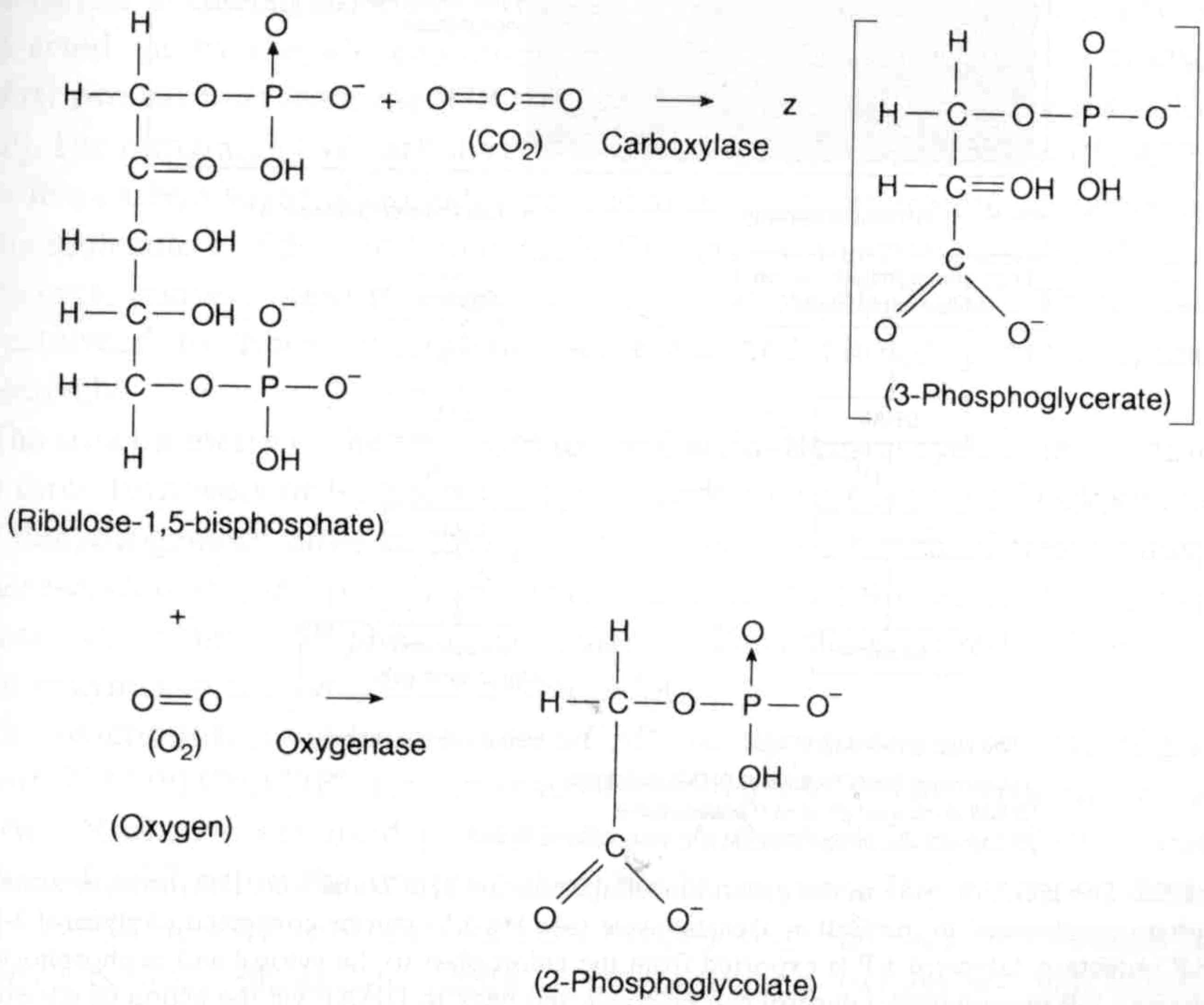
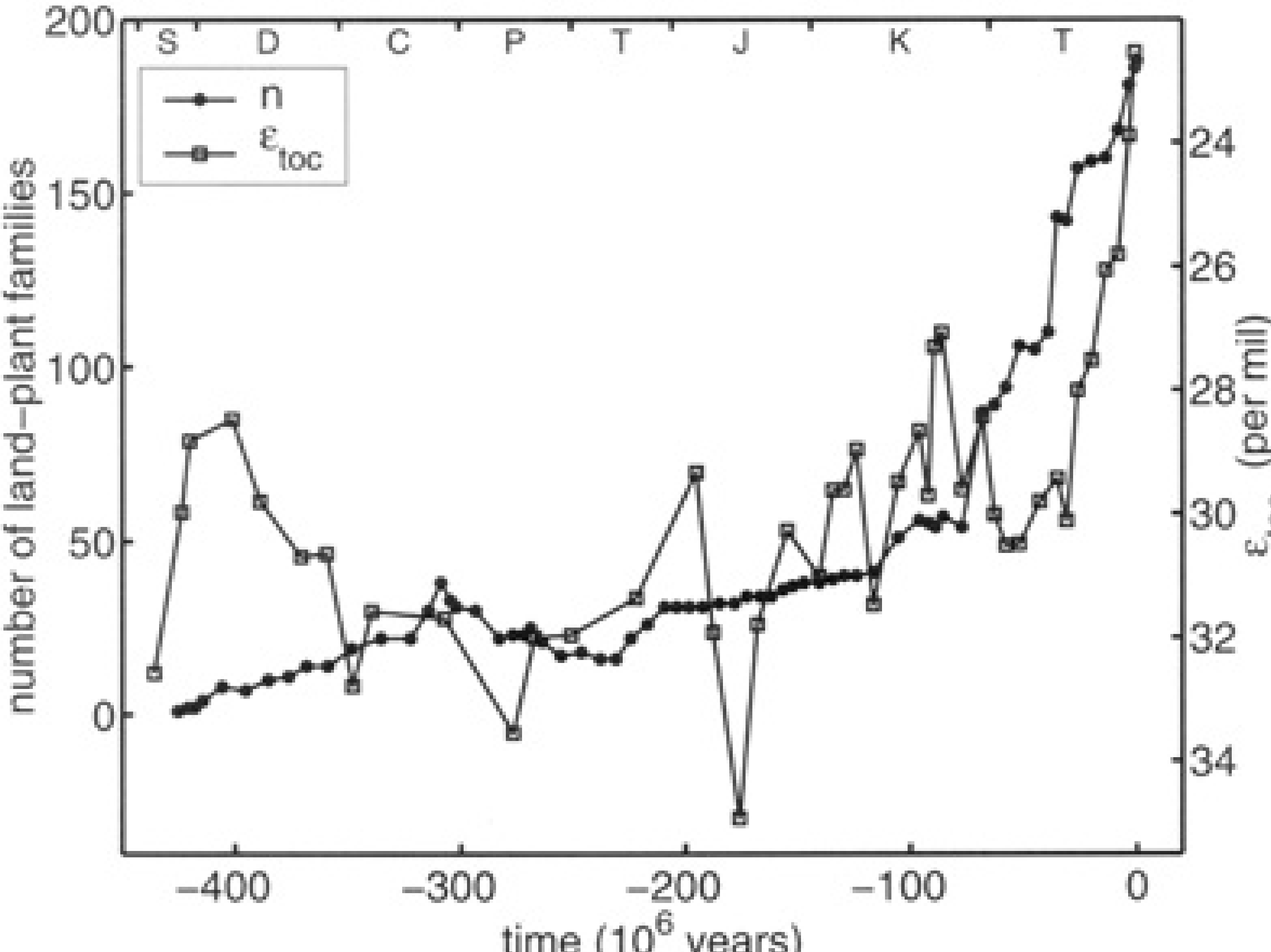


