Satellite-Derived Fine Particulate Matter ($PM_{2.5}$)

Randall Martin

with contributions from

Chi Li, Xuan Liu, Christopher Oxford, Yuxuan Ren, Siyuan Shen, Aaron van Donkelaar, Dandan Zhang

WashU

ACAG

Michael Brauer (UBC), Michael Garay (JPL), Christina Hsu (NASA), Olga Kalashnikova (JPL), Ralph Kahn (CU Boulder), Robert Levy (NASA), Alexei Lyapustin (NASA), Yinon Rudich (Weizmann), Andrew Sayer (NASA)

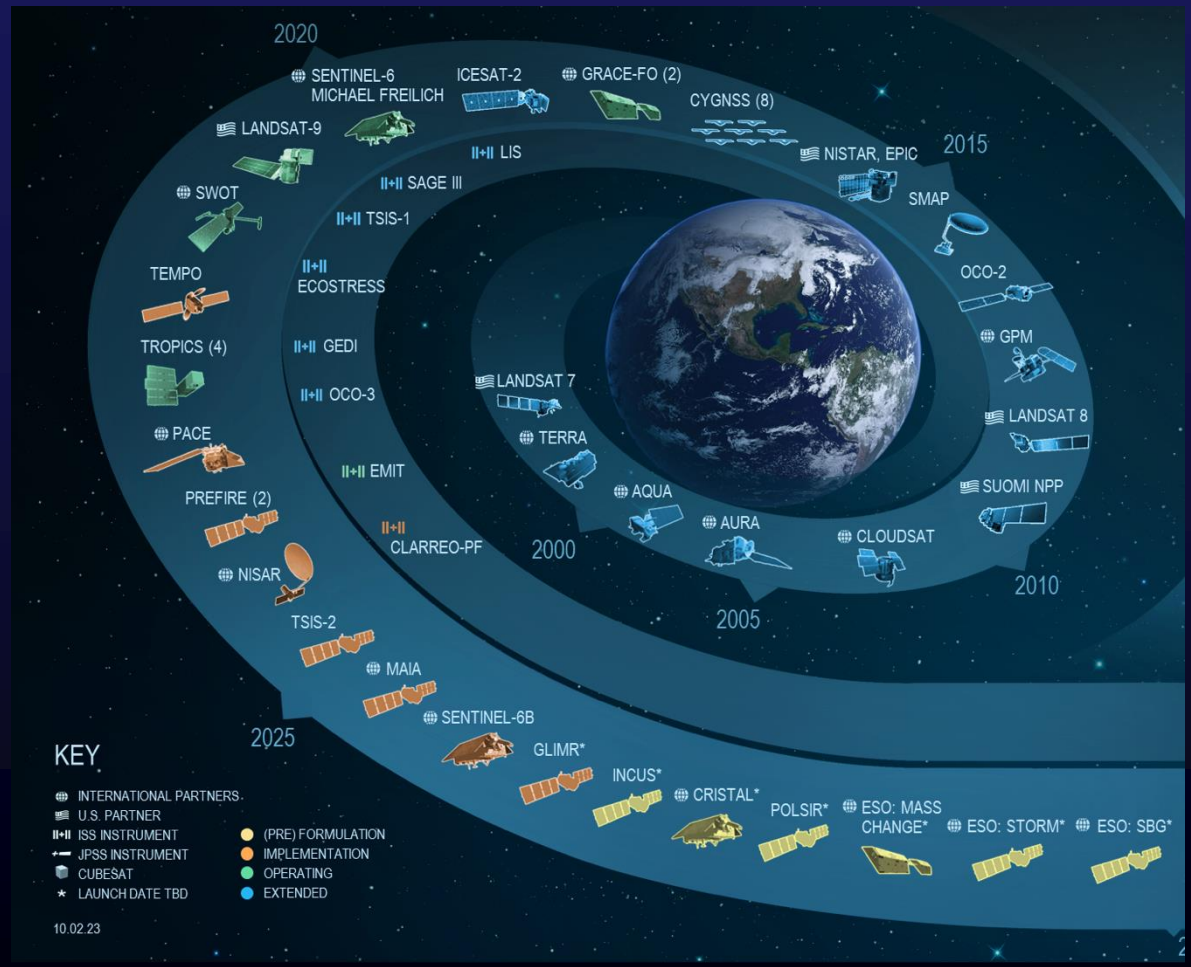
HAQAST Showcase
Washington DC
January 28, 2025

Use Satellite Observations as Primary Data Source
Motivated by Large Gaps in Ground-Based Monitoring

