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Observed changes and variability of atmospheric parameters in the Baltic Sea region during the last 200 years

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BACCII(2013) Assessment of Climate Change for the Baltic Sea basin, Eds H. von Storch and A. Omstedt

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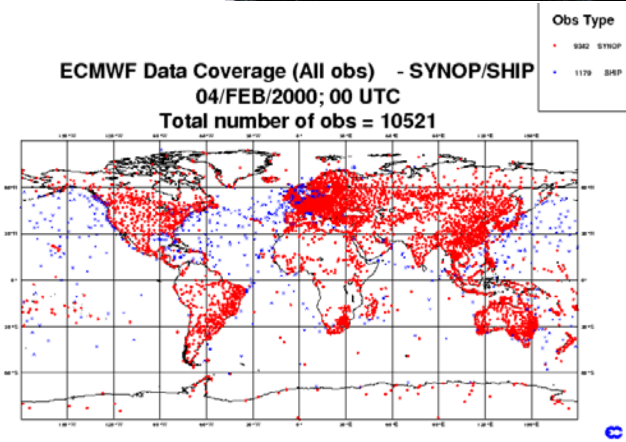
Why past 200 years?

- In-situ measurements
  - Temperature measurements (Uppsala record 1722).
  - Soundings (kite soundings 1905, Lindenberg)
  - Denser network during the 1900s.
- Satellite
  - Introduced 1978, dense network in space and time
- Problems when studying trends
  - Data density and homogeneity
- Anthropogenic signature
  - Indication of impact of anthropogenic emissions of GHG could be detected in the later part of this period



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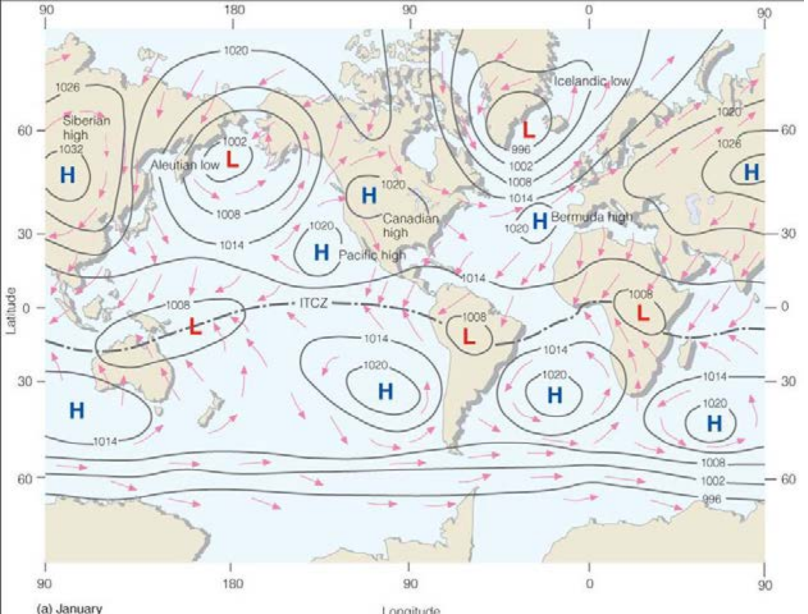
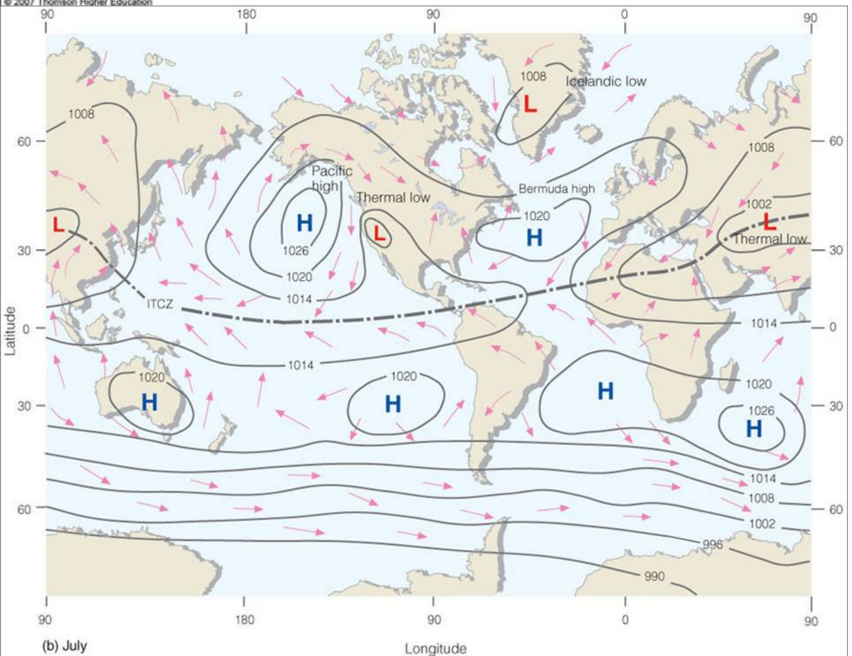
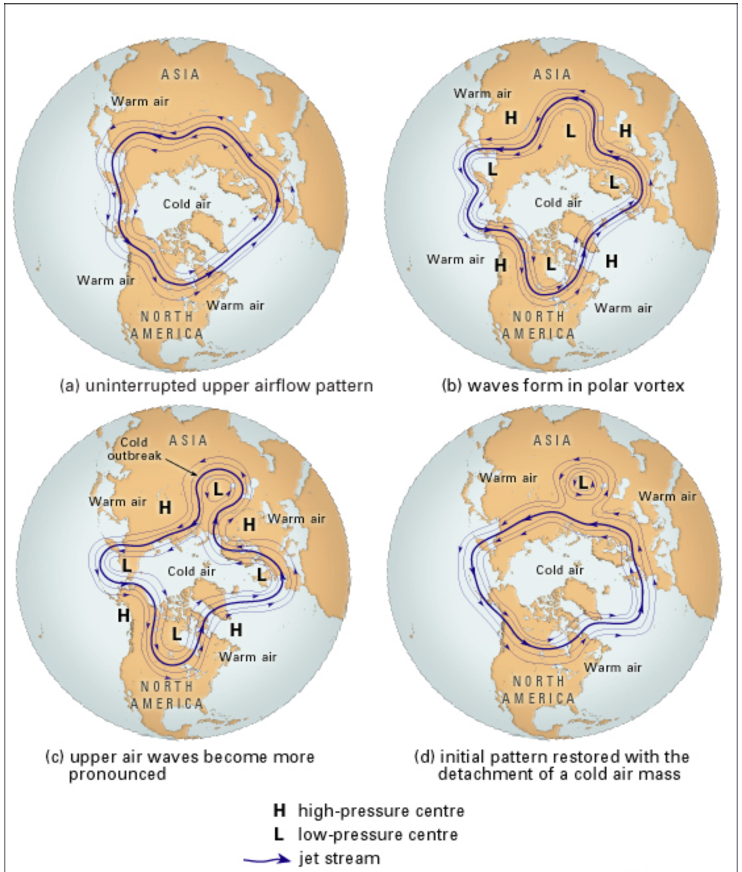
Investigated parameters

