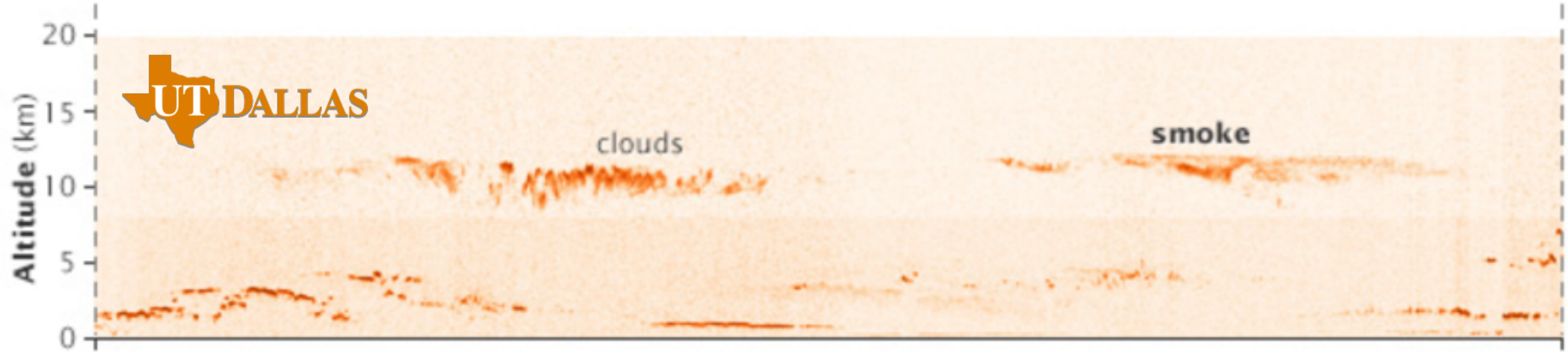
Using Zero-Emission Aerial Vehicles in Support of the ACE Mission

Hanson Center for Space Sciences

Prof. David Lary



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What?

ACE will answer:

- What are the detailed aerosol composition and vertical profiles?
- Where are the aerosols: Above, below or in the clouds?
- What is the aerosol particle number density?

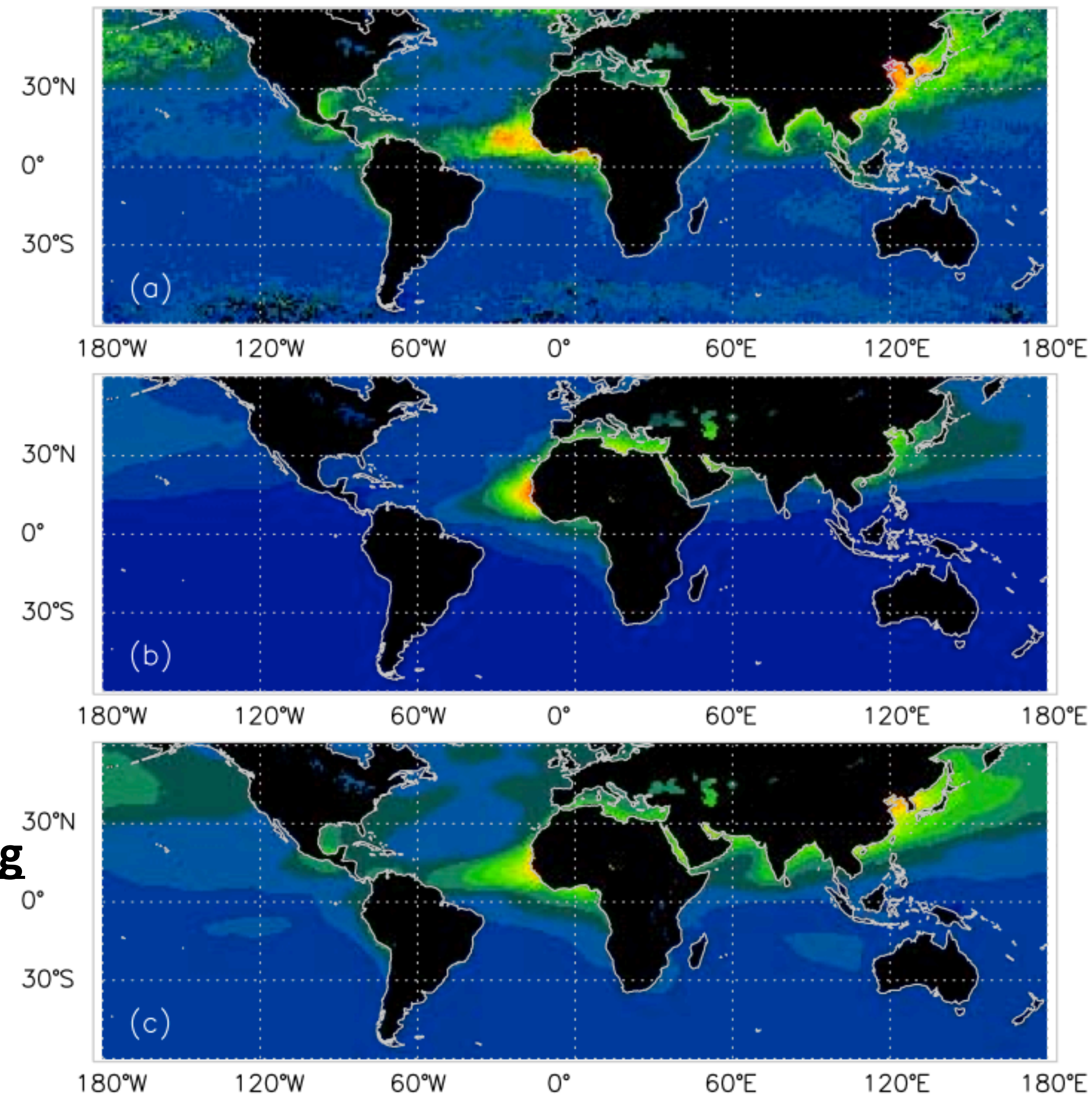
Sources, processes, transport and sinks (SPTS)

SPTS

Three months of MODIS aerosol observations

Aerosol forecast model loading for same period

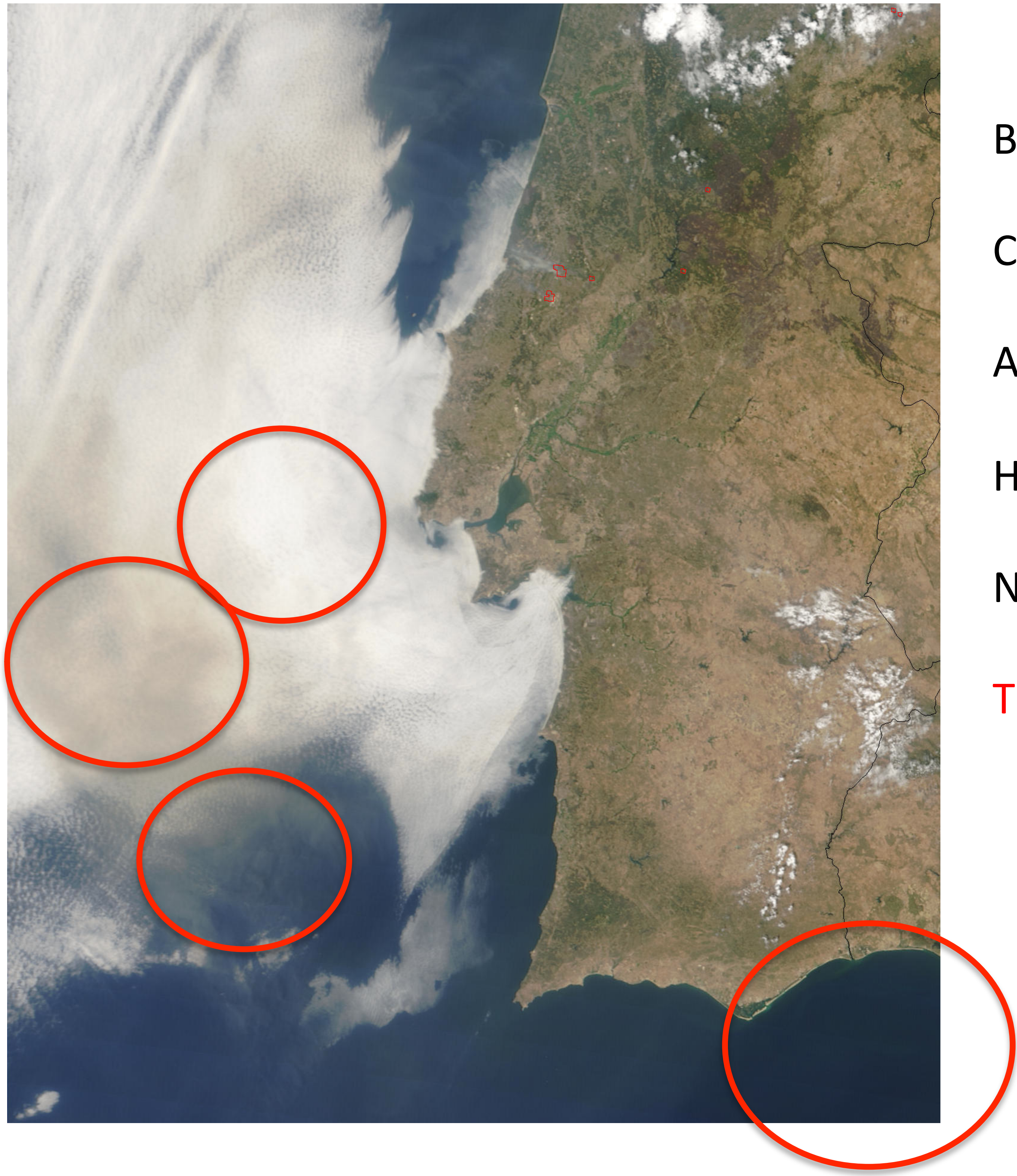
Aerosol forecast model **assimilating** satellite observations looks more like observations



- Satellite observations improve our modeling capabilities
- ACE observations will further improve models by providing more detailed information on aerosol **composition and vertical distribution**
- Improved models are key to (i) forecasts of extreme aerosol and weather event and (ii) predictions of aerosol impacts on climate

Zhang, Reid

Direct aerosol radiative forcing and heating (DARF)



MODIS day=220 year=2003; Portugal

DARF

Brightening or darkening?

Cooling or warming?

Above the cloud or below or inside?

How dark (absorption properties)?

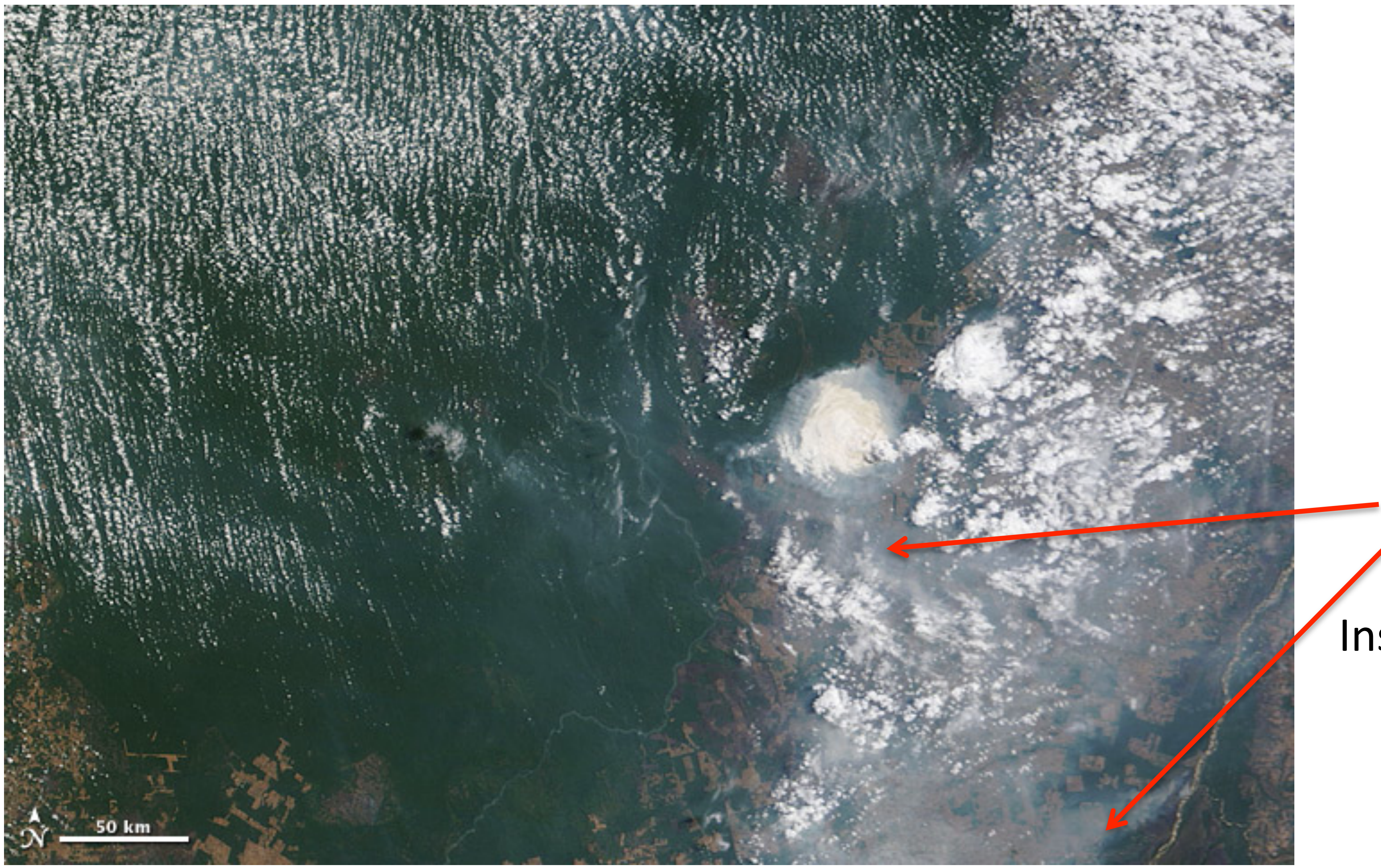
Natural or anthropogenic?

