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Changes in atmospheric aerosol parameters after Gujarat earthquake of January 26, 2001

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Abstract

The analysis of Sea-Viewing Wide Field-of-view Sensor (SeaWiFS) data from Gujarat coast has been carried out after Gujarat earthquake of January 26, 2001. The aerosol parameters (aerosol optical depth and Angstrom coefficient) have been deduced. The aerosol parameters have been deduced along the Gujarat coast and also along the profile from the coast to remote ocean. Variation of aerosol parameters shows significant changes after Gujarat earthquake. The source of the high aerosol optical depth is located using HYbrid Single-Particle Lagrangian Integrated Trajectory (HYSPLIT4) developed by NOAA Air Resources Laboratory. The aerosol parameters from SeaWiFS and the result of HYSPLIT4 model show that the strong wind from the Gujarat region brought the aerosol particles over the Gujarat coast which is attributed to the emission of dust due to the total destruction of villages during Gujarat earthquake.

Keywords: Aerosol; SeaWiFS; HYSPLIT4; Earthquake

1. Introduction

Atmospheric aerosols are produced from various sources through anthropogenic and natural emission. Smoke aerosols are emitted from the biomass-burning place while mineral dust particles are blown by the strong wind from the desert area. These aerosol particles work as scatterers for solar light or absorbers for thermal earth emission depending on the aerosol type. Also some mineral dust particles blown from desert areas are considered to serve as nutrition for the coastal marine biology as iron inputs.

With the advent of remote sensing technique, the characteristic parameters of aerosol particles can be retrieved from satellite as synoptic images. In the present paper, we have retrieved aerosol parameters from Sea-Viewing Wide Field-of-view Sensor (SeaWiFS) before- and after- the Gujarat earthquake of January 26, 2001. This earthquake was one of the deadly intraplate earthquakes which took about 20,000 lives. The magnitude of the earthquake was 7.8. It damaged vast areas upto radii of about 400 km from epicenter. This earthquake brought out changes in ocean and land parameters which have been mapped using various satellite data (Singh et al., 2001a,b,c; Yusuf et al., 2001).

In the present paper, we present the analysis of aerosol parameters using SeaWiFS data. Higher aerosol optical depth has been found after the earthquake event of January 26, 2001. The pathway of particles to the high optical depth areas is seen on January 27 and 28, which have been analyzed using the HYbrid Single-Particle Lagrangian Integrated Trajectory (HYSPLIT4) Model developed at NOAA Air Resources Laboratory.

2. Data and method

In the present study, SeaWiFS data have been used to retrieve two aerosol parameters (aerosol optical depth and Angstrom coefficient). SeaWiFS has eight observing wavelengths range covering visible and near-infrared (0.412, 0.443, 0.490, 0.510, 0.555, 0.670, 0.765 and 0.865 μm). The aerosol parameters have been retrieved using

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the data in near-infrared wavelengths where the contributions from the oceanic surface waters become negligible (Pope and Fry, 1997). By using two near-infrared wavelengths (0.765 and 0.865 μm), aerosol optical depth in near infrared wavelength and aerosol model (Gordon and Wang, 1994). Aerosol model is defined as four types (oceanic, maritime, coastal and tropospheric) with different relative humidity. Aerosol optical depth in shorter wavelengths is interpolated from the near-infrared wavelengths based on the optical thickness in the near-infrared and aerosol model determined. The aerosol optical depth gives information about the amount of aerosols. The Angstrom coefficient gives spectral variation of aerosol optical depth which is related to the aerosol model, using the following equation:

$$\alpha = -(\ln \tau_{0.510} / \ln \tau_{0.865})/(\ln 0.510/ \ln 0.865). \quad (1)$$

Higher value of Angstrom coefficient shows the dominance of smaller aerosol particles and vice versa. SeaWiFS data are processed with SeaWiFS Data Analysis System (SeaDAS) (Baith et al., 2001) to produce these two aerosol parameters with operational algorithm.

