2nd Baltic Earth Conference
The Baltic Sea Region in Transition
11-15 June 2018, Helsingør Denmark

Changing effect of large-scale atmospheric circulation on the regional climate variability of the Baltic Sea over the period 1948-2017

Andreas Lehmann*, Piia Post**, Katharina Höflich*

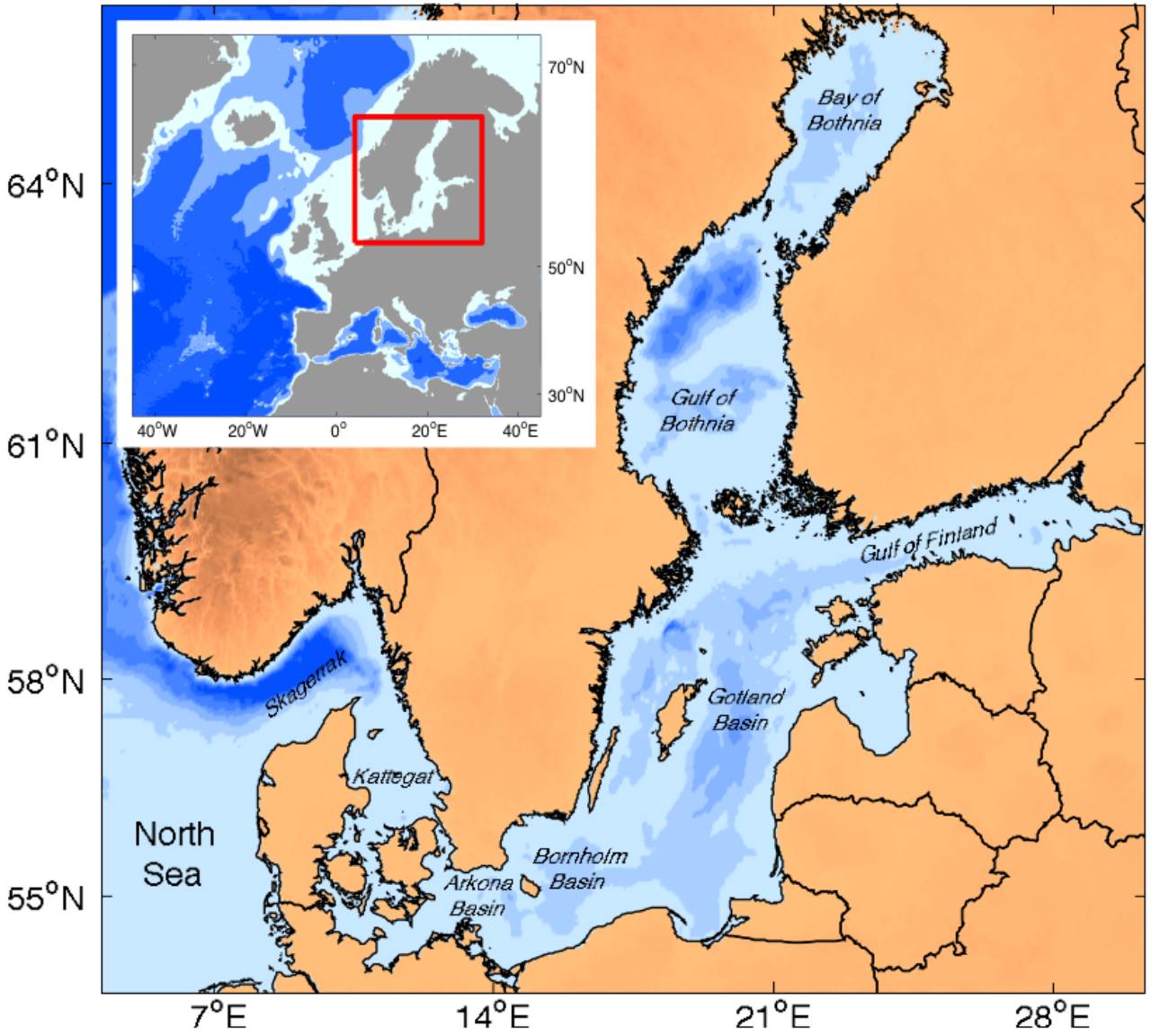
*GEOMAR Helmholtz Centre for Ocean Research Kiel, Germany
Institute of Physics University of Tartu, Estonia

Baltic Earth
Earth System Science for the Baltic Sea Region

1632 UNIVERSITY OF TARTU Institute of Physics

GEOMAR

Changing effect of large-scale atmospheric circulation on the regional climate variability of the Baltic Sea over the period 1948-2017



From large-scale atmospheric variability (North Atlantic sector)

to

Regional scale variability (Baltic Sea area, North Sea Norwegian Sea)

to

the Baltic Sea area

GEOMAR

Motivation

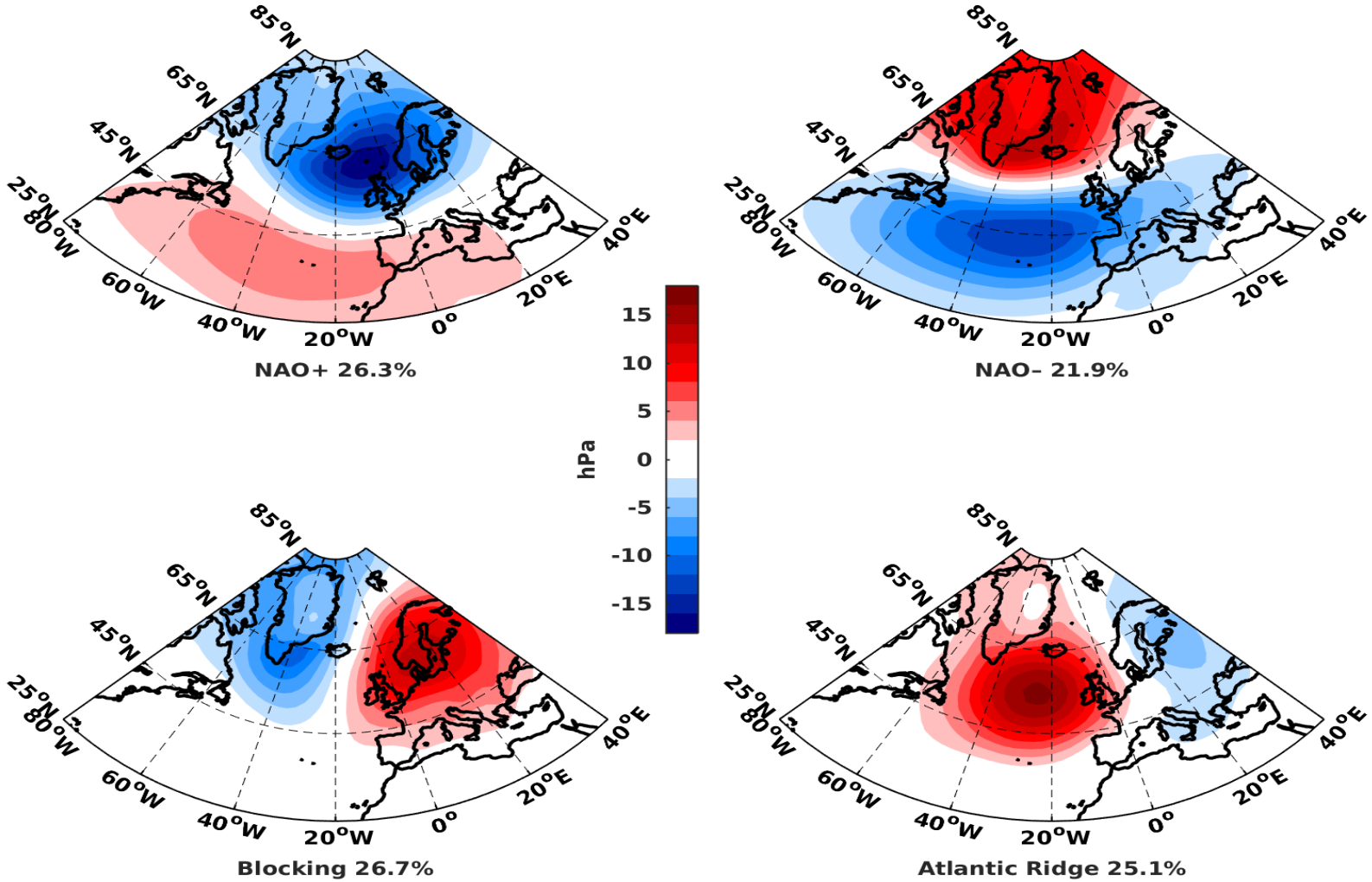
- Lehmann et al. 2011: Detailed assessment of climate variability in the Baltic Sea area for the period 1958 to 2009.
  - What happened to the eastward shift of the NAO centers of action?
  - Update of the analysis because of the availability of new data until 2017/2018

Data & Methods

- Sea level pressure data (NCEP/NCAR reanalysis 1948-2018, Kalnay et al. 1996)
  - 6 hourly, 2.5° horizontal resolution
  - 1948-2018 (-March)
  - Cluster analysis (Cassou et al. 2004; Hurrell and Deser 2009, Lehmann et al. 2011)
  - Empircal orthogonal function (EOF) analysis (Lehmann et al. 2011)
  - Deep cyclones (Lehmann et al. 2011)

