ESR 320

GLOBAL WARMING
GREENHOUSE EFFECT

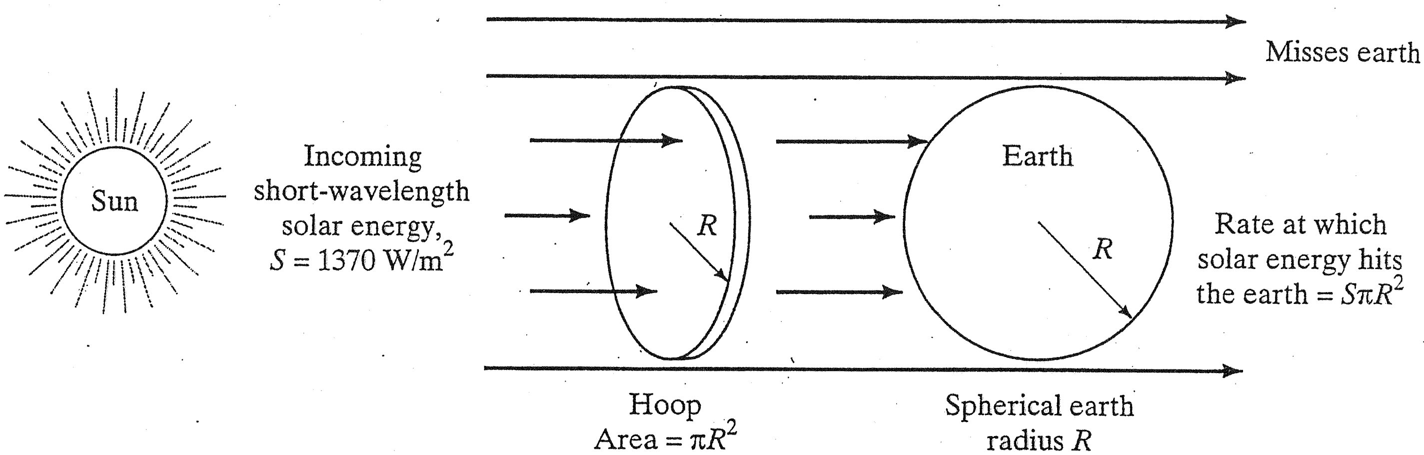
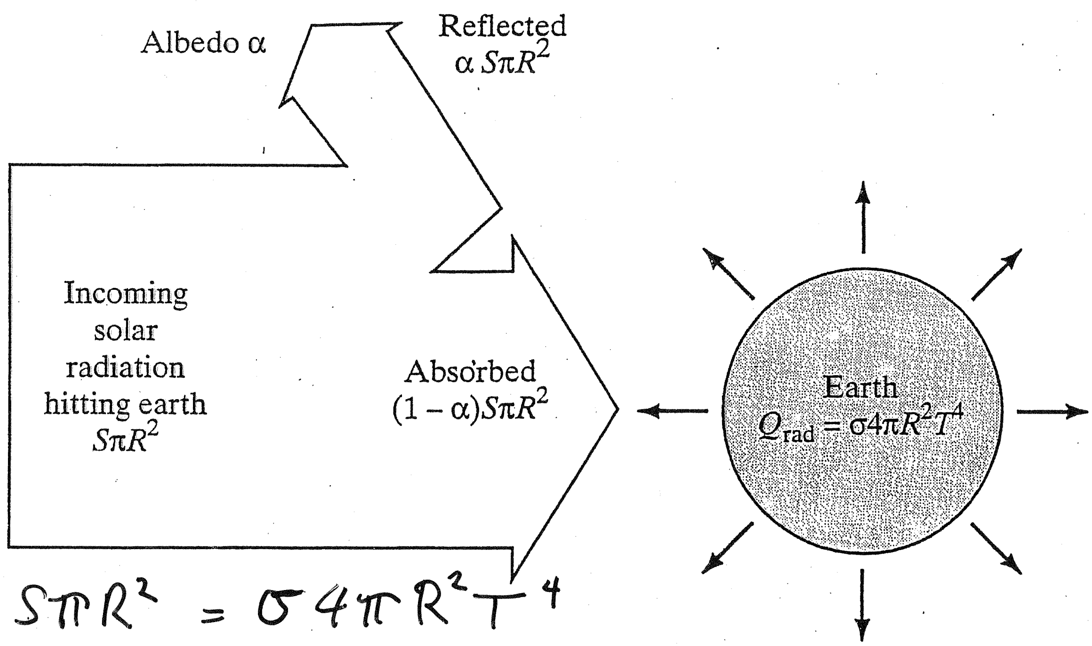


FIGURE 8.8. Solar energy passing through a "hoop" with the same radius as that of the earth hits the earth. Radiation that misses the hoop also misses the earth.



AT THERMAL EQUILIBRIUM

$$(1-\alpha) S \pi R^2 = \sigma 4 \pi R^2 T^4$$

FIGURE 8.9. Simple global temperature model.

