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Exploring Extreme Weather and Climate Events with Aeolus 2.0: A Multi-layer moist-convective Thermal Rotating Shallow Water (mcTRSW) Dynamical Core

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Aeolus 2.0 is an open-source numerical atmosphere model with intermediate complexity designed to capture the dynamics of the atmosphere, especially extreme weather and climate events. The model's dynamical core is built on a novel multi-layer pseudo-spectral moist-convective Thermal Rotating Shallow Water (mcTRSW) model, and it utilizes the Dedalus algorithm, renowned for its efficient handling of spin-weighted spherical harmonics in solving pseudo-spectral problems. Aeolus 2.0 comprehensively characterizes the temporal and spatial evolution of key atmospheric variables, including vertically integrated potential temperature, thickness, water vapor, precipitation, and the influence of bottom topography, radiative transfer, and insolation. It provides a versatile platform with resolutions ranging from smooth to coarse, enabling the exploration of a wide spectrum of dynamic phenomena with varying levels of detail and precision.

The model has been utilized to investigate the adjustment of large-scale localized buoyancy anomalies in mid-latitude and equatorial regions, along with the nonlinear evolution of key variables in both adiabatic and moist-convective environments. Our findings highlight the triggering mechanisms of phenomena such as the Madden-Julian Oscillation (MJO) and the circulation patterns induced by temperature anomalies and buoyancy fields. Furthermore, our simulations of large-scale localized temperature anomalies reveal insights into the impact of perturbation strength, size, and vertical structure on the evolution of eddy heat fluxes, including poleward heat flux, energy, and meridional elongation of the buoyancy field. We observe the initiation of atmospheric instability, leading to precipitation systems, such as rain bands, and asymmetric latent heat release due to moist convection in diabatic environments. This study identifies distinct patterns, including the formation of a comma cloud pattern in the upper troposphere and a comma-shaped buoyancy anomaly in the lower layer, accompanied by the emission of inertia gravity waves. Additionally, the role of buoyancy anomalies in generating heatwaves and precipitation patterns is emphasized, particularly in mid-latitude regions.

In summary, Aeolus 2.0, with its specific capabilities, contributes to our understanding of the complex interactions of moist convection, buoyancy anomalies, and atmospheric dynamics, shedding light on the dynamics of extreme weather events and their implications for climate studies.

References

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