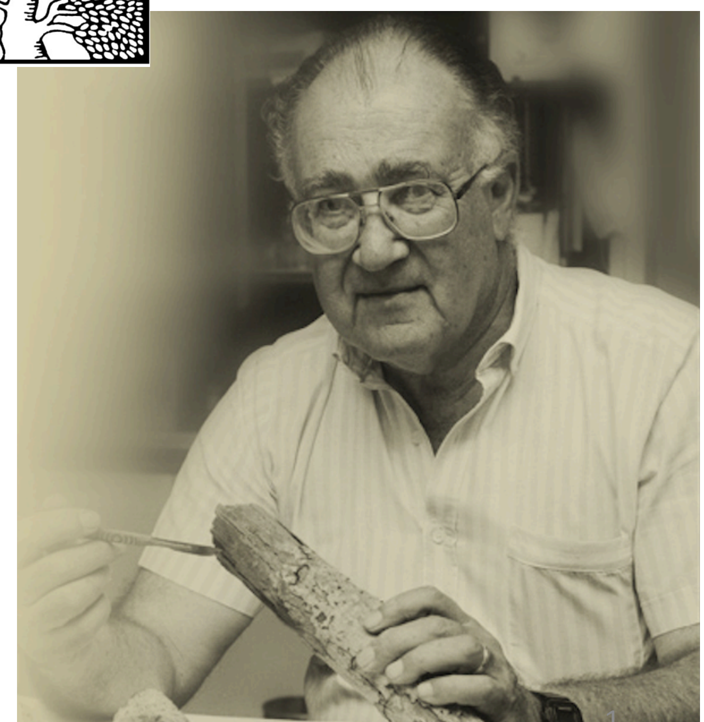
Association between $^{18}\Delta$ and carbonyl sulfide uptake during CO_2 exchange between the atmosphere and land plants

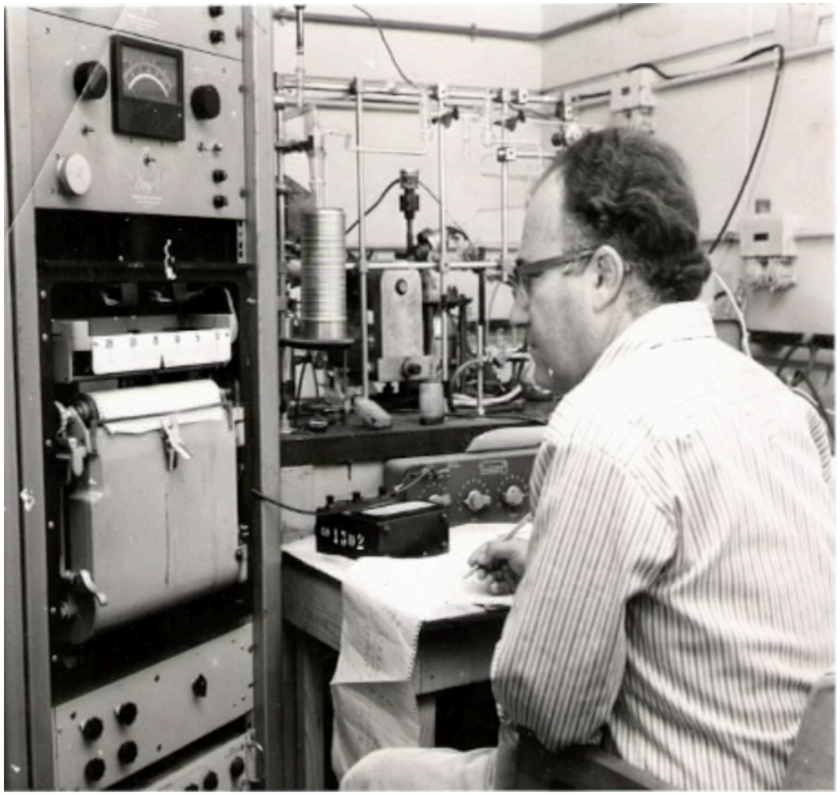
Dan Yakir
Earth & Planetary Sciences
מכון ויצמן למדע
WEIZMANN INSTITUTE OF SCIENCE

