

Satellite-Based $PM_{2.5}$ Datasets and Access

Melanie Follette-Cook and Pawan Gupta

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:

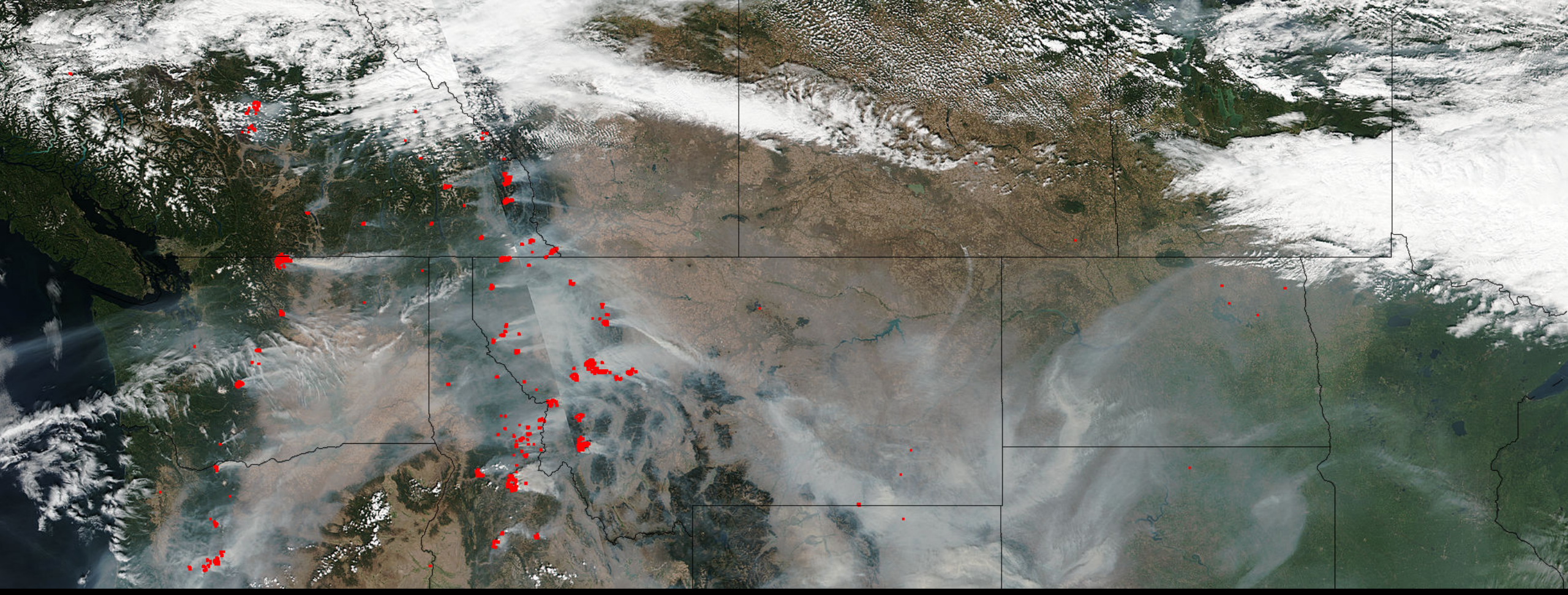
- give examples of applications for surface PM_{2.5} estimates
- recognize the DIMAQ model used to calculate PM_{2.5} estimates
- use online tools to access and view World Health Organization (WHO) surface PM_{2.5} estimates



Outline

- Examples of Applications using Surface PM_{2.5} Estimates
- NASA SEDAC Surface PM_{2.5} Estimates
- Learn about the DIMAQ model used to calculate PM_{2.5} 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 PM_{2.5} estimates
- NASA GMAO MERRA-2 model output

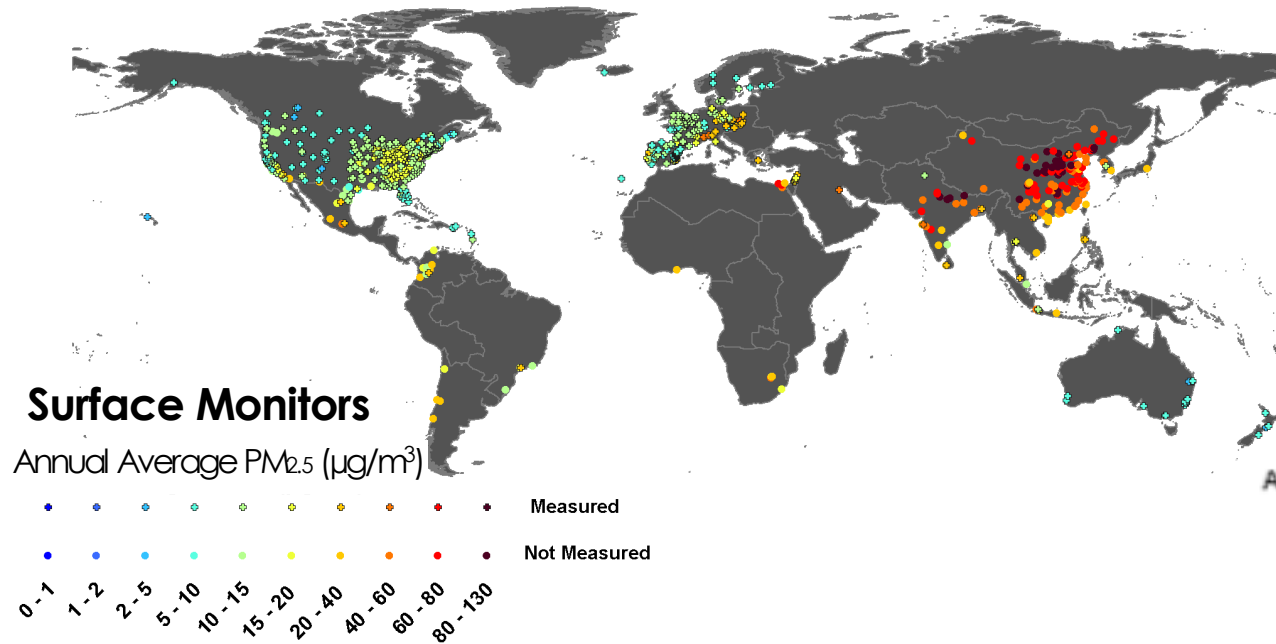




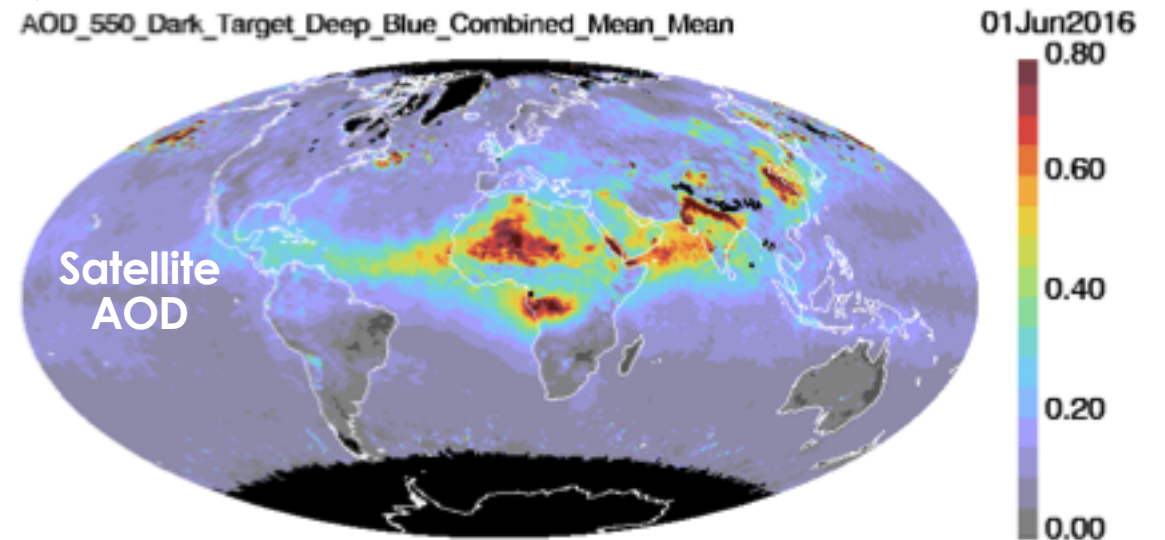
Examples of Applications Using Surface PM_{2.5} Estimates

