Response to Anonymous Referee #1

We thank the referee for his/her constructive comments and perceptive questions. Below, we quote each comment, followed by our response.

1. "The cause for the strengthened ENSO-rainfall relationship over eastern Australia by dust is not well explored. The authors mentioned that dust have both positive and negative effects on local rainfall. However, this information belongs to the discussion rather than the analysis of results. The authors may need to do some diagnosis of the dynamic circulations (e.g. vertical convection as shown by Lau et al., 2006, atmospheric stability changes as shown by Miller et al., 1998) before they conclude the 'possible' mechanism in page 1612."

   The major comment from the other referee was similar, and (in hindsight) we agree that the mechanism wasn't adequately explored in the discussion paper. After a lot of additional analysis, we concluded that the mechanism we proposed in the discussion paper is incorrect. The revised manuscript makes it clear that the mechanism is related to changes in moisture transport induced by the radiative forcing of dust over the oceans to the east of Australia. There are several new figures, showing changes in stability, moisture convergence and transport, surface evaporation, radiative forcing and atmospheric heating profiles due to dust. Probably the single figure that most convincingly shows that the mechanism is related to changes in moisture transport, rather than local radiative effects of dust as we previously suggested, is the one that is reproduced here as Fig. 1. This shows the difference (DUST minus NODUST) of the regression slopes of lower-tropospheric moist instability versus Niño3.4 SST. Based on the total moist static energy (Fig. 1a), the DUST run shows an amplification of the change in stability in response to ENSO, over most of eastern Australia. This is due to changes in moisture (Fig. 1b), whereas there is a smaller offsetting effect due to changes in temperature (Fig. 1c). Further analysis (in the revised manuscript) shows that, in the DUST run, enhanced (reduced) moisture convergence over eastern Australia under La Niña (El Niño) conditions can be related to dust-induced changes in evaporation from the surface of the Pacific Ocean.

2. "Page 1607, lines 18-24: why there is an increase in surface air temperature after considering dust radiative effect, even for the daily maxima? The two studies the authors referred to (Washington et al., 2006 and Yue et al., 2010) showed decrease in the daily maxima (at the local noon or early afternoon) due to dust scattering effect."

   This is an interesting point. Although our small increase in daily maxima differs from the result of Washington et al. (2006) over the Sahara, it's not clear that it's inconsistent with the simulations of Yue et al. (2010) over Australia. Since this isn't the core topic of the paper, we have added just a few sentences, as follows:

"It's noteworthy that our model indicates a small increase of average daily maxima due to dust over Australia. This differs from the observational result of Washington et al. (2006) for Saharan dust in the Bodélé Depression, where daily maximum temperatures were lower in the presence of dust. However, our result appears to be not inconsistent with that of Yue et al. (2010), whose simulated afternoon temperatures over central and eastern Australia were increased in the presence of dust (their Figure 7b, which corresponds to 4 pm over eastern Australia). This is an interesting result, but we do not consider it further in the present paper."

3. "Why the profile of atmospheric heating by dust (upper panel in Fig. 11, centered at 130°E) does not match the location of maximum surface response (bottom panel in Fig. 11, centered at 137°E) and the vertical profile of dust concentrations (Fig. 12, centered at 140°E).

   To answer the question, it is important to first point out that Fig. 11 shows the *mean* dust radiative forcing, whereas Fig. 12 shows the *regression* of dust concentration against Niño3.4 SST. The regression of dust concentration against Niño3.4 SST is shifted towards the east, due to higher rainfall there, and a stronger correlation of rainfall with Niño3.4 SST. A plot of the mean vertical profile of dust concentration, which is directly comparable with Fig. 11, indicates that the maximum dust concentration is at 135°E (Fig. 2, below). When we re-examined the plot of dust atmospheric heating and surface forcing (Fig. 11 in the discussion paper), we found that there was an error in the script, which caused the maxima to be slightly displaced. The corrected version (Fig. 3 below) shows maxima at 135°E for both fields, consistent with the location of the maximum in dust concentration.

4. "Equation (1): there may be an incorrect additional right parenthesis in the equation."

   Yes, and it's now fixed.

5. "Equation (3): what's the difference between Veff and U10m? Are they the same in your model description?"

   We have revised the notation to make it clearer, using V for all wind-speed terms, and ensuring that each one is defined.

6. "The left color bar of Figure 2 seems incorrect."

   For some reason, the figure was corrupted during production (when the figures were converted from EPS to PDF files). The technical editor and I will both check that this doesn't happen in the revised manuscript.

7. "What's the observation for rainfall in Figure 5. Is it from the Australian Water Availability Project as you mentioned in section 3.3? You need to introduce it a little earlier."

Actually, the original plot of observed annual rainfall was based on an earlier data set from the Australian Bureau of Meteorology. Although it only makes a small difference, we updated the figure so that it uses consistent data from the Australian Water Availability Project, and modified the text so that the data set is defined when it is first used.

References

Washington, R., Todd, M. C., Engelstaedter, S., Mbainayel, S., and Mitchell, F.: Dust and the low-level circulation over the Bodélé Depression, Chad: Observations from BoDEx 2005, J. Geophys. Res., 111, D3201, doi:10.1029/2005JD006502, 2006.

Yue, X., Wang, H., Liao, H., and Fan, K.: Simulation of dust aerosol radiative feedback using the GMOD: 2. Dust-climate interactions, J. Geophys. Res., 115, D4201, doi:10.1029/2009JD012063, 2010.

