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Interactive comment on "High-resolution modelling of interactions between soil moisture and convection development in mountain enclosed Tibetan basin" *by* T. Gerken et al.

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Response to Reviewer 2

Tobias Gerken et al.

22 July 2015

We would like to thank Reviewer 2 for their work. The reviewer's comments are much appreciated and will improve the clarity and legibility of the manuscript. We are happy to revise our text in accordance to the reviewer's suggestions.

Below is our response to all reviewer comments including proposed changes to the revised manuscript. Our response is always printed in **red**. Text modifications are put in quotation marks. Line numbers correspond the initially submitted manuscript and may change in the new document.

1 Major comments

1. A key aspect that is not discussed in much detail is the role of flux heterogeneity on the development of convection. Much of the paper takes a 1D approach, looking at mean turbulent fluxes and the evolution of convection throughout the domain, but the highly heterogeneous terrain will surely induce mesoscale circulations which will have a significant impact on convective initiation. For example, the authors argue that the reduction in convection for the highest soil moisture

values are due solely to a reduction in radiation due to increased cloud cover. From the results it is clear that this is indeed a factor. However, the reduction in sensible heat fluxes over land due to the high soil moisture will also reduce the land-lake temperature gradient, potentially reducing the magnitude of any mesoscale flows, and therefore convergence over land, which will also reduce the intensity of convection. I think the impact of surface heterogeniety in your results needs to be discussed throughout the paper (e.g. in P4649, L1-9). For example, the authors could show 2D plots of surface fluxes/temperatures, and some quantification of convergence in the different simulations. $\rightarrow$ **One of the primary reasons, why flux heterogeneity was not discussed in detail in this work was the 2D-simulation approach. We believe that a 3D-approach, which was too computationally expensive for the resolutions used in this work would be more suited to analyze and discuss spatial organization. Also, soil moisture driven mesoscale circulations are typically much less strong than lake-breezes or upslope winds. Additionally, they require comparatively large areas to develop. Previous work by Gerken et al, 2014 (10.1007/s00704-013-0987-9) investigated the influence of mesoscale circulations from both the complex terrain and the lake breeze on the development of convection, which we believe to be much more important than land induced circulations. One measure of spatial heterogeneity included in the present work is interquartile range of surface energy fluxes and solar irradiance, which is presented in Figure 5. We agree with the reviewer that there is little discussion about this aspect and propose to add the following to section 3.2 (see response to P4636 L20 for additional text):**
"The spatial variability of surface energy fluxes and solar radiation also shows that surface-atmosphere interactions change with increasing soil moisture. With the onset of cloud development, solar irradiance of shaded grid cells begins to decrease, while the median irradiance and turbulent surface fluxes remain unaffected. With increasing cloud optical depth me-

dian shortwave radiation fluxes begin to decrease. This occurs first in the most shaded cells and then progresses to the mean fluxes. For the moister simulations (1–2$\times FC$) there is little difference between lower and upper quartile latent heat fluxes in the early afternoon, indicating widespread cloud cover as the main driver for the decrease. However, in the later afternoon, there is again increased variability in the simulated turbulent fluxes (both median and upper quartile) that is not accompanied with a corresponding increase in the median solar irradiation flux. This indicates that in addition to solar irradiance, local circulation systems likely play a role in the surface energy balance. The impact of local circulations on the surface energy balance, turbulent fluxes and convective triggering was investigated in Gerken et al. (2014). "

2. My other main issue (although with an easy solution) is the description of the model domain, as it is not shown in Figure 1 and there are no lat/lon coordinates of the end points. Locations such as the Nyenchen Thangla mountain chain may not be known by many readers (including myself), and although a reference to another paper is provided, this information should be included here. $\rightarrow$ **The Figure will be updated with the extent of the domain as in Gerken et al 2013 (JGR)**

