7. Climate variability and analysis

Climate System II

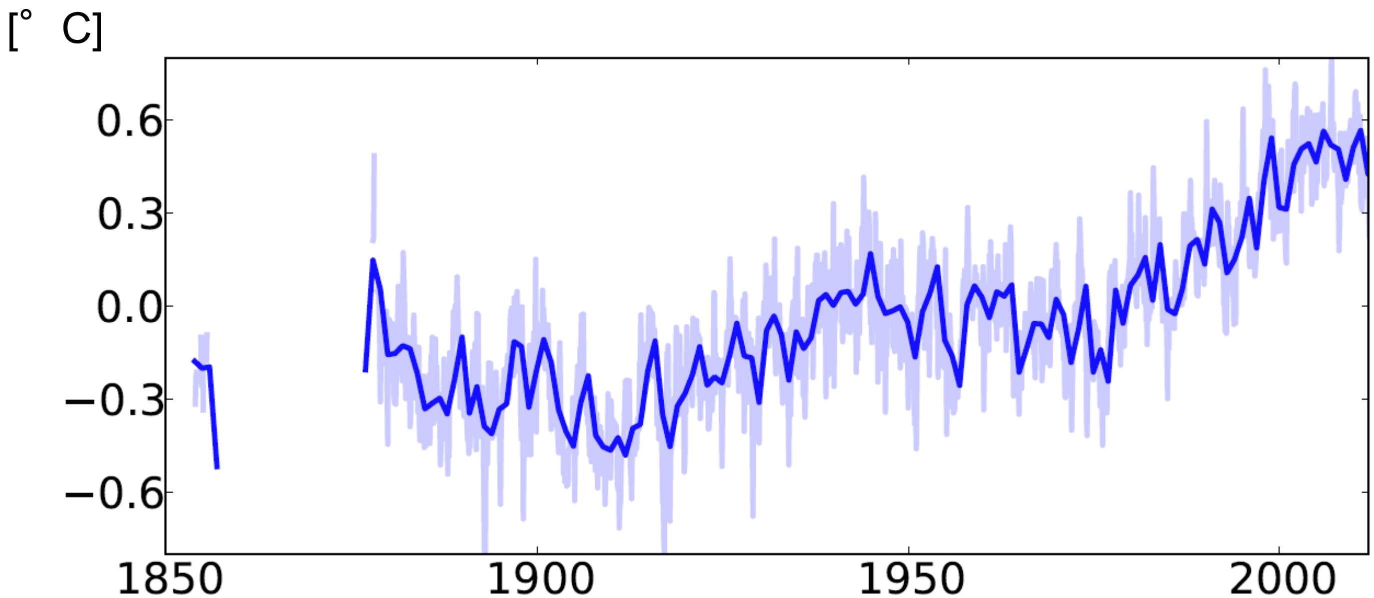
Gerrit Lohmann
Martin Werner

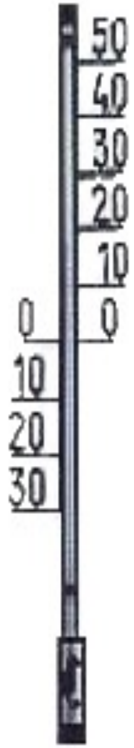
Climate Trends at different Timescales

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

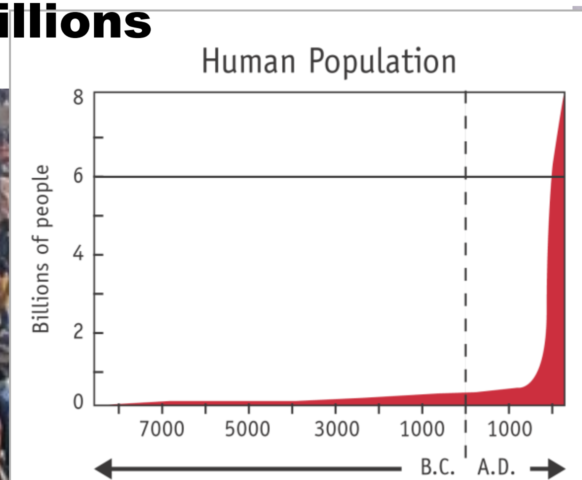
Northern Hemisphere Temp. anomaly

HadCRU





Human Population: 7 billions

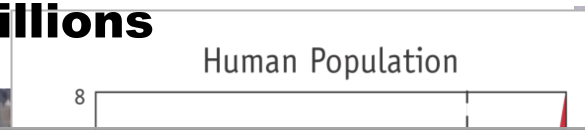


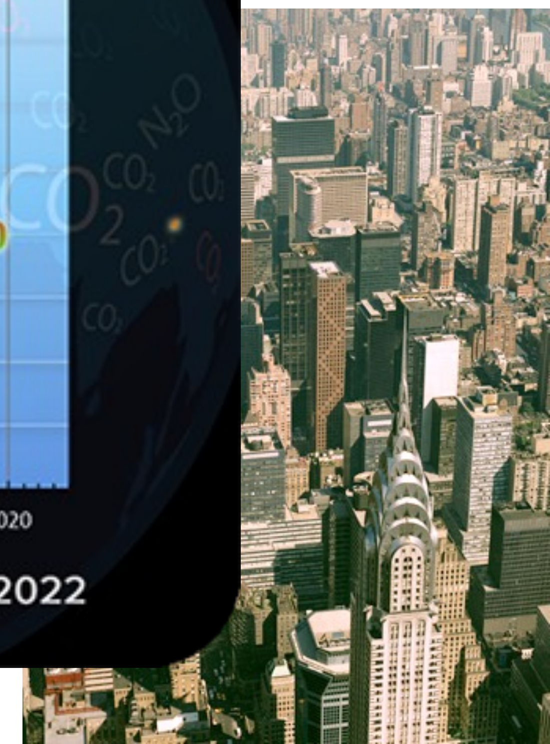
CO_2 Increase:

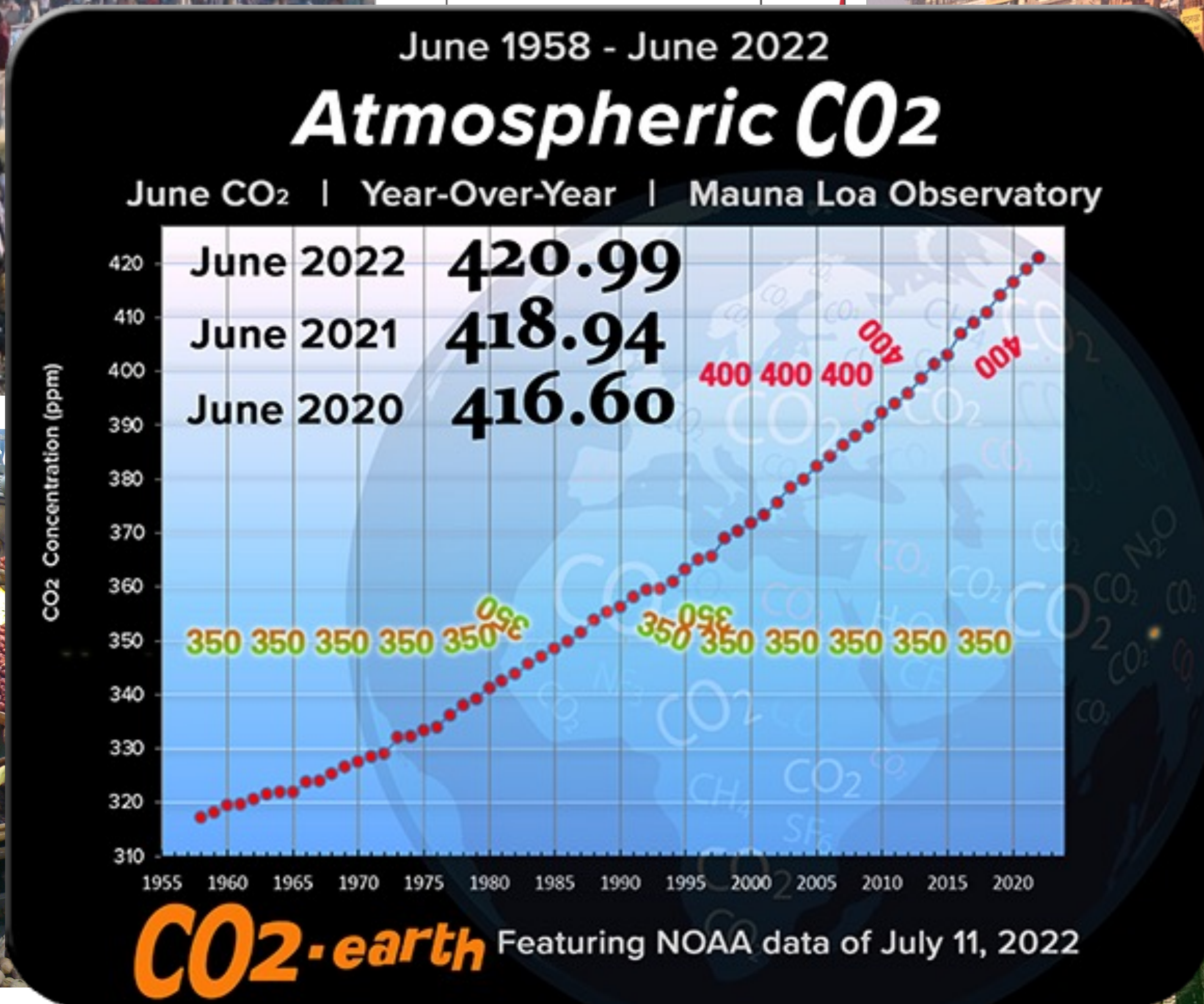
Land cover: 22%

CO_2-Emissions: 78%

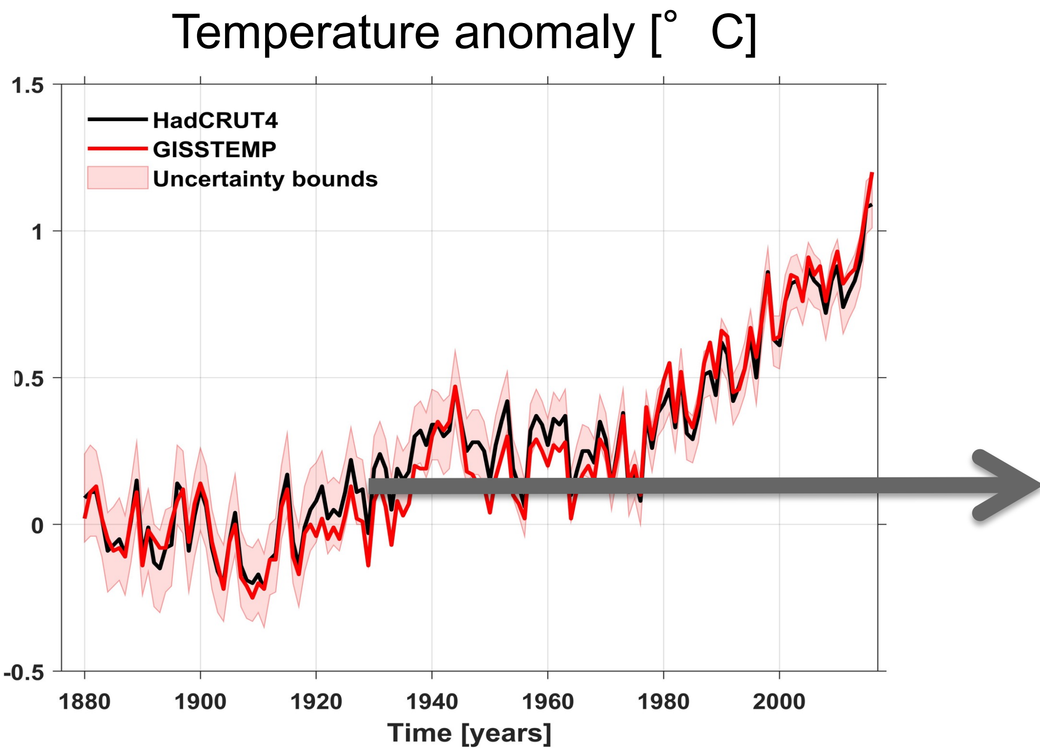
Human Population: 7 billions



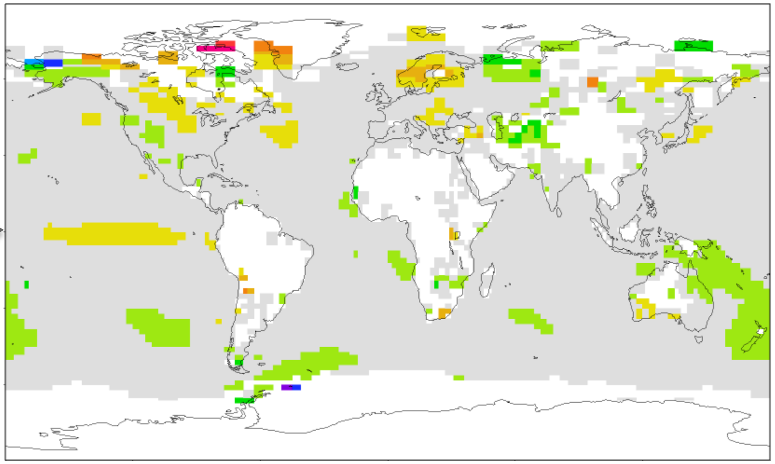




Motivation: Observational Record

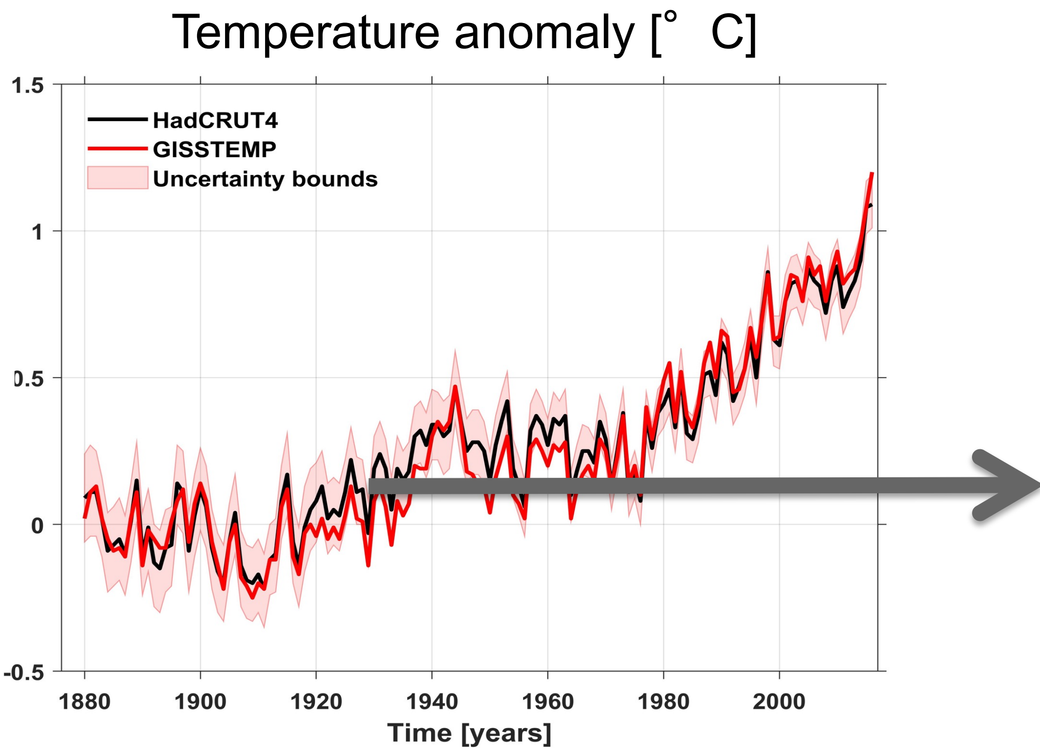


Uncertainty largely due to missing information at high latitudes



Temperature Anomaly 1930
White areas: not enough data

Motivation: Observational Record



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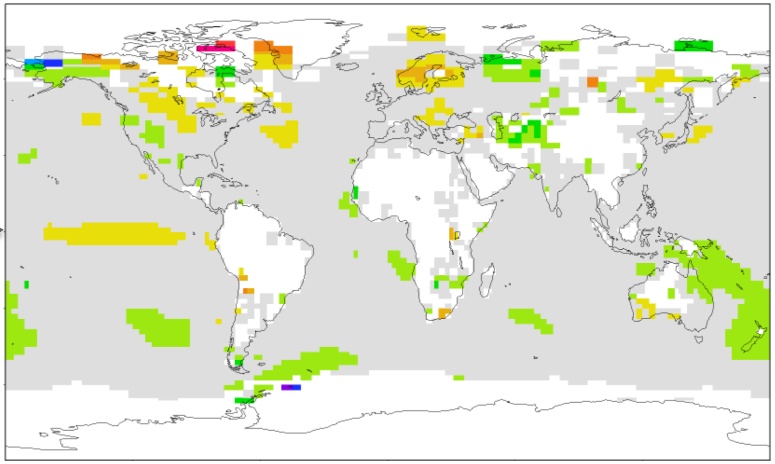
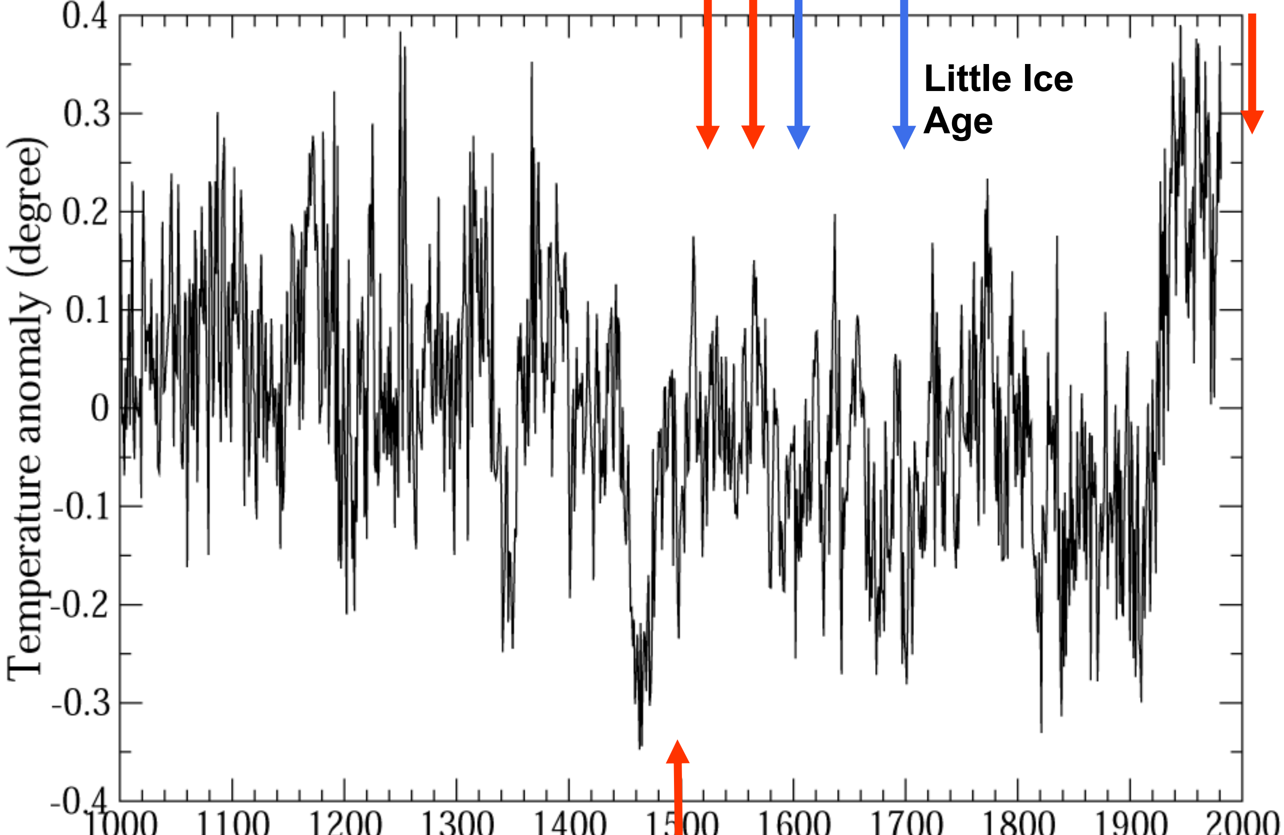


Temperature Anomaly 1930
White areas: not enough data

Climate variability beyond the instrumental record: Decadal, centennial, millennial

