of isolated water bodies is represented by deposits of units D, C-D1 and C-D2 (Fig. 2). Both radiocarbon dates and pollen analysis show the development of these units during the late Vistulian climate amelioration which happened during the Allerød and has continued until the end of the early Holocene. Similar development has been observed for this time period in the Szczecin Lagoon area (cf. Borówka et al. 2005). The deposits of the lithological unit E corresponding to a marine transgression in the study area, were discovered in a core drilled in the vicinity of a fossil cliff and hence could be a marker of a contemporaneous lateral sea extent (Cedro, 2004, Witkowski et al. in print). Sea level rise at ca. 8640-8330 cal y BP resulted in a beginning of biogenic sedimentation on the fossil plateau (core Trz-2). The age of the *Cardium* sp. shells found in situ indicated a date of ca. 7680 - 7400 cal y BP. However, within the marine sandy sediments of the cores Trz-23, Trz-24, Trz-21, Trz-29, Trz-20 and Trz-17 an intercalation of gyttja and peat i.e. limnic/swampy deposits, was observed. The change in lithology from marine (sands) into limnic/swampy (gyttja and peat) sediments corresponds to changes in diatom assemblages. The diatom assemblage composed of marine and brackish-water forms dominant in marine sands is replaced in the gyttja and peat by forms occurring in freshwater (Witkowski et al. in print). Thereafter a sea level increase is again observed and marine sands were deposited. The intercalation of gyttja and peat in marine sands is interpreted as an indication of a distinct environmental change during a general sea level rise induced by marine transgression (Cedro, 2008). The break in the marine sedimentation is a very good match for a distinct climatic event, the so-called 8200 cal y BP event, which has so far been observed only in south-eastern Sweden (Berglund et al. 2005). Our data are the first record of this event at the Southern Baltic Sea coast. These data are best expressed in core Trz-15 in which salinity decrease and water level drop were recorded in a lagoon close to the sea-shore by means of diatom and cladoceran assemblages (Witkowski et al. in print, Zawisza unpublished observations). In this core marine sediments are also eroded by fluvial deposits of lithological unit G. The level of the sole part (marked by the gravel level) of the riverine deposit occurrence is ca. 5 m below sea level (Cedro, 2005). These phenomena are related to changes in the Baltic Sea level during the time period of 9000 - 4200 cal y BP which were reported by Rotnicki (2001). The further lithological units correspond to the development of the lower Rega river valley during the period of ca. 6900 cal y BP to recent times. The deposits of lithological unit F constitute gyttja rich in freshwater mollusk fauna. The swampy deposits are represented by unit H and cover the whole study area. Later on the whole area was covered with extensive Aeolian deposits of unit I.

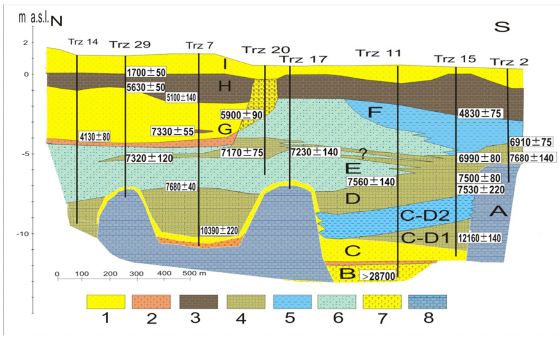

Figure 1. Geological cross section: Mrzeżyno-Rogowo - Stara Rega. 1 – sand, 2 – sand and gravel, 3 – peat, 4 – lagoon deposits (peat, gyttja, clay and mud), 5 – gyttja and mud, 6 – marine sand, 7 – organic matter rich sand, 8 – boulder clay.

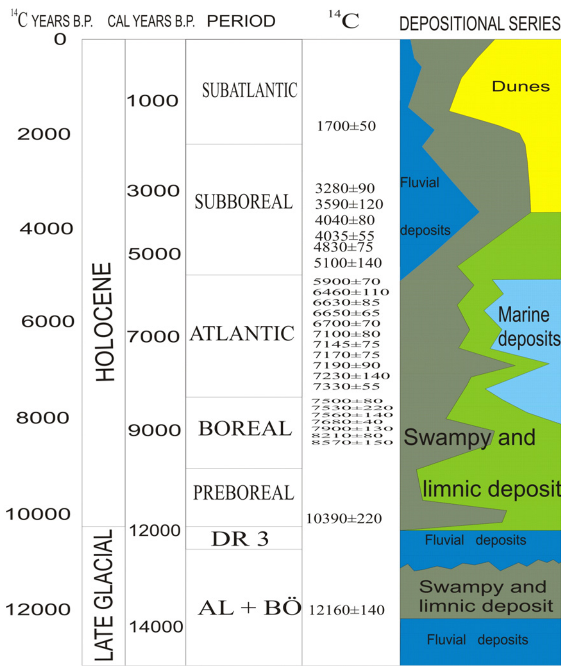

Figure 2. Age depositional series

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Long-term changes in the rate of coastal erosion in the Kaliningrad Oblast (south-east Baltic)

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The long-term changes in the location of the coastline and rate of erosion were studied by comparison of results of the aero-photo survey of 60^{th} and nowadays satellite images for the coast of Sambian Peninsula, Kaliningrad Oblast (Russian Federation). The most eroded coastal segments were reveled, and 7 segments were assigned as segments ‘in danger’.

On the basis of the regular monitoring data from last 5 years the rate of erosion was asset for different segments of the Kaliningrad Coast. Variations of yearly changes are rather high – from 1-1.5 m per year up to tenth meters per year for some particular parts.

General conclusion is that marine sandy coasts of Sambian Peninsula and of the Curonian spit are permanently eroded. The rate of erosion increased during last 10 years, despite to the fact of decreasing of average wind speed in the region. For the Vistula Spit, in opposite, stabilization is observed practically for whole Russian part of the spit. Only 4-5 kilometers near the Baltiysk Straight is experienced very intensive erosion.

The most probable reason of the increase of rate of erosion is in the sophisticated changes in trajectory of cyclones over the area, which led to the situation, when common for this region western storms are coming at the background water level which is higher than it was usually before.

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Measured sea level rise at the Baltic Sea coast of Mecklenburg Vorpommern and implications for the design of coastal structures

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1. Introduction

The assessment of local sea level rise is, for example, necessary for the examination of storm surges and also for the design of coastal structures.

Sea level rise at the Baltic Sea Coast of Mecklenburg Vorpommern can clearly be identified on the basis of water level measurements. The main reasons for long term water level rises in the Southern Baltic Sea are changes of the local conditions as well as isostatic and eustatic subsidence and elevation processes.

2. Sea level rise - analysis check

At the whole earth the sea level was investigated and is investigated with different methods, which may lead to different results in the determination of the sea level rise, see for examples *Dietrich and Liebisch* (2000).

Hence, one aim of the paper is to check the influence of the different analysis methods on the results of sea level rise analyses.

In a first step the water levels of selected gauges at the Baltic Sea Coast of Mecklenburg-Vorpommern were analyzed. Table 1 shows examples of the different sea level rises at the Station Warnemuende.

The calculated sea level rises of different data sources (Warnenmuende (PSMSL), Warnemuende (WSA)) were compared. Furthermore was analyzed, how much are the differences between calculated sea level rises of different time period und different sample choice (hourly, monthly, annual).

Strong differences have been identified for calculated sea level rises based on different data sources. Other bigger differences of calculated sea level rises resulted from the selection of different time periods, which is obvious if we consider the discussions on accelerated sea level rise in the last 30 years.

In absolute consideration the differences are low, with maximum 0.9 mm/y. But with percentaged consideration the maximum differences are approximately 50 %.

The differences between different samples selected from a probe are comparatively small. On the base of this analysis, the calculated sea level rises of yearly samples are smaller than the calculated sea level rises of hourly or monthly samples.

Station	Period	Sample	Sea level rise
Warnemuende (PSMSL)[1]	1856-2006	monthly	1.2 (mm/y)
		Annual	1.2 (mm/y)
	1956-2006	Monthly	1.6 (mm/y)
		Annual	1.5 (mm/y)
	1987-2006	Monthly	1.5 (mm/y)
		Annual	1.5 (mm/y)
Warnemuende (WSA)[1]	1956-2006	Hourly	2.3 (mm/y)
		Monthly	2.3 (mm/y)
		annual	2.2 (mm/y)
	1987-2006	Hourly	1.4 (mm/y)
		monthly	1.4 (mm/y)
		annual	1.3 (mm/y)

Table 1: calculated sea level rise for different samples

3. Influence of Sea Level Rise on Design of Coastal Structures

A long-term sea level rise has been considered in the design of coastal structures since approximately 50 years. This so called seculary sea level rise was in the range of 15cm to 25cm per 100 years.

This value was extrapolated to the design period of the structure and was then directly added to the design water level.

In the last decades, possible climate change and resulting accelerated sea level rises have been discussed heavily. At present, this fact is also under discussion in the whole coastal engineering community, and two of the German Federal States (Lower Saxony and Bremen) have already included an additional value to be prepared for a (comparatively moderate) accelerated sea level rise.

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A laser scanning application for volumetric changes of beach and dune analyses

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The coastal zone is hardy available from the sea and from the land. Research vessels can not operate in water less than 1m dept. It is very difficult to measure a bottom shape less then 1m dept from the land. In both cases different techniques should be used: Echosounder in profiles on the sea and GPS RTK from the land. There are different density of the data, which can cover area of beach and dune versus shallow water area.
A new remote sensing technology – laser scanning (LiDAR – Light Detection and Ranging) recently became an adequate tool for coastal monitoring (Brock *et al.*, 2002, Lindstaedt, Kersten, 2005). The LiDAR technology for topography consists of the red laser but for coastal zone purposes combine of two laser scanners: the red one for dune and beach and the green & IR one for bathymetry. The laser scanner measures a distance from the scanner to a land (red) or to a bottom (green) with the certain density. As a result of the registration one can obtain points cloud with determined x, y, z coordination's. DTM (Digital Terrain Model) for whole area can be rich as a result of LiDAR registration as a homogenous data. The integrated laser scanning (LiDAR) technology gives new possibilities to obtain fast, accurate and simultaneous data of the sea bottom and the beach relief. The analysis of Digital Terrain Model (DTM) obtained from laser scanning allows finding a relationship between causes and effects of dynamic processes observed in the coastal zone (Dudzinska-Nowak, 2007).
At the paper authors presents initial results of the first application of laser scanning registration of Polish coastal zone. An investigation was provided at the southern Baltic coast near the Swinoujscie town and cover about 3,5 km of the coastal zone. The first laser scanning registration of this area was done at 29.04.2007 using Hawk Eye laser dedicated for the coastal zone registration (red, green&IR). The second registration was done at 31.08.2008 by topographic laser scanner LMS – Q560i Riegl (red).
On a base of two registered points cloud the DTM's of the investigated area, taken in 2007 and in 2008, were created. The whole data were converted to the same coordinate system. Two DTM's for 2007 and 2008 were subtracted for calculating dune and beach volumetric changes.
As a result of project authors present a map of beach and dune elevation differences. The spatial distribution of one year differences was discussed in an aspect of hydro-meteorological conditions, which were observed between both dates of LiDAR registrations. This kind of research allowed calculating volumetric changes of the beach and dune and indicates places of the most intensive coastal processes. Utility of the laser scanning gives better opportunities to understand conditions and phenomena observed in the coastal zone, especially storm damages.

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Using SEDSIM to predict the response of coastal sediments to climate change in Australia

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1. Introduction

Climate is changing. Climate has always changed over time, and by that we mean that climate statistics (significant wave height, storm frequency, temperature, etc.) are non-stationary over a given time period. The causes of such change, and indeed the rate of change, may vary according to cause, but humanity depends on our ability to predict the consequences of such change in time to adapt to, or mitigate, the effects. In 2003 CSIRO embarked on a project to predict the effects of possible climate change scenarios on the whole of the Australian Exclusive Economic Zone (EEZ). The modelling was carried out using the Sedsim sediment transport software at a grid resolution of 2 km from 2005 to 2055 assuming three climate scenarios, lower energy, higher energy, and a continuation of the present day. The project was completed in June 2008 and the results and data are being made available to the public via a web site and several publications. The five-year programme covered the complete EEZ, including carbonate and deep marine environments in nine separarate simulations (Figures 1 and 2).

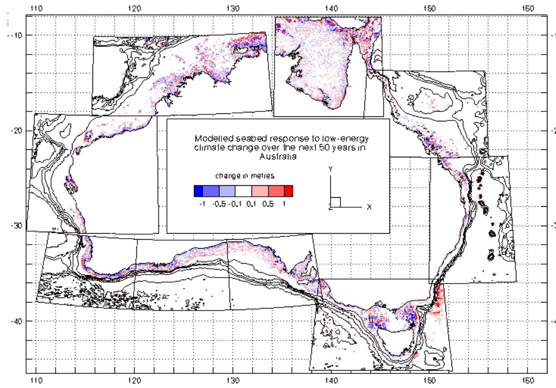

Figure 1. The nine regions of the EEZ modelled by Sedsim. Accretion and erosion predictions for the low-energy scenario are shown around the coasts of Australia.

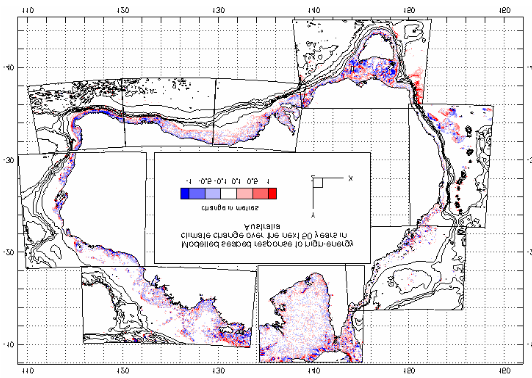

Figure 2. Accretion and erosion predictions for the high-energy scenario are shown around the coasts of Australia.

2. The Australian environment

The Australian environment varies considerably around the coast. In the far north the system is dominated by carbonate growth and precipitation, with frequent cyclones and high tides. In the south the main sediment is siliciclastic material moved by waves, currents and tides with occasional winter storms. On both the east and west coasts ocean currents play a significant role in moving sediment and nutrients. Capturing the interplay between these various processes over large areas and decadal time intervals was challenging.

3. Seabed observations

Gathering the data upon which such simulations depend is not a trivial matter. Seabed grainsize and composition data have been sparsely collected at varying times over the past hundred years or so and are of varying quality. The most comprehensive data-base of sediment grain sizes and composition around the coast and shelfal regions of Australia is that assembled in the auSEABED database (*Jenkins (2003)*). From this source grain size and sediment compositions are interpolated onto a regular 2 km grid and overlaid on the high-resolution bathymetry. Depth to rock-head is also available in some cases and this is used to prepare an intial (erodable) sediment layer of variable thickness.

