Global Estimates of Long-Term Fine Particulate Matter Concentrations Derived from Multiple Data Sources

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with contributions from

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CEOS Virtual Meeting
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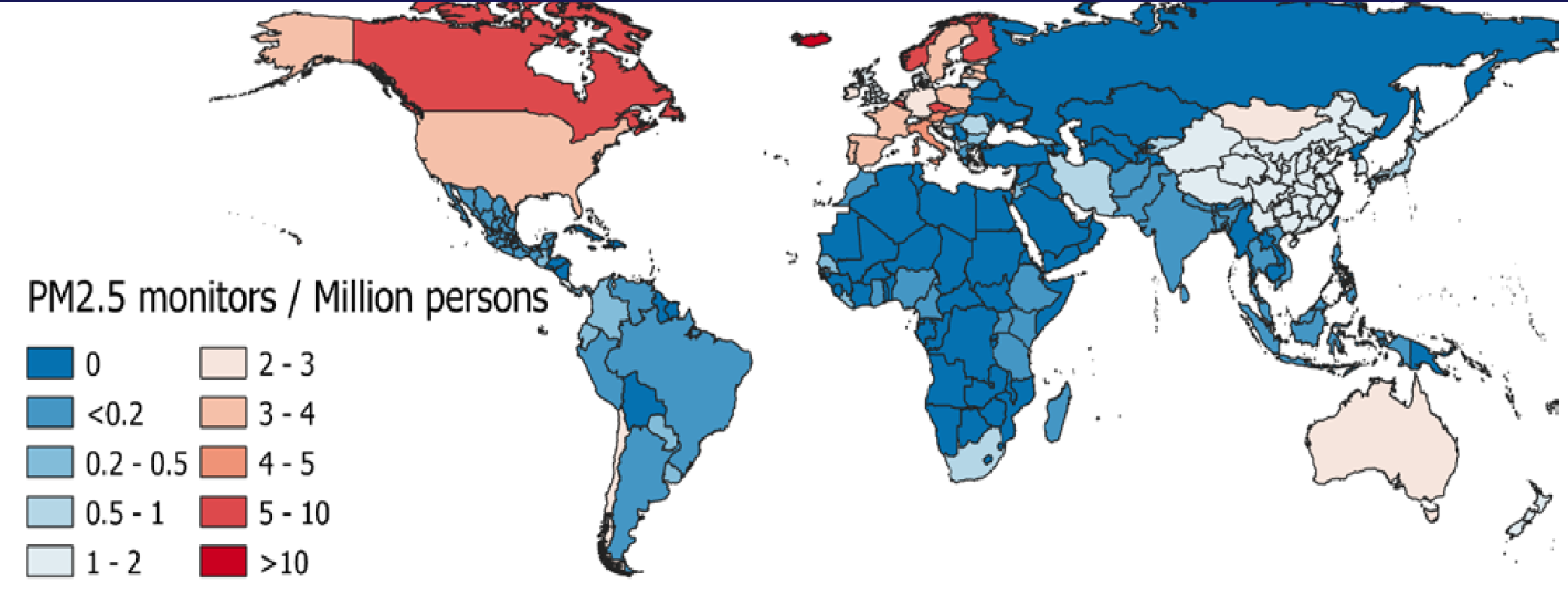
Vast Regions Have Insufficient $PM_{2.5}$ Measurements for Exposure Assessment

No One Knows Where is the City with the Highest $PM_{2.5}$ Concentrations

Density of Long-Term $PM_{2.5}$ Monitoring Sites



Number of $PM_{2.5}$ monitors per million inhabitants by country for any of the years 2010-2016.

