Back to the future 3: Analysing tectonically induced tidal resonance with conceptual models

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Introduction

This work is the third iteration of a project to couple tectonics and tides over geological timescales, using GPlates and OTIS. It is known that the present day Atlantic tide is larger than the historical average because it is near half wavelength resonance for the M_2 tide (Green et al., 2017). We have hypothesised that these periods of enhanced global tidal dissipation will occur in the future as oceans form, open and close as part of their Wilson cycles, which is intrinsically linked to the Supercontinent cycle (Davies et al., 2020). In the present work, we aim to establish the true relationship between the tides and the orbital and tectonic state of a planet by simulating the tide on a conceptual "Earth.

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Aim: To establish the relationship between tectonics and tides conceptually.

Goals:

Tidally analyse a simplified "Earth" by altering the variables listed below:

- Ocean depth (400 m, 4000 m, 10 000 m)
- Day length (3 h, 24 h, 72 h) – and thereby M_2 period (1.5 h, 12.42 h, 40.4 h)
- Ocean bathymetry - "Bathtub" and "Bathtub with shelves"

Model set up:

- Two rectangular continents which represent 33% of Earth surface area.
- Interior ocean set to width of "half wavelength resonance (L)"
  Where $L = (gh)^{0.5}\,T$ where $g = 9.81\ ms^{-2}$ h = water depth, and T = tidal period (12.42 h).
- First set simulated with bathtub ocean bathymetry: ocean depth and day length varying between sets.
- Second set with bathtub and continental shelves on internal ocean: ocean depth and day length varying between sets.
- I am happy to discuss the methods in more detail during the online discussion!

Results:

- Dissipation is higher in almost all cases of ocean depth and day length when a shelf is included in the simulations.
- Present day ocean depth and day length appears to result in the highest dissipation (close to "present day" illustrated as a dashed line on figures 3 and 4).
- Shallow ocean and fast rotation simulations have lower dissipation than the present day or 72 hour simulations.
- Deep ocean and slow rotation simulations have lower dissipation than present day, however the inclusion of shelves reduces the effect.

