Climate Change and Global Warming

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ETP 401 Guest Lecture
University of Virginia
April 12, 2005

`The balance of evidence suggests that there is a discernible human influence on global climate '

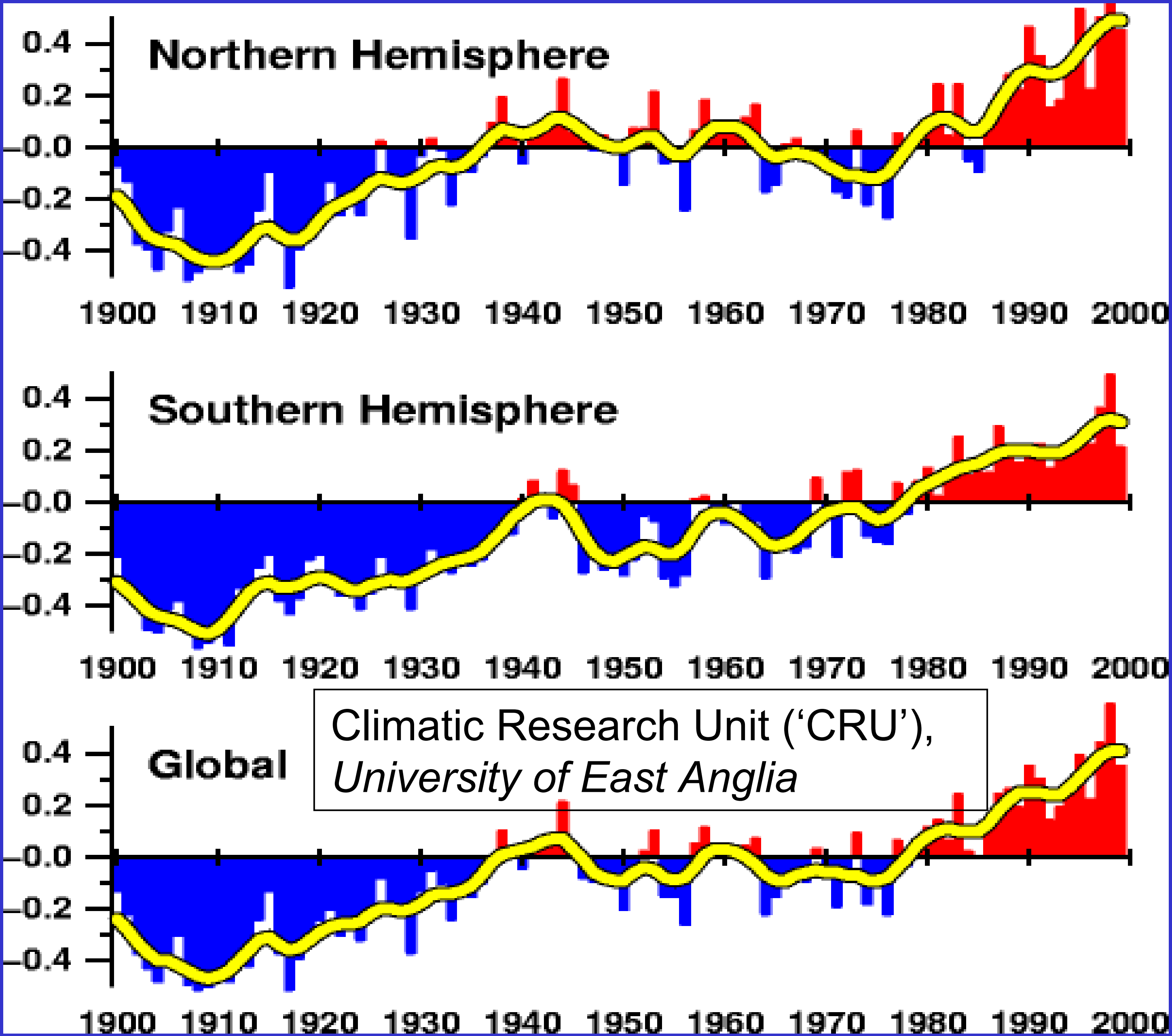
Intergovernmental Panel on Climate Change
(United Nations), Second Assessment Report, 1996

`There is new and stronger evidence that most of the warming observed over the last 50 years is attributable to human activity'

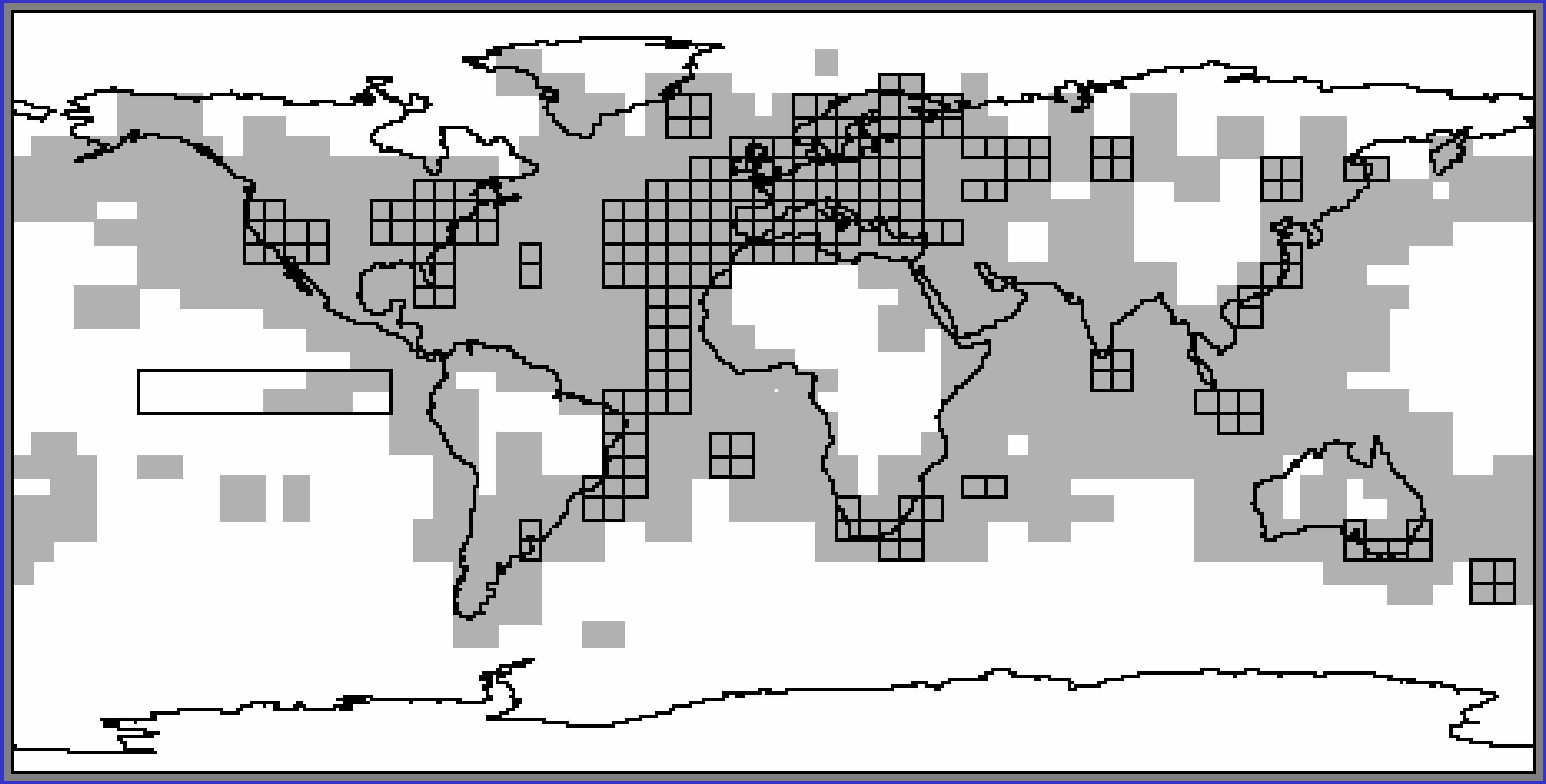
Intergovernmental Panel on Climate Change
(United Nations), Third Assessment Report, 2001

THE EMPIRICAL RECORD

Surface Temperature Changes



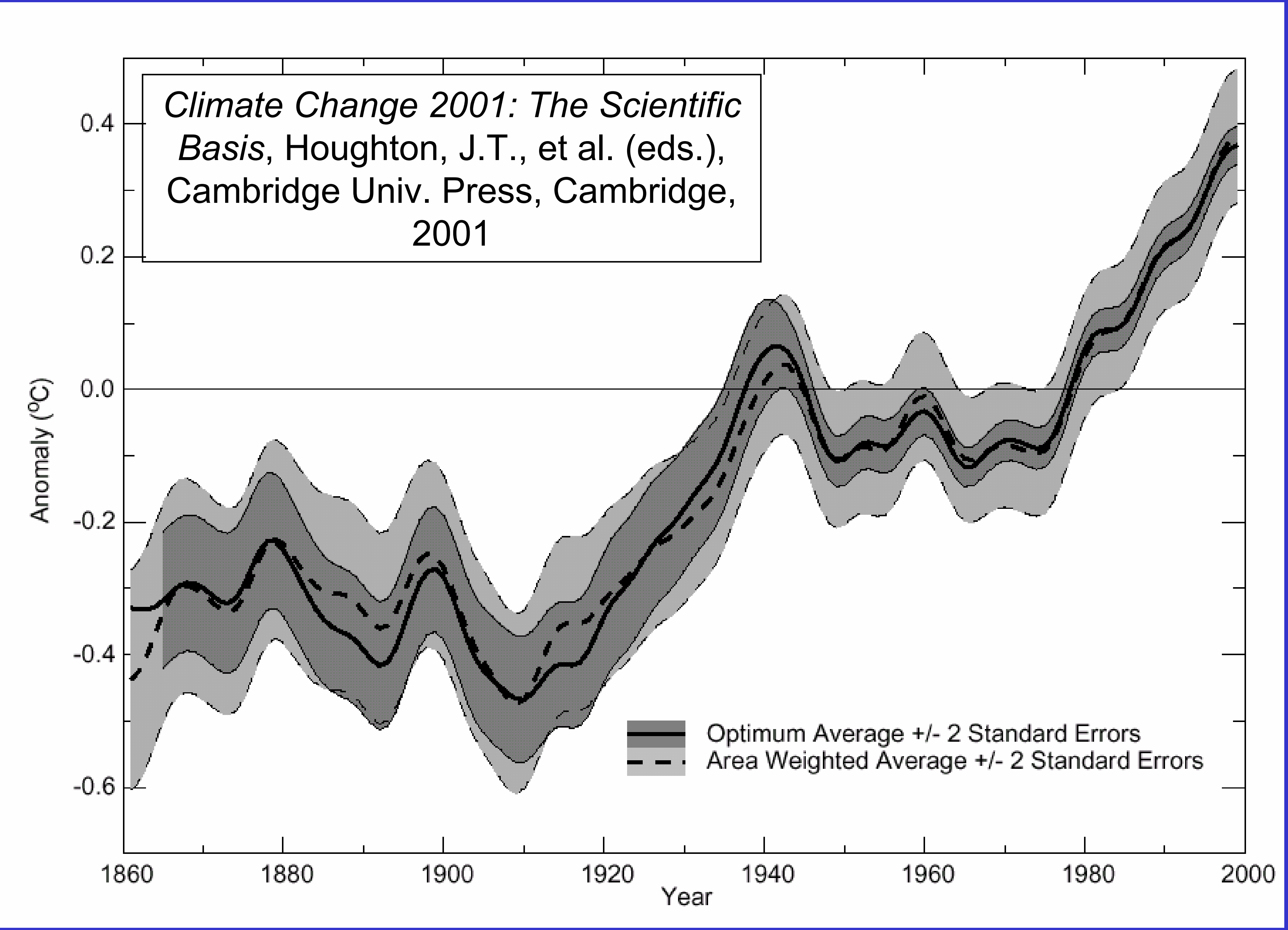
Surface Temperature Changes



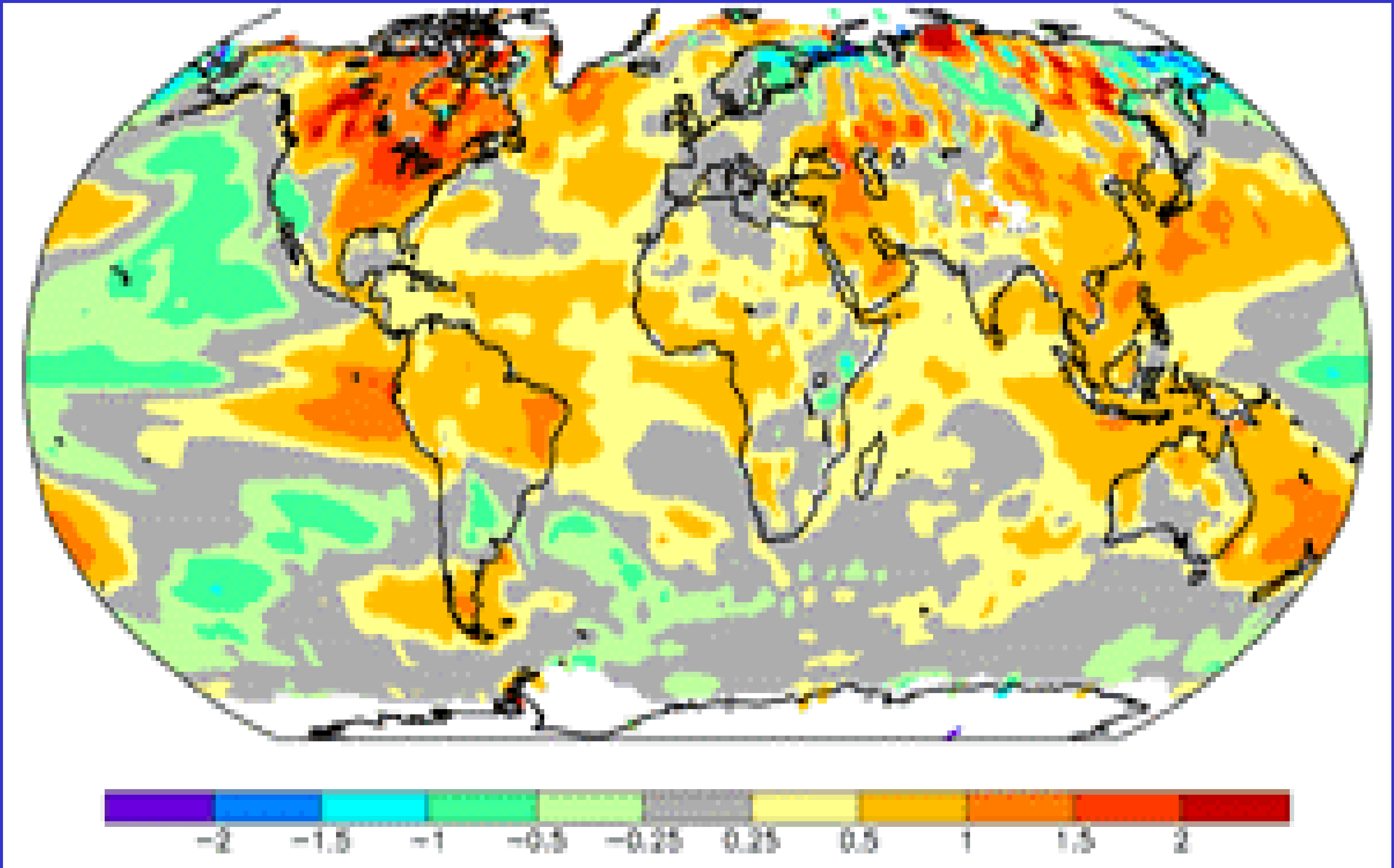
Shaded: 20th century

Boxes: since mid 19th century

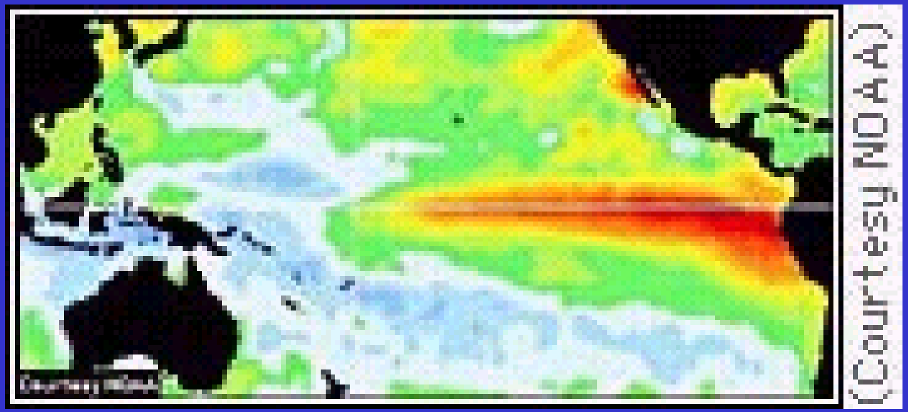
Surface Temperature Changes



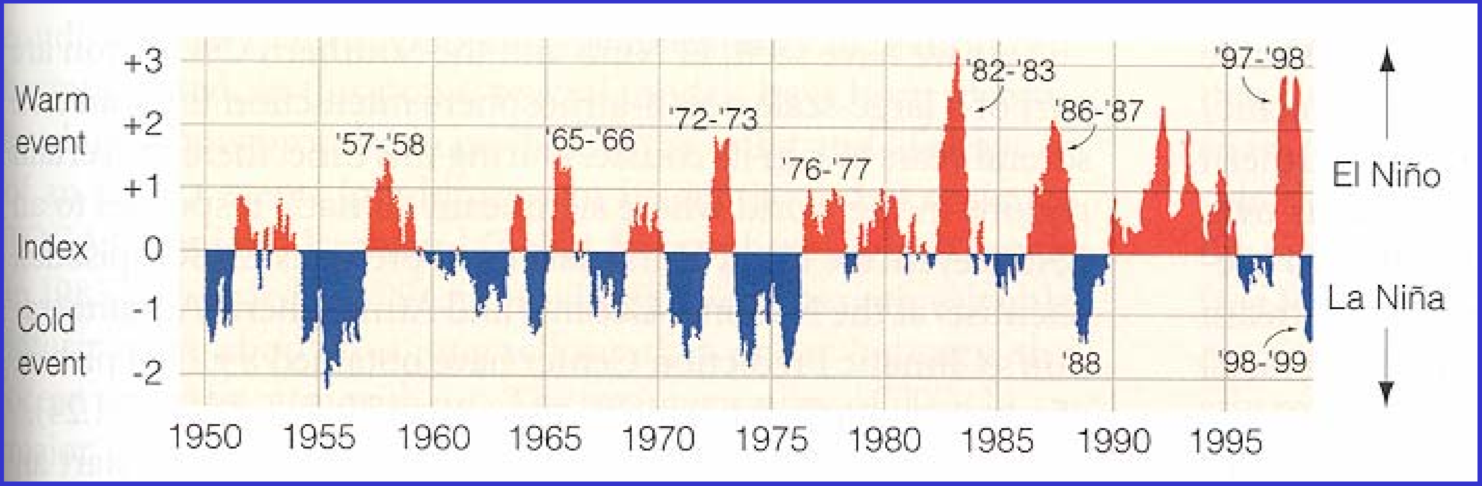
1998 Global Temperature Pattern



EL NINO/SOUTHERN OSCILLATION ("ENSO")

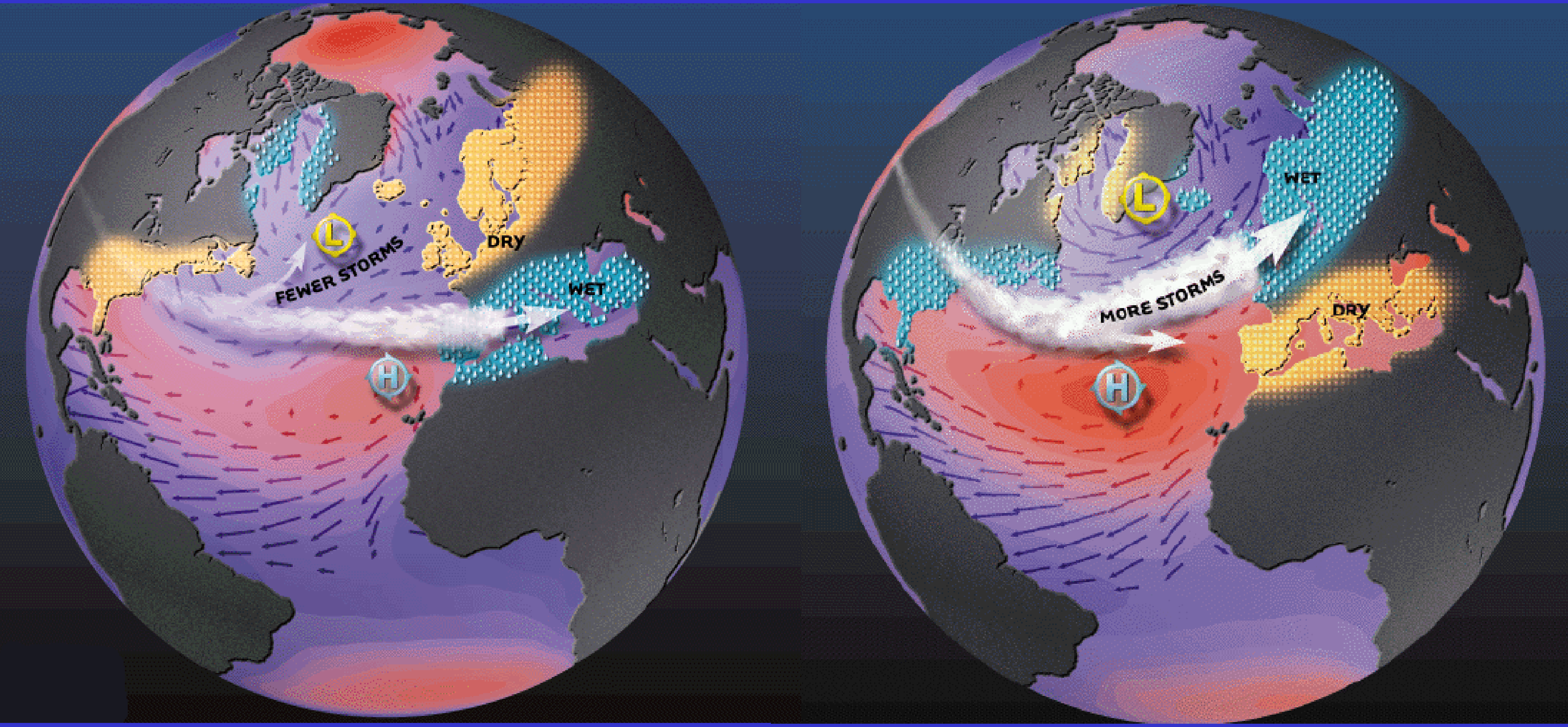


Substantial *interannual* climate variability associated with ENSO, but *decadal* variability is also evident as well. The recent decadal trend towards El Nino conditions *could* be natural or anthropogenic.



