Exo-oceanography and the search for life in uncharted waters

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Existing models for exoplanet habitability and atmospheric biosignatures generally neglect ocean dynamics (e.g., by using a slab ocean) or exclusively consider the role of ocean circulation for heat transport and climate regulation. However, the implications of ocean circulation patterns for exoplanet life detection studies are much broader. For example, wind-driven ocean upwelling recycles nutrients lost to the deep ocean back to the sunlit shallow ocean where they stimulate photosynthesis. Photosynthesis in turn provides energy in the form of chemical disequilibrium that sustains life more broadly on our planet. Ocean circulation is thus a first-order control on the productivity and distribution of life on Earth today and throughout our planets' history.

Moreover, ocean circulation patterns, sea ice coverage, and sea-to-air gas exchange kinetics modulate the extent to which biological activity within the ocean is communicated to the atmosphere. The chemical evolution of Earth's atmosphere has ultimately been an imperfect reflection of the evolution of Earth's marine biosphere owing to these oceanographic phenomena. It is thus essential to understand how ocean dynamics may manifest on habitable exoplanets differing from Earth—and to distinguish between planets that are capable of supporting life and those that are particularly hospitable to globally productive, *detectable* life.

We explored ocean dynamics on a diverse range of habitable exoplanets using ROCKE-3D, a fully coupled ocean-atmosphere GCM. This presentation will (1) summarize the sensitivity of ocean circulation to key planetary parameters, (2) link unobservable oceanographic phenomena to potentially observable planetary and atmospheric properties, (3) discuss the biological constraints imposed by differing ocean habitats on other worlds, and (4) offer suggestions regarding the most favorable targets for exoplanet life detection studies.