Wind vector and wind strength have the relation with transportation and diffusion of aerosol particles from the source region. With the strong wind, aerosol particles are transported to the distant location from the aerosol source region. Due to the weak wind, aerosol particles may be transported only at the nearby place from the source region and the wind stagnation may cause the pollution episodes around the source region (Ristori et al., 2001). In the present paper, we have used HYSPLIT4 model developed by NOAA Air Resources Laboratory to locate the source of aerosol particles considering the various meteorological data including information of the wind fields. NCEP/NCAR Reanalysis data have been used as input meteorological data into HYSPLIT4 model to calculate the pathway of the airmass. The temporal resolution of NCEP/NCAR Reanalysis data is every 6 h and the spatial resolution is 2.5° grid. These Reanalysis data represent up to 17 layers of vertical information.

3. Results and discussion

Fig. 1 shows aerosol optical depth around the Arabian Sea from January 23–28, 2001. Due to satellite path, the SeaWiFS data close to the northern the Arabian Sea is not available and estimate of aerosol parameter was not possible just after the earthquake of January 26, 2001 (Fig. 1(c)). Figs. 1(a) and (c) show how aerosol optical depth is in general around the northern part of the Arabian Sea. Higher aerosol optical depth is found around the northern part of the Arabian Sea on January 27, 2001 (Fig. 1(e)). Similarly on January 28, 2001, aerosol optical depth was increased around the northeastern part of the Arabian Sea as shown in Fig. 1(f).

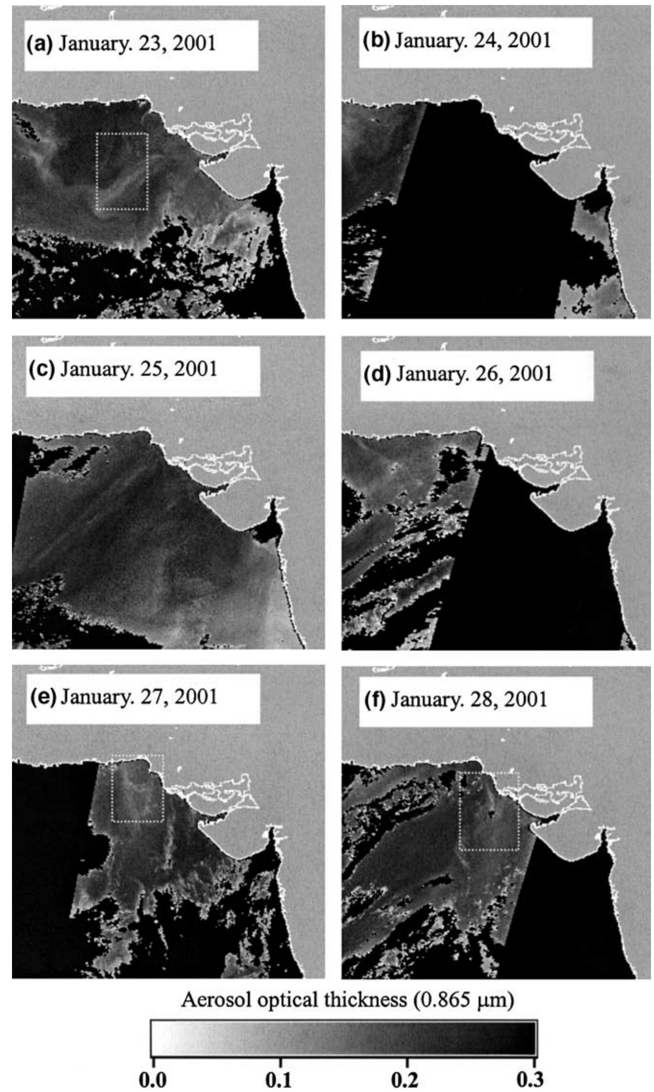

Fig. 1. Aerosol optical depth at 0.865 μm retrieved from SeaWiFS.

Fig. 2 shows Angstrom coefficient and scatterplot between aerosol optical depth and Angstrom coefficient before (Fig. 2(a)) and after (Figs. 2(b) and (c)) the earthquake. The scatterplot between aerosol optical depth and Angstrom coefficient shows different characteristics with different aerosol types (dust, sea-salt, sulfate and carbonaceous aerosols). For example, heavy Saharan dust aerosols are located at the place with high aerosol optical depth with nearly zero value of Angstrom coefficient (Holben et al., 1991). On the other hand, Smirnov et al. (2002) have shown the Angstrom parameter frequency distribution observed in Persian Gulf region with a peak around 0.7 for dominant dust aerosol and 1.2 for outflow from the Gulf region with less dust situation. Urban/industrial aerosol particles show high Angstrom coefficient because of the contribution of accumulation mode sized aerosol particles. The data shown in right images of Fig. 2 have been extracted from the region drawn as boxes in Fig. 1 and

