Holocene and Interglacial dynamics

Krakow 2014

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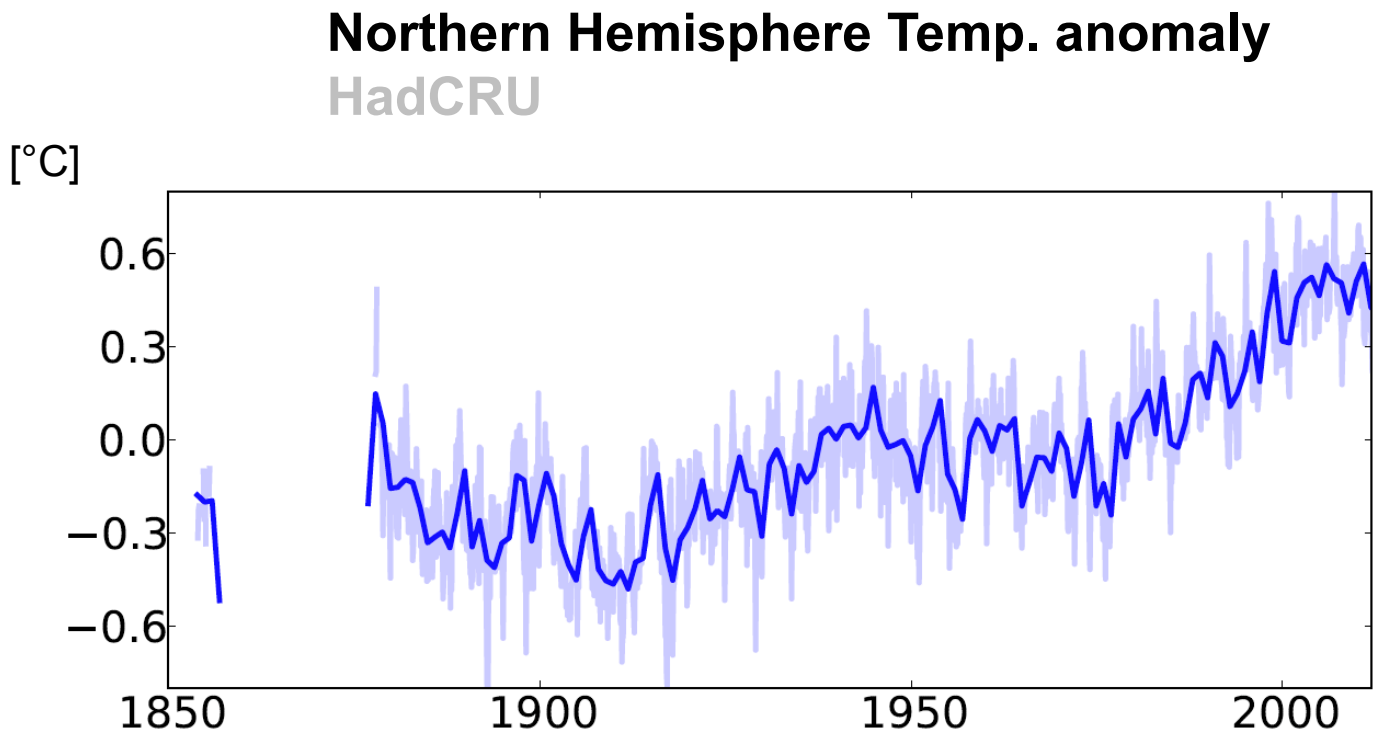
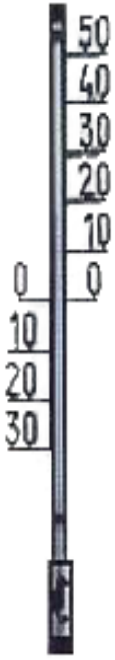
Alfred Wegener Institute
Helmholtz Centre for Polar and Marine Research

Climate Trends at different Timescales

Temperature of the last **150 years** (instrumental data)





History

last **1000 Years**

Pieter Breughel d.Ä.

Thermometer

Barometer
(Torricelli)

Little Ice
Age

present

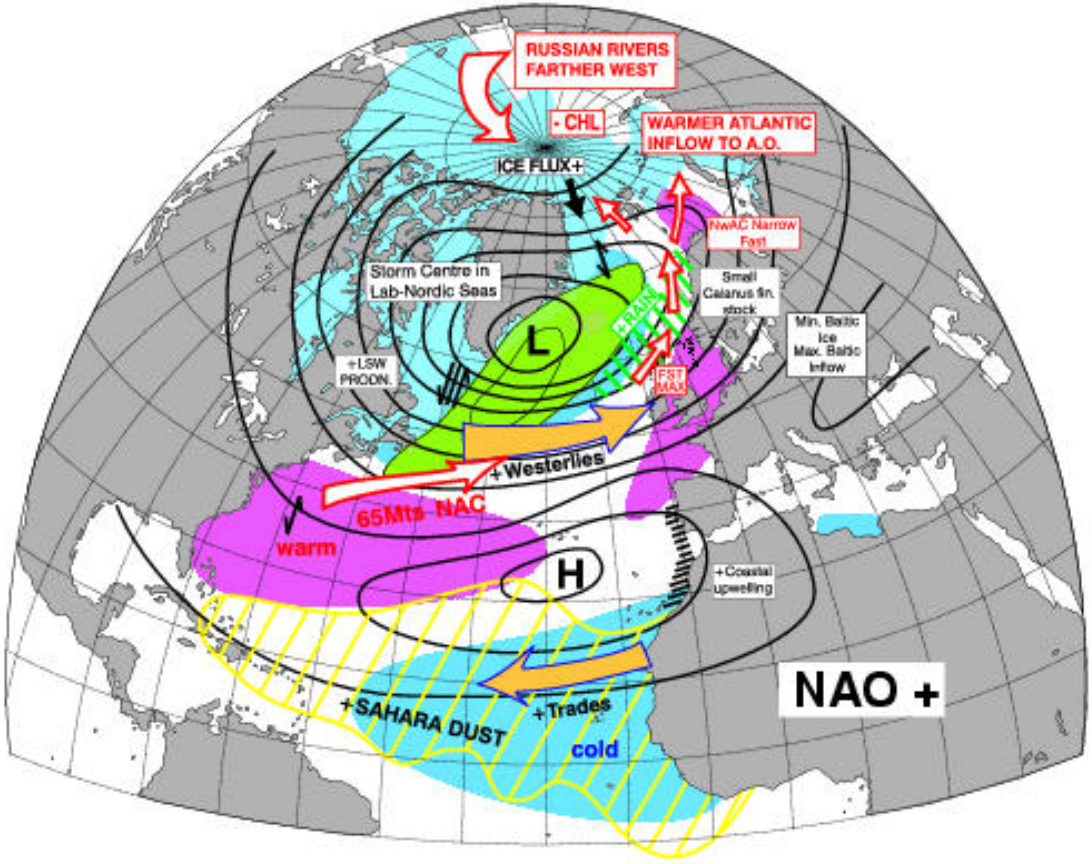
Temperature anomaly (degree)

0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4

1000 1100 1200 1300 1400 1500 1600 1700 1800 1900 2000

Nicolaus Kopernikus In Krakow

The Phases of the North Atlantic Oscillation

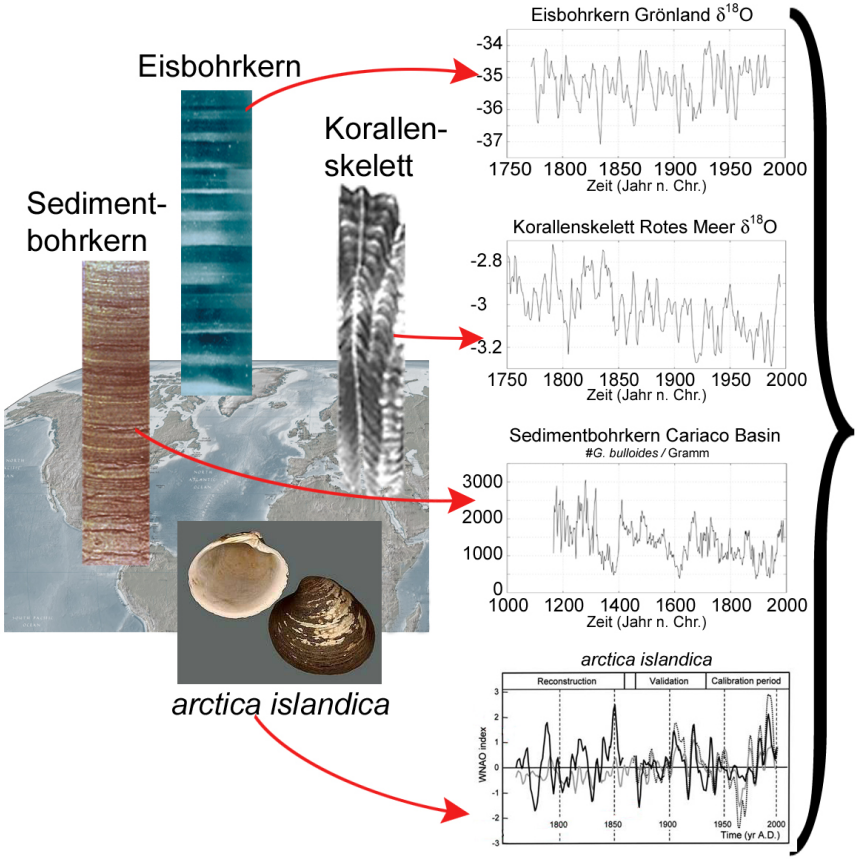


During the high phase of the NAO westerlies in the North Atlantic are enhanced, resulting in mild and wet winter conditions over Northern Europe. (Courtesy of CEFAS, UK)

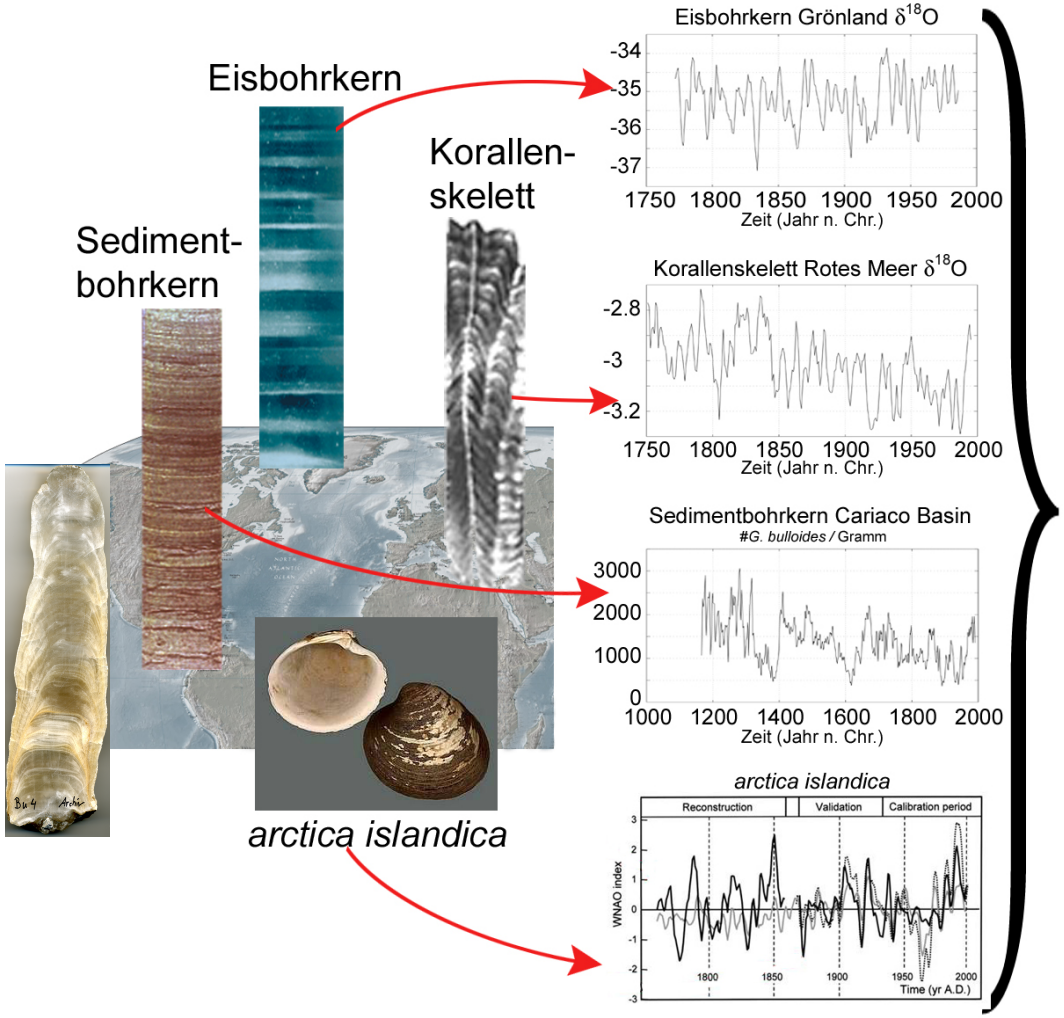
AV/D1/99-1

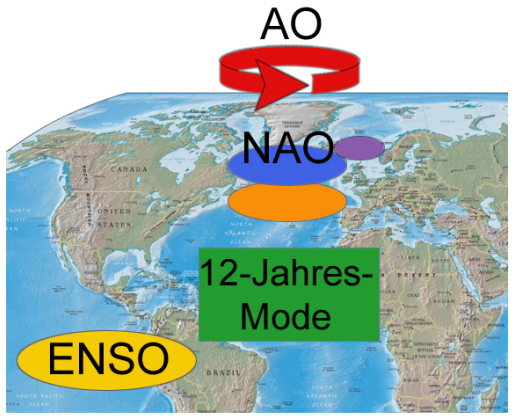
Proxy Data

- Indirect data, often qualitative
- Long time series from archives
- Information beyond the instrumental record



