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THE ENIGMATIC MARINE CLIMATIC STAGE 11

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Geophysical Information for Theachers (GIFT) Workshop,
EUROPEAN GEOSCIENCES UNION, Vienna 27 April 2005

Last Glacial Maximum 21kyr BP

$\Delta T = -5°C$

Δsea level = –130m

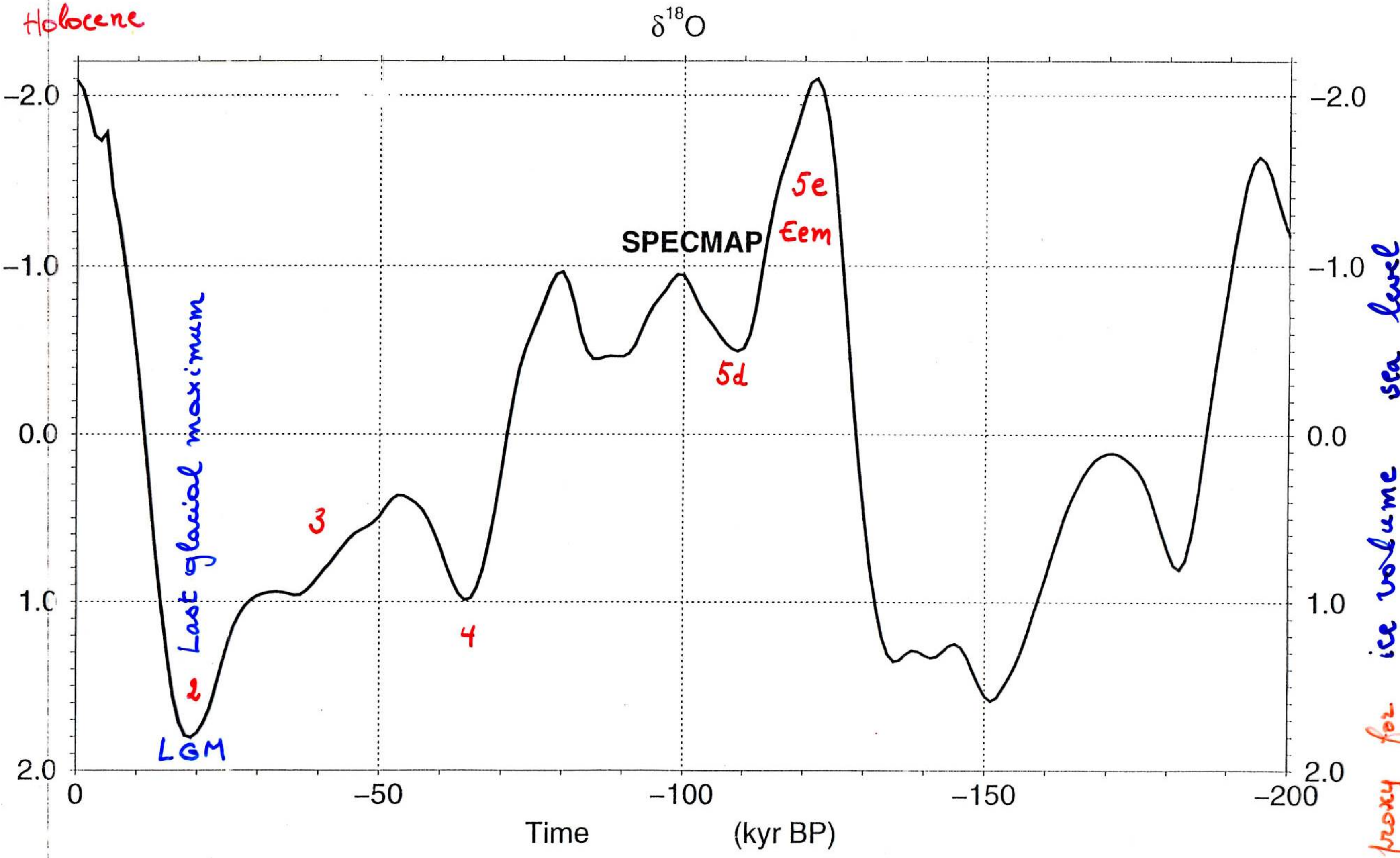
Δice volume = +52 $10^6 km^3$

CO_2 = 200 ppmv

Pre-industrial CO_2 = 280 ppmv

2000 AD CO_2 = 370 ppmv

(Joussaume, 1993)



Last Glacial Maximum

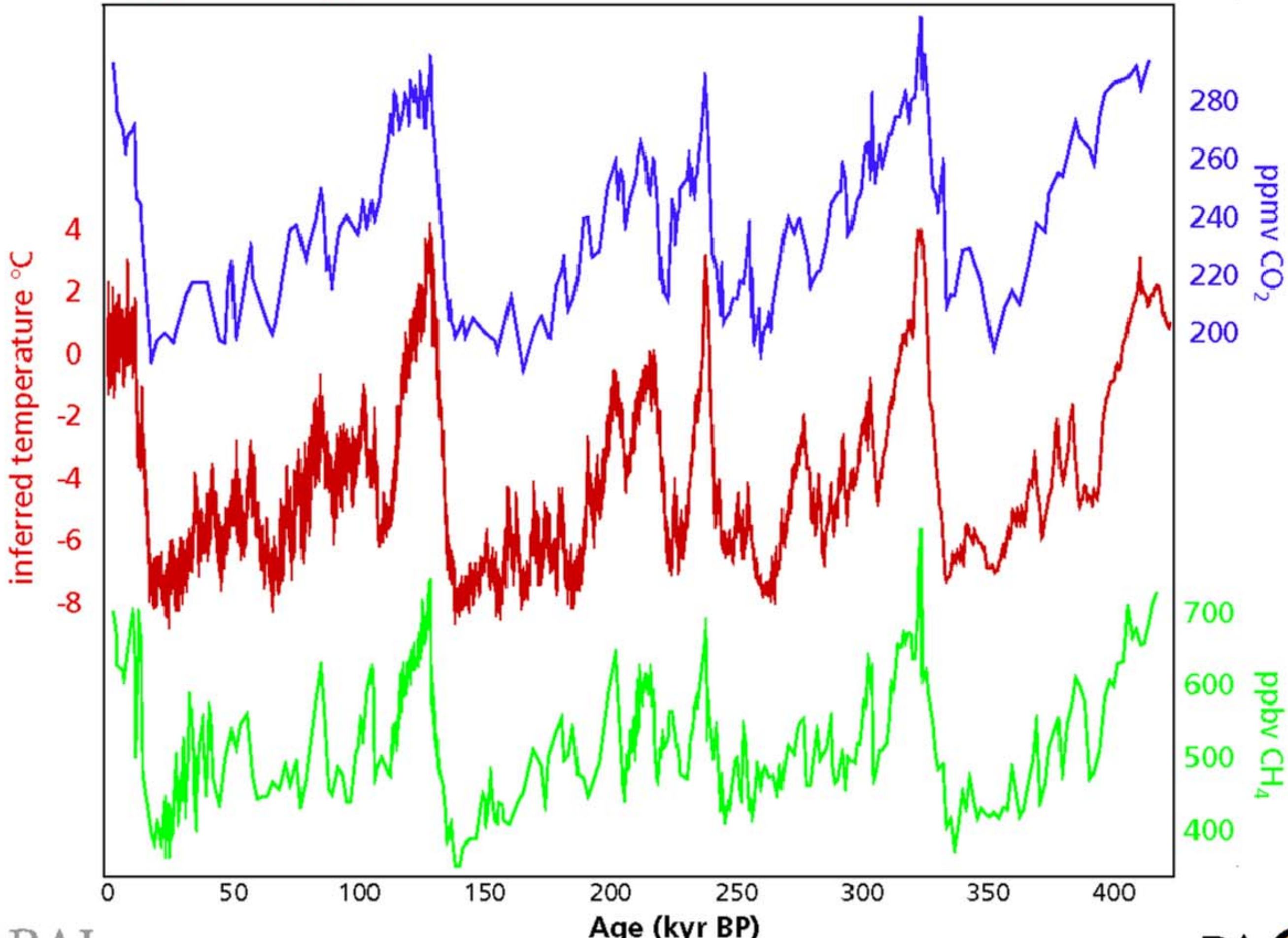
relative to present. day

Δ ice volume = + 40 - 50 $10^6\ km^3$

Δ sea level = − 100 − 120 m

Δ temperature = − 5°C

4 glacial cycles recorded in the Vostok ice core

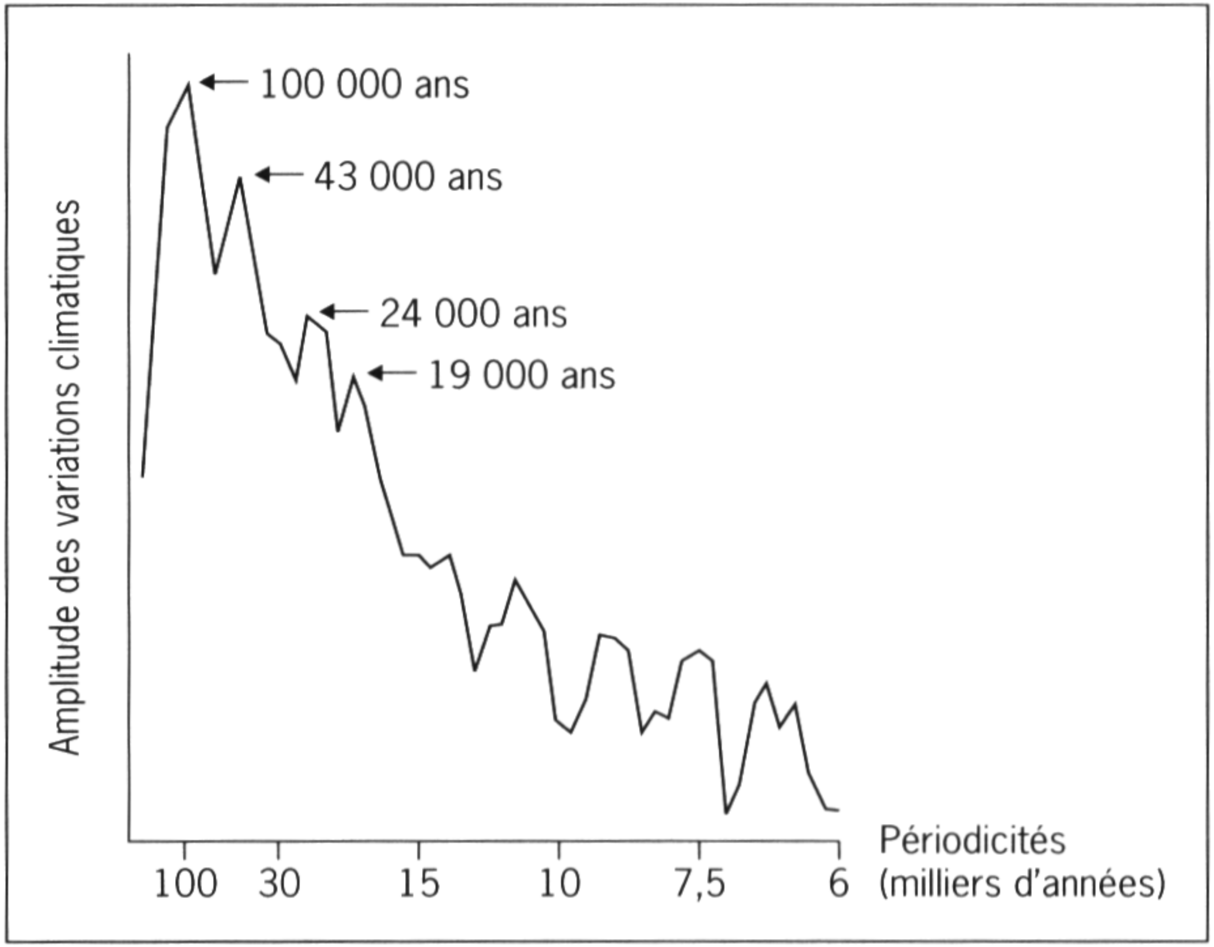


GLOBAL IGBP CHANGE

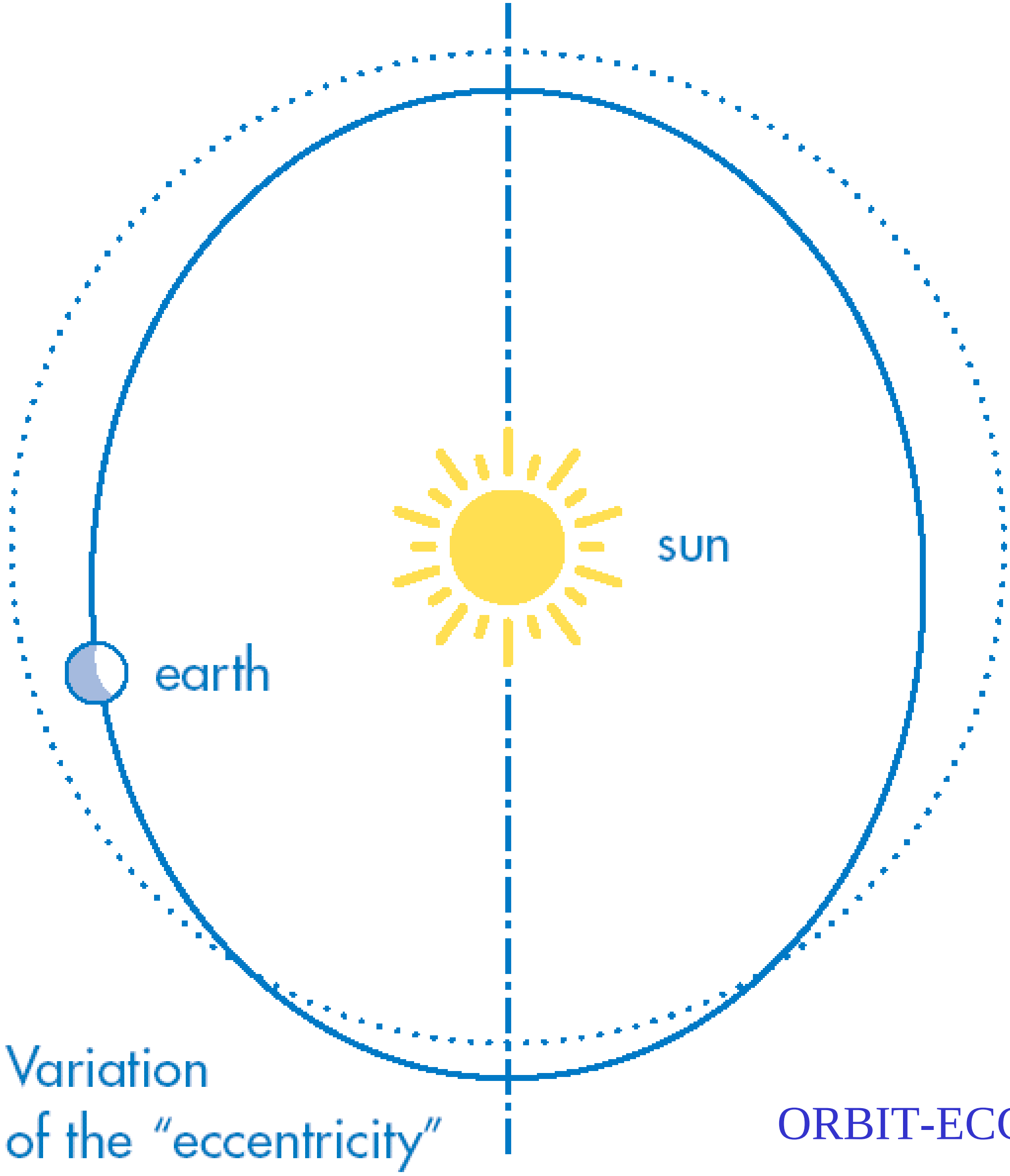
J.R. Petit et al., *Nature,* **399**, 429–36, 1999.

