Integrating Speleothem Proxies from Temperate Regions: Prospects from Monitoring and Imaging Studies

Jay L. Banner and Nathan R. Miller
Jackson School of Geosciences
University of Texas at Austin

June 25, 2013

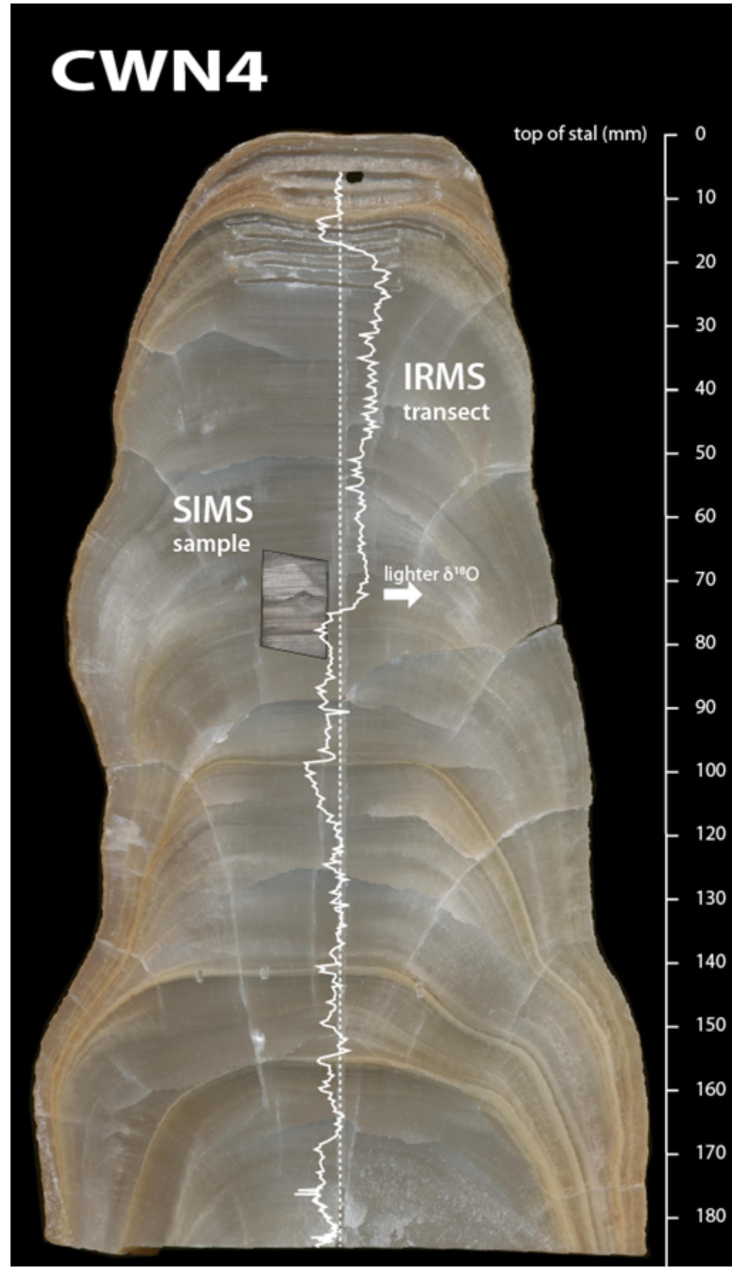
High Resolution Proxies of Paleoclimate
University of Wisconsin-Madison
June 23-26, 2013

WiscSIMS

Speleothems as climate proxies

- Widespread occurrence
- Long and continuous growth
- Accurate geochronology
- Range of proxies
  - Growth rate
  - Stable isotopes
  - Trace elements
  - Radiogenic isotopes

Texas stalagmite CWN4



What are the opportunities for high resolution study of paleoclimate proxies?

Growth rates of some paleoclimate proxies

Forams: 3 μm/day (Spero)

Ice cores: <10 - 22 mm/year (Muller)

Nautilus: 30 μm/day (Linmeier)

Speleothems: 40 μm/year

Outline

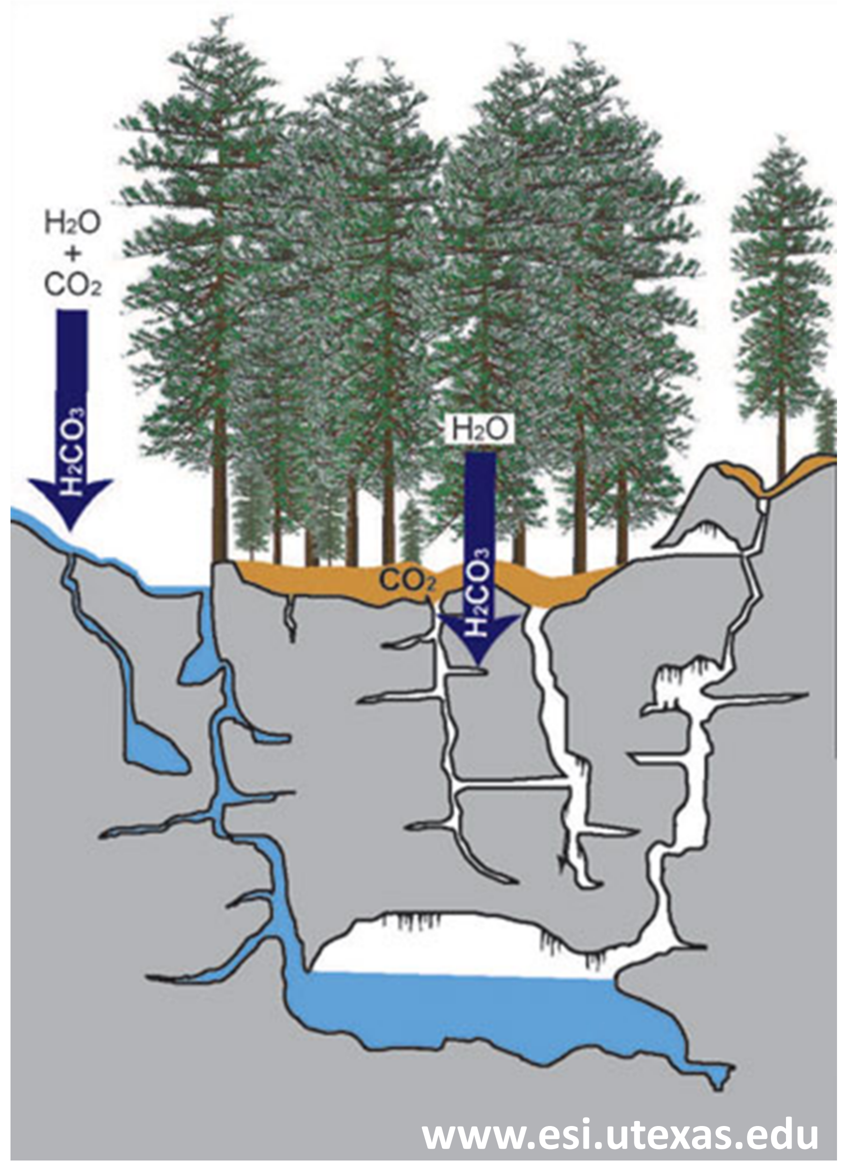
1. High-resolution climate change potentially recorded by speleothems
2. Monitoring processes in modern karst systems
3. Integrating high-resolution geochemistry and imaging
4. Forward modeling

