A Mobile SURFRAD Platform for validation of GOES-R products (Aerosol Optical Depth and Surface Solar Radiation)

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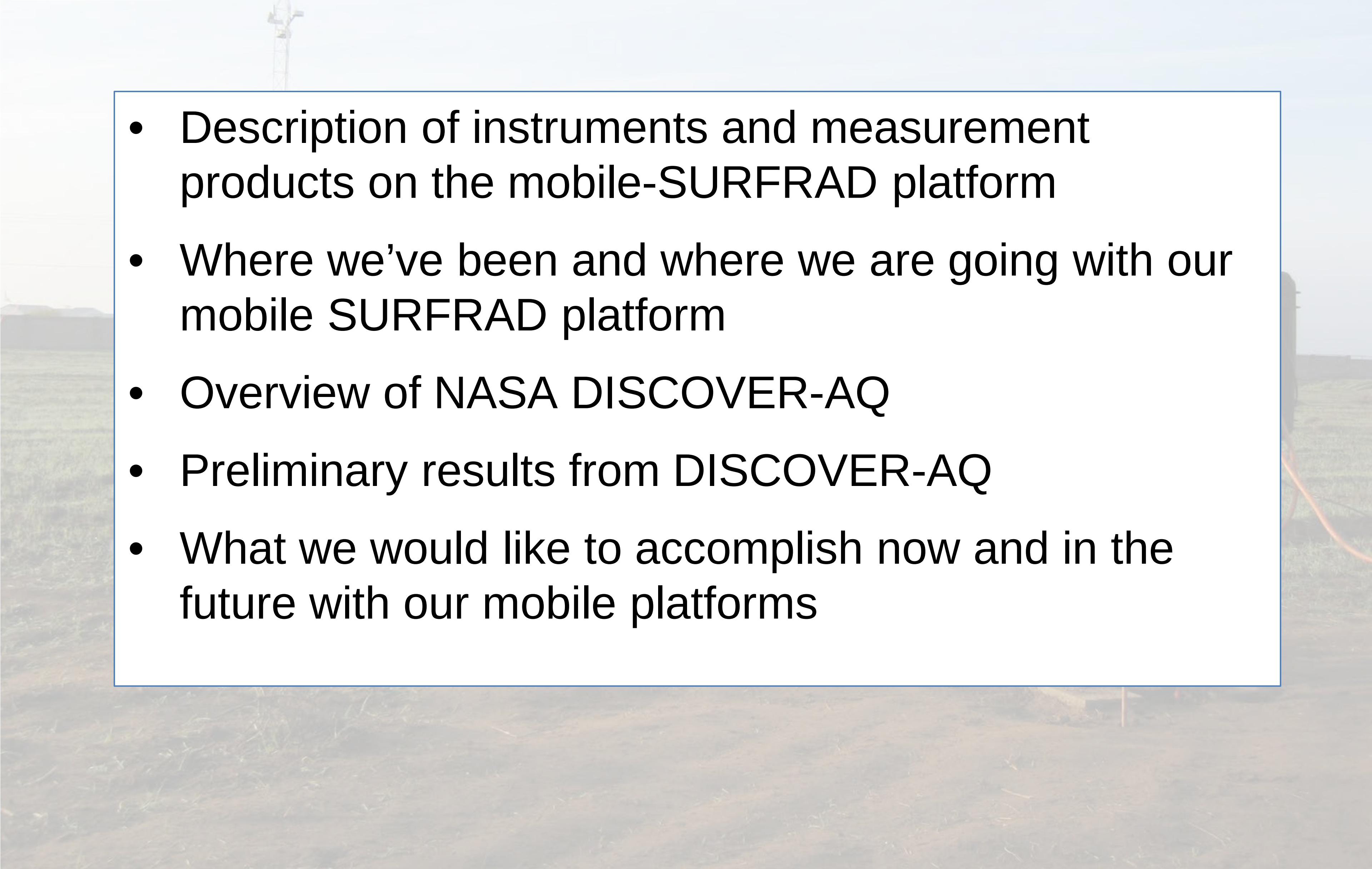
Outline



- Description of instruments and measurement products on the mobile-SURFRAD platform
- Where we’ve been and where we are going with our mobile SURFRAD platform
- Overview of NASA DISCOVER-AQ
- Preliminary results from DISCOVER-AQ
- What we would like to accomplish now and in the future with our mobile platforms

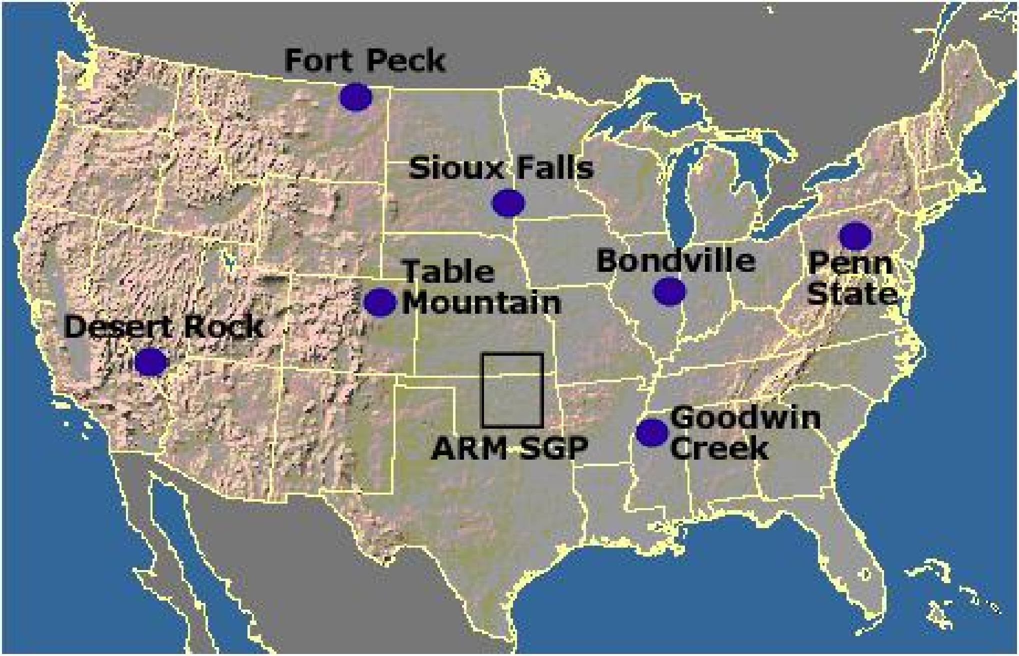
NOAA SURFRAD Network

SURFRAD (Surface Radiation Budget Network) Mission Statement:

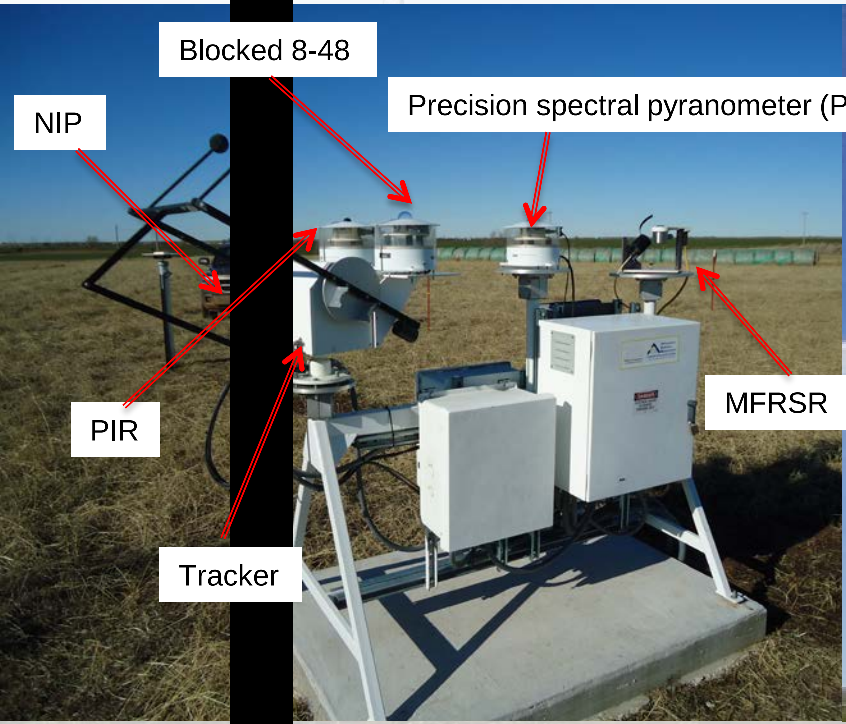
Provide accurate, continuous, long-term measurements of the Surface Radiation Budget (SRB) in different representative climatic regions.

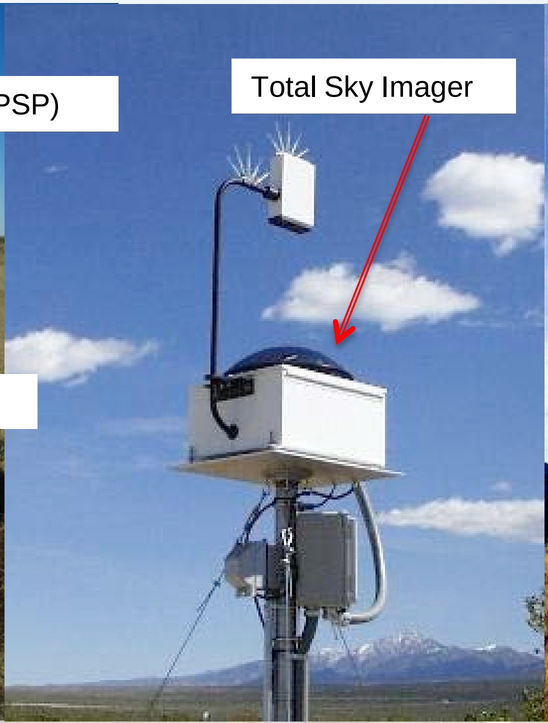
On going, high quality surface radiation and aerosol observations are necessary for addressing climate research, air quality, and renewable energy.

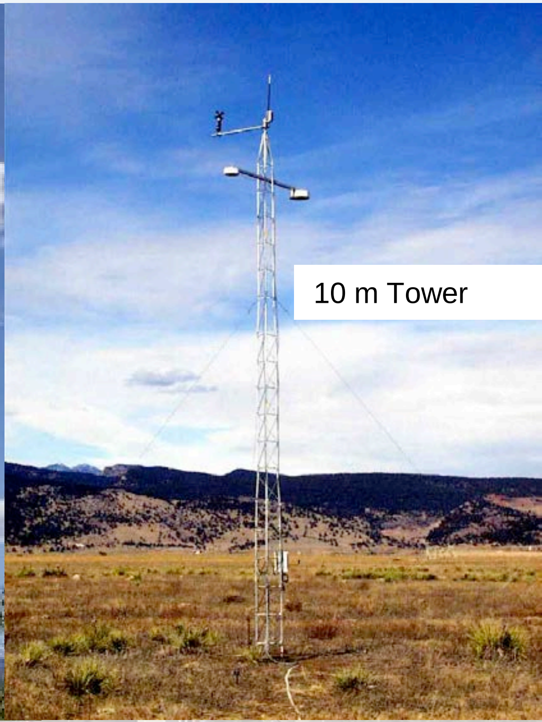
A mobile SURFRAD platform has been built and tested to address local and regional scale research to augment our longer term network.



SURFRAD Measurements







Instrument[redacted]n suite on table (in-coming):

- Global solar [redacted]um and Precision Spectral Pyranometer (PSP)
- Diffuse sola[redacted]locked 8-48 Pyranometer on tracker
- Direct solar [redacted]rmal Incidence Pyrheliometer (NIP)
- Thermal Infr[redacted]d – Precision Infrared Radiometer (PIR)
- Spectral tota[redacted]rect, diffuse irradiance – MFRSR
  (415, 500, 6[redacted]673, 870. 940, 1625 nm)
- Aerosol Properties – MFRSR
- Cloud fraction – Total Sky Imager (TSI)

Instrumentation suite on tower (out-going):

- Upwelling Solar - PSP
- Upwelling Thermal Infrared - PIR
- Spectral surface albedo – MFR*
- Wind, temperature, pressure, RH

* m-SURFRAD and Table Mountain site only

GOES-R Overview

GOES-R Launch : Geostationary Environmental Operational Satellite for more timely and accurate weather observations and forecasts. GOES-R is scheduled for launch in 2015 into the GOES-West position.

GOES-R Improvements: The Advanced Baseline Imager (ABI).

- 3 times more spectral information
- 4 times the spatial resolution
- > 5 times faster temporal coverage

GOES-R Baseline Products:

Aerosol Optical Depth (AOD)
Surface Downward SW Radiation

GOES-R Option 2 Products:

Surface Downward LW Radiation
Surface Upward LW Radiation
Surface Albedo
Vegetation Index
Green Vegetation Fraction
Aerosol Particle Size

Partners: NOAA/NESDIS/STAR: Itsvan Lazslo, Shobha Kondragunta

Mobile SURFRAD Platform Deployments

Recent Campaigns:

DOE ARM TCAP; Cape Cod, MA, July 2012 – August, 2012.

