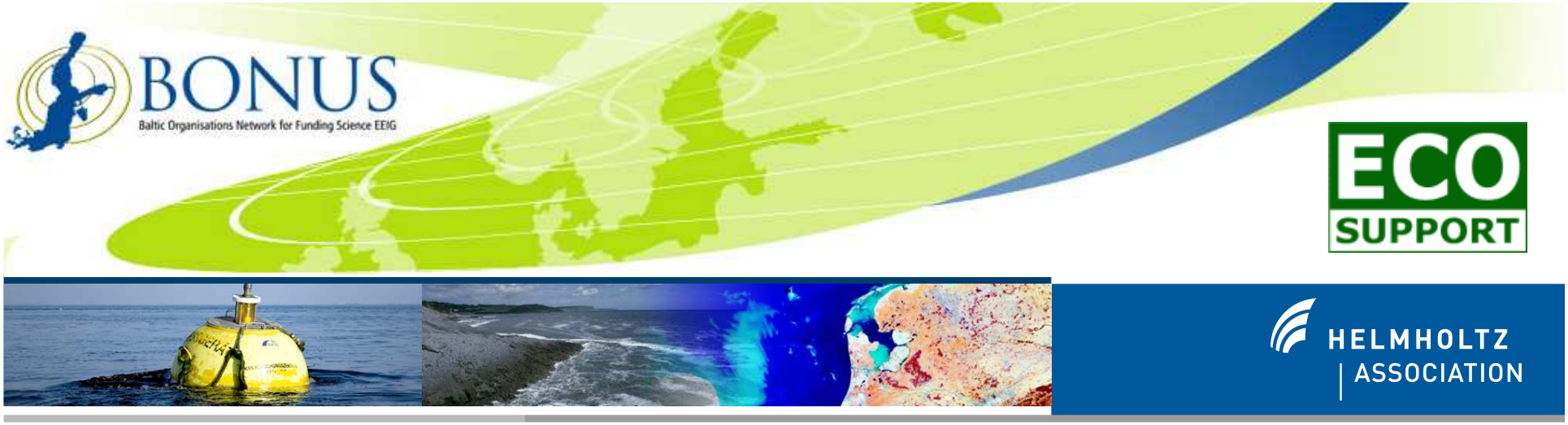
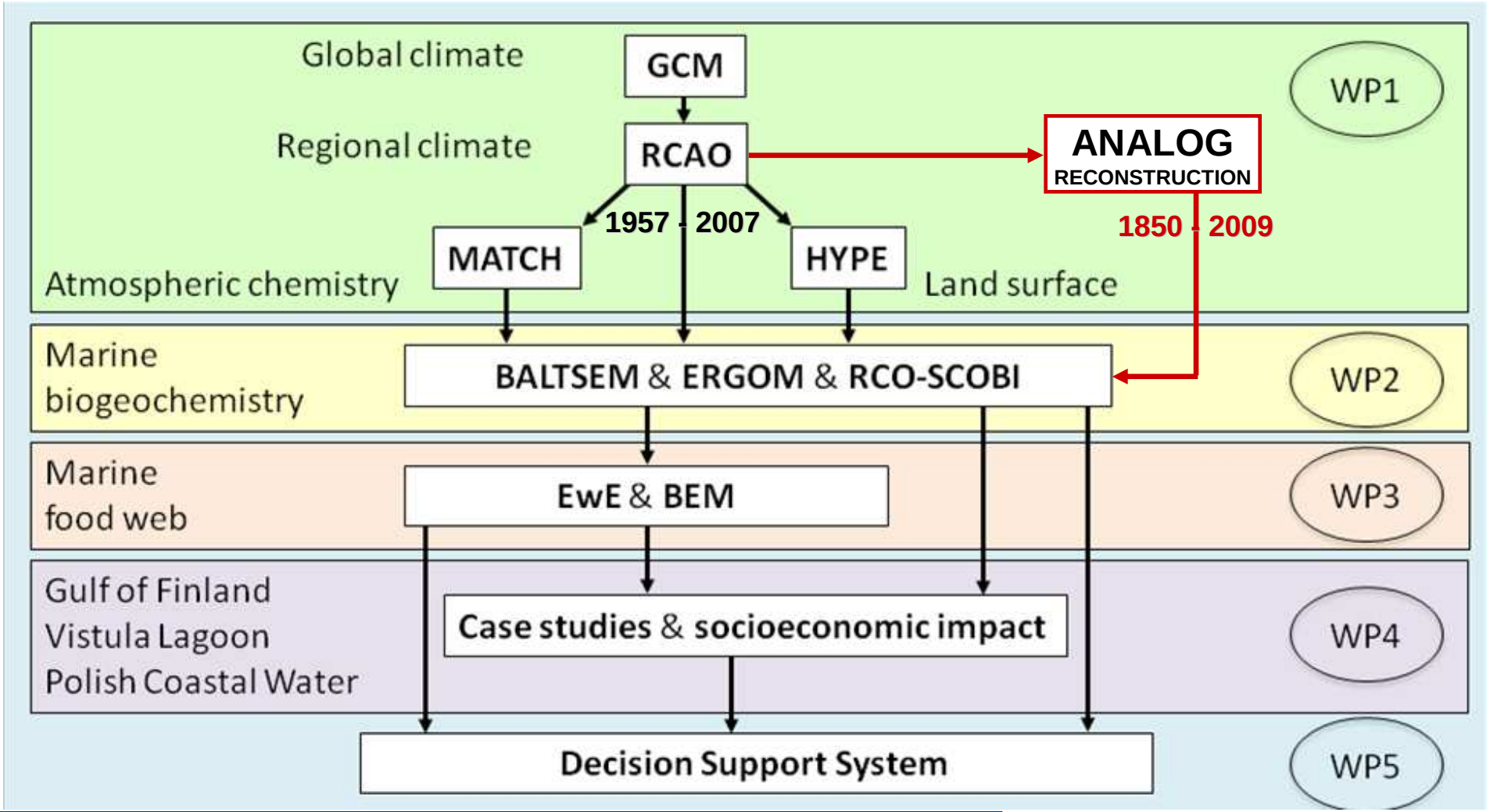
SMHI Norrköping, 16. October 2010
2nd General Assembly of ECOSUPPORT

Reconstruction of highly resolved atmospheric forcing fields for Northern Europe since 1850 AD

Frederik Schenk & Eduardo Zorita



Working Packages

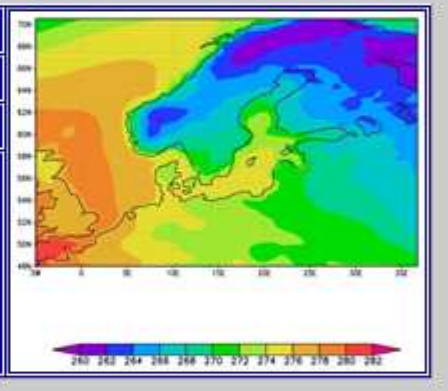


Data ready for use

New Data set HIRESAFF since 1850 A.D.
Reconstruction of Higly Resolved Atmospheric Forcing Fields for NE-Europe

We reconstructed a new dataset of spatio-temporal **HI**ghly **RES**olved **A**tmospheric **F**orcing **F**ields (**HIRESAFF**) for Northern Europe since 1850. As an outcome of the BONUS project ECOSUPPORT, the reconstructed fields provide a new basis for ecosystem (or similar) models to run longer simulations also prior to a large human impact on the Baltic Sea. The dataset also allows a better validation and estimation of model uncertainties under different climatic or nutrient load conditions.

Domain	NE-Europe, 71°N to 48°N / 5°W to 37°E
Horizontal Resolution	regular LatLon grid, 0.25° x 0.25°
Temporal Resolution	daily, 1850-01-01 to 2009-09-29
Variables	sea-surface pressure (SLP) [hPa] zonal (U) and meridional (V) wind [m/s] relative humidity (RH) [%] total cloud cover (TCC) [%] near-surface temperature (T2m) [K] and precipitation (PREC) [mm]



The **Analog-Method (AM)** is used as a simple non-linear upscaling tool to reconstruct daily atmospheric fields from long historical station data of daily SLP and monthly T2m since 1850 (predictor). "Analogue" fields for every day (predictand) are searched by the AM from a pool of atmospheric fields taken from a regional climate model (1958-2007). As the AM is not assuming a specific shape for the probability distribution of the variables, non-normally as well as normally distributed variables are reconstructed. Hence, the AM reconstruction captures the extremes (magnitudes, frequencies), the probability distributions of the variables as well as the variability reasonably well on the daily scale.

http://coast.hzg.de/staff/schenk/hiresaff.html

Outline

Reconstruction Method

Data

Some Reconstruction Skills

Take Home

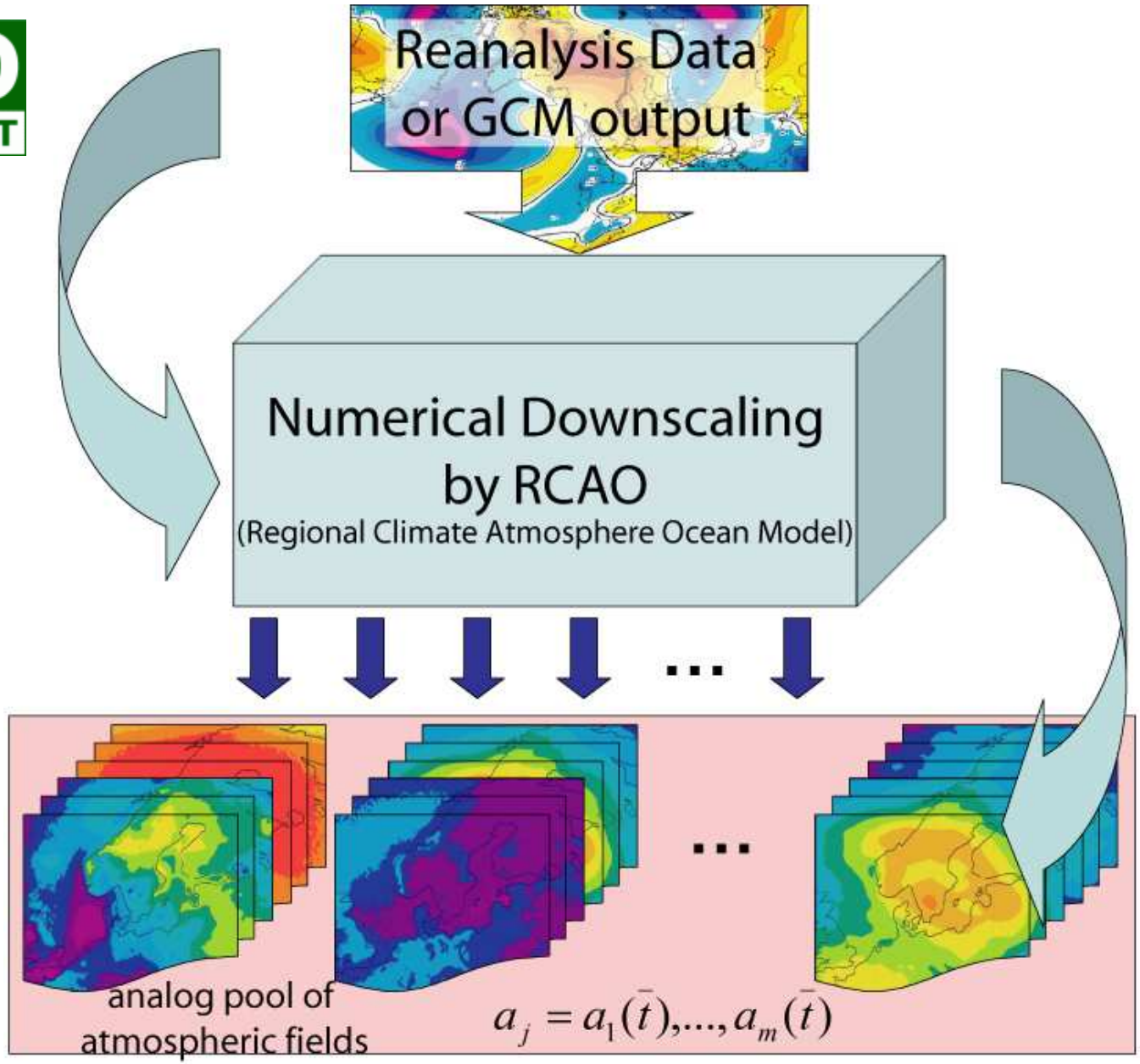
The Analog-Method as upscaling tool

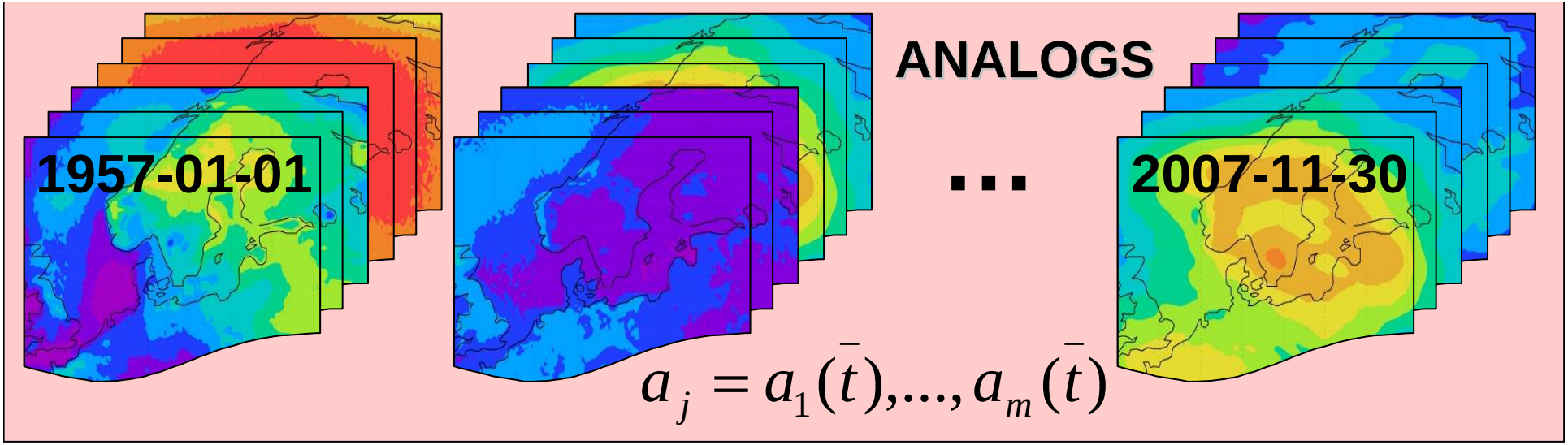
1) Generate consistent Analog fields

= numerical downscaling

2) Find Analog fields for station data

= statistical upscaling

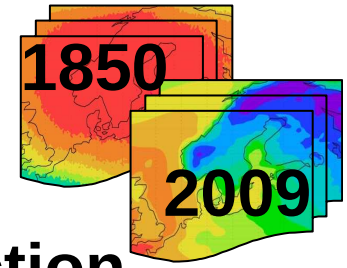

Reanalysis Data
or GCM output
Numerical Downscaling
by RCAO
(Regional Climate Atmosphere Ocean Model)
...
...
analog pool of
atmospheric fields
$a_j = a_1(\bar{t}),\ldots,a_m(\bar{t})$