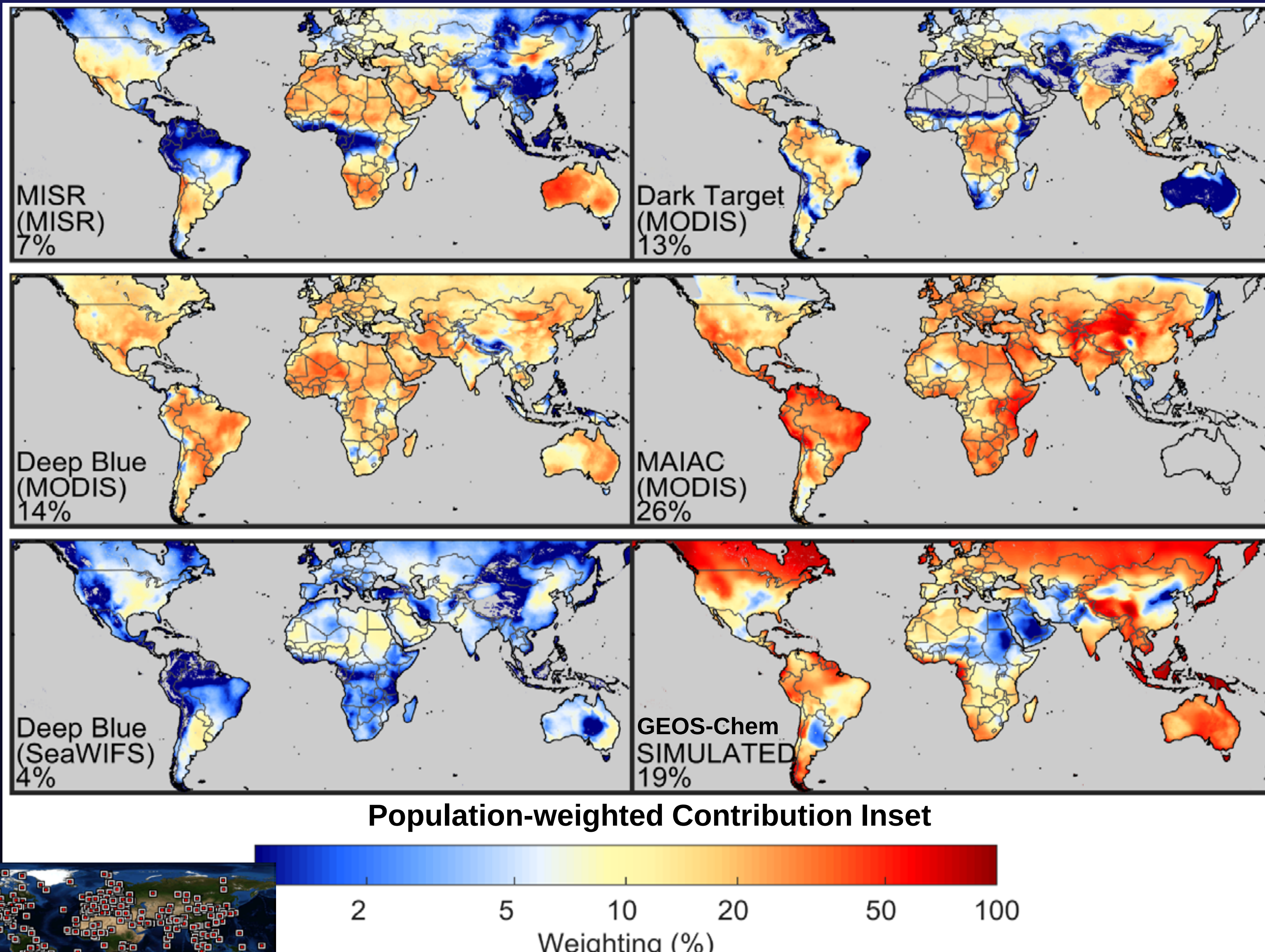
Many countries have no $PM_{2.5}$ monitoring

Global population-weighted distance to monitor = 220 km

Martin et al., AE, 2019

Long-Term (1998-2018) Aerosol Optical Depth (AOD)