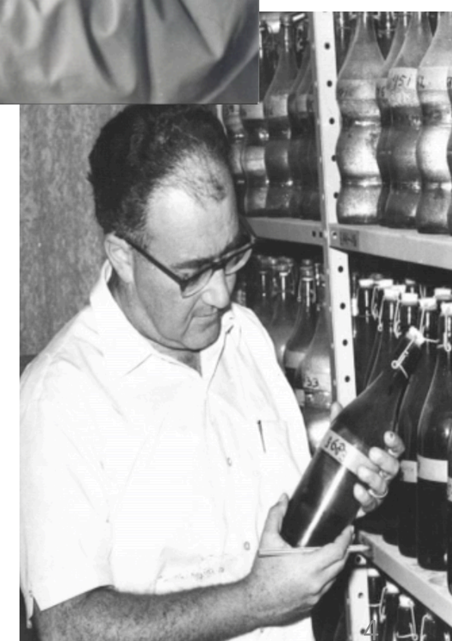


A tribute to the memory of Prof **Joel Gat**
1926-2012

Born 1926, Germany

Young bright, and brash…

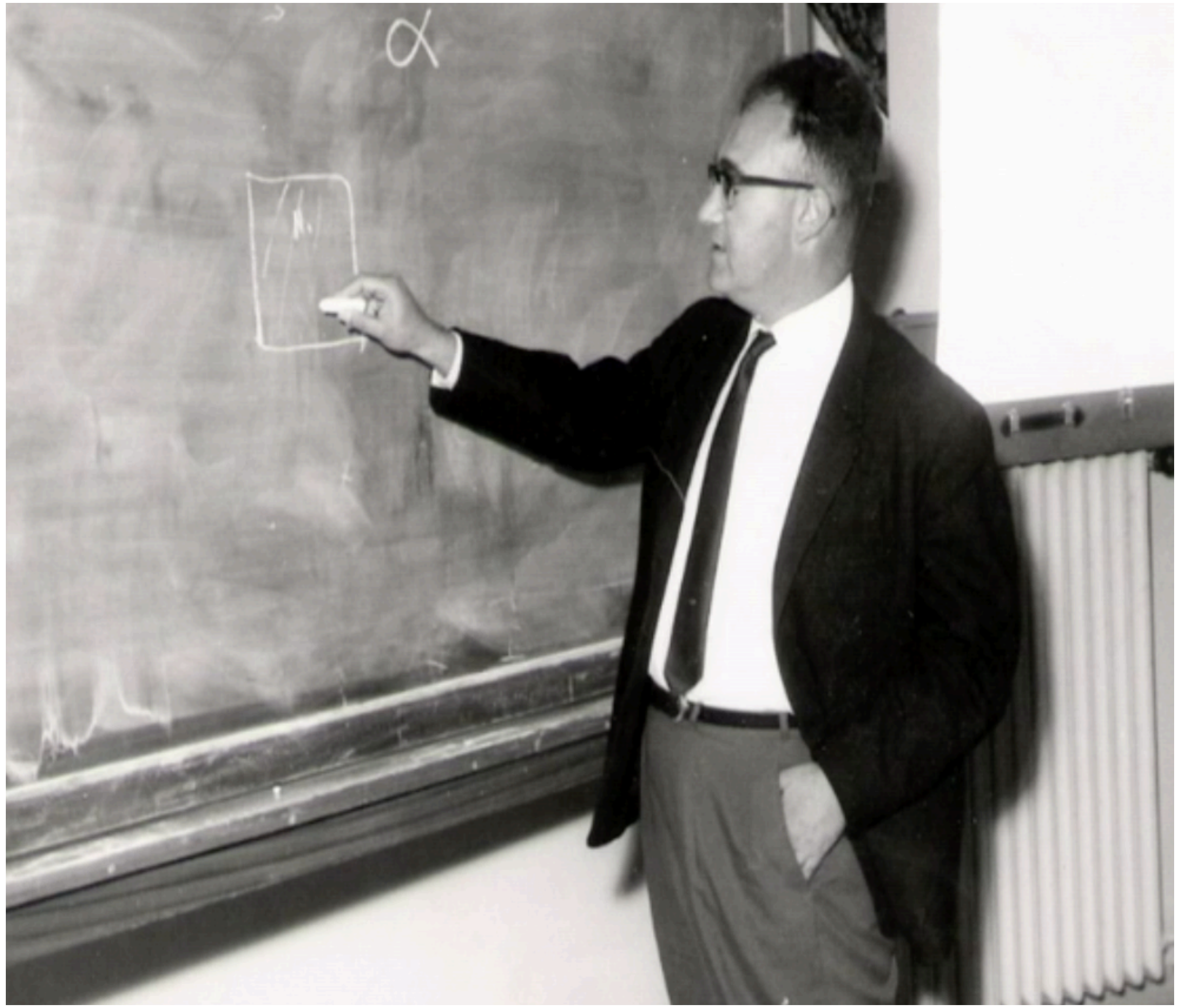




The hands-on scientist and the home made lab…

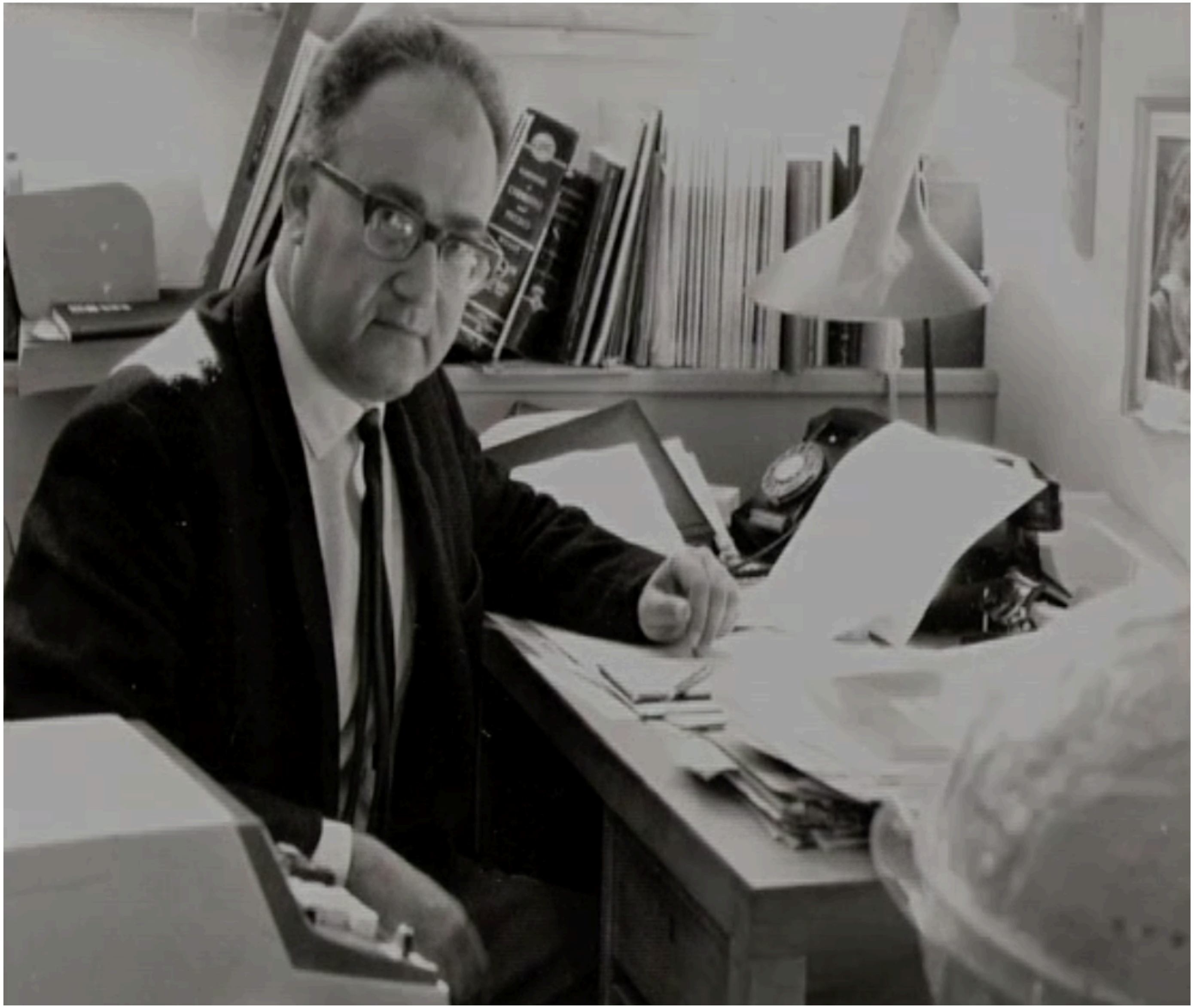
The pre-GNIP collection…

The teacher
(always with jokes)



Going beyond hydrology…

The administrator
(Dept. Chair, Dean)



The politician…

Meeting with Thatcher, 1986

Meeting with PM Rabin and President Katzir 1970s

Joel's favorite places: Brazil, the Dead Sea, IAEA-Vienna

Joel's favorite research topics: The Amazon, and…

Water Resources Research
AN AGU JOURNAL

Recycling of water in the Amazon Basin: An isotopic study

Eneas Salati,Attilio Dall'Olio,Eiichi Matsui,Joel R. Gat

First published: October 1979 Full publication history

....the Dead Sea

Science 5 October 1979:
Vol. 206 no. 4414 pp. 55-57
DOI: 10.1126/science.206.4414.55

Science AAAS

‹ Prev | Table of Contents | Next ›

REPORTS

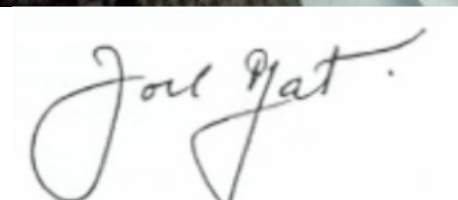
The Dead Sea: Deepening of the Mixolimnion Signifies the Overture to Overturn of the Water Column

ELSEVIER

Earth and Planetary Science Letters
Volume 71, Issue 2, December 1984, Pages 361–376

