STi | Sonoma Technology

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

By Nathan Pavlovic,[1] Sean Khan,[2] and Brian Sullivan,[3]
[1]Sonoma Technology, Petalma, CA; [2]UN Environment, GEMS/AIR Program, Nairobi, Kenya
[3]Google, Mountain View, CA

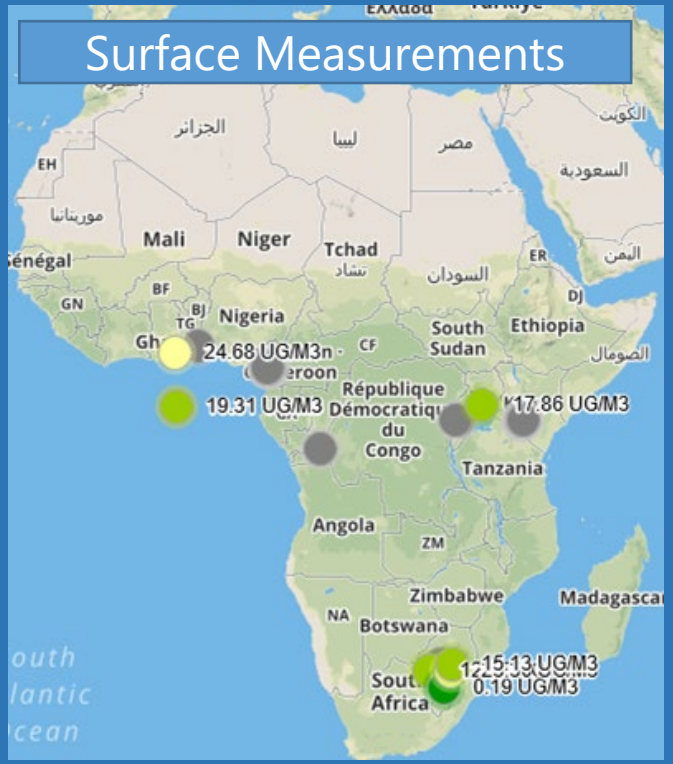
For Air Sensors International Conference