PAGES PAST GLOBAL CHANGES

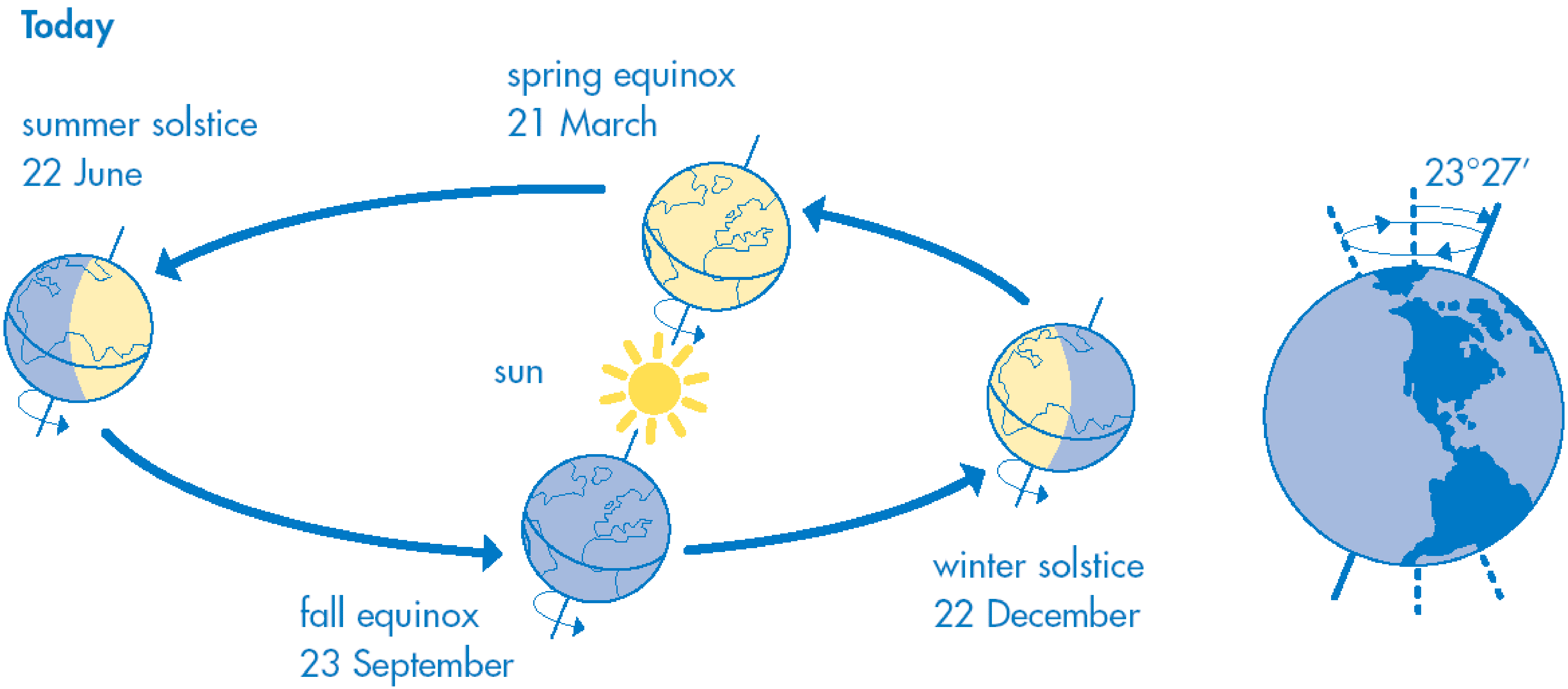
6.1



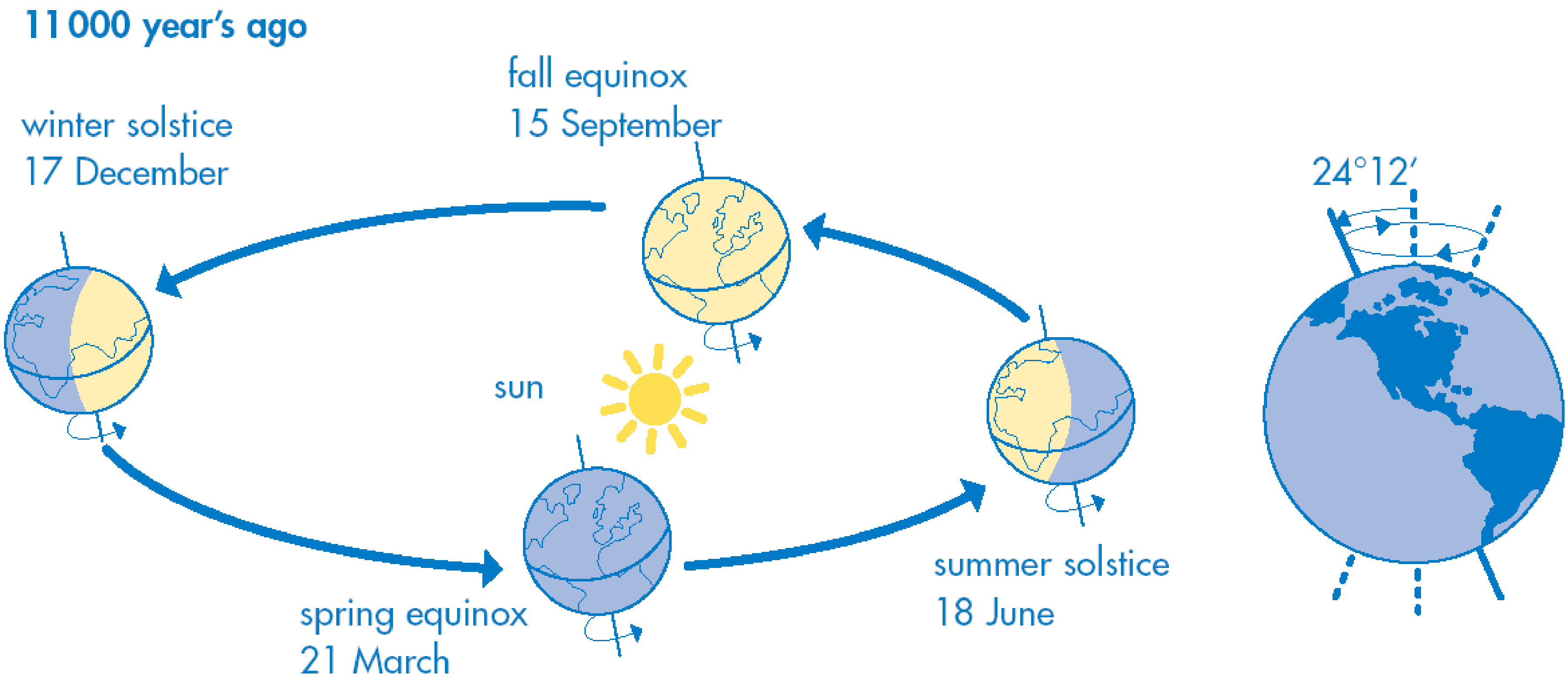
100 000 ans
43 000 ans
24 000 ans
19 000 ans
Amplitude des variations climatiques
100
30
15
10
7,5
6
Périodicités
(milliers d'années)



ORBIT-ECC-LATSIS,2001



ORBIT-O-LATSIS,2001



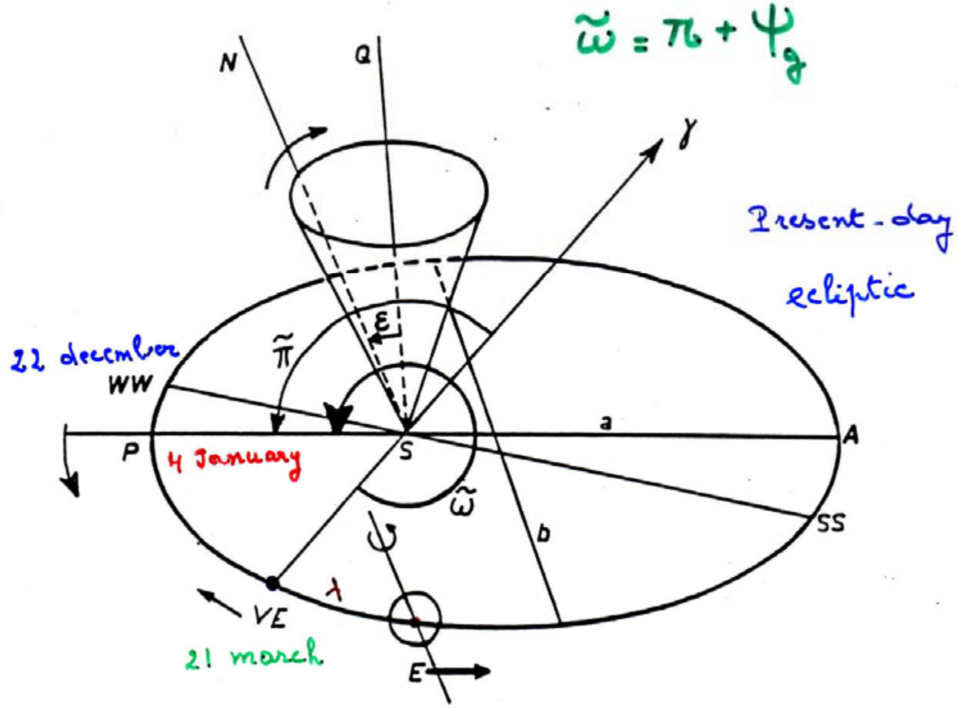
ORBIT-11ky-LATSIS,2001

ASTRO – CLIMATIC SOLUTION

$$e = e_0 + \Sigma\, E_i \cos(\lambda_i t + \phi_i)$$

$$e \sin\tilde{\omega} = \Sigma\, P_i \sin(\alpha_i t + \varsigma_i)$$

$$\varepsilon = \varepsilon^* + \Sigma\, C_i \cos(\tilde{f}_i t + \tilde{\delta}_i)$$



PERIODS ASSOCIATED TO THE MAIN TERMS

IN THE ANALYTICAL EXPANSIONS OF

PRECESSION

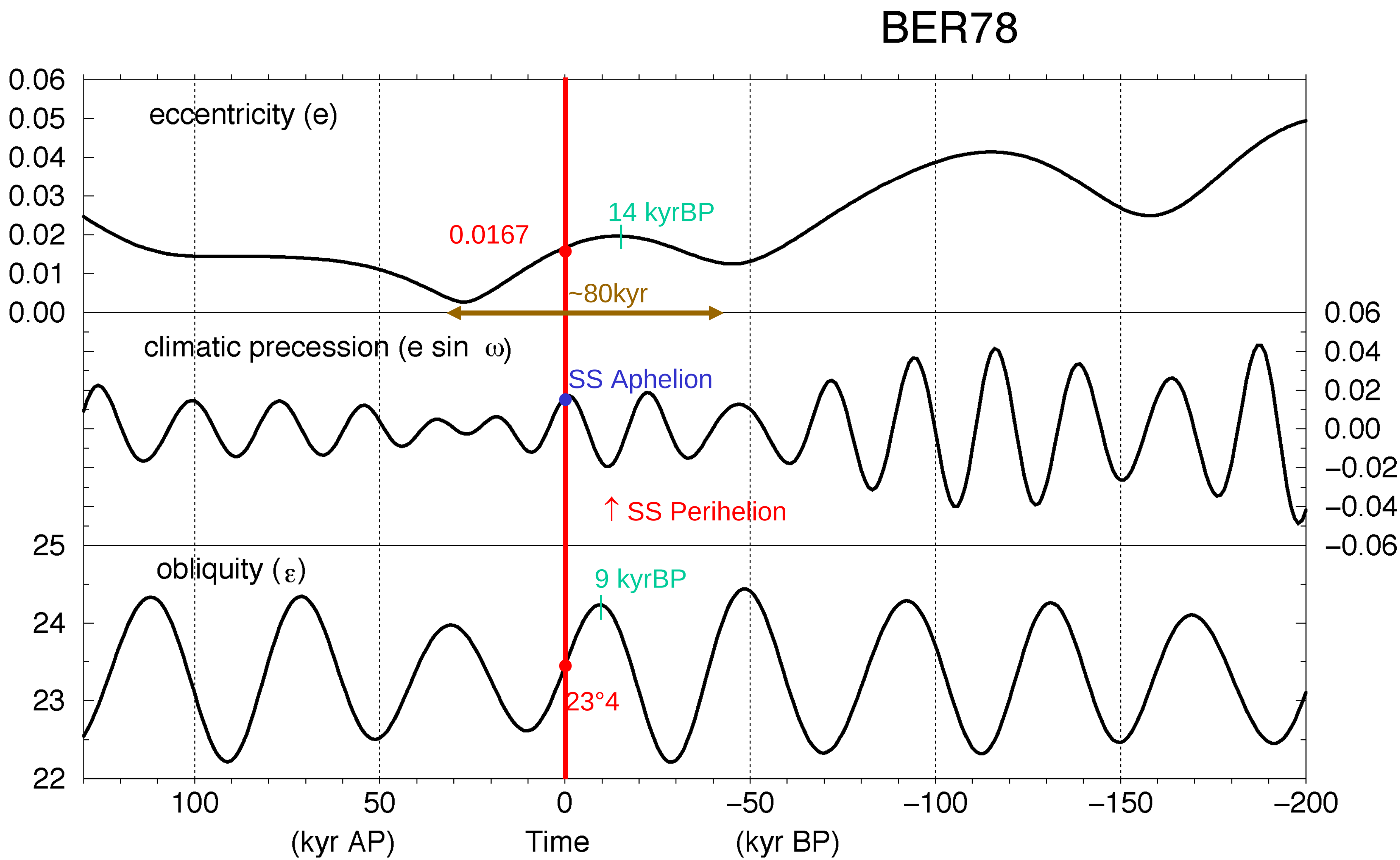
N	Ampl.	Period (years)
1.	0.0186080	23716
2.	0.0162752	22428
3.	–0.0130066	18976
4.	0.0098883	19155

OBLIQUITY

N	Ampl. (")	Period (years)
1.	–2462.22	41000
2.	–857.32	39730
3.	–629.32	53615
4.	–414.28	40521
5.	–311.76	28910

ECCENTRICITY

N	Ampl.	Period (years)
1.	0.011029	412885
2.	–0.008733	94945
3.	–0.007493	123297
4.	0.006724	99590
5.	0.005812	131248
6.	–0.004701	2305441



ε large

SS Perihelion (ϖ=270°; e sin ϖ min)

