Determining Geographic Origins of Foods Using Stable Isotope Ratios

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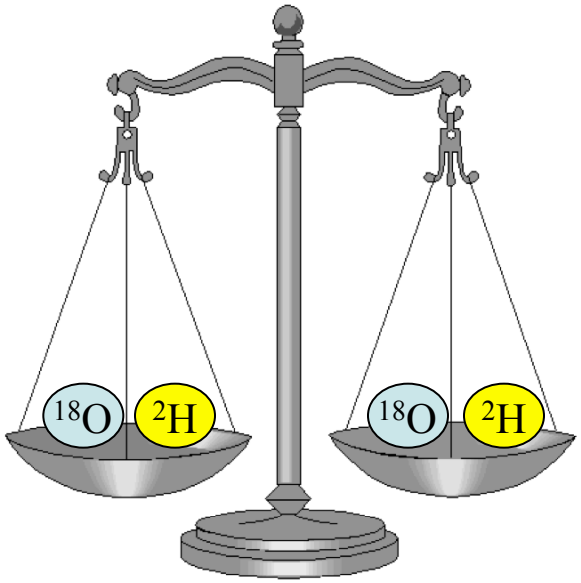
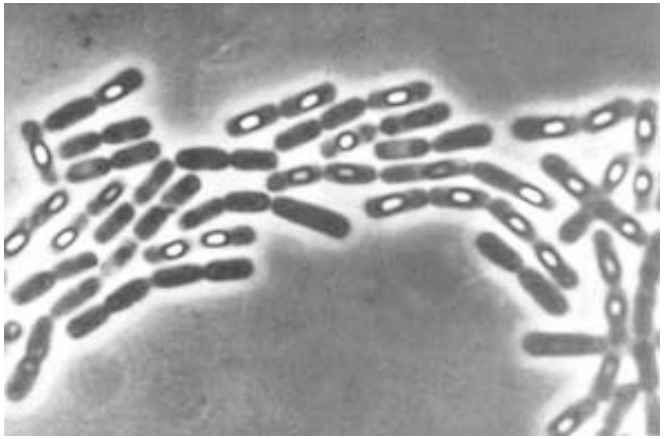


Thesis: geographical information is recorded in organic matter



There are multiple approaches to relate biology and geography

Stable isotopes of light elements

- biological-environmental interactions
- hydrological- and climate-based variations

Stable isotopes of heavy elements

- soil surface based variations

Elemental composition

- soil surface based variations

Genetic composition

- adaptive based variations
- breeding based variations

Applications of isotope analyses at natural abundance levels

Hydrogen and oxygen isotopes

- geography of water and water-based products
- geography of protein foods (e.g., meats, seeds)
- geography of carbohydrate foods (e.g., honey, flour)
- geography of lipid-based foods (e.g., oils, waxes)
- adulteration of beverages and juices

Carbon isotopes

- food sources for animals (e.g., C3 versus C4)
- adulteration of foods, beverages, juices, spirits

Nitrogen isotopes

- nitrogen sources for plants (i.e., fertilizers)
- food sources for animals

Sulfur isotopes

- inland versus coastal geography
- sulfur sources for plants (i.e., fertilizers)
- food sources for animals

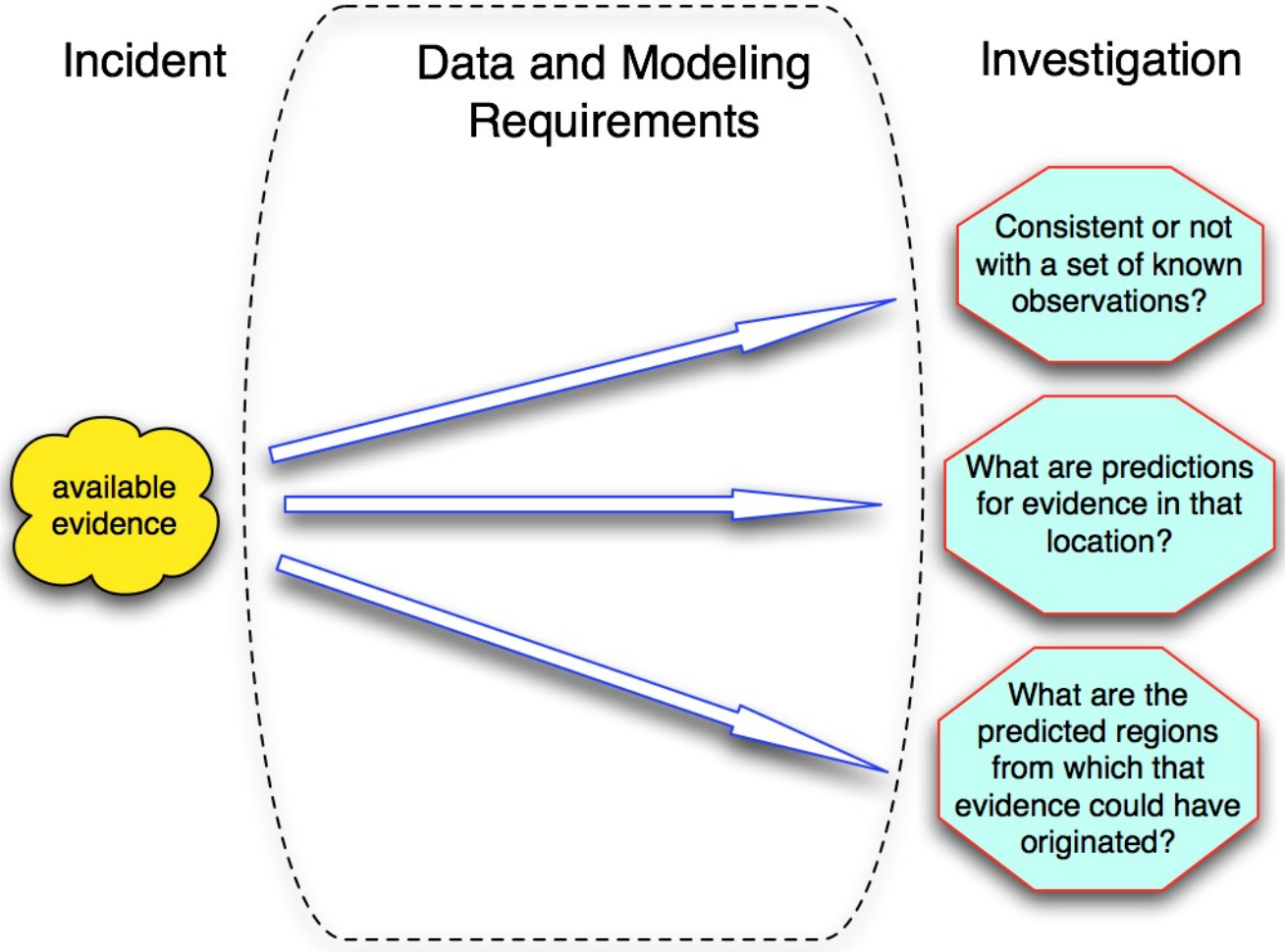
Stable isotope analyses are increasingly useful in forensic studies

Floyd Landis is guilty of drug use

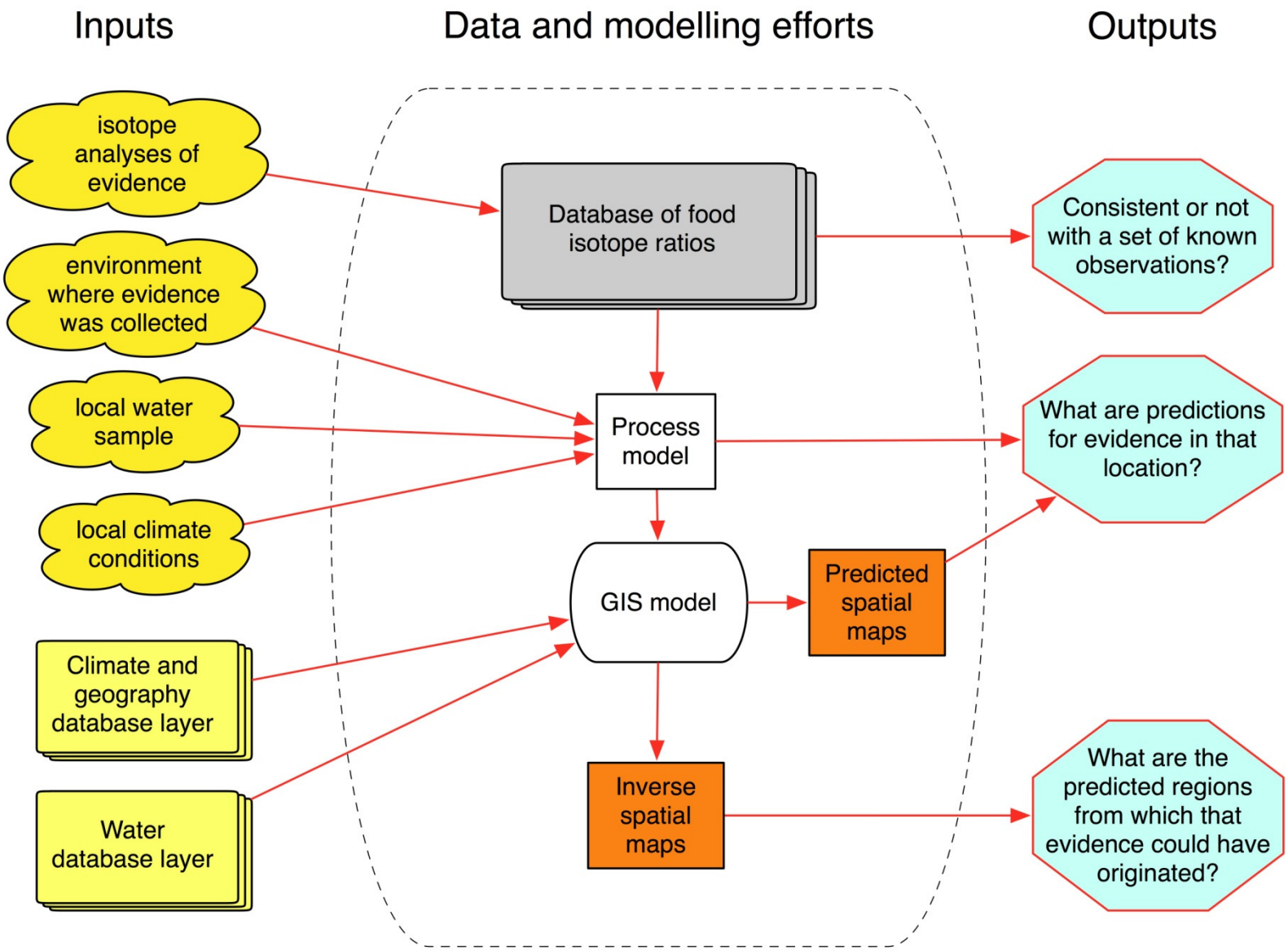
"Saltair Sally"

