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Satellite Retrieved Aerosol Optical Depth Observations Over A Semi-Arid Region in Southern Peninsular India

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Abstract
In this study, we investigate the seasonal and annual variation of Aerosol Optical Depth (AOD) retrieved from Moderate resolution Imaging Spectroradiometer (MODIS), Multi-angle Imaging SpectroRadiometer (MISR), and Ozone Monitoring Instrument (OMI) satellite products from 2007-2013over a semi-arid region in Southern peninsular India. The seasonal mean MODIS (MISR) are found to be 0.20 ± 0.05 (0.22± 0.00), 0.31 ± 0.06 (0.42 ± 0.10), 0.30 ± 0.08 (0.26 ± 0.02), 0.17 ± 0.05 (0.23 ± 0.04) during winter, summer, monsoon and post-monsoon, respectively. It can be seen from that for each season MISR AOD values are slightly higher than other AOD values, except monsoon season. The significant variations of aerosol optical depth variation in seasonal cycle corresponded to the seasonal variability in aerosol anthropogenic activities and synoptic wind patterns. During winter, the highest frequencies of the MODIS, MISR and OMI AOD data points showed in the range of AOD ≤ 0.4, and their corresponding frequencies was about 64%, 56% and 89% respectively. It should be noted that during summer majority of MODIS AODs (41%) and MISR AODs (48%) are lies between 0.3 < AOD < 0.4. The synoptic wind pattern showed the arrival of a north-westerly air mass improves the movement of mixed aerosols to the observation location during summer season.

Keywords: Aerosol optical depth, Synoptic winds, Frequency distribution, Semi-arid region

1. Introduction

Aerosols are tiny particles in the 0.001 to 100 μm range suspended in the atmosphere and one of the most variable components of the Earth's atmospheric environment. Aerosols have generally short atmospheric life times (from a few days to several weeks), are associated with local sources, and possibly undergo rapid chemical evolution, thereby affecting transport and removal processes (Ramanathan et al., 2001). Validation of either satellite or model product must rely upon direct comparisons with ground-truth, stratified based on observational conditions to isolate the systematic effects of different algorithmic assumptions and instruments sensitivities (Kaufman et al., 1997;Remer et al., 2005; Mischenko and Geogdzhayev, 2007; Kahn et al., 2005, 2010). Satellite products, surface measurements and aerosol transport models are contributing more to create global and regional picture of aerosol distributions. Aerosol optical depth (AOD) has been provided by various satellite sensors such as Advanced Very High Resolution Radiometer (AVHRR), Total Ozone Mapping Spectrometer (TOMS), Moderate resolution Imaging Spectroradiometer (MODIS), Multi-angle Imaging SpectroRadiometer (MISR), Ozone Monitoring Instrument(OMI), and Sea-viewing Wide Field-of-view sensor (SeaWiFs), etc. In the present study, a comparison between the Terra/Aqua MODIS (C005) AOD_{550} (Level 3) , MISR and OMI aerosol optical depth is made over the semi-arid region of Anantapur, India to better understand the accuracy and reliability of satellite retrieval in this region for different seasons during 2007–2013. The paper starts with a brief description of the study area and theoretical background, followed by the description of the different datasets (satellite-based) that are used.