History

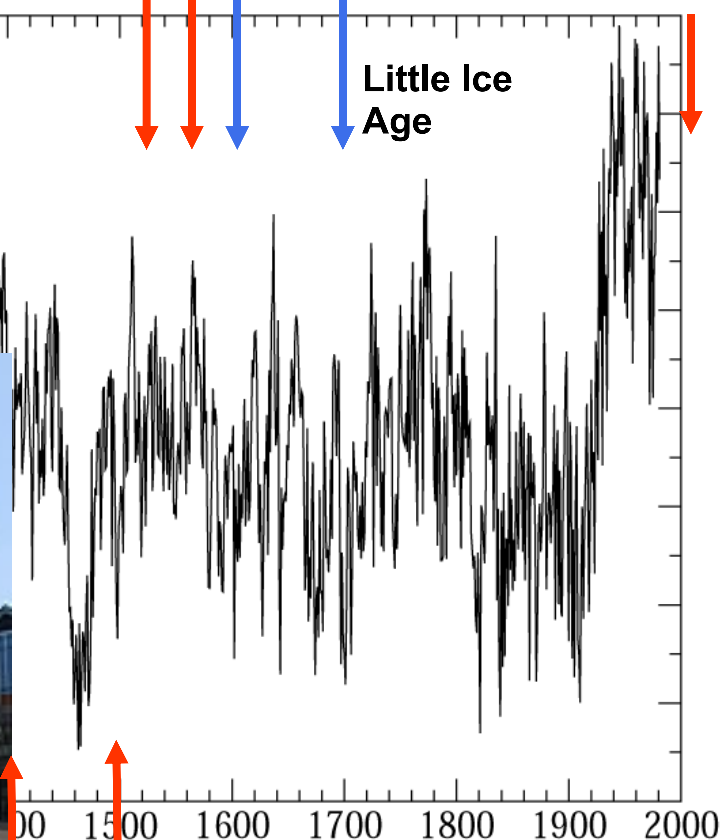
last **1000 Years**



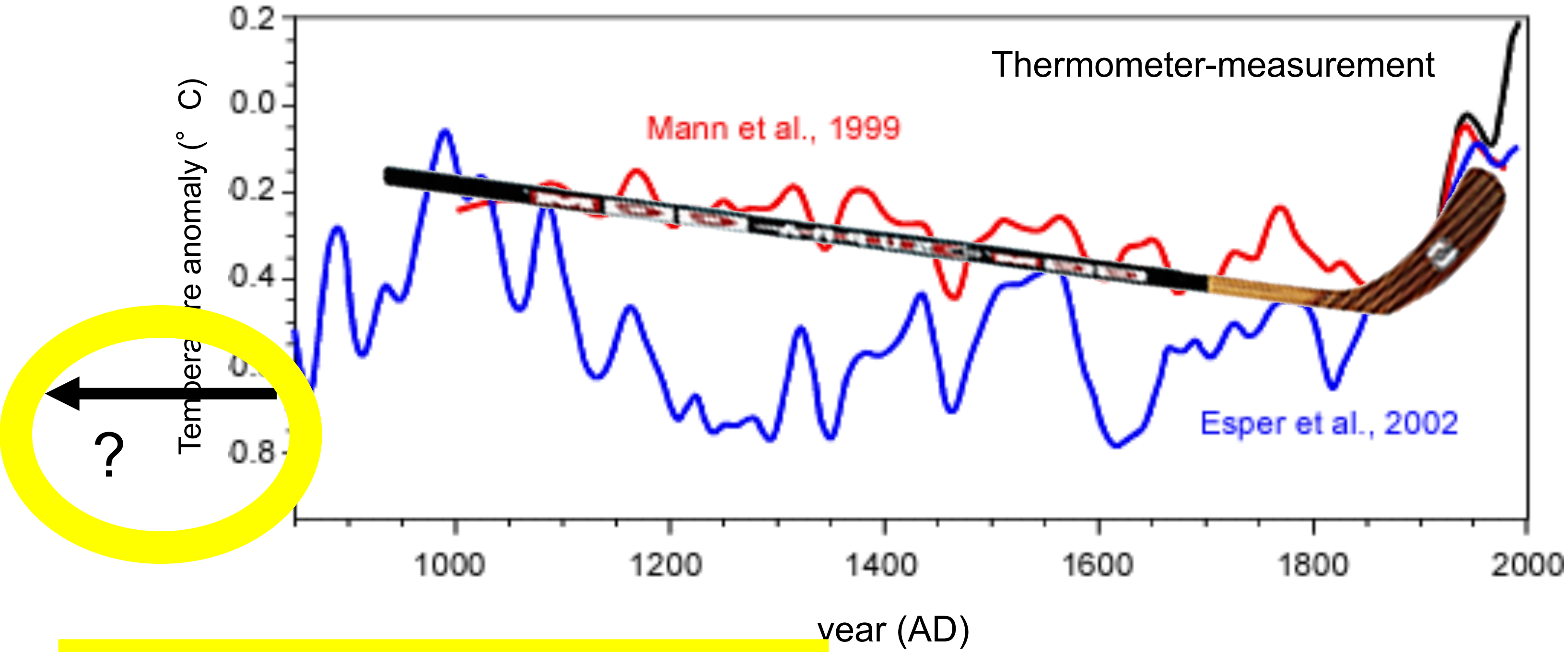
History

last **1000 Years**

Pieter Breughel d.Ä.



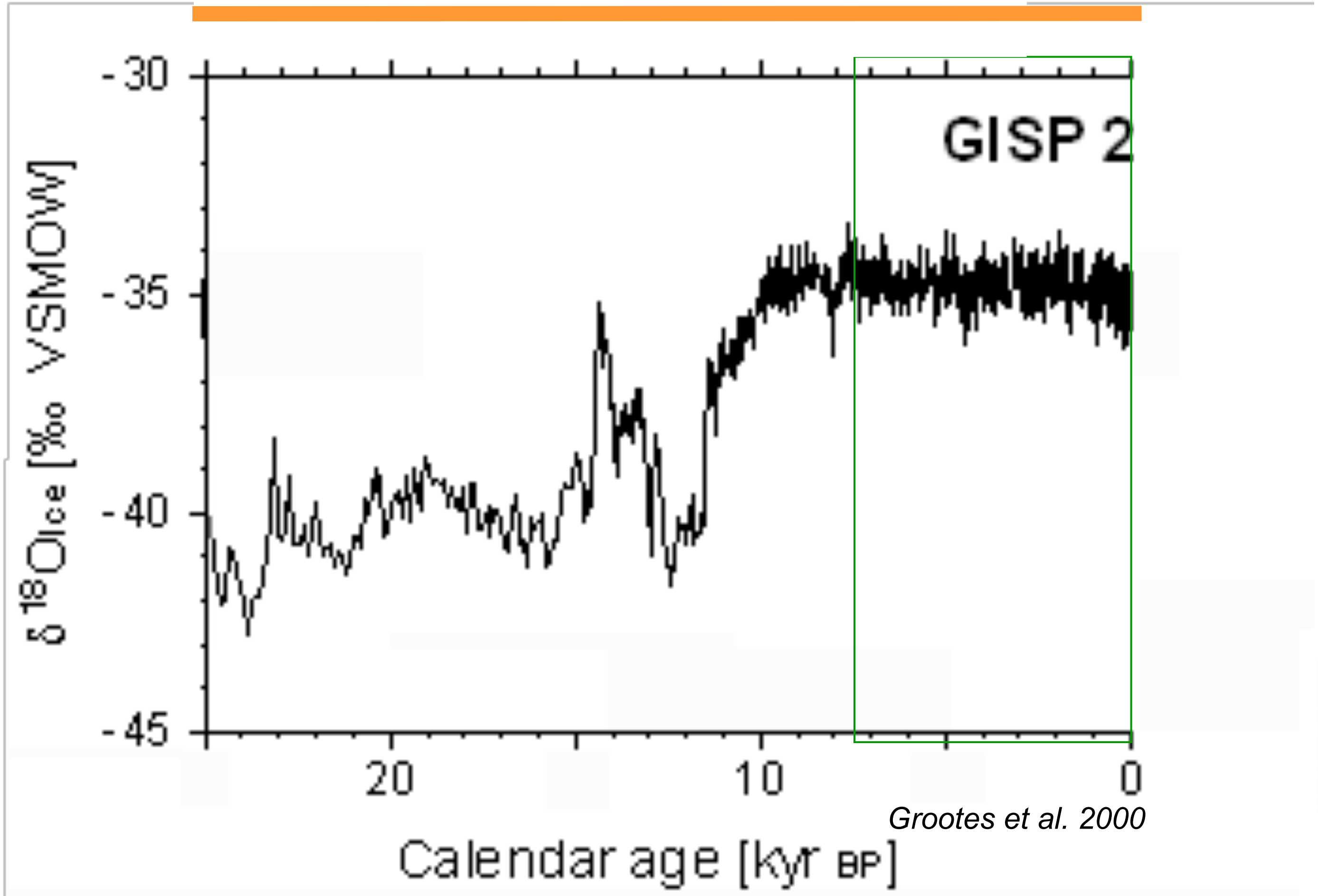
Bremen townhall



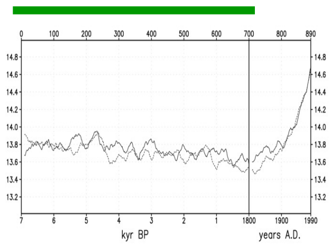
Further back in time?

