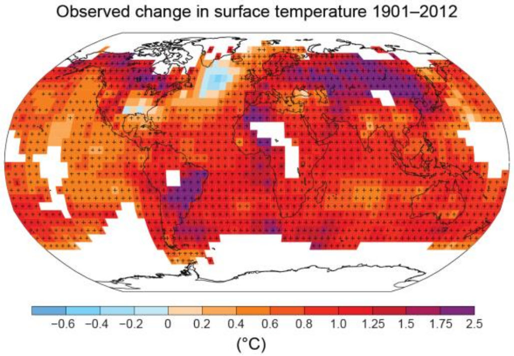
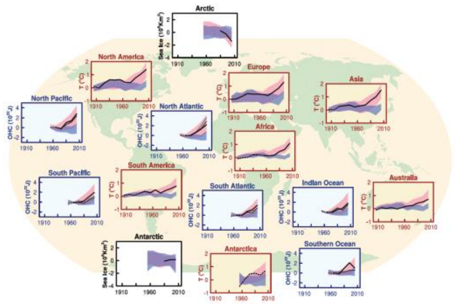
Georges Lemaître Center for Earth and Climate Research
Formely Institute of Astronomy and Geophysics George Lemaître
Place L. Pasteur, 3
1348 Louvain-la-Neuve

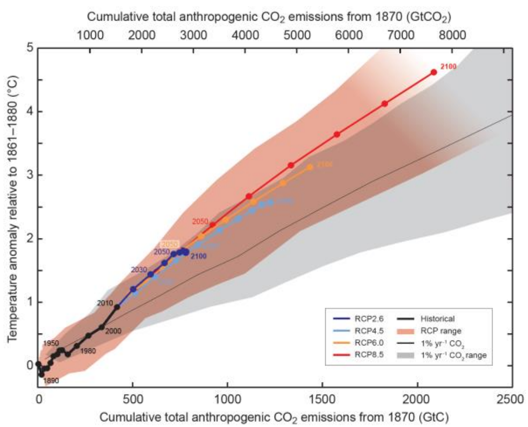
Le Passé du Climat, Leçon pour l'Avenir

André Berger

Présentation invitée à 7ème Université d'Été de Sauvons le Climat,
Bordeaux 2-4 octobre 2014







Le réchauffement climatique est sans équivoque

L'influence humaine sur le climat est claire

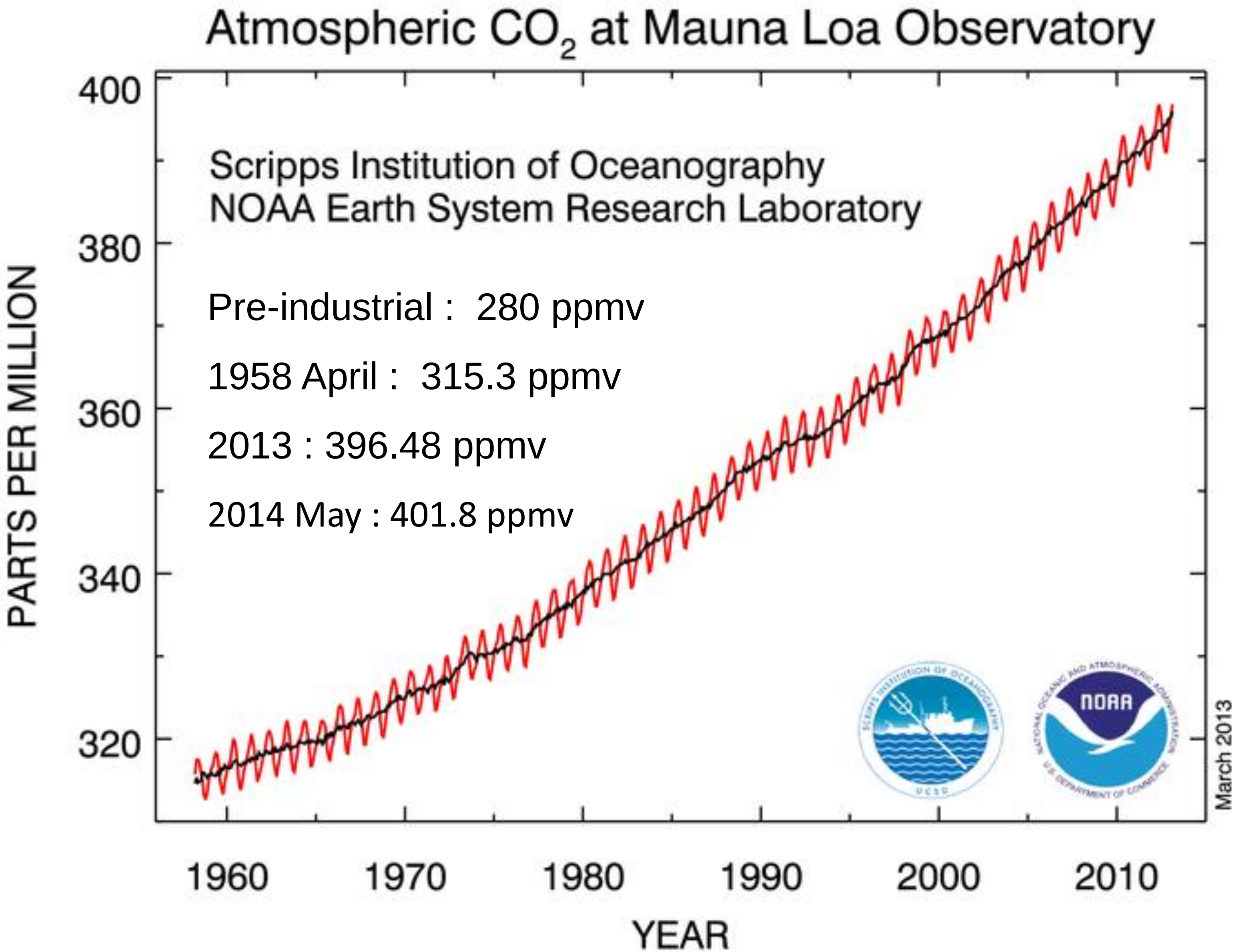
Limiter le réchauffement requiert des réductions subsentielles et persistantes des émissions de GES

2013

IPCC AR5 Working Group I
Climate Change 2013: The Physical Science Basis

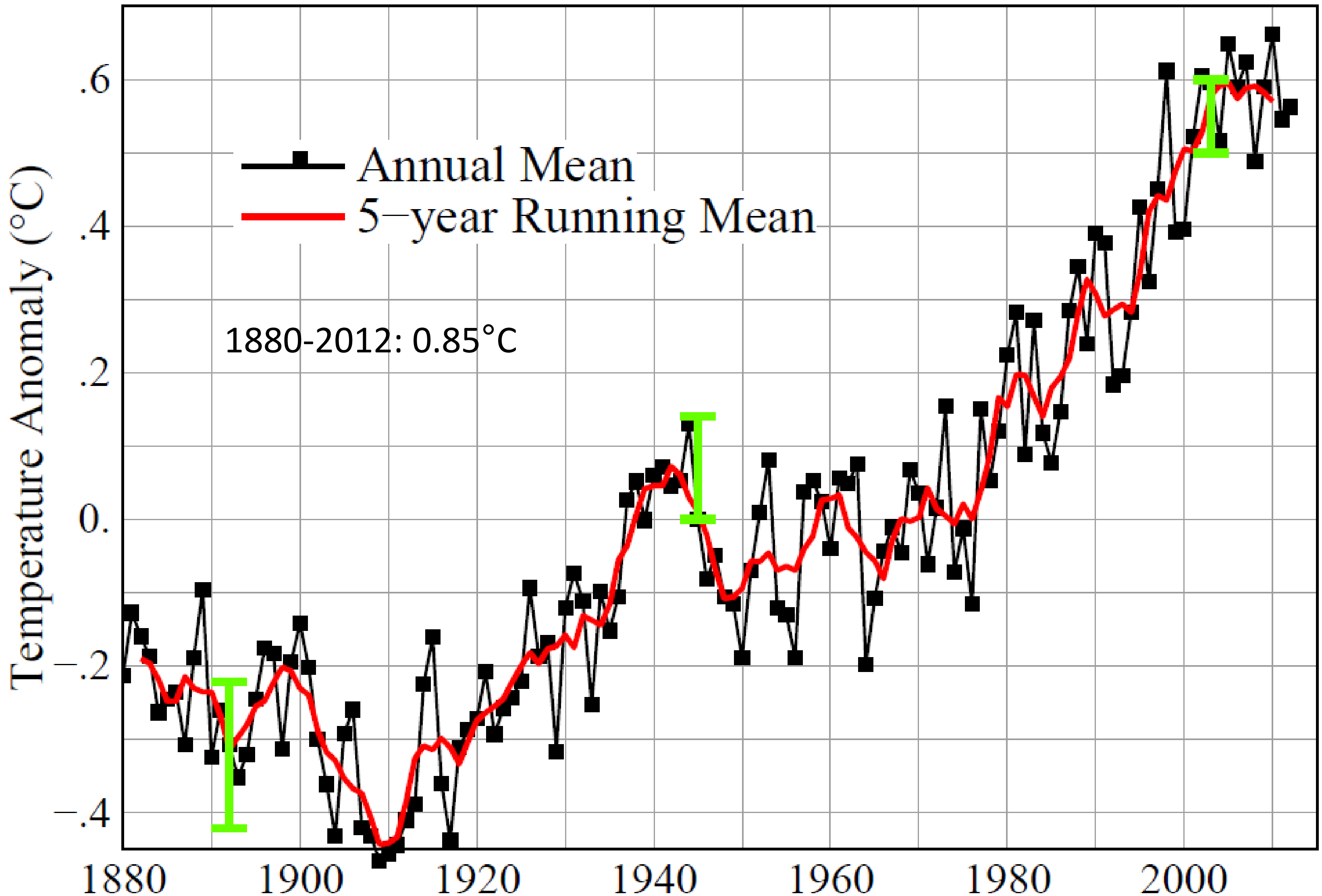
ipcc
INTERGOVERNMENTAL PANEL ON climate change

WMO UNEP



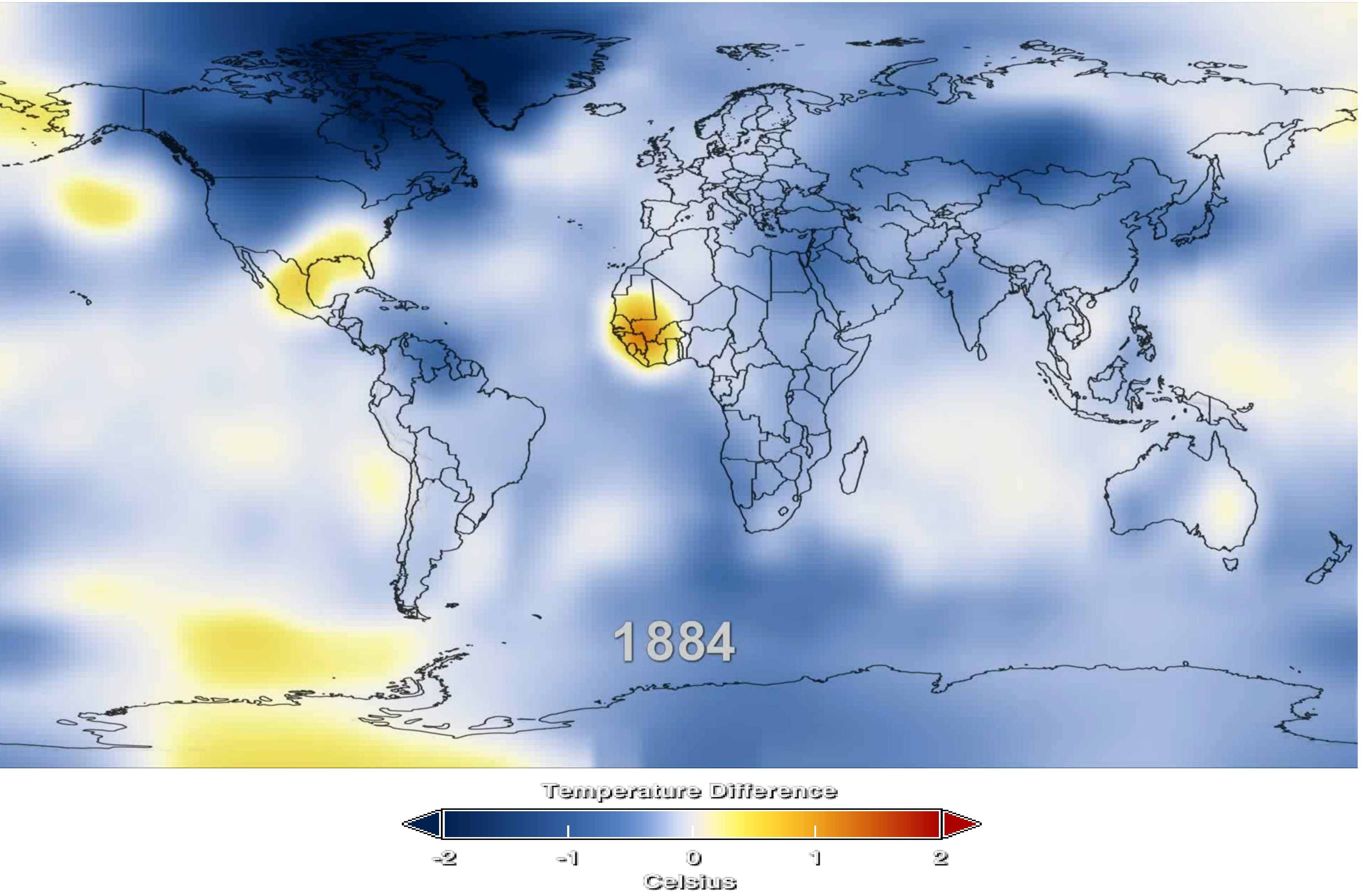
http://www.esrl.noaa.gov/gmd/ccgg/trends/

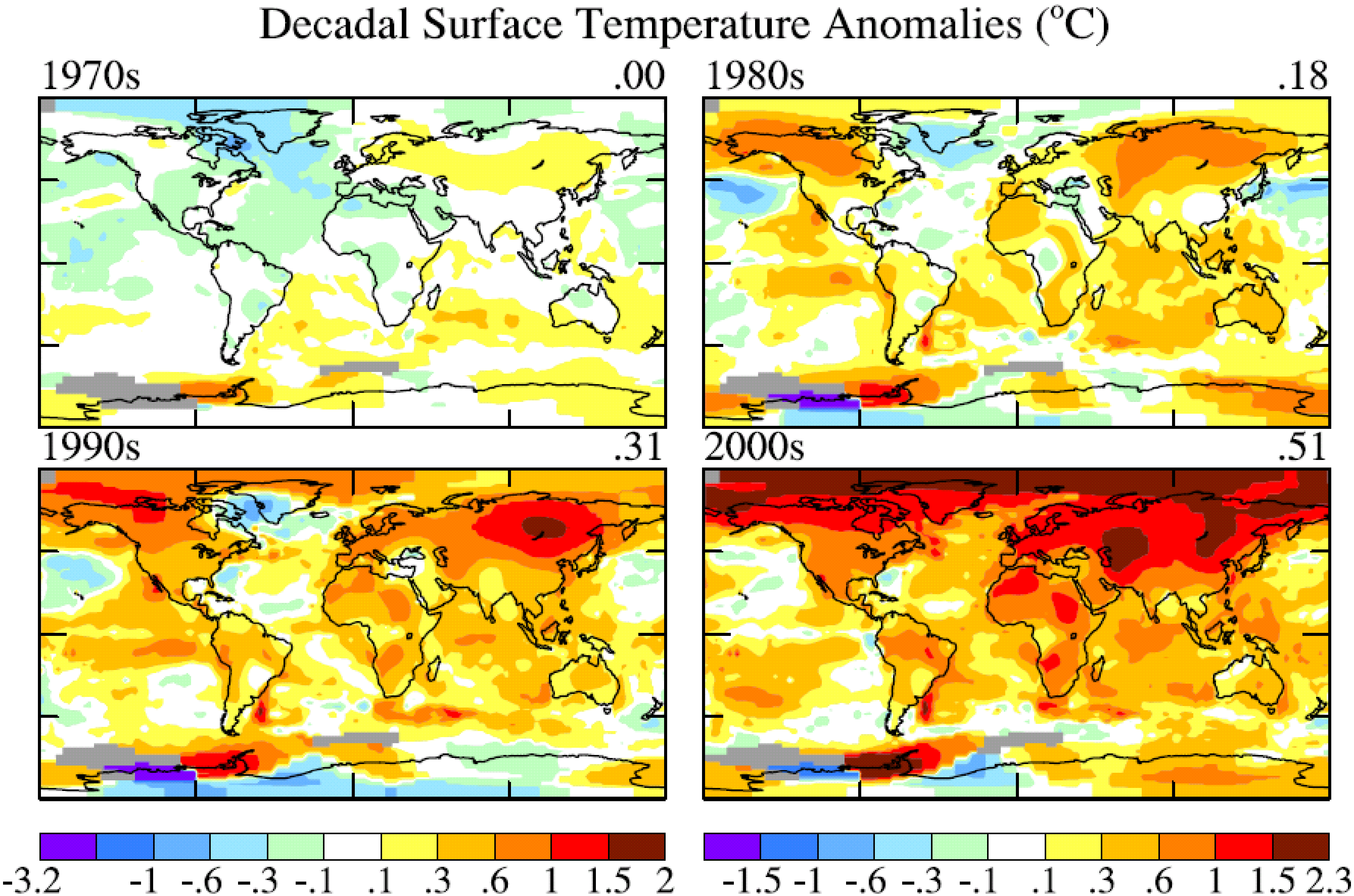
Global Land–Ocean Temperature Index



Hansen, J., Mki. Sato, R. Ruedy, K. Lo, D.W. Lea, and M. Medina-Elizade, 2006: Global temperature change. *Proc. Natl. Acad. Sci.*, **103**, 14288-14293, doi:10.1073/pnas.0606291103 http://data.giss.nasa.gov/gistemp/

Temperature anomalies relative to the base period 1951-1980.





Decadal mean surface temperature anomalies relative to base period 1951-1980.

Source: update of Hansen et al., GISS analysis of surface temperature change. *J. Geophys. Res.***104**, 30997-31022, 1999.

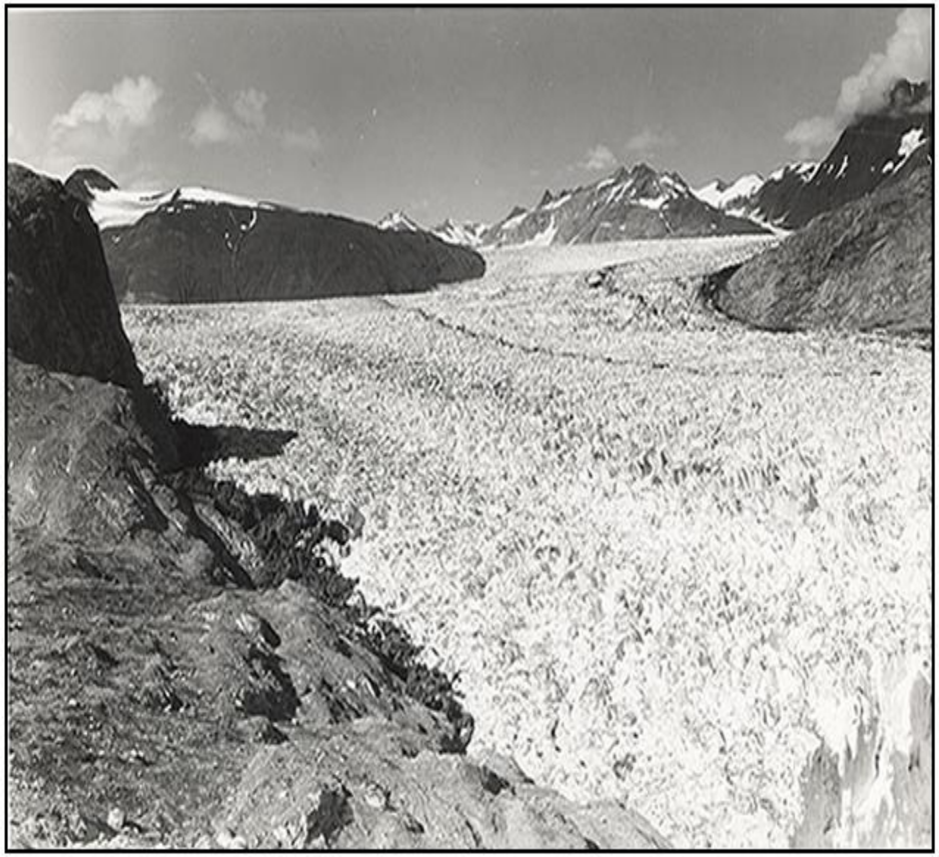
glacier d’Argentière

1864

1896

1995

Fily, 2006-ERCA

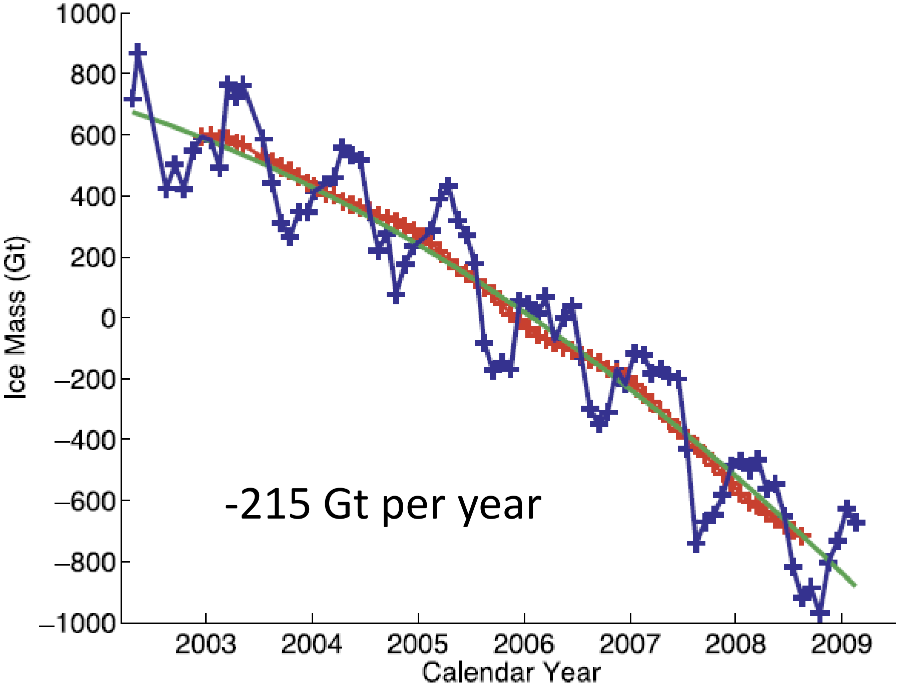


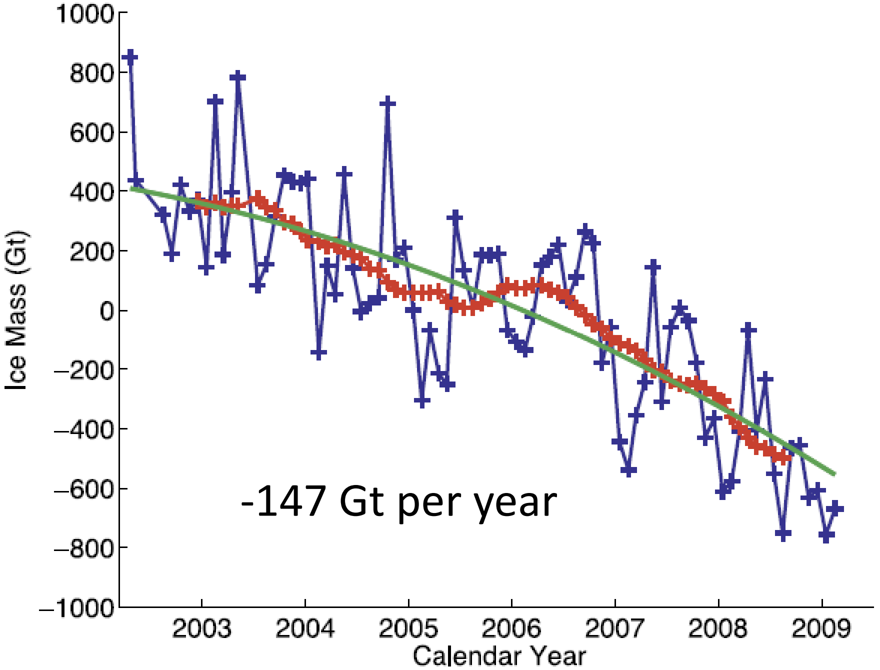
On the left is a photograph of Muir Glacier (Alaska) taken on August 13, 1941, by glaciologist William O. Field; on the right, a photograph taken from the same vantage on August 31, 2004, by geologist Bruce F. Molnia of the United States Geological Survey (USGS).