These questions cannot be answered today with the necessary accuracy or coverage.

We need a more quantitative characterization of the aerosol system.

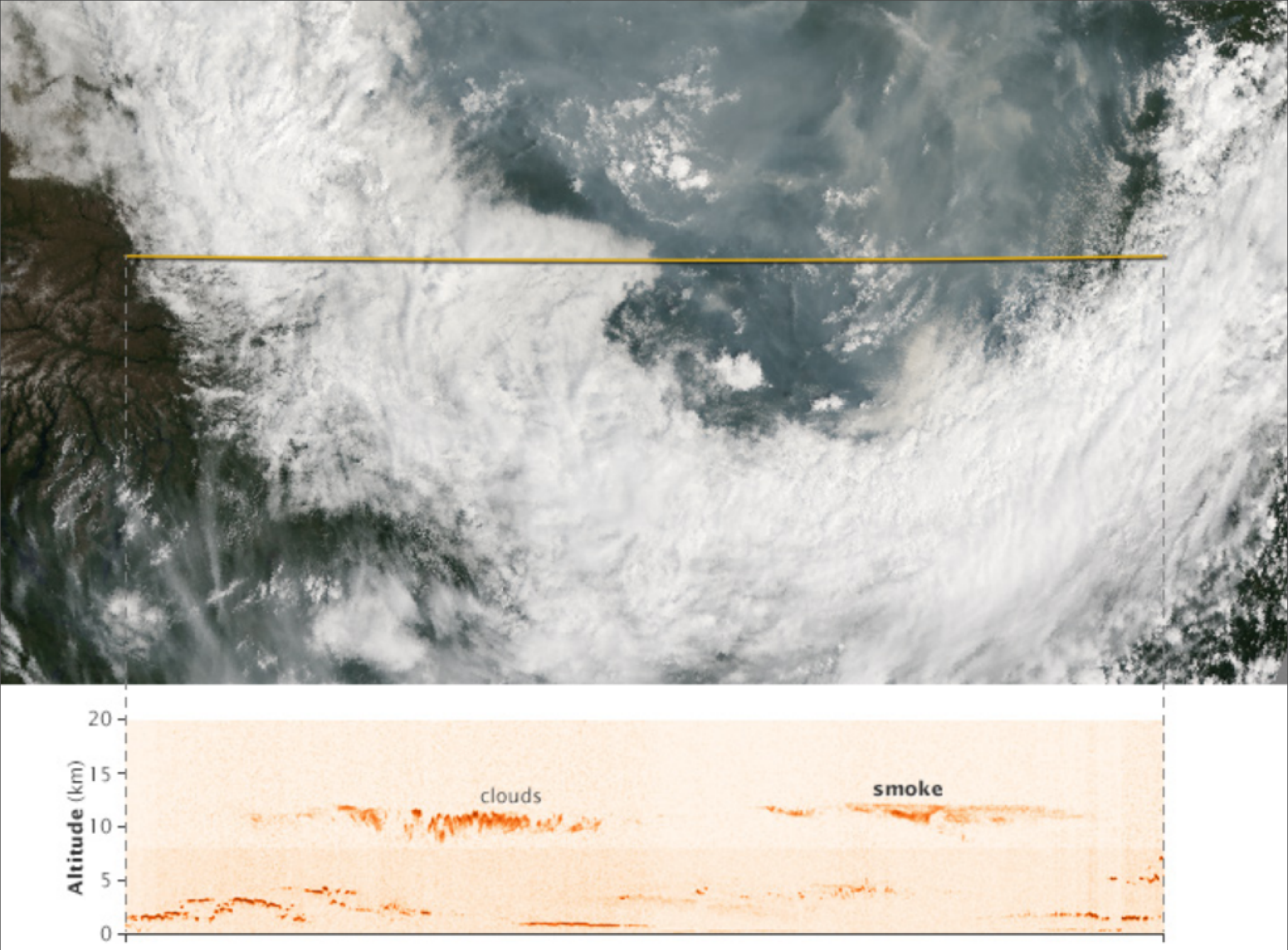
Cloud-Aerosol Interaction (CAI)

CAI



Changes of clouds due to aerosols depend on <u>particle number concentration</u>

ACE will be able to derive this parameter for the first time


20
15
10
5
0
Altitude (km)
clouds
smoke

What we are doing?

Using Zero Emission Aerial Vehicles in Support of ACE

PI: David Lary, University of Texas - Dallas

Objective

Address a key gap in existing validation capabilities for ACE by measuring the size distribution and vertical profiles in the boundary layer in the 100m closest to the surface using a small aerial vehicle. The project will

- Demonstrate feasibility of using zero emissions remote control aircraft for satellite validation
- Determine if a key gap in existing validation capabilities for the Aerosols, Cloud systems, ocean Ecosystems (ACE) can be filled with this technology
- Develop proper size distribution and vertical profiles of aerosols in the boundary layer 100m closest to the surface for ACE mission

The model aircraft is equipped with a full suite of meteorological instruments for temperature, pressure, humidity, wind speed and direction as well as an EPA certified Grimm Model 1.109 Aerosol Spectrometer & 1.320 Nano Check which provides extremely precise size distributions within the size range 12 nm - T 32 µm in 43 size channels.

Approach

Major tasks include:

- Characterize surface variability of aerosol size distribution and abundance across the ACE footprint (250 m resolution) using a Grimm Model 1.109 Aerosol Spectrometer & 1.320 Nano Check and a full weather station measuring temperature, pressure, humidity, dew point, and wind speed and direction
- Integrate the Grimm Spectrometers and full weather station into the model aircraft
- Fly at a range of locations and times to demonstrate the ability to characterize the aerosol size distribution and vertical profiles in the boundary layer in the 100 m closest to the surface

Co-Is/Partners

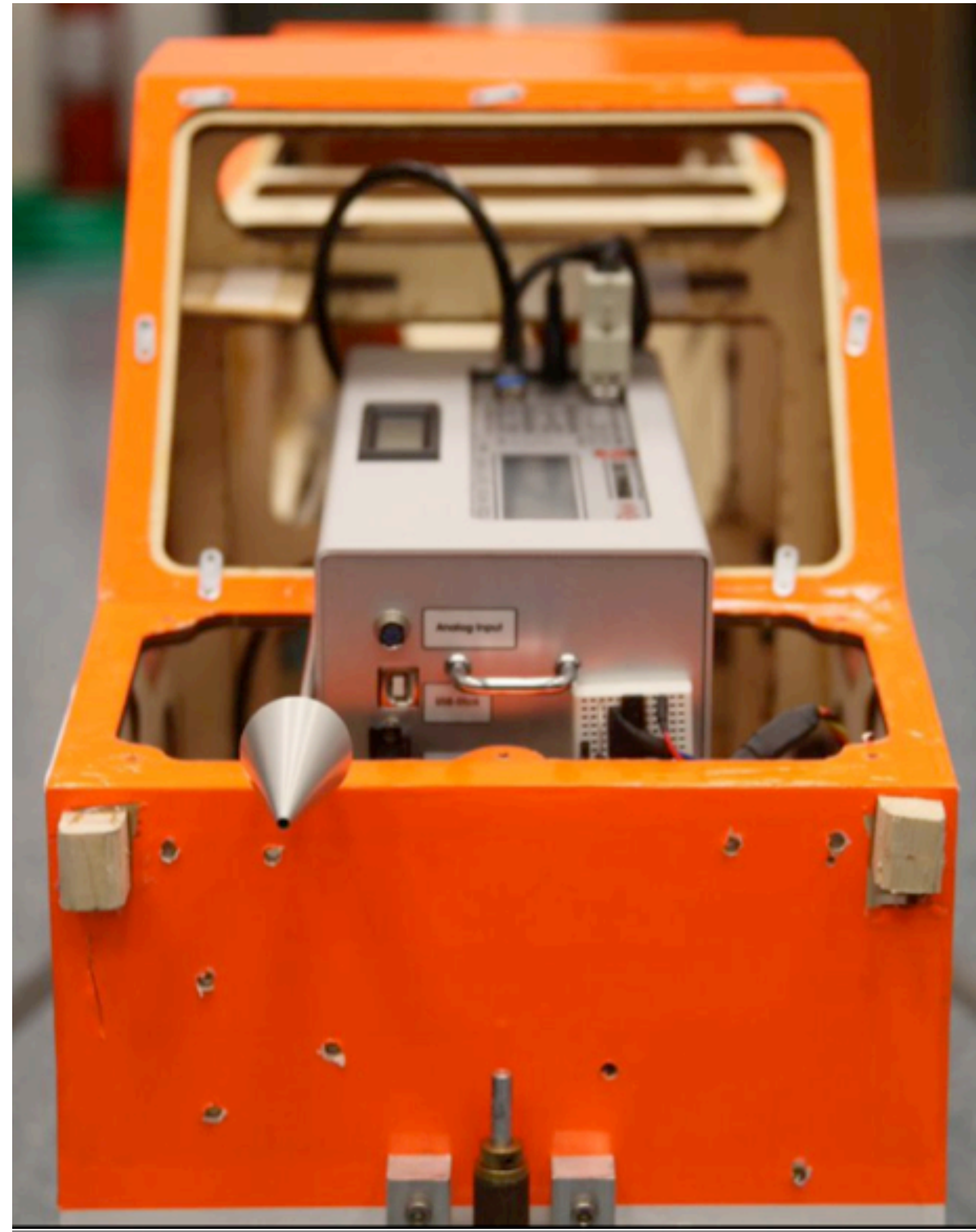
None

Key Milestones

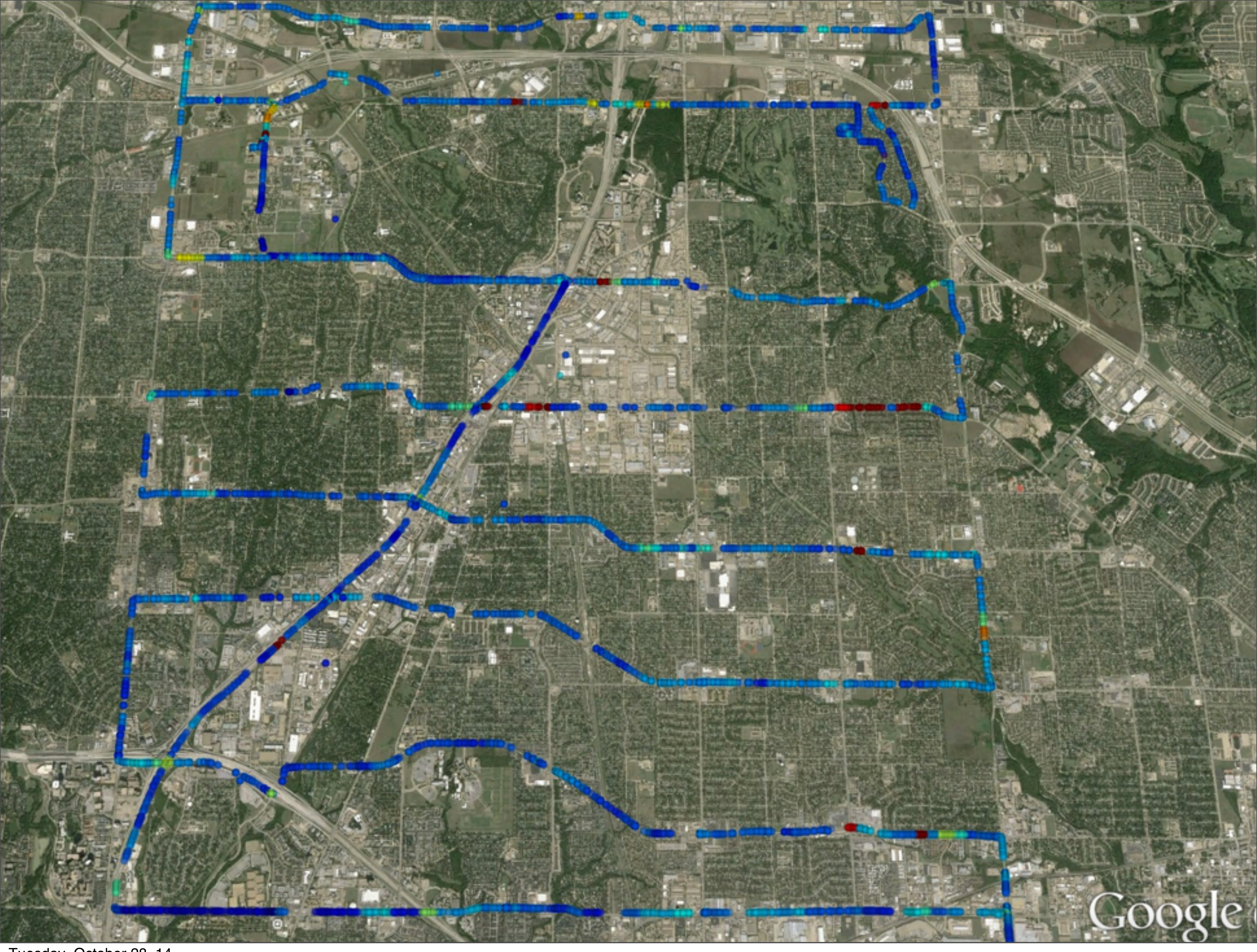
•Characterize surface variability of aerosol size distribution and abundance across the ACE footprint	8/14
•Integrate aerosol spectrometer into the model aircraft	10/14
•Fly at a range of locations and times to demonstrate the ability to characterize the aerosol size distribution and vertical profiles	6/15

