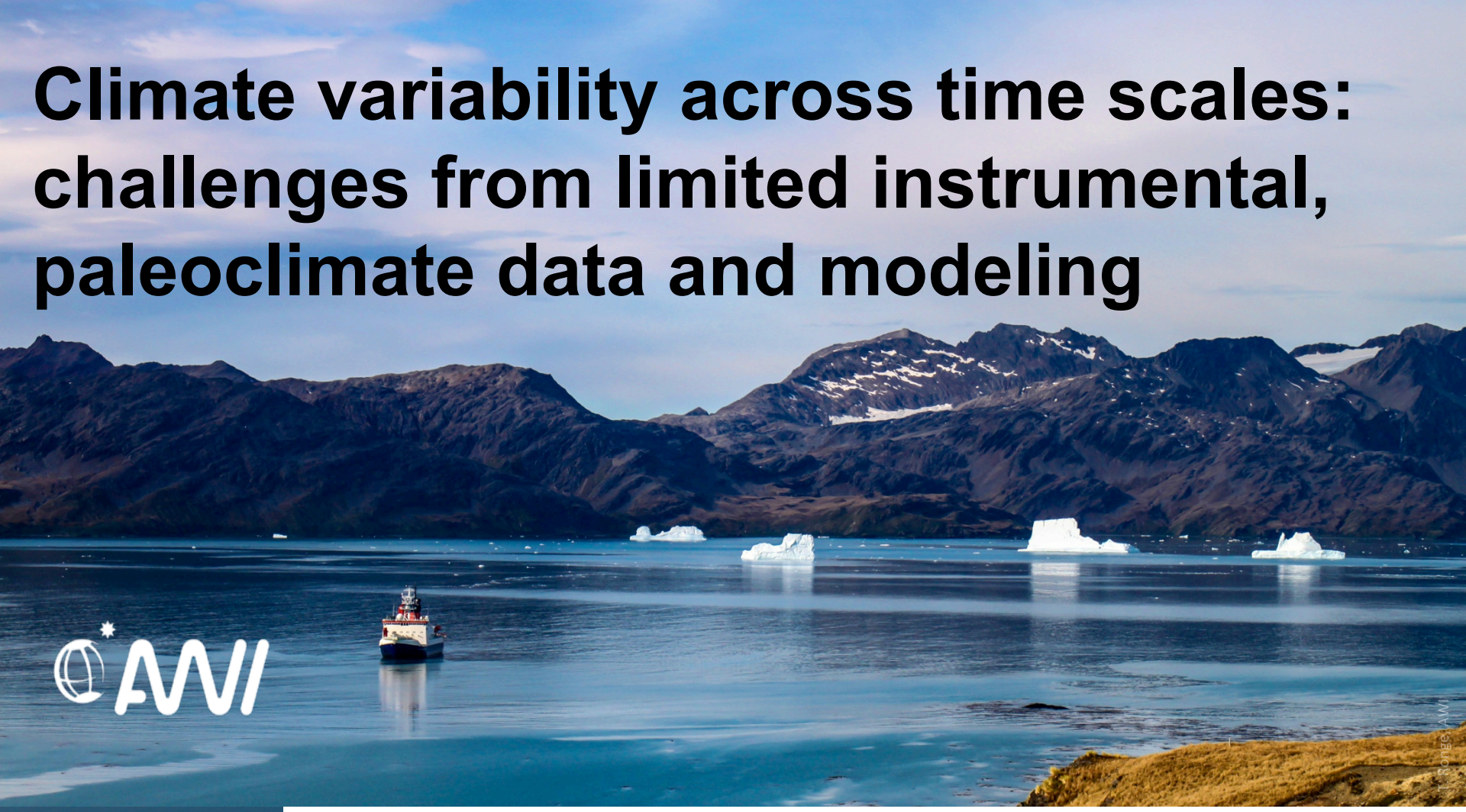
Climate variability across time scales: challenges from limited instrumental, paleoclimate data and modeling



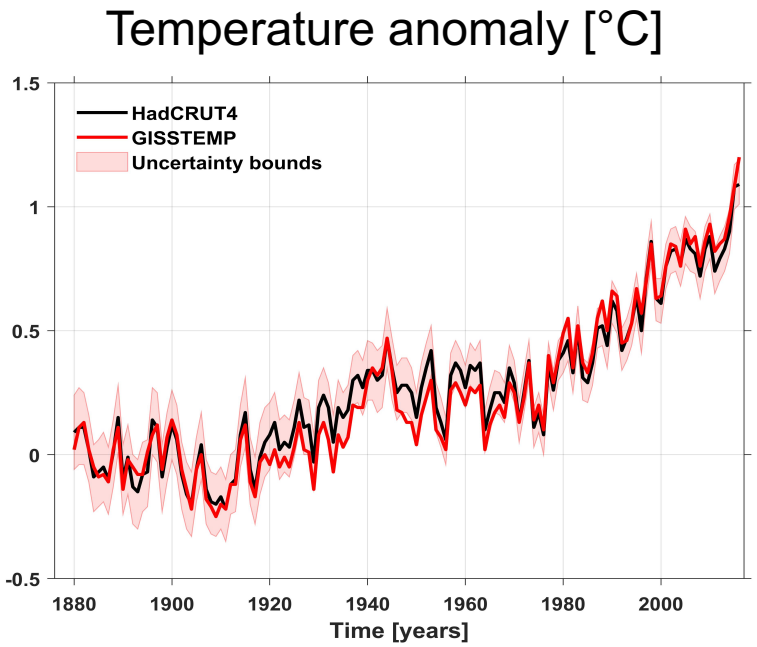
Alfred-Wegener-Institut

Helmholtz-Zentrum für Polar- und Meeresforschung

Gerrit Lohmann, IUP Bremen, May 25, 2018

HELMHOLTZ ASSOCIATION

Motivation: Observational Record

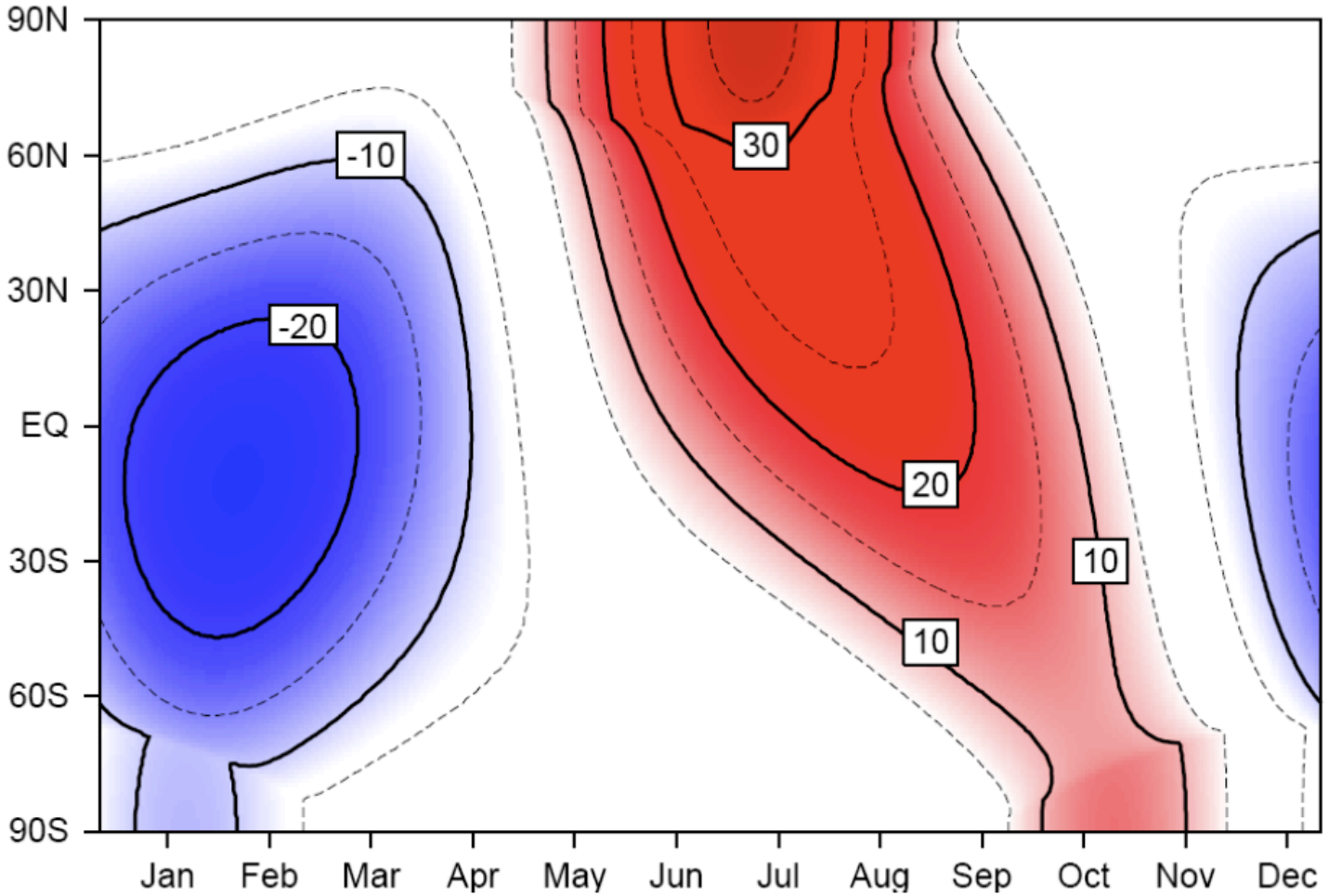


pronounced multi-decadal component with warm 1935-1945 and after 2000.

Prior to 1960: very limited data
Prior to 1920: very, very limited data

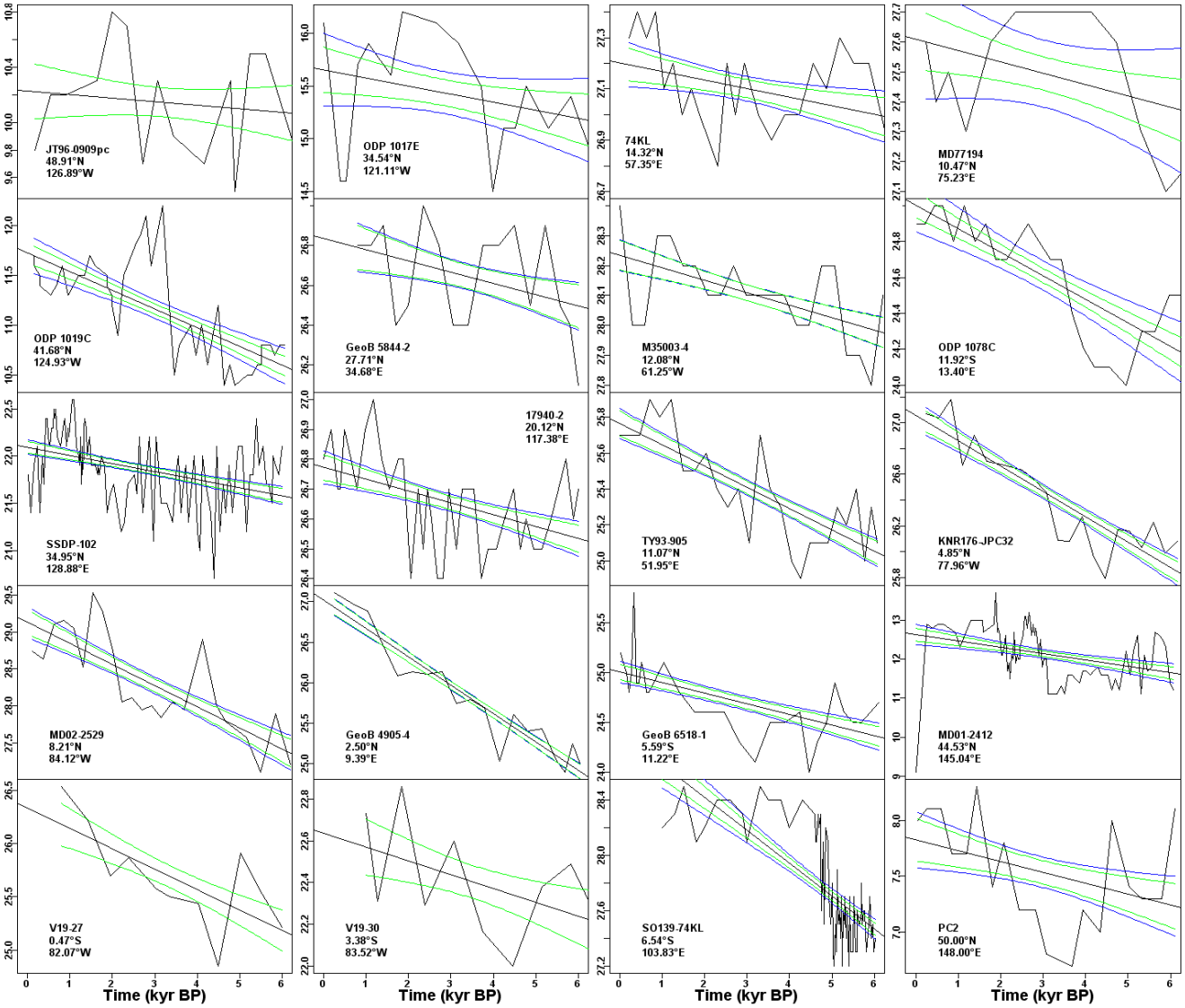
Climate variability beyond the instrumental record: Decadal, centennial, millennial

Insolation (6k minus present)

