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Speleothems: powerful geological archives

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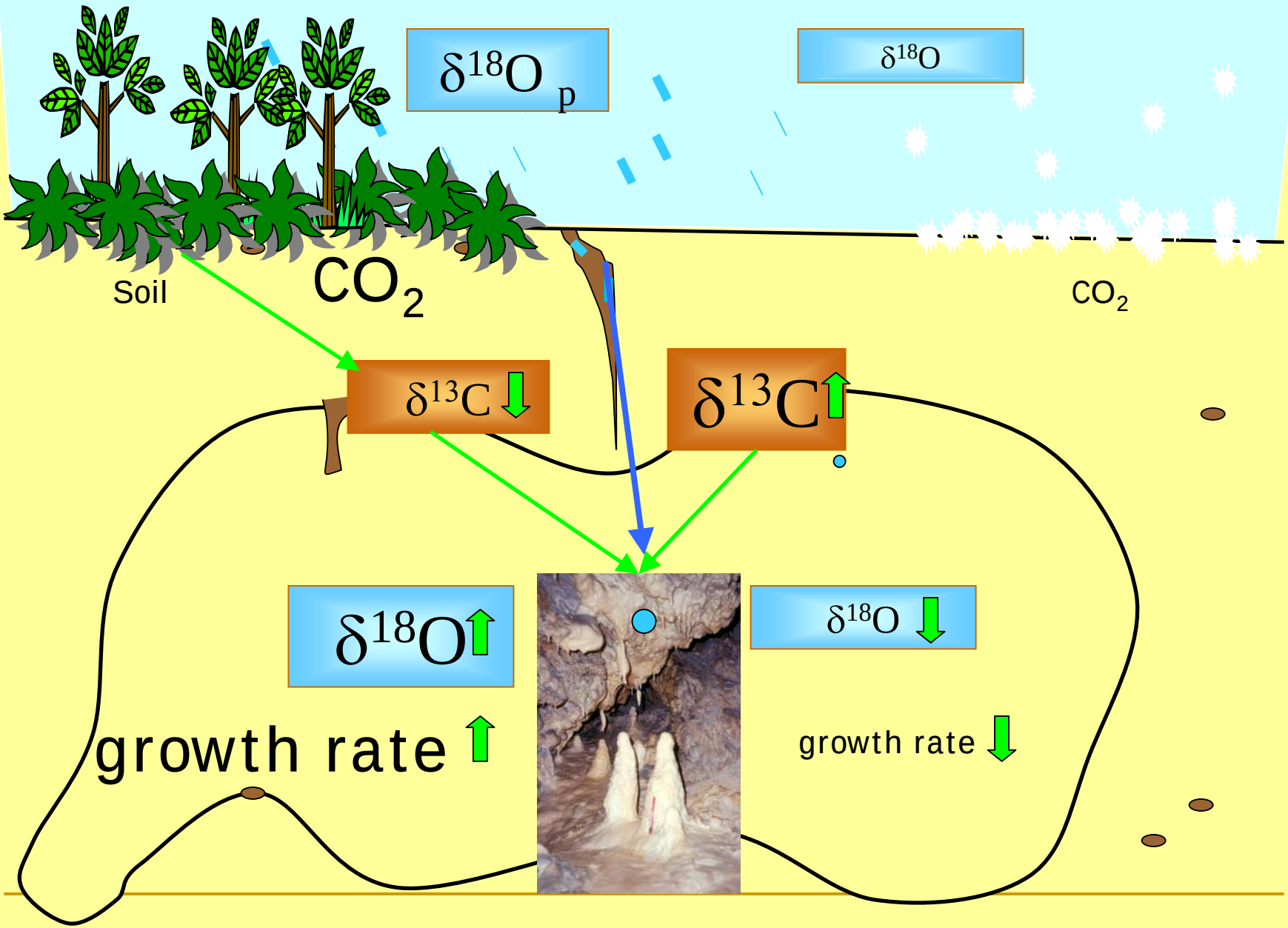
They capture climate changes

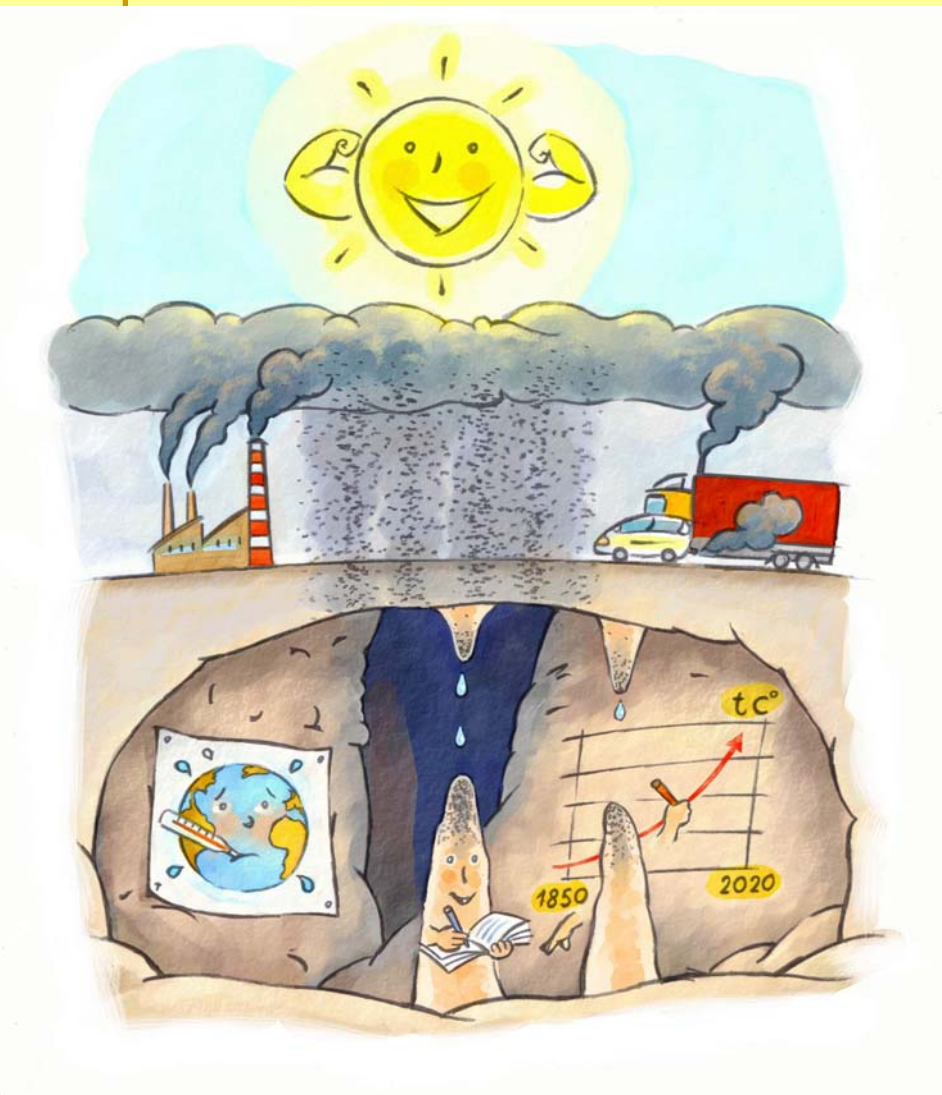
They capture environmental responses

HOW?