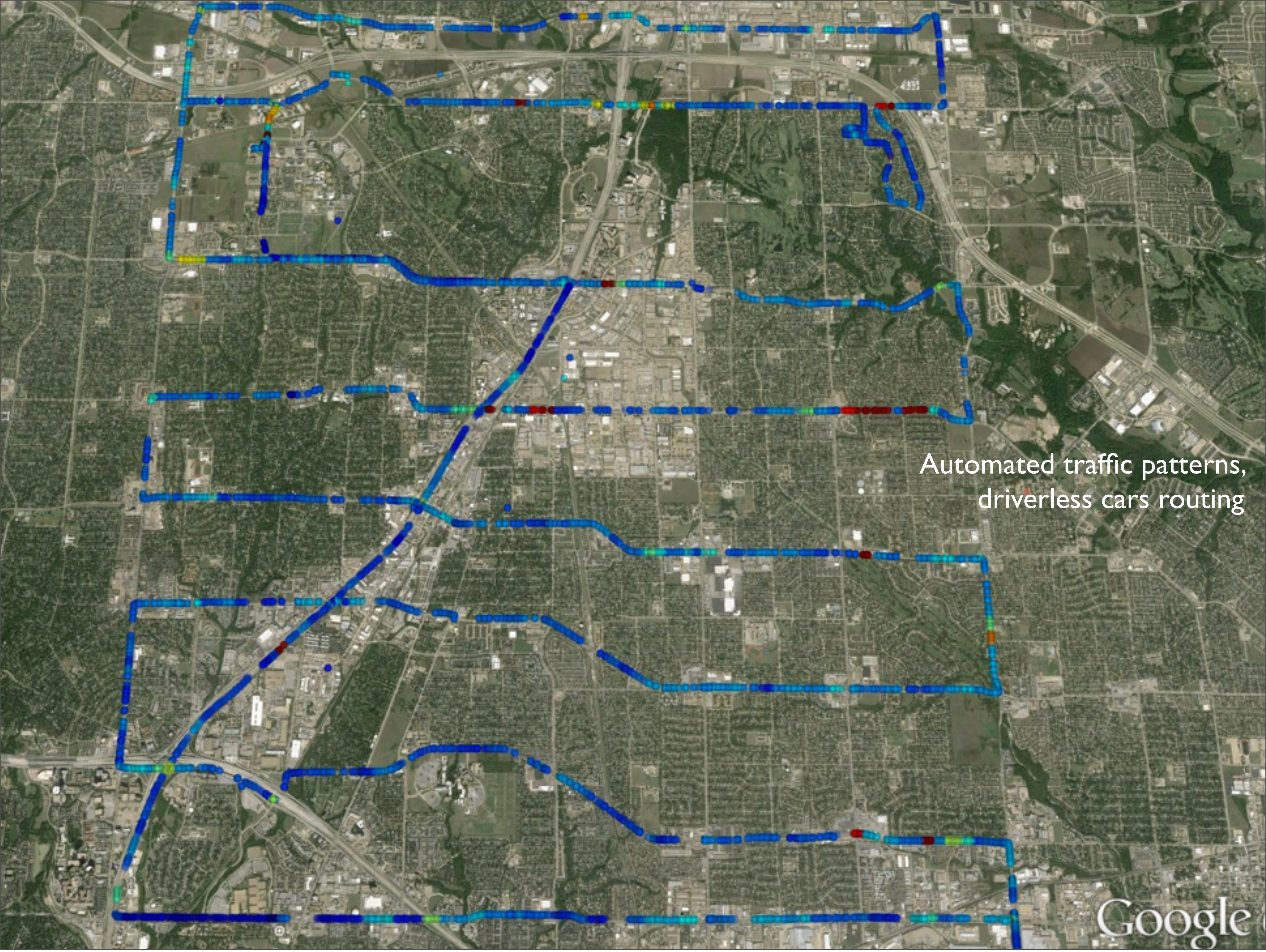
TRL_{in} = 5 $TRL_{current}$ = 5

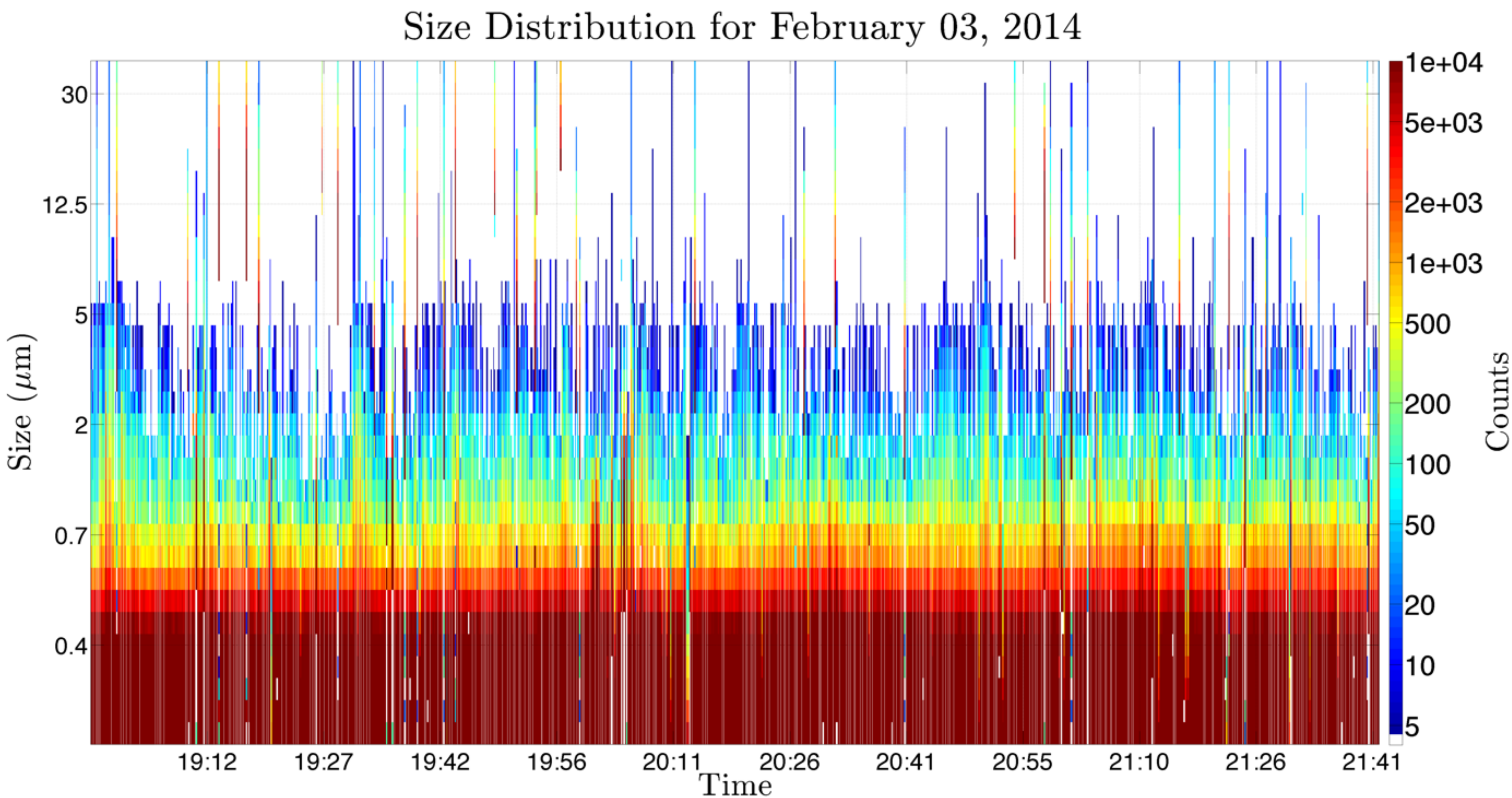

UT DALLAS
GO
GREEK



Small scale variability in the horizontal & vertical


Google


Automated traffic patterns,
driverless cars routing
Google



Size Distribution for February 03, 2014
Size (μm)
30
12.5
5
2
0.7
0.4
19:12
19:27
19:42
19:56
20:11
20:26
20:41
20:55
21:10
21:26
21:41
Time
1e+04
5e+03
2e+03
1e+03
500
200
100
50
20
10
5
Counts

Why else?

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

7 million deaths annually linked to air pollution

In new estimates released, WHO reports that in 2012 around 7 million people died - one in eight of total global deaths – as a result of air pollution exposure. This finding more than doubles previous estimates and confirms that air pollution is now the world's largest single environmental health risk. Reducing air pollution could save millions of lives.