$$\sum_{k=1}^{n}\left(a_k - p_k(t)\right)^2 \overset{!}{=} \min$$

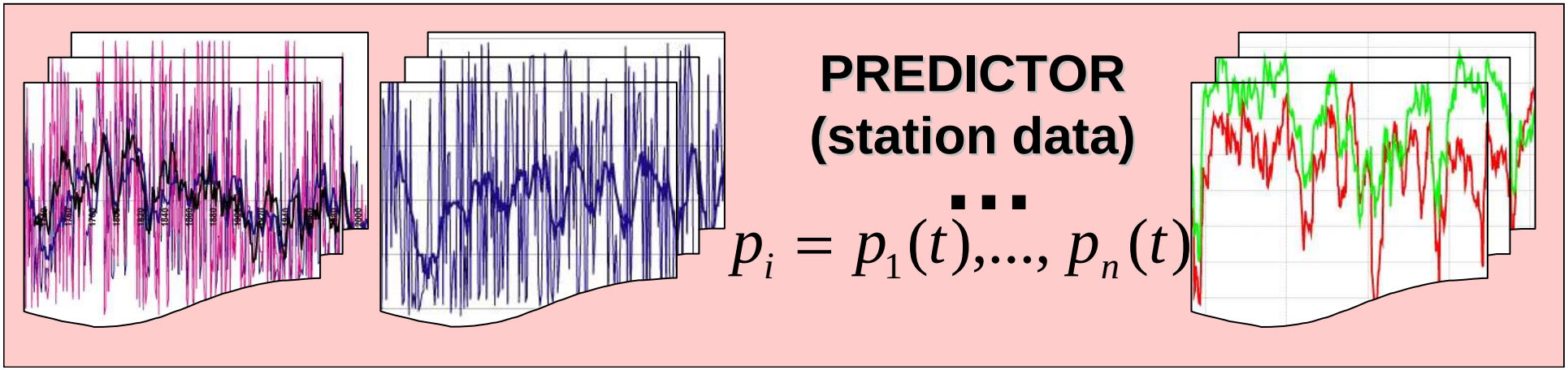
Analog-Method:

find for $\forall t \rightarrow \bar{t}$**:**



Reconstruction

$$\bar{a}_i(\bar{t}) = \bar{a}_1(\bar{t}),\ldots,\bar{a}_n(\bar{t})$$



Settings

Test: Cross-wise cal/val for 25 years

- **Predictand** = daily analog fields from RCAO model
- **Predictor** = daily SLP (N=23 stations)

Increase sample size for analogs:

- **days of month m → analogs in M {m-1, m, m+1}**
  - allows seasonal shifts if forced by predictor
  - additional „tricks“ for the T2m reconstruction

Reconstruction: cal. 1958-2007 → 1850-2009

Data

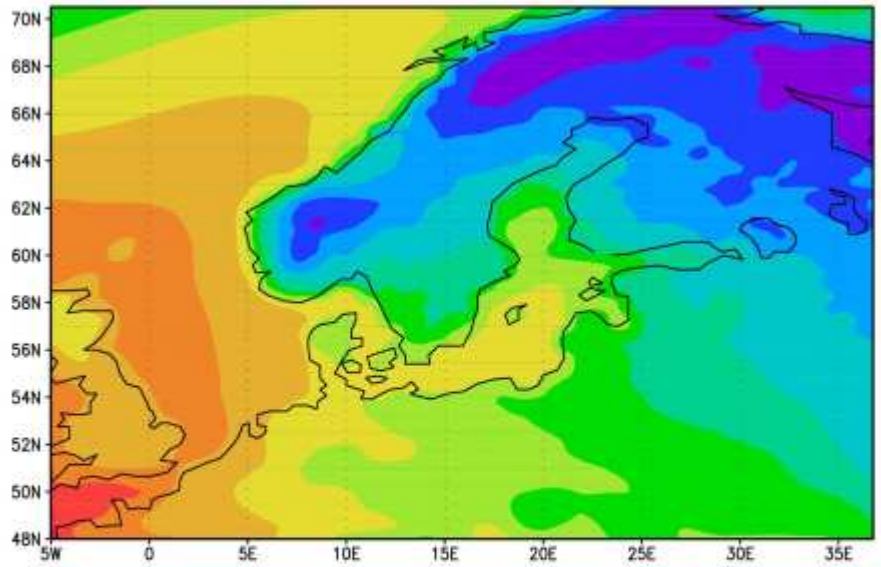
Atmospheric Fields (Analogs)

Station Data

Analogs of Atmospheric Fields

Atmospheric Fields for:

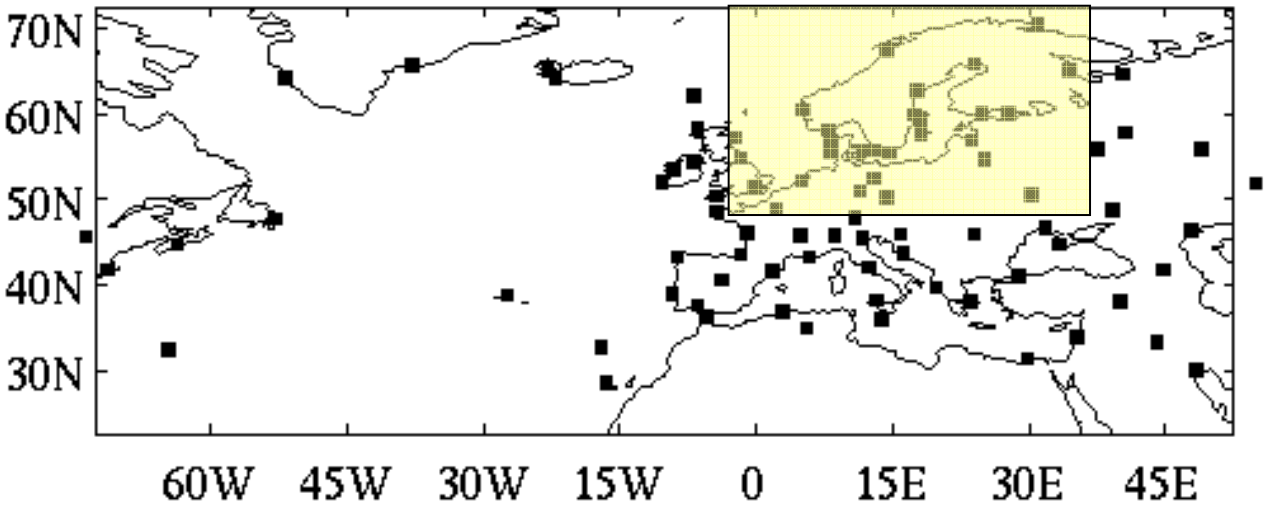
- Sea-Level-Pressure [Pa]
- U- and V-Wind [m/s]
- Relativ Humidity [%]
- Total Cloud Cover [%]
- Precipitation [mm]
- Temperature [K]



Source: RCAO

Swedish Regional Climate Model with Coupled Ocean for Baltic Sea

Daily SLP Station Data



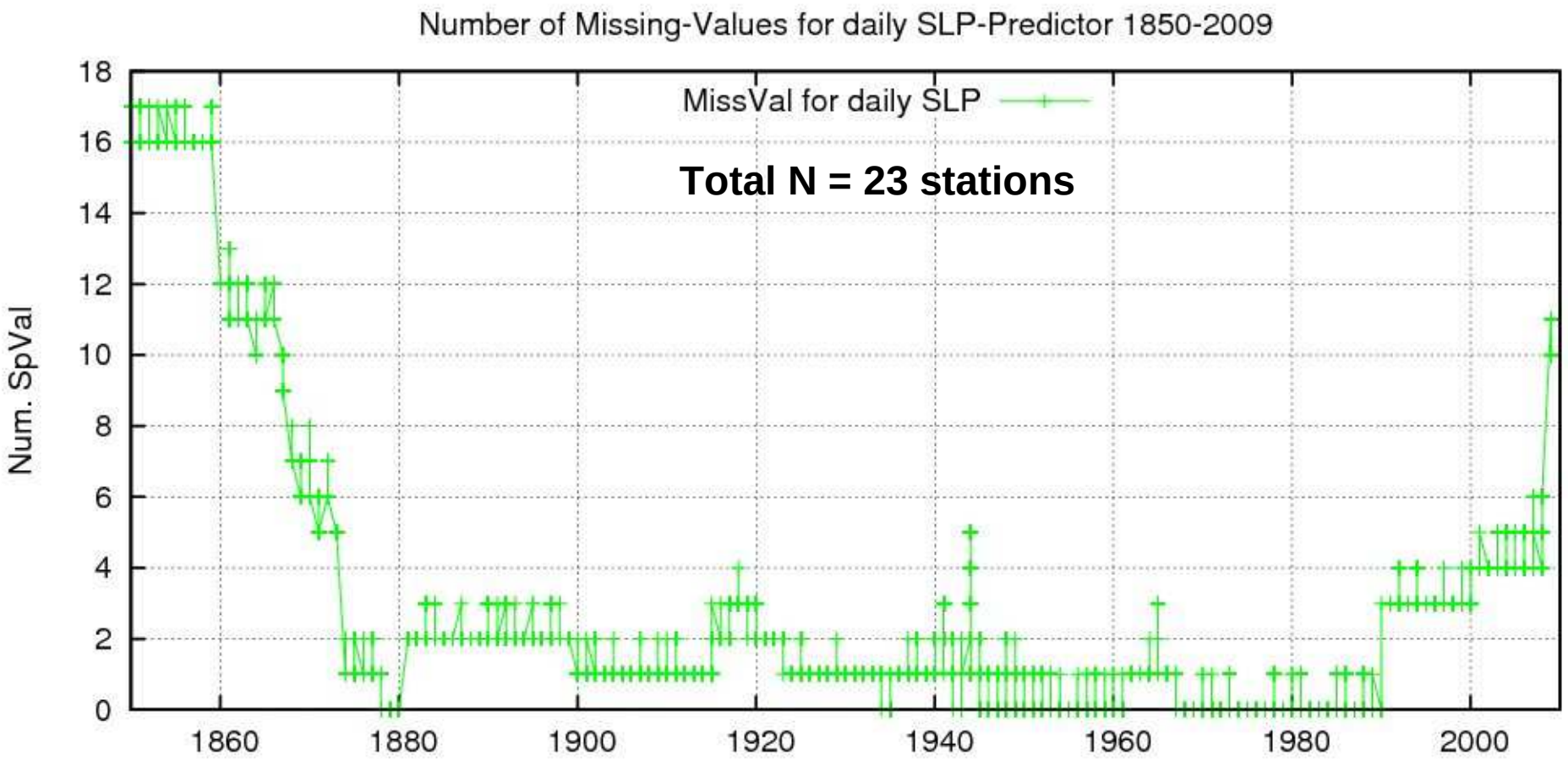
EMULATE Mean Sea Level Pressure data set (EMSLP)

→ provides ~ 20 stations for RCAO-domain

→ partly covers **1850 - 2002**, updates by WMO, **ECA&D**

Ansell, T. J. et al. (2006) Daily mean sea level pressure reconstructions for the European - North Atlantic region for the period 1850-2003', Journal of Climate, vol 19, No. 12, pp 2717-2742.

