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Idealized Simulations of the Quasi-Biennial Oscillation and Sudden Stratospheric Warmings with an Ensemble of Dry GCM Dynamical Cores

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The ability of atmospheric General Circulation Models (GCMs) to simulate the stratospheric Quasi-Biennial Oscillation (QBO) in the tropics and Sudden Stratospheric Warmings (SSWs) in polar regions is an important model characteristic which has been under investigation for several decades. Both the QBO and SSWs are examples of major coupling mechanisms between the troposphere and stratosphere. Typically, it is believed that the moist convective parameterization, topography and a gravity wave drag parameterization are the key GCM components that trigger a wide range of waves in the troposphere. Once the waves propagate upward and break in the stratosphere they force wave-mean flow interactions. Typical GCM setups incorporate highly nonlinear interactions between the dynamical core (the resolved fluid flow component) and the subgrid-scale physical parameterization package. This makes it difficult to distinguish the causes and effects of waves and their wave damping mechanisms. This paper disentangles these interactions.

We show that both QBO-like oscillations and SSWs can already be simulated with an ensemble of four dynamical cores that are part of the Community Atmosphere Model (CAM version 5) from the National Center for Atmospheric Research (NCAR). These are the spectral transform semi-Lagrangian (SLD), spectral transform Eulerian (EUL), Finite-Volume (FV), and Spectral Element (SE) dynamical cores. The simulations are configured for a dry and flat earth, and thereby omit the typical wave triggering mechanisms like moist convection or orographic forcing. The dynamical cores are driven by Rayleigh damping near the surface and the model top, and a prescribed Newtonian temperature relaxation. Wave analysis is performed to understand the driving mechanisms behind the QBO and SSWs in the different dynamical cores. In particular, the Transformed-Eulerian-Mean (TEM) analysis is used to explore the relative roles of the forcing by the resolved waves, the TEM advection terms and unresolved waves. It is shown that the choice of the numerical schemes and diffusion mechanisms in the dynamical cores greatly impact their ability to resolve and propagate waves, and thereby simulate the QBO-like oscillations and SSWs.