Speleothem capture of climate changes



Speleothem time scale

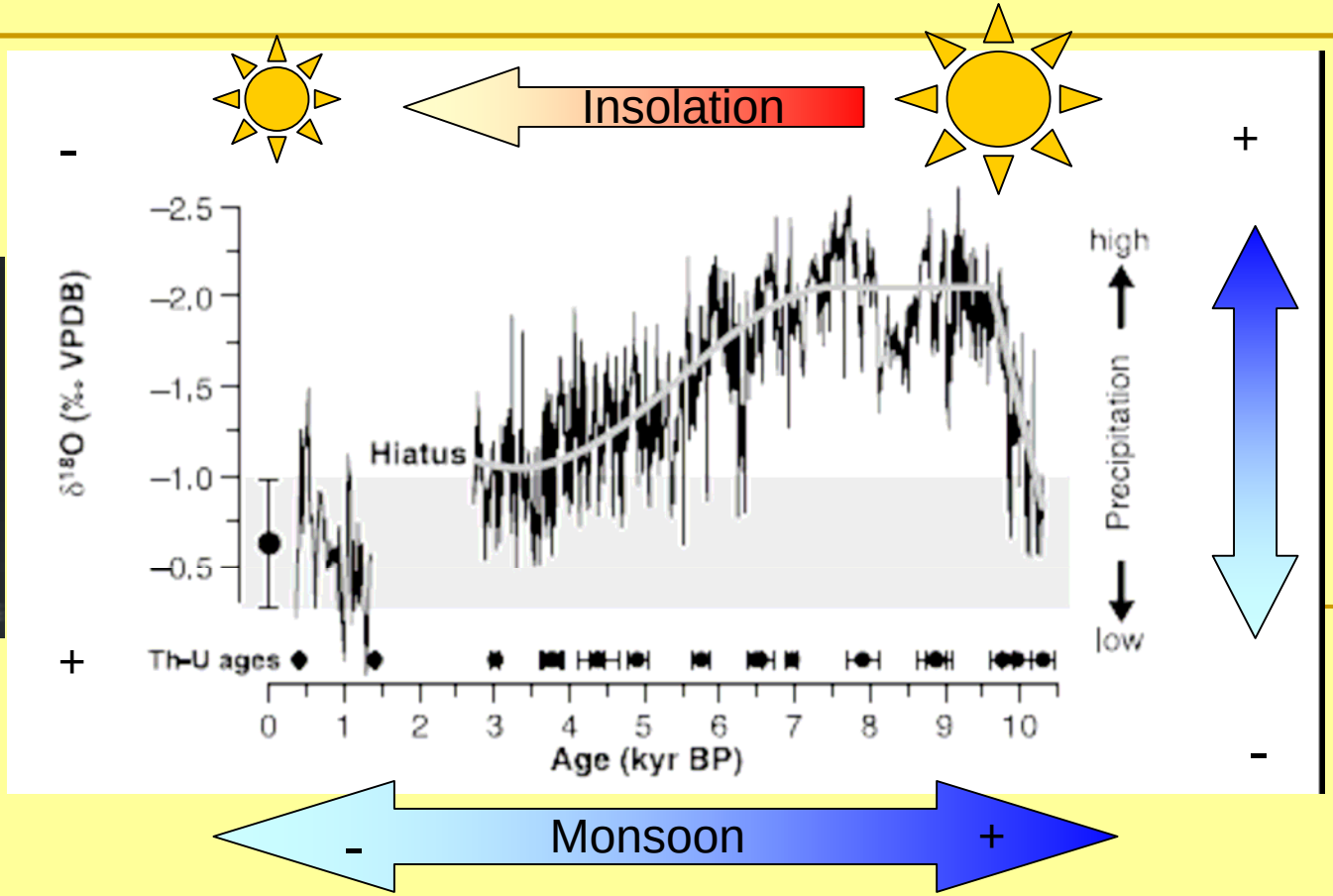


For an immense time span of Earth's history prior to the invention of instruments, speleothems are one of the best climate archives.

This because they can be dated through the U-series method, which allows to date geological material older than millions of years.

Speleothems & Orbital forcing: Monsoon

Insolation-monsoon intensity in the Arabian Peninsula stalagmites

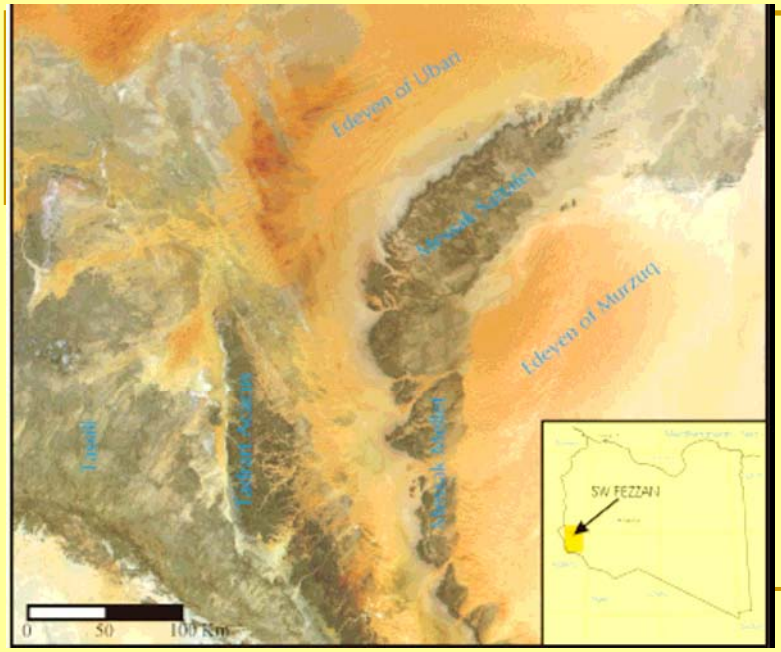


Oman

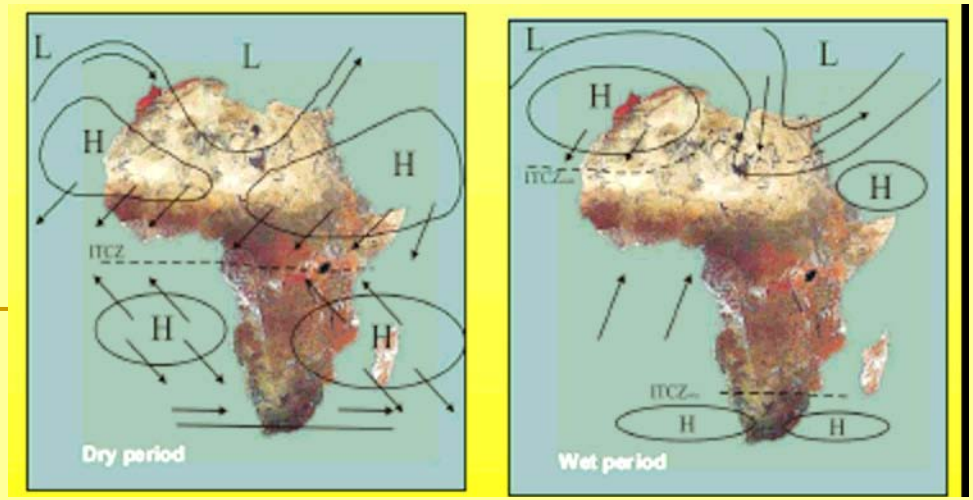
From: Neff et al., 2001, Science

Insolation & Monsoon in Africa

From Zerboni et al., 2007

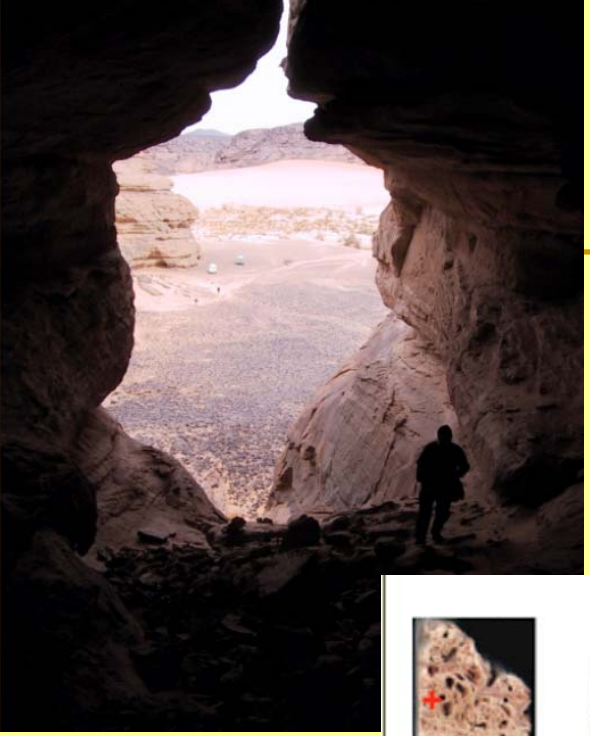


The Acacus speleothems & the “green Sahara”



Climate of the Sahara is related to shifts of the African monsoon & ITCZ.
A N shift of the African monsoon results in higher rainfall in the Sahara and concomitant recharge of deep aquifers.

Ca. 9000 years ago the Lybian Fezzan was a wet savannah. Desertification of the area is documented at ca. 6000 yr BP.



