Bjerknes Centre
for Climate Research

Eystein Jansen:

Ocean and atmosphere interactions in the North Atlantic - How is Europe affected?

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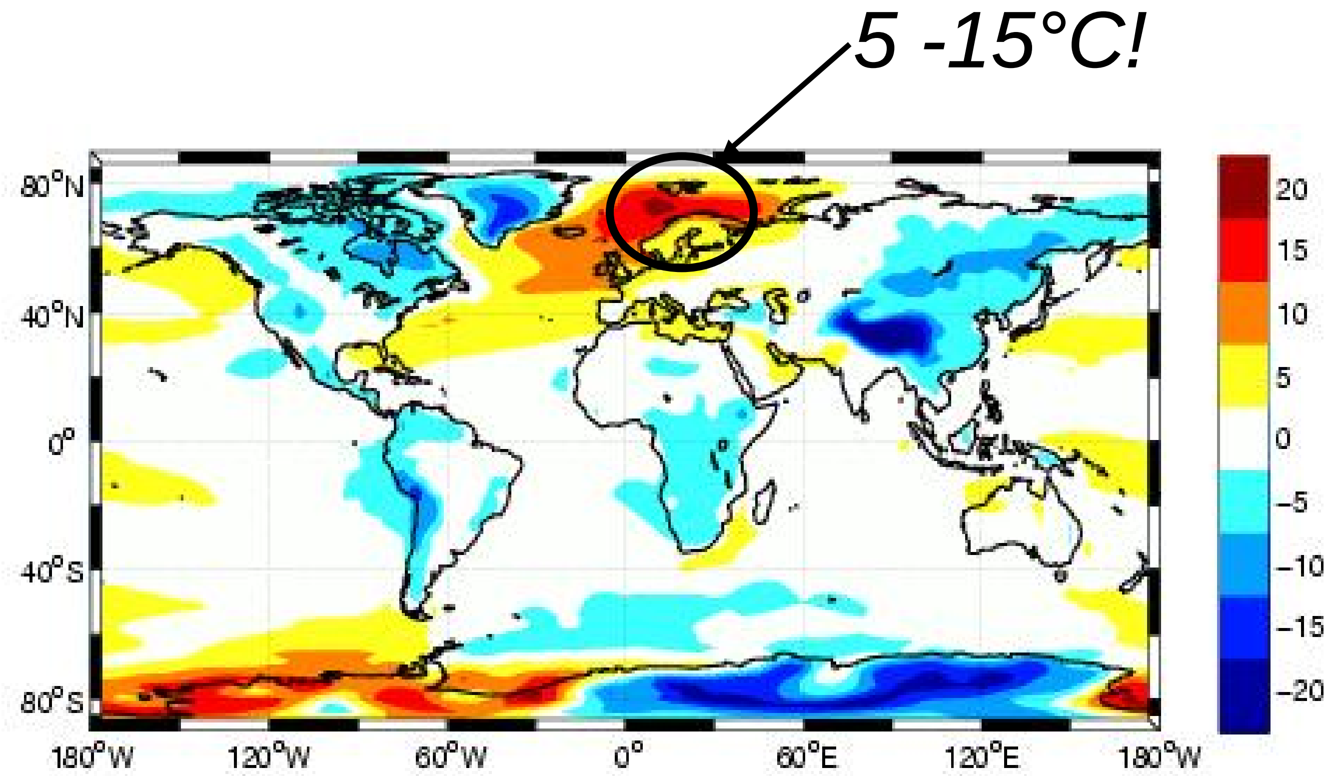
Bjerknes Centre for Climate Research

Outline

1. The oceanic heat pump
2. Decadal scale climate change
3. When the ocean failed us
4. The climate problem
5. Are we changing the system?
6. Climate models
7. What will happen in the next 100 years?

Temperature anomalies for each latitude based on observations



Causes:

- **Warm ocean gives off heat to atmosphere**
- **Atmosphere moves heat via Atlantic low pressure systems**

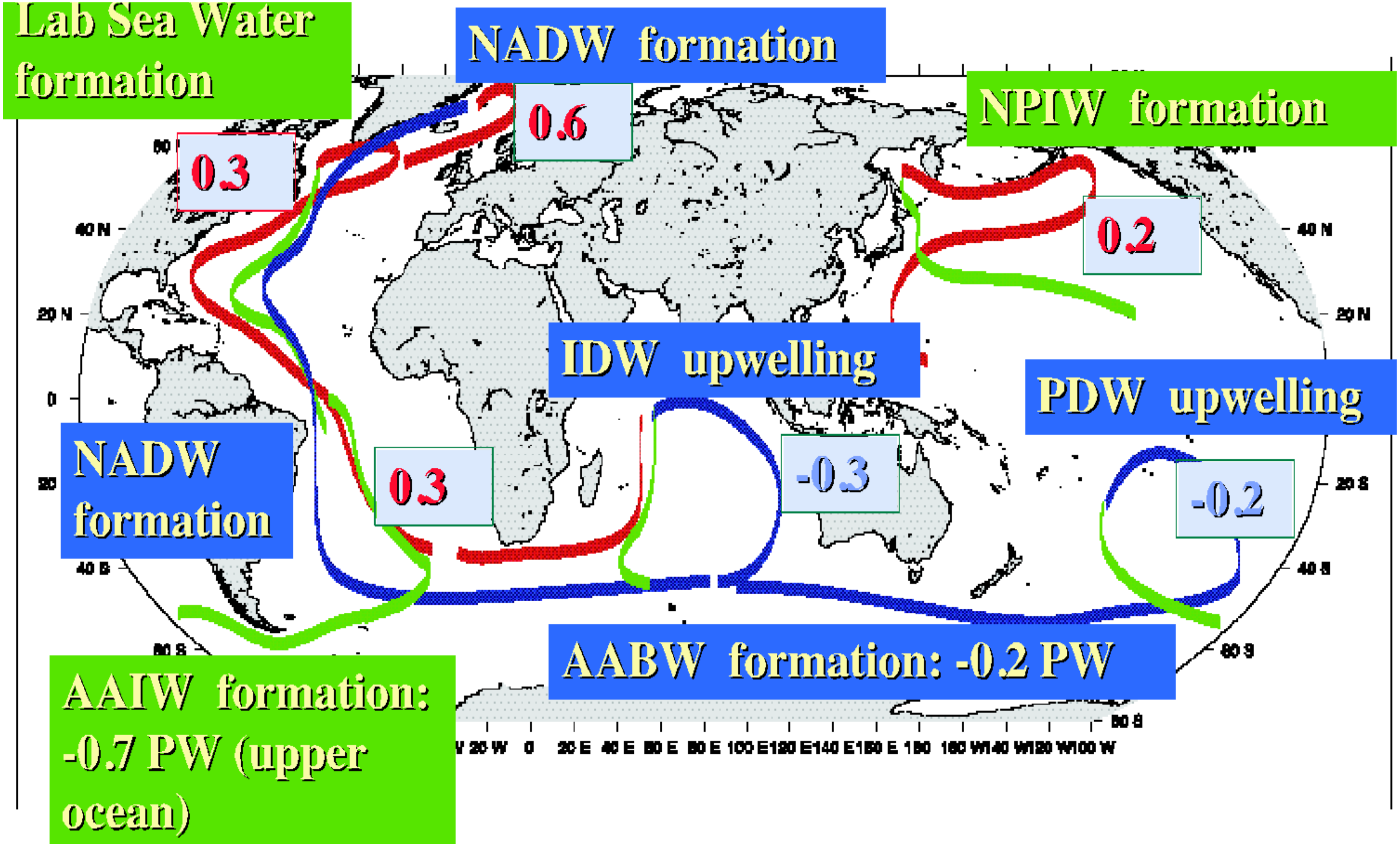
Forecasted pressure field over N-Atlantic and Europe

- **Azores High**
- **Iceland Low**
- **Blocking high over Scandinavia**

QuickTime™ og en
TIFF (ukomprimert)-dekomprimerer
kreves for å se dette bildet.

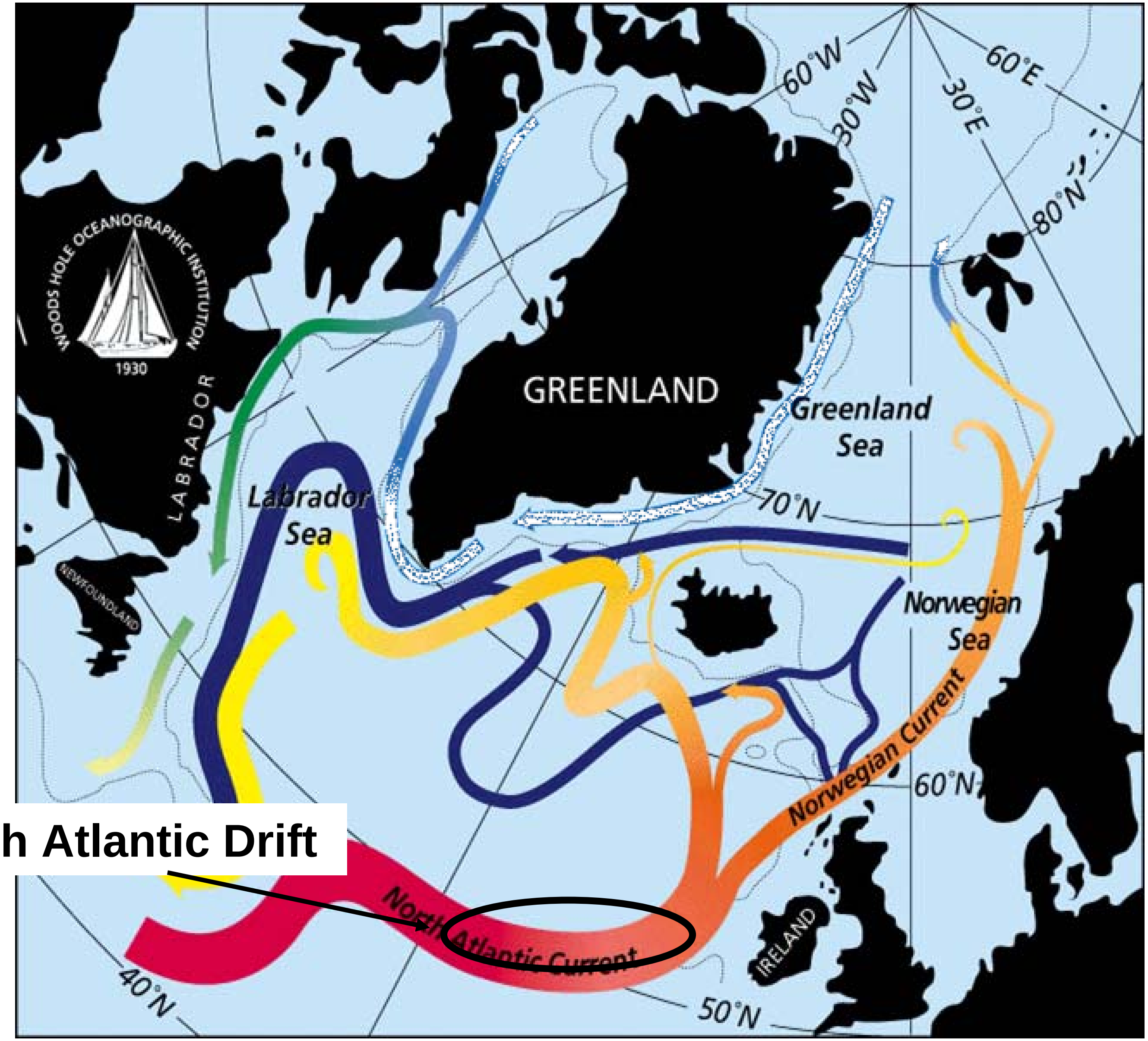
The global oceanic heat system

Note excess heat flux from ocean to atmosphere in the North Atlantic and cross-equatorial heat transport from S to N



after Lynne D. Talley, e.g. 1999

AMOC (Atlantic Meridional Overturning Circulation)



The North Atlantic Drift

Inflow across Greenland -Scotland Ridge

> 8 Sv

Sum of global rivers:

1.2 Sv

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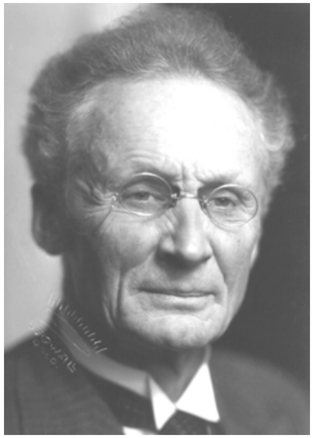
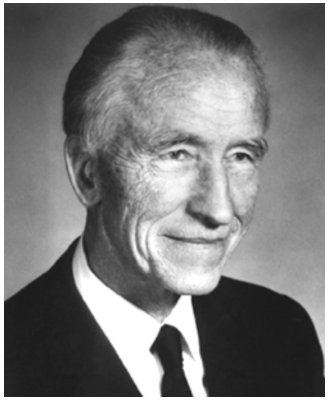


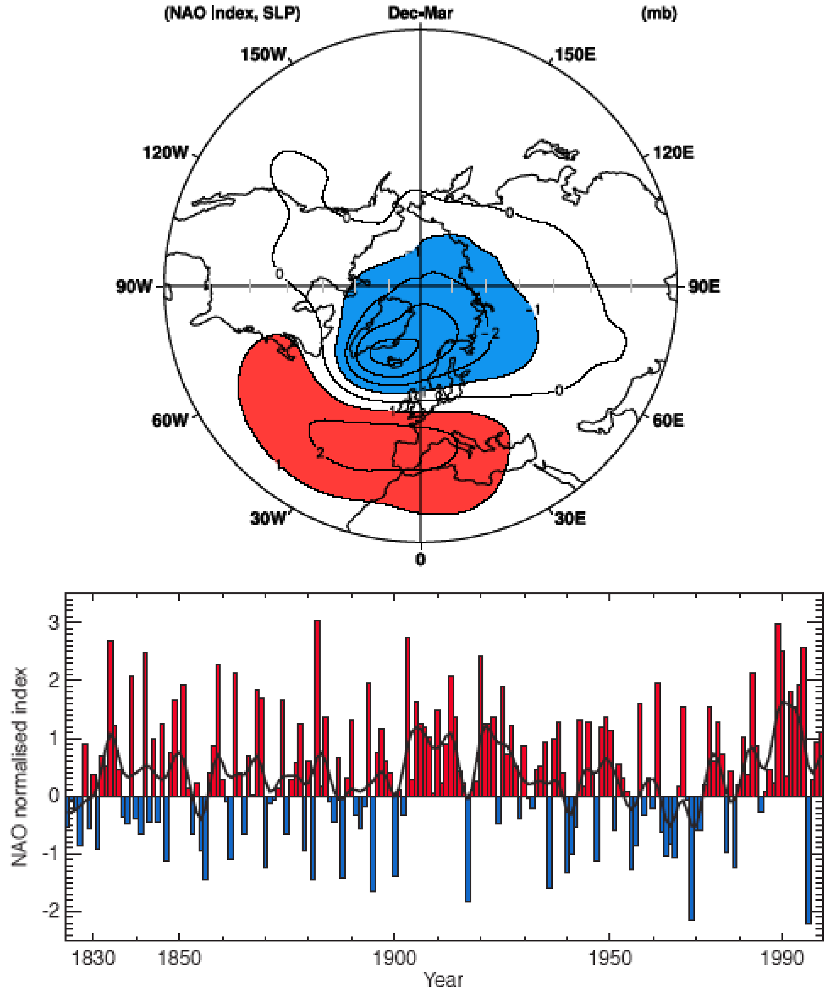
Vilhelm E. K. Bjerknes
(1862-1951)



Jacob A. B. Bjerknes
(1897-1975)

- **VB & JB: Modern weather forecasting**
- **JB: El Nino and North Atlantic Oscillation**

The North Atlantic Oscillation



Upper panel: Observed Dec-March change in SLP associated with a 1 standard deviation change in the NAO index (after Hurrell, 1995, Science, 269, 676-679).

Lower Panel: Winter (December to March) index or the NAO based on the difference of normalized pressure between Lisbon, Portugal and Stykkisholmur, Iceland from 1864 to 1995. The SLP anomalies at each station were normalized by division of each seasonal pressure by the long-term mean (1864-1995) standard deviation. The heavy solid line represents the meridional pressure gradient smoothed with a low pass filter with seven weights (1,3,5,6,5,3, and 1) to remove fluctuations with periods less than 4 years (after Hurrell, 1995, Science, 269, 676-679, this version: courtesy of T. Osborn, CRU, UEA.

