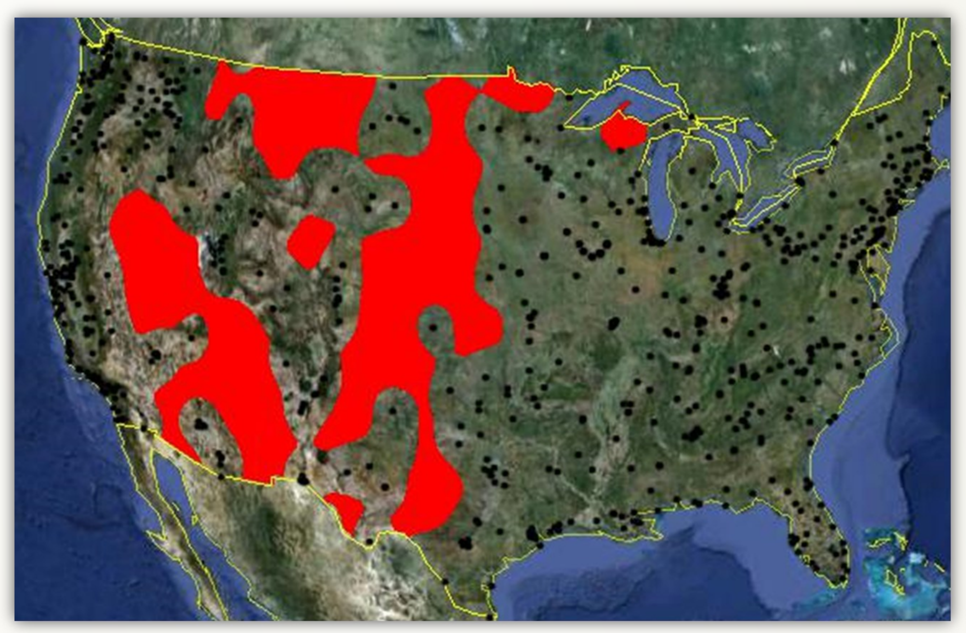
AirNow Satellite Data Processor: Improving EPA's AirNow Air Quality Index Maps Using NASA/NOAA Satellite Data and Air Quality Model Predictions

Adam Pasch[1], Patrick Zahn[1], Jennifer DeWinter[1], Michael Haderman[1], James Szykman[2], John White[3], Phillip Dickerson[3], Tim Dye[1], Aaron van Donkelaar[4], and Randall Martin[4]
[1]Sonoma Technology, Inc., Petaluma, CA; [2]NASA Langley Research Center, Hampton, VA; [3]U.S. EPA, Research Triangle Park, NC; [4]Dalhousie University, Halifax, Nova Scotia, Canada