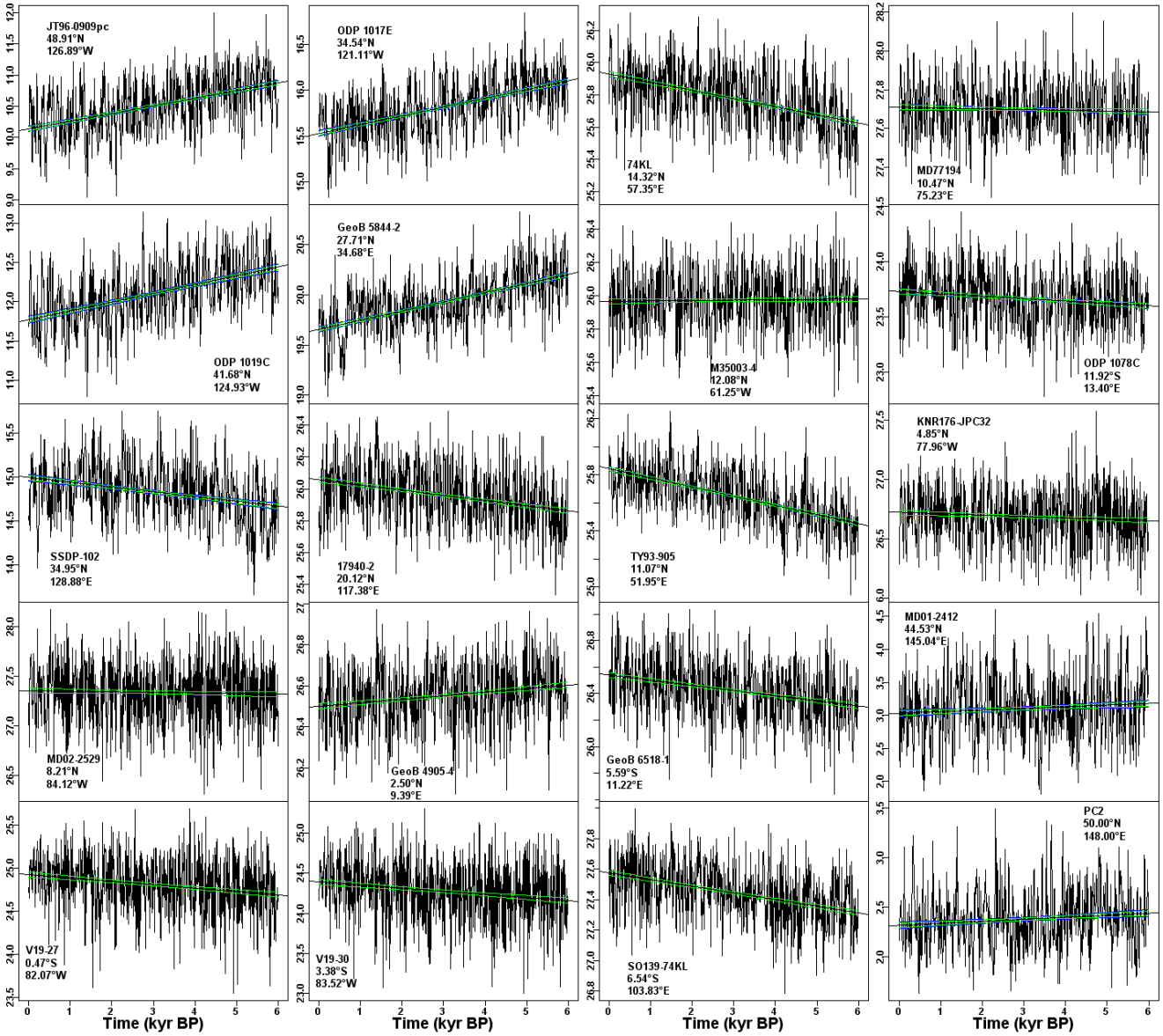


(after Berger, 1978)

Alkenone Records + Trends

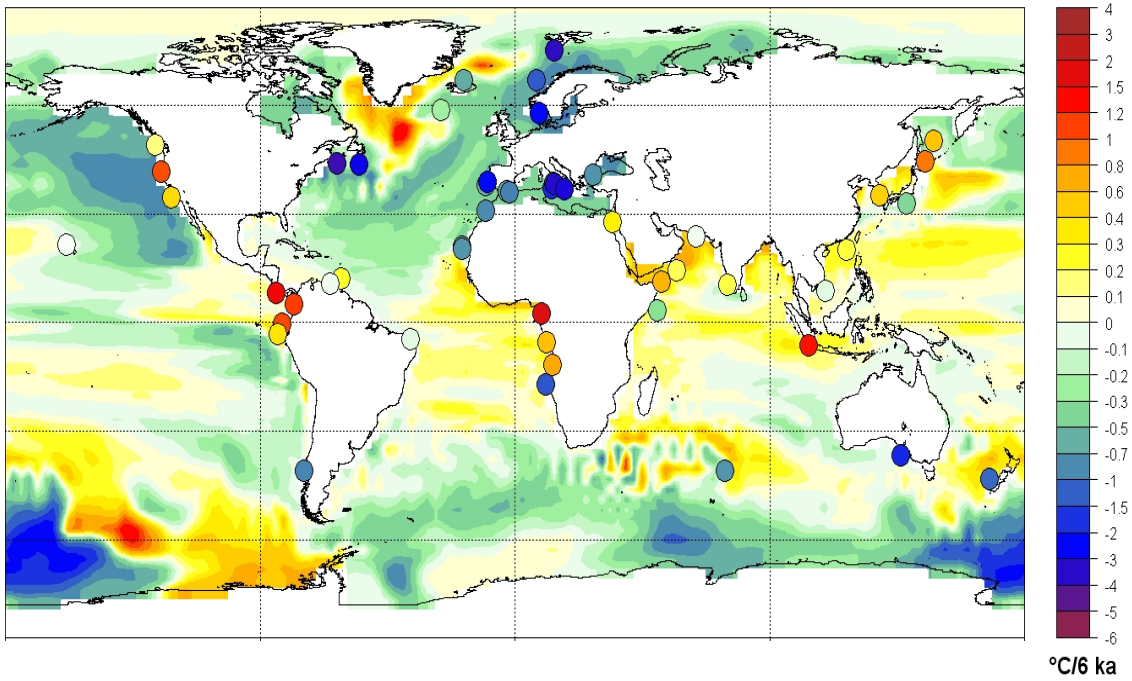


Model SST at core locations



Marine temperature trends of the last 6000 years

Annual mean sea surface temperature trends

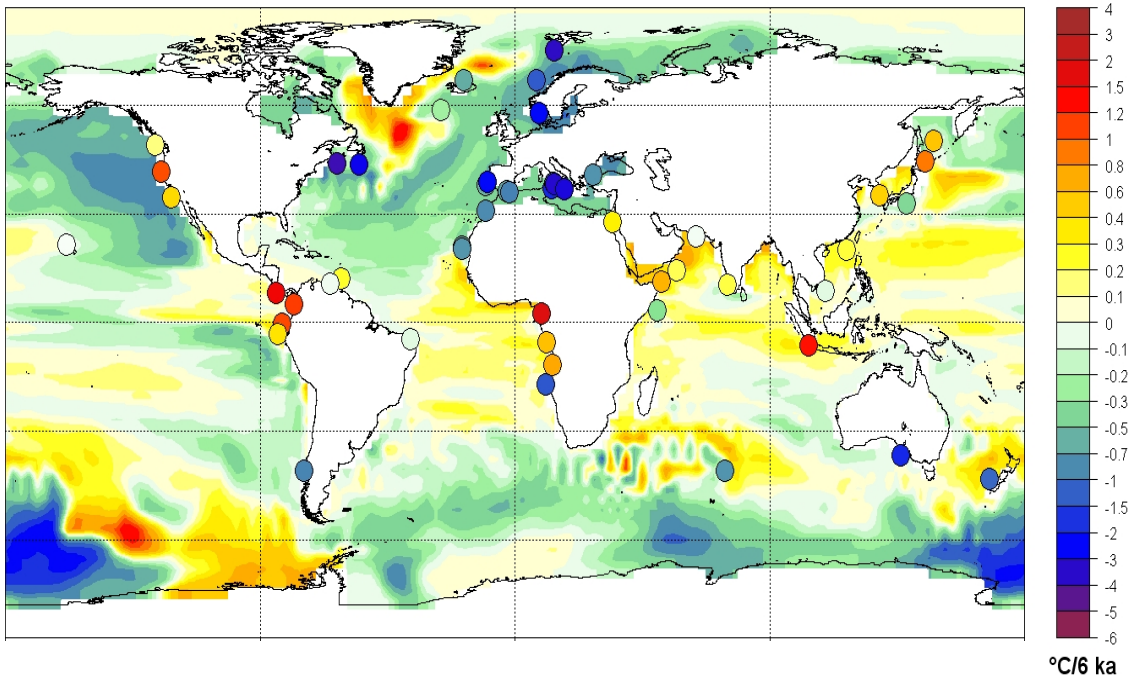


Alkenone-based temperature trends

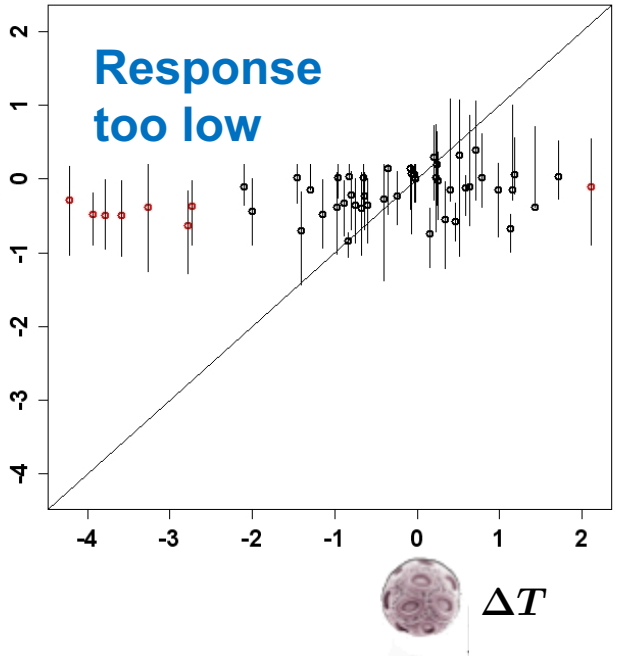
Lohmann et al., 2013, CP

Marine temperature trends of the last 6000 years

Annual mean sea surface temperature trends



ΔT



Alkenone-based temperature trends

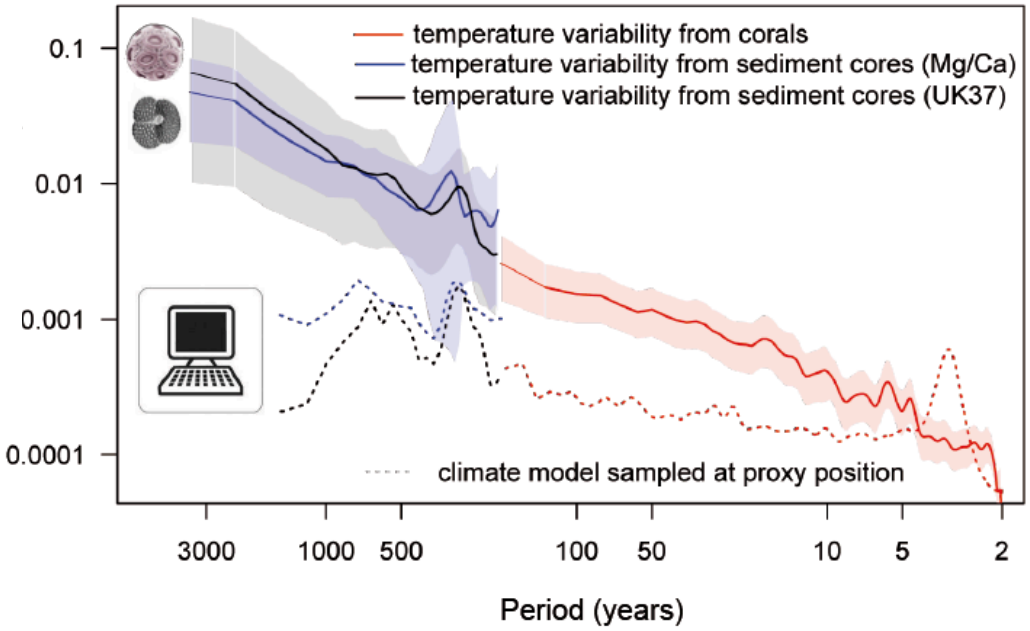
Lohmann et al., 2013, CP

Marine temperature variability

(annual to millennial time scales)

