Using Remote Sensing Satellite Products to Evaluate Aerosol Distribution for Forest Fire Events in the Pacific Northwest

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Introduction

Forest fires inject significant amounts of aerosols into the atmospheric boundary layer. This study examines distributions of aerosols emitted by forest fires in the Pacific Northwest as simulated by the Air Information Report for Public Access and Community Tracking (AIRPACT) regional air quality model. Simulated distributions are compared to satellite retrievals to identify biases in the model. Horizontal distribution of emitted aerosols is investigated using 550 nm Aerosol Optical Depth (Equation 1). Simulated distributions are compared to Aqua Moderate Resolution Imaging Spectroradiometer (MODIS) Level 2 Aerosol Optical Depth (AOD) retrievals. Vertical aerosol distribution is examined using masked vertical curtains of simulated aerosol species and coincident Lidar Level 2 Vertical Feature Mask (VFM) data retrieved by the Cloud-Aerosol Lidar with Orthogonal Polarization (CALIOP) instrument aboard the Cloud Aerosol Lidar and Infrared Pathfinder Satellite Observation (Calipso) satellite. The AIRPACT modeling system utilizes the Weather Research Forecasting (WRF), Community Multiscale Air Quality (CMAQ), and Sparse Matrix Operating Kernel Emissions (SMOKE) platforms in simulating air quality in the Pacific Northwest (Chen et al.). AIRPACT fire emissions are estimated using BlueSky data which utilizes United States Forest Service ICS209 reports in identifying both fire location and size.

$$\tau = \ln\left(\frac{I}{I_o}\right)$$

Equation 1. Theoretical AOD formula in which τ represents AOD, I is the observed radiation intensity after transmission, and I_o is source radiation intensity.

Identifying Forest Fire Events

Calipso Overpass Locations and AIRPACT Domain

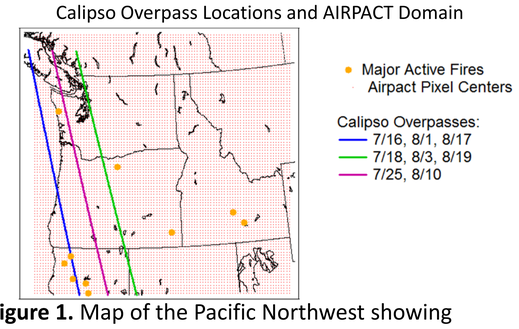

Figure 1. Map of the Pacific Northwest showing AIRPACT pixel, Calipso overpass, and ten largest fire locations.

Significant fire events during the summer of 2008 were identified for analysis using BlueSky Smartfire data (Figure 1). BlueSky Smartfire reconciles satellite observations with fire ICS209 reports to locate and approximate the size of forest fires across the United Sates. Analysis of vertical distribution data focuses on Northern California as this region had the highest concentration of large fires.

Horizontal Aerosol Distribution

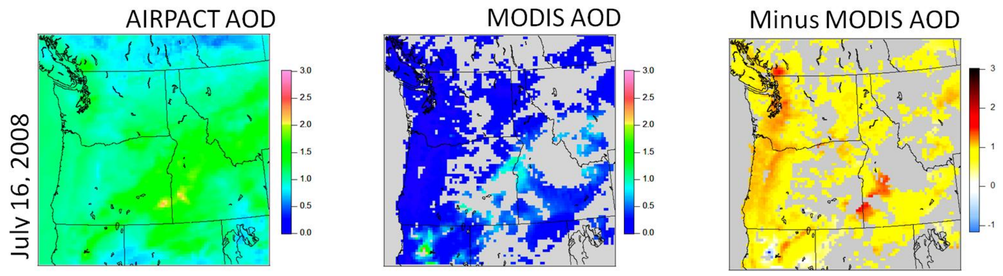

Figure 2. Simulated, retrieved, and simulated minus retrieved AOD for the first day of the study period.

MODIS AOD at 550 nm is interpolated from retrievals at 470 nm and 660 nm (Remer et al). AIRPACT AOD is calculated from simulated aerosol species concentrations using algorithms developed by Binkowski and Roselle. AIRPACT AOD and MODIS AOD are interpolated to a 95 x 95 grid of 12km x 12km squares. Bias is characterized by subtracting MODIS AOD from AIRPACT AOD. Correlation is calculated by plotting each MODIS pixel versus its AIRPACT counterpart. Pixels with no MODIS retrieval are omitted from the difference map and correlation calculations.

Vertical Aerosol Distribution

Calipso VFM data use LIDAR extinction coefficients to characterize features along a vertical curtain by both type and subtype (Omar et al). Coincident AIRPACT-simulated aerosol species distributions were obtained for all modeled aerosol species: nitrates, sulfates, ammonium, black carbon, biogenic and anthropogenic particulates, and coarse mode aerosols. A VFM curtain was derived from these AIRPACT-simulated aerosol distributions (Figure 3). Along-track MODIS AOD is obtained for further aerosol location comparison (Figure 4).

