Laboratoire de Glaciologie et Géophysique de l'Environnement

Séminaire

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Modeling and dynamics of the non-traditional Coriolis force in geophysical flows

Large-scale atmospheric and oceanic motion are often well described using hydrostatic primitive equations (HPE) based on (i) the shallow-atmosphere approximation, in which the thickness of the atmosphere is taken to be small in comparison with the planetary radius and (ii) the traditional approximation, in which the horizontal component of the earth's rotation is neglected. The two approximations are usually made together in order to preserve absolute angular momentum. We show however that it is possible to retain the non-traditional (NT) component of the Coriolis force under the shallow-atmosphere approximation while still satisfying all conservation laws, both in the 3D compressible equations [3] and in the spherical shallow-water (SW) equations [4], significantly extending previous work done on the plane. The derivation invokes Hamilton's principle of least action with an approximate Lagrangian capturing the small increase with height of the solid-body entrainment velocity due to planetary rotation.
For flows with a small aspect ratio, the new NT model is both consistent and accurate. In this limit, two analysis of idealized oceanic flow (1) and (2) have been undertaken using continuously stratified (Boussinesq) models taking into account the complete Coriolis force:
(1) Mid-latitude inertial instability of an ageostrophic zonal jet. We show that NT effects significantly increase the growth rate of the instability at small enough Burger numbers (weak stratifications) for realistic aspect ratios of the jet [2].
(2) Propagation of near-inertial waves (NIWs) beneath atmospheric storm tracks. While the inclusion of NT effects permits sub-inertial wave propagation, fluctuating zonal winds over an eddying ocean do not excite these motions very strongly. However a poleward energy flux, carried by super-inertial waves, is found to be as strong as the equatorward flux [1].

References:

[1] M. Tort and K. B. Winters, propagation of near-inertial waves beneath atmospheric storm tracks on the non-traditional beta-plane, Proceeding to ISSF 2016
[2] M. Tort, B. Ribstein and V. Zeitlin, Symmetric and asymmetric inertial instability of zonal jets on the f-plane with complete Coriolis force, J. Fluid Mech., 788, 274-302 (2016).
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[3] M. Tort and T. Dubos, Dynamically consistent shallow-atmosphere equations with a complete Coriolis force, Q. J. R. Meteorol. Soc. 140 , 2388-2392 (2014a).
[4] M. Tort, T. Dubos, F. Bouchut and V. Zeitlin, Consistent shallow-water equations on the rotating sphere with complete Coriolis force and topography , J. Fluid Mech. 748 , 789-821 (2014).