2. Instrumentation and site description

The first MODIS instrument was launched on board the Terra satellite on 18 December 1999, with daytime equator crossing at 10:30 local time (LT), as part of the NASA's Earth Observing System (EOS) mission; and the second one on 4 May 2002 onboard the Aqua satellite with daytime equator crossing at 13:30 LT. These are uniquely designed (wide spectral range, high spatial resolution, and daily global coverage) to observe and monitor the changes in the Earth's atmosphere. MODIS is a sensor which has 36 spectral bands covering the range between 0.415 and 14.235 μm, with a viewing swath of ~2330 km and variable spatial resolution of 1 km, 0.5 km and 0.25 km depending on the spectral band with repeat coverage of 2 days. The MODIS (dark-target) aerosol products are retrieved with special algorithms based on raw measurements following a lookup table approach in which a small set of aerosol types, loading and geometry are assumed to span the range of global aerosol conditions (Tanre et al., 1997; Levy et al., 2007, 2010; Remer et al., 2005, 2008). Daily MODIS C051 Level-2 (10 km × 10 km spatial resolution) aerosol products, which provide the best fits to surface reflectance observations (Remer et al., 2008), from the Terra and Aqua satellites for the years 2007–2013 were downloaded from the MODIS website and used to prepare the analysis presented in this paper. MISR employs nine cameras, one viewing nadir and four each viewing in forward and aft directions and has four spectral bands, i.e., blue, green, red, and near-infrared (Diner et al., 2001). The global coverage time is every 9 days with repeat coverage between 2 and 9 days depending on the latitude. The aerosol retrieval algorithm over land is dependent on the surface types within a scene i.e., dark water bodies, heavily vegetated areas or high contrast terrain (Kahn et al., 2005). We have also downloaded the MISR Terra Level-2 AOD_{550} global product on a daily basis with 17.6 km × 17.6 km resolution for inter comparison during the same study period. The OMAERUV level 2 daily files are available at the Goddard Earth Sciences Data and Information Services Center (GES DISC) site. The retrieved values of AOD, AAOD, and Single Scattering Albedo (SSA) are reported at 388 nm. Similar values are also reported at 354 and 500 nm by conversion from the 388 nm retrieval. The wavelength conversions from 388 nm to 354 and 500 nm are done using the spectral dependence associated with the assumed aerosol particle size distribution and retrieved absorption information (Torres et al., 2007; Jethva and Torres, 2011). NCEP/NCAR global reanalysis meteorological data was used to identify aerosol transport process during the study period.

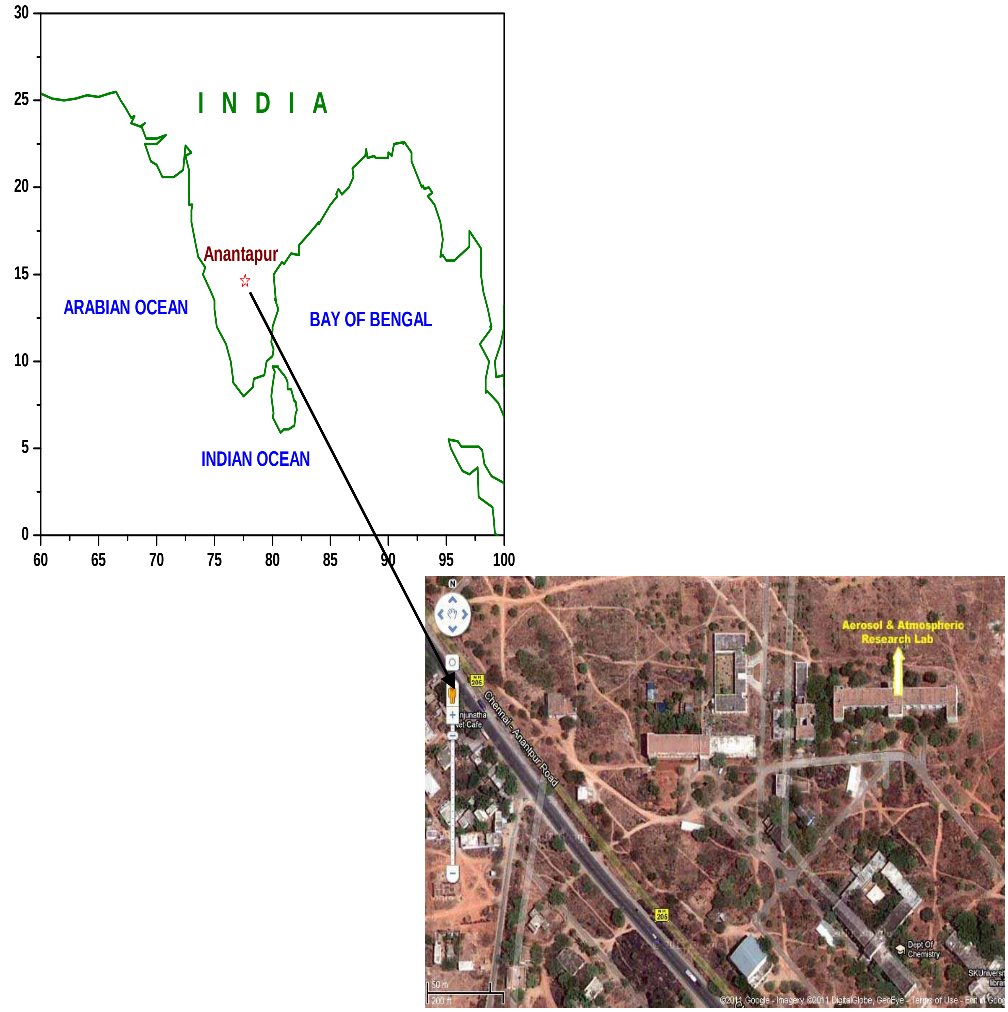


Fig.1. Location map of (top panel) the Sri Krishnadevaraya University campus area in Anantapur (bottom panel) satellite aerial view of monitoring site building in the SKU campus indicated with an arrow head.

