Journal of Indian Society of Remote Sensing
V. 32, No. **4** (**December,** 2004 Issue)

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COVER ARTICLE

Variability of Aerosol Optical Depth Over Indian Subcontinent Using MODIS Data

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Satellite data have been proved to impart information about air quality (Chu *et al.,* 2003; King *et al.,* 2003). Satellite derived column aerosol optical depth (AOD) is a cost effective way to monitor and study aerosols distribution and effects over a long time period. Moderate Resolution Imaging Spectroradiometer (MODIS) derived AOD is well suited for such study due to its revisit cycle of 1-2 days as a result a close estimate of AOD is made for a given region throughout the year. Monthly average MODIS AOD has been used to investigate AOD distribution in spatio-temporal domain over Indian subcontinent since 2000. Aerosols have an impact on cloud formation process largely affecting monsoonal rainfall distribution over Indian subcontinent especially in the Ganga basin. Aerosols are found to be substantially increasing in the Ganga basin.

Aerosols are responsible for lowering of land surface temperature i.e. cooling effect which restricts warming effect of Greenhouse gases over Indian region. Its indirect negative effect also cannot be neglected. Higher aerosol loading is causing substantial decrease in sunlight reaching to the surface thereby affecting vegetation which depends on sunlight for their growth. Indo-Asian aerosols have impact on radiative forcing that cause negative forcing (cooling) at surface and positive effect (warming) at top of atmosphere (Satheesh and Ramanathan, 2000; Ramanathan *et al.* 2001b; Kaufman *et al.,* 2002). Ramanathan *et al.* (2001a) have found that this additional heating and cooling affect tropical rainfall patterns and disturb hydrological cycle. AOD distribution during pre-monsoon affects cloud formation and hence rainfall distribution which is found to be prominent in last 4 years. INDOEX experiments studied extensively the nature of aerosols, its transcontinental transport and its effect on climate (Ramanathan *et al.*, 2001b). Complex interaction between aerosols, clouds, climate and vegetation needs to be addressed in the light of harmful effects observed in several studies by different workers (Liao and Seinfeld, 1998; Rotstayn *et al.*, 2000; Kaufman *et al.*, 2002).

Aerosol Optical Depth (AOD) Data

Aerosol optical depth have been obtained using Level-3 MODIS gridded atmosphere monthly global product 'MOD08_M3' (ESDT Long Name: MODIS/Terra Aerosol Cloud Water Vapor Ozone Monthly L3 Global 1Deg CMG). Monthly average MOD08_M3 product files are available in Hierarchical Data Format (HDF-EOS) at spatial resolution of 1 degree by 1 degree (MODIS, 2004). Spring season consists of month of March. Summer season consists of months April, May and June. The mean of July to October is used as monsoon season over India. Winter season is considered from November to February.

Results and discussion

AOD is found to be very high (>.6) in Ganga basin with increasing aerosol concentration at an alarming rate in eastern part of basin in last four years (Fig. 1, summer 2000 and 2004). Southern parts of India show a much cleaner environment with AOD less than 0.4. The spatial gradient of AOD is showing increase from southern part of Indian subcontinent to northern part up to Himalaya. The central India shows moderate AOD values. The Gujarat state in western India also shows a very high AOD in summer due to effect of Thar Desert in its north-east region and also transport of dust from Middle East (Dey *et al.* 2004). Input of aerosols (mostly coarser fraction) from Thar Desert and dry season during pre-monsoon cause high AOD in the Ganga basin. Fine soil dust from dry un-vegetated agricultural land during summer is another big source of aerosols in this region.

Monsoon Season

Fig. 1 (monsoon 2002 and 2003) shows a strong gradient in AOD distribution from high to low from east to west in the northern part of India. The low AOD during 2003 corresponds to the normal rainfall (Fig. 1, monsoon 2003). The year 2002 was a drought year in which northern belt especially central part of Ganga basin suffered from very low rainfall. As a result AOD was found to be much higher (>0.5 in eastern part near Kolkata and >0.6 in central part near Kanpur) even during monsoon season in 2002 (Fig. 1, monsoon 2002).

Winter season

Post monsoon winter season comparatively shows much low aerosol loading over entire India. Aerosol loading in entire region is low after monsoon rainfall as rainfall washes out most of the aerosol concentration. About 3000 km long E-W and ~200 km wide N-S regions having high AOD (>0.4) is observed (Fig. 1, winter 2003). AOD concentration is unusually high in the central part of basin (>0.5 near Kanpur and Banaras region) and western part of Ganga belt (Kolkata). Winter season shows reversal of spatial gradient of aerosol loading (compared to pre-monsoon and monsoon season) which is low in western zone to high in eastern zone. Dense fog as observed over Delhi-Kanpur region during winter needs attention by the scientists since it causes enormous economic loss and also the daily life becomes stand still.

