Aerosols over the Indo-Gangetic Basin from 2000 - 2012

November 14th, 2014

M. M. WONSICK AND R. T. PINKER

DEPARTMENT OF ATMOSPHERIC AND OCEANIC SCIENCE

UNIVERSITY OF MARYLAND

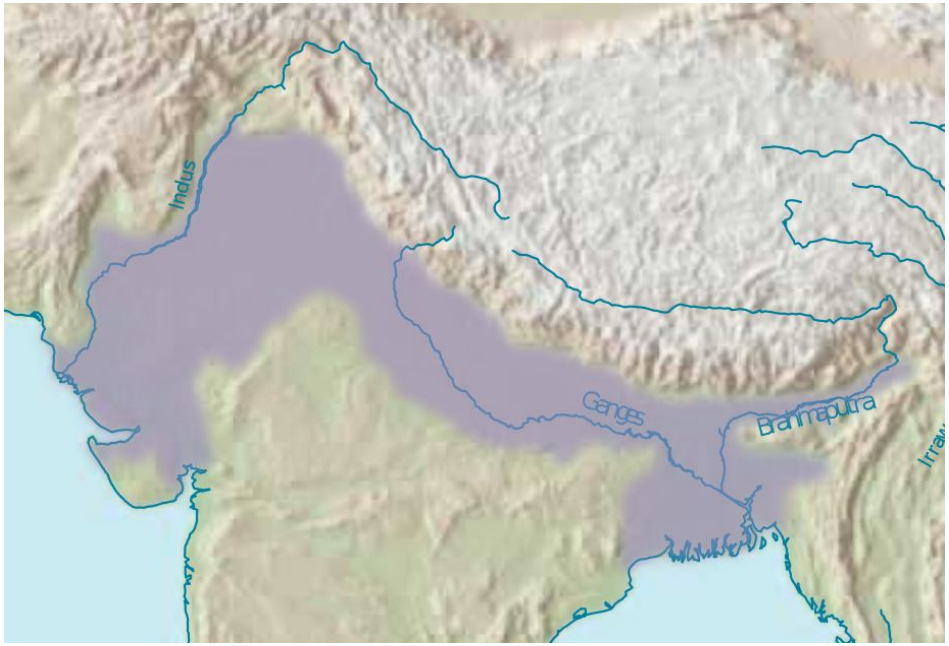
Abstract

- Numerous studies have sought to shed light on how the intensity of the Asian and Indian monsoons is impacted by the direct, indirect, and semi-direct effects of aerosols that build up in the Indo-Gangetic Basin (IGB) during the pre-monsoon season.
- These aerosol effects depend on their *optical depth*, *absorbing properties*, and *vertical distribution*.
- Several of the above issues have been addressed in *Wonsick et al. (2014)*.*

This presentation is limited to information on the inter-annual and spatial variability of aerosols in the IGB used in above study, and as obtained (primarily) from the Giovanni System.

* Wonsick, M. M., R. T. Pinker and Y. Ma, 2014. Investigation of the "Elevated Heat Pump" Hypothesis of the Asian Monsoon Using Satellite Observations. Atmos. Chem. Phys., 14, 8749–8761, 2014.

The Indo-Gangetic Basin



The Indo-Gangetic Basin (from Wikipedia, the free encyclopedia).

The Indo-Gangetic Basin (IGB), shown as the shaded area at left, is known to be a region with a high concentration of aerosols, particularly in March through May, the months that precede the Indian monsoon.

The main aerosol sources are:

- Dust from the Thar Desert and deserts of Western China, Afghanistan, Pakistan
- Black carbon produced by industries in northern India
- Black carbon from cooking fires within the IGB

Aerosol Impact on Asian and Indian Monsoons

- Solar dimming - aerosols reflect incoming solar radiation
  This can weaken the land-sea temperature gradient, shifting the Asian monsoon circulation southward and decreasing its intensity (Ramanathan et al., 2005; Chung and Ramanathan, 2006)

- Atmospheric heating – some aerosol types, such as dust and black carbon, absorb solar radiation and heat the surrounding atmosphere
  This has been shown to strengthen the monsoon in southern China, northern India, and the Bay of Bengal by impacting circulation patterns, vertical motions, and atmospheric stability (Menon et al., 2002; Meehl et al. 2008; Lau et al., 2006; Collier and Zhang, 2009; Randles and Ramaswamy, 2008)

