How to design continents for maximum tides

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The shape and size of continents control the size of ocean tides on Earth-like planets, according to a new study that simulated the effects of random continental configurations on the energy of tides. The results have implications for Earth's early history as well as the search for habitable planets beyond the solar system.

Modern day Earth's arrangement of continents creates large tides at the extreme end of what is possible for Earth-like planets, according to the researchers.

"Earth's current tides are the biggest we've found in 750 million years. I certainly think the tides now may be among the biggest in Earth's history," said Mattias Green, an oceanographer at Bangor University in Wales, the United Kingdom, and an author of the new study in AGU's journal *Geophysical Research Letters*.

The width of an ocean basin controls the magnitude of the tides contained in it. The current Atlantic Ocean happens to be the perfect size and shape to produce large tides.

"The Atlantic is an almost perfectly tuned organ pipe for the tide. It resonates," Green said, amplifying the tidal energy and making tides higher. Although the Pacific Ocean is larger than the Atlantic, its tides are smaller, because, Green said, "the Pacific is poorly tuned."

Tides influence life on Earth by stirring the oceans, moving nutrients and distributing heat. On a long timescale, tides slow the speed of a planet's rotation. Eventually, planets become tidally locked to their stars, with the same face always in sunlight.

Because tectonic activity constantly remodels Earth's surface, the size of its tides has varied widely over repeated cycles of supercontinent formation and break-up.

Testing tidal limits

The new study investigated the upper and lower limits of tides on Earth-like planets by simulating 123 different topographies, from waterworlds to present day Earth to planets with tiny oceans covering only 10% of their surfaces (about the size of the Arctic Ocean).

The range in in energy conveyed by tides was larger than the researchers expected, Green said, extending over three orders of magnitude due to continental complexity alone. Tides on Earth today are 1,000 times more energetic than on an ocean world of the same size, according to the new study.

"If you're just one big ocean it's difficult to have a big tide. Adding one New Zealand-sized continent doesn't make much difference, but add a couple New Zealands and you get tides 100 times more energetic," Green said.

Tides on Earth are generated, primarily, by the pull of the moon's gravity. If the seabed were perfectly frictionless, and there were no continents to get in the way, Earth would spin smoothly under the bulge of water, which would always align with the moon.

"The key thing is that there is friction between the ocean and land. If we didn't have that, the tidal bulge would point directly at the moon," Green said. "We don't have high tide when the moon is directly overhead, and that lag is what slows Earth's spin and pushes the moon away."

Tides don't peak when the moon is directly overhead because the viscosity of the water and friction against solid ground resist the relative motion of the water. Friction causes the release of tidal energy. The bulge of water lags behind the moon, and this lag creates drag on Earth's rotation, which has been slowing throughout its 4-billion-year history. Near the end of the time of dinosaurs, 70 million years ago, Earth's day was only 23.5 hours long.

Modeling exoplanets

Day length is important to scientists studying exoplanets because it has huge consequences for climate and habitability. Planets that rotate very slowly, like Venus, have deep temperature contrasts between their sunward and spaceward facing hemispheres. This could be good or bad news for the possibility of life on the planet, depending on the proximity of its sun.

But the rotation of distant planets is difficult to observe directly. Astronomers have proposed estimates based on size, age and water content. Green said the new study sets useful bounds for such models when considering how fast tides can slow spin.

"Planets may spin down a lot quicker than we think," he said.

More information: B. W. Blackledge et al. Tides on Other Earths: Implications for Exoplanet and Palaeo-Tidal Simulations, *Geophysical Research Letters* (2020). DOI: 10.1029/2019GL085746

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