PROXY EVIDENCE FOR THE ROLE OF GLOBAL TELECONNECTIONS IN MIDDLE EAST HYDROCLIMATE VARIABILITY

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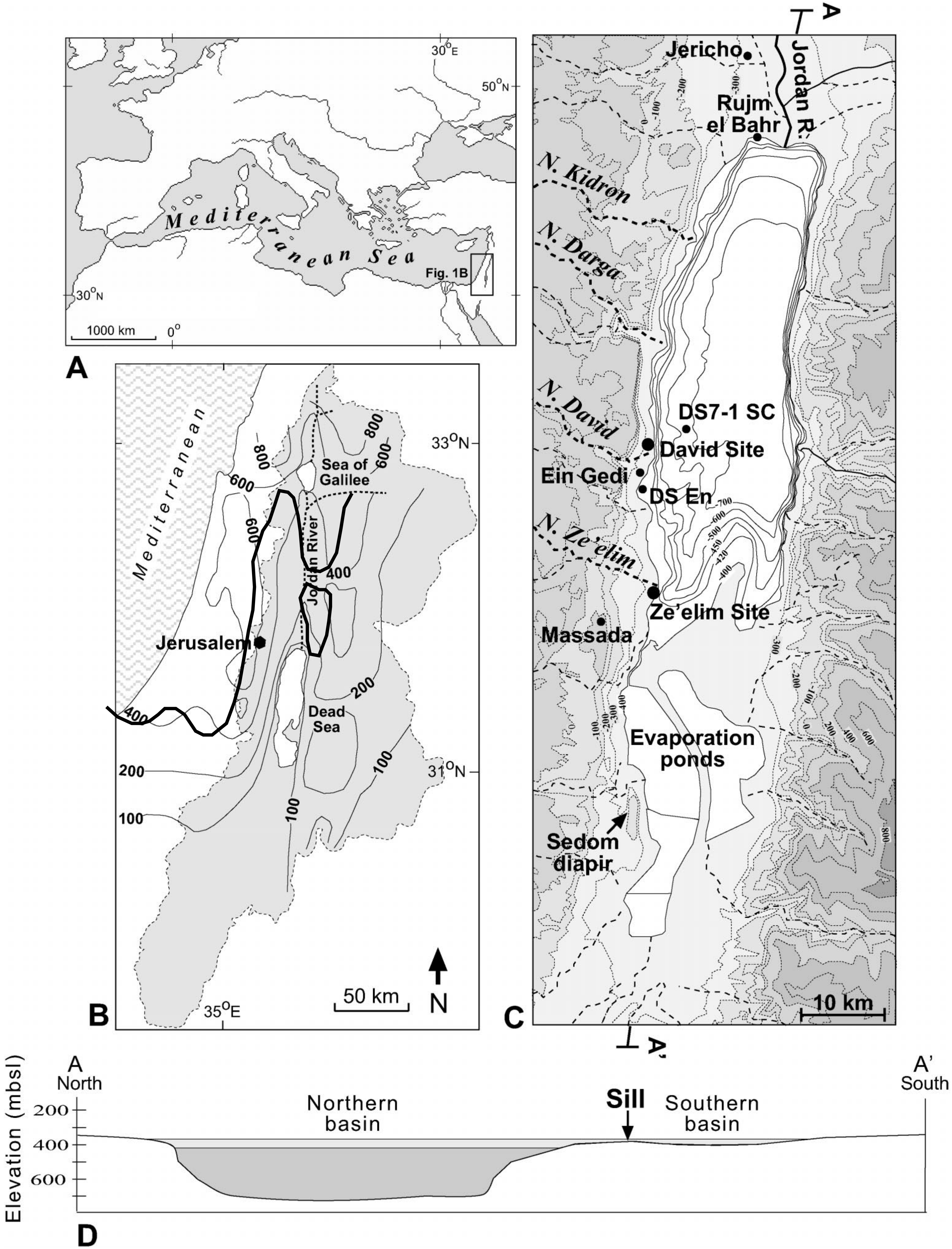
The Dead (Salt) Sea

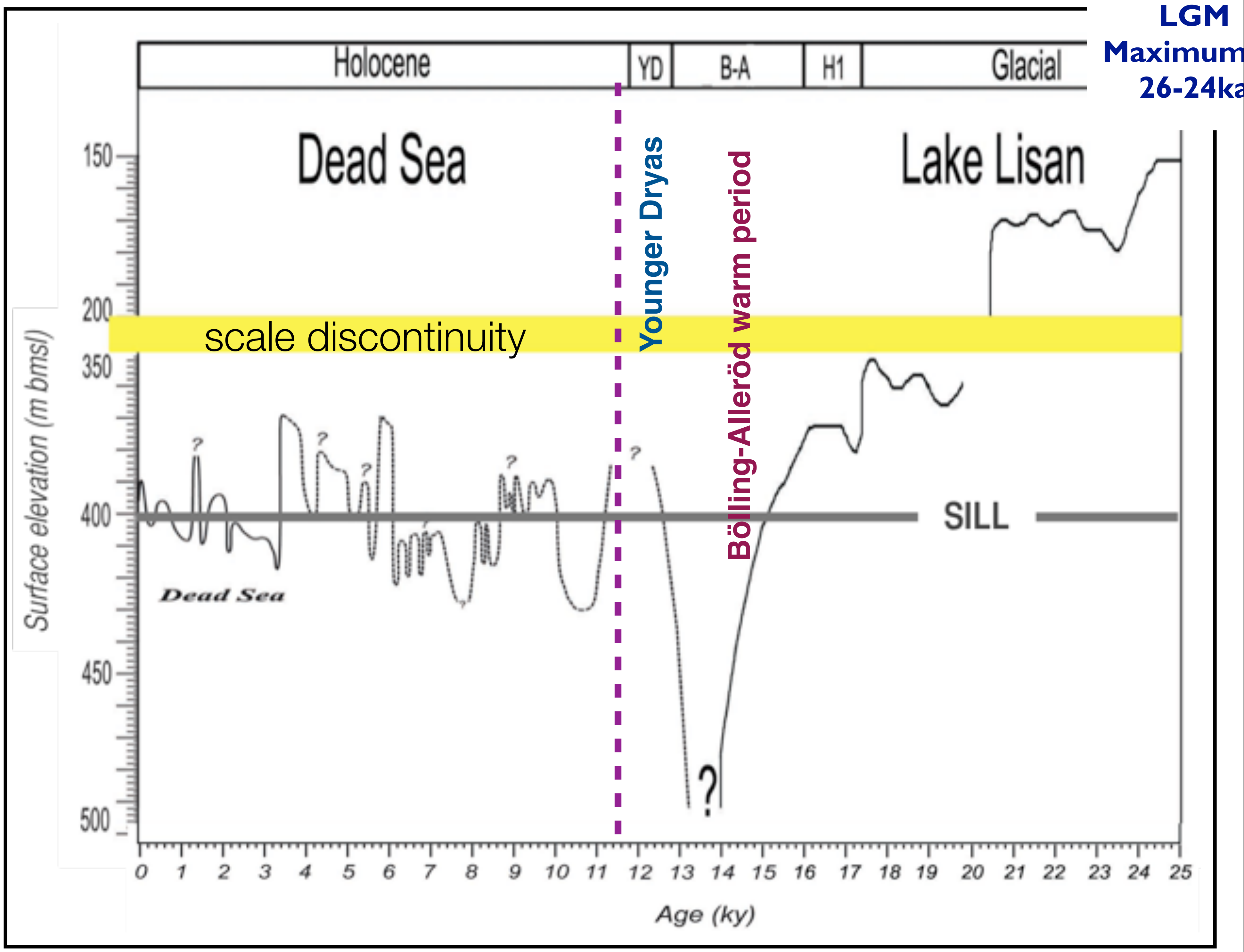


Paleo-indicator of hydroclimate variability in the Levant

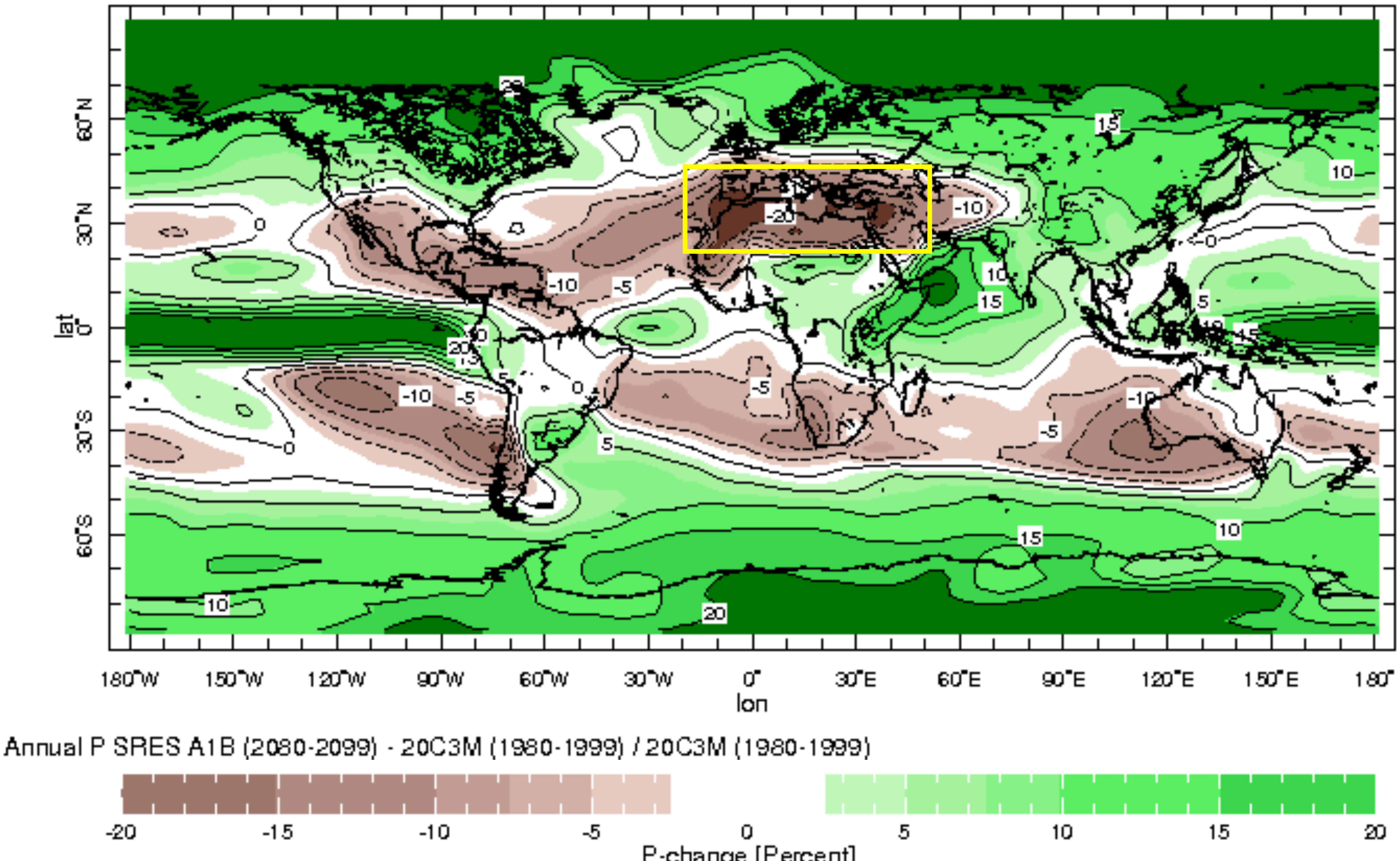
Source: Bookman et al. (2004)

Dead Sea Levels — LGM to present

Dead Sea level (DSL) curve is a composite based on geological evidence from paleo-shore levels and lake sediment cores. The record was constructed in studies by Bartov et al. (2002), Migowski et al. (2006), and Bookman et al. (2004).

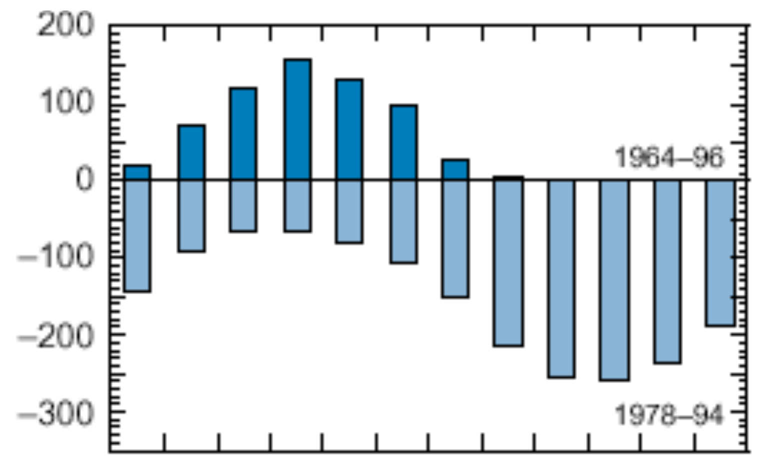


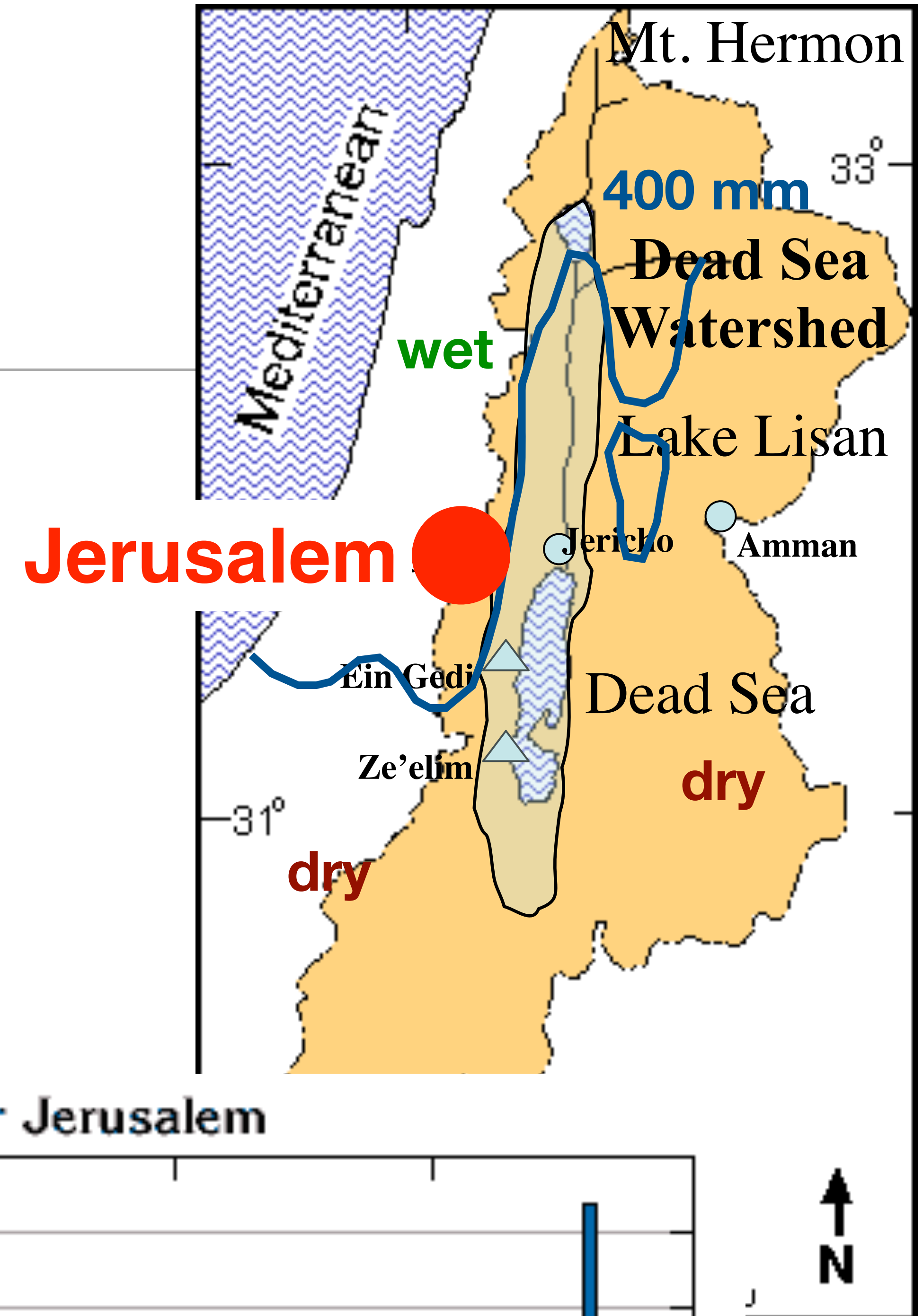
The backdrop: The Mediterranean - a hotspot of projected Subtropical Drying

