REMOTE SENSING PERSIAN GULF OIL FIRE AEROSOLS

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Optical properties of Persian Gulf oil fire aerosols were investigated by simultaneous analyses of ground based solar radiation measurements and satellite remote sensing technique for a period of June 12 - September 17, 1991 at Bushehr, Iran. The atmospheric turbidity at Bushehr increased nearly regularly with a period of one week. Especially this phenomenon was significant in June with an increase of optical thickness as large as 1.3 at wavelength of 0.5 μm. The absorption index also increased as large as 0.03-0.05 in these events showing an effect of oil fire aerosols from Kuwait.

INTRODUCTION

The Persian Gulf oil fire event in the Gulf war provided unique chance for validating aerosol models for large scale air pollution and disasters. There were observed two kinds of smoke with carbon rich small particle aerosols and water rich large particle aerosols. The single scattering albedo for these two aerosol types has been measured as about 0.4 and 0.9 (Weiss and Hobbs, 1992). This optical properties are much different from the aerosol model used in the nuclear winter studies (Turco et al., 1983). The optical properties of aerosols played an impor-

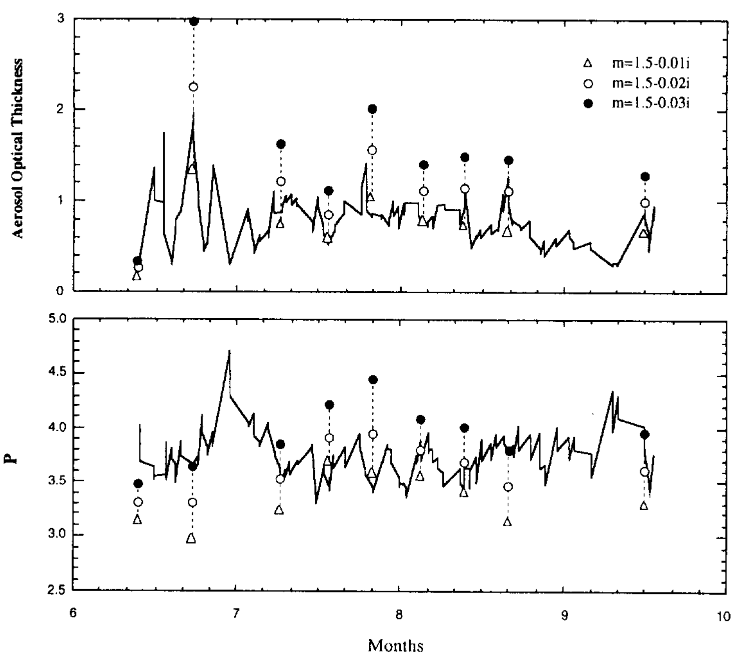

Fig. 1 The time series of aerosol optical thickness at 0.5 μm and power of size distribution derived from sunphotometer at Bushehr. Symbols show values retrieved from AVHRR remote sensing.

tant role in formation of the local climate of the Persian Gulf area in the event of oil fire aerosol loading. However, there were less studies other than aircraft measurements along the intense smoke plume for optical properties of aerosols far from the fire origin. To understand the effect of oil fire smoke to the adjacent region, we curried out solar radiation measurements by using a sunphotometer and pyranometer during June 12 - September 17, 1991 at Bushehr, Iran (5°N, 50.8°E) and at the same time we analyzed AVHRR images of the same location.

SOLAR RADIATION MEASUREMENTS

A sunphotometer (EKO MS-120) and pyranometer (EKO MS-801) were used to measure the spectral direct solar radiation and total horizontal solar flux. Figure 1 displays the optical thickness at wavelength of 0.5 µm, $\tau_{0.5}$, and the power of aerosol size distribution, p, when it is approximated as $dN/d\ln r = C\, r^{-p}$, where r is the particle radius. The aerosol optical thickness increased as large as 1.0 - 1.3. The satellite images have shown a distinct difference in the plume flow pattern, i. e., the steady north-westerly seasonal wind blew the smoke plume along the Persian Gulf when the aerosol optical thickness at Bushehr was small, whereas the puff-like smoke layer spread around the smoke source and covered the Bushehr area when the aerosol optical thickness became large about once a week when the seasonal wind stopped. The value of p ranges from 3.5 - 4.0, though no obvious correlation with the optical thickness was found.

