Overview of palaeo-climate modelling for the Mediterranean climate and future challenges (focus on terrestrial ecosystems during the Holocene)

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Outline

- 1. Introduction
- 2. Paleodata syntheses and Holocene climate variations in the Mediterranean
- 3. Data-model comparison: large scale climate variations and climate models simulations
- 4. Future challenges: Inverse modelling and data assimilation

1. Introduction

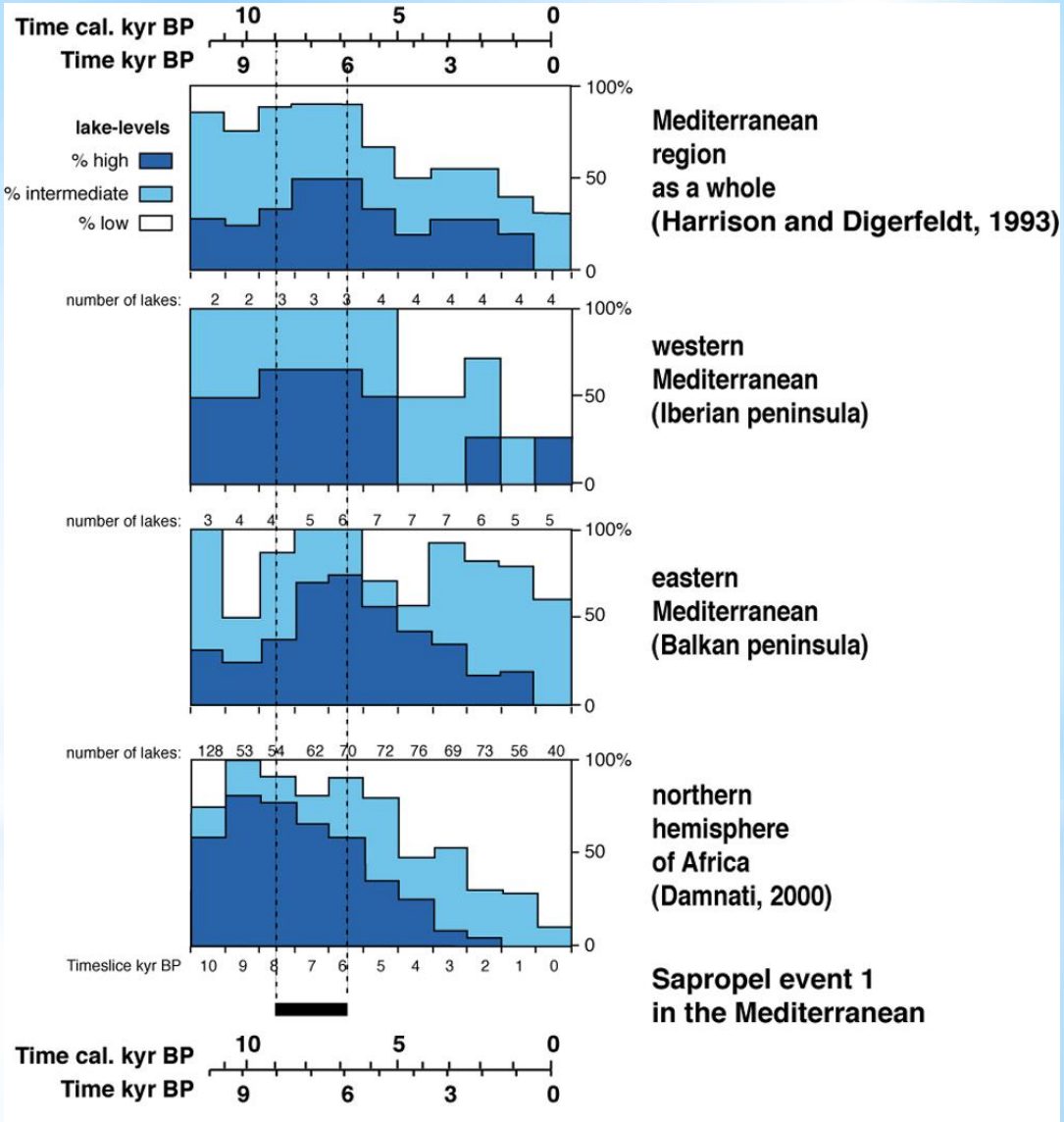
- Understanding past climatic changes needs comparison of data and model simulations
- From the data side, we need
  - Spatial syntheses representing large scale climate changes
  - Well understand the response processes of the proxies to climatic change (which climate variables are recorded by the proxy?)
- From the model side, we need
  - Downscaling at the appropriate spatial and temporal scale for the ecosystems
  - An appropriate method of comparison (from visual to data assimilation)
- From both sides, we need a good knowledge of the respective limits and uncertainties of data and models

2. Paleo-data syntheses and Holocene climate variations in the Mediterranean

- Lake-levels
- Pollen
- Speleothems
- Micro-charcoals
- Chironomids
- Etc…

* Lake levels in Mediterranean and Africa

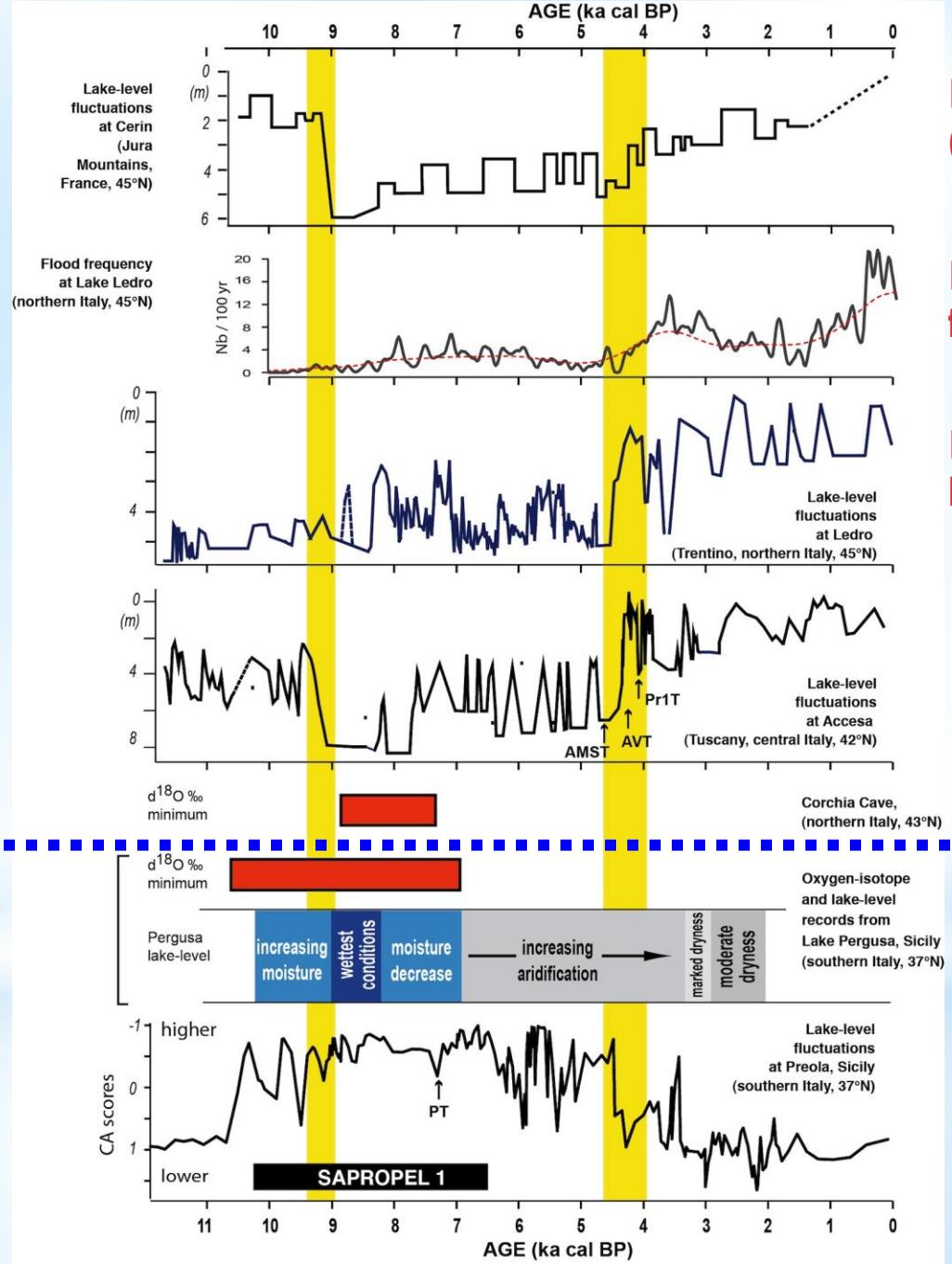
* A maximum of humidity 8-6 ka BP
* Dry period after, especially Eastern Med and in Africa
* 5 ka BP: end of "African Humid Period"



