The climate over the past 2000 years

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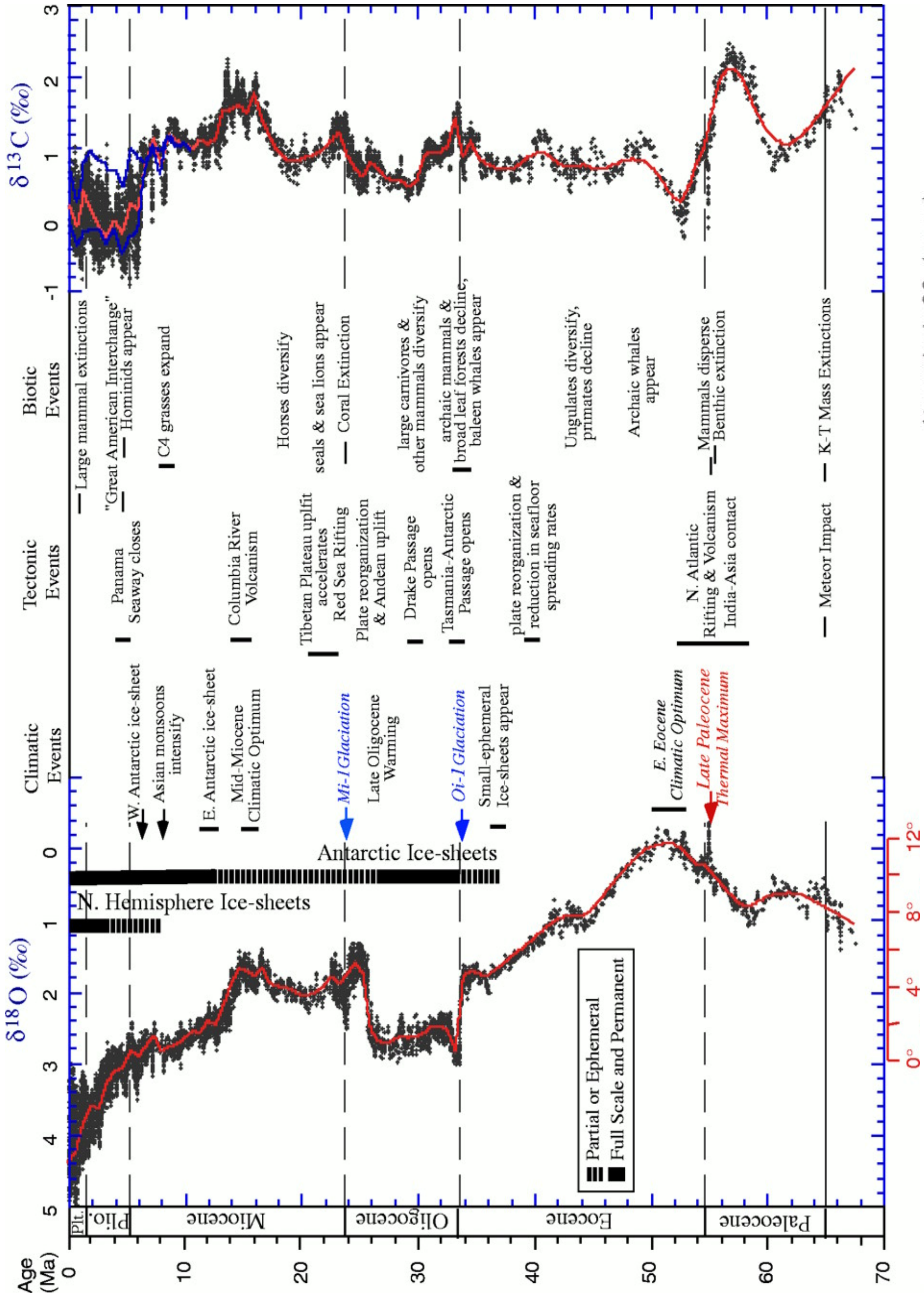
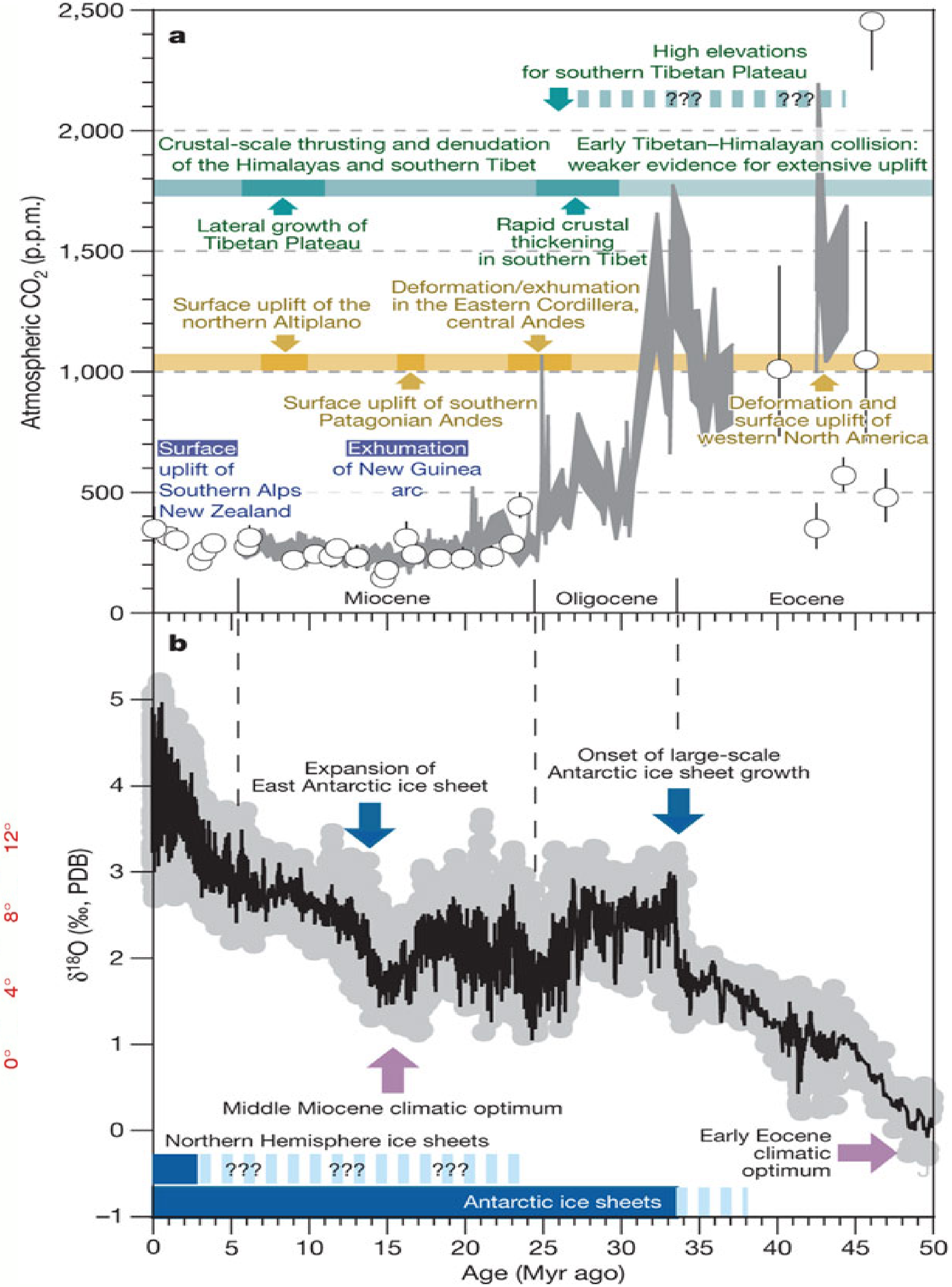
Askö, Sweden, 23rd-30th 2015

Helmholtz-Zentrum Geesthacht
Centre for Materials and Coastal Research

High-latitude near-surface temperature in the last 70 mill. years

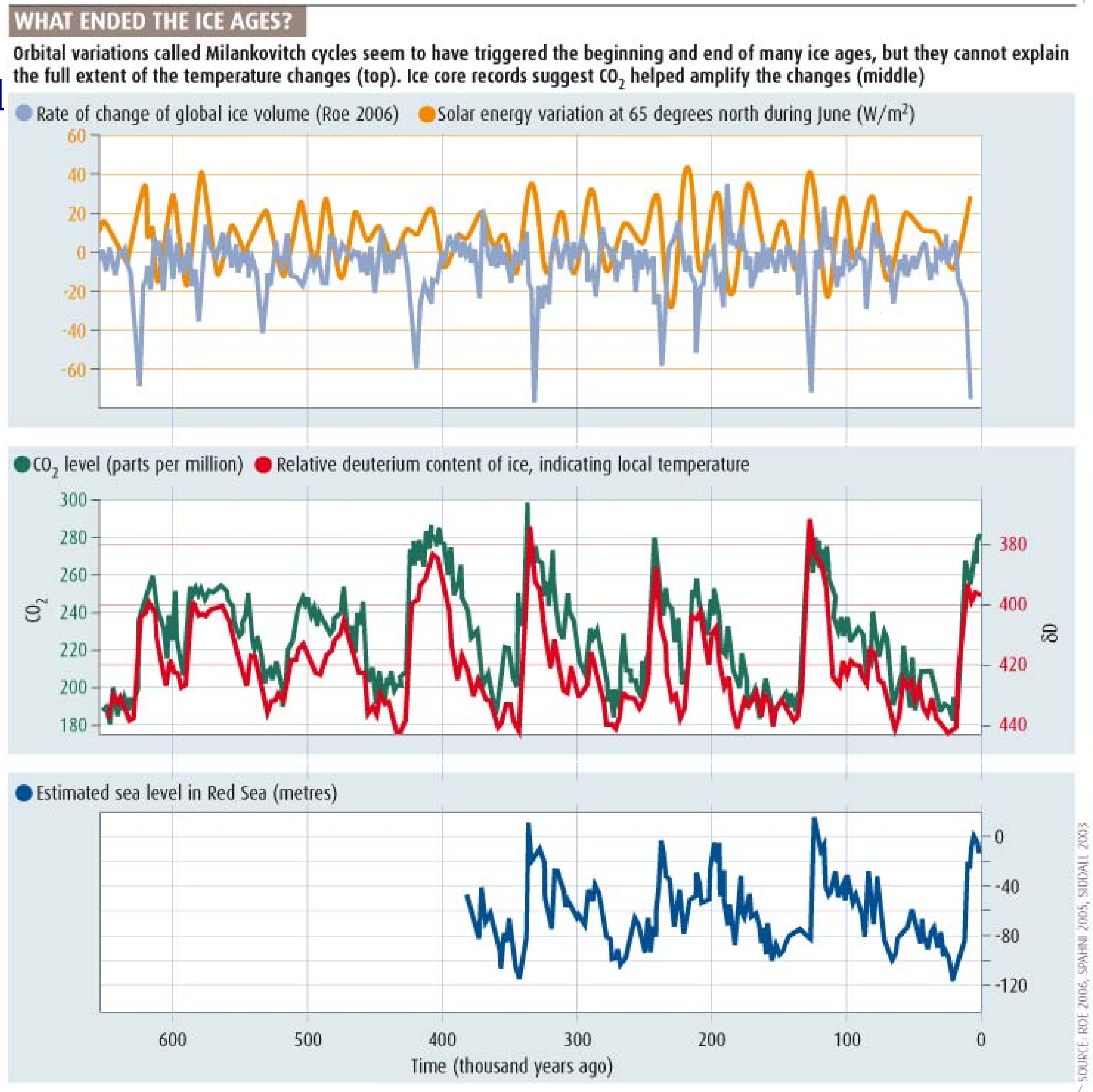




J. Zachos et al., Science 292, 686 -693 (2001)

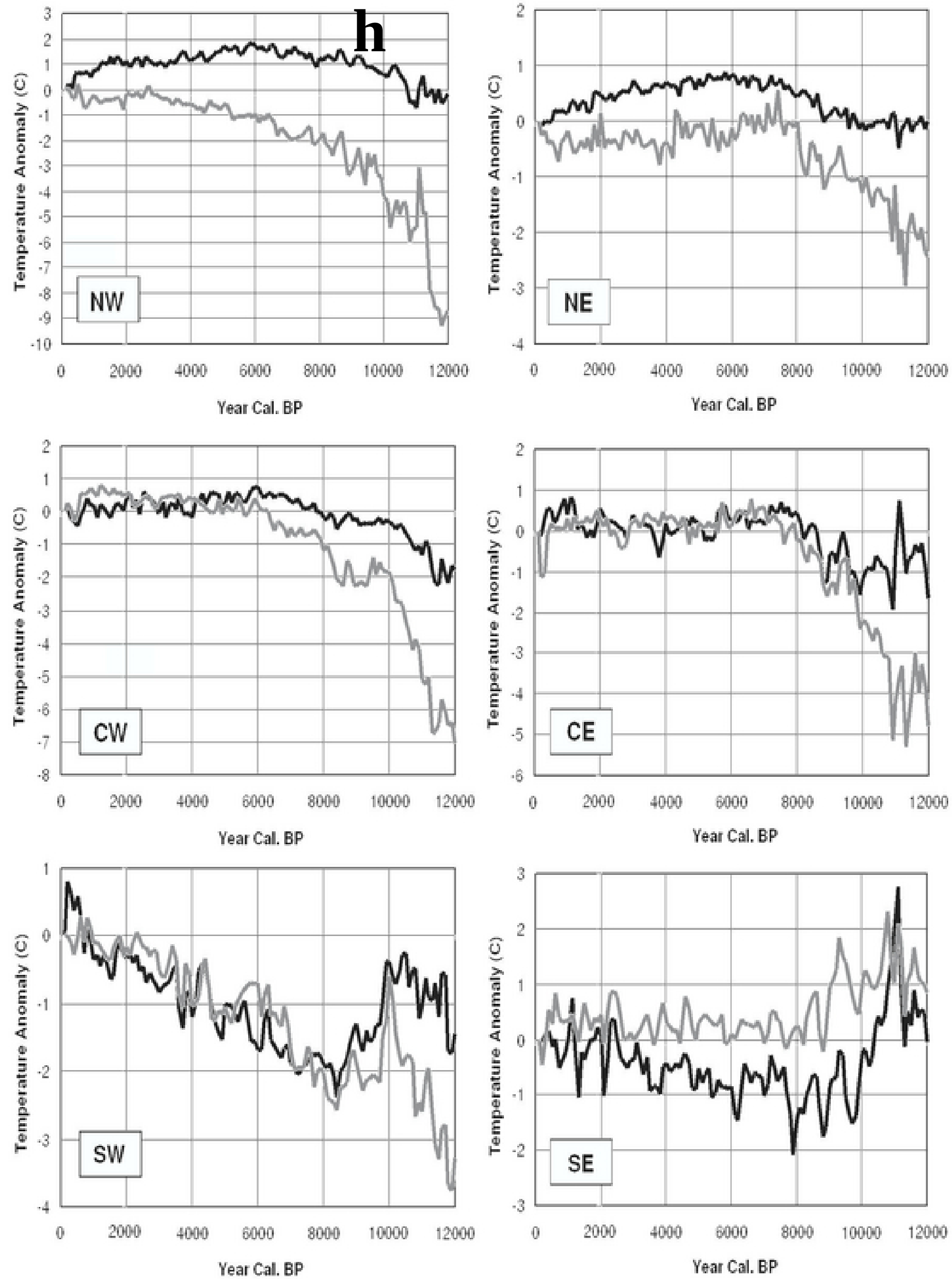
M Pagani *et al. Nature* **460**, 85-88 (2009) doi:10.1038/nature08133

