MS6S_11313

XXI International Congress of Theoretical and Applied Mechanics
Warsaw, Poland, August 15–21, 2004

Agradient Velocity and Vortical Motion in Rotating Fluids

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A new approach to modelling slow vortical motion and fast inertia-gravity waves is suggested within the rotating shallow-water primitive equations with arbitrary topography. The velocity is exactly expressed as a sum of the gradient wind, described by Bernoulli function, and the rest, agradient part, proportional to the velocity tendency. Then the equation for inverse potential vorticity, as well as momentum equations for agradient velocity include the same source of adiabatic flow evolution expressed as a single term of the Jacobian operator of Bernoulli function and potential vorticity. This approach allows for the construction of balance relations for vortical dynamics and potential vorticity inversion schemes even for moderate Rossby and Froude numbers. The components of agradient velocity are used as the fast variables slaved to potential vorticity. The ultimate limitations of constructing the balance are revealed in the form of the ellipticity condition for balanced tendency of Bernoulli function which incorporates both known criteria of the formal stability: the gradient wind modified by the characteristic vortical Rossby wave phase speed should be subcritical.

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