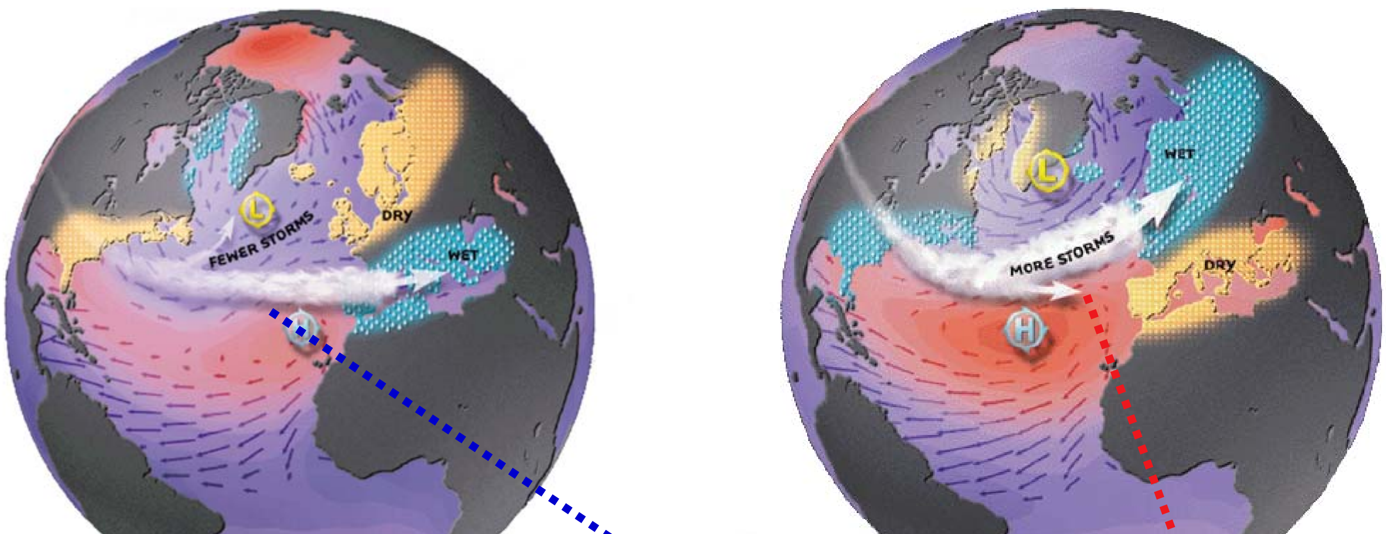
LB/D1/99-1

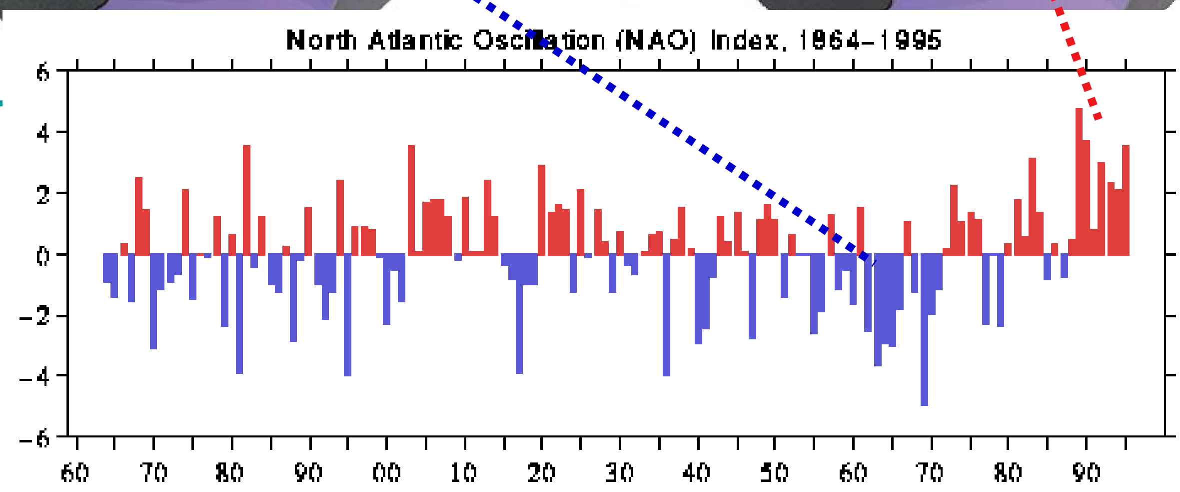
NAO = index of pressure gradient between Iceland and Azores/ Iberia

NAO drives European winter weather => strength of westerlies

Negative NAO

Positive NAO





Increase last decades

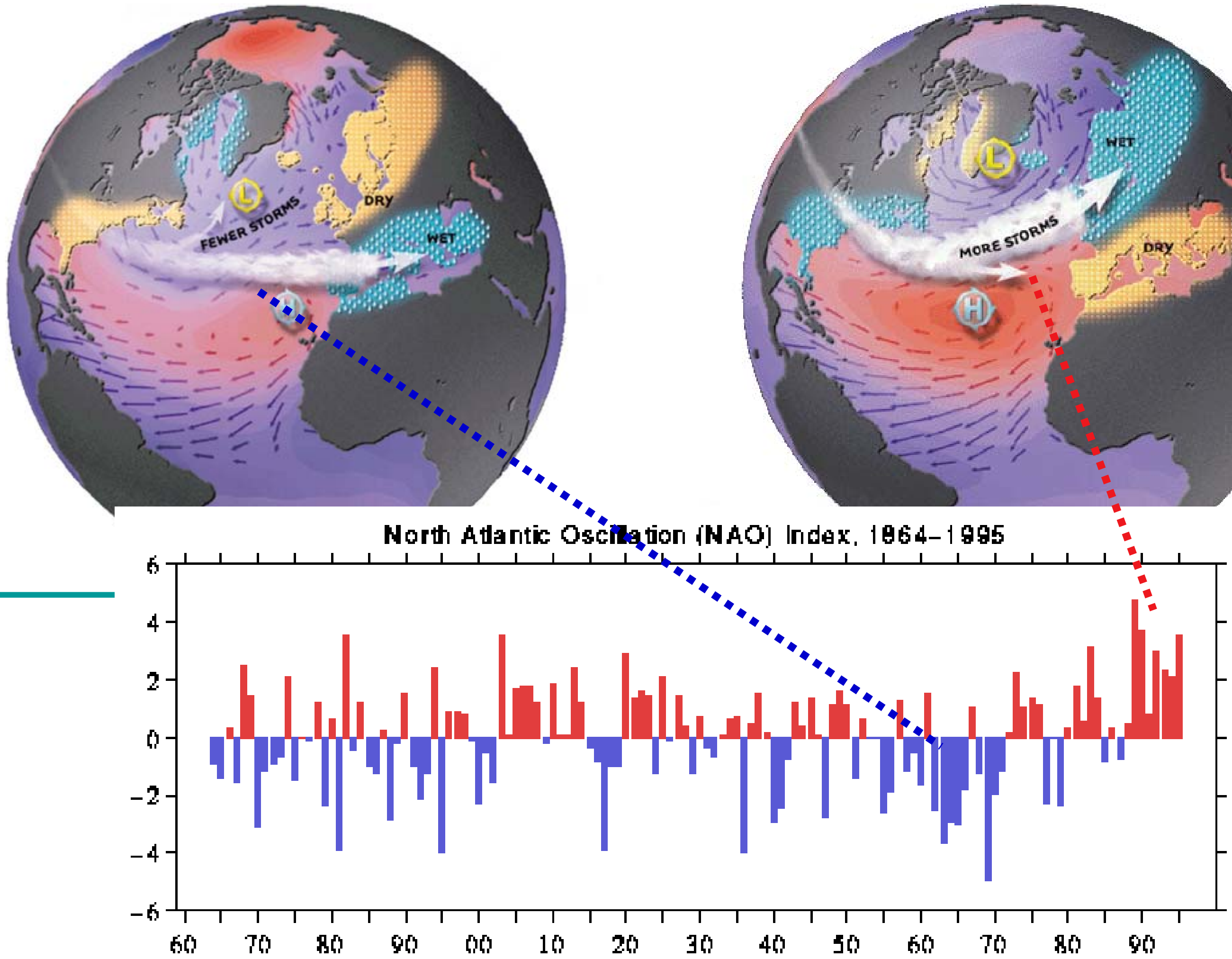
Example of NAO effect

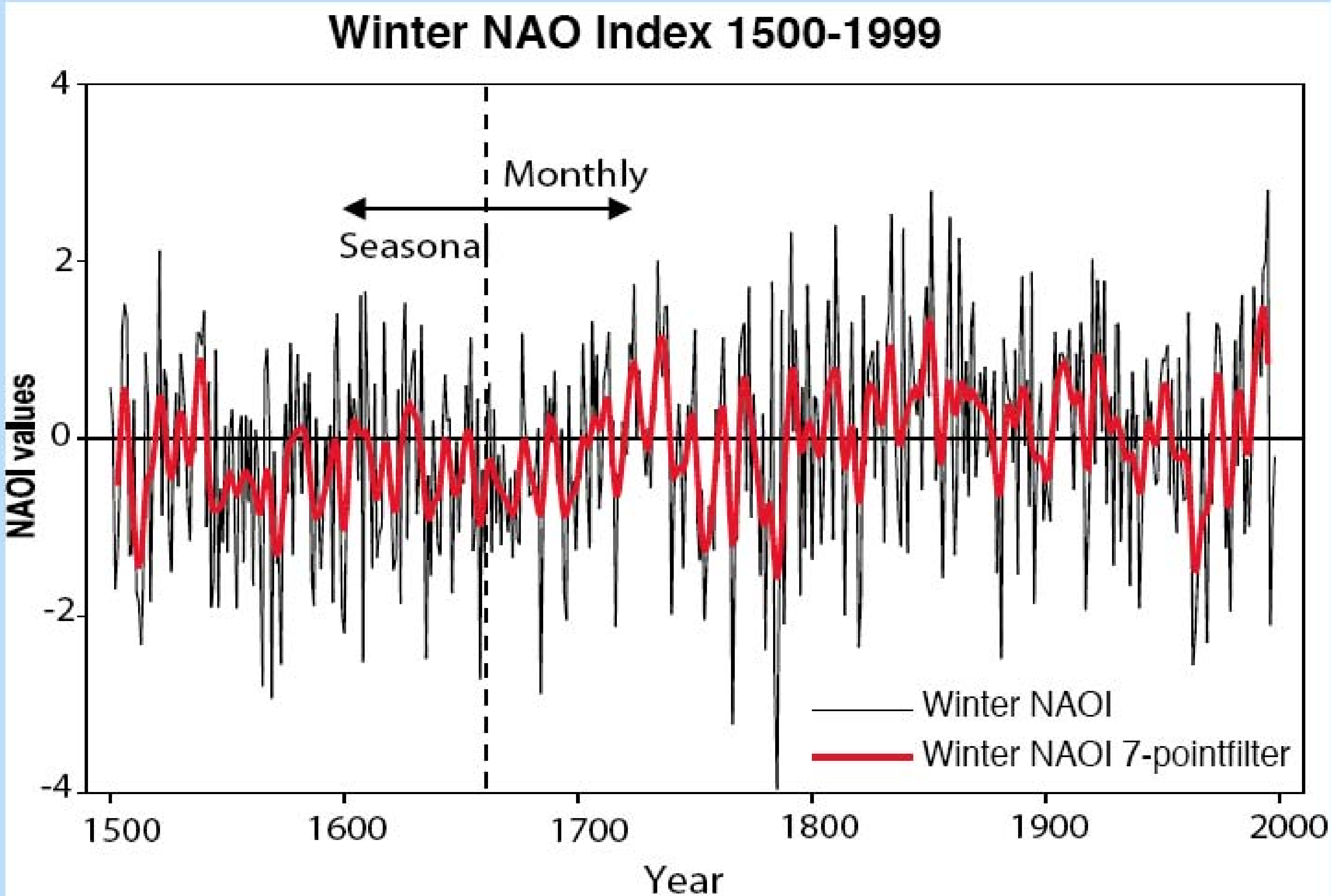
❖Expansion of Briksdal glacier Western Norway 1989 to 1996 due to doubling of winter snowfall

CAUSES.....

Negative NAO

Positive NAO





From: Luterbacher, J., Xoplaki, E., Schmutz, C., Jones, P.D., Davies, T.D., Gyalistras, D. and Wanner, H., 2001: Extending Highly Resolved NAO Reconstructions Back to AD 1500. Jim Hurrell, Yochanan Kushnir and Martin Visbeck (eds.) "The North Atlantic Oscillation", AGU Mongraph, American Geophysical Union.

AV/D1/0110

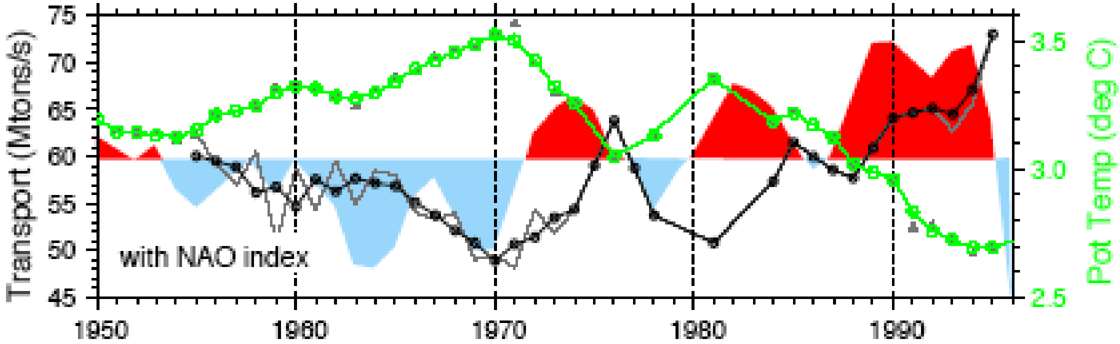
Possible causes behind NAO decadal variability:

- Ocean heat storage creates longer time scale i.e. a coupled system?
- Teleconnections from tropics
- Interactions between higher atmosphere (stratosphere) and the lower atmosphere (troposphere) in polar regions

Possible impacts of prolonged dominance of NAO+ phase :

- Wet N-Europe, dry Mediterrenean
- Reduced sea ice
- More winter storms
- Changes in ecosystems and fisheries

The NAO:
- The Role of the Ocean -

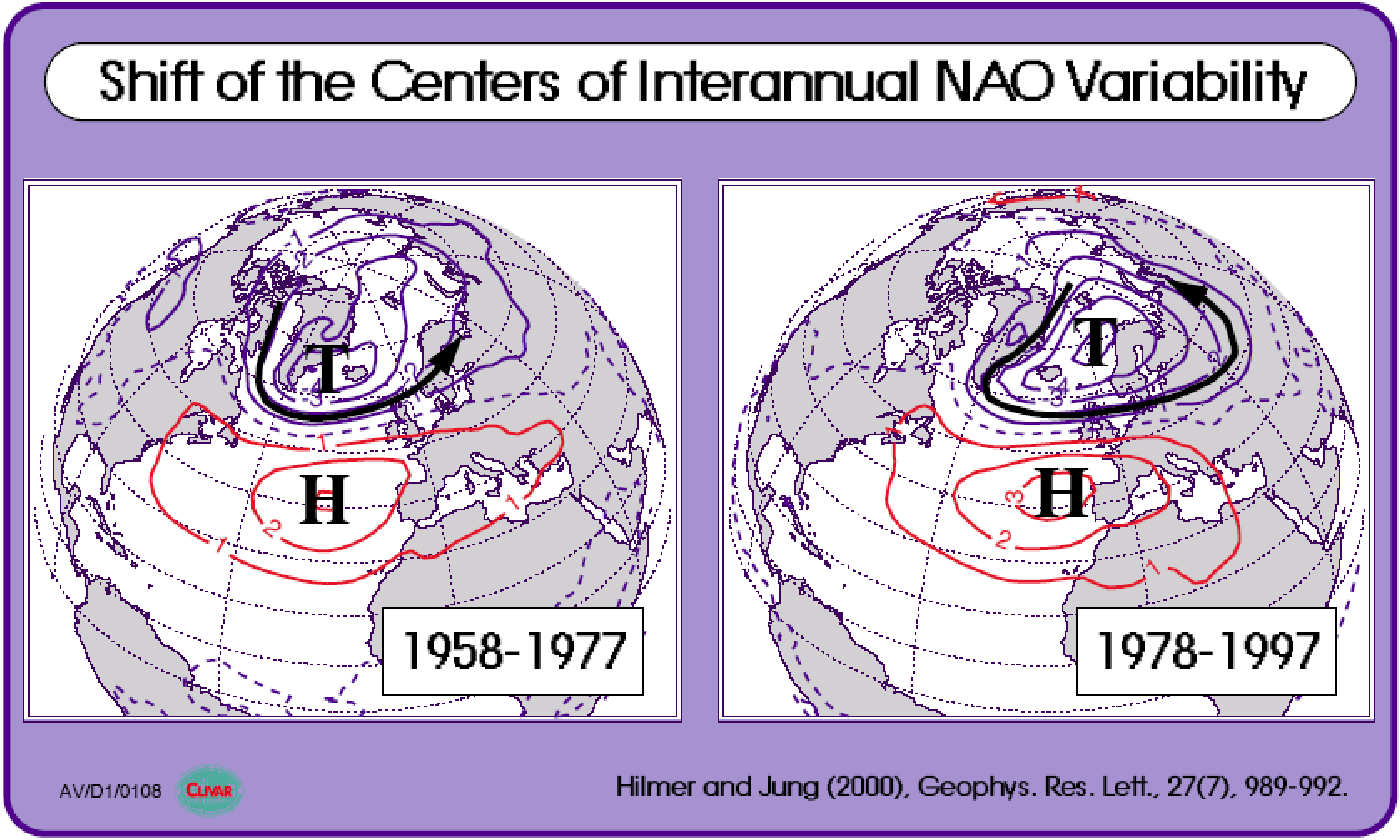


Ocean temperatures and transports related to the NAO: Low-passed winter NAO index (Hurrell, 1995, red=high, blue=low), the variation in the temperature of deeply convected water in the Labrador Sea (green line, right scale) and the variation in eastward baroclinic transport of the Gulf Stream/ North Atlantic Current, as indexed (heavy black line, left scale) by potential energy anomaly differences between the Labrador Sea and Bermuda (an oceanic analogue of the atmospheric NAO index).