Pong Su, North Korea ship, found loaded with heroin

. . . where the objective is linking evidence to potential sources



Our approach to addressing the regions-of-origin



Stable isotopes are multiple forms of the same element

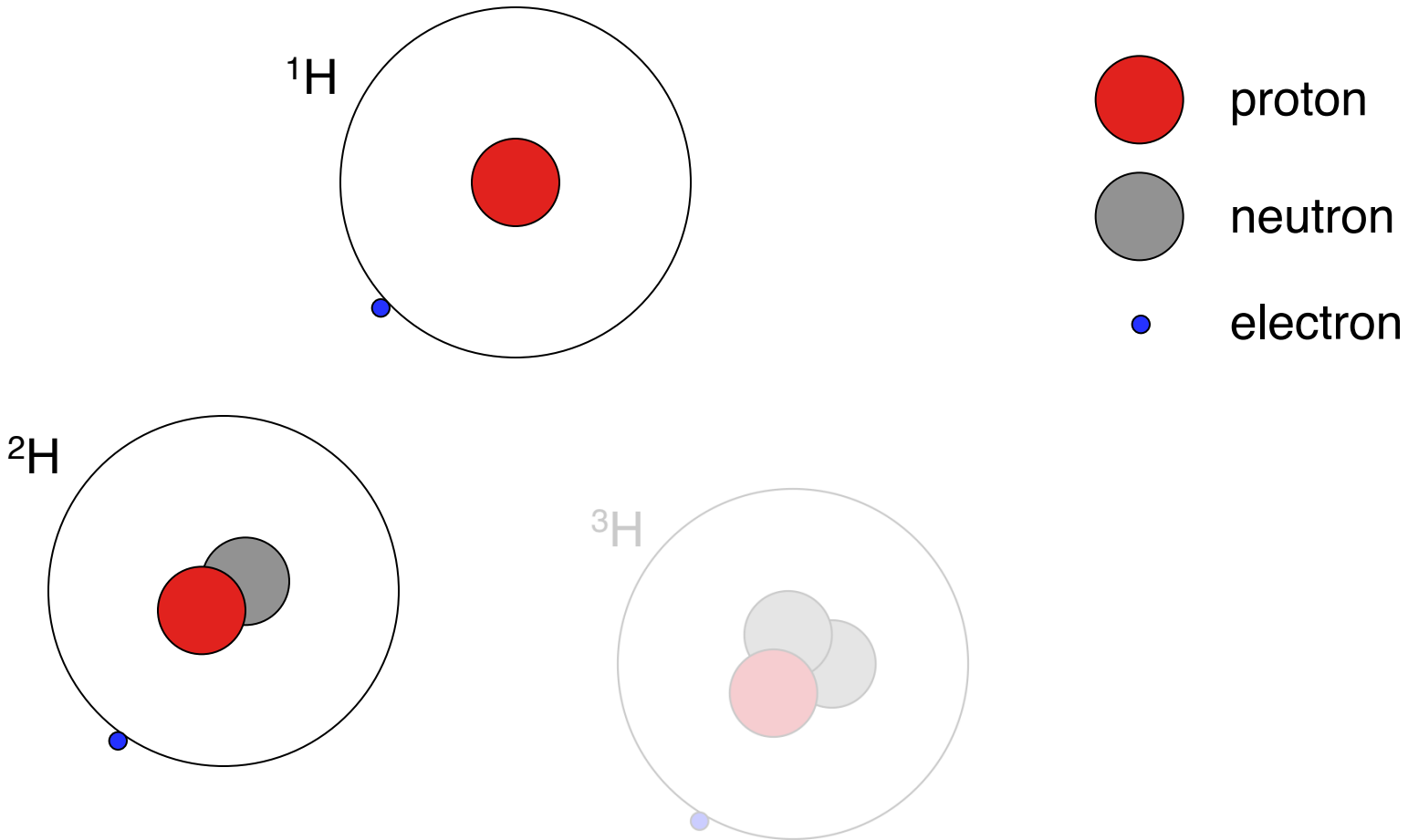
For example,

Hydrogen stable isotopes = ^{1}H and ^{2}H

Carbon stable isotopes = ^{12}C and ^{13}C

Nitrogen stable isotopes = ^{14}N and ^{15}N

Heavier stable isotopes contain an additional 1-2 neutrons



How do we express stable isotope abundances?

$$R = \frac{\text{heavy isotope}}{\text{light isotope}}$$

what do we mean by ratio

carbon as an example

$$R = \frac{^{13}C}{^{12}C}$$

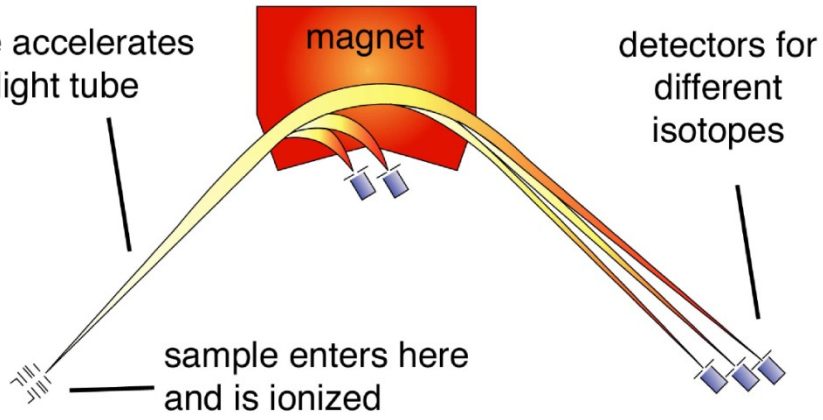
the isotope ratio is typically presented in delta notation

$$\delta = \left(\frac{R_{sample}}{R_{standard}} - 1 \right) \bullet 1000 \text{ ‰}$$

An isotope ratio mass spectrometer measures isotope ratios

light gas elements

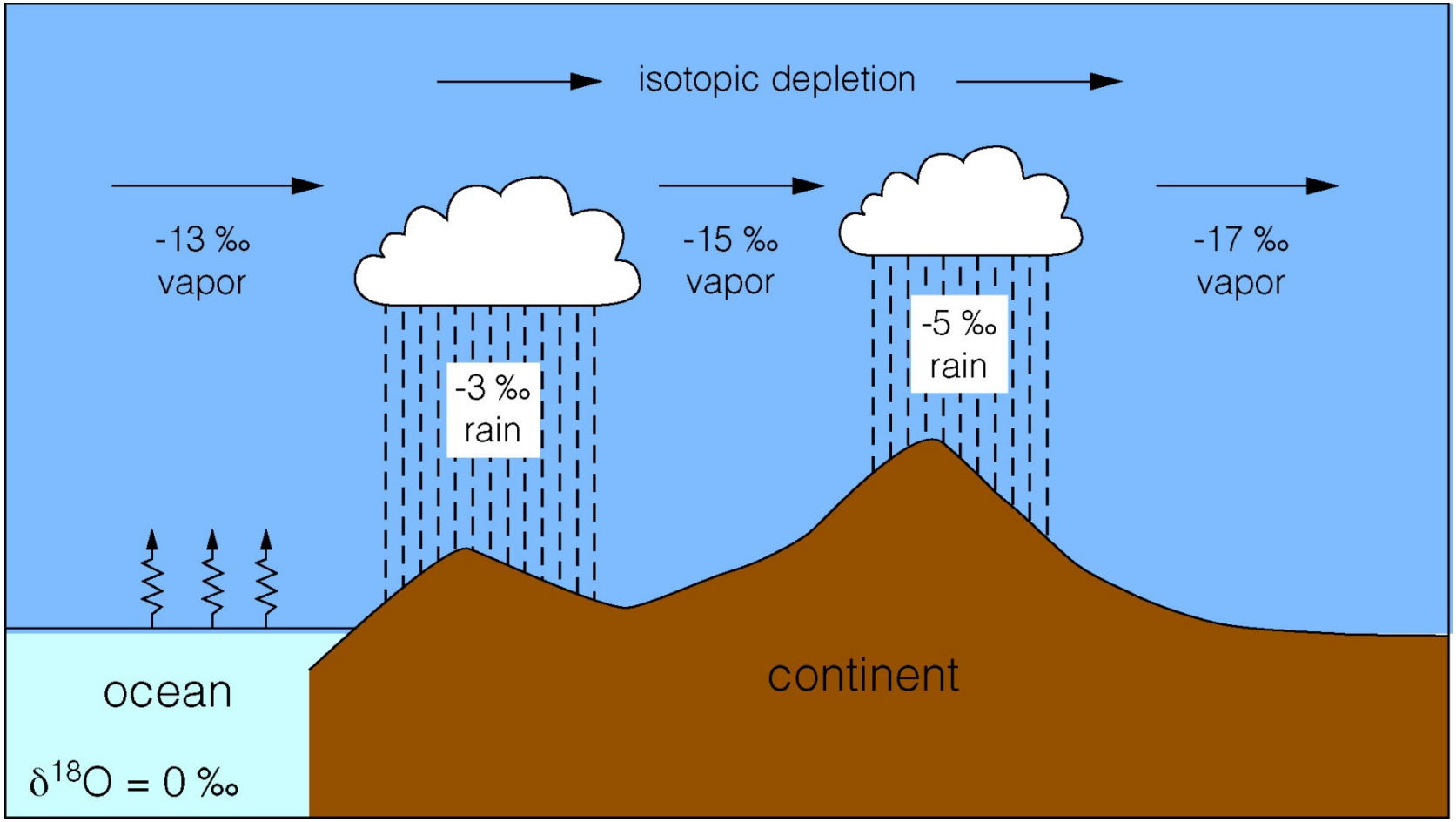
H_2
CO
CO_2
N_2
SO_2



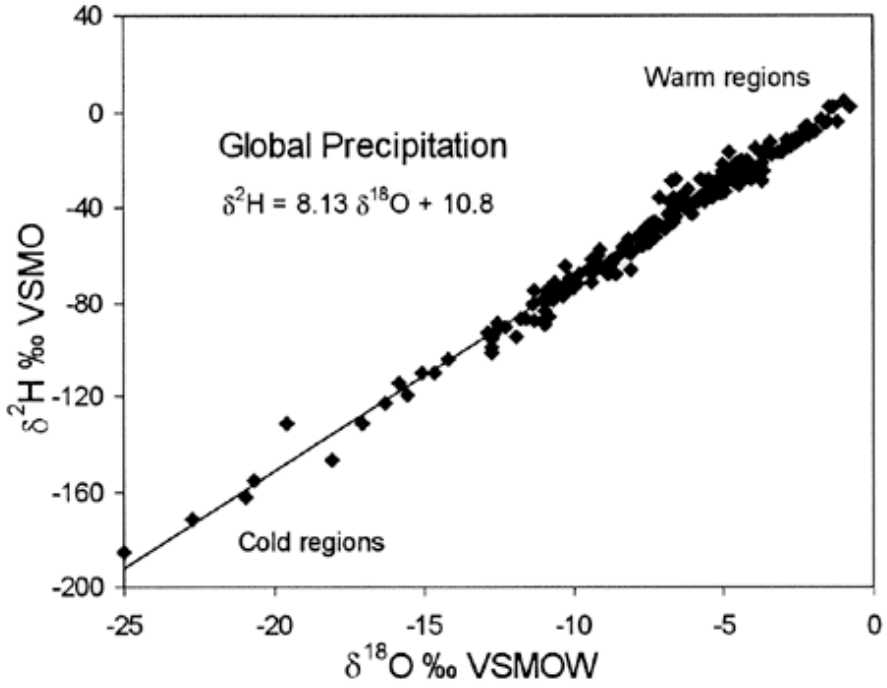
continuous flow linkage

- elemental analyzer
- gas chromatography
- liquid chromatography
- laser ablation

^{2}H and ^{18}O isotopes preferentially fall out of precipitation first, leaving a residual cloud mass that is isotopically depleted



