Geographical provenancing of food using spatial prediction models of light and heavy isotopes

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Food fraud


HOW THE PUBLIC CAN BE DECEIVED
MEAT
Selling non-organic meat as organic.
Adding excessive water to meat without declaring it.
Selling meat unfit for human consumption.
Adding beef and other meat to 100% pork sausages.
Selling 'lean' meat that contains as much fat as standard.
Substituting Parma ham with a cheaper product.
FISH
Selling farmed fish as wild.
Mislabelling the geographic origin.
FRUIT AND VEGETABLES
Selling conventional produce as organic.
Giving the wrong geographical origin.
Selling cheaper varieties of potato as an expensive variety such as King Edwards.
Adding GM soya beans to conventional beans, without declaring them.
EGGS
Selling battery farm eggs as free-range.
CHEESE
Using cow's milk rather than buffalo milk to make mozzarella.
OLIVE OIL
Dyeing it dark green with chlorophyll to make it look like extra virgin.
Diluting olive oil with cheaper hazelnut oil.
ORANGE JUICE
Diluting it with inferior quality juice.
Adding beet sugar to sweeten 'natural' orange juice.
COFFEE
Adulterating highly sought-after arabica beans with cheaper varieties.
ALCOHOL
Selling counterfeit versions of big brands, which can include dangerously high levels of methanol.
Watering down spirits.
Substituting cheap varieties for expensive premium brands in bars.
Adding extra sugar during wine making to increase alcohol content
RICE
Using cheap varieties to bulk up expensive basmati rice.

Food fraud related to geographical origin

Link with human forensics

Link with human forensics

theguardian

Tracing Adam

Two years ago a small boy's torso was pulled out of the Thames. With so little to go on, standard forensics were almost useless. It was time to get creative, explains Giles Tremlett.

Giles Tremlett
The Guardian, Thursday 7 August 2003 02.18 BST

It was not much to go on. All they had was one tiny boy's torso, already bloated with river water from the Thames and drained of blood. There was no head, no arms and no legs. The only clothes were a pair of bright orange shorts. It was, of course, a shocking sight, lying there in the unzipped body bag on Wapping Pier a few minutes after it had been fished out of the murky river. "I'd never seen a child that young dismembered. There hadn't been one in Britain for 40 years," says Detective Inspector Will O'Reilly, who is leading the murder investigation.

But, when O'Reilly first saw the mutilated remains of the five-year-old boy he would call Adam, he did not think this would be a difficult case. "Your immediate reaction is you are going to find the parents of this child soon. He is going to be reported missing... and it will be a fairly simple but unusual domestic-type murder."

Link with human forensics

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"What we came up with was a reasonably high strontium isotope ratio signature indicating rocks of the Pre-Cambrian era, greater than 2,500m years old. We got the areas shown here," says Fysh, pointing to a map of west Africa shaded with colours, that hangs in the south London murder squad room.

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The samples brought back from Africa were enough for Professor Pye to rule out northern Nigeria and narrow Adam's place of origin down to a large stretch of Nigeria, with the best matches coming from near Benin City.

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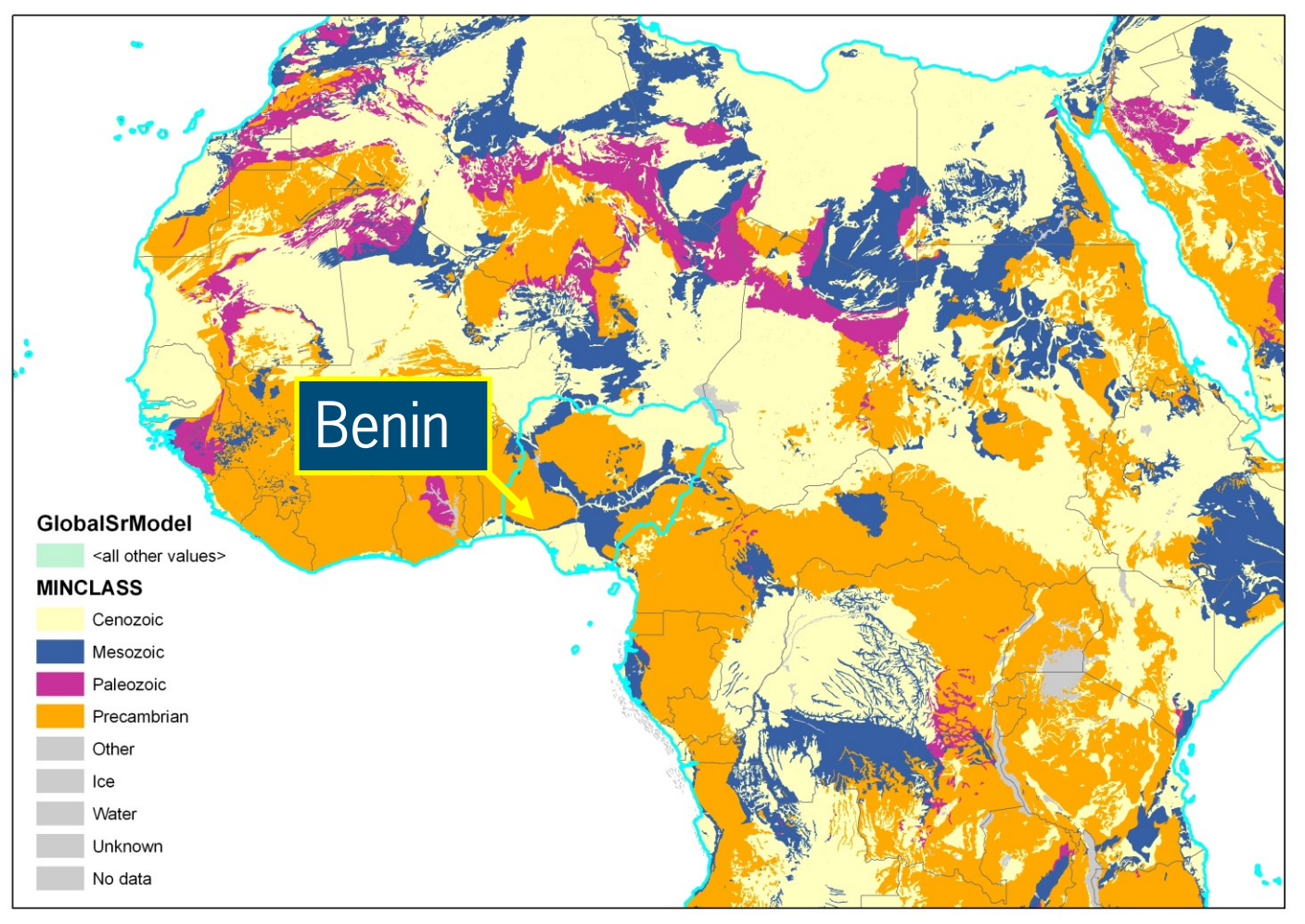
Link with human forensics



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The upper intestine was empty, meaning Adam had not eaten for a while, and the lower intestine contained strange elements that suggested some sort of potion used in a ritual killing.

For various reasons, including the input of cultural anthropologists who were suggesting this was an African-style ritual killing, London and the Caribbean were soon ruled out as Adam's place of origin.