Anantapur is located in southern India (Fig. 1.) which represents a very dry semi-arid, rain shadow and continental region of Rayalaseema, Andhra Pradesh, India Within a 50 km radius, this region is surrounded by a number of cement plants, lime kilns, slab polishing and brick making. In the direction of east and north number of stone crushing and the brick making activities are located. They continuously emitted pollutants. The national highways (NH 7 and NH 205) are located in the direction of northwest and release large quantities of particulate matter every day into the atmosphere. Number of villages is located in the south at the distance 0.5km and the vegetation is in the west direction.

3. Results and discussions

3.1 Inter-comparison of annual and seasonal variations of Satellite AODs

Figure 2 and 3 represents the seasonal and annual variation of AODs retrieved from MODIS , MISR and OMI satellites over a semi-arid region from 2007-2013. It can be seen from that for each season MISR AOD values are slightly higher than other AOD values, except monsoon season. The sampling differences, assumptions made in the algorithms about boundary conditions, missing particle property or mixing options, reflectance used in the retrievals are the main reasons differences AOD values.

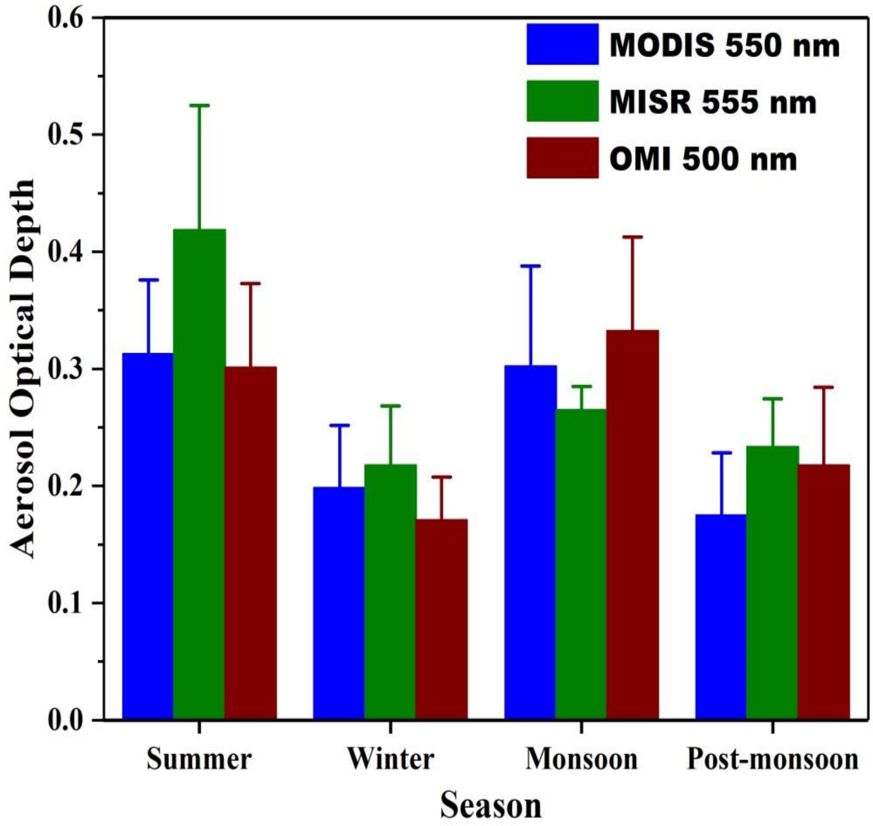


Fig.2. Seasonal variation of aerosol optical depth retrieved from MODIS,MISR and OMI during 2007-2013.