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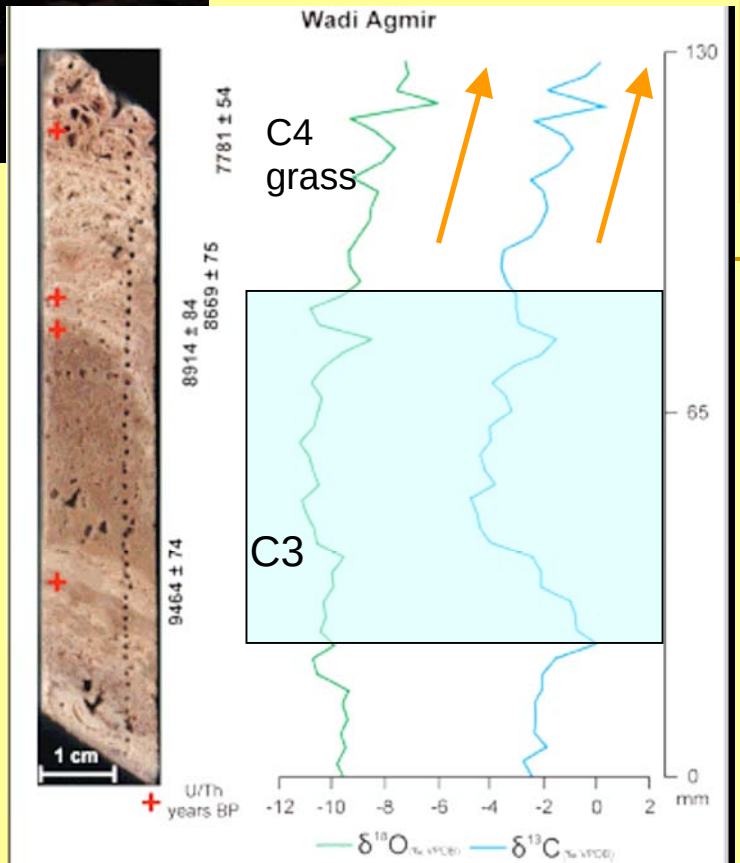
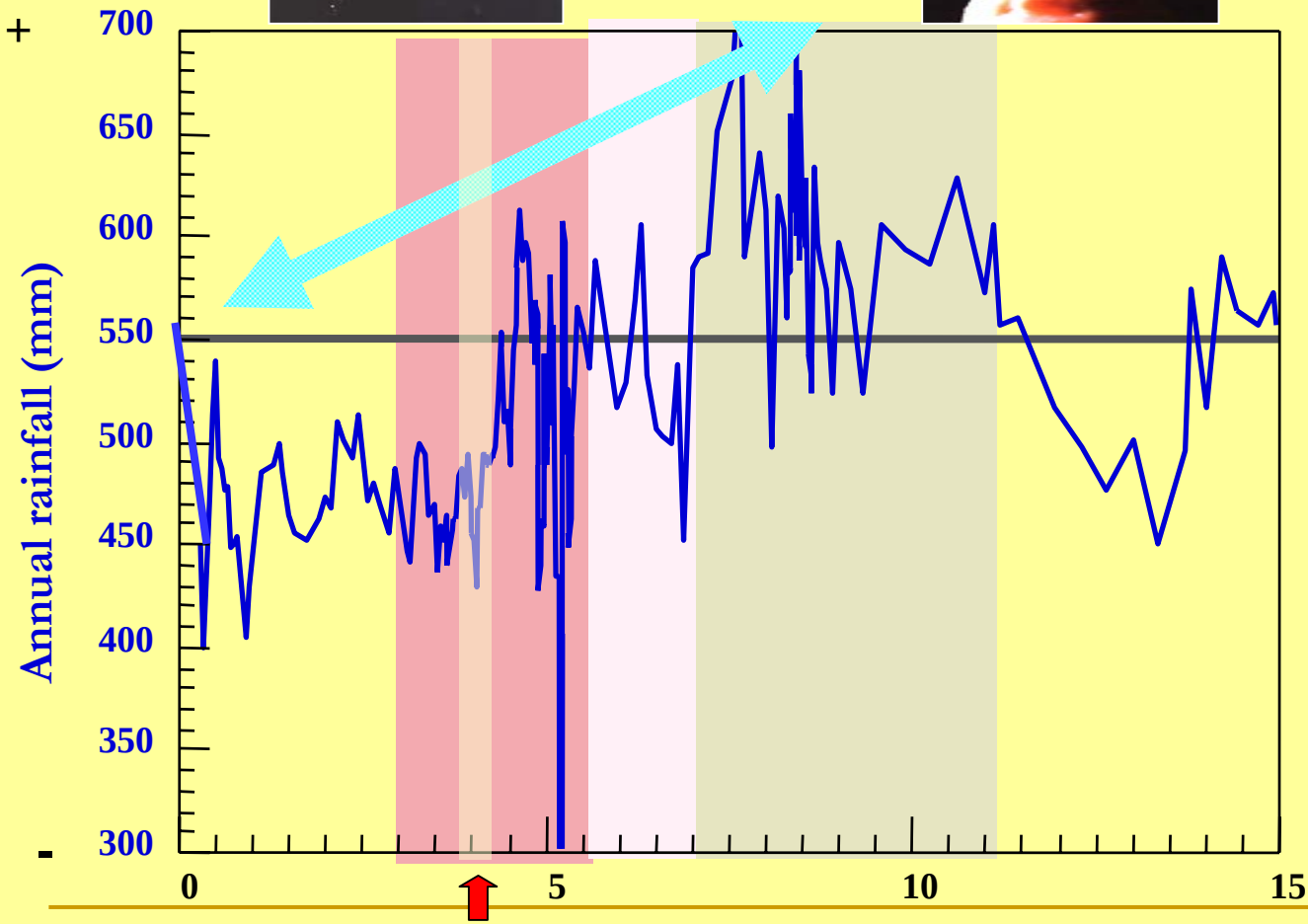


Acacus speleothems formation (WET) from ca. 10000 years ago to ca. 7000 BP. Strong monsoon.

The "low" $\delta^{18}O$ of the Acacus speleothems marks the period of highest rainfall from ca. 9500 to 8500 years ago.
The low $\delta^{13}C$ marks the presence of trees (C3 plants).
Lower rainfall by 7800 years ago.

Insolation & rain in the Mediterranean

Soreq cave
Israel



From: Bar-Matthews et al., 1999

Insolation & Rain in Trentino

Tufa & Moonmilk

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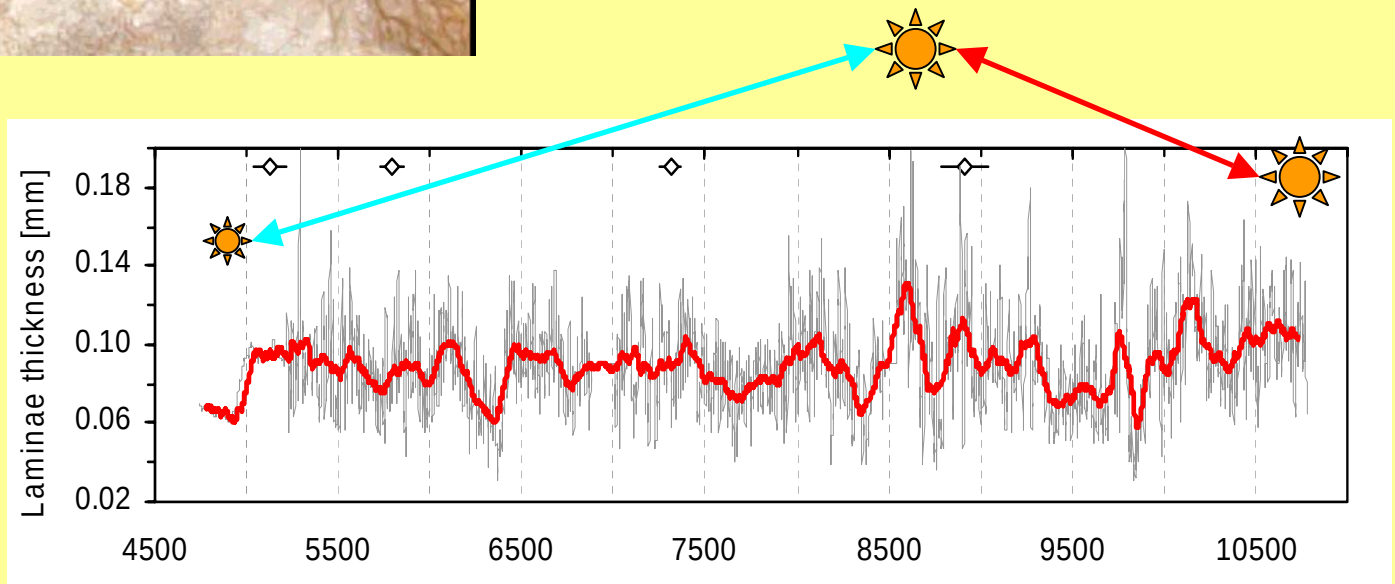
10.500 to ca. 8.000 BP:
Thicker laminae.
High inter-annual variability.
Higher mean rainfall