Spring season

Spring season shows continuation of trend observed for AOD distribution as in winter. High AOD (>0.5) is observed in eastern zone compared to western zone of Ganga belt (Fig. 1. spring 2004). Southern India experiences low aerosol loading except parts of Maharashtra state (near Mumbai). Dust storm events begin at the end of spring season that drastically changes AOD distribution pattern during pre-monsoon and monsoon seasons. In general AOD is less than 0.6 in most parts of Indian subcontinent during spring season except some small pockets.

Conclusion

High AOD is observed over the Ganga basin throughout the year unlike southern India, is alarming as this basin is one of the most productive basins of Indian subcontinent having population of more than 460 million. AOD is found to be increasing rapidly since 2000 in summer season that may cause adverse effect to the agricultural crops and also to the human health. Increased aerosol loading may likely affect the rainfall which is responsible for the observed drought conditions over the Indian subcontinent. Detailed analysis of AOD, crop yields and rainfall data are required to understand the impact of increasing aerosol loading over the Indian subcontinent.

Acknowledgement

The work was carried out at UNEP/GRID Sioux Falls, SD, USA, when one of us (AKP) was a visiting scientist during May-September, 2004.

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Figure

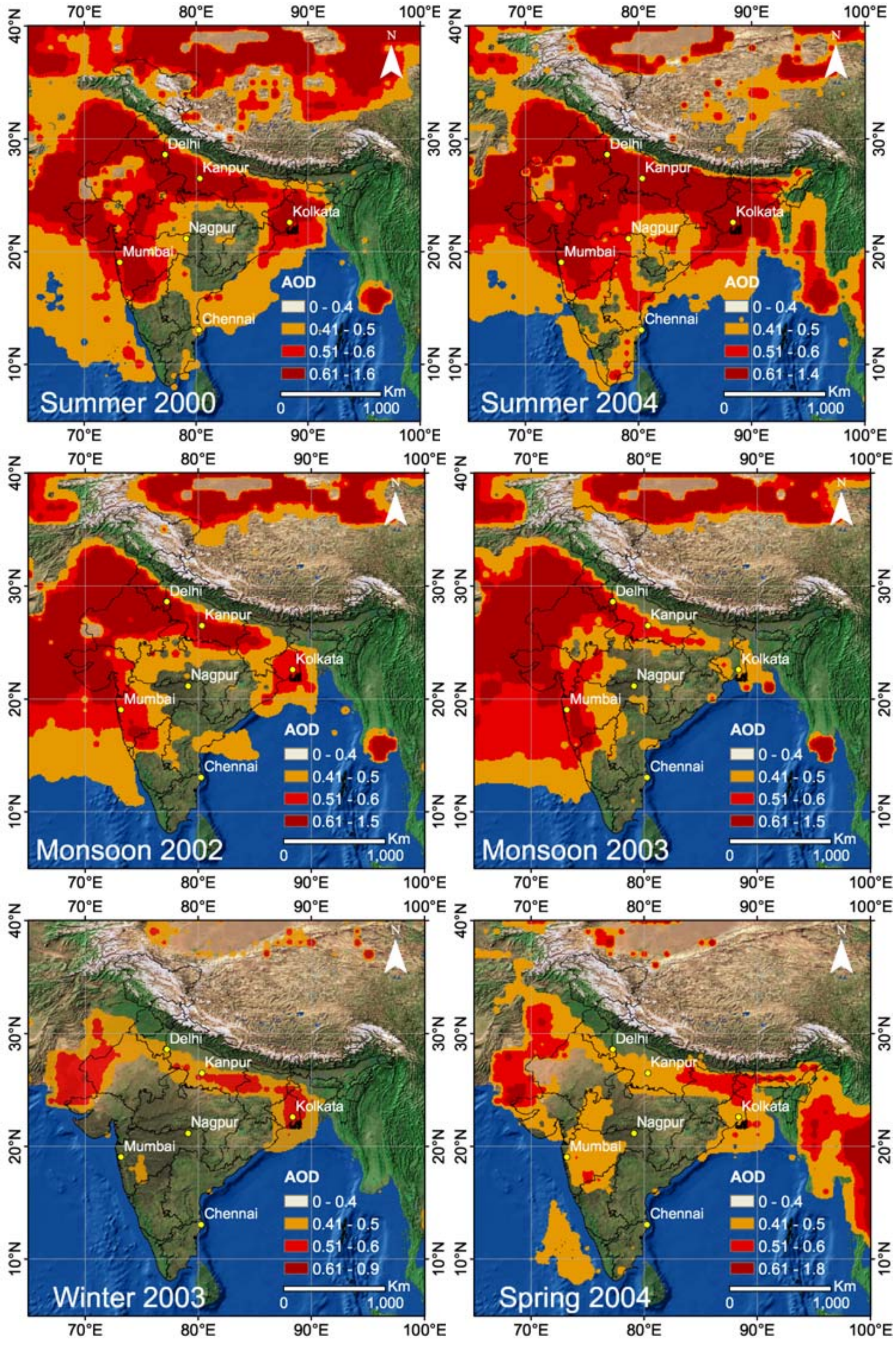

Fig. 1. MODIS AOD over Indian Subcontinent during summer 2000 and 2004, monsoon 2002 and 2003, winter 2003 and spring 2004.