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Exploring the Link Between Droughts and Atmospheric Aerosol Loading

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Exploring the link between droughts and atmospheric aerosol loading

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Abstract

Are higher atmospheric aerosol levels and droughts related? To address this question, we explore the relation between atmospheric aerosol loading and droughts using insitu and satellite observations over different urban/rural settings and heterogeneous drought conditions. A related objective was to report on the relationship and the variability between aerosol optical depth (AOD) retrieved from the Moderate Resolution Imaging Spectroradiometer (MODIS) and insitu particular matter (PM2.5 and PM10) over different land use. Daily measurement of PM2.5 and PM10 data were retrieved from seven EPA air quality monitoring stations in Indiana: Virgo, Lake and Clark County in urban area, Marion, Know and Henry County in agriculture area, and Delaware County in suburban area during summer (June 1 – August 31, 2007) and winter (January 1, 2007 – March 31, 2007). The MODIS AOD data were extracted from the daily MODIS L2 land aerosol products at 0.55 um wavelength with 10 x 10 1 km resolution grids. The Geographic Information System (GIS) was used to determine the closet coordinate of observation stations from MODIS images. The drought status was obtained from the US Drought Monitor and the Standardized Precipitation Index. A regression analysis was undertaken to compare daily insitu PM 2.5 and PM10 measurements with the column integrated MODIS AOD values. Results indicate higher AOD values under drought conditions during summer period and severe drought occurrence. The data also shows higher variability and lesser correlation between the column integrated MODIS AOD and the PM measurements during summer and fall seasons. The difference between column integrated versus surface measurements is more with high values of AOD and drought condition. The average correlations between AOD and PM2.5 and PM 10 are 0.6 and 0.3 respectively for all land use. The average bias during drought condition (summer) is 0.23 and during non drought (winter) is 1.44 in urban area. In agriculture area the bias is higher than urban area during drought(0.48) but is lower than urban area during non drought (-0.14). The correlation of AOD, PM2.5 and PM 10 in agricultural area is higher than the correlation in urban area with AOD being relatively comparable with the PM 2.5 concentration. Further study is underway to understand the relationship between the air pollution feedback and climate variability and local drought conditions using satellite datasets.

Methodology

This study used L2 aerosol products downloaded from MODIS website and daily particular matter data obtained from US EPA. US EPA used Tapered-Element Oscillating Microbalance (TEOM) instrument to collect particulate matters with hourly $\pm 1.5 \mu\text{g}/\text{m}^3$ accuracy. First fourteen stations had been selected according to the coordination of monitoring stations as in Figure 1. The sites had been categorized into urban, suburban and agricultural area. The MODIS AOD pixels at 0.55 um were extracted from the satellite images by using the stations' coordinates with Geographic Information System (GIS) toolbox. The MODIS AOD uncertainty ranged from $\pm 0.05 \pm 0.20$ AOD overland (Chu et al., 2002). The cloud screening process of the pixels based on aerosol algorithm as mention above. After extraction process, seven stations which obtained a significant number of data from satellite over passing were used for comparison. Seven stations included Virgo, Lake and Clark County in urban area, Marion, Know and Henry County in agriculture area, and Delaware County in suburban area. The study used regression analysis to compare daily PM10 and PM2.5 measurements with MODIS AOD values. The time series plots were used to show the variability and distribution of PM10, PM2.5 and MODIS AOD values during summer (JAS, July, August, and September) and winter seasons in 2007.



Figure 1 shows 14 stations of EPA monitoring sites which have been selected in different parts of Indiana depending on air quality index to compare with MODIS data.

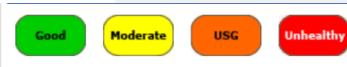


Figure 2 shows an example of dailyMODIS images contain AOD data from satellite TERRA. The station number changed to 7 stations due to they were not on the paths of TERRA and Aqua.

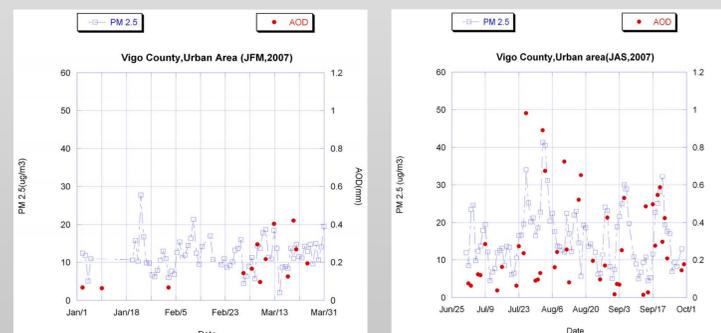
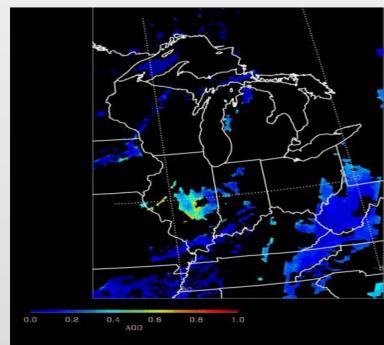


Figure 3 shows the time series plot between PM2.5 mass concentration and MODIS AOD values during summer (A) and winter (B) in Vigo county (urban area).

