Characterizing the Measured Vertical Profile of Aerosols using Remote Sensing, and Combining with a Bottom-up Source and Plume Rise Models

***Wang Shuo*[1]** *Jason Cohen*[1]
1 School of Atmospheric Sciences, Sun Yat-Sen University
wangshuococo@gmail.com; jasonbc@alum.mit.edu

INTRODUCTION

In this paper, we analyze the spatial and temporal distribution of MISR satellite data on a global scale over the three years from 2008 to 2011. Next we apply different models to reproduce the vertical distribution of aerosol pollutants. Finally, we find the best fit model for different land types over each region. We addressed the problem of the traditional model's ability to predict the altitude of aerosol plumes. Our ultimate goal is to establish a correct emission inventory, accurately predict the spatial distribution of aerosols, and how they participate in the dynamic processing of the atmosphere and impact other regions.

We use a simple plume model based on first principles, and attempt to reproduce the measured MISR plume heights. We then quantify how and under what conditions our model works well, and how and under what conditions it performs poorly. Such analysis considers not only the difference in the mean, but also any bias that may cause the underlying energetics of the system to not be well constrained, and hence obstruct the ability to reproduce the plume's rise. Then we apply a linear regression model to consider the contributions of the pollutants NO_2 and CO (as proxied for aerosols) on the heights.

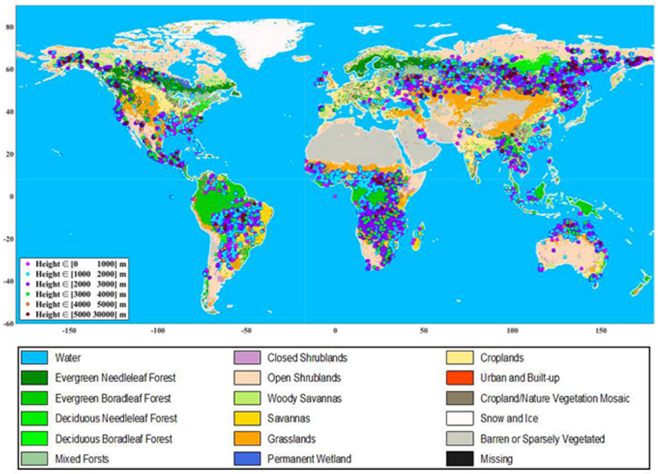


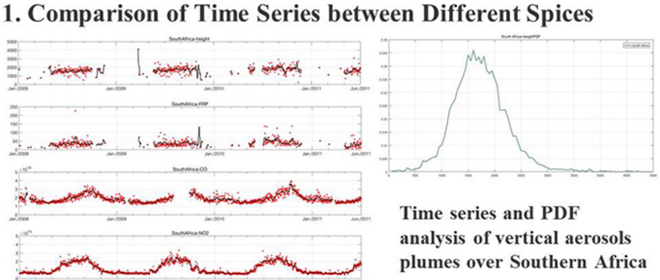
Fig 1 Global Distribution of MISR Measurement Height Data

METHODS and DATA

- Global Geography
- MISR height profile measurements; FRP; Wind
- MOPITT CO
- OMI NO2
- NCEP Omega, dT/dz, Surface temperature
- Statistical and Regression Models
- Plume Rise Model

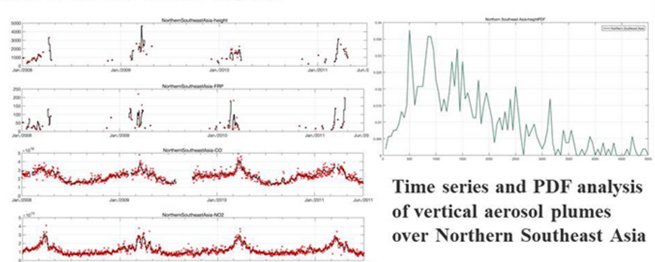
RESULTS

1. Comparison of Time Series between Different Spices



Time series and PDF analysis of vertical aerosols plumes over Southern Africa

The distribution of measured aerosol heights in Southern Africa: surface is clean, lower free troposphere & upper boundary layer polluted, the variation of the time series is very low.



