EPSC Abstracts
Vol. 9, EPSC2014-757-1, 2014
European Planetary Science Congress 2014
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Three dimensional atmospheric dynamics of terrestrial exoplanets over a wide range of orbital and atmospheric parameters

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Abstract

The recent discoveries of terrestrial exoplanets and super Earths extending over a broad range of orbital and physical parameters, suggests that these planets will span a wide range of climatic regimes. Characterization of the atmospheres of warm super Earths has already begun and will be extended to smaller and more distant planets over the coming decade. The habitability of these worlds may be strongly affected by their three-dimensional atmospheric circulation regimes, since the global climate feedbacks that control the inner and outer edges of the habitable zone–including transitions to Snowballlike states and runaway-greenhouse feedbacks–depend on the equator-to-pole temperature differences, pattern of relative humidity, and other aspects of the dynamics. Here, using an idealized moist atmospheric general circulation model (GCM) including a hydrological cycle, we study the dynamical principles governing the atmospheric dynamics on such planets. We show how the planetary rotation rate, planetary mass, surface gravity, heat flux from a parent star and atmospheric mass affect the atmospheric circulation and temperature distribution on such planets. We elucidate the possible climatic regimes and diagnose the mechanisms controlling the formation of atmospheric jet streams, Hadley cells, and the equator-to-pole temperature differences. Finally, we discuss the implications for understanding how the atmospheric circulation influences the global-scale climate feedbacks that control the width of the habitable zone.