Satellite-Based PM$_{2.5}$ Datasets and Access

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Satellite Remote Sensing of Dust, Fires, Smoke, and Air Quality, July 10-12, 2018
Learning Objectives

By the end of this presentation, you will be able to:

• give examples of applications for surface PM$_{2.5}$ estimates
• recognize the DIMAQ model used to calculate PM$_{2.5}$ estimates
• use online tools to access and view World Health Organization (WHO) surface PM$_{2.5}$ estimates
Outline

• Examples of Applications using Surface PM2.5 Estimates
• NASA SEDAC Surface PM2.5 Estimates
• Learn about the DIMAQ model used to calculate PM2.5 estimates as well as the various datasets that are used as inputs
• Learn about several online tools to access and view World Health Organization (WHO) surface PM2.5 estimates
• NASA GMAO MERRA-2 model output
Examples of Applications Using Surface PM$_{2.5}$ Estimates
Satellites Provide a “God’s Eye” View of the Earth

Spatial coverage is the primary advantage of satellite data

The spatial coverage afforded by satellite data offers increased statistical power that strengthens inference of the relation between pollutants and health outcomes.
Health Studies of Exposure

Ambient Air Pollution Exposure Estimation for the Global Burden of Disease 2013

Michael Brauer¹, Greg Freedman¹, Joseph Frostick¹, Aaron van Donkelaar³, Randall V. Martin⁴, Frank Dentener⁴, Rita van Dingenen⁴, Kara Estep⁵, Heresh Amini⁵, Joshua S. Apte⁵, Kalpana Balakrishnan⁶, Lars Barregard⁶, David Broday⁷, Valery Feigin⁷, Santu Ghosh⁷, Phillip K. Hopke⁴, Luke D. Knibbs⁸, Yoshihiro Kokubo⁸, Yang Liu⁶, Stefan Ma⁸, Lidia Morawska⁹, José Luis Texcal Sangrador⁶, Gavin Shaddick⁴, H. Ross Anderson⁵, Theo Vo⁴, Mohammad H. Forouzanfar², Richard T. Burnett⁵, and Aaron Cohen⁵

Annual Average PM₂.⁵ (µg/m³)

WHO Interim Targets


NASA’s Applied Remote Sensing Training Program
UN Sustainable Development Goals (SDGs)
Transforming Our World: The 2030 Agenda for Sustainable Development

Goal 3 – Good Health and Well Being
• Target 3.9; Indicator 3.9.1
• Mortality rate attributed to household and ambient air pollution (annual mean levels of air pollution (PM2.5))

Goal 11 – Sustainable Cities and Communities
• Target 11.6; Indicator 11.6.2
• Annual mean levels of fine particulate matter (e.g. PM2.5 and PM10) in cities (population weighted)

Text adapted from "Transforming Our World: The 2030 Agenda for Sustainable Development"
Satellite-Based Estimates of Surface PM$_{2.5}$ – NASA SEDAC – Van Donkelaar et al. (2016)
## Satellite-Based Estimates: AOD from Satellites

Eight retrievals of AOD from four different instruments

<table>
<thead>
<tr>
<th>Instrument</th>
<th>MODIS: Terra/Aqua</th>
<th>MISR</th>
<th>SeaWiFS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Retrieval Algorithm</td>
<td>Deep Blue</td>
<td>Dark Target</td>
<td>MAIAC</td>
</tr>
<tr>
<td>Horizontal Resolution</td>
<td>10 km</td>
<td>10 km</td>
<td>1 km</td>
</tr>
</tbody>
</table>

Satellite-Based Estimates

AOD \Rightarrow PM_{2.5}

Combine estimates (weighted uncertainty) and calculate annual mean

Calculate PM\textsubscript{2.5} from AOD using model AOD-to-PM\textsubscript{2.5} relationship

Calibrate all using surface observations of AOD from the AERONET network

AOD (8 retrievals) & AOD from model simulations

The Van Donkelaar product is available at: http://sedac.ciesin.columbia.edu/data/set/sdei-global-annual-avg-pm2-5-modis-misr-seawifs-aod-1998-2012. Image (right) Van Donkelaar et al., 2016, Figure 2 (Only MODIS-Terra shown)
Satellite-Based Estimates

Geographic Weighted Regression (GWR)

GWR corrects the satellite estimate using the relationship between PM$_{2.5}$ from ground monitors and variables such as model aerosol composition, elevation data, and land use indicators.