Power spectrum

$S(\omega)$



Current climate models seem to underestimate long-term variability

Laepple and Huybers, 2014; GRL, PNAS

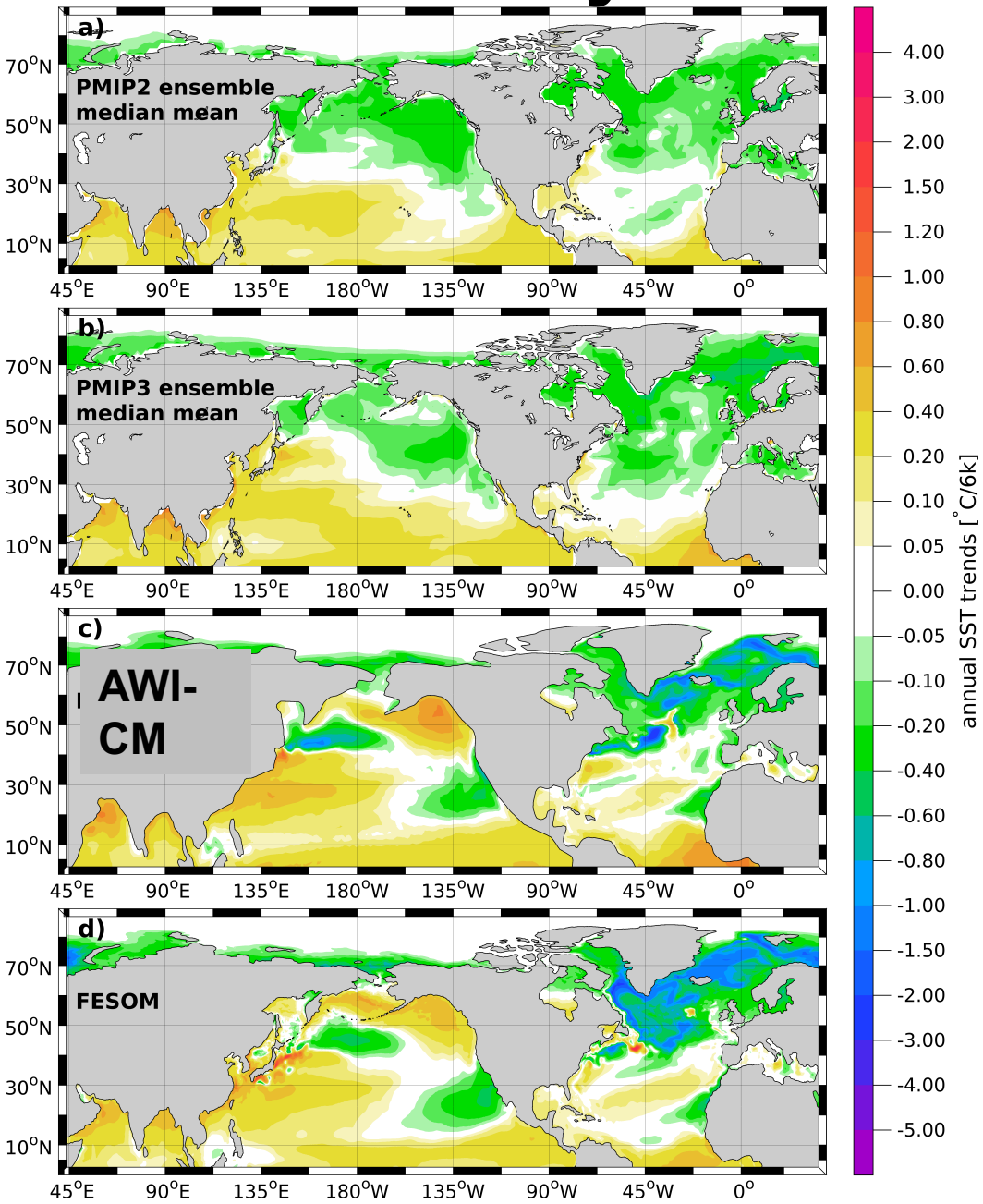
Holcene SST -Trends 6000 years

PMIP2, ~3° resol

PMIP3, ~2° resol

Climate model ECHAM6-FESOM

Downscaling Ocean

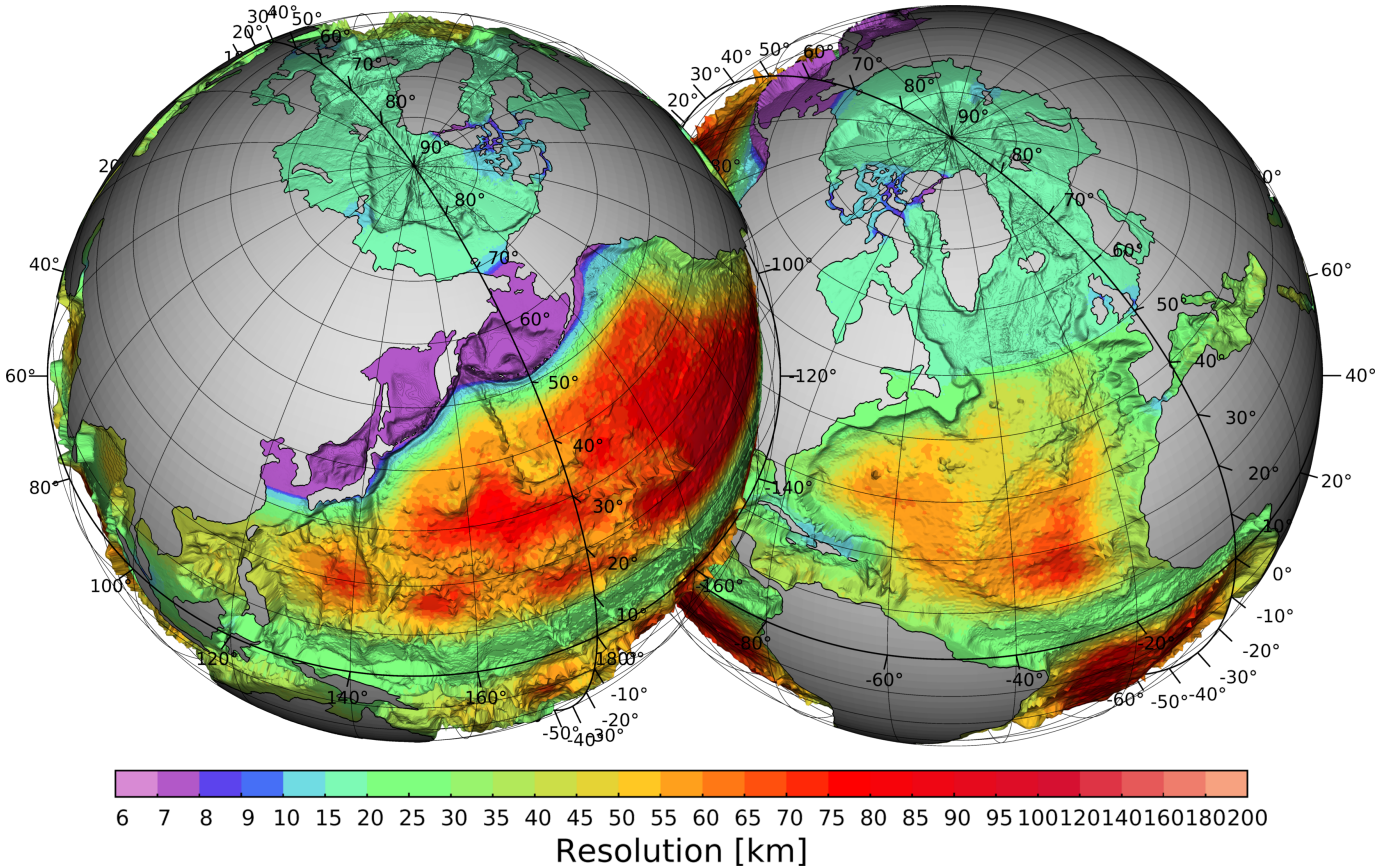


Climate model ECHAM6-FESOM

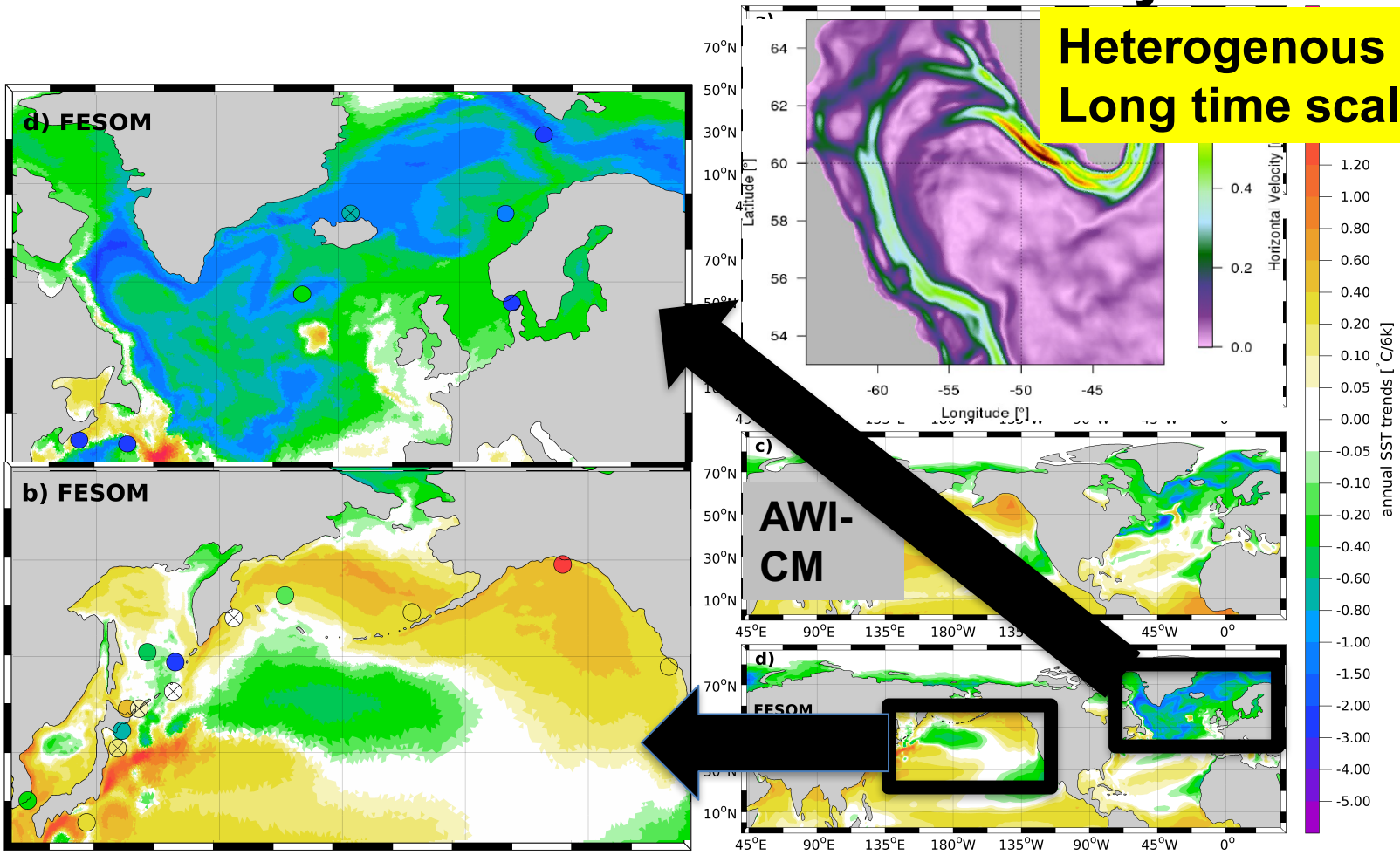
Atmosphere: general circulation model ECHAM6 (MPI) T63

Sea ice and ocean: finite-element model FESOM (AWI)

Resolution (km) of FESOM:

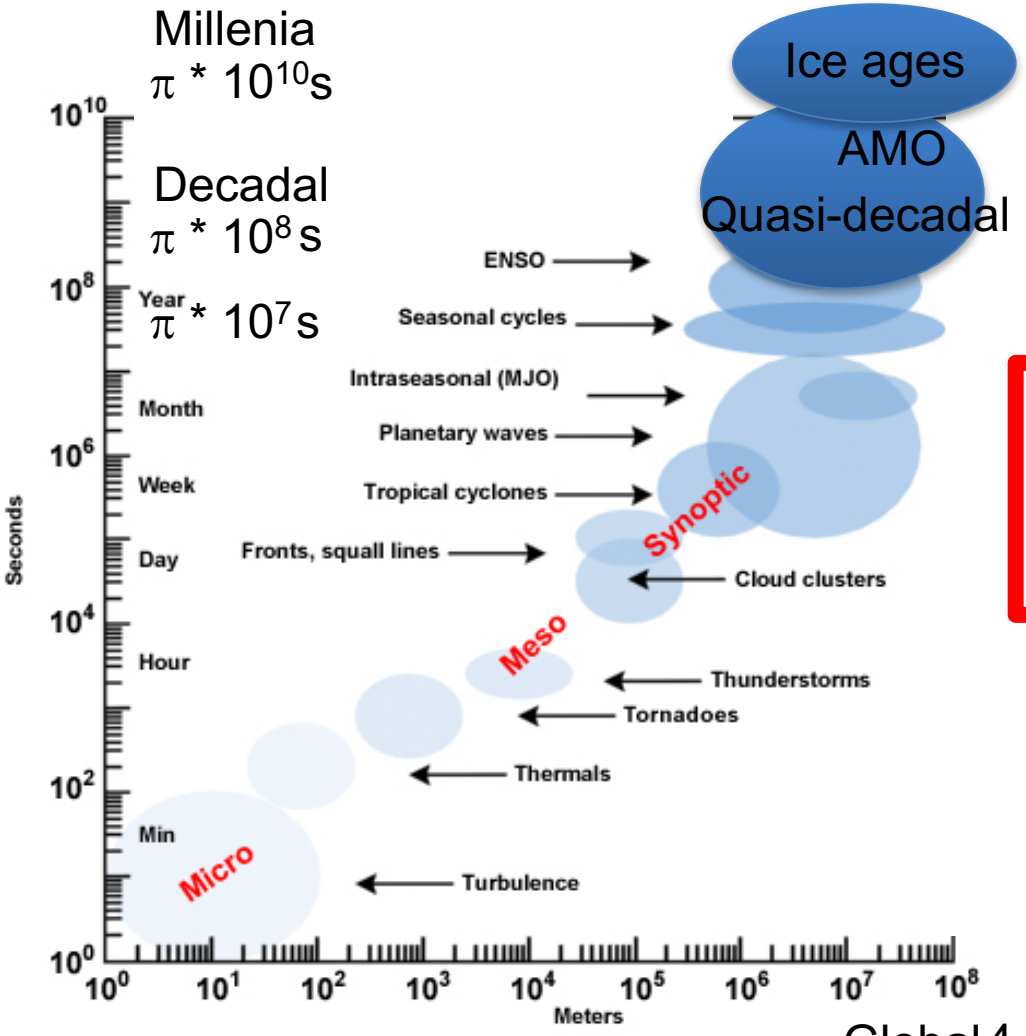


Holocene SST -Trends 6000 years



Assumption: Spatial Scales || temporal Scales

Dissipative Systems (as atmosphere & ocean) cannot maintain large gradients on long time scales

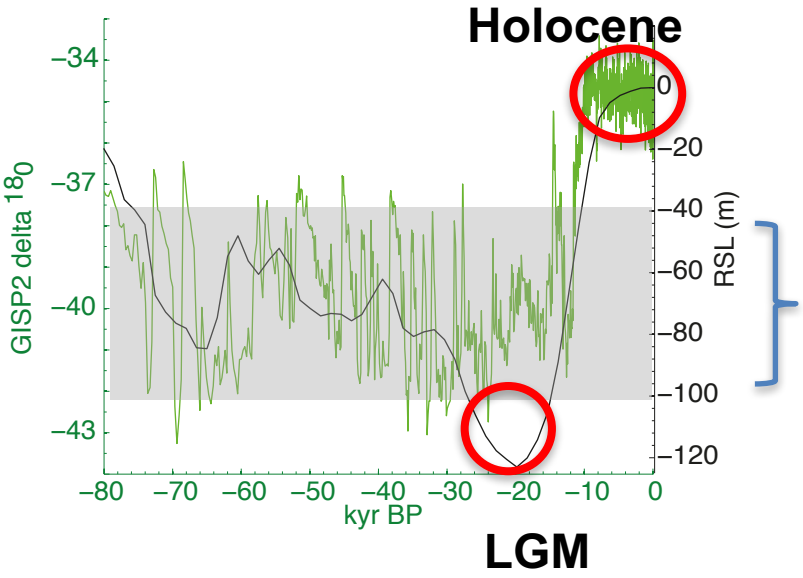


No:
Persistence Jets, atm. dyn, Western BC, sea ice

Role of meso–scale eddies, etc.

Global $4 * 10^7$

Paleoclimate Data: Millennial variability



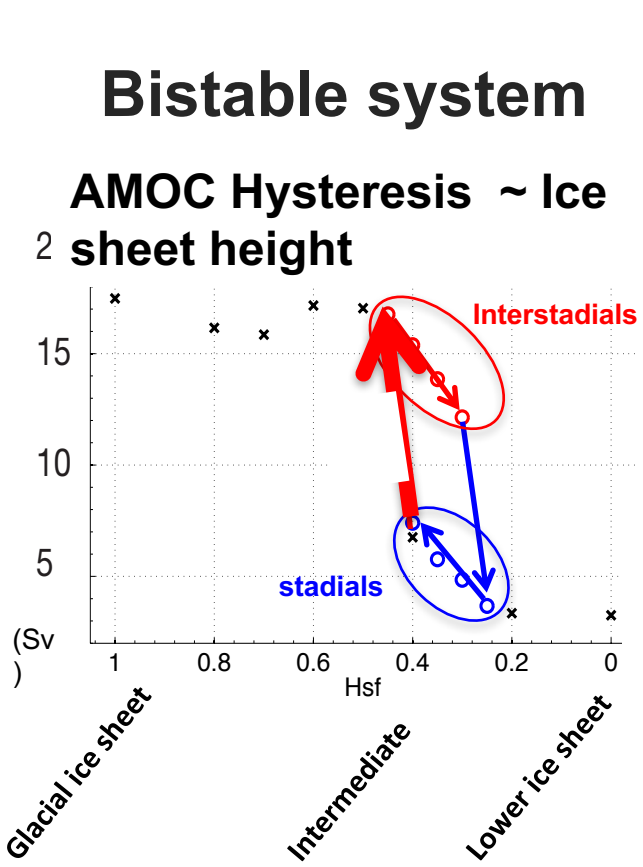
Millennial variability occurs ...