Figure 5.7 Structures of substrates and products of reactions catalyzed by Rubisco.



S
D
C
P
T
J
K
T
n
ε_{toc}
number of land-plant families
ε_{toc} (per mil)
time (10^6 years)
200
150
100
50
0
24
26
28
30
32
34
−400
−300
−200
−100
0

$$\frac{(^{18}O/^{16}O)c}{(^{18}O/^{16}O)w} = \alpha_{c-w} = 1.0286 \ @ \ 25\ ^{\circ}C$$

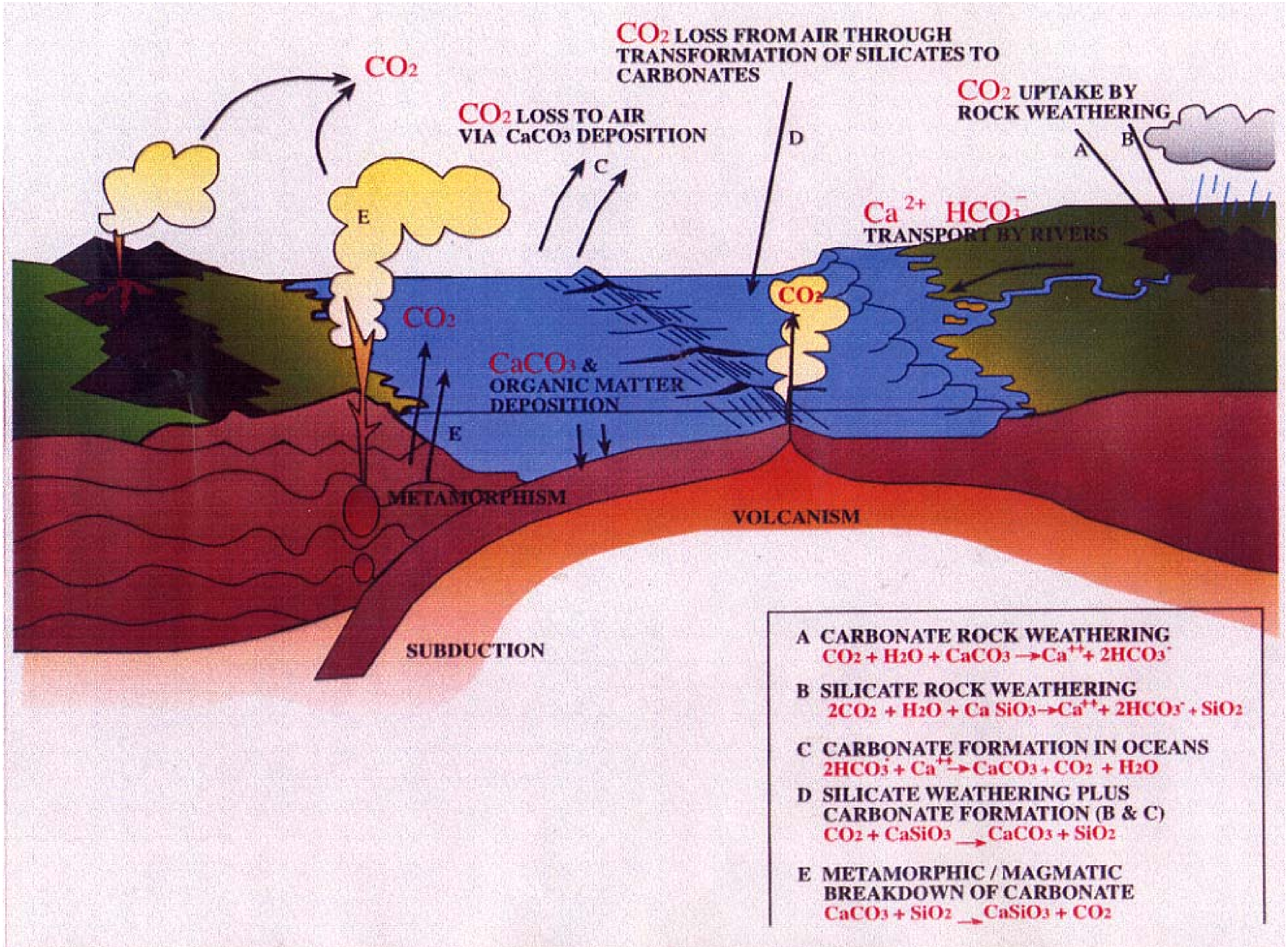
Differences in isotopic fractionation between samples are small and delta values are a Convenient way of expressing small differences

$$\delta^{18}O = 1000 * \left(\frac{^{18}O/^{16}O \text{ sample}}{^{18}O/^{16}O \text{ standard}} - 1\right)$$

$$\text{Temp} = 16.9 - 4.38\ (\delta c - \delta w) + (0.1\ (\delta c - \delta w)^2$$

Simplified version:

$$\text{Temp} = 16.9 - 4.0\ (\delta c - \delta w)$$



CO_2
CO_2 LOSS FROM AIR THROUGH TRANSFORMATION OF SILICATES TO CARBONATES
CO_2 LOSS TO AIR VIA $CaCO_3$ DEPOSITION
C
D
CO_2 UPTAKE BY ROCK WEATHERING
A
B
E
Ca^{2+} HCO_3^-
TRANSPORT BY RIVERS
CO_2
CO_2
$CaCO_3$ & ORGANIC MATTER DEPOSITION
E
METAMORPHISM
VOLCANISM
SUBDUCTION
A CARBONATE ROCK WEATHERING
$CO_2 + H_2O + CaCO_3 \rightarrow Ca^{++} + 2HCO_3^-$
B SILICATE ROCK WEATHERING
$2CO_2 + H_2O + CaSiO_3 \rightarrow Ca^{++} + 2HCO_3^- + SiO_2$
C CARBONATE FORMATION IN OCEANS
$2HCO_3^- + Ca^{++} \rightarrow CaCO_3 + CO_2 + H_2O$
D SILICATE WEATHERING PLUS CARBONATE FORMATION (B & C)
$CO_2 + CaSiO_3 \rightarrow CaCO_3 + SiO_2$
E METAMORPHIC / MAGMATIC BREAKDOWN OF CARBONATE
$CaCO_3 + SiO_2 \rightarrow CaSiO_3 + CO_2$

Redox Reactions are Coupled on a GLOBAL SCALE

Oxygenic Photosynthesis:

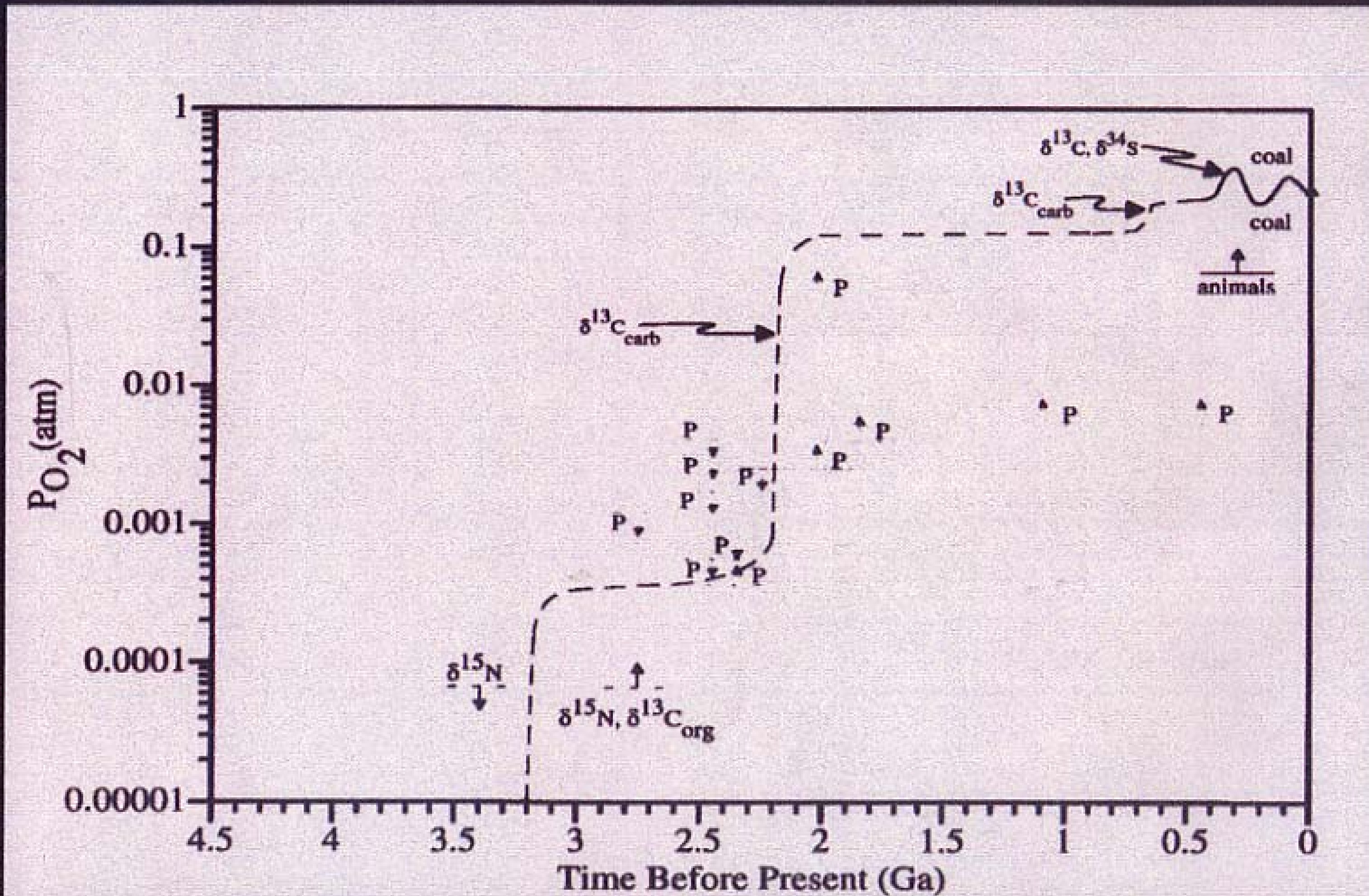
$$2H_2O + CO_2 \rightarrow (CH_2O)_n + O_2$$

Aerobic Respiration:

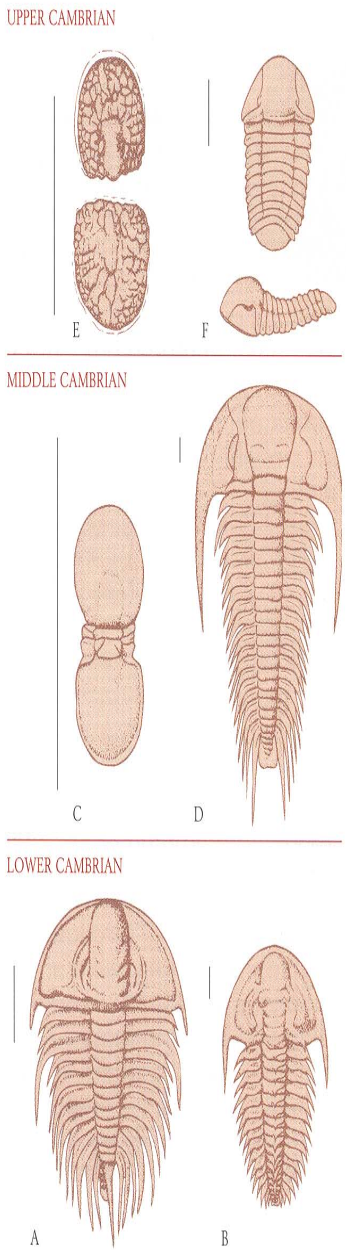
$$(CH_2O)_n + O_2 \rightarrow 2H_2O + CO_2$$

Q: Is Photosynthesis and Respiration balanced on a global scale?