- Semi-direct aerosol effect – aerosols cause cloud dissipation through atmospheric warming
  This has been linked to deficient springtime precipitation in India during high-aerosol years (Bollasina et al., 2008)

Data used in study

- We used the Giovanni system to obtain information on aerosol optical depth (AOD) in the IGB from two data sources:

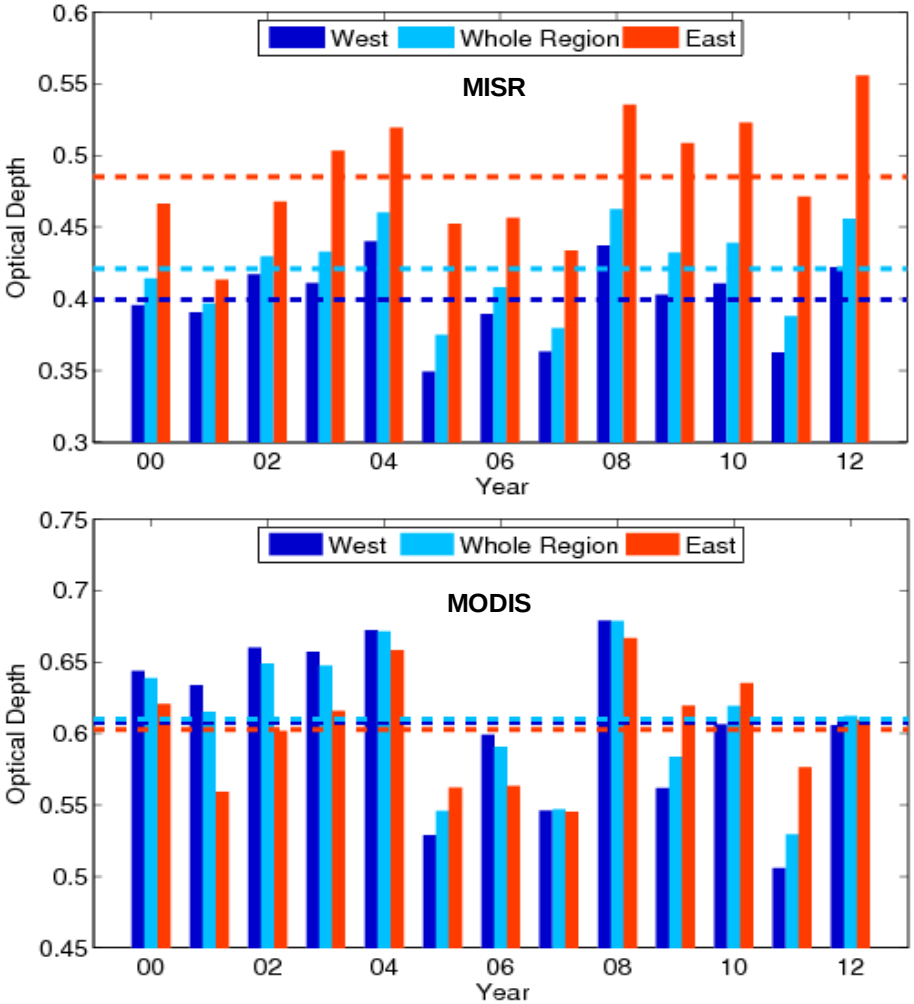
  - The Multi-angle Imaging Spectroradiometer (MISR) and
  - The Moderate Resolution Imaging Spectroradiometer (MODIS).

- Information on the absorbing properties of aerosols comes from a newly developed approach that uses the Goddard Chemistry, Aerosol, Radiation, and Transport Model (GOCART) as constrained with Modern–Era Retrospective Analysis for Research and Applications (MERRA) meteorology.

- For the period 2000 – 2012, we analyzed the aerosol build-up during the pre-monsoon months of March – May, which is the critical timeframe for aerosol impacts on the Asian and Indian monsoons.

.