Upscaling Konzept

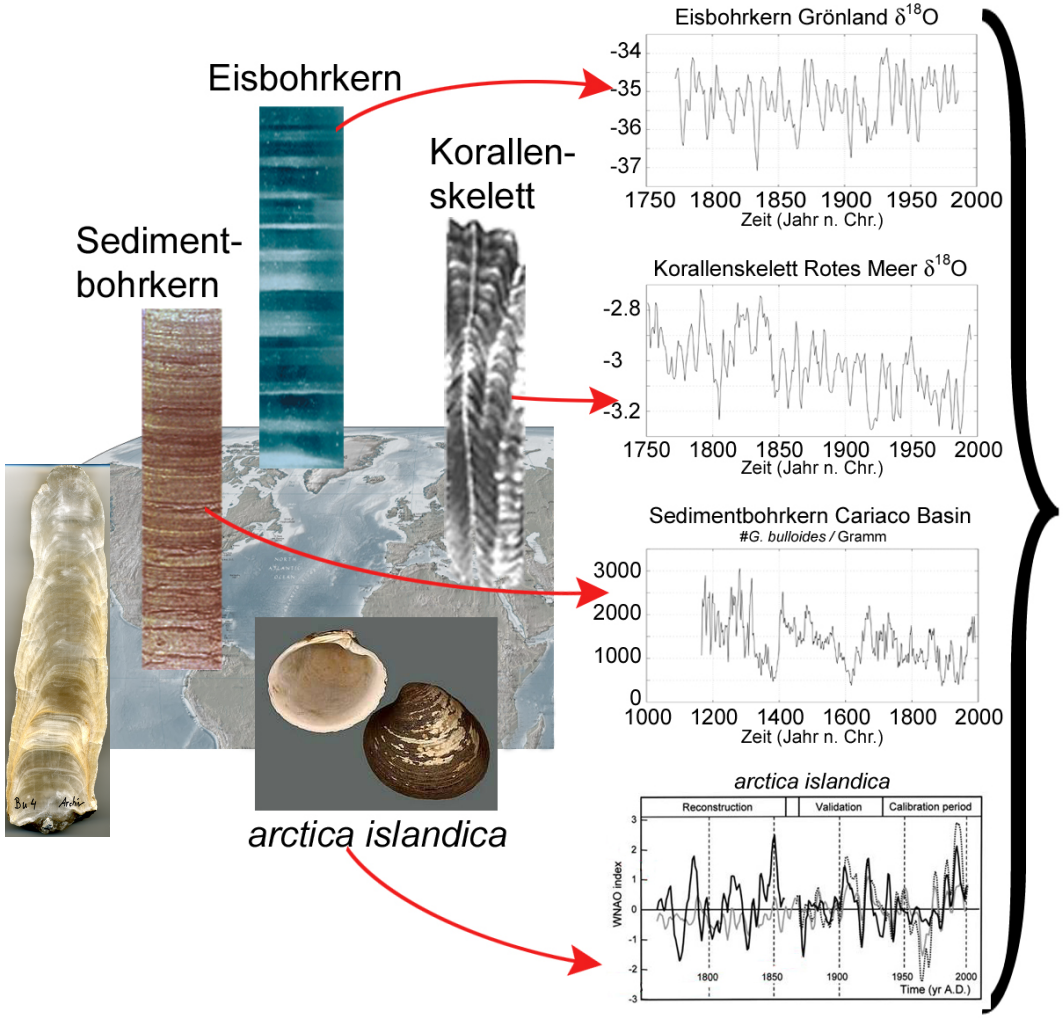


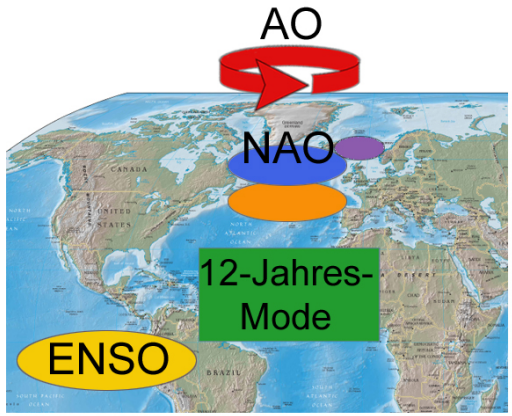


Climate archives

Climate variabiliy

Upscaling Concept





Climate archives

Climate variabiliy

Statistic

Covariance (cross, auto)

$$\gamma(\Delta) = E\left((x(t) - \bar{x}) (y(t + \Delta) - \bar{y}) \right)$$

e.g. coral e.g. meteorol. data

Correlation (cross, auto)

$$\rho_{xy} = \frac{\gamma(\Delta)}{\text{normalized}}$$

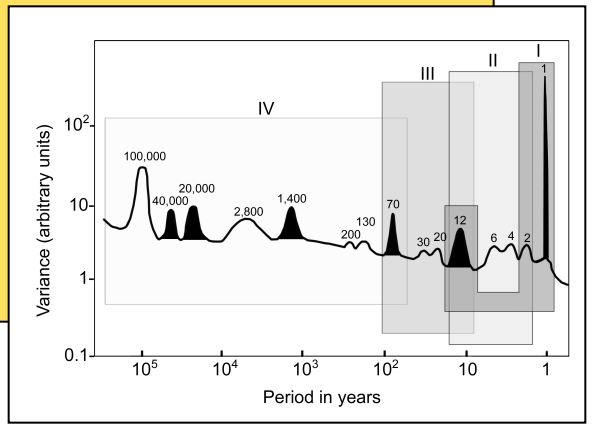
measures the tendency of x (t) and y (t) to covary

Spectrum (cross, auto)

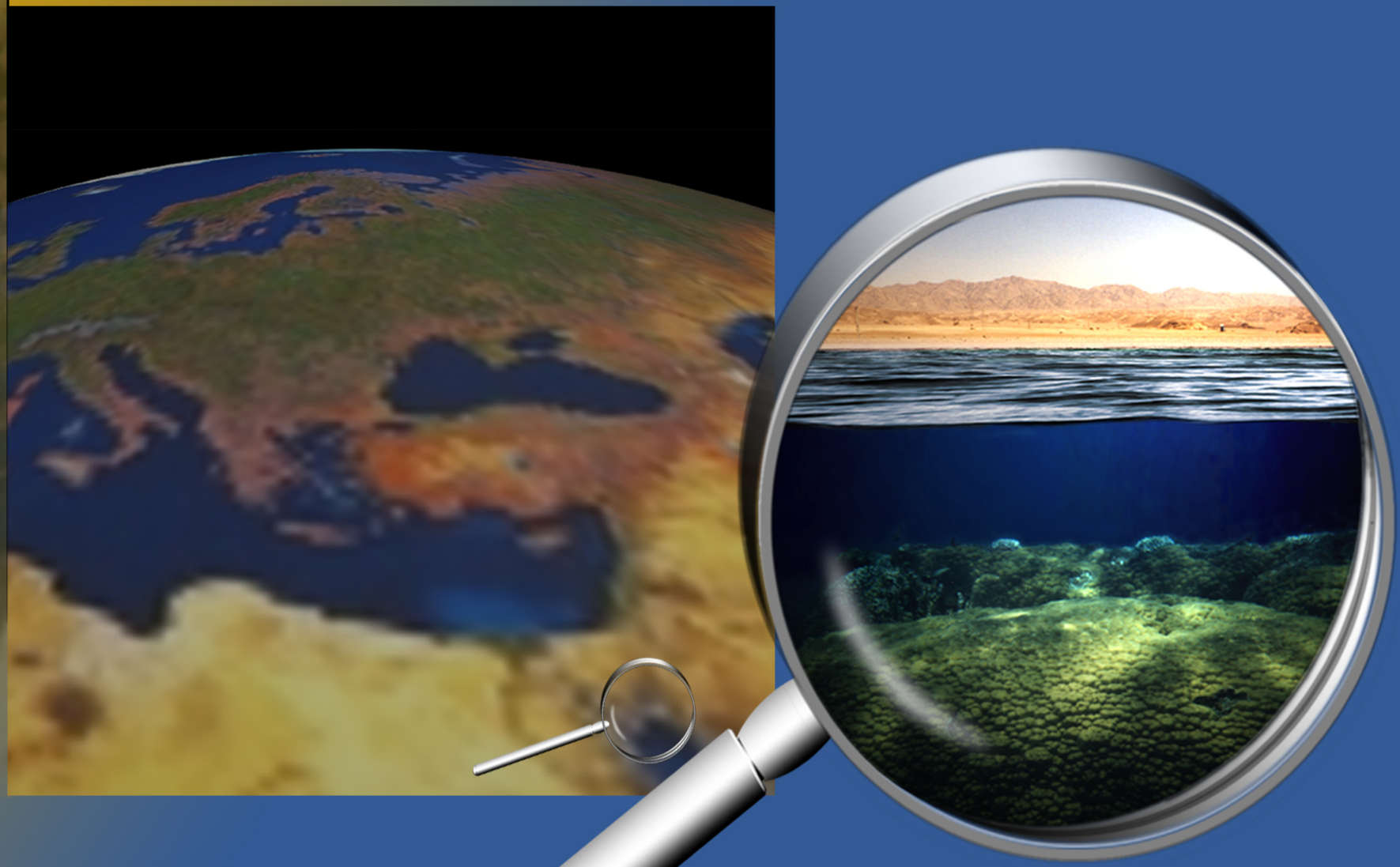
(spectral density)

$$\Gamma(\omega) = \sum_{\Delta=-\infty}^{\infty} \gamma(\Delta)\, e^{-2\pi i \Delta}$$

