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Waterbelt states to avoid a hard Snowball Earth

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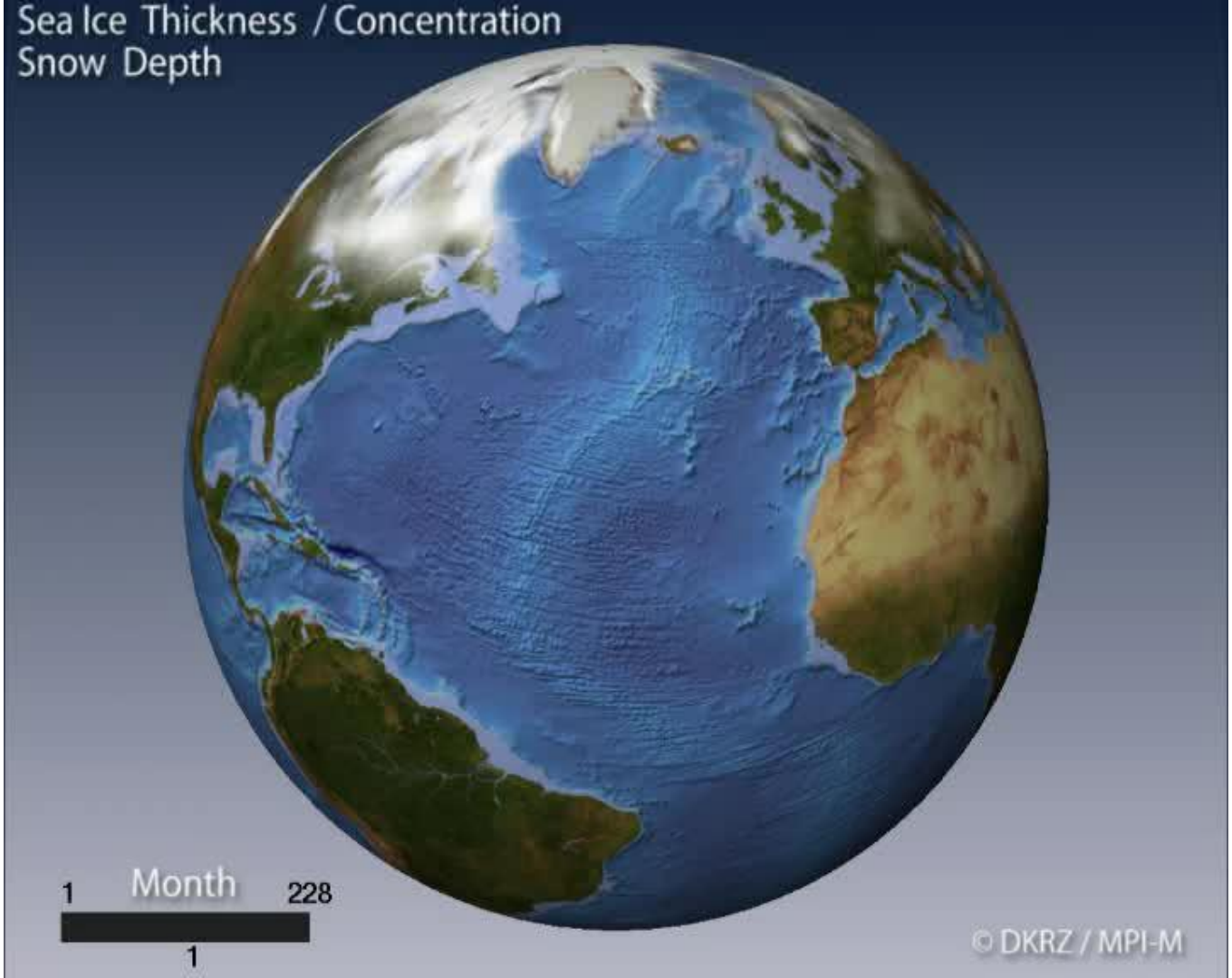

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Snowball Earth pan-glaciations in Earth's deep past