Motivation

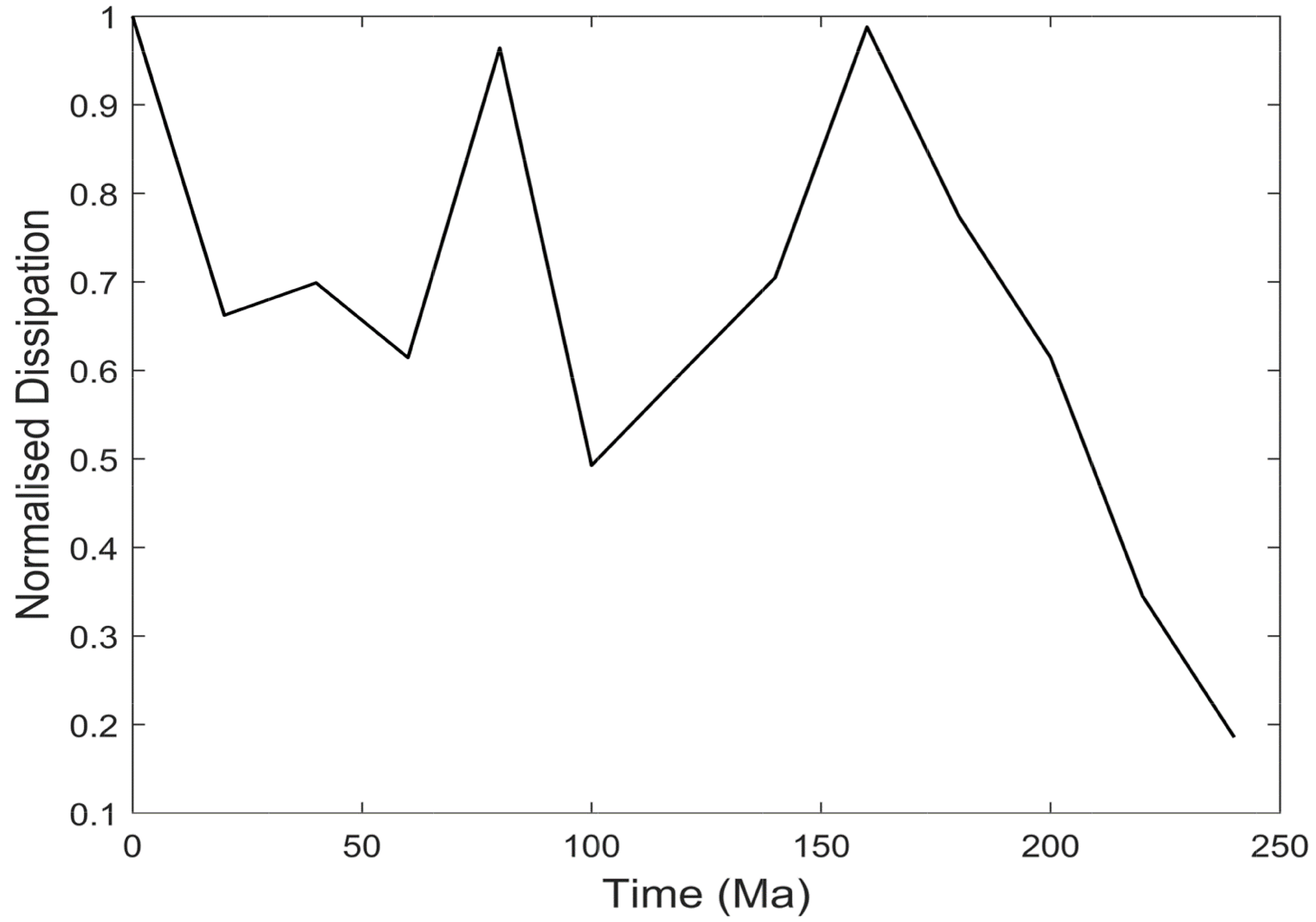


Fig 1. Averaged total global tidal dissipation (normalised to the present day global total dissipation) for the next 250 Myr of Earth's future. The graph shows peaks and troughs as the Earth moves in and out of "Super-tidal" periods as the supercontinent cycle progresses (Davies et al., 2020).

