Supporting Timely, High-Resolution Air Quality Data Availability in Africa by Fusing Satellite Observations of Aerosol Optical Depths, $PM_{2.5}$ Model Data, and $PM_{2.5}$ Surface-Based Measurements

Nathan Pavlovic[1], Sean Khan[2], Brian Sullivan[3]
[1]Sonoma Technology, Petaluma, CA; [2]United Nations Environment, Nairobi, Kenya; [3]Google, Inc., Mountain View, CA

The International Data Fusion System

- We developed a framework for fusing satellite observations, air quality model data, and ground-level observations of $PM_{2.5}$ to help fill the air quality data gap in Africa.
- The data fusion framework calculates daily ground-level $PM_{2.5}$ at 1 km spatial resolution.
- Results suggest that data fusion shows promise for near-real-time monitoring of air quality in Africa.
- Operational production of satellite-based $PM_{2.5}$ shows promise for applications now, while facilitating additional evaluation and enhancement in the future.

Motivation

- Almost 4.5 million premature deaths per year can be attributed to fine particulate matter ($PM_{2.5}$) pollution.
- In many parts of the world, there are a limited number of ground-based air quality monitoring instruments.
- Growing low-cost sensor networks compliment reference-grade instrument observations to fill the data gap.
- By combining ground observations (including low-cost sensors) with information from satellites, a promising solution to help fill the information gap on air quality may be possible.

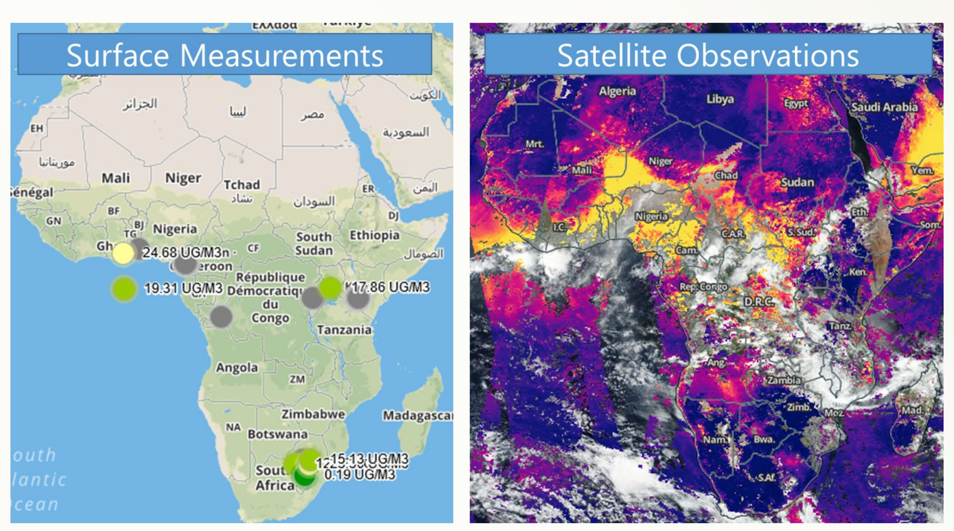

Figure 1. Surface measurements available in Africa and satellite data showing aerosol optical depth (AOD) on sample day. Satellites provide data coverage that can help to fill gaps in the monitoring network.

Input Data

- Surface estimates of $PM_{2.5}$ are derived from satellite aerosol optical depth (AOD) retrievals and modeling results (e.g., van Donkelaar et al., 2012).
- Satellite $PM_{2.5}$ estimates are combined with surface observations where available.

Table 1. Data sets used in the fusion.

