GEF4400 “The Earth System”

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Prof. Dr. Kirstin Krüger (UiO)

- **Lecture/ interactive seminar/ field excursion**
  Teaching language: English
  Time and location: Monday 12:15-14:00
  Thursday 14:15-16:00, CIENS Glasshallen 2.
- **Study program**
  Master of meteorology and oceanography
  PhD course for meteorology and oceanography students
- **Credits and conditions:**
  The successful completion of the course includes an **oral presentation (weight 50%)**, a **successful completion of the Andøya field excursion** (mandatory), a **field report**, as well as a final **oral examination (50%)**. Student presentations will be part of the course.

GEF4400/9400 changed time schedule

Changed GEF4400/9400 time schedule during November 2015:

Mo. 02.11.15: 10:00-12:30, Wed 04.11.15 10:15-12:00

Mo. 09.11.15: 10:00-12:30, Wed 11.11.15 10:15-12:00

Mo. 16.11.15: 10:00-12:30, Wed 18.11.15 10:15-12:00

Mo. 23.11.15: 10:00-12:30, Wed 25.11.15 10:15-12:00

IPCC Chapter 6: **Carbon and other biogeochemical cycles**

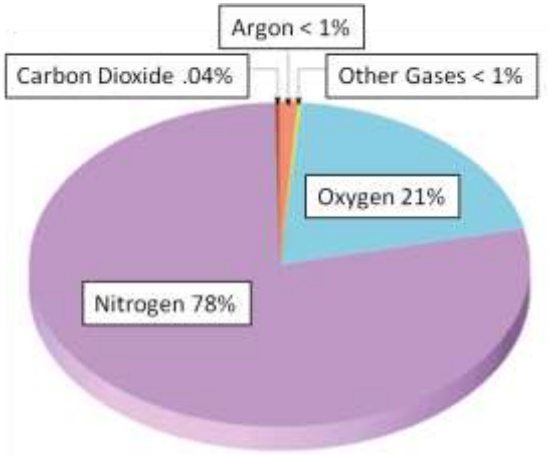
- Background
- Introduction: Global Carbon Cycle *(Section 6.1)*
- Variations in Carbon cycle before the fossil fuel era *(Section 6.2)*
- Evolution of biogeochemical cycles since industrial era *(Section 6.3)*
- Projections of future carbon cycles *(Section 6.4)*
- Executive Summary (Ch. 6)

Ciais, P., Cet al., 2013: Carbon and Other Biogeochemical Cycles. In: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press.