Harrison et Digerfeldt, 1993, QSR

Magny et al., 2002, Pal. Pal. Pal.

* Opposite paleo-hydrological patterns north / south 40°N in central Mediterranean (Magny et al, 2011)



Lake Cerin (Jura): lake level

Lake Ledro: floods

Lake Ledro: lake level

Lake Accesa: lake level

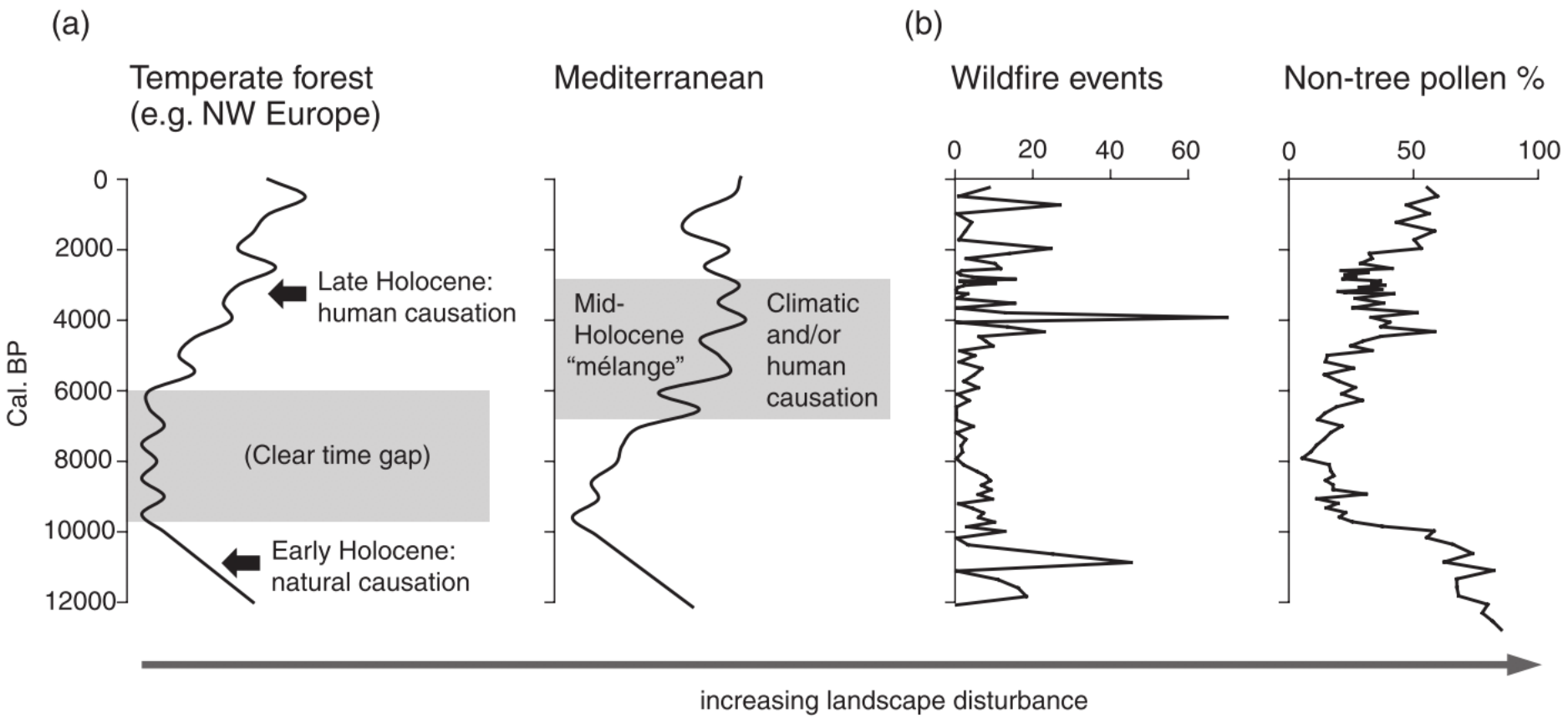
Corchia cave

Lake Pergusa: lake level

Lake Preola (Sicily) : lake level

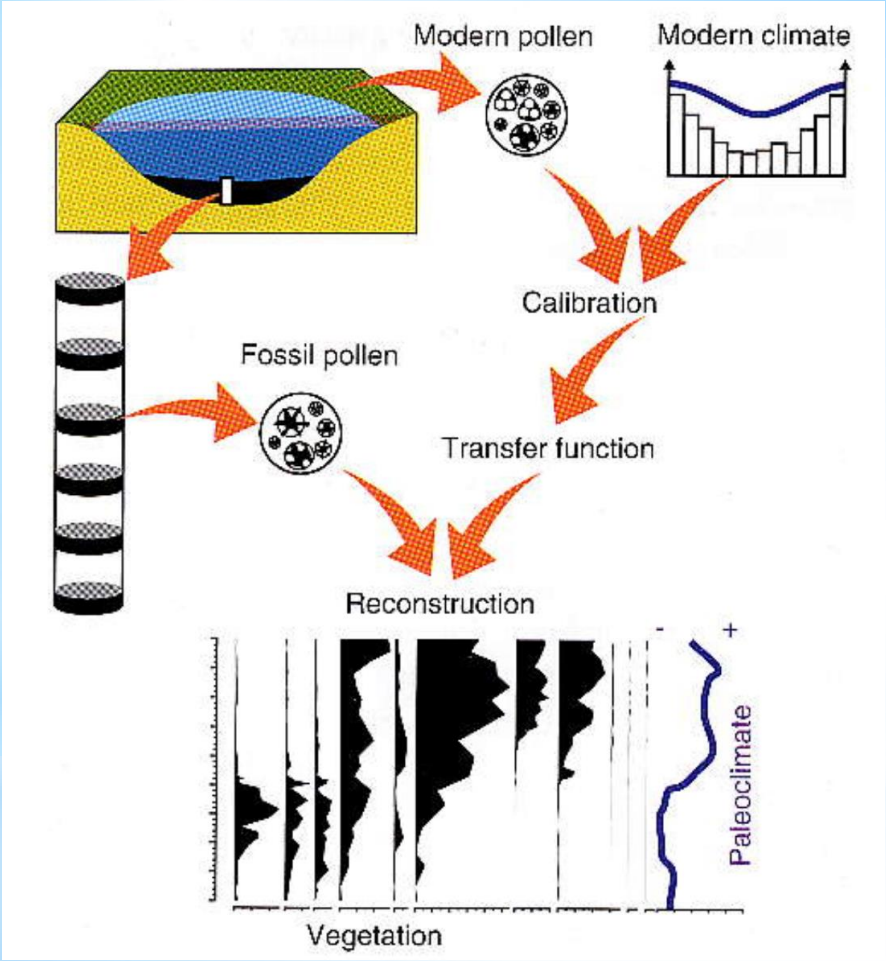
* The model of landscape evolution in the Mediterranean area

* The modern landscapes are the results of climate change and human action



Roberts et al, 2011

* 2. The pollen transfer function to reconstruct past climates

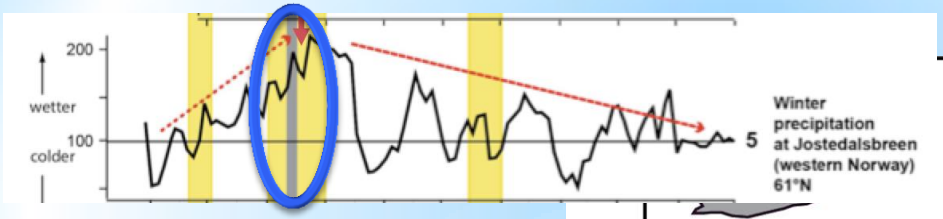