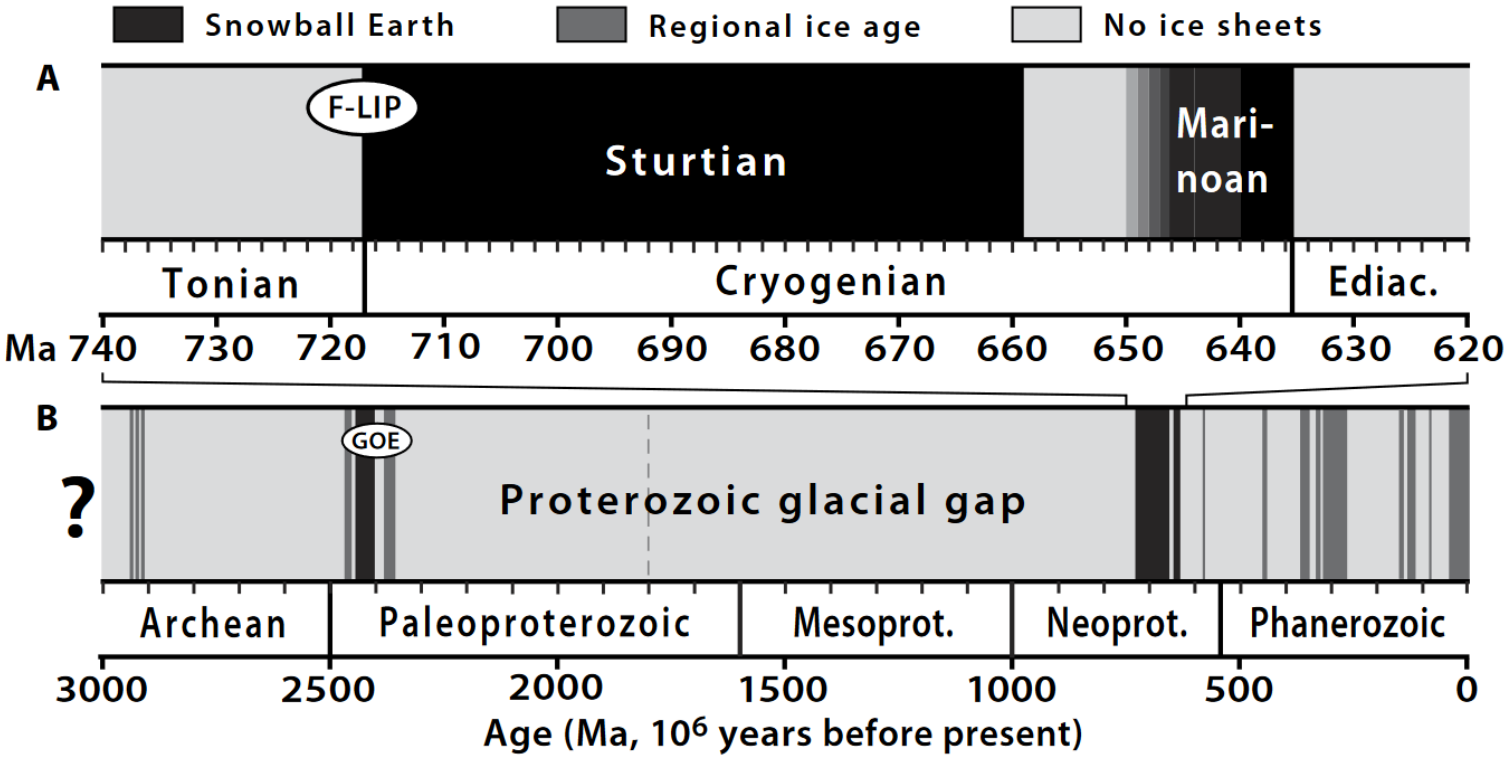
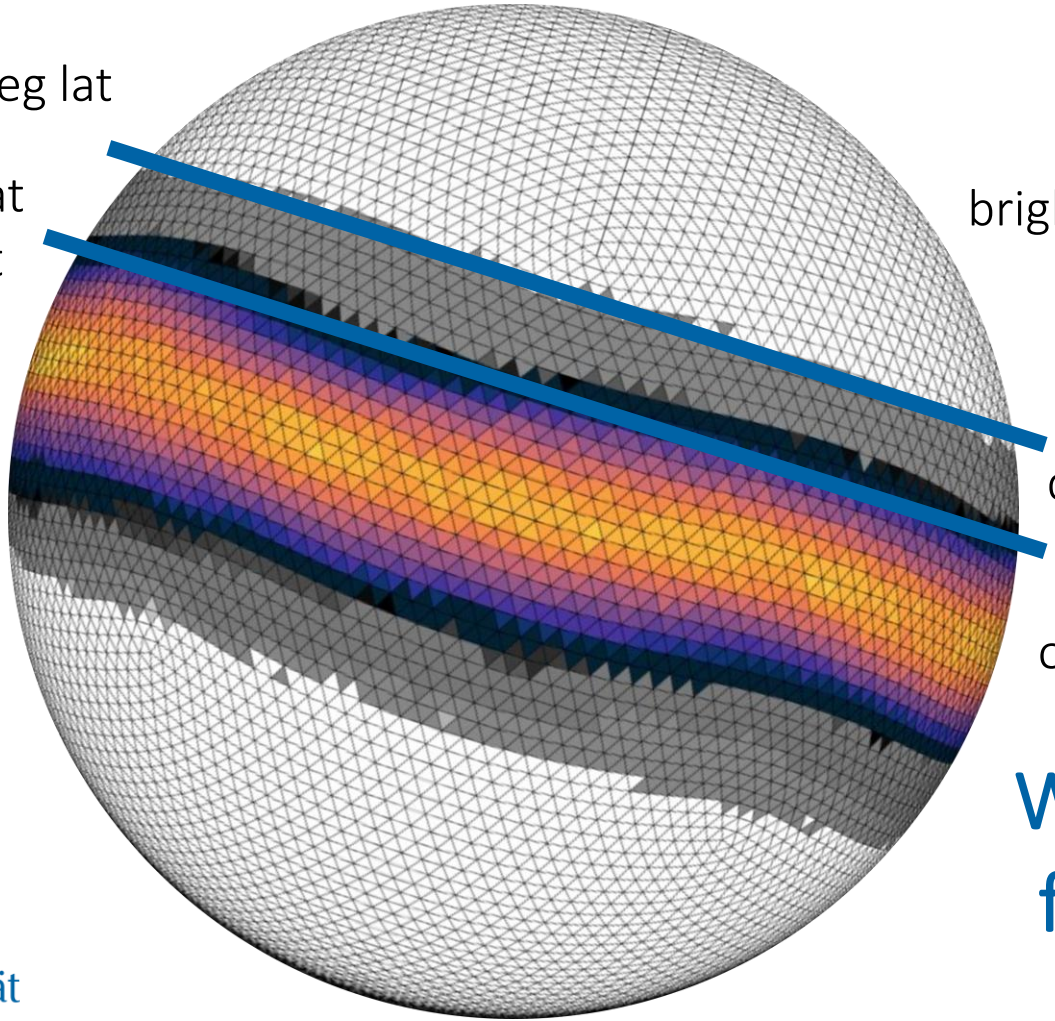