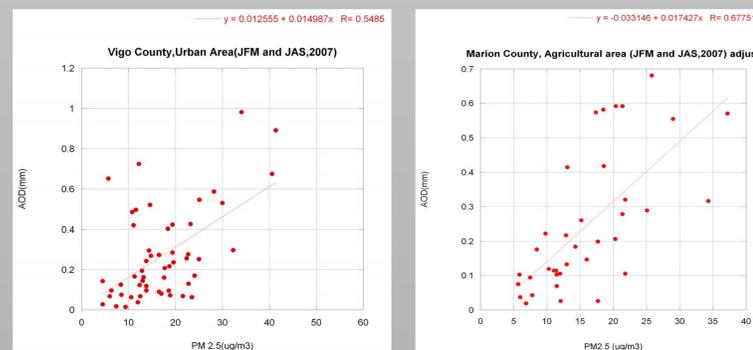


Figure 4 shows the correlation plots between PM2.5 mass concentration and MODIS AOD values for both summer and winter.

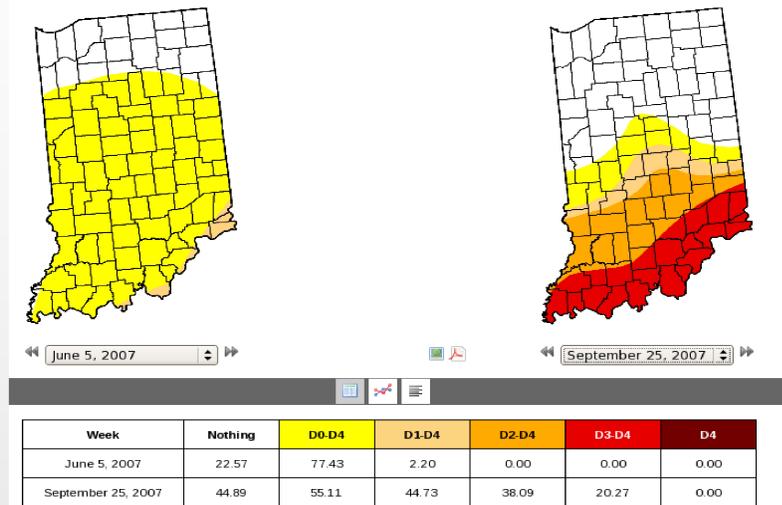


Figure 5 shows drought conditions during summer during June 5 and September, 2007. The severe drought occurred in Southern Indiana (Vigo, Knox county).

$$\text{PM}_{2.5} (\mu\text{g}/\text{m}^3) = 0.01897 + 0.015398 \text{ AOD}, r = 0.56$$

$$\text{PM}_{10} (\mu\text{g}/\text{m}^3) = 0.14205 + 0.0074 \text{ AOD}, r = 0.31$$

| Locations | AOD PM2.5 | | | AOD – PM10 |
|--------------------------|-----------|---------------|---------------|------------|
| | R value | Bias (summer) | Bias (winter) | R value |
| Urban Area | | | | |
| Vigo County | 0.55 | 0.43 | 2.89 | 0.45 |
| Lake County | 0.65 | 0.14 | N/A | 0.13 |
| Clark County | 0.51 | 0.11 | 0.0023 | 0.63 |
| Agricultural Area | | | | |
| Marion County | 0.68 | 0.48 | -0.22 | 0.74 |
| Knox County | 0.71 | | | 0 |
| Henry County | 0.52 | 0.47 | -0.054 | N/A |
| Suburban Area | | | | |
| Delaware County | 0.57 | -0.6 | 0.21 | |
| Total | 0.56 | | | 0.31 |

Conclusion

- During drought condition, the AOD values has higher variability and less correlation with insitu observations than non drought condition.
- The PM 2.5 has higher correlation with AOD values than PM 10.
- In Agriculture area, the correlation values with AOD and PM were higher than Urban area.
- In agriculture area the bias is higher than urban area during drought (0.48) but is lower than urban area during non drought (-0.14).
- Future study recommended to analyze the relationship between the air pollution feedback and climate variability and local drought conditions using satellite datasets.