Overview of Earth Observations, Satellite Applications, and Atmospheric Monitoring

Presented by:

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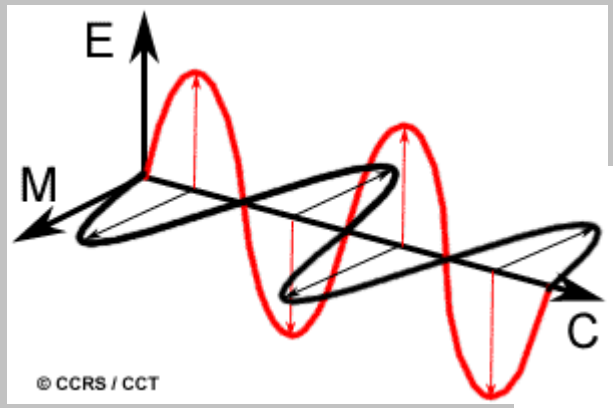
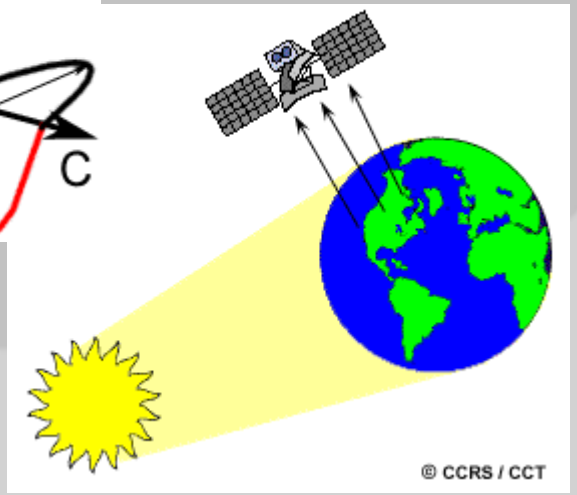
Satellite Remote Sensing

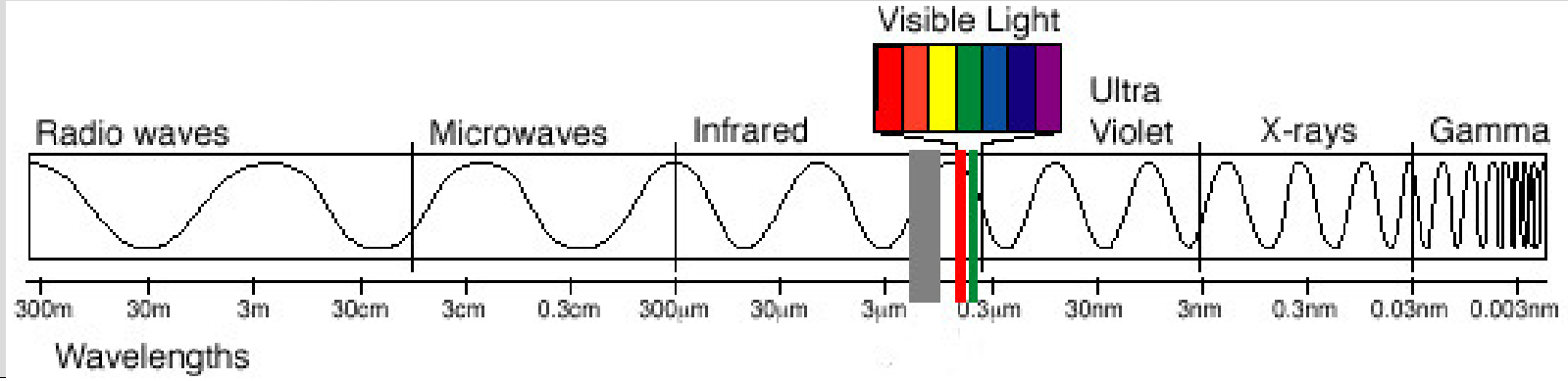
Remote sensing *is the measurement of an object by a device that is not in physical contact with the object.*





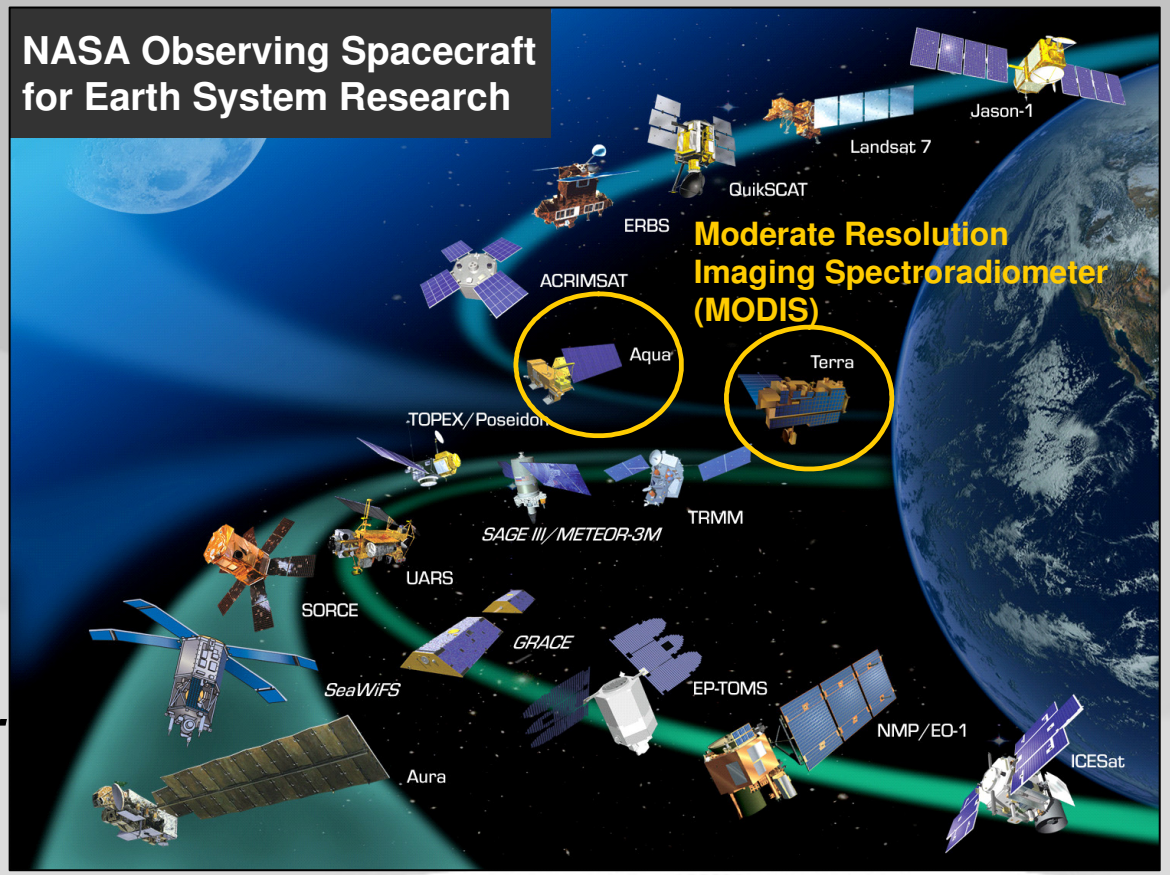
Passive Sensors : Satellites

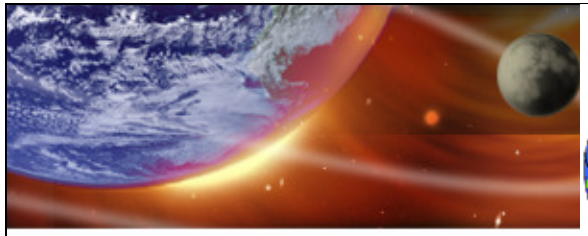
Active Sensors : Radar



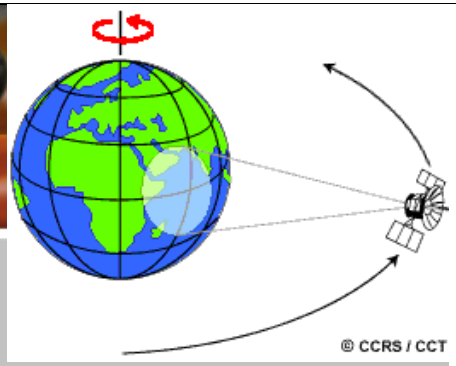
Satellite Remote Sensing

- Advantages: *Repeated reliable measurements*
- Disadvantages: *Expensive and need expertise to convert measurements to geophysical values such as temperature.*