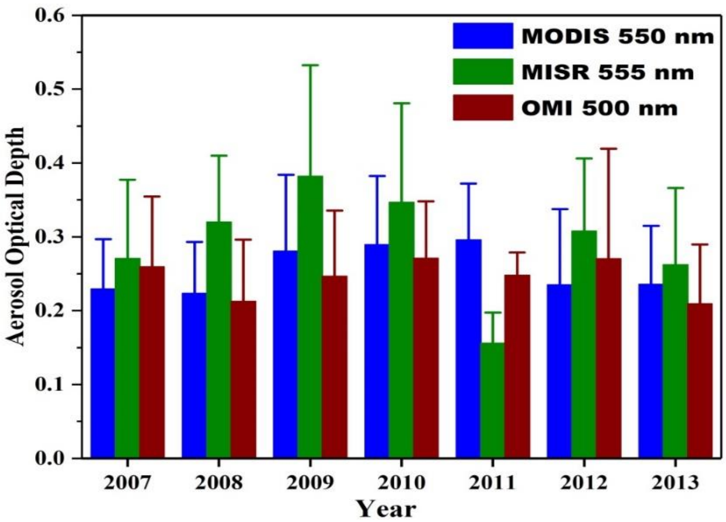
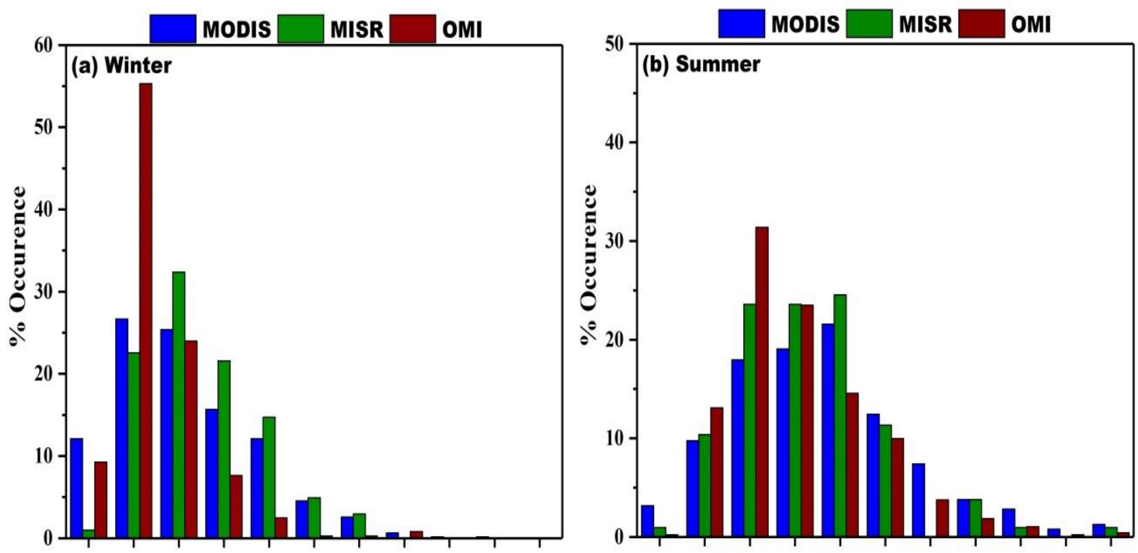


Fig.3. Annual variation of aerosol optical depth retrieved from MODIS,MISR and OMI satellites.

The seasonal mean MODIS (MISR) are found to be 0.20 ± 0.05 (0.22± 0.00), 0.31 ± 0.06 (0.42 ± 0.10), 0.30 ± 0.08 (0.26 ± 0.02), 0.17 ± 0.05 (0.23 ± 0.04) during winter, summer, monsoon and post-monsoon, respectively (Fig.2). Similarly, the corresponding mean OMI AOD are about 0.17 ± 0.03, 0.30 ± 0.07, 0.33 ± 0.08, 0.22 ± 0.06. The seasonal cycle in aerosol optical depth corresponded to the seasonal variability in dust, biomass burning and mixed aerosol emission. Annual mean values of AOD are obtained by taking the daily mean values of AOD from 2007 to 2013 and varied from 0.22 ± 0.06 to 0.30 ± 0.07 for MODIS, 0.16 ± 0.04 to 0.38 ± 0.15 for MISR, 0.21± 0.08 to 0.27 ± 0.07 for OMI (Fig.3). Inter – annual variation in MISR AOD showed the year 2009 had a higher aerosol concentration compared to the other years with AOD value of 0.38 ± 0.15 over the study location. Similarly the lower MISR AOD values were noticed in 2011 (0.16 ± 0.04).

