Topological Origin of Geophysical Waves

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Abstract

Equatorial Kelvin and Yanai waves are an important component of El Niño Southern Oscillation, and Madden-Julian Oscillation. These waves are unidirectional, with eastward groupd velocity, and can be surprisingly robust to perturbations. Do dynamics alone account for this stability, or are there deeper principles at work?
A clue is provided by the physics of quantum hall effect and topological insulator in condensed matter, which has recently found applications in a variety of other classical systems. Those systems share the common feature that low-energy waves propagate in only one direction with no backscattering, a result that can be understood with topology, and related to discrete symmetries in the system.

Here we show that, as a consequence of the rotation of the Earth that breaks time reversal symmetry in the shallow water model, equatorially trapped Kelvin and Yanai waves have a topological origin. These unidirectional edge modes are guaranteed to exist by the non-trivial global structure of the bulk Poincaré modes encoded through a first Chern number of value 2. Our results demonstrate the topology plays an unexpected role in Earth's climate system. These and other geophysical waves of topological origin are protected against static perturbations by time scale separation from other modes that inhibits scattering.

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