- Atmospheric circulation
  - Control of most other parameters
- Wind
  - See also Schenk and Zorita
- Temperature
  - See also Jaagus et al
- Precipitation
- Radiation/clouds
  - Control of other parameters
- Variability/extreme events

Large scale circulation patterns







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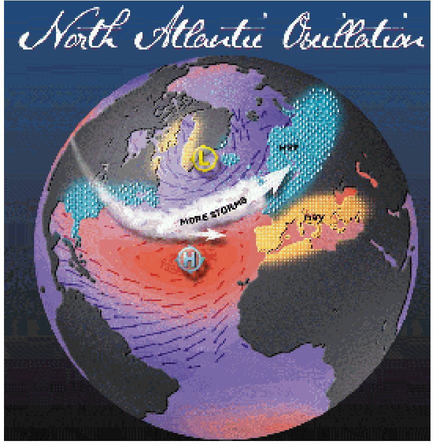
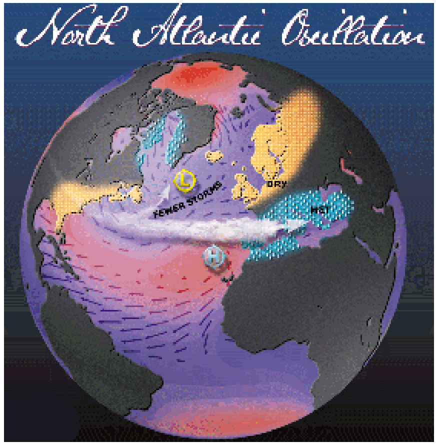
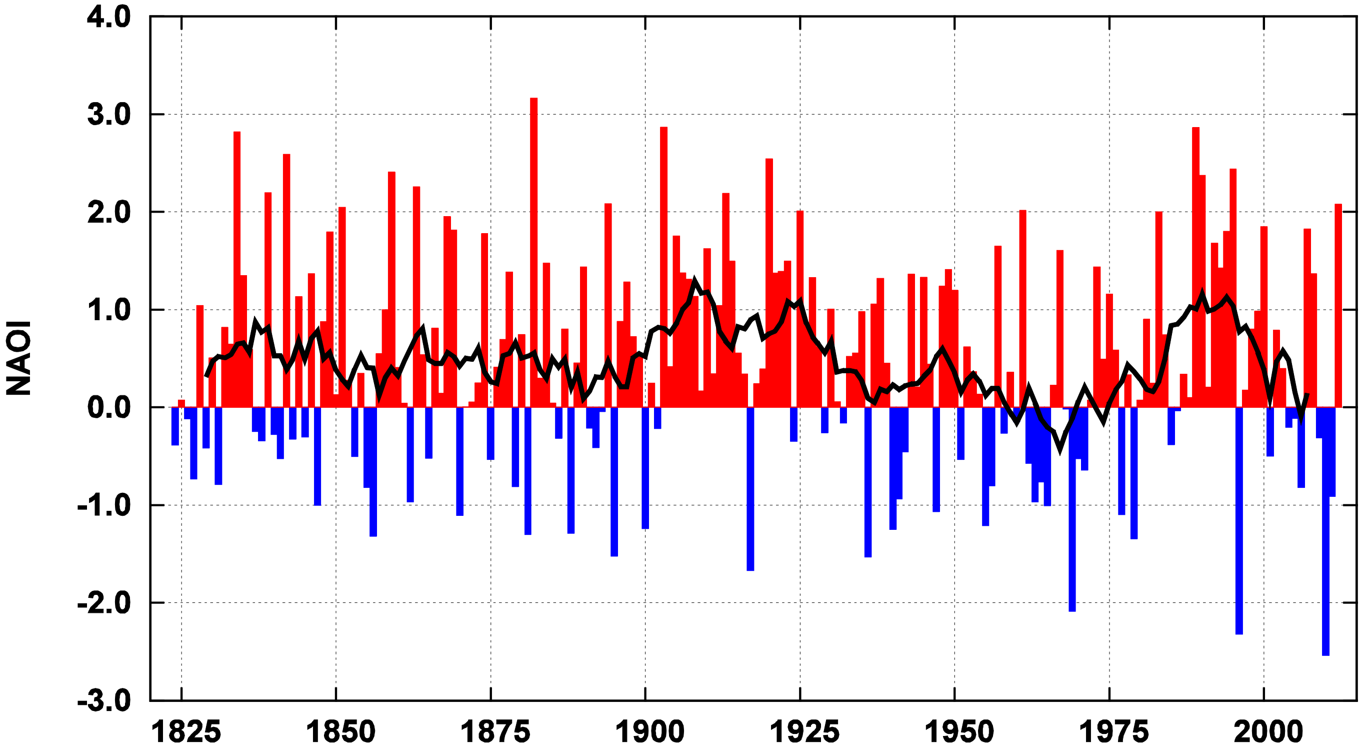
Atmospheric Circulation





The climate of the Baltic Sea region is to a large extent determined by the circulation.

- NAO
  - positive (warm, wet winters)
  - negative (cold, dry winters)



NAO index for boreal winter (DJFM) 1823/1824-2011/2012.

