

Milankovitch cycles and sea level high stands in western Mediterranean: A cave approach

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PRESENTATION'S OUTLINE

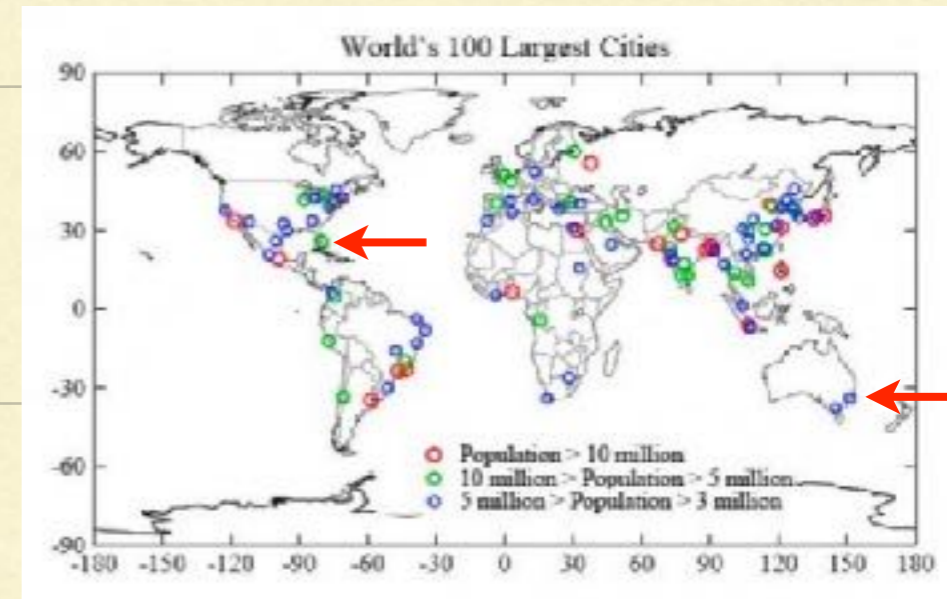
- ◆ why we care?
- ◆ lessons from the past
- ◆ paleo-sea-level indicators
 - coral reefs
 - cave deposits
 - ◆ Pliocene sea-level in Mallorca
 - ◆ MIS 5e
 - ◆ MIS 5a
- ◆ Future work



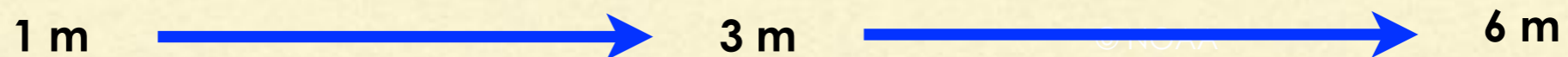
WHY WE CARE?

1/3 of Earth's population is living within 100 km of sea coasts;
low-lying coastal areas are very vulnerable to even small sea-level rise and storm surge

- beach & coastal erosion;
- flooding



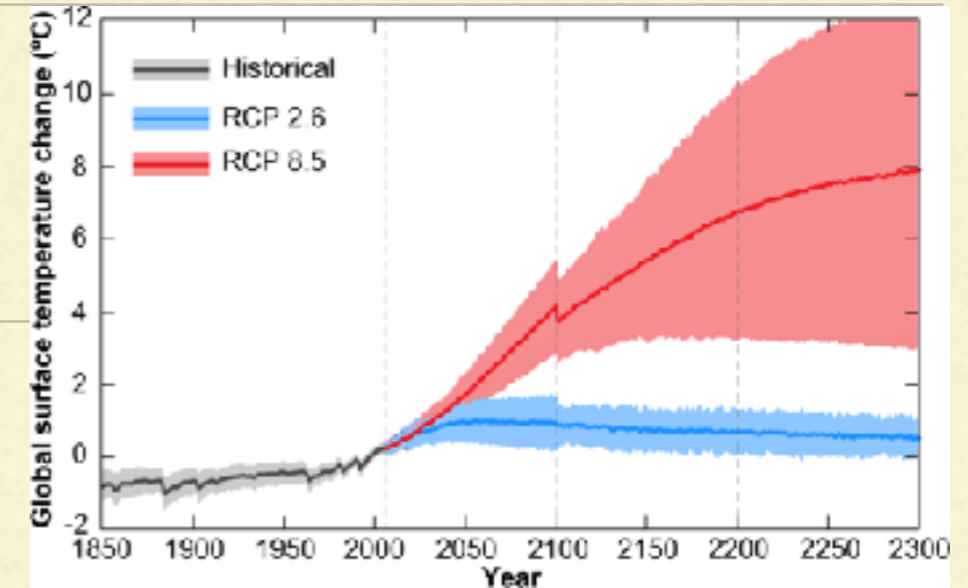
<https://www.e-education.psu.edu/geog438w/node/289>



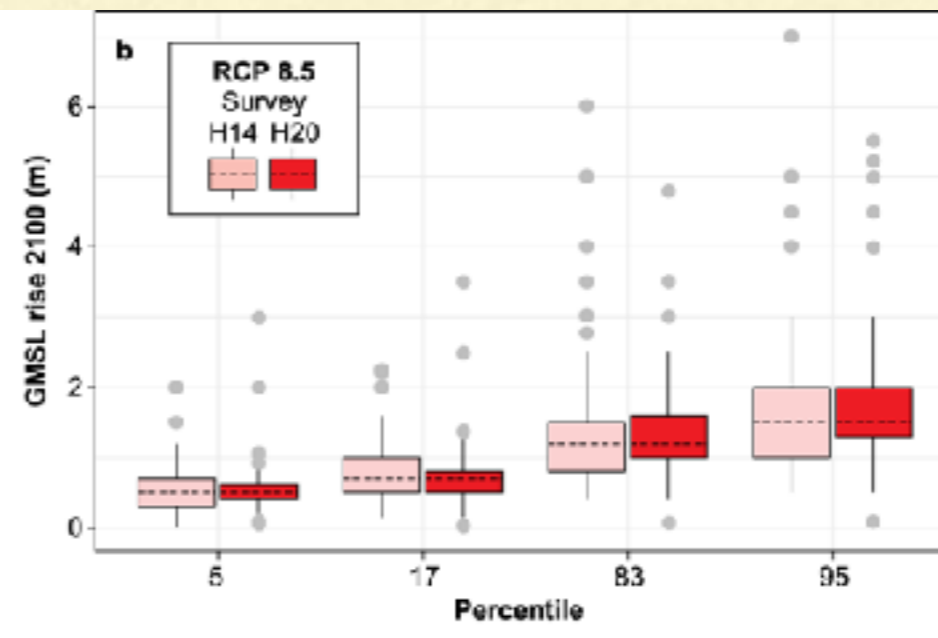
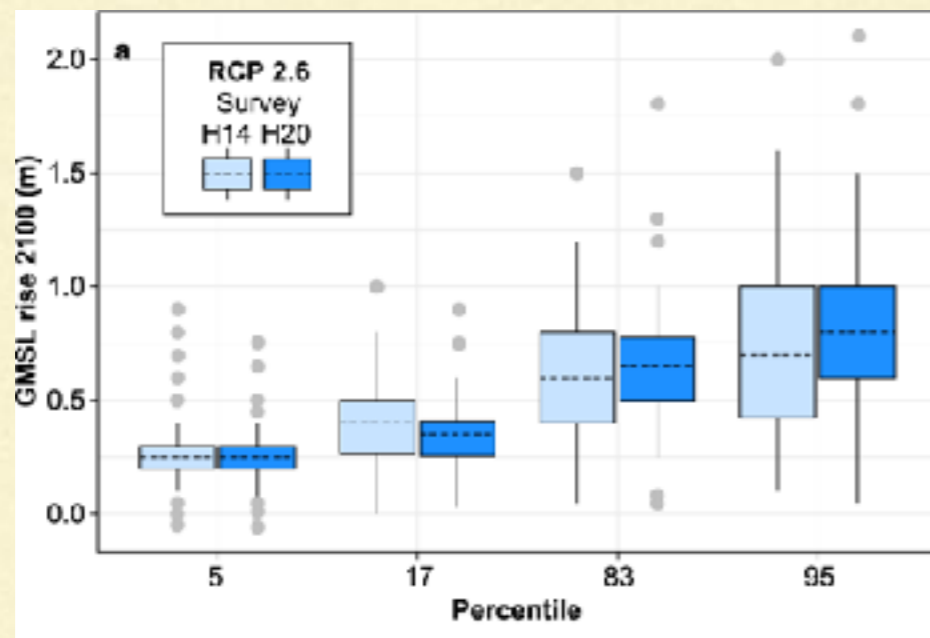
WHY WE CARE?