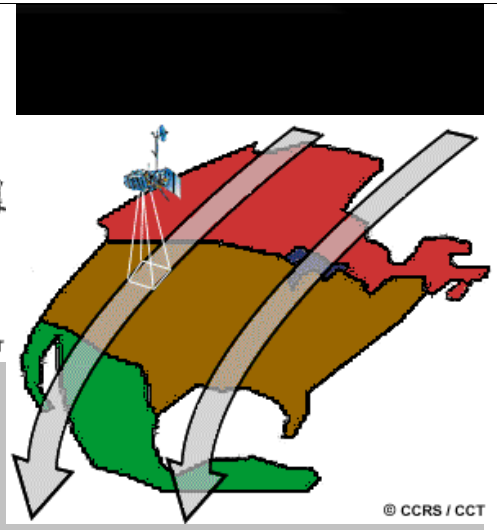


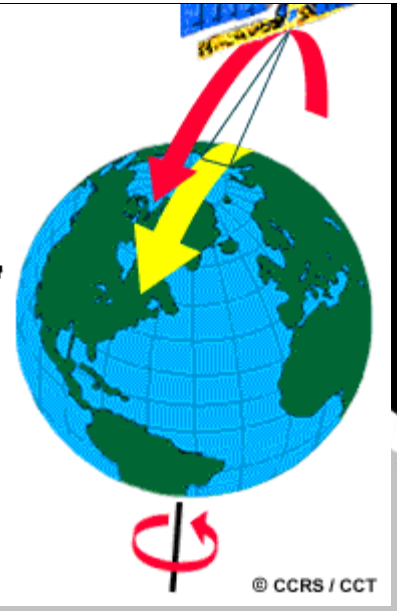


Orbits

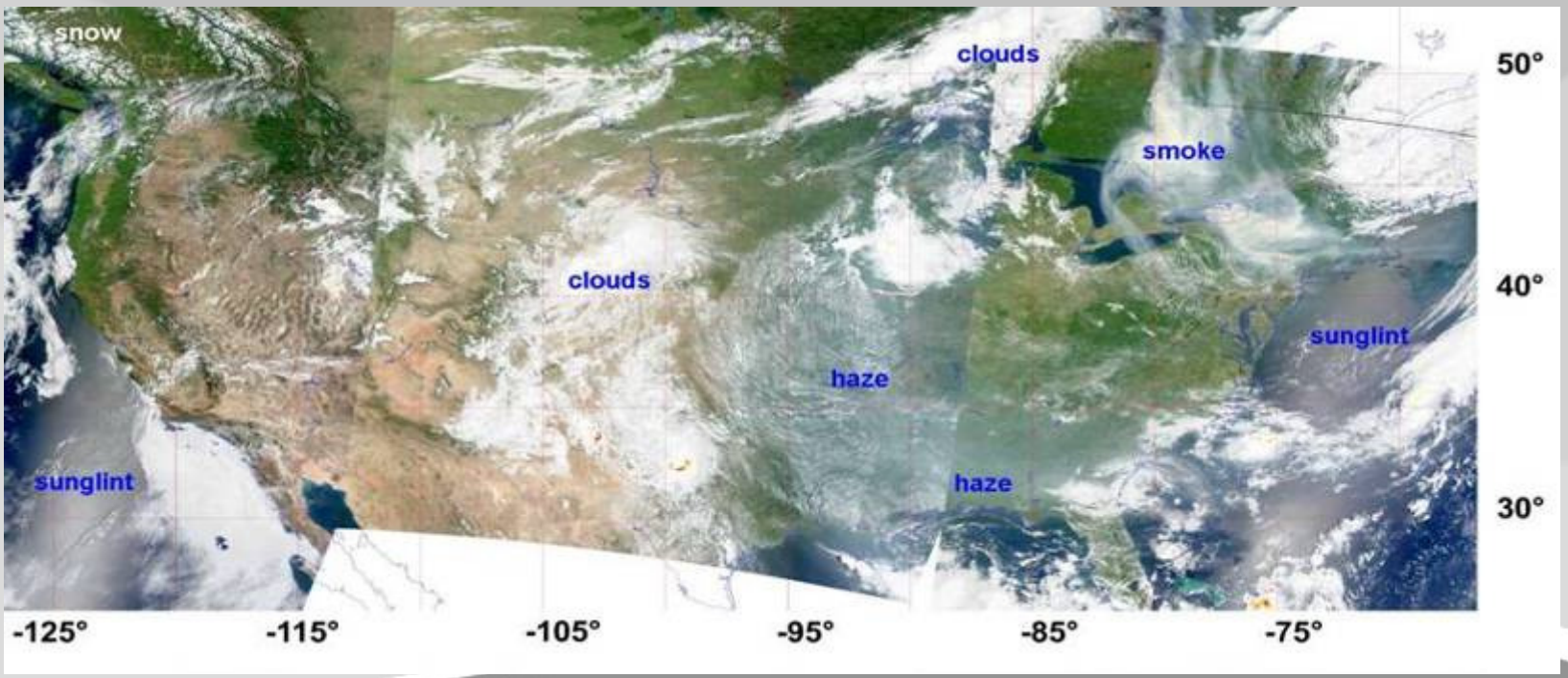


Geostationary



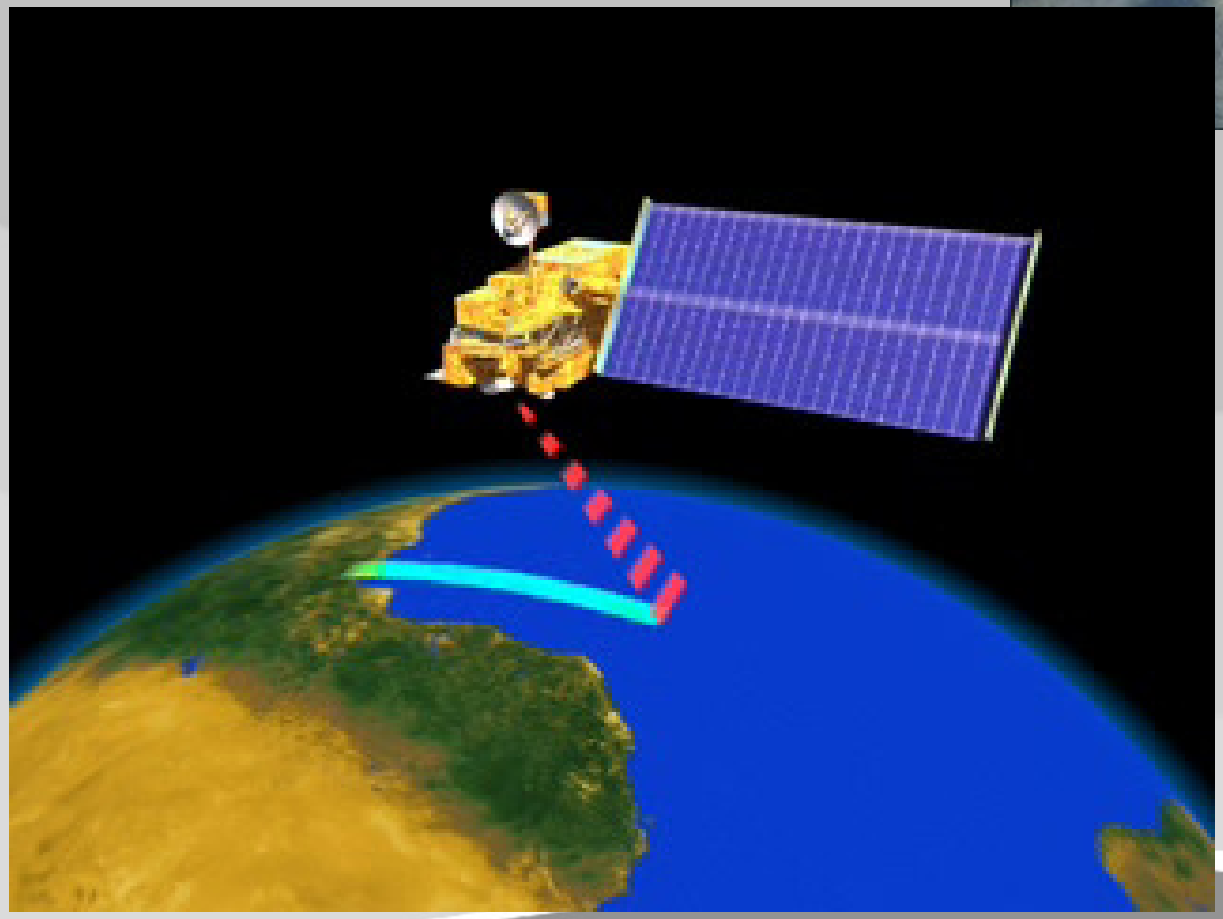


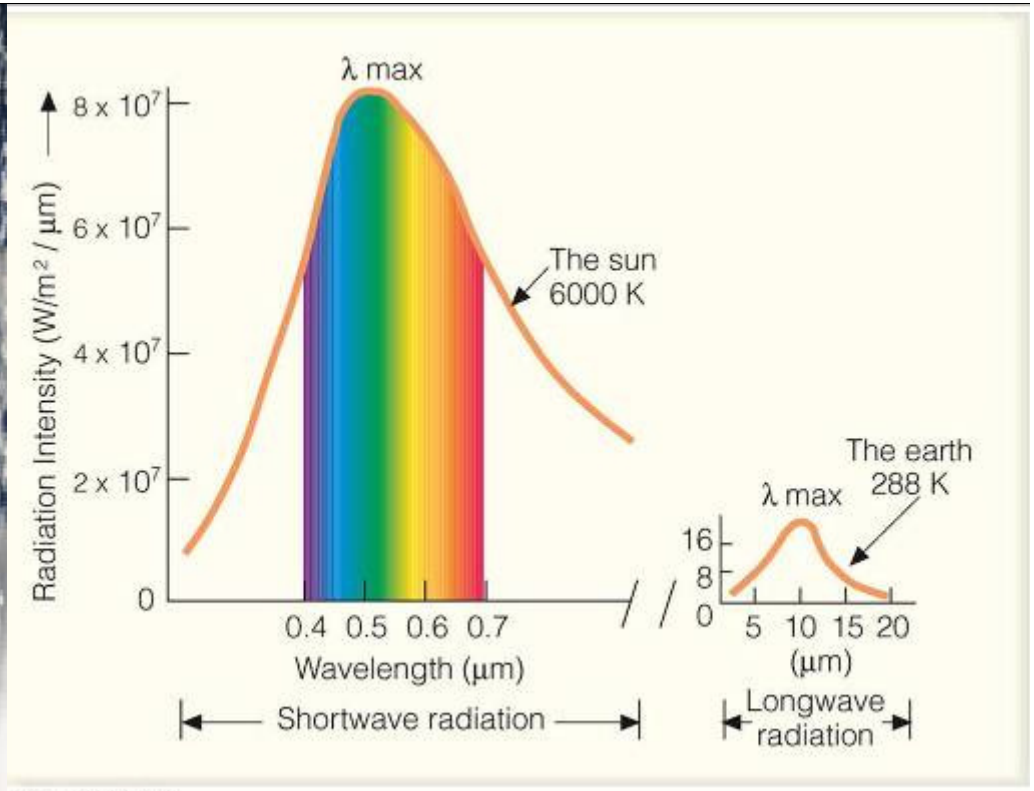
Polar Orbiting

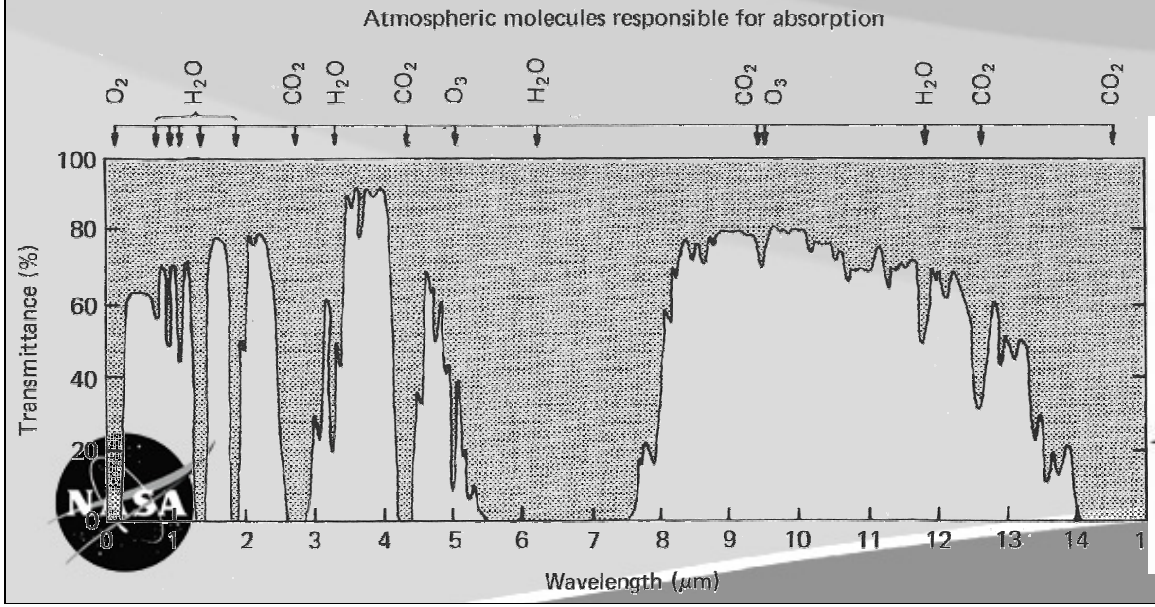


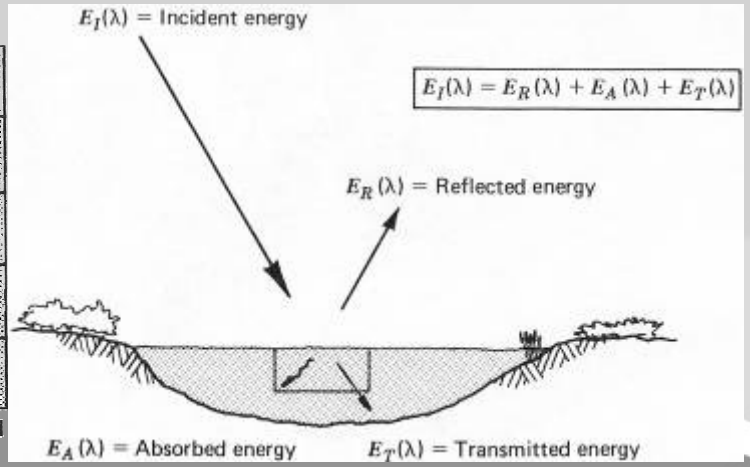
Polar Orbiting orbit

Sun synchronous



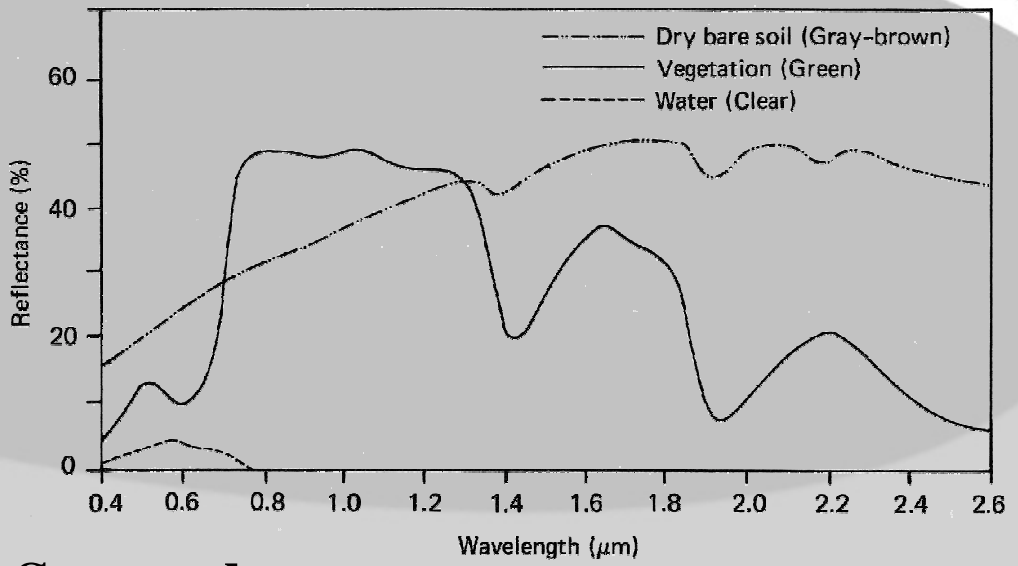






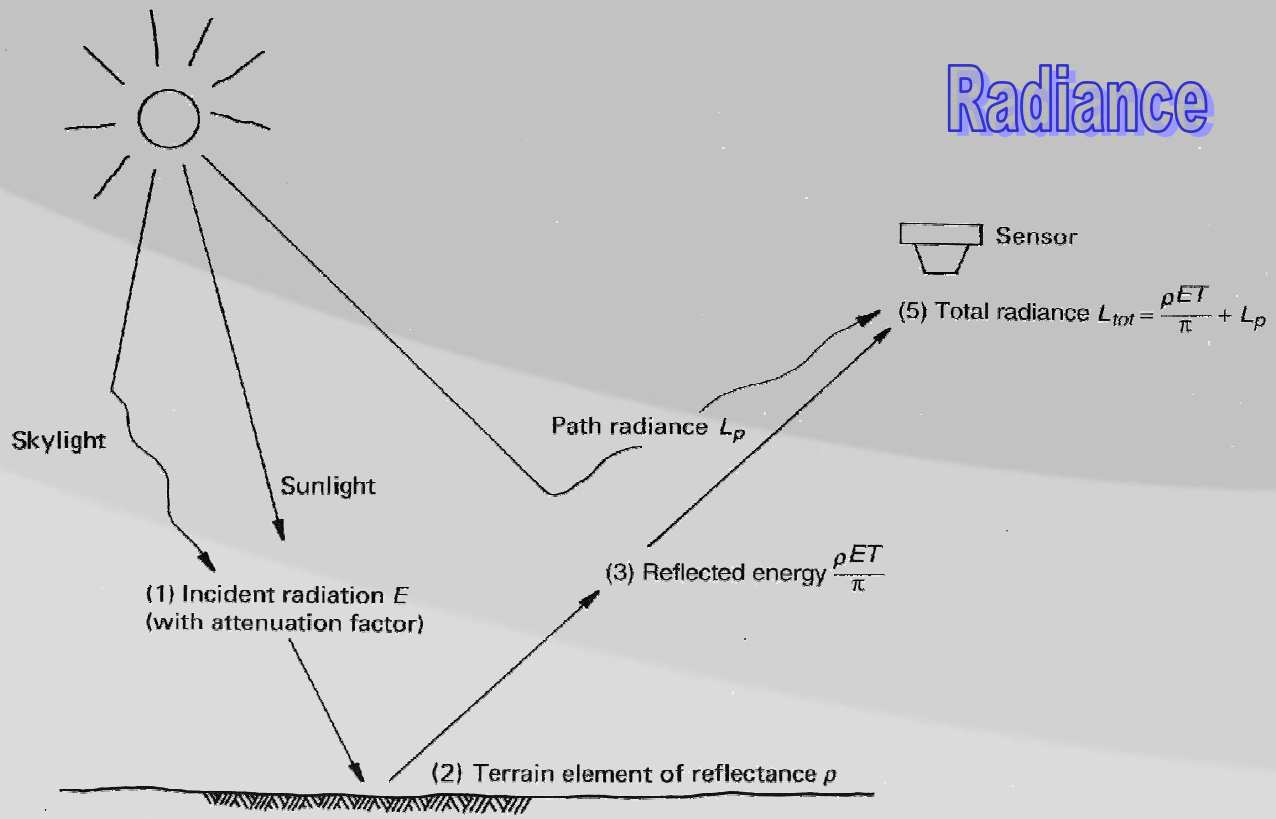
Remote Sensing - Resolutions

- *4 major resolutions*
  - Spectral resolution
  - Spatial resolution
  - Temporal resolution
  - Radiometric resolution

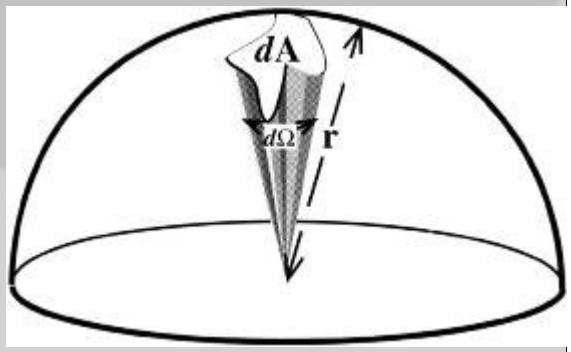


Spectral Signatures

What does satellite "see"

