The impact of continents on the tidal energy dissipation of ocean planets

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Problem

As observed on Earth, where they represent 95% of the present day tidally dissipated energy, surface oceans primarily drive the long-term evolution of planetary systems. Besides, the associated tidal heating may have an impact on planetary climates and surface conditions. Whereas continents strongly affect the oceanic tidal response, their role has not been fully elucidated yet. The present analysis is a first attempt to characterise this role by showing how the oceanic tide varies with the continental size and position on the globe.

Physical setup

- Thin ocean basin of uniform depth H.
- Single continent of radius θ_c and latitude $\hat{\theta}_S$.
- Linear drag of coefficient σ_R.
- Visco-elastic solid regions (Andrade model).
- Point-mass tidal perturber.

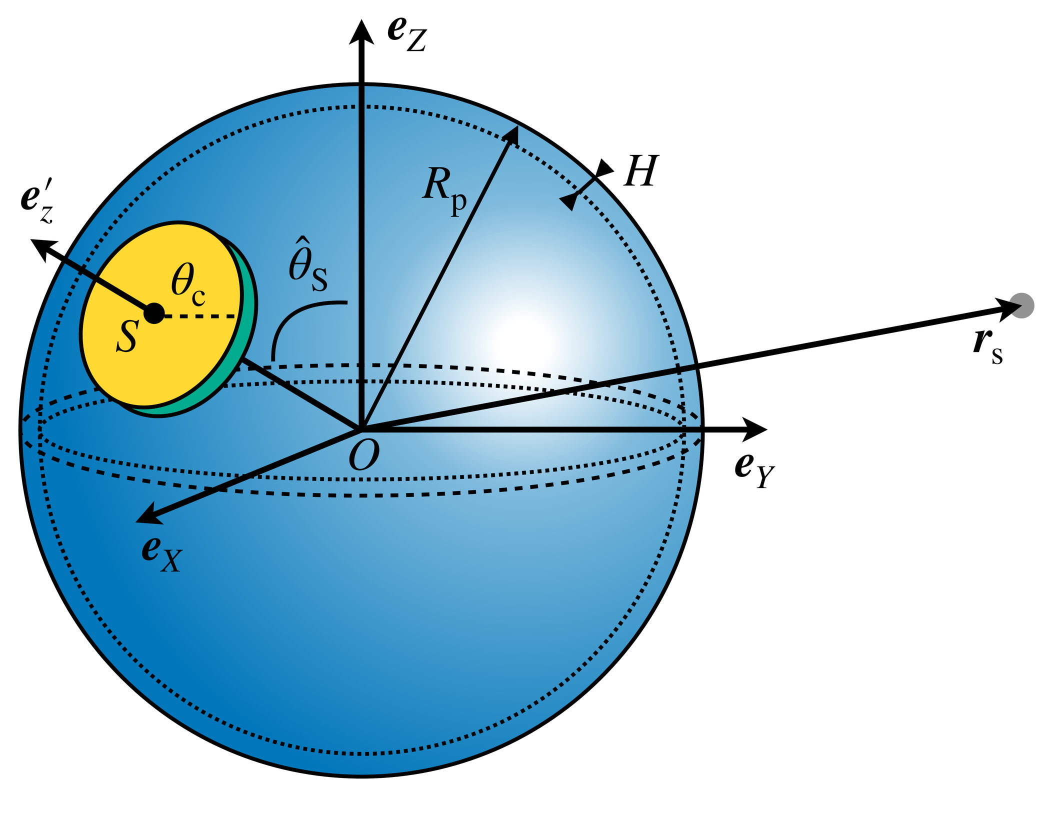

Figure 1: Studied planet-perturber system.

Conclusions

Continents leads to:

- symmetry breaking effects;
- attenuated resonant peaks (~3 times lower);
- more resonant peaks;
- no qualitative change in the response if they are smaller than South America ($\theta_c < 30°$).

Table 1: Variations of the spectral features of the k_2^2 Love number as $\hat{\theta}_S$, θ_c, H or σ_R increases.

