

7th Study Conference on BALTEX, Borgholm, Island of Öland, Sweden

Sea level variations of the Baltic Sea in response to climate variability for the period 1970-2010

Andreas Lehmann, Wilma Huneke, Klaus Getzlaff and Kai Myrberg*

*Finnish Environmental Institute/Marine Research Centre, Helsinki Finland





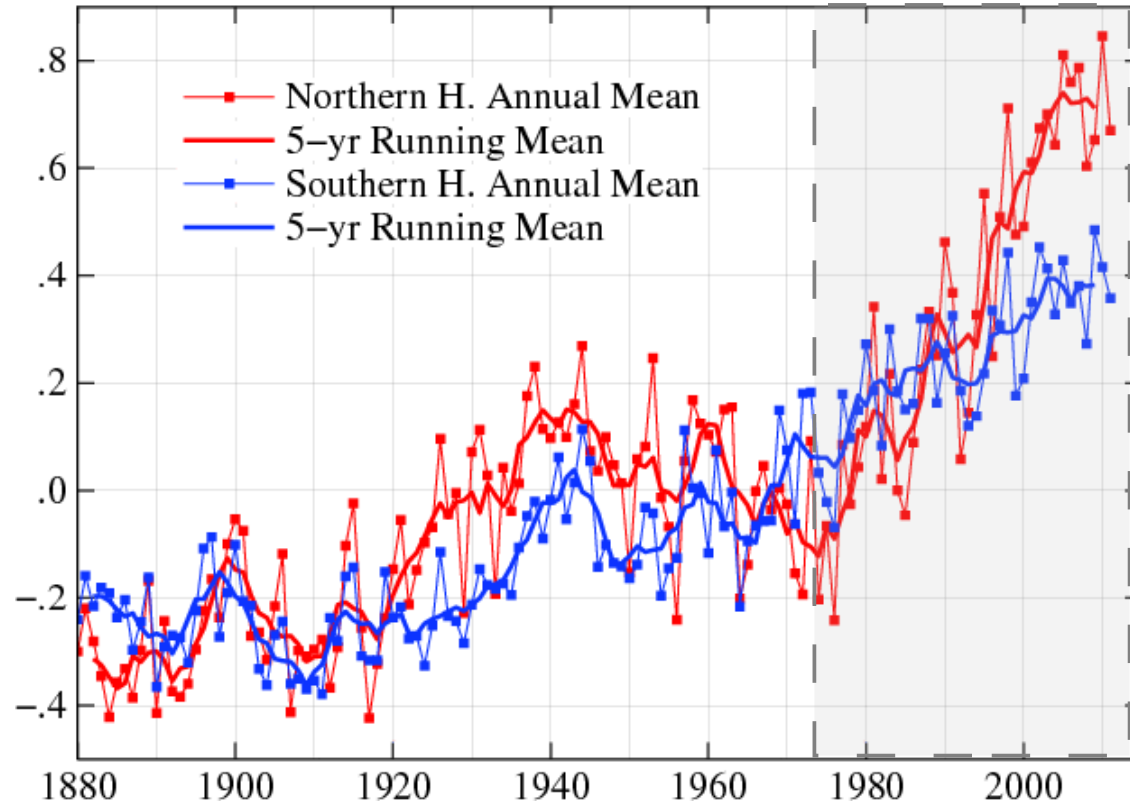
Sea level variations of the Baltic Sea ...

Motivation

Motivation

Hemispheric Temperature Change

Hemispheric Temperature Change



- Global warming trend (1850-2005) of $0.04^{\circ}\text{C}/\text{decade}$
- Specific warming period of $0.17^{\circ}\text{C}/\text{decade}$ (1980-2005 onwards?)

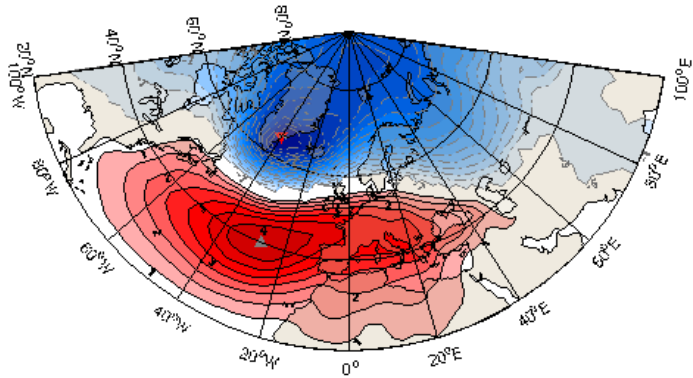
[Trenberth et al. 2007]

updated: Apr 2012 (<http://data.giss.nasa.gov/gistemp/graphs/>)

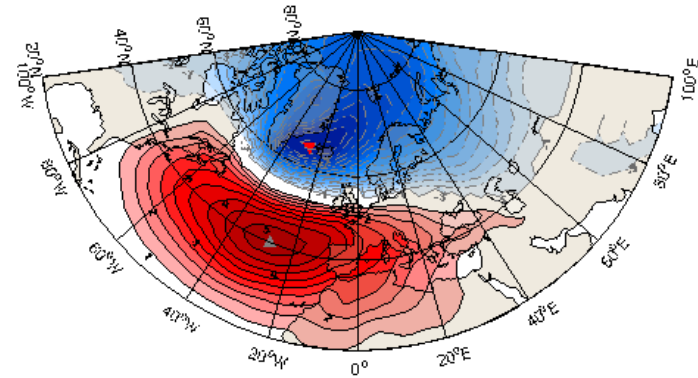
Motivation

Large-scale SLP variability

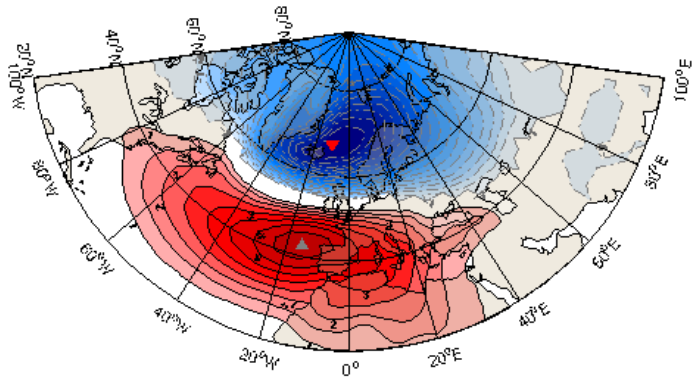
1st EOF of winter (DJFM) monthly mean SLP anomalies (NCEP/NCAR)