measures variance

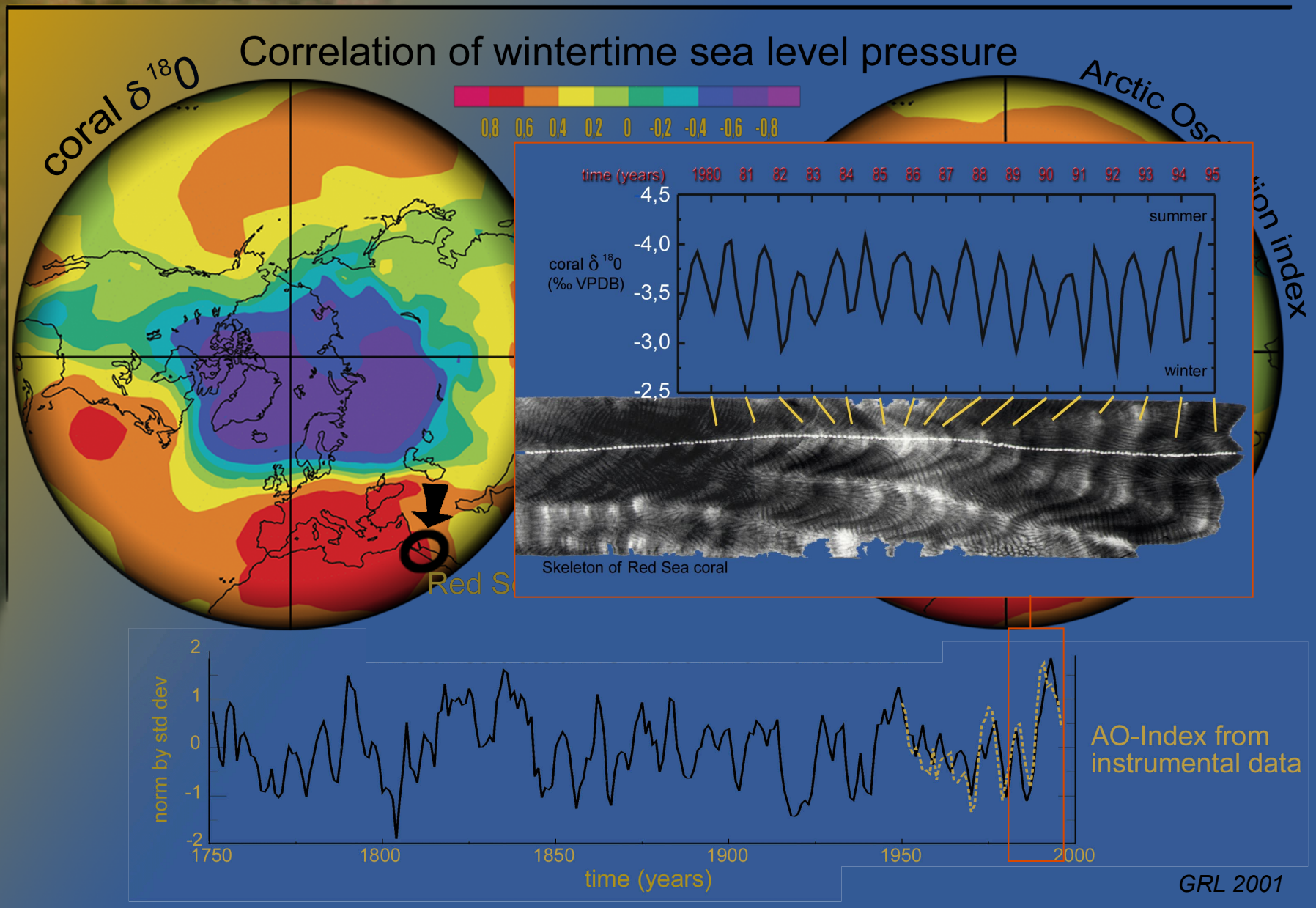


Climate Modes from Proxy Data

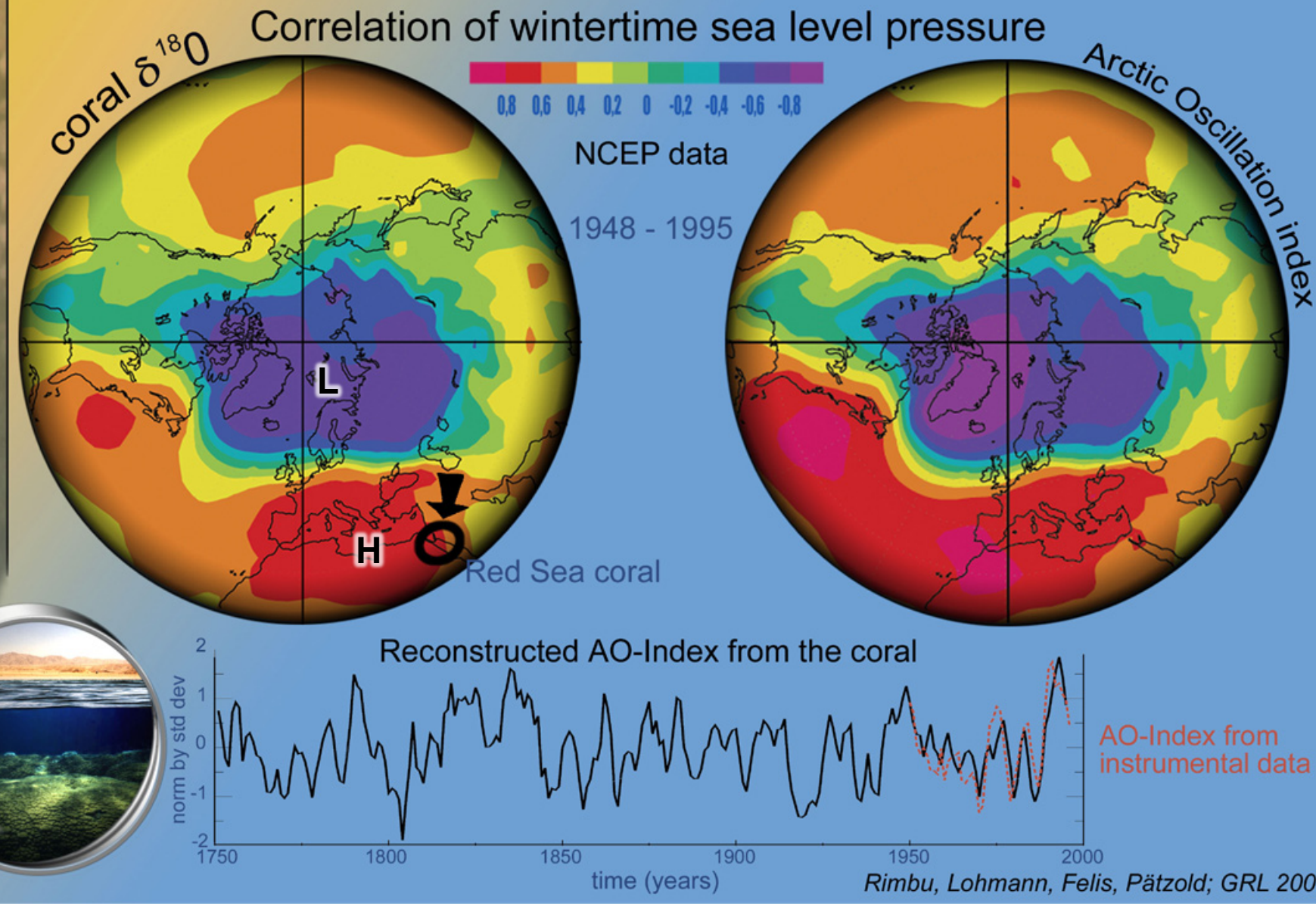


Red Sea coral

Climate Modes from Proxy Data

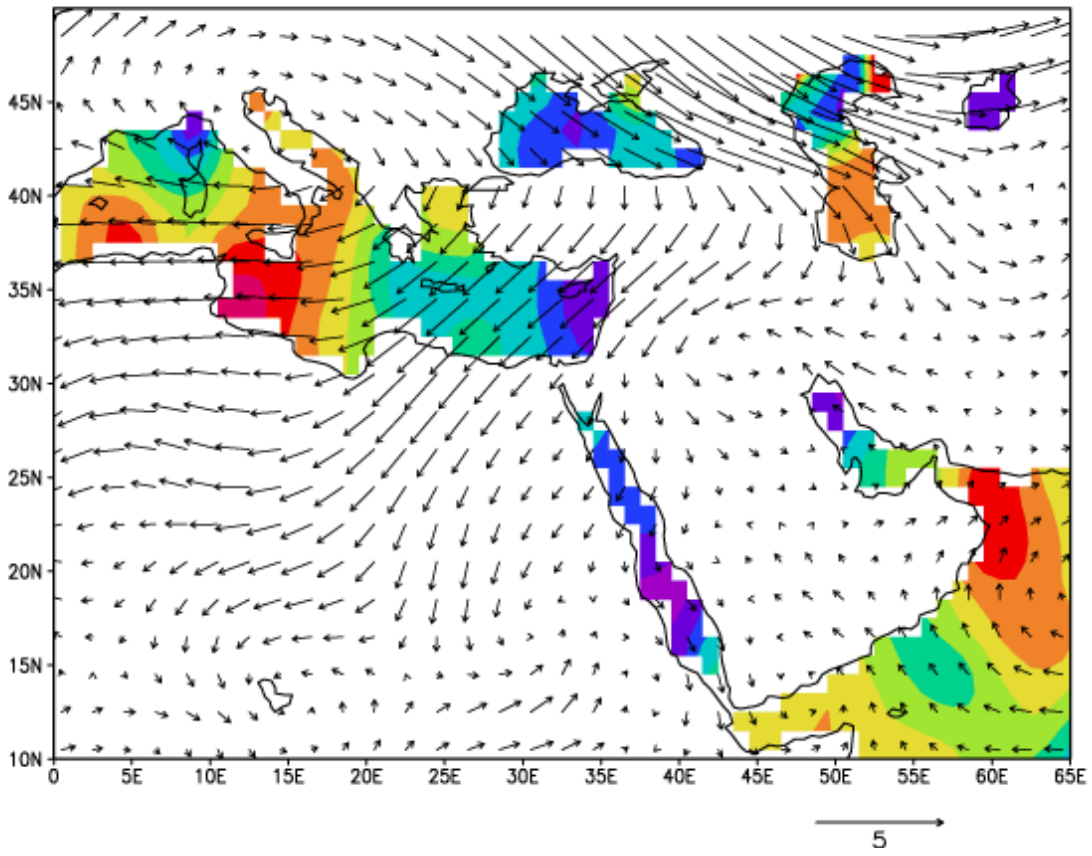


ARCTIC OSCILLATION SIGNATURE IN A RED SEA CORAL



Linking observations with corals

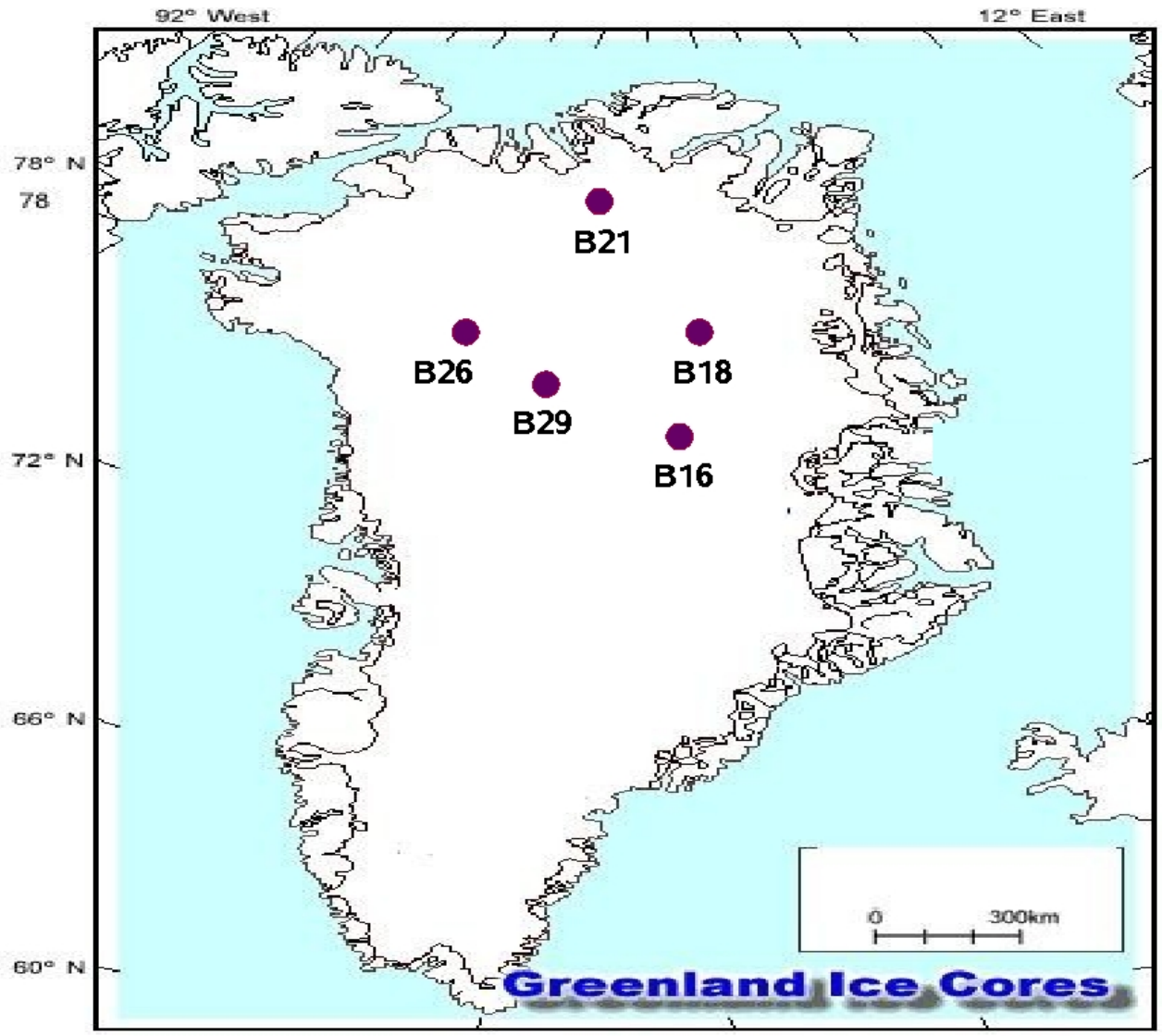
ARCTIC OSCILLATION SIGNATURE IN A RED SEA CORAL



Composite Map of SST [°C] and 925 hPa wind [m/s] for 1948 -1995, January - February

mechanistic understanding

SNOW ACCUMULATION ICE CORE



Greenland Traverse AWI (1993-1995)

- Shallow ice core (depths up to 150 m)
- Mean accumulation rates vary between:

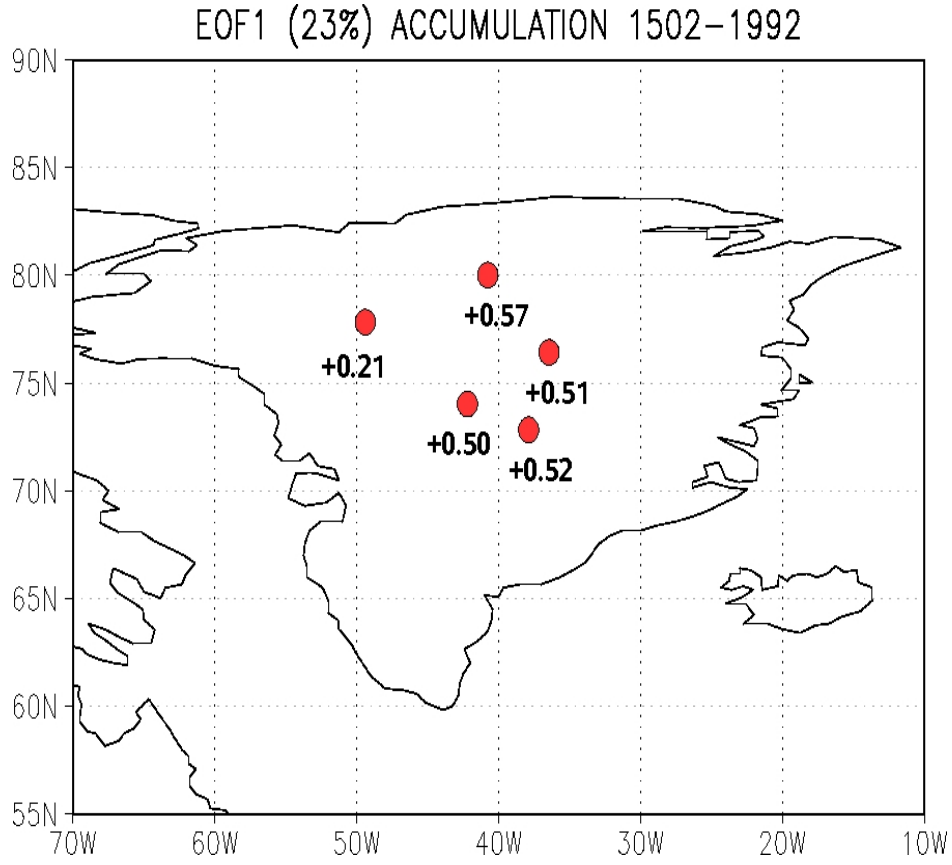
$$104 \pm 32\, mm_{w.e.}\, a^{-1}$$

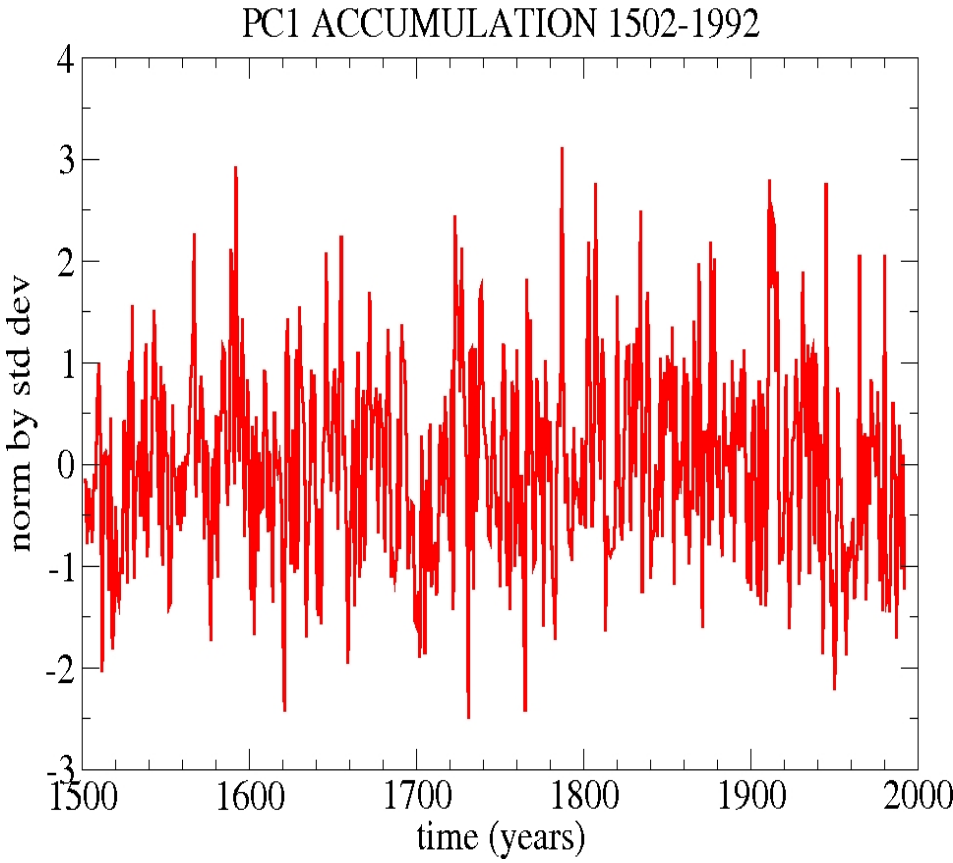
and:

$$179 \pm 49\, mm_{w.e.}\, a^{-1}$$

Description: Schwager, AWI report, 2000

DOMINANT PATTERN OF ACCUMULATION VARIABILITY



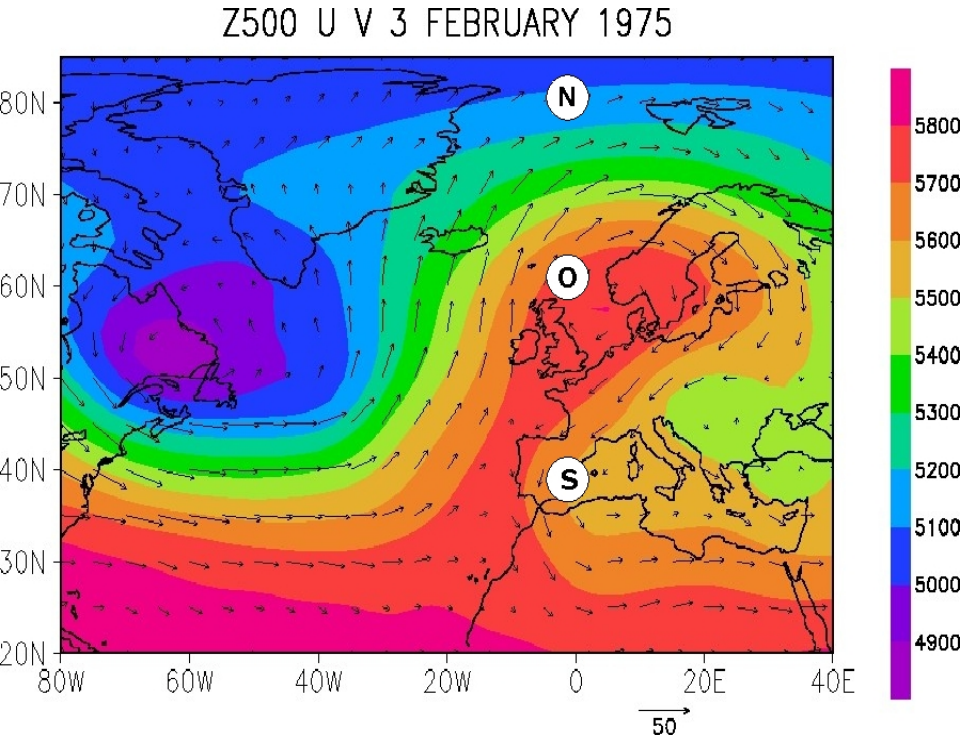


EOF1- MONOPOLAR STRUCTURE POSSIBLE RELATED TO LARGE-SCALE ATMOSPHERIC CIRCULATION

PC1 – INTERANNUAL AND DECADAL VARIATIONS

Rimbu, Lohmann, Grosfeld, GRL, 2007

ATMOSPHERIC BLOCKING (Tibaldi &Moltini)



$$GHGS = (Z(\Phi_O) - Z(\Phi_S))/(\Phi_O - \Phi_S)$$

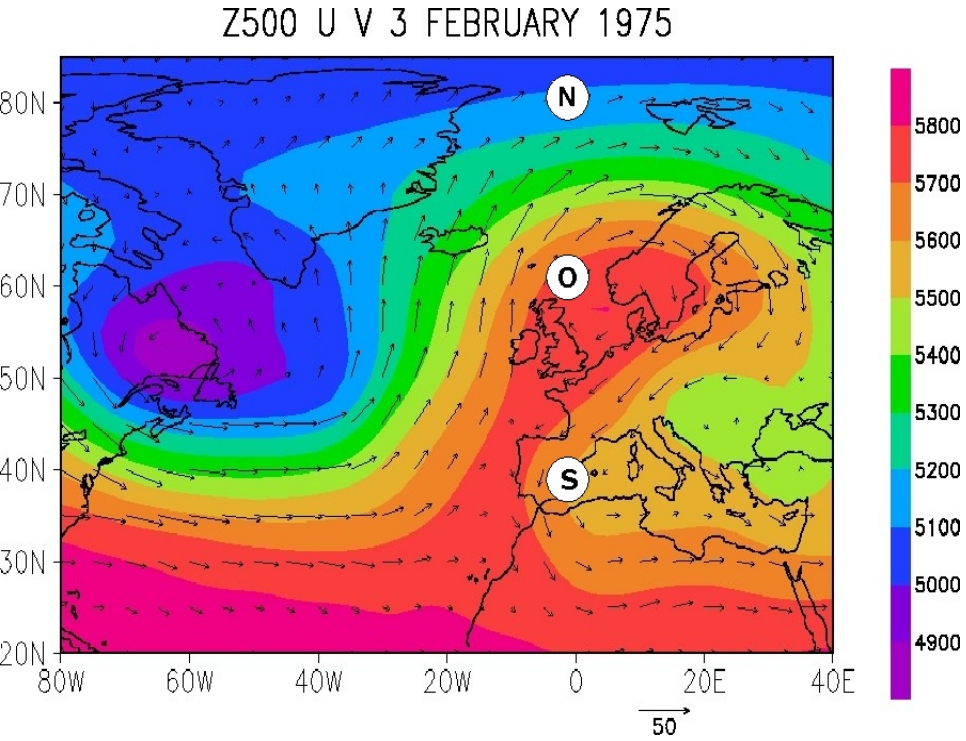
$$GHGN = (Z(\Phi_N) - Z(\Phi_O))/(\Phi_N - \Phi_O)$$

$$\Phi_N = 80^o N + \Delta,\ \Phi_O = 60^o N + \Delta,\ \Phi_S = 40^o N + \Delta,$$

$$\Delta = -5^o, 0^o, 5^o$$

Z500 (NCEP): 1948-2005 (57 winters)
TM index (Tibaldi and Molteni,1990)

ATMOSPHERIC BLOCKING



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A longitude is blocked if:

$$GHGS > 0$$

$$GHGN < -10\mathrm{m}/(deg.lat.)$$

for at least one Δ

Z500 (NCEP): 1948-2005 (57 winters)
TM index (Tibaldi and Molteni,1990)

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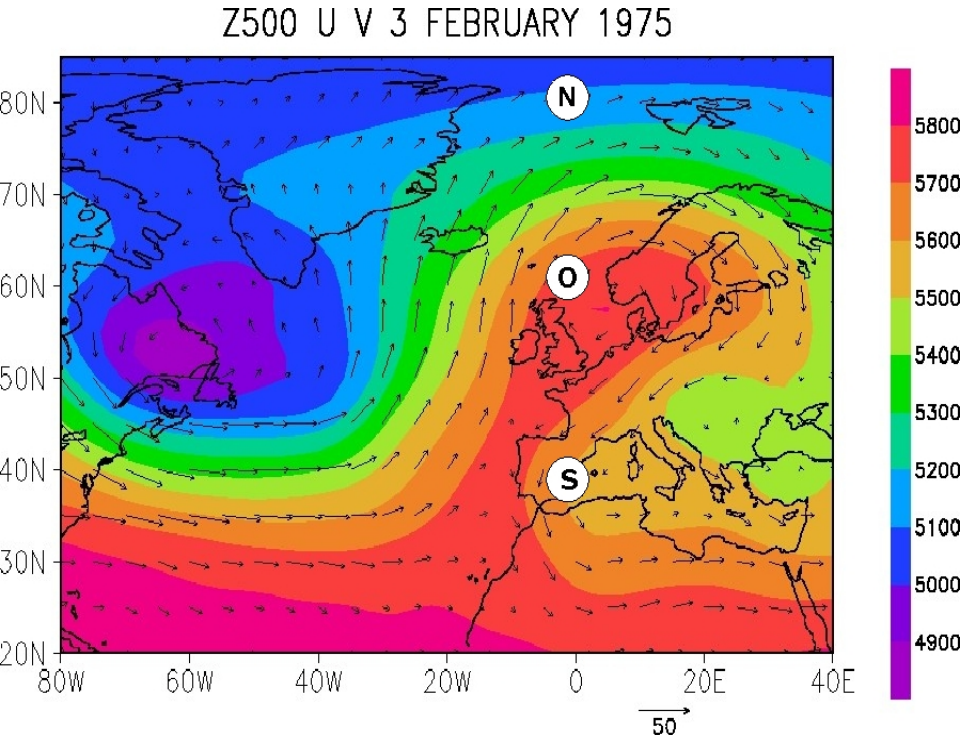