4. Climate change

The Australia Bureau of Meteorology has prepared a series of 50 year climate projections based on possible realistic scenarios (*McInnes et al(2003)*). In addition to a continuation of the present day climate, two "realistically possible" climate change scenarios were considered (Hennessy, 2006). Thus three representative climatic scenarios for the next 50 years were used to simulate seabed responses:

1. stationary climate: no climate change, present climate continues;
2. low-energy climate change scenario: lowest rainfall, lowest sediment load, lowest outflow, and El Niño year oceanographic conditions, no sea level rise in next 50 years;
3. high-energy climate change scenario: highest rainfall, highest sediment load, highest outflow, and La Niña year oceanographic conditions, maximum sea level rise in next 50 years;

The first "base case" simulation investigated the response of the seabed over 50 years under the present climate conditions. For the first scenario we used the mean values observed in the 1991 - 2005 period. For the high-energy scenario, we extracted the conditions of the strongest La Niña year in 1998 and the low-energy ocean current is represented by 1997 El Niño year conditions.

5. The Sedsim program

Sedsim is a process-based stratigraphic forward model initially developed under a consortium at Stanford University in the 1980s. Since the 1990s the program has been systematically modified and adapted. **Sedsim** has now been tested and applied to many of the major erosional, transport and depositional processes including fluvial, aeolian, shallow and deep marine, coastal waves and storms, carbonate growth, slope failure, turbidity flows, and deep ocean geostrophic currents (*Koltermann and Gorelick (1992), Griffiths et al. (2001), Martinez and Harbaugh (1993), Tetzlaff et al. (1989), Li et al. (in press, 2007, 2006, 2003)*). In **Sedsim** the Navier-Stokes equations and the continuity equation are simplified and solved by using a marker-in-cell technique in two horizontal dimensions. Flow velocity and sediment load are represented at points that move with the fluid. A two-dimensional square grid is used to represent depth of flow and elevation of the water-sediment interface. At each time step each fluid element's position and velocity are recalculated. This technique combines the advantages of Eulerian and Lagrangian representations of fluid flow. To allow for the computation of seabed morphological evolution on time scales of decades and spatial scales of hundreds of kilometres, substantial simplification schemes are essential because the full scale, direct simulation of all involved processes is not feasible. Major model assumptions include a) morphological seabed change has a negligible effect on deep ocean current, tides and waves; b) oscillatory water movement caused by wave and tides creates negligible long-term net sediment transport in deep water. They are only responsible for mobilising sediment and making sediment available for transportation by large-scale ocean circulation.

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Application of MODIS satellite data for the analysis of coastal water dynamics and suspended matter distribution in the south-east Baltic Sea

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1. Introduction

The last decades were characterized by significant change of hydrometheorological conditions and intensification of coastal processes along the sandy coasts of the south-eastern Baltic Sea region, which are mostly vulnerable to erosion and therefore sensitive to sea level change combined with overall extreme hydrometeorological conditions.

Studies of coastal hydrodynamics and spatio-temporal changes of suspended matter distribution, as well as dispersion of fresh water inflow from rivers along the sea coast gain particular importance in understanding of coastal change phenomena. Analysis of optical and thermal remote sensing data provide sensor-based, regular and seamless coverage of large areas, thus improving the knowledge of movement of coastal water masses, as well as making operational remote sensing information available for qualification and interpretation of numerical models and extension of assessments provided by expensive and limited in-situ monitoring.

2. Objectives of the study:

- assessment of capabilities and analysis methods of remote sensing data sampled by ocean color satellite sensors for studies of coastal hydrodynamics in the south-eastern Baltic Sea region;
- identification of the main characteristics of coastal water mesoscale circulation in the study area and its dependence on hydrometeorological conditions, stability/variability of hydrodynamical structures and related analysis of spatial distribution of suspended matter in coastal waters.

3. Materials and methods

A large archive of satellite images sampled by MODIS sensors on satellites Terra and Aqua during the period from 2001 till 2007 were used for the study. L1B level data were downloaded from LAADS center in USA (http://ladsweb.nascom.nasa.gov/index.html). Satellite images were processed for further analysis in several different ways.

Production of “true-color” composites was carried out by a chain of steps including atmospheric correction (crefl), reprojection (MRT-Swath), brightness adjustment, land masking and combination of channels 1, 3 and 4 (GDAL) into RGB-143 color images of 250 m/pixel resolution. Those high resolution images were very useful for visual analysis and assessment of situations, as they provide relatively high level of detail and broad spectral bands.

Detailed analysis of water dynamics, distribution of suspended and dissolved matter and sea surface temperature was carried out on the basis L2 level satellite data processed by SEADAS 5.3 software. Special algorithm MUMM (Ruddick et al., 2000), developed for turbid coastal waters and most suitable for the optically complex Baltic Sea (Woźniak et al., 2008) was used for atmospheric correction of satellite data. Normalized water-leaving radiance (nLw) values were calculated for channels 412, 443, 469, 488, 531, 551 555, 645, 667, 678 and SST with 500 m/pixel (for bands 469, 555, 645) or 1000 m/pixel (all the others) spatial resolution. Calculation and analysis of physical values of suspended and dissolved matter concentrations was not carried out because of high level of uncertainty in standard algorithms under the conditions of the Baltic Sea (Darecki, Stramski, 2004; IOCCG, 2000). Earlier studies (Karabashev et al., 2005, 2006, 2007) have revealed that nLw values can be successfully used for general analysis of water exchange processes, in case if there is no need to obtain quantitative information on the physical substance present in the water.

All processing and analysis of satellite data was carried out on Linux (Ubuntu 8.10) operating system and open source software applications.

The collection of satellite images for current analysis mainly focused on periods characterized by relatively low intensity of algal blooms. Winter period satellite images were mostly not available due to intensive cloud cover over the study area, even though those images are mostly valuable for the studies of suspended matter distribution, as those taken during the periods of intensive algal blooms are characterized by overwhelming presence of phytoplankton, which becomes the main substitutive factor of the surface water colour. Despite the fact that phytoplankton often serves as a tracer for the analysis of hydrodynamical processes in surface water layer (indicating extensive surface flows or eddies), it also completely eliminates the possibility of mineral suspended matter and CDOM detection in water column.

4. Results

Specific optical properties of the Baltic Sea reduce the possibility of suspended matter analysis to a narrow depth range (less than 10 m) of surface water. This is caused mainly by high CDOM concentration with high absorption in short-wave range and subsequent shift of transparency window towards 550-570 nm range, as well as high concentration of suspended matter in the coastal waters. All those factors significantly reduce the effective depth range of optical remote sensing studies in the Baltic (Jerlov, 1976; Wozniak, 1987, Karabashev, 2005).

Our study was focused mainly on analysis of spatial distribution and dynamics of suspended matter originating from coastal erosion processes in close vicinity to highly abrasive sections of the sea coast. In particular, the analysis of coastal area between the northern part of Vistula Spit and southern part of Curonian Spit, including the coast of Sambian Peninsula was carried out.

The study area is located far away from large liver inlets, therefore the only sources of inorganic suspended mater are coastal and bottom erosion and discharges from amber mining facility located in the western part of Sambian Peninsula. Abrasive type of the coast and heterogeneous shape of the coast line with intense sequence of coastal capes and bays along the Sambian Peninsula cause very complex patterns of water circulation (Babakov, 2003; Zhindarev et al., 1998). Satellite images clearly identified several mesoscale hydrodinamical features in the study area, like for instance a massive outflow of suspended material from the coastal zone from the areas of the capes towards the west under the condition of moderate (up to 6 m/s) eastern winds, formation of a persistent anticyclonal eddies between capes Taran and Gvardeysky observed during a period of 6 consequent days, periodical development of an increased turbidity area along the zone of high coastal abrasion of the Curonian Spit between Zelenogradsk town and Lesnoe settlement. The same area has been often featured by cyclonic eddies with up to 9-15 km diameter and up to 10-20 cm/s water current velocity, as revealed by radar measurements of surface currents by CODAR (Coastal Radar) equipment (Gorbatsky, Gurova, Babakov, Chubarenko, 2007).

We also studied along-shore suspended matter transportation along the western coast of Sambian Peninsula, its directional variability and stability of persistence under different wind conditions. Those phenomena were analyzed in different spectral ranges of optical imagery and corresponding patterns of sea surface temperature, including the analysis of gradients, spectral profiles and dynamics related to hydrometeorological conditions measured by coastal meteo-stations in Poland (Hel, Gdansk), Kaliningrad region (Baltiysk, Pionersky) and Lithuania (Nida, Klaipeda). Along with long-term information on dominating wind conditions, remote sensing methods make it possible to study the impact of climate change on development of coastal processes in south-eastern Baltic.

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Sinking Coasts – Geosphere, ecosphere and anthroposphere of the Holocene southern Baltic Sea (SINCOS)

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The Baltic Sea (Figure 1) with its ublifting basin on the Baltic Shield and its southern part belonging to the subsiding belt which surrounds the uplifting shield forms an ideal field to study the interrelation of natural and anthropogenic processes on differnt time scales from the decadal to the millennial. Figure 2 shows the cause-effect relation of factors influencing coastal development to be studied in SINCOS. First interdisciplinary results of the project are published by Harff and Lüth (in print). Models and empirical data analysis are combined in order to investigate as well the history of coastline change in the Baltic area through the Holocene as also to elaborate future scenarios.

Models of different types are used for reconstructions of the history of the system and its components as well as for the derivation of a prognostic scenario of relative sea level change by forward modelling. Proxy-variables derived from geological, archaeological, and biological sampling along the southern sinking Baltic coast play a key role in the historical reconstruction by calibrating the models for forward modelling. Prognostic coast line scenarios, integrating IPCC assumptions, but also statistical analysis of climate data demonstrate possible implications for the future.

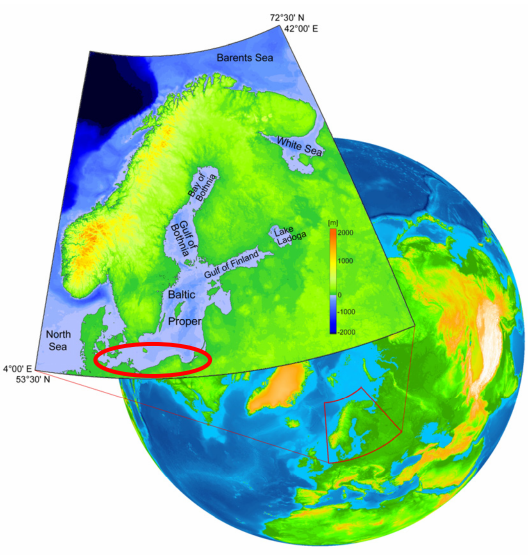

Fig. 1. The Baltic Sea and the and area (red ellipse) for sub-regional and local SINCOS-studies

Relative sea level curves are used for the reconstruction of paleo-geographic scenarios. Own sea level studies have been carried out within the Wismar Bay the Darss-Zingst Peninsula and at Rügen Island. Archaeological findings play an important role for the elaboration of local sea level curves. 3D models of sea level scenarios are received by spatial interpolation between isochronous values of relative sea level curves comprising information about climatically controlled sea level change and vertical crustal movement (neotectonics).

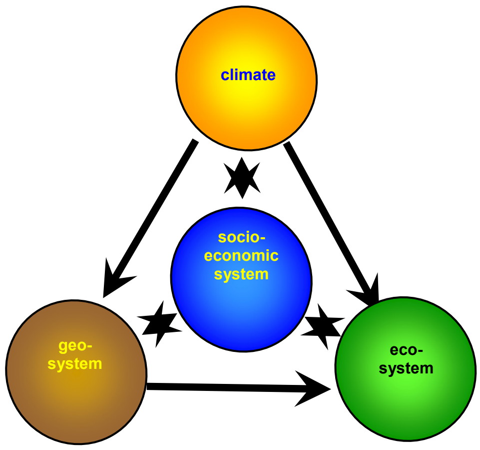

Fig. 2 Cause-effect relation of factors influencing coastal developments

For future projections of coastline scenarios, models of vertical crustal movements have to be superimposed with sea level predictors. The latter ones are taken from an ensemble of climate simulations with the global climate model Echo-G driven by IPCC SRES future scenario of anthropogenic radiation forcing B2. It is obvious, that the trend in sea-level rise caused by regional factors is much larger than the past variability and may be of the order of 1 mm/year. Sea level scenarios projected to the future are supposed to assist local authorities and planning agencies in the development of strategies for sub-regional and local management of the coastal zones. Methods developed in SINCOS are designed in a manner to facilitate the a general application also outside the Baltic Sea.

Reference

Harff, J., Lüth, F. (eds.) (acc.) Sinking Coasts – Geosphere Ecosphere and Anthroposphere of the Holocene Southern Baltic Sea.- Reports of the Roman Germanic Commission, Special Issue

Soft-sediment deformation in Pleistocene sediments on the SW Baltic Sea (NE Germany) – Evidence for neotectonic activity

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1.Aim of the study

This paper follows the hypothesis that the deglaciation during the Late Pleistocene and associated unloading of the crust triggered seismic activity.

Sedimentological evidences for neotectonic activity along the southern Baltic Sea coast and their influence on the dynamics of coastal processes are in the focus of this study. Difficulties in detecting neotectonic activity are given as the Quaternary cover of unconsolidated sediments in combination with humid conditions and associated erosional processes easily erases possible traces. Holocene deposits are situated below present sea-level. Therefore no outcrops exist to directly study the Holocene neotectonic activity. By comparing relative sea-level curves along the coast noetectonic movements are traceable (cf. *Schumacher & Bayerl 1999, Hoffmann et al. 2009*).

2.Study area

The southwestern Baltic Sea is part of the Northeast German Basin, south of the Sorgenfrei-Tornquist Zone and the Teisseyre-Tornquist Zone and generally is not regarded as a neotectonic active area. However, repeated glaciations during the Quaternary shaped the area geomorphologic and caused glacio-isostatic adjustment of the crust. These processes are most probably related with neotectonic movements as the NGB is composed of different fault-bounded crustal blocks. For the Swedish part of the formerly glaciated area neotectonic seismic activity related to glacio-isostatic adjustment are reported by *Mörner (2004)*.
The Baltic Sea developed during the Holocene and as a result of coastal dynamics large spits and beach barriers formed on its southern coast. The coastal evolution is governed by eustatic water-level development as well as non-eustatic factors (isostacy and neotectonics) which have an effect on e.g.: sediment availability and accommodation space. Knowledge of these factors is essential for long-term planning concepts within the coastal zone.
Pleistocene sediments crop out in cliff sections along the coast. Although the stratigraphic relationships are not well constrained, mainly Weichselian ages - and only partly older deposits - are assigned. The Pleistocene deposits show a variety of faults (both normal and reverse). Most authors interpret these as glaciotectonic features (*Katzung 2004*). However, at a cliff section on Usedom Island, we have evidence for large scale liquefaction within glaciofluvial sediments, which may be attributed to an increased tectonic activity during the Late Glacial and Early Holocene.

3. Results

The outcrop represents a cross-section through a kame; it is 1700m long with a maximum height of 30m. The sediment sequences exposed compromises a succession of glacial and glacio-limnic to glacio-fluvial siliciclastic deposits. The base is made up of a lodgement till, overlain by a warved silty clay, followed by sand in a coarsening upward-sequence. To the top gravel filled channels are observed. The uppermost Pleistocene sediments is a meltout till which shows a maximum thickness of 7m.