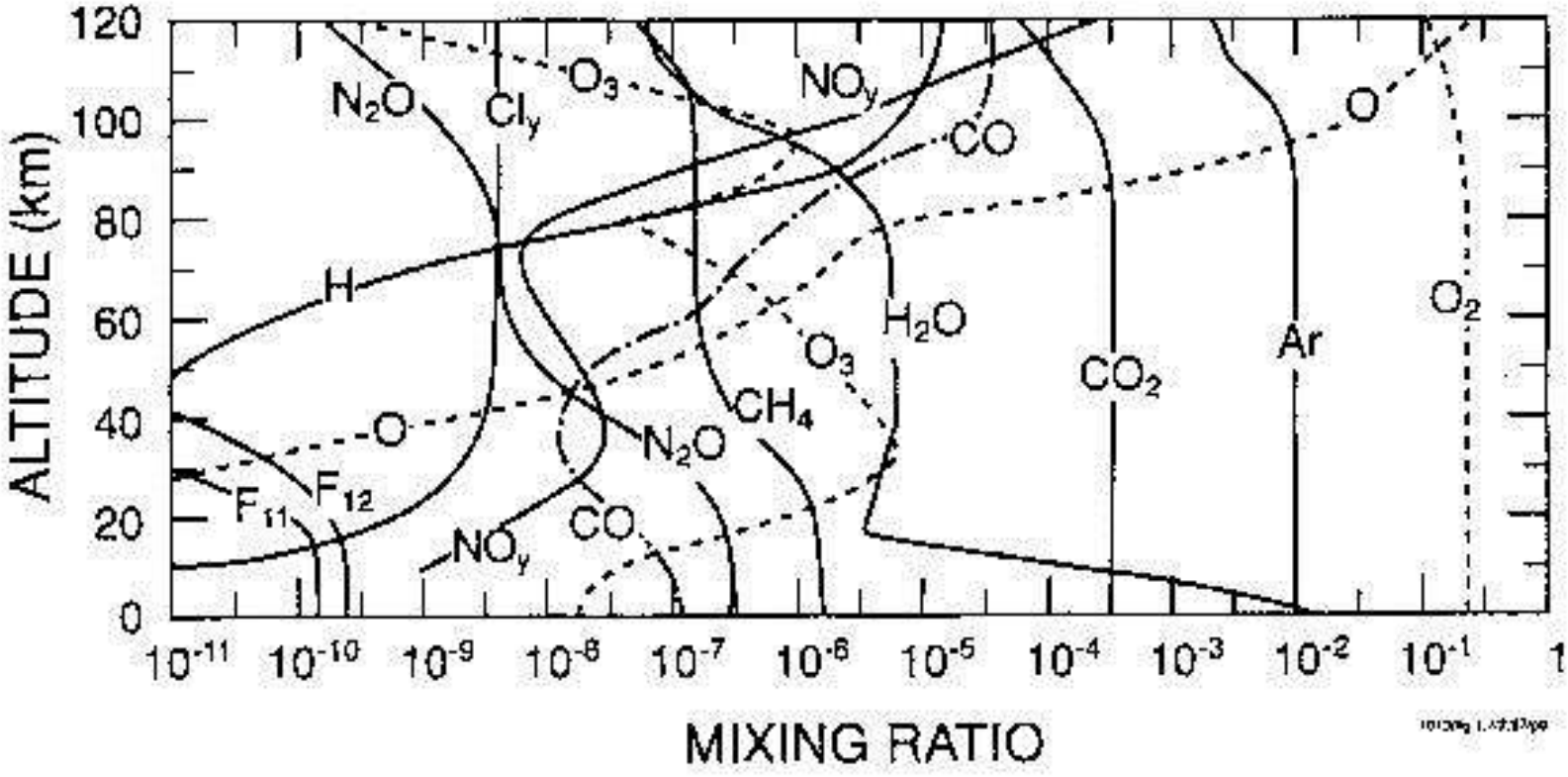
Carbon dioxide (CO_2) in the atmosphere

Content of air

		Percent of volume (%)
Nitrogen N_2	78	
Oxygen O_2	21	
Inert gases (Ar)	0.9	
	99.9	



Carbon dioxide CO_2	0.04, varying
Ozone O_3	0.00005, varying
Water vapour H_2O	highly varying
+ other trace gases	



Typical vertical distribution of chemical species within the air [Brasseur, 1999].

Mixing ratios of trace gases

1 ppm (1 part per million) 1 particle CO_2 per 10^6 particles air
1 ppb (1 part per billion): 1 particle CO_2 per 10^9 particles air
1 ppt (1 part per trillion): 1 particle CO_2 per 10^{12} particles air

"v": per volume
"m": per mass

Mixing ratio is a relative unit → taking the air density into account

Absolute unit: concentration of a trace gas (e.g. given in mPa, nbar, Dobson units for ozone)

Carbon dioxide

Molecular formula	CO_2
Molar mass	44.010 g/mol
Appearance	colorless, odorless gas (gas at 1 atm and 0 °C; 1 atm =1013.25 hPa) (solid at 1 atm and −78.5 °C) (liquid at 56 atm and 20 °C)
Dipole moment	zero
Molecular shape	linear
Spectral data	UV, IR