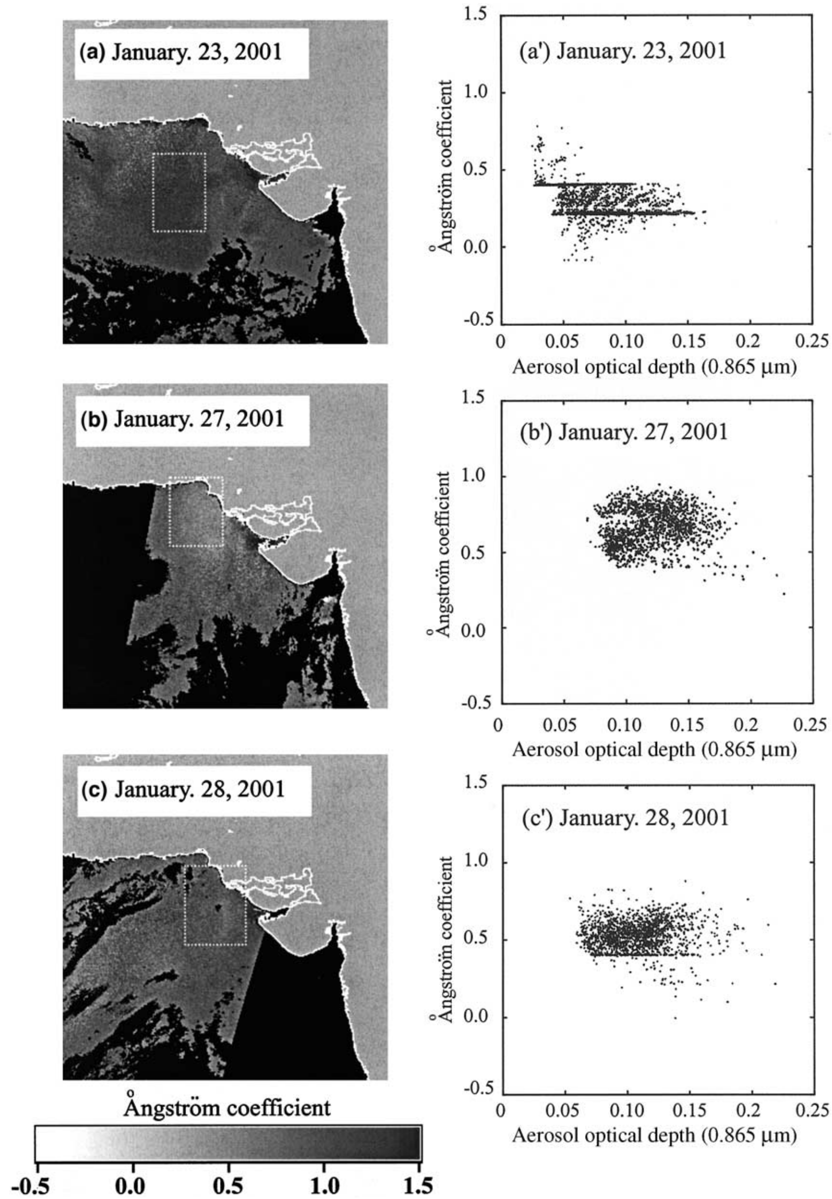

Fig. 2. Angstrom coefficient (a–c) and the scatterplot between aerosol optical depth and Angstrom coefficient (a′–c′).

in the left images of Fig. 2. The boxed region represents the high aerosol optical depth around the northern part of Arabian Sea. Left images of Fig. 2 show the change of aerosol type before (January 23, 2001) and after (January 27 and 28, 2001). The average and standard deviation of aerosol optical depth in January, 2001 before the earthquake are 0.083 and 0.023 within the range of the box shown in Fig. 1(e). Compared with these values, the average and standard deviation of aerosol optical thickness at 0.865 μm for January 27, 2001 (0.119 and 0.023, respectively) show the higher average value. Also, the increase in the Angstrom coefficient after the Gujarat earthquake denotes the contamination of the particles a bit smaller than background maritime aerosol particles. The duration of the increased aerosol optical depth is obscured because of the contamination of clouds in data of after January 28, 2001.