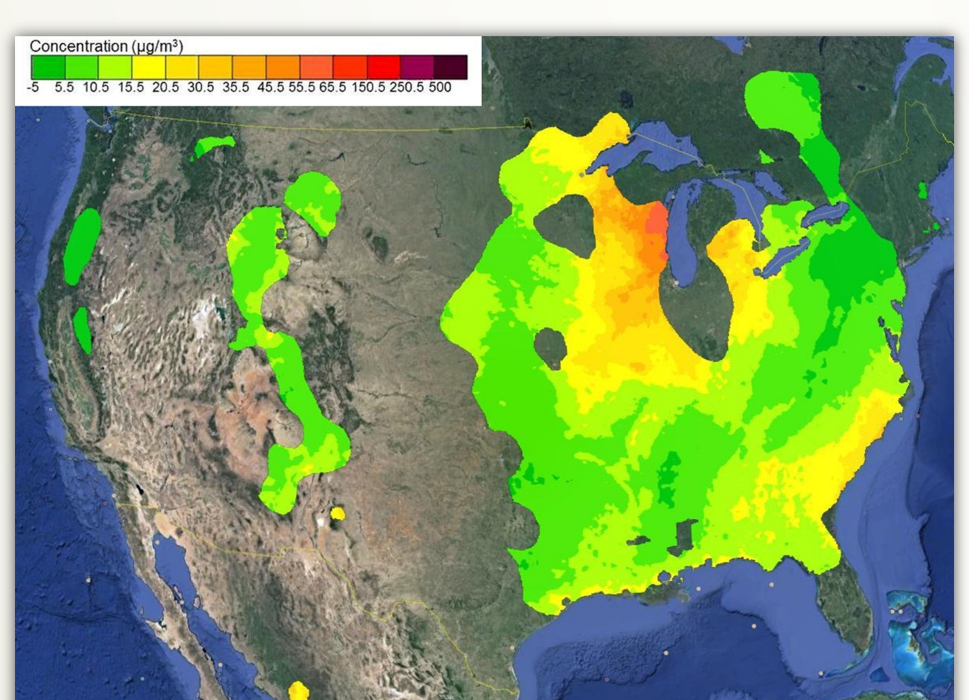
Motivation & Background

Gaps in the current AirNow $PM_{2.5}$ monitoring network leave many citizens without accurate air quality information. AirNow is the national framework for acquiring and distributing air quality information. The EPA map below illustrates the network of active $PM_{2.5}$ monitors reporting data to AirNow (black dots) and regions lacking sufficient monitoring, which are currently masked (red) in AirNow data products, including contoured Air Quality Index maps.



- Large areas in the Intermountain West and Great Plains lack surface monitors.
- Satellite aerosol optical depth retrievals can provide decision makers with air quality information containing larger spatial coverage than *in situ* measurements (Zhang et al., 2009).
- Ground observations combined with satellite estimates, as well as other data sets (e.g., air quality model predictions), can provide a more complete and accurate picture of national air quality conditions.
- The average uncertainty in satellite-estimated surface $PM_{2.5}$ concentrations is roughly ±(1 μg/m^3 + 42%) for the United States (van Donkelaar et al., 2012).

The map below illustrates satellite-estimated surface $PM_{2.5}$ concentrations for a sample day—July 1, 2011 (data only shown where available).



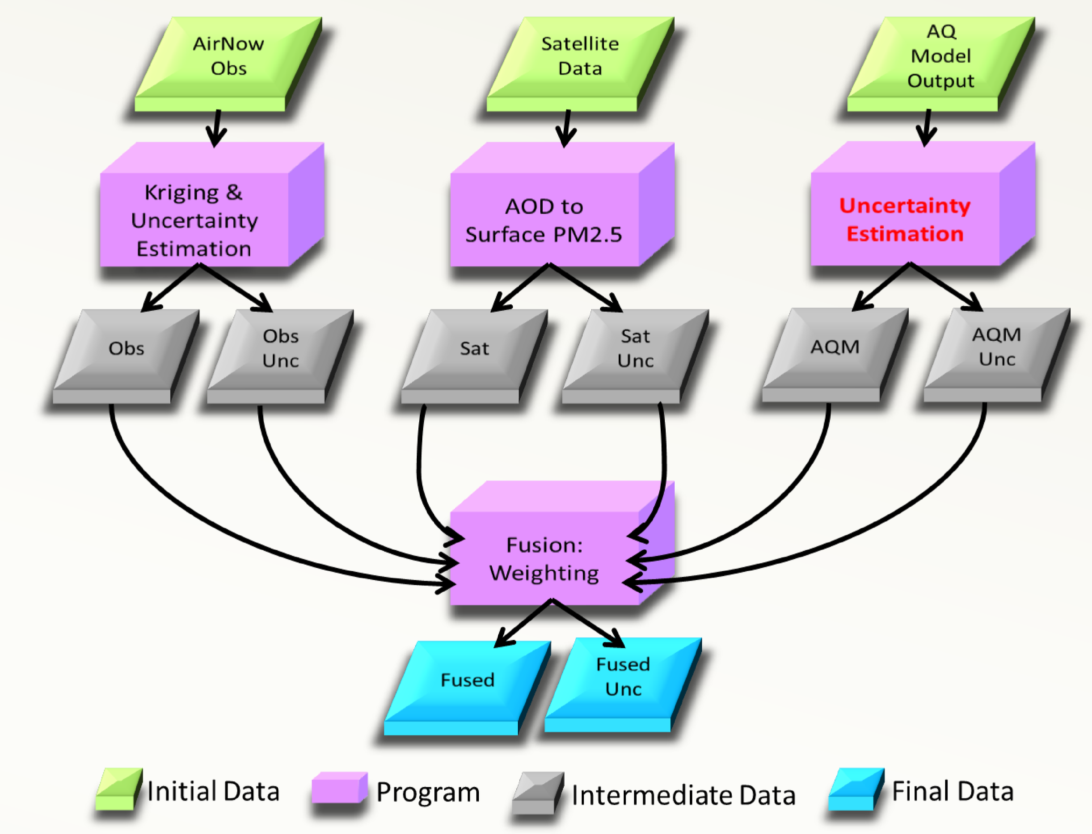
Method: Application to Air Quality Modeling