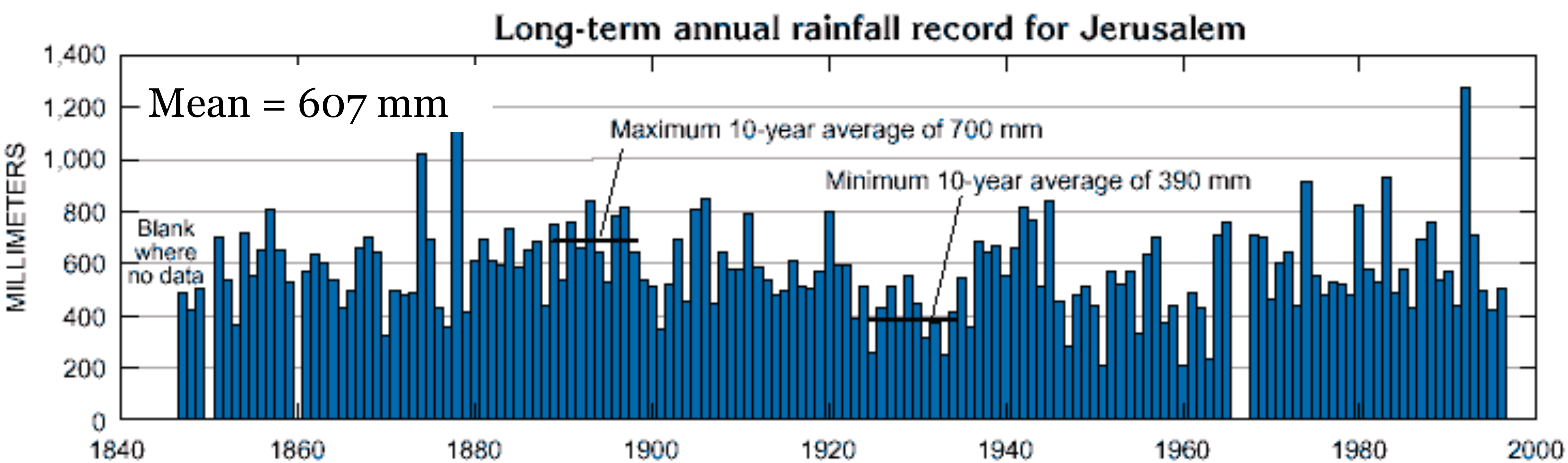


Jerusalem Rainfall

P and E climatology: rainfall (positive values) and potential evaporation (negative values) in mm





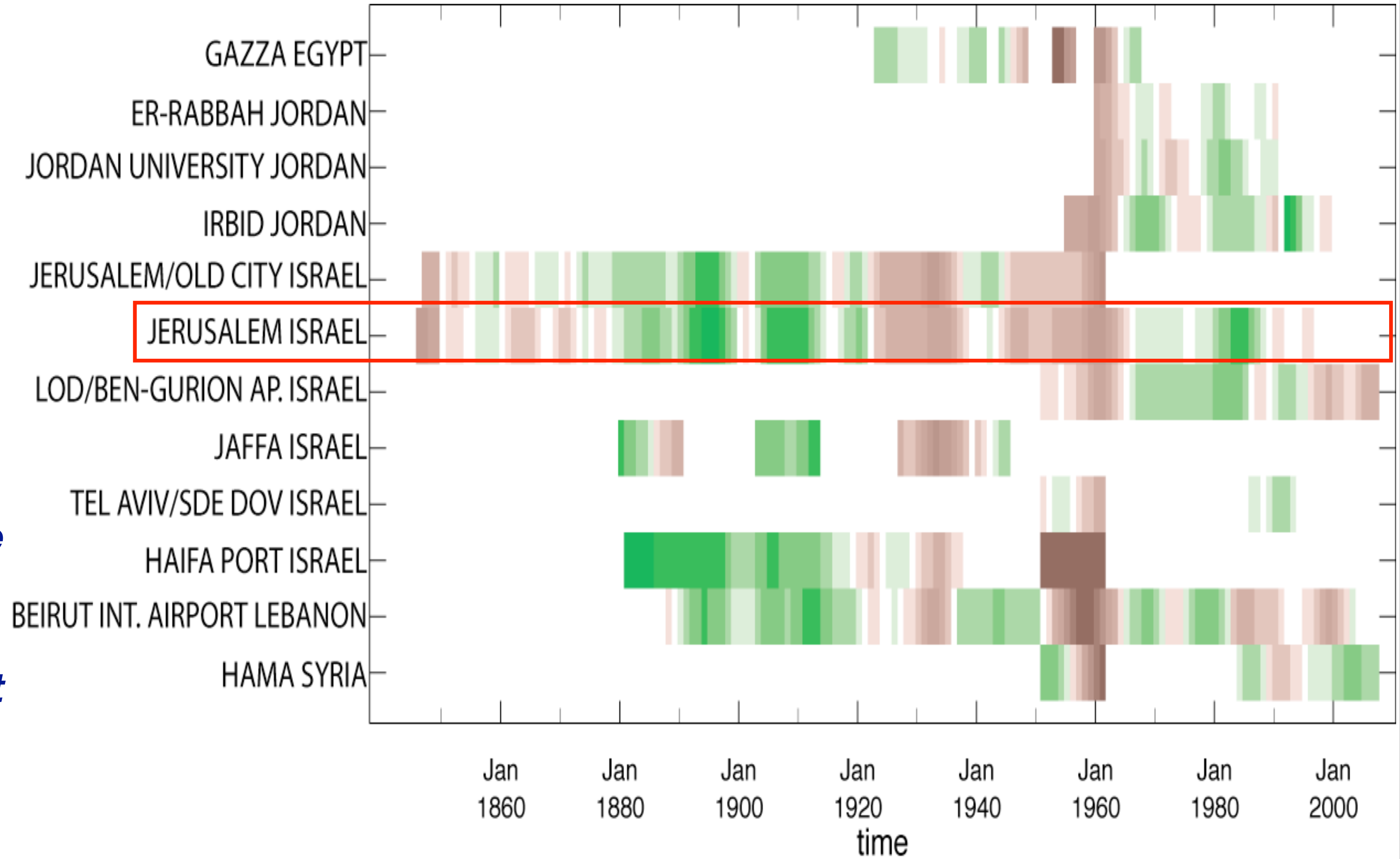


Source: Overview of Middle East Water Resources, USGS, 1998

The instrumental record: Central Levant multi-decadal rainfall variability

Low-pass, ranked (values between -0.5 and 0.5), October to April rainfall variations in different Levant rain gauge stations during the 19th and 20th century.

Brown colors indicate negative anomalies (dry years) and green ones are positive (wet years).



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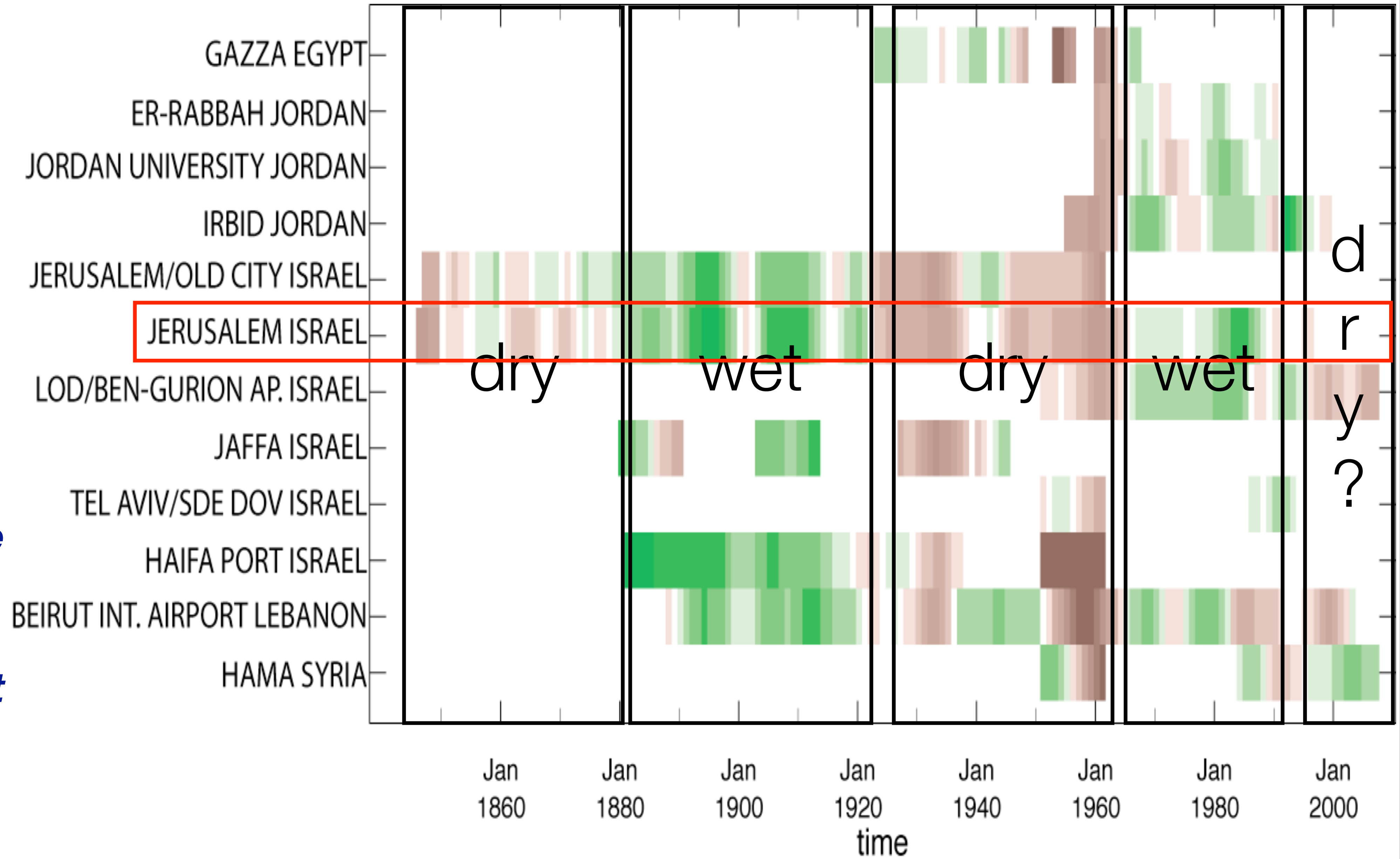
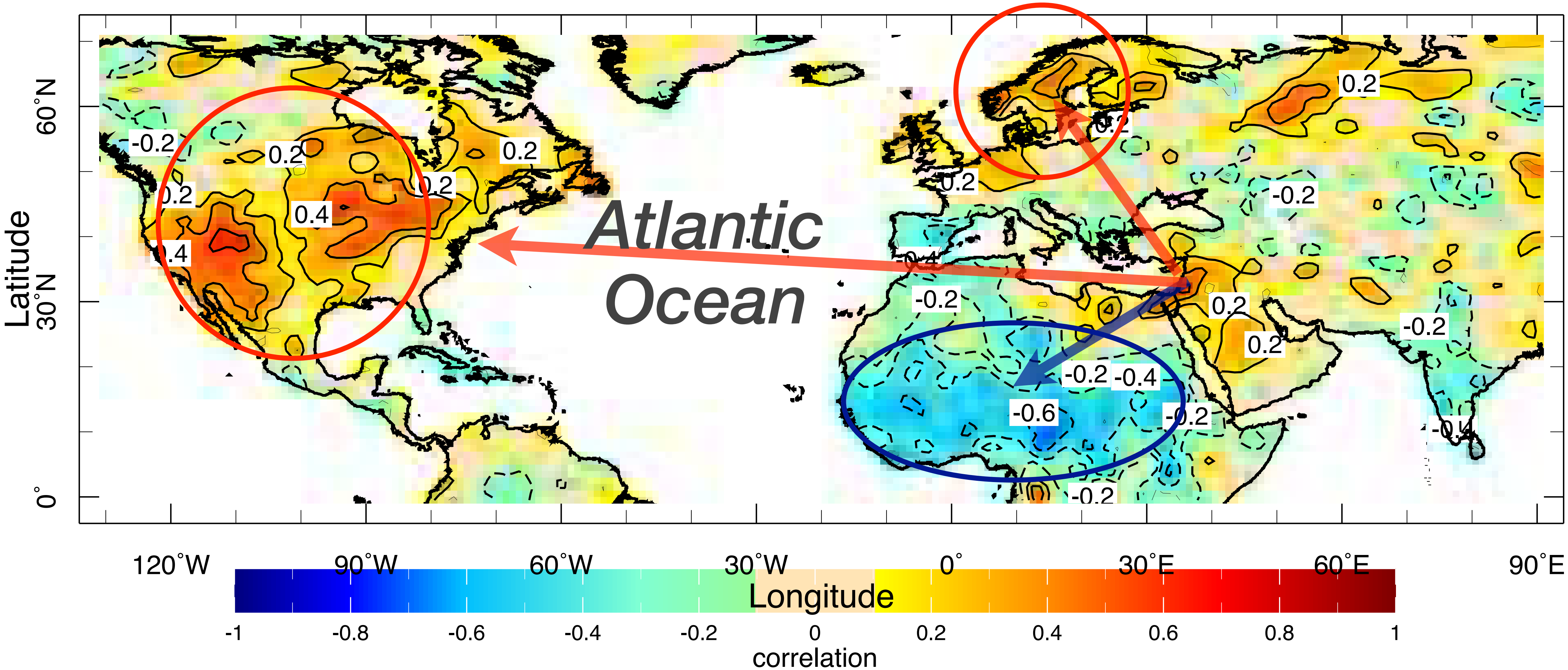


The (relatively short) instrumental record displays a coherent multi-decadal pattern in Levant rainfall variations.

