9. Climate variability and extremes

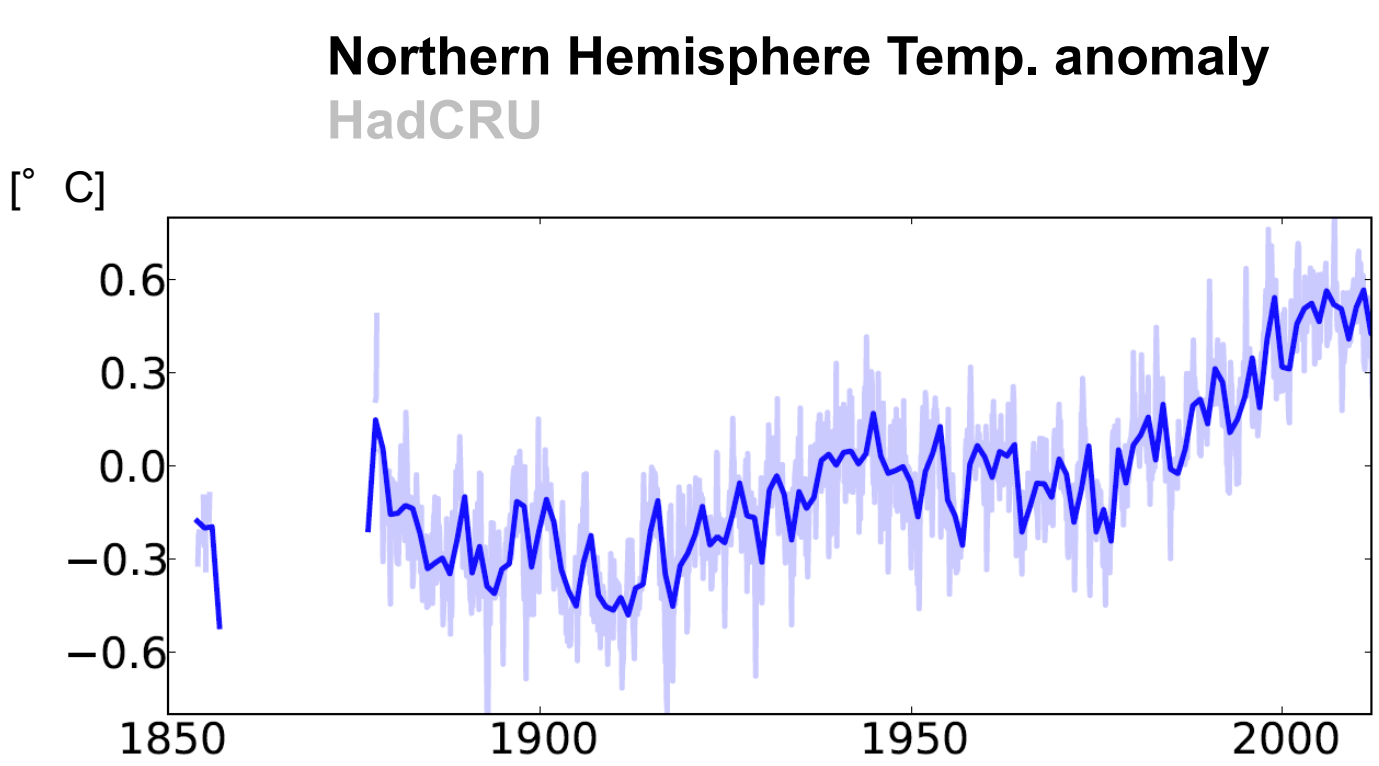
Climate System II

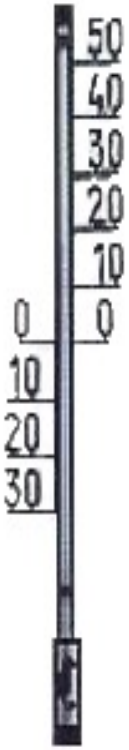
Gerrit Lohmann
Martin Werner

With Justus Contzen

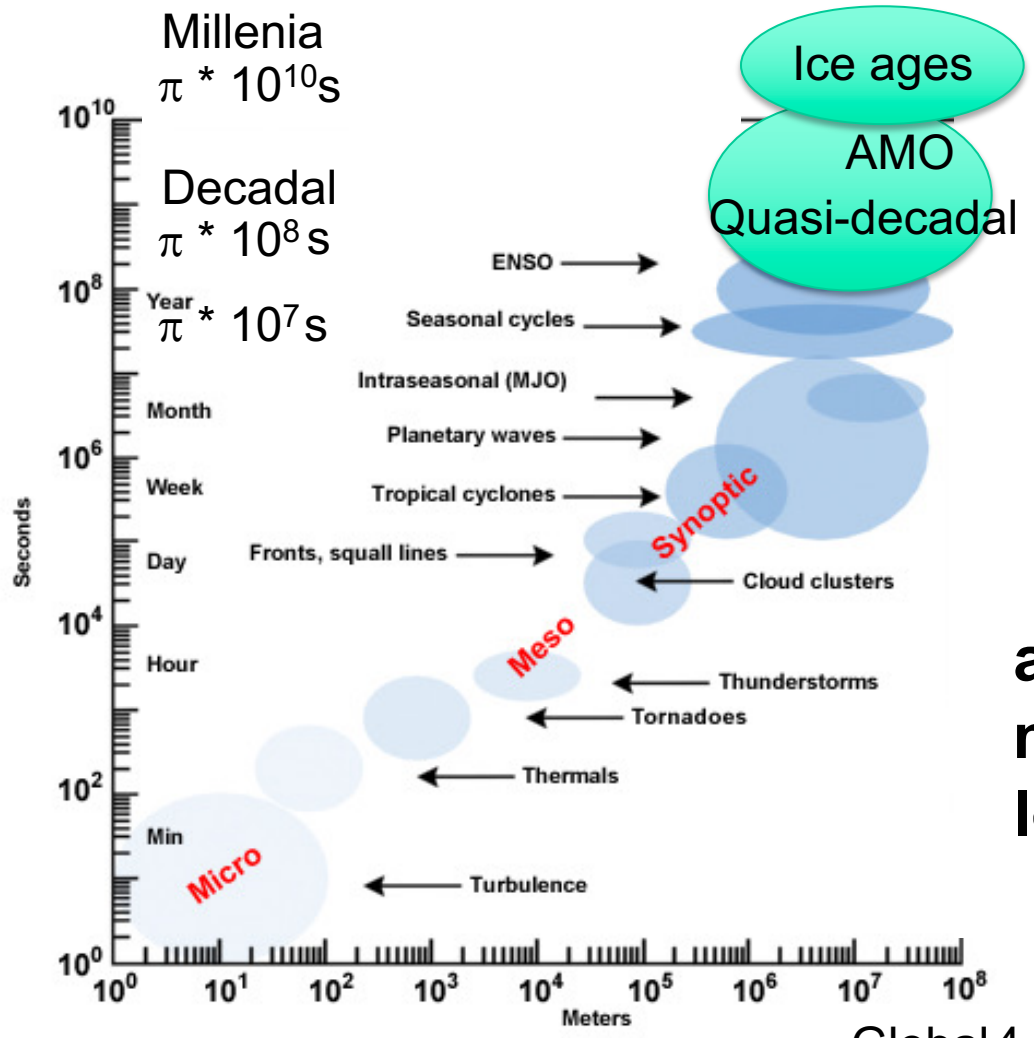
Climate Trends at different Timescales

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





Spatio-Temporal Scales



Spatial || temporal Scales

atmosphere & ocean cannot maintain large gradients on long time scales

Global $4 * 10^7$

History

last **1000 Years**

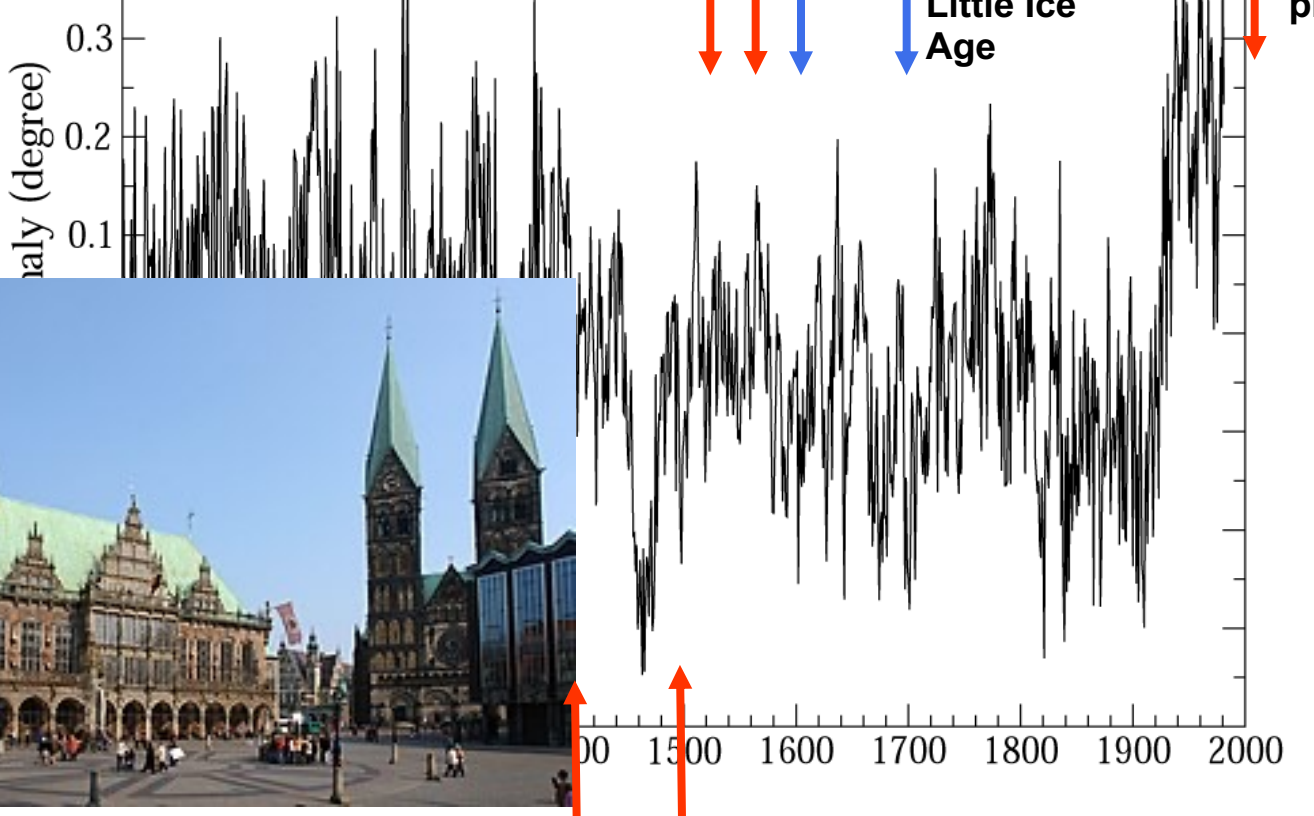
Pieter Breughel d.Ä.

Thermometer

Barometer
(Torricelli)

Little Ice
Age

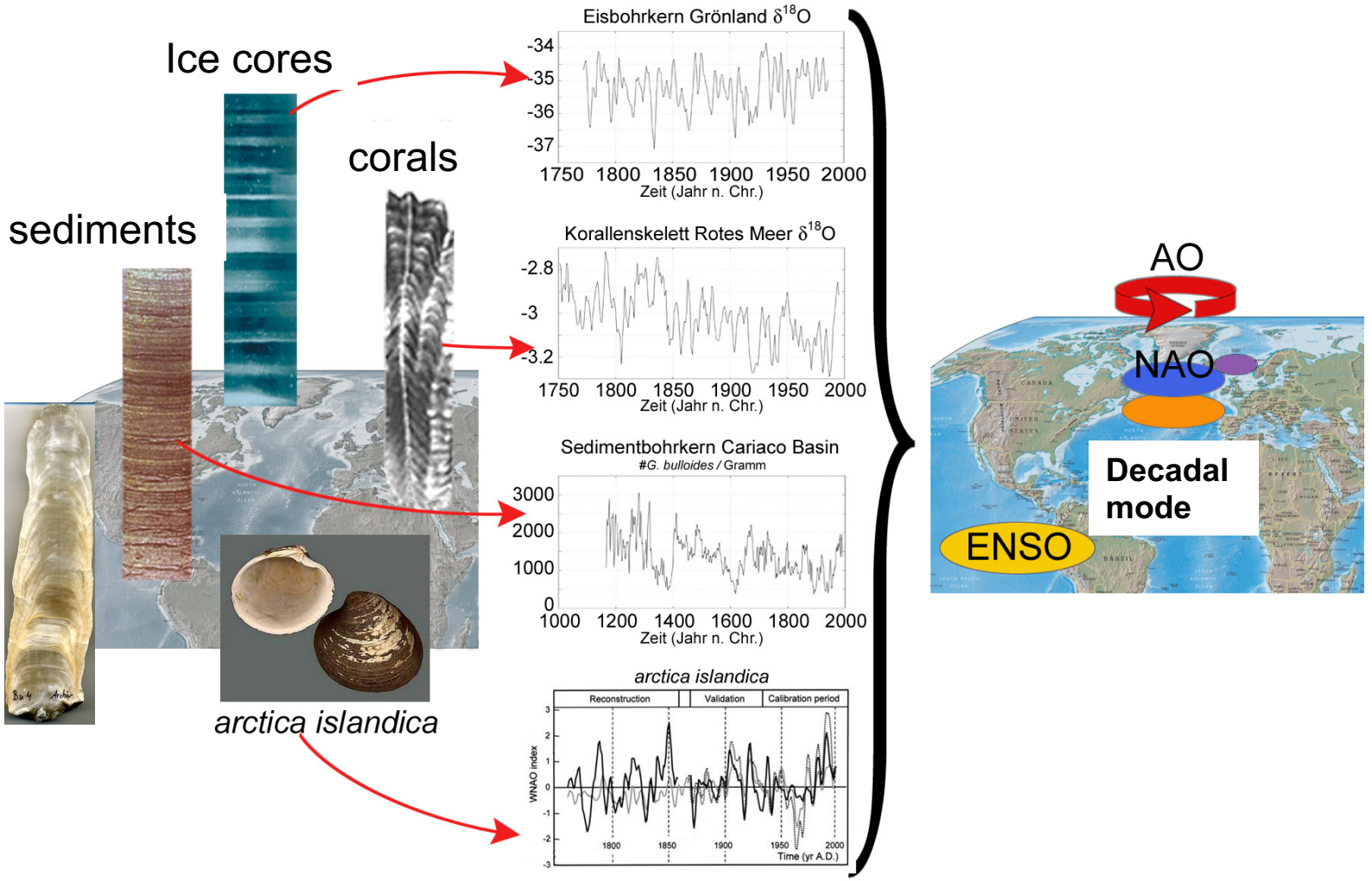