8.000 BP to ca. 4.500 BP: Thinner laminae.
Lower inter-annual variability.
Decrease in rainfall

At 4500 a threshold is reached: no speleothem growth



From: Borsato et al., 2007

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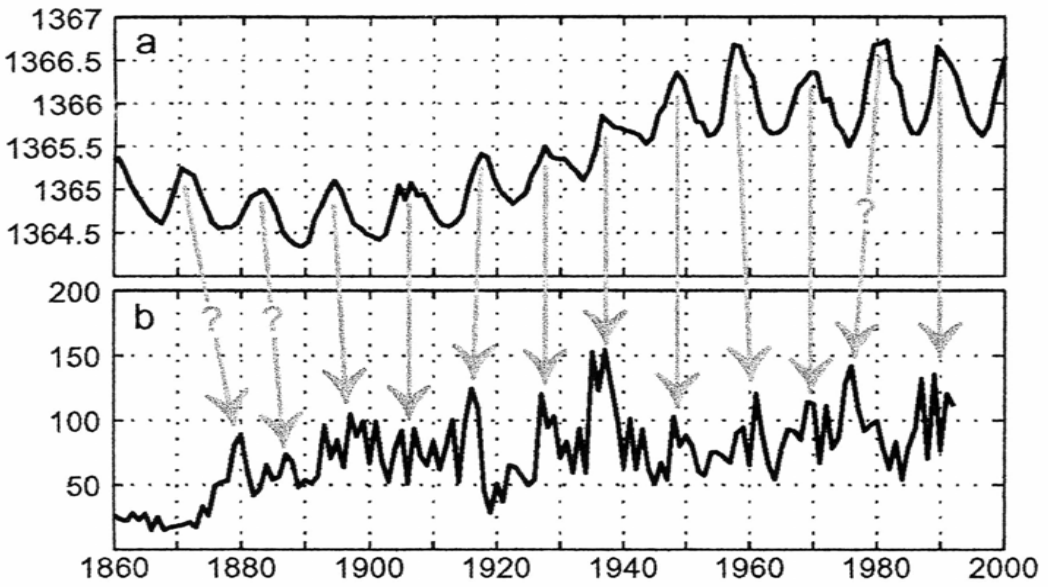
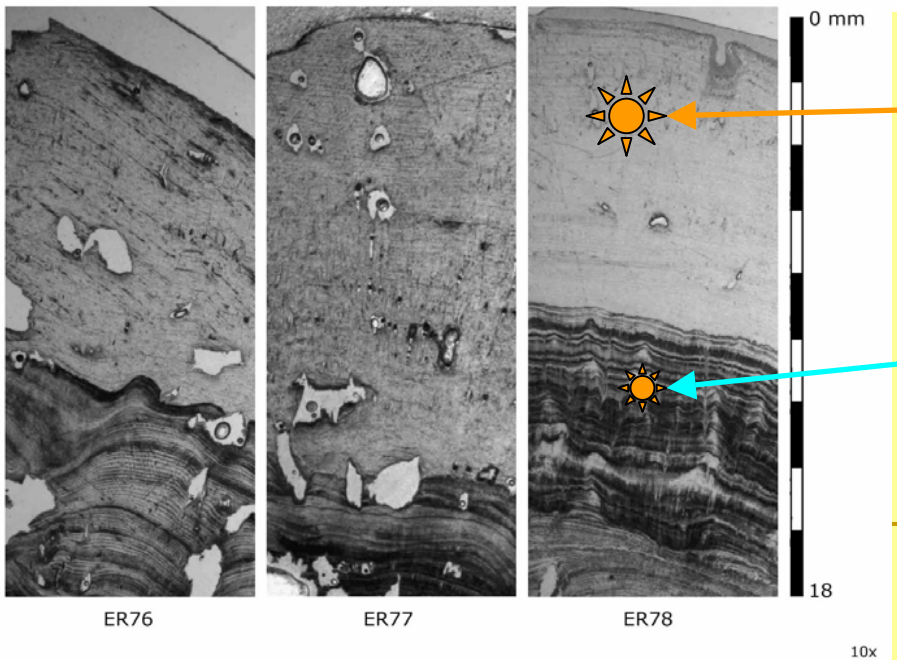
Speleothems & Solar Forcing

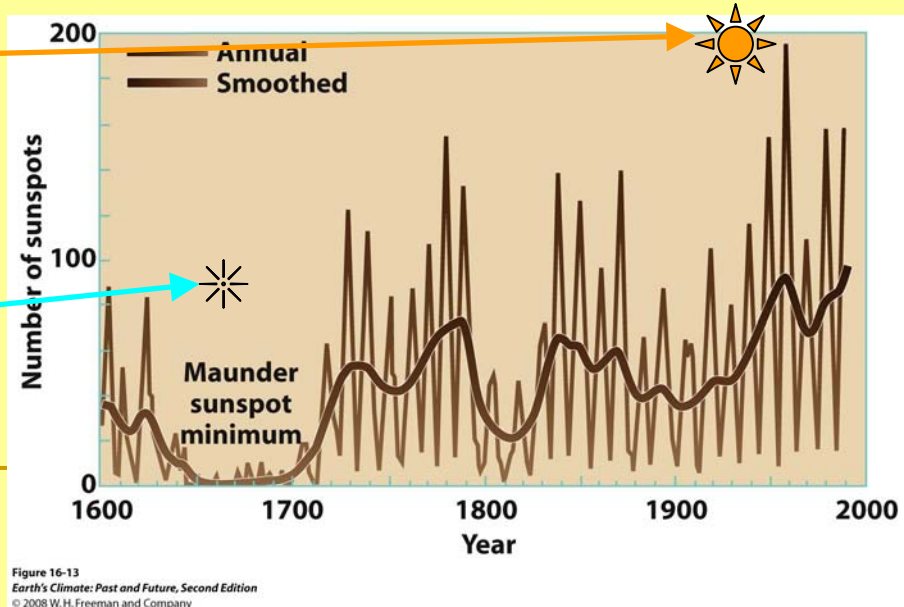
Grotta di Ernesto in Trentino

Lamina thickness correlates with sunspot number

More sunspots: higher growth rate.
Less sunspot = lower growth rate
Solar minima are recorded by thin, dark laminae