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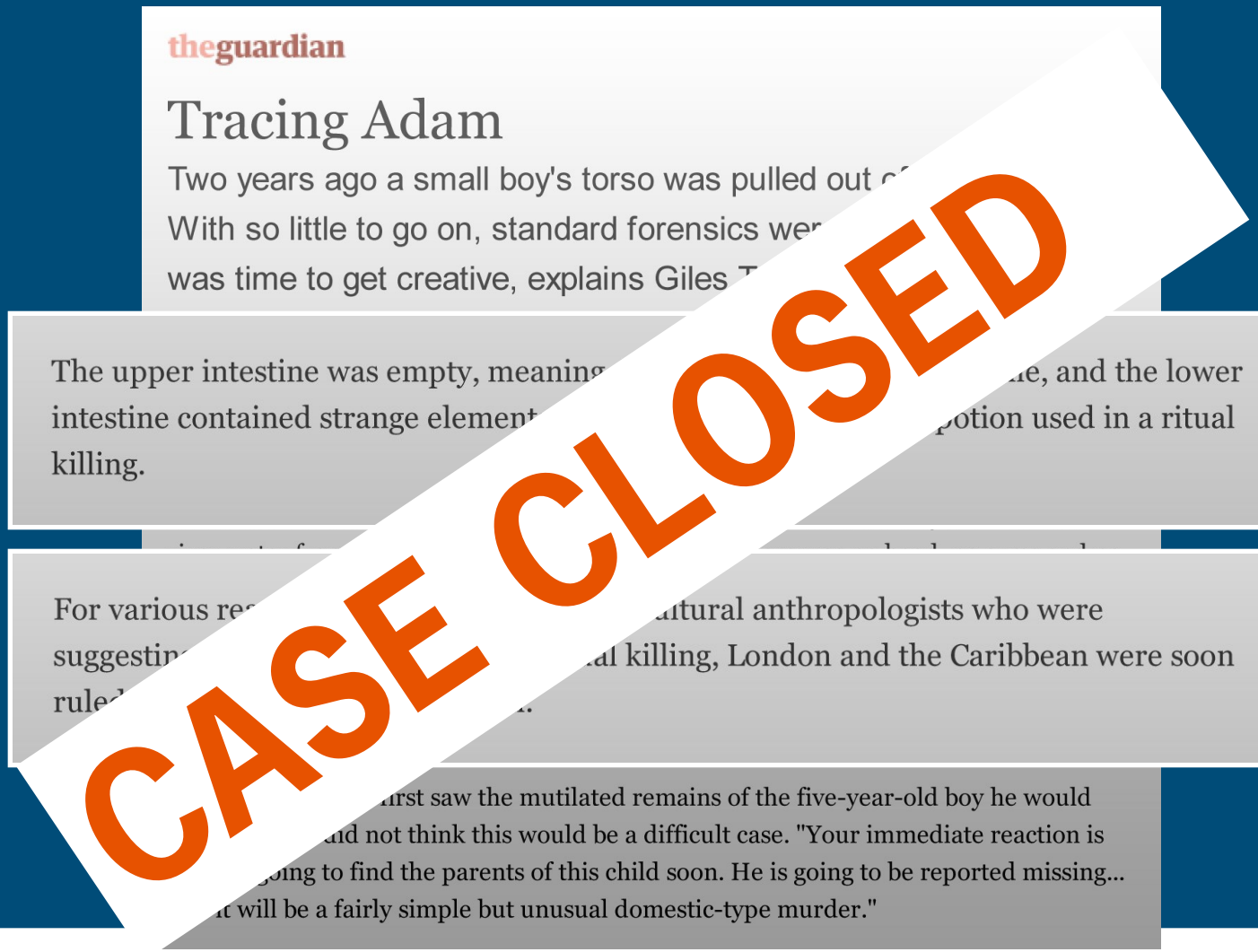


Geographical provenancing & isotopes

- Important lesson:

  1) The success of a “match” can only be appreciated having a fair understanding of all other relevant options.

  2) Additional evidence is often required to confine the possible area of origin.

Geographical provenancing & isotopes

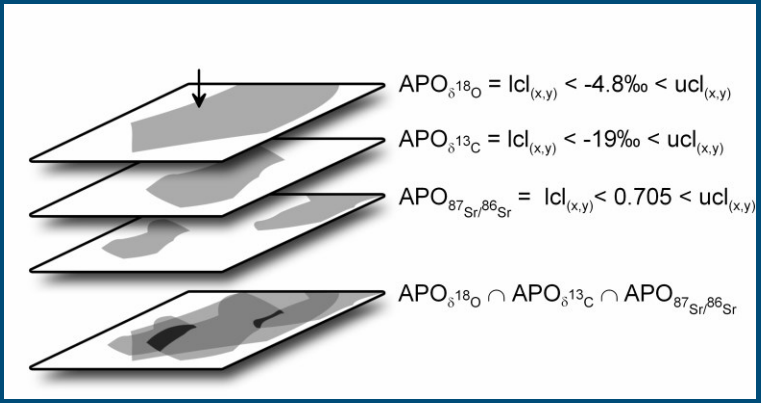
- General concept:

  1) Isotopes provide a geo-climatic fingerprint

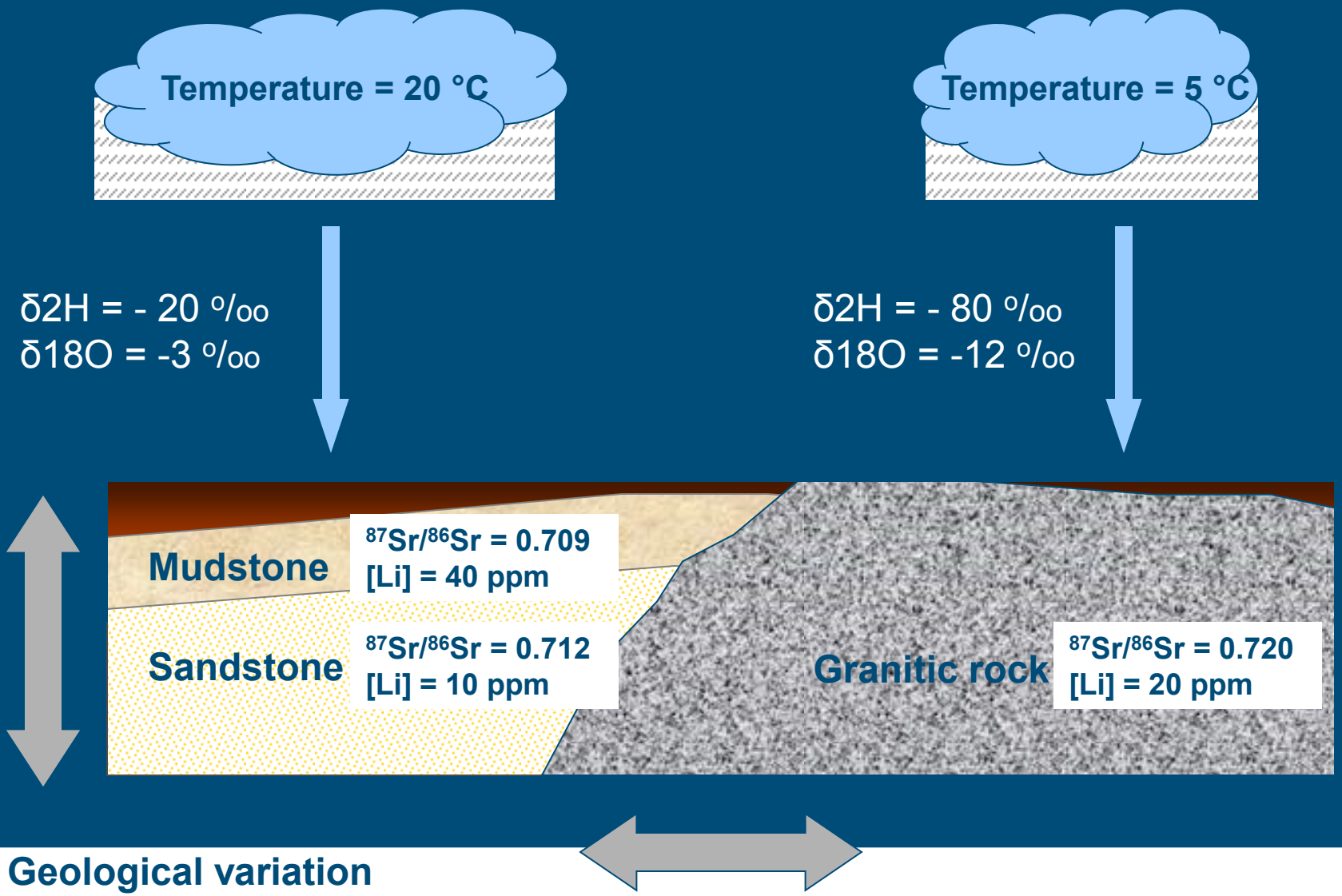
  2) You are what you eat (~most isotopes)