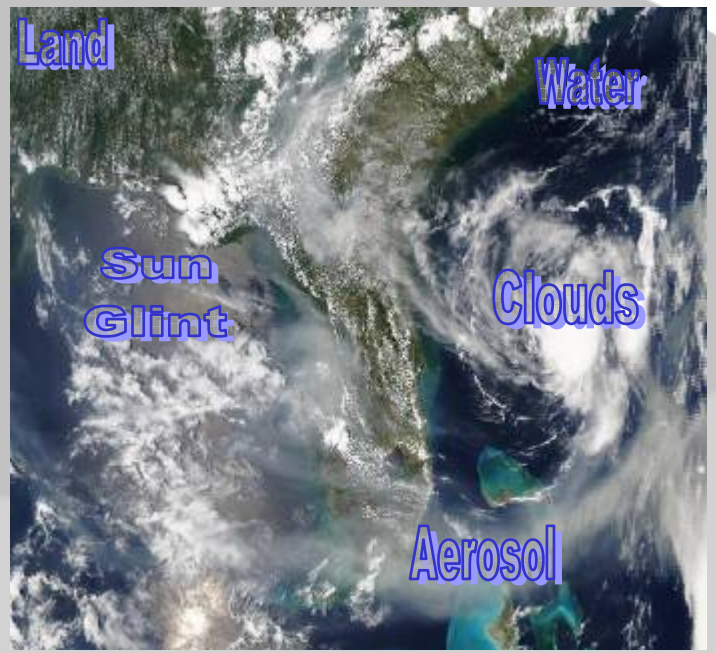


I **= flux per unit area per unit solid angle normal to the direction of propagation [$Wm^{-2}sr^{-1}$]**



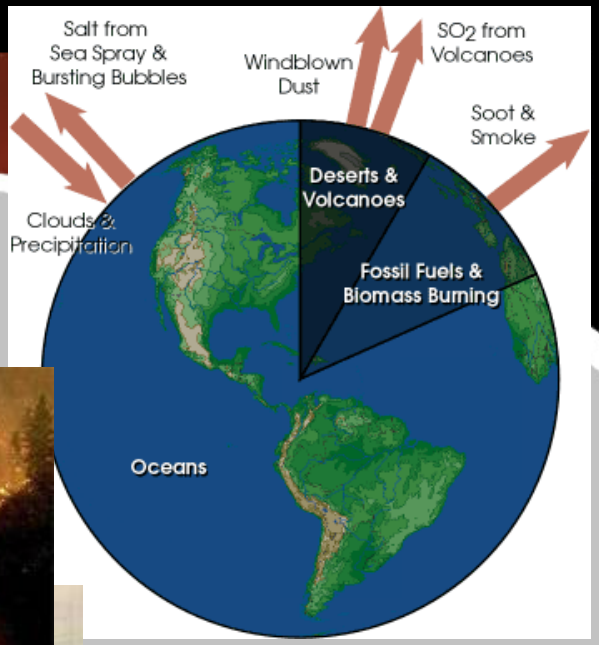
From pretty pictures to numbers

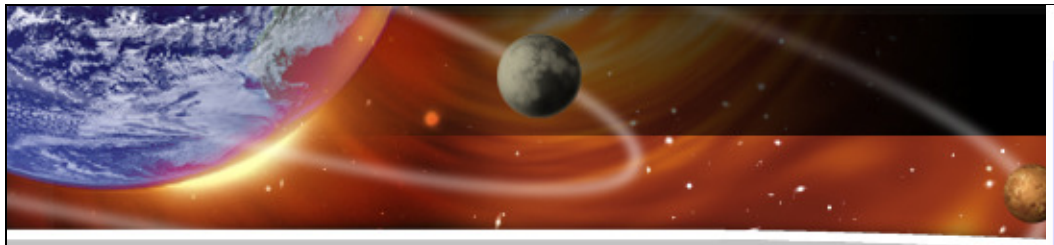
- Radiance is converted to reflectance and temperature
- Multi-spectral Image must be separated into various features (clouds, aerosols, ocean, land etc.)
- This must now be converted to geophysical parameter
- Examples include : Cloud top temperature
- Relevant Example : Aerosol Optical Depth



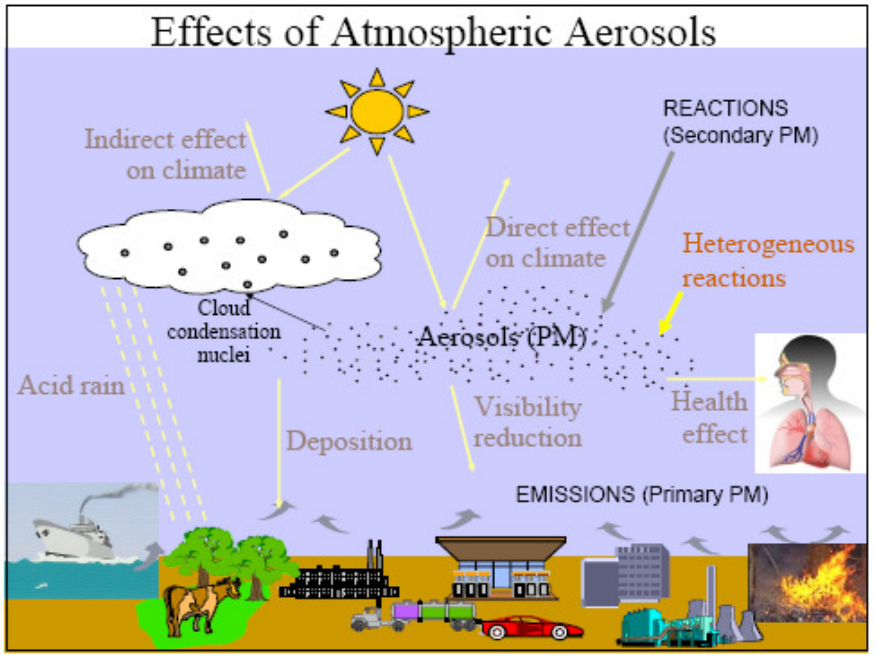
Aerosols - Introduction

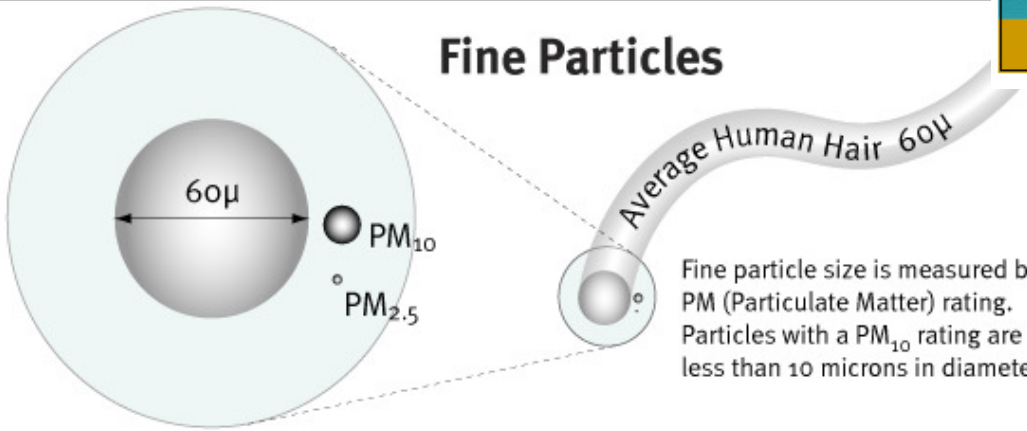
- Climate
- Visibility
- Health
- Hydrology
- Nutrient source