Daily SLP Station Data



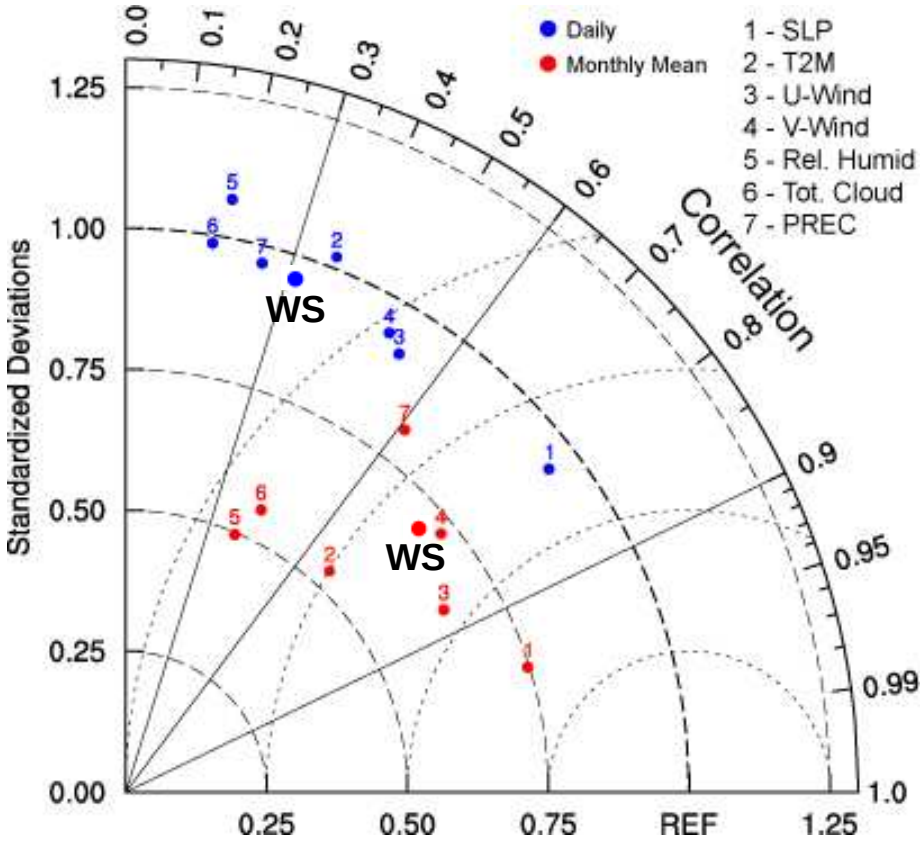
Reconstruction Skills

Field Correlation

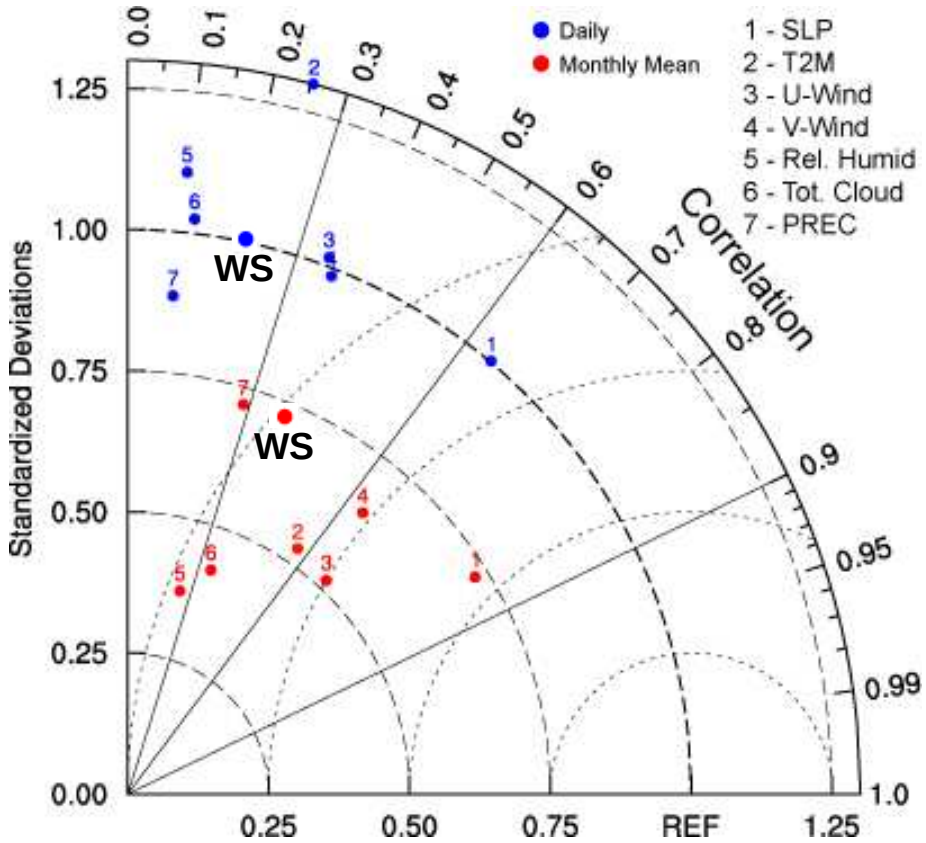
Ratio of Variance

$$SD = \frac{Var(REC)}{Var(REF)}$$

Reconstruction Skills



Taylor Diagram JAN 1958-2007



Taylor Diagram JUL 1958-2007

Mean field correlation and ratio of variances between the reconstruction and the reference fields from RCAO model.

Temperature Reconstruction

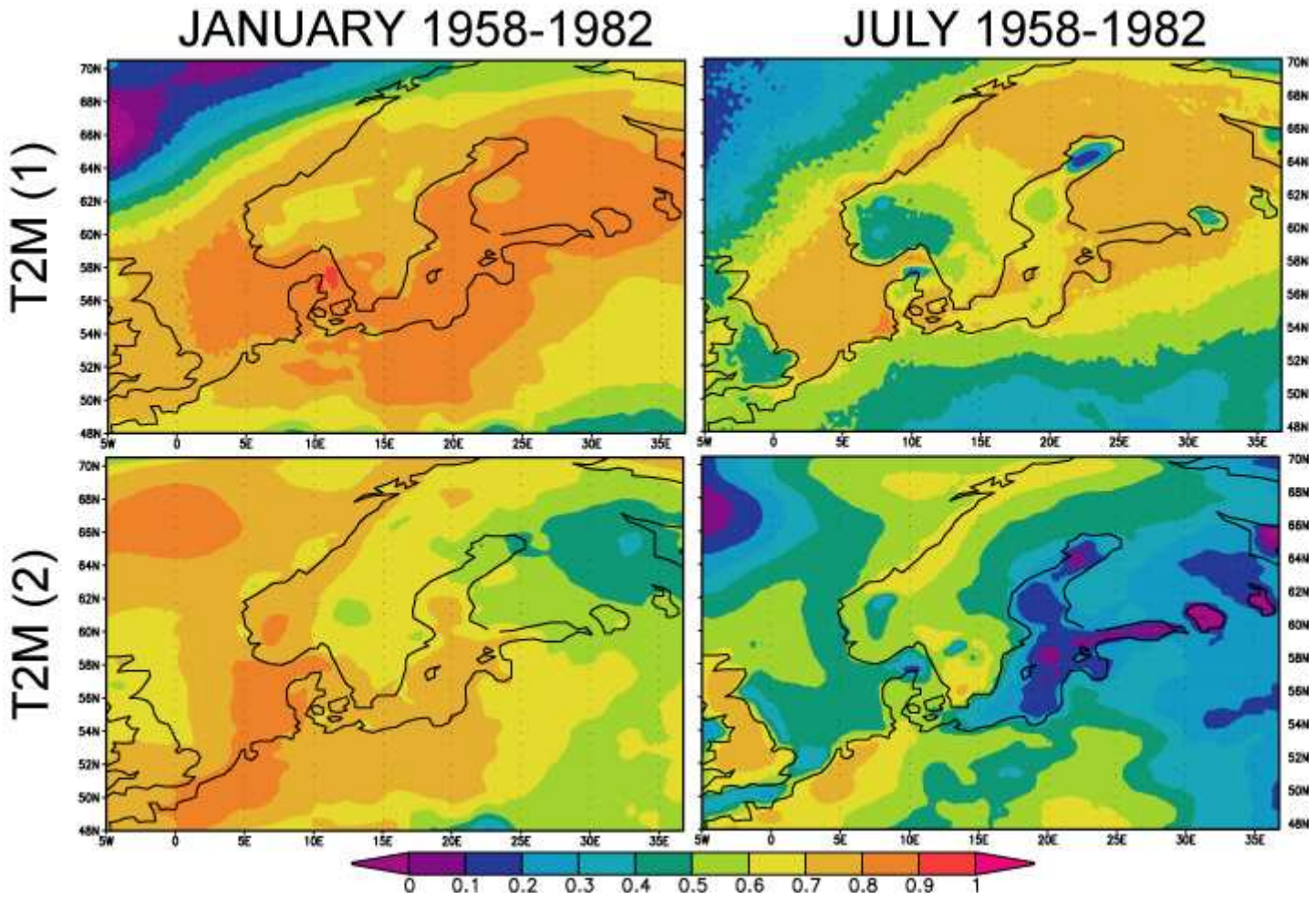
Version 3

Temperature Reconstruction

SLP has a too weak physical link to T2m

- **additional predictor T2m** (N=22 stations, **monthly**)
  - reconstruction of **monthly T2m fields**
  - projected onto daily T2m anomalies reconstructed by daily SLP
  - includes also T2m changes NOT affected by SLP

Temperature Reconstruction



SLP + T2m

SLP only

Temperature Reconstruction

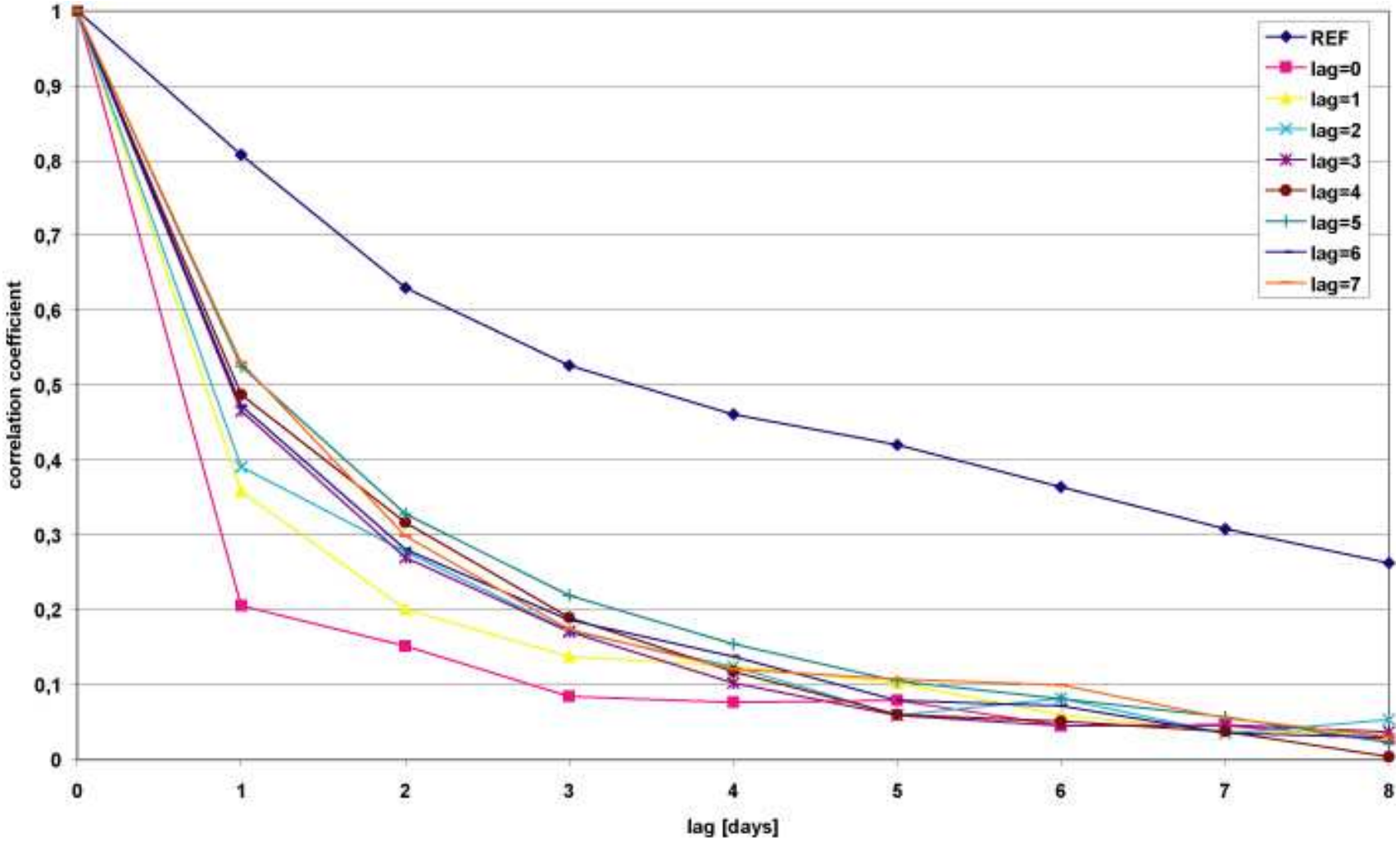
Time-invariance of the Analog-Method:

- A single day doesn't know anything about the days before, i.e.
- much too low daily auto-correlation for daily T2m when being reconstructed by daily SLP

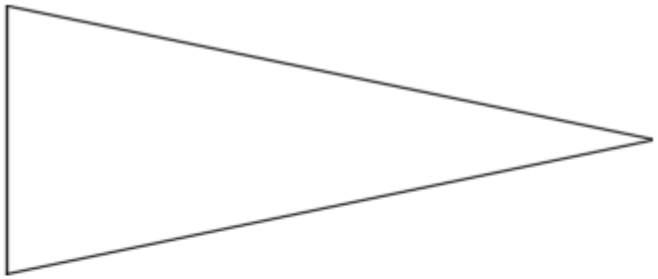
How to account for memory effect in daily T2m?

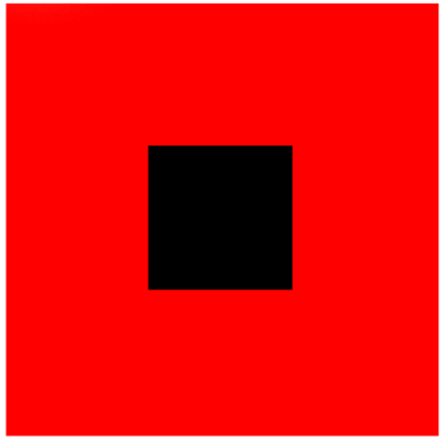
- Search Analog for highest similarity over n days…

Memory Effect over n Days



Auto-Correlation [AR(1)] of daily T2m for January 1958-2007
in reconstructions searching analogs by similarity over n days





Reconstruction Skills for Wind Speed

Field correlation & Variance

Wind speed distribution

99% treshhold values

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July 2010:

Algae bloom of
377.000 km² (~90%)

Reasons:

(1) nutrient loads (?)