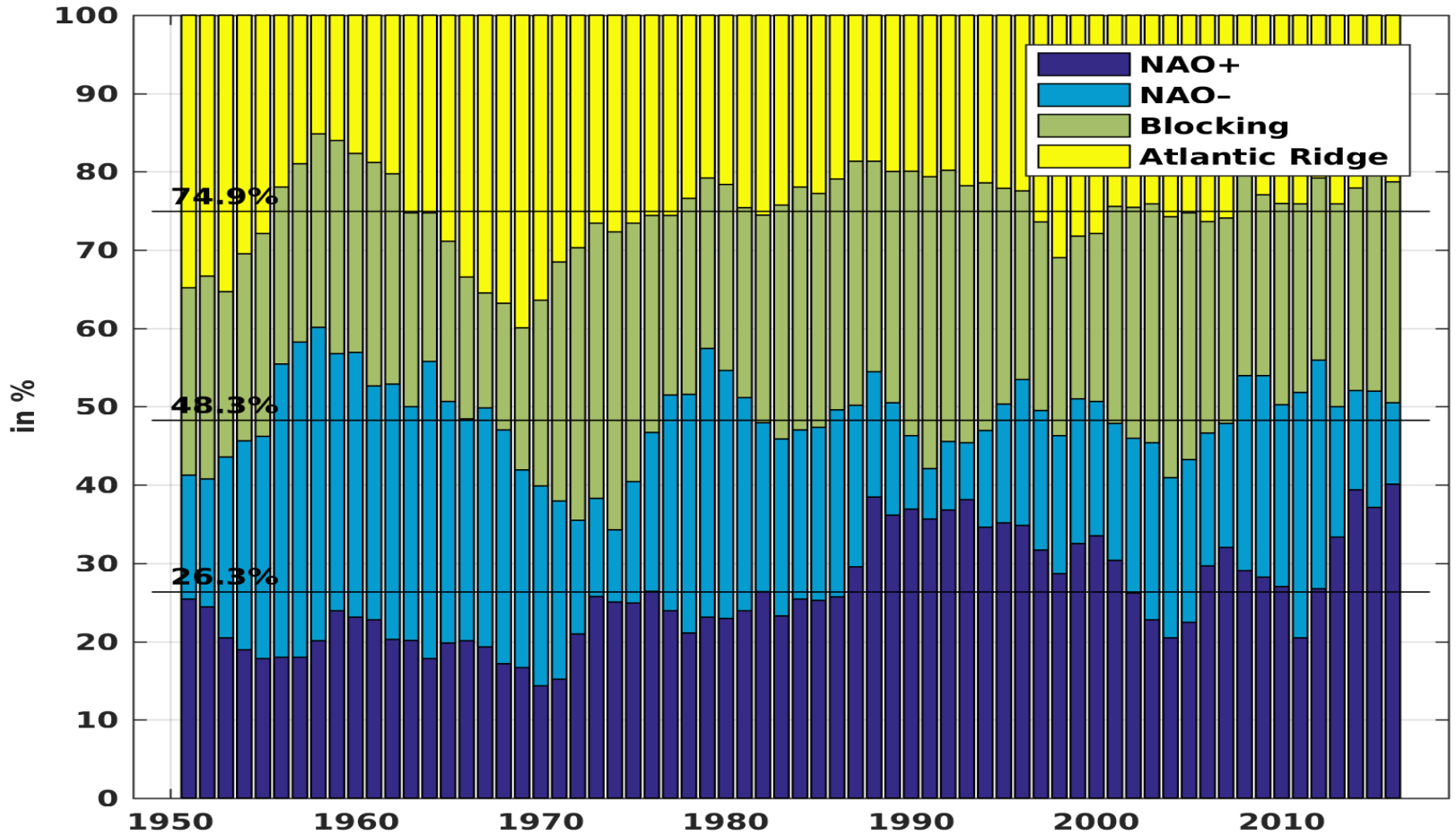
- 10 m wind (wind forcing of BSIOM - 3D coupled sea ice-ocean model of the Baltic Sea (Lehmann et al. 2014) based on sea level pressure data ERA-Interim reanalysis 1979-2017, Dee et al. 2011)
  - 3 hourly, horizontal resolution 2.5 km
  - 1979-2017

Large scale atmospheric variability
Cluster analysis (Hurrell & Deser 2009)



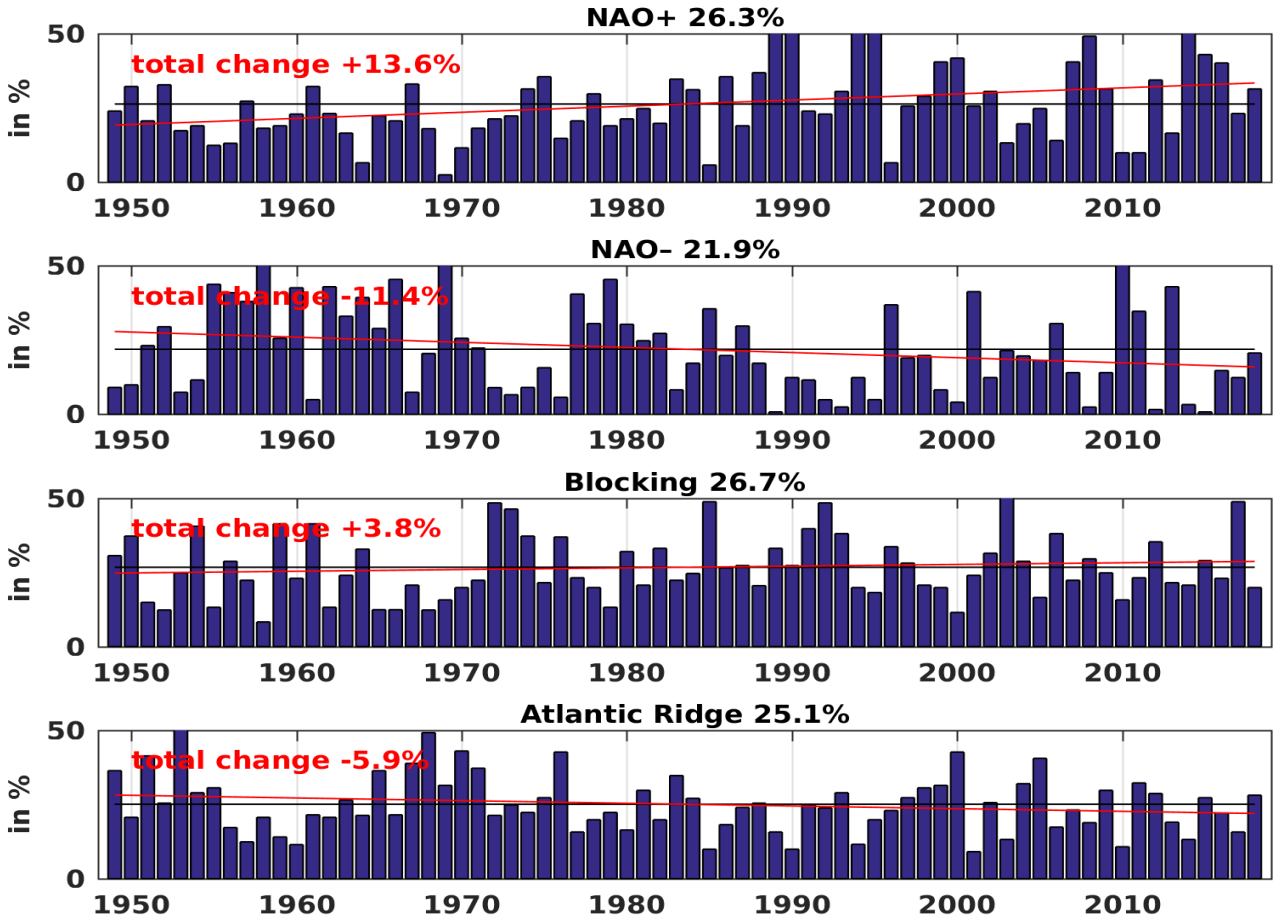
Winter (DJFM) climate regimes in SLP, NCEP-NCAR reanalysis data 1950-2017

Large scale atmospheric variability
Cluster analysis



Time history of daily occurrences of winter (DJFM) climate regimes (5year running mean), based NCEP-NCAR reanalysis SLP data 1950-2017

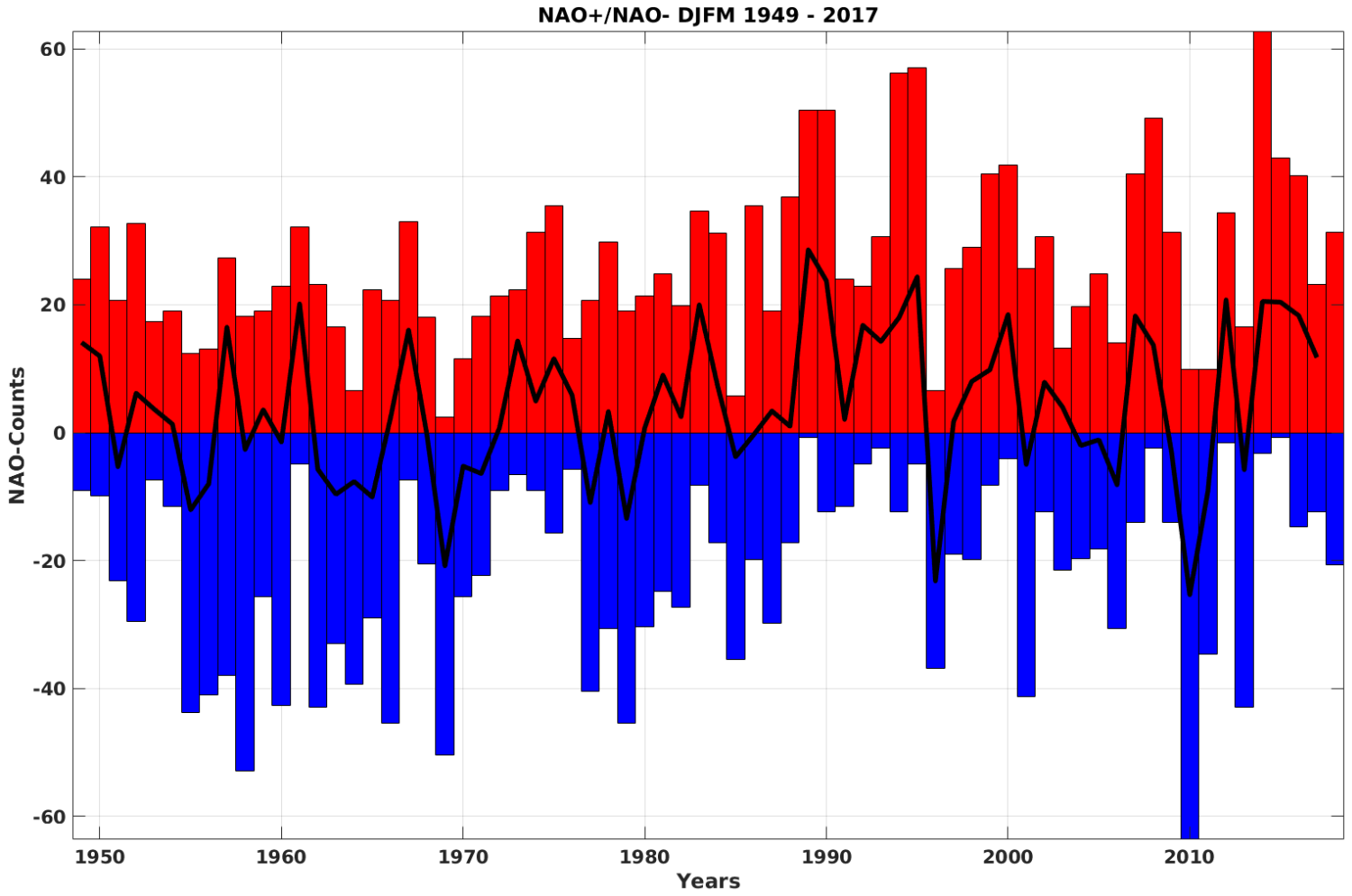
Large scale atmospheric variability
Cluster analysis