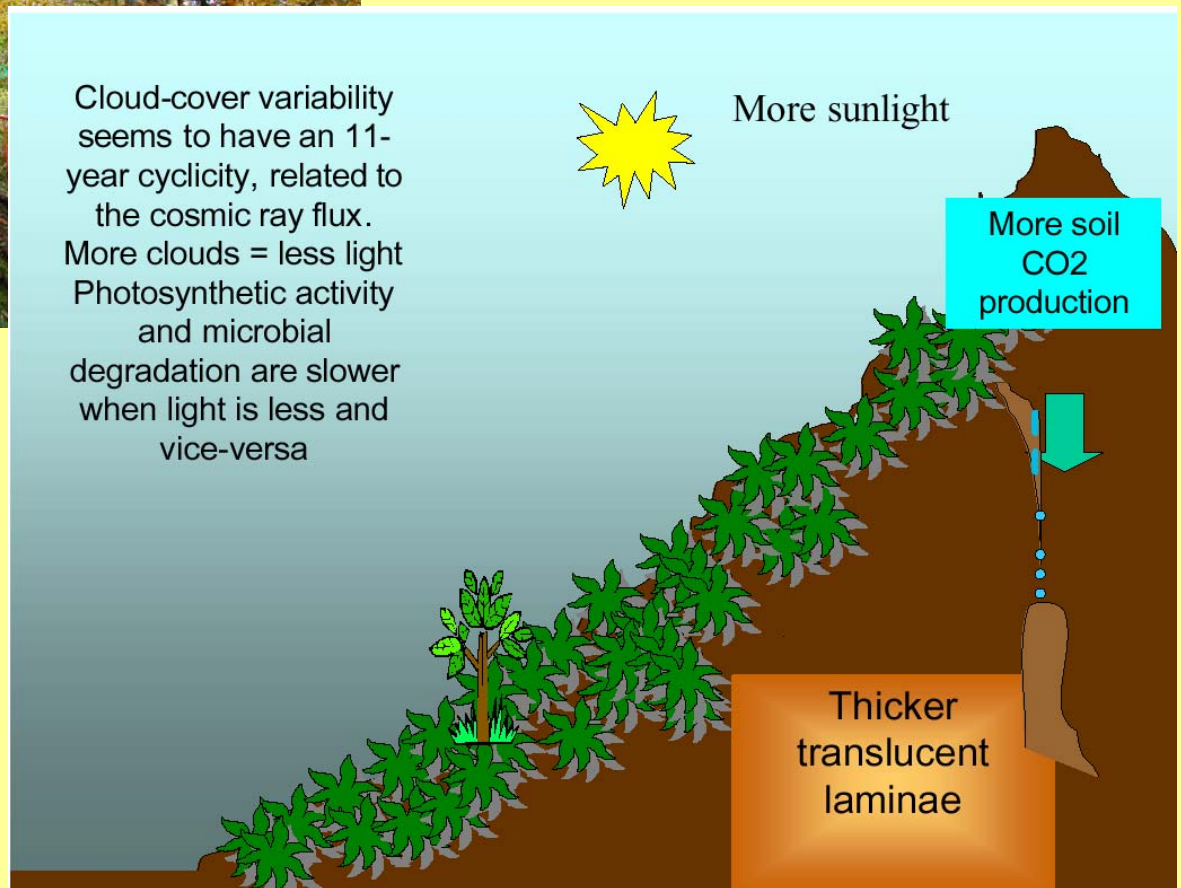


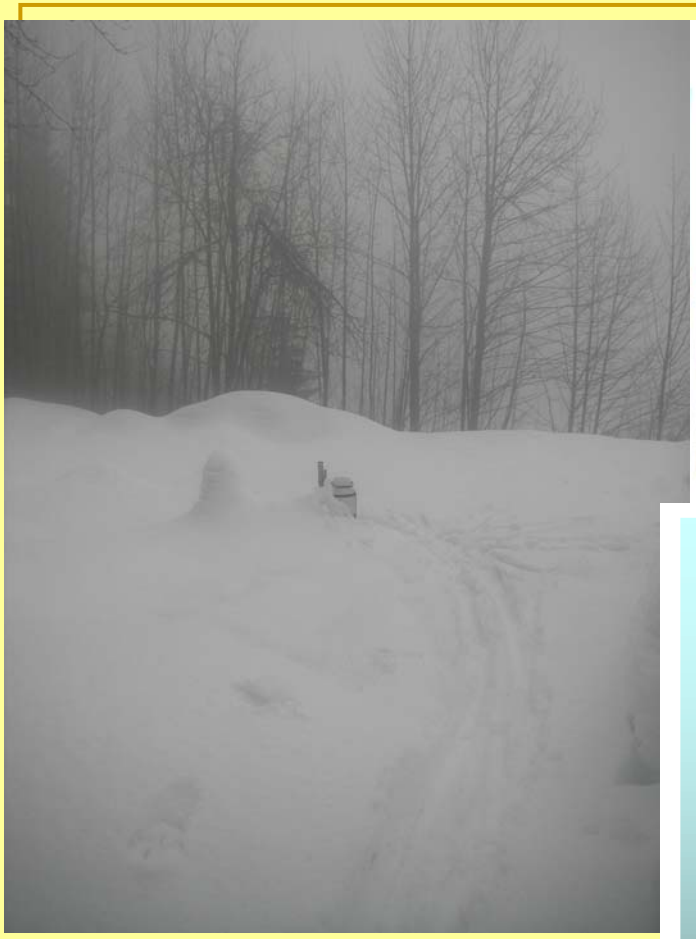


WHY? The cloud cover hypothesis tested

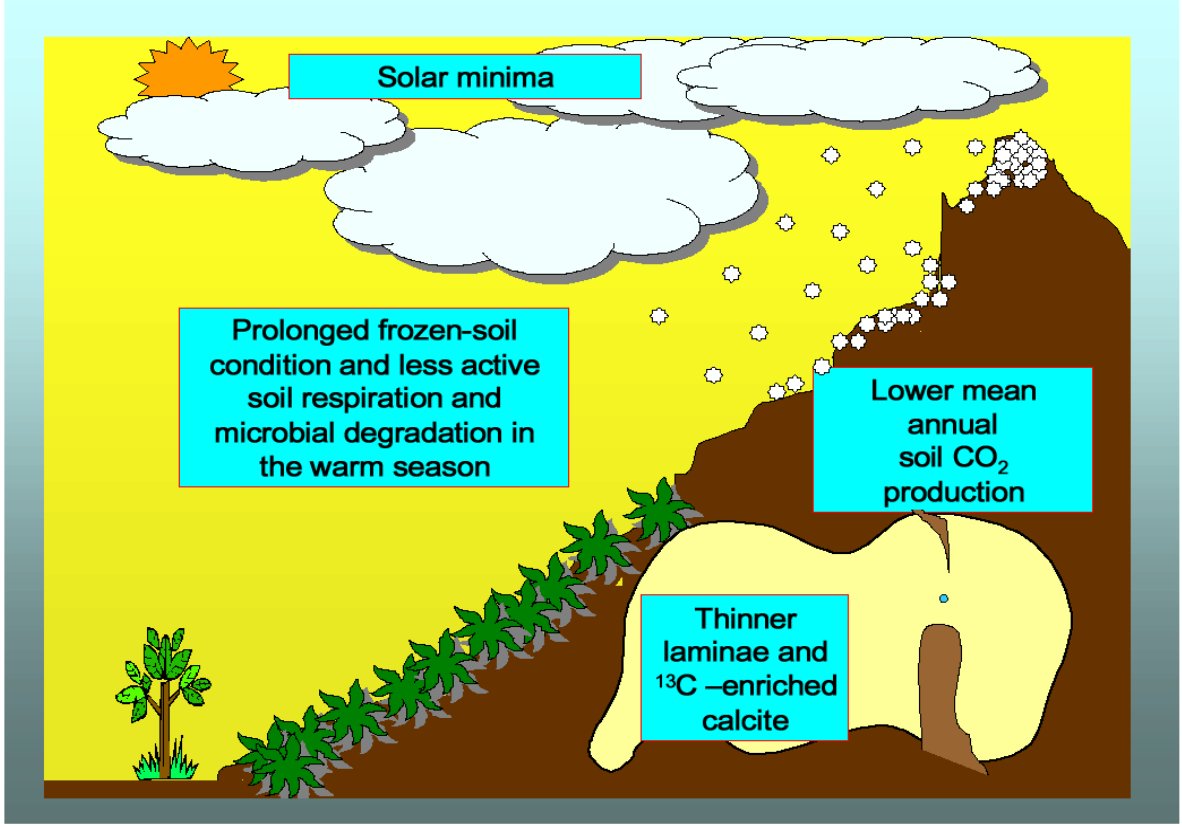
Solar maxima, less clouds, more light.