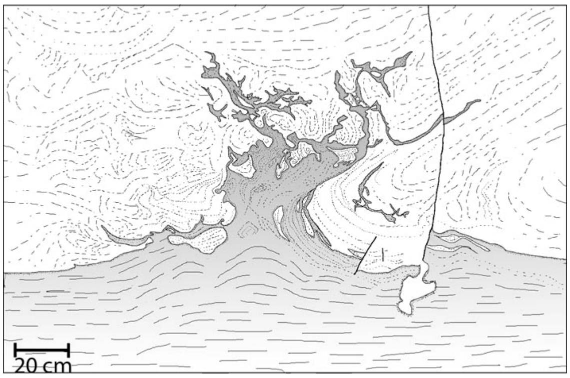

Figure1: Liquefaction structure within Pleistocene sediments on Usedom Island. Gray: silt; dotted white: sand.

The deformation structures observed range from millimetre-scale to deformations in the range decimetres to meters. Besides faulting and folding liquefaction structures are common (fig.1). These are associated with intercalated sand and silt layers, where the silt layers serve as an impermeable layer overlying the sand. Soil-liquefaction structures are formed when the porewater pressure increases and consequently the shear strength is lowered.

4. Discussion

Deformation structures within Pleistocene glacial deposits are a common feature due to the depositional environment. Faults are commonly associated with glacial tectonics whereas folds are interpreted as synsedimentary loading structures under water-saturated conditions (e.g. water-escape structures). The liquefaction structures observed on Usedom Island include sand-venting, flames and ball- and pillow-structures. Earthquakes are possible triggers of soil-liquefaction (*Galli 2000*).

5. Conclusions

The soft-sediment deformations including liquefaction structures within a sequence of Late Pleistocene deposits are interpreted as evidences for palaeoseismic activity in the vicinity of the former Weichselian ice sheet. These neotectonic movements result from the ongoing differential glacio-isostatic adjustment of the crust and bear direct implications for the coastal evolution.

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How stable is the cliff north of the 'Königsstuhl' (Jasmund/Rügen)? – Coastal evolution during the last 50 years

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1. Motivation

After the large cliff slides on Jasmund, especially in the years 1999 till 2005, and the mass media reports about them, the slope stability at the steep coast of the island of Rügen came into the focus of scientific investigations. The area surrounding the 'Königsstuhl', which is the most famous site of the remarkable white cliffs made of chalky limestone and visited by thousands of people every year, were also affected by mass movements. Thus, recent mapping has been carried out to evaluate the landslide susceptibility and to document temporal changes of the coast line since the 1950ies.

2. Investigation area – Jasmund (NE Rügen)

The investigation area is located in the southern Baltic Sea on the Jasmund peninsula between the 'Königsstuhl' in the south and 'Hankenufer' in the north. This cliff section has a length of almost 1,300 m. The geology is dominated by Upper Cretaceous chalk and Pleistocene glacial and interglacial units. The Pleistocene sequence forms together with the underlying Cretaceous rocks an intensively deformed SW-verging batch of slices. The causing glacio-tectonic event took place during the late Weichselian ice advances. Post-glacial sea level rise led to formation of a steep coast between Sassnitz and Lohme with cliffs up to nearly 120 m high. The slope at this bluff, especially at the chalky sections, can reach 90°, whereas the parts of the cliff made of Pleistocene sediments are much lower inclined due to the more soft sedimentary record.

This very complex geological structure, of which its genesis is still in debate, has a significant effect on the coastal development. Investigations of larger cliff collapses, for example near Lohme harbour at the northern coast of Jasmund, point to a connection between bedding conditions, precipitation and groundwater flow with these events (*Obst & Schütze* 2006).

3. Techniques

Coastal evolution can only be made visible by observation of the orientation and shape of the cliff and rock exposures documented from time to time either by geological mapping, landslide inventories, comparison of aerial photographs and including new GIS-based methods. Annual monitoring using, for example, laser scanning techniques to determine the coastal erosion rate will be rather expensive and, we will obtain results only for the most recent years. Cheaper and suitable for a longer time period would be the comparison of geological cliff profiles described by different authors during the last five decades. Hereby it is possible to compare the documented sections with each other, in order to find places with intensive seawater-induced erosion activity or changes due to land-driven forces.

The useful papers for a comparative study of the cliff evolution north of the 'Königsstuhl' are the unpublished diploma thesis by *Brückner* (1958) and the path-breaking work by *Steinich* (1972) that is rich in detailed drawings. These two papers are compared with the results of the youngest mapping of this cliff section (*Kenzler* 2007).

4. Results

One important result of our investigations is the fact that the appearance of cliff slides and caldrons are strongly related to faults and the occurrences of Pleistocene deposits. Especially the outwash caldrons are arranged in expanded sandy-gravely sediments, for example at 'Stubbenhörn' (Pleistocene 'stripe 25') and the Pleistocene outcrop ('stripe 24') south of it. But also the fissures, which open the way for ground water through the otherwise impermeable chalky limestone, triggered break-offs along the steep coast. The strongest changes along the cliff observed within 50 years are located in the sections where Pleistocene sediments crop out at the cliff. So the results make it possible to recognize critical cliff sections with high landslide activity but they were also the basis for new interpretation of the development of cauldrone-like landformes, such as the 'Teufelsgrund', a 200 × 100 m large outwash cauldron.

Figure 1. Remains of the youngest cliff slide at 'Stubbenhörn' that occurred in 1999 (cliff elevation is over 80 m)

The section with the substantial changes in the coastal shape is localized at ‘Stubbenhörn’ (Figure 1). Here you can find three cauldrons side by side, each of different age and history of development. The last cliff slide occurred in 1999, where a great block of Cretaceous rocks slipped off together with the overlying Pleistocene material. The chalk had stabilized unconsolidated Pleistocene sediments landwards, before. But due to coastal erosion the thickness of the ‘chalk pillar’ decreased. After the cliff collapse the resulting cauldron reached the high coast way used by visitors of the National Park. Because of the high morphology and the rather steep slope made of soft, unconsolidated Pleistocene sands and gravels at ‘Stubbenhörn’, this cliff section is not stable until today. Thus, it is only a question of time, when the enlarging cauldron will destroy the path for tourists completely. Meanwhile, many tourists, who are underestimating the risk of down falling sediments from the top of the cliff, will be in danger while standing directly near the cliff edge.
However, our investigations show also that some parts of the cliff suffered only from minor changes in the last 50 years. Sections of the chalk cliff with slopes of nearly 60° or less are relatively stable. One reason could be the gravely beach wall, which is protecting the cliff foot. Only large storm waves are arriving this part of the coast and contribute to further erosion.

5. Outlook

To guard the visitors of the Jasmund National Park it is very important to observe the critical cliff sections frequently. But also a displacement of the high coast way, for example at ‘Stubbenhörn’, must be taken in to consideration to protect live. Anyway, we suggest that this cliff should be monitored by geologists continuously to detect evidences for larger cliff slides in the near future, e.g. cracks near the cliff surface. It has to bear in mind, however, that the coast is changing all the time and human beings can only try to manage this changes, but we are not able to avoid them.

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Extreme storm surges in winter 2007 in the Pomeranian Bay and Szczecin Lagoon and their modelling

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1. The storm surge description

Heavy storm surges at the southern Pomeranian Bay coasts occur as a result of the passage of deep and intensive low-pressure systems over the Baltic Sea. They produce flooding of coastal areas; impact shore and beach stability; result in coastal erosion; destroy the coast and dune ridge environment; negatively affect port operations and navigation; and impinge on the coastal zone infrastructure. The flood risk is anticipated to increase in the future as a result of sea level rise and increased frequency of heavy storms.
In winter 2007, at the coasts of the Pomeranian Bay there were recorded as many as 6 heavy storm surges. Between 18 January and 2 February 2007, the level of 1.0 m amsl, as recorded in Świnoujście, was exceeded during five of them. The highest sea level of 1.38 m amsl was observed on 19 January 2007 (Fig. 1). During the night of 24 January, the level of 1.0 m amsl was exceeded for 16 hours. That period was also characterized by significant increases and decreases in sea level. On 26 January the rise in sea level amounted to 101 cm within four hours (Fig. 2). During the period discussed, in the Szczecin Lagoon, the warning levels were exceeded from 18 January to 11 February. In Trzebież, the highest water level of 0.98 m amsl was observed on 25 January 2007. Those unusual conditions were caused by the passage of series of intensive low-pressure systems over the Baltic Sea and initial high sea levels in the Baltic.

2. The model study

A 3-D, operational hydrodynamic model of the Baltic Sea (M3D_UG), developed at Institute of Oceanography, University of Gdańsk, is a baroclinic model that describes water circulation, with a due consideration to advection and diffusion processes. The model is based on the Princeton Ocean Model (POM), described in detail by *Blumberg and Mellor* (1987). Adapting the model to the Baltic Sea required certain changes in the numerical calculation algorithm (*Kowalewski* 1997). The open boundary was located between the Kattegat and the Skagerrak with a radiation boundary condition. Hourly changes in sea level in Göteborg were used for approximation of sea level on the open boundary. Meteorological data were taken from the Unified Model for Poland Area (UMPL). Because of wind-driven water back-flow in the Lower Odra channels, a model of the Odra discharge based on water budget in a stream channel was developed (*Kowalewska-Kalkowska and Kowalewski* 2006). In the latest version of the model, in order to describe bathymetry of the area with a high accuracy, two grids with different spatial spacing were used: about 1 km for the Pomeranian Bay, and about 300 m applicable to the Szczecin Lagoon.
The model verification was carried out on the basis of observed and calculated water levels in the years 2002-2007. The routine observed data sets were obtained from Szczecin-Świnoujście Harbour Master's Office and from the website of BSH (Germany).
As the evaluation of the latest version of the model's performance in the Pomeranian Bay and Szczecin Lagoon showed a very good fit between modelled and observed distributions of data sets the accuracy of the model was tested in the cases of rapid water level fluctuations i.e. during storm surges.
Testing the applicability of the model on storm surge events in 2002-2007 showed a good agreement between the simulations and readings of sea level from gauges located at the Pomeranian Bay and Szczecin Lagoon coasts. The model correctly reflected events involving rapid water level fluctuations and generated good predictions of all the storm phases (Fig. 1 & 2).

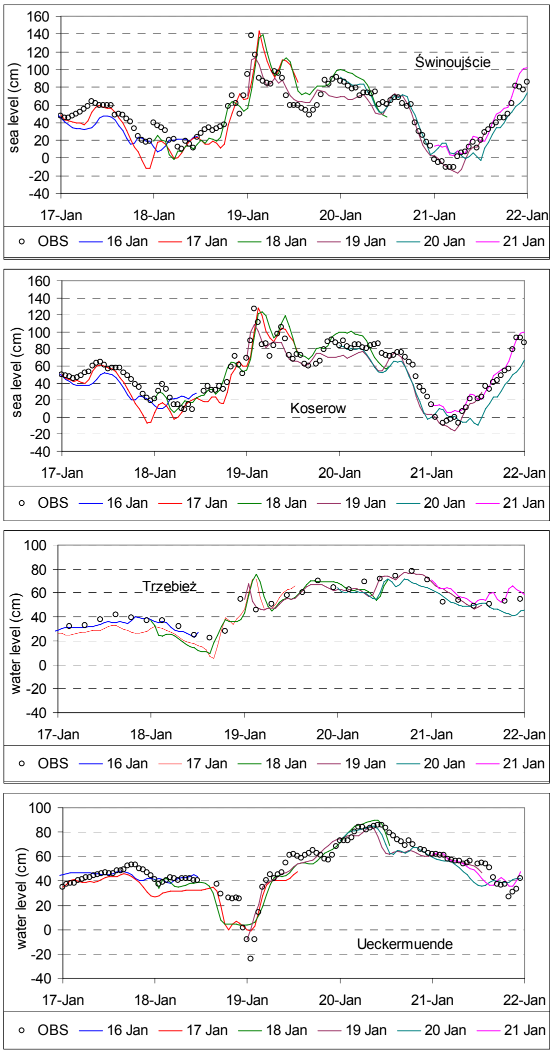

Figure 1. Observed and predicted water levels during the storm surge of 18-21 January 2007; Legend: forecasts from 16, 17, 18, 19, 20, and 21 January

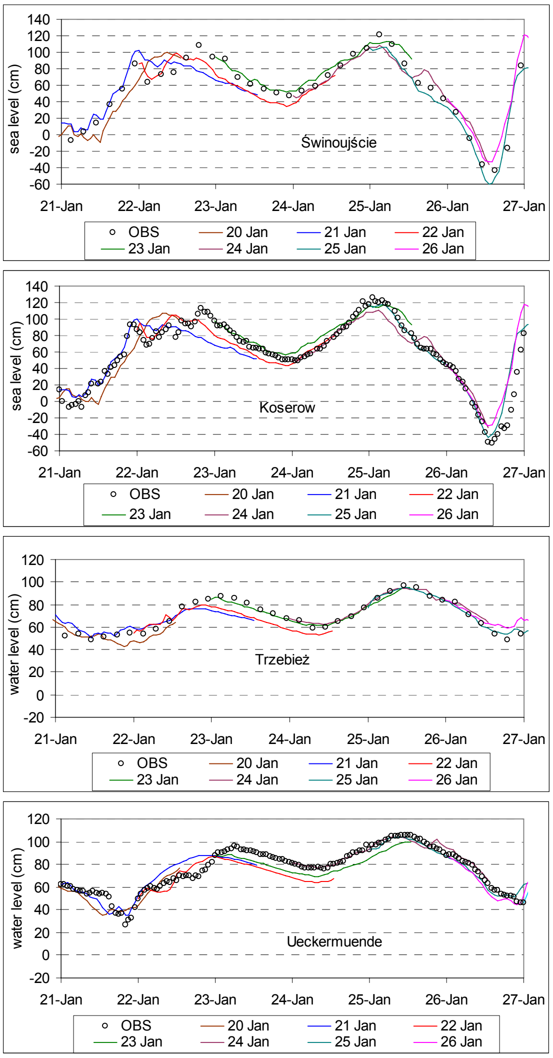

Figure 2. Observed and predicted water levels during the storm surge of 21-26 January 2007; Legend: forecasts from 20, 21, 22, 23, 24, 25, and 26 January

The high quality of simulations generated by the hydrodynamic model allowed to consider the model as a reliable flood protection tool. The regularly updated hydrodynamic forecast may provide assistance in decision-making by emergency command centres and bodies that are responsible for navigation safety, port operations as well as flood protection of coastal areas of the Pomeranian Bay and Szczecin Lagoon

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Coastal abrasion of the coasts of the Świna Gate Sandbar caused by the heavy storm surge in November 2004

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1. Introduction

The Polish coast is a non-tide area, where only wind waving and nearshore currents play main role in coast development. Morphodynamics interactions in coastal dunes are not well understood. Nowadays need of research over coastal dunes development is becoming more important because of increasing threats as storm surges and human impact.

2. Study area

The study area is located on the Islands of Wolin and Usedom on the Pomeranian Bay coast (Southern Baltic). In Poland, the sandbar extends for 16 km. It consists of two sand spits formed between morainic plateau of the islands. Nowadays, along the central and western parts of the spit marine sediments are still being accumulated and the coastline slowly shifts towards the north. The study area is affected primarily by westerly and southerly (S, SW, W) winds. Mean sea level for Baltic Sea is 500 cm. In Świnoujście mean sea level, measured from long period data carried 497.1 cm.). Lower part of the sandbar is endangered by the increasing sea level and increasing storm surges. Many times in the past dune ridges of the sandbar were broken by strong waves and water flooded land. The biggest were noted in 19th century with water level of 2 m above the average level (f.e. in 10.02.1874 water reached 696 cm).