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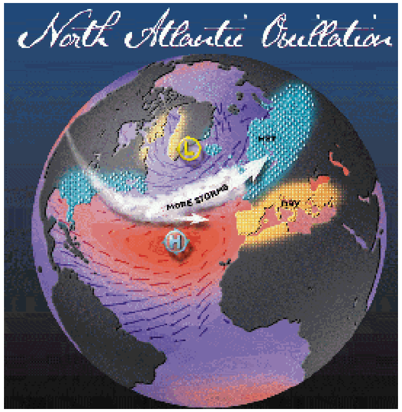
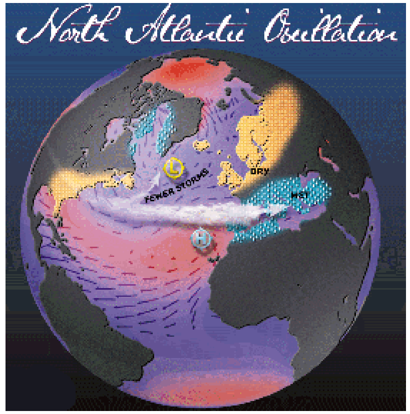
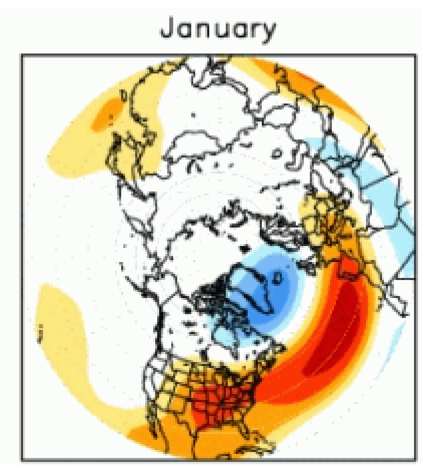
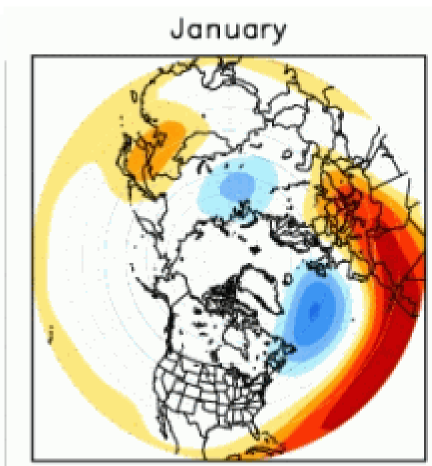
Atmospheric Circulation









EA+

EA-

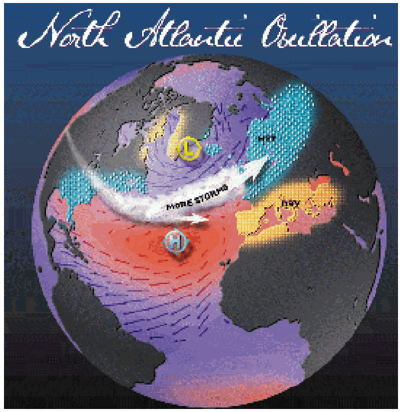
NAO: strength of pressure difference.

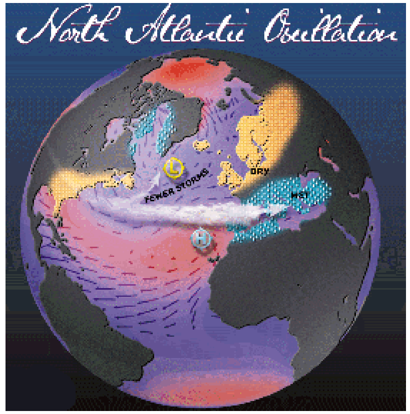
EA: East Atlantic Pattern, represents north-south location of the NAO.

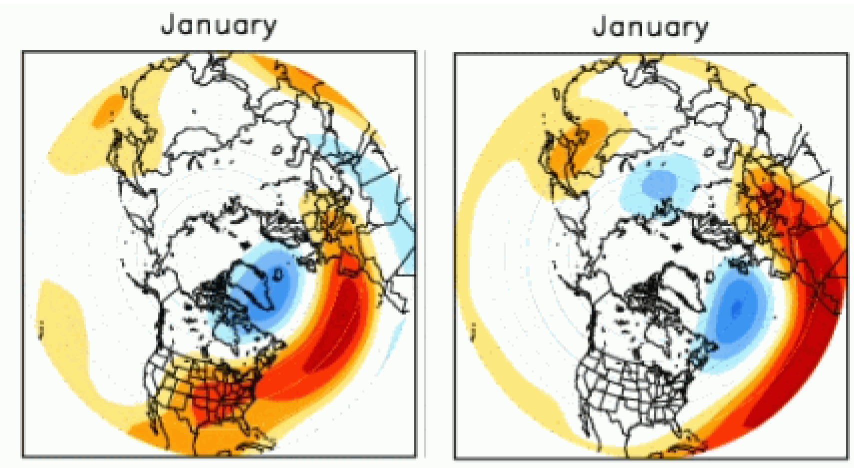
positive means a northward displacement (more zonal flow)

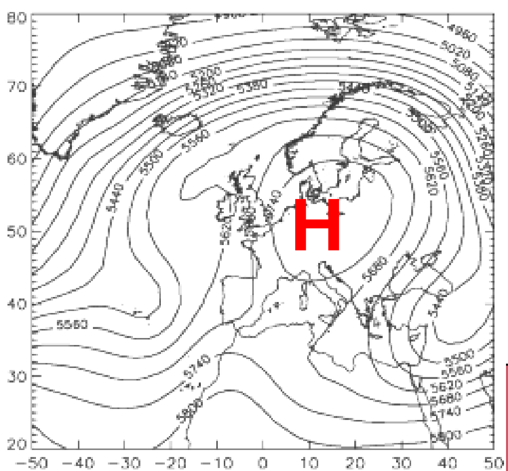
negative means a southward displacement (lower temperatures?)

Atmospheric Circulation









NAO: strength of pressure difference.

EA: East Atlantic Pattern, represents north-south location of the NAO.

Scandinavian pattern: blocking, represents an east-west shift of the centres of variability.