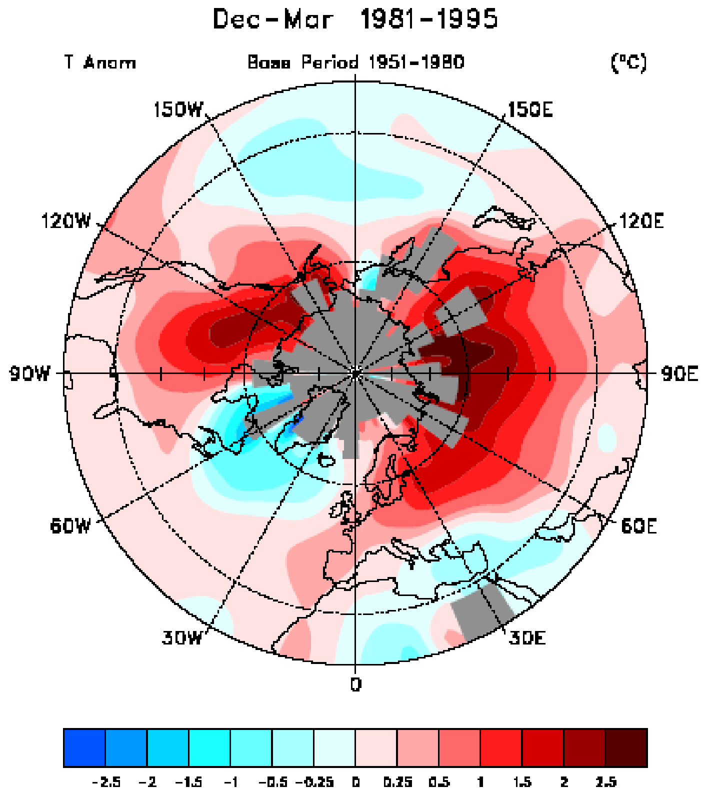
The warming temperatures before 1970 (low NAO index) and cooling thereafter (high NAO index) are also reflected in subpolar SST. These changes are the underlying cause of the Cold Ocean part of the "Cold Ocean - Warm Land" pattern in the Atlantic sector in the past 25 years. Oceanic transports appear to lag the NAO by 4-5 years, and decline with the warming Labrador Sea (and general subpolar SST) and declining NAO index of the 1950's and 1960's. The oceanic transports rise again with the cooling Labrador Sea (and general subpolar SST) and strengthening NAO index of the 70's, 80's and 90's. The 0.8°C temperature range of this large pool of subpolar water, and the fluctuation range of more than 30% in circulation intensity are some of the indications of a powerful participation of the ocean in this North Atlantic Atmosphere-Ocean Oscillation (from Curry and McCartney, 1999, JPO, submitted).

LB/D1/99-3

Increased NAO-index in the last decades, but also centers of action closer to Europe:

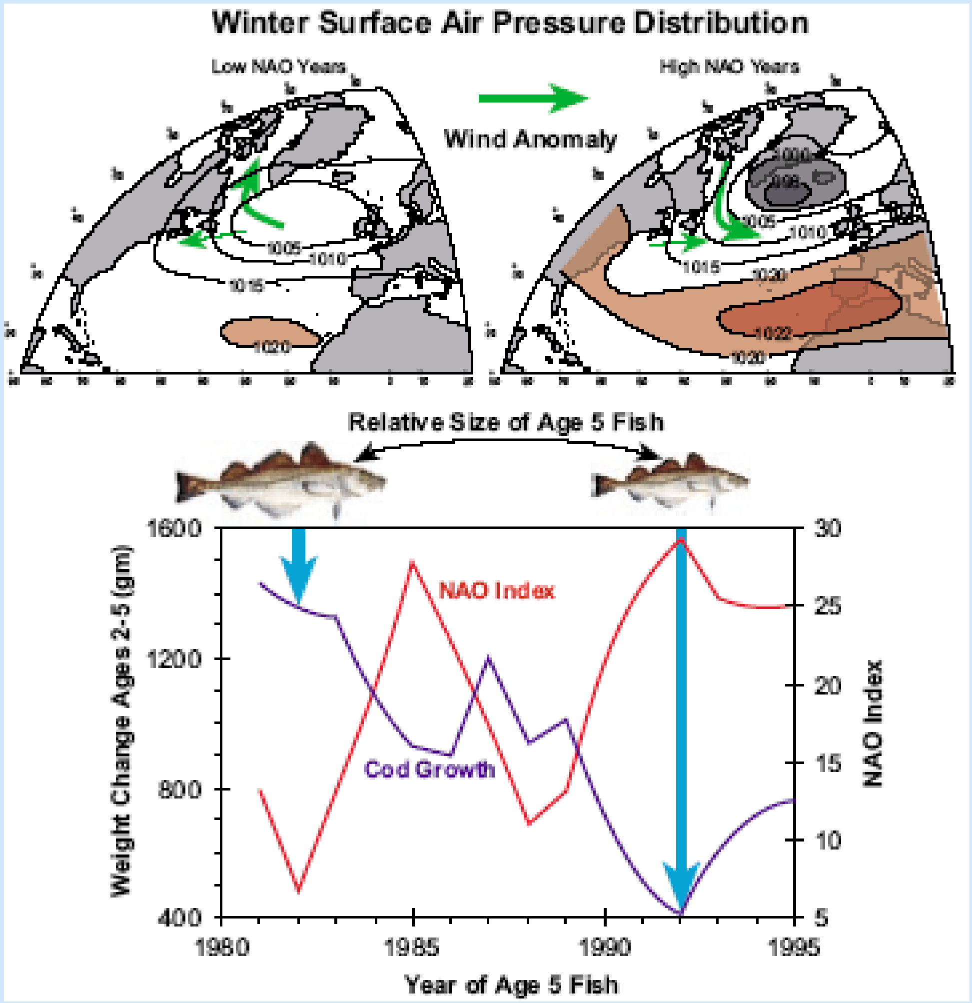


Impacts of the NAO



Observed Dec-March surface temperature anomalies associated with a high NAO index; the period 1981-1995, when the NAO was high, relative to the period 1951-1980, when the NAO was low (after Hurrell, 1996). The temperature data consists of land surface temperature blended with SST data (Jones and Briffa, 1992, The Holocene, 2, 174-188).

LB/D1/99-5

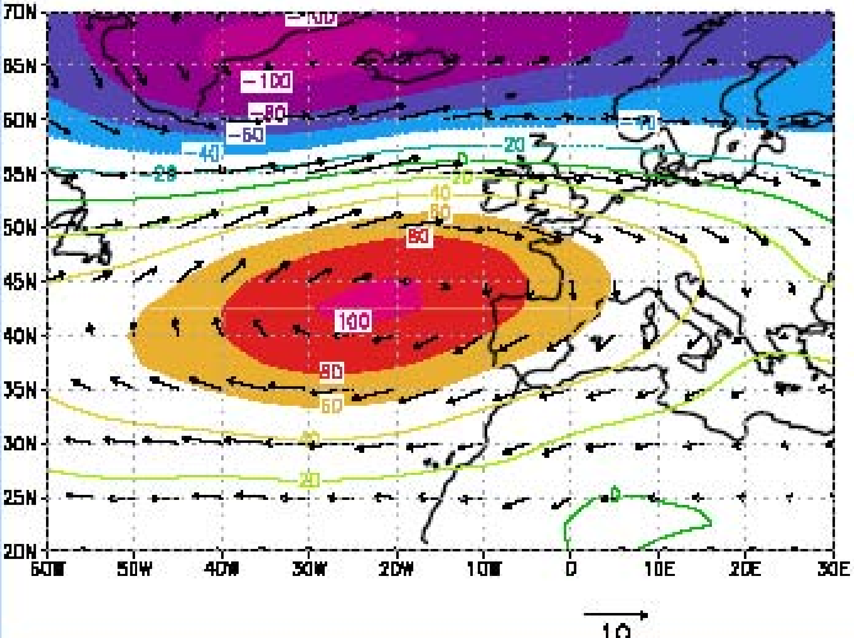


The Impact of the NAO on the Growth of Atlantic Cod off Labrador and Newfoundland. The grow of northern cod, as defined by the weight gain between ages 2 and 5, is inversely related to the NAO index. The index is the average over the 3 years the cod is growing. A high index, which produces cold ocean temperatures, strong winds and lots of ice off Labrador and Newfoundland, results in low growth. The pictures of the cod show the relative size of 5-year old fish under maximum and minimum NAO conditions (courtesy K. Drinkwater (BIO)

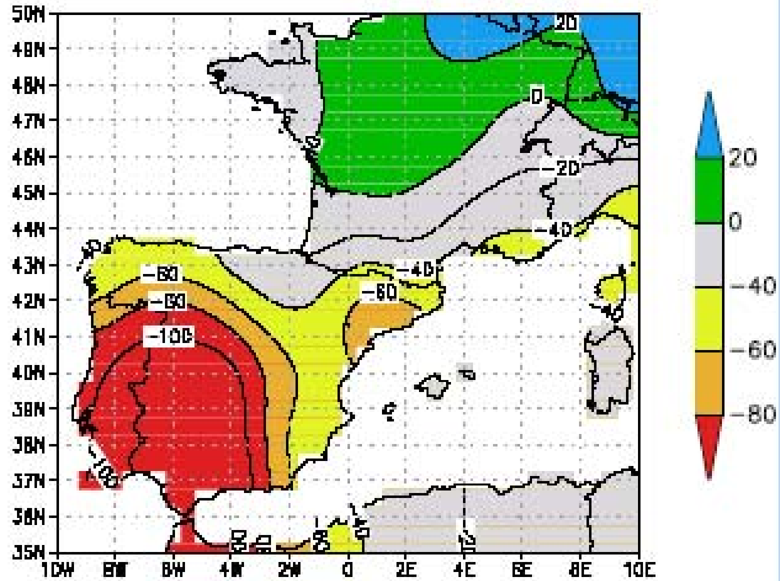
AV/D1/0105

Impact of the NAO on Southwestern Europe

Geopotential Height (700hPa) and wind anomalies
(81, 83, 89, 94)-(64, 69, 79)



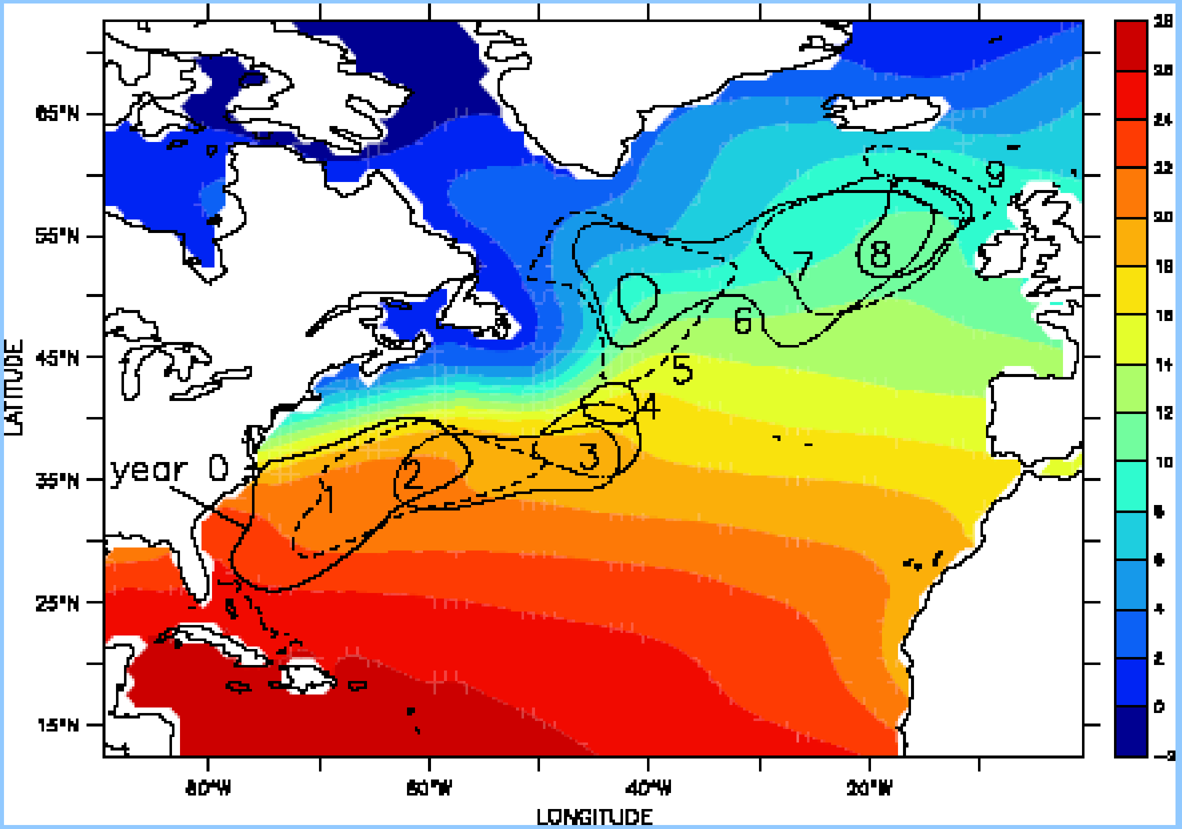
Relative Precipitation Anomalies
(81, 83, 89, 94)-(64, 69, 79)



Study of Frequency Variability of Winter Precipitation over the South-Western Europe and its Relationships with Teleconnection Indices. Authors: C. Rodríguez-Puebla*; J. Sáenz**; A.H. Encinas*** and J. Zubillaga**** * Dept. of Atmospheric Physics, University of Salamanca. Spain ** Dept of Applied Physics. University of Basque Country. Spain *** Dept. of Applied Mathematics. University of Salamanca. Spain **** Dept. of Condensed Matter. University of Basque Country. Spain.

AV/D1/0106

Decadal Predictability of North Atlantic SST's ?



Correlation between low frequency fluctuations in local wintertime SST and low frequency fluctuations in wintertime SST averaged over the region 80-60°W, 31.5-38.5°N (the vicinity of Cape Hatteras (VCH)) as a function of lag. The contours pick out the regions where lag-correlation with VCH is maximised. The numbers next to each contour indicate the lag in years. In all cases SST in the vicinity of Cape Hatteras is leading. The contour value is 0.8 for lags of 0 to 8 years and 0.75 for the lag of 9 years. The contours are superimposed on the SST files averaged over all winters between 1945 and 1989 (contour scale in °C) (from Sutton and Allen, 1997, Nature, 388, 563-567).