NASA DISCOVER-AQ, Central Valley, CA; January – February, 2013

Upcoming:

NASA DISCOVER-AQ, Houston, TX; January – February, 2013

DOE-NOAA Solar Forecasting Project, NCAR Team, Xcel Electric, San Luis Valley, CO

DOE-NOAA Solar Forecasting Project, IBM Team, Tuscon Electric, Tuscon, AZ

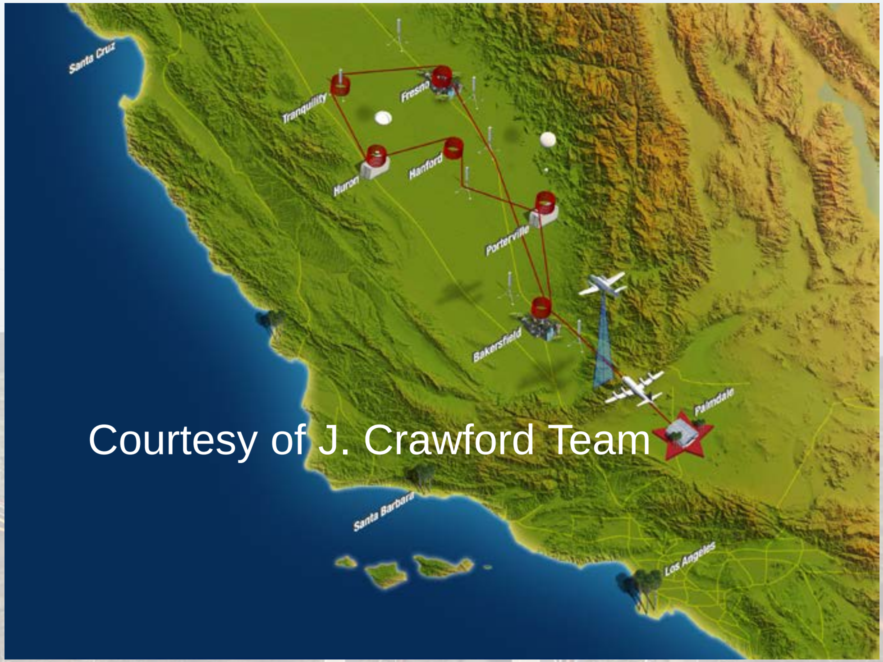
DISCOVER-AQ
Science Mission

DISCOVER-AQ

A NASA Earth Venture program funded mission

PI(s): James Crawford and Ken Pickering

Deriving Information on Surface Conditions from Column and Vertically Resolved Observations Relevant to Air Quality.



Courtesy of J. Crawford Team

SITES:
2010: Baltimore, MD
2013: Central Valley, CA
2013: Houston, TX
2014: TBD (Denver/Atlanta?)

OVERVIEW:

Main Objective: Improve air quality information derived from satellites using a comprehensive set of measurements on aircraft and on the ground that measure in-situ, column, and vertically resolved quantities. (20 Ground sites, 12 Flights (PB-3 and B200)

DISCOVER-AQ
Central Valley Motivation

U.S. Most Polluted Cities Year-round:

American Lung Association 2011

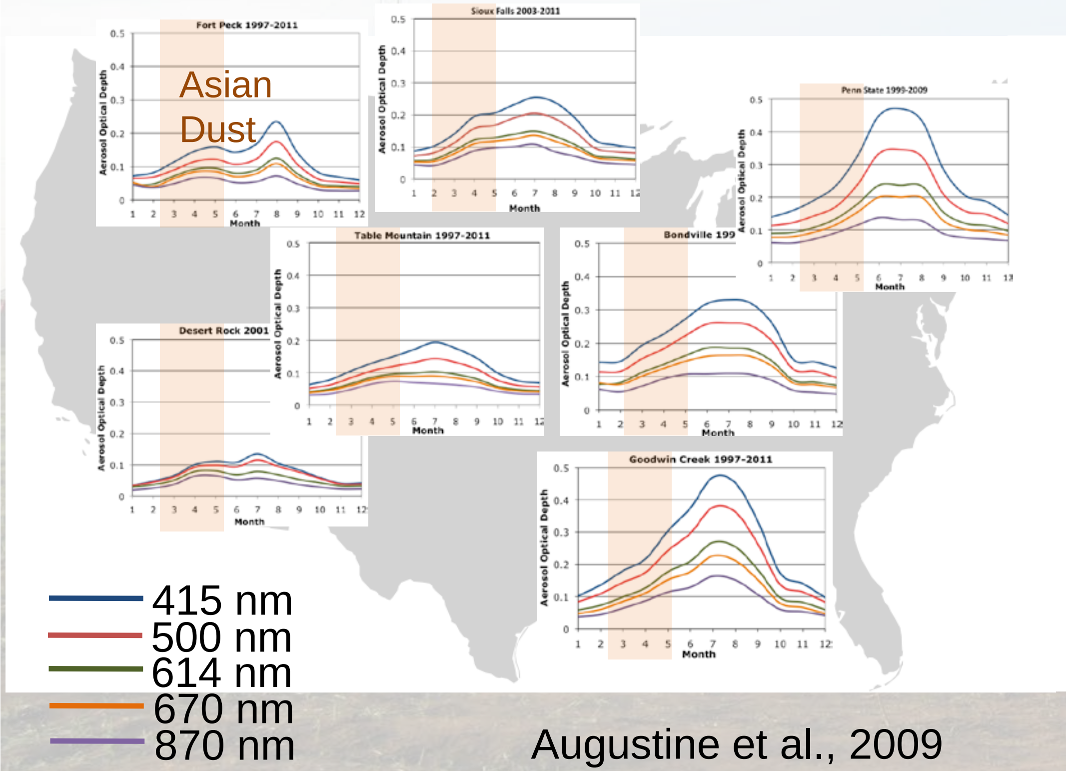
©1997 MAGELLAN Geographix^{SM} (805) 685-3100 www.maps.com

Assessment: Worst O_3, short-term particulate, and long-term particulate.

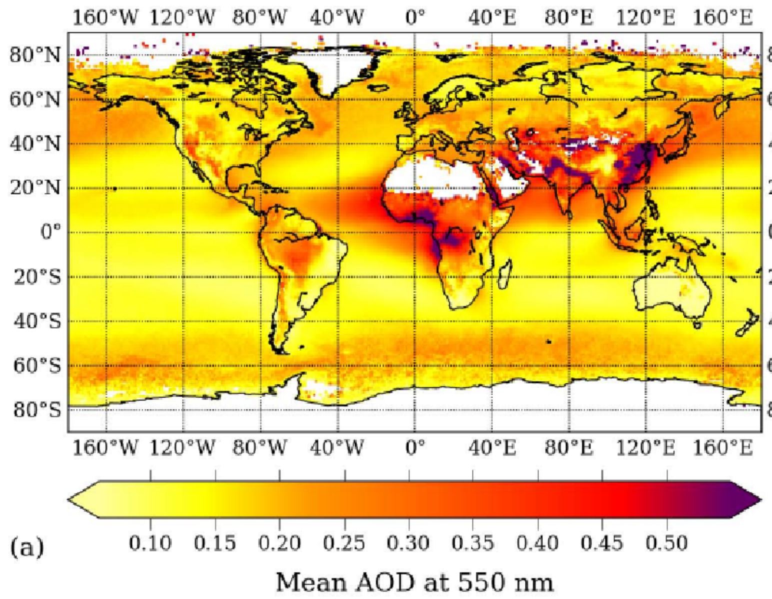
U.S. Cities:

1. Bakersfield-Delano, CA
2. Los Angeles-Riverside, CA
   Phoenix, AZ
   Porterville, CA
3. Hanford, CA
4. Fresno, CA
5. Pittsburgh, PA
6. Birmingham, AL
7. Cincinnati, OH
8. Louisville, KY
9. Modesto, CA

SURFRAD AOD Climatology
MODIS AOD



Augustine et al., 2009



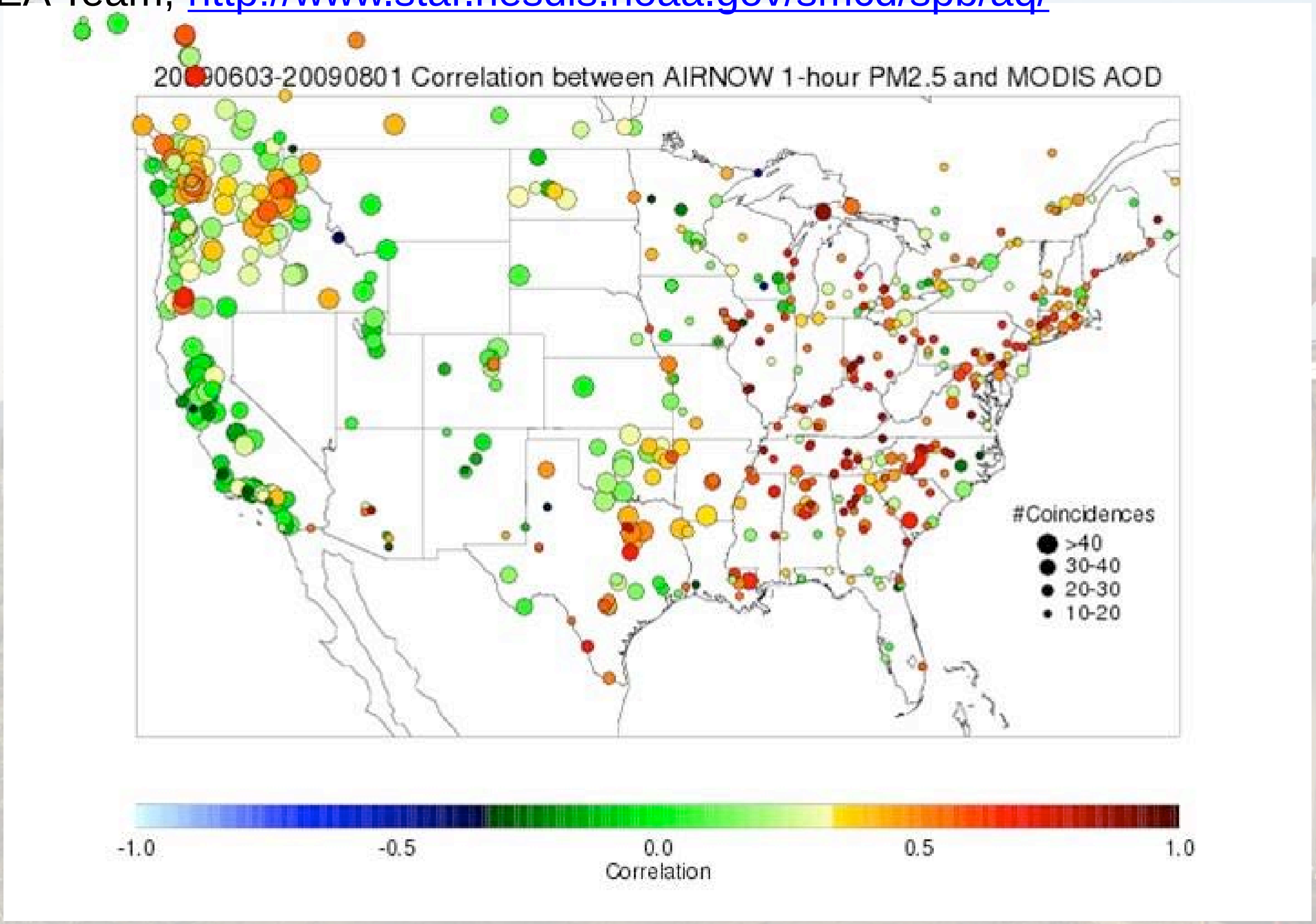
Ruiz-Arias et al., 2013

Main point: SURFRAD AOD climatology show larger AOD in the eastern U.S than the western US, where MODIS AOD shows the opposite.

Question: What are the causes for these differences in AOD between satellite calculations and ground-based column measurements?