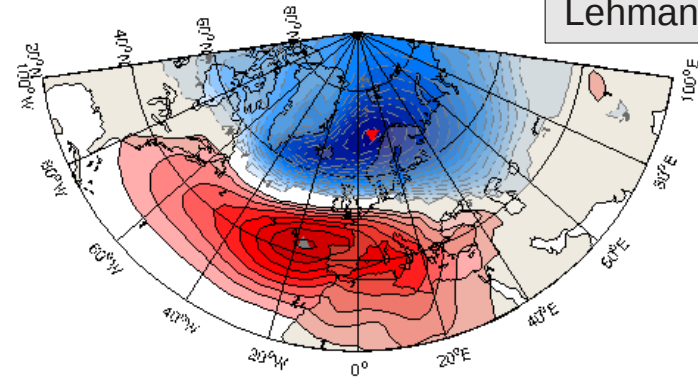
P1: 1958/59-1977/78 44.9%



P2: 1968/69-1987/88 47%



P3: 1978/79-1997/98 52.8%

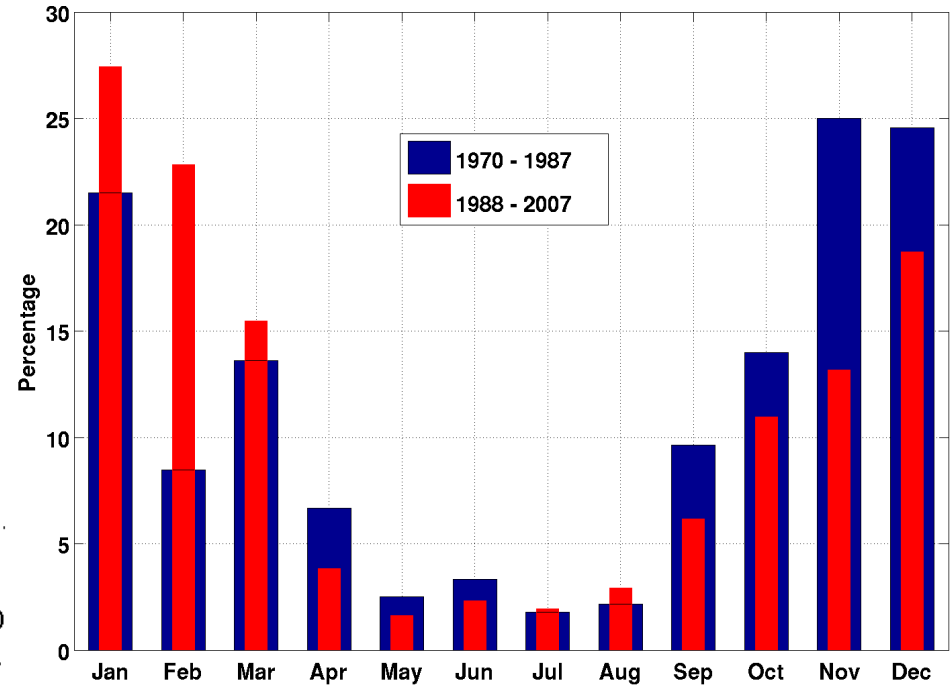
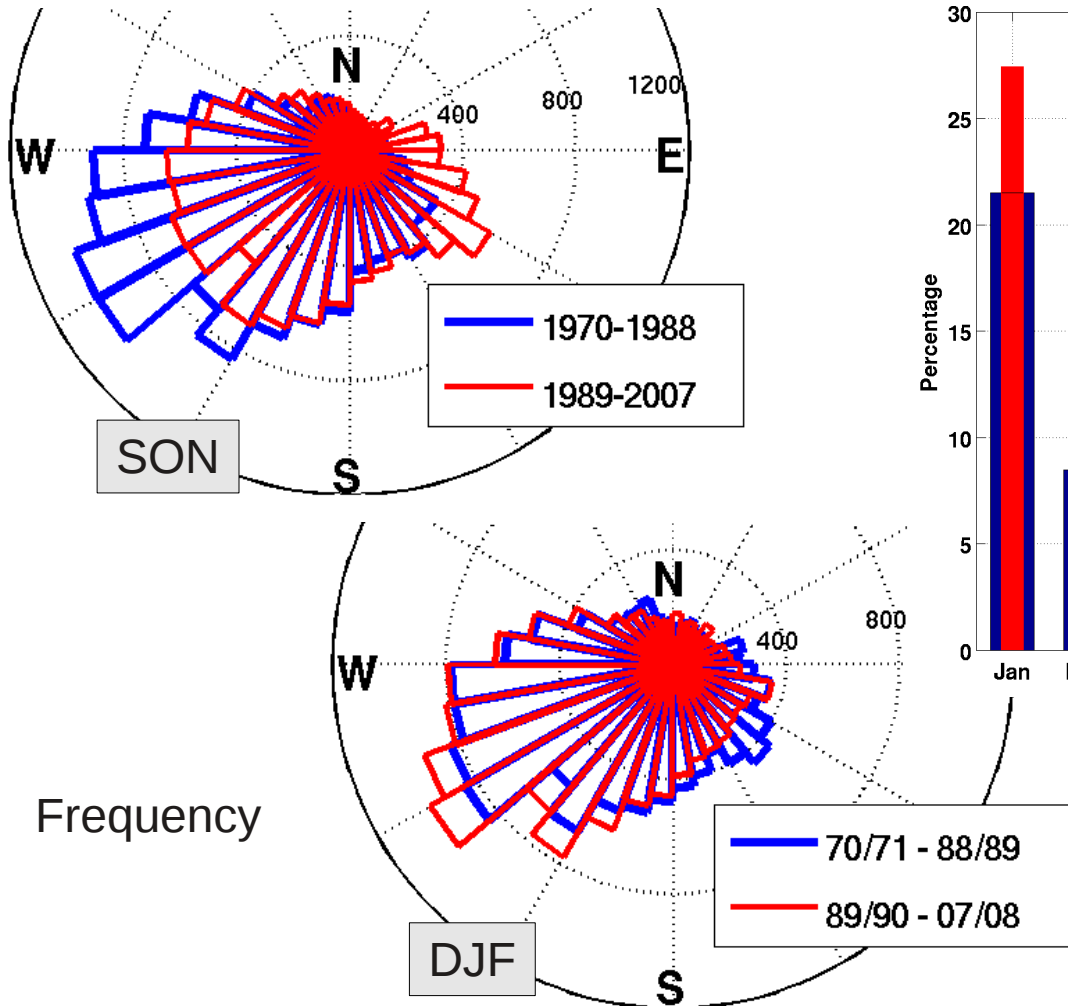


P4: 1988/89-2007/08 47.8%

Lehmann et al 2011

Motivation

Local decadal variability:
Lighthouse Kiel, 10 m-wind



Percentage of wind > 7 bft

Lehmann et al 2011

BACC 2008



Sea level variations...