RCP 2.6 = CO₂ emissions are zero by 2100; CH₄ = half of 2020
 RCP 8.5 = CO₂ emissions continue to rise through 21st century

depending on the model, sea-level rise by 2100 is in the range of 0.5 to 1.2 m (at present T°C & ppm CO₂)

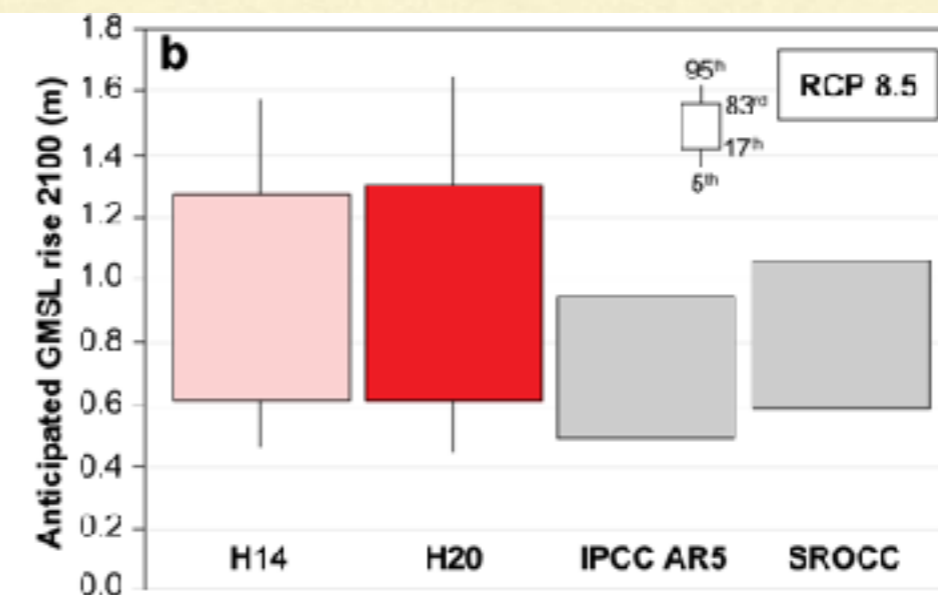
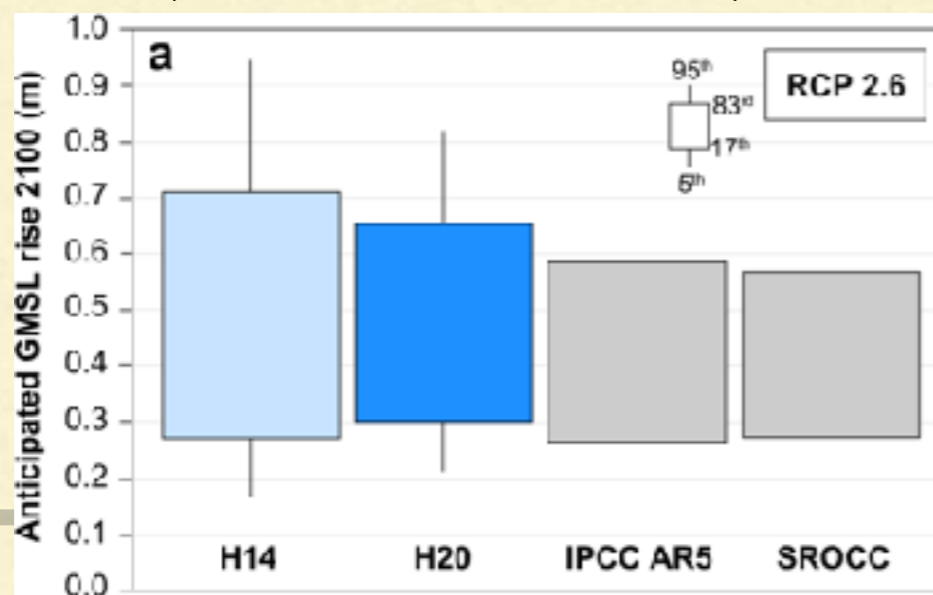


(Horton et al. 2020)



RCP = Representative Concentration Pathway

(Horton et al. 2020)



LESSONS FROM THE PAST

Milankovitch suggested that the glacial/deglacial cycles were triggered by small changes in the Earth's **obliquity** and **precession**, which caused changes in the intensity of solar radiation reaching at 65°N in summer.

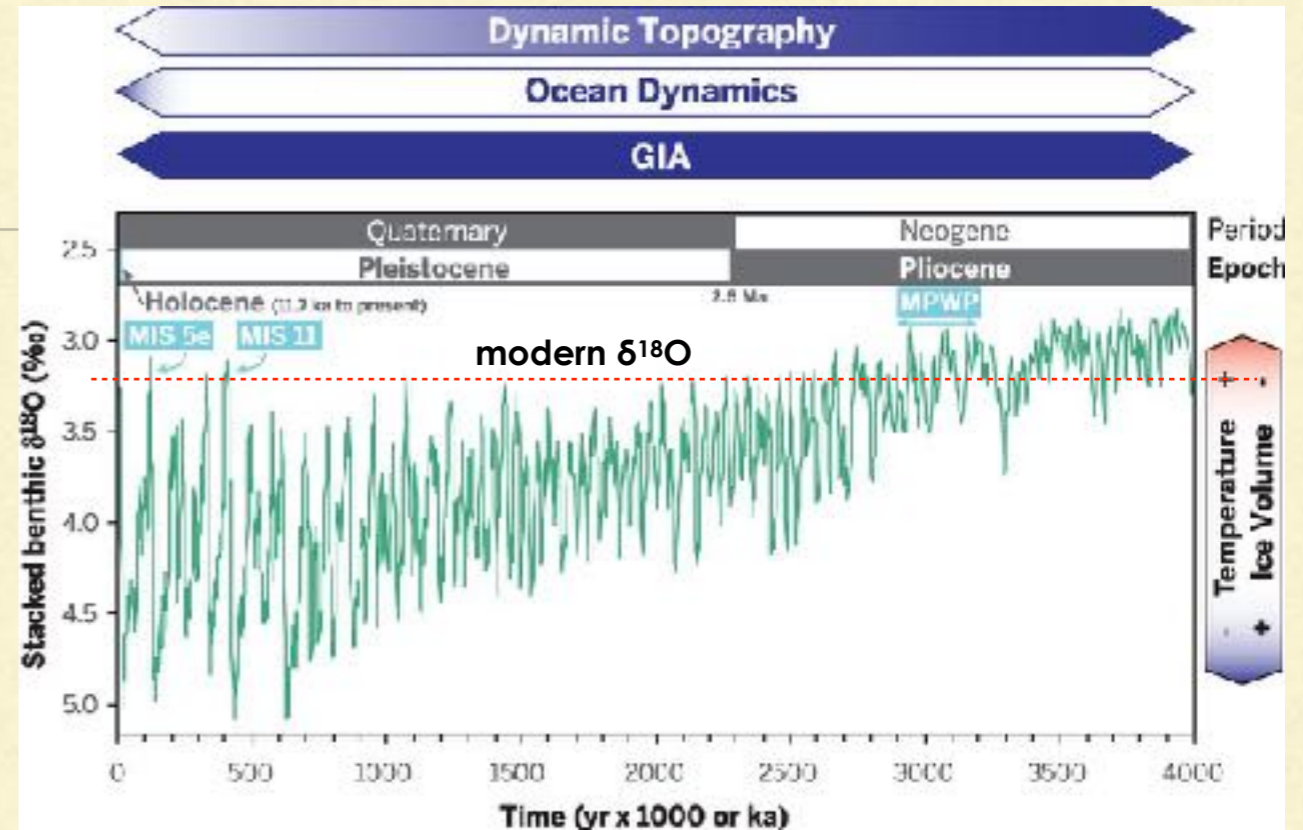
- eccentricity has a very weak impact on insolation;
- there is a direct relationship between climate (temperature, CO₂ concentration) and sea-level changes;
- global ice volume varied at ~41,000 yrs between 2.58 and 0.78 Ma and 100,000 yrs thereafter.

sea-level reconstructions based on oxygen isotopes contain uncertainties in the range of **±10 m or larger**

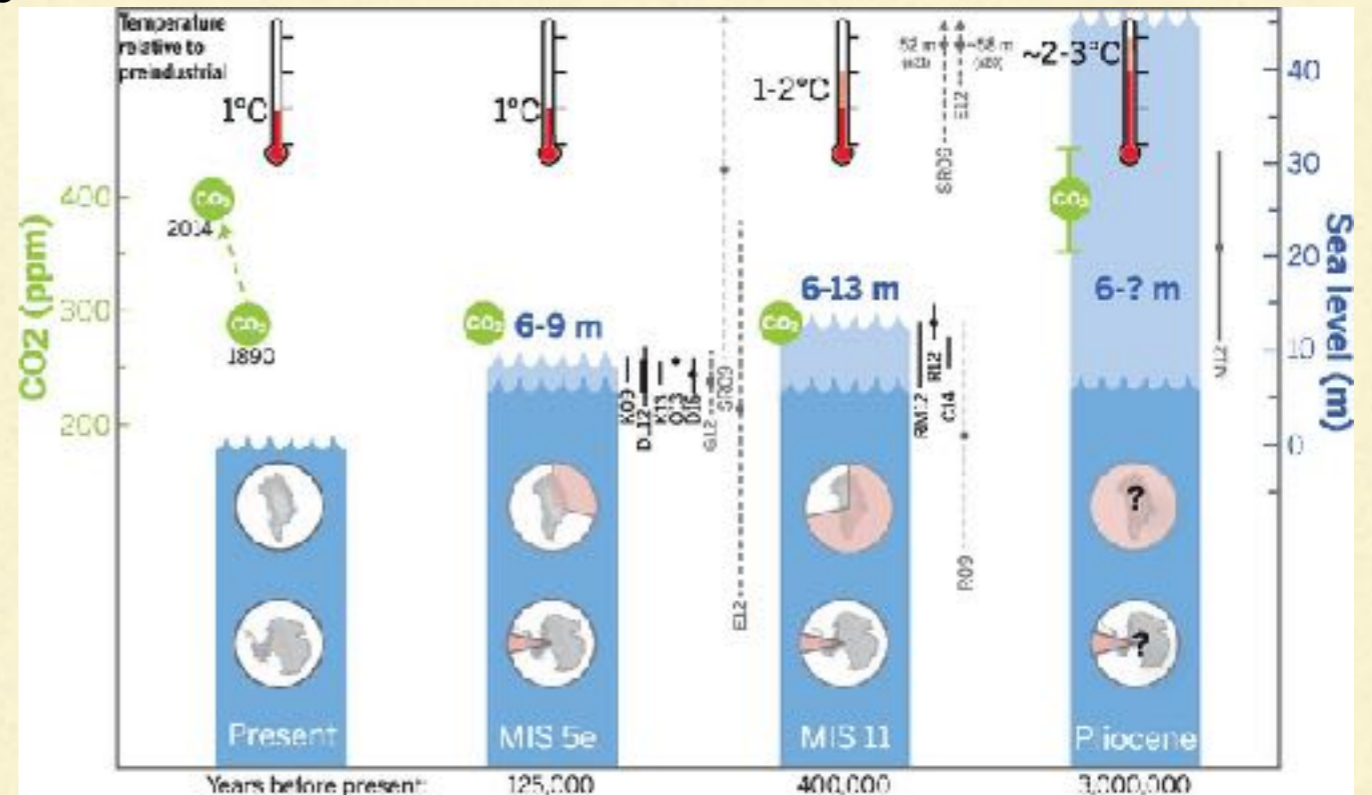
warmer-than-modern climate:

during mid-Pliocene Warm Period (**MPWP**) proxy data suggest that atmospheric CO₂ levels were similar to today (between 350 and 450 ppmv) and that global mean temperature was elevated by as much as 2-3°C with respect to pre-industrial;

Last interglacial (**MIS 5e**) 1-1.5°C & similar CO₂ levels.



