

- **Tracerhydrologie und Hydrochemie**
 - Grundlagen, Ansätze
 - Verfügbare Tracer
- **Natürliche Tracer**
 - Wdh., Anwendungen
 - Umweltisotope N,C

Grundprinzip:

Isotopenfraktionierung bei mikrobiell katalysierten Prozessen

- Anreicherung der leichteren Isotope im Produkt und somit Anreicherung der schwereren Isotope im Edukt

Denitrifizierung im Laborversuch:

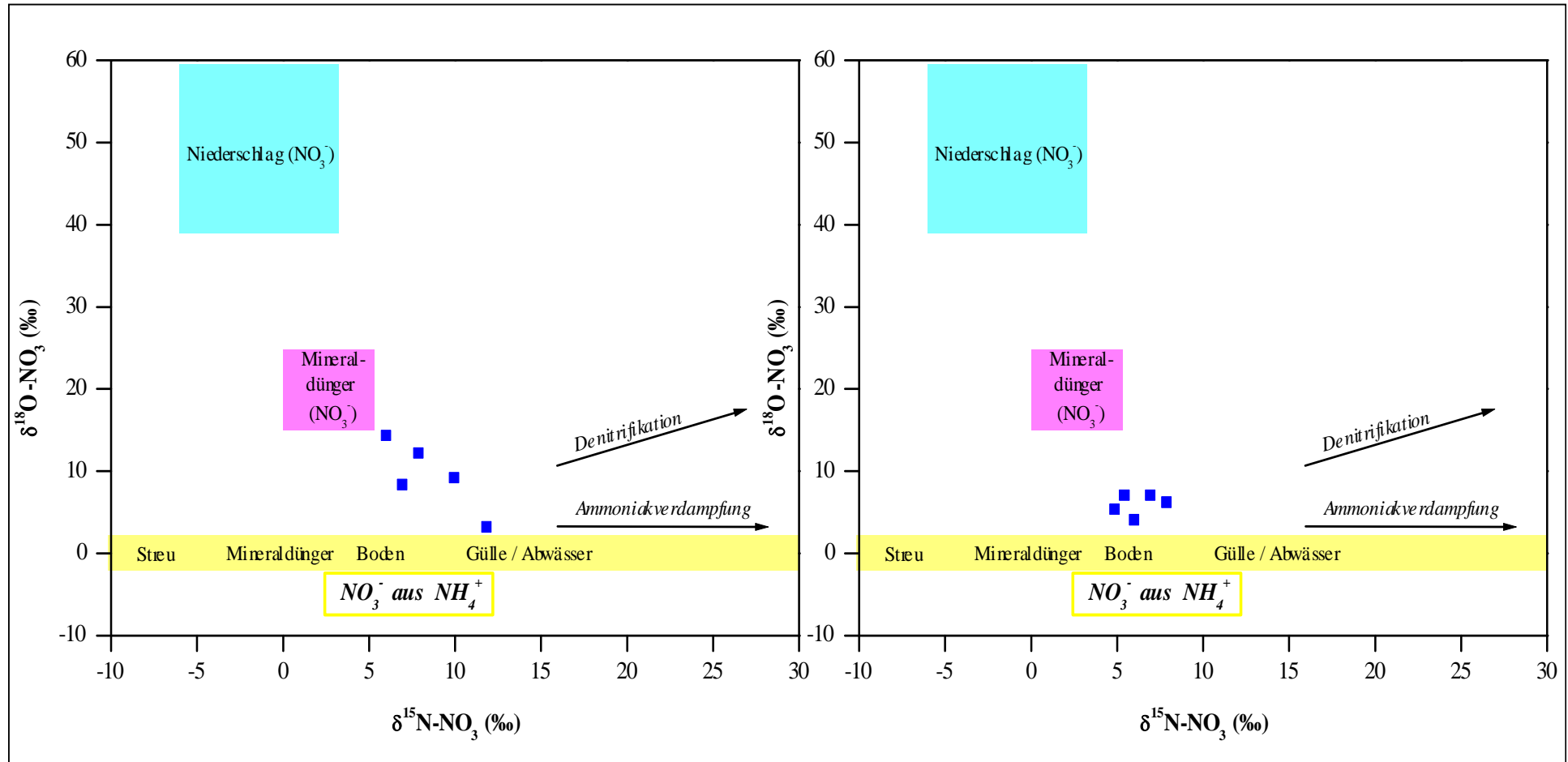
- linearer Zusammenhang zwischen Nitrat-Abnahme und Anreicherung von ^{15}N und ^{18}O
- Anreicherungsfaktor für ^{15}N ist doppelt so groß (-30‰) wie für ^{18}O (-15 ‰)