Satellites Provide a “God’s Eye” View of the Earth

Spatial coverage is the primary advantage of satellite data



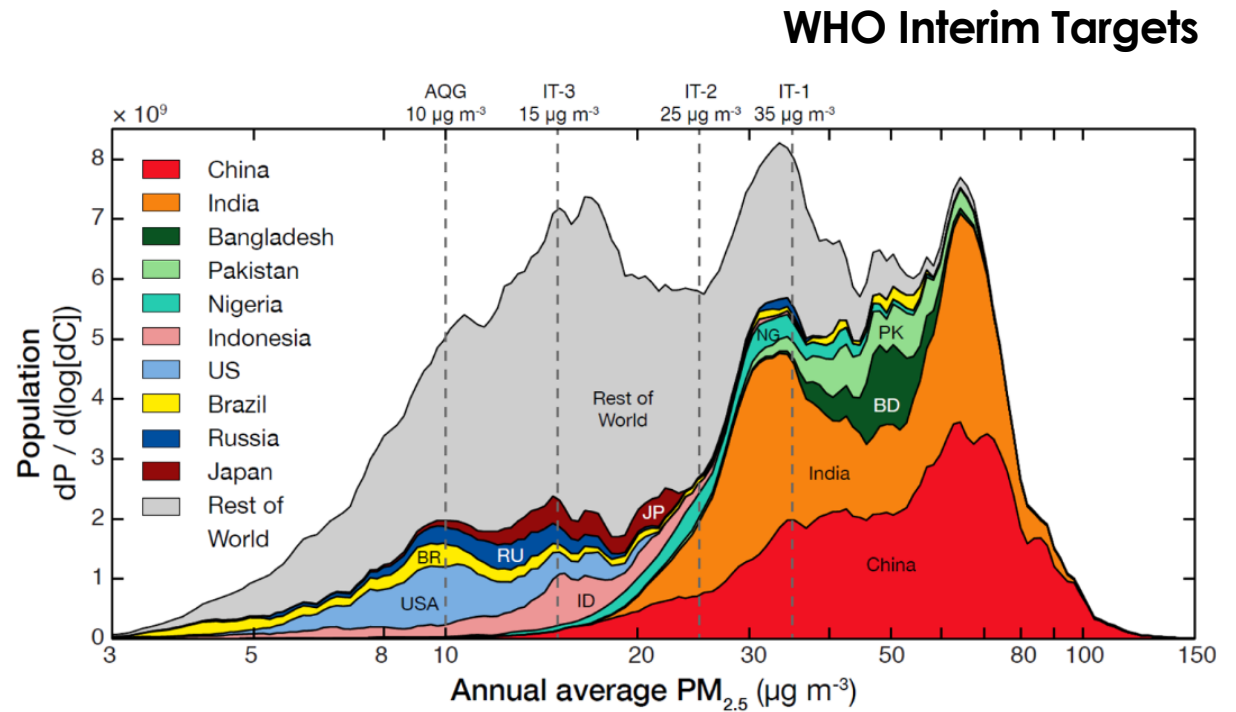
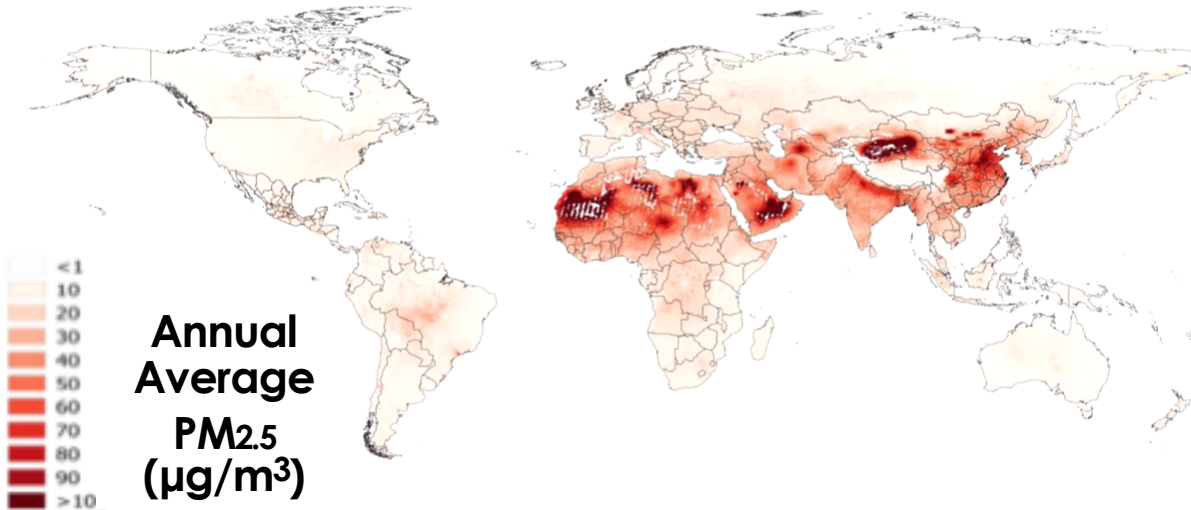
The spatial coverage afforded by satellite data offers increased statistical power that strengthens inference of the relation between pollutants and health outcomes



Health Studies of Exposure

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

Michael Brauer[†], Greg Freedman[†], Joseph Frostad[†], Aaron van Donkelaar[§], Randall V. Martin[§], Frank Dentener[¶], Rita van Dingenen[¶], Kara Estep[†], Heresh Amini[†], Joshua S. Apte[#], Kalpana Balakrishnan[∇], Lars Barregard[¶], David Broday[◊], Valery Feigin[◊], Santu Ghosh[∇], Philip K. Hopke[¶], Luke D. Knibbs[▲], Yoshihiro Kokubo[◊], Yang Liu[★], Stefan Ma[⊗], Lidia Morawska[¶], José Luis Texcalac Sangrador[⊗], Gavin Shaddick[†], H. Ross Anderson[◁], Theo Vos[†], Mohammad H. Forouzanfar[†], Richard T. Burnett[✕], and Aaron Cohen[‡]



Brauer, M., et al., Ambient Air Pollution Exposure Estimation for the Global Burden of Disease 2013, Environ. Sci. & Tech., 50 (1), 79-88, doi: 10.1021/acs.est.5b03709, 2016.



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 (PM_{2.5}))

Goal 11 – Sustainable Cities and Communities

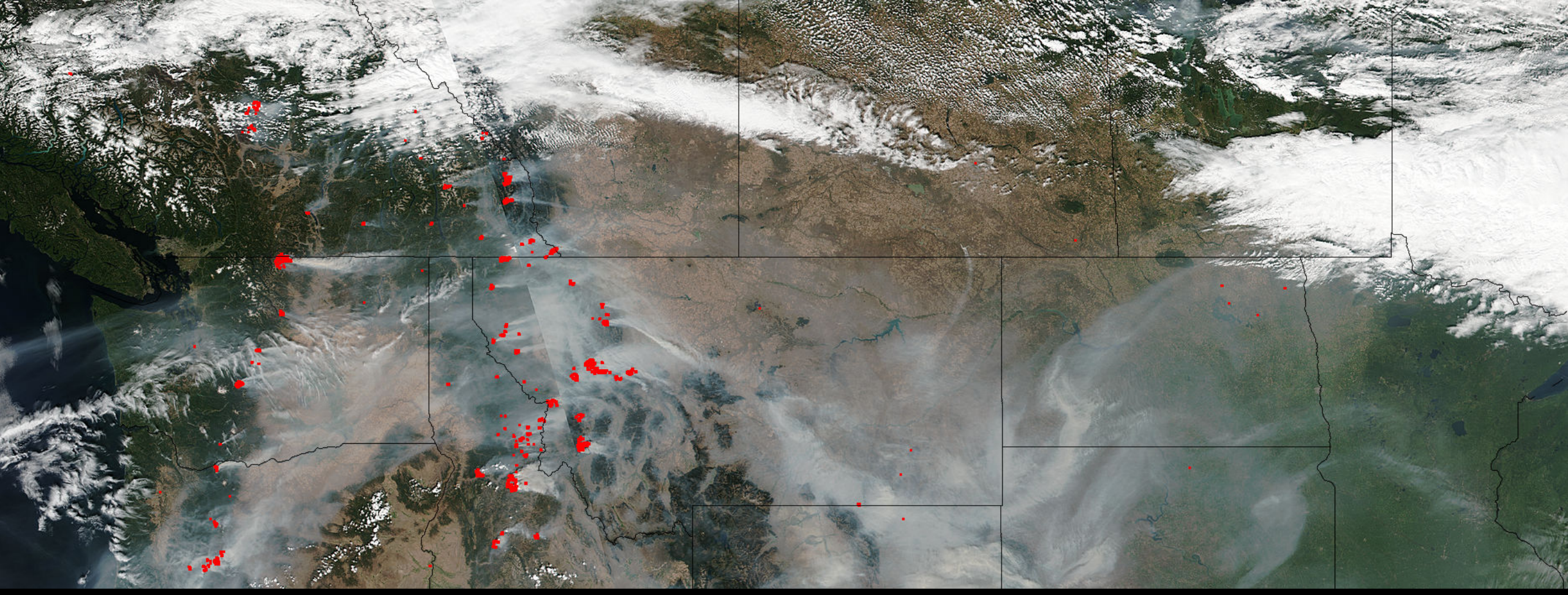
- Target 11.6; Indicator 11.6.2
- Annual mean levels of fine particulate matter (e.g. PM_{2.5} and PM₁₀) in cities (population weighted)

SUSTAINABLE DEVELOPMENT GOALS



Text adapted from "Transforming our world: the 2030 Agenda for Sustainable Development"

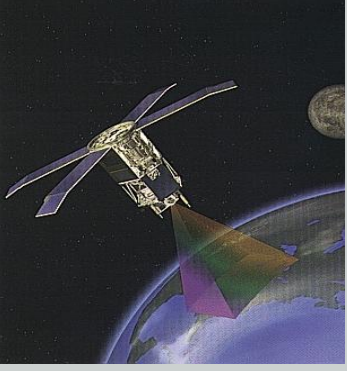




Satellite-Based Estimates of Surface PM_{2.5} –
NASA SEDAC – Van Donkelaar et al. (2016)

Satellite-Based Estimates: AOD from Satellites

Eight retrievals of AOD from four different instruments

Instrument	MODIS: Terra/Aqua			MISR	SeaWiFS
					
Retrieval Algorithm	Deep Blue	Dark Target	MAIAC	MISR	Deep Blue
Horizontal Resolution	10 km	10 km	1 km	17.6 km	13.5 km

Van Donkelaar et al., 2016, doi:10.1021/acs.est.5b05833. The Van Donkelaar product is available at: <http://seaac.ciesin.columbia.edu/data/set/saer-global-annual-avg-pm2-5-modis-misr-seawifs-aod-1998-2012>



