Friends of Science, Calgary

16th May 2011

Human-induced global warming: Why I am sceptical

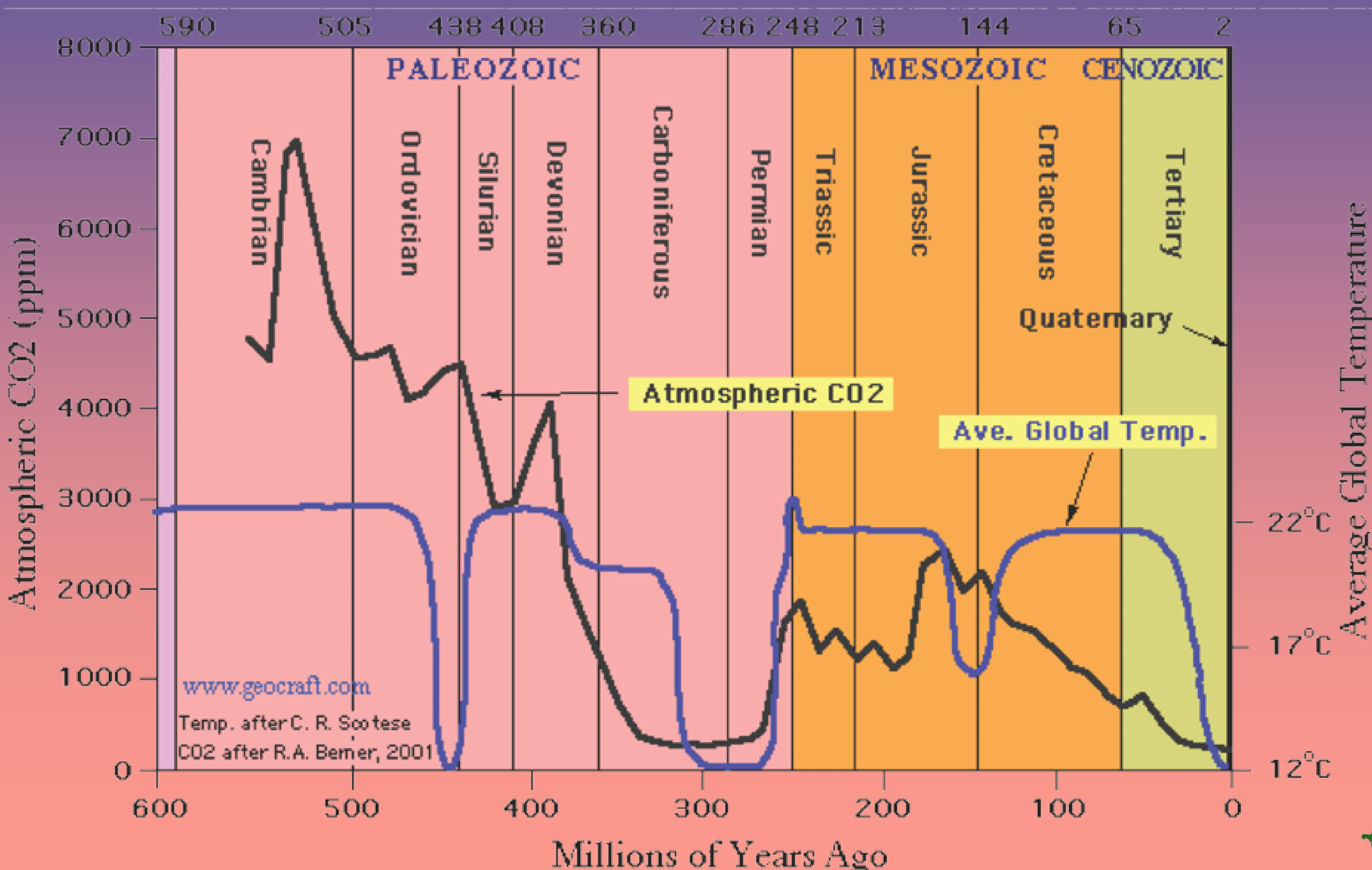
Ian Plimer

Earth and Environmental Sciences, The University of Adelaide
Emeritus Professor of Earth Sciences, The University of Melbourne

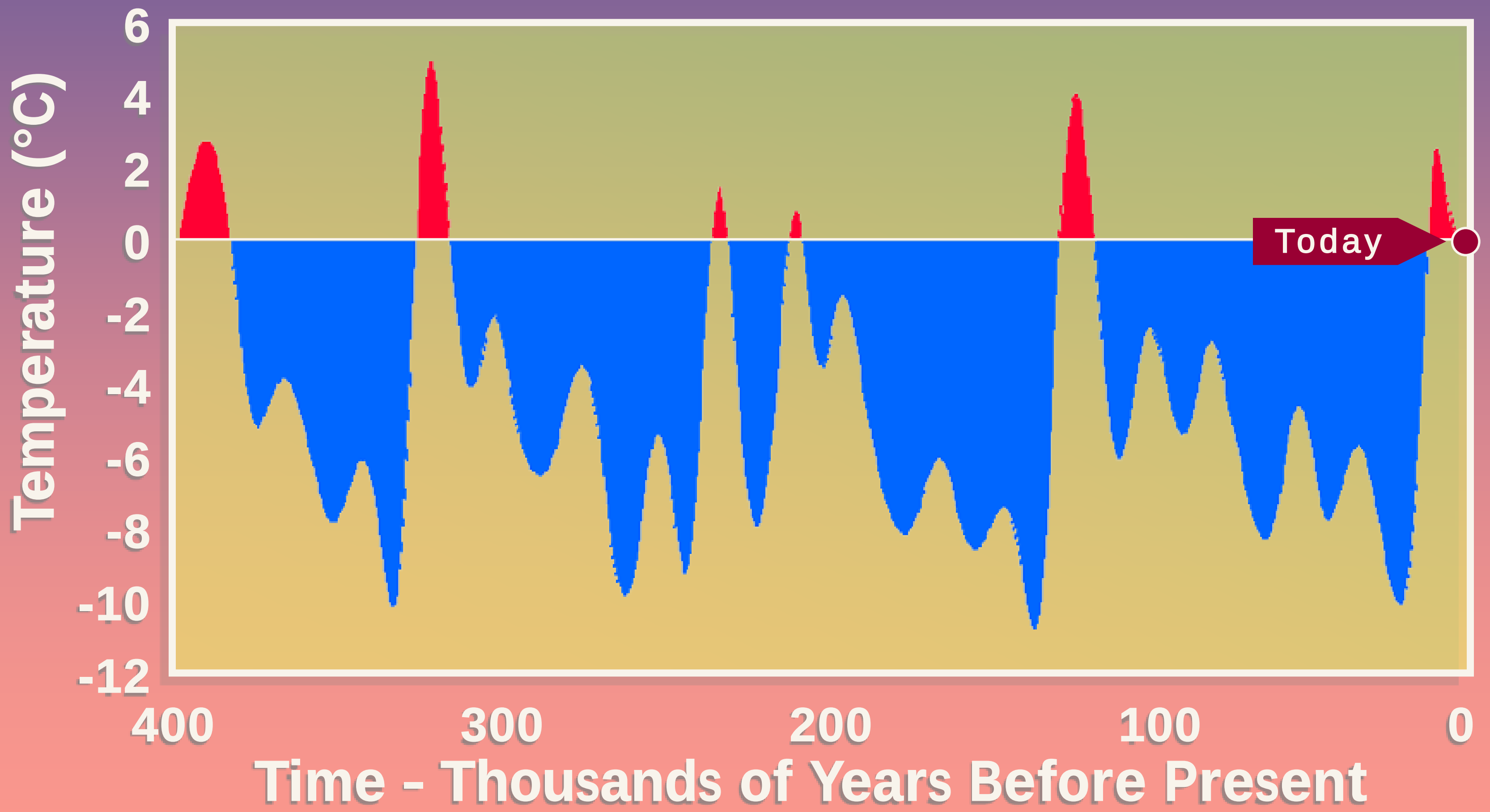
Constant cyclical climate change

Known Cycles	
Variable	**tectonic, PDO**
143 million year	**galactic**
100,000 years	**orbital**
41,000 years	**orbital**
23,000 years	**orbital**
1,500 years	**solar**
210 years	**solar**
87 years	**solar**
22 years	**solar**
18.7 years	**lunar**
11 years	**solar**

Climate change over time



Is the speed and degree of modern climate change unprecedented?

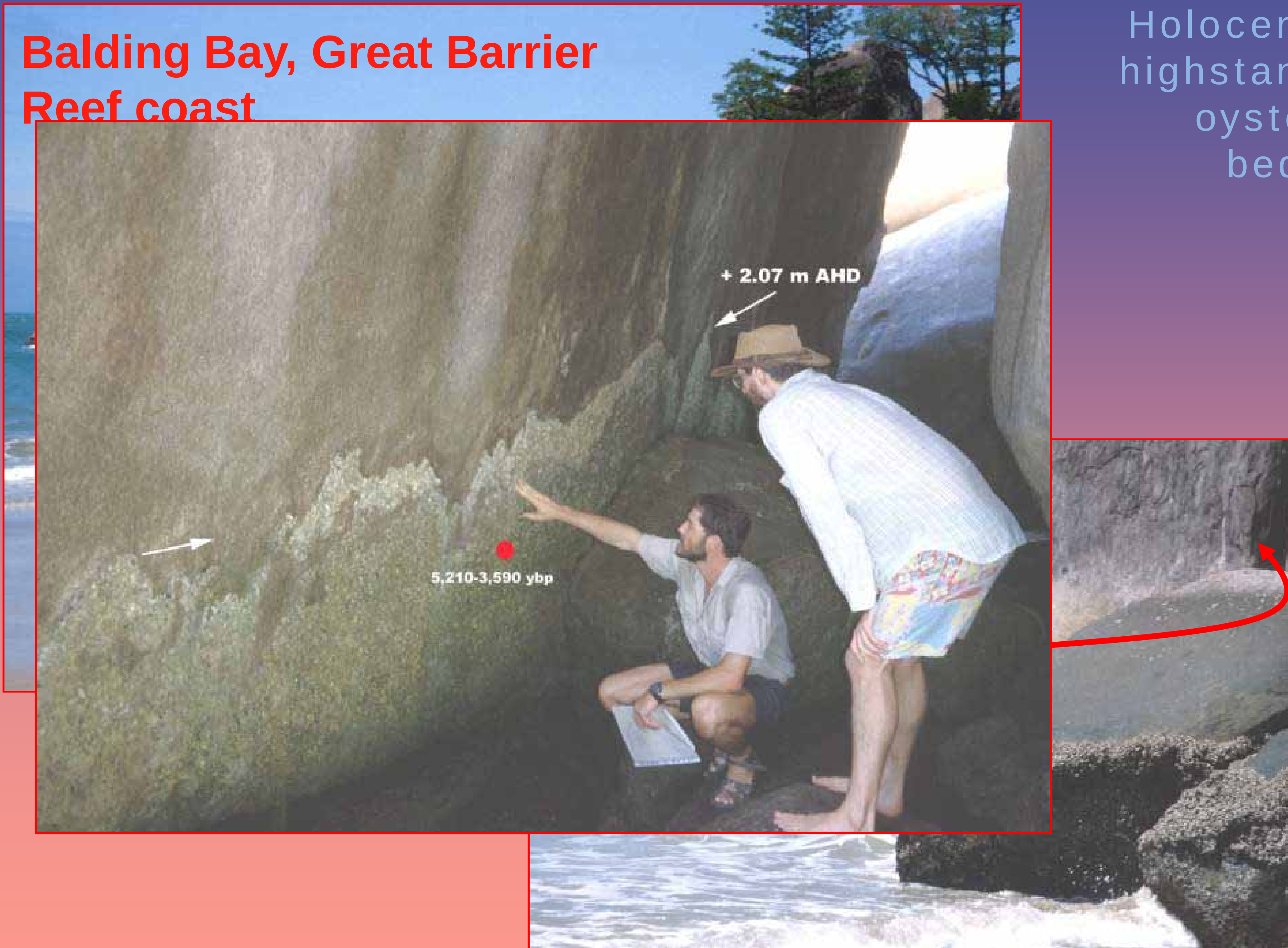


Sea levels

- SL always changing (Neoproterozoic glaciation ±1500 m, Quaternary glaciation ±130 m)
- 116,000-128,000 years bp SL +7m
- 6,000 years bp SL in Indian/Pacific Oceans +2m
- Atolls rise as SL rises
- Many reasons for SL change

Balding Bay, Great Barrier Reef coast

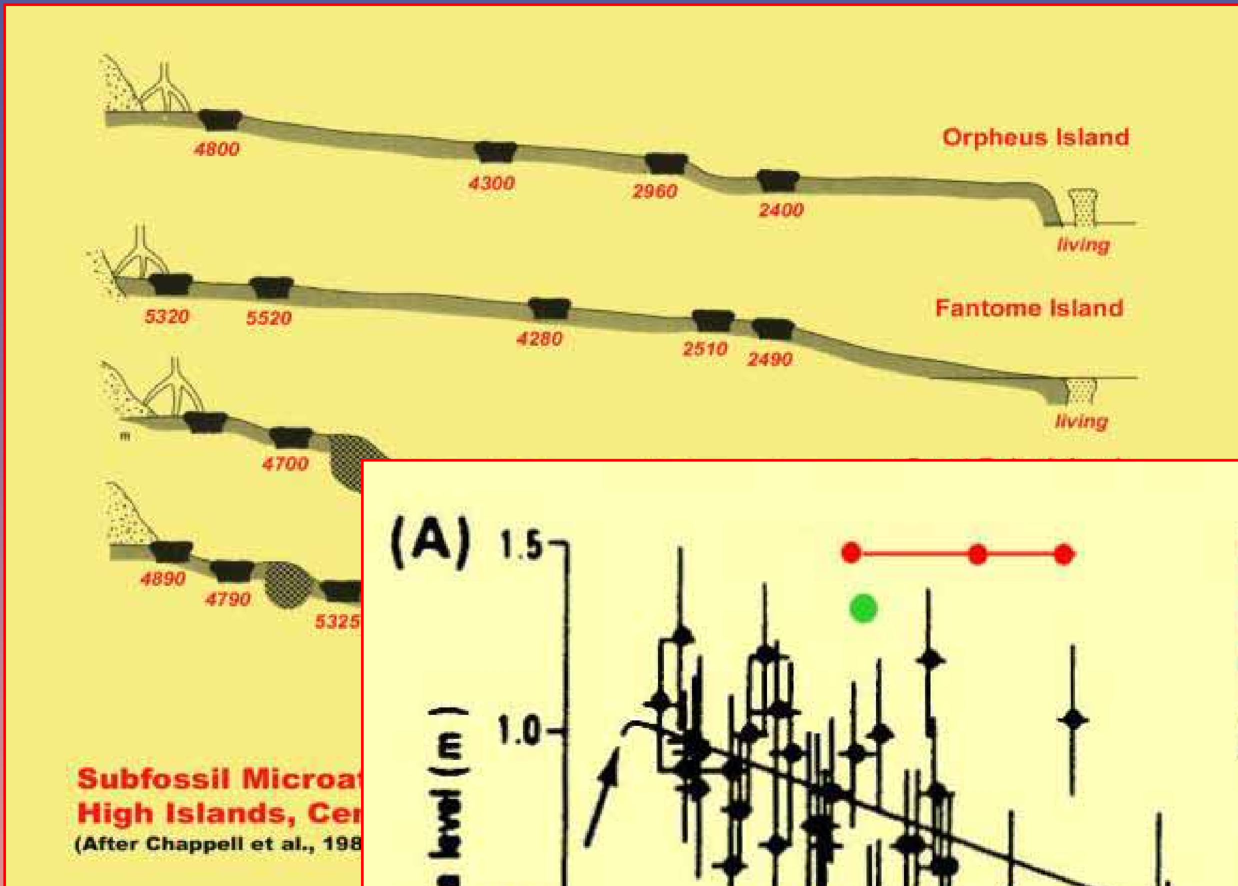
Holocene highstand oyster beds

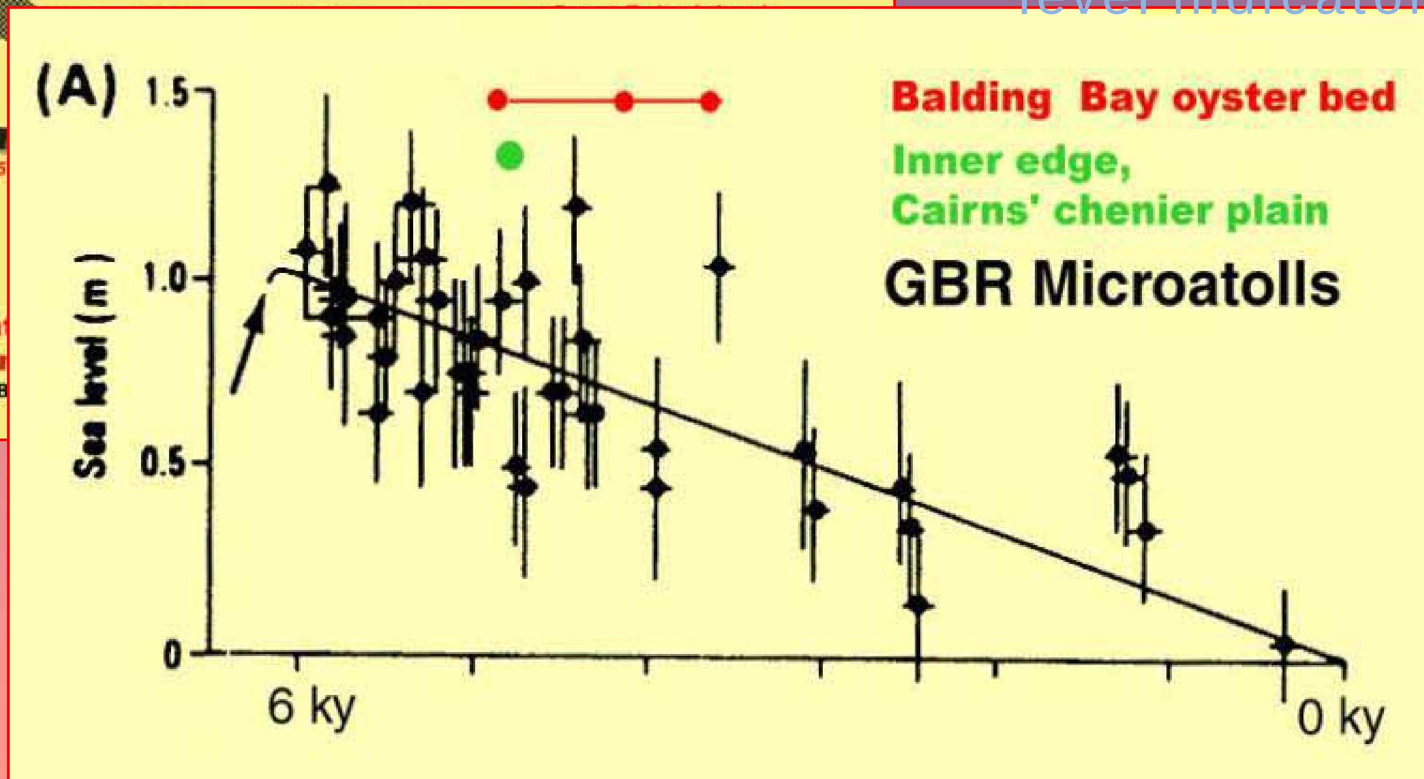


Holocene highstand coral microatolls

Great Barrier Reef margin

Summary of Holocene local relative sea-level indicators





Holocene glacio-isostatic rebound

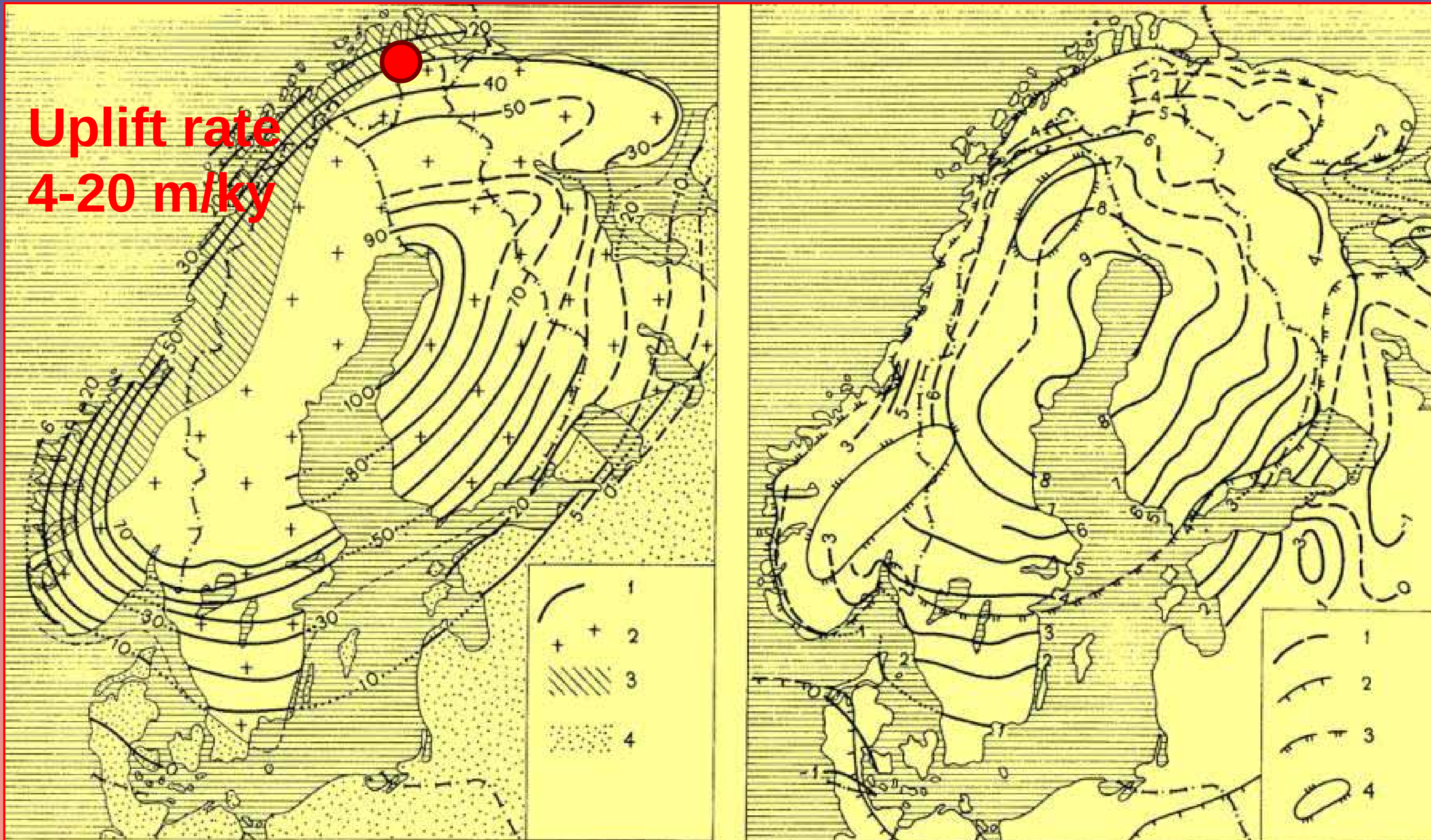
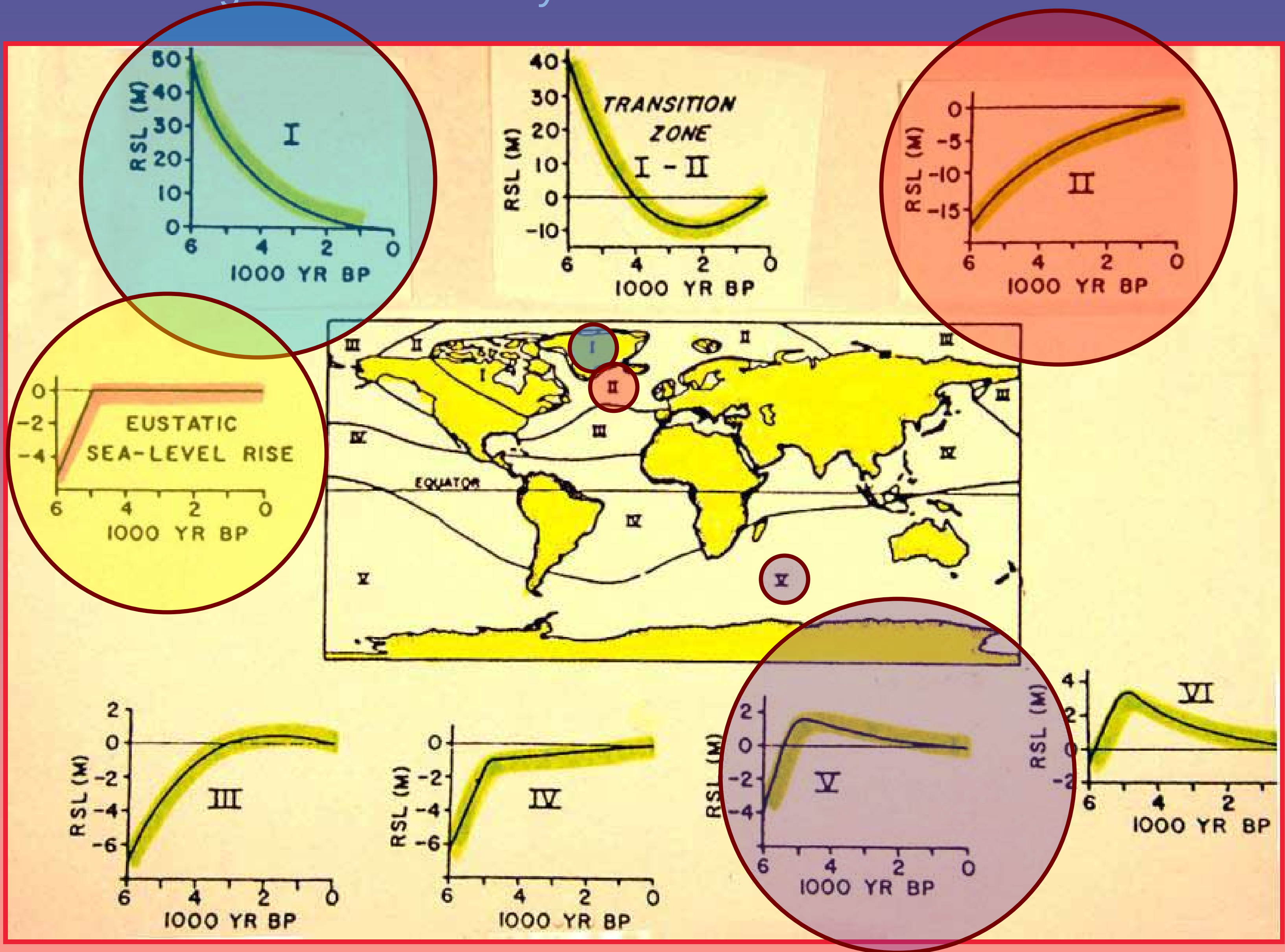