Hemispheric rainfall teleconnections

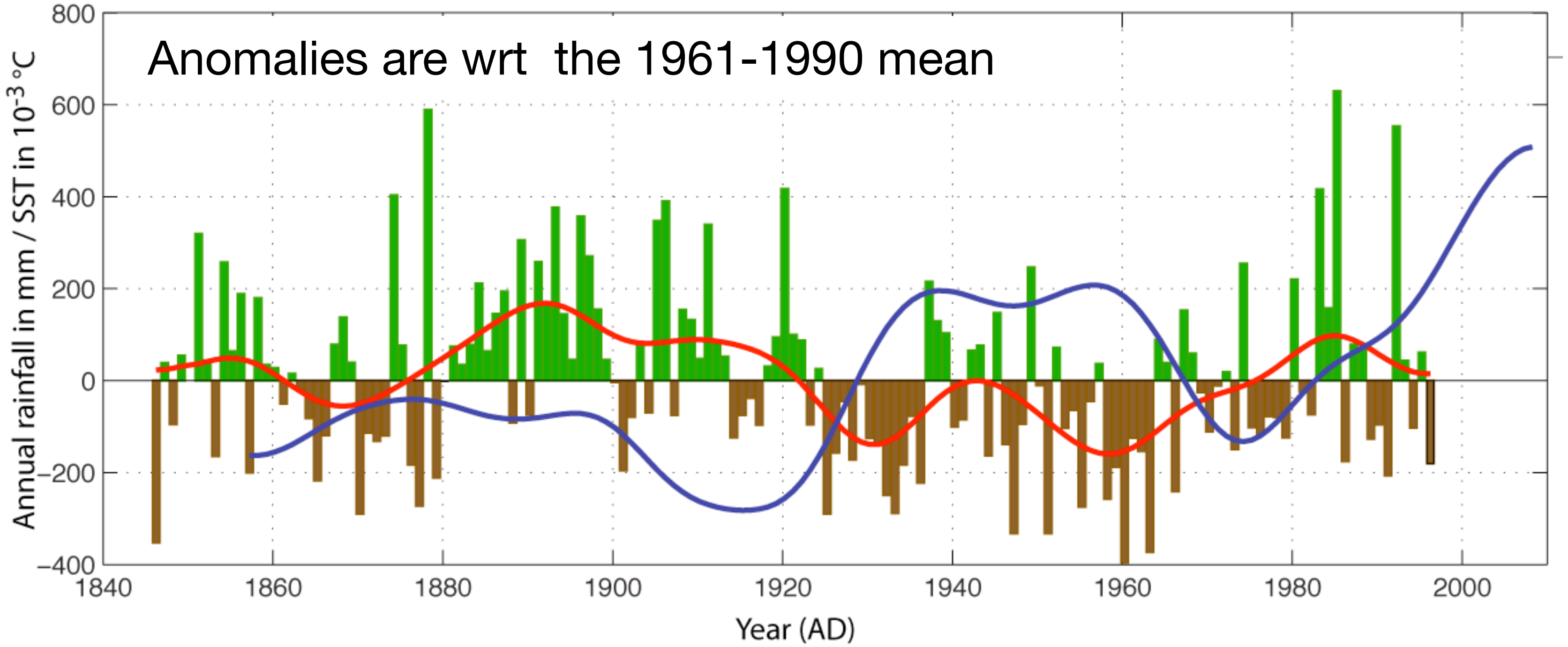


Annual (Oct-Sep) Jerusalem precipitation correlated with precipitation elsewhere. Time series were smoothed by 1 pass of a 2-nd order binomial filter.
Precipitation from GPCC 1930-1995. Areas with significant correlations are circled.

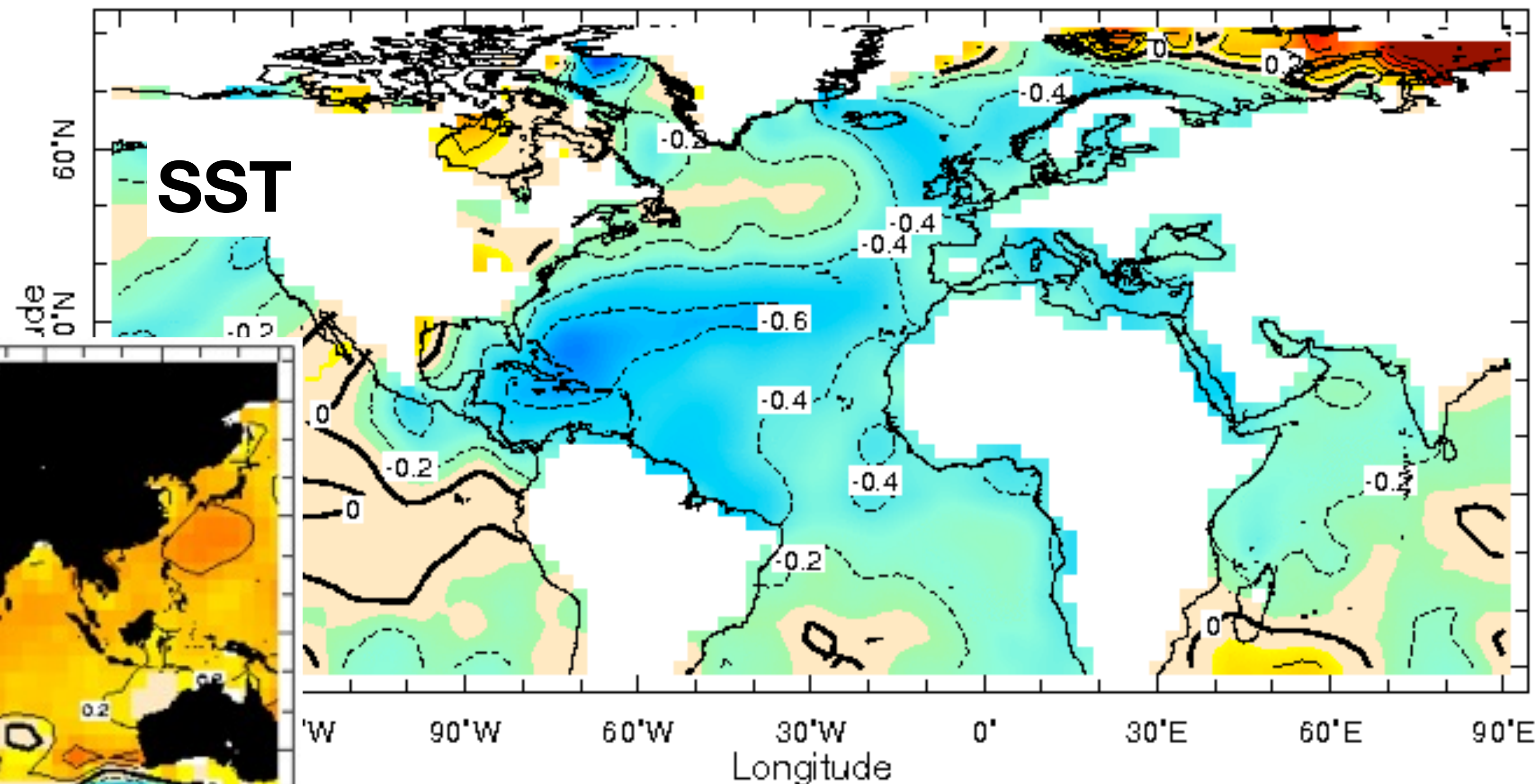
What is causing this hemispheric pattern?

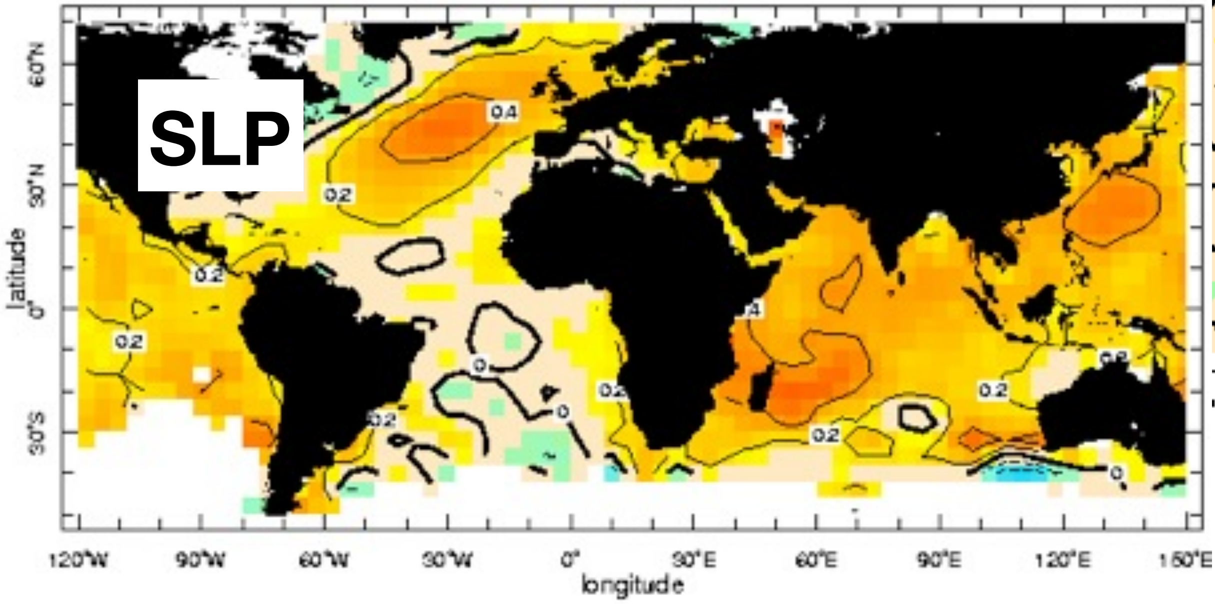
Jerusalem rainfall -- Atlantic SST link

Jerusalem ppt: annual anomaly(bars) and its 20-yr lowpass series (red line) and lowpass North Atlantic SST anomaly.



Correlation with SST (right) and SLP (below) (Data: Oct 1856 - Sep 1857 to Oct 1996 - Sep 1997)



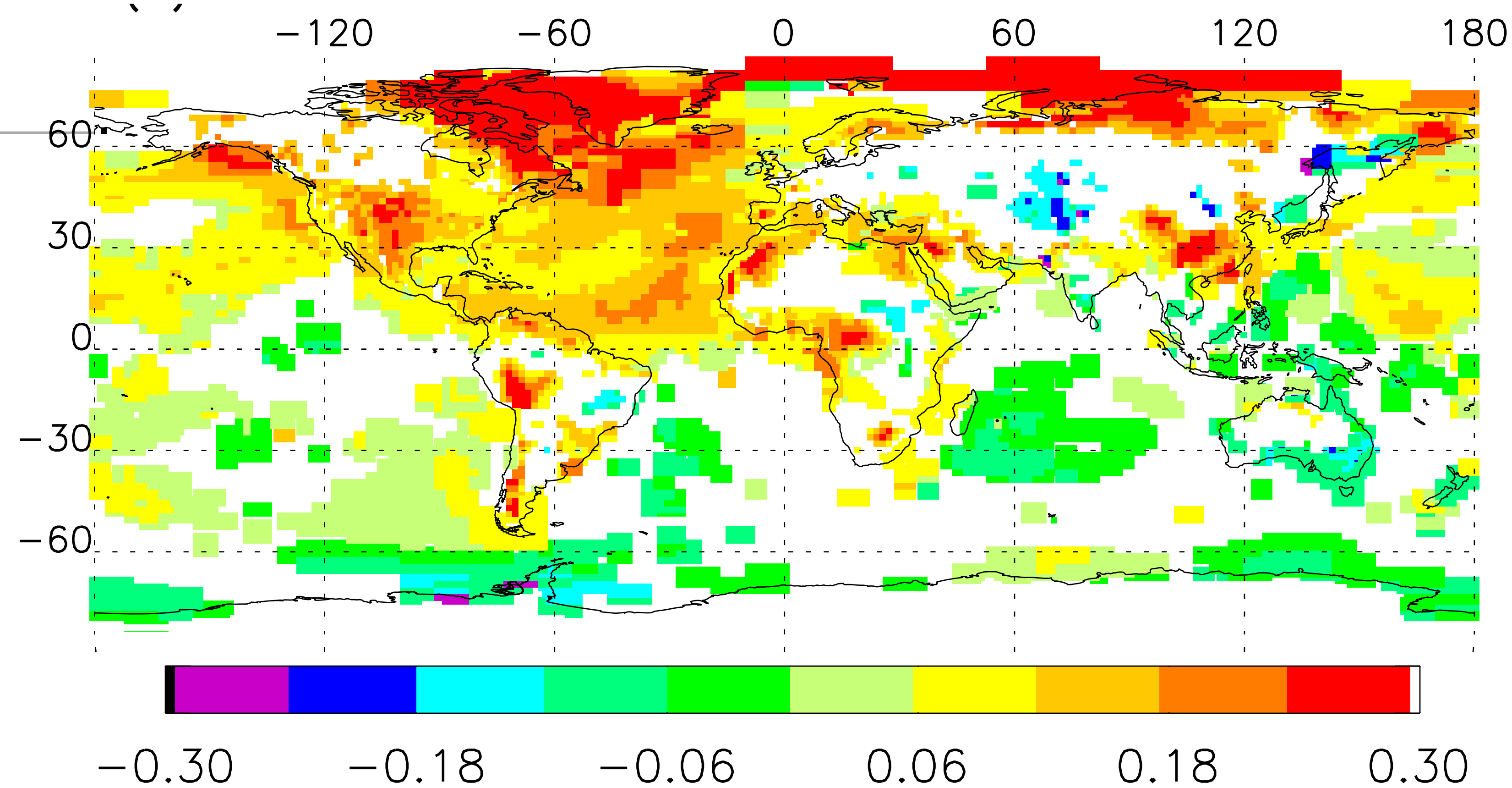


Atlantic Multidecadal Variability (AMV)