Satellite-Based Estimates

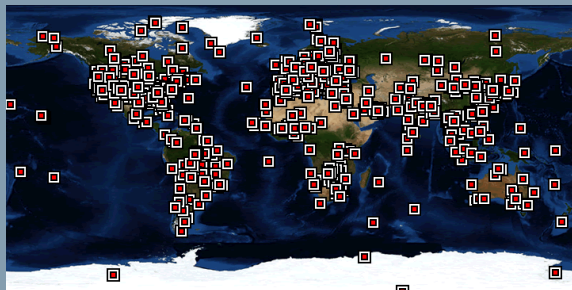
AOD \Rightarrow PM_{2.5}

AOD
(8 retrievals)

&

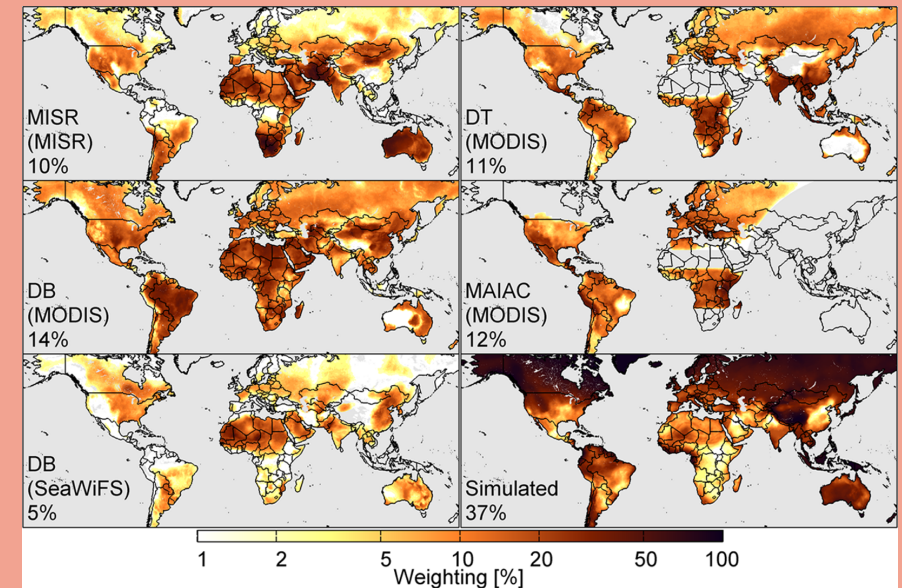
AOD from
model
simulations

Calibrate all using surface
observations of AOD from the
AERONET network



Calculate PM_{2.5}
from AOD using
model AOD-to-PM_{2.5}
relationship

Combine estimates (weighted
uncertainty) and calculate
annual mean



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



The Van Donkelaar product is available at: <http://seamless.usgs.gov/data/seamless/global-annual-avg-pm2-5-modal-mis-seawifs-aod-1998-2012>. Left Image: Van Donkelaar et al., 2016, Figure 3. Right Image: Van Donkelaar et al., 2016, Figure 5

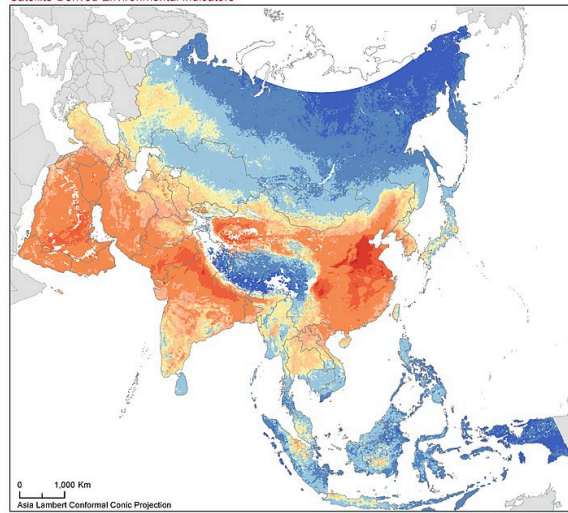


Annual Mean Surface PM_{2.5}

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

- Download data (GeoTIFF files) and pre-made images of surface PM_{2.5} inferred from satellite observations

Global Annual PM_{2.5} Grids from MODIS, MISR and SeaWiFS
Aerosol Optical Depth (AOD), 2001–2010: Asia
Satellite-Derived Environmental Indicators



The Global Annual PM_{2.5} Grids from MODIS, MISR and SeaWiFS Aerosol Optical Depth (AOD) data sets represent a series of three-year running mean grids (1998–2012) of fine particulate matter (solid particles and liquid droplets) that were derived from a combination of MODIS (Moderate Resolution Imaging Spectroradiometer), MISR (Multi-angle Imaging Spectro-Radiometer) and SeaWiFS (Sea-Viewing Wide Field-of-View Sensor) AOD satellite retrievals. A global decadal (2001–2010) mean PM_{2.5} concentration grid was also produced and is mapped here. Together the grids provide a continuous surface of concentrations in micrograms per cubic meter of particulate matter 2.5 micrometers or smaller (PM_{2.5}) for health and environmental research. The raster grid cell size is approximately 10 km at the equator, and the extent is from 70 degrees north to 55 degrees south latitude.

Center for International Earth Science Information Network
EARTH INSTITUTE | COLUMBIA UNIVERSITY
Data Source: van Donkelaar, A., R.V. Martin, M. Brauer, and B.L. Boys. 2015. Global Annual PM_{2.5} Grids from MODIS, MISR and SeaWiFS Aerosol Optical Depth (AOD), 1998–2012. Palisades, NY: NASA Socioeconomic Data and Applications Center (SEDAC). <http://dx.doi.org/10.7927/H4028PFS>.
© 2015. The Trustees of Columbia University in the City of New York.

SOCIOECONOMIC DATA AND APPLICATIONS CENTER (SEDAC)
A Data Center in NASA's Earth Observing System Data and Information System (EOSDIS) — Hosted by CIESIN at Columbia University

Search SEDAC... Data [Q] [User Icon]

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Map Gall
DATA SETS
DATA COLLECTIONS
FEATURED DATA USES
DATA CITATIONS
CITATIONS DATABASE

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Gridded Population of the World (GPW), v4
India Data Collection
Population Dynamics

India Winter Cropped Area, 2016
A new map collection featuring annual winter cropped area for India (2001–2016).

Featured Data Sets [More...]

Global Man-made Impervious Surface (GMIS) Dataset From Landsat, v1 (2010)
Global High Resolution Urban Data from Landsat
Overview
Download Documents
(2) Maps
To provide high spatial resolution estimates of global man-made imperviousness for the target year 2010, derived from global 30m Landsat satellite data and a companion dataset to the Global Human Built-up And Settlement Extent

Global Human Built-up And Settlement Extent (HBASE) Dataset From Landsat, v1 (2010)
Global High Resolution Urban Data from Landsat
Overview
Download Documents
(2) Maps
To provide high spatial resolution estimates of global urban extent derived from global 30m Landsat satellite data for the target year 2010 and a companion dataset to the Global Man-made Impervious Surface

News [More...]

- Population Data, Hazard Exposure, and Sustainable Repositories Addressed in Three DC Area Talks
- New Report Ranks Nations' Environmental Performance, Reveals Trends
- CIESIN Staff Honored for Ten Years of Service
- Earth Science Data Experts Hold Joint Meetings in Maryland



Annual Mean Surface PM_{2.5}

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

The screenshot shows the SEDAC website interface. At the top, the NASA logo and the text 'SOCIOECONOMIC DATA AND APPLICATIONS CENTER (SEDAC)' are visible, along with a navigation bar containing 'DATA', 'MAPS', 'THEMES', 'RESOURCES', 'SOCIAL MEDIA', 'ABOUT', and 'HELP'. A search bar at the top right contains 'PM2.5'. Below the navigation bar, the 'Data Sets (3)' section is displayed. On the left, there is a search sidebar with a search box containing 'PM2.5' (circled in red), and various filters for 'Theme' and 'Year Published'. The main content area shows search results for 'All Fields: PM2.5'. The first result is 'Global Annual PM2.5 Grids from MODIS, MISR and SeaWiFS Aerosol Optical Depth (AOD), v1 (1998–2012)', which is highlighted with a red box. This result includes an 'Overview' section, a 'Download' button, and links to '(7) Maps' and '(2) WMS'. A red arrow points from the 'Download' button to the 'Maps' link. The second result is 'Global Annual Average PM2.5 Grids from MODIS and MISR Aerosol Optical Depth (AOD), v1 (2001–2010)', which also includes an 'Overview' section, a 'Download' button, and links to '(7) Maps' and '(1) WMS'. The third result is 'Environmental Performance Index, 2014 Release (2002–2014)', which includes an 'Overview' section, a 'Download' button, and links to '(13) Maps' and '(13) WMS'.

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}

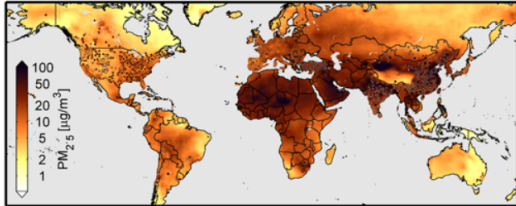
http://fizz.phys.dal.ca/~atmos/martin/?page_id=140

Atmospheric Composition Analysis Group

Research	Publications & Presentations	GEOS-Chem	Satellites	Datasets	SPARTAN	Group Info
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Surface PM_{2.5}

Global Estimates (V4.GL.02):



We estimate ground-level fine particulate matter (PM_{2.5}) by combining Aerosol Optical Depth (AOD) retrievals from the NASA MODIS, MISR, and SeaWiFS instruments with the GEOS-Chem chemical transport model, and subsequently calibrated to global ground-based observations of PM_{2.5} using Geographically Weighted Regression (GWR) as detailed in the below reference.

