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TIGAR - a new global atmospheric model for the simulation of Transient Inertia-Gravity And Rossby wave dynamics

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Resolving inertia-gravity (IG, or gravity) waves poses a real challenge for the formulation of numerical schemes for numerical weather prediction (NWP) and climate models due to different time scales of Rossby wave dynamics and fast-propagating IG waves. With ever increasing emphasize placed on high-resolution simulations, the importance of the issue is growing due to the implications of Courant-Friedrich-Levy (CFL) stability criterium. It is especially prominent in the tropical atmosphere, where a significant part of variability is associated with divergence-dominated dynamics. Detangling gravity and Rossby wave dynamics in the tropics is a challenging problem due to a lack of sepaartion between the Rossby and gravity regime that is present in the extra-tropics.

TIGAR (Transient Inertia Gravity and Rossby wave dynamics) targets this problem by employing the eigensolutions of the linearized primitive equations on the sphere as the basis functions for the numerical representation of dynamical variables. This leads to the description of dynamics in terms of physically identifiable structures, i.e. the Rossby and gravity waves, which are fully dynamically separated at the linearization level. The benefits of such approach can be reaped on analytical, modelling and computational sides. As a research tool, TIGAR allows to study wave-wave interections directly in the model, without the need of intermediate software for wave filtering. Simplified models aimed at particular dynamical regime can be obtained from a full model with a simple configuration change. For instance, retaining only the Rossby modes in the spectral expansion will result in the quasi-geostrophic model, while additionally keeping the Kelvin and mixed Rossby-gravity waves will reproduce essential features of tropical circulation.

Numerically, high precision computation is achieved in TIGAR through the use of higher order exponential time-differencing schemes, which take advantage of the normal modes framework, leading to the major increase in computational efficiency and stability. The comparison with classical time-stepping schemes in the horizontal component of the model shows accuracy improvements of several orders of magnitude at the same computational cost. In our testing on multiscale flows, the stability gains associated with the enhanced representation of gravity wave dynamics raise CFL time-step bound for explicit schemes by a factor of 4-6.

We present TIGAR solutions of some classical steady and time-dependent problems including barotropic and baroclinic instability tests.