Im Fließgewässer

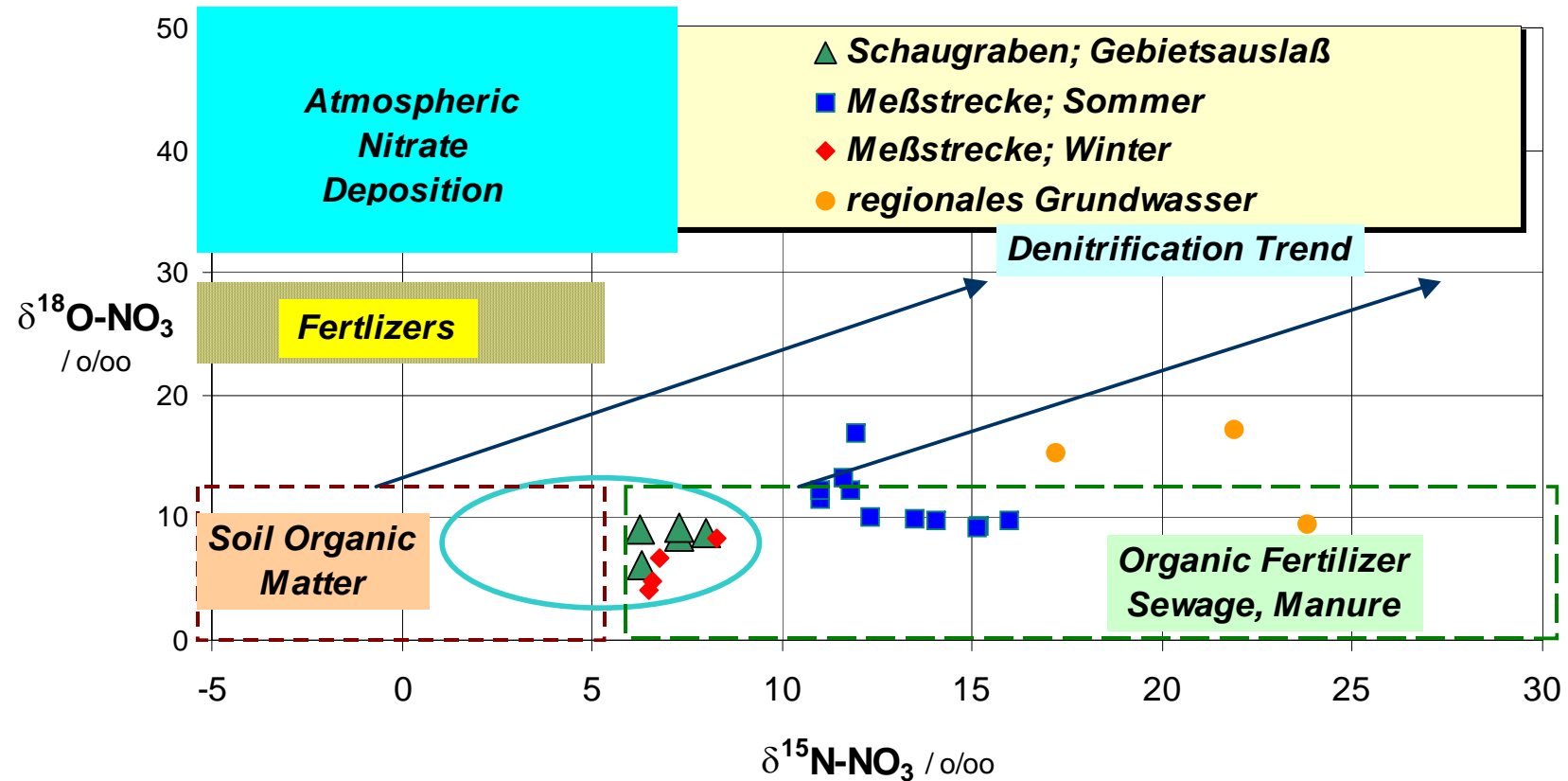
- Assimilation: nicht fraktionierender Prozess
- Denitrifizierung durch Isotopenanreicherung prinzipiell bestimmbar

Aber: Mischung, Einträge, etc.

^{18}O / ^{15}N Isotope im Nitrat



$\delta^{18}\text{O}/\delta^{15}\text{N}$ - Relation in Nitrate from Surface and Groundwaters



¹³C Kohlenstoff-13

	¹² C	¹³ C	¹⁴ C
stability	stable	stable	radioactive
natural abundance	0.989	0.011	< 10 ⁻¹²
natural specific activity			< 0.25 Bq/gC
decay mode / daughter			β ⁻ / ¹⁴ N
half-life (T _{1/2})			5730 a
decay constant (λ)			1.21×10 ⁻⁴ /a = 1/8267 a ⁻¹
max. β energy			156 keV
abundance range in hydrological cycle		30‰	0 to 10 ⁻¹²
reported as		¹³ δ or δ ¹³ C	¹⁴ A, ¹⁴ a, ¹⁴ δ, or ¹⁴ Δ
in		‰	dpm/gC, Bq/gC, ‰, or ‰
instrument		MS	PGC, LSS, AMS
analytical medium		CO ₂	CO ₂ , C ₂ H ₂ , CH ₄ , C ₆ H ₆ , graphite
usual standard deviation		0.03‰	1‰ to 1% at natural level
international standard		VPDB	Oxalic acid: Ox1, Ox2
with absolute value		0.0112372	13.56 dpm/gC