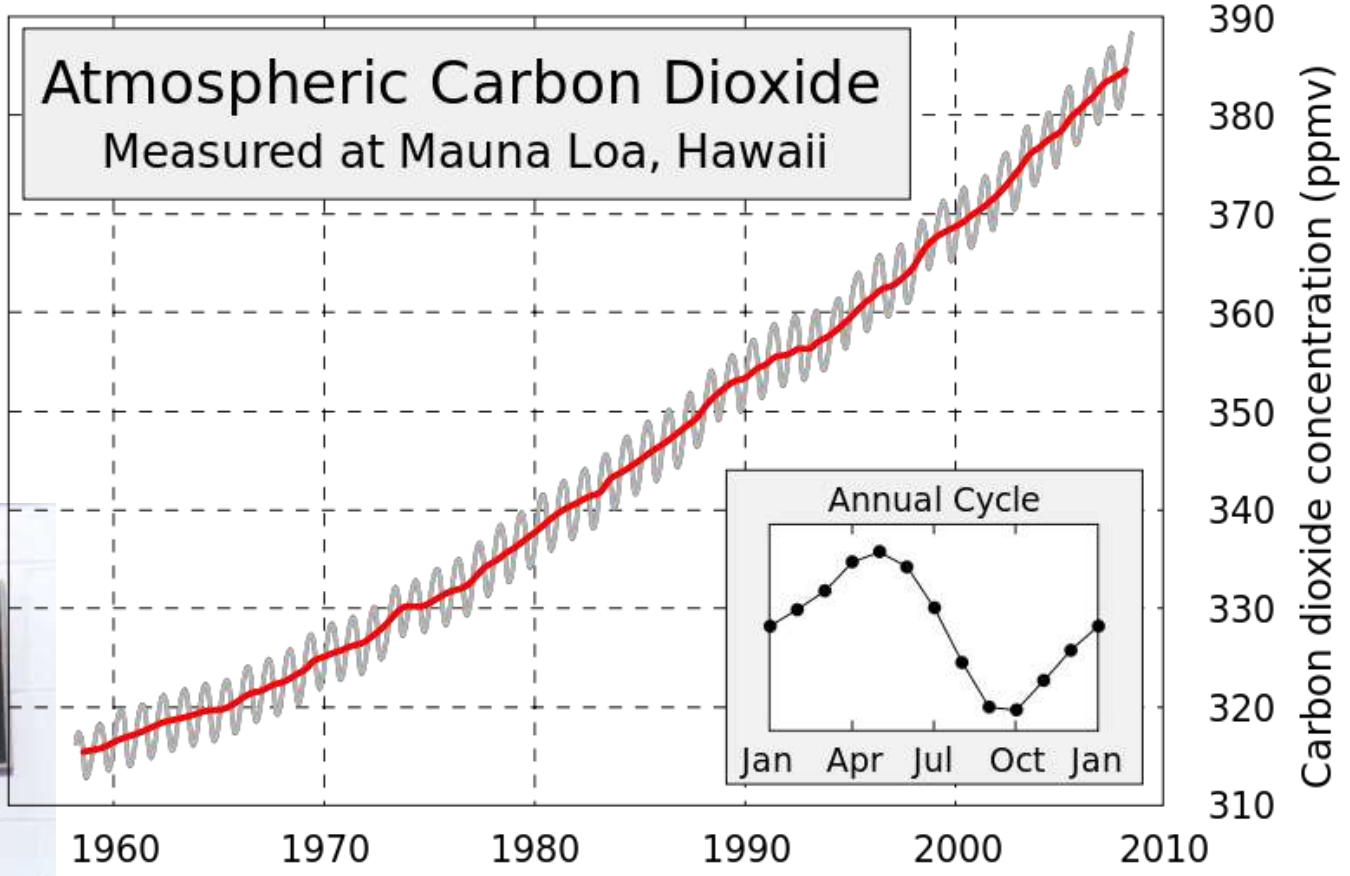
O=C=O

CO_2: **trace gas, 0.038%** concentration of the atmosphere,
sources and sinks are at the surface, uniform distribution up to 90 km.

Sources: combustion of fossil fuels, burning of vegetable matter, chemical processes, respiration, volcanoes , geothermal processes, dissolution of carbonates in crustal rocks.

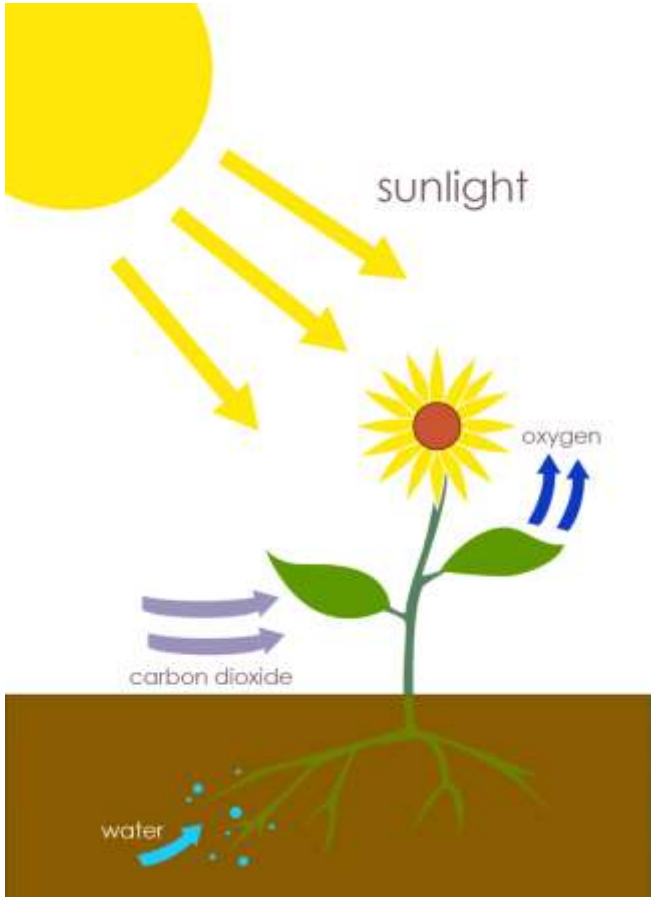
Sinks: ocean, sediments, biosphere(photosynthesis)