2 Specific Figure comments

1. Figure 1: This figure is key to orient the reader during the subsequent analysis, but is not very useful at the moment. I think the results in the paper can be applied beyond the Tibetan Plateau, so many readers may not be familiar with the region. At the moment it mainly shows land use type, but this is not referenced during the analysis at all (except land vs lake, of course). I would make the following

suggestions: - The figure should show topography, as this is probably the most important forcing of convection. Either add this as a line contour, or replace the land use colour contours with topography. - Add a line showing the model domain. Also show what part of the model domain is the 'edge' - where fluxes are reduced to zero I assume this part is excluded from the subsequent analysis?) as well as which parts count as 'basin' and 'plain' (e.g. in figure 7). - Change the colour of the cross showing the location of the Nam Co station, as it is very hard to see. - In the caption: "the markers indicate 10km a.g.l..." I'm not sure what markers are being referred to here. - It would be helpful to label locations referenced in the text (e.g. the Nyenchen Thangla mountain chain). - either as an extra panel here, or in Figure 3, it would be useful to have a plot of topography along the model domain. → **Yes, the area, where fluxes are reduced to zero is not included in the analysis. The marker of 10 km agl refers to the small marker on the trajectory of the sounding. It shows the location, in which the sounding reached 10 km above ground level height. We will improve the figure by adding the domain, increasing marker sizes and by adding additional labels. We will also add a plot of topography along the model domain.**

2. Figure 2: I suggest that the y-axis is changed to height agl, to be consistent with all the other figures. → **The figure will be changed according to the reviewer's suggestions.**

3. Figure 3: The axis and legend labels are too small. The colour contour range seems to wide, as I can only see light red/blue, so maybe this could be reduced? Maybe some of the variability is hidden by the line contours. It would be clearer if the line contours were thinner (I can't see the w values inside). It is hard to distinguish the black and blue lines (either make the blue lighter, or remove the black lines and add a panel showing topography) → **The figure will be changed according to the reviewer's suggestions.**

4. Figure 5: Like in Figure 3, the blue and black are hard to distinguish, especially with so many lines. A lighter blue would be helpful. → **The figure will be changed according to the reviewer's suggestions.**

5. Figure 9: All labels need to be bigger. → **The figure will be changed according to the reviewer's suggestions.**

6. Figure 10: It is quite hard to read this plot as it is quite small, especially the dashed line (maybe make this another colour?) → **The figure will be changed in order to improve legibility, by increasing plot size, fonts and linewidths or colors.**

3 Minor comments

1. P4636, L20: There is quite a large body of literature showing the effect of urface heterogeneity at those scales on winds and convection in aircraft observations (Taylor et al 2007, Garcia-Carreras et al 2010), satellite (Taylor et al 2012) and models (Cheng et al, 2004 amongst others). In particular, Taylor et al (2012) shows that, in flat terrain, a negative soil moisture - rainfall feedback appears to be the norm (consistent with the convection-permitting simulations described in the following paragraph). → **We will amend the introduction following the reviewer's suggestions: "Taylor et al. (2012) showed that the likelihood of convective precipitation over wet soils was increased. This can potentially attributed to the development of mesoscale circulations between dry and wet patches. Clark et al. (2004) has shown that moisture variability on the 10 km scale can induce regional circulations that enhance convection. Additional evidence for the influence of soil moisture induced mesoscale circulations on convective development was found in observational (Taylor**

et al., 2007) and modelling studies (Cheng et al., 2004; Garcia-Carreras et al., 2010)."