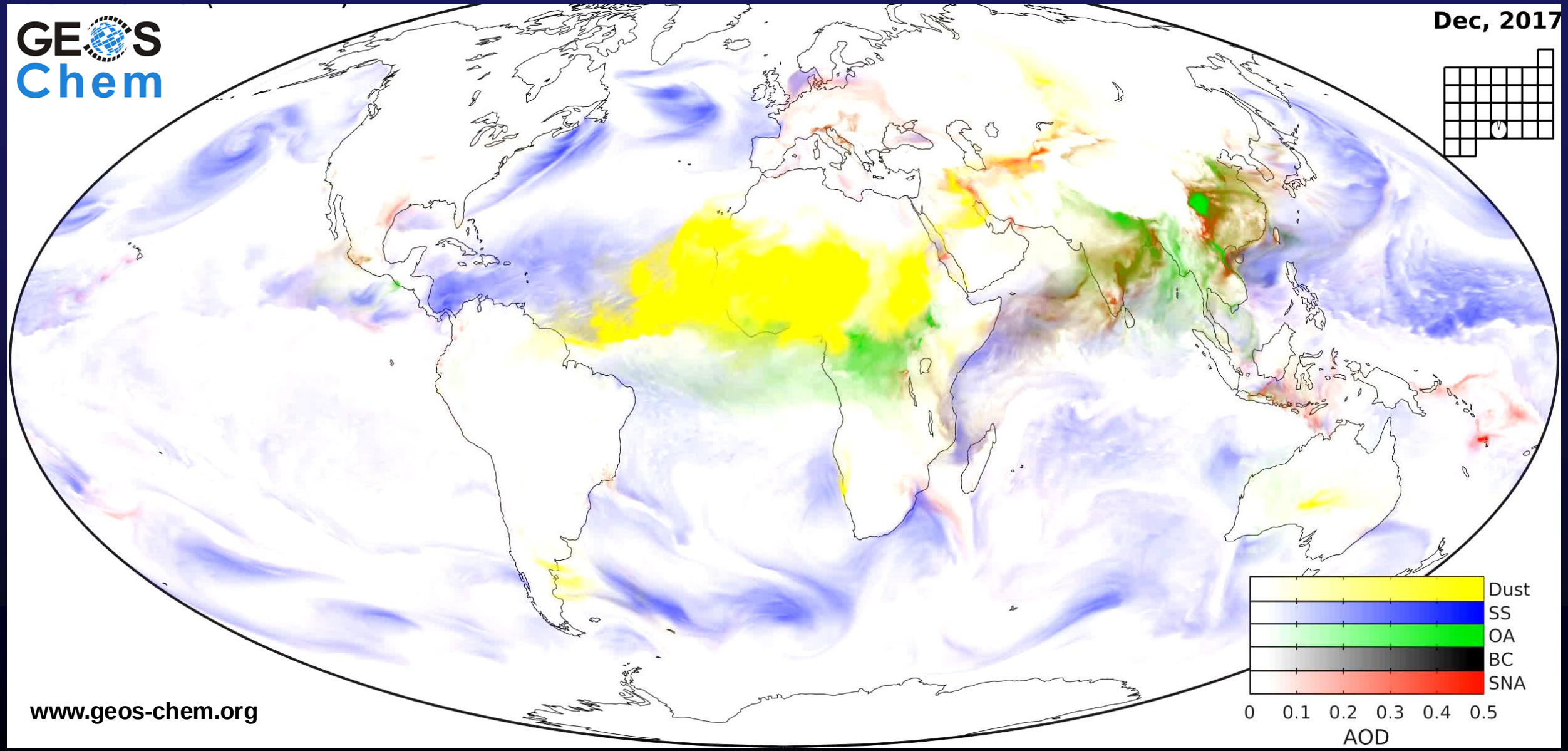
Instruments: MODIS-Terra, MODIS-Aqua, VIIRS-SNPP, VIIRS-NOAA20, MISR, SeaWiFS