Aerosol Optical Depth in IGB from Giovanni



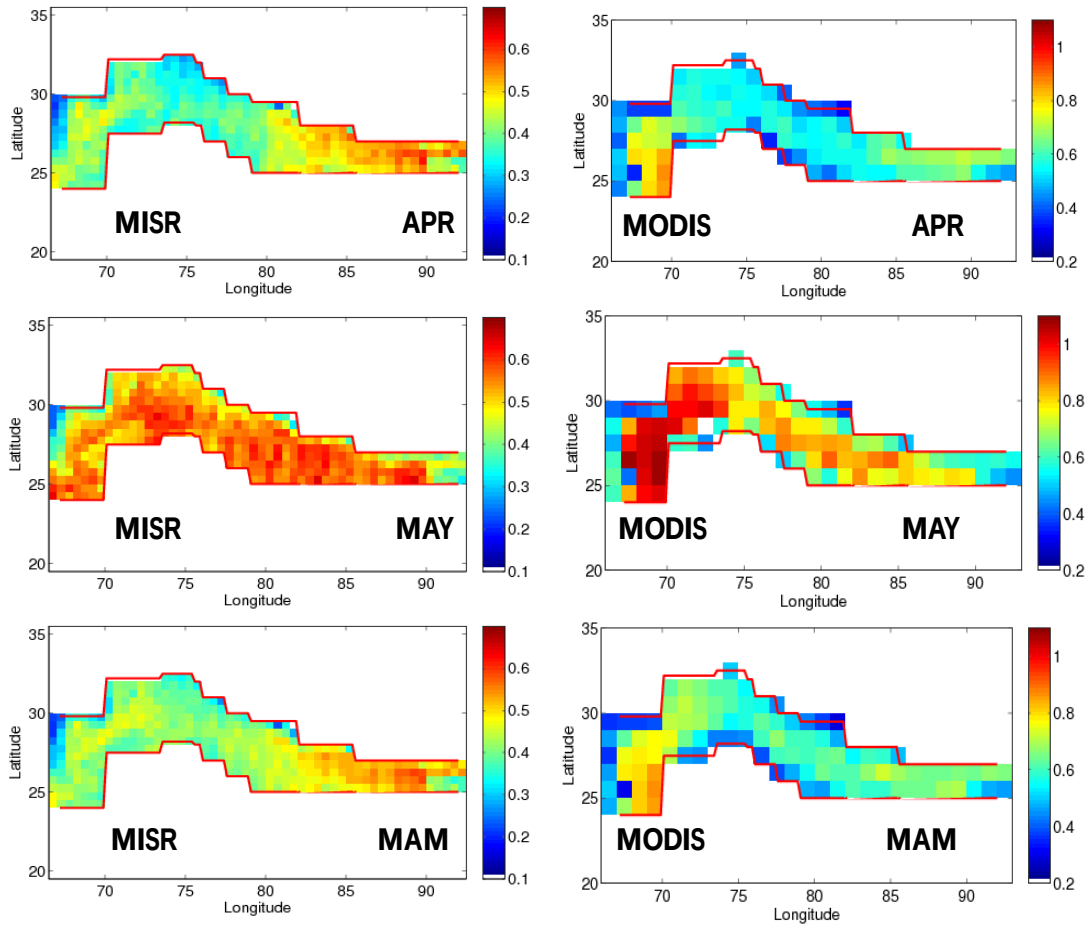
Time series of mean AOD at 0.55 nm in IGB *(light blue)* averaged over March – May from MISR *(top)* and MODIS *(bottom).*

Values also given for eastern *(orange*) and western *(dark blue)* portions of the IGB, separated at 82° E.

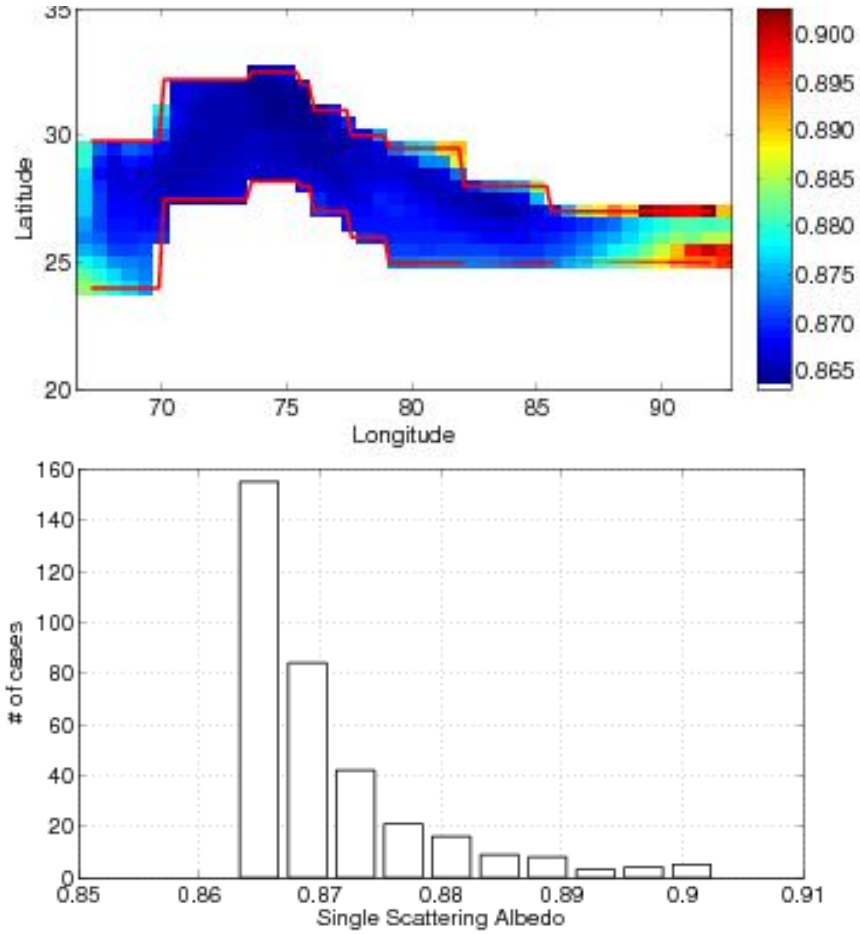
Dashed lines: Mean AOD for the region averaged over March – May for the period 2000 – 2012 for the entire domain and eastern and western portions.