Cloud-cover variability seems to have an 11-year cyclicity, related to the cosmic ray flux. More clouds = less light Photosynthetic activity and microbial degradation are slower when light is less and vice-versa

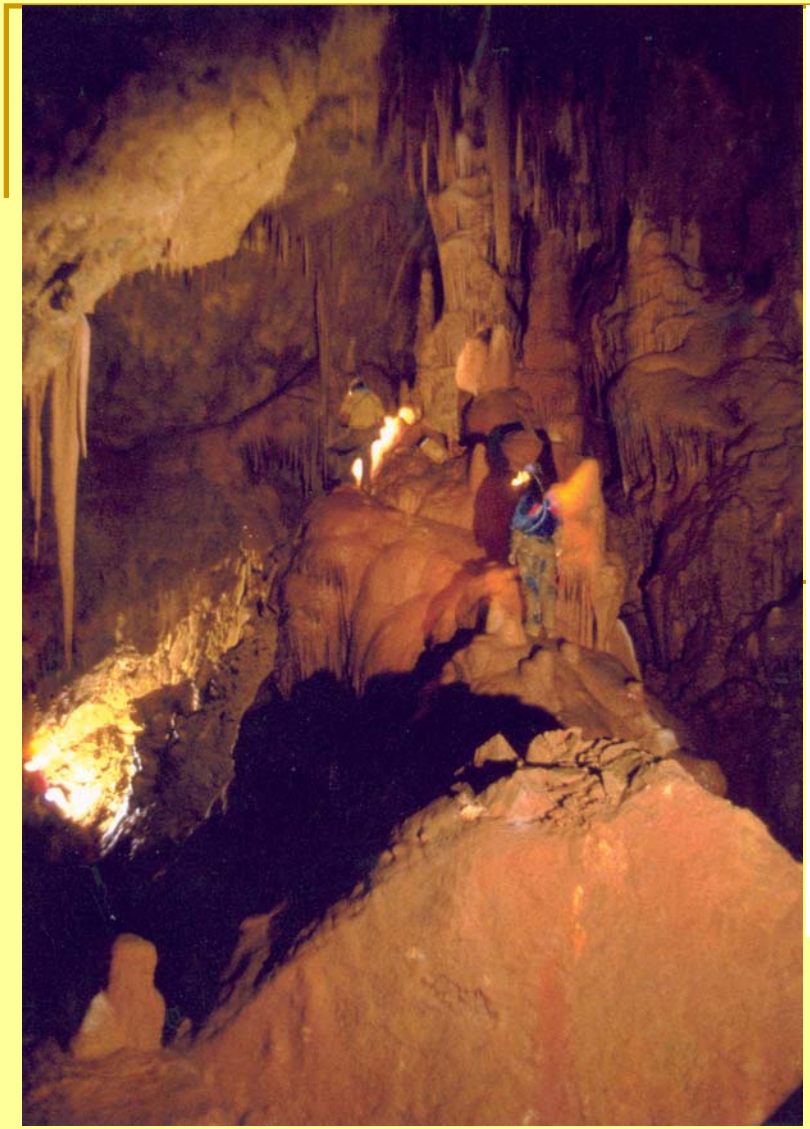


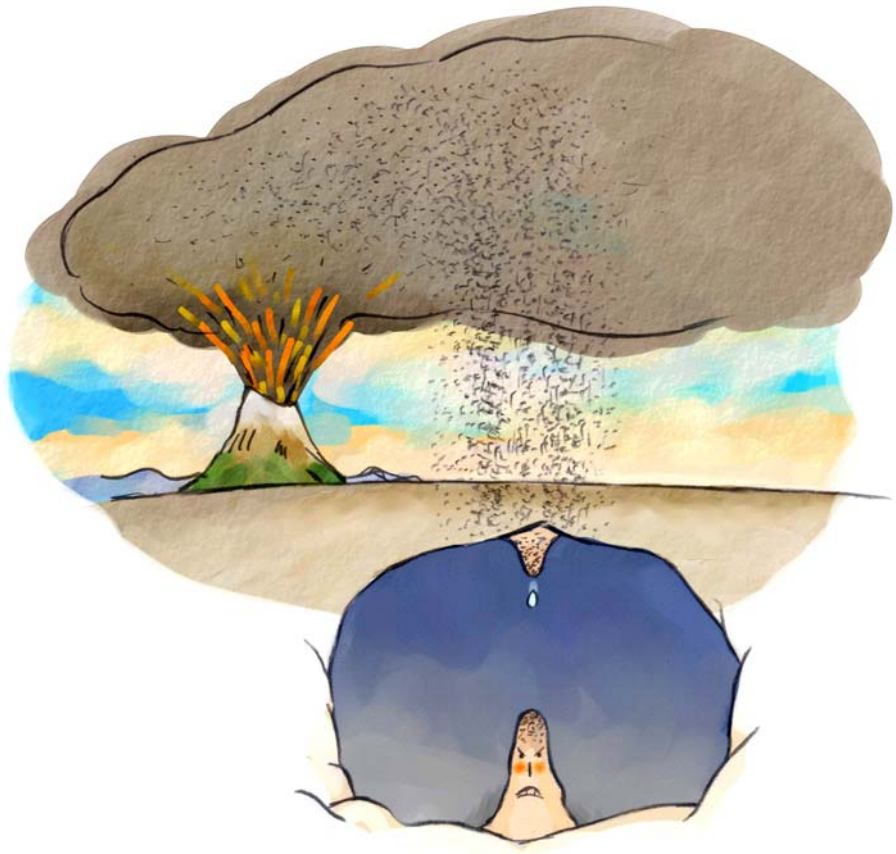


Solar minima. More cosmic rays. More clouds (physics aspects to be understood). Less sunlight. Stalagmites …starve!