  3) Additional evidence is required; one isotope is not enough.

→ A combination of isotope prediction maps is required:



Geographical provenancing & isotopes



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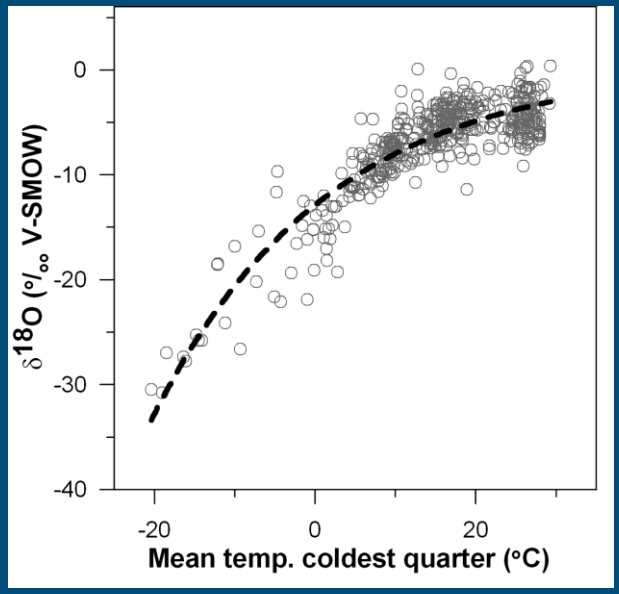
Spatial prediction models isotopes

Examples for European mineral water:

- Example 1: δ2H/δ18O <-> climate
- Example 2: Sr-isotopes <-> geology

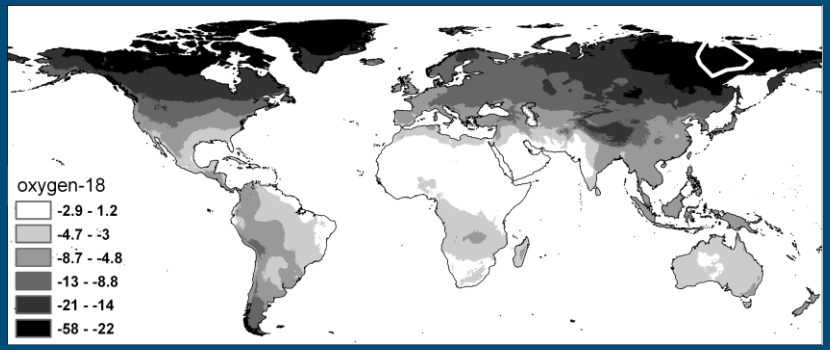
Modelling δ2H and δ18O

Global dataset δ2H and δ18O in precipitation (IAEA)

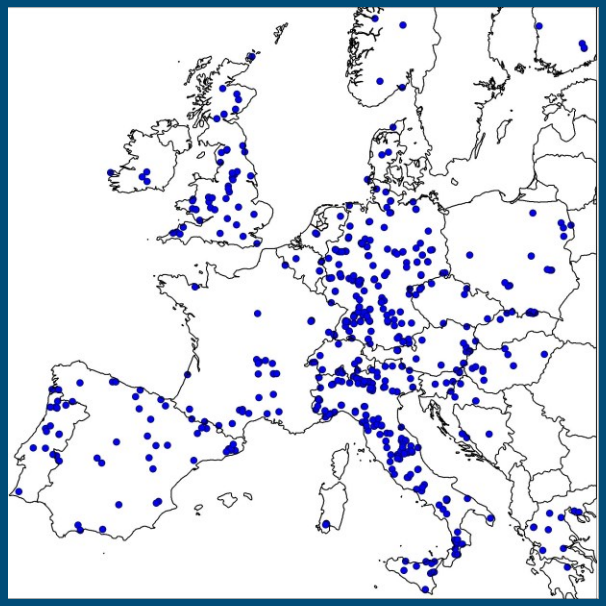


Relation between temperature and δ18O = -5.9exp(-0.041Tcq) -2.4

Modelling δ2H and δ18O



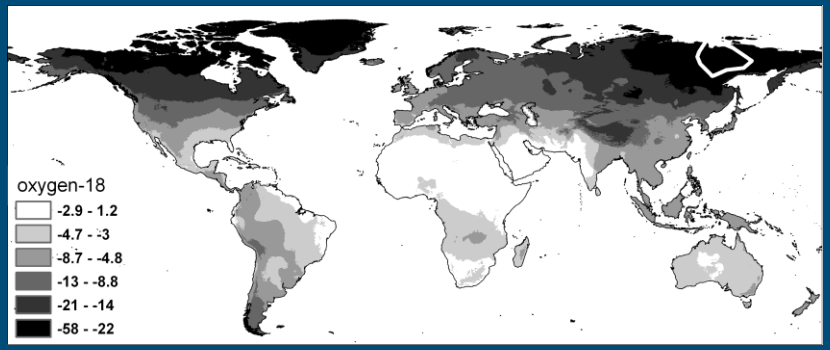
Global prediction model of δ18O in precipitation using simple kriging with varying local means (SKlm; Van der Veer et al. 2009)



Sampling of commercial mineral water across Europe

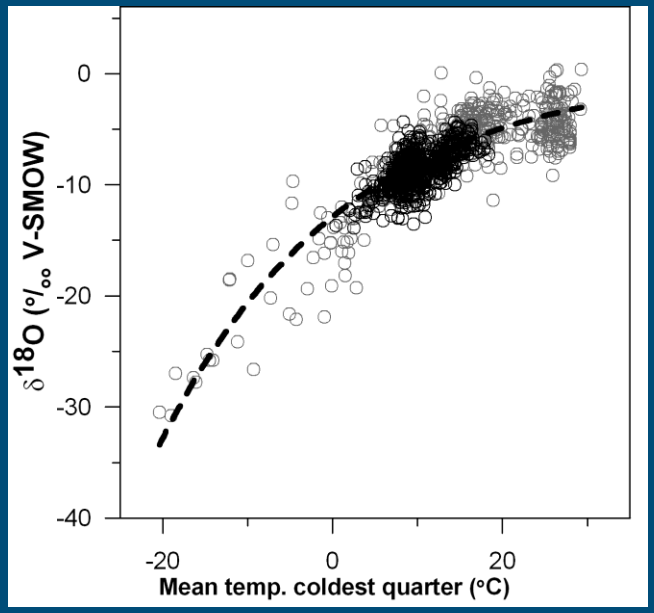
Modelling δ2H and δ18O

Provides: P(x,y) +/- Conf. limits (x,y)



