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EFFECT OF DUST AEROSOL LAYER ON VERTICAL TEMPERATURE PROFILE

1. Particles of dust or other solids in the atmosphere affect both the incoming solar radiation and the outgoing thermal or infrared radiation emitted by the earth-atmosphere system. The aerosol absorption, scattering and emission will change the longwave fluxes crossing the atmosphere boundaries and also the radiative heating or cooling rates within the atmosphere with possible effects upon global circulation pattern and climate.

1.1. Studies by Bryson and Baerries (1967) indicate that presence of dust over Rajasthan desert in northwest India changes atmospheric radiation and hence low rainfall over the region. A series of infrared radiation soundings (Suomi *et al*. 1958; Kuhn and Johnson, 1966) indicated that the measured fluxes and net flux divergence in the dusty Rajasthan desert atmosphere departed significantly from values calculated assuming dust absent (Bryson *et al*. 1964). Peterson (1968) computed the change in atmospheric transmissivity due to dust in infrared region and concluded that the dust strongly decreases the transmissivity in spectral region. Estimates of anthropogenic dust inputs and observations of dust optical properties are used to show the radiative forcing by human generated dust and anthropogenically generated mineral aerosols (Sokolik and Toon, 1996). Tegen and Fung (1995) studied contribution of mineral dust from disturbed soils to the total atmospheric mineral aerosol load. They found that observed features like the seasonal shift of maximum optical thickness caused by Saharan dust over Atlantic ocean are best reproduced if disturbed sources contribute 30-50 % of the total atmospheric dust loading. Similar studies by Tegen *et al*. (1997) shows contribution of different aerosol species to estimate the aerosol climate effect as well as for aerosol retrievals from satellite measurements. Further studies show that mineral dust from disturbed soils needs to be included among the climate forcing factors that are influenced by human activities (Tegen *et al*. 1996). The effects of various processes and greenhouse gas induced climate change have been studied using radiative convective models by many authors (Ramnathan & Coakley, 1979; Potter & Cess, 1984).

1.2. For climate studies it is desirable to have the knowledge of the vertical thermal structure of the atmosphere. In the present study, heating rate perturbations due to aerosol forcings within the Earth-atmosphere system is studied for three aerosol concentrations *viz*., background concentration, wind carrying dust concentration and sandstorm concentration, by using one-dimensional (1-D) radiative convective model (RC) (Ramnathan, 1981).

2. The study of the radiative characteristics of a dust laden atmosphere requires the knowledge of various parameters such as reflectance (*Re*), absorption coefficient (*A*), single scattering albedo (ω) and asymmetry factor (g). These are given below

$$Re = \omega(1\text{-}g)(1\text{-}e^{\tau e}) \qquad (1)$$

$$A = (1\text{-}\omega)(1\text{-}\, e^{\tau e}) \qquad (2)$$

where, ω is single scattering albedo, g is asymmetry factor and τ_e is aerosol optical depth.

2.1. For background, wind carrying dust and sandstorm aerosol concentrations, these parameters have been evaluated in the SW and IR region (D'Almeida, 1987). The average values for various parameters have been calculated using the relation

$$\overline{A} = \frac{\sum A_i(\lambda)\lambda_i}{\sum \lambda_i} \qquad (3)$$

where, $A_i(\lambda)$ is a particular parameter and λ_i is the wavelength associated with that parameter. The model used in the study is the 1-D RC model. The model consists of the 16-layer upto a height of 54 kms. The model uses pressure as a vertical coordinate. The model has four heating processes *viz*, solar radiation, longwave radiation, vertical eddy heat flux and latent heat flux.

2.2. The calculation of the radiation flux requires a radiative transfer model and knowledge of the vertical distribution of the principle gaseous absorbers such as water vapour, carbon dioxide, ozone and clouds. For obtaining the radiative perturbations that satisfies the condition of radiative-convective equilibrium, Newton–Raphson method was followed. Radiative equilibrium temperature profile was solved by forward time–marching technique until steady state is reached. The sensitivity of this simple model's climate illustrates the interconnected role of various parameters in radiative transfer

TABLE 1

Various minor atmospheric constituents with their band centers and estimated current concentrations

Chemical	Composition	Band centers (/cm)	Surface mixing ratio
Ozone	O_3	1041,1103,590,790	3.43 min STP
Carbon dioxide	CO_2	667	340 ppmv
Nitrous oxide	NO_2	589,1168,1285	0.3 ppmv
Methane	CH_4	1306.1534	1.7 ppmv
CFCs	CF_2Cl_2	915,1095,1152	$2*10^{-4}$ ppmv
	$CFCl_3$	846,1085	$1.5*10^{-4}$ ppmv

Source: Wuebbles *et al*. (1984)

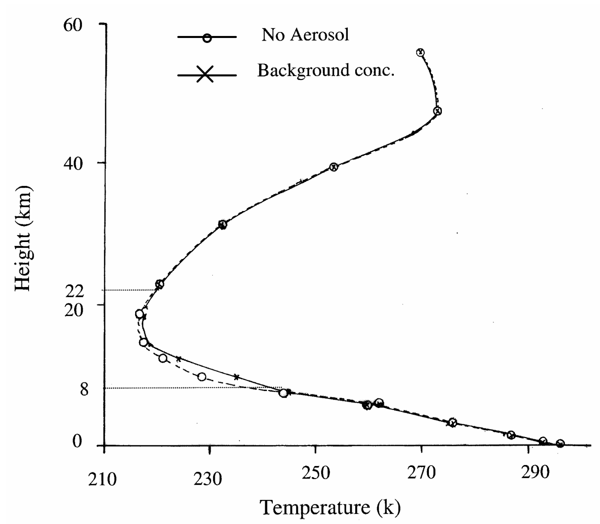

Fig 1. Model simulated vertical temperature profile for background aerosol concentration