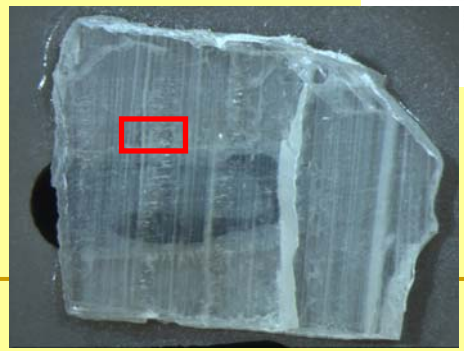
Summers with no Sun: Volcanic forcing -

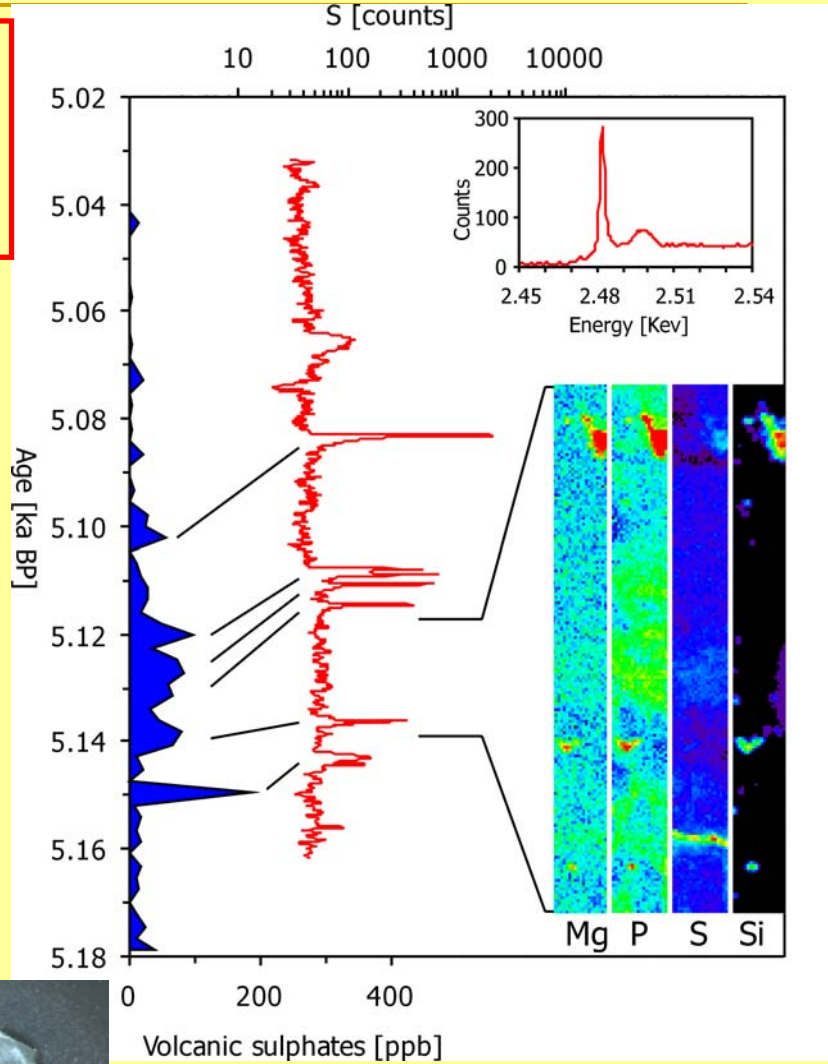




Sulphate in Stalagmites
Grotta Gualtiero Savi, Trieste

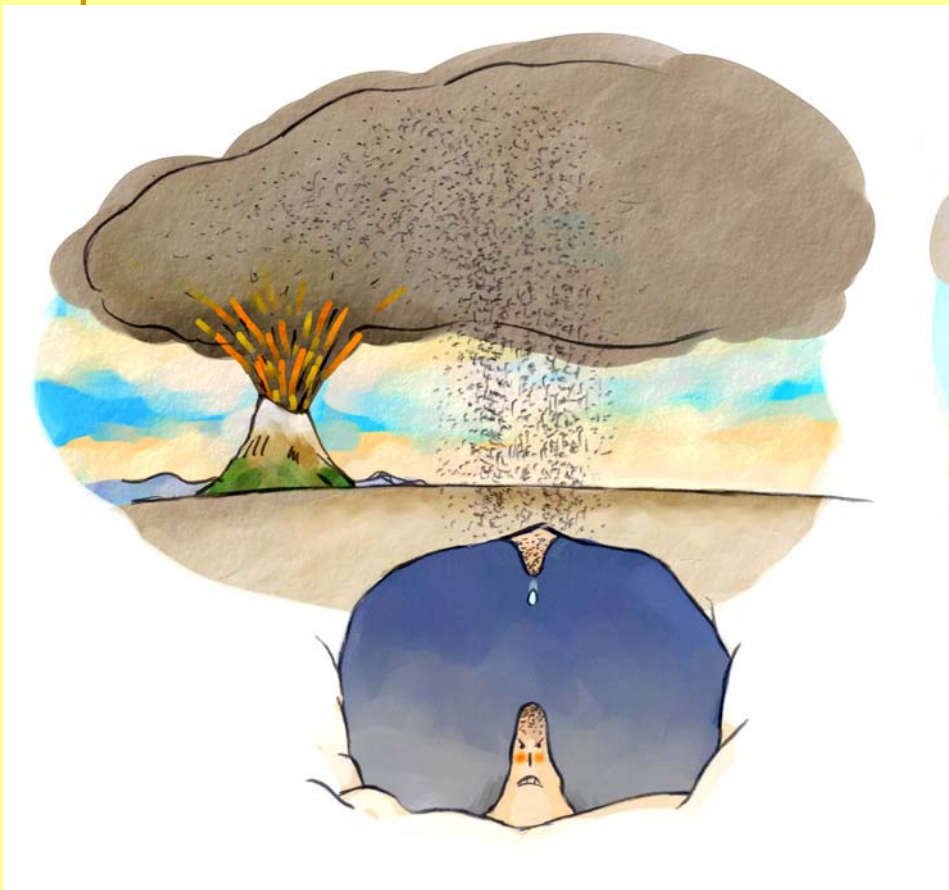
Synchrotron radiation micro-XRF on SV1, revealed S-sulphate peaks from ca. 5200 to 5100 years ago. These correspond to volcanic sulphate peaks in the ice cores.

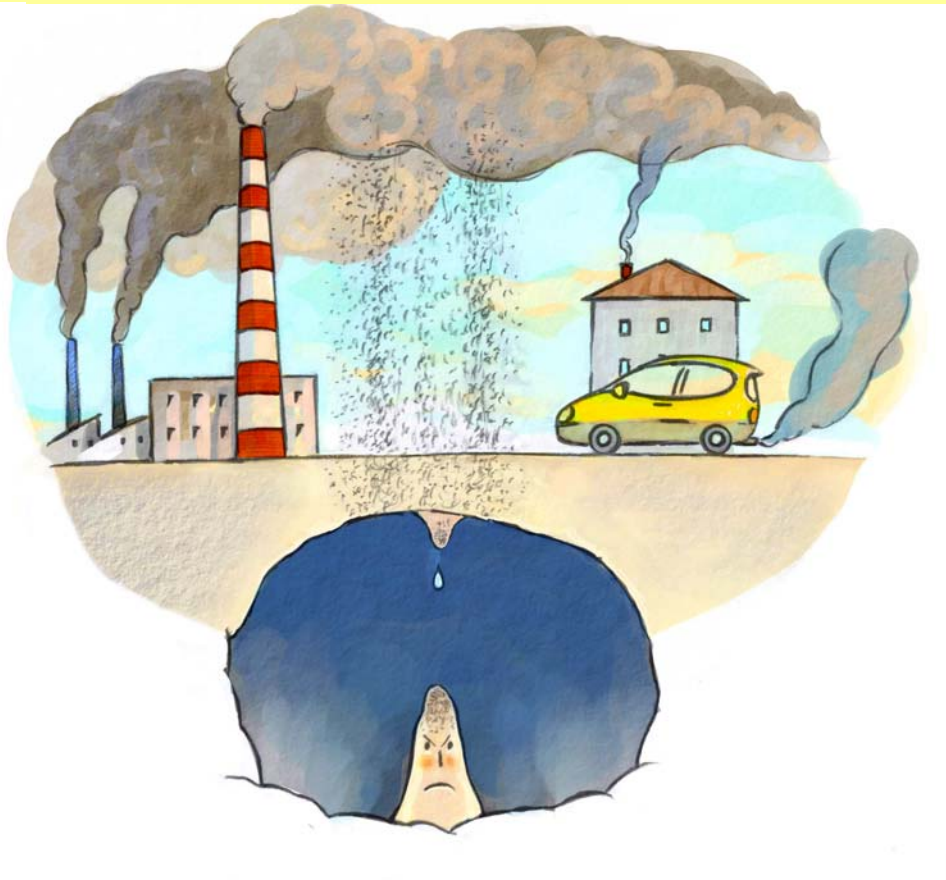




From Frisia et al., 2005

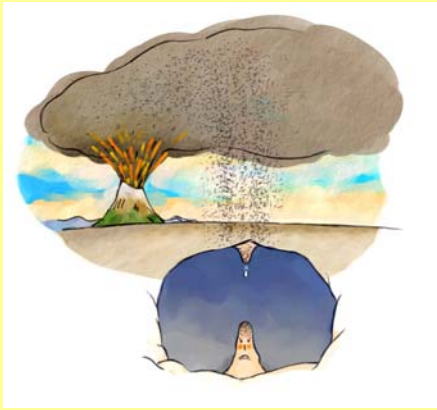
Volcanic & Anthropogenic sulphate emissions