present



Bremen townhall

Nicolaus Kopernikus

Upscaling concept



Climate archives

Climate variabiliy

Lohmann, 2007

Statistics

covariance is a measure of how much two random variables change together

Covariance (cross, auto)

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

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

$$\operatorname{cov}(X, Y) = \frac{1}{n} \sum_{i=1}^{n} (x_i - E(X))(y_i - E(Y)).$$

Correlation (cross, auto)

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

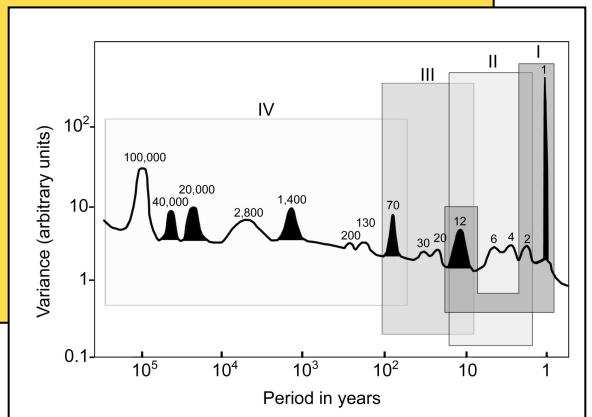
measures the tendency of x (t) and y (t) to covary, between -1 and 1

Spectrum (cross, auto)