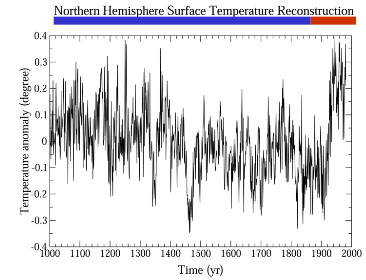
Climate Trends at different Timescales

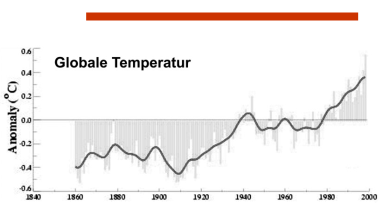
Deglaciation – Greenland ice core



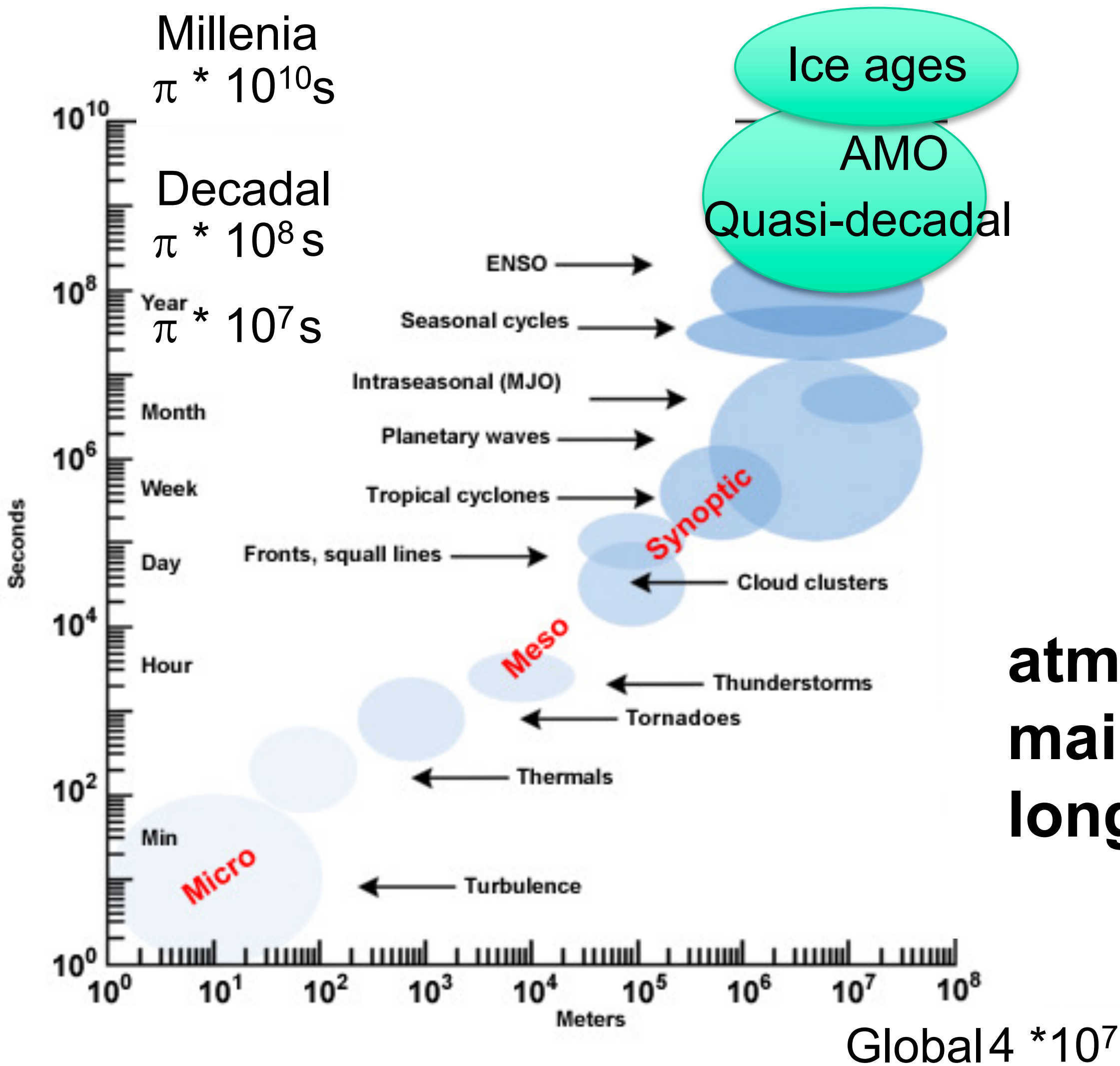
Grootes et al. 2000







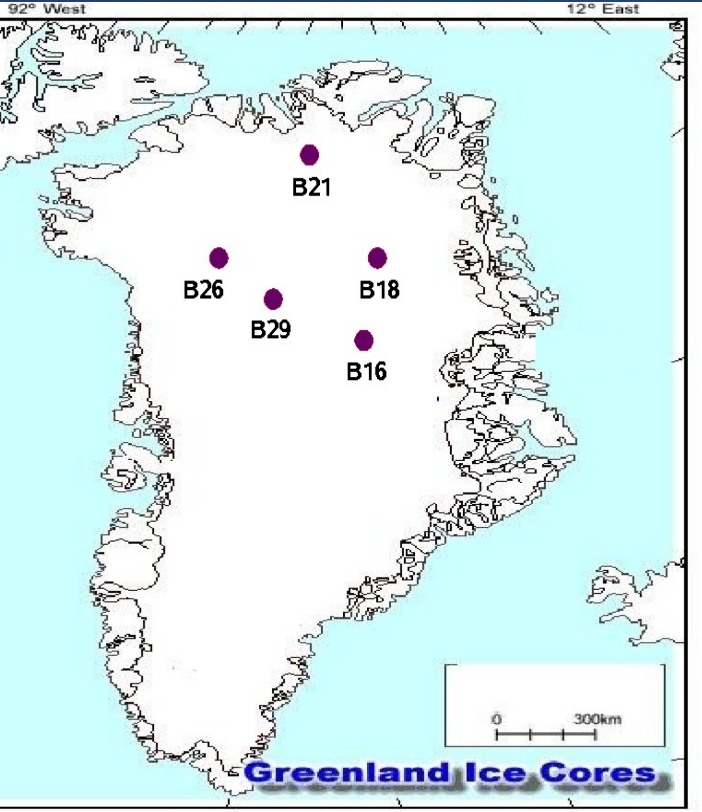
Spatio-Temporal Scales

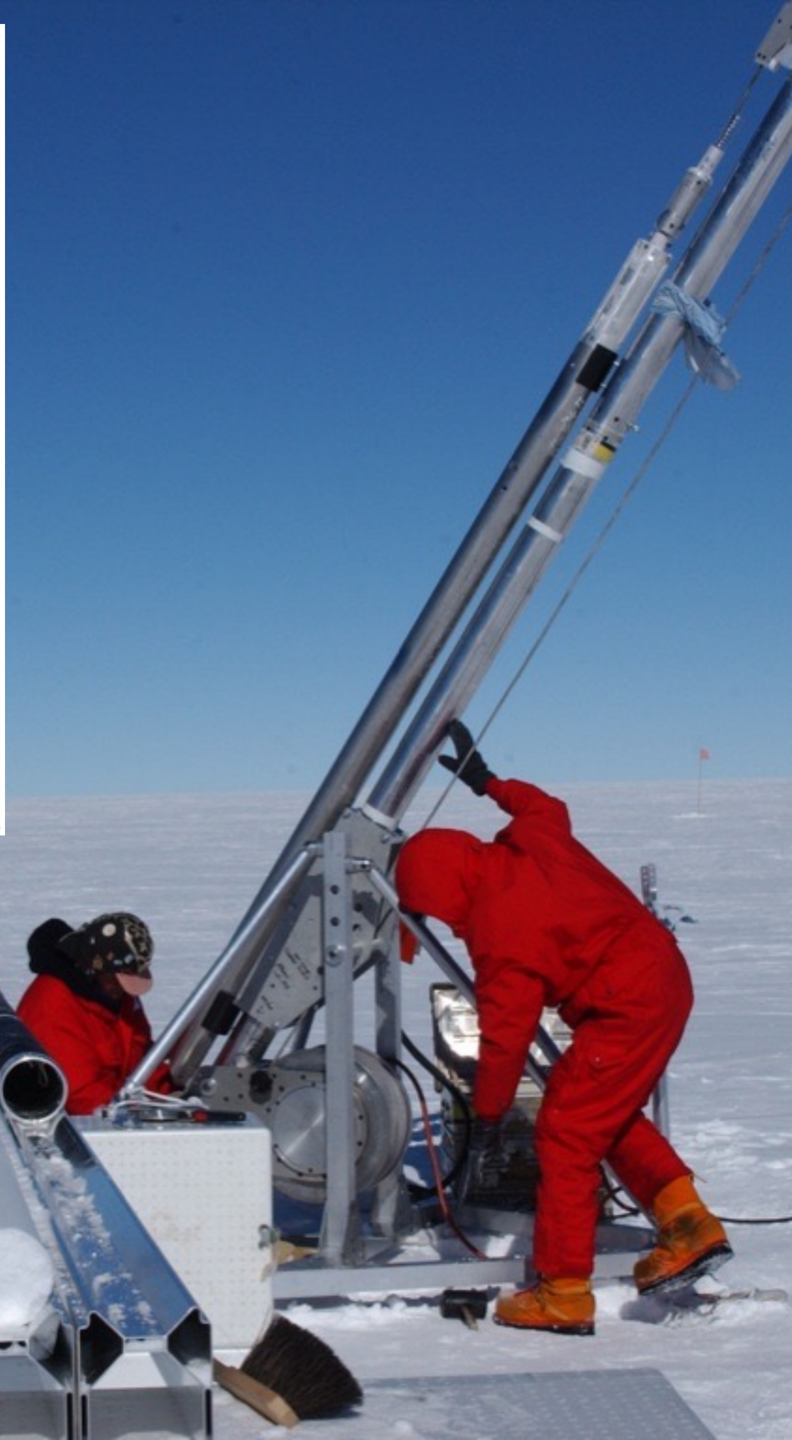


Spatial || temporal Scales

atmosphere & ocean cannot maintain large gradients on long time scales

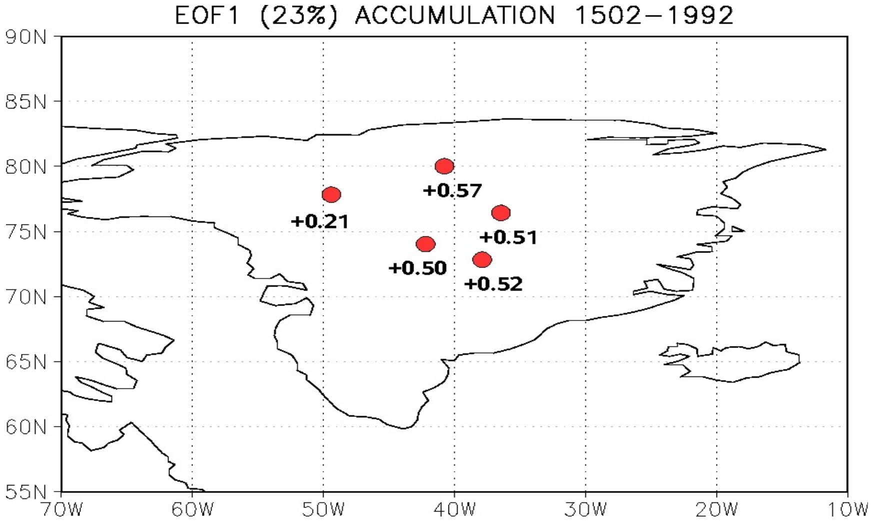
Shallow ice cores



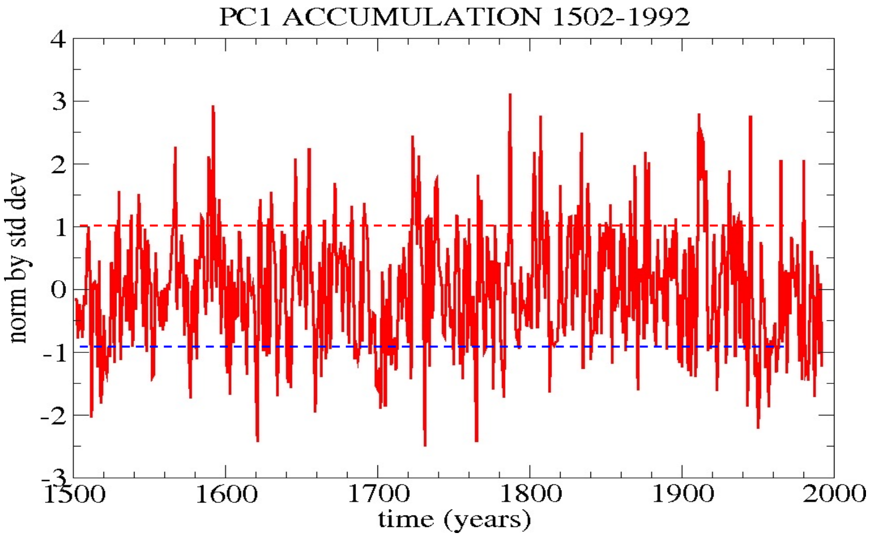


Atmospheric Blocking Circulation

Greenland Shallow Ice Core Positions



Variability of Accumulation Rate



Rimbu and Lohmann 2009

Atmospheric Blocking Circulation

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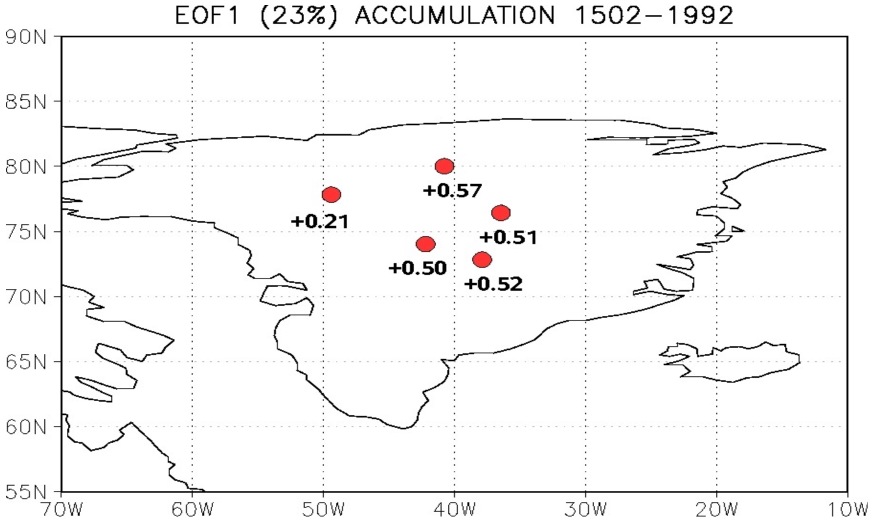

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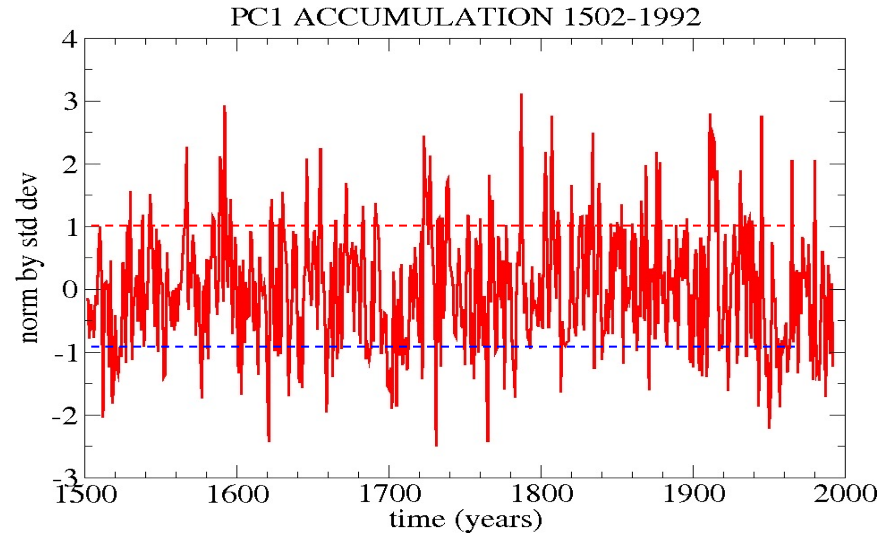
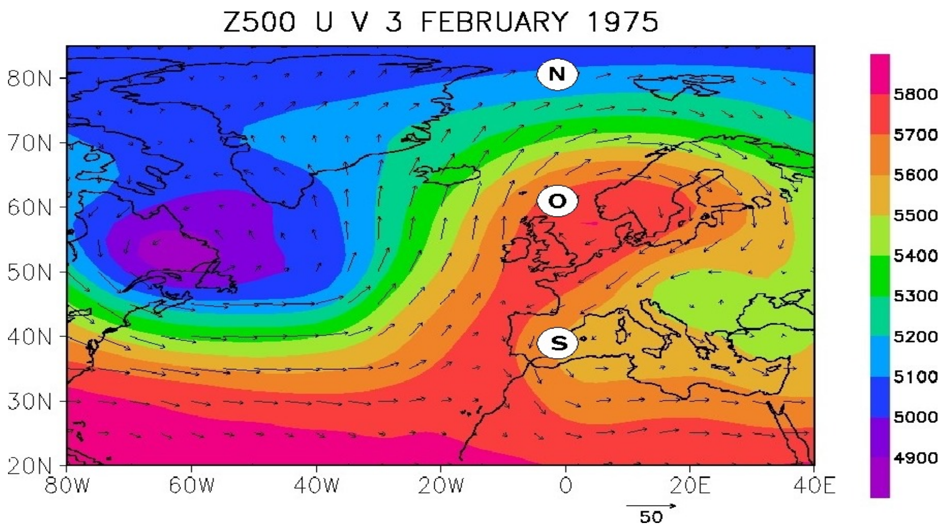
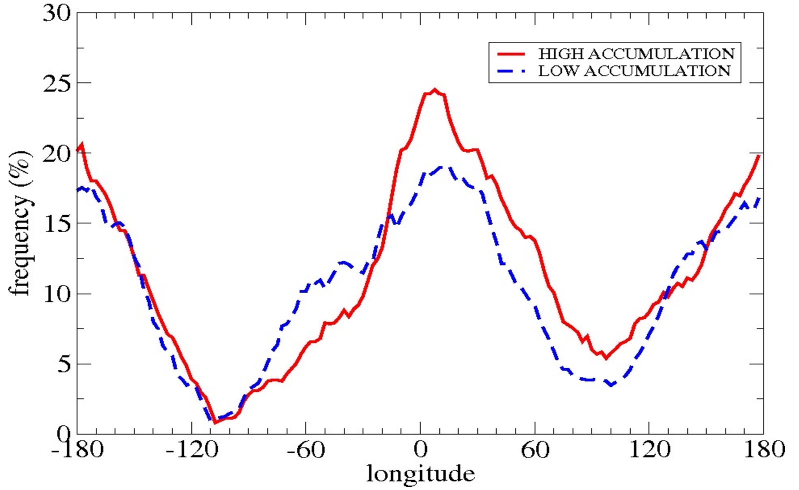


