Ocean heat transport and glaciation dynamics on tidally locked planets

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The habitability of tidally locked planets orbiting M stars is of significant interest given their prevalence in the Universe. Among the many factors affecting planetary habitability, resiliency against, and the ability to recover from, global glaciation is a key consideration.

Whereas rapidly rotating planets like Earth are vulnerable to runaway glaciation as the consequence of the ice-albedo feedback, previous work has shown that this effect is muted on tidally locked M-star planets (Checlair et al., 2017). Global glaciation is suppressed on tidally locked planets because the sharp increase in stellar irradiation approaching the substellar point overwhelms the ice-albedo feedback, imparting stability to partially glaciated states.

A notable limitation of this previous study was the use of a model that neglected redistribution of heat within the ocean. In principle, however, efficient ocean heat transport away from the substellar point may reintroduce a snowball bifurcation.

We revisited this issue using ROCKE-3D, a 3D ocean-atmosphere GCM with a thermodynamic-dynamic sea ice model (Way et al., 2017). We find that ocean heat transport strongly influences the progression of sea ice by stabilizing the western ice margin—but it does not reintroduce a snowball bifurcation because ocean currents are not radially symmetric. The inhibition of ice advance in one dimension is balanced by enhanced glaciation along another. Our results thus confirm that snowball glaciation is unlikely on planets within the habitable zone of M star hosts.

References:

Checlair, J., Menou K., Abbot, D.S. (2017) *ApJ* 845: 132.
Way, M. et al. (2017) *ApJ Supplement Series* 231.