THE EVOLUTION OF OXYGEN ON EARTH



FROM HOLLAND AND RYE, NATURE (in press)



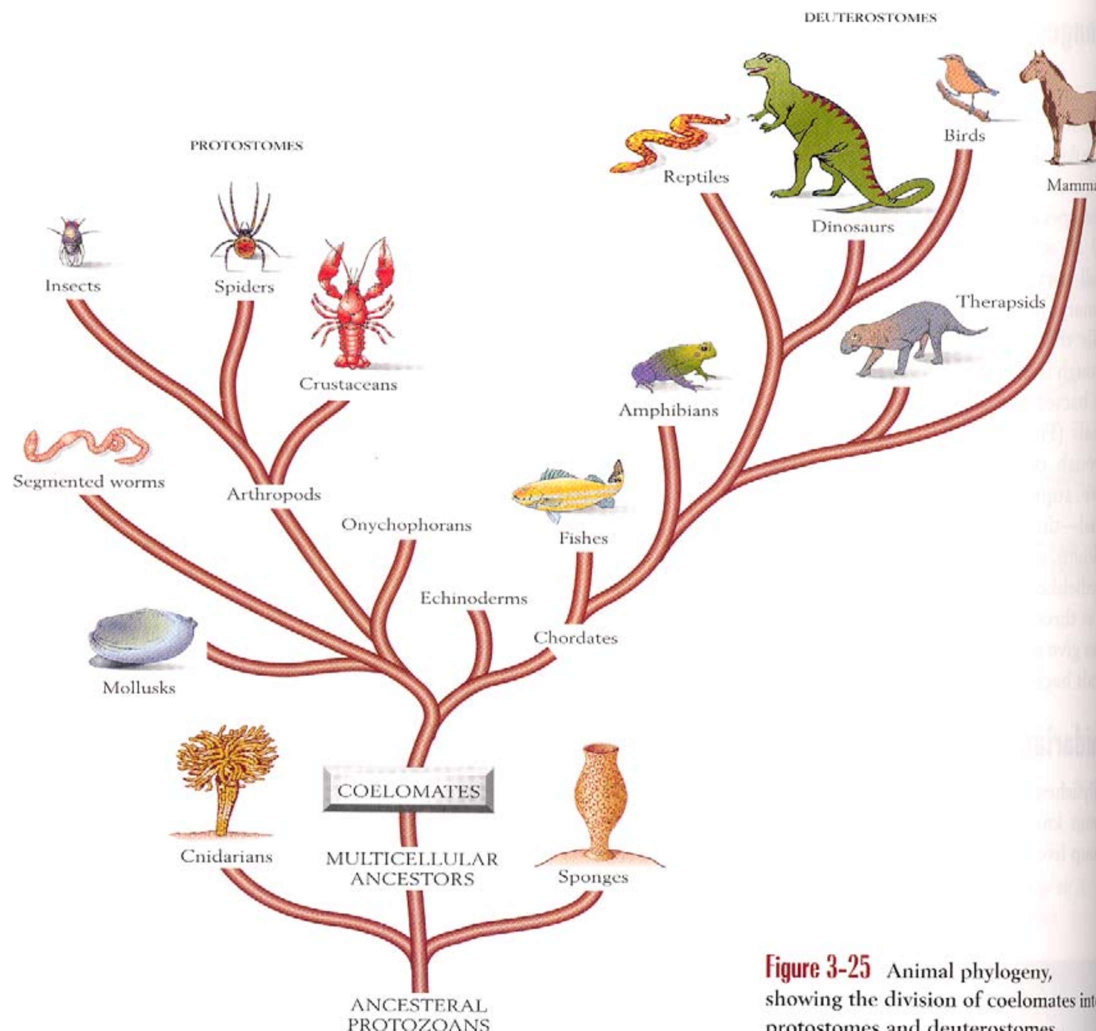


Figure 3-25 Animal phylogeny, showing the division of coelomates into protostomes and deuterostomes.