The AirNow Satellite Data Processor (ASDP) uses a weighted-average approach to combine multiple data sets, producing a new "fused" product containing the most accurate information. This approach uses uncertainty information about each data set to effectively weight each one. The uncertainty is based on the degree of confidence in the predicted values when interpolating to a grid. The general equation for fusing gridded $PM_{2.5}$ concentration data sets from ground-based monitor observations, satellite estimates, and air quality model (AQM) predictions is:

$$PM_{2.5,fused} = \frac{(PM_{2.5} \times E^{-1})_{obs} + (PM_{2.5} \times E^{-1})_{sat} + (PM_{2.5} \times E^{-1})_{AQM}}{E^{-1}_{obs} + E^{-1}_{sat} + E^{-1}_{AQM}}$$

where **E** represents data errors (or uncertainties), and **obs**, **sat**, and **AQM** indicate values corresponding to kriged monitor observations, satellite estimates, and AQM predictions of $PM_{2.5}$ concentrations, respectively.

The ASDP is flexible and can fuse additional data sets, such as future satellite data products, data from other surface observation networks, and AQM data. The flowchart at right illustrates how AQM predictions can be included in the ASDP. It outlines the pre-processing steps required to obtain intermediate data inputs from the initial data sets, and the weighted-average approach for fusion of the input data to produce the final product. The process for estimating uncertainties in observed and satellite-estimated $PM_{2.5}$ concentrations in a consistent manner is described in the section below. Incorporating AQM predictions in the ASDP also requires a consistent approach for estimating the corresponding uncertainty. This is indicated by the red text in the flow chart and will be considered in future work.



ASDP Fusion of Satellite and Observed Data: Estimating Data Uncertainties

Uncertainties in each data set in the fusion program affect the performance of ASDP, which is improved by estimating those uncertainties in a consistent manner. We developed a relationship between the values of variance of prediction (VOP) from the kriged surface for *in situ* ground observations to the one-sigma error envelope for the satellite-derived surface. We compared observed $PM_{2.5}$ concentrations at monitor locations with kriged values under a variety of VOP values and $PM_{2.5}$ concentrations from June 2011 to May 2012.