2. P4643, L24: Here the authors are not using a single model grid point, but the model domain-mean, which will additionally introduce systematic differences due to hetero- geneity in the domain(which the authors allude to earlier in the paper). How does Figure 5 change if the closest model grid point to the station is used, instead of the whole domain? Is 0.75 x FC still the 'best'? There is no need to necessarily show the figure, but a comment in the text would be useful. → **We believe that a 1:1 comparison between a single cell and the station is not meaningful, as the changes in exact cloud location, wind field etc during a single day, will have large effects on the simulated fluxes. In our opinion one would need more simulations (i.e a climatology or ensemble to get a meaningful comparison. However, we will produce a comparison with the nearest cell and provide comment in the text.**

3. P4644, L10-11: This directly contradicts the 2D vs 3D comparison, which shows stronger convective development in the 3D simulation. → **In our opinion, this is not a direct contradiction to the previous statement, as we are talking first about the comparison of 2D and 3D simulations, while later we discuss the comparison between reality and 2D simulations. A lack of the third dimension will reduce entrainment and will thus increase convective strength. This is well established in the literature (i.e. Wu et al, 2009, Kirshbaum et al, 2011; cited in the manuscript).**

4 "Technical" comments

1. P4633, L11: I would change 'convection development' with either 'convective develop- ment' or 'development of convection' (here and elsewhere in the paper).

→ **changed to "convective development"**

2. P4633, L14: "and sensible heat fluxes, WHICH has a strong..." → **changed**

3. P4634, L21: Remove 'semi-arid' (mountains are important triggers of convection ev- erywhere). → **changed**

4. P4637, L21: "it is situated AT 300 m distance FROM a small lake... to the north-west BY a 500 m" → **changed**

5. P4637, L24: "AT 00:00, 06:00 ..." → **technically radiosondes were not released at the times given, but circa 30 minutes before. As the the total time of the radiosonde ascent trough the topopshpere takes approximately 1 hour, 00:00 refers to the representative time for the ascent.**

6. P4640, L21: How come the simulation begins at 0400 LT while the initial profile is for 0600LT? → **Soundings were launched at standard meteorological times, while the model was started 2 hours before sunrise, to allow for the interaction of turbulence and atmospheric profiles, prior to starting the solar forcing. It was confirmed that the change in the mean profile was minimal during the two hours.**

7. P4641, L9: Use LT instead of UTC. → **changed to "06:00 LT (00 UTC)"**

8. P4641, L17: What do T1 and T2 refer to? → **this refers to the two soil layers. We clarified to "first and second layer mean temperatures T1 andf T2"**

9. P4645, L14: "to soil moistures IN the moister 1.5 x FC case" → **changed**

10. P4646, L7-9: Unclear, suggest rewriting this sentence. → **Compared to the land surface, sensible heat fluxes from the water surface are small and have little variation between cases. We clarify to: "There is little variation of evaporation from the lake surface between cases and total daytime evaporation**

is less than 0.5 mm (Fig. 6d) and thus 50 % smaller than evpotranspiration from the land surface of even the driest case, highlighting the role of the land surface as a source of water."

11. P4647, L8: "which is associated WITH INCREASED cloud cover". The following two sentences are unclear.' → **Thank you for pointing this out: In the editing process these sentences got garbled. We meant to express that after 12:00 the moist cases show a leveling off in exchanged surface energy, while the intermediate case, initially levels off, but then starts to increase again, which shows that due to decreased cloud cover surface fluxes pick up again. We clarify to: "While there is also a reduction in fluxes after 12:00 LT, but unlike for the moister cases, this results in only a temporary reduction in the surface to atmosphere transfer of latent heat which then increases again, while the transfer of sensible heat is as large as for case $0.5 \times FC$."**

12. P4651, L22: Add a one sentence summary of the modelling approach (i.e. the fact that the model was run with a range of soil moistures). → **added: "The ATHAM model, with a fully coupled surface, was used to investigate surface-atmosphere interactions in a cross section through the Nam Co Lake basin for simulations with different initialized soil moistures."**

13. P4651, L4-6: move "only with very dry land surfaces" to the end of the sentence. → **changed**

14. Figure 7 (caption): "sensible and latent energy over THE lake, over THE plain ... in THE total domain". → **changed**

15. Figure 8 (caption): replace 'cloud particle concentrations' with 'liquid water' (or what- ever specific diagnostic is actually plotted) → **changed**