Without Atmosphere

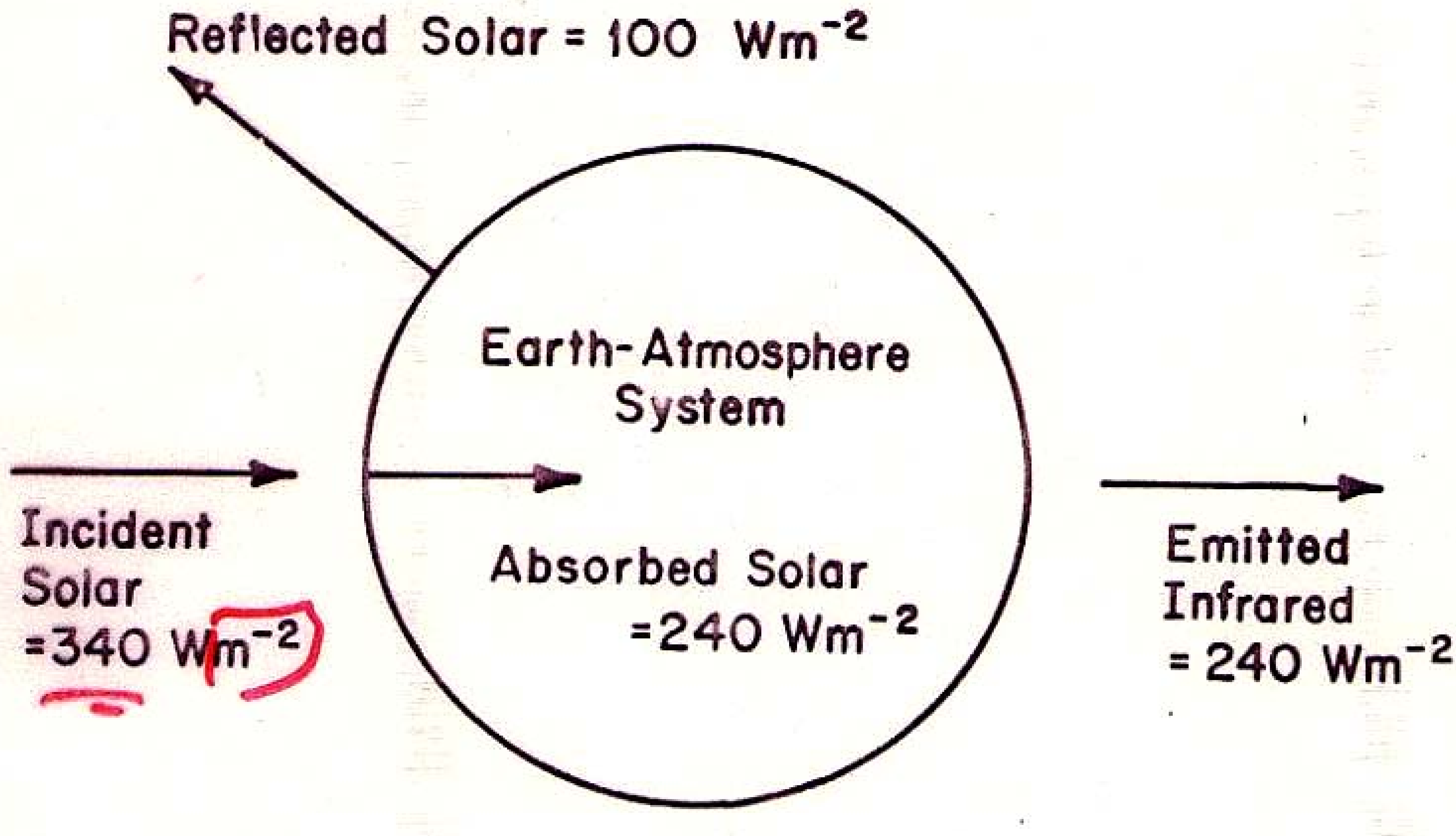
T_E = 255 K (-18C)