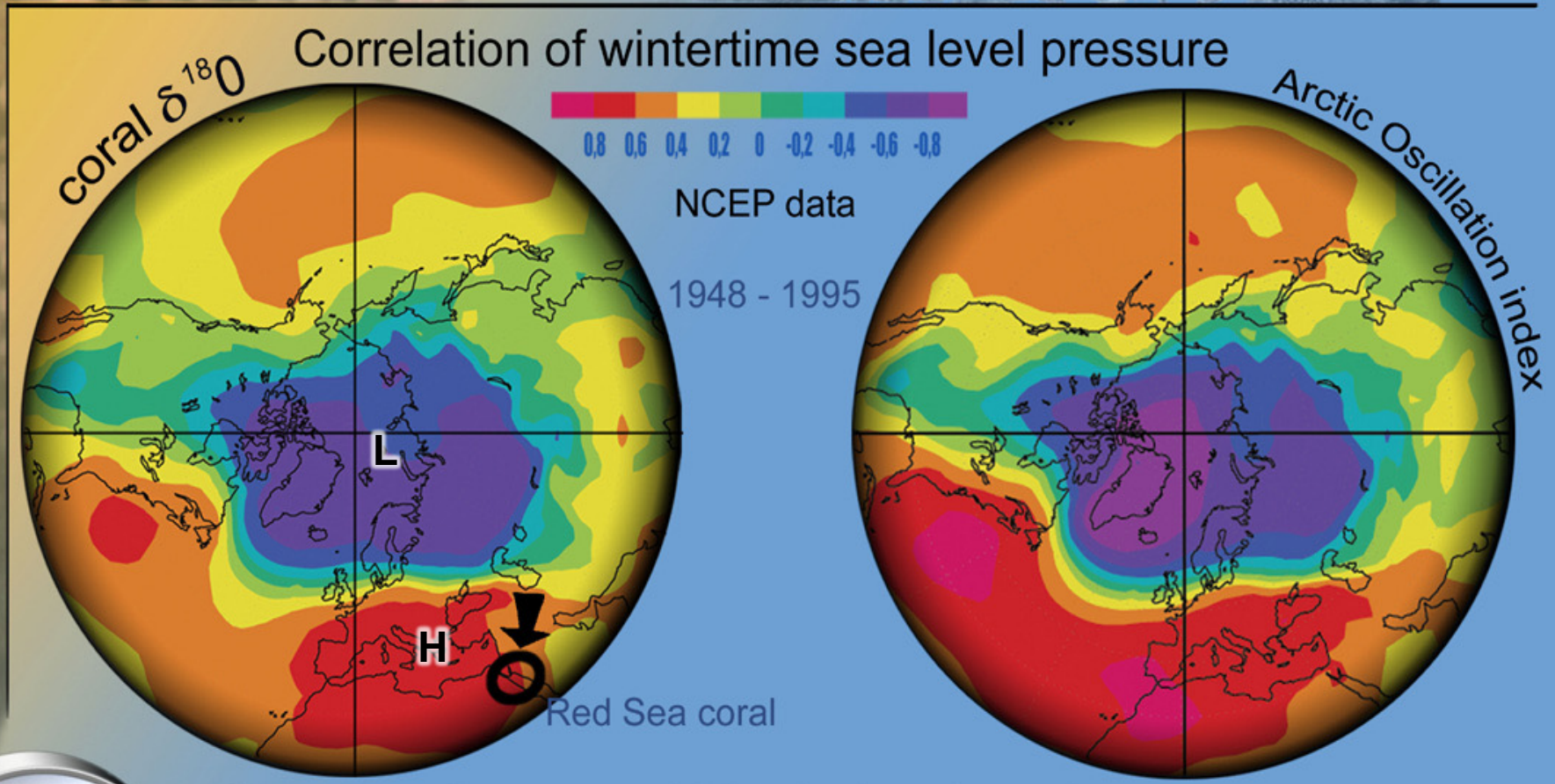
(spectral density)

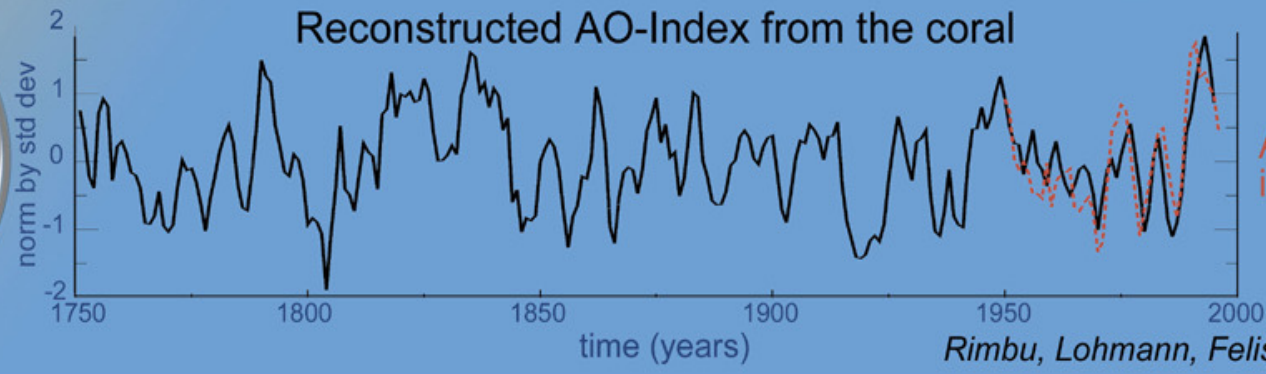
$$\Gamma(\omega) = \sum_{\Delta=-\infty}^{\infty} \gamma(\Delta)\, e^{-2\pi i \Delta}$$

measures variance



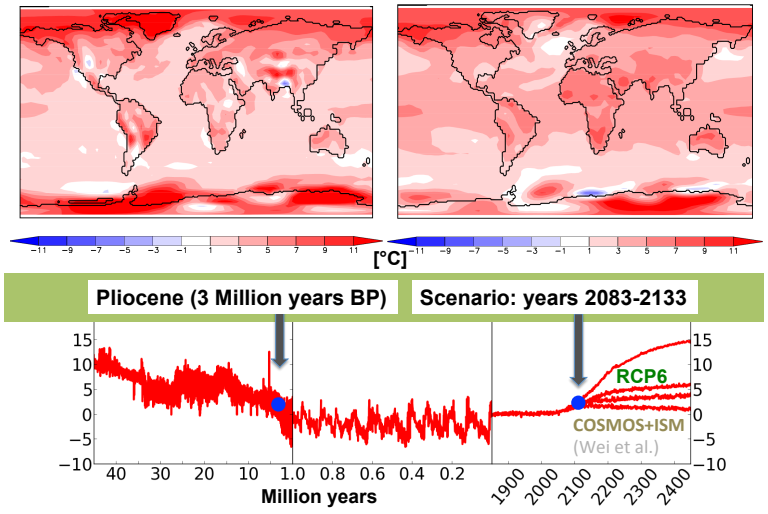
ARCTIC OSCILLATION SIGNATURE IN A RED SEA CORAL



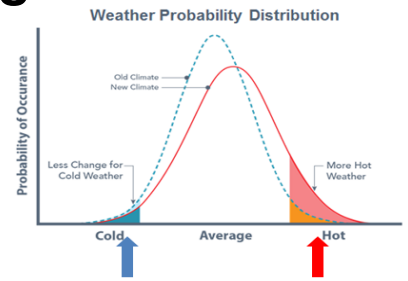


Rimbu, Lohmann, Felis, Pätzold; GRL 2001

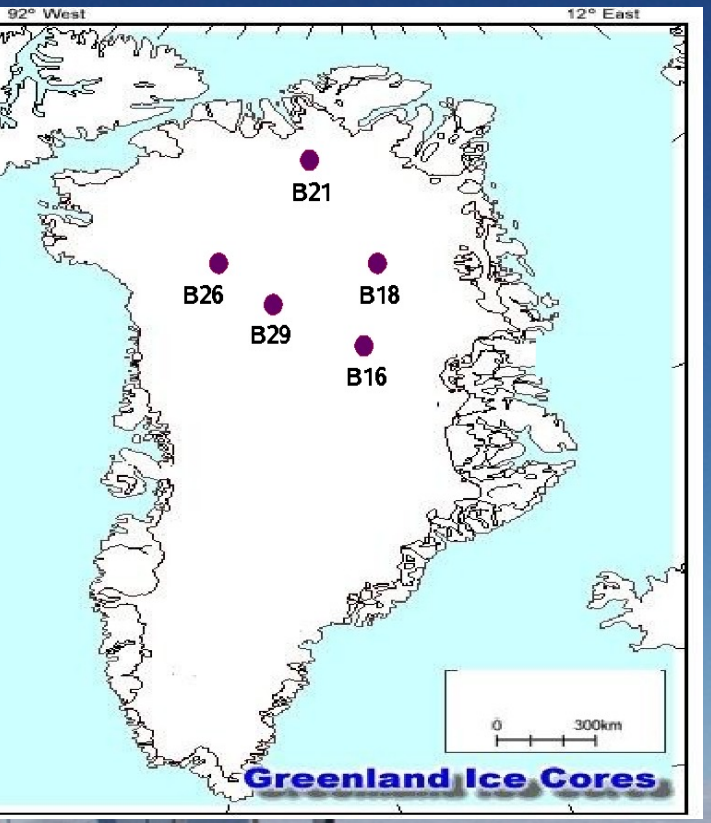
Until now: Climate science concentrates on the mean changes („climate sensitivity“)



