

Is the Eocene's climate affected by ocean tides?

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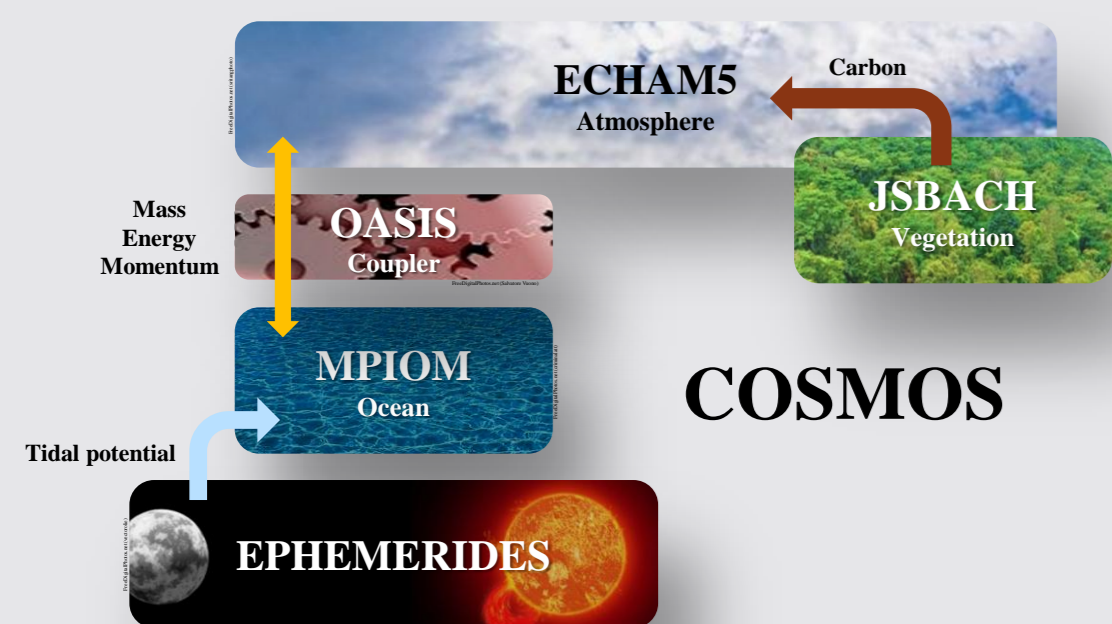


1. Motivation

During the **Early Eocene (56-50 Ma)** changed land-ocean configuration, higher temperatures with 20-26°C in the tropics and 10-15°C in high latitudes (Zachos et al., 1994; Pearson et al., 2007), and a decreased equator-to-pole temperature gradient altered ocean circulation.

Circulation models used for paleoclimate simulations usually consider dynamics due to the ocean's general circulation, while **tidal dynamics most commonly are neglected** due to their strict periodicity and high frequencies. Nevertheless, **tides alter ocean circulation and energy fluxes** on longer timescales. This brings tidal dynamics into the focus of paleo-climate simulations, when both **different celestial constellations and geometric shapes of ocean basins** affected tidal currents.

Using a **coupled atmosphere-ocean general circulation model** with an integrated **tidal module based on luni-solar ephemerides** enables us to simulate the Early Eocene's tides and quantify their impact on climate.



2. Models

As an atmosphere and ocean general circulation model (AOGCM), the COmmunity Earth System ModelS (**COSMOS**) is being used. It consists of the atmosphere model **ECHAM5** (T31L19), vegetation model **JSBACH**, and ocean model **MPIOM** (GR30L20).

The **tidal model** (Thomas et al., 2001) calculates the ephemerides of **sun and moon**, determines their **tidal potential** and forces hereby the ocean.

3. Results: Early Eocene vs. pre-industrial

Resonance conditions of ocean basins differ in the Early Eocene and pre-industrial model runs due to changed bathymetry and land-sea-distribution. This leads to an **augmentation of the M2 tidal amplitude**, especially in the Indo-Pacific Ocean, doubling amplitudes around Australia. In contrast to the pre-industrial ocean, in the Early Eocene **the southern hemisphere has higher amplitudes** than the northern hemisphere (fig. 1 & 2).

4. Results: Tides vs. general circulation

Due to tidal residual currents, **local transports are strengthened** and the direction of ocean flow is changed (fig. 3 & 4). This effect is not only visible in coastal areas, but also in the open ocean and oceanic gateways, such as the Indo-Pacific Gateway. **Horizontal velocities are affected from the surface to the bottom** (fig. 4). Hereby, formerly not existing bottom and intermediate currents are induced.