(2) warm SST

(3) low winds (!)

→ compare to 2005
→ analog cases?

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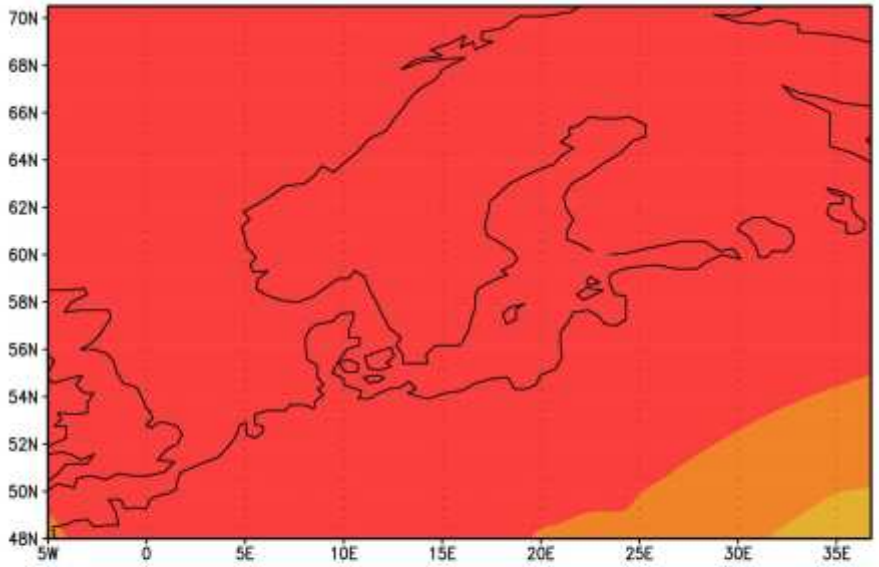
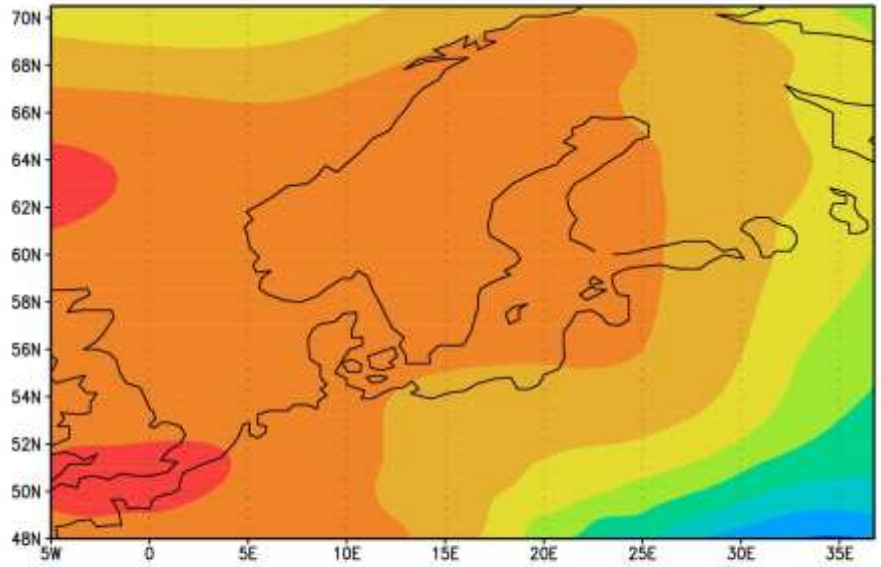
SLP-Reconstruction



