GeOGEM

DFG Project
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Simulations to the tides of ancient oceans and the evolution of the Earth-Moon-system

P. Nerge, University of Hamburg; Prof. T. Ludwig, University of Hamburg; Prof. M. Thomas, GFZ German Research Centre for Geosciences; Dr. J. Jungclaus, Max Planck Institute for Meteorology; Prof. J. Sündermann, University of Hamburg, Prof. P. Brosche, University of Bonn

Contact: petra.nerge@informatik.uni-hamburg.de

Abstract

The angular momentum transfer in the Earth-Moon system is mainly determined by the ocean tides and closely interlinked with their resonance characteristics (e.g. Brosche and Sündermann, 1971; Thomas and Sündermann, 1999). The latter are considerably presupposed by the topography of the ocean basins which has changed significantly in the Earth's history.

For the current epoch astronomic and geodetic observations confirm a secular increase of the length of day of ca. 2 ms/century and a lunar recession rate of ca. 4 cm/year (Williams, J.D., et al., 2008), which equals a decrease of Earth's rotational energy of ca. $4 \cdot 10^{12}$ W. The limited availability of geological proxy data has so far prevented a detailed quantification of the transfer of angular momentum in the Earth-Moon-system far back in the Earth's history. Considering recent palaeontological data and advances in computing science the project GeOGEM, funded by the German Research Foundation (DFG), will strive to reduce these deficits.

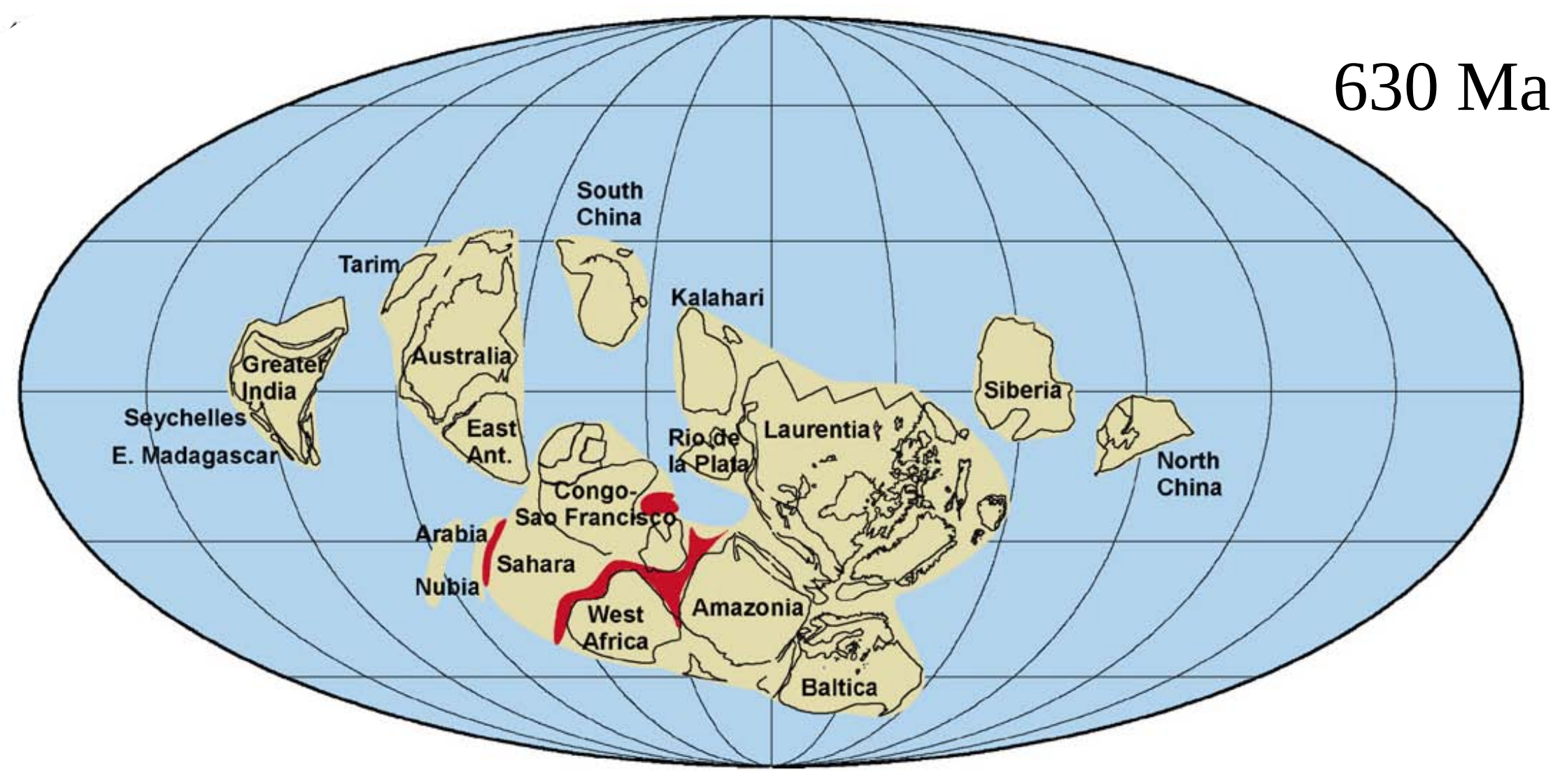
Firstly, self-consistent geological data on ocean tides, Earth's rotational parameters and orbital elements of the Moon have been provided by the research of Williams (2000) on the sediment layers of South Australia for the Neoproterozoic ~620 Ma back. For this time slice we will reconstruct the spatial and temporal characteristics of the tides by means of simulations with the three-dimensional Max-Planck-Institute-Ocean circulation model MPI-OM forced by the complete tidal potential expressed by the ephemerides. The numerical results will be evaluated with the recent geological proxy data.