Dutton et al. 2015



PALEO-SEA-LEVEL INDICATORS: CORALS

strengths:

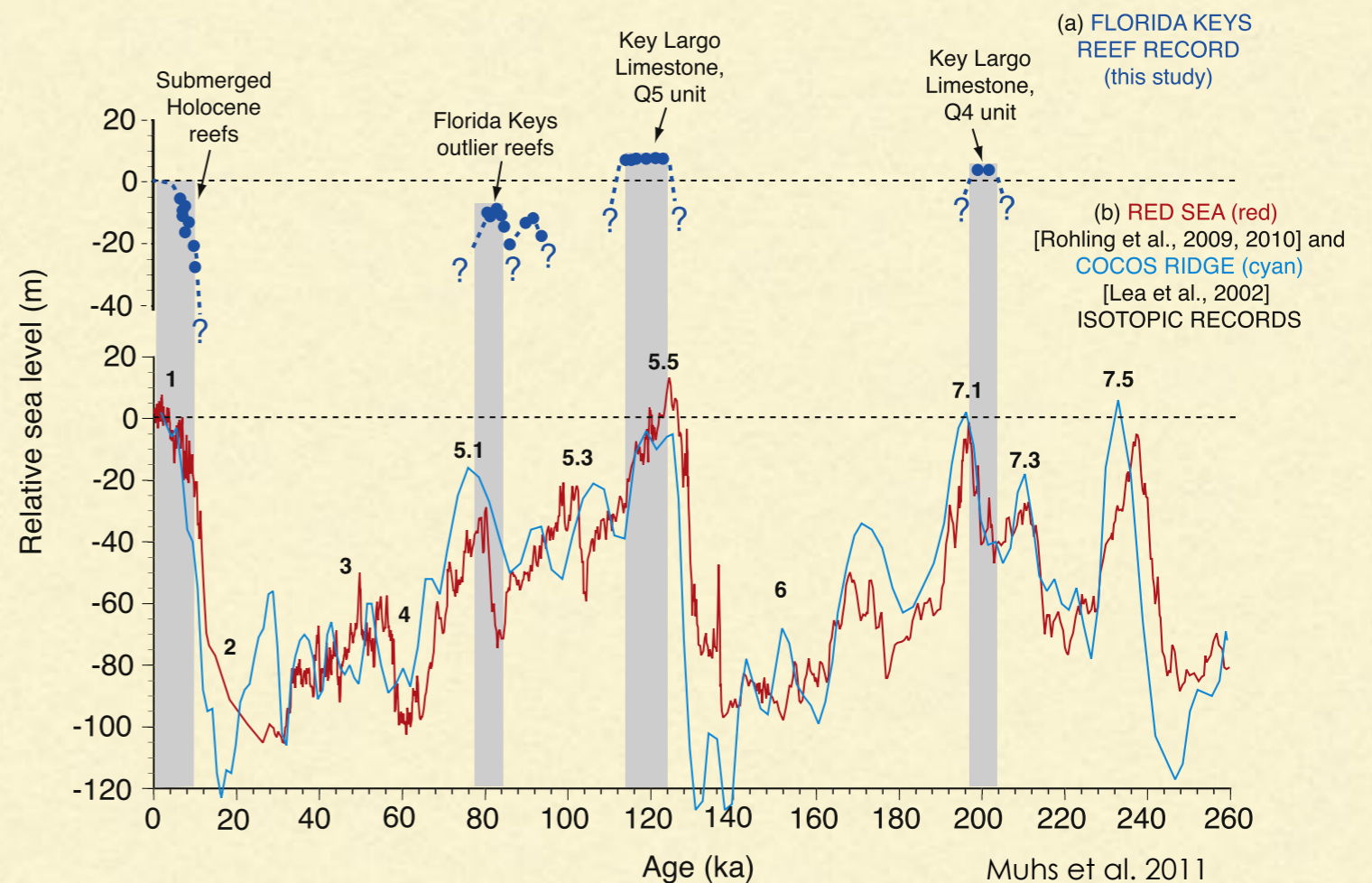
- fossil coral reefs capture the position of sea level directly and with absolute dating (U-series);
- widespread nature of reefs throughout the warm regions of the world;



© A. Cohen, WHOI

weaknesses:

- uncertainties of water depth above the reef;
- in-situ vs reworked;
- lags between the timing of sea level change and the timing of reef growth (1000's yrs);
- uncertainties on age estimates due to coral diagenesis;
- reef reconstructions from tectonically active areas also contain significant uncertainties related to the rates and consistency of tectonic movements



PALEO-SEA-LEVEL INDICATORS: CAVE DEPOSITS

coastal karst basins: contain sea-level indicators in caves (above/below psl*) and sinkholes;

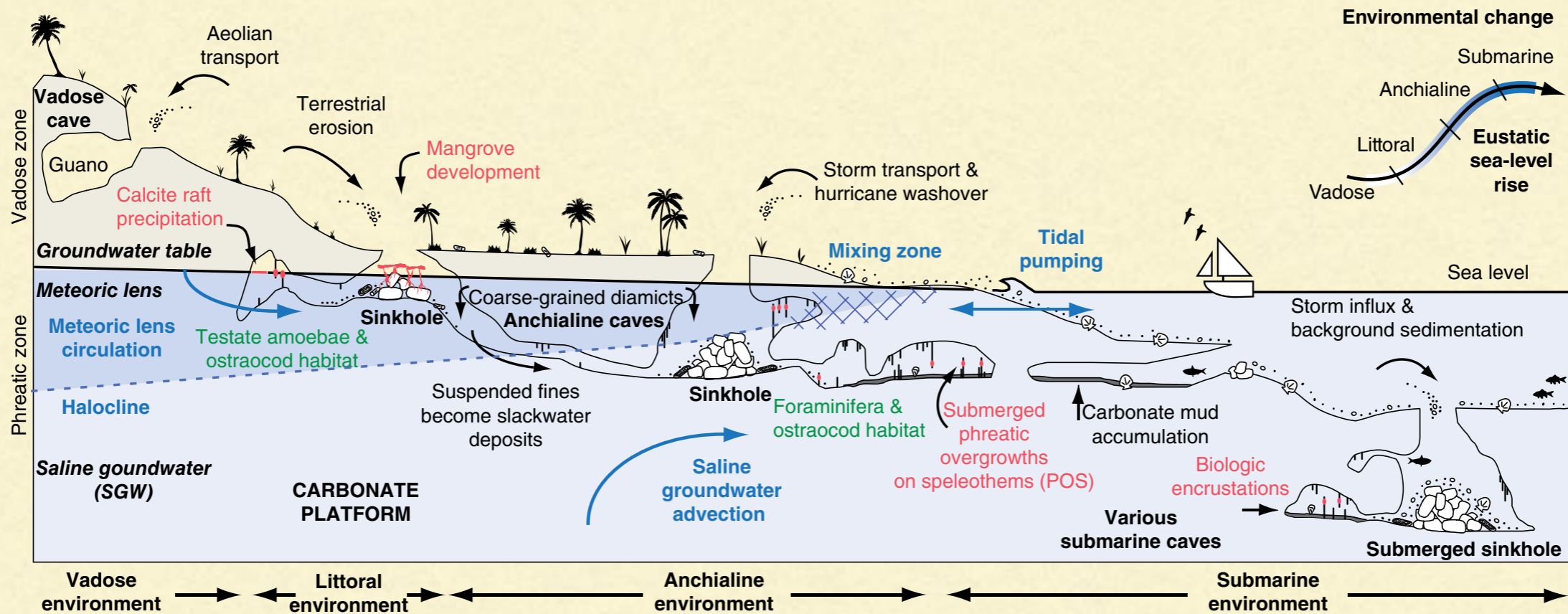


Fig. 6.1. Coastal karst basins (CKBs) provide accommodation space for unique environments, sedimentation patterns, and ecosystems that are distinct from all other coastal environments. All four environmental categories can be observed with increasing distance from the coastline, and sea-level rise causes predictable environmental succession in CKBs (top right corner). The distinctive environmental change that occurs during sea-level oscillations is preserved in the geologic record through speleothems and sediments in CKBs. Green: microfossil remains; red: sea-level indicators; blue: groundwater hydrography and flow; black: common sedimentary processes. For color details, please see Plate 15.