AV/D1/99-3

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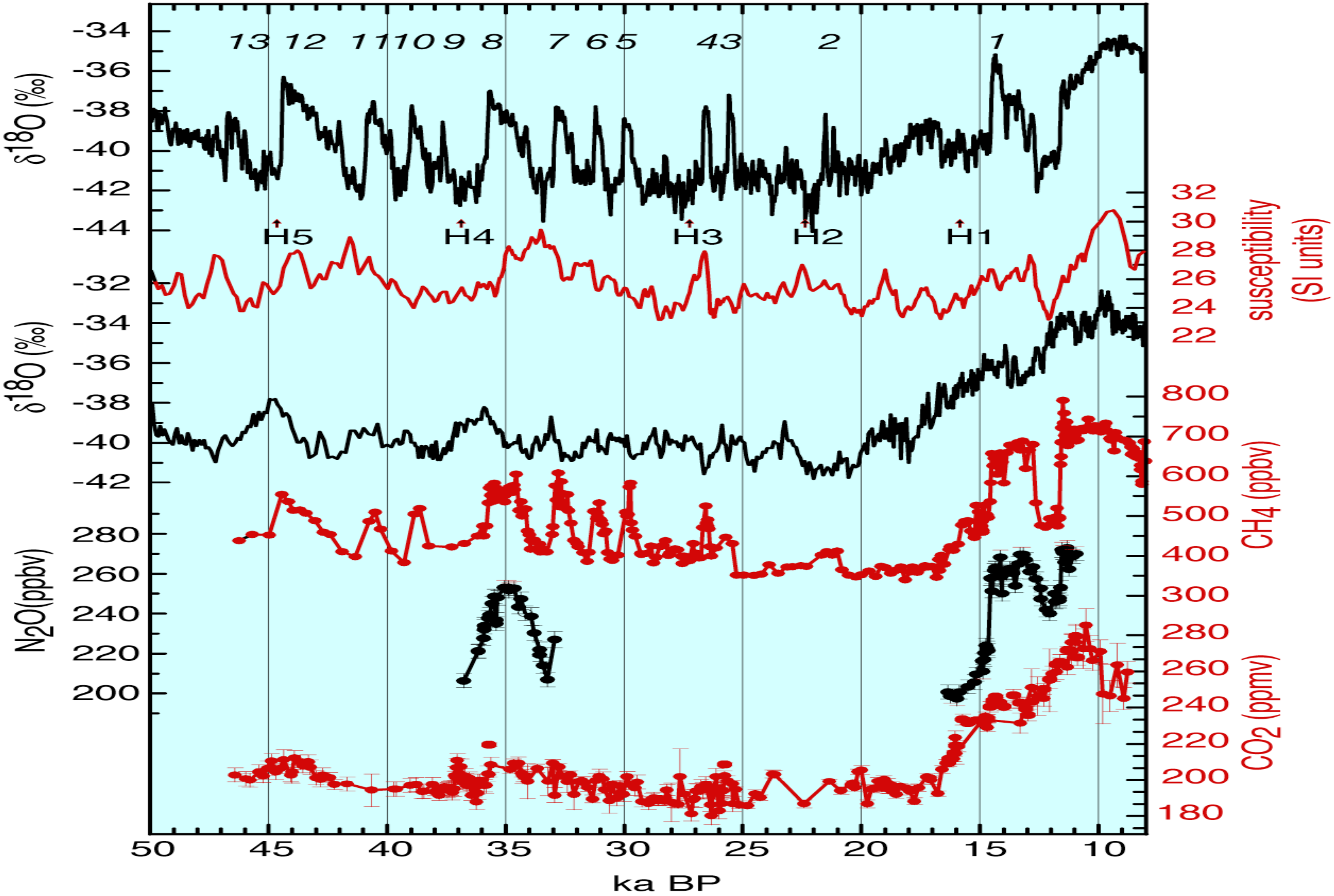
Millennial Scale Climate Changes



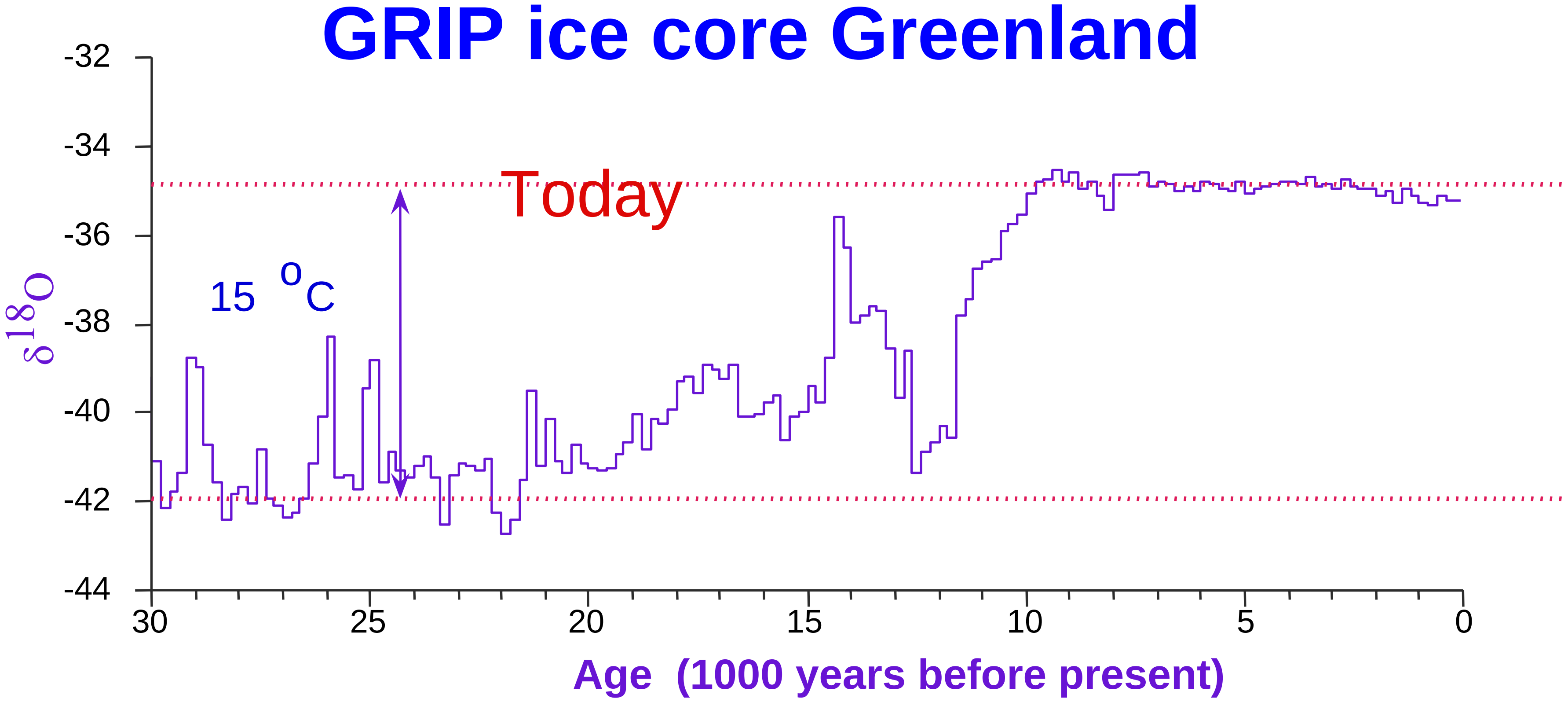
Paleoclimate, Global Change and the Future
Alverson, Bradley and Pederson eds., 2002

Chapter 2: D. Raynaud et al., fig. 2.4, p. 23

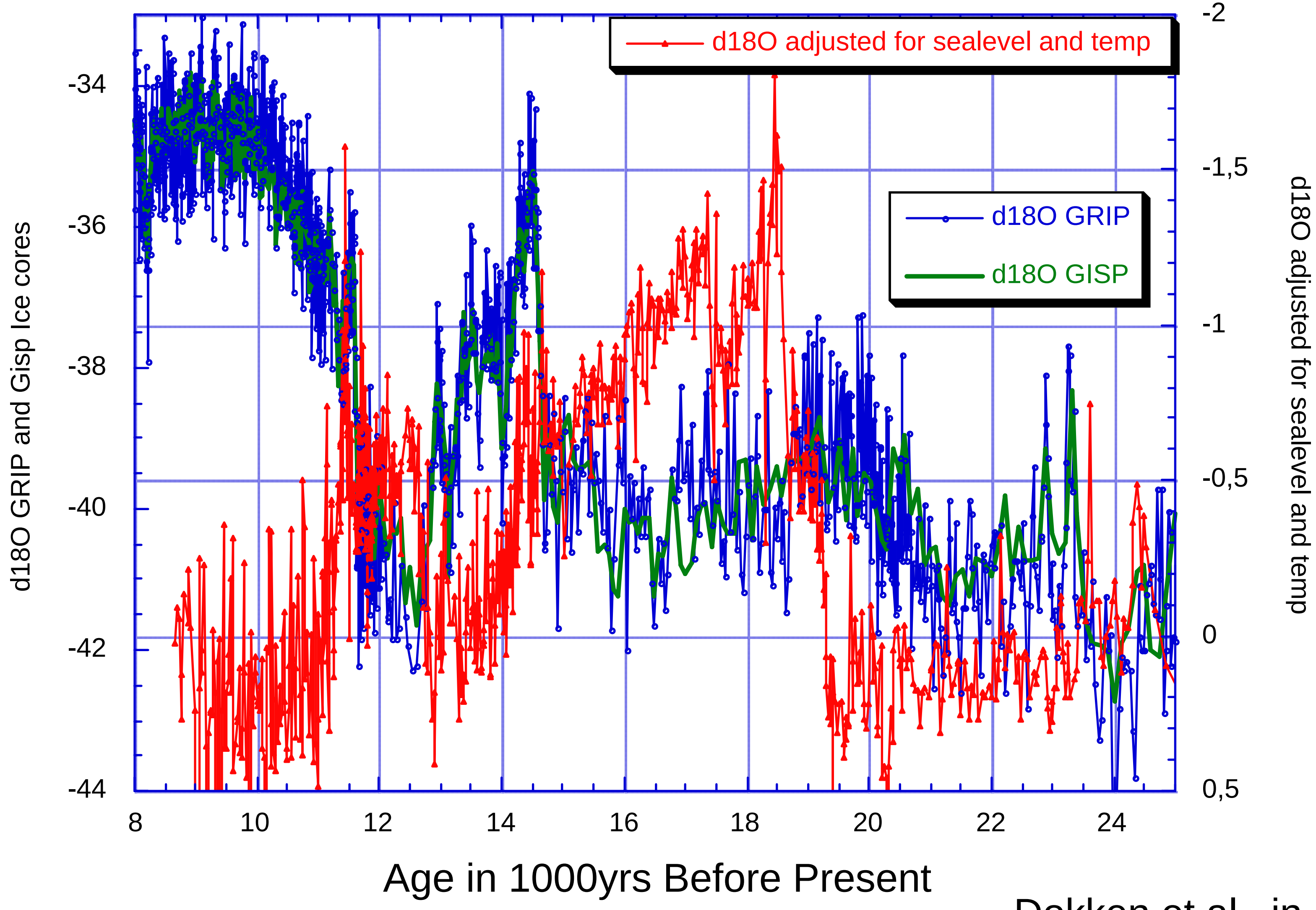
GLOBAL IGBP CHANGE

PAGES PAST GLOBAL CHANGES

Climate change amplitudes



Freshwater input leads to coolings?
Red = fresh water input to North Atlantic
Blue= GRIP Ice core



Dokken et al., in prep

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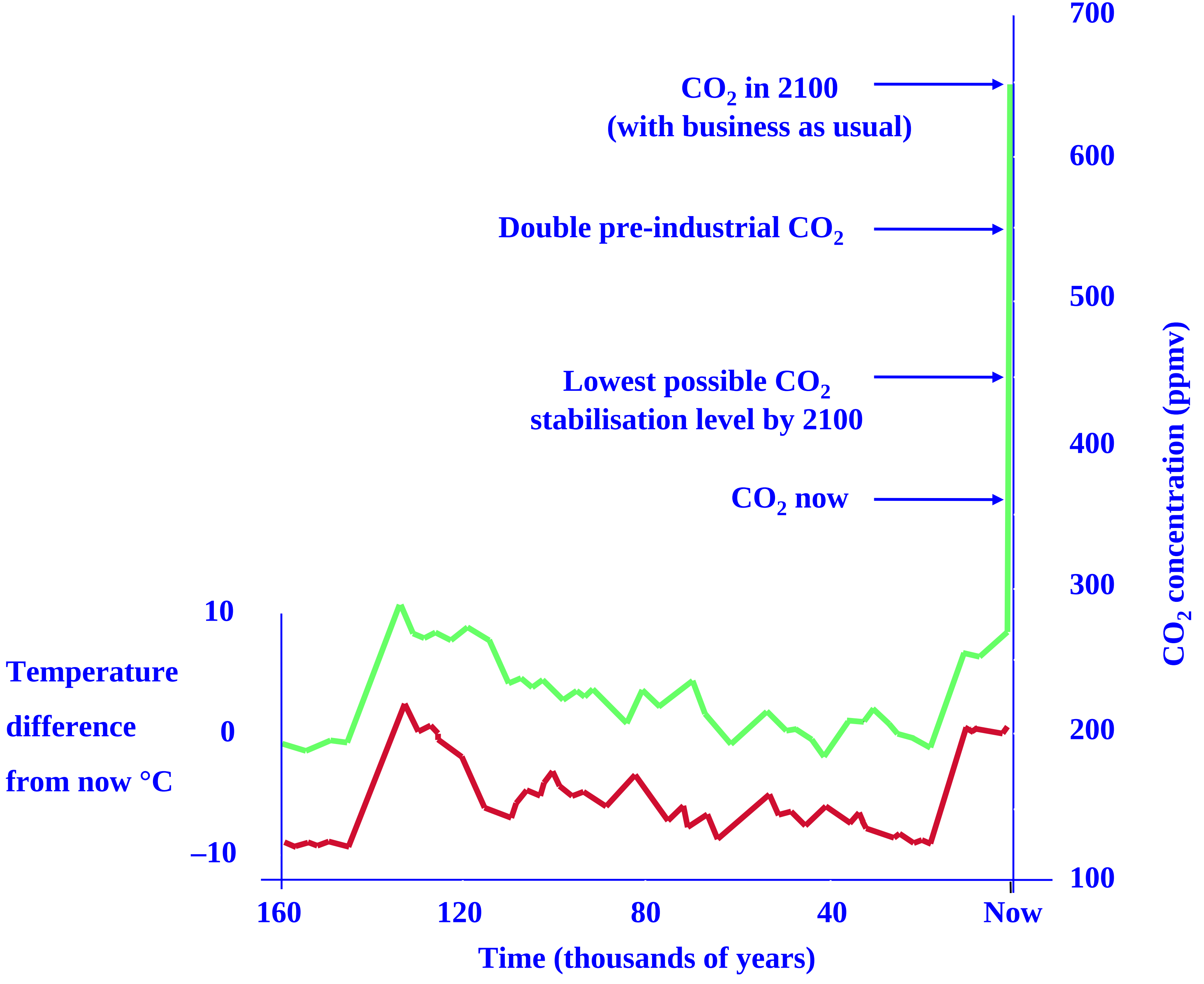
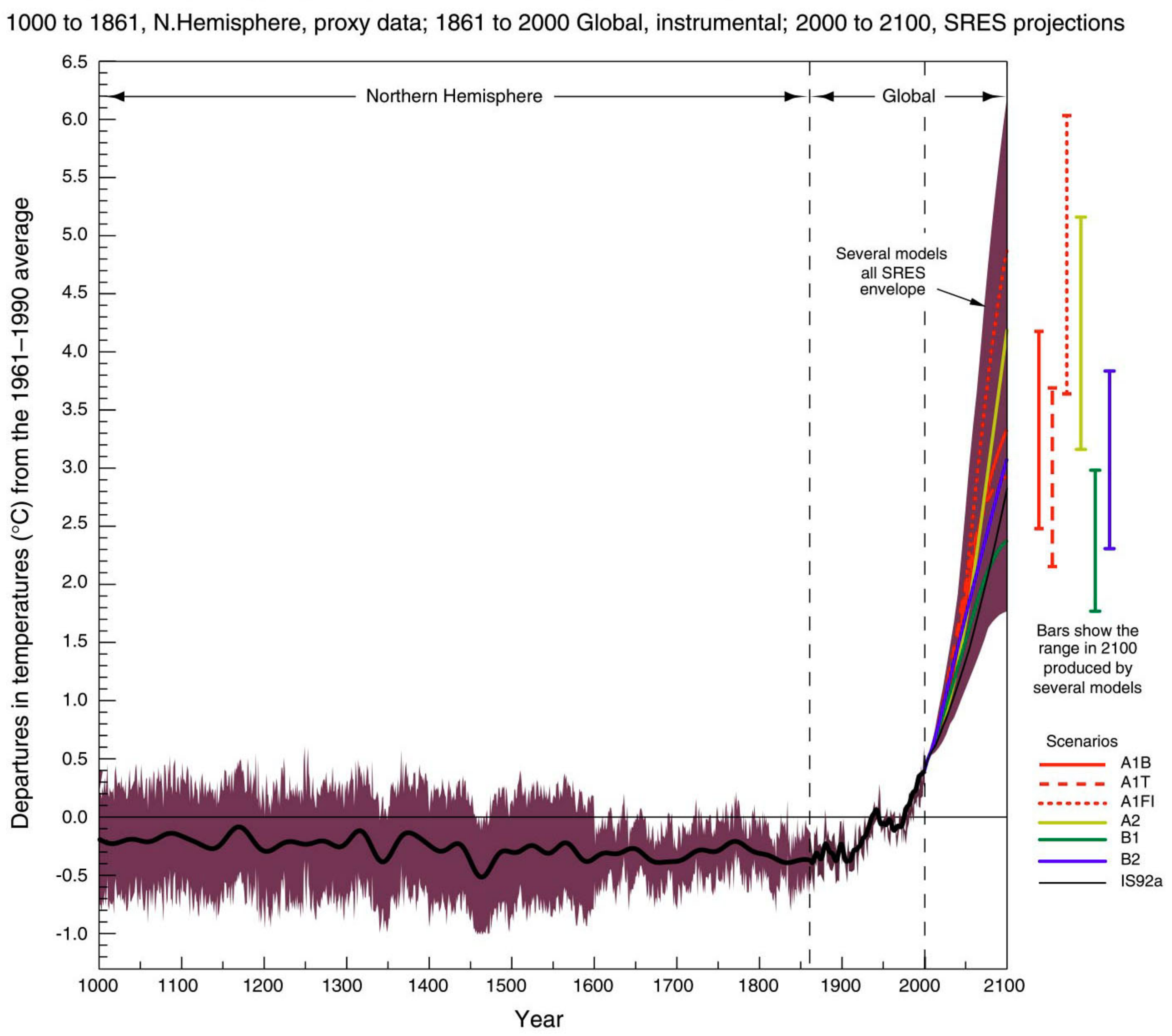