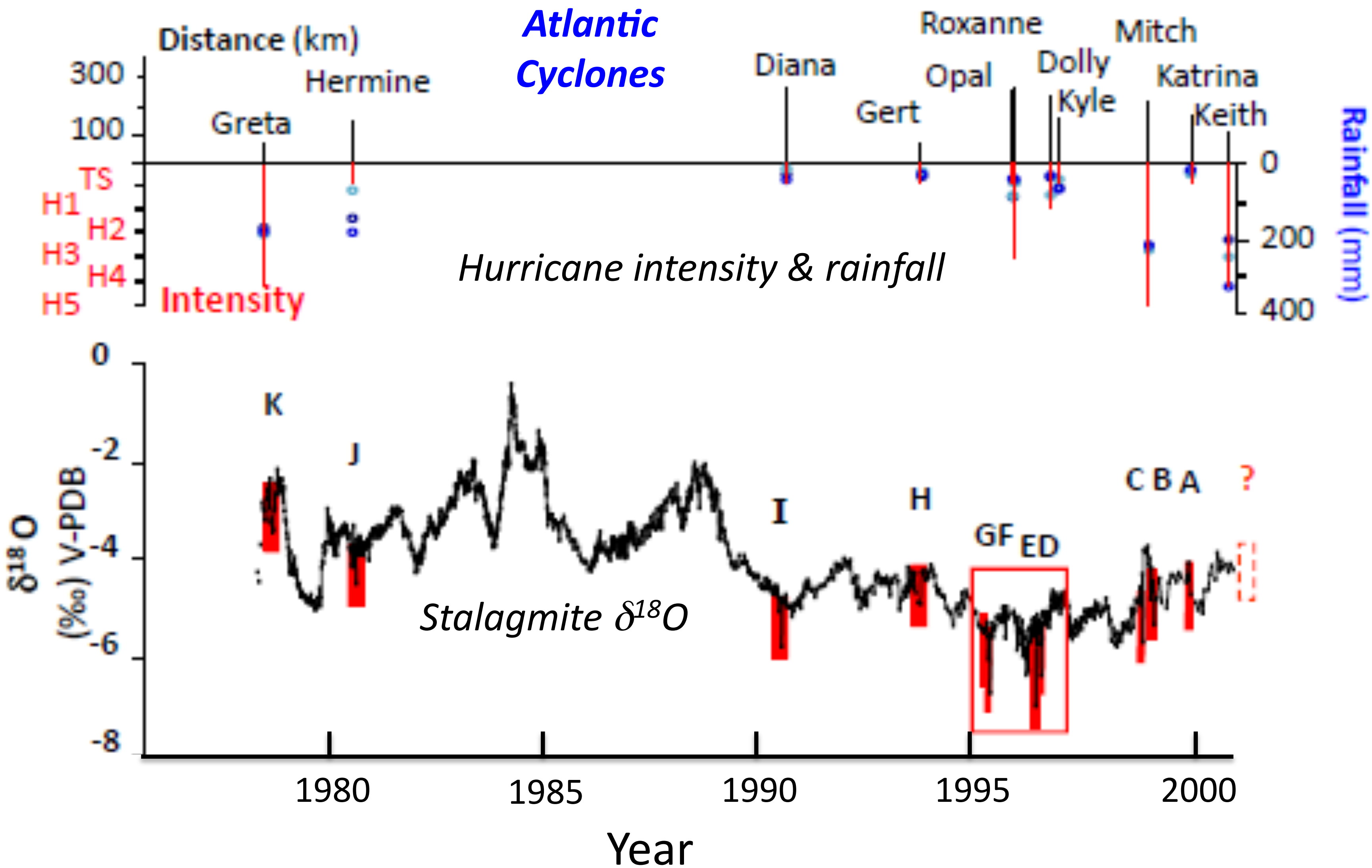
High-resolution paleoclimate processes potentially recorded by speleothems

1. Extreme events
   – Tropical cyclones
2. Abrupt climate change
   – Transitions such as Bølling-Allerød, Younger Dryas
3. Seasonality

Potential processes controlling seasonality of drip-water compositions

- Rainfall seasonality in amount and composition
- Soil zone organic activity
- Ventilation of cave atmosphere
- Calcite growth
- Water flux and flow paths through vadose zone



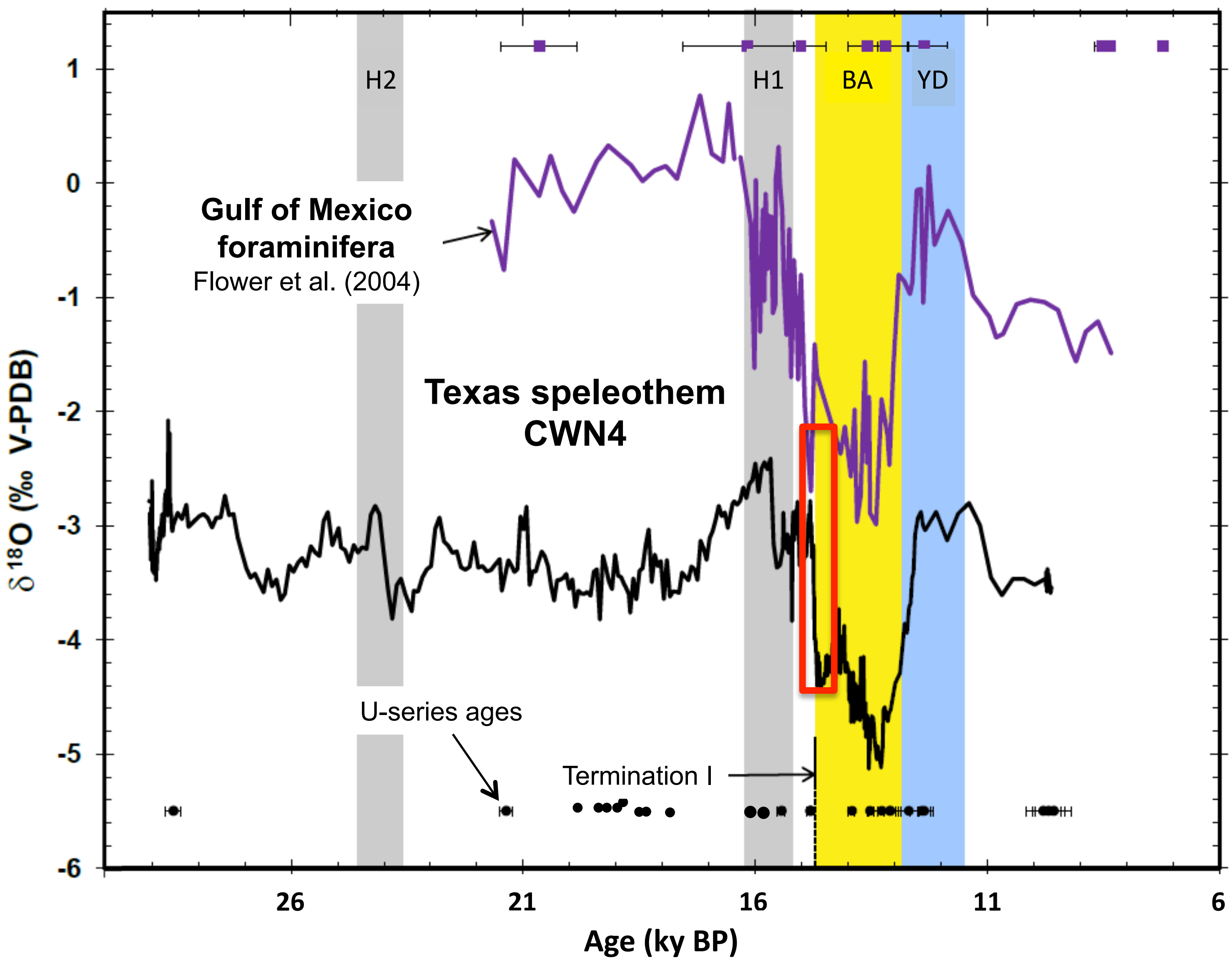


1. Extreme events: Tropical cyclones and Belize stalagmite

Analyses by IRMS (1,500 μm/yr)

