THOR: A Fast and Flexible 3D GCM for the Study of Exoplanets

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Abstract

We present THOR version 2.0, a non-hydrostatic, GPU enabled 3D general circulation model, which is the culmination of 8 years of work in the Heng group in Bern. THOR is the first fully global, non-hydrostatic GCM that has been built from the ground up for the study of exoplanets. Thus, it is entirely free of tunings toward solar system planets and contains as few assumptions as possible. It is also publicly available and we actively encourage the community to become involved in further development. With this model, we have the capability to model atmospheres with or without the hydrostatic approximation, independent of the additional approximations that lead to the primitive equations of meteorology. We use the model to study whether the climate structures of exoplanets are robust to the assumption of hydrostatic equilibrium. We demonstrate that the hydrostatic approximation alone is sufficient to significantly alter the zonal and vertical winds of hot jupiters. This implies that aerosol sizes derived from spectra may be miscalculated, if the wind velocities are based upon hydrostatic GCMs. We further discuss improvements and additions to the model that have been implemented since the release of version, including grey radiative transfer, chemical tracers, and an insolation scheme that allows for arbitrary orbits and rotation parameters. We have begun adapting the model for terrestrial planets with the goal of studying atmospheric collapse on tidally-locked worlds, which will have implications for the habitability of a large number of planets. Additionally, we reproduce a number of benchmark tests for dynamical cores.

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