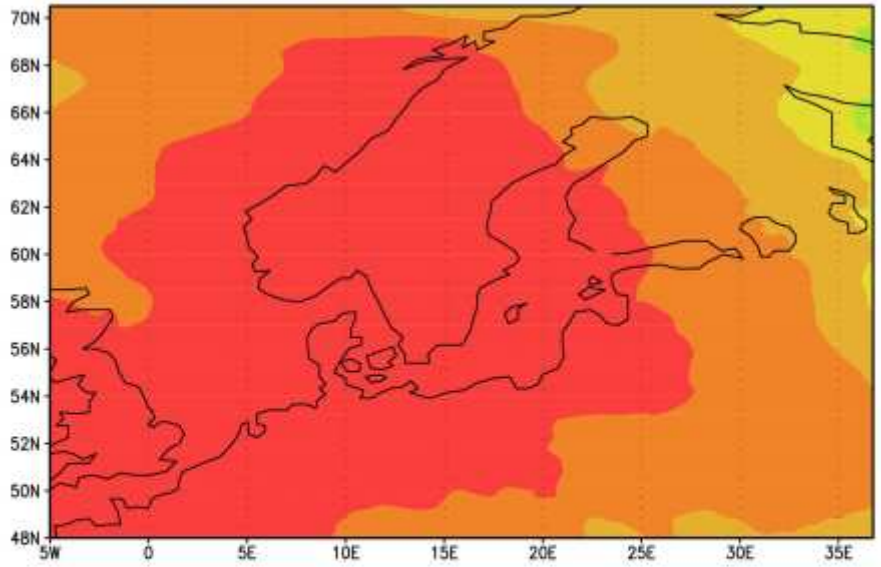
Fieldcor for JAN 1958-1983



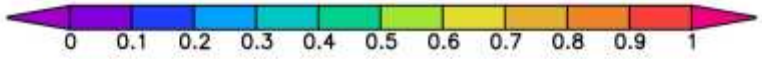
Fieldcor for JUN 1958-1983

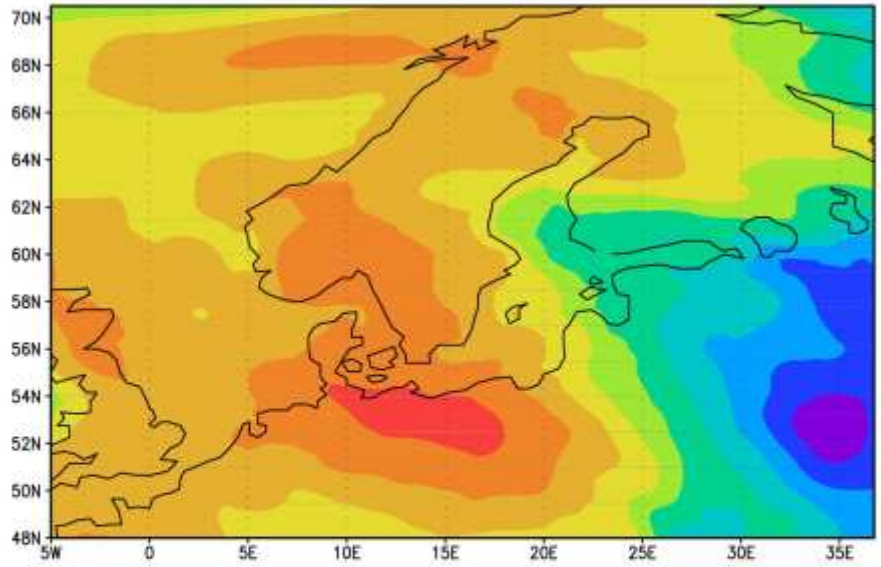
Calibration: 1984-2007

U-Wind-Reconstruction



Fieldcor for JAN 1958-1983

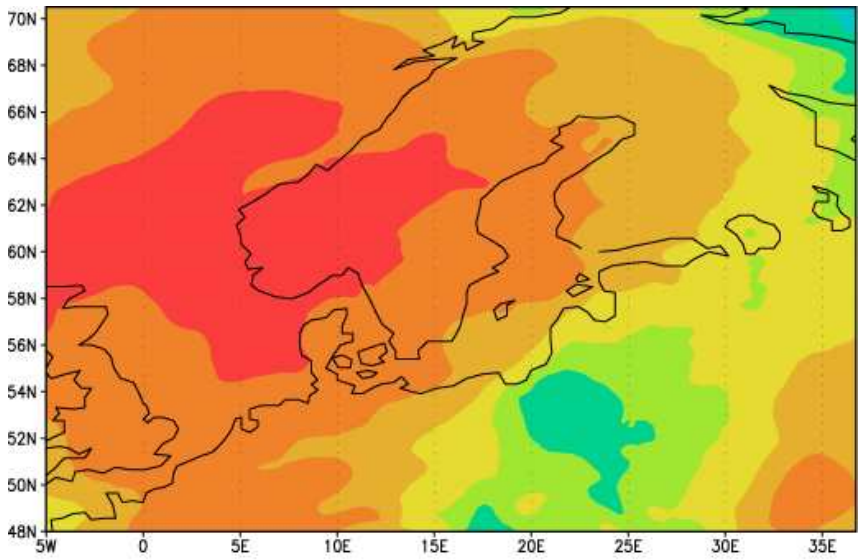




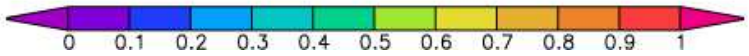
Fieldcor for JUN 1958-1983

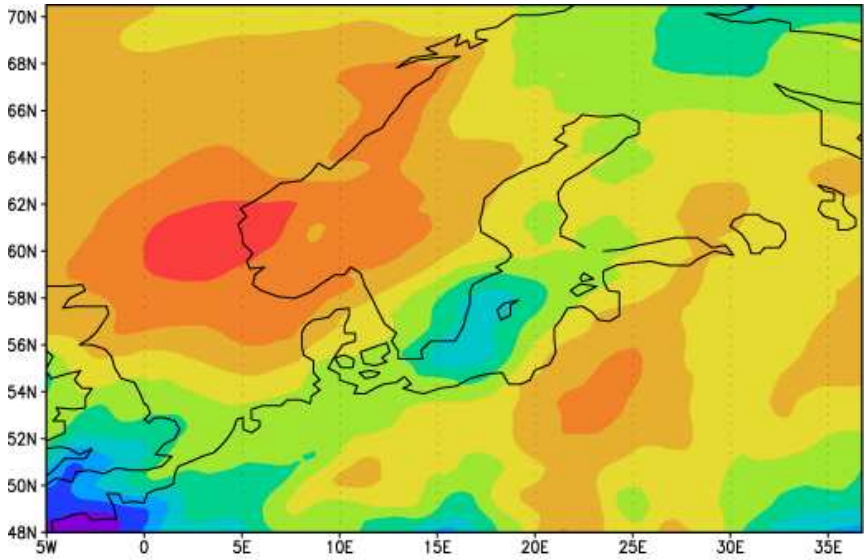
Calibration: 1984-2007

V-Wind-Reconstruction

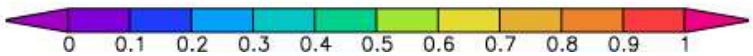


Fieldcor for JAN 1958-1983

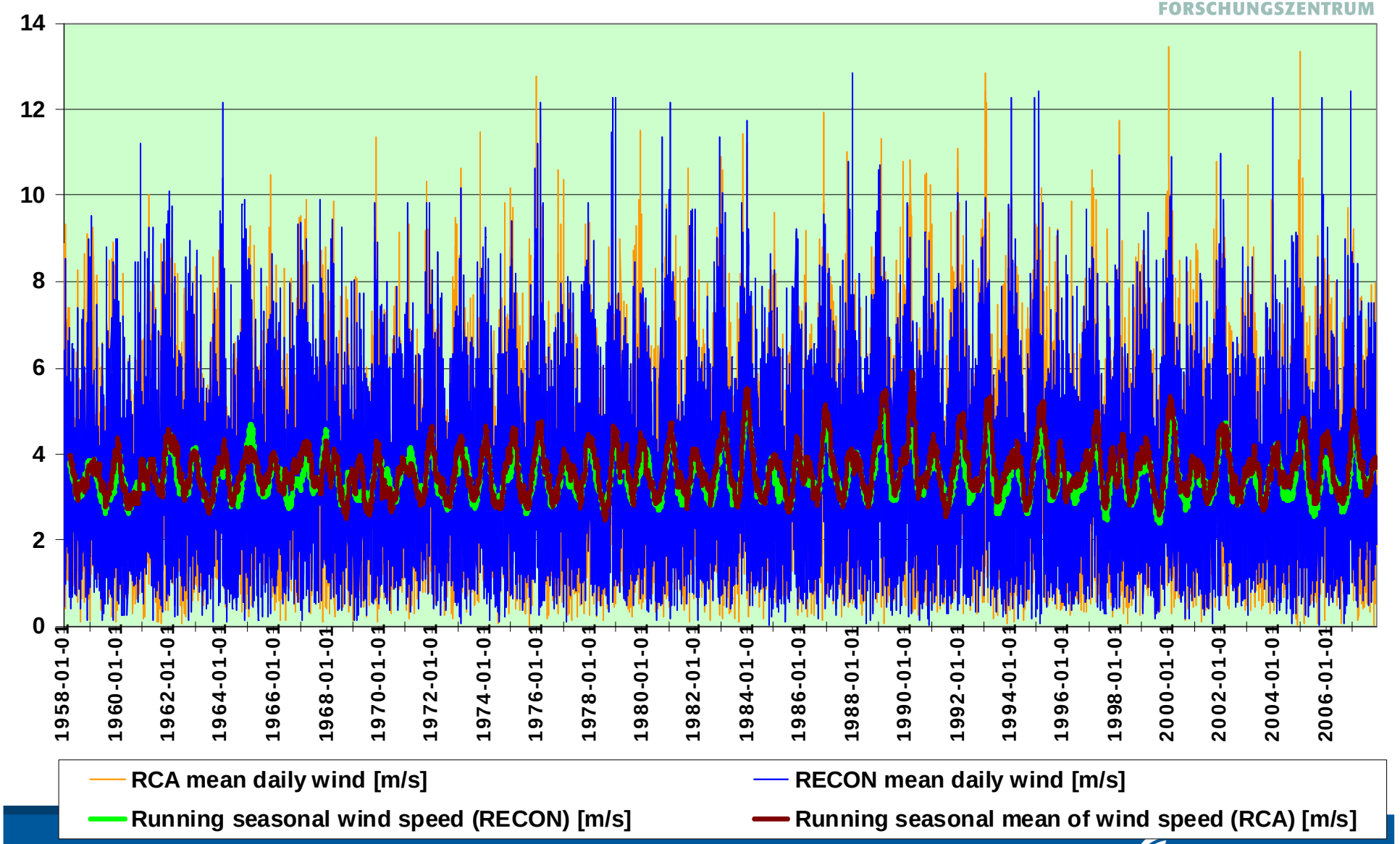




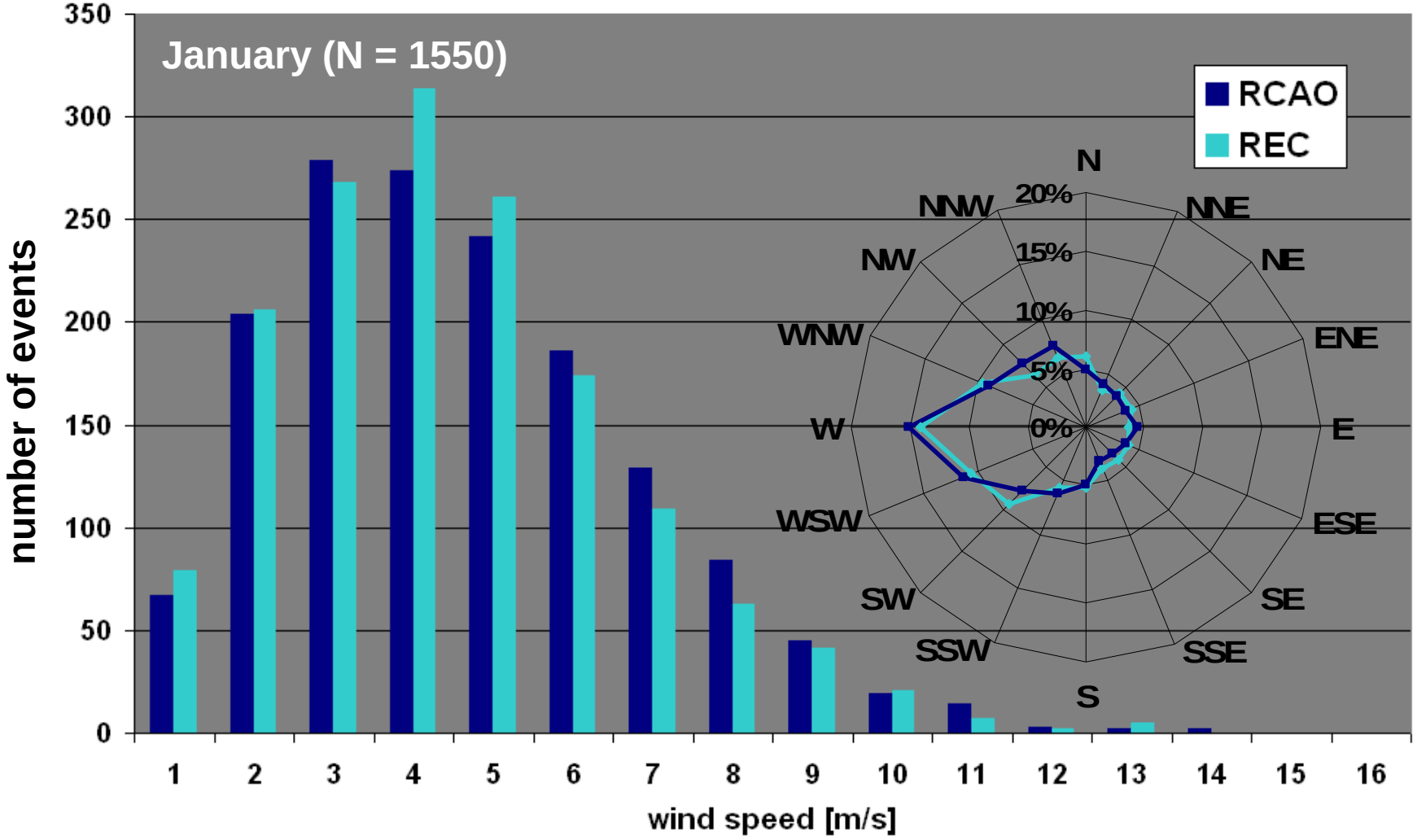
Fieldcor for JUN 1958-1983



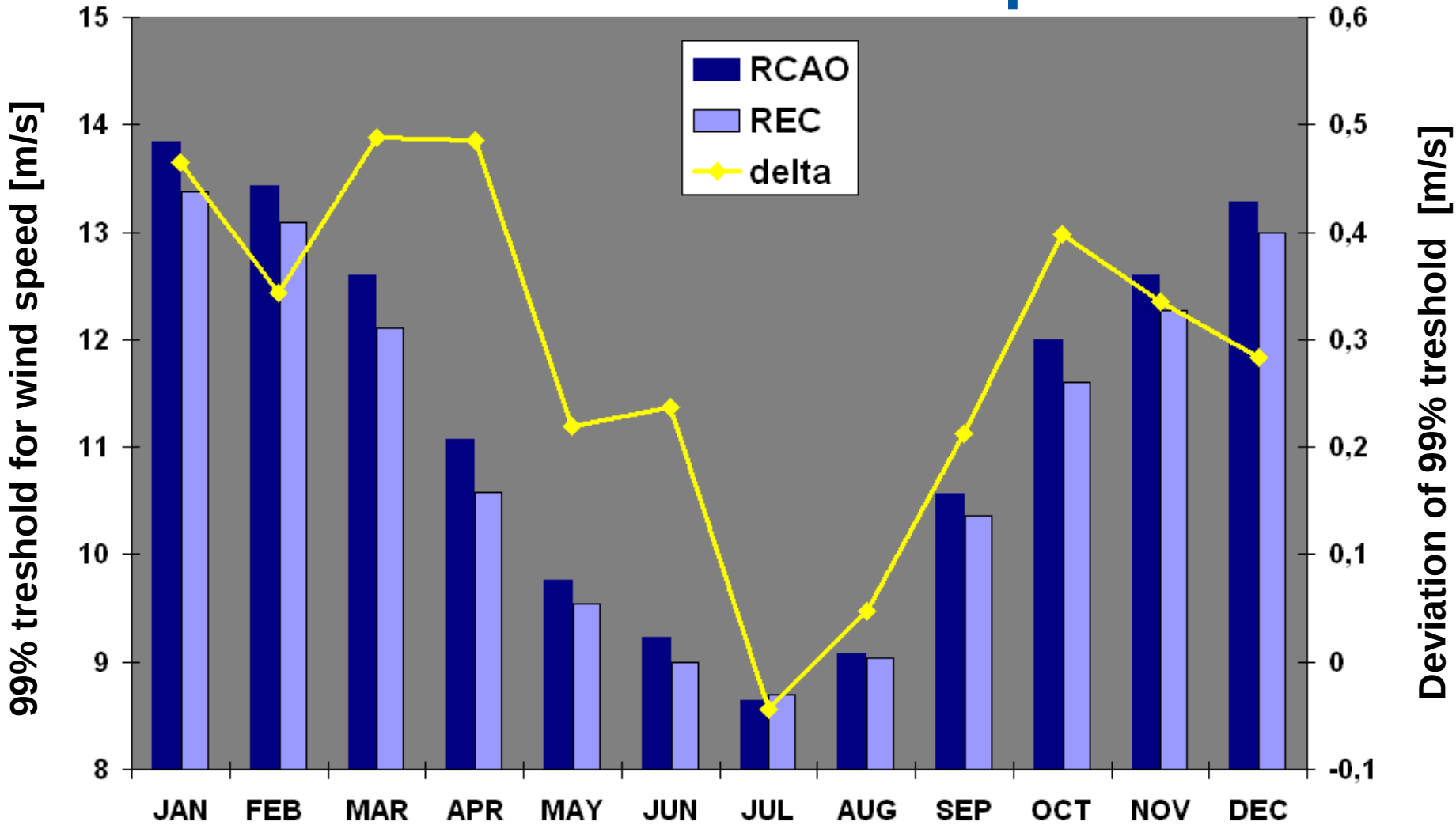
Calibration: 1984-2007


14
12
10
8
6
4
2
0
1958-01-01
1960-01-01
1962-01-01
1964-01-01
1966-01-01
1968-01-01
1970-01-01
1972-01-01
1974-01-01
1976-01-01
1978-01-01
1980-01-01
1982-01-01
1984-01-01
1986-01-01
1988-01-01
1990-01-01
1992-01-01
1994-01-01
1996-01-01
1998-01-01
2000-01-01
2002-01-01
2004-01-01
2006-01-01
RCA mean daily wind [m/s]
RECON mean daily wind [m/s]
Running seasonal wind speed (RECON) [m/s]
Running seasonal mean of wind speed (RCA) [m/s]