SOLVE FOR T_e:

$$T_e = \left[\frac{S(1-\alpha)}{4\sigma} \right]^{1/4}$$

S VARIES W/ ORBIT, etc.
α VARIES W/ ICE COVER

$$T_e = \left[\frac{(1370\ \text{W/m}^2)(1-0.3)}{4\left(5.7\times10^{-8}\ \frac{\text{W}}{\text{m}^2\,\text{K}^4}\right)} \right]^{\frac{1}{4}} = 254\ \text{K} = \boxed{-19°\text{C}}$$

GENERAL PATTERN:

Gradual Cooling, Rapid Warming

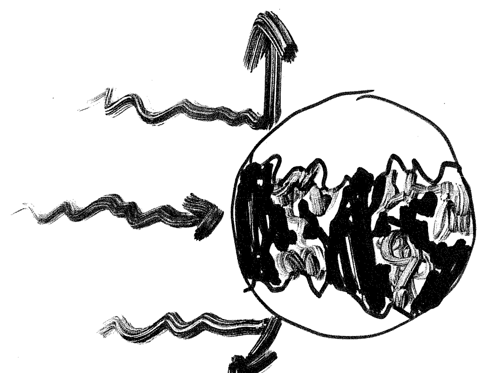
Why such rapid warming?

One explanation:

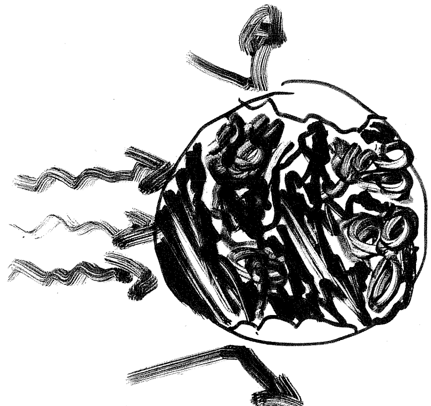
AUTOCATALYTIC PROCESSES

("self reinforcing"; positive feeback)

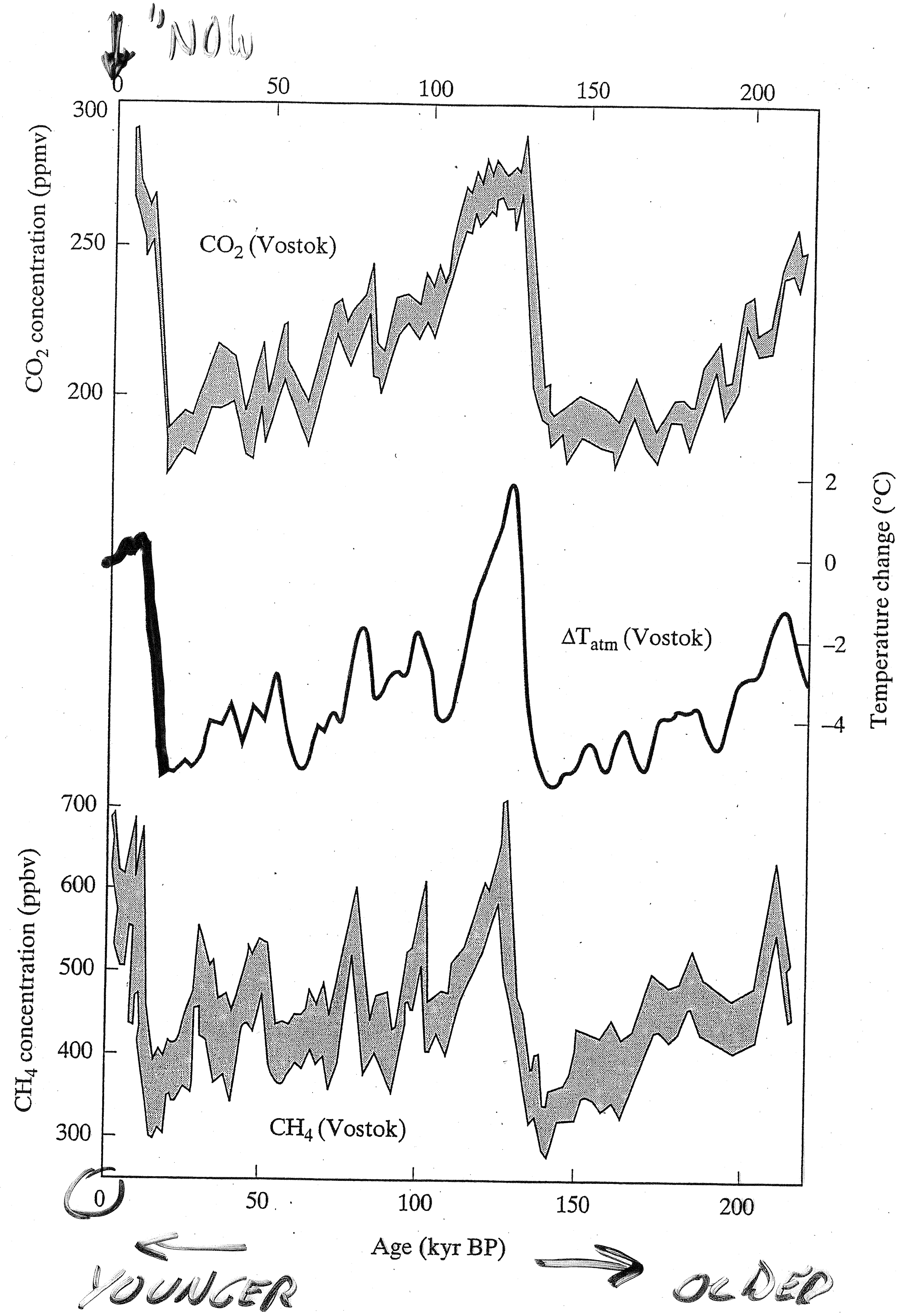
1.