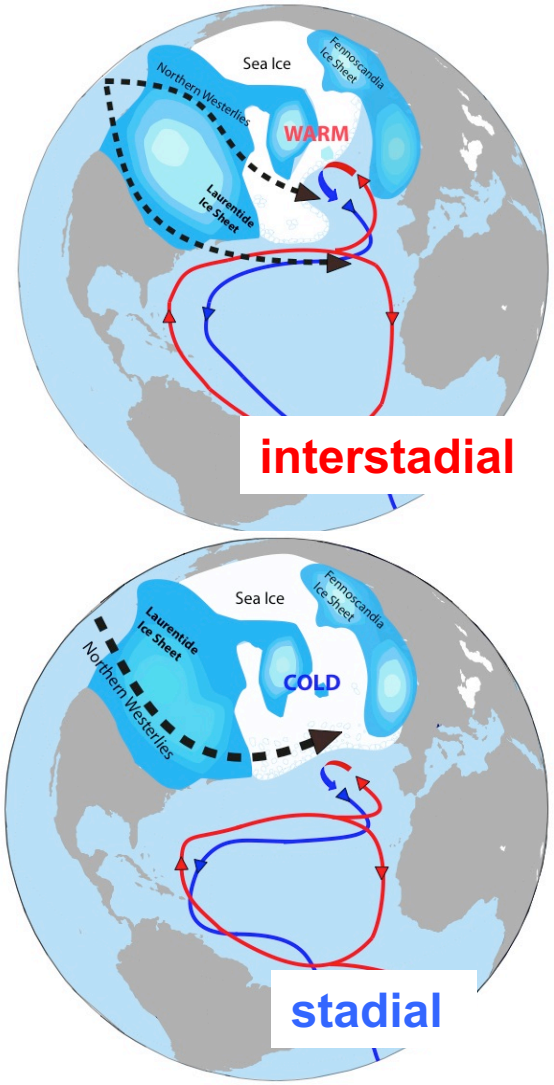
at intermediate sea level

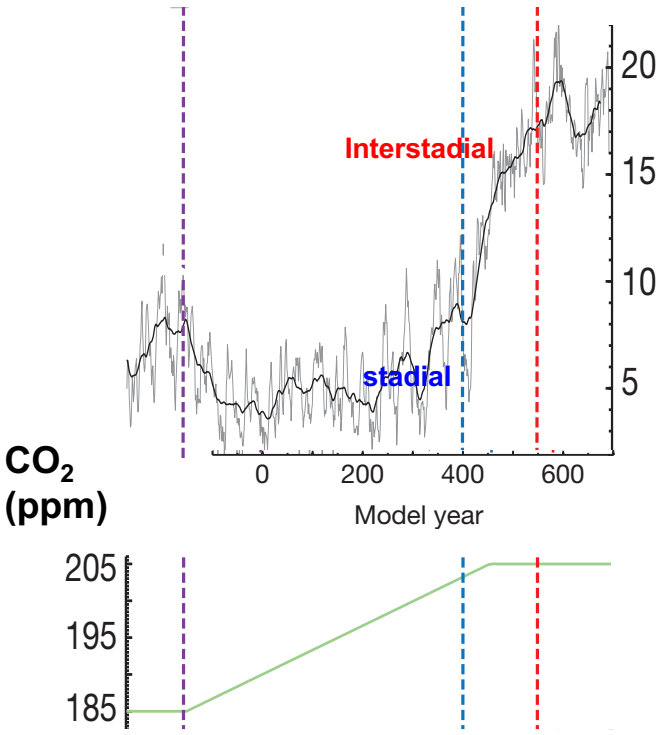
ice volume
not during the Holocene & LGM

Schulz, 2002, GRL

Bistable system





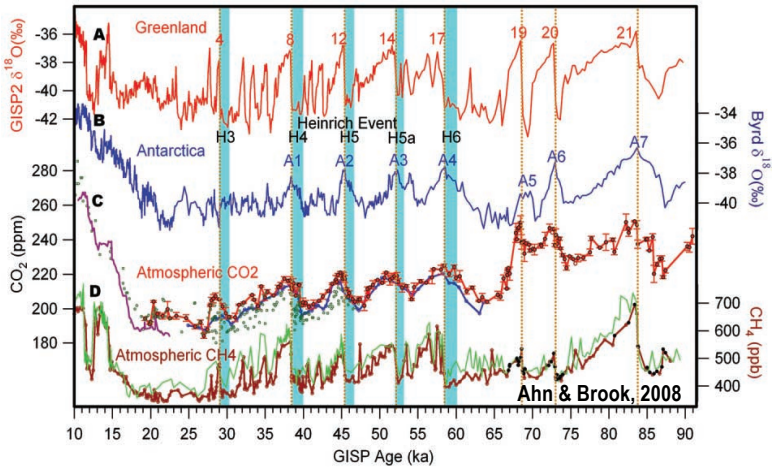


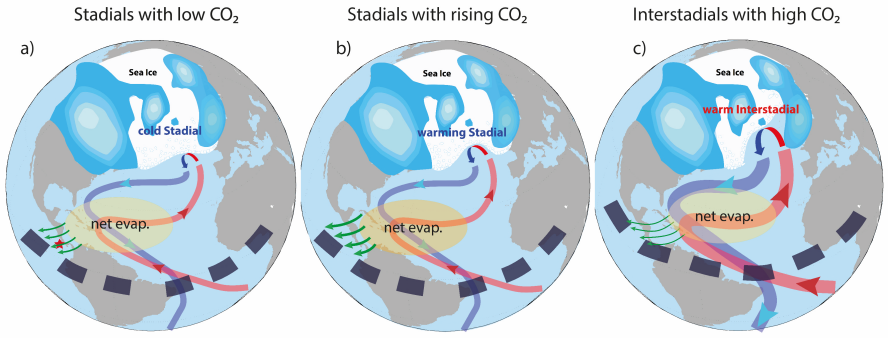
COSMOS
T31

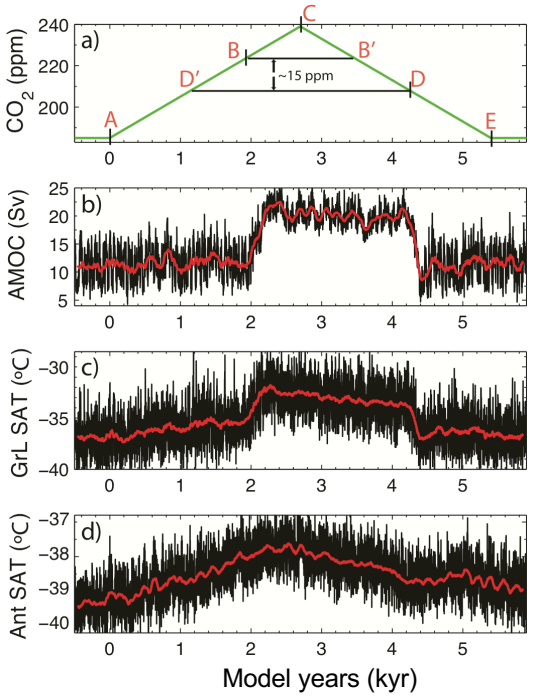
Zhang et al., 2014, Nature

Role of CO_2 for Glacial Climate Stability

Xu Zhang, Gregor Knorr, Gerrit Lohmann, Stephen Barker





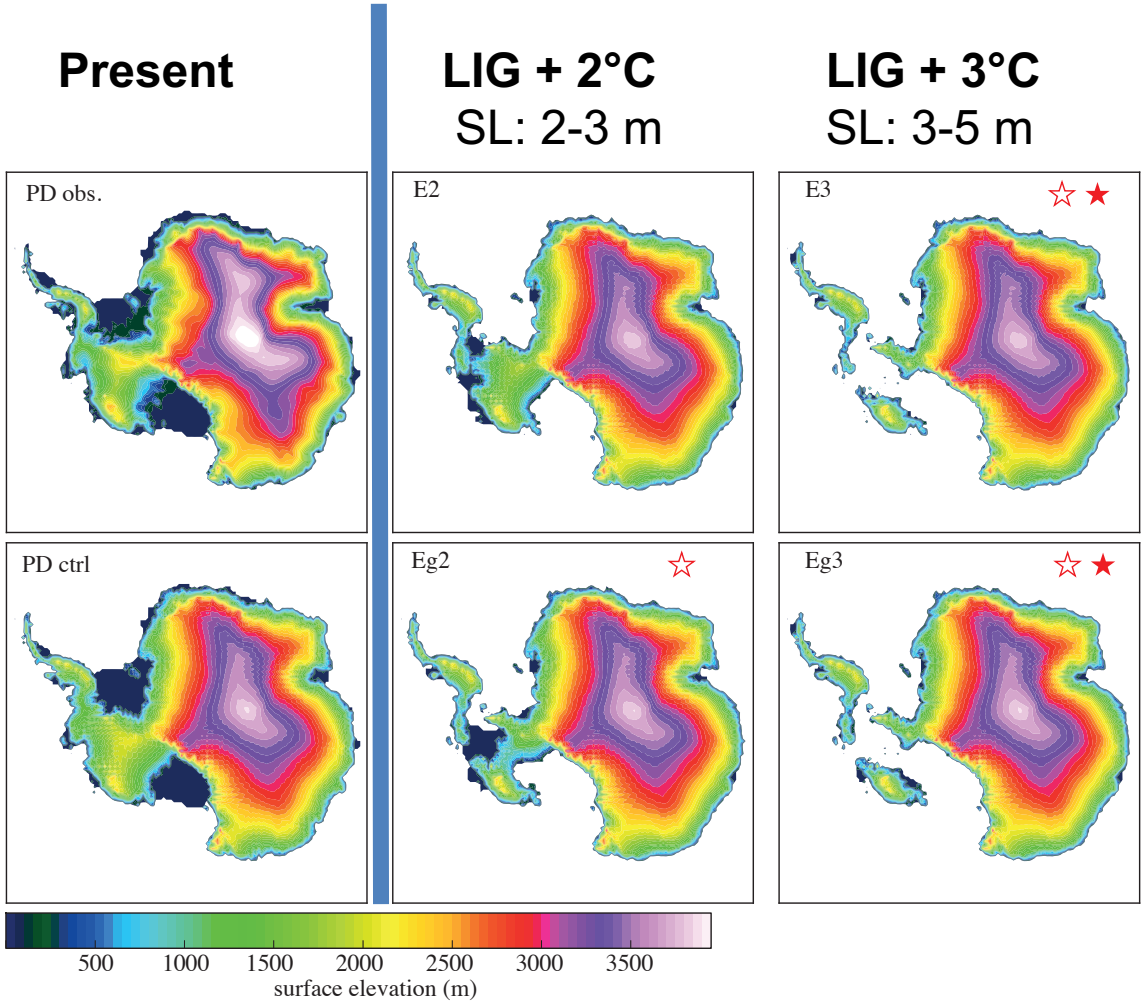


COSMOS
T31

Zhang et al., 2017, Nature Geo

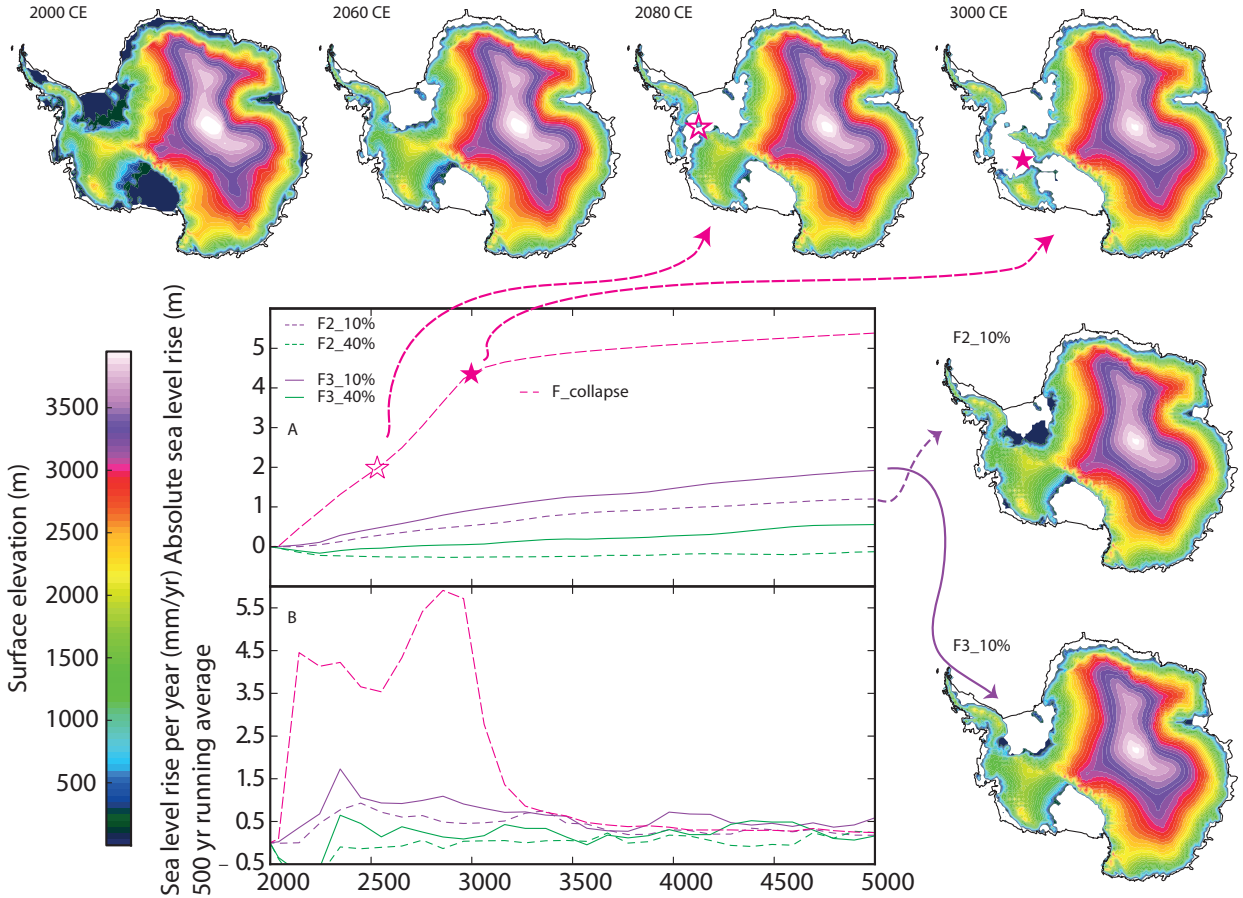
Federal Ministry of Education and Research
DLR Project Management Agency