Correlation – MODIS AOD and surface PM2.5

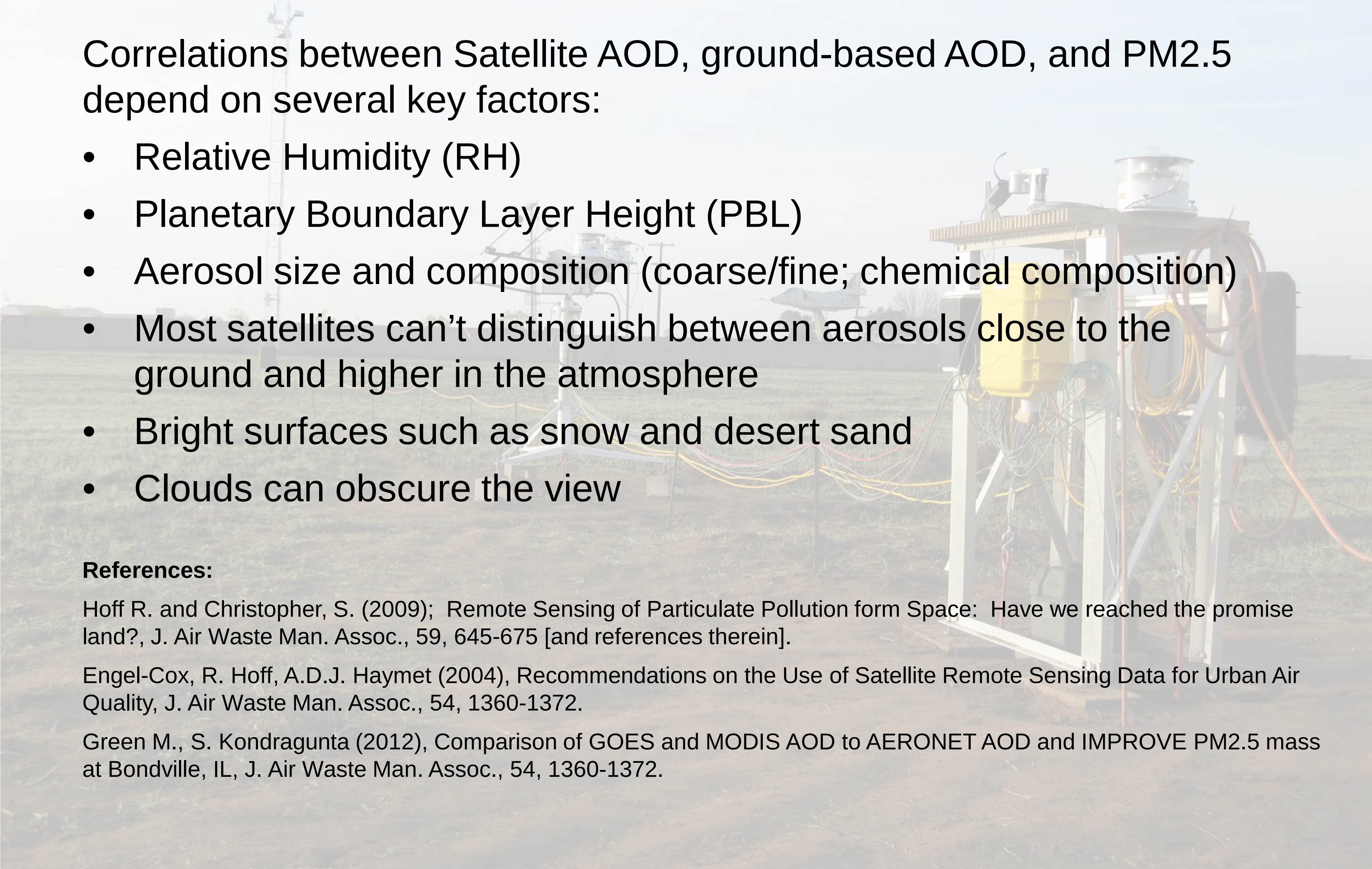
Credit: IDEA Team, http://www.star.nesdis.noaa.gov/smcd/spb/aq/



Main point: Correlations between MODIS AOD and surface PM2.5 vary widely across the U.S. with poorer correlations being more typical in the west.

Question: What are the causes for the poorer correlations in the west?

Correlations between Satellite and Ground-based AOD and PM2.5



Correlations between Satellite AOD, ground-based AOD, and PM2.5 depend on several key factors:

- Relative Humidity (RH)
- Planetary Boundary Layer Height (PBL)
- Aerosol size and composition (coarse/fine; chemical composition)
- Most satellites can’t distinguish between aerosols close to the ground and higher in the atmosphere
- Bright surfaces such as snow and desert sand
- Clouds can obscure the view

References:

Hoff R. and Christopher, S. (2009); Remote Sensing of Particulate Pollution form Space: Have we reached the promise land?, J. Air Waste Man. Assoc., 59, 645-675 [and references therein].

Engel-Cox, R. Hoff, A.D.J. Haymet (2004), Recommendations on the Use of Satellite Remote Sensing Data for Urban Air Quality, J. Air Waste Man. Assoc., 54, 1360-1372.

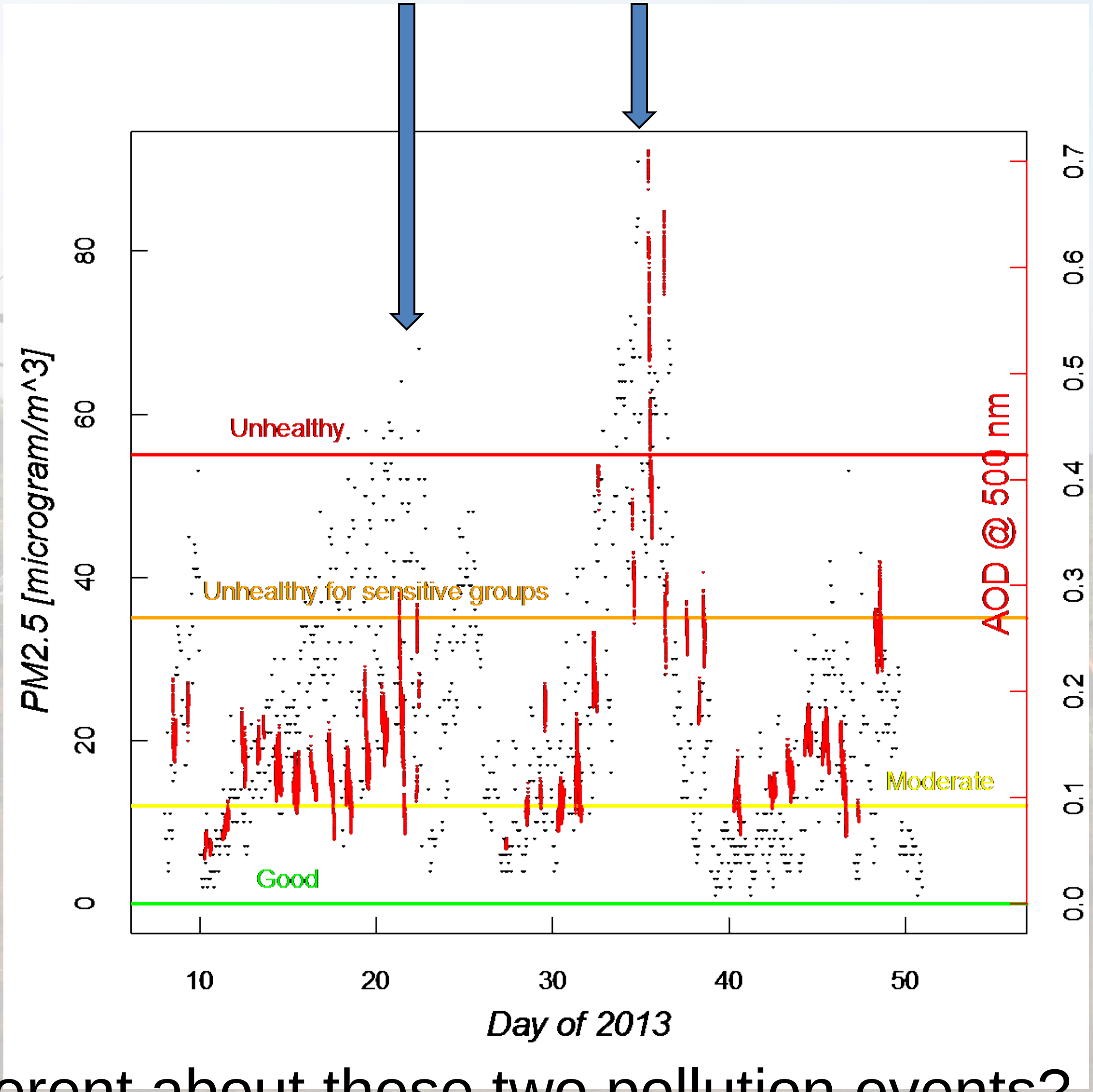
Green M., S. Kondragunta (2012), Comparison of GOES and MODIS AOD to AERONET AOD and IMPROVE PM2.5 mass at Bondville, IL, J. Air Waste Man. Assoc., 54, 1360-1372.

Two Air-Pollution Events

Event 1: Peak January 21, 2013

Event 2: Peak February 4, 2013

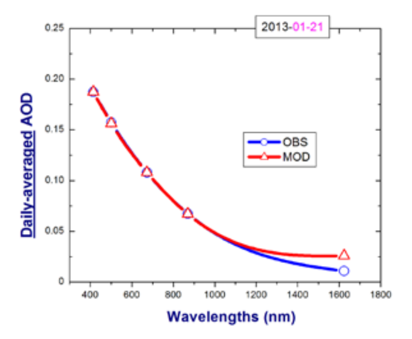
0 to 50	Good	Green
51 to 100	Moderate	Yellow
101 to 150	Unhealthy for Sensitive Groups	Orange
151 to 200	Unhealthy	Red
201 to 300	Very Unhealthy	Purple
301 to 500	Hazardous	Maroon

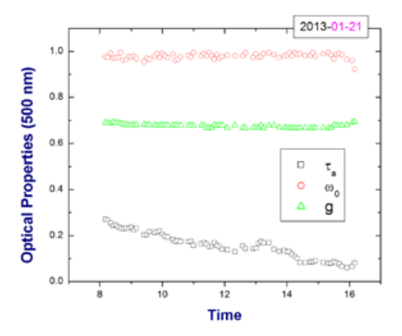


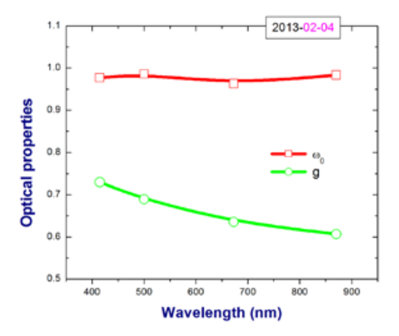
Question: What is different about these two pollution events?

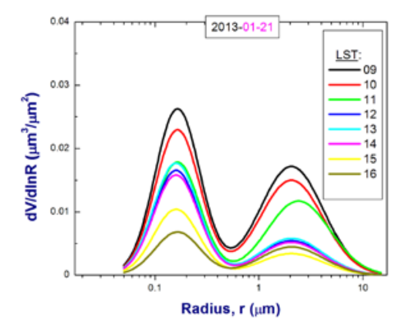
Aerosol Optical Properties during two pollution events

Event 1: Peaks around January 21, 2013

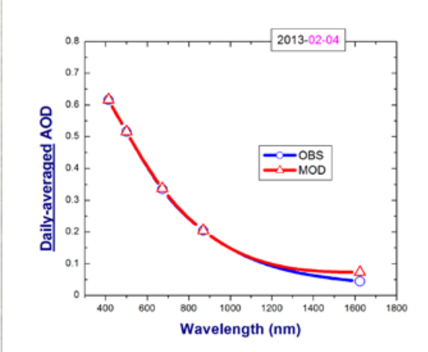


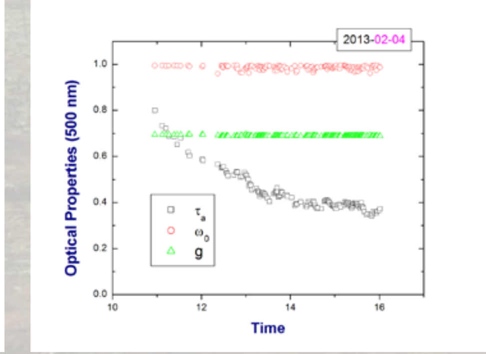


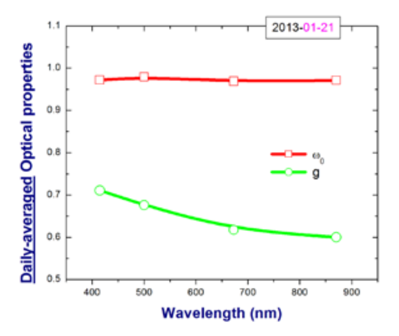


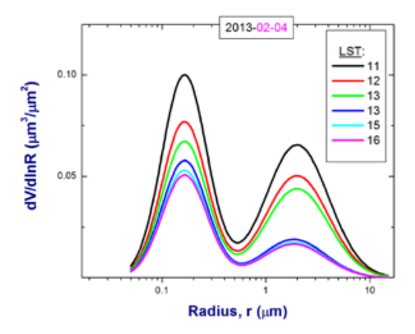


Event 2: Peaks around February 4, 2013





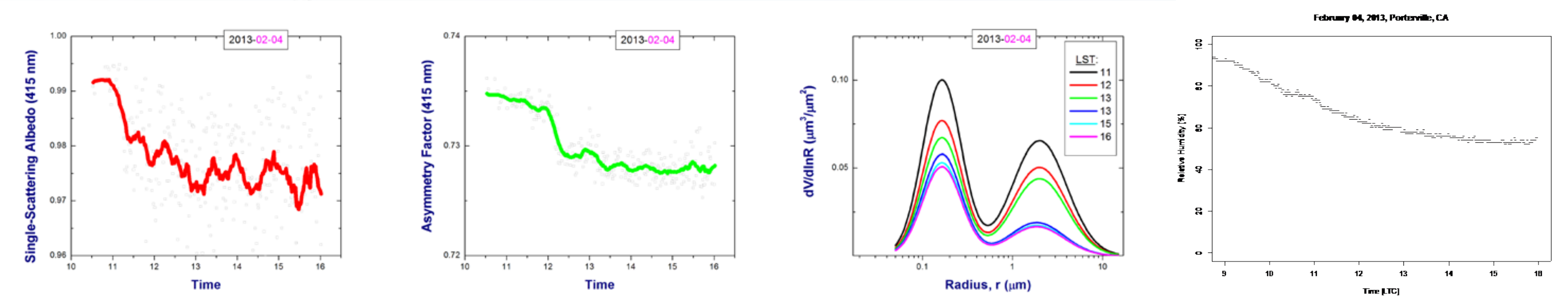




MFRSR aerosol retrieval references:

E. Kassianov, et al, Retrieval of aerosol microphysical properties using surface Multi-Filter Rotating Shadowband Radiometer (MFRSR): Modeling and observations, J. Geophys. Res. 2005.
E. Kassianov, et al., Aerosol single-scattering albedo and asymmetry parameter from MFRSR observations during the ARM aerosol IOP 2003, Atmos. Chem. Phys., 2007.
J. Michalsky et al., Comparison of UV-RSS spectral measurements and TUV model runs for clear-sky for May 2003 ARM IOP, Atmos. Chem. Phys., 2008.