Atmospheric Circulation

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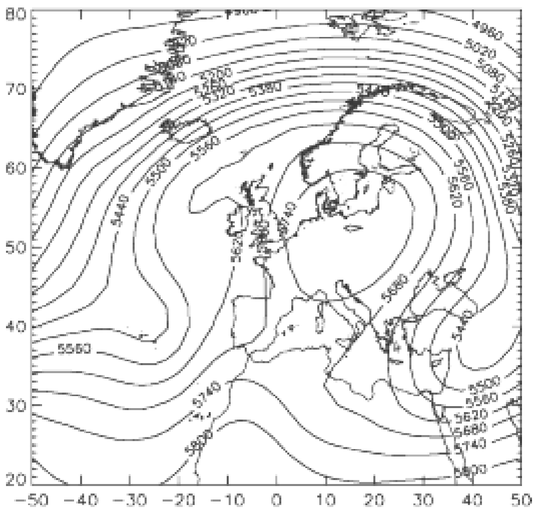
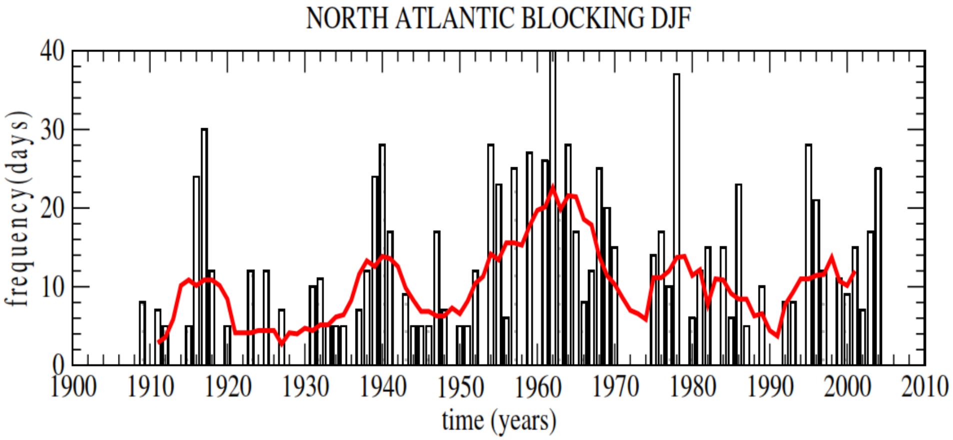
- Blocking situations are quasi-stationary and often related to extreme weather.
  - Winter: warm conditions over southwestern Greenland are related to high blocking activity over the Baltic Sea and low temperatures (and partly dominated by a negative phase of the NAO).
  - Summer, however, warm conditions over southwestern Greenland are related to low blocking activity over the Baltic Sea and a positive phase of the NAO.



The 500 hPa height field on March 6, 1948, showing a typical blocking situation. From Barriopedro et al. (2006).



Blocking index (bars) and its decadal variation (seven year running mean; red) for boreal winter (December-February) 1908 to 2005. From Rimbu and Lohmann (2011).

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Forcing of NAO

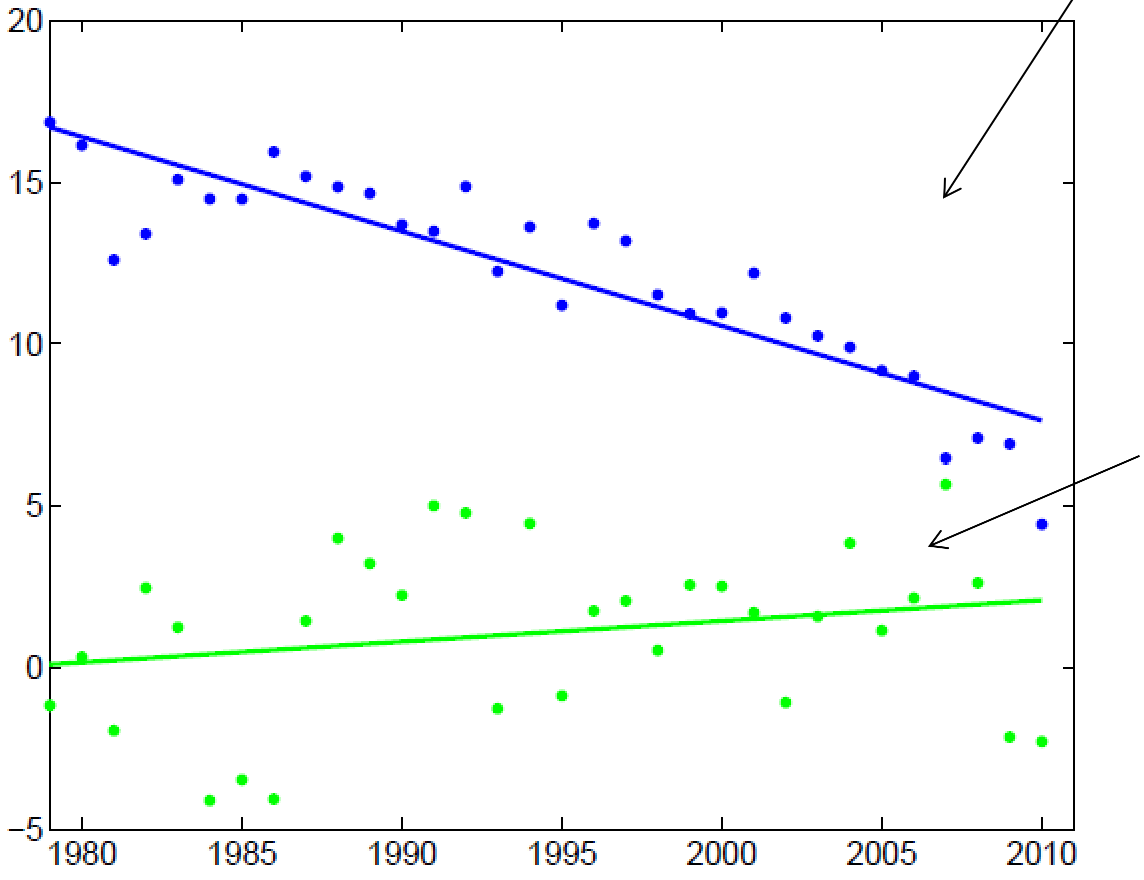
Are winter temperatures related to ice in the Arctic?

Idea – reduced summer ice in the Arctic give lower winter temperatures in northern Europe.