Data Set	Spatial Resolution	Spatial Coverage	Temporal Resolution	Time Period	Uses
Copernicus Atmosphere Monitoring Service (CAMS) Near-Real-Time $PM_{2.5}$	40 km, interpolated to 12.5 km	Global	3 hours	2014 - Present	Adjust MAIAC AOD to surface $PM_{2.5}$
Multi-Angle Implementation of Atmospheric Correction (MAIAC) AOD	1 km	Global	Daily	2000 – Present	Develop surface $PM_{2.5}$
Monthly $PM_{2.5}$ (data set V4.GL.03)	1 km, smoothed	Global	Monthly	2012-2017	Adjustment for MAIAC AOD
Ground Measurements of $PM_{2.5}$	Point-based	Limited Urban Areas	Hourly	Variable	Validation and data fusion

Data Fusion System

- We implemented data processing on Google Earth Engine (GEE) for retrospective analysis from 2014 to 2019.
- Data are ingested to GEE, where processing is completed at 1 km spatial resolution daily.
- Satellite-derived ground-level $PM_{2.5}$ are combined with ground-level air quality observations using uncertainty estimate (Lee et al., 2012).

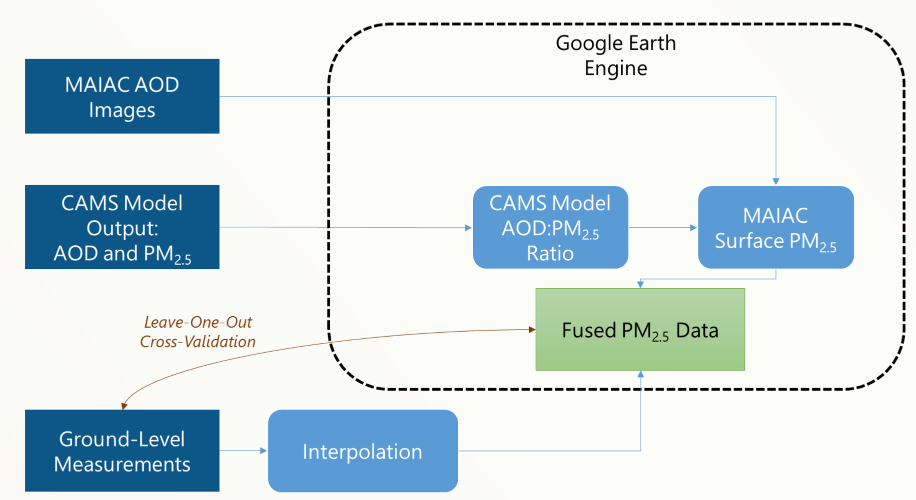

Figure 2. Data processing flow used to calculate fused $PM_{2.5}$ data in the data fusion system.

