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Exploring the Potential of Satellite Data for Air Quality Applications

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Introduction

Particular matter, or aerosols, reduce visibility, affect human health, and also cause several ecological effects. As defined by Environment Protection Agency (EPA), the dry mass content of particular matter with aerodynamic diameter less than 2.5μm ($PM_{2.5}$) in the atmosphere is an important parameter for the evaluation of air quality. However, the large spatio-temporal variations of particular matter make it a challenge to judge the air quality and issue prompt health alert from the current ground-based measurement network, especially when the aerosol events come from sources outside the U.S. The launch of EOS TERRA and AQUA satellite provides an unprecedented opportunity to monitor air pollution over the globe. The intent of this study is to explore the potential of satellite aerosol datasets for air quality applications.

Hypothesis

Aerosols with diameters around 1 ~2μm are efficient in scattering the visible light. During MODIS passing time (locally, 10:30AM for TERRA and 1:30 for AQUA) in cloud-free conditions, the atmospheric boundary layer is well mixed. Hence, the MODIS visible reflectance and its column aerosol optical thickness (AOT) retrievals can be used as indicators of the $PM_{2.5}$ mass at the surface.

Methodology

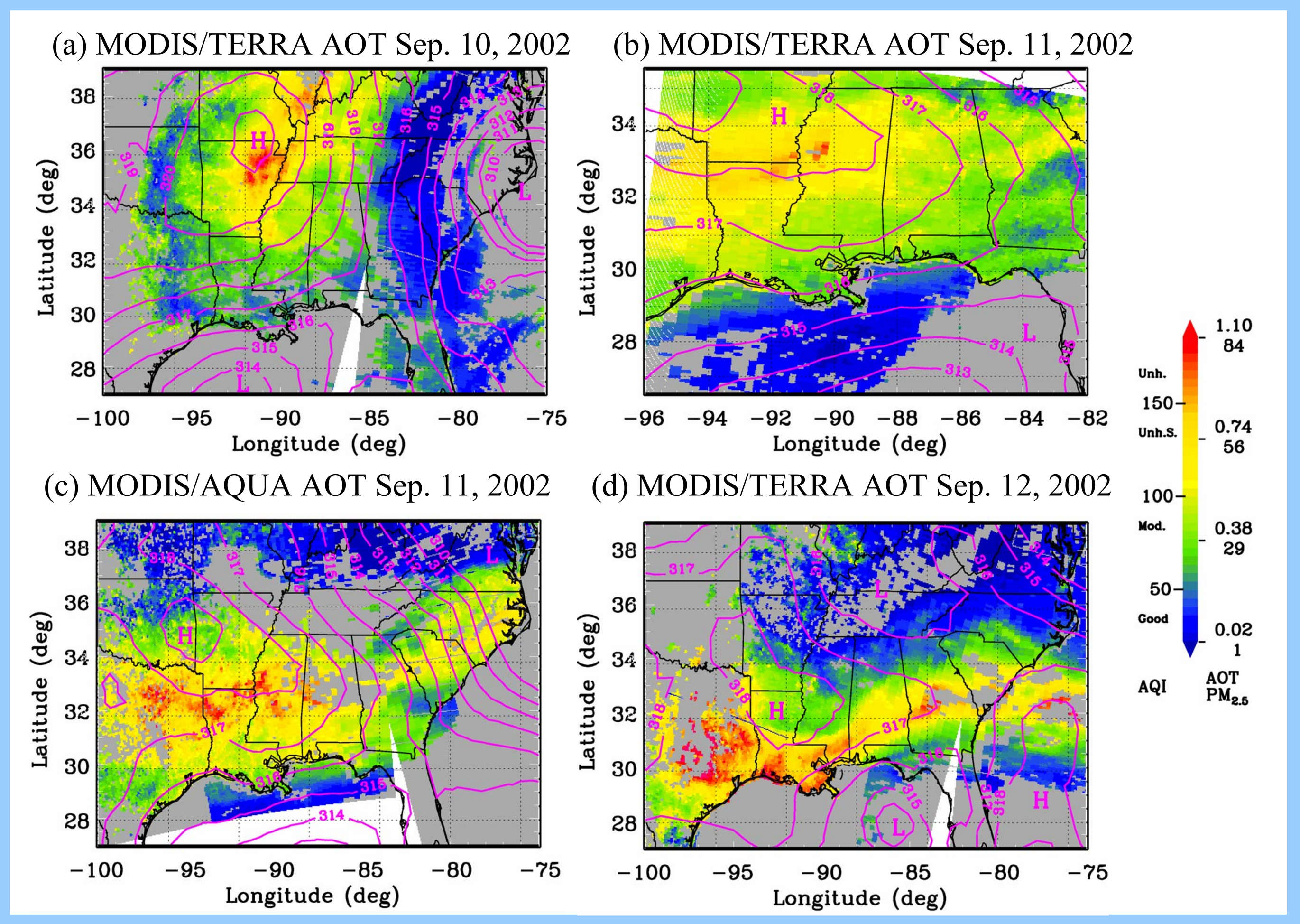
Compare MODIS AOT with the ground-based $PM_{2.5}$ hourly measurements. For each comparison, MODIS AOT time is centered around the $PM_{2.5}$ observation time period.