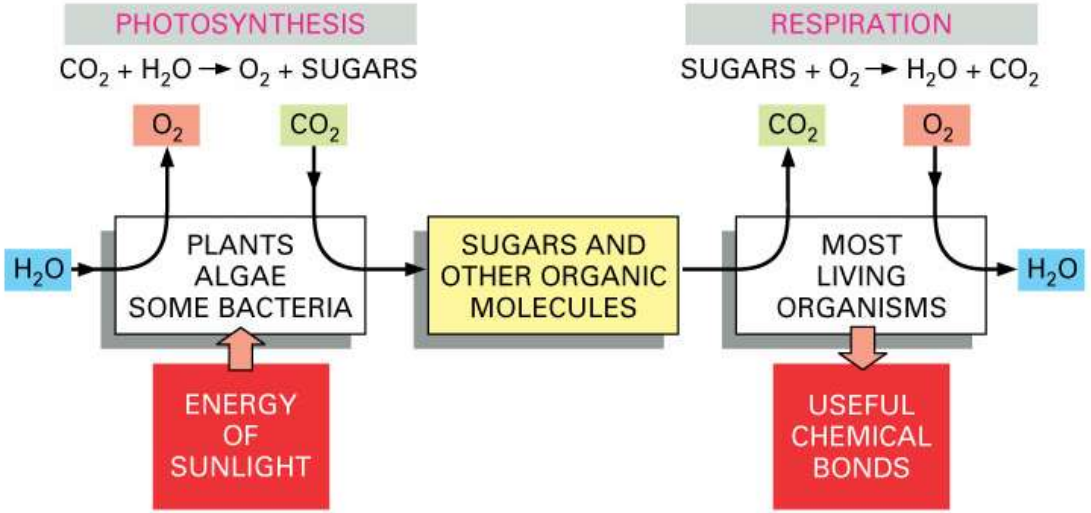
Mauna loa curve (Keeling curve)