Time history of daily occurrences of winter DJFM climate regimes

Large scale atmospheric variability

Cluster analysis NAO+/NAO- and NAO-I winter index DJFM



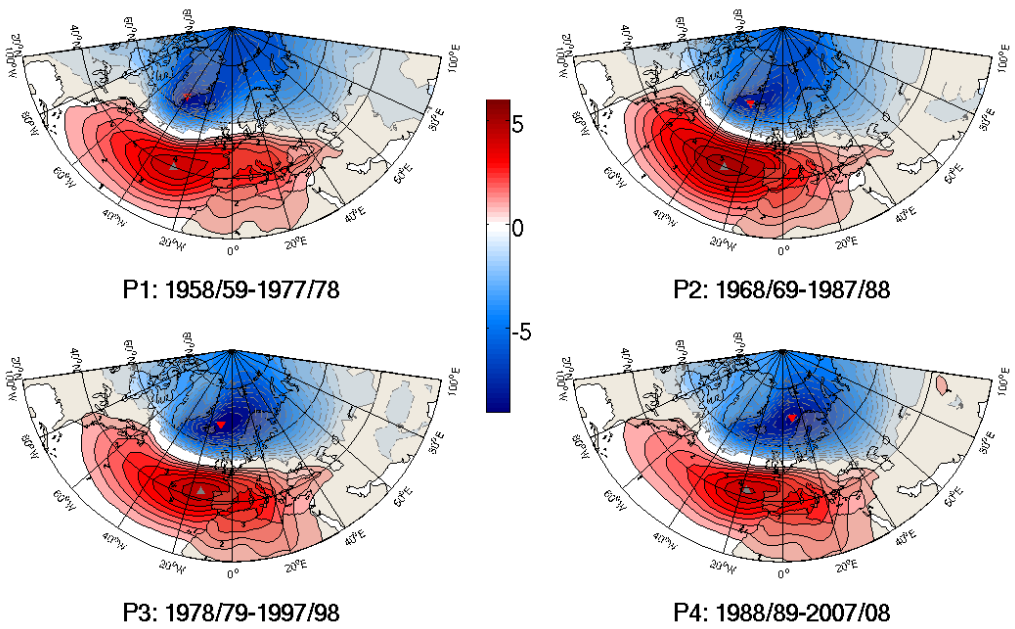
NAO-I*10 updated from Jones et al. 1997

Time history of NAO^+ (red) NAO^- (blue) winter NAO-I (black) DJFM (1949-2017)

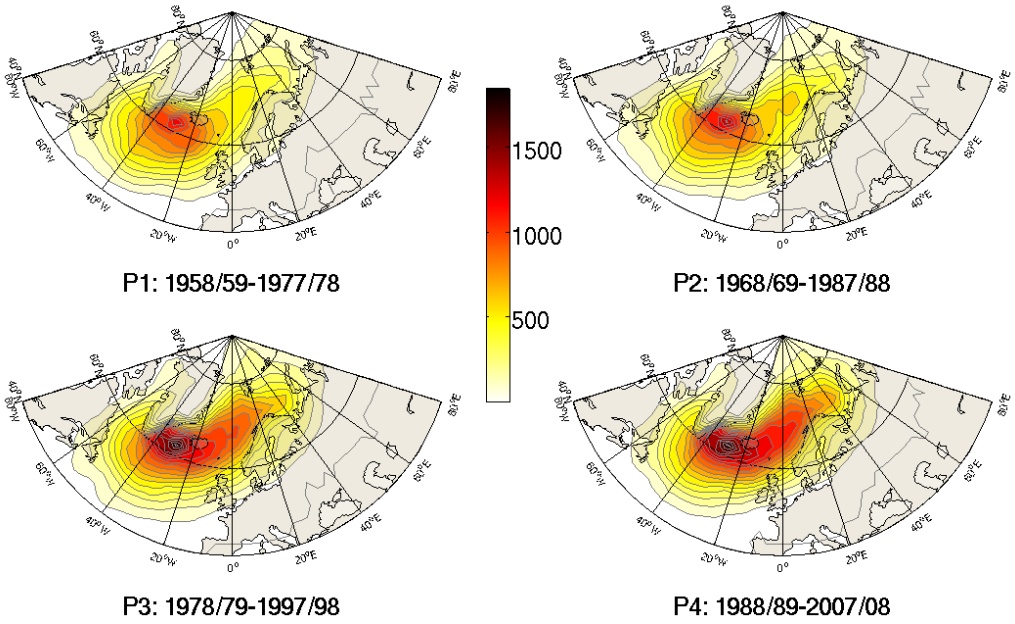
Large scale atmospheric variability
Lehmann et al. 2011

GEOMAR

Shift of NAO pattern to the east



Change of deep cyclones pathways



Lehmann et al. 2011

First EOF DJFM-averaged SLP-anomalies, NCEP-NCAR reanalysis data 1958-2008

Total number of (DJFM) deep cyclones < 980 hPa, NCEP-NCAR reanalysis data 1958-2008

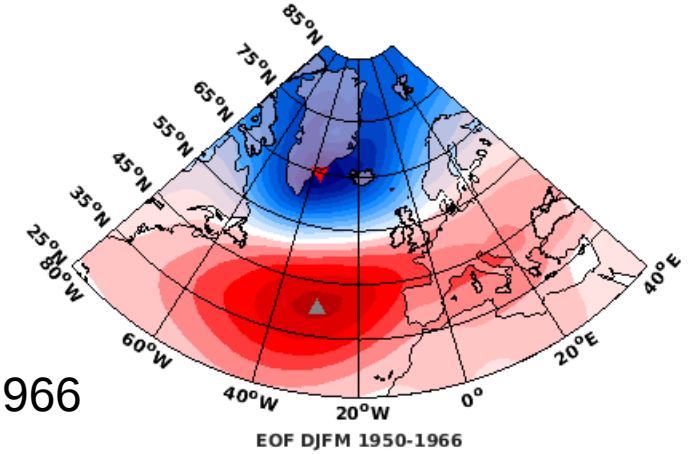
HELMHOLTZ ASSOCIATION

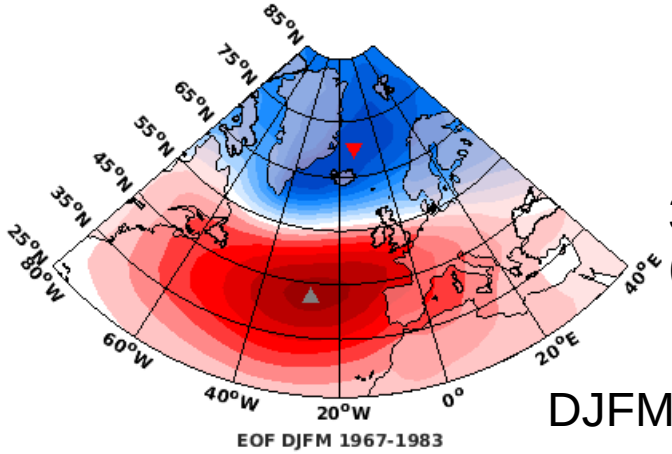
Large scale atmospheric variability
Shift of NAO pattern 1950 - 2017

GEOMAR

Expl. Var.
36.5%
(19.8%)

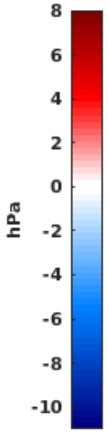
DJFM 1950-1966





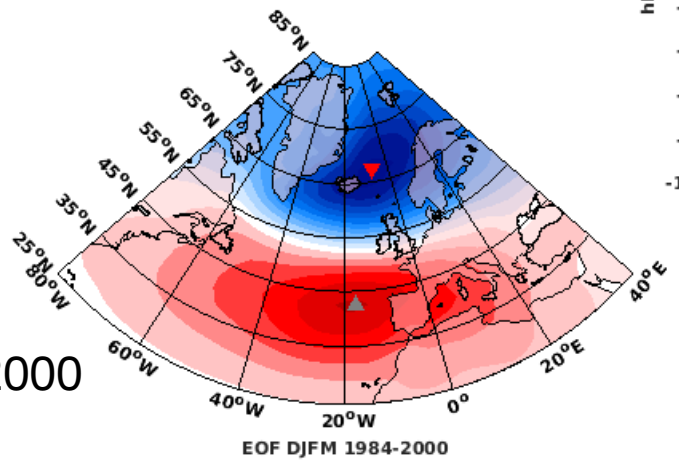
35.5%
(25.4%)

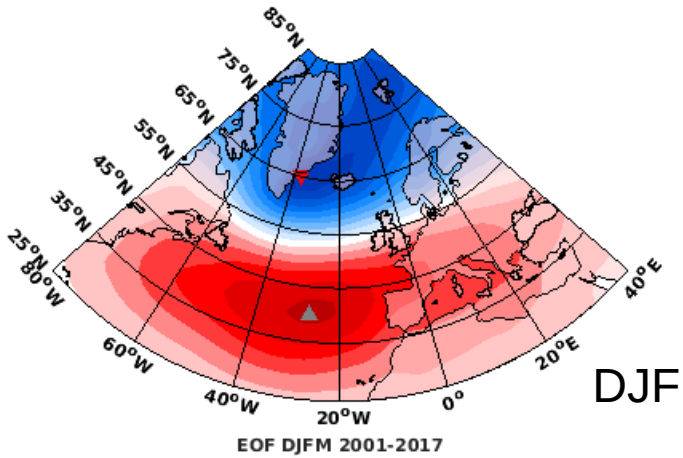
DJFM 1967-1983



43.6%
(16.6%)

DJFM 1984-2000





43.0%
(17.3%)