Material & Methods

Material & Methods

Sea level data & Hydrodynamic model

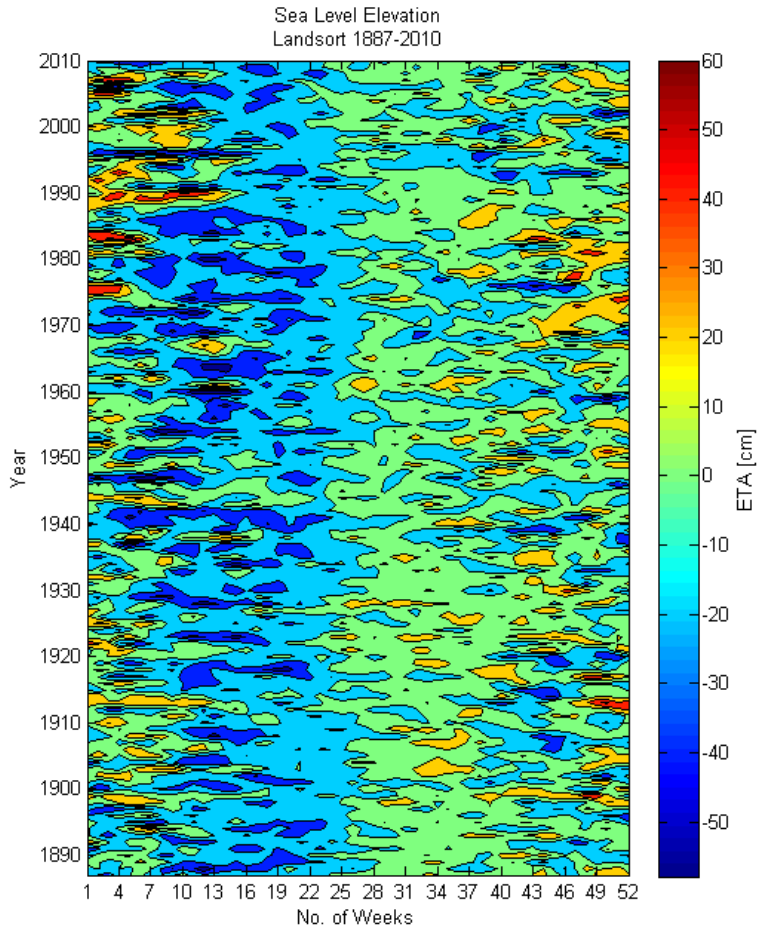
- PSMSL – Permanent Service for Mean Sea Level
 - ▶ Monthly mean sea level data
- SMHI & BSH
 - ▶ Hourly sea level data Landsort/Stockholm & German Baltic Sea coast
- BSIOM - 3D coupled sea ice-ocean model of the Baltic Sea (Lehmann & Hinrichsen 2000)
 - ▶ Horizontal resolution 2.5 km
 - ▶ 60 vertical levels
 - ▶ Model domain: Baltic Sea including Skagerrak & Kattegat
 - ▶ Forcing: river runoff (Kronsell & Andersson 2011), atmosphere SMHI Met data base (Lars Meuller pers. Comm.)
 - ▶ Western boundary condition: low-frequency SL-variations are prescribed from the BSI (Novotny et al. 2006)
 - ▶ Daily mean sea level data for the period 1970-2010
 - ▶ Correlation PSMSL data – BSIOM $r > 0.7$

Sea level variations...

Results

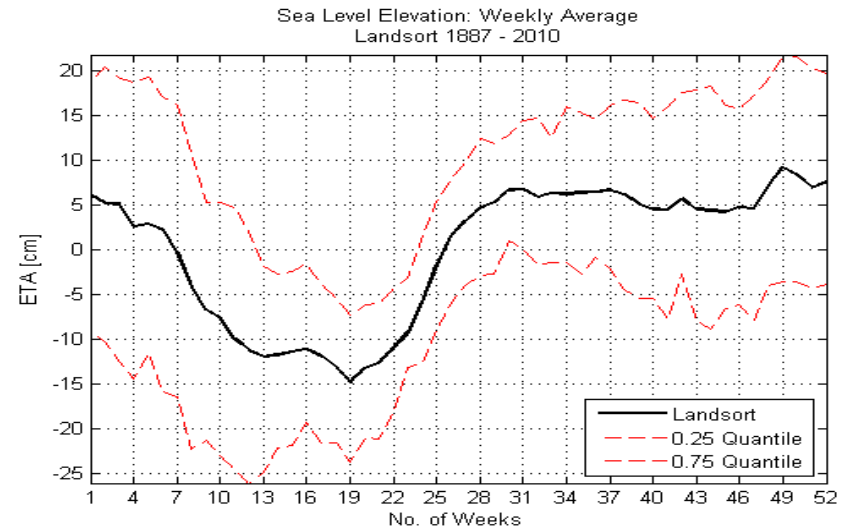
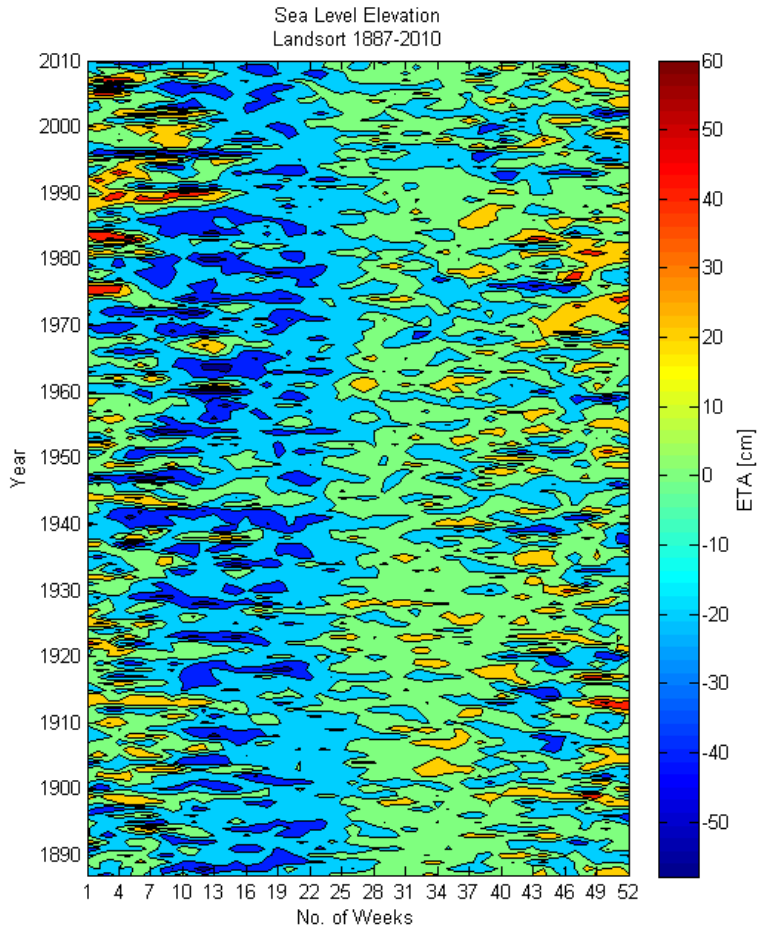
Results