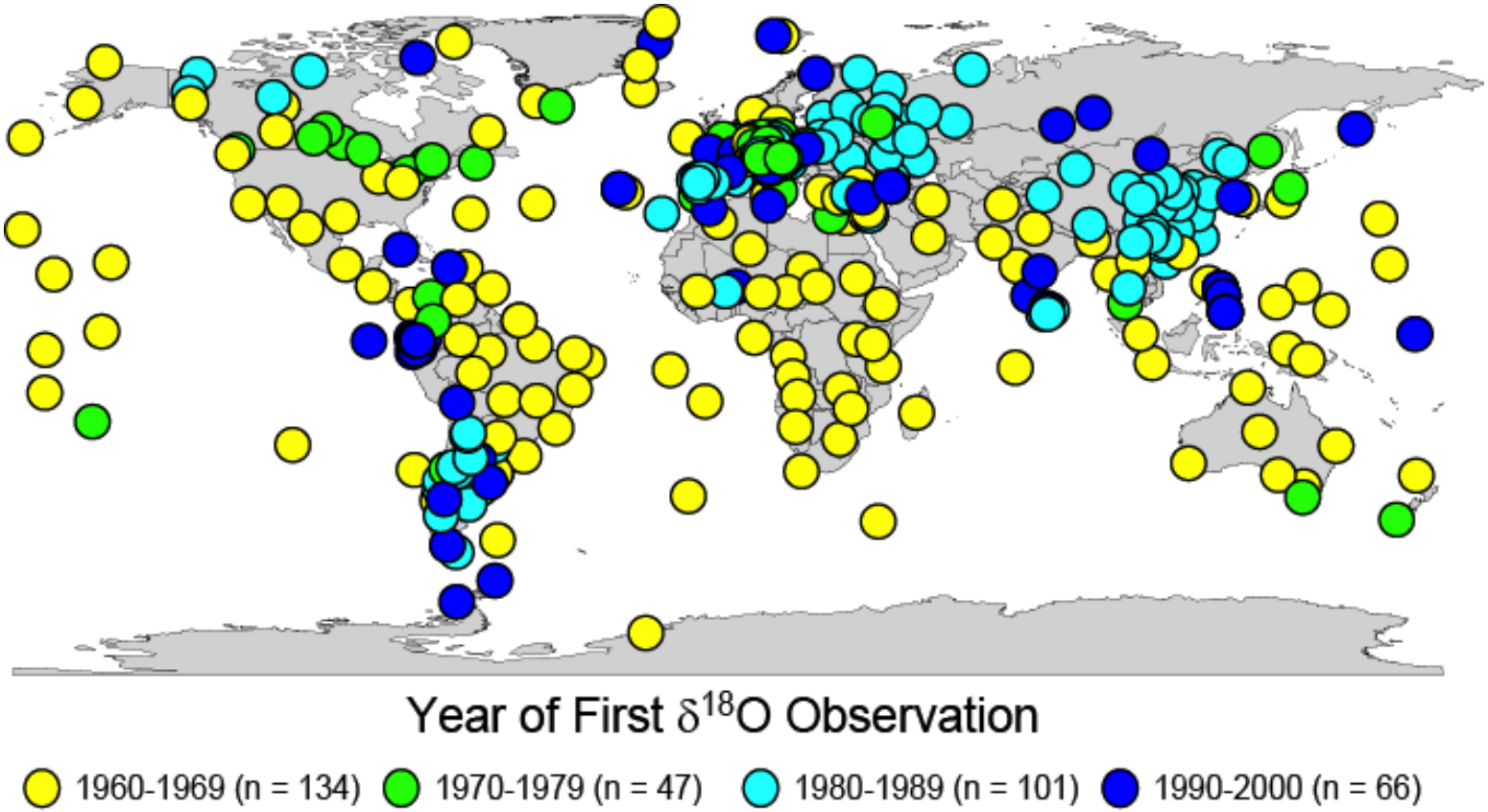
H and O isotopes of rain follow a linear relationship



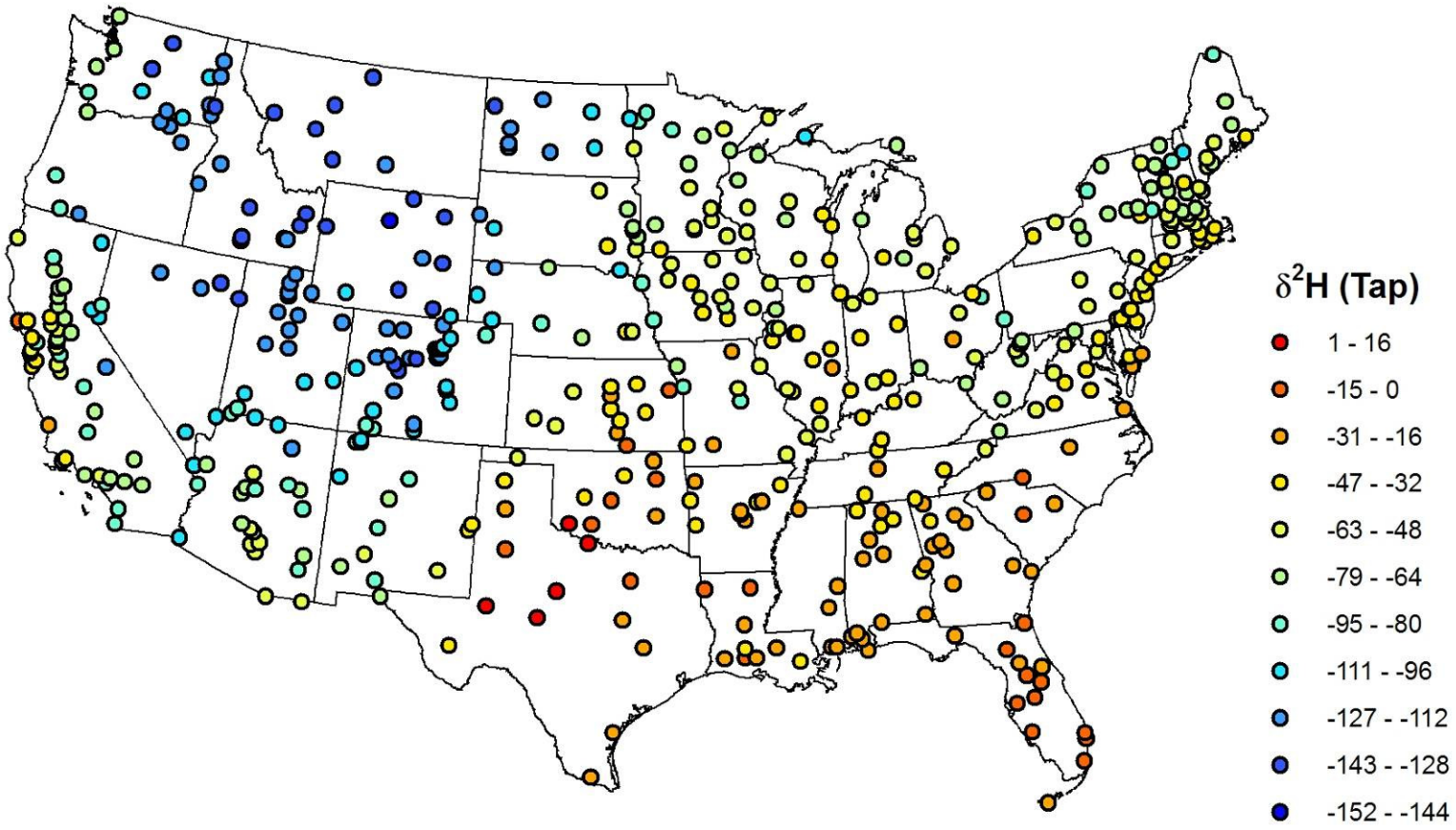
The slope of this line is 8 and is known as the meteoric water line; evaporated water has a slope of less than 8.

We determine patterns using observational data --- e.g., rainfall

- http://isohis.iaea.org/



We spatially integrate using observational data --- e.g., tapwater



Bowen et al., 2007

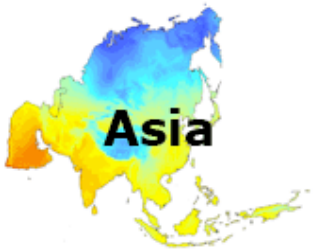
Maps are produced in GIS using isotope, latitude, and elevation