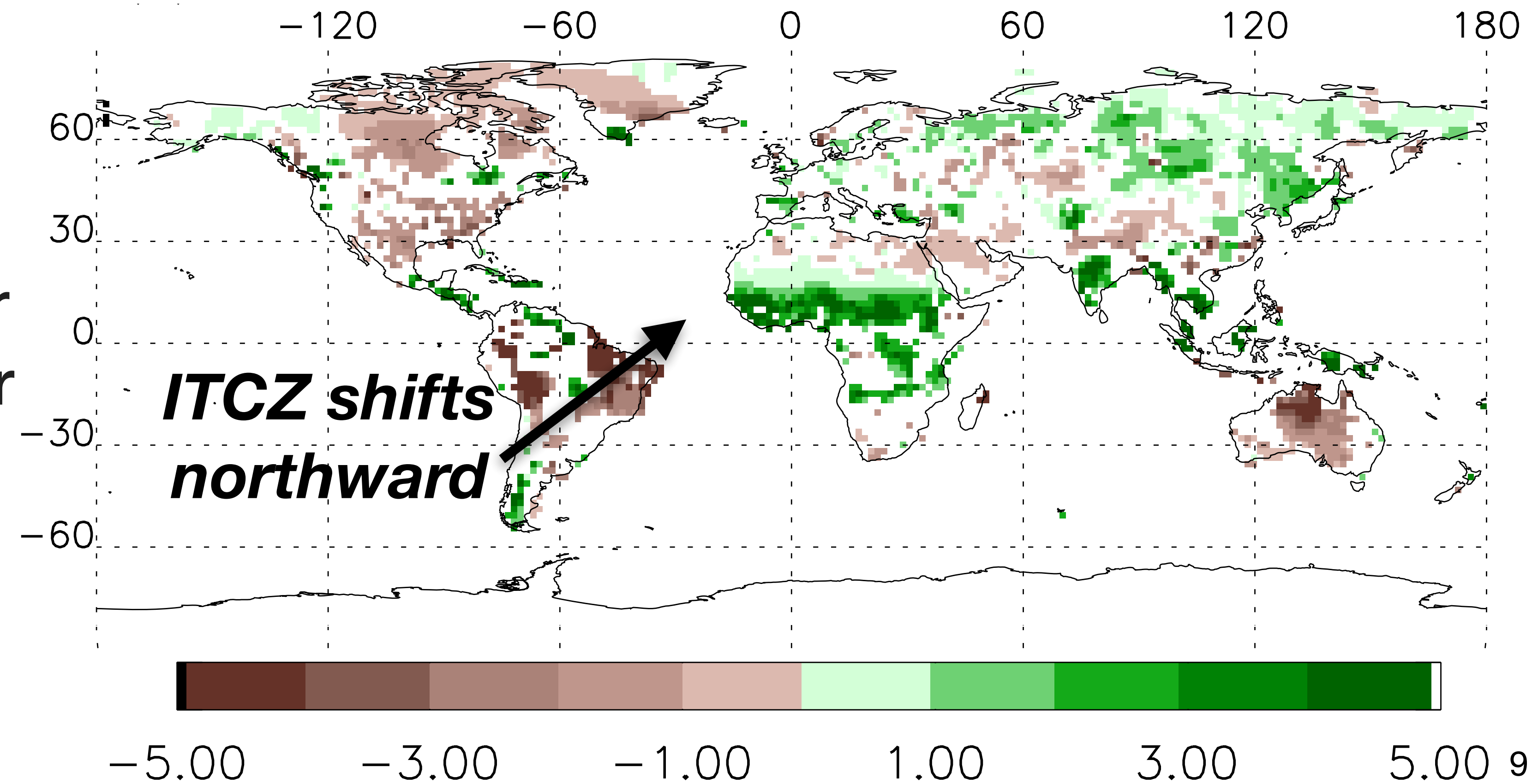
Ting et al. (2009)

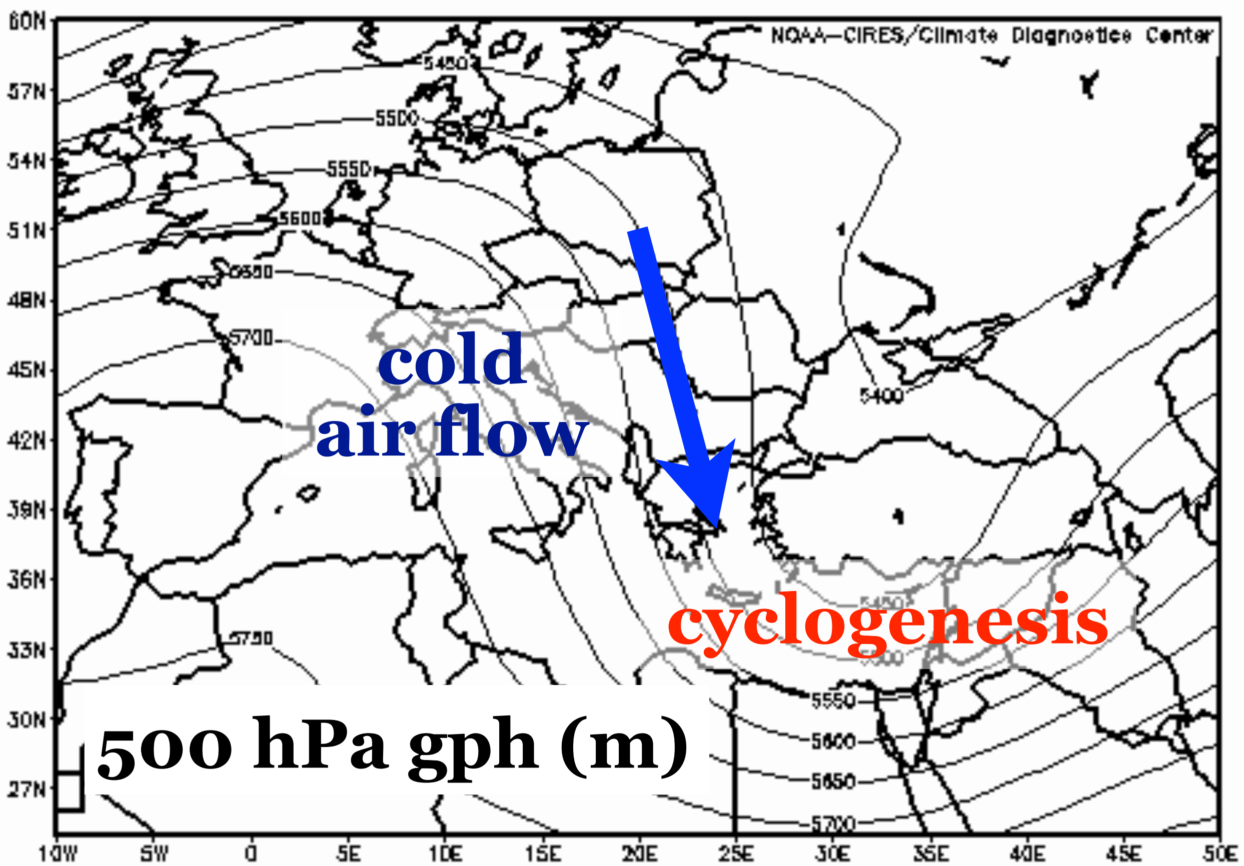
Top: Observed, annual mean surface air temperature anomaly (°C) regressed on the 20th century AMV index.

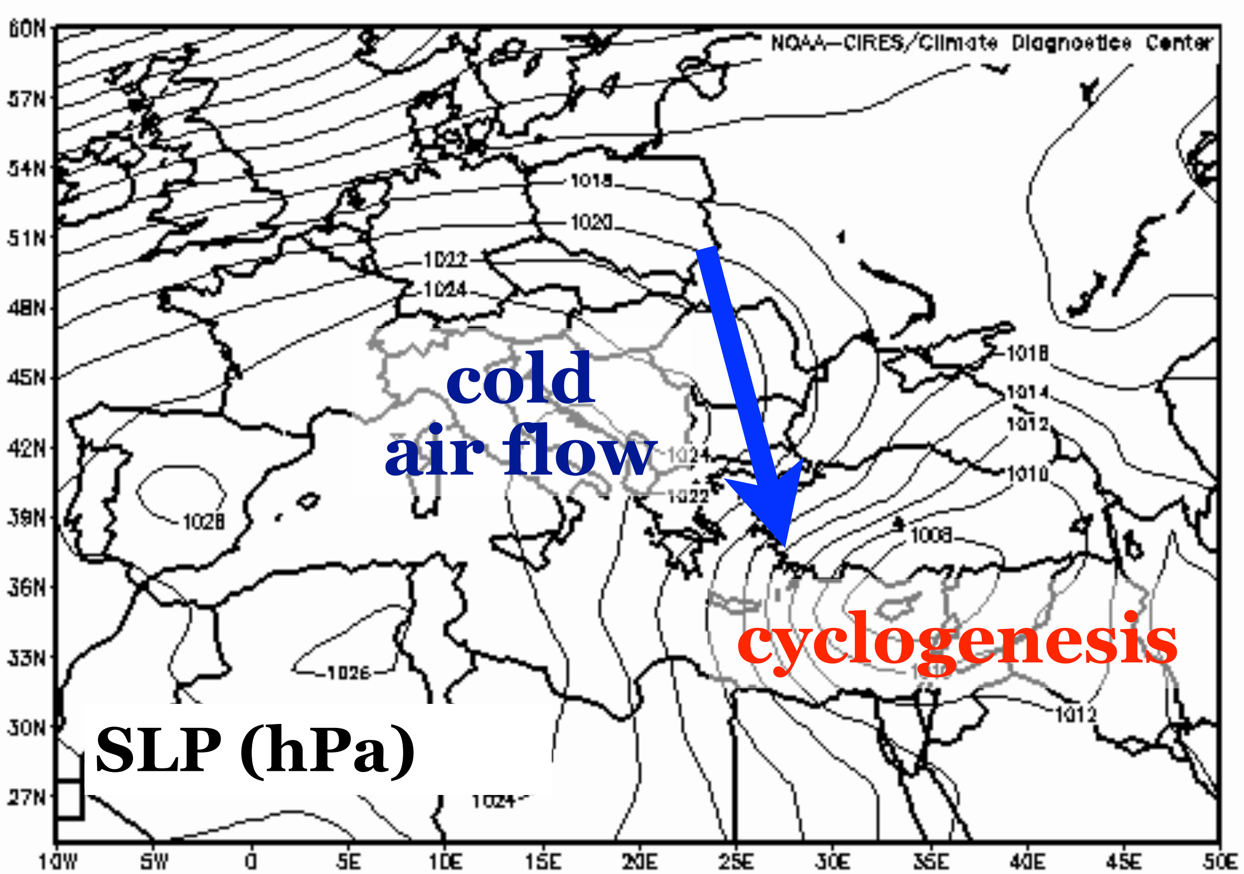
Bottom: The same as above but for precipitation (mm/mo).



AMV links winter (Mediterranean) and summer (African summer monsoon) variations over land because its SST footprint varies little throughout the year.





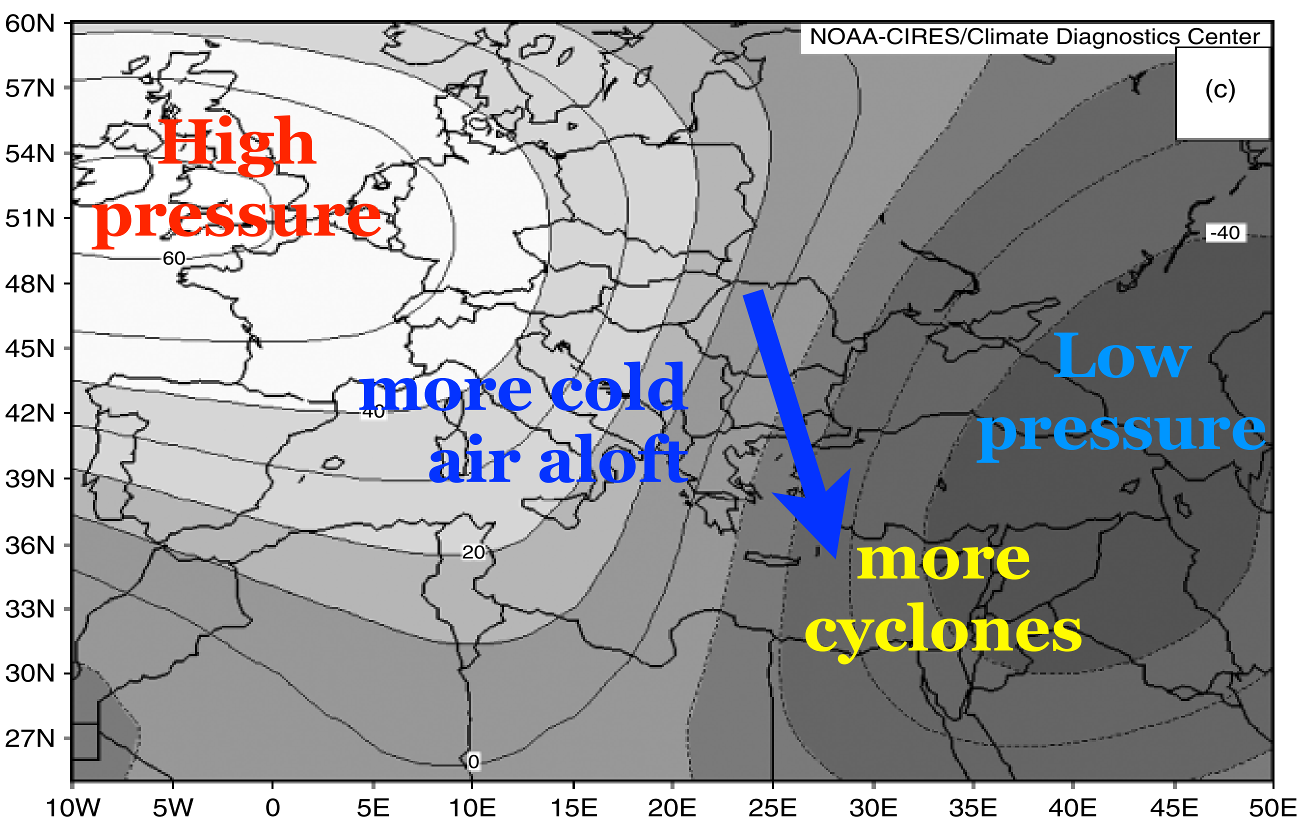


Ziv et al. (2006)

Cyprus Low: The rain-causing mechanism

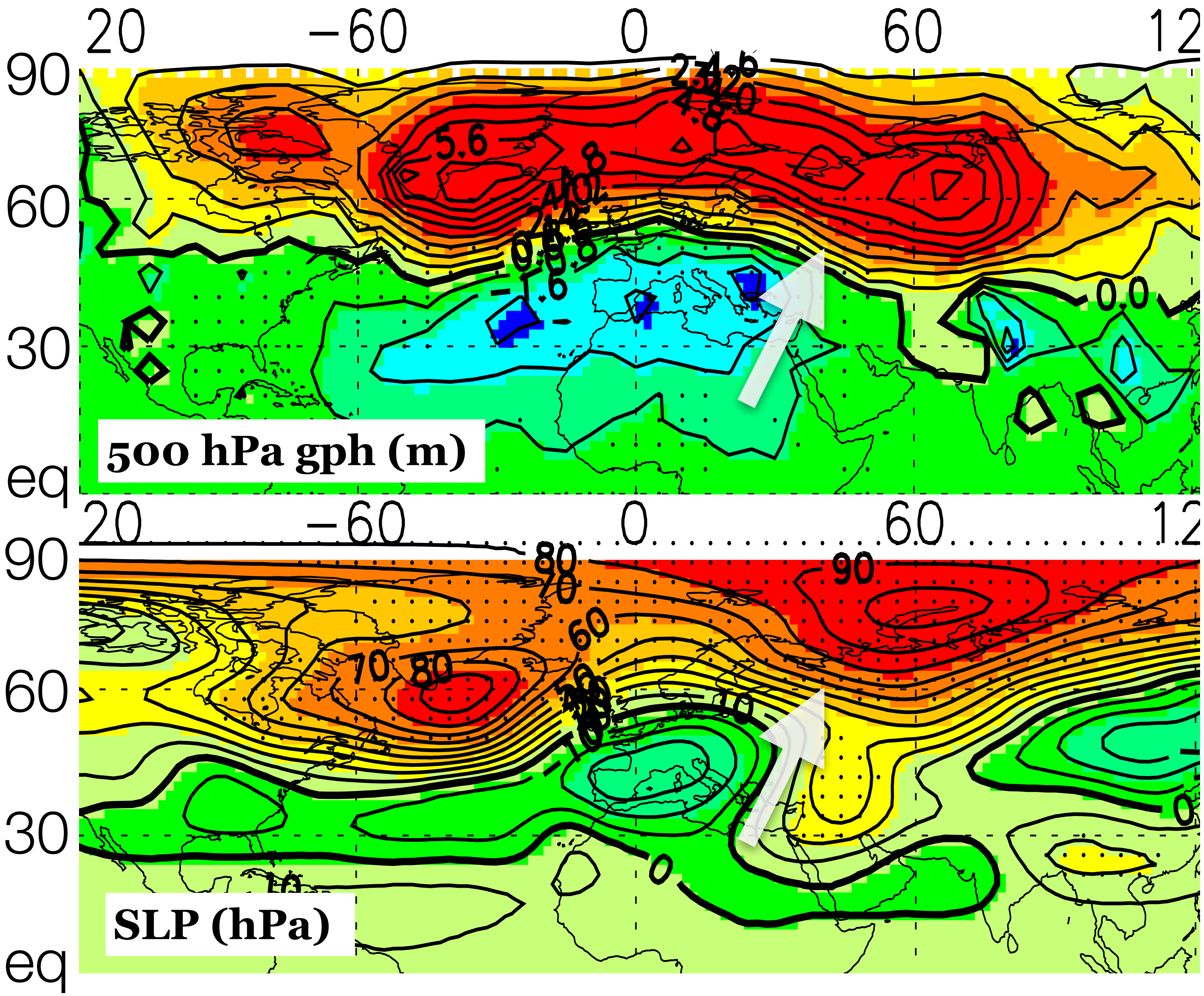
Right (top & bottom): The short-term (synoptic) pattern. Composite maps for 10 days with heavy rainfall in Israel