Altered features	$\hat{\theta}_S$	θ_c	H	σ_R
Peak frequencies	–	↗	↗	–
Peak heights	–	–	↗	↘
Peak widths	–	–	–	↗
Background	–	–	–	↗
Spectral irregularity	↗	↗	–	↘

Reference

[1] Pierre Auclair-Desrotour, Mohammad Farhat, Gwenaël Boué, Mickaël Gastineau, Jacques Laskar, *Can one hear supercontinents in the tides of ocean planets?*, 2023, A&A, 680, A13

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Method

- Laplace's tidal equations (LTEs):

$$\partial_t \boldsymbol{V} + \sigma_R \boldsymbol{V} + \boldsymbol{f} \times \boldsymbol{V} + g\nabla\left(\Gamma_D \zeta - \Gamma_T \zeta_{eq}\right) = 0,$$
$$\partial_t \zeta + \nabla \cdot (H\boldsymbol{V}) = 0.$$

- LTEs solved using a spectral method.
- Explicitly defined basin modes.
- Solution written as a series of excited modes.
- Numerical calculations with ~900 modes.

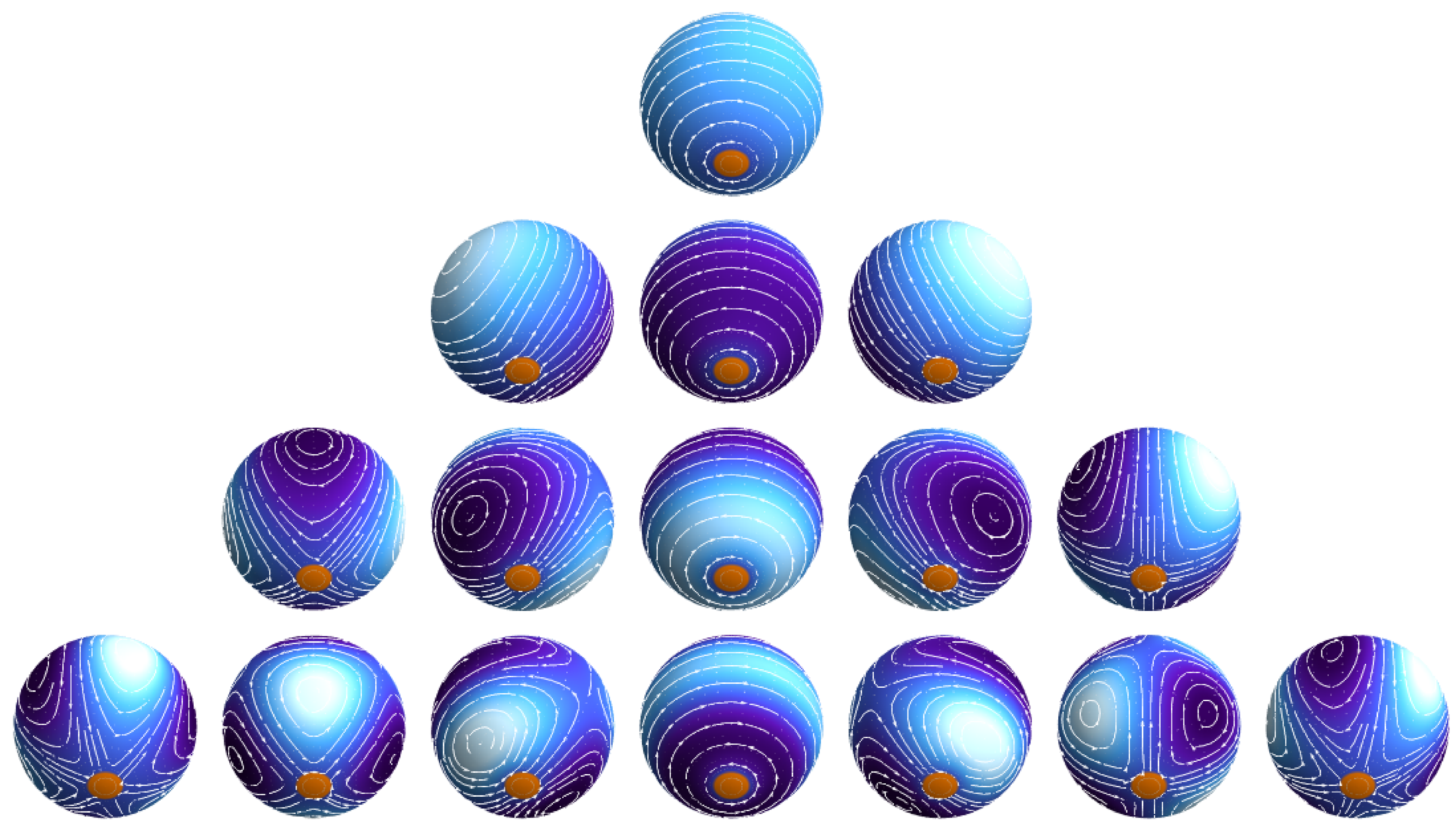

Figure 2: Ocean normal modes of degrees $n = 0, \ldots, 3$ for a 20°-large continent.