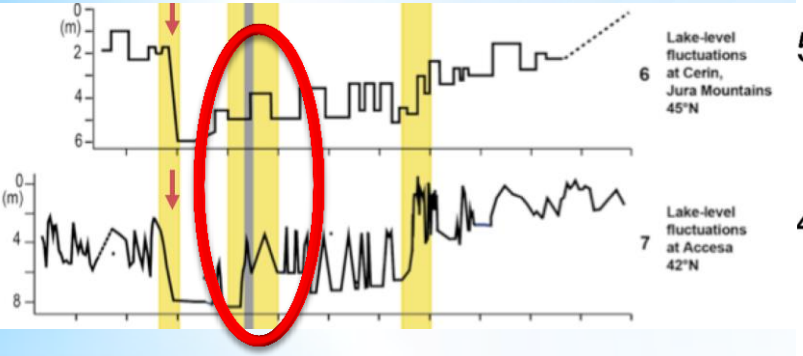
* Calibration of a regression between climate variables and pollen assemblages on a modern training dataset
* Or comparison of the fossil assemblage to modern assemblages to select the best analogues

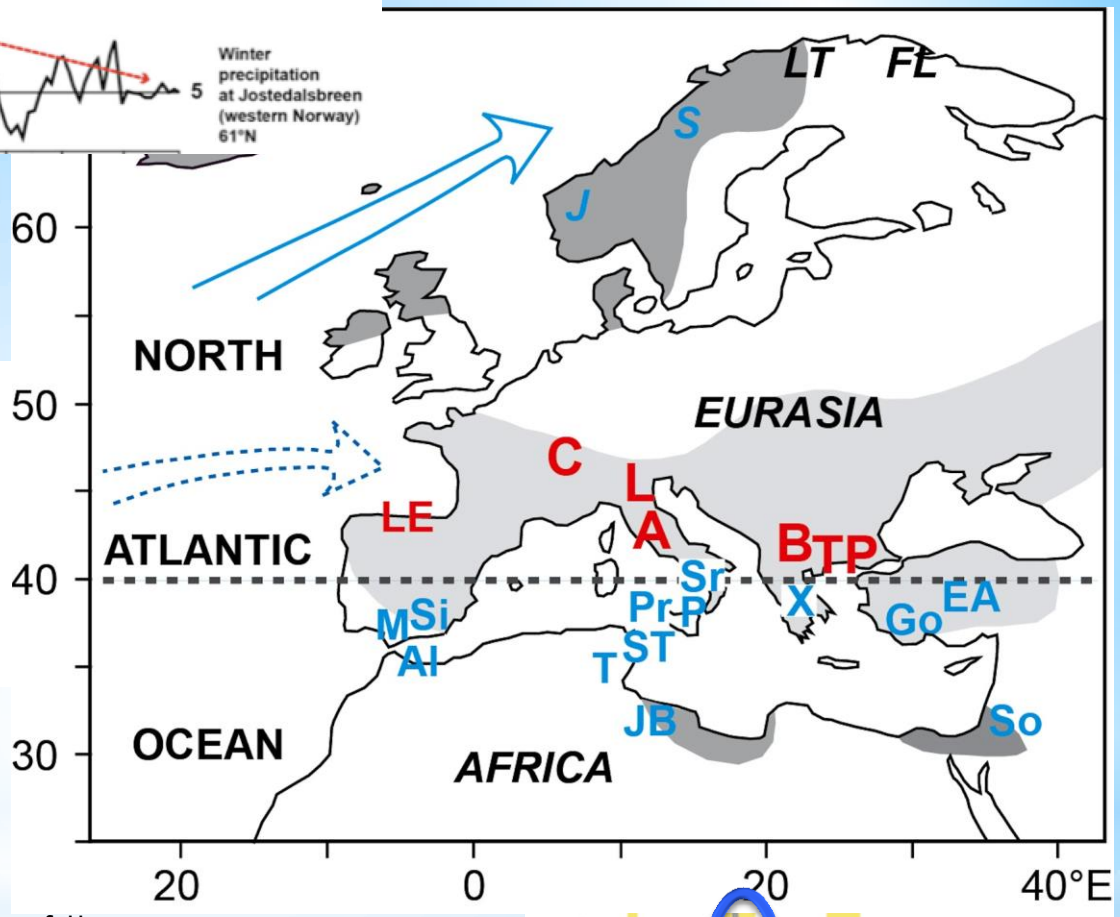
* 3. Data-model comparison: large scale climate variations and climate models simulations

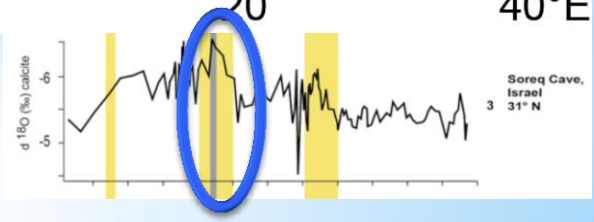
* A NAO+ type pattern at 7-6 ka BP
* African Humid Period (6 ka BP) vs present biomes
* Holocene precipitation: data-model comparison using lake data
* Holocene precipitation: Data-model comparison using pollen data
* Pollen-based summer temperature biased by precipitation, Chronomids say !