One suggested mechanism:

Low ice conc over Arctic Ocean → More heat into the atmosphere → Reduced vertical static stability → Circulation anomaly resembling of negative NAO

Decay of Arctic ice



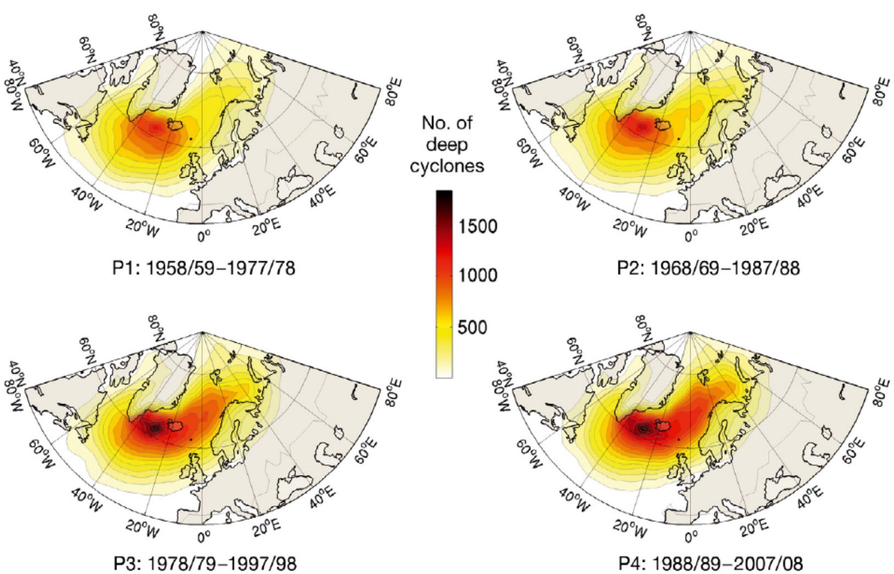
Minimum ice volume [10^3 km^3] from satellite. (PIOMAS Daily Ice Volume Data)

Mean DJF temperature anomaly Baltic Sea region [degC]. From BACCII

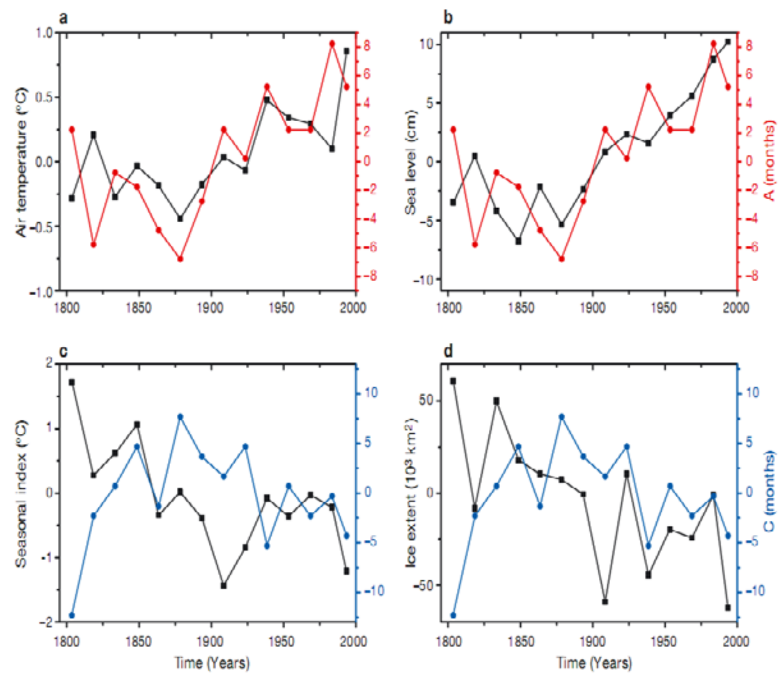
Correlation between deviation from trends: 0.31 (10% explained variation)

Atmospheric Circulation

- Northward shift of low pressure tracks agrees with increased frequency of anticyclonic circulation.
- Increased frequency of westerlies.
- Increase in number of **deep** cyclones (not total number of cyclones).



Number of deep cyclones counted for four 20-year periods P1 to P4 (December-March) (Lehmann et al., 2011).



Anomalies and circulation types that describe the vorticity of the atmospheric circulation. Red indicates anticyclonic and blue cyclonic circulation. (a) air temperature, (b) sea level, (c) difference between summer (JJA) and winter (DJF) seasonal temperatures, and (d) ice cover, Omstedt et al. (2004).

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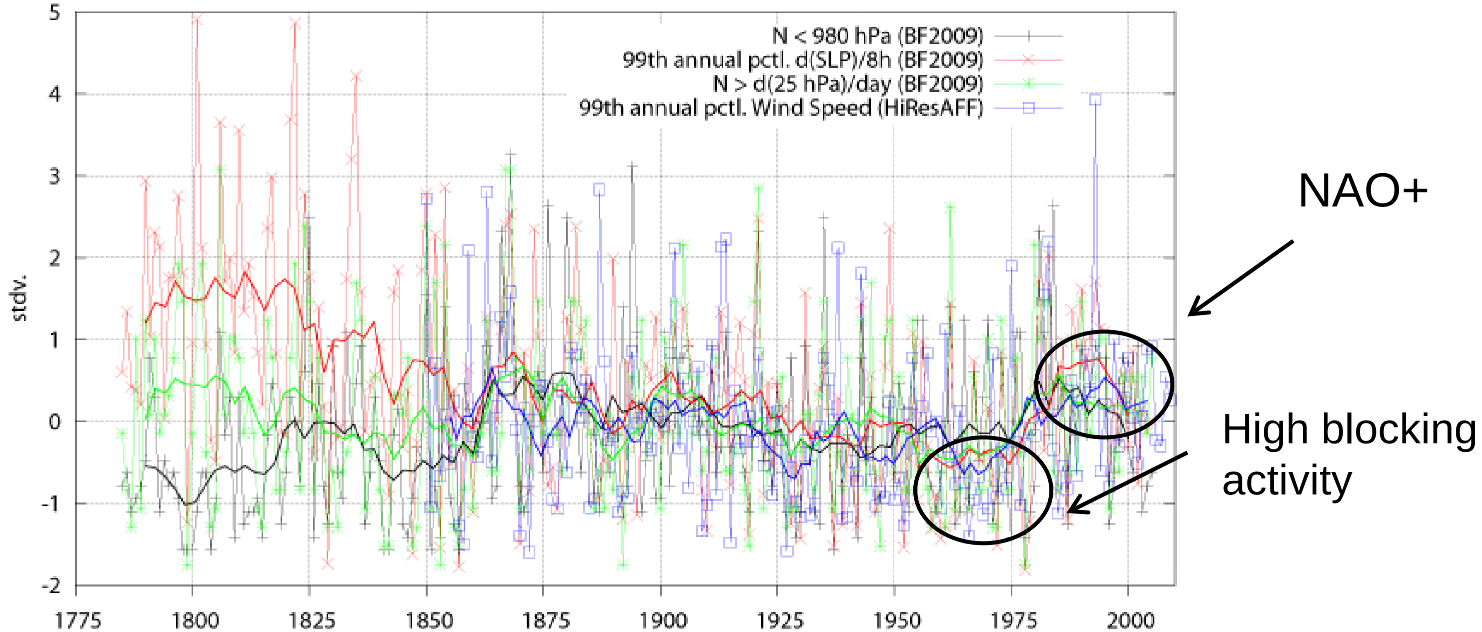
Wind