Charles D. Keeling
1928-2005

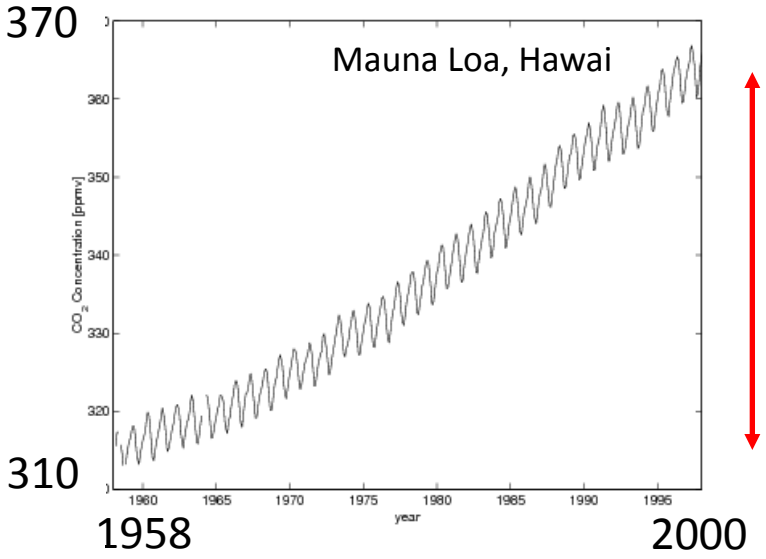
Photosynthesis + Respiration



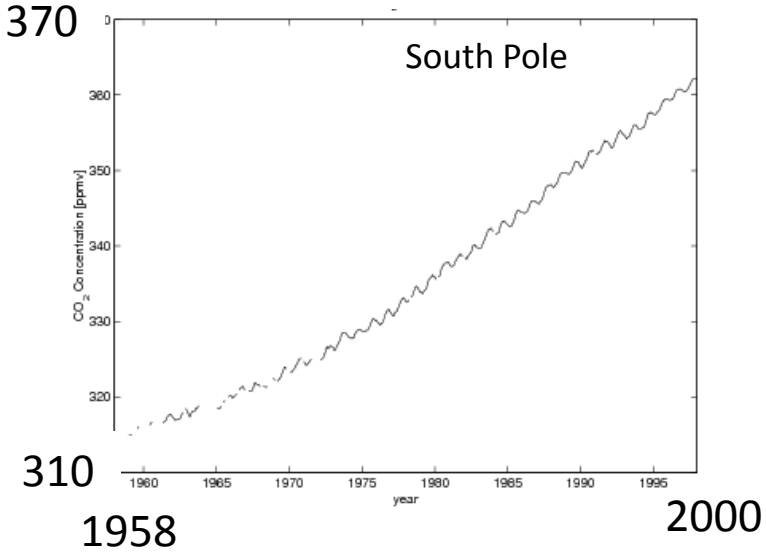


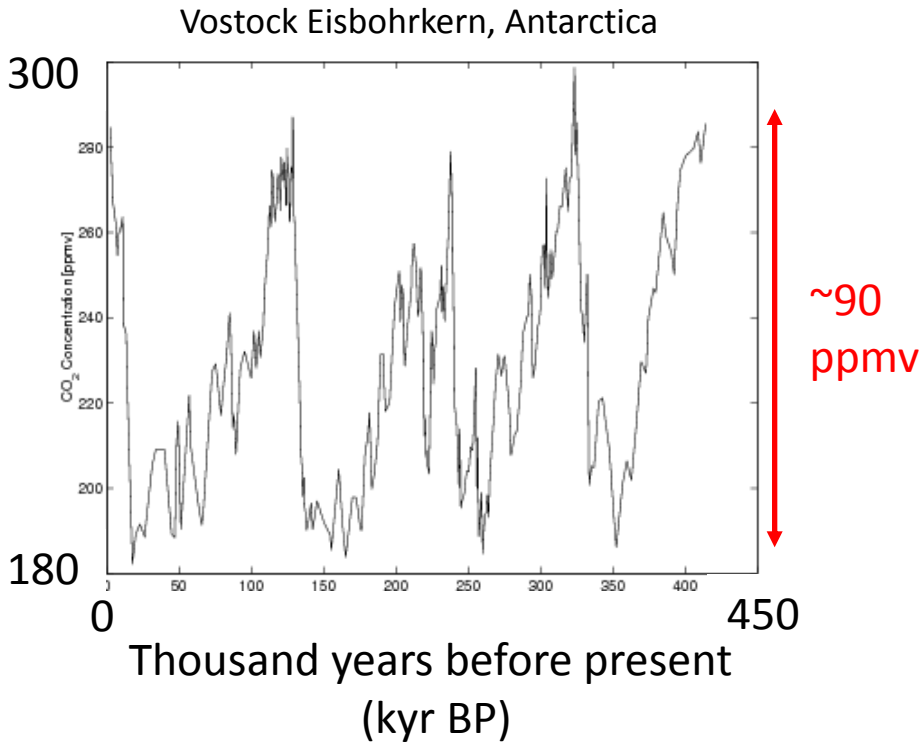
$6CO_2$ Carbon dioxide + $6H_2O$ Water $\xrightarrow{\text{Light}}$ $C_6H_{12}O_6$ Sugar + $6O_2$ Oxygen

Past and present CO_2 mixing ratio (ppmv)