3. The description of the storm surge

A 22-25th November 2004 storm surge was caused by the passage of a deep low-pressure system moving from the North Sea over the central part of the Baltic Sea and then eastwards (Wiśniewski, Kowalewska-Kalkowska, 2007). At the beginning, on 22nd November, the water level along the southern coasts of the Pomeranian Bay dropped rapidly as a result of the passage of the low (991 hPa in the centre) over the North Sea and the development of a high-pressure system over Central Europe. That situation resulted in the outflow of the Baltic water into the North Sea and additionally generated the system of S–SW winds (4-5 Bft) at the Pomeranian coasts. In Świnoujście, the sea level decreased to 475 cm (25 cm below MSL) at noon. Then, the sea level began to rise rapidly to reach the maximum on 23 November as a result of the low centre's fast shift over the central Baltic (984 hPa in the centre, an average speed of 13.2 m/s) and strong (8-9 Bft) northerly winds. In Świnoujście, the maximum of 631 cm (131 cm above MSL) was recorded at 8 p.m. Subsequently, the low shifted eastwards and the high over Central Europe developed, generating south-westerly winds at the Pomeranian coasts that resulted in a significant decrease of the water level at the Pomeranian coasts during the next few days (negative phase of the baric wave). The minimum sea level (457 cm, i.e. 43 cm below MSL) was observed on 25th November at 8 a.m.

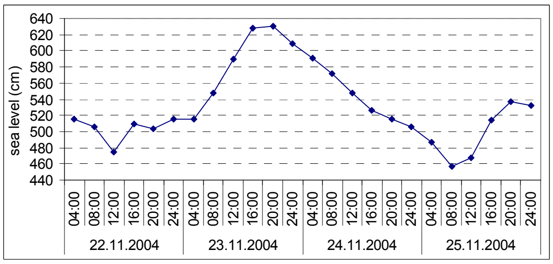

Figure 1. Sea levels as measured at Świnoujście gauging station during the 21-25 November 2004 storm surge

4. Field measurements

Field measurements were carried out during the storm on the 23rd November 2004, from 7.30am to 4 pm, and on 27th and 28th November after the end of the storm. On 23rd November, we analyzed the development of the surge on the coast and the effect of runup on the beach profile in the middle accumulative part of the sandbar (in the area of the 421km), and the more abraded eastern (415km) and western (422km) parts.

The measurements were carried out using specialised geodetic equipment. We also measured the wind speed at the bottom and at 1 m high.

On 27th and 28th November 2004, surveying exercises were carried out along the fixed and previously determined profiles from the town of Międzyzdroje (412km) to the mouth of the Świna River in the town of Świnoujście (424km). The range of wave runup was measured according to the observed detritus range and erosive undercutting of the foredune.

As a result of laboratory examinations, we determined the parameters of the storm and wind. During field surveys and comparisons of profiles before and immediately after the storm, we calculated the changes in relief and sediment balance for the beach and foredune. Moreover, we determined the height above mean sea level (amsl) of the waves on the shore. The sediment balance showed the volume of material that underwent abrasion or accumulation on a 1m wide section along the profile.

5. Results

Results show that the middle part of the sandbar shore (421km), which shows accumulative tendencies, does not reveal signs of abrasion on the beach or the foredune (Figure 2b). The beach was only levelled and deprived of eolic forms. Thanks to the high level of the upper beach, water did not destroy eolic forms at the foot of the foredune. Its ridge was also intact.

In the eastern part of the sandbar, both beach and foredune were subject to a considerable wash-off, losing on average 0.57 m^3/m^2 sediment on the profile (Figure 2a, Table 1). Strong wind from the sea resulted in eolic accumulation behind the foredunes. 2 to 15cm of sand was accumulated, depending upon exposure to the predominant direction of wind.

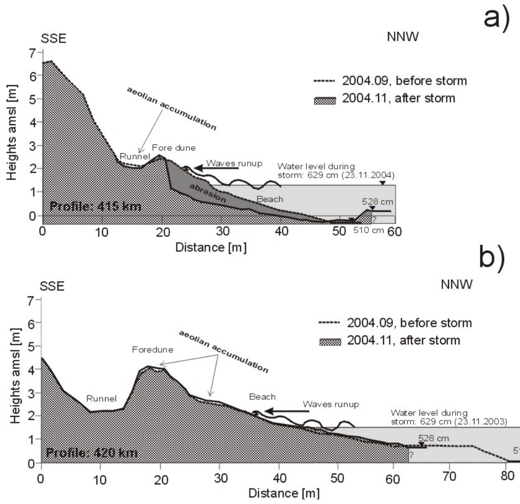

Figure 2. The dune morphodynamics caused by heavy storm surge (23.11.2004) related to beach height above sea level, Świna Gate Sandbar; a) Profile similar to reflective: low beach, big foredune abrasion; b) Profile similar to dissipative: high beach, no abrasion (Łabuz 2009, modified)

The greatest eolic accumulation was 0.15 m3/m2 sediment per day. During the storm surge, water eroded several times more - 1.19 m^3/m^2. In order to balance the loss induced by the storm, wind would have had to transport sediment for two consecutive springs, the season of greatest accumulation with an average of 0.65 m^3/m^2 per three months.

Table 1. The examples of the foredune wash off during storm surge on 23rd November 2004 on the Świna Gate Sandbar

Unit for 1 m along coast	The balance of the foredune sediments [m^3]		
	Profile 415 km eastern part	Profile 422 km western part	Profile 421 km middle part
Mean per m^2	- 0,57	-0,39	-0,04
Max per m^2	-1,19	-1,05	-0,26
Sum	-5,13	-6,98	-0,79

6. Conclusions

Storms induced significant erosion of the dune shore in the western and eastern part of the examined area of the sandbar. The changes were considerable and depended on the sea level during the storm and the storm duration. Even a short-lived surge that is 1m higher than the mean sea level leads to erosion of beaches up to 2.5m high and the erosion of dune ridges. If ridges are lower than 3.2m amsl, water flows into their background. If there was only one narrow ridge, then a background area up to 3m amsl would be threatened by flooding.

The most catastrophic sea surges are observed with a sea level 1 m above its mean level, which floods the beach and overflows water over the depressions and low ridges up to 4 m amsl. All relief forms below this level are abraded, and dune ridges in the beach hinterland are subject to regression. The size of coastline erosion and retreat depends both on the sea surge height and its duration. The levelling measurements in this study determined the height of the coast reached by storm surges is up to 3-3.2 m amsl. On part of sandbar with beaches narrower and lower than 3 m amsl, the rate of coastline retreat is higher.

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Palynological determination of the age and ecological character of sediment series in the Szczecin Lagoon, southern Baltic Sea

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1. Introduction

The bottom sediments of the present-day Szczecin Lagoon are an important palaeohydroogical and palaeoecolgical archive in which the data on the Late Glacial and Holocene environmental history of this area is preserved. However, fluvial activity of the Odra River and marine transgression of the Southern Baltic Sea resulted in sediment disturbances and, in consequence, in several hiatuses covering different periods. The situation is complicated not only because of sediment erosion but also due to redistribution of the older material and its redeposition on the younger strata. All these processes restrict reconstruction of the evolution of the basin, especially the detailed chronostratigraphy of the events. In such case radiocarbon dating is rather hazardous – it gives perfect result or - due to contamination of a deposit - completely false one.

Pollen analysis is a method enabling better understanding of the sedimentation processes in the coring place. It reflects sedimentation breaks, other disturbances of sediments as well as presence of the redeposited matter. It verifies the accuracy of radiocarbon dating and indicates potential pitfalls in age determination in a concrete sediment profile.

Several pollen diagrams have been produced both in the western (e.g. Janke 2002) and eastern part of the Szczecin Lagoon (e.g. Wypych 1980; Witkowski et al. 2004; Miotk-Szpiganowicz 2008). In this paper we present our own results concerning the eastern part of the basin (the Great Lagoon).

2. Results

Five pollen diagrams from the area of the Szczecin Lagoon and one profile from the area adjacent to the basin show several common features. The oldest sediments of the Late Glacial age occur in fragments in single sites only. The most frequent situation is the Preboreal sequence in the bottom-most part of the organogenic deposit. In all the profiles studied so far, a hiatus covering the Boreal and the older Atlantic period occurs. The new sedimentation phase started in the middle part of the Atlantic period, most probably around 7300-7000 BP. It has been interrupted by the Littorina transgression transporting large amount of mineral sediments into the basin. Radiocarbon dates from plant macrofossils collected in the organic layer beneath the marine series and from *Cardium glaucum* shells occurring in the bottom part of this series, are in agreement and show the age of about 6400-6300 BP (Borówka et al. 2005).

The younger sediments are much diversified according to the specific area of the lagoon. The violent environment resulted in frequent hiatuses covering most of the younger part of the Holocene. However, in some profiles, the process of transformation of the Littorina bay into present-day Szczecin Lagoon is well illustrated. Large number of the so-called non-pollen palynomorphs enables ecological characteristics of particular episodes, complementary to other kinds of palaeoecological data based on diatom and malacological analyses.

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The sea-defence function of coastal brackish grasslands and reed beds at the southern Baltic Sea region

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Knowledge of the feedback mechanisms between coastal vegetation and wave dissipation is a key factor in understanding the response of coastal habitats of the Baltic Sea to sea level rise and associated changes in incident wave type/energy. Previous studies at macro-tidal environments have highlighted that wave attenuation over vegetated habitats (e.g. salt marshes) can be significantly greater than over unvegetated intertidal surfaces. However, no study have focused on the sea-defence function of micro-tidal habitats of the Baltic sea such as coastal brackish grasslands and reed beds, where irregular inundation by meteorologically driven storm surges dominate over tidal inundation.

Figure 1: Cross-shore transect with bottom mounted pressure transmitters on a coastal brackish grassland near Greiswald, Germany.

The present study addresses the need to quantify the wave-dissipating function of coastal brackish grasslands and reed beds of the southern Baltic Sea. On four cross-shore transects near the city of Greifswald, Germany, wave measurements were conducted. On each transect, five bottom mounted pressure transmitters were deployed. Besides wave monitoring, we estimated plant species composition, vegetation density and plant biomass production.

We will present results of six month's wave and vegetation monitoring. Our first results show that there are significant differences between the Baltic shore habitats and those of the US and the UK. As well as quantifying the sea-defence function of coastal brackish grasslands and reed beds, we will discuss how the ecological functions of those habitats might be maintained, enhanced, or restored in the context of global change.

Modelling historical coastline change with SEDSIM: The development of the Darss-Zingst peninsula since 1696 AD

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Information about coastline change is of vital interest for the densely populated coastal regions around the Baltic Sea. Besides the general sea level rise, erosion, transport, and accumulation of sediment play a major role on a local scale. The numeric modelling package Sedsim is used to calculate these processes, integrating climatic and geological parameters. Previous publications (*Meyer et al. 2008, Meyer et al.subm.*) deal with prognostic scenarios for the Darss-Zingst peninsula, adopting the present situation as initial model state. For a validation of the modeling procedure a reconstruction of the paleographic development of the Darss-Zingst coast during the last three hundred years using the Sedsim model is compared with the coastline change recorded by historical maps. The maps used here are dated back to 1696, and provide quite precise information about the location of the coastline at that time. The initial model setup for Sedsim is adjusted to these data. Elevation changes caused by eustatic and isostatic processes during the past are considered as well. The comparison of the modeling results towards the 20th century with recent maps serves as a validation of the model and its parameters.

1. Area of investigation

The Darss-Zingst peninsula is part of the German Baltic Sea coast. Fischland, Darss, and Zingst form a chain of island cores connected by shallower sand barriers. Behind the peninsula, a chain of lagoons is sheltered from the open sea (Figure 1).

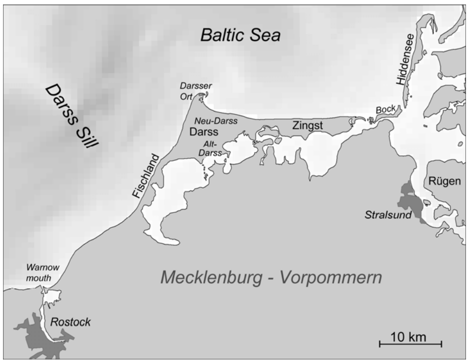

Figure 1. Area of investigation.

In general, elevations are shallow with 0.5 to 2.0 m a.s.l.. Prominent heights are located in Fischland and Altdarss areals with about 15 m. The development of the peninsula results from the erosion of glacial sediment complexes (*Schumacher 2000, Lampe 2002*). During the last 4000 years fine grained material was transported crosshore into deeper areas of the Baltic Sea, whereas longshore transport and accumulation of coarser sediments formed the shape of the peninsula.

2. Methodology

At the end of the 17th century Swedish cartographers have mapped coastal areas along the now German Baltic Sea coast, including the area of investigation (Curschmann 1950). These maps have been digitized and georeferenced, finally integrating the information about the historical and recent coastline into a GIS. Lateral distances between these two lines indicate erosion and accumulation, ranging up to hundreds of meters, with highest accumulation rates in the area of the Darsser Ort. Based upon a recent digital elevation model with a spatial resolution of 150 m (*Meyer et al. 2008*) the altered terrain has been recalculated by geostatistical means, using the coastline from 1696 as zero elevation contour line. The effect of isostasy and eustasy to the terrain elevations during the last centuries has been taken into account, too. In result, a historical digital elevation model was constructed that serves as a new initial state for sediment transport modelling with Sedsim. The coastline displacement modelled by Sedsim is compared with the recent situation. Model result and recent state show similarities despite the fact that anthropogenic coastline protection activities have not been taken into account here.

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From the field to the map: Landslide inventory and geohazard assessment of the steep cliff coast in NE Germany

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1. Introduction

The knowledge of slope behavior and their failure is necessary to evaluate slope stability. That means geology and soil conditions have to be investigated to characterize the factors that cause instability. Especially rise in groundwater followed by increased pore water pressure contributes to a reduced shear strengths of soil, but also the occurrence of clay minerals and their potential for swelling, creep and strain softening has negative effects on soil stability. Slope collapses are known to occur at steep coasts, where costal erosion additionally influences the stability of slopes.

The slope instabilities have an elevated risk potential when endangering constructed areas or infrastructure and safety of residents or tourists, e.g. visitors of the National Park Jasmund on the island of Rügen. Therefore, the landslide susceptibility and cliff slope stability are evaluated in a pilot study carried out by federal and state geological institutions (BGR Hannover, LUNG M-V Güstrow and StAUN Rostock) in cooperation with the Universities of Greifswald and Tübingen. This include both physically based and statistical, landslide inventory based methodologies and a combination of these. Besides stability analysis to determine critical cliff sections, a few slopes are further investigated by long-term monitoring with a terrestrial laser scanner. First results have been presented by *Kuhn & Prüfer* (2007) and *Thiel et al.* (2007).

Furthermore, a geohazard database will be established to document slope failures at the steep cliffs of Mecklenburg-Vorpommern and to classify the resulting mass movements inclusive estimation/calculation of their size. Recent examples of larger slope collapses along the coast of Rügen are presented here to explain the main features of the database that can also provided in a GIS-based application

2. Factors controlling cliff instability hazards

Several cliff slides in 2005 that occurred on the island of Rügen have especially affected the famous cliffs of Jasmund peninsula situated in the north-eastern part of the island. Results of field studies carried out immediately after these events suggest that a variety of factors - geological structure and morphology of the cliff, the climate, the hydrological and hydrogeological environment as well as coastal changes caused by human activity - have initiated and controlled the mass movements (*Obst & Schütze* 2006).

