Journal of Basic and Applied Engineering Research
Print ISSN: 2350-0077; Online ISSN: 2350-0255; Volume 1, Number 9; October, 2014 pp. 47-50

http://www.krishisanskriti.org/jbaer.html

Study of Temporal Variation of Aerosol Optical Depth in Dehradun using Satellite Data

Manu Mehta

PRSD, Indian Institute of Remote Sensing, 4-Kalidas Road, Dehradun

Abstract: **The paper presents a study of temporal variation of aerosol optical depth (AOD) using MODIS and MISR Level 3 data for twelve years (2001-2012) over Dehradun. Dehradun, located at 30.3°N, 78.0°E at an average elevation of 695m a.m.s.l. is the capital of Uttarakhand. It is located in a valley surrounded by hills with an undulating topography accompanied by high altitude hills to its North and East. The AOD data (at 550 nm) under study is taken from MODIS and MISR sensors for the twelve year period 2001-2012. MODIS (MOD08_M3) Level 3 monthly aerosol data at global 1°x 1° grid is used along with MISR (MIL3MAE) level 3 monthly aerosol data product at 0.5°x0.5° global grid which further is resampled to 1°x 1° grid. A correlation analysis for AOD over the study area for both the sensors shows a linear fit with a correlation coefficient of 0.75. Overall the AOD reported by MISR is less than that of MODIS both annually and seasonally. The lowest mean values of AOD are found in winter season spanning from December to February (MODIS estimate: 0.33, MISR estimate: 0.24). Further, tendency for increasing or decreasing AOD has also been estimated for the study region. The percentage tendency values are calculated by taking the difference of mean of last 6-year period (2007-2012) and mean of first 6-year period (2001-2006) with mean of first 6-year period as the reference. It is observed that the nature of AOD tendencies for Dehradun is decreasing as estimated by both the sensors i.e. MODIS estimate: -7.3% and MISR estimate: -1.4%.**

1. INTRODUCTION

A study over North India shows that the increase in absorbing aerosol loading may possibly amplify the seasonal warming [1]. It has been found that there is a variation in the sources of aerosols and their transport in Indian region [2]. Trends across different regions of India have been found during a decadal period 2000-2009 using MODIS level 2 data [3]. A similar trend analysis has been done for a decade with MISR level 2 data [4]. A comparative study over MISR and MODIS level 3 AOD data has been carried out over the Indo-Gangatic basin during the winter and summer seasons for 2000-2005 period where it was found that MISR performs better when compared with AERONET data [5]. Efforts have been made to study the potential causes and impact indicators for the trend of AOD over different parts of India using data from ARFINET locations [6]. In yet another study, AOD trends have been estimated over megacities of the world using MODIS and MISR Level 3 datasets [7]. The present paper presents a temporal study of variation of aerosols using MODIS and MISR Level 3 data for twelve years (2001-2012) over Dehradun.

2. STUDY AREA AND DATA

Dehradun is the capital city of Uttarakhand (Figure1). There are some small scale industries located in the city. The site receives heavy rainfall during monsoon with a climate which is hot in summers and becomes very cold in winters.

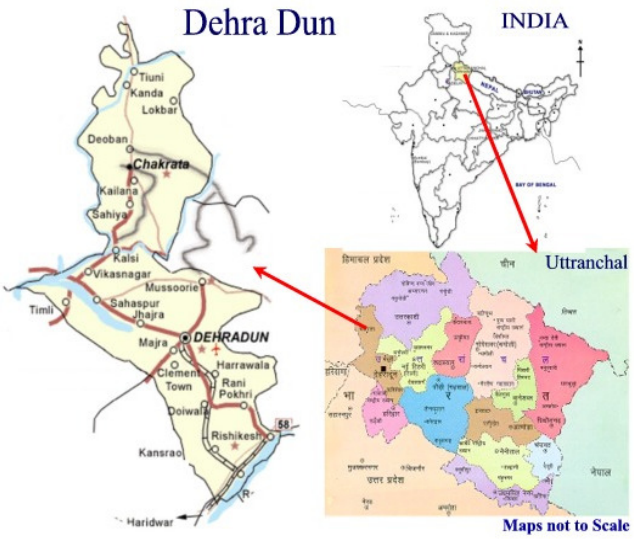

Fig. 1 Dehradun map (source : http://vitalindia.com/sara_industrial_estate_ltd.htm)