~55 ppmv

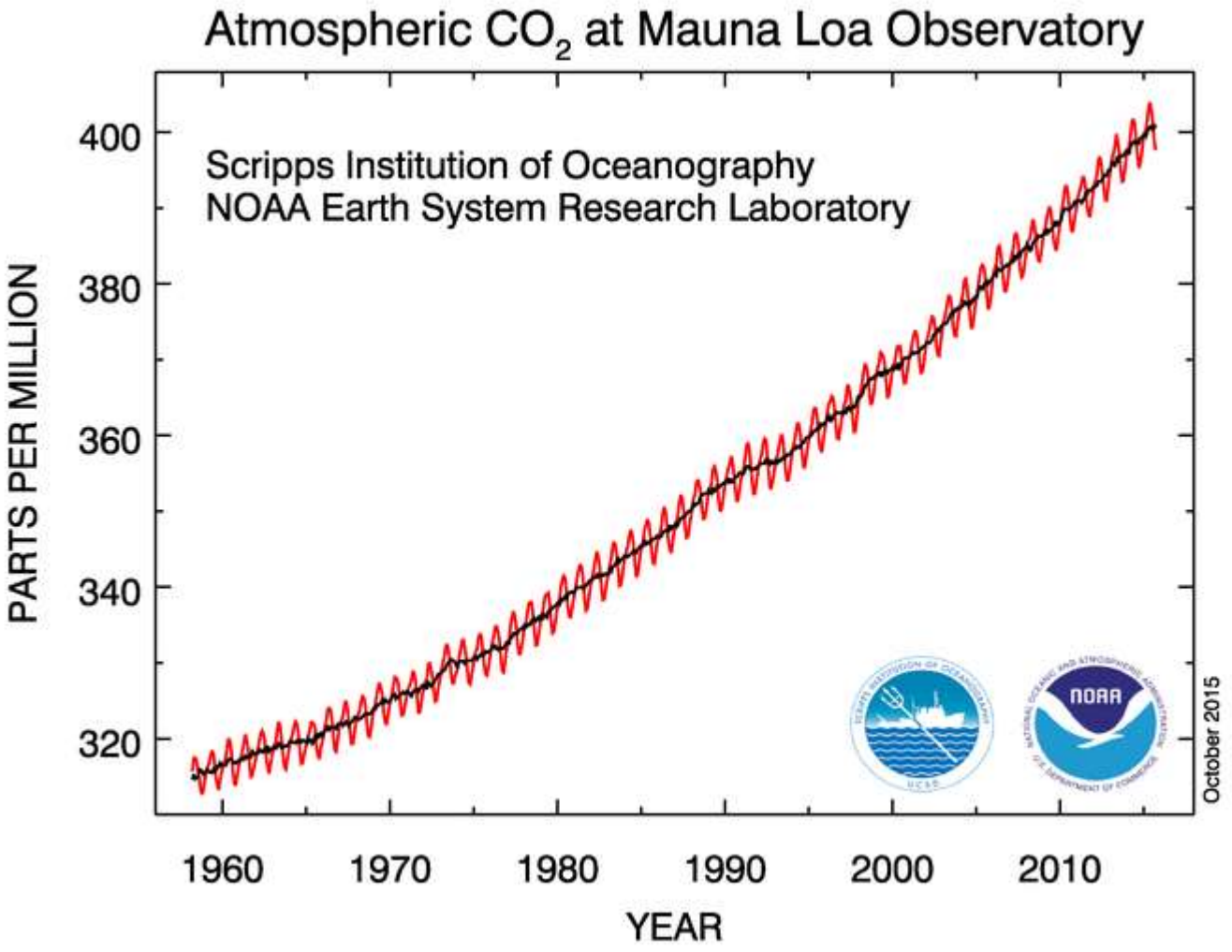




~90 ppmv

(Macke, 2004)

Background



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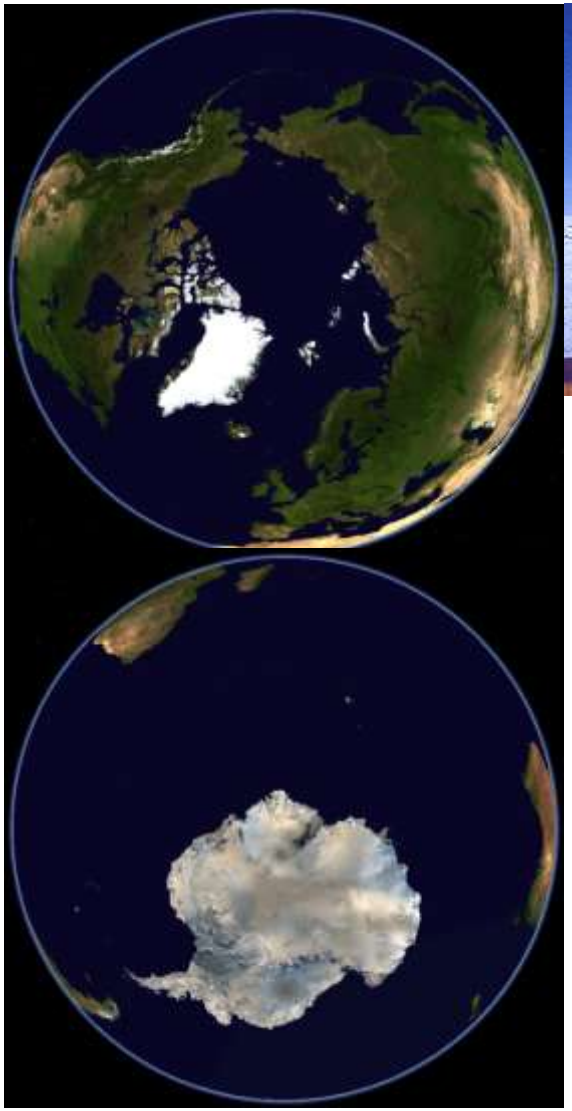
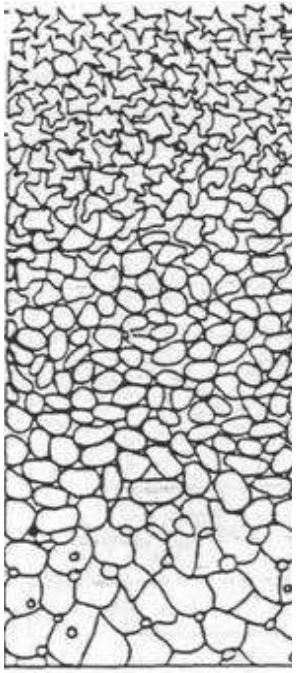
Ice cores as climate archives