Subsequently, the evolution of the ocean tides under the influence of the continental drift from the Neoproterozoic till today will be simulated. In this process a focus will be on the transfer of angular momentum between Earth and Moon in order to explain physically the geological proxy data.

Starting Point

Maps of the Neoproterozoic, Li et al. (2008)

- Synthesis on the formation (1300 Ma – 900 Ma) and break-up (<600 Ma) of the supercontinent Rodinia.
- 530 Ma formation of Gondwanaland completed.
- Based on palaeomagnetic constraints and on geological correlations.



Maps of the Phanerozoic

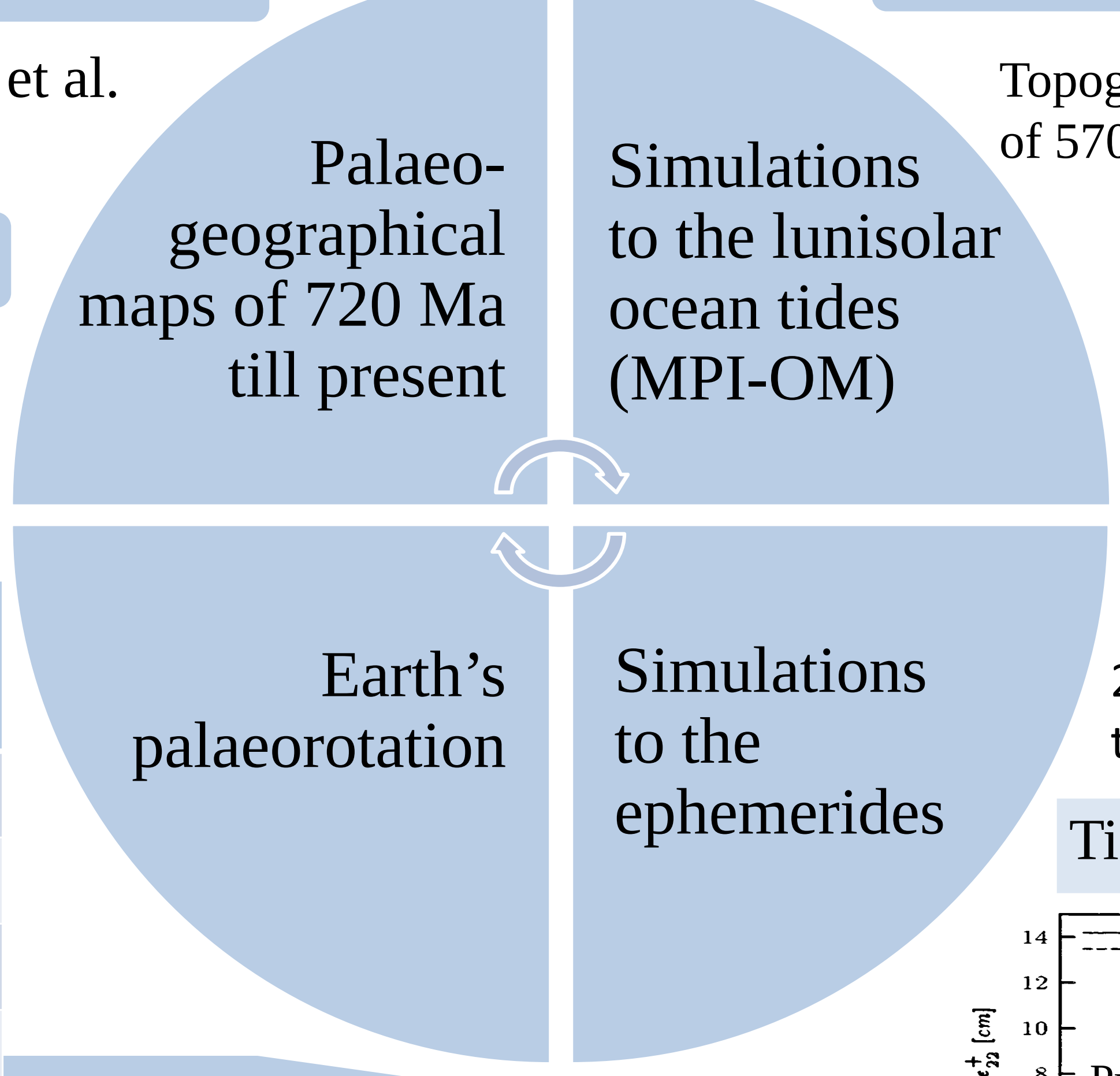
- Li and Powell (2001), Schettino and Scotese (2005), Müller et al. (2008) and the Paleomap Project of C. R. Scotese.

