# Reply to Referee 1.

First of all we want to thank a lot Referee1 for her/his excellent comments and suggestions. As much as possible we tried to address her/his concerns in the following reply.

The different points of Referee1 are in **bold**, our response in normal and main insertions / changes to the revised manuscript are in *italic*.

Additional Figures are proposed for the revised version and are displayed at the end of this reply. Modified Figures from the manuscript are also displayed.

**Two major points:**

**1. More comparisons of the dust distribution to observations are necessary. For the dust can you show some AERONET and other in situ comparisons, including size distribution, and seasonal cycle?**

We tried to address this point by adding to the manuscript some comparisons of :

1) Simulated and AERONET AOD for the station of Solar Village, Karachi, Meizera and Kuwait airport. These are stations with reasonably long time series (level 2 obs.) over our period of simulations. We propose monthly comparisons, for which monthly averages are calculated from daily averages and screened for day without observations. A scatter plot for the four stations is proposed (Figure R7). AOD seasonal cycle is more particularly discussed for solar village (Arabian source) and Karachi (influenced by Indo-Pakistanese source with a contribution of anthropogenic sources) cf Figures R8 a and c.

2) Simulated vs. observed AERONET size distribution over the stations of solar village and Karachi , representative of JJAS 2009 (Figure R8 b and d ). Observations of size distributions for the studied period show quite a lot of gaps and we thought that choosing one specific year would be good enough given that size distribution is not likely to show a strong inter-annual variability (notably given uncertainties e.g. in AERONET inversions). JJAS was selected because of the relevance for Indian monsoon interactions discussed in the paper.

Text added to the revised manuscript:

….

*Additional comparisons of simulated AOD and ground based AERONET retrieved AOD (500 nm) are proposed in Figure for the stations of Solar Village, Meizera, Kuwait airport and Karachi. Dust aerosol dominates over these stations, except perhaps during winter season over Karachi. For both model and observations, monthly averages are built from daily means and account for missing days in observations. Figure .a shows that the model tends in general to slightly underestimate observed AOD. This underestimation is perhaps more pronounced for the Karachi station, as also shown on JJAS comparisons (Figure R). The simulation of AOD seasonal cycles shows an overall consistency with observations (Figure R). However we note that for certain years AOD spring maxima tend to be underestimated by the model over solar village, while summer peaks tends to be overestimated. This slight shift of the seasonal cycle is also discussed in Shalaby et al. (ACPD,2015).*

*On Figure we compare simulated aerosol size distribution to size distribution retrieved by AERONET inversions and re-binned to match model dust bins (Figure R8). Due to lack of observational data and given the scope of the study, we restrict this comparison to JJAS 2009. Inter-annual variation of JJAS size distribution might anyway be of secondary order, especially given the possible uncertainties in AERONET inversions (Dubovik et al., 2000). For both Solar Village and Karachi, the model tends to show a consistent relative distribution between bins compared to observations. However we can note an overestimation of simulated fine and/or medium bins compared to underestimated coarse bin, especially in the case of Karachi. One of the possible reasons for this might lie in the emission size distribution (Kok et al., 2011) who tends to be more uncertain to represent coarse particles as for example discussed in Mahowad et al., 2014. Other reasons could be linked to accuracy in sources geo-location, removal and transport processes. Bearing in mind observational uncertainties, the implication of a simulated dust size distribution shifted towards smaller particles would be to enhance SW scattering vs. SW absorption and LW emission with implications on radiative forcing discussed further.*

…

**How sensitive are your results to optical properties and dust size assumptions you are making? Why should we believe your results? Please indicate where your dust optics are from, why they are correct, and show us some more comparisons to convince us you are doing a good job. Please also add a paragraph discussing optical properties sensitivities and how that might impact your results. Consider Perlwitz et al., 2001, for example, and how different the climate response is depending on small changes in optics.**

Dust optical properties considered are given in supplementary information of the manuscript with adequate refernces.

*Dust bin size and corresponding short wave optical properties for the visible band (350-640 nm) of the RegCM model. These values were determined from a Mie code and considering a dust sub-bin size distribution from Alfaro and Gomez 2001 with parameters detailed in Crumeyrolle et al., 2010. Dust refractive indices were taken from the OPAC data set (d'Almeida et al., 1991). For the visible band the considered refractive index is 1.55 – 0.0055i.*

Sensitivity of the results to optical properties and size distribution.

In the revised manuscript we discuss further this point by adding the following paragraph as well as the suggested reference.