Challenges and open issues: sea level in a warmer world



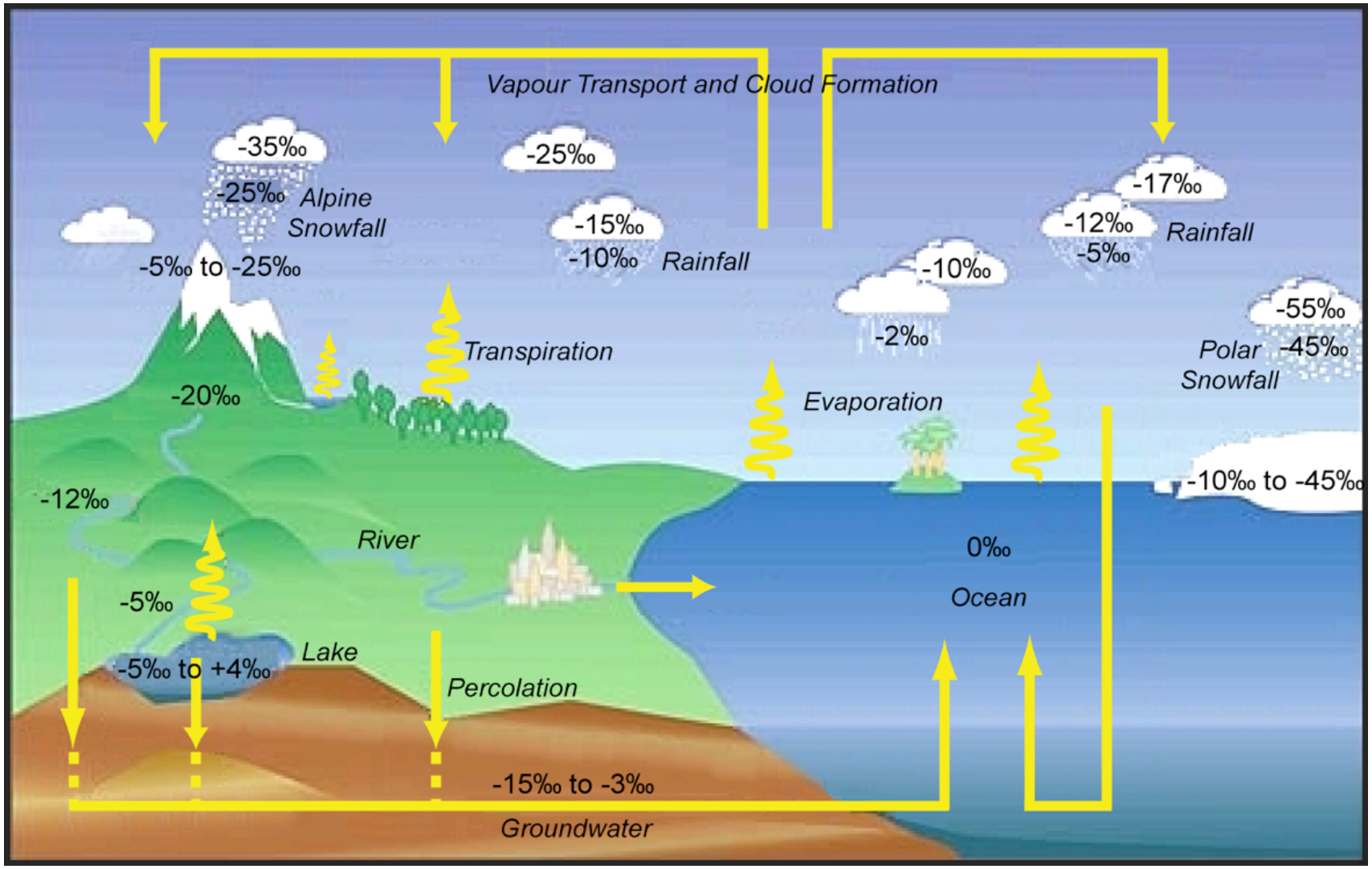
Sutter et al., 2016

Future


2000 CE
2060 CE
2080 CE
3000 CE
Surface elevation (m)
3500
3000
2500
2000
1500
1000
500
F2_10%
F2_40%
F3_10%
F3_40%
F_collapse
A
B
Sea level rise per year (mm/yr) Absolute sea level rise (m)
500 yr running average
5
4
3
2
1
0
5.5
4.5
3.5
2.5
1.5
0.5
−0.5
2000
2500
3000
3500
4000
4500
5000
F2_10%
F3_10%

$\delta^{18}O$ Signal in the Hydrological Cycle

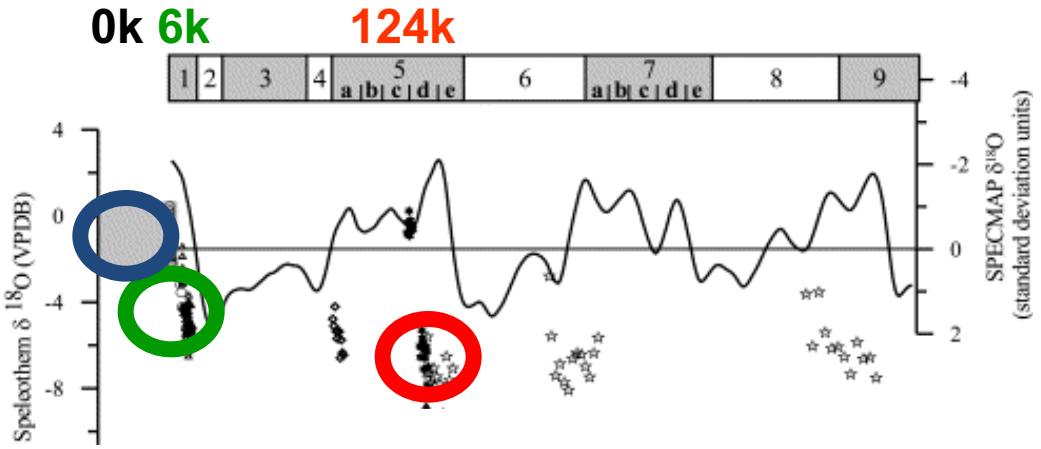
Scheme of typical isotope depletion in various parts of the hydrological cycle



[plot adapted from the GNIP brochure, IAEA, 1996]

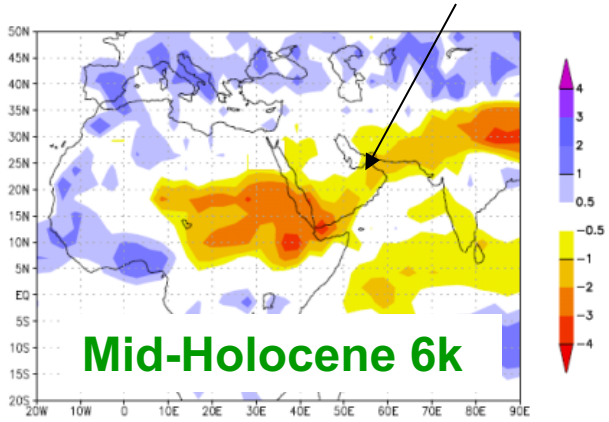
Every phase change of a water mass is imprinted in its isotopic signature

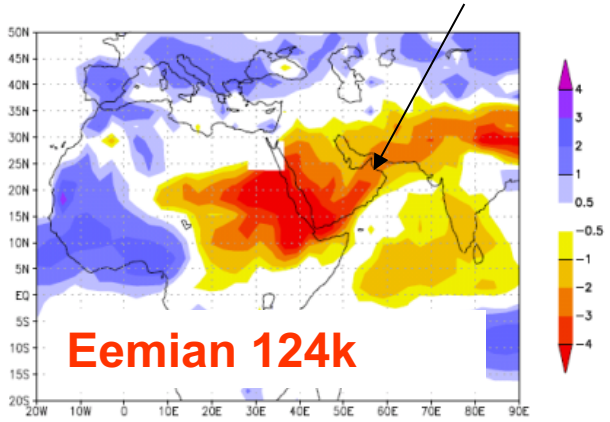
Comparison with O isotope records: Hoti Cave



$\delta^{18}O$ (° /oo) of Speleothem

$\delta^{18}O$ (° /oo) of Precipitation



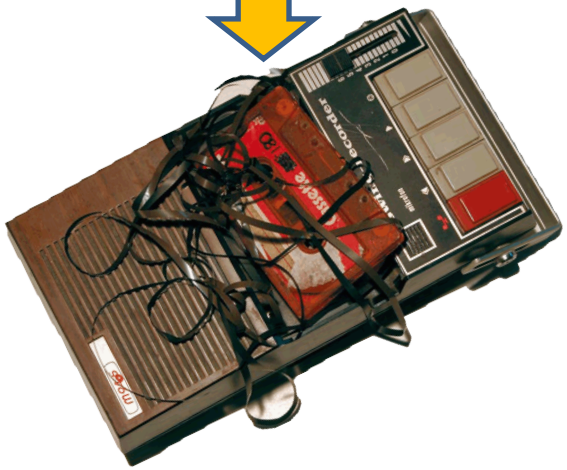


Fleitmann et al., 2003

Lohmann, Herold, Werner, Fleitmann, in prep

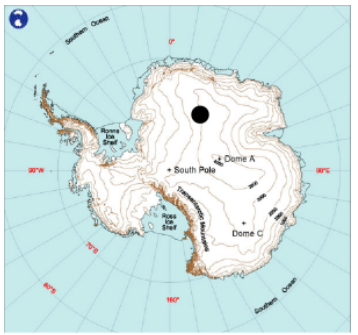
Recorder Problem: Antarctic

Climate system



e.g.

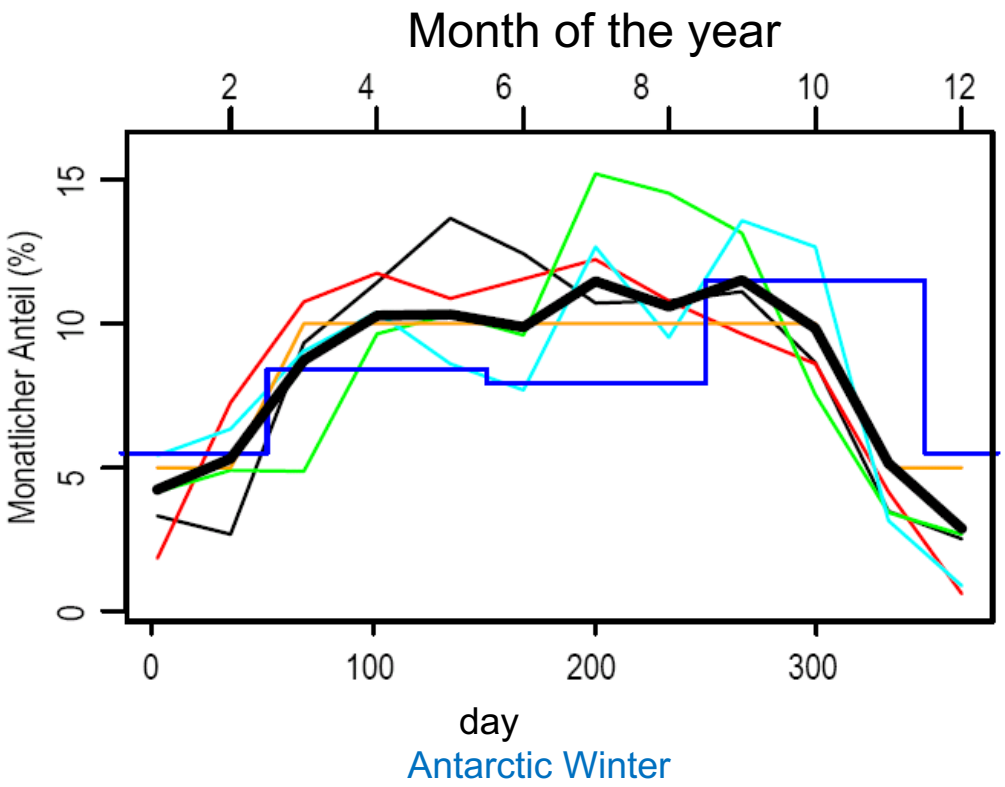
Antarctic ice cores



Laepple, Werner, Lohmann, Nature 2011

Isotope signal weighted with accumulation

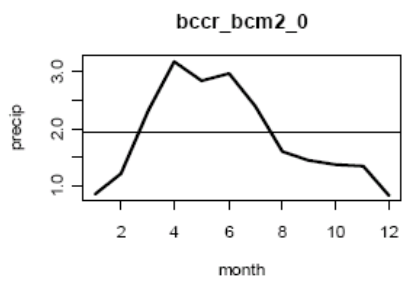
$$T_{isotopic}(t) = \frac{\int_{Sample} T(t) * Accum(t)dt}{\int_{Sample} Accum(t)dt}$$

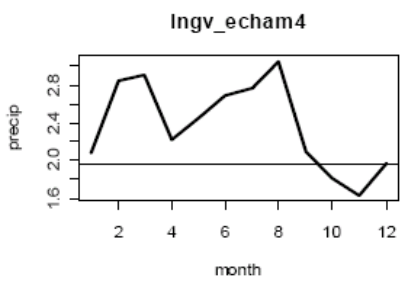


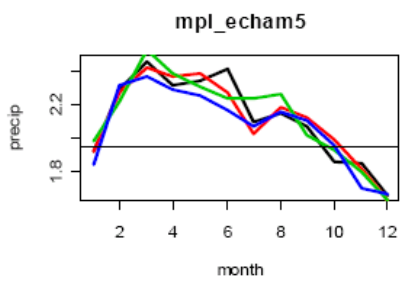
Vostok, Precip.(1958-2007)
Vostok, Akkum.(1970-1995)
ECMWF P-E h > 2500m,
Mizuho Precip.,
Ostsektor, P-E Radiosonder
Dome Fuji: 50% Subl.