- LARGE ICE COVER
- LARGE ALBEDO
- LESS NET HEAT

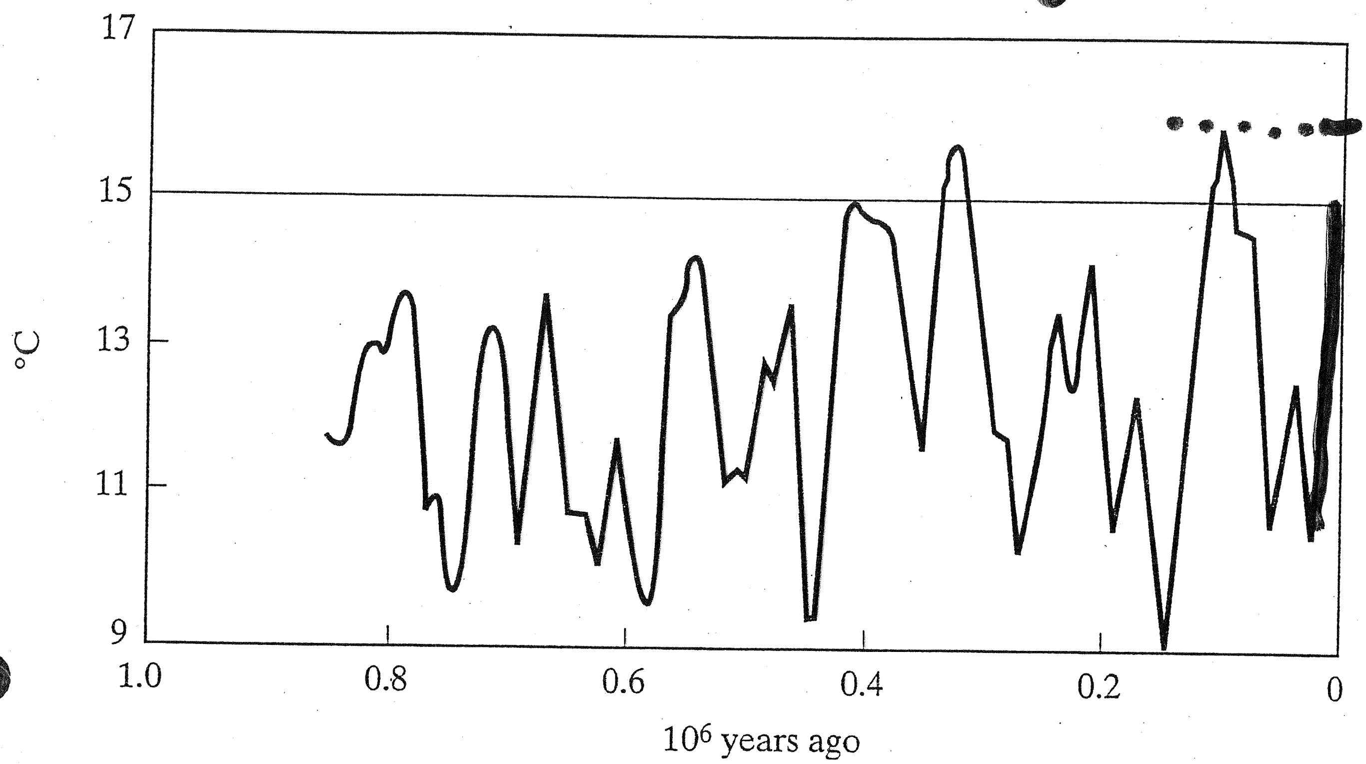


- AS ICE RETREATS
- ALBEDO DROPS
- REINFORCES WARMING TREND



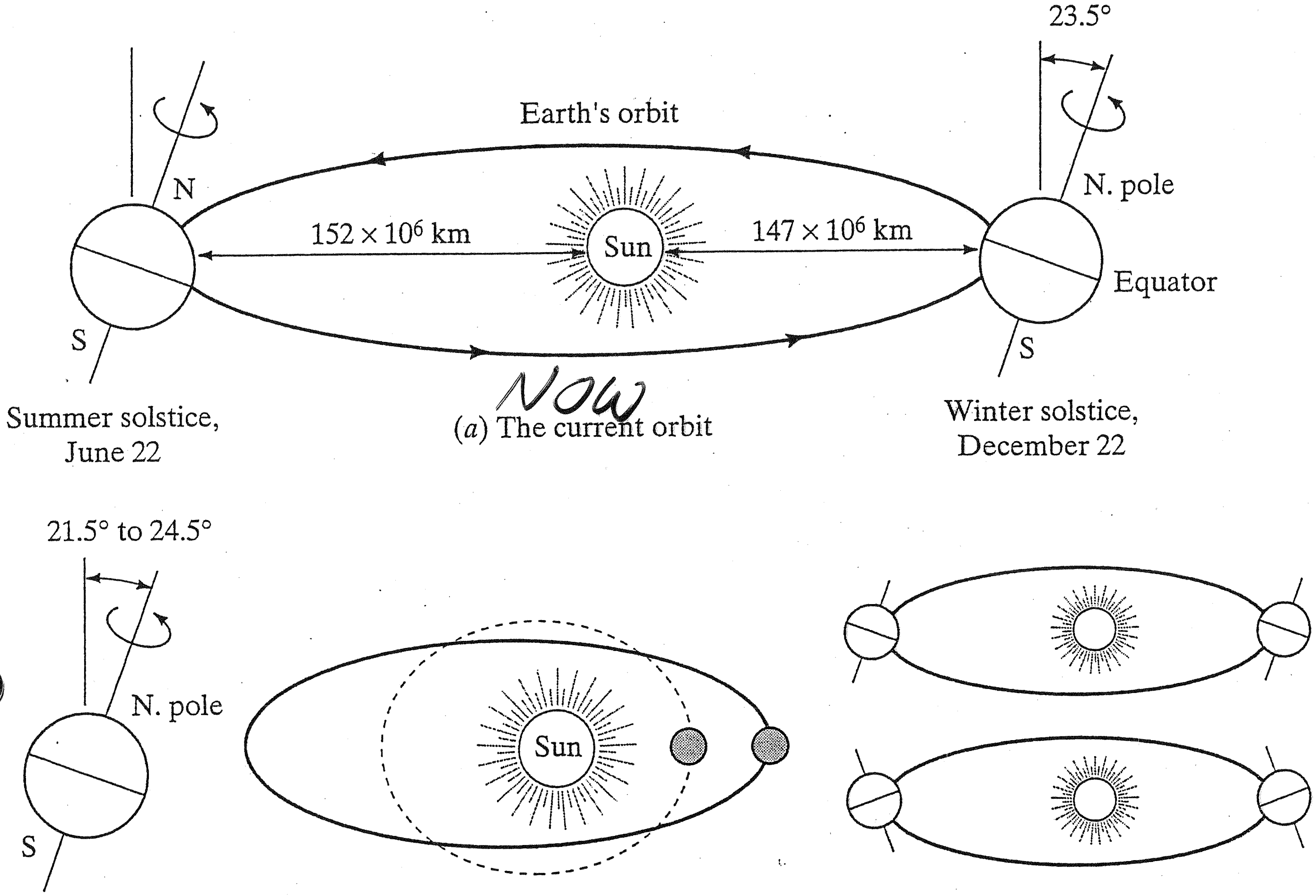
"NOW
0
50
100
150
200
300
250
200
CO_2 concentration (ppmv)
CO_2 (Vostok)
2
0
−2
−4
Temperature change (°C)
ΔT_{atm} (Vostok)
700
600
500
400
300
CH_4 concentration (ppbv)
CH_4 (Vostok)
0
50
100
150
200
Age (kyr BP)
YOUNGER
OLDER

PAST 850,000 yrs



RE 8.4 Northern Hemisphere, midlatitude air temperatures over the past one million years. (*Source:* :e, W. C., ed., *Carbon Dioxide Review 1982*. Copyright © 1982 by Oxford University Press. Reprinted rmission of Oxford University Press.)

- ΔT RATHER "RAPID"
- ΔTs NOT THAT BIG COMPARED TO, SAY, CARBONIFEROUS PERIOD (DINOSAURS)
- BUT ΔT of FEW DEGREES = HIGHEST T IN 10^6 YRS



Obliquity 41,000 years (c) Eccentricity, 100,000 years (c) Precession, 23,000 years

RE 8.6 Orbital variations affect the timing of ice ages. (*a*) The current orbit; (b) The tilt angle variation, with d 41,000 years; (*c*) eccentricity variation, with period 100,000 years; (*d*) precession, with period 23,000 yrs.

MILANKOVITCH
OSCILLATIONS

GLOBAL WARMING

1st: Must understand Composition of Atmosphere

TABLE 8.1 Composition of Clean, Dry Air (fraction by volume in troposphere, 1994)

Constituent	Formula	Percent by volume	Parts per million
Nitrogen	N_2	78.08	780,800
Oxygen	O_2	20.95	209,500
Argon	Ar	0.93	9300
Carbon dioxide	CO_2	0.035	358
Neon	Ne	0.0018	18
Helium	He	0.0005	5.2
Methane	CH_4	0.00017	1.7
Krypton	Kr	0.00011	1.1
Nitrous oxide	N_2O	0.00003	0.3
Hydrogen	H_2	0.00005	0.5
Ozone	O_3	0.000004	0.04

