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Earth System Dynamics Discussions

Interactive comment on "Two drastically different climate states on an Earth-like terra-planet" *by* Sirisha Kalidindi et al.

Anonymous Referee #3

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Summary:

This paper explores a climate bifurcation for dry/desert planets, including implicit water cycling through the assumption of a sub-surface aquifer. This work represents a step forward from the classic work by Abe et al. 2011. I feel that this paper is interesting and deserves to be published. I suggest that the authors try to do more to explain why this transition happens, in terms of the cloud albedo and water vapor greenhouse forcing.

General Comments:

1) "It should be noted that the present paper is mainly descriptive in nature and is not meant to explain the mechanisms for the emergence of the two climate states and the way the transition between them happens. This is still under investigation."

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Discussion paper

You should explain the mechanisms for the emergence of the two climate states in this paper. This should be included in this paper to make it complete. I think you can do so by examining the changes in cloud albedo and water vapor greenhouse effect.

2) In your simulations, water is in theory made available everywhere on the planet via diffusion of water from the subsurface water-table into the atmosphere. How is the temperature, clouds, and water vapor in your terraplanet simulations different from an aquaplanet case, given an equal albedo? It would be useful to run 1 aquaplanet simulation with albedo = 0.07 for comparative purposes. (Note that 0.07 is fine for a typical ocean albedo).

Specific Comments:

1) I may suggest changing the title from "…Earth-like terra planet" to "…Earth-like Dune planet", or "…water-limited terrestrial planets." The term "terra-planet" isn't a common term in the literature. Also, the adjective "Earth-like" connotes a planet where surface liquid water is freely available. These dry worlds are perhaps more so Mars-like in description. OR, due to the ambiguity of the term "terra-planet", you should explicitly state somewhere early in the Abstract, perhaps the in the first sentence, that you are dealing with water-limited land planets.

2) Page 2, line 5 "Second, terra-planets with optically thin atmospheres (like present day Earth's atmosphere) can maintain their inner edge of the habitable zone much closer to their parent star compared to aqua-planets due to their higher surface albedo (Abe et al., 2011; Zsom et al., 2013)."

While it is true that dry planets will have a higher albedo than ocean planets, this is just one piece of the puzzle, and I don't think the dominant one. One of the primary reasons that dry planets can maintain habitability at higher stellar fluxes is due to the lack of available water vapor. With less water in the system, the water-vapor greenhouse feedback is severely muted and thus there is significantly less greenhouse warming of the climate system. This is true regardless of surface albedo.

3) Page 3, line 5. Can you give the model horizontal resolution in either degrees lon X degrees lat, or in number lon grids X number of lat grids?

4) what does “Leaf Area Index (LAI) =3” mean? Is your surface vegetated or bare soil? How might the vegetation type affect your results?

5) “overland water recycling” You are not really considering overland water recycling. You are considering a ubiquitous sub-surface aquifer that sources water into the model. Thus you are considering “subsurface” water recycling.

6) “α varying from 0.07 to 0.24” what kind of land surfaces are these appropriate for? igneous rock? desert sand?

7) Page 3, line 32. While the surface temperatures reach equilibrium quickly for dry planets, what about the atmosphere-land water balance? It is my understanding that in some models it can take a considerable amount of model time for water to permeate out of the sub-surface aquifer.

8) It would be interesting to see a figure similar to figure 5, but showing the integrated water vapor column amount, the integrated cloud water amount, and the integrated cloud fraction.

9) It would be interesting to see a additional panels on figure 7 showing cloud and TOA albedo, and also the greenhouse effect. You can estimate the greenhouse effect as G=sigma*Tsˆ4 - OLR

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