Use AERONET AOD to Assess Relative Accuracy & Combine



Hammer, van Donkelaar, et al., ES&T, 2020

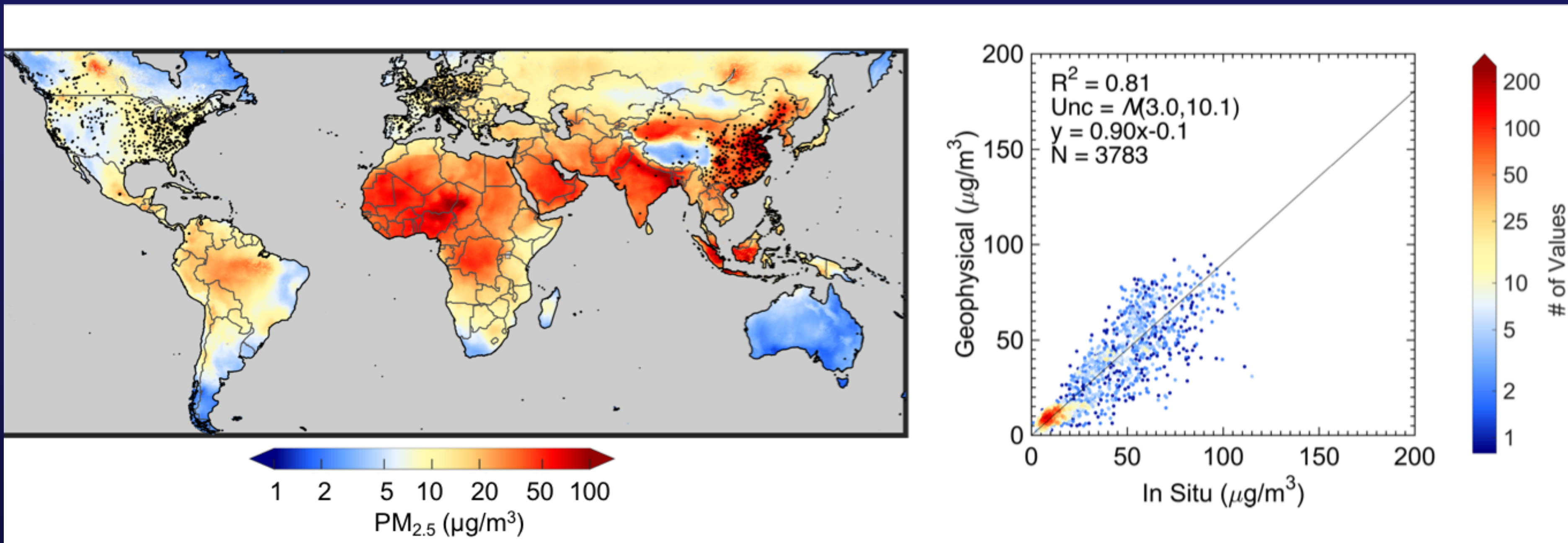
Apply Chemical Transport Model (GEOS-Chem) to Calculate Solution to $PM_{2.5} = f(x,y,t,AOD)$

Simulate suite of processes relating AOD&$PM_{2.5}$: e.g. aerosol vertical profile, mass scattering efficiency, hygroscopicity, relative humidity, chemical composition, diurnal variation, irregular sampling

