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Aeolus 2.0: Novel Bulk Aerodynamics and Moist Convection Schemes in an mcTRSW Dynamical Core to Capture Dynamics of Extreme Events

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Abstract

In this work, we elucidate the dynamical core of the Atmosphere model Aeolus 2.0, characterized by intermediate complexity. This model is grounded in the pseudo-spectral moist-convective Thermal Rotating Shallow Water (mcTRSW) framework with minimal parametrization over the full sphere. The Dedalus algorithm, renowned for its handling of spin-weighted spherical harmonics, manages the pseudo-spectral problem-solving tasks. We introduce an improved version of moist convection and a novel approach to refine the estimation of sea surface evaporation flux and the columnar bulk of humidity, pivotal components of the bulk aerodynamic scheme. The proposed scheme incorporates factors such as zonal wind velocity, variations in lower troposphere (potential) temperature, and free convection to enhance accuracy.

Indeed, we demonstrate how the model enables the simulation of various atmospheric phenomena such as the Madden-Julian Oscillation and localized extreme heatwaves. For example, Aeolus 2.0 has facilitated the proposal of a novel theory for the genesis and dynamics of the MJO (Rostami et al., 2022). According to this theory, an eastward-propagating MJO-like structure can be generated in a self-sustained and self-propelled manner due to the nonlinear relaxation (adjustment) of a large-scale positive buoyancy anomaly, a depressed anomaly, or a combination of these. This occurs when the anomaly reaches a critical threshold in the presence of moist convection at the Equator. This MJO-like episode possesses a convectively coupled 'hybrid structure' consisting of a 'quasi-equatorial modon' with an enhanced vortex pair and a convectively coupled baroclinic Kelvin wave (BKW), exhibiting a greater phase speed than that of a dipolar structure on an intraseasonal time scale.

Additionally, we demonstrate the model's capability to simulate extreme localized heatwaves in mid-latitudes (Rostami et al., 2024). This study examines the influence of large-scale localized temperature anomalies in mid-latitude regions on condensation patterns and corresponding circulation in various environments. Depending on the perturbation’s characteristics, they can induce atmospheric instability, leading to precipitation systems such as rain bands and distinctive cloud patterns. The study also demonstrates the initiation of an anticyclonic high-pressure rotation in the upper troposphere due to heating on lower troposphere, resulting in an anisotropic northeast-southwest tilted circulation of heat flux.

Relevant references:

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