Pleistocene Climate variations recorded in Antarctic Ice



Reconstructed European Holocene temperatures from pollen assemblages

North



West

East

South

Northern and Central Europe warmer in the Mid-Holocene Optimum

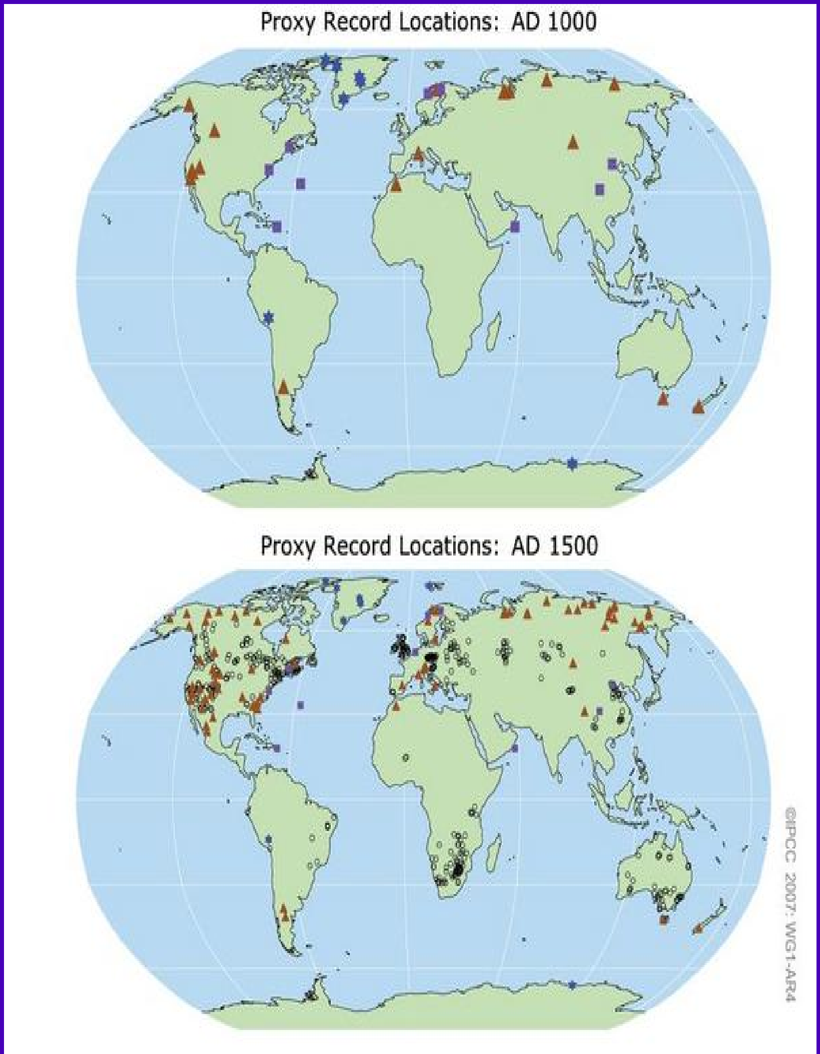
Winter

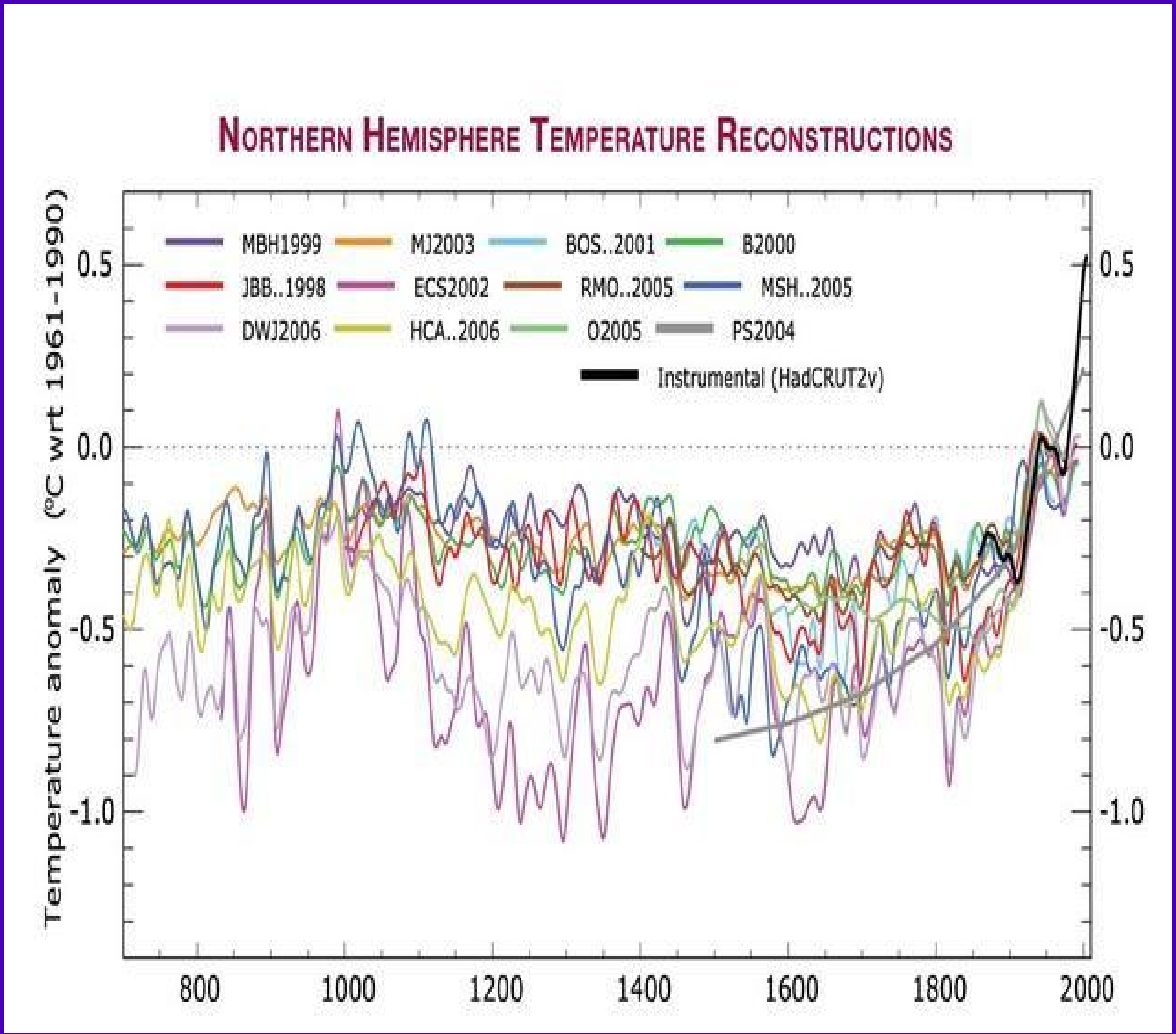
Summer

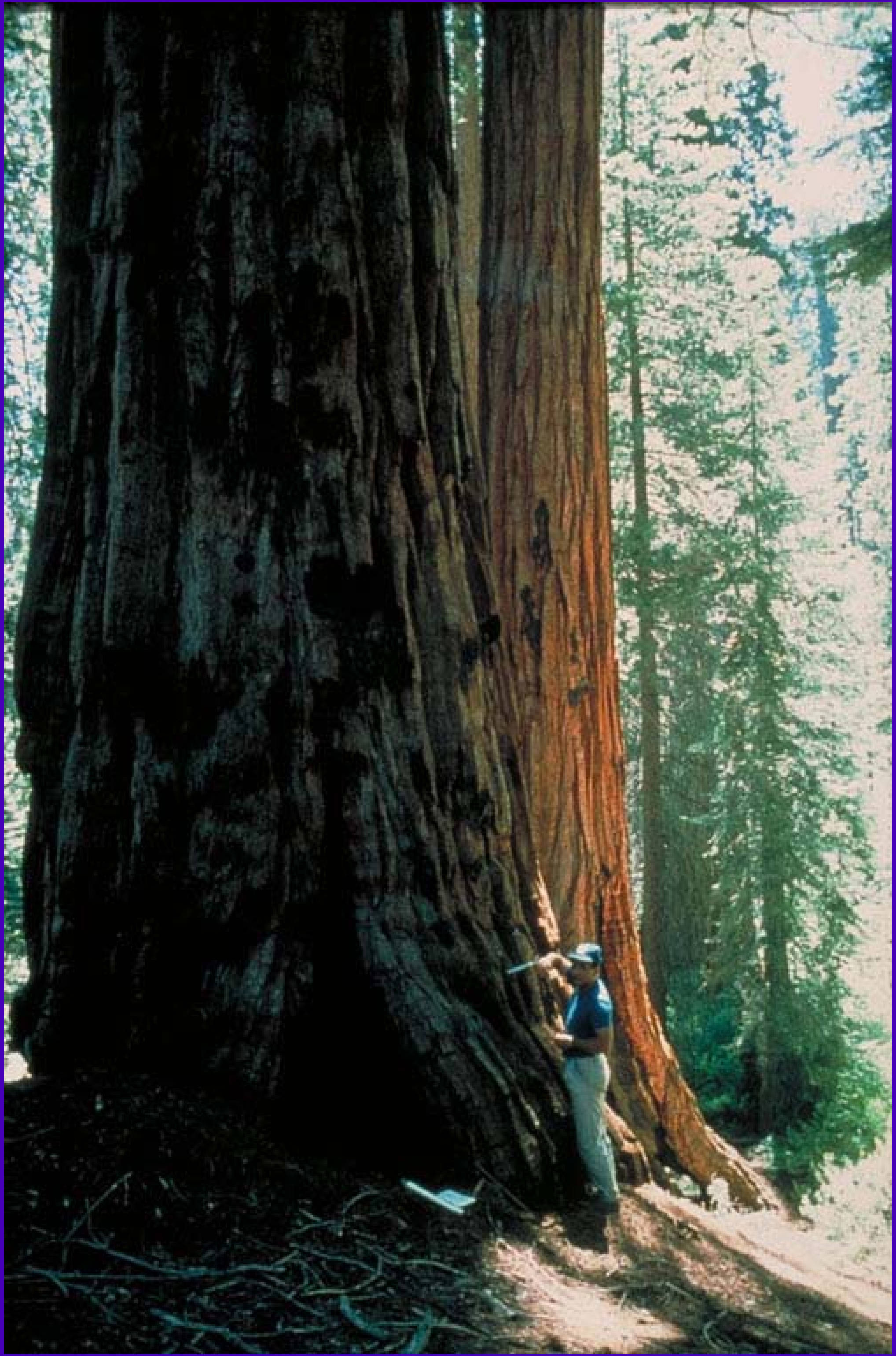
Davis et al. Quat. Sci. Rev 2003

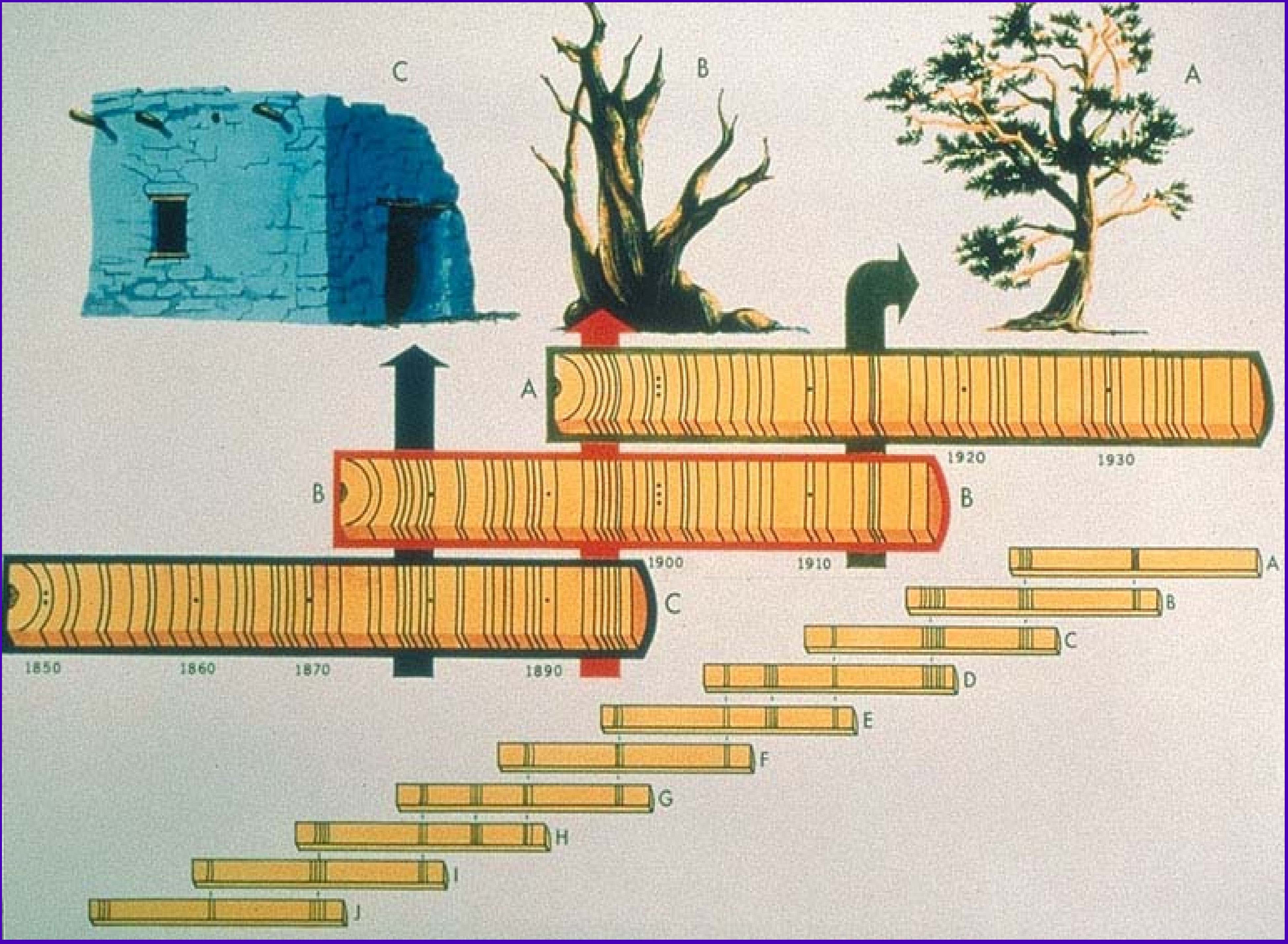
Reconstructed Northern Hemisphere temperatures in the past two millennia

Medieval Warm Period ->Little Ice Age ->Recent Warming









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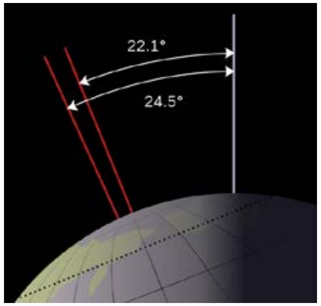
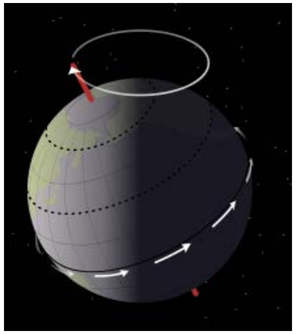
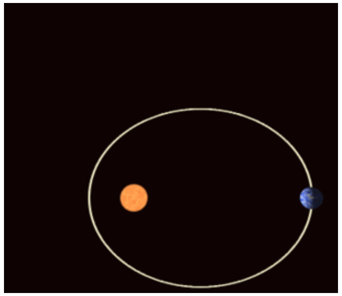
Important climate forcings during the Holocene (last millennia)

Orbital parameters

High certainty

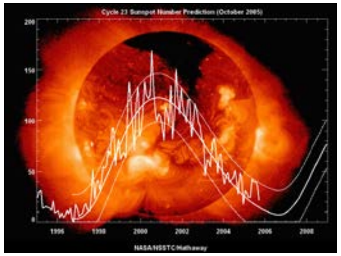






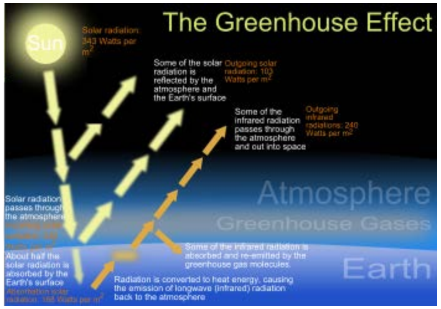
Solar activity: Total Solar Irradiance or UV variability