Pollution Event 2: Aerosol Optical Properties



Summary:

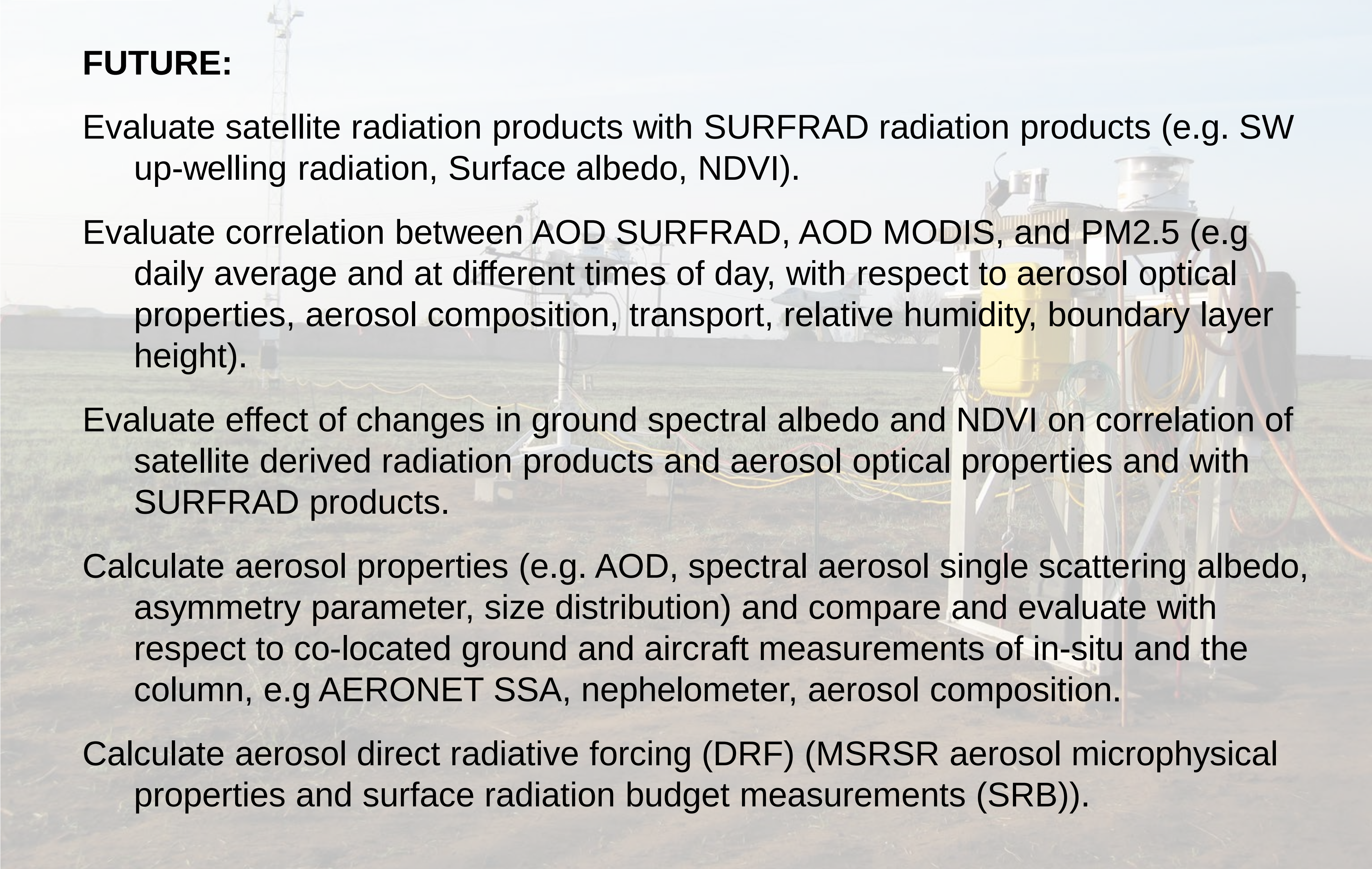
A closer look at the aerosol properties during the second pollution reveals interesting diurnal changes.

- The SSA and g are decreasing indicating less scattering (more absorbing) aerosol and smaller aerosols as the day progresses.
- Changes in the size distribution show a decrease in the coarse mode compared to the fine mode as the day progresses.

Diurnal changes in aerosol properties may reflect changes in relative humidity or aerosol type/composition.

Preliminary comparisons between SURFRAD MFRSR and AERONET CIMEL retrievals (AOD, ω_o and g) show they agree within the uncertainty of the measurements.

What’s Next?



FUTURE:

Evaluate satellite radiation products with SURFRAD radiation products (e.g. SW up-welling radiation, Surface albedo, NDVI).

Evaluate correlation between AOD SURFRAD, AOD MODIS, and PM2.5 (e.g daily average and at different times of day, with respect to aerosol optical properties, aerosol composition, transport, relative humidity, boundary layer height).

Evaluate effect of changes in ground spectral albedo and NDVI on correlation of satellite derived radiation products and aerosol optical properties and with SURFRAD products.

Calculate aerosol properties (e.g. AOD, spectral aerosol single scattering albedo, asymmetry parameter, size distribution) and compare and evaluate with respect to co-located ground and aircraft measurements of in-situ and the column, e.g AERONET SSA, nephelometer, aerosol composition.

Calculate aerosol direct radiative forcing (DRF) (MSRSR aerosol microphysical properties and surface radiation budget measurements (SRB)).

Future Deployments

Recent Campaigns:

DOE ARM TCAP; Cape Cod, MA, July 2012 – August, 2012.

NASA DISCOVER-AQ, Central Valley, CA; January – February, 2013

Upcoming:

NASA DISCOVER-AQ, Houston, TX; September, 2013

DOE-NOAA Solar Forecasting Project, NCAR Team, Xcel Electric, San Luis Valley, CO

DOE-NOAA Solar Forecasting Project, IBM Team, Tuscon Electric, Tuscon, AZ

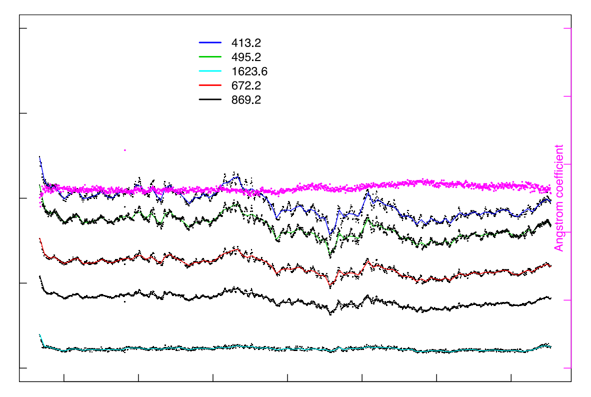
Acknowledgements

Pictured: Gary Hodges, Kathy Lantz, Emiel Hall
Not Pictured: Joe Michalsky, E. Kassianov, Jim Wendell, Dave Longenecker, John Augustine

SURFRAD AOD MFRSR

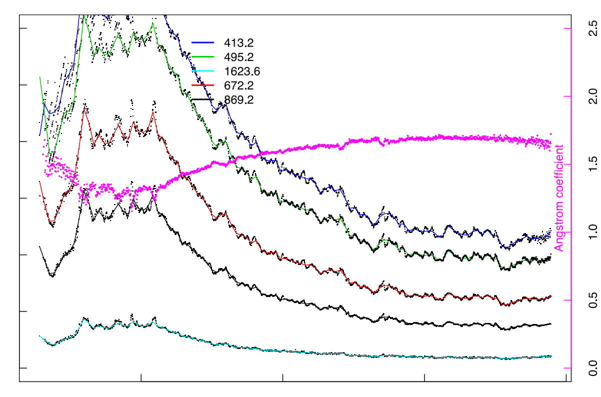
Pollution Event 1

SURFRAD AOD



Pollution Event 2

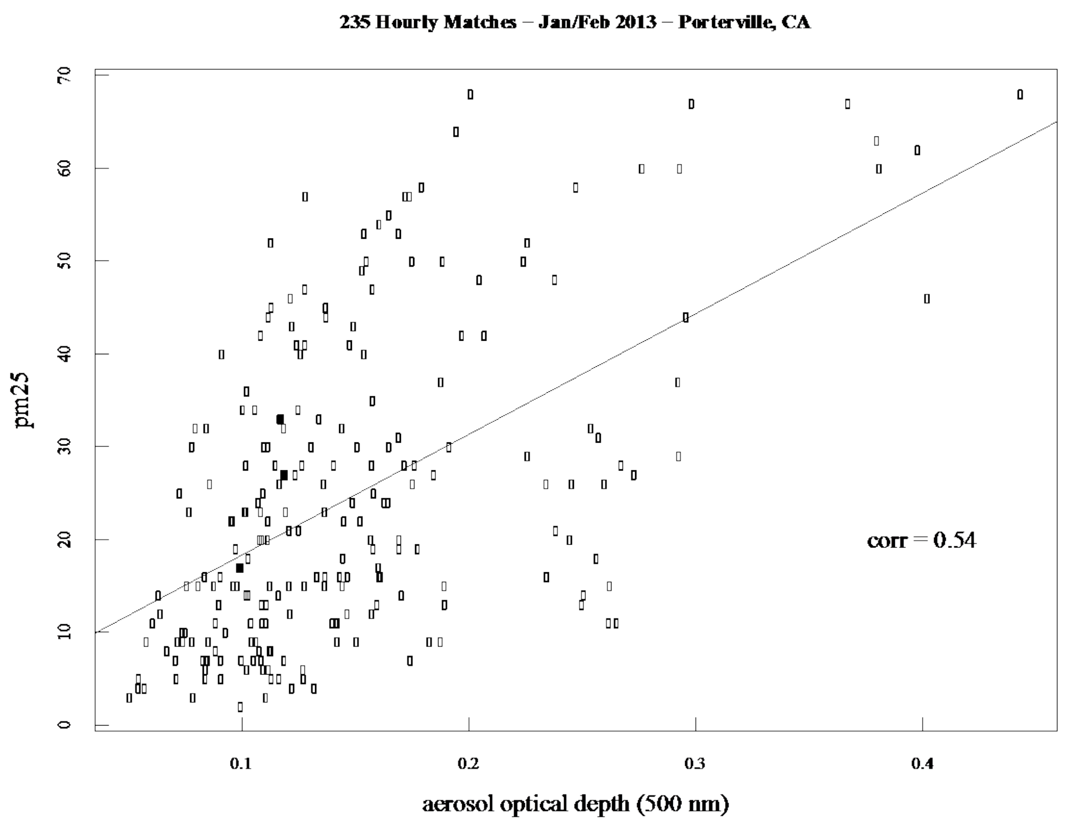
SURFRAD AOD



AOD is significantly larger in event 2 (compared with PM2.5). Note AOD scale changes from 0.4 to 1.2 from top to bottom.

The Angstrom coefficient increases from pollution event 1 to event 2 from 1.3 to 1.6. This indicates larger particles in pollution event 1.