Below: the seasonal patter is determined by the underlying synoptic events



500 hPa difference between rainy and dry winters in Israel

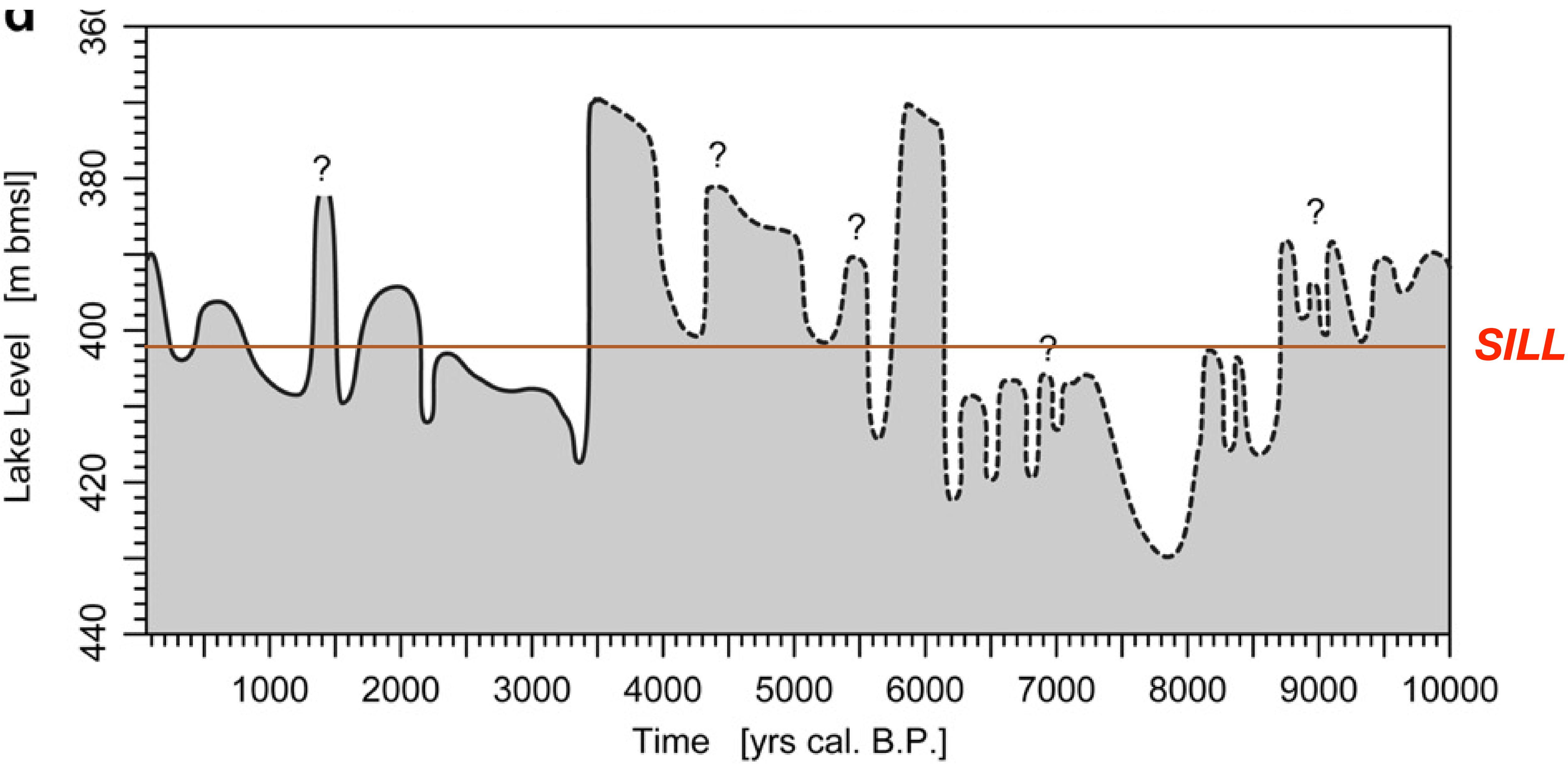
AMV *winter* circulation anomalies



Regression of the wintertime 500 hPa and sea level pressure fields on the AMV index

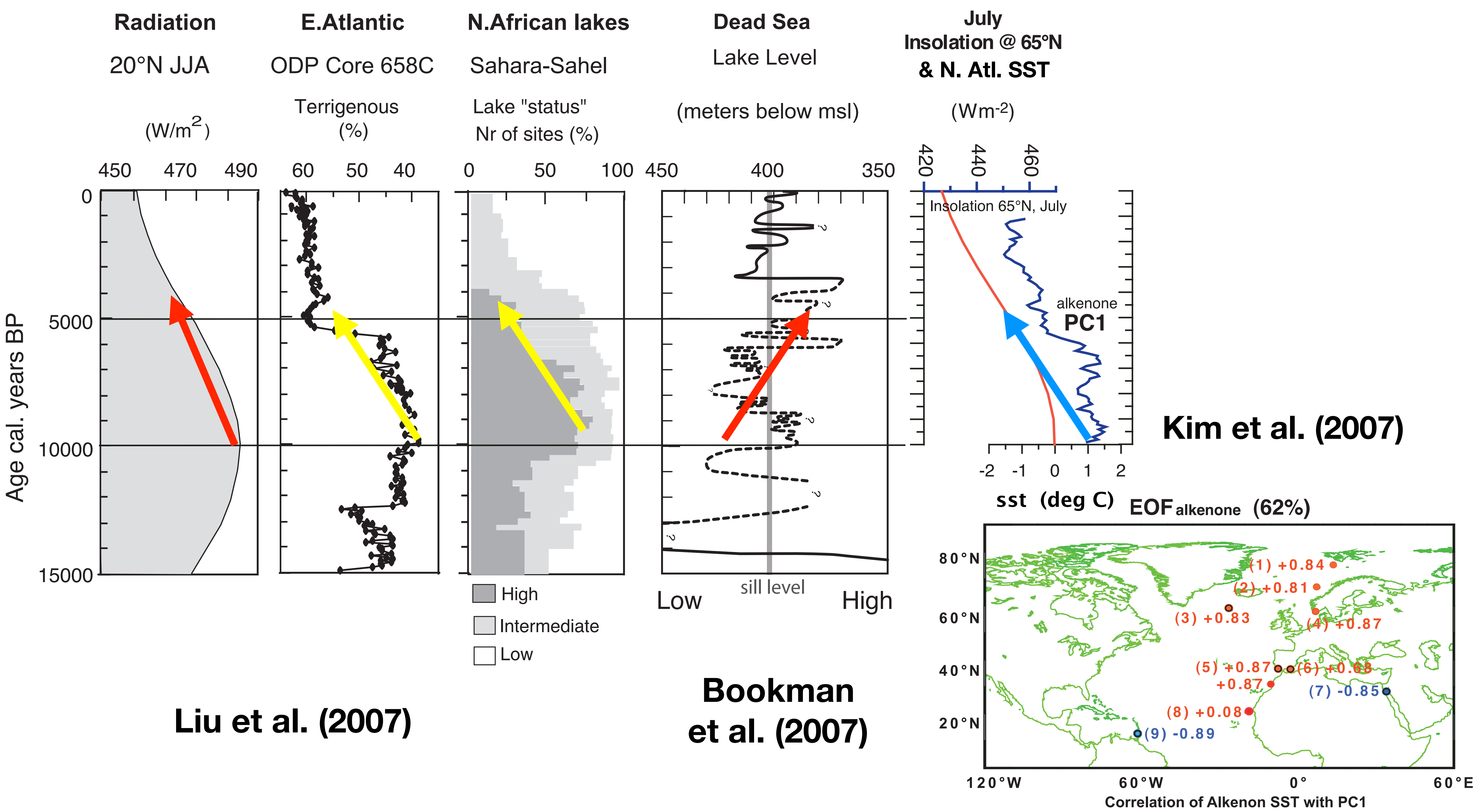
When the AMV is in its warm phase both surface and upper level *wintertime* anomalous flows over the Eastern Mediterranean (EM) are directed from south to north indicating a weakening of cold-air supply from the north and the potential for cyclogenesis is reduced. In both fields there is anomalous low pressure over the western Mediterranean and anomalous high pressure over the EM.

Holocene Dead Sea Levels



Litt et al. (2012)

Epochal Levant-Sahel-Atlantic link: Insolation-driven changes



Simulation of precession forcing - winter

LORENZ ET AL.: ORBITAL FORCING ON HOLOCENE CLIMATE TRENDS *(2005)*

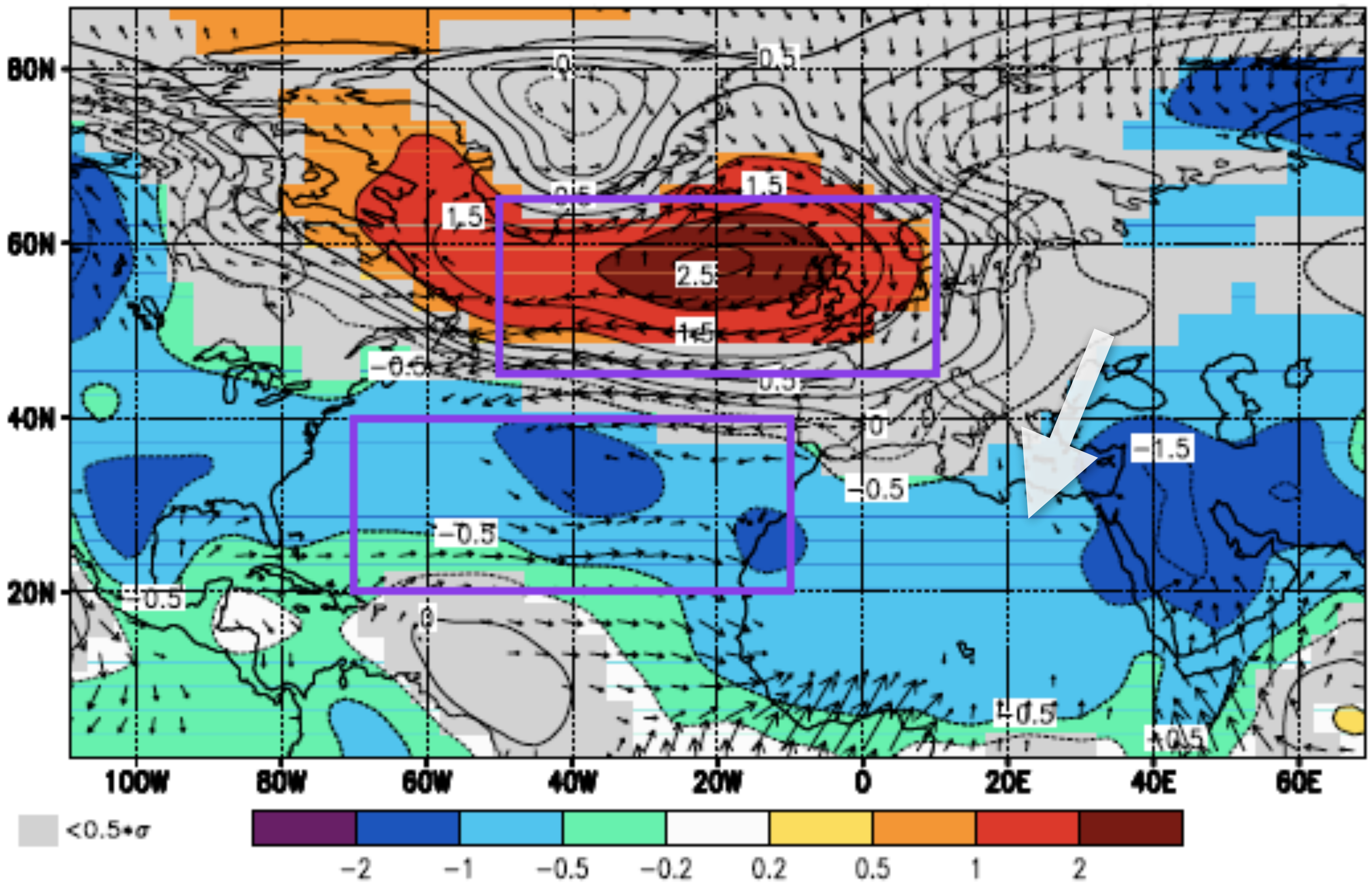
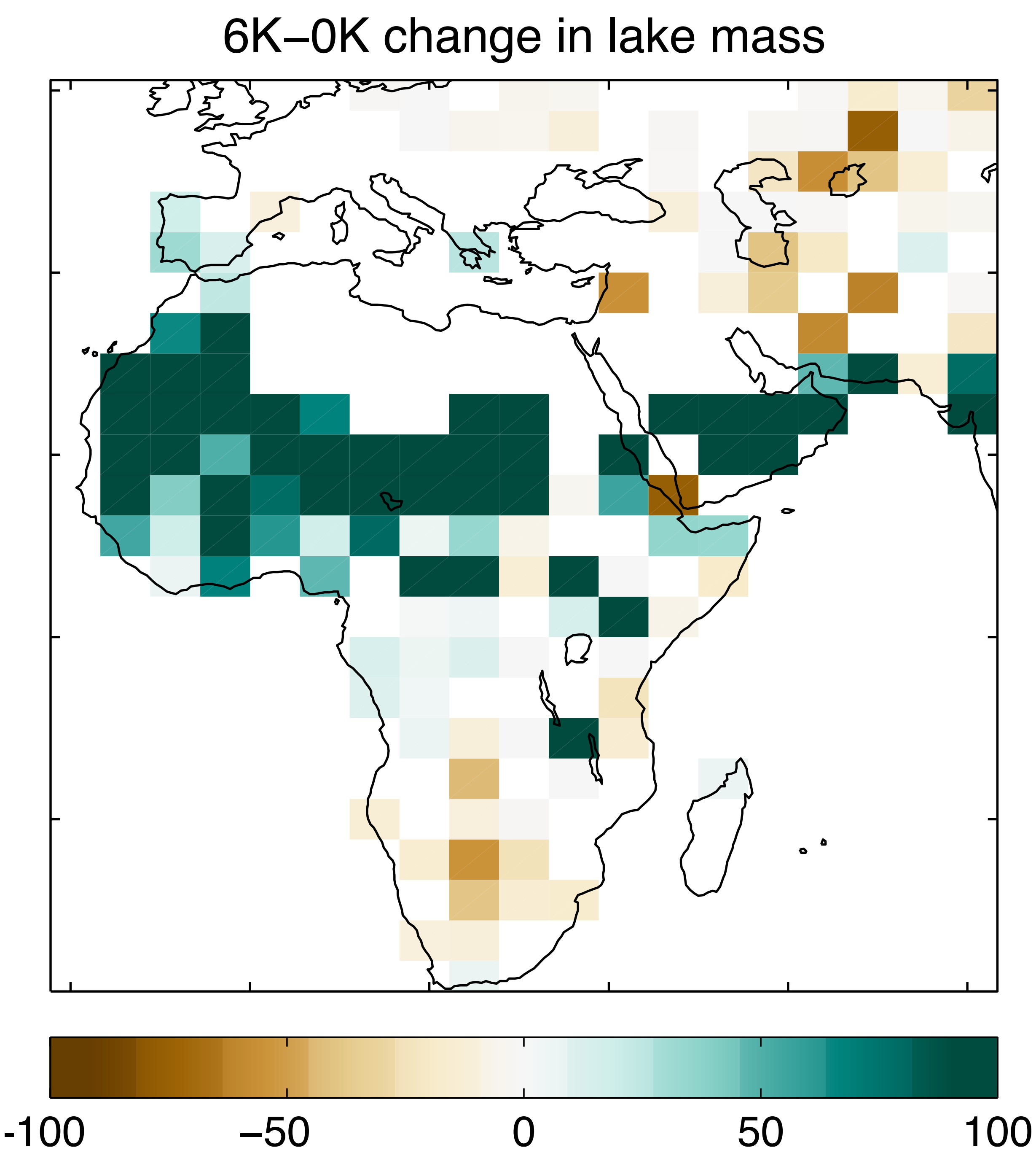


