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LAIDLAW SCHOLARS

The Ocean Dynamics Of Icy Moons

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Introduction

Europa is a moon of Jupiter that hosts a deep ocean of water underneath an ice crust. We expect there to be on average, 80km of water, and 20km of ice.

The combined ice-ocean dynamics were simulated, with attention paid to the effects of the ocean floor's temperature profile, and the effects of the ice topology (or shape) on the system.

Pinning down the ocean dynamics, and salt transport in the ocean could be instrumental in determining Europa's habitability for life.

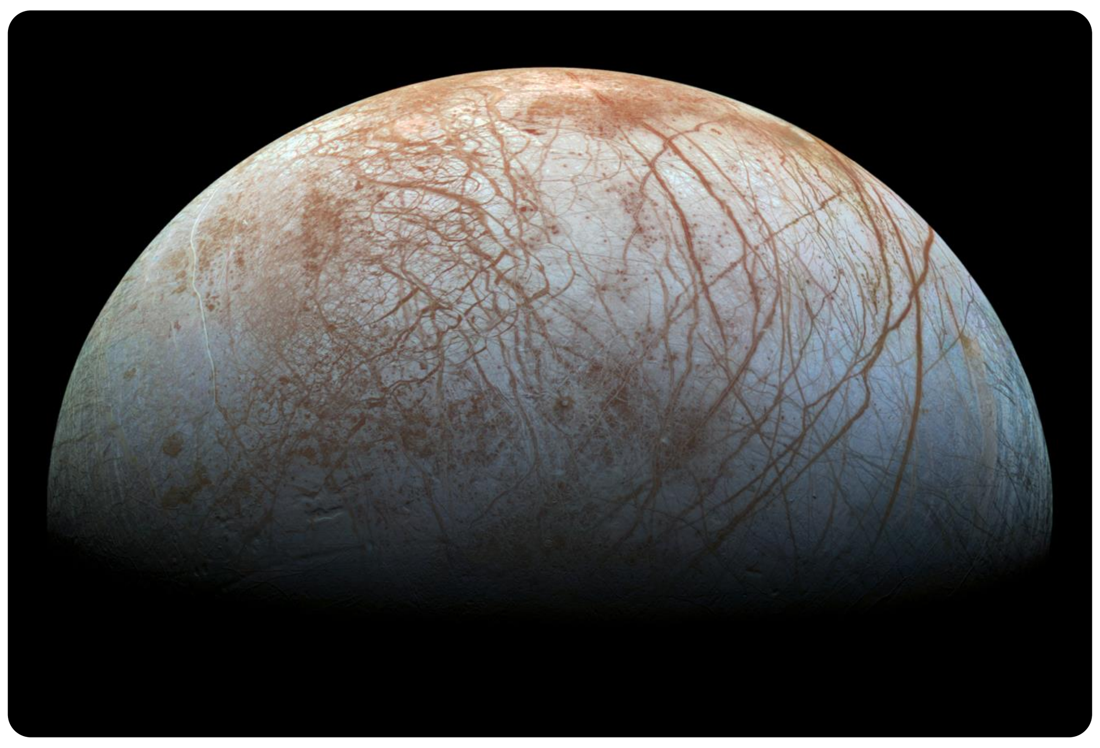

Fig 1: An image of Europa. Image credited to NASA/JPL-Caltech.

Convection In The Ocean

Europa experiences varying gravitational forces from Jupiter as its orbit is not perfectly circular. This causes the planet to deform.

Frictional forces within the moon results in a temperature variation on its ocean floor.

The density of a fluid decreases at higher temperatures, resulting in an instability where hot fluid rises and cold fluid falls.

Depending on the temperature profile at the bottom boundary (ocean floor), we see different types of instabilities.

We modelled a 2D equatorial cross section of the icy moon, and investigated how changing various parameters affects the ice-ocean dynamics.