Global prediction model δ18O in precipitation using simple kriging with varying local means (SKlm)

(Van der Veer et al. 2009)

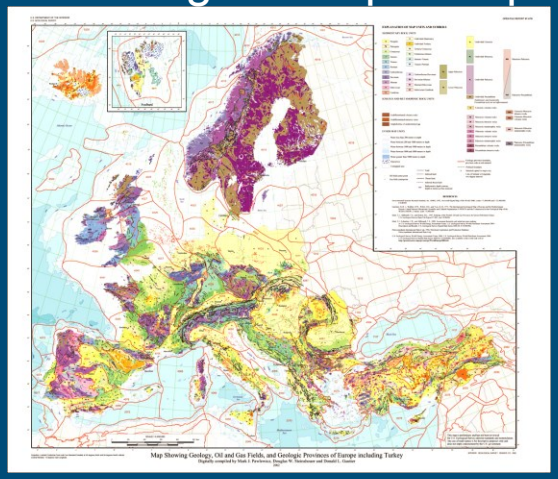


δ18O in precipitation (grey) and in mineral water (black)

= mineral water

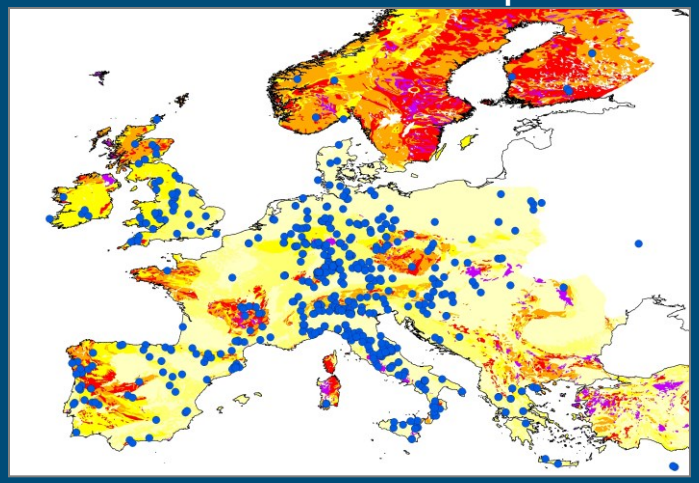
Modelling Sr-isotopes

Geological map Europe



Reclassification

Reclassified map



87Sr/86Sr in mineral water

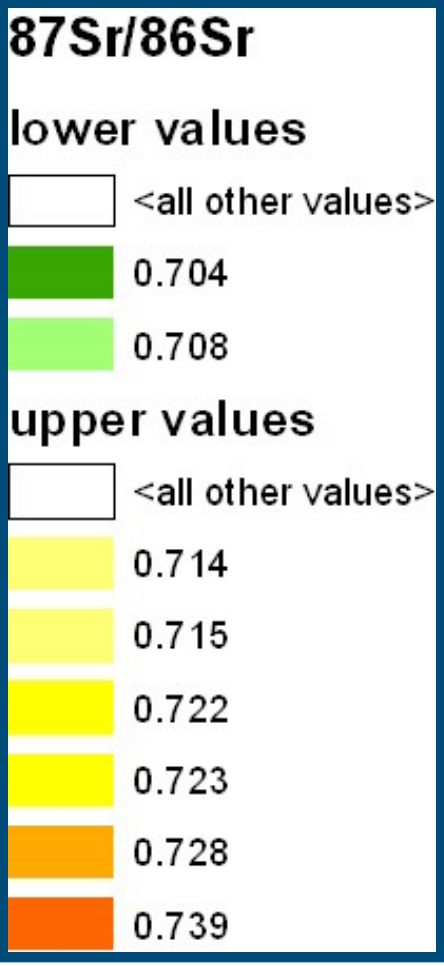
New classes	2.5perc	97.5perc
Cenozoic	0.708	0.715
Mesozoic	0.708	0.722
Palezoic	0.708	0.723
Paleozoic-Precambrian	0.708	0.739
Intrusives	0.708	0.728
Volcanics	0.704	0.714

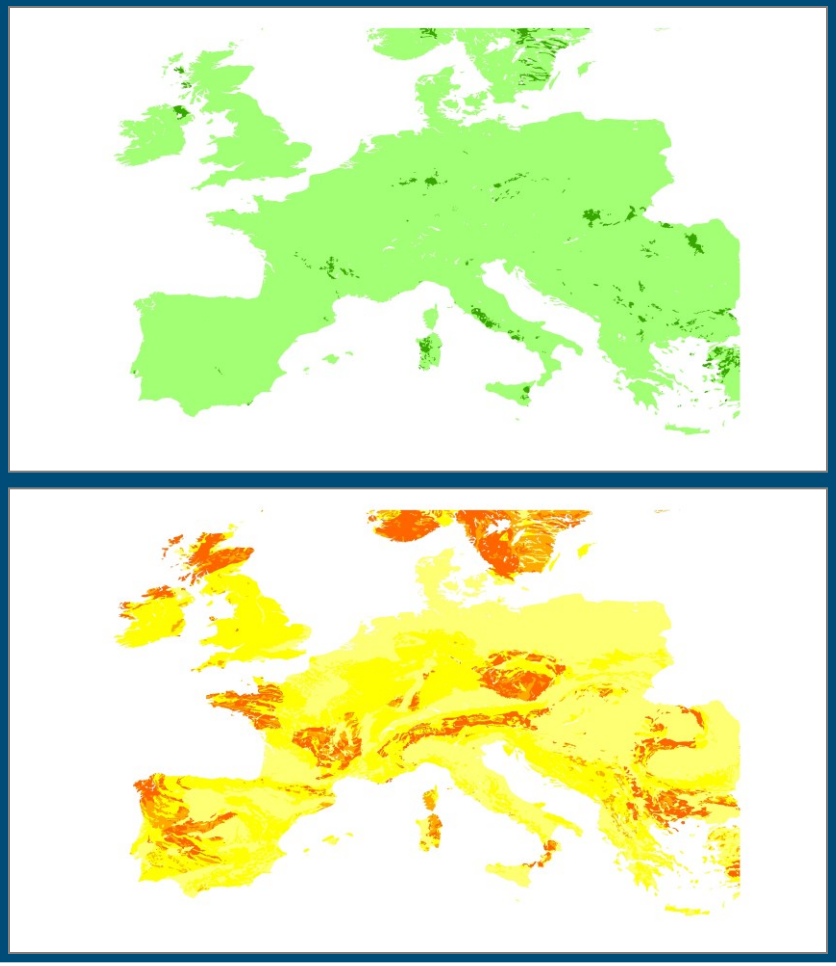
Sampling of commercial mineral water across Europe

Prediction model for Sr-isotopes in mineral water

Modelling Sr-isotopes

Prediction model Sr-isotopes in mineral water (upper and lower range)





TraceTool v2.0

The TraceTool is a GoogleEarth webapplication that was developed to facilitate working with a combination of isotope prediction maps for food authentication

Commodities:

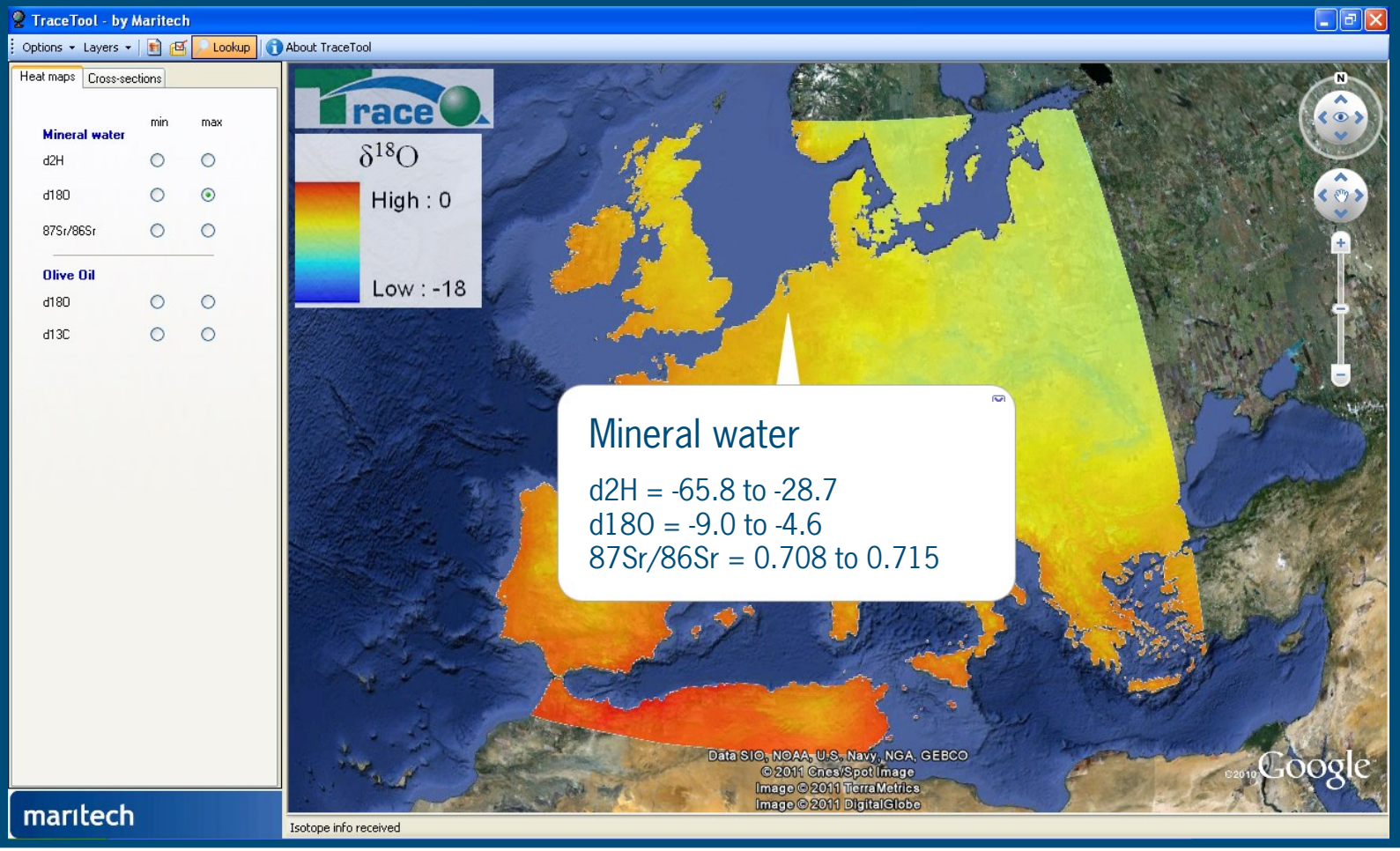
- Mineral water (Europe): δ2H, δ18O, 87Sr/86Sr
- Olive oil (S-Europe and N-Africa): δ2H, δ13C

Download:

http://update.maritech.is/tracetool/publish.htm

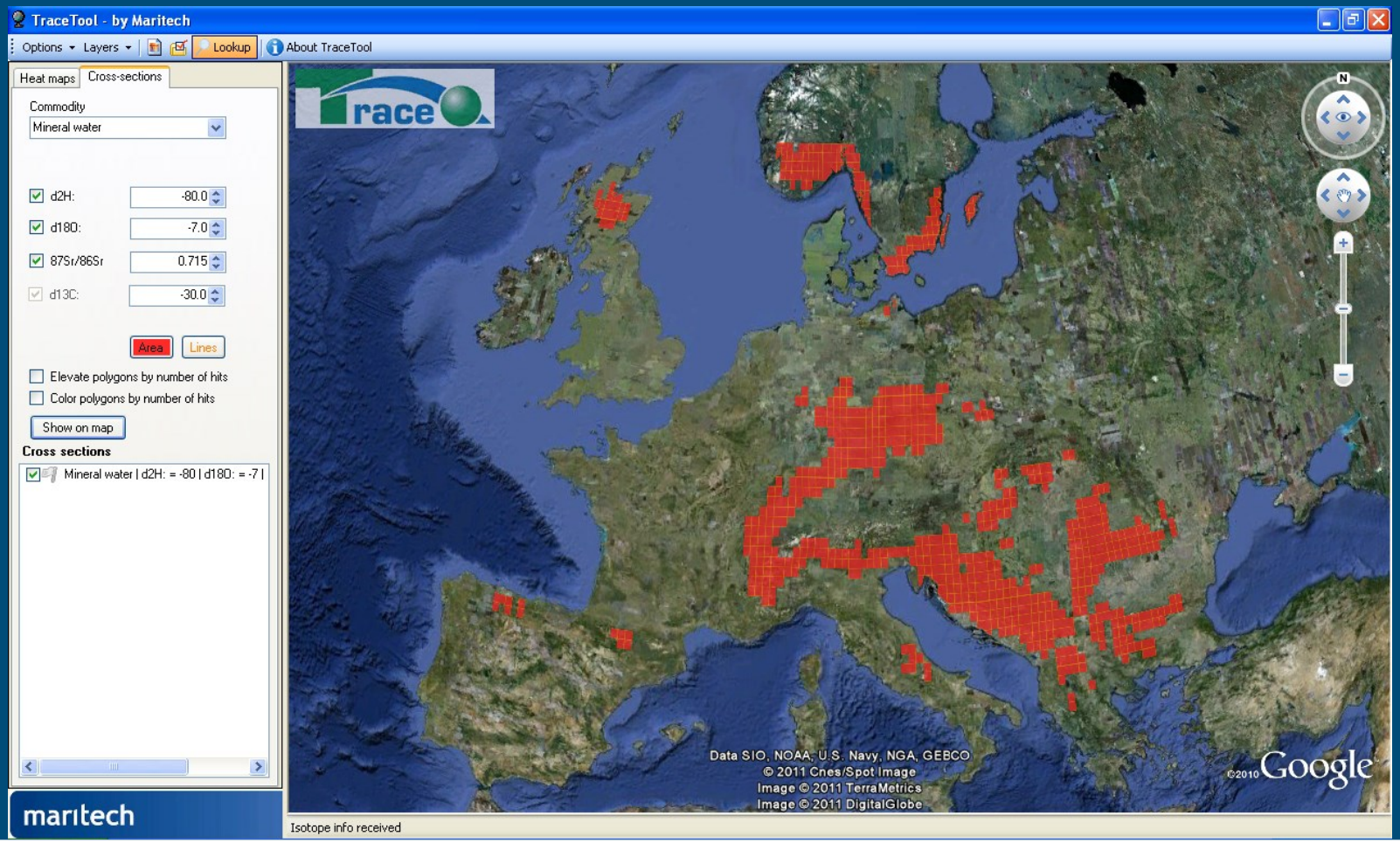
TraceTool v2.0

- **Retrieve predicted range of isotope values for a certain production area:**



TraceTool v2.0

- **See how specific a combination of isotope values is:**



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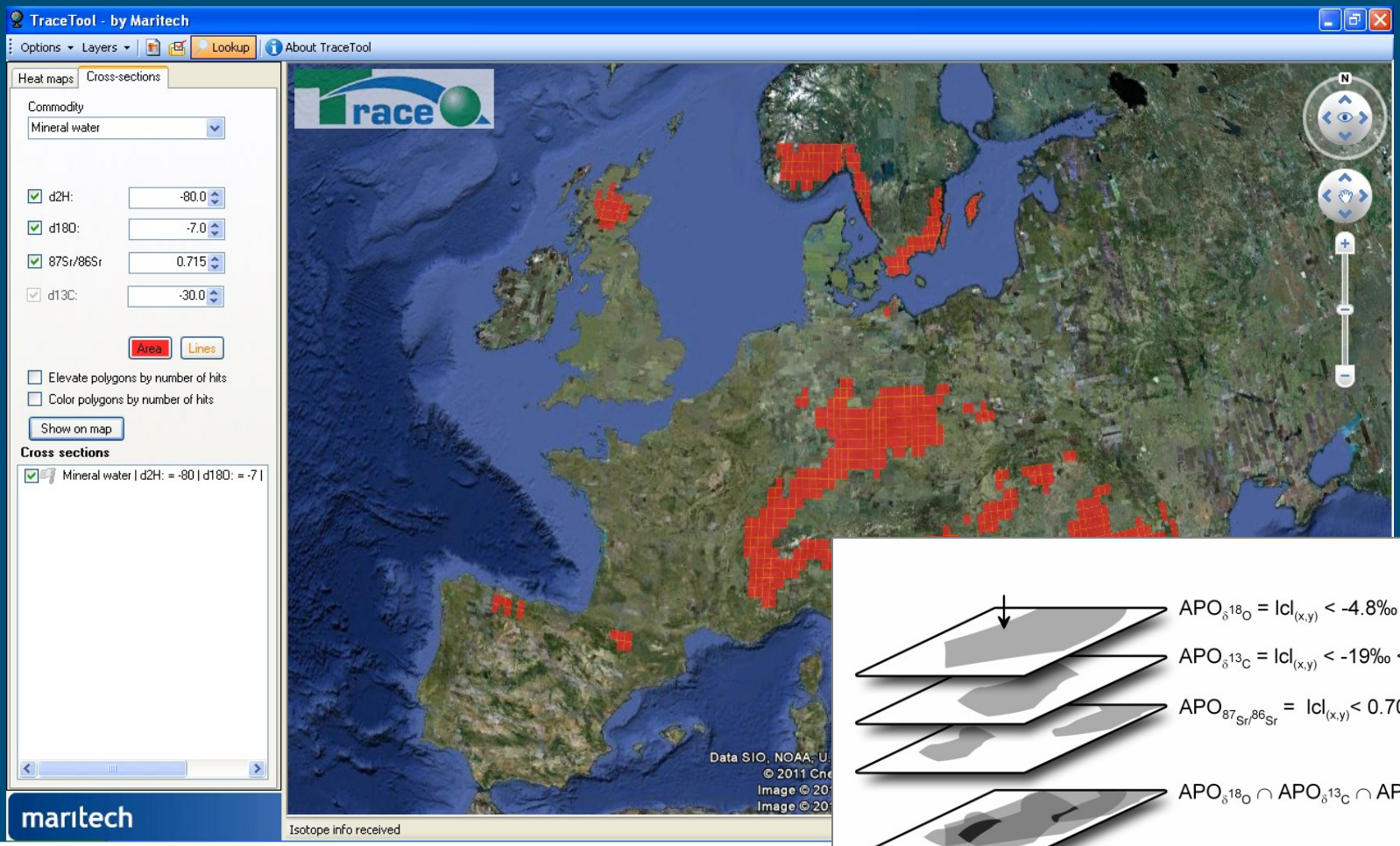
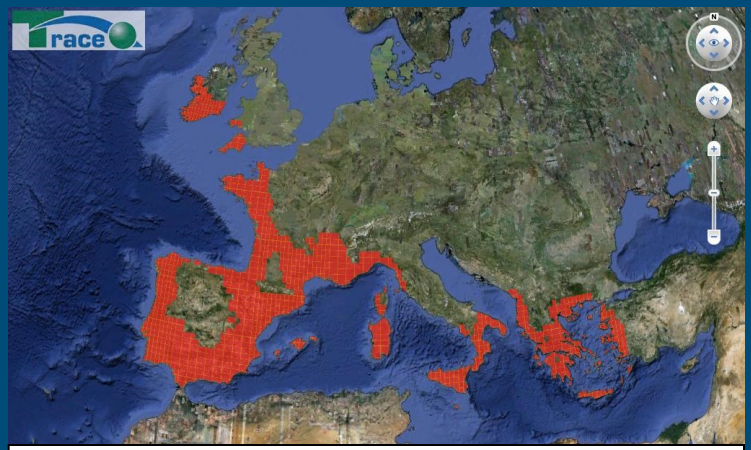
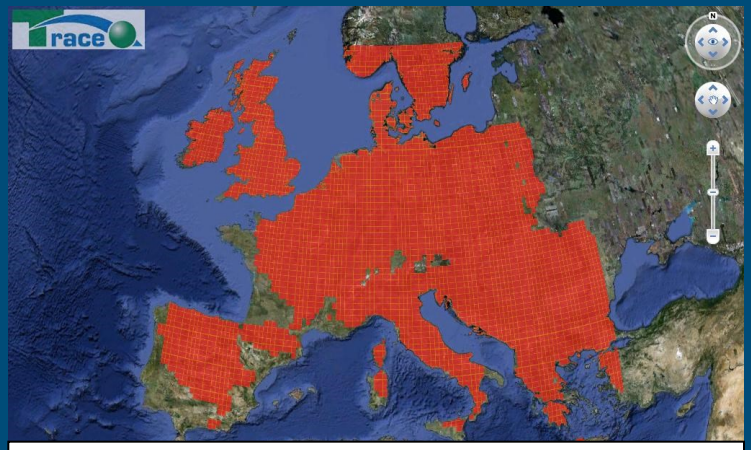


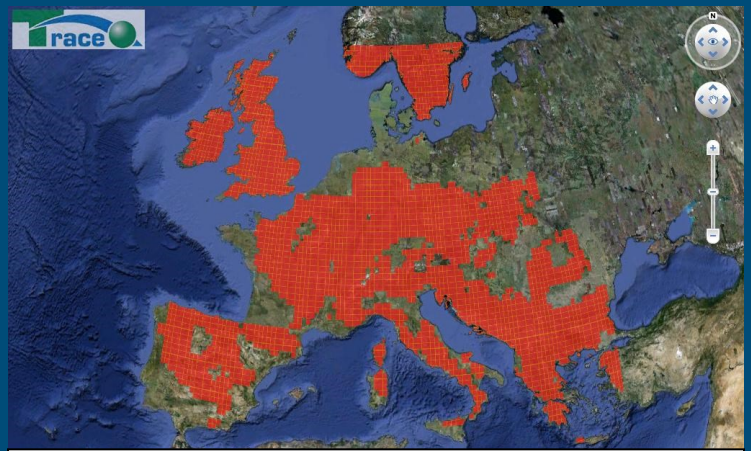
TraceTool v2.0 – Mineral water



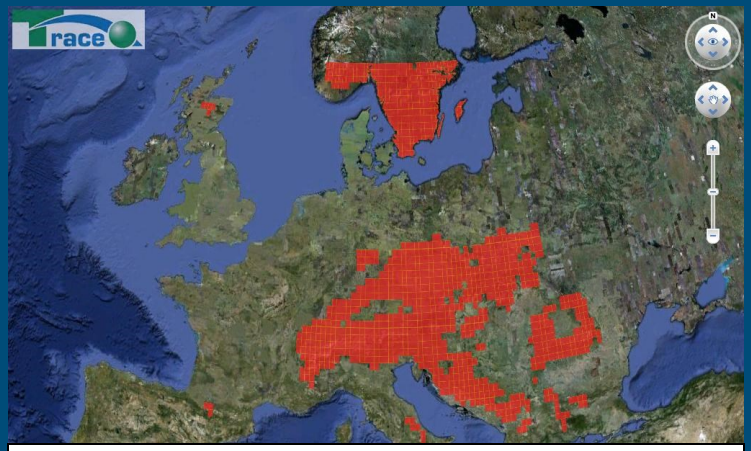
δ^2H = -30.4 ‰; $\delta^{18}O$ = -5.3 ‰; $^{87}Sr/^{86}Sr$ = 0.709



