Towards an energy-conserving quasi-hydrostatic deep-atmosphere dynamical core

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Atmosphere dynamics of our planet is quite well described by traditional primitive equations based on the so-called *shallow-atmosphere* approximation. Thus, the model is dynamically consistent i.e. it possesses conservation principles for mass, energy, potential vorticity and angular momentum, when certain metric terms and the $\cos\phi$ Coriolis terms are neglected (Phillips, 1966). Nevertheless, to simulate planetary atmospheres, the shallow-atmosphere approximation should be relaxed because of the low planet radius (such as Titan) or the depth of their atmospheres (such as Jupiter or Saturn). The full Coriolis force needs then to be taken into account, in addition to all metric terms. Non-traditional terms have some dynamical effects (Gerkema and al., 2008) but they are little-known and rarely integrated into general circulation dynamical cores (Wood and Staniforth, 2002).

We have shown recently how the complete Coriolis force can be consistently combined with the *shallow-atmosphere* approximation (Tort and Dubos, 2013). The goal of the present work is to incorporate the quasi-hydrostatic *deep-atmosphere* as well as non-traditional *shallow-atmosphere* equations into the general circulation model LMD-Z while retaining discrete conservation properties. We formulate the model in longitude/latitude coordinates and mass-based vertical coordinates (Laprise, 1992) using Hamiltonian formalism. The natural prognostic variable for momentum is the absolute angular momentum instead of relative velocity. Discrete energy-conserving scheme is then obtained by discretizing the Poisson bracket and the energy themselves (Salmon, 2004 ; Gassmann, 2013).

A prototype implementation of the method is applied to the general circulation of Titan and to idealized circulation of an Earth-like small planet (Held and Suarez, 1995).