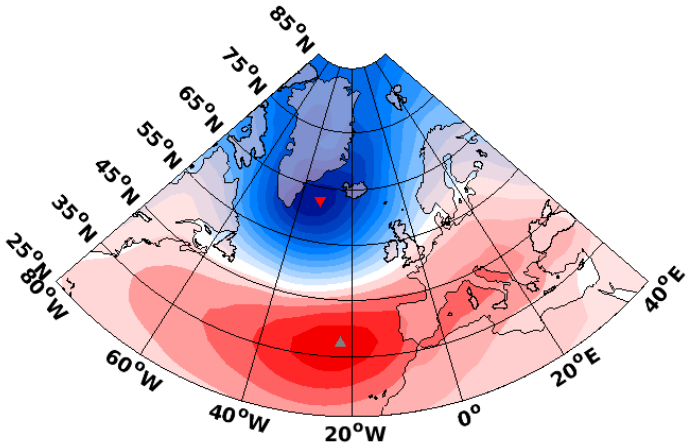
DJFM 2001-2017

First EOF DJFM-averaged SLP-anomalies, NCEP/NCAR reanalysis data 1950-2017

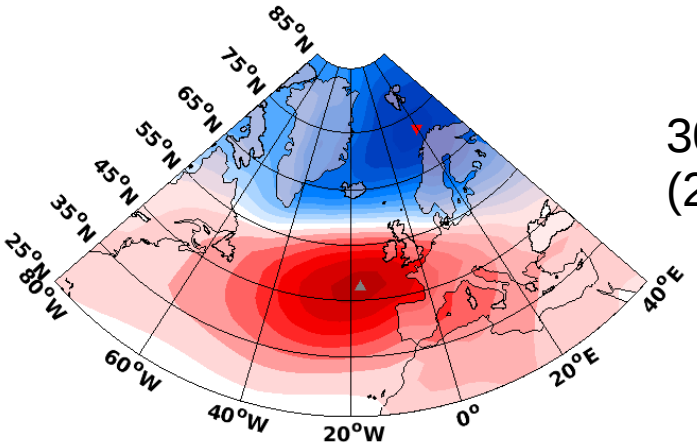
HELMHOLTZ ASSOCIATION

Large scale atmospheric variability
First EOF of NAO$^+$ and NAO$^-$ conditions

Expl. Var.
31.3%
(21.4%)

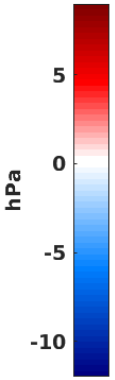


DJFM NAOI ≤ -0.75 (12)

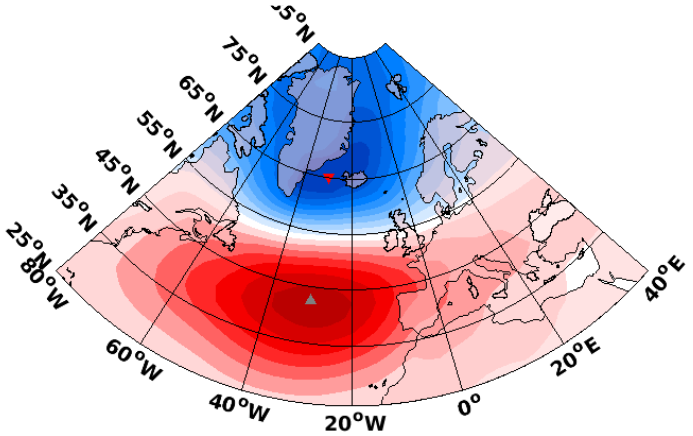


30.6%
(24.0%)

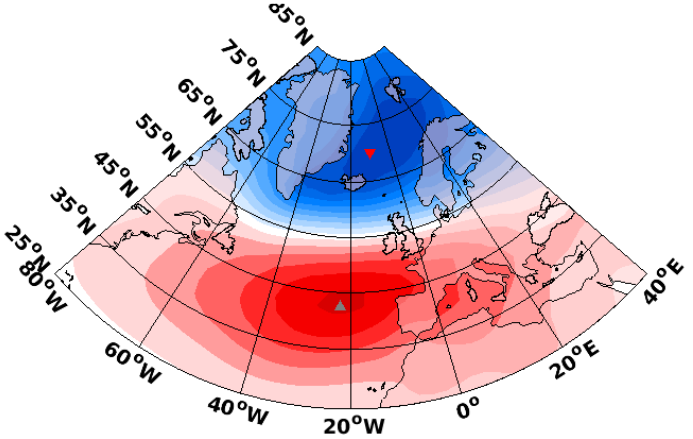
DJFM NAOI ≥ 1.5 (15)



35.6%
(20.2%)



DJFM NAOI < 0 (26)



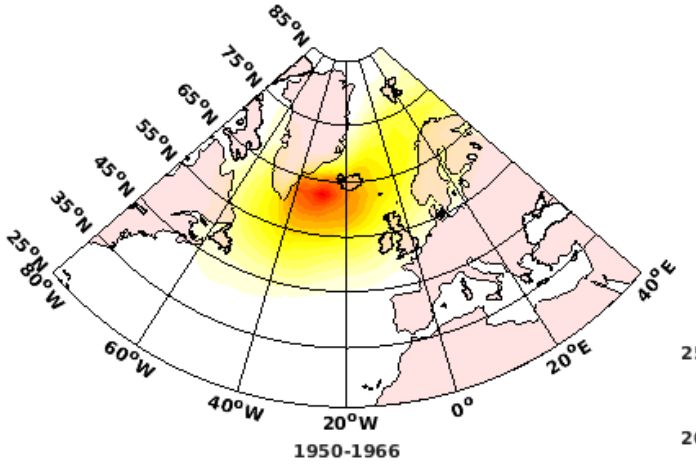
32.8%
(19.2%)

DJFM NAOI > 0 (12)

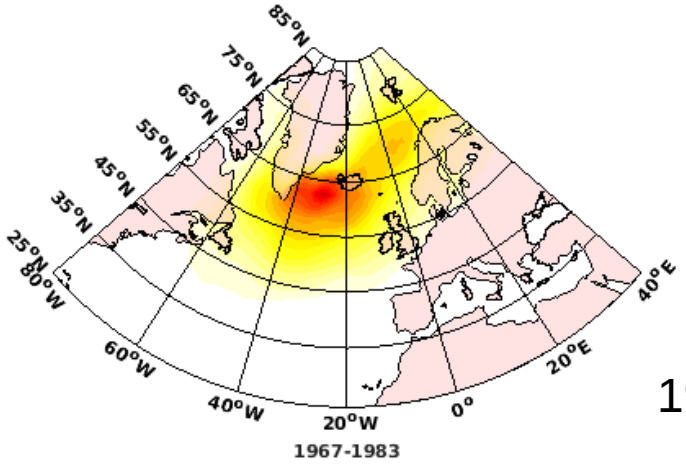
First EOF DJFM-averaged SLP-anomalies, NCEP/NCAR reanalysis data 1950-2017

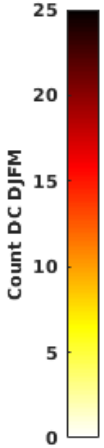
Large scale atmospheric variability
Deep cyclone counts 1950 - 2017