Read the news release on air pollution attributable deaths

Read the feature story on air pollution

FAQs on air pollution and health
pdf, 169kb

Air pollution estimates
pdf, 1.16Mb
Summary of results and method descriptions

World Health Organization

3.7 million deaths

attributable to ambient air pollution

Mortality from ambient air pollution for 2012 - summary of results
pdf, 293kb

4.3 million deaths

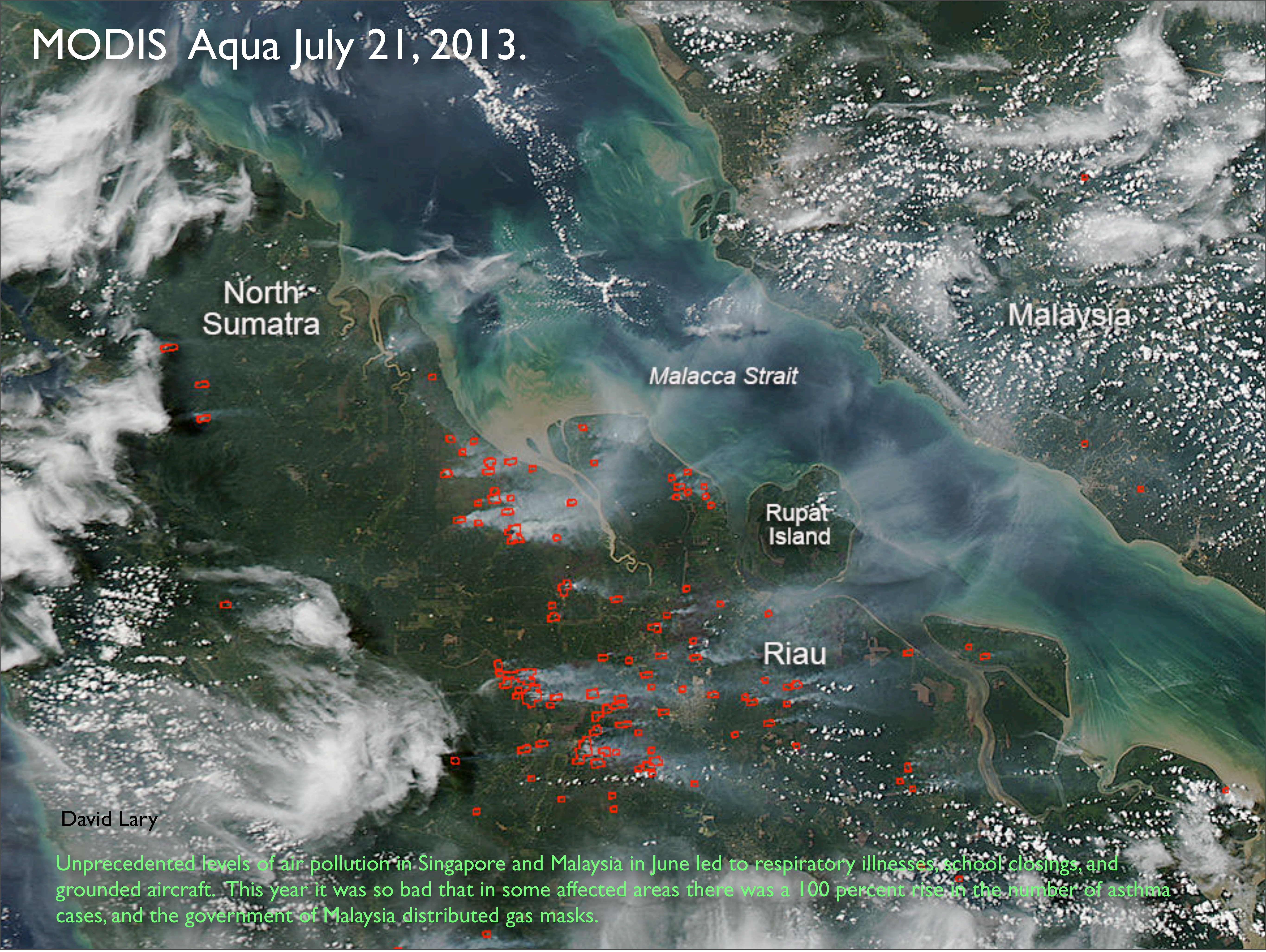
attributable to household air pollution

Mortality from household air pollution 2012 - summary of results.
pdf, 558kb

1600 cities

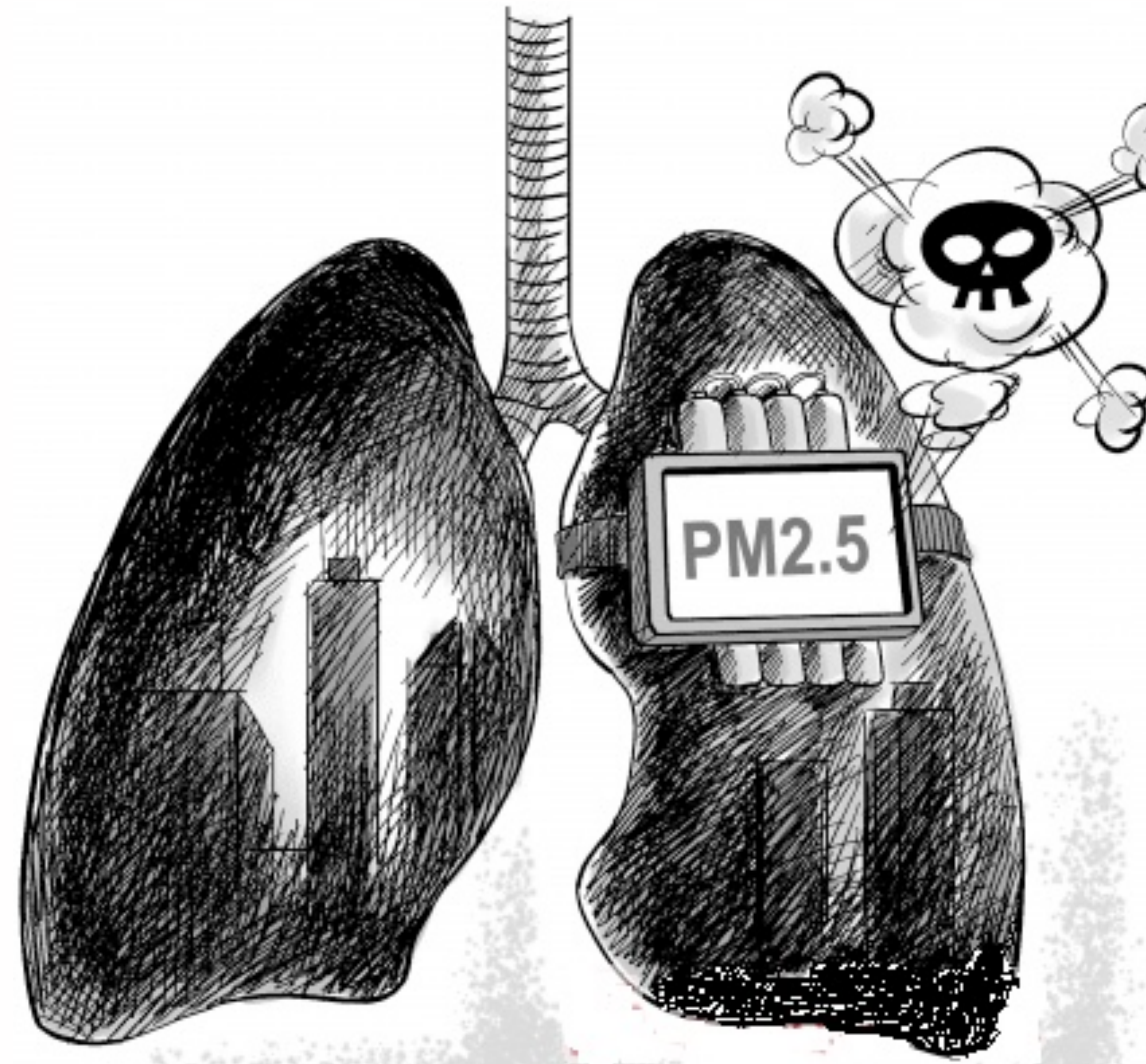
worldwide are reporting air pollution levels

Air quality in cities database – summary of results
pdf, 304kb


MODIS Aqua July 21, 2013.
North Sumatra
Malacca Strait
Malaysia
Rupat Island
Riau
David Lary
Unprecedented levels of air pollution in Singapore and Malaysia in June led to respiratory illnesses, school closings, and grounded aircraft. This year it was so bad that in some affected areas there was a 100 percent rise in the number of asthma cases, and the government of Malaysia distributed gas masks.

Air pollution in Ulaanbaatar, Mongolia

PM2.5 Invisible Killer

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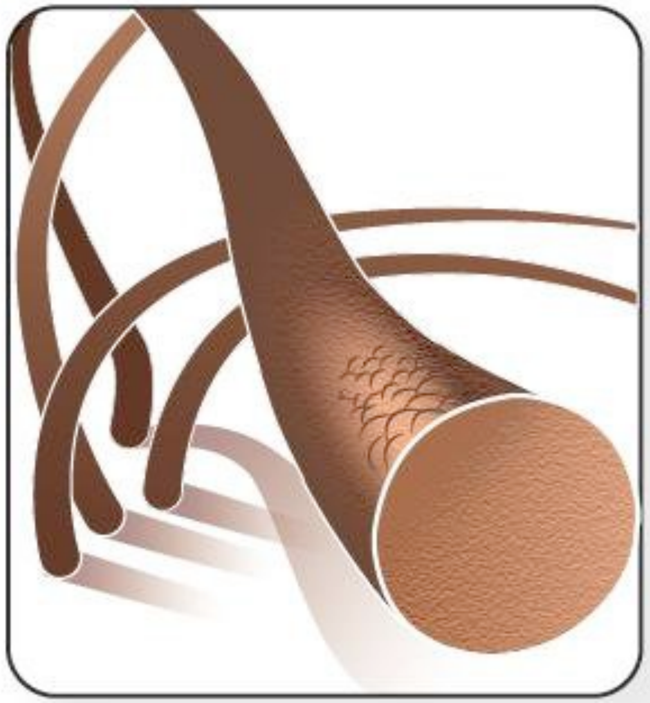
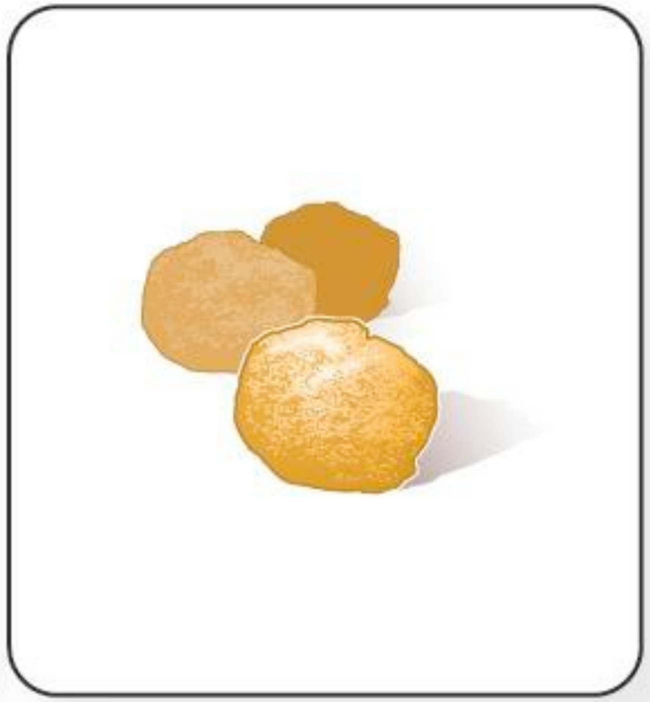
GREE

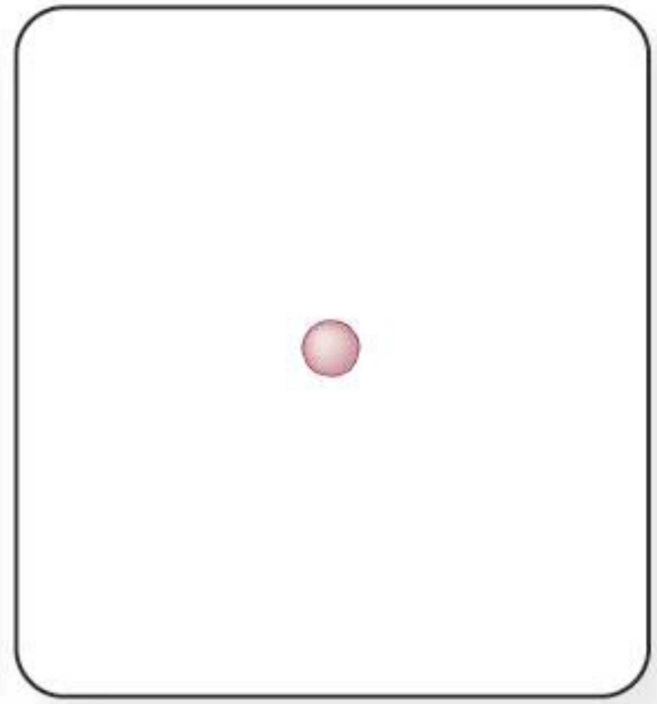
Fine Particulate Matter Size Comparison



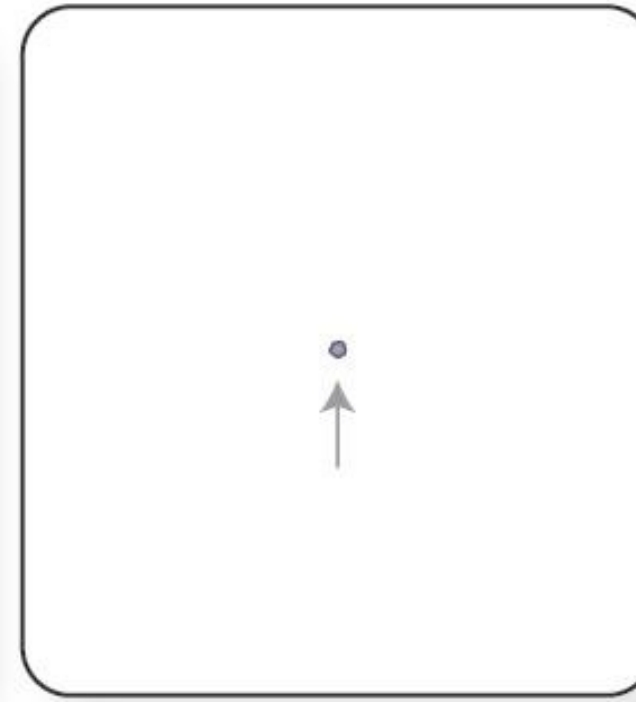
Human hair (about 70µm wide)



Grain of sand (about 50µm wide)

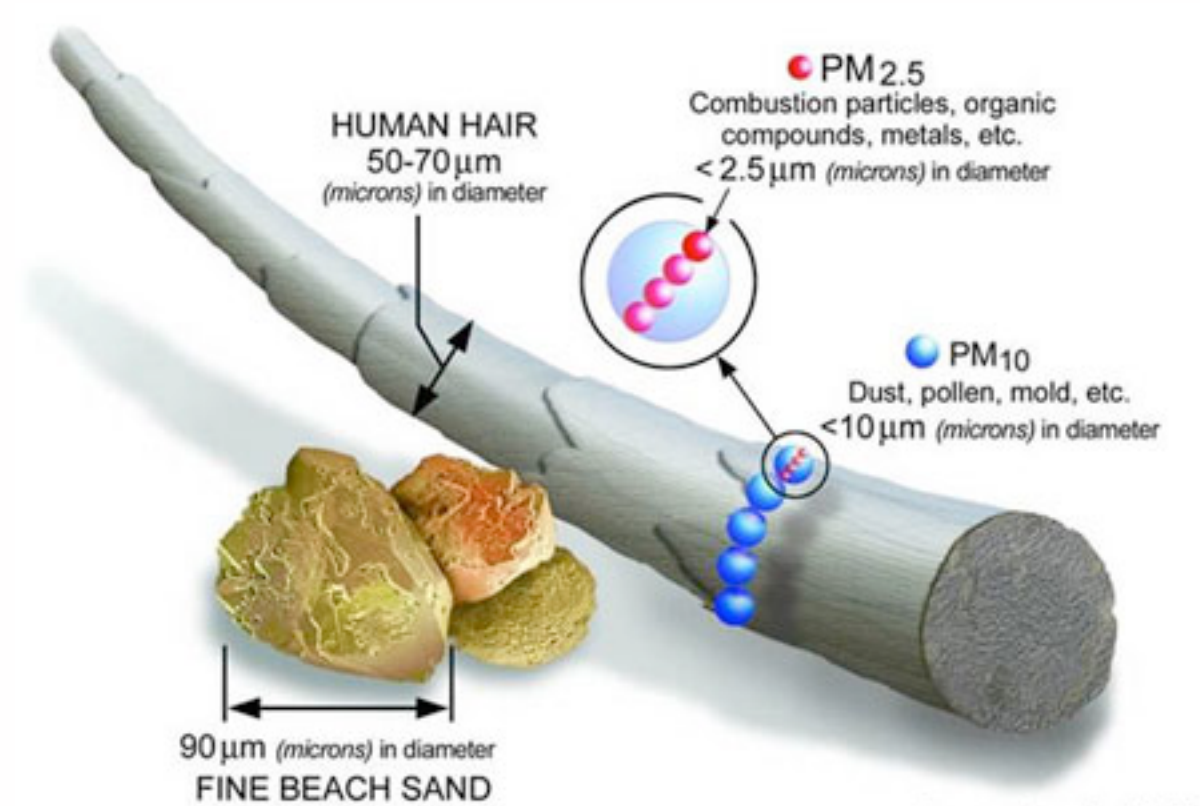


PM_{10} (less than 10µm wide)



