An Evaluation of Modeled Plume Rise With Satellite Data

Sonoma Technology, Inc.
Air Quality Research and Innovative Solutions

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AIRFIRE

INTRODUCTION AND BACKGROUND

During the past decade, both the number and the intensity of wildfires in the United States have increased (Westerling et al., 2006). As a result, attention has been focused on modeling and forecasting smoke impacts from wildfires and efforts are being made to improve existing smoke modeling and forecasting systems.

Plume rise is currently a large source of uncertainty in air quality models that predict smoke impacts from wildfires. Plume rise errors for large fires can result in an order of magnitude error in predicted downwind $PM_{2.5}$ concentrations (Larkin et al., 2009).

Plume rise algorithms used in dispersion models were developed in the 1960s to characterize industrial emissions from tall smoke stacks. They were not designed to characterize highly complex and broadly distributed wildfire smoke plumes.

This work uses satellite observations of smoke plume heights from wildfires to better evaluate real-world smoke plume characteristics and sources of uncertainty associated with plume height algorithms commonly used in air quality models.

PLUME HEIGHT OBSERVATIONS

Cloud-Aerosol Lidar with Orthogonal Polarization (CALIOP)

- Down-pointing lidar onboard the Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations (CALIPSO)
- Data acquired from the Atmospheric Science Data Center (ASDC)
- Plume heights determined from aerosol vertical profiles
- High vertical resolution (30-60m), but narrow swath misses most plumes

Multi-angle Imaging SpectroRadiometer (MISR)

- Passive remote sensor on board the MODIS TERRA satellite
- Smoke plume summary data acquired from the MISR Plume Height Climatology Project (http://www-misr2.jpl.nasa.gov/EPA-Plumes)
- Plume heights determined by stereoscopic analysis of plumes based on multiple-angle views

PLUME HEIGHT MODELING

BlueSky Smoke Modeling Framework

- Enabled with the BlueSky Framework
- Fire emissions modeling pathway: Satellite Mapping Automated Reanalysis Tool for Fire Incident Reconciliation (SMARTFIRE) fire information, FCCS 1-km fuel loading map, CONSUME3 consumption, and FEPS emissions
- Plume rise calculated with an adaptation of the Briggs plume rise algorithm

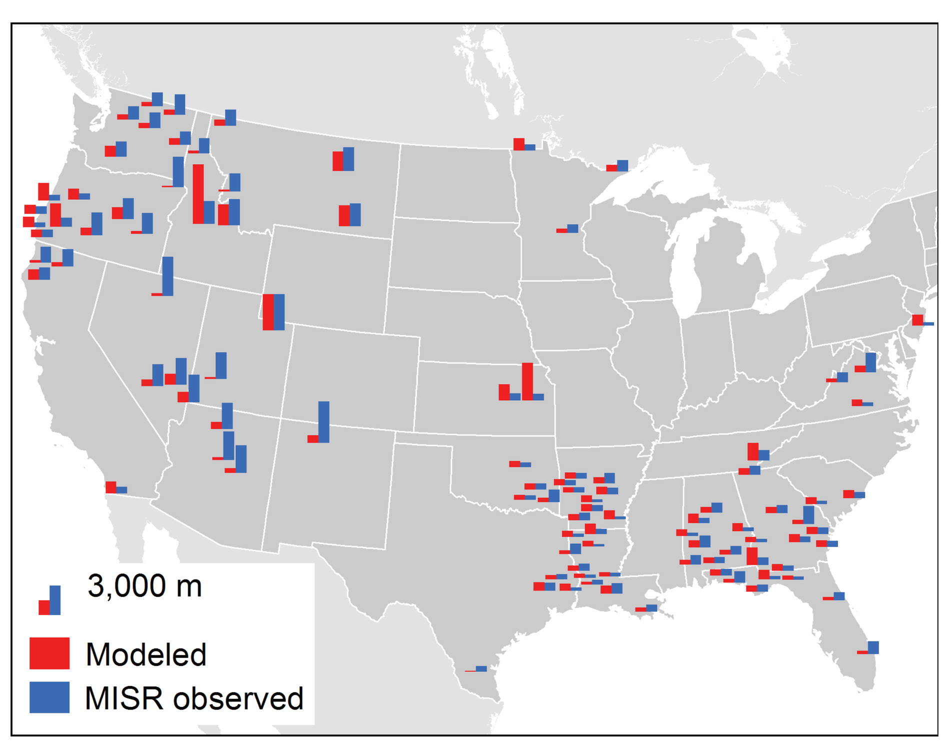
Chemical Transport Modeling

- CMAQ version 4.5.1, with fire emissions input from the BlueSky Framework, and meteorological input from MM5 version 3.7
- 36-km Regional Planning Organization (RPO) grid
- Three-dimensional output files saved for $PM_{2.5}$ vertical profile extraction