*… That said, it must be noted that radiative forcings and impacts might strongly depends on dust chemical composition and absorption/scattering properties (Tegen et al., 2001; Solmon, et al., 2008), which exhibit a large regional variability (Deepshikha, et al., 2005), but are unfortunately poorly constrained by observations. In the present simulations we do not account for regional variation of dust refractive indices as proposed in recent studies (Scanza et al., 2014). This point might be especially important over the Indo-Pakistanese region where single scattering albedo might be close to its critical value in relation to surface albedo. A slight change in optical properties and/or a misrepresentation of size distribution could result in a change in the sign of radiative forcing resulting in opposite dynamical feedback (in this case enhancement of elevated heat pump versus dimming over Pakistan and northern India). Some simple tests modifying dust SSA values in RegCM4 and performed over the same domain tend to show that the more absorbing the dust, the more intense is the positive feedback on convergence and precipitation over India (S. Das personal communication, 2015). Finally we do not account for possible dust indirect effects on warm and ice cloud microphysics for which there is still a considerable debate and regional impacts difficult to assess.*

..

Rq : We would like to point out that some colleagues working with RegCM4 have been investigating the sensitivity of the dust feedback to SSA, independently from this study. Their conclusion is that increasing dust absorption leads to an intensification of dust induced convergence and precipitation over India. Reversely more scattering dust tends to inhibit this feedback. However since the model configuration used is quite different from the one used in the present study (e.g. no slab ocean, which is an important factor) and since these colleagues have proposed a manuscript for publication it is not possible for us at this point to include extra material beyond the proposed qualitative discussion.

**Minor points:**

**"Comparison of Fig. 2b, d, f and h shows that radiative effects of dust tends to reduce model biases over continental India southern and northwestern re-gions." This is a really important statement, and yet is very difficult to see in the figures. Maybe add another set of plots which show TRIMM (or PERSIAN or APHORODITE) minus the dust case?**

Additional plots are proposed in the revised version supplementary material.

**Please consider the possibility of anthropogenic sources varying the sources of dust over this period, and incorporate some of the analysis from Ginoux et al., 2012.**

Thank you for this suggestion. Indeed the anthropogenic component might be non negligible for explaining the observed dust trend. We point out to this reference in the introduction and conclusion.

**For the Rf, could you please show SW and LW separate? There are observations that suggest that over the North African plume, when over desert regions (bright), there is no net Rf of dust (Patadia et al., 2009). Can you capture this type of behavior? I can't really tell from your net RF that you are getting that in the SW. This is likely very dependent on the optics and size distribution your choose.**

We made the following modif to the revised version:

a) Add dust radiative forcing efficiency diagnostics (cf Figure R9, b and c).
b) Add in SI the surface and TOA SW and LW radiative forcing components (cf Figure SI 1) There are indeed some sub-regions where the combination of LW and SW forcing induce a net radiative forcing almost equal to zero (e.g the Thar Desert source region).

**"the TOA radiative forcing efficiencies (i.e. TOA normalized by AOD) shows relatively less of a warming e_ect in the Indo-Pakistanese and Northern India desert regions due to lower surface albedo." Where is this? Sounds interesting, please include! (you refer to this later also, on p4890, line 18, so it would help to have the figure).**

It is an interesting point. We added a figure of dust radiative forcing efficiency (Figure R9) illustrating the differences between Arabian and Indo-Pakistanese dust sources, as well as the evolution of radiative forcing efficiency linked to changes in surface albedo and dust size distributions as one move from sources to the Indian subcontinent.
Furthermore we propose an experiment where Indo-pakistanese dust source are removed (cf reply to Referee2), essentially showing that the contribution of this source is to strengthen the dimming effect and stabilisation over northern India. Indo Pakistanese source effects tends to compete with the positive feedback associated to radiative heating over the Arabian source. Optical properties over the Indo-Pakistanese regions might be a very sensitive point here (cf reply to comment 2).

**“Consequently the 2005–2009 pentad (P0509) shows sensibly higher averaged AOD relative to the 2000–2004 pentad (P0004).” Why don’t you use more intuitively obvious casenames, like DUSTY and NONDUSTY? You use these later anyway to explain these, and it will make the text easier to follow.**

This is done in the revised version.

**English Edits:**

**“A specific attention” remove “a”“pretty closely” remove ‘pretty’ “convective precipitation tend to be inhibited” tends**

Done in revised version.

**“This regional stabilization is induced by a relatively large surface radiative dimming which decreases continental 10 and sea surface temperatures (Fig. 4c), and for which inhibiting e_ect on convection is predominant over dust absorption radiative warming, consistently with a negative simulated TOA radiative forcing (Fig. 4b).” please reword “for which inhibiting effect on convection is predominant” sounds very awkward “to shape out regional contrast” out**
**our?**

Fixed in the revised version.