Model design

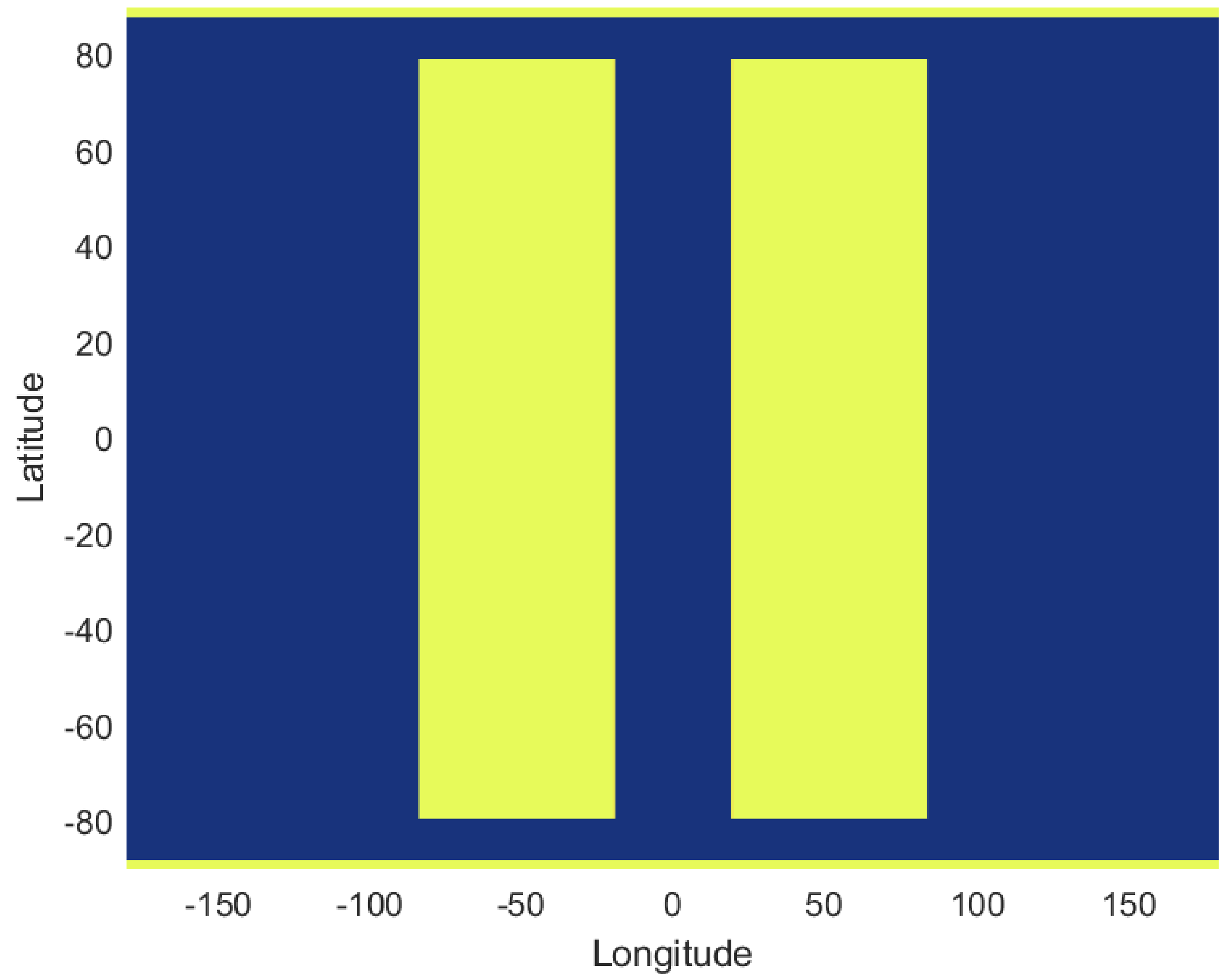
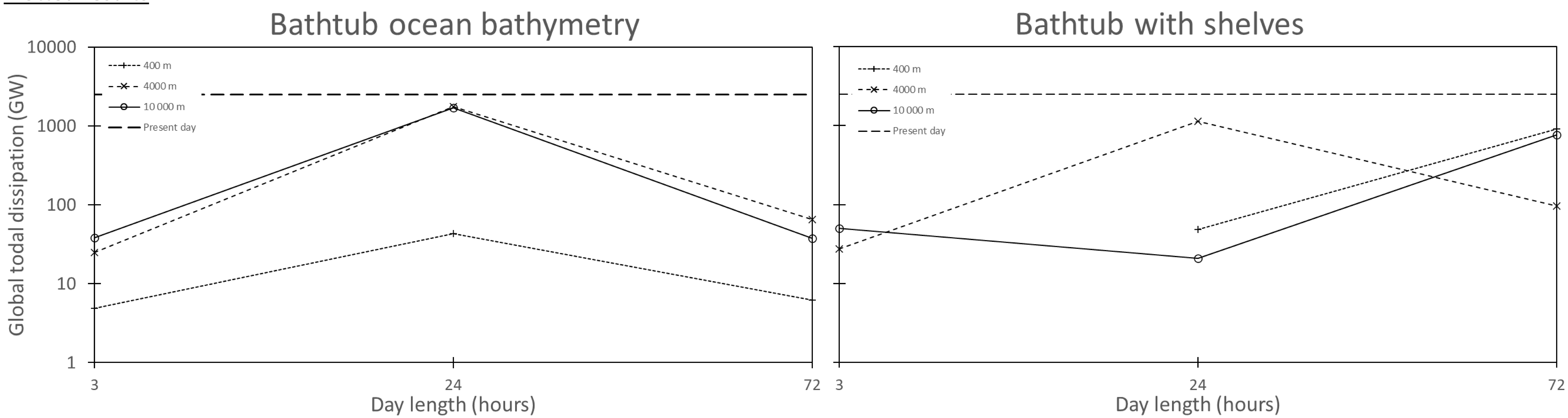


Fig 2. A plot of a conceptual "Earth" used in the simulations. The ocean is a uniform 4000 m and the interior ocean is set to half wavelength resonance width for 4000 m deep oceans and 12.42 hour M_2 period.

Plotted results



Figs 3 & 4. Global total M_2 tidal dissipation for a collection of simulations with varying ocean depths (400 m, 4000 m, and 10 000 m) and day lengths/M_2 tidal dissipation (3 h/1.5 h, 24 h/12.42 h, and 72 h/40.4 h) the simulations are divided into an ensemble with "bathtub" ocean bathymetry and "bathtub" ocean bathymetry with continental shelves on the internal ocean coasts.

Acknowledgements

H. Davies: FCT- project UIDB/50019/2020 – IDL & Earthsystem PhD Program grant PD/BD/135068/2017.
J. A. Mattias Green: NERC (MATCH, NE/S009566/1),
J. Duarte: FCT Researcher Contract IF/00702/2015.
Simulations were done on Supercomputing Wales
Further thanks to: C. Scotese, S. Balbus, F. Rosas, M. Pacheco

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