The soft and intensely jointed Cretaceous chalky limestones are pseudoconcordantly overlain by Pleistocene glacial deposits, consisting of glacial till and glacio-fluvial to glacio-limnic sand, silt or clay deposits. Both stratigraphic successions have undergone strong subglacial deformations in the late Quaternary, resulting in tight folding and shearing of the Pleistocene deposits and thrusting and more open folding of the Cretaceous rocks. Thus, the stability of the chalk is mostly controlled by the orientation and condition of discontinuities (joints, bedding planes), while the sliding susceptibility of the Pleistocene sediments is mainly governed by their structural position, geomorphological setting and material composition (*Günther et al.* 2007).

Due to the relatively high altitude up to 161 m of the Jasmund pensinsula and a position in the vicinity of the Baltic Sea, the climate is characterized by a high amount of precipitation (>700 mm/yr) and a rather long period of freeze-thaw cycles. Unusual heavy rain and snow falls occurred in autumn 2004 and winter 2005, respectively. Melt water and limited drainage facilities led to increase of water pressure within the soft rocks close to the cliff causing catastrophic failure (*Obst & Schütze* 2006).

3. Landslide mapping

Any landslide hazard assessment should begin with the collection of information, e.g. by landslide mapping. A landslide inventory records the location and, where known, the date of occurrence and types of landslides that have left discernable traces in an area (*Hansen* 1984). Landslide inventory maps may show all the slope failures triggered by a single event (event inventories), or they may show the cumulative effects of many events over a period of years (historical inventories; *Guzzetti et al.* 2000).

Inventory maps were obtained during several field campaigns in the last years, especially at the coast of Jasmund. Based on a classification scheme suggested by *Thiel* (2007) and *Lange* (2007) type, size, relative age and other features of landslides were determined. Furthermore, areas of low up to very high landslide activity could be classified. The results were incorporated in the GIS register of the LUNG (Figure 1).

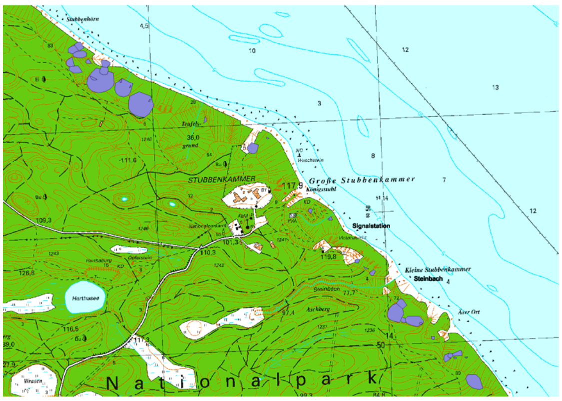

Figure 1. Example of a GIS-based map with topography and information of location and size of historical and recent landslides (marked in blue) that occurred at the coast of Jasmund/Rügen.

Other data used for the GIS application derived from topographic and geological maps, pictures and drawings of outcrops, aerial photographs and digital elevation models. Critical cliff sections were additionally monitored using airborne and terrestrial laser scanning techniques. By interpreting multiple sets of aerial photographs or laser scanning data, multi-temporal inventory maps can be prepared (e.g. *Obst et al.* 2007).

4. Inventory of landslides and GIS application

It is essential for all levels of landslide inventories and susceptibility, hazard and risk zoning that those carrying out the study have a detailed knowledge of slope processes which lead to landslides. This includes knowledge of geology, geomorphology, hydrogeology and the soil or rock mechanics of areas affected by landslides.

The inventory database comprise location, type, volume, activity and the date of occurrence for each landslide. Other parameters such as vegetation, exposition, slope, position are also included, if determined. All these parameters are important for the GIS application and the modeling of the landslide susceptibility, i.e. a quantitative or qualitative assessment of the classification, type, volume or area. Susceptibility estimations on a local scale may also include descriptions of the velocity and intensity of existing or potential landsliding.

One of the most important capabilities of GIS is the ability of the software to manage spatial data from different sources. An important point is that all in the GIS incorporated data remain available for editing and updating, for reproduction in form of maps or on-screen review, manipulation and querying and for GIS-based development and modeling of susceptibility. With the available data in place various methods can be applied to establish interrelationships and ultimately to establish levels of susceptibility and hazard.

Key vector data sets typically used in landslide zoning studies include landslide polygons, geology, geomorphologic and/or terrain units, cadastre, road, rail and utilities, land use and vegetation. Other data that can be imported may include borehole information, soil strength parameters, pore water pressures, rainfall etc. The key grid or raster data is the digital elevation model (DEM). GIS software can derive numerous data sets useful in landslide zoning from the DEM such as slope, aspect, flow accumulation, soil moisture indices, distance to streams and curvature to name only a few. A GIS model can be used to combine a set of input maps or factors using a function to produce an output map. The function can take many forms including linear regression, multiple regression, condition analysis and discriminate analysis etc.

5. Outlook

Landslide inventories as well as geohazard analyses are needed to develop innovative concepts for coastal protection and new coastal zone management approaches. This also means that mapping and monitoring along the steep coast in NE Germany has to be done continuously by state geologist and in co-operation with universities and other research institutions.

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Historical tsunami events on the southern Baltic coast

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1. Introduction

Tsunami phenomena on the Baltic Sea are relatively rare. Reference to written descriptions of paleoseismic events and to the sediment record allows to distinguish their complex genesis. More intensive seismic events were occurring in the former center of the Sscandinavian ice cap. At the outer margin of this cap (N Germany and N Poland) they were occurring less intensively.

2. Historical tsunami events on the southern Baltic coast

In the area of southern Baltic coast at least three major and certain events of a tsunami documented in written form since their time of occurrence, have taken place. These are: the tsunami of Darłowo and Kołobrzeg area AD 1497, the tsunami in the Trzebiatów and Mrzeżyno area AD 1757 and the tsunami of the Łeba and Kołobrzeg area AD 1779.
In other regions of the Baltic coast a number of similar events was recognized in the sediment record, i.e. in the Hudikswall area, dated to 6100 ^{14}C years BP.

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A morphotectonic map of the European lowland area, sheets Szczecin, Dziwnów – Preliminary report

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1. Introduction

A morphotectonic map was prepared based on the methodology the 6th Framework Programme of MCA. This map consists of two charts: chart I and II. The map contains morphology, active surface and subsurface processes in connection with deep tectonic structures activity . The scale 1: 200 000 was used for the study area. The results of morphotectonic analysis show a significant influence of Baltic Sea level changes on the coastal zone.

2. The morphotectonic outline

The Odra Flood Plain was formed at the front of a receding glacier from a frontal moraine of the Szczecin sub-phase to the Wolin sub-phase, as a result of deposit accumulation, mainly fine sand, in a vast water area, a huge hydrographic hub collecting waters from the South, the East and the West. The stages of accumulation and water level lowering are visible in the form of terraces, but without clearly-marked edges. The horizontal outline of the Odra Flood Plain has some characteristics that show interrelations from a sub-Cenozoic structure of substratum. Most of the southern end is made up of uplifts located above Gr. Spiegelberg, Löcknitz and Szczecin salt structures and uplifts elevated glacitectonically: Warszewskie Hills and Bukowe Hills. Uplifts elevated glacitectonically do not strictly overlap salt structures. Salt structures, however, had an influence on their genesis (*Schoeneich*, 1962; *Piotrowski*, 1991, 1999, 2006). The western border of the plain is a moraine uplift located to the West from the Little Lagoon in Germany. The Northern border of the water area was made up of an ice-front that built Pleistocene uplifts, front moraine hills of Uznam Island with Lütow and Ahlbeck salt structures in the substratum and Wolin Island with Międzyzdroje salt structures and the southern end of the island, which overlaps the course of the Świnoujście – Drawsko dislocation zone, constituting a tectonic border of the Szczecin Basin with the Pomeranian-Kujawski embankment.

The northwestern border of the plain is the end product of an uplift running meridionally, overlapping the Kamień Pomorski dislocation zone. From the Zielonczyn salt structure, the uplift border runs along the Gowienica syncline towards Czarnogłowów (near-fault upthrust of salt) to the border with the Pomeranian-Kujawski embankment up to Nowogard salt structure. The Eastern border of the Odra Flood Plain has a characteristic orientation running in accordance with the Maszewo and Marianowo axis, i.e. NNW-SSE and departures towards the east to the north of the salt embankment end.

The vertical topography of Odra Flood Plain and the layout of the surface water system have a series of characteristics that show the influence of salt structures. Disappearance of the surface water system is observed in the Nowe Warpno and Krakówka anticlines. A relatively higher congestion of the surface water system is evident on the Tanowo embankment (*Piotrowski,* 1991)

Lack of edges and the occurrence of convexities, which is characteristic for terraces, indicate local elevation tendencies within the plain. *Schoeneich* (1962) specifies the level of elevation within the plain terraces as from 3.0 m do 8.0 m.

On the syncline line next to an increased congestion of a more expansive surface water system, which can be observed in the background of anti-flood embankments, there is a declining tendency within synclines (*Schoeneich*, 1962).

In the area of the Odra Flood Plain, several kilometers to the South from Zielonczyn, there is a half-pierced Wierzchosław salt pillar. The NNW-SSE orientation of the structure axis runs in accordance with the faults accompanying it. With these structures in the topography, the passage from low through medium to high terraces is noticeable. There are no clearly visible edges, and the terrace borders are merely symbolic (*Piotrowski,* 2006).

3. Summary

Morphotectonic analysis of the study area permits important conclusions on factors affecting human life. Both maps show the present state and forecast of development of geological engineering conditions for the next 100 years, the extent of Baltic and Szczecin Lagoon coastline, seismic hazards and possibilities for exploring and storage of hydrocarbons. The map informs us not only about various hazards but also about positive aspects for the economy.

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Luminescence dating of coastal sand deposits from the Baltic Sea – Examples from the Darss-Zingst and Świna Gates

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The southern Baltic Sea have been formed in different stages after the Littorina transgression 8.000 y BP (Harff et al. 2005). With a decelerating sea level rise about 6000 y BP the formation of sandy spits and barriers started due to coastal erosion and increasing longshore sediment transport. A successful paleogeographic reconstruction of the processes of coastal morphogenesis depend significantly upon reliable dating of sediments. In case of sufficient organic constituents of the sediments radiocarbon dating leads to satisfying results. For beach sediments, in particular dune sands, poor in organic components, optically stimulated luminescence (OSL) methods show great promise for dating. Within a Leibniz-Project, we want to provide a more detailed and reliable chronological frame derived from optically stimulated luminescence (OSL) dates of coastal sand successions (e.g. sandy beach ridges, fore dunes ore coastal dune successions). Two coastal areas have been selected for the study: The Darss-Zingst Peninsula and the dune systems of the Świna gate. Both areas are located at the southern Baltic coast. Here, the vertical crustal movement plays a secondary role for coastal formation (Fig. 1). The morphogenesis is mainly driven by meteorological and hydrographic forces and climatically controlled sea level rise.

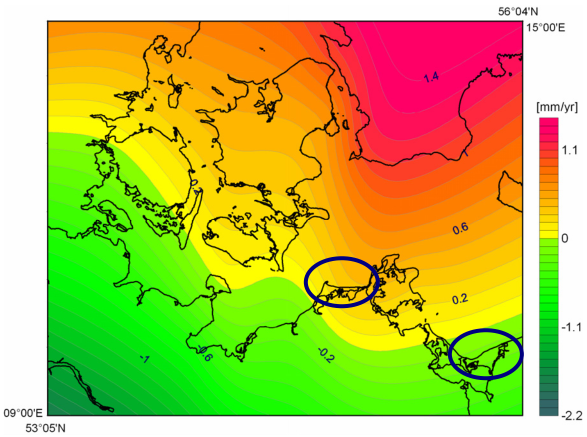

Fig. 1: Recent vertical crustal movement (in mm/yr) for the western Baltic Sea (after Harff and Meyer in print) Baltic Sea, and work areas (blue ellipses mark work areas: Darss-Zingst Peninsula west and Świna Gate east)

In particular the Świna Gate is marked by dune systems discriminated by morphological features and sedimentary facies.

Based on basic studies of Keilhack (1912) Borówka et al. (1986) and Osadczuk (2002) have ordered the systems systematically in a genetic succession. These dune systems may serve as a key area for the application of OSL dating in the southern Baltic. First results showed that we are able to establish an appropriate measurement protocol and that the sediment of the Darss-Zingst area as well as the ones of the Świna Gate are suitable for OSL dating as well as sufficiently bleached prior to deposition. The derived OSL ages for the Darss-Zingst area are consistent with the stratigraphy and in agreement with the existing evolutional models.

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The extreme storm surge at the German coasts of the Baltic Sea in November 1872 – Reanalysis of the wind fields for coastal purposes

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In November 1872, a devastating storm surge occurred in the south-western Baltic Sea. The most outstanding water levels by far since the beginning of instrumental registrations were recorded along the Danish and German coast and since then, there has not been any storm surge like that (see figure 1).

The sheer enormity gives reasons for special research. Of course, there is special interest among coastal engineers to reconstruct the weather situation as exactly as possible using present-day methods. In order to demonstrate the dimension of this storm surge event, a study on extreme events of storm surges along the German Baltic coast on November 13 in 1872 was carried out aiming at reconstructing the wind field.

The Baltic Sea is a brackish inland sea. The only flow in and out occurs through the relatively narrow Danish straits. The mechanisms inducing storm surges differ from those at open sea. Beside wind stress and air pressure influence, the filling level of the Baltic Sea and the seiche are relevant, whereas the tidal influence is relatively small. The filling level of the Baltic Sea is determined by the inflow from the North Sea during the preceding 2 to 3 weeks. Thus it was necessary to investigate the weather development in all northern Europe for a longer period before the storm surge event happened.

As there are insufficient wind data from those early days, the wind field was estimated indirectly by calculating the geostrophic wind from pressure data reduced to mean sea level. We succeeded to get pressure readings from 175 stations from northern and central Europe more than 50 of which had at least two readings per day. After a comprehensive data check as to status of reduction, unit, time, geographic position, height etc. the pressure fields of the period November 1 to 13 were analysed manually (see fig. 2).

