Is the Eocene's climate affected by ocean tides?

Tobias Weber[1,2], Maik Thomas[1,2]

(1) Helmholtz Centre Potsdam, GFZ German Research Centre For Geosciences, Potsdam, Germany
(2) Institute of Meteorology, Freie Universität Berlin, Berlin, Germany

www.gfz-potsdam.de
tobias.weber@gfz-potsdam.de

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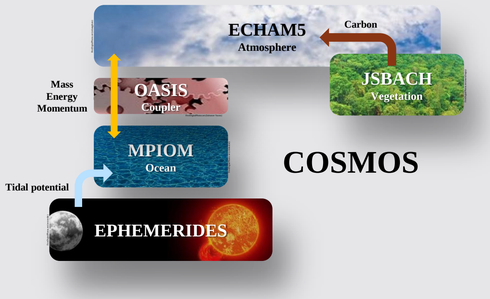
South Atlantic Margin Processes and Links with onshore Evolution

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.

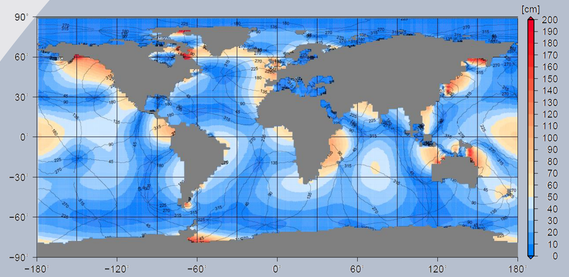


Figure 1: Amplitude and phase of the M2-Tide in the pre-industrial run.

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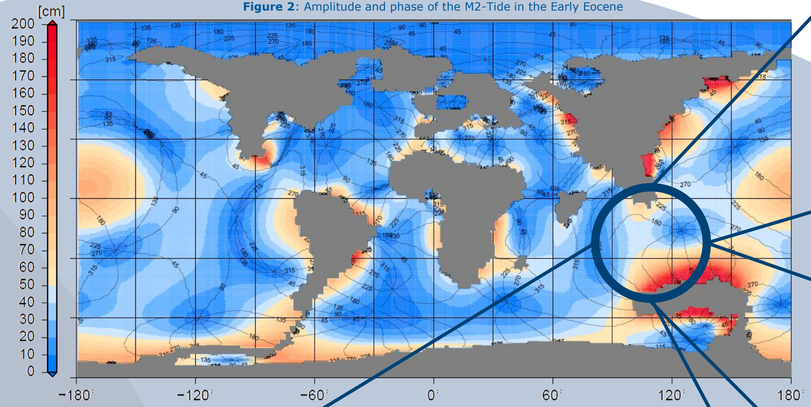
5. Outlook

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



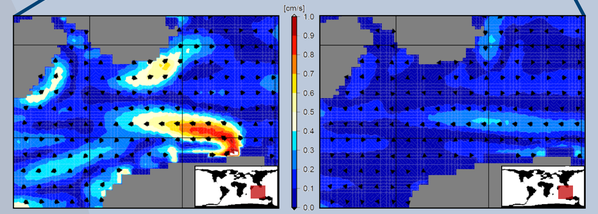


Figure 3: Horizontal velocities of the Early Eocene ocean model run at 1750m depth with (left) and without (right) inclusion of the tidal module

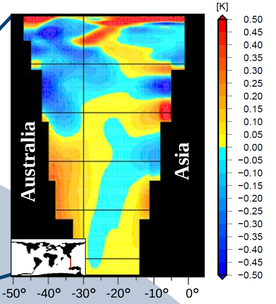


Figure 5: Difference in temperature between Early Eocene ocean simulations with and without tidal module

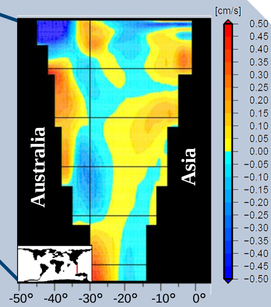


Figure 4: Difference in zonal velocity between Early Eocene ocean simulations with and without tidal module

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