National Aeronautics and Space Administration

Postdoc Research

Tidal seismicity in the silicate interior of Europa

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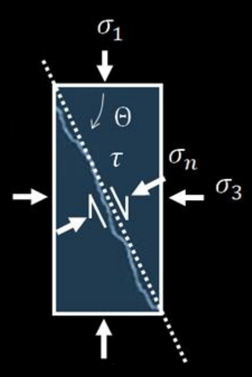
Background

Seismology is a powerful tool to **probe the interior of planetary bodies**. Most of the knowledge on the Earth interior comes from it, and the NASA InSight mission successfully probed the deep interior of Mars with a single station on its surface. The Apollo seismometers on the Earth's Moon surface have measured **numerous seismic events driven by the Earth tides** deep in the lunar mantle, **providing information on the deep structure of the Moon**. Such tidally-driven events may occur on icy moons of giant planets, such as **Europa**, one of the most promising, potentially habitable world in the Solar System.

Objectives:
- **Are deep tidal quakes likely to occur inside Europa?**
- **What information on Europa's interior structure could their detection provide?**

Approach and results

- Full 3D tidal response of the moons along their complete orbit
- State-of-the-art models of the Moon for validation
- Self-consistent Europa models using PlanetProfile [1] from JPL
- Mohr-Coulomb failure criterion for estimating likelihood of quakes



Mohr Coulomb failure criterion. Failure is reached when shear stress τ dominates normal stress σ_n and cohesion.

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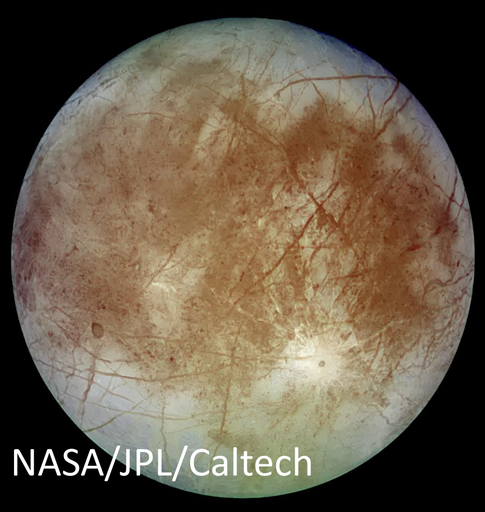