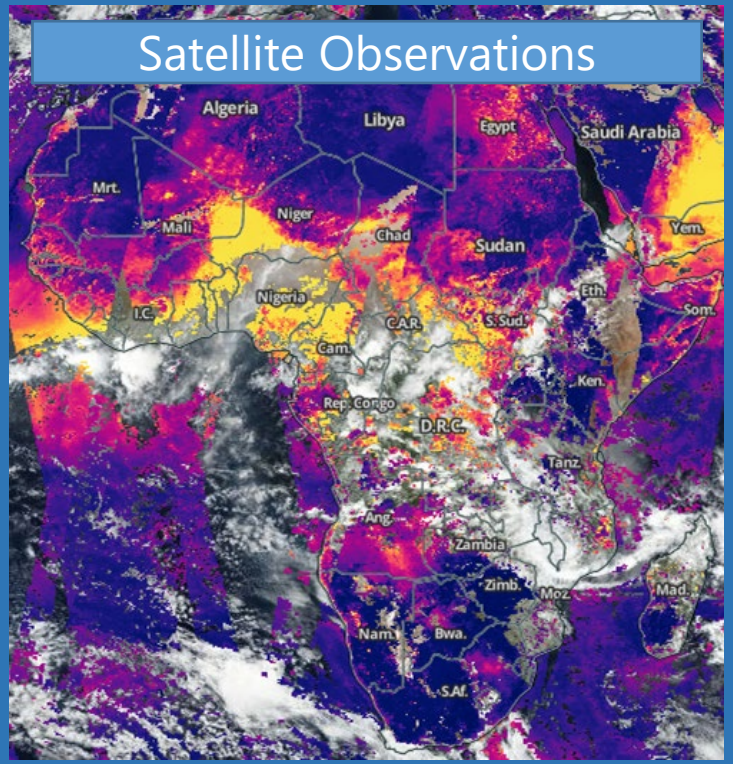
May 11, 2022

UN environment

Google

GEMS/Air Global Air Quality Monitoring Framework



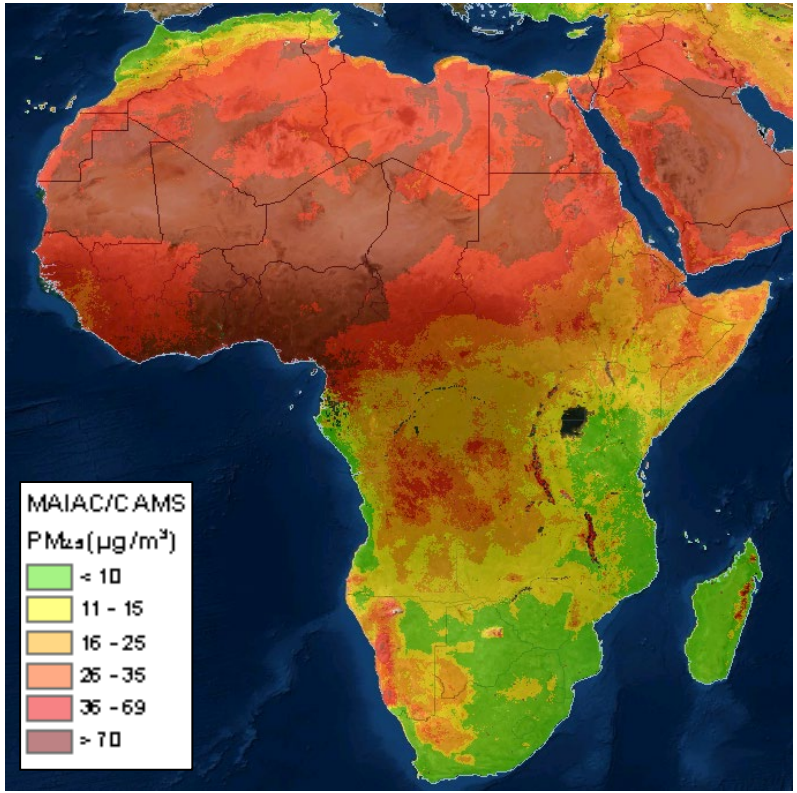


Data fusion to support high-resolution air quality information

- Merge surface measurements with satellite observations
- Pilot initiative with focus on African cities
- Support decision-making and local control of data