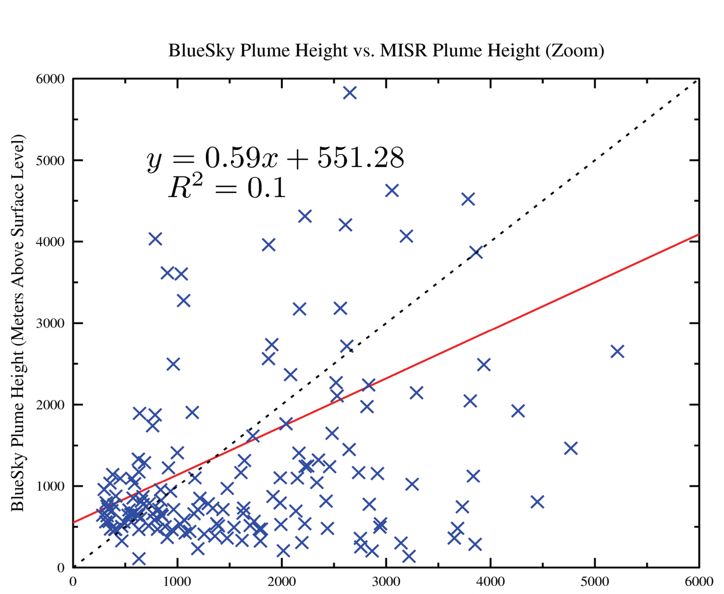
MISR VERSUS MODEL COMPARISON

MISR plumes were matched to fires from the SMARTFIRE database by selecting the nearest same-day fire location in the SMARTFIRE database that was greater than 40 hectares in size.

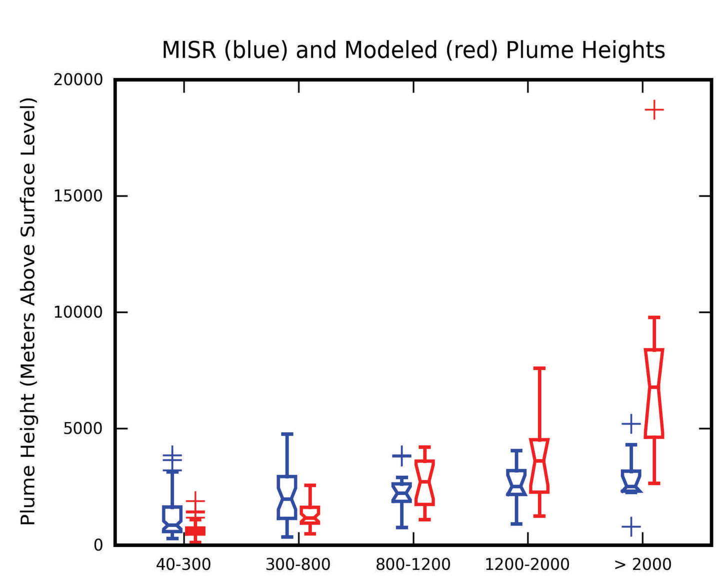
Median wind corrected plume heights from MISR from 2006 to 2008 were compared to modeled median plume heights *before transport was modeled*.



- Lower observed and modeled plume heights in the southeastern U.S. compared to the western U.S.
- Statistically significant differences between observed and modeled plume height are large in the mountain West and Pacific Northwest regions.
- Modeled and observed plume height differences were not statistically significant in the Southeast.

