Orbital variability in climate and proxies; Learning from the modern seasonal cycle

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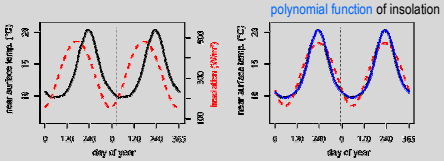
Earth's climate is influenced by orbital insolation forcing. Climate feedbacks and proxy "recorders" modify this orbital signal. To better understand this process we analyse the modern seasonal cycle for which the temperature response and the seasonality of proxy recorders are largely known. Extrapolating this modern response, we study the implications for Quaternary temperature variability and the interpretation of proxy records.

Modern seasonal cycle of temperature and insolation

The local temperature is described as function of local insolation. Example SST North Pacific (40°N 200°E)

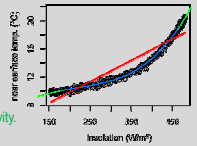
(1) observed daily temperature and insolation

(3) temperature predicted: as linear function of insolation /as polynomial function of insolation

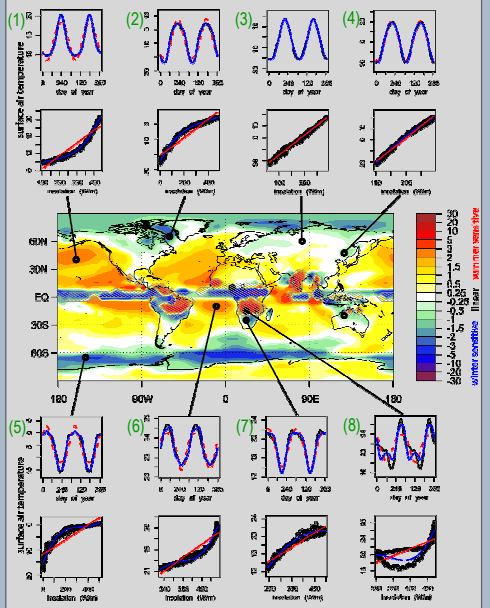


(2) a linear and 3rd order polynomial is fitted between daily insolation and daily temperature after the time-lag is removed

The green lines inidicate the different summer and winter sensitivity.



Global map of seasonal temperature sensitivity (summer – winter sensitivity) and characteristic temperature responses



Physical mechanisms for the observed temperature responses

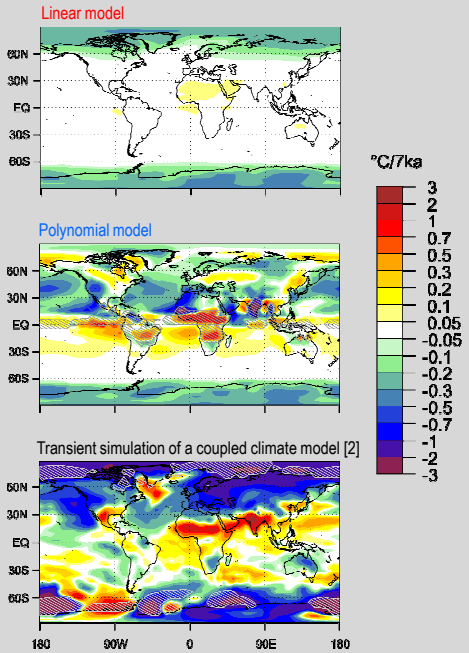
- enhanced mixing in local winter; summer sensitive (1)(6)
- seasonal sea ice cover; winter sensitive as the sea ice insulates the atmosphere from the warmer ocean (2)(5)
- monsoon regions; winter sensitive, as the summer precipitation cools the SAT (4)(7)
- extratropical land areas; linear behavior (7)
- the seasonal cycle in tropical regions has a strongly non local origin, the local model does not fit well (8)

Application of the modern temperature response to past insolation; Implications for the Quaternary temperature variability