The International Data Fusion System

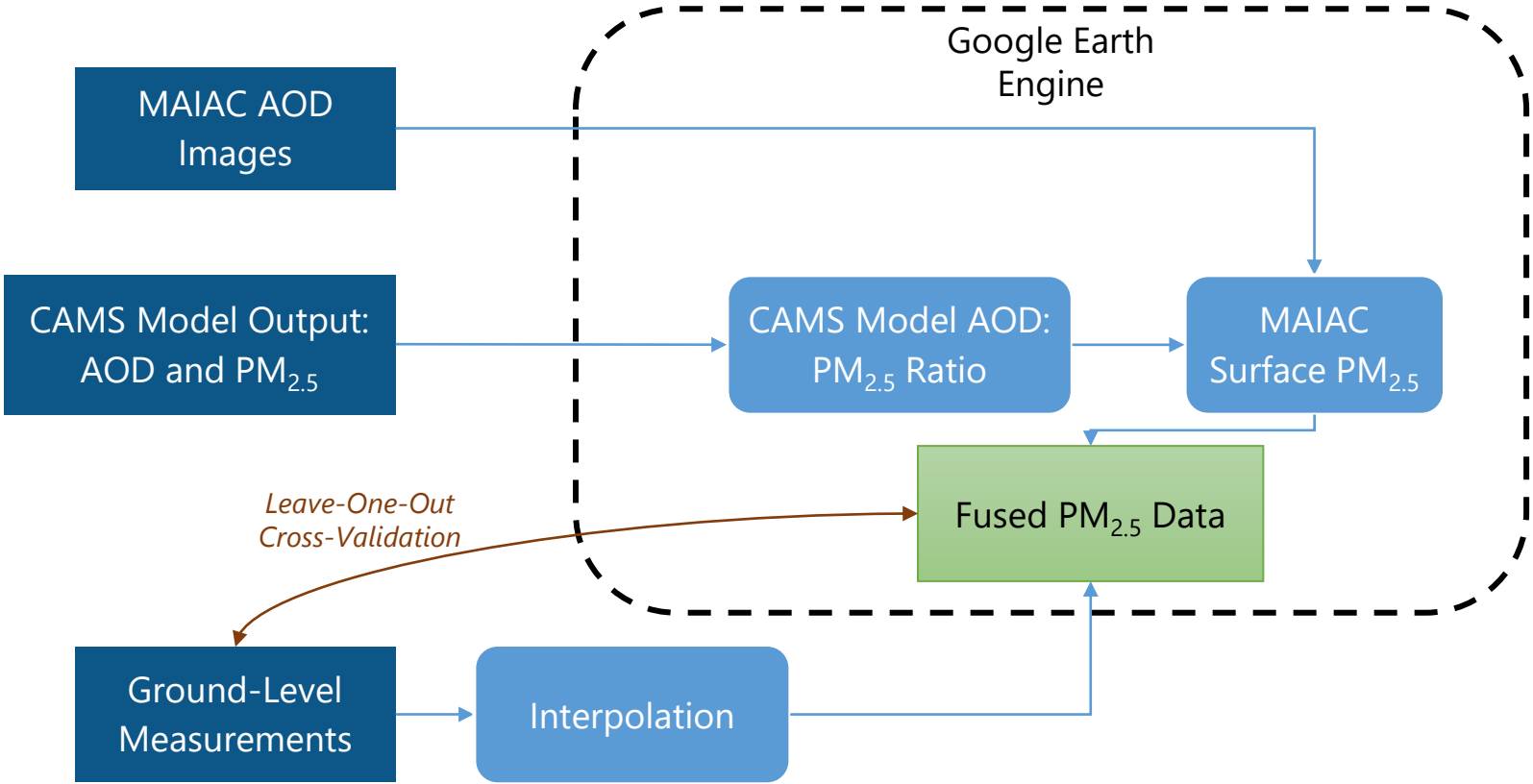
- Provides **near-real-time, high spatial resolution** data for surface-level $PM_{2.5}$
- The system offers advantages including:
  - International coverage
  - High spatial resolution data
  - Near-real-time data availability
  - Data from both low-cost and regulatory-grade monitors
  - Incorporate model data