Evolution of AOD in the IGB

- During April, the largest AOD is found in the eastern IGB in the MISR analysis, while MODIS shows more aerosol in the west. Both data sources agree that AOD is lower in the central IGB.
- By May, the entire IGB experiences high aerosol loading.
- The overall patterns for the Mar-Apr-May average are similar for both data sources, although there are differences in magnitude.



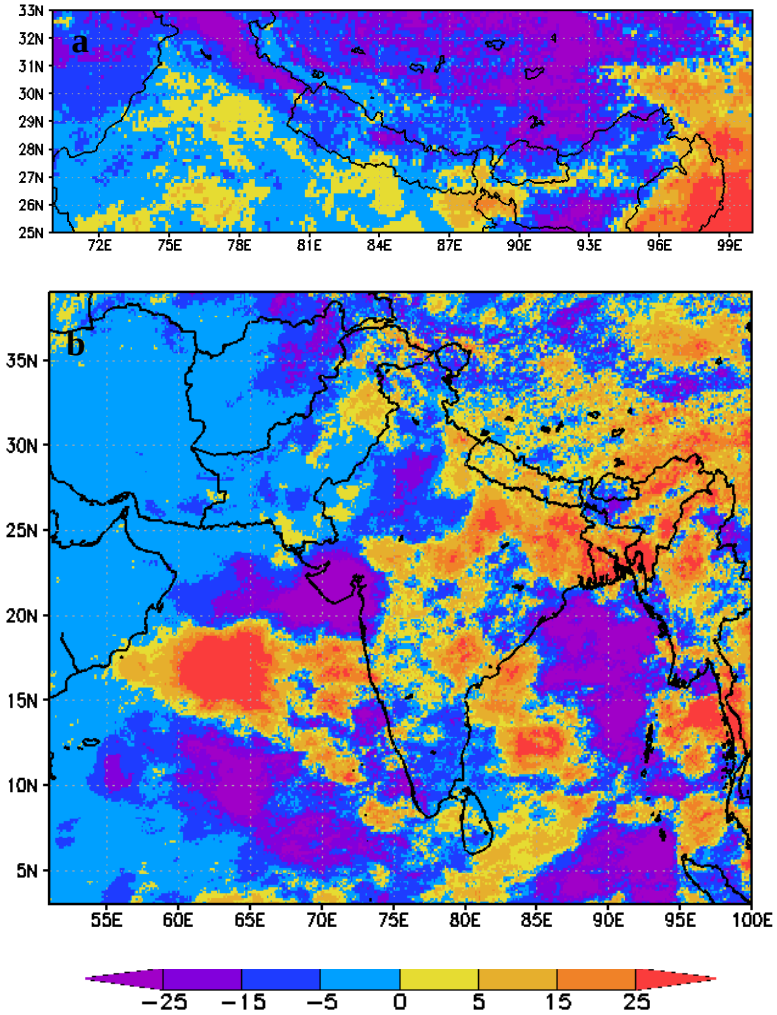
Evolution of SSA in the IGB



- We used the GOCART/MERRA analysis to estimate SSA of the aerosols in the IGB during the years when AOD was high (2004, 2008, and 2012).
- Analysis shows that the SSA during the pre-monsoon season of the high aerosol years was overwhelmingly at or below 0.86, indicating the aerosols were mainly of the absorbing type.