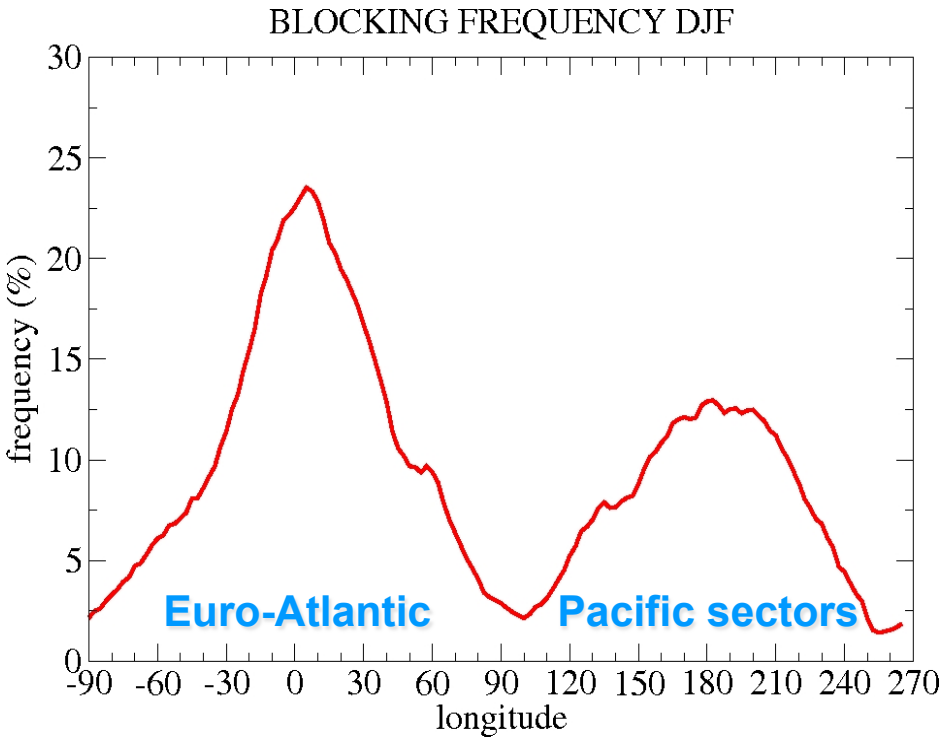

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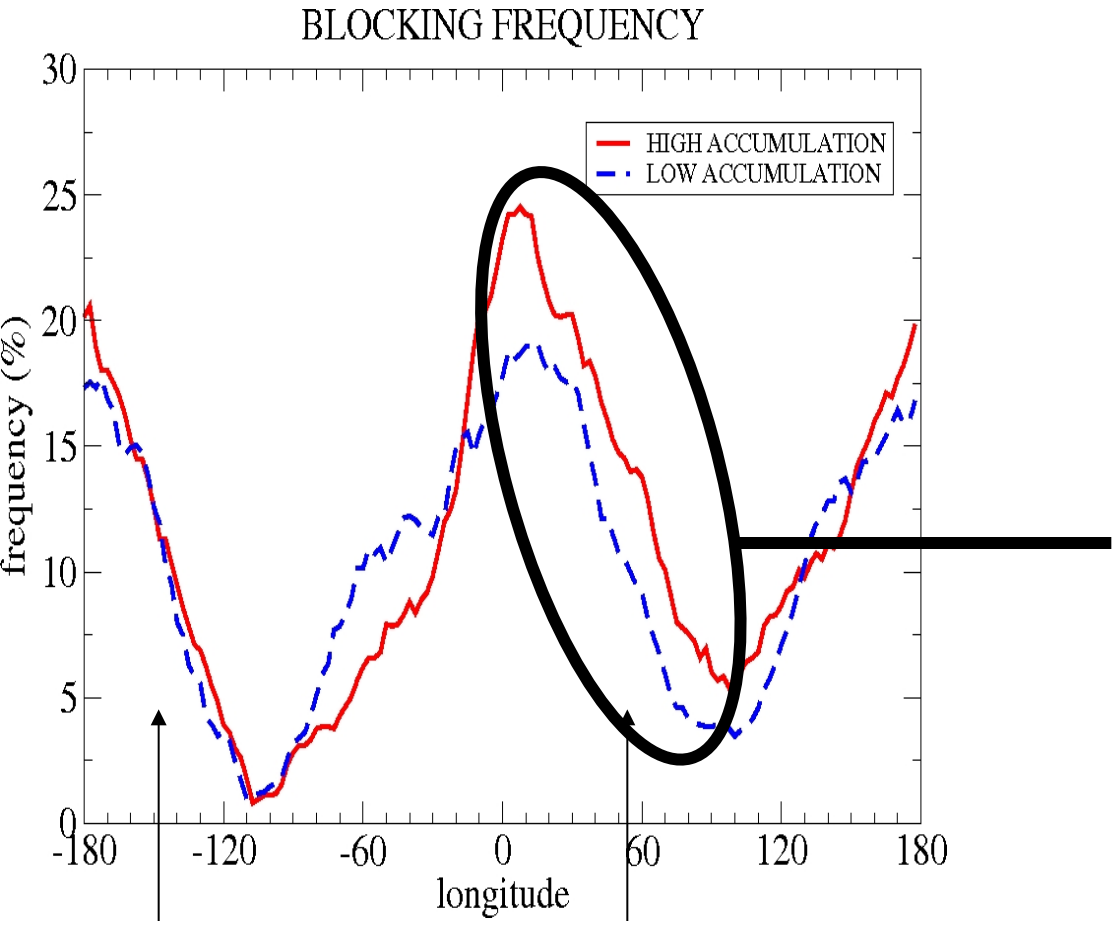
TM index (Tibaldi and Molteni,1990)

BLOCKING FREQUENCY FOR HIGH AND LOW ACCUMULATION YEARS

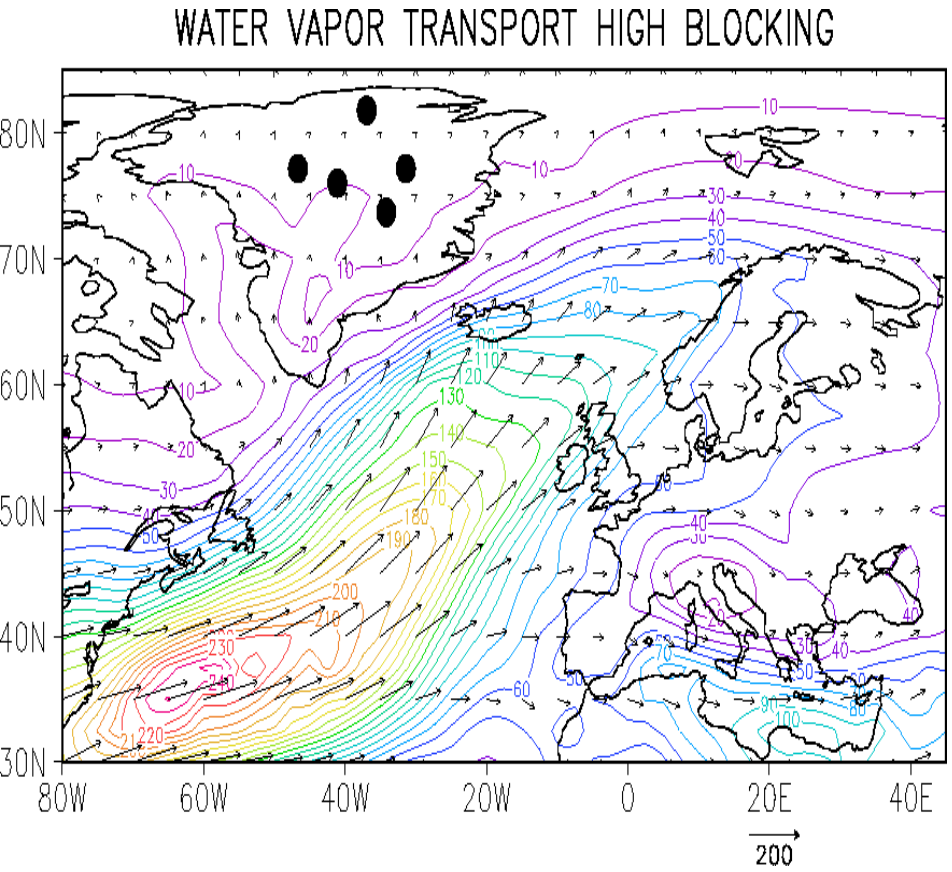


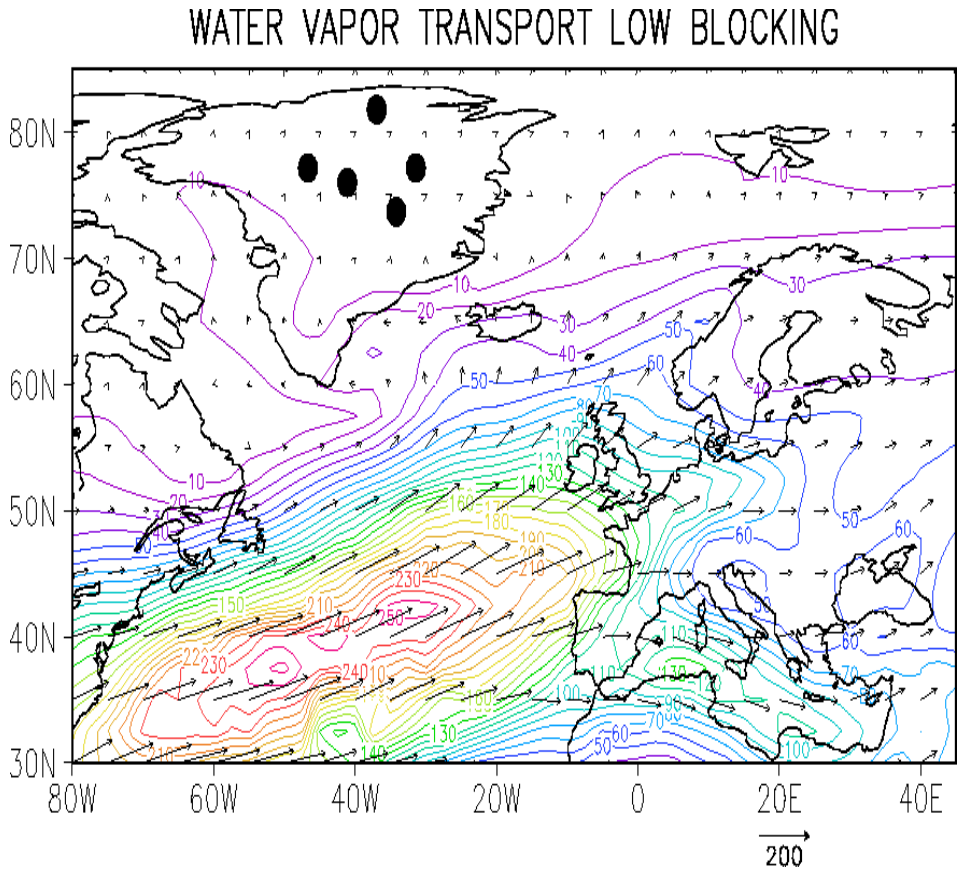
Frequency of blocking is higher during high accumulation years