* A NAO+ type pattern at 7-6 ka BP



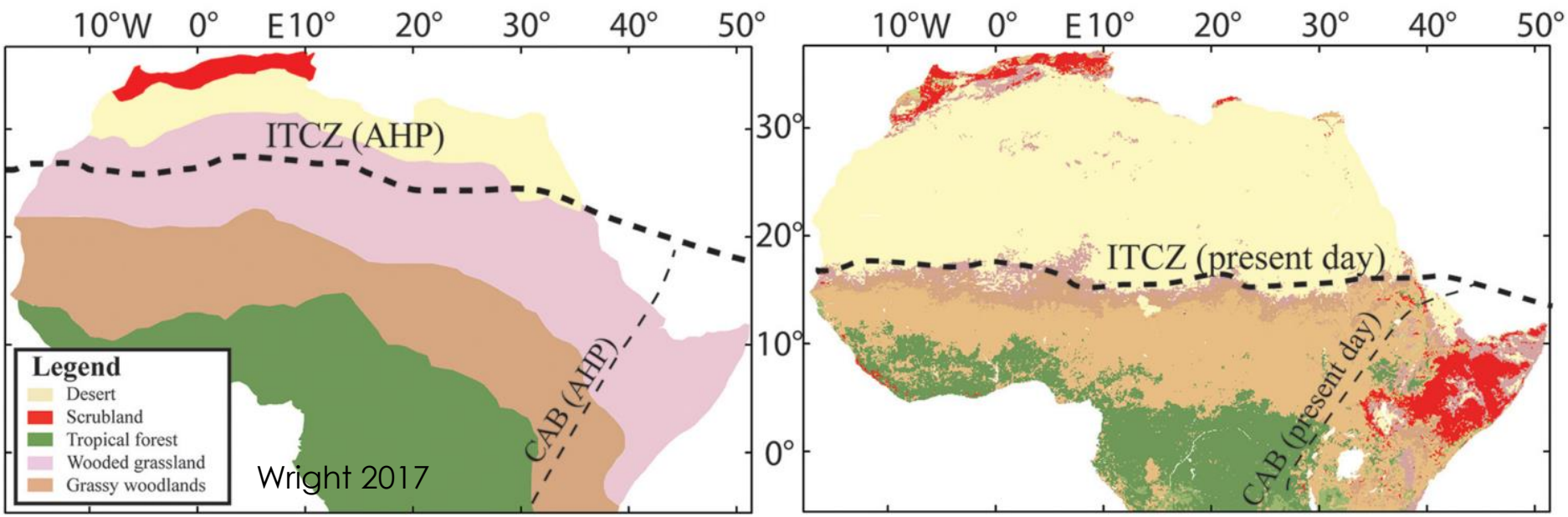




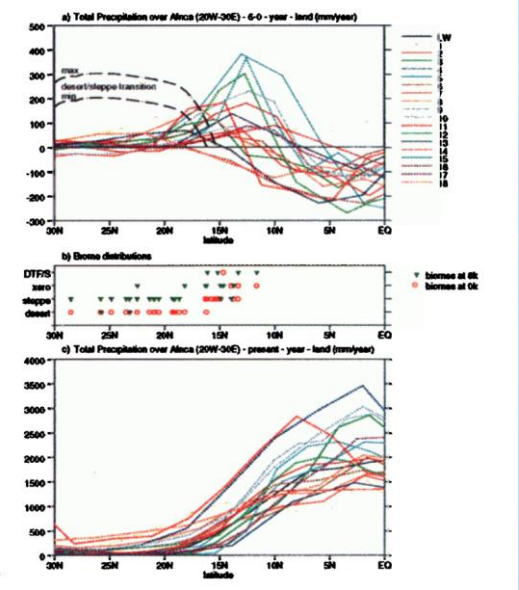


The Mediterranean is subject to the effects of the NAO, notably in West-Med. In East-Med, precipitation and pressure over the southern Levant and Egypt show an inverse correlation with the NAO index – the so-called Mediterranean see-saw (Oldfield and Thompson, 2004)

* African Humid Period (6 ka BP) vs present biomes



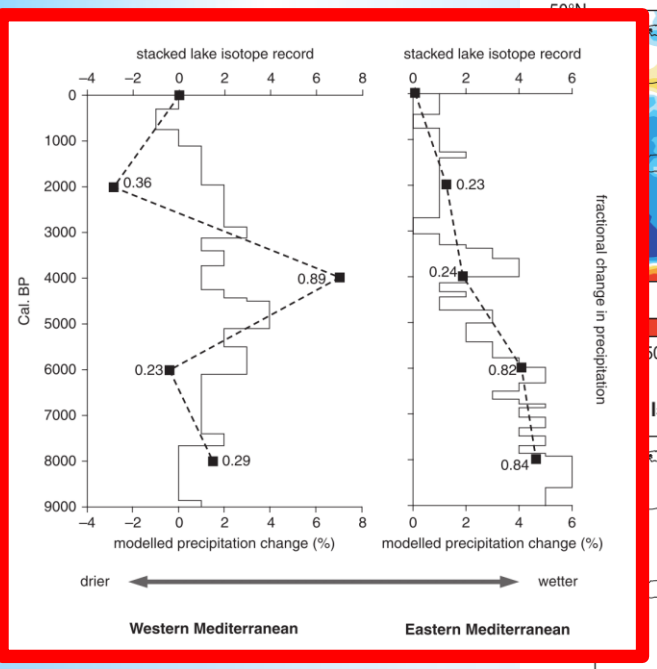
* At 6 ka BP, the ITCZ was 10° more north (according data) transforming a large part of the desert by steppes
* According to present gradient, this implies an increase of 100 mm annual precipitation
* The models are only able to push the limit steppes-desert by 5° north