Palaeobathymetry

- The shelf and the ocean will be taken into consideration as well as possible (Williams, G.E., et al., 2008; Li and Powell, 2001).

Palaeorotation parameters, Williams (2000)	~620 Ma	Present
Lunar days per synodic month	29.5 ± 0.5	28.53
Solar days per synodic month	30.5 ± 0.5	29.53
Solar day per sidereal month	28.3 ± 0.5	27.32
Synodic months per year	13.1 ± 0.1	12.37
Sidereal months per year	14.1 ± 0.1	13.37
Lunar apsides periode [a]	9.7 ± 0.1	8.85
Lunar nodal periode [a]	19.5 ± 0.1	18.61
Solar days per year	400 ± 7	365.24
Length of solar day [h]	21.9 ± 0.4	24.00
Lunar semimajor axis [R_E]	58.16 ± 0.30	60.27

- Analysis of sedimentary rhythmites from South Australia
- 60-year record of 1580 neap-spring cycles
- 4.2-year record of 1337 diurnal laminae from 110 neap-spring cycles



Palaeo-geographical maps of 720 Ma till present

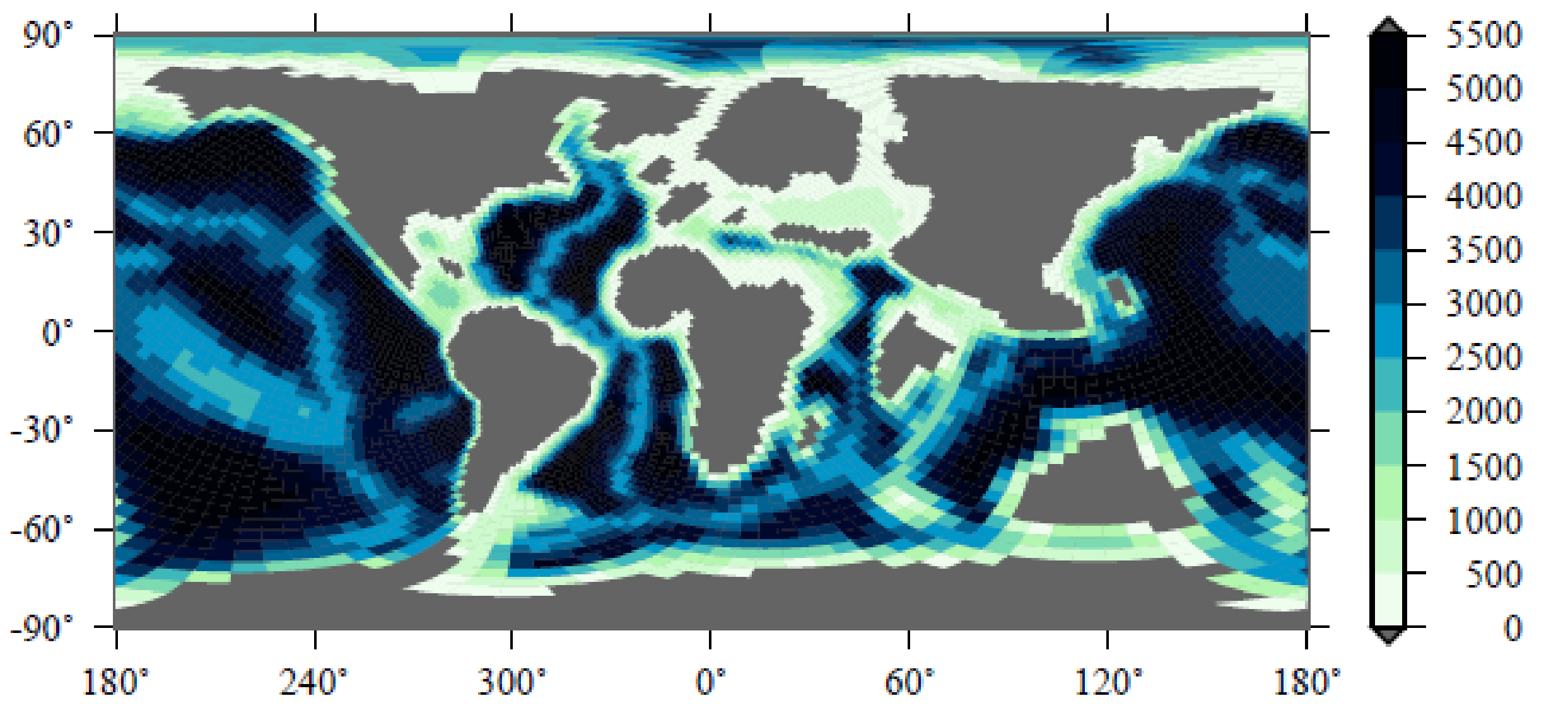
Simulations to the lunisolar ocean tides (MPI-OM)