CO2 in 2100
(with business as usual)
Double pre-industrial CO2
Lowest possible CO2
stabilisation level by 2100
CO2 now
700
600
500
400
300
200
100
CO2 concentration (ppmv)
10
0
–10
Temperature
difference
from now °C
160
120
80
40
Now
Time (thousands of years)

Temp. variations: 1000 to 2100



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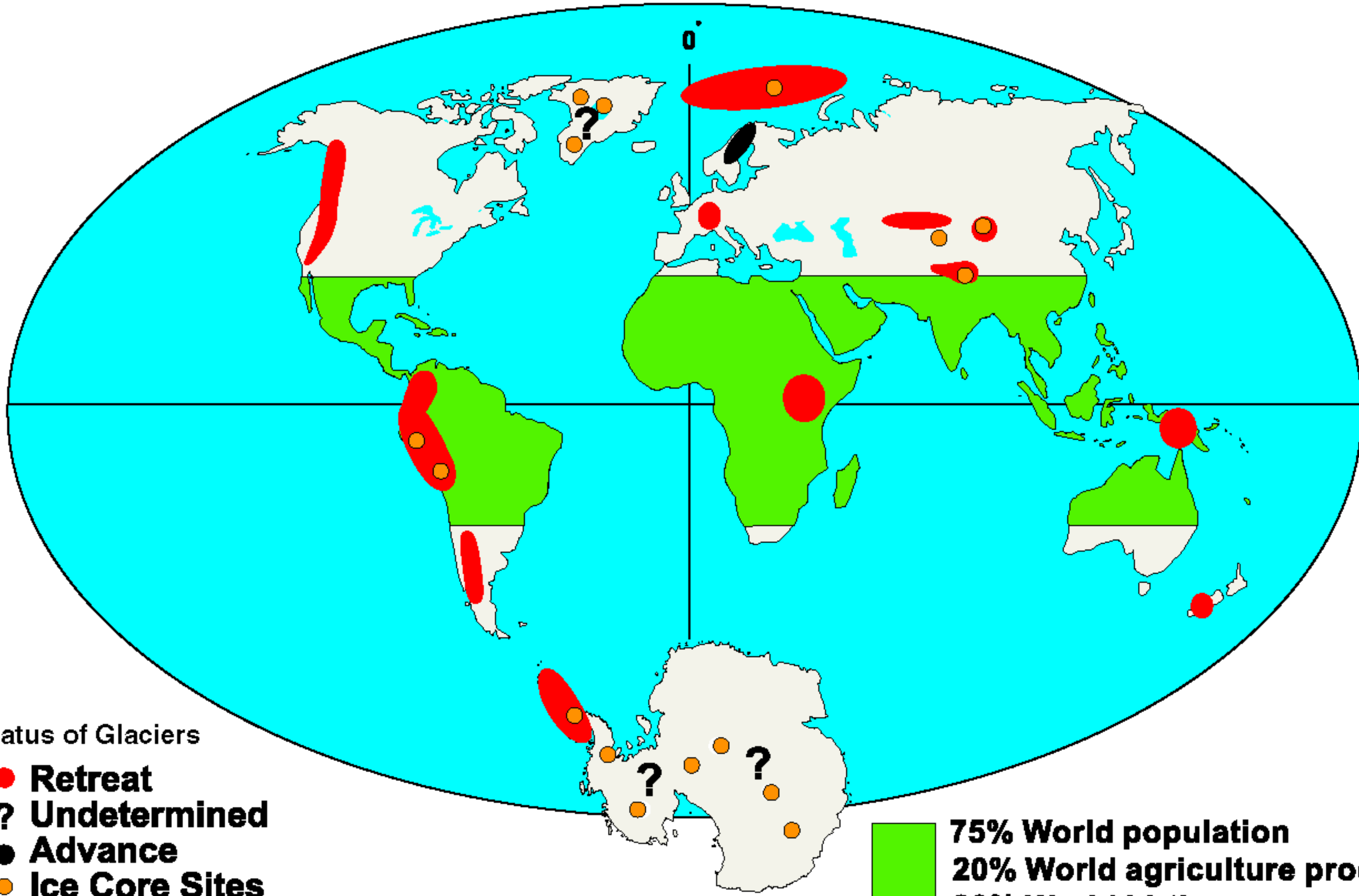
20th Century Changes in Glaciers



Status of Glaciers

- **Retreat**
- **? Undetermined**
- **Advance**
- **Ice Core Sites**

75% World population
20% World agriculture productions
80% World births

GLOBAL IGBP CHANGE

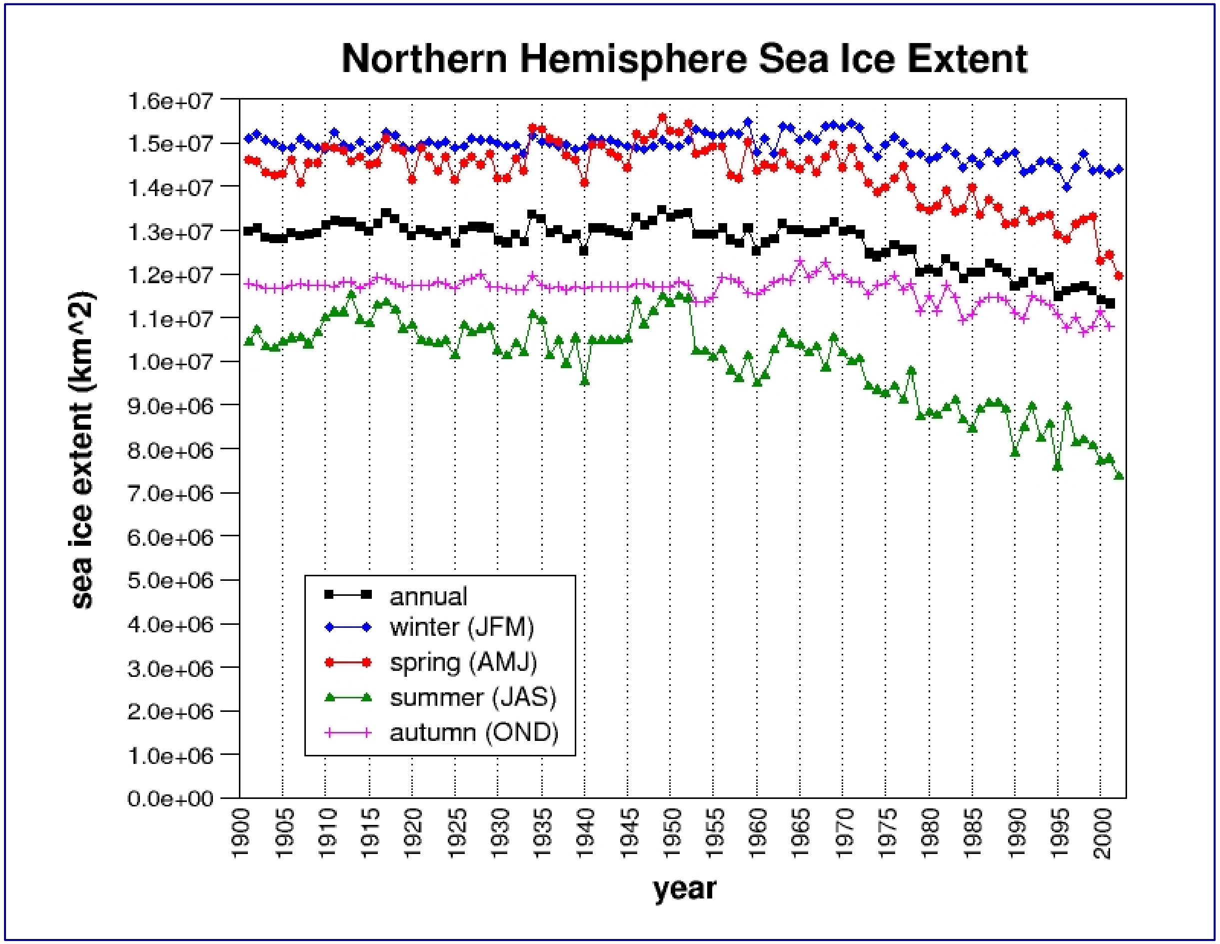
Past Global Changes and Their Significance for the Future
Alverson, Oldfield and Bradley eds.
Thompson (2000) QSR, 19, 19–35.