van Hengstum et al. 2015

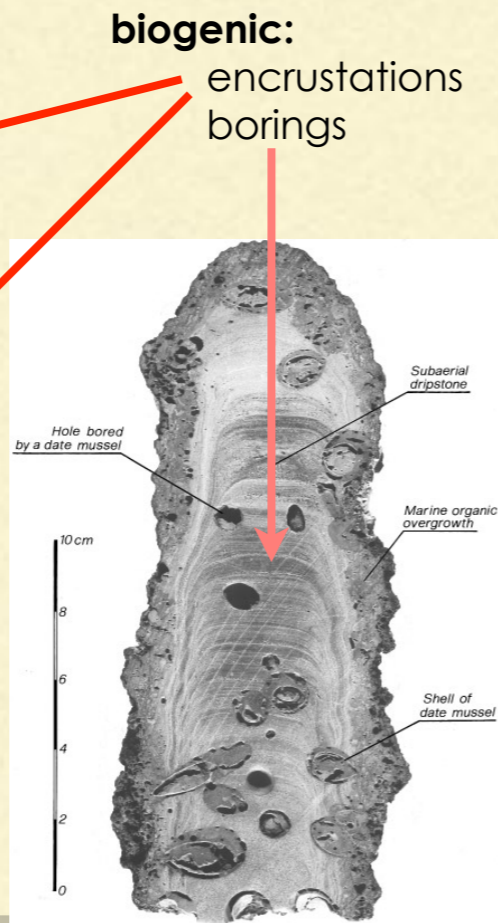
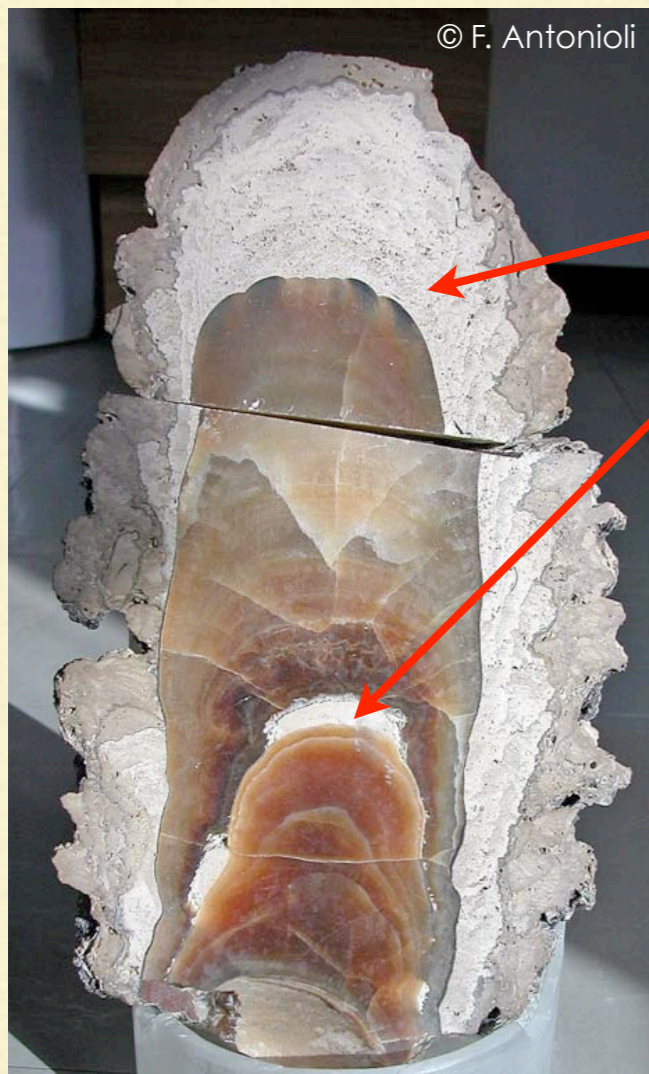
* present sea level

PALEO-SEA-LEVEL INDICATORS: CAVE DEPOSITS

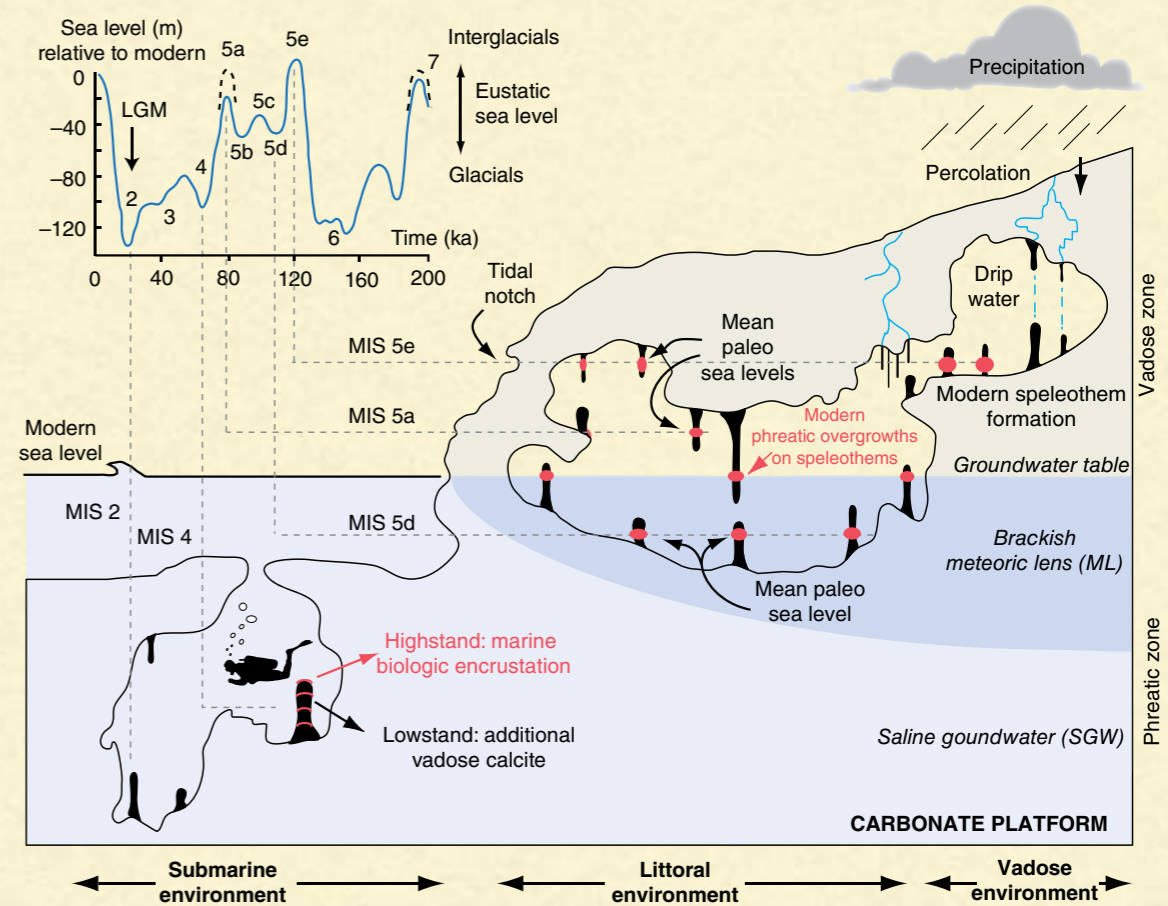
cave deposits: biological (e.g., borings), mineralogical (sediments, speleothems), archeological;

speleothems:

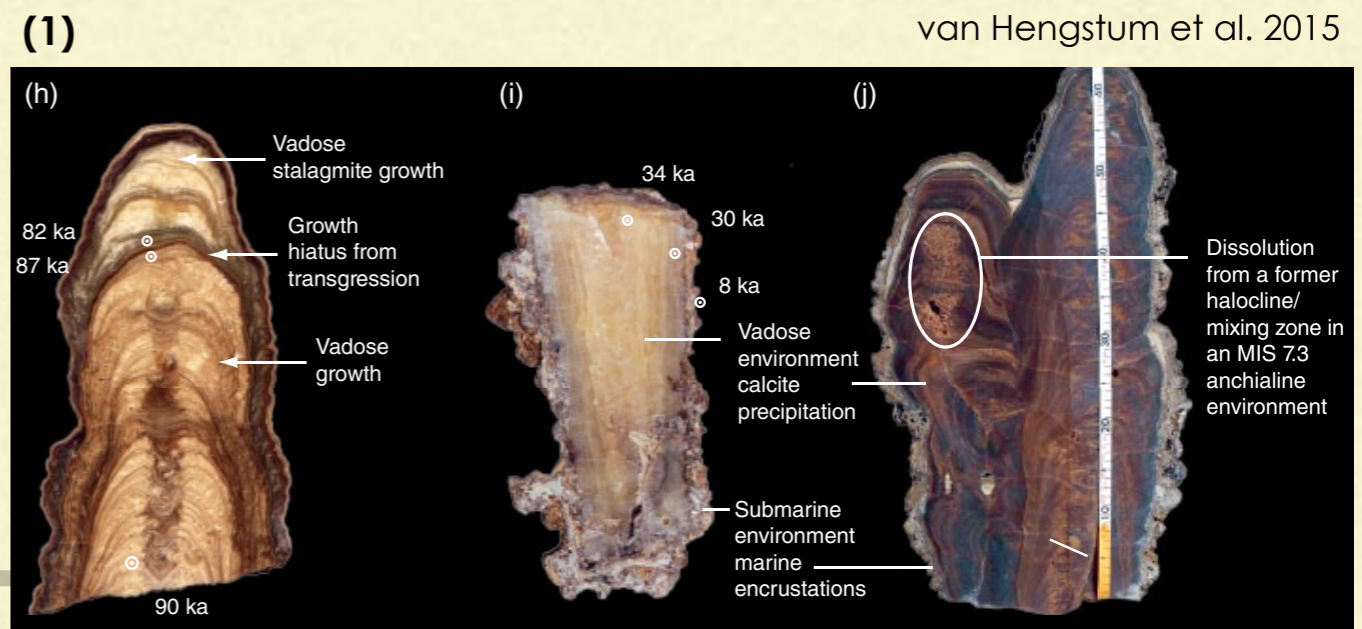
- 1) ordinary vadose speleothems drowned by sea-level rise;
- 2) submerged speleothems coated by biogenic encrustations;
- 3) phreatic overgrowths on speleothems