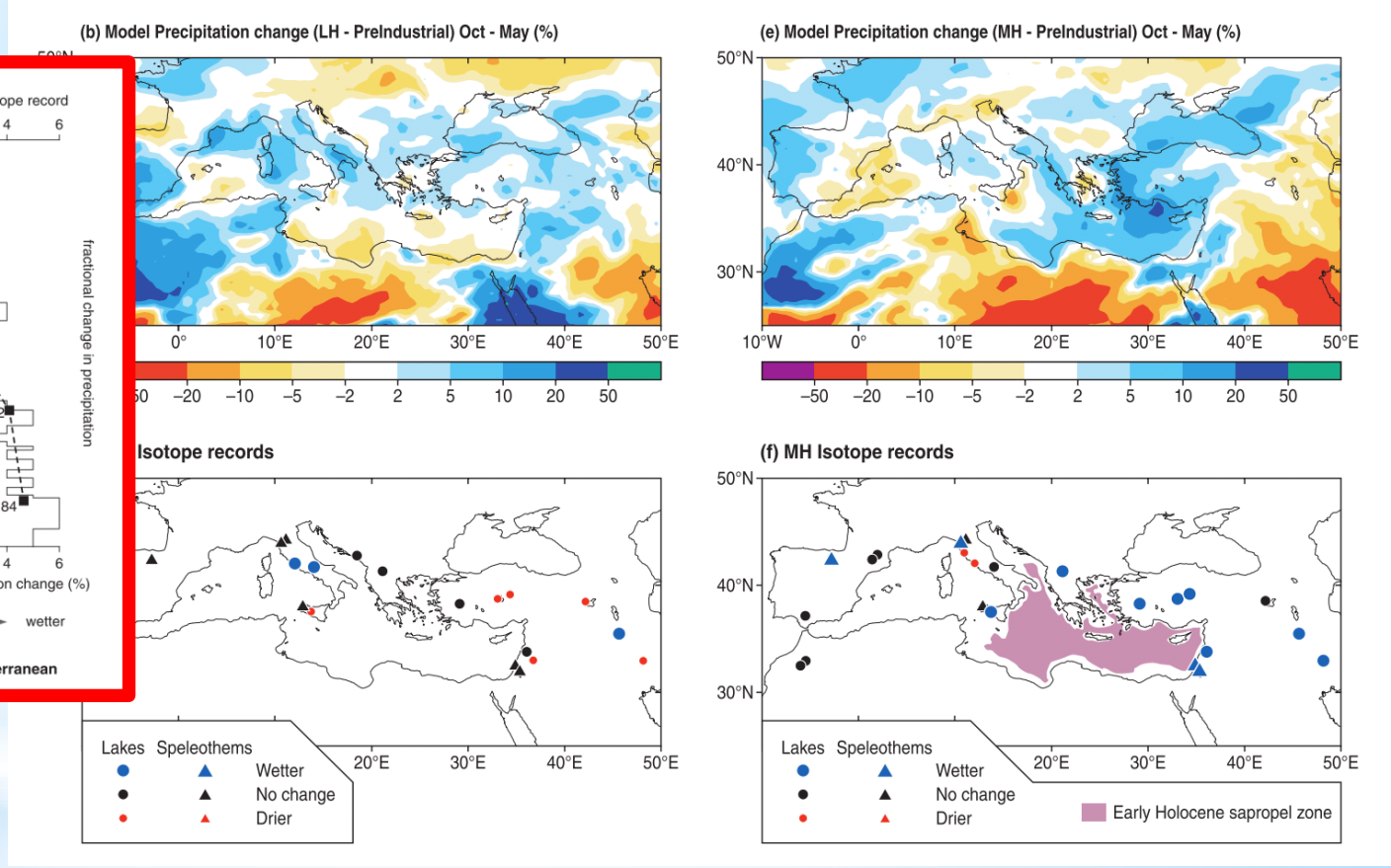


PMIP

Joussaume et al 1999

* Holocene precipitation: data-model comparison using lake data and speleothems

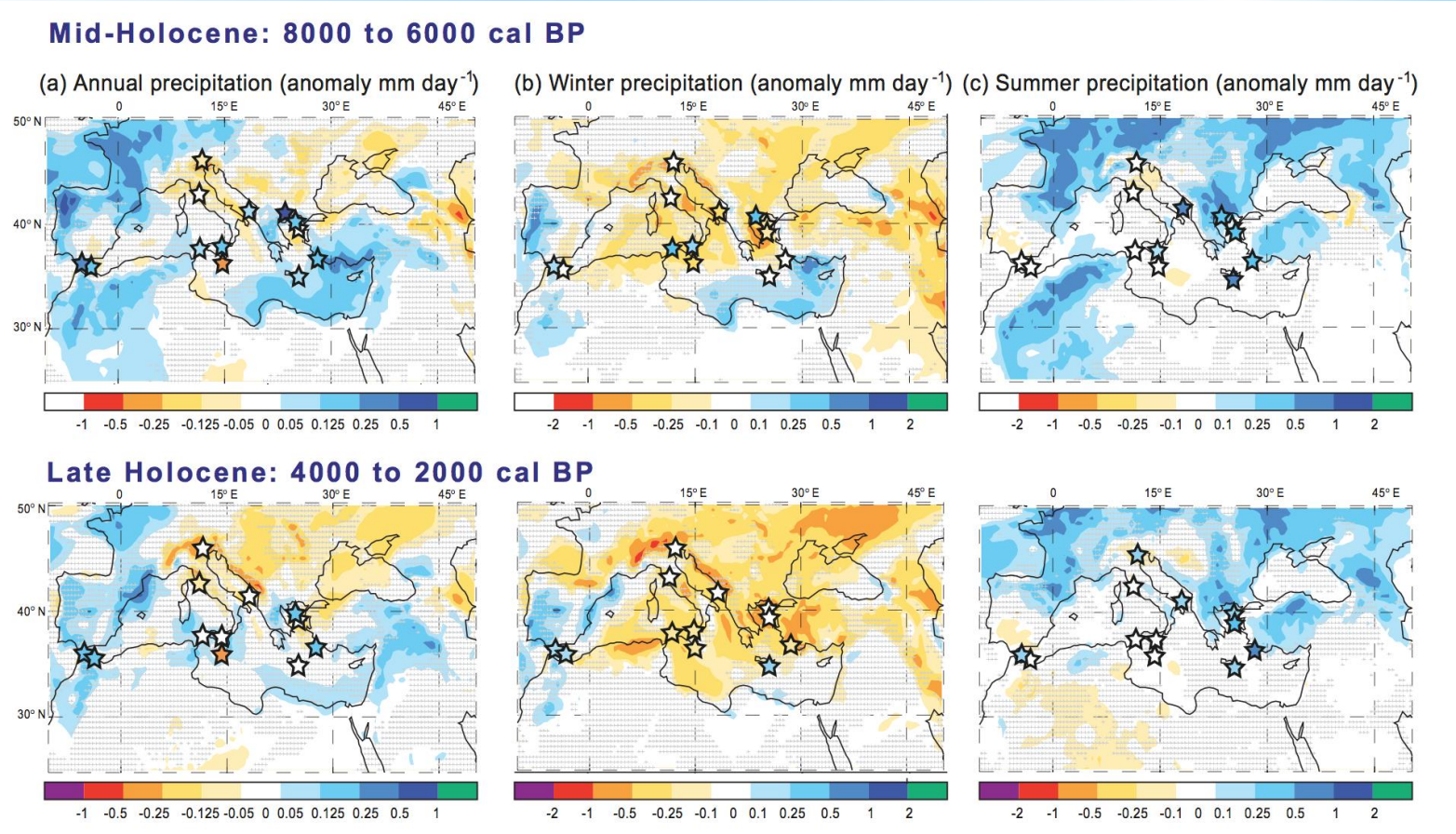




* LH (4-2 ka BP) vs MH (8-6 ka BP)
* LH: see-saw effect
* MH: a little more complicated than a NAO+ situation (patchy)
* In average, good agreement between data and models