According to Molnia, between 1941 and 2004 the glacier retreated more than twelve kilometers (seven miles) and thinned by more than 800 meters.


TuoTuo-DangXiong-20aug05
2005 8 20

Gravity Satellite Ice Sheet Mass Measurements





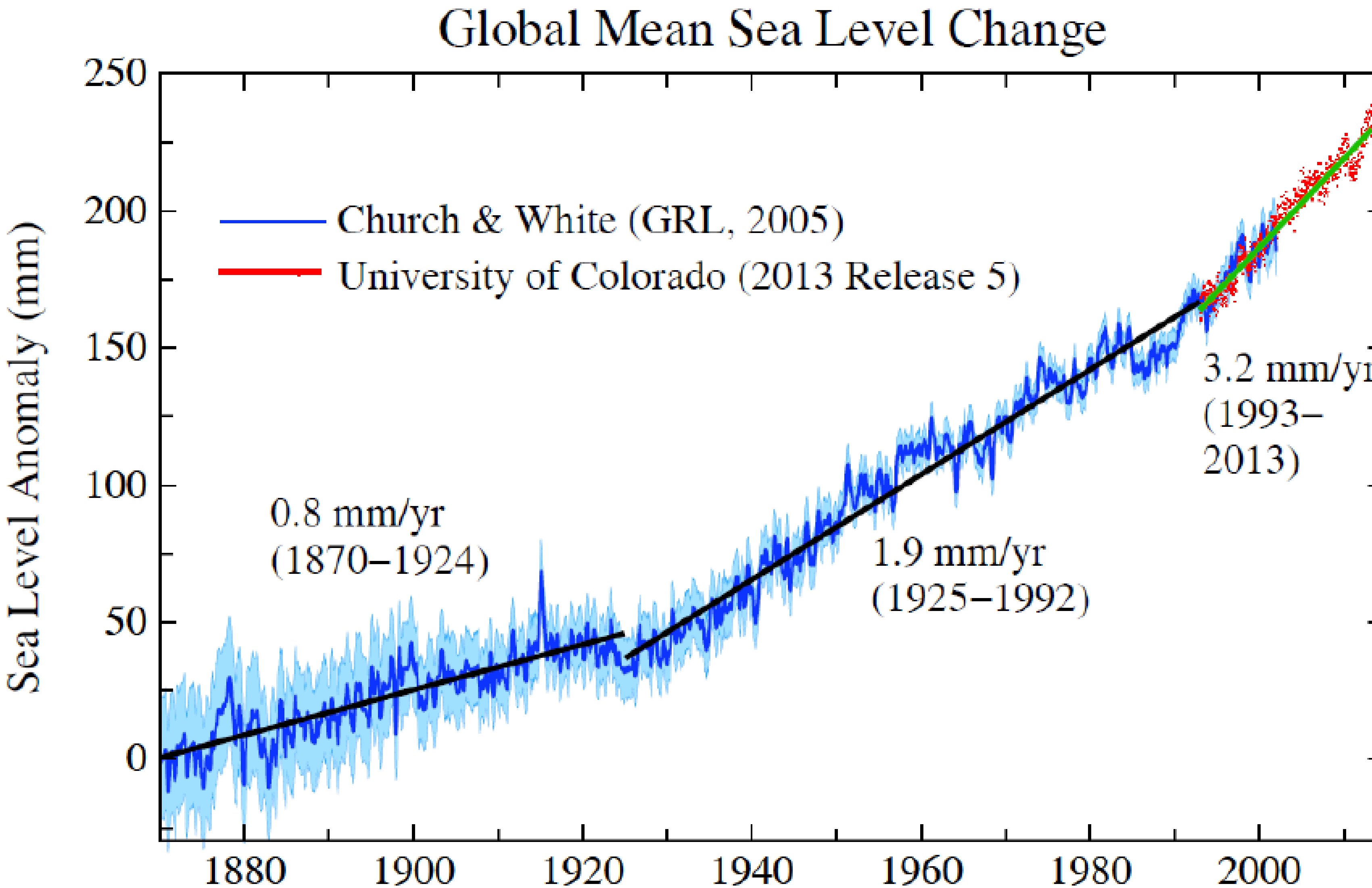
Greenland Ice Sheet

1.756.000 km^2 2.850.000 km^3
2.612.600 Gt

Antarctic Ice Sheet

14.000.000 km^2 26.600.000 km^3
24.384.000 Gt

Source: Velicogna, I. *Geophys. Res. Lett.*, **36**, L19503, doi:10.1029/2009GL040222, 2009
IPCC 2013 .5th Report



Accelerating rate of sea level rise during the past century.

Hansen, 2014. Symposium on a new type of Major Power relationship. Beijing, China.

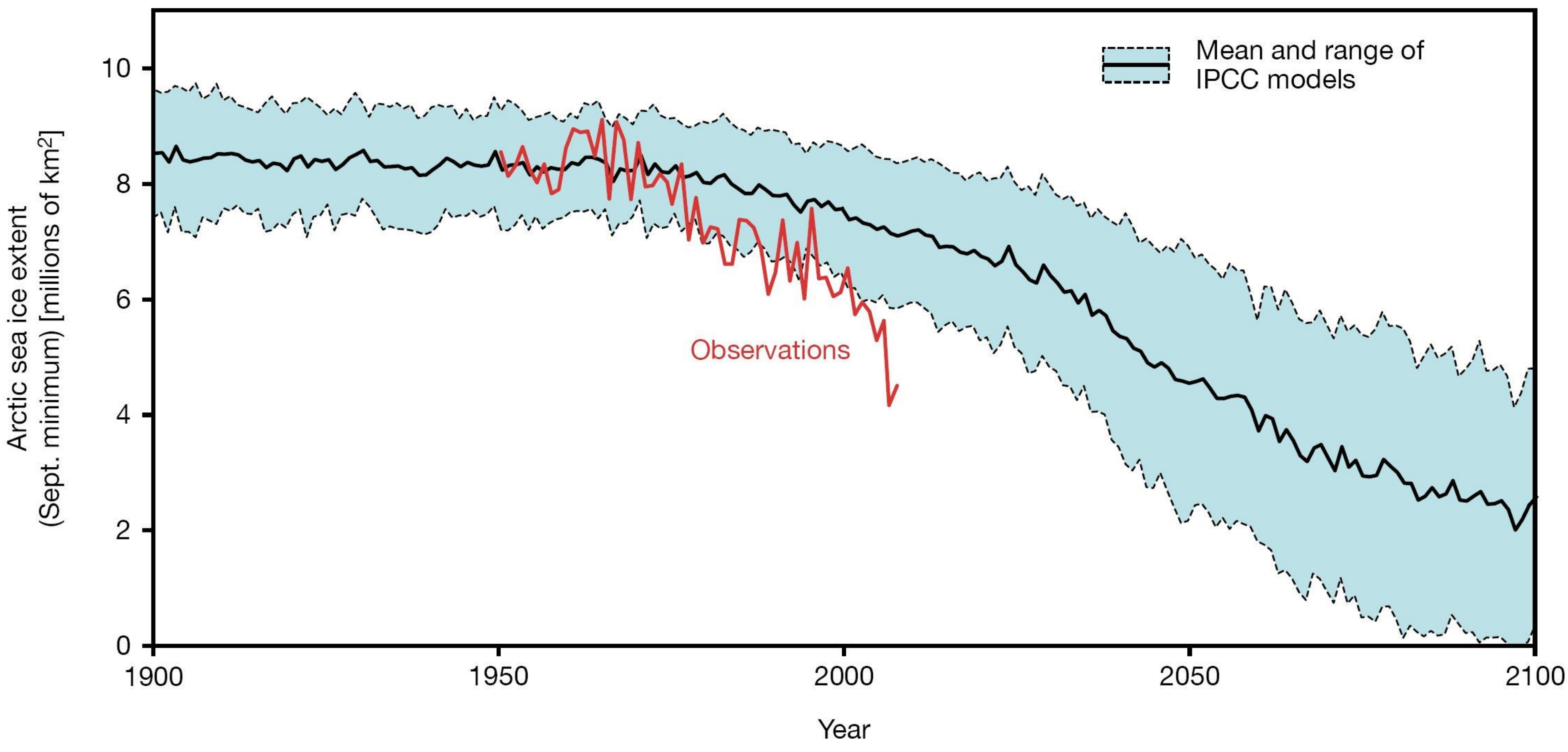
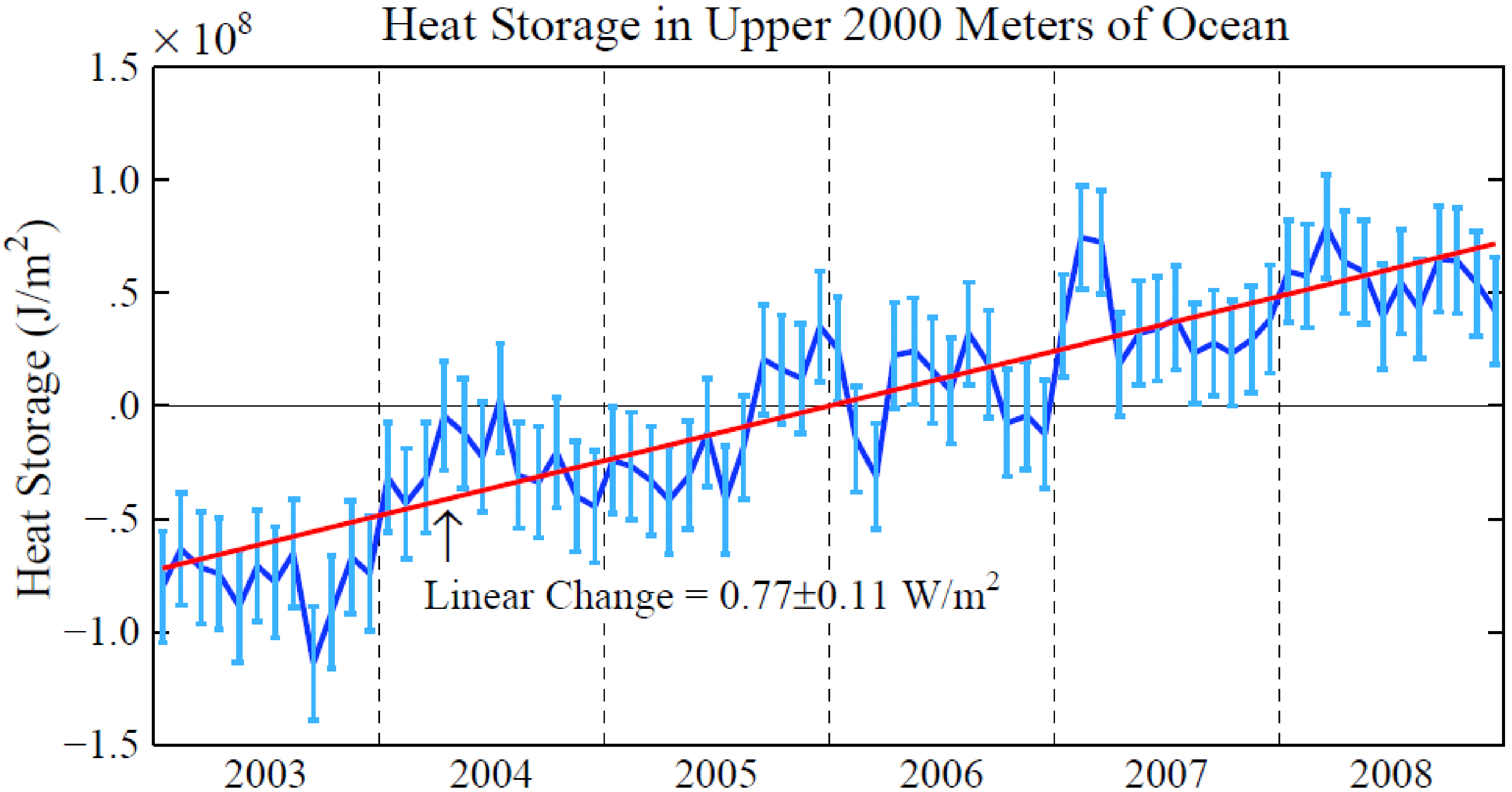


Figure 13: Observed and modeled min Arctic sea-ice extent (September)



Heat storage in upper 2000 meters of ocean during 2003-2008 based on ARGO data.

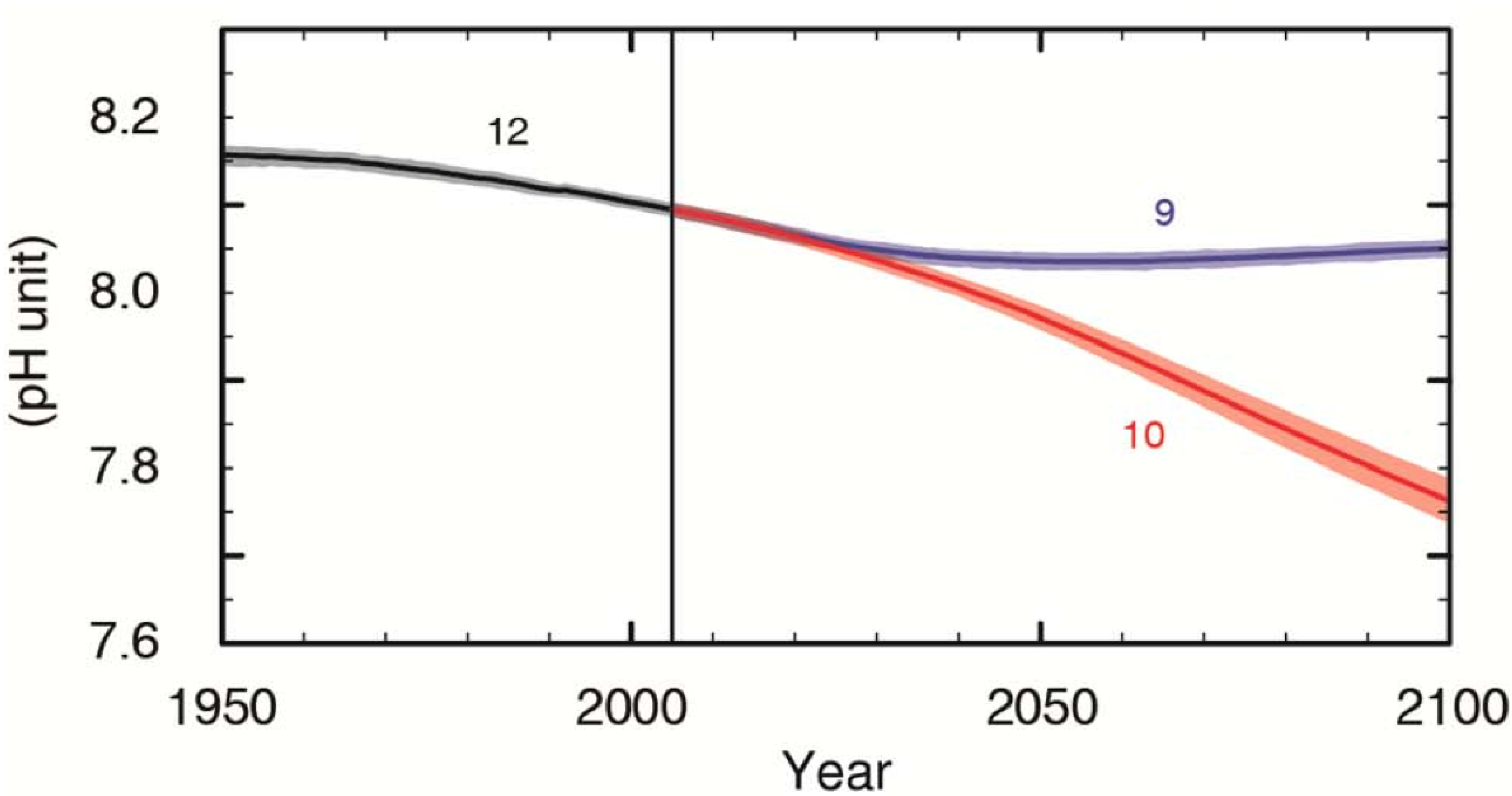
Knowledge of Earth's energy imbalance is improving rapidly as ARGO data lengthens.

Data must be averaged over a decade because of El Nino/La Nina and solar variability.

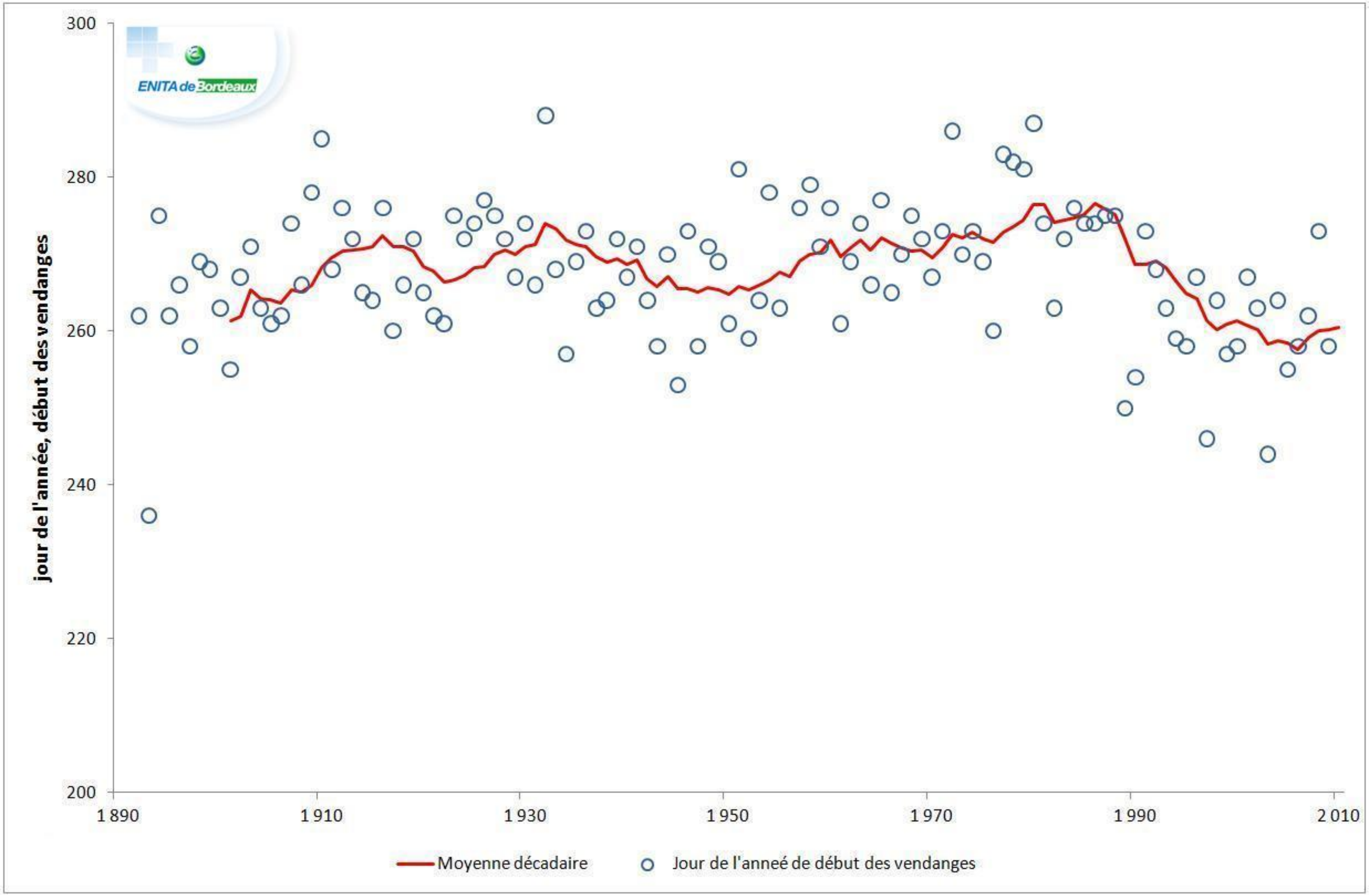
Energy imbalance is smoking gun for human-made increasing greenhouse effect.

Data source: von Schuckmann *et al. J. Geophys. Res.* **114**, C09007, 2009, doi:10.1029/2008JC005237.