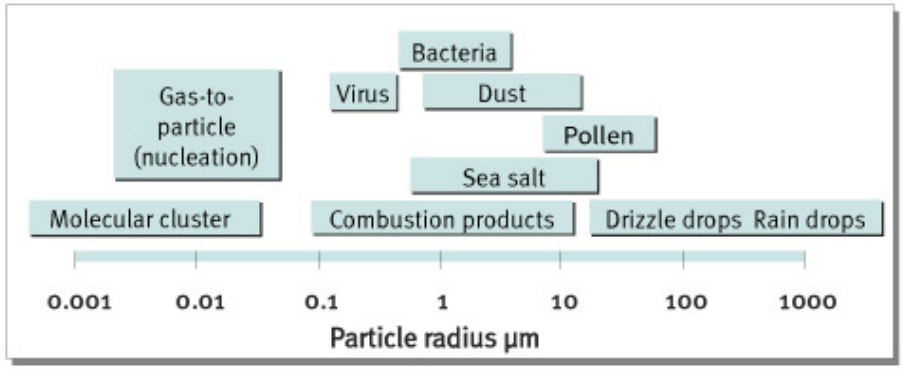


Tiny but potent





Fine particle size is measured by a PM (Particulate Matter) rating. Particles with a PM_{10} rating are all less than 10 microns in diameter



Queensland Government
Environmental Protection Agency

Pollution and Breathing

News Focus

Particle air pollution clearly causes substantial deaths and illness, but what makes fine particles so toxic—the size, the chemical compound, or both?

Mounting Evidence Indicts Fine-Particle Pollution

At risk. Studies with elderly volunteers have shown that slight changes in outdoor particle levels can change heart rate variability.

Industrial Air Pollution: Possible Effect on Lung Cancer

Abstract. *Higher lung cancer mortality rates occurred in males living in certain heavily industrialized areas of Los Angeles County, California. These areas were characterized by elevated concentrations of benzo*[a]*pyrene and other polynuclear aromatic hydrocarbons of primarily industrial origin in the soil and air.*

Industrial pollution linked to lung cancer

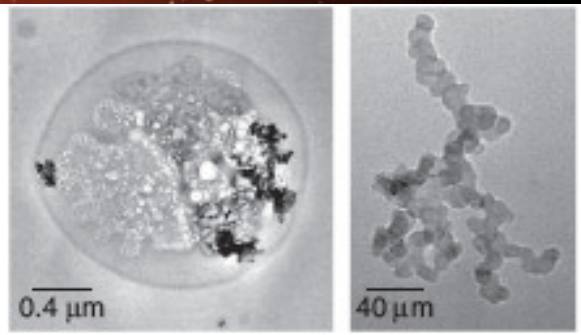
Pollution and Health

Air Pollution–Related Illness: Effects of Particles

André Nel

Worldwide epidemiological studies show a consistent increase in cardiac and respiratory morbidity and mortality from exposure to particulate matter (PM) (*1*–*3*). PM is a key ingredient of polluted air and is estimated to kill more than 500,000 people each year (*4*).

Enhanced online at www.sciencemag.org/cgi/content/full/308/5723/804



Dangerous dirt. (**Left**) Electron micrograph of a fine mode particle collected by an impactor from air outside an engineering laboratory at the University of California, Los Angeles. A halo surrounds residues of what are probably inorganic salts and polar organic compounds dissolved in the original aqueous droplet. Sootlike particles are also present. (**Right**) Aggregates of ultrafine particles collected on the last stage of an eight-stage impactor. These are soot particles emitted from diesel engine sources such as buses. More volatile particles may have evaporated in the electron microscope.

Increase in cardiac and respiratory illnesses

Pollution Suppresses Rain

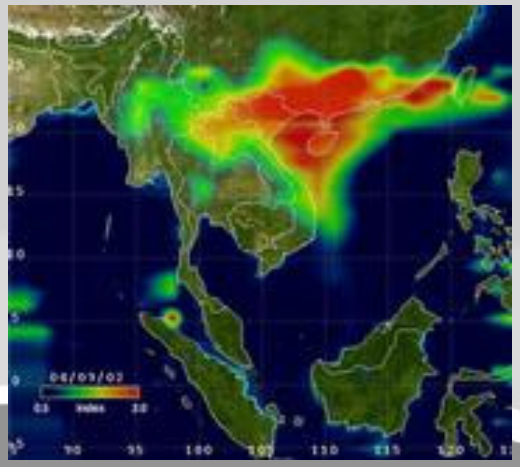
Suppression of Rain and Snow by Urban and Industrial Air Pollution

Daniel Rosenfeld

Direct evidence demonstrates that urban and industrial air pollution can completely shut off precipitation from clouds that have temperatures at their tops of about –10°C over large areas. Satellite data reveal plumes of reduced cloud particle size and suppressed precipitation originating from major urban areas and from industrial facilities such as power plants. Measurements obtained by the Tropical Rainfall Measuring Mission satellite reveal that both cloud droplet coalescence and ice precipitation formation are inhibited in polluted clouds.

Pollution reduces size of cloud droplets

Shuts off rain processes



Aqua Satellite

Sun

Aerosol Optical Thickness :Basis

Column Satellite Measurement

Multiple MODIS bands are utilized to derive aerosol properties

0.47, 0.55, 0.65, 0.86, 1.24, 1.64, and 2.13 μm

10X10 km^2 Res.

Ozone

10km

Rayleigh Scattering

Water vapor + other gases (absorption)