PAGES PAST GLOBAL CHANGES

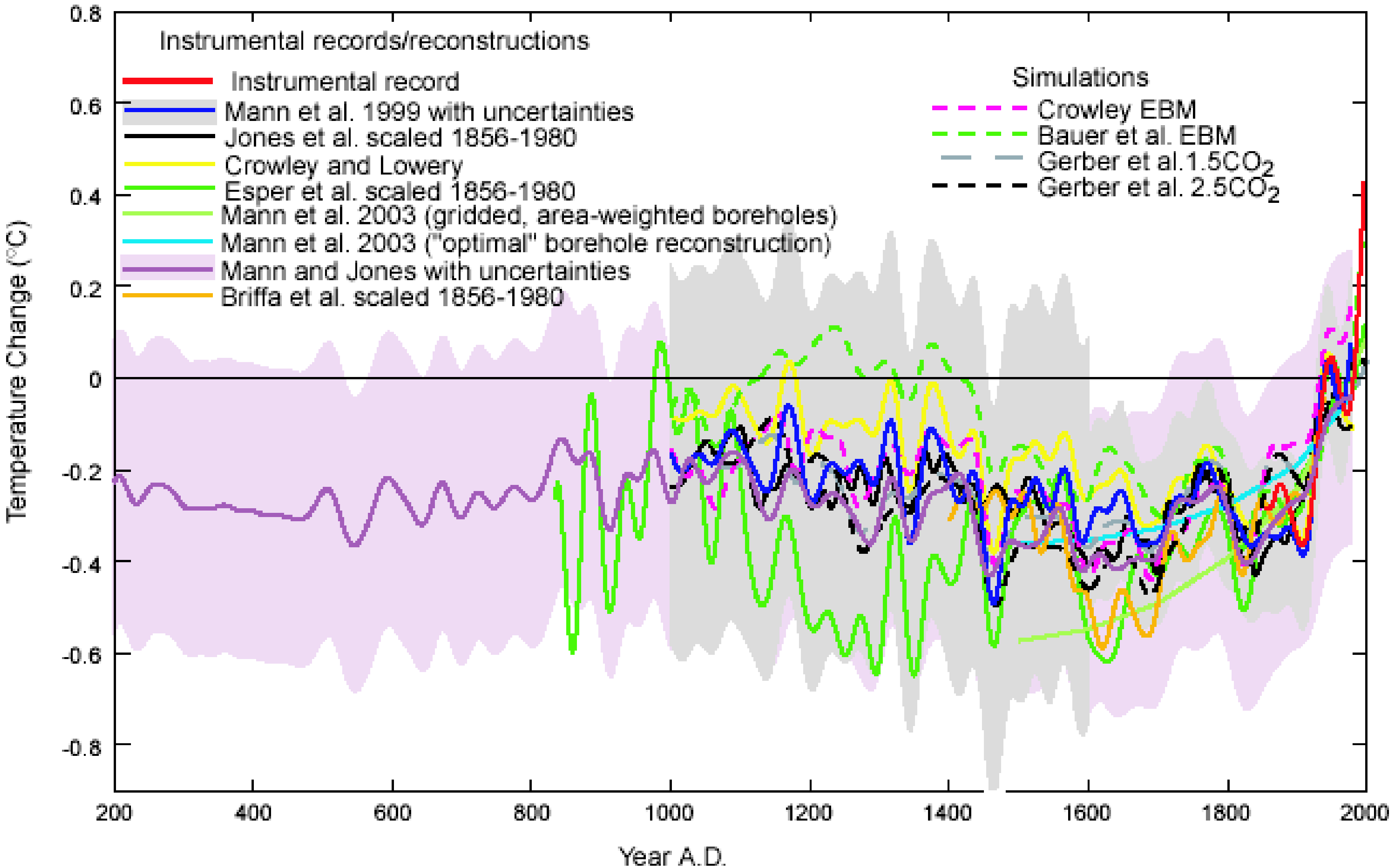
Sea ice cover

Observations document reduced sea ice cover in the Arctic

- **Largest reduction in summer and since 1980**

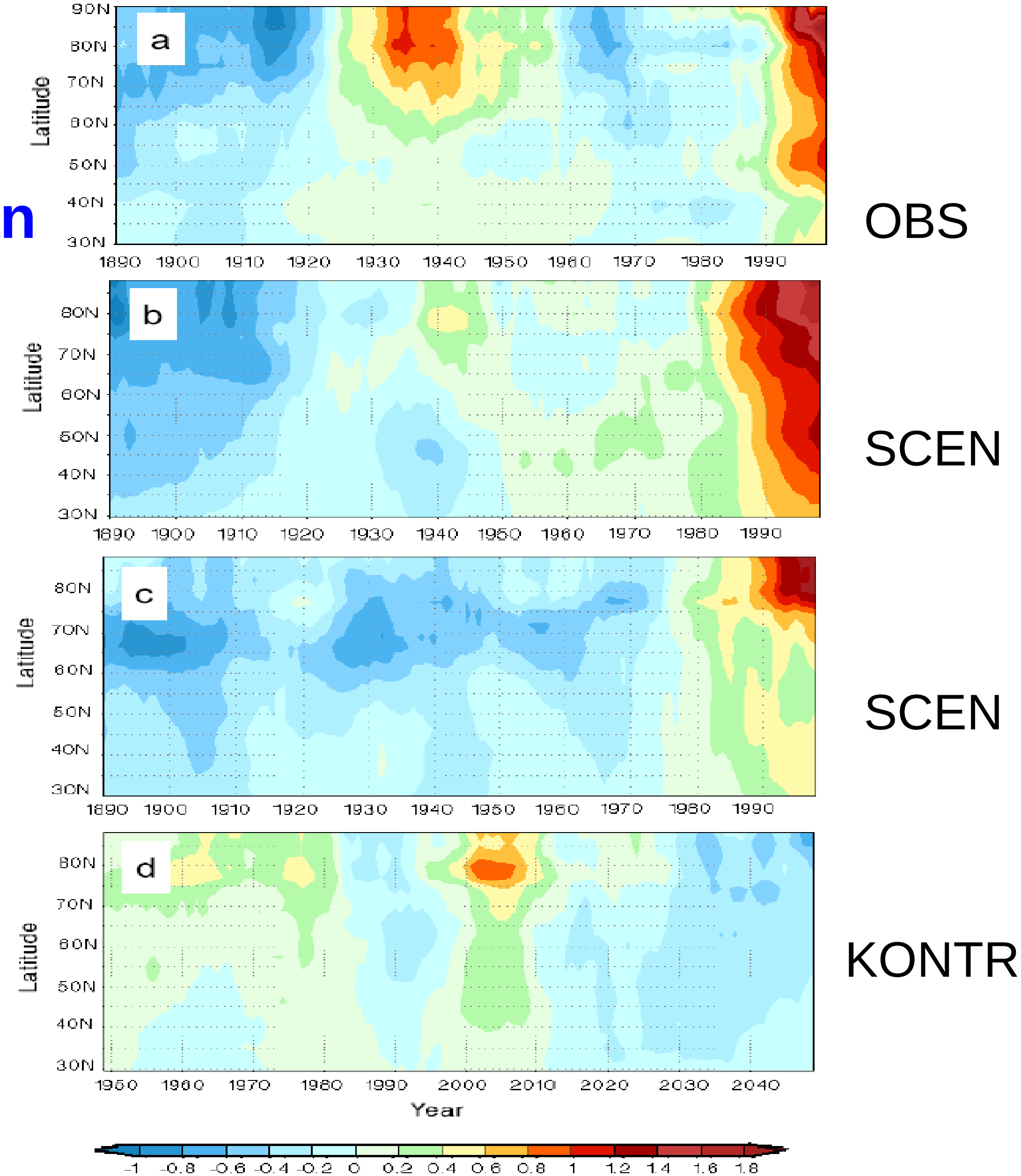


“reconstructions of climates during the past 1000 years indicate that the last half of the past century was not characterised by natural processes alone” (IPCC)



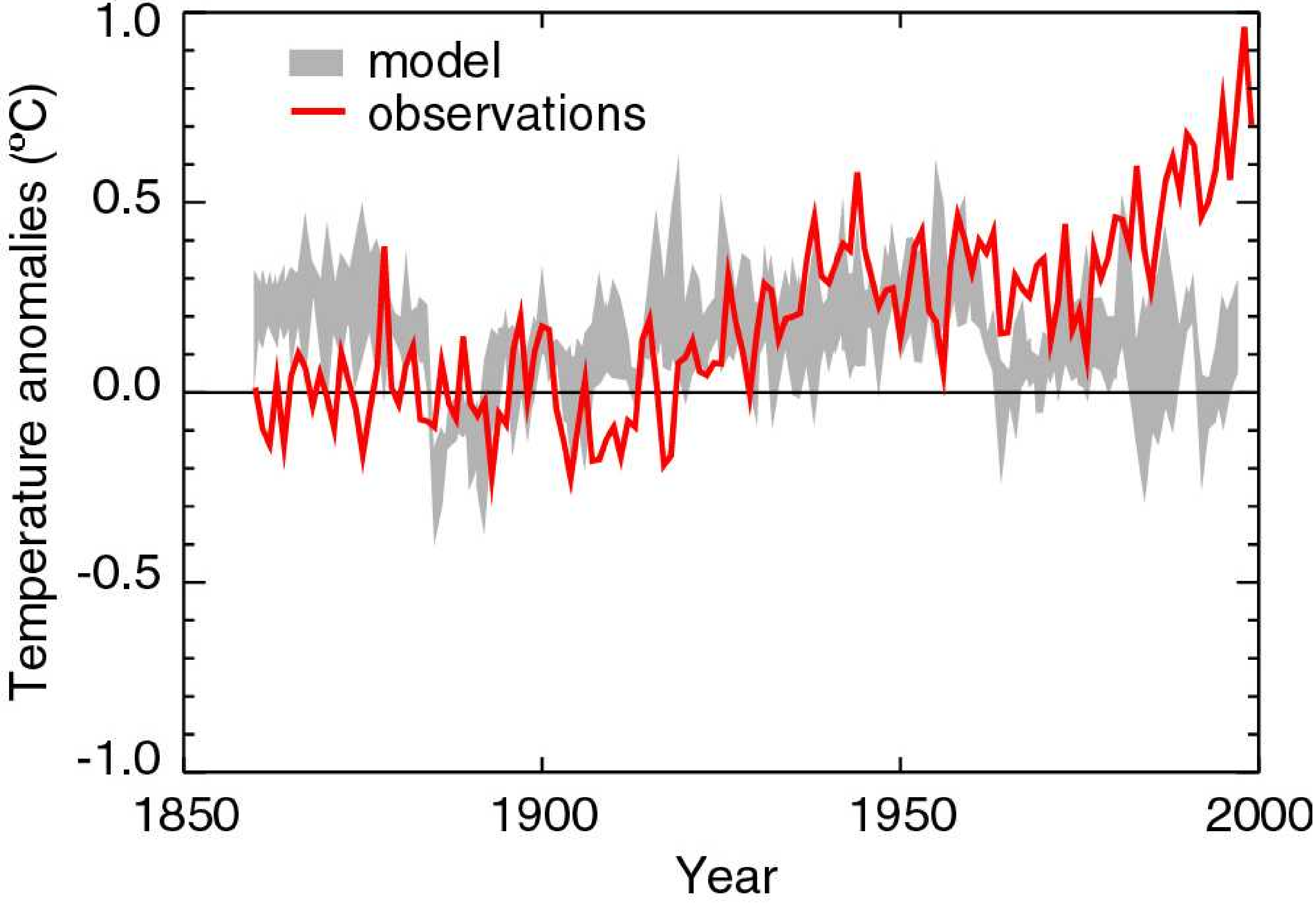
Arctic warming:
1930-40 mainly natural
1970-2000 mainly human

Temp. anomalies



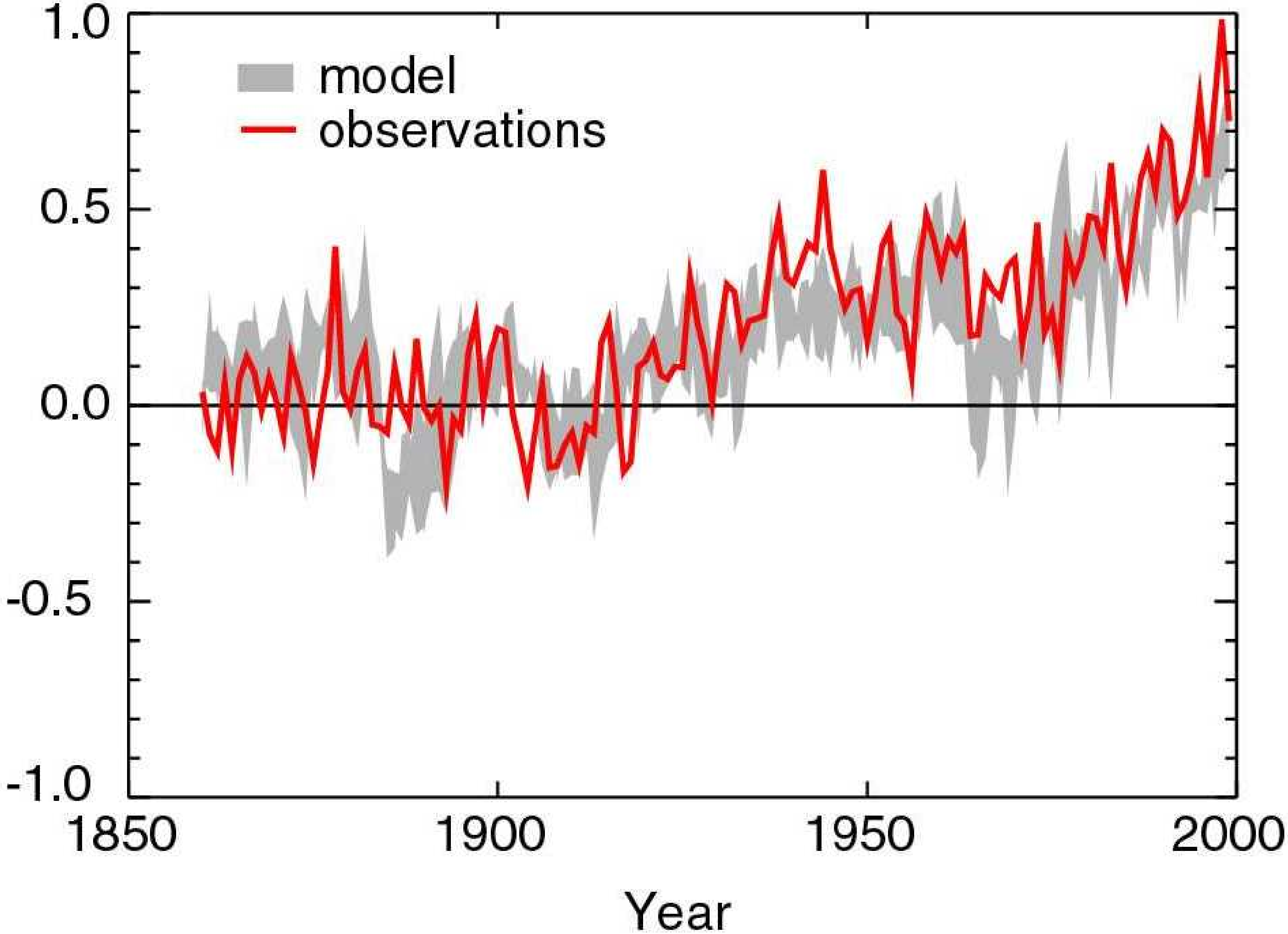
Johannessen *et al. 2003*

“Simulations of the response to natural forcings alone … do not explain the warming in the second half of the century” (IPCC)



Stott et al, Science 2000

“..model estimates that take into account both greenhouse gases and sulphate aerosols are consistent with observations over this period”(IPCC)



Stott et al, Science 2000

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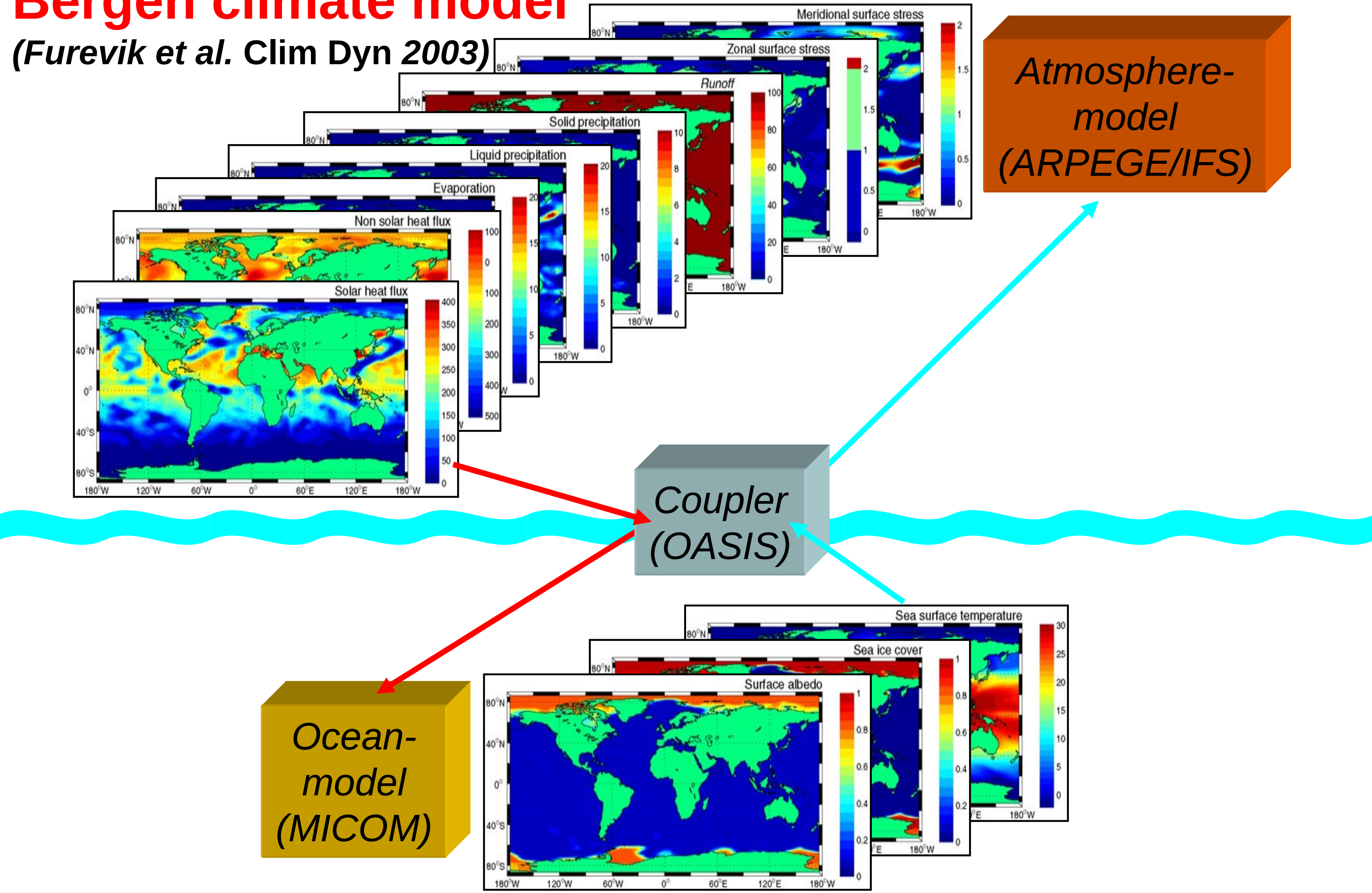
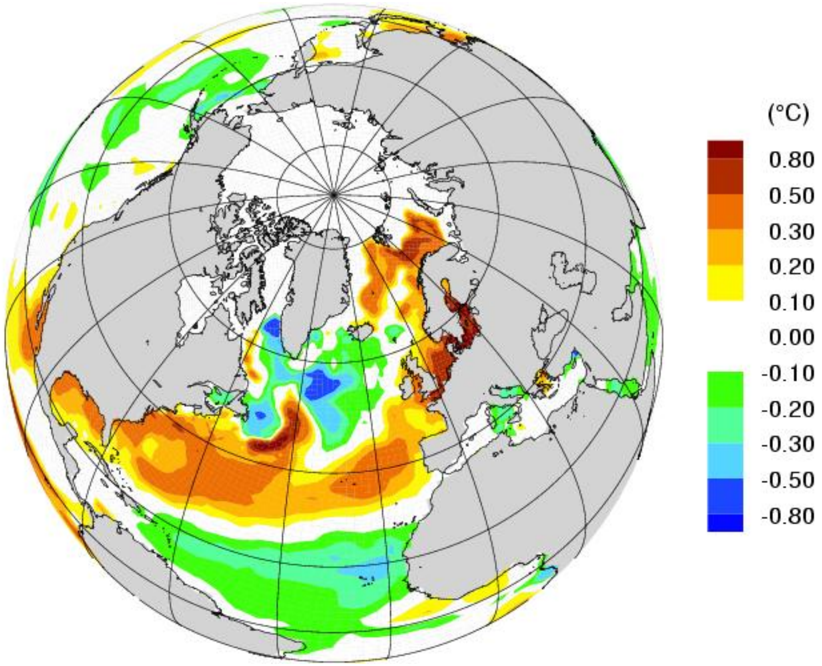
Bergen climate model

(Furevik et al.* Clim Dyn *2003)