Fig. 1. Schemes of Holocene (A) and recent (B) crustal movements in Fennoscandia

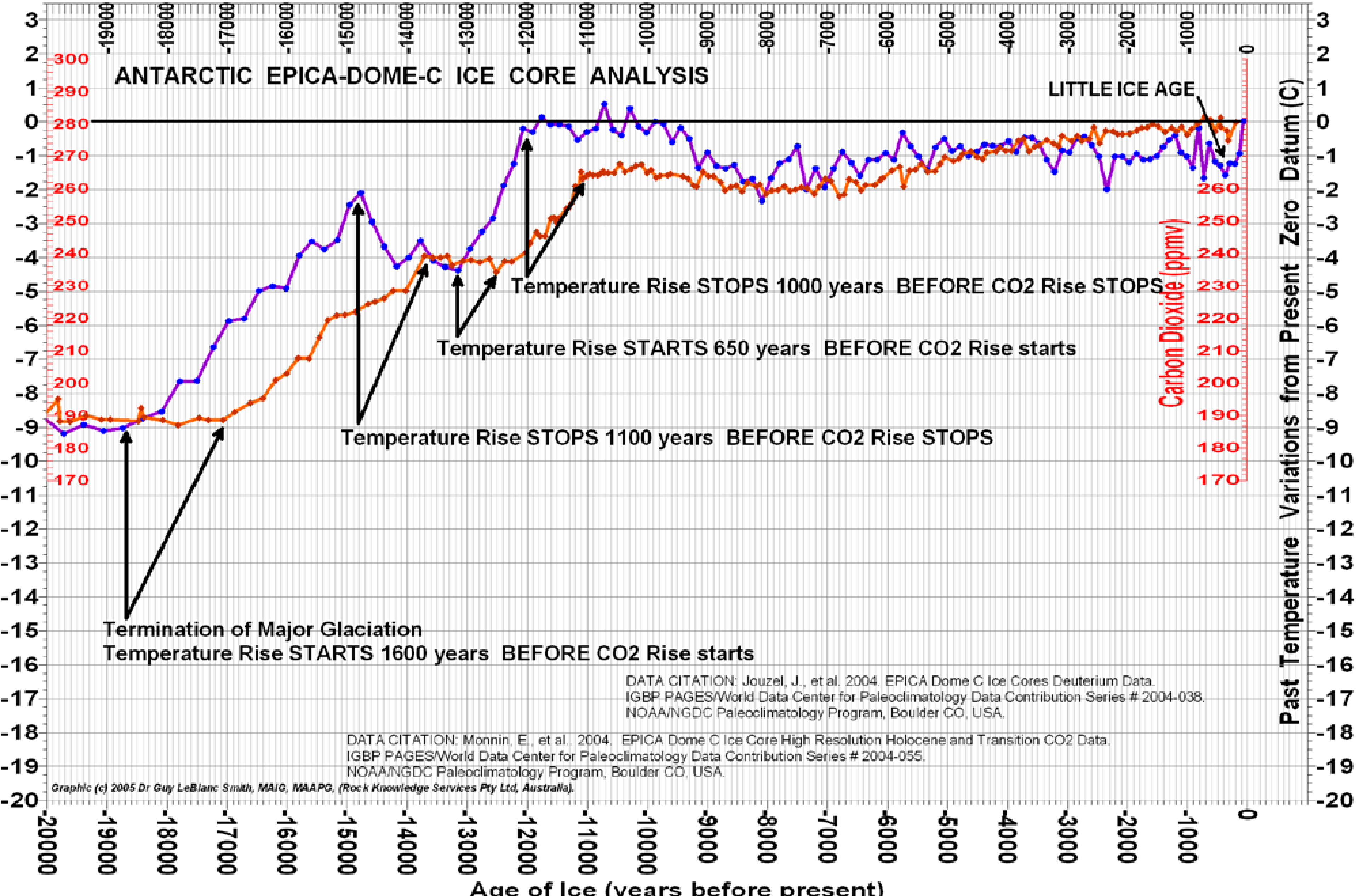
A. 1, isolines of uplift since Middle Holocene (about 6000 yr), in metres; 2, crystalline rocks of the PreCambrian within the Baltic shield; 3, Caledonides; 4, Paleozoic and Mezozoic strata on the platform

B. 1, isolines of rate of recent movements, in mm/yr; 2, boundary line of the Würm (Valdaj) ice sheet; 3, limit of the ice sheet about 10,000 yr BP; 4, ice sheet remnants about 8000 yr BP

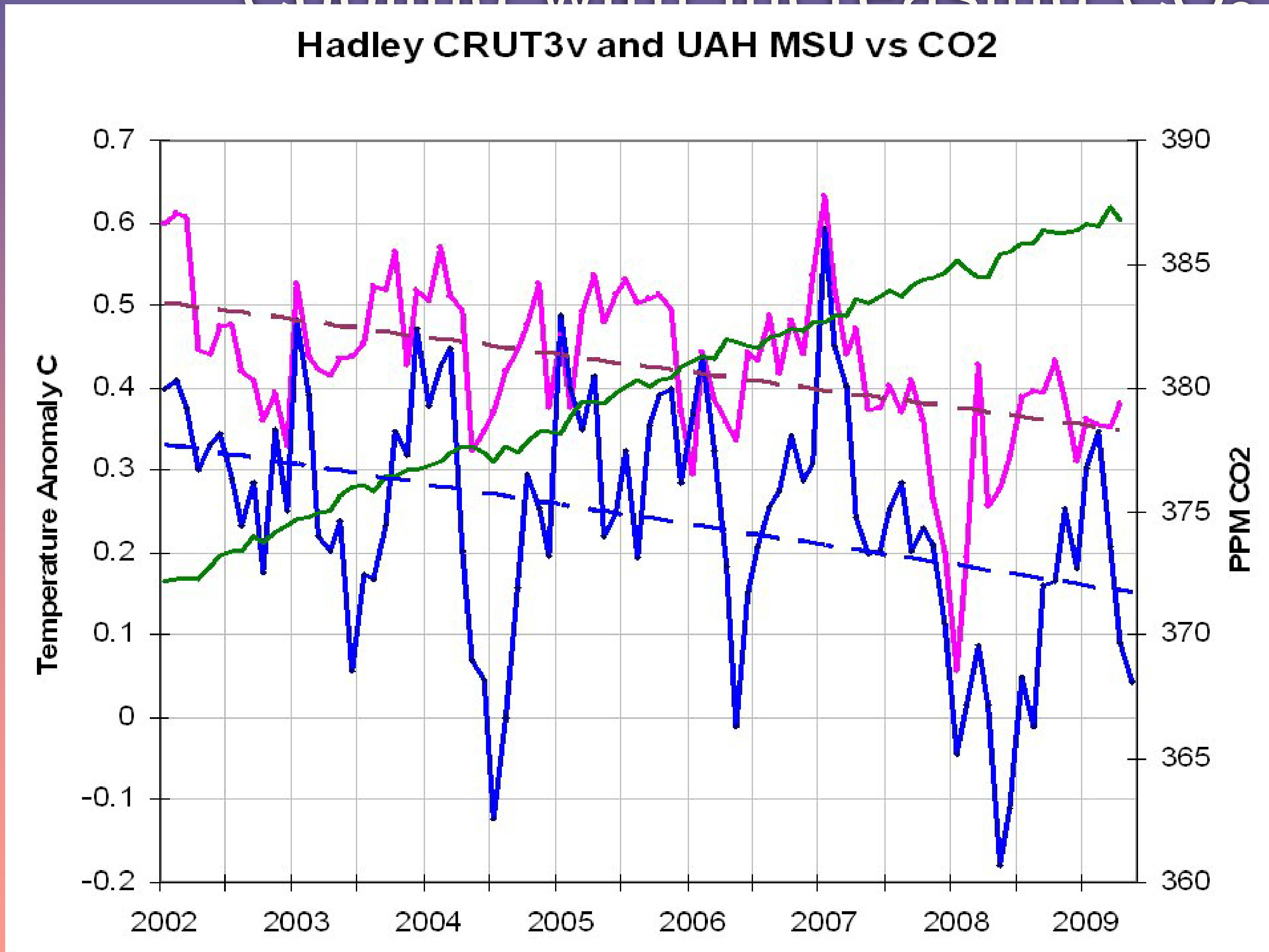
Regional isostasy & local relative sea-level since 6 ka



Clark, J.A. & Lingle, C.S. 1979 Predicted relative sea-level changes (18,000 Years B.P. to present) caused by late-glacial retreat of the Antarctic ice sheet. Quaternary Research 11, 279-298.

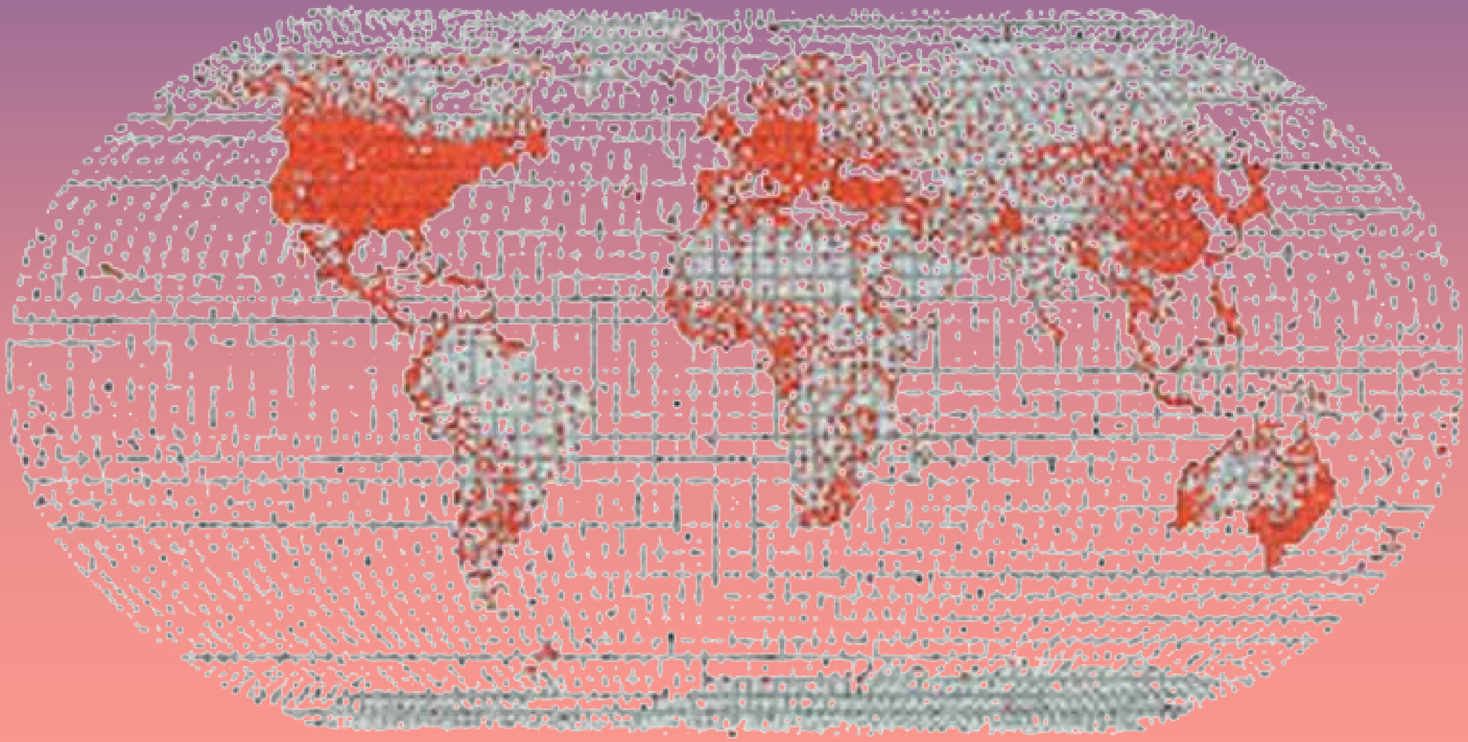

ANTARCTIC EPICA-DOME-C ICE CORE ANALYSIS
LITTLE ICE AGE
Temperature Rise STOPS 1000 years BEFORE CO2 Rise STOPS
Temperature Rise STARTS 650 years BEFORE CO2 Rise starts
Temperature Rise STOPS 1100 years BEFORE CO2 Rise STOPS
Termination of Major Glaciation
Temperature Rise STARTS 1600 years BEFORE CO2 Rise starts
Carbon Dioxide (ppmv)
Past Temperature Variations from Present Zero Datum (C)
Age of Ice (years before present)
DATA CITATION: Jouzel, J., et al. 2004. EPICA Dome C Ice Cores Deuterium Data.
IGBP PAGES/World Data Center for Paleoclimatology Data Contribution Series # 2004-038.
NOAA/NGDC Paleoclimatology Program, Boulder CO, USA.
DATA CITATION: Monnin, E., et al.. 2004. EPICA Dome C Ice Core High Resolution Holocene and Transition CO2 Data.
IGBP PAGES/World Data Center for Paleoclimatology Data Contribution Series # 2004-055.
NOAA/NGDC Paleoclimatology Program, Boulder CO, USA.
Graphic (c) 2005 Dr Guy LeBlanc Smith, MAIG, MAAPG, (Rock Knowledge Services Pty Ltd, Australia).

Cooling with increasing CO_2

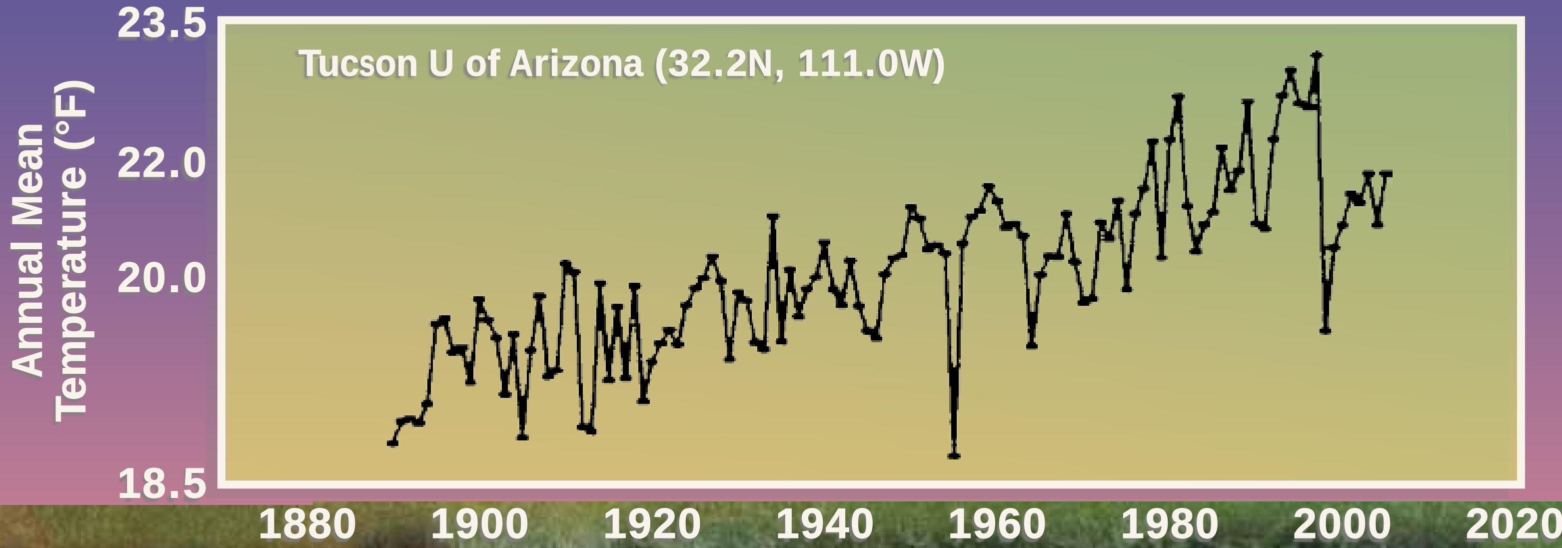


Temperature

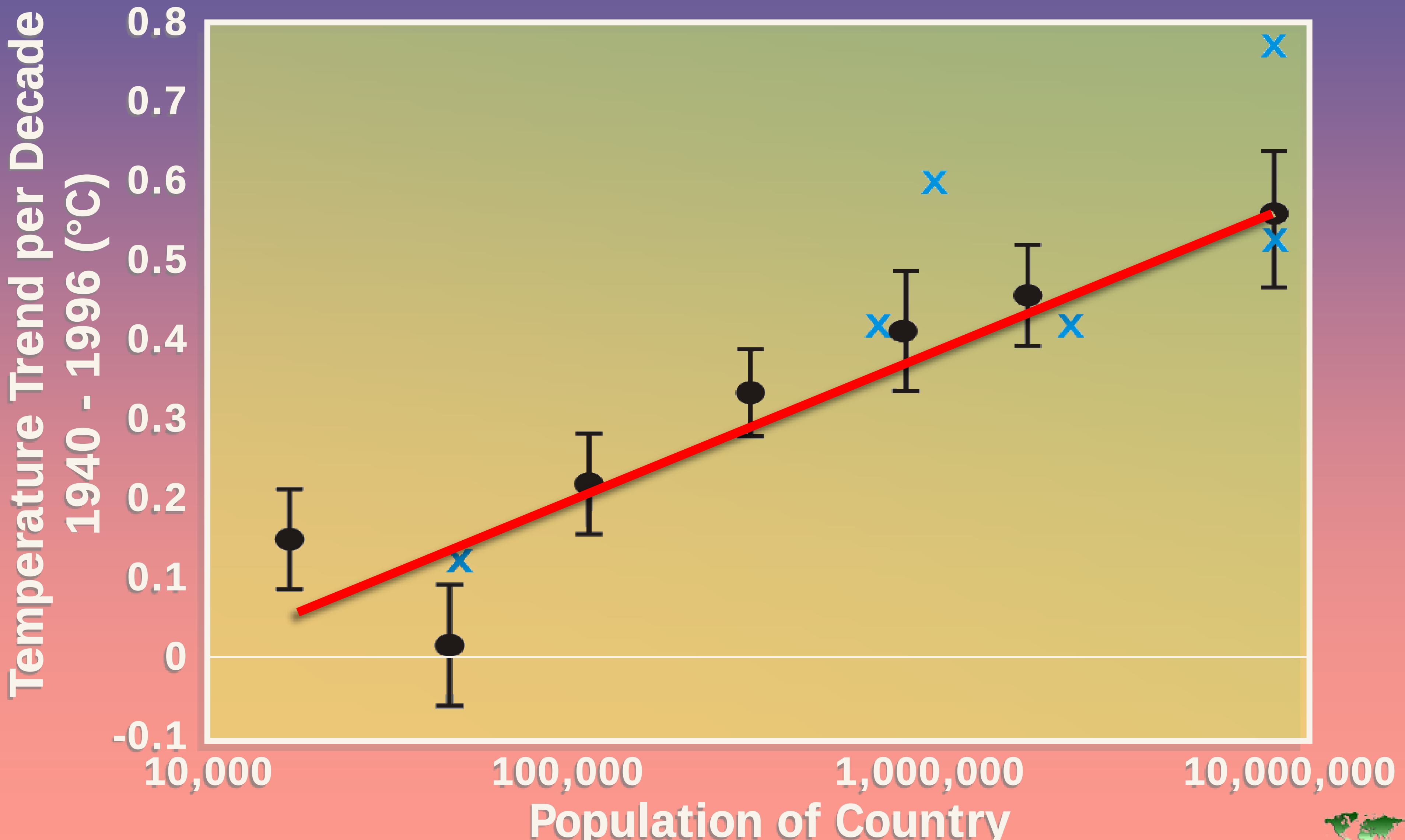
Location, location, location…..