The wind climate is strongly connected with circulation.

- Wind climate show large decadal variations but **no robust long-term trends** for annual storminess



Storminess indices for Stockholm 1785-2005 (Bärring and Fortuniak 2009), 99th percentile of wind speeds in the vicinity of Stockholm 1850-2009 from HiResAFF (Schenk and Zorita 2011, 2012). Data normalized with respect to the period 1958-2005. Bold lines represent the 11y-running mean to highlight decadal variations.

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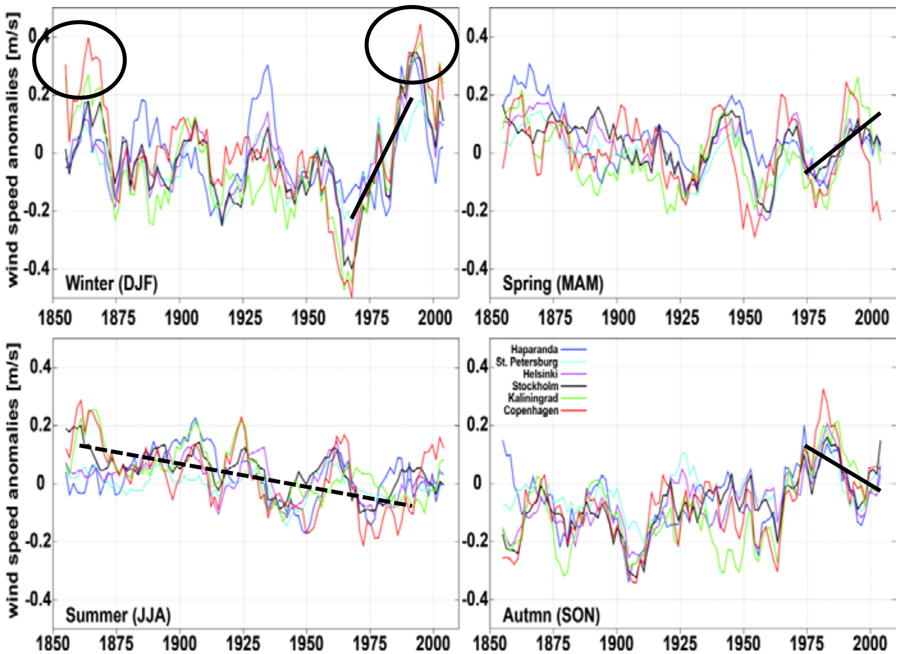
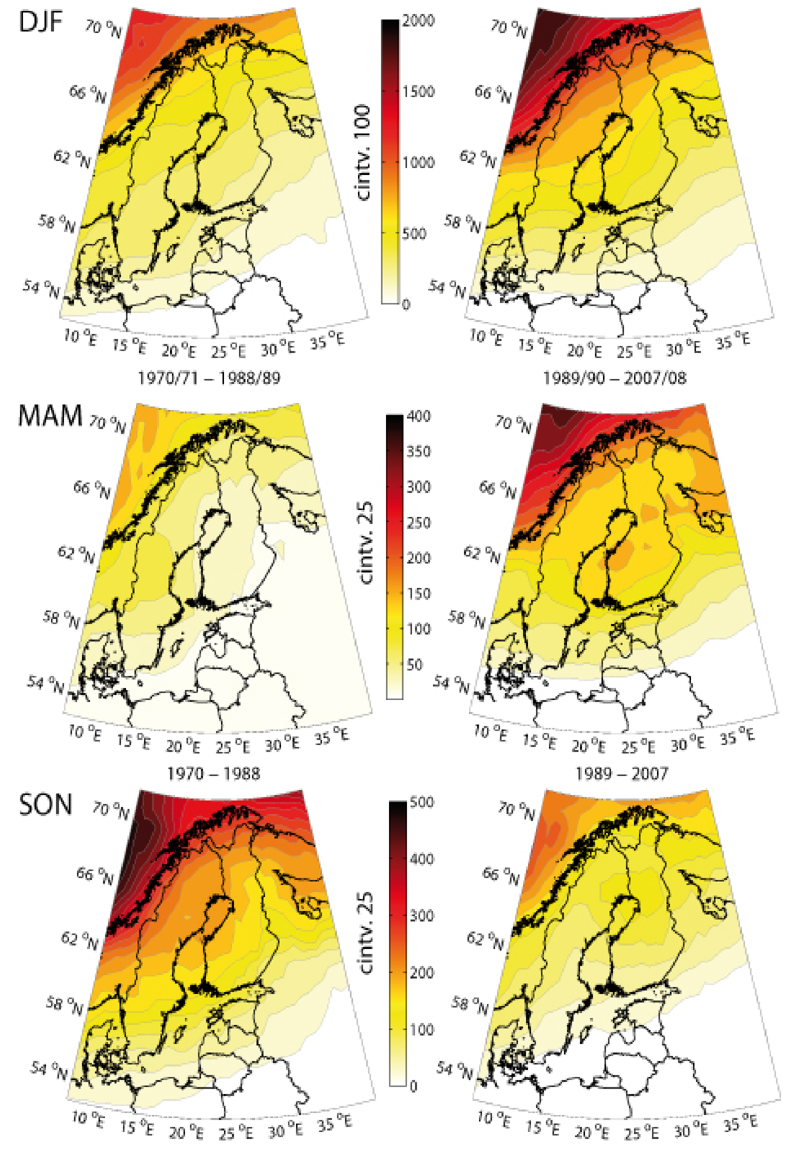
Wind/circulation

Seasonal differences:

- Increase **and northeastward shift** of **deep** cyclones in winter and spring
- Decrease in fall



Sliding decadal (11-y) mean seasonal wind speed anomalies for the Baltic Sea regions for 1850-2009 (Schenk and Zorita, 2011, 2012).