Fig. 2 of Hoffman et al., 2017, Sci. Advances



Waterbelt states for habitability?

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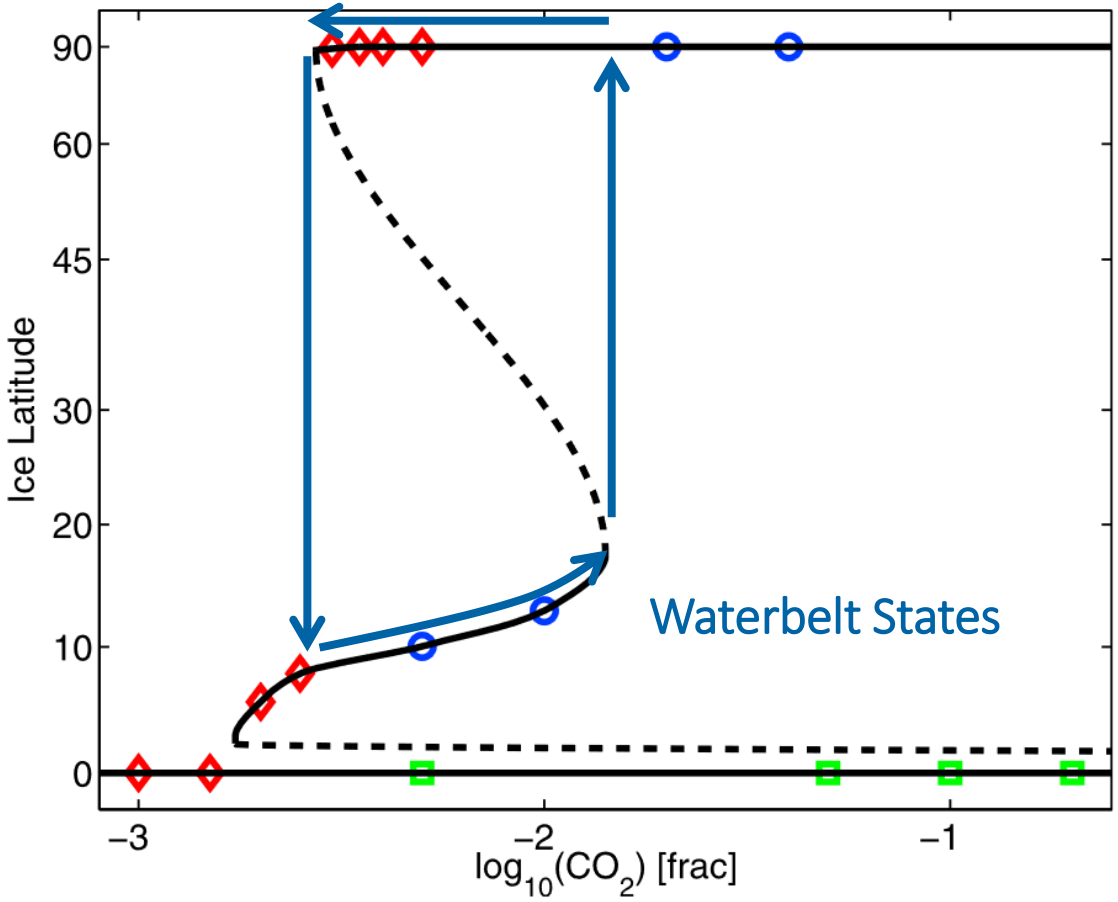