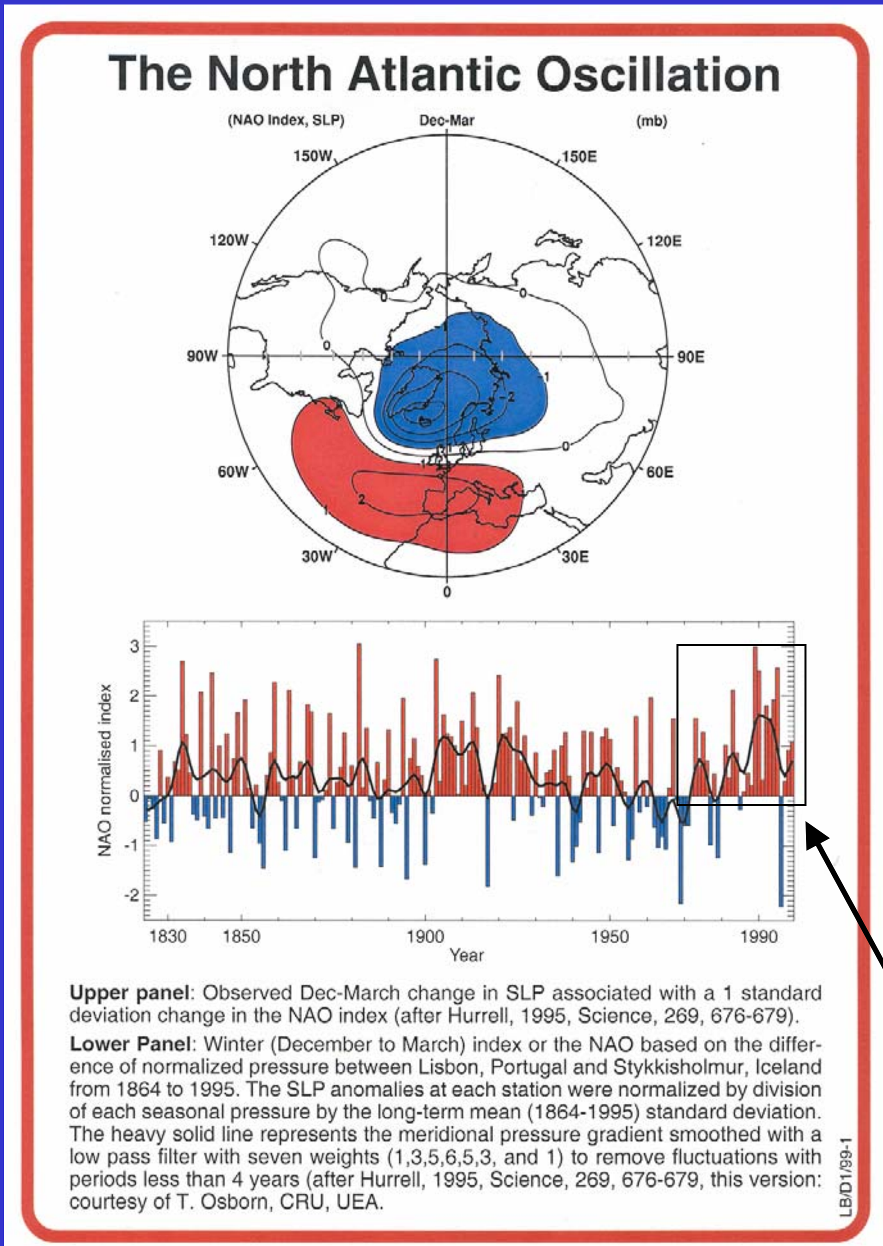
Multivariate ENSO Index ("MEI")

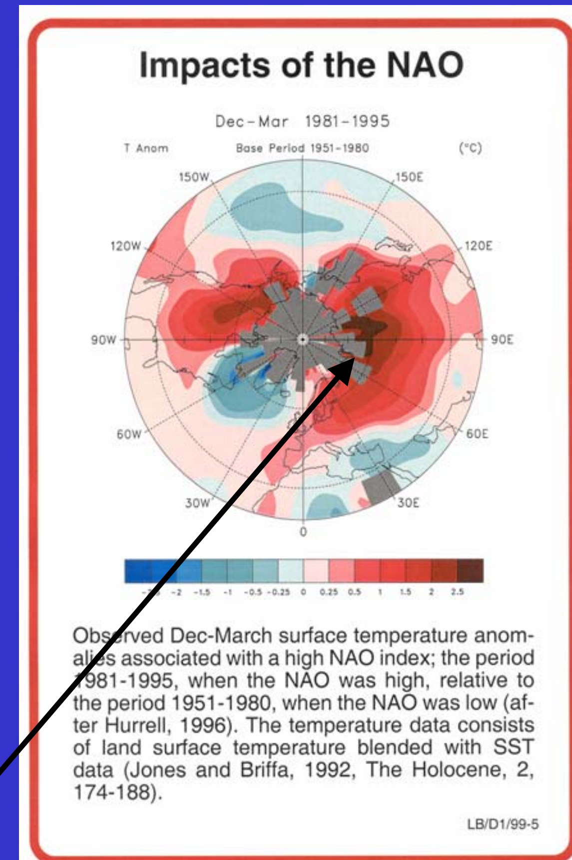
NORTH ATLANTIC OSCILLATION



Negative Phase **_Positive Phase_**

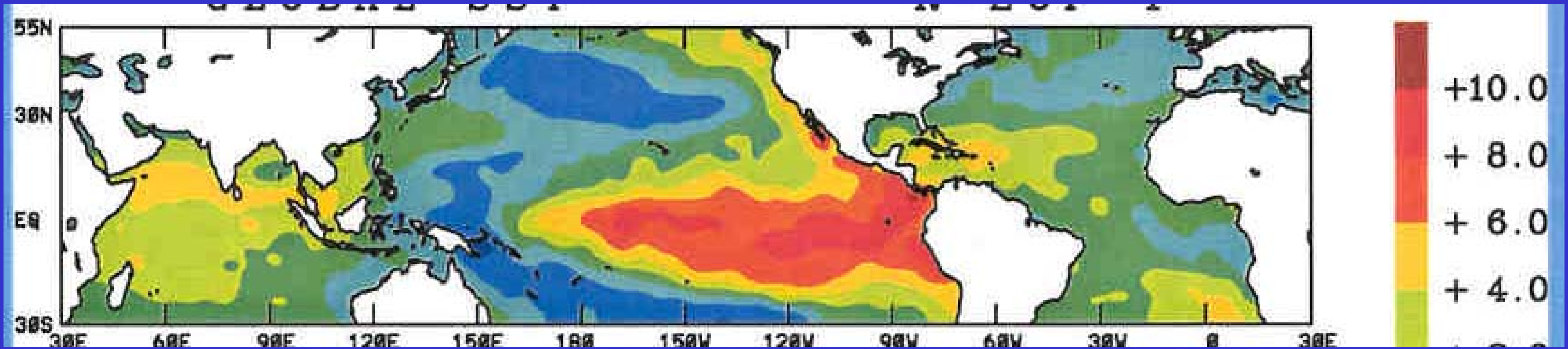
NORTH ATLANTIC OSCILLATION

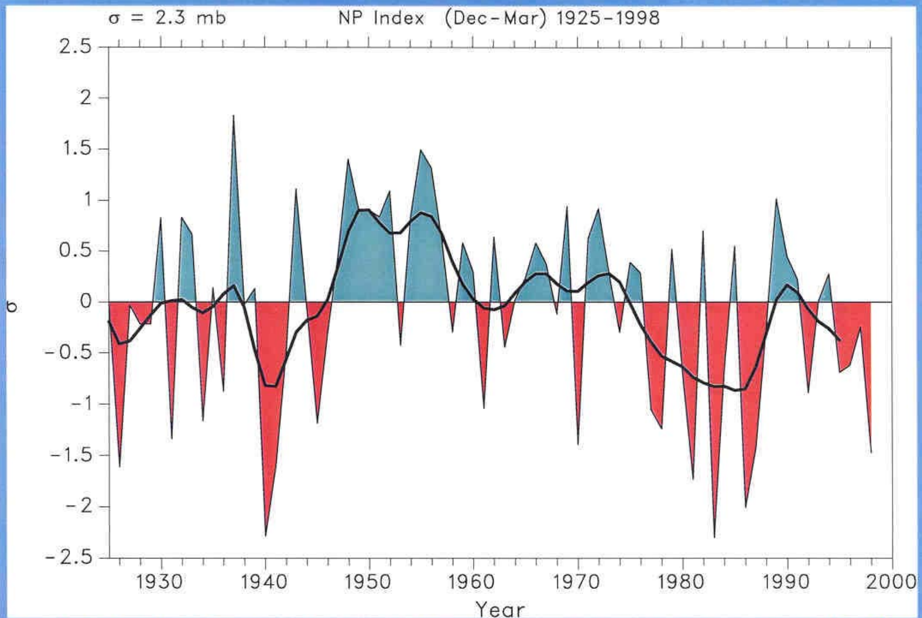




This NAO trend could be **Anthropogenic**

"PACIFIC DECADAL OSCILLATION"

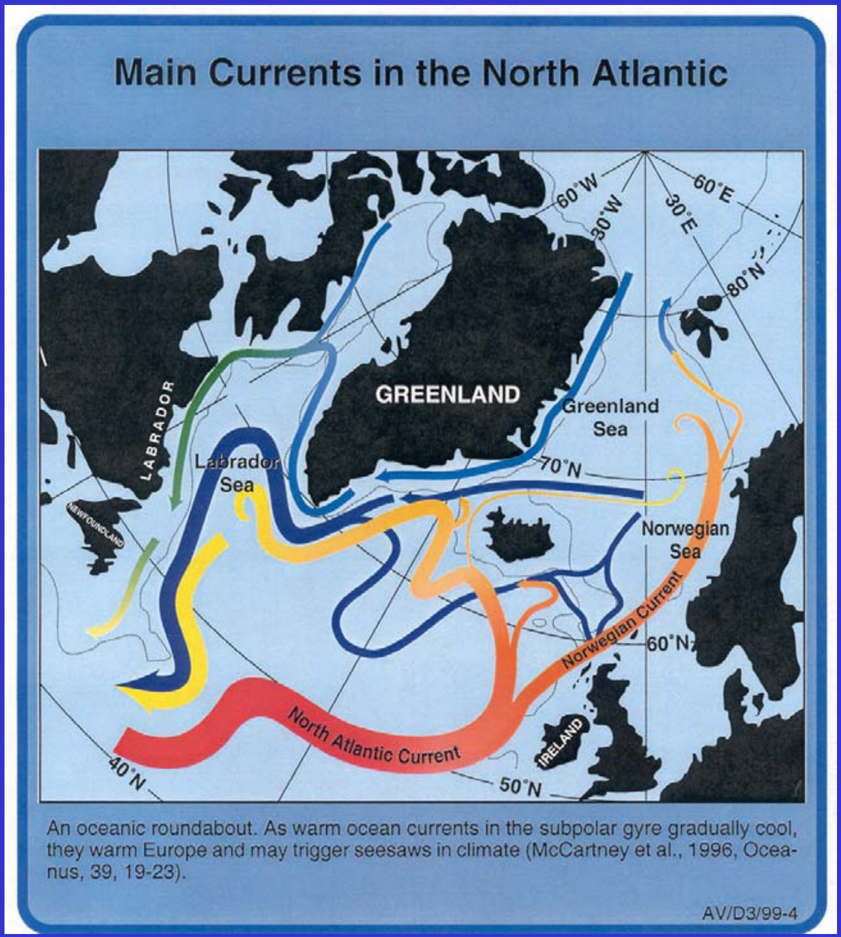


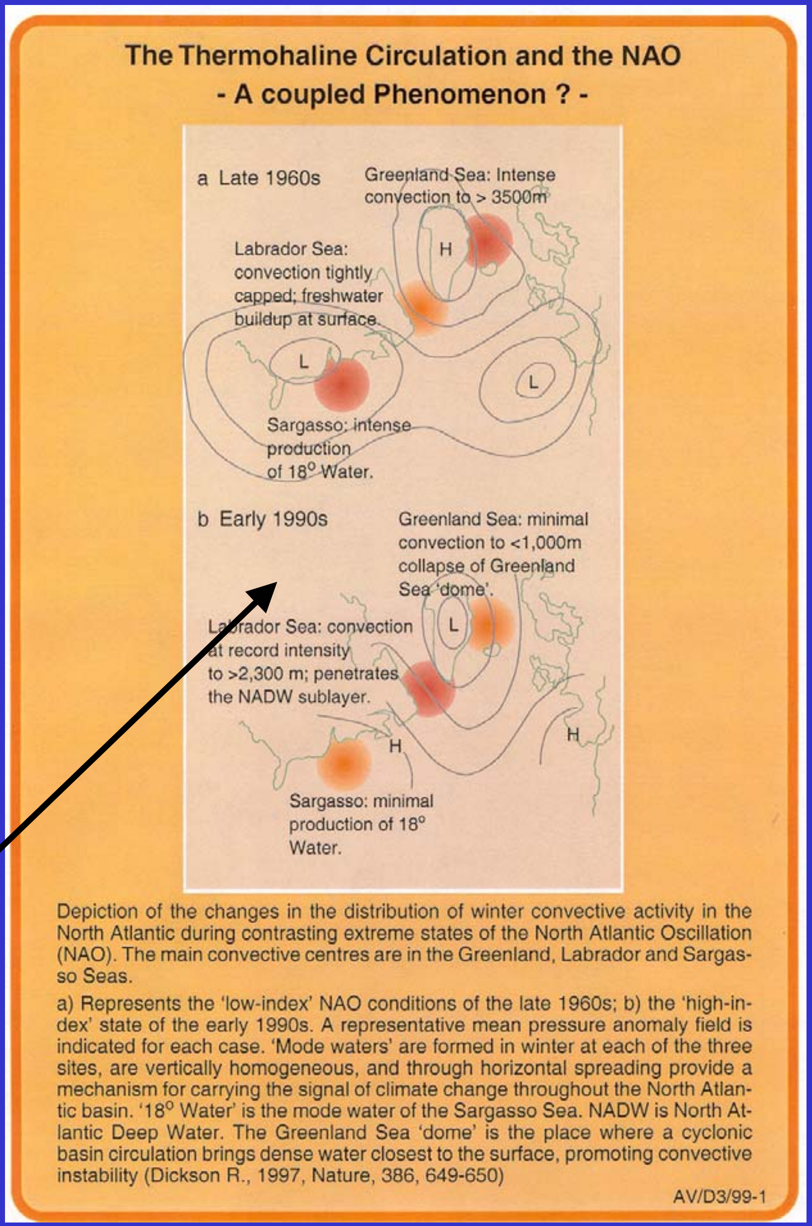


The North Pacific (NP) Index is the area-weighted sea level pressure over the region 30°N-65°N, 160°E-140°W and shows a high level of decadal time scale variability (after Trenberth and Hurrell, 1994, Climate Dynamics, 9, 303-319).

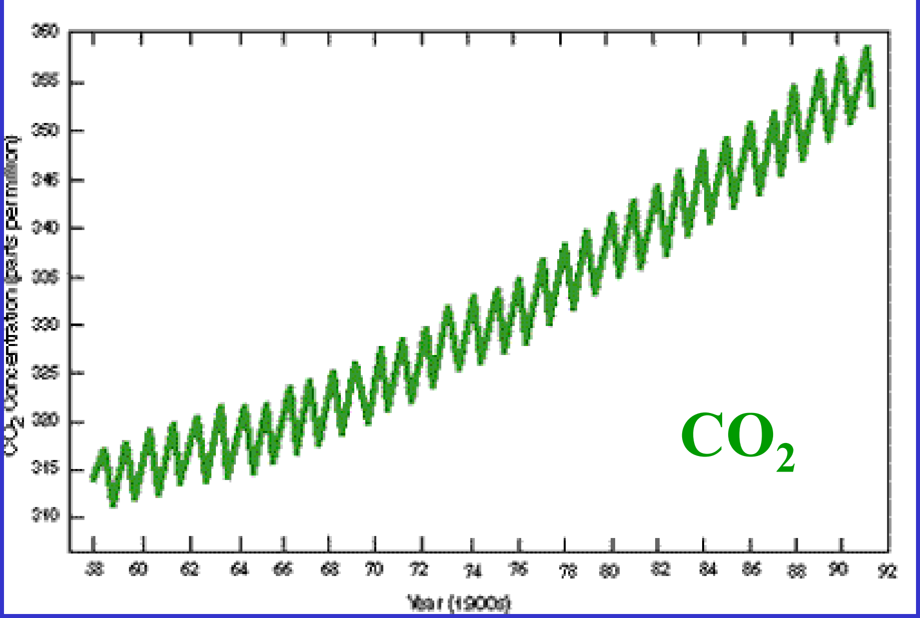
AV/D4/99-5

Atlantic Multidecadal Oscillation

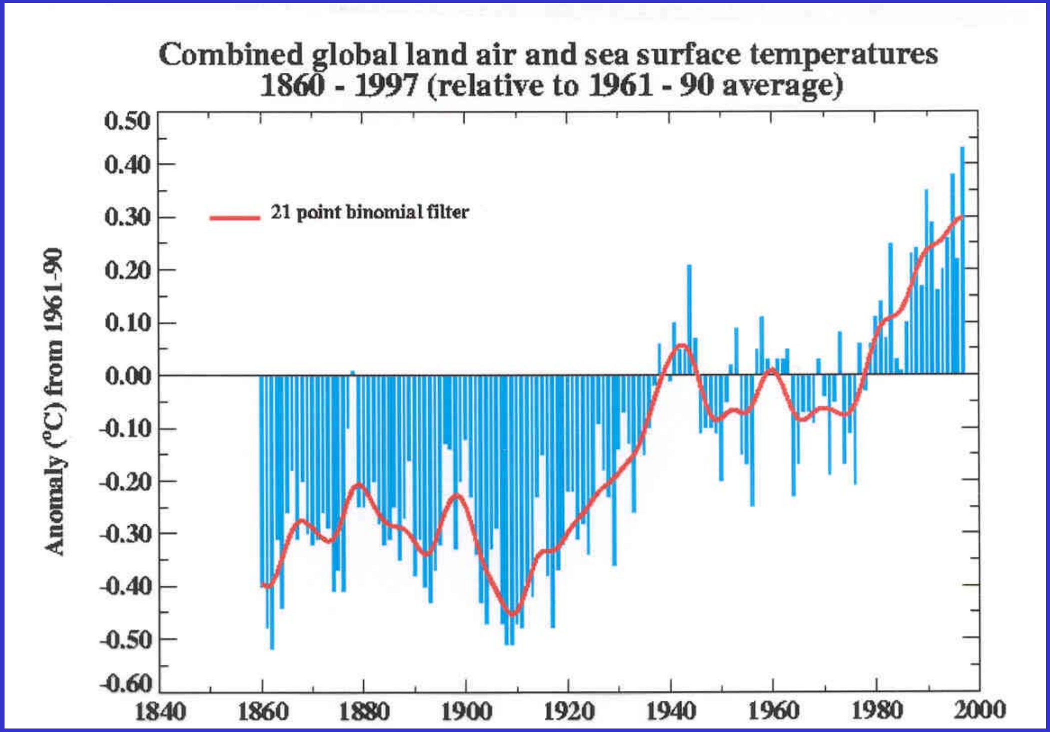




There is evidence of multidecadal natural variability in the North Atlantic ocean circulation

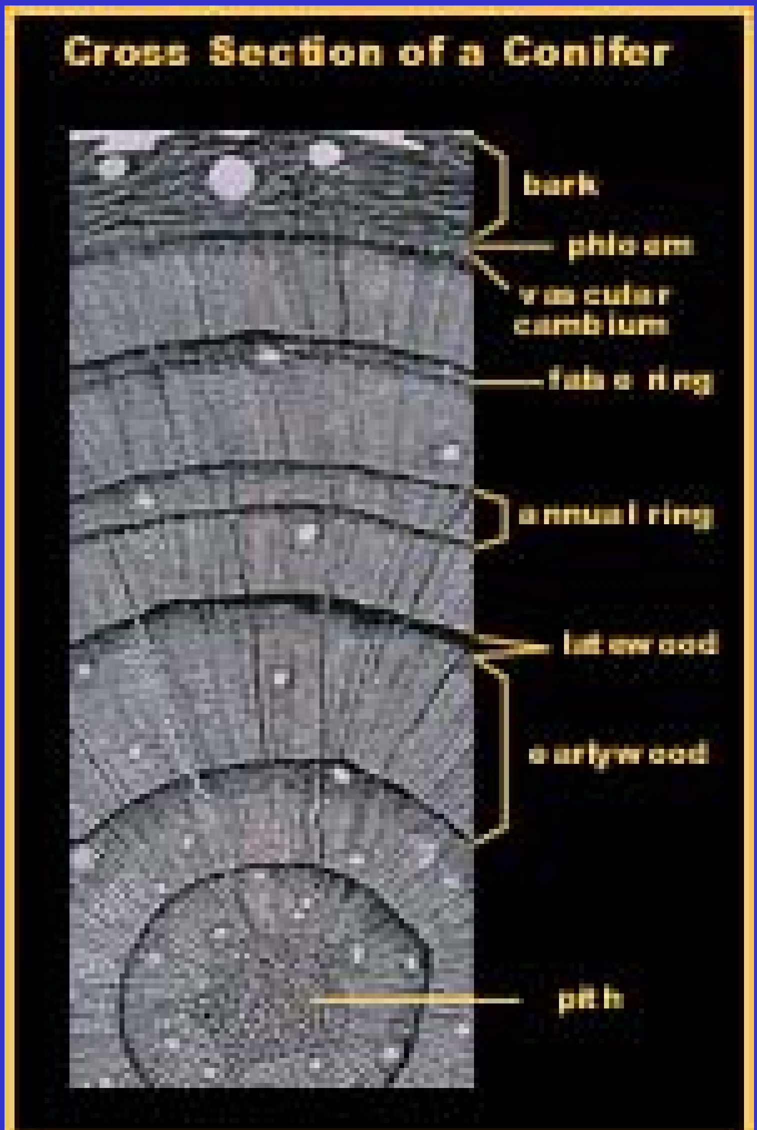


Greenhouse Gases and Warming



Related?