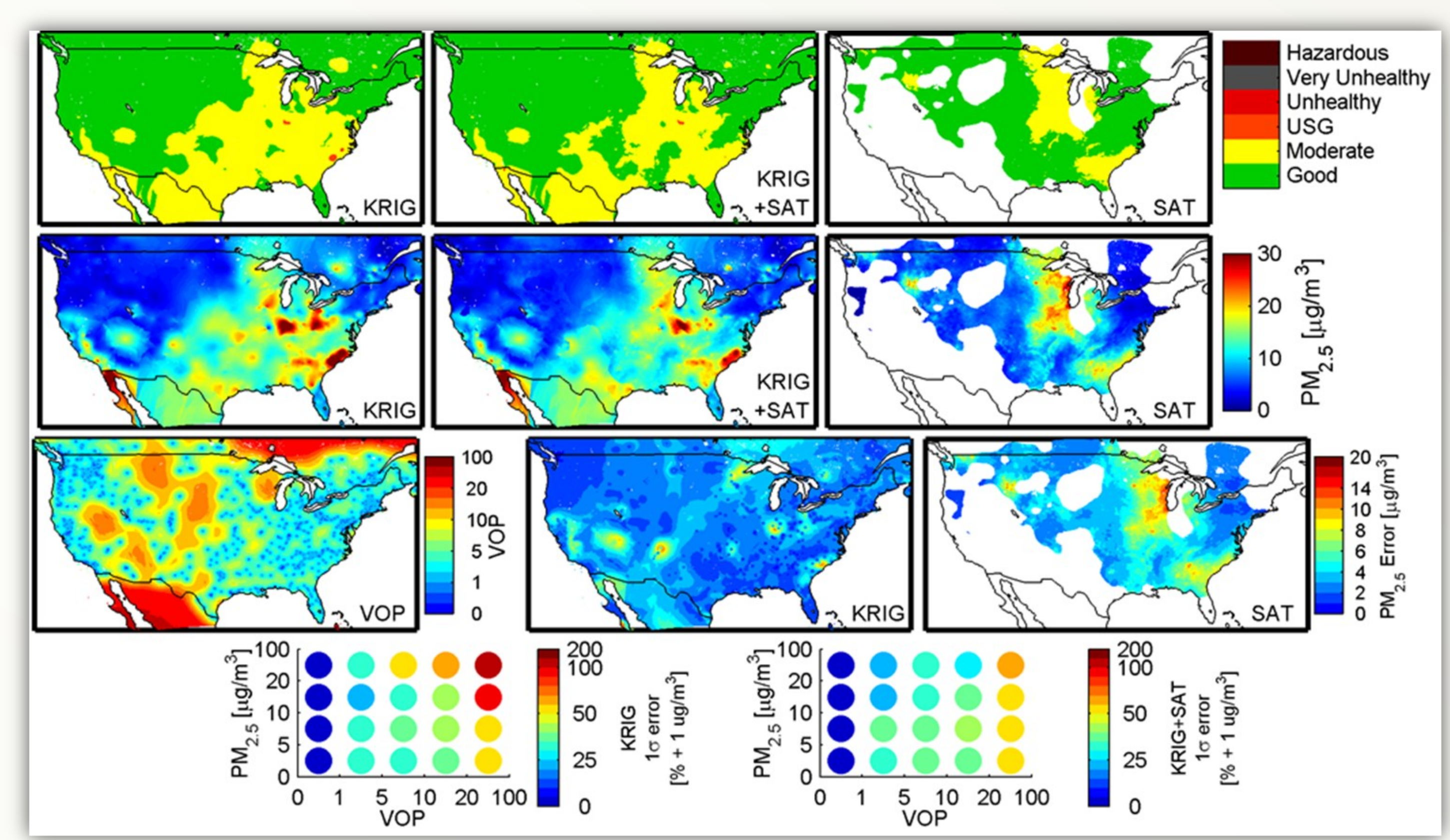
Approach

- We created kriged surfaces using "dead zones" (0, 5, 10, 30, 50, 100, 250, 500, and 1000 km), within which all observational values were removed, and we evaluated the local effect of VOP on kriged surface accuracy.
- We determined optimal error estimates at each monitor location by comparing the accuracy of the final combined kriged and satellite-estimated $PM_{2.5}$ concentrations with observations within a 90-day running window.
- We grouped similar values within bins, allowing kriged errors to vary by VOP values and $PM_{2.5}$ concentrations.
- We extended local error estimates of each bin nationally using an inverse distance weighted average.

Findings

- Uncertainty in the kriged surface is generally lower than in satellite-derived values.
- The combined surface demonstrates improved agreement with observations at elevated $PM_{2.5}$ concentrations and increased VOP values.
- Highest levels of VOP values (>20) showed the greatest improvement, but were rarely found under operational conditions.
- Error reductions of 10-30% were found for this sample day for the operationally realistic VOP of 1-20, under high $PM_{2.5}$ concentrations of >20 μg/m^3.

Sample Results for July 1, 2011



Kriged (KRIG), combined (KRIG+SAT), and satellite-derived (SAT) air quality index (first row); $PM_{2.5}$ concentrations (second row); variance of prediction (third row); and observed error as a function of $PM_{2.5}$ concentrations and VOP for the kriged and combined surface for July 1, 2011 (fourth row).

Next Steps

- Complete a statistical analysis of ASDP predictions of $PM_{2.5}$ concentrations for 2010-2013, focusing on the performance of the ASDP when each observation site is removed from the ensemble of all sites and compared to the kriged, satellite-estimated, and fused $PM_{2.5}$ concentrations.
- Conduct case studies, evaluating the performance for multiple regions and seasons.

References & Acknowledgments

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