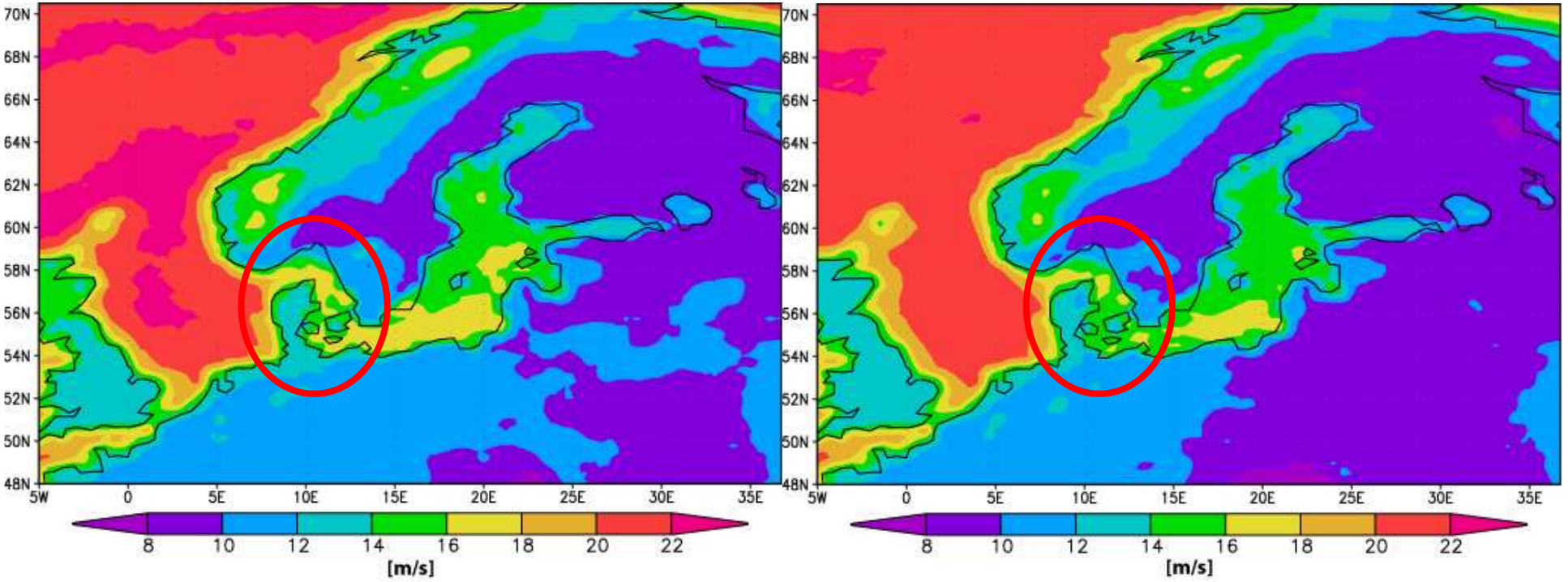
Wind speed distribution



99 Percentile of wind speed



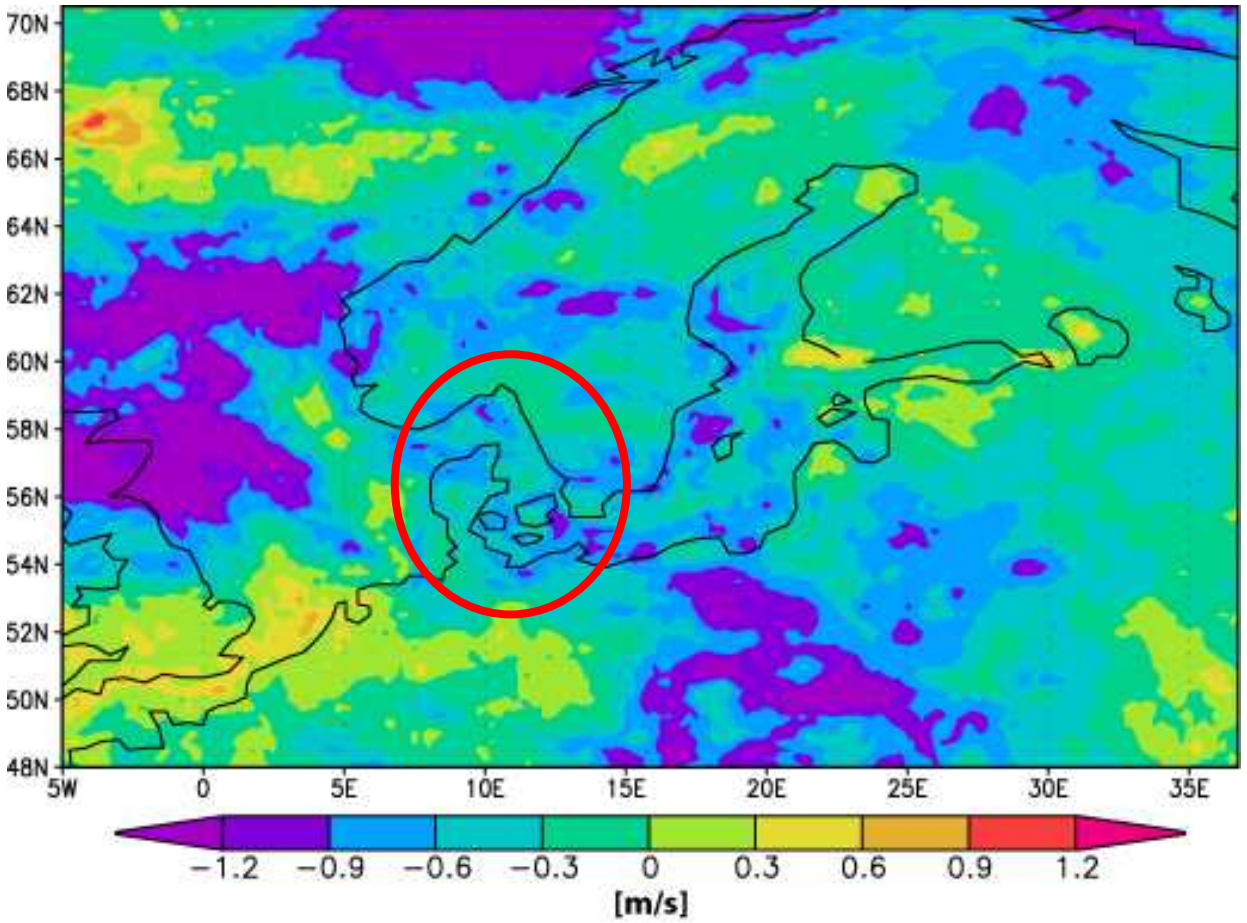
99 Percentiles of Wind Speed



99% treshold values for daily wind speed for JANUARY (1958-2007)

RCAO **RECONSTRUCTION**

99 Percentiles of Wind Speed



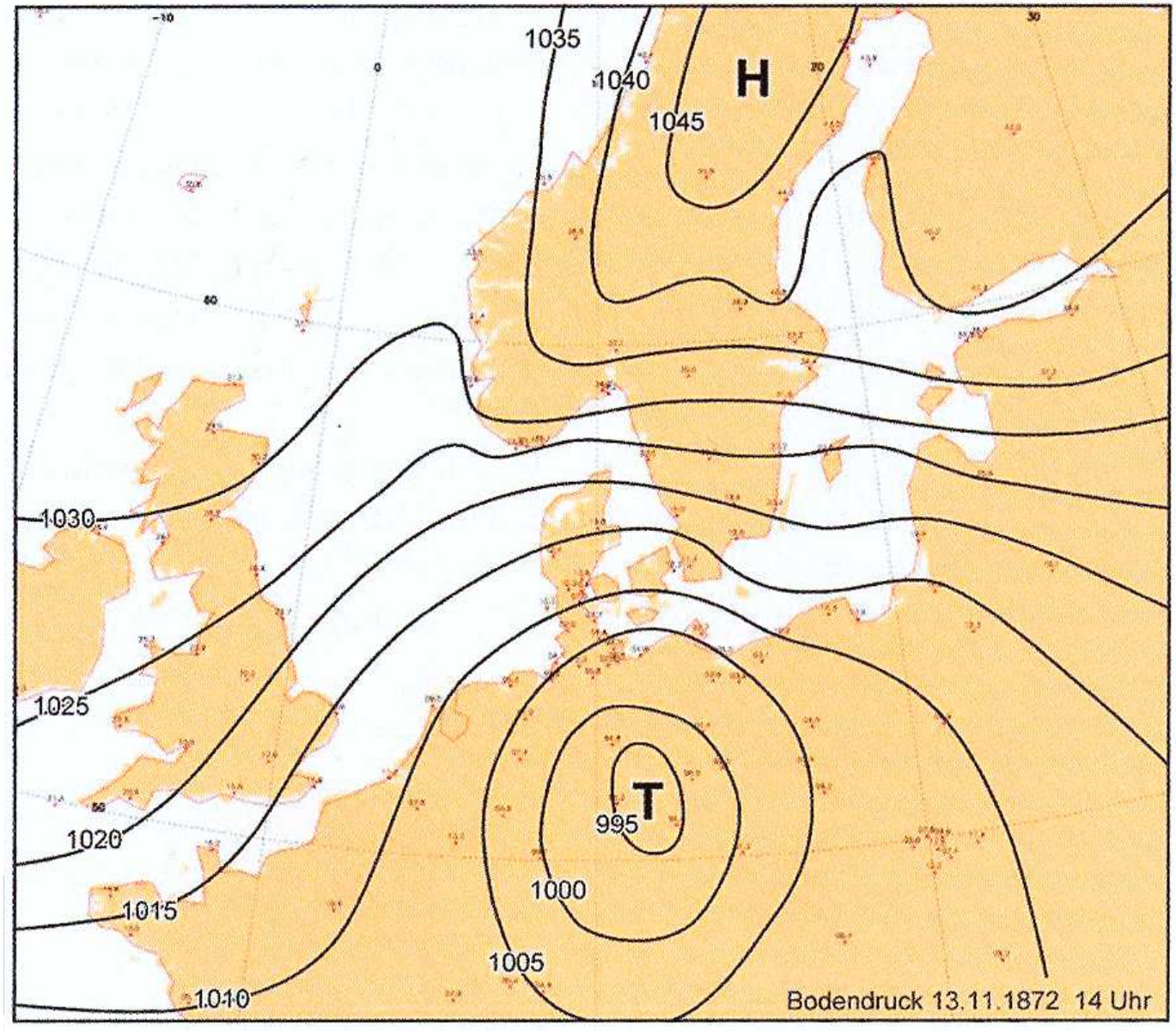
Deviation of 99% treshold values for daily wind speed (REC – RCAO)

Test case: Storm flood 1872

SW-Baltic Sea 12/13th of November 1872

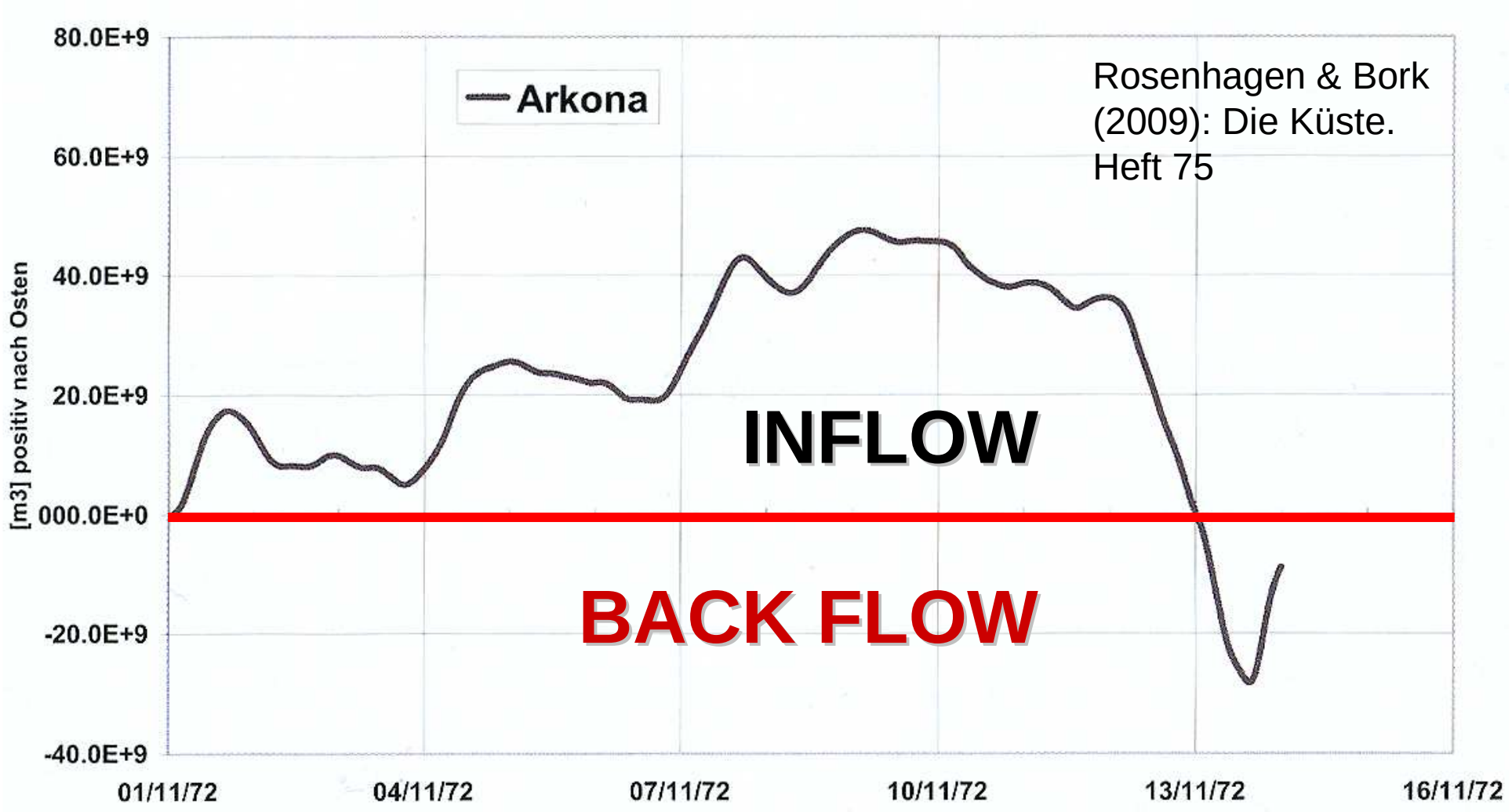
- **Biggest measured storm flood since today**
- **Strong westerly flow over weeks**:
  - Storms from SW → filling up Baltic Sea from North Sea
- **12/13th Storm surge:**
  - Storm increase to 120 km/h
  - sudden change to NE
  - +3,50 m storm flood (> 2,70 m over one day)

