Response to Referee #2 comments:

General comments

Referee #2 comment: In this paper, the authors modelled the climate of a terra planet (or land planet), a planet with a global land surface, without ocean. The particularity of the present study is the presence of an unlimited underground water layer providing water at all latitude but behaving differently as an ocean. The authors perform various simulations, changing obliquity, snow albedo and a test with a different convection scheme.

Depending on the value of the surface albedo, two different stable climate states appear. A hot and dry state and a cold and wet state. This latter is a novelty, due to the addition of the underground water reservoir and is an interesting result. However, as the main novelty is the presence of an underground reservoir, more discussion would be useful. For instance the authors tested only a fixed depth of 1.2m to mimic a "recycling" of water from higher to lower latitudes. This setup is somewhat artificial and a justification of the current assumptions as well as the potential effect of varying them would be welcomed.

Authors' response: *We thank the referee #2 for the comment. Our main idea behind this study was to explore how water recycling can shape the climate of water-limited planets. In the traditional land planet studies with limited water inventories, all the water on the planet is exported to the higher latitudes by atmospheric circulation where it is permanently piled up as snow on the icecaps and is no longer a part of the hydrological cycle and has no effect on the climate. However, in reality there is a limit on how large an ice cap can grow and beyond a particular threshold, parts of the ice cap can break off and flow towards warmer regions due to gravity and lead to liquid water formation. Also, as the thickness of the ice cap increases, geothermal flux at the bottom of the ice caps can cause melting and liquid water formation. This water then flows back to the lower latitudes through river flows or if the surface is porous like our present-day Earth the water can percolate into the ground and refill some kind of underground reservoir. Thus, it again becomes a part of the hydrological cycle and therefore can affect the climate in the lower latitudes. In our study, we mimic such a water recycling from higher to lower latitudes by means of a homogenous global subsurface reservoir. Indeed, referee #2 is correct concerning our assumption of a homogenous recycling over the whole globe to be artificial. In reality, recycling may occur at different speeds and might be less or more effective than what we consider in our study. Based on the speed of recycling, the water level of this subsurface reservoir would vary. In our study, the choice of the fixed ground water table depth of 1.2 m was not random and we performed a sequence of simulations starting from a swamp simulation and changed different parameters (including the depth of the ground water table) and various schemes in our land surface model (Table 1; Fig. 1) until we arrived at the bi-stability for a ground water table depth of 1.2 m. Overall, our study should be considered as a first attempt towards understanding how water recycling can shape the climate of land planets with reasonable assumptions. We will include all the information regarding the sequence of simulations performed to arrive at the bi-stability in the appendix of the revised manuscript.*

Specific comments

Referee #2 comment: lines 29-30 of page 4. The authors describe the Hadley cells in Figure 4 "narrower" and "wider". Is it in the vertical direction? Because they look in both cases 30 degrees wide ...

Authors' response: *The reviewer is indeed correct that the Hadley cells in both the terra-planet states look very similar and have the same width close to the surface. But with height the Hadley cell in the CW state gets slightly narrower compared to that in the HD state (when measured around 500hPa). We will rewrite the sentences related to width of the Hadley cell in the revised manuscript to make our point clear.*

Simulations	Background soil albedo	Surface roughness	Heat capacity	Snow albedo	Water reservoir depth from the surface
Aqua-planet	0.07	Ocean	Ocean	0.07	50 m slab ocean, no heat transport
Swamp1	0.07	Ocean	Ocean	0.07	Constant ground water table at a depth of 0.3 m
Swamp2	0.07	Land	Land	0.07	Constant ground water table at a depth of 0.3 m
HD	0.07-0.14	Land	Land	Dynamic (0.4 -0.8)	Constant ground water table at a depth of 1.2 m
CW	0.15-0.24	Land	Land	Dynamic (0.4 -0.8)	Constant ground water table at a depth of 1.2 m

Table 1. Summary of simulations performed to illustrate the procedure by which we found bi-stability on our terra-planet.

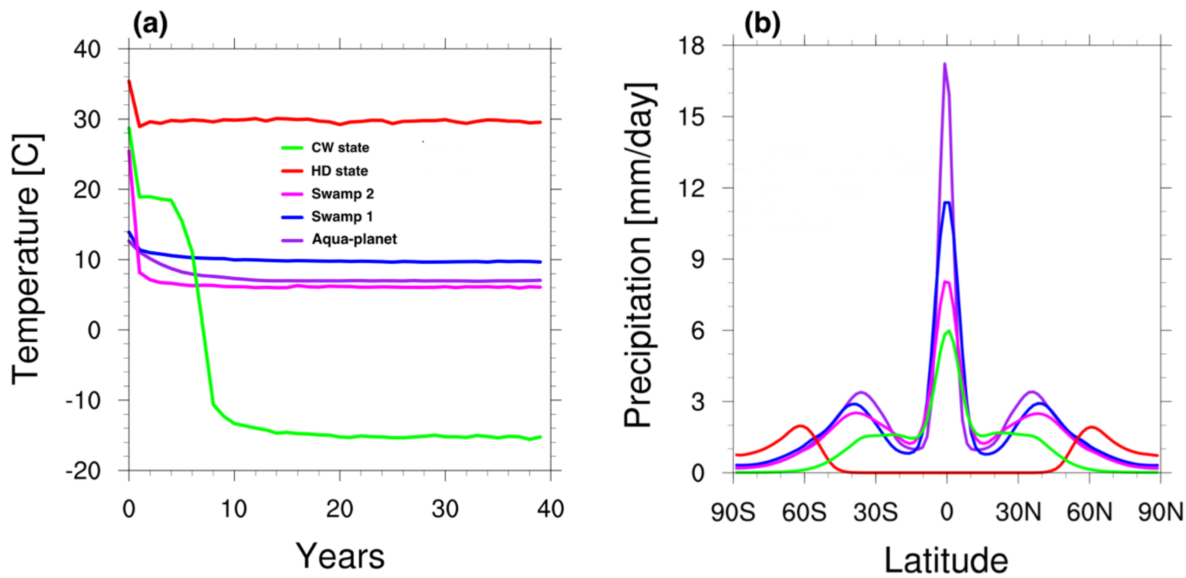

Figure 1: (a) Time series of global mean surface temperature (°C) and (b) annual mean meridional profile of precipitation (mm day^{-1}) for different simulations performed to illustrate the procedure by which we found bi-stability on our terra-planet.