3.2 Frequency distribution of MODIS, MISR and MISR AOD

Seasonal frequency distribution of all AOD data points retrieved from MODIS, MISR and OMI is shown in Fig. 4 (a) - (d). From fig 4(a) it is clear that during winter the majority of AOD values is less than 0.3. In the range of AOD ≤ 0.4, the frequencies of the MODIS, MISR and OMI AOD data points are about 64%, 56% and 89% respectively. In the AOD range of 0.1 – 0.3, the frequencies of MODIS AODs frequencies are are well matched with those of the MISR AODs. It should be noted that during summer majority of MODIS AODs and MISR AODs values are lies between 0.3 < AOD < 0.4 and their corresponding frequencies was about 41% (MODIS) and 48% (MISR) respectively (Fig.4(b)). The frequencies of OMI 0.3 < AOD < 0.4 are considerably lower than those of MODIS AODs and MISR AODs, and their corresponding frequency difference noticed as 3% and 10% respectively. It is made from clear that from Fig. 4 (c) that at the bin size 0.1 - 0.3, the frequency of occurrence of the MISRAODs (OMI AODs) was maximum during the monsoon and their corresponding frequencies was about 88% (89%) respectively. Also, for the bin size range AODs < 0.3, frequencies of MODIS AODs, MISRAODs, and OMI AODs are maximum and their corresponding frequencies was about 83%,93%, and 99%, respectively during post-monsoon (Fig. 4(d)).



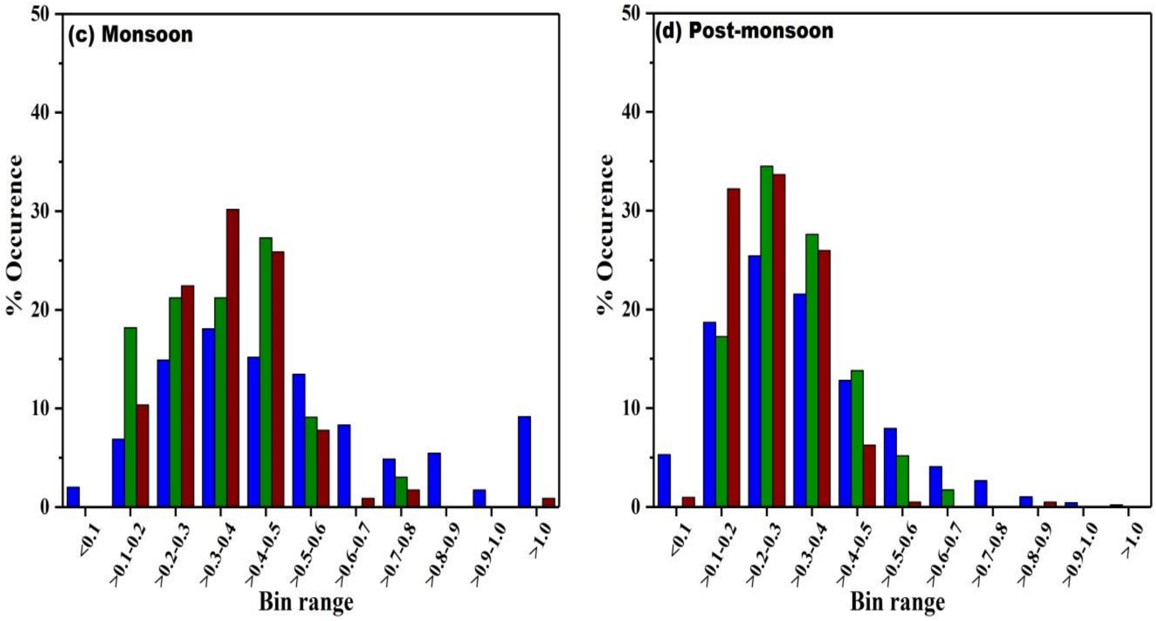
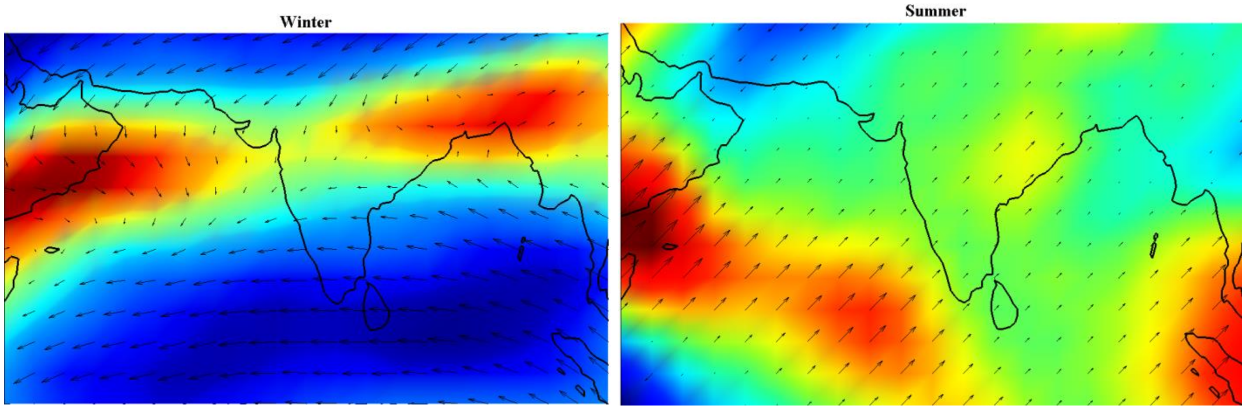