Antonioli & Oliverio 1996

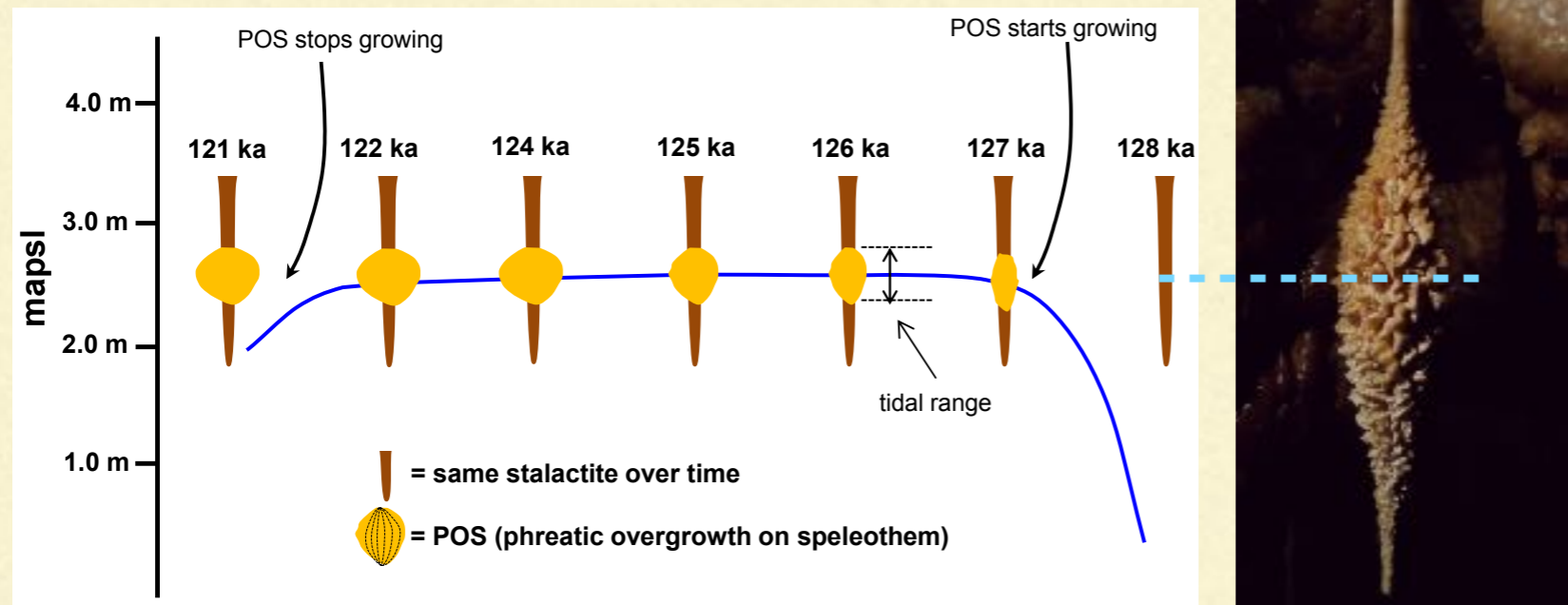


van Hengstum et al. 2015



PHREATIC OVERGROWTHS ON SPELEOTHEMS (POS)

- precise sea-level index points (elevation, absolute age, indicative meaning, geographic positioning)
- indicative of tidal range