The stable isotope composition of Dead Sea waters

Joel R. Gat

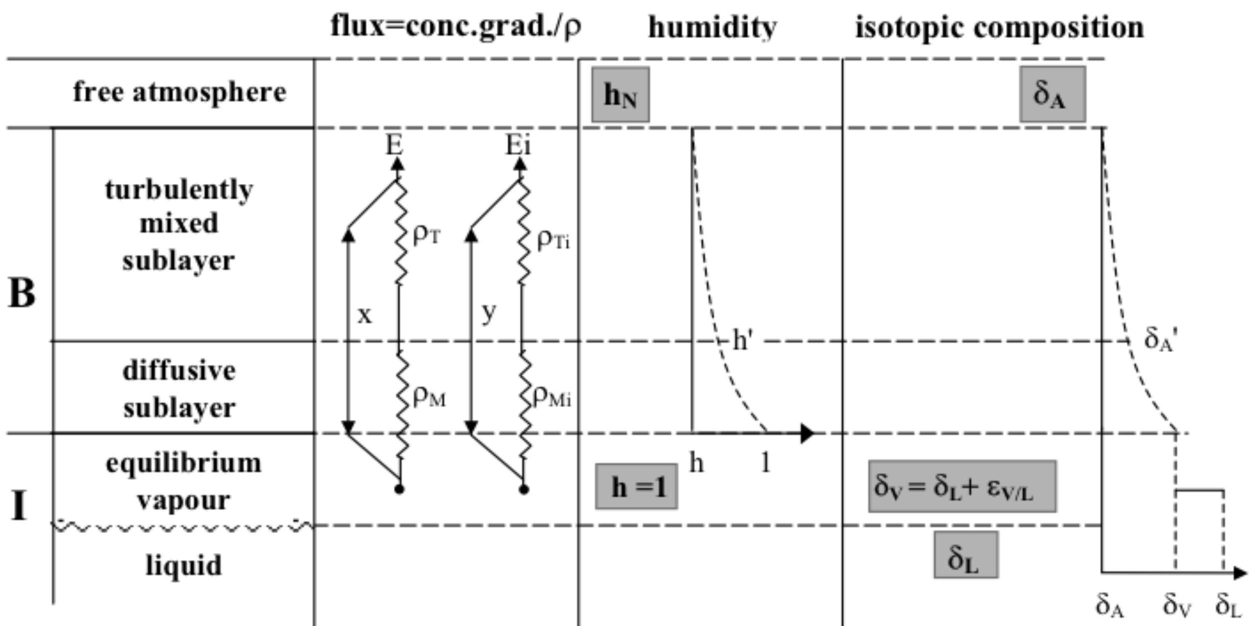


The foundations of isotope hydrology

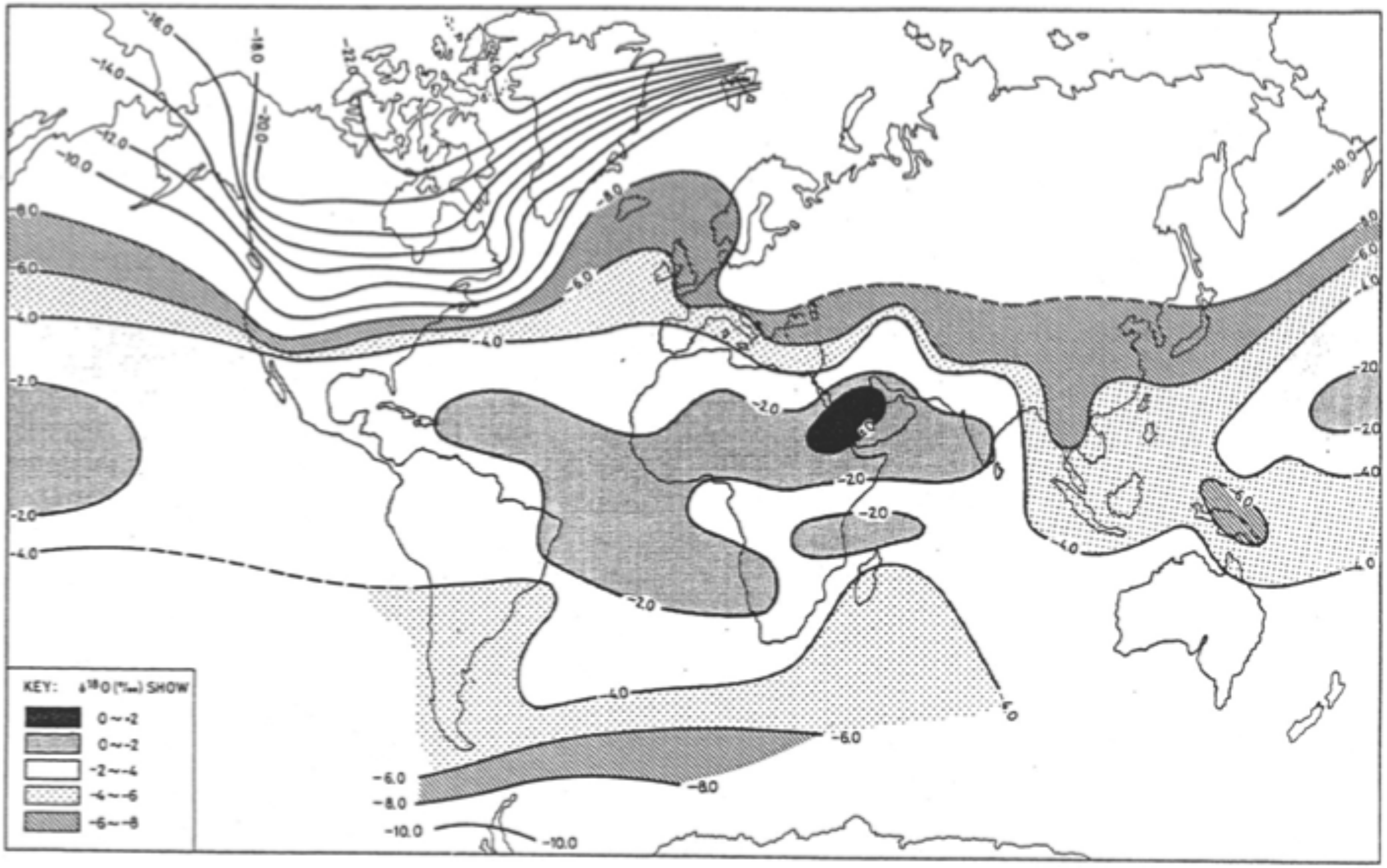
1929 Discovery of ^{18}O *(Giauque & Johnston)*

1932 Discovery of ^{2}H *(Urey et al.)*

1965 Craig-Gordon evaporation model *(Craig & Gordon)*



$$\delta = \frac{\alpha\delta_L(1 - E\rho) - h\delta_a - \varepsilon}{(1-h) + \Delta\varepsilon + \alpha * E\rho}$$



Gat 1980

Isotopic variations in meteoric waters

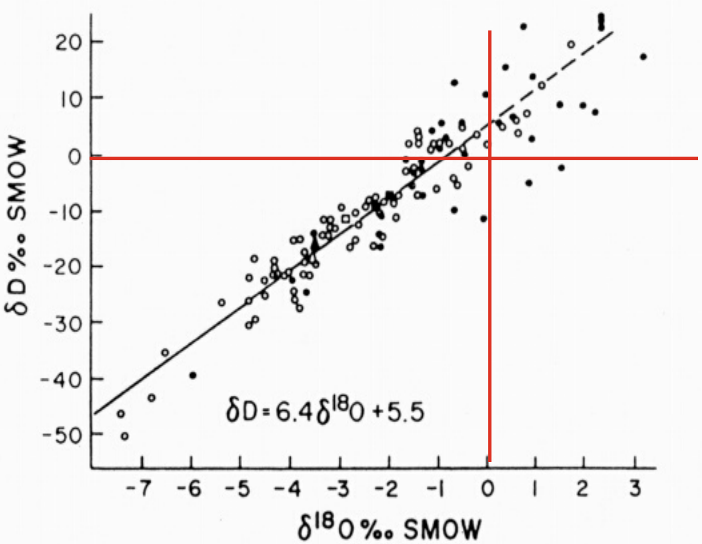


Fig. 9.5 Isotopic composition of precipitation in the Pajeu River basin, Brazil: o, months with rain over 50 mm/month; ●, months with lower precipitation amounts. A local meteoric line is obtained with the equation $\delta D = 6.4\delta^{18}O + 5.5$ (Salati et al., 1980).

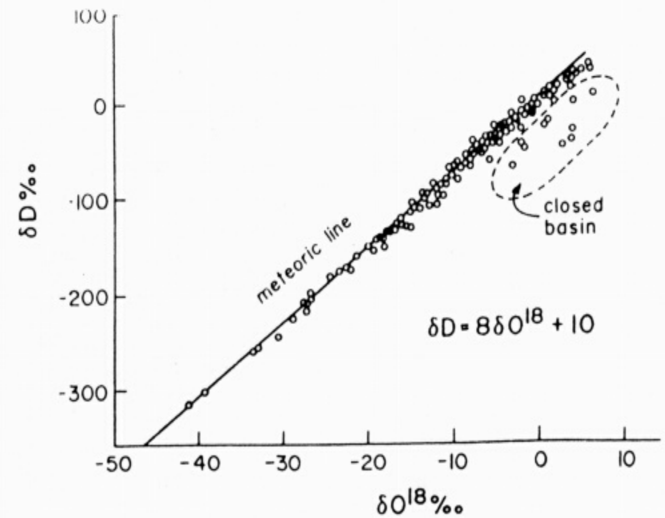


Fig. 9.4 Isotopic data of about 400 samples of rivers, lakes, and precipitation from various parts of the world. The best-fit line was termed the *meteoric line*. Its equation, as found by Craig (1961a), is $\delta D = 8\delta^{18}O + 10$. The data in the encircled zone of "closed basins" is for East African lakes with intensive evaporation.