Changed horizontal and vertical velocities and increased vertical mixing **lower temperatures in the upper 2000m** (fig. 5) and increase temperatures below. Sea Surface Temperatures are also affected, **lowering annual mean Sea Surface Temperature by 0.2K**.

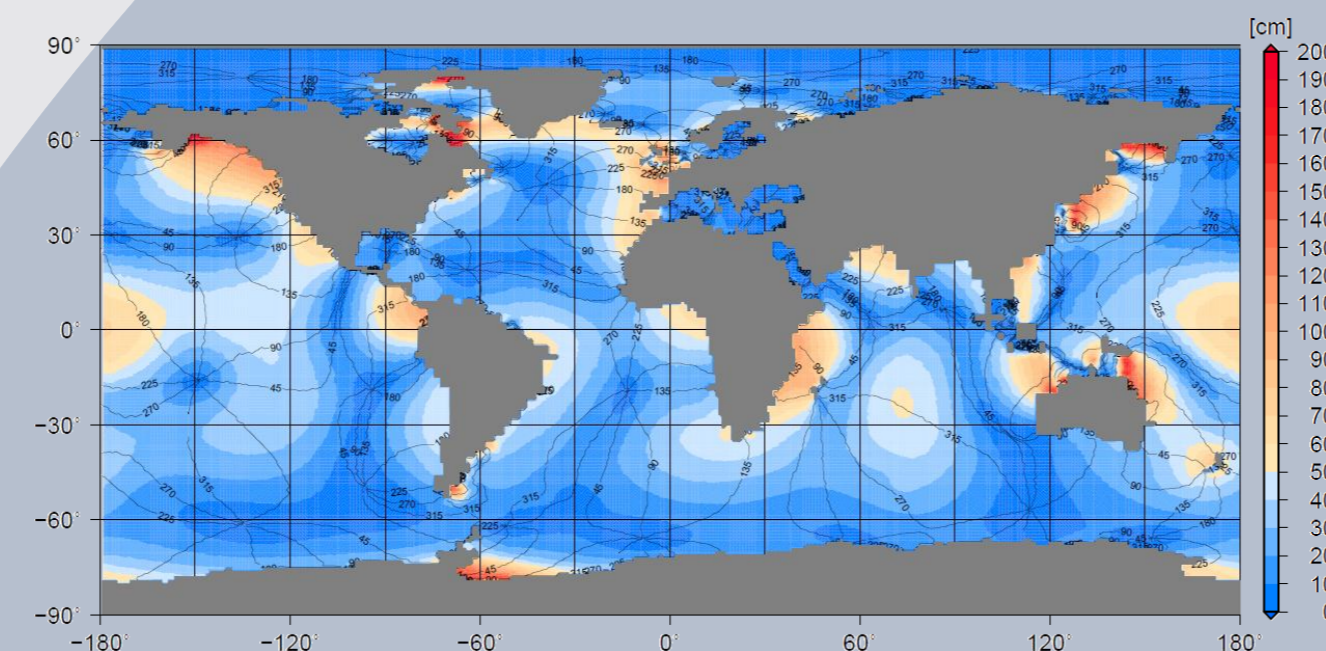


Figure 1: Amplitude and phase of the M2-Tide in the pre-industrial run.

5. Outlook

Recognizing the **impact of tides on ocean circulation**, not only at the surface but also the deep ocean, **sensitivity studies** with respect to different reconstructions of orbital parameters will be performed (e.g., Laskar et al., 2004) for a **variety of time slices**.

