Equable climates: a meridional flux paradox?

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A commonly found property of warmer climates on Earth is the tendency, principally through polar amplification, towards more equable conditions with reduced meridional temperature contrasts. Numerical climate models historically have had quite some difficulty in reproducing meridional temperature gradients as low as those suggested by various proxies. It seems self-evident that an equable climate is governed by enhanced meridional fluxes of heat, to sustain mild high latitude temperatures while keeping low latitudes from becoming exceedingly warm. However, a common hypothesis, borrowed from turbulence theory, is that the meridional heat flux is proportional to the meridional temperature gradient. A more equable climate should, therefore, exhibit reduced rather than enhanced meridional heat fluxes, posing a physical paradox.

Here, we use a unique set of long and well equilibrated (~25,000 years combined) climate simulations for various past periods using the CESM1. In terms of complexity and resolution, this climate model is comparable to the CMIP5 suite. Comparing the modelled climates of the Eocene (~40Ma), Oligocene (~30Ma), Pliocene (3Ma), pre-industrial era and present-day equilibrium climate confirms the hypothesis that warmer and more equable states overall feature weaker meridional heat fluxes (Figure 1).

This effectively shows that meridional heat fluxes on a global scale are a result of, rather than the driver of the climate state. It is, therefore, the regional radiative balance that determines the temperature distribution and by extension the meridional heat flux. Still, the different components of that flux (atmospheric vs oceanic; sensible vs latent) are crucial in shaping the climate and these are strongly dependent on the background state. Meanwhile, a strongly divergent behaviour is seen in response to an imposed RCP8.5 future scenario which drives the model far from equilibrium. In this presentation, we will address why all of the cases follow a similar slope (with a different reference) in the considered parameter space, the roles of related heat flux components, and the processes responsible.

Using appropriate boundary conditions, sufficient resolution and an adequate level of equilibration, the model is able to reproduce the warmer and more equable climates of the past. This gives confidence that the physics determining the modelled climate states under a widely varying external forcing are sound and should help us understand meridional temperature gradients in a future warmer climate.