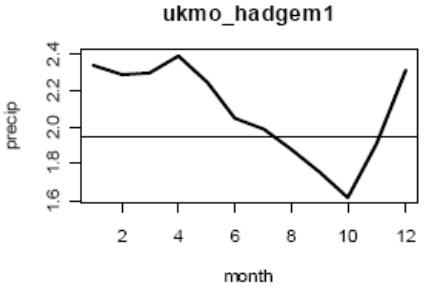
Antarctic Winter

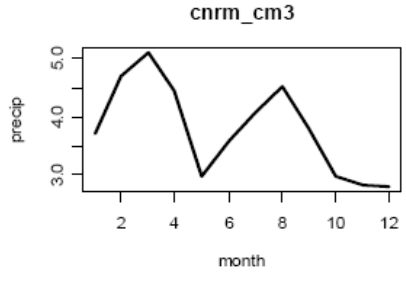
Simulated modern precipitation at Dome Fuji, CMIP3 climate models

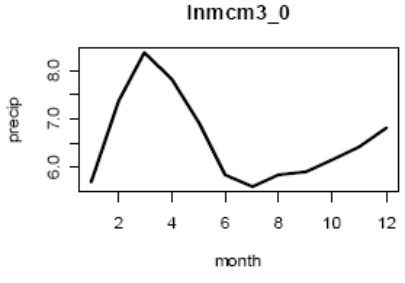


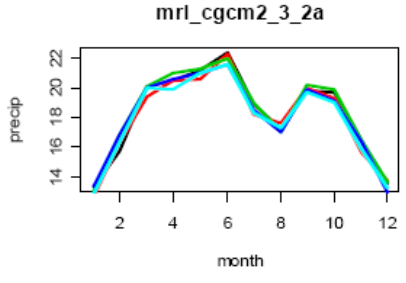


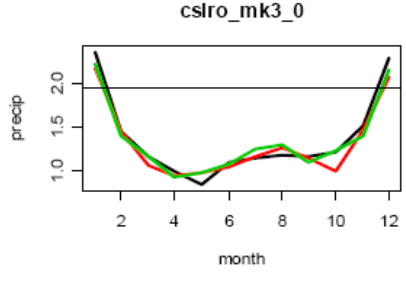


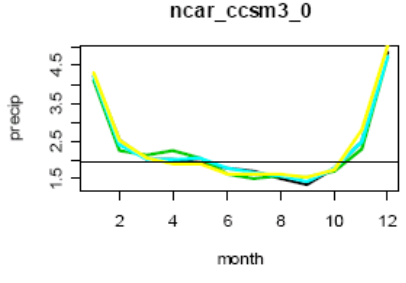


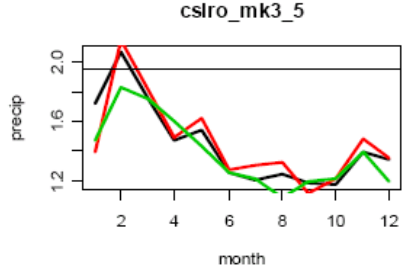


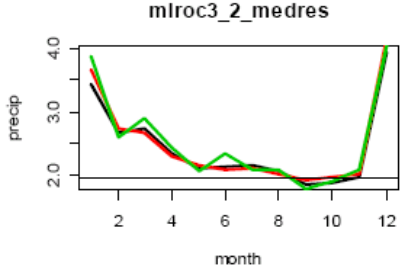


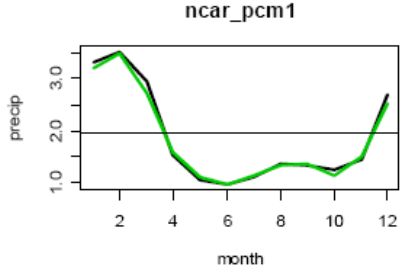


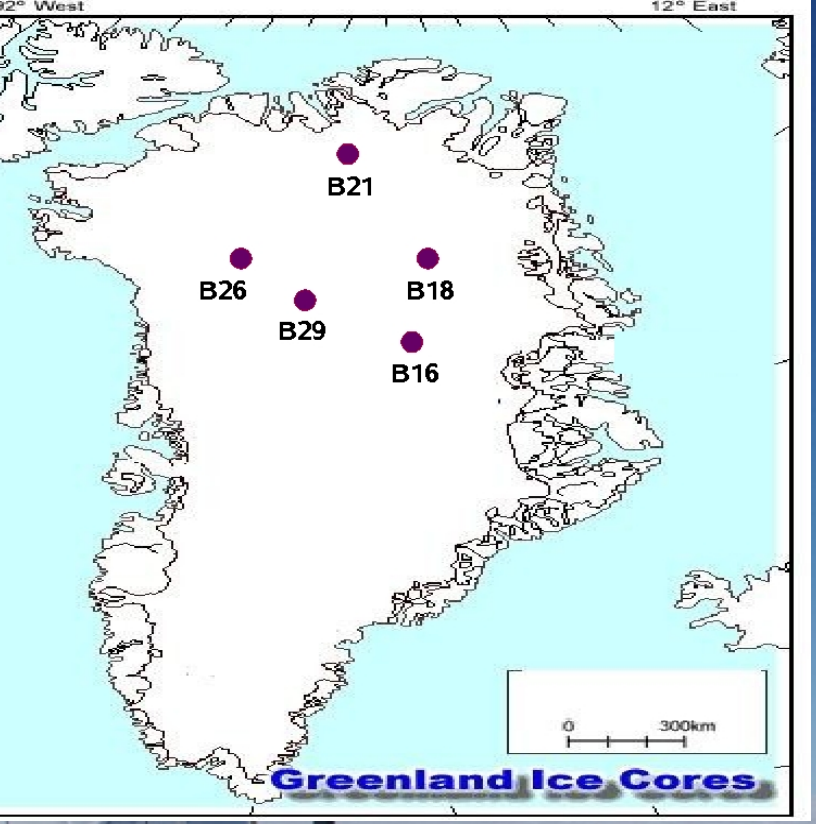








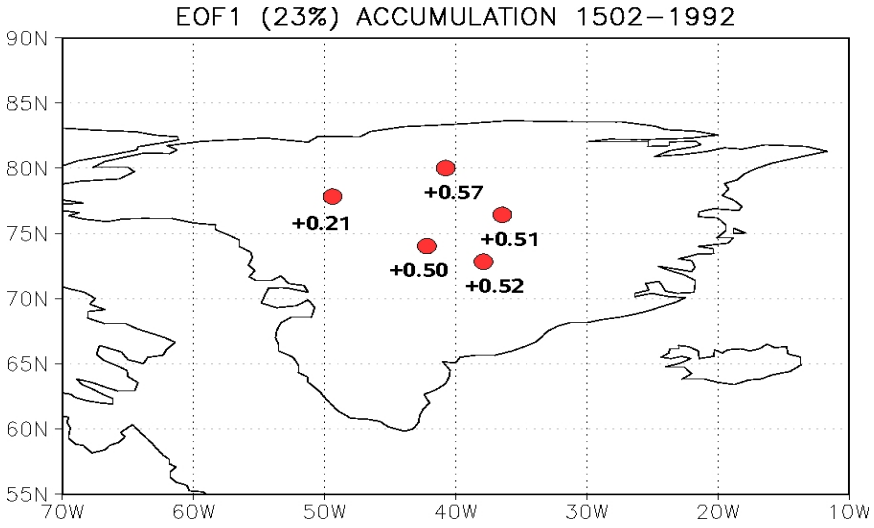




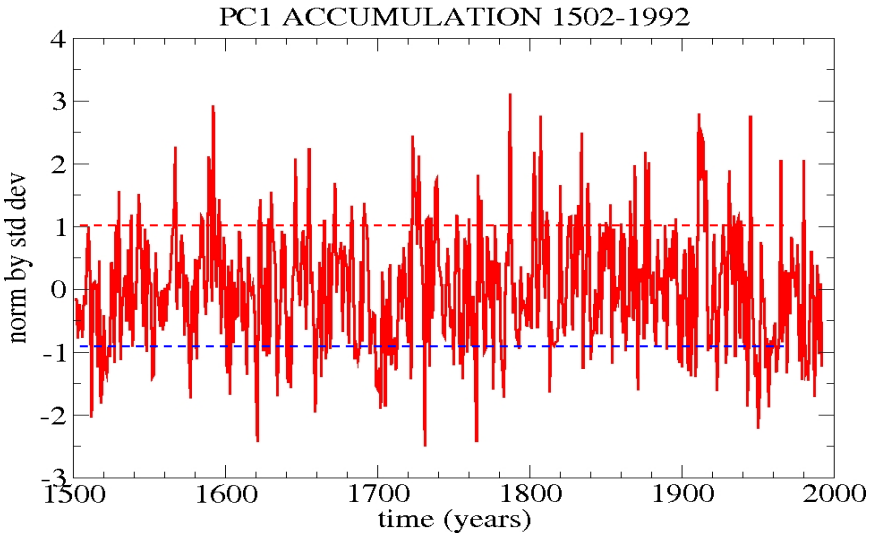
Shallow ice cores

Atmospheric Blocking Circulation

Greenland Shallow Ice Core Positions



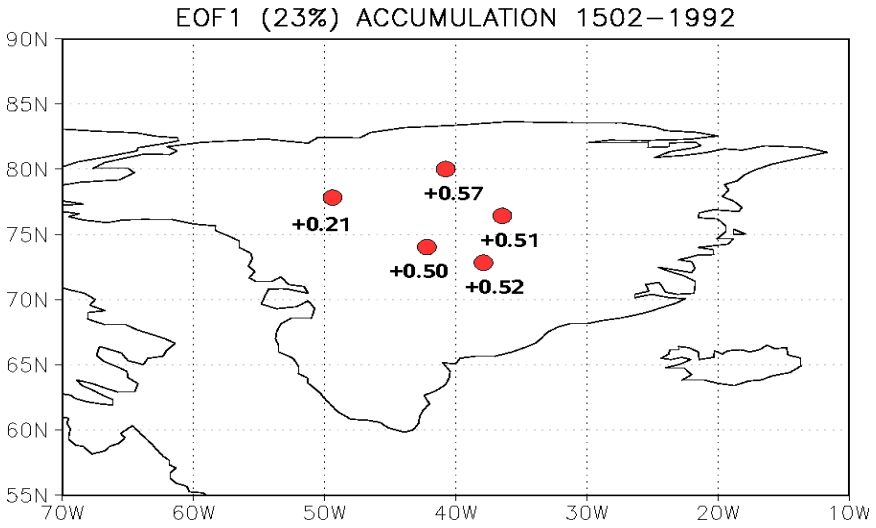
Variability of Accumulation Rate