TREE RINGS



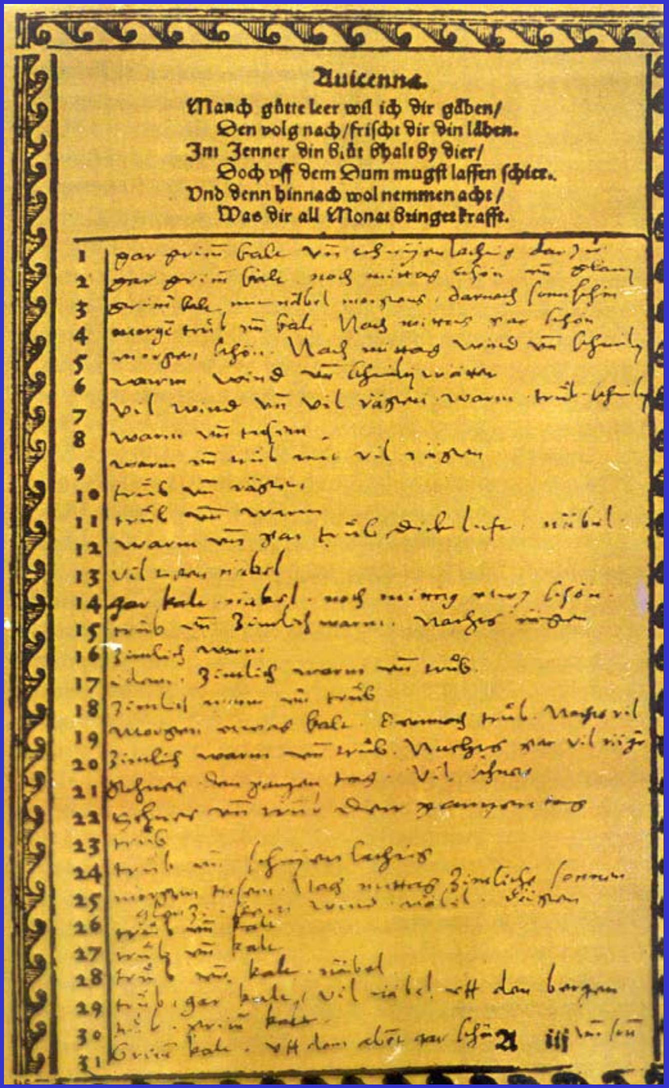
Cross Section of a Conifer
bark
phloem
vascular
cambium
false ring
annual ring
latewood
earlywood
pith

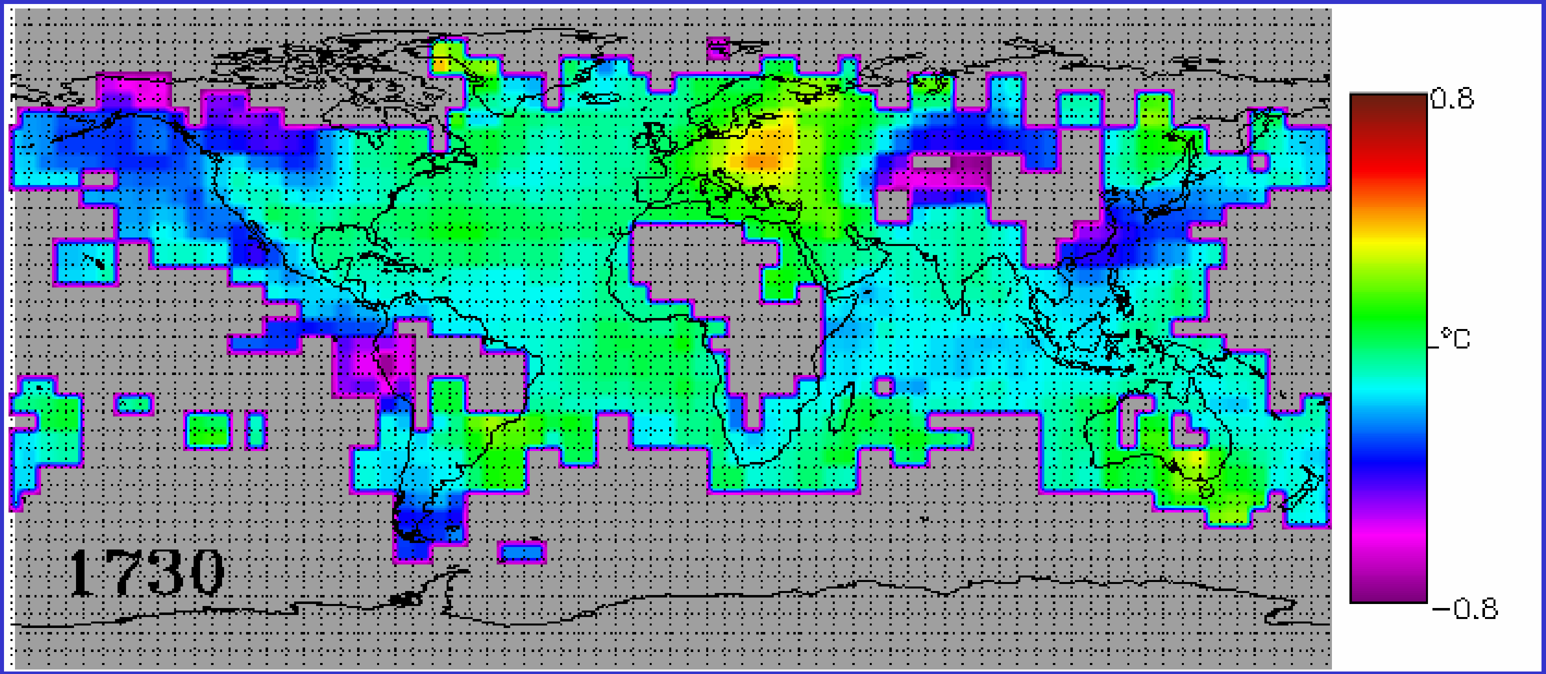
CORALS

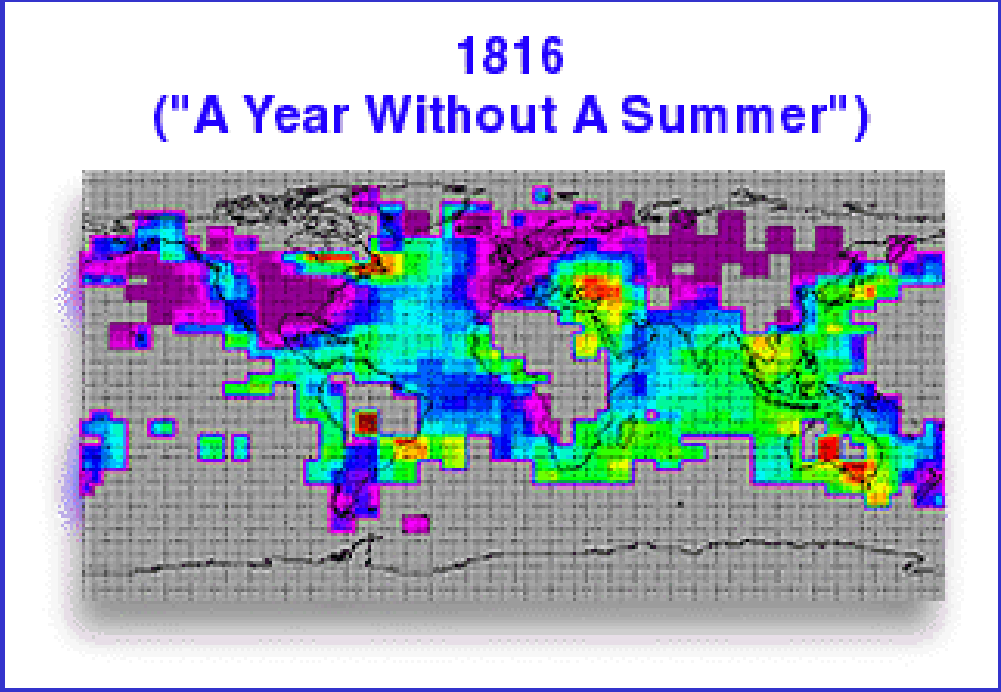
ICE CORES

VARVED LAKE SEDIMENTS

HISTORICAL DOCUMENTS

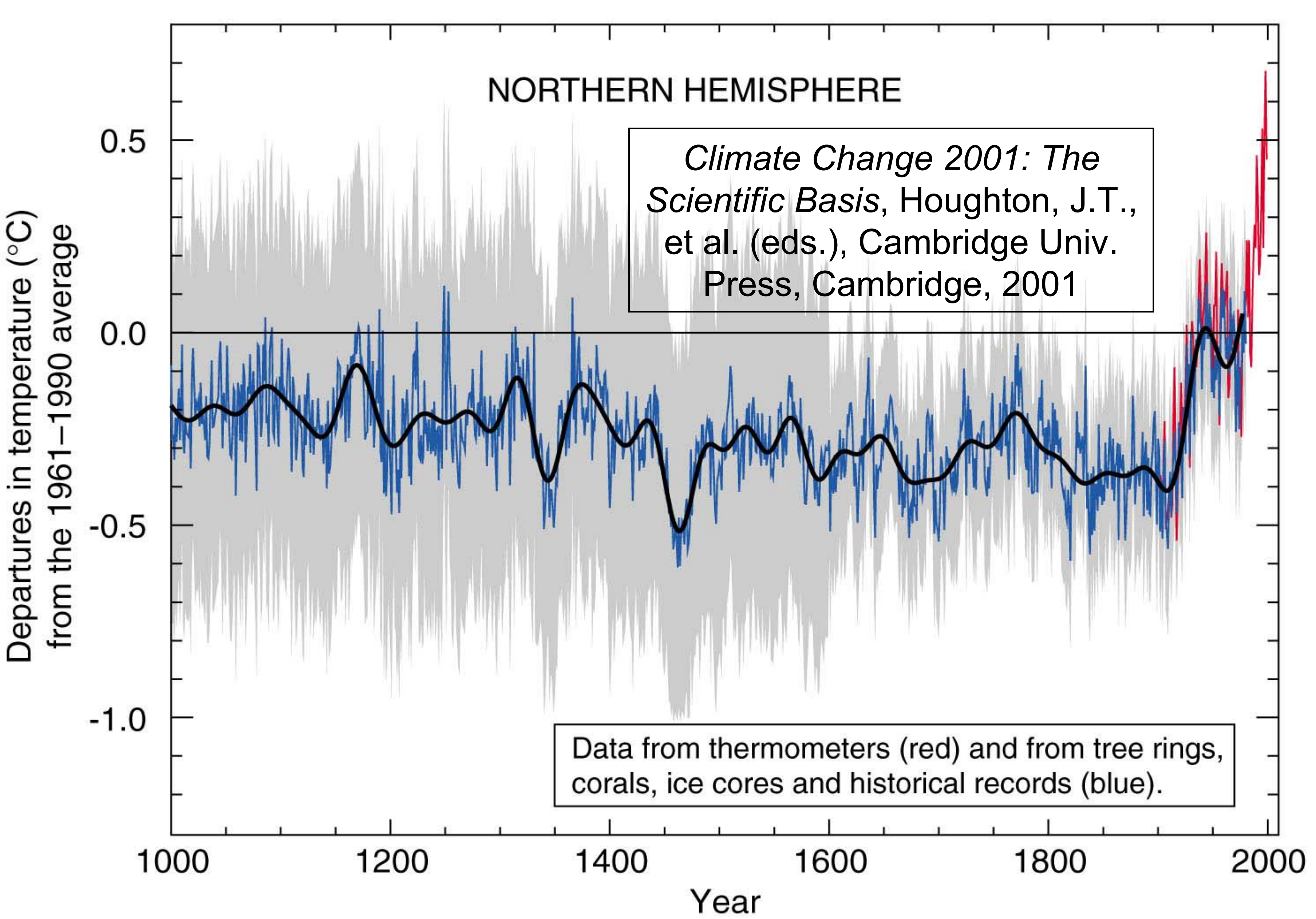


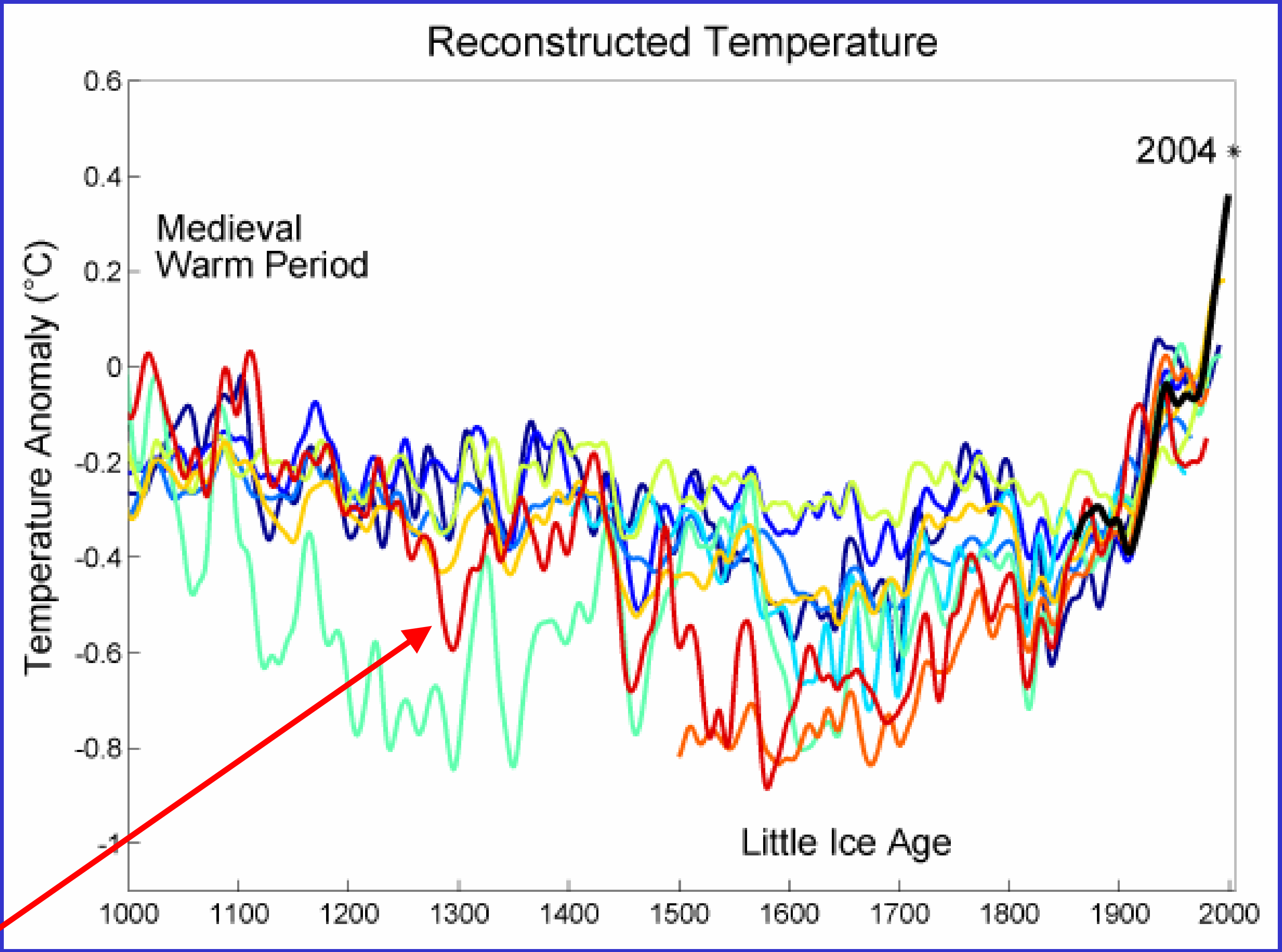




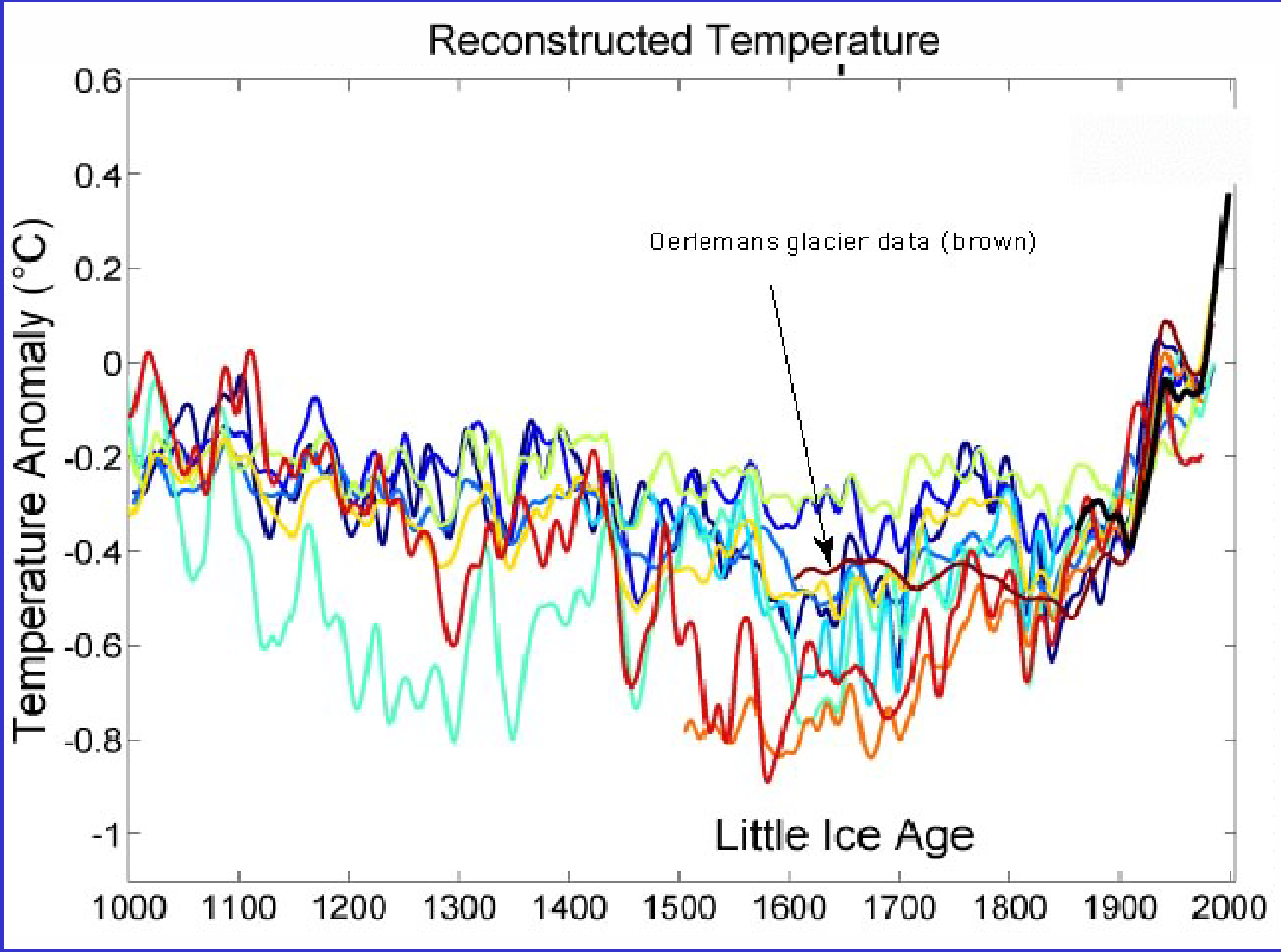
RECONSTRUCTED GLOBAL TEMPERATURE PATTERNS

Reconstructed Surface Temperatures





Moberg, A., Sonechkin, D.M., Holmgren, K., Datsenko, N.M., Karlen, W., Highly variable Northern Hemisphere temperatures reconstructed from low- and high-resolution proxy data, *Nature*, 433, 613-617 (2005).

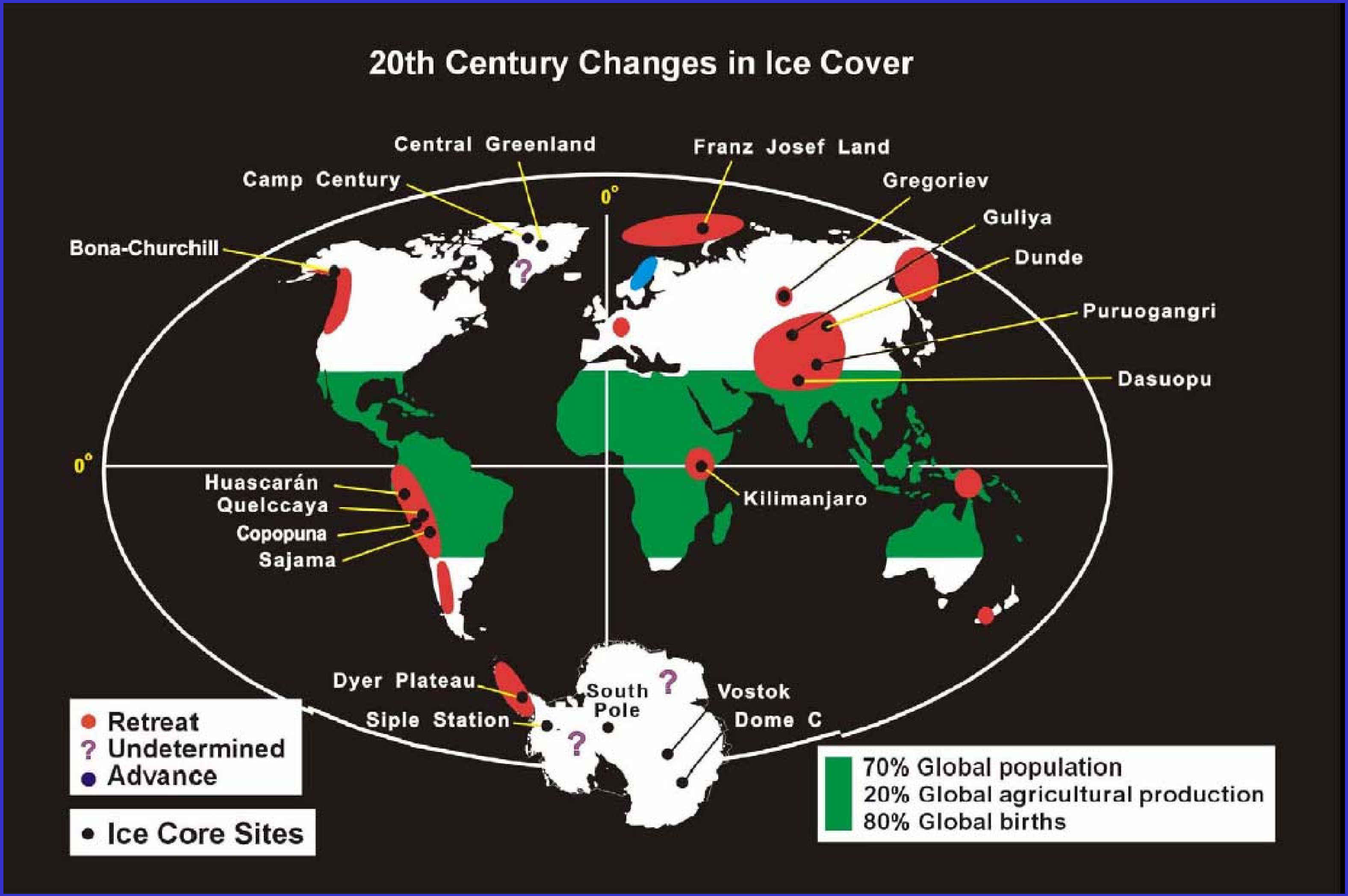


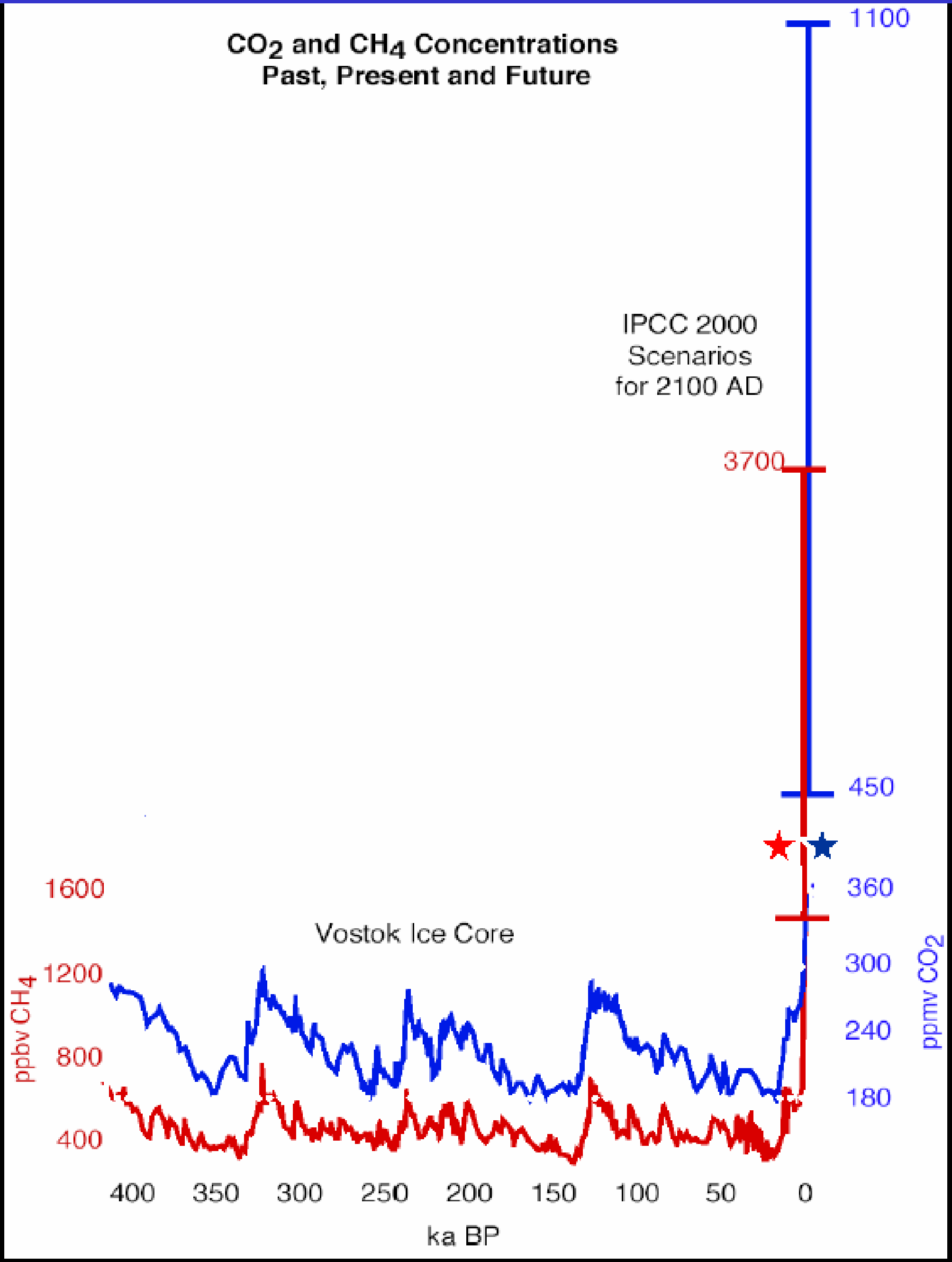
Oerlemans, J., Extracting a climate signal from 169 Glacier Records, *Science (express)*, March 3 (2005).