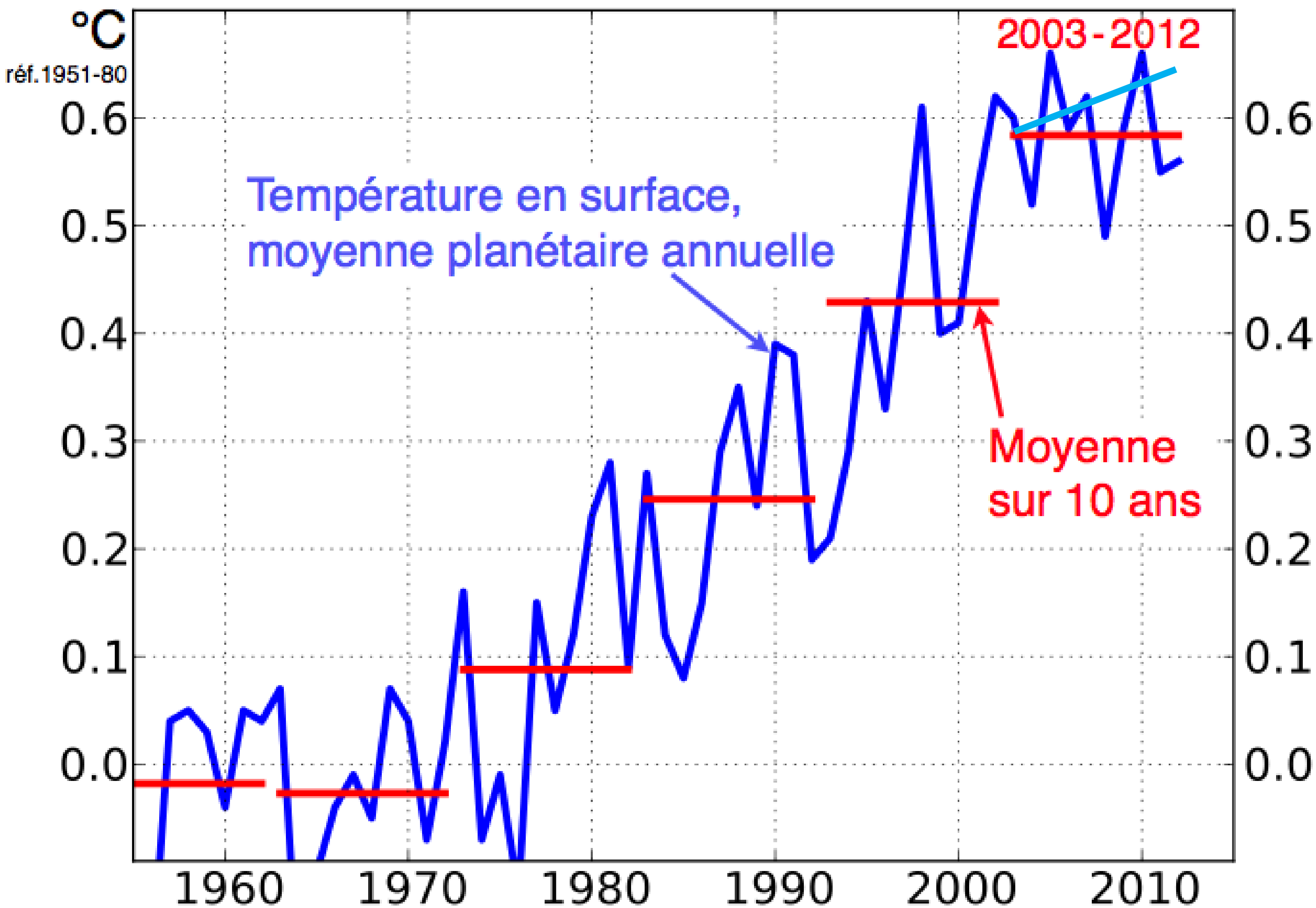
Ocean Acidification, for RCP 8.5 (orange) & RCP2.6 (blue)



Dates des vendanges à Saint Émilion



Revised 2013 with Arctic data



Données : NASA GISS, méthode publiée dans PNAS (Hansen et al. 2006). Graphe : UCL

Selon le GIEC, le hiatus pourrait être dû :

-à une lacune dans les observations de température dans l’Arctique

-à une absorption plus grande de chaleur par l’océan, voir à un transfer accru de chaleur vers l’océan profond

-à une activité volcanique accrue ou à une activité solaire faible

-à la variabilité naturelle liée ou non aux interactions atmosphère-océan (El-niño)

-à la décroissance de la vapeur d’eau stratosphérique ou des émissions de CHCs et du méthane

MAIS:

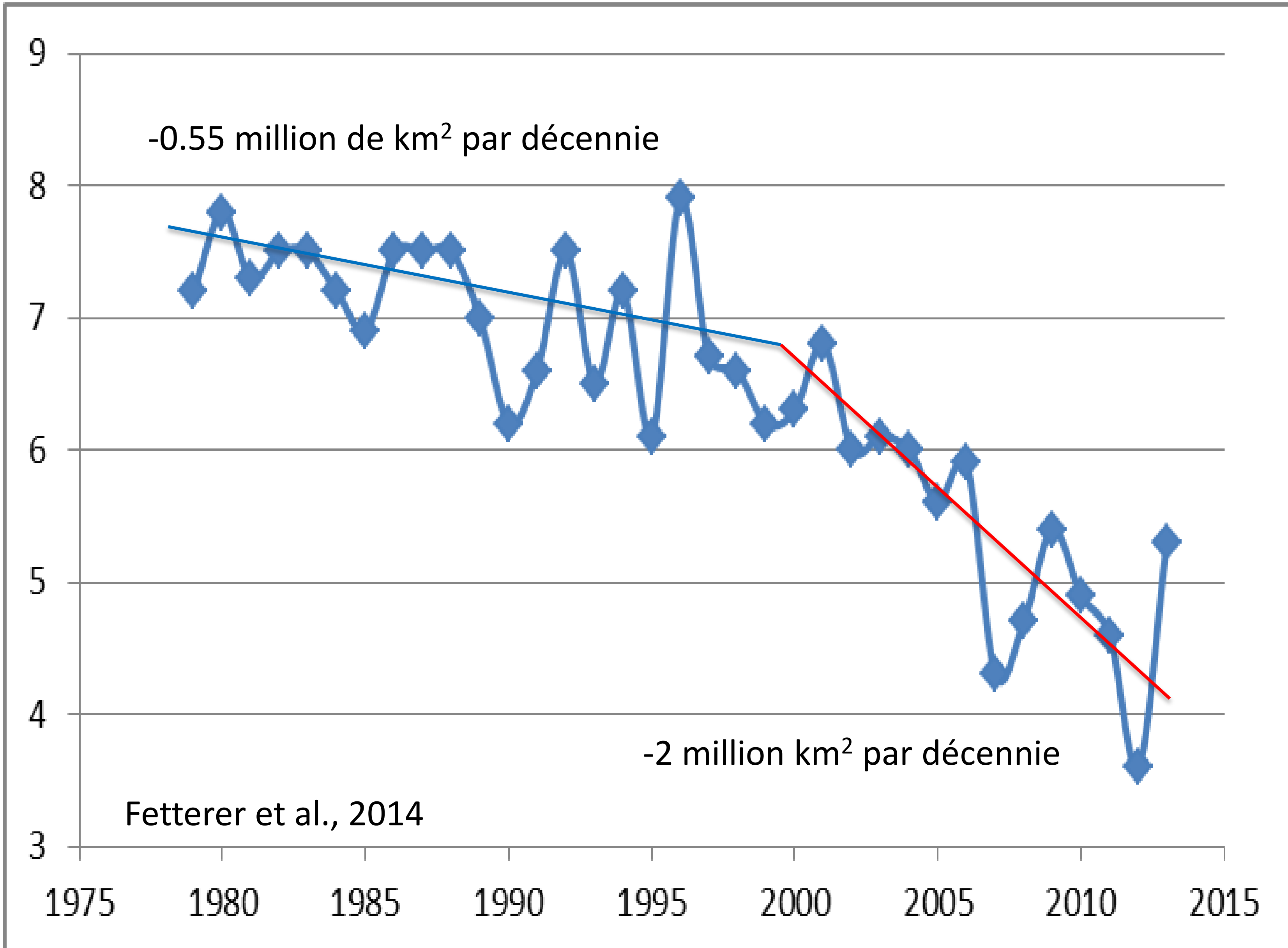
-le ralentissement du réchauffement allant de 0.26°C par décennie de 1984 à 1998 à 0.05 de 1998 à 2012 correspond à une enthalpie de 10^{20} J par an qui a pu être utilisée à d'autres fins que celle de réchauffer l'air

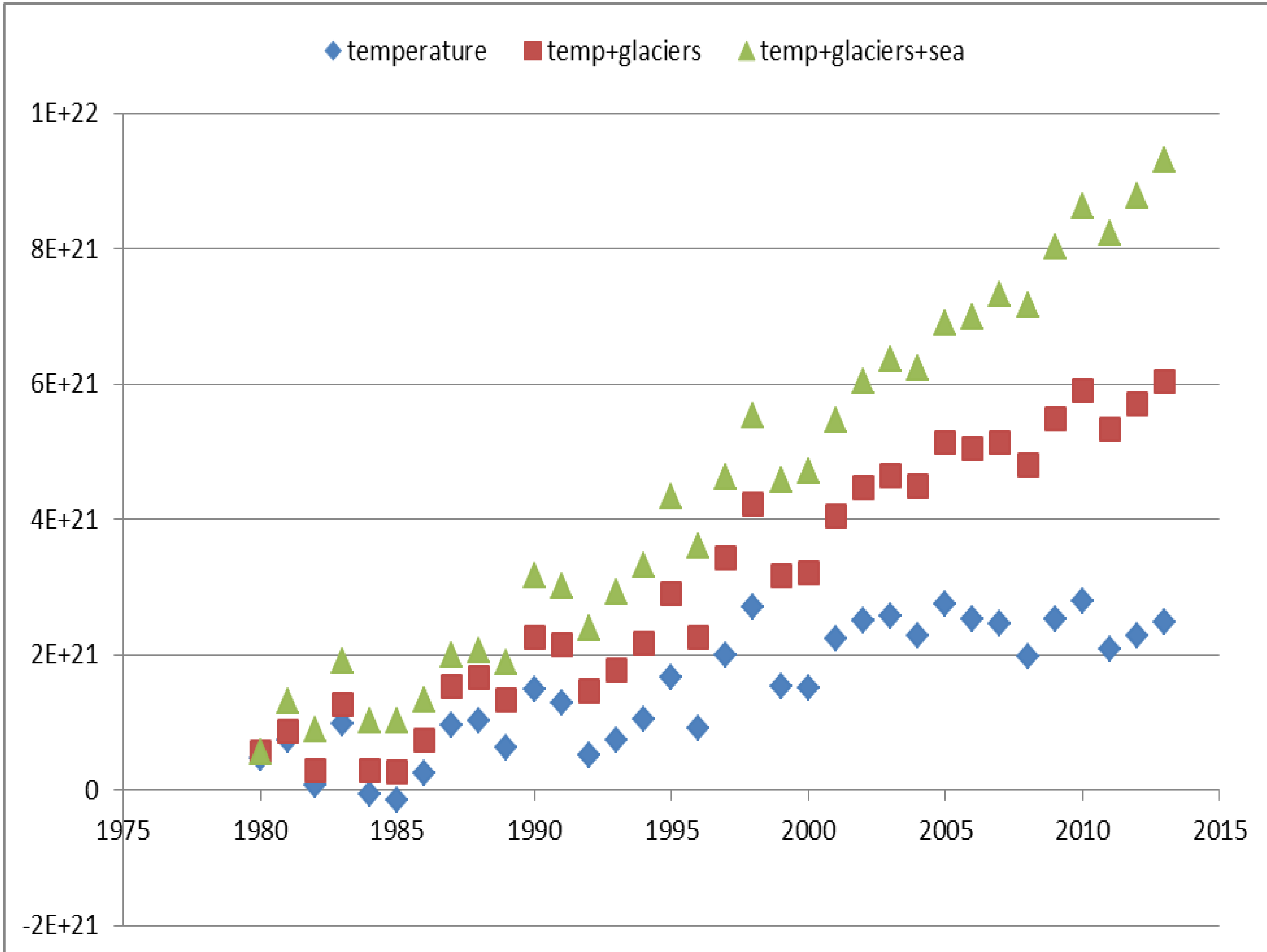
-en particulier pour fondre la moitié des 1300 Gt de glace qui ont disparu sur la même période, cette contribution de l'atmosphère à une telle fonte nécessitant 2×10^{20} J par an

-dans ces conditions le hiatus expliquerait 25% de la fonte des glaces avec comme conséquence une continuation de ce ralentissement du réchauffement tant que la glace pourra fondre, en particulier les glaciers et la glace de mer dans l'Océan Arctique

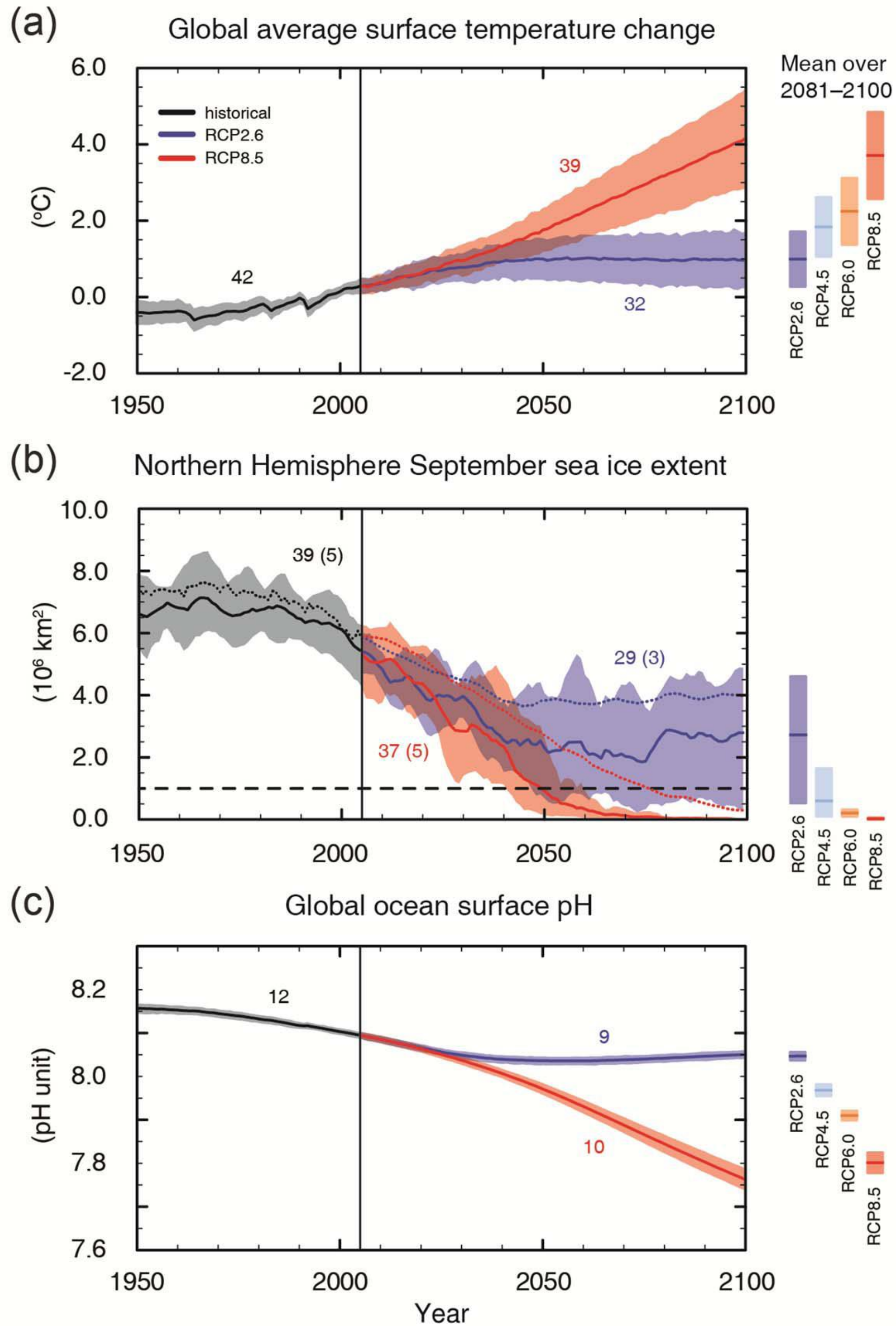
Berger, Nifenecker, Poitou, Yin, 2014

Glace de mer au-dessus de l'Arctique





Berger,Nifenecker, Poitou, Yin, 2014


(a)
Global average surface temperature change
Mean over
2081–2100
historical
RCP2.6
RCP8.5
(°C)
6.0
4.0
2.0
0.0
-2.0
39
42
32
1950
2000
2050
2100
RCP2.6
RCP4.5
RCP6.0
RCP8.5
(b)
Northern Hemisphere September sea ice extent
10.0
8.0
6.0
4.0
2.0
0.0
(10^6 km^2)
39 (5)
29 (3)
37 (5)
1950
2000
2050
2100
RCP2.6
RCP4.5
RCP6.0
RCP8.5
(c)
Global ocean surface pH
8.2
8.0
7.8
7.6
(pH unit)
12
9
10
1950
2000
2050
2100
Year
RCP2.6
RCP4.5
RCP6.0
RCP8.5

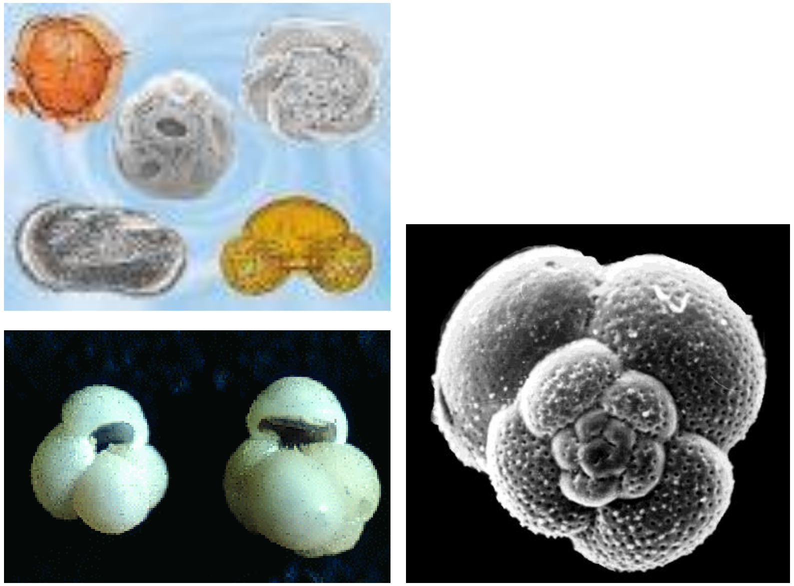
IPCC, 2013

QUE NOUS

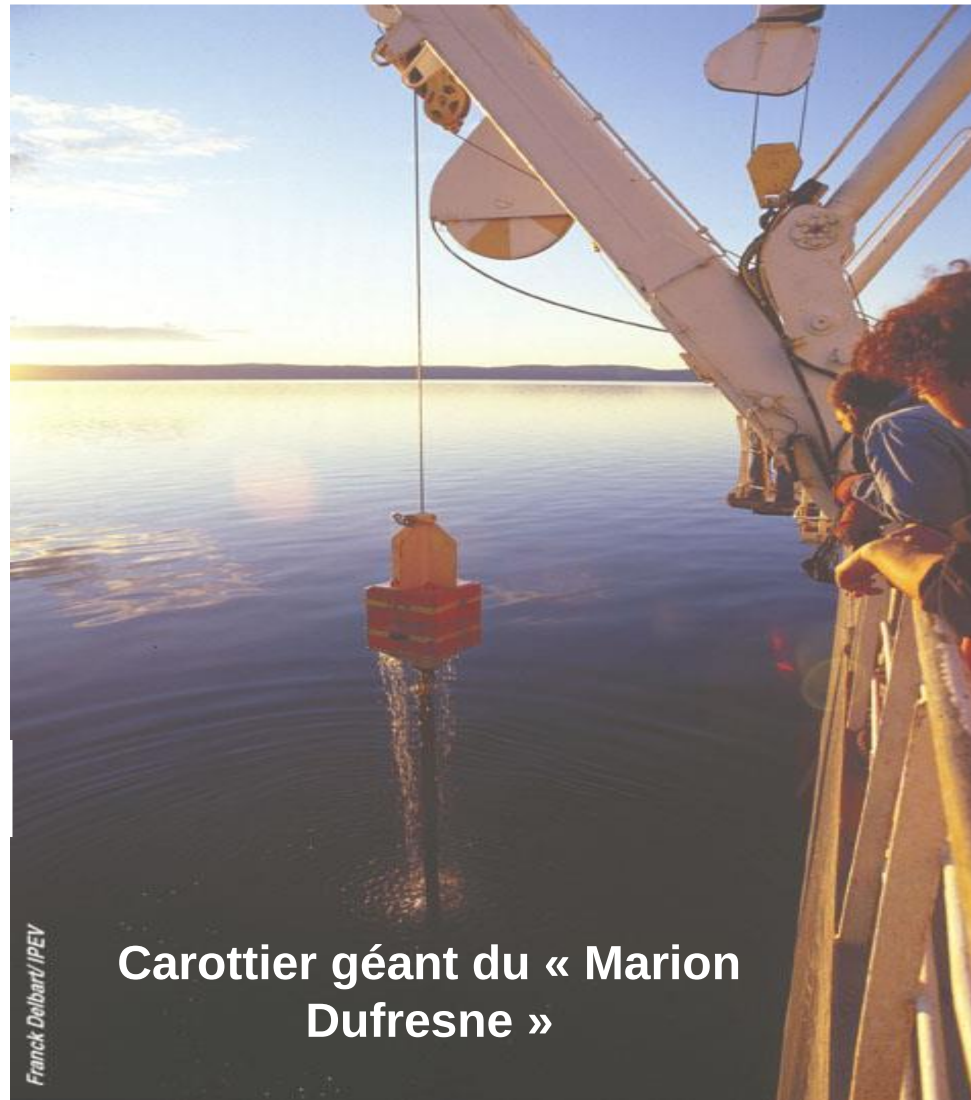
APPREND LE PASSÉ?

Site de EPICA Dome C

Enregistrements marins



Navire de recherche
« Marion Dufresne »
Institut Polaire Français
IPEV



Quaternary loess-soil sequences in northern China

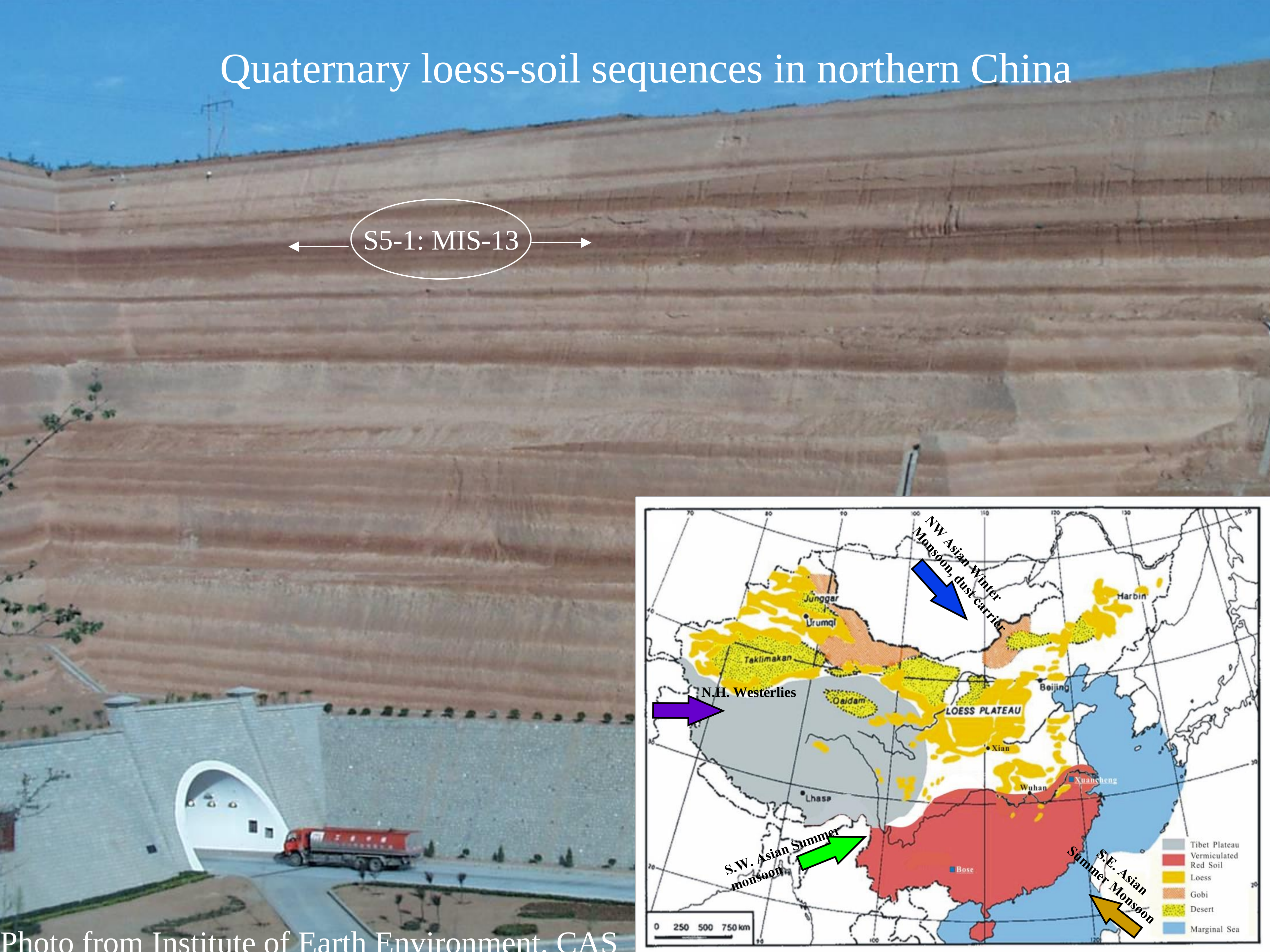
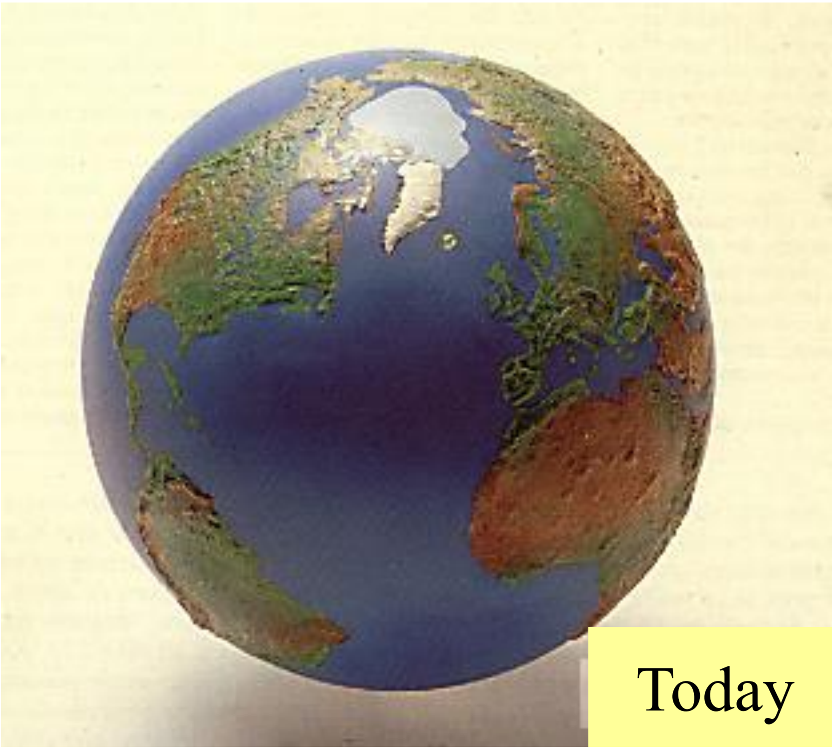
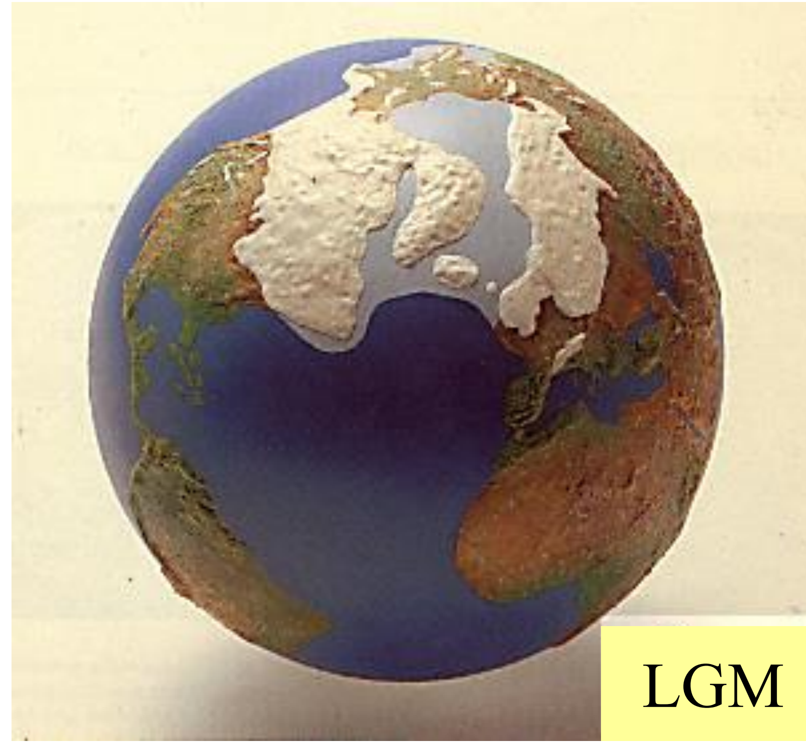


