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Interactive comment on "Diurnal land surface energy balance partitioning estimated from the thermodynamic limit of a cold heat engine" *by* Axel Kleidon and Maik Renner

Anonymous Referee #2

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General comments

This is one of a series of papers using thermodynamic principles (first and second law) together with optimization concepts to investigate aspects of the climate system. Here, the authors apply this approach to turbulent energy fluxes at land surfaces. They show that fluxes derived from optimizing a Carnot cycle modified by heat storage compare well with observed fluxes, and conclude that the applied concept can help to better understand the role of land surfaces and to parameterize the surface-atmosphere interaction. I find the paper interesting as it illustrates a promising approach, and may help to stimulate further investigations in this direction. Thus, I would recommend pub-

lication. However, I have few points, which, in my view, need clarification/consideration before final acceptance.

Specific comments

1) 'cold heat engine': The authors frequently use the term 'cold heat engine', which, honestly, was not known to me before. It seems that a cold heat engine is defined as a heat engine with some storage (P2L29), but a more precise definition may be given.

2) Fig. 1 and Eqs. 1,5,6 : From Fig. 1 it seems that the heat engine discussed by the authors is confined to the radiative-convective layer with Jout being a flux into the free atmosphere above. However, combining Eqs 1,4,5 gives Jout=Rl,out-Rl,net, i.e. the cooling of the whole atmospheric column by thermal radiation. Thus, either it is assumed that there is no exchange between the radiative-convective layer and the free atmosphere, or the heat engine comprises the whole column. This needs to be clarified (in Fig.1 and/or the text introducing the heat engine).

3) Eq. 2: Eq. 2 gives the entropy budget of the heat engine. However, Jout=Rl,out-Rl,net (see above), and Rl,net is the sum of thermal flux coming from the atmosphere (approx. R,l,out, say) and from the surface (Rl,surf). Thus, instead of Jout/Ta I would expect a term (Rl,surf/Ts) and something like 2Rl,out/Ta appearing in Eq. 2, representing both the import of entropy from the soil and the respective export from the atmosphere. It seems that Rl,surf/Ts can be of the same order as Jin/Ts. The authors need to explain why the entropy import from the surface (Rl,surf/Ts) is not considered, in particular as Jout/Ta is used to obtain Eqs. 3,4,7.

4) Eq. 7 (Jopt vs Jin, Part I): Eq. 7 gives an estimate for Jin derived from optimization based on the second law. However, using Eqs. 1,5 to replace dUa/dt and dUs/dt in Eq.7 (or replacing dUs/dt in Eq. 5 by Jobt with dUa/dt as described in Sec. 2.4) shows (if I'm not wrong) that Jobt is not equal Jin. Thus, while Jobt results from utilizing the second law it seems not to be consistent with energy conservation (the first law) within the same model framework (Eqs 1,5). If the conclusion (and the approach taken) that

the turbulent fluxes optimize the heat engine constrained by energy conservation holds, this surprises me. What is the explanation (perhaps it is trivial)?

5) Jopt vs Jin, Part II: The difference between Jopt and Jin (as explained above) is given by Rl,net-Rl,out/2 (again, I hope that I'm not wrong). In Fig 3, although it is hard to judge, this difference seems to be relatively large, and larger than the difference between Jopt and Jobs. If so, this surprises me too. Perhaps, the authors may like to compute this Jin (consistent with energy conservation constraint), compare it with Jopt (Jobs), and discuss the result in the context of the optimization concept.

6) Fig2: I do not understand Fig 2a: A more comprehensive explanation may be given in the text: e.g. what defines the particular shape of the atmospheric heat storage change (pink area).

Technical corrections

1) P4L12: Rs -> Rs,ave

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