climate variability and extremes



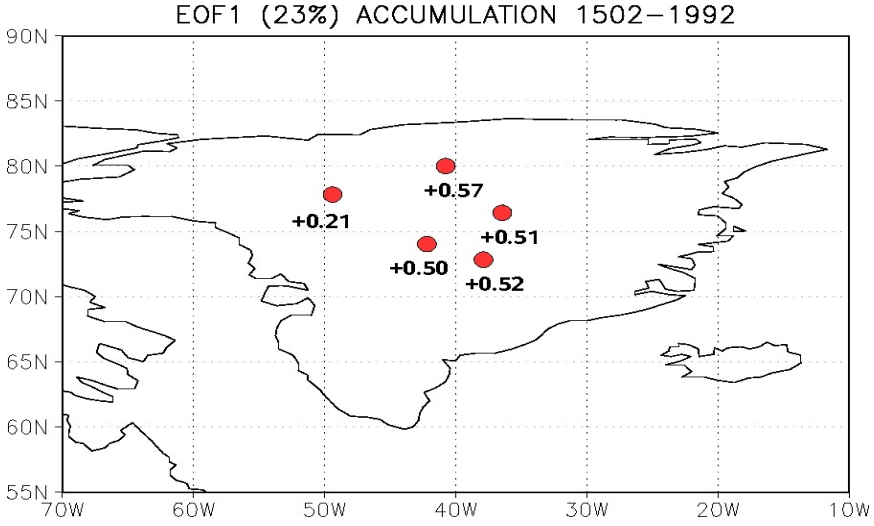
OBSERVATIONS MODELS PROXY DATA



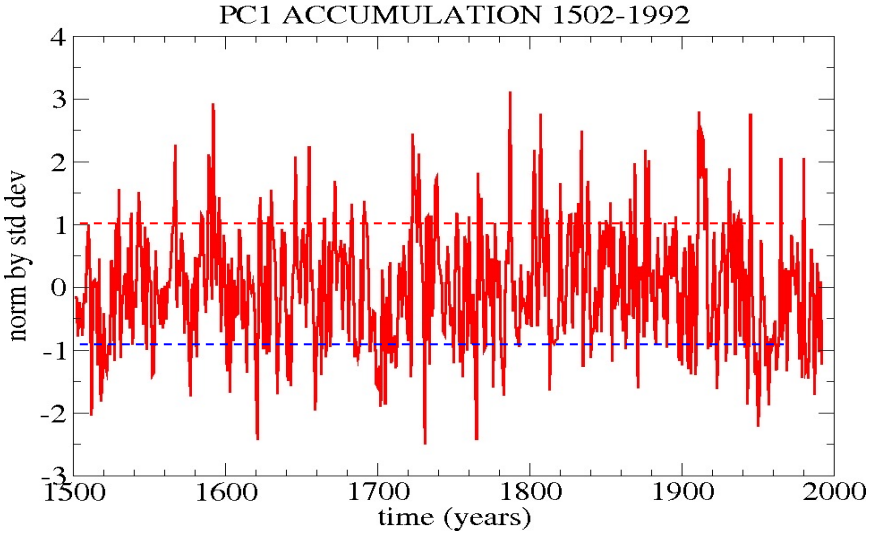
Shallow ice cores

Atmospheric Blocking Circulation

Greenland Shallow Ice Core Positions



Variability of Accumulation Rate



Rimbu and Lohmann 2009

Atmospheric Blocking Circulation

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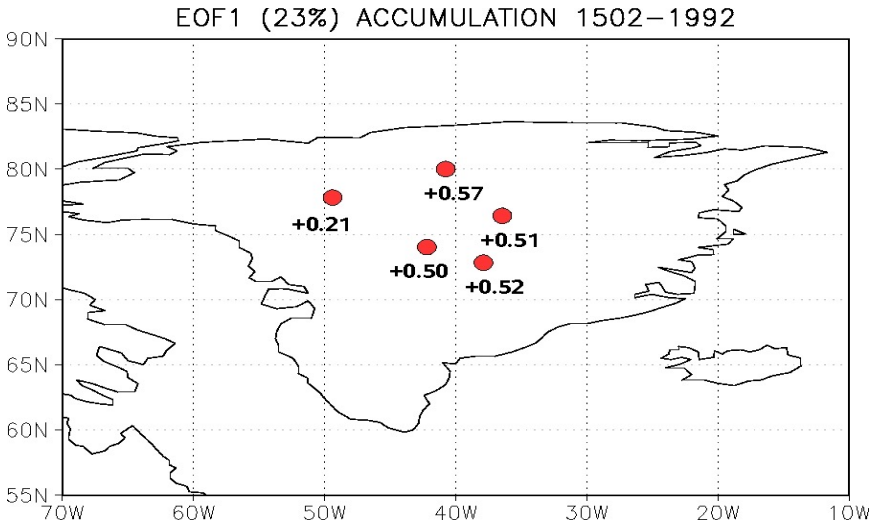
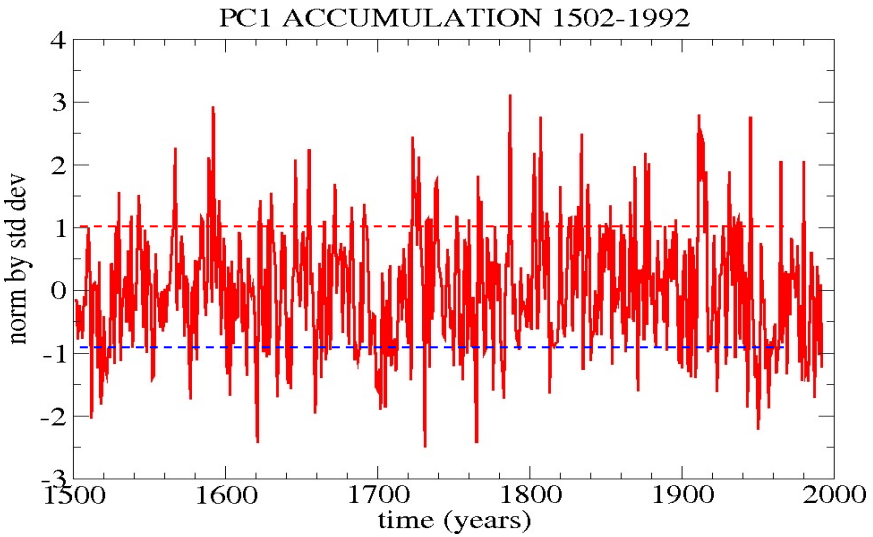
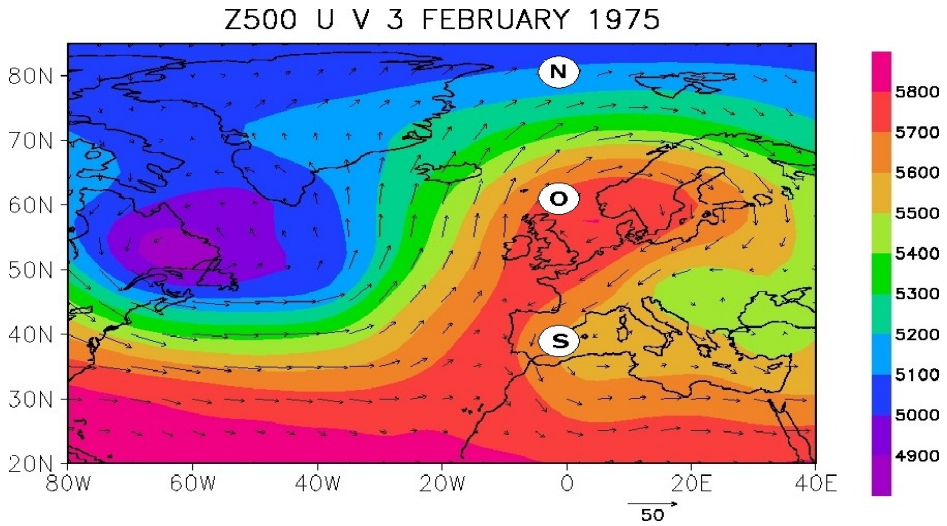