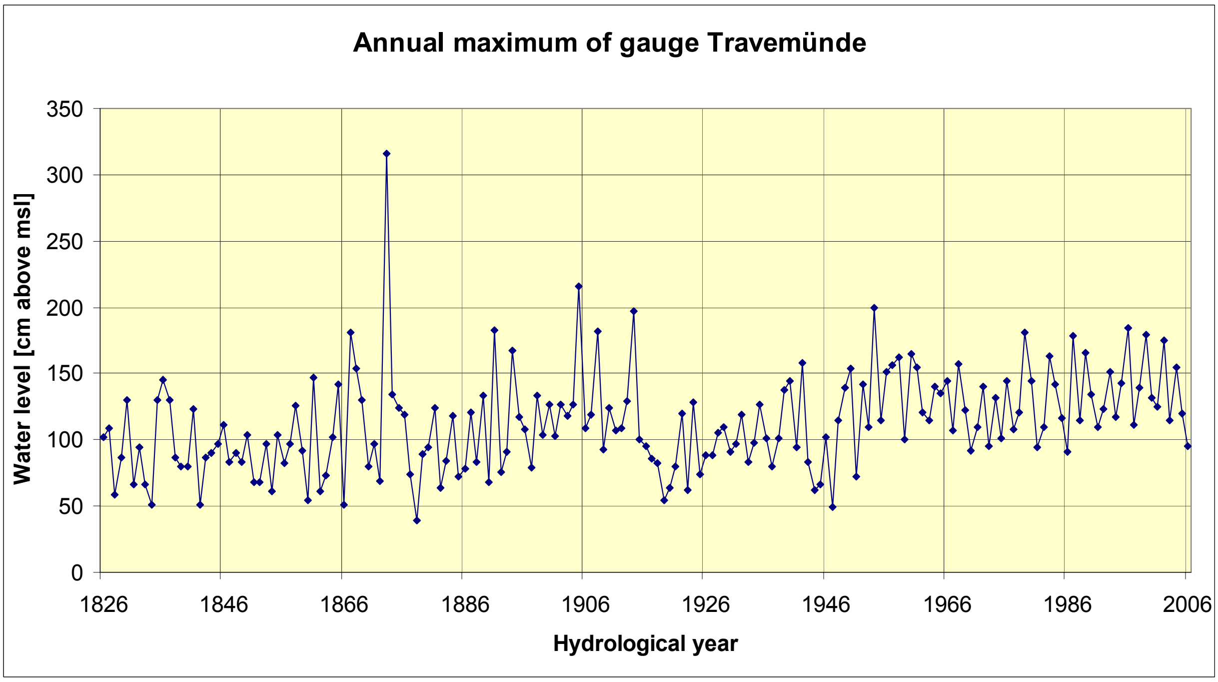

Figure 1. Annual maximum of water gauge at Travemünde, Germany, between 1826 and 2006.

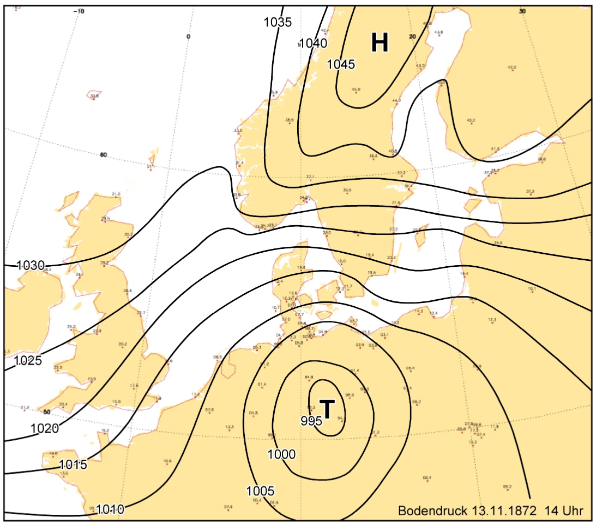

Figure 2. Pressure field (in hPa), November 13, 1872, 14 h.

The pressure field was now digitized and raster data for a 0.5 degree x 0.5 degree grid evaluated. These gridded pressure fields were used to calculate the geostrophic wind. Those data, in turn, were reduced to 10 m height above sea level [1], see fig. 3.

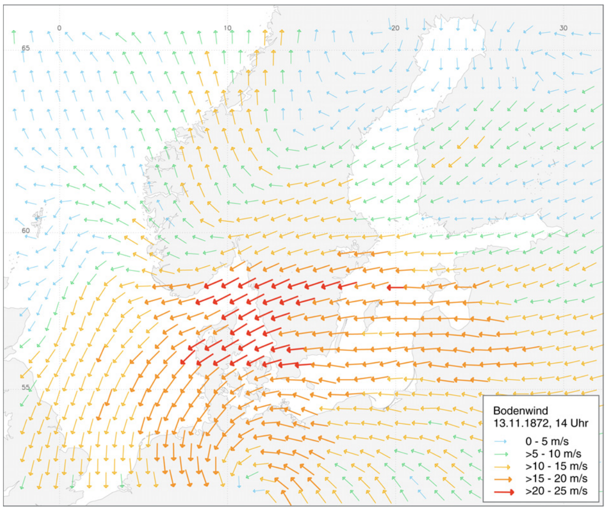

Figure 3. Surface wind field, November 13, 1872, 14 h.

The data set is a valuable help for coastal engineers to calculate the water level and estimate the impact a similar severe storm would cause nowadays.

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Sea level and coastal changes of the southern Baltic Sea during the last 9,000 calendar years and their controlling factors

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The level of the southern Baltic Sea at the Polish Middle Coast was mainly controlled by climatic factors in the past 9,000 calibrated years. The glacio-isostatic factor may have influenced the sea level changes during the Atlantic.

This climatic factor is responsible for:

1. Two highstands during the Atlantic Climate Optimum: H1 and H2 in time periods 9,000-8,000 cal BP and 7,000-6,100 cal BP, respectively.
2. The post-Atlantic sea regression and long period of its lowstand, which showed slight raising tendency (between 6,000 and 1,800 cal BP) divided by the short higher sea level H3 (between 3,900 and 3,100 cal BP). The H3 was marked by high sea level at the southern North Sea Coast (Behre 2007). The long period of this lowstand ended at the beginning of the Middle Subatlantic (2,750 cal BP, i.e. A.D. 150 BP).
3. The higher sea level around 2,000 cal BP.
4. The Middle Subatlantic ingression and the highstand H4 covering the period time from A.D. 850 to 1,200 BP (Little Climatic Optimum). At the Polish Middle Coast the sea level, higher than the present sea level by 0.5 m, corresponded to the detritus lacustrine gyttja and is proved by three radiocarbon dates from the top of gyttja deposits.
5. Very marked sea level regression – exceeding 1 m – during the Little Ice Age. The rate of this process is estimated at 4 mm y^{-1}.
6. The sea level rise after the Little Ice Age and its further rising due to recent global climate warming. In the period of next 100 years the sea level will reach the highest Holocene level, equalled to that of the Little Ice Age, and by 2200 will probably exceed it.

The ice balance of inland ices and alpine glaciers is responsible for the general trend of sea level rise in the Holocene, independently of the changes listed above. The glacio-isostasy may act as factor modifying the events governed by climate and may be partly responsible for the sea regression during the time period ca. 8,300-8,000 cal BP and its lowstand (L1) between 8,000 and 7,500 cal BP. It is possible that the glacio-isostatic foreland bulge moved across the Polish Middle Coast during that time. However, sea level changes in this period may also have resulted from the interaction between glacio-isostasy and the world-wide cold event recorded in Greenland ice cores in the period 8,200-8,000 cal BP. This event is termed by Berglund et al. (2005) as the 'regional catastrophic event around 8,200-8,100 cal BP' and it is correlated with rapid regression and successive transgression occurred in the Blekinge region.

The above-mentioned sea level changes influenced the formation and evolution of barrier coasts and cliff erosion. Others factors controlling the development of the southern Baltic Sea coast during the Holocene are: 1) compaction of lagoonal-lacustrine-swampy deposits, in some cases reaching high values, and 2) frequency and intensity of storm surges, particularly important during the Younger Holocene. Extreme storm surges, the origin of which is not well known, caused serious changes in coastal morphology and environment.

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Sand barriers: Disappearing resources; the Hel peninsula case

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Hel peninsula is a typical sandy spit, intensely eroded and consistently, but temporarily, protected using a range of methods.

Intensification of erosion is usually combined (as in cases of other barriers) with sea level rise and increased intensity of wave action (due to global climate change) in the conditions of reduced sediment supply caused by natural and/or artificial reduction of longshore transport.

However, results of own investigations and published and archival materials clearly demonstrate that coastal erosion is caused mostly by growing scarcity of sediment resources in their source areas, cf. *List* (2004).

Detailed investigations of nearshore seabed along the intensely eroded coast, using non-invasive methods (mainly multibeam echosounder, sidescan sonar, seismo-acoustic profiling) revealed a complicated system of transverse bars. Deposits in the bars consist of various sized sand (also coarse sand), forming the so called dynamic layer, which is of relatively small thickness (up to 3-5 m). Under the bars there are lagoon type sandy silt deposits (partly organic muds), temporarily uncovered at bottom surface in the interbar throughs.

Analysis of the structure and pattern of transverse bars, supported by direct measurements of sea currents and results of modelling, indicates storm-generated irreversible washing out of the deposits into deep sea.

Analysis of aerial photographs showed that a complex system of circulation cells is present, with rip currents along cells axes, which drive the deposits from the shore and nearshore bottom outside the breaker zone.

The Hel Peninsula spit, during its development, changed (and still changes) not only its length, but also location, moving, in its whole form, into the lagoon. In result, as the coast develops, the barrier's foreshore is currently located at the former site of the lagoon bottom, composed mostly with muds, usually organic, which are not an appropriate bar building material.

Intensive coastal protection interrupts natural development of the barrier, disallowing formation of washover fans at its lagoon side. The material, which could be deposited there, and later serve as a basis for future development of the above-water part of the barrier, is currently, together with the material from coastal erosion and from the artificially nourished beach, irretrievably washed out by currents generated by the complex wave transformation system.

The Hel Peninsula is a model example of a barrier, where human activity (economically and socially desirable) is realised in contradiction to natural processes. The seemingly simple solution – stopping all any human activity and leaving bars only under power of nature – is not possible since it would lead to destruction of infrastructure, which cannot move together with the barrier. Hence only intense regular artificial nourishment remains as the only effective method of protection of the coast of this and of other similar barriers. However, this in turn disrupts the environment in the borrow areas.

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The state of Cape Hel

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Detailed and pioneering investigations of the Cape Hel seafloor were conducted using non-invasive methods in years 2006-2007 by Department of Operational Oceanography of the Maritime Institute in Gdańsk. A side-scan sonar, a multi-beam echosounder, subbottom profiler and underwater ROV TV system were used. Grab and core samples of the surface sediments were taken in selected locations. Maps, profiles and cross-sections provide a basis for determining the relief and structure of Cape Hel. Two bottom sections are clearly distinct in the relief of Cape Hel: a shallow, flat nearshore “shelf” (width of up to 500 m and depth of up to ca. 6 m) and a steep slope (inclination over 15^{O}) descending to a depth of over 50 m. Sediments provided by longshore transport are moved along and across the “shelf” and next down the slope. The slope experiences intensive activity of surface mass movements of different types and sizes and also activity of internal waves. A diverse seafloor relief and occurrence of poorly sorted sediment shows that Cape Hel bottom is undergoing strong processes activity. There are plenty of small and large fragments of plants, and anthropogenic objects such as rubble and rubbish. The eastern part of Cape Hel is in a state of relative balance. The beach here is wide and the dune baseline is relatively invariable. The “shelf” is narrow and is an area of intensive sediments movement on the slope. Main types of mass movement are semi-fluid debris creeping, “sheet” slips and slide troughs. Series of long, wavy, curved ridges, which were probably formed by internal waves, were observed at the bottom section of the slope. There are no large walls of slide depressions and tongues. The entire eastern part of Cape Hel is relatively stable. There is no threat of seashore and seafloor abrasion if there will be sediment supply by longshore transport. The western part of Cape Hel is visibly abrasive. The beach is very narrow and dunes are abraded. The wide “shelf” is a kind of abrasion platform. Sandy deposits are strongly compacted. Provided sediments are entirely transported down the slope. The slope is cut by huge slide scars that currently also erode “shelf” edge. The western side of the cape is undergoing intensive erosion because of a negative deposit balance. An artificial nourishment with coarse sand is required to prevent abrasion. The studies were supported by the State Committee for Scientific Research (grant no 4136/P01/2007/32).

Analysis of changes in meteorological and hydrological characteristics for marine coasts and lagoons in the Kaliningrad Oblast (south-east Baltic)

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Long-term changes and trends in meteorological and hydrological characteristics for the open Baltic coast and lagoons of the Kaliningrad Oblast were studied by the data of different sources. Due to some gaps in series of data the conclusions made show the main tendencies in state of some characteristics. Warming in terms of increase by 1-3 degrees of water and air temperature (especially in spring and summer) is an evident fact for the studied region.

Analysis of the time series of the annual mean sea level in the Baltiysk Strait in the period from 1990 to 2006 showed obvious positive linear trend (up to 11 cm for 17 years), while range of variations is 26 cm, minimal value is -17 cm (1996) and maximum value is 9 cm (2004). This increase is higher then for the neighbouring areas - Klaipeda and Hel peninsula, where positive trend of 3-4 cm for the same period was observed. The possible reason is in the location of the point of sea level measurements – not at the open coast, but within the Vistula Lagoon.

Based on statistics for 10 years (1992-2002) a decreasing trend in duration of stormy time was revealed (from 55 up to 35 days in average). This duration of stormy time is defined as number of hours when wind speed exceeds 15 m/s. This duration fluctuated between 65 days in 1997 and 30 days in 1996. The same tendency is observed separately for wind power ranges 15-20 m/s, 20-25 m/s and more 25 m/s.

Recent measurements at the marine station on the sea platform near the Curonian Spit showed that wind rose in the opens sea is symmetric against the east-west direction. Statistics of wind direction is the following: western quarter - 25.7%, eastern quarter - 10.6%, southern quarter - 11.5%, northern quarter - 10.7%. Western winds are predominant. The most probable is the western wind with wind speed in a range of 6-9 m/s – 37.8%. Wind speed of 2-5 m/s were measured in 26.4%, 10-13 m/s - 23,3%. Strong winds (21-24 m/s) were observed in 0.5%, and once the wind was in the range of 26-28 m/s.

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Sedimentary structures of the coastal zone in the area of Pogorzelica, Poland

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1. Introduction

Relief forms in the coastal zone are induced by many variable factors that change in time and space. This variability, difficult to capture by geodetic measurements and remote sensing, is visible in sedimentary structures of the coastal zone, including the easily accessible areas of coastal dunes and the beach.

In this work, we examined the sedimentary structures and deposits that form the beach and foredune in the area of Pogorzelica, Poland. The examinations were performed from the summer 2007 and spring 2008. During two seasons (summer and spring), we formed two crosswise cuttings in the beach, and the coastal dune ridges and interdune depression, which exposed sediment structures. The structures were recorded and from each layer we collected deposit samples who were then subjected to granulometric examinations at the laboratory at the Marine Geomorphology Department at the University of Szczecin.

The obtained results gave the image of the sedimentary environment of beaches and dunes in the area of Pogorzelica, Poland. The research may help in forecasting the dynamics in the examined coast section.

2. The results of the study

In the cuttings made in the leeward slopes, we observed diagonal stratification. The recorded shape of the leeward slop, sand grain size and slope height all indicated a significant force of the strong storm winds that transport sandy sediment.

Another kind of stratification that we observed in the area of Pogorzelica was cross stratification. It probably resulted from the frequent changes in the direction and speed of wind, and different ways of sand transportation along the leeward slope of the foredune (Izmaiłow 1998). The observed layers crossed one another. Their inclination angle ranged from 30° on the dune slopes to almost horizontal stratification on the dune ridges and in interdune depressions.

During field measurements, at three sites we observed structures which abruptly ended (Fig.1). For example it occurred in the windward slope of the foredune, where layers broke off which could have resulted from the slope erosion (I in Fig. 1). The inner structure of the leeward slope of the first dune ridge showed the stratification that was consistent with the slope's southward inclination.