Present-Day-Like States

Waterbelt States

Hard Snowball

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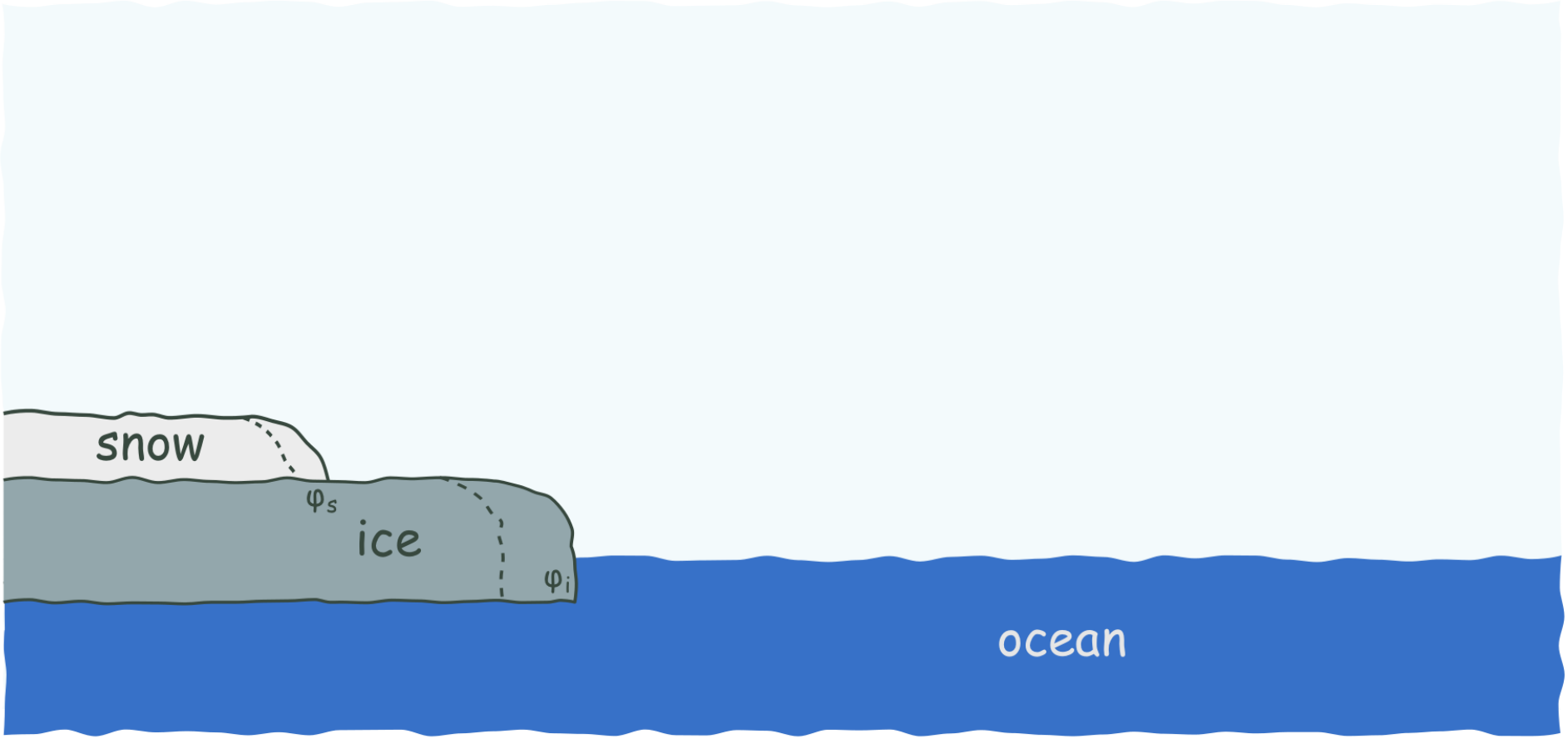