$$AOT\ (\tau) = \int \beta_{ext}\, dz$$

Particle size
Composition
Water uptake
Vertical Distribution

Aerosol

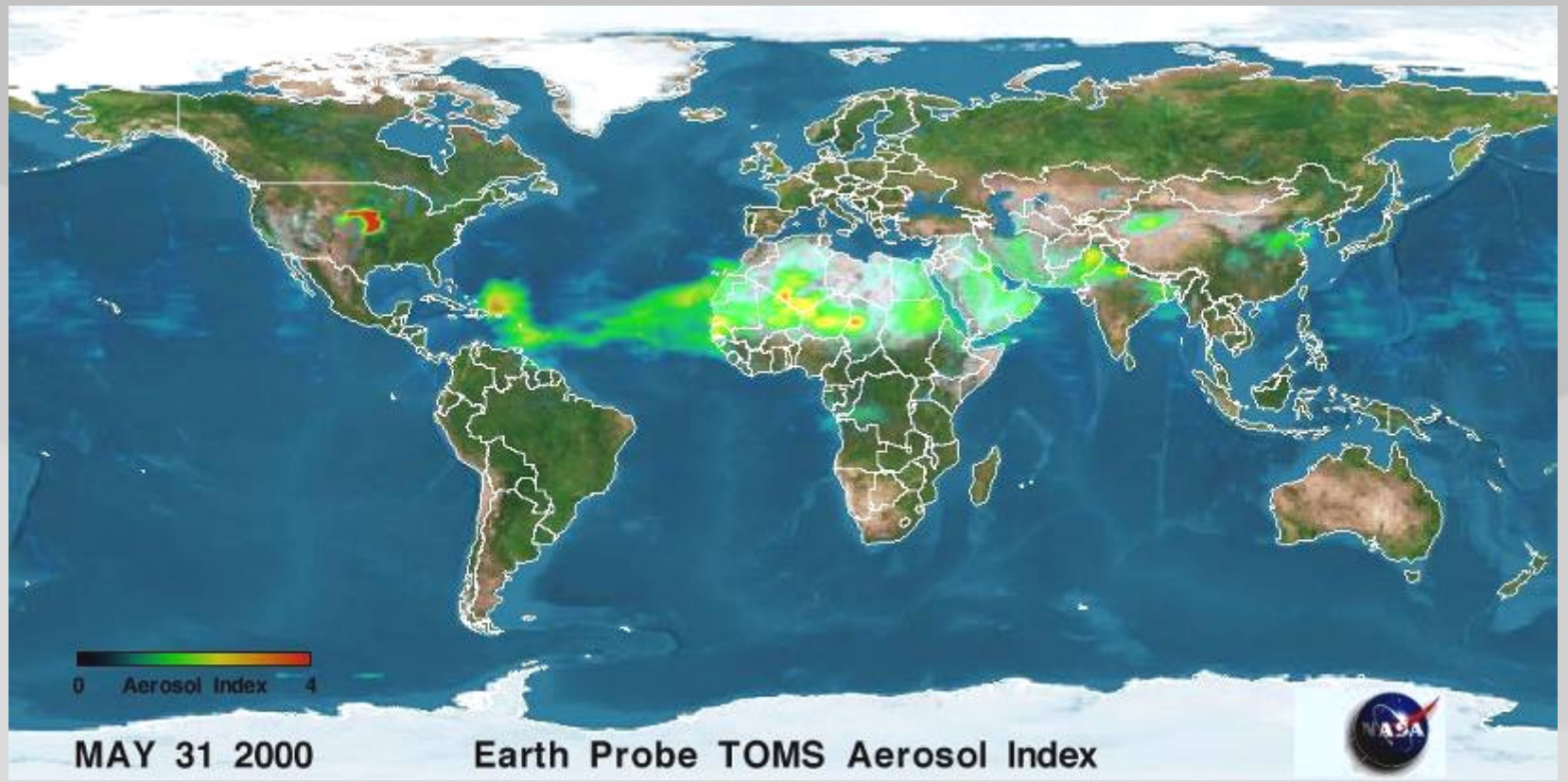
TEOM

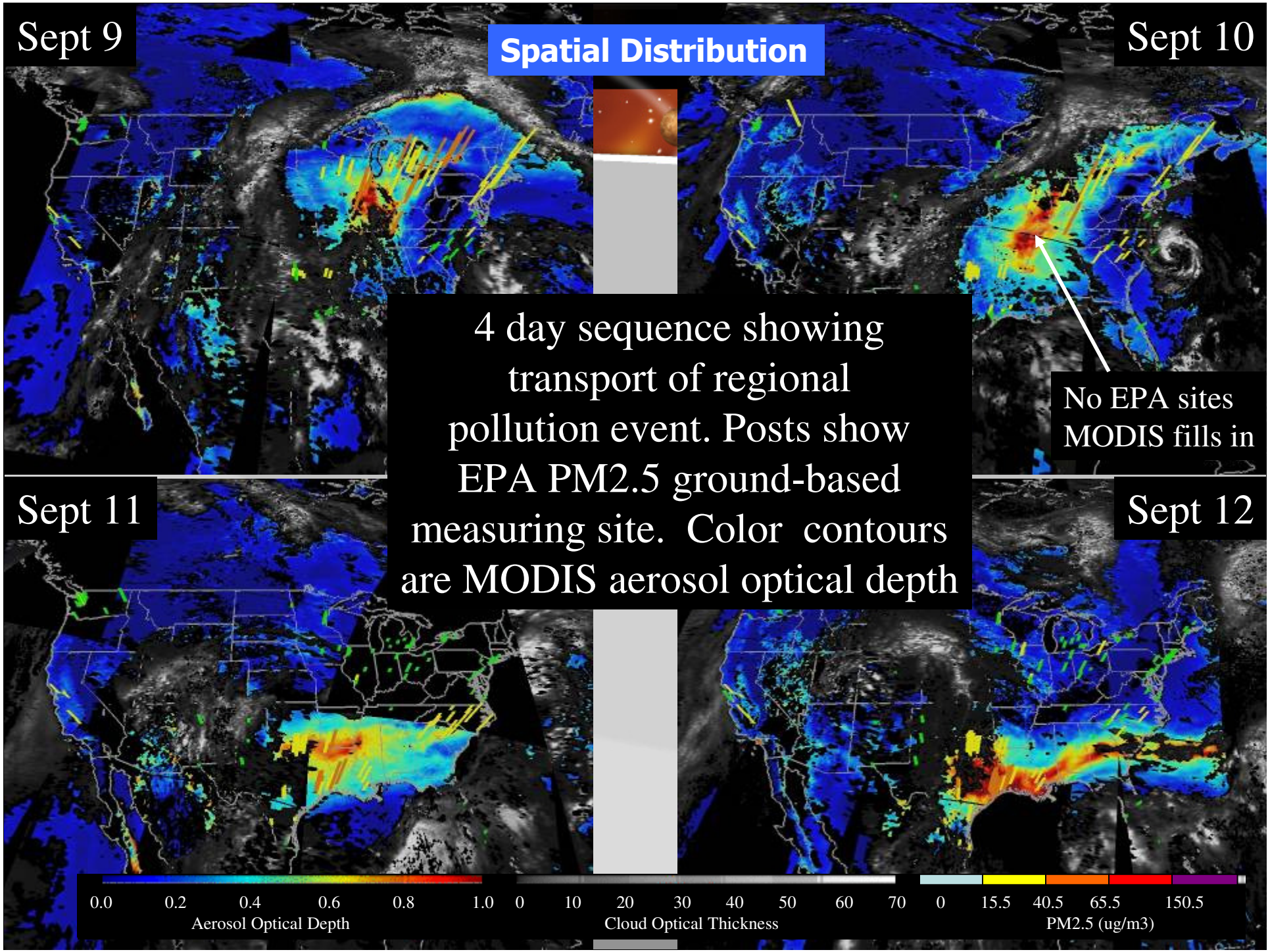
Surface

Point Measurement PM2.5 mass

Satellite retrieval issues - inversion (e.g. aerosol model, background).

Aerosols from Space, Example




Sept 9
Spatial Distribution
Sept 10
4 day sequence showing transport of regional pollution event. Posts show EPA PM2.5 ground-based measuring site. Color contours are MODIS aerosol optical depth
No EPA sites MODIS fills in
Sept 11
Sept 12
0.0 0.2 0.4 0.6 0.8 1.0
Aerosol Optical Depth
0 10 20 30 40 50 60 70
Cloud Optical Thickness
0 15.5 40.5 65.5 150.5
PM2.5 (ug/m3)

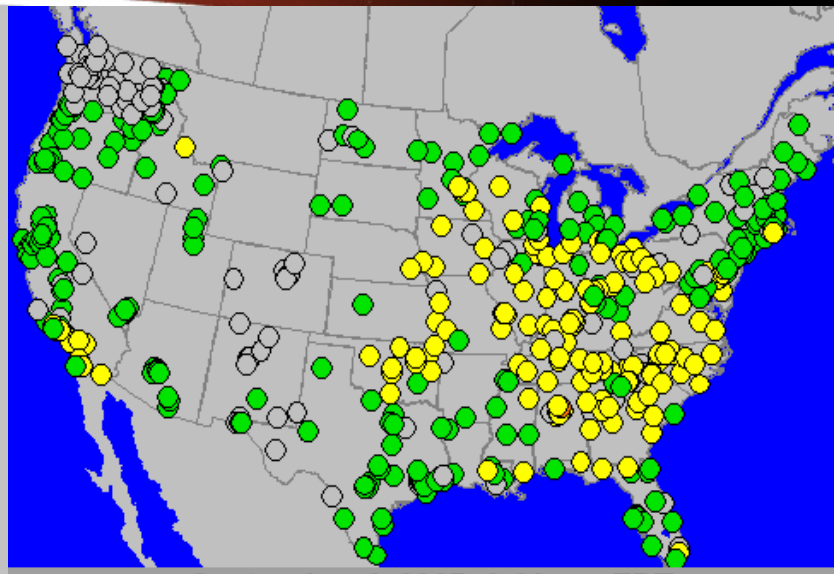
From AOT to air quality

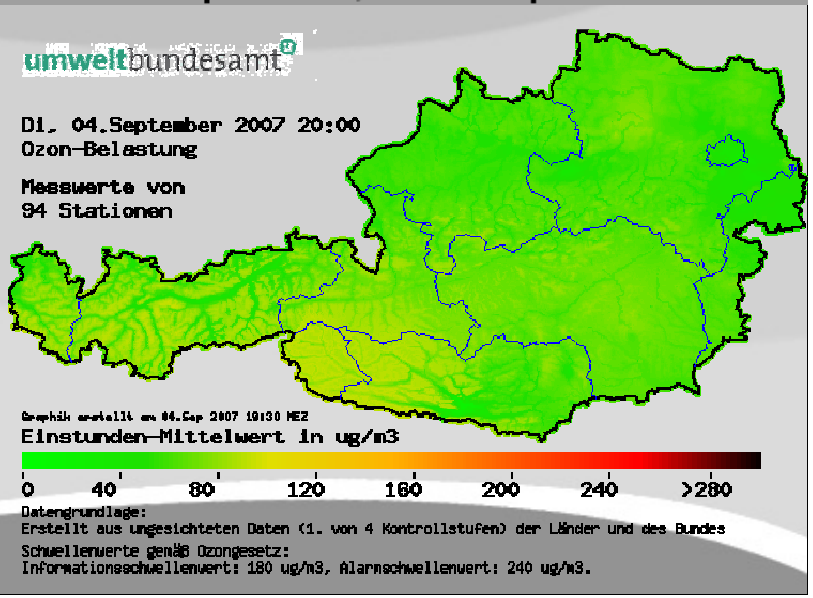
- The next 30 minutes….
- Ground-based air pollution monitors and air quality index
- Relationship of AOT to ground-based measurements
- Strengths and limitations

Index Values	Category	Cautionary Statements	$PM_{2.5}$ (ug/m^3)	PM_{10} (ug/m^3)
0-50	Good	None	0-15.4	0-54
51-100	Moderate	Unusually sensitive people should consider reducing prolonged or heavy exertion	15.5-40.4	55-154
101-150	Unhealthy for Sensitive Groups	Sensitive groups should reduce prolonged or heavy exertion	40.5-65.4	155-254
151-200	Unhealthy	Sensitive groups should avoid prolonged or heavy exertion; everyone else should reduce prolonged or heavy exertion	65.5-150.4	255-354
201-300	Very Unhealthy	Sensitive groups should avoid all physical activity outdoors; everyone else should avoid prolonged or heavy exertion	150.5-250.4	355-424

Air Quality Monitors at the Ground Level

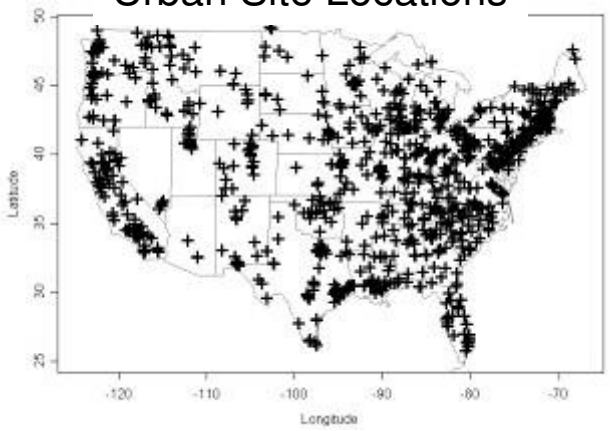
- Air quality experts are concerned about human health so interested in air quality where people breath – at the ground!
- Ambient air pollution monitors for various pollutants: fine particles, ozone, carbon monoxide…
- Satellites usually average vertically at specific points in time, so…
- Important to understand relationship of satellite column data to ground monitor data



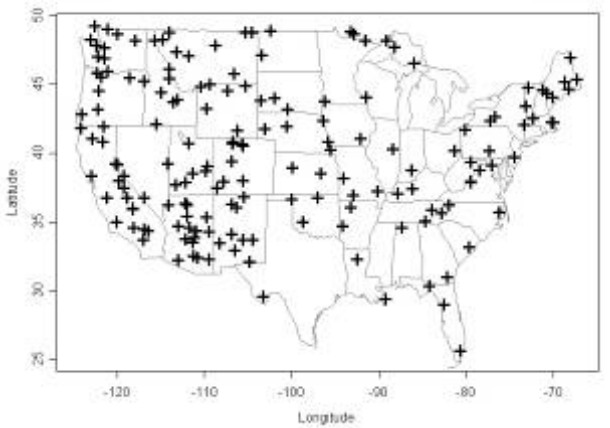


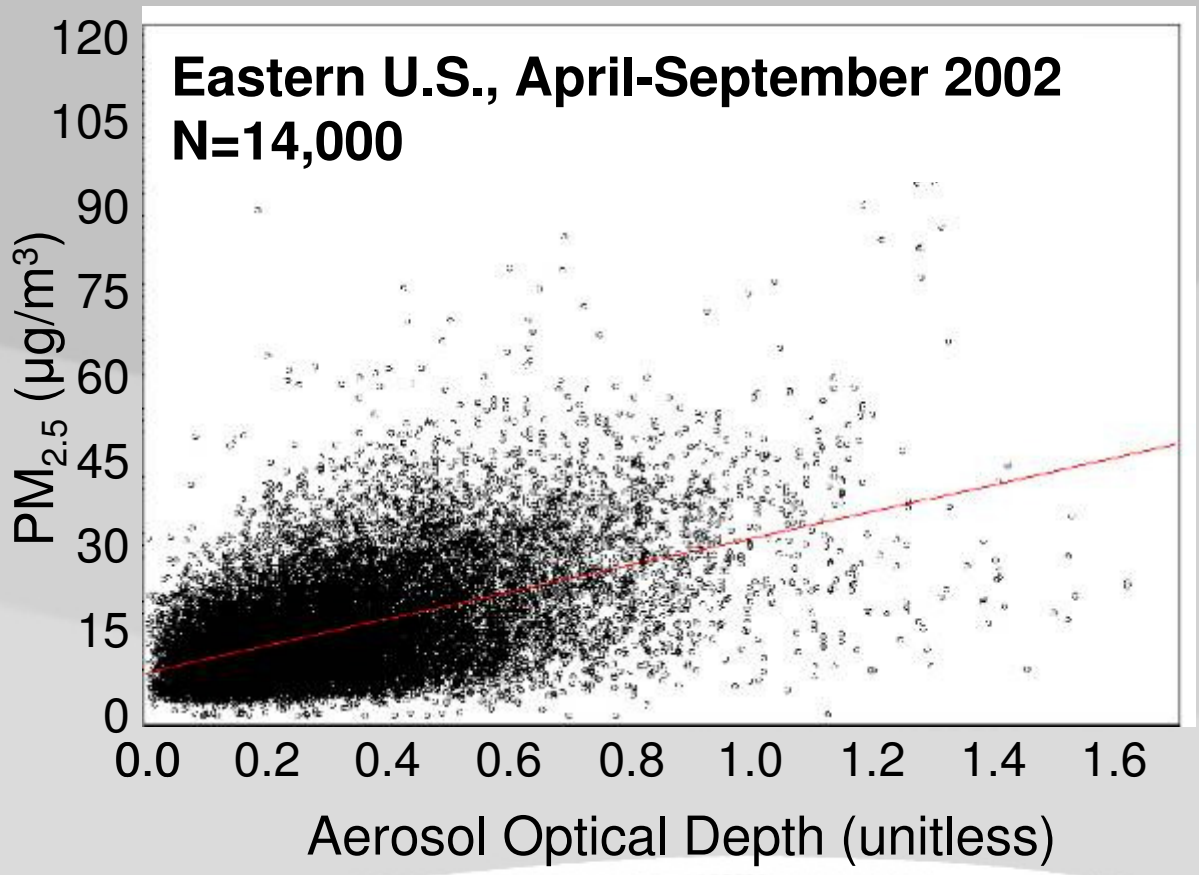
Example Quantitative Analysis for U.S.: $PM_{2.5}$ Concentrations vs. MODIS AOD

