A new line-by-line general circulation model for simulation of diverse planetary atmospheres

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Investigating exoplanet and solar system planet climates requires a diverse range of tools, including flexible and accurate three-dimensional general circulation models (GCMs). Here we describe the development of a new GCM that for the first time uses a line-by-line model to describe radiative transfer. Compared to other widely used radiative parameterization schemes in GCMs such as the correlated-k method, our direct algorithm allows high computational accuracy and avoids calculating high-dimensional coefficient tables, of which only a small fraction may be used for GCM long-term integration. The model also includes a cubed-sphere gridding technique for dynamics, which improves both computational performance and accuracy vs. conventional latitudinal-longitudinal gridding, and a robust scheme for representing moist convection in both dilute and non-dilute regimes.

This new type of model opens new territory to study a wide variety of important planetary climate problems, including topics on planetary habitability such as characterization of both the inner and outer edges of the habitable zone, water loss, and abiotic oxygen build-up in water-rich atmospheres. The model is designed to be both more accurate and flexible than conventional parameterized GCMs. Here we describe the model framework and validation, and present new results on the problem of atmospheric collapse on tidally locked terrestrial planets.