Data Sets Used in This Work

Data Set	Spatial Resolution	Spatial Coverage	Temporal Resolution	Time Period	Uses
Copernicus Atmosphere Monitoring Service (CAMS) Near-Real Time $PM_{2.5}$ and Aerosol Optical Depth (AOD)	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 $PM_{2.5}$
$PM_{2.5}$ from Dalhousie University (V4.GL.03)	1 km, smoothed	Global	Monthly	2012-2017	Alternate adjustment for MAIAC AOD
Ground Measurements of $PM_{2.5}$	Point-based	Limited Urban Areas	Hourly	Variable	Validation and data fusion

$PM_{2.5}$ Data Fusion Processing Approach



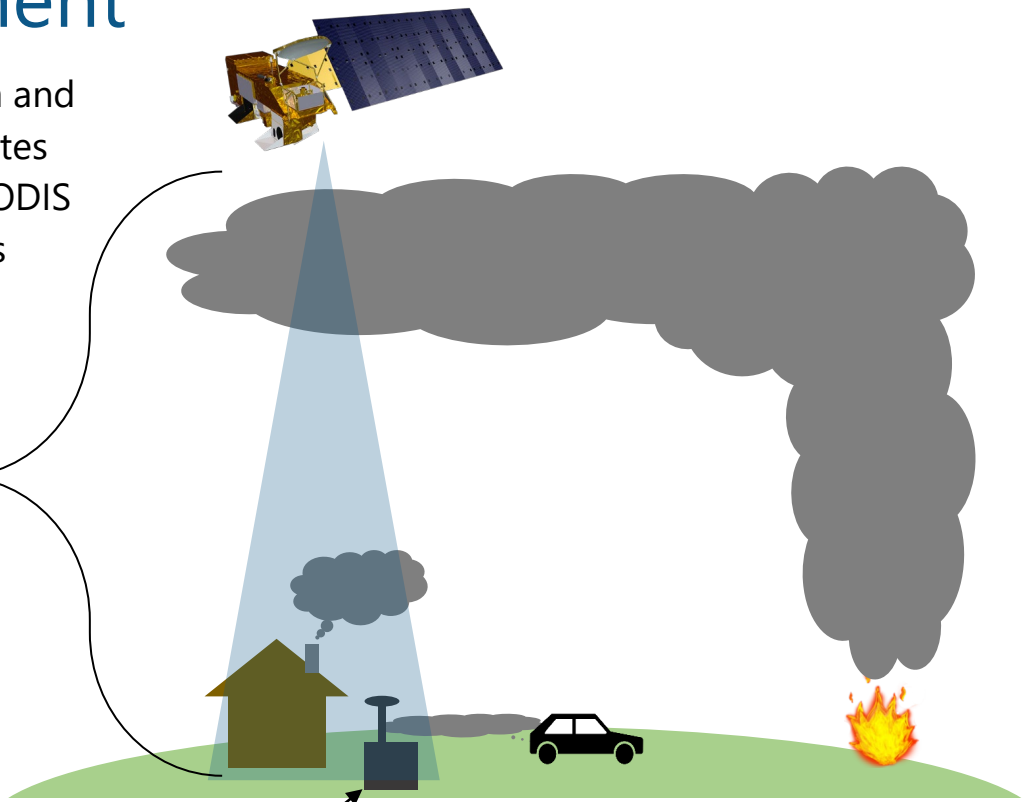
MAIAC AOD Measurement

NASA Aqua and Terra satellites carrying MODIS Instruments

MODIS images used to generate MAIAC AOD reflect:

- Ground-level air pollution
- Air pollution aloft
- Humidity

Imagery alone cannot distinguish among these components



Air monitoring station *measures only ground level* $PM_{2.5}$

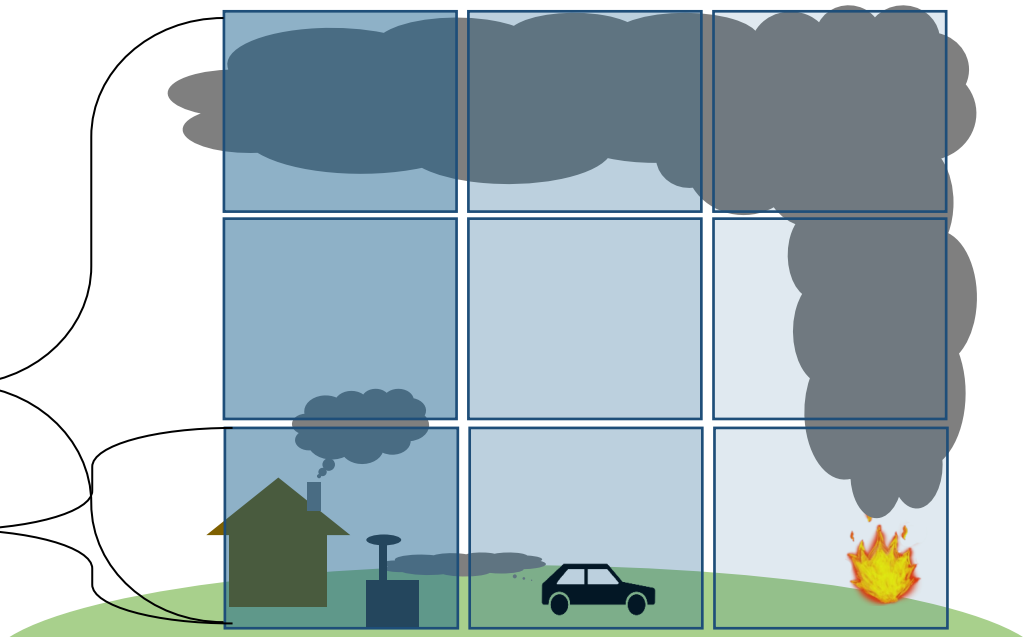
Estimation of Surface Level Pollution from AOD with Photochemical Modeling

CAMS photochemical model creates vertically and horizontally gridded, disaggregated representation of:

- Ground-level air pollution
- Air pollution aloft
- Humidity

Vertical layers are summed to calculate AOD

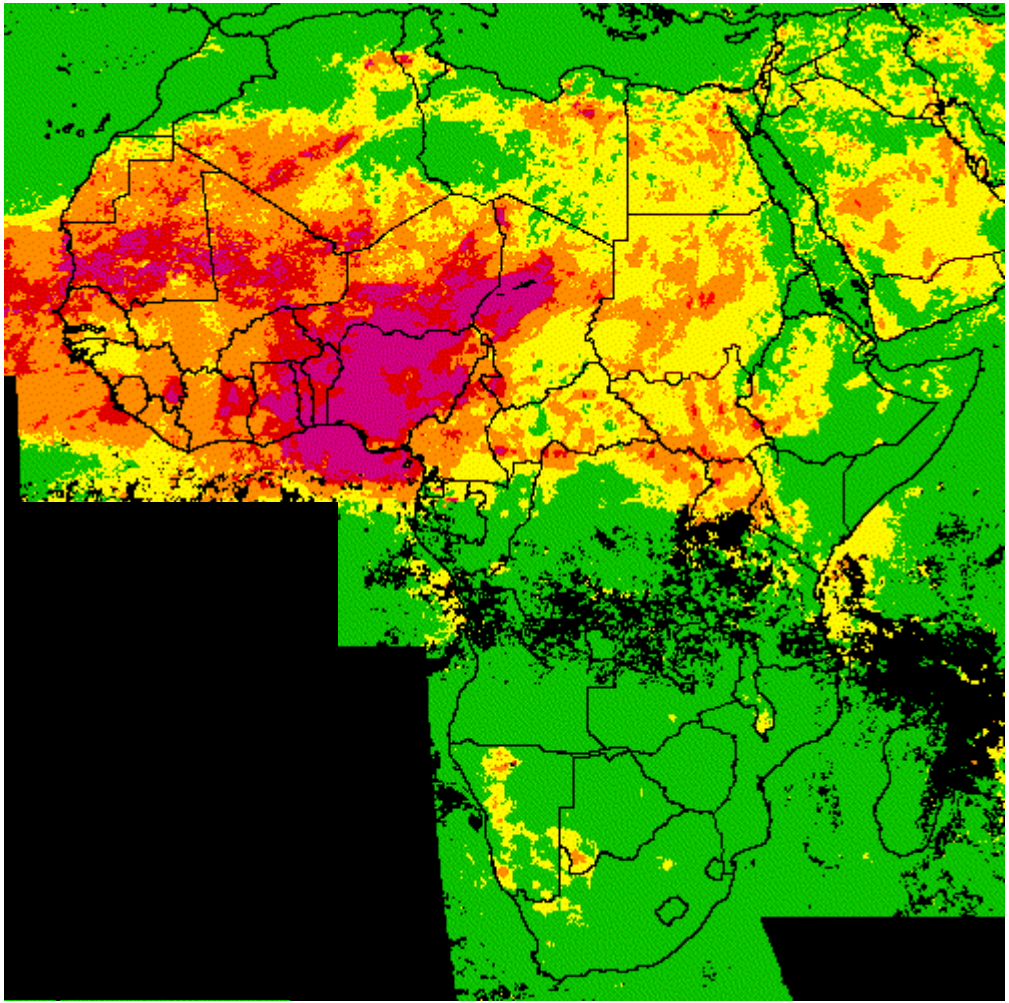
Lowest model layer is used to calculate ground-level $PM_{2.5}$