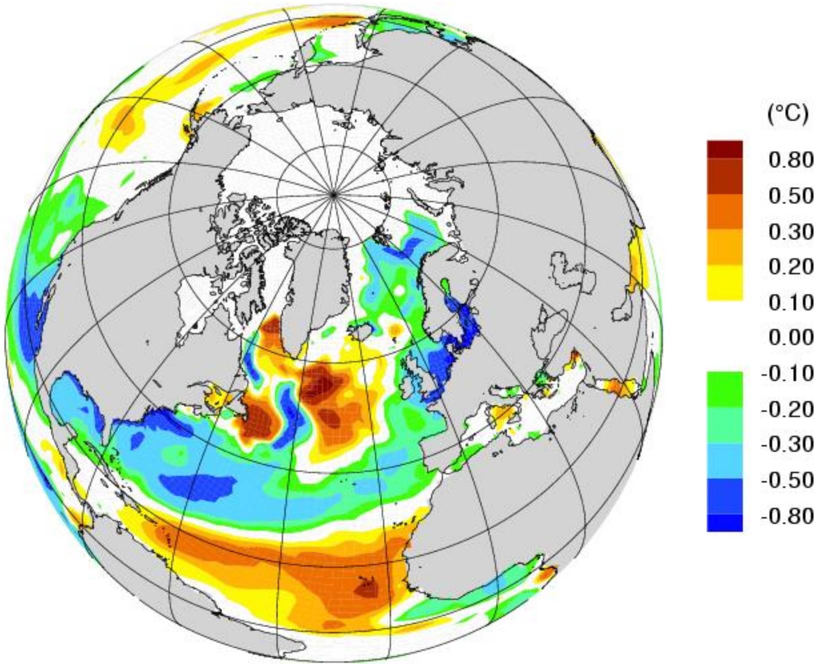


When driven with observed atmosphere, the ocean response seems realistic:

Simulated March SST-anomalies for high/low NAO



High NAO index



Low NAO index

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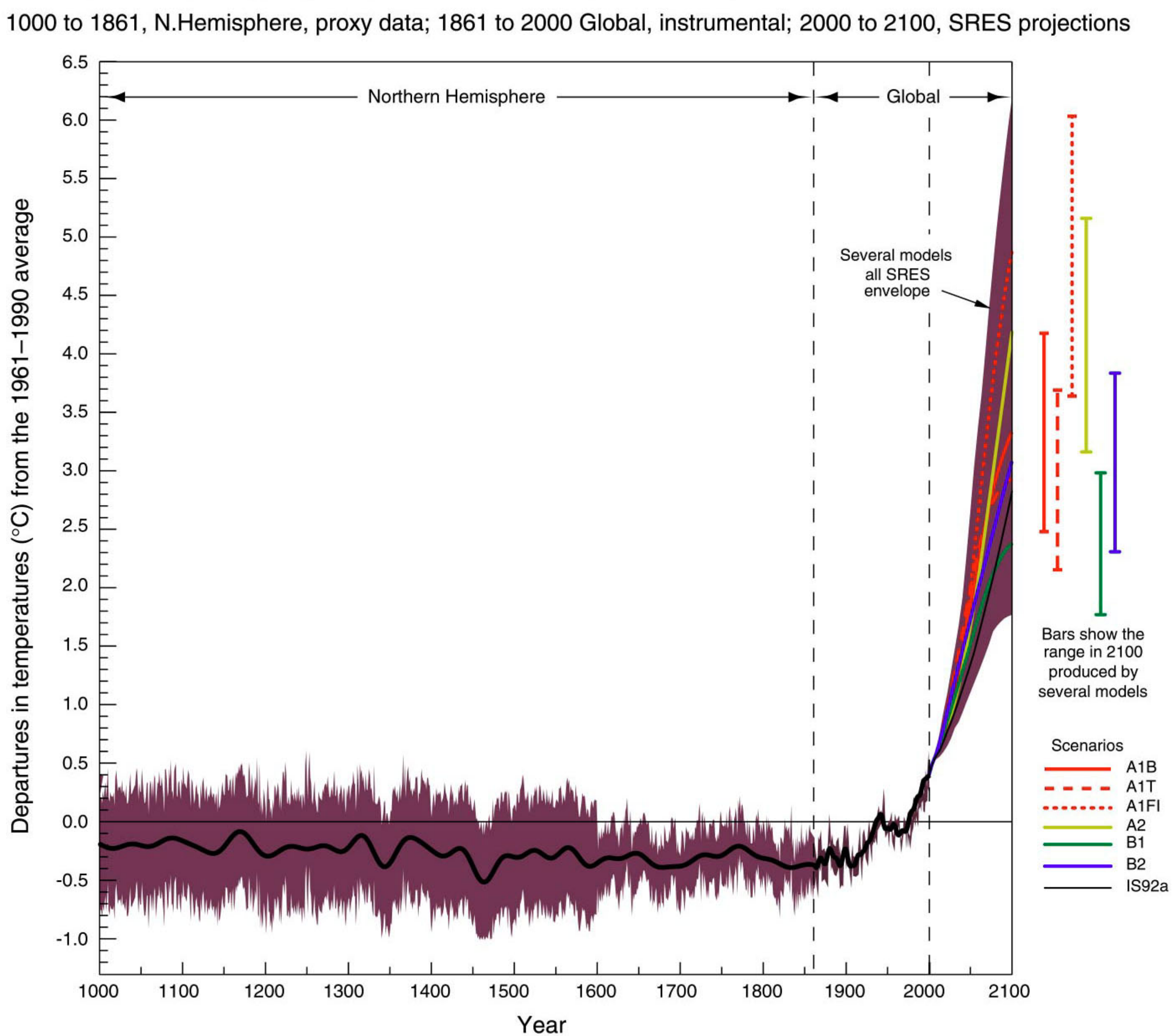
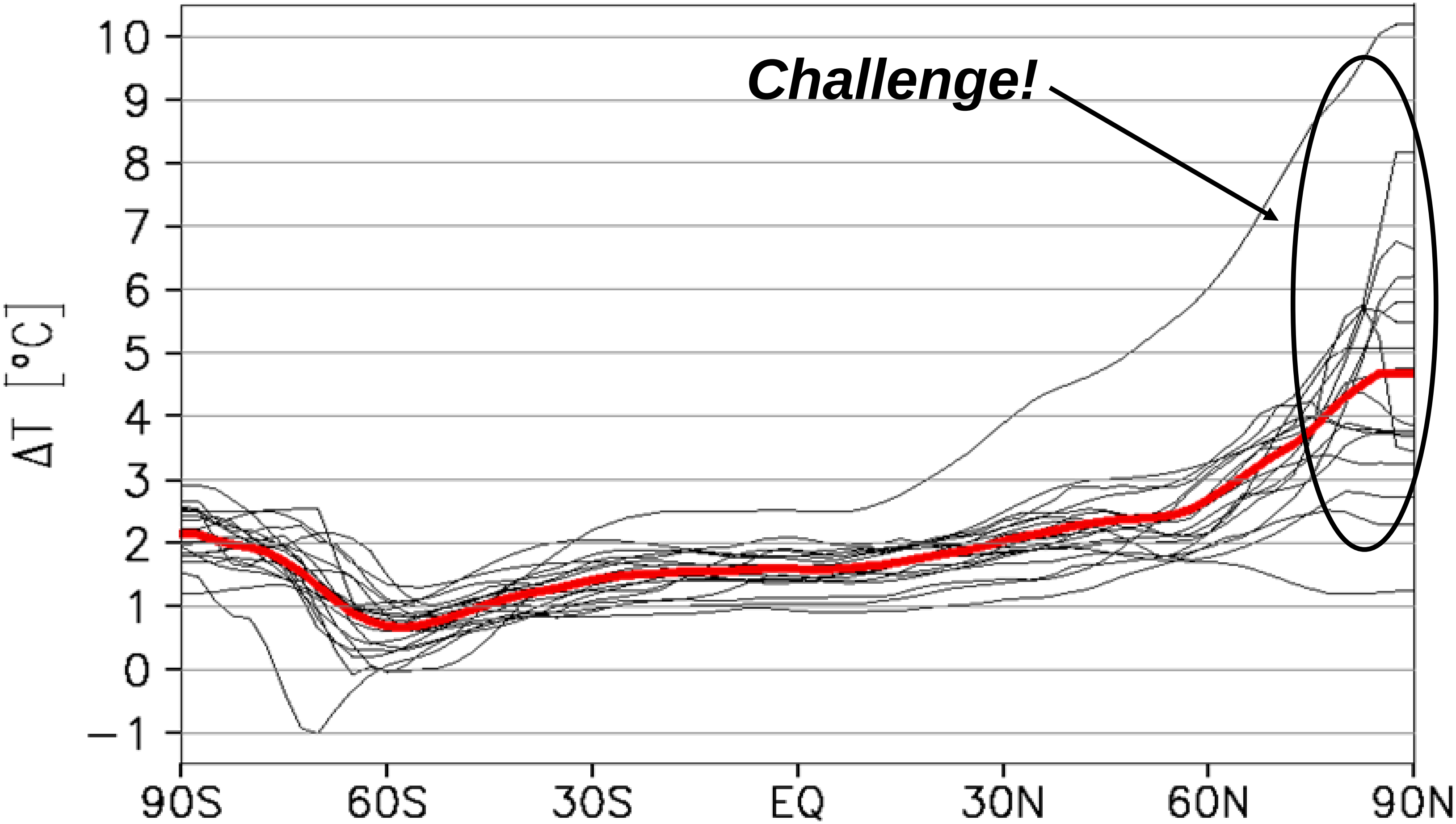
Temp. variations: 1000 to 2100



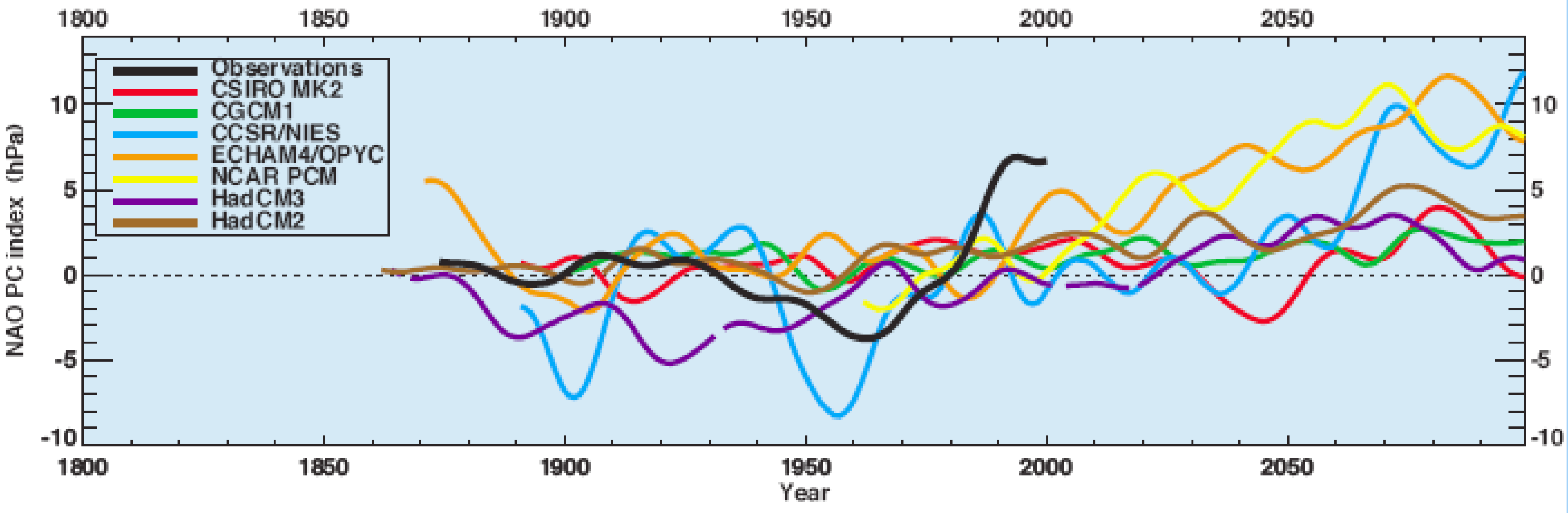
Mean ΔT at 2070 from 19 different climate models driven with same CO_2 increase



http://www-pcmdi.llnl.gov/cmip

More winter storms due to Climate Change ?

- Observed and simulated (winter) North Atlantic Oscillation -



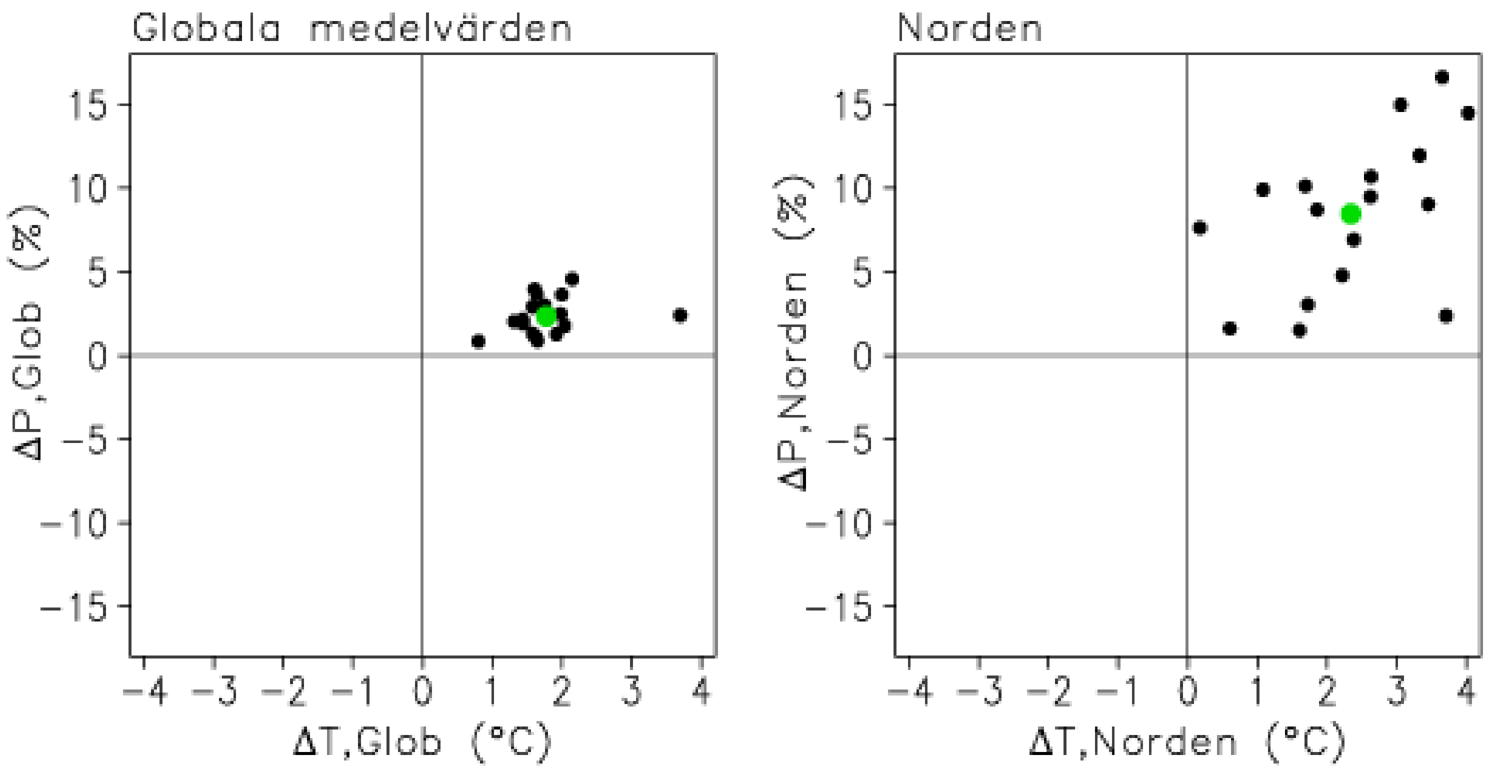
Winter NAO indices (hPa) from observations (black) and from seven model simulations forced with increased carbon dioxide concentrations showing a shift towards positive NAO index that are consistent in sign though not in magnitude. All series have been smoothed by a 30-year low-pass filter. (from Osborn, CLIVAR Exchanges, 3/4 2002).