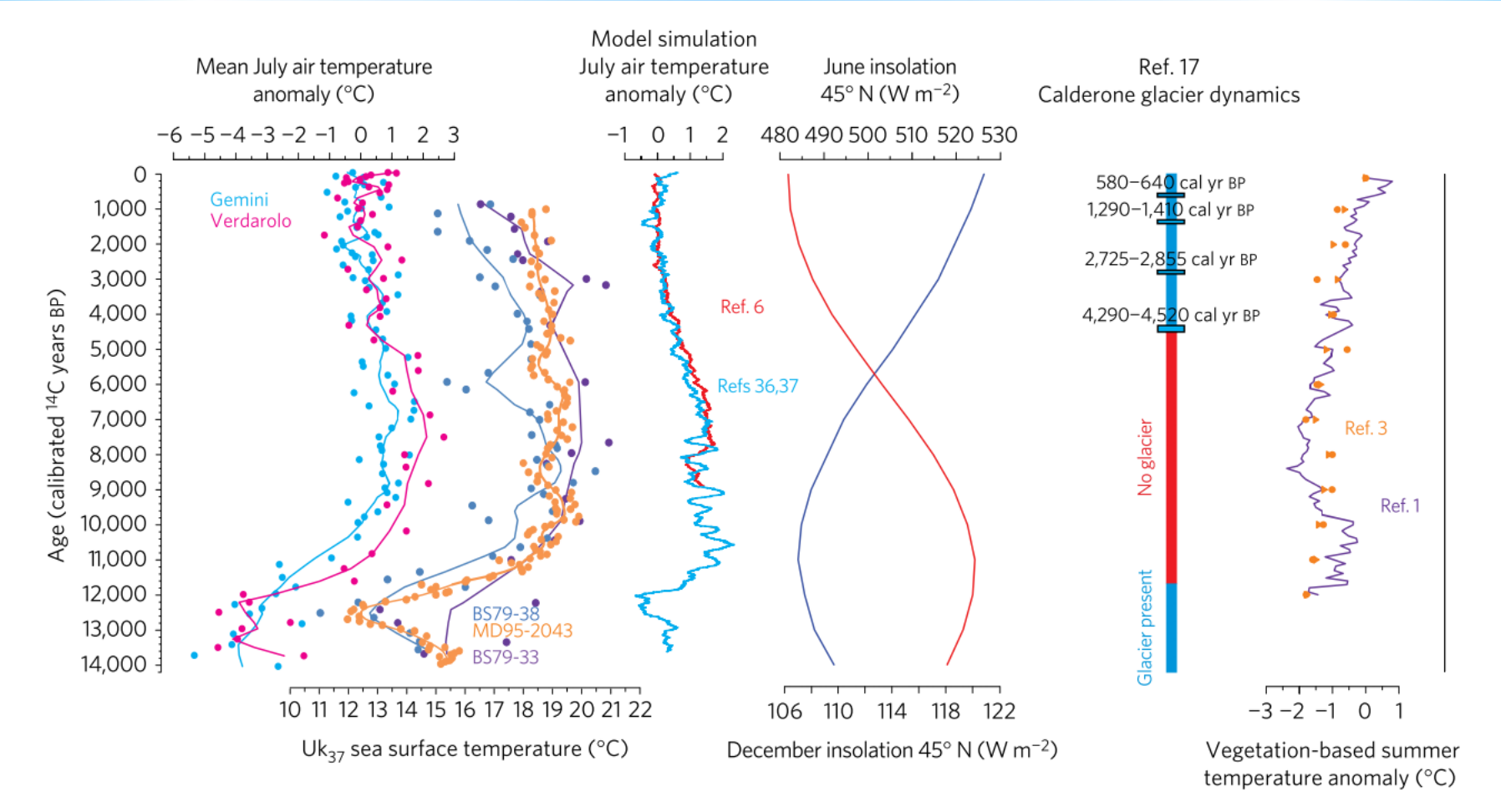
* Holocene precipitation: Data-model comparison using pollen data

Peyron et al, 2017



* North–south partition of precipitation regimes during the Holocene
* Seasonal dependent west–east precipitation dipole
* Strong westerly circulation in winter (positive Arctic Oscillation–North Atlantic Oscillation (AO–NAO)) and a weak westerly circulation in summer associated with anticyclonic blocking

* Pollen-based summer temperature biased by precipitation, chronomids say! (Samartin et al, 2017)



Renssen et al, 2009
Liu et al, 2009; 2014

Giraudi et al, 2011
Davis et al, 2003
Mauri et al, 2015

* Many possible reasons

* Proxies record different climate variable ?
  * Pollen records air temperature and chironomids water temperature
  * Vegetation is less dependent on a single month (July) than chronomids
* not enough records to conclude ?
  * chironomid cores are in Italy, where the pollen signal is less clear
* Effect of hidden variables?
  * Vegetation responds also to CO2 variations (much lower in the Holocene than in the present time)

This is one of the justification of the use of process models

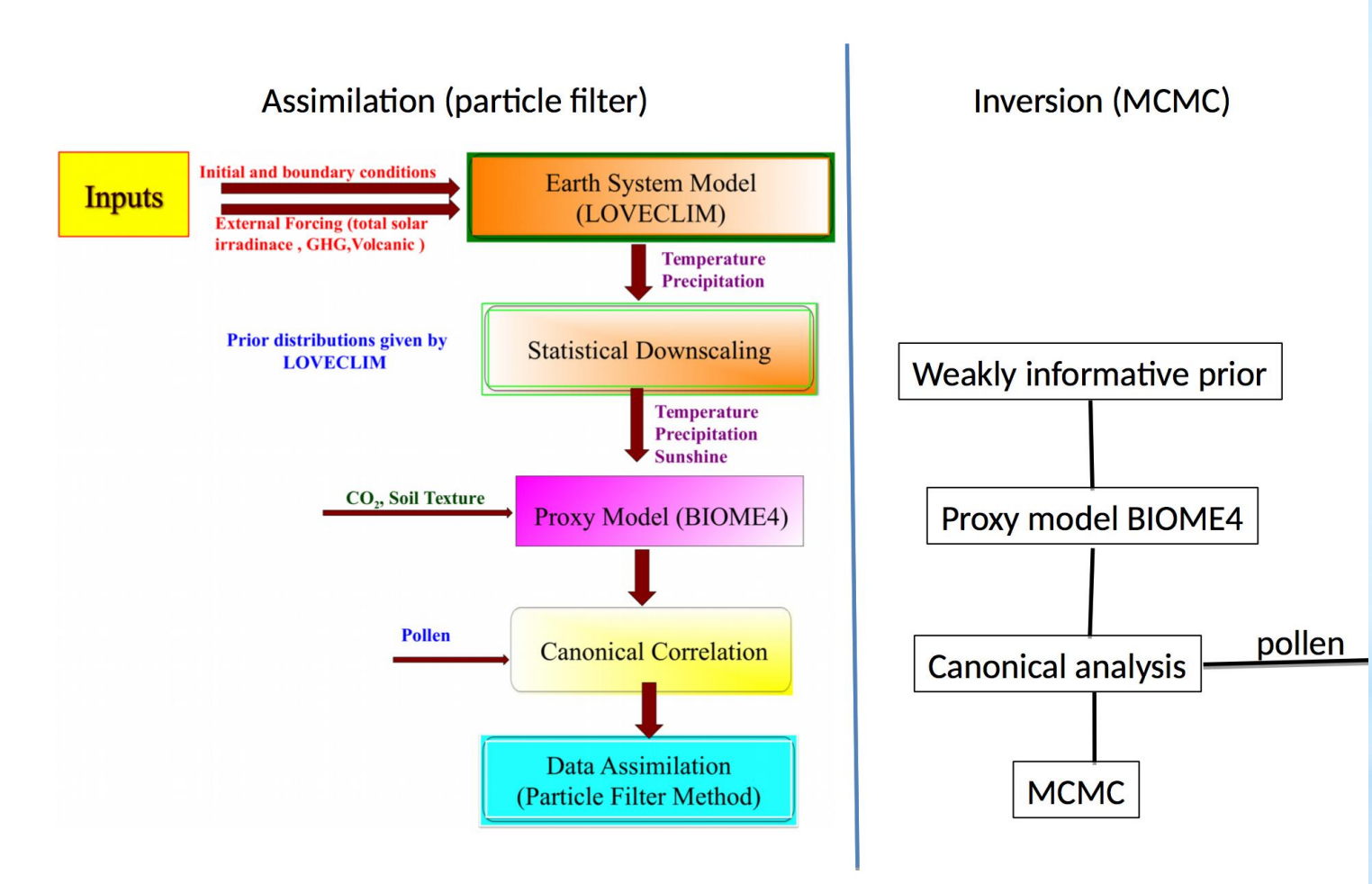
* Future challenges: how to reconcile proxies together and proxy with models?