Weekly Average Ground-Level $PM_{2.5}$ from Satellite

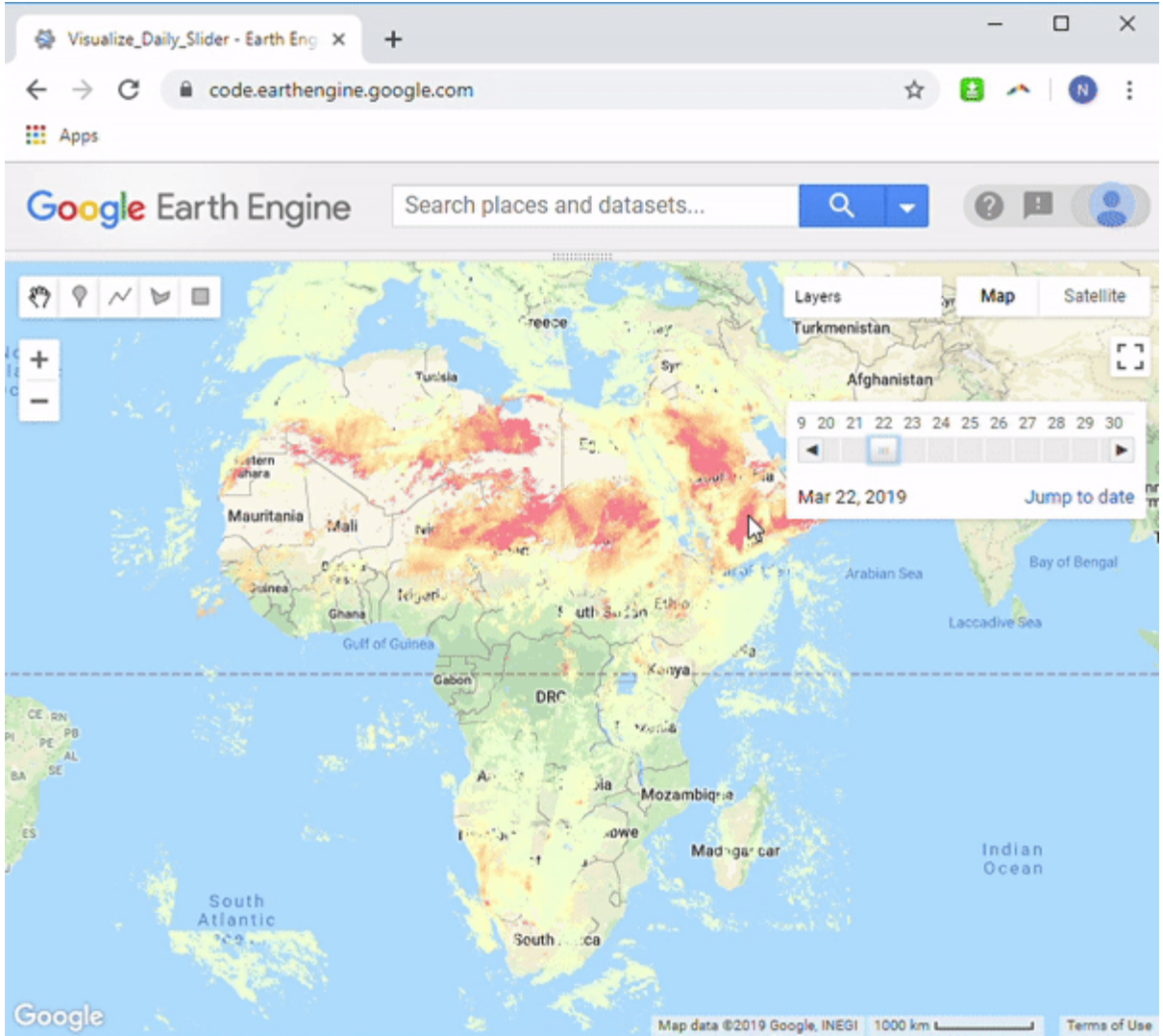
- Within WHO Guideline
- 1-2 Times WHO Guideline
- 2-4 Times WHO Guideline
- 4-6 Times WHO Guideline
- >6 Times WHO Guideline