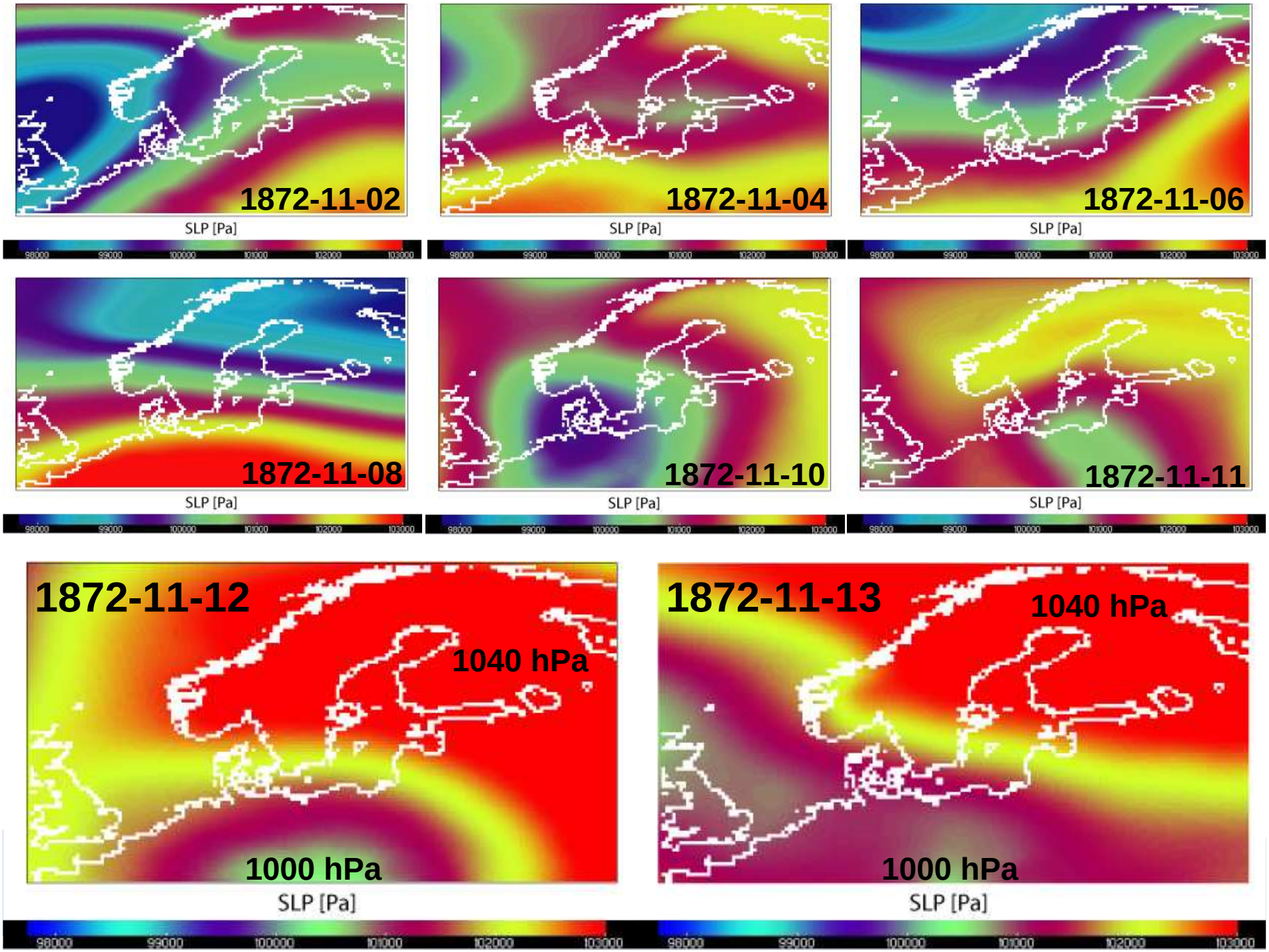
Storm Surge 13th Nov. 1872

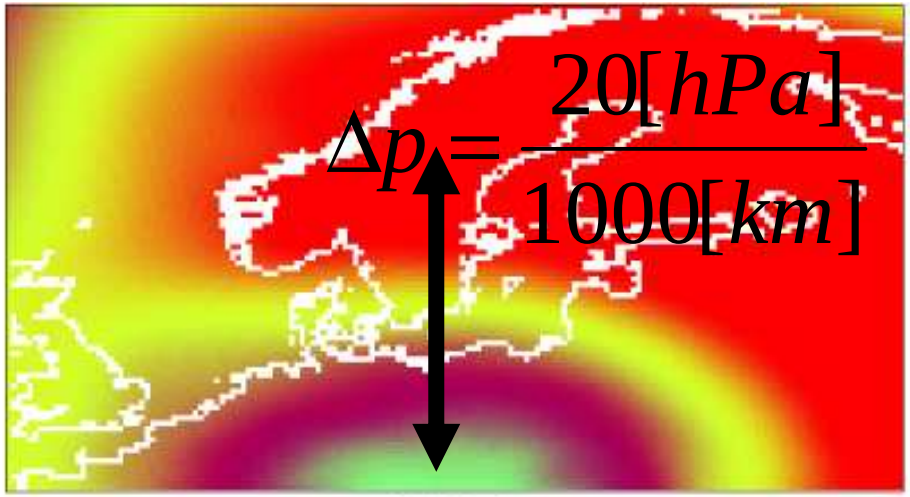


Reconstruction from station data by Rosenhagen & Bork (2009): Die Küste. Heft 75

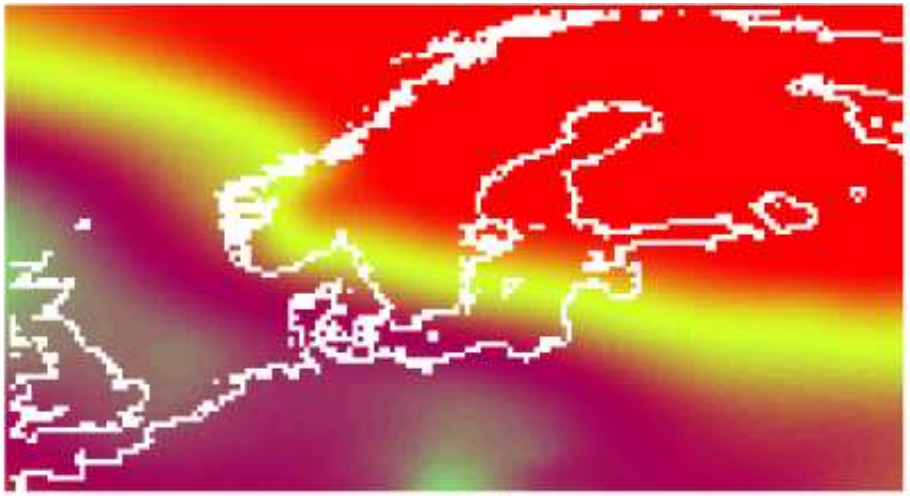
In-/Outflow of Baltic Sea



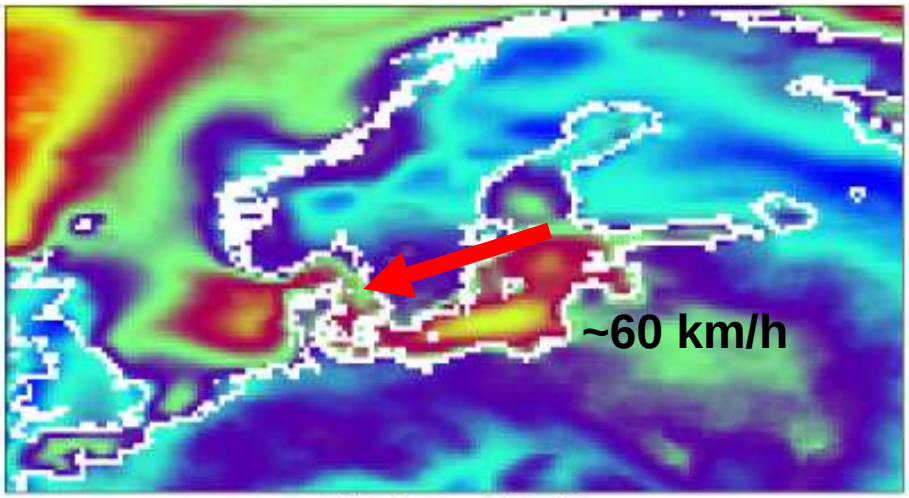

1872-11-02
SLP [Pa]
1872-11-04
SLP [Pa]
1872-11-06
SLP [Pa]
1872-11-08
SLP [Pa]
1872-11-10
SLP [Pa]
1872-11-11
SLP [Pa]
1872-11-12
1040 hPa
1000 hPa
SLP [Pa]
1872-11-13
1040 hPa
1000 hPa
SLP [Pa]



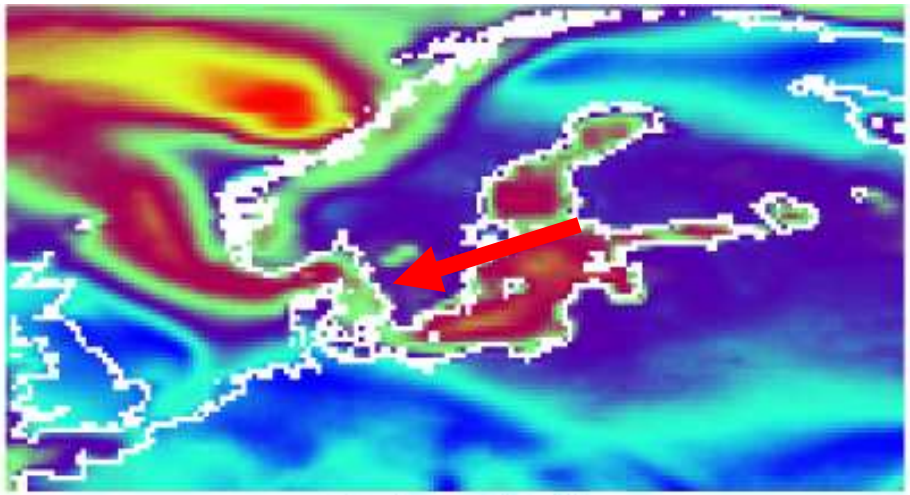
SLP [Pa]



SLP [Pa]



Wind speed [m/s]



Wind speed [m/s]

1872-11-12

Daily mean values of SLP and wind speed

1872-11-13

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Take Home

I. Analog-Method as statistical upscaling tool

- needs analog-fields and (historical) station data
- yields very similar probability distributions/variance

II. Reconstructed atmosph. Forcing fields

- realistic daily statistics including extremes
- good correlations for all variables on monthly scale

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FORSCHUNGSZENTRUM

Thank you for your attention!

HELMHOLTZ
ASSOCIATION

GKSS
FORSCHUNGSZENTRUM

Additional Materials

i.e. References for the analog-method as statistical downscaling tool

The Analog-Method

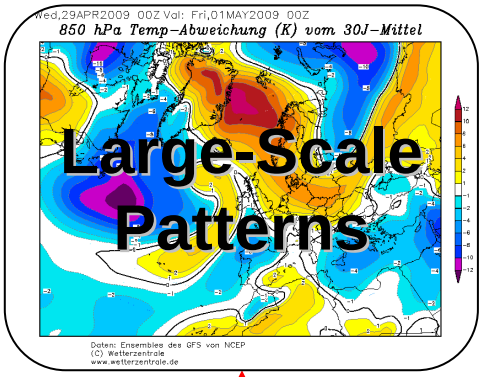
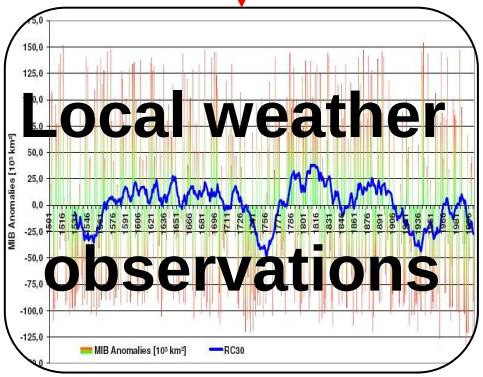
A small history @ GKSS

= statistical downscaling

i.e. find local features to given GCM fields

(mostly precipitation)

Analog-Method

Stat. Downscaling	Sample of Analogs	Stat. Upscaling
PREDICTOR: GCM simulated large-scale patterns		PREDICTAND: related to RCA simulated large-scale patterns
PREDICTAND: related to simultaneously observed local weather		PREDICTOR: observed station data of local weather

Analog-Method @ GKSS

The Analog Method as a simple statistical Downscaling Technique: Comparison with more complicated Methods

- **Zorita & v. Storch (1999), J. of Clim. 30: 133-144**
- AM most simple method → serves best

Improved field reconstruction with the analog method: searching the CCA space

- **Fernández & Sáenz (2003), Clim. Res. 24: 199-213**
- CCA better correlation, EOF/Analog better variance

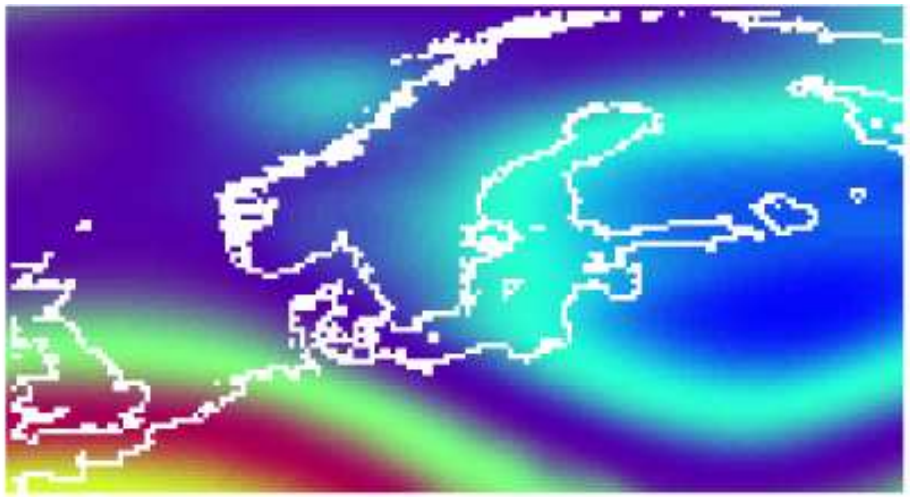
Analog-Method @ GKSS

Influence of similarity measures on the performance of the analog method downscaling daily precipitation

- **Matulla et al. (2008), Clim. Dyn. 30: 133-144**
- Most simple method (Euclidian distance) serves best

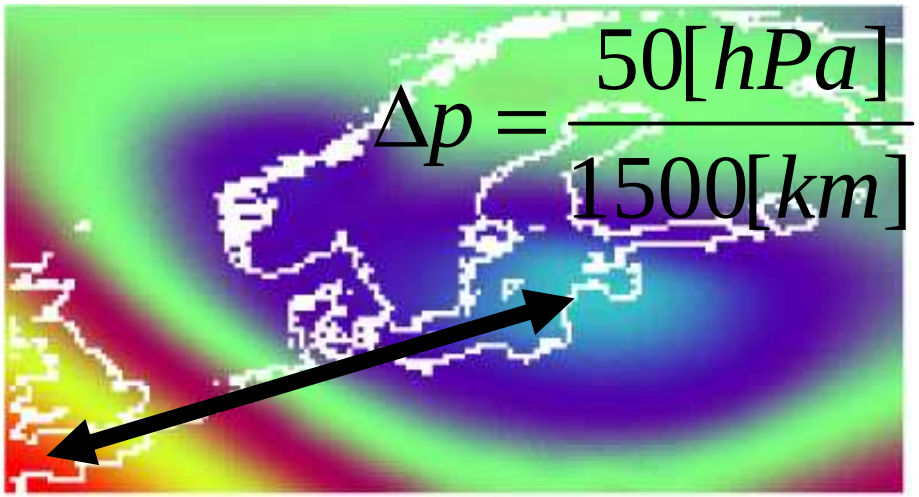
Reconstructing highly resolved atmospheric forcing fields using analog method for statistical upscaling

- **Schenk & Zorita (2011), in prep.**
- AM can be used also as simple non-linear upscaling tool



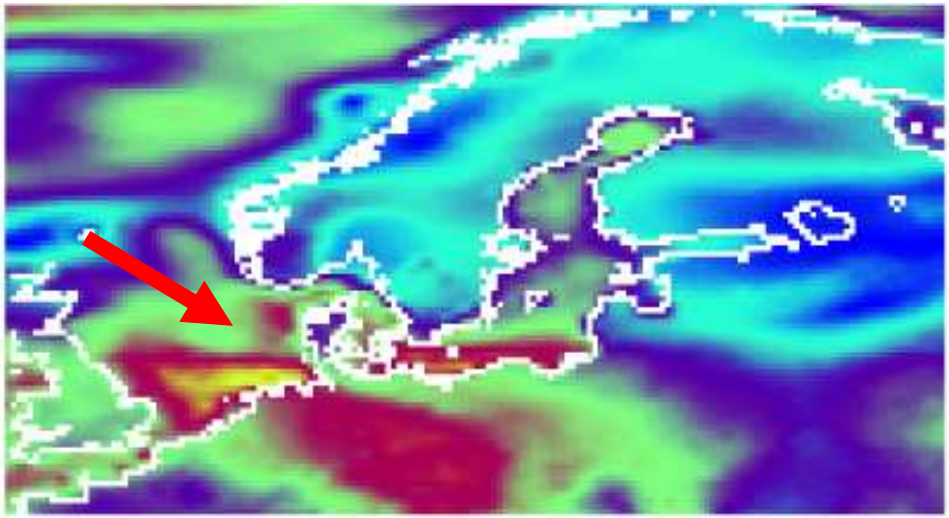
SLP [Pa]