Urban heat island effect

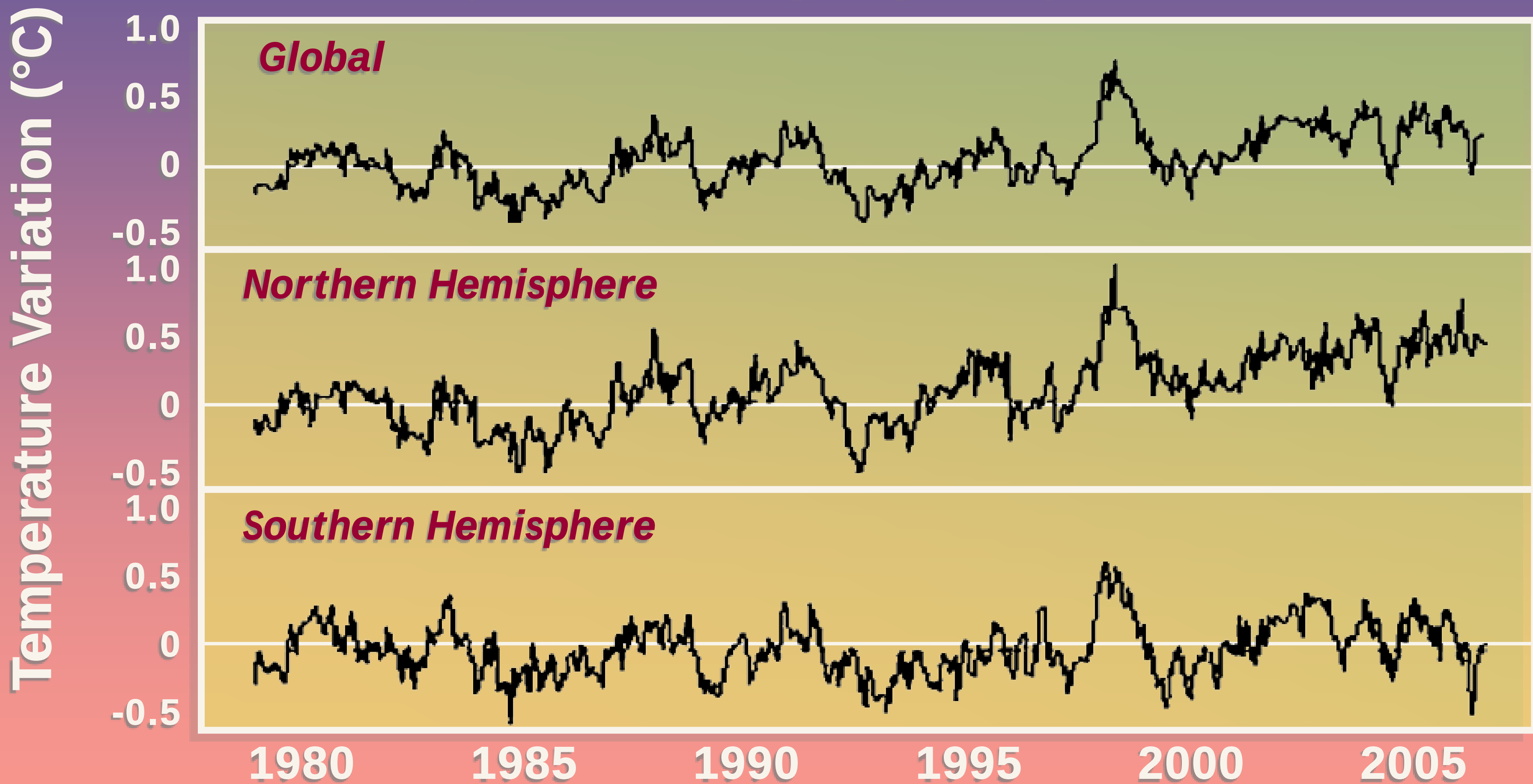


What is really measured?



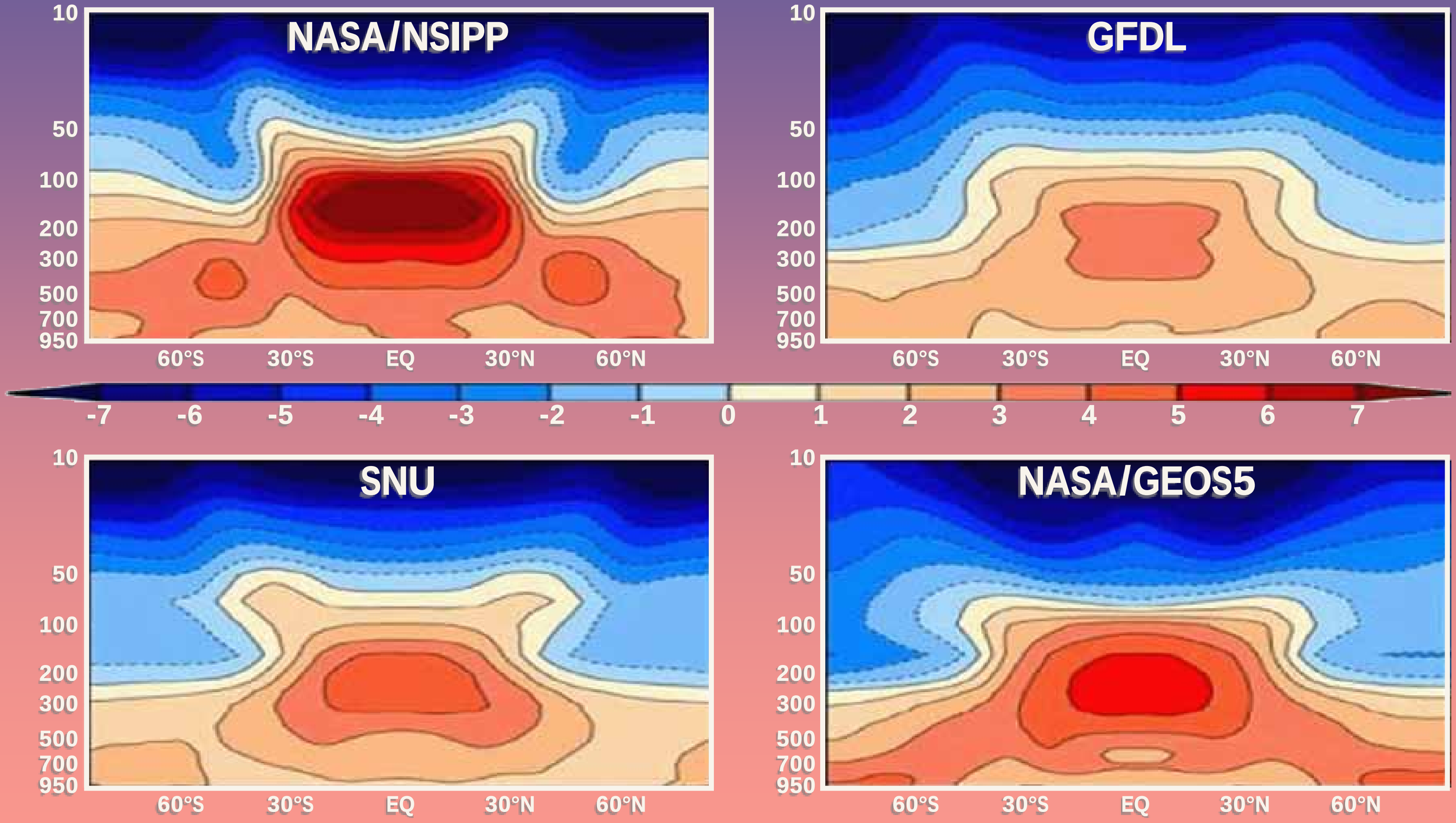
Reliability of surface measurements

The 28 years of high quality satellite data



The Southern Hemisphere is the same temperature it was 28 years ago,
The Northern Hemisphere has warmed slightly

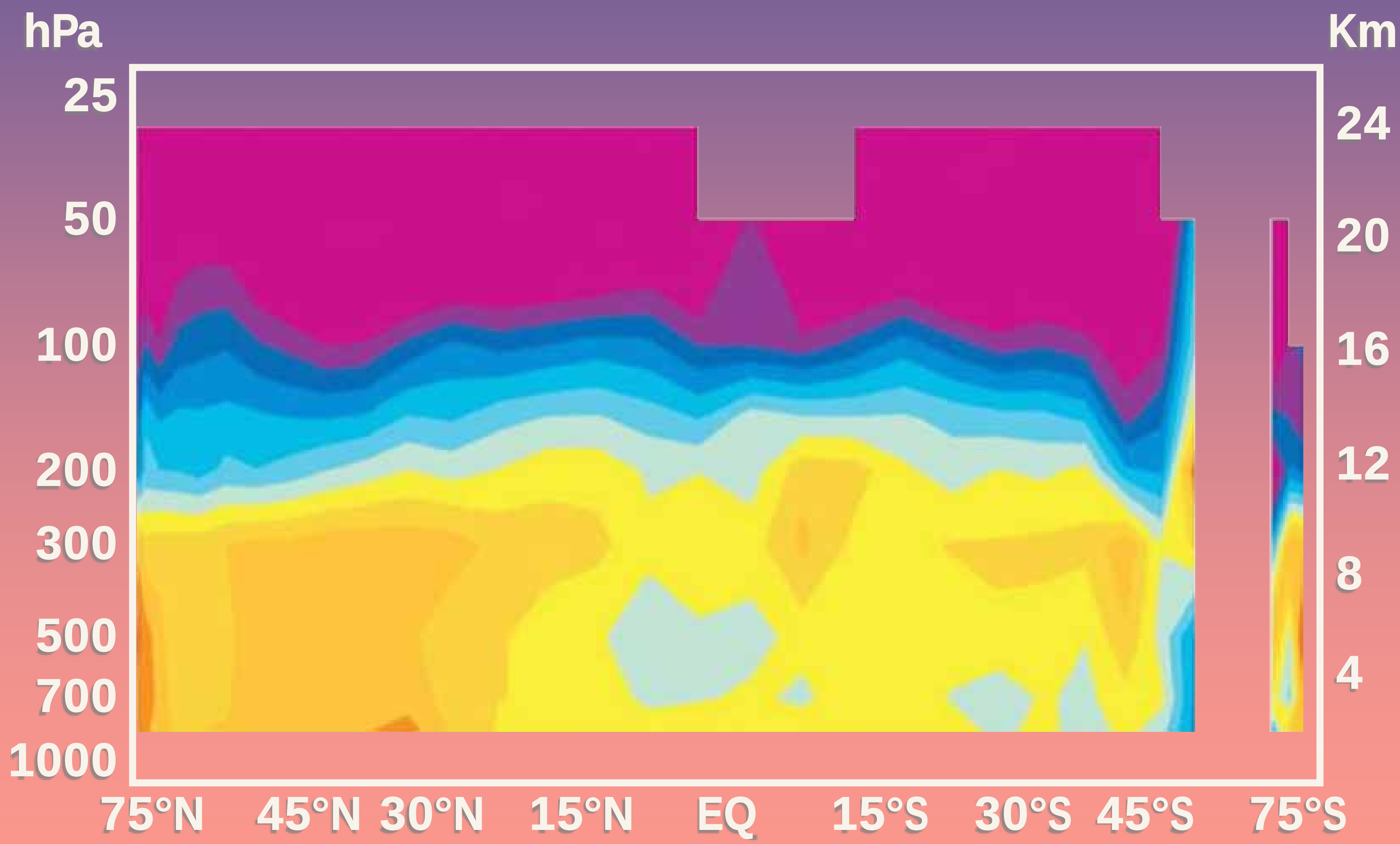
Models for atmospheric temperature



Zonally-averaged distributions of predicted temperature change in °K at CO_2 doubling ($2xCO_2$-control), as a function of latitude and pressure level, for four general-circulation models (Lee et al., 2007)

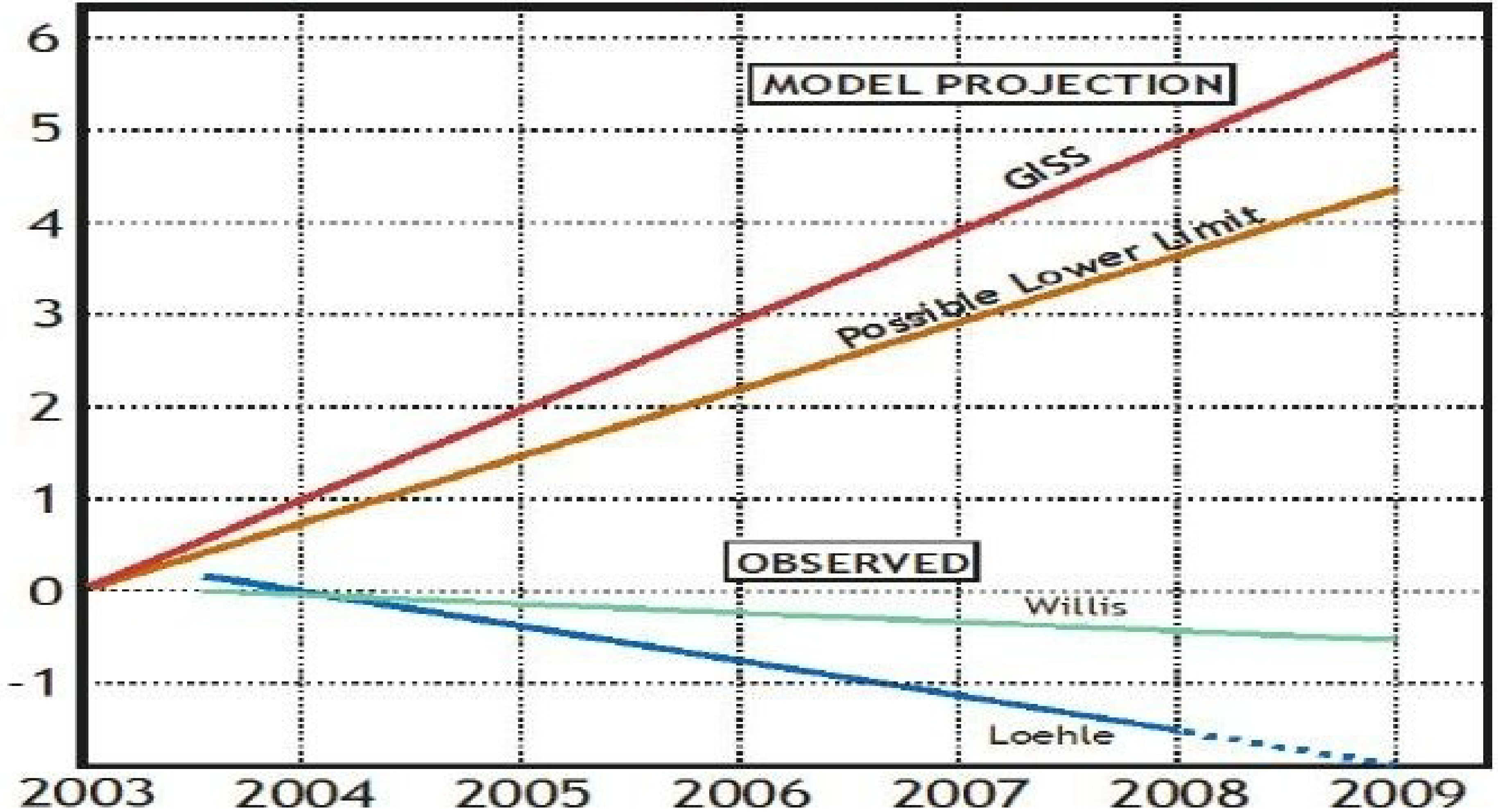
Radiosonde measurements

No “greenhouse warming” signature is observed in reality



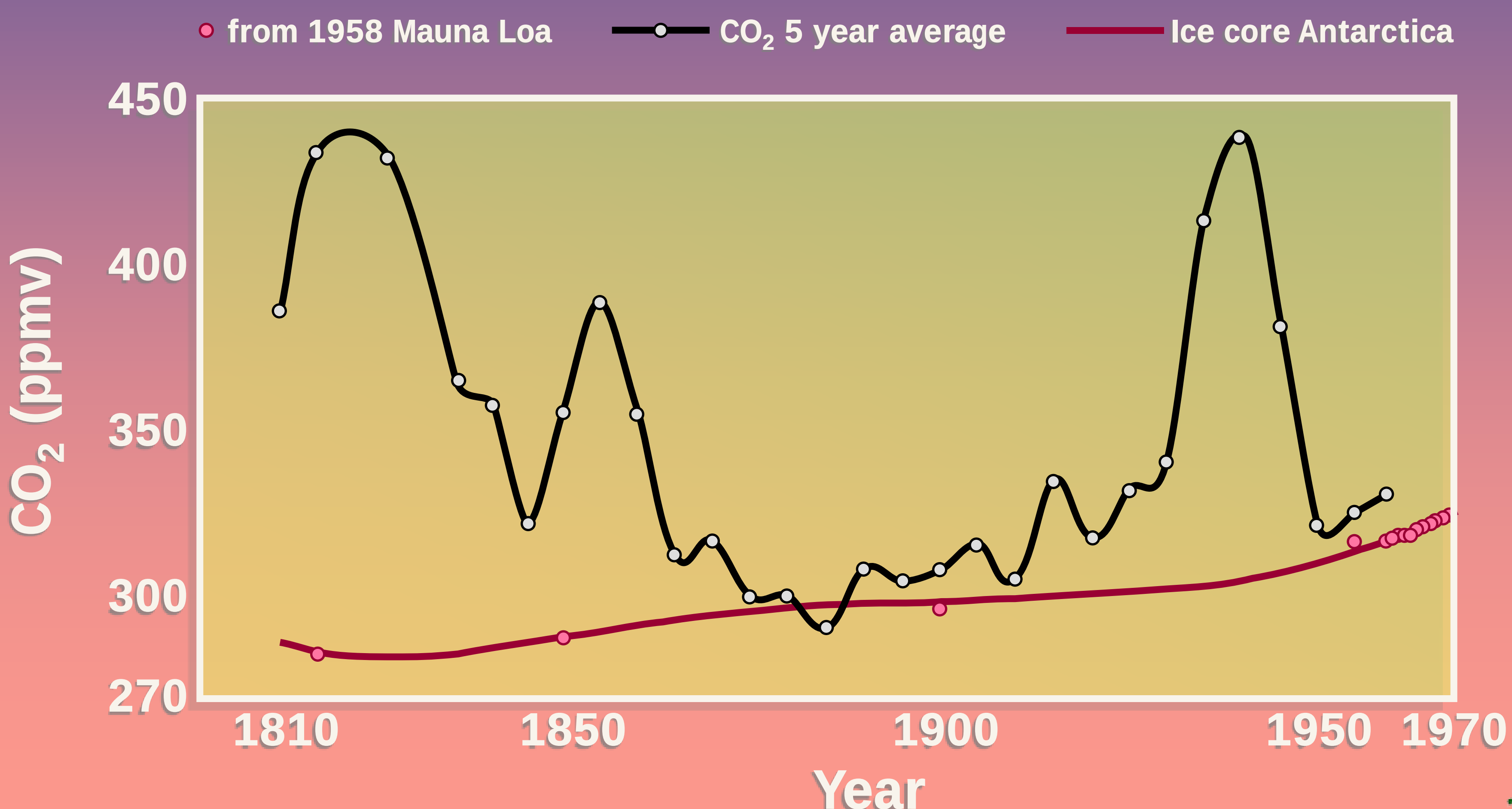
Source: HadAT2 radiosonde observations, from CCSP (2006), p116, fig. 5.7E

Five years' global ocean cooling: reality yet again disobeys models



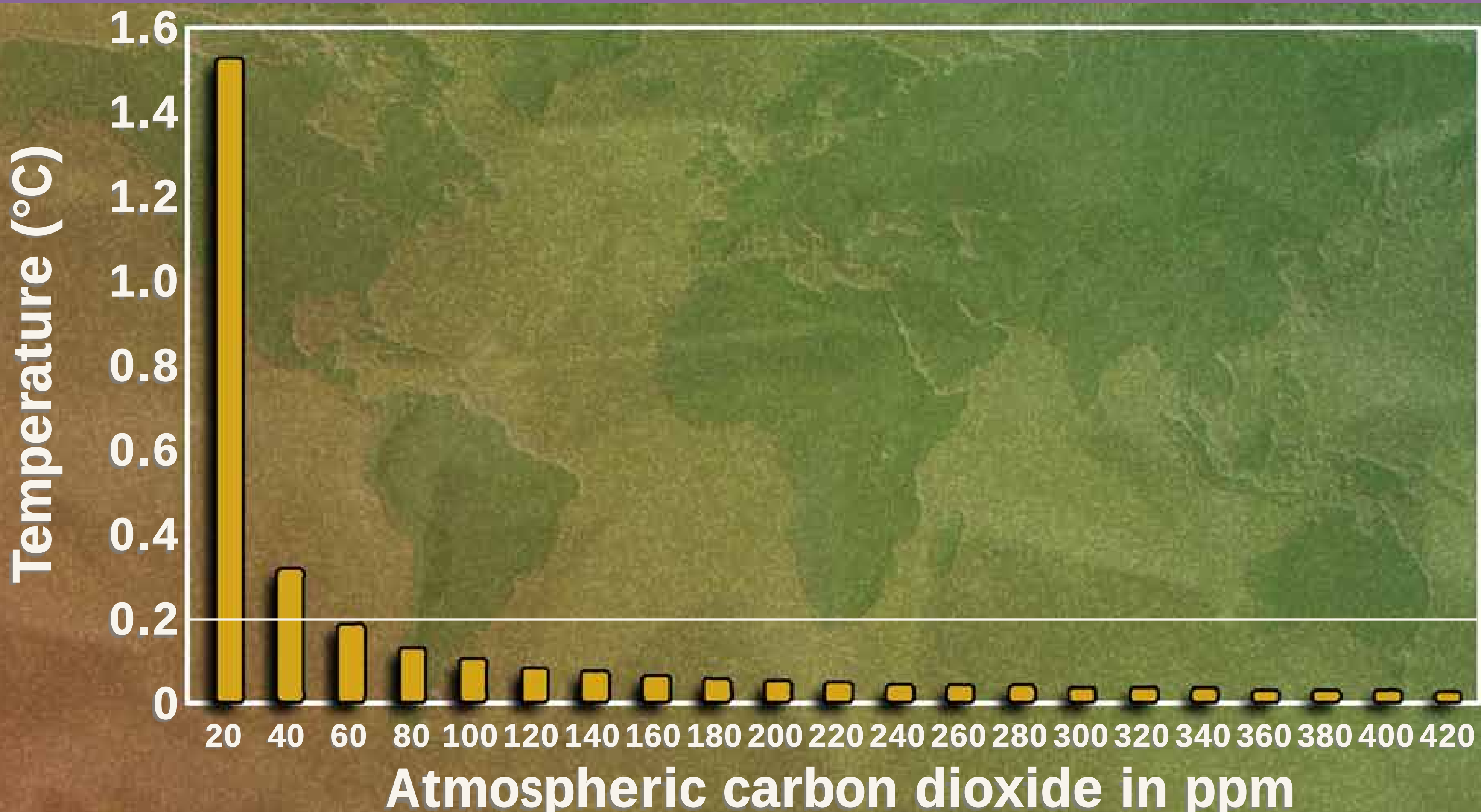
Smoothing of ice core CO_2 data - why pre-industrial choice of 280ppm?