Detrended SLE, Landsort 1887-2010, SMHI



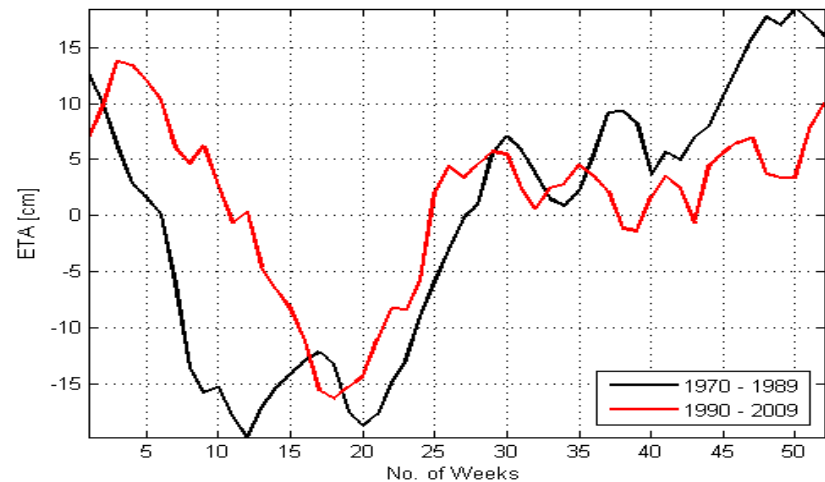
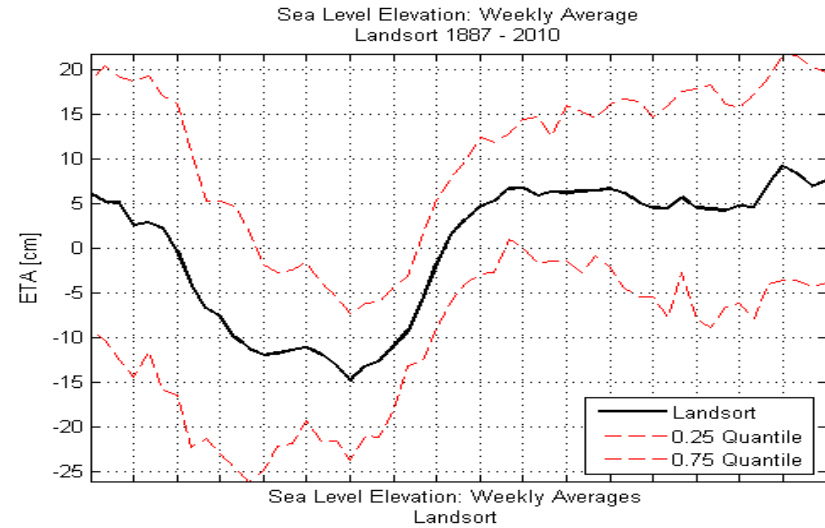
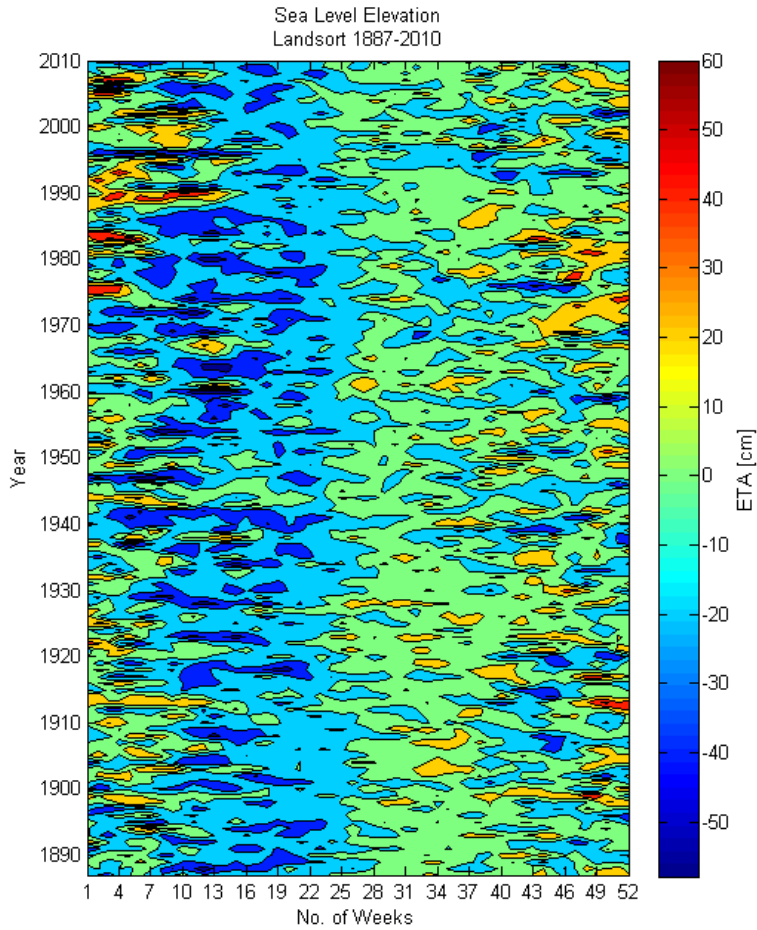
Results