Waterisotopes.org

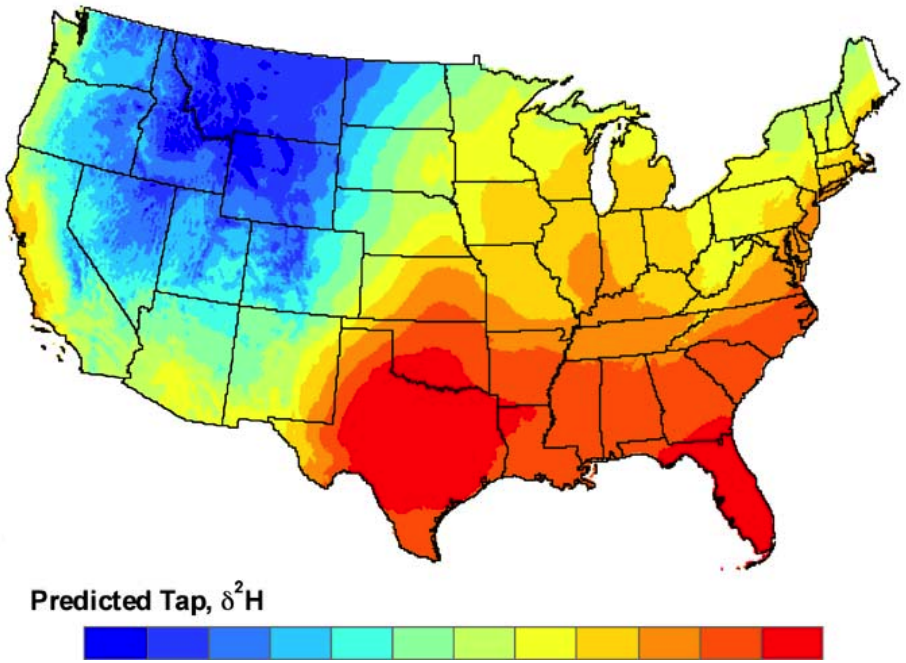
ISOSCAPES

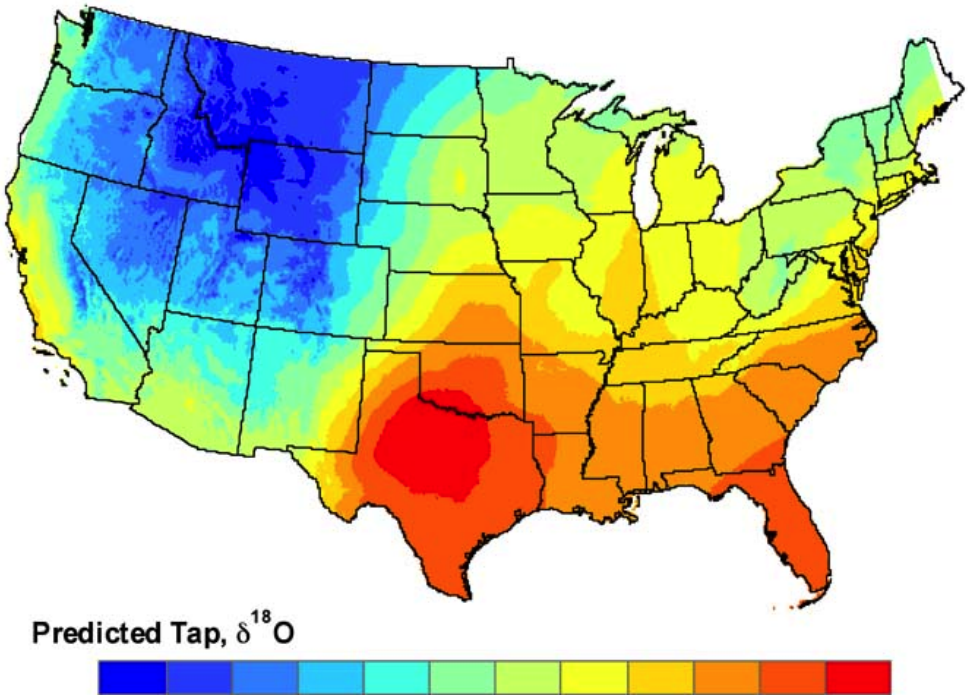
Gabe Bowen

PURDUE UNIVERSITY



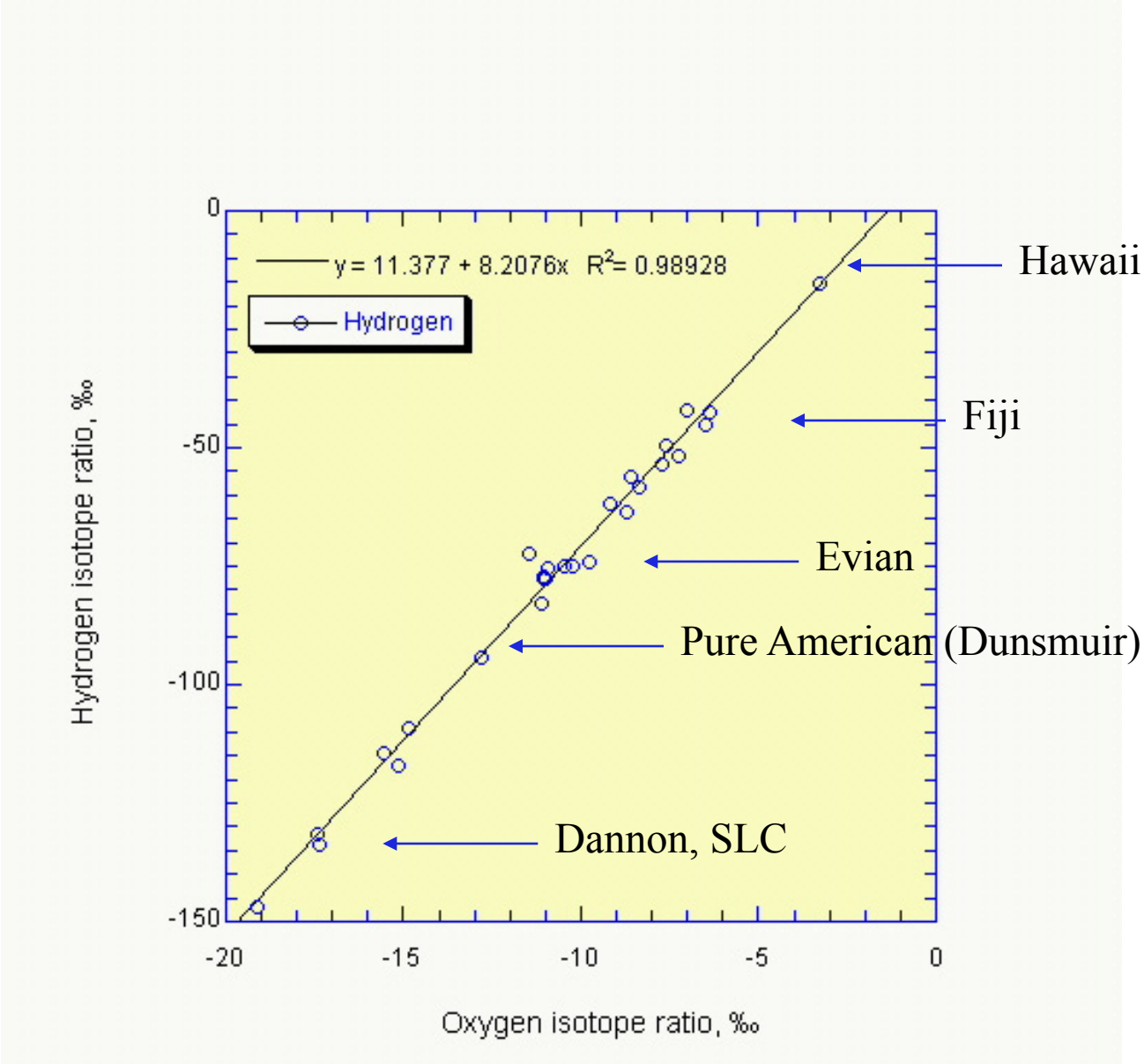
Water isotopes reveal consistent predictable patterns





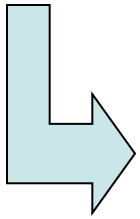
Bowen et al., 2007

Application: verifying the origins of bottled waters



An organism's water isotopes reflect the water source geo-environment

environment water



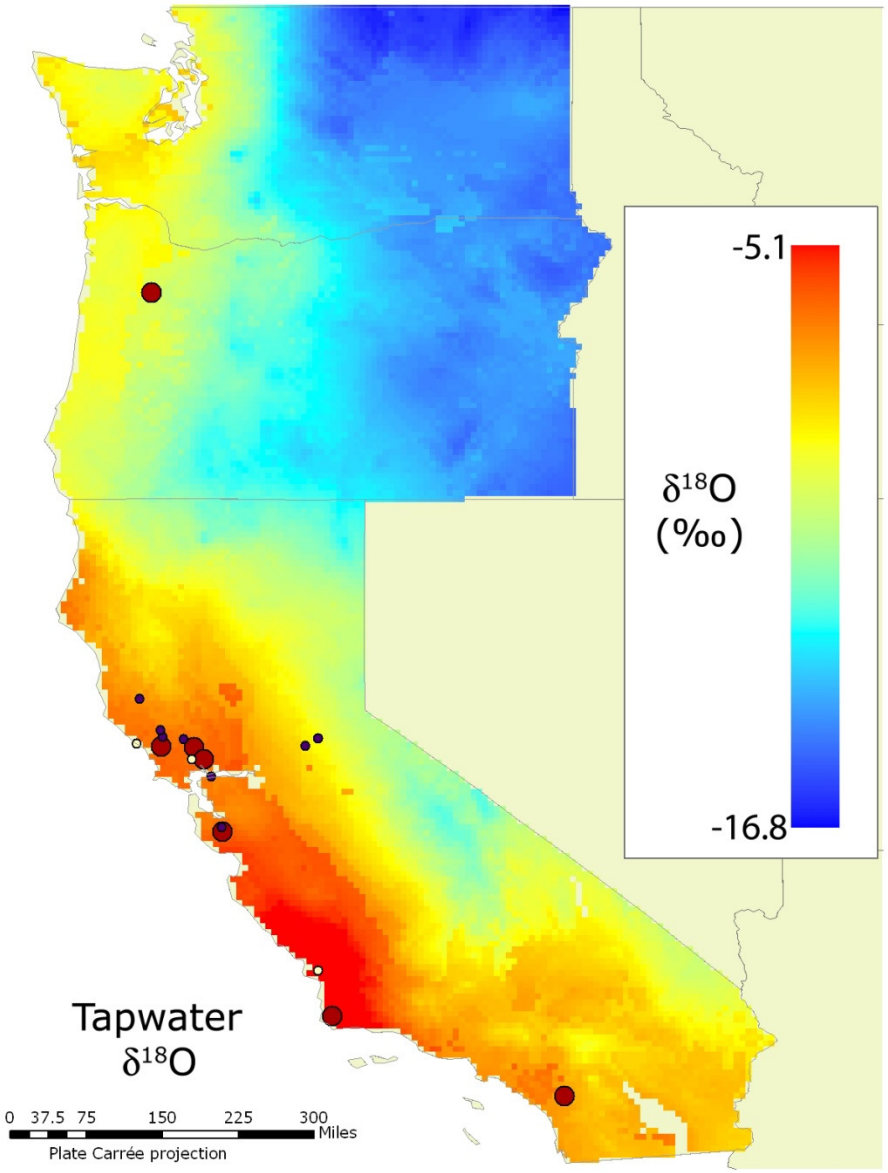
organism water
(blood, leaf water, etc.)

A series of fractionation events occur along the sequence from the water in a geographical region to the water in the organism. Included are evaporation, metabolism, and respiration factors (can be modeled).