$PM_{2.5}$ (less than 2.5µm wide)

µm = micrometer



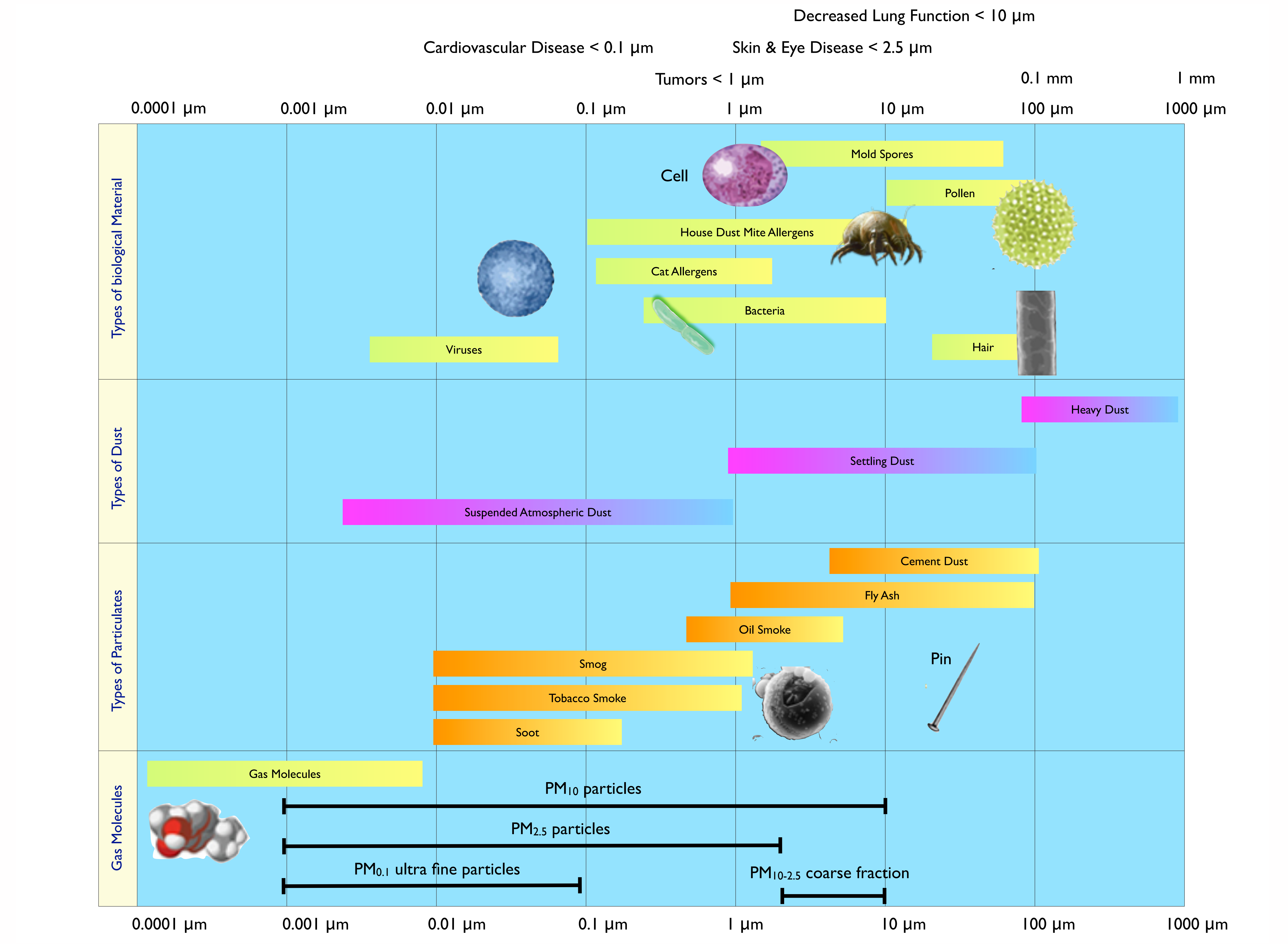
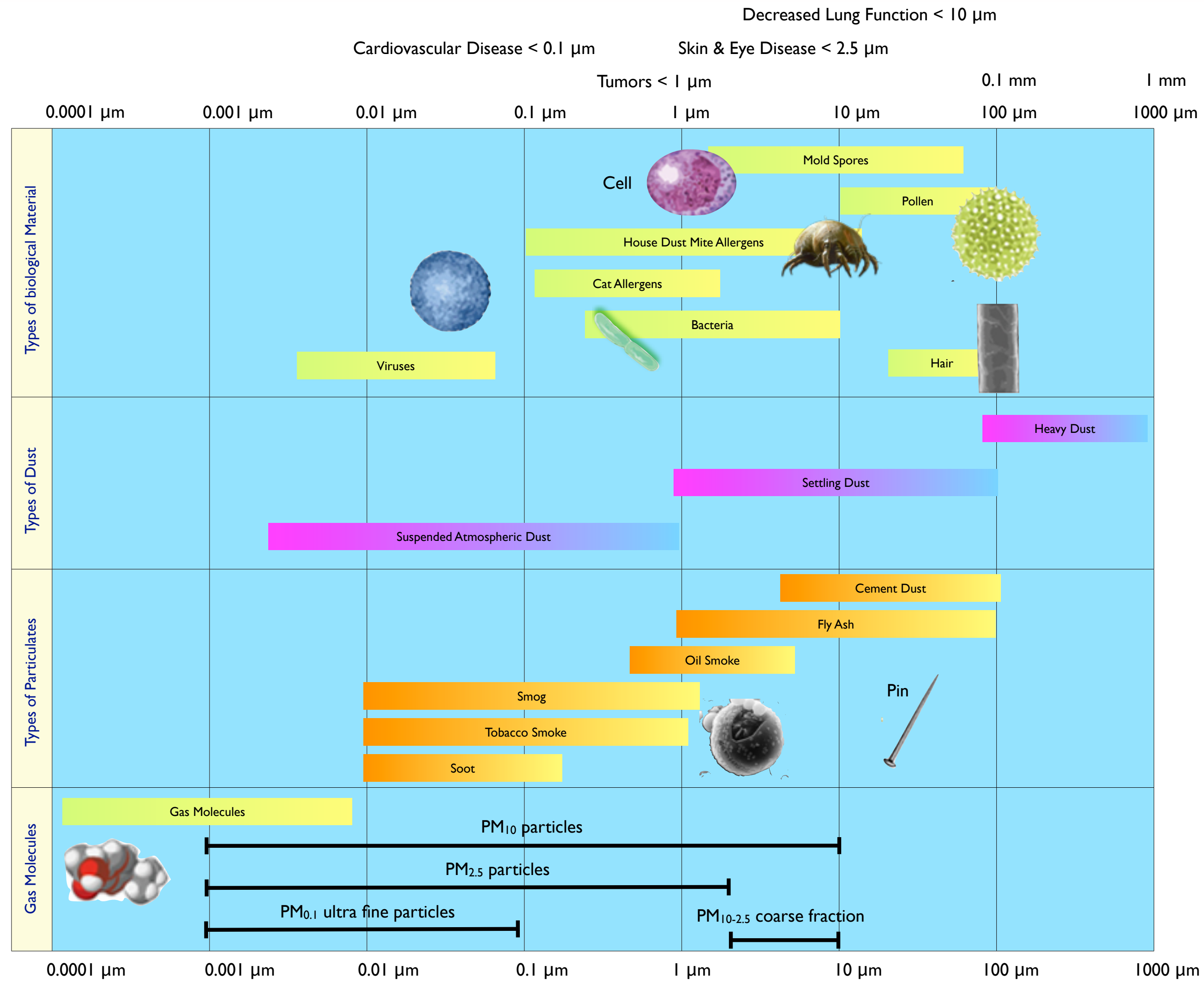

Decreased Lung Function < 10 µm
Cardiovascular Disease < 0.1 µm
Skin & Eye Disease < 2.5 µm
Tumors < 1 µm
0.1 mm
1 mm
0.0001 µm
0.001 µm
0.01 µm
0.1 µm
1 µm
10 µm
100 µm
1000 µm
Types of biological Material
Cell
Mold Spores
Pollen
House Dust Mite Allergens
Cat Allergens
Bacteria
Viruses
Hair
Types of Dust
Heavy Dust
Settling Dust
Suspended Atmospheric Dust
Types of Particulates
Cement Dust
Fly Ash
Oil Smoke
Smog
Tobacco Smoke
Soot
Pin
Gas Molecules
Gas Molecules
PM10 particles
PM2.5 particles
PM0.1 ultra fine particles
PM10-2.5 coarse fraction
0.0001 µm
0.001 µm
0.01 µm
0.1 µm
1 µm
10 µm
100 µm
1000 µm

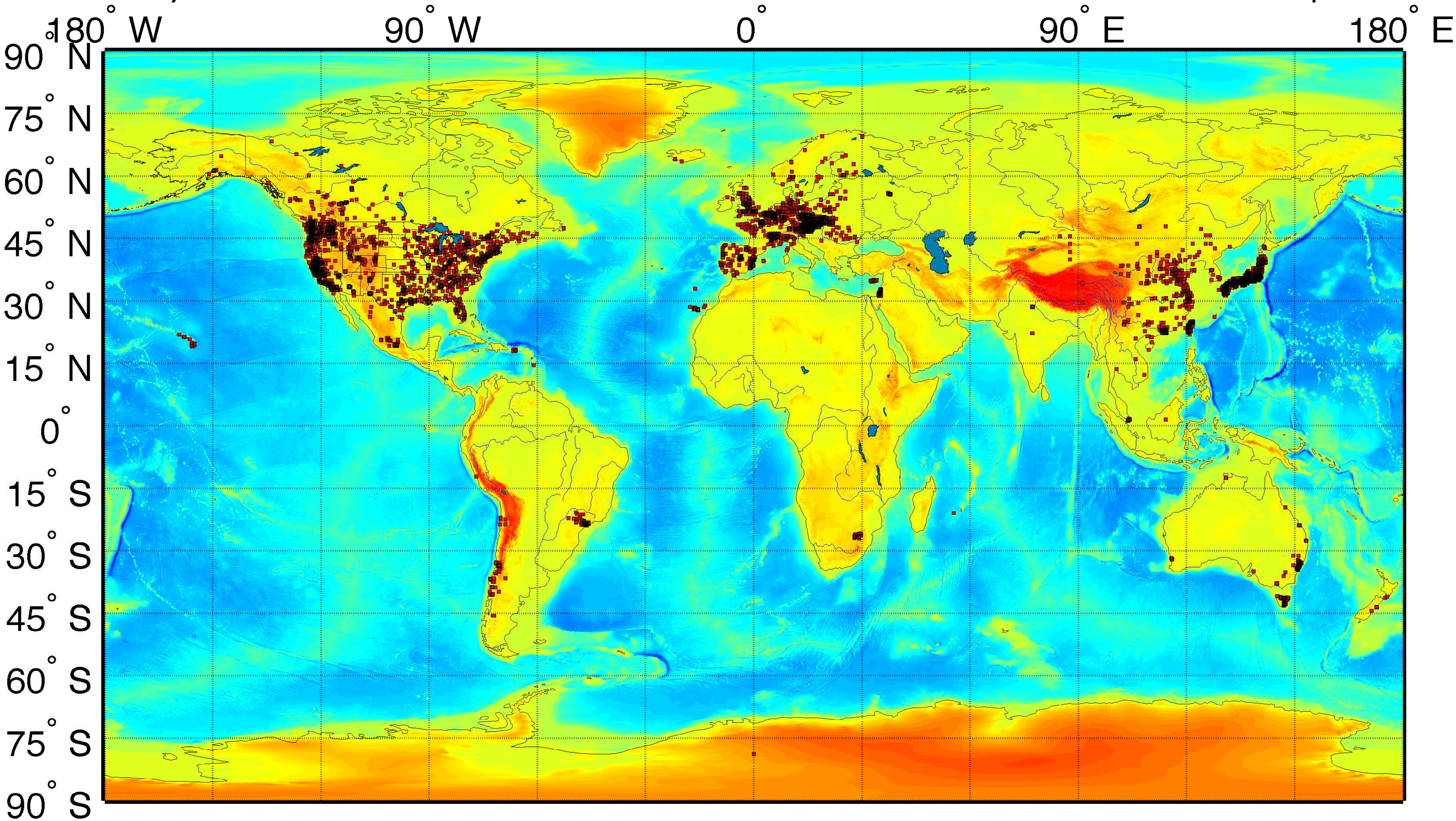
Table 1. PM and health outcomes (modified from *Ruckerl et al.* (2006)).