Correlation – SURFRAD AOD and surface PM2.5



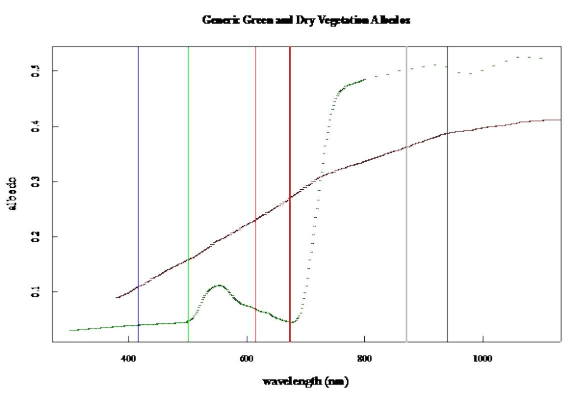
235 Hourly Matches – Jan/Feb 2013 – Porterville, CA

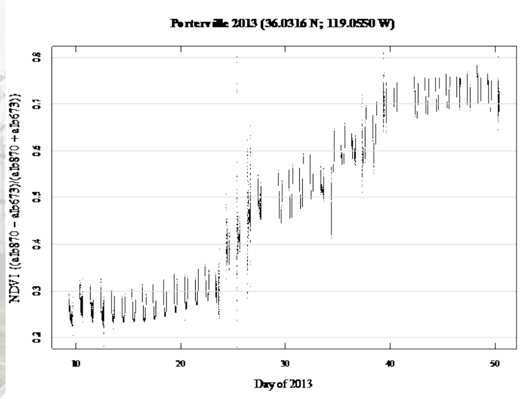
Previous literature correlations of PM2.5 and AOD range from 0.4 – 0.98 [Hoff and Christopher, 2008]. Correlations improve significantly when taking into account RH and PBL height.

Spectral Surface Albedo
NDVI - Normalized Difference Vegetation Index

Normalized Difference Vegetation Index – A simple indicator of live green vegetation and to monitor plant growth.

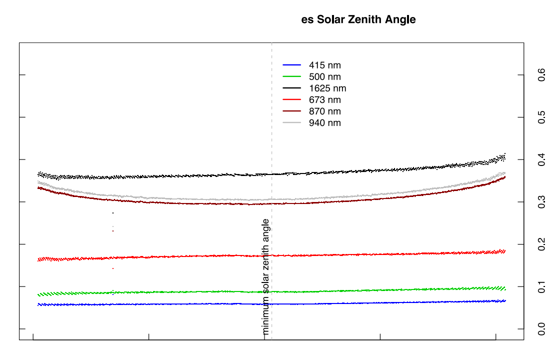
$$NDVI = \frac{NIR - VIS}{NIR + VIS}$$

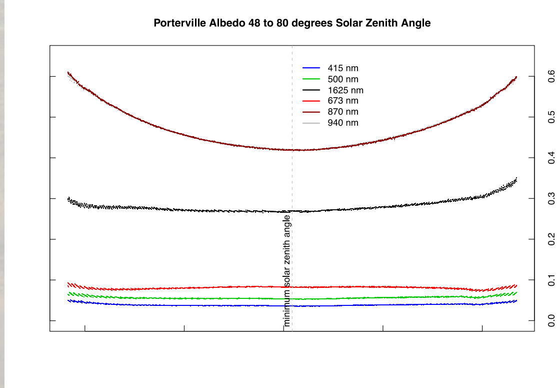




$$NDVI_{mfrsr} = \frac{A_{870} - A_{673}}{A_{870} + A_{673}}$$

Spectral Surface albedo –





Beijing, Jan 13, 2013

Air pollution in Beijing goes off the index

5:27a.m. EST January 13, 2013

(Photo: Ed Jones, AFP/Getty Images)

BEIJING (AP) — People refused to venture outdoors and buildings disappeared into Beijing's murky skyline on Sunday as the air quality in China's notoriously polluted capital went off the index.

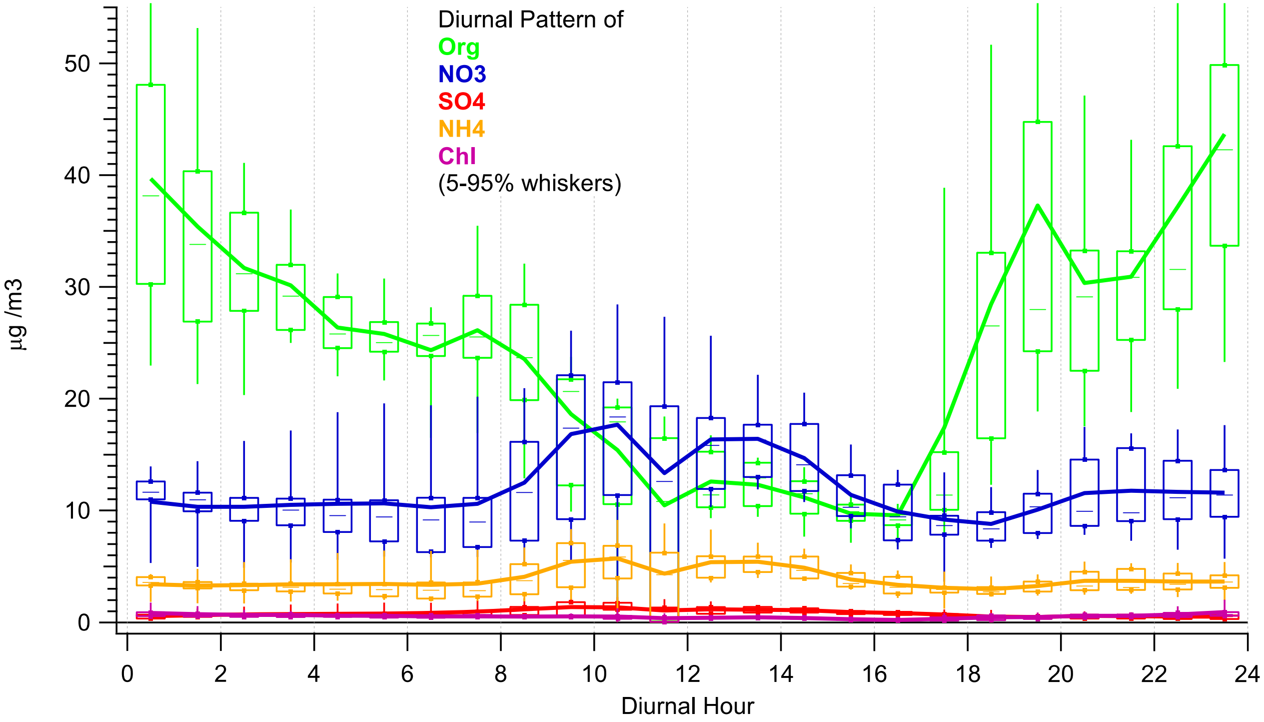
The Beijing Municipal Environmental Monitoring Center said on its website that the density of PM2.5 particulates had surpassed 700 micrograms per cubic meter in many parts of the city. The World Health Organization considers a safe daily level to be 25 micrograms per cubic meter.

PM2.5 are tiny particulate matter less than 2.5 micrometers in size, or about 1/30th the average width of a human hair. They can penetrate deep into the lungs, so measuring them is considered a more accurate reflection of air quality than other methods.

Fresno-Garland Site
Chemical Composition from UC Davis

All species show strong diurnal patterns:

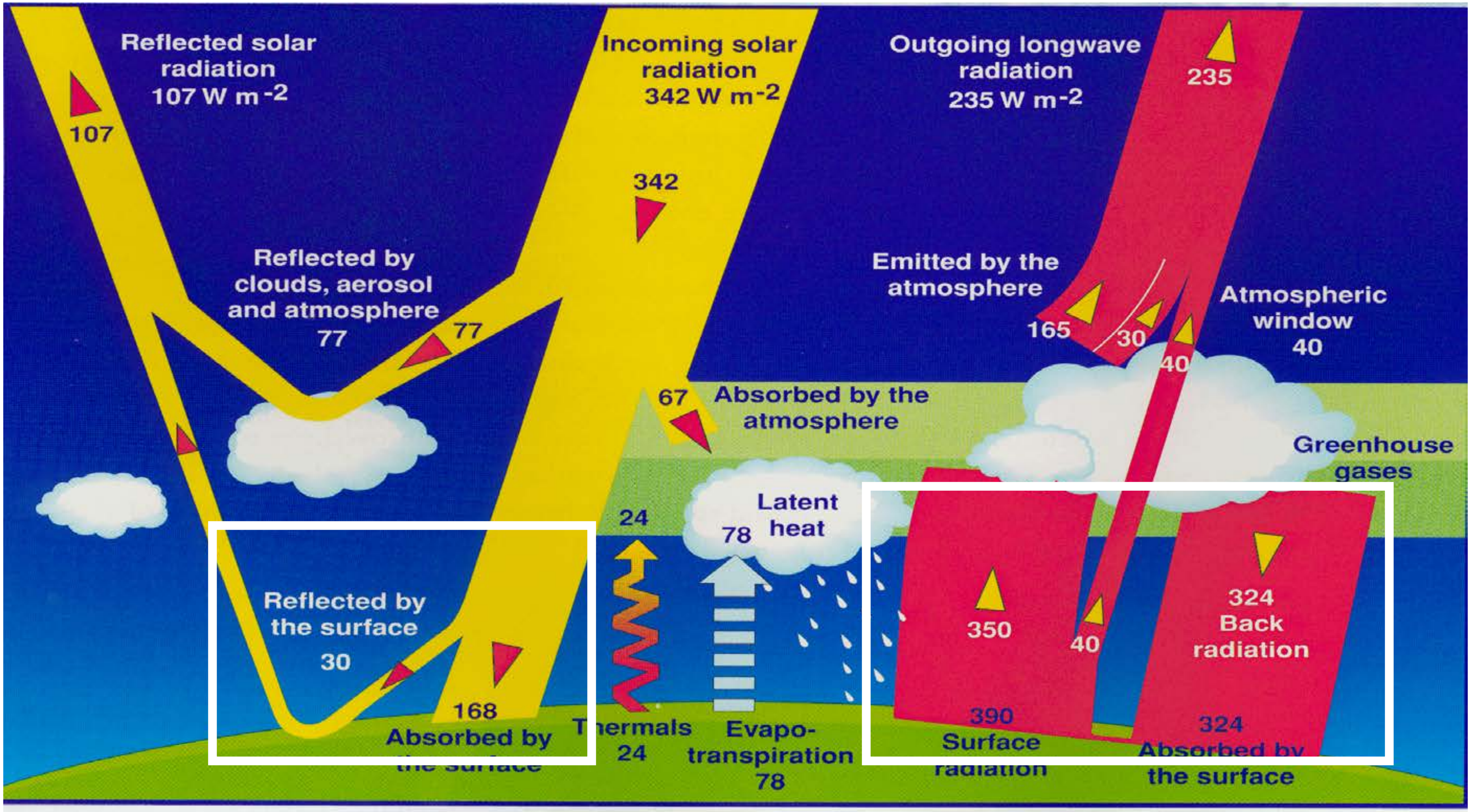
- Org elevated during night and early morning, mainly due to primary emissions – traffic and wood burning
- Secondary species, nitrate, sulfate, and oxygenated organics increased during the day



Courtesy of H. Kim, S. Chou, C. Parworth, Q. Zhang, UC Davis

Surface Radiation Budget
(White boxes)

Earth's Energy Budget



Radiation Balance of the Earth (Jeffrey T. Kiehl)