blood
leaf water
juices
beverages
wine
fruit

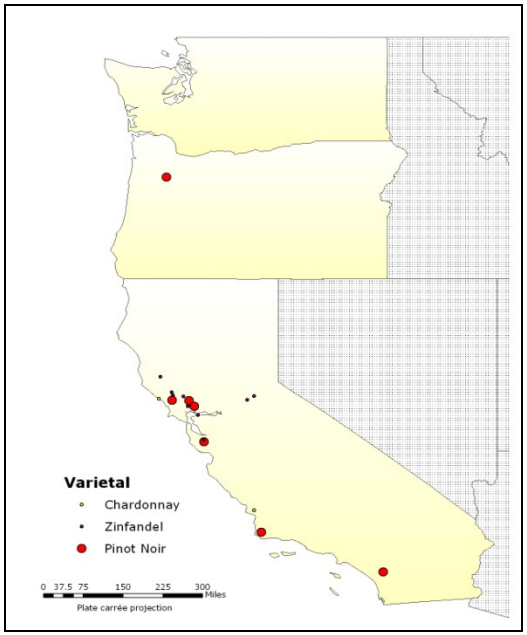

(c) 2005 reto ambühl

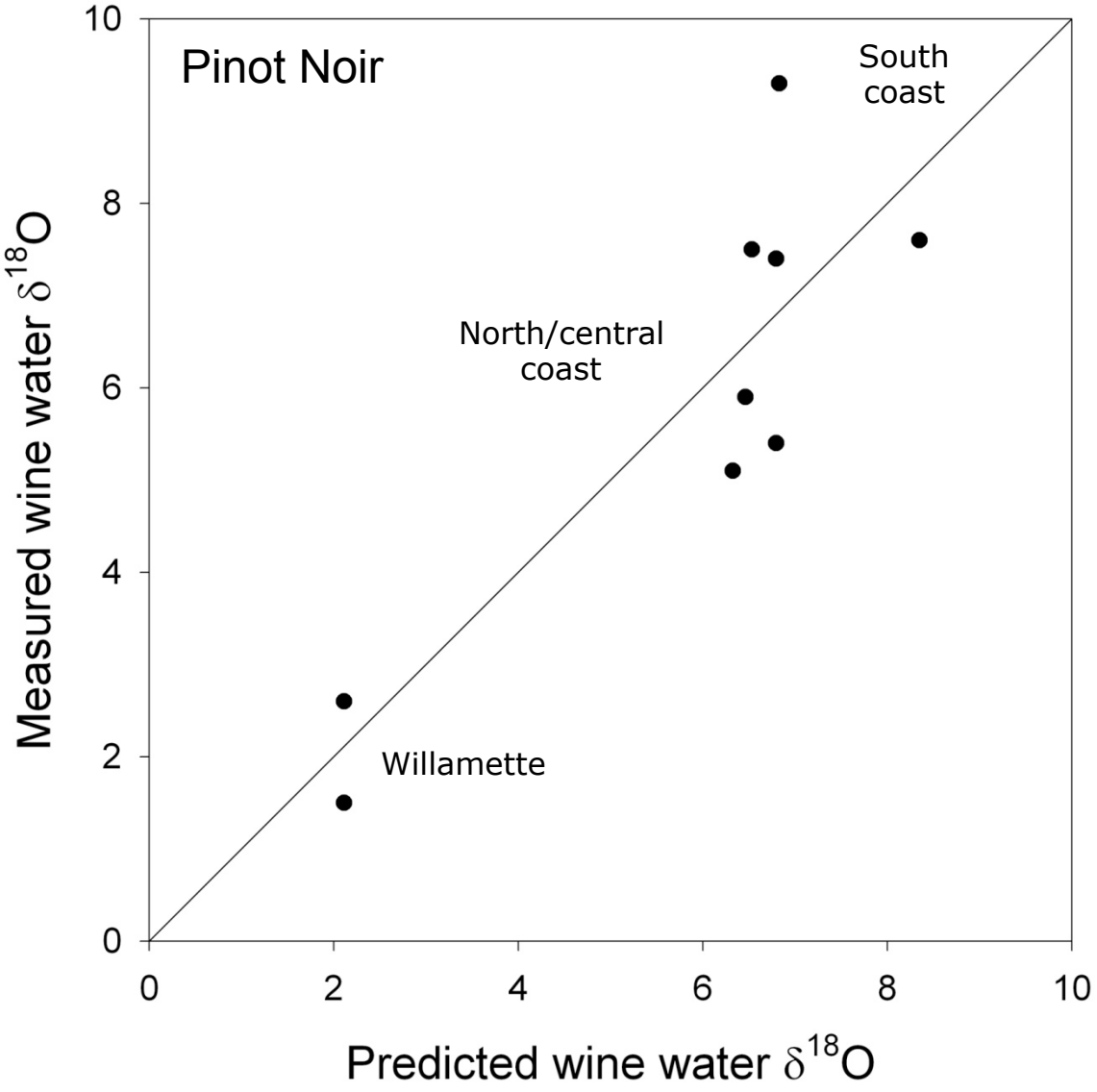
Application: predicting the origins of wine



West et al. (2007)

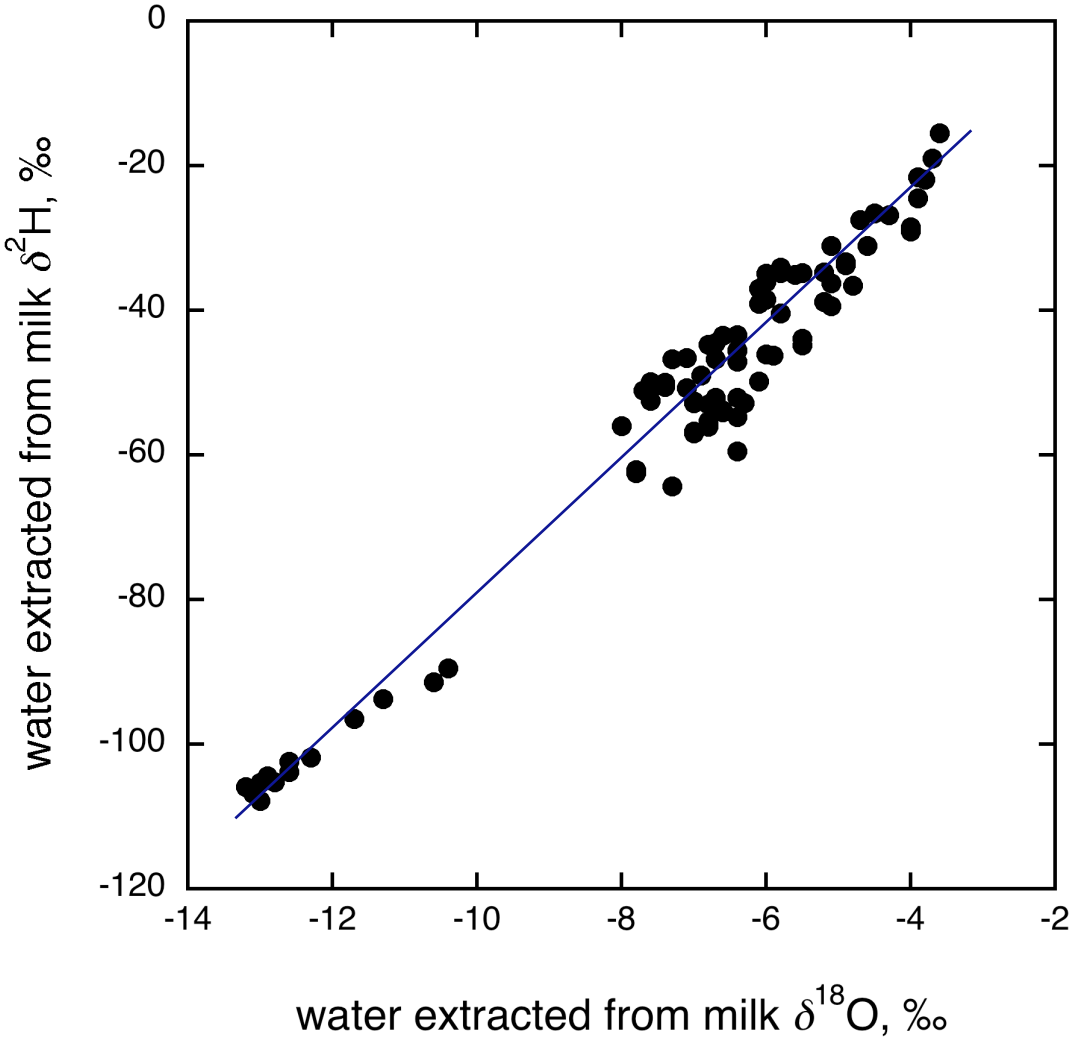
Stable isotopes predict origins of wine varietals

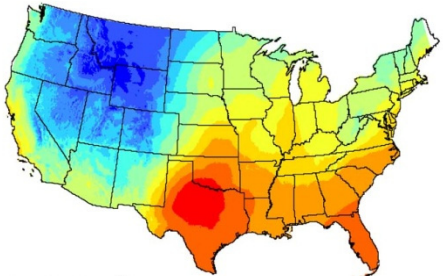




West et al. (2007)

Water in milk across the USA exhibits geographic variation



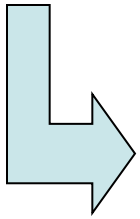


Chesson et al., unpublished (see poster)

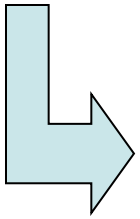
Organic H and O isotopes record water environment

A series of fractionation events occur along the sequence from the water in a geographical region to the organic matter of the organism.

environment water

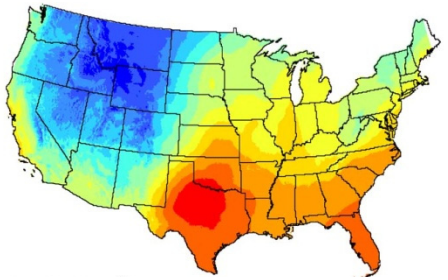


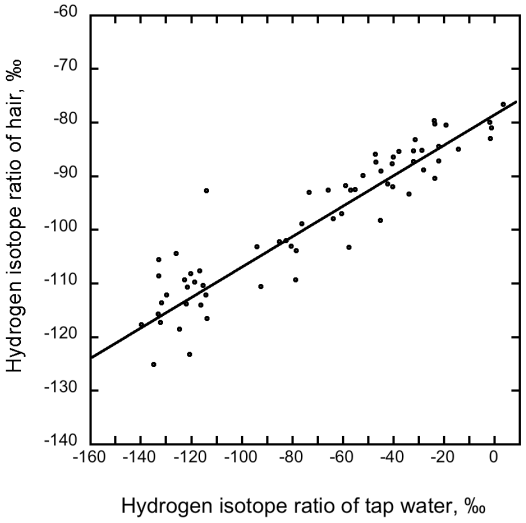
organism water
(blood, leaf water, etc.)

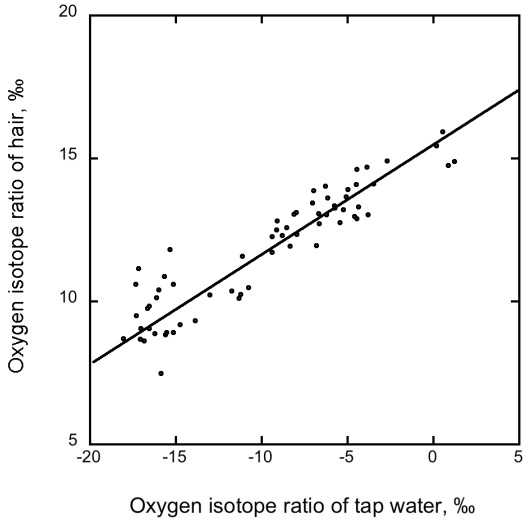


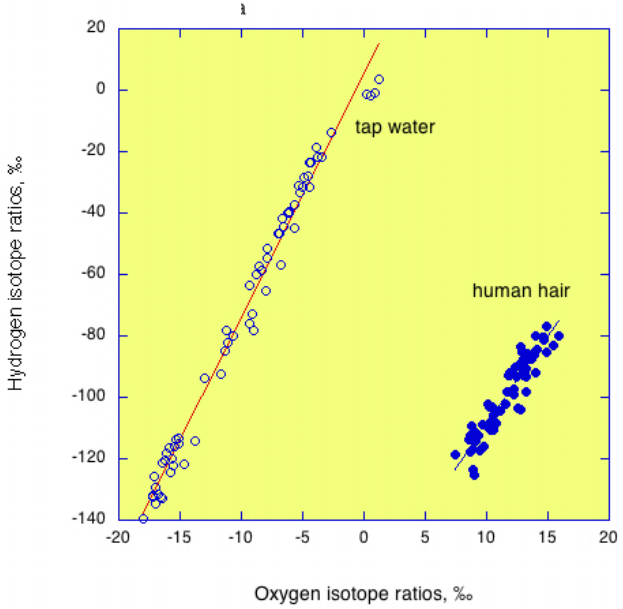
plant or animal
organic matter

Hydrogen and oxygen isotope ratios of keratin protein are correlated with tap water