1812-2004 Northern Hemisphere, Chemical Measurement

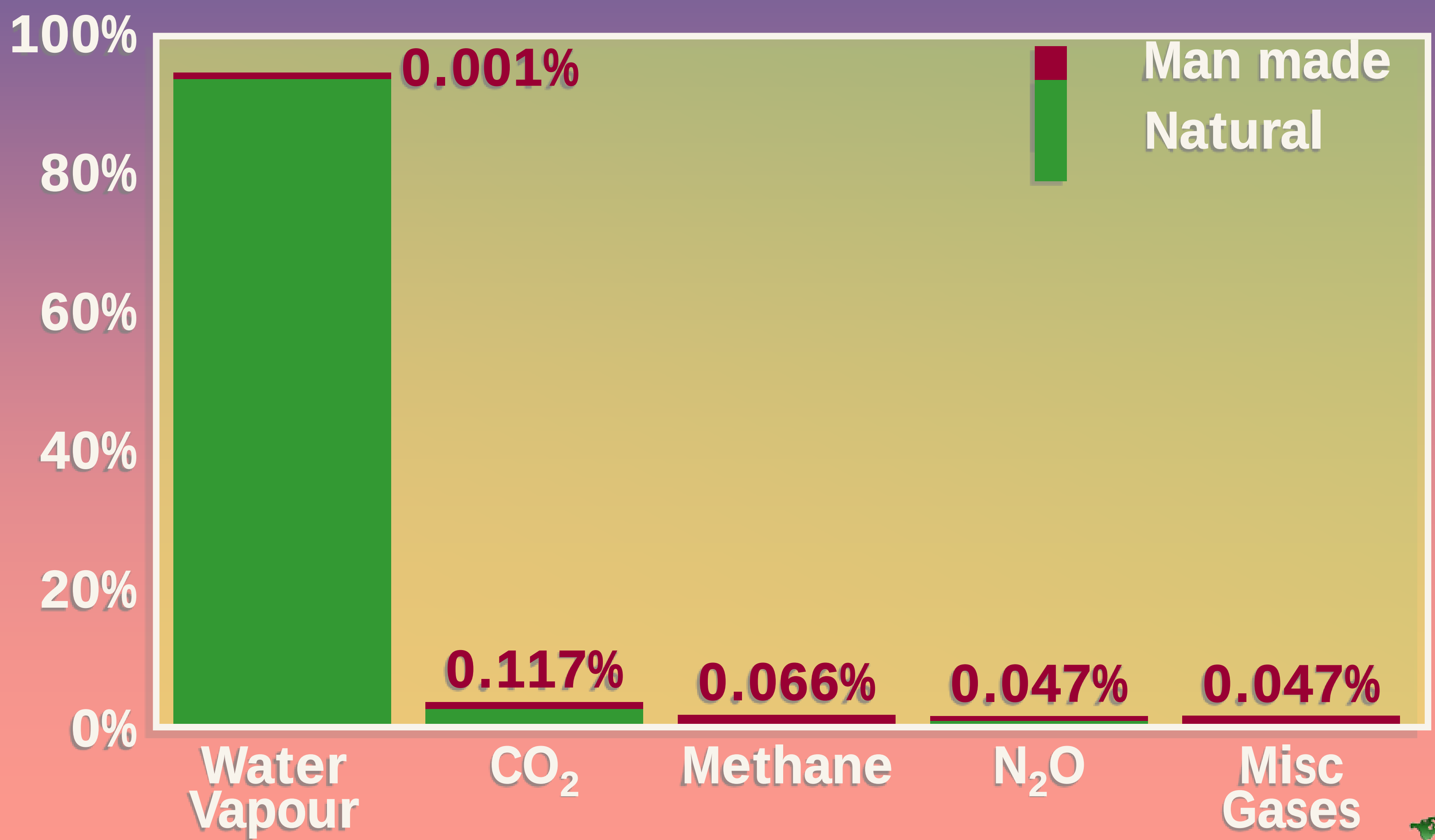


Doubling CO_2 at 388ppm has no effect

The warming effect of atmospheric carbon dioxide

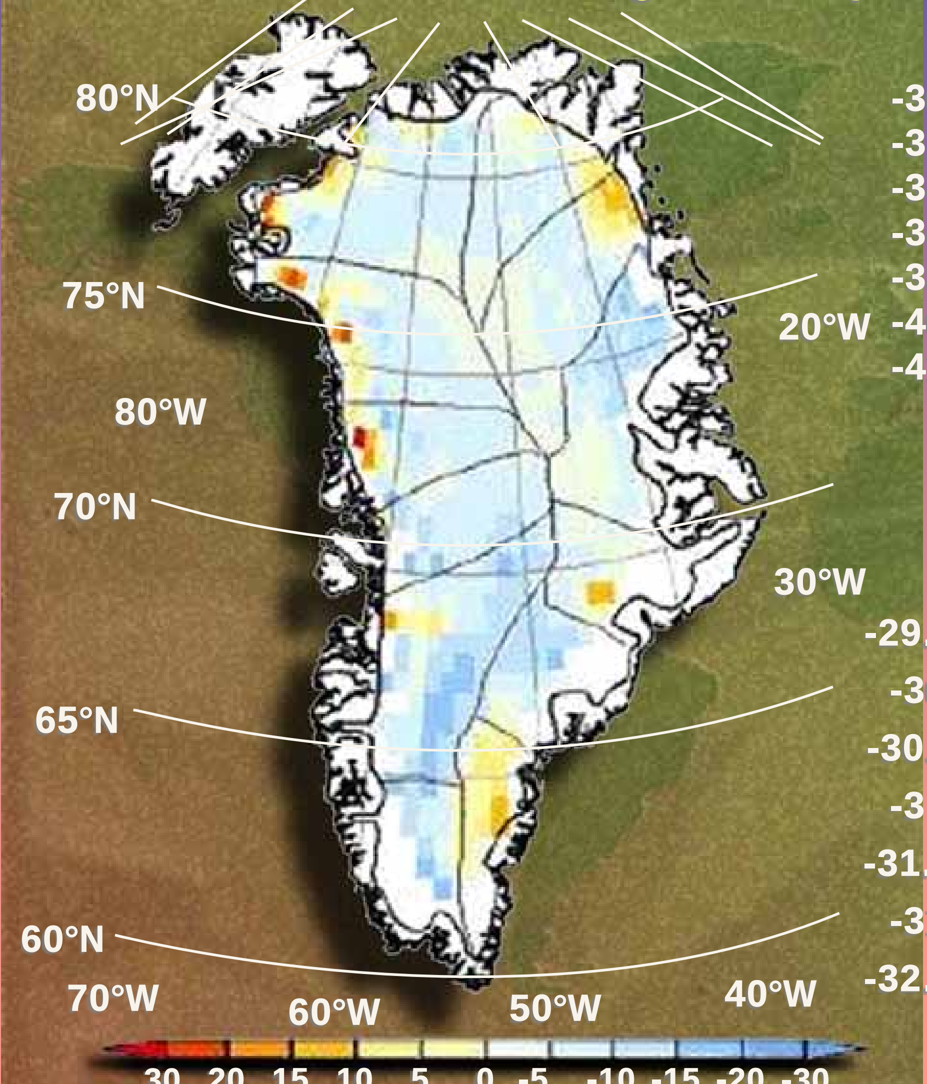


Water: Main greenhouse gas & driver of CO_2

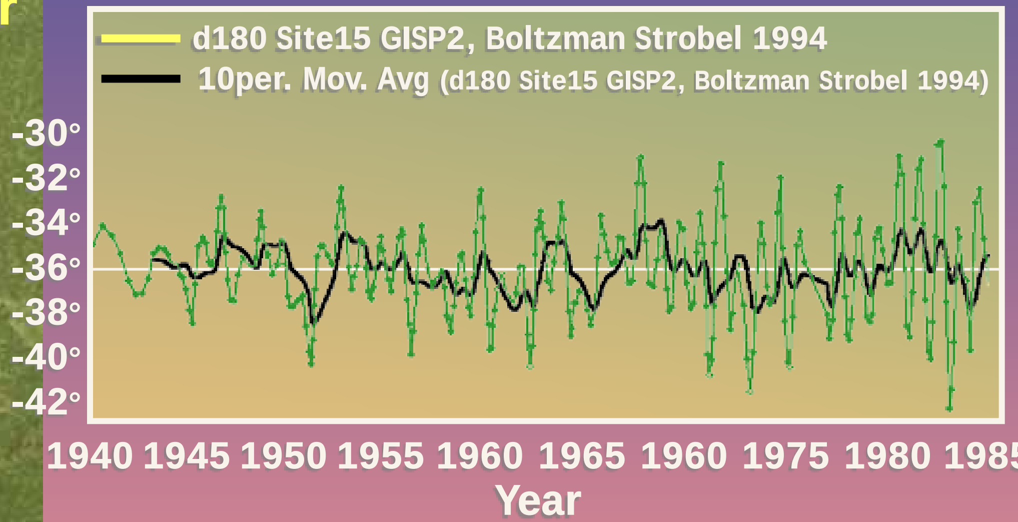


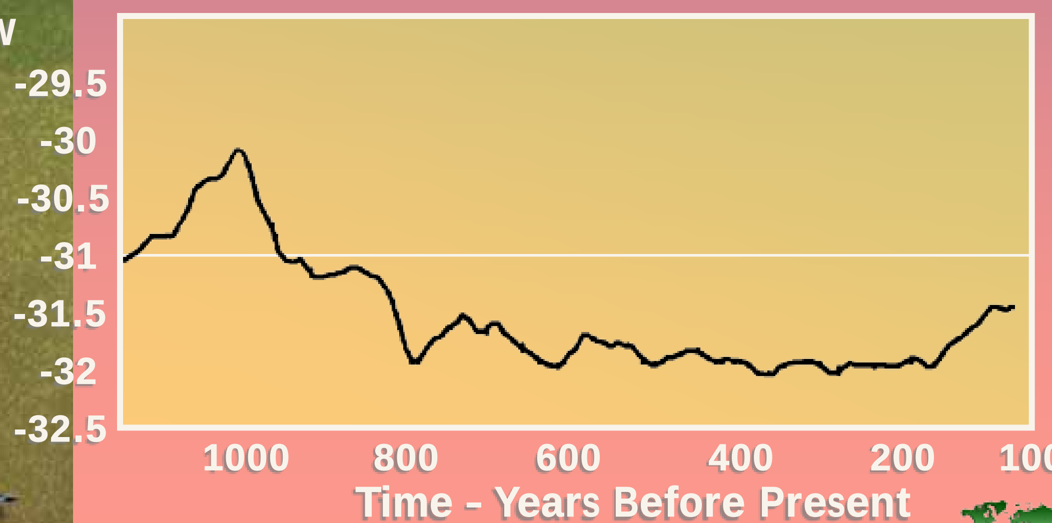
Greenland ice sheet

Greenland ice sheet change in cm/yr

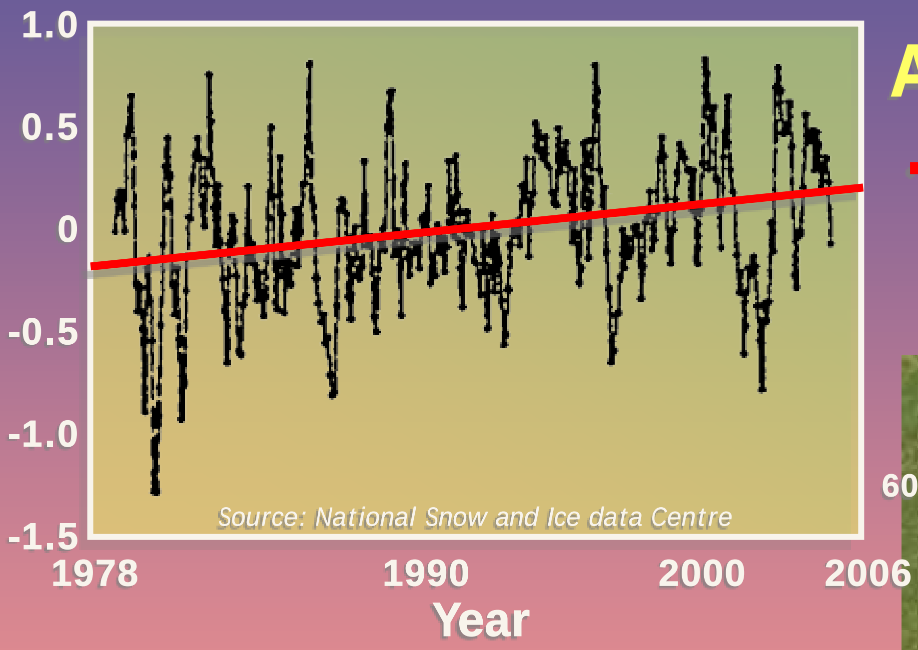


*Derived from 11 years of ERS-1/ERS-2 satellite altimeter data, 1992-2003

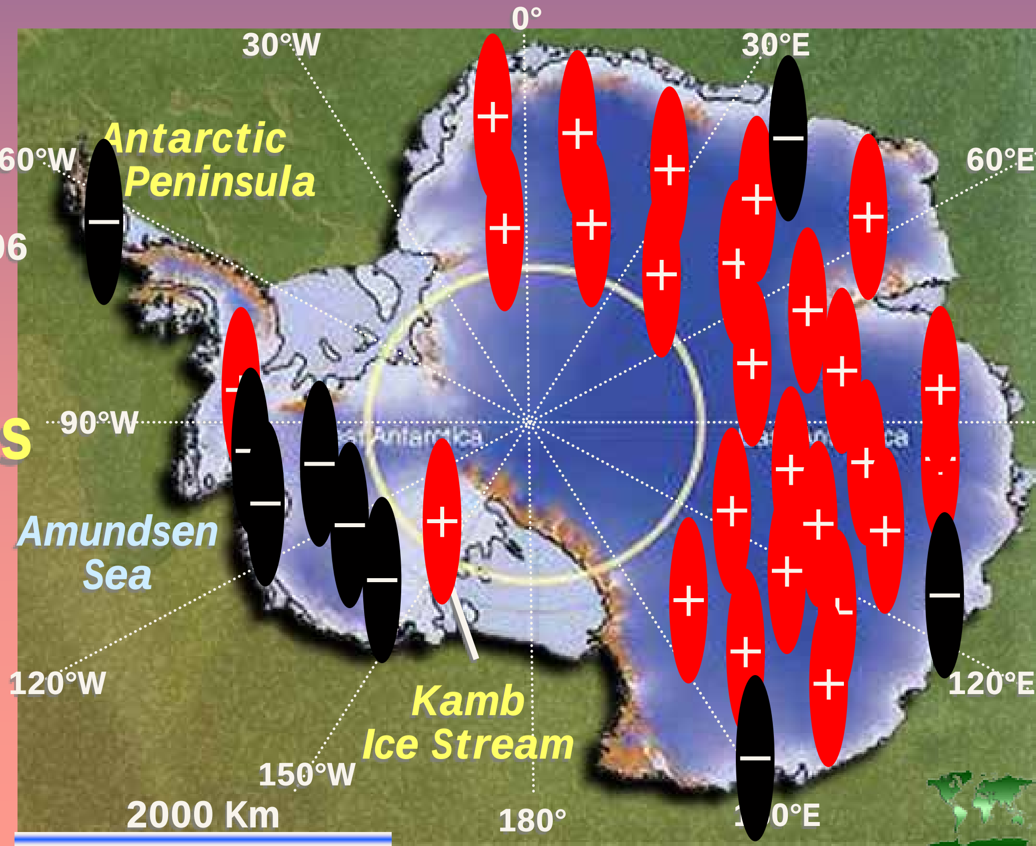




Is global warming melting the ice caps and reducing sea ice? NO!



Antarctic Sea Ice Trends
.... going up!



Antarctic Land Ice Trends
.... going up over most of the continent!

Source: Vaughn, D.G., 2005. Science, 3008, 1877-1878.

Carbon reservoirs on Earth

The carbon in the Earth's lithosphere and atmosphere has come from degassing of CO_2 from the Earth's mantle. The amount of CO_2 in air is minute compared to the other reservoirs. Without sediments, the partial pressure of air CO_2 alone would be 40-60 atmospheres.

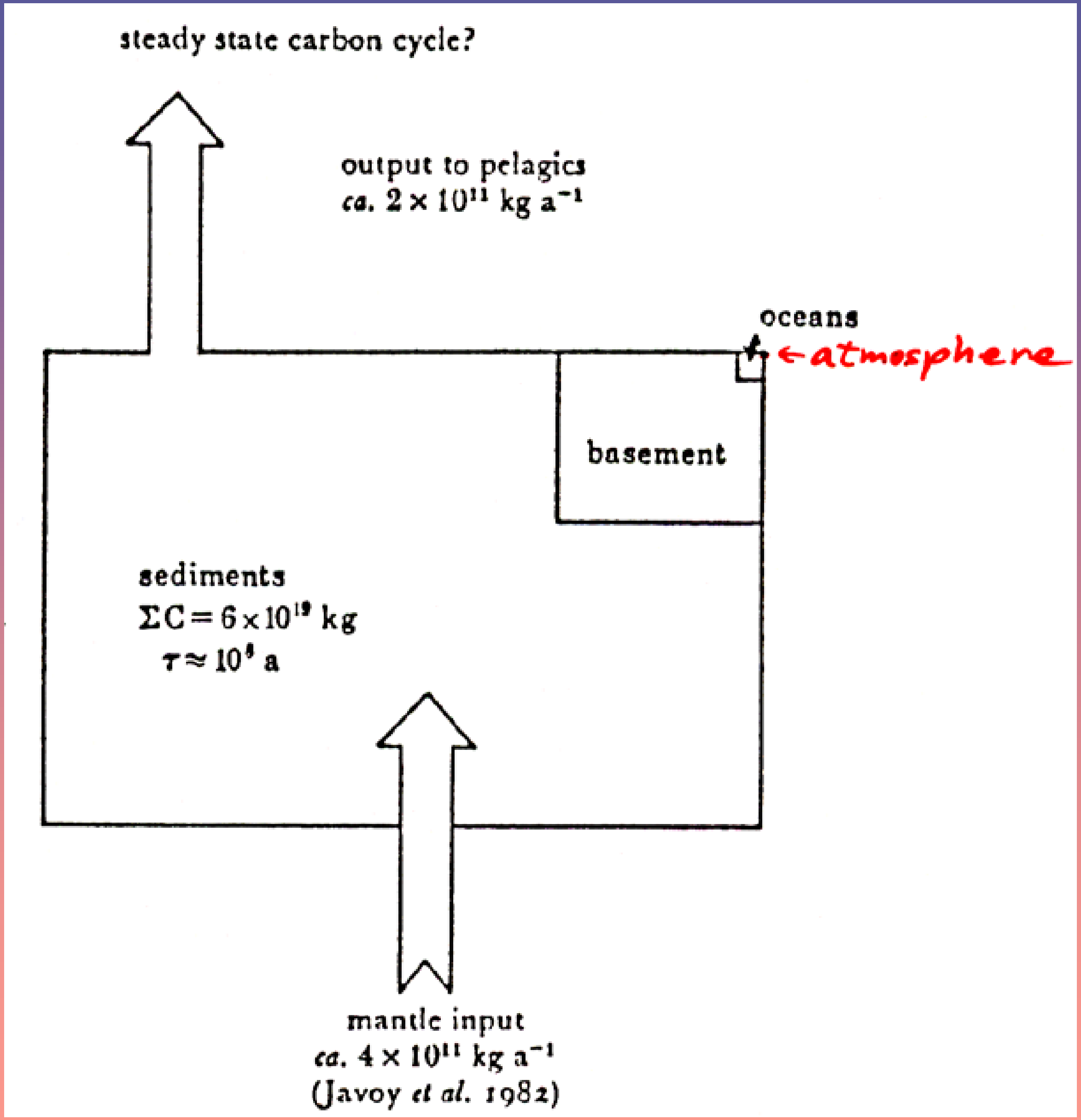
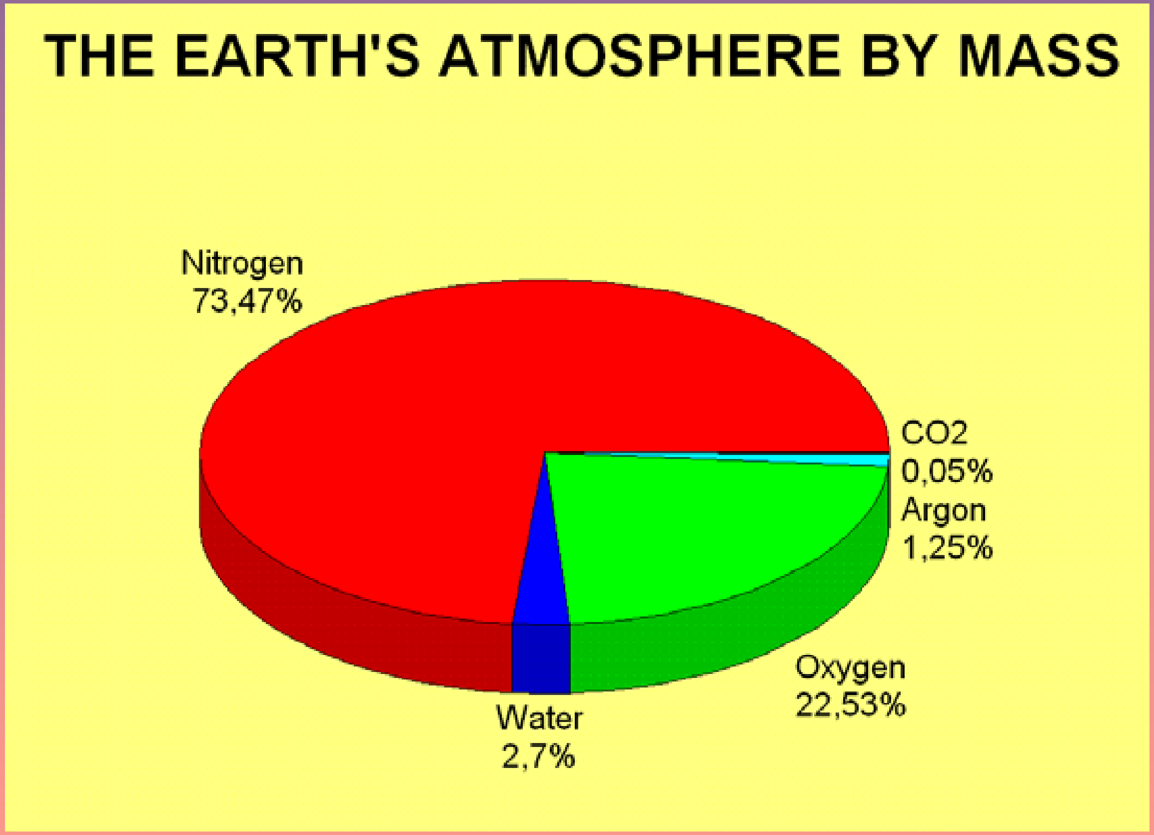


Figure from O'Nions (1984)

Atmospheric evolution

Evolution from reduced CO_2-rich (>5%) to oxygenated.



CO_2 and volcanism

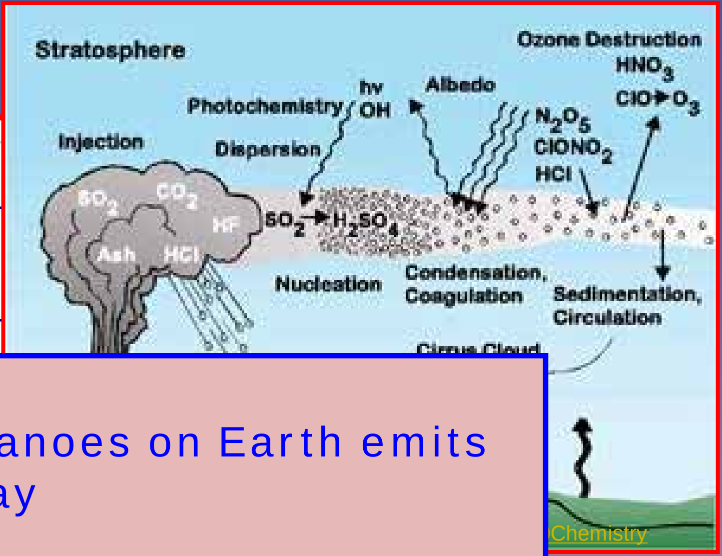
USGS

Table 2. Volcanic CO2 Emissions

Volcano	CO2 Flux (tonnes per day)	Percent from soil degassing	
Mt. Etna	70,000	XXX	
Popocatep			
Oldoinyo L			
Augustine			
Mt. St. Hel			
Stromboli			
Kilauea			
White Islan			
Erebus			
Redoubt			
Grimsvotn			
Vulcano	270	20	413

* The values presented are averages taken from data by Symonds et al., 1994.