**“Fine dust transported from Arabian, Indo Pakistanese and Iran sources to northern India are relatively diffusive and induce a moderate radiative” how can dust be diffusive? I think you mean small in magnitude or diffuse??**

**“This, on average, favor a stabilization” Favors**

**“and for which regional impact is diffcult to assess.”THE regional impact**

**“Our work 5 hypothesis is that” , WorkING “strong positive trend are” make verb and subject match**

Thanks for pointing out to these errors. We tried to improve the English in the revised version.

**Figures.**

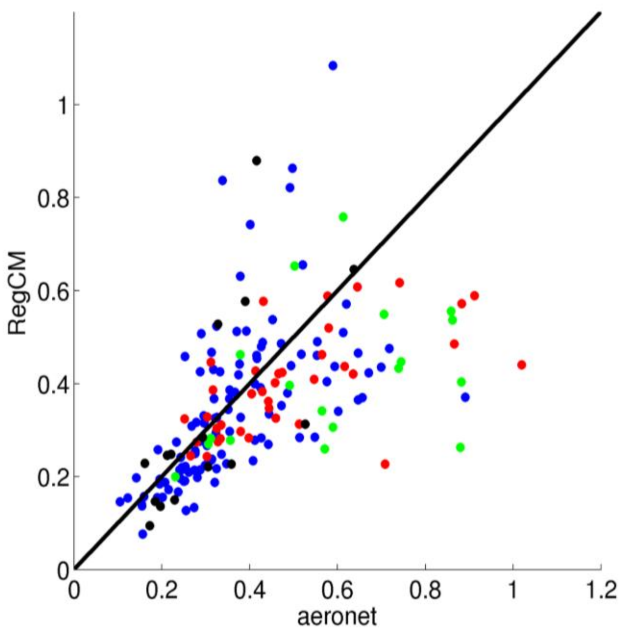


**Figure R7**.Simulated monthly AOD vs AERONET measured monthly AOD for the period of 2000-2009. Blue dots represents the solar Village Station, red dot represents Karachi, green dots represents Kuwait airport and black dots Meizera.