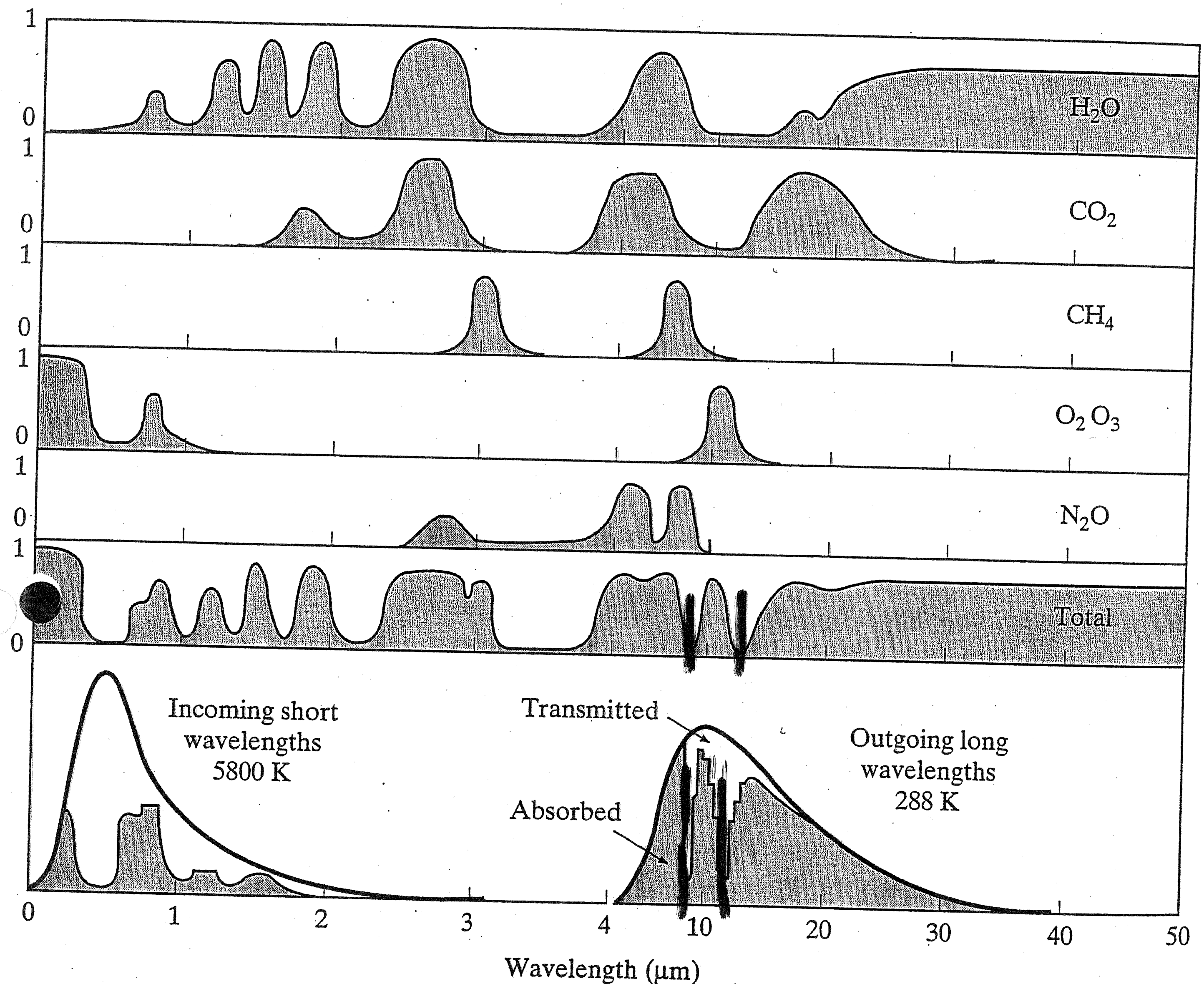
ΔF W/m^2

CO_2	1.56
CH_4	0.47
Halocarbons	0.28
N_2O	0.14
	$2.45\ W/m^2$

← $\Delta F = \Delta Q_{RAD} - \Delta Q_{ABS}$

"FORCING"

CAN SEE TRUE RELATIVE IMPORTANCE OF GASES



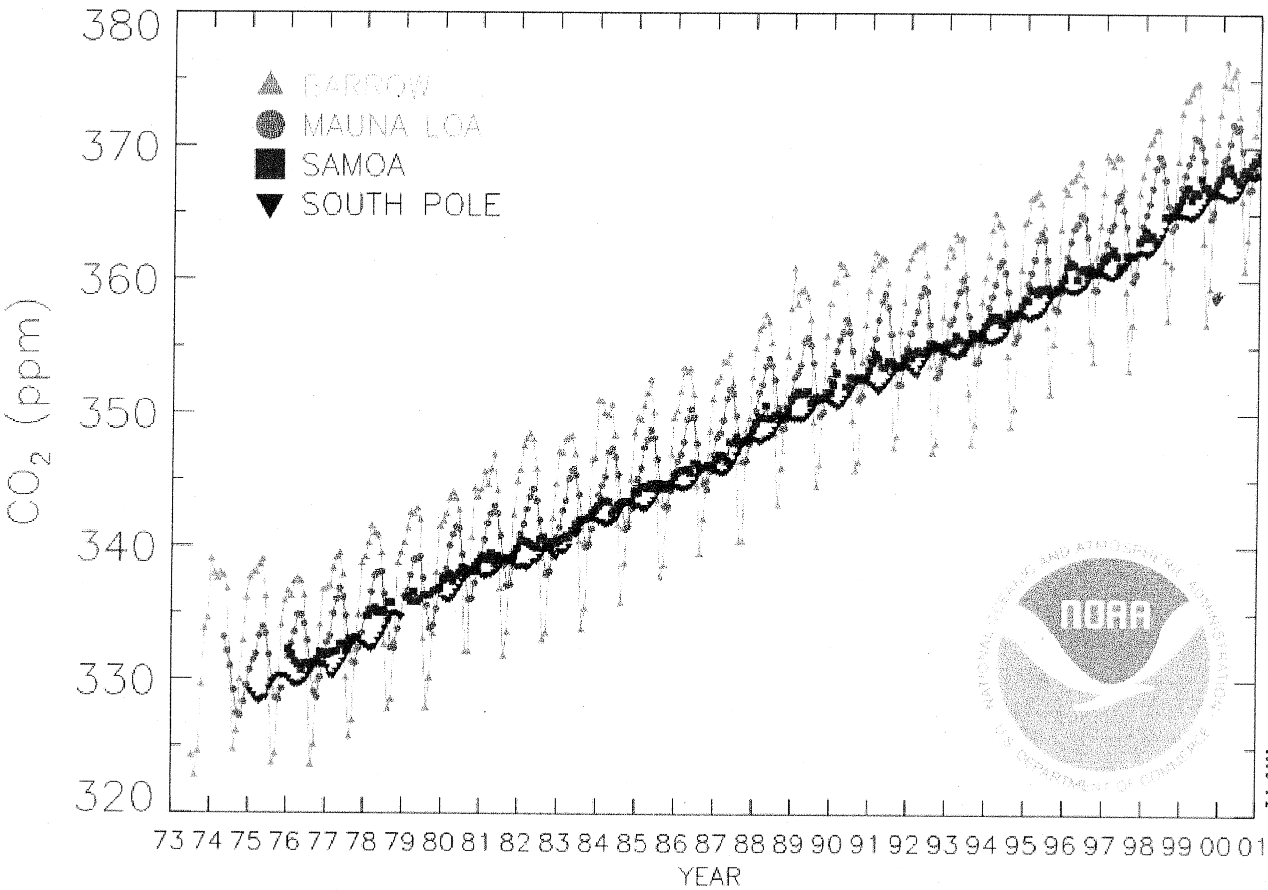
8.11 Absorptivity as a function of wavelength for water vapor (H_2O), carbon dioxide (CO_2), methane oxygen and ozone (O_2, O_3), and nitrous oxide (N_20), and the total absorptivity of the atmosphere. Shown here spectra for incoming solar energy and outgoing thermal energy from the 288 K surface of the earth. Note the ngth scale change at 4 μm.

