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Intercomparison of General Circulation Models for Hot Extrasolar Planet Atmospheres[1]

JAMES CHO, Queen Mary, University of London

In this collaborative work with I. Polichtchouk, C. Watkins, H. Th. Thrastarson, O. M. Umurhan, and M. de la Torre-Juárez, we compare five general circulation models (GCMs) which have been recently used to study hot extrasolar planet atmospheres (BOB, CAM, IGCM, MITgcm, and PEQMOD), under three test cases useful for assessing model convergence and accuracy. Such a broad, detailed intercomparison has not been performed thus far for extrasolar planets study. The models considered all solve the traditional primitive equations, but employ different numerical algorithms or grids (e.g., pseudospectral and finite volume, with the latter separately in longitude-latitude and "cubed-sphere" grids). The test cases are chosen to cleanly address specific aspects of the behaviors typically reported in hot extrasolar planet simulations: 1) steady-state, 2) nonlinearly evolving baroclinic wave, and 3) response to fast timescale thermal relaxation. When initialized with a steady jet, all models maintain the steadiness, as they should—except MITgcm in cubed-sphere grid. A very good agreement is obtained for a baroclinic wave evolving from an initial instability in spectral models (only). However, exact numerical convergence is still not achieved across the spectral models: amplitudes and phases are observably different. When subject to a typical "hot-Jupiter"-like forcing, all five models show quantitatively different behavior—although qualitatively similar, time-variable, quadrupole-dominated flows are produced. Hence, as have been advocated in several past studies, specific quantitative predictions (such as the location of large vortices and hot regions) by GCMs should be viewed with caution. Overall, in the tests considered here, spectral models in pressure coordinate (PEBOB and PEQMOD) perform the best and MITgcm in cubed-sphere grid performs the worst.

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