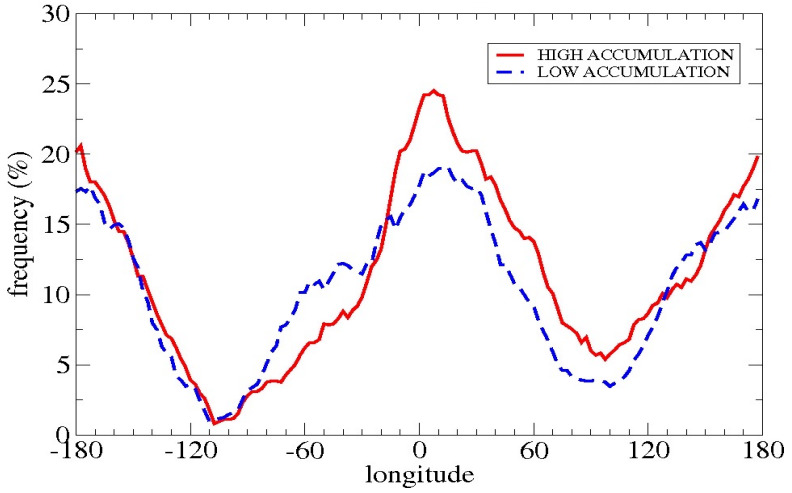
Variability of Accumulation Rate



Synoptic Scale Blocking Situation

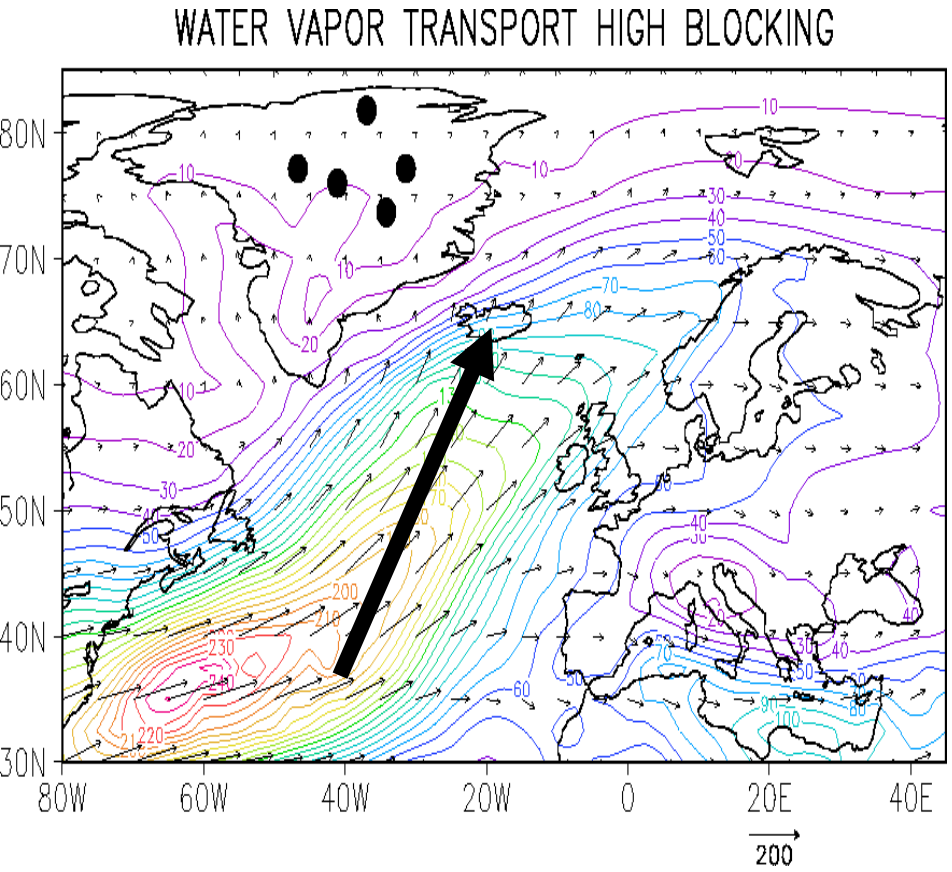


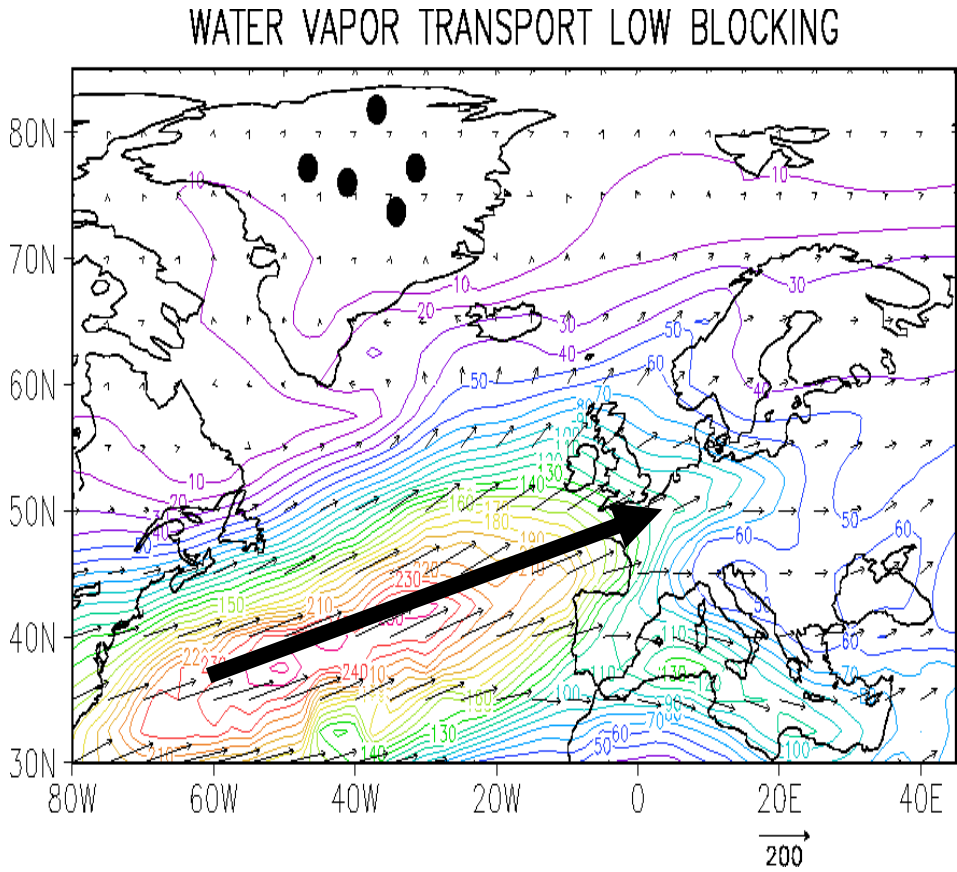
Blocking Frequency for 1948-1992



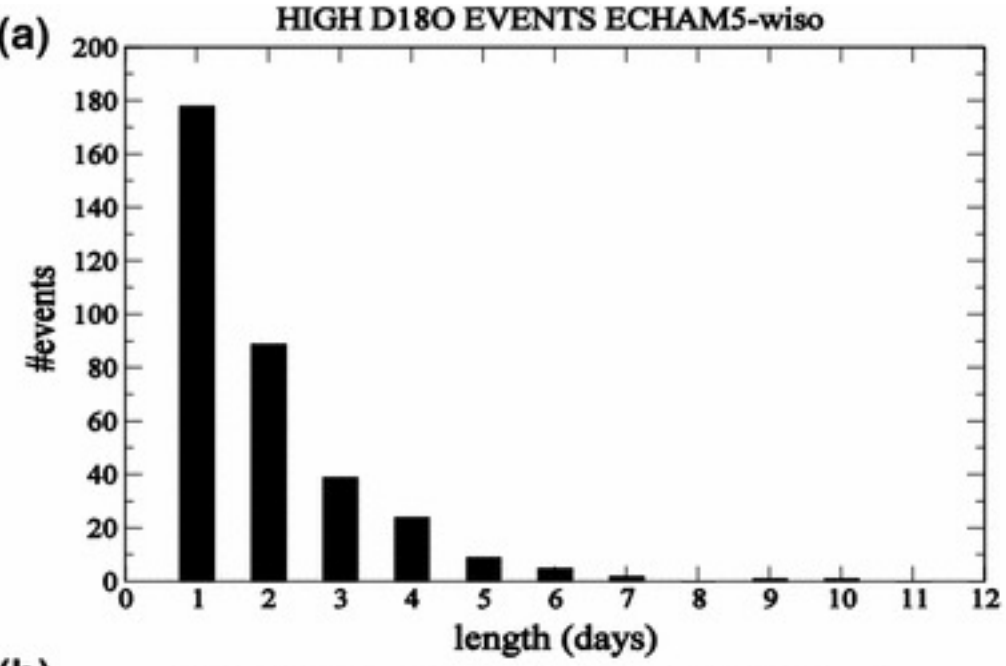