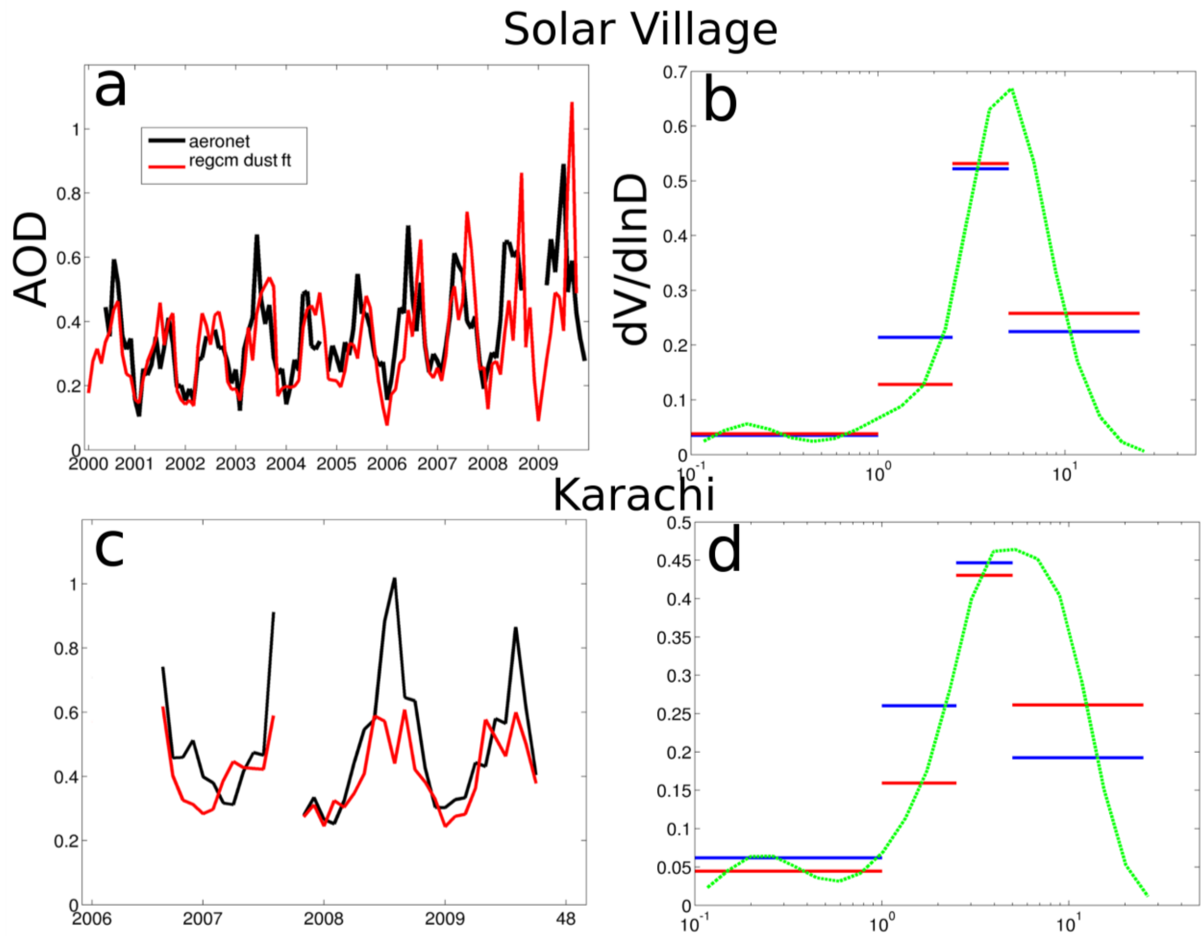


**Figure R8.** (a) comparison between simulated and AERONET monthly AOD (see text) for Solar Village station. (b) Comparison of simulated and measured aerosol normalized volume size distribution averaged for JJAS 2009 over Solar Village. For comparison, the AERONET distribution (green dotted line) is re-binned to match model size bins (red lines). Blue lines show the corresponding simulated distribution. (c) Same than (a) for Karachi station. (d) Same than (b) for Karachi station.