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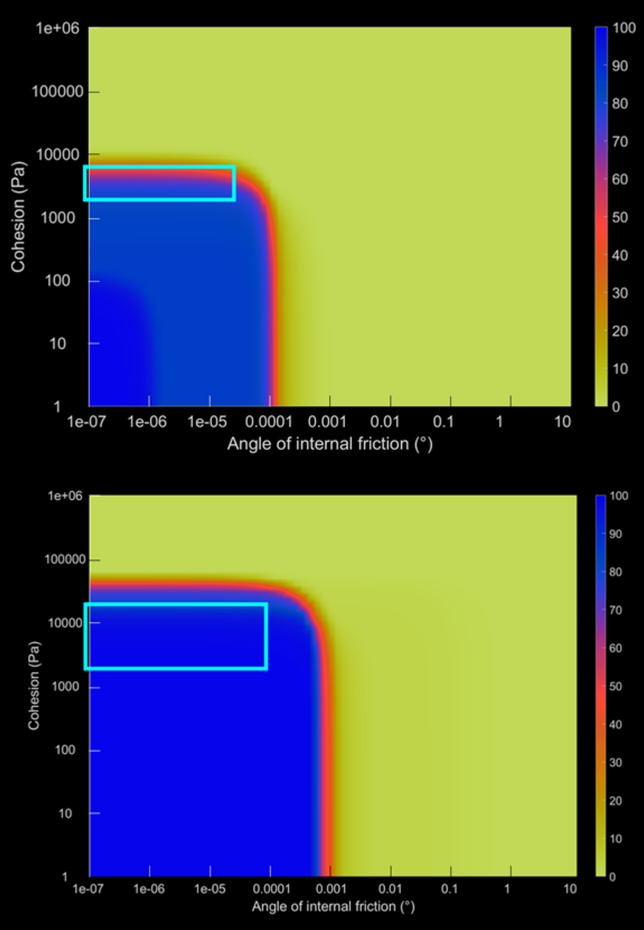
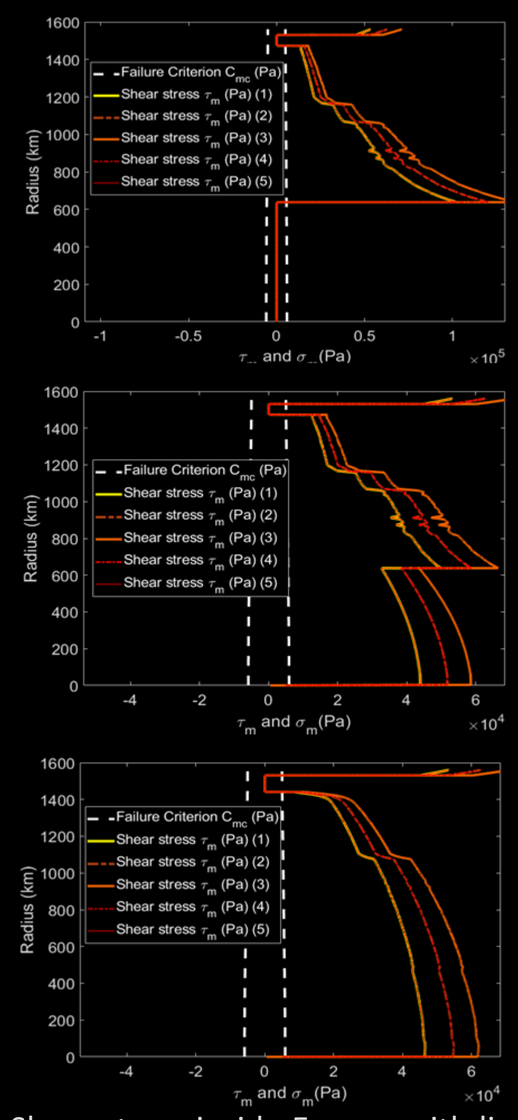


Failure map for the Moon **(top)** and Europa **(bottom)**. Moon model shown is assuming a solid inner core. Europa model shown is with a liquid core.
Red box is for replicating depth of observed deep moonquakes.



Shear stress inside Europa with liquid core **(top)**, solid core **(middle)** and no metallic core **(bottom)**.

Significance

Europa interior	Likelihood of quakes	Max. event strength	Favored locations
Liquid core	Yes (10x Moon)	Strongest (1 bar)	Core-mantle boundary (CMB)
Solid core	Yes (10x Moon)	Medium (0.5 bar)	CMB, Bottom of ocean floor
No metallic core	Yes (10x Moon)	Medium (0.5 bar)	1/3 of mantle deep

Europa is likely to have deep tidal quakes
Their strength and location depend on the interior structure of Europa
These events may be detectable by a surface seismometer [2]: **Strong argument for a future seismic mission to Europa [3]**

Future works

- Generation of simulated seismic waveforms, propagation to Europa's surface, and inversion
- Potential application to Titan, Enceladus, and other icy moons
- Ongoing discussion with Dragonfly, Martian Moons eXplorer, Farside Seismic Suite, Hera missions; Presentations at LPSC [4] and AGU [5] international conferences and seminars with Earth seismologists

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[1] M. J. Styczinski et al., 2023 (in rev) [2] A. Marusiak et al. 2022, Earth Space Sci. 9 [3] L. Pou, et al. 2023 (in prep) [4] L. Pou, et al. 2023, LPSC 2023 [5] L. Pou, et al. 2023 (submitted for AGU Fall Meeting 2023)

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