1950-1966

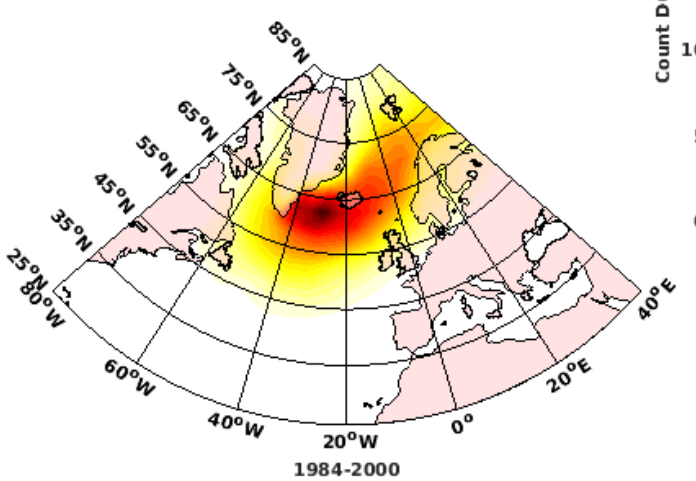


1967-1983

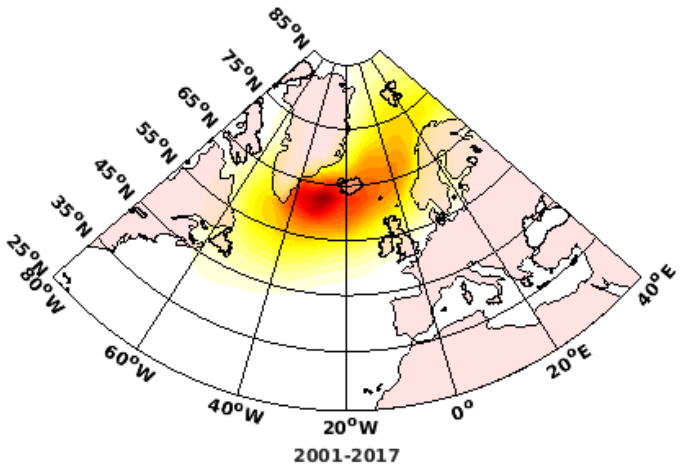




1984-2000

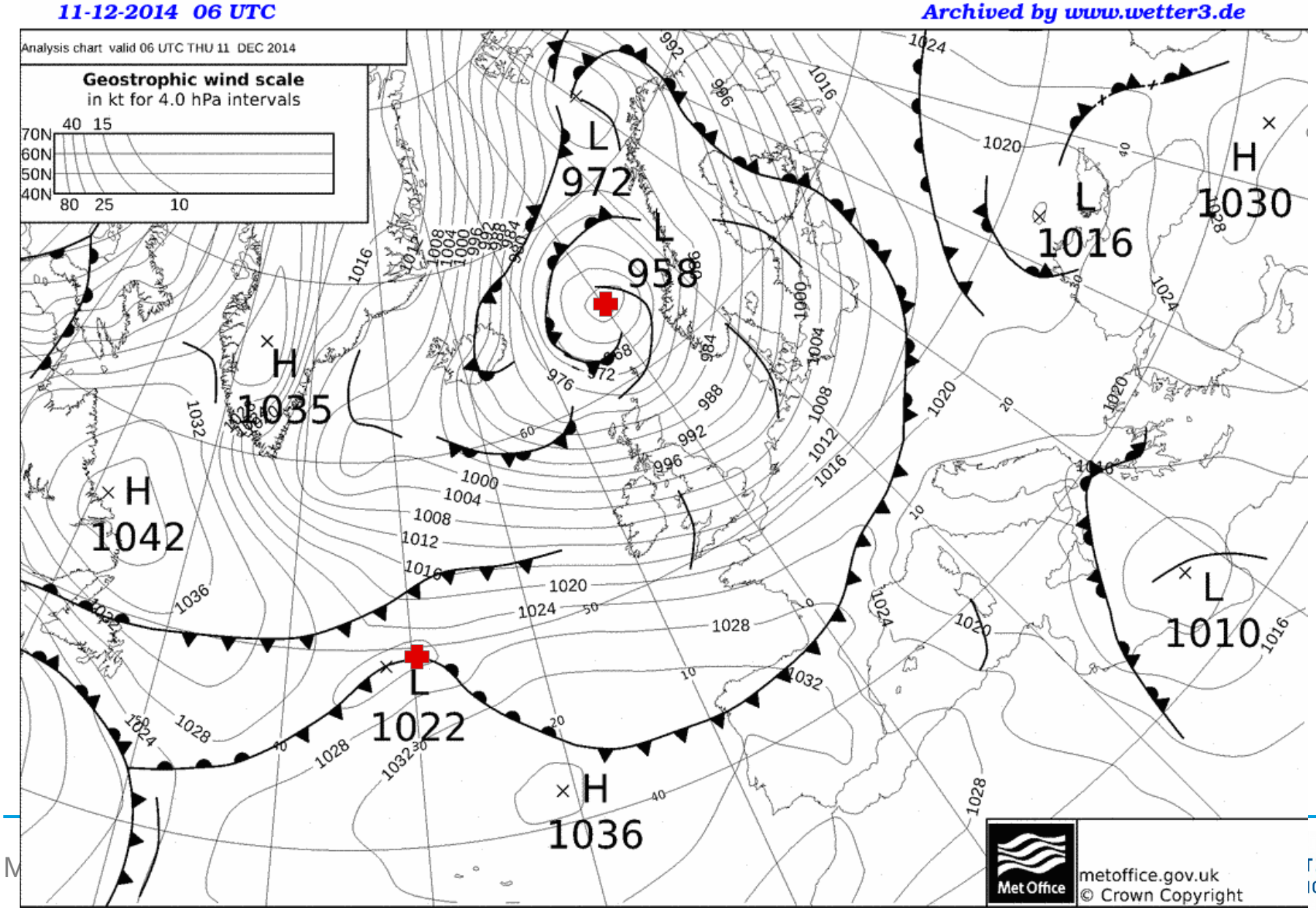


2001-2017

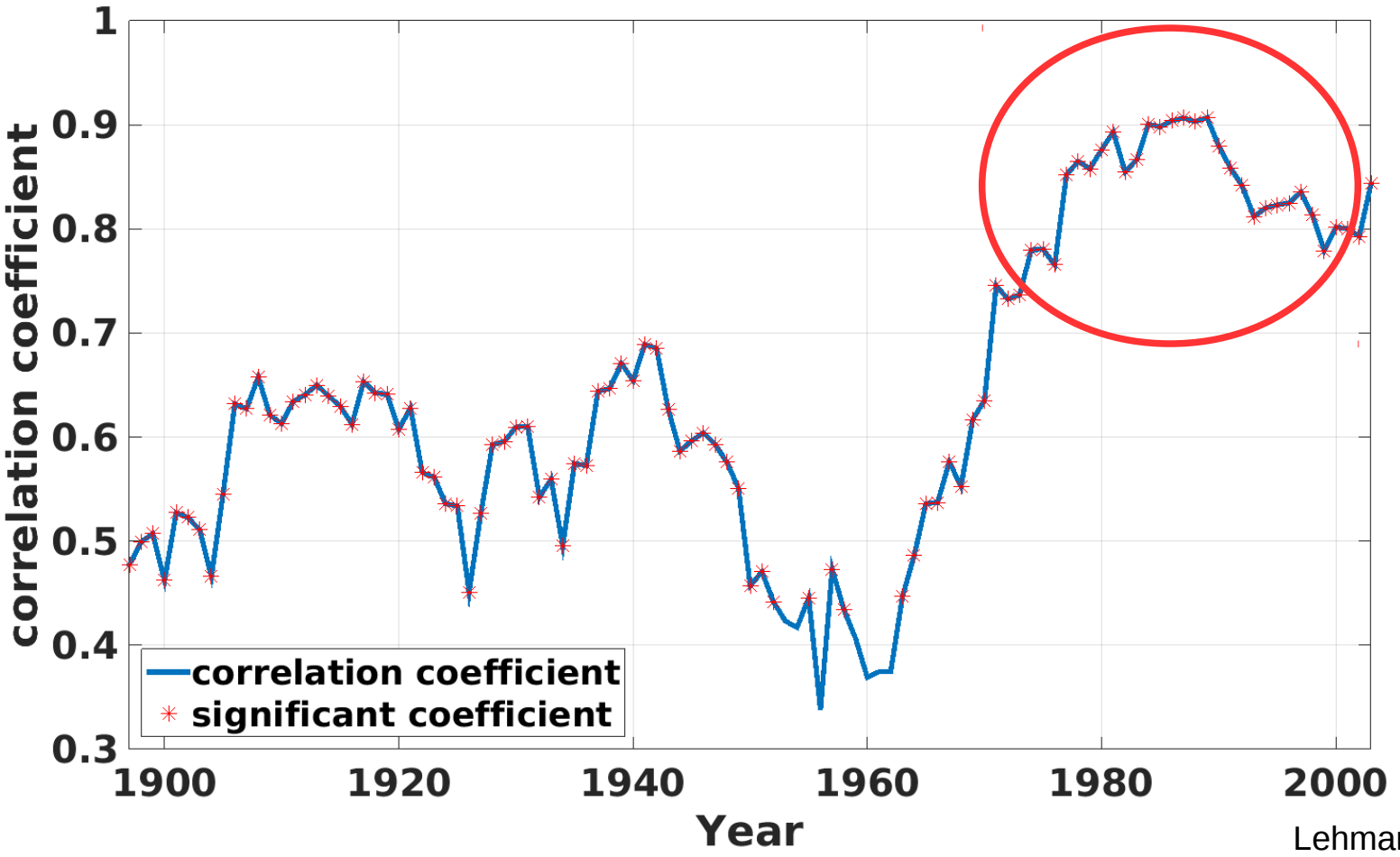


Deep cyclone counts DJFM (SLP < 980 hPa), NCEP-NCAR reanalysis data 1950-2017

Deep cyclones SLP < 980 hPa areal extension



Correlation Baltic Sea mean sea level (Landsort) and NAO (DJFM)

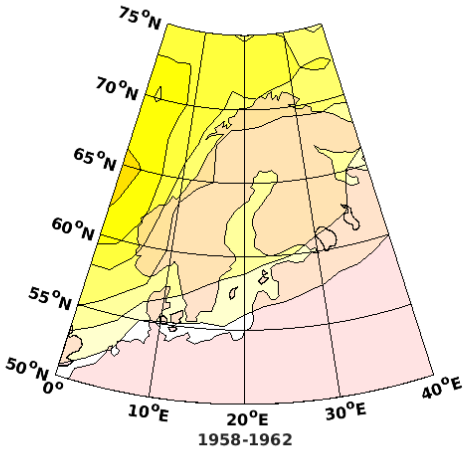


Lehmann et al. 2017

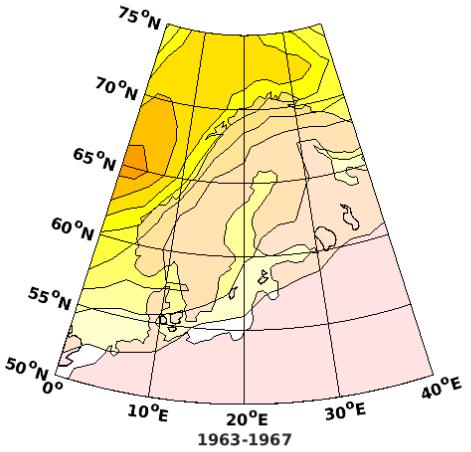
Running correlation (20-year window) NAO (DJFM) – Landsort SSE

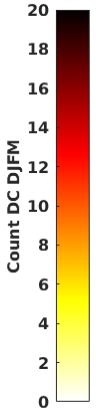
Regional-scale atmospheric variability
Deep cyclone counts 1958 - 1977

1958-1962

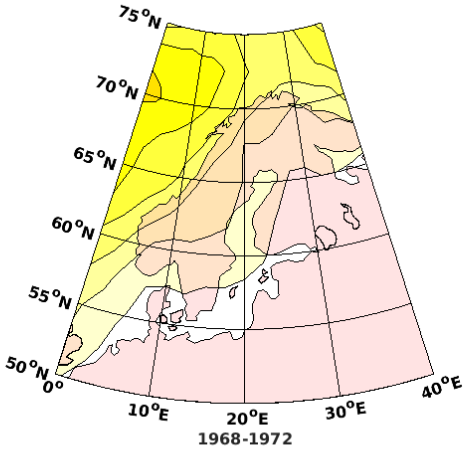


1963-1967

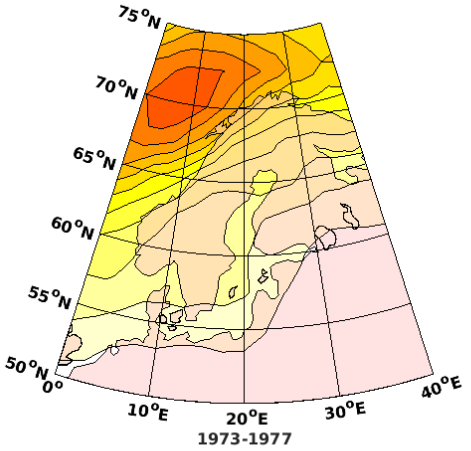




1968-1972



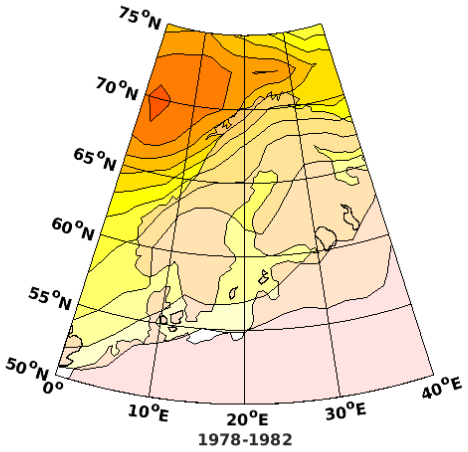
1973-1977

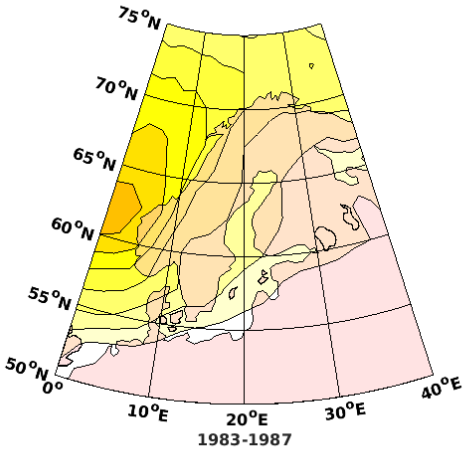


Deep cyclone counts DJFM (SLP < 980 hPa), NCEP/NCAR reanalysis data 1958-1977

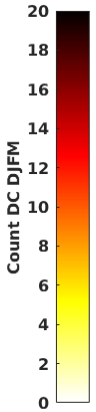
Regional-scale atmospheric variability
Deep cyclone counts 1978 - 1997