RADIATIVE "WINDOW" TO SPACE

$\lambda = \sim 7-12\ \mu m$

Monthly Mean Carbon Dioxide

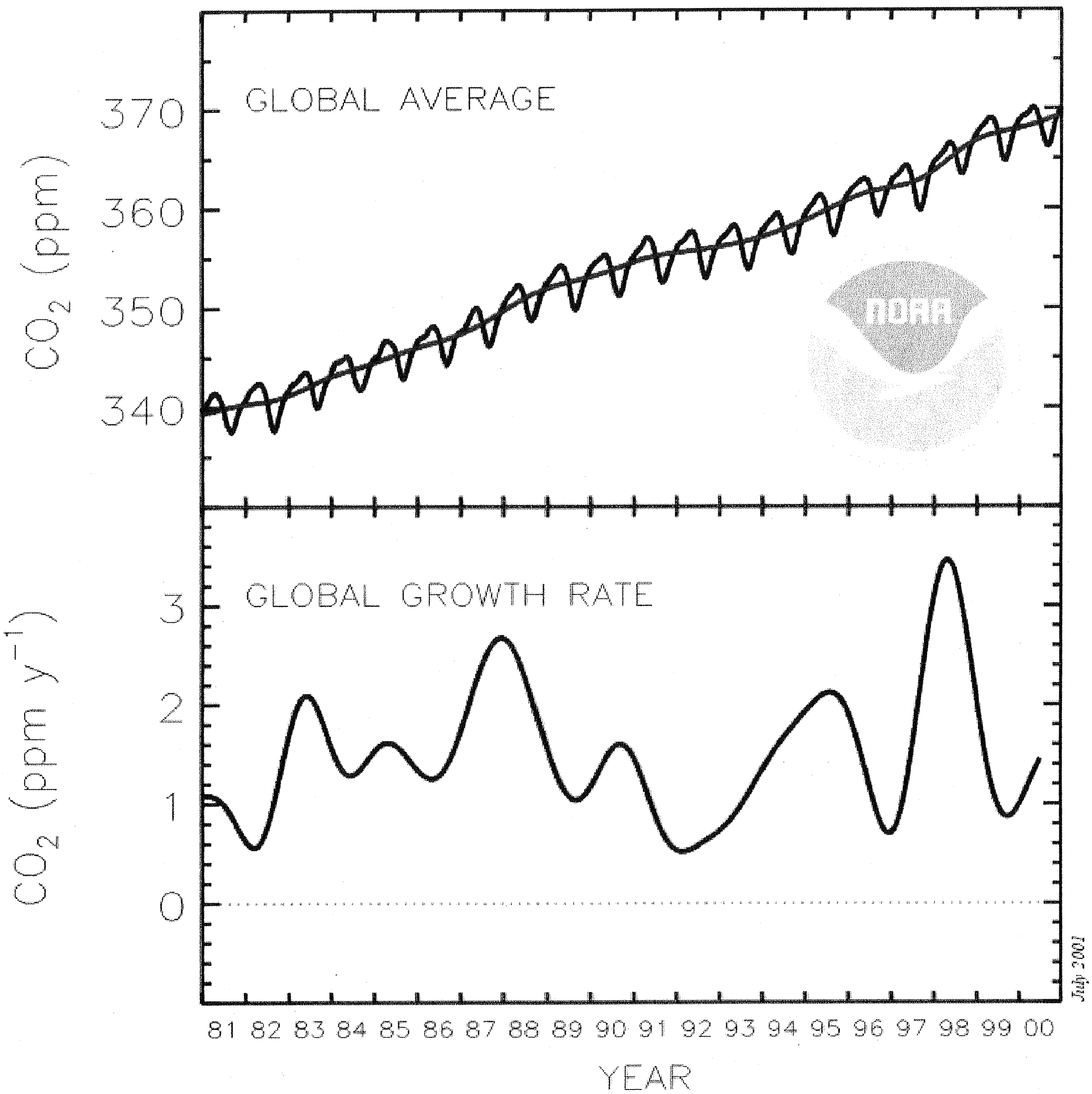
NOAA CMDL Carbon Cycle Greenhouse Gases



Atmospheric carbon dioxide mixing ratios determined from the continuous monitoring programs at the 4 NOAA CMDL baseline observatories. Principal investigator: Dr. Pieter Tans, NOAA CMDL Carbon Cycle Greenhouse Gases, Boulder, Colorado, (303) 497-6678. ptans@cmdl.noaa.gov.

Carbon Dioxide Measurements