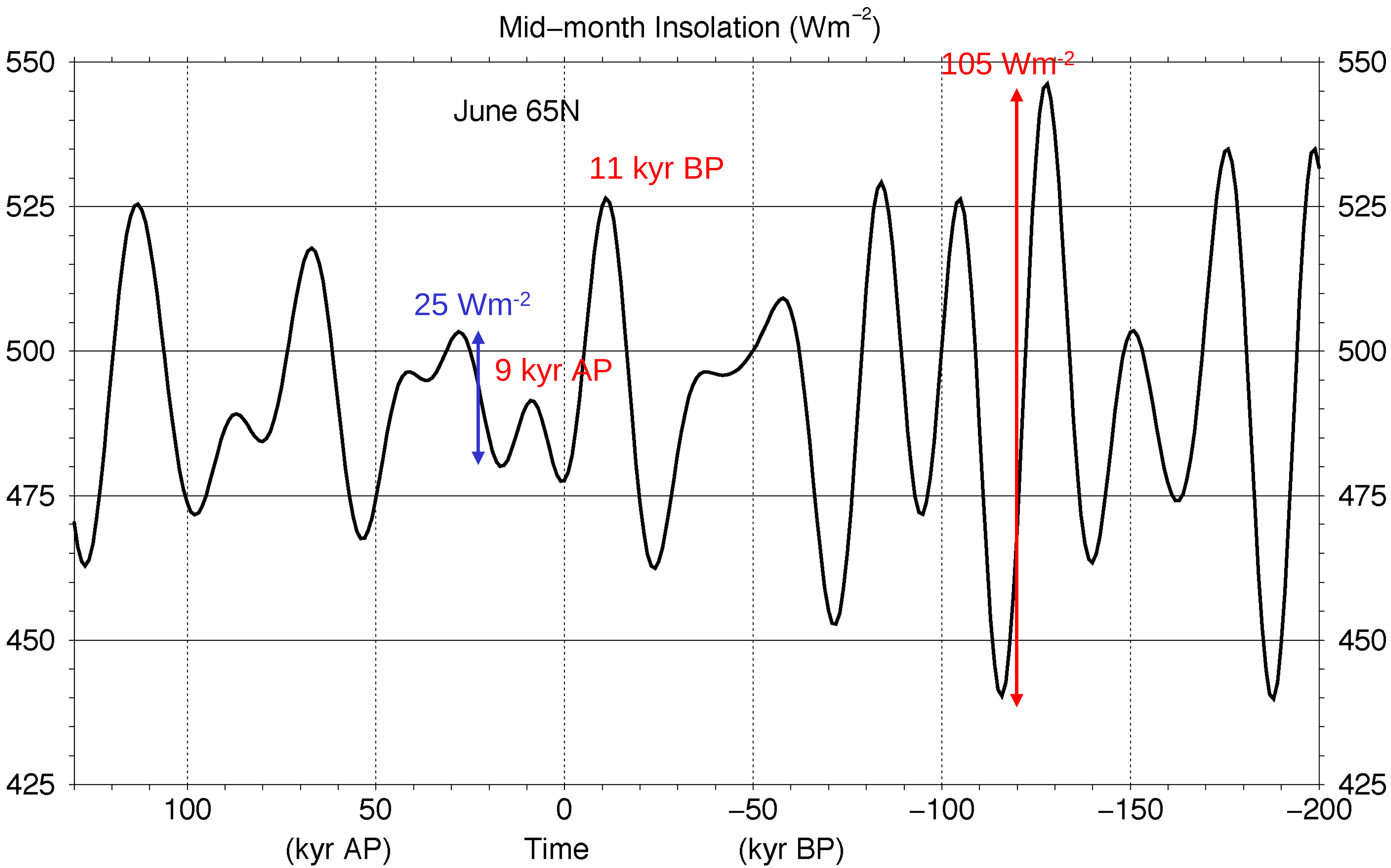
} High insolation

Lat. MAX

NH in summer

Δ lat in summer

Δ season in high lat NH } MAX

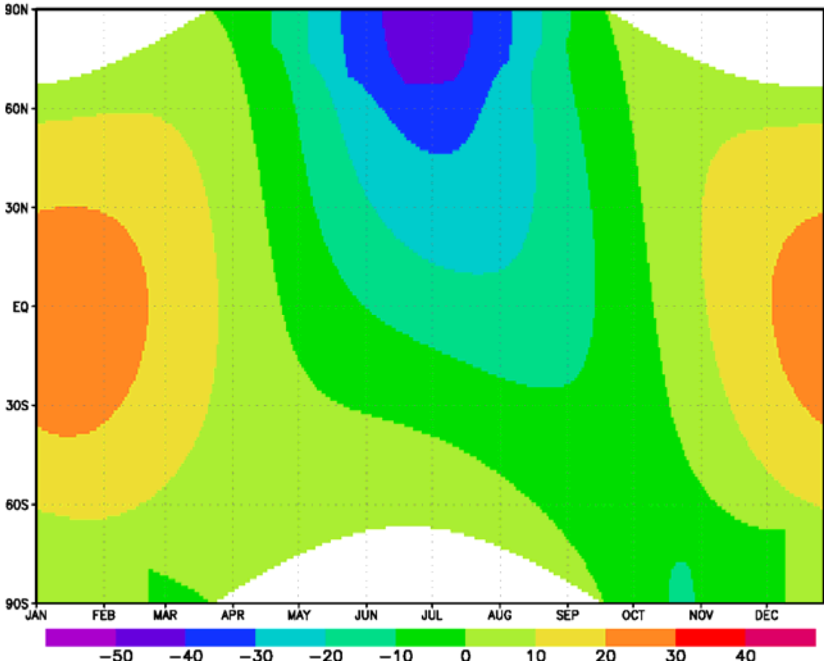


Mid–month Insolation (Wm^{-2})
June 65N
11 kyr BP
25 Wm^{-2}
9 kyr AP
105 Wm^{-2}
550
525
500
475
450
425
100
50
0
–50
–100
–150
–200
(kyr AP)
Time
(kyr BP)

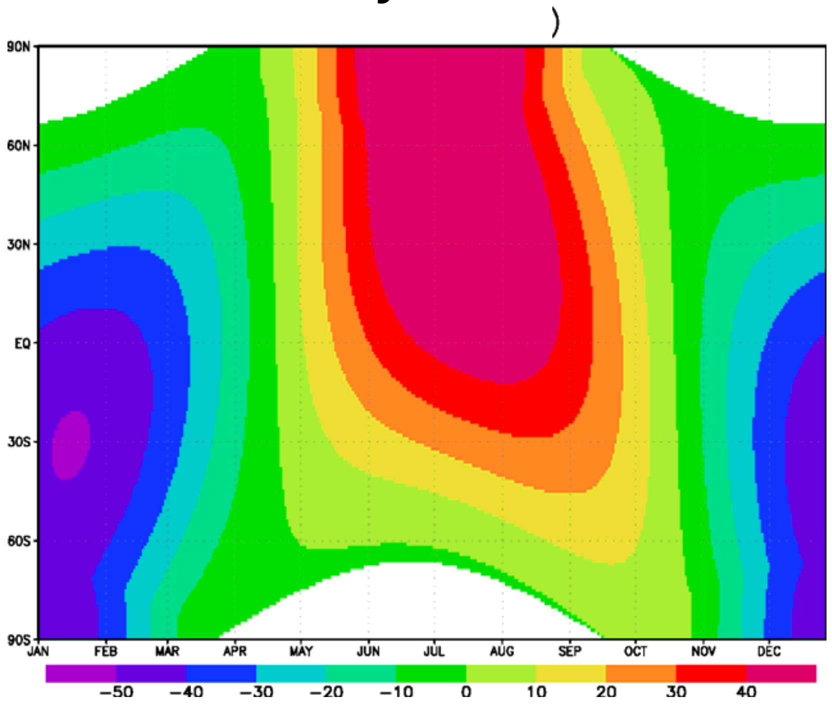
Insolation (Wm^{-2})

Deviation from present day value

115 kyr BP



125 kyr BP



(Paja Jovanovic, 1943)

MILANKOVITCH

FOR GLACIAL :

Snow accumulated during winter does not melt in summer.