Coincident sampling with observations

Aaron van Donkelaar & Melanie Hammer

Geophysical Satellite-Derived $PM_{2.5}$ for 2015



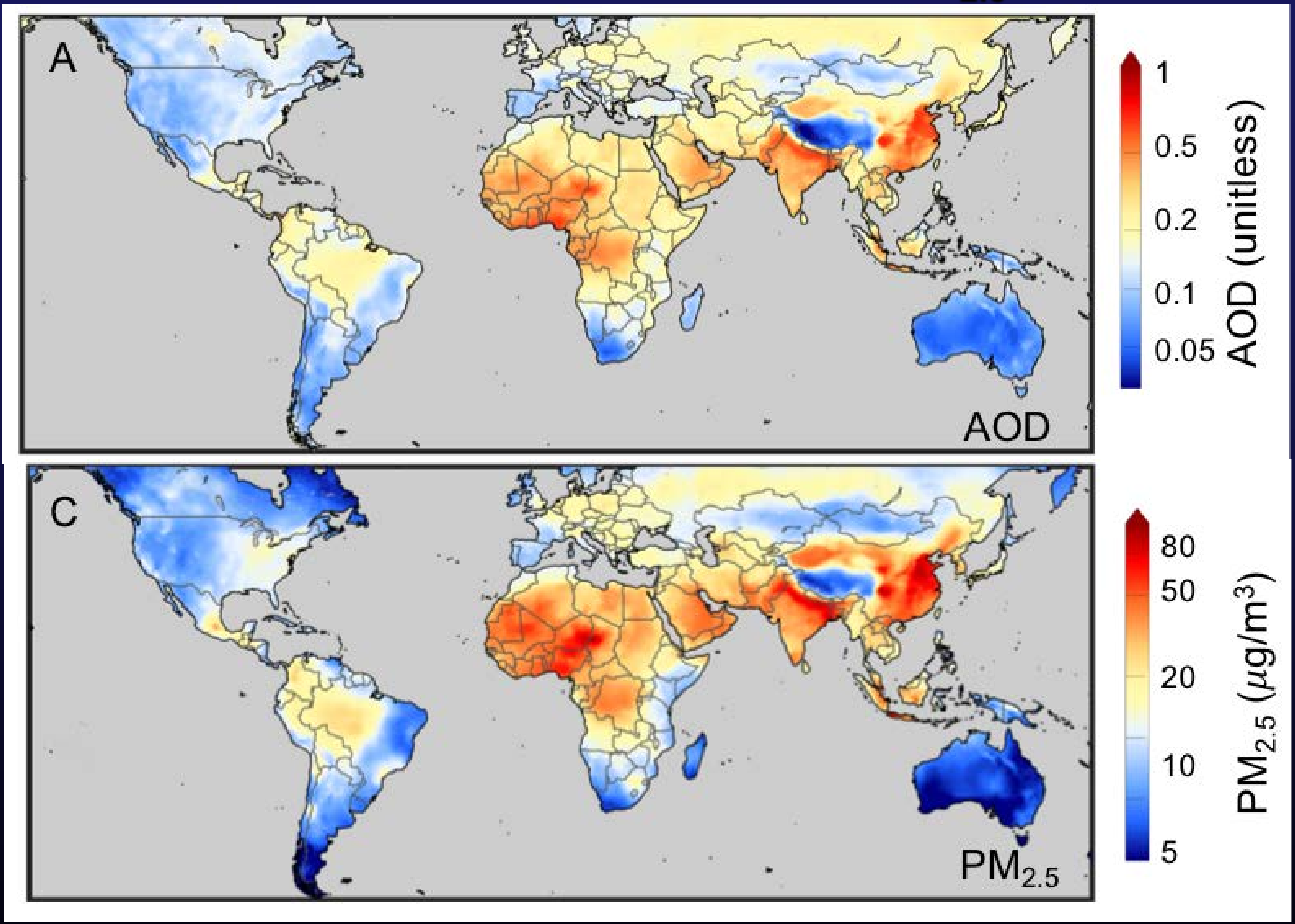
If GEOS-Chem AOD/$PM_{2.5}$ excluded: R^2 → 0.73
If only single satellite AOD retrieval: R^2 → 0.5-0.7

Information source for:

- **Global Burden of Disease**
- **OECD Regional Well Being Index**
- **World Health Organization**
- **World Bank**
- **HEI State of Global Air**
- **UNICEF**
- **Energy Policy Institute**