Detrended SLE, Landsort 1887-2010, SMHI



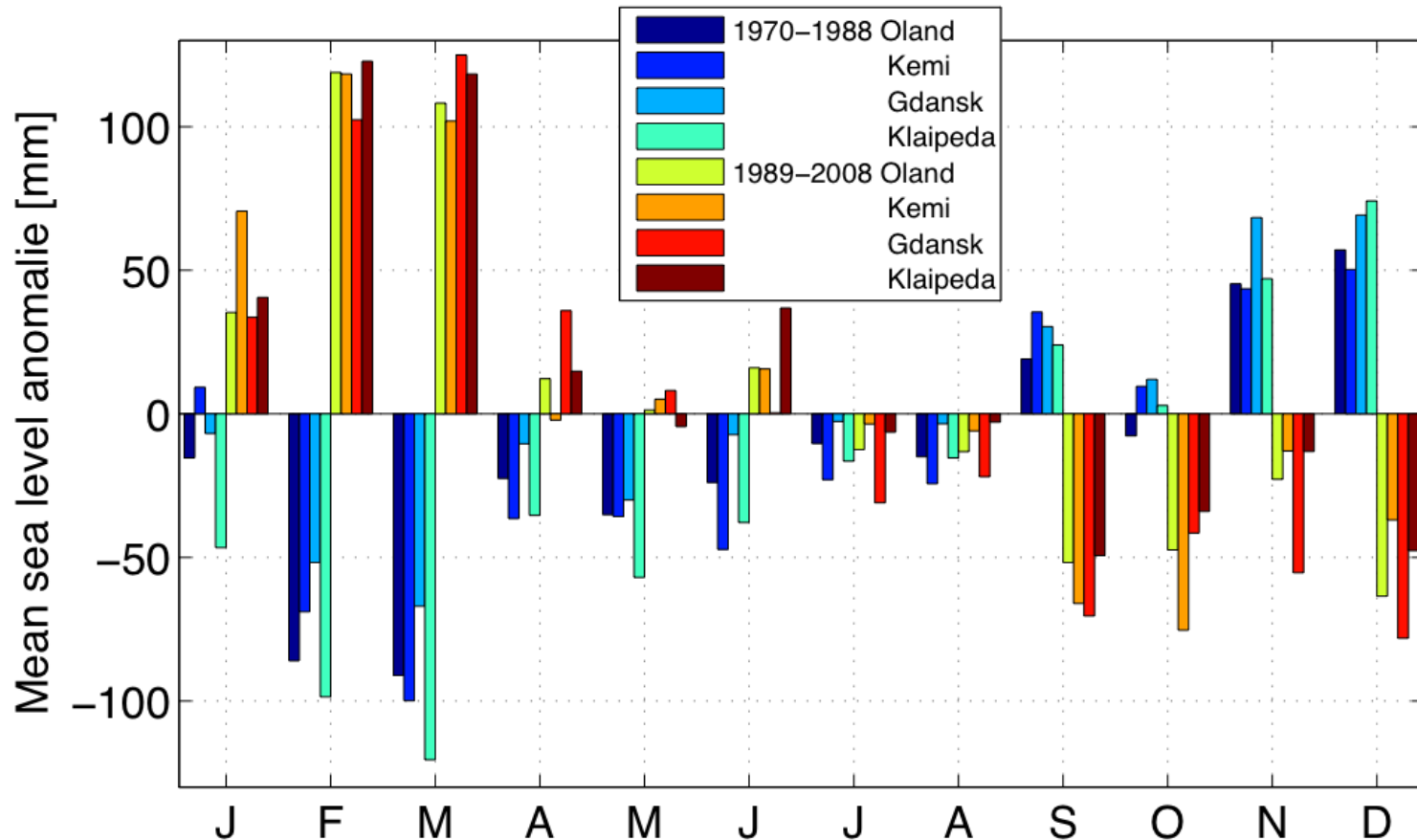
Results

Detrended SLE, Landsort 1887-2010, SMHI



Results

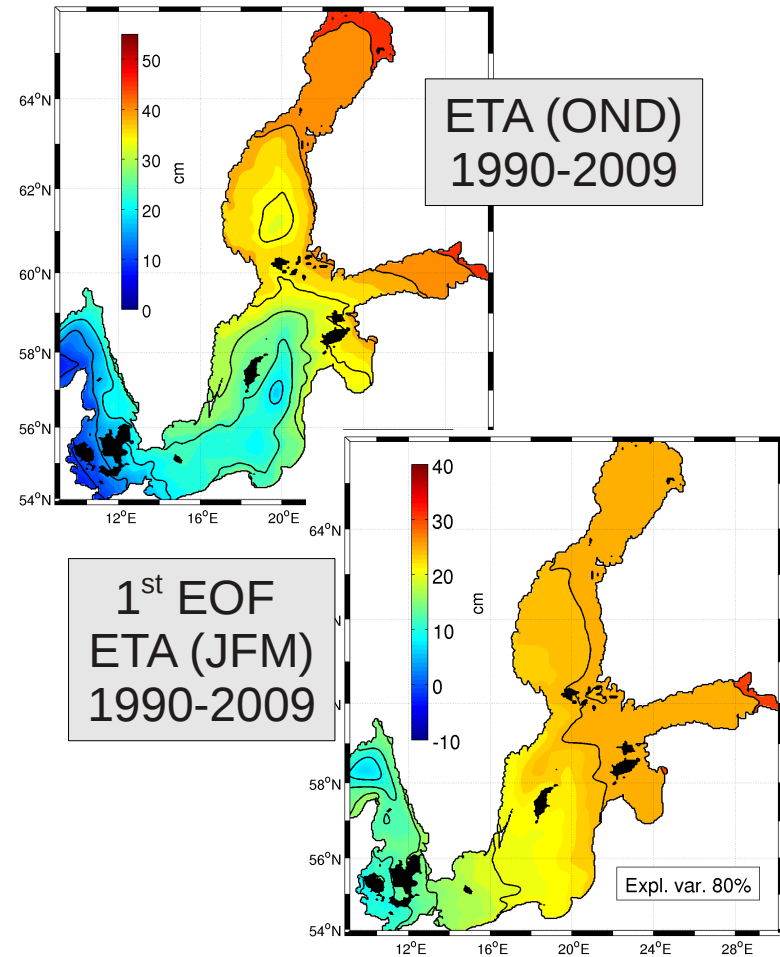