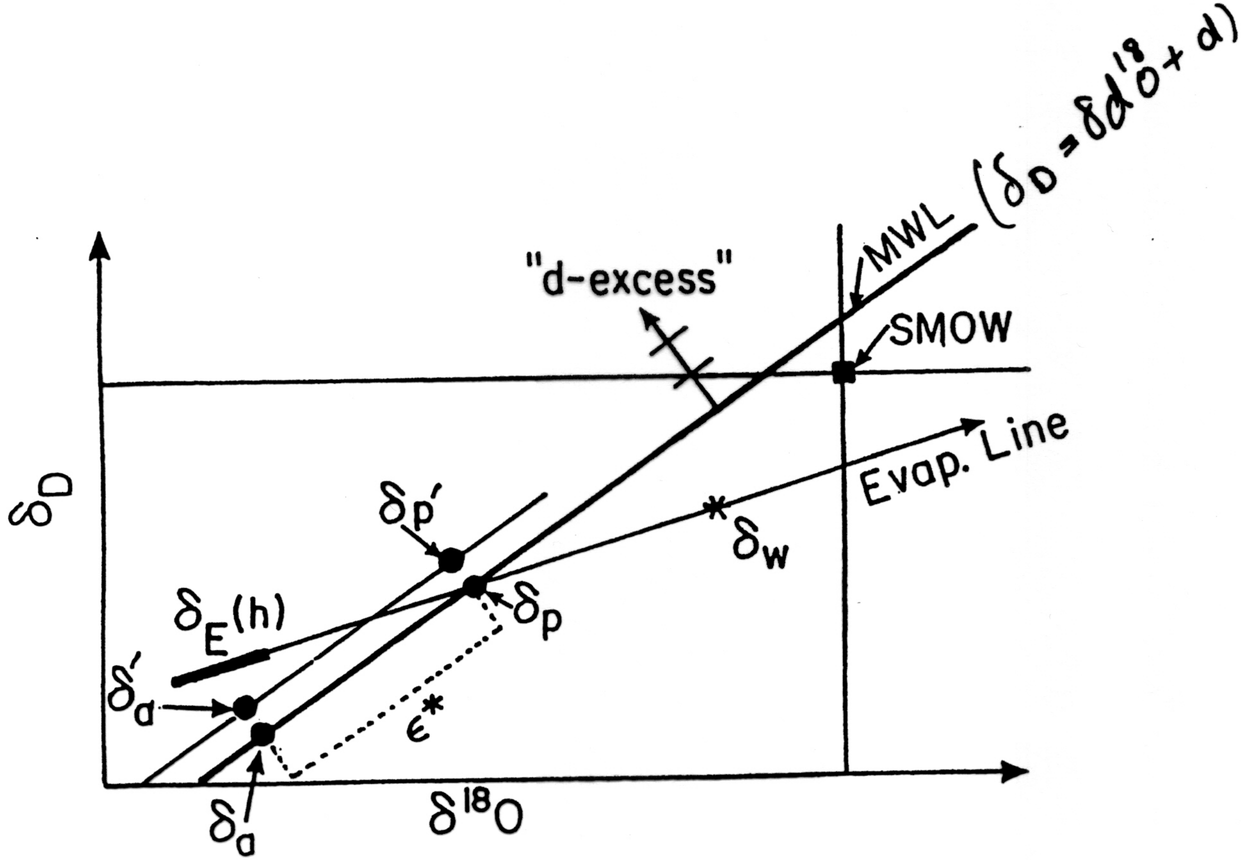


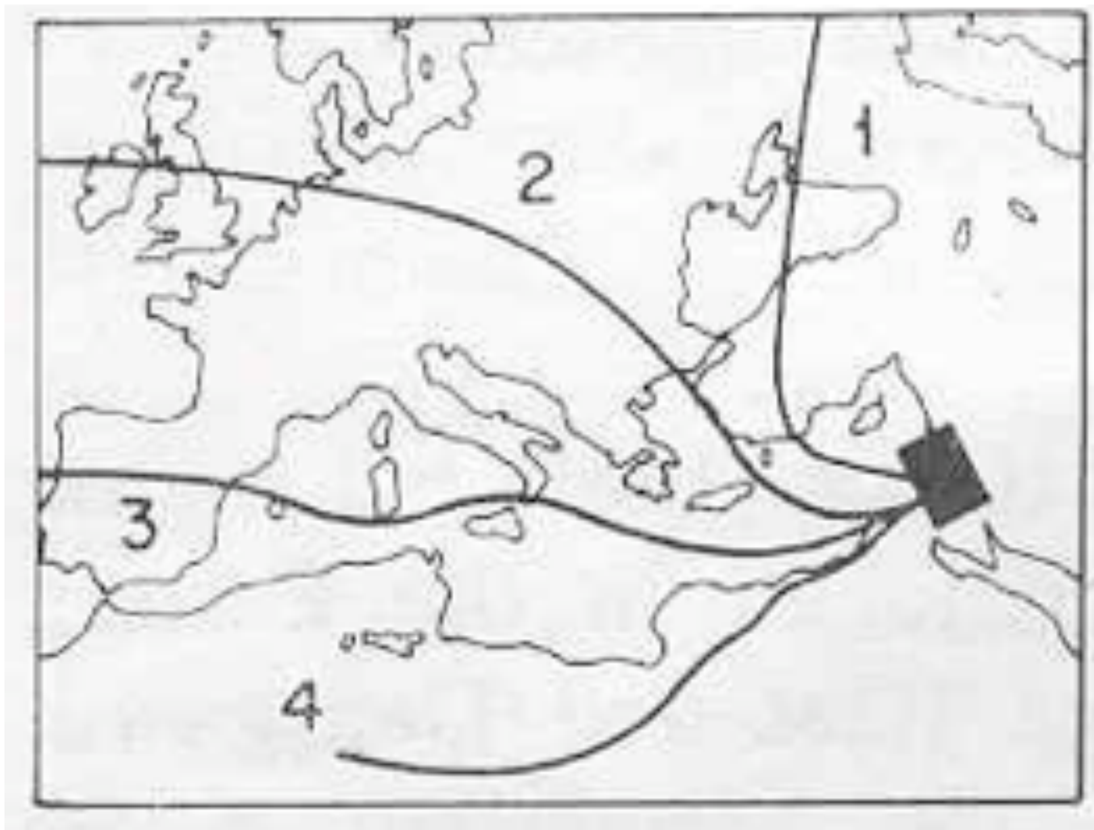
Figure 8 Schematics of the addition of evaporated moisture from surface water into the ambient atmosphere on the δ-diagram. $\delta_p = \delta$ value of precipitation; $\delta_w = \delta$ value of the residual water after evaporation; $\delta_E =$ the evaporation flux; δ_a and δ'_a are the atmospheric moisture before and after mixing with δ_E.

THE RELATION BETWEEN THE ^{18}O AND DEUTERIUM CONTENTS OF RAIN WATER IN THE NEGEV DESERT AND AIR-MASS TRAJECTORIES

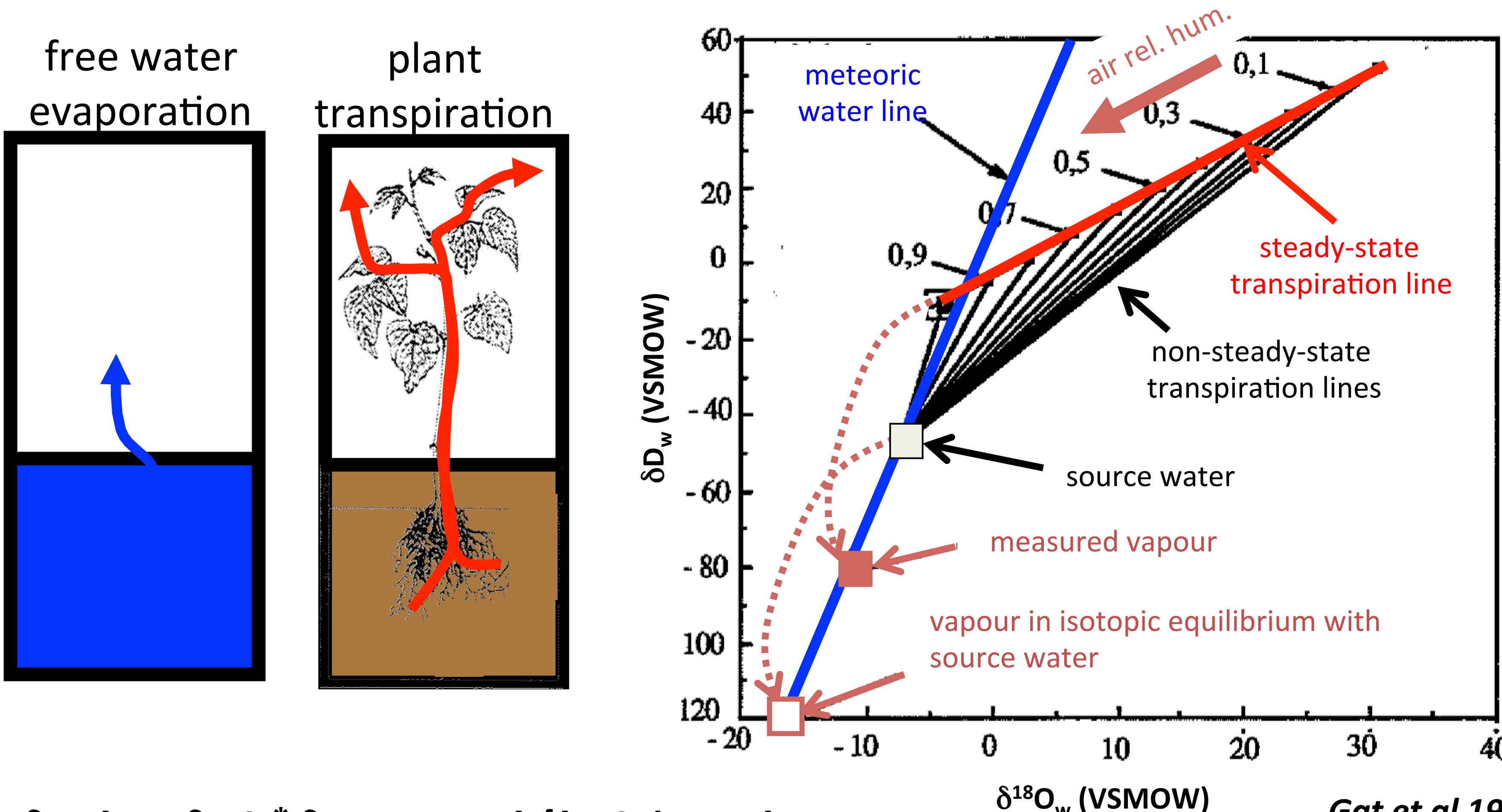
CLAUDE LEGUY[1], MICHAEL RINDSBERGER[2,3] A. ZANGWIL[1], ARIE ISSAR[1] and JOEL R. GAT[3]