Hammer, van Donkelaar, et al., ES&T, 2020

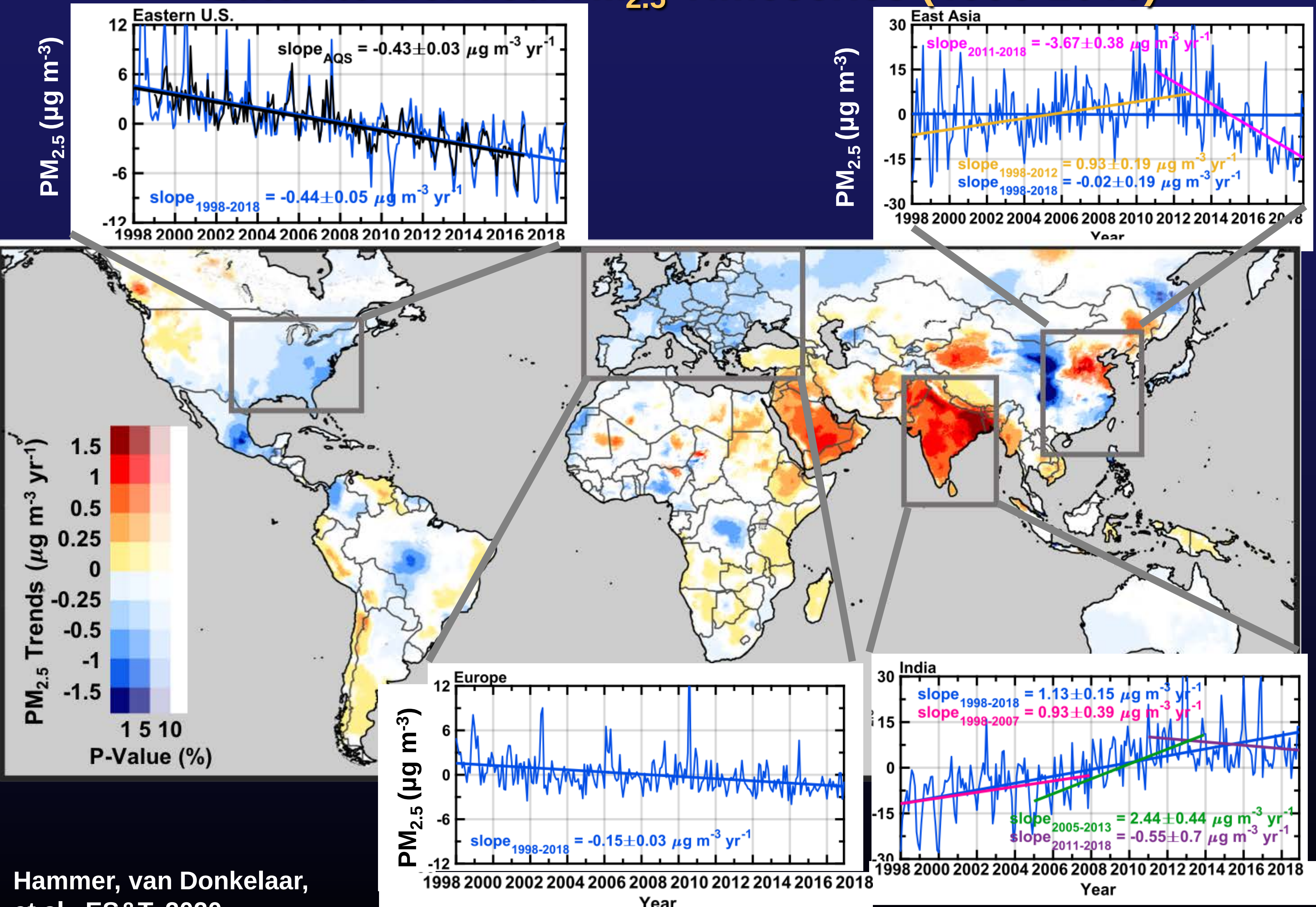
Similarity Between Annual Mean AOD and $PM_{2.5}$ Encouraging for Satellite-Derived $PM_{2.5}$