Low -to-Medium certainty



Anthropogenic Greenhouse gases

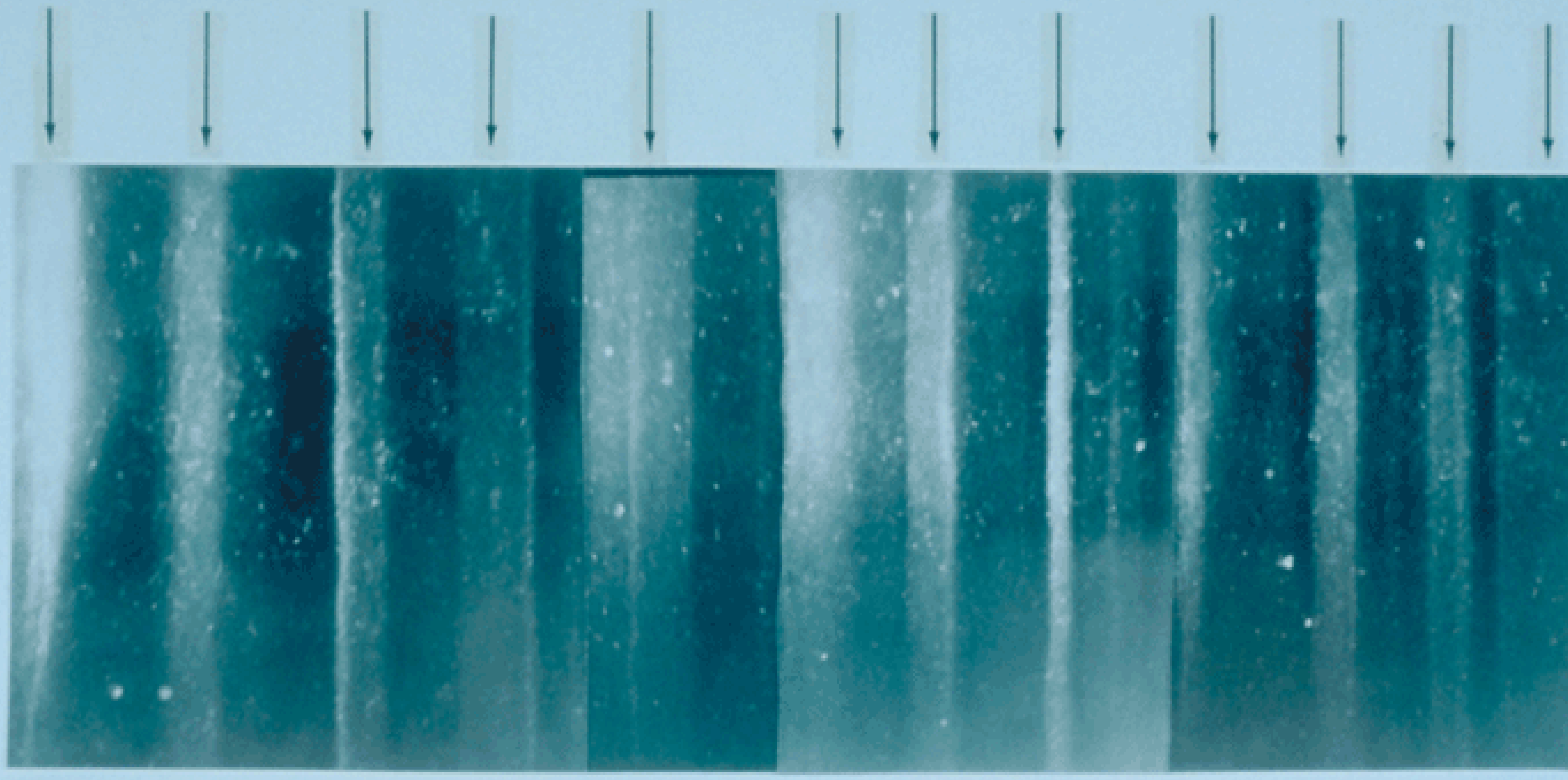
high certainty



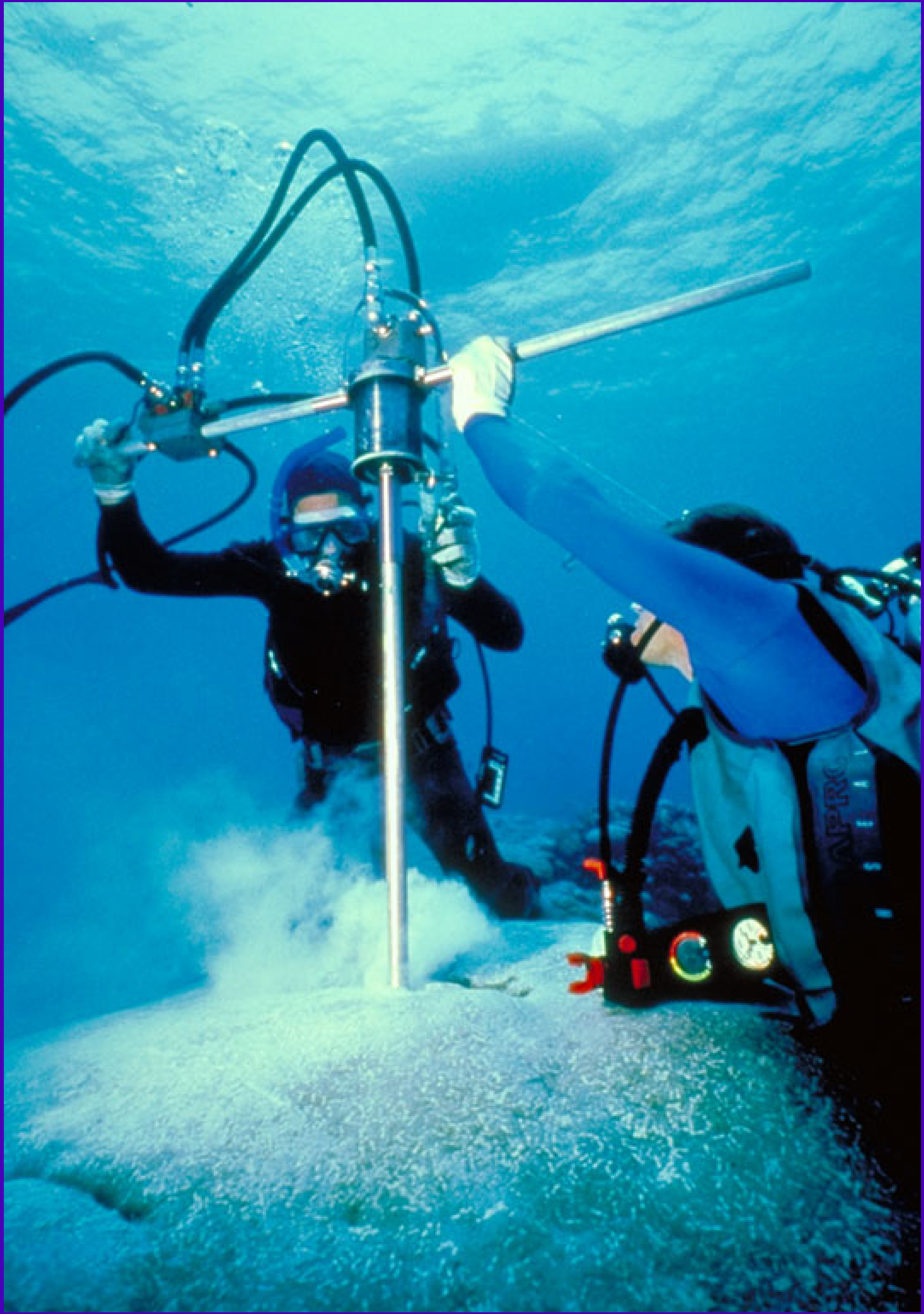
Volcanic eruptions

Low certainty

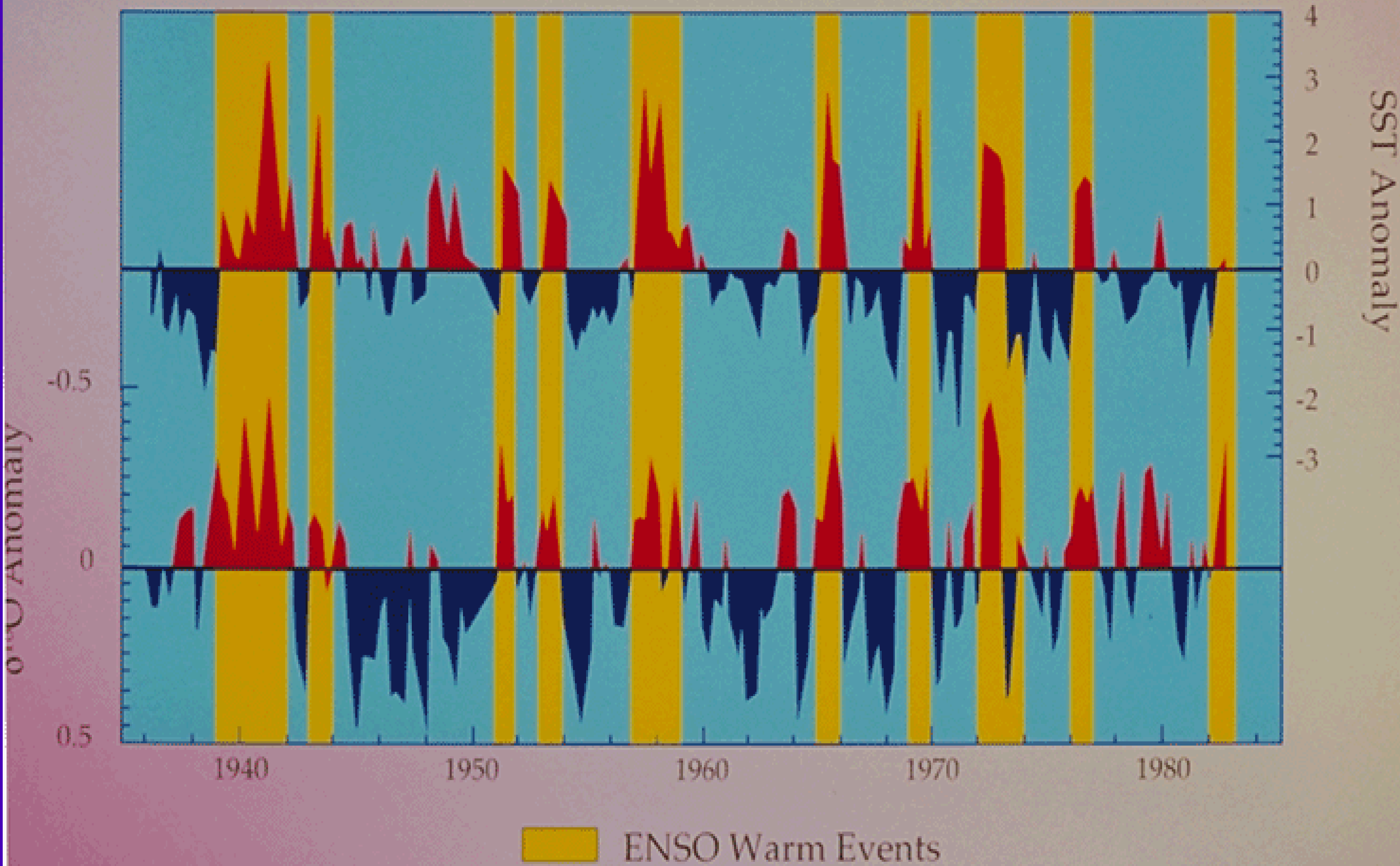
Proxies for climate reconstructions



19 cm long section of GISP 2 ice core from 1855 m showing annual layer structure illuminated from below by a fiber optic source. Section contains 11 annual layers with summer layers (arrowed) sandwiched between darker winter layers.

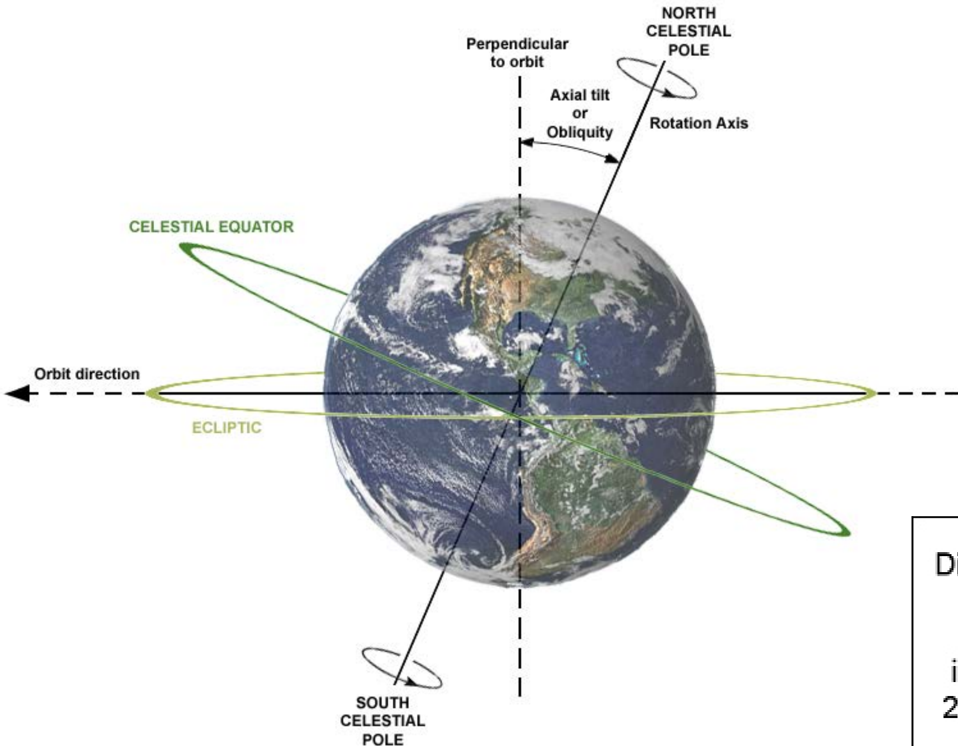


Coral $\delta^{18}O$ at Punta Pitt, Galápagos Provides a Record of Sea Surface Temperatures in an El Niño Sensitive Area



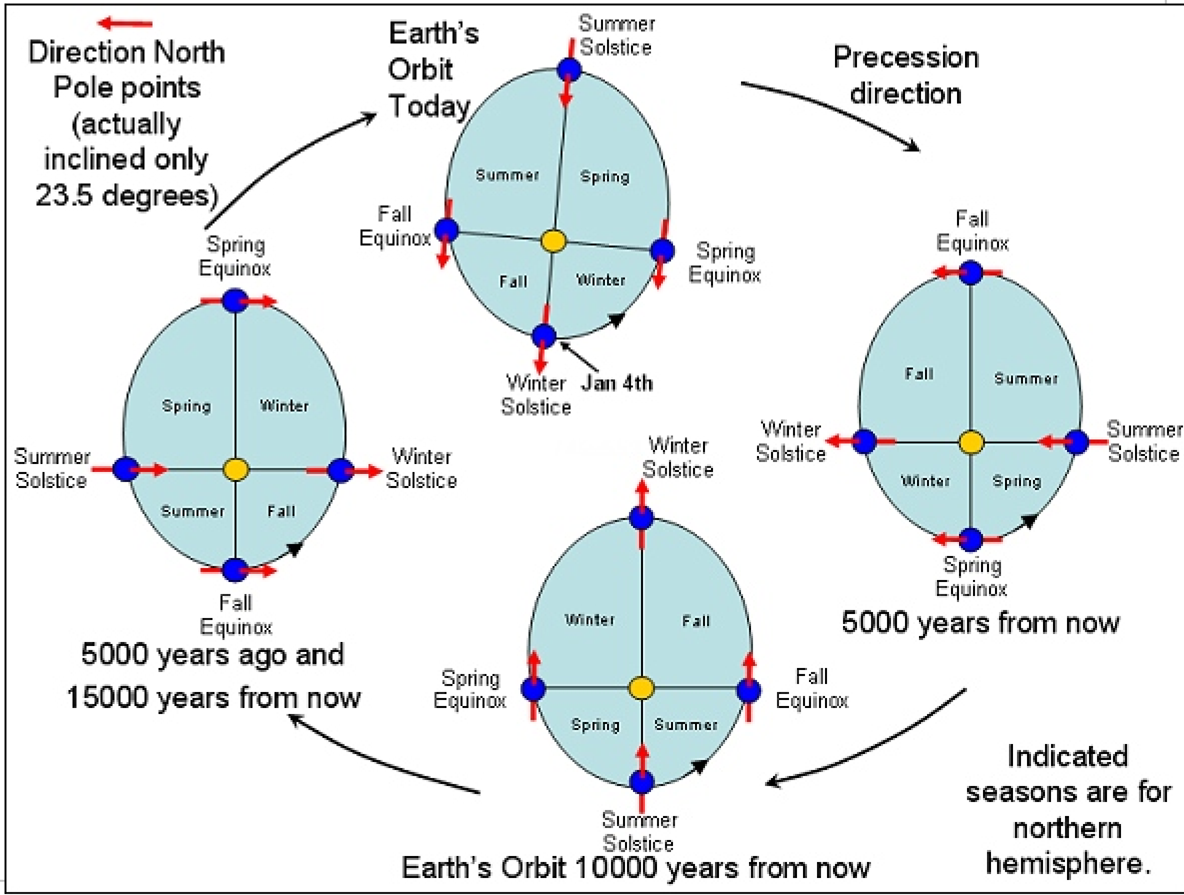
Data from Shen *et al.* (1992)

Long-term orbital forcing:

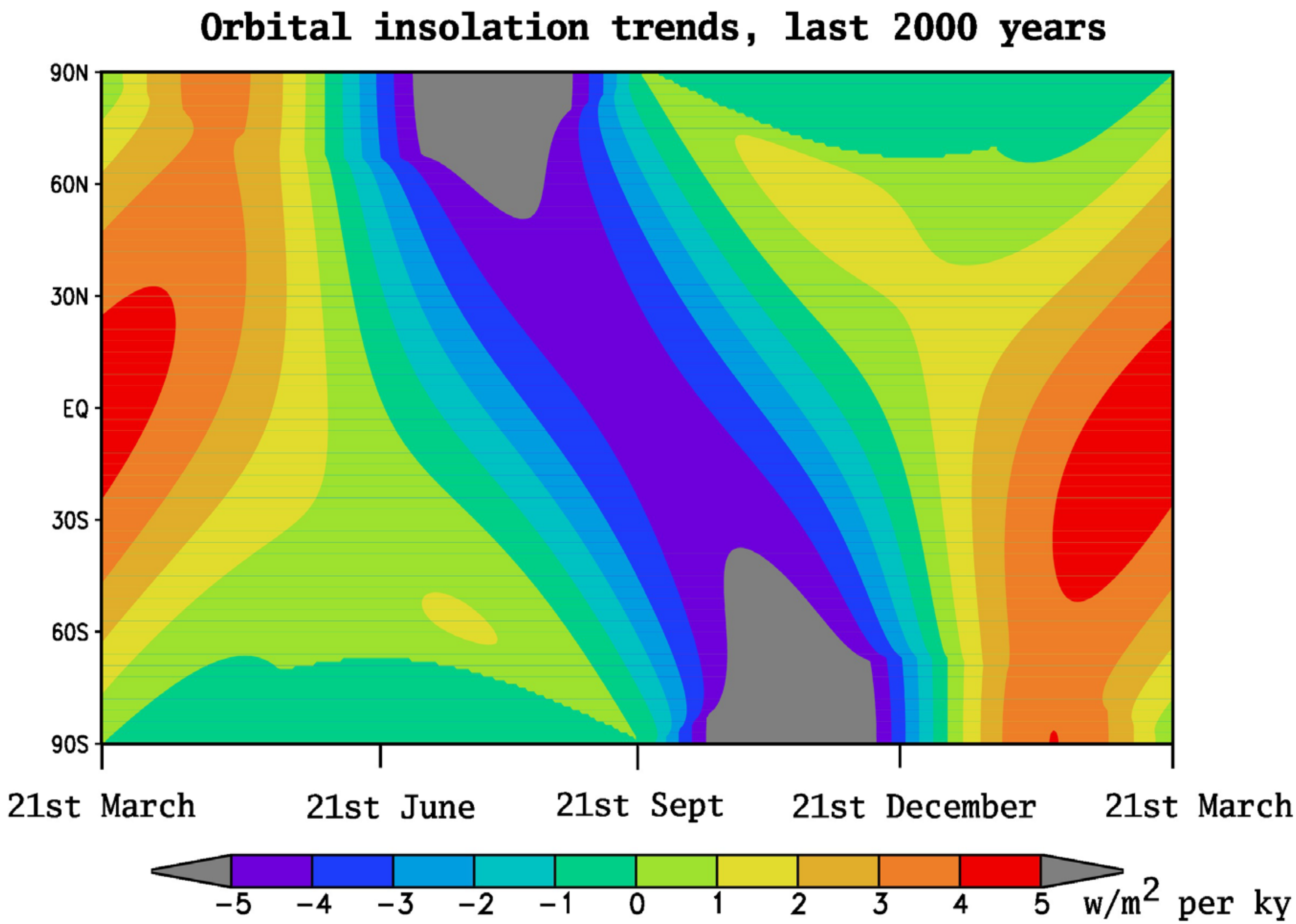


Obliquity

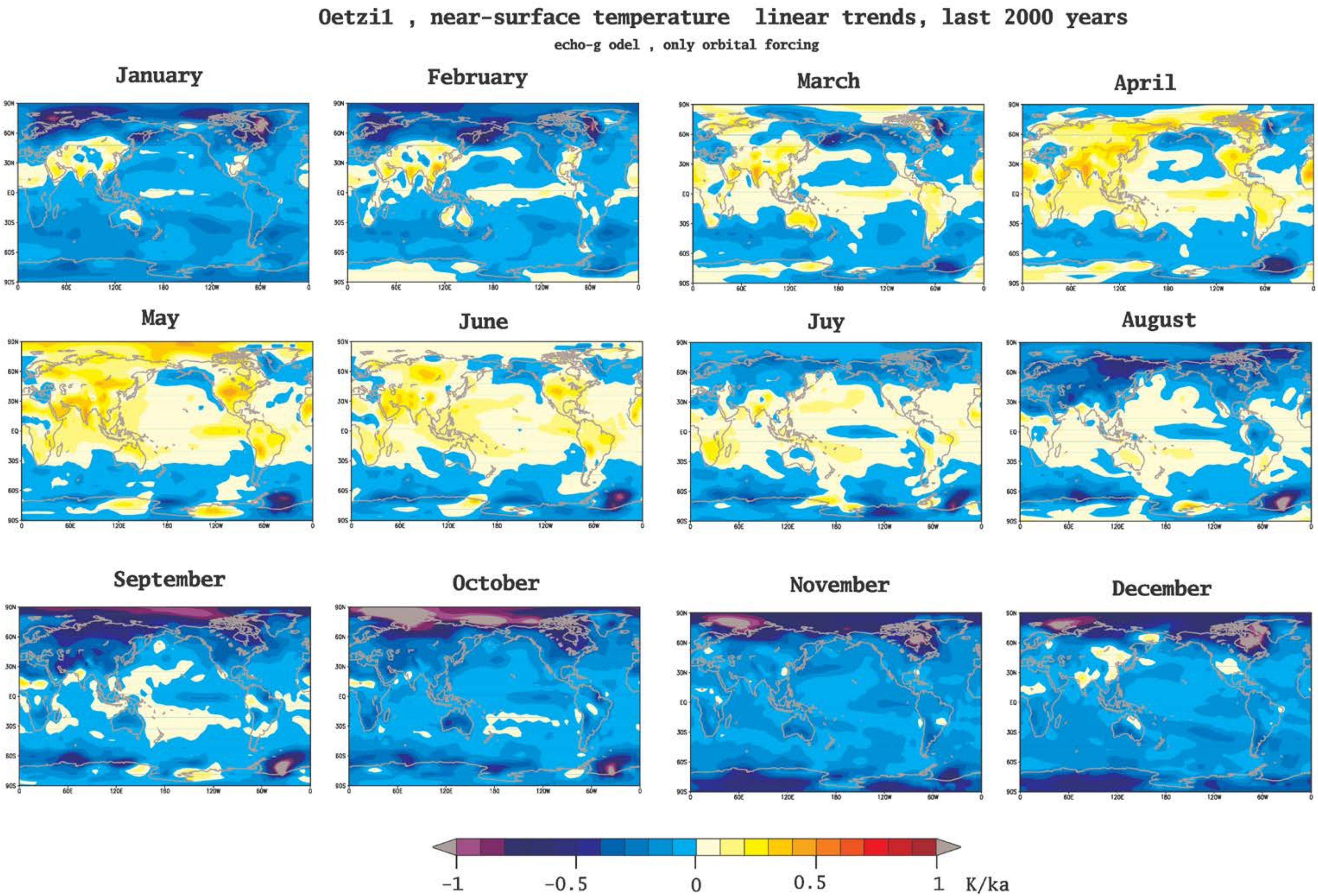
Precession



Recent trends in insolation due to orbital changes



Model response to purely orbital forcing (model ECHO-G)

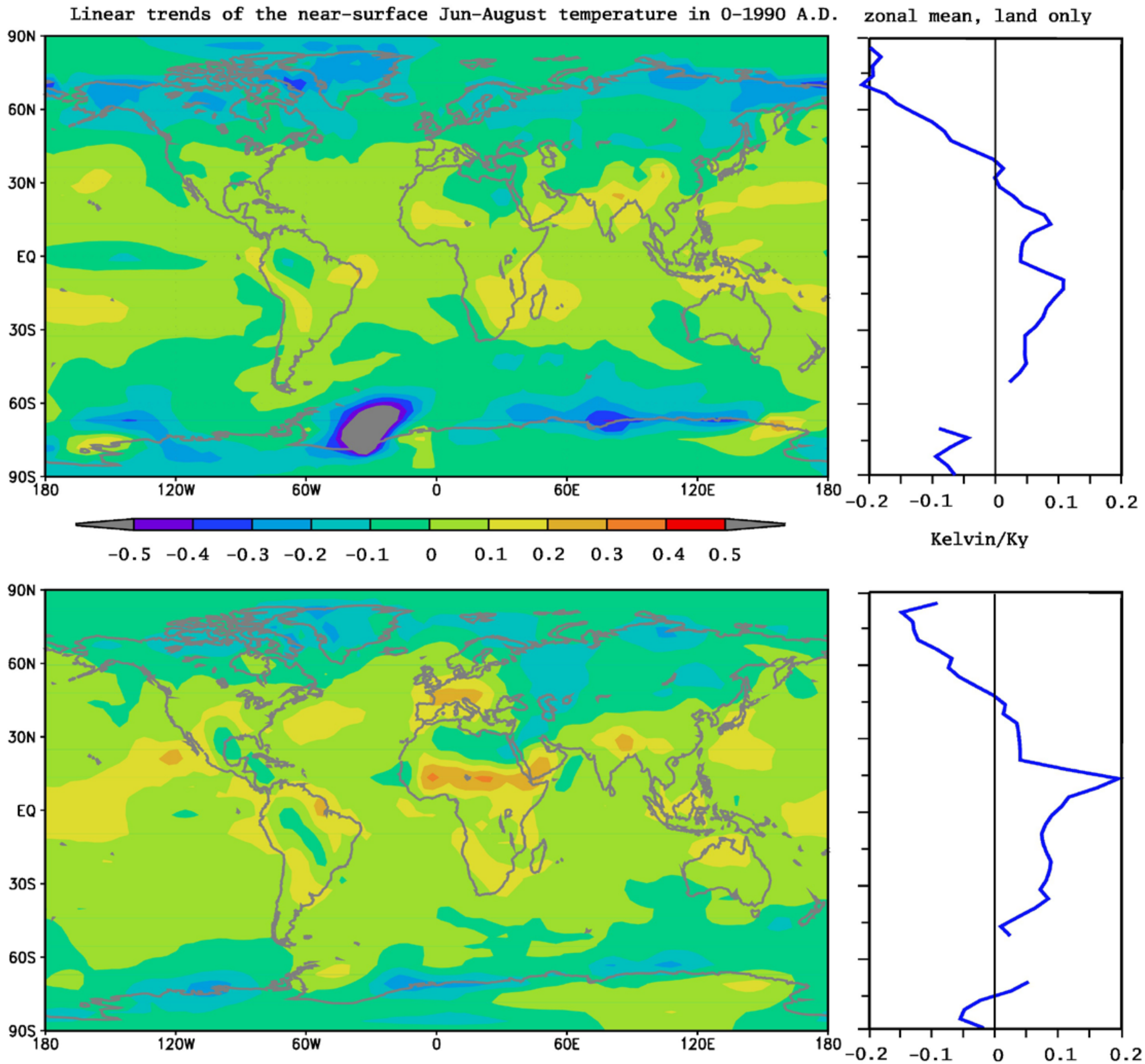


June-August temperature trends caused by orbital forcing last 2000 years

ECHO-G

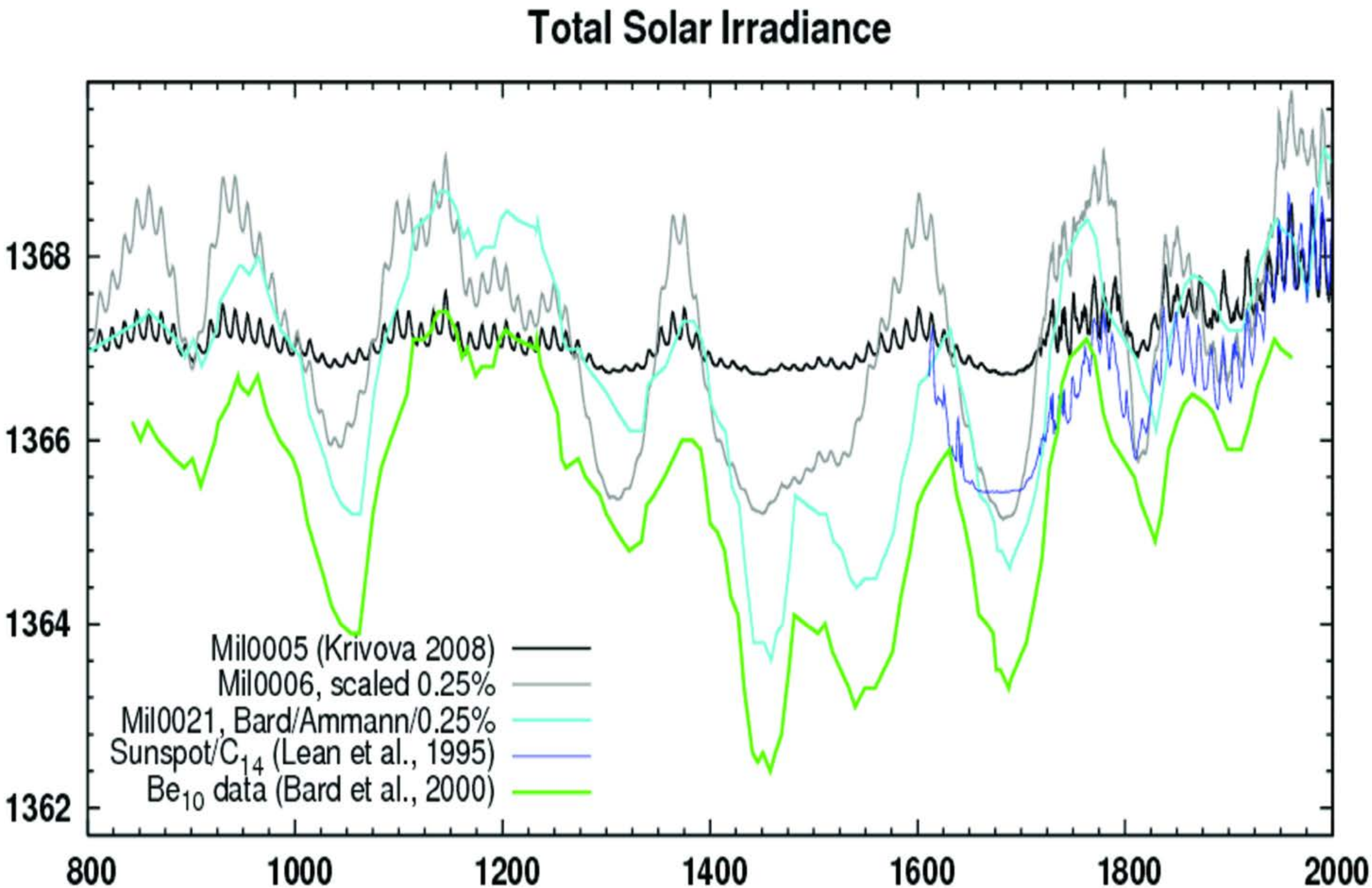
ECHAM4-HOPE

ECHAM5-MPIOM



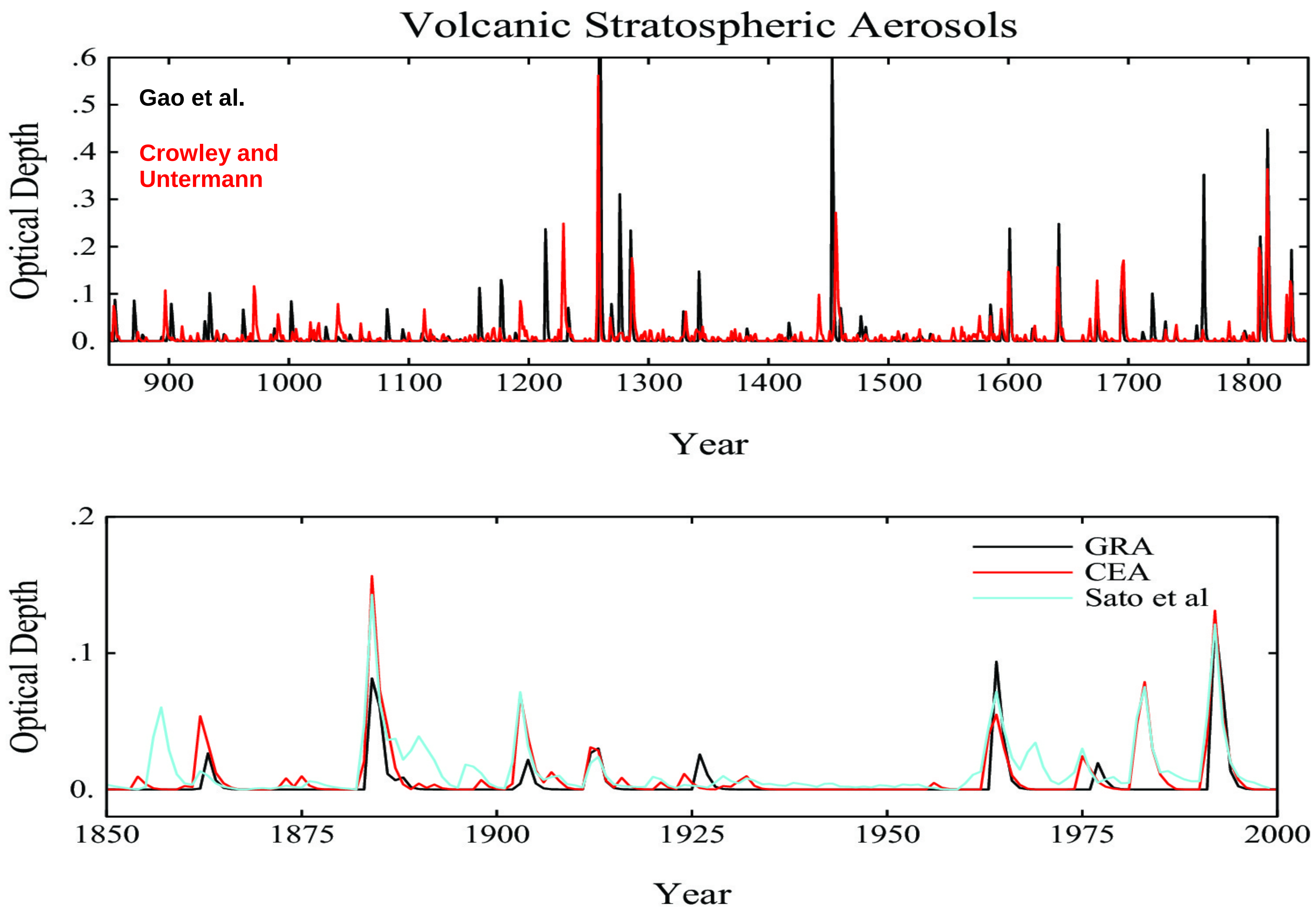
Esper et al., Nature Climate Change, 2012