[1]*Jacob Blaustein Institute for Desert Research and Geological Department Ben Gurion University of the Negev, Beer-Sheva (Israel)*
[2]*Israel Meteorological Service, Bet Dagan (Israel)*
[3]*Department of Isotope Research, The Weizmann Institute of Science, Rehovot (Israel)*

(Received November 15, 1982; revised and accepted May 17, 1983)



Inversion of the Craig-Gordon equation to solve for water bodies in isotopic steady state



Gat et al 1985

$$\delta_E=(\alpha_{eq}\delta_L-h^*\delta_a+\varepsilon_{eq}+\varepsilon_k)/(1-h^*-\varepsilon_{eq})$$

$$\delta_L=\varepsilon_{eq}+\varepsilon_k+\delta_i+h^*(\delta_a-\varepsilon_{eq}-\delta_i)$$

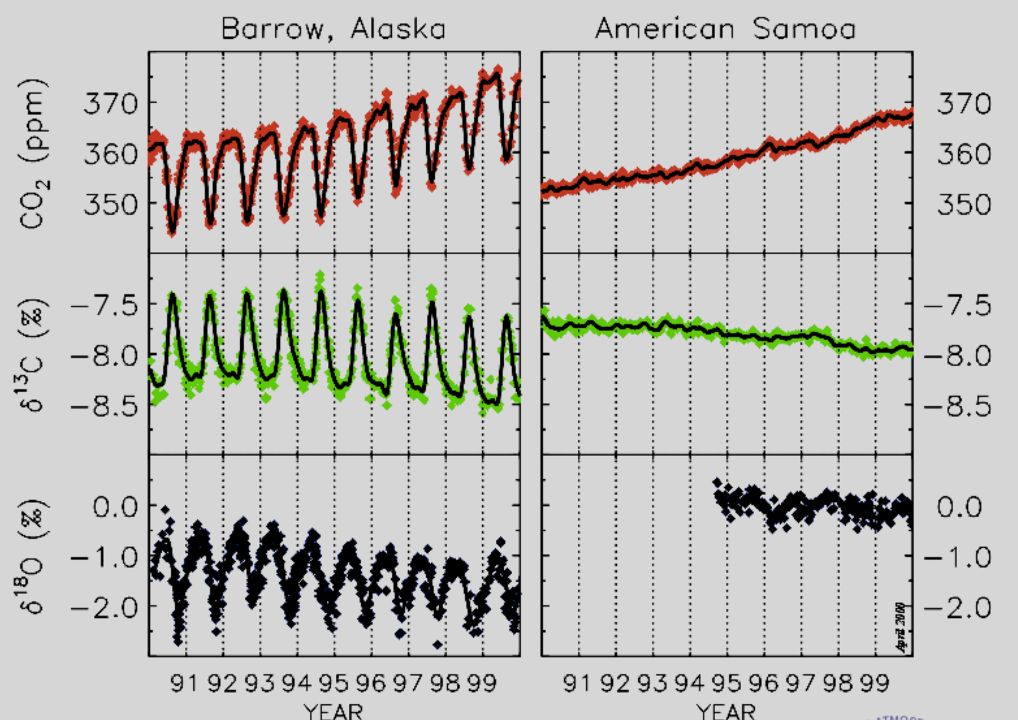
letters to nature

Nature **327**, 495 - 497 (11 June 1987); doi:10.1038/327495a0

Latitudinal variation in oxygen-18 of atmospheric CO_2

ROGER J. FRANCEY* & PIETER P. TANS†

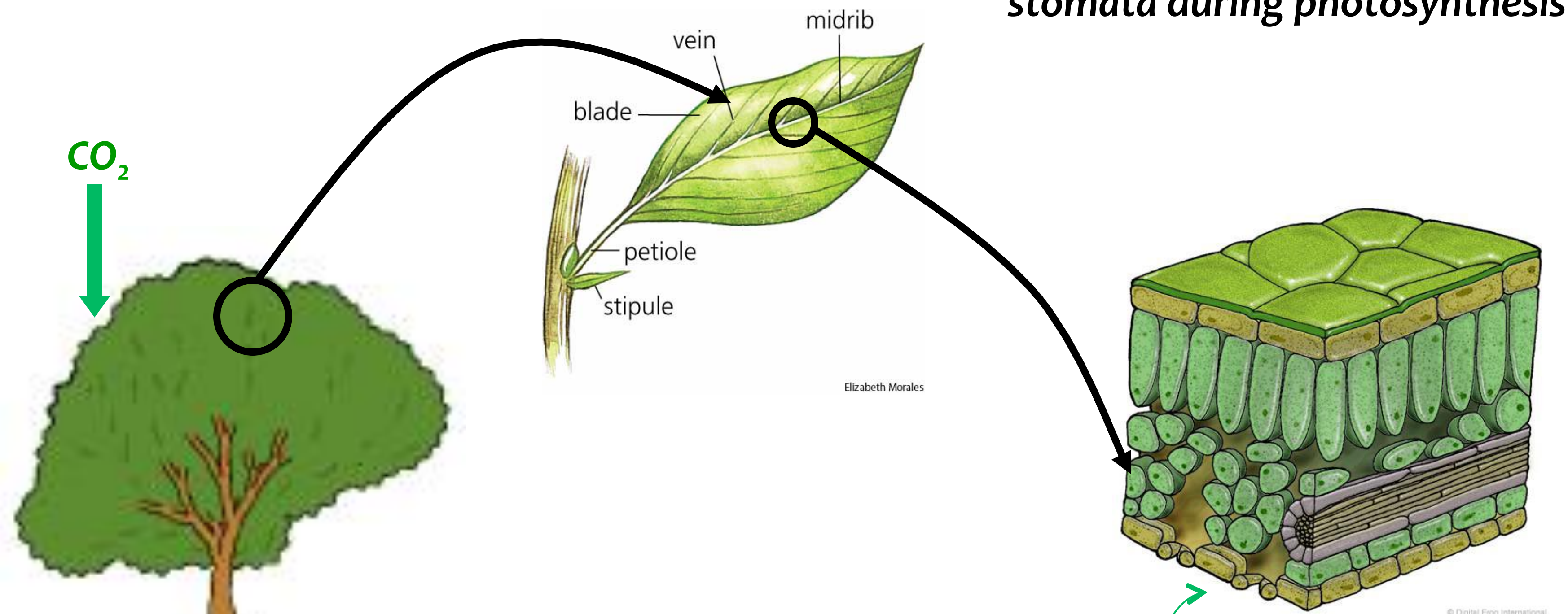
$$CO_2 + H_2O \rightleftarrows HCO_3^- + H^+$$

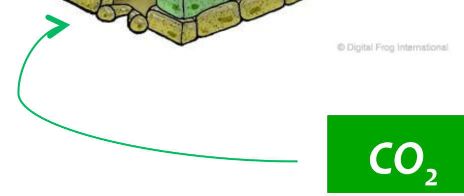


Time series showing the relationships between atmospheric carbon dioxide (upper panel), carbon-13 (middle panel) and oxygen-18 (lower panel) isotopic composition in the marine boundary layer. The measurements were made at NOAA CMDL and the University of Colorado INSTAAR using samples provided by the NOAA CMDL cooperative air sampling network. Data are shown for Barrow and Samoa, revealing the greater seasonal variations at high northern latitudes driven by the terrestrial biosphere. The isotope data are expressed as deviations of the carbon-13/carbon-12 ratio in carbon dioxide from the VPDB-CO_2 standard, in per mil (parts per thousand) Contact: Dr. Jim White, CU INSTAAR Boulder, Colorado, (303) 492-5494. james.white@colorado.edu.

