Modeling Optical Properties of Mineral Dust over the Indian Desert

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1. Introduction

The Thar desert, sometimes also described as ‘The Great Indian Desert’, lying in the Northwest part of India with an area of 0.32*106 km², is known to be the source of natural mineral dust (*Dey et al., 2004; Chinnam et al., 2006*).The mineral dust particles are mostly non-spherical having sharp edges, which show different scattering signature compared to that of equivalent spheres while interacting with the radiation. Furthermore accurate mineralogical information, that governs their refractive indices, is essential for scattering calculations. The radiative impacts of dust particles therefore depend on their morphology and mineralogy. Present aerosol radiative forcing calculations, however treat them as spherical.

Most of the present satellites consider the particle to be spherical while retrieving their optical properties except very few newly launched spacecraft instrument (e.g. MISR) that accounts for their non sphericity by including spheroid particles in its retrieval algorithm (*Kahn et al., 1997*). Clearly, there exits a need for improvement in dust model used in retrieval algorithm to account for their sharp edges together with their index of refraction based on the latest chemical composition at the sensing wavelengths.

2. Dust Morphology (Scanning Electron Microscope image)

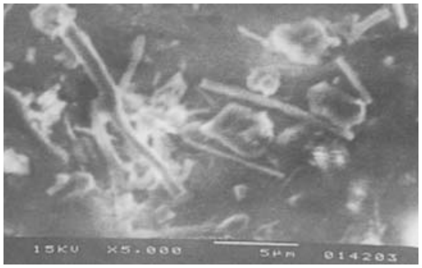

Fig. 1 SEM image of dust particles collected at Gurushikar, Mt. Abu (Adapted from Negi et al., 1996).

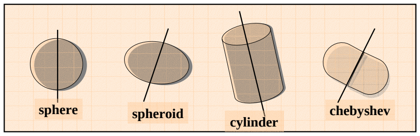

Fig. 2 Model shapes with their axis of symmetry assumed on the basis of SEM image of dust particles collected at Gurushikar, Mt. Abu.

3. Result and Discussion

The optical properties of mineral dust of the Thar desert has been modeled using T-matrix method with realistic dust shapes based on SEM images (Fig. 2) of the dust over the desert (*Negi et al., 1996*) with particle size ranging from 0.1-1.0 μ m at wavelengths spanning from ultraviolet to near infrared (0.38-1.2 μ m). Fig. 2 shows representative dust particle’s shapes based on SEM analysis; the modeled dust shapes are sphere, cylinder, spheroids and chebyshev.

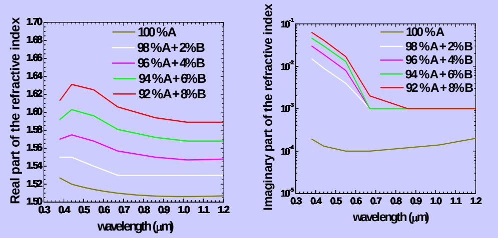

Figure 3. Spectral variation of optical constants of mineral desert dust over Indian desert with varying Fe_2O_3 (B) percentage in the mineral dust.

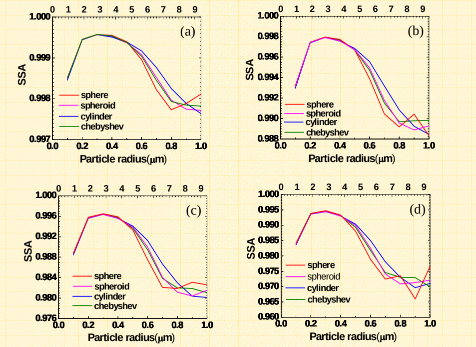

Figure. 4 Variation of SSA of mineral dust over Indian desert with particle size at 0.67 μ m wavelength for (a) no hematite (b) 2% hematite (c) 4% hematite (d)6% hematite.

Mineralogical analysis of airborne dust over Northwest India has revealed the presence of only basic non-metallic minerals such as Quartz, Feldspar, Mica and Calcite (*Peterson,1968*), which posses negligible imaginary part of refractive index at the considered wavelength domain. However, the subsequent dust sampling over Rajasthan desert has revealed significant iron content (*Negi et al., 1996*), which causes sufficient absorption of solar radiation. This iron occurs in the form of Hematite (Fe_2O_3) as metallic mineral with varying fraction in the desert dust (*Koven and Fung, 2006*). The effective refractive index of composite mineral dust accounting for hematite (Fe_2O_3) has been calculated using Bruggman’s effective medium mixing rule (*Bohren and Huffman, 1998*). Fig. 3 shows the spectral variation of optical constants of composite mineral dust where A and B represent non-metallic mineral component and hematite, respectively.

Figure 4 shows Single Scattering Albedo (SSA) sensitivity towards the hematite percentage in the mineral dust composition. SSA of mineral dust over the Indian desert was found to be reducing due to increase in hematite percentage from 0 to 6 % at 0.67 μ m wavelength .

Since no exact volume percentage of Hematite in Thar dust particles is known till date, so optical properties of mineral dust over the Thar desert have been modeled by varying the metallic mineral. Figures 4 and 5 show variation of SSA with hematite and spectral variation of asymmetry parameter (g) for no hematite case, respectively.

Figure 5 shows the spectral variation of asymmetry parameter (g) for the mineral dust particles (with no hematite) for the given size-range.

➢ For the ultraviolet regime, for size-parameter, x ≤ 3, there occurs negligible difference between the asymmetry parameter of non-spherical and its volume equivalent spherical particle but beyond this the difference is substantial (~0.1). Model results suggest that a 10% reduction in g leads to a 19% reduction of aerosol radiative forcing at the top of atmosphere while at the surface it is 13% (*Ogren et al., 2006*).

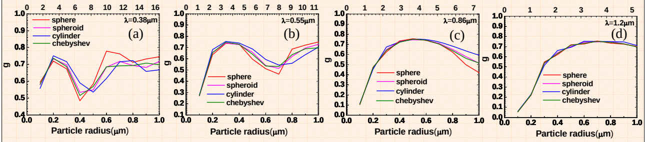

Figure 5. Spectral variation of asymmetry parameter (g) for the mineral dust with no hematite.

➢For the visible wavelength (0.55μm), for x ≥ 4, the variation of g of the particles follows the sinusoidal pattern in which the first half of the cycle shows lesser g values for spherical particles compared to that of volume equivalent non-spherical one while the second half shows the vice-versa with increasing size.

➢ In the infrared regime (0.86 and 1.2 μm), for x ≥ 4.5-5, the difference between non-spherical and volume equivalent spherical particle diminishes with increasing wavelength as evident from Figure 5(c), (d).

➢The increase in g values of the particles has been noted for the increasing wavelength for large size particles in the infrared regime.

4. Conclusion and Future plans

The accuracy of satellite aerosol (mainly dust) retrievals depends critically upon the accuracy of the aerosol optical model used in these retrievals. Keeping this goal in mind the optical properties of the desert dust over the Indian desert have been modeled, for the first time, based on experimental data of mineral dust morphology and mineralogy using the T-matrix method. The results show significant differences between the optical properties of assumed realistic dust shape and that of a sphere, which can modify the previous estimates of radiative forcing drastically.

Acknowledgements

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