av_d1_0302

Regional scenarios more uncertain

Global og region changes

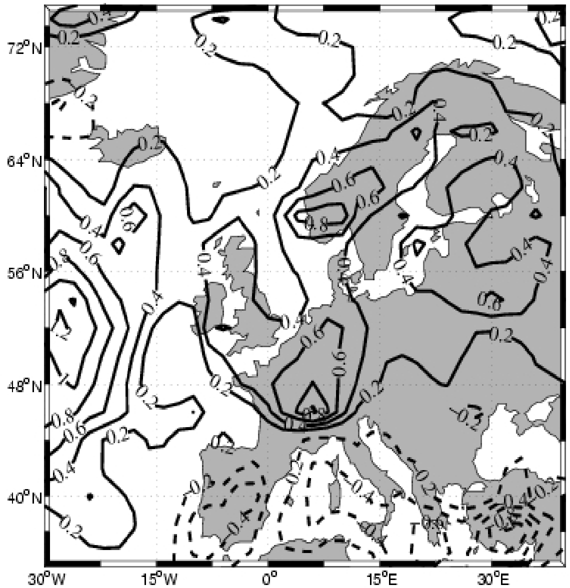
when CO_2 has doubled



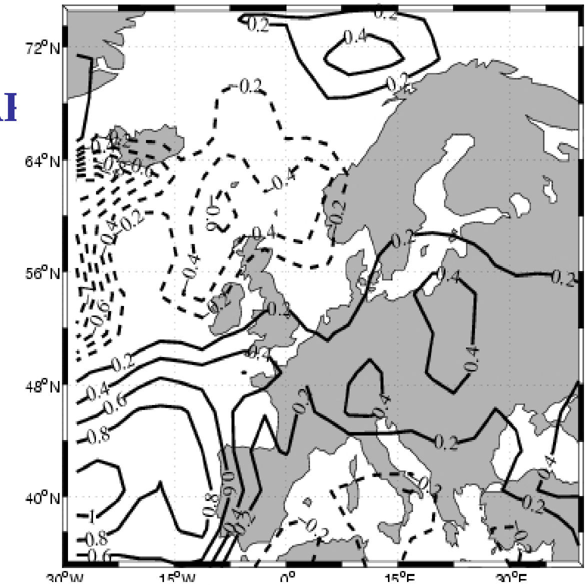
Changes in precipitation after CO_2 doubling

DJF

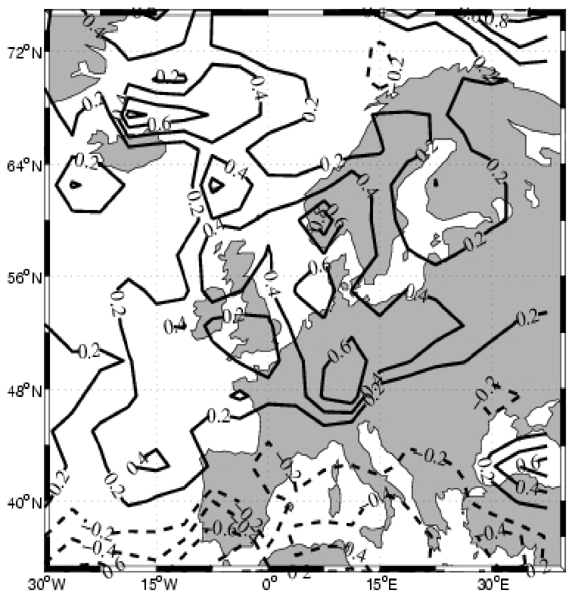
BCM



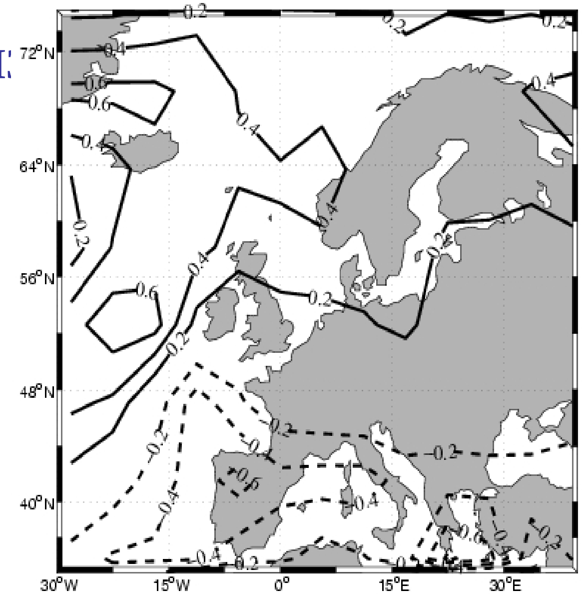
NCAI



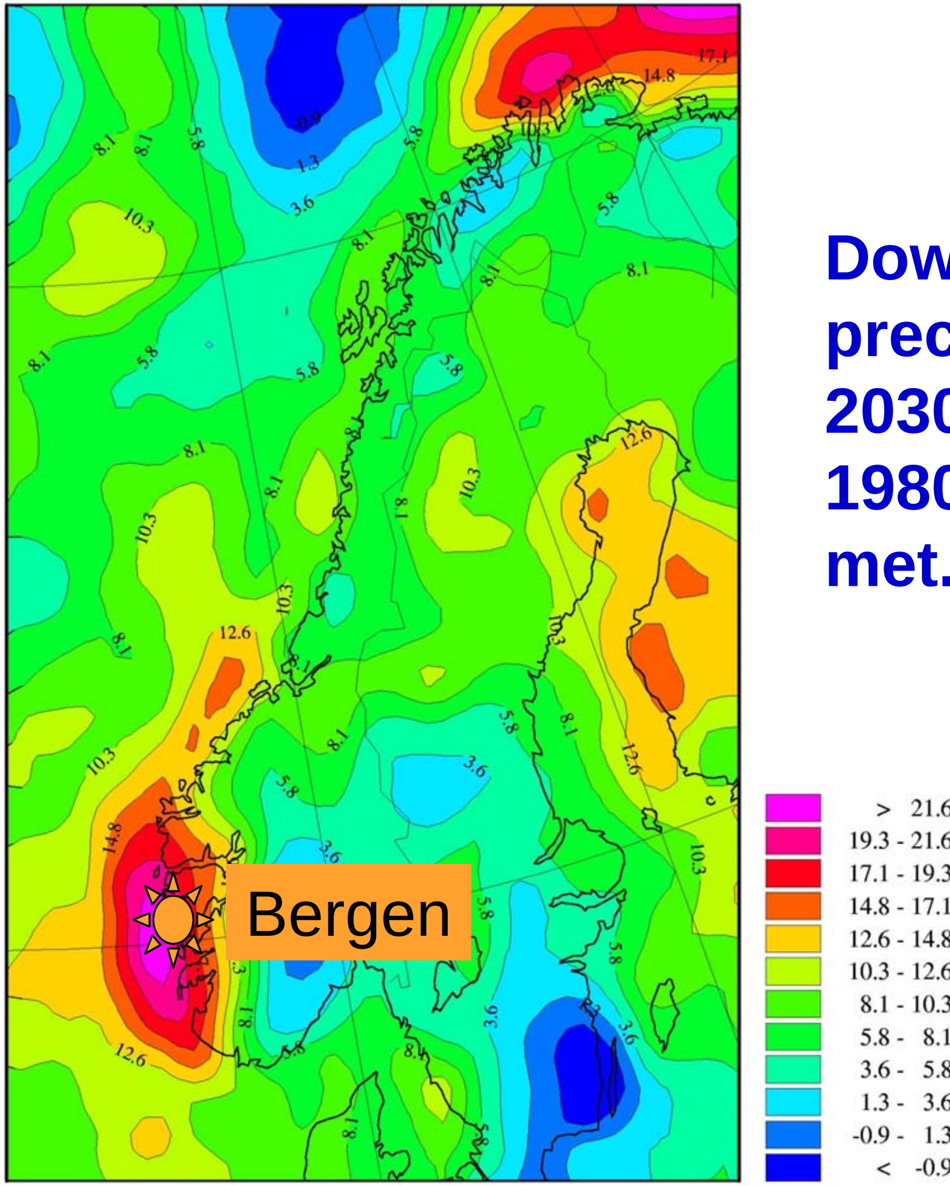
IADCM3



ECHAM:

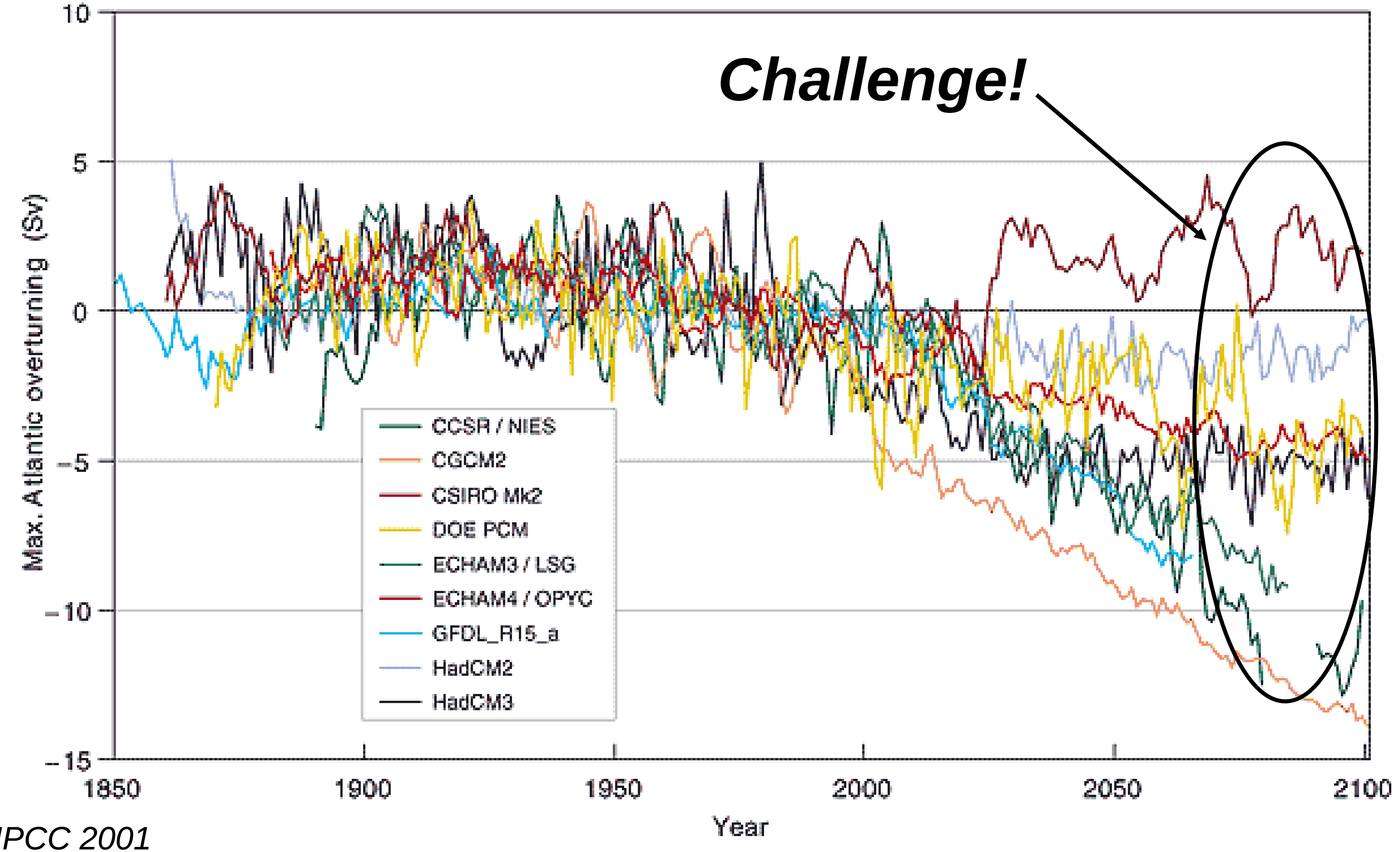


Downscaled winter precipitation change 2030-2050 relative to 1980-2000 (RegClim - met.no)



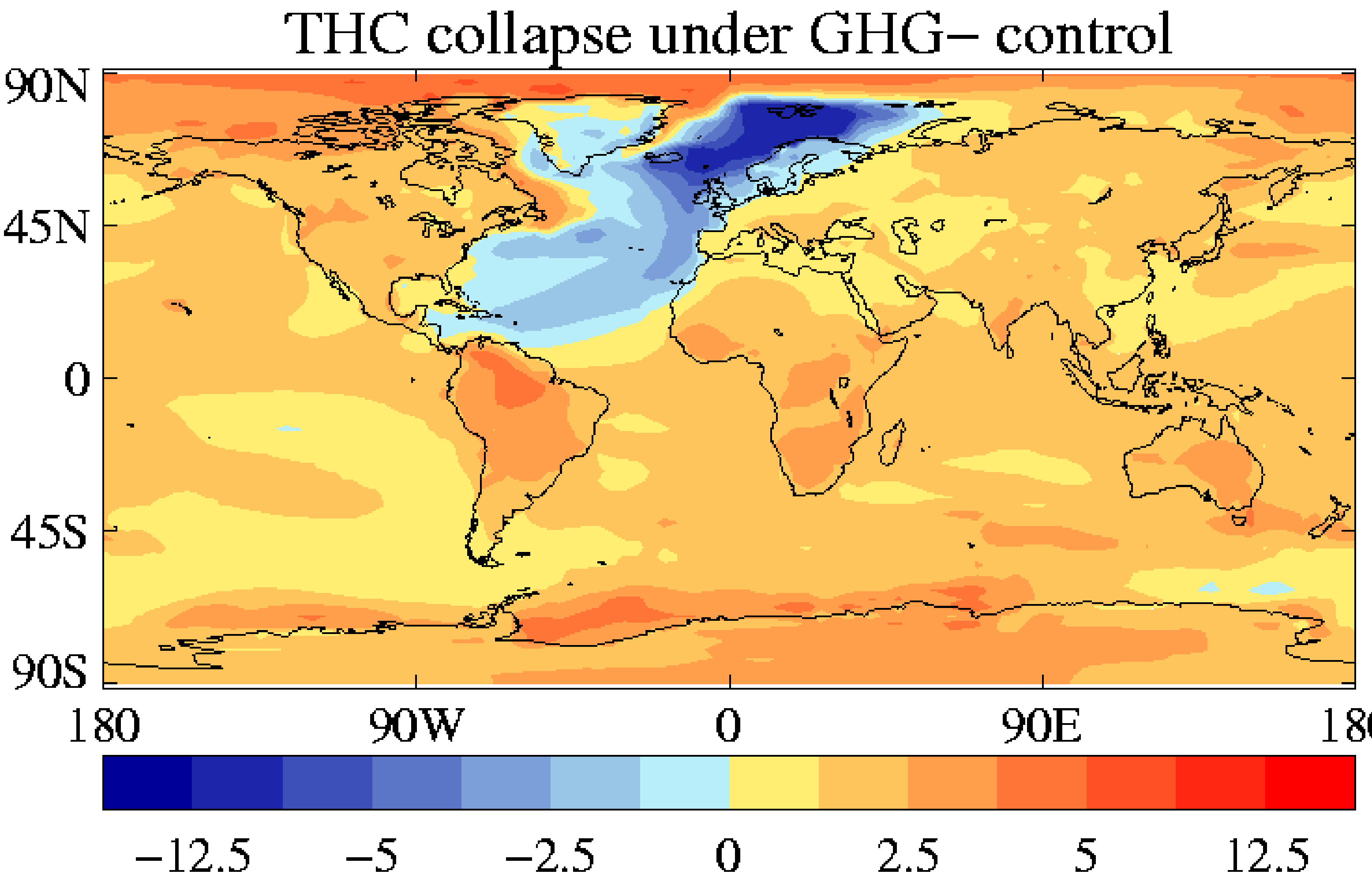
Change in precipitation (%), Jan-Dec.

Simulated changes in Atlantic overturning circulation in the future in different climate models



IPCC 2001

Net effect if the circulation collapses during global warming



From Wood et al. 2003

Hadley Centre

Summary

- man made climate change is a reality
- strongest warming expected in the Arctic
- økt høst- og vinternedbør i nord
- The ocean cirulation is probably stable...
- But: There is strong uncertainty and climate surprises may appear as a consequence of ocean heating and increased fresh water input

- **it is likely that summer sea ice will dissappear toward the end of the century**
- **we cannot say with certainty the fate of the NAO, but if there is a change it is more likely to be towards a positive phase:**
- **This implies wetness in the north and desertification in the south of Europe.**