Data sources for available CO2 emissions: Gerlach et al., 1997; Allard et al., 1998; Varley et al., 1998; Delagdo et al., 1998; Kopenick et al., 1996; Allard et al., 1994; Wardell and Kyle, 1998; Brantley et al., 1993; and O'Keefe, 1994.



If each of the 1511 active land-volcanoes on Earth emits 5,000 t C-equivalent of CO_2 each day

=> 7,5 Mt/day

If 4X more CO_2 is emitted from submarine volcanoes (30.0 Mt)

=> 37,5 Mt total

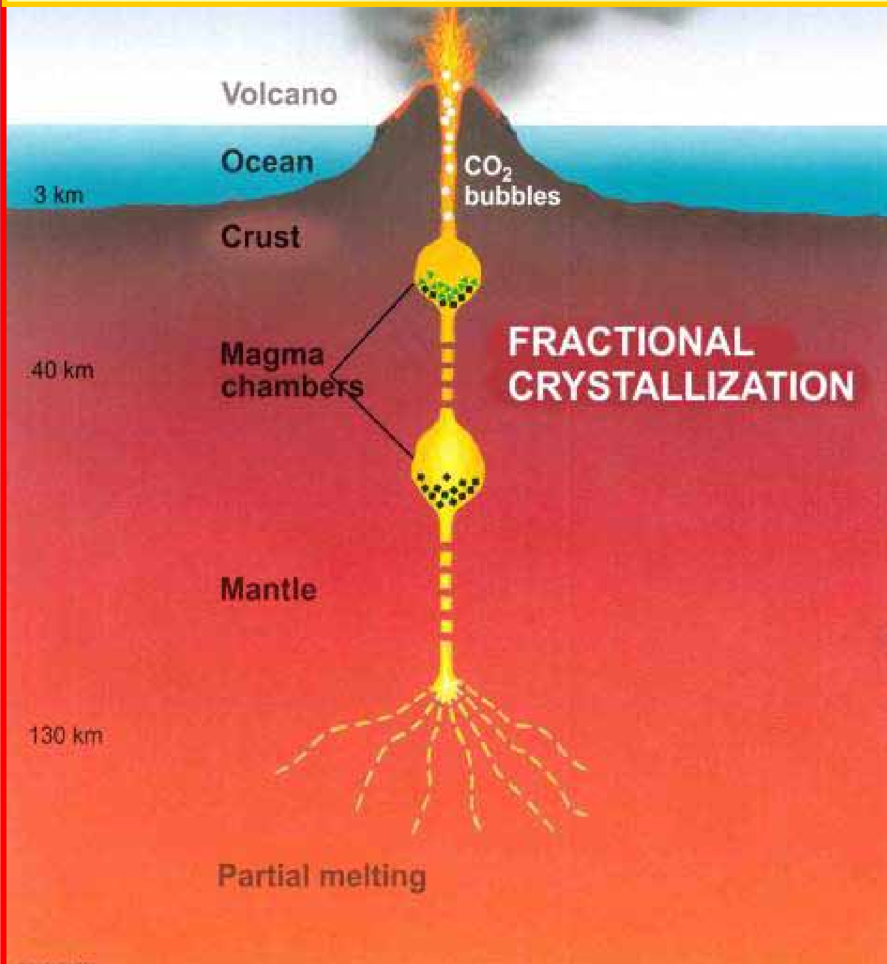
This is approximately double the amount of CO_2 derived from human burning of fossil fuels (<20 Mt/day).

Slide after Tom Segalstad, Oslo

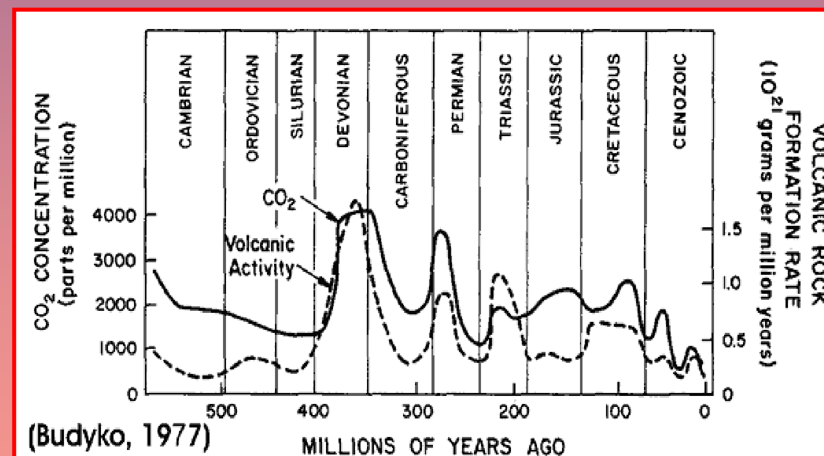
CO_2 and volcanism

A mantle melt may have up to 8 wt.% CO_2 at ~125 km depth. Surface lava can only hold 0.01-0.001 wt.% CO_2 dissolved.

The difference is degassed to the atmosphere.



Oldoinyo Lengai, active carbonatite volcano, East Africa, North Tanzania

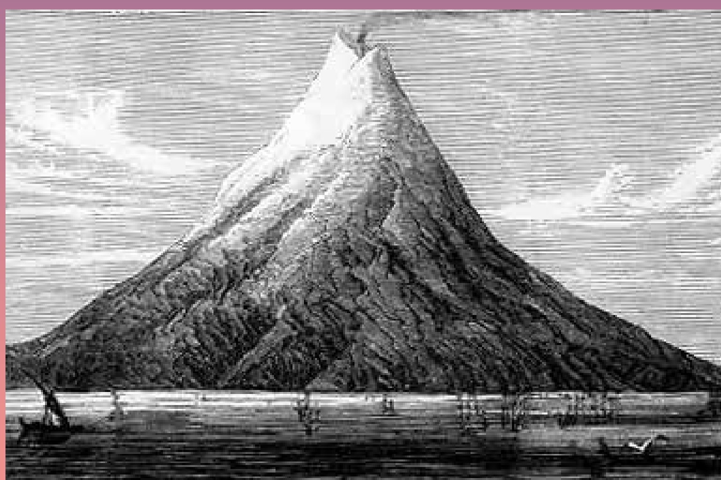


A strong correlation exists between emissions of CO_2 at times of extensive volcanism and deposition of limestones during the last ~600 million years (Mikhail Budyko).

Slide after Tom Segalstad, Oslo

Terrestrial felsic explosive volcanicity

- Pathetic: Mt St Helens (1 km^3)
- Weather changing: (Krakatoa 1883, Tambora 1815, Thira 1470 BC)
- Gases: H_2O, CO_2, CH_4, HCl, HF, SO_2, H_2S (e.g. White Island [NZ] 1150-4120 tpd CO_2, 320-1200 tpd SO_2)



From Simkin and Fiske, 1983

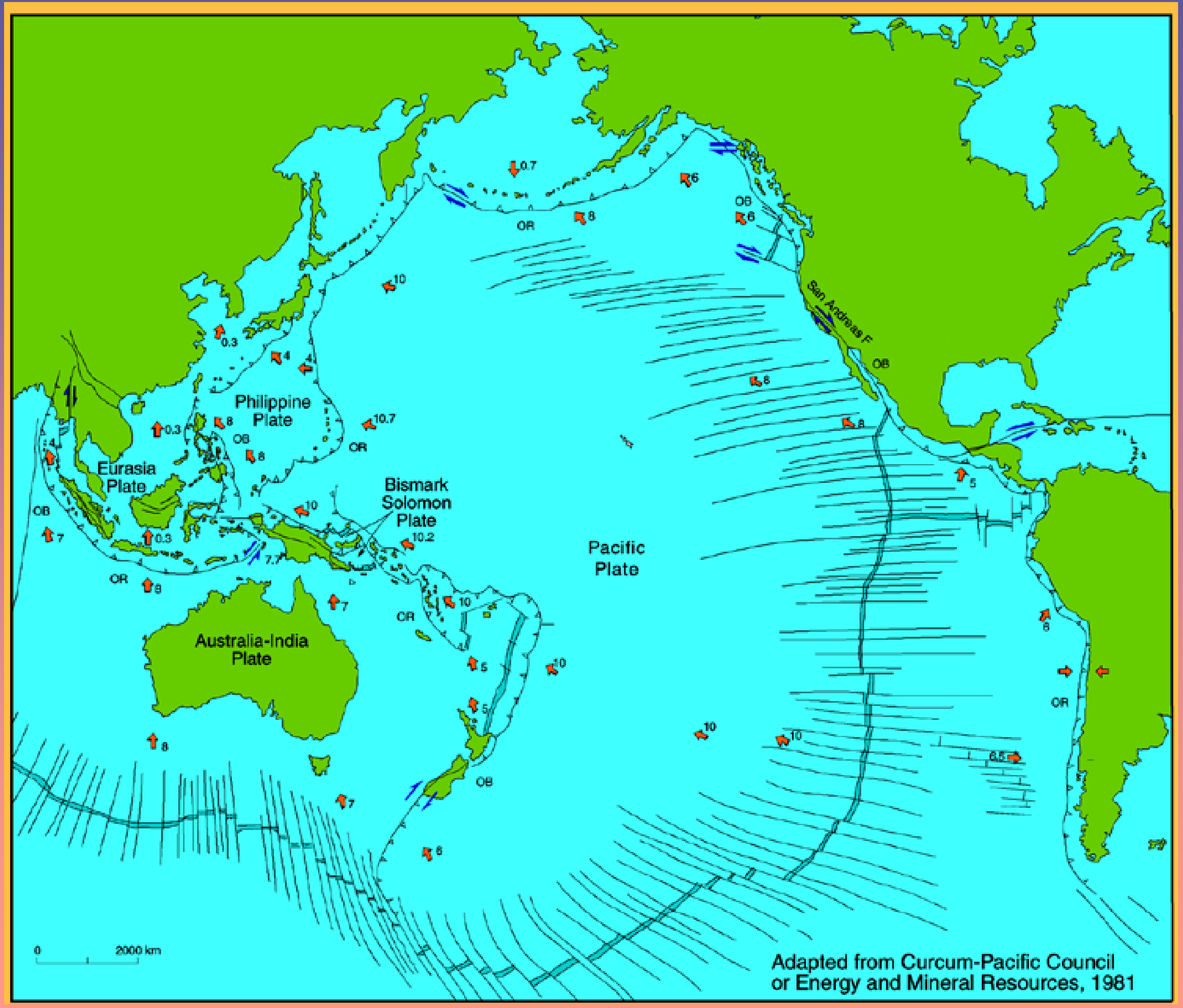
Terrestrial felsic volcanicity

Structurally-controlled volcanicity, gas vents and epithermal systems (Andes,Chile)

Subglacial terrestrial volcanicity

Antarctica (felsic), Iceland (mafic)

Submarine basaltic volcanicity



Submarine basaltic volcanism

Acid oceans: When the planet runs out of rocks, the oceans become acid

$$2Ca^{2+} + 2HCO_3^{-} + KAl_2AlSi_3O_{10}(OH)_2 + 4H_2O = 3Al^{3+} + K^{+} + 6SiO_2 + 12H_2O$$

$$2KAlSi_3O_8 + 2H^{+} + H_2O = Al_2Si_2O_5(OH)_4 + 2K_{+} + 4SiO_2$$

$$2NaAlSi_3O_8 + 2H^{+} + H_2O = Al_2Si_2O_5(OH)_4 + 2K^{+} + 4SiO_2$$

$$CaAl_2Si_2O_8 + 2H^{+} + H_2O = Al_2Si_2O_5(OH)_4 + Ca^{2+}$$

$$KAl_2AlSi_3O_{10}(OH)_2 + 3Si(OH)_4 + 10H^{+} = 3Al^{3+} + K^{+} + 6SiO_2 + 12H_2O$$

$$CO_2 + CaSiO_3 = CaCO_3 + SiO_2$$

$$CO_2 + FeSiO_3 = FeCO_3 + SiO_2$$

$$CO_2 + MgSiO_3 = MgCO_3 + SiO_2$$

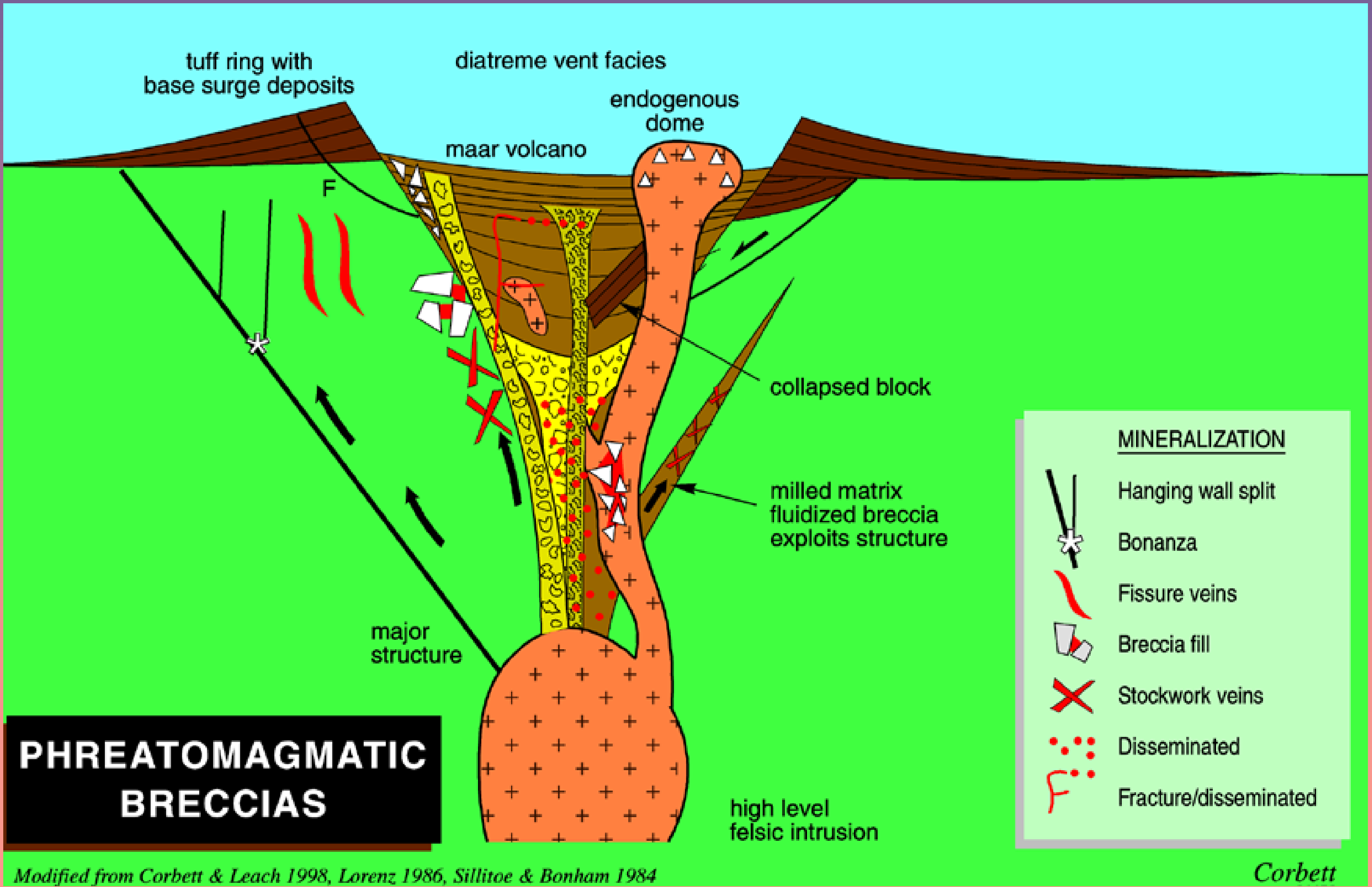
- **In the oceans, CO_2 exists as dissolved gas (1%), HCO_3^{-} (93%) and CO_3^{2-} (8%)**
- **Ocean pH is 7.9 to 8.2**
- **Rainwater pH is 5.6**

Submarine basaltic volcanicity

Extension, continental fragmentation, basalts and degassing

Terrestrial felsic explosive volcanicity

Gas-driven explosions



Terrestrial felsic explosive volcanicity

CO_2-driven explosions (Tahkt-e-Sulieman, Iran)

Terrestrial felsic explosive supervolcanoes

- Toba: 74,000 bp (2,900 km^3)
- Yellowstone: 2.1, 1.3, 0.64 Ma (1,000-5,000 km^3)
- Taupo: Many recent (5,000-10,000 km^3)

Terrestrial basalt supervolcanoes

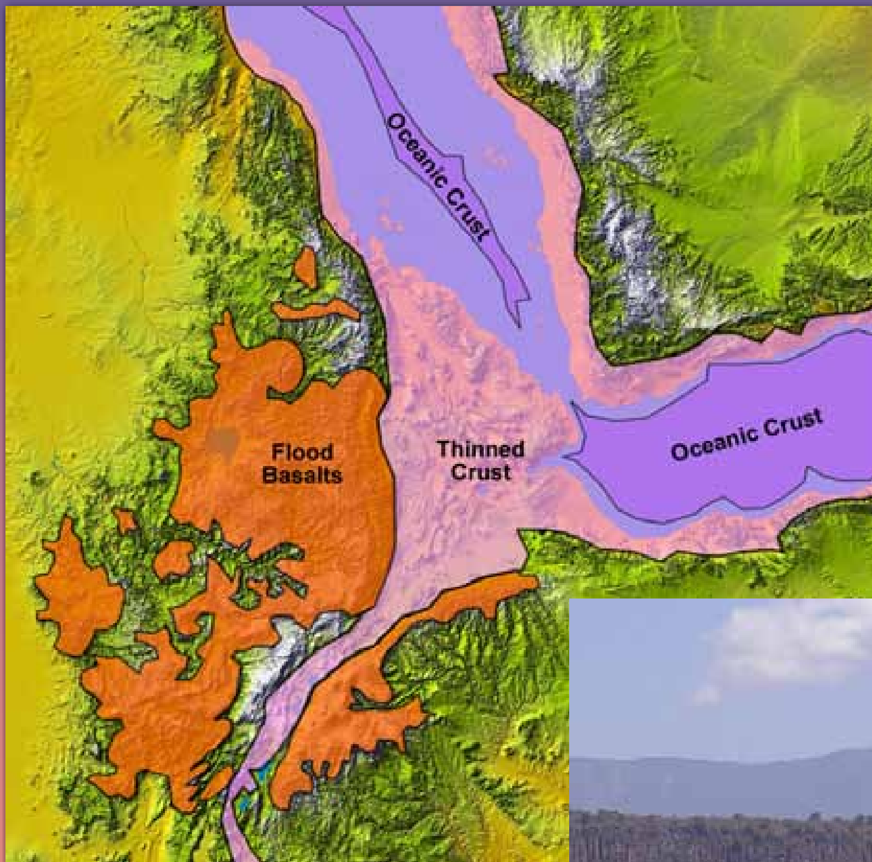
- 10^6 km^3 lava in <1 Ma
- Huge H_2S and SO_2 emissions, temporary surficial ocean acidity and life loss
- Roza Flow, Columbia River Basalt

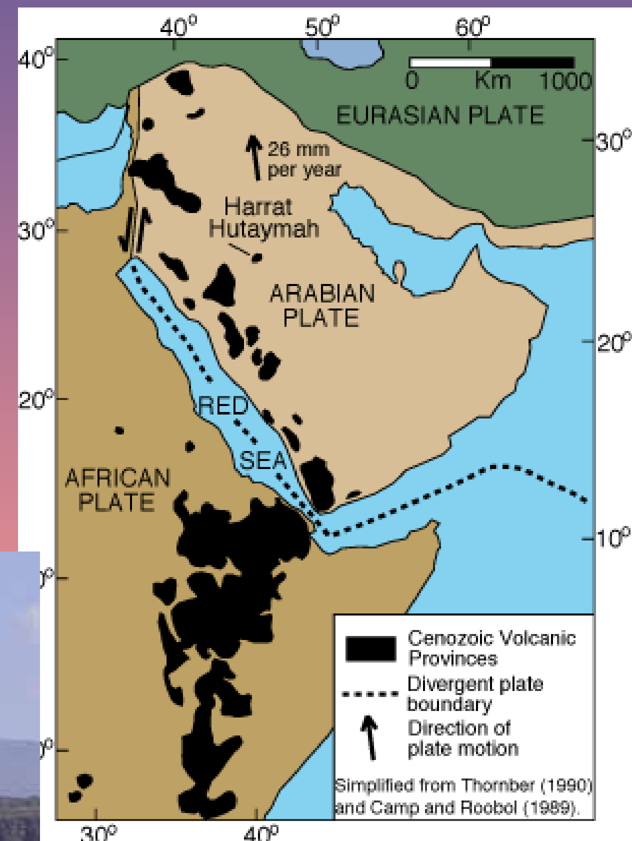
  >1000 km^3 lava

  >10,000 Mt SO_2 aerosols

Terrestrial basalt supervolcanoes

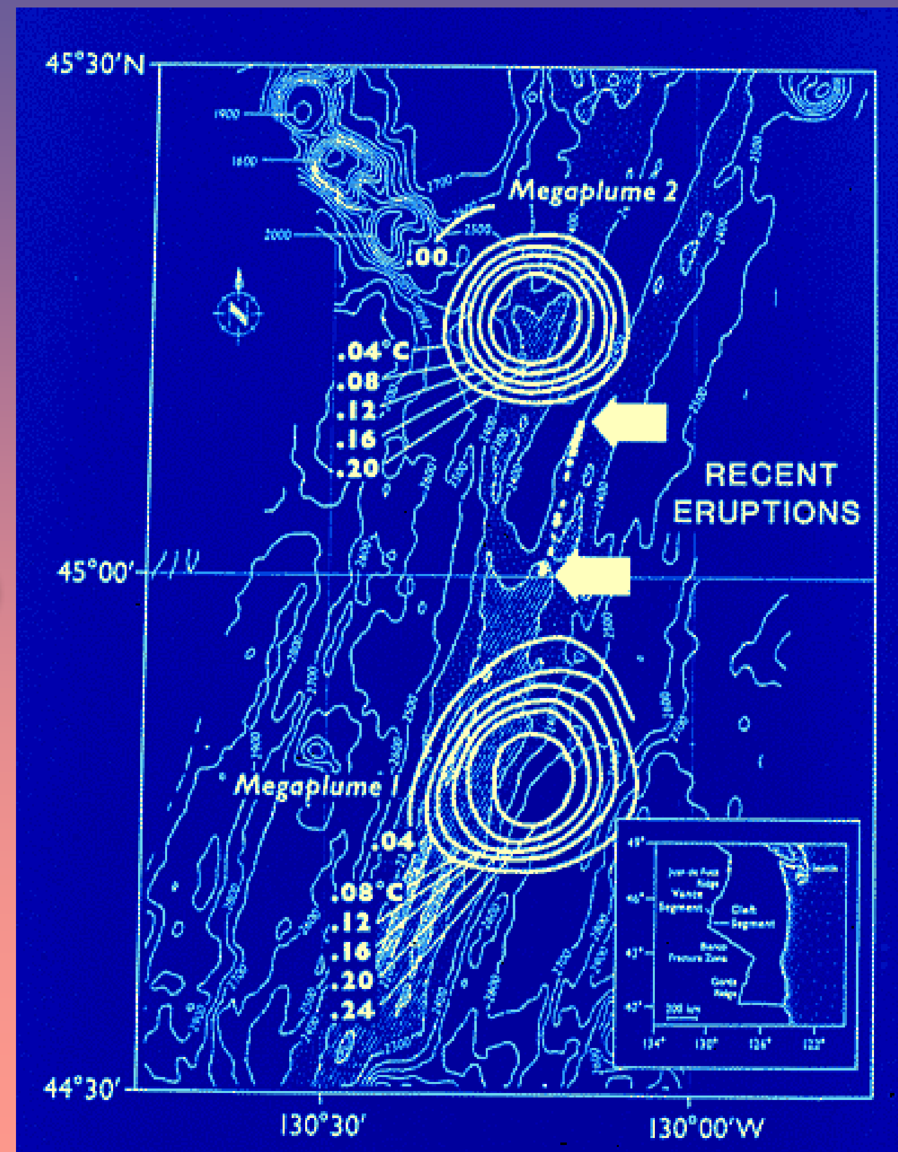
- Large provinces, sites of juvenile CO_2 degassing





