1. Motivation & Research Question

Waterbelt states have been proposed as an alternative scenario for Snowball Earth that might explain the survival of life.

The Jormungand mechanism can stabilize such a state: subtropical sea ice is not covered in snow, resulting in lower albedo. This stops the runaway ice-albedo feedback.¹

Surface melting of sea ice and surface albedo is sensitive to sea-ice thermodynamics.²

What is the impact of sea-ice thermodynamics on the stability of Waterbelt states?

2. Model Setup

ICON-ESM (160km res.), mixed-layer ocean, aquaplanet, 5% weaker sun, ice-free initial conditions, CO₂ constant in time.

Sea ice models used: **O-layer Semtner** (without heat capacity) and **3-layer Winton** (with heat capacity)

3. Results

The Waterbelt state exists with the 0-layer model but does not exist with the 3-layer model. Simulations with the 3-layer model are transitioning faster into a Snowball state.



Waterbelt solutions for Snowball Earth can be stabilized by a bare, low-albedo seaice edge. But the width of the bare sea-ice edge and ultimately the stability of the climate state is controlled by sea-ice thermodynamics.



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The bare sea-ice edge is narrower with the 3-layer model. This reduces surface albedo and results in a stronger ice-albedo feedback destabilizing the Waterbelt state.



4. Conclusion & Outlook

Our work demonstrates the importance of an adequate representation of sea-ice thermodynamics in model studies of Snowball Earth.

Why is the Waterbelt state hysteresis so small even with the 0-layer model? We find a strong positive cloud feedback in ICON-ESM that was not as pronounced in previous studies using ICON-A.³

Sea ice and clouds determine planetary albedo. Their feedbacks are responsible for stabilizing - or destabilizing - Waterbelt states.

5. References

1) Abbot, D. S., A. Voigt, and D. Koll, 2011: The Jormungand global climate state and implications for Neoproterozoic glaciations. J. Geophys. Res. 2) Hörner, J., A. Voigt, and C. Braun, 2022: Snowball Earth Initiation and the Thermodynamics of Sea Ice. J. Adv. Model. Earth Syst. 3) Braun, C., J. Hörner, A. Voigt, and J. G. Pinto, 2022: Ice-free tropical waterbelt for Snowball Earth events questioned by uncertain clouds. Nat. Geosci.