The Fates of Low-Latitude Glaciers

Lonnie G. Thompson
The Ohio State University

Ice Core Paleoclimate Research Group

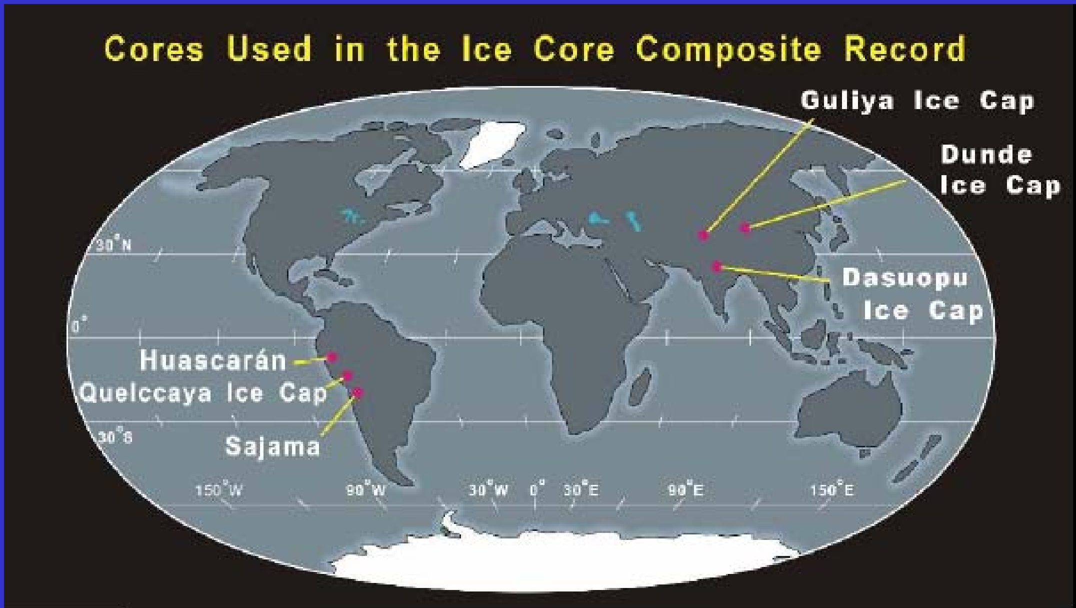


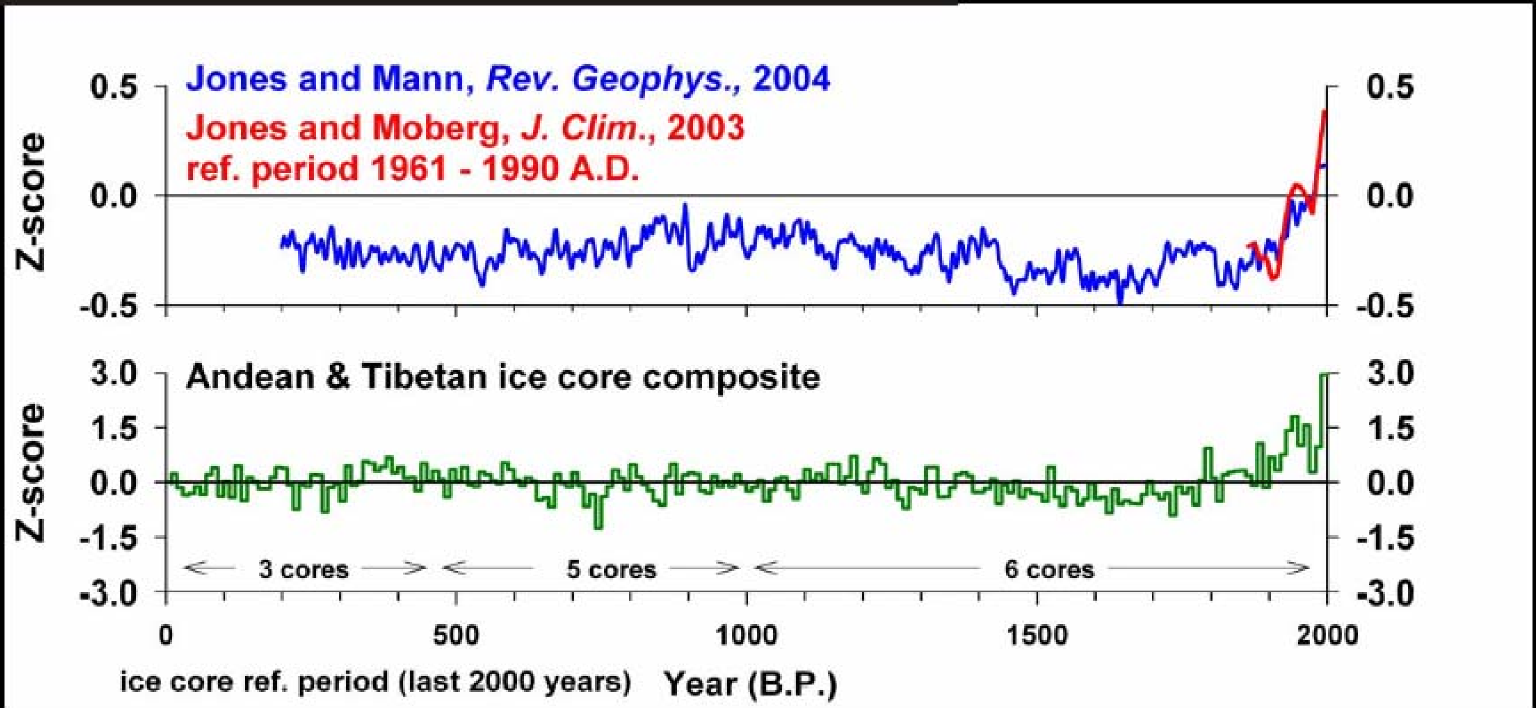


In 2100:
CO_2 ~ 1100 ppmv

2100:
CH_4 ~ 3750 ppbv

Houghton et al., 2001





Ice core data for last 1000 years (Thompson *et al.*, *Climatic Change*, 2003)

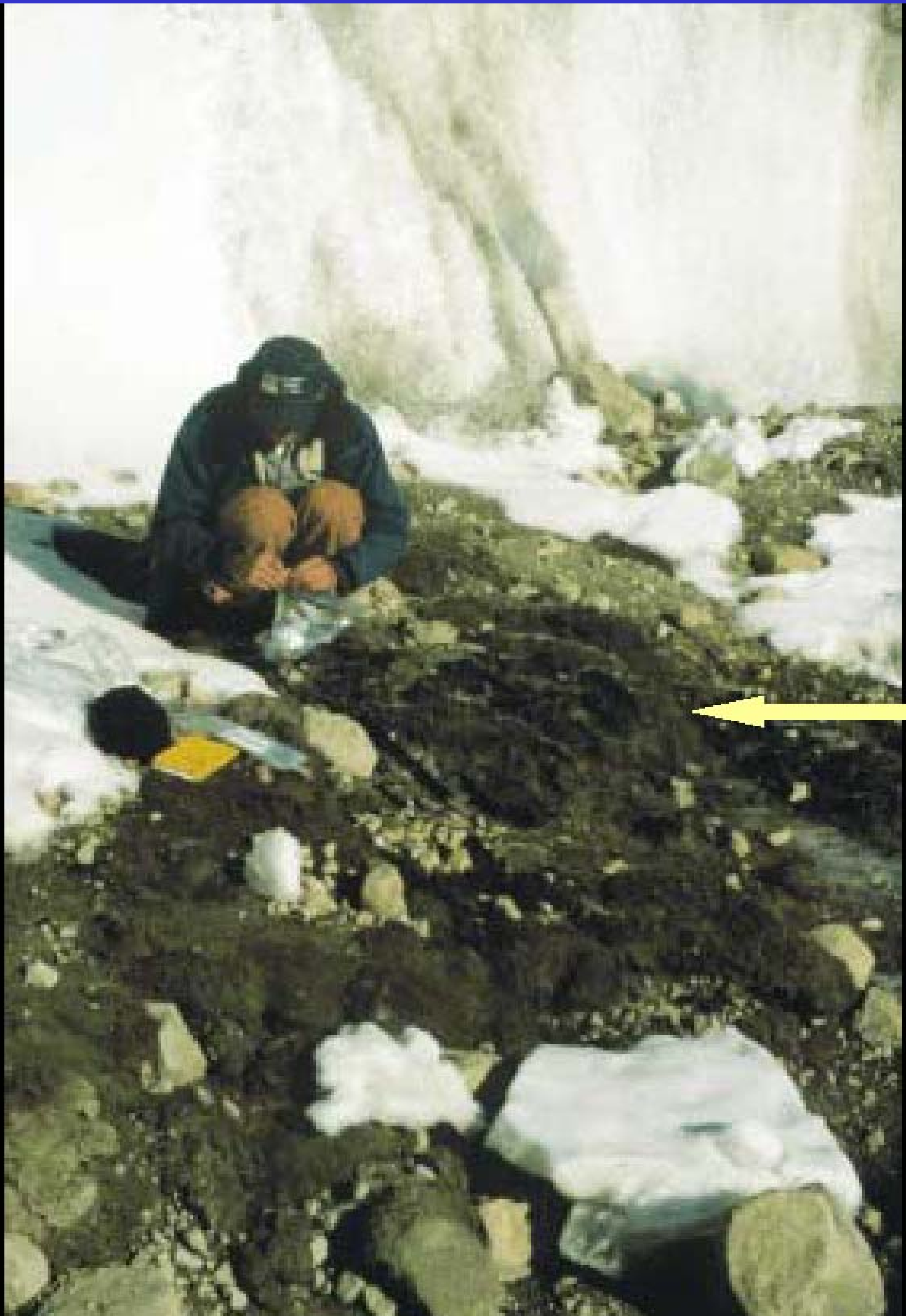
Quelccaya Ice Cap, Peru

1977

2002

Quelccaya
Ice Cap, 2002

200 – 400 m
above its
modern range



Plant

Quelccaya Ice Cap, 2002

200 – 400 m above its modern range

Radiocarbon dates of plants from base of Quelccaya Ice Cap

	^{14}C age	Error (+/-)	Calibrated age (Before 1950 A.D.)	Relative area under probability distribution
Lawrence Livermore National Laboratory				
Sample 1 First run	4470	60	5284-5161 (1σ) 5302-4961 (2σ)	.534 .926
Sample 1 Second run	4525	40	5186-5121 (1σ) 5311-5047 (2σ)	.413 1.000
Sample 2 First run	4530	45	5186-5120 (1σ) 5317-5040 (2σ)	.396 .993
Sample 2 Second run	4465	40	5278-5171 (1σ) 5295-4967 (2σ)	.580 .984
National Ocean Sciences AMS Facility at Woods Hole Oceanographic Institution				
Sample 1	4530	45	5186-5120 (1σ) 5317-5040 (2σ)	.396 .993
Sample 2	4510	40	5188-5119 (1σ) 5307-5040 (2σ)	.404 .988

Glacier National Park, Grinnel Glacier

Photo: Fred Kiser, Glacier National Park archives

Photo: Karen Holzer, US Geological Survey

Glacier National Park, Boulder Glacier

Photo: George Grant, Glacier National Park archives

Photo: Jerry DeSanto, National Park Service

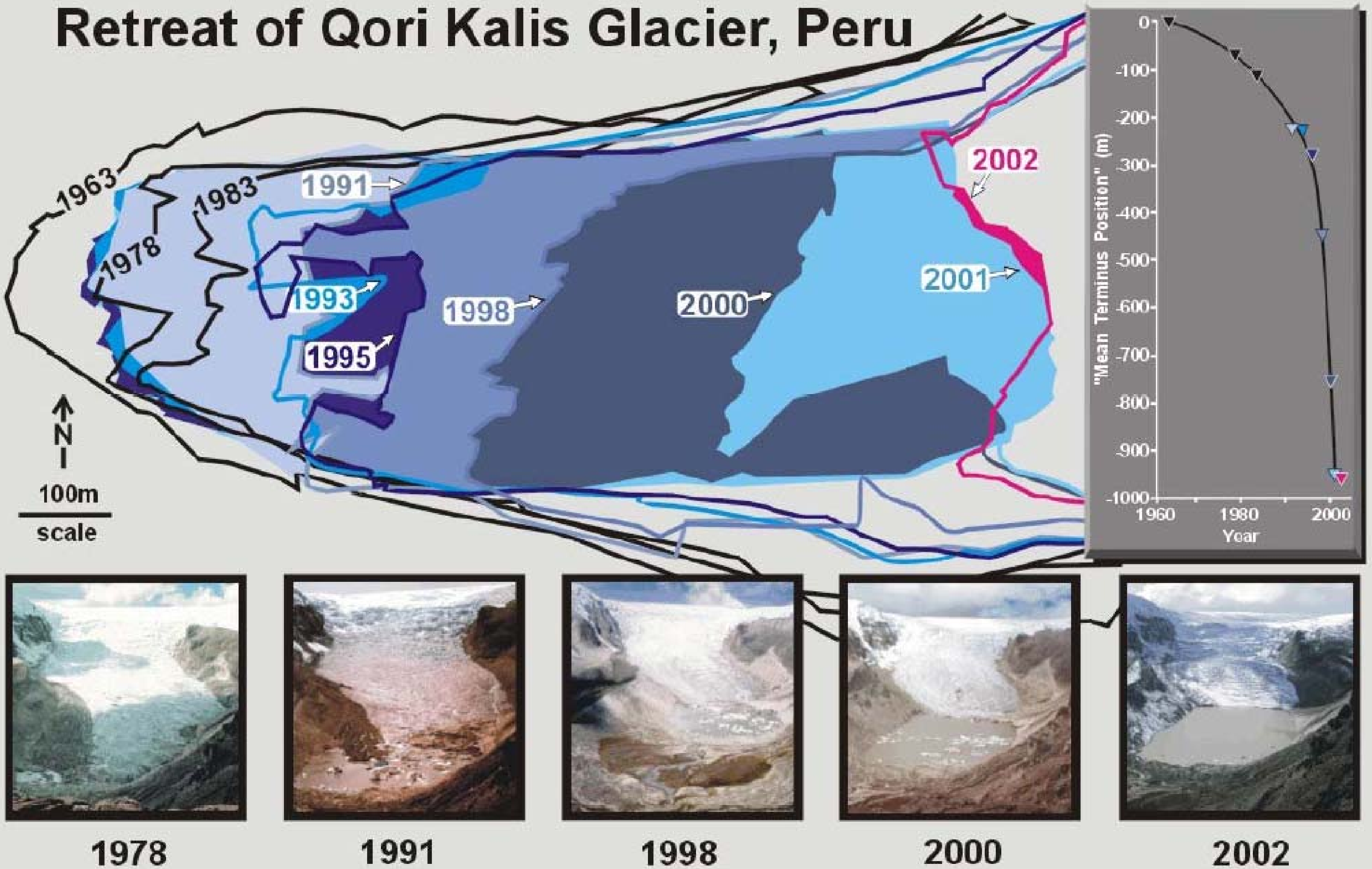
Source: *BioScience*, Vol. 53 No. 2, Feb 2003