GOES-R and Ground-based MFRSR wavelength bands

GOES-R Bands

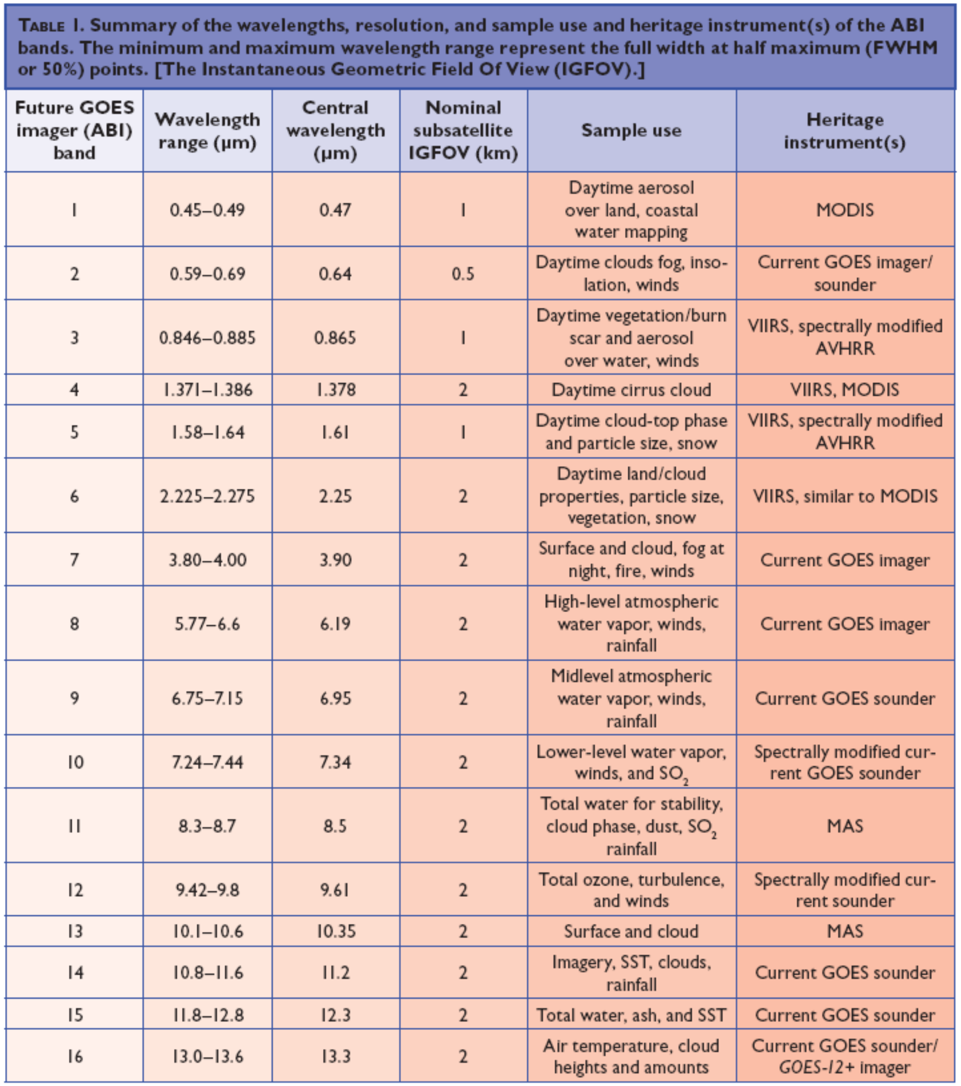
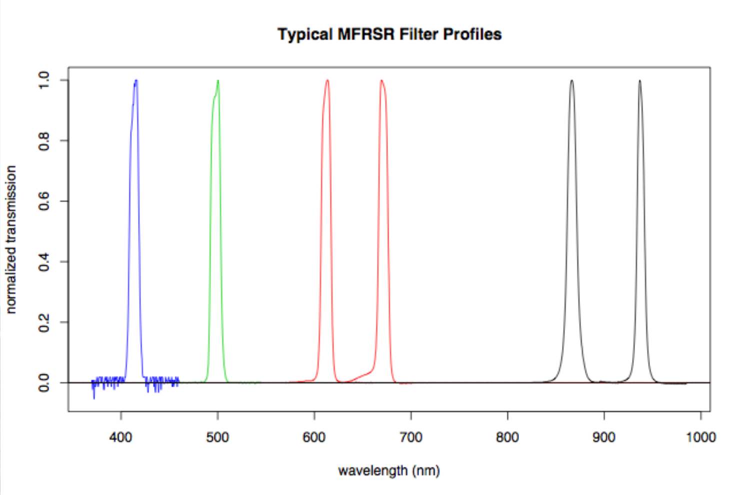


Table 1. Summary of the wavelengths, resolution, and sample use and heritage instrument(s) of the ABI bands. The minimum and maximum wavelength range represent the full width at half maximum (FWHM or 50%) points. [The Instantaneous Geometric Field Of View (IGFOV).]

Future GOES imager (ABI) band	Wavelength range (μm)	Central wavelength (μm)	Nominal subsatellite IGFOV (km)	Sample use	Heritage instrument(s)
1	0.45–0.49	0.47	1	Daytime aerosol over land, coastal water mapping	MODIS
2	0.59–0.69	0.64	0.5	Daytime clouds fog, insolation, winds	Current GOES imager/sounder
3	0.846–0.885	0.865	1	Daytime vegetation/burn scar and aerosol over water, winds	VIIRS, spectrally modified AVHRR
4	1.371–1.386	1.378	2	Daytime cirrus cloud	VIIRS, MODIS
5	1.58–1.64	1.61	1	Daytime cloud-top phase and particle size, snow	VIIRS, spectrally modified AVHRR
6	2.225–2.275	2.25	2	Daytime land/cloud properties, particle size, vegetation, snow	VIIRS, similar to MODIS
7	3.80–4.00	3.90	2	Surface and cloud, fog at night, fire, winds	Current GOES imager
8	5.77–6.6	6.19	2	High-level atmospheric water vapor, winds, rainfall	Current GOES imager
9	6.75–7.15	6.95	2	Midlevel atmospheric water vapor, winds, rainfall	Current GOES sounder
10	7.24–7.44	7.34	2	Lower-level water vapor, winds, and SO_2	Spectrally modified current GOES sounder
11	8.3–8.7	8.5	2	Total water for stability, cloud phase, dust, SO_2 rainfall	MAS
12	9.42–9.8	9.61	2	Total ozone, turbulence, and winds	Spectrally modified current sounder
13	10.1–10.6	10.35	2	Surface and cloud	MAS
14	10.8–11.6	11.2	2	Imagery, SST, clouds, rainfall	Current GOES sounder
15	11.8–12.8	12.3	2	Total water, ash, and SST	Current GOES sounder
16	13.0–13.6	13.3	2	Air temperature, cloud heights and amounts	Current GOES sounder/ *GOES-12+* imager

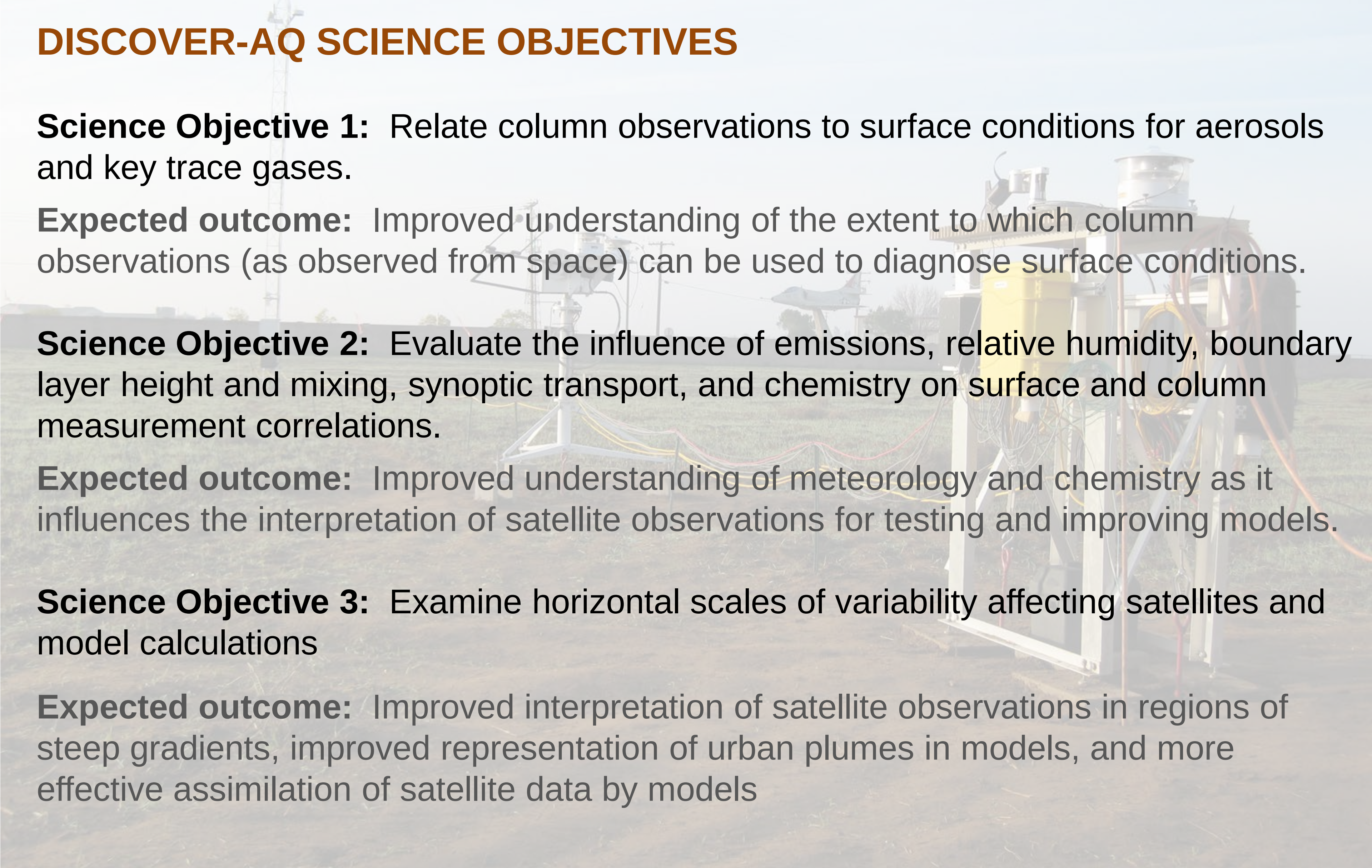
MFRSR Bands



415, 500, 615, 673, 870, 940, 1625 n

DISCOVER-AQ Science Objectives

DISCOVER-AQ SCIENCE OBJECTIVES



Science Objective 1: Relate column observations to surface conditions for aerosols and key trace gases.

Expected outcome: Improved understanding of the extent to which column observations (as observed from space) can be used to diagnose surface conditions.

Science Objective 2: Evaluate the influence of emissions, relative humidity, boundary layer height and mixing, synoptic transport, and chemistry on surface and column measurement correlations.

Expected outcome: Improved understanding of meteorology and chemistry as it influences the interpretation of satellite observations for testing and improving models.

Science Objective 3: Examine horizontal scales of variability affecting satellites and model calculations

Expected outcome: Improved interpretation of satellite observations in regions of steep gradients, improved representation of urban plumes in models, and more effective assimilation of satellite data by models

PB-3 and B200 Aircraft Aerosol Measurements

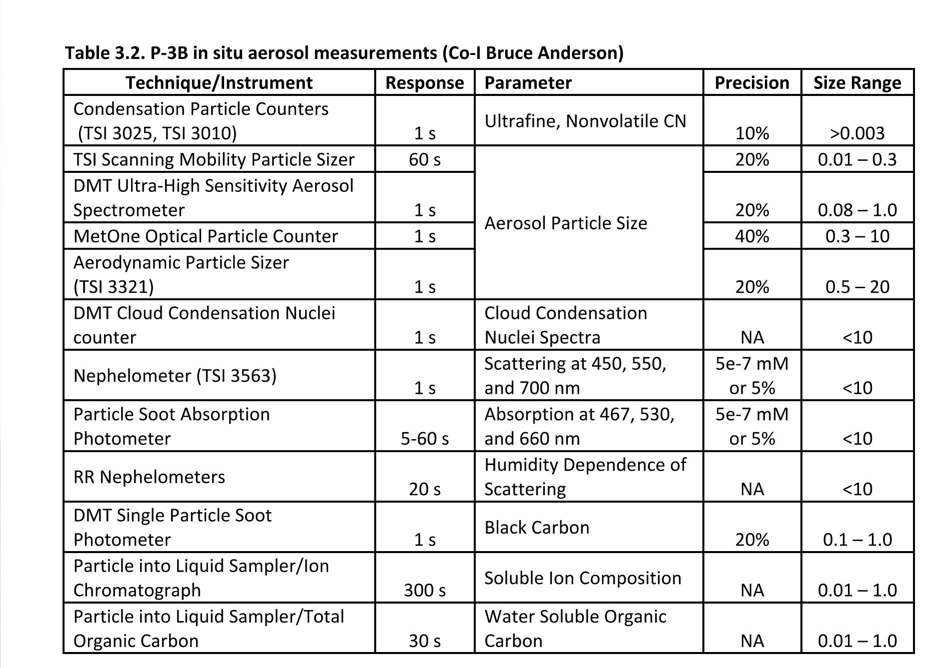


Table 3.2. P-3B in situ aerosol measurements (Co-I Bruce Anderson)

Technique/Instrument	Response	Parameter	Precision	Size Range
Condensation Particle Counters (TSI 3025, TSI 3010)	1 s	Ultrafine, Nonvolatile CN	10%	>0.003
TSI Scanning Mobility Particle Sizer	60 s	Aerosol Particle Size	20%	0.01 – 0.3
DMT Ultra-High Sensitivity Aerosol Spectrometer	1 s		20%	0.08 – 1.0
MetOne Optical Particle Counter	1 s		40%	0.3 – 10
Aerodynamic Particle Sizer (TSI 3321)	1 s		20%	0.5 – 20
DMT Cloud Condensation Nuclei counter	1 s	Cloud Condensation Nuclei Spectra	NA	<10
Nephelometer (TSI 3563)	1 s	Scattering at 450, 550, and 700 nm	5e-7 mM or 5%	<10
Particle Soot Absorption Photometer	5-60 s	Absorption at 467, 530, and 660 nm	5e-7 mM or 5%	<10
RR Nephelometers	20 s	Humidity Dependence of Scattering	NA	<10
DMT Single Particle Soot Photometer	1 s	Black Carbon	20%	0.1 – 1.0
Particle into Liquid Sampler/Ion Chromatograph	300 s	Soluble Ion Composition	NA	0.01 – 1.0
Particle into Liquid Sampler/Total Organic Carbon	30 s	Water Soluble Organic Carbon	NA	0.01 – 1.0