Algorithms: MAIAC, Deep Blue, Dark Target, MISR

Large and growing constellation of observations



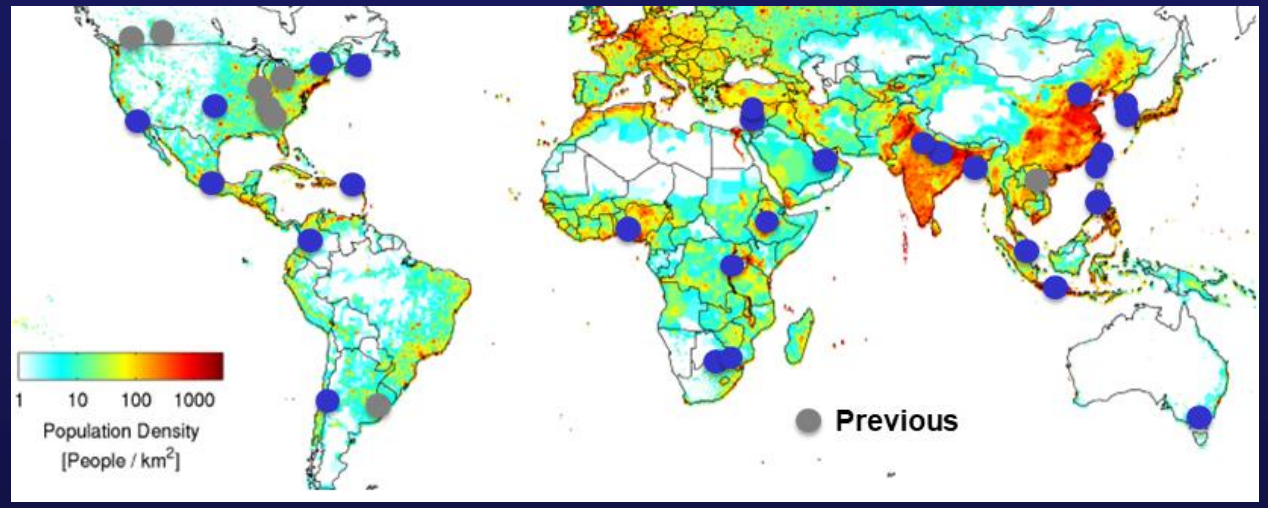
Apply Chemical Transport Model (GEOS-Chem) to Calculate Spatially- and Temporally-Varying Relationship of AOD with $PM_{2.5}$

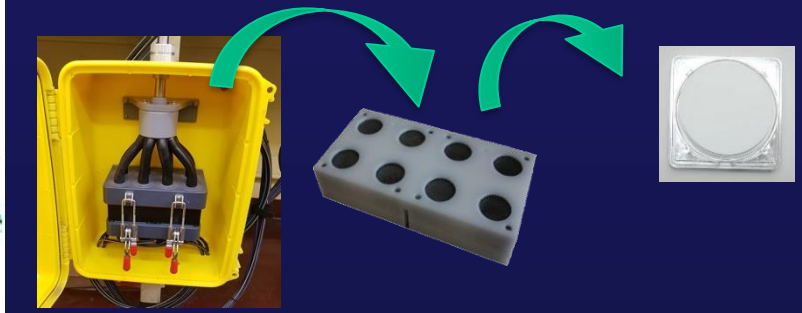


Simulation on NASA Pleiades supercomputer

Dandan Zhang

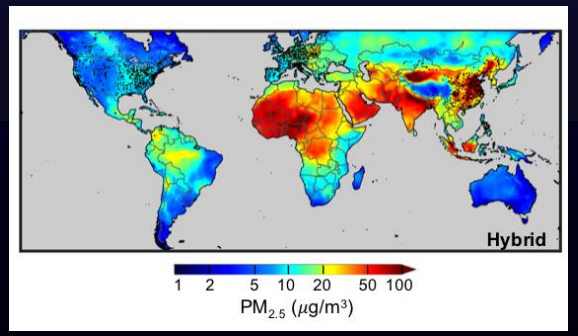
A Growing Harmonized Air Quality Network: Surface Particulate Matter Network (SPARTAN)





The only global $PM_{2.5}$ composition network: offers information about sources

Supporting satellite-based $PM_{2.5}$ inference



SPARTAN
Global Particulate Matter Network

www.spartan-network.org

Overall operations led by Chris Oxford

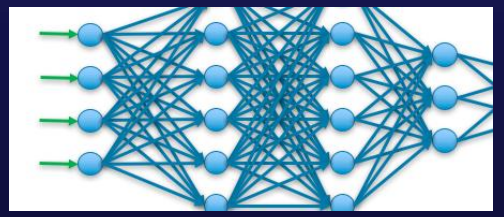
Deep Learning With Geophysical A Priori Information

Aerosol Optical Depth (AOD) from multiple satellite instruments and algorithms constrained with AERONET