Health Outcomes	Short-term Studies			Long-term Studies		
	PM10	PM2.5	UFP	PM10	PM2.5	UFP
Mortality						
All causes	xxx	xxx	x	xx	xx	x
Cardiovascular	xxx	xxx	x	xx	xx	x
Pulmonary	xxx	xxx	x	xx	xx	x
Pulmonary effects						
Lung function, e.g., PEF	xxx	xxx	xx	xxx	xxx	
Lung function growth				xxx	xxx	
Asthma and COPD exacerbation						
Acute respiratory symptoms		xx	x	xxx	xxx	
Medication use			x			
Hospital admission	xx	xxx	x			
Lung cancer						
Cohort				xx	xx	x
Hospital admission				xx	xx	x
Cardiovascular effects						
Hospital admission	xxx	xxx		x	x	
ECG-related endpoints						
Autonomic nervous system	xxx	xxx	xx			
Myocardial substrate and vulnerability		xx	x			
Vascular function						
Blood pressure	xx	xxx	x			
Endothelial function	x	xx	x			
Blood markers						
Pro inflammatory mediators	xx	xx	xx			
Coagulation blood markers	xx	xx	xx			
Diabetes	x	xx	x			
Endothelial function	x	x	xx			
Reproduction						
Premature birth	x	x				
Birth weight	xx	x				
IUR/SGA	x	x				
Fetal growth						
Birth defects	x					
Infant mortality	xx	x				
Sperm quality	x	x				
Neurotoxic effects						
Central nervous system		x	xx			

x, few studies; xx, many studies; xxx, large number of studies.



Hourly Measurements from 55 countries and more than 8,000 measurement sites from 1997-present



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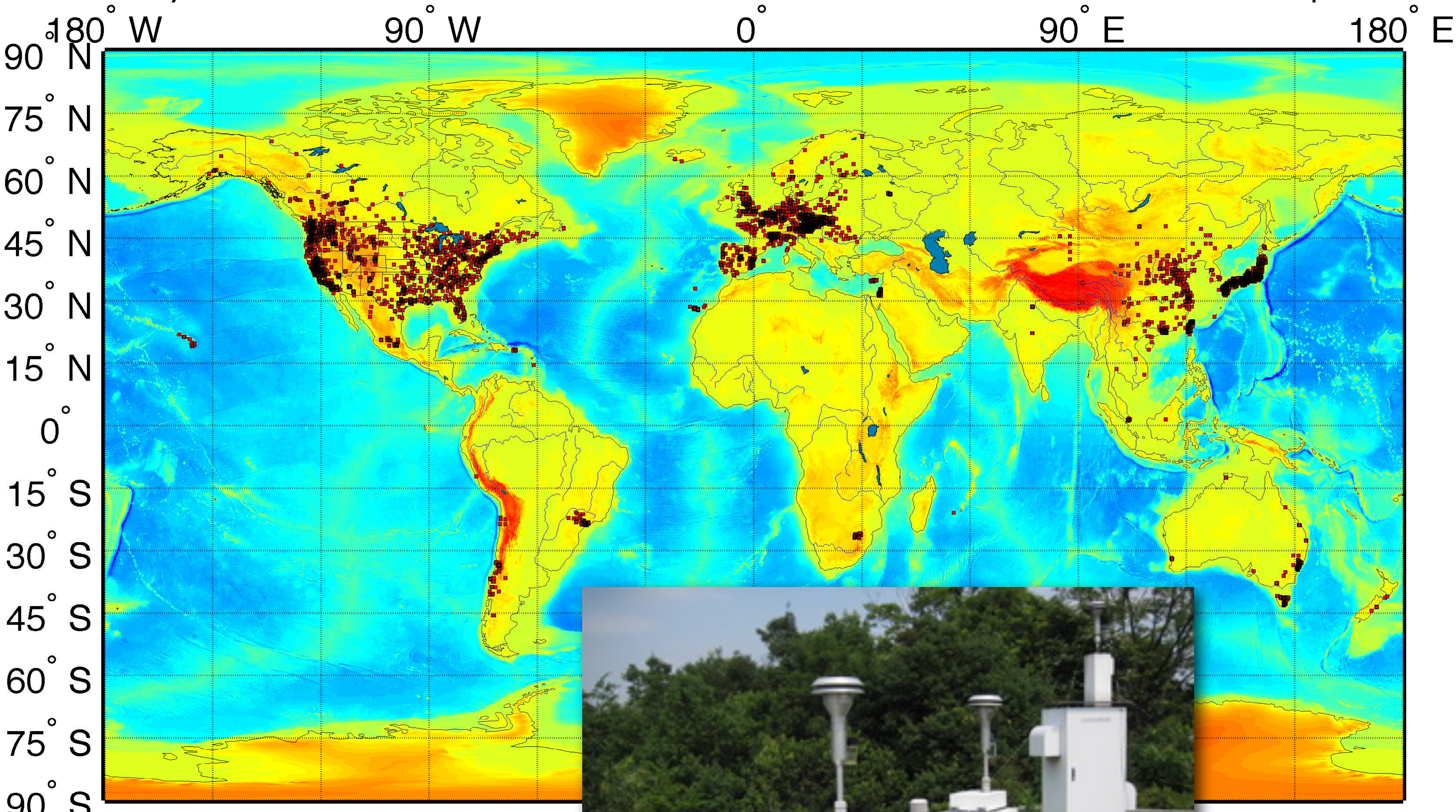
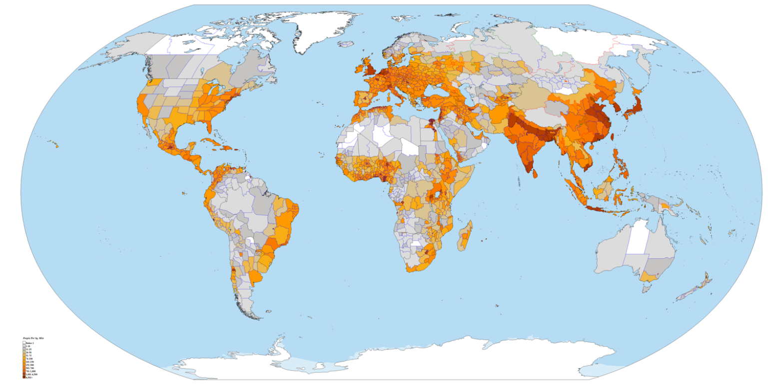
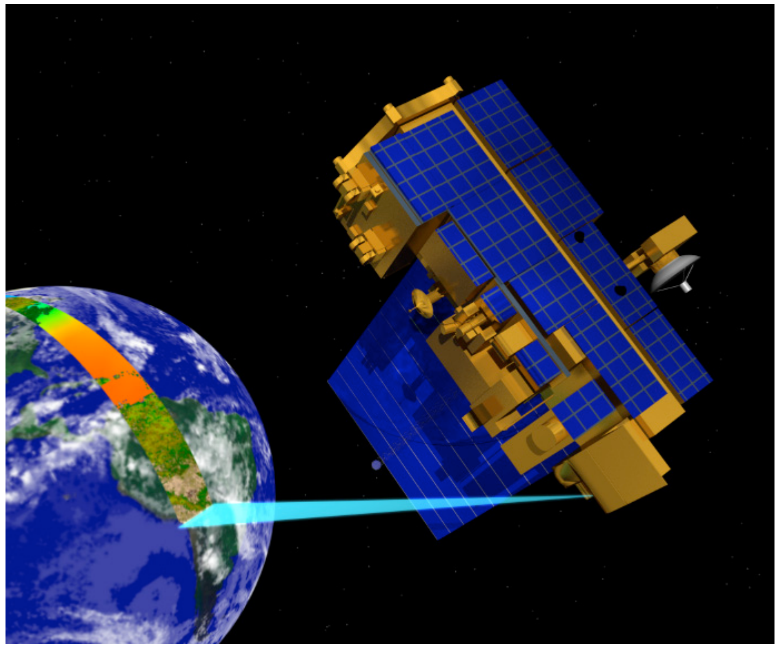


Virtual Sensors

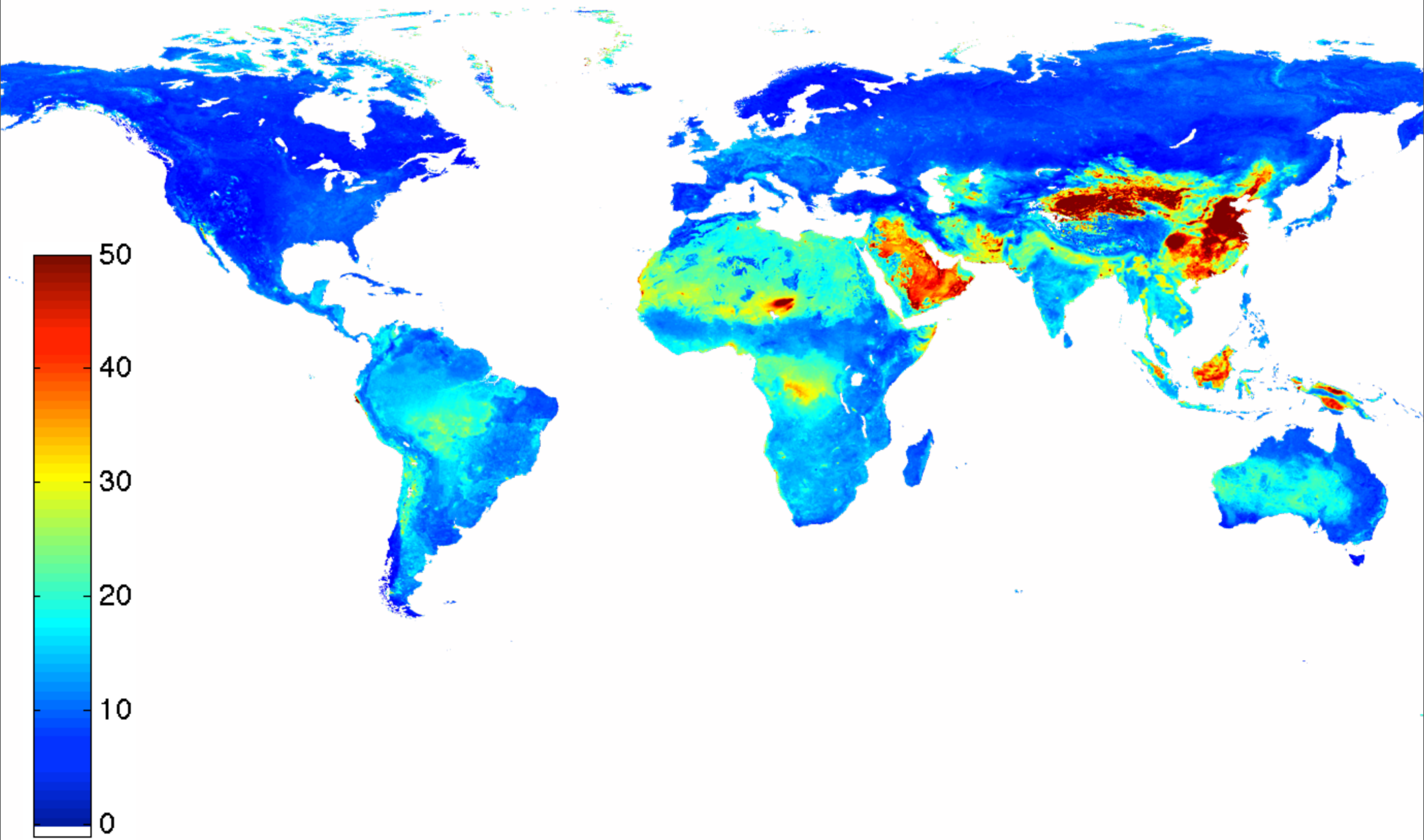
Terra DeepBlue

Rank	Source	Variable	Type
1		Population Density	Input
2	Satellite Product	Tropospheric NO_2 Column	Input
3	Meteorological Analyses	Surface Specific Humidity	Input
4	Satellite Product	Solar Azimuth	Input
5	Meteorological Analyses	Surface Wind Speed	Input
6	Satellite Product	White-sky Albedo at 2,130 nm	Input
7	Satellite Product	White-sky Albedo at 555 nm	Input
8	Meteorological Analyses	Surface Air Temperature	Input
9	Meteorological Analyses	Surface Layer Height	Input
10	Meteorological Analyses	Surface Ventilation Velocity	Input
11	Meteorological Analyses	Total Precipitation	Input
12	Satellite Product	Solar Zenith	Input
13	Meteorological Analyses	Air Density at Surface	Input
14	Satellite Product	Cloud Mask Qa	Input
15	Satellite Product	Deep Blue Aerosol Optical Depth 470 nm	Input
16	Satellite Product	Sensor Zenith	Input
17	Satellite Product	White-sky Albedo at 858 nm	Input
18	Meteorological Analyses	Surface Velocity Scale	Input
19	Satellite Product	White-sky Albedo at 470 nm	Input
20	Satellite Product	Deep Blue Angstrom Exponent Land	Input
21	Satellite Product	White-sky Albedo at 1,240 nm	Input
22	Satellite Product	Scattering Angle	Input
23	Satellite Product	Sensor Azimuth	Input
24	Satellite Product	Deep Blue Surface Reflectance 412 nm	Input
25	Satellite Product	White-sky Albedo at 1,640 nm	Input
26	Satellite Product	Deep Blue Aerosol Optical Depth 660 nm	Input
27	Satellite Product	White-sky Albedo at 648 nm	Input
28	Satellite Product	Deep Blue Surface Reflectance 660 nm	Input
29	Satellite Product	Cloud Fraction Land	Input
30	Satellite Product	Deep Blue Surface Reflectance 470 nm	Input
31	Satellite Product	Deep Blue Aerosol Optical Depth 550 nm	Input
32	Satellite Product	Deep Blue Aerosol Optical Depth 412 nm	Input
	In-situ Observation	**$PM_{2.5}$**	**Target**

