FORUM

Improved Proxy Record of Past Warm Climates Needed

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Before the end of the present century, atmospheric carbon dioxide (CO_2) is projected to reach the high levels last seen in past warm periods such as the Eocene (~40 million years ago) [*Beerling and Royer,* 2011]. Climate reconstructions from sediment cores ("proxy data") and paleoclimate modeling studies show that such higher CO_2 periods are characterized by warmer temperatures, smaller ice sheets, and higher sea level than today. The proxy record of past warm climates is thus fundamental in guiding scientists' understanding of future climate changes. However, we believe that currently available data sets are not yet adequate for this task.

Under a doubling of CO_2, Intergovernmental Panel on Climate Change (IPCC) climate models simulate consistent tropical sea surface temperature (SST) changes but show large inconsistency at high latitudes (Figure 1). This illustrates the challenges in understanding high-latitude climate and highlights the tropics as a critical region for proxy-model comparison. For instance, if significant mismatch is identified in the tropics, as may be the case in the Pliocene (~5.33–2.59 million years ago) [e.g., *Dowsett et al.,* 2011] and Eocene [e.g., *Huber and Caballero,* 2011], then common biases are implied across the IPCC model ensemble.

For the Eocene, paleotemperature reconstructions from the few unevenly distributed core sites available indicate warmer temperatures and a lower latitudinal SST gradient than present [*Bijl et al.,* 2009], but climate models are only able to simulate these features using CO_2 levels approximately 3000 parts per million higher [*Huber and Caballero,* 2011] than the current proxies reconstruct for this period (500–1500 parts per million [*Beerling and Royer,* 2011]). Traditional proxy methods for reconstructing climate are limited for such periods as the Eocene due to unavailable archives (e.g., ice cores) or extinctions complicating modern analog techniques (e.g., foraminifera assemblages). Eocene proxies available [*Liu et al.,* 2009] are at or beyond their modern calibration limits (e.g., alkenone unsaturation index ($U_{37}^{K'}$)) or not yet well constrained (e.g., TetraEther indeX of 86 carbon atoms (TEX_{86})). To demonstrate the implications of reconstructing SST latitudinal gradients from limited spatial sampling, we regenerate the modern gradient using only modern data at the Eocene core locations and compare this to the full present-day SST data set (Figure 2). Because of lack of data, the Northern Hemisphere SST gradient is overestimated between ~50°N and 85°N and underestimated between 0° and 30°N. If we acknowledge proxy uncertainties and exclude problematic data from Figure 2, it becomes impossible to quantify any latitudinal SST gradient.

To understand past warm climates and better inform climate models, on which future climate projections are largely based, scientists need (1) more proxy data with better spatial coverage, (2) improved proxy methods, and (3) more proxy-model comparisons. Continued data retrieval by organizations such as the Integrated Ocean Drilling Program is therefore essential.

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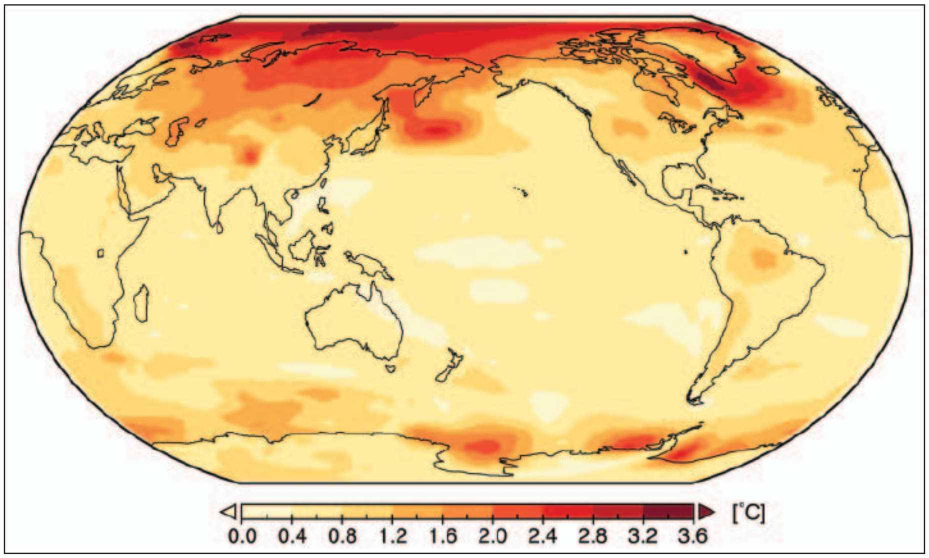

*Fig. 1. Standard deviation of annual mean surface air temperature change (from preindustrial) across Intergovernmental Panel on Climate Change Fourth Assessment Report/Coupled Model Intercomparison Project 3 (CMIP3) models [*Meehl et al., *2007] under a doubling of carbon dioxide.*

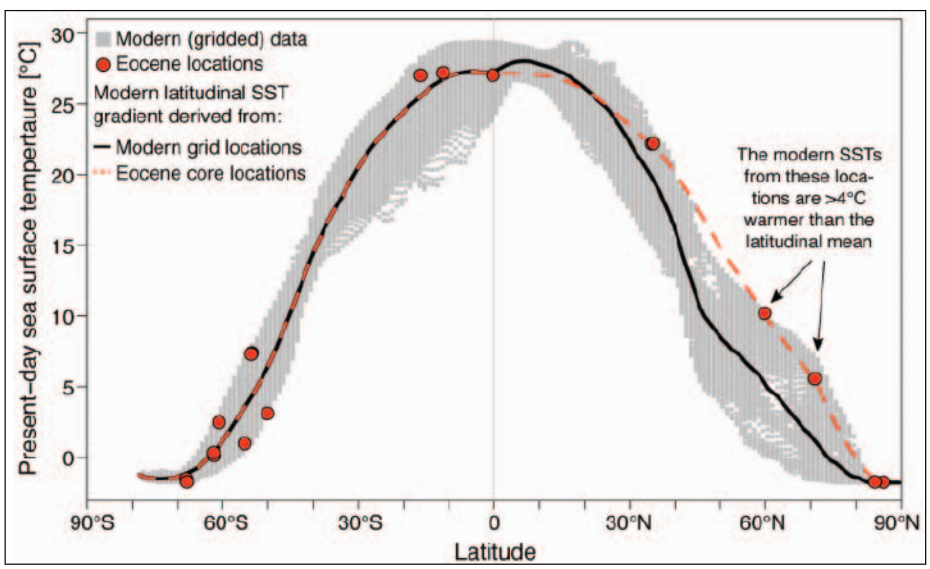

Fig. 2. Reconstructed present-day latitudinal sea surface temperature (SST) gradient using Eocene paleolocations (red [cf. Bijl et al., *2009]) or all annual mean Hadley SST data (black).*

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