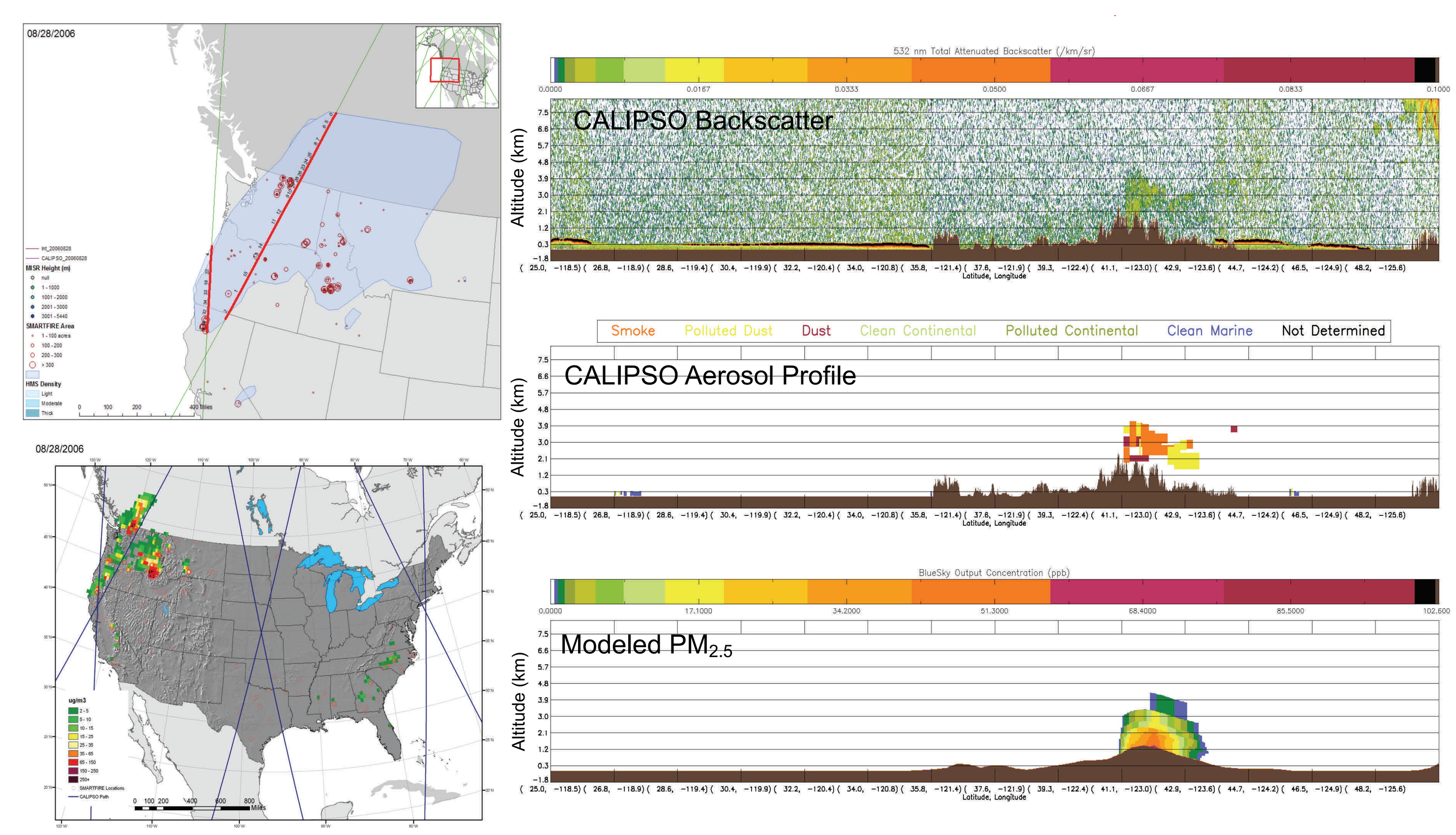


The median observed plume height was higher (statistically significant) than the median predicted plume height. Predicted plume heights were not well correlated to MISR plume heights.



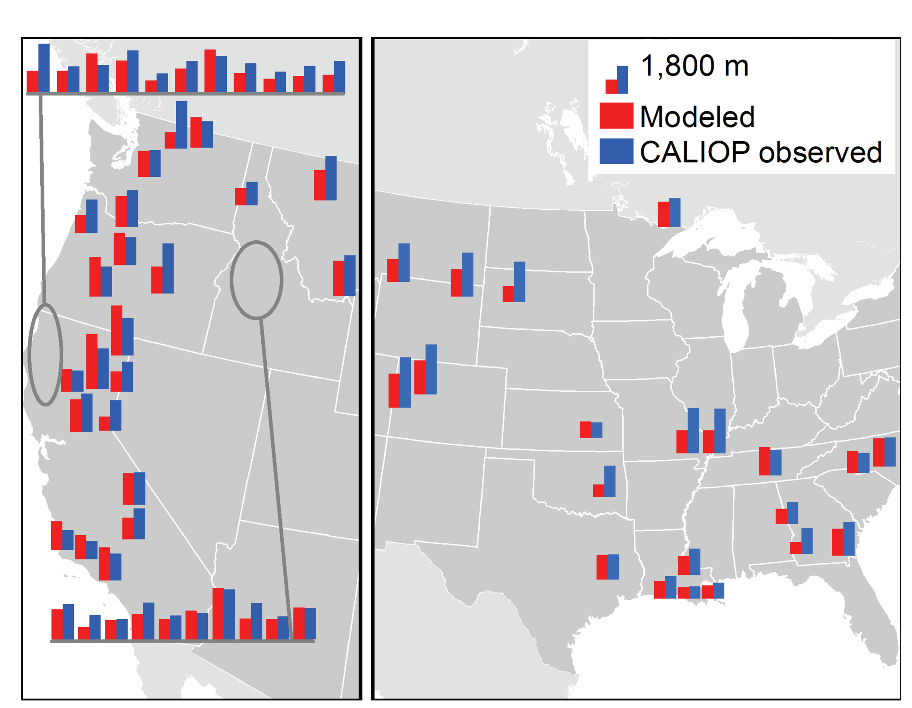
The model underpredicts plume heights for small fires, and overpredicts plume heights for large fires.