1978-1982

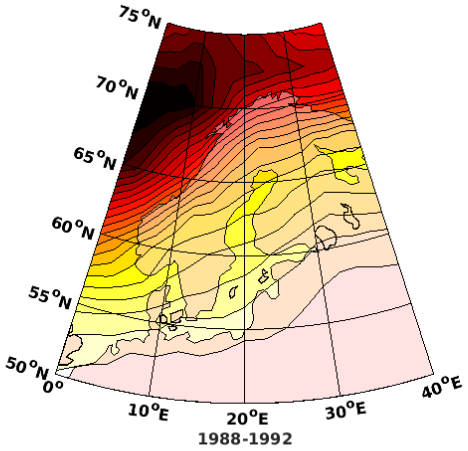


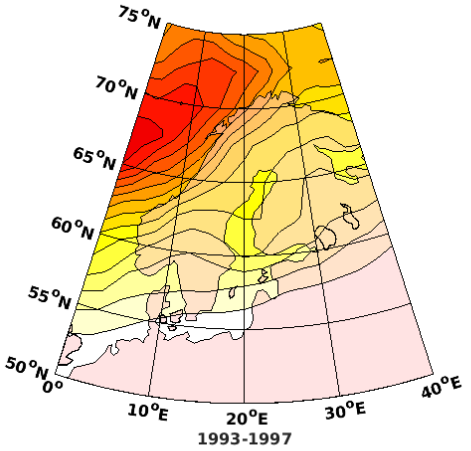


1993-1997



1988-1992



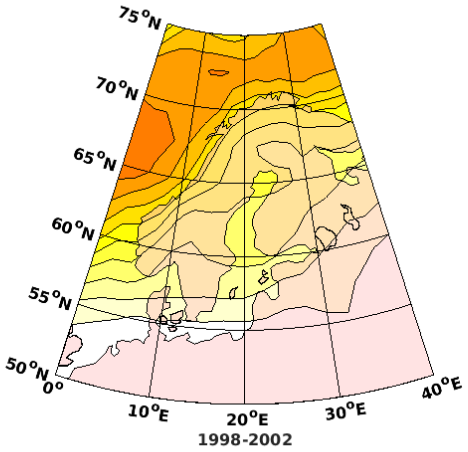


1993-1997

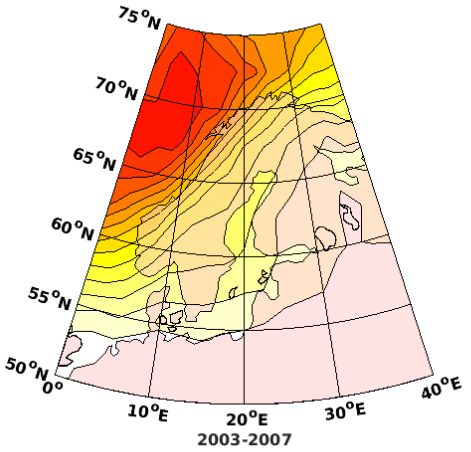
Deep cyclone counts DJFM (SLP < 980 hPa), NCEP/NCAR reanalysis data 1978-1997

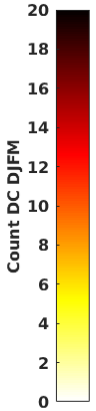
Regional-scale atmospheric variability
Deep cyclone counts 1998 - 2017

1988-2002

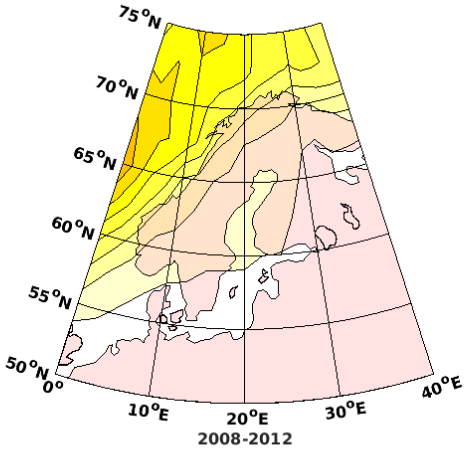


2003-2007

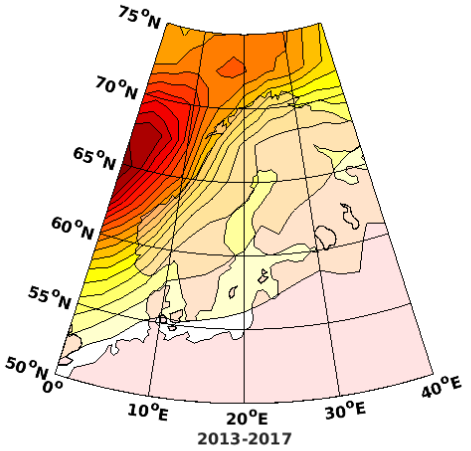




2008-2012



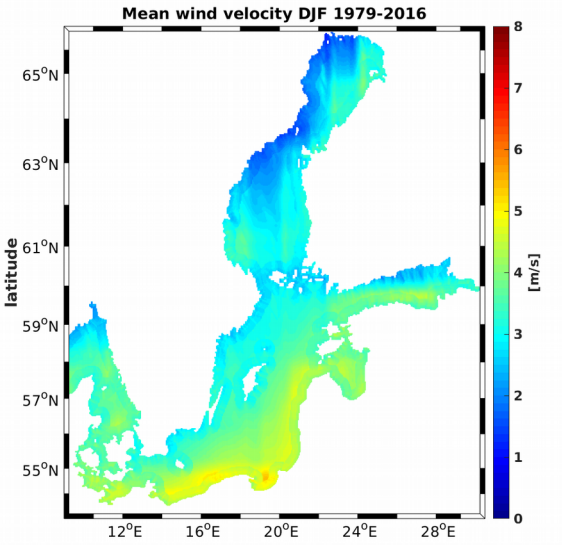
2013-2017

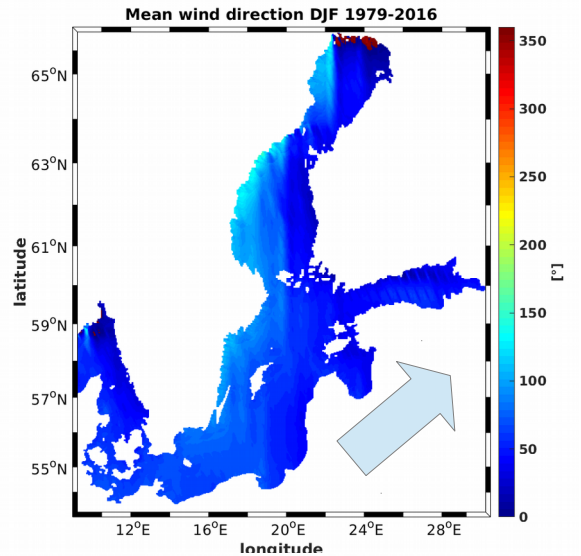


Deep cyclone counts DJFM (SLP < 980 hPa), NCEP/NCAR reanalysis data 1998-2017

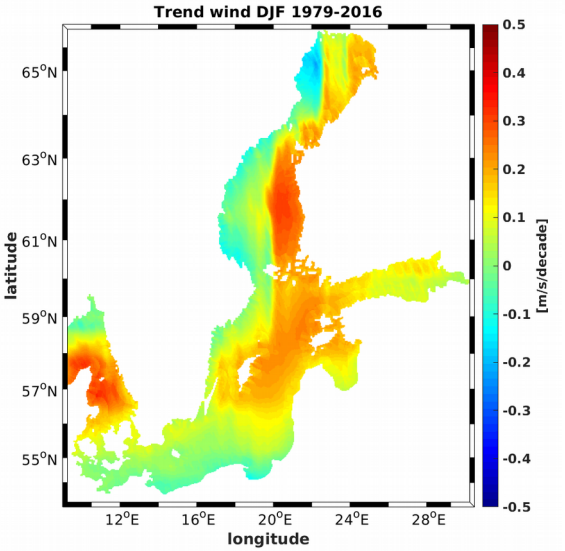
Regional scale atmospheric variability

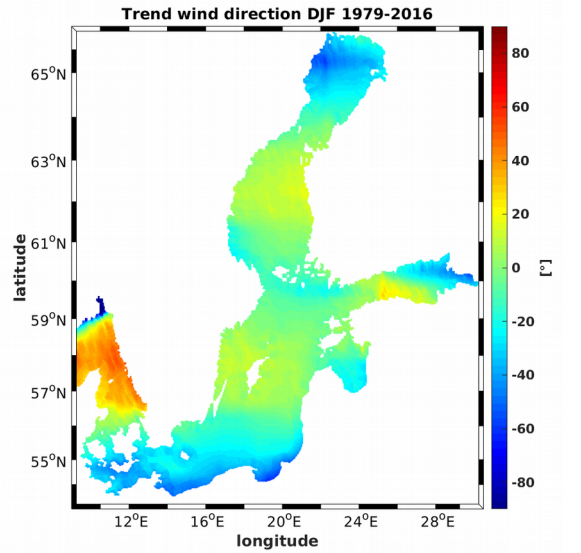
10 m wind Baltic Sea 1979 – 2016 (ERA-Interm reanalysis)





Mean wind velocity (10 m) and direction calculated from ERA-Interim reanalysis SLP data 1979-2016