Frappier et al. (2007)

2. Abrupt climate change:
Texas speleothem oxygen isotope time series



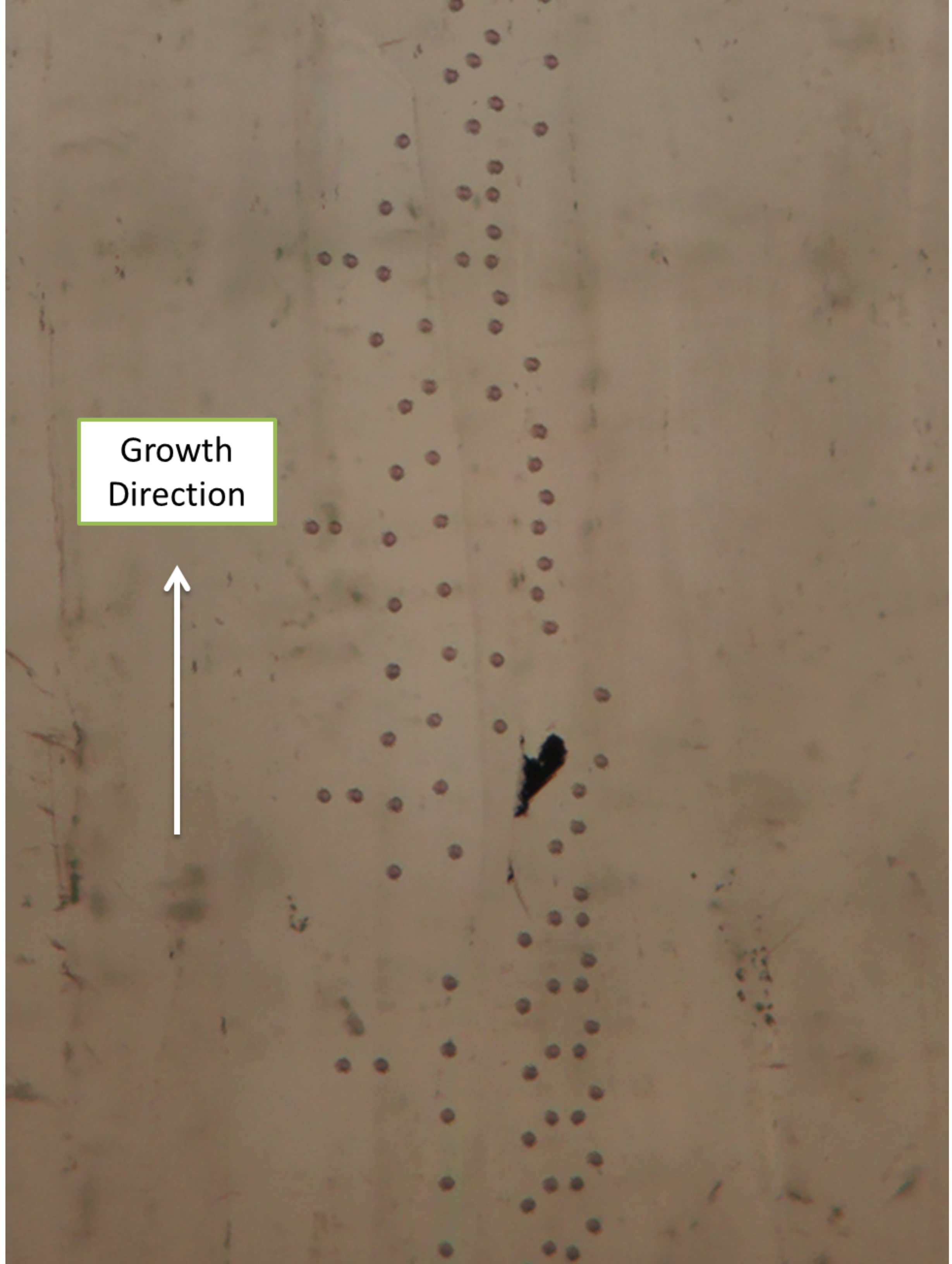
Feng et al. (in review)

Comparison of IRMS with WiscSIMS $\delta^{18}O$: Texas speleothem CWN4

- IRMS
  - 200 µm steps
  - ± 0.08
- SIMS 10 µm spots
  - 449 samples
  - 218 standards
  - ± 0.3 ‰
  - 48 hrs
  - SEM pit exam
  - Laser registration

U-series:

Edwards lab, U Minn.




Monitoring modern karst systems
understanding karst processes
assessing kinetic effects
seasonal/event transfer function

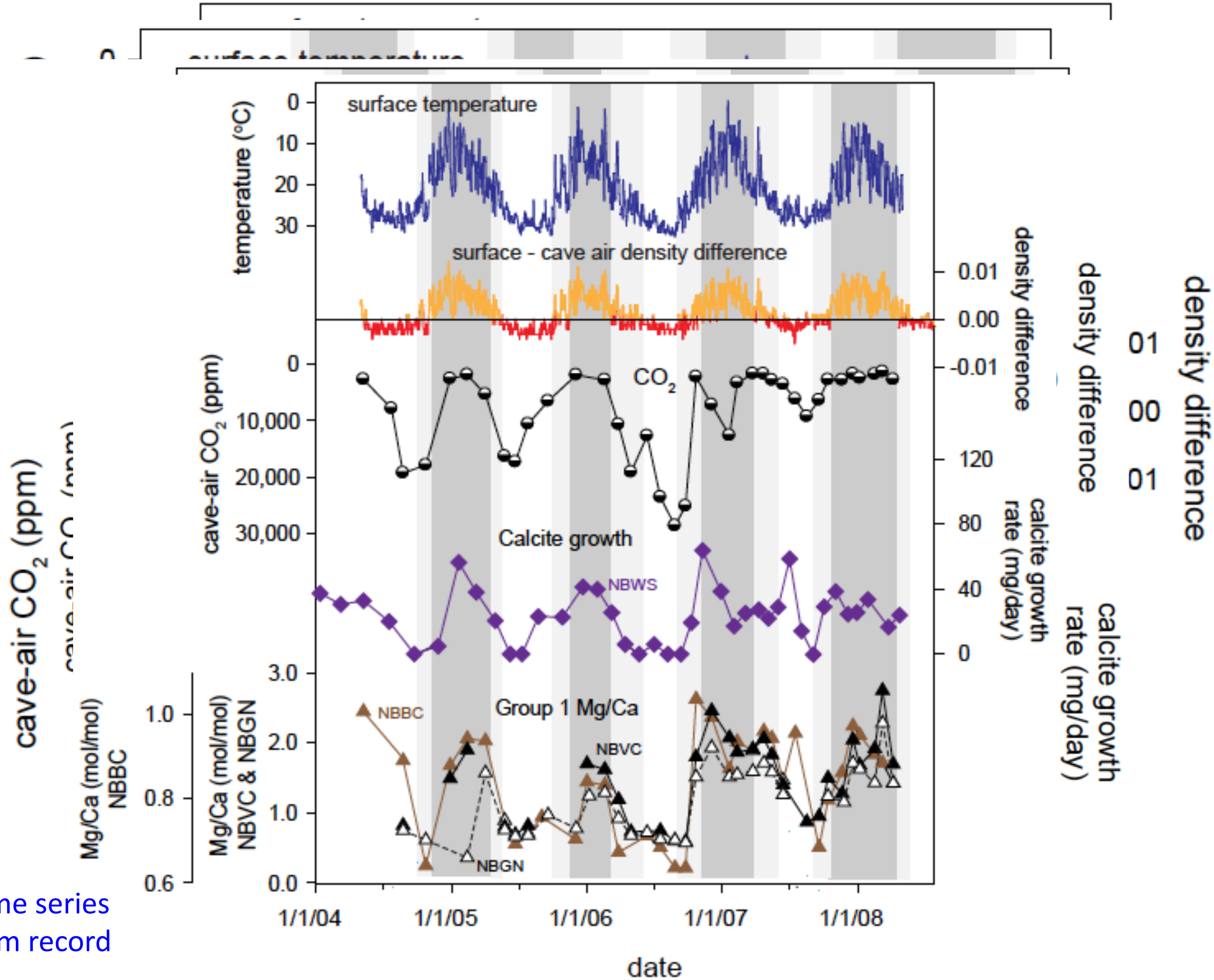
3. Seasonal changes in modern karst systems – three examples