McCall Glacier, Brooks Range, Alaska

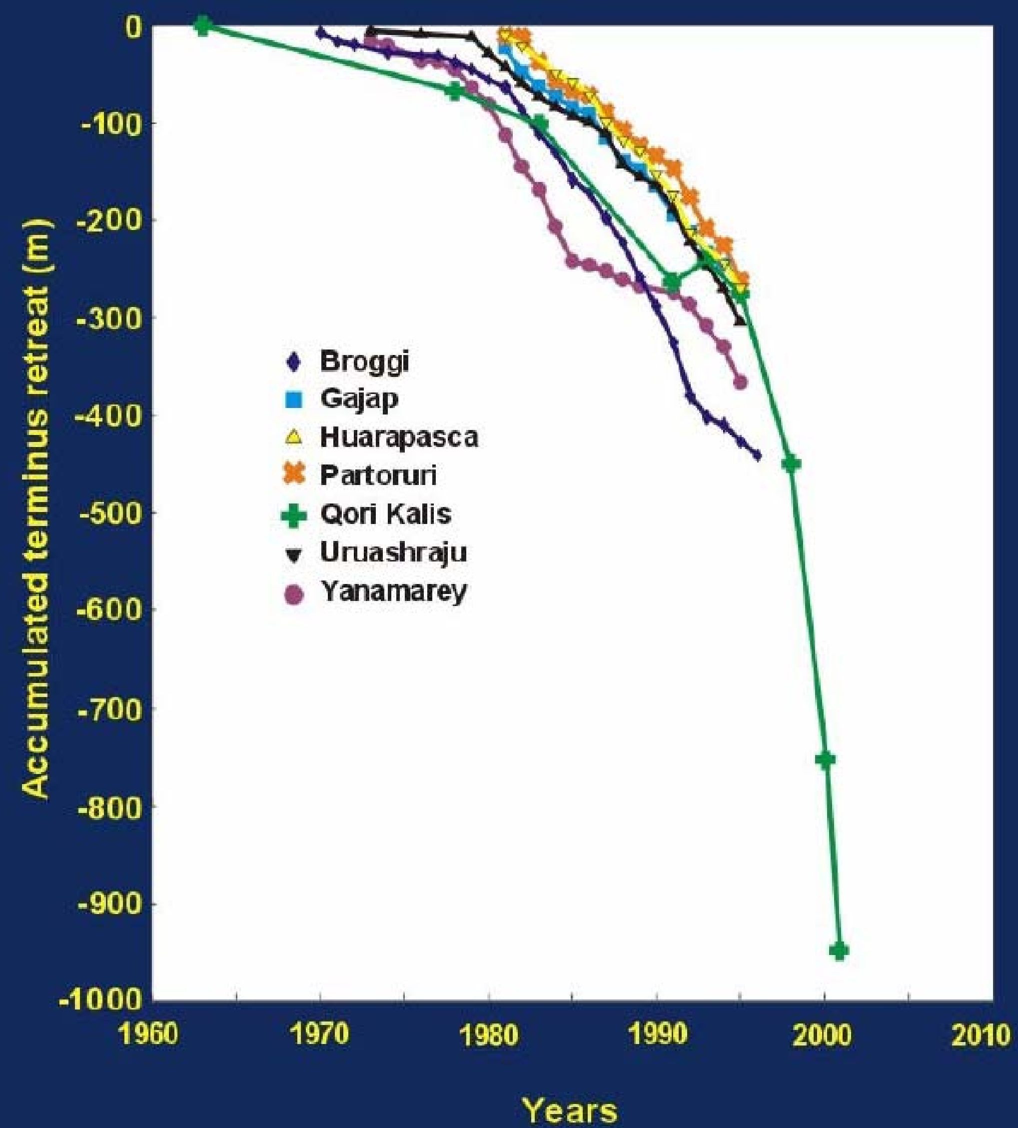
Austin Post,1958

Matt Nolan, 2003

Retreat of Qori Kalis Glacier, Peru

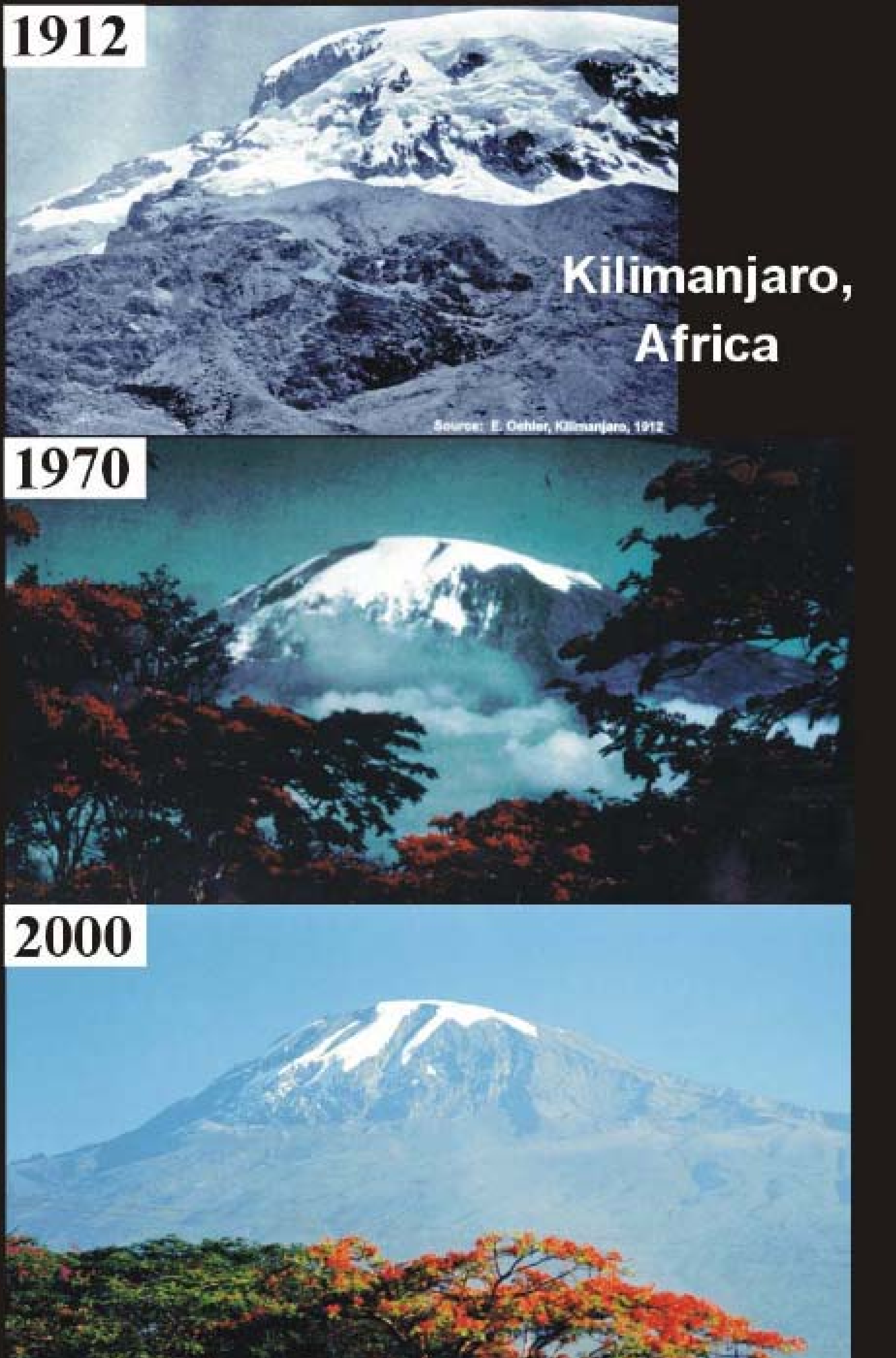


Recent Retreat of Perúvian Glaciers

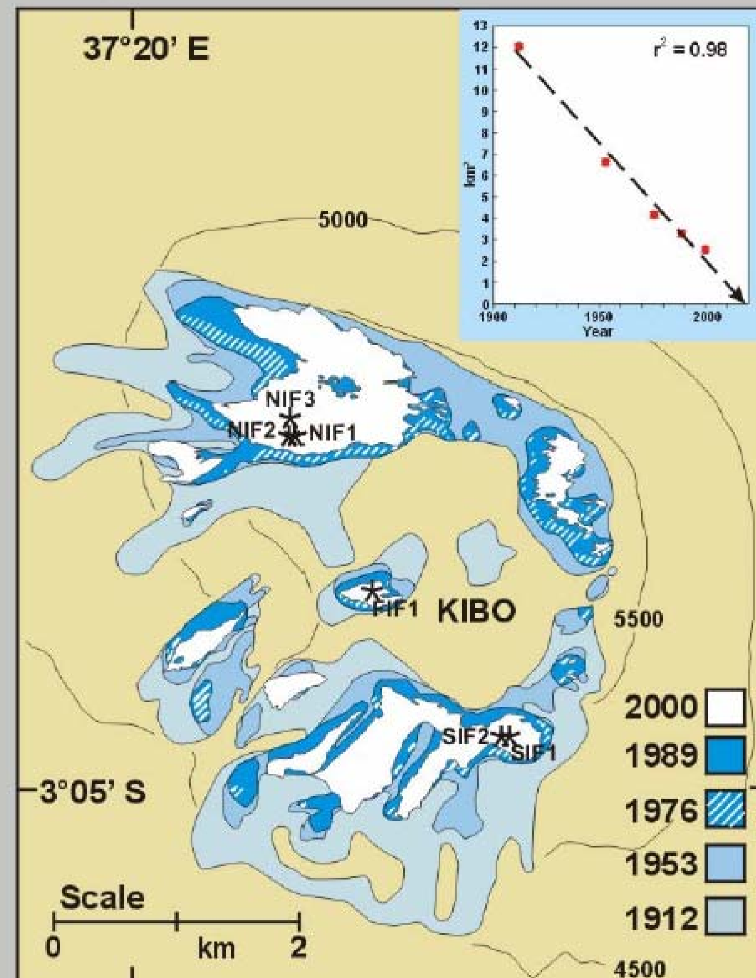


Portocarrero (personal comm.)
Qori Kalis - Ohio State University

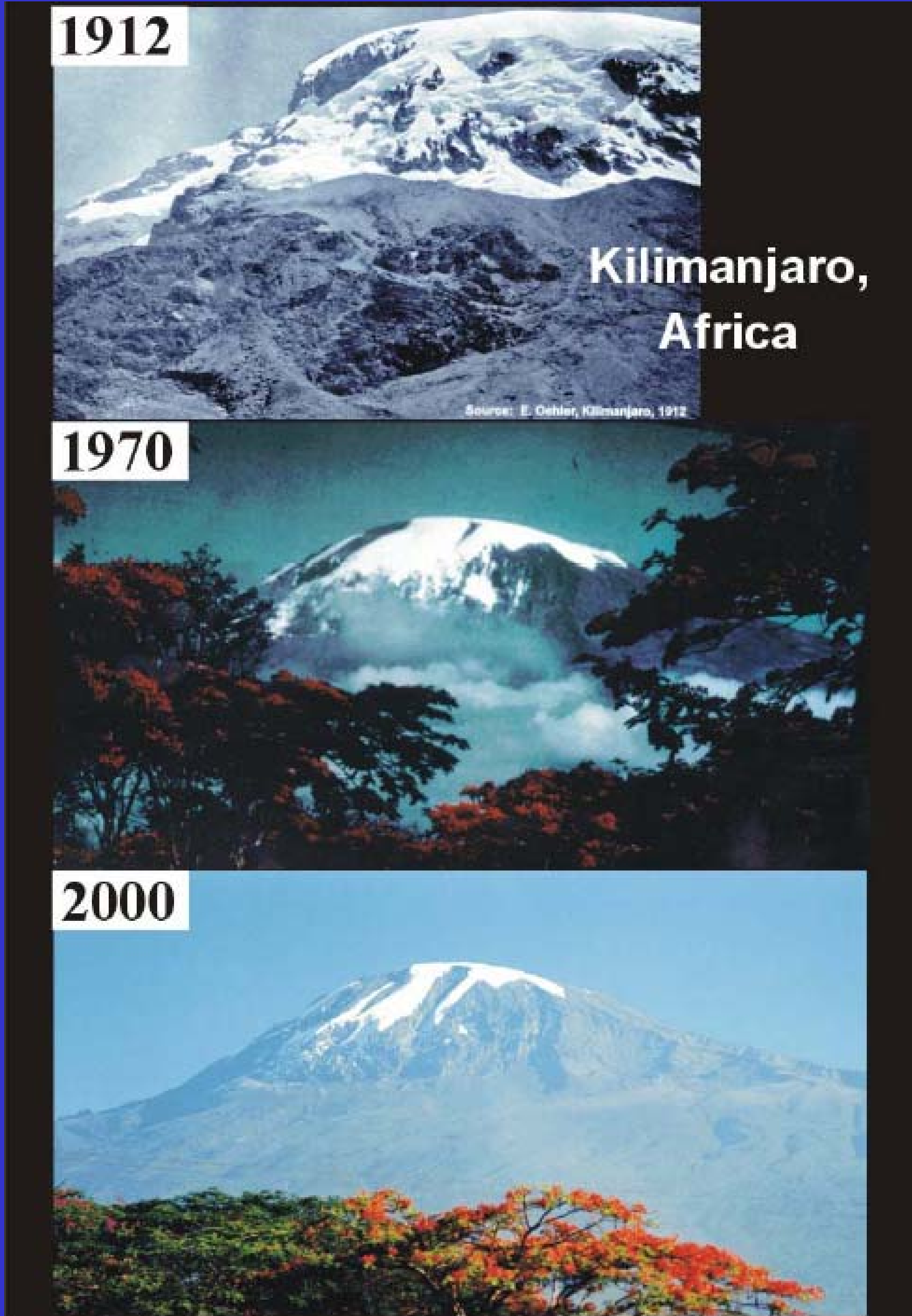
Lonnie G. Thompson, Byrd Polar Research Center, The Ohio State University
Privileged unpublished data



Total Area Of Ice On Kilimanjaro
(1912, 1953, 1976, 1989, 2000)

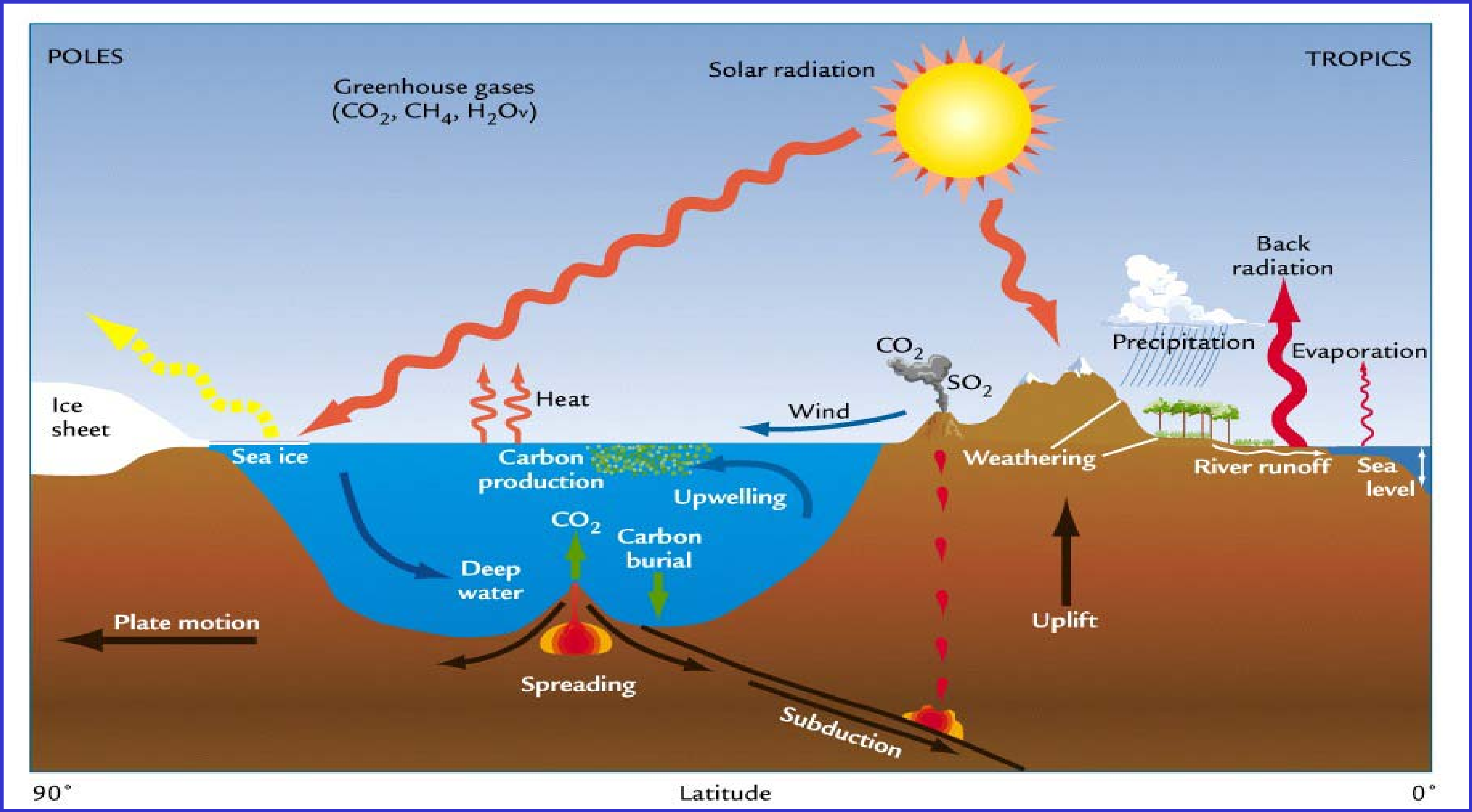


1912 - 1989 after Hastenrath and Greischar, *J. Glaciol.*, 1997
2000 after Thompson *et al.*, *Science*, 2002

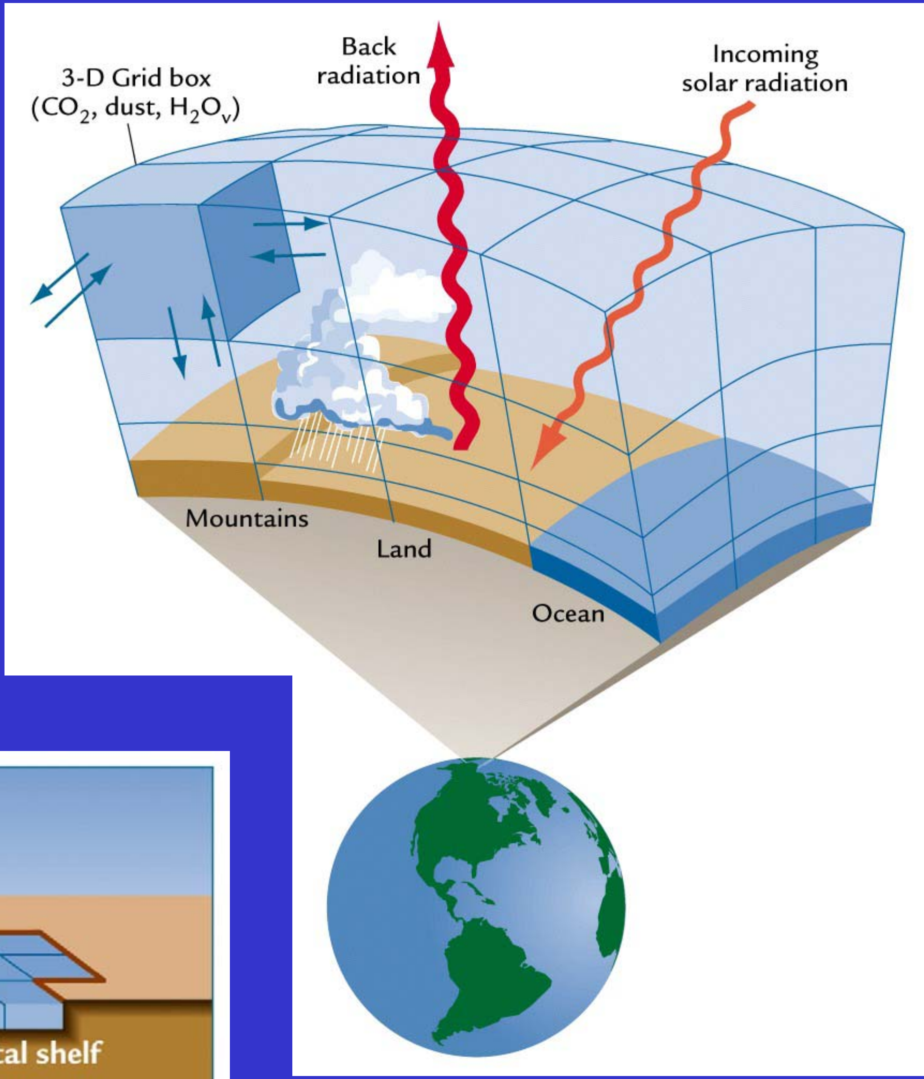

1912
Kilimanjaro,
Africa
Source: E. Oehler, Kilimanjaro, 1912
1970
2000

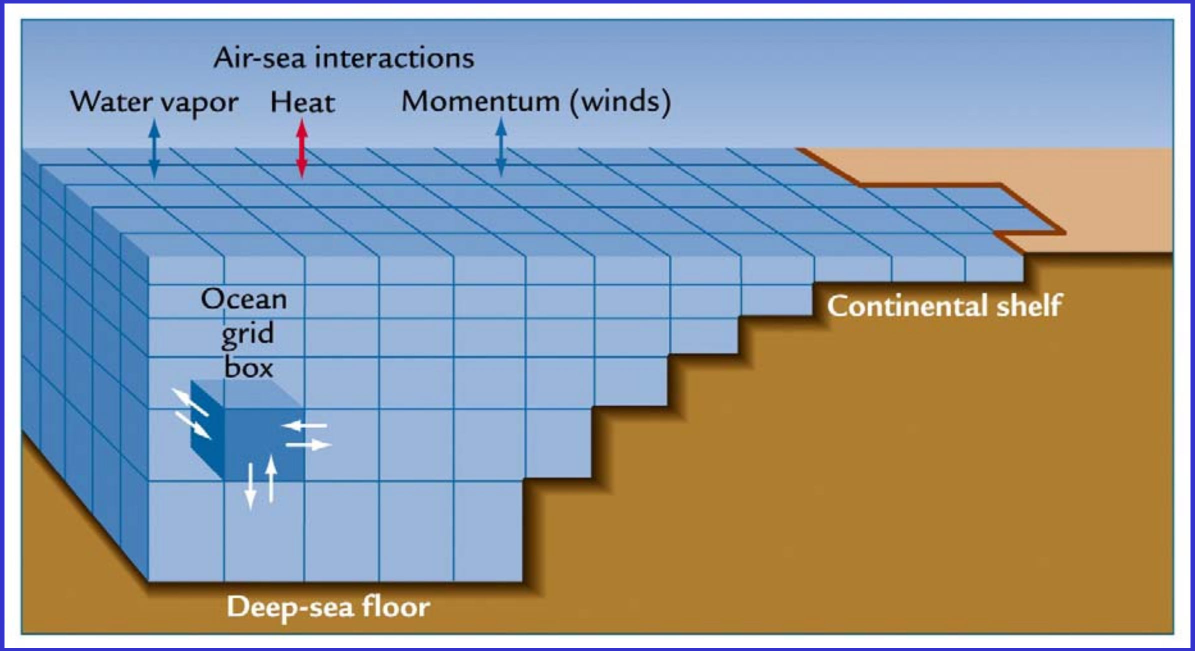
CLIMATE MODELS

*The **climate** represents a coupled system consisting of an atmosphere, hydrosphere, biosphere, and cryosphere*



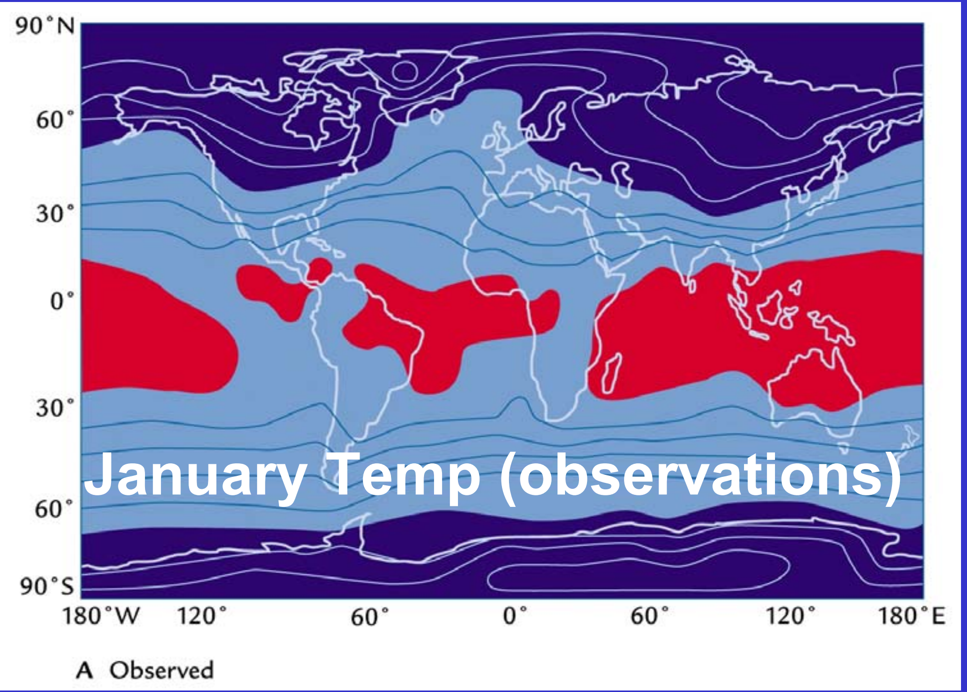
***General Circulation Models** take into account the full three-dimensional structure of the atmosphere and ocean*

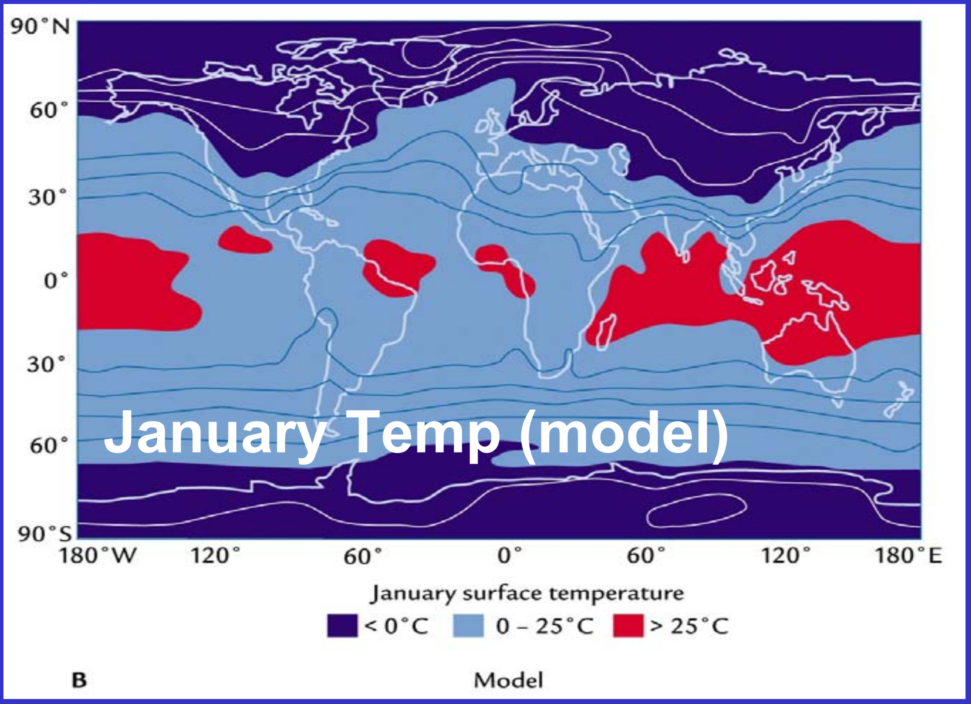




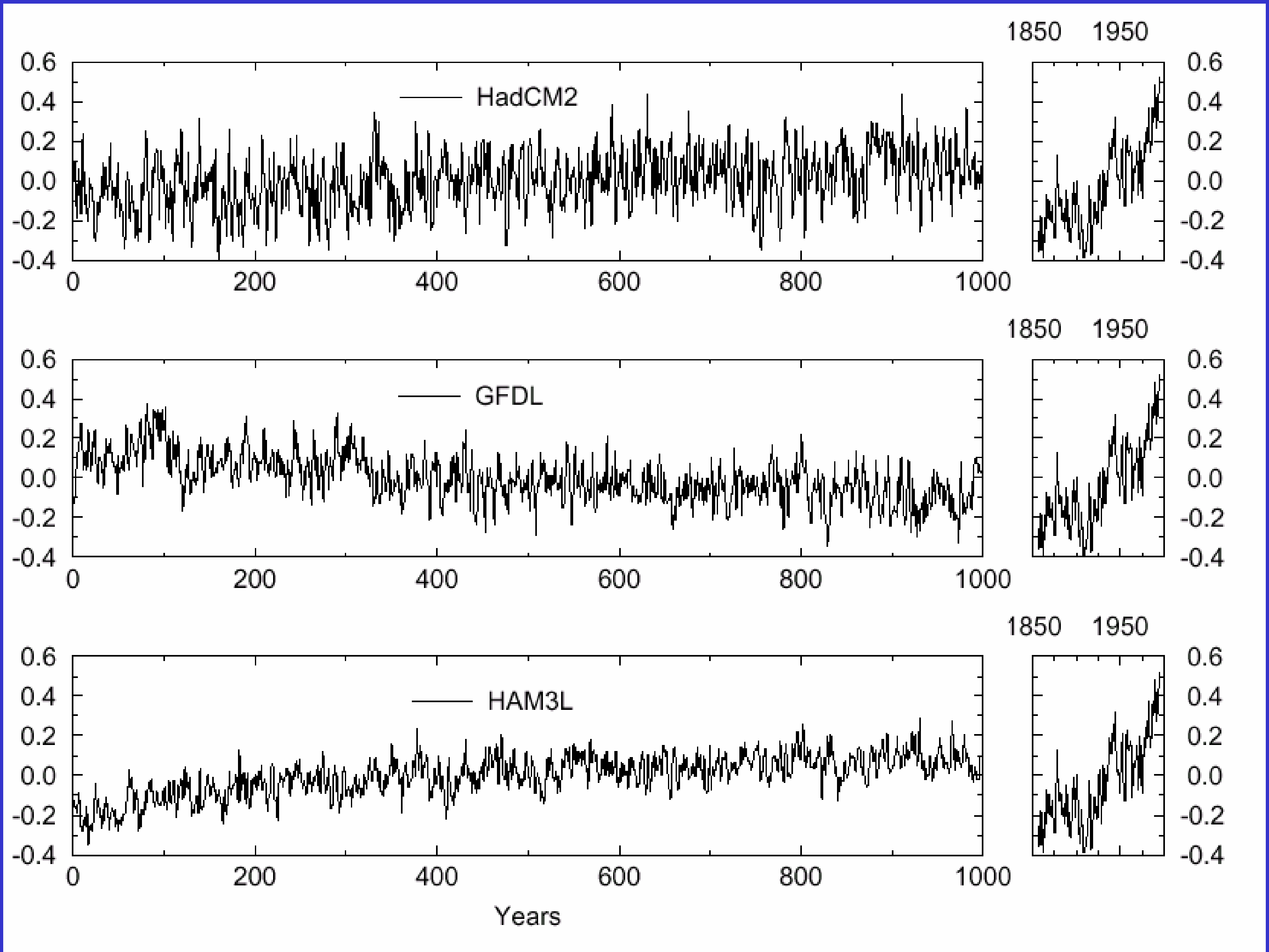
GCMs do a fairly good job of describing the seasonal cycle in surface temperature