Submarine basaltic supervolcanoes

- Not monitored, earthquake swarms and El Niño
- Particle and ^{3}He plumes
- No aerosols
- $CO_{2\ (gas)}$ and $CO_{2(liq)}$ dissolves (cool high pressure bottom water)



Submarine basaltic volcanicity

- Lava, hot springs, gas vents
- 64,000 km mid ocean ridges (10,000 km^3 water for cooling per annum; buffers seawater)
- Seamounts (>3,477,403* million > 0.1 km high), off axis volcanoes (cf 800 terrestrial felsic volcanoes)
- Slow spreading (Gakkel Ridge basalts; >13.5% CO_2; explosive [1999])
- No monitoring; gas measurements from 20 basaltic volcanoes, total emissions calculated at 0.08% of annual human emissions
- Upwelling thousands of years later

*Hiller & Watts (2007)

Terrestrial CO_2-rich springs, sinters, vents

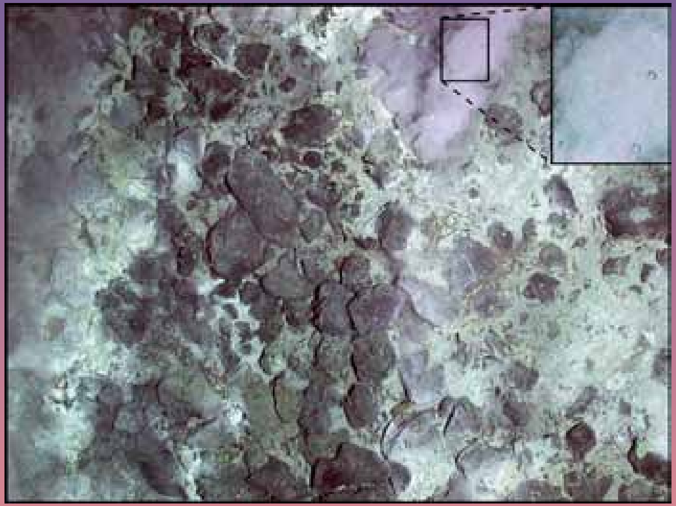
Terrestrial CO_2-rich springs, sinters, vents

Milos (Greece): CO_2 exhalations (2.5×10^6 tpa, $\delta^{13}C = -1.0$ to $+1.0$)

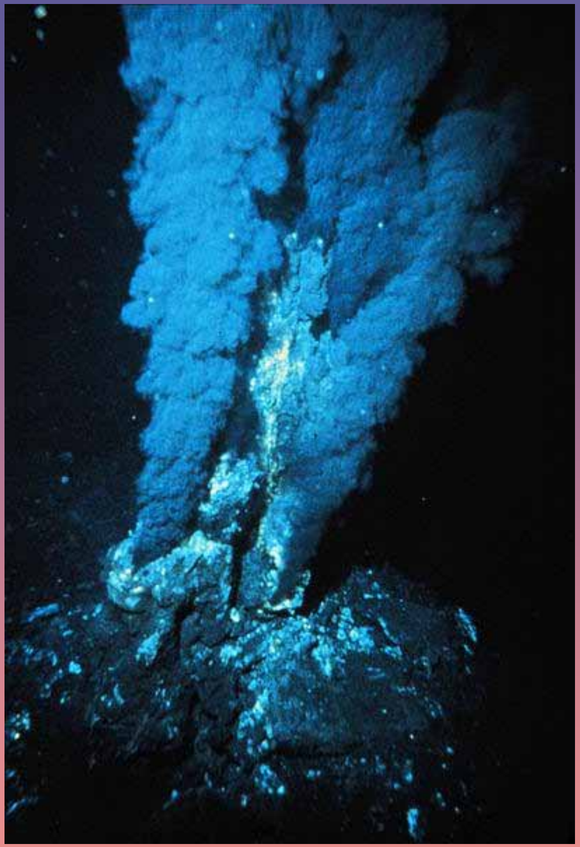
Terrestrial warm springs and travertine

Submarine basaltic volcanoes

Vent CO_2 (gas and liquid) exhalation



Hydrothermal fluids



Hot spring precipitates

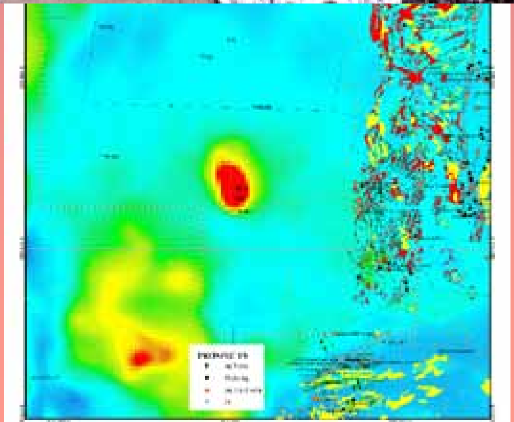
Epithermal carbonate replacement and laminated crack-seal carbonate veins (Acupan, Philippines)

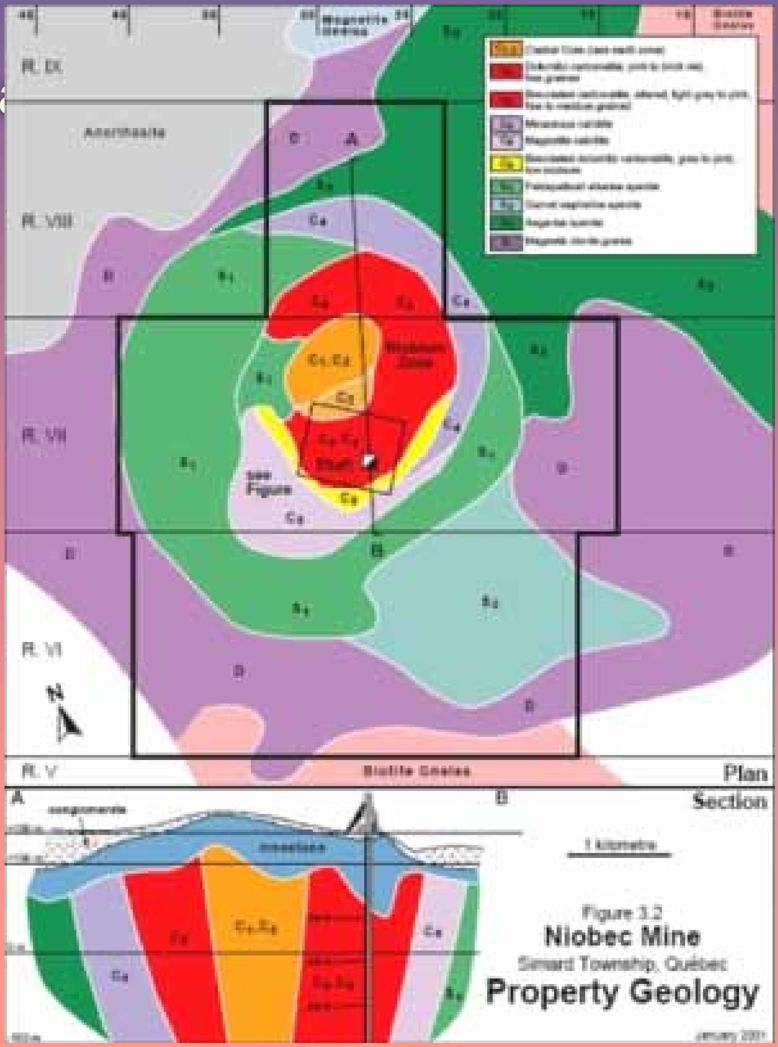
Continental evaporites?

Degassing

MOLTEN ROCKS (liquid, solid, gas): Degassing of molten rocks (2-15% gases in solution)

Carbonate lava

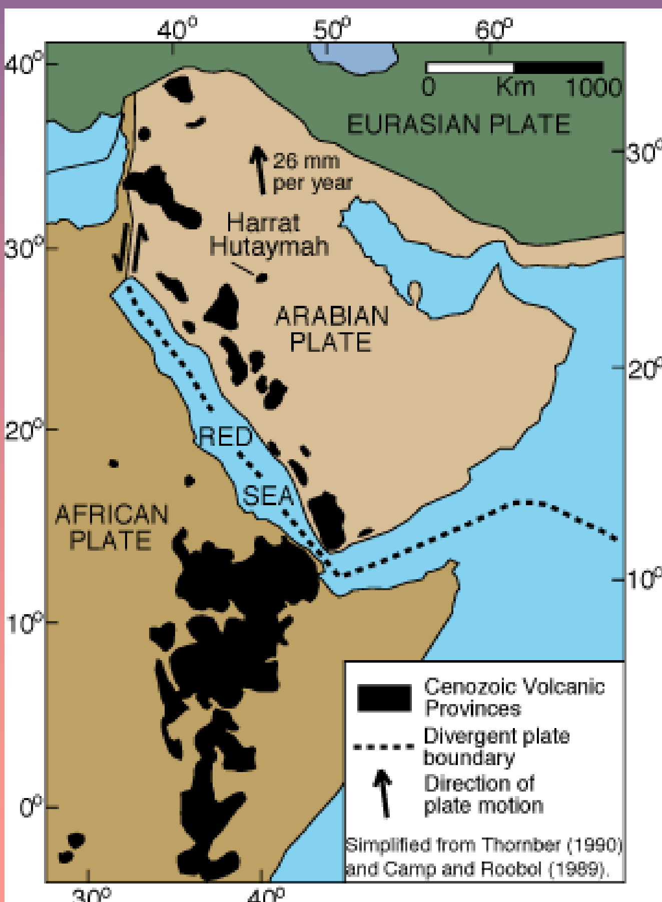


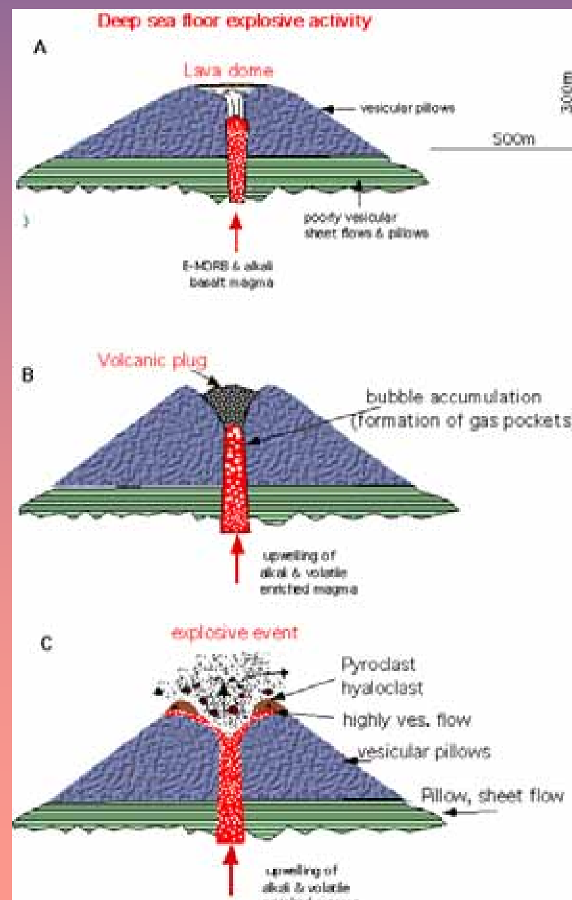


Basalt CO_2 degassing

<u>MOLTEN ROCKS </u>(liquid, solid, gas):

Extension settings such as rifts (basalts, twice temperature of felsic melts, higher gas solubility, main gas CO_2), mainly unseen)





Volcanicity, CO_2 and carbonate precipitation

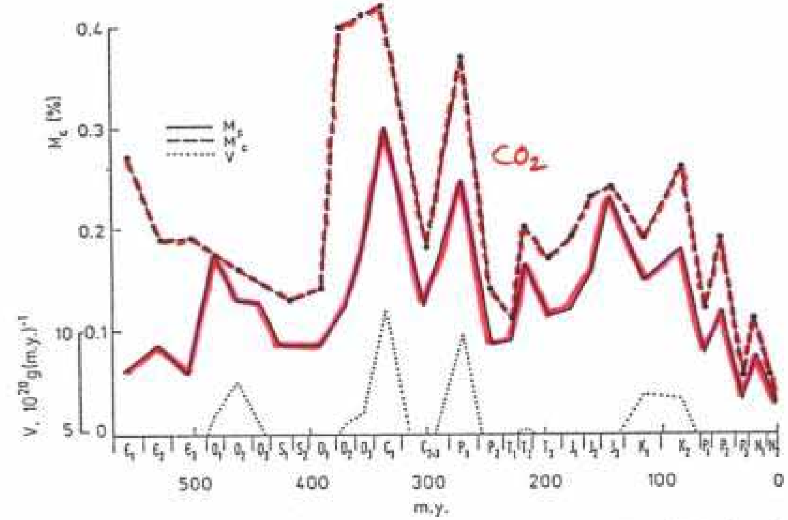


Fig. 24. Changes in carbon dioxide concentration (M_c, M_c^*) and the rate of formation of volcanic rocks (V) during the Phanerozoic

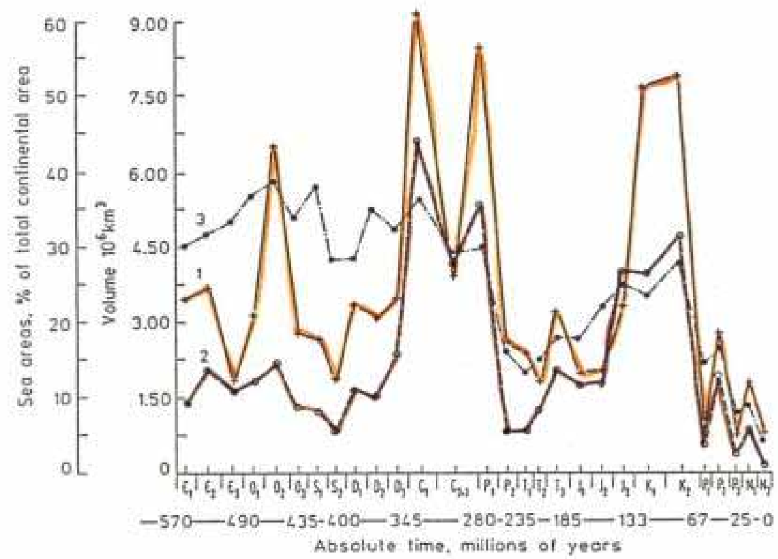
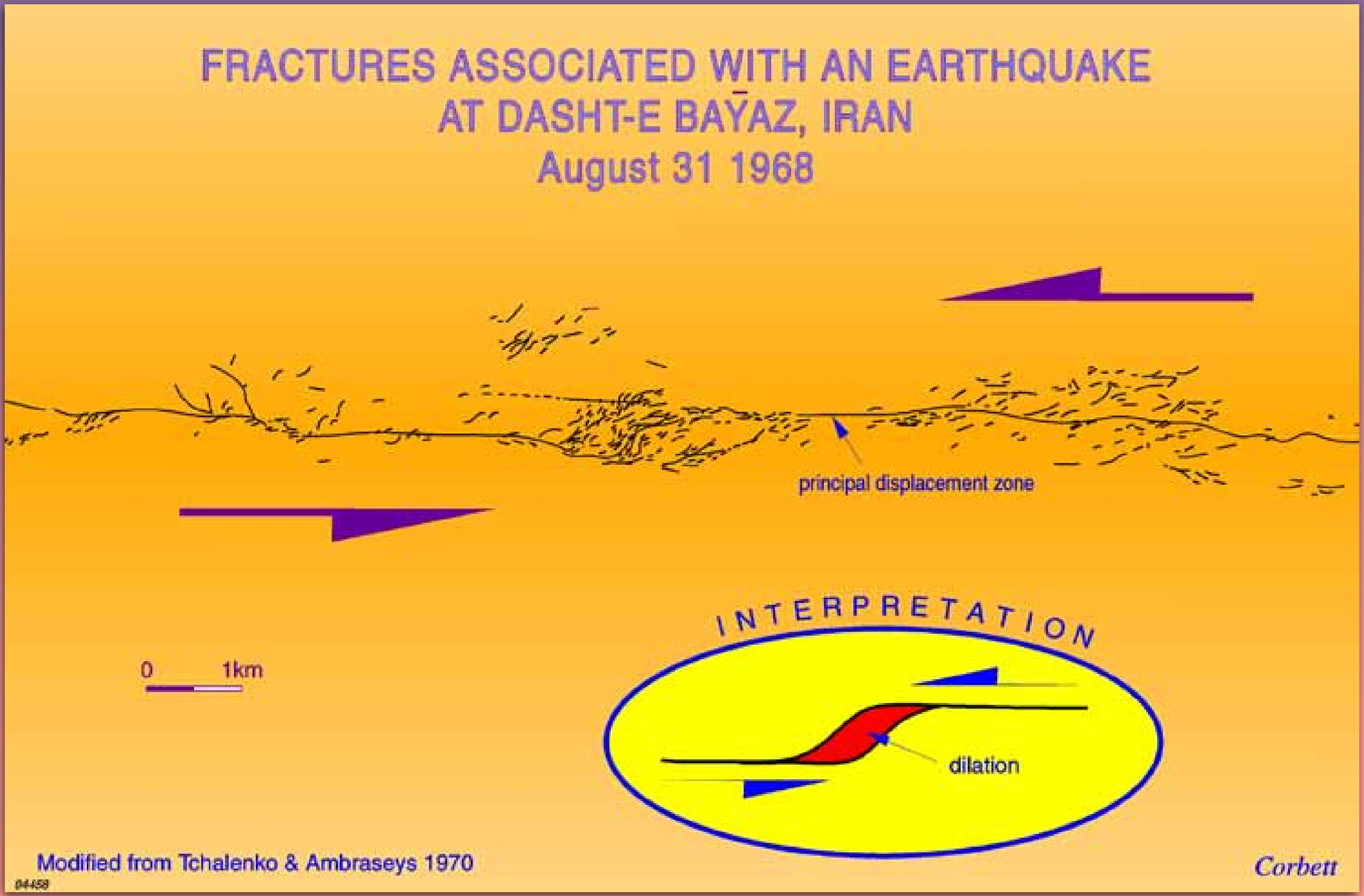


Fig. 14. Time changes in volcanogenic rock volumes *(1)*, CO_2 buried in synchronous carbonate rocks *(2)* and the ratio (%) of the continental sea area to the total area of the continents *(3)*

Warm CO_2-bearing earthquake fluids

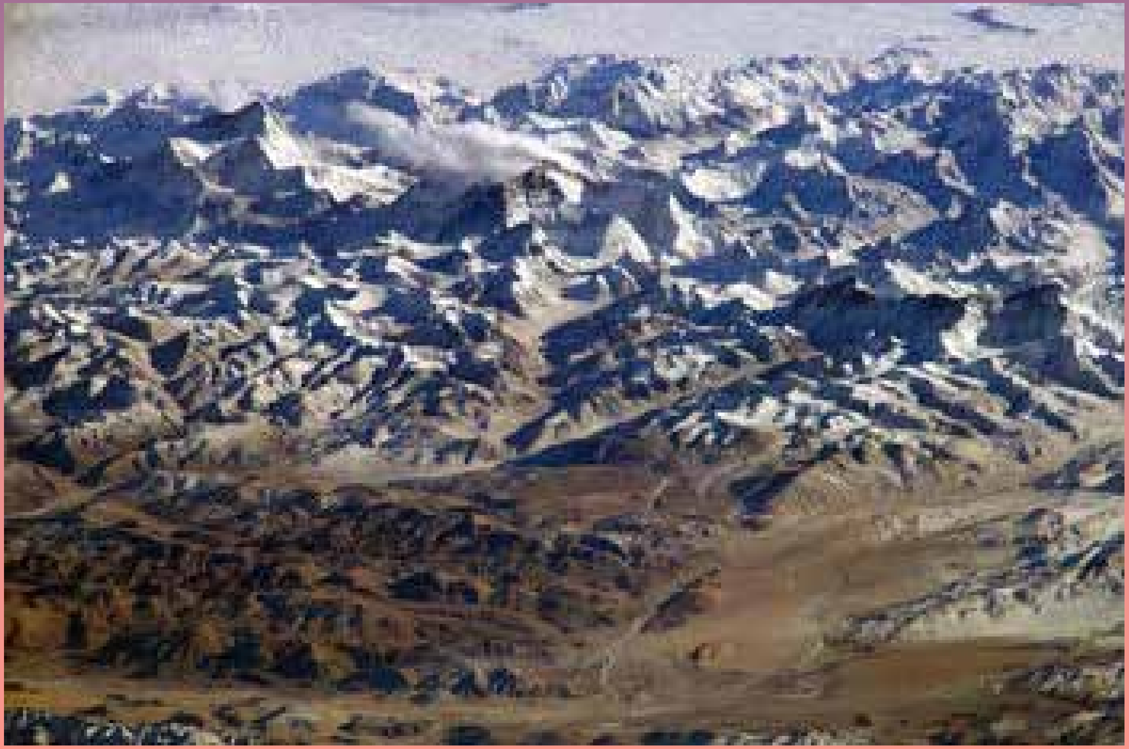
EARTHQUAKES

Warm water and gas CO_2, CH_4, He etc emissions)



CO_2-bearing springs

MOUNTAIN BUILDING: Thermal springs (bicarbonate), gas vents (CO_2)



Decarbonation from mountain building

MOUNTAIN BUILDING: Dewatering, degassing, precipitation of carbonate, CO_2- and bicarbonate-bearing springs

Atmospheric CO_2 residence time

Authors [publication year]	Residence time (years)
Based on natural carbon-14	
Craig [1957]	7 +/- 3
Revelle & Suess [1957]	7
Arnold & Anderson [1957]	10
including living and dead biosphere (Siegenthaler, 1989)	4-9
Craig [1958]	7 +/- 5
Bolin & Eriksson [1959]	5
Broecker [1963], recalc. by Broecker & Peng [1974]	8
Craig [1963]	5-15
Keeling [1973b]	7
Broecker [1974]	9.2
Oeschger et al. [1975]	6-9
Keeling [1979]	7.53
Peng et al. [1979]	7.6 (5.5-9.4)
Siegenthaler et al. [1980]	7.5
Lal & Suess [1983]	3-25
Siegenthaler [1983]	7.9-10.6
Kratz et al. [1983]	6.7
Based on Suess Effect	
Ferguson [1958]	2 (1-8)
Bacastow & Keeling [1973]	6.3-7.0

The effective lifetime for CO_2 in the atmosphere can be determined using radioactive, radiogenic and stable isotopes.

