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Reply to comment by S. Ramachandran on "Surface changes in solar irradiance due to aerosols over central Himalayas"

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[1] *Dumka et al.* [2006] (hereinafter referred as D06) made extensive measurements of radiative fluxes at the surface during December 2004 at Manora Peak, in the Shivalik ranges of the Central Himalayas during a comprehensive aerosol field campaign as a part of the Indian Space Research Organisation's Geosphere Biosphere Programme (ISRO-GBP). The surface radiative fluxes were used to estimate aerosol radiative forcing. Based on the data analysis D06 concluded that the anthropogenic aerosols (from valley below) transported upwards by atmospheric boundary layer (ABL) dynamics during daytime provide an atmosphere conducive for "mixed aerosols" and suggested that focused efforts are needed to address this issue.

[2] The concerns, raised by *Ramachandran* [2008] (hereinafter referred to as R08), pertain to the following three points. We address them one-by-one.

[3] (1) The first concern is that D06 have not used the conversion factor of 1.3 in converting the narrow-band measurements to broad-band.

[4] We believe that this comment arises from the inadequate understanding (of R08) about the data analysis methods reported in D06. In paragraph 6, D06 state explicitly "More details of methodology employed to estimate diurnally averaged forcing from observed radiative fluxes are provided by *Satheesh and Ramanathan* [2000] and are not repeated here." *Satheesh and Ramanathan* [2000] have used several independent radiometers having wavelength bands (a) 0.2 to 4.0 μm (b) 0.4 to 1.0 μm and (c) 0.4 to 0.7 μm. *Satheesh and Ramanathan* [2000] have multiplied the forcing values by the broad-band (short wave) to narrow-band (0.4 to 1.0) ratio (i.e., 1.3) to account for the difference in the wavelength bands. This is stated by D06 in the last sentence of section 2. Moreover, D06 states in paragraph 9 that "We employ methods described by *Satheesh and Ramanathan* [2000] for obtaining the aerosol short wave radiative forcing directly from the observed fluxes". Since the methodology is obvious and was extensively used in the past, we did not repeat this in D06 (owing to the constraints on page length in GRL). More recently, *Satheesh et al.* [2006] (cited by D06) have used the radiation measurements in the wavelength range (0.3 to 1.1 μm) and followed same methodology used by *Satheesh and Ramanathan* [2000] to obtain diurnally averaged short wave forcing values. It appears that R08 has overlooked the references to the earlier papers or missed the point stated explicitly by D06.

[5] We would like to re-emphasis that D06 have measured surface reaching radiation in the wavelength range (0.3 to 1.1 μm) and followed the methodology described by *Satheesh and Ramanathan* [2000] to estimate short wave aerosol radiative forcing. Hence there is nothing wrong in comparing D06's forcing values with those of *Podgorny et al.* [2000], *Conant* [2000], *Satheesh and Ramanathan* [2000], and *Bush and Valero* [2002] as all these studies as well as D06 discuss forcing in broadband region of the solar spectrum.

[6] For the comparison of measured radiative fluxes with those simulated using measured aerosol properties as input, we have used a Discrete Ordinate Radiative Transfer (RT) model developed by University of Santa Barbara (SBDART) (see *Ricchiazzi et al.* [1998] for details). In RT model, we have taken into account the altitude of observing site.

[7] (2) Second concern in R08 is FN-AN asymmetry in forcing.

[8] Again, R08 failed in understanding the data analysis methods followed by D06. D06 have inferred the FN-AN asymmetry in forcing using the direct measurements of radiation and NOT from aerosol optical depth measurements. D06 reported that during afternoon hours, model underestimates the observed forcing by $\sim$17 W m^{-2}, which is well above the measurement uncertainty.

[9] (3) The third concern of R08 is on the aerosol transport for which R08 examined the back-trajectories.

[10] We wish to point out that R08 appears to have confused vertical transport considered by D06 to advection. D06 did not attempt advection at all. D06 state (paragraph 9) "It appears that the anthropogenic aerosols (from valley below) transported upwards by evolution of boundary layer during midday and afternoon hours provide an atmosphere conducive for 'mixed' aerosols". Here, D06 were cautious, but provided only a plausible logic (because there were no measurements of atmospheric boundary layer parameters at the site). Such vertical transport of aerosols and pollutants from the valley to nearby mountain peaks have been reported elsewhere, world over. We would like to remind commentator that the vertical motion depicted by the

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trajectories (which are basically deduced from synoptic data and modelling (and having a 2.5 degree resolution) may not be suitable for delineating the mesoscale effects of slowly evolving atmospheric boundary layer (due to reduced heating in winter) in lifting the valley based pollutants to the Manora peak by afternoon.

[11] We have further examined the role of boundary layer dynamics in influencing the aerosol properties at Manora Peak using multi-year measurements of spectral aerosol optical depths during January 2002 to December 2004. We have observed significant changes in optical depths (within a daytime). Further investigations of this aspect (using radio sonde data) have revealed that boundary layer dynamics plays a key role in transporting aerosols from polluted valley region to higher altitudes causing large contrast in optical depths between forenoon and afternoon.

[12] The role of boundary layer dynamics in influencing aerosol properties at high altitude sites is not a unique feature of Manora Peak. Similar results have been reported by *Bhugwant et al.* [2001] in the case of aerosol black carbon. *Bhugwant et al.* [2000, 2001] showed that the high black carbon values during afternoon period at high altitude sites can be attributed to the vertical transport of aerosols from the near-by polluted urban and valley regions, which were initially confined to lower heights in night and early morning hours due to the low-level capping inversions. As the ground warms up due to solar heating during the day, the thermal convections become stronger. This lifts the capping inversion, which eventually breaks, flushing out the pollutants to higher altitudes. This would result in increase in the concentration of aerosols at high-altitude peaks, both at the surface and in the column. Consequently the concentration and optical depths increase during the afternoon periods.

[13] The rest of the comments of R08 are built on the above three concerns, as such need no reply. We sincerely feel that this comment of R08 resulted from a hurried reaction without carefully understanding the data analysis by D06 and the relevant references cited by D06. The commentator appears to be not conversant with radiation measurements and intricacies in its analysis as well as with the mesoscale atmospheric processes in mountain regions.

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