Solar forcing: CMIP basically follows the Krivova et al. reconstructions



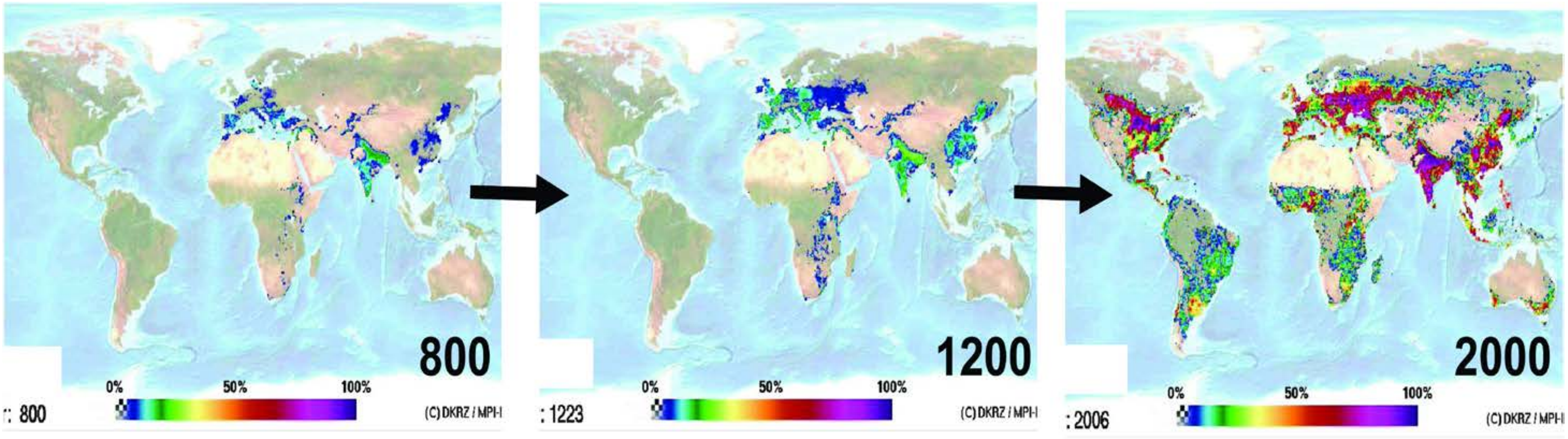
Two estimations of volcanic forcing

Likely, the most important forcing over the past 2000 years



Schmidt et al. 2011

An additional anthropogenic forcing, important at regional scales

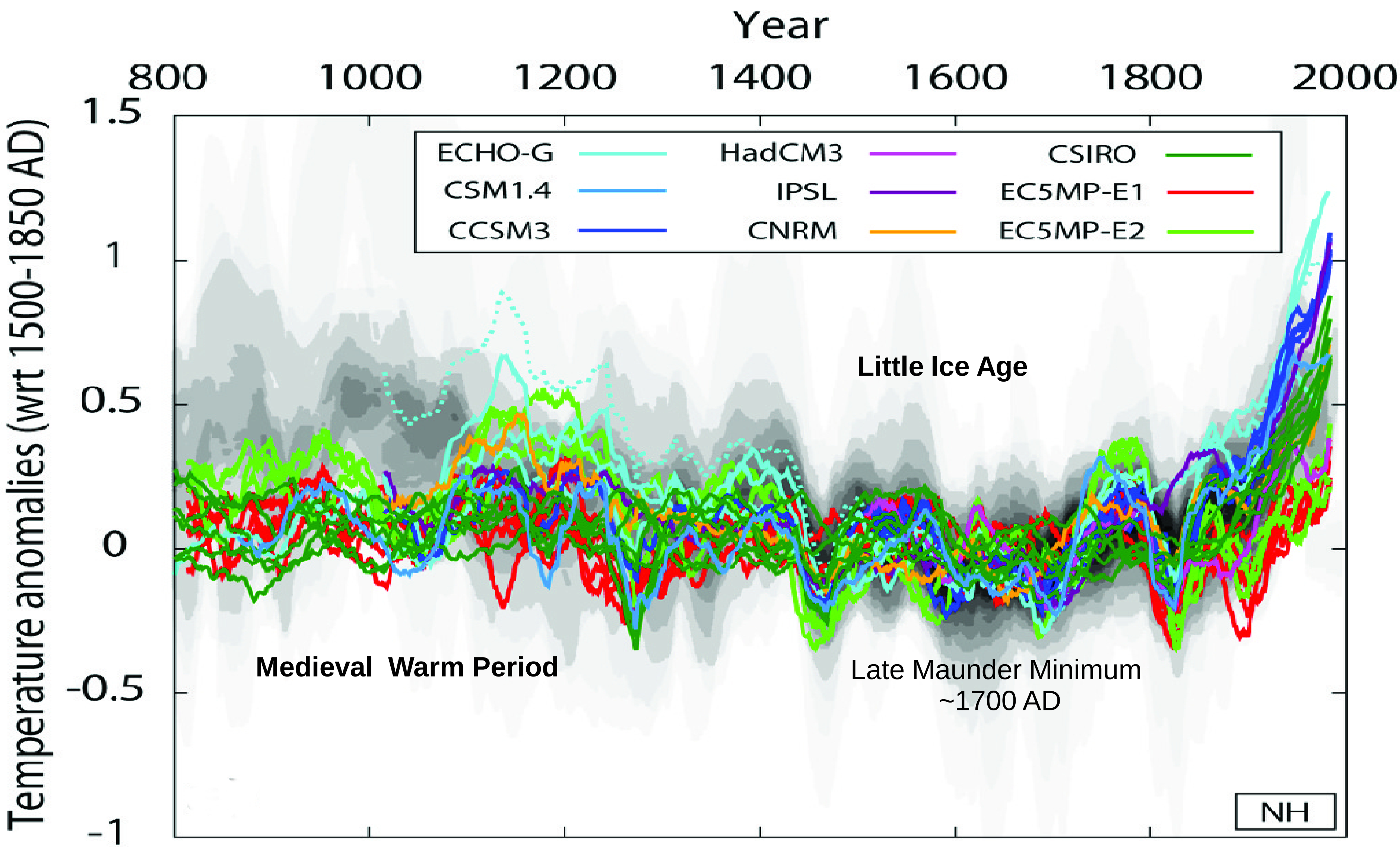


cropland distribution

Grid-cell-scale proportions of different land-use (13 classes) that modulate surface roughness, albedo, evapotranspiraion

Courtesy of Julia Pongratz, MPI Hamburg

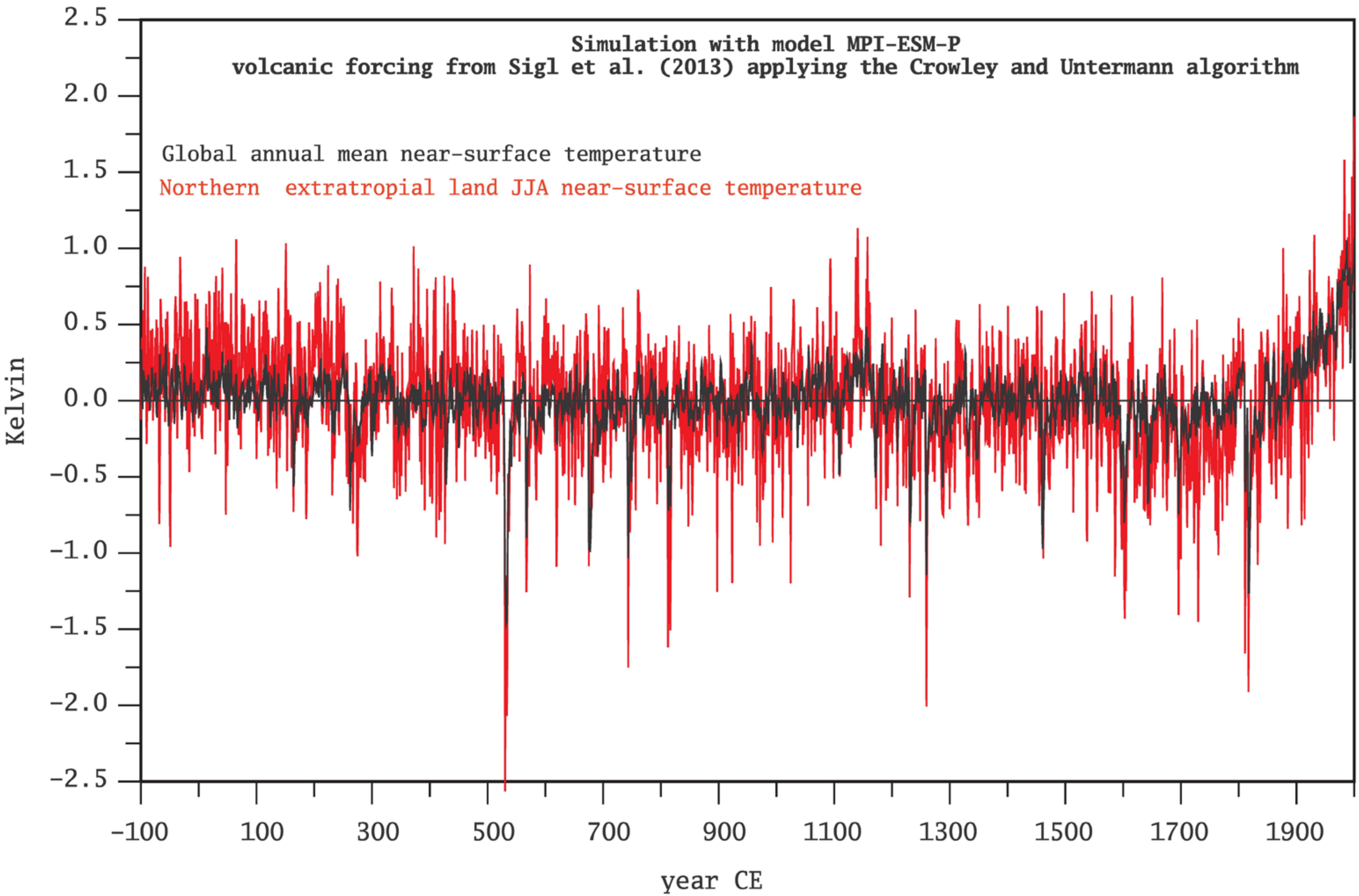
Northern Hemisphere temperature mean: simulations and reconstructions



Gray shading: envelope of reconstructions (with uncertainties)

Fernandez-Donado et al., Climate of the Past 2013

Simulated climate over the past 2000 years



Regional temperature reconstructions over the past 2000 years

PAGES 2k (Past Global Changes Program))

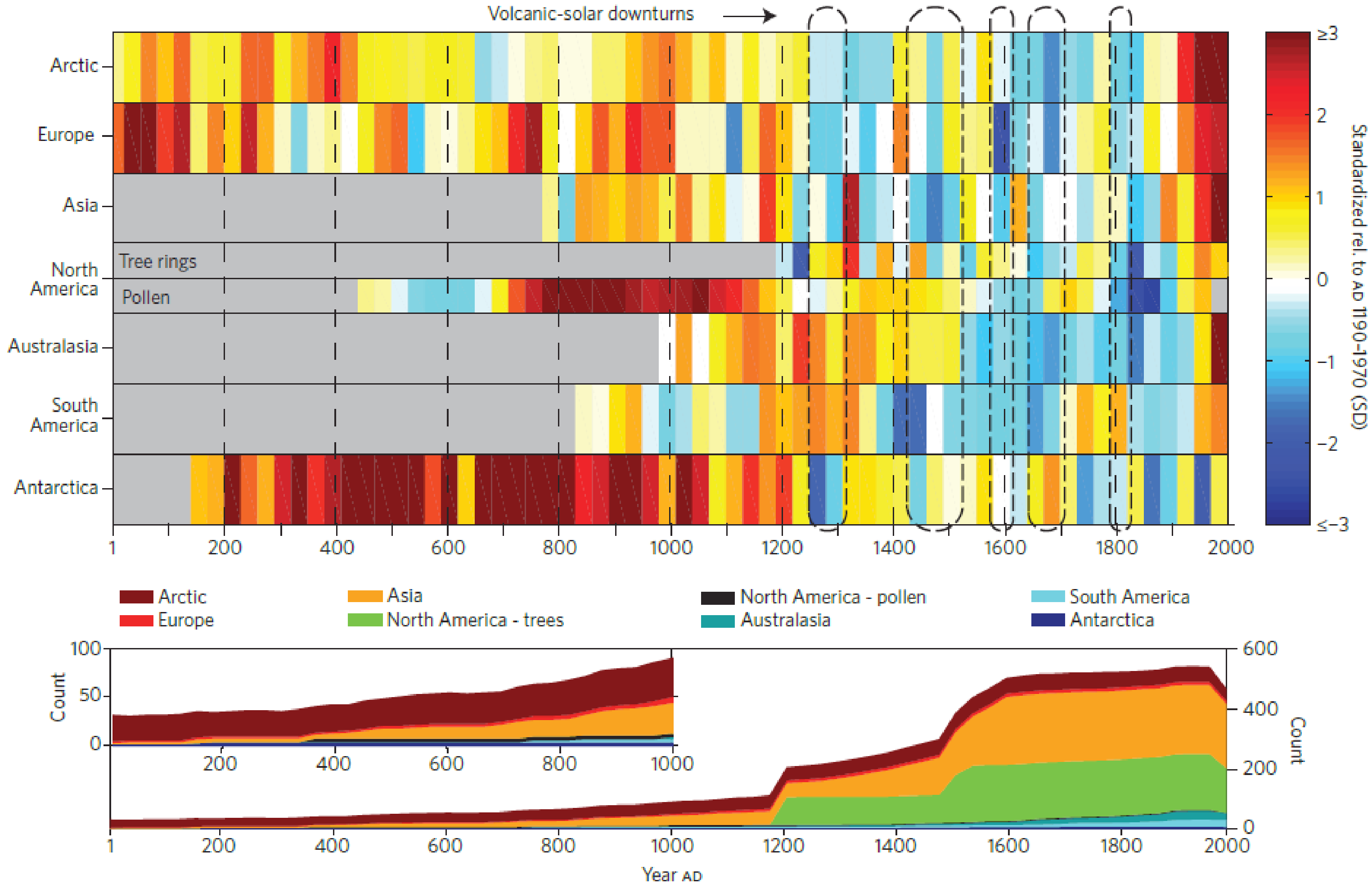
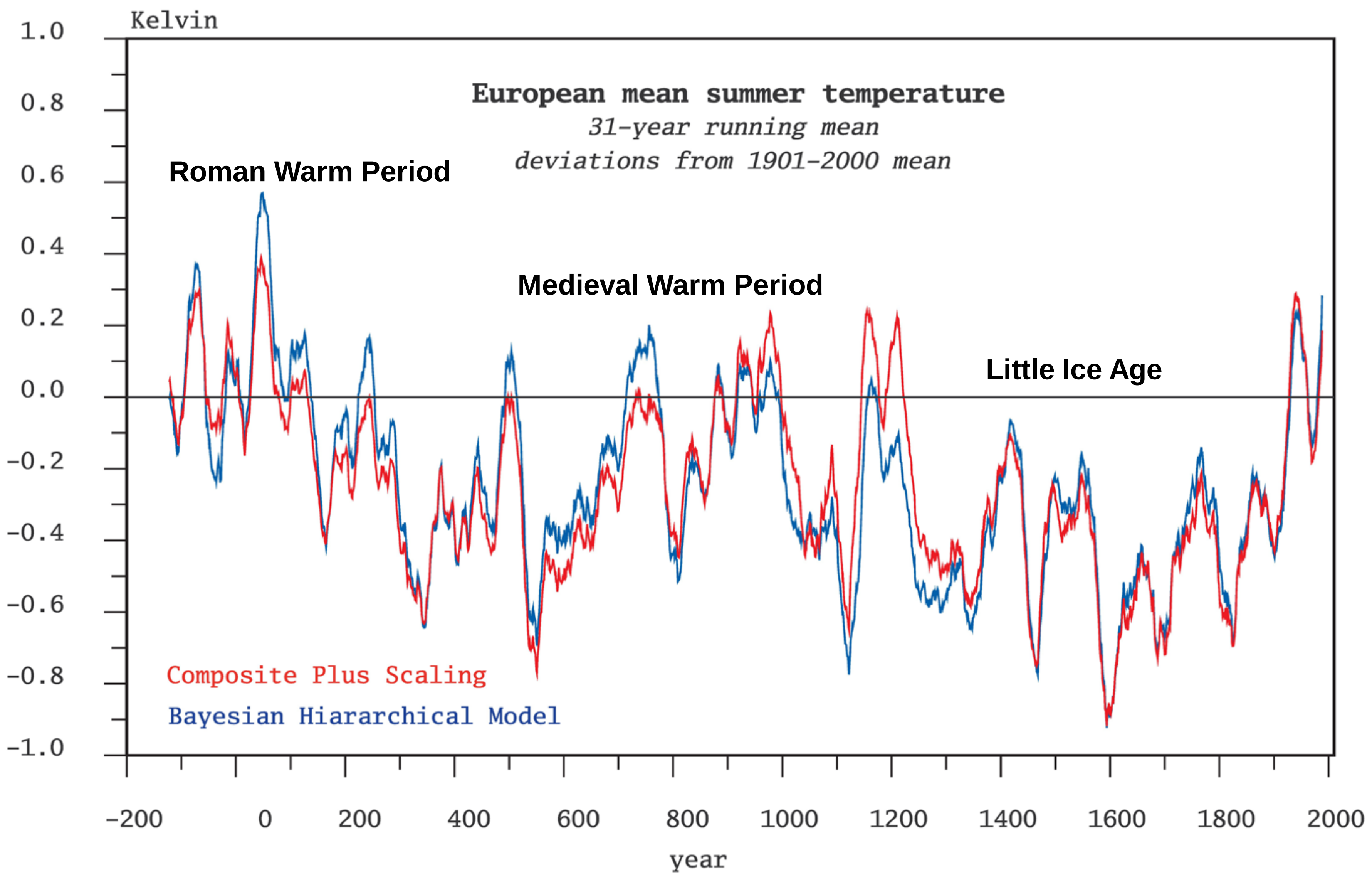