Data and Study Area

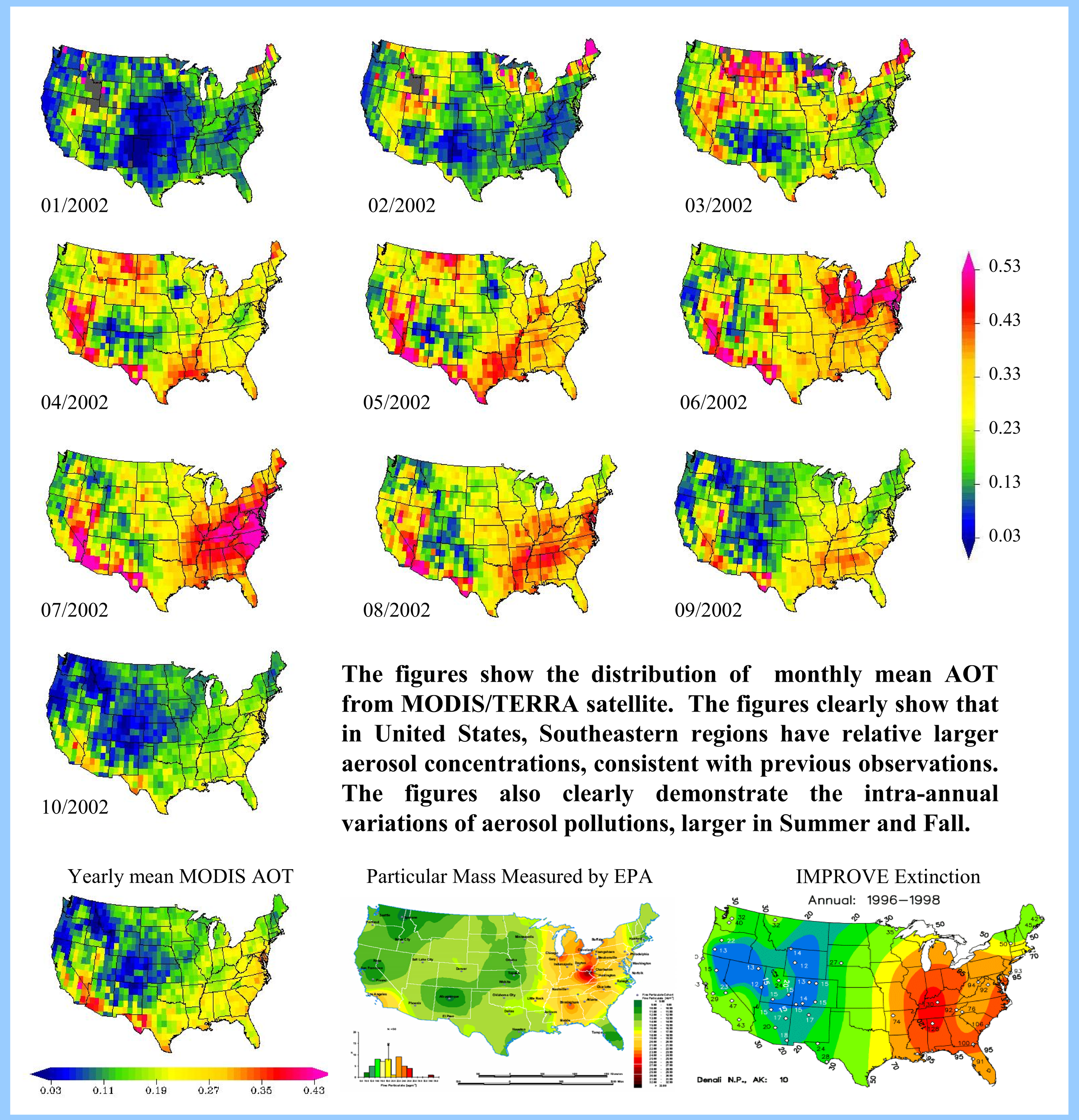
1) MODIS AOT from TERRA and AQUA, 2002.
2) $PM_{2.5}$ measured from Tapered-Element Oscillating Microbalance (TEOM) in Alabama and Texas.
4) Sunphotometer data in Stennis, MS.
3) EPA $PM_{2.5}$ analysis and extinction analysis from IMRPOVE measurements.

