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On the stability of low-latitude sea-ice edges in a comprehensive coupled climate model

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The Snowball Earth hypothesis assumes that a strong ice-albedo feedback inhibits stable low-latitude sea-ice edges. In contrast, we recently proposed the "Jormungand" mechanism that allows stable low-latitude ice edges in atmosphere-only climate models without continents and ocean heat transport (Abbot et al., 2011). These low-latitude sea-ice edges are possible by virtue of net evaporation in the subtropics and a low albedo for snow-free sea ice, because these two factors combine such as to strongly weaken the ice-albedo feedback in the subtropics.

Here, we show that the Jormungand mechanism in principle also works in coupled climate simulations with ECHAM5/MPI-OM when we use a low bare sea-ice albedo and disable sea-ice dynamics. These simulations apply Marinoan boundary conditions (635 Million years before present) and, due to the Jormungand mechanism, produce stable low-latitude sea-ice edges at 5-10^o. Nevertheless, when we take into account sea-ice dynamics, the sea-ice edge becomes unstable once it passes 20^o. This destabilizing effect of sea-ice dynamics results from strong equatorward wind-induced sea-ice advection in the Hadley cell region.

Moreover, we find that sea-ice dynamics promote Snowball initiation. Without sea-ice dynamics, Snowball initiation requires a CO_2 reduction to 4 ppmv, while a reduction to 204 ppmv is sufficient when sea-ice dynamics are included. Because climate models differ in their representation of sea-ice dynamics, our results might help to explain the reported climate model dependence of both the radiative forcing needed for Snowball initiation and the sea-ice latitude at which the collapse to a Snowball occurs.

References:

Abbot, D. S, A. Voigt, and D. Koll (2011), The Jormungand global climate state and implications for Neoproterozoic glaciations, J. Geophys. Res., 116, D18103, doi:10.1029/2011JD015927.