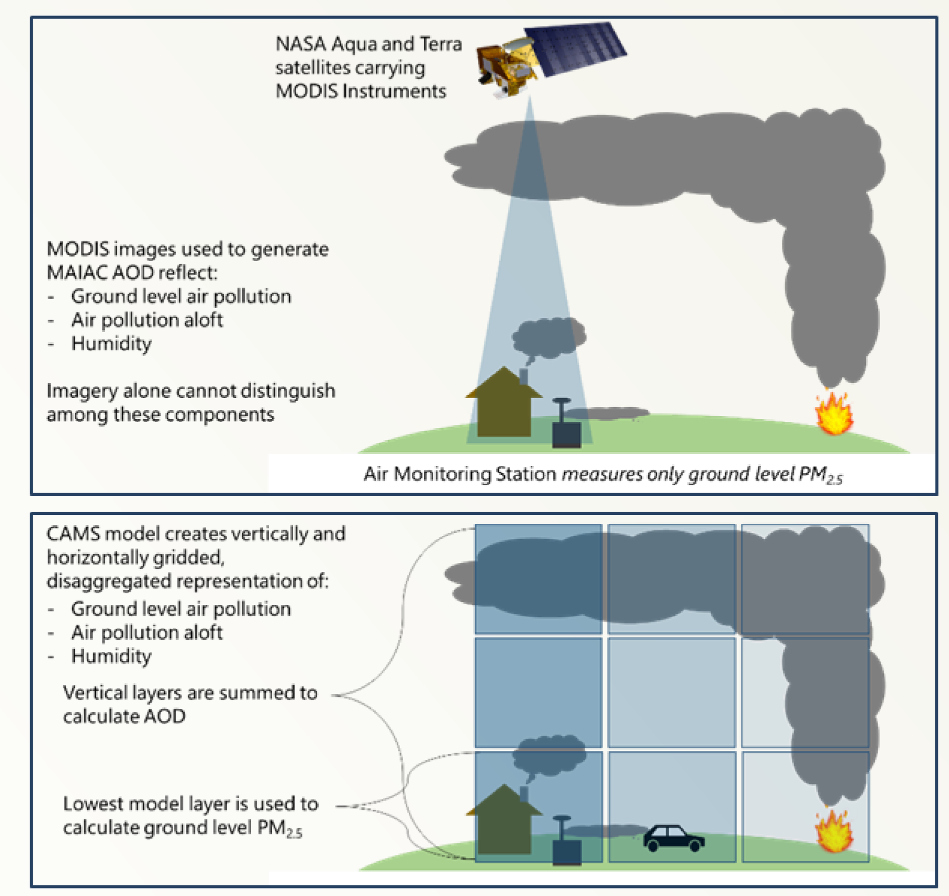

Figure 3. The combination of satellite retrievals of total-column aerosols with the vertical distribution information derived from modeling facilitates the calculation of ground-level $PM_{2.5}$.

Fusion Validation

- Validation of satellite (MAIAC) surface $PM_{2.5}$ was performed using reference-grade monitor data.
- For select locations (where two or more reference-grade monitors are available), validation of the ground-level $PM_{2.5}$ from fusion was performed.
- Independent surface observations were compared with fusion result for locations in Ethiopia (Addis Ababa Central) and Senegal (Bd. Rep.).

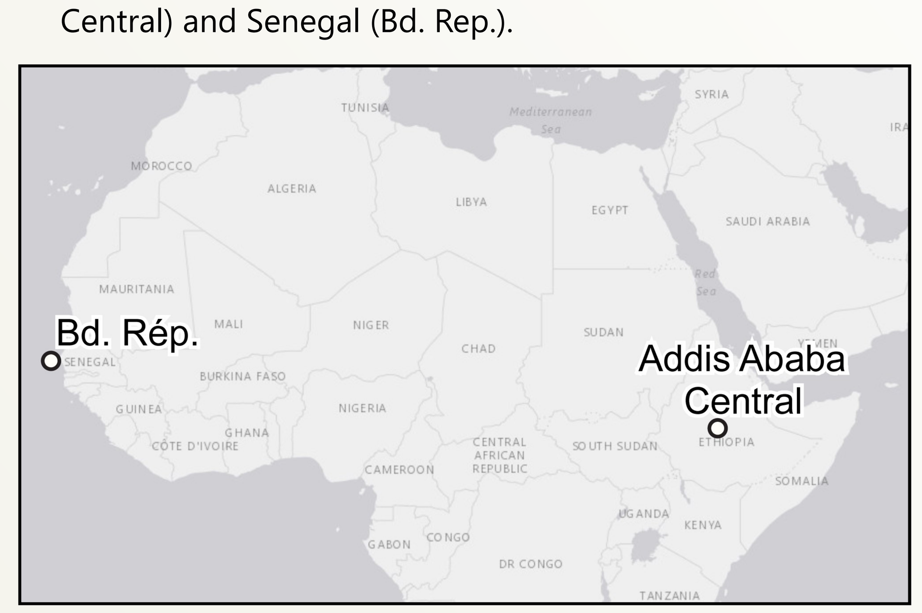

Figure 4. Validation site locations.