Pacific

Euro-Atlantic sectors

WATER VAPOR TRANSPORT





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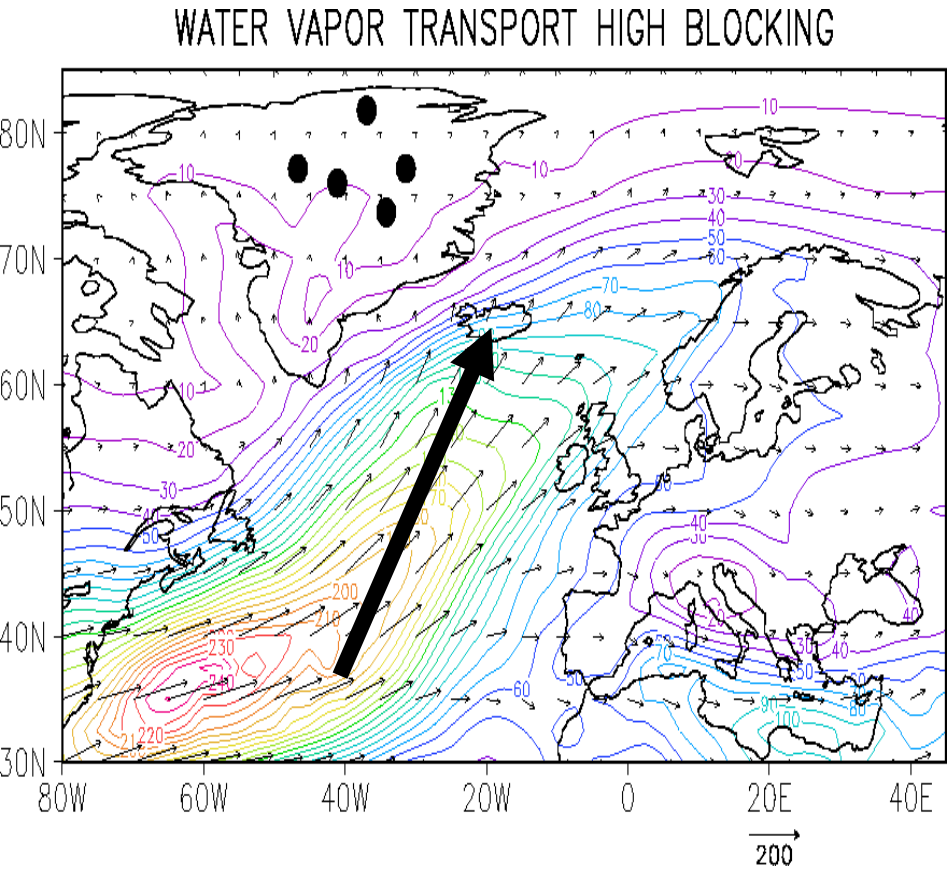
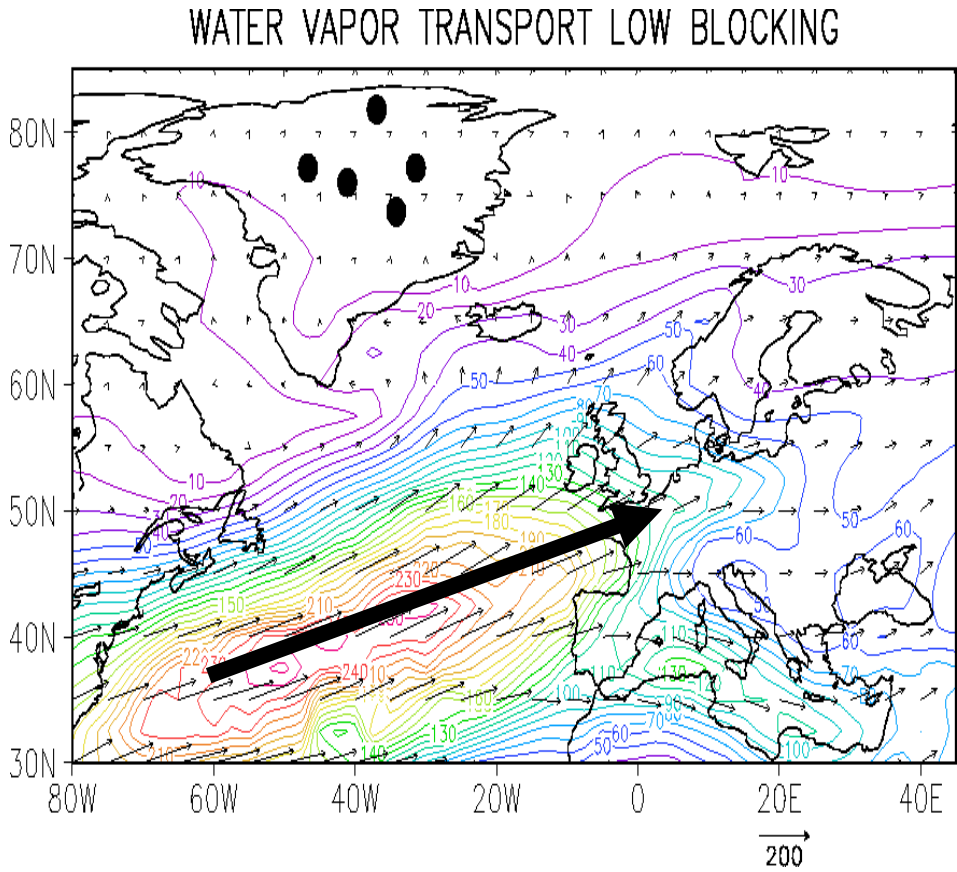
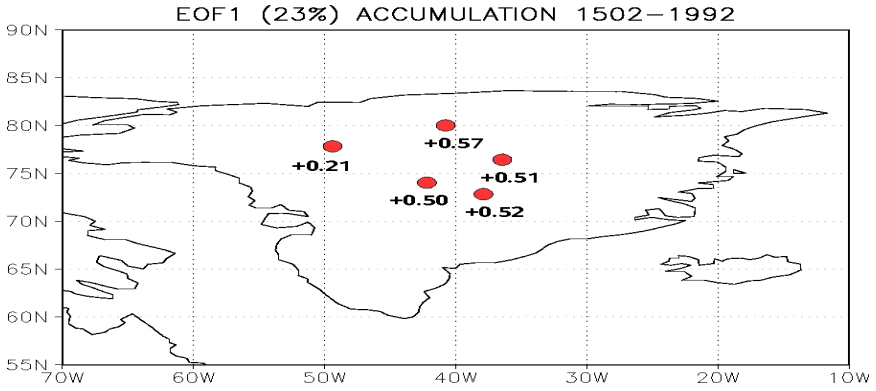




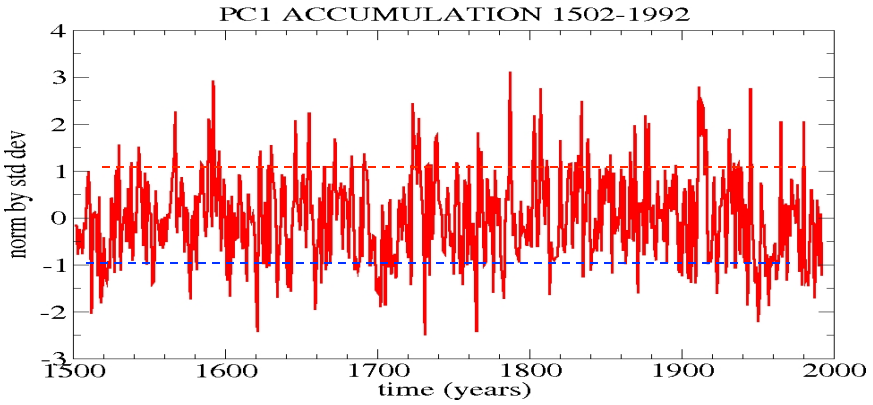
ENHANCED MOISTURE TRANSPORT TOWARD GREENLAND DURING HIGH BLOCKING ACTIVITY IN 20ºW - 20ºE SECTOR