The aerosol data (at 550 nm) under study is taken from Terra MODIS and MISR sensors for the twelve year period 2001-2012. MODIS has 36 spectral channels with the wavelength range spanning over 0.41 to 15 µm. We have used MODIS (MOD08_M3) Level 3 monthly aerosol data at global 1°x 1° grid. MISR (MIL3MAE) level 3 monthly aerosol data product at 0.5°x0.5° global grid is resampled to 1°x 1° grid in order to match up with the MODIS products resolution for comparison

purpose. The expected errors, i.e. for MODIS, $\Delta AOD_{MODIS} = \pm (0.17AOD^2_{MODIS} + 0.03AOD_{MODIS} + 0.05)$ for Indian [8][9] and for MISR $\Delta AOD_{MISR} = \pm (0.18AOD_{MISR} + 0.04)$ [10] are also included at relevant places in the paper.

Correlation analysis is performed for the monthly mean data and the seasonal data also. Four seasons are considered, namely, winter (December-January), pre-monsoon (March-May), monsoon (June-September) and post-monsoon (October0November) respectively. Monthly and seasonal means are computed for the twelve year period. Tendencies for increasing or decreasing AOD values are computed using the monthly mean data for first and last six year period. Trend analysis is done using the least square regression approach with and without taking into account the uncertainties involved in the datasets. All these details are mentioned in the sections to follow.

3. STATISTICAL CORRELATION BETWEEN MODIS AND MISR FOR STUDY AREA

A correlation analysis was performed for both the datasets for the study area region. The correlation has been estimated both for all the month data as well as on seasonal basis. It is found that there is positive correlation coefficient of 0.75 for all month data with a linear relationship between MODIS and MISR datasets (Figure 2). The error bars correspond to expected errors as mentioned in section 2.

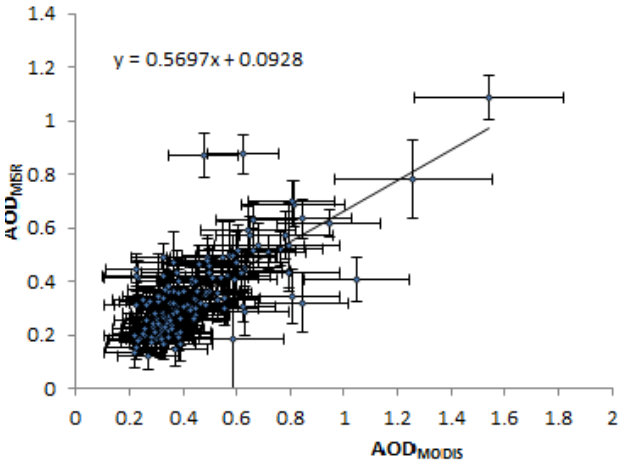

Fig. 2 Correlation between AOD from MODIS and MISR Level 3 monthly products, correlation coefficient: 0.75

In winter season, the correlation coefficient is the lowest, compared to all other seasons i.e. 0.59. The AOD values remain less than 0.6, for both the sensors. In pre-monsoon season, the correlation is high i.e. 0.75. In monsoon season, correlation again decreases to 0.65 with very high AOD values whereas, in post-monsoon season, the correlation between the two datasets becomes maximum i.e. 0.65 (Figure 3).