This alone doesn't guarantee that they should do a good job in describing ***climate change****!*



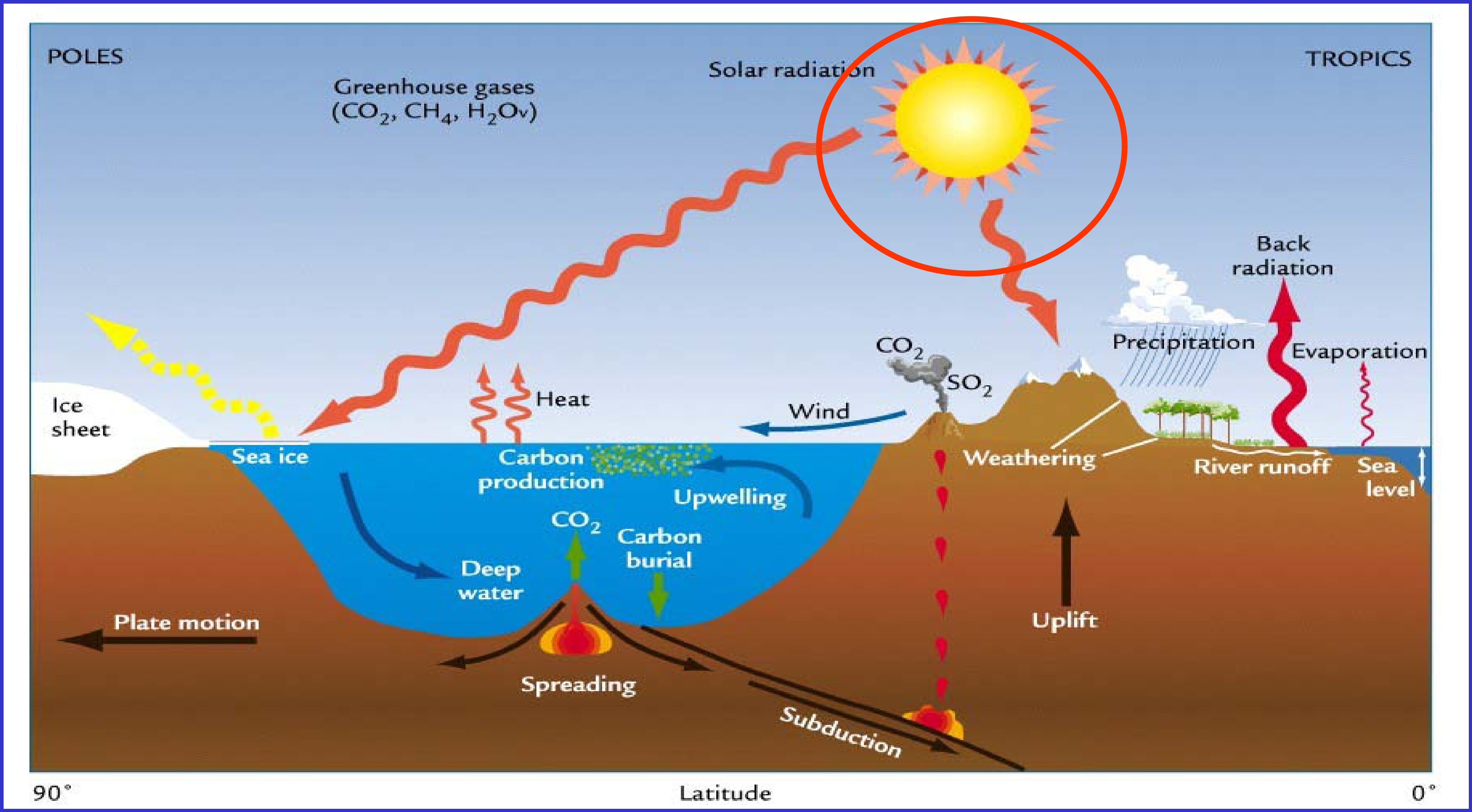


Modeled *Internal* Natural Variability   Observations

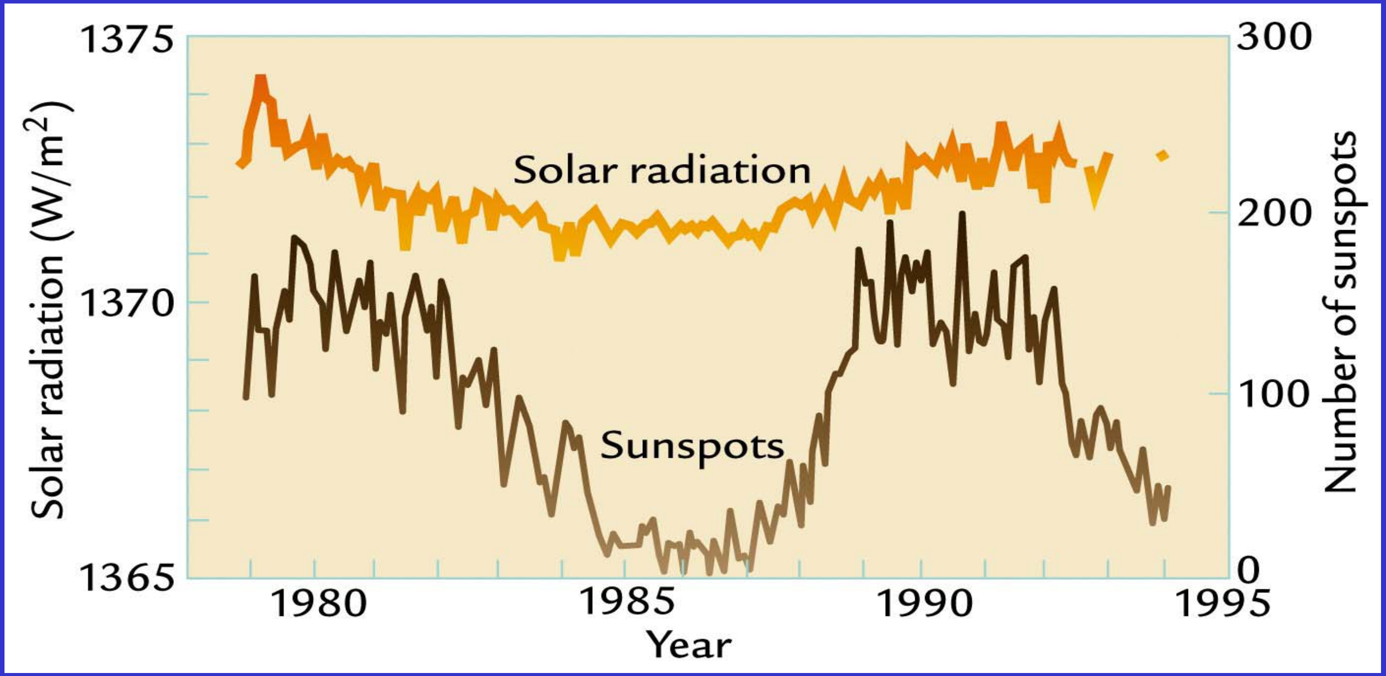


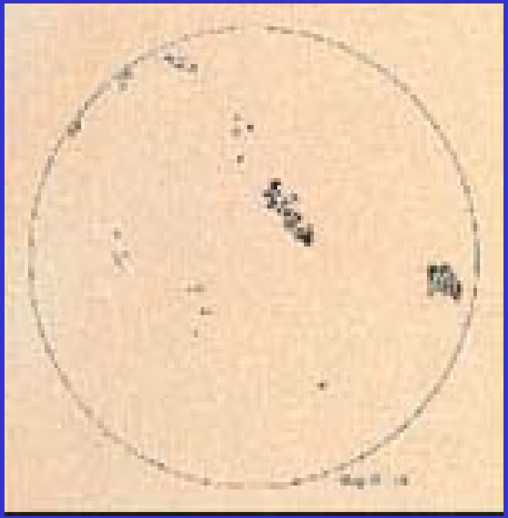
INFLUENCE OF EXTERNAL FACTORS

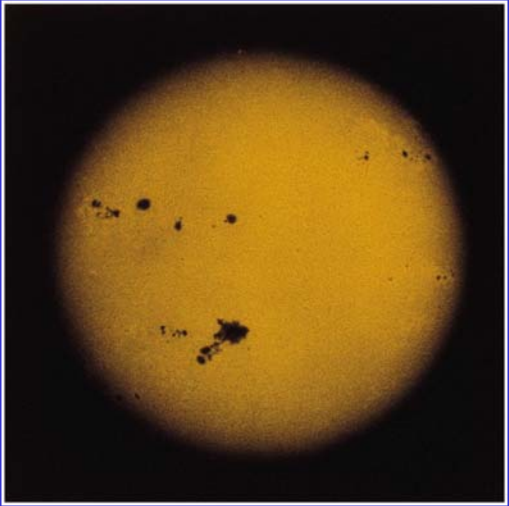
*The **climate** is governed by external factors, including the intensity of **solar output***

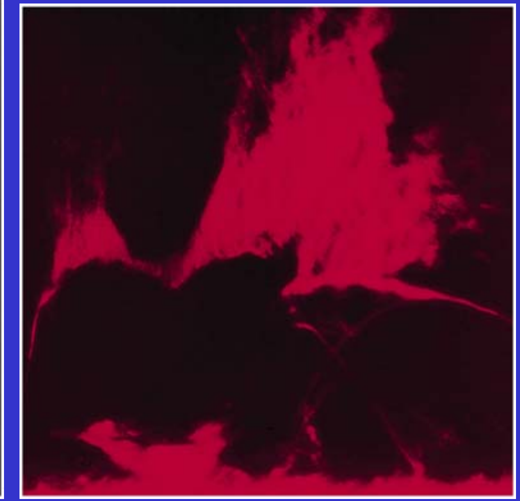


Solar Variations

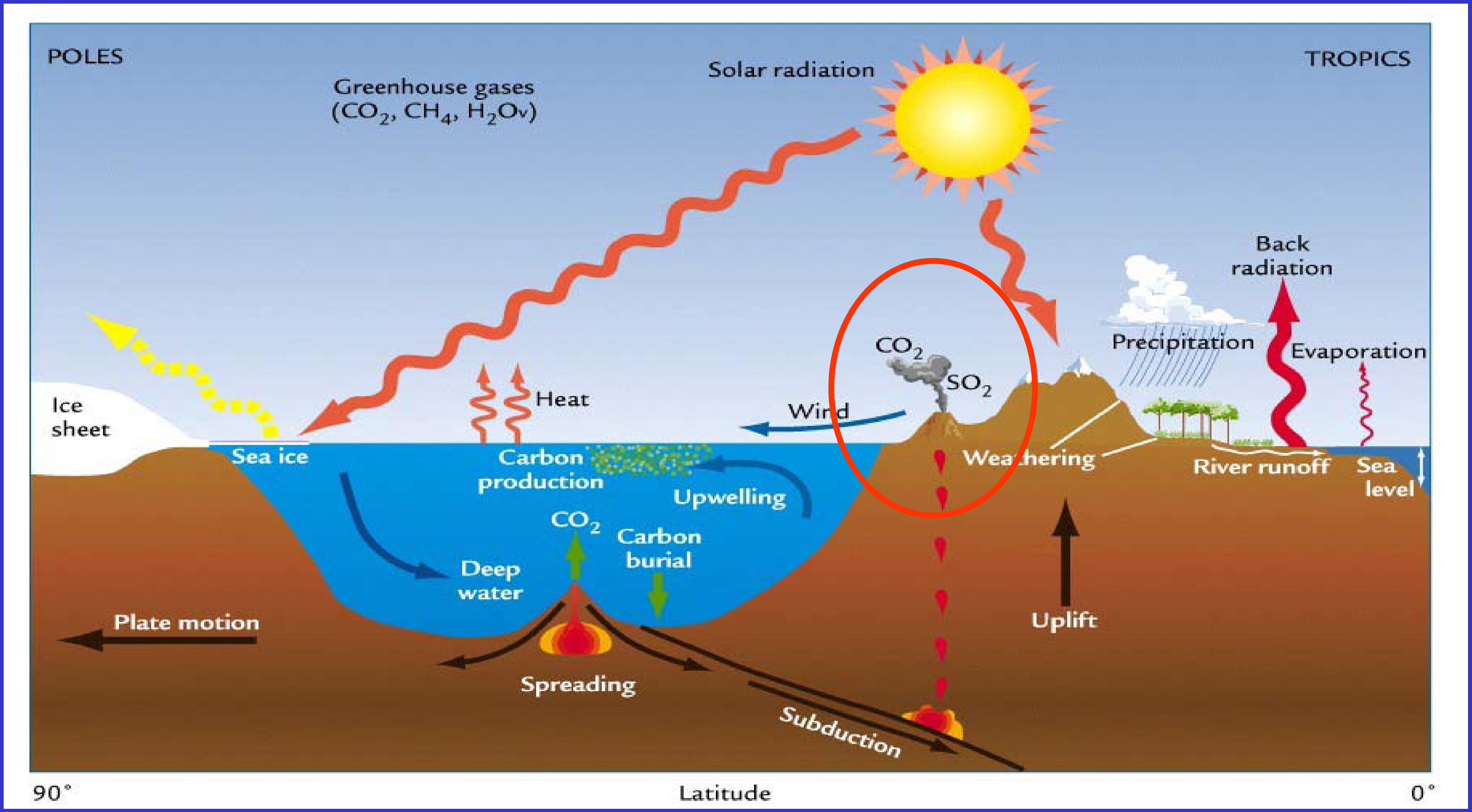




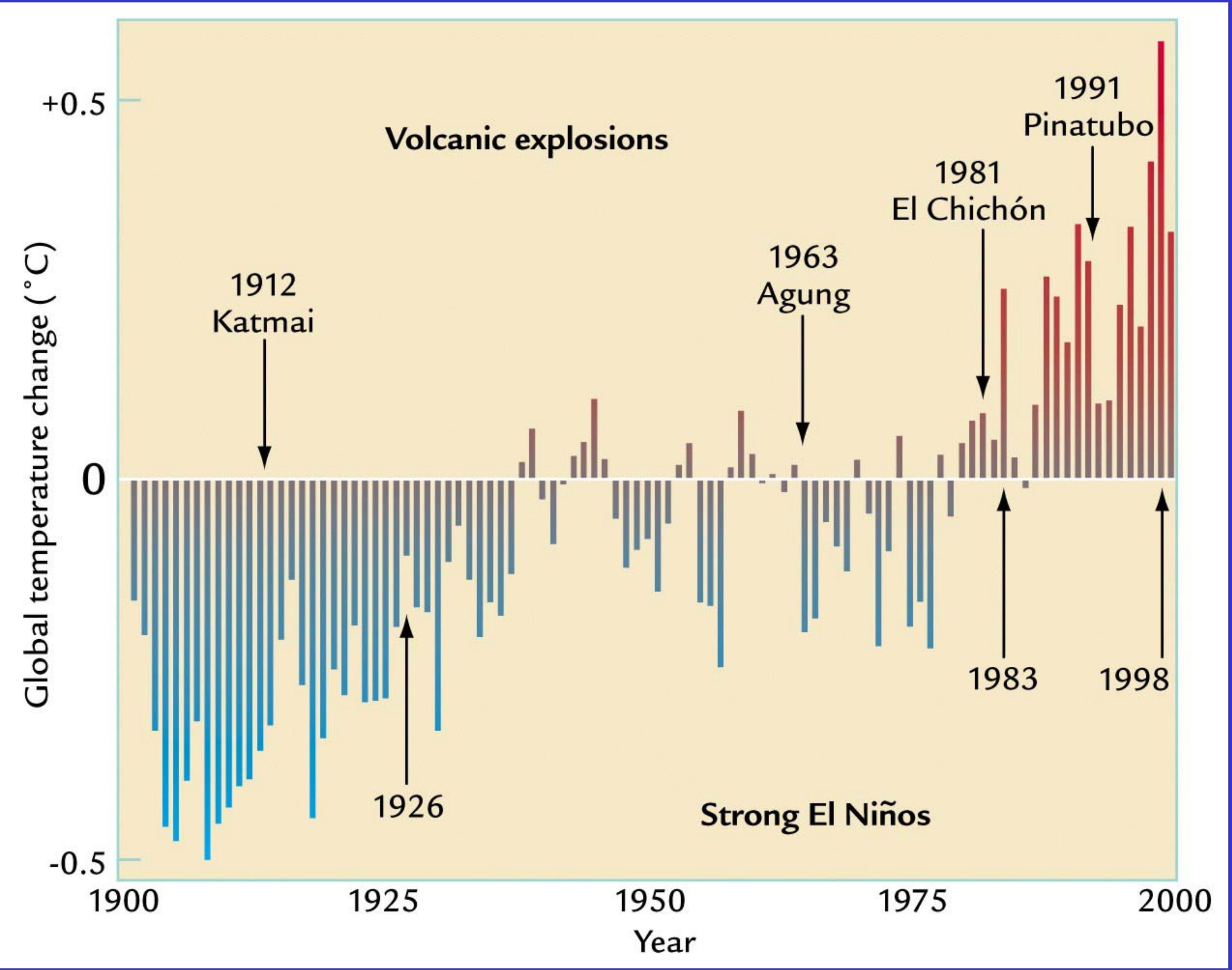




*The **climate** is governed by external factors, including the intensity of **solar output** and **volcanic aerosols***

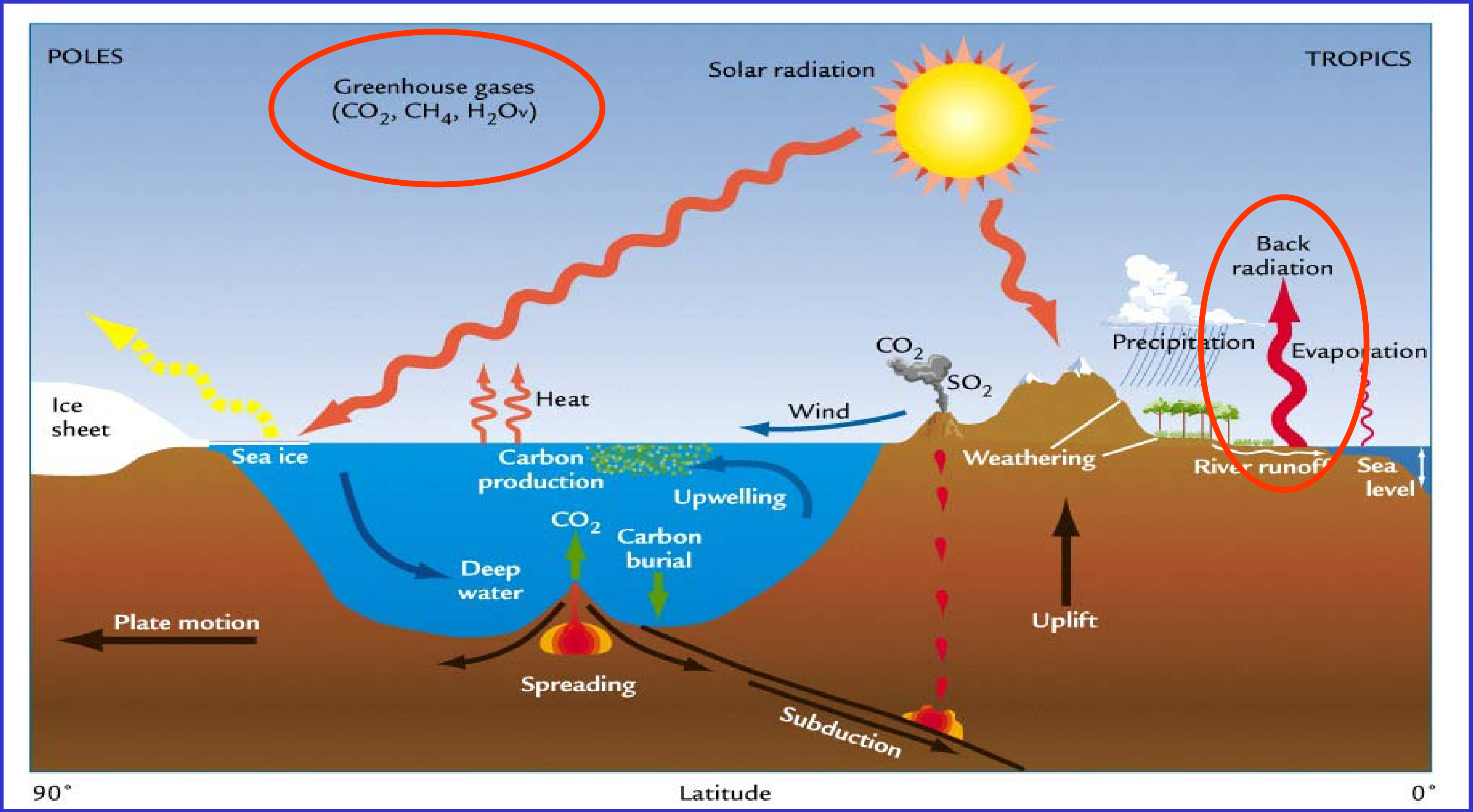


Volcanoes

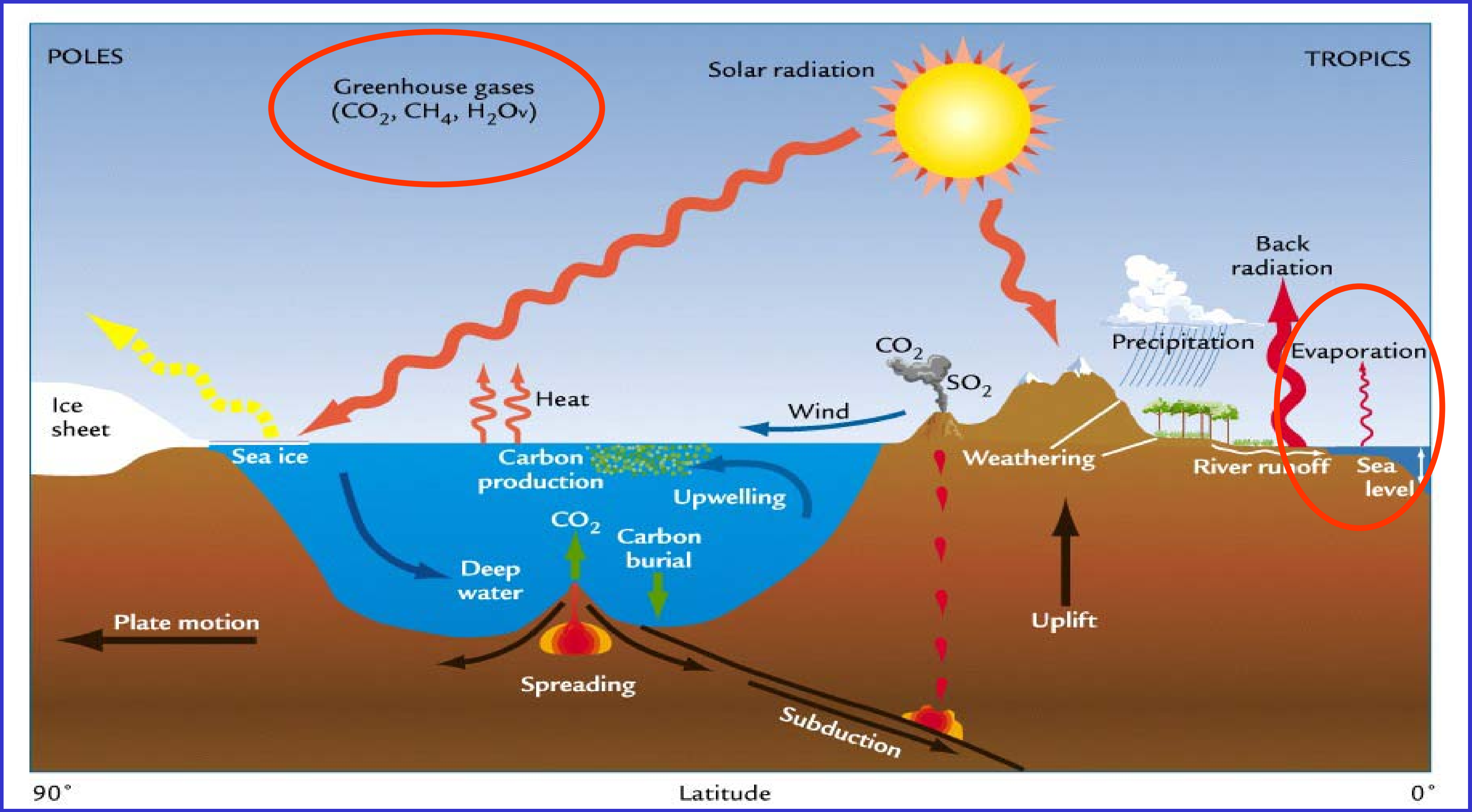


+0.5
0
-0.5
Global temperature change (°C)
Volcanic explosions
1912
Katmai
1963
Agung
1981
El Chichón
1991
Pinatubo
1926
1983
1998
Strong El Niños
1900
1925
1950
1975
2000
Year