References:
van Donkelaar, A., R.V. Martin, M. Brauer, N. C. Hsu, R. A. Kahn, R. C. Levy, A. Lyapustin, A. M. Sayer, and D. M. Winker, **Global Estimates of Fine Particulate Matter using a Combined Geophysical-Statistical Method with Information from Satellites, Models, and Monitors**, *Environ. Sci. Technol.*, doi: 10.1021/acs.est.5b05833, 2016. [\[Link\]](#)

Estimates prior to 2008 incorporate temporal information from:

Boys, B.L., Martin, R.V., van Donkelaar, A., MacDonell, R., Hsu, N.C., Cooper, M.J., Yantosca, R.M., Lu, Z., Streets, D.G., Zhang, Q., Wang, S., **Fifteen-year global time series of satellite-derived fine particulate matter**, *Environ. Sci. Technol.*, 10.1021/es502113p, 2014. [\[Link\]](#)

van Donkelaar, A., R. V. Martin, M. Brauer and B. L. Boys, **Global fine particulate matter concentrations from satellite for long-term exposure assessment**, *Environmental Health Perspectives*, 123, 135-143, DOI:10.1289/ehp.1408646, 2015. [\[Link\]](#)

Scientific Datasets:
Global resolved datasets are provided in ArcGIS-compatible NetCDF [.nc] or zipped ASCII [.asc.zip] file. Note that the unzipped ASCII files can be cumbersome. Gridded files use the WGS84 projection. Corresponding files for Google Earth are also provided [.kmz]. Country means are also provided in a comma separated ascii (.csv) format. Dust and Sea-Salt Removed PM_{2.5} estimates apply simulated compositional information to our full-composition values, following van Donkelaar et al., EHP, 2015. Other extractions can often be produced upon request. Please contact Aaron van Donkelaar (Aaron.van.Donkelaar@dal.ca) for further information.

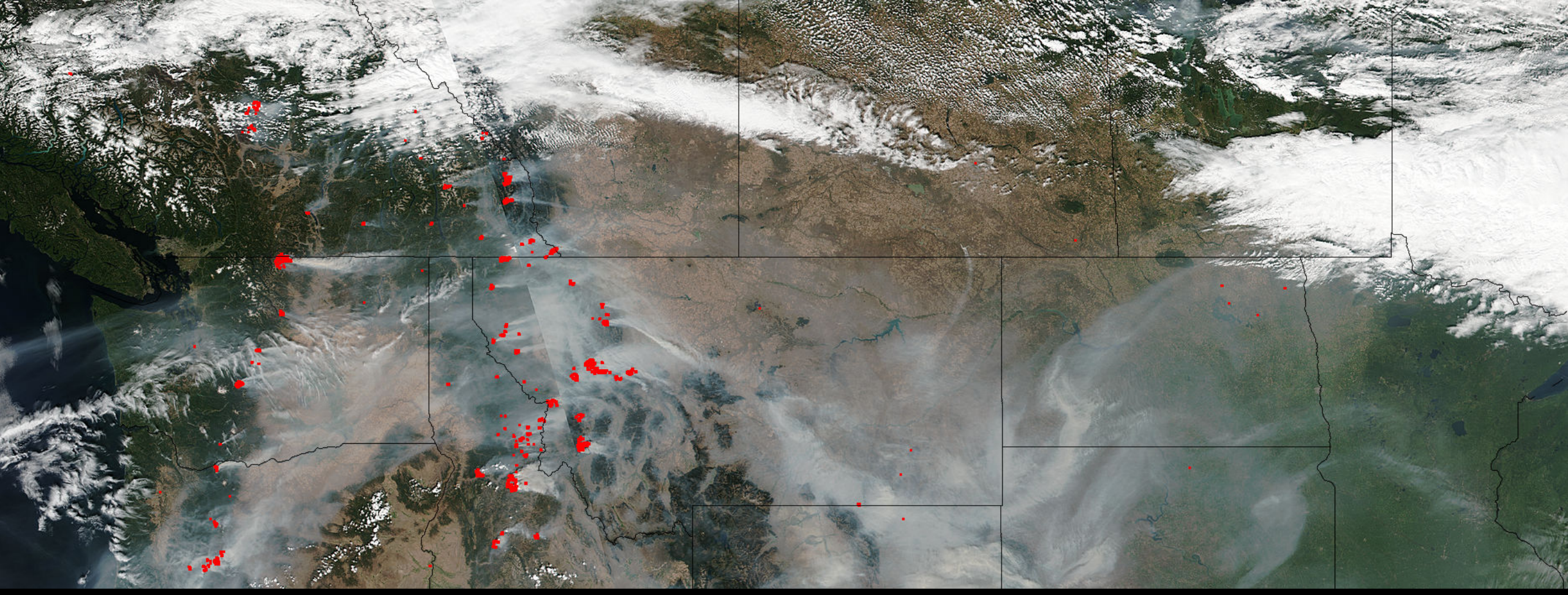


Satellite-Based Estimates

Limitations

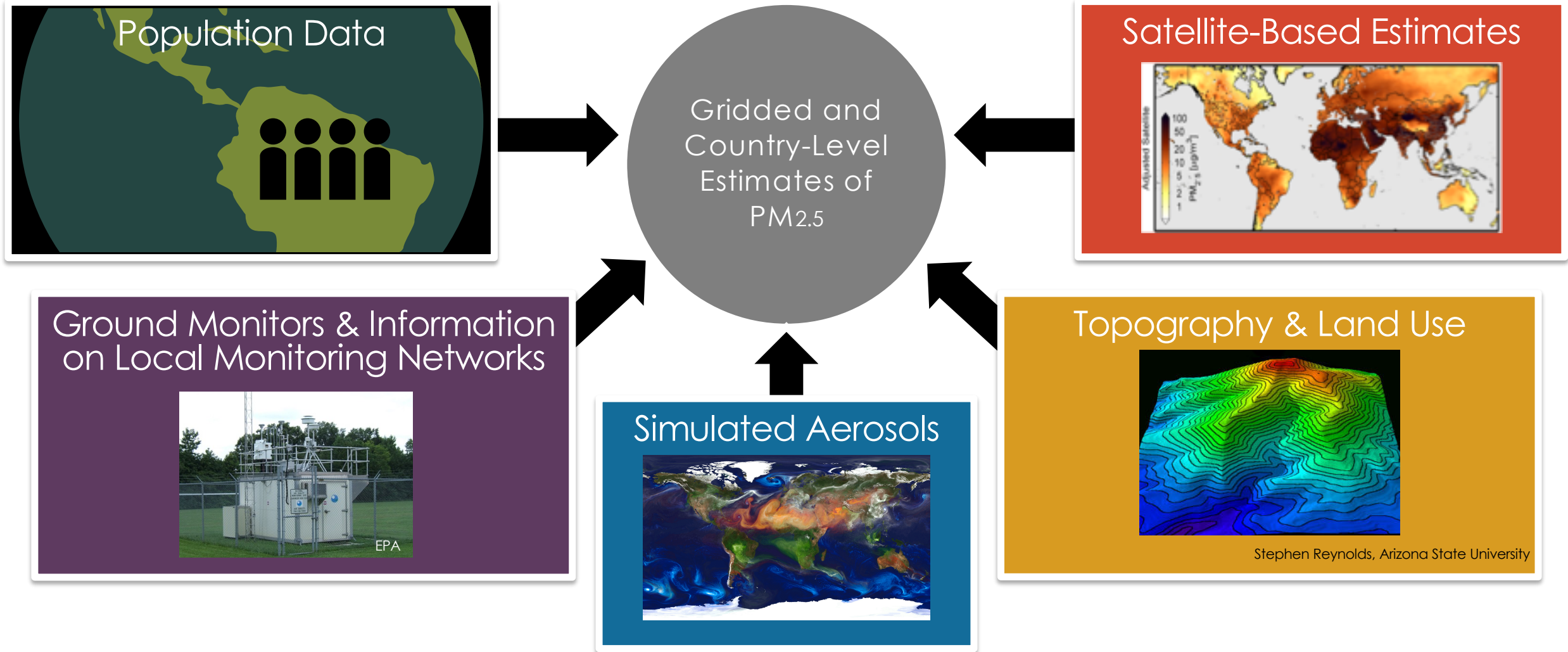
- The van Donkelaar estimate provides annual mean estimates of PM_{2.5}
- However, this and other estimates do not provide an analysis of uncertainties
- The WHO and the University of Bath have led the development of the Data Integration Model for Air Quality (DIMAQ)
 - This model estimates PM_{2.5}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





Data Integration Model for Air Quality (DIMAQ)

Data Integration Model for Air Quality (DIMAQ)



Data Integration Model for Air Quality (DIMAQ)