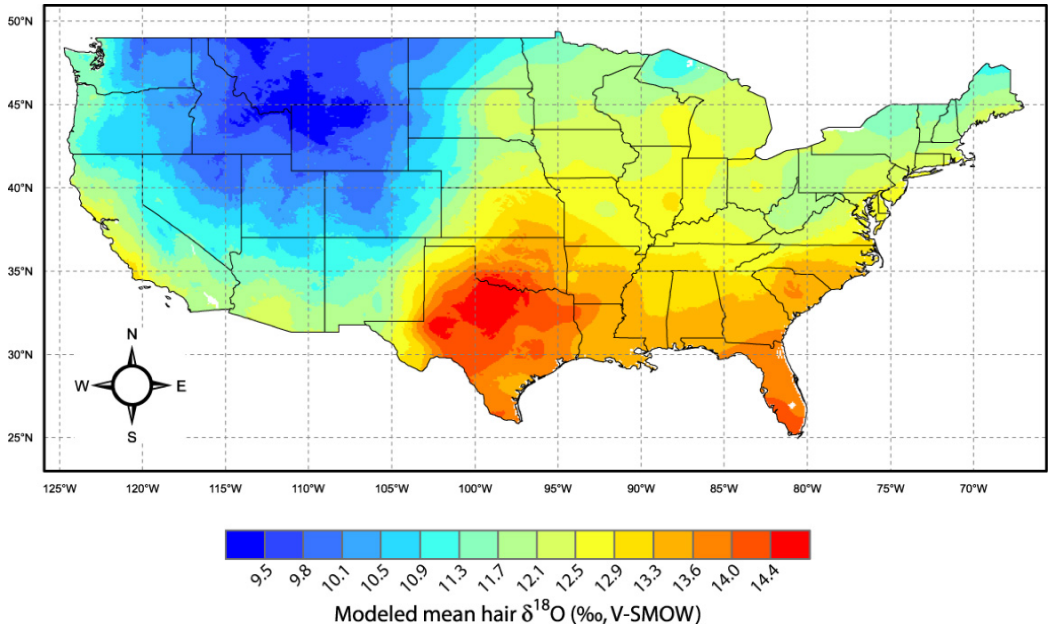




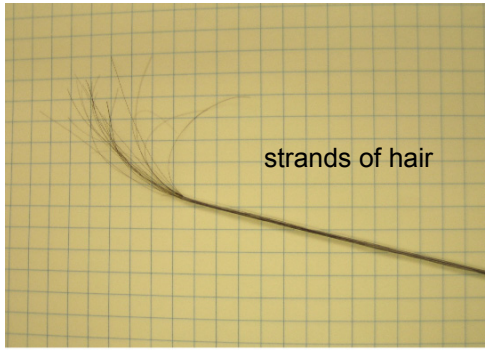


Ehleringer et al. (2008)

Application: O isotopes in hair reveal geographic movement



"Saltair Sally"



travel histories

Ehleringer et al. (2009)

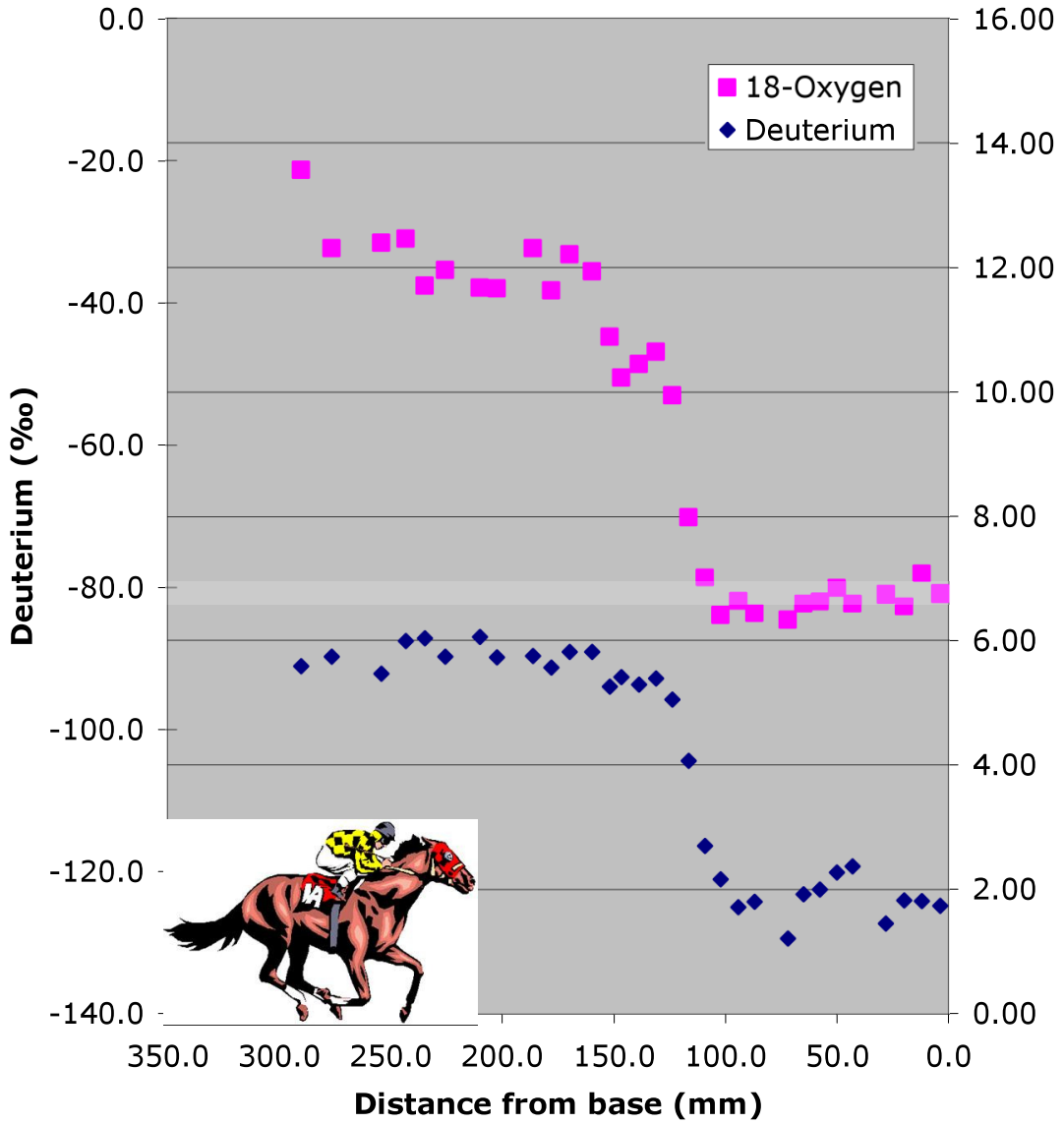
Application: O isotopes in hair reveal geographic movement

Consider the movement of an animal based on the stable isotope analysis of a single hair

History:

Jan - Nov 2002, Virginia

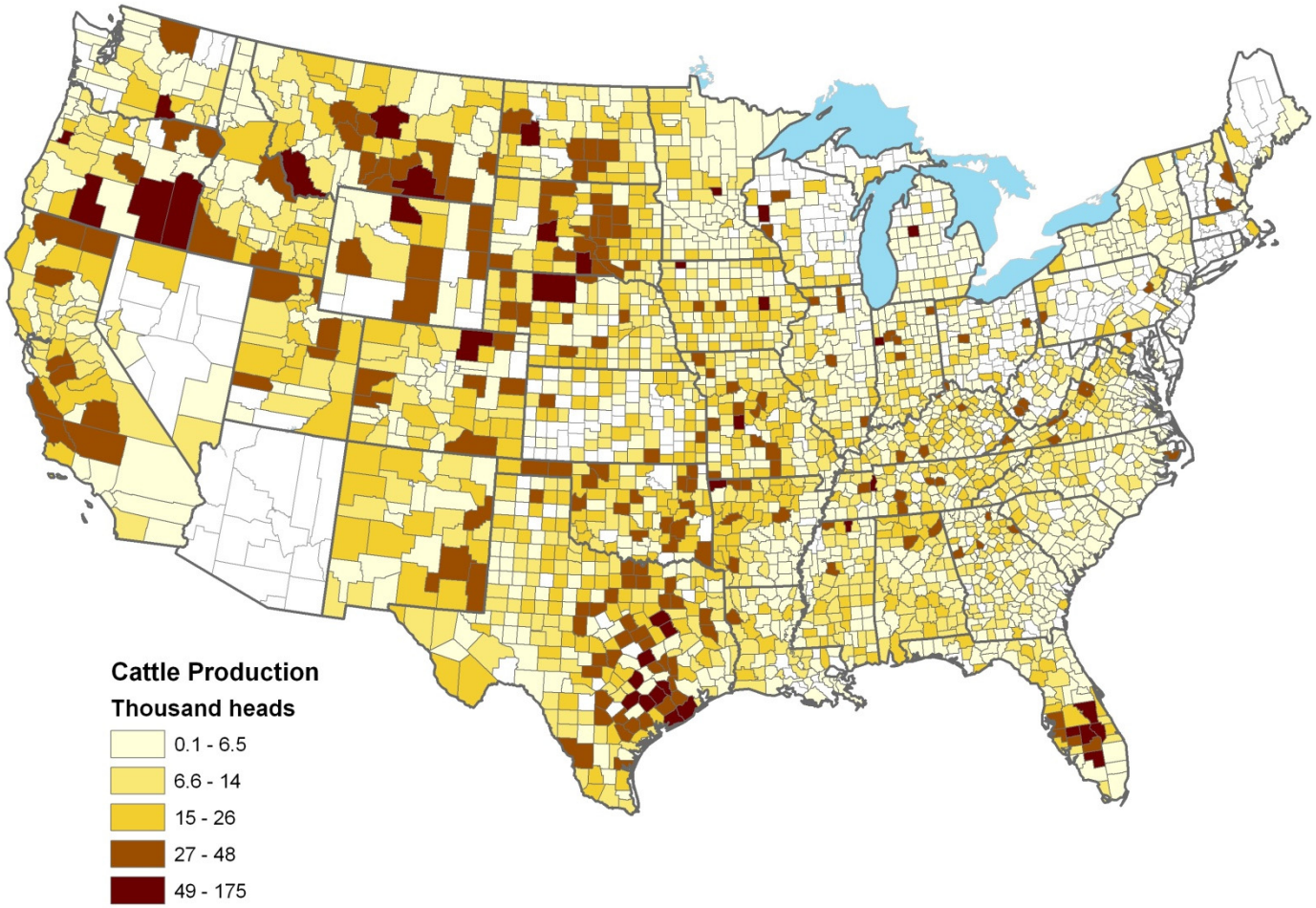
Nov - May 2003, Utah



(unpublished data)