Photo from Institute of Earth Environment, CAS

Last Glacial Maximum 21kyr BP





Pre-industrial CO_2 = 280 ppmv

2000 AD CO_2 = 370 ppmv

2014 AD CO_2 = 400 ppmv

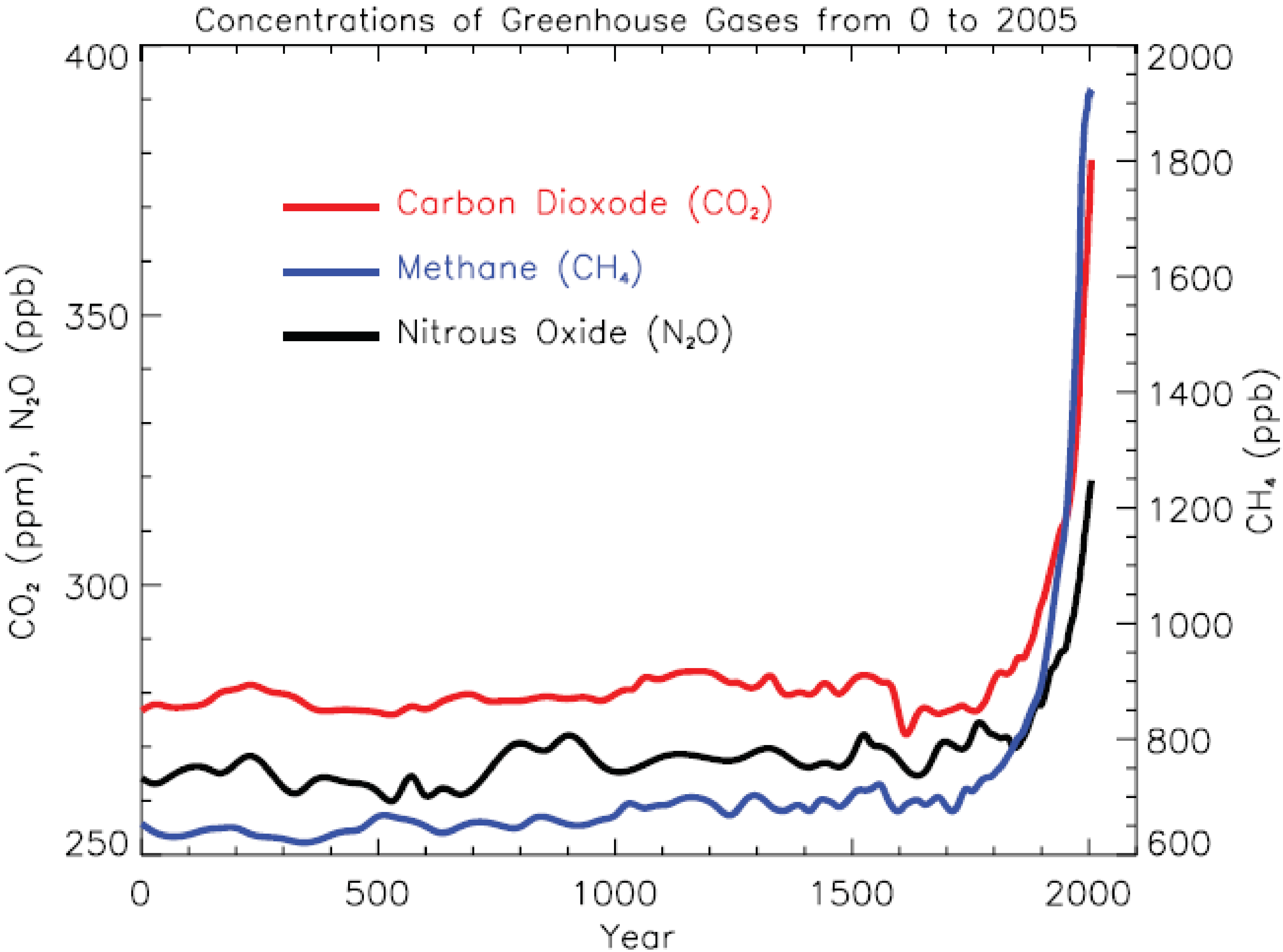
ΔT=-5°C

Δsea level = –130m

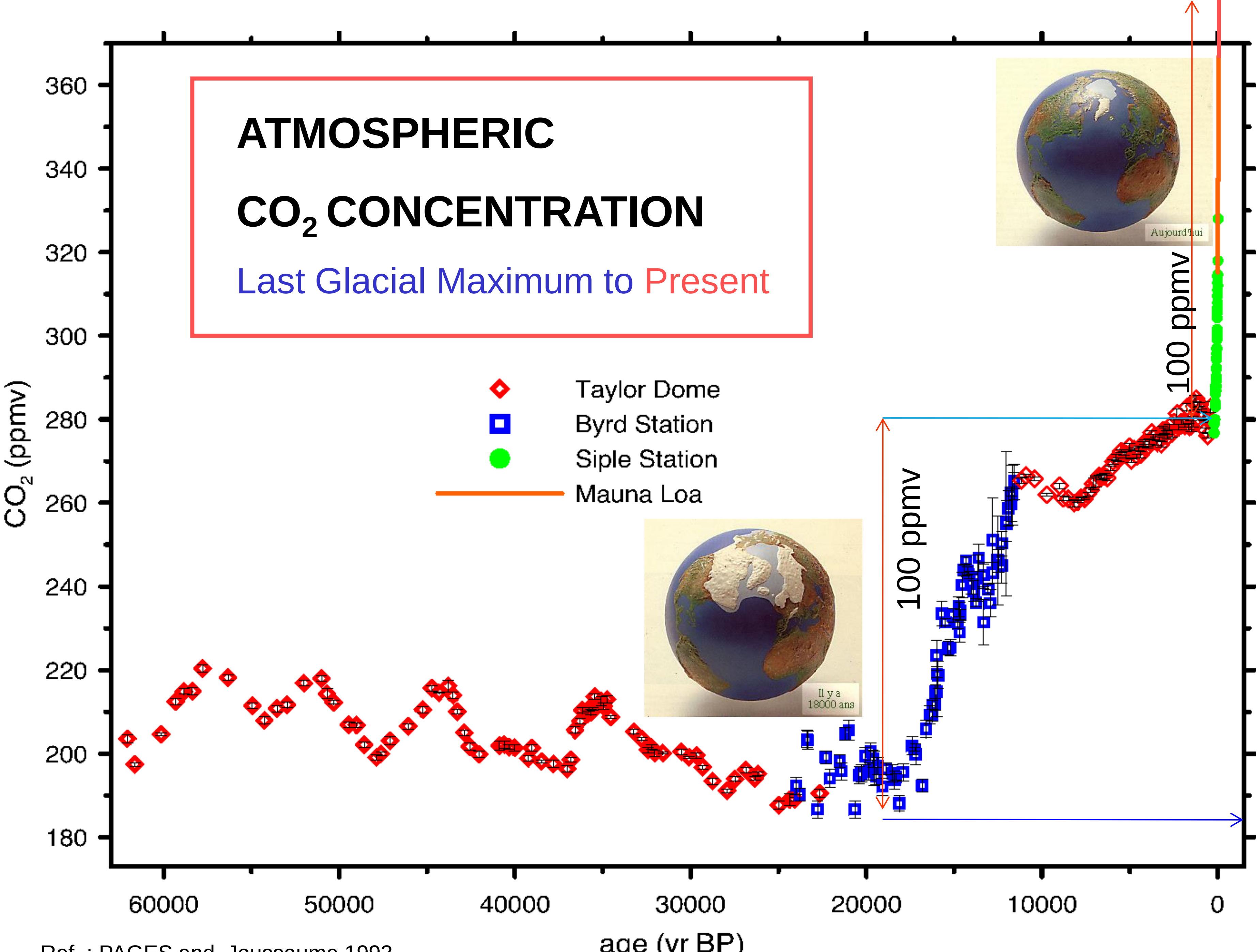
Δice volume = +52 $10^6 km^3$

CO_2 = 200 ppmv

(Joussaume, 1993)



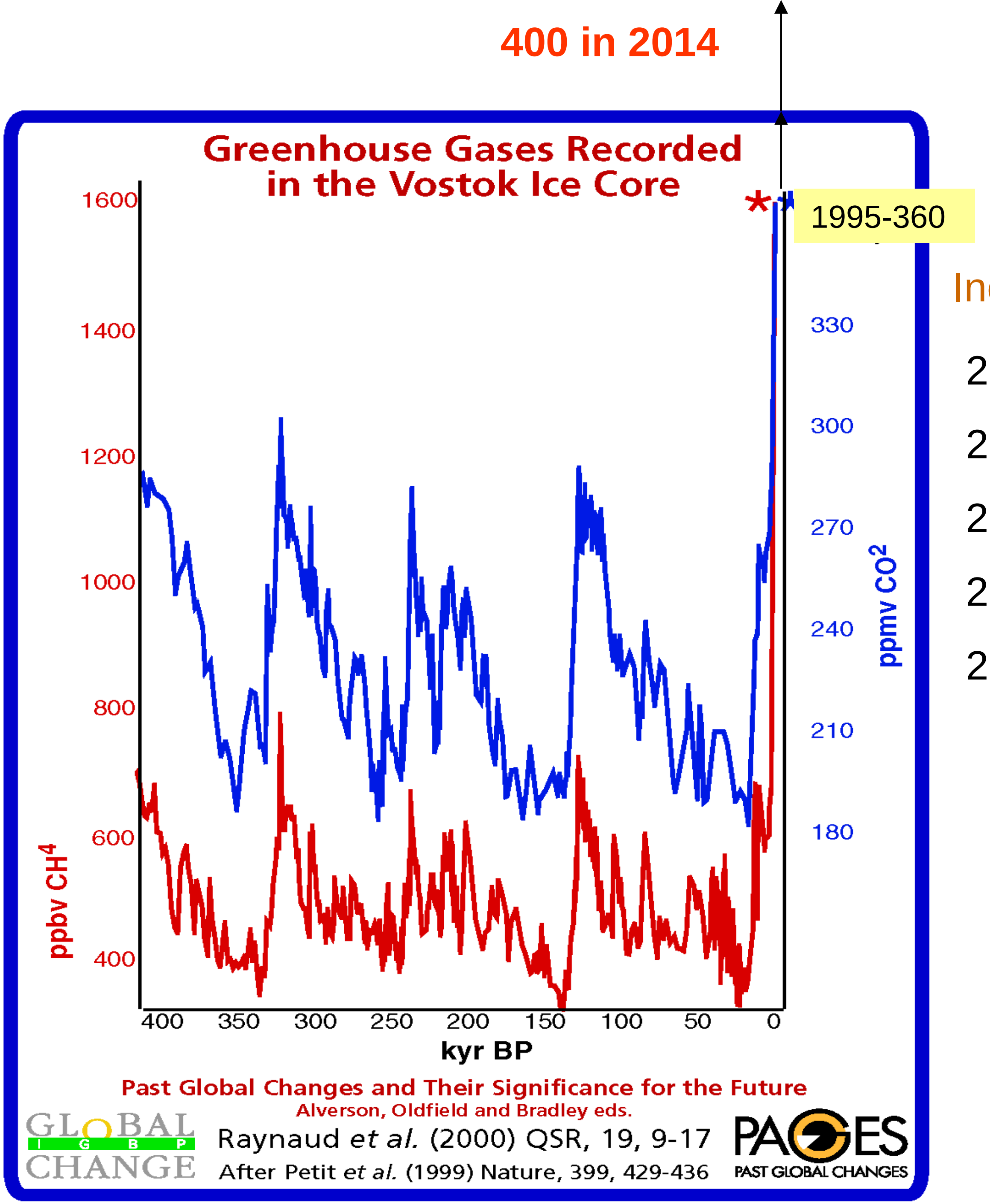
Concentrations of Greenhouse Gases from 0 to 2005
Carbon Dioxode (CO_2)
Methane (CH_4)
Nitrous Oxide (N_2O)
CO_2 (ppm), N_2O (ppb)
CH_4 (ppb)
Year
400
350
300
250
2000
1800
1600
1400
1200
1000
800
600
0
500
1000
1500
2000



Ref. : PAGES and Joussaume,1993

http://www.climate;unibe.ch/gallery_co2.html

In 2003 : 465 ppmv CO_{2eq}



Increase rate

2000 : 1.62

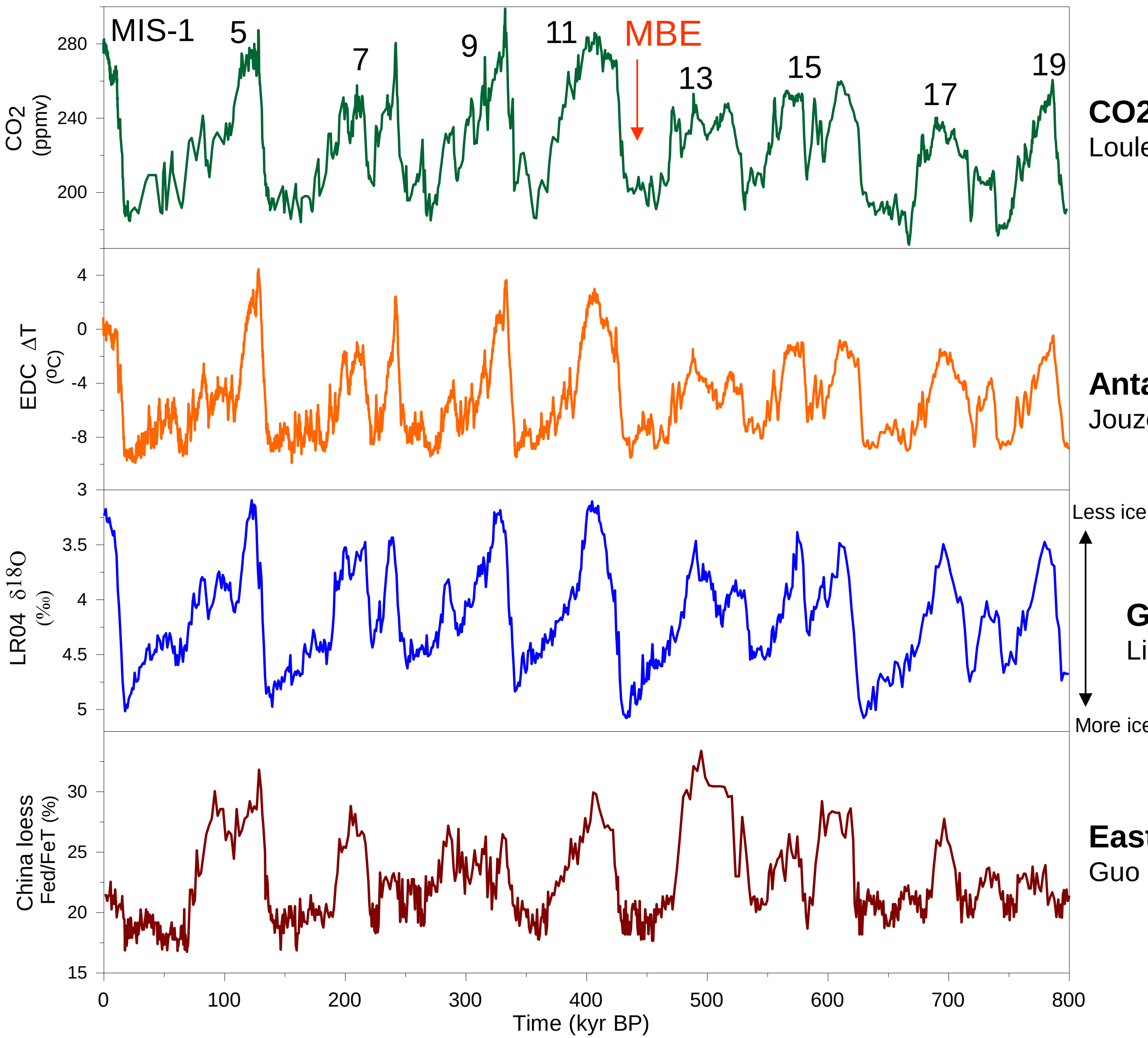
2001 : 1.58

2002 : 2.53

2012 : 2.66

2013 : 2.05

Interglacial diversity in time and space

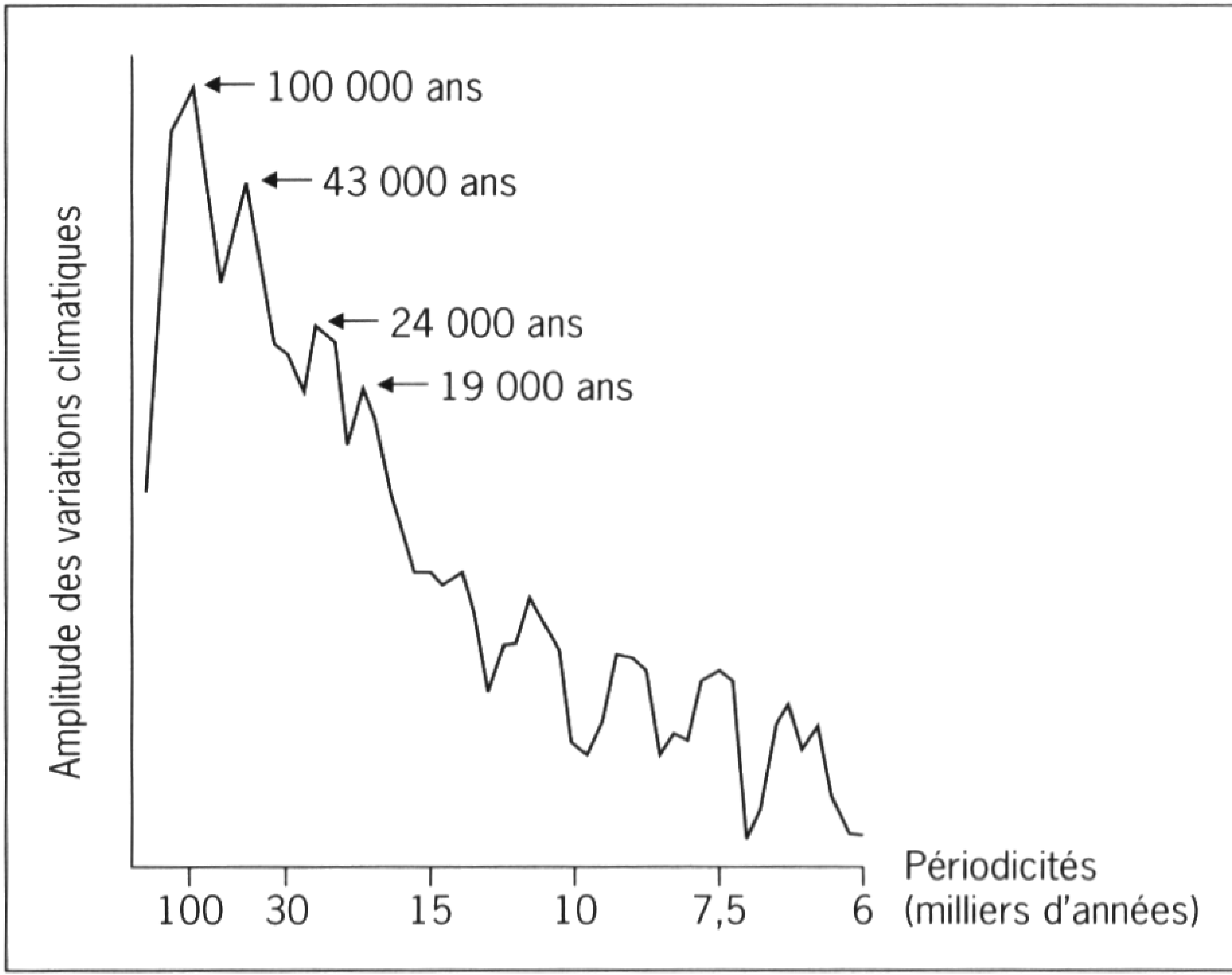


CO2 Concentration
Loulergue et al., 2008

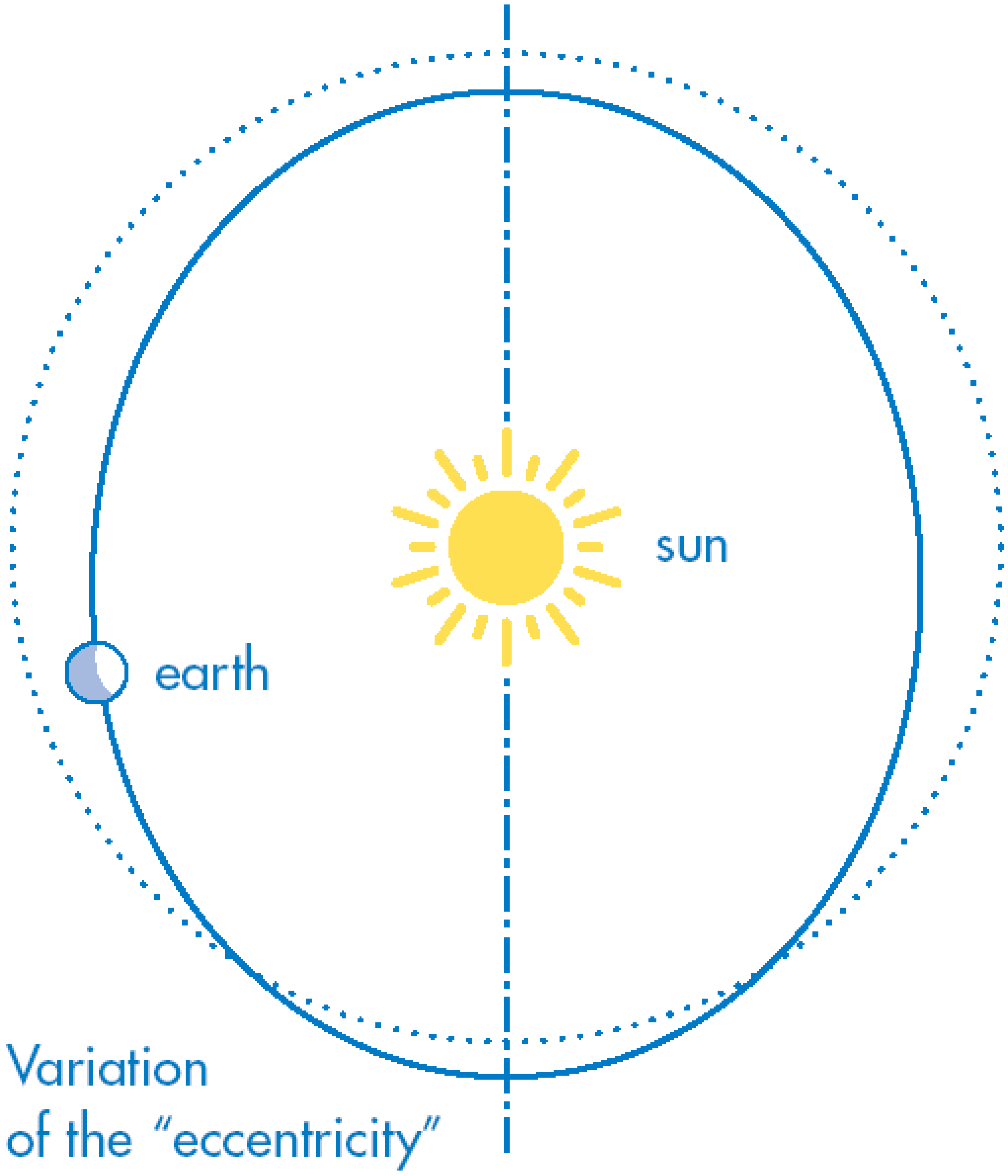
Antarctica temperature
Jouzel et al., 2007;