* DATA-MODEL FUSION
* Inverse process modelling to better separate complex signals
* Data assimilation in climate model for an integrated data-model comparison

* Data-model fusion

* Using process models to better infer the response of the proxies
* Decoding proxy variables, including hidden effects
* Better integrating climate models and proxies
* Example with pollen data and vegetation model: Holocene climate reconstruction in the Mediterranean region
* Taking into account the « reality » of the data and the physical coherency of the models
* Two approaches: proxy model inversion and data assimilation

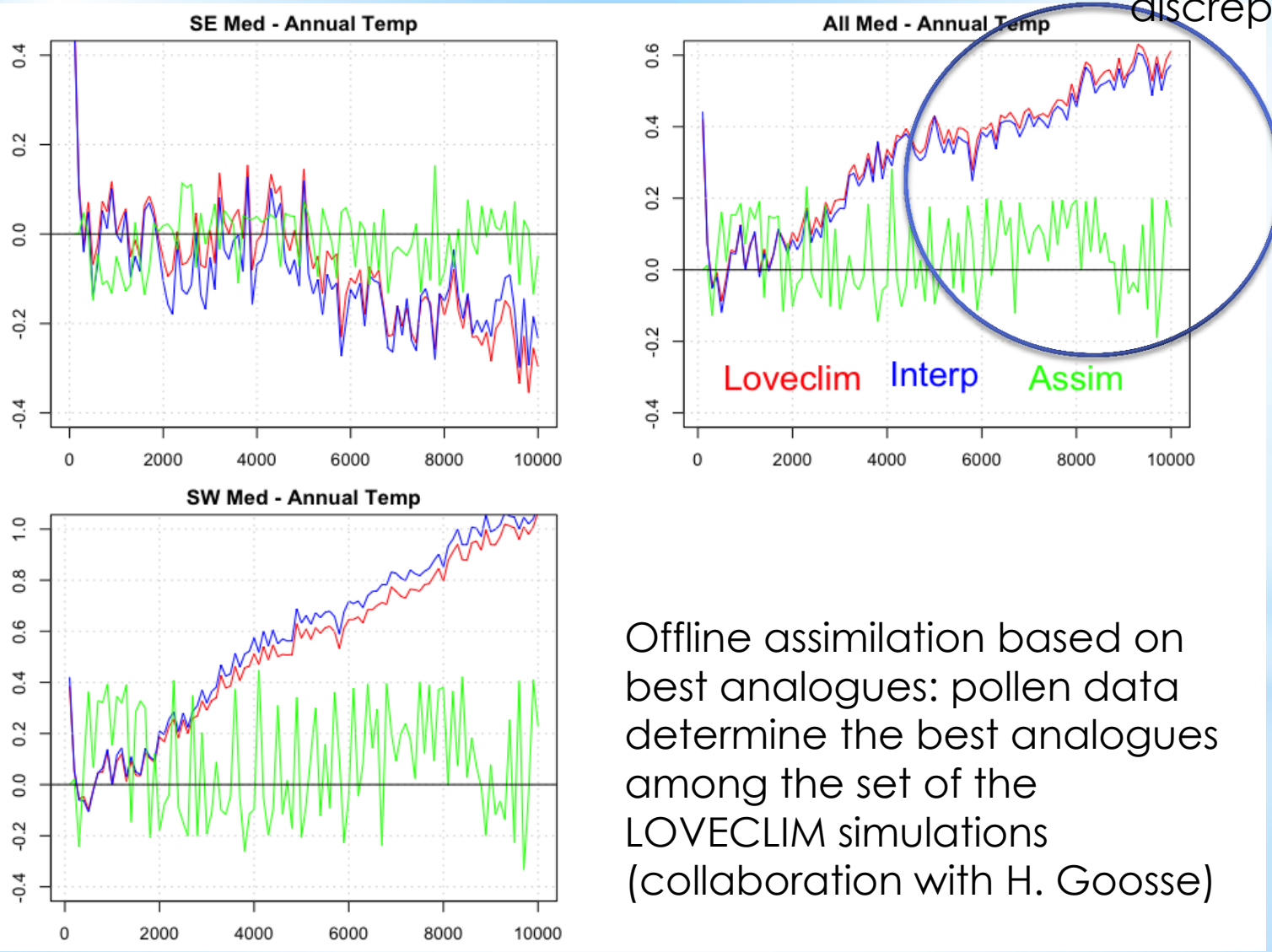
* Assimilation and inversion: two Bayesian approaches



- ✧ Bayesian concept: given priors, model and data, calculate posteriors
- ✧ With inversion, priors are given by educated guess (or are not informative)
- ✧ With assimilation, priors are given by climate simulations

