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Equatorial internal waves and associated boundary layers

U. Harlander and L.R.M. Maas
Royal Netherlands Institute for Sea Research (NIOZ), harland@nioz.nl

It is known that a non-viscous fluid confined in a rotating spherical shell neither possesses a discrete eigenvalue spectrum nor smooth eigenmodes. Mathematically, the motion of a fluid in a rotating spherical shell is governed by a hyperbolic boundary value problem. Generic features of such problems are singularities in the flow field, referred to as internal boundary layers. Physically, these singularities correspond to wave attractors, that are regions to which all internal waves in the fluid are inevitably drawn. This focusing results from multiple reflections of the internal waves at boundaries. Therefore, internal boundary layers typically occur for enclosed fluids.

The model studied here is a certain approximation to the rotating spherical shell. It describes the structure of slow, zonally symmetric waves of a homogeneous fluid in the neighborhood of the equator, enclosed between a flat lower and upper boundary. Exact solutions of this model are discussed, computed by a method that can handle hyperbolic boundary value problems. Solutions for different frequencies show internal boundary layers, corresponding with internal wave attractors. The boundary layers consist of alternating shear layers aligned along the wave attractor. They show a self-similar pattern that becomes infinitely thin at the position of the attractor.

In addition to the results discussed, the paper is intended to introduce the concept of internal boundary layers and wave attractors to the broader meteorologic and oceanographic community. As in almost all theoretical studies of geophysical flows, strong model simplifications are required to find solutions analytically. Nevertheless, it is believed that this approach is useful to highlight fundamental properties of equatorial internal boundary layers that might be important for atmosphere and ocean.