Internal Tides in the Oceans of Icy Moons

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Abstract

One of the most peculiar features on Saturn moon Enceladus is the so-called tiger stripe pattern near its south pole, as first observed in detail by the Cassini spacecraft early 2005. It is generally assumed that the four almost parallel surface lines that constitute this pattern are faults in the icy surface overlying a confined salty water reservoir. Indeed, later Cassini observations have shown that salty water jets are spawned from the faults.

The remarkable spatial regularity of Enceladus' southern polar region fault lines is reminiscent to that observed at the surface of confined stratified fluids by the action of induced internal waves. Both numerical simulations and water tank experiments indicate that wave attractors emerge in gravitationally (radial salt concentration or temperature differences) or rotationally stratified confined fluids as a function of forcing periodicity and fluid basin geometry.

The equations governing internal gravity waves in a stratified ideal fluid possess a Hamiltonian structure. A discontinuous Galerkin finite element method has been developed in which this Hamiltonian structure is discretized, resulting in conservation of phase space and of a discrete analog of energy. This required (1) the discretization of the Hamiltonian structure using alternating flux functions and symplectic time integration, (2) the discretization of a divergence-free velocity field using Dirac's theory of constraints and (3) the handling of the large-scale computational demands due to the three-dimensional nature of internal gravity waves and possibly its narrow zones of attraction.
Laboratory experiments on quasi two-dimensional wave attractors were performed. The forces exerted by wave attractors at the surface a gravitationally stratified fluid were measured. These measurements showed an intensification of wave motion near the reflection point of the attractor. The largest forces were measured near the reflection point of the wave attractor.

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