Fig. 3 shows pathways of particles at different heights to the selected areas calculated by HYSPLIT4 model with NCEP/NCAR Reanalysis data. The selected areas are (a) 24.20° north, 65.9° east for January 27, 2001 and (b) 23.05° north, 67.5° east for January 28, 2001. The variations of heights are considered from 500, 1000 and 1500 m above ground level to consider the possible aerosol vertical variations. Each point is selected so that each airmass represents particles of high aerosol optical depth shown in Fig. 1. As shown in Fig. 3, airflows along the various heights are coming into the high aerosol optical thickness region from the northeastern direction. Northeastern monsoon is dominant around the

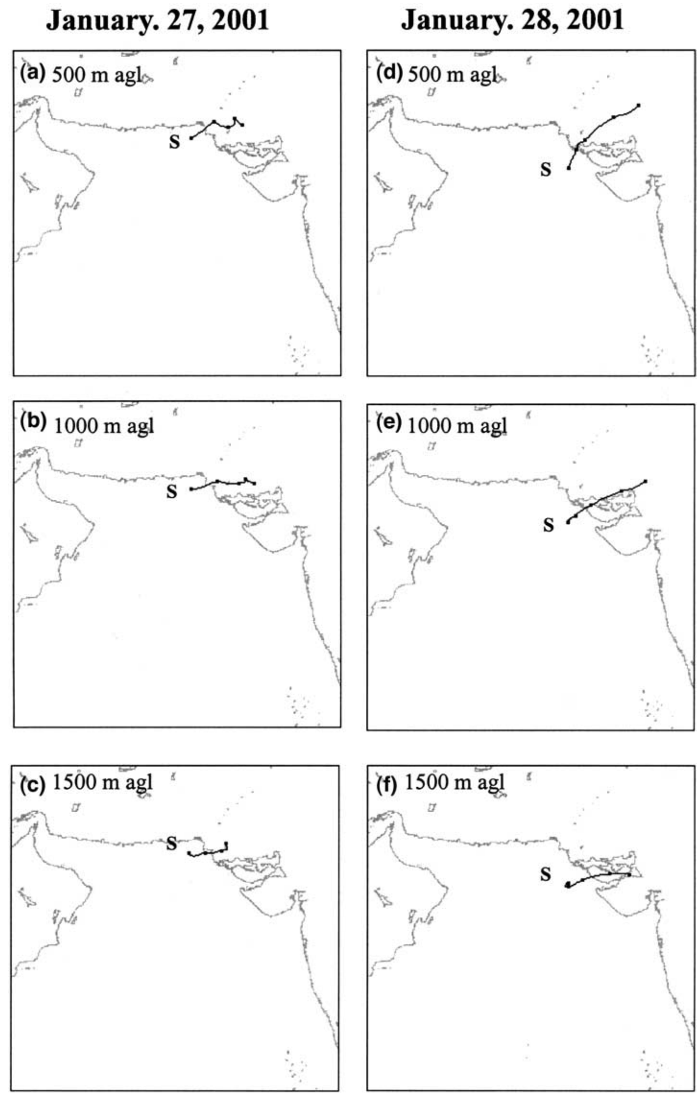

Fig. 3. Backward trajectories calculated with HYSPLIT4 model. (a–c) 27th January, 2001 and (d–f) 28th January, 2001. Starting point of the backward trajectories are shown with letter "S".

north Arabian Sea in January. Therefore, the results with HYSPLIT4 model reproduced the movement of aerosol particles from the place where Gujarat earthquake had large impact.

After the earthquake of January 26, 2001, aerosol characteristics are changed from low aerosol optical depth with small Angstrom coefficient considered as background maritime aerosols to high aerosol optical depth with larger Angstrom coefficient. These changes can be attributed from above figures to the earthquake dust broken and curled up by the earthquake joining the moving airmass along the northeastern wind.

4. Conclusion

The aerosol parameters deduced from SeaWiFS data show significant changes in aerosol parameters before and after Gujarat earthquake of January 26, 2001. From the scatterplot of two aerosol parameters (aerosol optical depth and Angstrom coefficient), changes in aerosol optical depth and Angstrom coefficient are seen around the northeastern part of the Arabian Sea soon after the earthquake (January 27 and 28, 2001). The movement of airmass from the northeastern direction calculated using the HYSPLIT4 model is found to be responsible for the high aerosol parameters.

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