Annual Mean Surface PM$_{2.5}$

http://sedac.ciesin.columbia.edu/

- Download data (GeoTIFF files) and pre-made images of surface PM$_{2.5}$ inferred from satellite observations
Annual Mean Surface PM$_{2.5}$

http://sedac.ciesin.columbia.edu/

The new van Donkelaar et al. PM$_{2.5}$ dataset provides

- higher accuracy
- longer temporal range
- higher resolution (0.1° x 0.1°)
- time varying AOD to PM$_{2.5}$ relationships necessary for appropriate representation of trends
Annual Mean Surface PM$_{2.5}$

http://fizz.phys.dal.ca/~atmos/martin/?page_id=140
Satellite-Based Estimates

Limitations

• The van Donkelaar estimate provides annual mean estimates of PM$_{2.5}$
• However, this and other estimates do not provide an analysis of uncertainties
• The WHO and the University of Bath have led the development of the Data Integration Model for Air Quality (DIMAQ)
  – This model estimates PM$_{2.5}$ along with associated measures of uncertainty
Data Integration Model for Air Quality (DIMAQ)
Data Integration Model for Air Quality (DIMAQ)

Population Data

Gridded and Country-Level Estimates of PM$_{2.5}$

Ground Monitors & Information on Local Monitoring Networks

Simulated Aerosols

Satellite-Based Estimates

Topography & Land Use

Stephen Reynolds, Arizona State University
Data Integration Model for Air Quality (DIMAQ)

Population Data
Ground Monitor Information & Data
Satellite-Based Estimates
Simulated Aerosols
Topography & Land Use

Bayesian Hierarchical Framework
Estimates PM$_{2.5}$ as well as measures of uncertainty

Annual Average PM$_{2.5}$ for 2014

Estimates on a 0.1° x 0.1° grid

Image Credit (Right): Shaddick, et al. (2018), Figure 7 (top)
Available World Health Organization (WHO) Tools
Where to Find and View the Data

WHO Website – Country Level


Follow this link to download 2014 country level data:
- Formats: csv, Excel, html, XML, etc.
- Can also filter by country and download
PM$_{2.5}$ at Country Level

http://gamapserver.who.int/gho/interactive_charts/phe/oap_exposure/atlas.html
PM$_{2.5}$ at Country Level

http://gamapserver.who.int/gho/interactive_charts/phe/oap_exposure/atlas.html
Where to Find and View the Data

WHO Website – Grid Level

PM$_{2.5}$ at Grid Level

http://maps.who.int/airpollution/
PM$_{2.5}$ at Grid Level

[Link to Global ambient air pollution map: http://maps.who.int/airpollution/]

Zooming in shows circles indicating monitoring stations.
PM$_{2.5}$ at Grid Level

http://www.who.int/phe/health_topics/outdoorair/databases/modelled-estimates/en/

Map from previous slides
.csv file with gridded PM$_{2.5}$ estimates
Link to Shaddick et al. paper
Meta-data for PM$_{2.5}$ estimates
Where to Find and View the Data

WHO Website - City Level

http://www.who.int/gho/phe/outdoor_air_pollution/exposure/en/

Maps of city level PM$_{10}$ and PM$_{2.5}$

.csv file with city level annual means
PM$_{2.5}$ at City Level

http://www.who.int/gho/phe/outdoor_air_pollution/exposure/en/
Where to Find the Data

NASA Aura Validation Data Center

- Dr. Pawan Gupta has subsetted the DIMAQ gridded data by country
- The individual country .csv files are available at:
- There is also a readme.txt file
Modern-Era Retrospective analysis for Research and Applications, Version 2 (MERRA-2)

https://gmao.gsfc.nasa.gov/reanalysis/MERRA-2/

- NASA’s Global Model and Assimilation Office (GMAO) produces estimates of surface PM$_{2.5}$ over the period of 1980 to the present day
- The model system assimilates meteorological data as well as some atmospheric constituents (e.g., ozone, AOD)
- Pawan Gupta will discuss the MERRA-2 products in more detail tomorrow
Questions