δ^2H = -60.5 ‰; $\delta^{18}O$ = -9.0 ‰; $^{87}Sr/^{86}Sr$ = 0.709



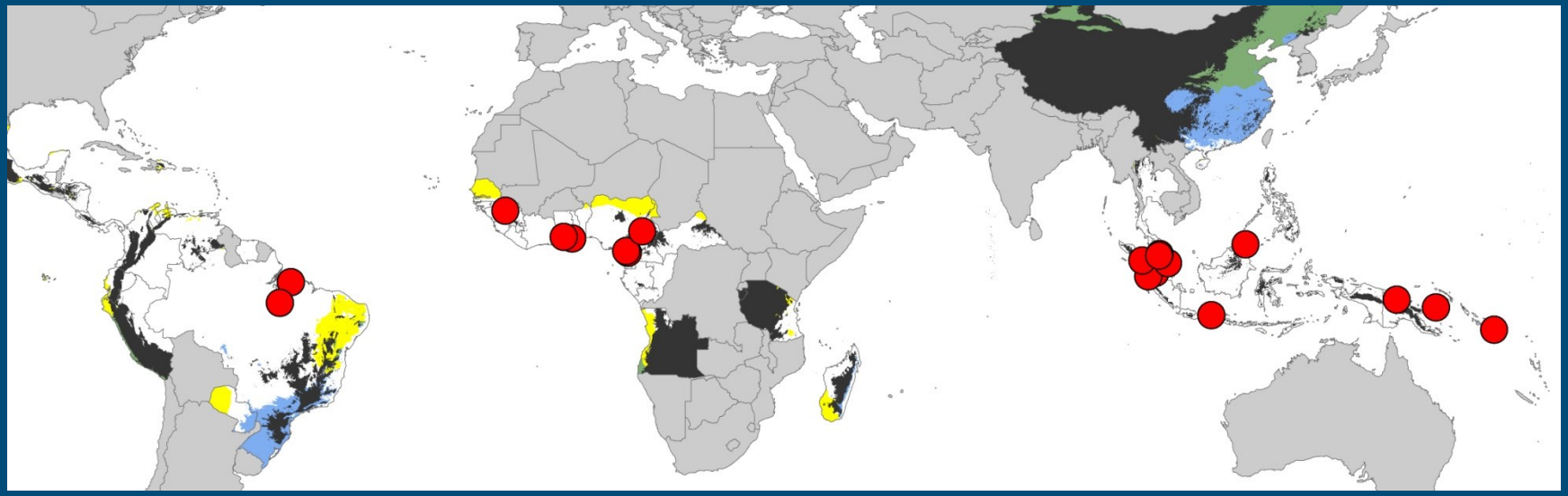
δ^2H = -60.5 ‰; $\delta^{18}O$ = -9.0 ‰; $^{87}Sr/^{86}Sr$ = 0.716



δ^2H = -80.4 ‰; $\delta^{18}O$ = -11 ‰; $^{87}Sr/^{86}Sr$ = 0.716

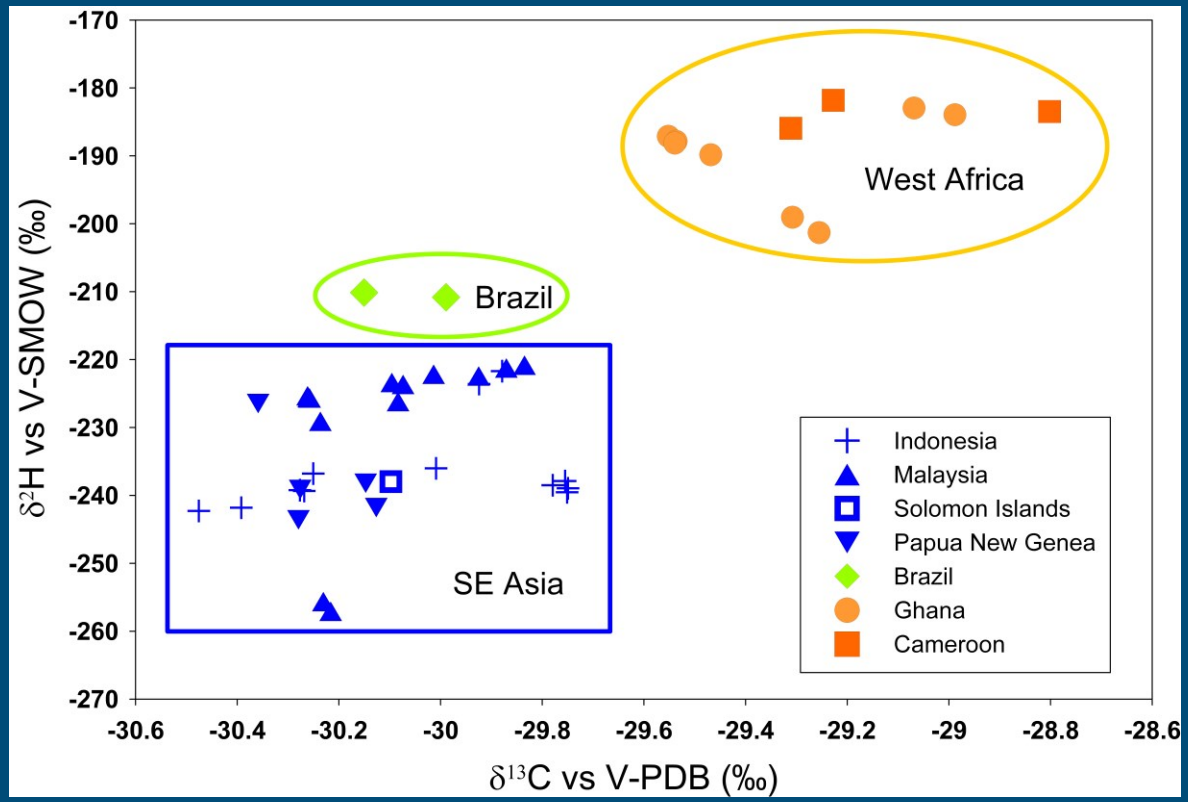
Latest development: Palm oil prediction model