Frequency spectra of the semidiurnal tidal Love number

- Resonantly excited modes enhance the tidally dissipated energy.
- Sharp transitions observed between polar and non-polar configurations, and between small and medium-sized continents.

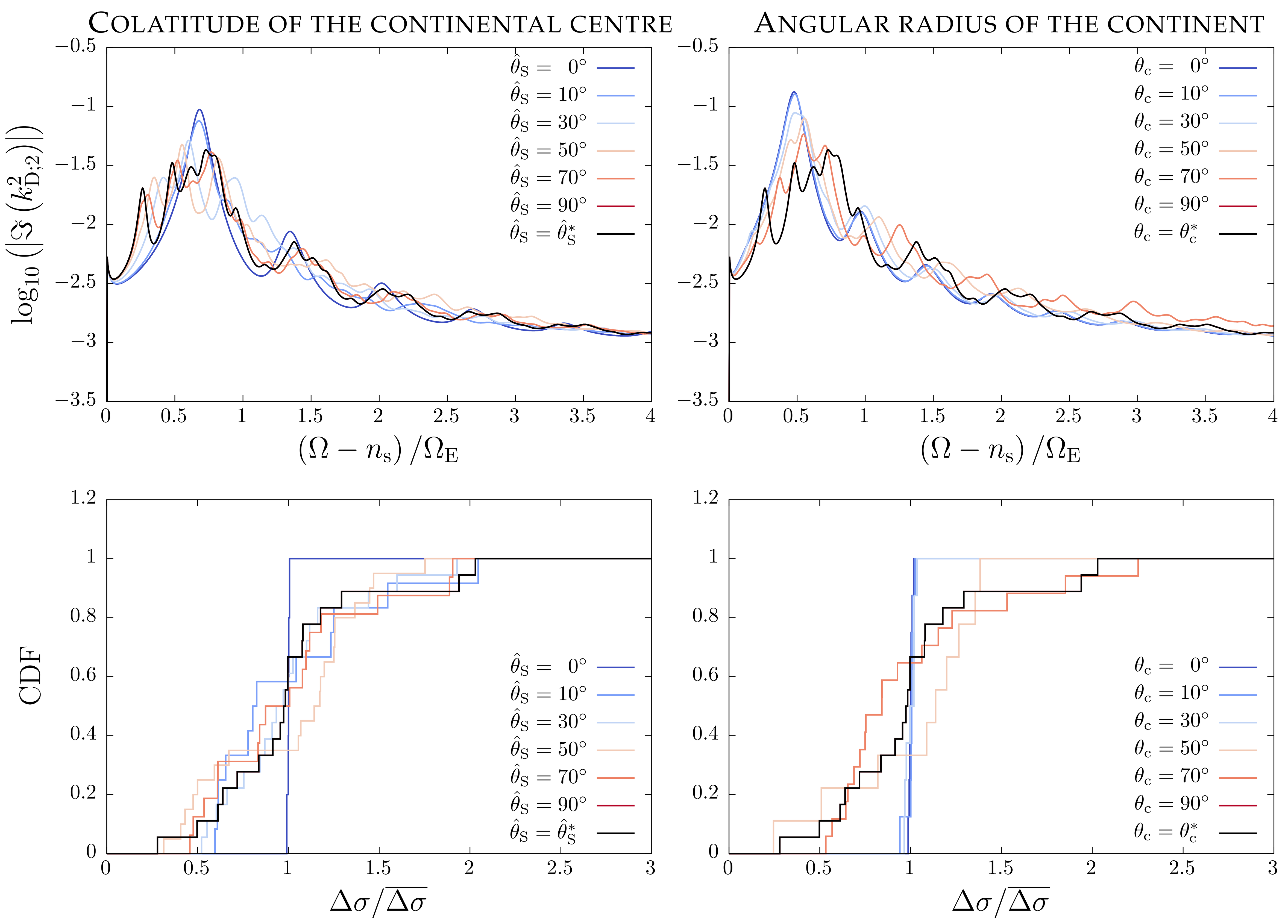

Figure 3: *Top:* Imaginary part of the semidiurnal tidal Love number as a function of the normalised tidal frequency for various values of the continental latitude (left) or size (right). *Bottom:* Cumulated distribution functions of the frequency intervals separating two consecutive maxima in the spectra ($\Delta\sigma$). The notation Ω designates the planet's spin angular velocity, n_s the mean motion of the satellite, and Ω_E the Earth present spin angular velocity.

Acknowledgements

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