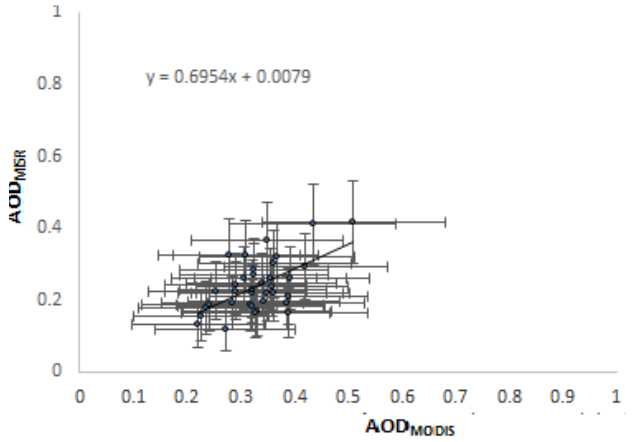

Fig. 3 (a) Correlation between AOD from MODIS and MISR Level 3 products for winter season, correlation coefficient: 0.59

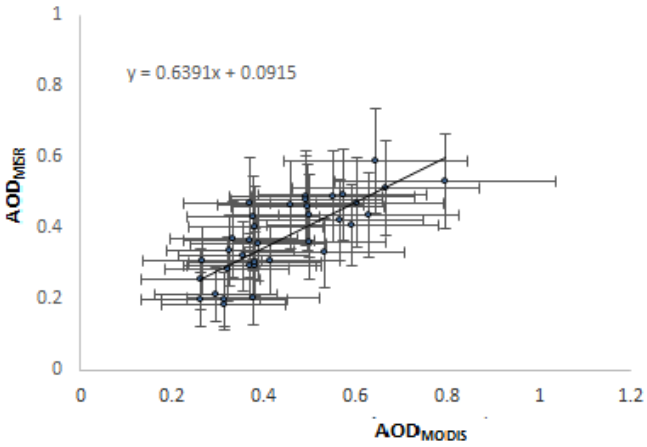

Fig. 3 (b) Correlation between AOD from MODIS and MISR Level 3 products for pre-monsoon season, correlation coefficient: 0.75

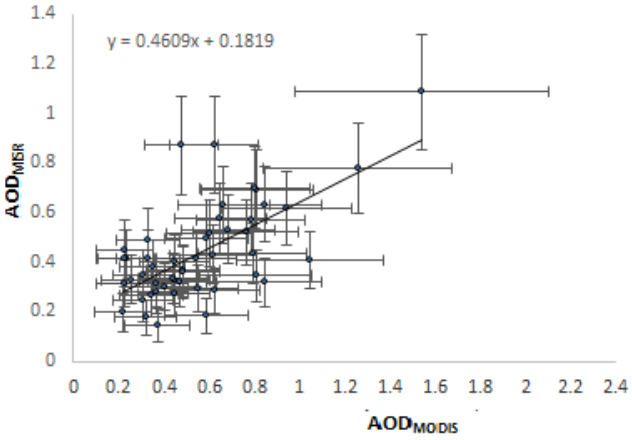

Fig. 3 (c) Correlation between AOD from MODIS and MISR Level 3 products for monsoon season, correlation coefficient: 0.65

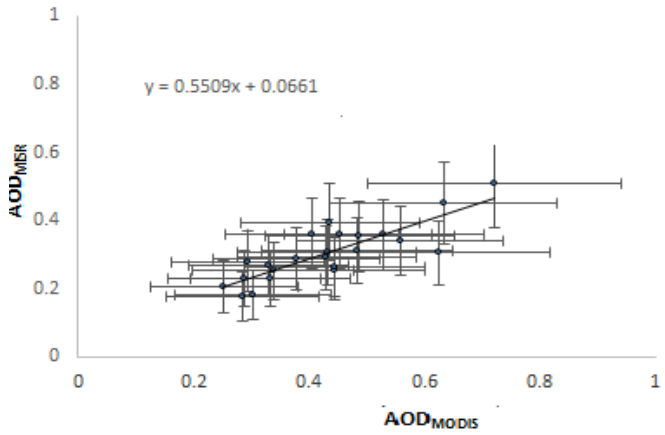

Fig. 3 (d) Correlation between AOD from MODIS and MISR Level 3 products for post-monsoon season, correlation coefficient: 0.83