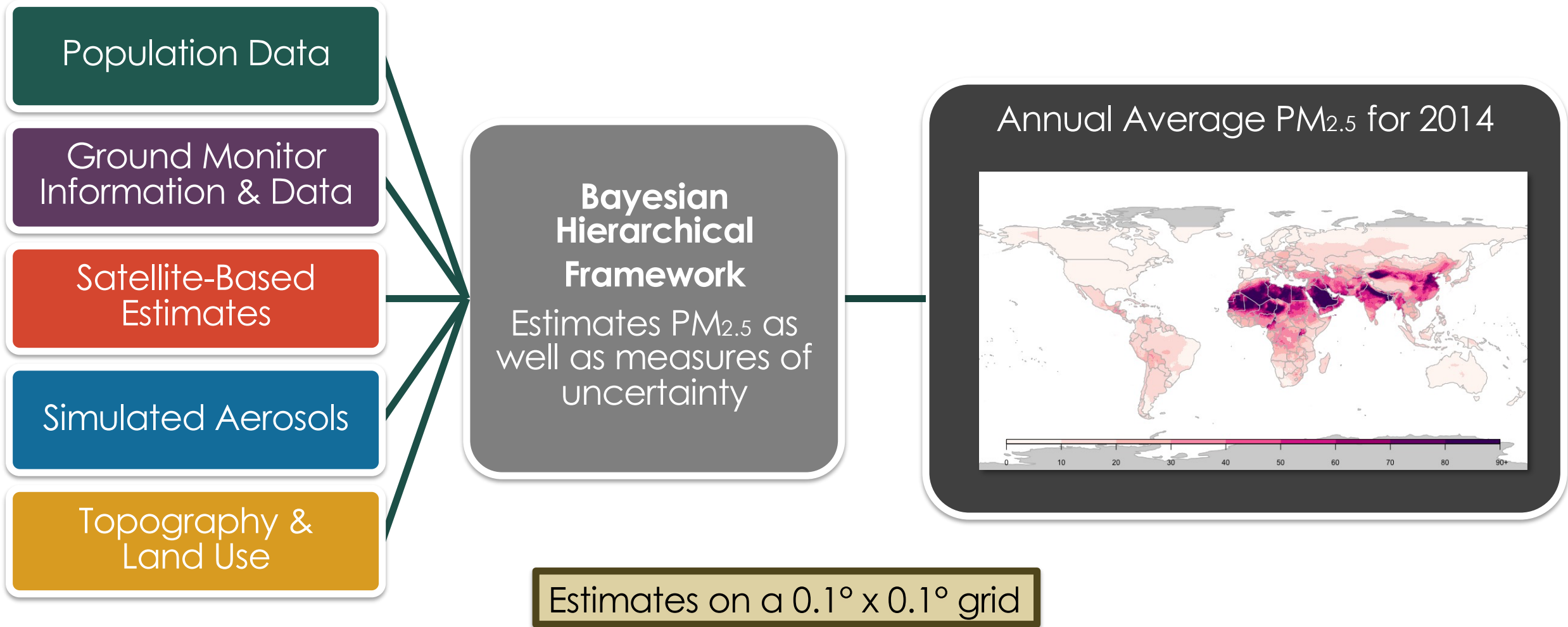
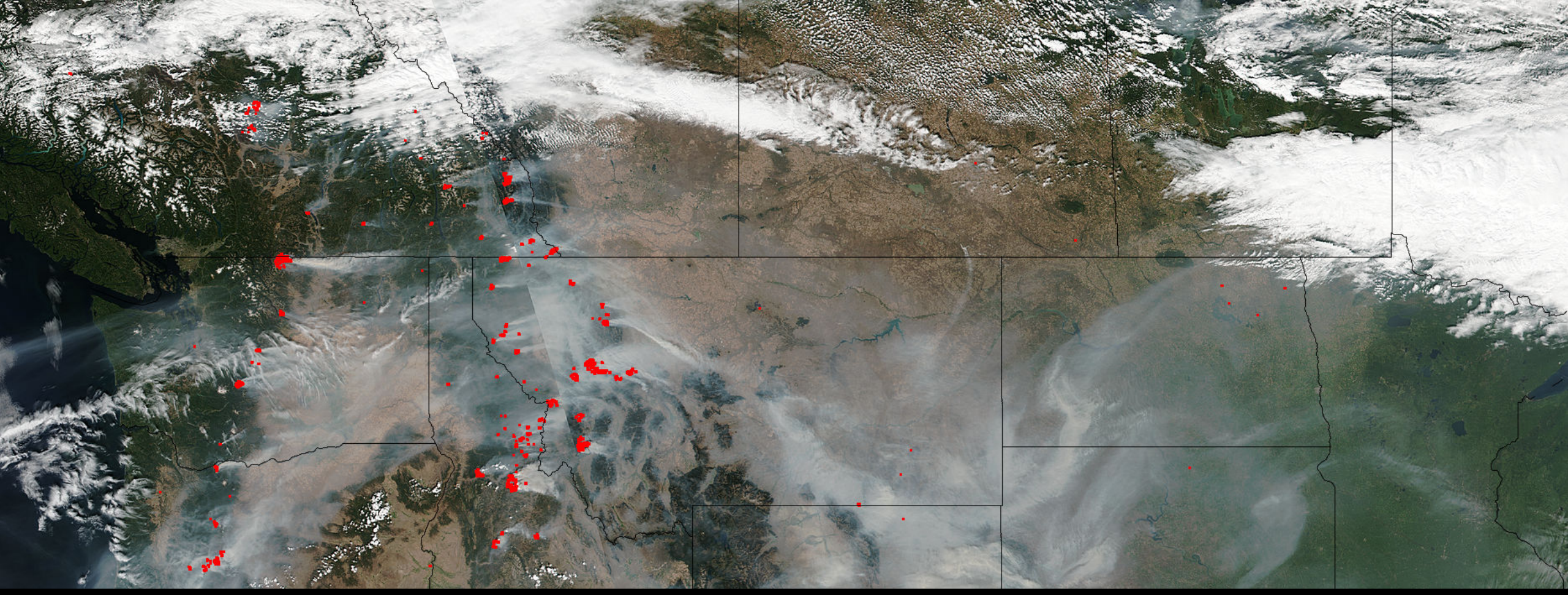


Image Credit (Right): Shaddick, et al. (2018), Figure 7 (top)





Available World Health Organization (WHO) Tools

Where to Find and View the Data

WHO Website – Country Level

Global Health Observatory (GHO) data

Global Health Observatory data

Data repository

Reports

Country statistics

Map gallery

Standards

Exposure to ambient air pollution

The mean ambient air pollution of particulate matter with an aerodynamic diameter of 2.5 μm or less (PM_{2.5}) in country urban areas ranges from less than 10 to over 100 $\mu\text{g}/\text{m}^3$. In urban areas, the mean concentration of particulate matter with an aerodynamic diameter of 2.5 μm or less (PM_{2.5}) ranges from less than 10 to over 100 $\mu\text{g}/\text{m}^3$, and from less than 10 to over 200 $\mu\text{g}/\text{m}^3$ for particulate matter with an aerodynamic diameter of 10 μm or less (PM₁₀)

Situation at country level

View interactive map/graph

View data

Read more

Situation at grid level

View interactive map

View data, metadata and detailed methods of estimation

Situation at city level

View full size map (PM₁₀)

View full size map (PM_{2.5})

View data | Read more

More PHE data products

Maps

Reports

Country profiles

Global Health Observatory (GHO) data - Ambient air pollution

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

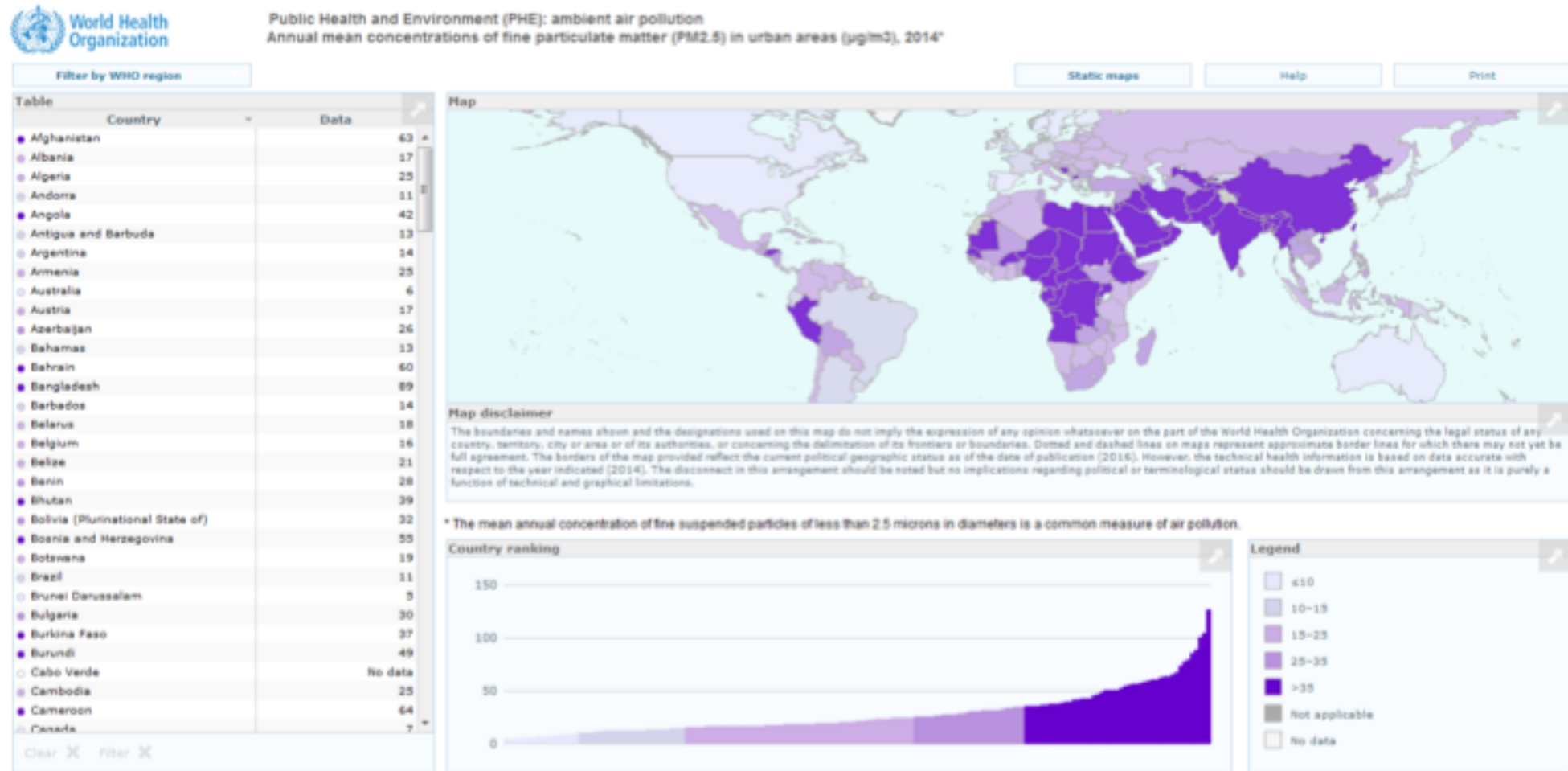
Follow this link to download 2014 country level data:

- 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

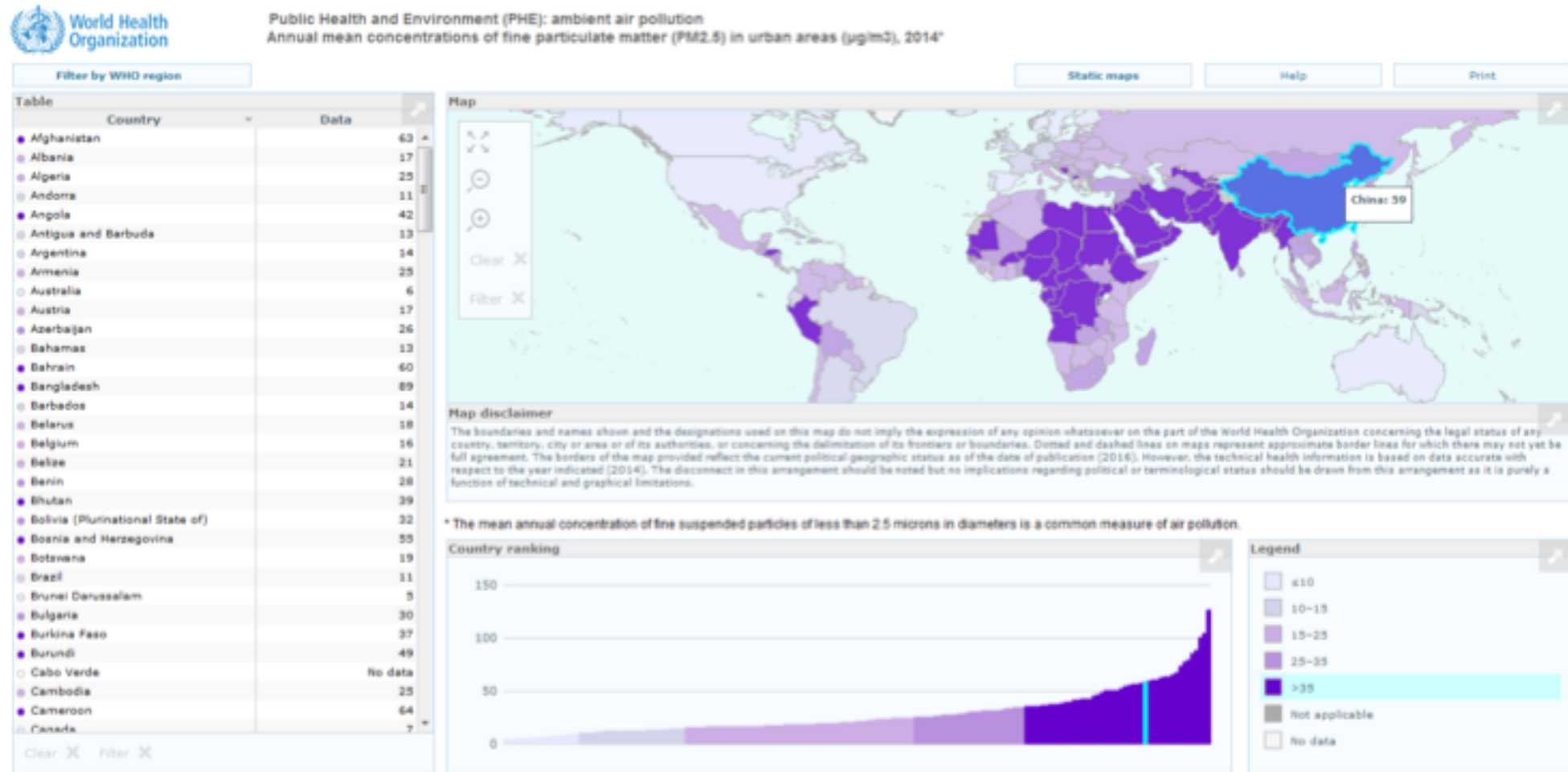


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PM_{2.5} at Country Level

http://gamapserver.who.int/gho/interactive_charts/phe/oap_exposure/atlas.html



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Where to Find and View the Data

WHO Website – Grid Level

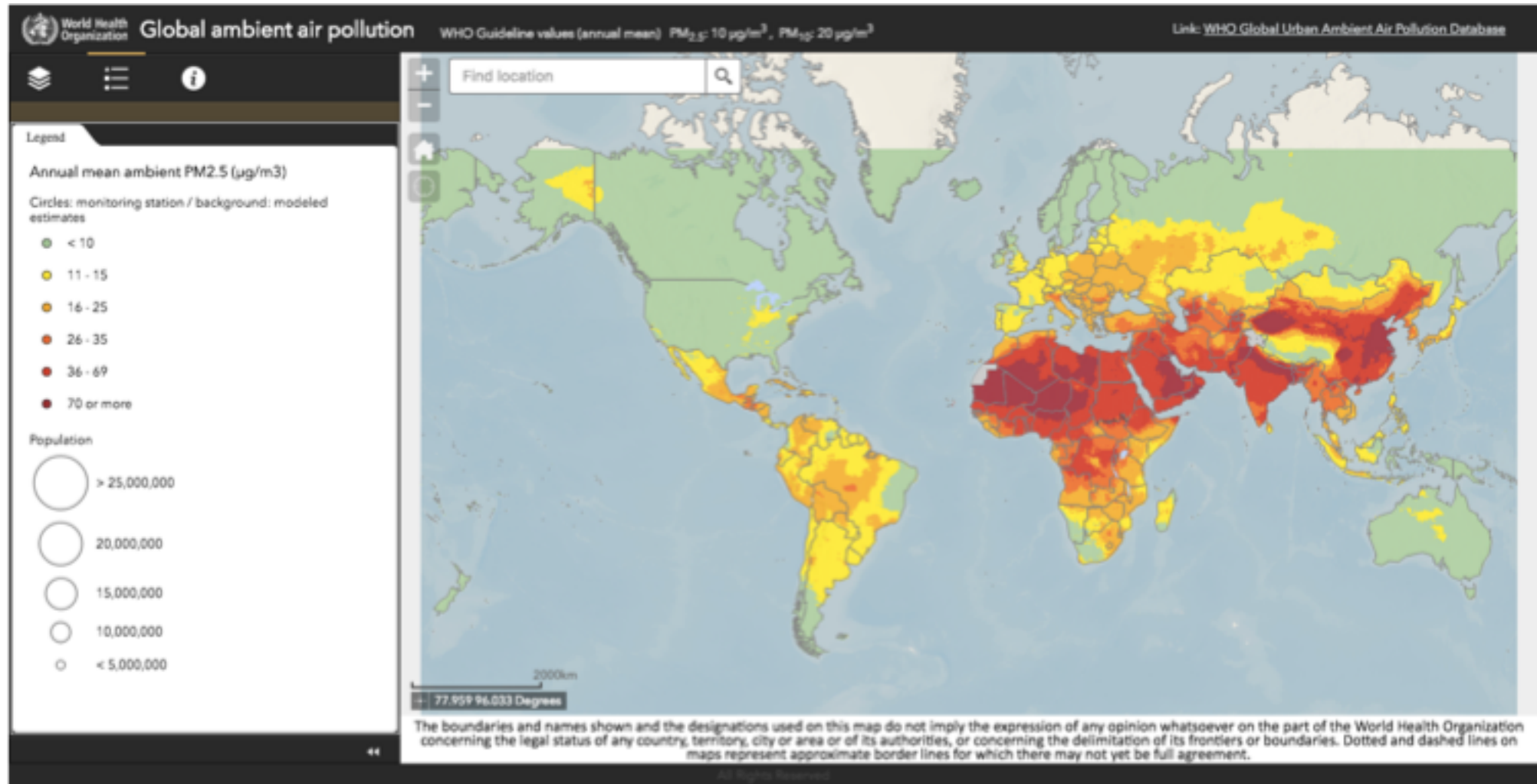
The screenshot shows the WHO Global Health Observatory (GHO) data page for ambient air pollution. The page is titled "Global Health Observatory (GHO) data" and "Exposure to ambient air pollution". It features a navigation menu on the left with links for "Global Health Observatory data", "Data repository", "Reports", "Country statistics", "Map gallery", and "Standards". The main content area is divided into three sections: "Situation at country level", "Situation at grid level", and "Situation at city level". The "Situation at grid level" section is highlighted with a red box and contains the following links: "View interactive map", "View data, metadata and detailed methods of estimation", and "View data, metadata and detailed methods of estimation". The "Situation at city level" section contains links for "View full size map (PM10)", "View full size map (PM2.5)", and "View data | Read more". A "More PHE data products" sidebar on the right includes links for "Maps", "Reports", "Country profiles", and "Links".