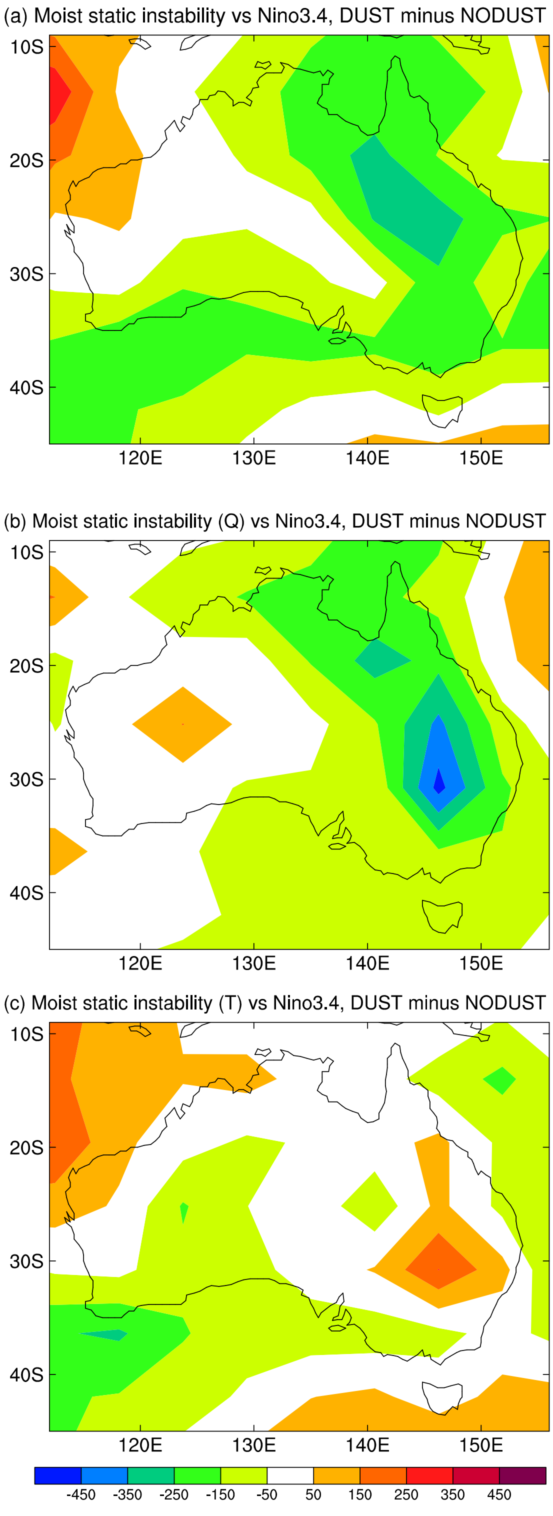

Figure 1: Difference of the regression slopes of moist instability versus Niño3.4 SST between the DUST and NODUST runs for SON. Moist instability is defined as the difference of moist static energy between near-surface air and the 700 hPa level (in J kg^{-1}): **(a)** based on total moist static energy, **(b)** contribution of moisture changes, **(c)** contribution of temperature changes.

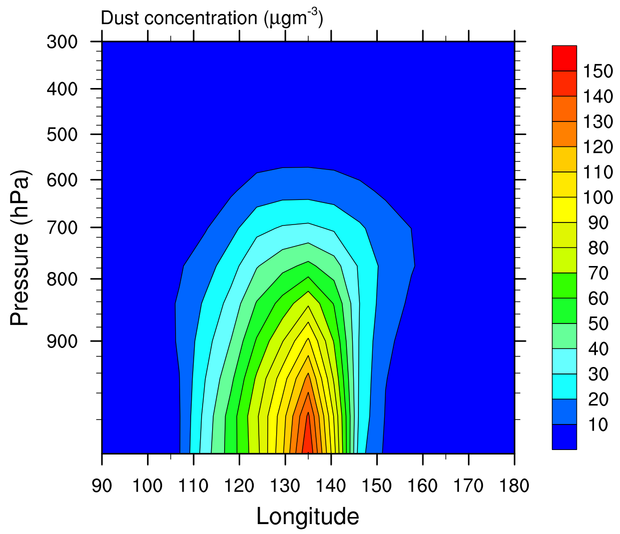

Figure 2: Dust concentration for SON, averaged over the latitude range 20.5°S to 29.8°S (in μg m^{-3}).

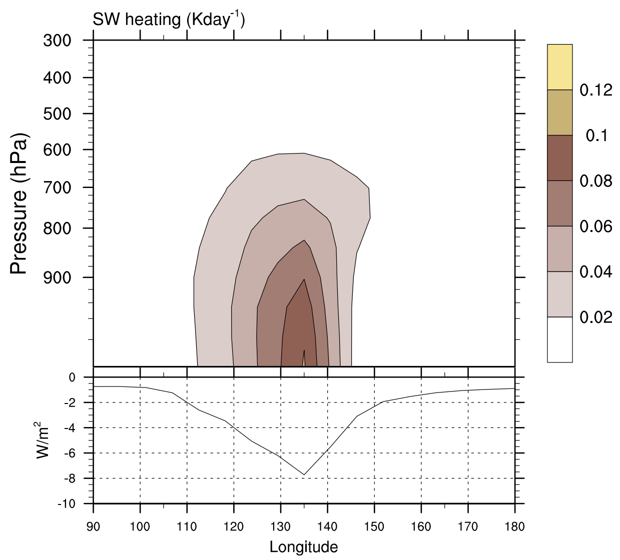

Figure 3: Dust shortwave radiative forcing for SON, averaged over the latitude range 20.5°S to 29.8°S. The upper panel shows dust atmospheric heating in K (day)$^{-1}$. The lower panel shows dust radiative forcing at the surface in W m^{-2}.