## Response to Comments from Anonymous Referee #1

We thank referee #1 for the comments.

1. *This paper seems more like a sensitivity study on soil properties (constant vs. functions of soil moisture), modeled soil depth (5m vs. 8m), and heat convection by rainfall. It is rarely compared to observational data, so I did not see any "improvements", which i thought should be concluded from evaluations against observations.*

**Answer:** This paper mainly focus on the physical process of soil thermodynamics modeling. The improvements are reflected by increasing the realism of models in the aspects of the soil thermal properties (taking into account both soil texture and soil moisture effects), soil vertical layers (consistent between water and temperature), and soil heat transfer process (coupled heat conduction and convection). The new developments together with the sensitivity experiments improve the understanding of the role of these factors in climate modeling. The comparison between LMDZOR with new soil thermodynamics and observations is planned in the next study. (The explanations are to be added in the revised manuscript.)

2. *It is not clear to me what thermal conduction processes were represented in the baseline model. What are the differences between the new one and the baseline model? What made the authors develop the new model?*

**Answer:** The following equations are used in the baseline model

$$C_P(\theta, st)\frac{\partial T}{\partial t} = \frac{\partial}{\partial z}\left[\lambda(\theta, st)\frac{\partial T}{\partial z}\right] \quad \text{(R1)}$$

$$C_S\frac{\partial T_S}{\partial t} = F_{rad} + F_1^h + LF_1^q + G_1 \quad \text{(R2)}$$

In the baseline model, the $-C_W\frac{\partial q_L T}{\partial z} - C_W ST$ in Eq.1 and $H_1$ in Eq. 2 are not included. These two terms describe the energy transferred by liquid water movement in the soil and at the soil surface.

The motivation of developing these processes is to represent the energy budget possibly close to the real world in the earth system model. Although the amount of energy by heat convection could be small at large time scale (e.g., monthly), the other components of the earth modeling system could be influenced through land surface temperature and surface energy budget (Wei et al., 2014). Therefore, it is necessary to

include these processes in the earth system model. (The explanations are to be added in the revised manuscript.)

3. *Please refer this paper on heat convection in the soil: Impact of precipitation-induced sensible heat on the simulation of land-surface air temperature. N Wei, Y Dai, M Zhang, L Zhou, D Ji, S Zhu, L Wang Journal of Advances in Modeling Earth Systems 6 (4), 1311-1320*

**Answer:** To be added and cited in the revised manuscript.

4. *It is not clear what the conclusions are drawn from the experiments. Please revise Section 5. summary and discussions to split it into discussions and conclusions.*

**Answer:** The main conclusions from the experiments include [Page 8426, Lines 22-29; and Page 8427, Lines 1-8 in the GMD Discussion paper]: The impact of the energy transported by the liquid water on the soil thermodynamics and on the near-surface meteorology is rather weak. In contrast, the introduction of a moisture/texture dependence of the thermal properties has a noticeable effect on the near-surface meteorology. The response of the diurnal cycle of the energy budget at the surface to a modification of the soil thermal properties is strongly asymmetric and is most pronounced during the night. The revised soil thermal properties induce a mean cooling, a mean increase of the diurnal temperature range and a mean increase of the intra-annual Extreme Temperature Range. The short-term variability depicted by the inter-diurnal temperature variability of the daily mean (ITV) and of the minimum temperature ($IT_NV$) is also partially controlled by the soil thermal properties. The effects of soil thermal properties on ITV and $IT_NV$ are most pronounced over arid and semi-arid areas, where the thermal inertia of the soil is the lowest. The overall increase of the mean values for both DTR and ITV is mostly due to a widening of the distribution towards high values (e.g., $75^{th}$ and $99^{th}$ percentile) and to the increased standard deviation, manifesting a more frequent occurrence of extreme values." (The summary and discussions are to be split in the revised manuscript ['Section 5 Discussions' and 'Section 6 Summary'].)