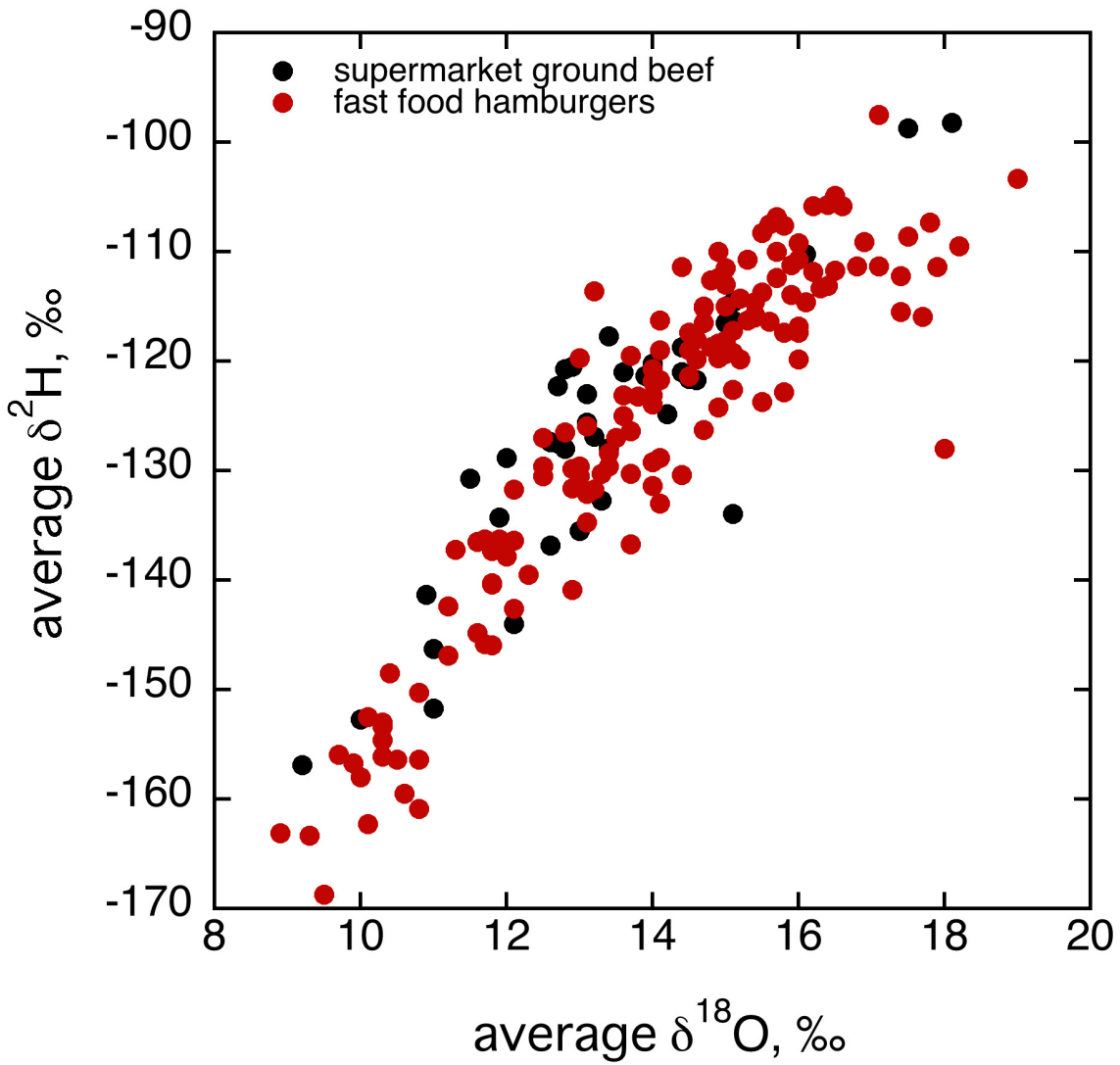
The same approach can be applied to food proteins

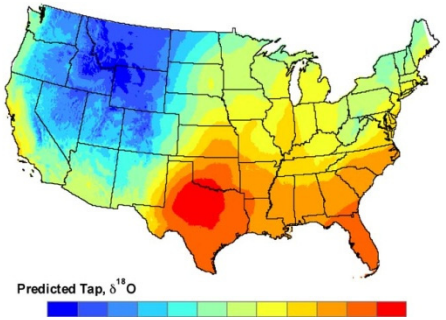
Cattle are concentrated in isotopically distinct regions



Data from 2002 (USDA National Agricultural Statistics Service)

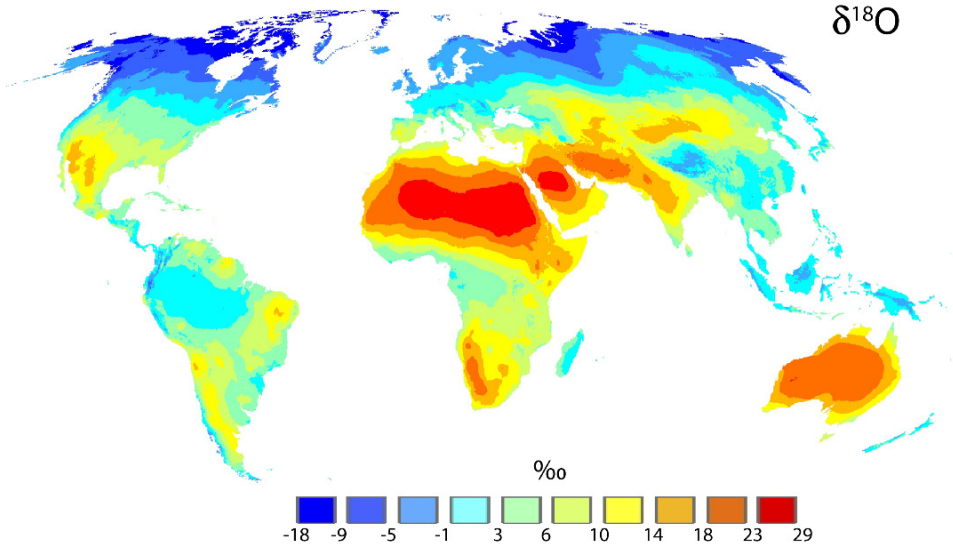
Beef H and O isotope values exhibit significant correlationship

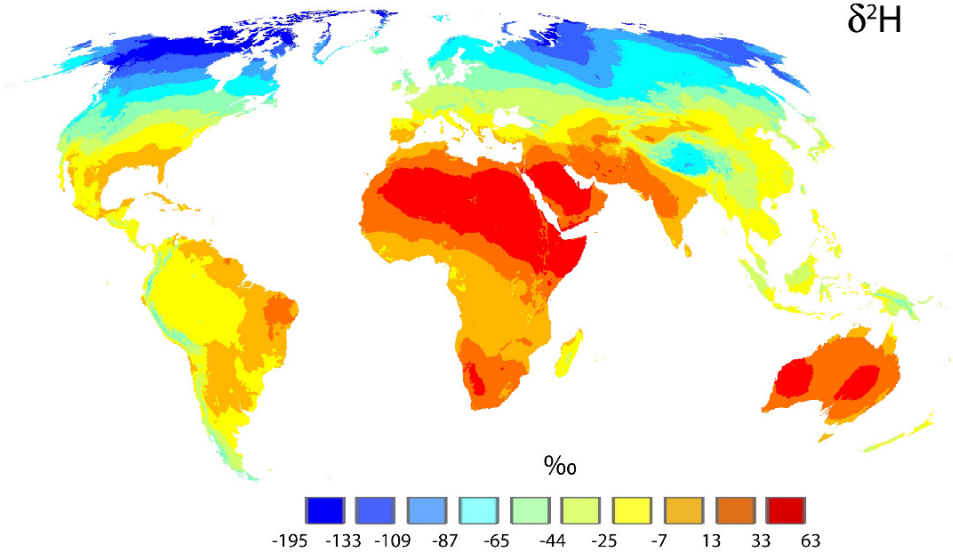




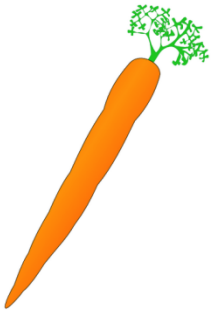
Chesson et al. 2008; in review

Evaporation enriches leaf water above meteoric water





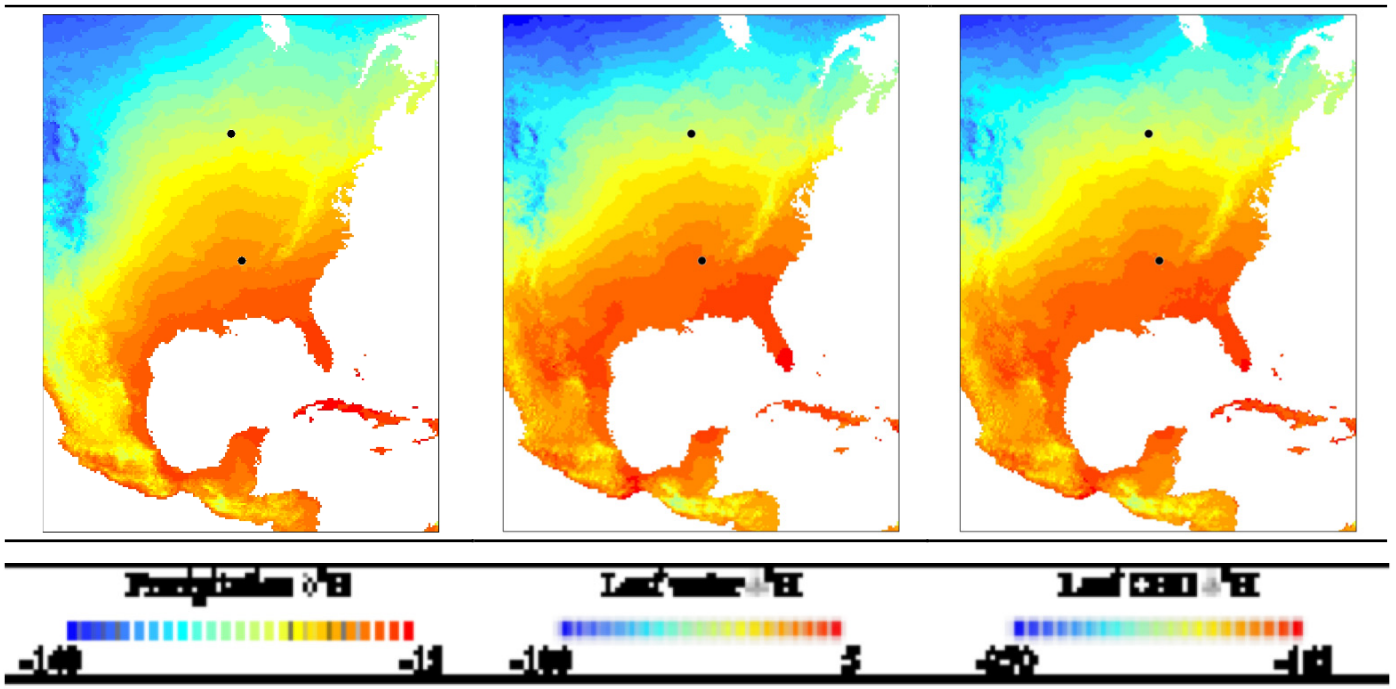
Applications:



West et al. (2008)