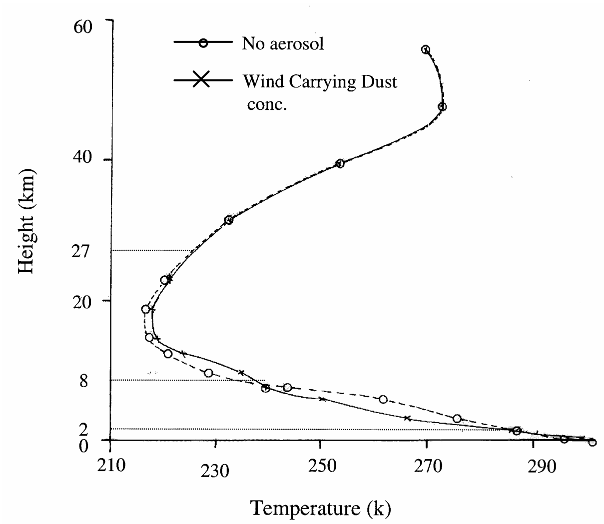

Fig 2. Model simulated vertical temperature profile for wind carrying dust aerosol concentration

calculations and in particular, the importance of the relative impact on the absorption of incoming solar radiation and the emission of infrared radiation.

3. Aerosols in the atmosphere affect the climate as per their properties to reflect absorb and scatter. In the present study, a homogeneous aerosol layer of 2 km thickness at 10 km above the ground is considered in the model atmosphere. The aerosol layer can affect the radiation budget by absorbing and scattering the incident solar radiation. A fraction $e^{-\tau e}$ of the normally incident radiation flux F(Z) (watt) emerges unaffected, while the remaining fraction (1- $e^{-\tau e}$) is scattered or absorbed. Here τ_e is vertical extinction optical depth of the aerosol layer.

3.1. Three types of aerosols, background concentration (BC), wind carrying dust concentration (WC) and sandstorm concentration (SC), are considered in the present study. Their average optical depths in solar region are taken 0.45, 2.0 and 4.0 respectively. These are based on the data of Saharan desert aerosol radiative characteristics. Input data used in the model is annually globally averaged mean values (D' Almeida, 1987). It is assumed that CO_2, CH_4 and NO_2 are uniformly mixed

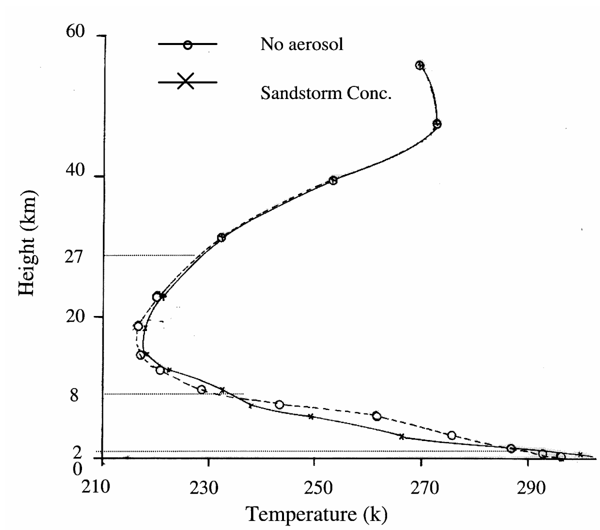

Fig 3. Model simulated vertical temperature profile for sandstorm aerosol concentration

throughout the atmosphere. The trace gases are assumed to be mixed upto 12 kms in vertical. Table 1 gives the globally averaged concentrations of various trace gases. Cloud fraction for low (top = 850 hPa, thickness = 100 hPa), middle (top = 500 hPa, thickness = 200 hPa) and high (top = 330 hPa, thickness = 130 hPa) clouds are 0.22, 0.11 and 0.24 respectively. The emissivities of these clouds are 1, 1 and 0.5 respectively. The albedos for these clouds are 0.69, 0.48 and 0.21 respectively.

3.2. From the model run results, heating rate perturbations are computed for BC, WC and SC. Fig 1 shows the change in equilibrium temperature due to the presence of BC. For the purpose of comparison, a temperature distribution for the case of no aerosols has also been plotted. It is seen that heating rate occurs at altitude 8.0 km to 32.0 km. Apart from these altitudes no significant change has been observed in heating rate. For the case of WC, Fig 2 shows that cooling occurs at lower troposphere, *i.e.*, upto approximately 8.0 km. The sign of the temperature change changes above this height and heating is observed upto a height of 22.0 km. Similar trends are also observed for SC as seen in Fig 3. The cooling occurs in lower part of the troposphere, approximately upto height 10.0 km, and heating is observed above that height. The aerosol induced cooling upto certain altitude in the atmosphere and at the surface, indicates that the aerosols in the lower part of the atmosphere absorb and reflect a part of solar radiation, which results in decreasing of solar flux at the surface and in the lower atmosphere.

3.3. A hypothetical profile of dust aerosol in the model is used for the study, which is more of academic in nature. Using a dust profile only instantaneous heating rate perturbations can be calculated that too on regional basis and on daily basis.

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