Rimbu and Lohmann 2009

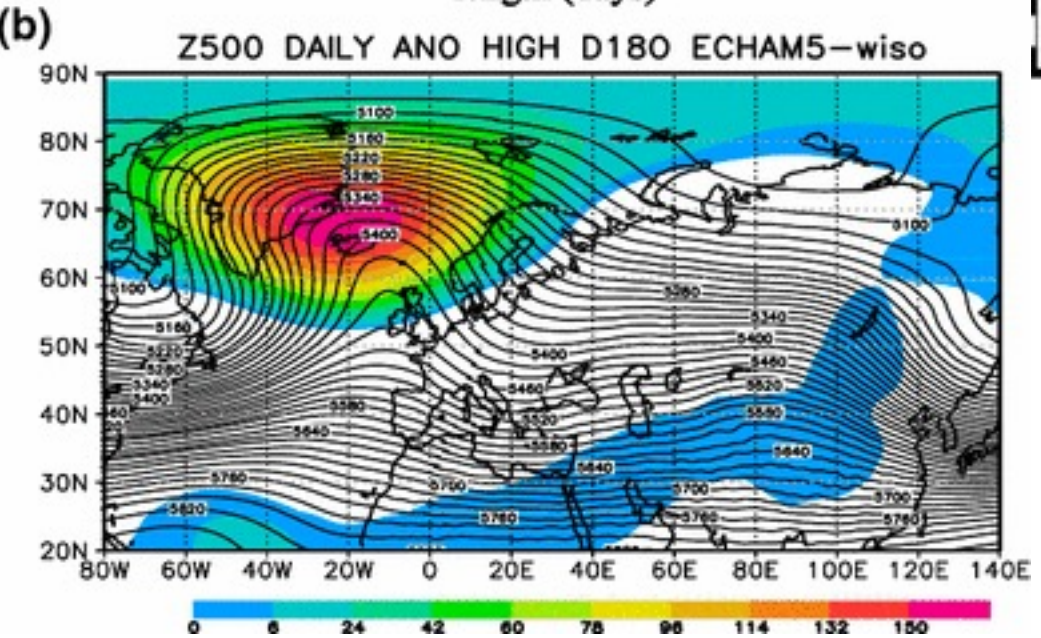
WATER VAPOR TRANSPORT



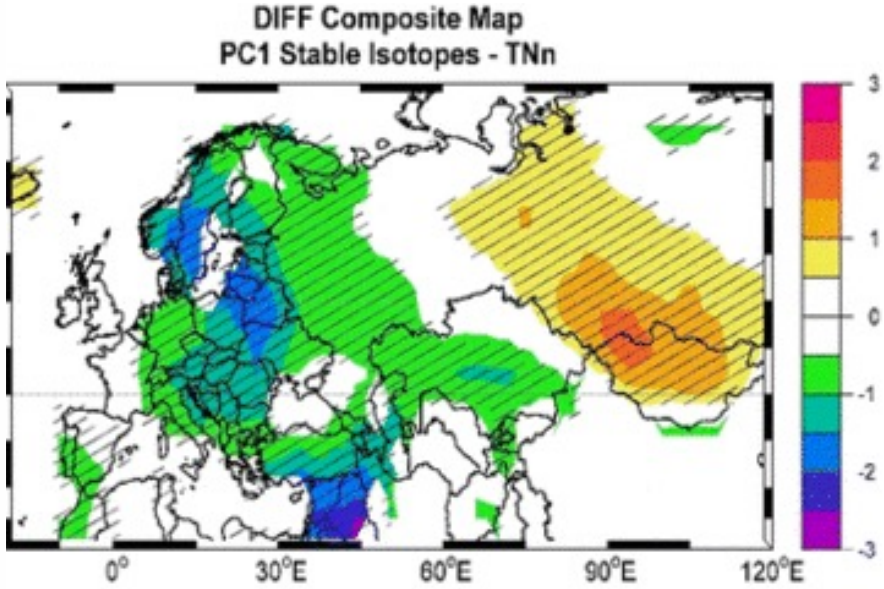


Enhanced moisture transport during high blocking activity

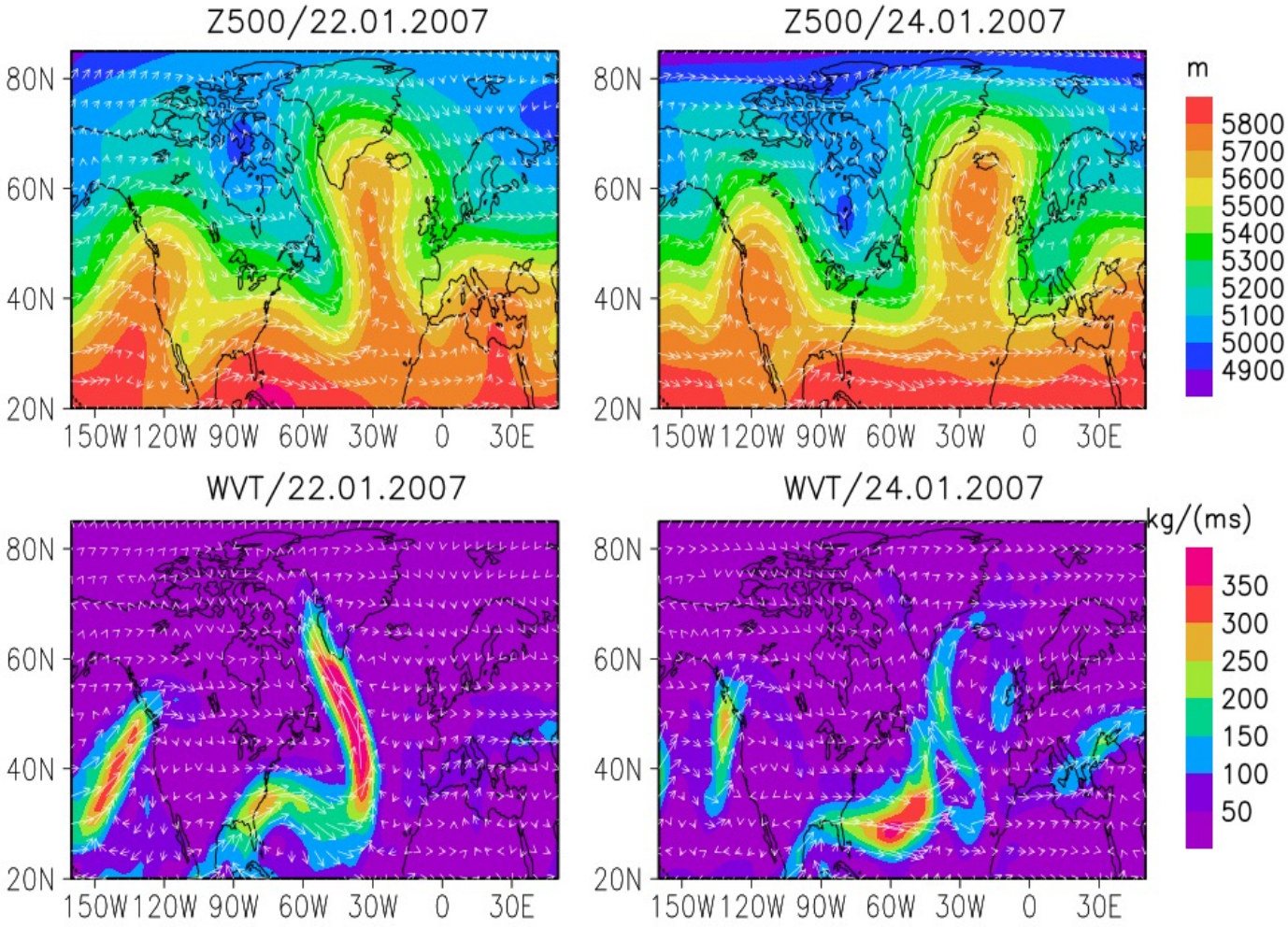




minimum value of daily minimum temperature (TNn)