Based on bomb carbon-14	
Bien & Suess [1967]	>10
Münnich & Roether [1967]	5.4
Nydal [1968]	5-10
Young & Fairhall [1968]	4-6
Rafter & O'Brian [1970]	12
Machta (1972)	2
Broecker et al. [1980a]	6.2-8.8
Stuiver [1980]	6.8
Quay & Stuiver [1980]	7.5
Delibrias [1980]	6.0
Druffel & Suess [1983]	12.5
Siegenthaler [1983]	6.99-7.54
Based on radon-222	
Broecker & Peng [1974]	8
Peng et al. [1979]	7.8-13.2
Peng et al. [1983]	8.4
Based on solubility data	
Murray (1992)	5.4
Based on carbon-13/carbon-12 mass balance	
Segalstad (1992)	5.4

Estimates made using many different methods show effective lifetimes for atmospheric CO_2 of only c. 5 - 7 years.

Slide after Tom Segalstad, Oslo

Carbonaceous rocks

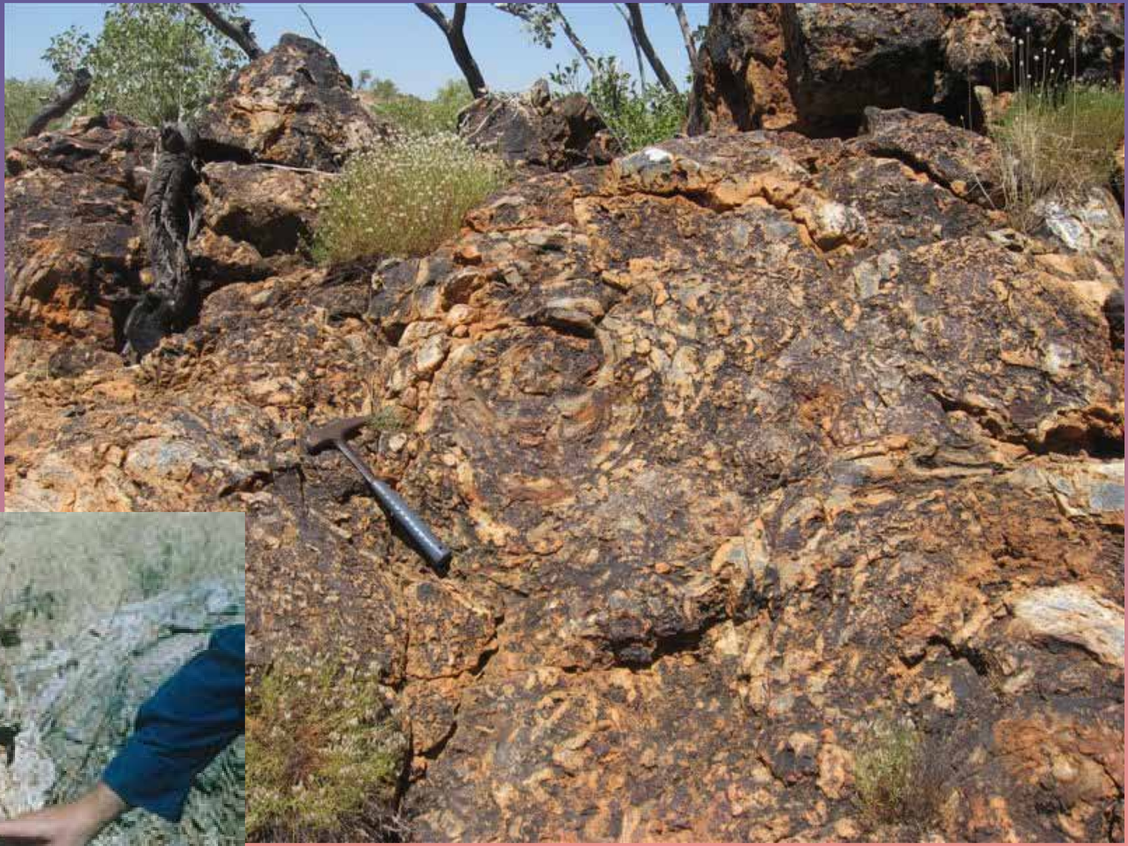
CARBONACEOUS SEDIMENTS: Natural sequestration

Carbonate sediments 2,750 Ma

1820 Ma

Corella Formation 1750 Ma

Esperanza Formation 1640 Ma



Cryogenian detritus

Flinders Ranges 800-600 Ma

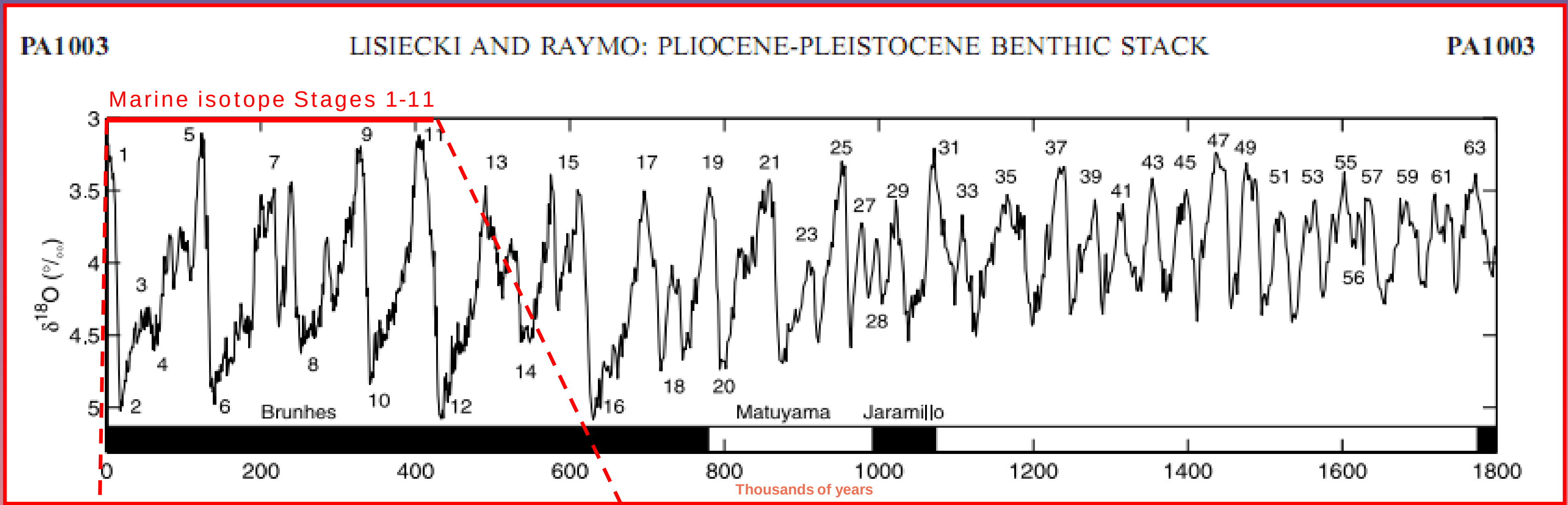
If $[CO_2]$ high, then dolomite $CaMg(CO_3)_2$

Great Barrier Reef, 400 Ma Napier Range

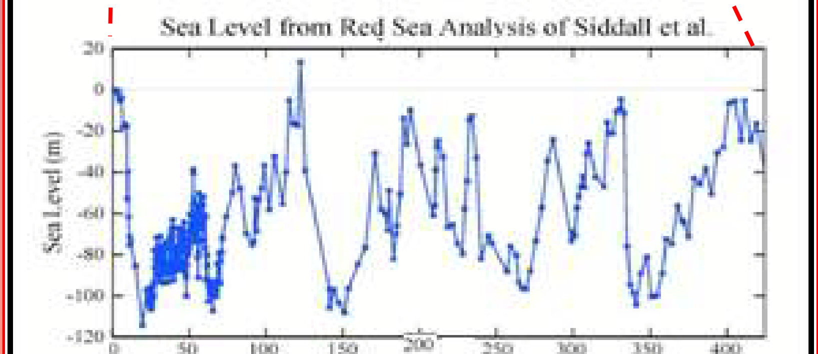
Guilin 360 Ma

Southern Victoria 50Ma

Late Tertiary: Oxygen isotopes: ocean proxy for ocean surface temperature



The Principle of



Global sea level extracted, via a hydraulic model, from an oxygen isotope record for the Red Sea over the past 470 kyr (concatenates Siddall's MD921017, Byrd, & Glacial Recovery data sets; AMS radiocarbon dating)

GLOBIGERINA OOZE

(from Murray & Reynard, 1891, Challenger Reports, plate XI)

Shark Bay, WA

Coral reefs

Soils

silicate + H_2O + CO_2

= hydrous silicate + carbonate

Where does CO_2 go to?

<u>OCEANS</u>: Especially polar and deep water

$$CO_2\ (g) \quad <=> \quad CO_2\ (aq)$$

$$CO_2\ (aq) + H_2O \quad <=> \quad H_2CO_3\ (aq)$$

$$H_2CO_3\ (aq) \quad <=> \quad H^+\ (aq) + HCO_3^-\ (aq)$$

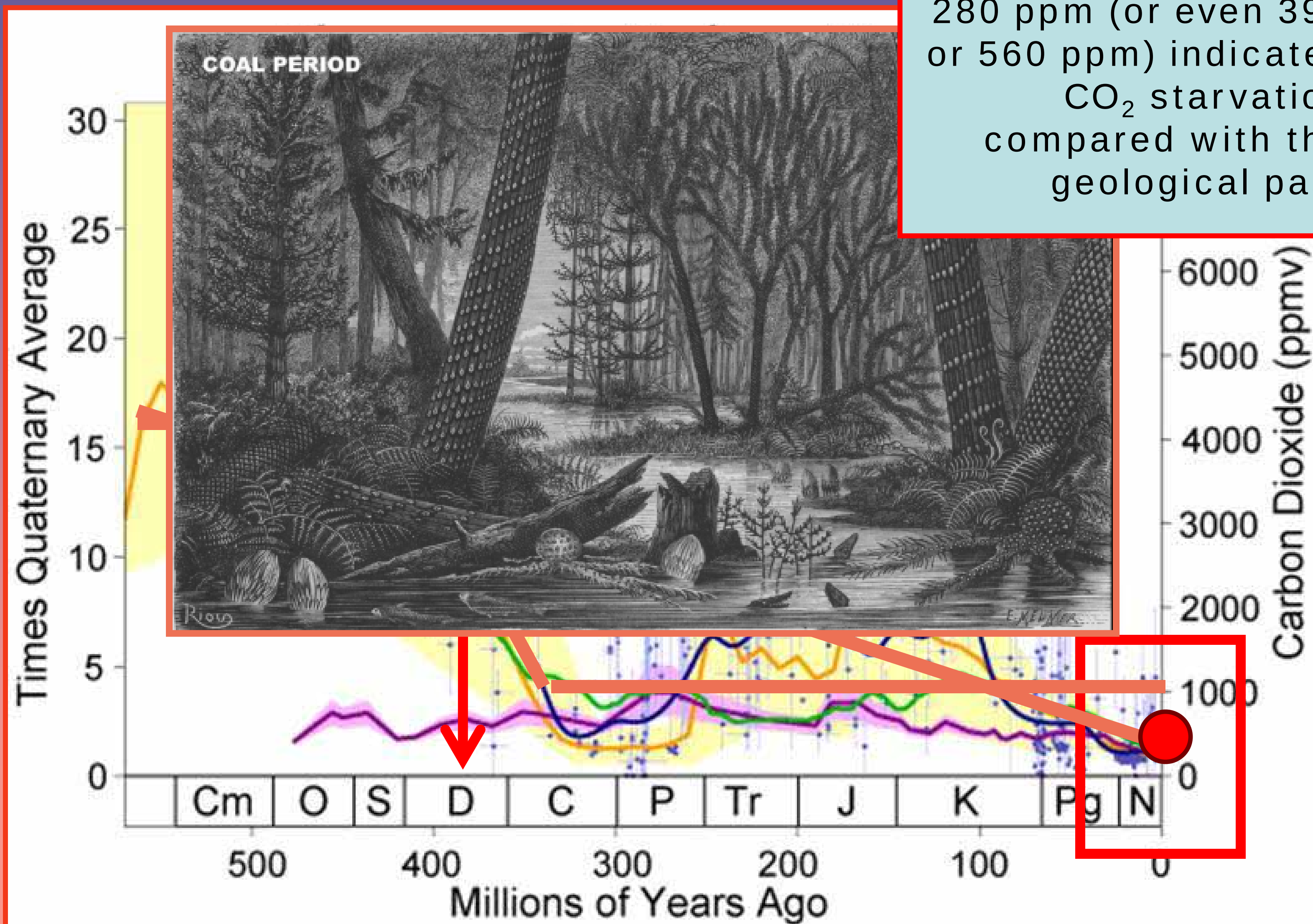
$$HCO_3^-\ (aq) \quad <=> \quad H^+\ (aq) + CO_3^{2-}\ (aq)$$

$$CO_3^{2-}\ (aq) + Ca^{2+}\ (aq) \quad <=> \quad CaCO_3\ (s)$$

Net reaction:

$$CO_2\ (g) + H_2O + Ca^{2+}\ (aq) \quad <=> \quad CaCO_3\ (s) + 2\ H^+\ (aq)$$

CONTEXT: CO_2 – levels through time



280 ppm (or even 390 or 560 ppm) indicates CO_2 starvation compared with the geological past

Temperature and time

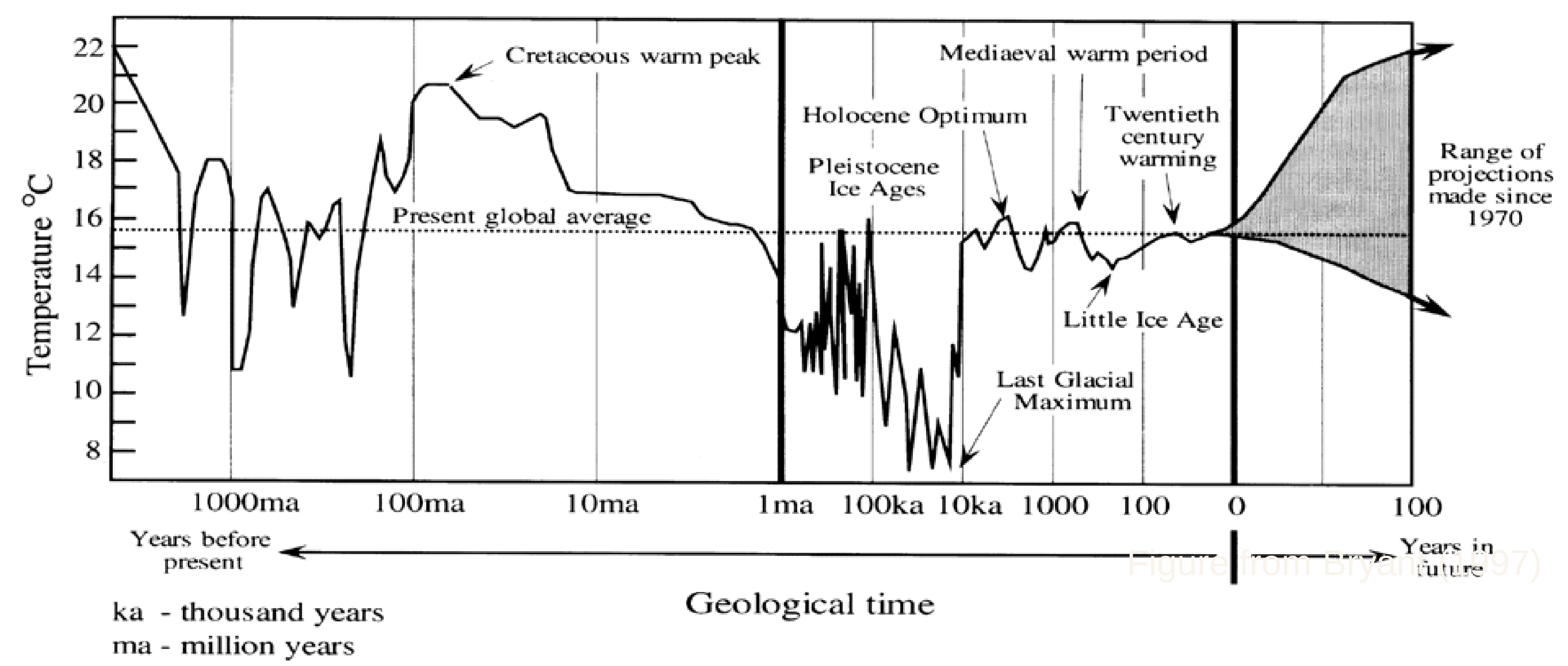
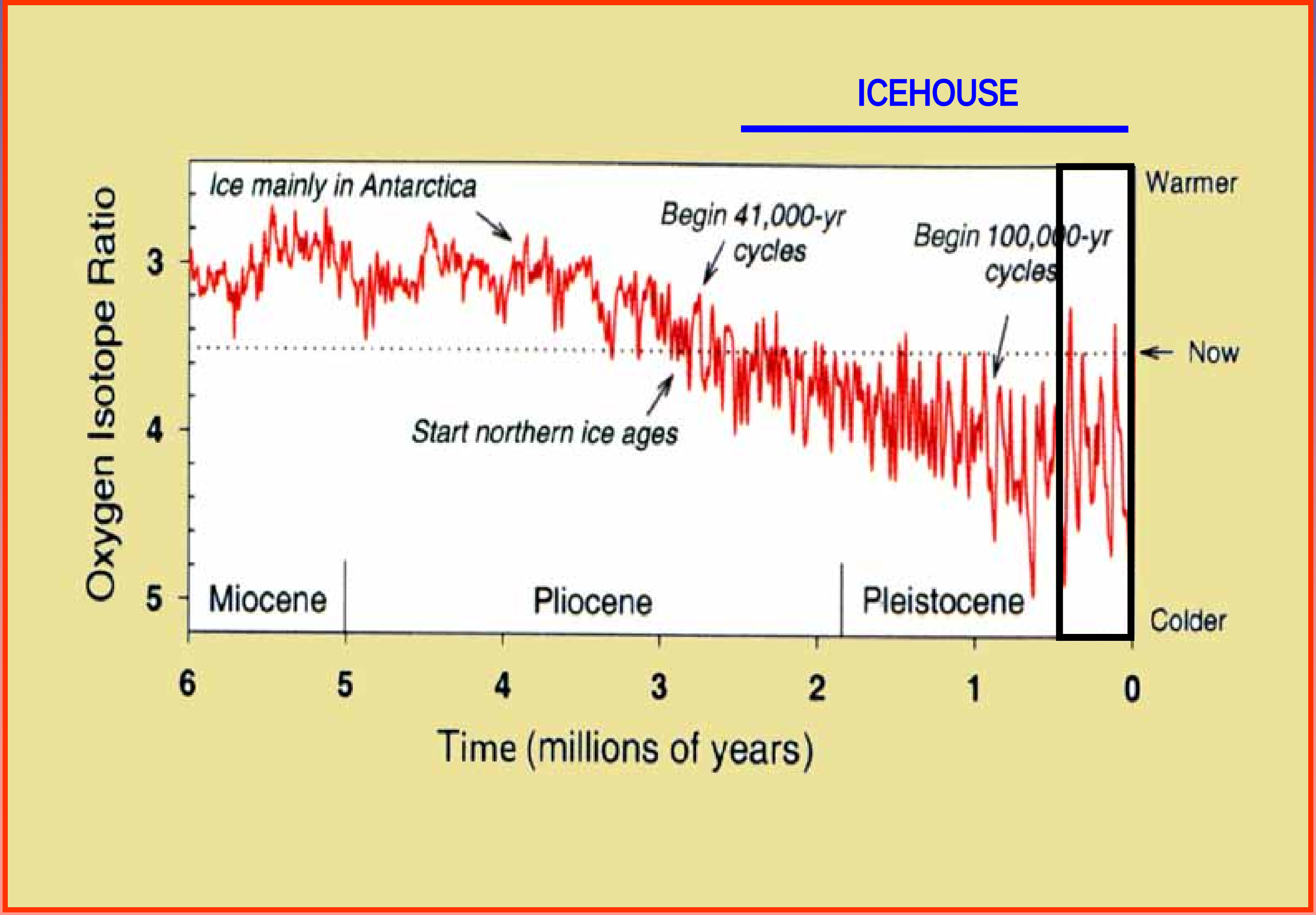
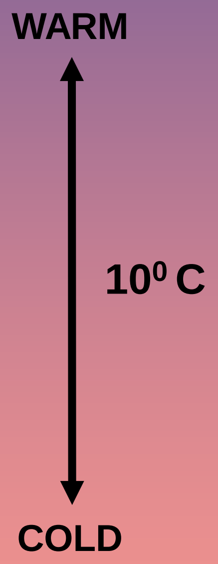


Figure from Bryant (1997)

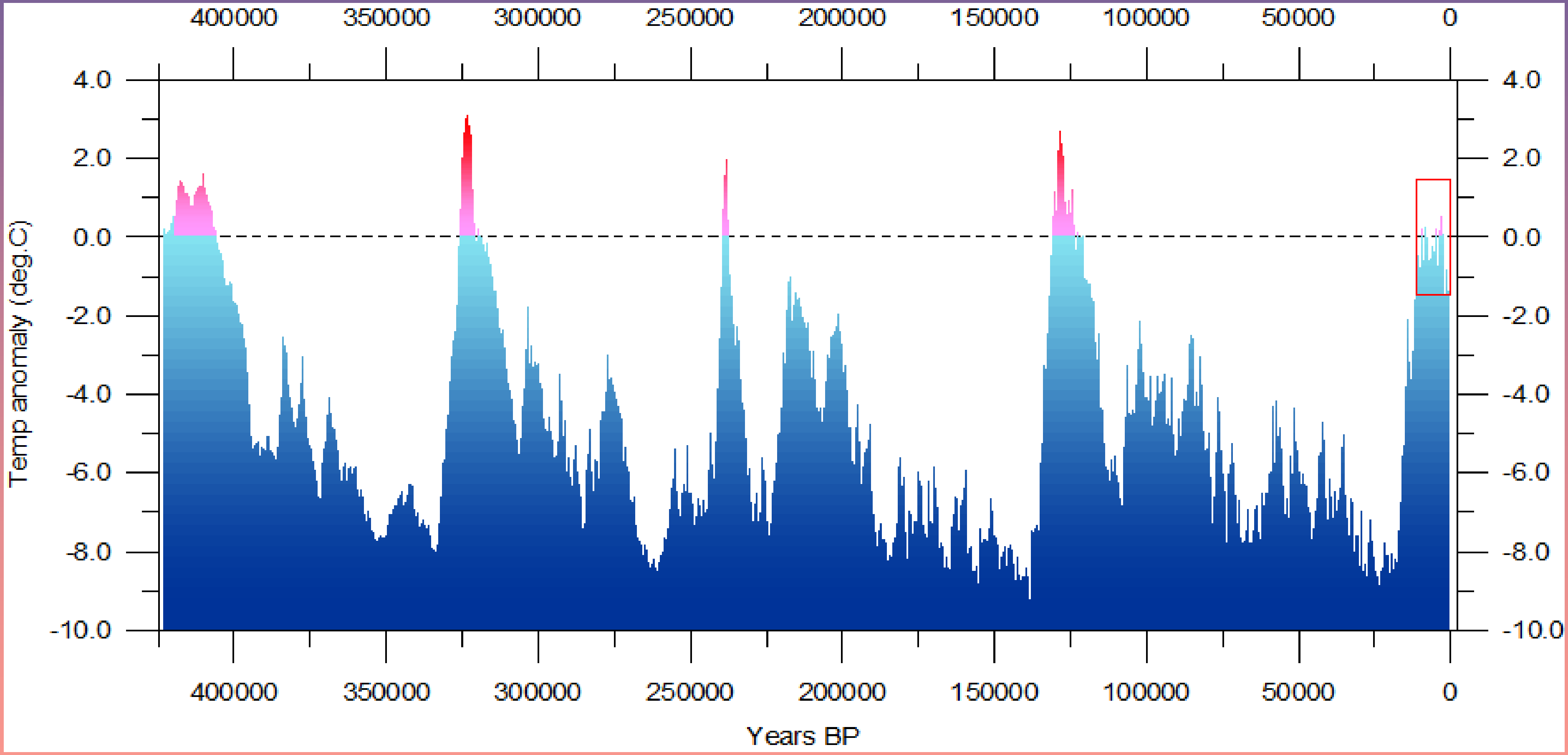
Is the magnitude of late 20th C temperature change unusual?