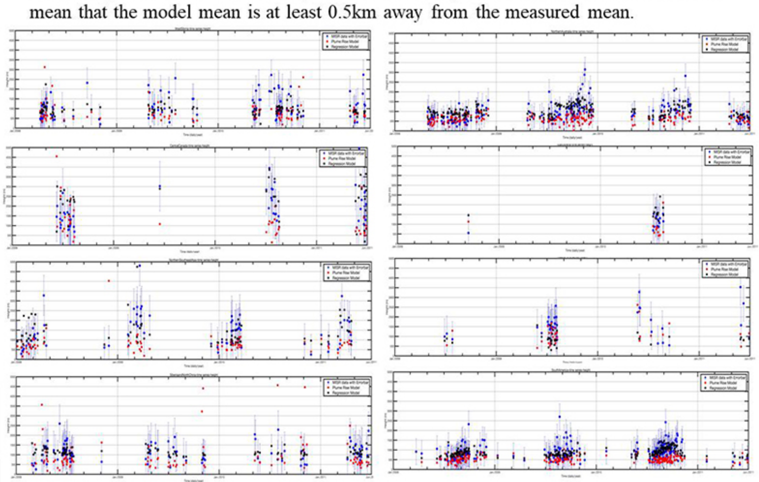
Time series and PDF analysis of vertical aerosol plumes over Northern Southeast Asia

The distribution of measured aerosol heights in Northern Southeast Asia: the height ranges from the surface to 5000m, the FRP values are higher, there is a lot of variance in the time series.

2. Summary of Regression Model and Plume Rise Model Results

Mean and SD	MISR data	Plume Rise Model	Regression Model
Siberia and North China	1.27*(0.90)*	Failed	1.07 *(0.30)*
East Siberia	1.27*(0.97)*	Failed	1.32 *(0.65)*
West Siberia	0.95 *(0.77)*	0.79 *(0.95)*	0.97 *(0.29)*
Northern Southeast Asia	0.95*(0.77)*	Failed	1.42 *(0.51)*
Northern Australia	1.57*(1.03)*	Failed	1.12 *(0.38)*
Alaska	1.57 *(0.91)*	1.39 *(3.03)*	1.26 *(0.45)*
Central Canada	1.97 *(1.26)*	1.73 *(2.19)*	2.13 *(1.72)*
South America	0.97*(0.66)*	Failed	0.95 *(0.22)*
Argentina	0.69 *(0.70)*	0.65 *(0.25)*	Failed
East Europe	1.41 *(1.05)*	1.27 *(2.67)*	Failed

Statistics are given in terms of the mean height (normal print) and standard deviation of height (*italics*) for all measurements from MISR and different modeling approaches. The time period considered is daily data from January 2008 to June 2011. Failed tests mean that the model mean is at least 0.5km away from the measured mean.



Comparing the RMS error of the time series generated using a plume rise model, a regression model, and the measured heights over the best-fit regions. All simulation results more than 3x the measurement have already been discarded. The extreme values are failed possibly because of errors in the RMS, or possibly because of a lack of atmospheric physical detail (i.e. special meteorology or dynamics)

RMS Errors (meters)	Plume Rise Model	Regression Model
Siberia and North China	Failed	419
East Siberia	Failed	351
West Siberia	667	466
Northern Southeast Asia	Failed	683
Northern Australia	Failed	520
Alaska	882	774
Central Canada	$1.36x10^3$	$1.20x10^3$
South America	Failed	374
Argentina	403	Failed
East Europe	852	Failed

We notices that in general, the plume rise model performs less well than the regression model. We also notice that the plume rise model has more variability than the regression model. Note however, that over two regions the regression model failed. This means that a measure of the aerosol loading itself is critical over most parts of the world if we are interested in reproducing the aerosol height profile.

CONCLUSIONS

By applying measurements of the mean and standard deviation of the daily data over the whole world, we have been able to derive the characteristics of aerosol distribution in different areas:

- In areas with rapid economic development, such as Southeast Asia and Eastern Europe, aerosol stratification is more obvious than other regions. In some forested areas, such as Alaska, Siberia, and Northern Southeast Asia there were more extreme aerosol events.
- The Plume rise model provides a fit in five regions, West Siberia, Alaska, Central Canada, Argentina (under 500m), and East Europe, the latter two in which the regression model failed.
- The Regression model provides a fit in eight regions (see the table), with 4 under 500m error.
- In general, the regression model fares better than the plume rise model, with the exception of Argentina. This indicates that in most places, the consideration of the aerosol amount is also important when trying to consider the aerosol vertical distribution.