Calculate coincident local solution to $PM_{2.5} = f(x,y,t,AOD)$

GEOS Chem

Geophysical Satellite-Based $PM_{2.5}$



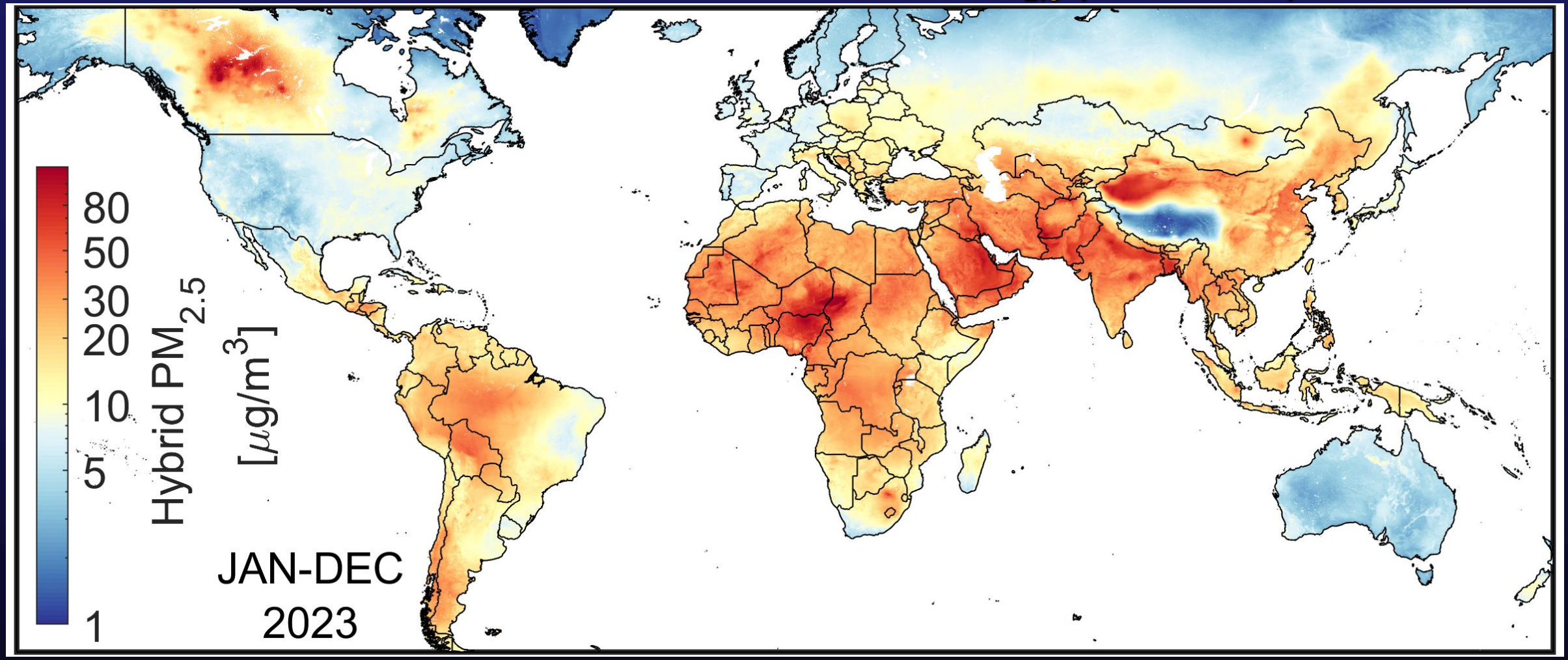
Deep Learning

Monitoring networks

Hybrid $PM_{2.5}$ Estimates

Shen et al., 2024

26-Year Record of Satellite-Derived $PM_{2.5}$ (1998-2023)