4. MONTHLY AND SEASONAL MEAN AOD

Monthly means for all the months are calculated for the period 2001-2012. It is found that for MODIS data, minimum AOD is found in the months of December, January and February, with the mean value of 0.33. The AOD starts increasing in March, April and May consistently and suddenly reaches a mean value of 0.72 in June with the maximum in July i.e. 0.73, which is the characteristic monsoon month. In August, there is a drastic fall in the mean AOD value to 0.44, with further fall in September. The loading again increases in the month of October and November. Almost similar behavior is encountered for MISR data also (Table 1)

Seasonally, the mean values for AOD are the lowest in winter, supporting lowest aerosol loading and the highest in the monsoon period in the study region (Table 2).

Table 1 Monthly means of MODIS and MISR AOD datasets for Dehradun

Month	MODIS mean	MISR mean
January	0.33	0.22
February	0.33	0.28
March	0.35	0.30
April	0.39	0.35
May	0.59	0.47
June	0.72	0.49
July	0.73	0.52
August	0.44	0.43
September	0.34	0.32
October	0.45	0.32
November	0.41	0.29
December	0.33	0.21

Table 2 Seasonal means of AOD from both MODIS and MISR Level 3 products

Season	MODIS mean	MISR mean
Winter	0.33	0.23
Pre-Monsoon	0.44	0.37
Monsoon	0.56	0.44
Post-Monsoon	0.43	0.30

5. AOD TENDENCIES AND TRENDS

The tendency for increasing or decreasing AOD has also been estimated for Dehradun using both the datasets. The percentage tendency values are calculated by taking the difference of mean of last 6-year period (2007-2012) and mean of first 6-year period (2001-2006) with mean of first 6-year period as the reference. It is observed that the nature of AOD tendencies for Dehradun is decreasing as estimated by both the sensors i.e. MODIS estimate: -7.3% and MISR estimate: -1.4% (Table 3). Further, trend analysis is done using the least square regression approach without weights as well as with weights where the weights are assigned corresponding to the uncertainty (expected error) in the data. The trend values are calculated as percent trend which is computed as (slope between the monthly AOD and time)*12*100/annual mean of 2001.

The annual trend using MODIS data both with and without weights comes out to be linearly decreasing whereas for MISR data, the trend is linearly decreasing without assignment of weights but increasing when weights are assigned in the regression (Table 3). In case when the nature of tendencies and trends are same, the results can be taken as reliable. In cases, when there is a mismatch in the signs of the two, more research is required in order to find the actual trend.

Table 3 AOD tendencies and trends estimated using MODIS and MISR Level 3 AOD data

Parameter		MODIS	MISR
AOD Tendency	Value (%)	7.3	1.4
	Nature	Decreasing	Decreasing
Annual AOD Trend without weights	Value (%)	1.5	0.05
	Nature	Decreasing	Decreasing
Annual AOD Trend with weights	Value (%)	0.78	0.36
	Nature	Decreasing	Increasing

6. CONCLUSIONS

The study focuses on analyzing the monthly Level 3 AOD data from two satellite datasets. The following conclusions can be drawn from the analysis:

1. The overall mean AOD, (annual, seasonal and monthly) remains low for MISR as compared to that of MODIS.

2. The correlation analysis for the study area using both the sensor datasets reveals that there is a linear relationship with positive correlation coefficient of 0.75. Out of all the four seasons, in post-monsoon period, the correlation is the best with coefficient of 0.83. The correlation in other three seasons also remains above 0.5, indicating a good agreement between the two sets.