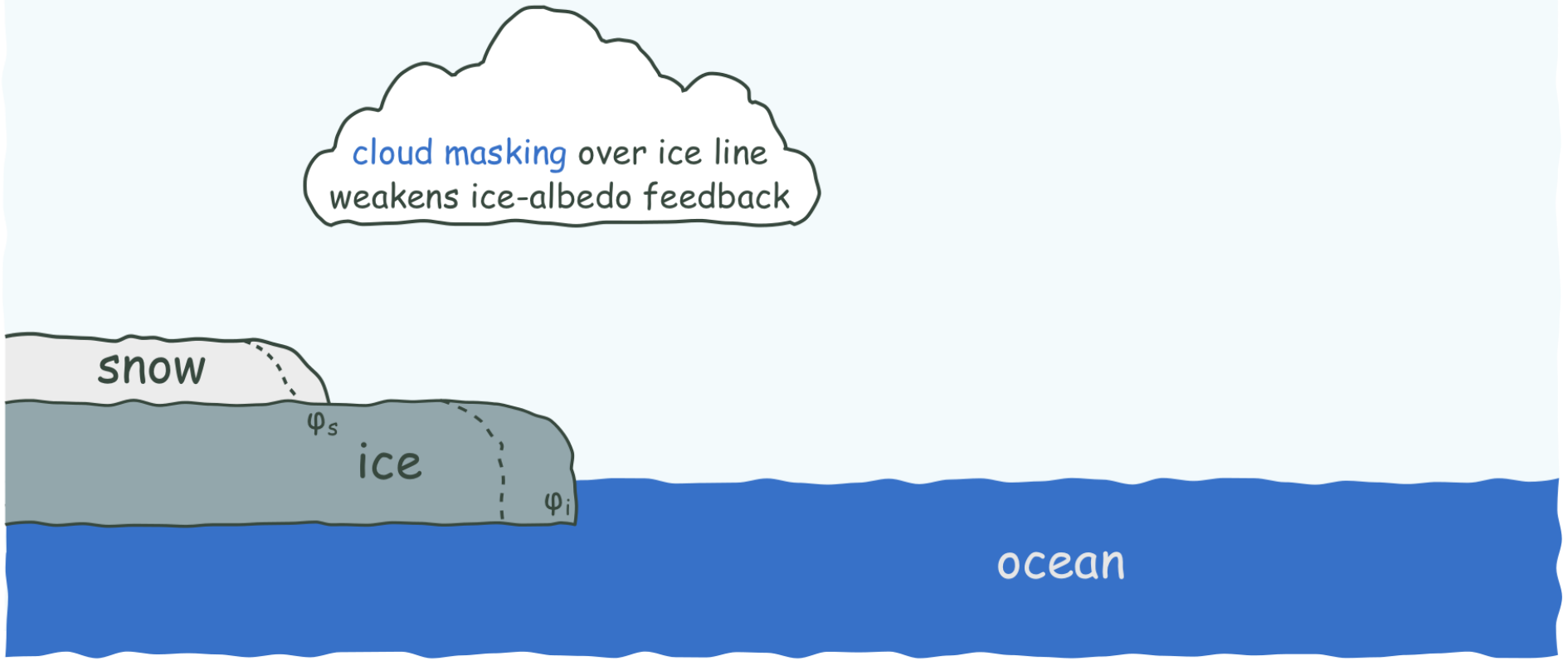
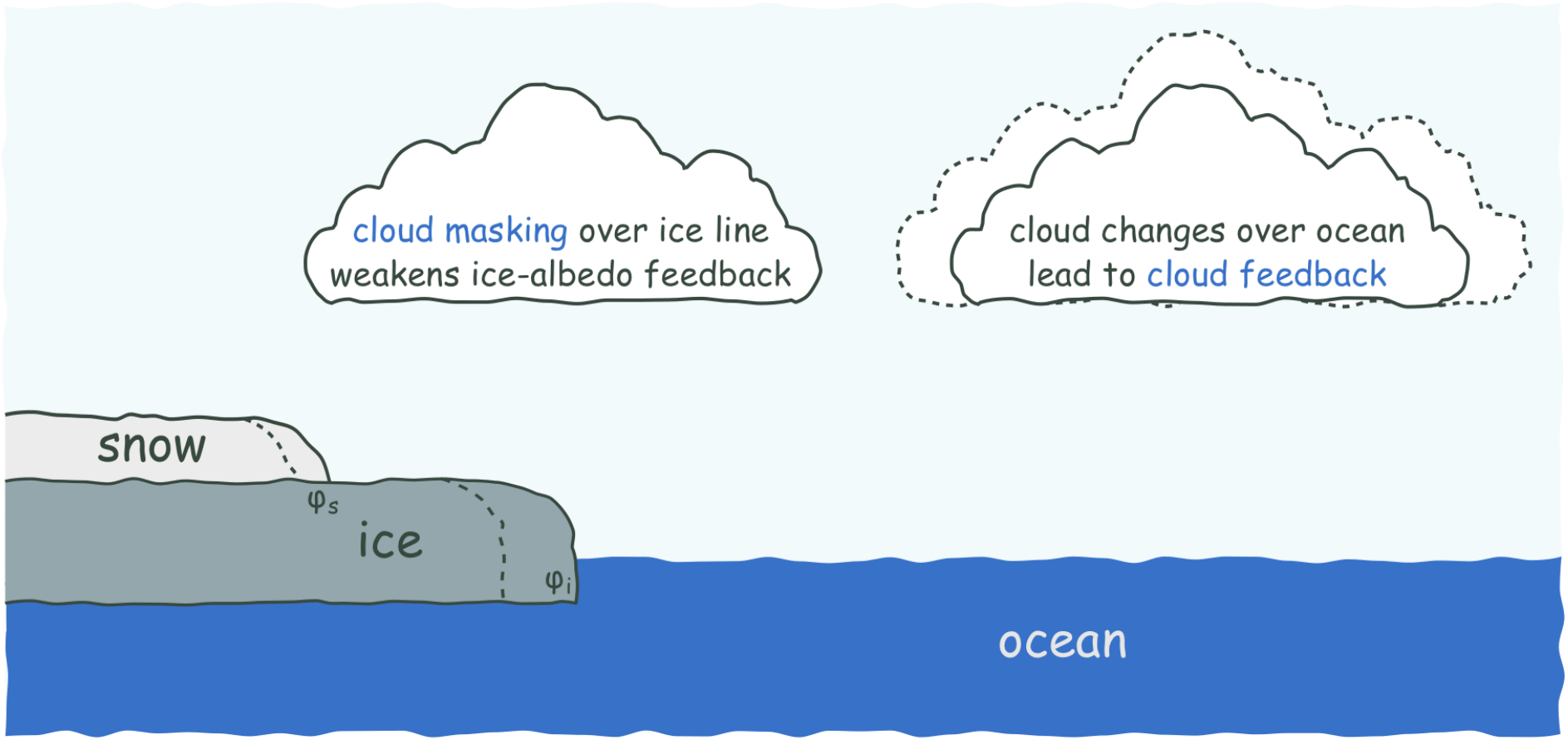
Figs. 1 and 2 of Abbot, Voigt and Koll, 2011, JGR-Atmospheres