Urban Site Locations

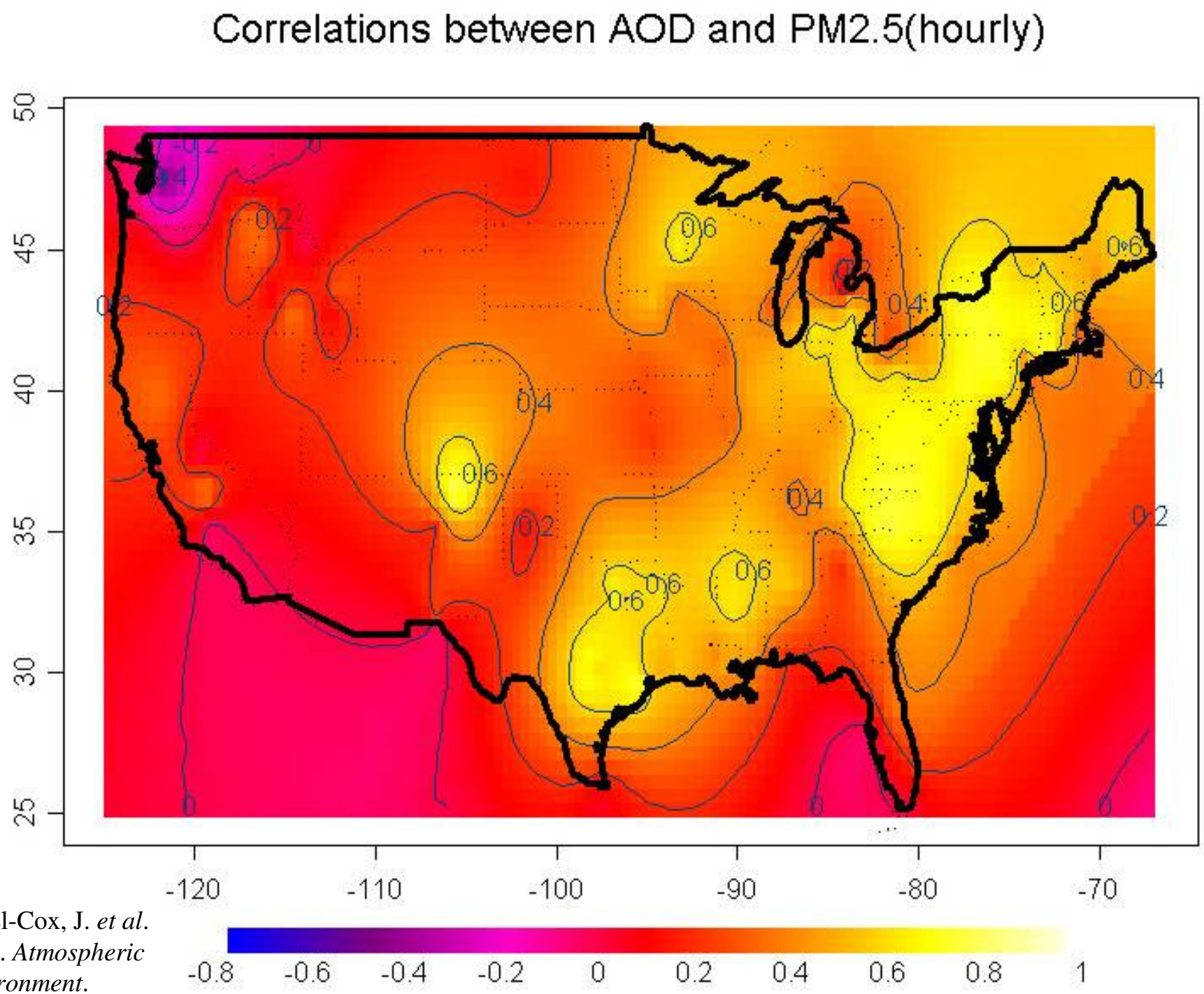


Rural Site Locations





Engel-Cox, J. *et.al*. 2004. *Atmospheric Environment*.



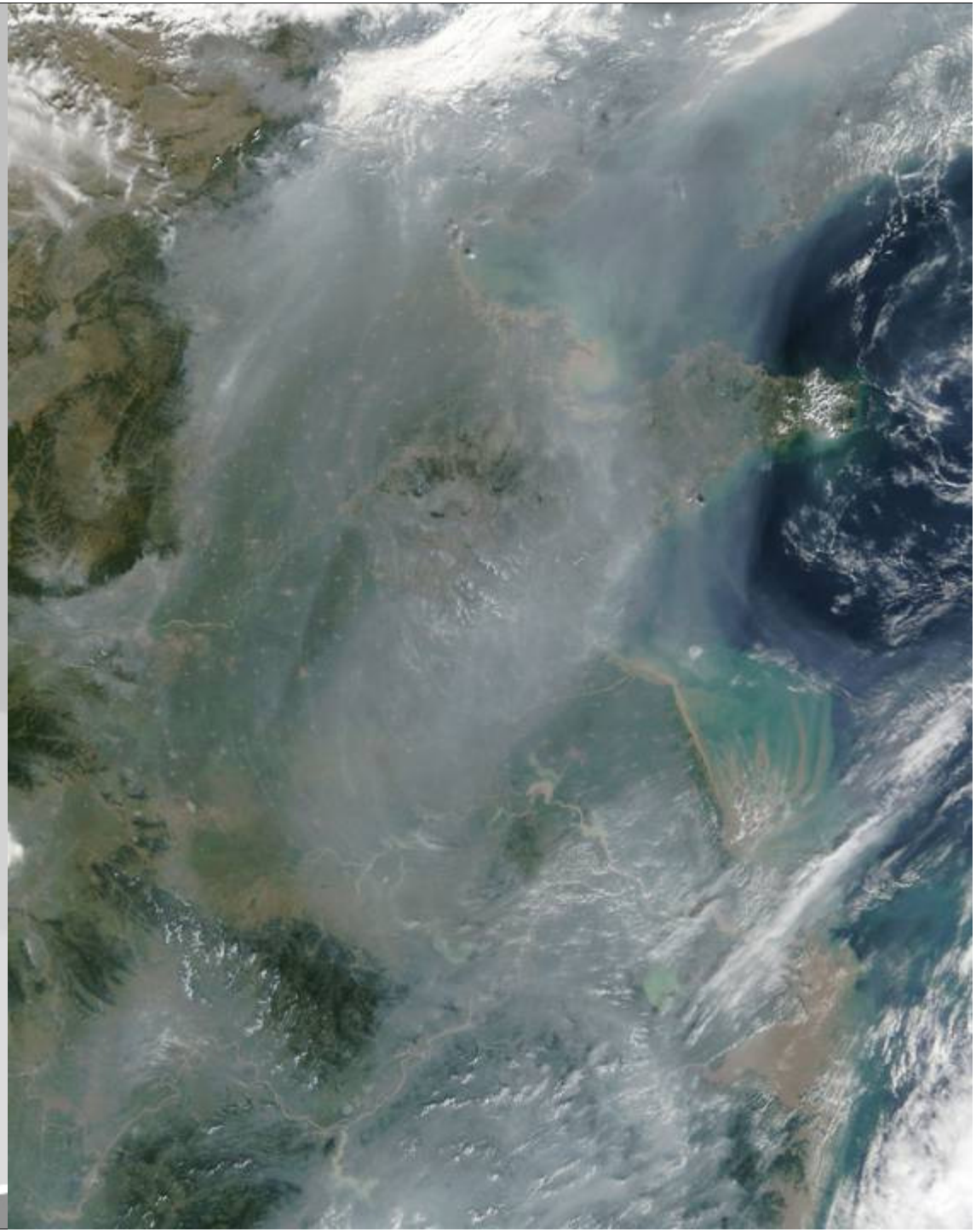
Engel-Cox, J. *et al*. 2004. *Atmospheric Environment*.

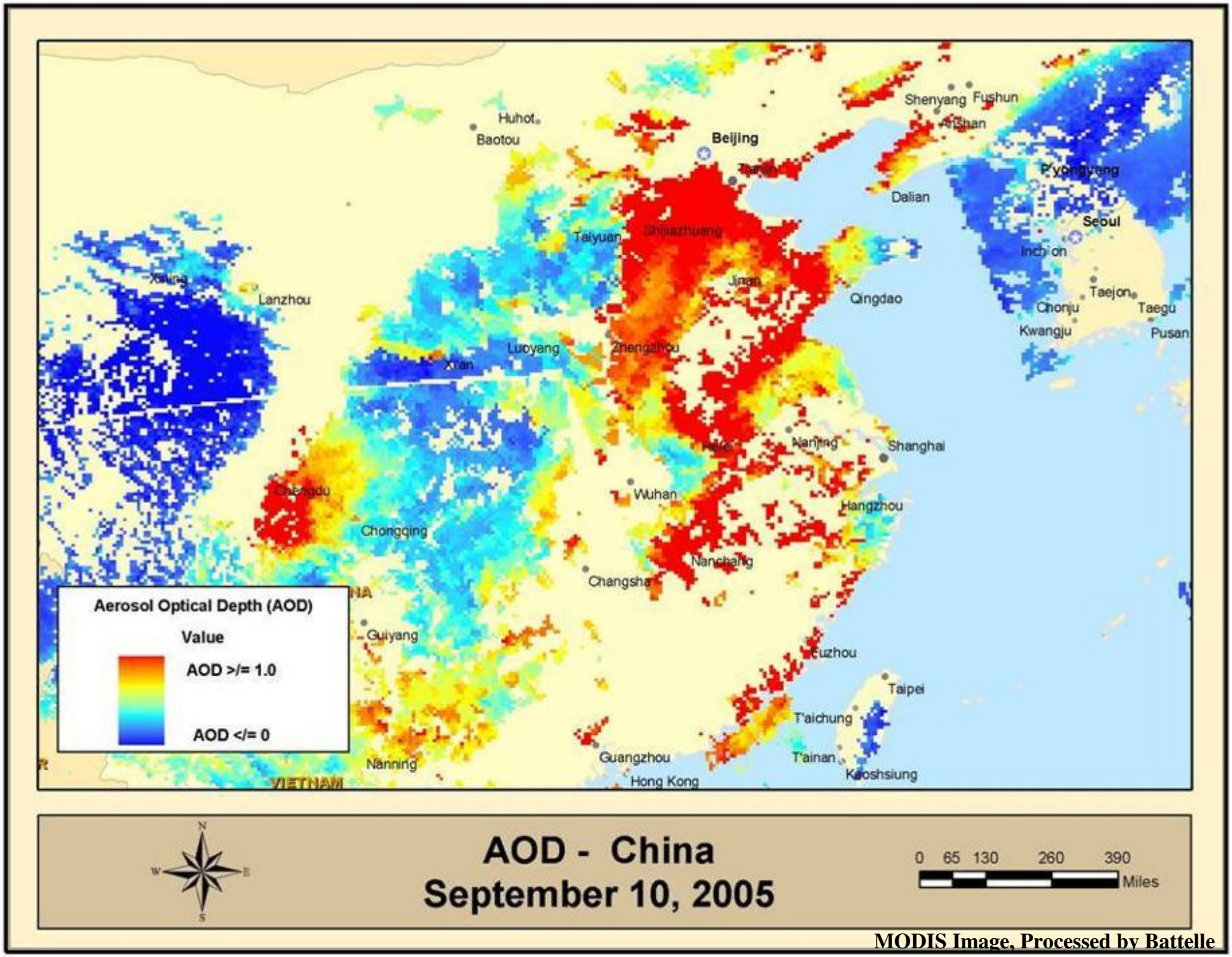
Important Applications of Satellite Data for Monitoring Air Quality