- **Palm oil sampling and analysis of δ2H, δ18O and δ13C**



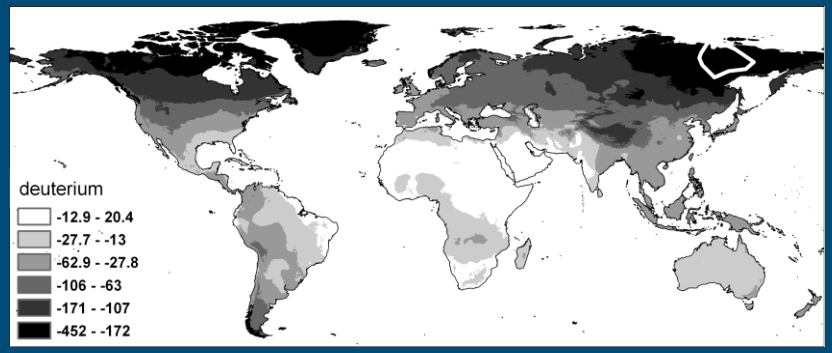
Latest development: Palm oil prediction model

- **Example: δ2H and δ13C**



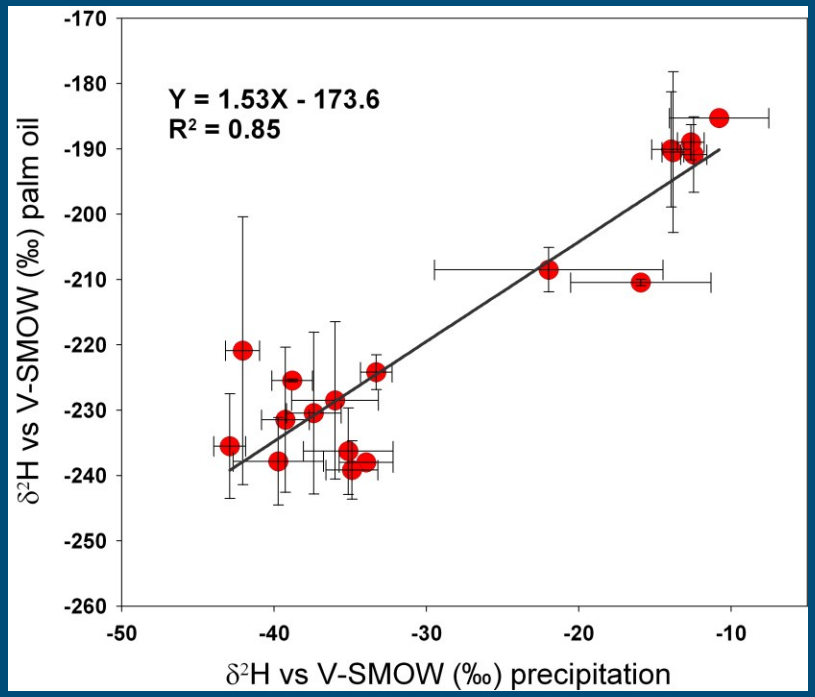
Latest development: Palm oil prediction model

- **Example δ2H**



Global prediction model δ2H in precipitation using simple kriging with varying local means (SKlm)

(Van der Veer et al. 2009)



Relation between δ2H in global precipitation and δ2H in palm oil

Latest development: Preliminary global Sr isotope prediction model (geology)

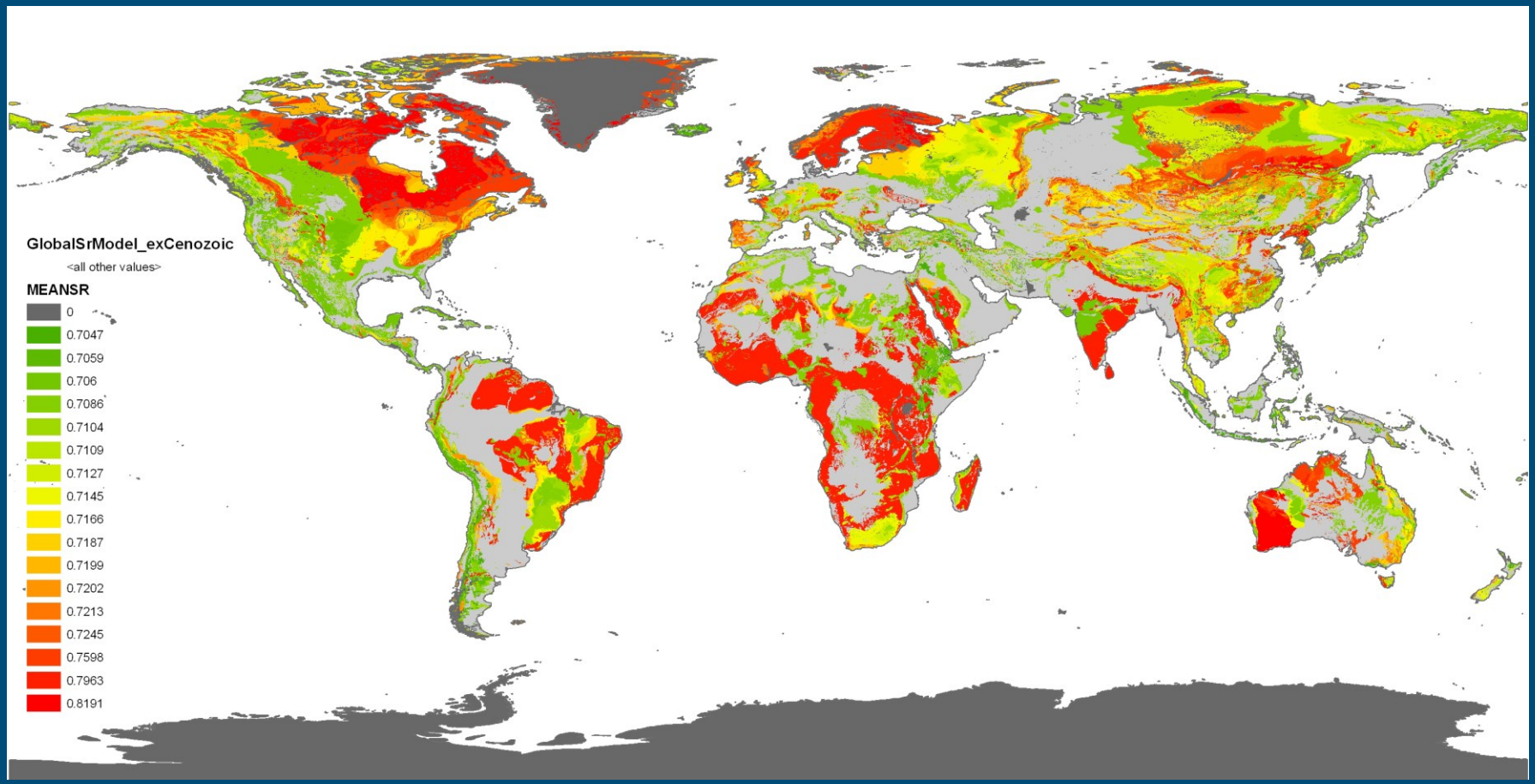
Using: $^{87}Sr/^{86}Sr = {}^{87}Sr/^{86}Sr_{initial} + {}^{87}Rb/^{86}Sr(age \times decay)$

Required input for base model:

- Global geological map with rock ages → USGS geol. maps
- Database 87Sr/86Sr & 87Rb/86Sr → NGDB2.0
- Outline of major sedimentary basins → Data Sets of Continental Watersheds (Graham et al.,1999)

→ Requires transfer function from geology to commodity

Latest development: Preliminary global Sr isotope prediction model (geology)



Conclusions

- Spatial prediction models based on light and heavy isotopes are indispensable tools for (food) forensics
- The approach allows to verify geographical origin of food, and moreover gives an indication of how specific the values are in a spatial sense
- Requires thorough understanding of the relation between isotopes in the environment and in food