CO_2 Uptake by Leaf During Photosynthesis

CO_2 is taken up through leaf stomata during photosynthesis

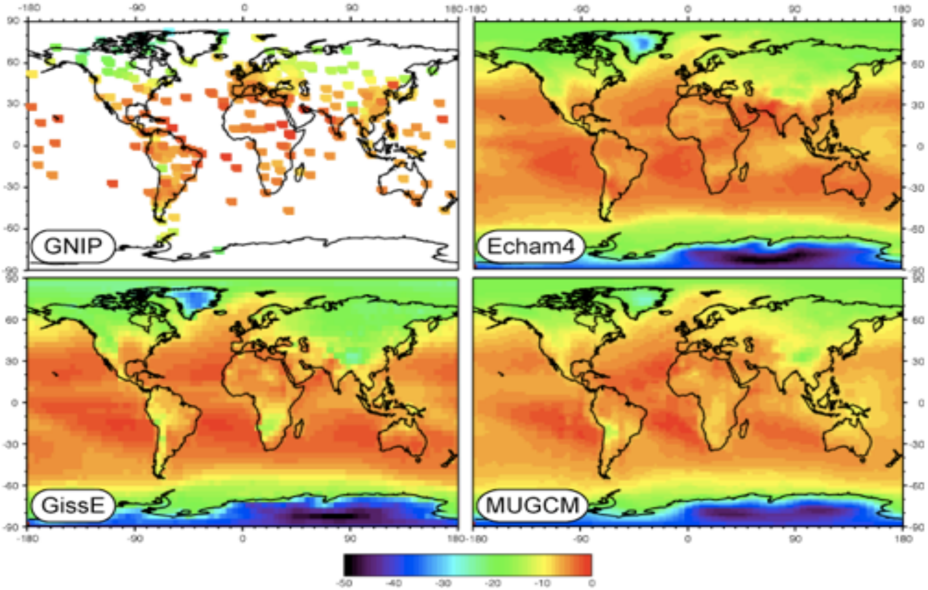




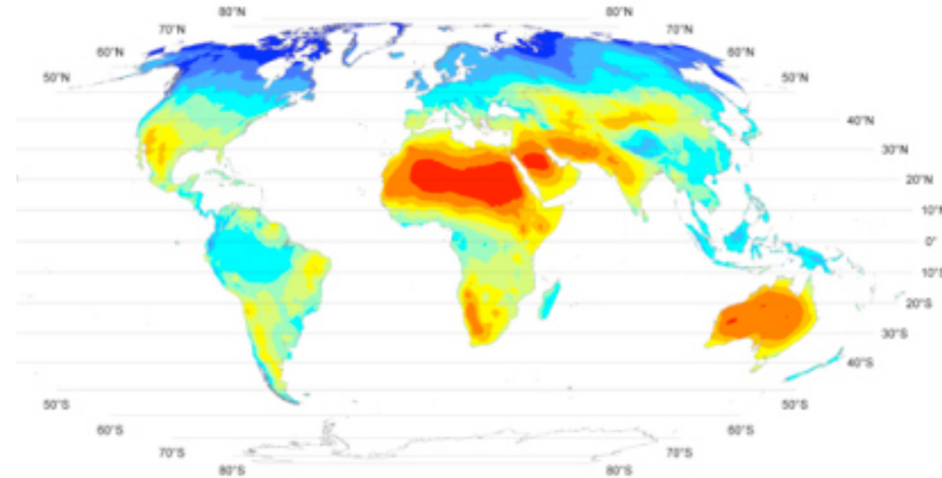
Carbonic anhydrase

$$CO_2 + H_2O \longleftrightarrow HCO_3^- + H^+$$

$$H^{18}_2O + CO_2 \overset{CA}{\leftrightarrow} H^+ + [HCO_3^{18}]^- \overset{CA}{\leftrightarrow} H_2O + CO^{18}O$$

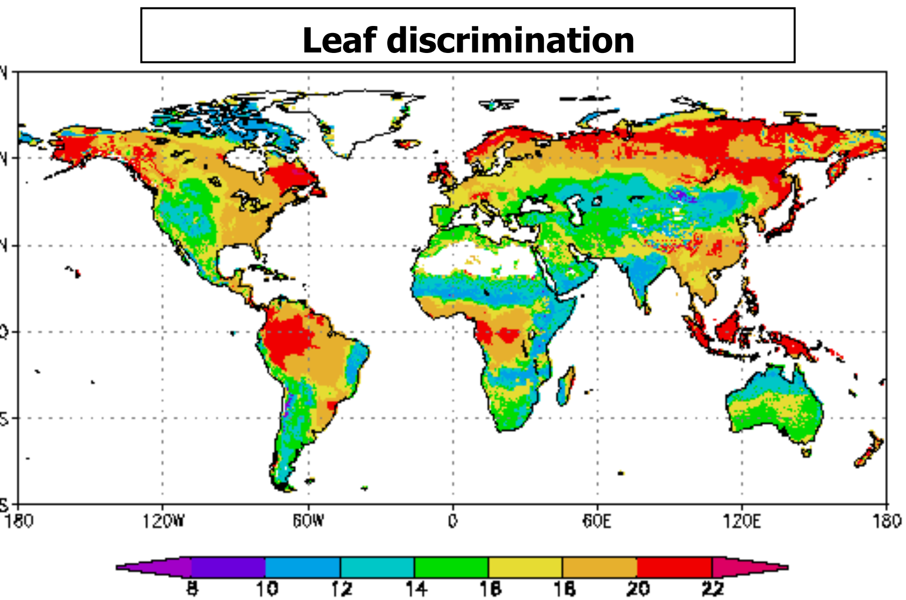


Fnung et al; Jousel et al, Henderson Sellers, Ciais



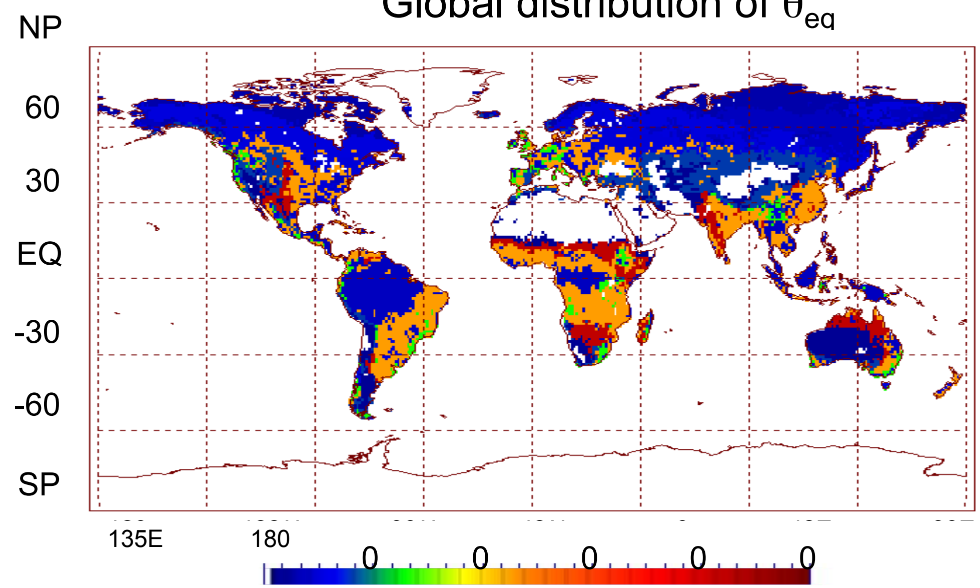
Leaf water ISOSCAPES (West & Bowen)

LPJ, J.Kaplan et al.