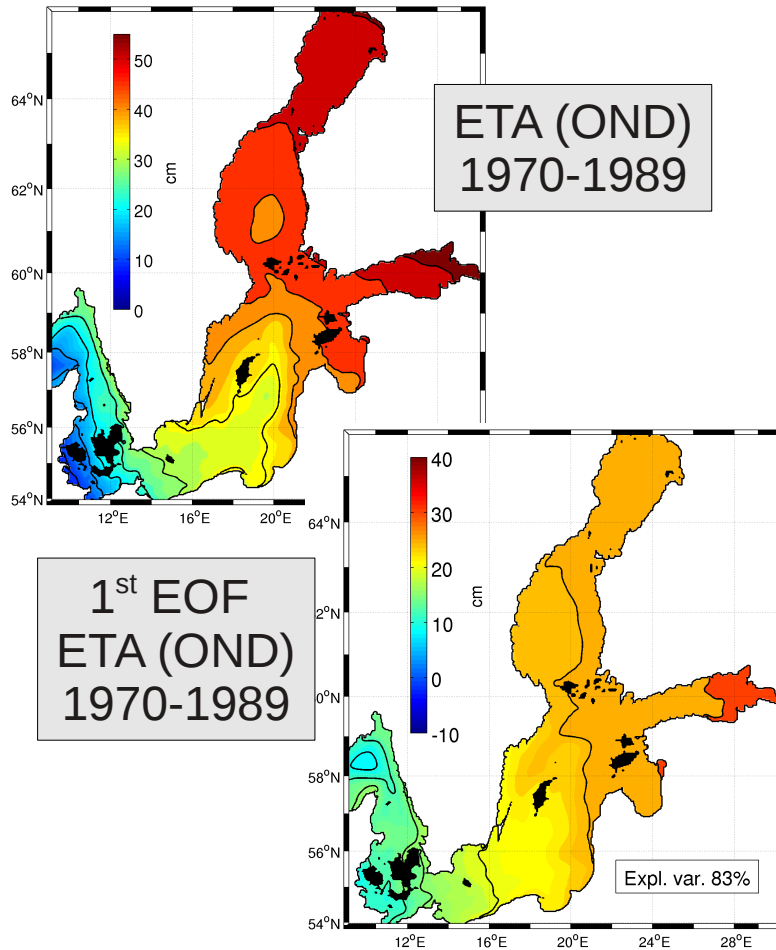
PSMSL detrended SSH anomalies



PSMSL detrended sea surface heigth anomalies

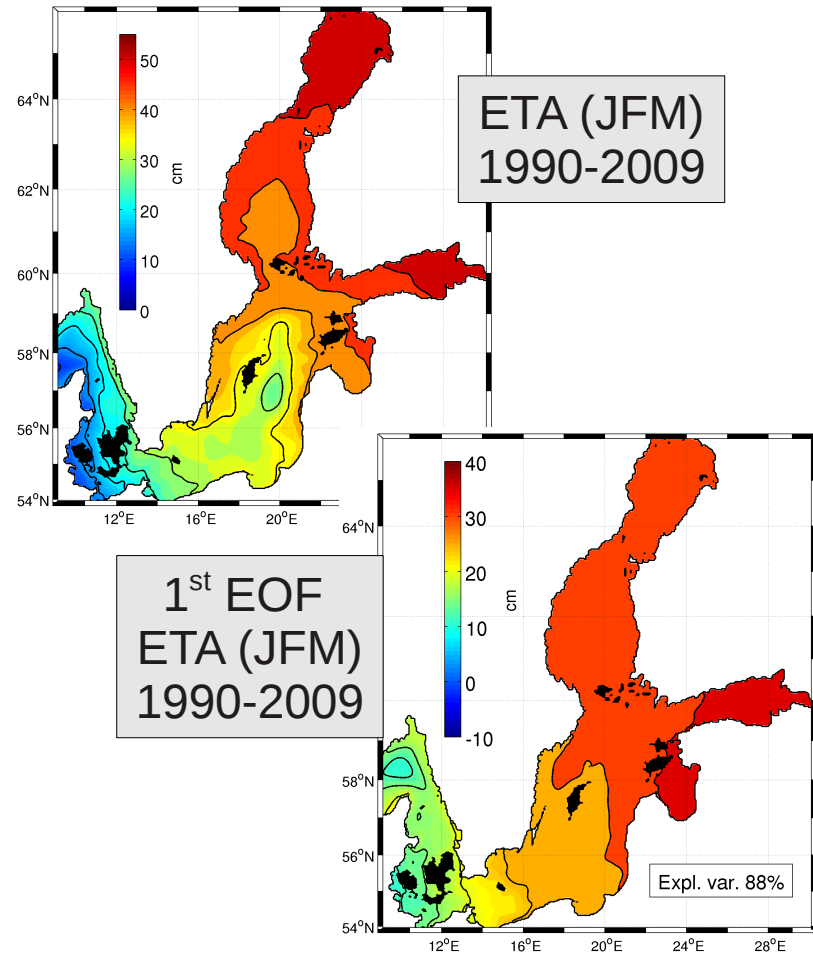
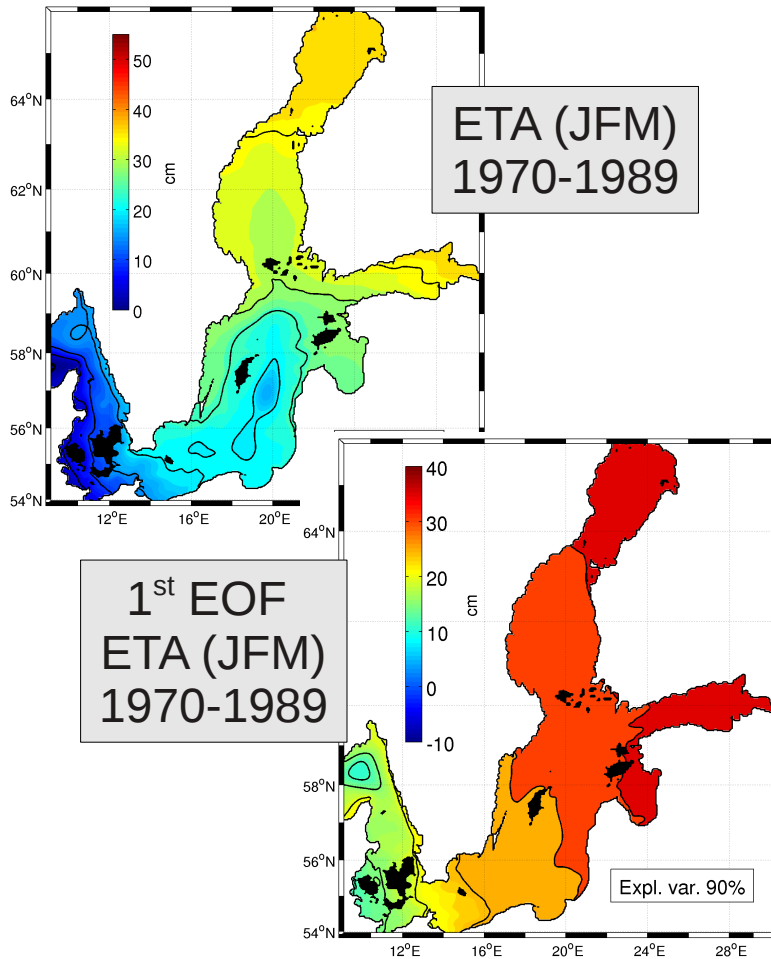
Results