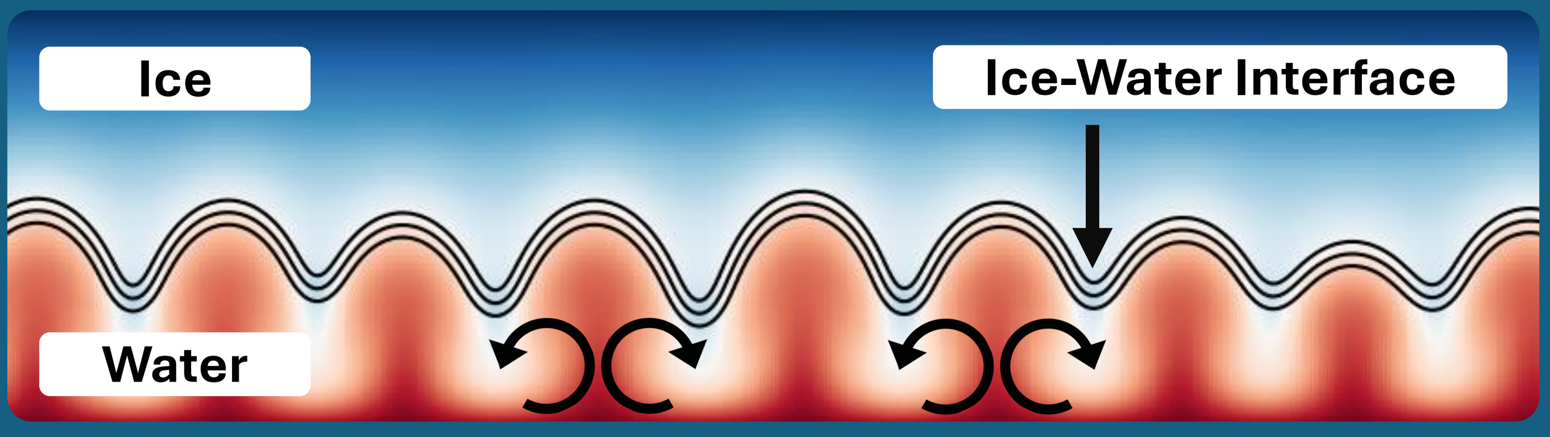

Fig 2: A Rayleigh-Bénard convection regime that requires a UNIFORM TEMPERATURE at the bottom boundary. The arrows in the water show examples of fluid flow.

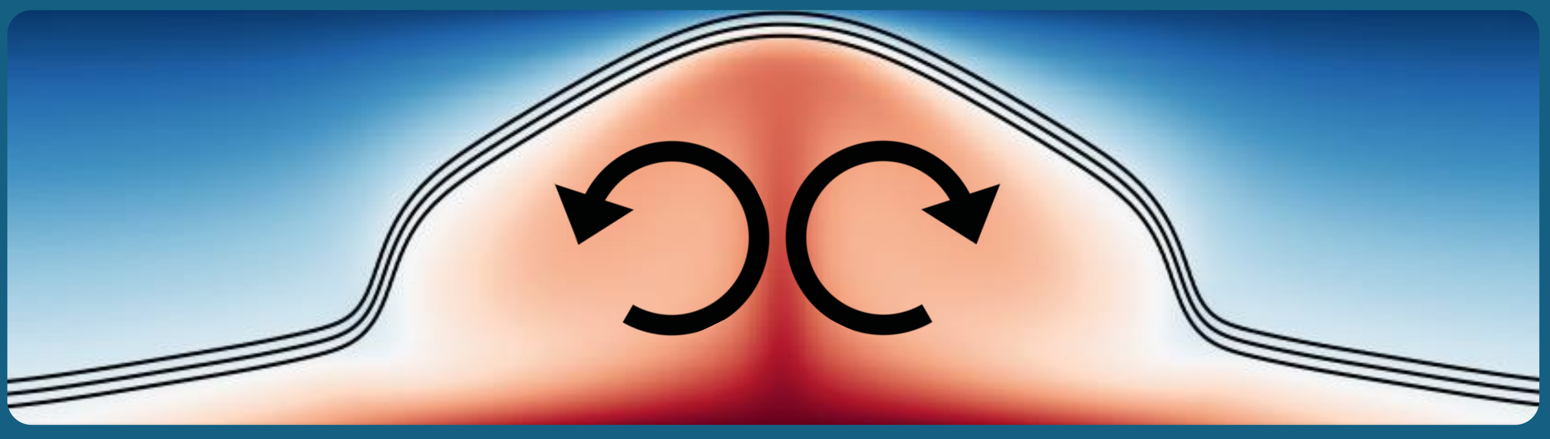

Fig 3: An example of what we define as Horizontal convection that requires VARIATIONS IN TEMPERATURE along the bottom boundary. The arrows in the water show examples of fluid flow.

Results

By systematically varying the initial boundary conditions of the system, we investigated how the fluid dynamics reacted.

At low temperature variations, we find that the system always prefers to be in a Rayleigh-Bénard regime. This holds despite varying the other parameters of the system.

At higher temperatures, we find that system exhibits both convection regimes, depending on the melting point of the ice. This was unusual as we wouldn't expect downward flowing fluid above regions of higher temperature.

Further experimentation showed that the initial ice-topology has a major impact on the evolution of the system and thus its final convection regime.

You can find more details in my report by following the link embedded in the QR code.

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