- Visualizing extent of pollution
- Understanding transport of pollutants
- Forecasting pollution events

Visualizing Extent of Pollution:

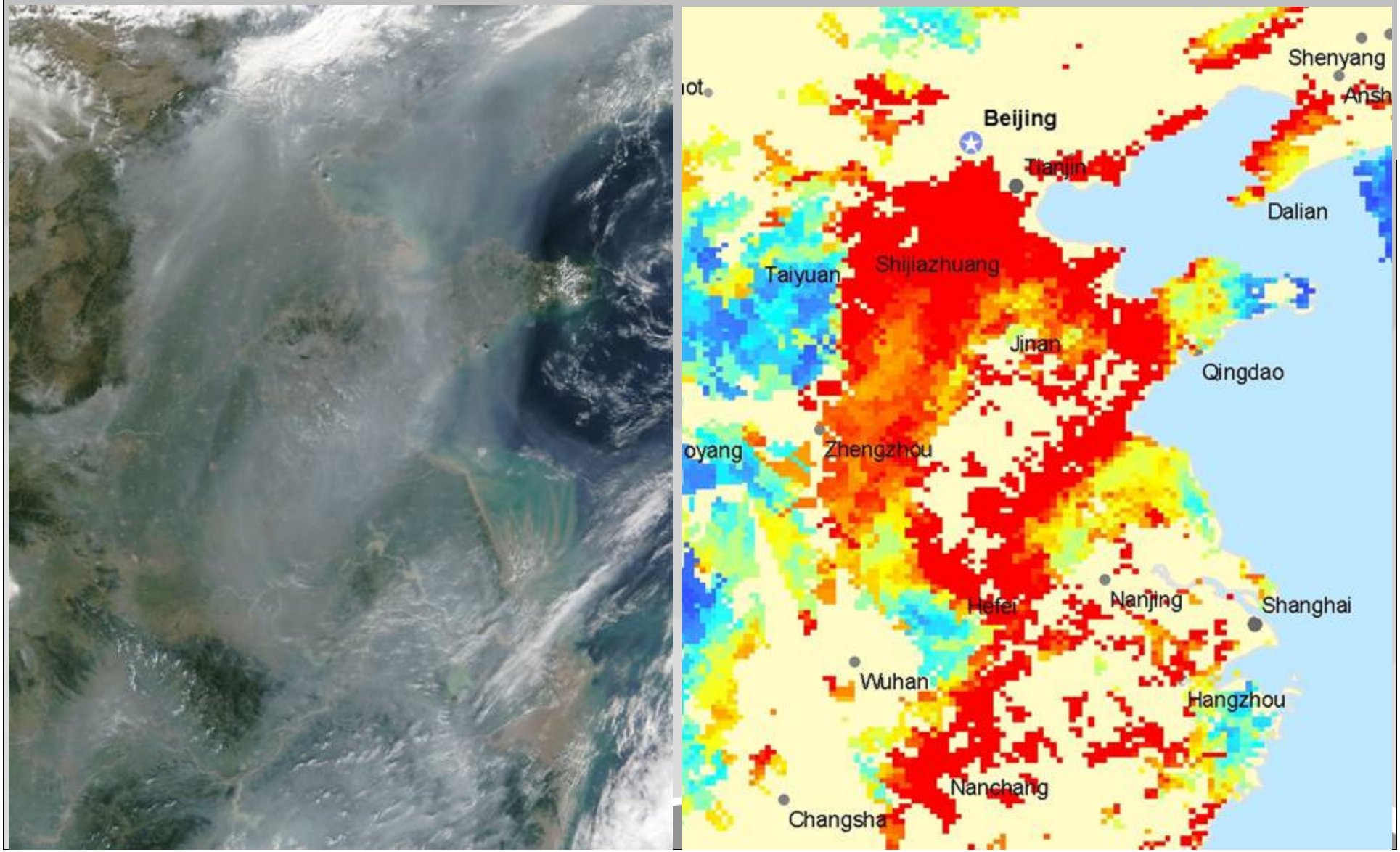
MODIS True Color Image of Eastern China 10 September 2005