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



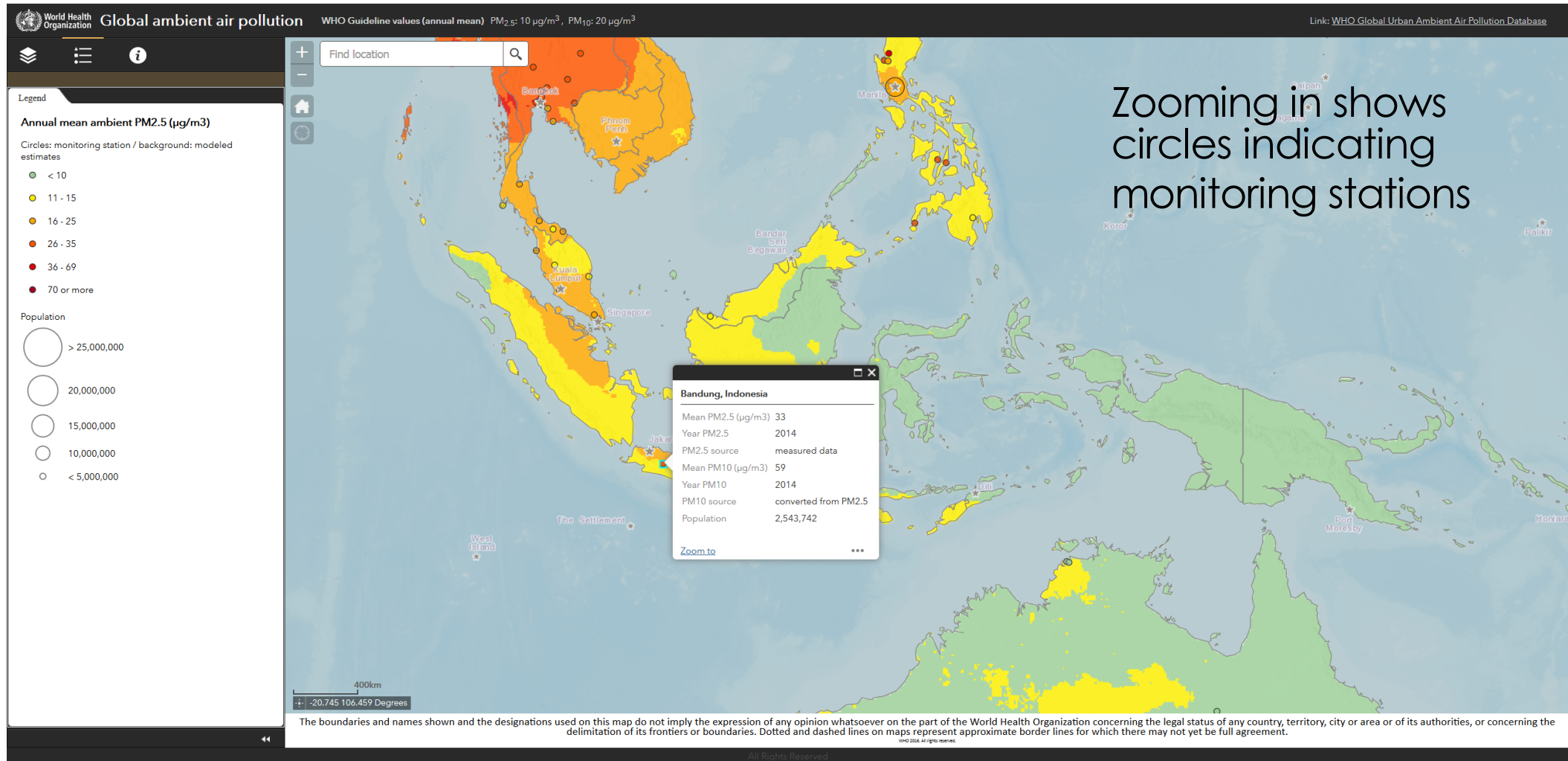
PM_{2.5} at Grid Level

<http://maps.who.int/airpollution/>



PM_{2.5} at Grid Level

<http://maps.who.int/airpollution/>



PM_{2.5} at Grid Level

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

Public health, environmental and social determinants of health (PHE)

Public health, environmental and social determinants of health

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Health topics





Publications

Modelled Global Ambient Air Pollution estimates

Estimation of global health risks from exposure to ambient air pollution requires a comprehensive set of air pollution exposure data covering all inhabited areas. The recently developed Data Integration Model for Air Quality (DIMAQ) has produced estimates based on data from ground measurements together with information from other sources including data from satellite retrievals of aerosol optical depth and chemical transport models. It provides estimates of annual exposures of PM_{2.5} levels at high spatial resolution (0.1° × 0.1°, which equates to approximately 11x11km at the equator) globally.

The sources of data include: Ground measurements from 6 003 monitoring locations around the world, satellite remote sensing; population estimates; topography; and information on local monitoring networks and measures of specific contributors of air pollution from chemical transport models. The DIMAQ model calibrates data from these sources with ground measurements. This model has provided produced estimates of air quality, expressed in terms of median concentrations of PM_{2.5}, for all regions of the world, including areas in which PM_{2.5} monitoring is not available.

This model has been developed by an international group of experts, and led by the University of Bath and WHO.

- [Global ambient air pollution map](#)  Global map containing both modelled and monitored annual mean PM_{2.5} levels.
- [DIMAQ database, 2014 data](#)  csv, 51.33Mb
Contains the following rows: longitude, latitude, country code, PM_{2.5} (annual average PM_{2.5} in µg/m³, for 2014)
- [Detailed methods for DIMAQ](#)  Data Integration Model for Air Quality: A Hierarchical Approach to the Global Estimation of Exposures to Ambient Air Pollution
- [Meta-data file for DIMAQ](#)  xlsx, 156kb



Related links

[Ambient air pollution: A global assessment of exposure and burden of disease](#)

[More on ambient air pollution](#)

- ← 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_a
ir_pollution/exposure/en/](http://www.who.int/gho/phe/outdoor_a
ir_pollution/exposure/en/)

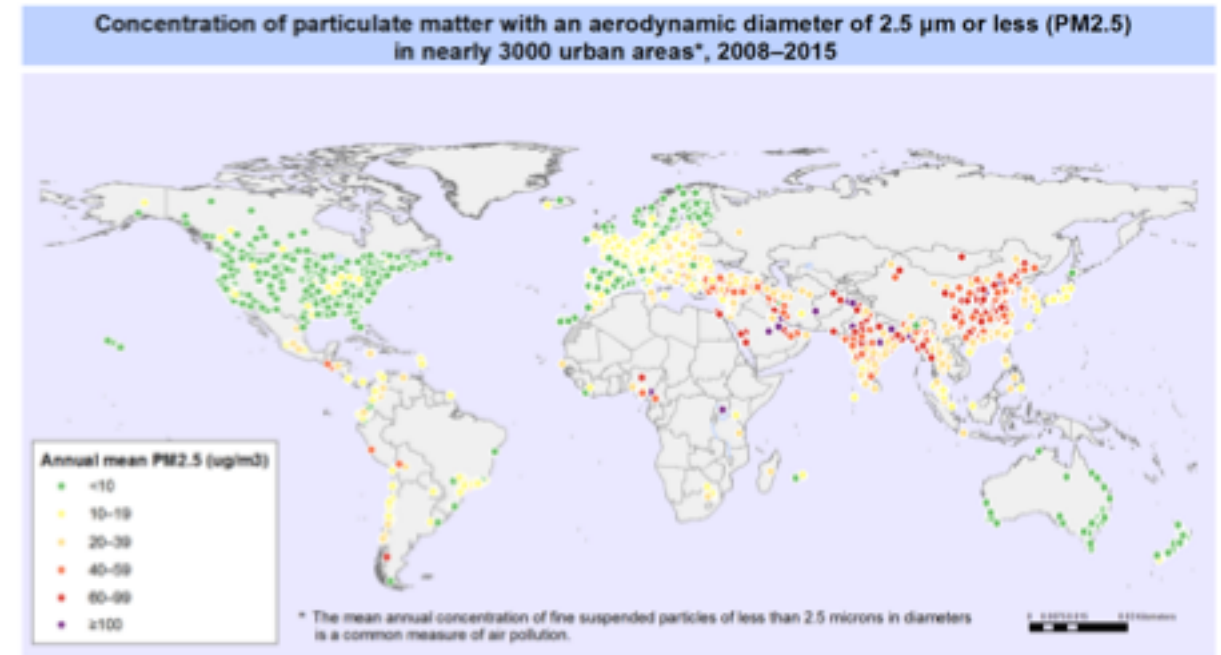
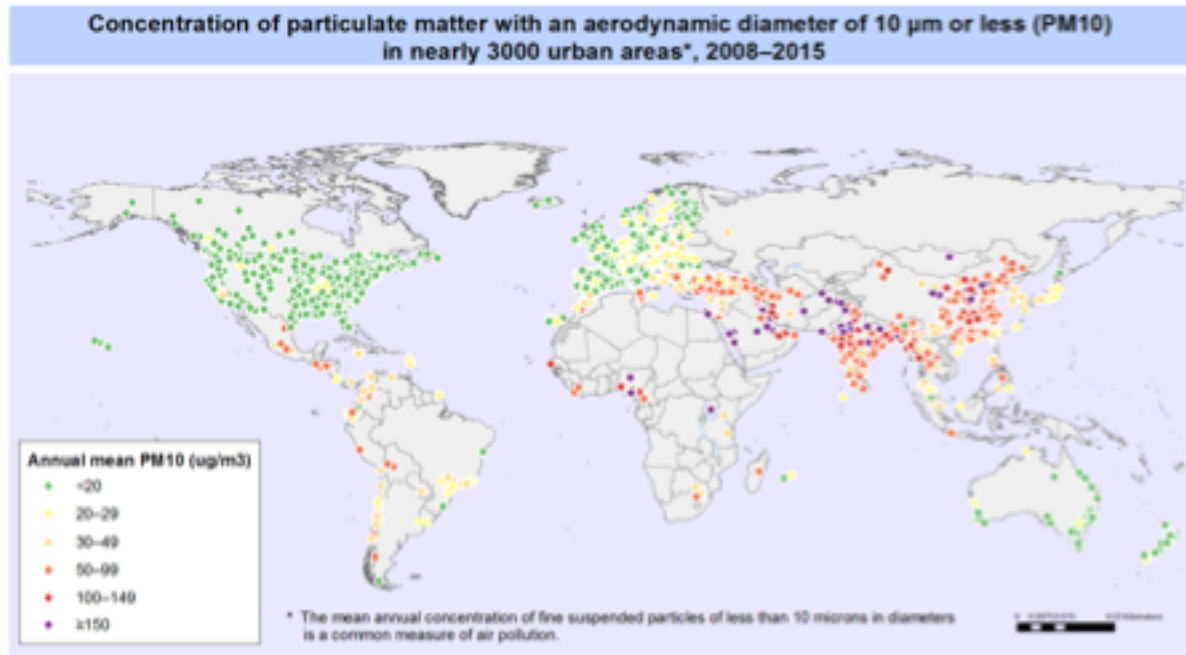
The screenshot shows the WHO Global Health Observatory (GHO) data page for 'Exposure to ambient air pollution'. The page is titled 'Global Health Observatory (GHO) data' and 'Exposure to ambient air pollution'. It features a navigation menu on the left with links for 'Global Health Observatory data', 'Data repository', 'Reports', 'Country statistics', 'Map gallery', and 'Standards'. The main content area includes a descriptive paragraph about ambient air pollution, a 'Situation at country level' section with a world map and a 'View interactive mapgraph' link, a 'Situation at grid level' section with a world map and a 'View interactive map' link, and a 'Situation at city level' section with a world map and links for 'View full size map (PM10)', 'View full size map (PM2.5)', and 'View data | Read more'. The 'View full size map (PM10)' and 'View full size map (PM2.5)' links are highlighted with a red box. A footer at the bottom reads 'Global Health Observatory (GHO) data > Ambient air pollution'.