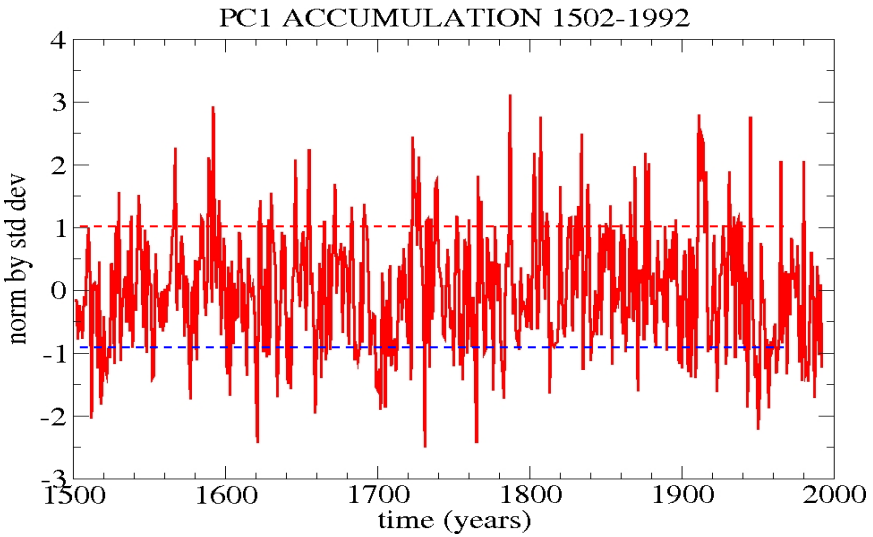
Rimbu and Lohmann 2009

Atmospheric Blocking Circulation

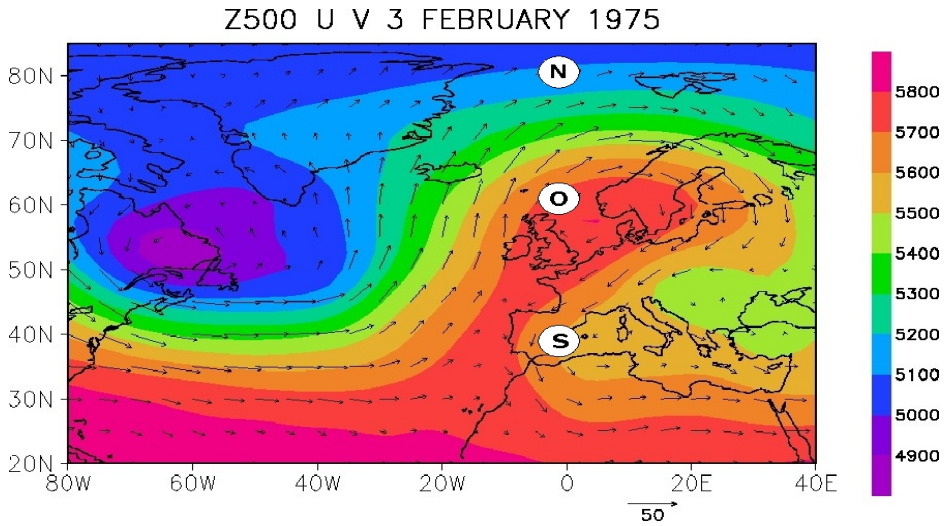
Greenland Shallow Ice Core Positions



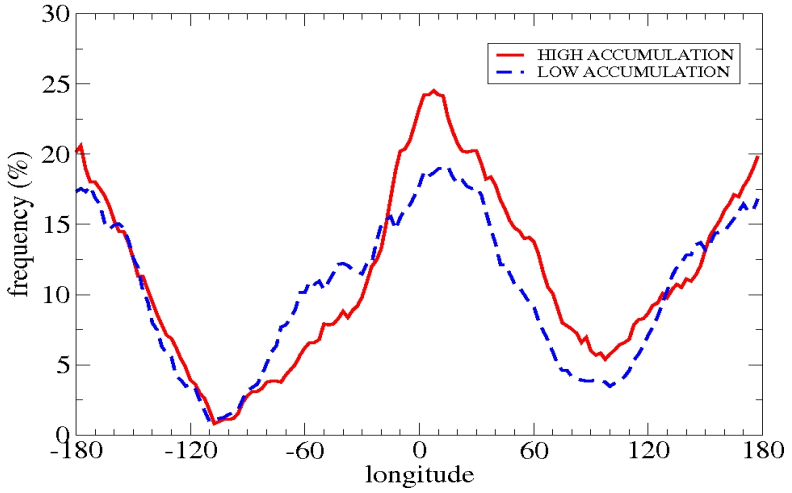
Variability of Accumulation Rate



Synoptic Scale Blocking Situation

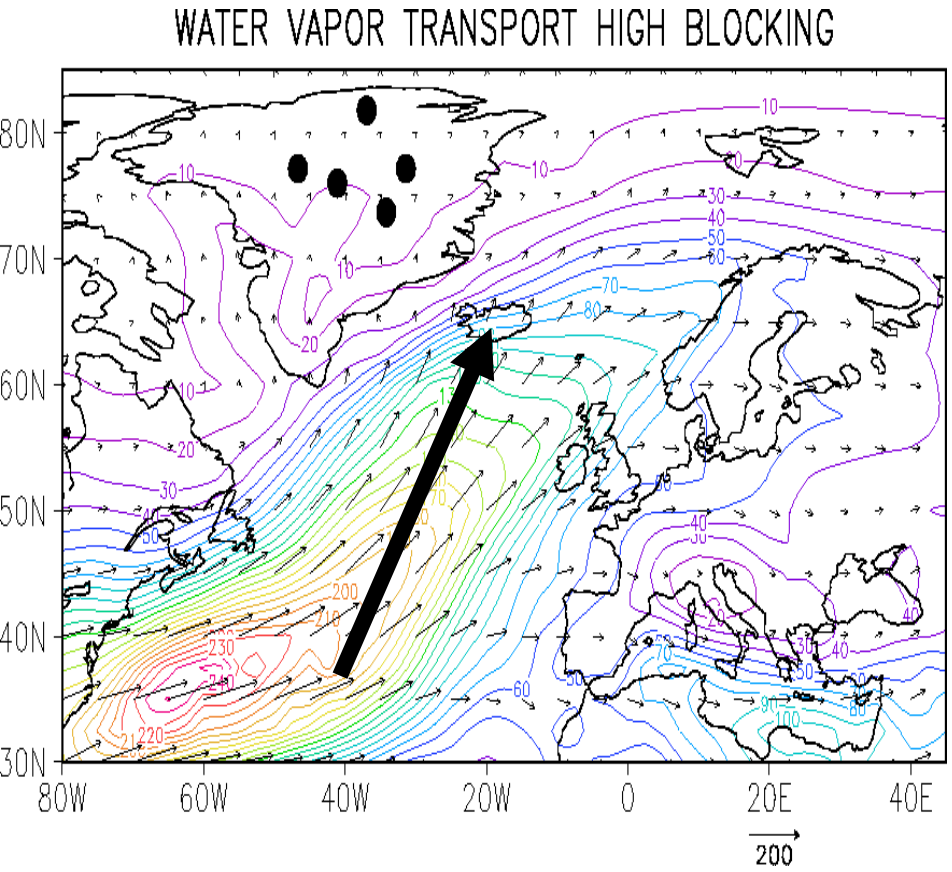


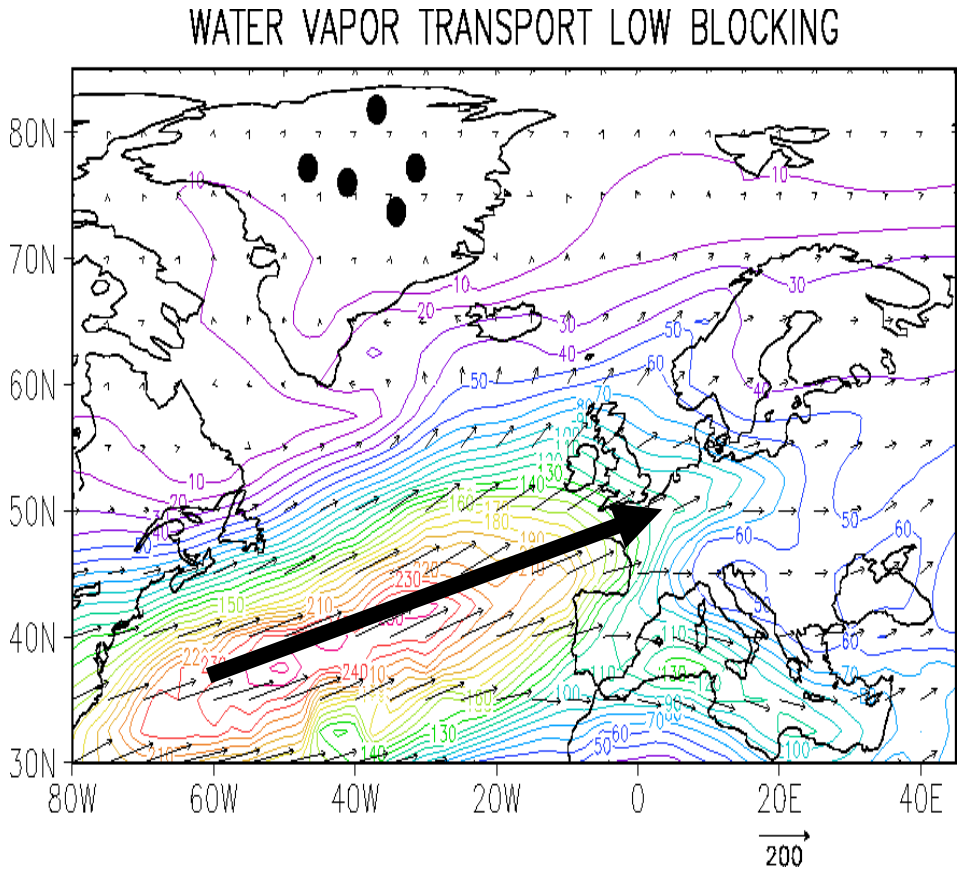
Blocking Frequency for 1948-1992



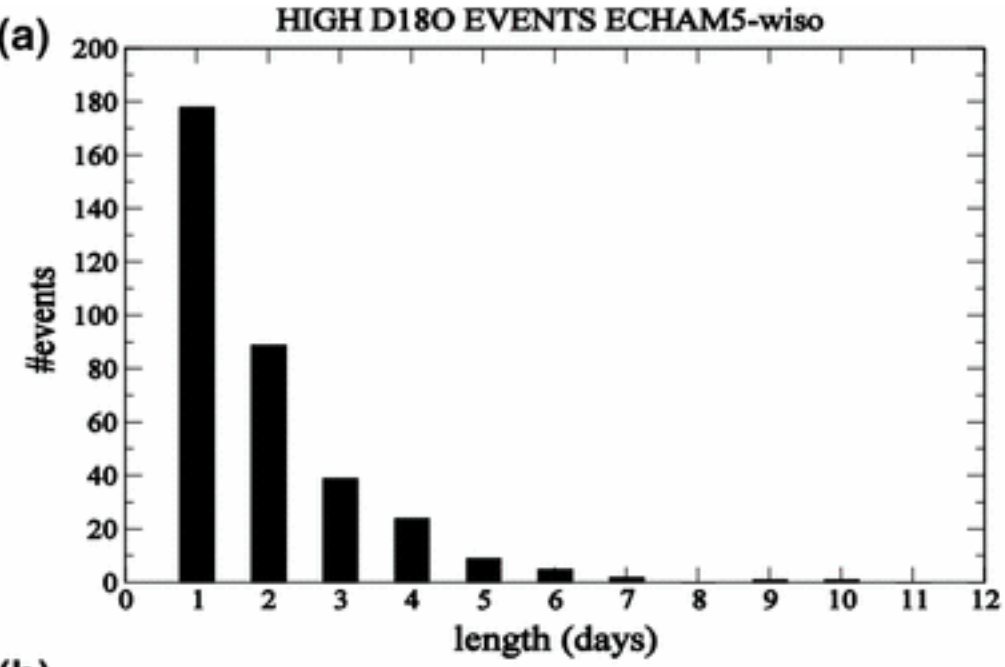
Rimbu and Lohmann 2009

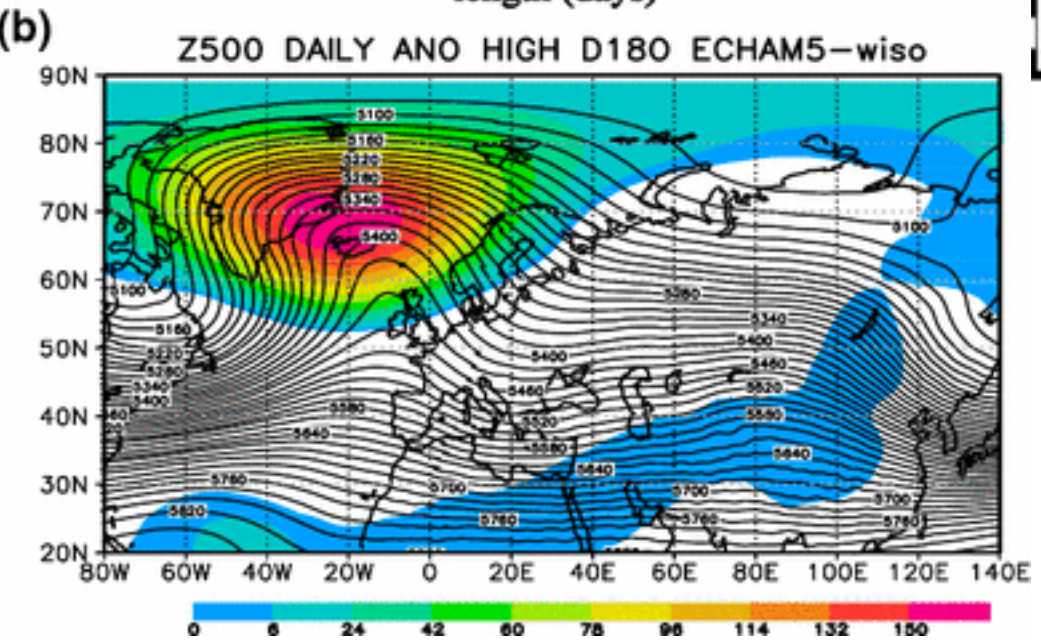
WATER VAPOR TRANSPORT



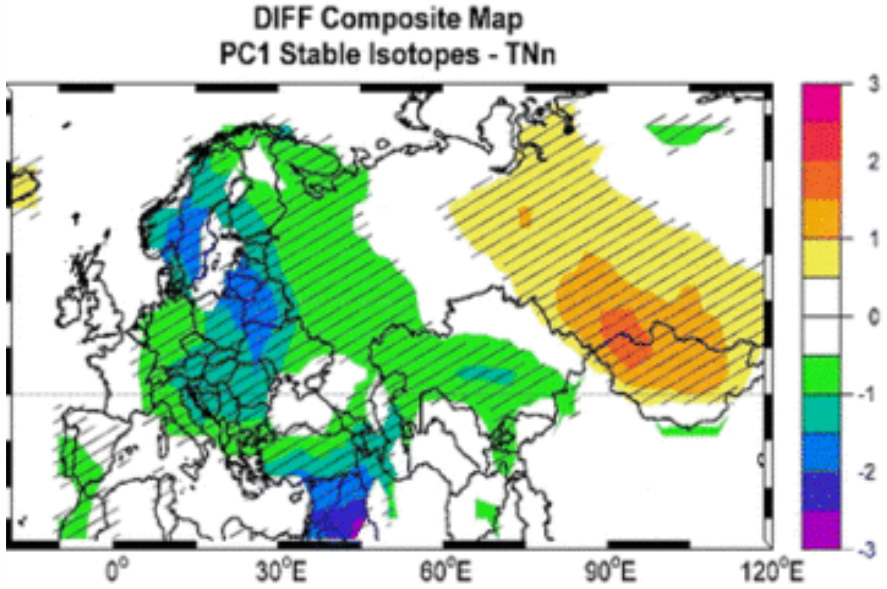


Enhanced moisture transport during high blocking activity

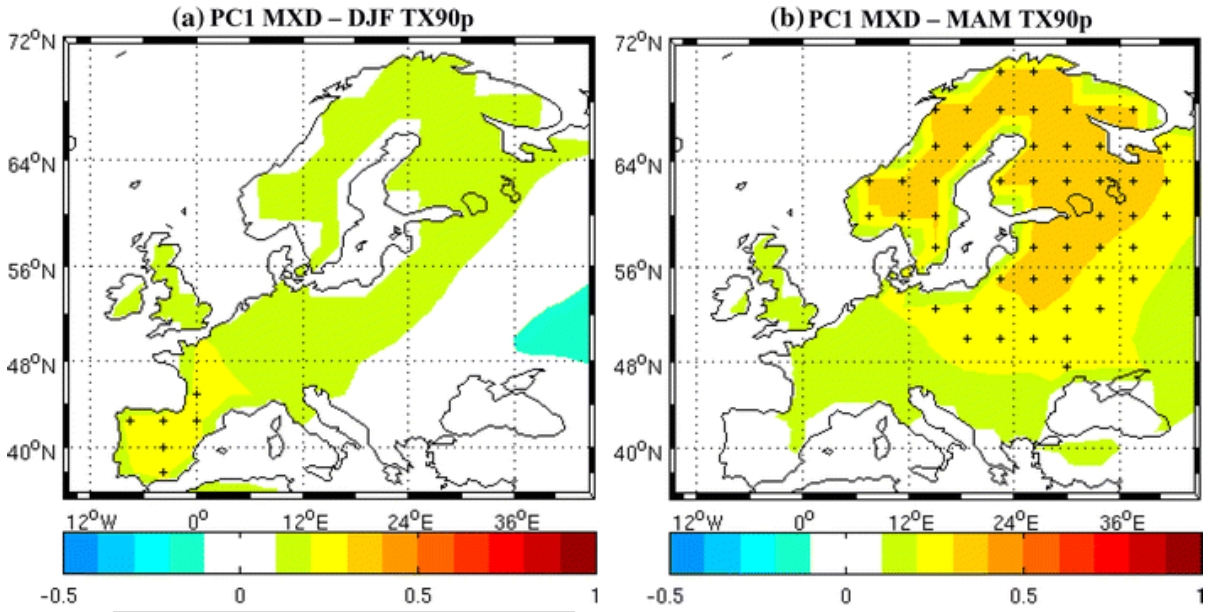




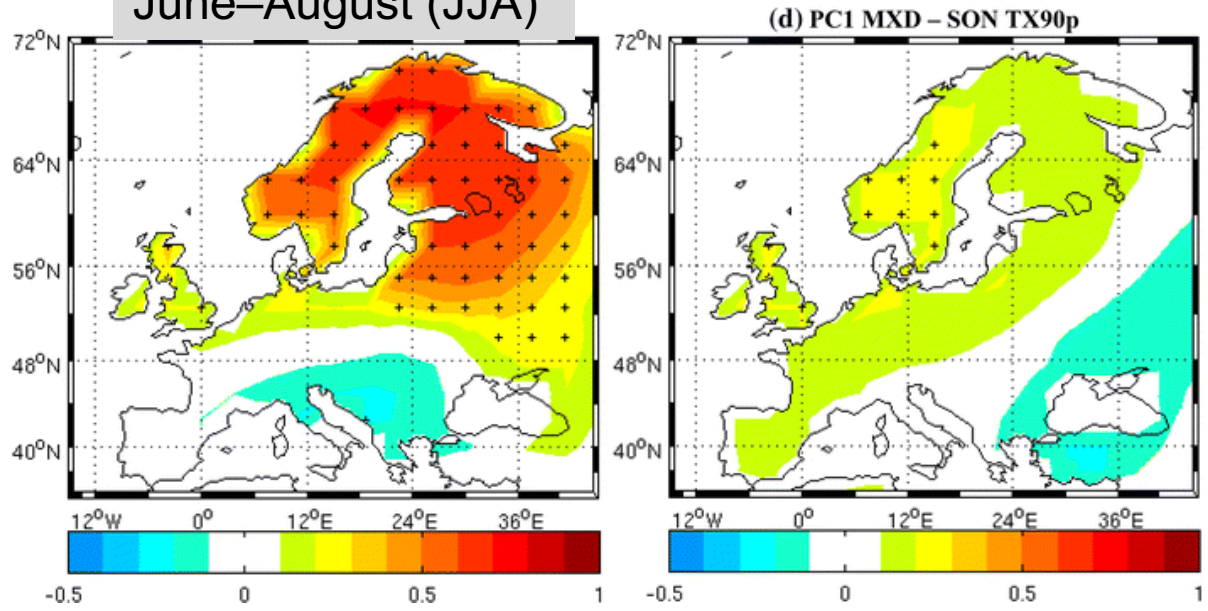
minimum value of daily minimum temperature (TNn)



