Atmospheric Dynamics in the Era of Comparative Planetology. Daniel D.B. Koll[1] and Dorian S. Abbot[1], [1]Department of the Geophysical Sciences, University of Chicago, Chicago, IL.

Abstract: Understanding the basic atmospheric dynamics of a planet is a crucial prerequisite for understanding atmospheric heat transport, atmospheric collapse, and planetary habitability. Based on the Solar System, we know that atmospheres can be in very different dynamical regimes. The atmospheric circulations of extrasolar planets could be more different still, as underlined by the prospect of tidally locked [1] or Dune planets [2]. Understanding the possible diversity of atmospheric circulation regimes will therefore help us understand the extent to which exoplanets might resemble planets in the Solar System, and would help us interpret near-term (sparse and error-prone) observations of terrestrial exoplanets.

We use a nondimensional framework to map out the range of dynamical regimes in an idealized general circulation model (GCM). Atmospheric circulations can be characterized in terms of nondimensional parameters (e.g., [3-4]). This allows us to compare planets that might be very different, e.g., in terms of size or surface pressure, but could turn out to have identical atmospheric dynamics as long as the relevant ratios of their atmospheric parameters are identical. This framework allows us to efficiently explore large parameter spaces in the GCM, and to identify which atmospheric properties a planet's dynamics and potential habitability are most sensitive to.

Our numerical results allow us to quantify to what extent Solar System atmospheres can, or cannot, be used as analogs for understanding the atmospheric circulations of exoplanets. Among other parameters, we investigate how tidally locked planets differ from planets in spin-orbit resonances and rapidly-rotating planets, and how the large-scale dynamics are influenced by the potential presence of a condensible gas and latent heat transport. We also use the GCM to comprehensively test theoretical scaling relations that have been proposed for the atmospheric structures and wind speeds of terrestrial planets, such as the surface temperatures and wind speeds of slowly-rotating planets in the weak-temperature gradient regime. We find that these relations often capture broad features of many atmospheric regimes, but can also quantify when they break down. Finally, we show how these results can be used to interpret observations and make a priori estimates of planetary habitability.

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