Figure 7. Simulated trend of boreal winter (DJF) sea level pressure from the six ensemble Holocene (7 kyr B.P. to present) simulations. Shaded areas represent the regions where the trend does not exceed 1/2 standard deviation. The rectangles indicate two regions in the North Atlantic, between which the meridional pressure difference for Figure 8 is calculated. Additionally, 10 m wind vectors of the 7000 years trend are shown but only where their magnitude exceeds 0.3 m s^{-1}.

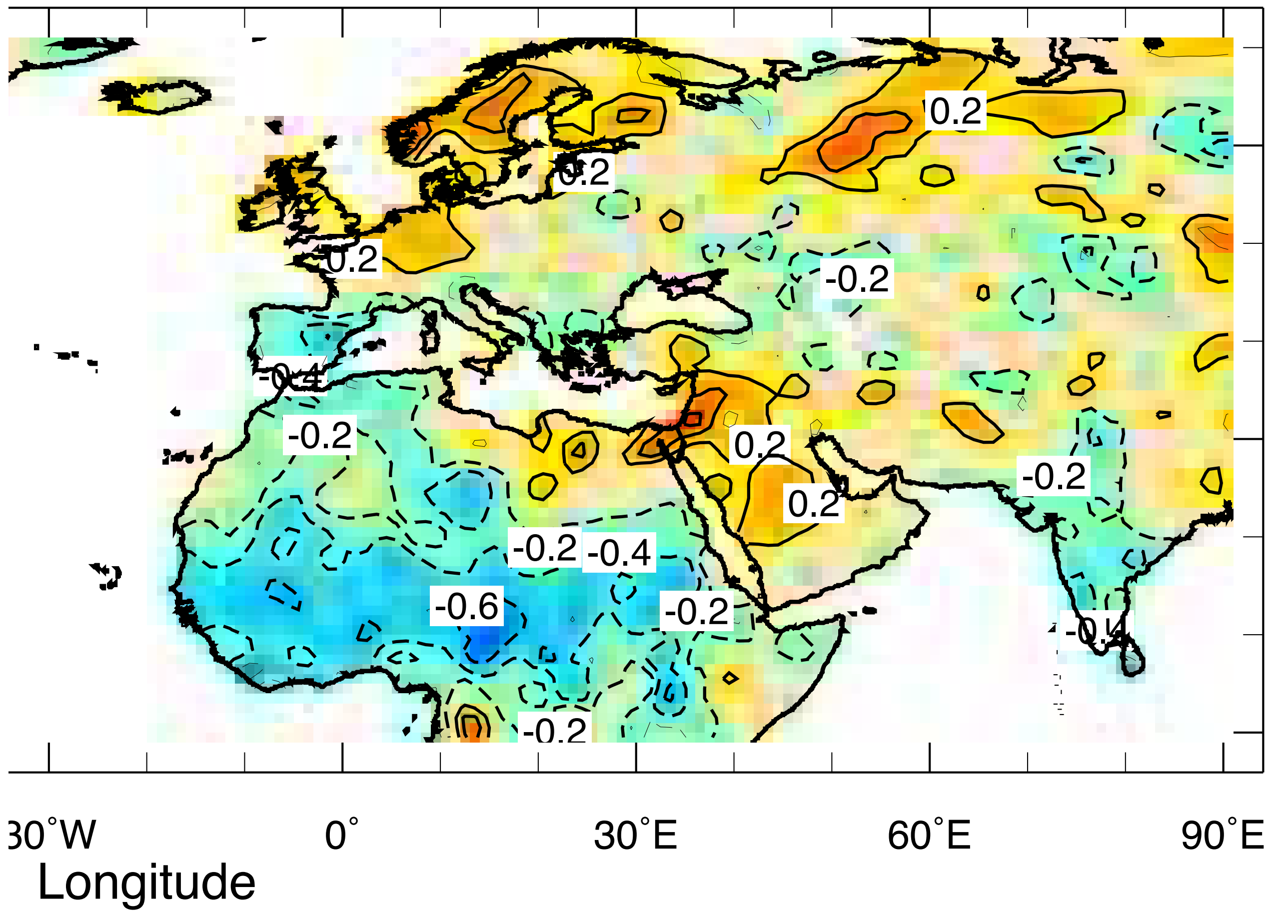
Between 7ka BP and the present, as North Atlantic SST cooled, SLP rose over the E subtropics intensifying the mean northerly flow of wintertime cold air from Europe into the Mediterranean Basin.

Simulation of precession forcing - summer



Left: Simulated 6K–0K change in lake mass, expressed as a percentage of 0K lake mass such that a 100% increase indicates a doubling of lake mass (***Tierney et al. 2011***).

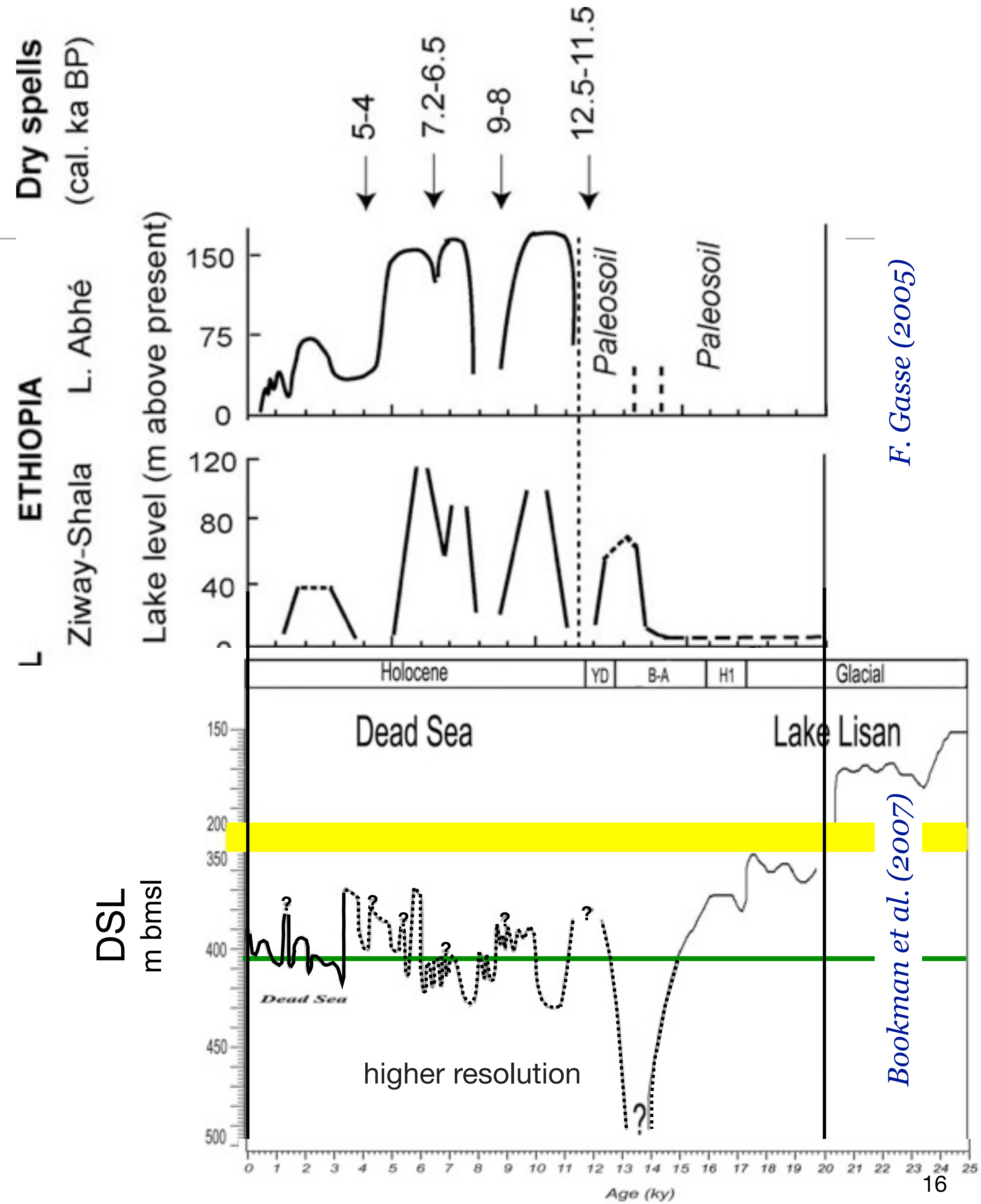
Below: Present-day correlation.



Millennial variability

- B-A, YD & several other millennial lake-level fluctuations exhibit anti-phase behavior (colors indicate wet/dry epochs in the Levant)

- However, some rapid drying events are in phase



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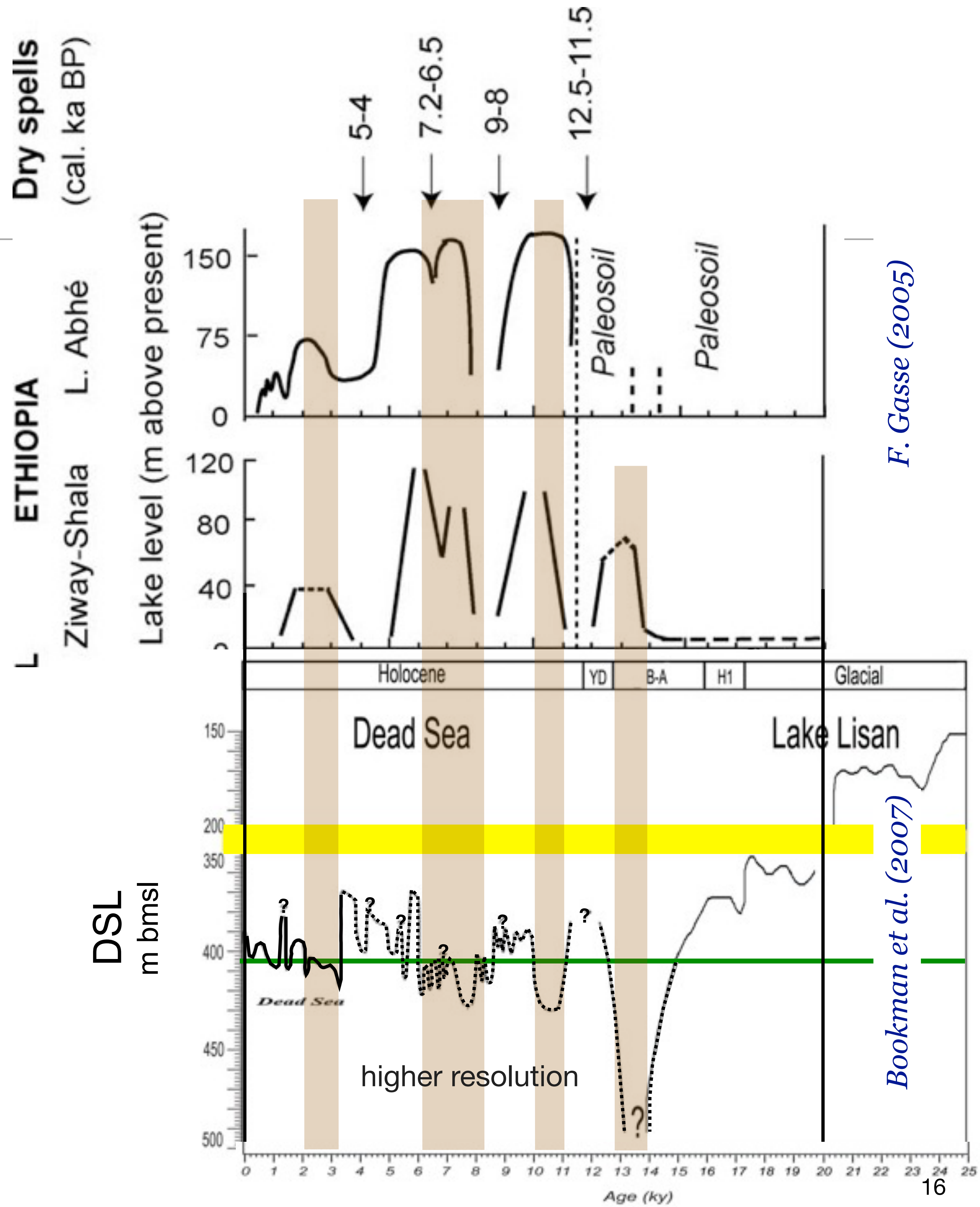