Method

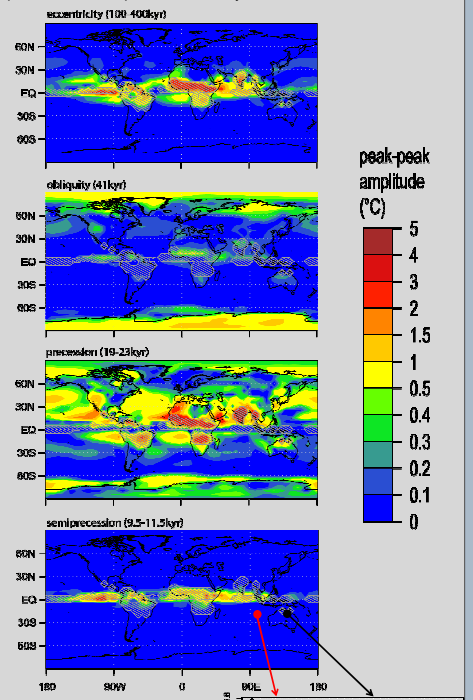
We apply the present day transfer functions (linear model and polynomial model) on the daily insolation of the last 750 thousand years [1] and analyse the annual mean temperature.

Holocene temperature trend (7K-0K BP), predicted by the linear and polynomial model and simulated by a coupled climate model [2]

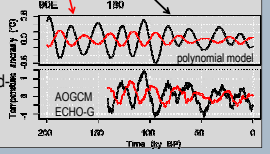


Temperature evolution of the last 750ka using the polynomial model.

Amplitudes of the temperature variability in the orbital bands are shown



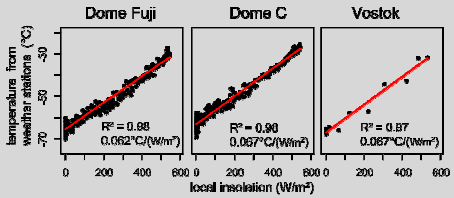
Simulated temperatures for two locations 20°S 100°E, 20°S 135°E exemplify the strong spatial dependence of the temperature response.



Climate feedbacks that shape the seasonal cycle have a strong impact on orbital temperature variations. Strong spatial variations of amplitude and phase of Quaternary temperature variability are expected. Local insolation in combination with seasonal accumulation provides a local interpretation for Antarctic temperature records, independent of Northern Summer insolation forcing.

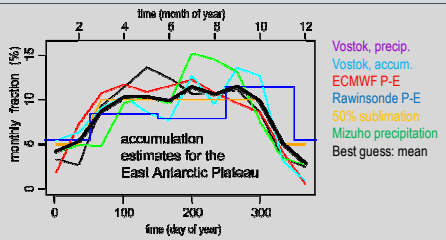
The influence of seasonal proxy recorders: Interpretation of Antarctic ice-core derived temperature records

Observed modern seasonal temperature response is linear



Assumption: linear relationship of insolation and temperature in the past

Observed modern accumulation has a minimum in austral summer

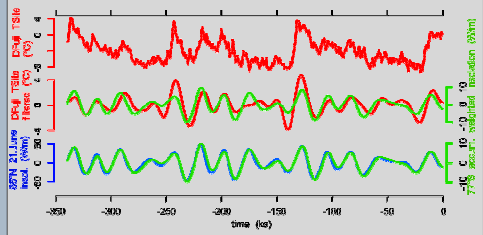


Assumption: relative seasonal cycle was constant over time

Isotopic temperature record is modeled as accumulation weighted insolation

$$T_{isotopic}(t) \propto \frac{\int_{Sample} I(t) * Accum(t)\,dt}{\int_{Sample} Accum(t)\,dt}$$

Result



The accumulation-weighted insolation shows very similar temporal variations compared to the local temperature reconstruction from Dome Fuji [3] in the orbital bands. It cannot be distuingished from Northern summer insolation.

References

[1] Berger A., J. Atmos. Sci., 35, (1978)
[2] Lorenz S.J. et al.,Paleocean,21, (2006)
[3] Kawamura et al., Nature, 448 (2007)
Laepple, T. and G. Lohmann ,The seasonal cycle as template for climate variability on astronomical time scales, Paleoceanography, accepted, 2009