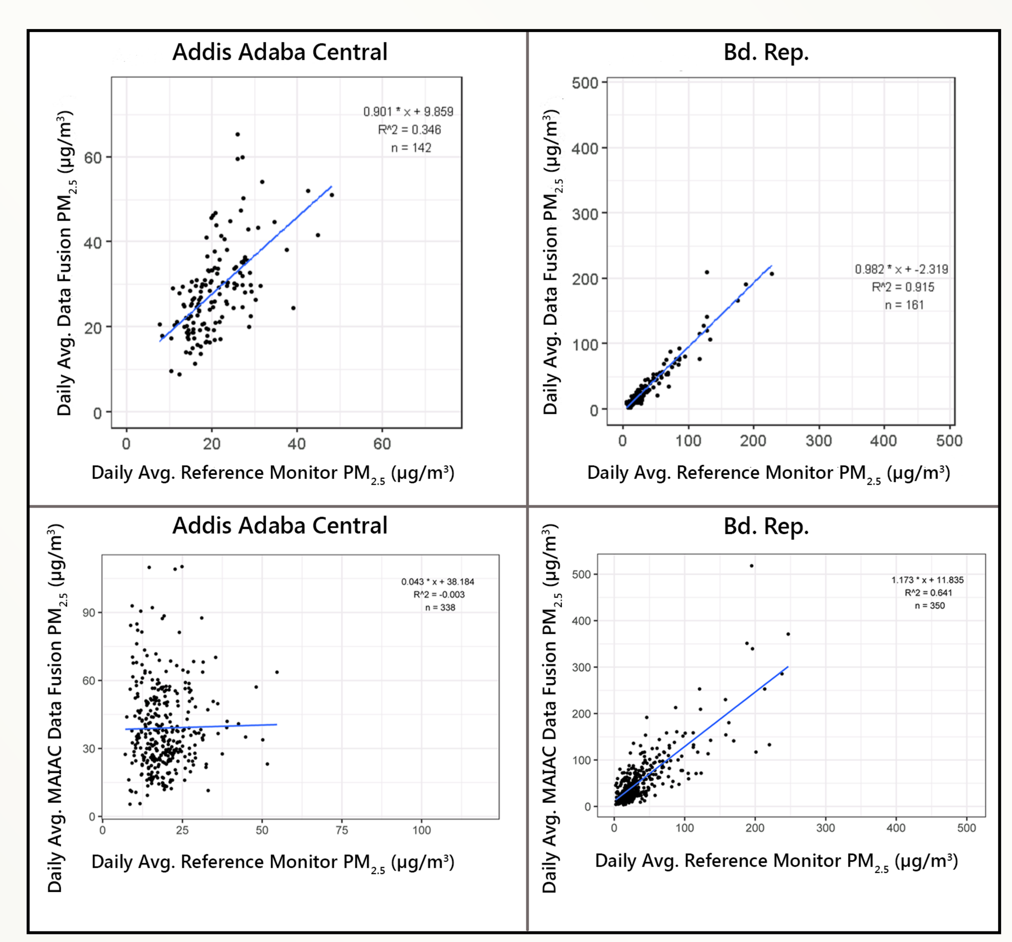

Figure 5. Results of independent validation of (1) data fusion for locations with multiple reference-grade monitors where full fusion can be conducted (top) and (2) satellite-only $PM_{2.5}$ data at those locations (bottom).