The last 6 million years – ODP Site 677, North Atlantic Ocean



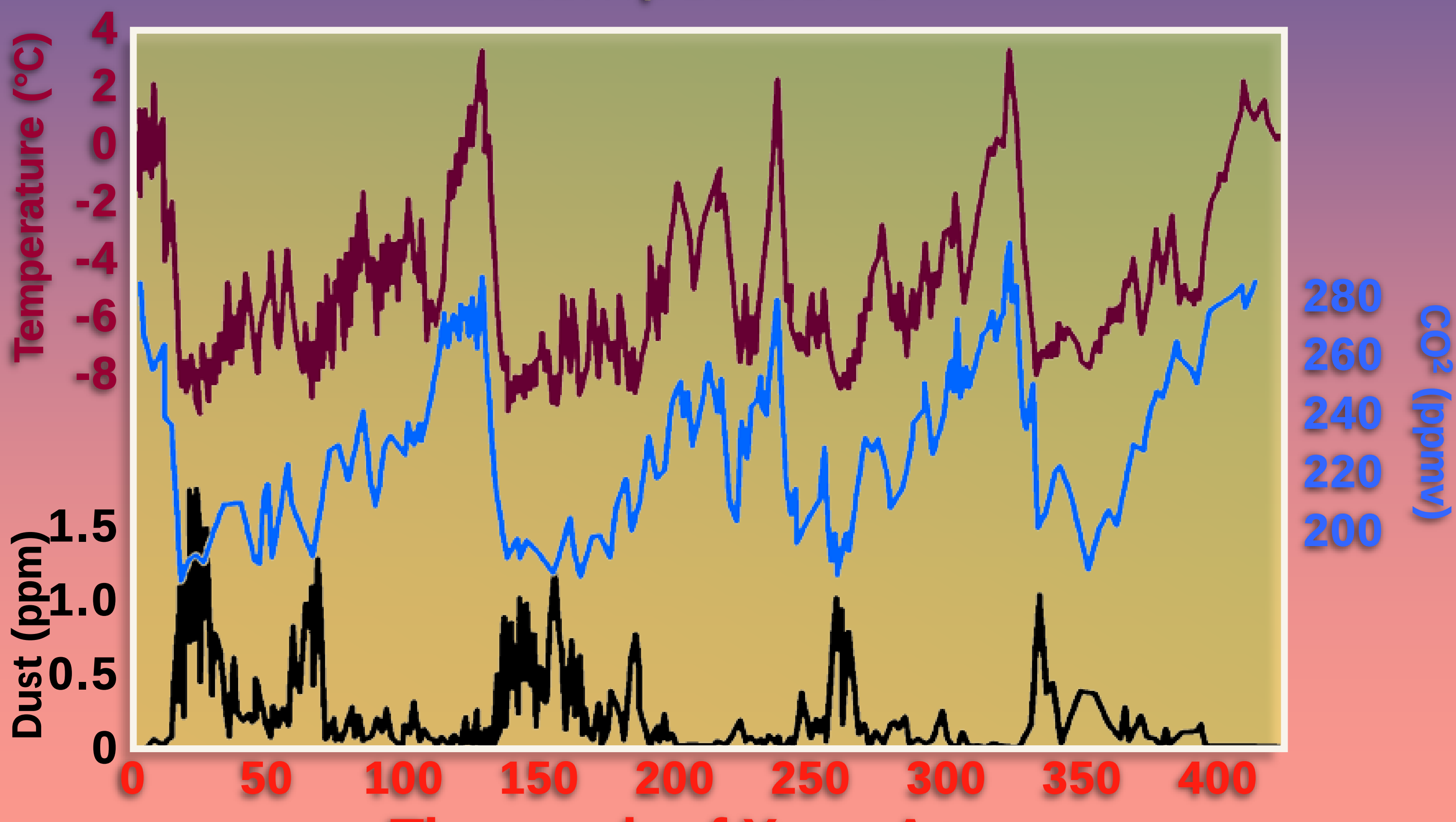


Is the speed and degree of modern climate change unprecedented (Vostok ice core; Salamatin *et al.* 1998; Petit *et al.* 2001)



Temperature proxy

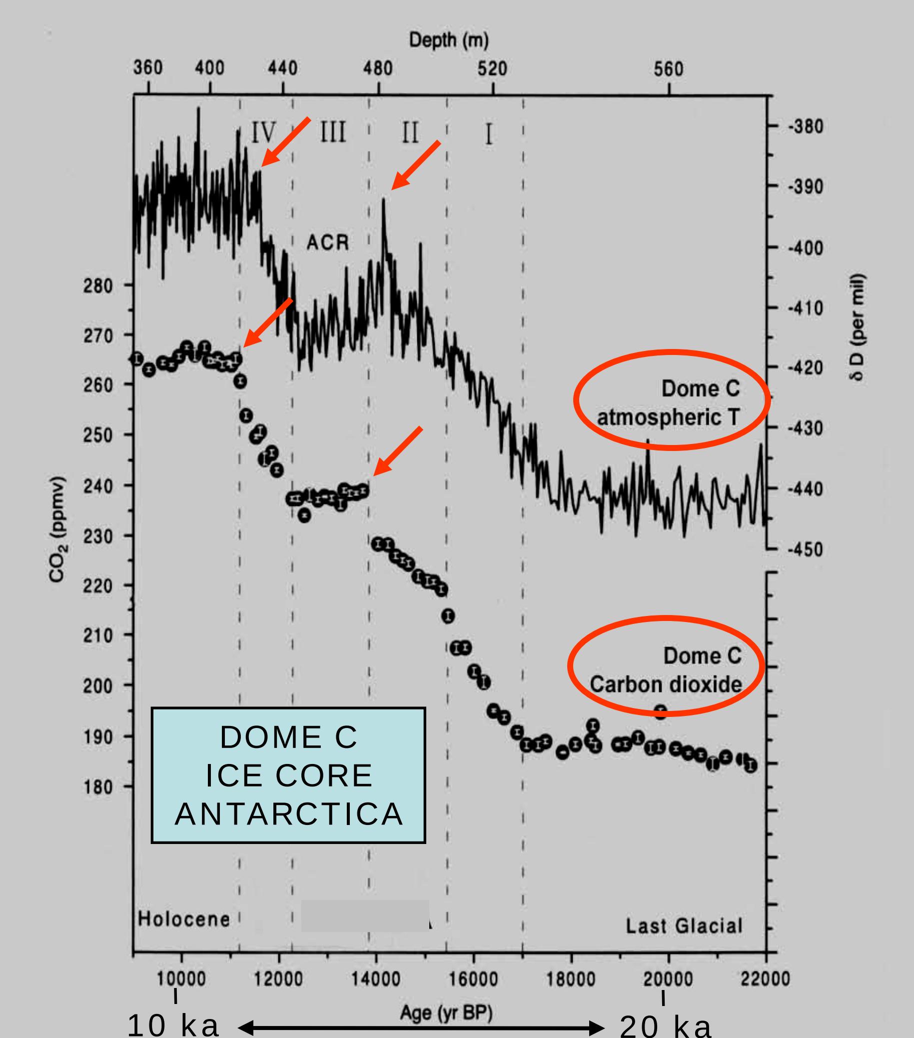
$H_2O_{(vap)}$ buffer to maximum and minimum temperature



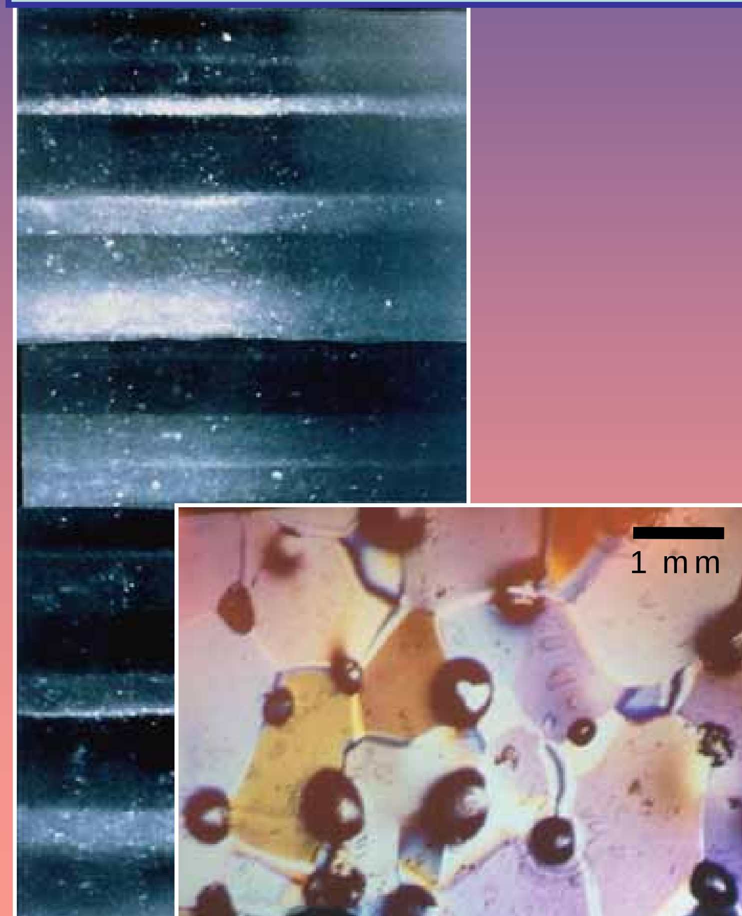
DOES CO_2 LEAD OR LAG TEMPERATURE CHANGE?

In ice cores, changes in T precede changes in CO_2 by ~800-2000 yrs.

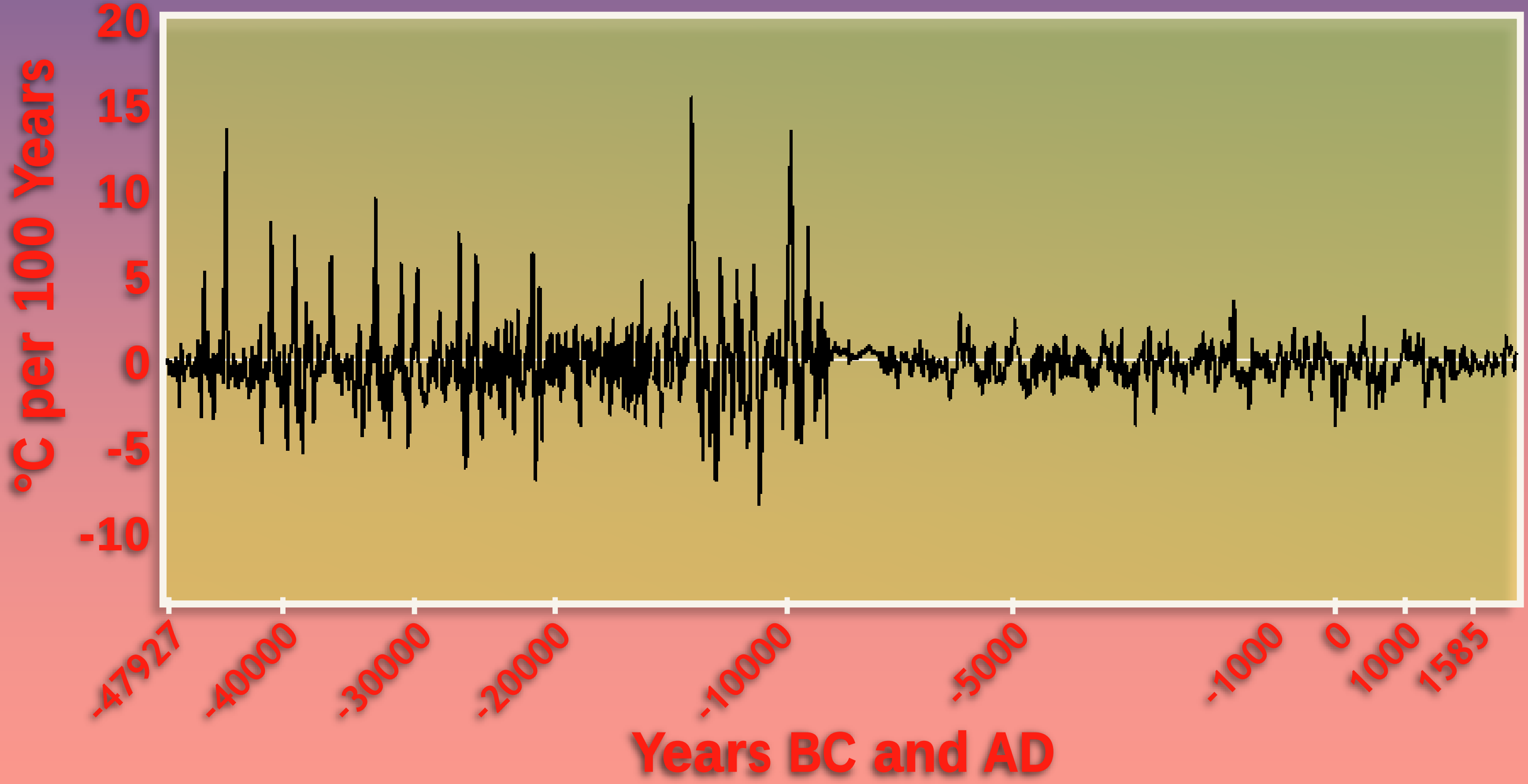
CO_2 does NOT force temperature at the G/I scale



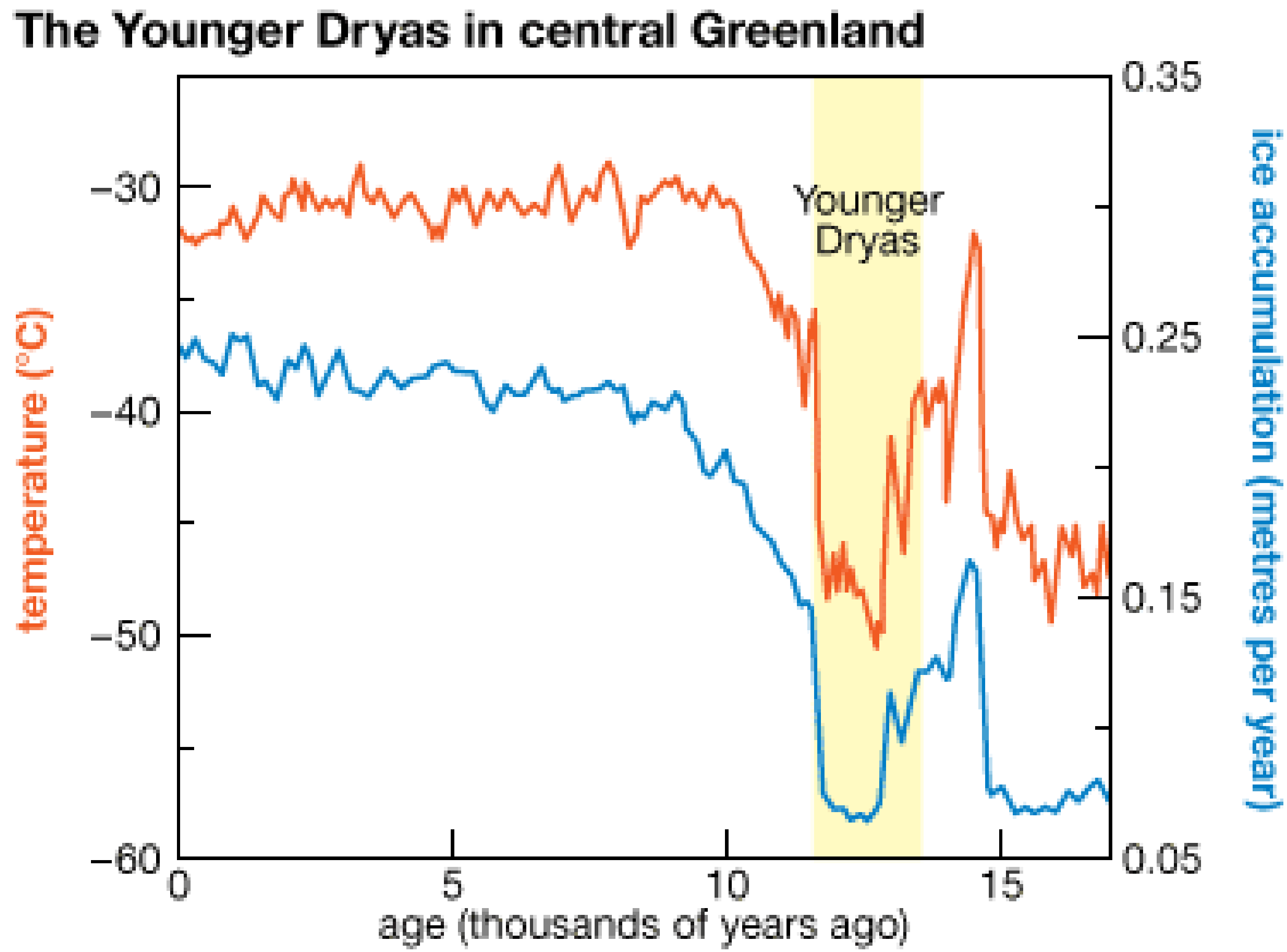
Monnin et al.,
SCIENCE VOL 291 5 JANUARY 2001



Is the 20th Century temperature outside natural variability?



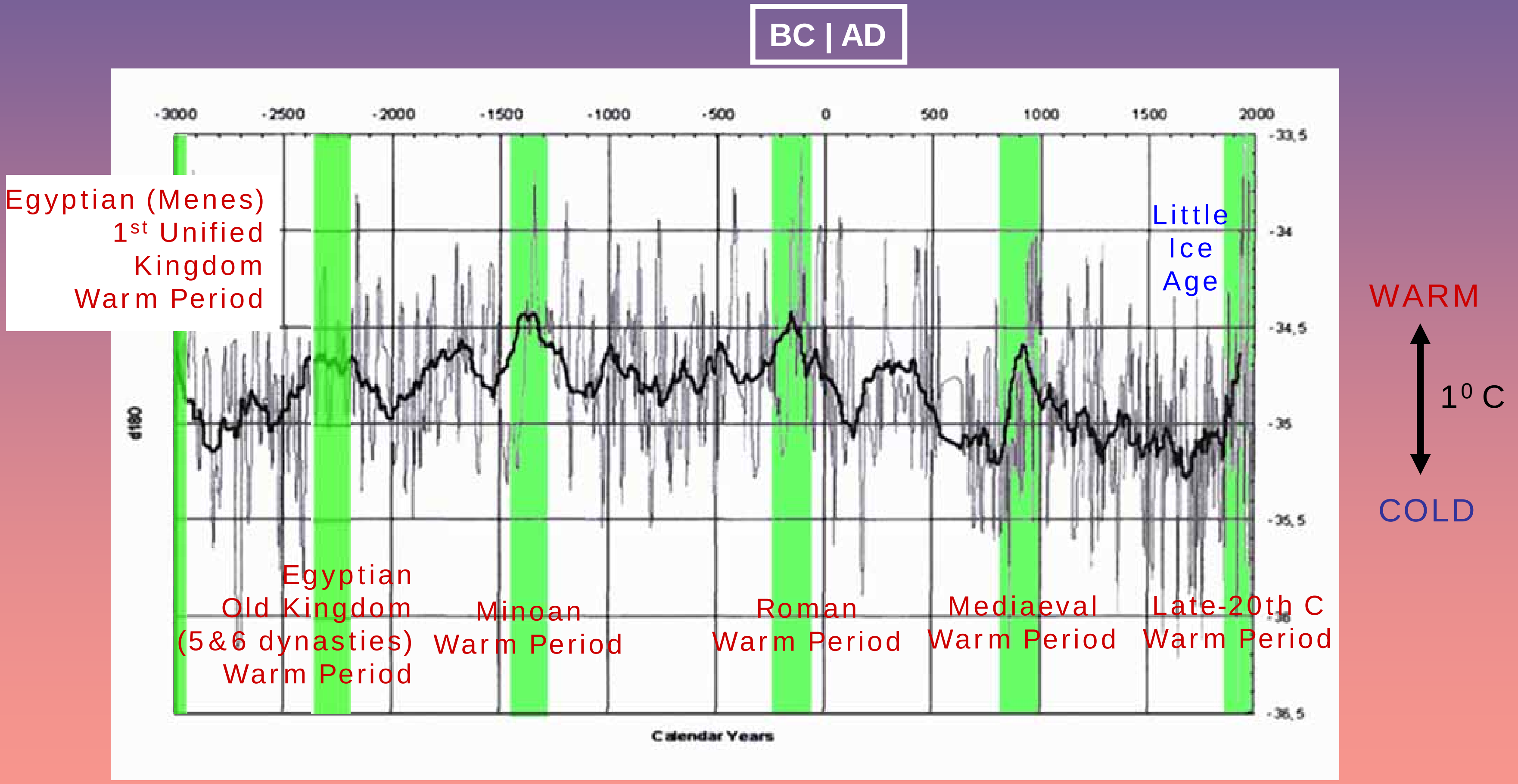
Cold snaps, rates of climate change



Source: Lamont-Doherty Earth Observatory at the Earth Institute of Columbia University and *Abrupt Climate Change: Inevitable Surprises*, National Academy of Sciences, Committee on Abrupt Climate Change, 2002

Is the magnitude of late 20th C temperature change unusual?

The last 5,000 years – Greenland Ice Core



Grootes, P.M., Stuiver, M., White, J.W.C., Johnsen, S.J., Jouzel J., Comparison of oxygen isotope records from the GISP and GRIP Greenland ice cores. Nature 366, 1993, pp. 552-554.

Slide after A. Illarionov, Powerpoint presentation, December 2004.

What does the history of the planet tell us?

- Earth always changes
- Climate change is normal
- Climate change occurred well before humans were on Earth
- The rate of climate change today is no different from thousands, millions or billions of years ago
- >80% time, Earth has been warmer and wetter than at present
- Ice is rare
- Just because change occurs in our lifetime does not mean that we humans are driving the change

The gas of life

- CO_2 gas of life, increase beneficial
- Part of massive natural cycle (mantle-atmosphere-oceans-organisms-sediments)
- Atmospheric CO_2 short temporary stock, marine reservoir 50x larger governs atmospheric CO_2
- Heat stored in oceans and thermostat effect of clouds
- Carbon isotopes show <4% atmospheric CO_2 anthropogenic, small effect compared to total
- To argue that human emissions of CO_2 drive climate change is non-scientific political activism akin to creationism