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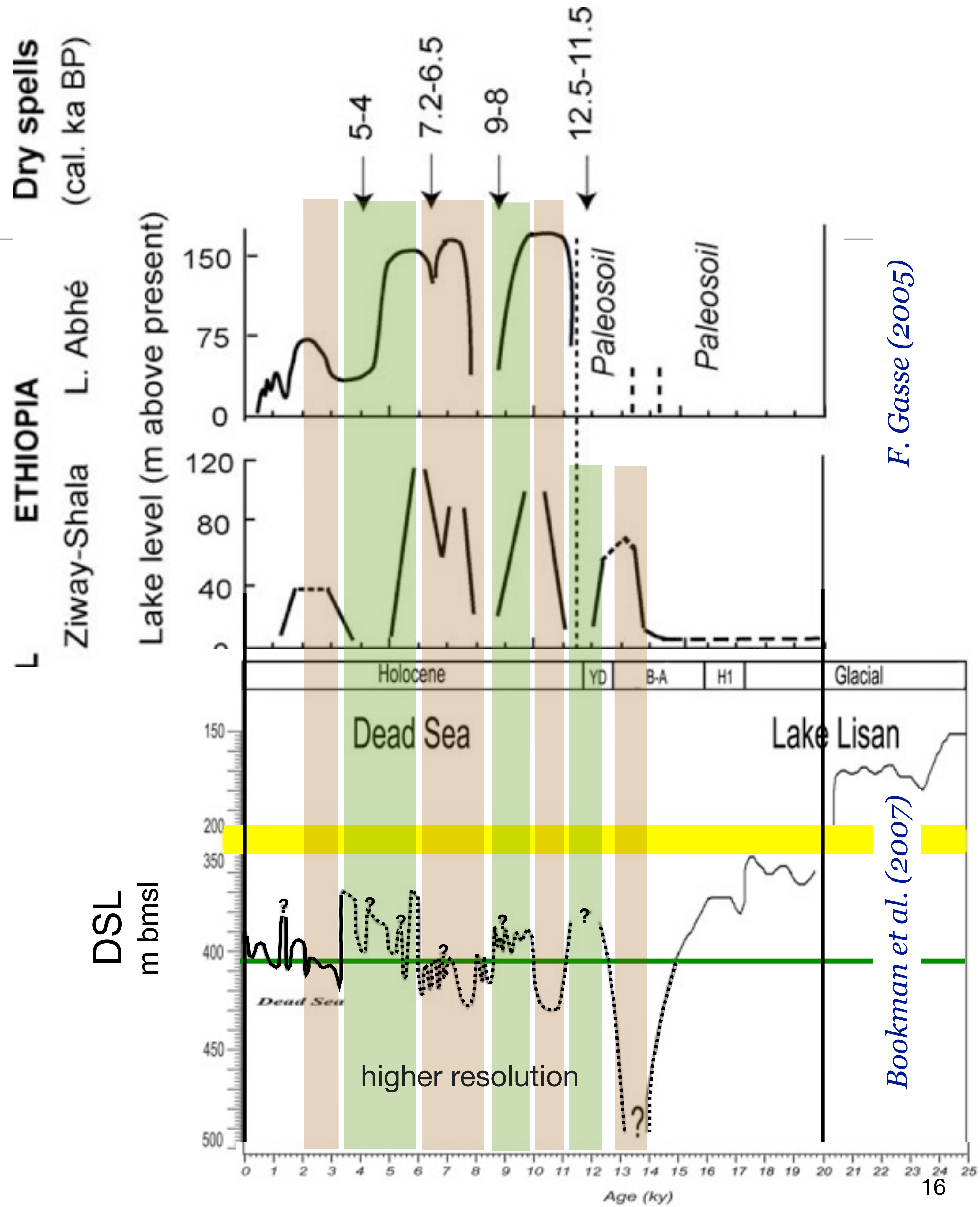

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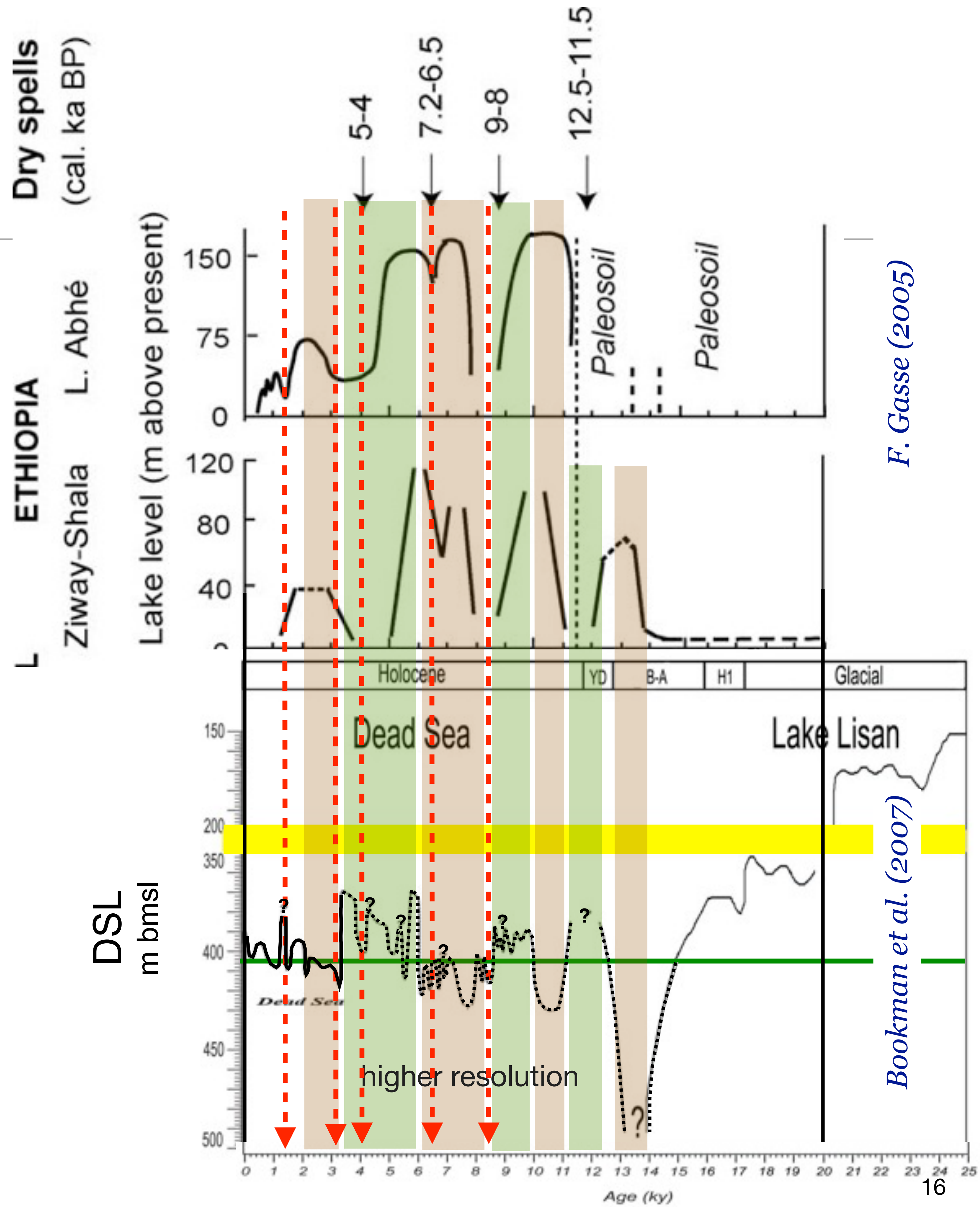
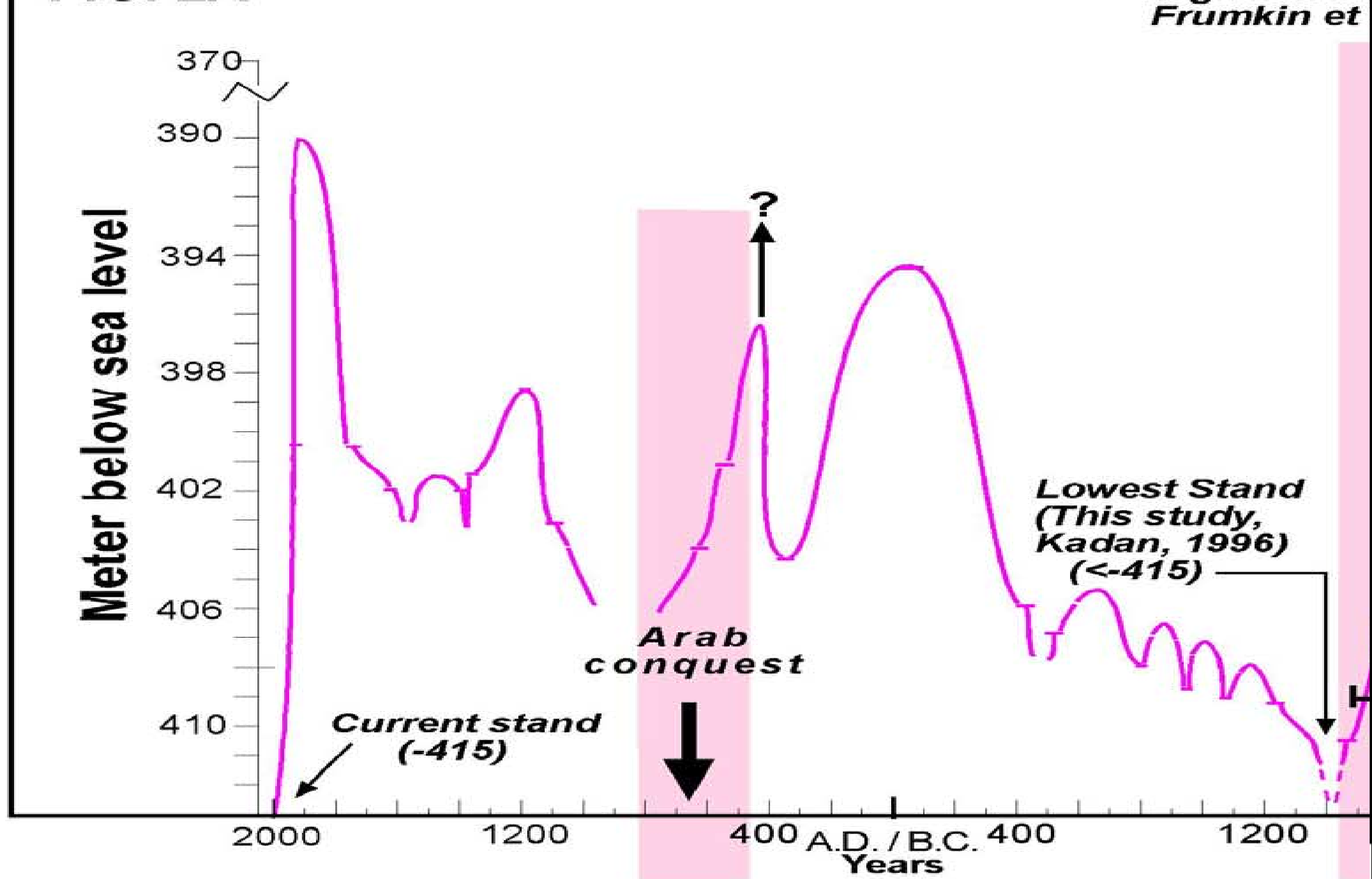
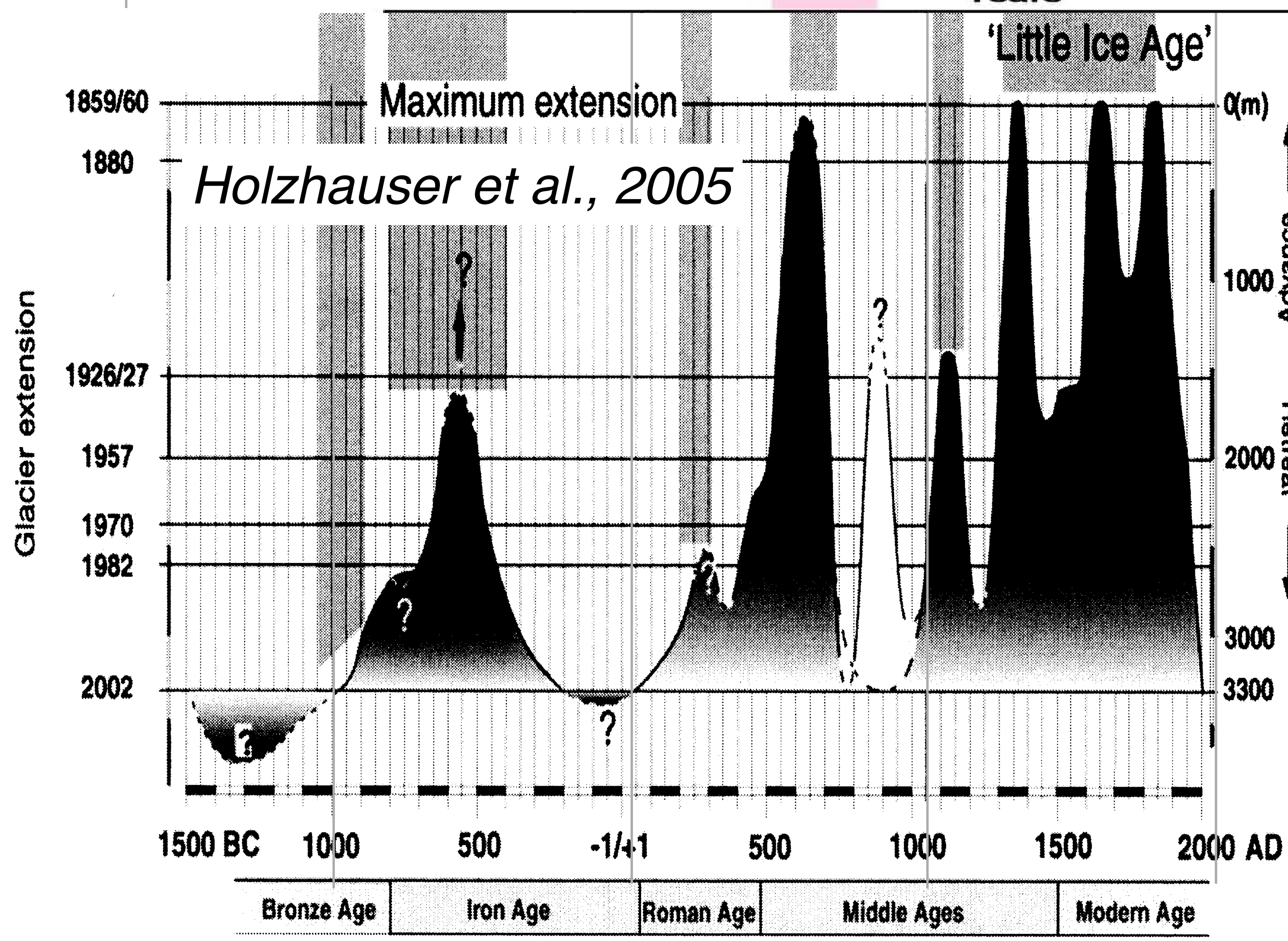


Late Holocene fluctuations

- Late Holocene Dead Sea Level fluctuations (*Enzel et al., 2003*) are correlated with Alpine glacier advance/retreat record (*Holzhauser et al., 2005*) - a proxy for Atlantic SST fluctuations (*Denton and Broecker, 2008*) and with Keigwin (1996) Sargasso SST.