Atmospheric Blocking Circulation

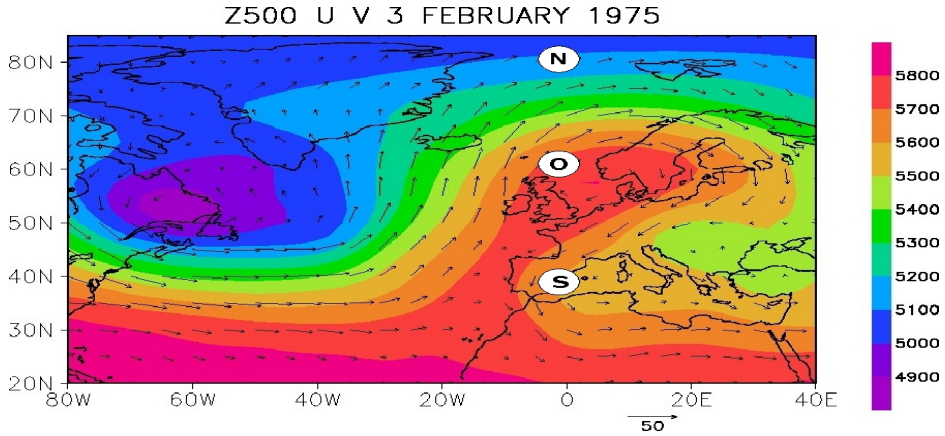
Greenland Shallow Ice Core Positions



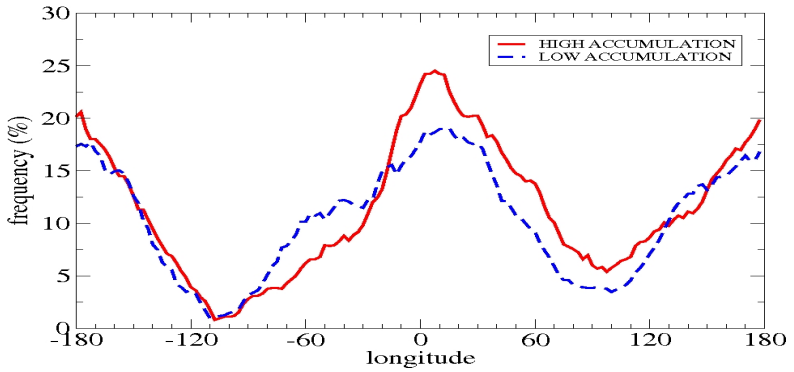
Variability of Accumulation Rate



Synoptic Scale Blocking Situation

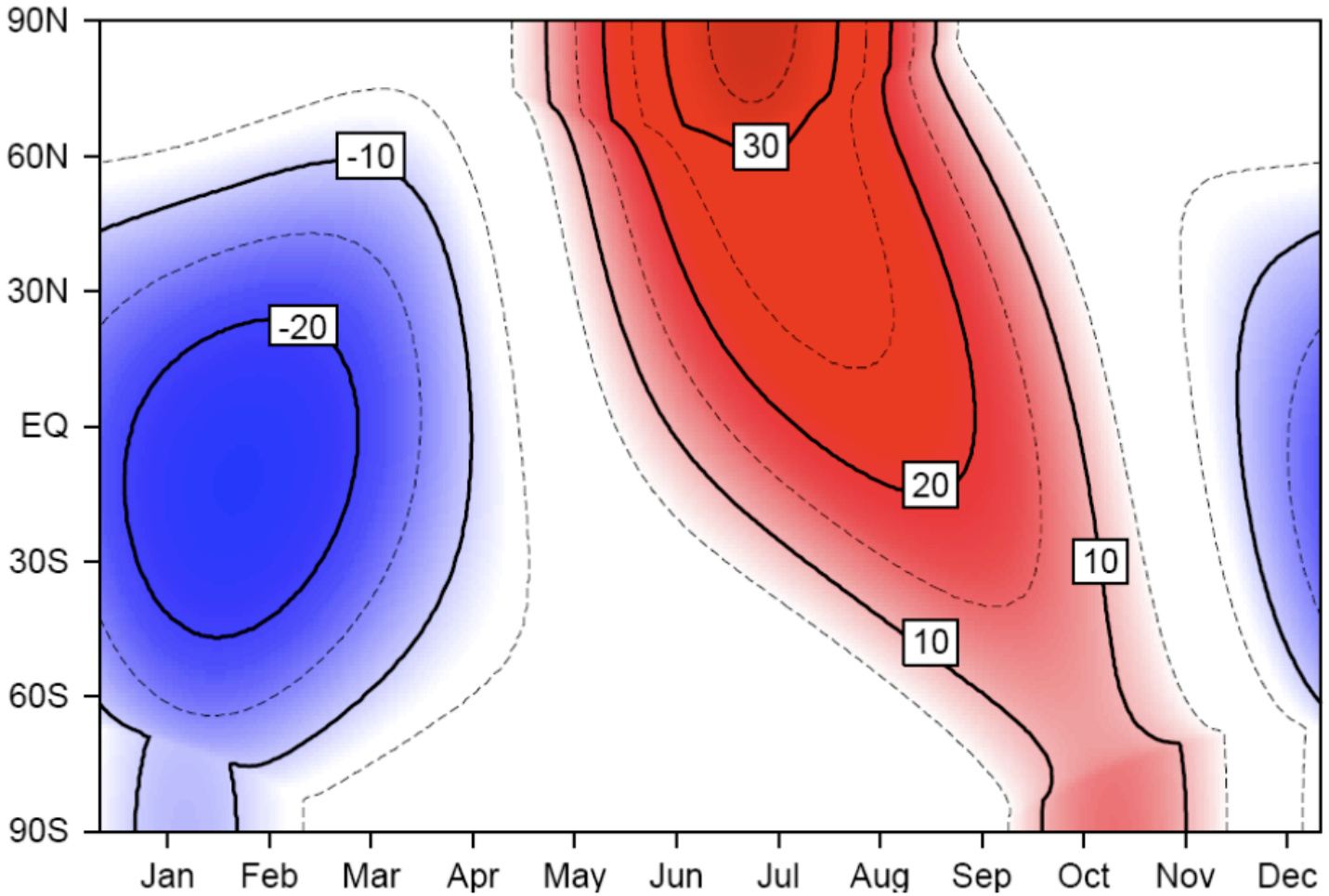


Blocking Frequency for period 1948-1992

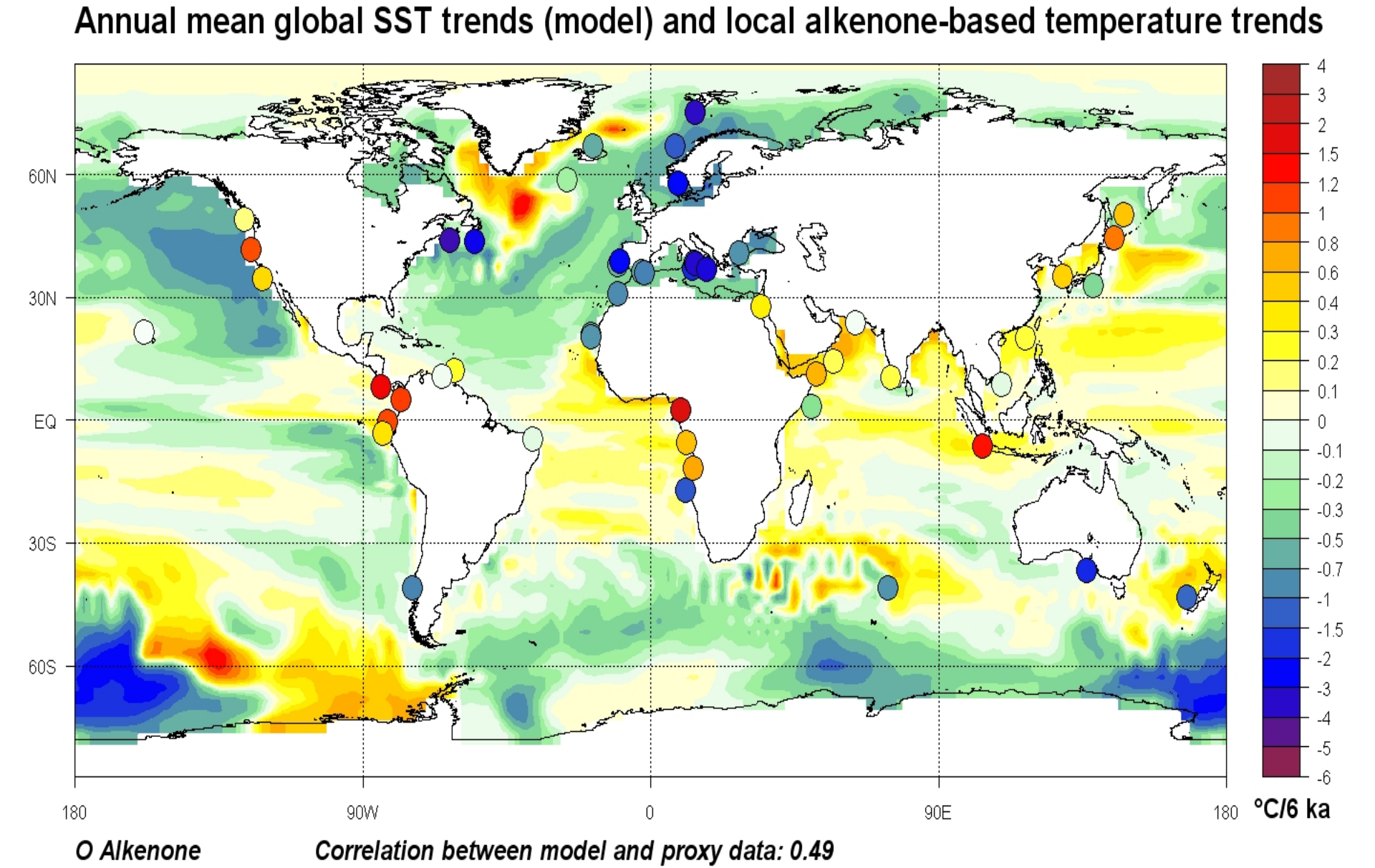


Rimbu, Lohmann, Grosfeld, 2007;
Rimbu and Lohmann 2009

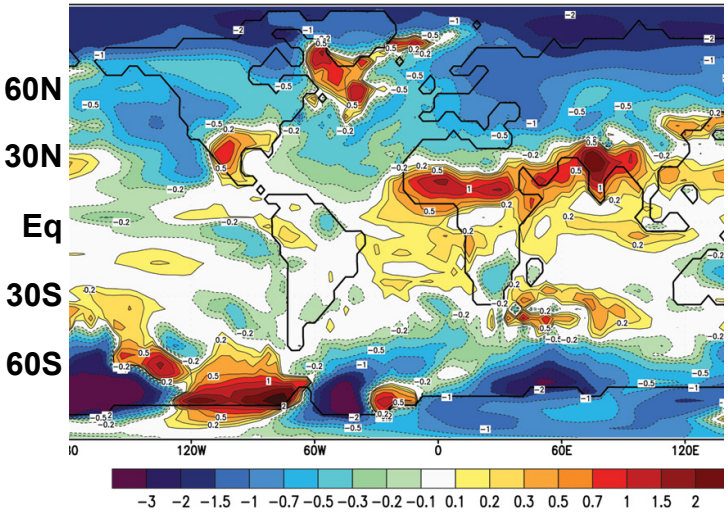
Insolation (6k minus present)



Model-Data Comparison Using the ECHO-G Model



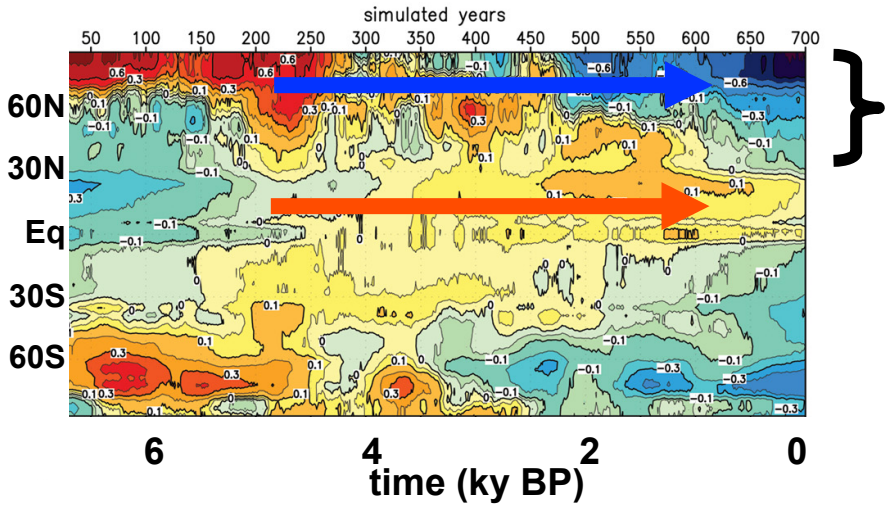
last 7000 years: Models & Data



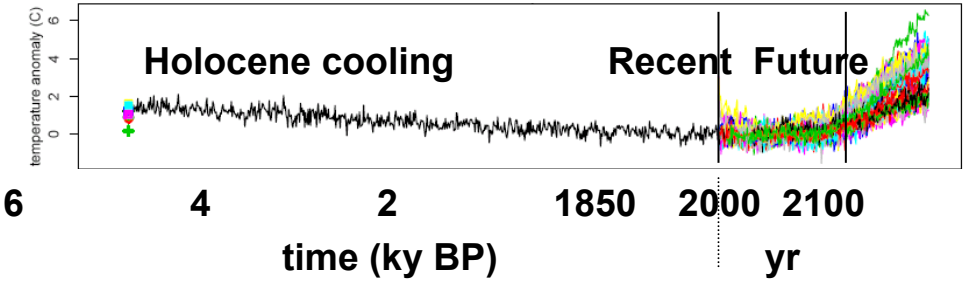
°C/7 ky

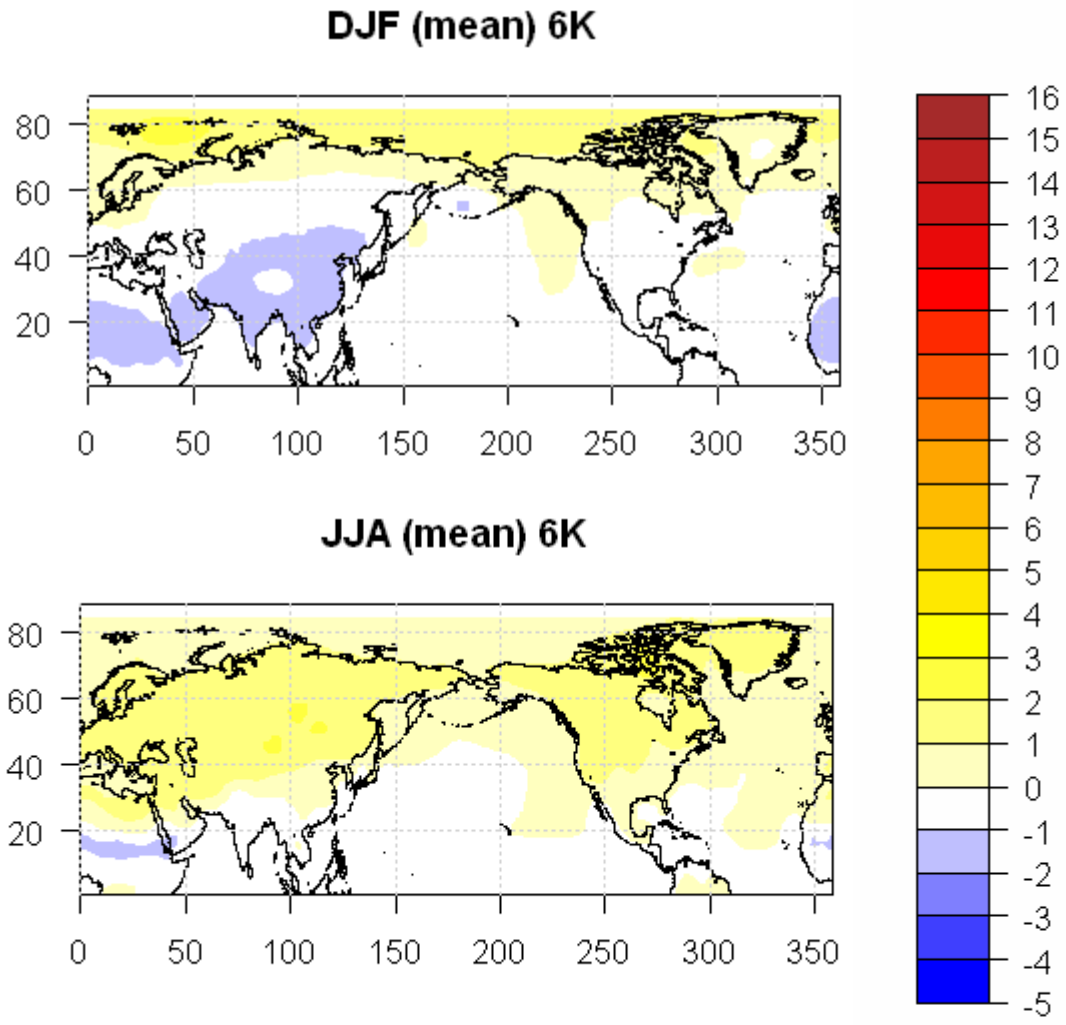
Holocene temperature trend

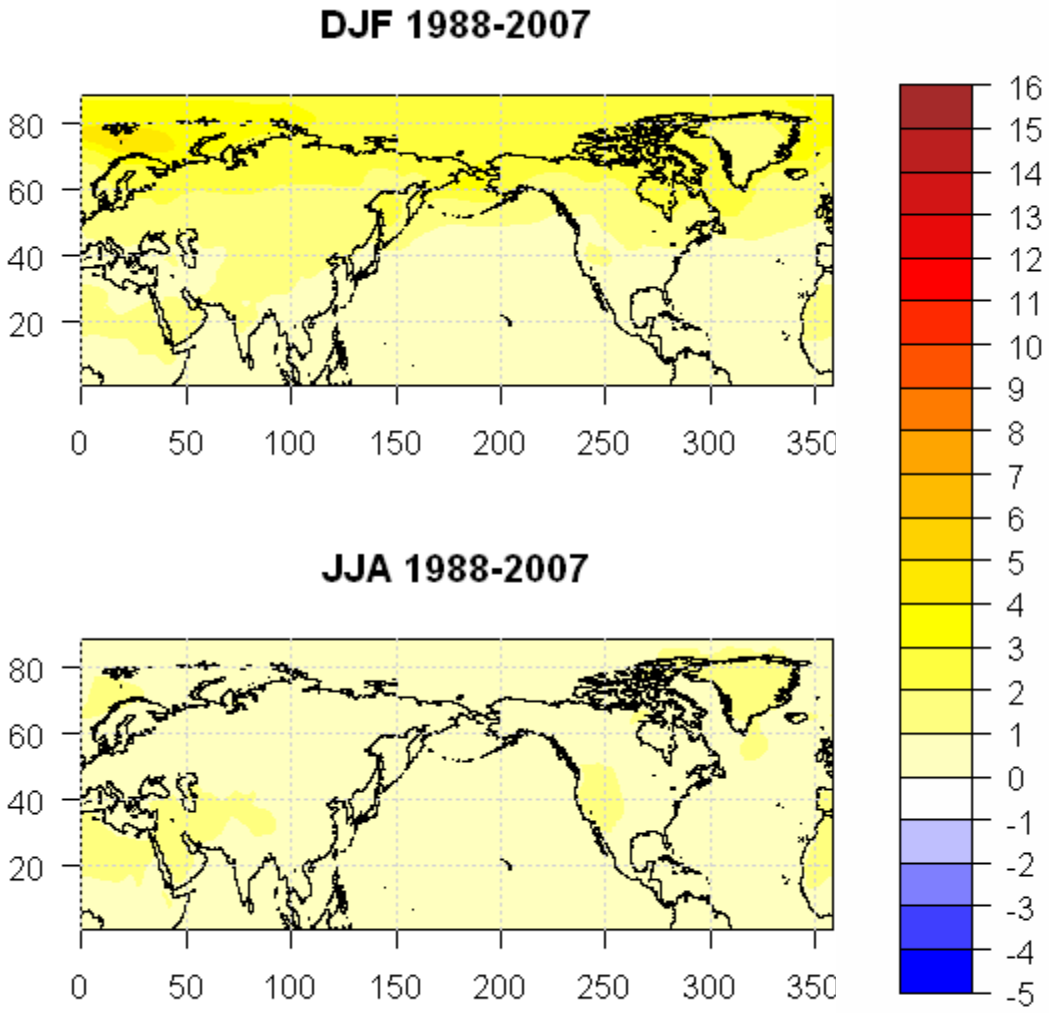
Erwärmung in den Tropen
Abkühlung in hohen Breiten