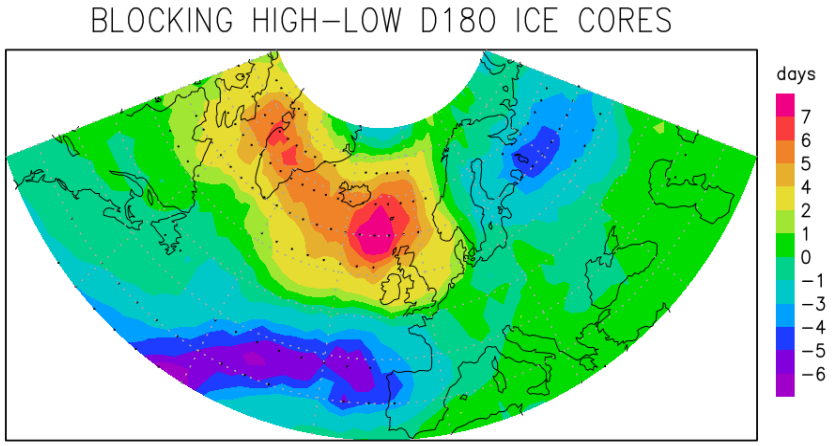
A cyclonic Rossby wave breaking event



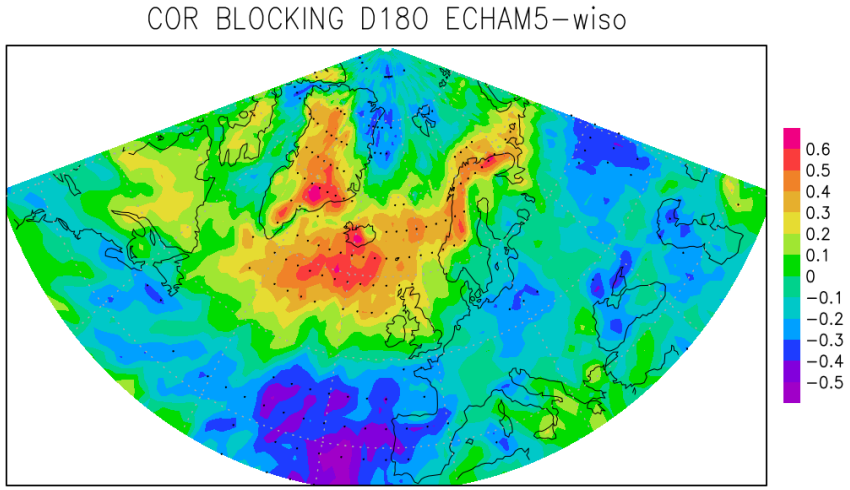
ICE CORES

Blocking pattern associated with $\delta^{18}O$ ice cores

-more frequent blocking circulations detected in the Greenland-western Europe region (red area) is associated with positive $\delta^{18}O$ anomalies in central Greenland ice cores



-a model simulation (ECHAM5-wiso) shows that enhanced blocking activity in the Greenland-western Europe region is associated with a regional precipitation $\delta^{18}O$ anomaly pattern showing positive anomalies over central Greenland



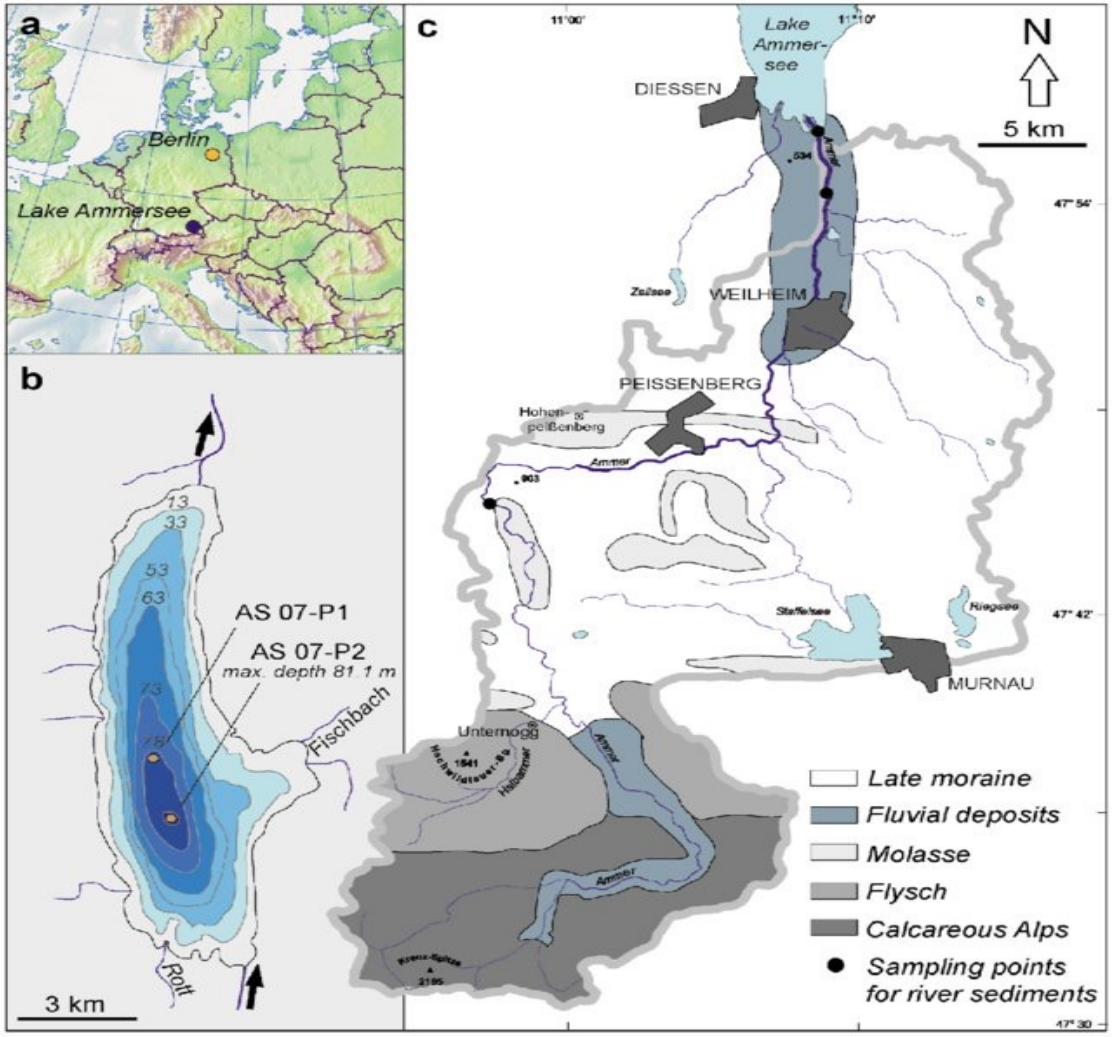
ECHAM5-wiso-atmospheric general circulation model
Equipped with stable isotope module wiso; nudged simulation
(ERA-40/Interim; 1960-2017 (Werner et al. 2017)