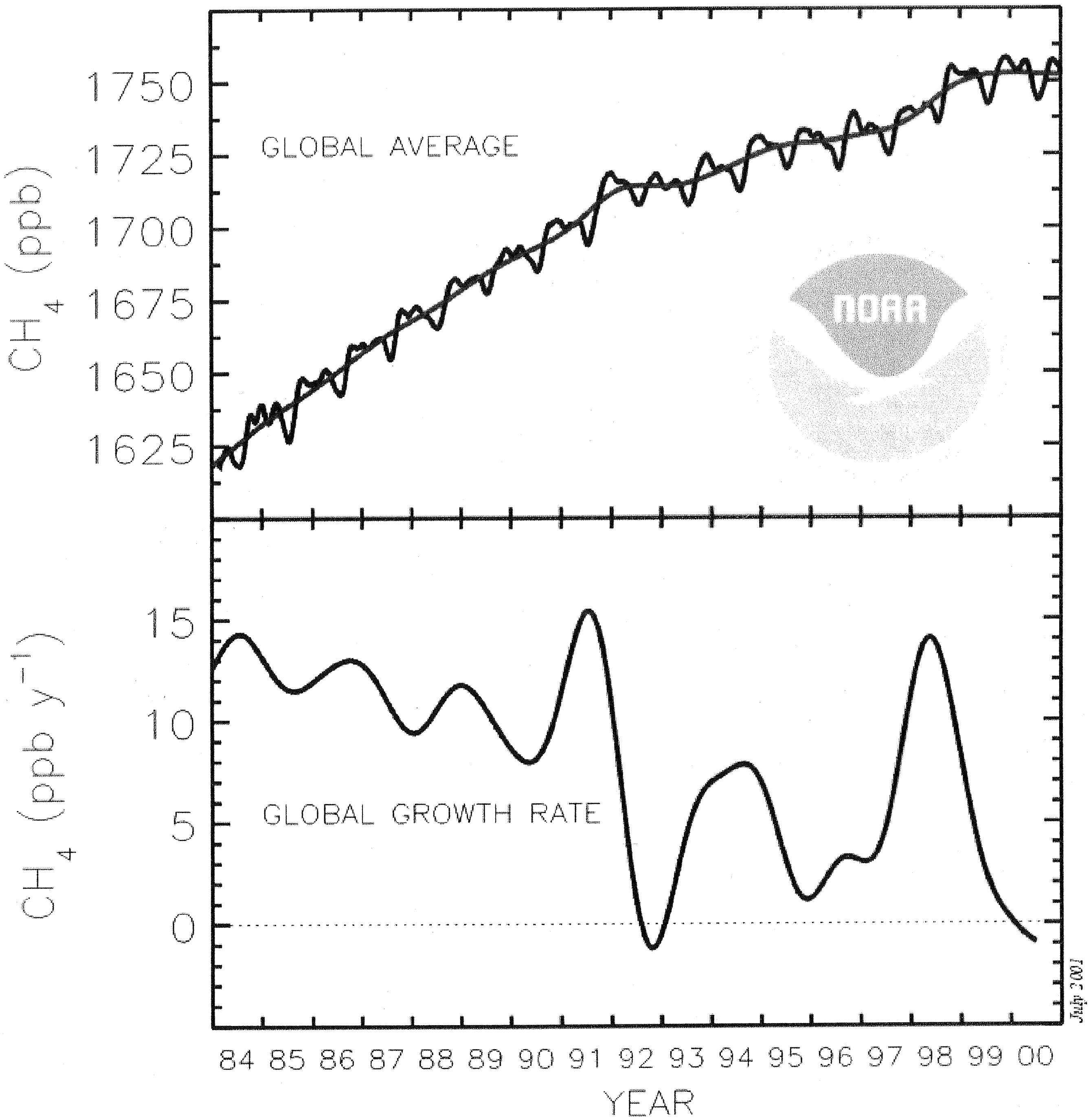
NOAA CMDL Carbon Cycle Greenhouse Gases



Top: Global average atmospheric carbon dioxide mixing ratios (blue line) determined using measurements from the NOAA CMDL cooperative air sampling network. The red line represents the long-term trend. Bottom: Global average growth rate for carbon dioxide. Principal investigator: Dr. Pieter Tans, NOAA CMDL Carbon Cycle Greenhouse Gases, Boulder, Colorado, (303) 497-6278. ptans@cmdl.noaa.gov.