98000 99000 100000 101000 102000 103000



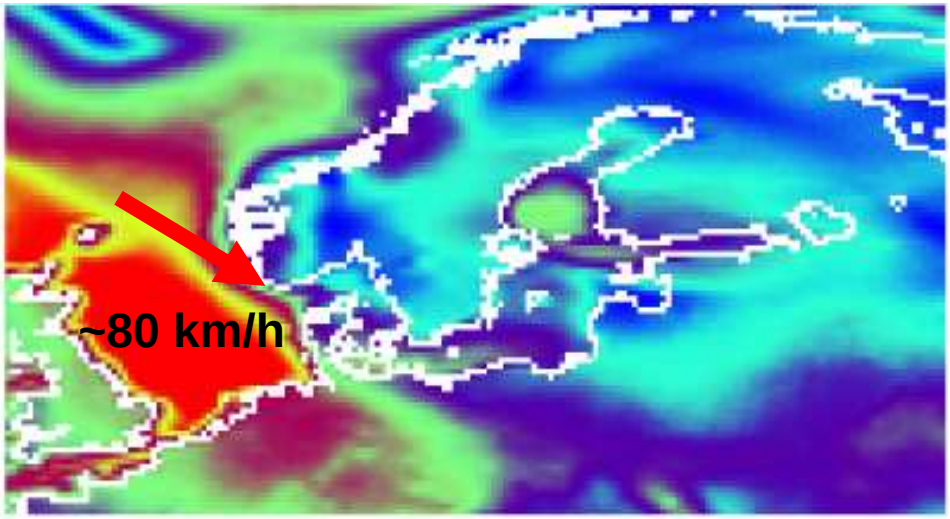
SLP [Pa]

98000 99000 100000 101000 102000 103000



Wind speed [m/s]

2 4 6 8 10 12 14 16 18 20



Wind speed [m/s]

2 4 6 8 10 12 14 16 18 20

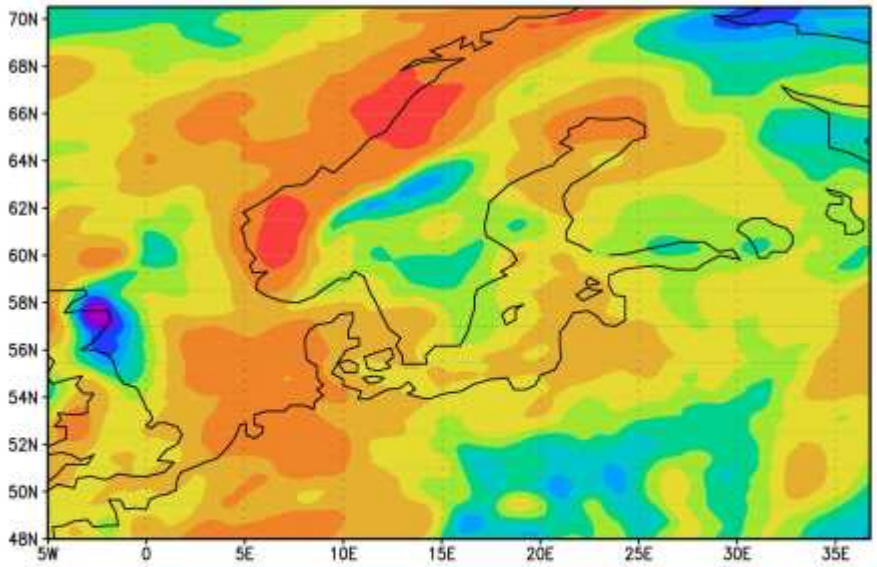
1962-02-16

Storm flood in Hamburg

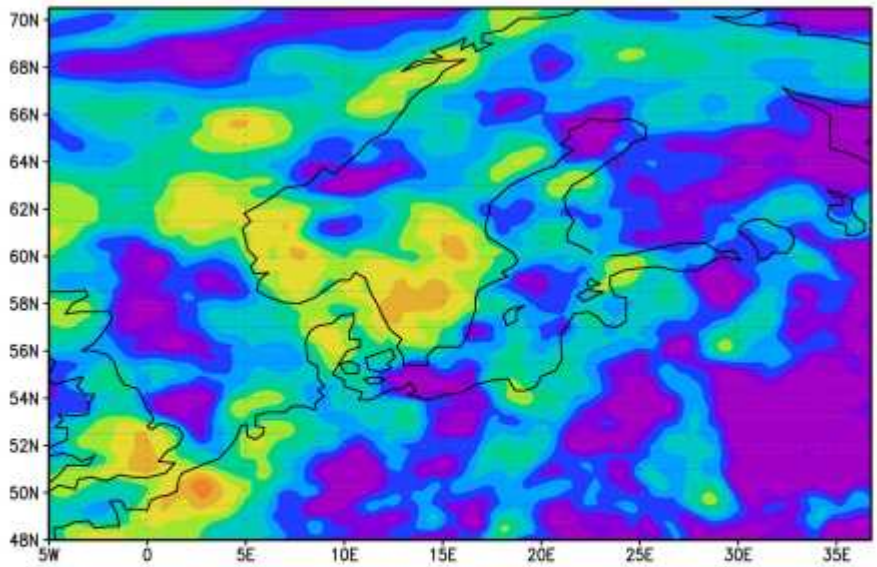
1962-02-17

HELMHOLTZ ASSOCIATION

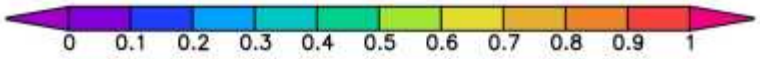
Precipitation

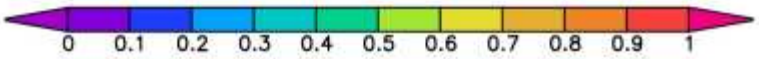


Fieldcor for JAN 1958-1983



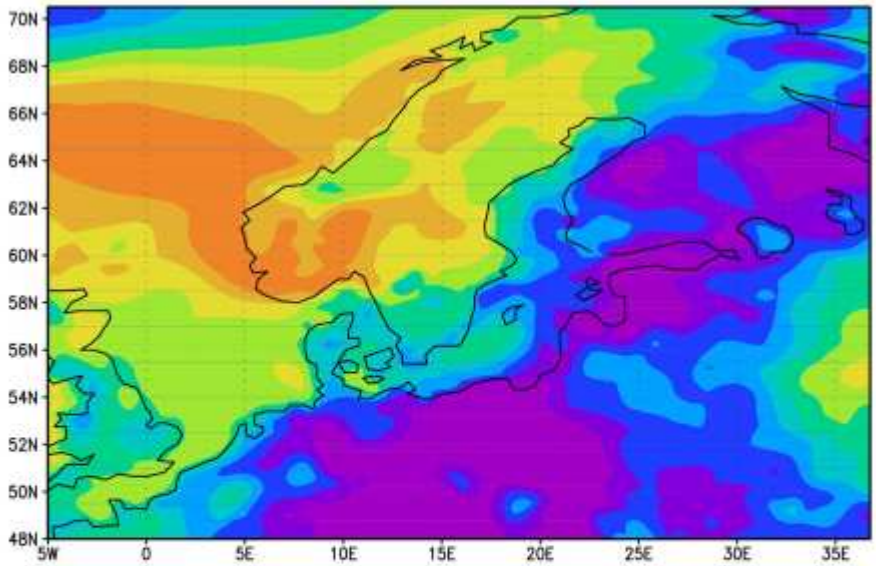
Fieldcor for JUN 1958-1983



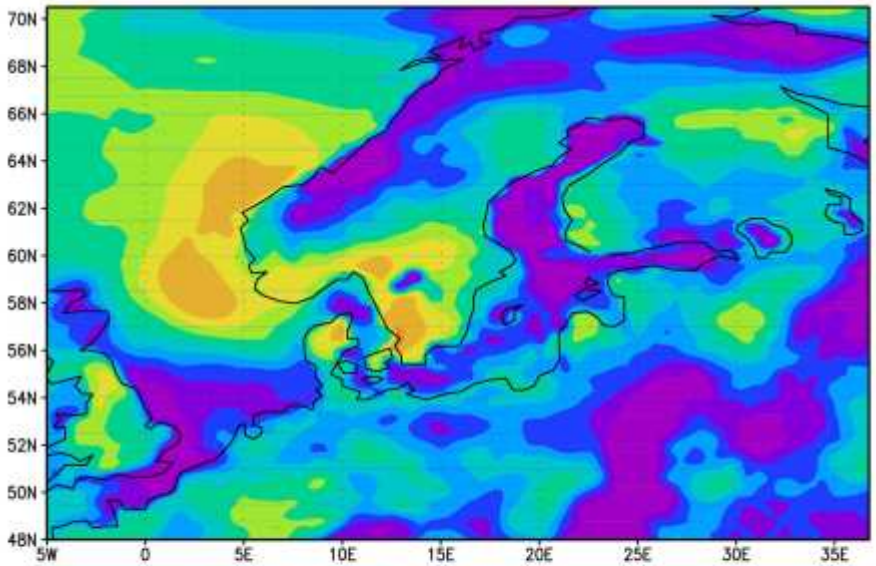


Calibration: 1984-2007

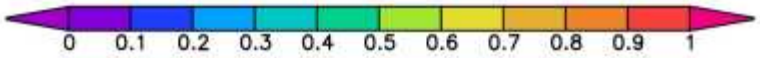
Rel. Humidity

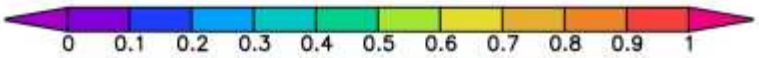


Fieldcor for JAN 1958-1983



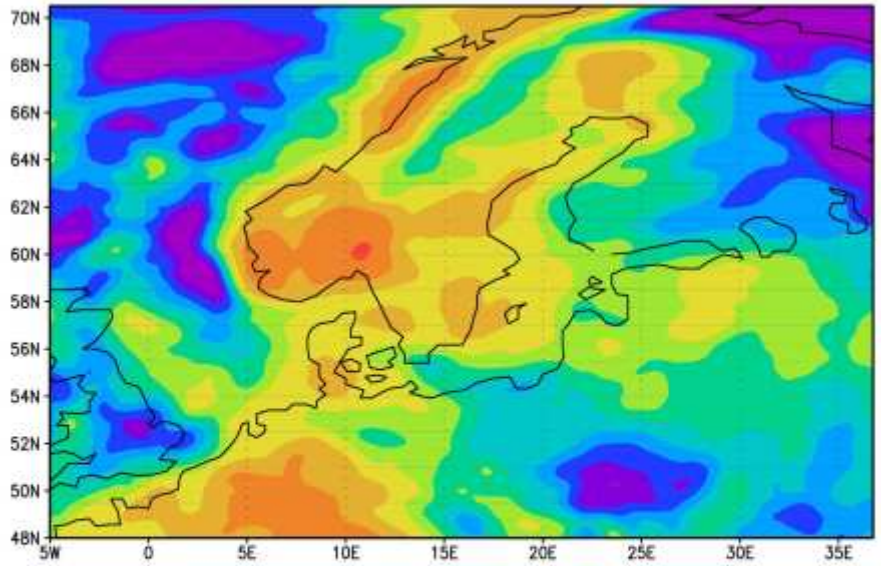
Fieldcor for JUN 1958-1983



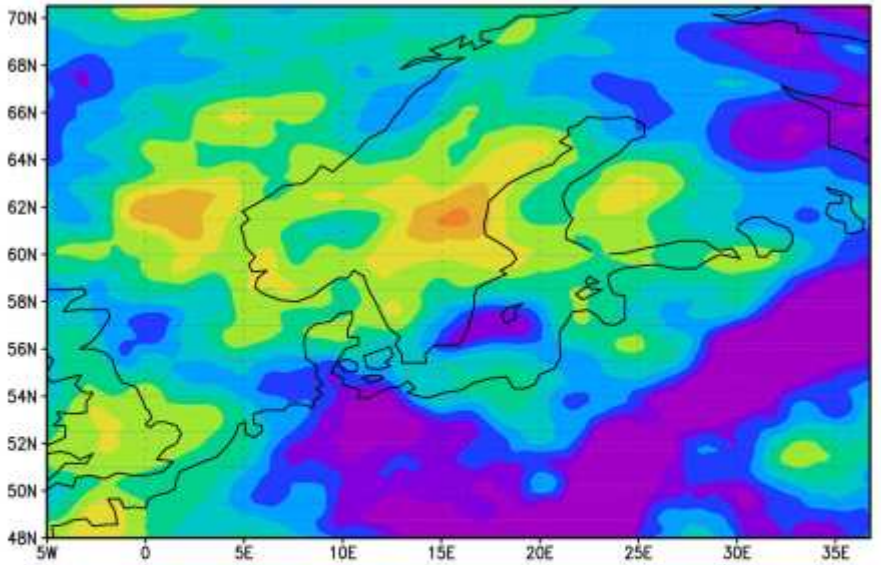


Calibration: 1984-2007

Tot. Cloud Cover



Fieldcor for JAN 1958-1983



Fieldcor for JUN 1958-1983

Calibration: 1984-2007