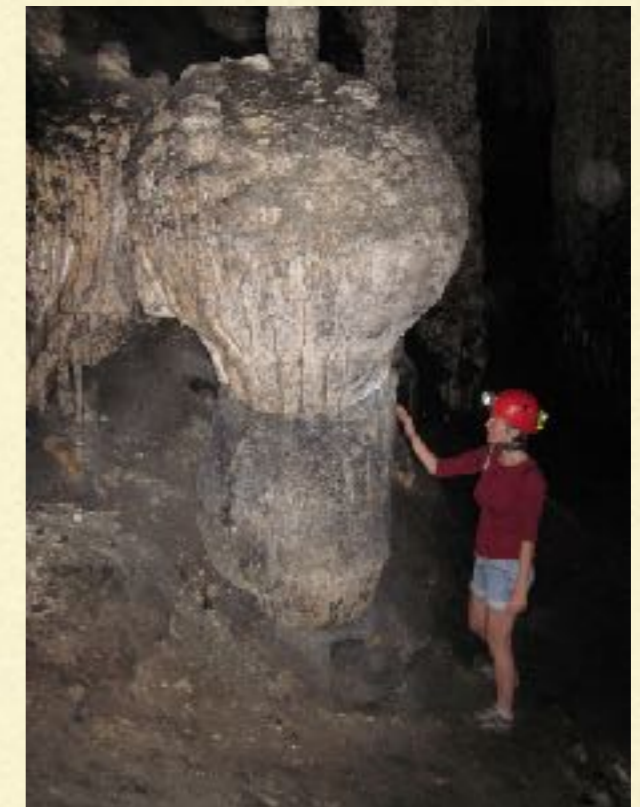
Polyak et al., 2018



photos: BP Onac

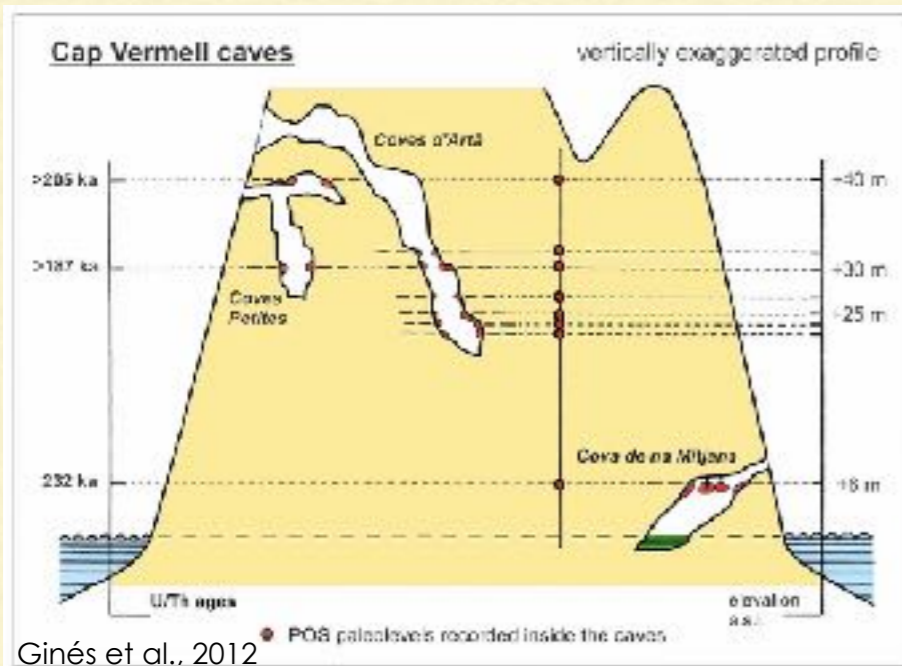


photos: A. Merino

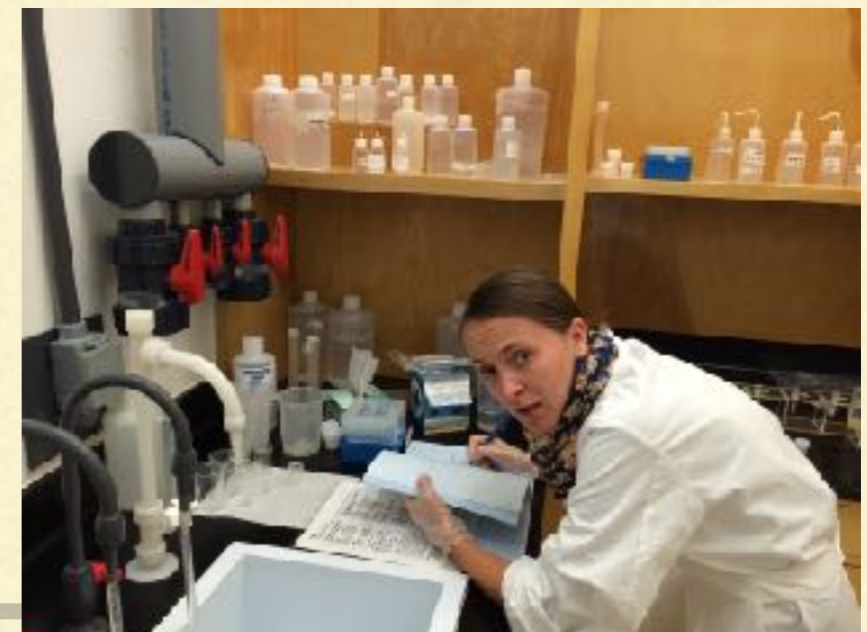


PLIOCENE SEA-LEVEL IN MALLORCA

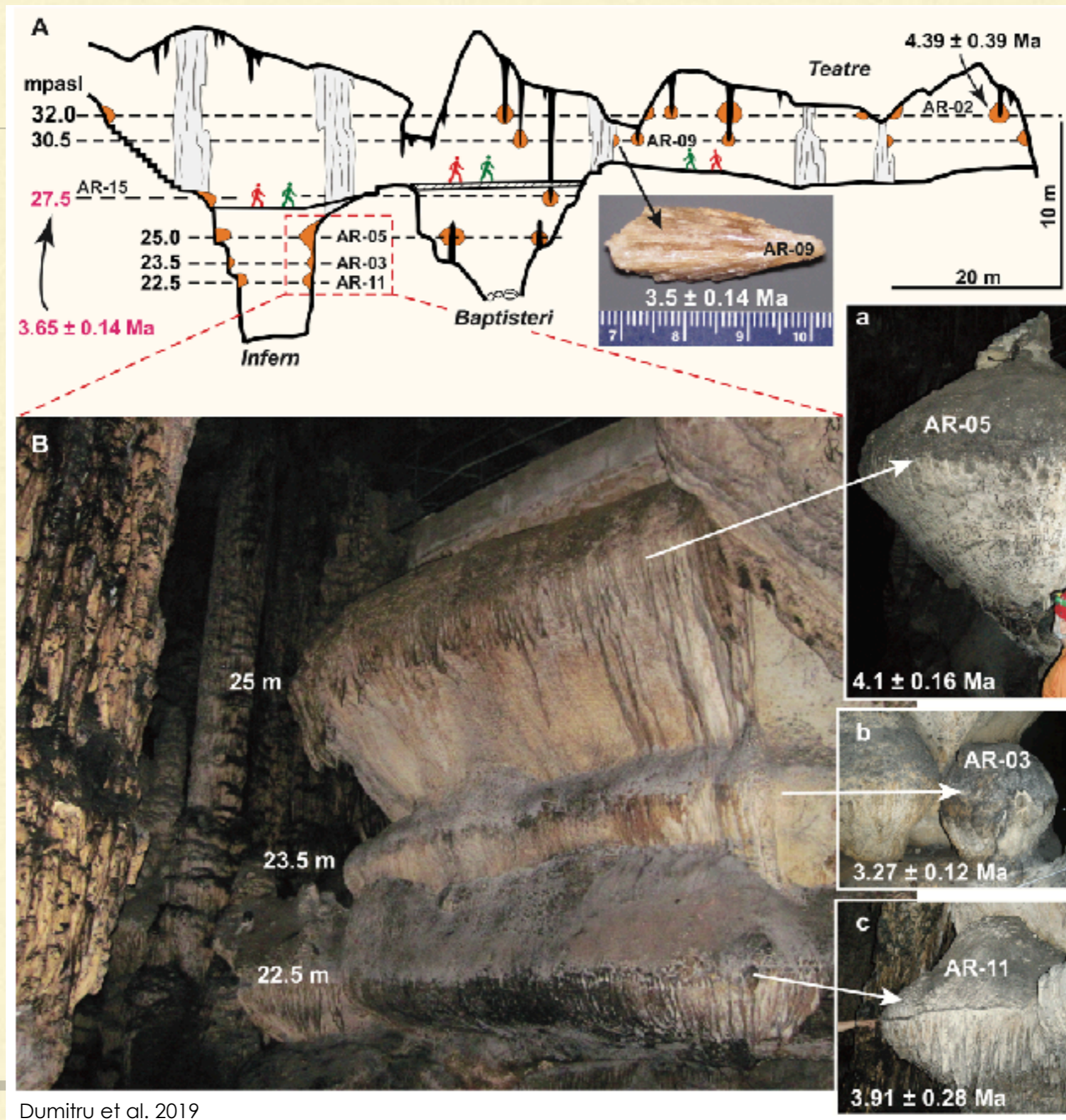
Coves d'art & Petites highest POS on the island



Ginés et al., 2012



PLIOCENE SEA-LEVEL IN MALLORCA



PLIOCENE SEA-LEVEL IN MALLORCA

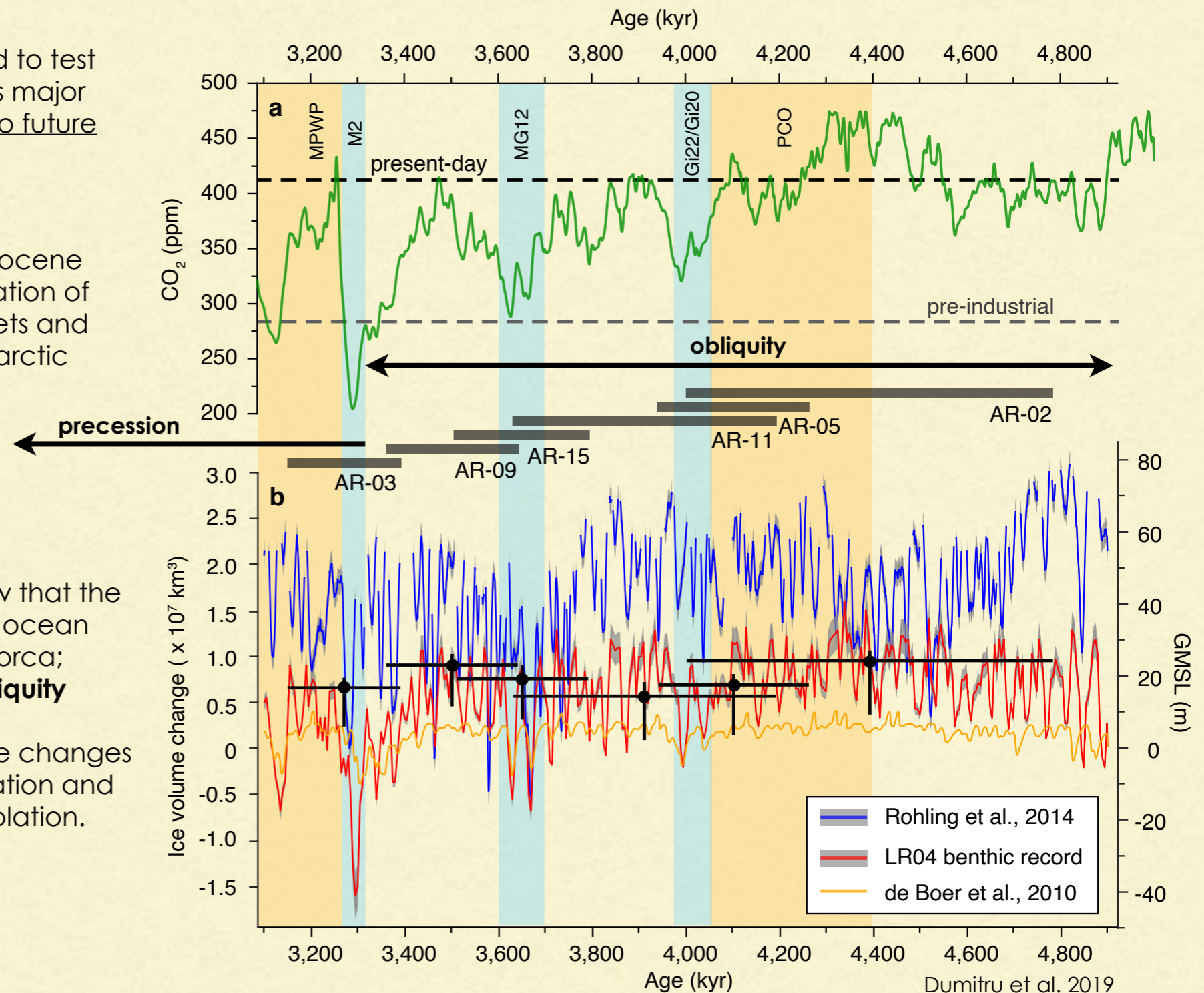
FINDINGS & PREDICTIONS

Pliocene is a particularly suitable period to test the sensitivity and stability of the Earth's major ice sheets in an environment relevant to future global change

The elevations and U-Pb ages of the Pliocene POS from Artà Cave, imply full deglaciation of Greenland and West Antarctic ice sheets and varying contributions from the East Antarctic Ice Sheet

Between 5 and 3.3 Ma proxy data show that the Antarctic margin experienced warmer ocean temperatures → high sea level in Mallorca; fluctuations in ice extent paced by **obliquity**