How do clouds affect waterbelt states?


snow
φs
ice
φi
ocean


cloud masking over ice line
weakens ice-albedo feedback
snow
φ_s
ice
φ_i
ocean



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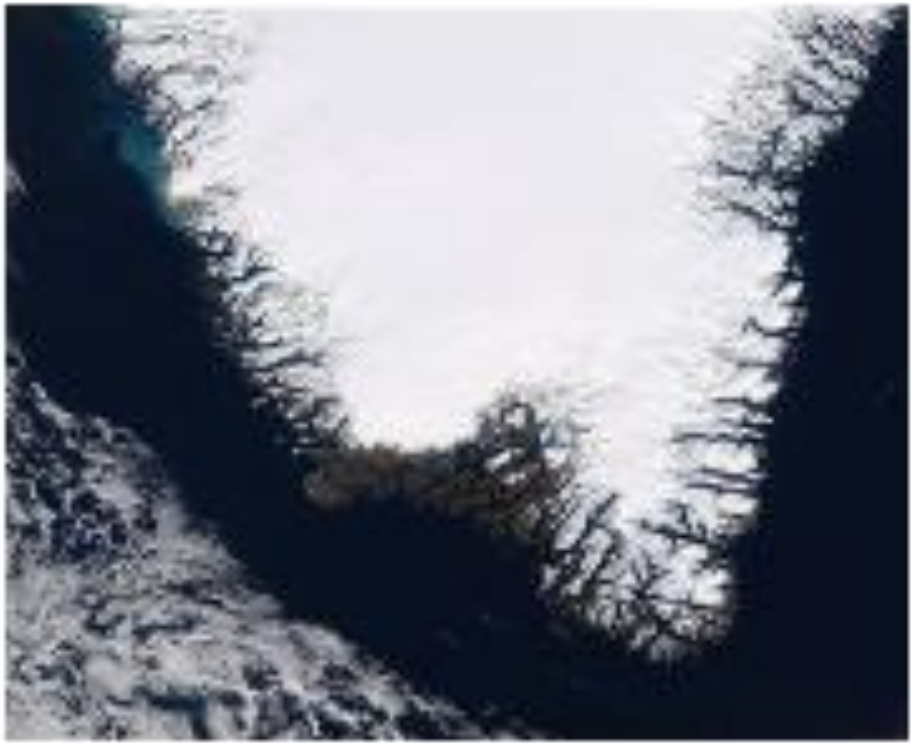
Zero cloud masking: Strong ice-albedo feedback