Methane Measurements

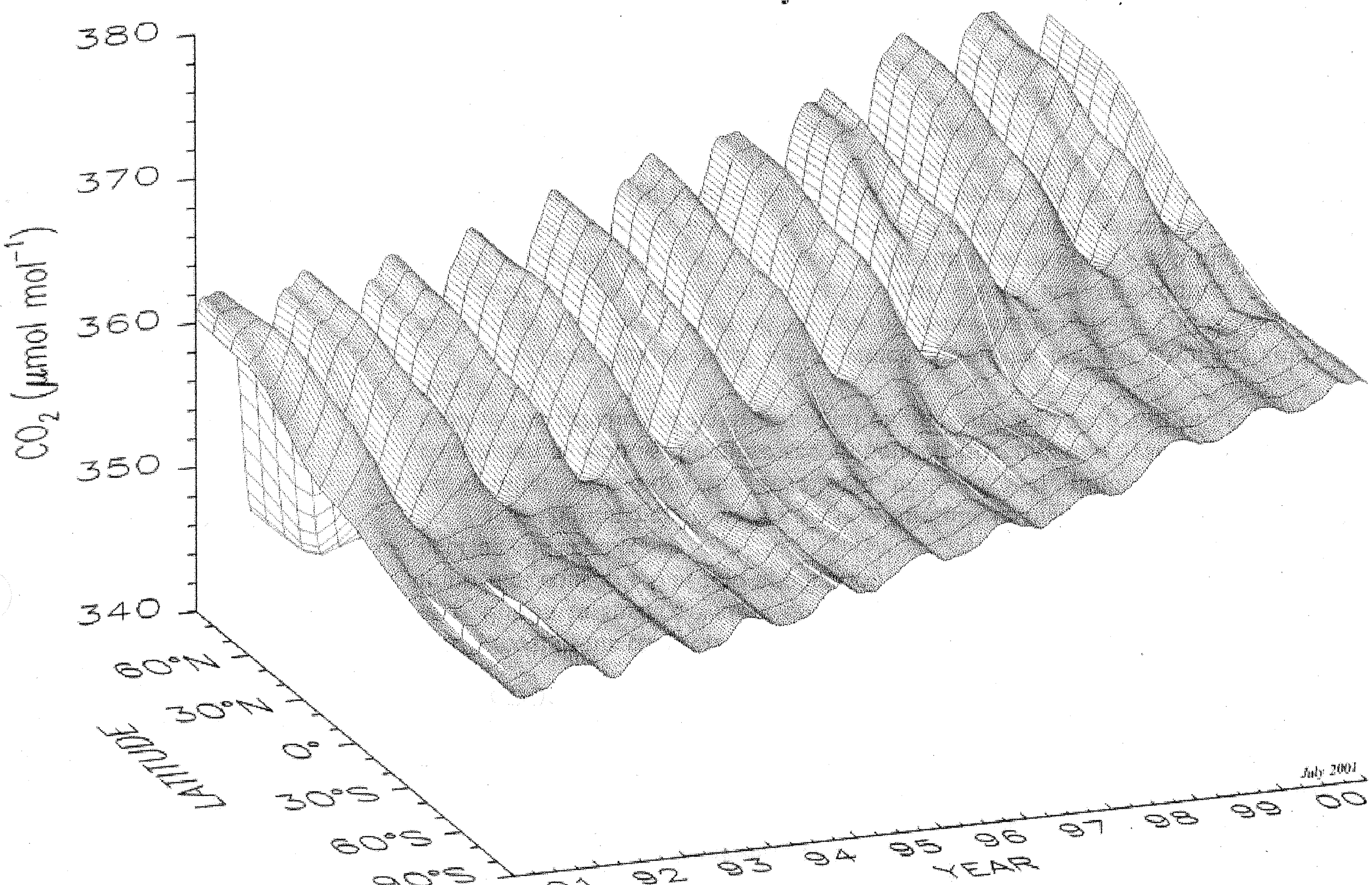
NOAA CMDL Carbon Cycle Greenhouse Gases



Top: Global average atmospheric methane mixing ratios (blue line) determined using measurements from the NOAA CMDL cooperative air sampling network. The red line represents the long-term trend. Bottom: Global average growth rate for methane. Principal investigator: Dr. Ed Dlugokencky, NOAA CMDL Carbon Cycle Greenhouse Gases, Boulder, Colorado, (303) 497-6228. edlugokencky@cmdl.noaa.gov.

Global Distribution of Atmospheric Carbon Dioxide

NOAA CMDL Carbon Cycle Greenhouse Gases



Three dimensional representation of the latitudinal distribution of atmospheric carbon dioxide in the marine boundary layer. Data from the NOAA CMDL cooperative air sampling network were used. The surface represents data smoothed in time and latitude. Principal investigators: Pieter Tans and Thomas Conway, NOAA CMDL Carbon Cycle Greenhouse Gases, Boulder, Colorado, (303)497-6678. ptans@cmdl.noaa.gov

BUT WHAT ABOUT NEGATIVE FEEDBACK PROCESSES?

(Warming creates results that cancel out further warming)

2. E.g CLOUD COVER:

- Warmer oceans
- → More evaporation
- → More Clouds
- → More ALBEDO
- ∴ TENDS TO NEGATE WARMING.

BUT NOT ALWAYS THAT SIMPLE