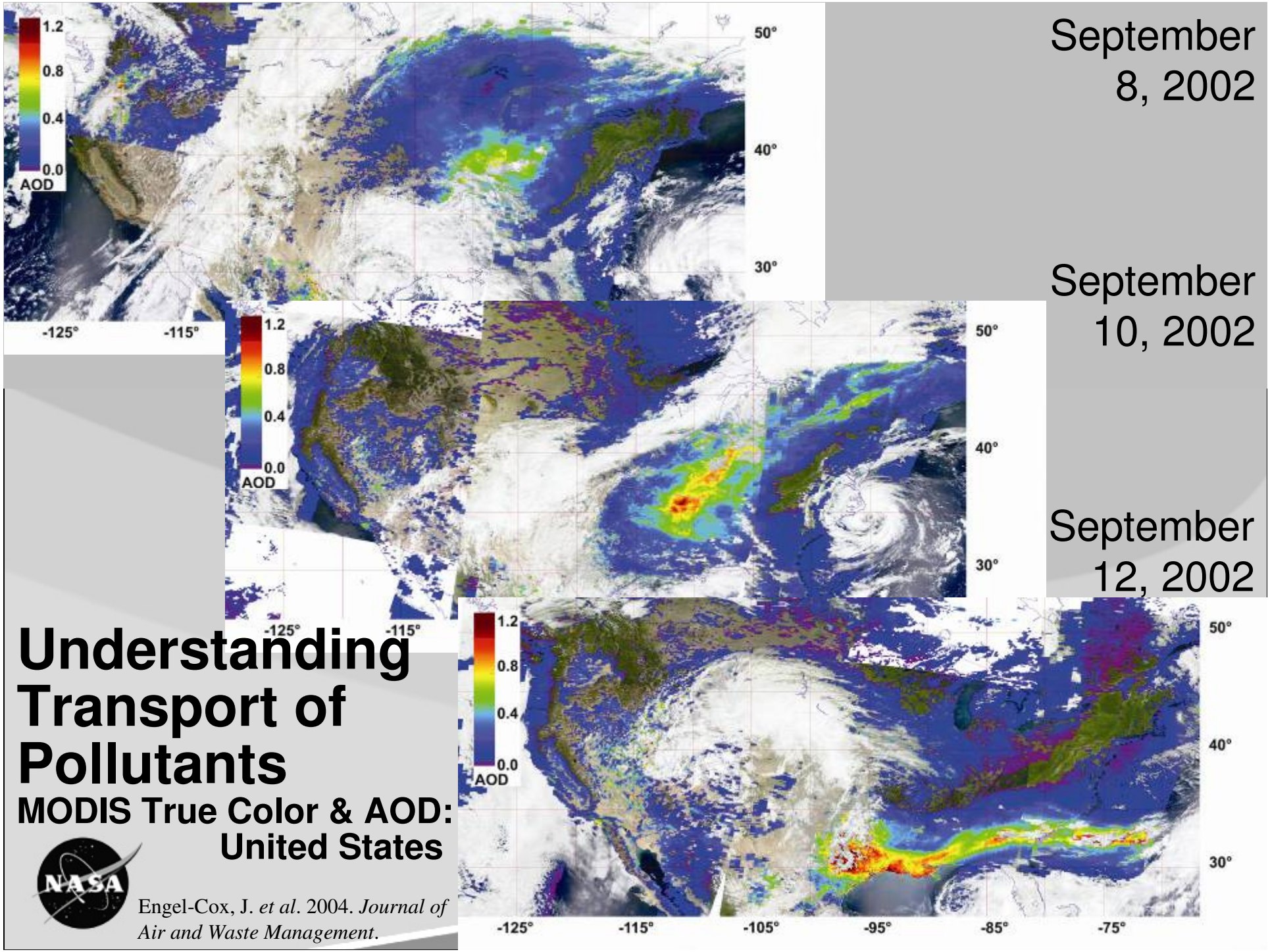




MODIS Image, Processed by Battelle

Eastern China
True Color vs. AOD – 10 September 2005





Understanding Transport of Pollutants

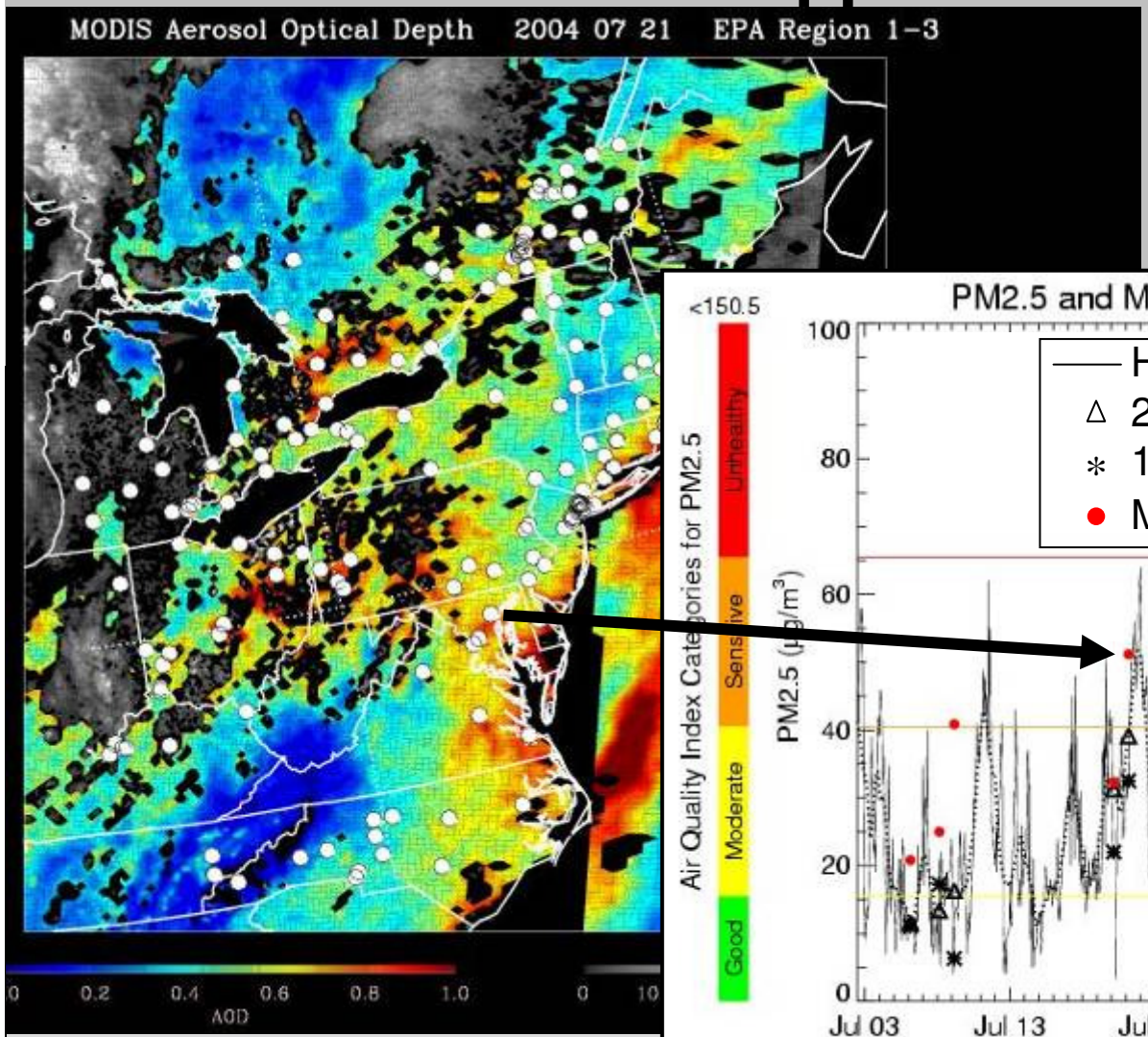
MODIS True Color & AOD: United States

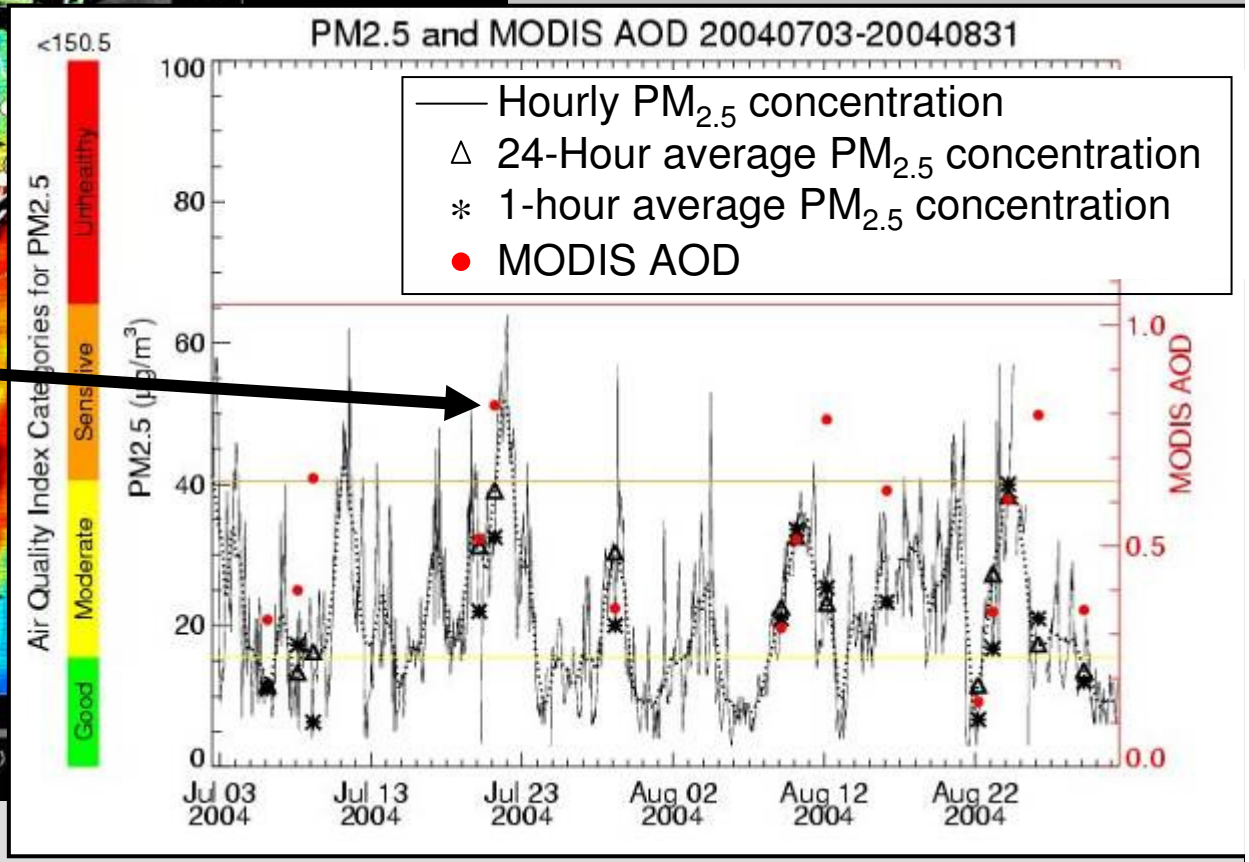
Engel-Cox, J. *et al*. 2004. *Journal of Air and Waste Management*.

Forecasting: NASA/EPA Infusing satellite Data into Environmental Applications (IDEA) site

http://idea.ssec.wisc.edu/

Baltimore, Maryland





Forecasting Support

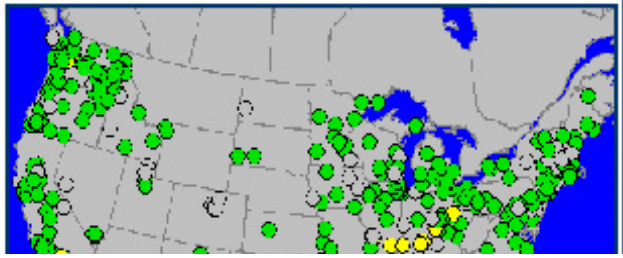
U.S. Air Quality (The Smog Blog), http://alg.umbc.edu/usaq

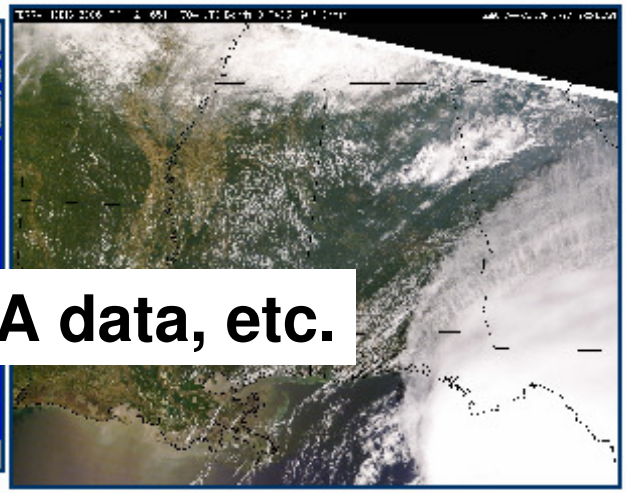
U.S. Air Quality
The Smog Blog

June 12, 2006

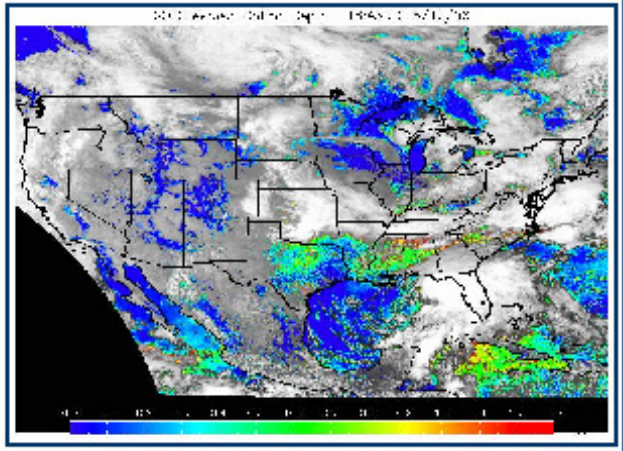
MODERATE AQI IN THE SOUTH

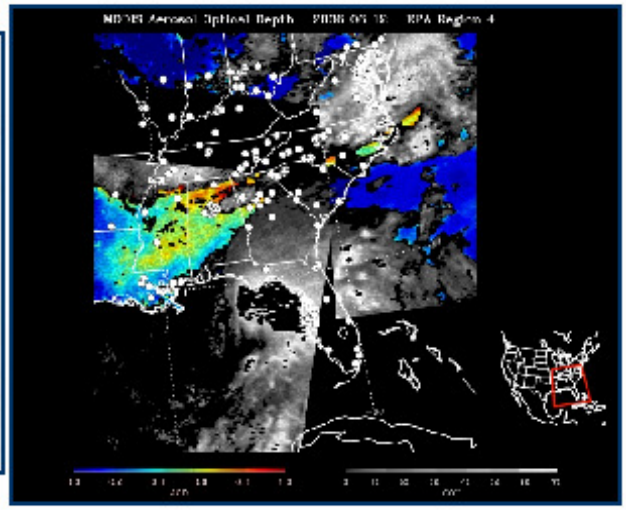
Particulate Matter measurements rem **Daily posts** outh. Tropical Storm Alberto (source: NOAA OSEI) is also visible in today's satellite images, ol load over the south (also mentioned by Jill in yesterday's post). Both GASP and IDEA show the intensity of aerosols; AOD reached unity in some places.





Satellite images, EPA data, etc.





About U.S. Air Quality

USAQ is a daily diary of air quality in the U.S. using information from NASA satellites, ground-based lidar, EPA monitoring networks, and other monitors. Interpretation and analysis is provided by the staff of the University of Maryland, Baltimore County Atmospheric Lidar Group.

Search

Search this site: Search

Recent Entries

- Moderate AQI in the South
- Southern haze and Alberto, the first named Atlantic storm
- Hazy in Louisiana
- CALIPSO comes alive!
- Still hazy in the east
- Moderate AQI Continues...
- Moderate AQI in the East

Index & Links

Main Data Sources

- UW MODIS Direct
- NASA MODIS Rapidfire Browse / Subsets
- EPA AirNow / ParticlesNow
- NASA/EPA/NOAA/UW IDEA
- NOAA NESDIS GASP
- NASA OMI Ozone and Aerosol
- NOAA Hazard Mapping System Fire and Smoke Product
- Baltimore-DC Air-Watch.net
- UMBC-ALG Webcam
- NPS DC WebCam/McMillan Reservoir AQ

Help Files

- MODIS Red Green Blue Image (MODIS Direct)

Image Interpretation Help Files

Other Links

Potential and Limitations of Satellites and Air Pollution

- Limitations
  - Lack of specificity about some pollutants (best for fine particles, but other pollutants are possible)
  - Resolution and temporal scales sometimes too large
  - Vertical layer sometimes not clear (sum over column of air)
  - Large complex datasets difficult to acquire and use
- Advantages
  - Greater detail over regions especially those with no ground monitors
  - Synoptic and transboundary view (time and space)
  - Adds value when combined with other data and models
  - Visual appeal

New satellite sensors and tools will help address some limitations, especially if the air quality community stays involved.

Global Applications

- Hemispheric, regional, country, and urban scales
- Improved qualitative and quantitative air quality monitoring
  - Remote areas without monitors
  - Ground-based network supplementation & validation
  - Data for evaluation of modeling tools
  - Characterization of large-scale sources and intercontinental & regional transport
- Air quality visualization
  - Eye-catching for policymakers
  - Near-real time displays (support for forecasts and public use)
- Support Multilateral Treaties
  - e.g., Convention on Long-range Transboundary Air Pollution (LRTAP)


Questions?
MODIS Aqua, 25 August 2007
Image courtesy of Rapid Response System, NASA GSFC