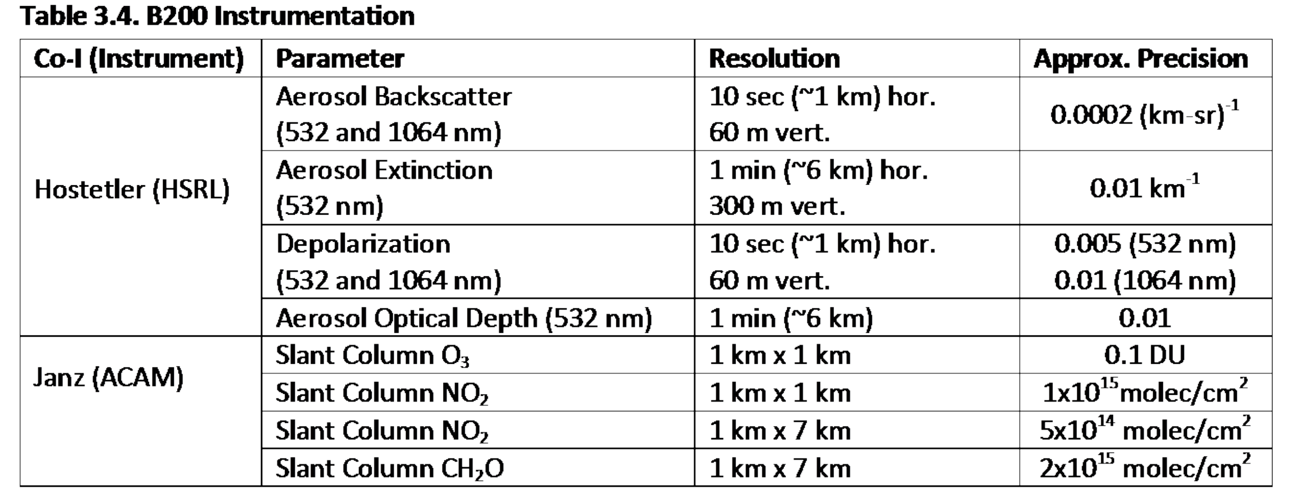
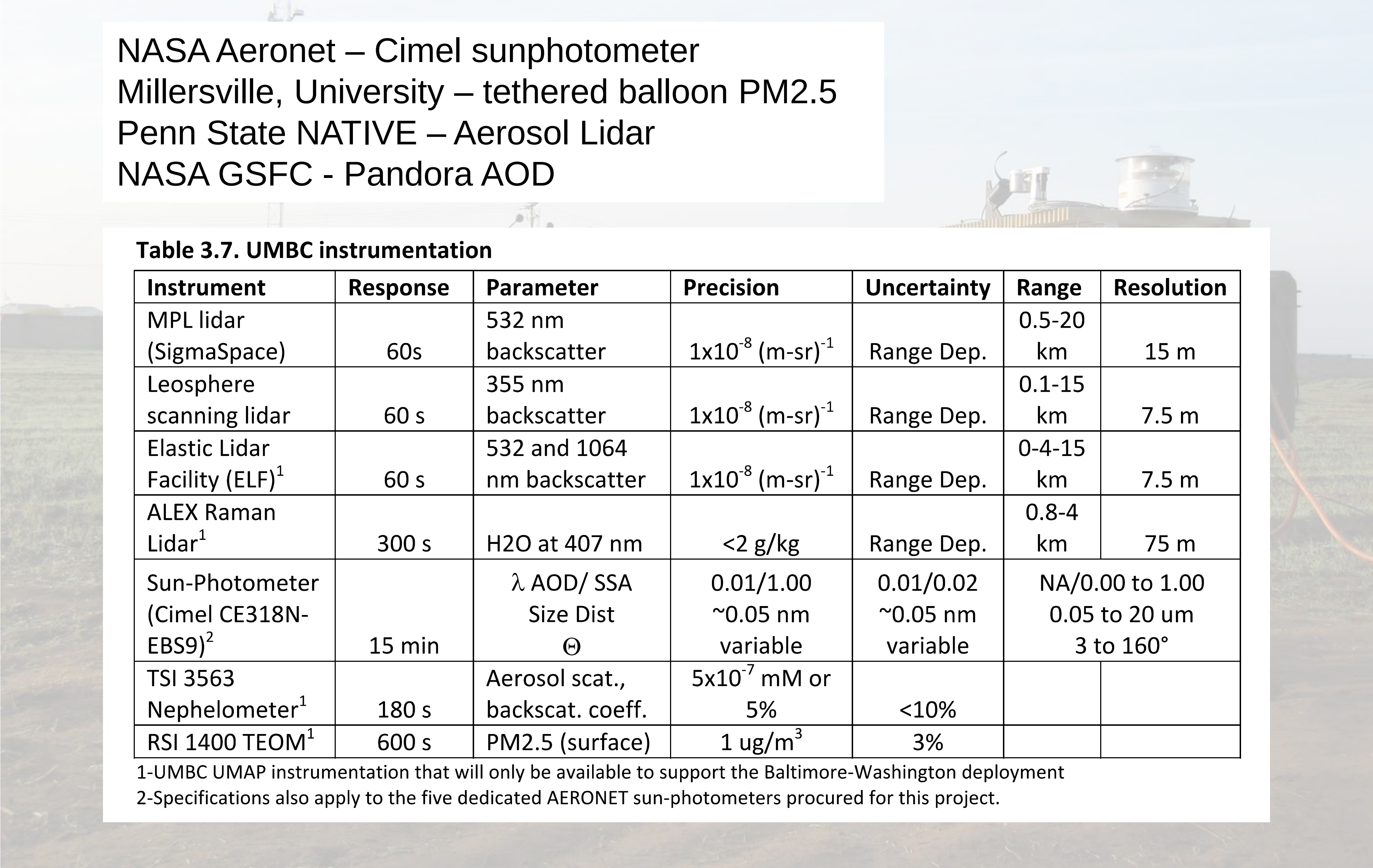


Table 3.4. B200 Instrumentation

Co-I (Instrument)	Parameter	Resolution	Approx. Precision
Hostetler (HSRL)	Aerosol Backscatter (532 and 1064 nm)	10 sec (~1 km) hor. 60 m vert.	0.0002 (km-sr)$^{-1}$
	Aerosol Extinction (532 nm)	1 min (~6 km) hor. 300 m vert.	0.01 km^{-1}
	Depolarization (532 and 1064 nm)	10 sec (~1 km) hor. 60 m vert.	0.005 (532 nm) 0.01 (1064 nm)
	Aerosol Optical Depth (532 nm)	1 min (~6 km)	0.01
Janz (ACAM)	Slant Column O_3	1 km x 1 km	0.1 DU
	Slant Column NO_2	1 km x 1 km	1x10^{15}molec/cm^2
	Slant Column NO_2	1 km x 7 km	5x10^{14} molec/cm^2
	Slant Column CH_2O	1 km x 7 km	2x10^{15} molec/cm^2

Ground-Based Aerosol measurements



NASA Aeronet – Cimel sunphotometer
Millersville, University – tethered balloon PM2.5
Penn State NATIVE – Aerosol Lidar
NASA GSFC - Pandora AOD

Table 3.7. UMBC instrumentation

Instrument	Response	Parameter	Precision	Uncertainty	Range	Resolution
MPL lidar (SigmaSpace)	60s	532 nm backscatter	$1x10^{-8}$ (m-sr)$^{-1}$	Range Dep.	0.5-20 km	15 m
Leosphere scanning lidar	60 s	355 nm backscatter	$1x10^{-8}$ (m-sr)$^{-1}$	Range Dep.	0.1-15 km	7.5 m
Elastic Lidar Facility (ELF)[1]	60 s	532 and 1064 nm backscatter	$1x10^{-8}$ (m-sr)$^{-1}$	Range Dep.	0-4-15 km	7.5 m
ALEX Raman Lidar[1]	300 s	H2O at 407 nm	<2 g/kg	Range Dep.	0.8-4 km	75 m
Sun-Photometer (Cimel CE318N-EBS9)[2]	15 min	λ AOD/ SSA Size Dist Θ	0.01/1.00 ~0.05 nm variable	0.01/0.02 ~0.05 nm variable	NA/0.00 to 1.00 0.05 to 20 um 3 to 160°	
TSI 3563 Nephelometer[1]	180 s	Aerosol scat., backscat. coeff.	$5x10^{-7}$ mM or 5%	<10%		
RSI 1400 TEOM[1]	600 s	PM2.5 (surface)	1 ug/m^3	3%		

1-UMBC UMAP instrumentation that will only be available to support the Baltimore-Washington deployment
2-Specifications also apply to the five dedicated AERONET sun-photometers procured for this project.

Table 1. DISCOVER-AQ Trace Gas and Aerosol Observations

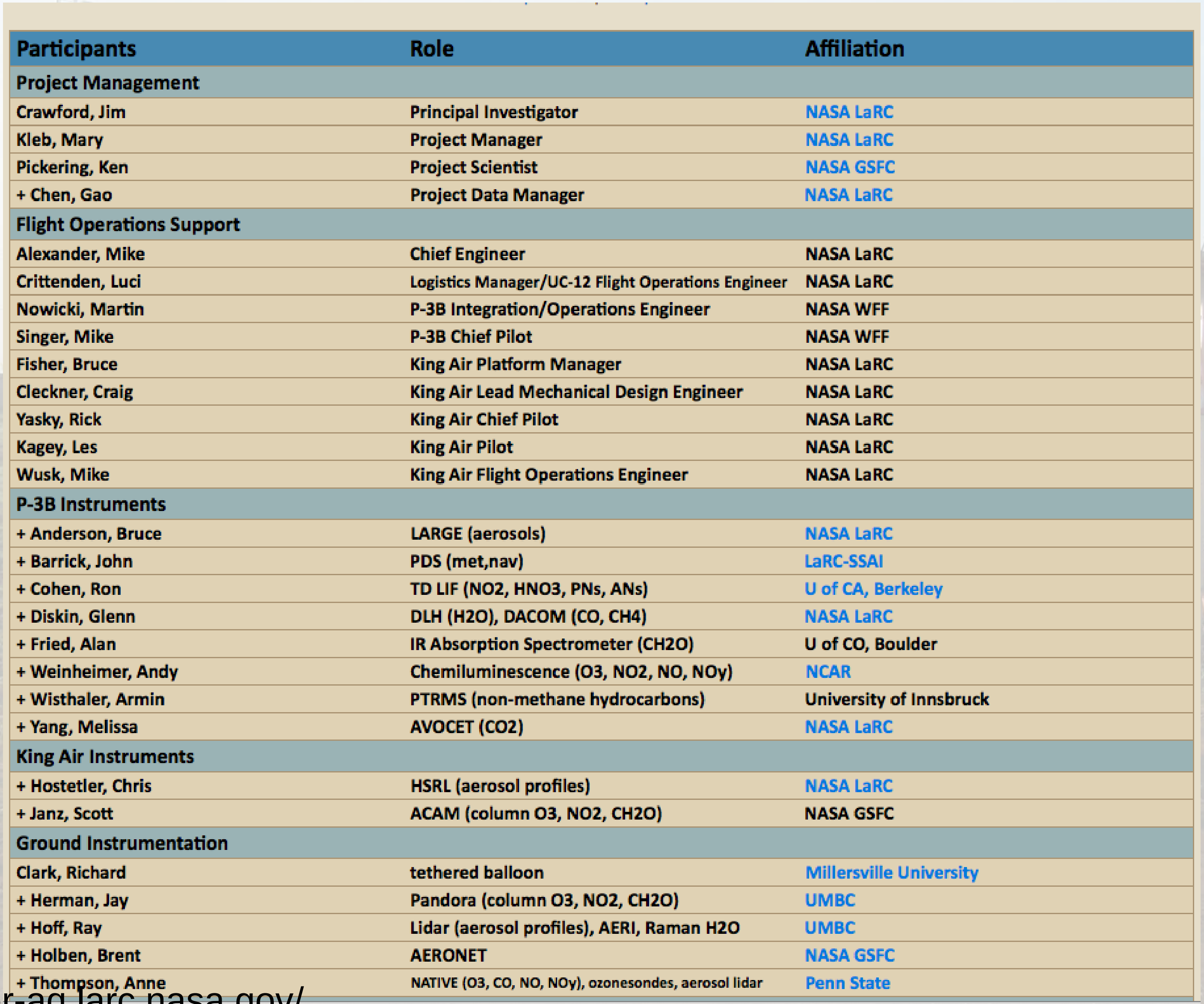
Trace Gas Observations	O_3	NO_2	CH_2O	NO	NO_y	CO	CO_2	CH_4	H_2O	VOC
Pandora, total column[1]	X	X	X						X	
ACAM, nadir column (B200)[2]	X	X	X							
In situ airborne profiles (P-3B)[3]	X	X	X	X	X	X	X	X	X	X
In situ surface observations (AQS)[4]	X	X			X	X			X	X
NATIVE in situ surface observations[5]	X			X	X	X			X	
NATIVE sondes[6]	X								X	
Aeronet[7]									X	

Aerosol Observations (X) = dry aerosol measurement	AOD	PM2.5	Scattering	Absorption	Extinction	Non-Sphericity	f(RH)	Black Carbon	Soluble Ions	Size Distribution	PBL Height
HSRL, nadir aerosol profiles (B200)[2]	X		X[10]		X	X					X
In situ airborne profiles (P-3B)[3]	(X)[9]		(X)	(X)	(X)		X	X	X	(X)	X
In situ surface observations (AQS)		(X)									
NATIVE lidar[5]			X[10]								X
UMBC UMAP site with AERI	X	X	X[10]		X[11]		X[12]			X	X
AERONET[7]	X			X						X	
Pandora[8]	X		X	X							