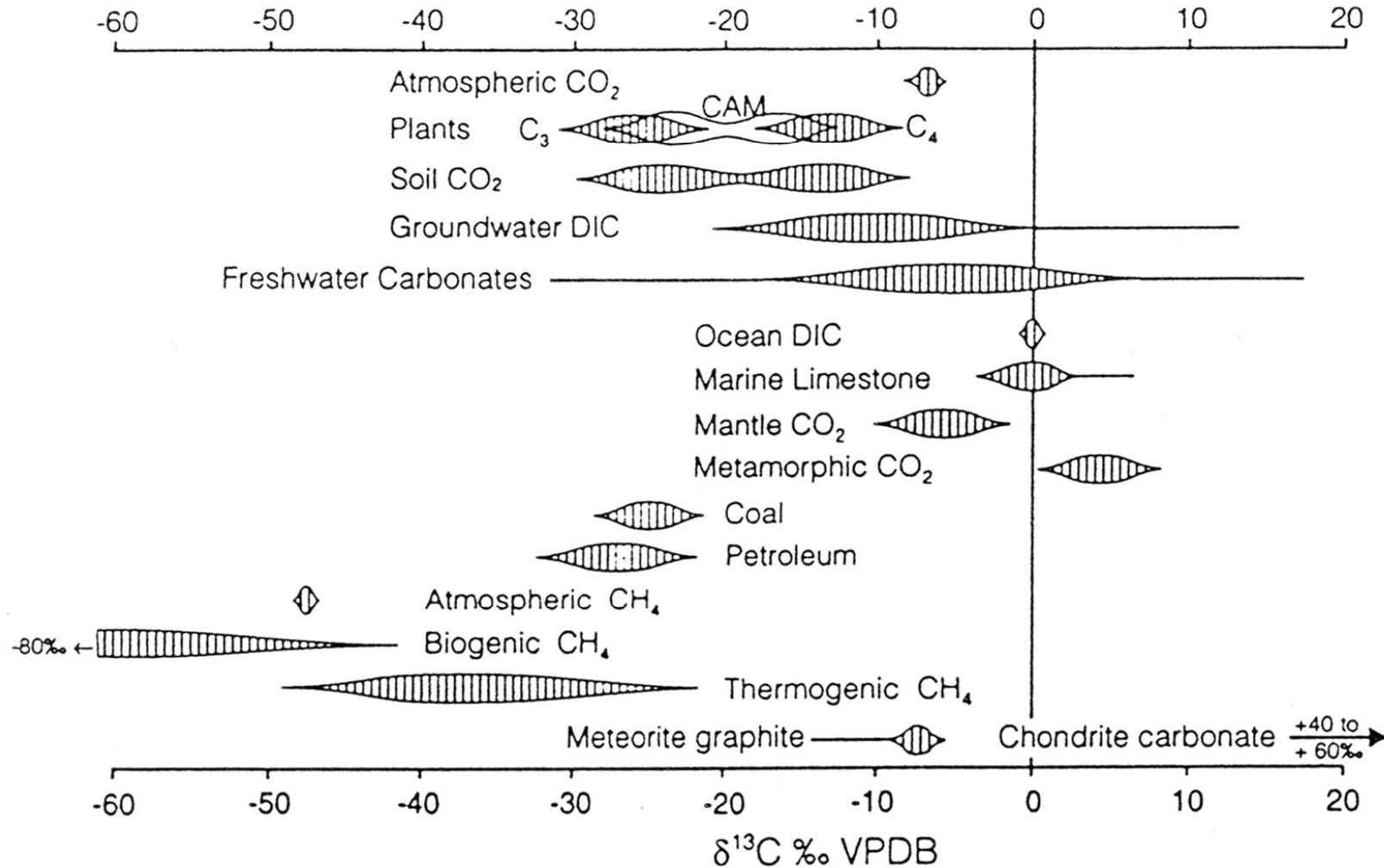
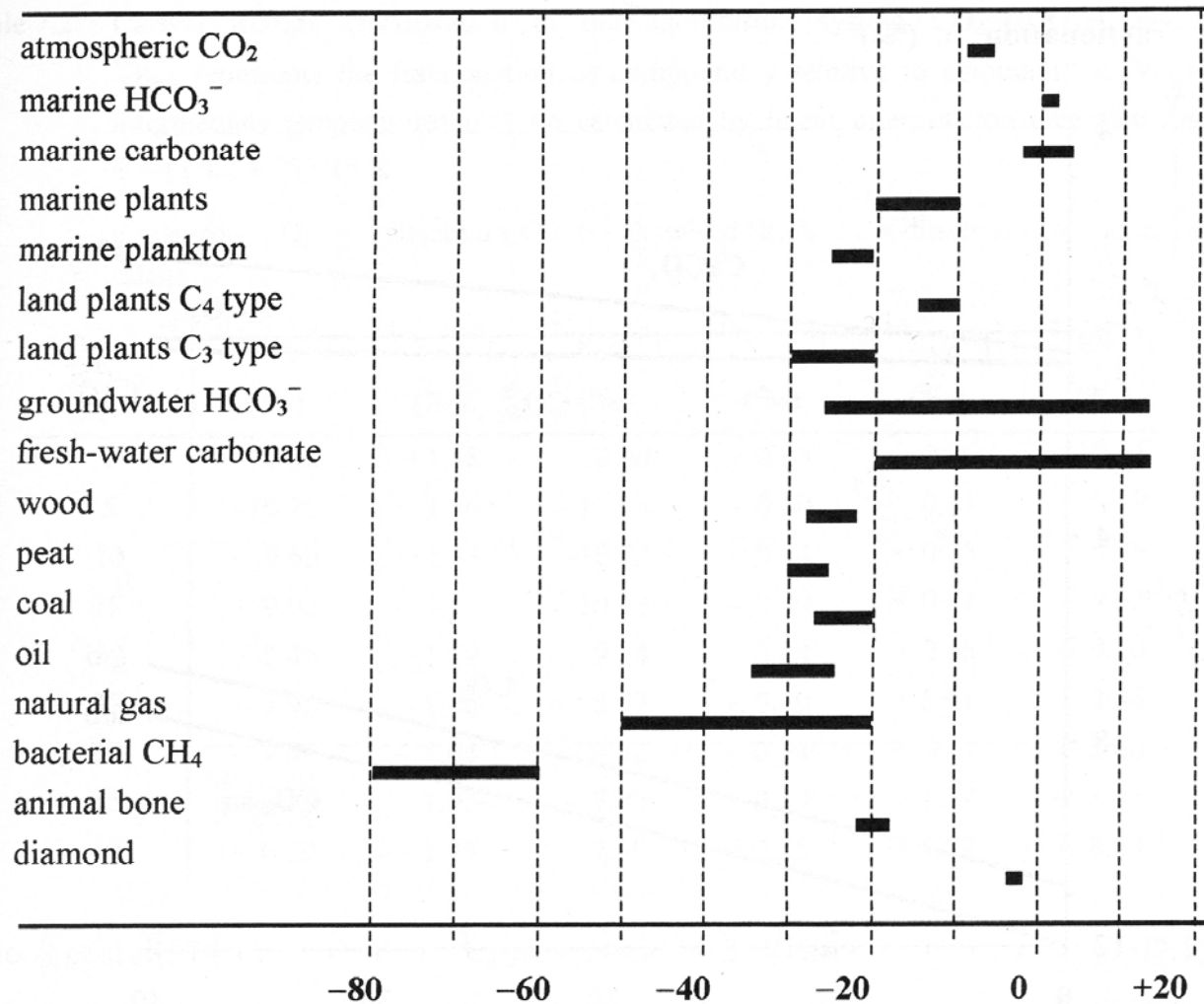