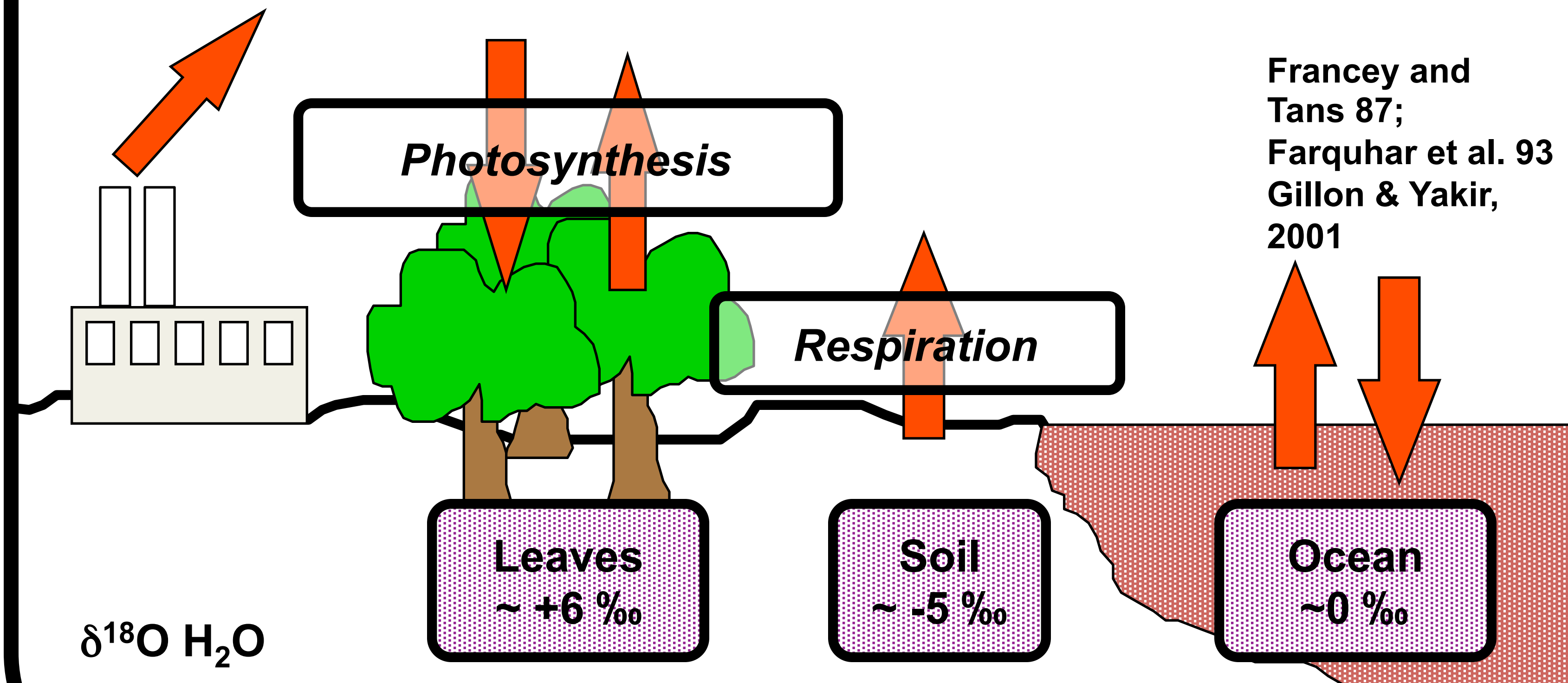
Gillon & Yakir, 2001

Global distribution of θ_{eq}



atmospheric $\delta^{18}O$ CO_2

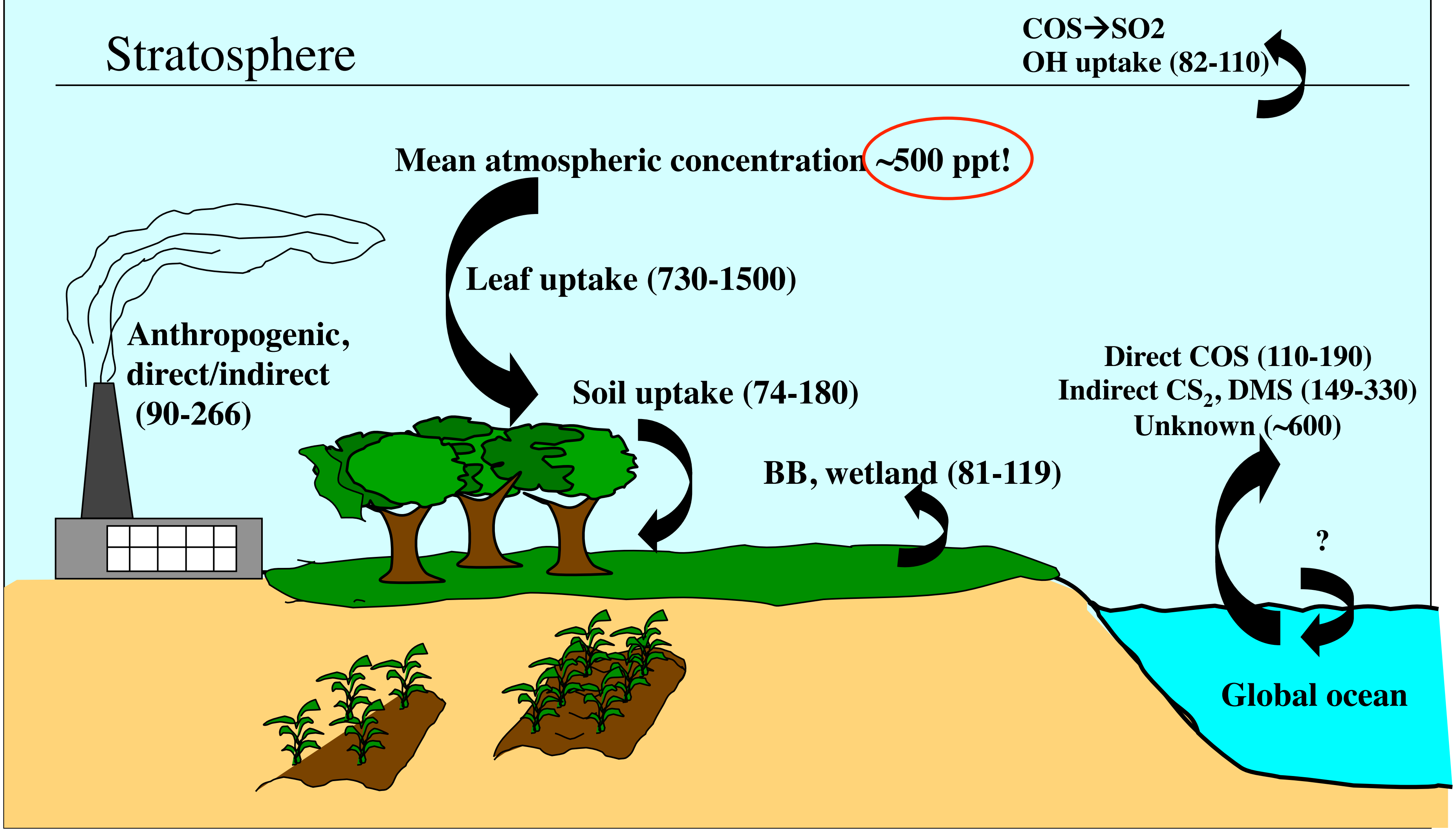
$$c_a \frac{d\delta_a}{dt} = \langle GPP\Delta_A \rangle + \langle F_R(\delta_s - \delta_a - \varepsilon_{eff}) + F_I(\delta_s - \delta_a) \rangle$$
$$+ \langle F_f(\delta_f - \delta_a) \rangle + \langle F_{oa}(\delta_o - \delta_a) + \varepsilon_w N_o \rangle$$



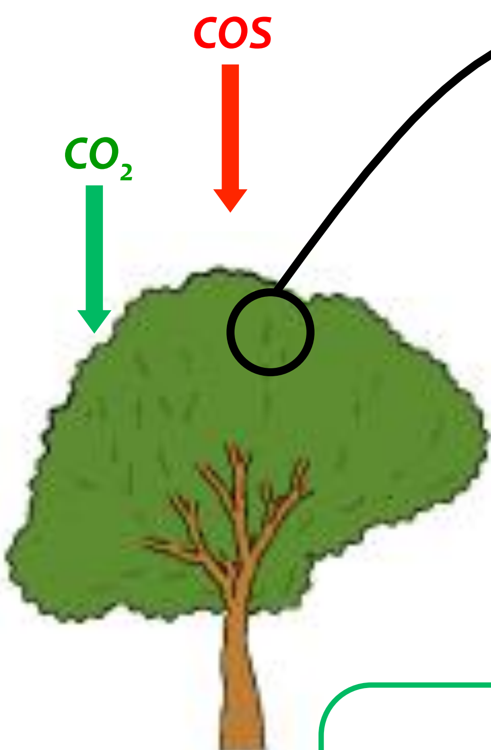
$CO_2 + H_2O \rightleftarrows HCO_3^- + H^+$

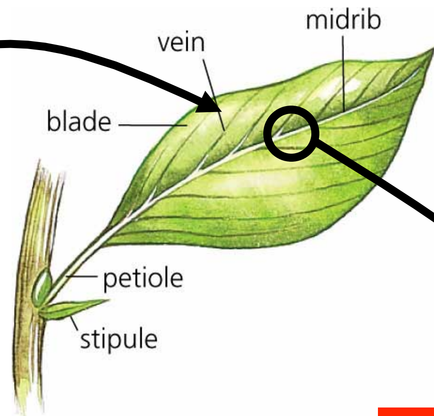
Global COS Budget

($Gg\ S\ a^{-1}$; Kettle et al., 2002; Montzka et al., 2007; Berry et al., 2013)