← Maps of city level PM₁₀ 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/

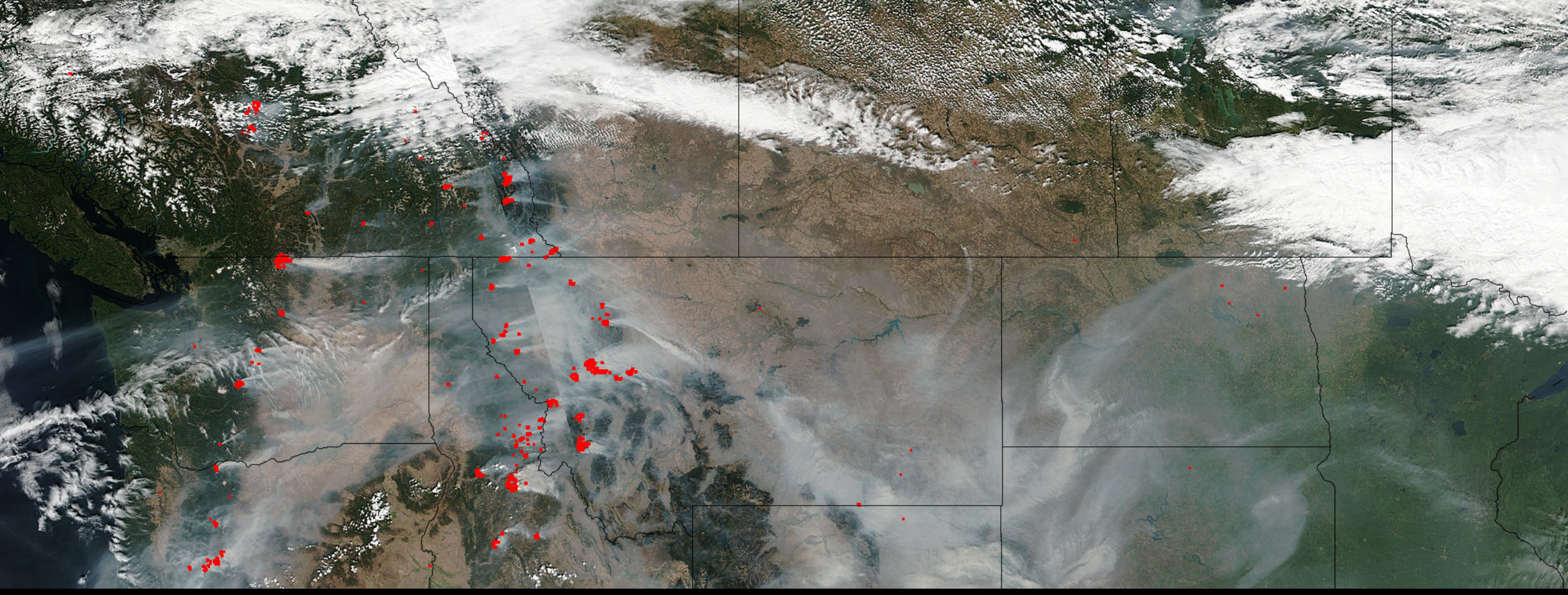


Where to Find the Data

NASA Aura Validation Data Center

- Dr. Pawan Gupta has subsetted the DIMAQ gridded data by country
- The individual country .csv files are available at:
 - http://avdc.gsfc.nasa.gov/pub/tmp/WHO_PM25_2014_COUNTRY_DATA/
- There is also a readme.txt file



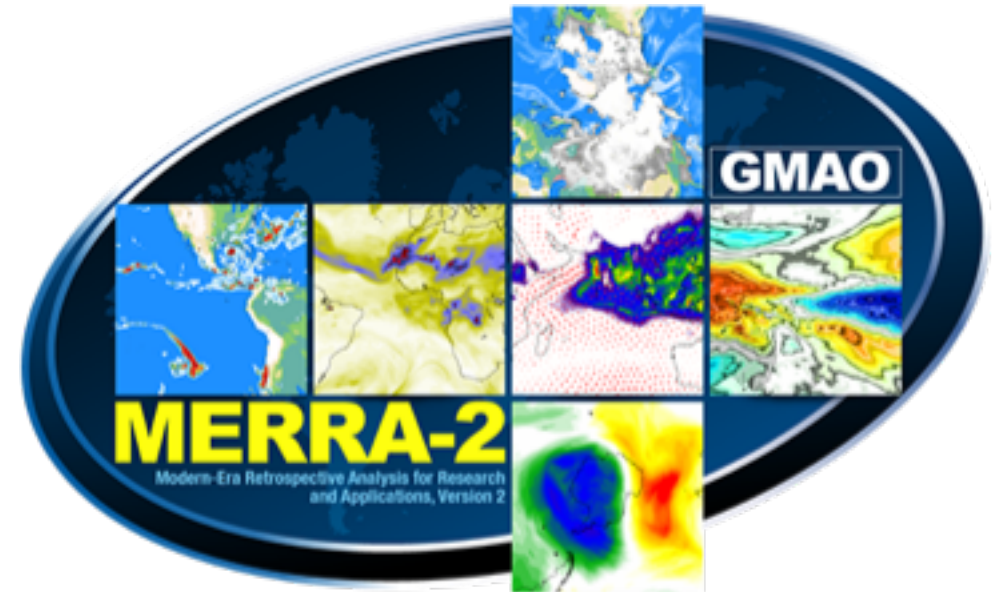


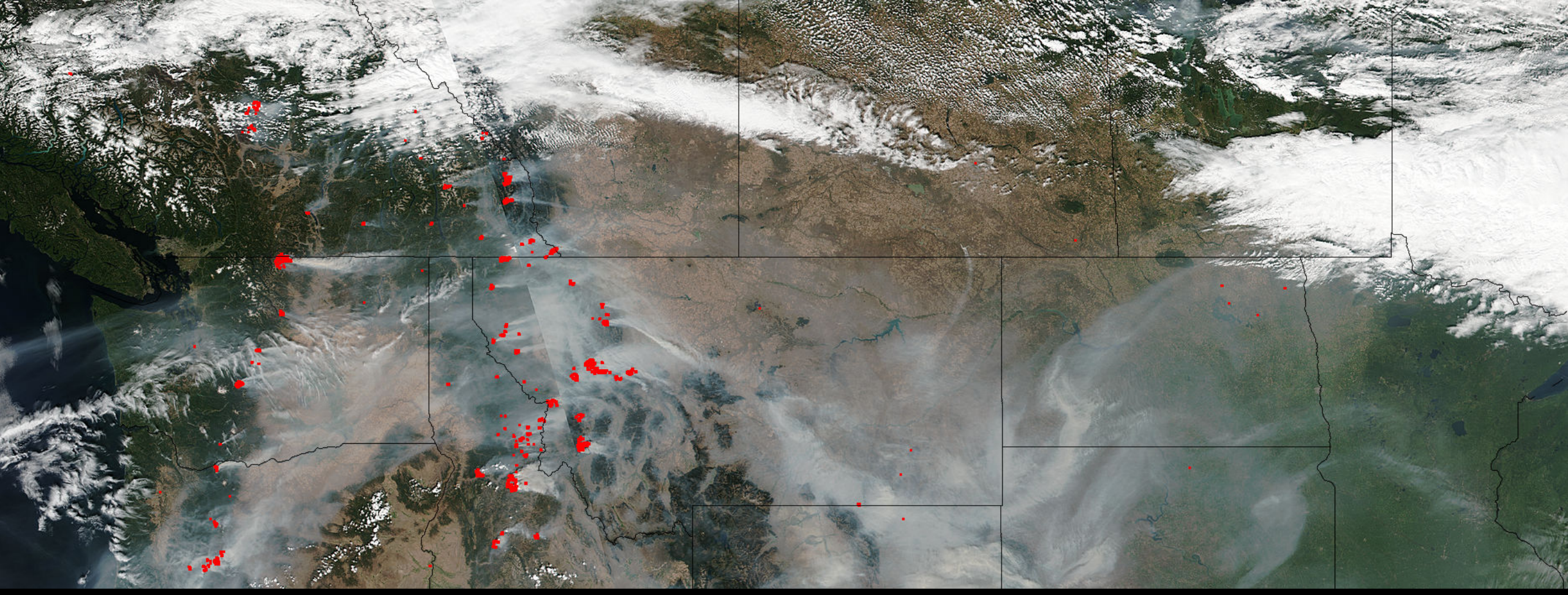
NASA GMAO MERRA-2 Model Output

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