Strong cloud masking: Zero ice-albedo feedback

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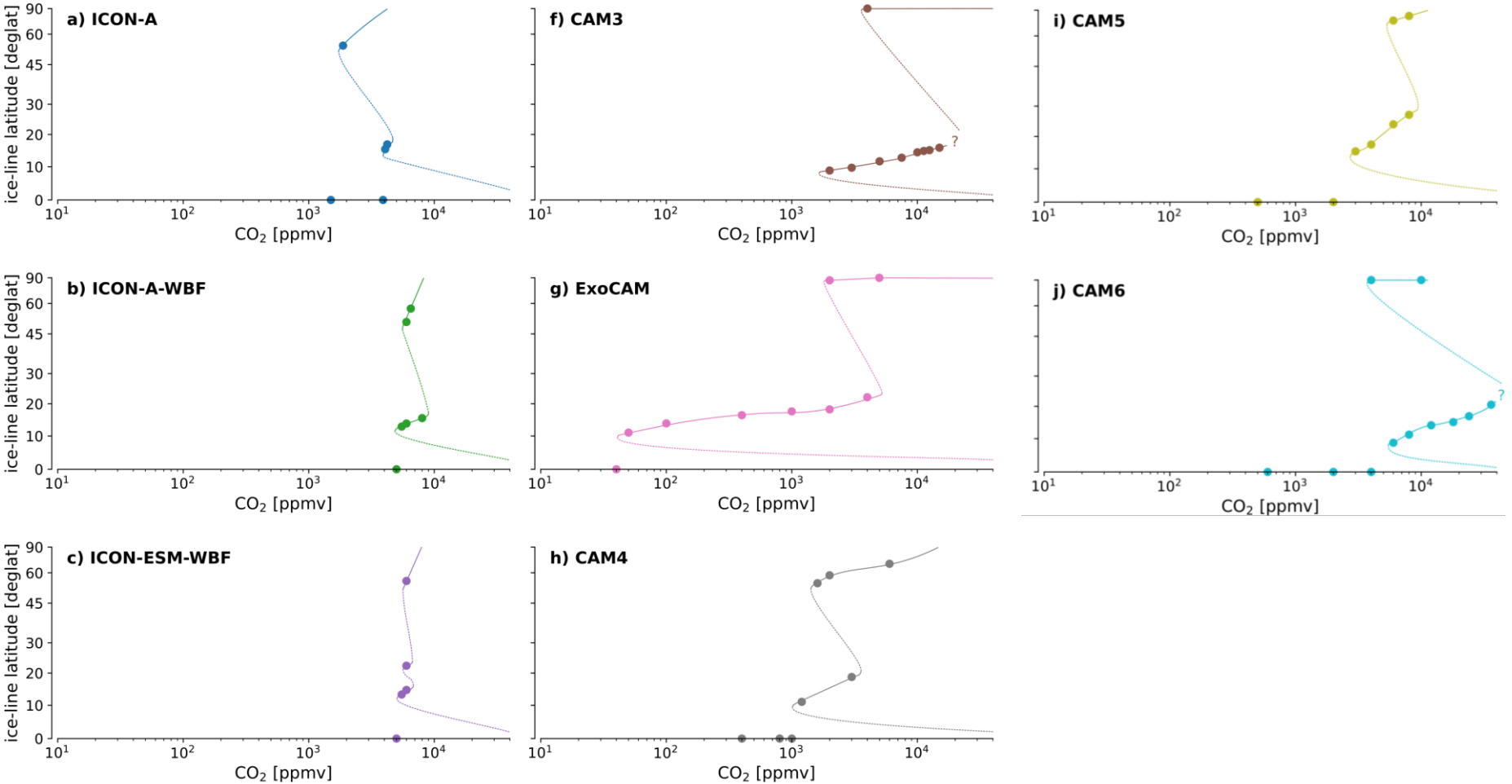
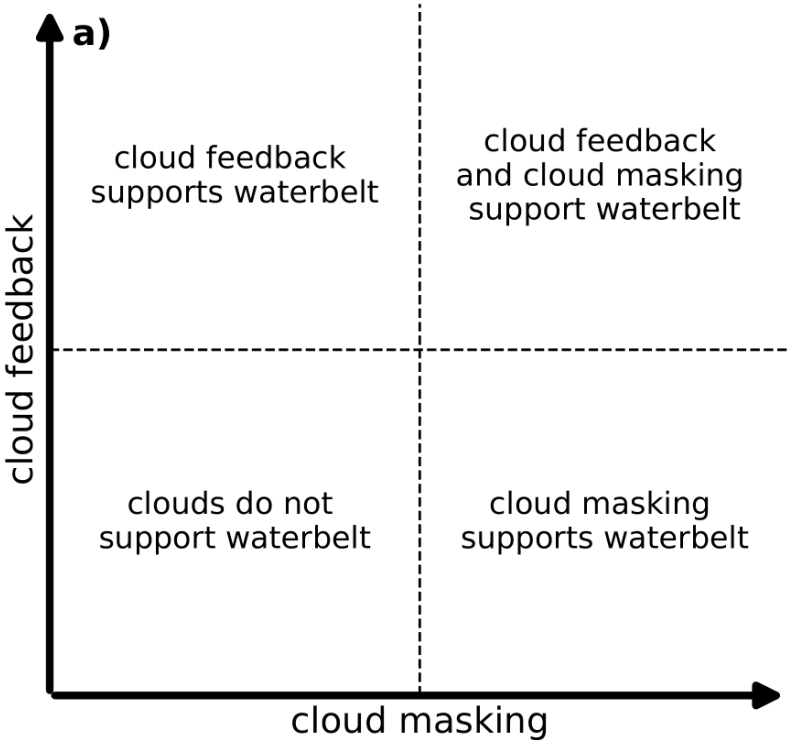
Fig. from Sledd and l'Ecuyer (2019)

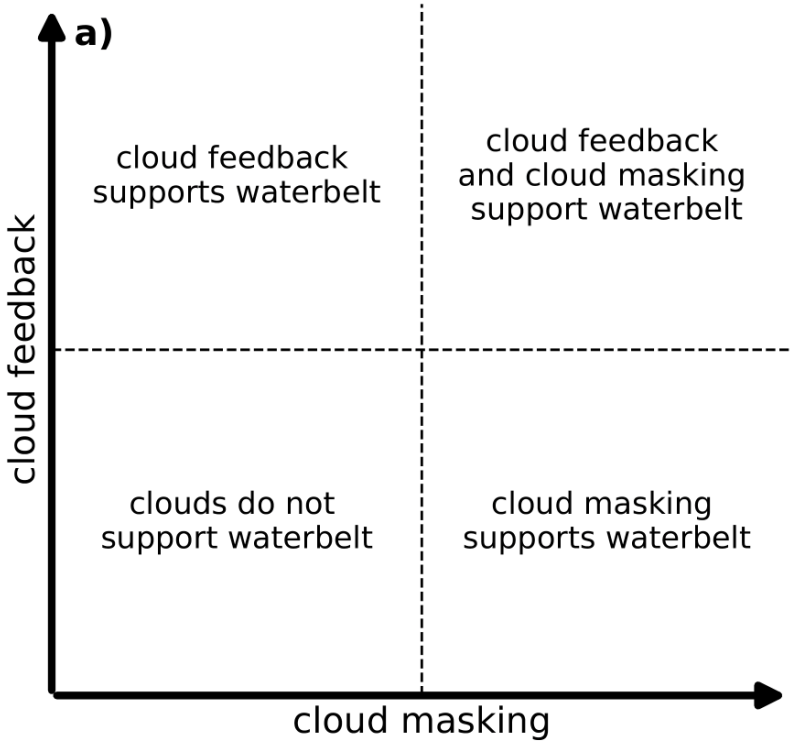
German saying: “Wenn ich nicht mehr weiter weiss, gründ ich einen Arbeitskreis.” (“When i don't know what to do, I set up a working group.”)