$R^2 = 0.83$

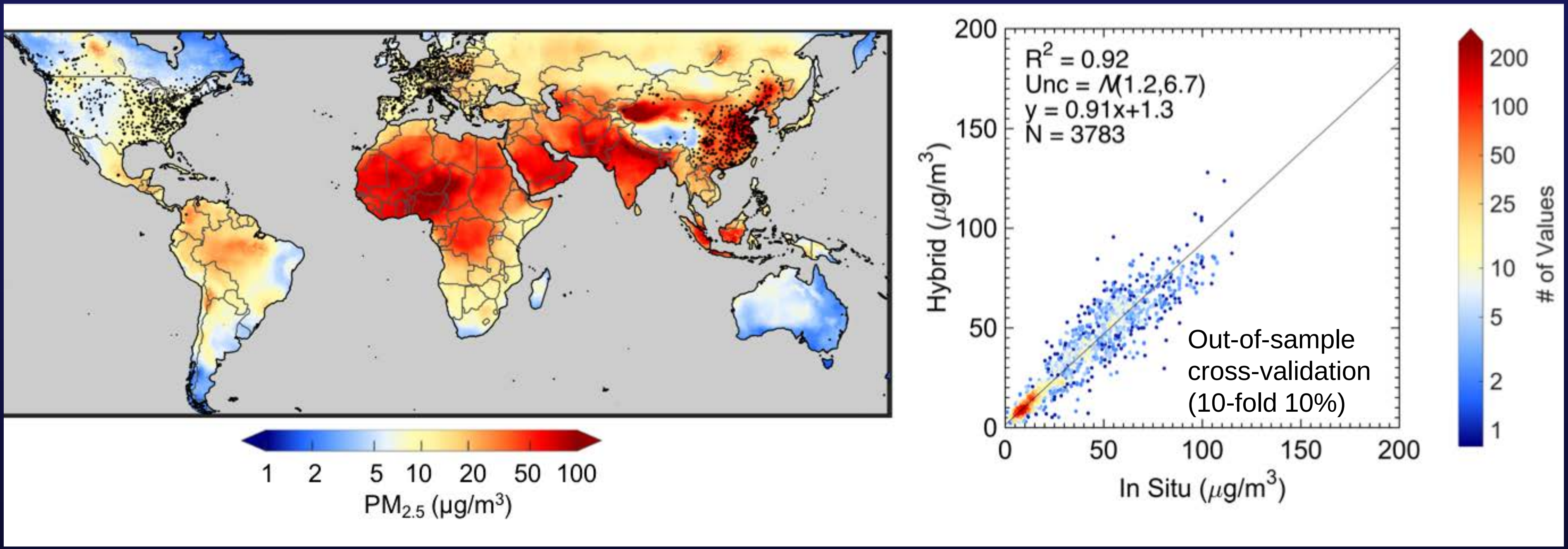
Hammer, van Donkelaar, et al., ES&T, 2020

Satellite-Derived $PM_{2.5}$ Timeseries (1998-2018)



Hammer, van Donkelaar, et al., ES&T, 2020

Statistical Fusion with Ground-Based Monitors Further Improves Consistency; Still Room for Improvement