* Holocene time-series of annual temperature

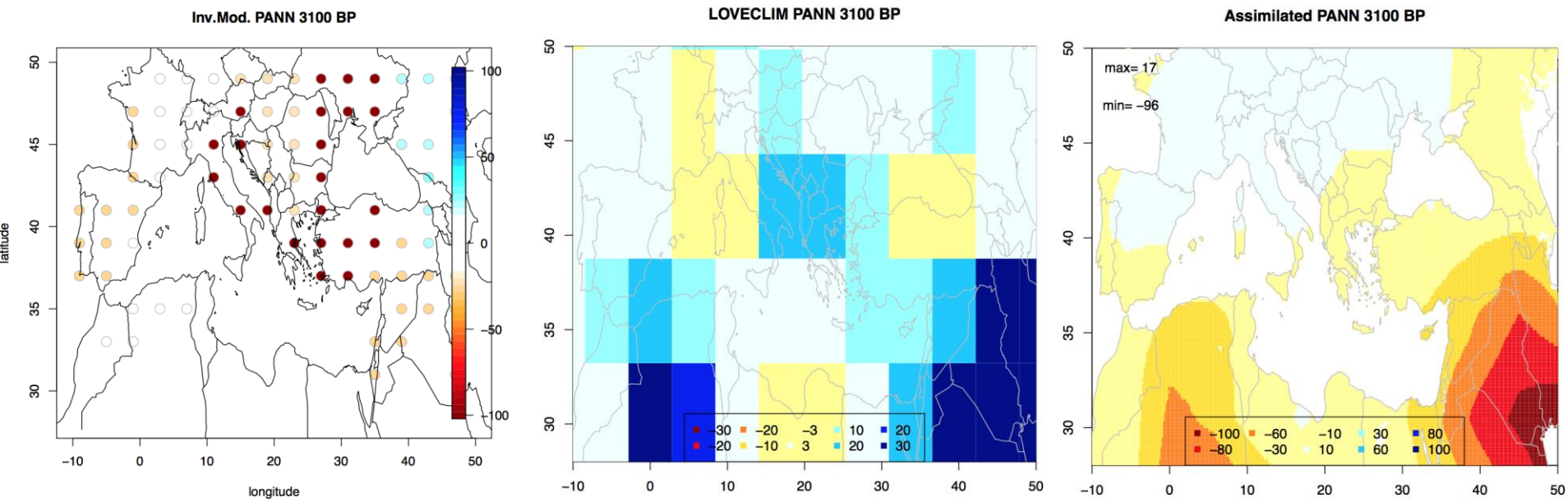
Strong data-model discrepancies



Offline assimilation based on best analogues: pollen data determine the best analogues among the set of the LOVECLIM simulations (collaboration with H. Goosse)

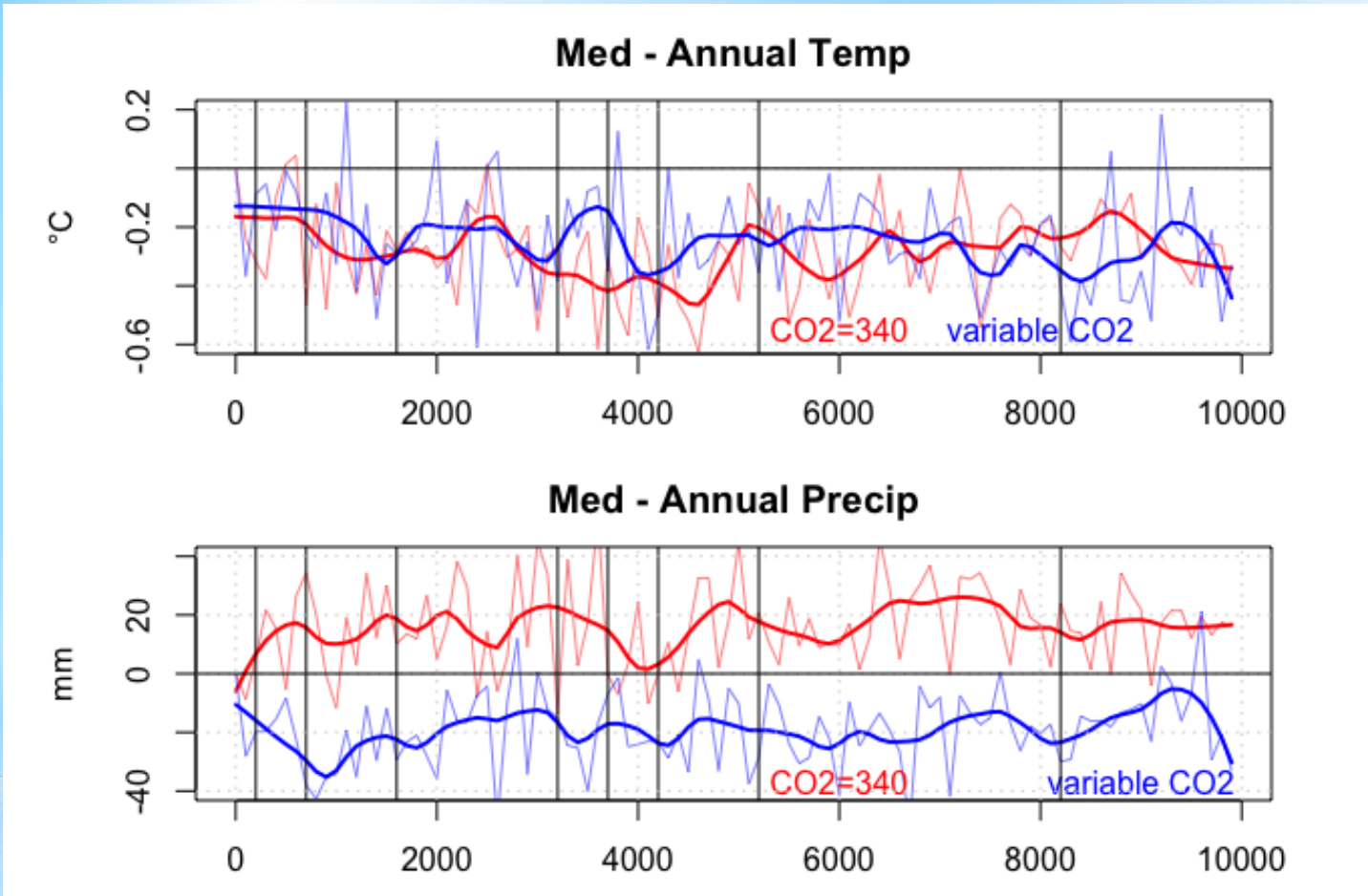
* Example: 3.2-3.1 ka BP (end of Bronze Age)

INVERSE MODELLING | LOVECLIM | ASSIMILATION



* Dry period, as reconstructed from pollen using the inverse modelling method
* Loveclim simulates high precipitation
* Data constrains Loveclim towards dry climate, especially in the southeast
* From an historical point of view, this period is known for collapse of important civilisations (Hittites, Palestinian cities, Aegian cities, Sea People)
* "*Drought may have hastened the fall of the Old World by sparking famine, invasions, and conflicts, leading to the political, economic, and cultural chaos termed 'Late Bronze Age collapse*" (Kaniewski et al, 2015)

Inverse modelling: comparison of reconstructions with present CO2 and with true CO2



Annual temperature

Annual precipitation

- The use of the present high level CO2 in the reconstruction biases the values towards higher precipitation (as it is done by the standard statistical methods)
- Mediterranean region remains cooler during the Holocene; large differences for the precipitation
- Higher fertilization effect from higher CO2 is attributed to higher precipitation)

Conclusion

- Deconvoluating the climate signal recorded by the proxies is a complex problem
- Proxies appear sometimes contradictory
- Proxy models are a solution to solve this apparent contradiction
- Uncertainties associated to data and to models need to be better estimated
- Model inversion is an interesting way to work with data independently on the climate models
- Data assimilation is an interesting way to integrate proxies and climate models (DAPS project PAGES)
- Progress is still necessary: downscaling, pollen-vegetation relationship
- Possibility to use the PMIP simulations (paleoclimate re-analyses)