Global ice volume
Lisiecki and Raymo, 2005

East Asian summer monsoon
Guo et al., 2009



Hays, Imbrie, Shackleton, 1976

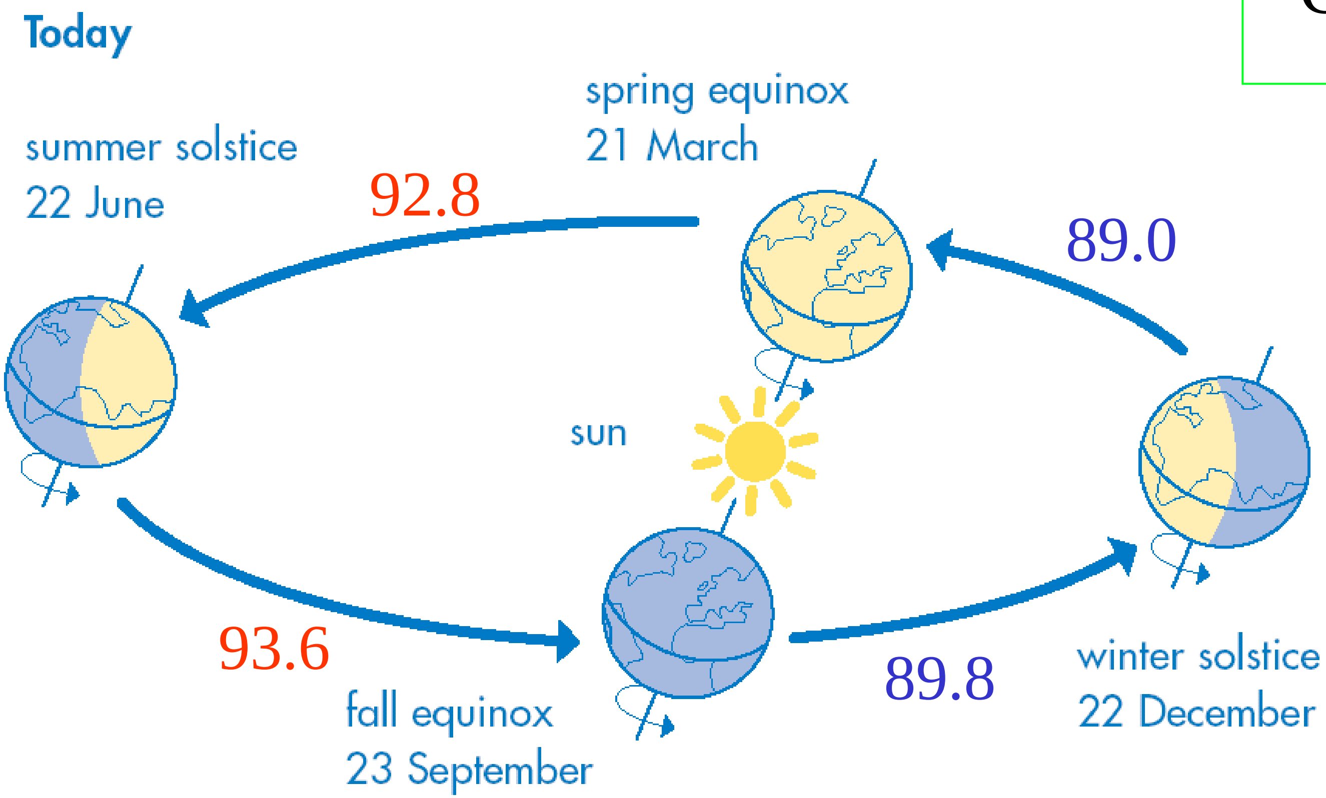


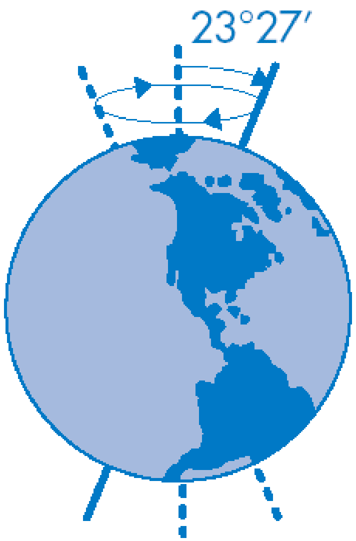
100 kyr
Excentricity
Cycle

Berger, ORBIT-ECC-LATSIS,2001

The 21 kyr Precession Cycle

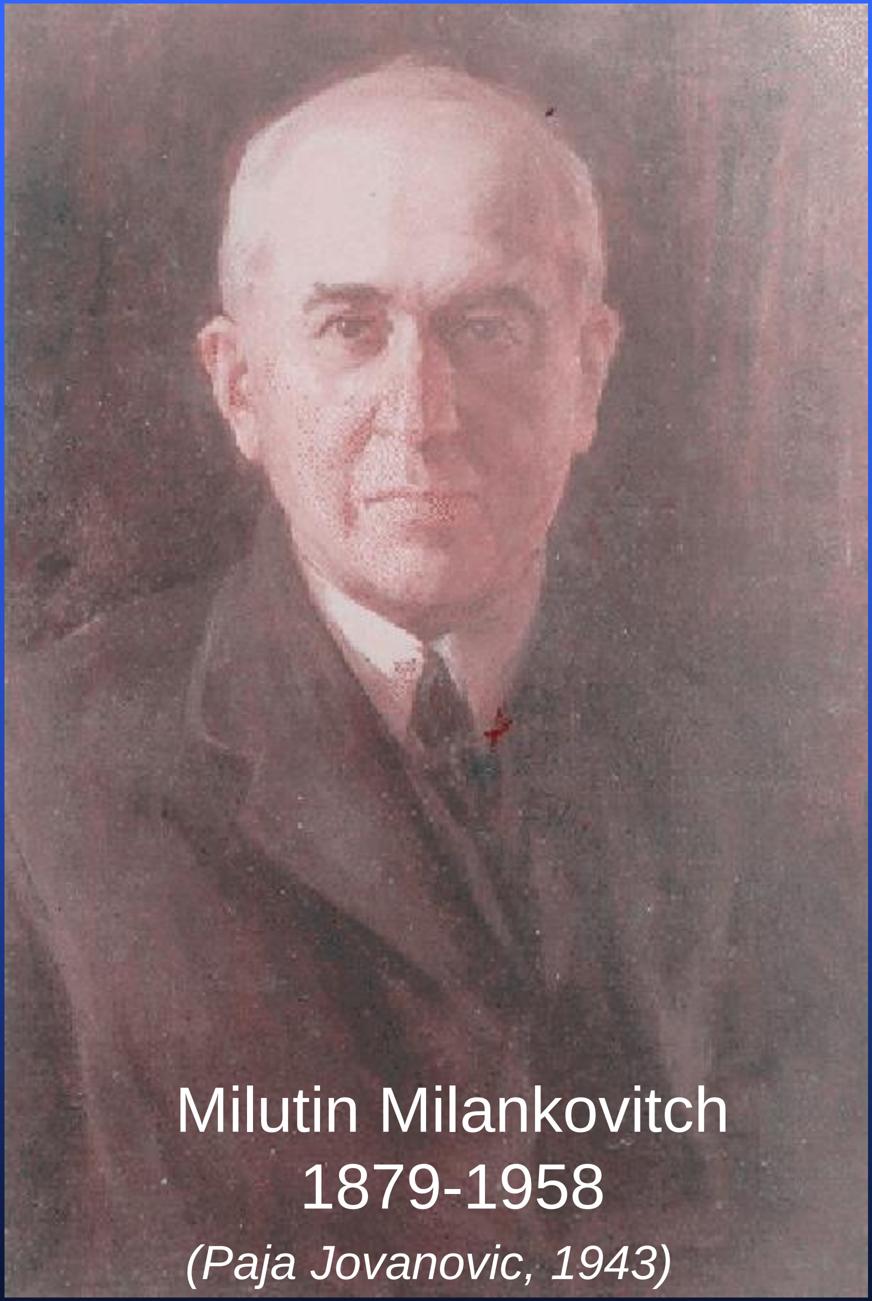
The 41 kyr Obliquity Cycle





Berger, ORBIT-O-LATSIS,2001

André Berger
Institut d'Astronomie et de Géophysique Georges Lemaître
berger@astr.ucl.ac.be
UCL Université catholique de Louvain



Milutin Milankovitch
1879-1958
(Paja Jovanovic, 1943)

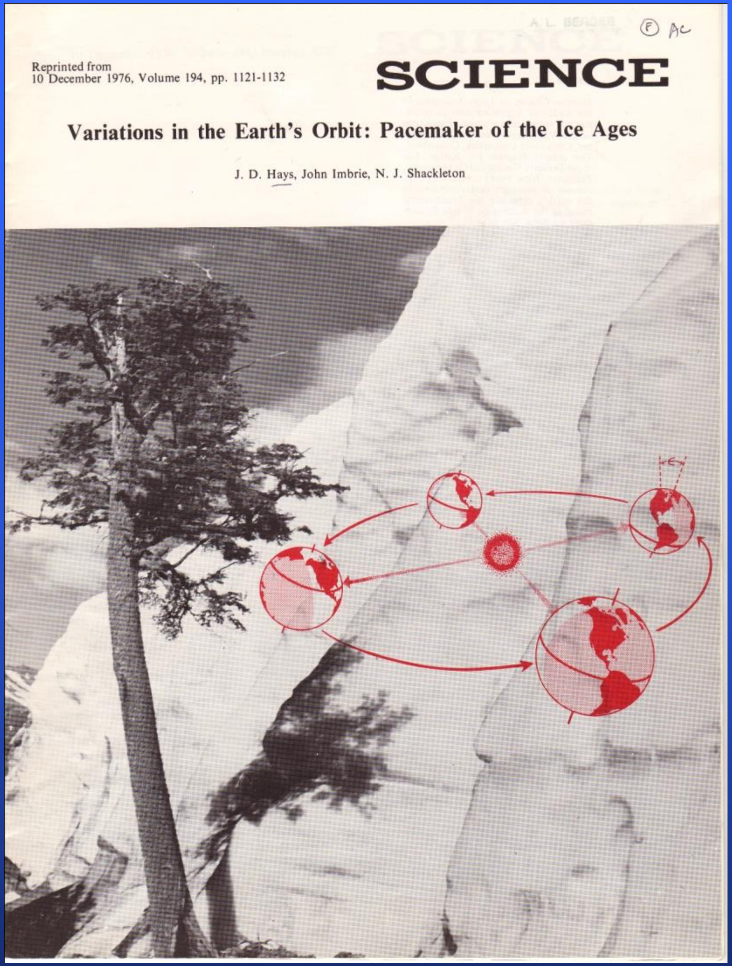
berger@astr.ucl.ac.be
André Berger
Georges Lemaître Center for Earth and Climate Research
UCL
Université catholique de Louvain

RENAISSANCE of MILANKOVITCH

J. HAYS, V. MILANKOVITCH, J. IMBRIE, A. BERGER, N. SHACKLETON

Lamont December 1982

(1)



Reprinted from
10 December 1976, Volume 194, pp. 1121-1132

SCIENCE

Variations in the Earth's Orbit: Pacemaker of the Ice Ages

J. D. Hays, John Imbrie, N. J. Shackleton

FUNDAMENTAL FREQUENCIES

Long-Term Variations of Daily Insolation and Quaternary Climatic Changes

ANDRÉ L. BERGER[1]

Institut d'Astronomie et de Geophysique, Universite Catholique de Louvain, 1348 Louvain-la-Neuve, Belgium

15 February 1978 and 18 September 1978

ABSTRACT

The first part of this note provides all trigonometrical formulas which allow the direct spectral analysis and the computation of those long-term variations of the earth's orbital elements which are of primary interest for the computation of the insolation. The elements are the eccentricity, the longitude of the perihelion, the precessional parameter and the obliquity. This new formulary is much more simple to use than the ones previously designed and still provides excellent accuracy, mainly because it takes into account the influence of the most importan' hig'ier order terms in the series expansions. The second part is devoted to the computation of the daily insolation both for calendar and solar dates.

Climatic precession	Obliquity	Eccentricity
23716	41000	412885
22428	39730	94945
18976	53615	123297
19155	40521	99590
19261	28910	131248
23293	41843	2305441
18873	29678	102535
16907	40190	1306618
22818	42354	136412
19445	30365	603630

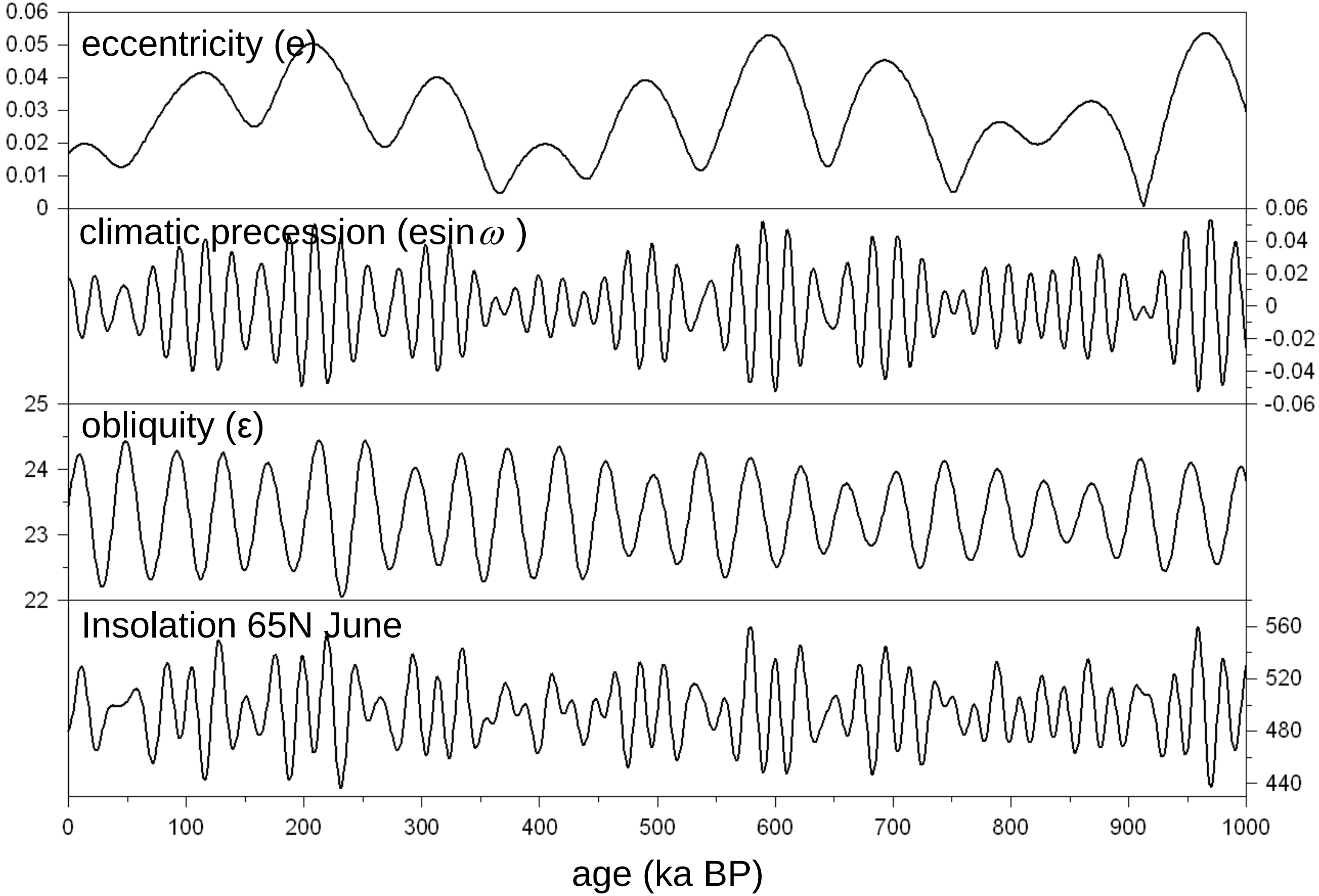
berger@astr.ucl.ac.be

André Berger

Georges Lemaître Center for Earth and Climate Research

UCL Université catholique de Louvain

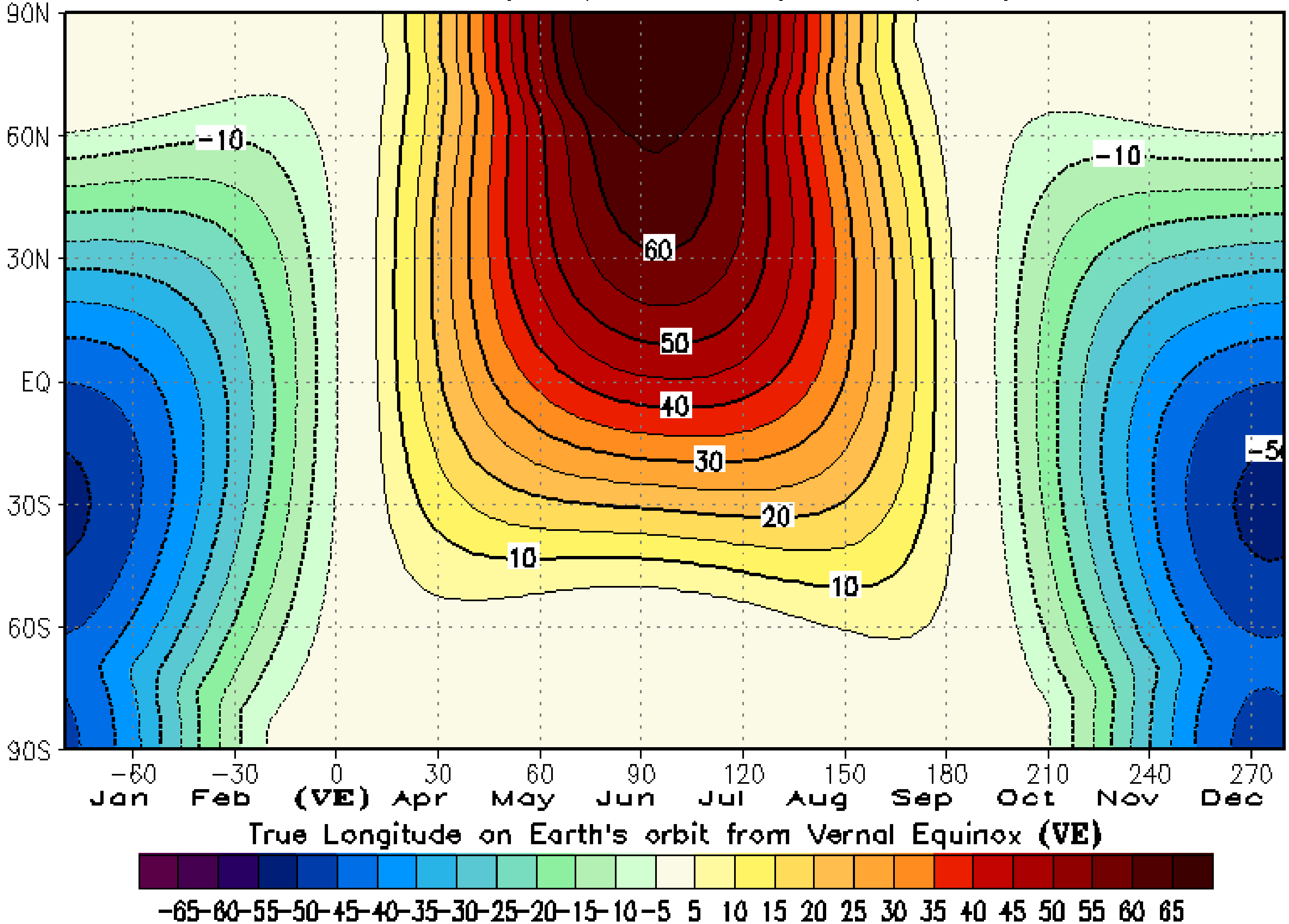
Astronomical forcing



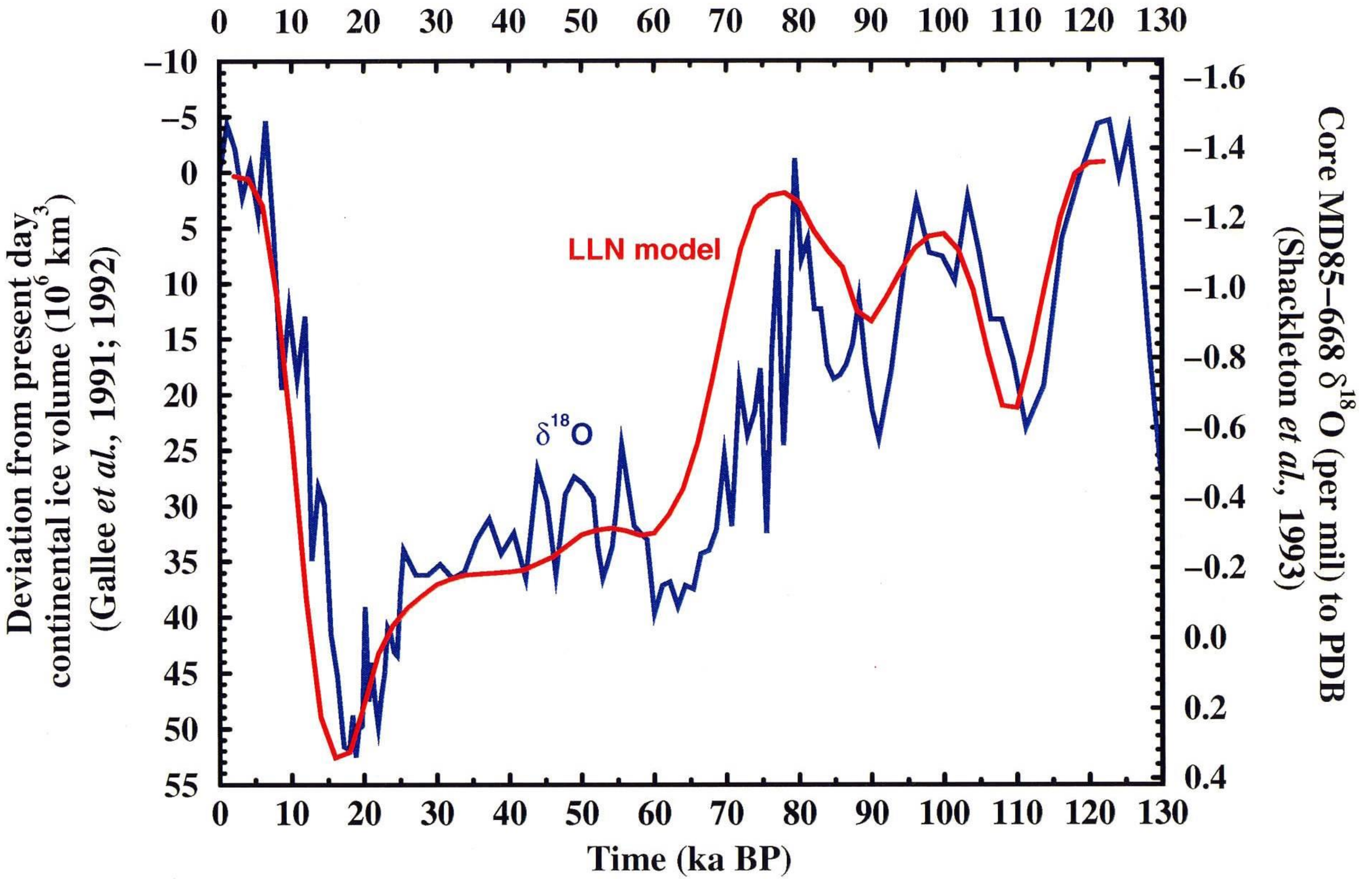
Berger, 1978

Insolation (Berger 1978): latitude/orbit distribution [Wm⁻²]