➥ positive balance ⟶ larger polar cap

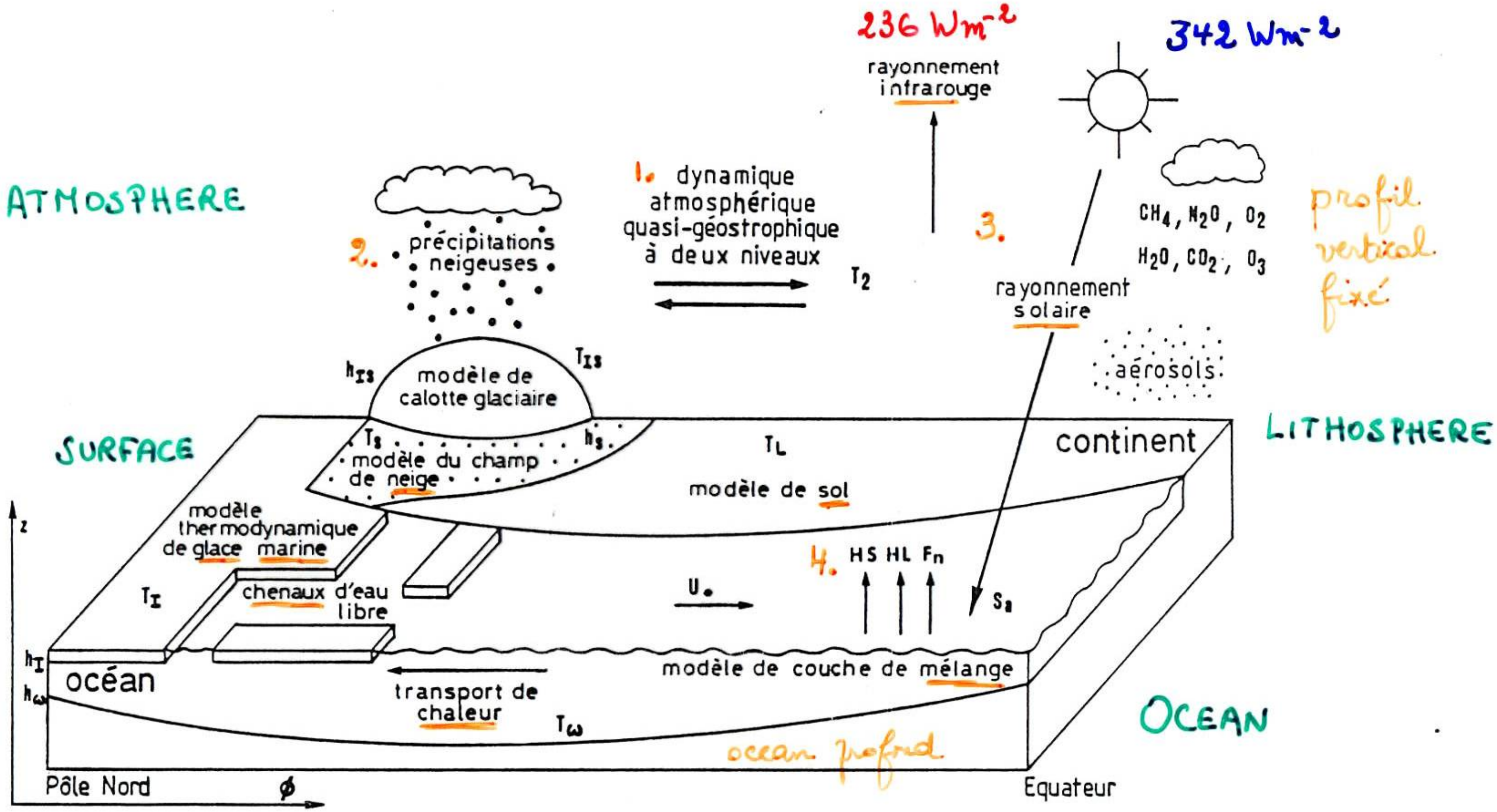
↑ ↓

less insolation available at the surface ⟵ higher albedo

⇓

POSITIVE feedback

MODELE 2.5-D LLN



Gallée et al. JGR 1991 96
13139 - 13161

FEEDBACKS in LLN 2.5-D Coupled Climate Model

Albedo-temperature

Water vapor – temperature

Snow/albedo – land cover

Taïga – Tundra

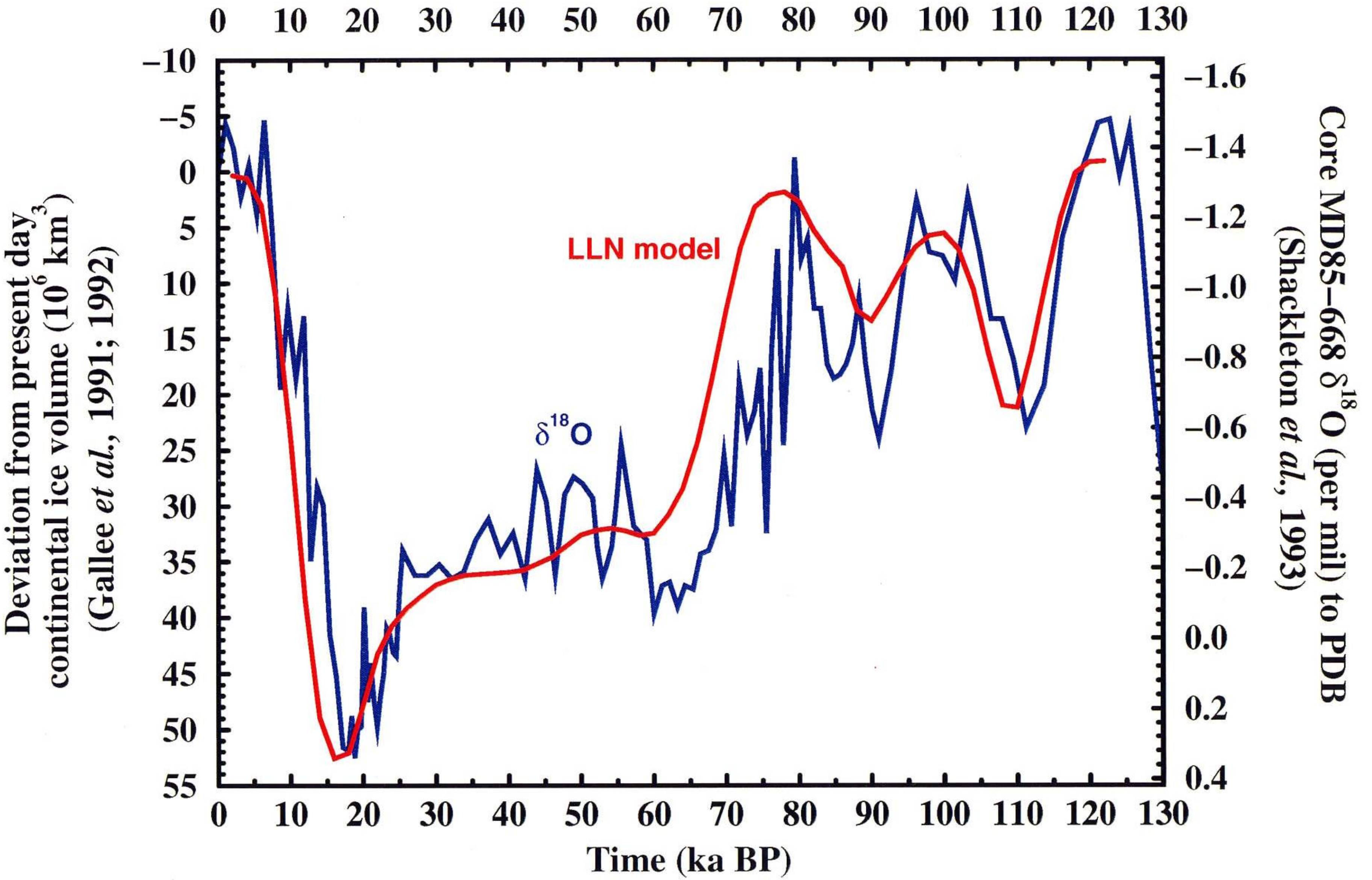
Sea level - ice volume – land cover

Ice sheets - lithosphere – climate

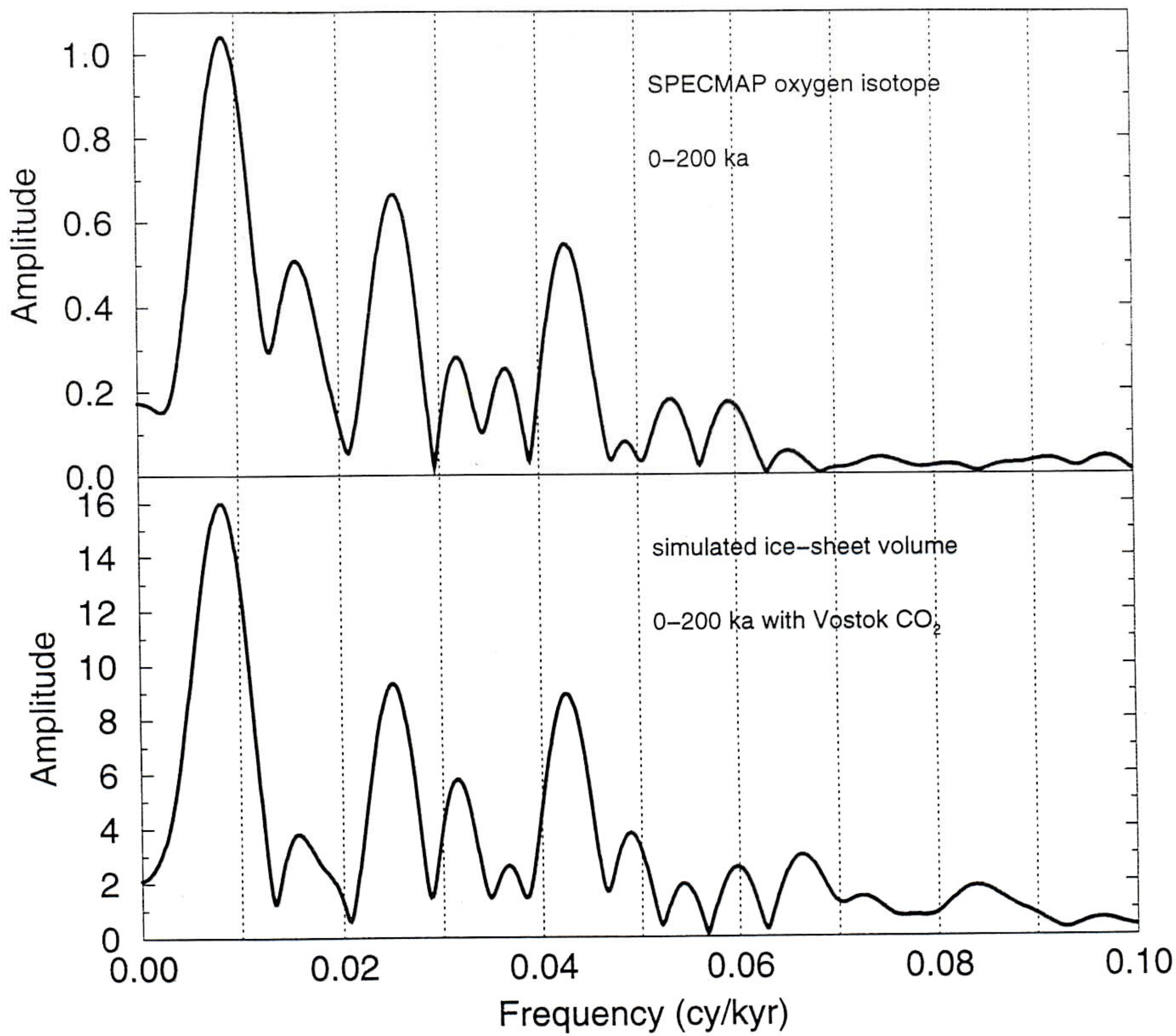
isostatic rebound

continentality

altitude

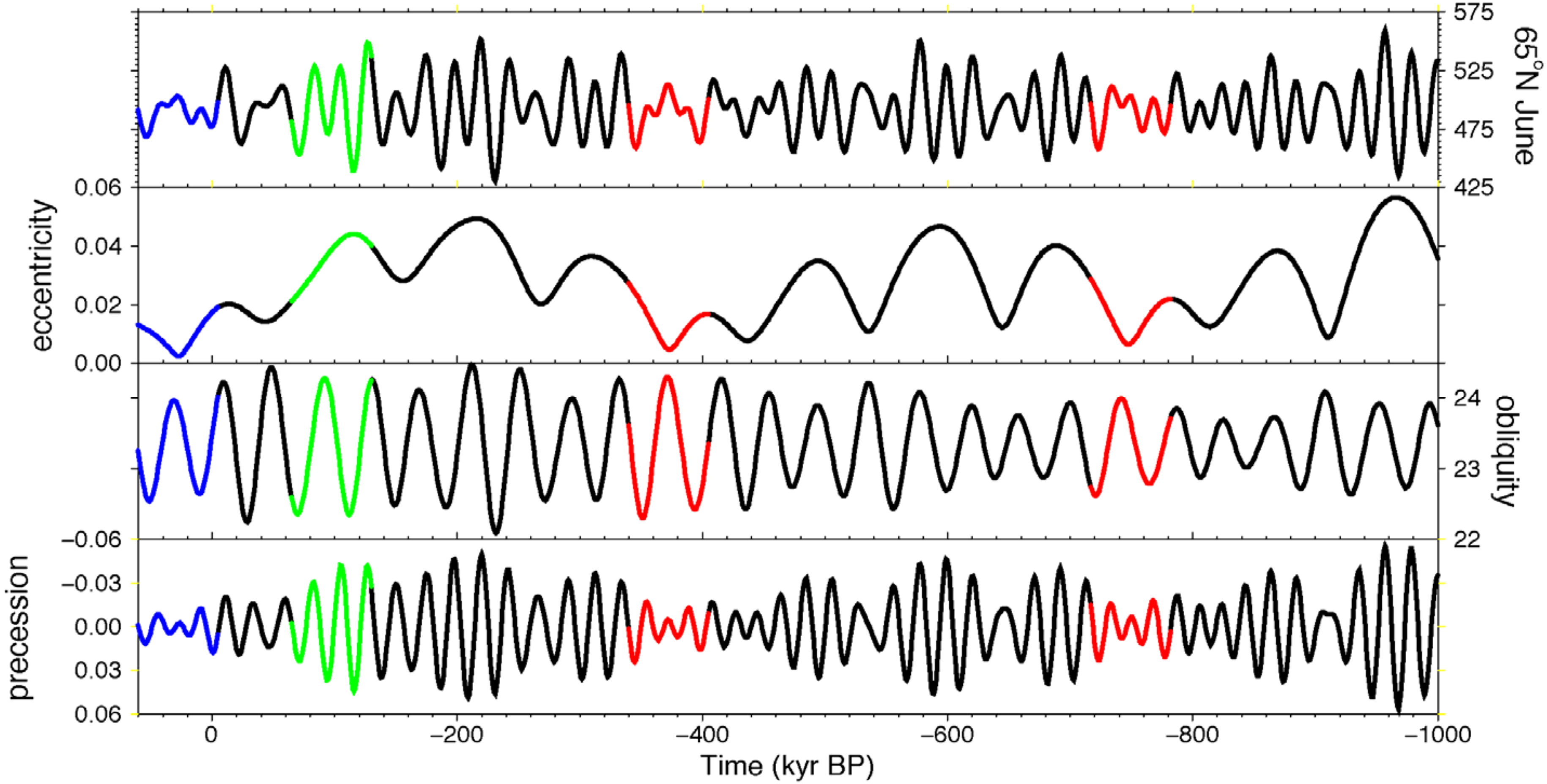


0 10 20 30 40 50 60 70 80 90 100 110 120 130
−10
−5
0
5
10
15
20
25
30
35
40
45
50
55
Deviation from present day continental ice volume (10^6 km^3) (Gallee et al., 1991; 1992)
−1.6
−1.4
−1.2
−1.0
−0.8
−0.6
−0.4
−0.2
0.0
0.2
0.4
Core MD85–668 δ^{18}O (per mil) to PDB (Shackleton et al., 1993)
LLN model
δ^{18}O
Time (ka BP)



SPECMAP oxygen isotope
0–200 ka
simulated ice–sheet volume
0–200 ka with Vostok CO_2
Amplitude
1.0
0.8
0.6
0.4
0.2
0.0
Amplitude
16
14
12
10
8
6
4
2
0
0.00
0.02
0.04
0.06
0.08
0.10
Frequency (cy/kyr)

Orbital parameters : an analogue for the future

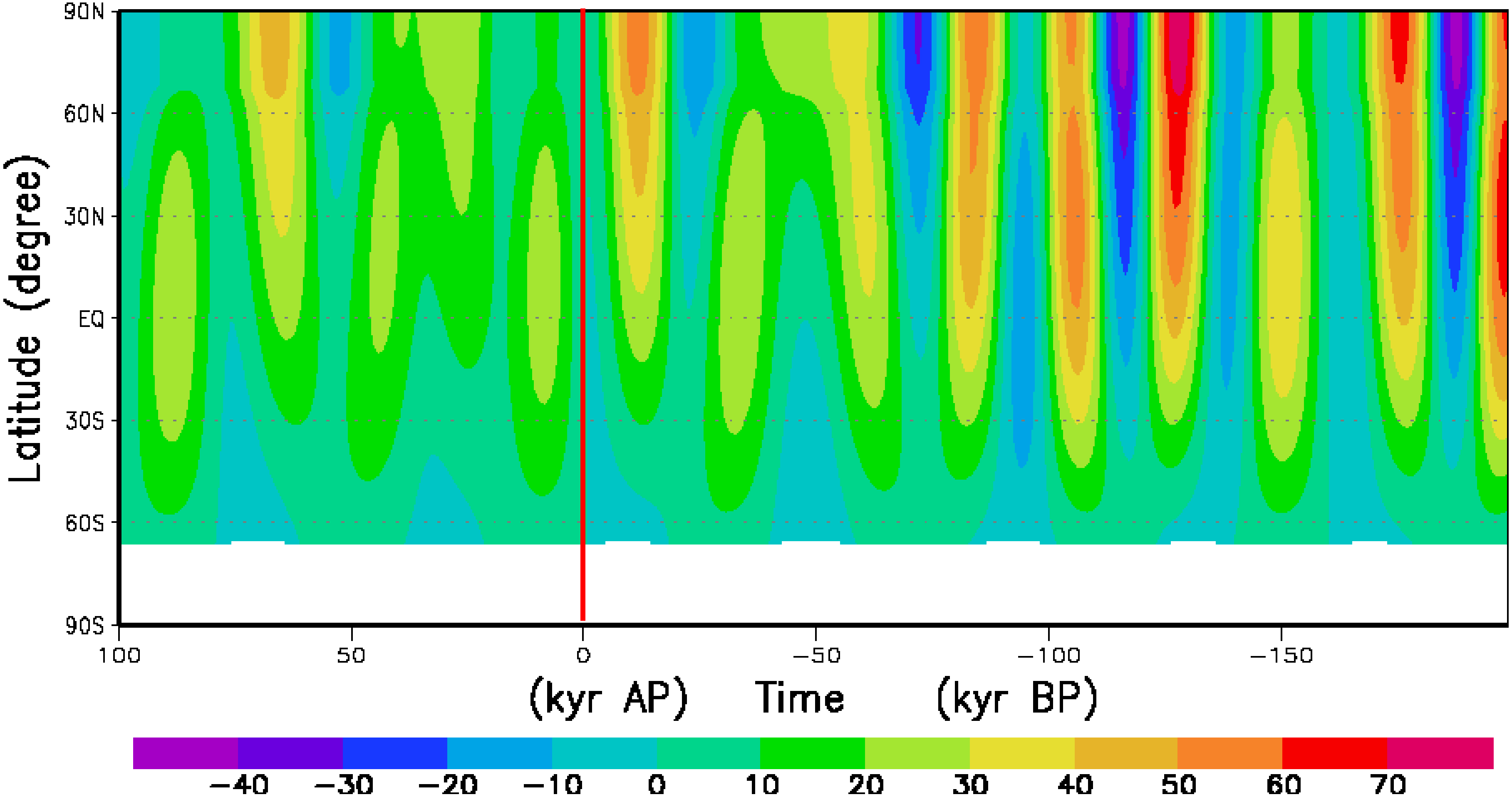


STAGE 11 / STAGE 1

and its Future

24h mean irradiance (Wm^{-2})