A Case Demonstration

The following figures show a heavy haze event identified by the spatial distribution of MODIS AOT. Also shown is the linearly derived Air Quality Index (AQI) and the 700mb geopotential heights. Grey regions are areas where MODIS AOT is not available due to possible sun glint or cloud contamination.



Aerosol Pollution Distribution in U.S. inferred from MODIS AOT and Inter-comparison with ground observations



The figures show the distribution of monthly mean AOT from MODIS/TERRA satellite. The figures clearly show that in United States, Southeastern regions have relative larger aerosol concentrations, consistent with previous observations. The figures also clearly demonstrate the intra-annual variations of aerosol pollutions, larger in Summer and Fall.

Quantitative Inter-comparison between $PM_{2.5}$ and MODIS AOT

(1) $PM_{2.5}$ mass vs. MODOS AOT in Jefferson County, AL. The comparison shows MODIS AOT has a good positive correlation with $PM_{2.5}$, which can be used to identify air quality category (e.g., good, moderate, unhealthy, etc) with high accuracy (>90%).

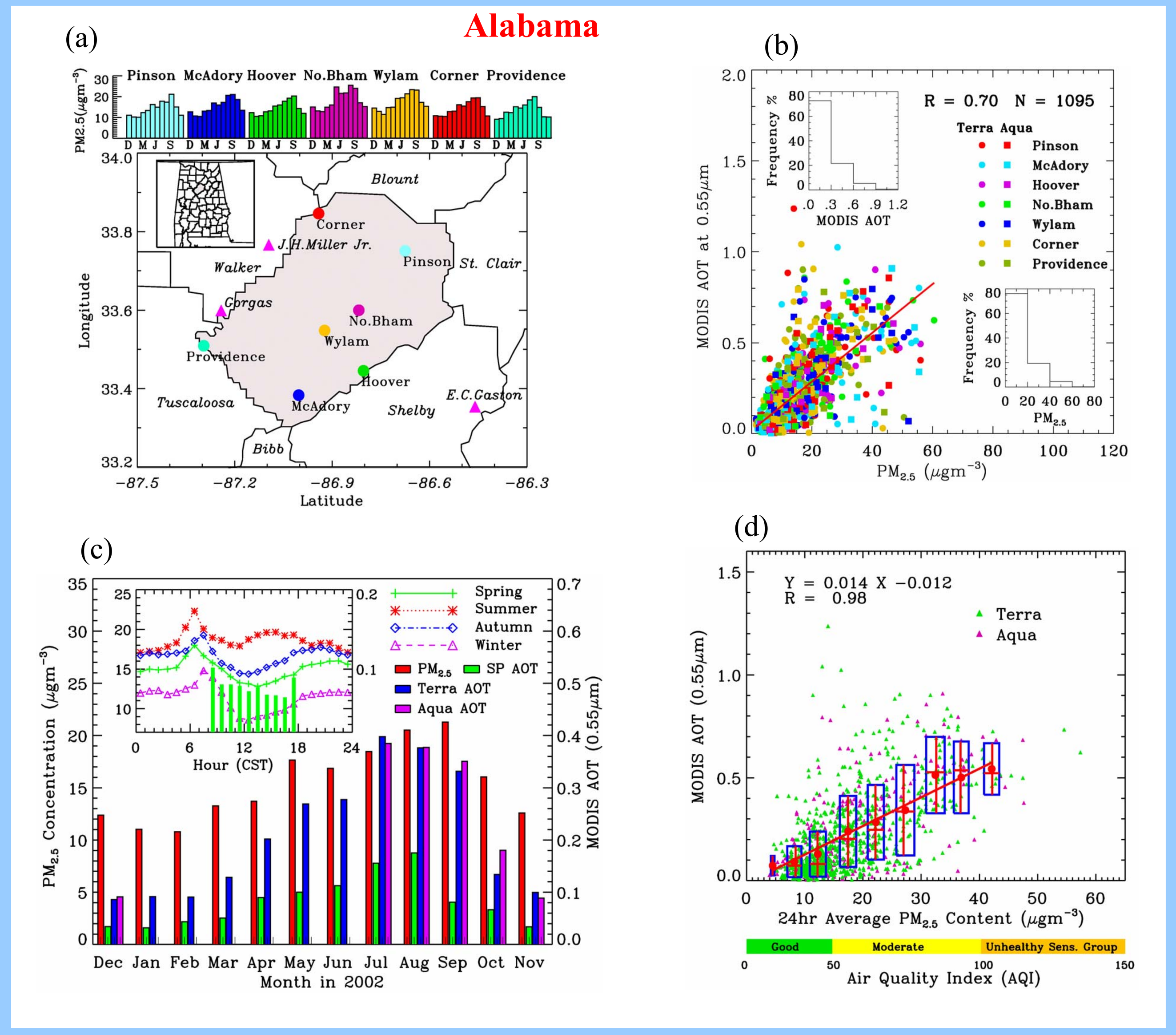
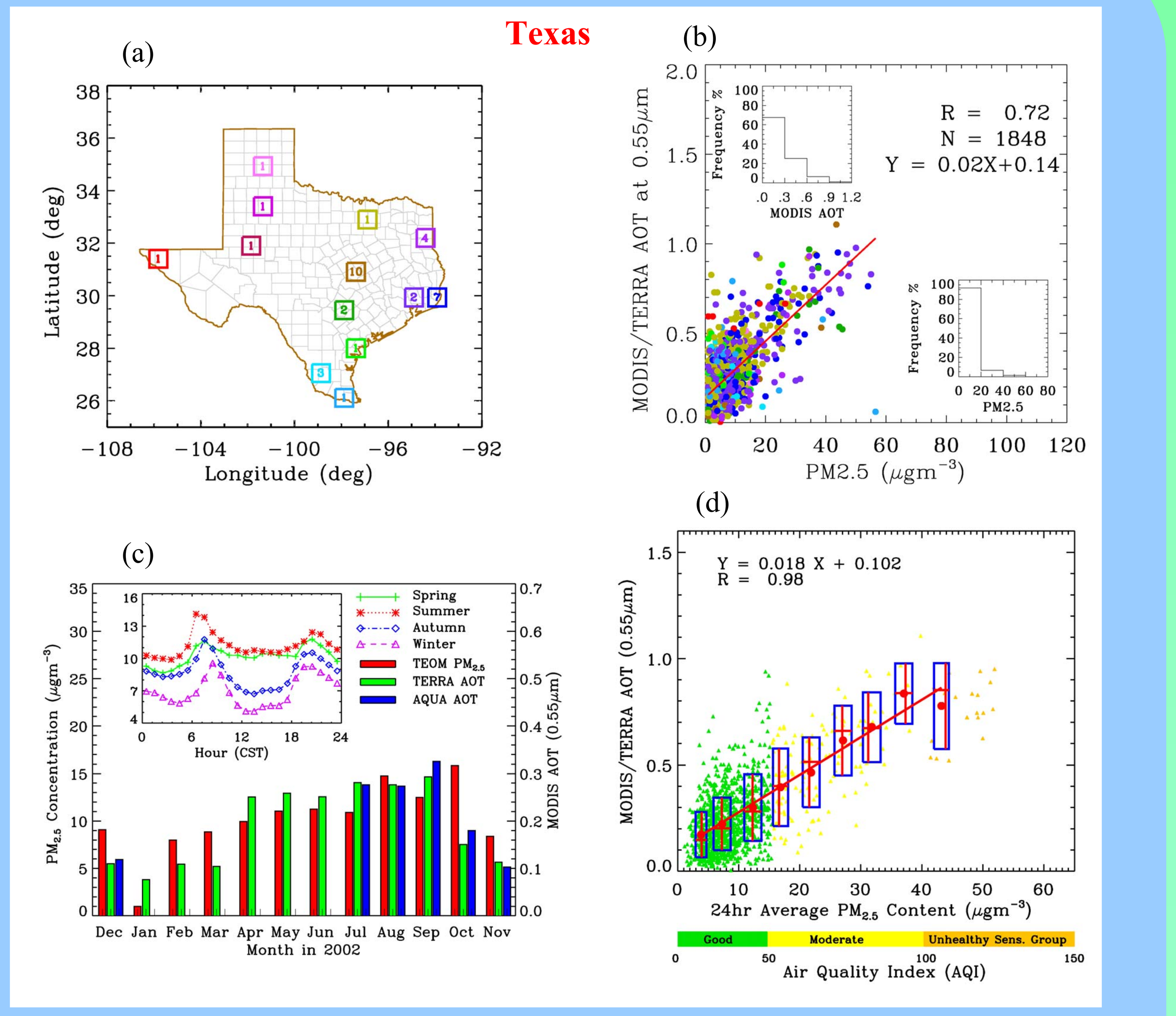