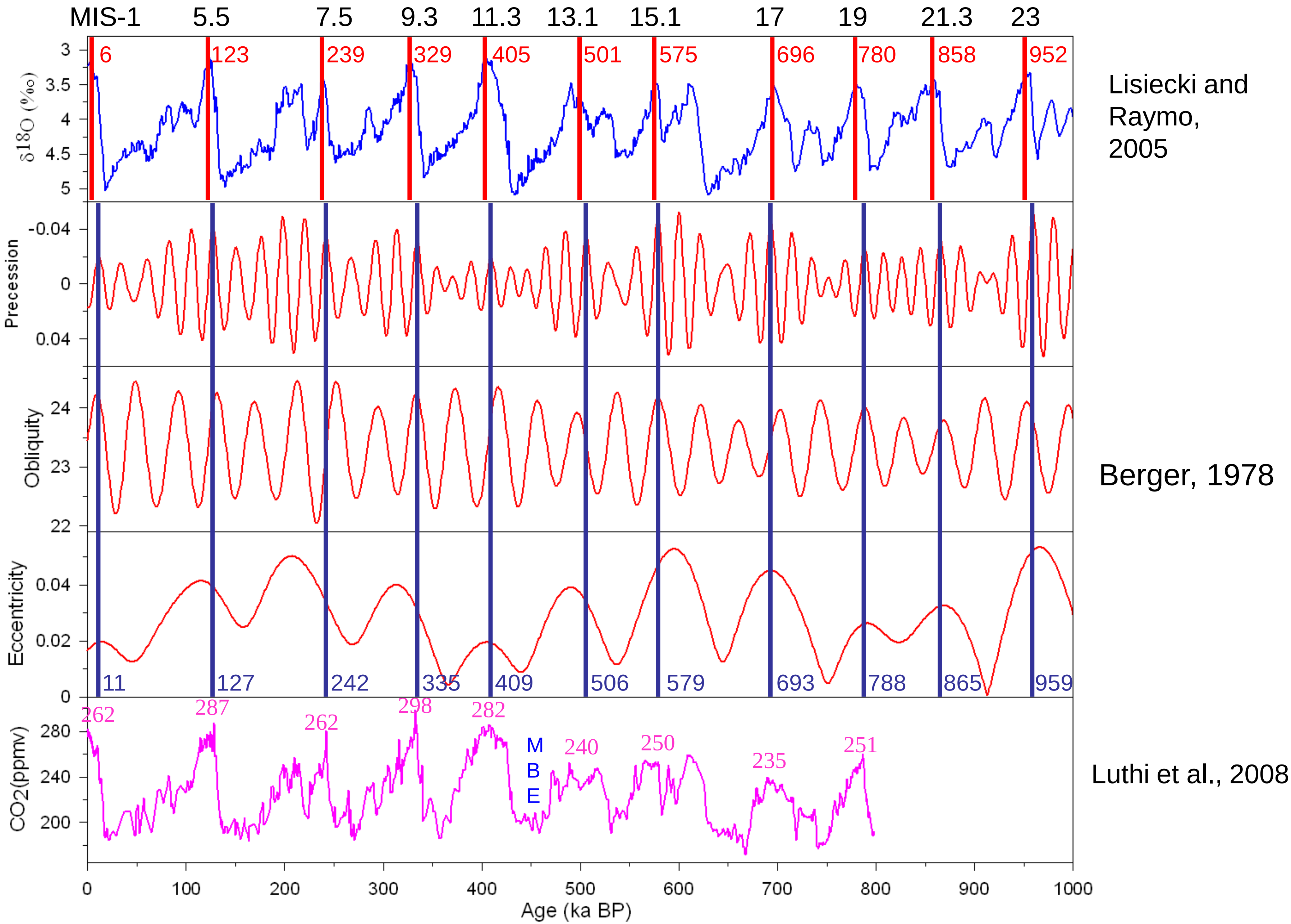
time = 127 ky BP (deviation from present-day value)



Calculation according to A. Berger, J. Atmos. Sci., 35, 2362–2367, 1978

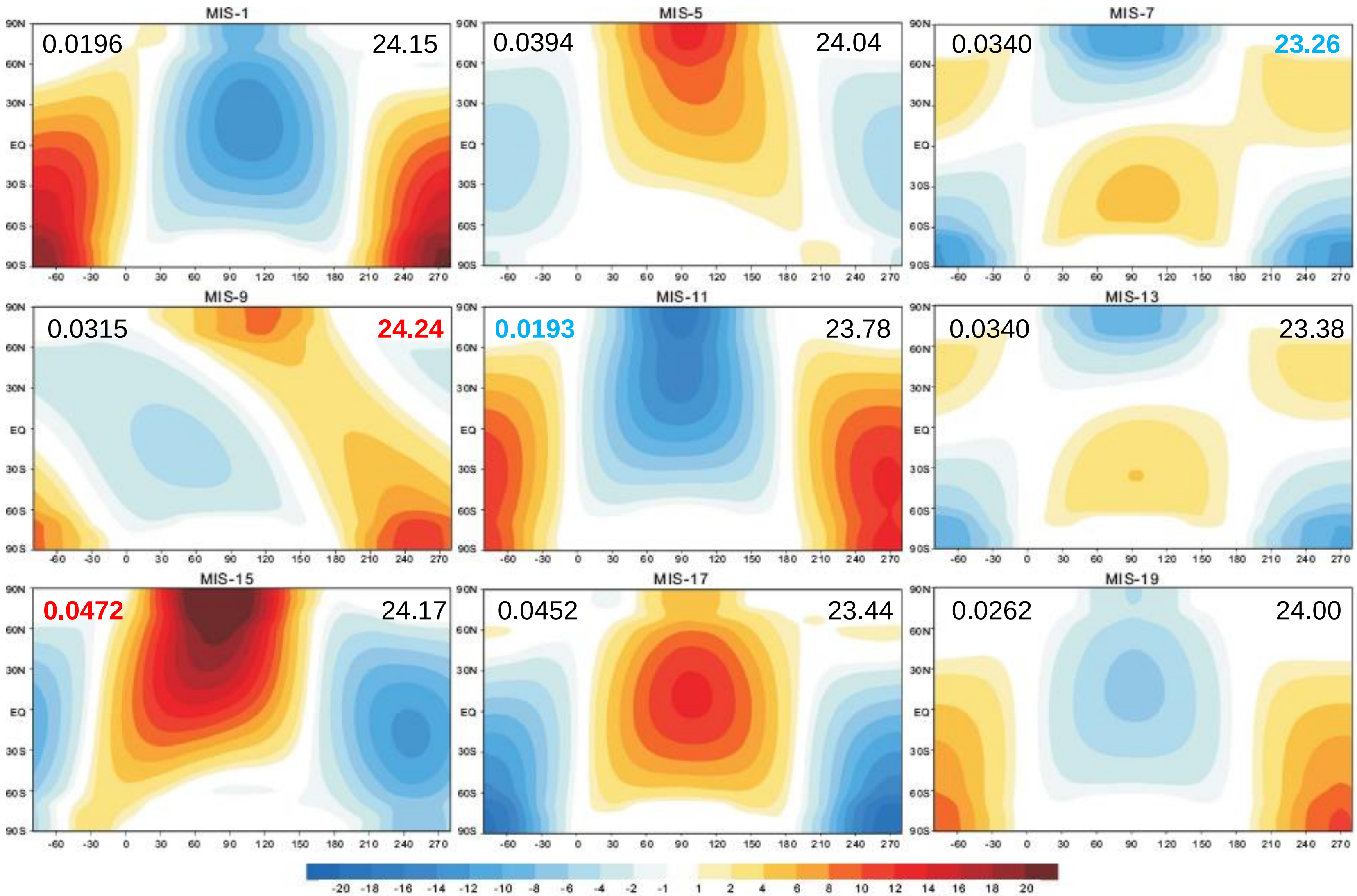


Gallée et al., 1992, 1993

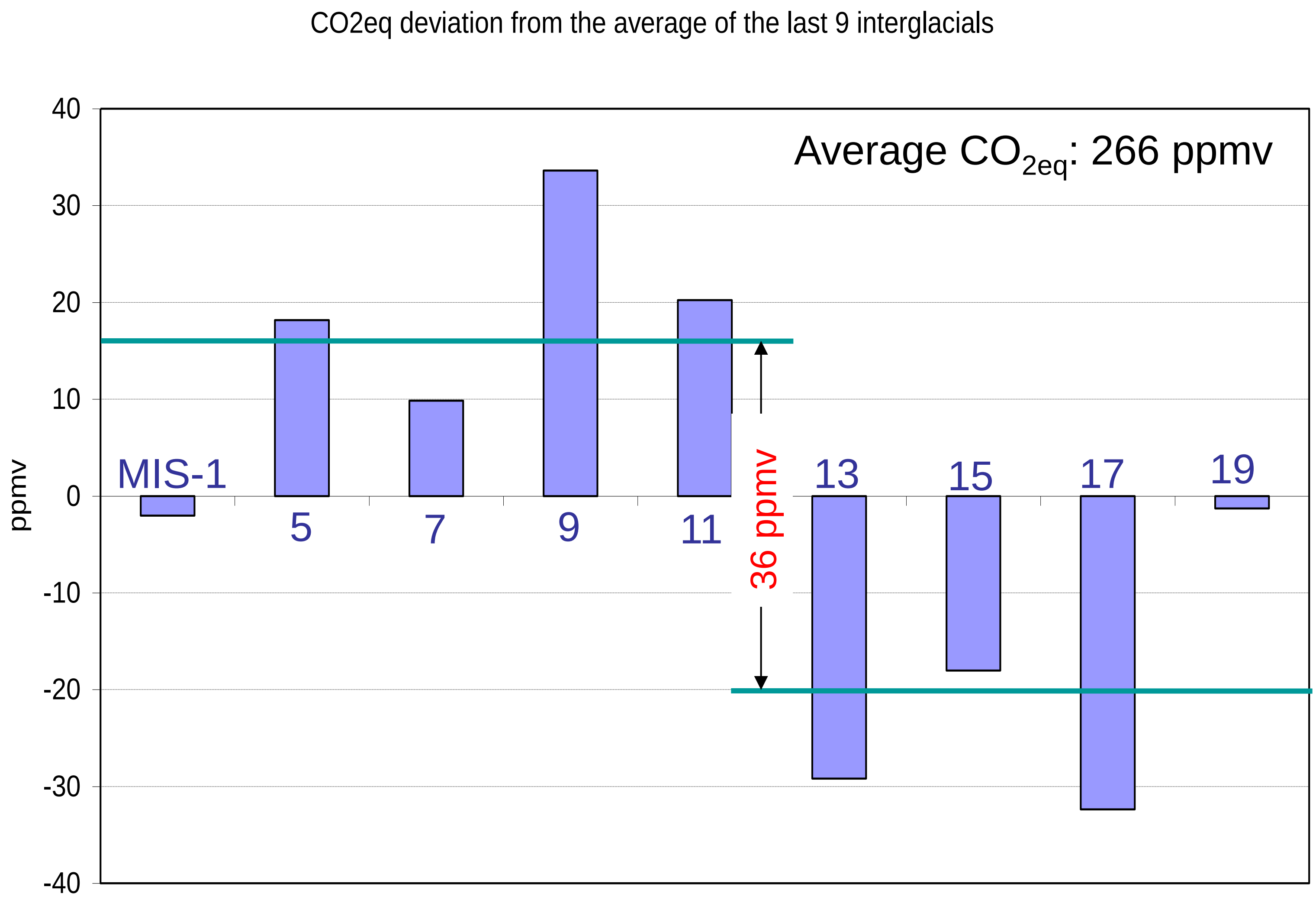


Scenarios as in Yin and Berger, Nature Geoscience, 2010

Fig. 5. Insolation at each interglacial (NHS at P) minus the insolation calculated from the orbital parameters averaged over the last 9 interglacials e = 0.0328   obl = 23.82

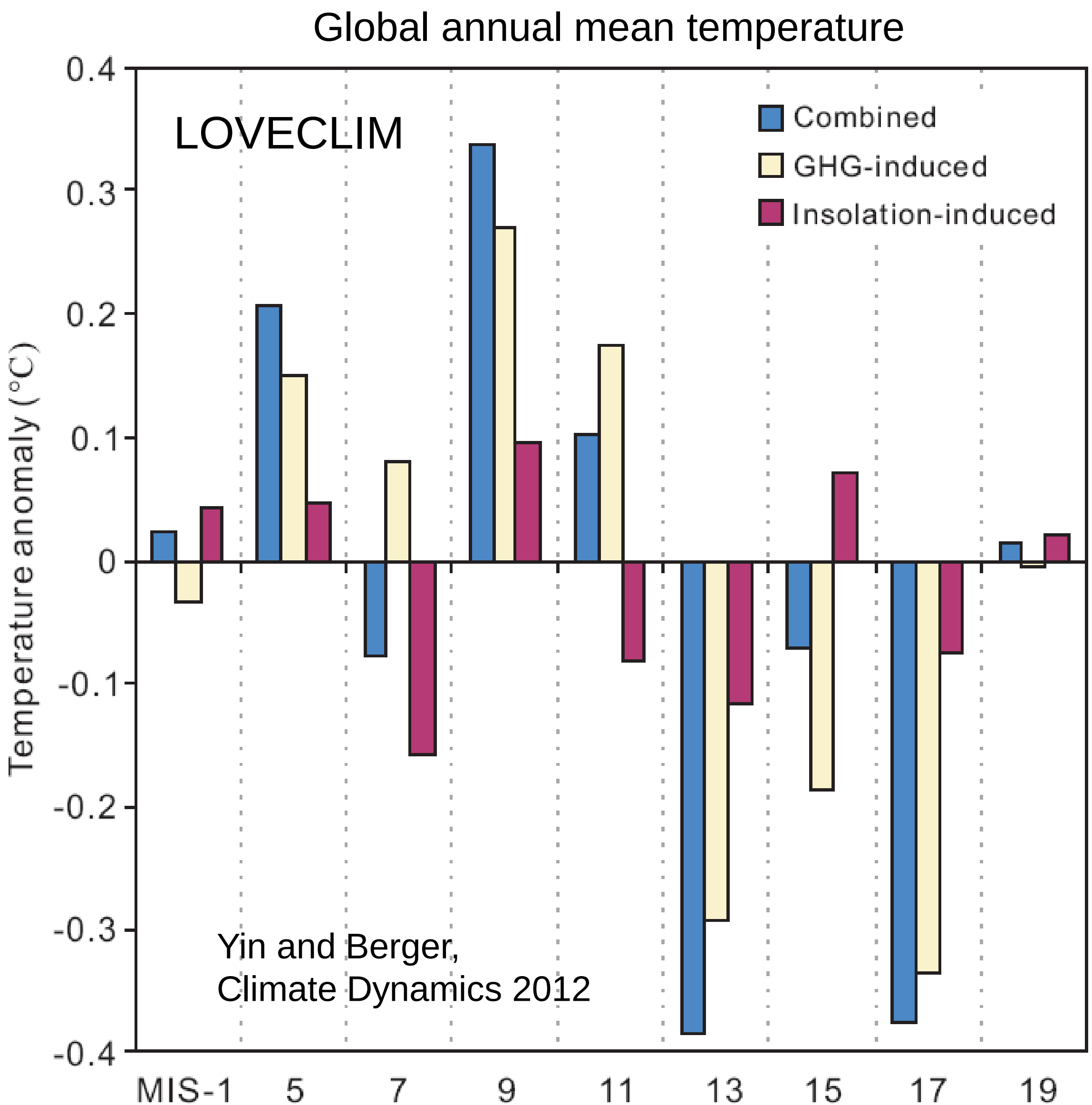


Berger, 1978; Yin and Berger, 2012



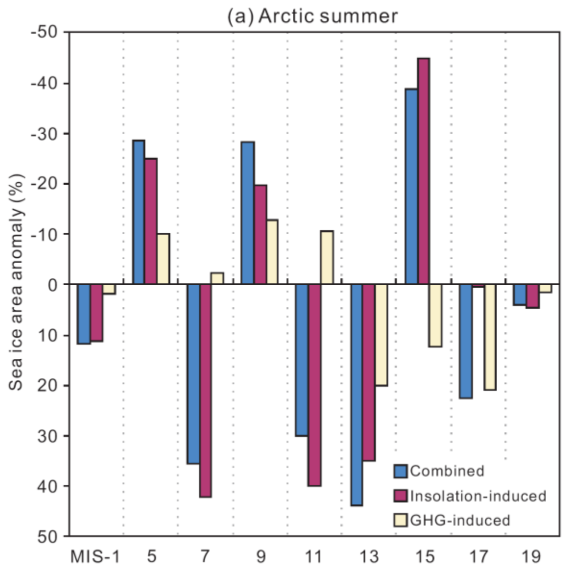
CO2eq deviation from the average of the last 9 interglacials
Average CO2eq: 266 ppmv
ppmv
40
30
20
10
0
-10
-20
-30
-40
MIS-1
5
7
9
11
13
15
17
19
36 ppmv

Relative importance of GHG and insolation on the warmth intensity is different from one interglacial to another.



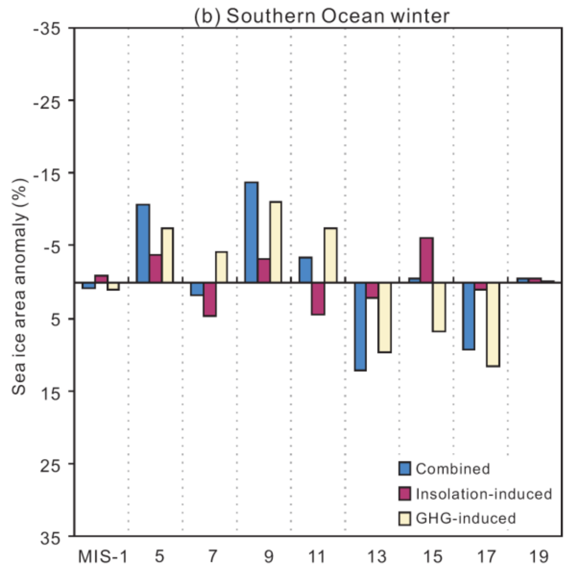
Sea ice

Arctic summer



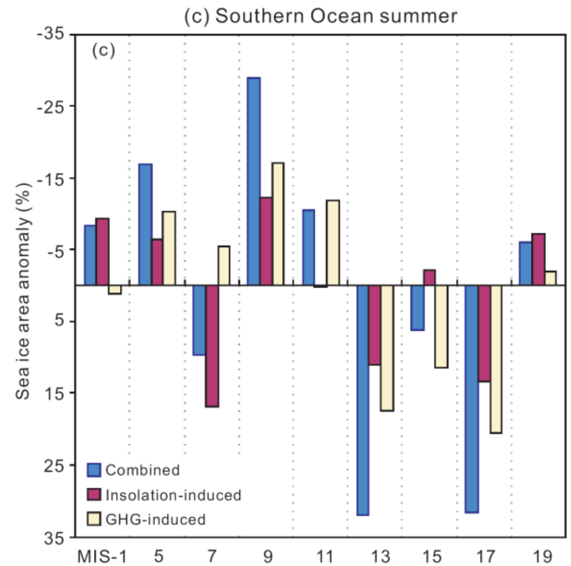
Summer temp-insol

South Ocean winter



Winter temp-GHG+SRE

South Ocean summer



Summer temp-GHG+Insol

obli + eccent

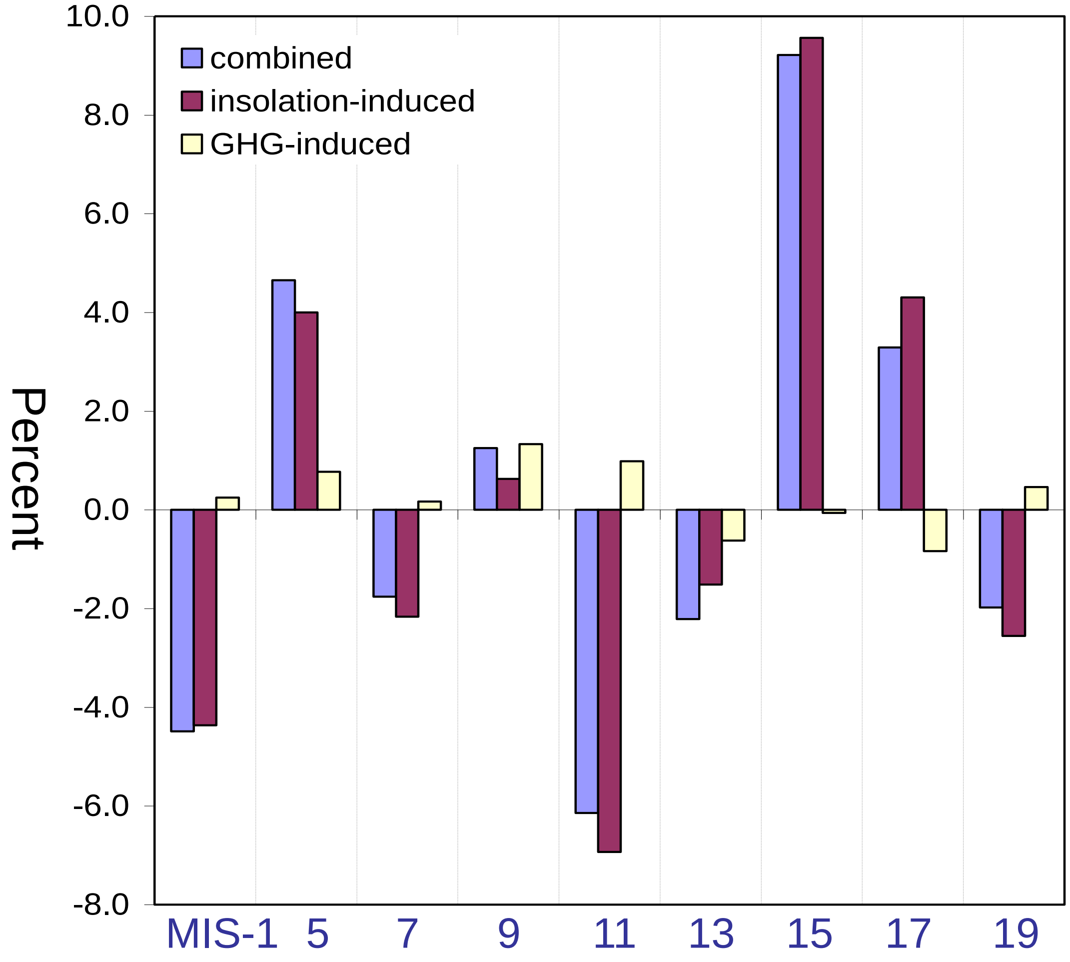
open SH ocean-
total energy-obliquity

	Arctic summer	South Ocean winter	South Ocean summer
GHG	0.30	0.87	0.63
Insolation	0.94	0.46	0.50