Synoptic Scale Blocking Situation

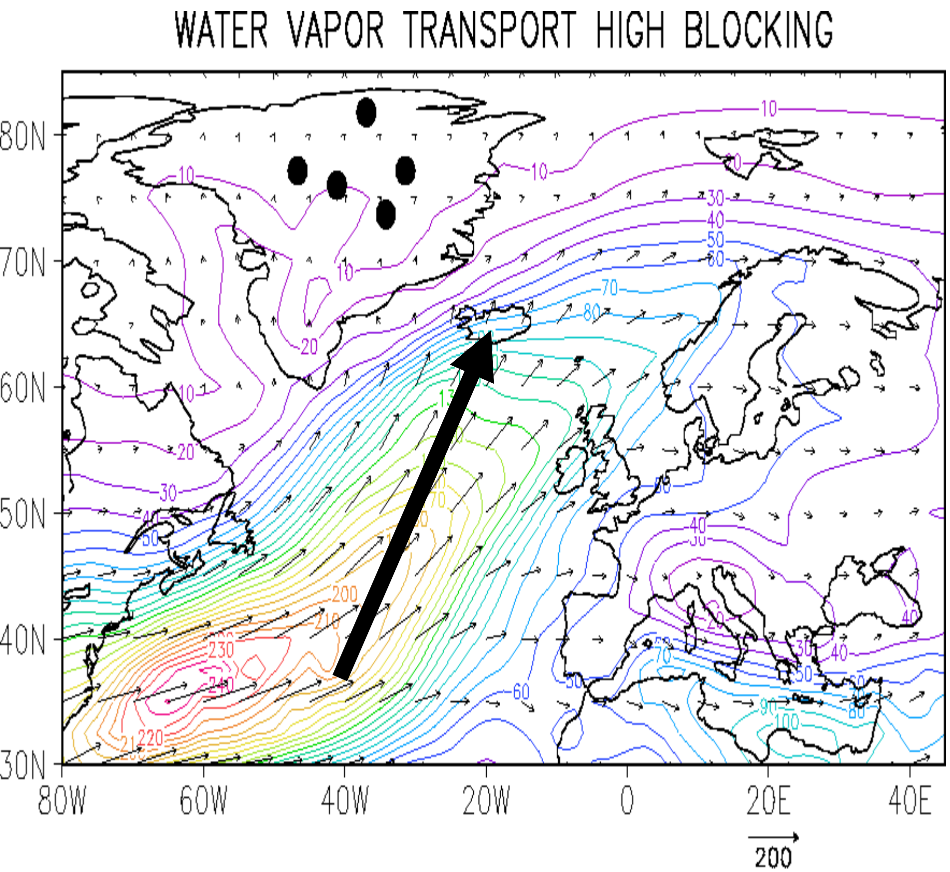


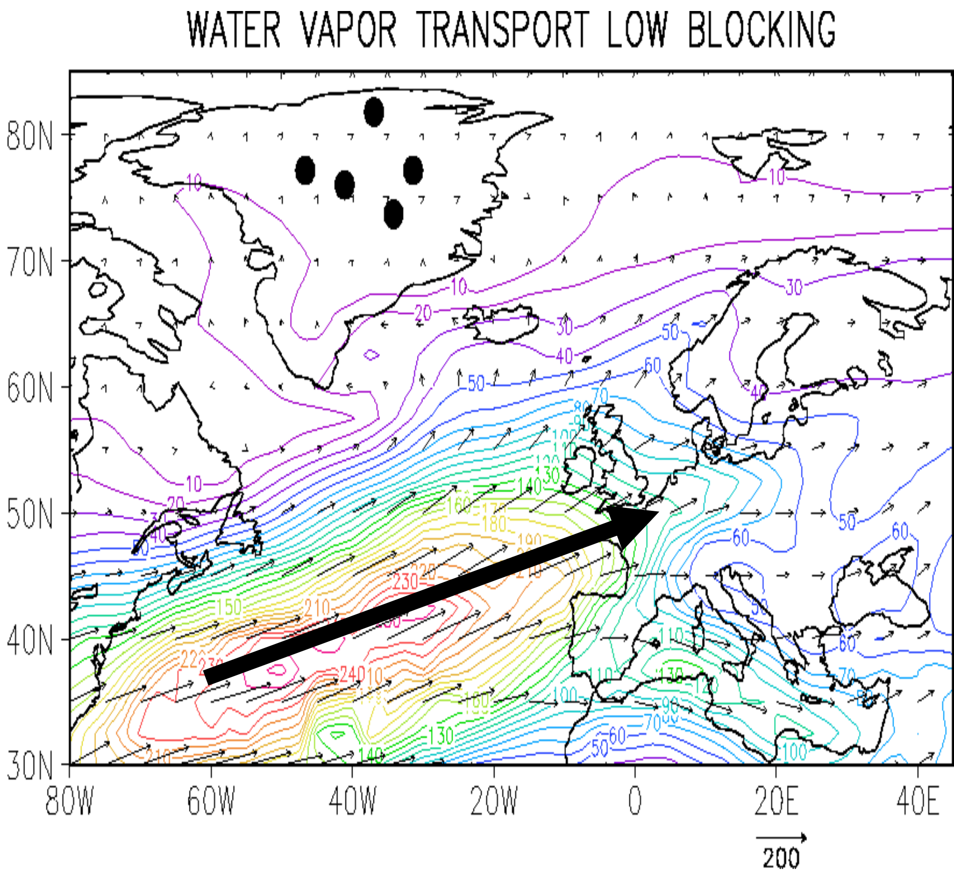
Blocking Frequency for 1948-1992



Rimbu and Lohmann 2009

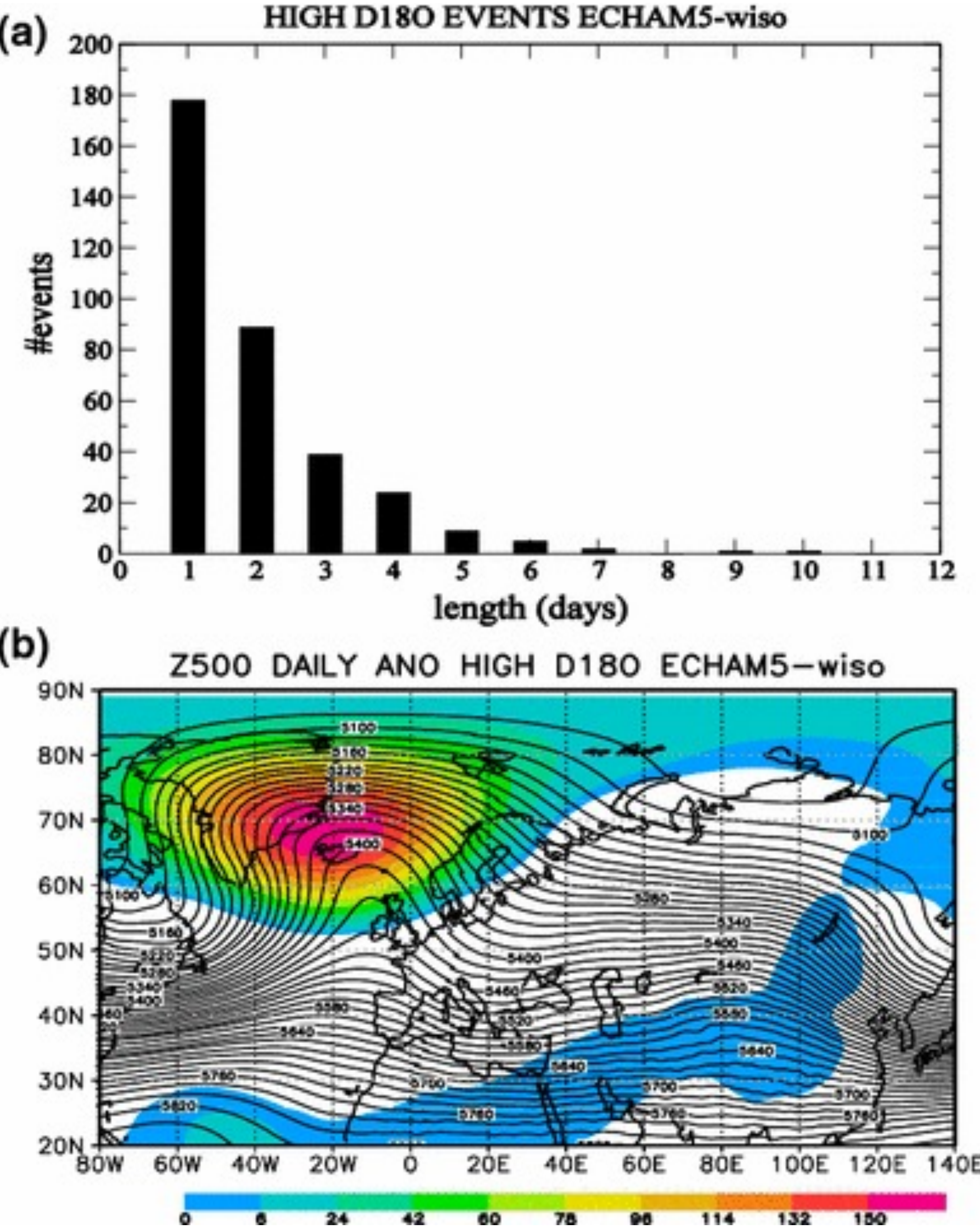
WATER VAPOR TRANSPORT

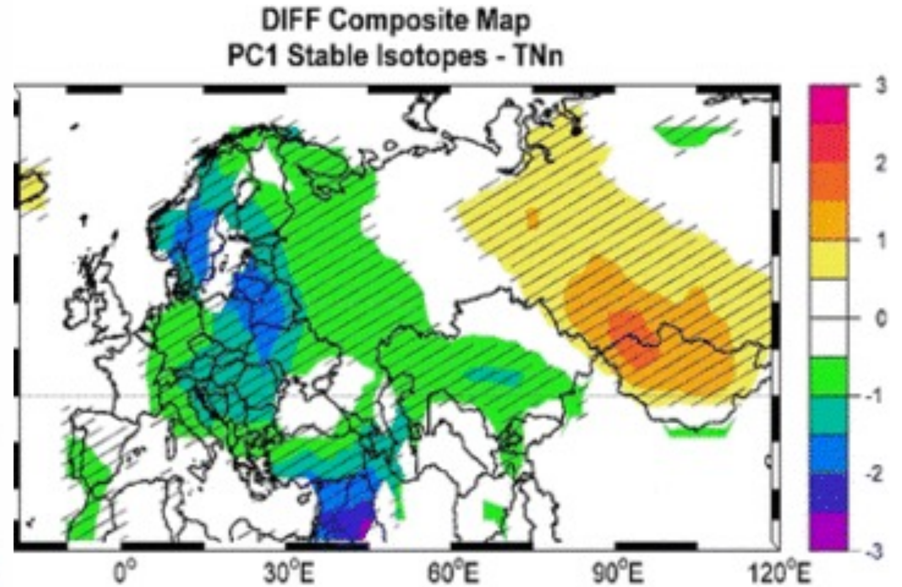




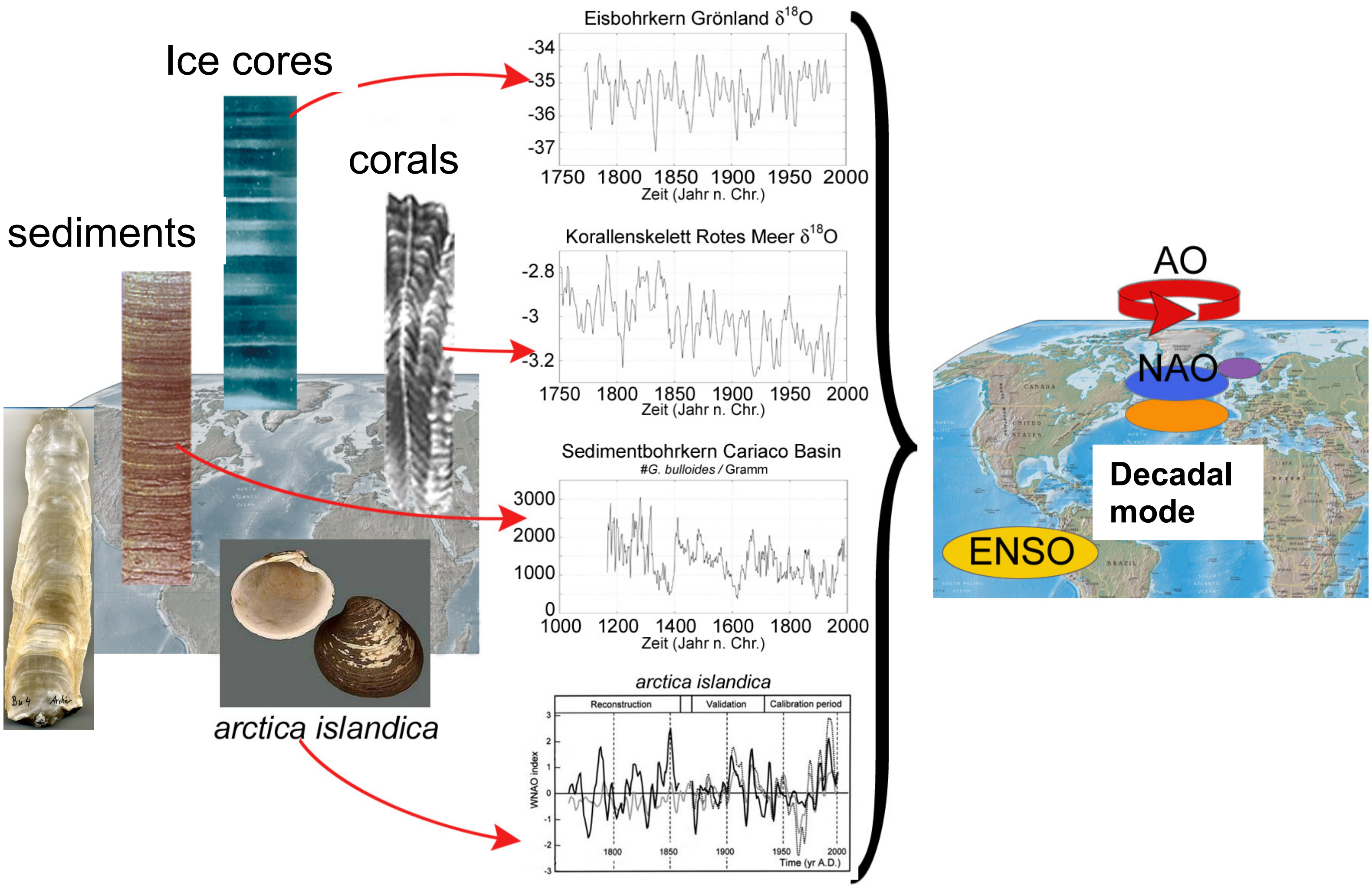
Enhanced moisture transport during high blocking activity

minimum value of daily minimum temperature (TNn)





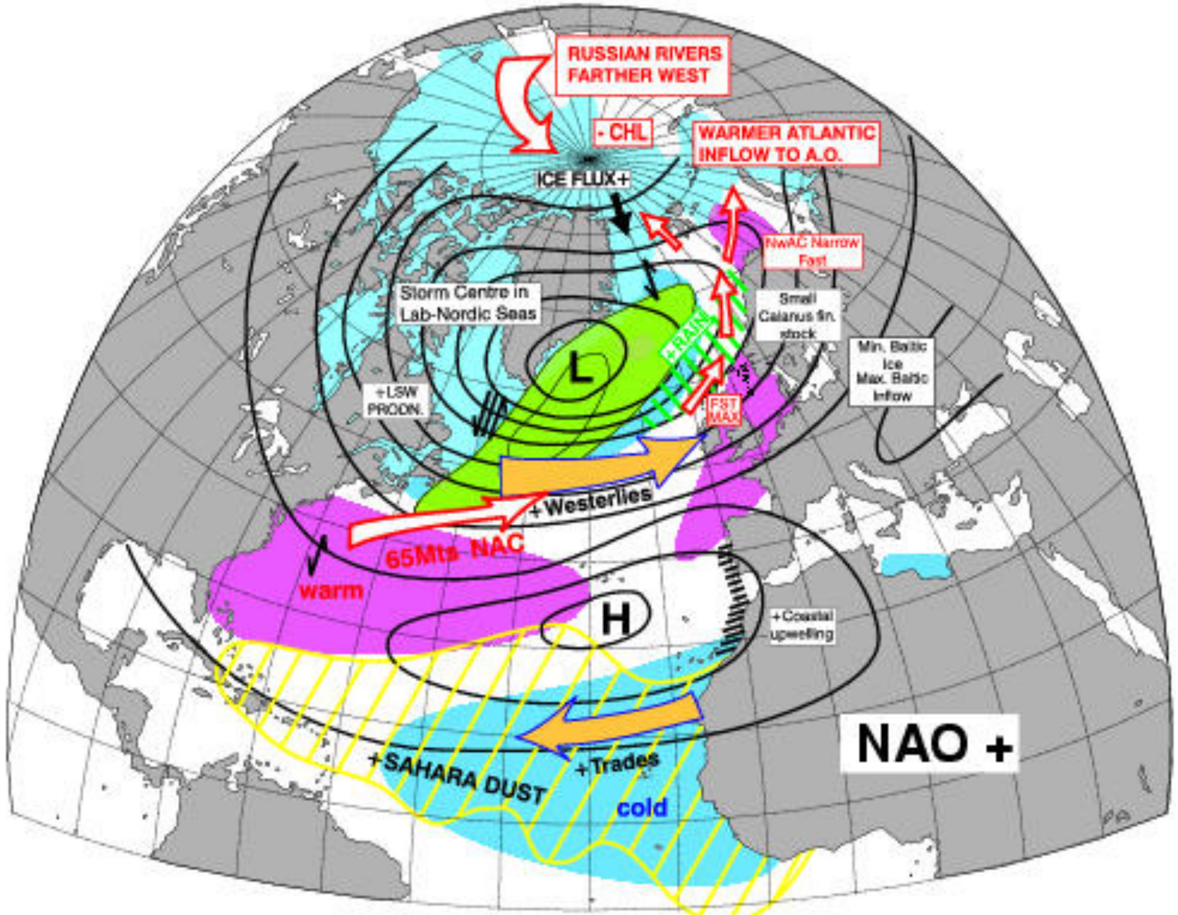
Upscaling concept



Climate archives **Climate variabiliy**

Lohmann, 2007

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

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