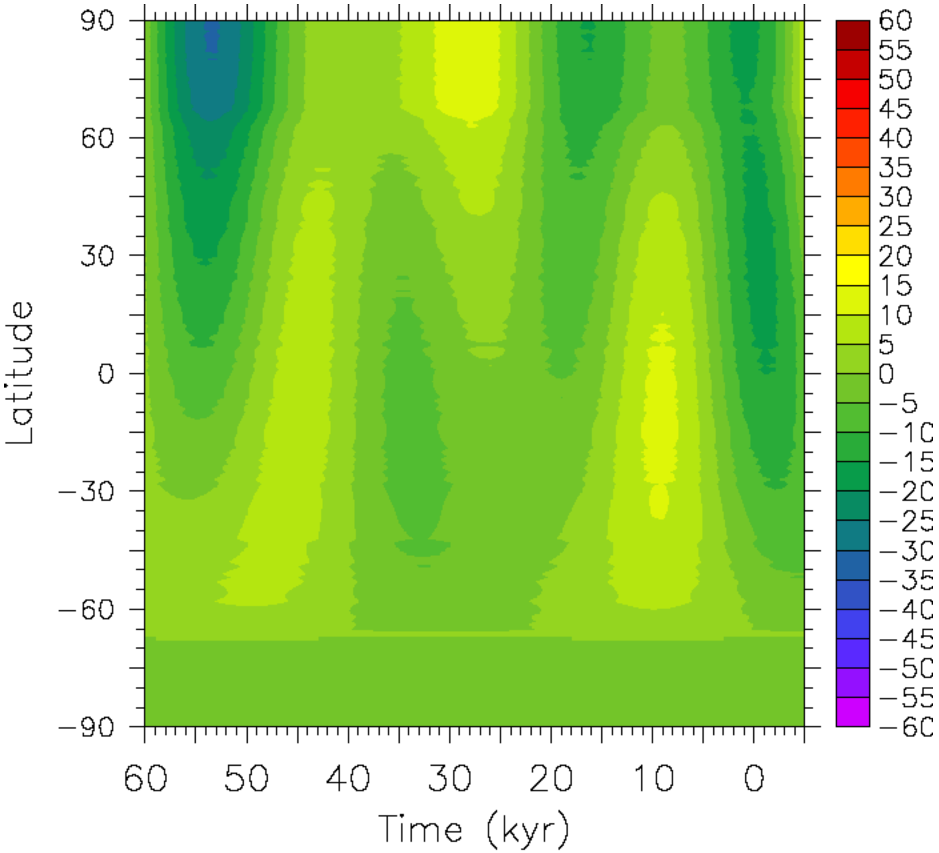
Mid-month June



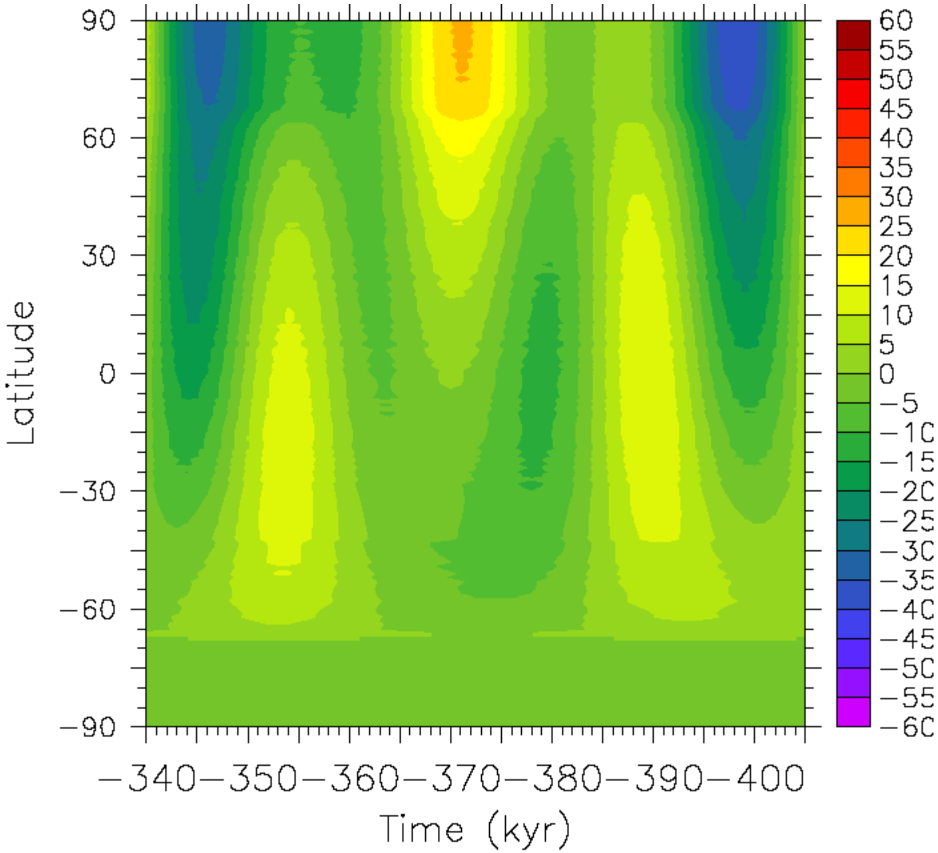
Forte ressemblance entre l'interglaciaire actuel et MIS11

Insolation au solstice de juin

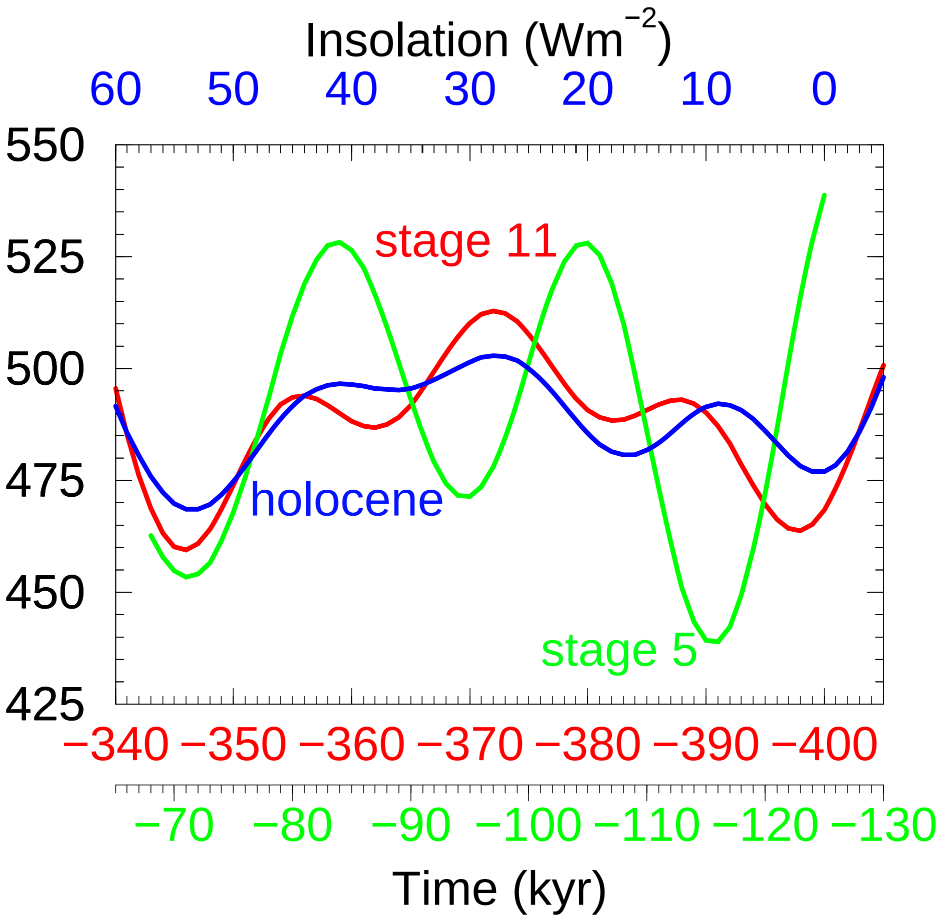
Futur



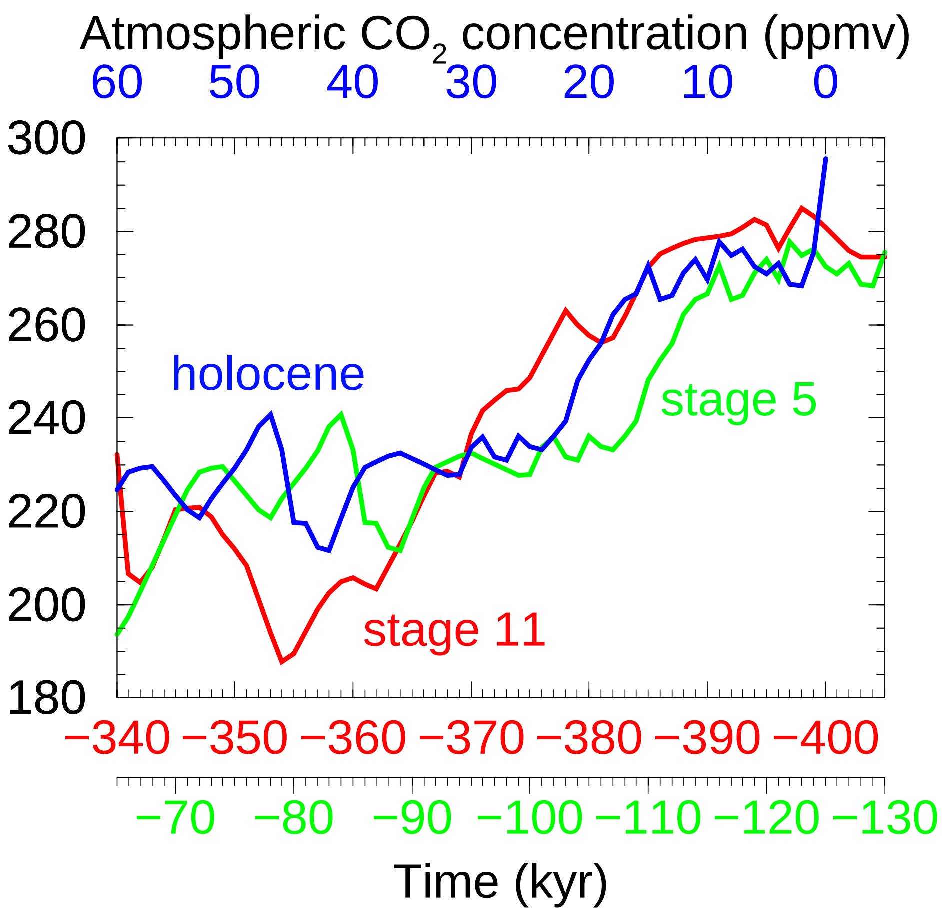
MIS11



MIS11 :
an analogue for the future



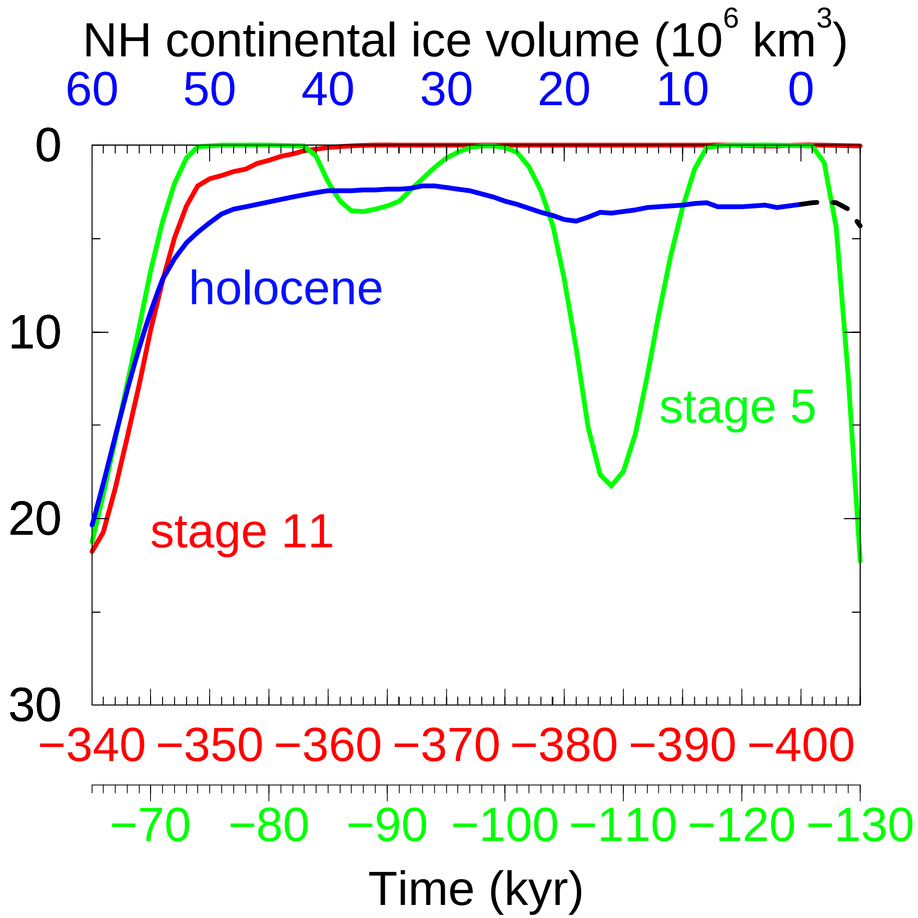
MIS11 :
an analogue for the future



Ref :

Petit et al., 1999

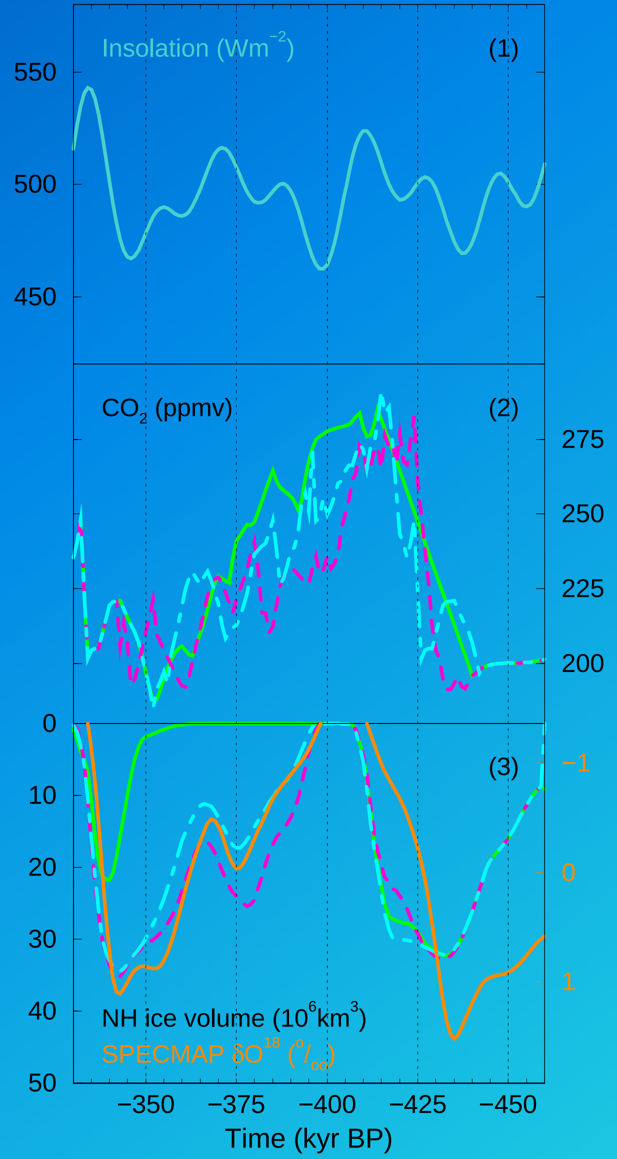
MIS11 : an analogue for the future



CO_2 = Vostok

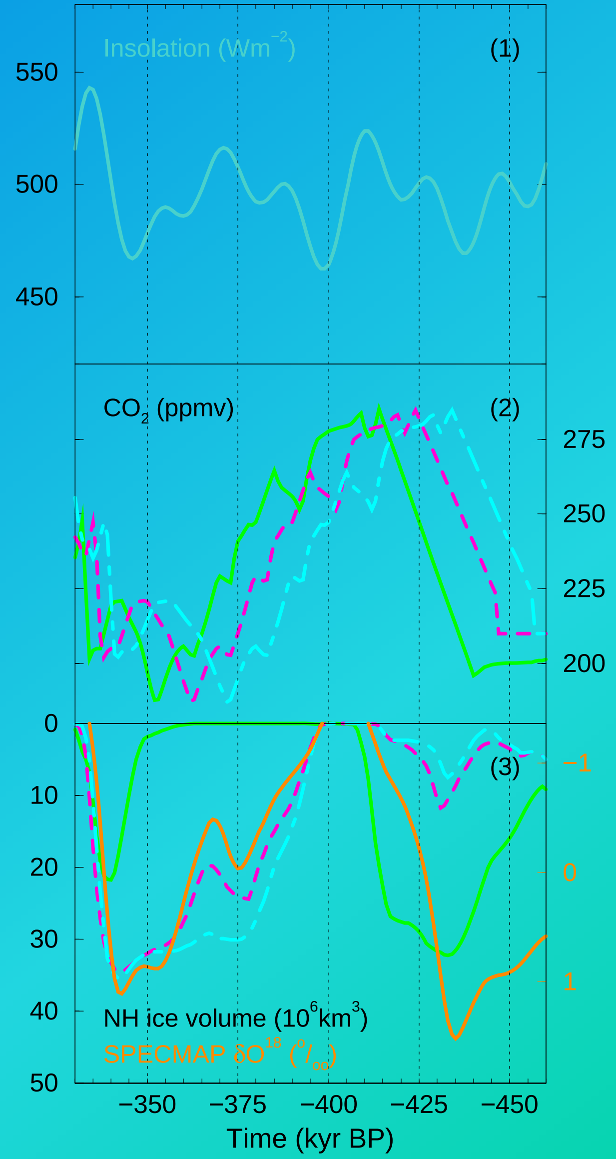
SENSITIVITY To The PHASE BETWEN INSOLATION and CO_2 FORCINGS AT STAGE 11 and STAGE 1