Figure 1: (a) Study area with locations (filled circle) of the seven $PM_{2.5}$ sites in Jefferson County (shaded area), AL. The triangles show major power plant locations. The upper left inset shows all counties in AL and the upper panel shows the monthly mean $PM_{2.5}$ concentration ($\mu g m^{-3}$) as a function of month in 2002. (b) Relationship between MODIS aerosol optical thickness and $PM_{2.5}$ mass, (c) Monthly variation of $PM_{2.5}$ and MODIS and Sunphotometer (SP) AOT, inset shows the diurnal variations (in Central Standard Time, CST) of $PM_{2.5}$ in different seasons. (d) Air Quality Index (AQI) derived from MODIS data. The box shows the ±1 standard deviation of $PM_{2.5}$ and AOT centered in the mean value (red filled circles) in each bins. The red line in the box shows the median value in each bin.



(2) $PM_{2.5}$ mass vs. MODIS AOT in Texas. The figure layout is same as the figure 1 (on the left) except in panel (a) the color boxes denote different observation regions. The number in each box indicates the number of observation sites in that region. Again, comparison shows similar and promising results as in figure 1.

Conclusion

Using one year of the MODIS AOT from the TERRA/AQUA satellites collocated with hourly particular matter mass measured at about 40 ground stations over Alabama and Texas, we show that

•The MODIS AOT has a good positive correlation with $PM_{2.5}$ mass (linear coefficient around 0.7). Through statistical analysis, the MODIS AOT product can be used to discern air quality categories such as good, moderate and unhealthy to a relatively high degree of confidence.

•However we would like to outline several factors that could affect the relationship between $PM_{2.5}$ and satellite-derived AOT. These factors include vertical distribution, optical and hygroscopic properties of aerosols. Aerosol extinction profile from ground based lidars or from satellite measurements such as CALIPSO are highly important for further enhancing the use of satellite data for air quality studies.

•This study implies that assimilation of MODIS AOT has the potential to improve the air quality forecasts.

References:

Wang, J., and S.A. Christopher, Intercomparison between satellite-derived aerosol optical thickness and $PM_{2.5}$ mass: Implications for air quality studies, *Geophys. Res. Lett.*, *30*, doi:10.1029/2003GL018174, 2003.

Acknowledgements

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