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

Statistics

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

Covariance (cross, auto)

$$\gamma(\Delta) = \mathrm{E}\Big((x(t) - \bar{x})\,(y(t+\Delta) - \bar{y}) \Big)$$

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

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

Correlation (cross, auto)

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

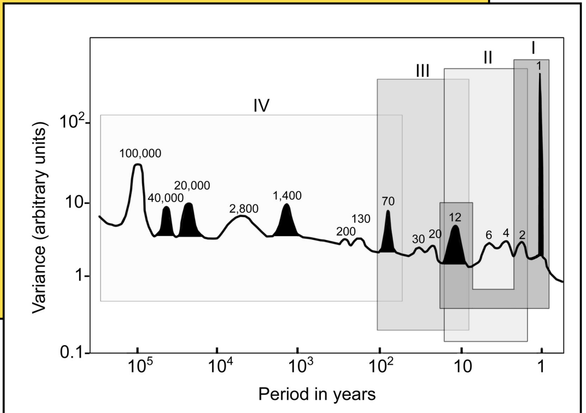
measures the tendency of x (t) and y (t) to covary, between -1 and 1

Spectrum (cross, auto)

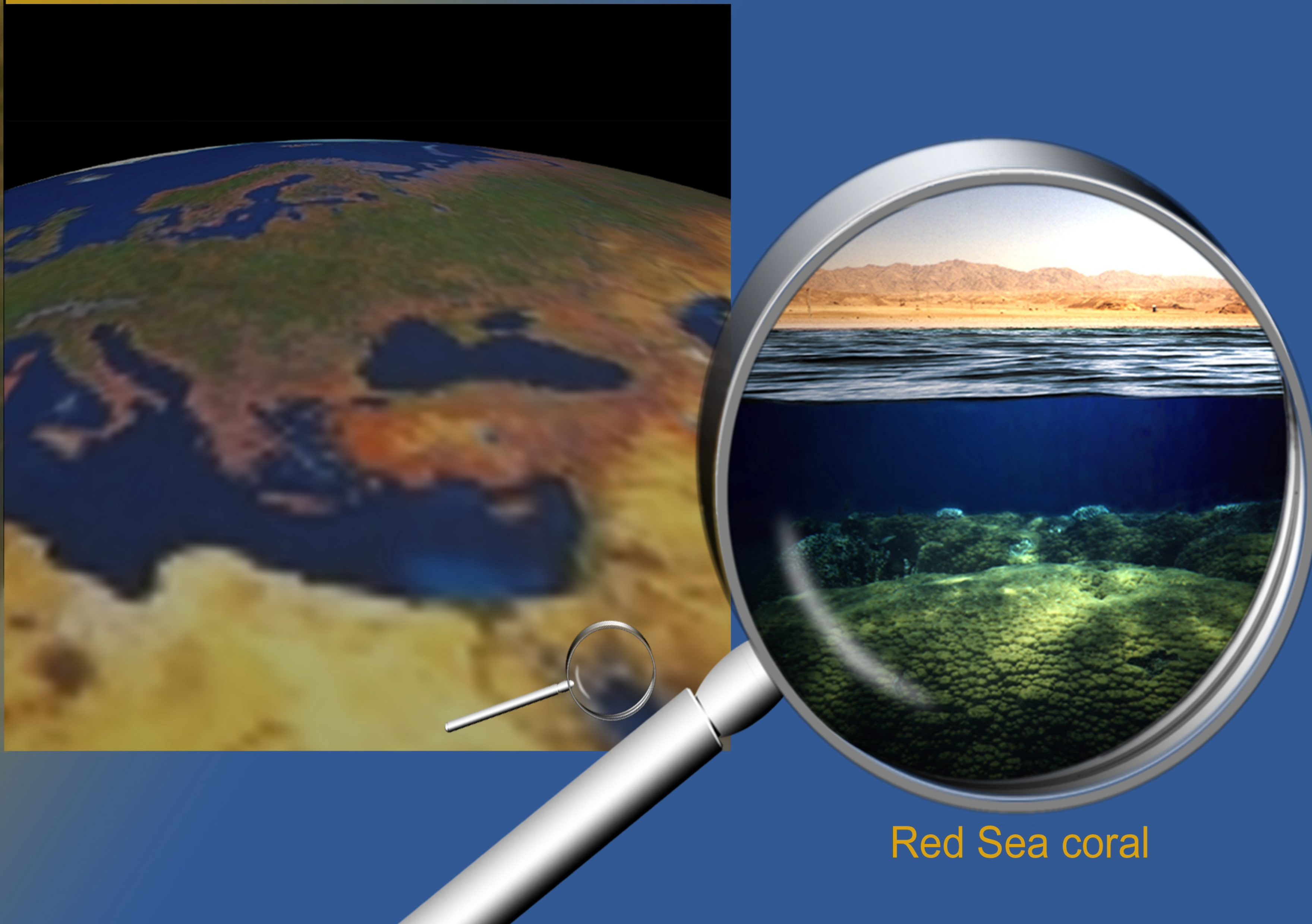
(spectral density)