MIS11 : other CO_2 scenarios

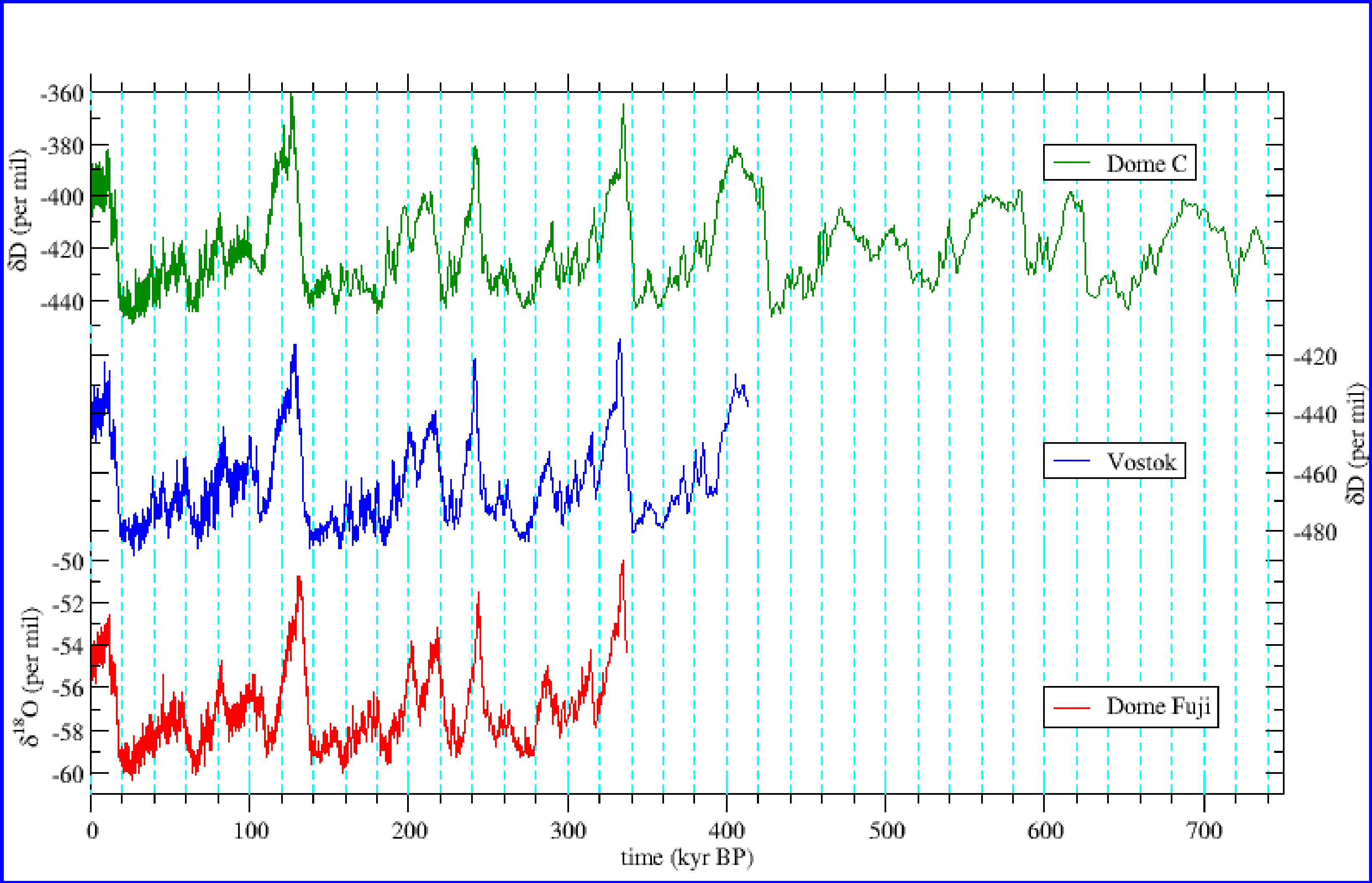


Stage 11 is replaced by **stage 9** or **stage 5**

Stage 11 is made older by **10 kyr** or by **20 kyr**

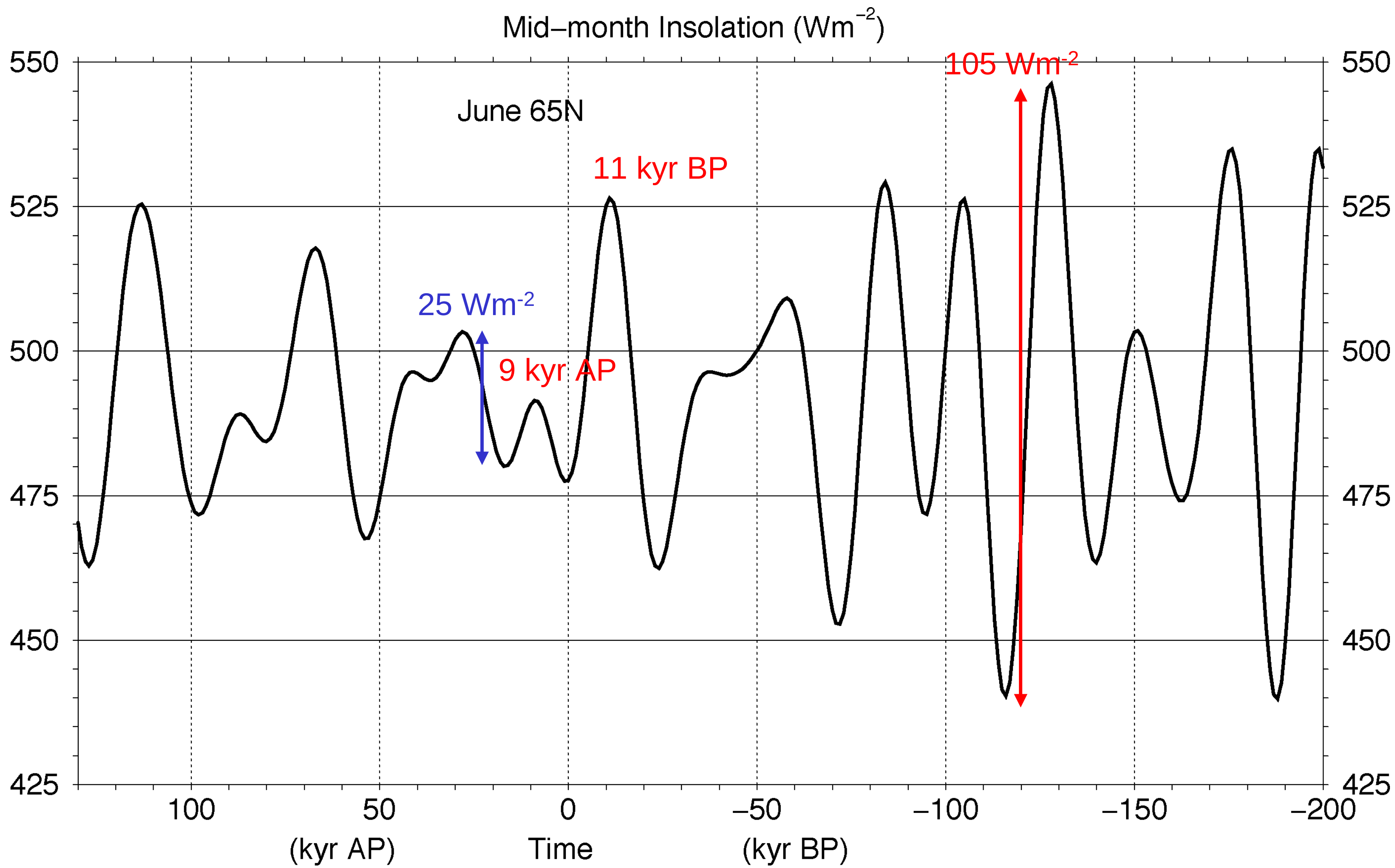


Archives of climate in Antarctica



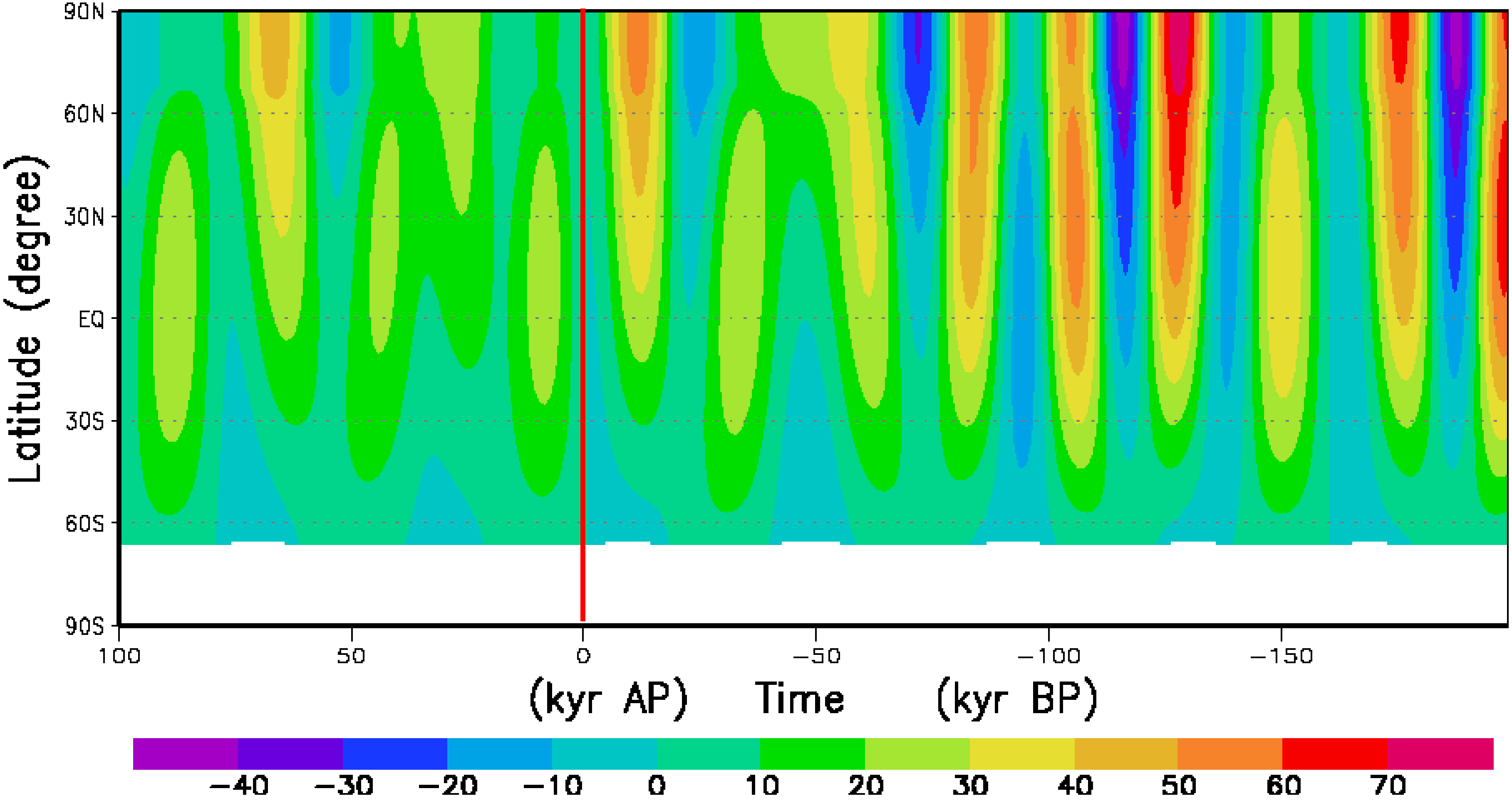
EPICA community members, Nature, 2004

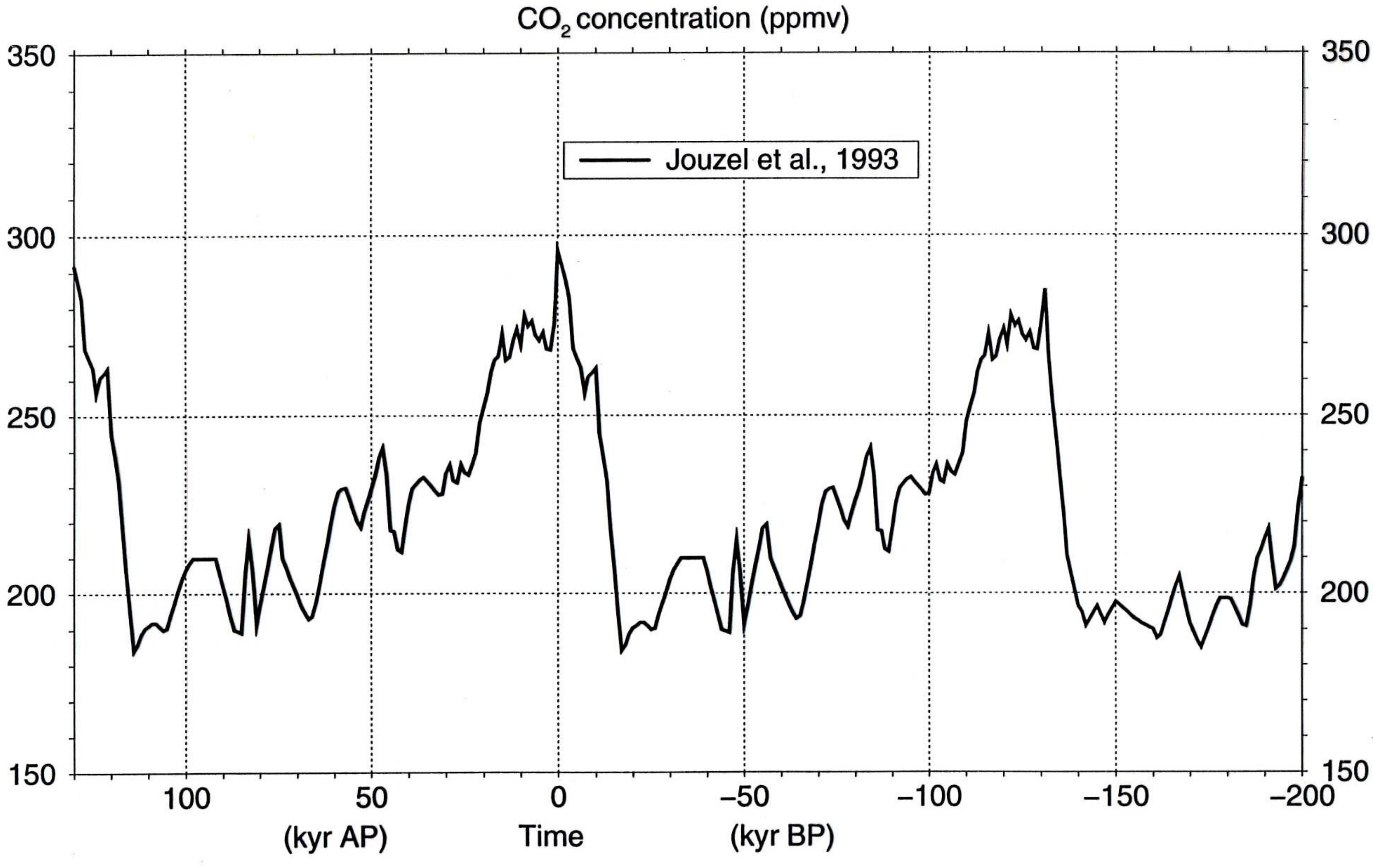
The EXCEPTIONAL astronomical forcing over the next 50 kyr