3. The monthly mean calculations for the two datasets reveal that there is maximum loading in the month of July i.e. the characteristic monsoon month. Seasonal analysis also show that the loading is highest in the monsoon period whereas, in winter, minimum aerosol loading is found.

4. The AOD tendency as estimated by both the sensors is found to be decreasing, though with differing values. The linear regression analysis without using the uncertainty in the datasets also suggest that there is a declining trend in the AOD.

   The regression using the uncertainties involved in the datasets, suggests that there is a declining trend estimated by MODIS data whereas an increasing trend estimated by MISR data. In this case, when nature of AOD trends estimated by two sensors differ, more research is required to find the actual trend of AOD.

7. ACKNOWLEDGEMENTS

The authors are extremely thankful to the entire MODIS and MISR team for proving the data used in the analysis.

REFERENCES

[1] Gautam, R., Hsu, N. C., Lau, K.M., Tsay, S.-C. and Kafatos M., "Enhanced pre-monsoon warming over the Himalayan-Gangetic region from 1979 to 2007", *Geophysical Research Letters*, **36**, 2009, L07704, doi:10.1029/2009GL037641, 2009.

[2] Habib, G., Venkataraman, C., Chiapello, I., Ramachandran, S., Boucher, O., Reddy, M.S., "Seasonal and inter-annual variability in absorbing aerosols over India derived from OMS: relationship to regional meteorology and emissions", *Atmospheric Environment* **40**, 2006, 1909e1921.

[3] Ramachandran, S., Kedia, Srivastava, R., "Aerosol optical depth trends over different regions of India", *Atmospheric Environment* **49,** 2012, pp.338-347, doi:10.1016/j.atmosenv.2011.11.017.

[4] Dey, S. and Girolamo, L. D., "A decade of change in aerosol properties over the Indian subcontinent", *Geophysical Research Letters*, **38**, 2011, L14811, doi:10.1029/2011GL048153, 2011.

[5] Prasad, A. K., Singh, R. P., "Comparison of MISR-MODIS aerosol optical depth over the Indo-Gangetic basin during the winter and summer seasons (2000–2005)", *Remote Sensing of Environment* **107,** 2007, pp. 109–119, doi:10.1016/j.rse.2006.09.026.

[6] Babu, S. S., et al.,"Trends in aerosol optical depth over Indian region: Potential causes and impact indicators*", J. Geophys. Res. Atmos.*, **118** (11), 2013, pp.794–11,806, doi: 10.1002/2013JD020507.

[7] Alpert, P., Shvainshtein O. and Kishcha, P. "AOD Trends over Megacities Based on Space Monitoring Using MODIS and MISR," *American Journal of Climate Change*, 1(3), 2012, pp. 117-131, doi:10.4236/ajcc.2012.13010.

[8] Remer, L. A., Kaufman, Y. J., Tanre, D., Mattoo, S., Chu, D. A., Martins, J. V., Li, R., Ichoku, R. C., Levy, R. C., Kleidman, R.G., Eck, T. F., Vermote, E. and Holben, B. N., "The MODIS aerosol algorithm, products and validation", *Journal of the Atmospheric Sciences*, **62**, 2005, pp.947–973

[9] Levy, R.C., Remer, L.A., Kleidman, R.G., Mattoo, S., Ichoku, C., Kahn, R. and Eck, T.E., "Global evaluation of the Collection 5 MODIS dark-target aerosol products over land", *Atmospheric Chemistry and Physics,* **10***,* 2010, pp.10399–10420, doi: 10.5194/acp-10-10399-2010.

[10] Liu, Y., Sarnat, J.A., Coull, B.A., Koutrakis P. and Jacob, D.J., "Validation of Multiangle Imaging Spectroradiometer (MISR) aerosol optical thickness measurements using Aerosol Robotic Network (AERONET) observations over the contiguous United States", *Journal of Geophysical Research*, **109**, 2004, D06205.doi:10.1029/2003JD003981..