A. Trace elements: Seasonality in drip waters driven by cave ventilation and calcite precipitation

B. Oxygen isotopes: Seasonality in drip waters driven by changes in rainfall $\delta^{18}O$

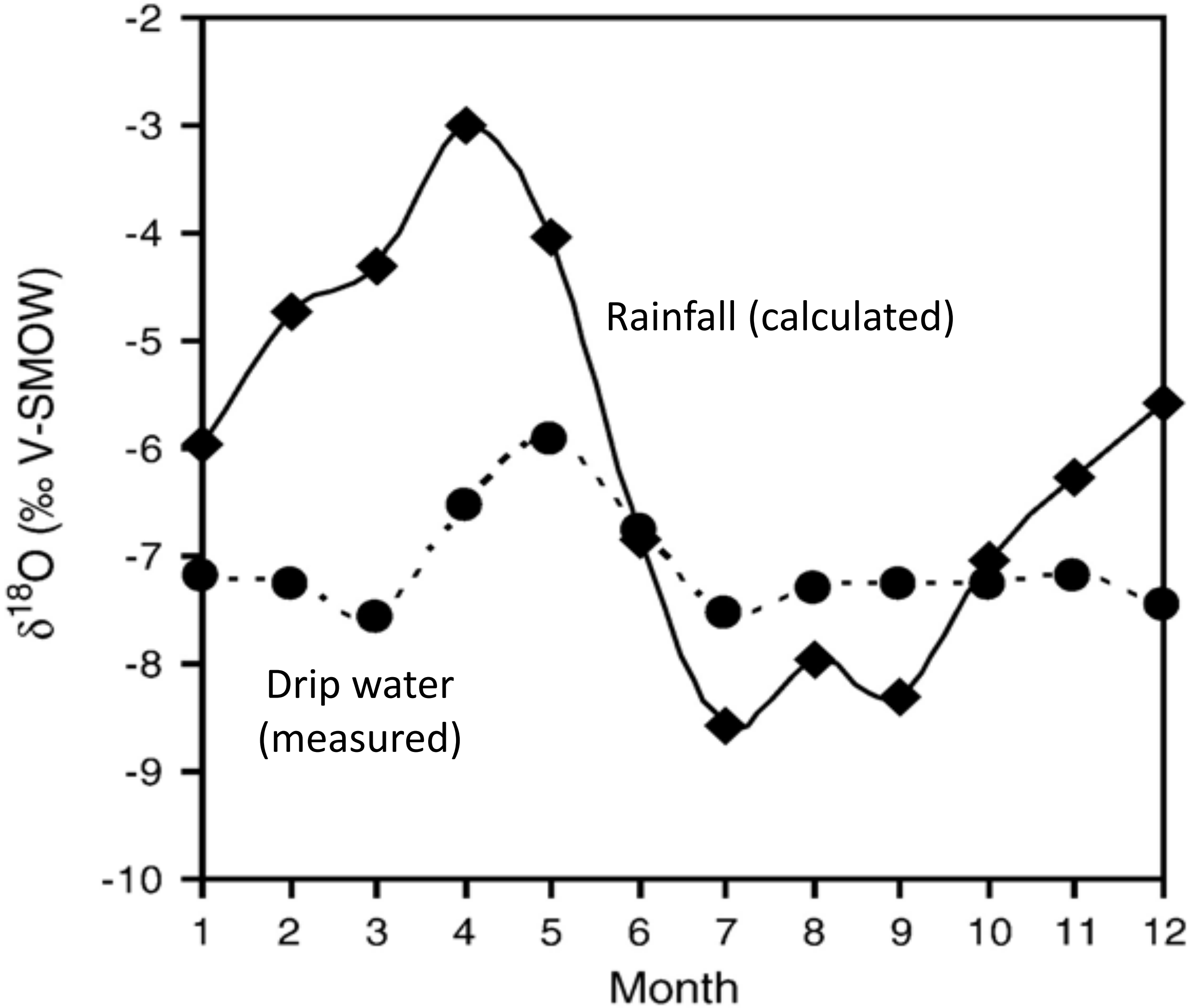
C. Oxygen isotopes and trace elements: Seasonality in drip waters and speleothem calcite driven by changes in temperature