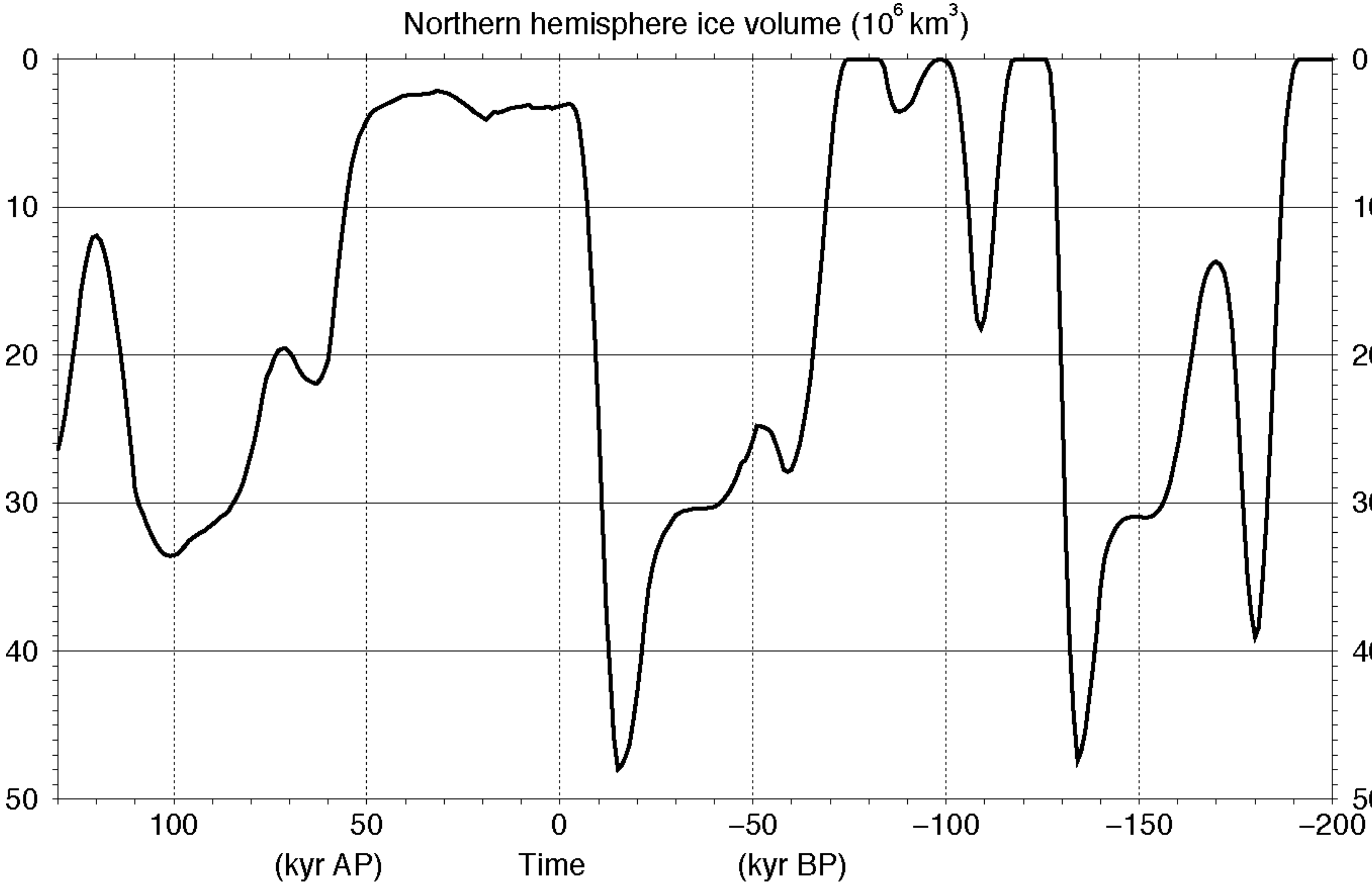

Mid–month Insolation (Wm^{-2})
June 65N
25 Wm^{-2}
9 kyr AP
11 kyr BP
105 Wm^{-2}
550
525
500
475
450
425
100
50
0
−50
−100
−150
−200
(kyr AP)
Time
(kyr BP)

24h mean irradiance (Wm^{-2})

Mid-month June

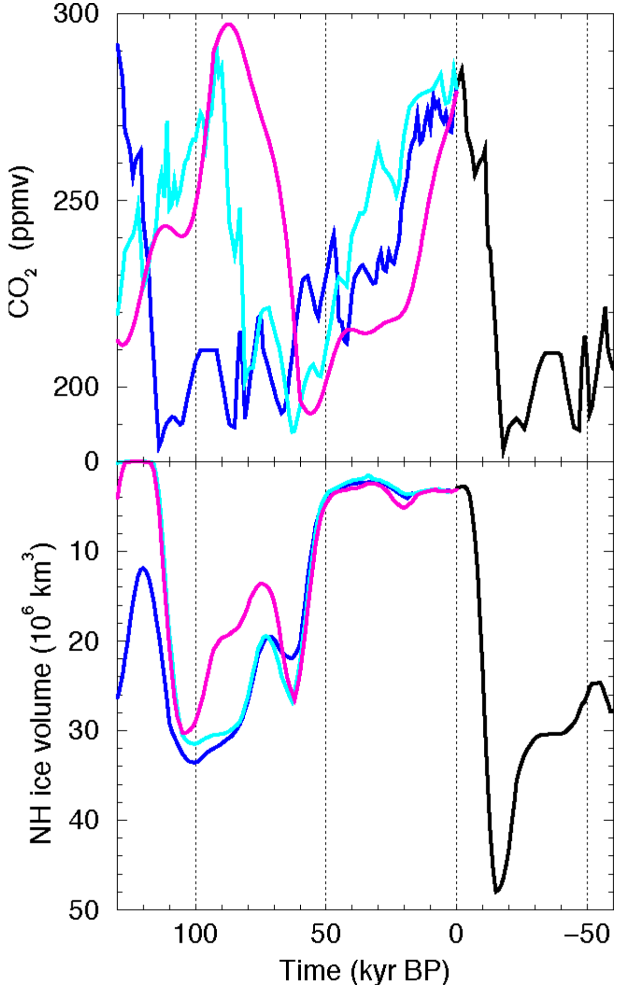



CO2 concentration (ppmv)
Jouzel et al., 1993
350
300
250
200
150
100
50
0
−50
−100
−150
−200
(kyr AP)
Time
(kyr BP)


Northern hemisphere ice volume (10^6 km^3)
0
10
20
30
40
50
100
50
0
−50
−100
−150
−200
(kyr AP)
Time
(kyr BP)

A long interglacial ahead?
Different natural CO_2 scenarios for the future

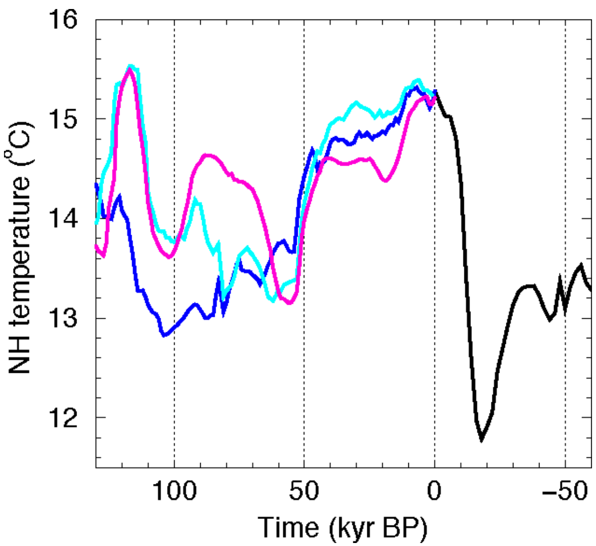
Berger and Loutre, Science, 2002.



Long interglacial : ~50kyr

Small NH ice sheets

Warm temperature



Results confirmed by Vettoretti and Peltier

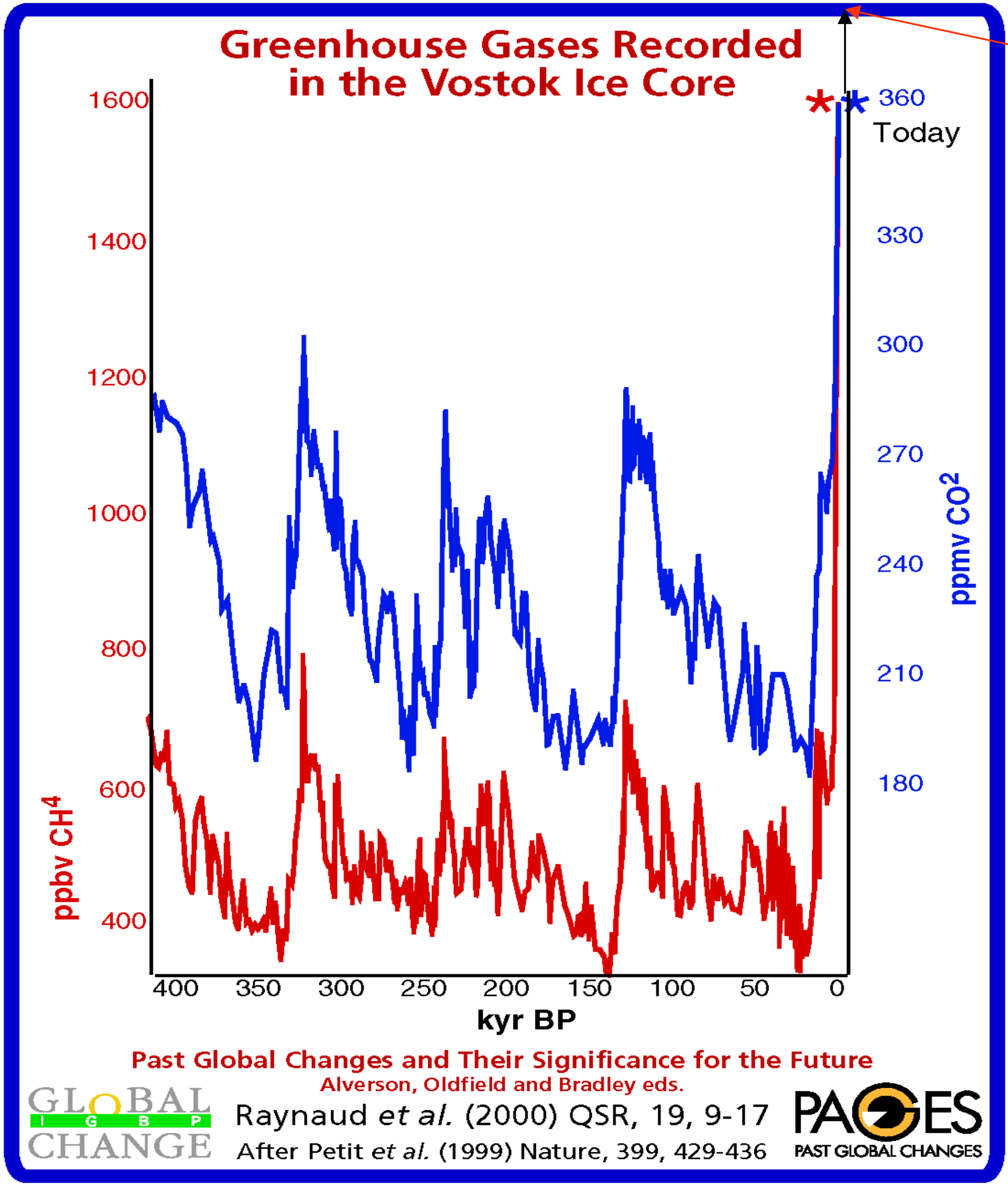
The present interglacial, how and when will it end?

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.