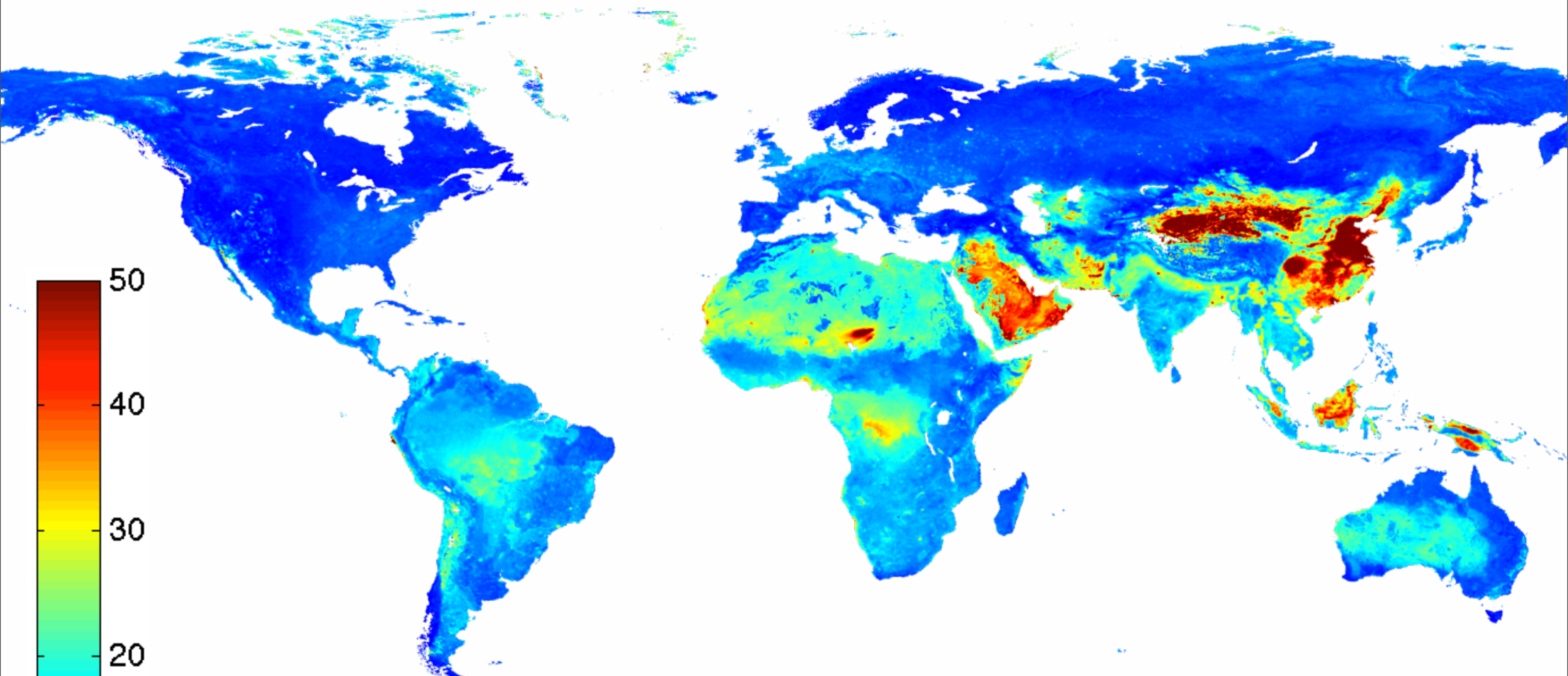




Long-Term Average 1997-present

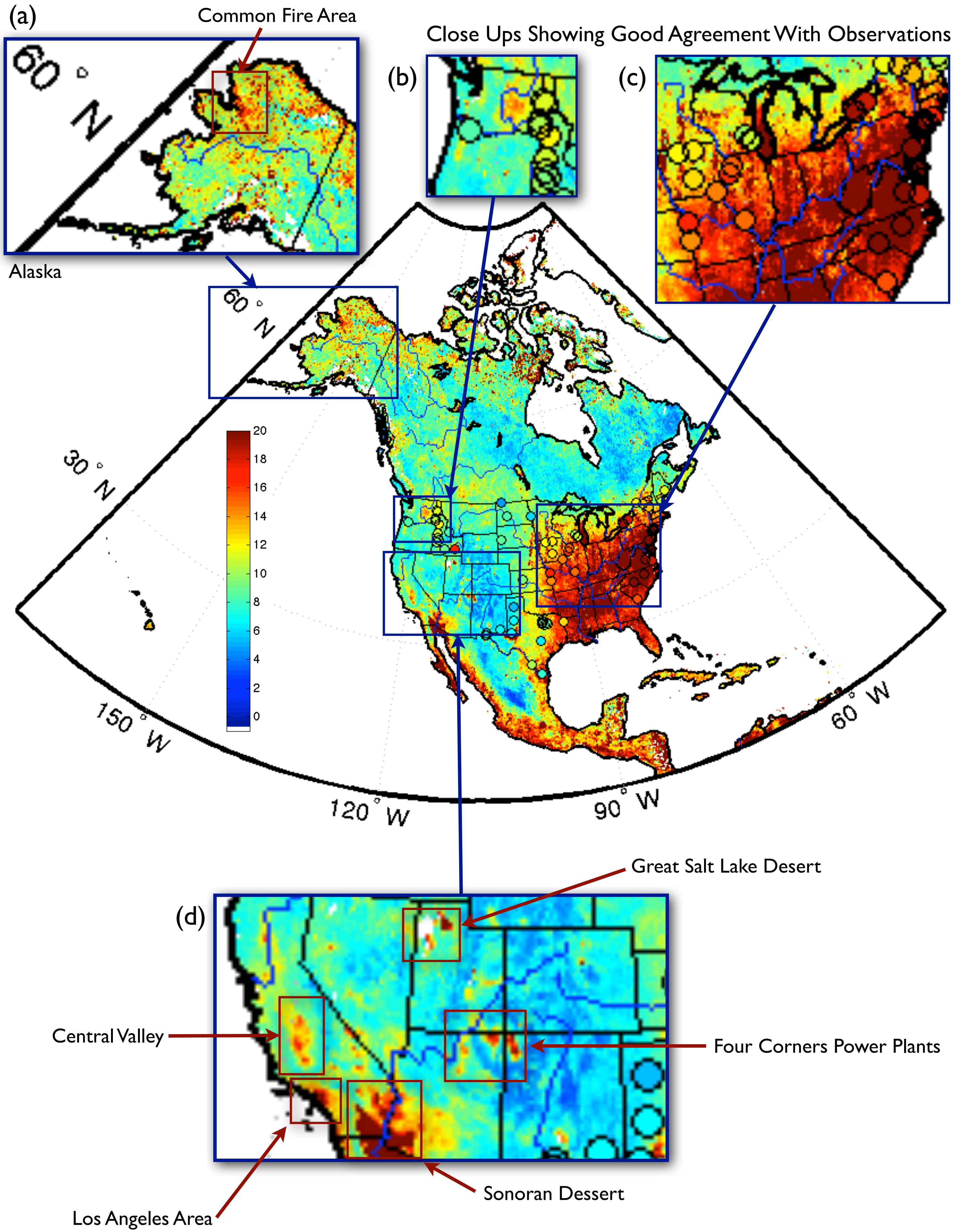


Long-Term Average 1997-present



Mobile Sensors

Wearable Sensors

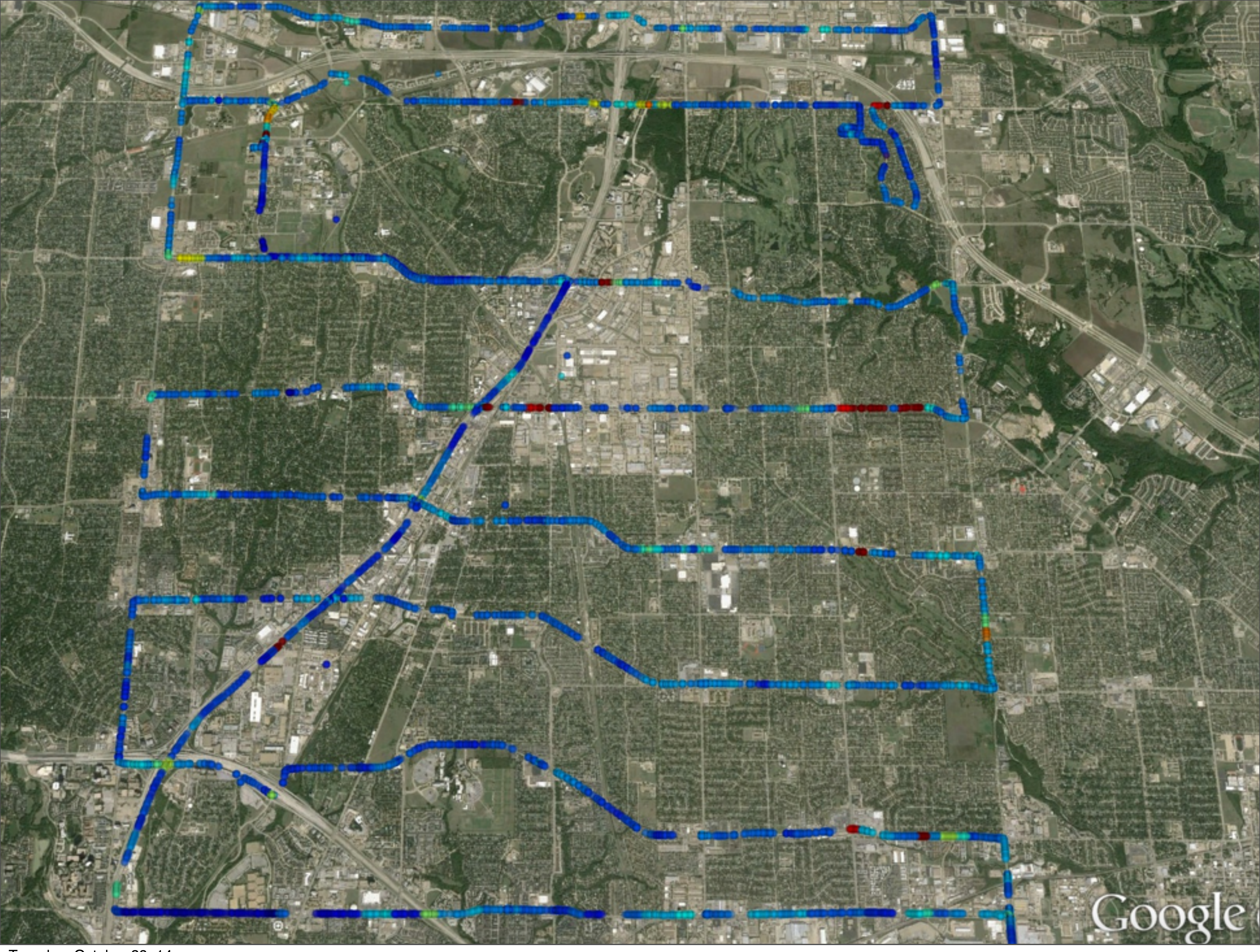

(a)
Common Fire Area
Alaska
Close Ups Showing Good Agreement With Observations
(b)
(c)
60 °N
30 °N
150 °W
120 °W
90 °W
60 °W
20
18
16
14
12
10
8
6
4
2
0
(d)
Great Salt Lake Desert
Central Valley
Four Corners Power Plants
Sonoran Dessert
Los Angeles Area