Spatial distribution (top) and frequency (bottom) of single scattering albedo values in the IGB averaged over MAM for the high aerosol years (2004, 2008, 2012) (from GOCART/MERRA, A. da Silva, private communication).

Effect of Aerosols on Convection



- We analyzed the impact of high aerosol loads in the IGB on monsoon convection, as derived from Meteosat-5 (Wonsick et al., 2009)
- As predicted by the Elevated Heat Pump proposed by Lau et al. (2006):
  - Enhanced convection in the foothills of the Himalayas in May was observed in the high-resolution Meteosat-5 analysis
  - Suppression of precipitation in southern India in June was observed

Difference in frequency of occurrence of convection per month for 2004 (high absorbing aerosol year) minus 2005 (low aerosol year) for (a) a detailed view of the Himalaya foothills region in May and (b) India and surrounding waters in June.

Summary of Findings

- The magnitudes of the AOD as derived with the two instruments differ, with MODIS reporting mean values near 0.6 compared to the MISR values that are closer to 0.45.
- The inter-annual variability in AOD follows the same general pattern for both data sources.
- Differences are larger between the MODIS and MISR analyses when the eastern and western regions of the IGB are separated (at 82° E).
- In the MISR data, AOD in the eastern region is consistently higher than in the west. Average values are 0.4 in the west and 0.5 in the east.
- In the MODIS data, AOD is higher in the west from 2000 – 2004 but more often higher in the east afterwards. Over the 13-year period, the mean AOD is roughly 0.6 for both sides of the IGB. Therefore, one side is not consistently higher than the other as in the MISR record.
- For both data sources, regional differences in spatial variability of aerosols across the IGB are apparent in April, but the entire IGB experiences higher aerosol loading by May.
- These findings were used to examine differences in monsoon precipitation and mid-tropospheric temperature for low- and high-aerosol years (Wonsick et al., 2014).

References

Bollasina, M., Nigam, S., and Lau, K.-M.: Absorbing aerosols and summer monsoon evolution over South Asia: An observational portrayal, J. Climate, 23, 3221–3239, 2008.

Chung, C. E. and Ramanathan, V.: Weakening of North Indian SST gradient and the monsoon rainfall in India and the Sahel, J. Climate, 19, 2036–2045, 2006.

Collier, J. C. and Zhang, G. J.: Aerosol direct forcing of the summer Indian monsoon as simulated by the NCAR CAM3, Clim. Dynam., 32, 313–332, doi:10.1007/s00382-008-0464-9, 2009.

Lau, K.-M., Kim, M. K., and Kim, K. M.: Asian summer monsoon anomalies induced by aerosol direct forcing: the role of the Tibetan Plateau, Clim. Dynam., 26, 855–864, 2006.

Meehl, G. A., Arblaster, J. M., and Collins, W. D.: Effects of black carbon aerosols on the Indian monsoon, J. Climate, 21, 2869–2882, 2008.

Menon, S., Hansen, J., Nazarenko, L., and Luo, Y. Climate effects of black carbon aerosols in China and India, Science, 297, 2250–2253, 2002.

Ramanathan, V., Chung, C., Kim, D., Bettge, T., Buja, L., Kiehl, J. T., Washington, W. M., Fu, Q., Sikka, D. R., and Wild, M.: Atmospheric brown clouds: Impacts on South Asian climate and hydrological cycle, P. Natl. Acad. Sci. USA, 102, 5326–5333, doi:10.1073/pnas.0500656102, 2005.

Randles, C. A. and Ramaswamy, V.: Absorbing aerosols over Asia: A Geophysical Fluid Dynamics Laboratory general circulation model sensitivity study of model response to aerosol optical depth and aerosol absorption, J. Geophys. Res., 113, D21203, doi:10.1029/2008JD010140, 2008.

Wonsick, M. M., Pinker, R. T., and Govaerts, Y.: Cloud variability over the Indian monsoon region as observed from satellites, J. Appl. Meteorol. Clim., 48(9), 1803-1821, 2009.

Wonsick, M. M., R. T. Pinker and Y. Ma, 2014. Investigation of the “Elevated Heat Pump” Hypothesis of the Asian Monsoon Using Satellite Observations. Atmos. Chem. Phys., 14, 8749–8761, 2014. www.atmos-chem-phys.net/14/8749/2014/. doi:10.5194/acp-14-8749-2014