	Arctic summer	South Ocean winter	South Ocean summer
eccentri	-0.71	-0.60	0.20
obliquity	-0.83	-0.88	-0.93

Summer precipitation over northern monsoon regions

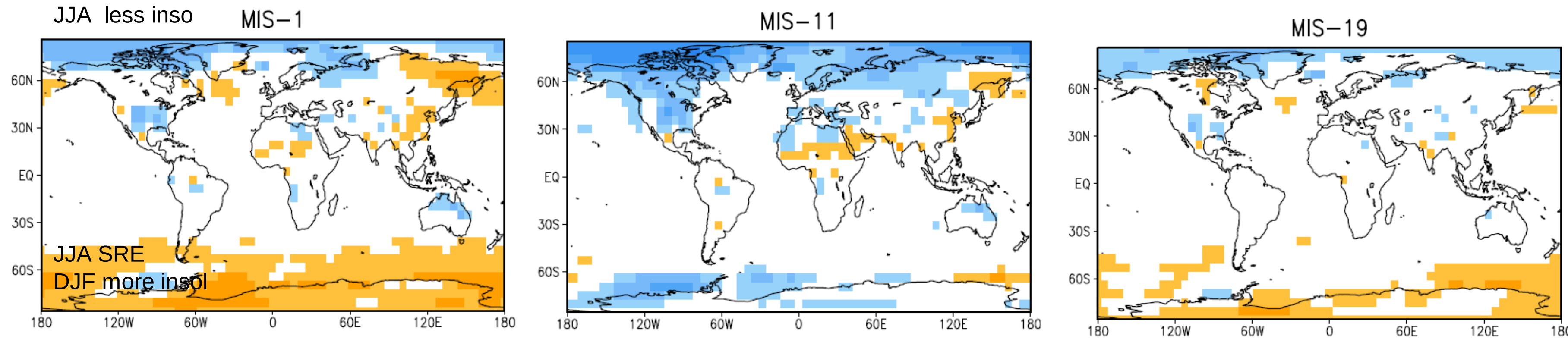
Insolation is dominating, leading to no MBE



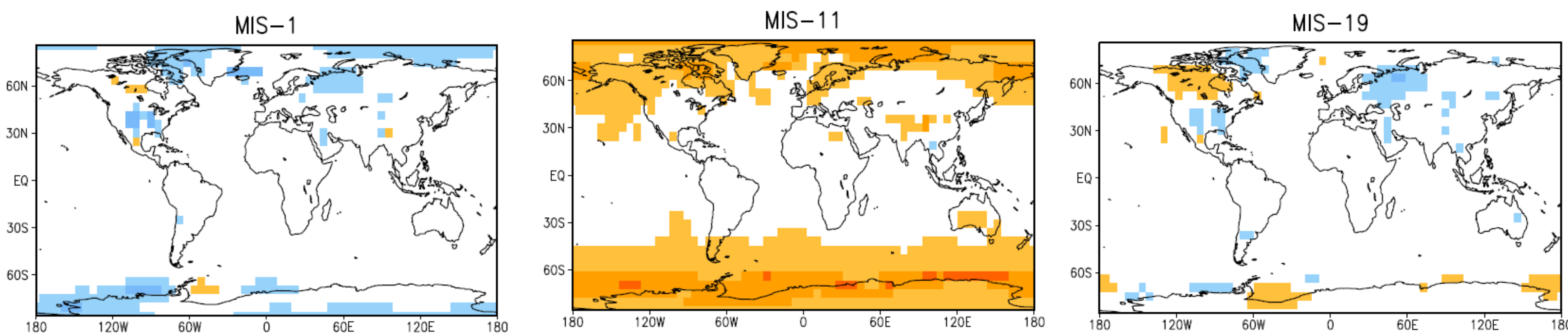
GHG-induced	0.12 (*)
Insolation-induced	1.03

eccentricity	0.99
obliquity	0.37

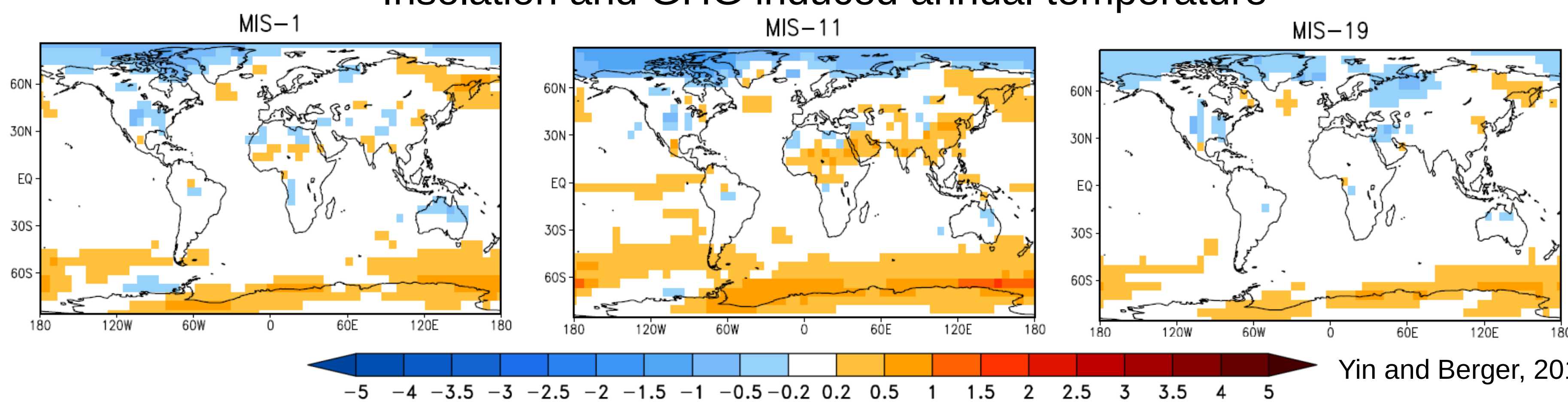
Insolation-induced annual temperature



GHG-induced annual temperature

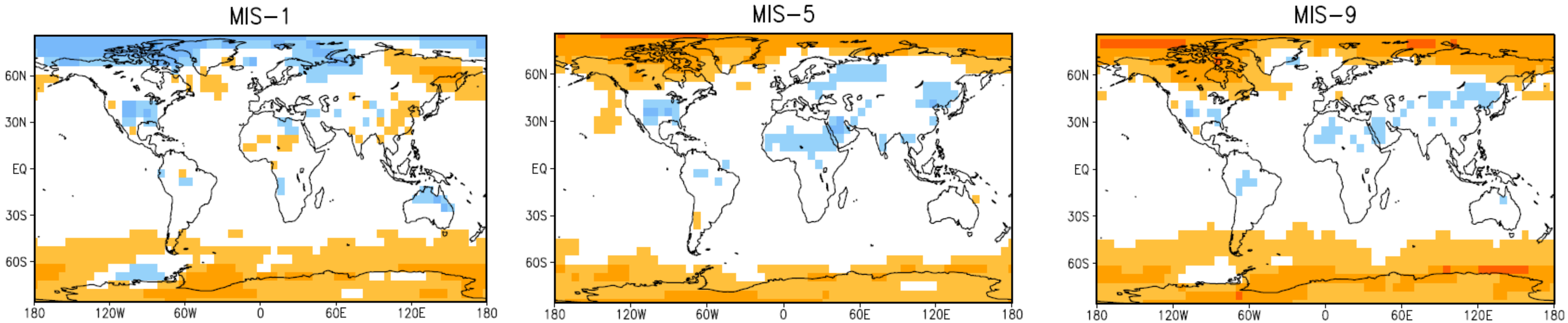


Insolation and GHG induced annual temperature

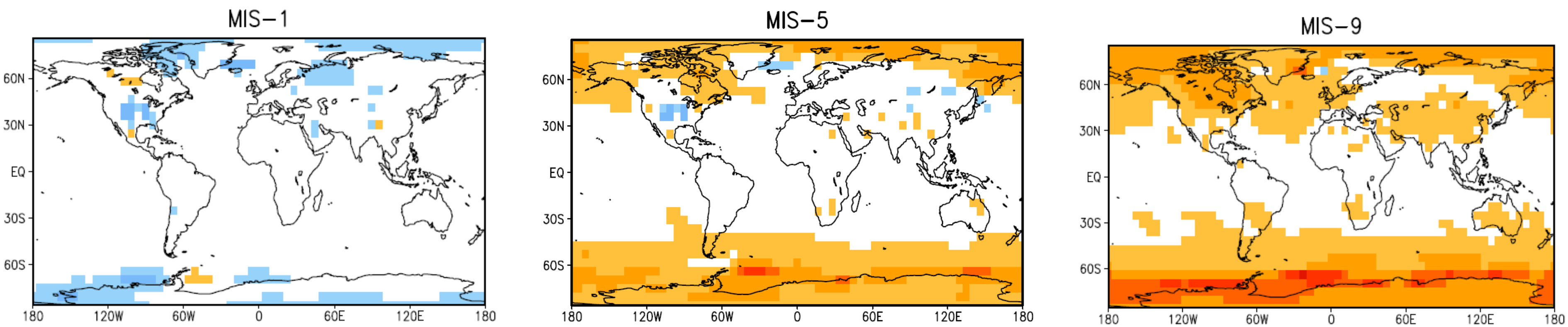


Yin and Berger, 2012

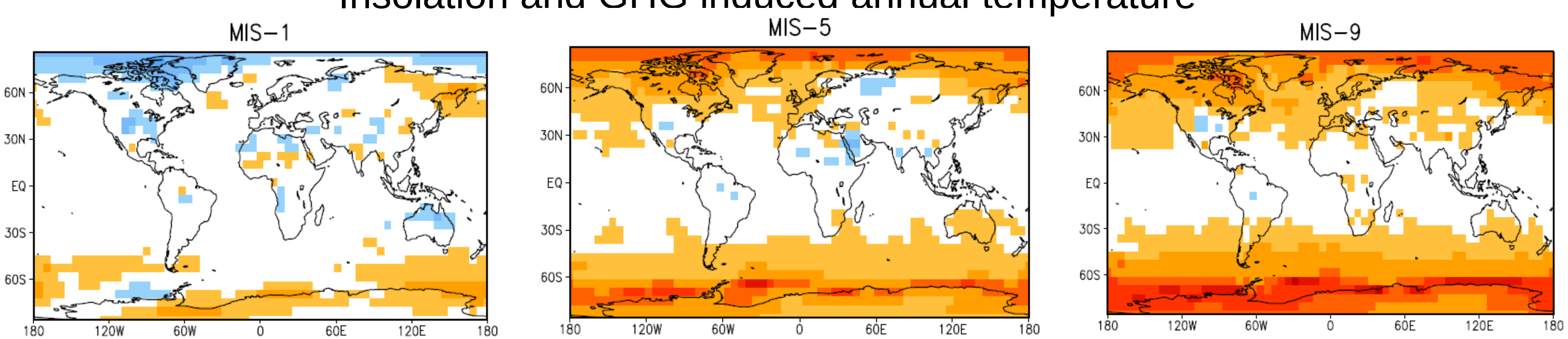
Insolation-induced annual temperature

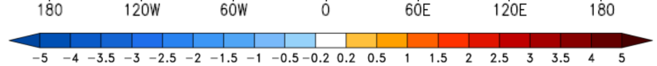


GHG-induced annual temperature

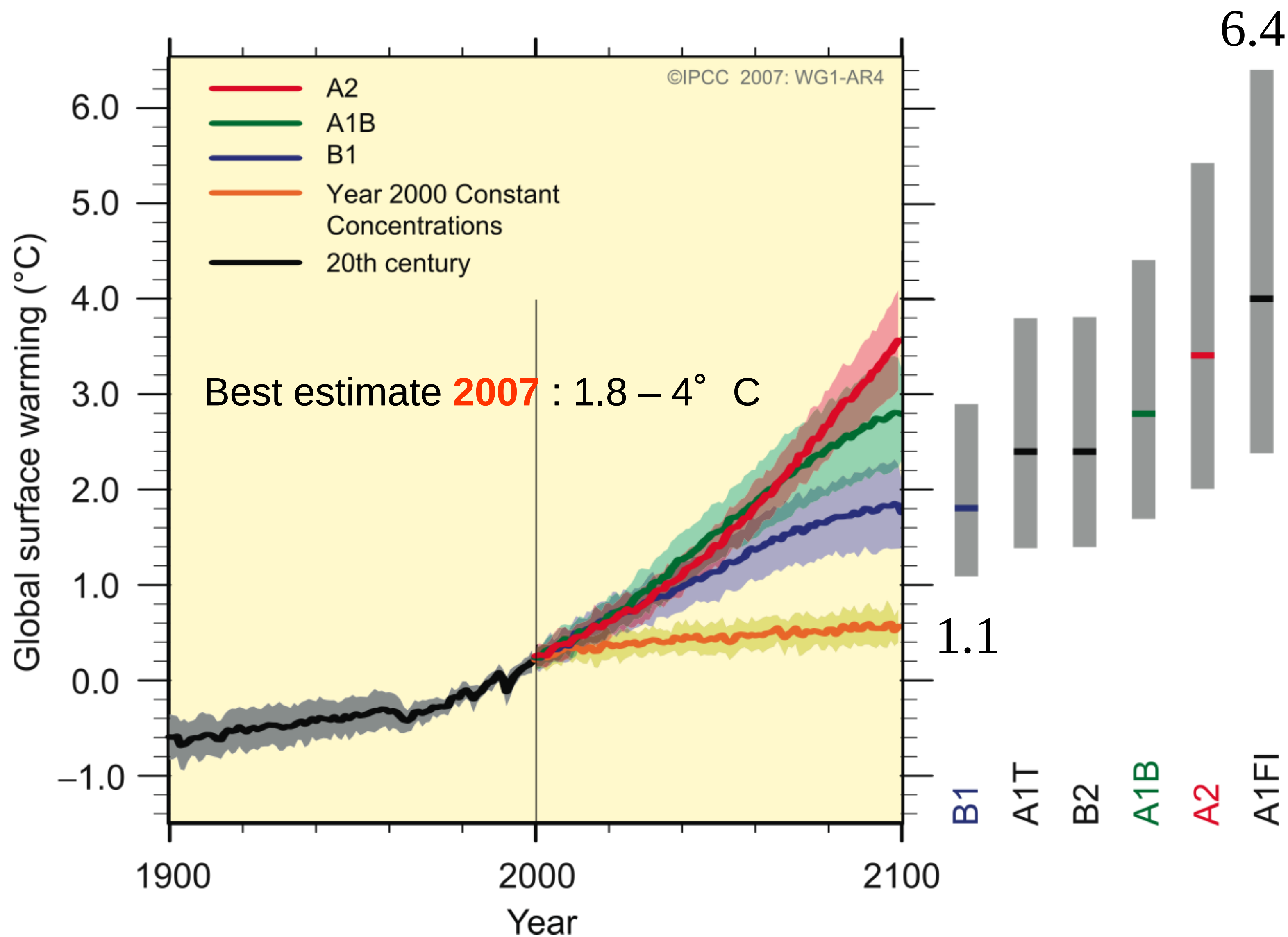


Insolation and GHG induced annual temperature

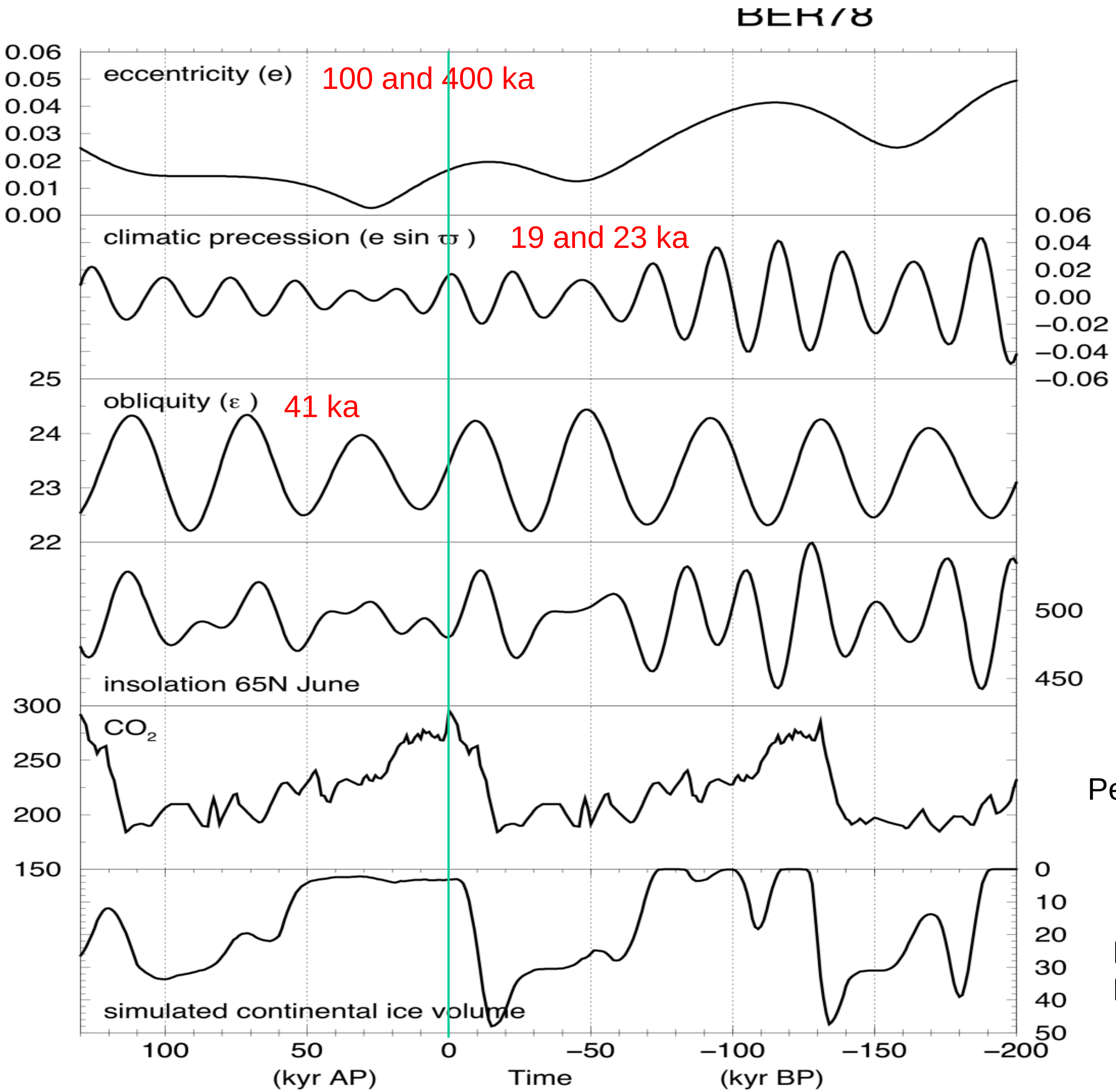




In and Berger, 2012



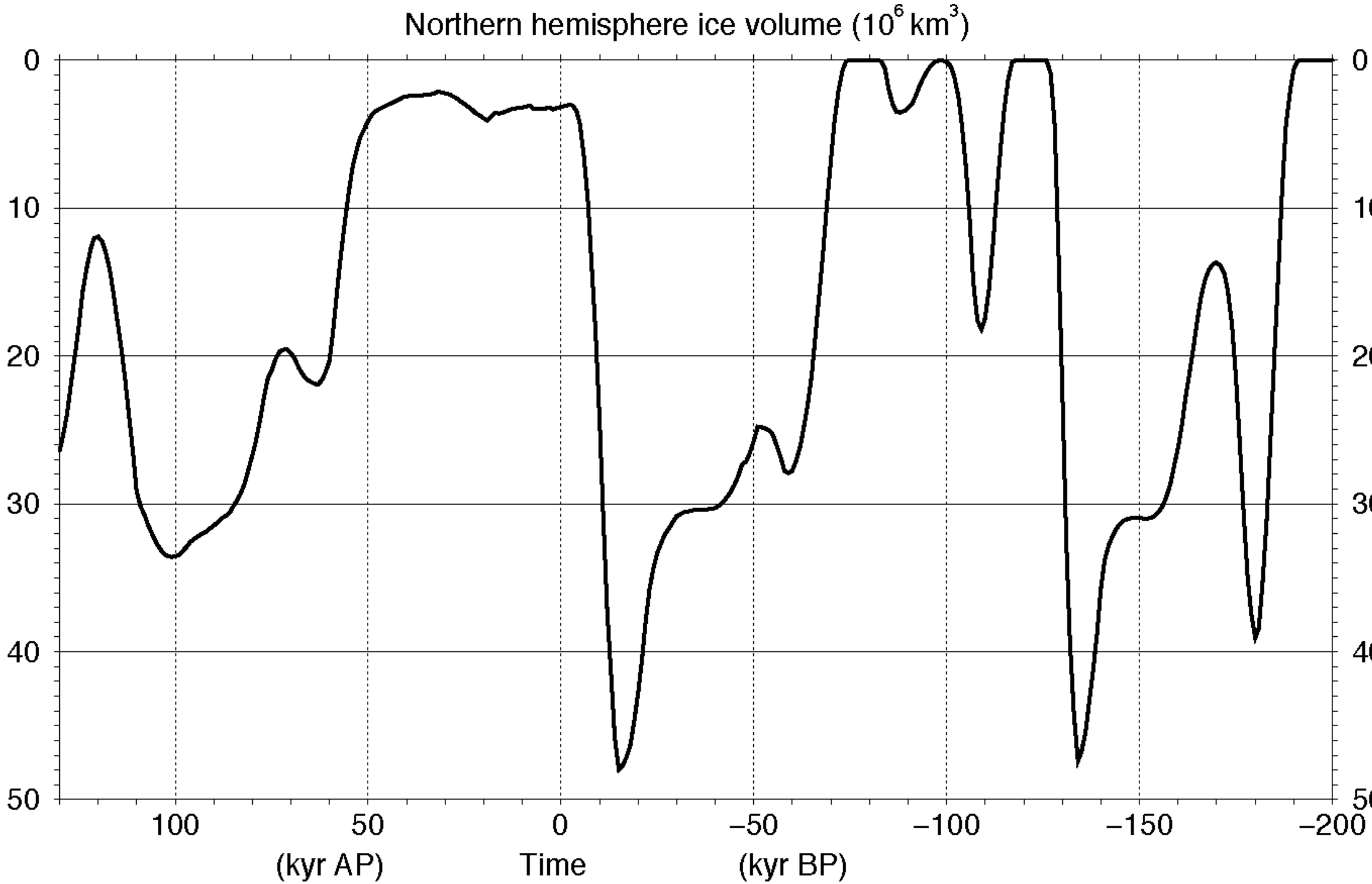
GLOBAL WARMING PREDICTION (IPCC, 2007)