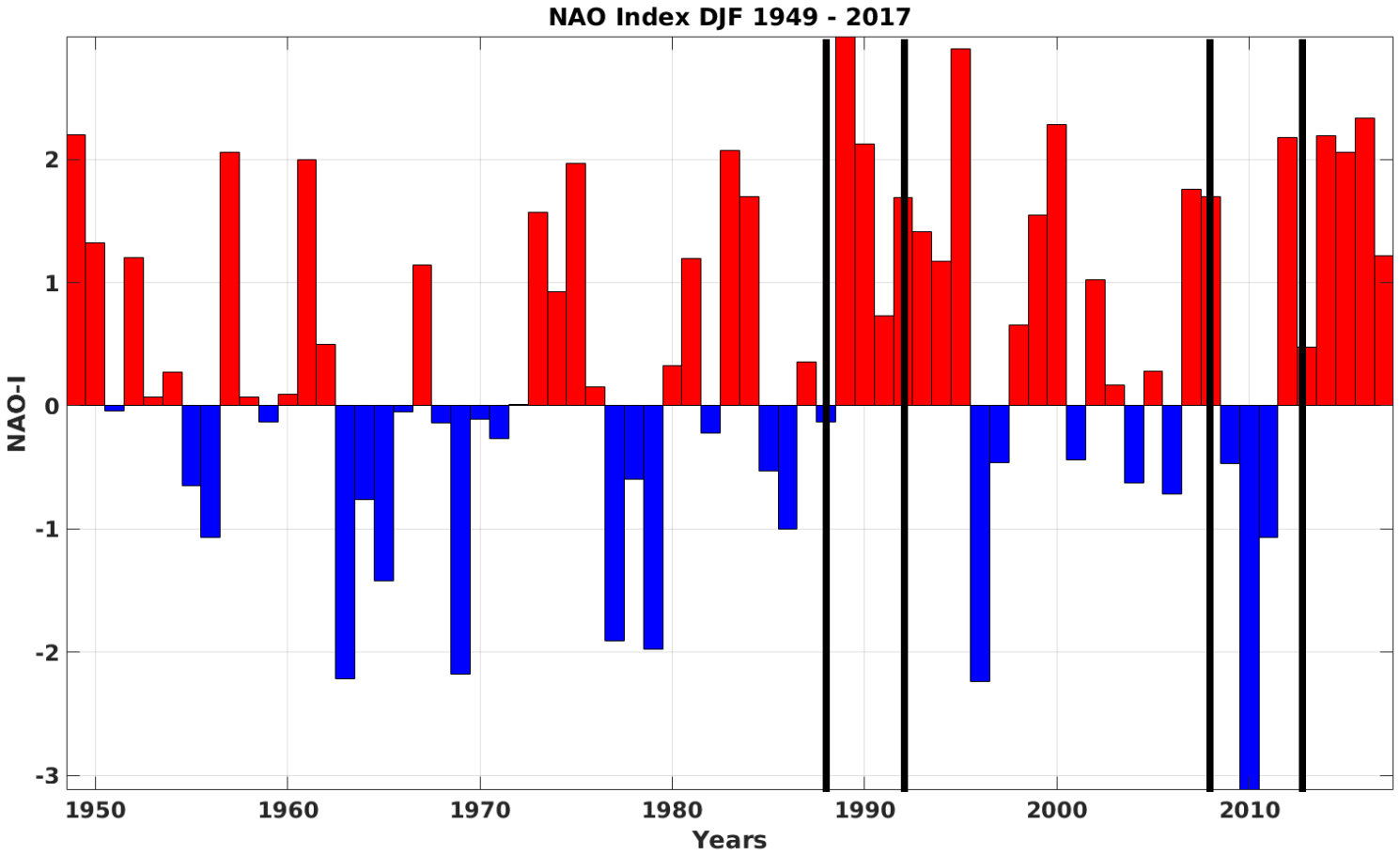




Trend of wind velocity (10 m) and direction calculated from ERA-Interim reanalysis SLP data 1979-2016

Regional scale atmospheric variability

NAO DJF winter index 1949 – 2017 (updated Jones et al. 1997)

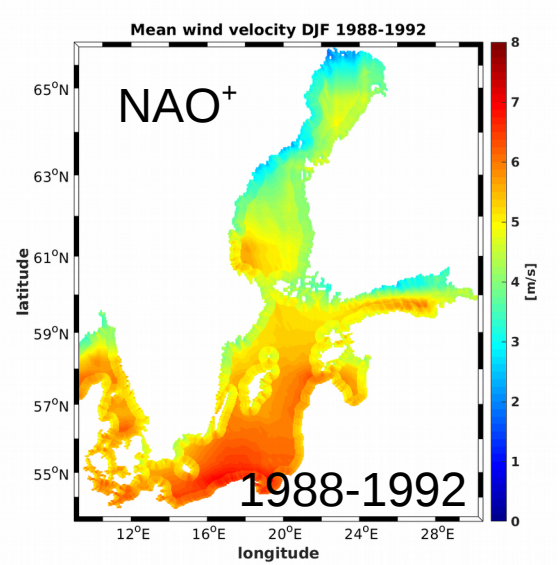


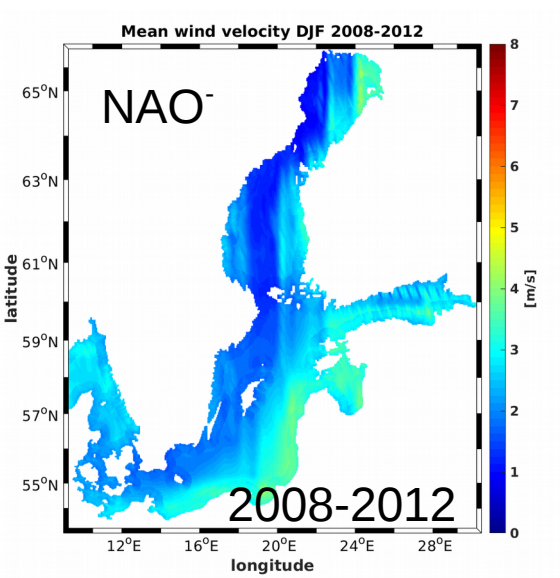
NAO DJF winter index 1949-2017, with marked 5-year periods 1988-1992, 2008-2012 and 2013-2017

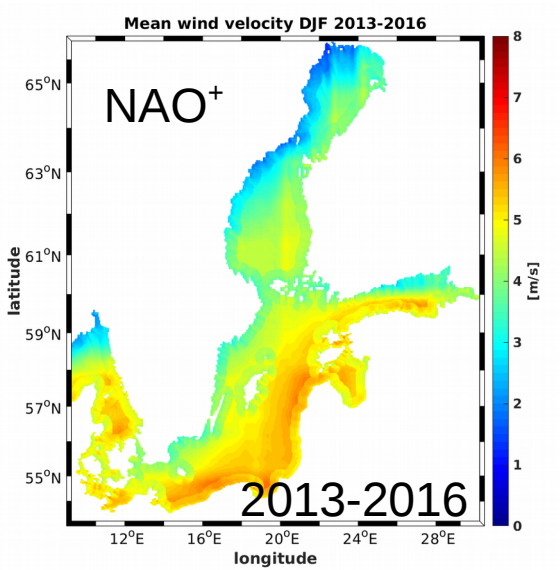
Regional scale atmospheric variability

10 m wind Baltic Sea 1979 – 2016 (ERA-Interm reanalysis)

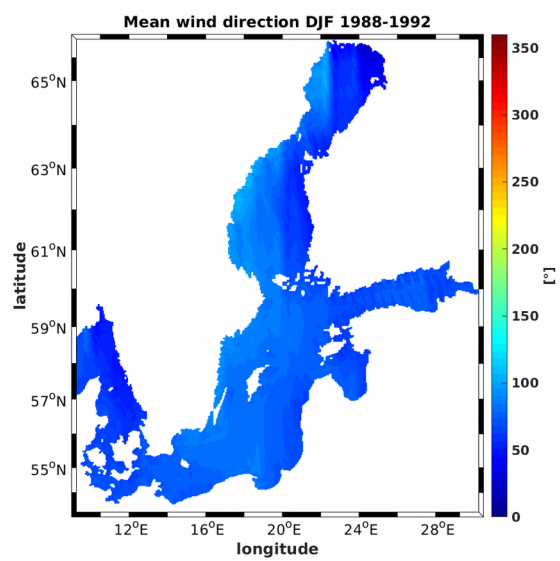
Mean wind velocity m/s

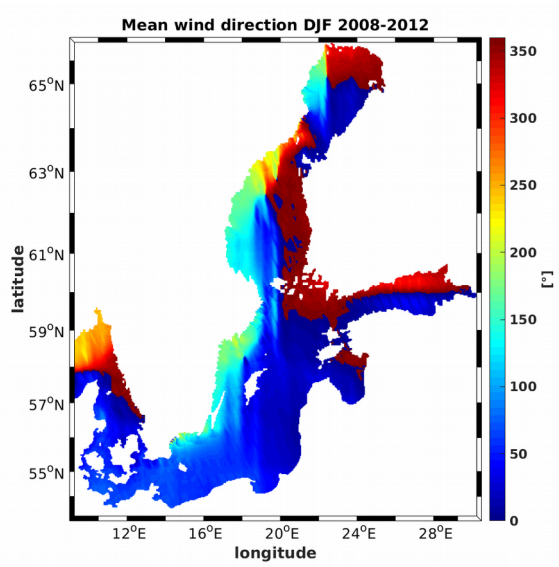


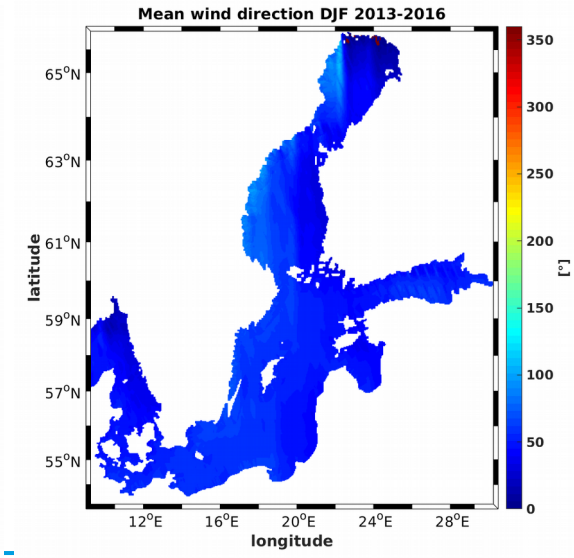




Mean wind direction °







Changing effect of large scale atmospheric circulation on regional climate variability of the Baltic Sea over the period 1948-2017
Conclusions

- The large-scale atmospheric circulation can be described by 4 dominant regimes
  - **NAO^+/NAO^-, Blocking and Atlantic Ridge** (Cassou et al. 2004, Hurrel & Deser 2009); high interannual variability, opposing trends.