However, immediately before the interdune depression, the layers changed their inclination angle into northward and abruptly ended. Abrupt breaking indicates deflation processes. The change in the inclination angle suggests that once a windward slope started at the site where we observed abrupt breaking of layers. (II in Fig. 1). In the structure of the second dune ridge, we observed internal structure that is characteristic for the leeward slope, as the stratification was southward (III in Fig. 1).

The seaward inclination of the beach in the examined section of the coast, ranged from 0° to 10°. Measurements showed that in the area of Pogorzelica the inclination and width of the beach are subject to seasonal changes. The recorded changes between the summer and spring measurements showed that the beach width during in August 2007 was on average 10m shorter (30m) than in April 2008 (40m), and its inclination decreased gradually towards the sea, ranging from 10°-2.5° at the foot of the foredune.

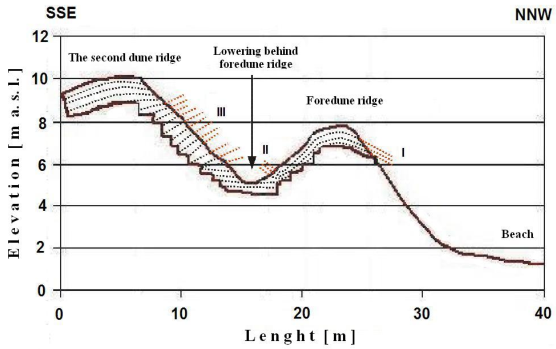

Figure 1. The sedimentological cross-section through dunes. Dashed line – structures and its interpolation. I – nowadays proximal slope II – proximal nowadays distal slope III – distal-nowadays proximal slope

The structure of the beach has straight, oblique and sinusoidal layers, which were inclined southward and whose width was from several milimeters to several centimeters. We observed the occurrence of layers with heavy minerals with thickness from 5 to 10cm, decreasing towards the sea. In several places, in the directed vicinity of water line, we also observed the accumulation of wood, algae and stems, deposited by waves on the shore. This deposit and the occurrence of heavy minerals was also observed at the foot of the foredune. They showed the high water levels when the water runup reached the foot of the foredune.

Figure 2. The sedimentary structures of the aeolian ripples on the beach (photo P. Sydor).

During the measurements from August 2007 in the middle part of the beach, we recorded a wavy layer (Fig. 2). It is probably the remnant of the previous mesoforms, that Mielczarski and Onoszko (1968) termed 'small beach dunes', transformed from sandy streaks that are produced by the transport of the dried sand from the moist part of the beach. The small beach dunes observed in Pogorzelica create the series of small hills with relatively regular intervals. Their height was about 15cm and they were symmetrical. During the field measurements in 2008 the forms were not observed.
The granulometric analyses showed that the deposits in the area were mainly very well sorted small and middle sized grain sands. The analysis of skewness showed that these sediments have a symmetric distribution which indicates the massive transit of sandy deposit. The analysis of kurtosis showed the domination of mesokurtic distributions in the coastal zone sediments, which according to Racinowski et al. (2001) indicate redeposition, transport or deposition during the saturation of the eroded material with minerals.

3. Conclusions

The performed examinations of sedimentary structures in the coastal zone in the area of Pogorzelica, with the dominant horizontal, diagonal and cross stratification, indicate the influence of factors with a significant force – strong storm winds in the area of dunes and upper beach, and the runup during the storm surge. The recorded disruptions in the distribution of layers helped determine the range of storm runups and the reconstruction of the changing position of dune ridges.
The granulometric analysis of the examined deposits and the calculated coefficients (sort, skewness and kurtosis) showed the dominating influence of massive deposition transport of the eroded debris flow saturated with sandy material.

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Climate change and anthropogenic impact on bottom sediment environment in the recent 30 years, Pearl River Estuary

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1. Introduction

Riverine hydrology and riverine material fluxes to the coastal zone have increased in both scale and rate of change in the last 200 years due to human activities. These changes happened dramatically in China over the past few decades because of remarkable economic development and sustainable high growth rate.

The Pearl River Estuary (PRE), also known as Lingdingyang Estuary, provides an excellent picture of the interaction between human impact and sediment environmental change between the river drainage and marine system. Studies shows that water discharge and sediment load into the estuary increased during the last 30 years because of human activities. The aim of this paper is to provide a connection between water discharge and sediment load increase and bottom sediment environment change over the past 30 years in the PRE. The grain size distribution pattern of bottom sediment between 1975 and 200x is illustrated to show the bottom sedimentation environmental change by anthropogenic impact and climate change.

2. Regional setting

The Pearl River water system includes three principal rivers: the West River, North River, and East River, and some small rivers draining the Pearl River Delta (Fig.1). All the West River, North River and East River rivers flow to the Pearl River Delta and empty through eight large outlets into the South China Sea.

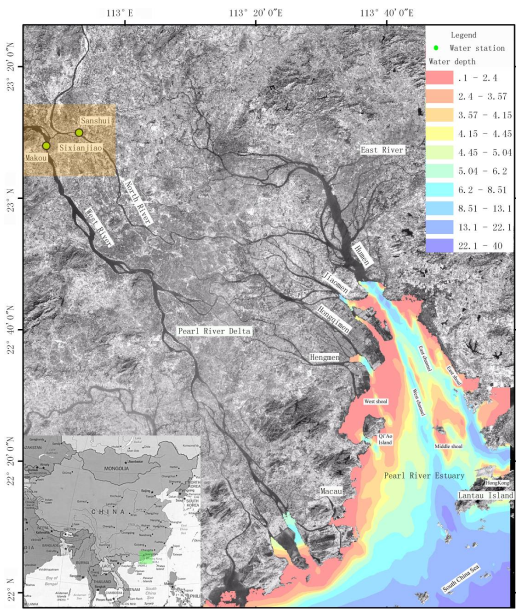

Figure 1. Locations of the Pearl River Estuary/Delta on the Landsat remote sensing image with bathymetry isobathic map from national nautical map.

Waters from the West River and North River mix and redistribute by the Sixianjiao channel, and a portion of the flow enters the West River network via the Makou station and the rest goes into the North River network through the Sanshui station (Fig.2).

Water exchange between the two major tributaries of the Pearl River, the West River and North River, had been significantly changed due to the down cutting of river channels since 1990s due to the booming economy (Luo et al., 2007). As a result, the water discharge into the PRE increased from 1,742×108 m^3 to 2,085×10^8 m3, and the stream load increased from 3,389×10^4 t to 3,989×10^4 t (Huang and Zhang, 2004).

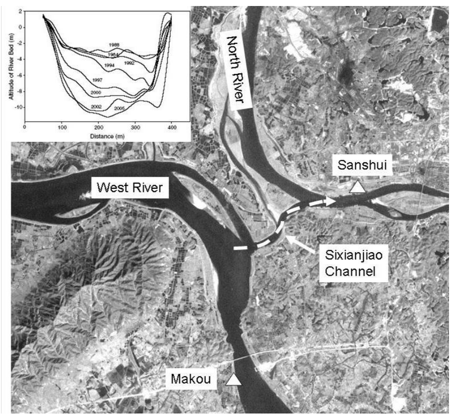

Figure 2. Relationship between the North River and the West River by Sixianjiao channel.△ represents the Makou and Sanshui water station respectively. The upside graph shows the temporal changes of the cross section at the Sanshui water station (from Luo et al., 2007)

3. Data and method

Surface sediment samples were collected from different resources. 284 grain size surface samples were taken in the PRE from 24th, April to 10th May in 1975 by Zhao Huanting and his colleagues in SCSIO, these samples were measured using sieve and pipette method, samples' positions were measured by the sextant with local reference site in detail record at that time, these points were digitized into the Arcmap® database from paper copy (Fig.3 A, C). In 2004, 63 surface sediment samples were taken during in July, these samples were taken grain size analysis in IOW by Cilas 1180L Lasersizer. Additionally 82 surface samples were taken by GMGS in 2003 and 2004, and measured by Malvern Mastersizer 2000. All 200x samples' positions were measure by the differential GPS and later on input into the database (Fig.3 B, D). Linear interpolation was used to calculate statistical parameters by the Folk and Ward graphical method. The resulting data sets were edited and further analysised using GRADISTAT, a grain size distribution and statistics package for the analysis of unconsolidated sediments (Blott & Pie, 2001).

4. Result and discussion

The sediments of the PRE are dominated by cohesive sediments which almost occupied 95% of the whole estuary. The relatively stable amount of clay probably indicates that the PRE hydraulic conditions are relatively strong. On the whole, the sediment outside of the estuary was finer than in the northern part of the estuary, but coarser than in the middle PRE. In spatial distribution, content of coarser sediment component decreased quickly from north and northwest to southeast and finer sediment component always had higher contents in the middle of the estuary where a estuary turbidity maximum(ETM) zone existed, which was related to the resuspension and flocculation in this zone. The area of fine sediment in the middle of the estuary in 1975 is larger than that in 200x.

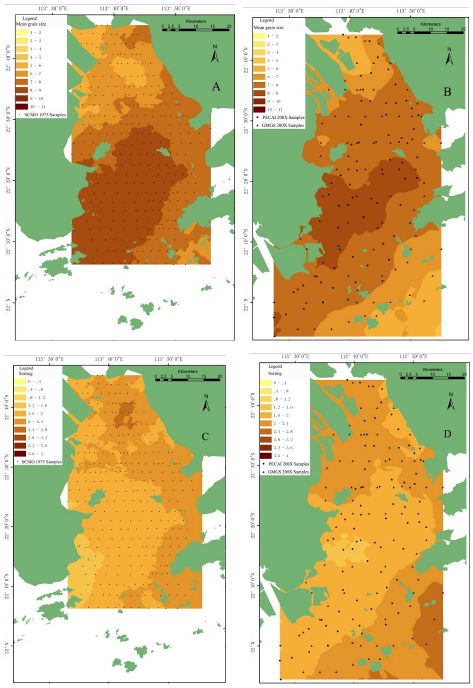

Figure 3. Mean grain size distribution of the PRE in 1975(A) and 2003-2005 (B), Grain size sorting in 1975(C) and 2003-2005 (D).

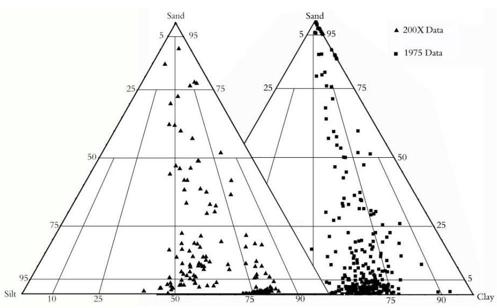

Figure 4. Ternary diagrams illustrating textural trends in 1975 and 200x based on the classification of Flemming (2000).

Almost all parts of the sediments show a bad sorting with value between 1.5-3, only part of the good sorting distribute in the north part of the estuary (Fig.3 C), east shoal (Fig.3 C, D) and south area of QiAo island (Fig.3 D). This reflects a low energy hydrodynamic depositional environment.

The ternary diagrams in Fig.4 reveals that the sand/silt/clay ratios plot in a band reflecting an intermediate engery gradient (cf. Flemming, 2000), which corresponds to the shore-normal trend reflected by a gradual increase in mud content. Compare with the data set in 1975, the clay content increase significantly, whereas the silt content decreases slightly in 200x. As a fact of more sediment load input over the past 30 years, this may be explained as more fines particles accumulate, and together with the loss of accommodation space for finer grained sediments caused by land reclamation.

There are several reasons responsible for this phenomenon:

(1) Riverine sediment load input increase. Hydraulic alteration, increased sediment transport to the ocean, and reduced riverbed height due to long-term and extensive sand excavation in the PRD may have profound impacts on the estuarine and coastal environments. The distribution of the bottom sediment grain size shows a distinct spatial pattern with fine sediments in the inner part and coarse sediments towards northern/southern parts of the estuary.

(2) Climate change. There is a notable upward tendency of SST from 1971 to 2003, the seasonal variation of SST correlates with the global warming significantly (Tang et al., 2006). It can be assumed that stronger current conveying more sediment from South China Sea into the PRE, while a deposition of mud is hindered in the ETM of the PRE due to more turbulent conditions in the water column.

(3) Reclamation around the Pearl River Estuary. The reclamation history of Pearl River Estuary has been last for hundred years, especially since 1970s. The rapid shrinkage of PRE is due to reclamation of shoals and beaches and loss of waterways. These changes in drainage network and hydraulic conditions present a great impact to coastal ecosystems and bottom sediment environment.

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On the move: The steep cliff coast of Jasmund (Rügen Island)

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1. Introduction

In succession of the huge sliding event (~100,000 m³) at Lohme Harbour in the northern part of the Jasmund peninsula in 2005, a cooperation project between LUNG (Landesamt für Umwelt, Naturschutz und Geologie), StAUN (Staatliches Amt für Umwelt und Natur) and BGR (Bundesanstalt für Geowissenschaften und Rohstoffe) was set up to quantify and assess the risks of mass movements at the coast of Rügen. Different empirical and numerical tools are used trying to identify areas of increased risk for residents and tourists. In this study, landslide forms and processes in the southern part of the steep coast of Jasmund were mapped, classified and empirically analysed to contribute to the project data base.

2. Study Area

The steep coast of Jasmund between Sassnitz and the location "Fahrnitzer Ufer" (**Figure 1**) is an intensively disturbed push moraine consisting of deformed Cretacous chalky limestone and Pleistocene glacial tills and sandy to silty intercalations (*Keilhack* 1912, *Steinich* 1972).

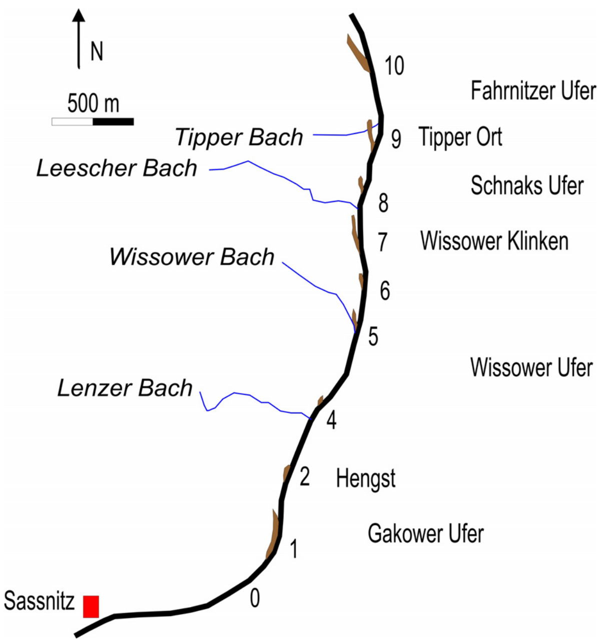

Figure 1. Schematic overview of the steep coastline of Jasmund/Rügen north of Sassnitz with typical names for locations and water outlets; numbers indicate outcrops of Pleistocene glacial tills.

3. Methods

We carried out two field campaigns – the first one in August 2007, the second one in May 2008 – to map the recent landslide inventory and to document changes on short time scales. A classification scheme by *Thiel* (2007) and *Lange* (2007) established in the northern part of Jasmund was used to characterize type, size and circumstances of landslides and classify areas of low up to very high landslide activity. The results were incorporated in the GIS data base hosted by the LUNG. Furthermore, we analysed water content and grain size distribution of point samples and compared present slope forms to historical mappings.