Fig.4. Frequency distribution of aerosol optical depth retrived from MODIS, MISR and OMI over Anantapur.

3.3 Seasonal variation of Synoptic winds

The northeast is typically the source of air masses during the winter. Before reaching the observation site, air masses occasionally cross the Bay of Bengal (Fig.5). Throughout the summer, the arrival of a north-westerly air mass improves the movement of mixed aerosols to the observation location. Aerosols above the measuring site are absorbed by local sources during the monsoon season, when winds primarily came from the Arabian Sea. During the post-monsoon, synoptic wind patterns come from central indo gangetic plain, which offers an extra source of aerosol absorption over the measurement site.



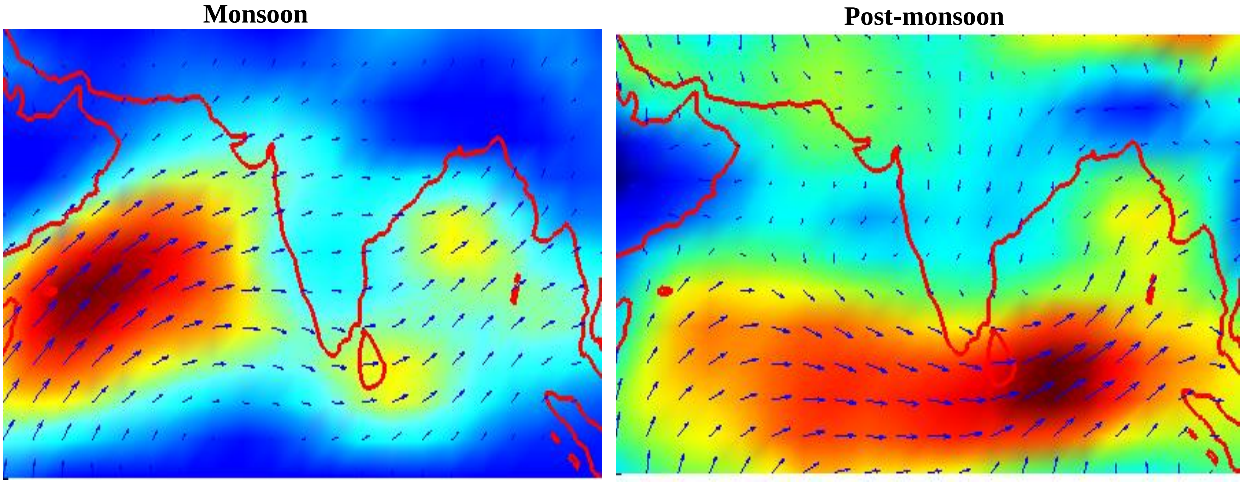


Fig.5. Synoptic wind pattern derived from ECMWF at 850 hPa pressure level over the entire Indian region.

4. Conclusions

The present study is carried out mainly focused on the retrieval of aerosol optical depths through different satellite observations over Anantapur, Southern peninsular India. The results show that a pronounced seasonal and annual variability in the aerosol optical depths is mainly due to anthropogenic emissions, synoptic wind patterns and assumptions made in the algorithms about boundary conditions, missing particle property or mixing options, reflectance used in the retrievals. During summer, north-westerly air masses arrival enhances the dust and biomass burning aerosols to the observation site.

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