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

measures variance

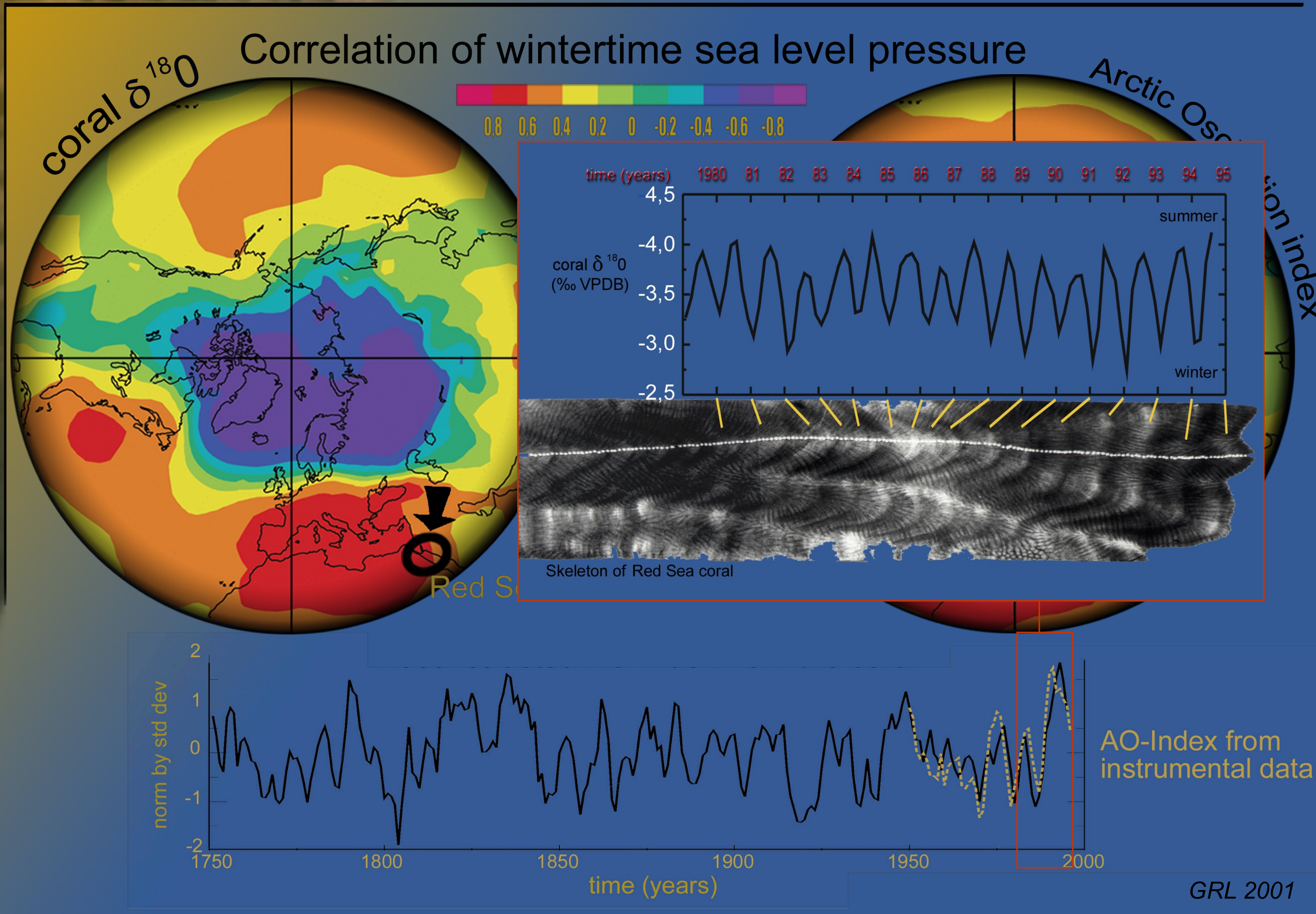


Climate Modes from Proxy Data

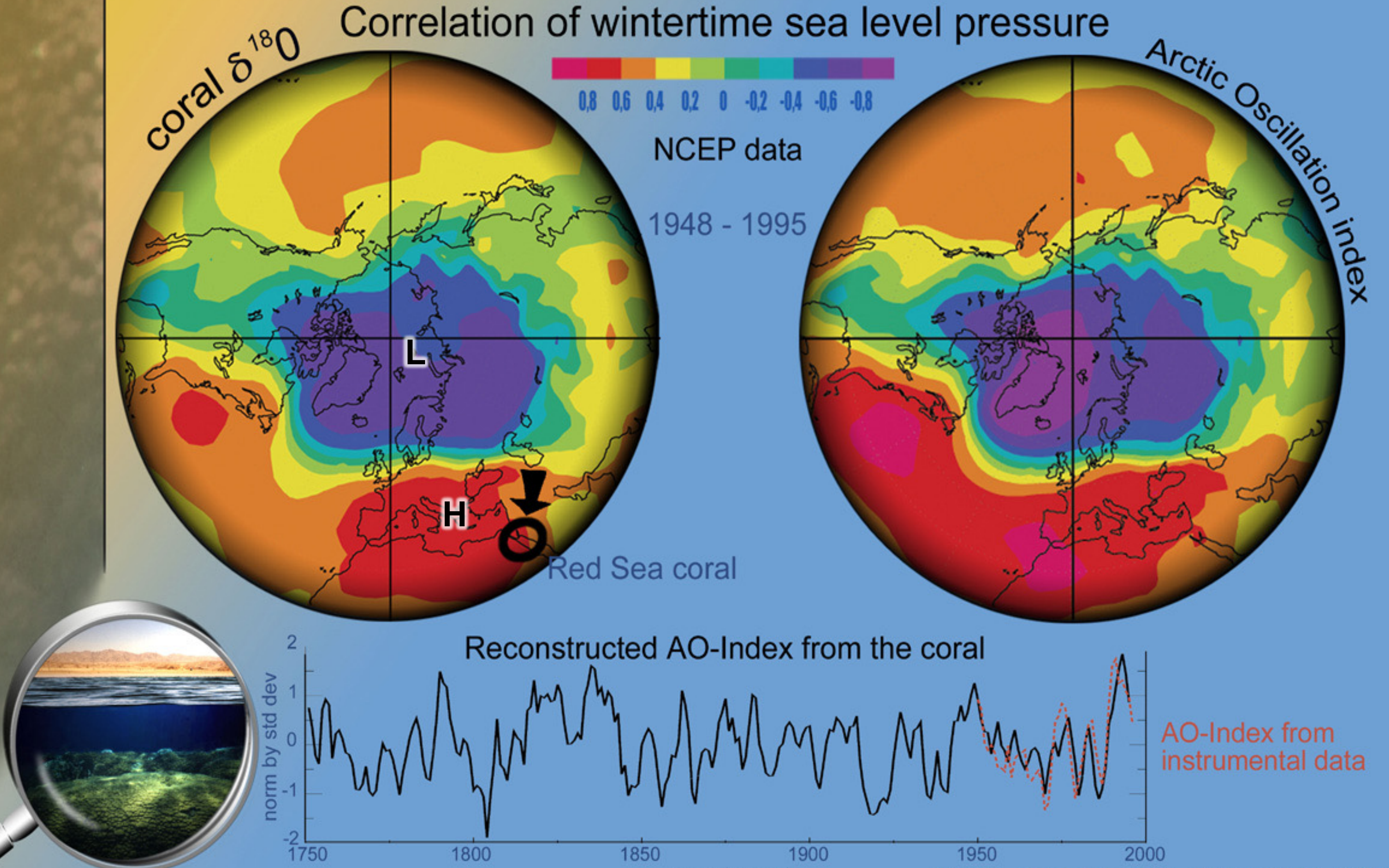


Red Sea coral

Climate Modes from Proxy Data

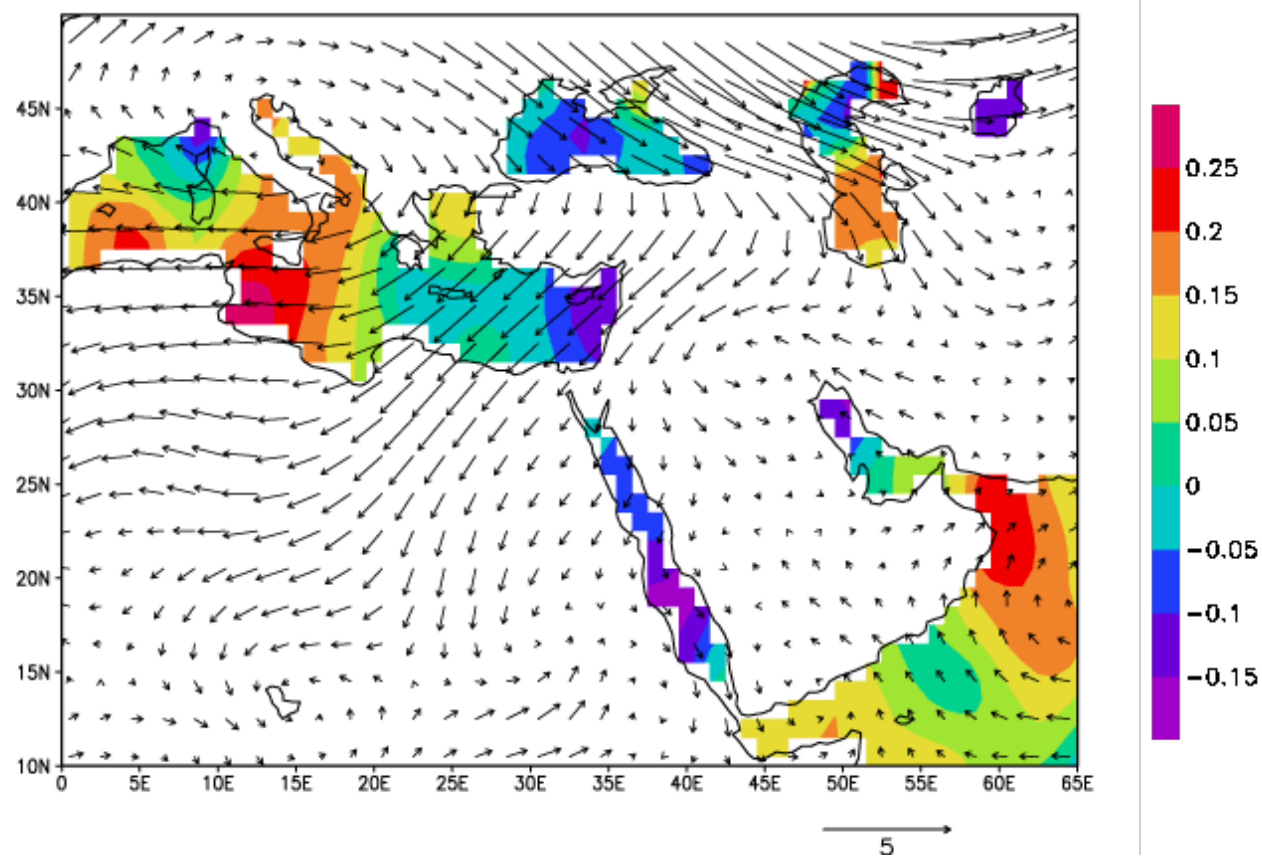


ARCTIC OSCILLATION SIGNATURE IN A RED SEA CORAL



Rimbu, Lohmann, Felis, Pätzold; GRL 2001

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

Exercise teleconnections
using http://climexp.knmi.nl

1) Monthly climate indices (temp, precip, ...)