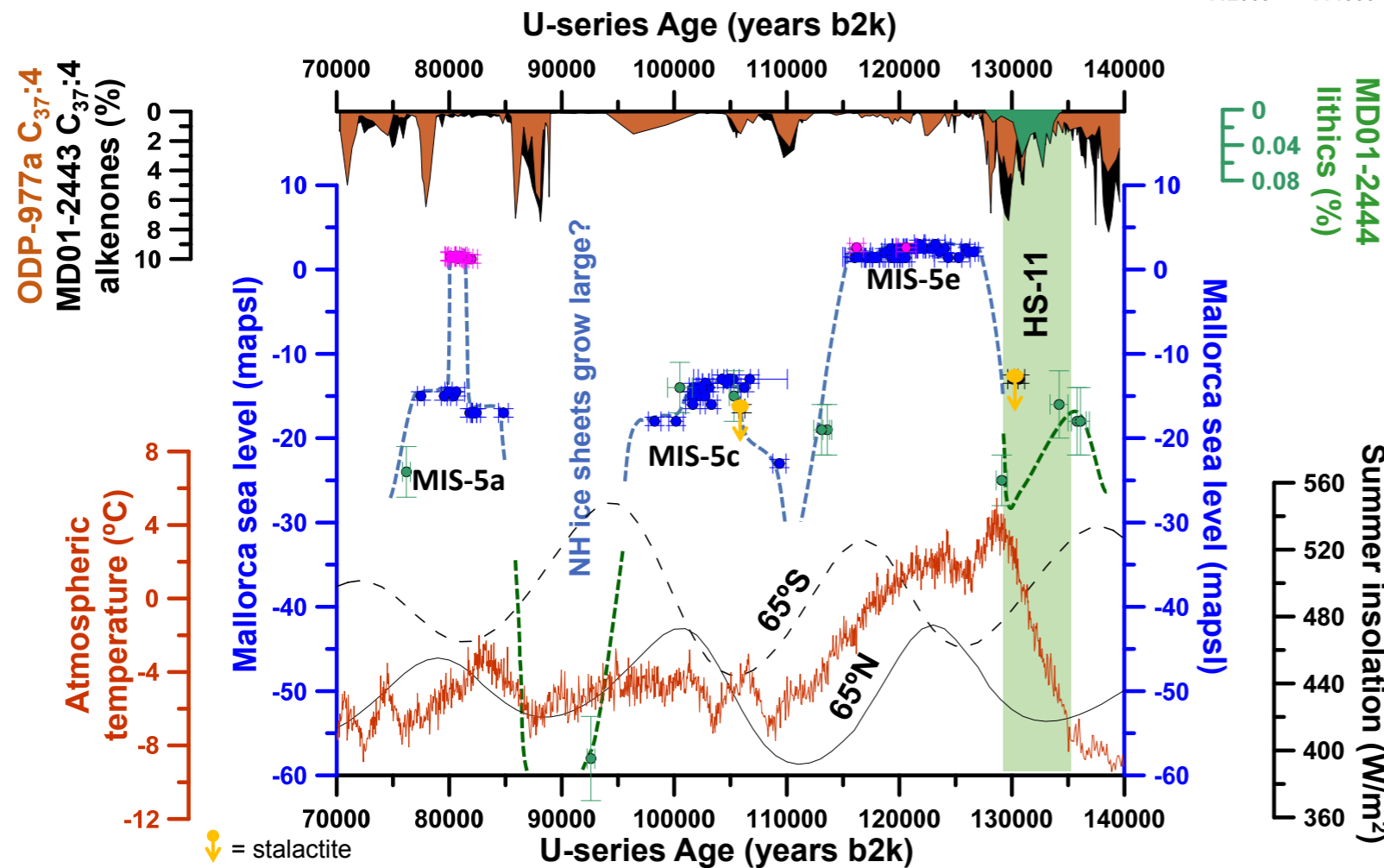
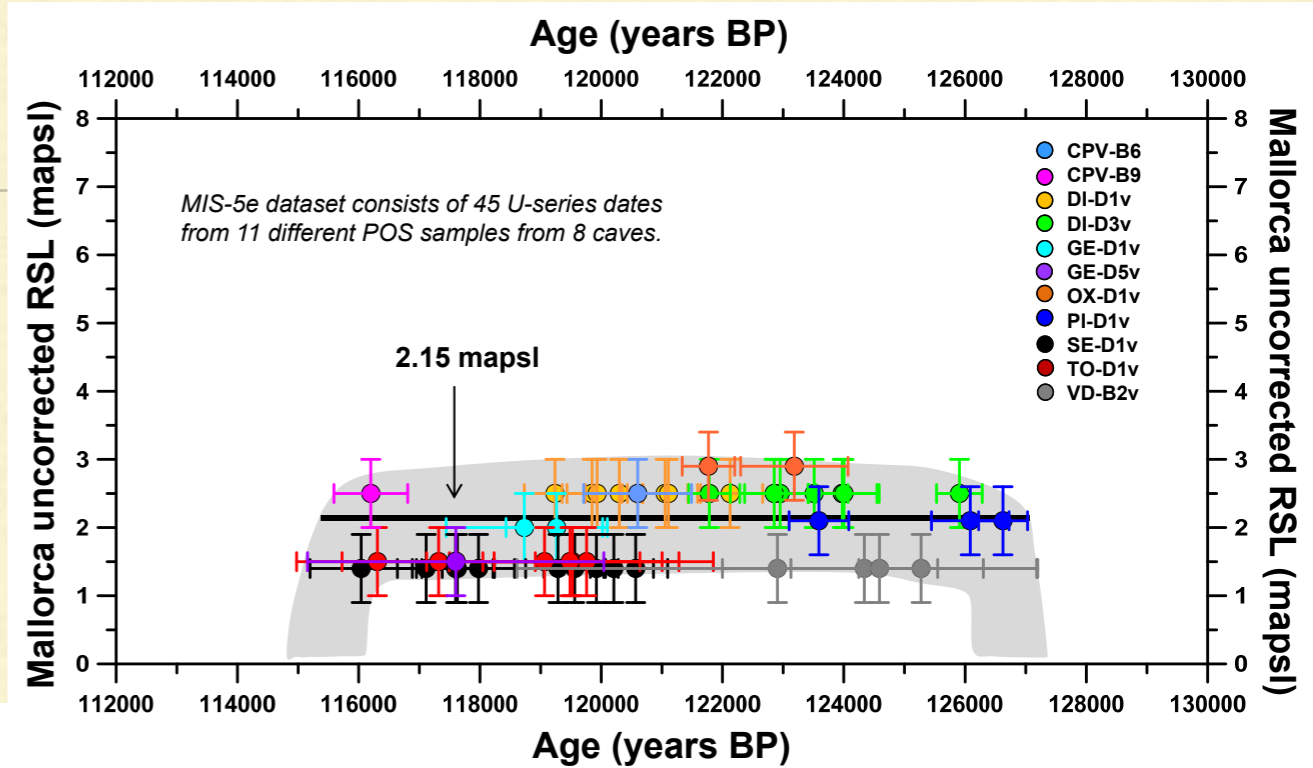
Precession-paced Antarctic ice volume changes begun to dominate after the M2 glaciation and were in-phase with high-latitude SH insolation.



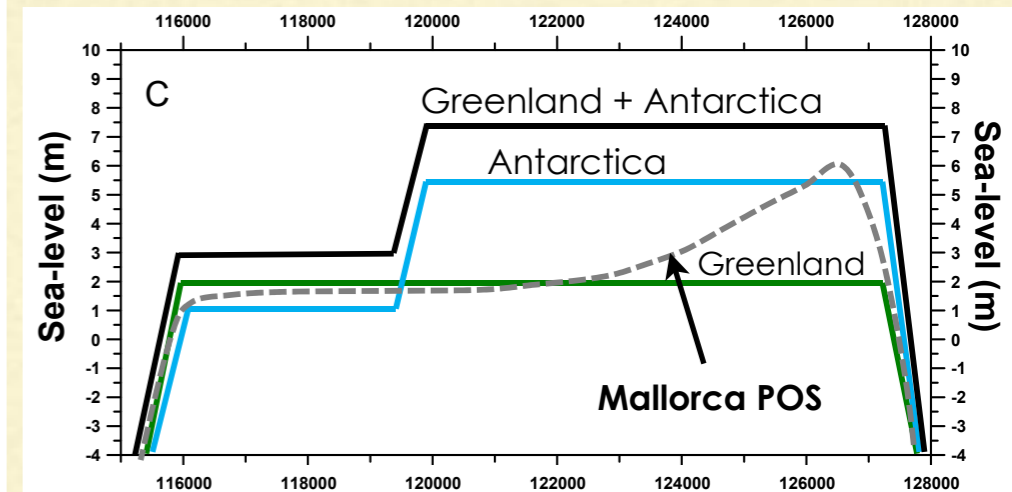
MARINE ISOTOPE STAGE (MIS) 5e

POS indicate that sea level was as high as present by 127 ka

The western Mediterranean Sea level high stand overlap with the NH summer insolation peak and occurred ~6-7 kyr after the SH, fact confirming an early Antarctic contribution to ESL



