

Quantifying Land Habitability for Earth-like Exoplanets

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Planetary obliquity modulates climate through its influence on the spatiotemporal distribution of incoming stellar radiation and atmospheric dynamics. The implications for planetary climate and the stability of liquid water have been thoroughly investigated in the past but their overall consequences for planetary habitability are less clear. Recent work suggests that high obliquity and/or high eccentricity planets may have more productive marine biospheres than their low obliquity and eccentricity counterparts [1]. However, the effects of the extreme seasonality generated by high obliquity could affect the survival of complex organisms, especially on land where seasonal temperature variations are large compared to ocean habitats owing to the high heat capacity of water. The habitability of land environments will also be modulated by the spatial position and distribution of continents, as the latitudinal position and shape of a landmass will strongly determine its climate and, at high obliquity, the magnitude of seasonal climate variability. Previous work has not systematically investigated the effects of obliquity and continental configuration in tandem.

To address this gap, we use cGENIE-PlaSim [2], a 3D biogeochemical model coupled to an atmospheric general circulation model, to simulate the climates of Earth-like exoplanets for various obliquities and continental configurations. We compare and contrast several existing metrics for describing exoplanet habitability and present an improved metric for evaluating land habitability for Earth-like vegetation. This presentation will identify the obliquity and eccentricity scenarios most favorable to land vegetation, which is a uniquely detectable form of life on Earth and the base of Earth's global ecosystem. We will then discuss the implications of our work for the detectability of surface biosignatures (e.g., vegetation red edge) on Earth-like exoplanets.

[1] Jernigan J. et al. (2023) ApJ, 944, 205.

[2] Holden, P. B. et al. (2016) GMD, 9, 3347–3361.