A. Mg/Ca seasonality in drip waters - Cave NB, Texas (Wong et al., 2011)



Drip water time series
vs. speleothem record

B. Oxygen isotopes: Seasonality in drip waters driven by changes in rainfall $\delta^{18}O$ - Henshang Cave, China

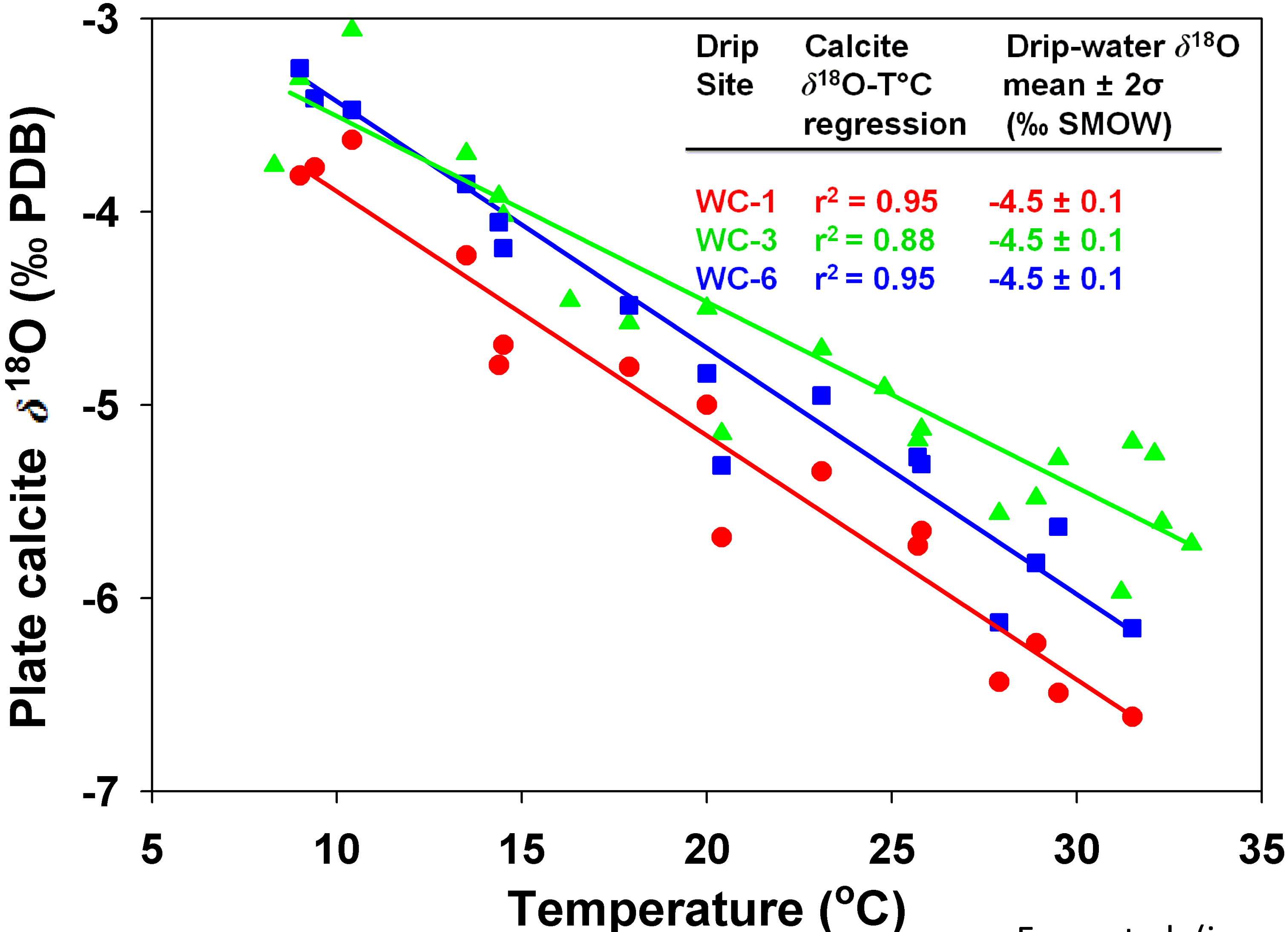


Vadose zone mixing

Johnson et al. (2006)

Seasonality recorded in speleothem calcite: Monitoring studies at Westcave, Texas

Substrate calcite $\delta^{18}O$ and temperature at Westcave (IRMS data)

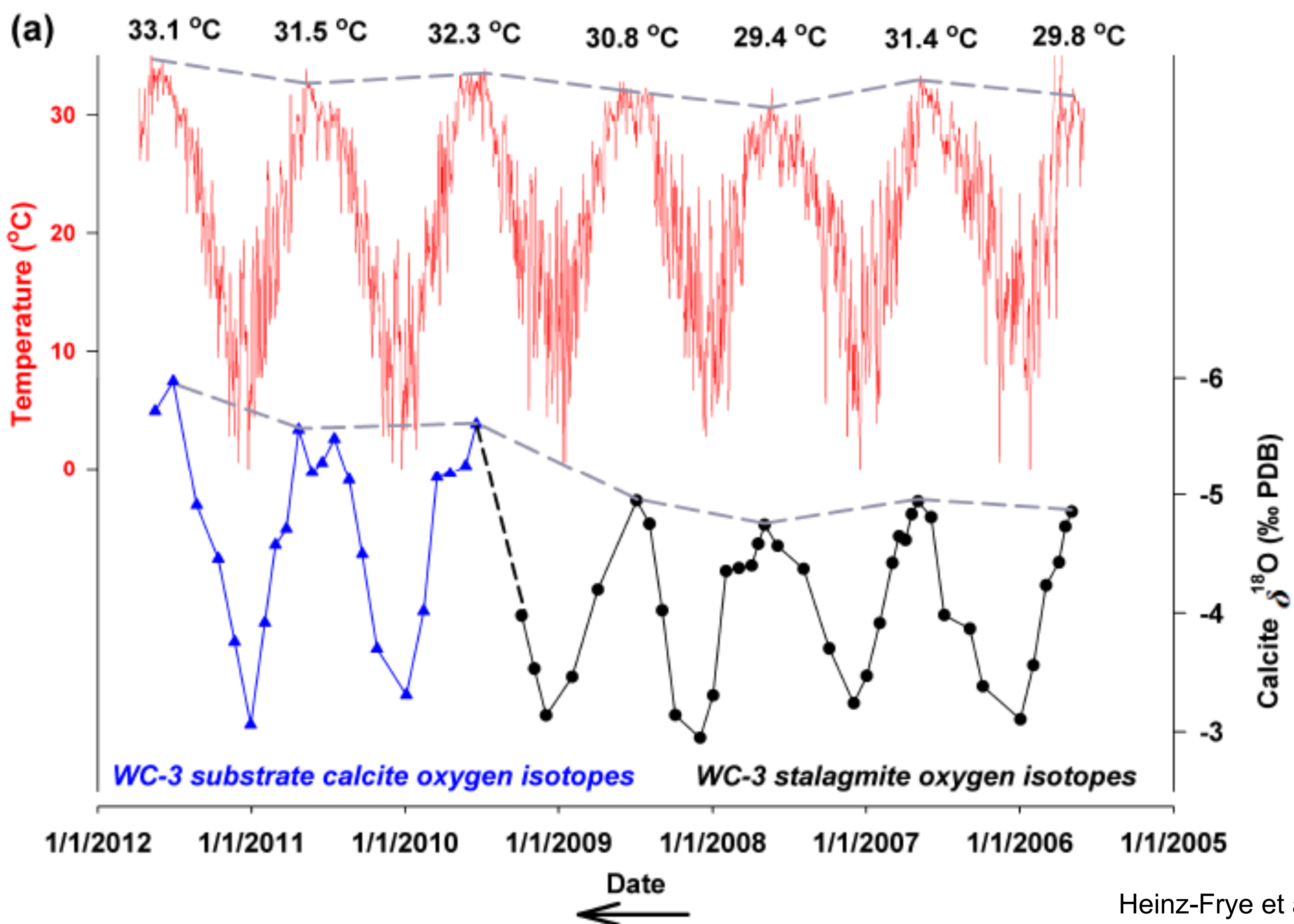


Feng et al. (in review)

Substrate calcite and stalagmite from Westcave

Oxygen isotope incorporation into speleothem corresponds to atmospheric temperature

ite



Heinz-Frye et al. (2011)
Feng et al. (in review)