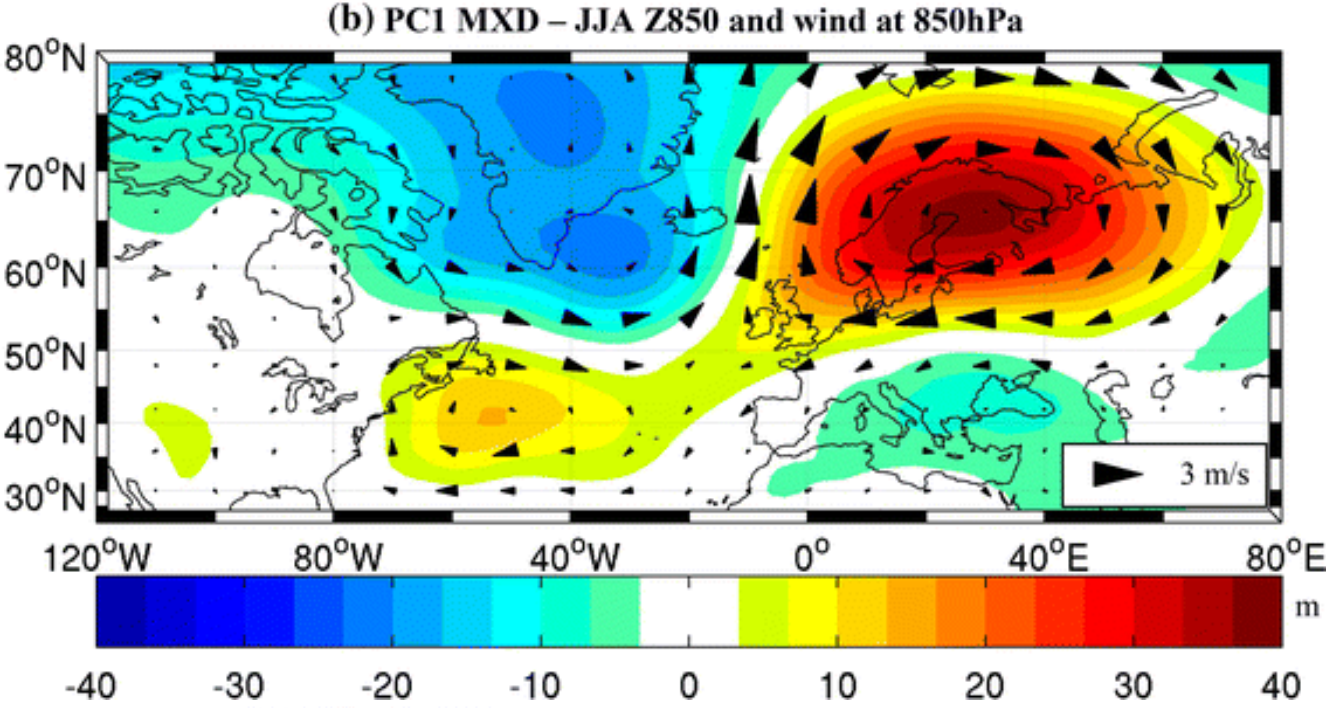
Fennoscandian tree-rings and warm-day extreme

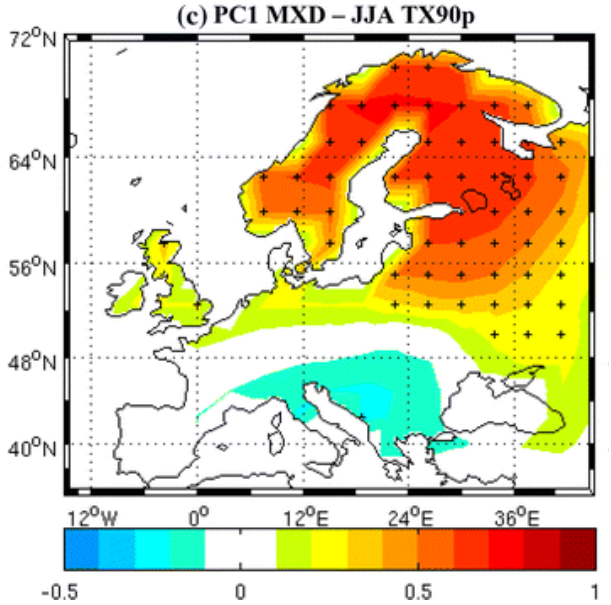


June–August (JJA)



Correlation maps between **Fennoscandian tree-rings and warm-day extreme** indices HadEx2 (Donat et al. 2013) for 1901–1978.





June–August (JJA)

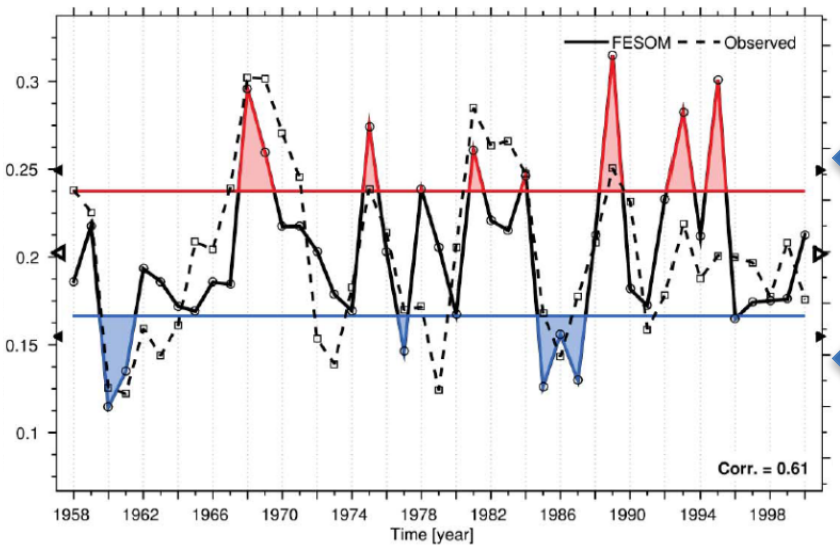
P. Zhang et al., 2017

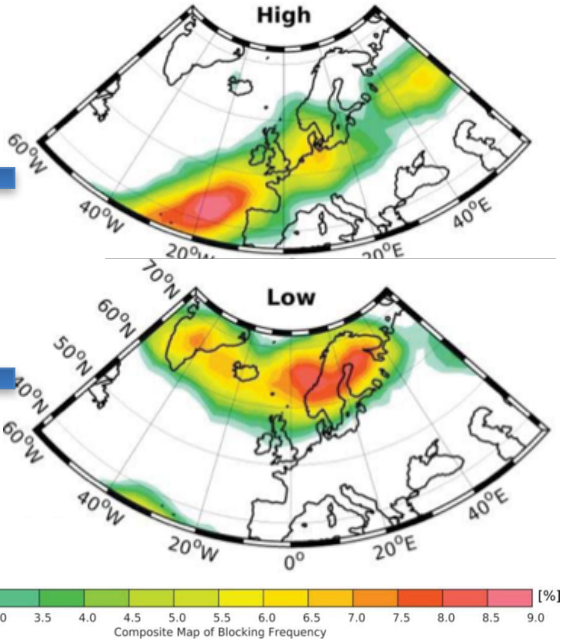
Correlation maps between Fennoscandian tree-rings and warm-day extreme indices HadEx2 (Donat et al. 2013) for 1901–1978.

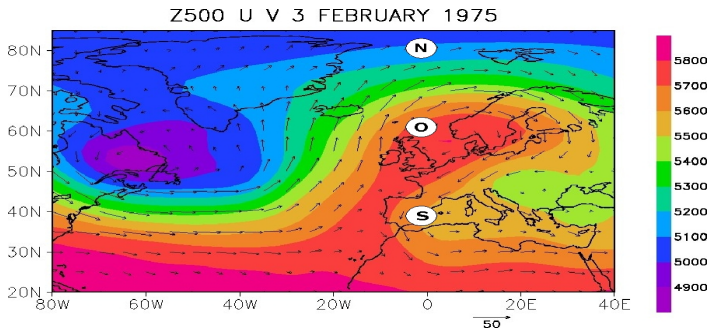
Atmospheric blocking & sea ice export

Fram Strait Sea ice export

(Sv)



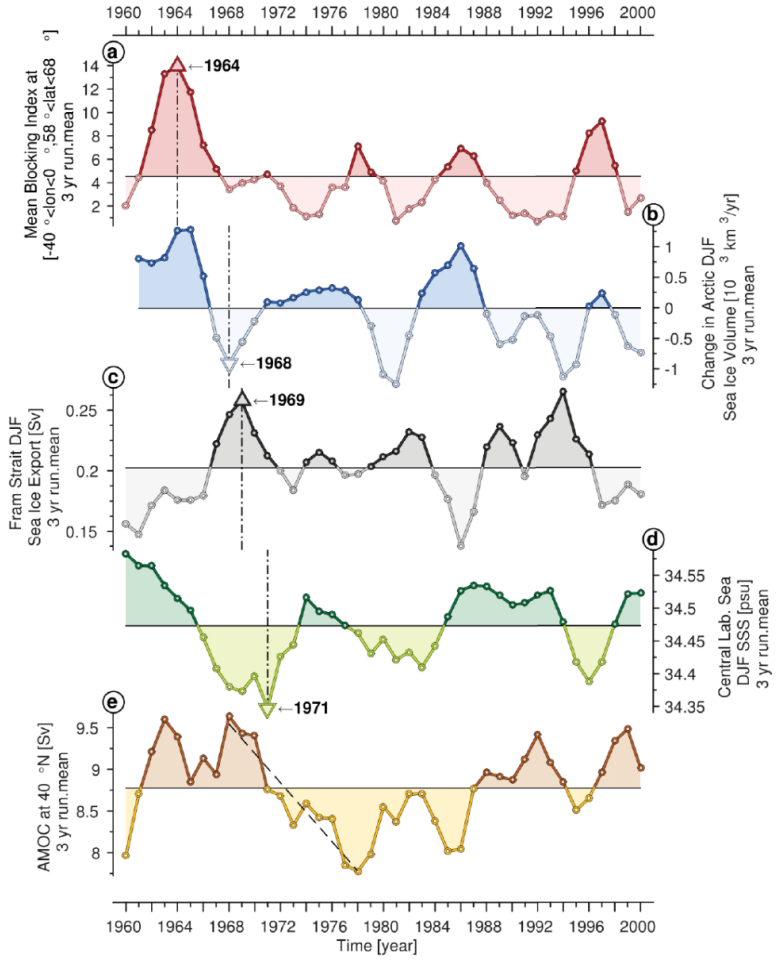




5-day persistence criterion

Ionita et al., 2017, Scientific Reports

Synoptic variability and multidecadal variability are not independent



Blocking

Arctic Sea ice

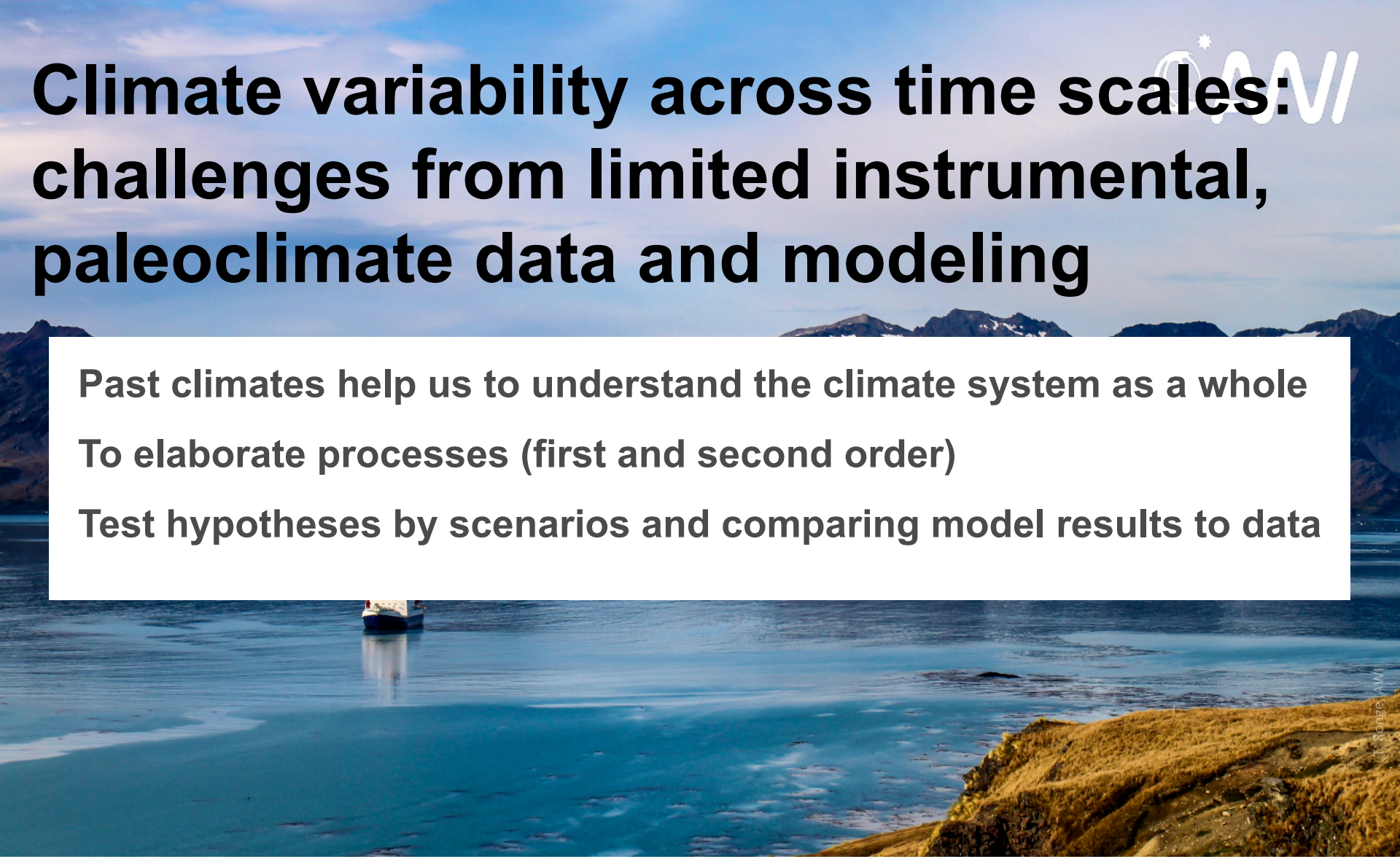
Fram Strait export

Salinity

AMOC

Ionita et al., 2017, Scientific Reports

Climate variability across time scales: challenges from limited instrumental, paleoclimate data and modeling



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

Climate variability across time scales: challenges from limited instrumental, paleoclimate data and modeling

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

Holocene: High latitude cooling, low-latitude warming
Models and data disagree in amplitude, variability underestimated (fdt)

Dynamics: Heterogeneities in temperature,
large gradients can persist on long time scales

Interpretation of proxy data: Seasonal to syonptic signatures
Bring the current climate into a long-term context, extremes