

## Aerosol properties over the Arabian sea during the north east monsoon

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**ABSTRACT.** Knowledge of the variations of the aerosol properties is essential for the development of the satellite atmospheric correction algorithms. The measurements were carried-out during a cruise using a six channel spectral sun photometer at wavelengths 440, 670, 870, 936, 940 and 1020 nm, in the Arabian Sea between 15.4 – 17.86°N and 73.28 – 69.3°E, during the North East monsoon period of 1-10 December, 1998. The aerosol optical properties derived from these data showed variations from the coastal region to the open ocean, with coastal regions showing comparatively higher optical depths than the open ocean. The Angstrom turbidity coefficient showed a similar trend and the mean value was found to be 0.102. The mean Angstrom exponent was found to be 1.32. The aerosols optical depths derived from the sun photometer were compared with the aerosol optical depth retrieved from the satellite data and the solar radiation model with the solar irradiance measurements. The variations observed with the satellite data and the results derived from the solar radiation model compared well with the measured values for the open ocean.

### 1. Introduction

More than 80% of the radiance detected at the top of the atmosphere by the satellite sensors are predominantly due to the air molecules and aerosols. Oceans that cover more than two thirds of the earth are significant contributors of aerosols and nearly one third of the natural aerosol flux are found to be of marine origin. (Prospero et al, 1983, Andreas, 1995). The marine types of aerosols are mostly salt sprays produced by the breaking of the bubbles and white caps and the non-sea salt types produced mainly by photolytic decomposition of dimethyl sulfide (DMS) whose sources are phytoplankton and other organic matter.

Aerosol content and their properties play an important role in the atmospheric correction algorithms for satellite. To determine the water leaving radiance from the signal received by the satellite, it is essential to know precisely the contribution of the atmosphere in this total radiance. Due to the variability of size, absorption properties, and concentrations, computing the contribution due to aerosol in the total path radiance is a difficult task. Incorrect assumptions in models can produce significant errors up to a factor of three. (Gordon, 1996). With the adequate knowledge of the behaviour of the aerosol optical properties over the Arabian Sea, it would help in the development of the regional algorithms and refinements of the available methods for the retrieval of the required geophysical parameters to a greater accuracy from the satellite data.

## 2. Measurements

One of the first attempted measurements of aerosol optical depth over the Arabian Sea was using a single wavelength sun photometer at 498 nm (Suresh et al, 1996), and thereafter intensive studies were carried using multi-spectral sun photometer with wavelengths from visible to IR region. (Jayraman et al, 1997, Moorthy et al, 1997, Satheesh, 1997) during the cruises for IRS-P3 MOS satellite validation and INDOEX programs.

The present reported measurements were carried-out during a cruise onboard research vessel, ORV Sagar Kanya in the Arabian Sea from 1-10 December 1997. (See Fig. 1 for cruise track). We have used a calibrated hand held sun photometer (CIMEL, France), with six channels at wavelengths 440, 670, 870, 936, 940 and 1020 nm. The meteorological data were recorded from an automatic weather station installed on the ship using calibrated sensors. (Prabhu Dessai et al, 1997). This station provided data at every 10 minutes interval of wind speed, wind direction, atmospheric pressure, relative humidity, solar radiation and air temperature. The unit provided the true wind speed and direction corrected for the ship motion. The radiometer (Satlantic, Canada) was used to collect solar irradiance at 412.5, 443.1, 489.8, 510, 554.6, 670.7 and 683.6 nm. Sun photometer and the direct solar radiation measurements were made from a clear unobstructed site on the deck. The sun photometer readings were recorded in the morning and evening and these measurements were carried-out at rapid intervals for low sun elevations.

## 3. Aerosol optical depth

The aerosol optical depths were obtained using the standard Langley plot method and removing from the total columnar optical depth contribution due Rayleigh scattering, ozone and trace gases. Results presented here are for the wavelengths of interest 440, 670 and 870 nm, which are close to that of satellite SeaWiFS and IRS-93 MOS. Variations of aerosol optical depth are observed while moving from coastal region to the open ocean. (Fig. 2)

## 4. Comparison with the satellite data

We looked at the aerosol optical depth derived from SeaWiFS and Meteosat satellite data. The Level-3 monthly mean optical depth at 865 nm for January to September, 1998 and October to December, 1997 were compared for the same location as the stations of our measurements (See Fig. 3).