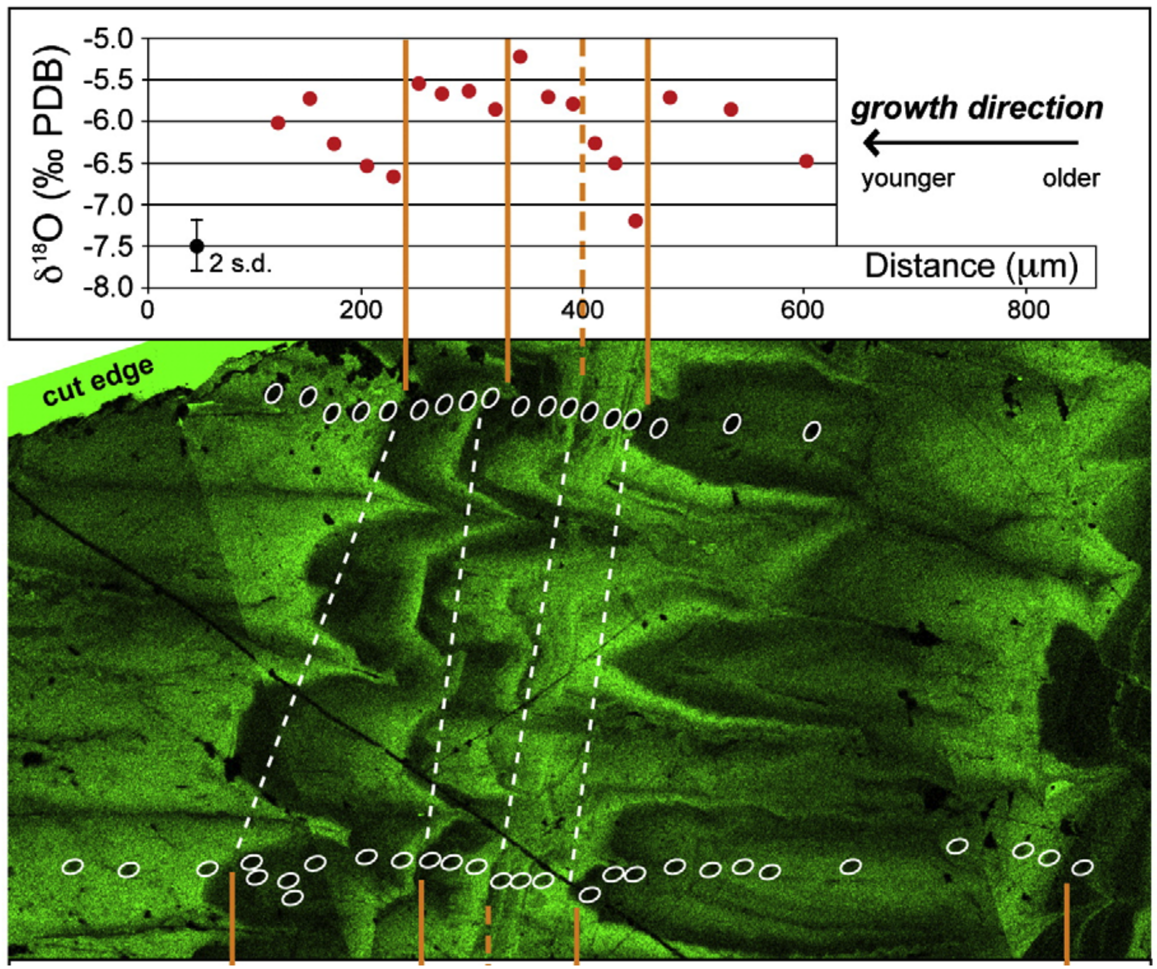
Is Westcave a freak?

Analytical challenges posed by slow-growth temperate speleothems

- Small sampling footprint (< 10 µm) needed for seasonal resolution
- Couplet signal must be resolvable above noise
- Calcite seldom reveals growth bands by conventional petrography
- Calcite growth fabric is often complex at fine scale

Growth band fabric imagery

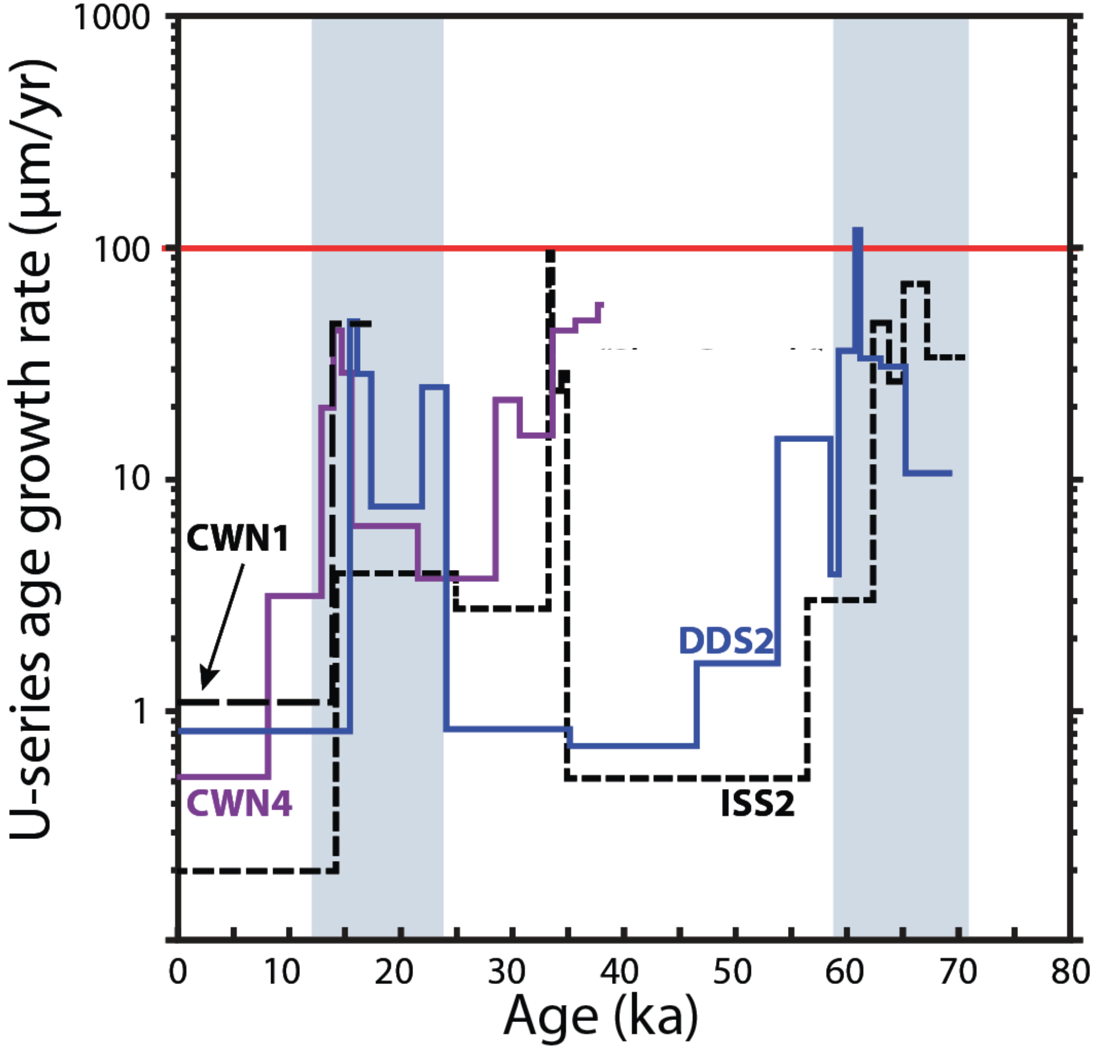
- Confocal laser scanning fluorescence microscopy reveals seasonal banding
- SIMS $\delta^{18}O$ - 10 µm spots
- Interpretation of seasonal $\delta^{18}O$ variation requires imaging of band morphology