LAKE SEDIMENTS

SOUTHERN GERMANY LAKE SEDIMENTS AS CLIMATE ARCHIVES

River Ammer floods
-small river in the southern Germany) (catchement-700 km2 length-84Km,q =18m3/s)
-river floods (discharge higher than 125 m3/s) are detected as flood layers in lake Ammer sediments
-summer floods are dominant

Flood layer records
-annual resolution
-cover instrumental period
-go back in time to mid-Holocene



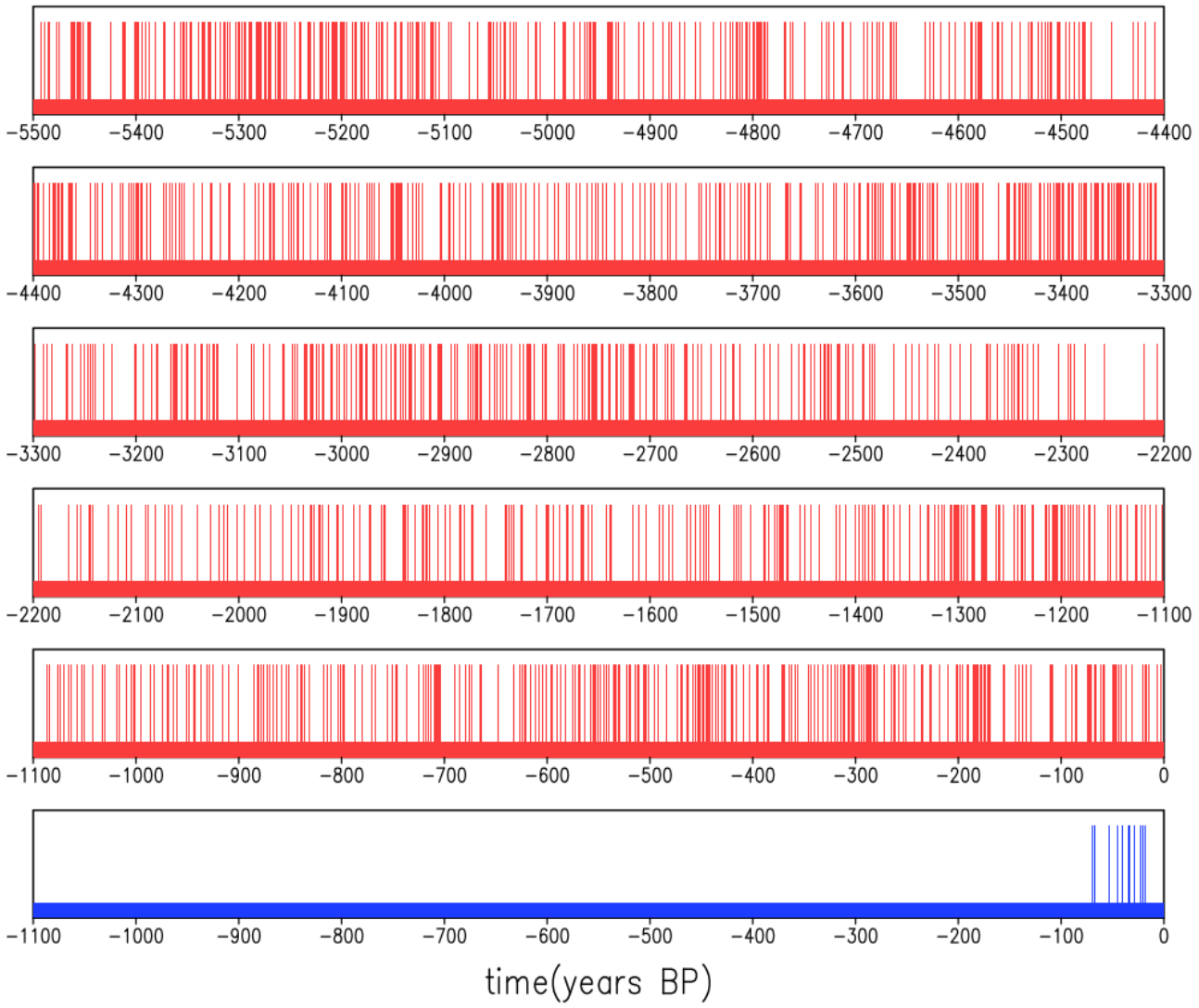
Source: Czymzik et al. ,Water Resources, 2010)

LAKE SEDIMENTS

OBSERVED AND PROXY FLOODS

-frequency of annual flood years (red bars) shows pronounced millennial scale variations during the last ~5500 years

-observed river Ammer flood years (blue bars) shows similar distribution as flood layers during observational period

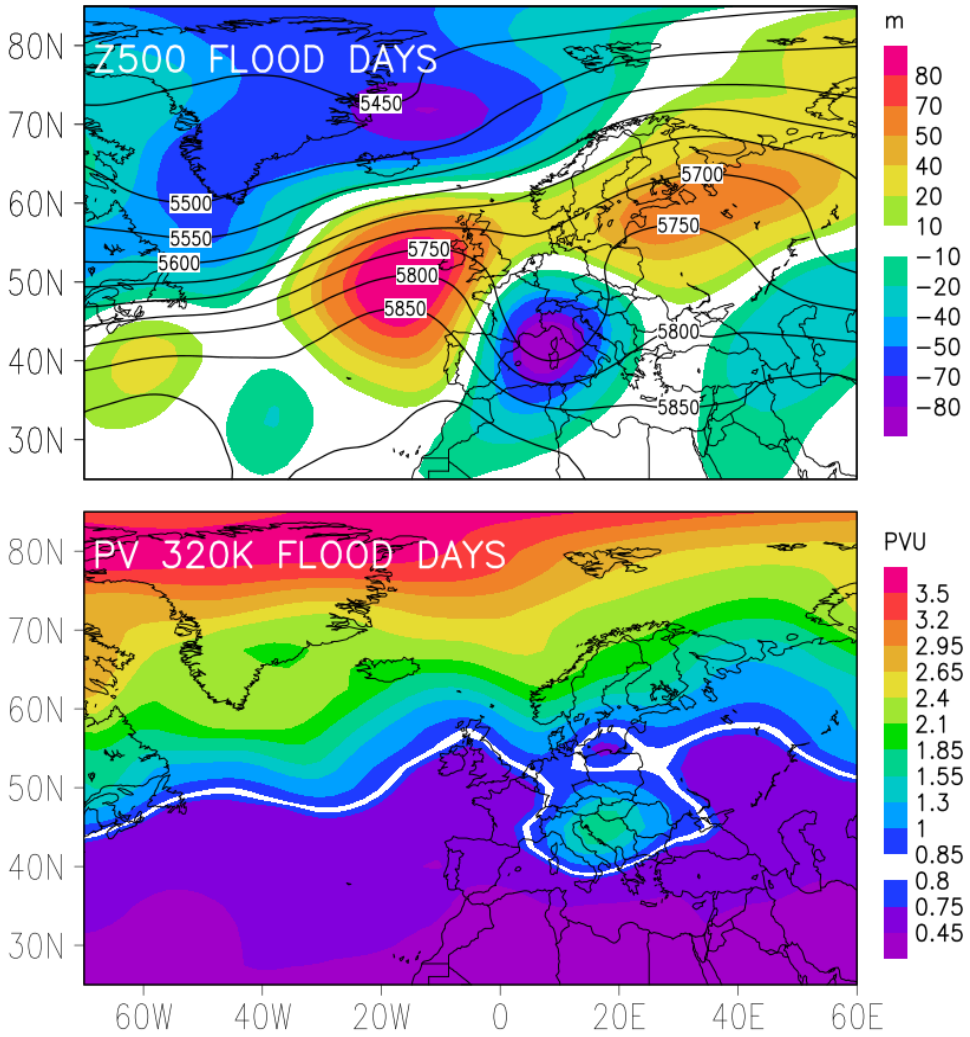


LAKE SEDIMENTS

ATMOSPHERIC CIRCULATION PATTERN

-A wave-train pattern with a pronounced trough over western Europe is associated with flood days

-An amplifying Rossby wave pattern is associated with Ammer flood days. The RWB breaks (anticyclonically??)
In the flood region



PVU-potential vorticity unit, 320 K potential temperature surface, Z500 500 hPa geopotential height

LAKE SEDIMENTS

EXTREME PATTERNS ASSOCIATED WITH FLOODS