

SIPo (Seminario de Investigadores Postdoctorales)

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Titulo: Generalized Quasi-Geostrophy for Moist Spatially Anisotropic Atmospheric Flows with Phase Changes .

Summary:

Traditionally, the simulation of precipitating convection use a non-Boussinesq dynamical core such as the anelastic equations, and would incorporate water substance in all of its phases: vapour (cloud and rain), liquid and ice. Furthermore, the liquid water phase would be separated into cloud water (small droplets suspended in air) and rain water (larger droplets that fall). Depending on environmental conditions, the moist convection may organize itself on multiple length and time scales. One of the minimal representations of water substance and dynamics that still reproduces the basic regimes of turbulent convection regime is the Fast Autoconversion and Rapid Evaporation (FARE) model, which can reproduces unorganized ("scattered") or organized convection, such as tilted rain water profiles and low-altitude cold pools (<https://doi.org/10.1017/jfm.2012.597>).

Among the simplified models referred to above, one of the most successful models is the celebrated quasi-geostrophic (QG) equations, which considers a balance between pressure gradients and Coriolis forces. The success of the QG equations is due in part due to its practical simplicity. Only one equation of motion is necessary for the potential vorticity (PV) and the velocity and density can be diagnosed from it. From the theoretical point of view, the QG equations lead a decomposition of balance (low frequency) and unbalanced (high frequency) components. Slow balanced components are associated to the vortices observed in the ocean and in the atmosphere and the fast unbalanced components are associated to inertia-gravity waves and move much faster (https://doi.org/10.1007/978-1-944970-35-2_14).

The slow and fast modes have been mainly studied in the Boussinesq and rotating shallow water equations. In the case of the atmosphere, that corresponds to the dry case where no moist is considered at all. Very recently, a huge effort has been dedicated to developing the concept of low and high frequency components in the presence of moist (<https://doi.org/10.1175/JAS-D-17-0023.1>), in the so-called Precipitating Quasi-Geostrophy equations (PQG). This model was analyzed, by separated, in both scenarios: with dry and moist atmosphere. Although this work has been very successful, the implementation of the model is very challenging because the moist potential vorticity involves stiff terms and the PV-inversion is very complicated.

By other hand, quasi-geostrophy was generalized for anisotropic rotating flows in the dry case in (<https://doi.org/10.1017/S0022112006008949>). The model was derived using asymptotic analysis in terms of the Rossby number and assuming certain assumptions for the characteristic scales. One notes that the asymptotic limit in this setting is different than the regular QG assumptions described above. In particular, the vertical extent is considered large compared to the horizontal length-scale. The leading vertical velocity does not vanish, as opposed to the regular QG equations.

In this talk, the last approach taking into account moist is presented. One contribution is the derivation of a new model that encompasses a concept of balance and unbalance components in the moist case. One aside advantage here is that no PV-inversion is required. The resulting model is multi-scale where the averaged moist and equivalent potential temperature evolve over a slow timescale and the fluctuations evolving on a fast timescale. Some results about linear (in)stability for the dry and the moist case are presented. For numerical results, periodic boundary conditions are assumed in the horizontal directions and a pseudo-spectral approach with the use of horizontal Fourier transform is taken. In the vertical direction, the discretization is implemented with the use of staggered grids. This numerical scheme used was developed in ([https://doi.org/10.1016/0021-9991\(91\)90238-G](https://doi.org/10.1016/0021-9991(91)90238-G)). These results include joint work with Gerardo Hernández-Dueñas (IMATE Juriquilla - UNAM)

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