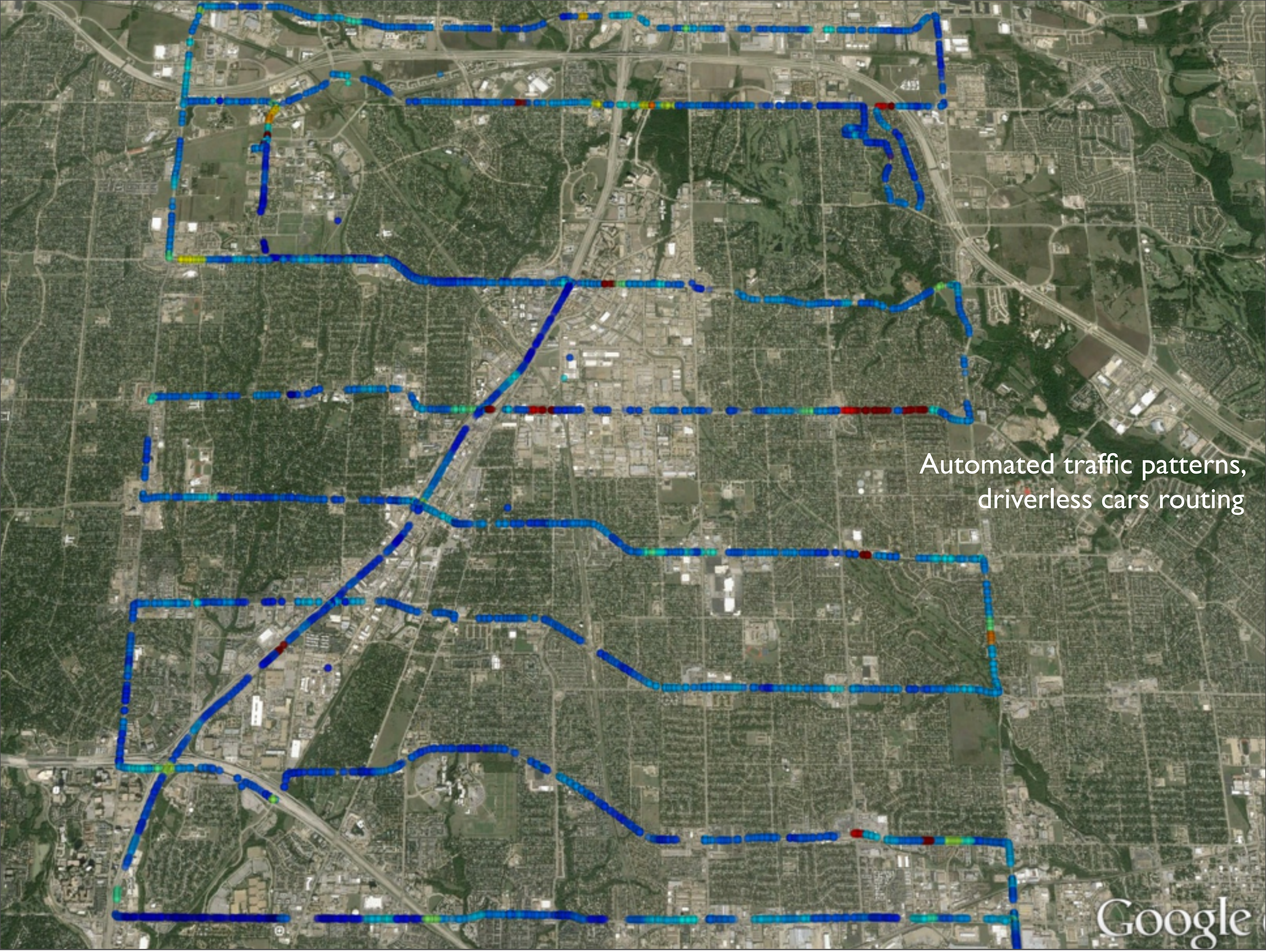

Thermo

This is a BigData Problem of Great Societal Relevance

- Collecting data in real time from national and global networks requires **bandwidth**.
- With the next generation of wearable sensors and the **internet of things** this data volume will rapidly increase.
- A variety of applications enabled by **BigData**, **higher bandwidth** and **cloud processing**.
- Future finer granularity and **two way** communication will dramatically increase the size of the data bringing air quality to the micro scale, just like weather data.

	Time Taken			
	10 Mbps	**20 Mbps**	**50 Mbps**	**1 Gbps**
40 TB training data	185 days	93 days	37 days	1 day 21 hours
4 Gb update	54m	27m	11m	32s


Google


Automated traffic patterns,
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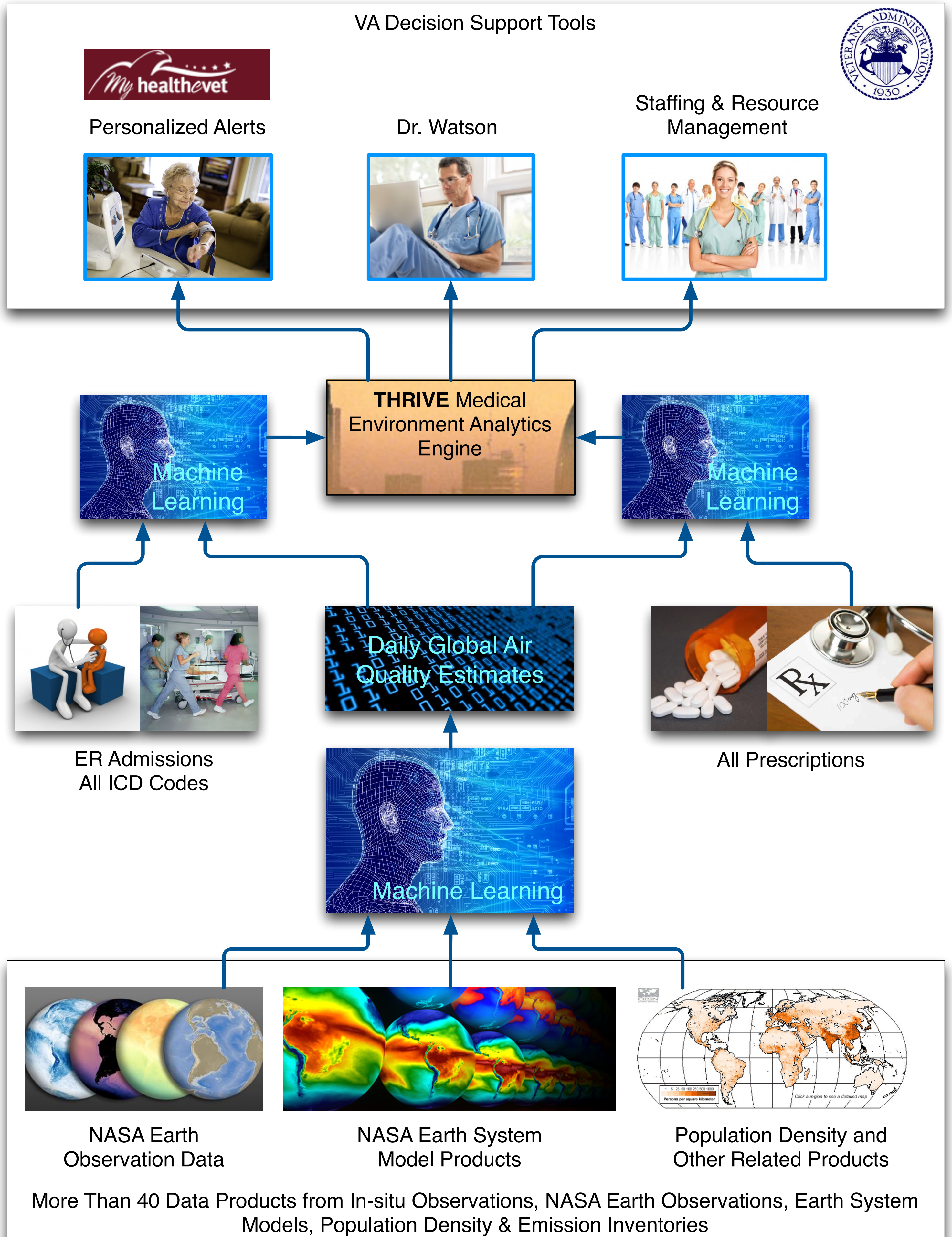
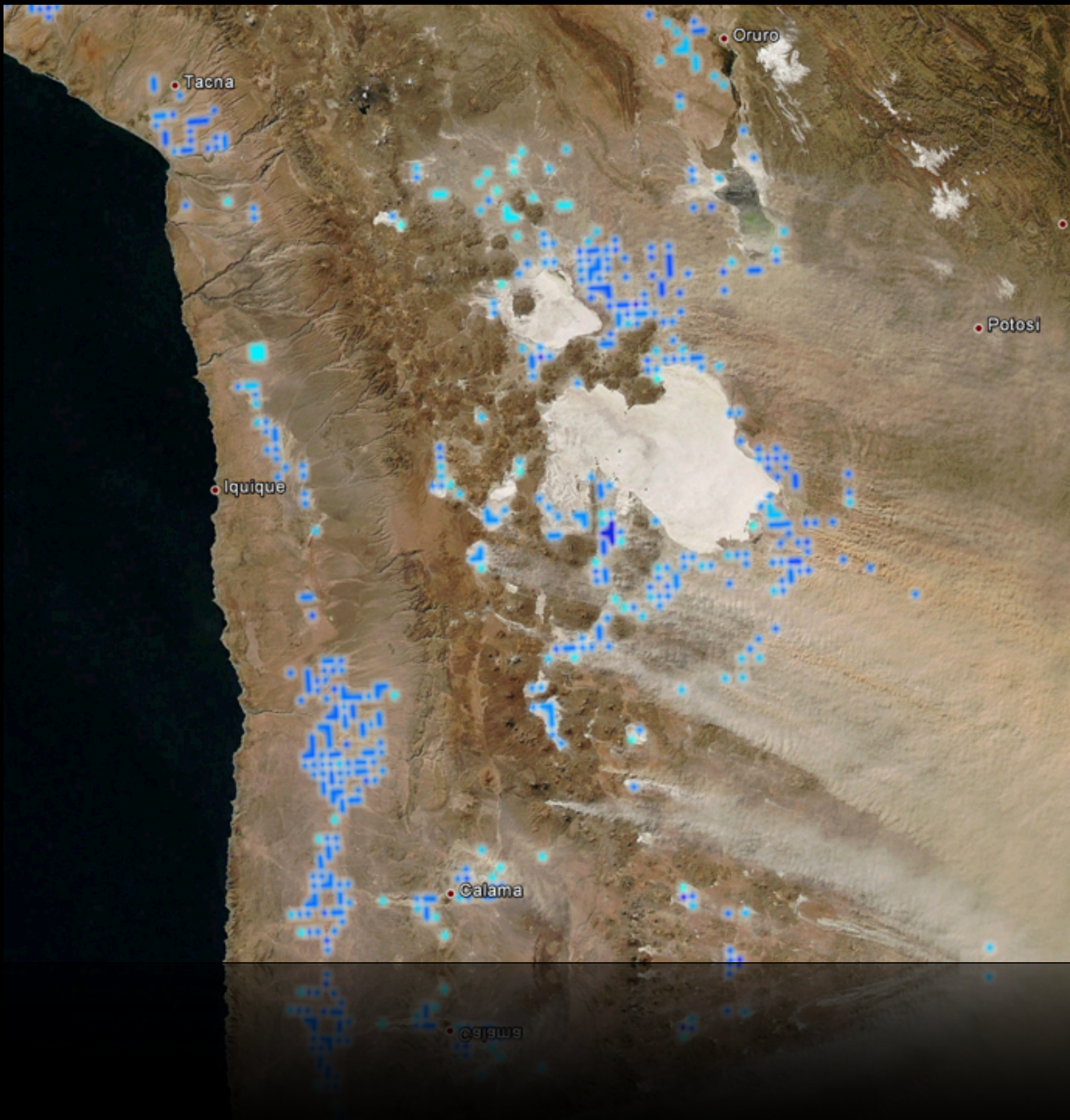
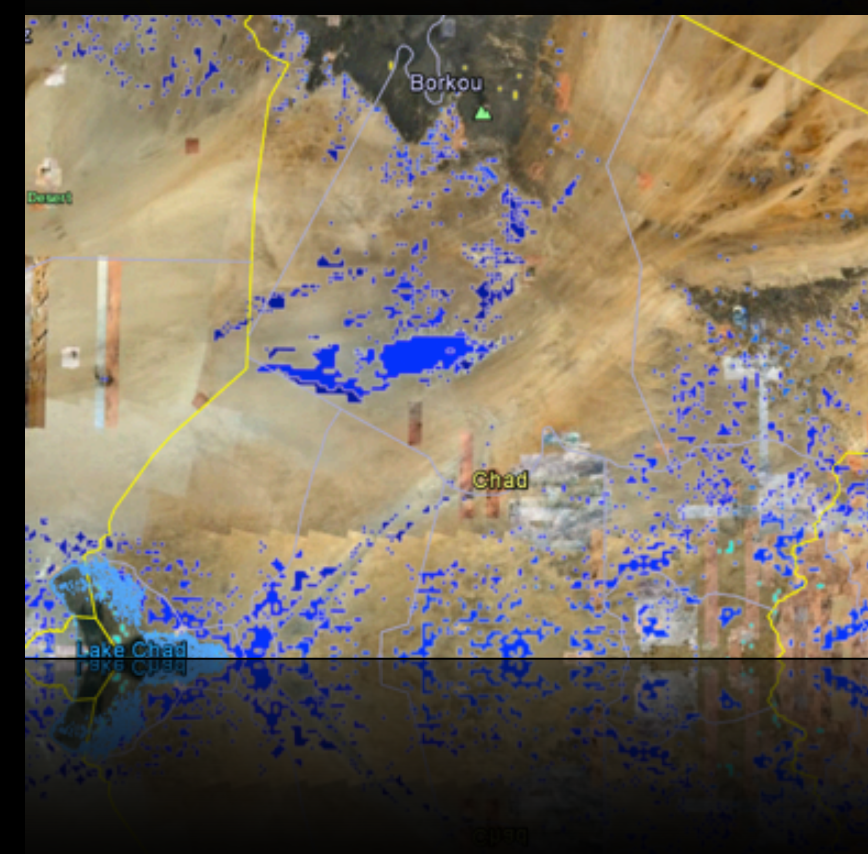

VA Decision Support Tools
My healthevet
Personalized Alerts
Dr. Watson
Staffing & Resource Management
VETERANS ADMINISTRATION 1930
THRIVE Medical Environment Analytics Engine
Machine Learning
Machine Learning
Daily Global Air Quality Estimates
ER Admissions
All ICD Codes
All Prescriptions
Machine Learning
NASA Earth Observation Data
NASA Earth System Model Products
Population Density and Other Related Products
More Than 40 Data Products from In-situ Observations, NASA Earth Observations, Earth System Models, Population Density & Emission Inventories


Oruro
Tacna
Potosi
Iquique
Calama


Borkou
Chad
Lake Chad


Borkou
Chad
Lake Chad

Happy Day!


DELI - PIZZA - SALADS - PA NI - WRAPS - BREAKFAST - LUNCH
ATM
AE JEANS
LIVE IN THESE
TITAN


212-213-0444
BREAKFAST · LUNCH


Street View
Pollution View