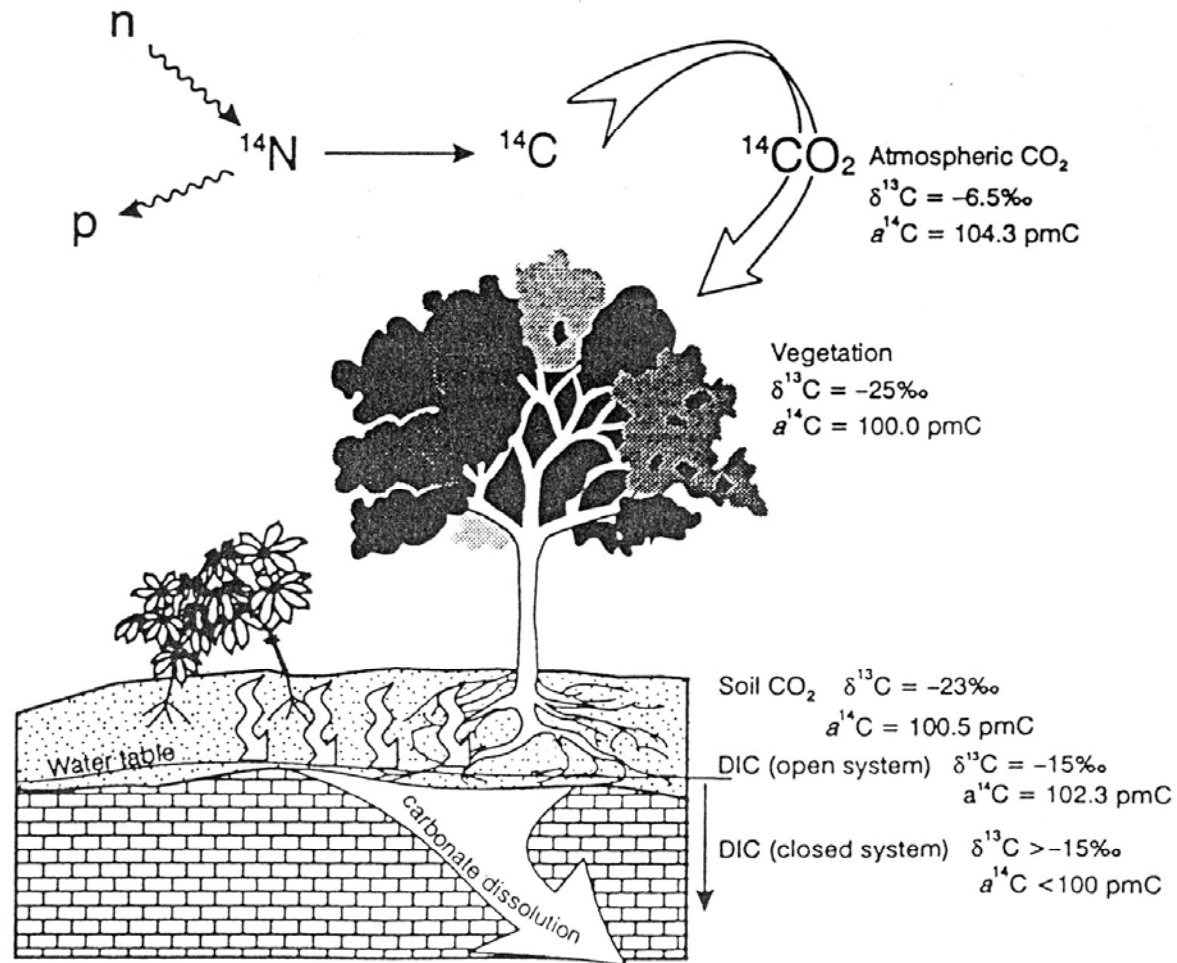
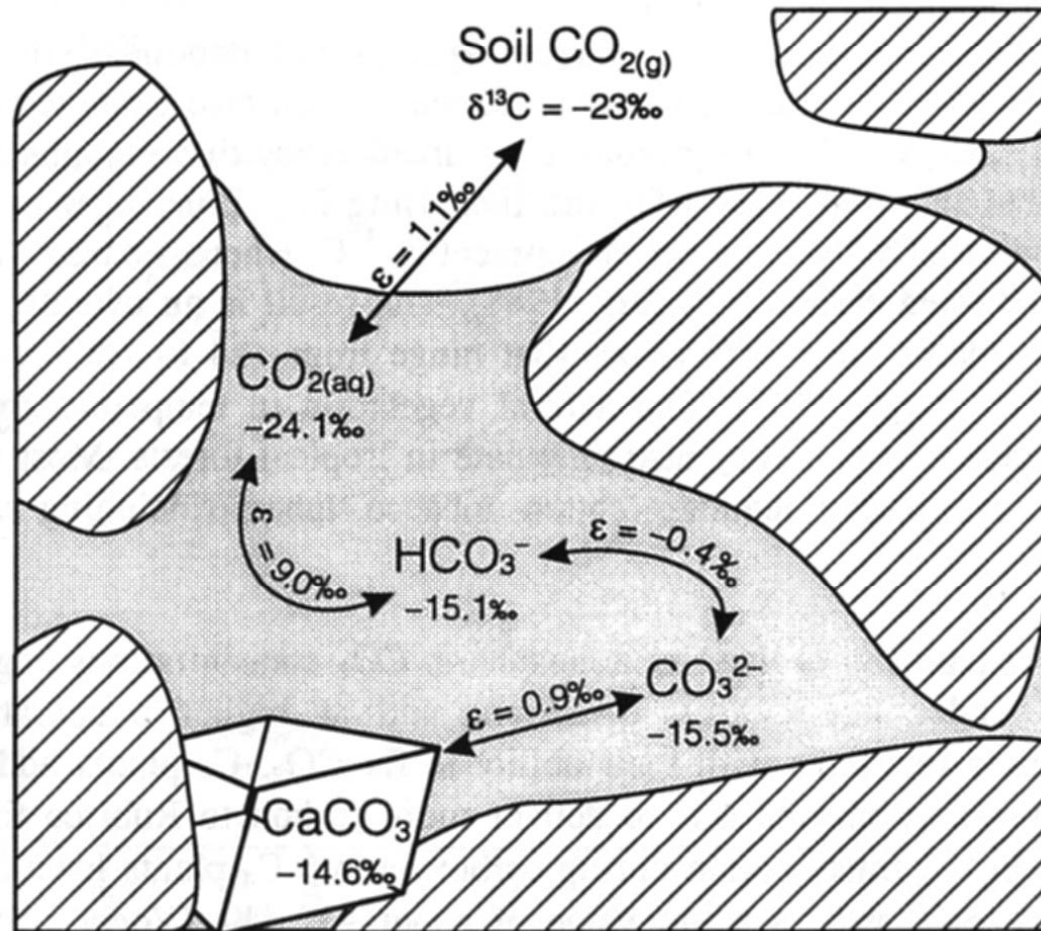