Sea surface height (OND), BSIOM



Results

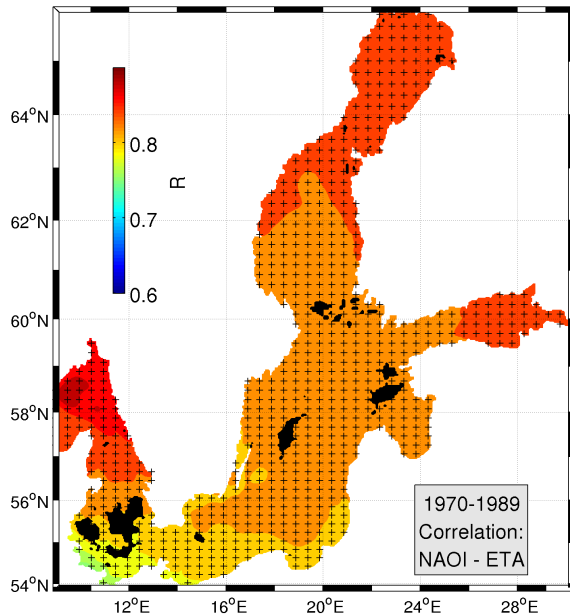
Sea surface height (JFM), BSIOM



Results

Correlation NAO-I – SSH (ETA) BSIOM

Correlation ETA / NAOI (DJFM mean) 1970-1989

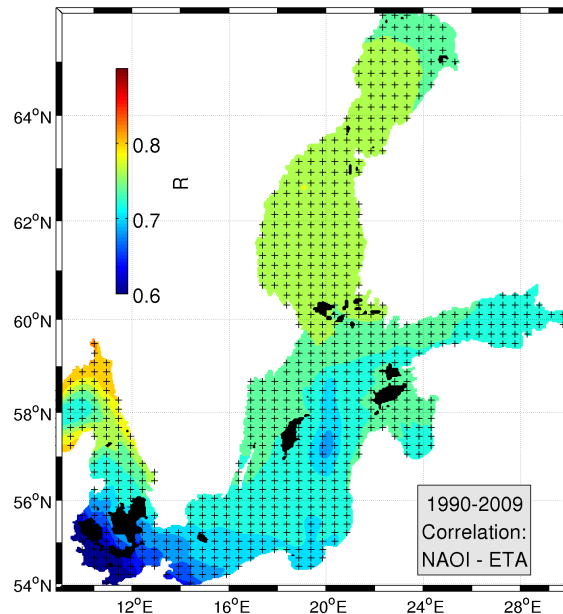


1970-1989
Correlation:
NAOI - ETA

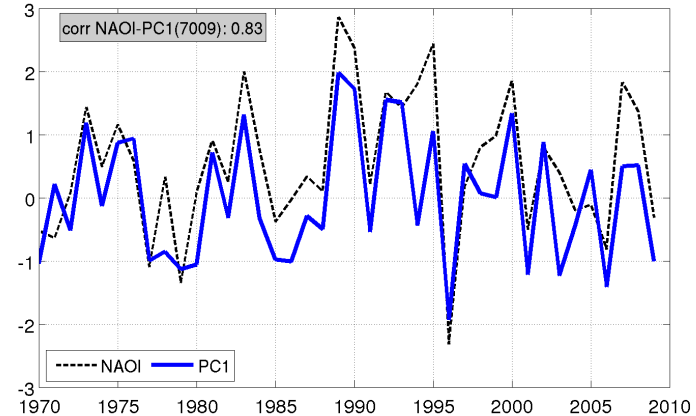
Correlation:
NAOI-ETA
1970-1989

Correlation:
NAOI-ETA
1990-2009

Correlation ETA / NAOI (DJFM mean) 1990-2009



1990-2009
Correlation:
NAOI - ETA



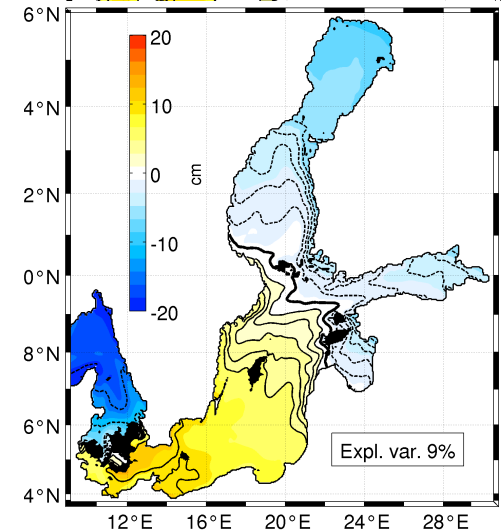
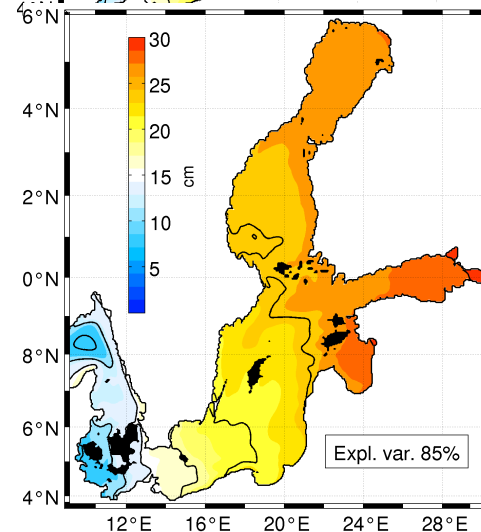
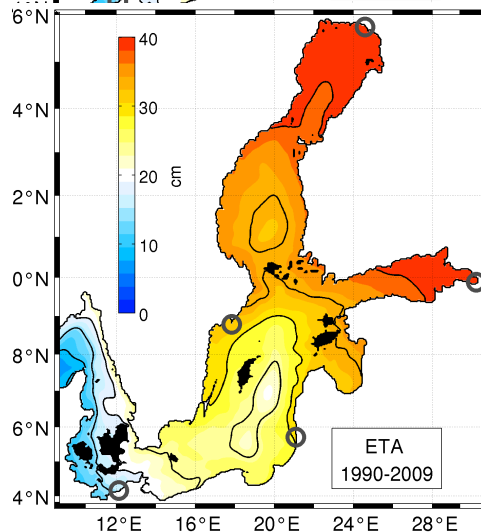
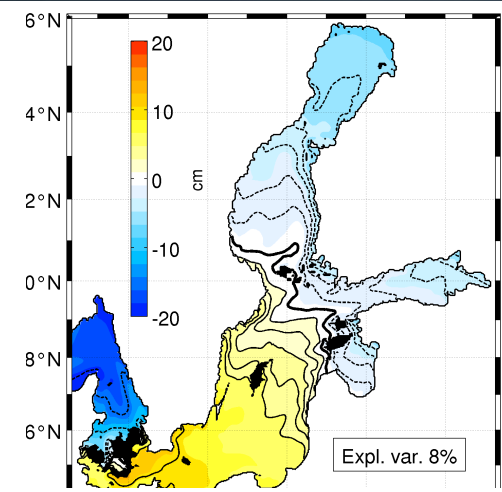
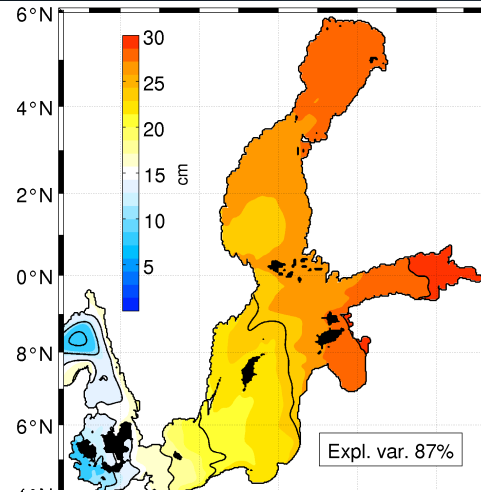
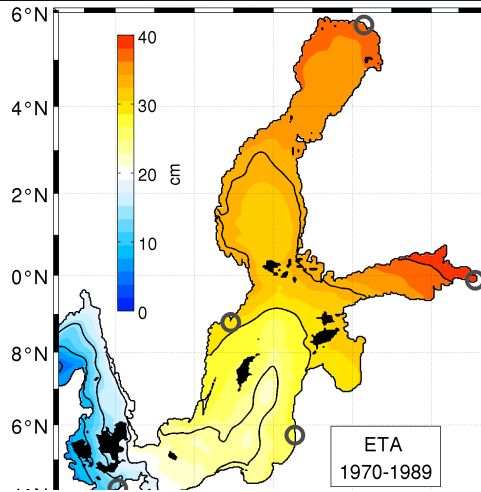
Correlation: NAOI-PC1
1970-2010

Similar results by
Hünicke 2008

Correlation with the BSI
shows similar structures
but higher correlations
coefficients

Results

BSIOM daily SSE 1970 – 2009



Correlation of EOF-Reconstructions and BSI (1970-1989, 1990-2009)

SSH-Station	BSI - RC1	BSI - RC2	BSI - RC1+2
Kemi	0.47/0.44	0.8/0.8	0.66/0.67
St. Petersb.	0.47/0.44	0.8/0.8	0.57/0.55
Landsort	0.47/0.44	-0.8/-0.8	0.35/0.31
Klaipeda	0.47/0.44	-0.8/-0.8	0.34/0.29
Warnemünde	0.47/0.44	-0.8/-0.8	0.02/-0.04

Sea level variations of the Baltic Sea in response to climate variability for the period 1970-2010

Conclusions

- Mean sea level decrease (~ 10 cm) in OND and increase in JFM on decadal time scales (1970-1988, 1989-2008)