4. Results and Discussion

In total 69 landslide forms were recognized and described in the study area. The reasons for mass movement processes at the coast are numerous and of a complex nature. Basically they can be divided into land-induced and sea-controlled activities, which are strongly interacting. Special features of the Jasmund cliff are the interbedded, inhomogeneous strata of Pleistocene deposits with extreme differences in water permeability due to soil mechanics and tectonic deformation (*Obst & Schütze* 2006). Sea-driven processes are mainly abrasion, undercutting and the exposure to the major wind direction (with special focus on the exposure to the direction of the spring storms). High rainfalls in summer 2007 (values about 100 mm/yr over hitherto maxima since 1993) seemed to play an important role. According to the distribution of landslides the study area can be divided into two sections with specific characteristics:

Section A – *Sassnitz northwards to the cliff of the "Wissower Ufer"* – is slightly turned away from the major storm wind direction and inhibits a relatively broad shingly beach, which indicates less sea-water influence. Nevertheless very high to high slide activity occurs in this section, suggesting major land-driven forces.

Section B – *from the „Wissower Ufer" to the „Fahrnitzer Ufer"* – is exposed to the major spring storms (coming from the east) and shows a wide range of sliding activity from low to very high, e.g. at the famous tourist site of the "Wissower Klinken". Due to constant sea action the beach is very narrow and the cliff – up to 80 m high in this section – is very steep. However, in between both investigation periods no extreme storm flooding appeared. Therefore accumulation material at the cliff basis was only partially eroded and formed a protection barrier against further erosion by the sea.
Nevertheless, high sliding activity occurred near "Tipper Ort" in the northernmost part of the study area in April 2008. There, the upper part of the cliff teared on a 115 m long edge. This cliff collapse was indicated already in summer 2007 by pronounced undercutting and overhangs. Additionally, increasing pore water pressure in the Pleistocene layers on top of the Cretaceous rocks in this part of the costal section may also have contributed to the sliding event.
Relatively high land slide activity is also related to several coastal water outlets (Leescher, Wissower, Tipper Bach), which normally control the surface and also the subsurface water movement. Due to high precipitation in summer 2007 and in winter 2007/2008, however, the water pressure in the high permeable strata – and probably also

in cracks of the less permeable rocks – increased until the shear strength was reduced causing slope failures.

5. Outlook

The results of this study form the basis of further slide vulnerability analysis and the generation of integrated geohazard maps. In the future, special attention should be paid to the anthropogenic influenced area of the northern part of Sassnitz, where also inhabited and gardening areas will be increasingly affected by sliding activities.

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The influence of the North Atlantic Oscillation on air temperature and precipitation along the southern Baltic Sea coast

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1. The influence of NAO on air temperature

Monthly averaged data on air temperature and precipitation recorded at 12 coastal locations along the southern Baltic Sea coast and the indexed values of the North Atlantic Oscillation (NAO) are statistically analysed for 1961-2000. Obtained results showed significant positive correlation between air temperature and NAO, for all coastal stations with highest correlation's occurring during the winter time. The averaged correlation coefficients ranged between 0.40-0.56; 0.77-0.86; and 0.66-0.76 for December, January and February respectively. The spring, summer and autumn temperature records investigated against NAO showed more scattered and generally lower correlation, ranging from -0.06 to 0.58. Further investigations considering the latitudinal distribution of winter time NAO and air temperature interrelation showed its decreasing tendency towards more eastern locations along the southern Baltic Sea coast.

2. The influence of NOA on precipitation rates

To investigate the influence of the NAO on precipitation along the southern Baltic Sea coast a records of monthly precipitation rates collected at the same 12 coastal station are analysed. The results showed weaker correlation's during all seasons, with correlation coefficients ranging from -0.40 in Świbno (eastern station) to 0.60 in Świnoujście (western station). This indicates that the precipitation rates and the NAO index are weakly correlated along the southern Baltic Sea coast. Both spatial and temporal distribution of precipitation are influenced by several more complex processes, which include, among other, contribution of aerosol system influencing condensation and cloud formation processes over Europe.

3. Air mass trajectories over the North Atlantic

To reveal a typical property of the North Atlantic impact on the weather system over Europe in addition, a one year record of forward surface air mass trajectories originating along the longitude 10°W at latitudes 40°N, 50°N and 60°N has been investigated. The overall distribution of air mass trajectories confirmed that more extended latitudinal transport of air masses dominates for more northern air mass trajectories. The averaged distance of air masses transport, increase form 680 km to 740 km and to 800 km per day for trajectories originated at 10°W, 40°N; 10°W, 50°N and 10°W, 60°N respectively. It is revealing the increase of air masses fetch over the ocean for more northward trajectories. Obtained results indicated that during the winter time more latitudinal transport of air masses is formed, while during the spring, summer and autumn time in addition a pronounced longitudinal transport of air mass trajectories is formed. This confirms that during the winter time the northward regions of Europe are more influenced by the North Atlantic originated fluxes of heat and humidity as generally depicted by the NAO index. However, the ocean mediated influence decreases at more eastward locations along the southern Baltic Sea coast, as especially revealed by the 40 years record of air temperature distribution at 12 coastal stations. Similar conclusions where drown by other researchers investigating the influence of NAO on both the temperature and precipitation rates over northern Poland (Marsz, 1999; Panfil and Dragońska, 2004) as well as over Europe and north-western Asia (Marsz and Styszyńska, 2006).

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Maximum and minimum sea levels on the Polish coast

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1. The characterization of water level fluctuations on the Polish coast

Analysis of extreme sea levels calls for identifying and comparing the highest and the lowest levels recorded in a multi-annual period. In the present publication one analysed oscillations sea-level on 5 chosen stations on the Polish sea-coast: Świnoujście, Kołobrzeg, Ustka, Władysławowo and Gdańsk. Main results of the analysis are following:

- Amplitudes between maximum and minimum annual sea levels have increased, especially during the last 50 years.
- On the western part of the Baltic coast the amplitudes between extremes are higher than in the eastern part (fig 1).
- Extreme sea levels occur in autumn and winter months.

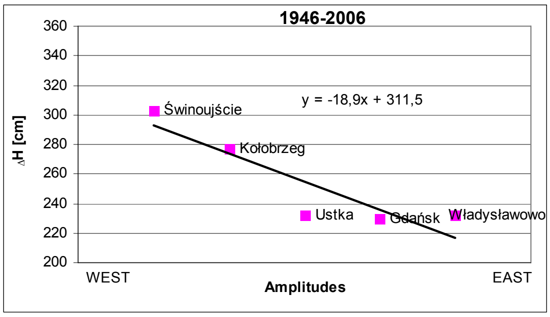

Figure 1. Trends of changes in amplitudes of extreme sea levels along the Polish coast.

2. The probability of the occurrence of maximum and minimum-sea levels

An additional aim of the work was the delimitation a long-term probabilistic forecast of annual maximum sea levels at shore stations. Sea level forecasts, at a pre-set probability level, are a necessary prerequisite of hydrotechnical construction designs, and are important in exploring storm surge characteristics and for aims of the safety of the shipping in consideration of lows of sea levels.
Most crucial is the knowledge on high sea levels which may occur once in a certain number of years e.g., once in 50, 100 or 200 years, a period of time called the recurrence interval. Maximum sea levels, calculated at pre-set probabilities with the quantile method and maximum likelihood method from the Gumbel distribution and from the Pearson distribution, are presented.

The results obtained should be regarded as representative due to the long sea level data series, particularly for Kołobrzeg (1867-2006), Gdańsk (1887-2006) and Świnoujście (1901-2006) (fig 2).

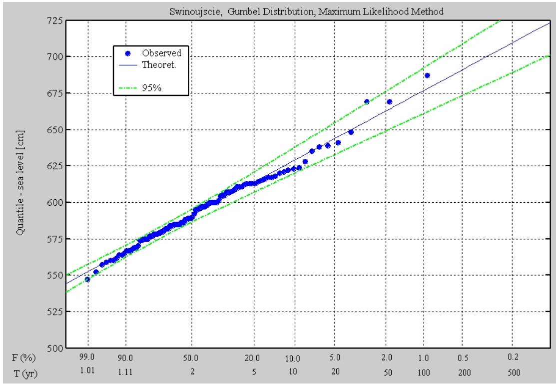

Figure 2. Probability of annual maximum sea levels in Świnoujście in 1901-2006 (Gumbel distribution, maximum likelihood method)

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A long-term morphodynamic model and its application to the southern Baltic coast

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Introduction

A long-term morphodynamic model is developed to study the evolution process of the Baltic coast under the effects of climate change. The model consists of 6 main modules, of which a hydrodynamics module, a sediment transport module and a long-term control module originate from a well-developed estuarine morphodynamic model PRD-LTMM which has been successfully applied in the study of Holocene evolution of the Pearl River Delta in China (*Wu et al*. 2006, 2007). A wind-induced wave module, a bottom boundary layer module and a cliff erosion module have been developed for the special hydrographic environment of the Baltic Sea. The Darss-Zingst peninsula at the southern Baltic has been formed after the Littorina Transgression about 8000 y BP (*Lampe* 2002) and may serve as an example for the study of coastal evolution under long-term climate change effect. Based on a recent digital elevation model, a map of sediment distribution (*Meyer et al*. 2008), a modeled eustatic dataset (*Meyer et al.* 2008) originated after IPCC scenarios, and statistical analysis of historical wind series (provided by R.Weisse, GKSS) the model has projected the evolution of Darss-Zingst peninsula for the next 800 years without taking into account coastal protection activities.

Regional Scenarios, Littoral Flow and Sediment Transport Pattern

The model is calibrated and verified by the coastline change measured for the 20th century. Model outputs vividly demonstrate the entire process of coastal development due to local imbalances in the sediment budget caused by along-shore sediment transport and sea level rise (see Fig.1). Model results indicate that the combination effect of the sea level rise and strong wind events is the dominant factor influencing the evolution of the Darss-Zingst peninsula in the next several centuries. The dissipation of wave energy due to offshore sea bottom friction decreases during the sea level rise, thus making the force attacking the coastline stronger. Due to the model the cliffs and sandy beaches along the western Darss coast are supposed to retreat with an increment of 5-10 meters every hundred year caused by the enhanced wave erosion force without coastal protection activities. While the Zingst coastline is more vulnerable to the wave erosion and an increment of 25-30 meters within one hundred year can be predicted.

Large scale sediment transport pattern can be observed in tidal areas, for instance the Pearl River estuary (*Wu et al.* 2006, 2007). The strong current induced by the runoff from the upper river and tide from the open sea plays an important role in transporting the sediment. Otherwise, in the non-tidal and weak-runoff area such as the Darss-Zingst peninsula, the wind-induced-wave and littoral current driven by the wind are the dominant factors in reshaping the coast topography.

Strong wind from different directions can be measured during a whole year in the southern Baltic. Statistical analysis of wind data series of the past 58 years serves as the input condition for the model. 4 different littoral flow patterns along the peninsula can be derived from the model. Strongest littoral flow is generated by the dominant WSW wind under a large fetch and the maximum near-shore current speed can be as high as 0.35 m/s along the Darss coast. Littoral flow carries the sediment load which is suspended from the sea bottom or eroded from the cliff by the wave action. The littoral flow redistributes the sediment within a small local area for the reason that most of the suspended sediment is composed of marine fine sand with a larger sinking velocity than cohesive sediment and the entrainment of sediment particles are always limited by a relatively low current speed.

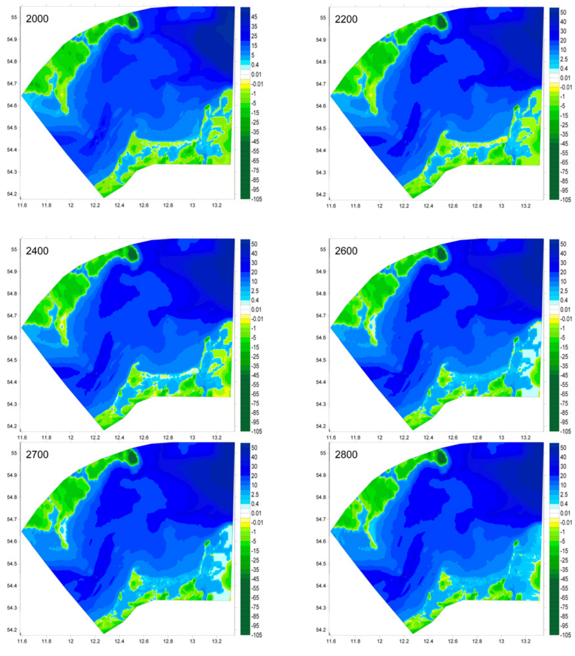

Figure 1. Predicted evolution of the Darss-Zingst peninsula in the next 800 years without taking into account coastal protection activities.

Storm Impact and Coast Profile Analysis

Yearly storms from the WNW direction with a maximum speed of 21.5 m/s and duration of 24 hours are included in the model input conditions according to the statistical analysis of historical wind data. Effects of such wind storm can be evaluated by coast profile analysis (see Fig.2). 6 profiles along the coastline have been analyzed after the first 50-years-run of the model. The results of profile analysis indicate that the effect of storms on the sea bottom change varies at different sites along the coast. In some places with shallower sea bottom, gentle-slope and directly facing to the storm attack, e.g. profile 1, the storm event can induce significant changes. Accumulative elevation change of the sea bottom caused by the yearly storm, either erosion at the upper part or deposition at the lower part, can take up 1/3 of the total sea bottom change at this site. In some places with steep-gradient sea bottom and facing to the storm attack, e.g. profile 2, the storm is mainly affecting the upper part of the sea bottom. Erosion at the upper part of the sea bottom after the storm contributes to 1/4 of the total bottom change at this site while deposition on the lower part caused by the storm is less than 1/6. In some sheltered places, e.g. profile 4, sediment transported by the storm current is the main source for deposition. The coast is not always suffering erosion when it is directly facing to the storm attack. In some places with abundant sediment supply, e.g. profile 6, the sediment transported by the storm current counterbalances the local erosion and thus it is deposited after the storm.

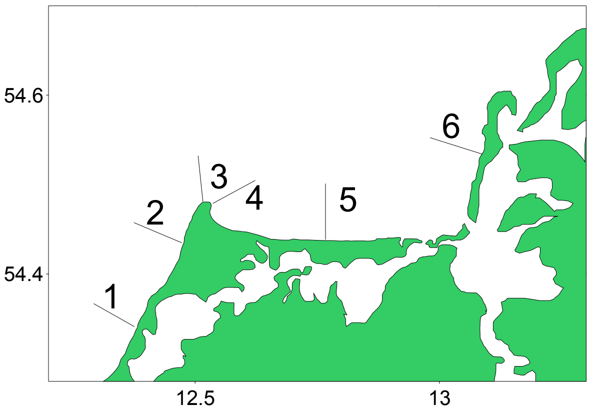

Figure 2. 6 profiles along the coast are analyzed after the first 50-years-run of the model.

Coast profiles along the Darss-Zingst peninsula are always changing under the effect of sea level rise. The rising of sea level will eventually counterbalance the siltation at some specific sites, e.g. the cusp of the peninsula and the Bock Island, and making these sites submerged by water in the next several centuries.

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