- The NAO DJF winter pattern (centers of action) is moving between eastern/western positions. These positions are associated with high/low NAO winter indices, and the number and pathways of **deep cyclones (DC):**
  - NAO^+: high numbers of DC, north-eastward extension
  - NAO^-: low numbers of DC, concentration between Greenland & Iceland
- There is an increasing/decreasing trend of NAO^+/NAO^- occurrences (> 10%) for the period 1948-2017.

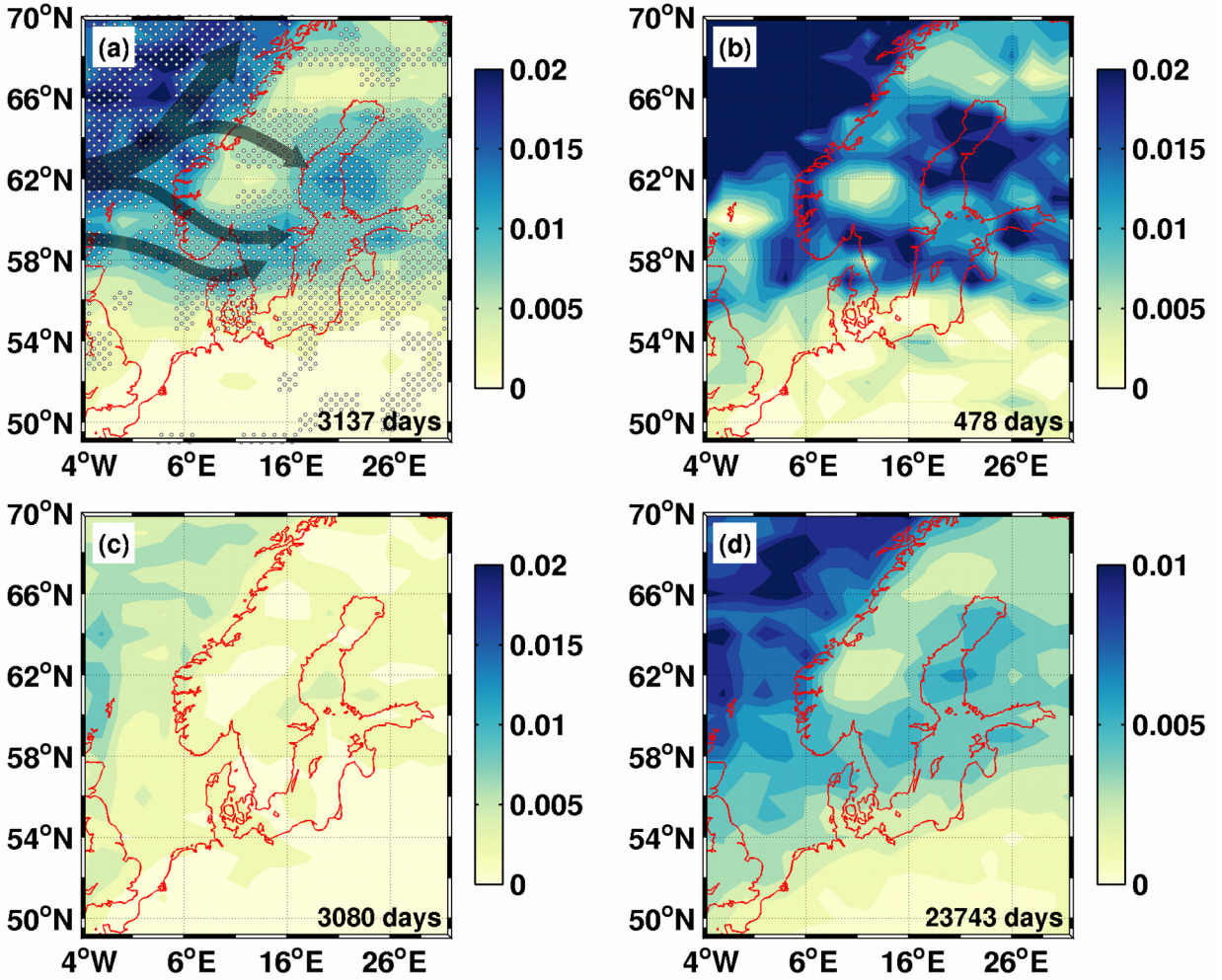
- During the recent decade, the **NAO centers of actions** moved back to a westward position. Accordingly, the number and extension of deep cyclone decreases.

- There is an increasing linear trend of the 10-m wind (1979-2016) over extended parts of the Baltic Sea.

- However, during NAO^+/NAO^- DJF winter conditions the mean wind increases/decreases due to the dominance of a particular regime.

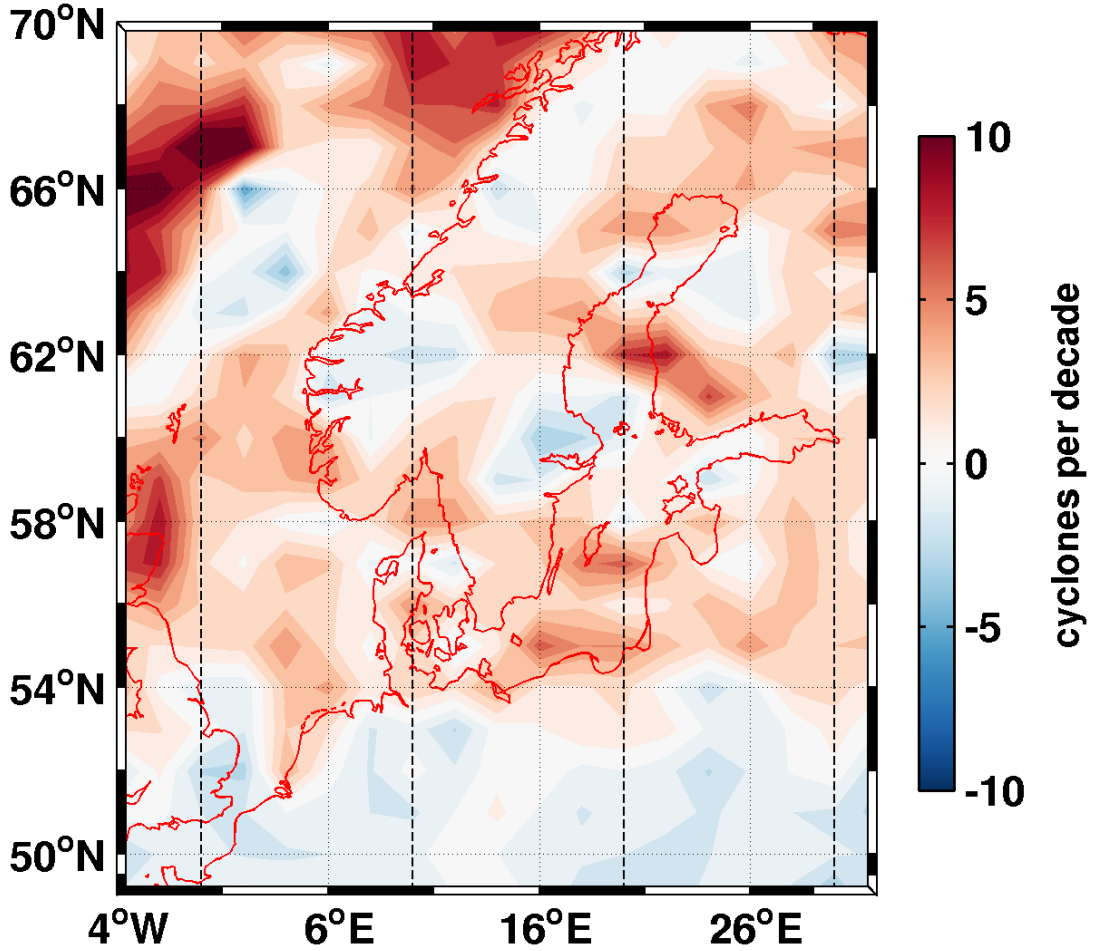
Large Volume Changes – LVCs
Deep cyclone tracking results

Cyclone tracking results:
4 distinct pathways
of deep cyclones
associated with LVCs
(Lehmann et al. 2017)

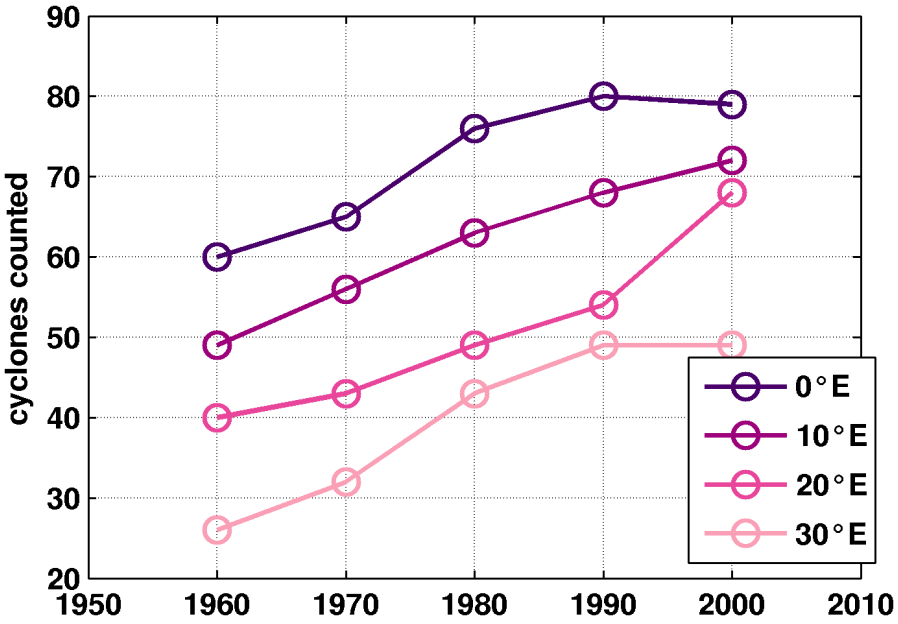


Relative cyclone frequency based on NCEP/NCAR SLPs and cyclone tracking (Tilinina et al 2013), (a) LVCs period, (b) MBIs period, (c) 40 days before SSE minimum, (d) climatology.

Large Volume Changes – LVCs



Counts of deep cyclones



Trend of **deep** cyclone frequencies for period 1950-2010 & counted **deep** cyclones crossing different meridional sections from west to east based on 20 years periods 1950-1970, 1960-1980, 1970-1990, 1980-2000, 1990-2010. (Lehmann et al. 2017)