FIG. 2A





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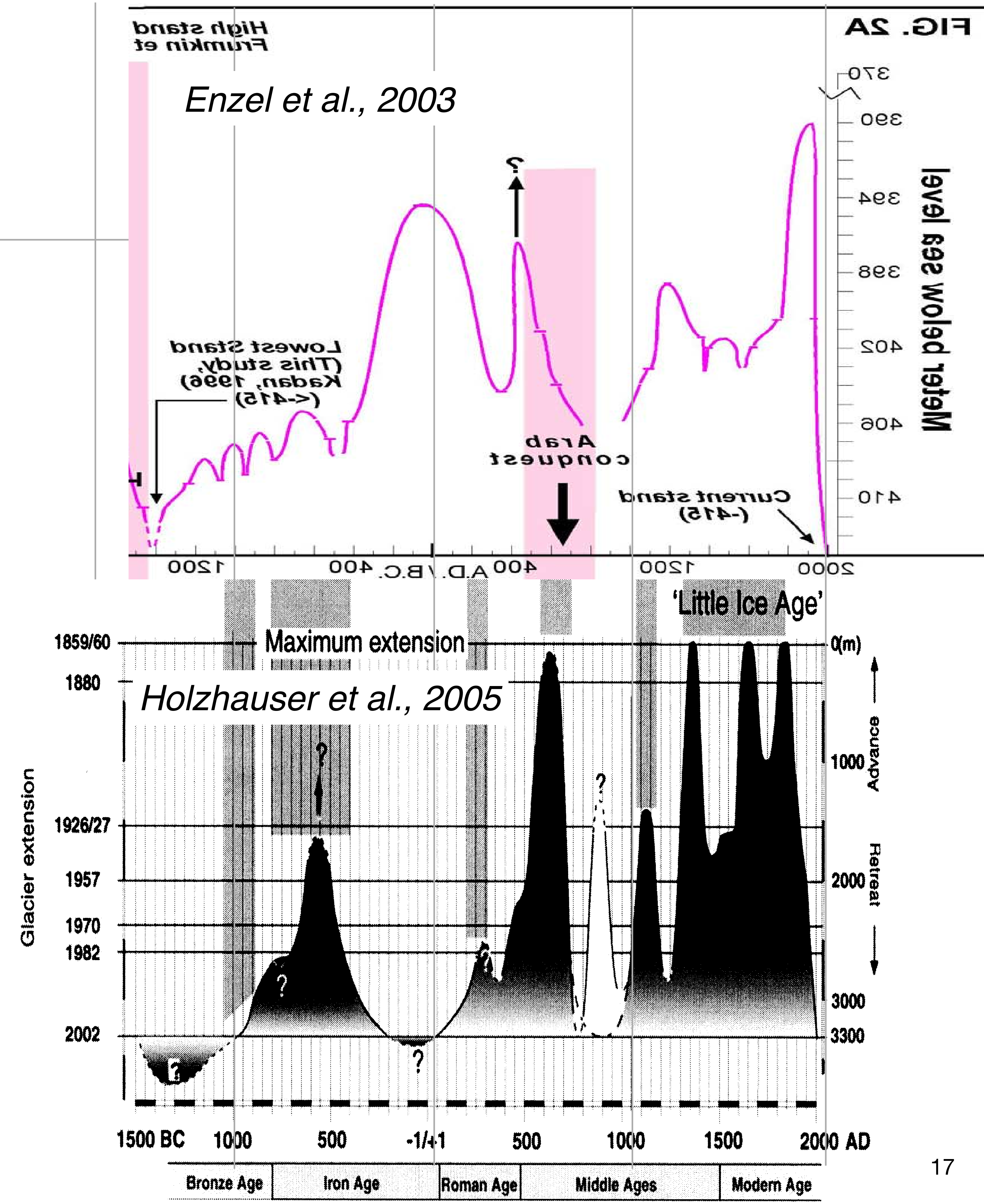

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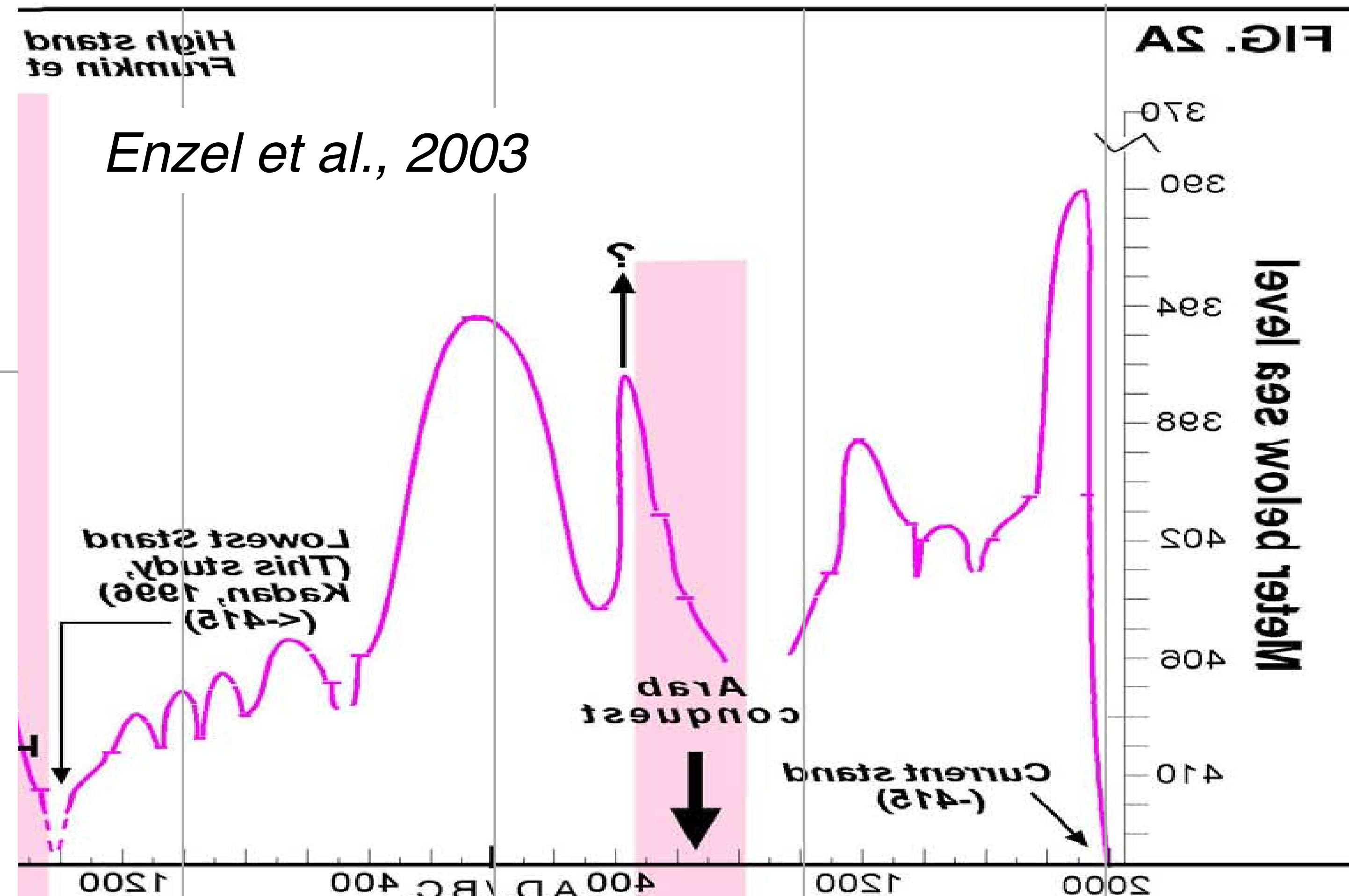

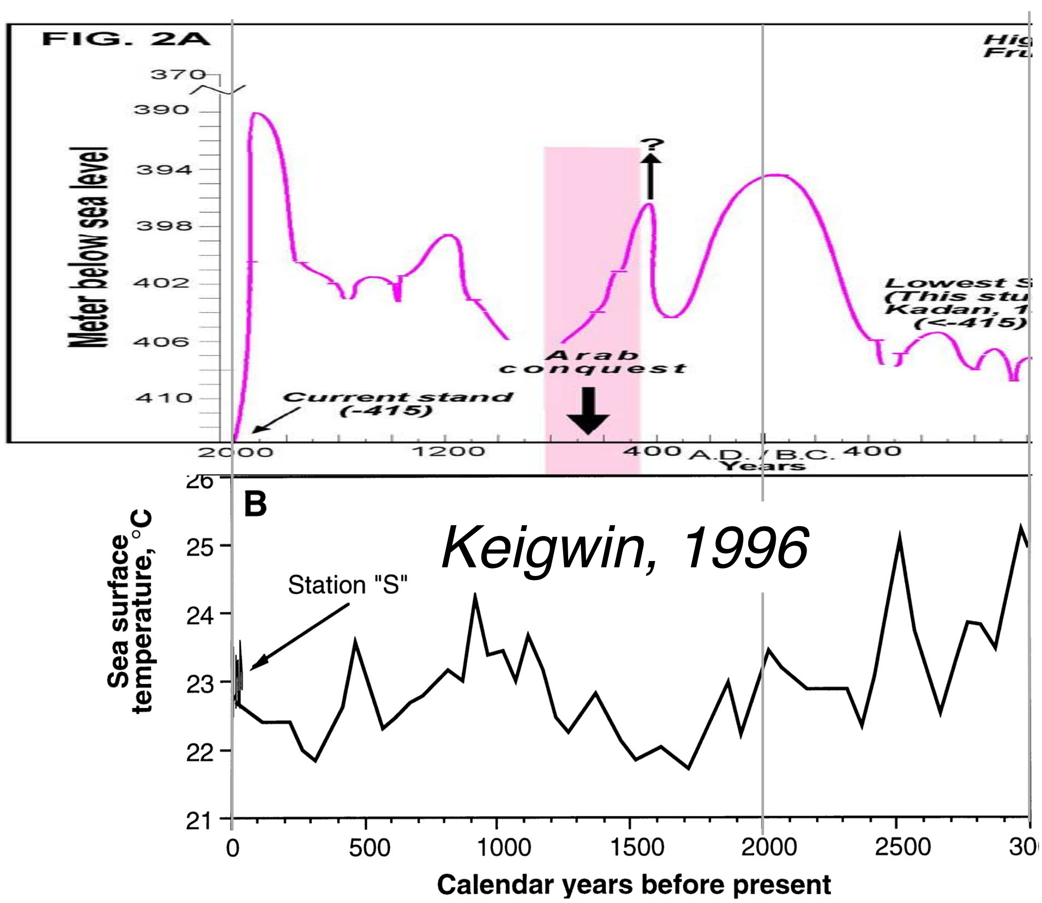

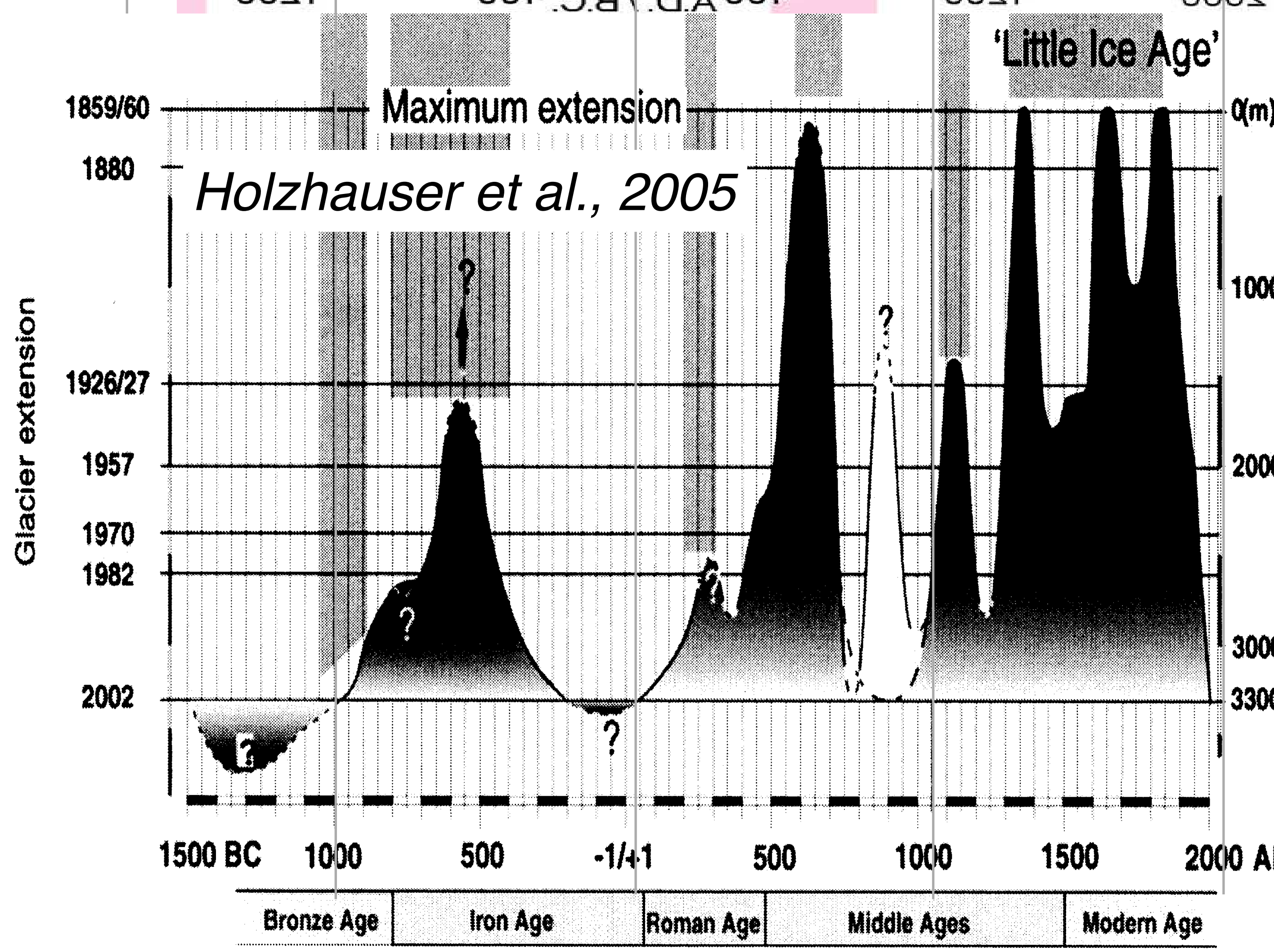

Summary

- Instrumental observations and paleoclimate proxies reveal a long-term, naturally occurring pattern of hydroclimatic variability in the Levant in anti-phase with changes in North Africa (Sahel), and in-phase with Europe (Alps) and North America.

- This pattern of variability is orchestrated by multidecadal to millennial SST changes in the North Atlantic

No. Atl. SST (-) = Levant ppt (+) = Sahel ppt (-) = Alps snow (+) = No. Amer. ppt (+)

- Atlantic SST impact is carried over to the Levant by an "*atmospheric bridge*": enhanced high pressure over the East Atlantic when SSTs are cold, forces cold air bearing troughs to deepen over the east Mediterranean, enhancing regional cyclogenesis and bringing more rain to the Levant.

- There are abrupt events (*which are associated with millennial ice-rafting events in the No. Atl.*) that break the anti-phase Levant-Sahel pattern.