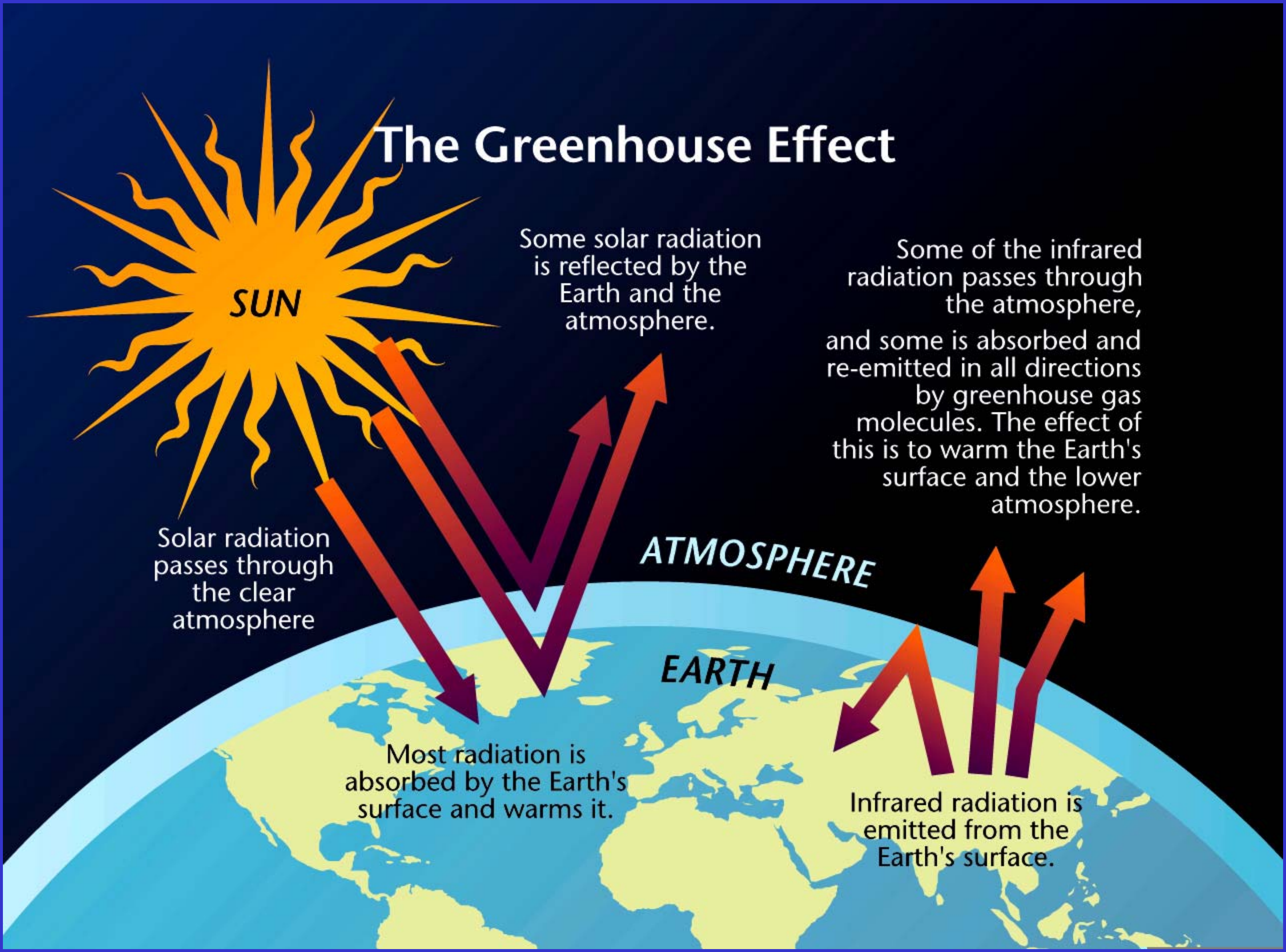
*The **climate** is governed by external factors, including the intensity of **solar output** and **volcanic aerosols** and **greenhouse gas concentrations***



*The **climate** is governed by external factors, including the intensity of **solar output** and **volcanic aerosols** and <u>**greenhouse gas concentrations**</u>*



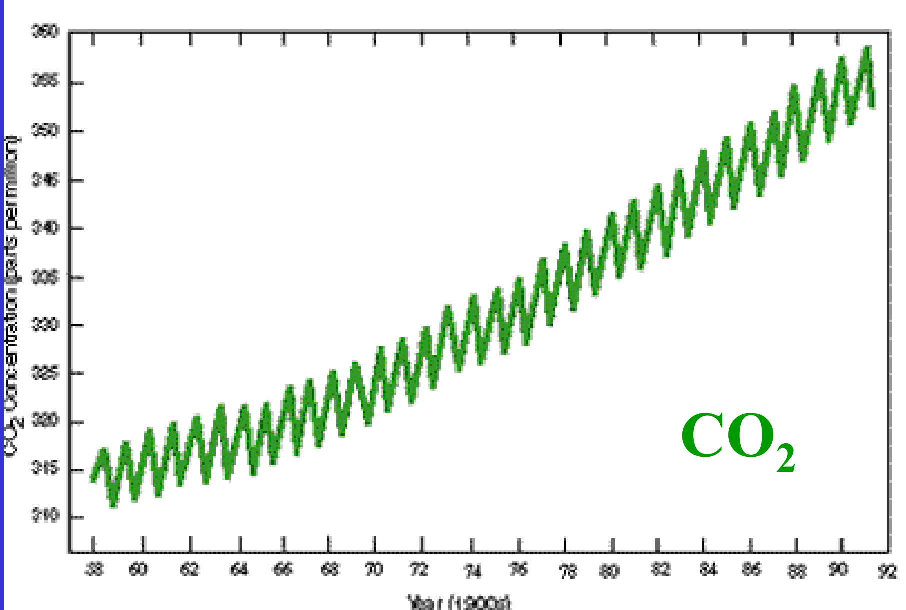
GREENHOUSE EFFECT?



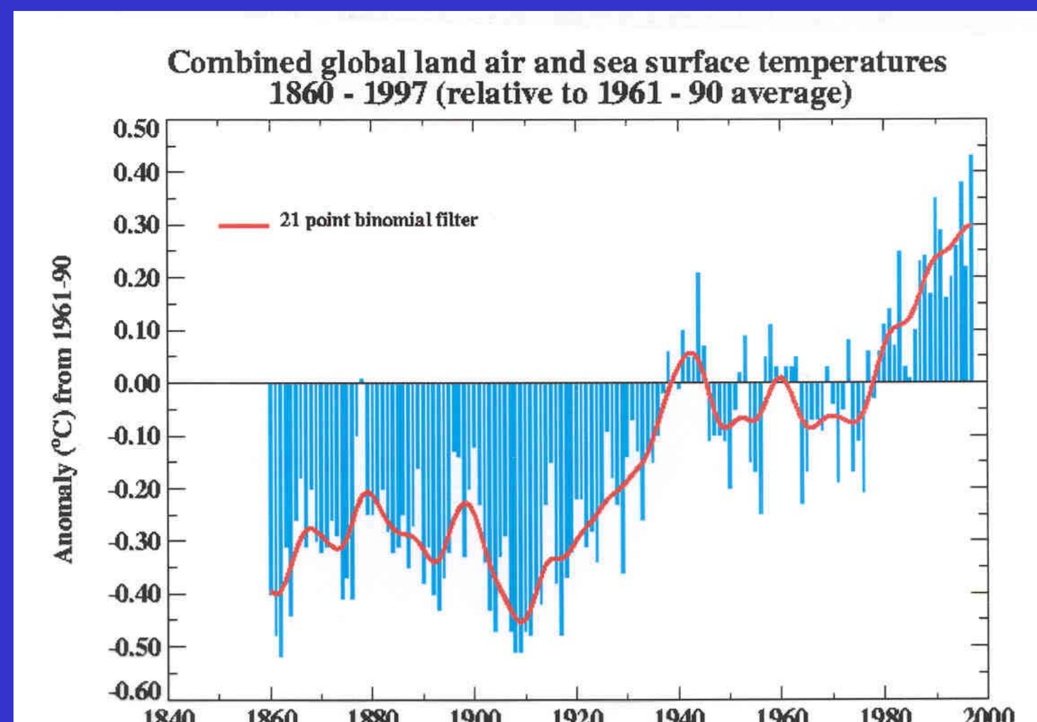
The Greenhouse Effect
SUN
Some solar radiation is reflected by the Earth and the atmosphere.
Some of the infrared radiation passes through the atmosphere,
and some is absorbed and re-emitted in all directions by greenhouse gas molecules. The effect of this is to warm the Earth's surface and the lower atmosphere.
Solar radiation passes through the clear atmosphere
ATMOSPHERE
EARTH
Most radiation is absorbed by the Earth's surface and warms it.
Infrared radiation is emitted from the Earth's surface.

ENHANCED GREENHOUSE EFFECT?

Greenhouse Gases and Warming

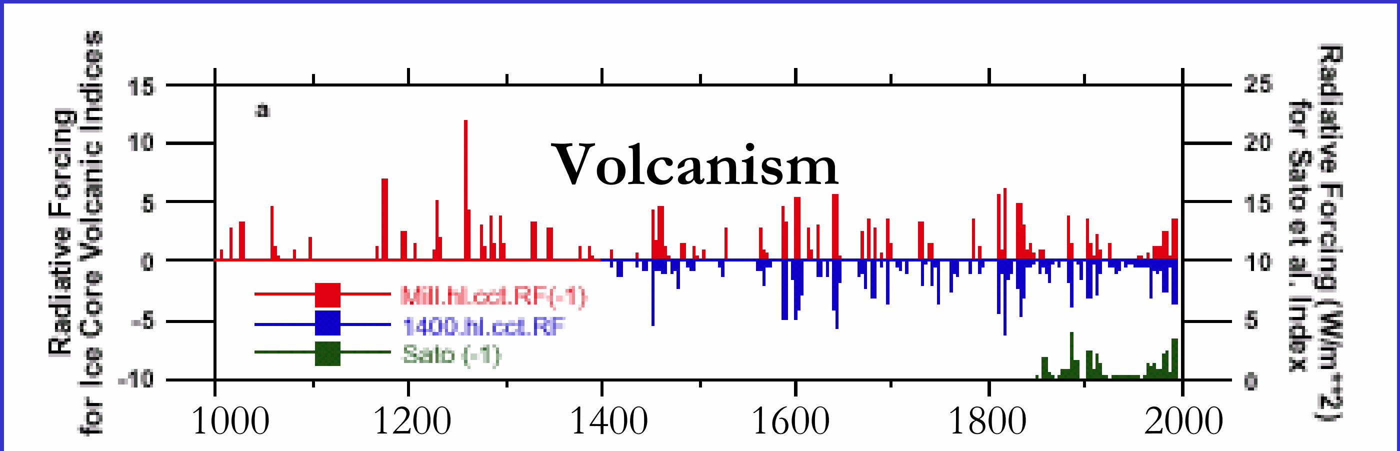


Related?

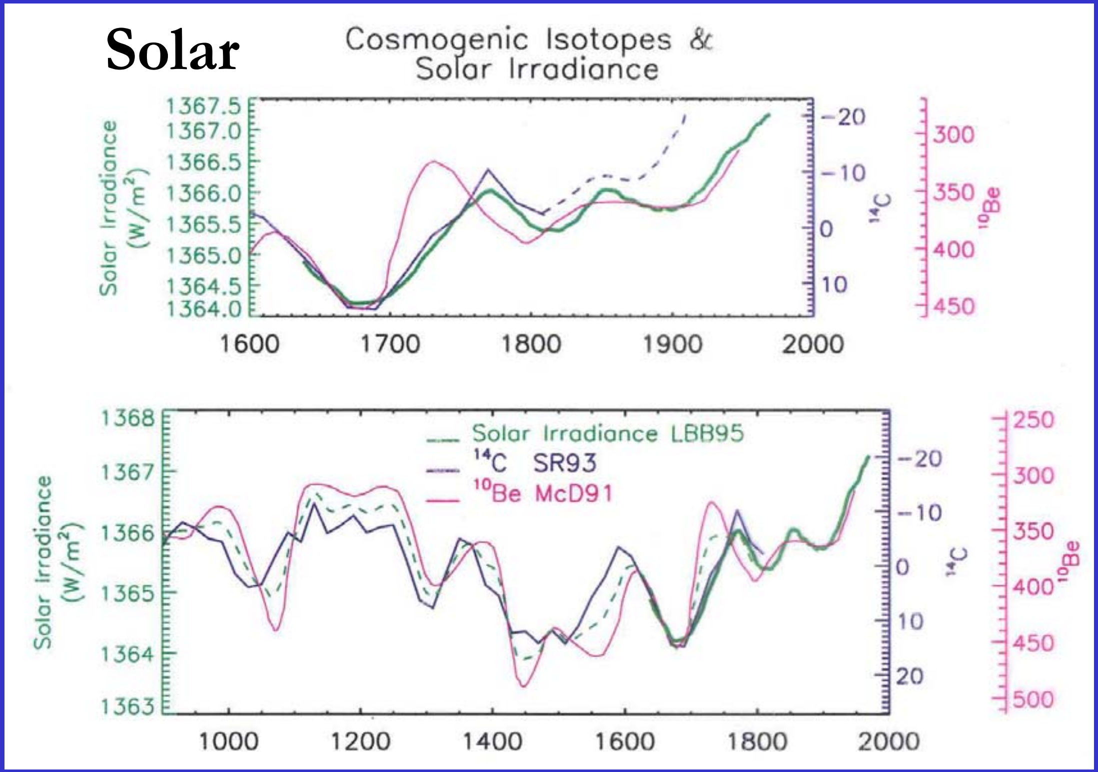


SIMULATIONS OF CLIMATE CHANGE

CLIMATE FORCINGS

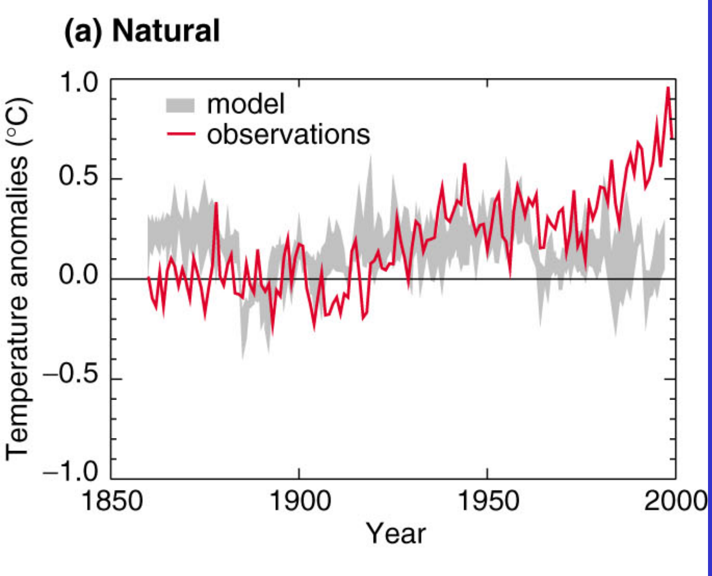


Natural



Simulated Annual Global Mean Surface Temperatures

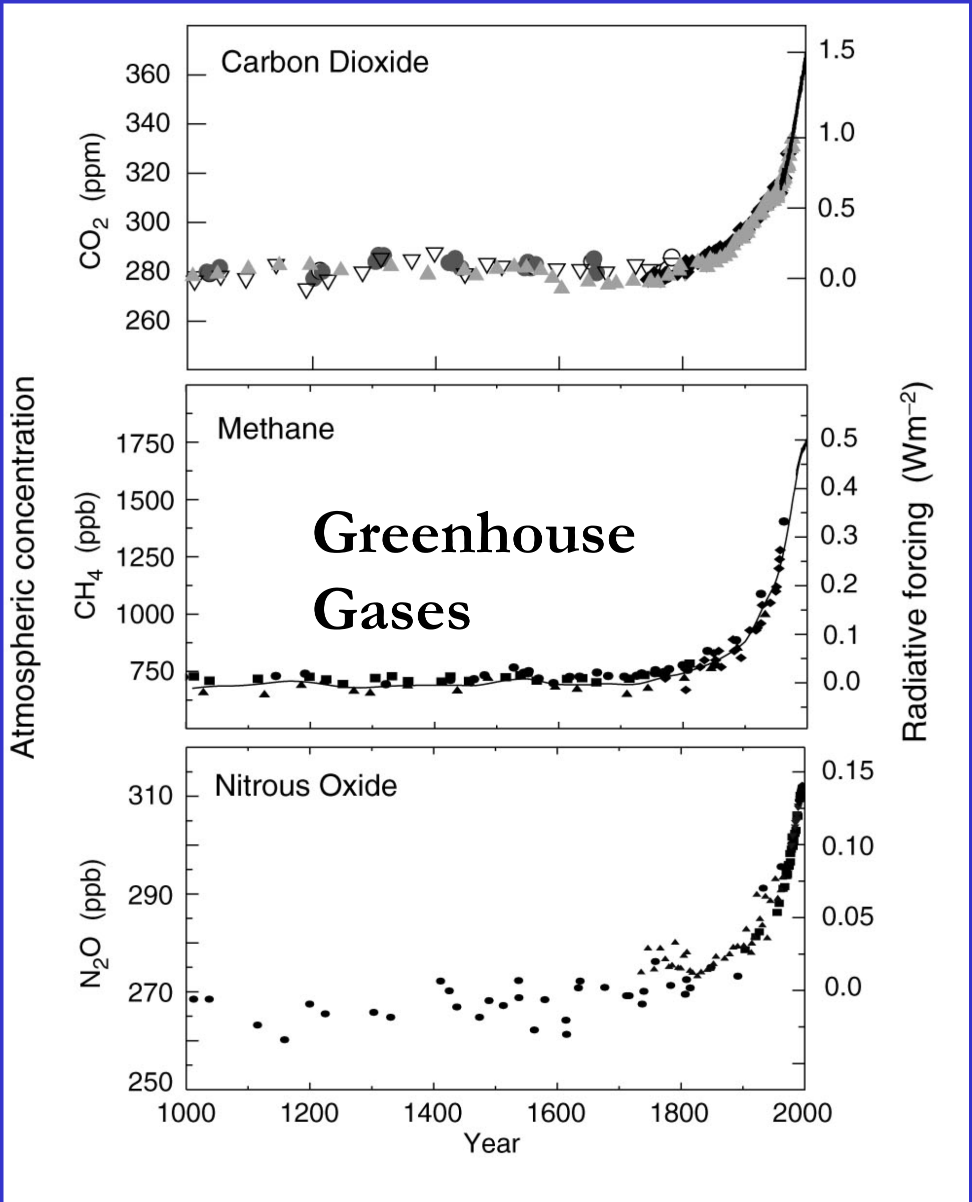
Climate Change 2001: The Scientific Basis, Houghton, J.T., et al. (eds.), Cambridge Univ. Press, Cambridge, 2001