## 5. Optical depth from solar radiation measurements

The solar irradiance data that were close to the wavelengths of the sun photometer, 443.1 and 670.7 nm, were used for the retrieval of aerosol optical depth using the solar radiation model. (Gregg and Carder, 1990). We computed Ediff using an empirical relation, that relates the total to the diffuse solar radiation for cloudless days. (Michulec et al, 1995). The values of aerosol optical depths were obtained using an iterative procedure providing minimum error between the measured and the model values. The values of aerosol optical depth at 670 nm compared well with the measured value in the open ocean, while large deviations were observed for coastal stations (See Fig. 4)

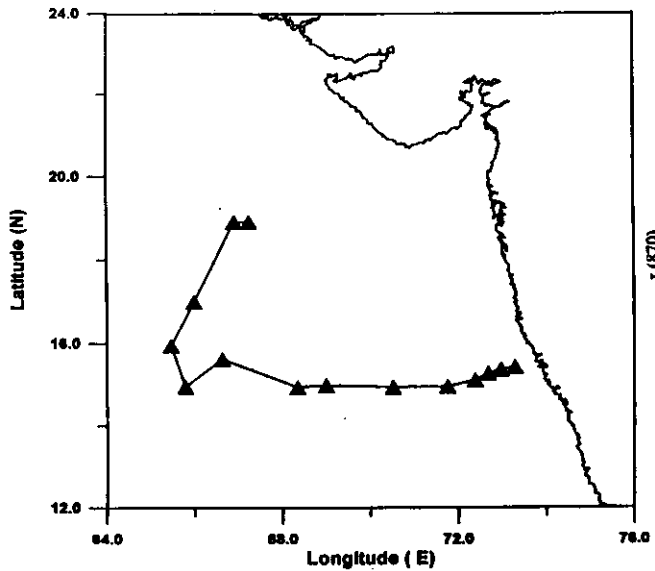


Fig 1. Stations for the cruise SK-140a

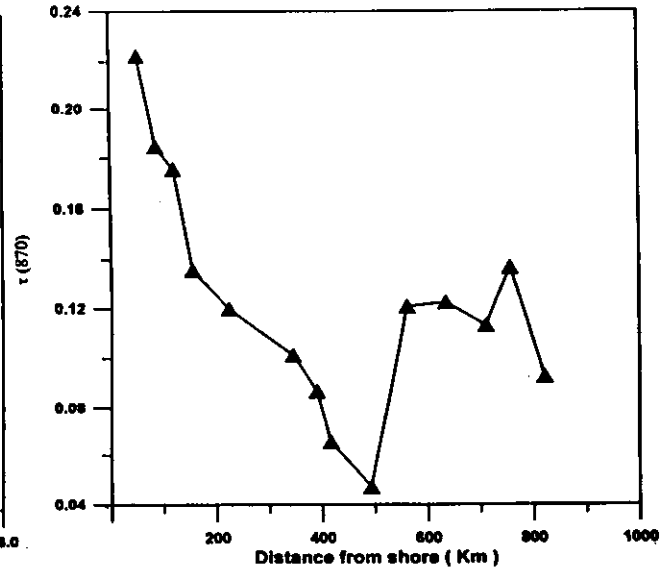


Fig 2. Variation of aerosol optical depth at 870 nm with distance

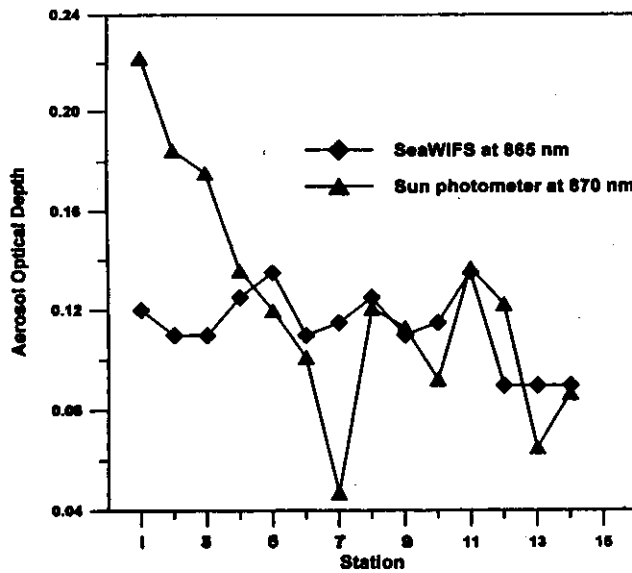


Fig 3. Comparison with man satellite SeaWiFS derived AOT for the 3-10 Dec. 98 with the measurement data using Sun Photometer

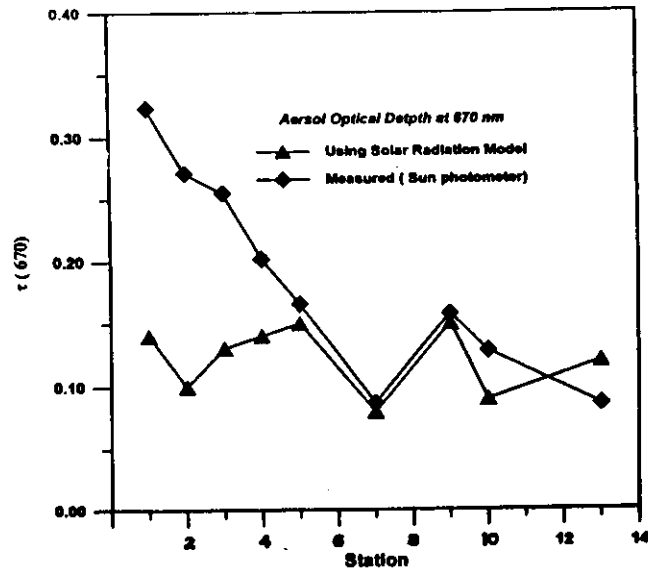


Fig 4. Aerosol optical depth at 670 nm, obtained from solar irradiance measurements.

## 6. Conclusions

(i) The aerosol optical depths varied from a 0.064 to 0.22 at 870 nm, while Angstrom exponent  $\alpha$  varied from 1.049 to 1.527 with a mean value of 1.35.

(ii) The variations in aerosol optical depths were high near the coastal stations, due to the anthropogenic effects and natural land sources. The aerosol in the coastal region are usually of continental type, and as they move away from the shore, most of the heavier and larger particles are lost by sedimentation. Hence it has been observed that while moving away from coastal stations the aerosol optical depth decreases and then attains a near steady value as the sources of aerosols in the open ocean are limited.