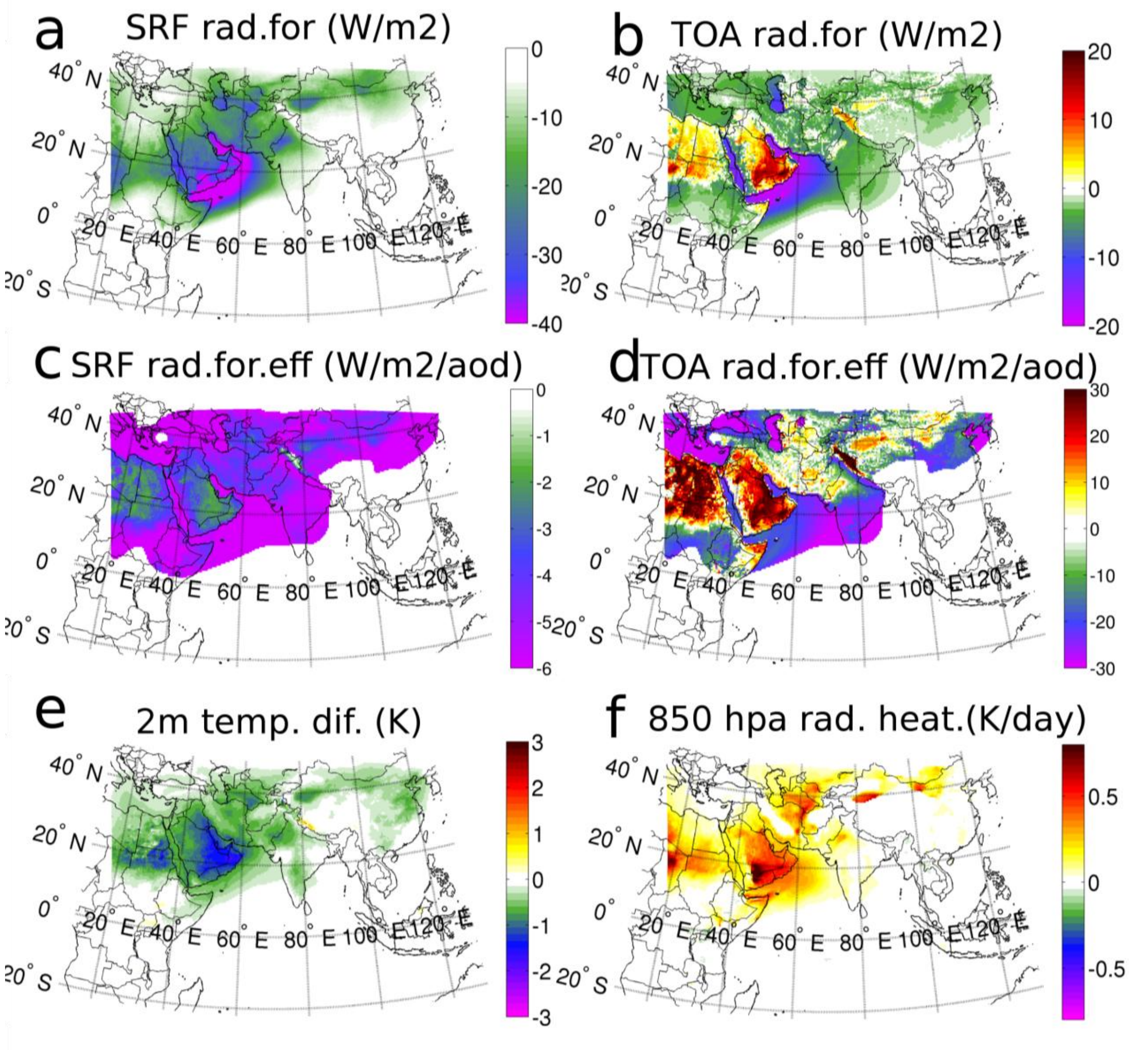


**Figure R9**. (a) JJAS 2000-2009 Dust aerosol surface radiative forcing diagnostic. (b) JJAS 2000-2009 Dust top of atmosphere radiative forcing diagnostic. (c) and (d) Corresponding surface radiative forcing efficiencies.(e) JJAS 2000-2009 2 m temperature difference between *dust* and *nodust* simulations. (f) 850 hpa radiative heating rate difference between *dust* and *nodust* simulations. All modeling results represent a 3 member's ensemble mean.

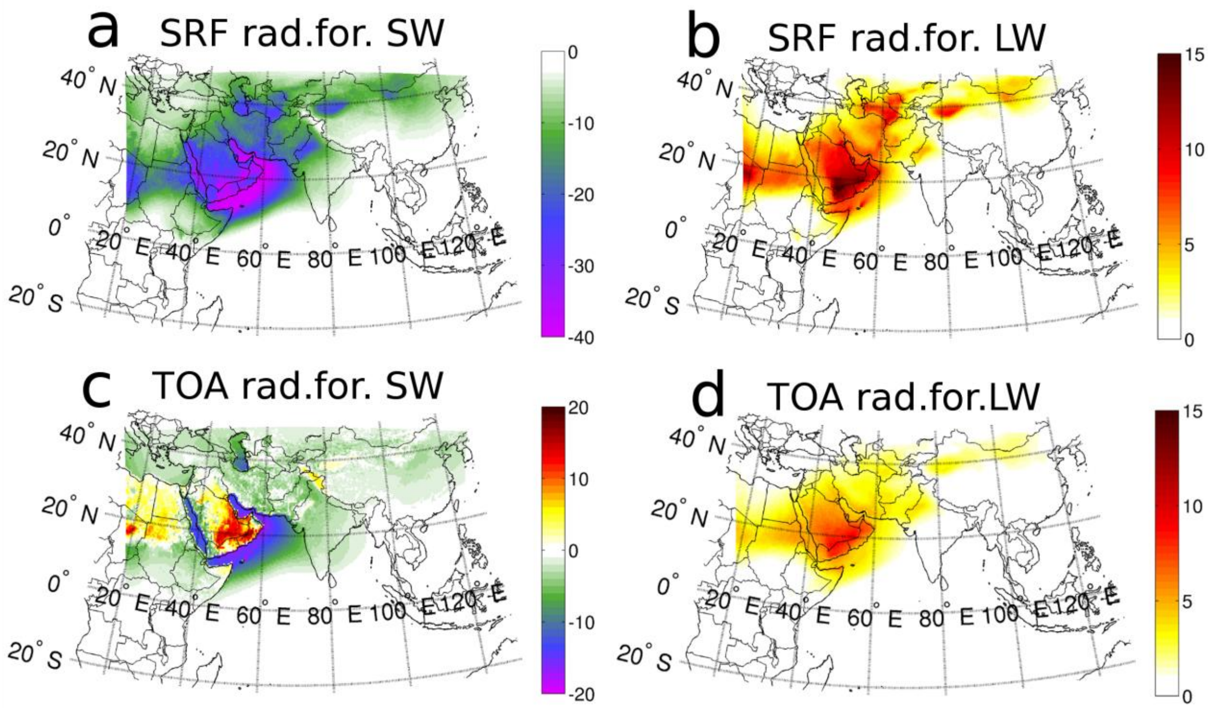


**Figure SI 1**: SW and LW dust surface and TOA radiative forcing averaged for JJAS 2000-2009.