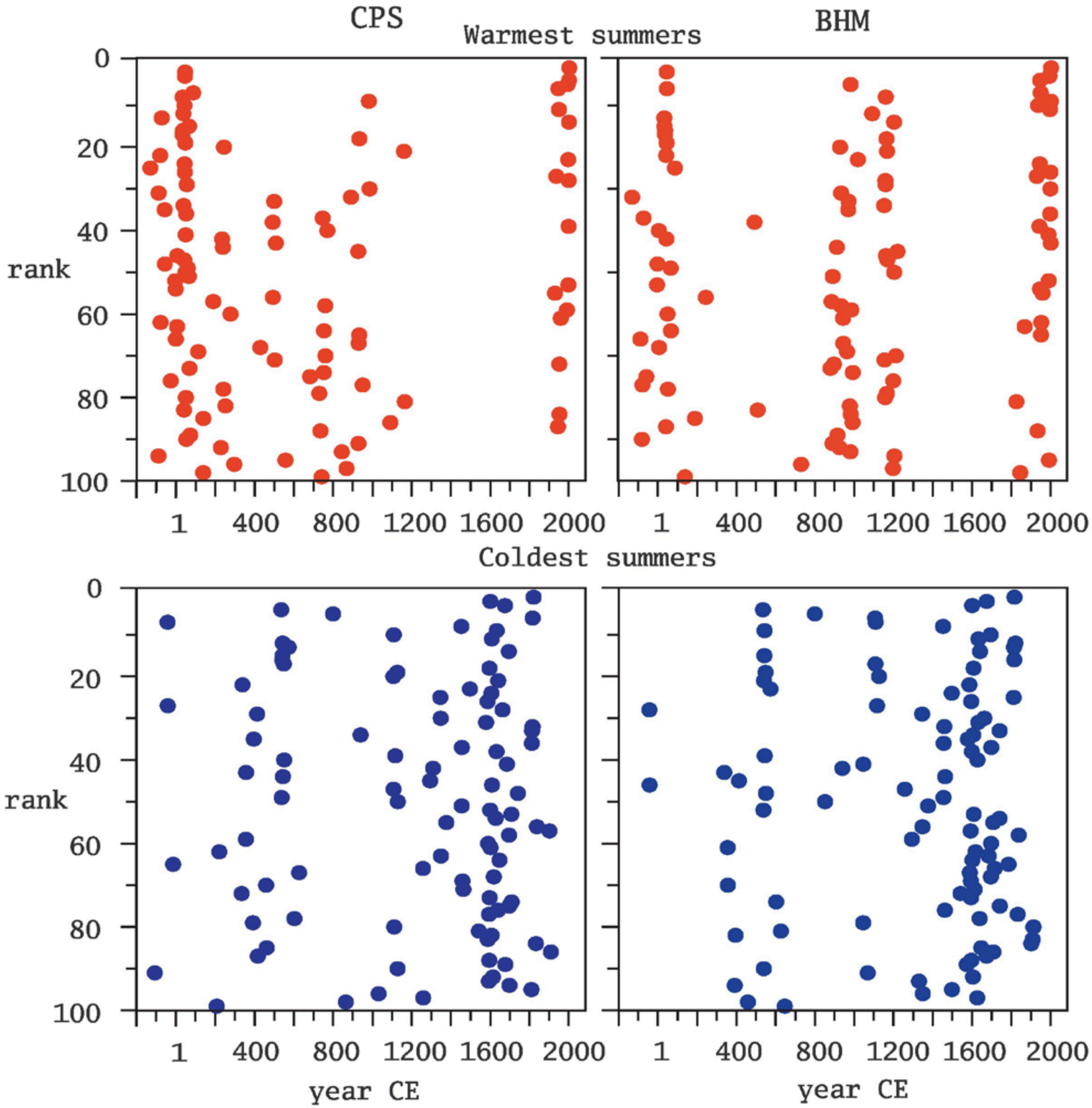
Figure 2 | Continental-scale temperature reconstructions. 30-year-mean temperatures for the seven PAGES 2k Network regions, standardized to have the same mean (0) and standard deviation (1) over the period of overlap among records (AD 1190–1970). North America includes a shorter tree-ring-based and a longer pollen-based reconstruction. Dashed outlines enclose intervals of pronounced volcanic and solar negative forcing since AD 850 (see Methods). The lower panel shows the running count of number of individual proxy records by region. Data are listed in Supplementary Database S2.

Reconstructed European summer temperature

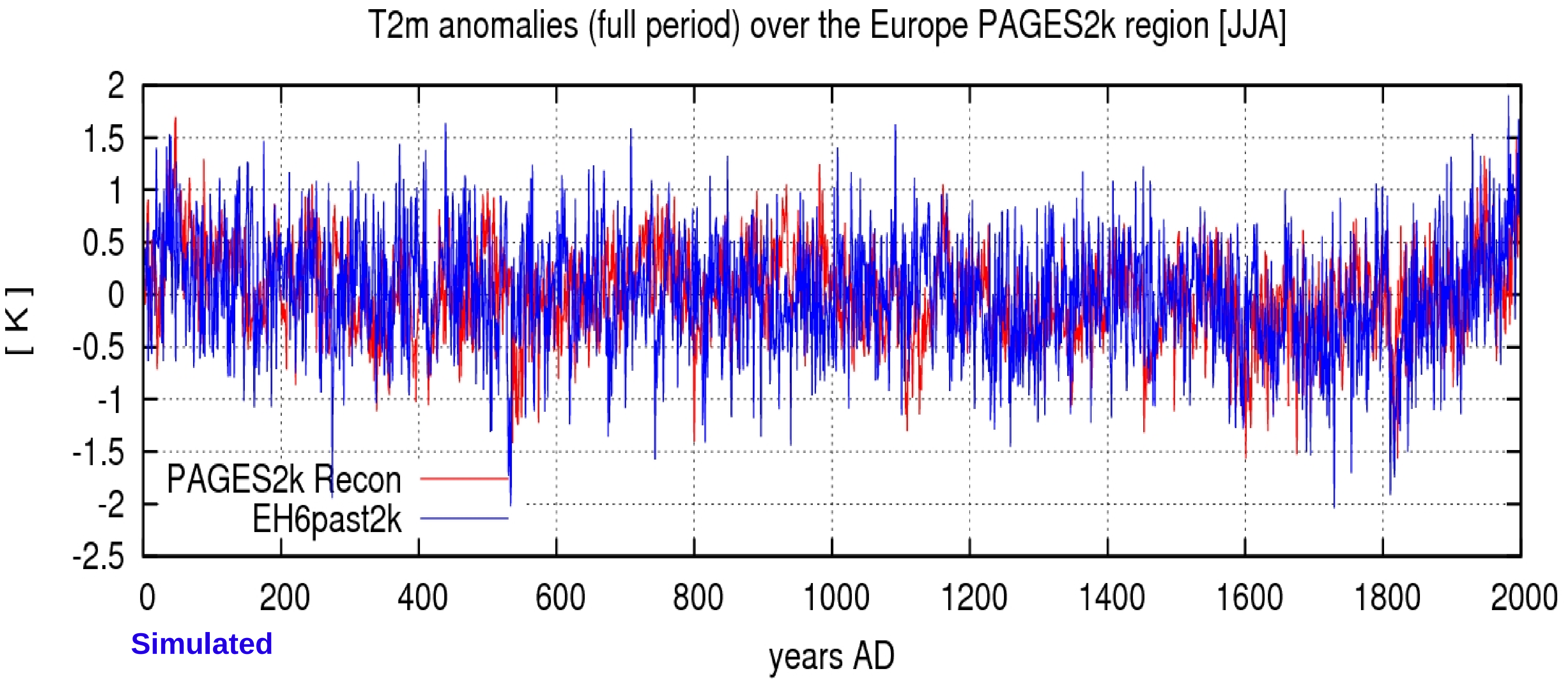
Pages 2K



Reconstructed European summer temperature: rank of extreme years



European summer temperature over last 2000 years: reconstructed and simulated



Simulated

Reconstructed

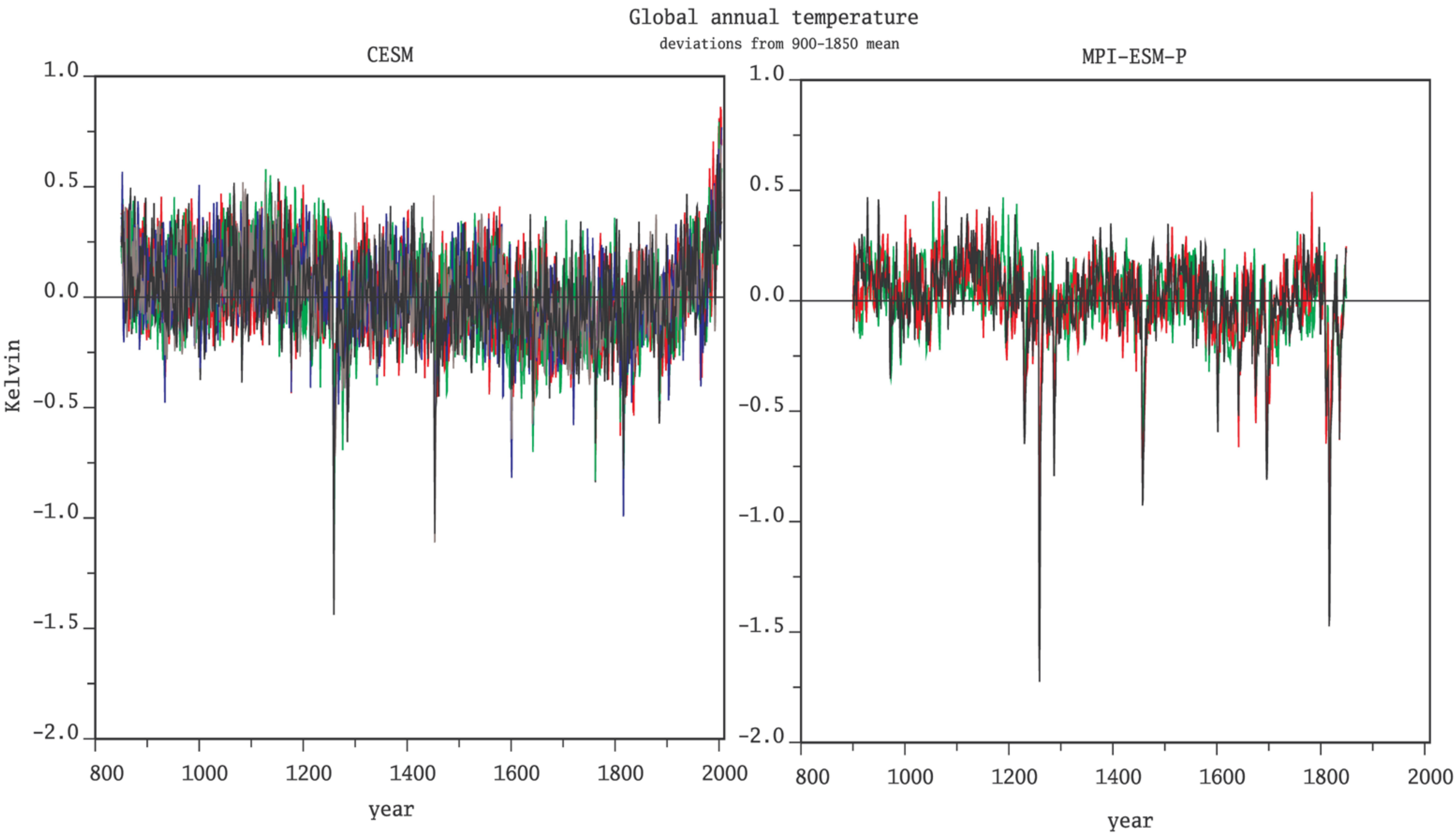
Climate simulations that we will discuss in this talk