Statistical fusion explains ~10% of variance

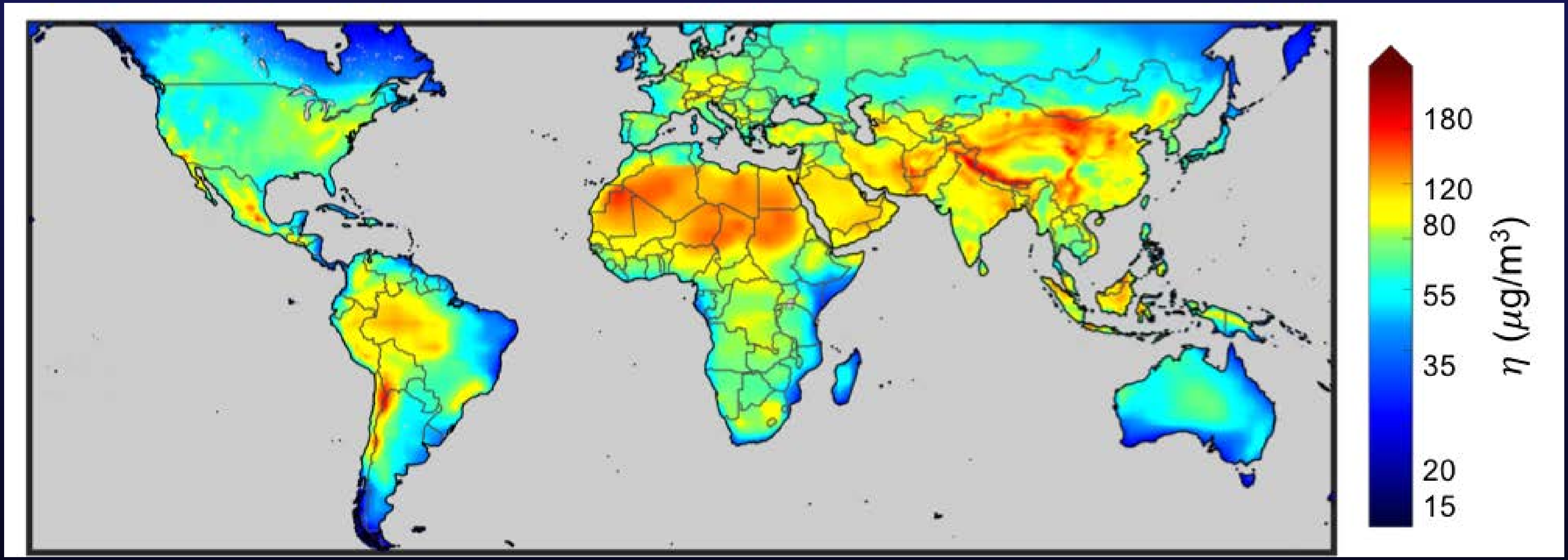
Error likely driven by modeled relation between AOD and $PM_{2.5}$

Hammer, van Donkelaar, et al., ES&T, 2020

Complex Relation of "Dry" $PM_{2.5}$ with AOD

Affected by aerosol properties, vertical structure, elevation
Dry (35% RH) vs ambient relative humidity (RH)
Ground-level vs column aerosol
Elevated topography

GEOS-Chem Simulation of $PM_{2.5}$ / AOD for 1998-2018



$\eta = PM_{2.5}$ / AOD ($\mu g\ m^{-3}$)

Model sampled coincidently with satellite observations
$PM_{2.5}$ calculated at 35% RH

Hammer et al., ES&T, 2020

Surface Particulate Matter Network (SPARTAN): Measures $PM_{2.5}$ Mass & Composition at Sites Measuring AOD

Semi-autonomous $PM_{2.5}$ & PM_{10} Impaction Sampling Station (AirPhoton)

Mass (35% RH)
BC (HIPS); BrC (UV-Vis)
Ions (IC)
Metals (XRF)
Organics (AMS, FTIR) in progress

3-λ nephelometer (AirPhoton) Scatter

AOD from Sunphotometer (e.g. AERONET)

SPARTAN
Global Particulate Matter Network

$$\frac{PM_{2.5}}{AOD} = \left(\frac{b_{sp,overpass}}{AOD_{overpass}}\right)\left(\frac{b_{sp,24h}}{b_{sp,overpass}}\right)\left(\frac{PM_{2.5,24h}}{b_{sp,24h}}\right)$$

Surface/Column — Diurnal — Mass Scattering Efficiency (Depends on size, composition, hygroscopicity)

b_{sp} = nephelometer measurements of aerosol scatter

overpass = satellite overpass time

www.spartan-network.org

Snider, Weagle, et al., AMT, 2015

Conclusions

- Growing interest in global estimates of $PM_{2.5}$
- Increasing consistency of global annual satellite-derived $PM_{2.5}$ concentrations with ground-based measurements
- Need for dedicated measurements of the relationship of AOD with $PM_{2.5}$ mass, scatter, and chemical composition to evaluate and improve simulations of the AOD to $PM_{2.5}$ relationship & to better understand relationships at shorter timescales