Geophysical Research Abstracts,
Vol. 11, EGU2009-2164, 2009
EGU General Assembly 2009

Effects of moisture in nonlinear dynamics in a simple atmospheric model

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The standard parametrization of the moist convection in current GCM's is the Betts-Miller scheme which introduces a threshold effect since precipitation starts once humidity reaches saturation. This parametrization is fundamentally nonlinear in nature with an immediate consequence that no traditional linear wave solution exists anymore in the moist regions. Another consequence is the possible formation of front at the interface between precipitating and non-precipitating regions. The study of this specific nonlinearity is crucial to understand the intrinsic properties of the models in use.

We derive a simplified tropical-CISK-type one-layer model by vertical averaging the moist primitive equations including the Betts-Miller parametrization. Following the works of Gill (1981) and Majda et al (2004), the model is studied analytically by the method of characteristics, and also by analyzing its weak solutions with the help of Rankine-Hugoniot conditions. The Betts-Miller parametrization is introduced into the finite-volume numerical scheme for rotating shallow water equations by Bouchut (2006) providing a reliable high-resolution fully nonlinear numerical model. We benchmark the model against the analytical results and use it to study the formation and propagation of precipitation fronts and other nonlinear phenomena in the presence of precipitation, like e.g. the wave scattering and wave-breaking.