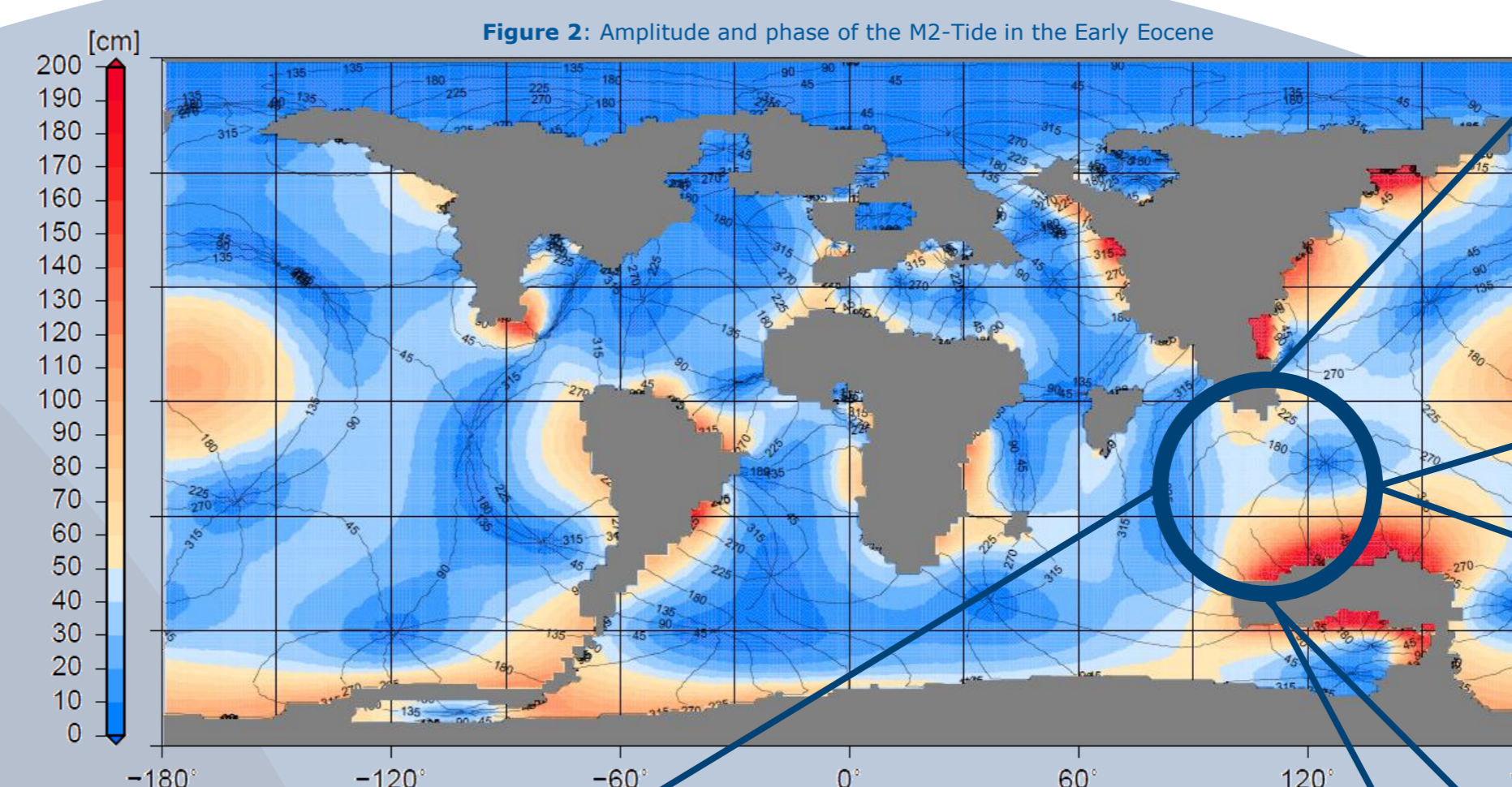


Figure 2: Amplitude and phase of the M2-Tide in the Early Eocene

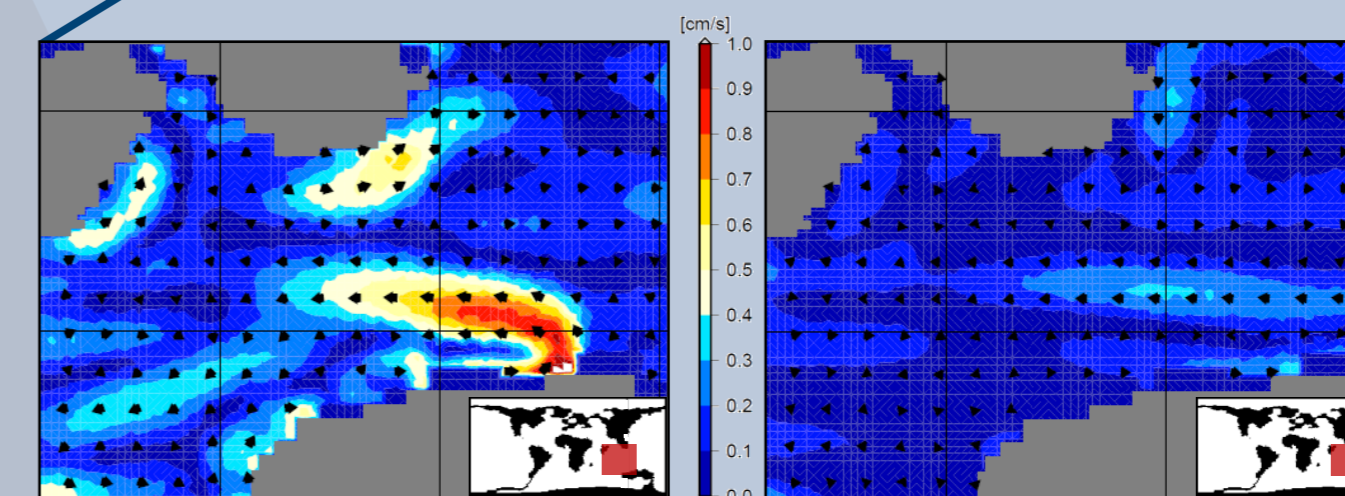


Figure 3: Horizontal velocities of the Early Eocene ocean model run at 1750m depth with (left) and without (right) inclusion of the tidal module

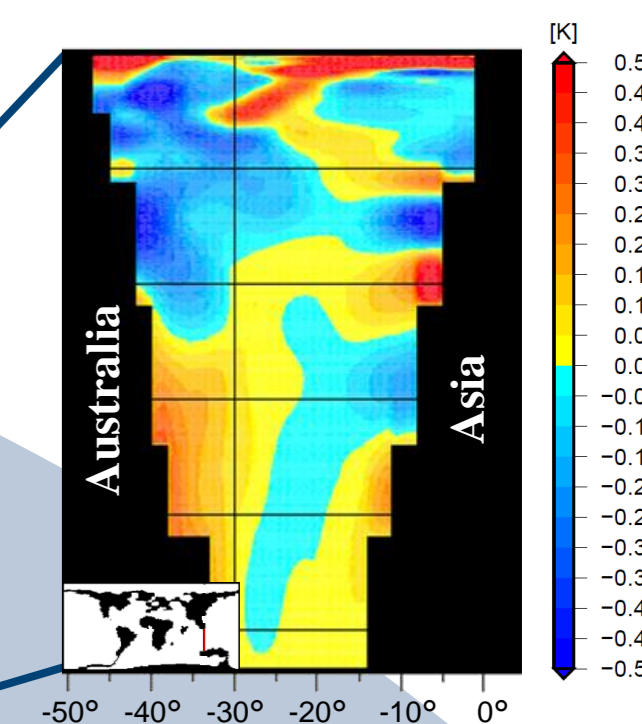


Figure 5: Difference in temperature between Early Eocene ocean simulations with and without tidal module

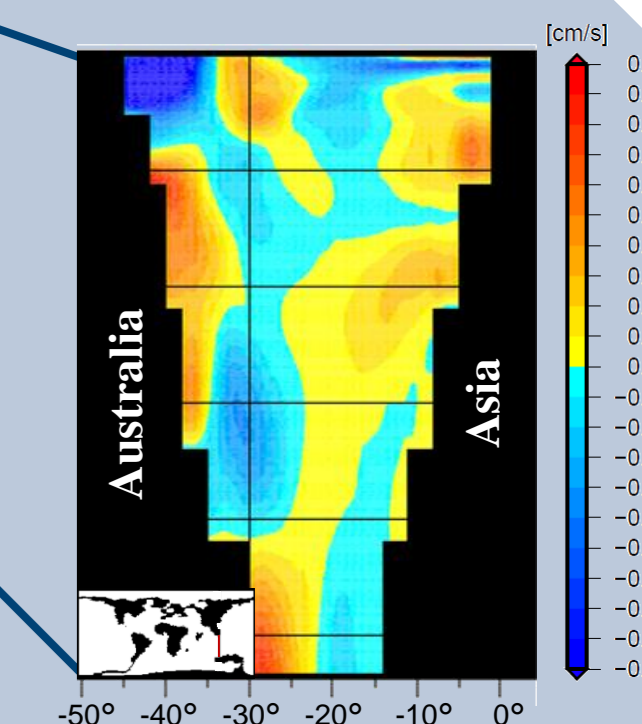


Figure 4: Difference in zonal velocity between Early Eocene ocean simulations with and without tidal module

Acknowledgements

We thank Helmut Haak for his help setting up the ocean model for PI and EE runs. We are also grateful to Jacob O. Sewall for the boundary conditions for the EE run. The model experiments were carried out on the supercomputing system of the German Climate Computation Centre (DKRZ) Hamburg. This study is funded by the Deutsche Forschungsgemeinschaft (DFG) as part of the priority program SPP 1375 SAMPLE (South Atlantic Margin Processes and Links with onshore Evolution).

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