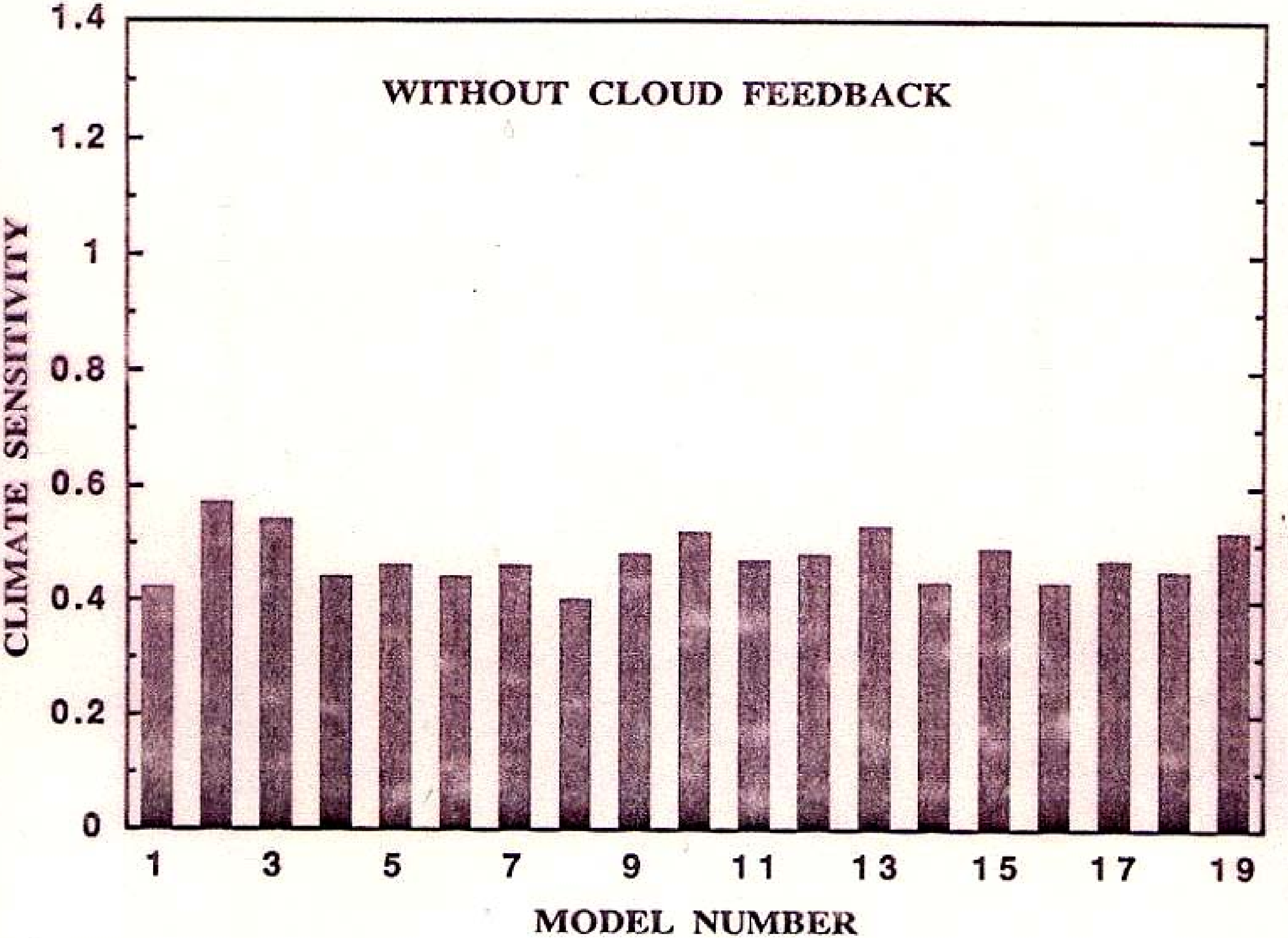
With Atmosphere

T_E = 286 K

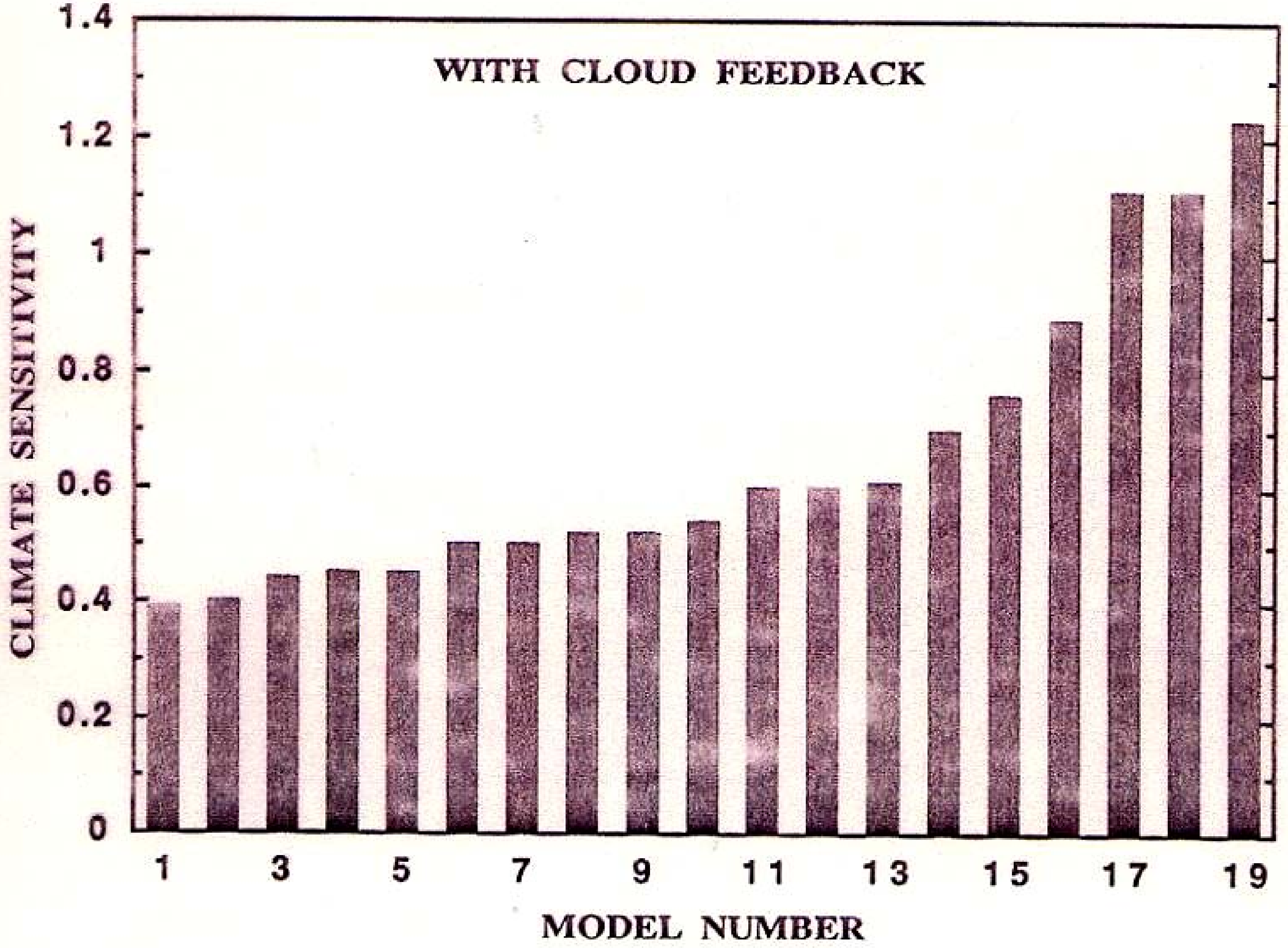
∴ "Greenhouse" effect = 31 K

GLOBAL RADIATION BUDGET AT TOP OF THE ATMOSPHERE





WITHOUT CLOUD FEEDBACK
CLIMATE SENSITIVITY
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1
3
5
7
9
11
13
15
17
19
MODEL NUMBER