Changes in the number of deep cyclones (core pressure < 980 hPa) between 1970-88 and 1989-2008 over the Baltic Sea region for winter, spring and autumn (Lehmann et al., 2011).

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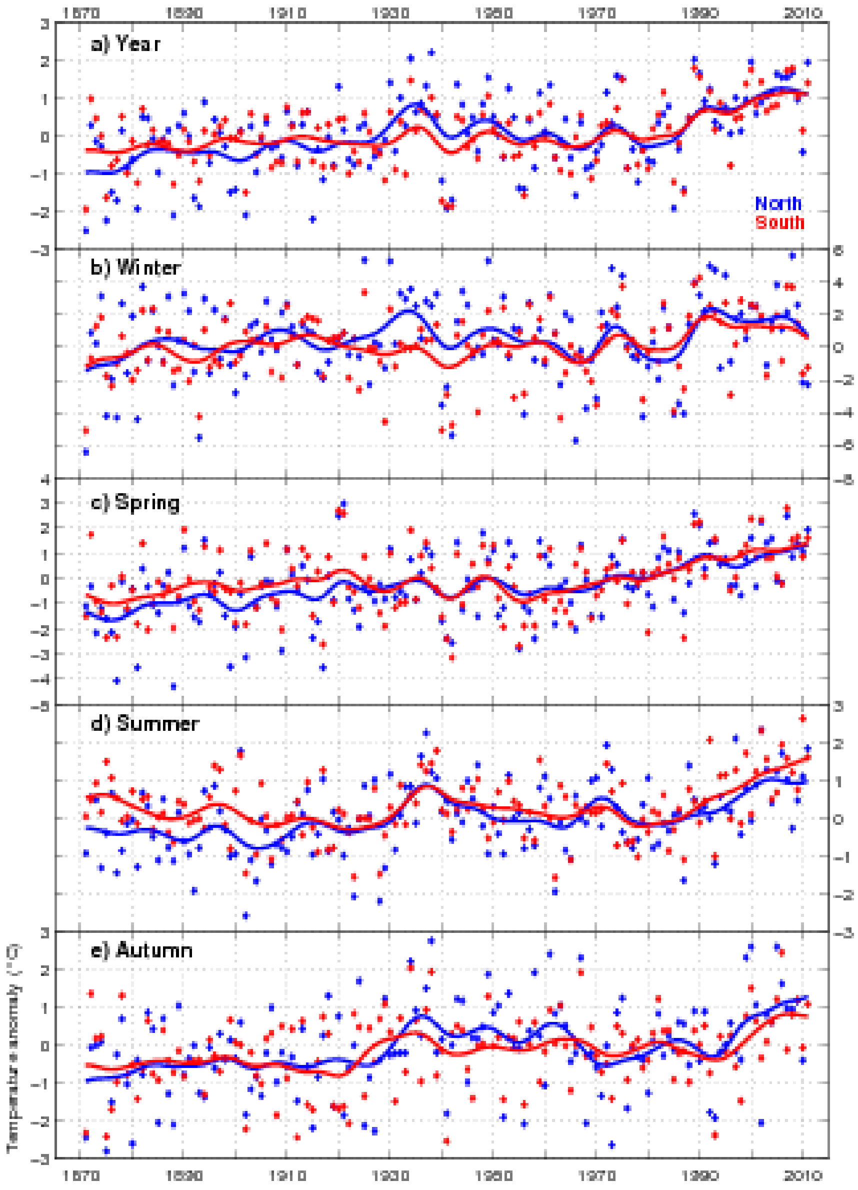
Temperature: Air

The warming of the low level atmosphere is larger in the Baltic Sea regions than the global mean for the corresponding period.

- Warming continued for the last decade
  - Not in winter
  - Largest in spring
  - Largest for northern areas



Annual and seasonal mean surface air temperature anomalies for the Baltic Sea Basin 1871-2011, Blue colour comprises the Baltic Sea basin to the north of 60° N, and red colour to the south of that latitude.

Linear surface air temperature trends (K per decade) for the period 1871-2011

Data sets	Year	Winter	Spring	Summer	Autumn
Northern area	**0.11**	0.10	**0.15**	**0.08**	**0.10**
Southern area	**0.08**	**0.10**	**0.10**	**0.04**	**0.07**