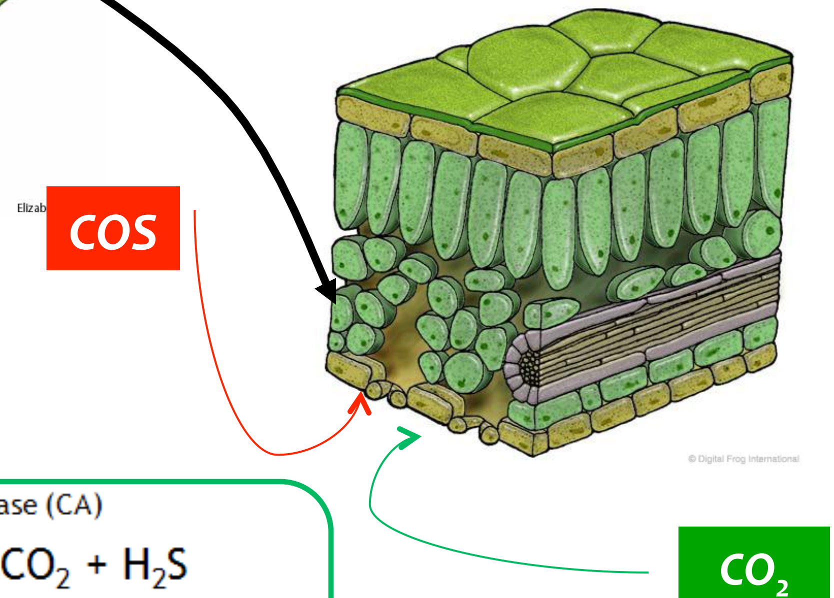


COS Uptake by Leaf During Photosynthesis





COS and CO_2 are taken up through leaf stomata during photosynthesis



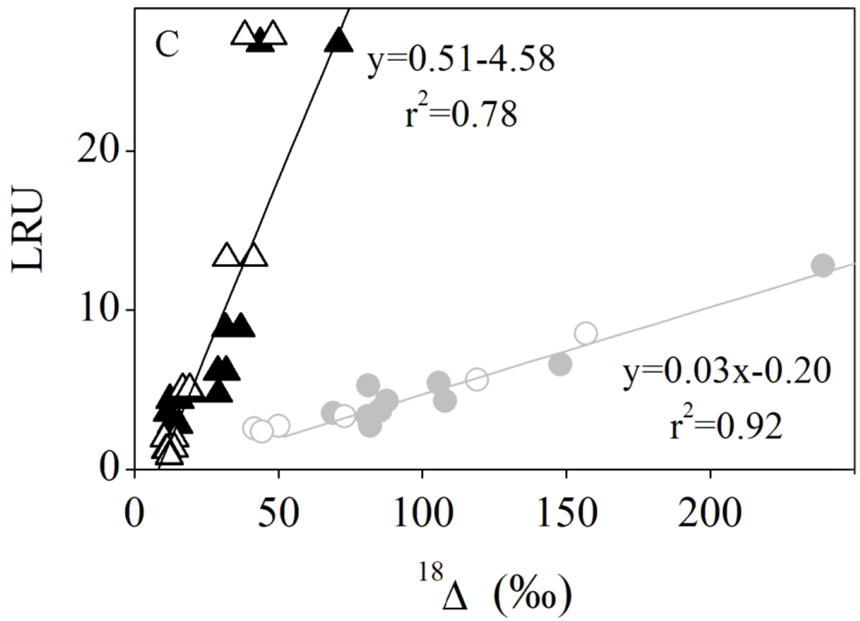
Carbonic Anhydrase (CA)

$$COS + H_2O \longrightarrow CO_2 + H_2S$$

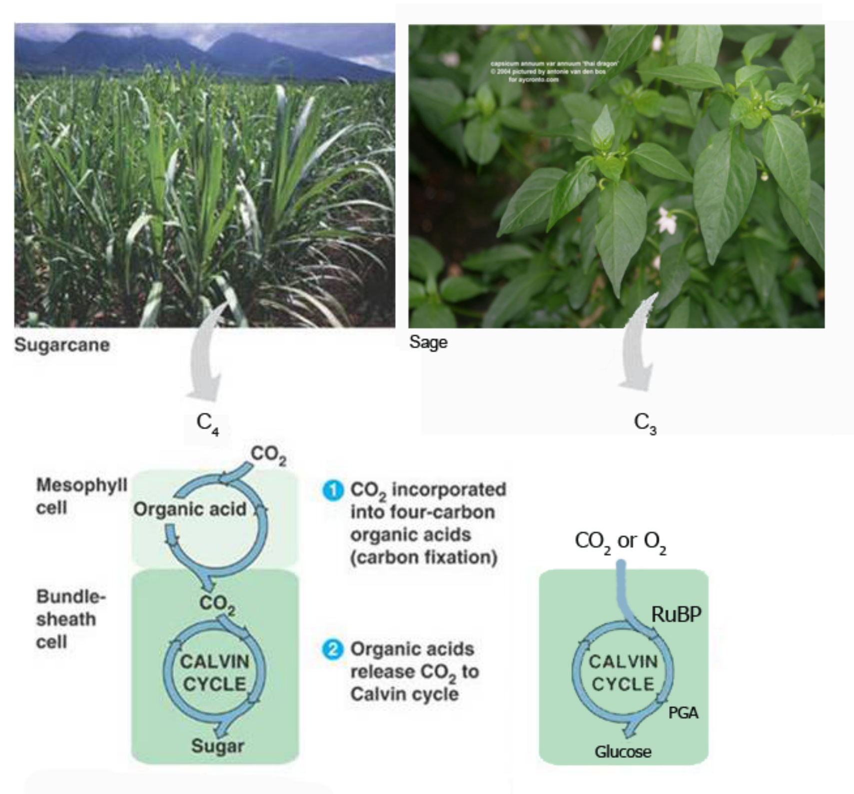
$$CO_2 + H_2O \longleftrightarrow HCO_3^- + H^+$$

$$H_2^{18}O + CO_2 \overset{CA}{\leftrightarrow} H^+ + [HCO_3^{18}]^- \overset{CA}{\leftrightarrow} H_2O + CO^{18}O$$

COS exchange and $^{18}\Delta$ on a leaf level



$$^{18}\Delta=a+\varepsilon[(\theta(\delta_e-\delta_a)-(1-\theta)(a/(\varepsilon+1)]$$

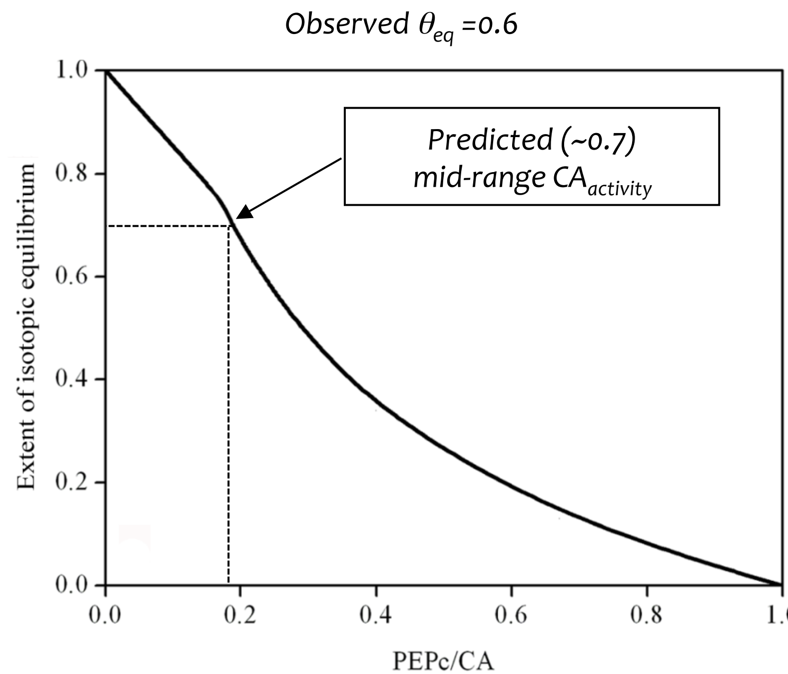


PEPc Influence θ_{eq}

$$CO_2 + H_2O \overset{CA}{\rightleftarrows} HCO_3^- + H^+$$

$$HCO_3^- \xrightarrow{PEPc} CO_2$$

$$\rho = \frac{\text{PEPc activity}}{\text{CA activity}}$$



$$\theta_{eq} = 1 - e^{-[CA_{leaf}(1-\rho)/F_{in}/3]}$$

$$^{18}\Delta = a + \varepsilon[(\theta(\delta_e - \delta_a) - (1 - \theta)(a/(\varepsilon+1))]$$

ρ	CA_{leaf} $\mu mol\ m^{-2}s^{-1}$	F_{in} $\mu mol\ m^{-2}s^{-1}$
0.18	80-3000	120

Unraveling the contemporary atmospheric CO_2 budget
(and the 50% "discount")

9.9 = **4.5** + **2.9** + **2.5**

Emission = Atmosphere + Ocean + Land




All in billion tons of carbon (Gt C or 10^{15} g C)

Final note

- Great scientists like Joel Gat laid the foundations to isotopic hydrology
  as we know it today

- Isotopic hydrology is the foundation for a powerful tracer
  In environmental sciences,

- This includes key links between the hydrological and the carbon cycles
  Leading to new 'frontiers' in Environmental Sciences

Thank you