Fig. 5-1 Ranges for $\delta^{13}\text{C}$ values in selected natural compounds. Especially noteworthy is the spread in ^{13}C seen in different plant groups and the resulting soil CO_2 .





^{13}C - Kohlenstoff-13



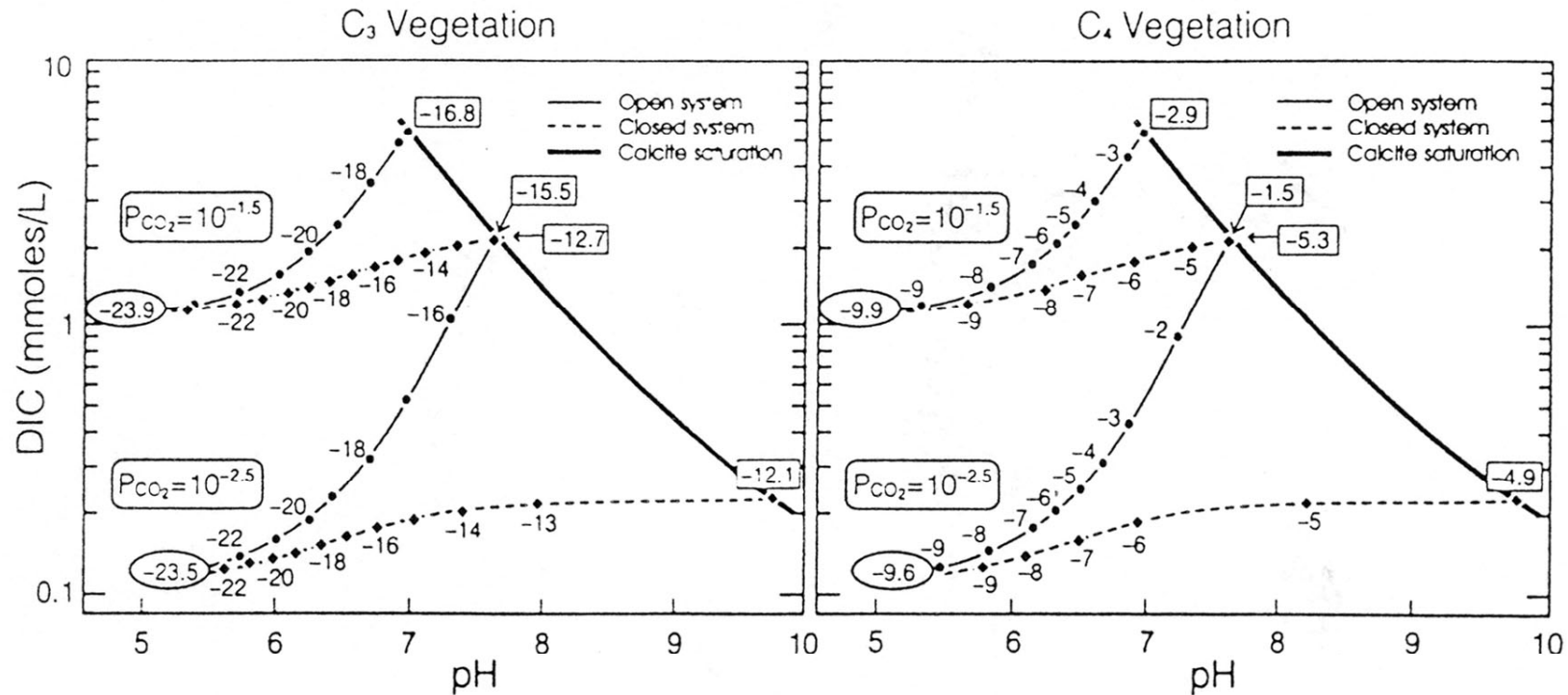
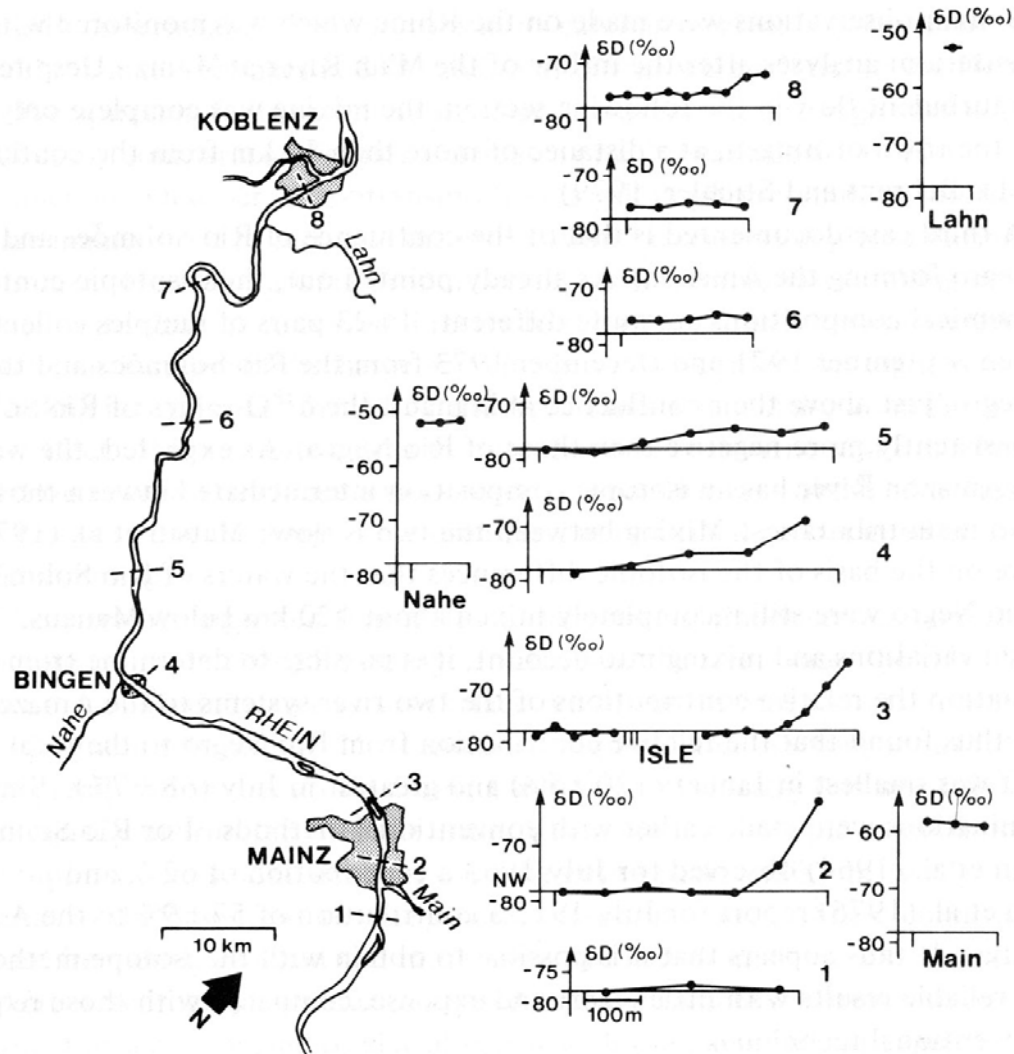
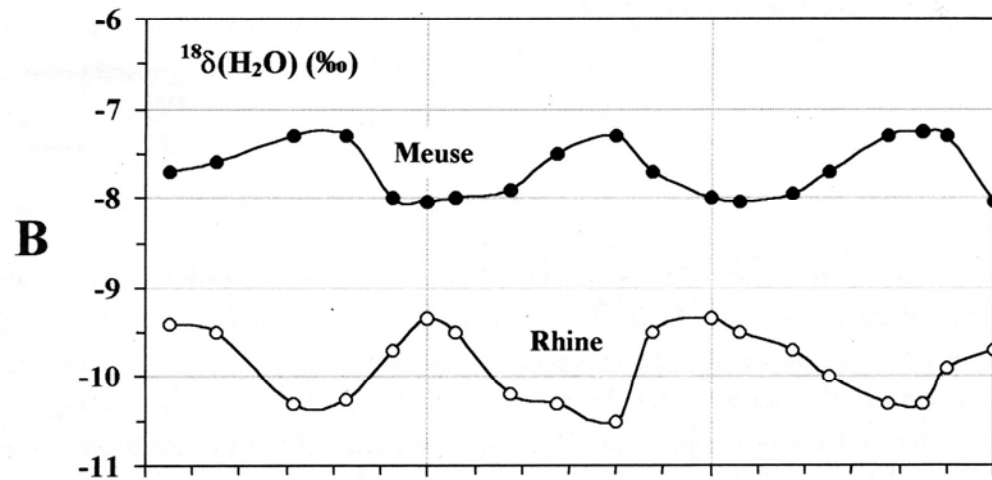
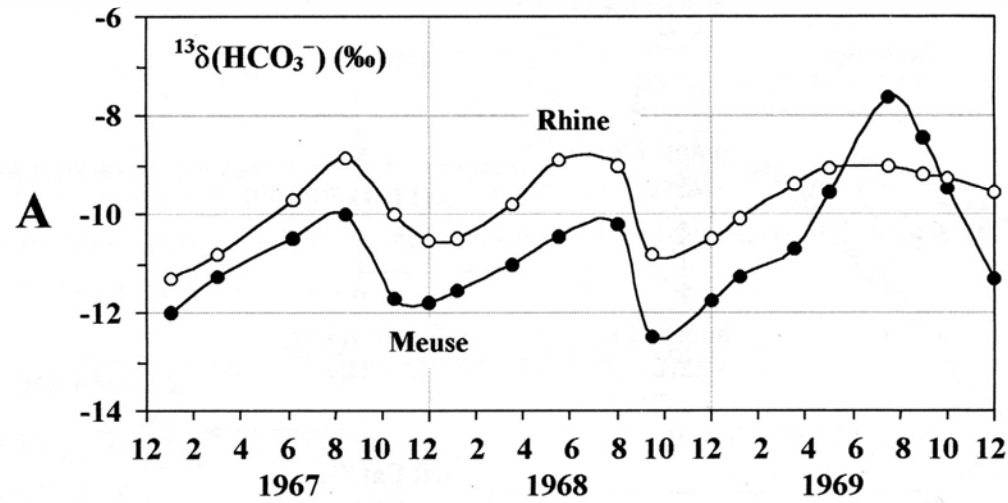
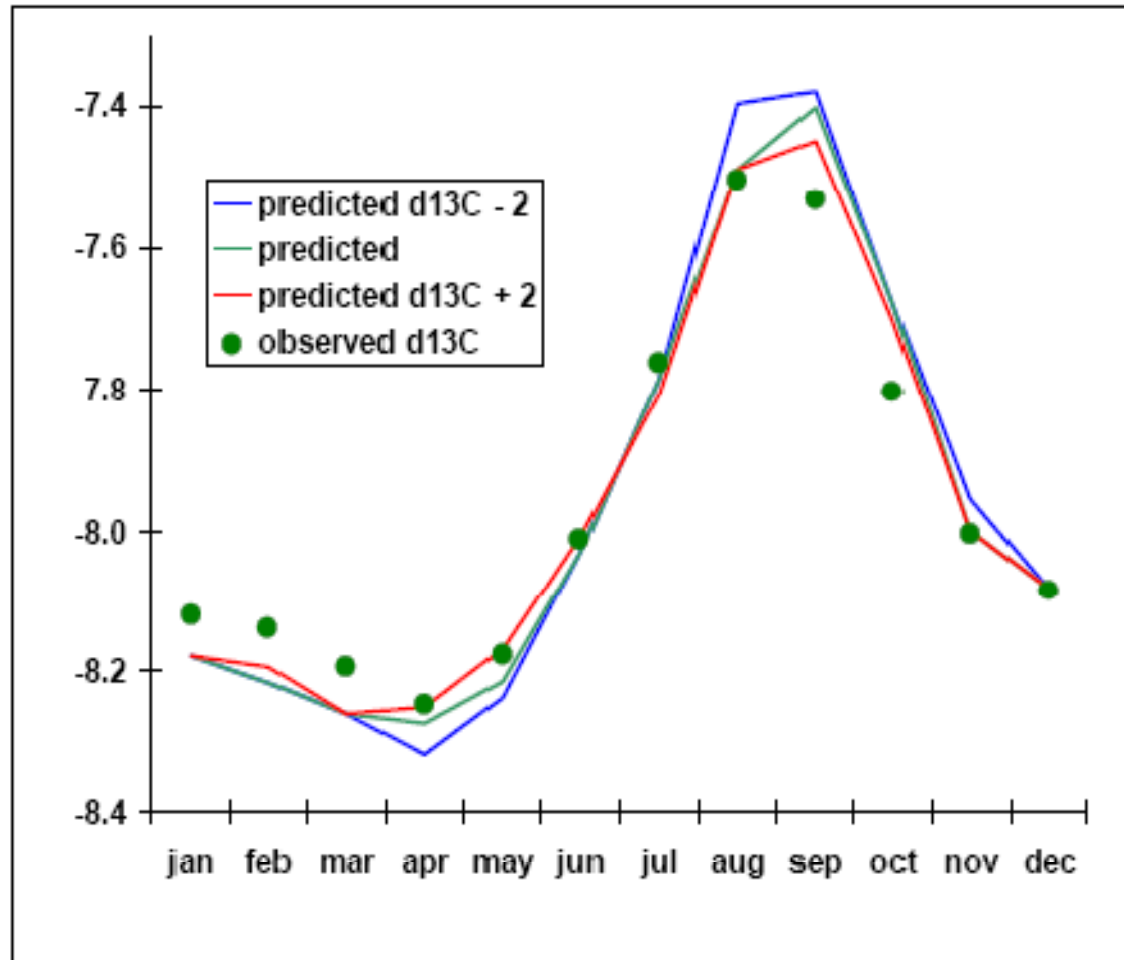