CALIOP VERSUS MODEL COMPARISON

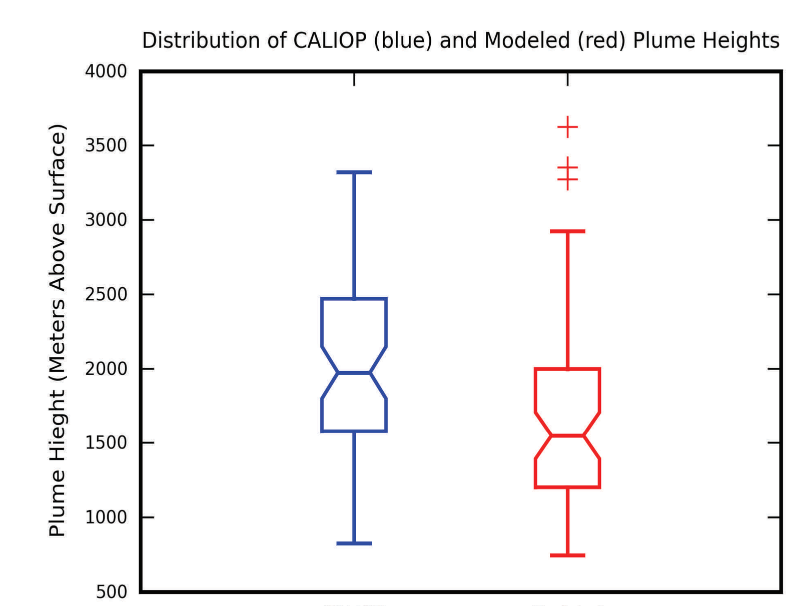


CALIPSO orbit path data from 2006 to 2008 were overlaid with daily Hazard Mapping System (HMS) smoke plume data and SMARTFIRE fire location data to determine times and locations when CALIPSO was likely to detect a smoke plume.

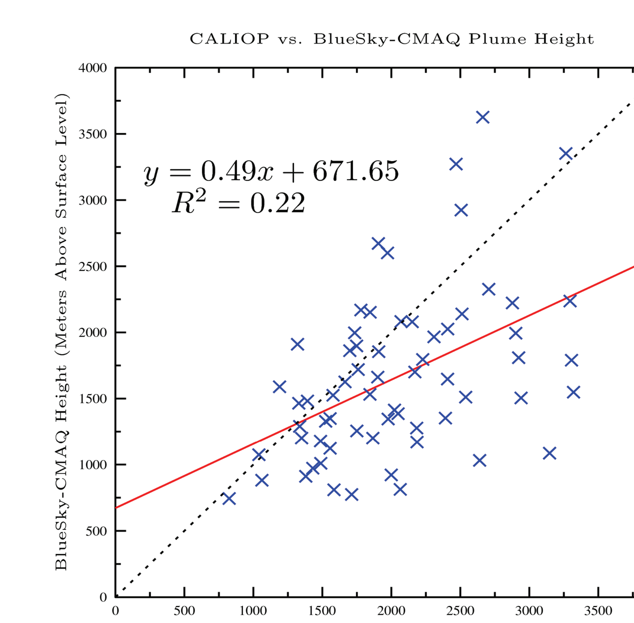
Plume heights derived from CALIPSO vertical aerosol profiles were compared to modeled plume heights *after transport was modeled.*



- Modeled plume heights tend to be lower than CALIOP observed plume heights, except for a few plumes in the West.
- Comparison is very good in Idaho.
- Sampling is spatially inconsistent because of the narrow CALIOP data swath.



The median modeled plume heights were lower than the median CALIOP observed plume height. A Kolmogorov-Smirnof analysis confirmed statistical significance.



Scatterplot of observed versus predicted plume heights. There was a weak positive correlation between predicted and CALIOP observed plume heights.

CONCLUSIONS

- Modeled plume heights correlated poorly with MISR and somewhat better with CALIPSO.
- Modeled plume heights tended to be biased low compared to both MISR and CALIPSO observations.
- Modeled plume heights exhibited greater variability than the MISR plume heights.
- Plume rise algorithms performed relatively well in the southeastern U.S., where fires tended to be small, well behaved controlled burns. Plume rise algorithms did not perform as well in the western U.S. where fires were larger and more intense with lower fuel moisture and more diverse vegetation.
- Plume height observations could be mined to develop improved parameterizations for plume rise calculations for fires.

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