Annual Average $PM_{2.5}$

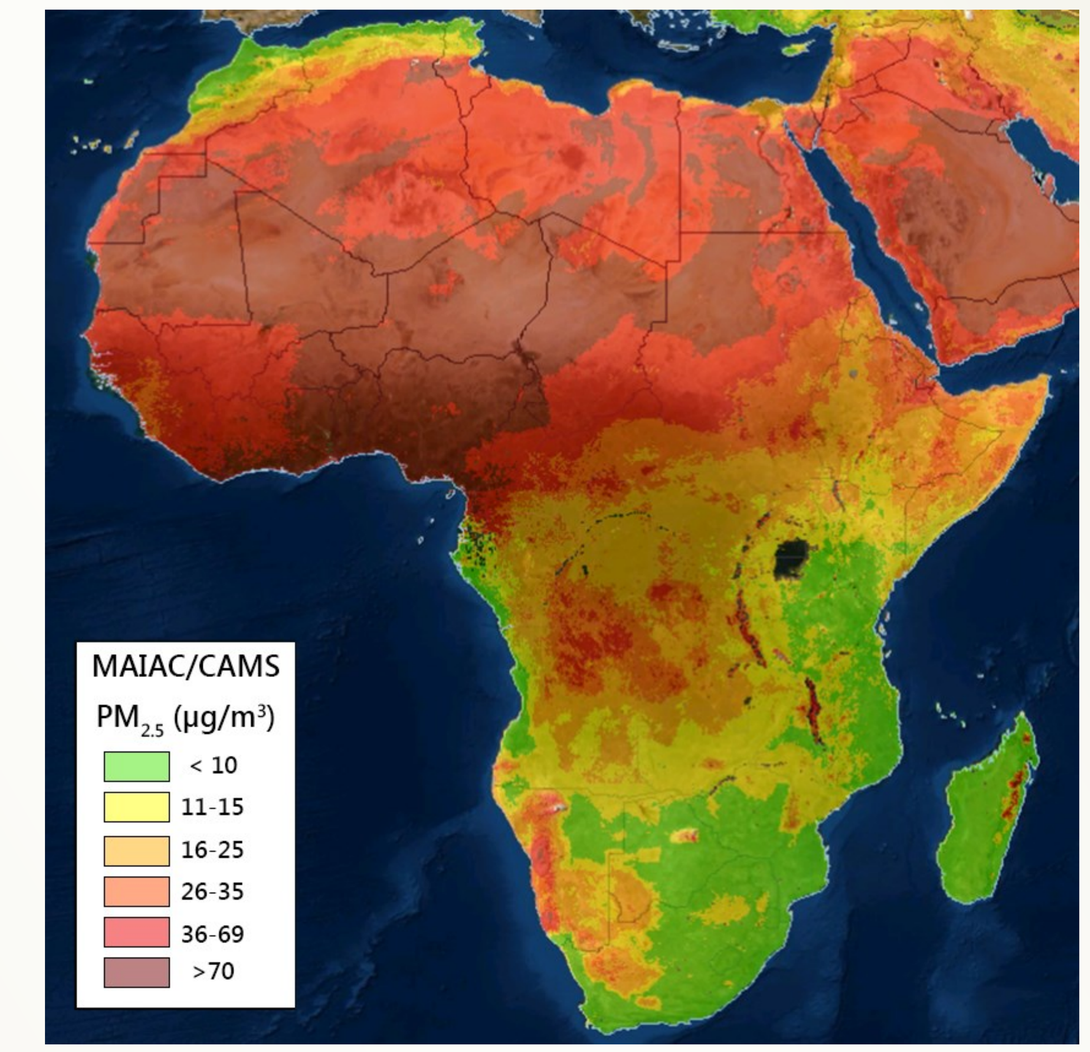

Figure 6. Annual average ground-level $PM_{2.5}$ concentrations for Africa calculated with MAIAC/CAMS.

Implications

- Evaluation shows promise for use of MAIAC data for near-real-time daily ground-level $PM_{2.5}$ calculations.
- CAMS and Monthly $PM_{2.5}$ (data set V4.GL.03) model data produce comparable daily results and can be used depending on data availability.
- Satellite data gaps can limit coverage in time, but several promising gap-filling approaches are available.
- Operational production of satellite-based $PM_{2.5}$ will provide useful data now, while facilitating additional evaluation and enhancement later.

Future Work

- Develop and implement operational satellite data surface $PM_{2.5}$ and fusion estimates.
- Continue to evaluate system where data are available.
- Develop system documentation and encourage system adoption through information sharing and support.

Project implemented by:

UN environment Google STi Sonoma Technology

Contact Us

707.665.9900 | sonomatech.com
Nathan Pavlovic (npavlovic@sonomatech.com)

Presented at the 2019 American Geophysical Union Fall Meeting, December 9-13, 2019, San Francisco, CA (A53T-2931, STI-7151)

Lee, S.J., Serre, M.L., van Donkelaar, A., Martin, R.V., Burnett, R.T. and Jerrett, M., 2012. Comparison of geostatistical interpolation and remote sensing techniques for estimating long-term exposure to ambient $PM_{2.5}$ concentrations across the continental United States. *Environmental Health Perspectives*, 120(12), pp.1727-1732.
Van Donkelaar, A., Martin, R.V., Pasch, A.N., Szykman, J.J., Zhang, L., Wang, Y.X. and Chen, D., 2012. Improving the accuracy of daily satellite-derived ground-level fine aerosol concentration estimates for North America. *Environmental Science & Technology*, 46(21), pp.11971-11978.