Fig. 5-6 The evolution of DIC and $\delta^{13}C_{DIC}$ in groundwaters as calcite ($\delta^{13}C = 0\text{‰ VPDB}$) is dissolved to the point of saturation. Open and closed system conditions are shown for the cases where the water is in equilibrium with soil P_{CO_2} of $10^{-1.5}$ and $10^{-2.5}$. Diagrams are shown for soil CO_2 from C₃ vegetation ($\delta^{13}C_{CO_2} = -23\text{‰}$) and from C₄ vegetation ($\delta^{13}C_{CO_2} = -9\text{‰}$). Final $\delta^{13}C_{DIC}$ values at calcite saturation are shown in squares. Open system dissolution maintains a fixed P_{CO_2} while under closed system conditions, the P_{CO_2} of the groundwater decreases as calcite dissolves. For open system conditions, the enrichment in ^{13}C reflects continual exchange with soil CO_2 at increasing pH (Fig. 5-5). The greater enrichments observed for closed system dissolution are due to dilution of the initial DIC with marine carbonate.



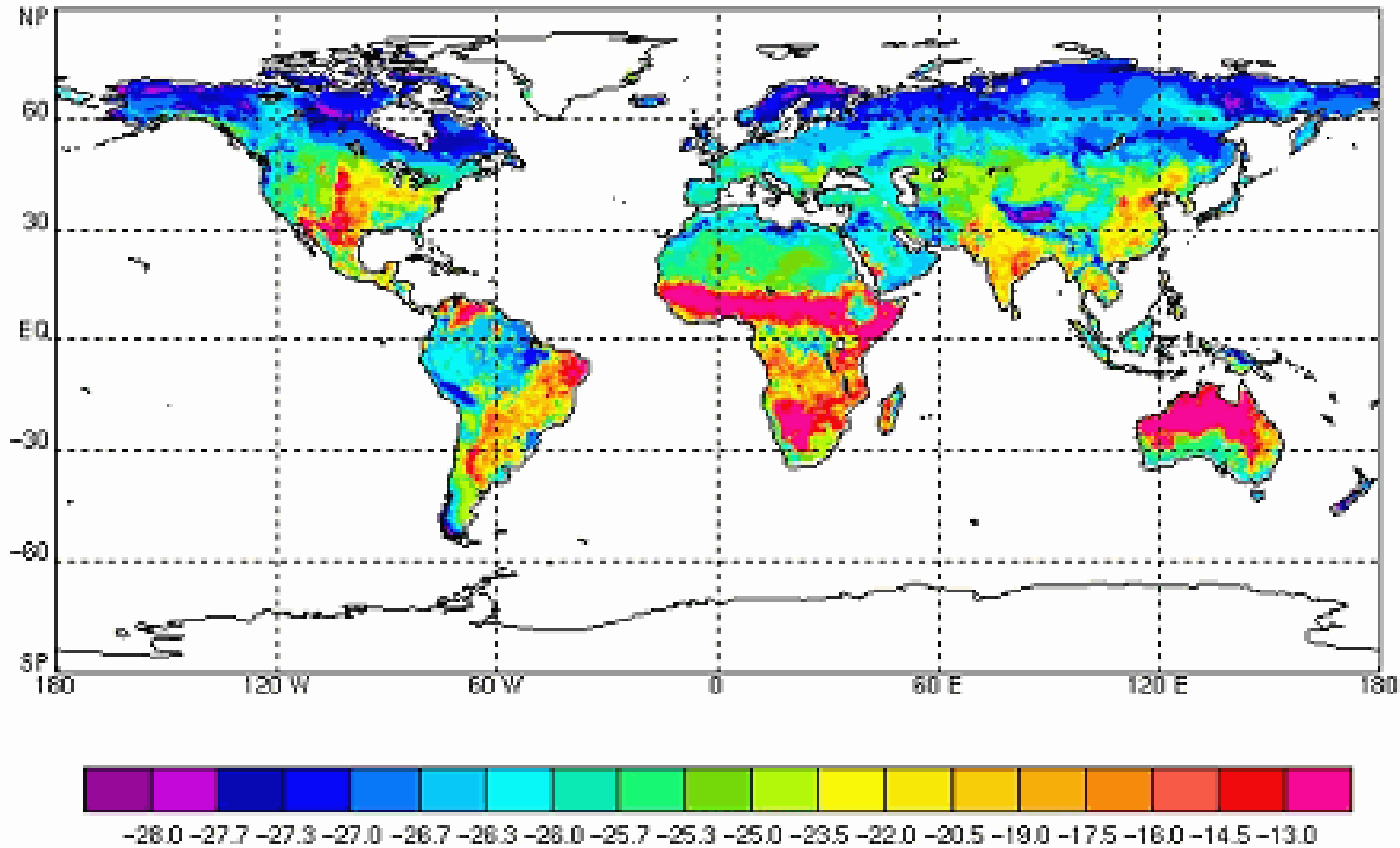


$\delta^{13}\text{C}_{\text{atm}}$ at Mace Head, Ireland

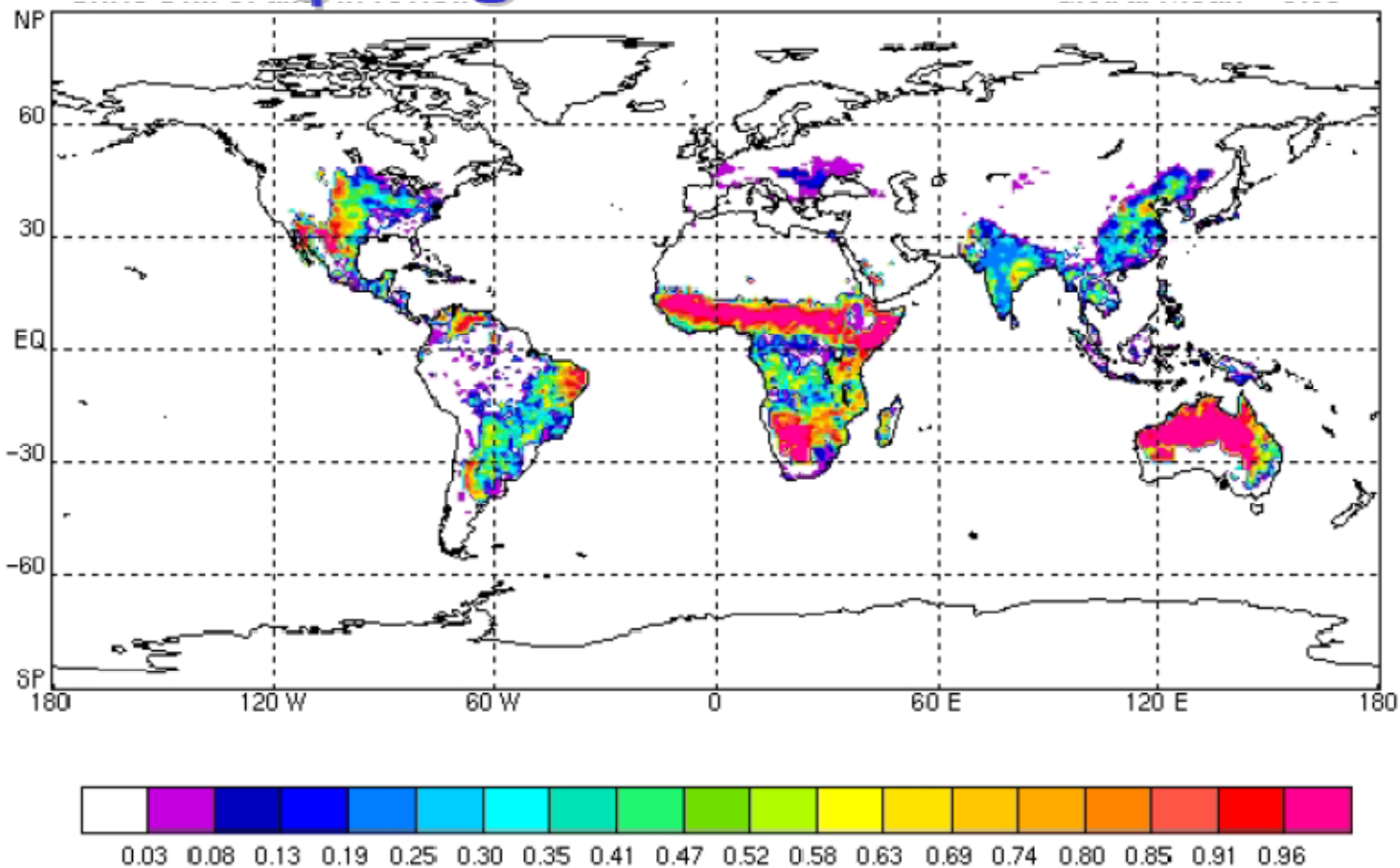


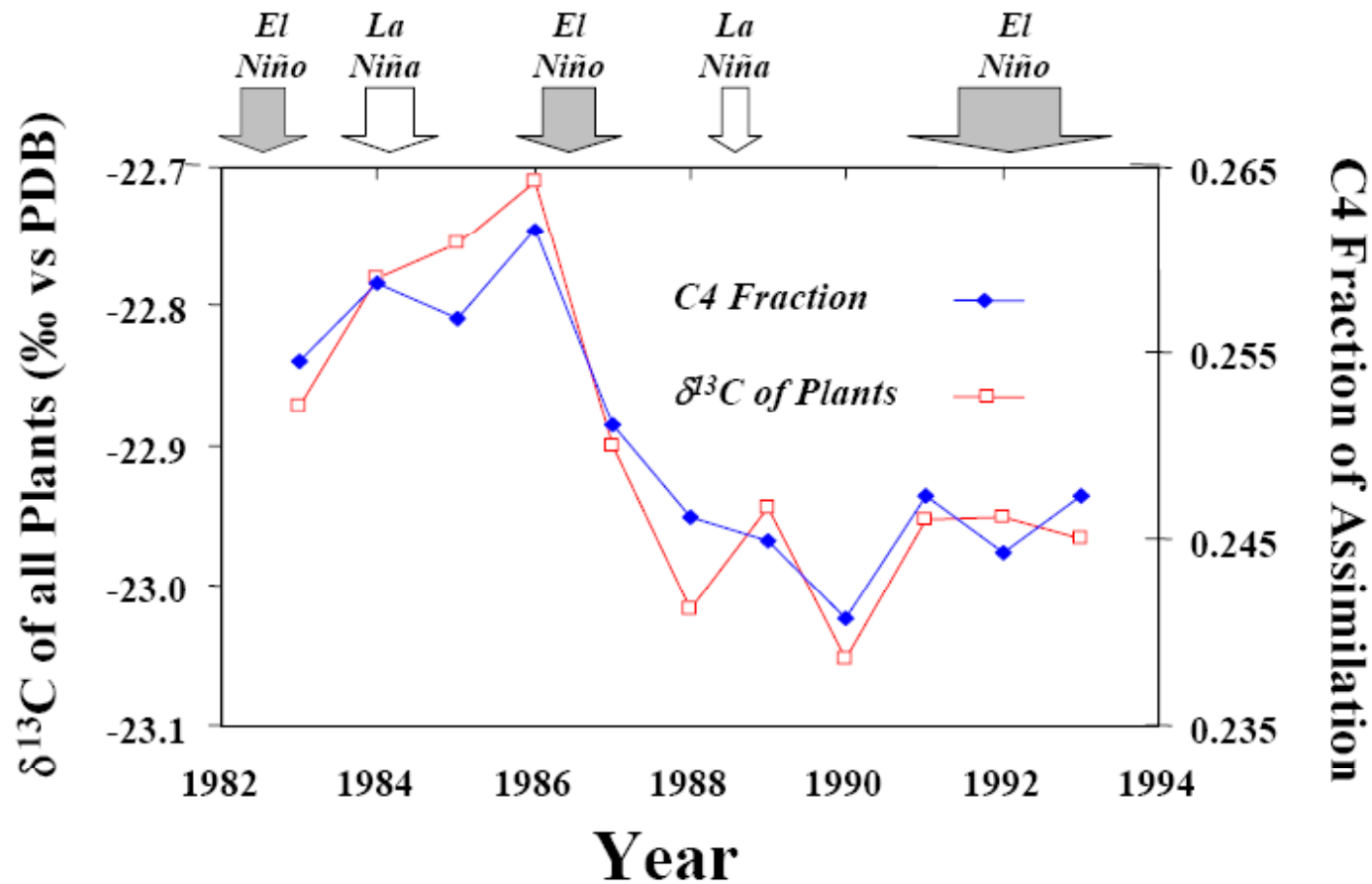
Simulated Annual Mean $\delta^{13}\text{C}$

Global Mean = -23.33



C₄ Vegetation Fraction





$^{13}\text{C}/^{12}\text{C}$ -Isotopenverhältnis liefert Informationen über

- **Herkunft der Schadstoffe (Verursacher)**
- **Abbauprozesse**
- **Alter des Schadens**

Ausgangsverbindungen:

Erdgas Erdöl Kohle

$\delta^{13}\text{C} = -25$ bis -50 ‰

**Technische Herstellung der LCKW verursacht
Isotopenfraktionierungen**

Chlorierte Kohlenwasserstoffe:

$\delta^{13}\text{C} = -8$ bis -45 ‰