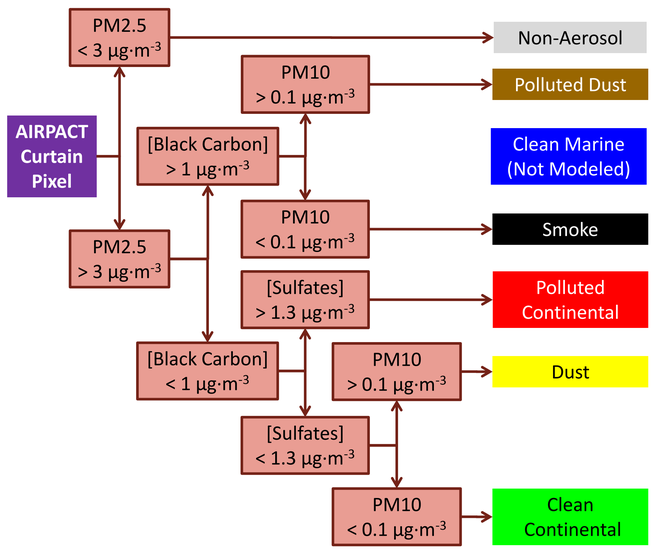

Figure 3. Decision tree for applying VFM based on AIRPACT-simulated aerosols

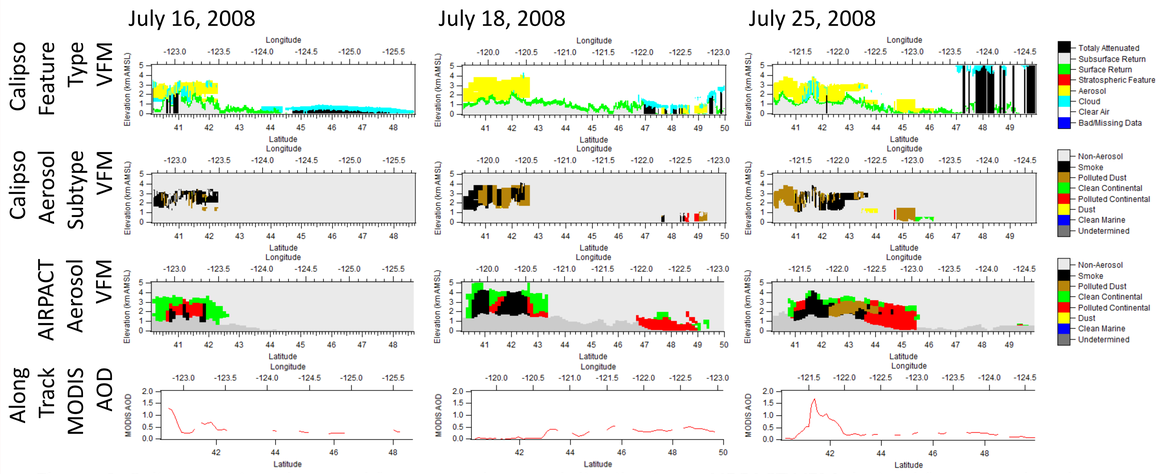

Figure 4. Calipso retrieved vertical feature and aerosol distributions, AIRPACT VFM derived from simulated aerosol distributions, and along track AOD for Northern California overpasses in late July 2008.

AOD Correlation

Correlation between AIRPACT AOD and MODIS AOD was low with an overall correlation of 0.275. Average bias between AIRPACT AOD and MODIS AOD showed AIRPACT AOD to be consistently higher than corresponding MODIS retrievals.

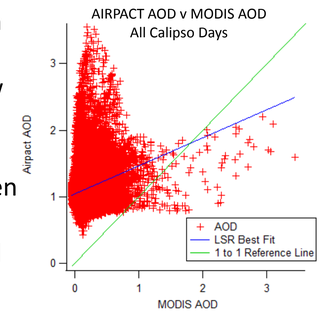

Figure 5. Correlation plot of MODIS AOD versus AIRPACT AOD

Table 1. Correlation and bias between AIRPACT AOD and MODIS AOD

Date	AOD Correlation (R)	Mean Bias (AIRPACT-MODIS)	Standard Deviation of Bias
7/16/2008	0.485	0.875	0.211
7/18/2008	0.521	0.932	0.215
7/25/2008	0.207	1.119	0.447
8/01/2008	0.366	0.881	0.240
8/03/2008	0.320	0.945	0.196
8/10/2008	0.426	0.967	0.240
8/17/2008	0.247	0.850	0.284
8/19/2008	-0.161	0.636	0.233
All Dates	**0.275**	**0.933**	**0.303**

Discussion

AIRPACT and MODIS AOD had low correlation, 0.275. On average, AIRPACT AOD is 0.933 greater than MODIS AOD with a standard deviation of 0.303. These results support previously observed discrepancies between MODIS AOD retrievals and modeled and observed aerosol concentrations in the Pacific Northwest (Engel-Cox et al.). Possible sources of error in MODIS retrievals include varied terrain, unique aerosol composition, and snow cover at high elevations.

AIRPACT and Calipso agree moderately well on Smoke distribution. However, AIRPACT shows greater spatial distribution of Polluted and Clean Continental Aerosols and lesser amounts of Dust than seen in Calipso retrievals.

Conclusions

AIRPACT-simulated and satellite-retrieved aerosol distributions are positively correlated though large discrepancies exist. Future integration of BlueSky Smartfire system into the AIRPACT system may increase correlation in both horizontal and vertical aerosol dispersion from forest fire events.

References

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Acknowledgements

This work was supported by the National Science Foundation's REU program under grant number 0754990. This research was also made possible by a NASA ROSES grant (NNA06CN04A) for the North-West-AIRQUEST Decision Support System. Calipso data were obtained from the NASA Langley Research Center Atmospheric Science Data Center. We would also like to thank Serena Chung for her assistance with this work.