young

old

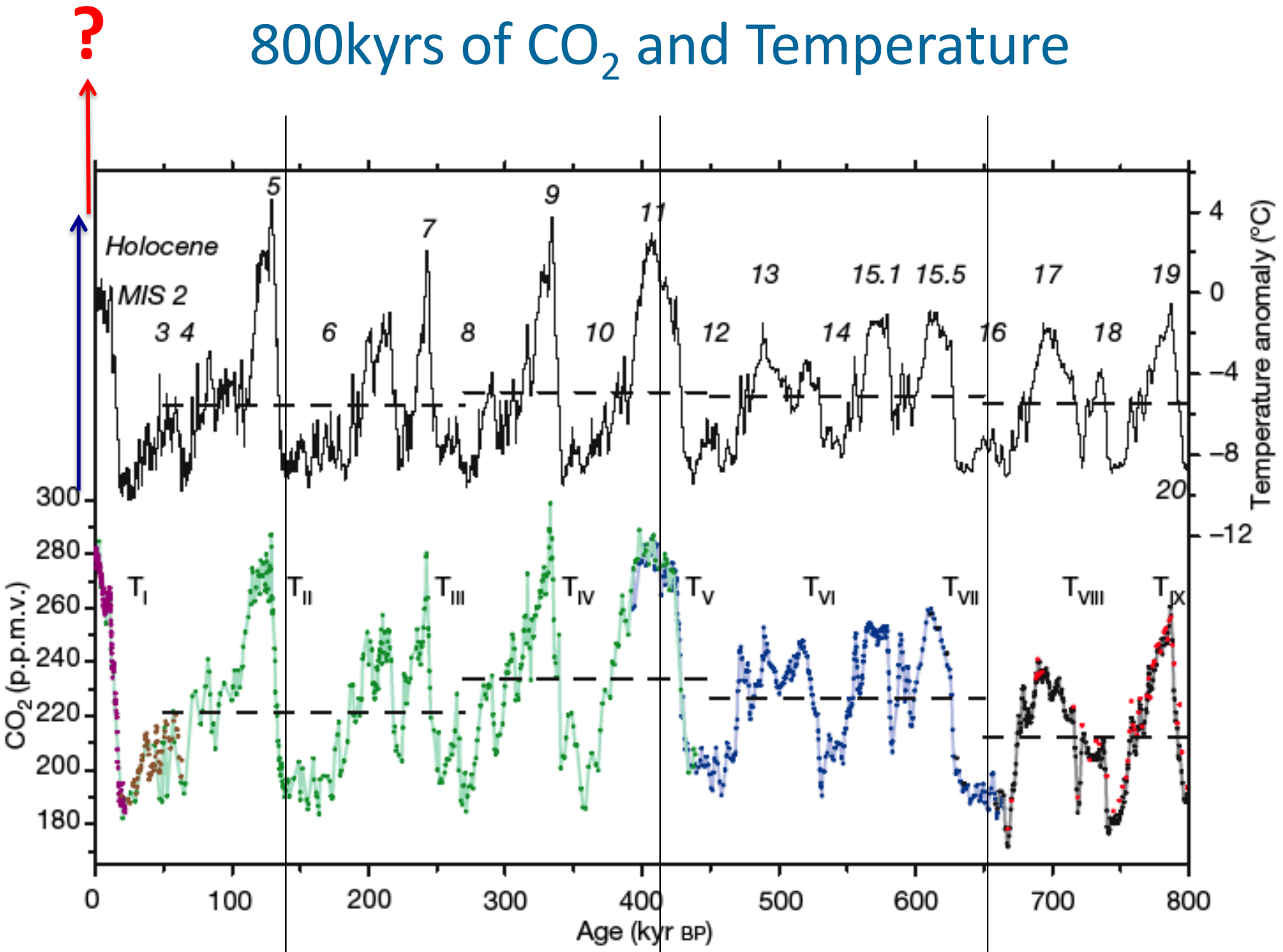


snow

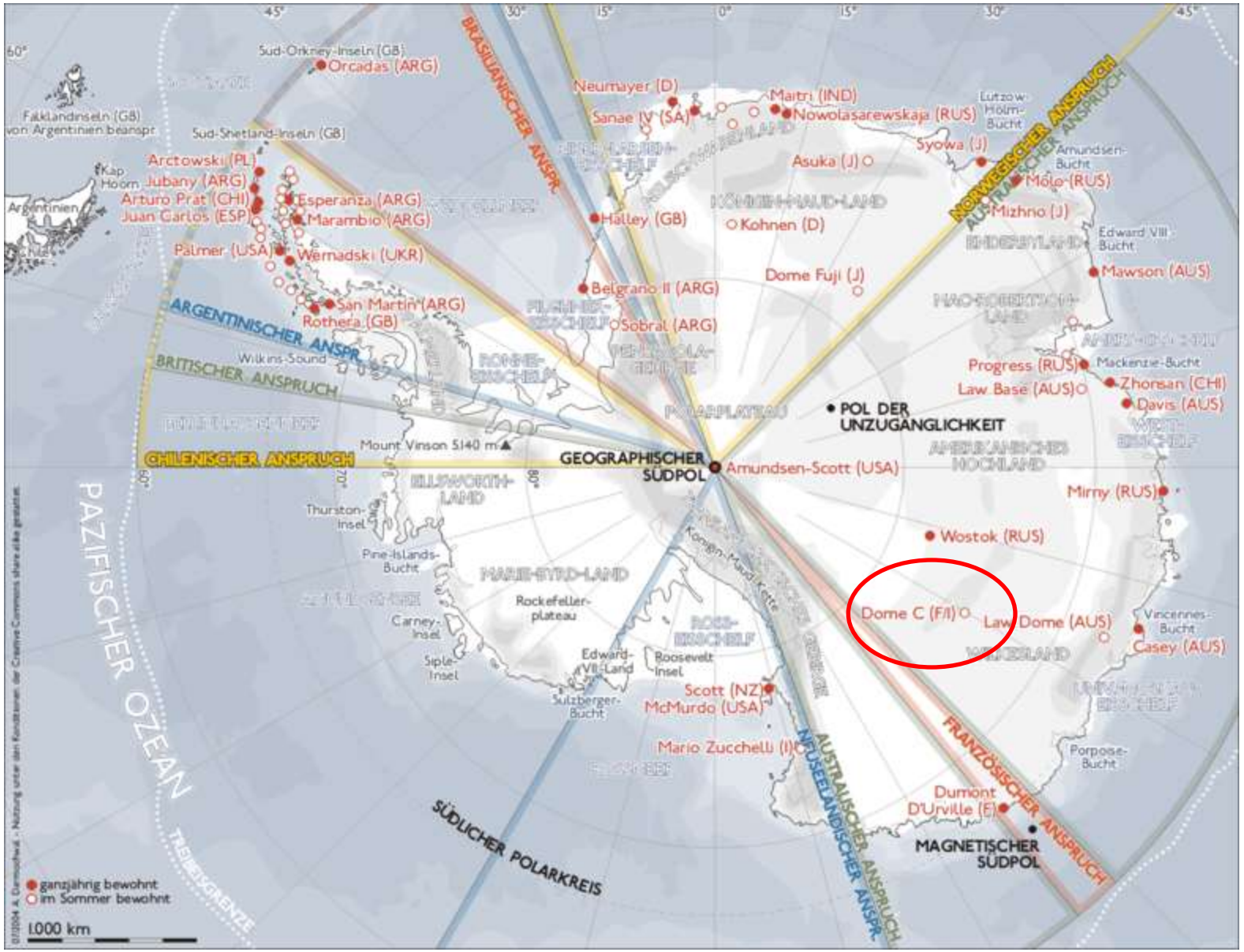
firn

ice

800kyrs of CO_2 and Temperature



Barnola et al., 1987 | Petit et al., 1999 | Siegenthaler et al., 2005 | Lüthi et al., 2008


Sud-Orkney-Inseln (GB)
Orcadas (ARG)
Falklandinseln (GB)
von Argentinien beansprt
Sud-Shetland-Inseln (GB)
Kap Hoorn
Argentinien
Chile
Arctowski (PL)
Jubany (ARG)
Arturo Prat (CHI)
Juan Carlos (ESP)
Esperanza (ARG)
Marambio (ARG)
Palmer (USA)
Wernadski (UKR)
San Martin (ARG)
Rothera (GB)
Wilkins-Sound
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ARGENTINISCHER ANSPR.
BRITISCHER ANSPRUCH
CHILENISCHER ANSPRUCH
Mount Vinson 5140 m
Thurston-Insel
Pine-Islands-Bucht
Carney-Insel
Siple-Insel
Rockefeller-plateau
Edward-VII-Land
Sulzberger-Bucht
Roosevelt Insel
Scott (NZ)
McMurdo (USA)
Mario Zucchelli (I)
Neumayer (D)
Sanae IV (SA)
Halley (GB)
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Sobral (ARG)
Maitri (IND)
Nowolasarewskaja (RUS)
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Kohnen (D)
Dome Fuji (J)
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Lutzow-Holm-Bucht
Syowa (J)
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Davis (AUS)
Mirny (RUS)
Wostok (RUS)
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Law Dome (AUS)
Vincennes-Bucht
Casey (AUS)
Porpoise-Bucht
Dumont D'Urville (F)
MAGNETISCHER SÜDPOL
FRANZÖSISCHER ANSPRUCH
NEUSEELÄNDISCHER ANSPR.
AUSTRALISCHER ANSPR.
SÜDLICHER POLARKREIS
PAZIFISCHER OZEAN
TREIBEISGRENZE
ganzjährig bewohnt
im Sommer bewohnt
1.000 km