(iii) sharp decline in aerosol optical depths were observed for a short fetch distance from the coast of less than 500 Km, unlike reported by others which extends beyond 2000 Km. (Moorthy, 1997)

(iv) The aerosol pattern did show variations with the weather conditions. The cruise was during a pre-cyclone period in the region. The wind speed was observed to be high, after the station 7 and the effect of the same was seen on the aerosol optical depths. The aerosol optical depth in the open ocean showed an increase due to the generation of salt sprays and breaking of bubbles from the white caps.

(v) Angstrom exponent also showed the variation moving from the coast to the open ocean. Near the coastal stations, the  $\alpha$  values were lower due to the abundance of larger size particle from land. The  $\alpha$  also showed diurnal variation, which is attributed to the variation in humidity, as no other factor seems to cause such changes in the open ocean. The  $\alpha$  values were found to be larger for stations covered during the evening.

(vi) The values of aerosol optical depth obtained from this cruise were comparable in range to the measurements carried out earlier near these regions in the open ocean during February, 1996 (Suresh et. al., 1996).

(vii) The values of  $\tau_a$  (870) compared well with the weekly mean satellite derived aerosol optical depth from SeaWiFS at 865 nm, for the period of 3-10 December, 1997.

(viii) Aerosol optical depth derived using the solar radiation measurements and the model, were found to match closely with the values derived from the sun photometer measurements in the open ocean, while large deviations were observed for coastal regions.

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