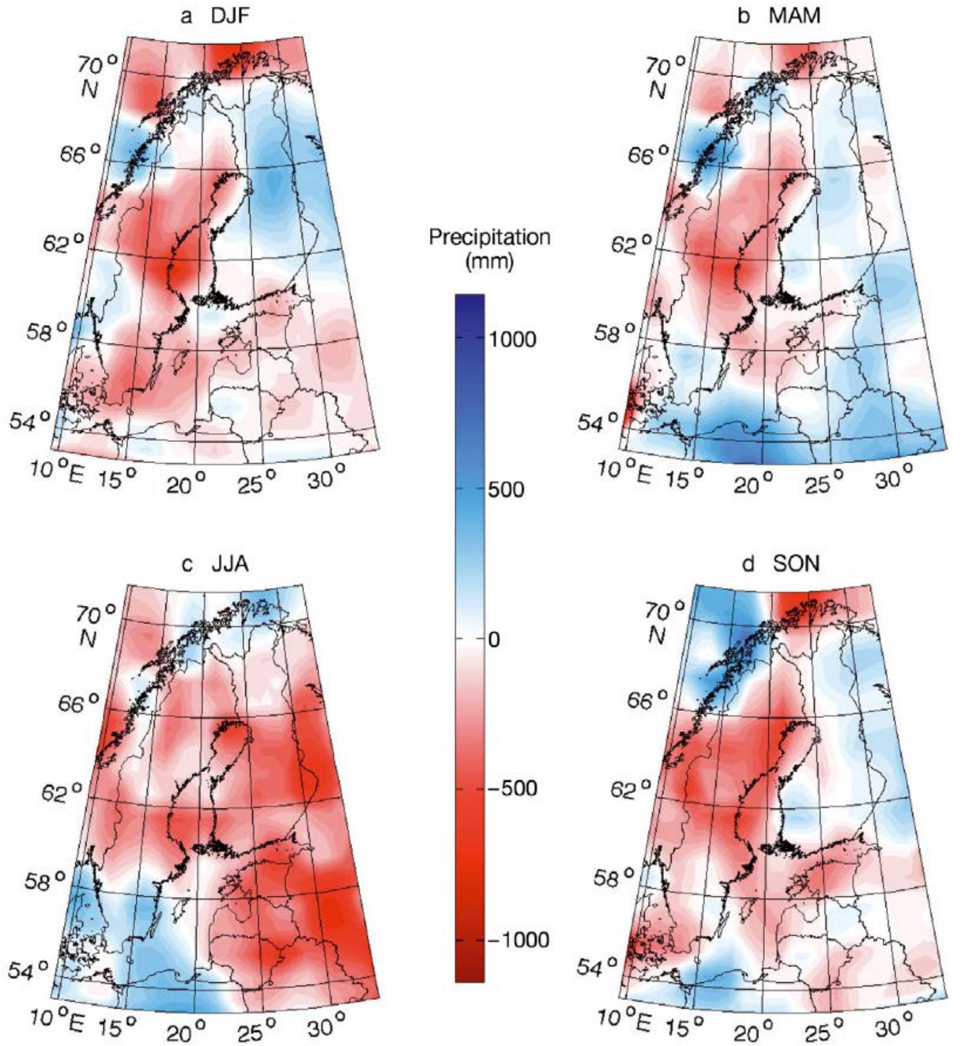
Precipitation

Precipitation is much more variable and show less clear patterns than most other parameters, with large inter-annual and large inter-decadal variations.

- No clear long-term trend, some regional exceptions:
  - Summer precipitation increased in Finland
  - Annual precipitation increased in Norway

Precipitation

- For the last decades
  - General increase in winter and spring precipitation in northern Europe.
  - Highest increase in Sweden and eastern coast of the Baltic Sea.
- Comparing 1994-2008 to the previous 15 years:
  - Less precipitation in northern and central Baltic Sea.
  - More precipitation in the southern parts.
  - Winter precipitation increased on the westward side of the Scandinavian mountian range.



Seasonal differences in 15-year totals of precipitation, period 1994-2008 minus period 1979-1993, based on the SMHI database (Lehmann et al. 2011).

Extreme events: last decades

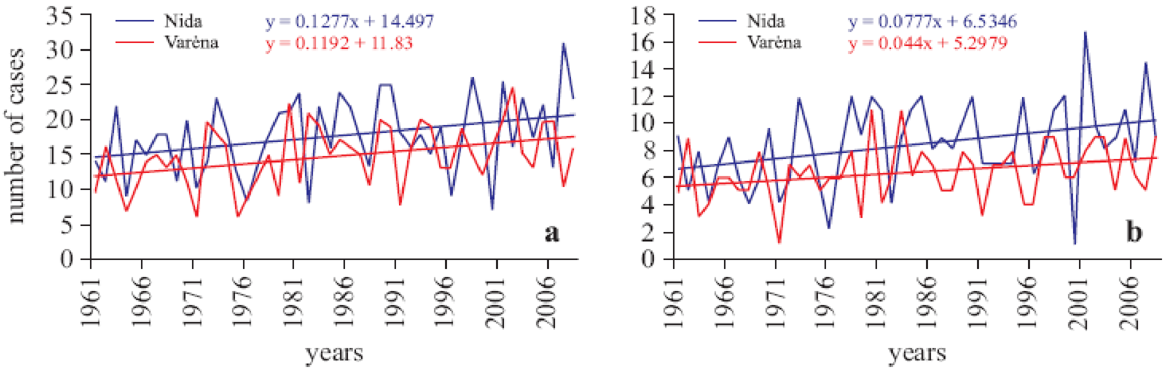
Often extreme events and changes in extreme situations are of more important than changes in mean climate.

- For all weather types (zonal, meridional or anticyclonic) an **increase in persistence is seen** (2-4 days from 1970s to 1990s).
  - Number of winter storms increased.
  - 10-percentile temperature events decreased (number of frost days decreased by 20-30 days).
  - Sum of number of wet and dry days increased in Estonia 1957-2006.

- Due to the rare occurrence of extreme events, statistically significant trends are difficult to detect.

Extreme events: last decades

– Number of days with heavy precipitation increased



Number of days with heavy precipitation (a) >10 mm per day and (b) >20 mm in three consecutive days in Nida (western Lithuania) and Varėna (south-eastern Lithuania) in 1961–2008. All trends are statistically significant according to a Mann-Kendall test (Rimkus et al 2011).

Extreme events: long term

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- Statistically significant trends:
  - Positive: in the number of tropical nights (T_{min}>20° C)
  - Positive: summer days (T_{max}>25° C)
  - negative trends: in the number of frost days (T_{min}<0° C)
  - Negative: ice days (T_{max}<0° C).
- Standard deviation of temperature in Poland:
  - The duration of extremely mild periods has increased significantly in winter
  - while the number of heat waves has increased in summer
- Very few statistically significant trends have been seen.
  - Increase in number of days with heavy precipitation in Latvia (1924-2008)
- Extreme relative sea level values are found to increase more rapidly or decreasing more slowly in regions with isostatic uplift.:
  - most obvious in the Northern Baltic Sea, but also seen e.g. in Estonia.
  - For the southern Baltic coastline of Germany and Poland, no climate driven changes in the magnitude of extreme water levels during the last 200 years could be detected.

Summary

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- In general the conclusions from BACC (2008) are confirmed.
  - Important to stress the extremely high inter-annual and inter-decadal variability in most variables.
  - Variability is much higher than long-term trends, trends depend very much on the selected period.
- New results includes:
  - Persistence of weather types has increased.

Summary

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- Disagreements in literature includes:
  - Winter storminess: a significant long-term increase in winter storminess since 1871 is shown by for example Donat et al. (2011). This is suggested by several other studies to be an artefact due to the changes in density of stations over time.
- Missing knowledge:
  - Changes in circulation patterns due to less ice in the Arctic (cold winters, moist summers are suggested).
  - Trends in extreme events.
  - Lack of data for some parameters for example clouds and radiation.