We have used a shadowing disk with the pyranometer to block the direct solar radiation for measuring the diffuse solar flux as well as the total solar flux. The imaginary part of aerosol refractive index (we refer this as absorption index hereafter) was retrieved from the ratio of diffuse to direct solar radiative fluxes (King and Herman, 1979), as shown in Fig. 2. Most of the retrieved values of the absorption index range from 0.01 to 0.03, but there were several cases with values as large as 0.1. There is a correlation of the large absorption index with the peak of the optical thickness.

SATELLITE REMOTE SENSING RESULTS

AVHRR image data have been analyzed for the same period to compare with the surface radiation analyses. Figure 3 shows the relationship between AVHRR channel 1 and 2 radiances simulated for the condition of a ground based measurement by a numerical radiative transfer model of coupled atmosphere-ocean system (Nakajima and Tanaka, 1983) for various values of $\tau_{0.5}$ and p. Unless the satellite view is inside the solar glitter we can get the value of $\tau_{0.5}$ and p from channel 1 and 2 radiances when we know the value of aerosol absorption index properly. The symbols plotted in Fig. 1 are values of $\tau_{0.5}$ and p thus derived by assuming three values of absorption index, i. e., $m_i = 0.01$, 0.02 and 0.03. Although the comparison is not so easy due to the sparsity of available satellite data, we may say that a large ab-

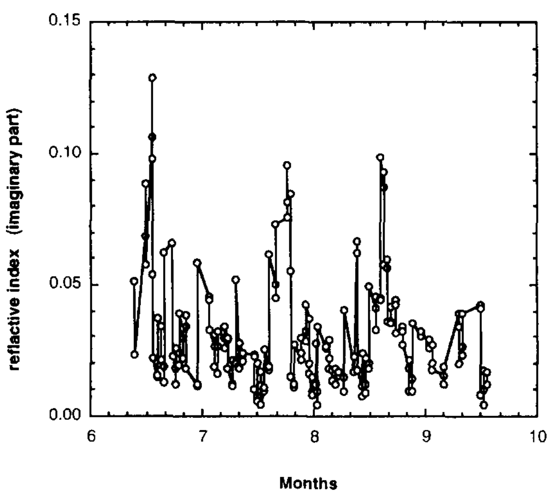

Fig. 2 Time series of the aerosol absorption index retrieved from a diffuse to direct flux ratio method.

sorption index like 0.03 is more suitable to explain the ground based values of $\tau_{0.5}$ and p for June period than smaller absorption indices, whereas a smaller absorption index about 0.01 is more compatible with the ground based retrievals in the July and August period. This observation is consistent with the absorption index values obtained from the ground based measurements as in Fig. 2.

SUMMERY AND PROSPECTS

We have shown the remote sensing methods of getting $\tau_{0.5}$ and p from ground based solar radiation measurements and AVHRR satellite data analyses. The comparison of the results from the two methods are consistent with each other and showed a possibility of retrieving either of two sets, i. e., ($\tau_{0.5}$, p) or ($\tau_{0.5}$, m_i), if the other one is known by independent observation. Especially the values of absorption index should be derived for several typical events appeared in the Persian Gulf region, i. e., the oil fire smoke event, desert dust storm events and background condition. It is also interesting to study the interaction between smoke and cloud optical properties (Kaufman and Nakajima, 1993).

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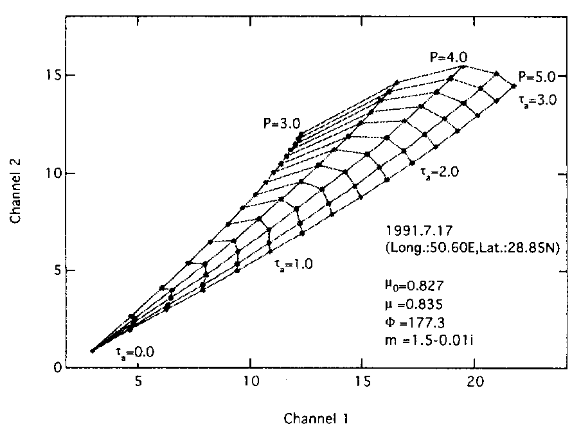

Fig. 3 Relationship between AVHRR channel 1 and channel 2 relectance (%) with coutours of fixed optical thickness (dashed lines) and fixed power of size distribution (solid lines). Theoretical curves for the geometry of July 17, 1991.