Application: sourcing of vegetable foods

environment water | organism water | organic matter

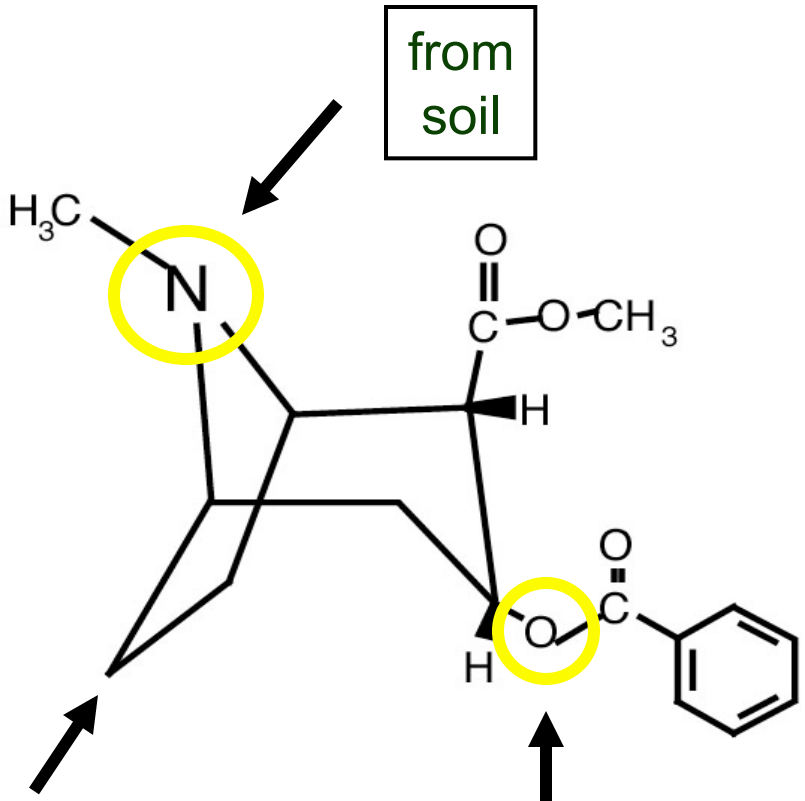


environment water | leaf water | carbohydrate

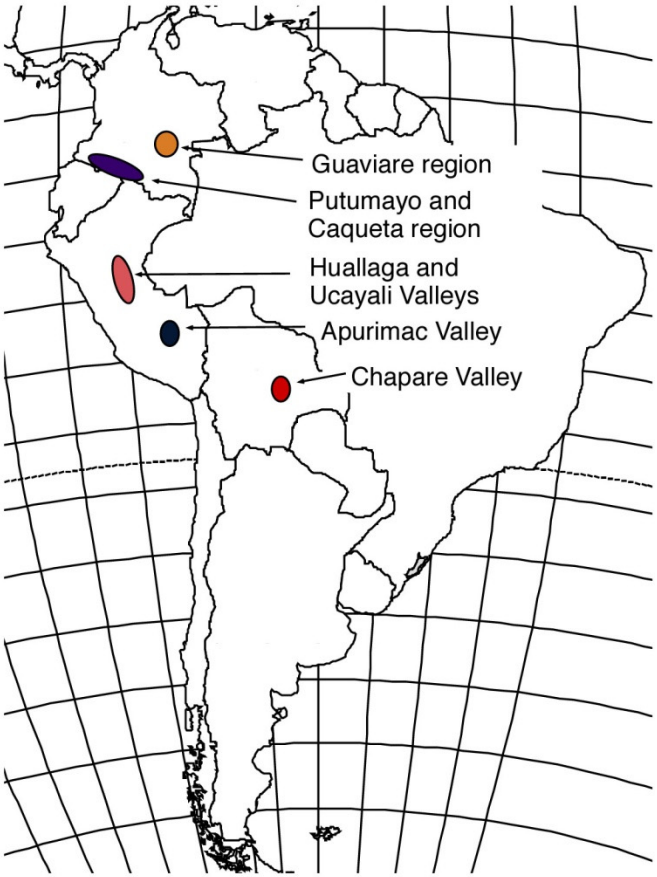
West et al. (2008)

Application: C & N isotopes can identify some geographic regions

Cocaine



Application: C and N isotopes can identify geographic region



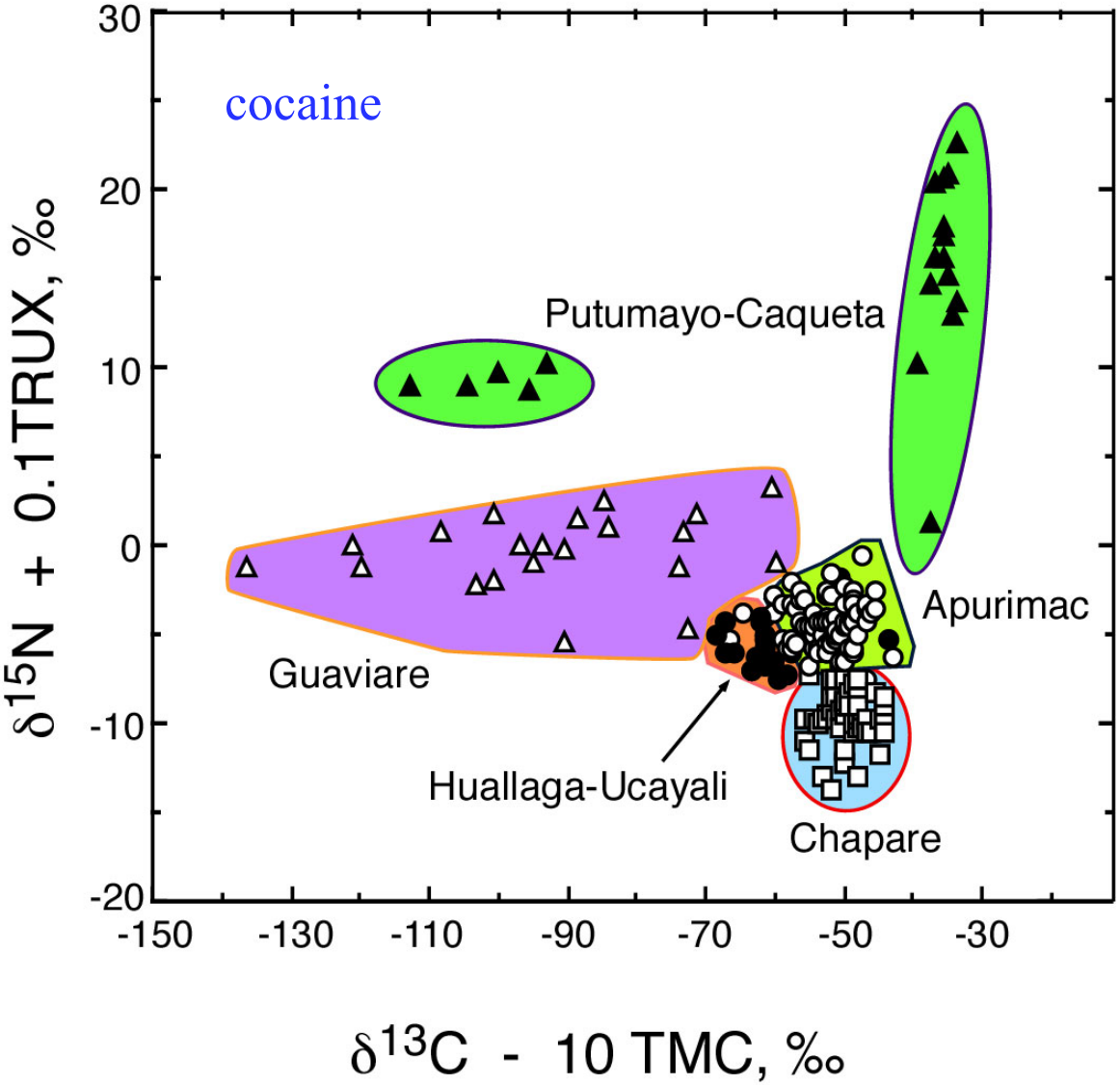
Almost all of the cocaine in South America originated from one of only 5 regions.

These regions fall along a climatic gradient with the wettest regions in the north and driest in the south.

Ehleringer et al. (2001)

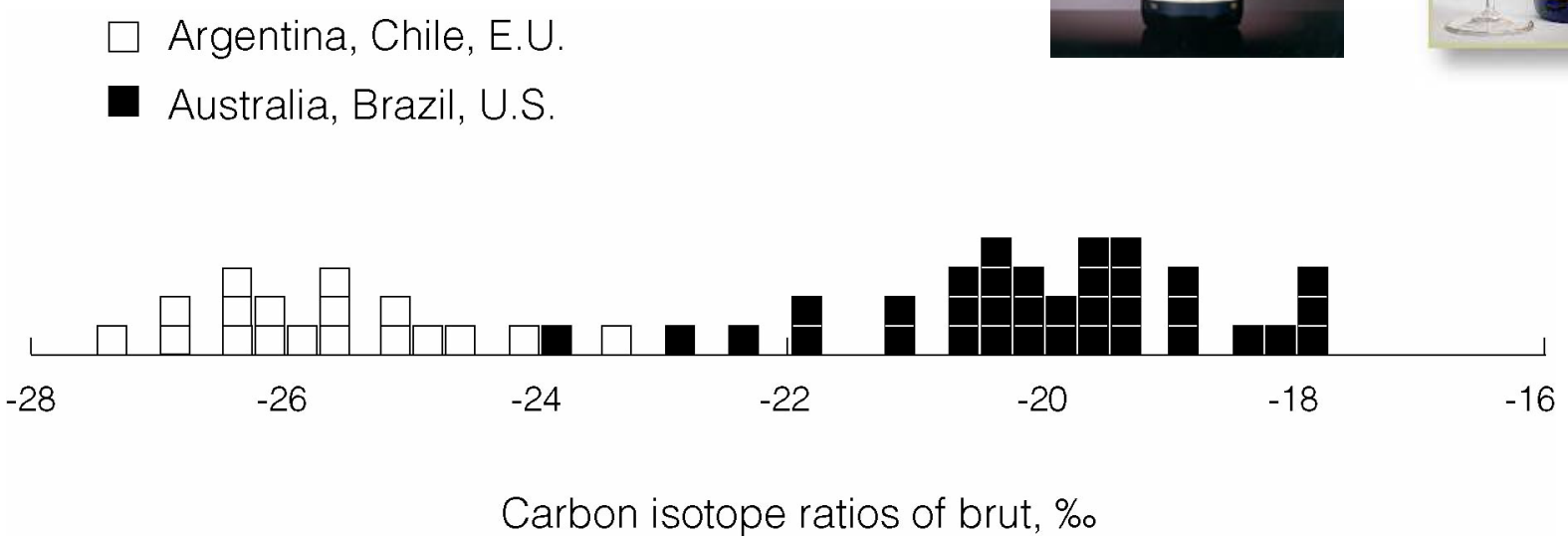
Collaboration with John Casale, DEA

Isotopes, TMC, and TRUX explain ~96 % of cocaine variation



Ehleringer et al. (2001)

Adulteration: C4 sugars in sparkling wines



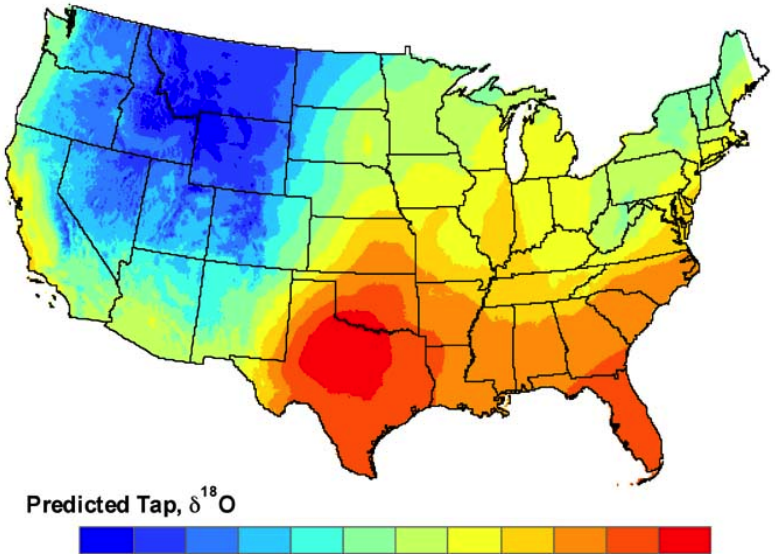
Martinelli et al. (2003)

Adulteration: C4 sugars in sparkling wines

Martinelli et al. (2003)

Nationwide and international stable isotope applications

- eliminating regions as a source of contaminant
- delineating regions consistent with source of a threat
- contribute to traceability of food items
- region-of-origin authentication



- beverages and juices
- protein sources
- vegetables and fruits
- fiber
- oils
- extracted compounds
- adulteration in foods
- adulteration in beverages