Earth's palaeorotation

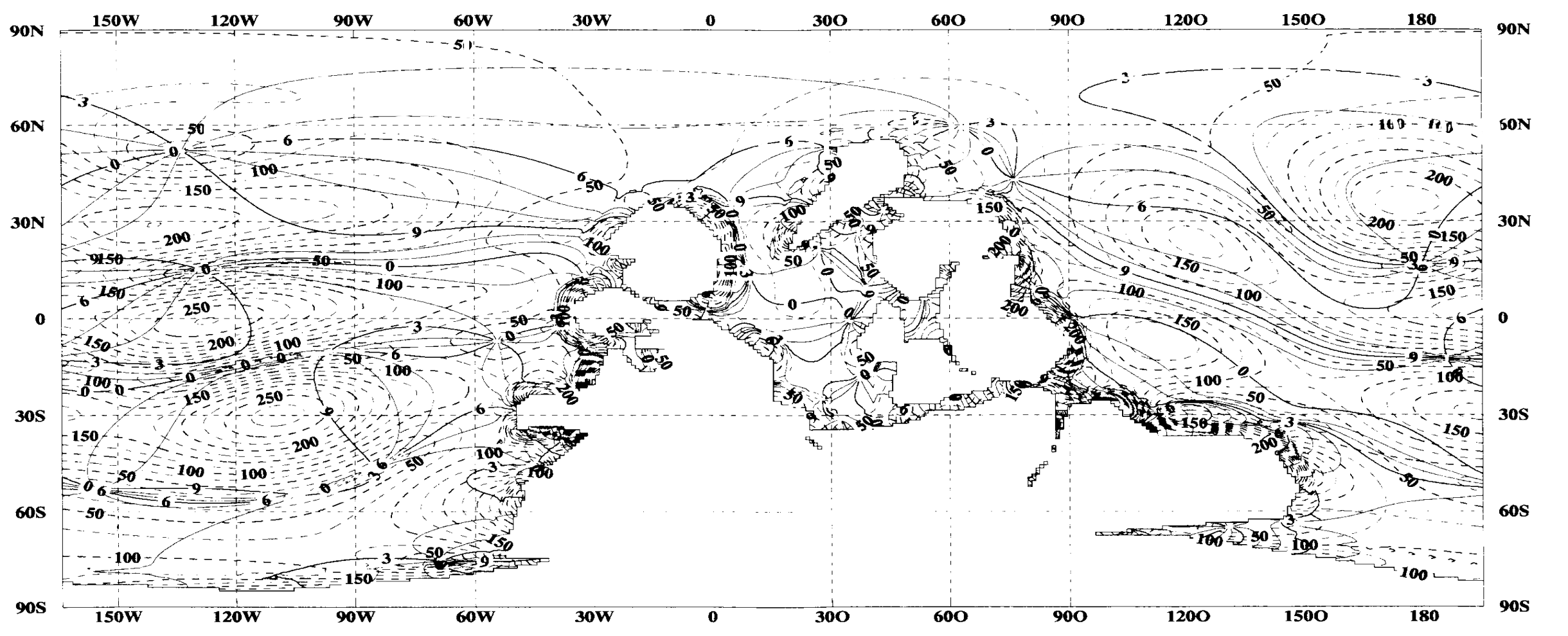
Simulations to the ephemerides

Palaeobathymetry of 55 Ma as used in MPI-OM, Heinemann et al. (2009)

- Grid-North Pole on Palaeo-Asia, grid-South Pole on Palaeo-South America.
- The grid poles are freely selectable in MPI-OM.
- Therefore we can efficiently increase the resolution around Australia for the evaluation of the results.

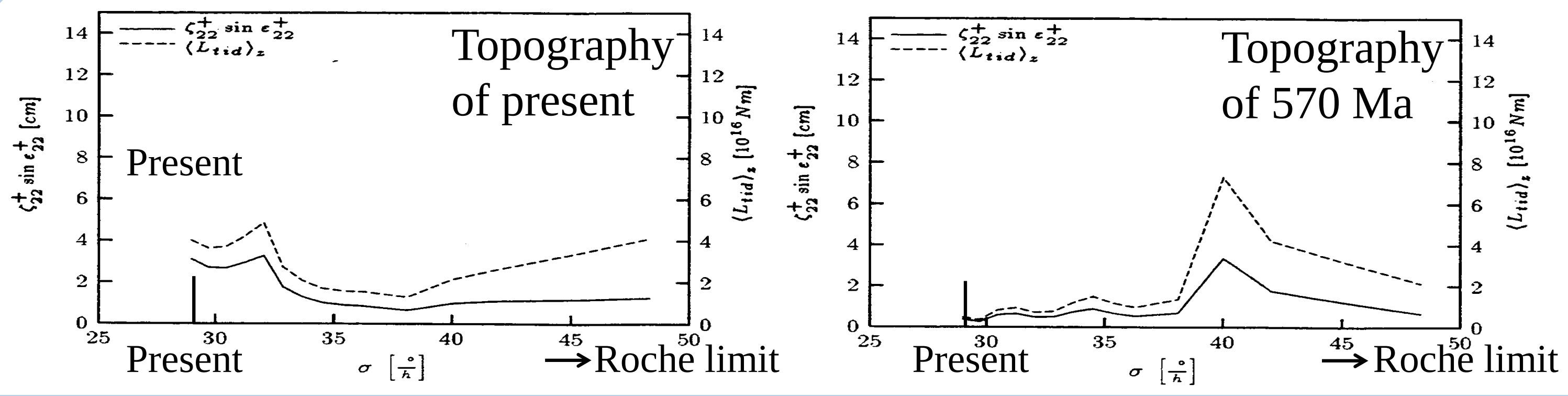


M_2 ocean tide for topographies of the Proterozoic, Nerge (1998)



—— Isocline of the phase in 30° intervals, - - - Isocline of the amplitude in 25 cm intervals, max. $\langle L_{tid} \rangle_z = 7.1 \cdot 10^{16}$ Nm at $T_{M2} = 8.99$ h ($\langle L_{tid} \rangle_z$: Mean tidal torque along the Earth's rotation axis, T_{M2}: Period of the M_2 tide)

Tidal torque in relation to the angular velocity σ of the M_2 tide



Ephemerides

- Astronomical computation of the insolation quantities on Earth spanning from -250 Ma to 250 Ma (Laskar, 2004).
- This ephemerides model we would like to enhance with our result and the geological data (Laskar, pers. comm.).

Outlook

Earth's system research

One considerably denser reconstruction of the tidal dynamic from Neoproterozoic till present and an important component of the evolution of the Earth-Moon system

Geodesy and Astronomy e.g.

Energy and angular momentum budgets for the evolution of the Earth-Moon system - Dissipative effects by tidal friction are one of the main uncertainties.

Geology e.g.

Analysis of periodic growth features or sedimentary rhythmites

The oceanographic data and the ensuing data to the celestial mechanics will be stored and made available at German Climate Computing Center (DKRZ).

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Acknowledgement

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