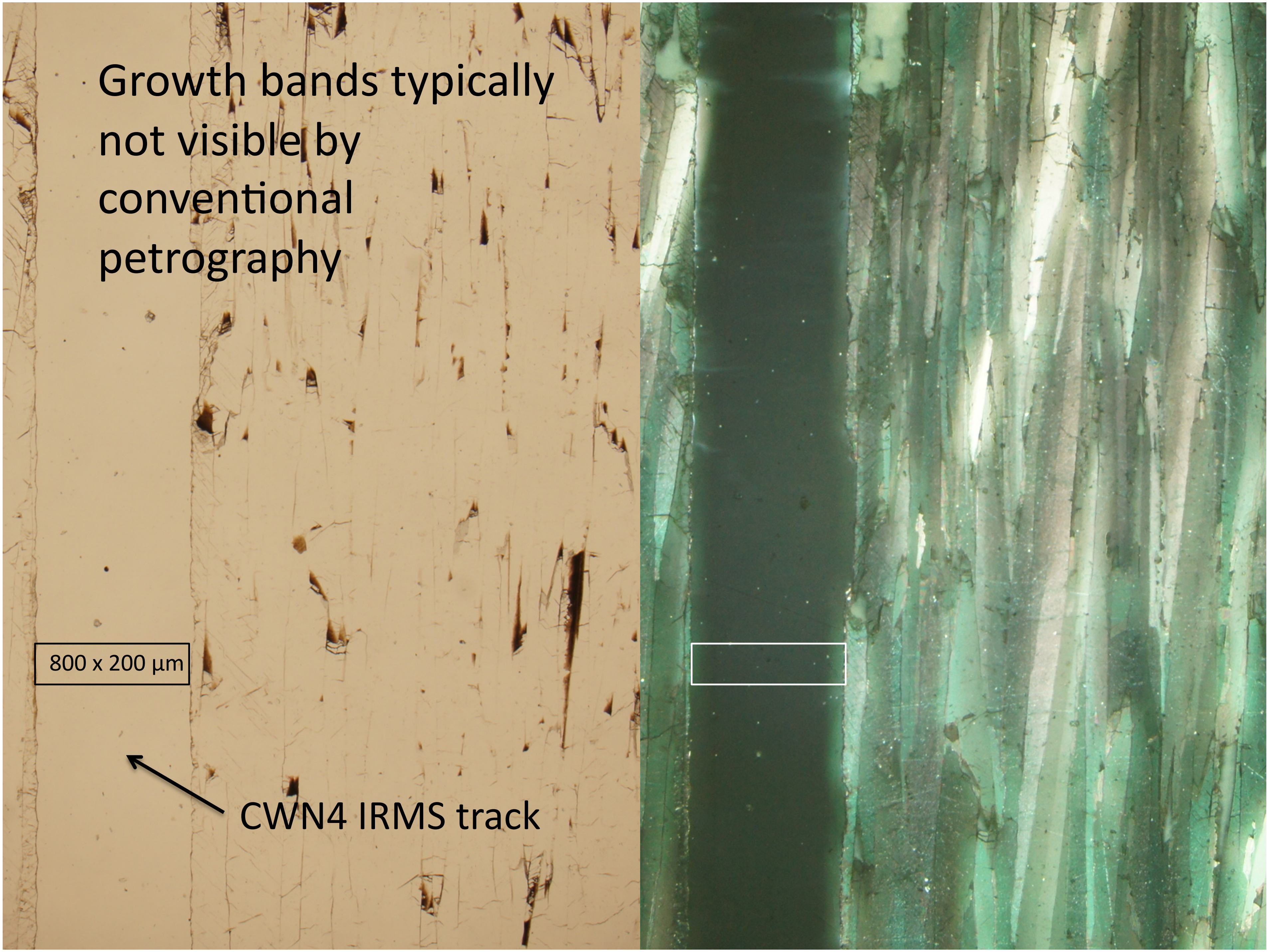
Holocene stalagmite, Soreq Cave, Israel

(Orland et al., 2009)

Texas Late Pleistocene speleothem growth rates



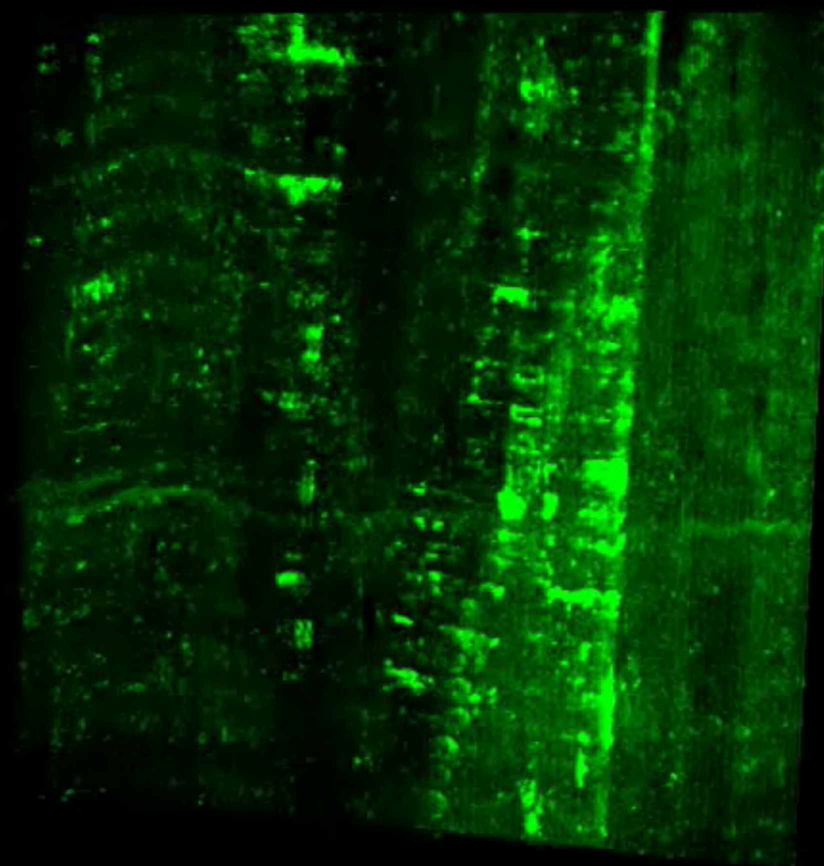
Musgrove et al. (2001)


Growth bands typically not visible by conventional petrography
800 x 200 µm
CWN4 IRMS track