WHO Guideline 24 Hour Average
PM2.5 Guideline: 25 µg/m^3

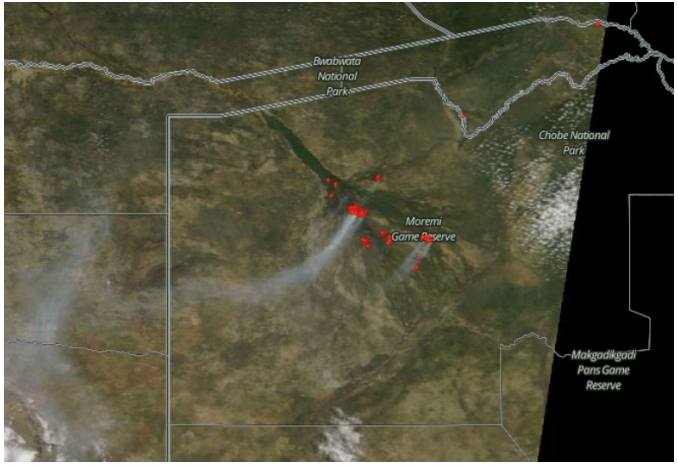


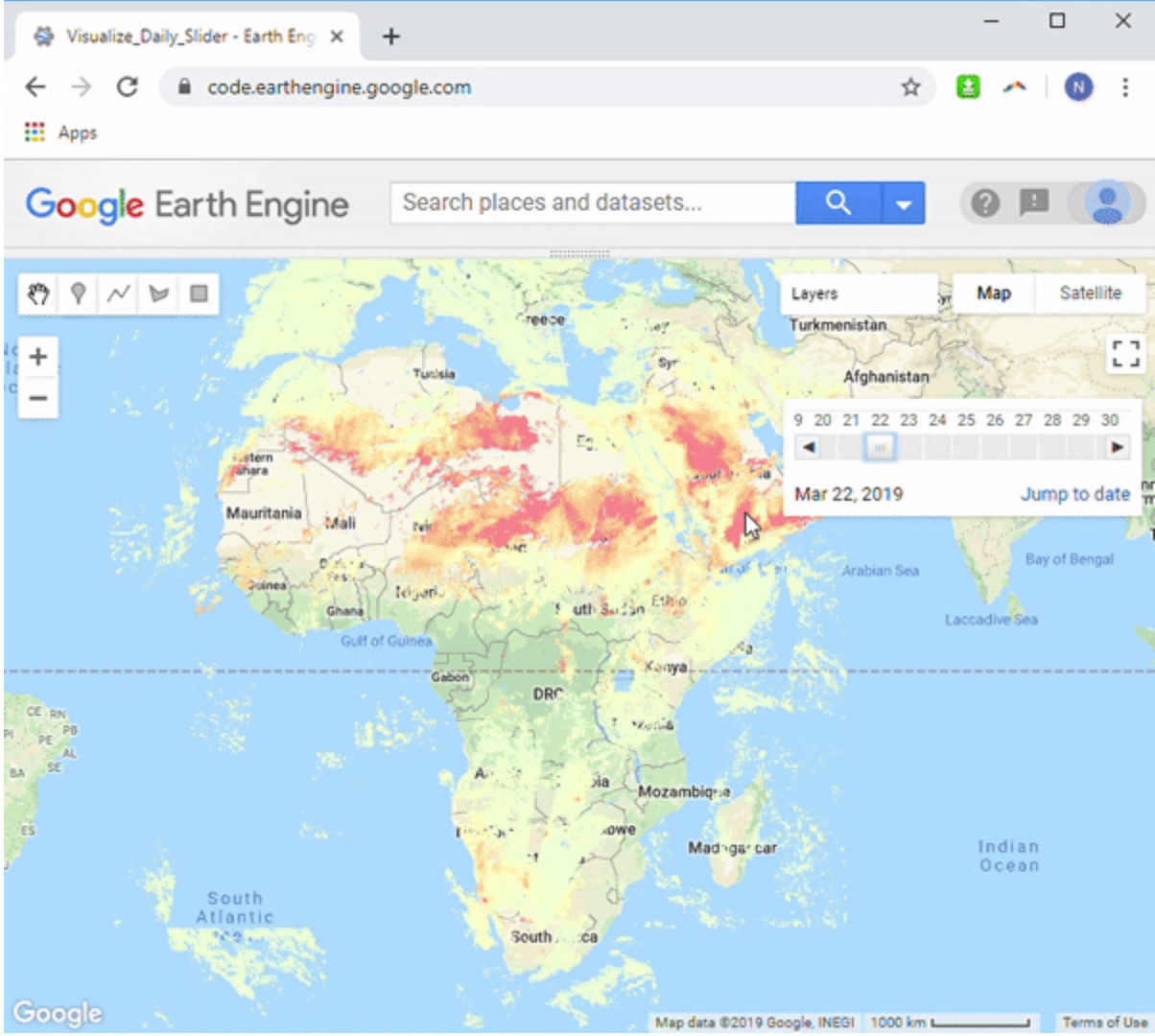
Daily Ground-Level $PM_{2.5}$ from Satellite

- Daily 24-hour average ground-level $PM_{2.5}$
- Continental coverage up to early 2019
- 1-km resolution



Daily Ground-Level $PM_{2.5}$ from Satellite





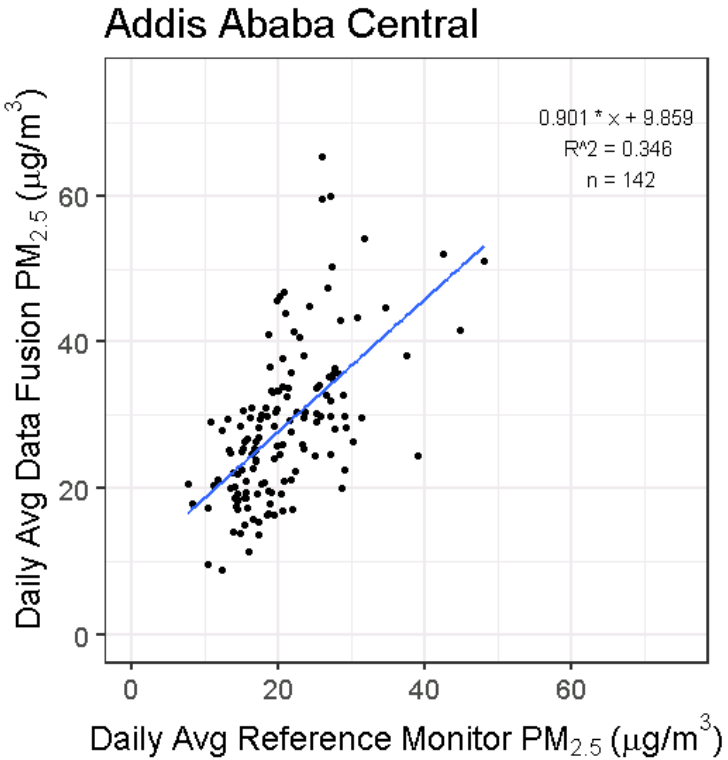
24-Hour CAMS Averaging and 5-km Smoothing Produce Promising Results at 4 of 6 Monitors