WITH CLOUD FEEDBACK
CLIMATE SENSITIVITY
MODEL NUMBER
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1
3
5
7
9
11
13
15
17
19

CLOUD OPTICAL THICKNESS

$$\delta_C = \pi r_e^2 Q_{ext} N z_C$$

δ_C is the optical thickness of the cloud

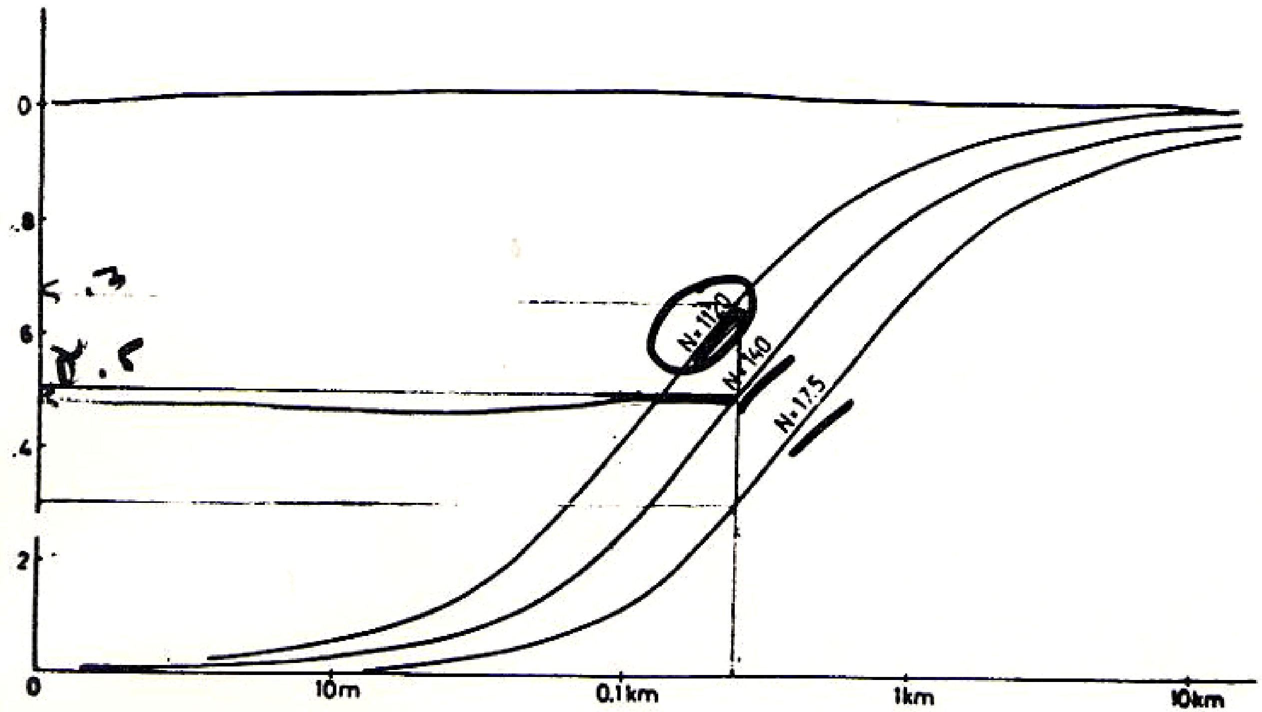
z_C is the physical thickness of the cloud

r_e is the effective radius of the cloud droplets

Q_{ext} is the average extinction efficiency ≈ 2.

N_C is the concentration (number density) of the cloud droplets

DEPENDENCE OF CLOUD-TOP ALBEDO ON CLOUD THICKNESS AND DROPLET CONCENTRATION



entral curve relates to fairly clean maritime conditions. fects of halving and doubling drop diameter (8-fold crease and reduction in droplet concentration, respectively) shown in the upper and lower curves. From Twomey, *mospheric Aerosols*, 1977.

EVALUATION OF PERTURBATION IN GLOBAL MEAN CLOUD RADIATIVE FORCING DUE TO ANTHROPOGENIC SULFATE

Quantity	Value	Units	Note
$\Delta \ln N$	0.15		(1)
F_T	1370	$W\ m^{-2}$	
A_{mst}	0.3		(2)
T	0.76		
R_{CT}	0.3 - 0.7		
ΔF_C	-0.7	$W\ m^{-2}$	

) Based on comparison of mass concentrations of non sea-salt sulfate aerosol at remote locations of the Northern and Southern Hemispheres and the assumption that CCN concentration scales linearly with non sea-salt sulfate mass (Schwartz, 1988).

Fraction of atmosphere occupied by non overlapped marine stratus and stratocumulus, (Charlson et al., 1987).