Polyak et al. 2018

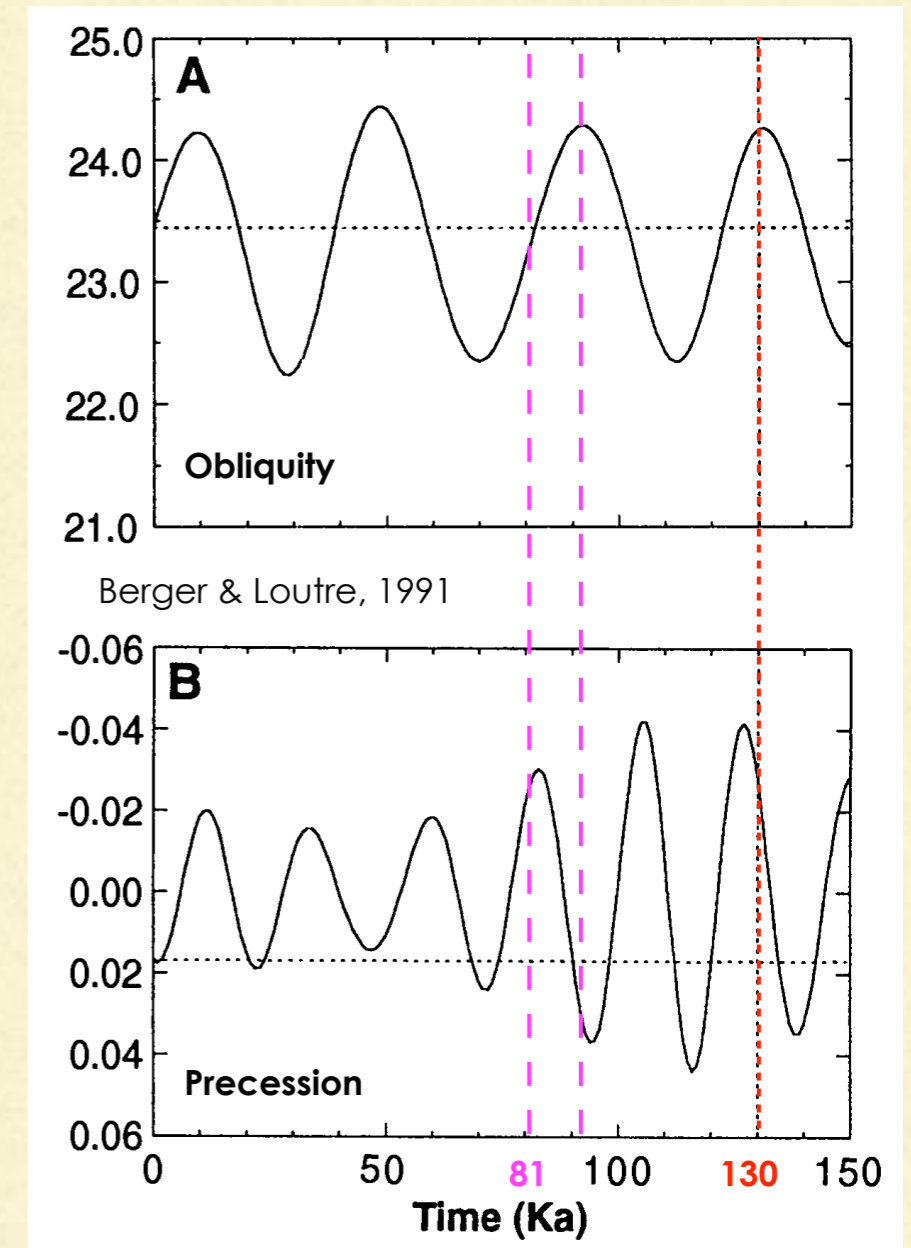


MARINE ISOTOPE STAGE (MIS) 5e

The different responses by region and latitude occurred because maximum obliquity occurred earlier than precession at the time of MIS 5e and because the obliquity effect is largest in high latitudes.

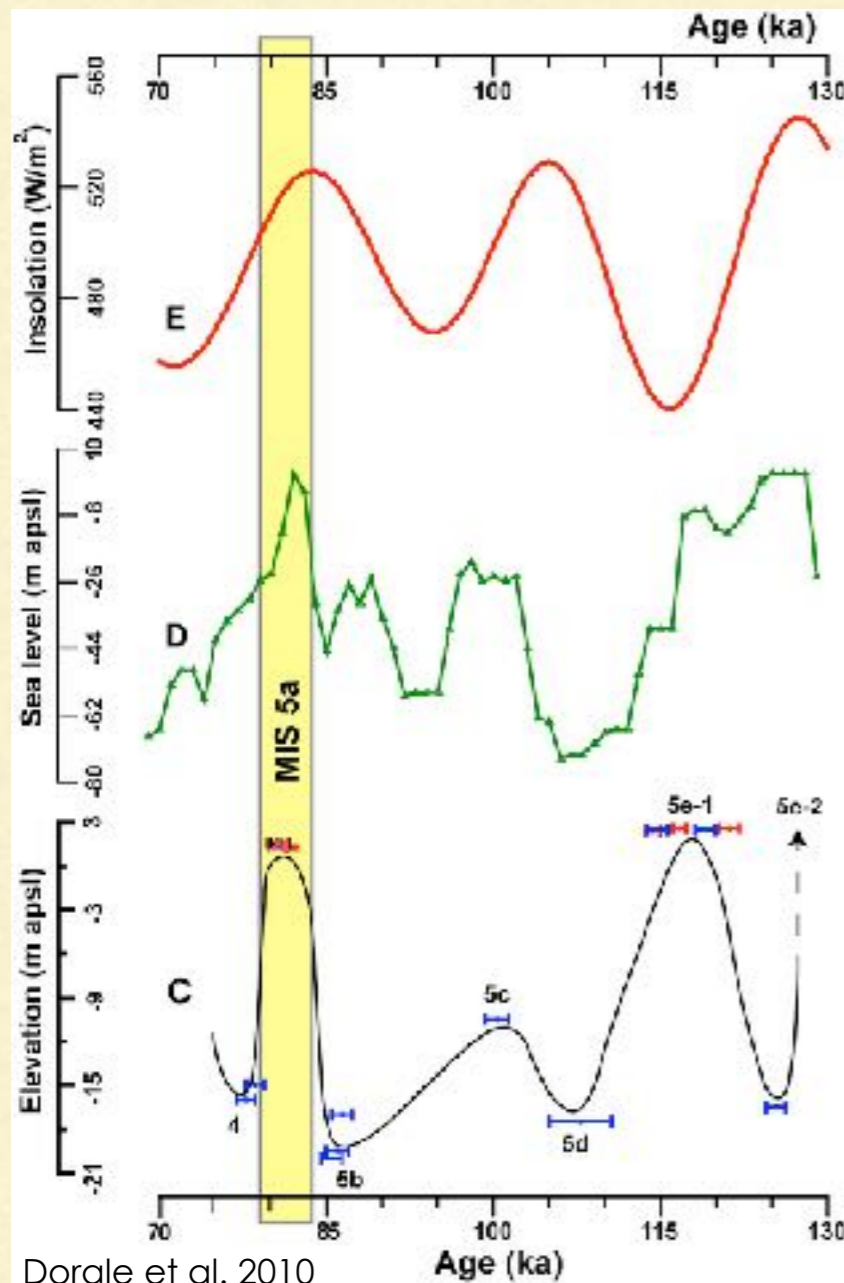
The low- and mid-latitude response is dominated by precession, which lags obliquity over this interval and is manifested most strongly on large landmasses (NH).

MIS 5e high sea level peak may be consistent with Milankovitch forcing, but the insolation from obliquity and precession have been sometimes out of phase (within the same hemisphere) and explaining other high sea level stands (e.g., MIS 5a) needs to consider other factors (e.g., ice sheet dynamics, atmospheric dust, concentration of CO₂, etc.).

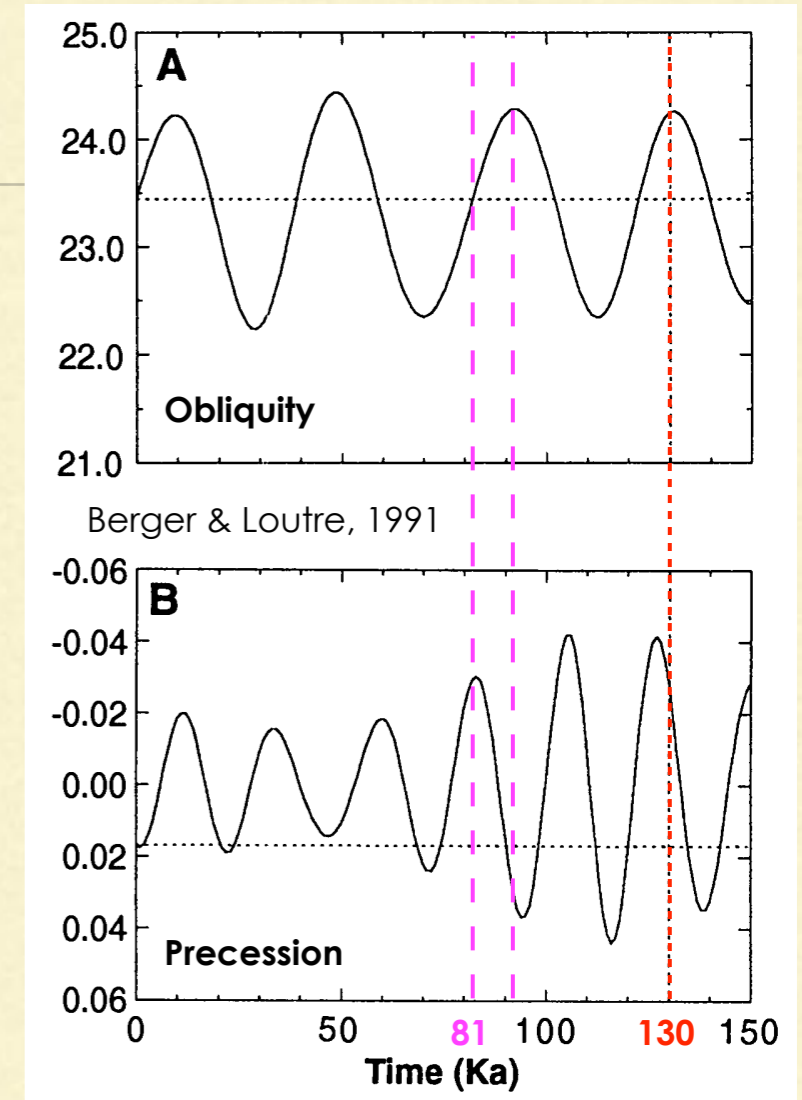


MARINE ISOTOPE STAGE (MIS) 5a

The ~81 ka timing of the Mallorca **MIS 5a** high stand (~1 m) closely matches the June 60°N insolation peak at ~84 ka, a pattern that is consistent with the Milankovitch model.



Dorale et al. 2010



Berger & Loutre, 1991

The 100-kyr cycle of glaciation model assumes gradual buildup and more rapid ice melt;

new evidence, however, suggests both process may happen very rapid indicating 100-kyr cycle applies rather poorly to ice growth/decay, but better to CO₂, CH₄, and T° recorded in polar ice and some sea proxies.

FUTURE WORK

Additional precise chronologies for various archives to better test Milankovitch hypothesis

for POS:

Additional locations (e.g., Croatia, Cuba, Japan, Mexico, Sardinia, etc.)

^{234}U \rightarrow ^{230}Th ingrowth in speleothems, 0-500 kyr;

U-Pb for older speleothems

In-between known ages, we must interpolate using plausible scheme (generally unprovable)



A person is silhouetted against a bright blue ocean and sky, viewed through a cave opening. The person is standing on a dark platform with a railing, looking out at the shimmering sea under a clear blue sky with a few wispy clouds. The cave's interior is dark, with the opening framing the scene.

THANK YOU !