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Comparative climatology of terrestrial planets with strong seasonality

Ilai Guendelman and Yohai Kaspi
Weizmann Institute of Science, Earth and Planetary Science, Israel (ilai.guendelman@weizmann.ac.il)

The increasing amount of detected exoplanets together with future missions planned in order to characterize these planets encourages the development of a better understanding of the planetary climate dynamics. Understanding the climate dependence on planetary parameters and atmospheric characteristics is essential for knowing the range of possible climates on different planetary bodies. In this study, we focus on the climate's seasonality, namely planets with non-zero obliquity. Using an idealized general circulation model (GCM) we explore the seasonal dependence of the planets' orbital configuration (obliquity, orbital period and rotation rate), and its radiative timescale (though the atmospheric mass). We focus mainly on the response of the surface temperature and Hadley circulation. Understanding the surface temperature and Hadley cell response to these parameters, also contribute to the understanding of the Hadley cell width of the solar system terrestrial planets. We show that despite the Hadley cell being thermally driven, the Hadley cell ascending branch does not necessarily coincide with the warmest latitude. This result is consistent with observations from the solar system terrestrial planets, that show that even in cases with very long seasonal cycle (e.g., Titan) or very small thermal inertia (e.g., Mars) the Hadley cell ascending branch does not coincide with the warmest latitude. In order to understand the characteristics of the Hadley circulation in cases of extreme planetary characteristics, we show using the axisymmetric theory that the thermal Rossby number dictates the character of the circulation. Given the possible variation of thermal Rossby number parameters, the rotation rate is found to be the most critical factor controlling the circulation characteristics.