- Global sea level rise since 1990 ~ 3 mm/year
- Baltic Sea level rise due to thermal expansion for $\Delta T \sim 1^\circ\text{C} \rightarrow 5 \text{ mm}$
- Baltic Sea level rise due to salt contraction for $\Delta S \sim 0.13 \text{ psu} \rightarrow 5 \text{ mm}$
- Baltic Sea level rise due to density changes for $\Delta \rho \sim 0.1 \text{ kg/m}^3 \rightarrow 5 \text{ mm}$ assuming a mean water depth of 50 m for the Baltic Sea
- With SST trend of $0.4^\circ\text{C}/\text{decade}$ the sea level rise due to thermal expansion \ll decadal sea level variations caused by changing wind conditions
- Changes in salinity of $\sim 1 \text{ psu}$ would contribute to 5 cm sea level rise, trend of $-0.12 \text{ psu}/\text{decade}$ (1970-2010)
- Changes in forcing conditions, storminess and wind direction contributed mainly to sea level changes in the Baltic Sea in the recent past
- Highest sea levels appear during inflow conditions i.e. increasing mean sea level with strong westerly winds \rightarrow risk of flooding

- **Low or less correlation of the sea levels in the western Baltic Sea with NAO/BSI compared to northern and eastern parts**
- **First PC is well correlated (+) with NAO/BSI**
- **Second PC is also well correlated (+/-) with NAO/BSI**
- **Combination of the 1st and 2nd reconstruction is highly correlated with the northern and eastern parts of the Baltic Sea, and less correlated with the southern and south-western parts**