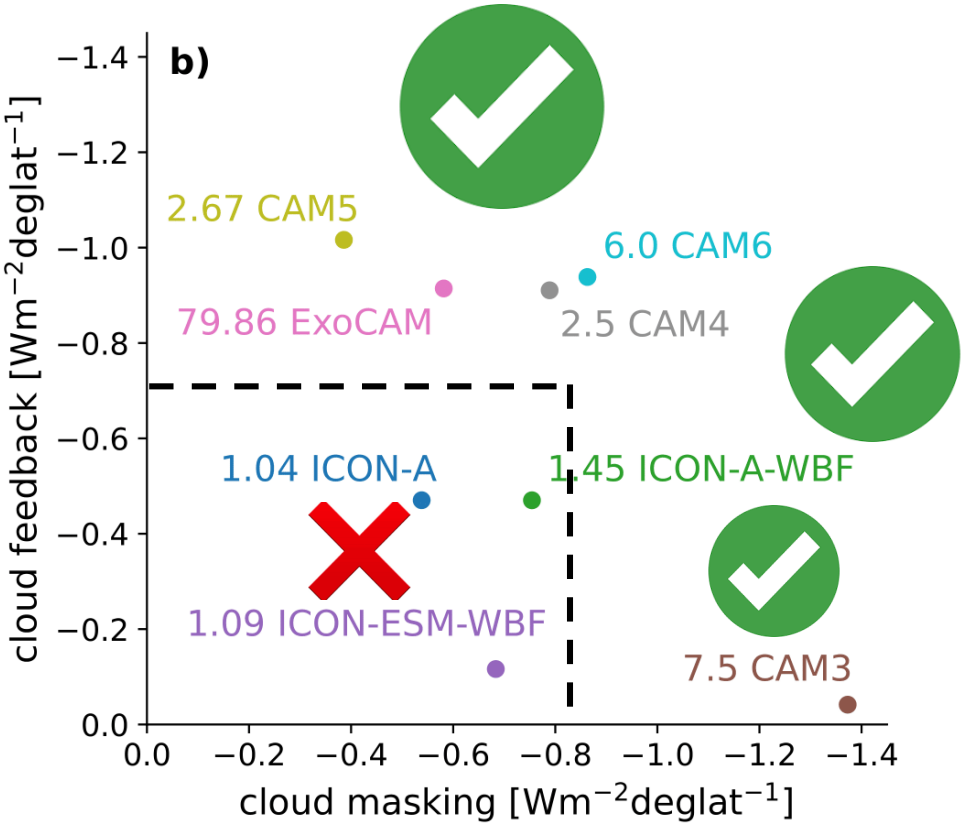
Climate modeling version: “When I don't know what to do, I set up a model intercomparison project.”


a) ICON-A
b) ICON-A-WBF
c) ICON-ESM-WBF
f) CAM3
g) ExoCAM
h) CAM4
i) CAM5
j) CAM6
ice-line latitude [deglat]
CO2 [ppmv]
?



We diagnose cloud masking and cloud feedback through the method of „Approximate Partial Radiative Perturbations“. (Taylor et al., 2007)


a)
cloud feedback supports waterbelt
cloud feedback and cloud masking support waterbelt
clouds do not support waterbelt
cloud masking supports waterbelt
cloud feedback
cloud masking


b)
2.67 CAM5
6.0 CAM6
79.86 ExoCAM
2.5 CAM4
1.04 ICON-A
1.45 ICON-A-WBF
1.09 ICON-ESM-WBF
7.5 CAM3
cloud feedback [Wm^{-2}deglat^{-1}]
cloud masking [Wm^{-2}deglat^{-1}]
0.0
−0.2
−0.4
−0.6
−0.8
−1.0
−1.2
−1.4

Take Home (tailored to climates of Earth-like exoplanets)

Habitable zone ≠ habitable climate:

A planet in the habitable zone might be in
a habitable temperate state,
a non-habitable hard Snowball state,
or a habitable waterbelt state.

Dual role of clouds:

Clouds are as key to climate dynamics of waterbelt states, as they are key to observations of Earth-like exoplanets.