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Geostrophic Shock Waves

Doron Nof

Department of Oceanography, The Florida State University, Tallahassee, FL 32306

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ABSTRACT

Organized depth discontinuities involving a balance between steepening and dissipation are usually referred to as shock waves. An analytical "educed gravity" model is used to examine a special kind of shock wave. The wave under study is a depth discontinuity associated with a transition between a supercritical and subcritical flow in a channel. Even though the wave itself is highly nonlinear, the adjacent upstream and downstream fields are exactly geostrophic in the cross-stream direction. For this reason we term the wave a geostrophic shock wave. We focus on a stationary shock wave whose horizontal projection is a straight line perpendicular to the side walls. Solutions for the entire field are constructed analytically using power series expansions and shock conditions equivalent to the so-called Rankine-Hugoniot constraints.

It is found that, for particular upstream conditions, a geostrophic shock wave can be formed if the particle speed exceeds the surface gravity wave speed (i.e., the flow is "supercritical"). Specifically, in addition to supercriticality, a stationary geostrophic wave requires the upstream velocity to have a particular structure which depends on the strength of the shock and the channel width. When the latter condition is not met, a shock wave is still possible, but its adjacent fields will not be geostrophic and its shape will correspond to an "S" rather than a straight line.

Being the only known analytical solution for the entire field of shock waves on a rotating earth, the geostrophic shock provides useful information on the wave structure. For instance, it is shown that even though momentum is conserved across the shocks, relatively large changes in potential vorticity take place. *For depth discontinuity of O(I) (i.e. high "amplitudes"), there is a generation of potential vorticity that is also of O(I).* Such a phenomenon does not occur on a nonrotating plane where the (zero) potential vorticity may be altered through the action of shock waves in channels and passages. Possible application of this theory to various oceanic situations is mentioned.

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Headquarters: 45 Beacon Street Boston, MA 02108-3693
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