Community Earth System Model, NCAR
8 simulations, all forcings, 850-2005

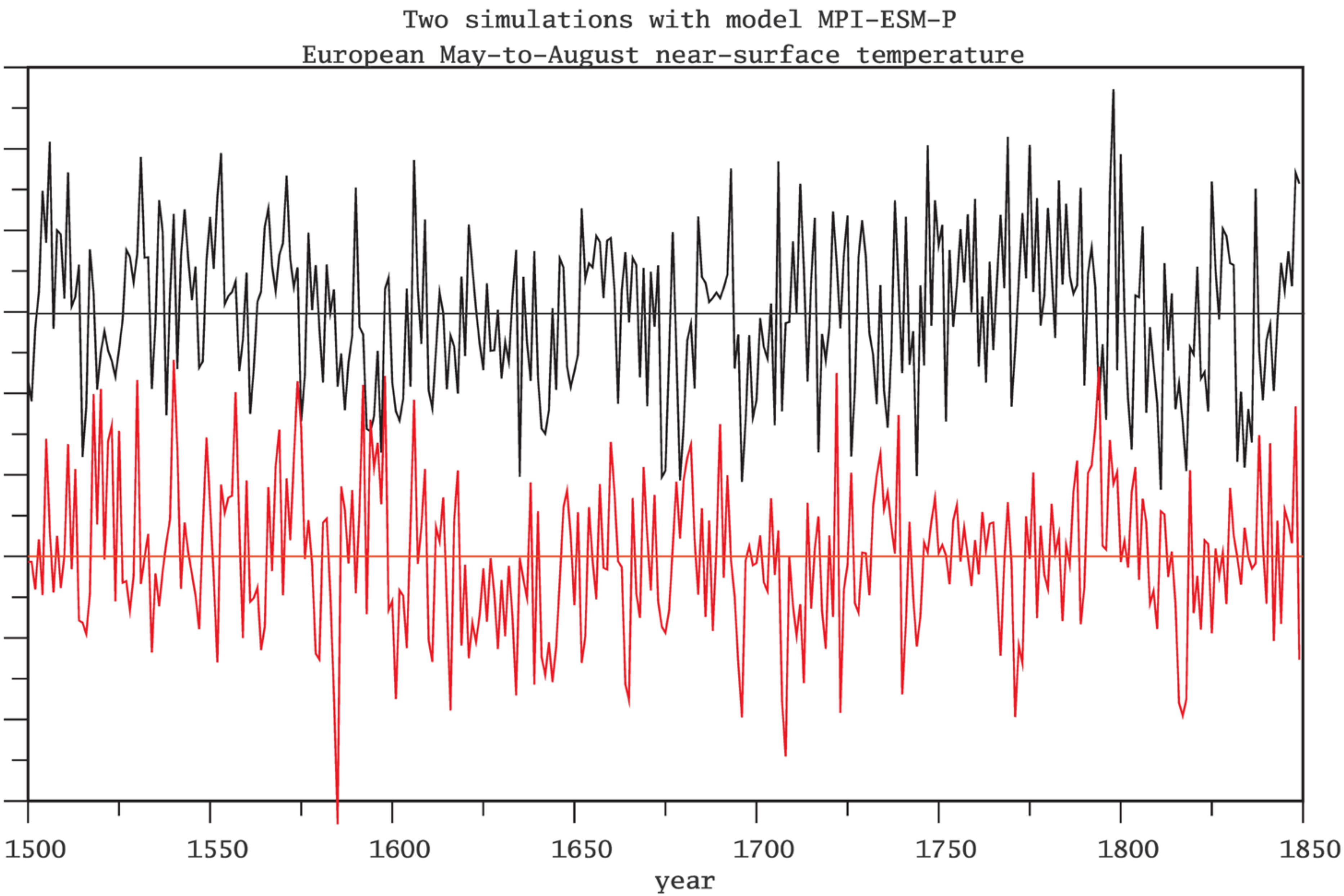
Gao et al. volcanic forcing

Max-Planck-Institute Earth System Model-P
3 simulations, all forcings, 900-1850

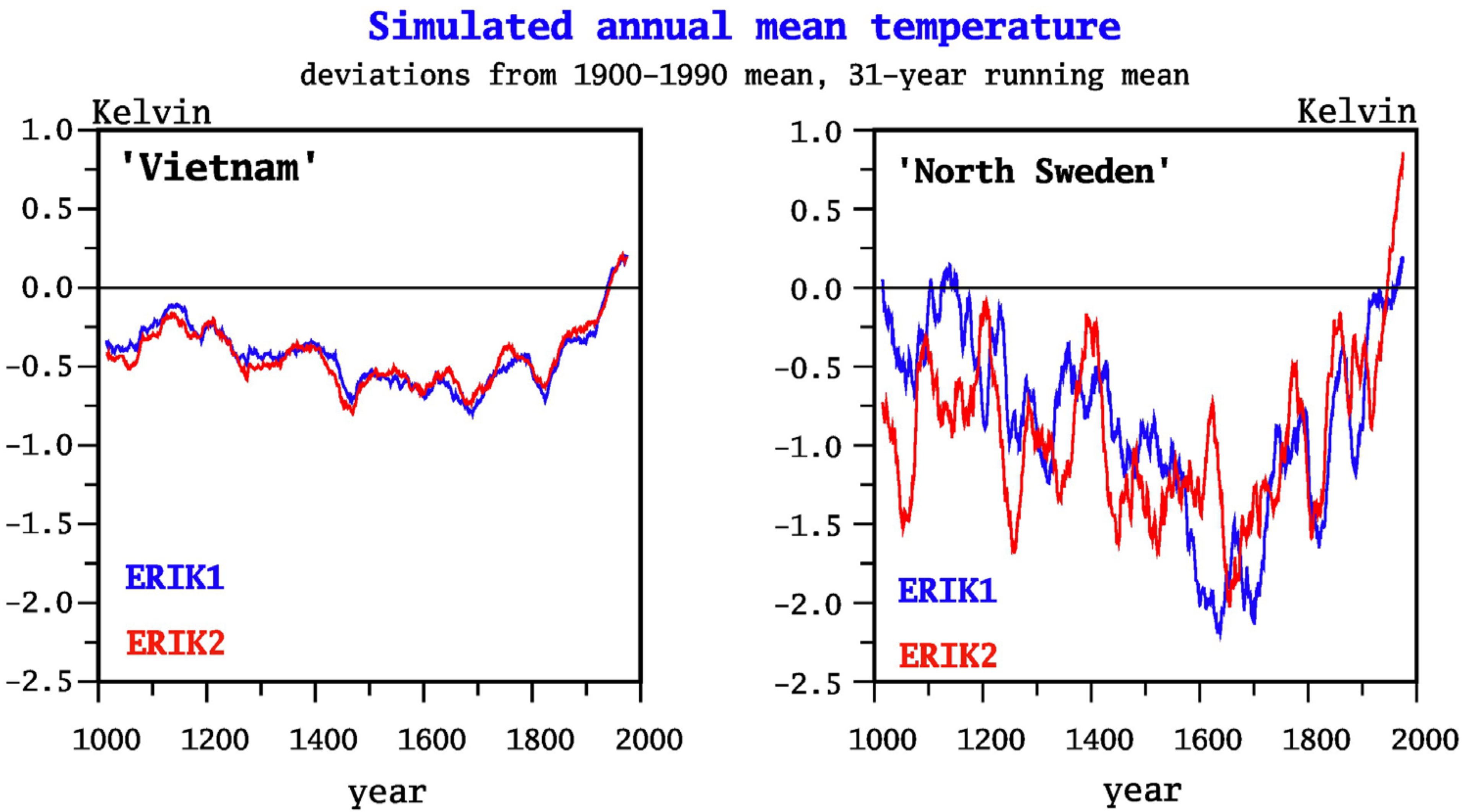
Crowley and Untermann volcanic forcing



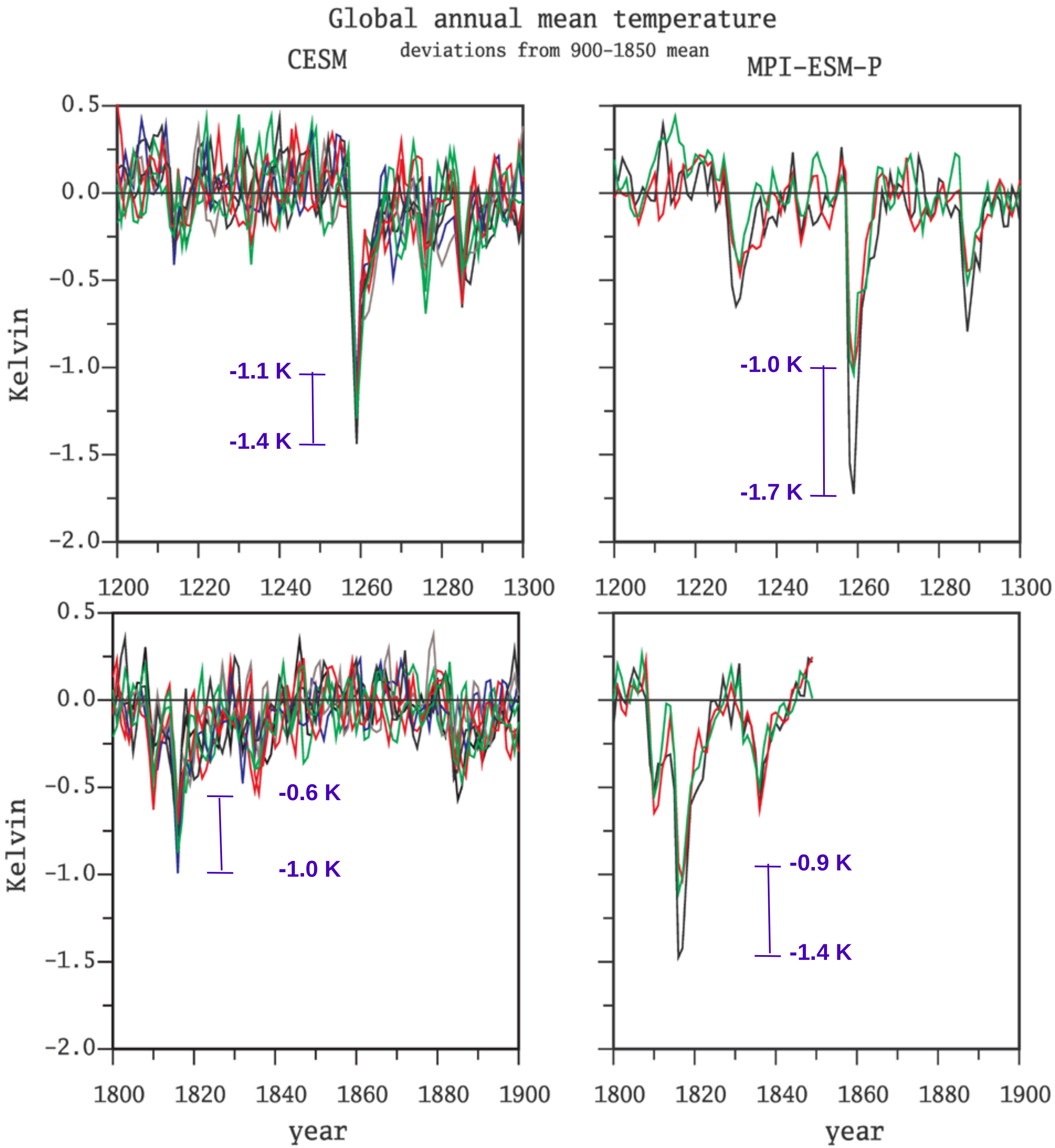
Assignment: can you identify one of the big eruptions ?



Amplitude of forced and internal variations is not spatially homogeneous



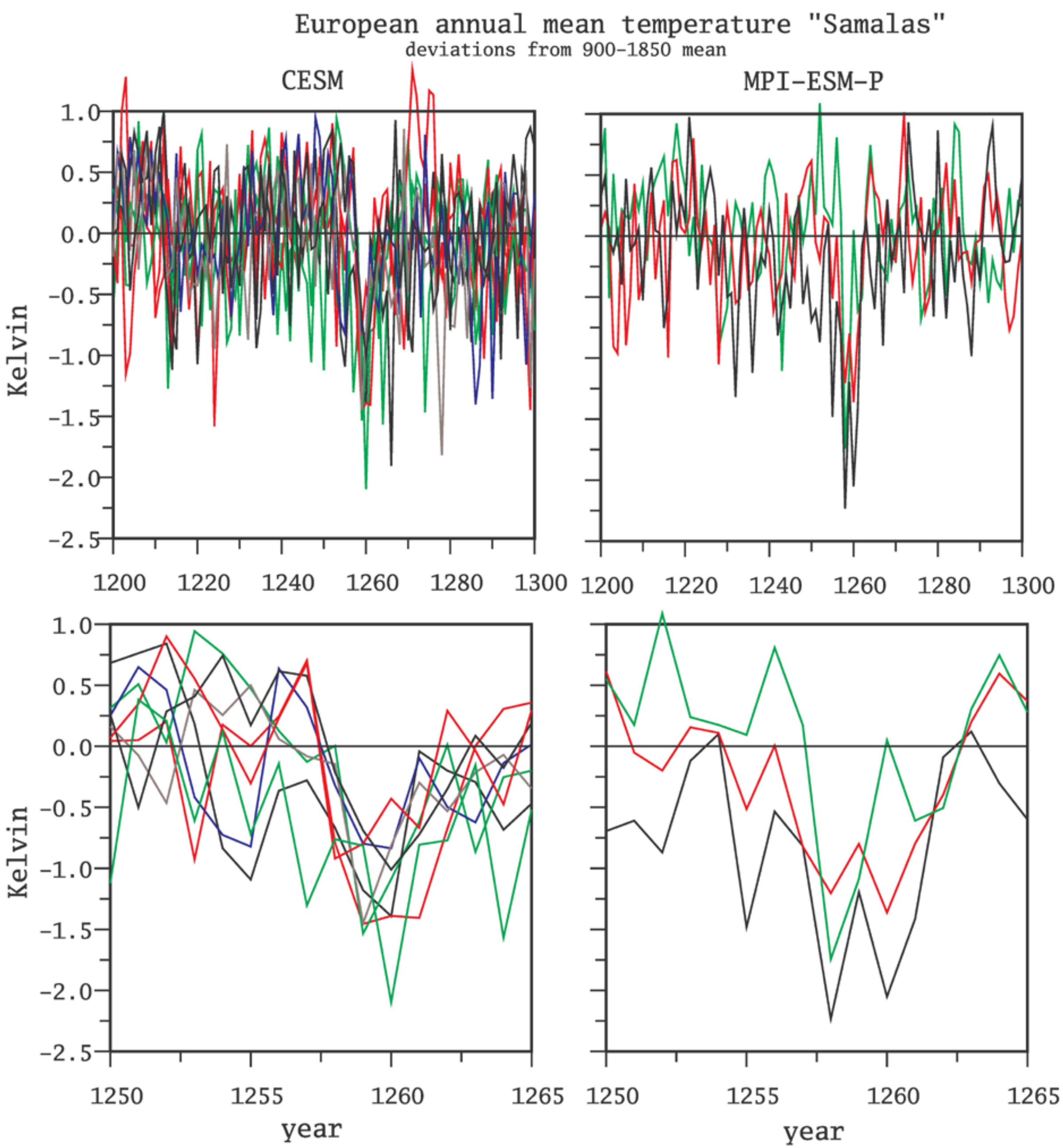
Samalas versus Tambora



1) Range of response ~50% of mean response

2) Recovery time < 10 years

European scale:
eruptions more difficult to distinguish from the 'internal background'



1) The ensemble of simulations tend to show cooling

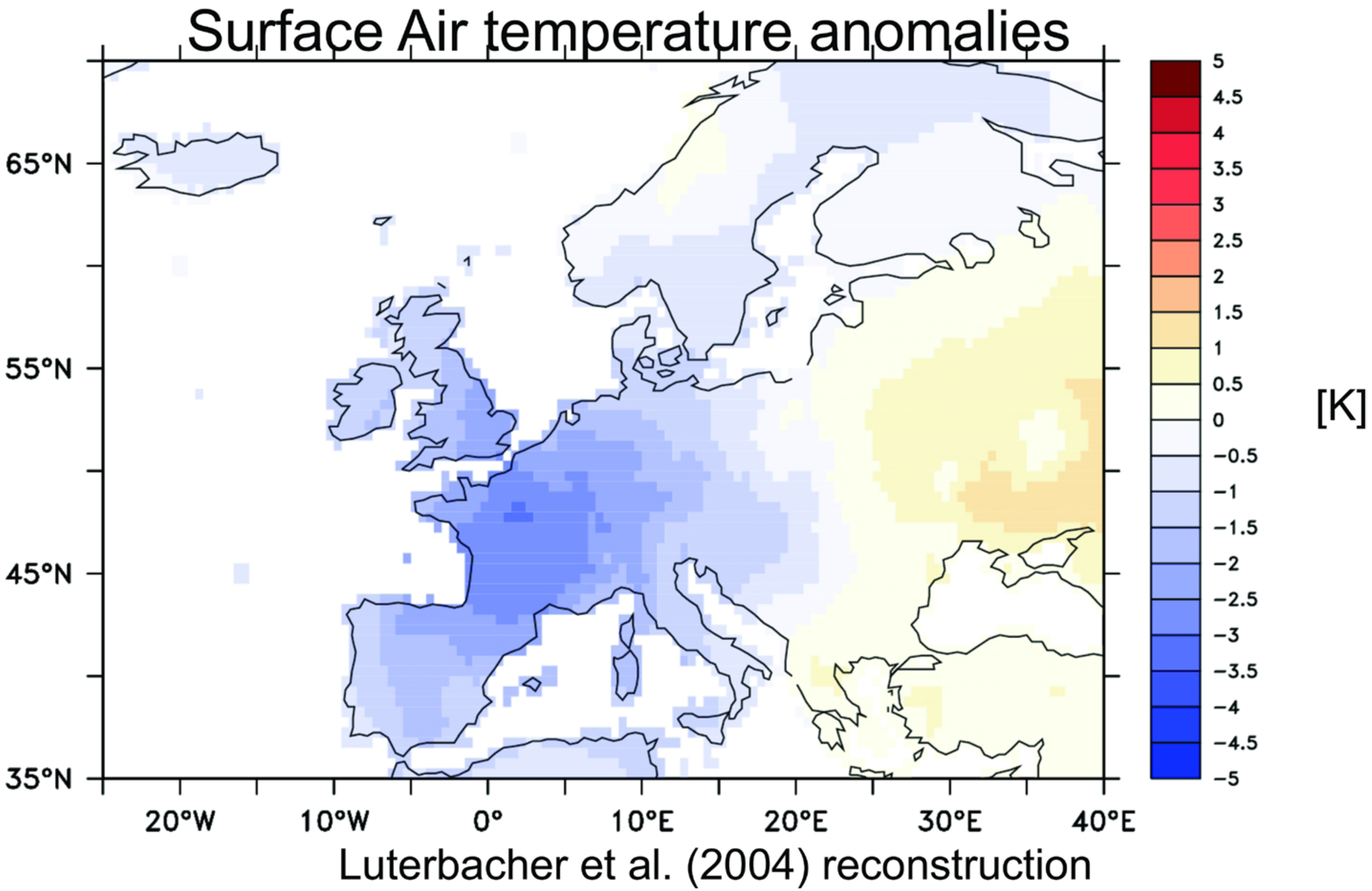
2) Whereas for some simulations this cooling is clear and even extreme..