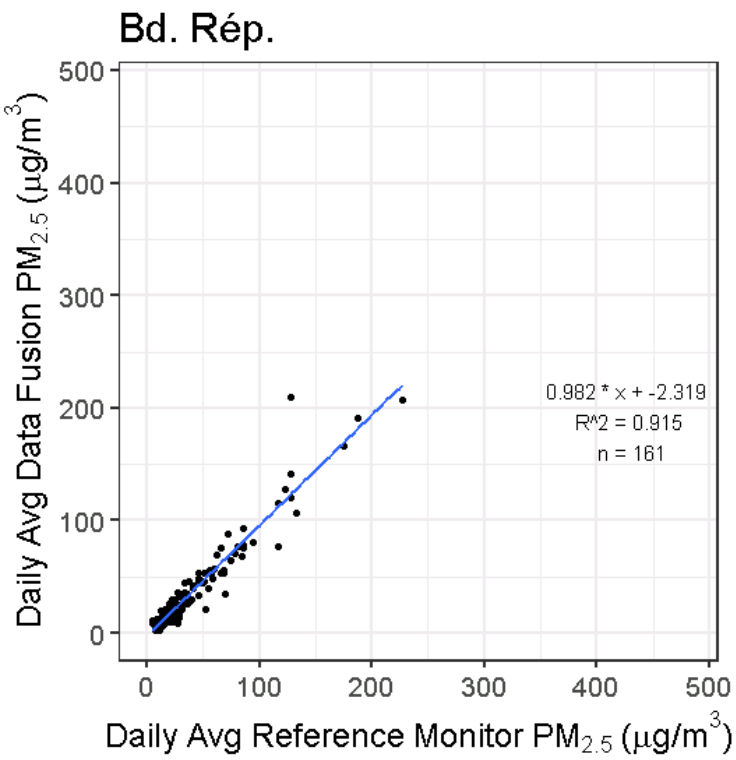
Evaluation of agreement between ground-level observations and satellite-derived ground-level $PM_{2.5}$ (MAIAC/CAMS)

Country	Site	R^2	RMSE
Ethiopia	Addis Ababa	0.00	28.1
Botswana	Gaborone City	0.00	17.8
Uganda	Kampala	0.25	27.5
Senegal	Bel Air, Dakar	0.54	38.1
Senegal	Guediawaye, Dakar	0.43	49.5
Senegal	Bd. Republique, Dakar	0.64	39.8

- Evaluation was performed using daily average ground-level $PM_{2.5}$
- R^2 represents the proportion of variability in ground monitor data reflected in the satellite-derived $PM_{2.5}$
- Root mean square error (RMSE) indicates the magnitude of the error between satellite-derived and observed $PM_{2.5}$
- Sites in Senegal showed the best agreement with surface data
- Botswana and Ethiopia sites showed very little agreement between ground observations and satellite-derived $PM_{2.5}$

Ground-Level Data Fusion Results for Selected Monitors





Opportunities for Low-Cost Sensor Applications

Addis Ababa, Ethiopia

2 Reference Grade $PM_{2.5}$ Monitors

12 Low-Cost Sensors

OpenAQ

Low-cost sensors provide:

- Dense monitoring network
- Enhanced spatial and temporal resolution opportunities for data fusion

Limitations:

- Lower accuracy
- Siting and maintenance challenges

Summary

- Benefits:
  - "Filling the gap" where surface data availability is limited
  - Near-real-time air quality event monitoring
  - Monitor siting decisions, in conjunction with other available data sets
- Fusing ground-level observations (where available) with satellite data can improve air quality data provided
- Satellite data gaps can limit daily coverage, but several promising gap-filling approaches are available
- Operational production of satellite-based $PM_{2.5}$ data will provide useful data now while facilitating additional evaluation and enhancement
- Low-cost sensors can provide higher spatial detail in locations where available
- Next steps: implement operational fusion approach and ongoing refinement

Nathan Pavlovic
Lead Geospatial Data Scientist
npavlovic@sonomatech.com
@n_pavlovic

UN environment

Google