En 2003 :
465 ppmv CO_{2eq}



376 en 2003

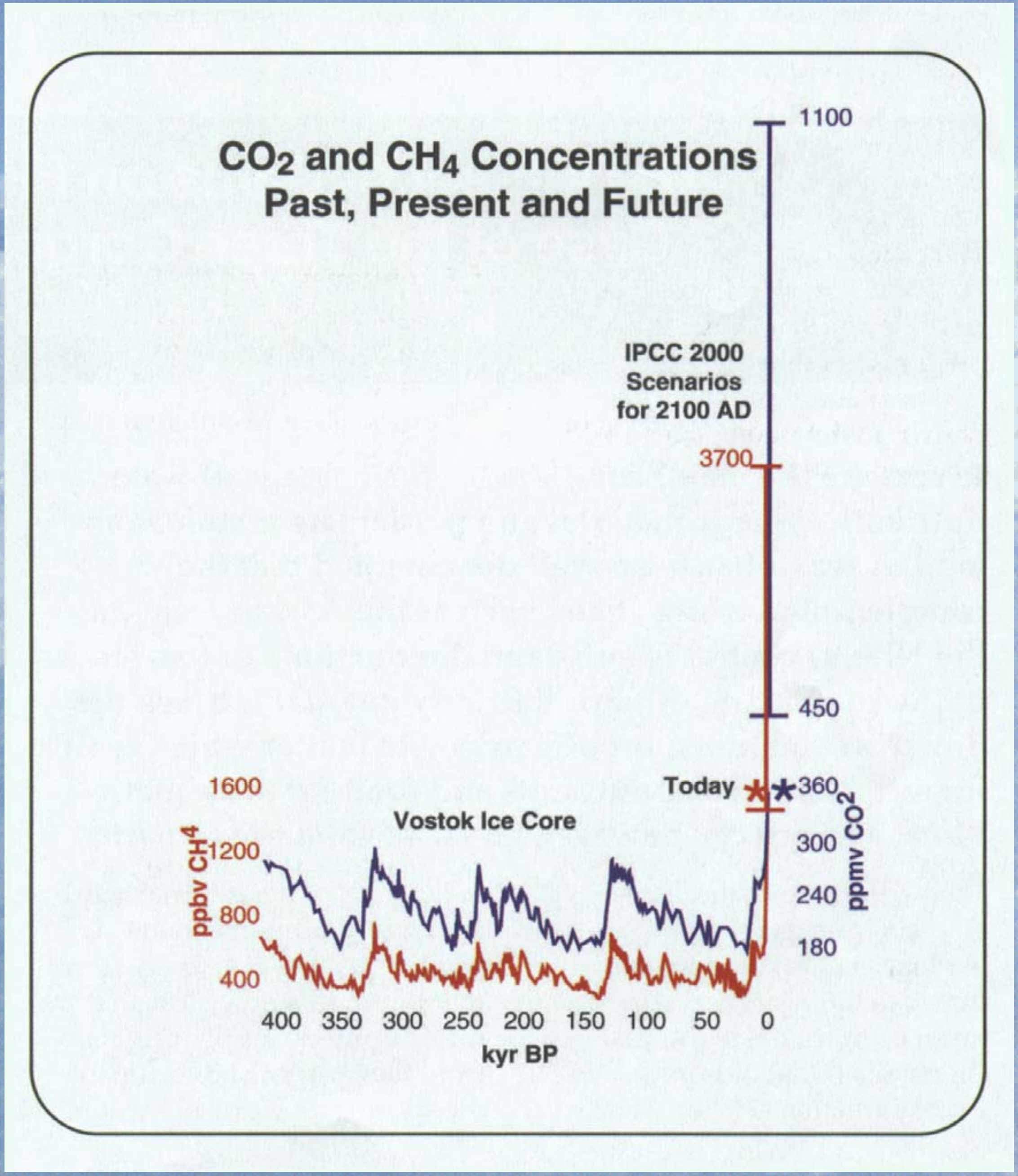
en 1995

accroissement

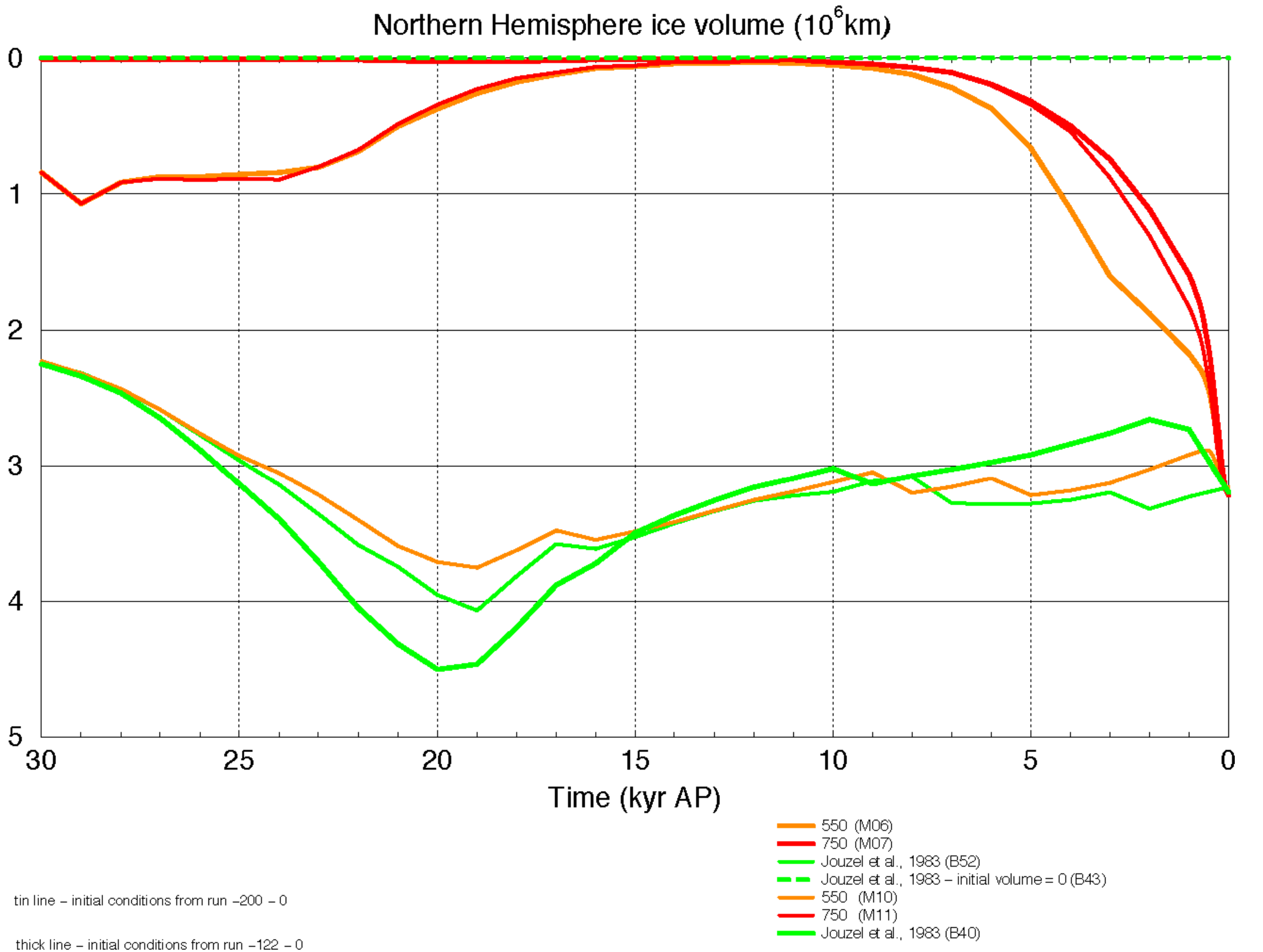
2000-01 : 1.5

2001-02 : 2.0

2002-03 : 2.5

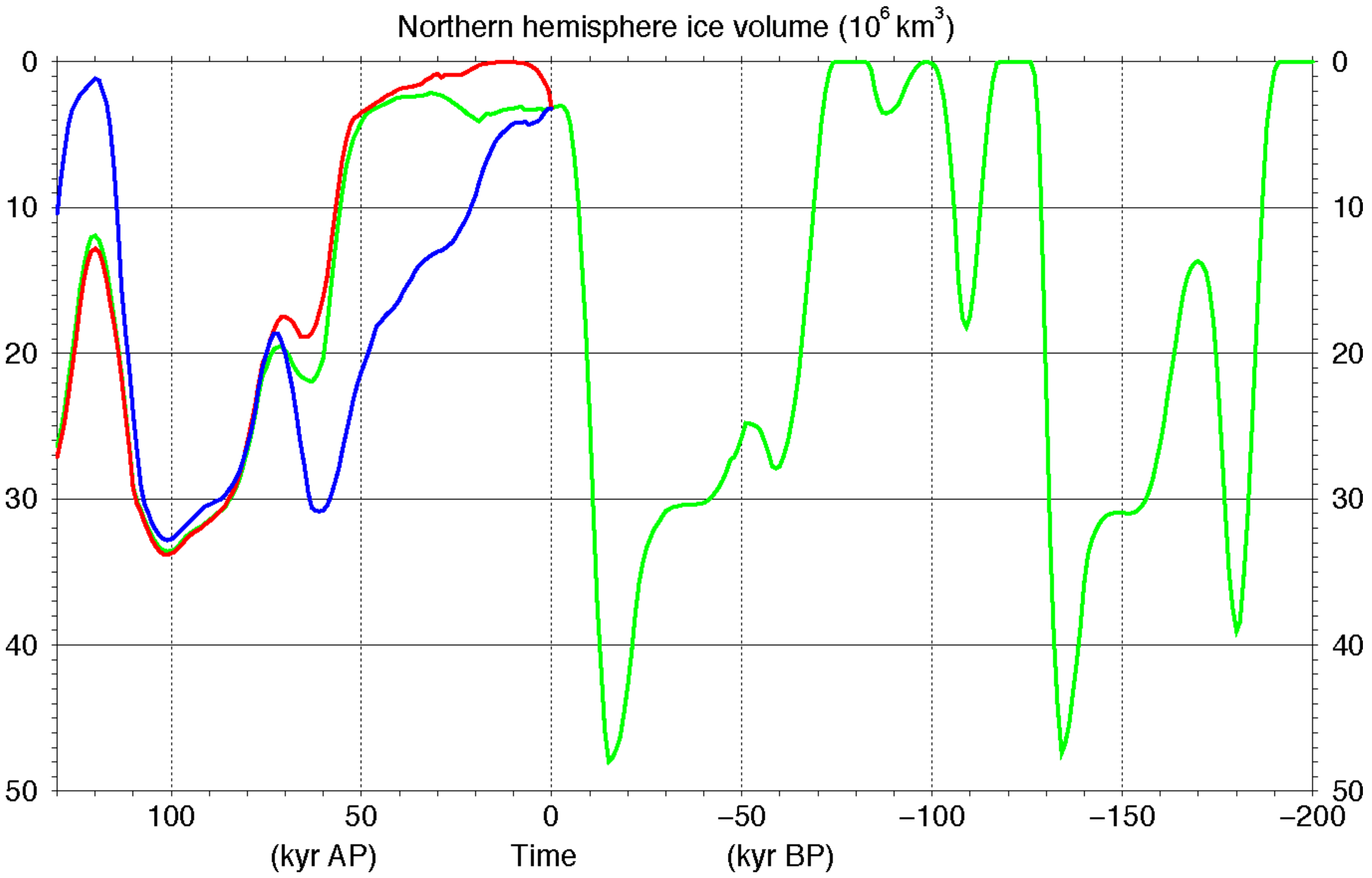


(Pedersen, IGBP Newsletter 44, dec 2000)



tin line – initial conditions from run -200 – 0

thick line – initial conditions from run -122 – 0



A double threshold : less than 230ppmv : glacial   more than 700ppmv : no ice

AT GEOLOGICAL TIME SCALE

FORCING : SOLAR IRRADIATION

RESPONSE : CHANGE IN CLIMATE → IN BIOGEOCHEMICAL CYCLES

FEEDBACK

AT PRESENT-DAY HUMAN TIME SCALE

FORCING: SOLAR IRRADIATION + GREENHOUSE GASES ...

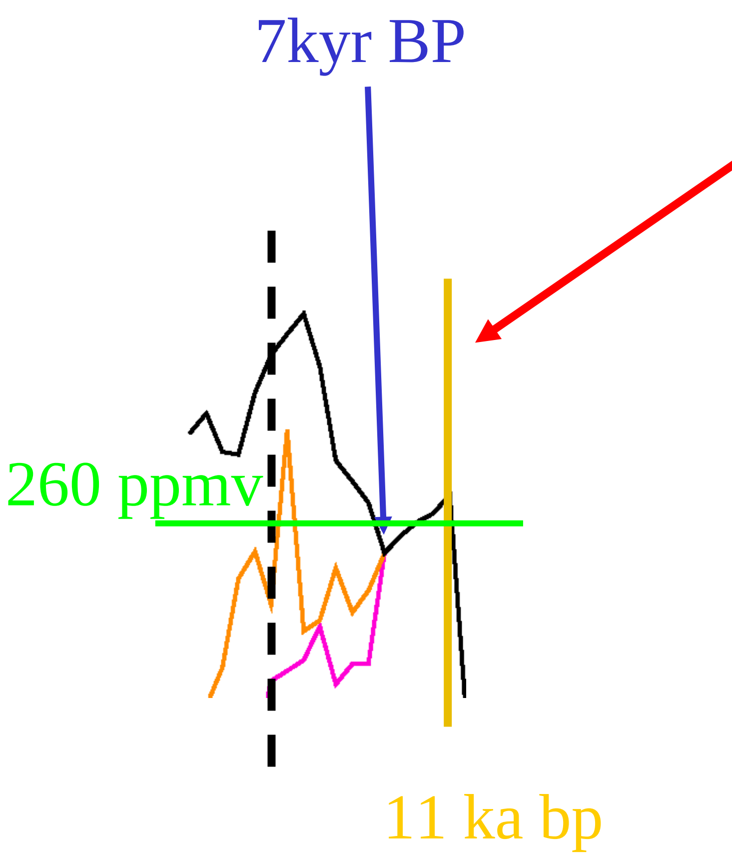
RESPONSE : CHANGE IN CLIMATE → IN BIOGEOCHEMICAL CYCLES

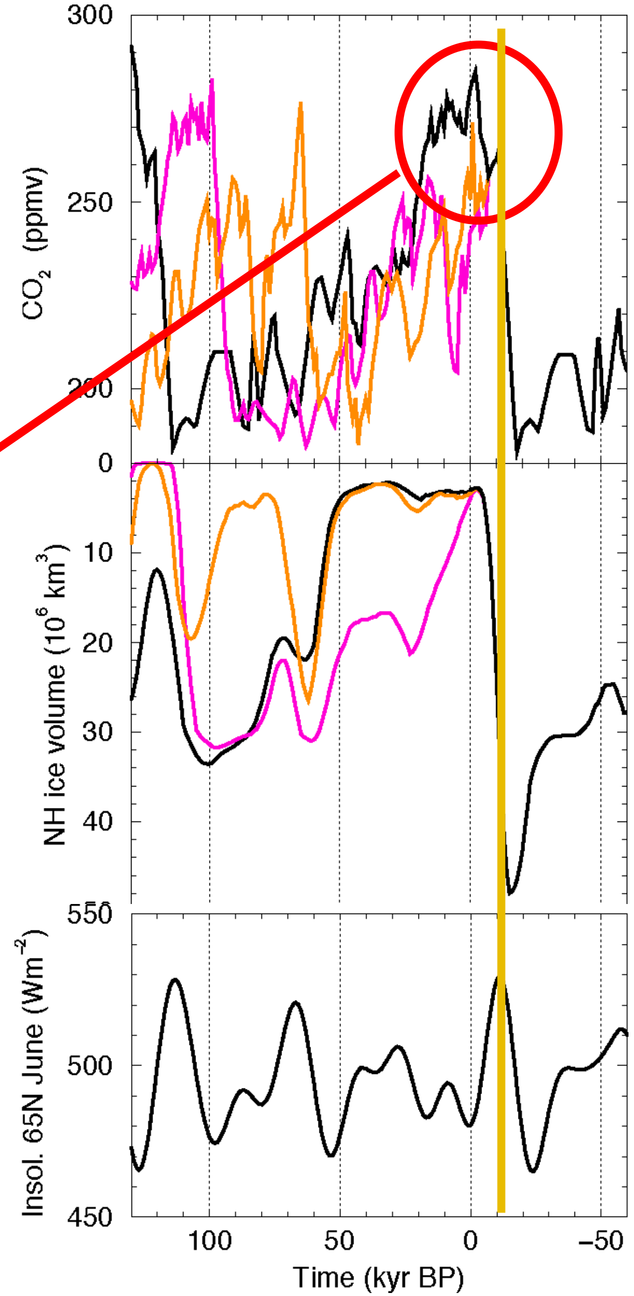
FEEDBACK

The anthropogenic greenhouse era began thousands of years ago

W.F. Ruddiman, climatic changes, 2004.

Human impact in the past





ICE AGE — **QUATERNARY**

↓

HOLOCENE

↓

ANTHROPOCENE (P. Crutzen)

↓

WARM PERIOD — **QUINTERNARY**

A. Berger, 2001

CONCLUSIONS

WE ARE LIVING

EXCEPTIONAL TIMES

1. BECAUSE THE MAIN FORCING AT THE THOUSANDS OF YEARS TIME SCALE WILLNOT VARY ANYMORE, THE OTHER FORCINGS (GHG) WILL HAVE AN EVEN STONGER INFLUENCE

2. ENTERING AN ICE AGE IS NOT ANYMORE AN EXCUSE FOR ALLOWING GHG RELEASE. ON THE CONTRARY, THE RESULTING GW MIGHT CAUSE AN EARLIER COOLING IN N NA DUE TO A WEAKER ENERGY TRANSPORT BY THE GULF STREAM