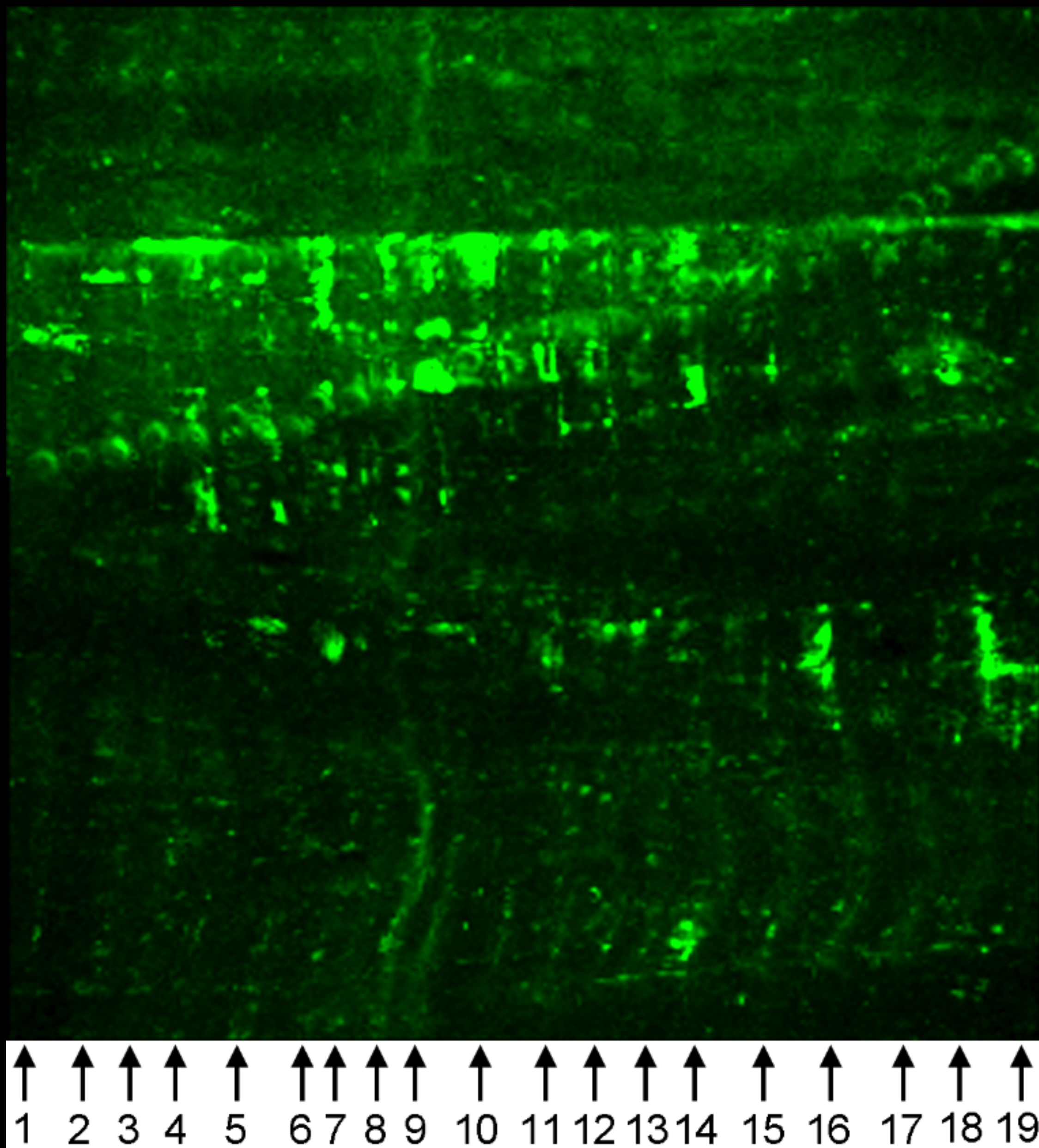
Confocal Scanning Laser Microscopy

Texas stalagmite CWN4

- 3D stack image shows growth bands
- 158 slices over 60 microns depth



Stalagmite CWN4 confocal couplet count



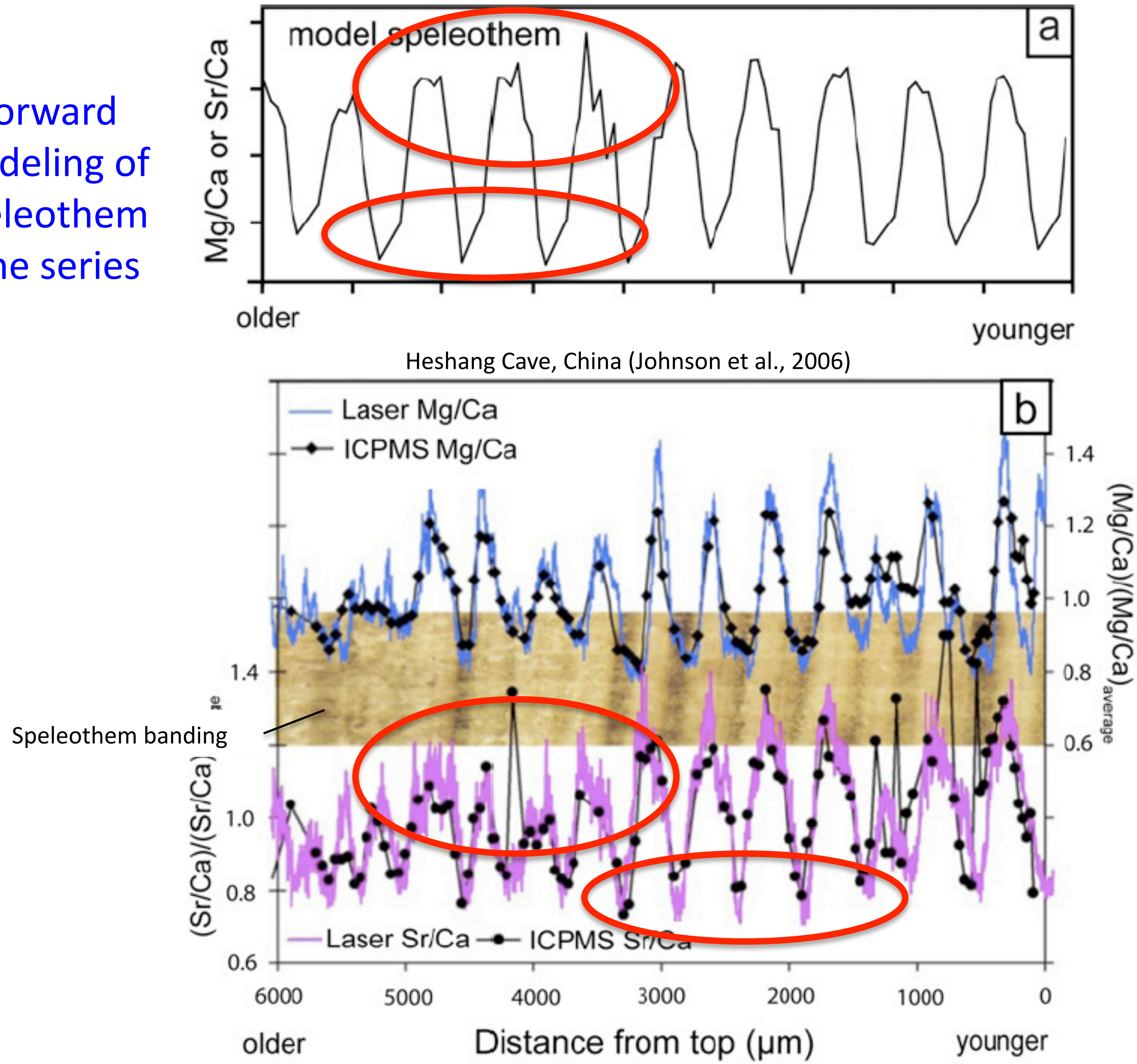
Average couplet thickness: 41 µm

U-series growth rate: 39 µm/yr

Integration of methods

- High resolution geochemical analysis
- Sample imaging
- Monitoring modern system
- Forward modeling

Forward modeling of speleothem time series



Wong et al (2011); see also Stoll et al. (2012)

Prospects

1. High-resolution analytical methods
   - reconstruct extreme events, abrupt climate change and seasonality
2. Monitoring of modern systems
   - key constraints on processes controlling speleothem proxies
3. Integration of methods, including imaging and forward modeling
   - maximize proxy accuracy and geochronology