Temperatures 30°-90°N




DJF (mean) 6K
JJA (mean) 6K
80
60
40
20
0
50
100
150
200
250
300
350
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
-1
-2
-3
-4
-5


DJF 1988-2007
80
60
40
20
0
50
100
150
200
250
300
350
JJA 1988-2007
80
60
40
20
0
50
100
150
200
250
300
350
16
15
14
13
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2
1
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-1
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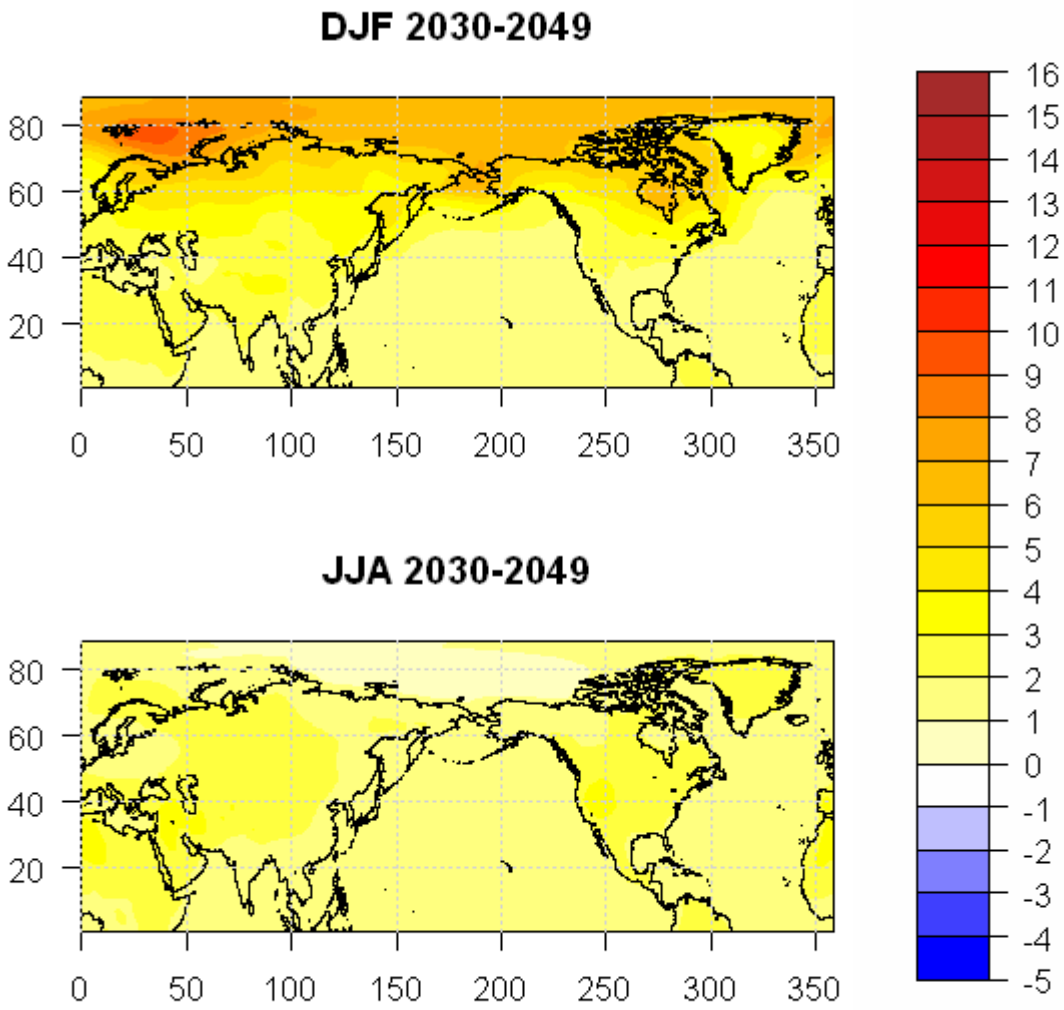
-3
-4
-5


DJF 2030-2049
80
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40
20
0
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100
150
200
250
300
350
JJA 2030-2049
80
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20
0
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200
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350
16
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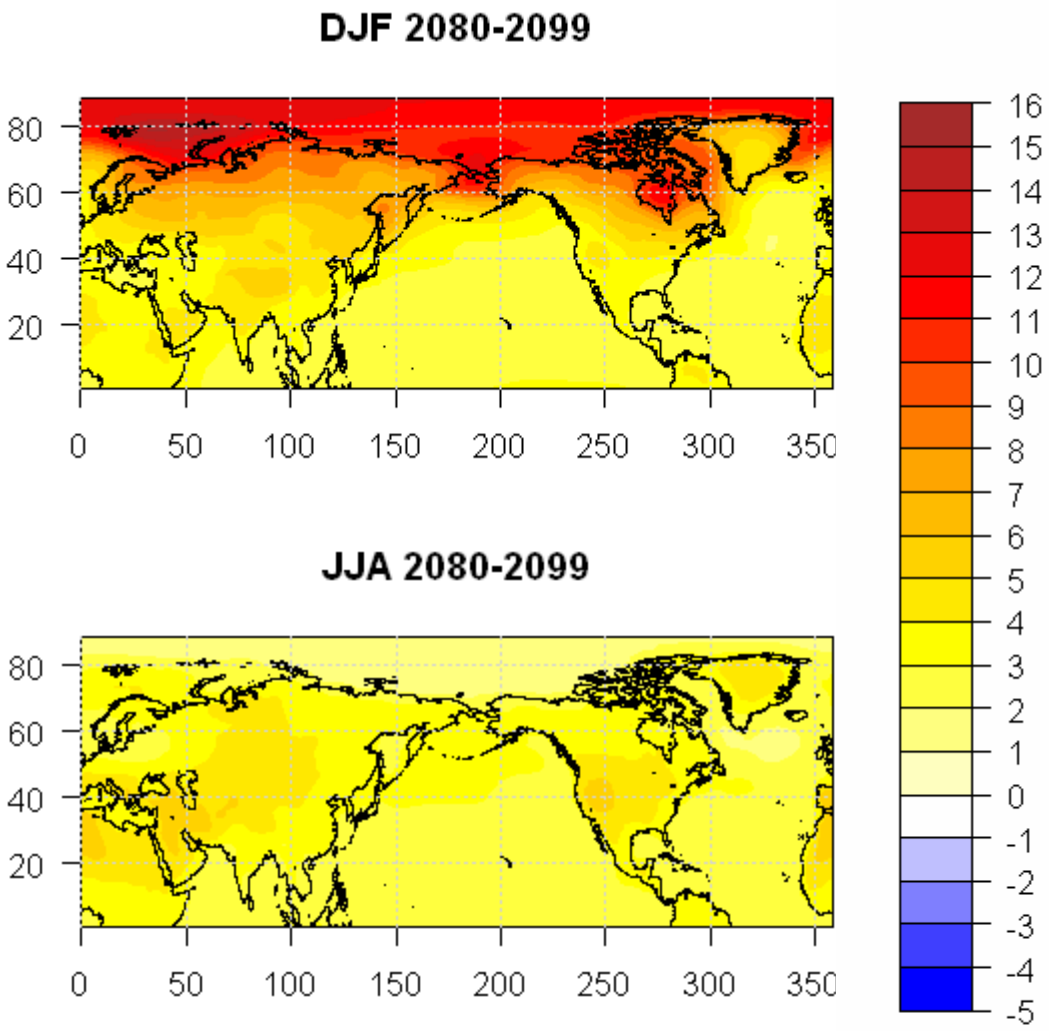
DJF 2080-2099
JJA 2080-2099
80
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0
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15
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12
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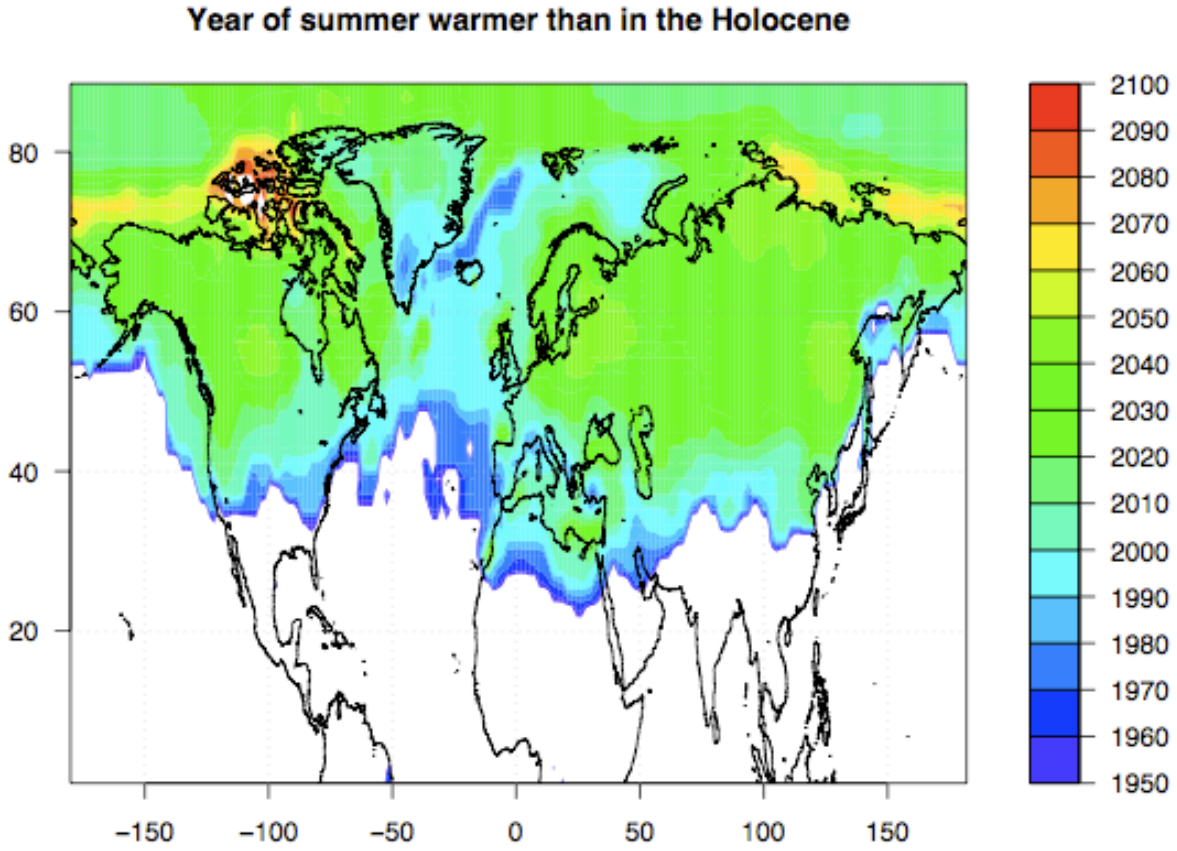
-3
-4
-5

When do we reach the temperature level of 6000 years before present (climate optimum)?



5300 year old man
Ötztaler Alpen 3210m H

http://climexp.knmi.nl

Monthly climate indices

Correlation!

Calculate different regions on the world (e.g. Krakow)