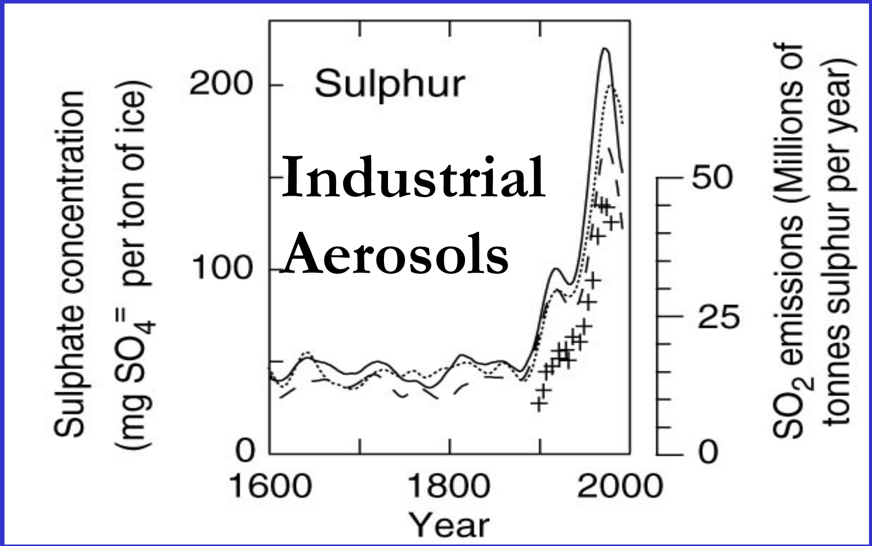


Forced Model simulations

CLIMATE FORCINGS

Anthropogenic





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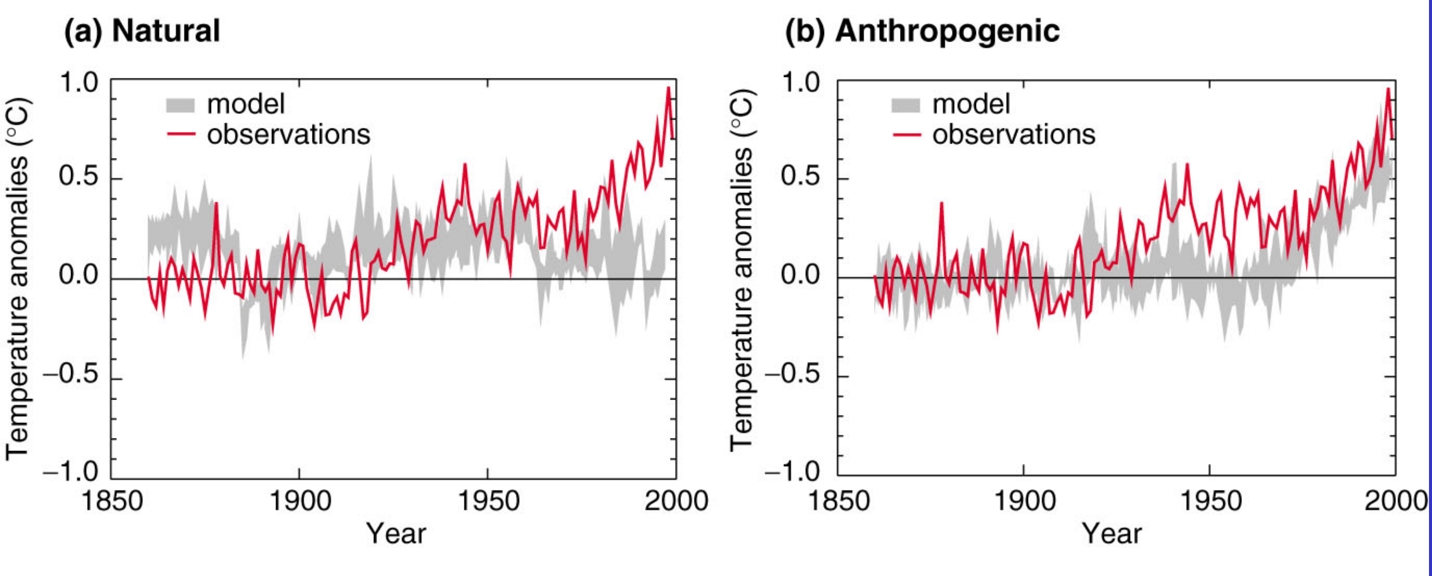

Forced Model simulations

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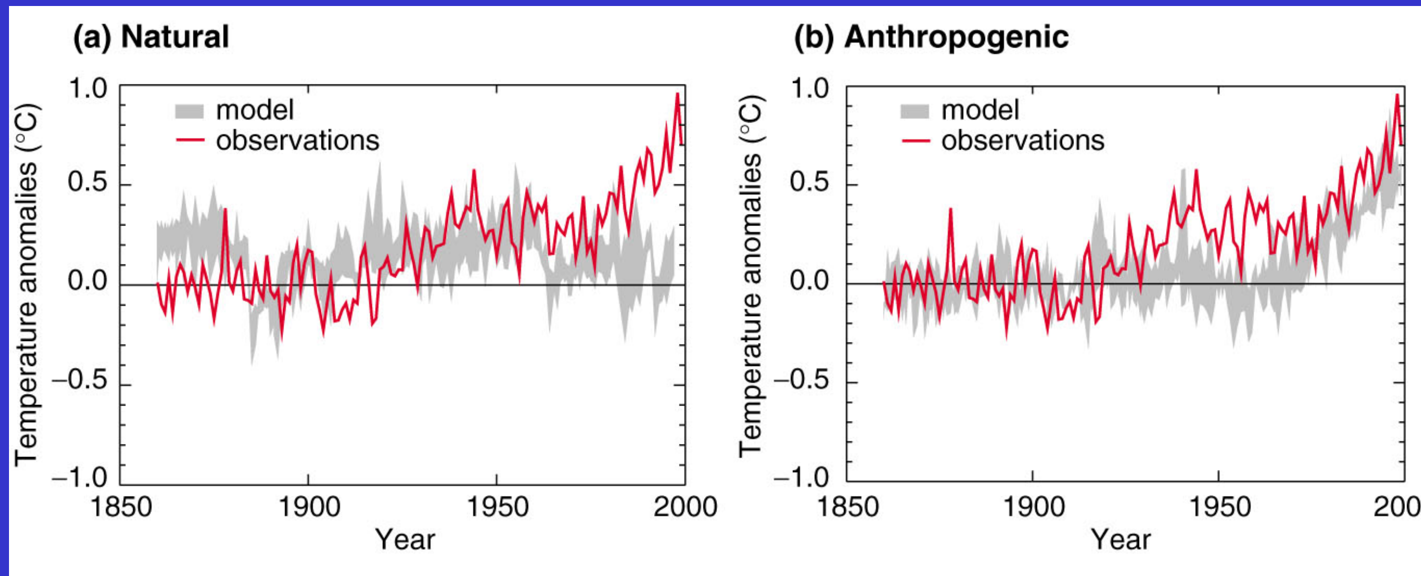
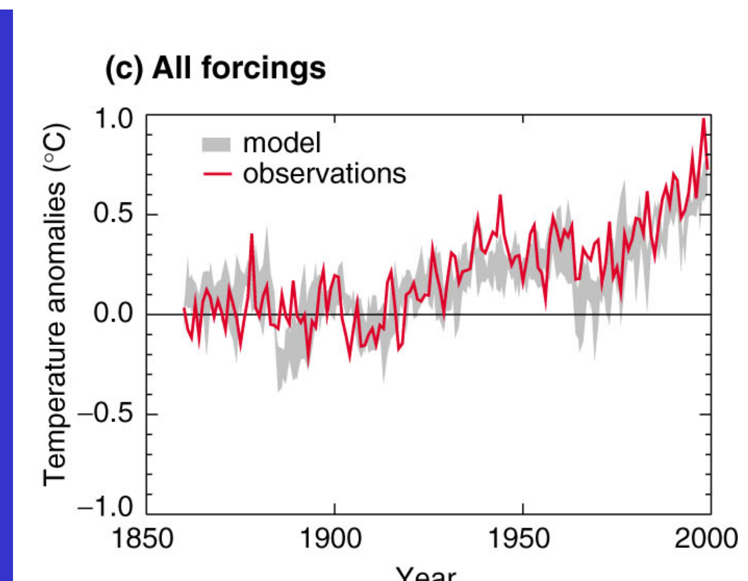
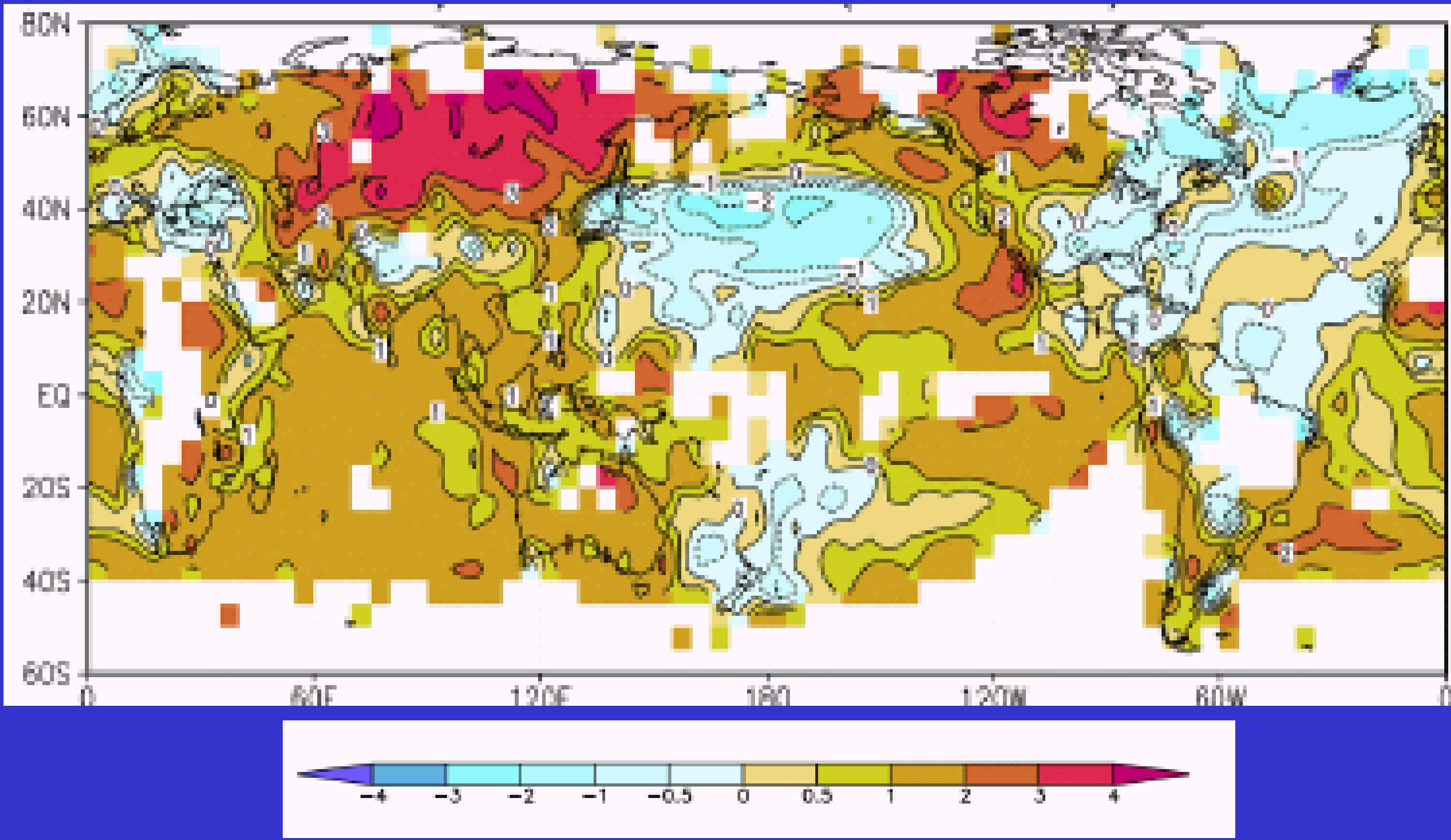


Forced Model simulations



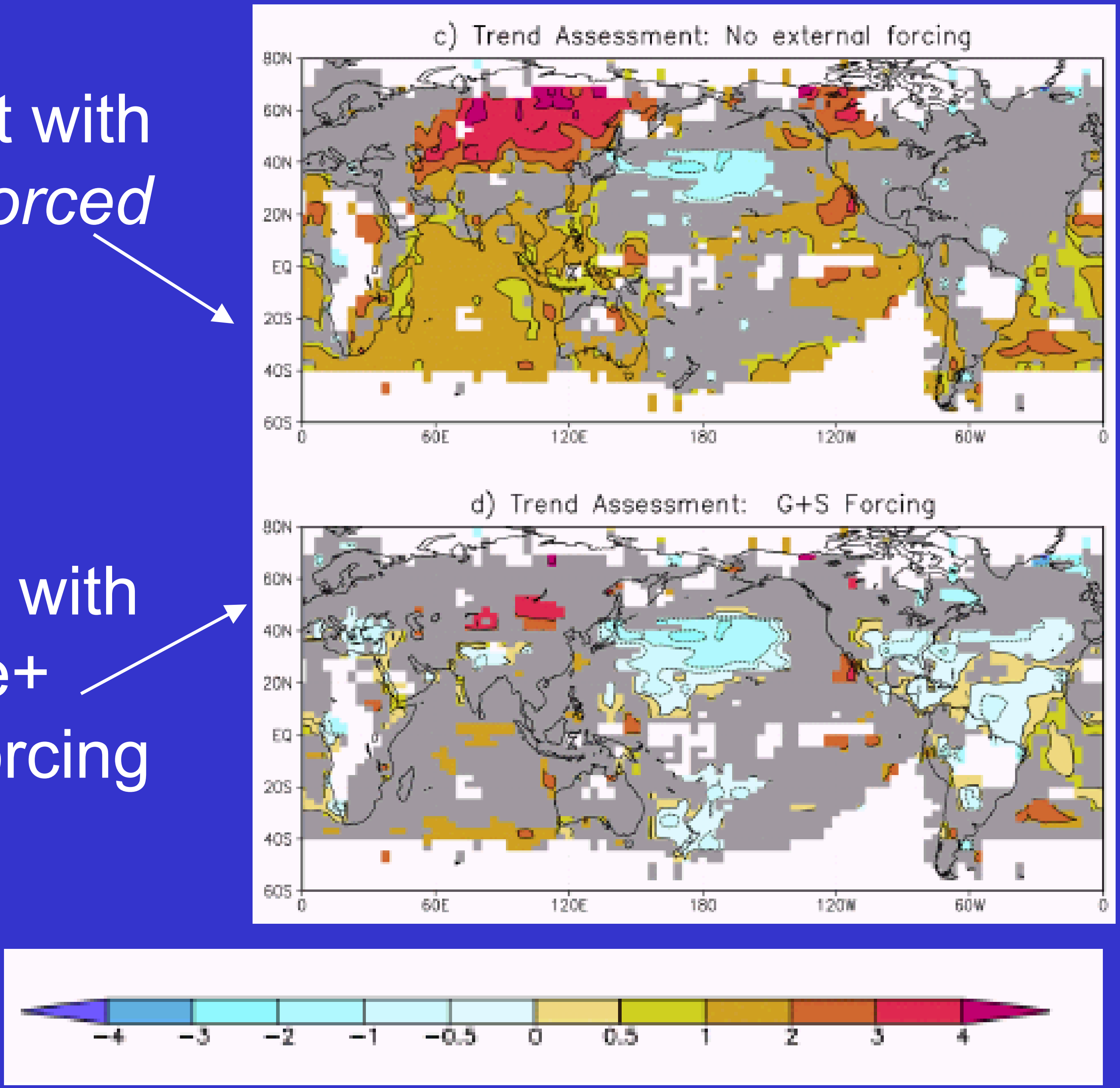


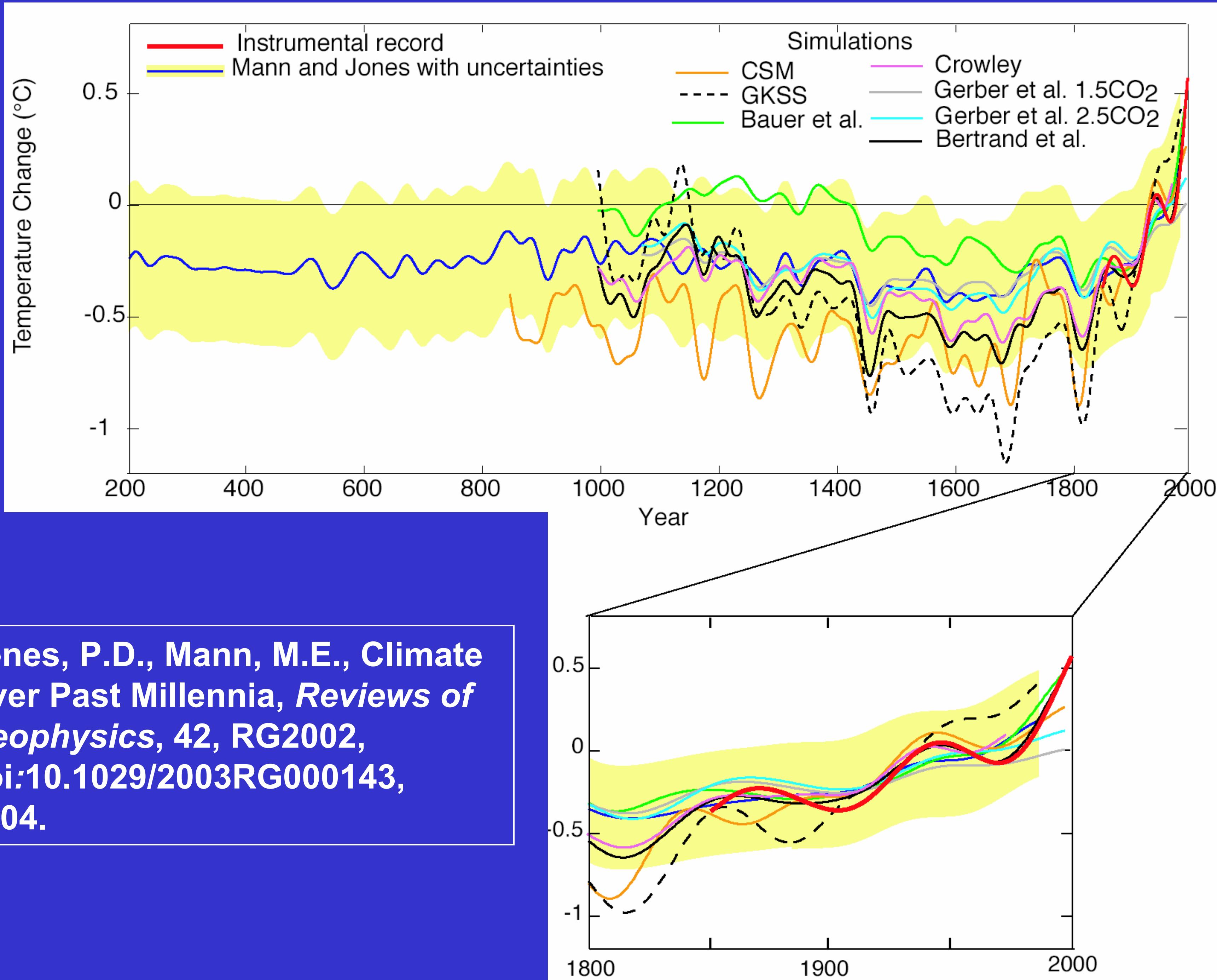
OBSERVED ANNUAL MEAN TREND 1949-1997

Knutson, T.R., T.L. Delworth, K.W. Dixon, and R.J. Stouffer, Model assessment of regional surface temperature trends (1949-1997), *Journal of Geophysical Research*, *104*, 30981-30996, 1999.

Inconsistent with Natural *unforced* Variability

Inconsistent with Greenhouse+ Sulphate Forcing

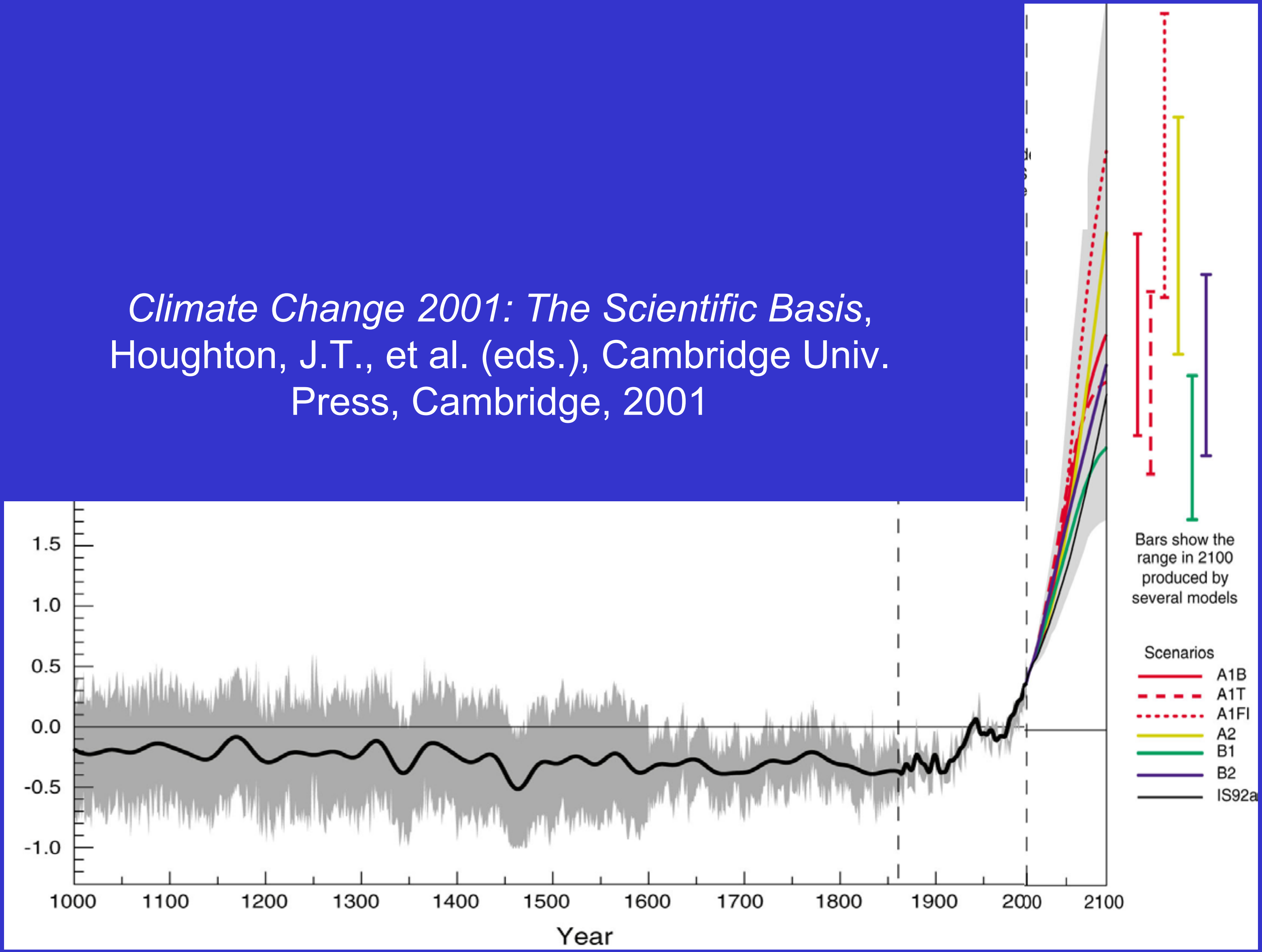




Jones, P.D., Mann, M.E., Climate Over Past Millennia, *Reviews of Geophysics*, 42, RG2002, doi:10.1029/2003RG000143, 2004.

Future Surface Temperatures Trends?

Climate Change 2001: The Scientific Basis, Houghton, J.T., et al. (eds.), Cambridge Univ. Press, Cambridge, 2001



RealClimate

``RealClimate is a commentary site on climate science by working climate scientists for the interested public and journalists. We aim to provide a quick response to developing stories and provide the context sometimes missing in mainstream commentary.''

Gavin Schmidt, Michael Mann

Eric Steig, William Connolley, Ray Bradley, Stefan Rahmstorf, Rasmus Benestad, Caspar Ammann, Thibault de Garidel

CONCLUSIONS

•Recent global surface temperatures are unprecedented this century, and likely *at least* the past millennium

•It is difficult to explain the recent surface warming in terms of natural climate variability

•Recent surface warming *is* largely consistent with simulations of the effects of anthropogenic influence on climate

•Uncertainties remain regarding the precise sensitivity of the climate to forcing, and the regional details of expected climate changes