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# *Interactive comment on* "A simple explanation for the sensitivity of the hydrologic cycle to global climate change" *by* A. Kleidon and M. Renner

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We thank Amilcare Porporato for his constructive comments. His comments are included below in italic typeface, followed by our response.

***Comment:*** *This is an interesting analysis using a simple thermodynamics model of the hydrologic cycle, based on the 'closure' hypothesis of functioning at maximum power (a reference or two to the finite time thermodynamics or endoreversible analysis of heat engines that treat these approximations would be useful).*

**Response:** We will provide more detail in the revised manuscript on the maximum power limit to explain this approach (as also mentioned by the other reviewers). The maximum power limit that we use in this manuscript is, however, not related to finite



time thermodynamics and the Curzon-Ahlborn efficiency, but rather very closely related to the proposed Maximum Entropy Production (MEP) principle. We will provide these details in an appendix in the revised manuscript.

***Comment:*** *1) the role of vapor pressure deficit (the 1.26 coefficient of Priestly Taylor is actually resulting from non-saturated atmosphere due to entrainment from free atmosphere into the ABL).*

**Response:** Our approach does not deal with the vapor pressure deficit explicitly because it is treated in our approach as an internal variable of the system. By dealing with the whole, global atmosphere as a black box, we only need to consider the exchanges of energy and mass between the atmosphere and the surface, and the exchange of radiation between the atmosphere and space to identify the thermodynamic limits of its functioning. Entrainment is thus also an internal process within the black box that we do not need to explicitly account for.

Yet, similar to the Priestley-Taylor coefficient, a deviation of the 1:1 partitioning between turbulent and radiative cooling fluxes of the surface is also reflected in the estimate of the global energy balance. In the estimate of Stevens et al. (2012, Nature Geoscience), the absorbed surface solar radiation of 165 W m$^{-2}$ is partitioned into 52 W m$^{-2}$ of net radiative cooling and 112 W m$^{-2}$ of turbulent cooling (sensible and latent), so that the partitioning is not 1:1, but rather biased towards turbulent fluxes (with the turbulent fluxes about 35% higher compared to an equal partitioning). We attributed this deviation from the 1:1 partitioning by the additional generation of motion and subsequent turbulent mixing by horizontal gradients of absorption of solar radiation (Kleidon and Renner, 2013, HESS).

In our model, we can easily account for such a deviation from the 1:1 partitioning by introducing a coefficient similar to the Priestley-Taylor coefficient (similar, because it is also applied to the sensible heat flux). As long as this coefficient is insensitive to surface temperature, our results are not affected by such a parameter, because we evaluate relative sensitivities. In other words, while the absolute sensitivity $dE/dT$ would change with such a coefficient, the relative sensitivity $1/E \cdot dE/dT$ would be unaffected. Thus, such deviations from the 1:1 partitioning are unlikely to affect the results of our study.

We will include this clarification in the revision of the manuscript.

***Comment:*** *Comment on the steady state assumption and time-adjustment of maximum power hypothesis.*

**Response:** The steady state is, of course, an approximation that we made to solve the model and that is reflected in the maximum power limit. This condition assumes that the atmosphere adjusts sufficiently fast such that the driving temperature difference between the surface and the atmosphere is depleted by the convective heat flux, and that both reach a steady state value. This assumption is well justified, as a common assumption in meteorology is that the vertical temperature profile is described by an adiabatic lapse rate that reflects radiative-convective equilibrium (e.g., Hartmann, Global Physical Climatology, Academic Press). In this equilibrium, a slight variation from the adiabatic lapse rate is compensated for by a convective adjustment. This adjustment is commonly assumed to take place fast, so that the steady state between flux and temperature difference is likely to be established at short time scales as well. Hence, it would seem that the steady state condition does not seem to be a major concern.

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Interactive comment on Earth Syst. Dynam. Discuss., 4, 853, 2013.