3) Other simulations just show a tepid cooling, comparable to other cool years

4) All simulation show a cooling trend already before the eruption

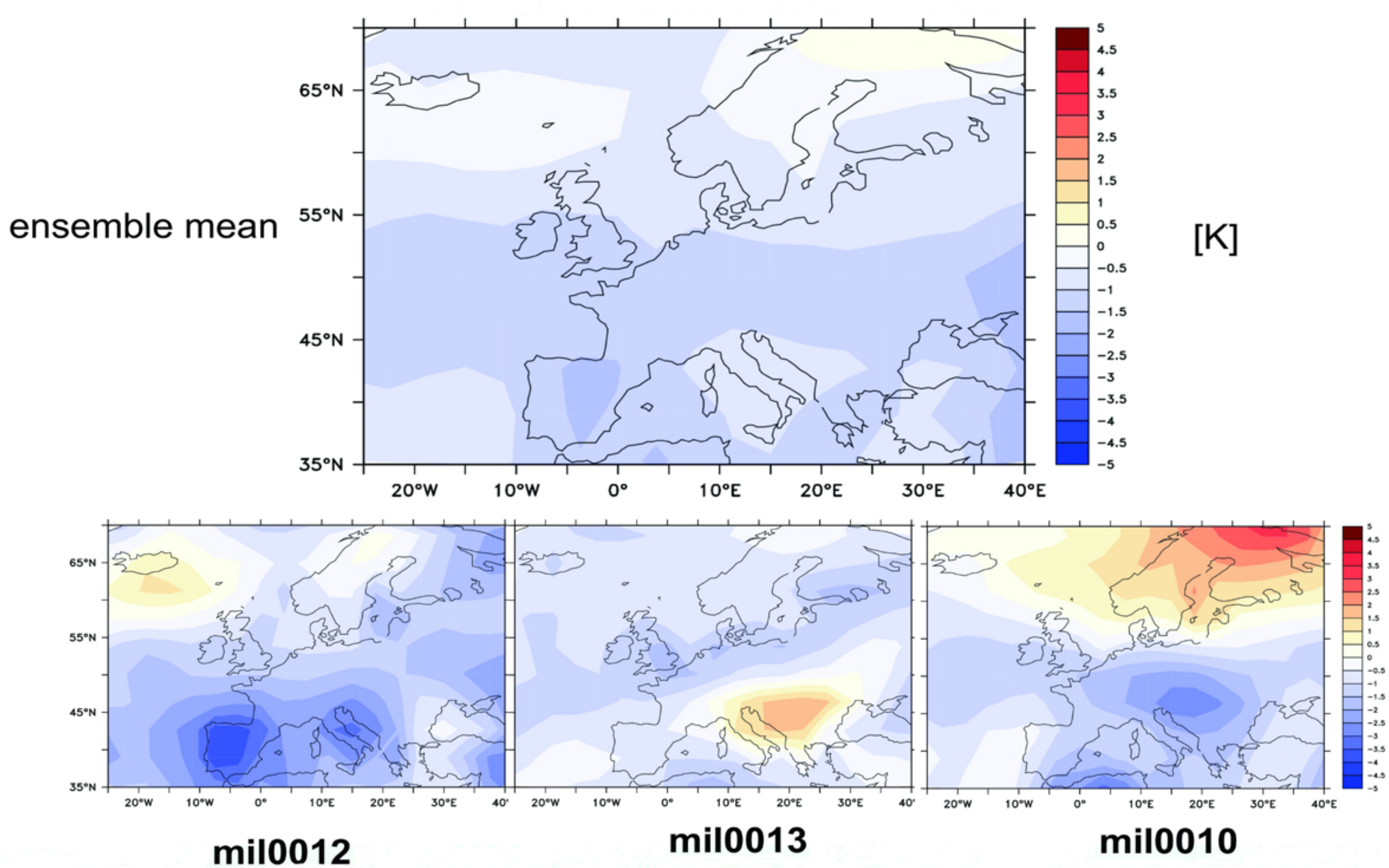
Internal variability superposed on large extreme events

Tambora eruption 1816



Internal variability superposed on large extreme events

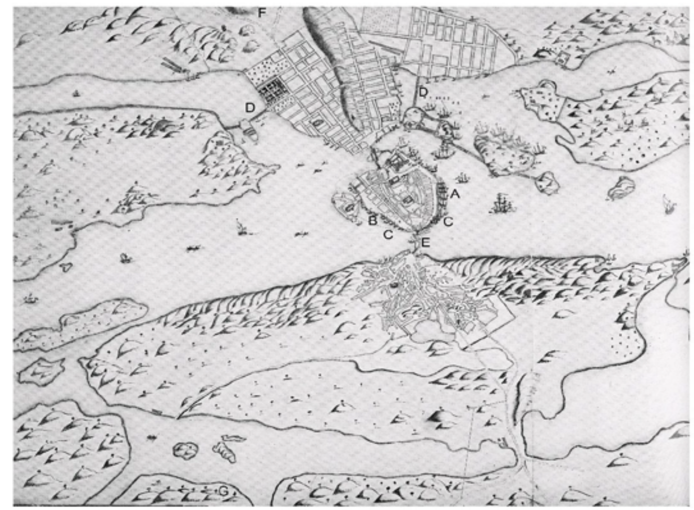
Tambora eruptions 1816



Jungclaus et al., MPI-Hamburg, Millennium project

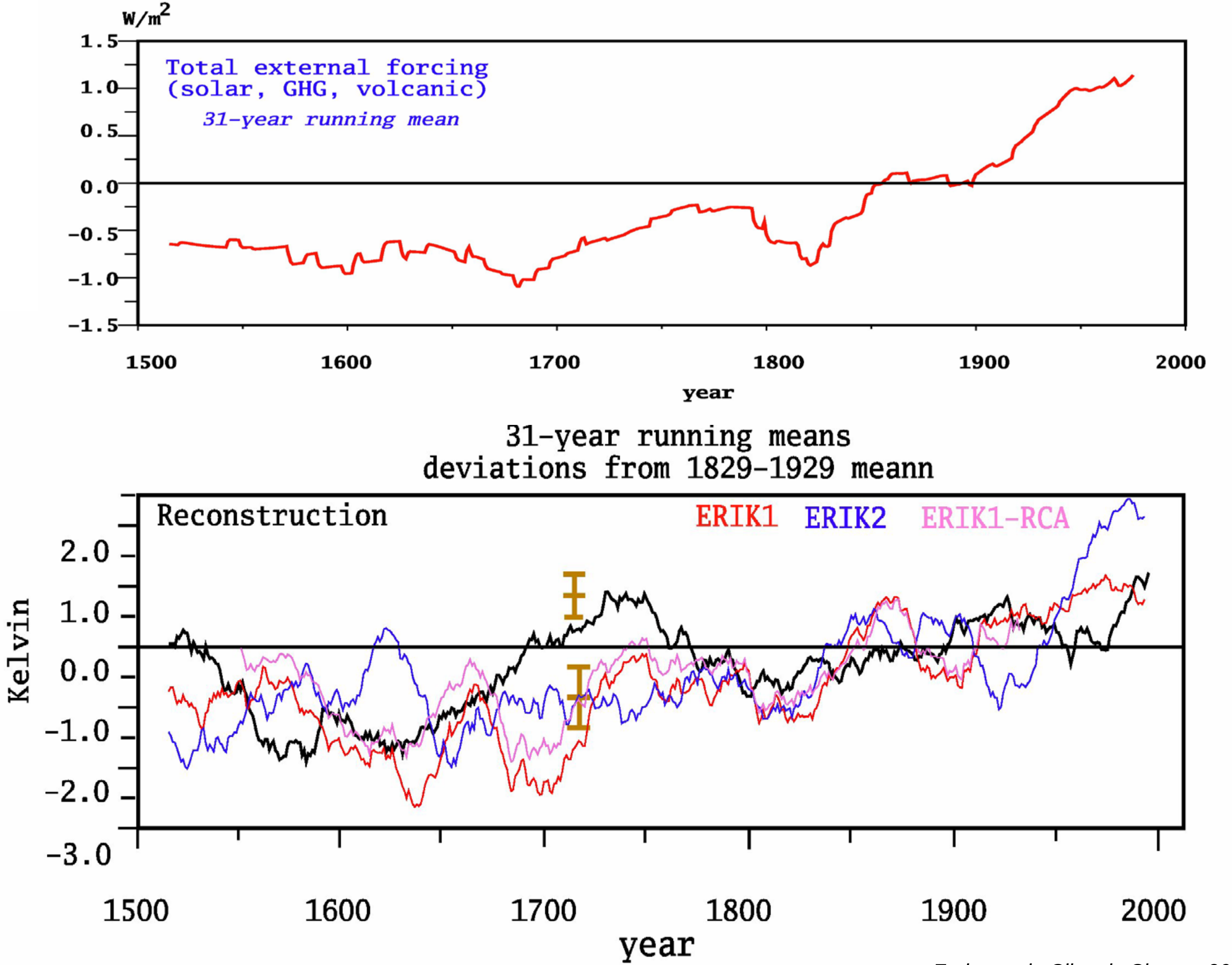
Reconstruction of Stockholm winter-spring temperature from tax records in the past 500 years

Stockholms universitet



- **Sailing season started each year as soon as ice conditions allowed**
- **Date of ice break-up closely related to seasonal mean Stockholm temperatures in winter and spring**

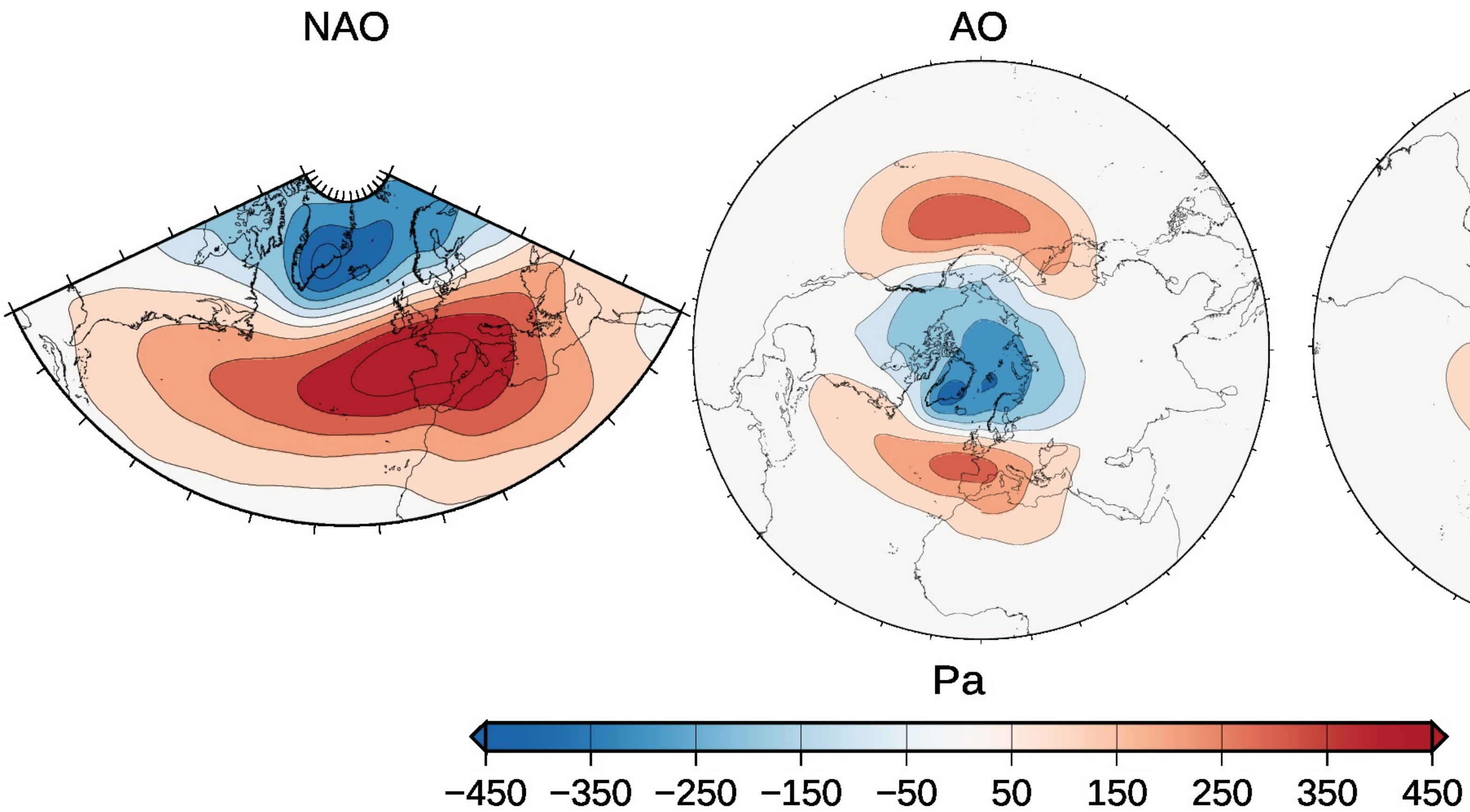
Anders Moberg, MILLENNIUM project



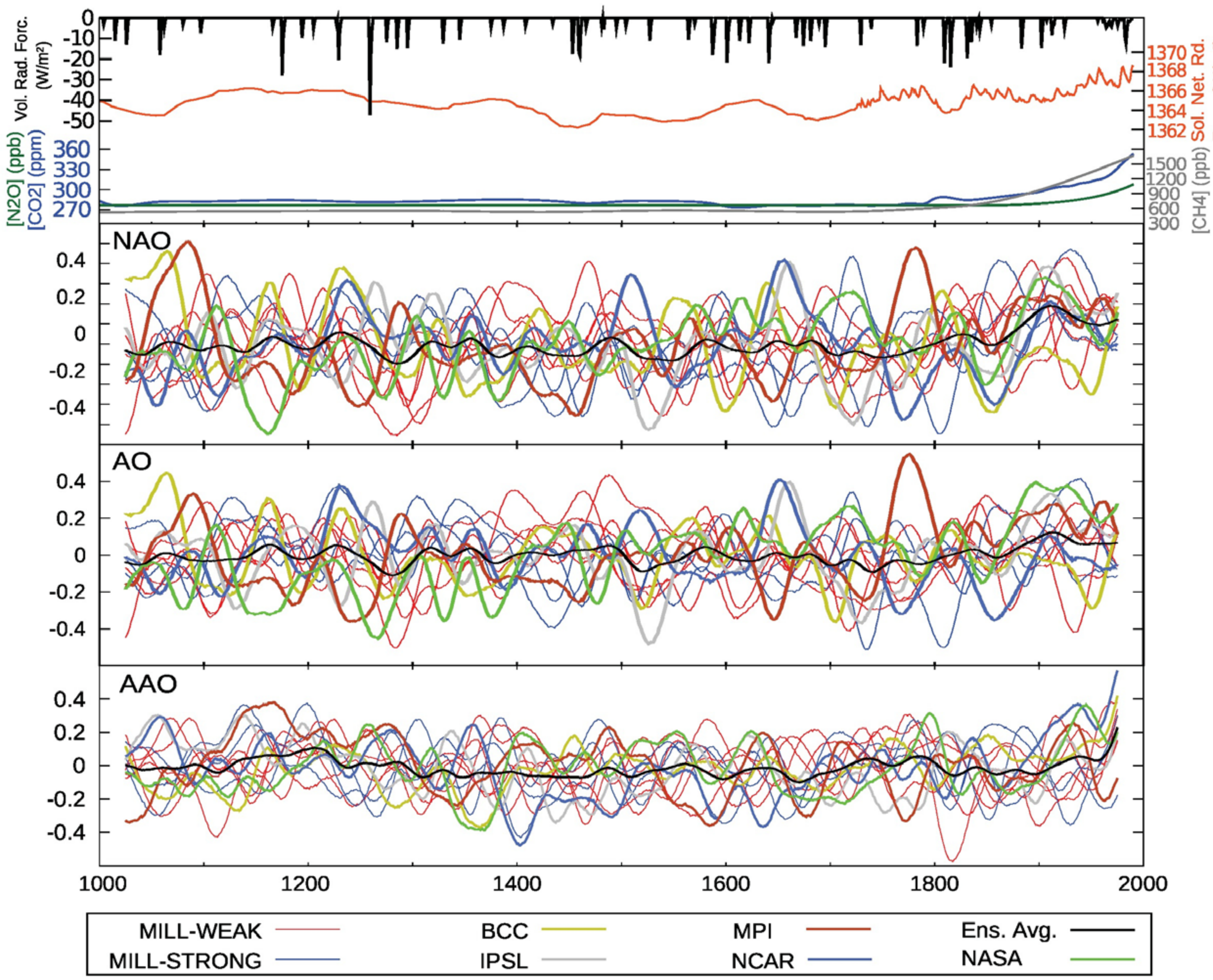
Zorita et al., Climatic Change 2010

The annular modes + NAO, simulated by a CMIP5 model

EOFs of the sea-level-pressure field in December-February



Simulated indices of the annular modes in a paleo-simulation ensemble



Gómez-Navarro and Zorita, Geophys. Res. Lett. 2013

Why is all this stuff relevant for future climate projections ?

- Understand how climate reacts to changes in external forcings

If we understand how temperature reacts to lower solar activity, we <u>may</u> better understand how climate reacts to increases in greenhouse gases

- Cross bad models off

If we identify models that do not perform well in simulating past climates, we may disregarded them for future climate projections