Volcanic eruptions recorded from stalagmites in Trentino

Grotta di Ernesto



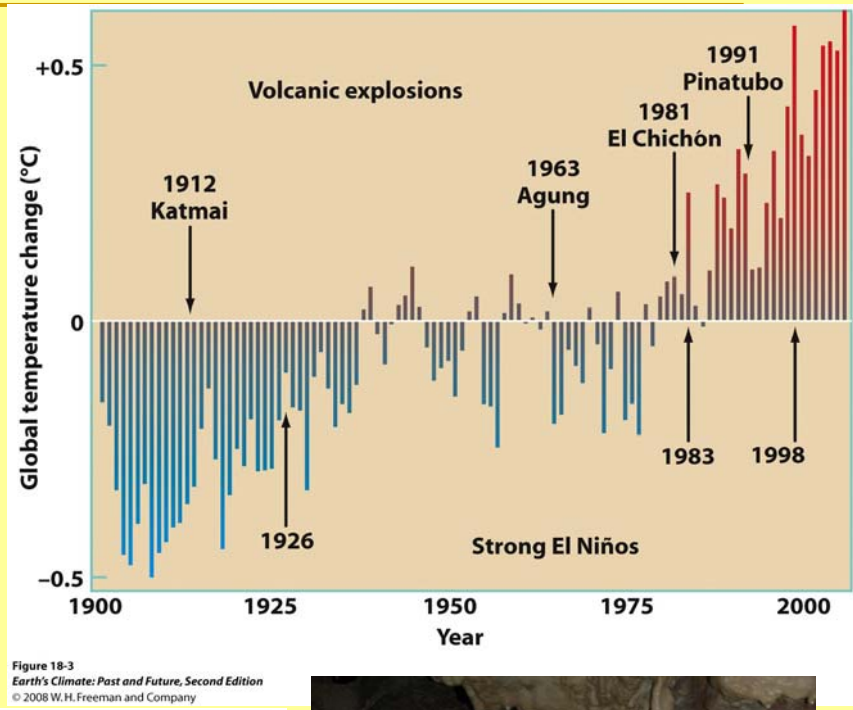
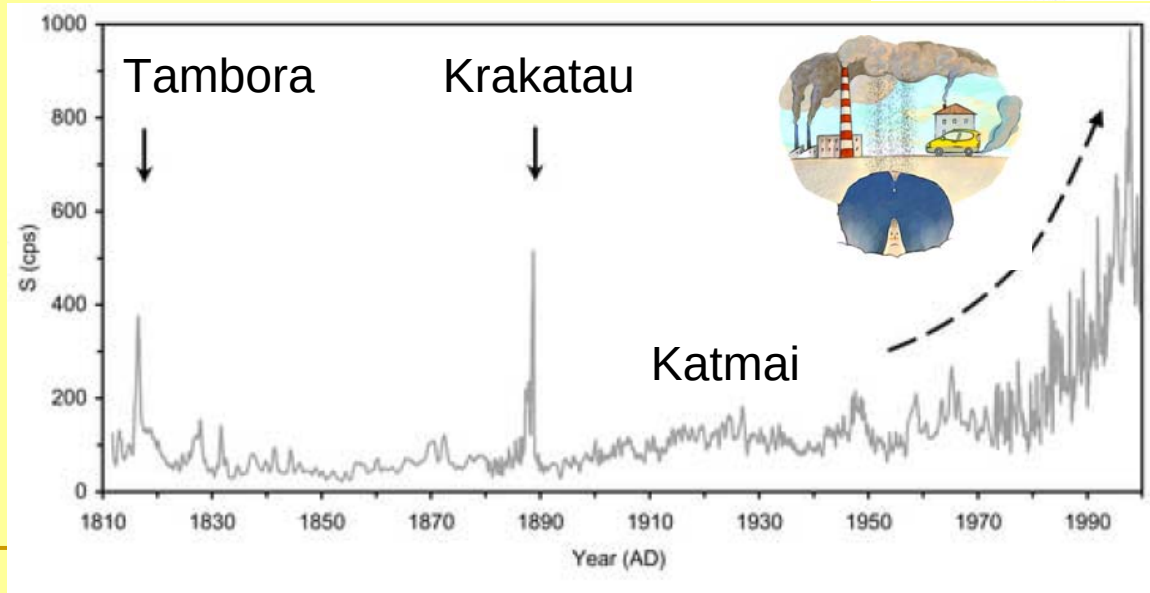
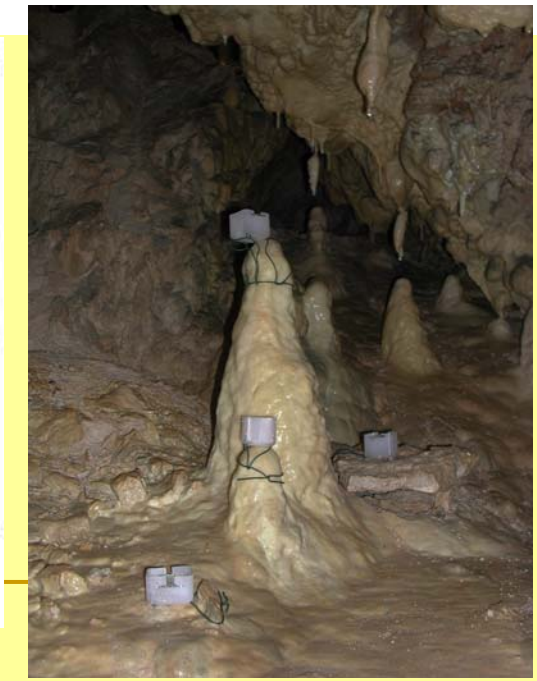


Figure 18-3
Earth's Climate: Past and Future, Second Edition





Sulphate, CO_2 & global warming … speleothems say…

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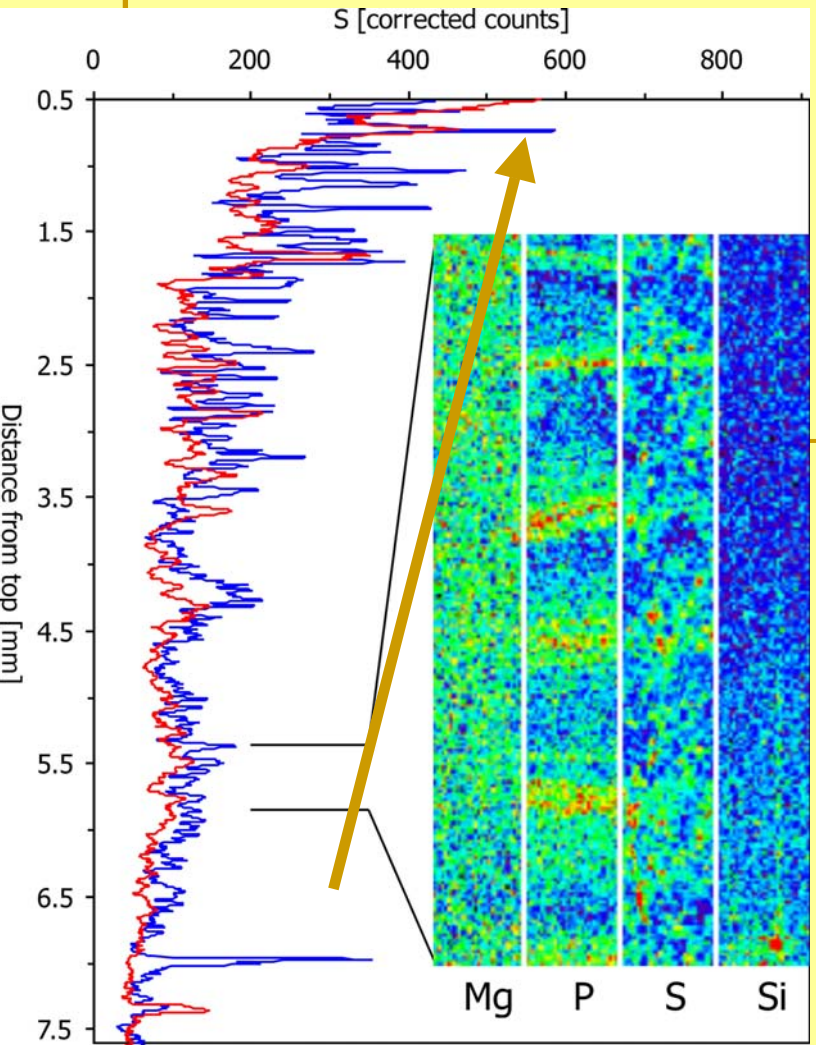
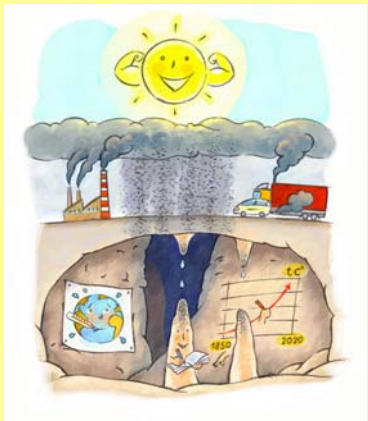
Past 100 years at Ernesto



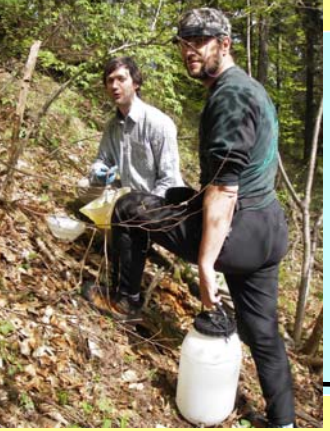


Trentino speleothems unequivocally record Sulphate increase in the past 100 years.

This causes acidification of forest soil due to SO_4 deposition.

What happens?

From Frisia et al., 2005



Atm. CO_2

Low pH

soil CO_2

dissolution

Colloidal transport

Pb, Zn, U, S, P associated with organic colloids enter the aquifer.

element depletion in soil

SPELEOTHEMS:

Capture climate changes at all scales of changes

Archive climate responses to all climate forcings

Record propagation of climate change responses at regional scale

Record ongoing environmental changes under the current warming

Capture anthropogenic perturbations of the natural system

CONCLUSIONS

Speleothems provide insight on causes of climate changes and their impacts on the environment.

They are the "ice cores" of the XXI Century

Their study is necessary to validate models