a) Select one pre-defined index

b) Correlation with temperature, precipiation, SLP

c) Explain the teleconnections for different seasons

2) Climate Index

a) Calculate different regions on the world
(home town, Bremen has 53° N, 8° E)

b) Correlation with temperature, precipiation, SLP

Exercise teleconnections and extremes using http://climexp.knmi.nl

1) **Monthly climate indices** (temp, precip, ...)

a) Select one pre-defined index

b) Correlation with temperature, precipiation, SLP,

c) Explain the teleconnections for different seasons

Nino3.4, PDO, NAO

Drought

Ground frost days

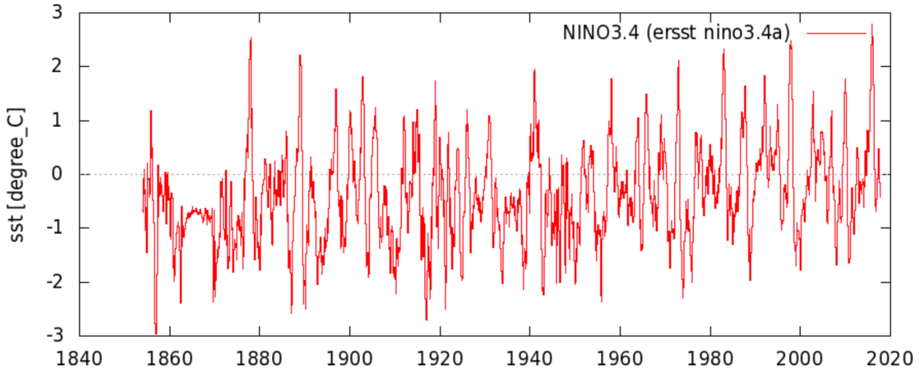
Select a monthly time series
Climate indices

Select a time series by clicking on the name		
ENSO	absolute NINO12, NINO3, NINO3.4, NINO4, relative NINO12, NINO3, NINO3.4, NINO4 (1880-now, ERSST v4, relative is relative to 20S-20N, i.e., without global warming, recommended)	i
	NINO12, NINO3, NINO3.4, NINO4 (1870-now, HadISST1)	i
	NINO12, NINO3, NINO3.4, NINO4 (1856-1981 Kaplan, 1982-now NCEP OISSTv2)	i
	SOI (1866-now, Jones)	i
	SOI (1882-now, NCEP)	i
	Precipitation Niño indices: GPCC land , CMORPH satellite	i
	MEI (1950-now, NOAA/ESRL/PSD)	i
	Warm Water Volume (5°S-5°N, 120°E-80°W, 1980-now, PMEL/TAO)	i
	WWV (5°S-5°N, 120°E-80°W, 1960-now, POAMA/PEODAS)	i
	temperature averaged to 300m (130°E-80°W, 1979-now, GODAS)	i
NAO	NAO Gibraltar-Stykkisholmur (1821-now, Jones)	i
	NAO Azores-Stykkisholmur (1865-2002, data from Jones)	i
	NAO (pattern-based, 1950-now, CPC)	i
	NAO reconstruction (1658-2001, Luterbacher)	i
SNAO	Summer NAO from NCEP/NCAR (1948-now), UCAR (1899-now), 20C (1871-2008) SLP	i
AO	Arctic Oscillation derived from SLP (1899-2002) and derived from SAT (1851-1997, Thompson, Colorado State)	i

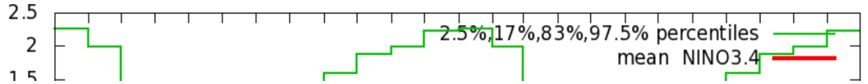
KNMI Climate Explorer

Time series
monthly NINO3.4

cutting out region defined by mask ersstv5 nino3.4 mask.nc, sst [degree C] from NOAA ERSSTAv5 (in situ only), SSTA normalized to 1981-2010, plotdat anomal 1981 2010 ersst nino3.4.dat, cutting out region defined by mask ersstv5 nino3.4 mask.nc, sst [degree C] from NOAA ERSSTv5 (in situ only), (eps, pdf, raw data, netcdf)



Two annual cycles, computed with all data available (eps, pdf, raw data)



Select a time series
- Daily station data
- Daily climate indices
- Monthly station data
- Monthly climate indices
- Annual climate indices
- View, upload your time series

Select a field
- Daily fields
- Monthly observations
- Monthly reanalysis fields
- Monthly and seasonal historical reconstructions
- Monthly seasonal hindcasts
- Monthly decadal hindcasts
- Monthly CMIP3+ scenario runs
- Monthly CMIP5 scenario runs
- Annual CMIP5 extremes
- Monthly CORDEX scenario runs
- Attribution runs
- External data (ensembles, ncep, enact, soda, ecmwf, ...)
- View, upload your field

Investigate this time series
- View per month, season, half year or full year (Jan-Dec or Jul-Jun)
- View last 1, 5, 10, N years
- Correlate with other time series
- Correlate with a field (correlation, regression, composite)
  - only observations
  - only reanalyses
  - only seasonal forecasts
  - only scenario runs
  - only user-defined fields
- Verify against another time series
- Spectrum, autocorrelation function
- Wavelet
- Running mean/s.d./skew/curtosis
- Trends in return times of extremes

Correlate time series with an observation field

NINO3.4

Observations		
Temperature	1850-now anomalies: HadCRUT4 median,	i
	1880-now anomalies: GISS 250km, 1200km	i
	1880-now anomalies: NCDC v3.2.1	i
	1850-now anomalies: HadCRUT4 filled-in by Cowtan and Way	i
Land	1850-2010 anomalies: CRUTEM4	i
	1880-now anomalies: GISS 250km, 1200km	i
	1880-now anomalies: NCDC v3.2.1	i
	1948-now: CPC GHCN/CAMS t2m analysis (land) 0.5°, 1.0°, 2.5°	i
	1901-2016: CRU TS 4.01 (land) 0.5°, 1.0°, 2.5°, #/value	i
	1901-2016: CRU TS3.25 (land) 0.5°, 1.0°, 2.5°, #/cell, #/value	i
	1750-now: Berkeley 1°	i
	0.25° 1950-now: E-OBS v15.0 Tg, 0.5° 1901-now with CRU TS (Europe)	i
	1895-now: PRISM 4km, PRISM 0.25°, (Contiguous US only)	i
Tmax	1901-2016: CRU TS 4.01 (land) 0.5°, 1.0°, 2.5°, #/value	i
Tmax	1901-2016: CRU TS3.25 (land) 0.5°, 1.0°, 2.5°, #/cell, #/value	i
	1833-now: Berkeley 1°	i
	0.25° 1950-now: E-OBS v15.0 Tx, 0.5° 1901-now with CRU TS (Europe)	i
	1895-now: PRISM 4km, PRISM 0.25°, (Contiguous US only)	i
	HadEX2 1901-2010 2.5° monthly: TXx, TXn, TX10p, TX90p, annual: TXx, TXn, TX10p, TX90p	i

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- Plot and fit distribution

Field
HadCRUT4.5 SST/T2m anom

…. Or select a position

HadCRUT4 near-surface temperature ensemble data - ensemble …
X axis: whole world in 72 5.00° steps, first point at 177.50° W, last point at 177.50° E
Y axis: regular grid with 36 5.00° steps, first point at 87.50° S, last point at 87.50° N

Monthly data available from Jan1850 to Jul2017 (2011 months)
Variable temperature_anomaly (near_surface_temperature_anomaly) in K
The associated land/sea mask is available for some operations

Get grid points, average area or generate subset

Mask:	no mask · add a mask to the list
Latitude:	53 °N - 54 °N
Longitude:	8 °E - 9 °E
Boundaries:	halfway grid points
Make:	(•) average ( ) max ( ) min ( ) set of grid points ( ) subset of the field

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Field correlations
HadCRUT4.5 SST/T2m anom 8-9E 53-54N mean with Trenberth SLP

Computing correlations... (this may take a minute or so)

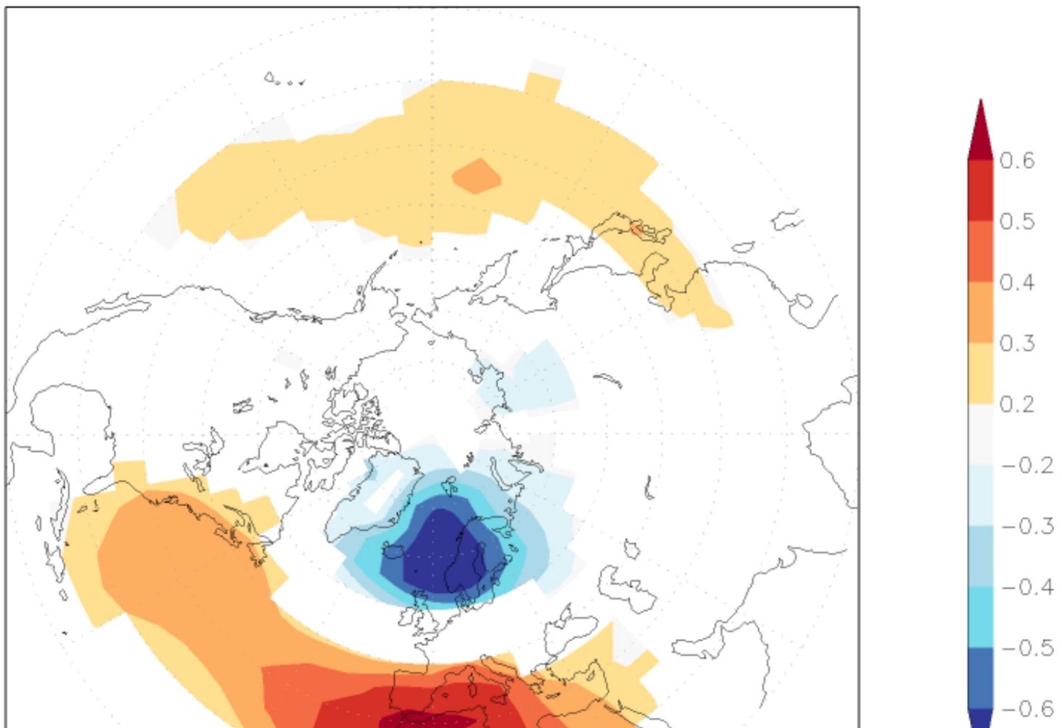
If it takes too long you can abort the job here (using the [back] button of the browser does not kill the correlation job)

Requiring at least 50% valid points

Plotting with GrADS 2.0...

corr Jan HadCRUT4.5 SST/T2m anom 8-9E 53-54N mean with Jan Trenberth SLP 1899:2017 p<10% (eps, pdf)

corr Jan HadCRUT4.5 SST/T2m anom 8–9E 53–54N mean with Jan Trenberth SLP 1899:2017 p<10%



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- Trends in return times of extremes
- Plot and fit distribution

Investigate this field
- Plot this field
- Plot difference with a field
- Compute mean, s.d. or extremes
- Trends in extremes
- Make EOFs
- Correlate with a time series
- Pointwise correlations with a field
  - only observations
  - only reanalyses
  - only seasonal hindcasts
  - only decadal hindcasts
  - only CMIP5 scenario runs
  - only user-defined fields
- Spatial correlations with a field
  - only observations
  - only reanalyses
  - only seasonal hindcasts
  - only decadal hindcasts
  - only CMIP5 scenario runs
  - only user-defined fields
- SVD
  - only observations
  - only reanalyses
  - only seasonal hindcasts
  - only CMIP5 scenario runs
  - only user-defined fields
- Verify field against observations

Climate variability across time scales

Past climates help us to understand the climate system as a whole

To elaborate processes (first and second order)

Test hypotheses by scenarios and comparing model results to data

Interpretation of proxy data: Seasonal to syonptic signatures

Bring the current climate into a long-term context, extremes