Berger, 1978

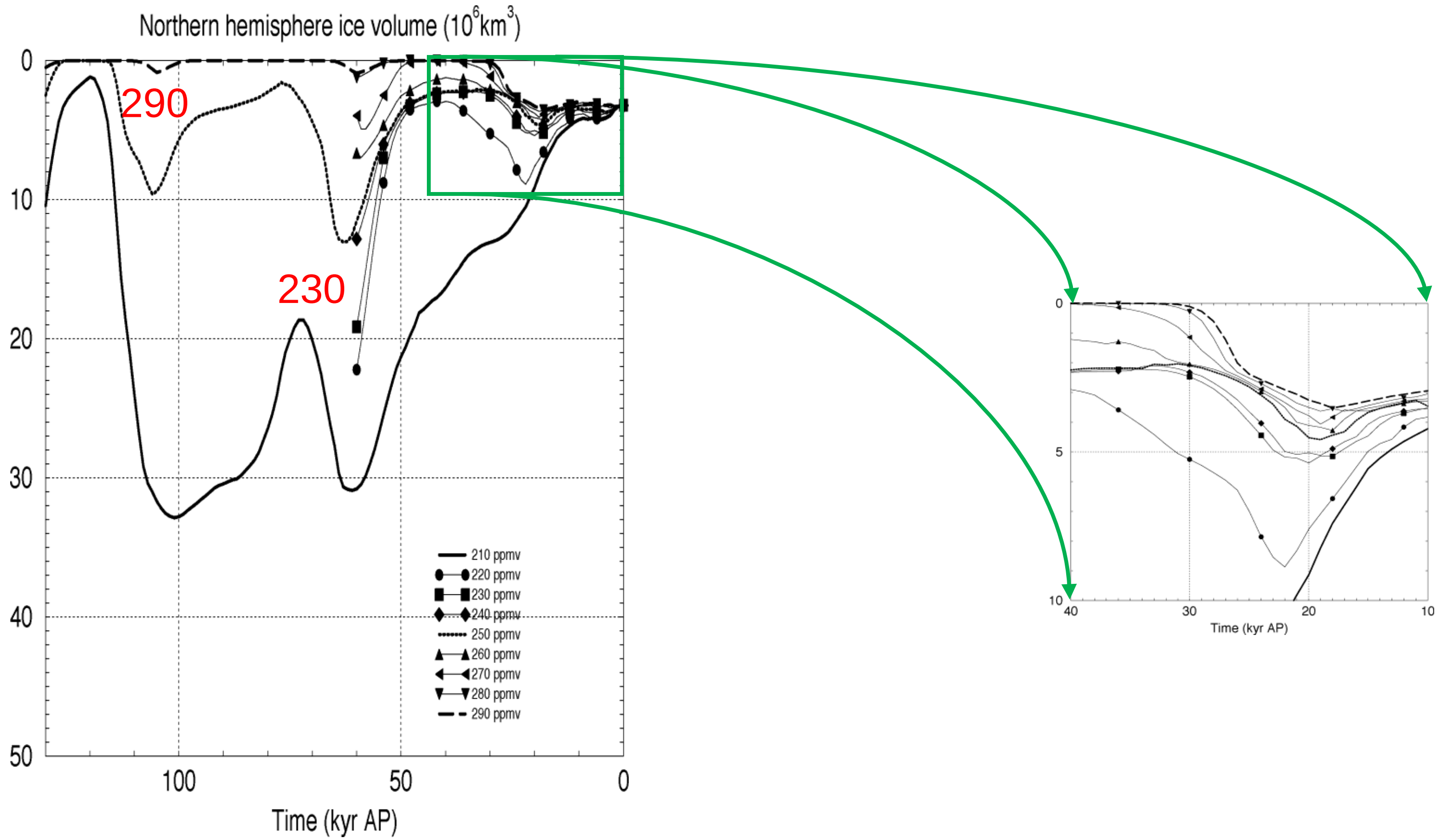
Petit et al., 1999

Berger and Loutre, 2002



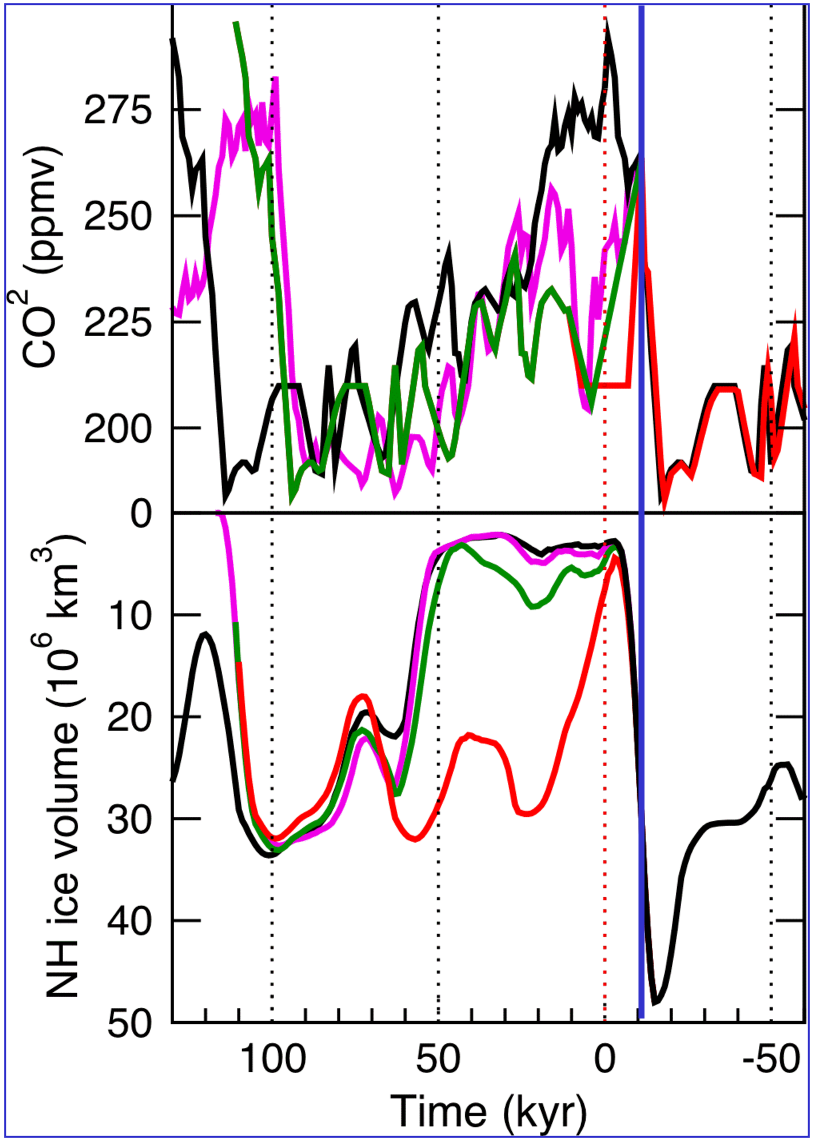
Berger et al., Ambio 1997, Science 2002, Surveys in Geophysics, 2003

Future climate under constant CO_2 scenarios



Loutre and Berger, Climatic Change, 2000

Human impact in the past



SCENARI - 52 to + 130 kyr

CO2

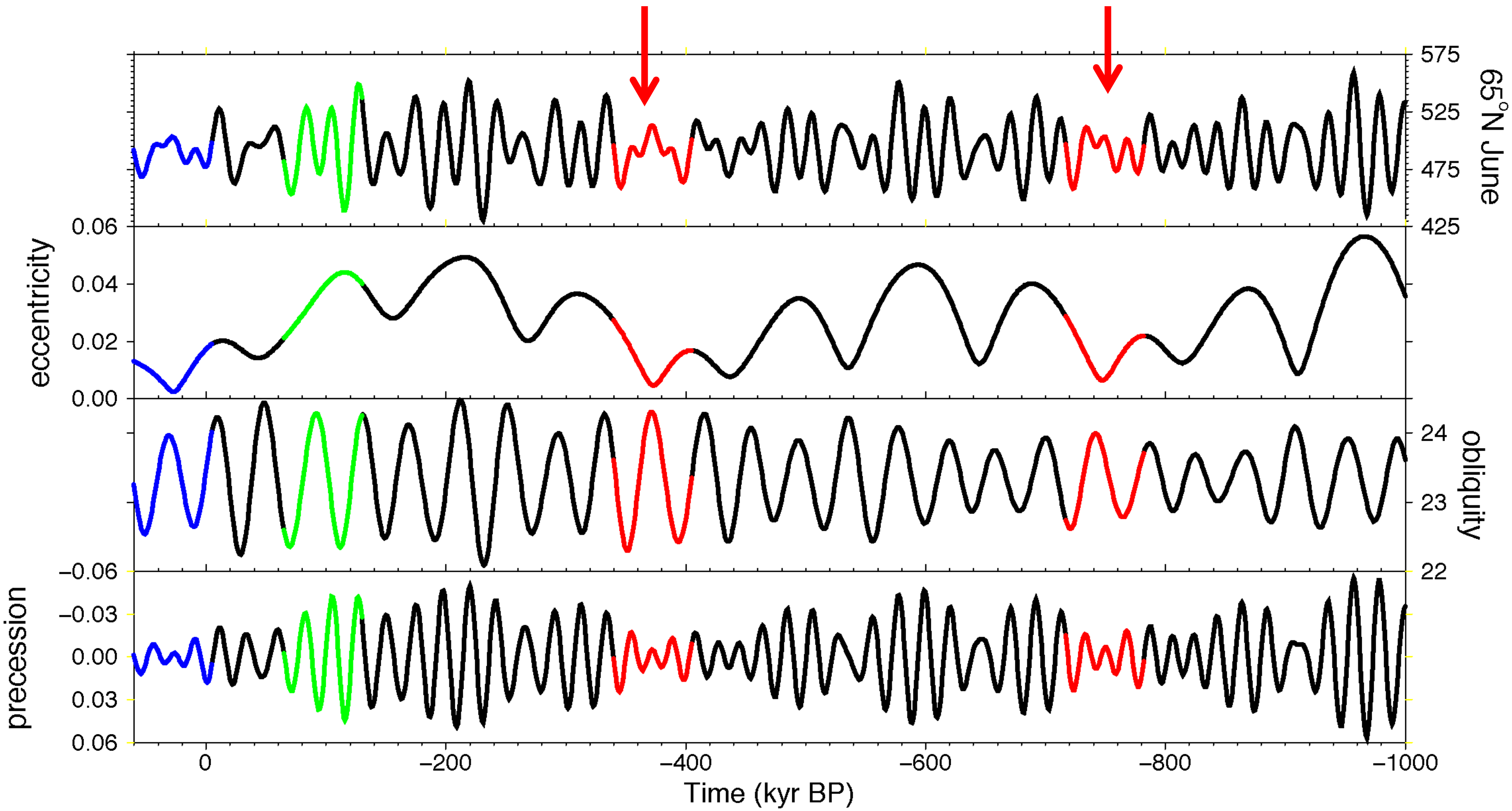
black VOSTOK 131 kyr BP shift to 0

purple MIS 7 shift to 11 kyr BP

green VOSTOK younger by 20 kyr

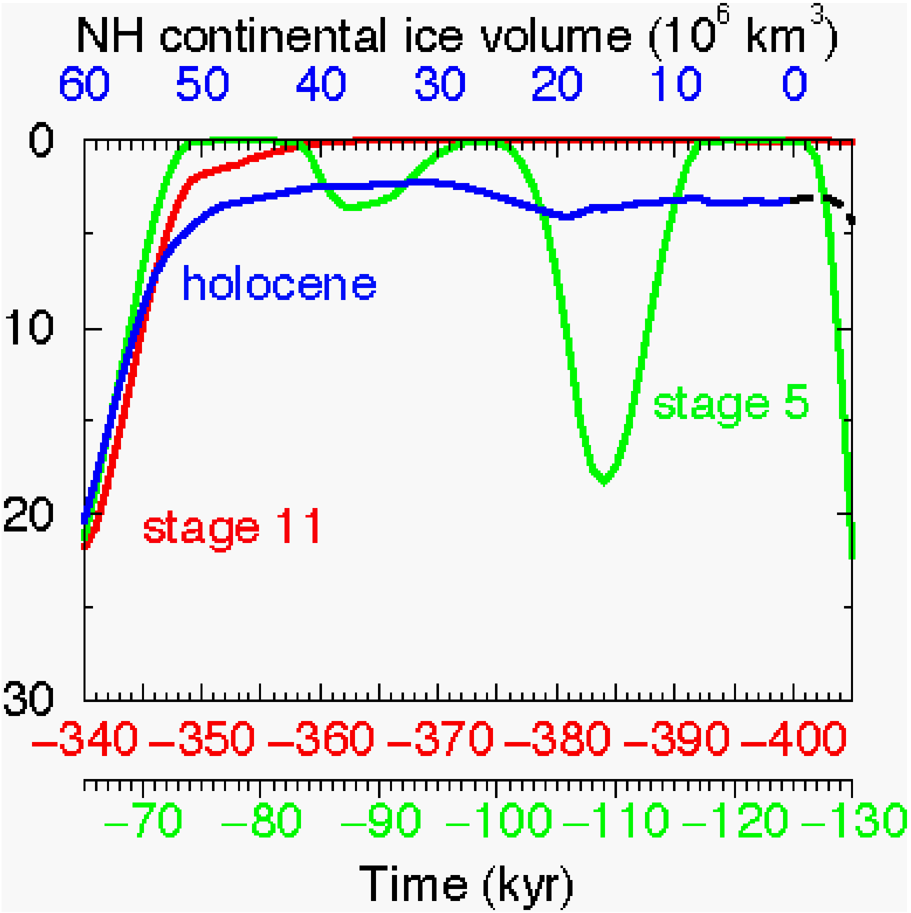
red green but decrease more rapid

Astronomical parameters : an analogue for the future



Berger, 1978

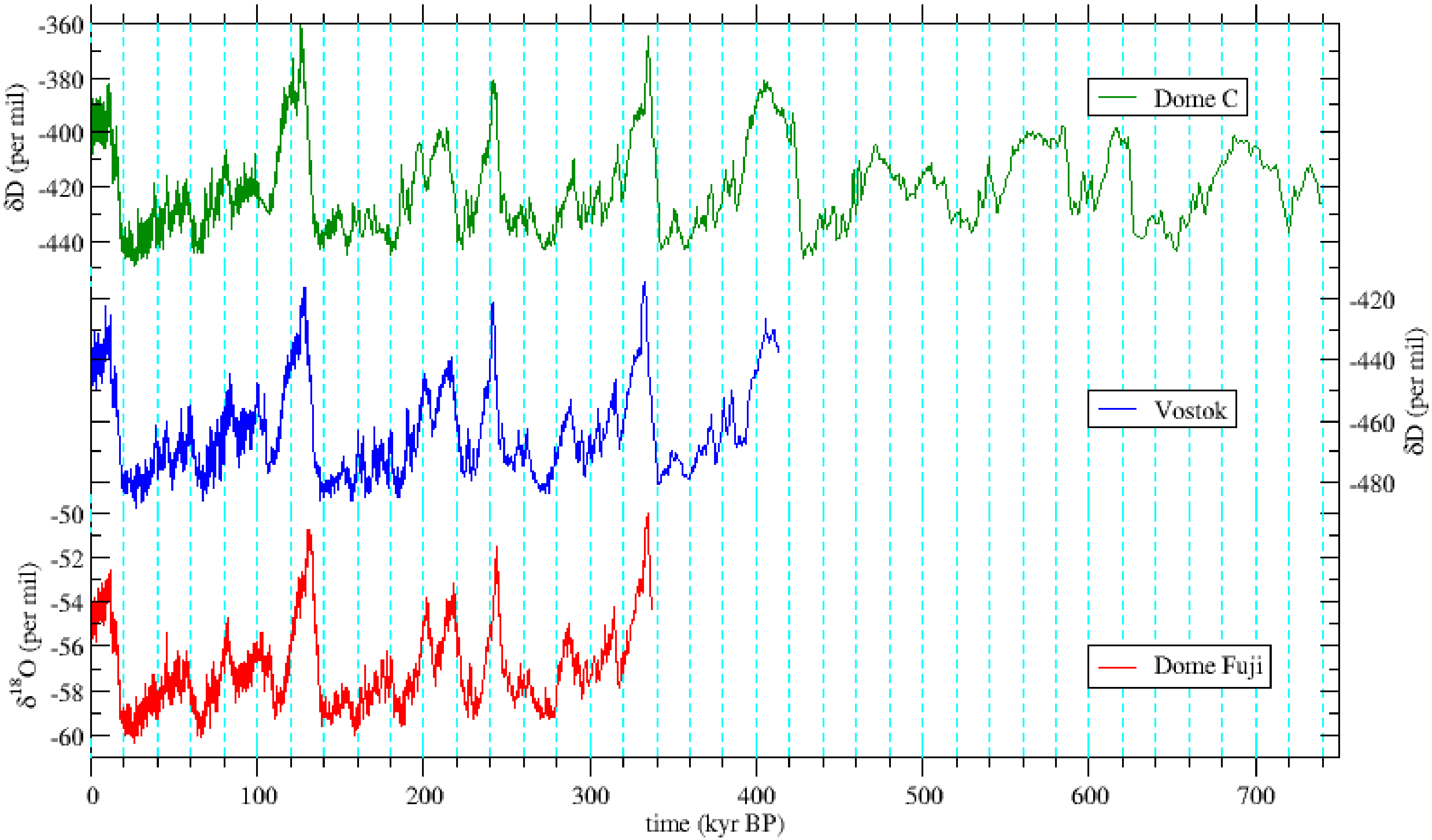
MIS11 :
an analogue for the future



CO_2 = Vostok

Berger and Loutre, in Droxler et al, 2003

Archives of climate in Antarctica



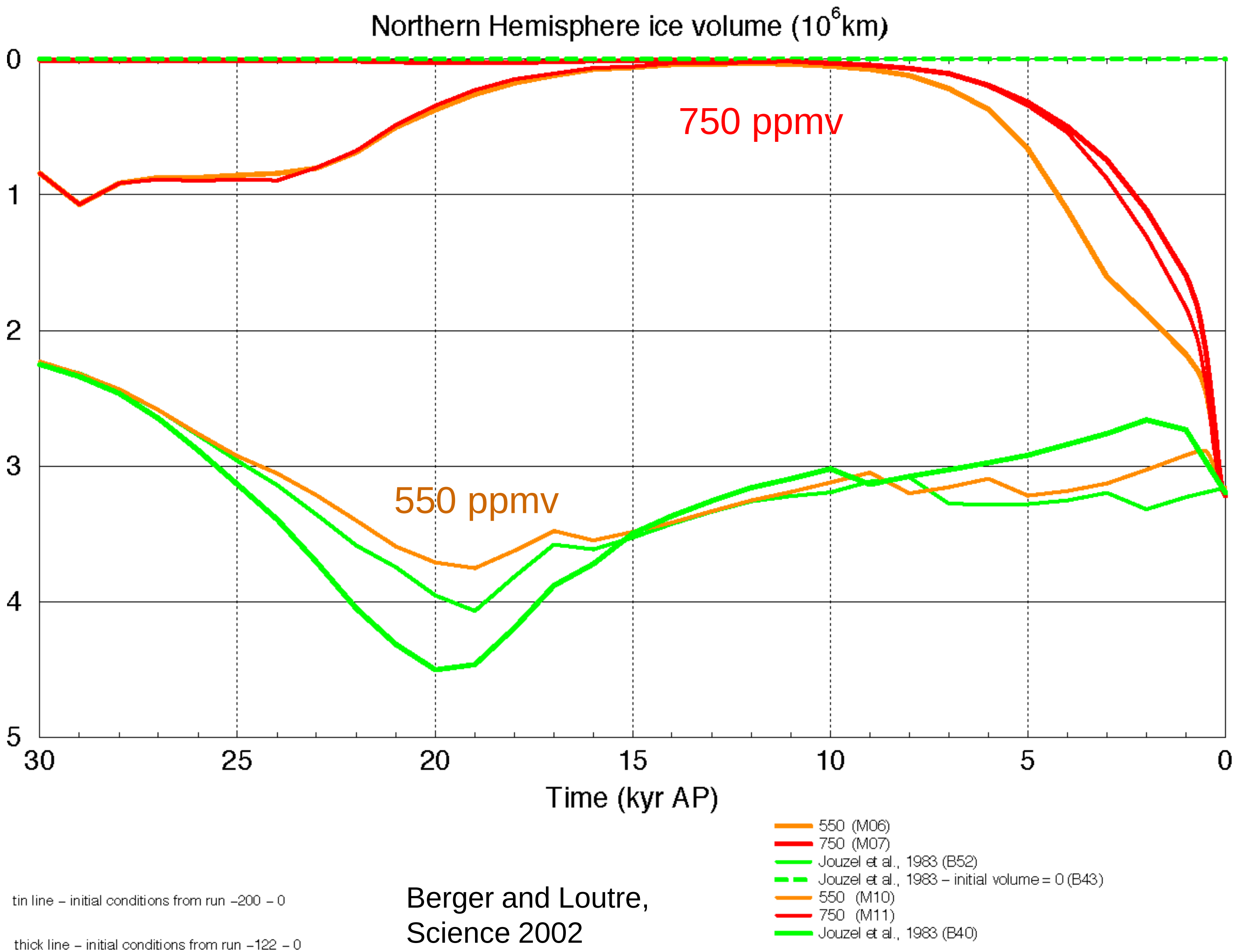
EPICA community members, Nature, 2004

The present interglacial, how and when will it end?

Department of Geological Sciences, Brown University, Providence, Rhode Island

January 26-27, 1972.

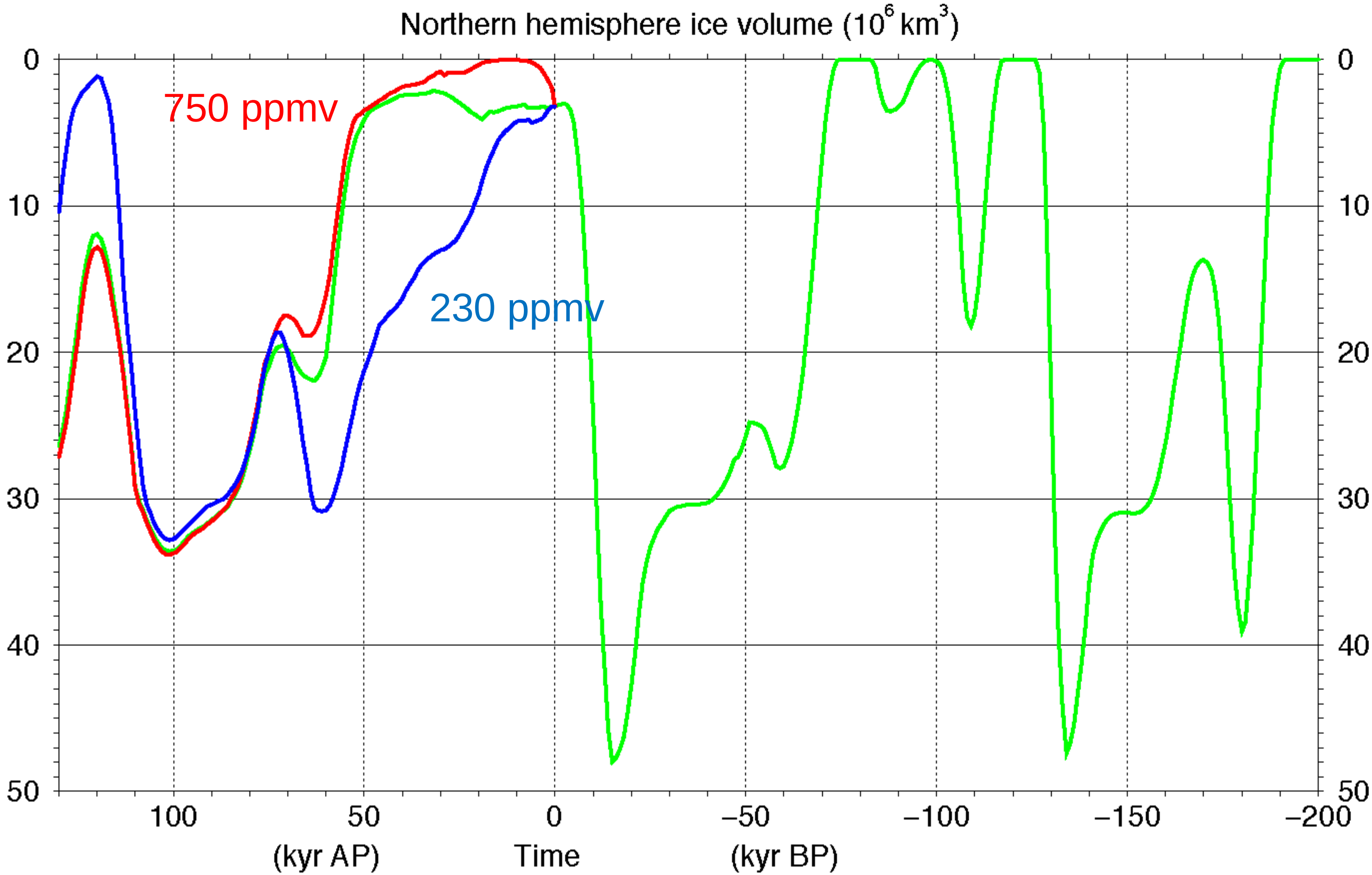
Previous warm intervals resembling the present one have all been sufficiently **short live**. It seems therefore likely that the present-day warm epoch will terminate relatively soon if man does not intervene.



tin line – initial conditions from run –200 – 0

thick line – initial conditions from run –122 – 0

Berger and Loutre, Science 2002



Berger and Loutre, 2002


AGIR MAINTENANT POUR
LES GÉNÉRATIONS FUTURES
MAIS RÉFLÉCHIR D'ABORD
MERCI DE VOTRE ATTENTION