World Health Organization global annual mean $PM_{2.5}$ guideline: 5 ug/m^3

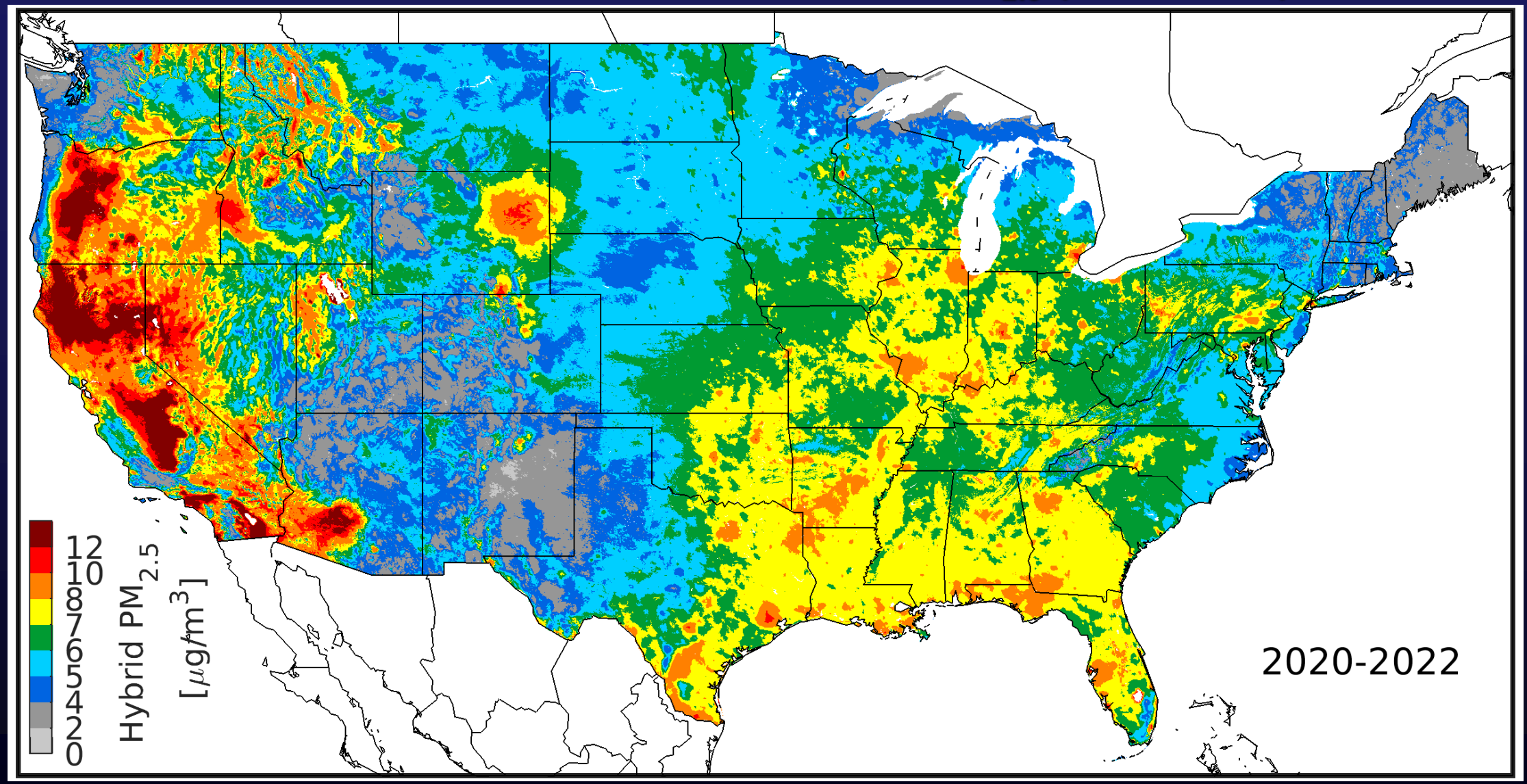
Information source for

Global Burden of Disease
OECD Regional Well Being Index
World Health Organization
UN Development Program

HEI State of Global Air
Air Quality Life Index
World Bank
UNICEF

Environmental Performance Index
Environmental Systems Research Institute (ESRI)

26-Year Record of Satellite-Derived $PM_{2.5}$ (1998-2023)



US annual mean $PM_{2.5}$ standard: 9 ug/m³

Information source for

EPA Science Assessments
American Lung Association State of the Air
US Census Bureau
Epidemiological studies

Learning about Association with Health Outcomes through Epidemiological Studies

Benefits from Large Statistical Power

- Cardiovascular disease (Bai et al., JAHA 2022; Liang et al., 2022; Kim et al., STOTEN, 2024)
- Cognitive development in children (Odo et al., Environ. Poll., 2023)
- COVID-19 outcomes (Bowe et al., Env. Int., 2021; Chen et al.,CMAJ,2022)
- Dementia (Li et al., Innovation, 2022; Shi et al., PNAS, 2023)
- Diabetes incidence (Elten et al., Environ. Res., 2021)
- Heart attack and stroke (Olaniyan et al., Env. Research, 2022)
- Pregnancy & birth outcomes (Johnson et al., Epidemiology, 2022)
- Respiratory infection in children (Odo et al., Env. Int., 2022)
- Shape of exposure-response function at low concentrations (Weichenthal et al., Science Adv., 2022)

Conclusions

- Utility of $PM_{2.5}$ concentrations inferred from satellite remote sensing, chemical transport modeling, and ground-based measurements
- Data supports national and international assessments