1. Surface network of 12 Pandora instruments to be integrated with existing sites (e.g., AQS)

DISCOVER-AQ

Participants



Participants	Role	Affiliation
Project Management		
Crawford, Jim	Principal Investigator	NASA LaRC
Kleb, Mary	Project Manager	NASA LaRC
Pickering, Ken	Project Scientist	NASA GSFC
+ Chen, Gao	Project Data Manager	NASA LaRC
Flight Operations Support		
Alexander, Mike	Chief Engineer	NASA LaRC
Crittenden, Luci	Logistics Manager/UC-12 Flight Operations Engineer	NASA LaRC
Nowicki, Martin	P-3B Integration/Operations Engineer	NASA WFF
Singer, Mike	P-3B Chief Pilot	NASA WFF
Fisher, Bruce	King Air Platform Manager	NASA LaRC
Cleckner, Craig	King Air Lead Mechanical Design Engineer	NASA LaRC
Yasky, Rick	King Air Chief Pilot	NASA LaRC
Kagey, Les	King Air Pilot	NASA LaRC
Wusk, Mike	King Air Flight Operations Engineer	NASA LaRC
P-3B Instruments		
+ Anderson, Bruce	LARGE (aerosols)	NASA LaRC
+ Barrick, John	PDS (met,nav)	LaRC-SSAI
+ Cohen, Ron	TD LIF (NO2, HNO3, PNs, ANs)	U of CA, Berkeley
+ Diskin, Glenn	DLH (H2O), DACOM (CO, CH4)	NASA LaRC
+ Fried, Alan	IR Absorption Spectrometer (CH2O)	U of CO, Boulder
+ Weinheimer, Andy	Chemiluminescence (O3, NO2, NO, NOy)	NCAR
+ Wisthaler, Armin	PTRMS (non-methane hydrocarbons)	University of Innsbruck
+ Yang, Melissa	AVOCET (CO2)	NASA LaRC
King Air Instruments		
+ Hostetler, Chris	HSRL (aerosol profiles)	NASA LaRC
+ Janz, Scott	ACAM (column O3, NO2, CH2O)	NASA GSFC
Ground Instrumentation		
Clark, Richard	tethered balloon	Millersville University
+ Herman, Jay	Pandora (column O3, NO2, CH2O)	UMBC
+ Hoff, Ray	Lidar (aerosol profiles), AERI, Raman H2O	UMBC
+ Holben, Brent	AERONET	NASA GSFC
+ Thompson, Anne	NATIVE (O3, CO, NO, NOy), ozonesondes, aerosol lidar	Penn State

http://discover-aq.larc.nasa.gov/

TCAP Campaign

TCAP Campaign: Two Column Aerosol Project

A DOE Atmospheric Radiation Measurement (ARM) program funded mission

PI(s): Larry Berg, Richard Ferrare, Chris Hostetler

SITE: Cape Cod, MA

DATES:

Ground-based: July 2012 – June 2013

Flights: Summer 2012 and Winter 201

Do diurnal aerosol changes affect daily average Radiative Forcing (as measured during TCAP)? E. Kassianov et al., 2013.

PM Standards

PM2.5 – Primary, Annual < 12 µg/m^3, Annual arithmetic mean, average over 3 years
PM2.5 – Secondary, Annual < 15 µg/m^3, Annual arithmetic mean, average over 3 years
PM2.5 – P/S, 24-hour < 35 µg/m^3, 98th percentile, average over 3 years
PM10 – P/S, 24-our < 150 µg/m^3, Not to exceed more than once per year on avg over 3 yrs

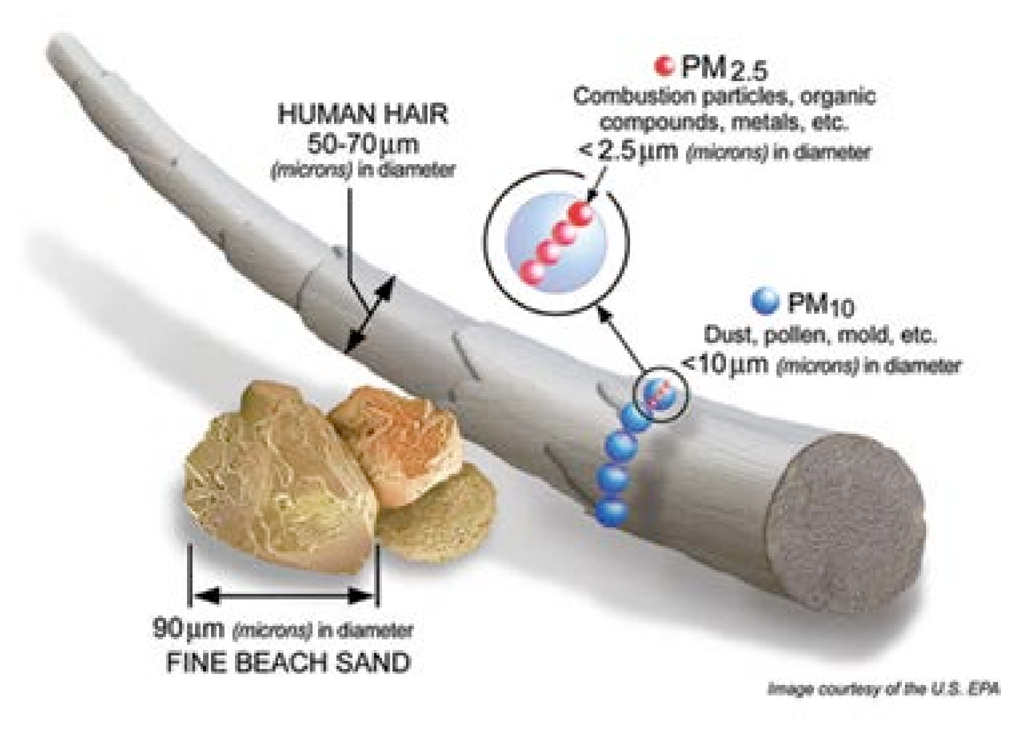
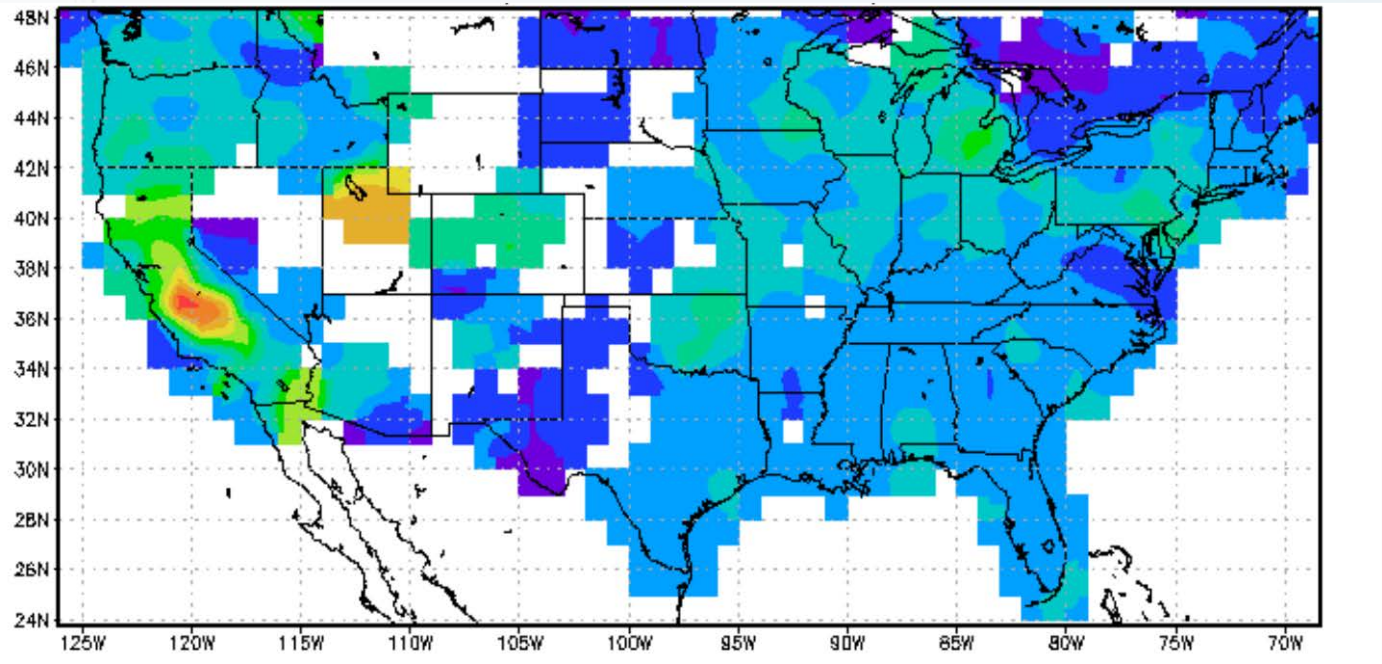


Image courtesy of the U.S. EPA

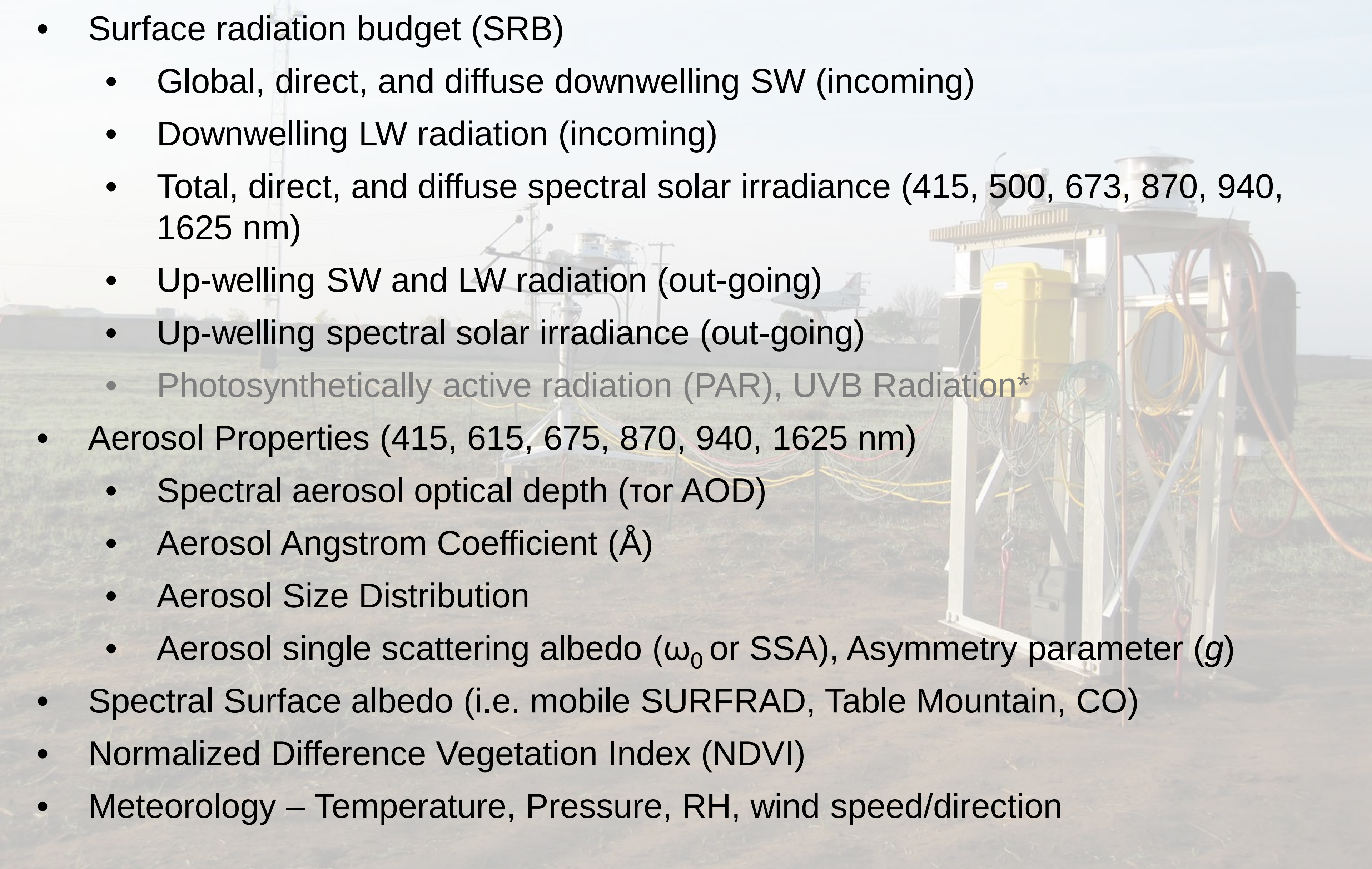
DISCOVER-AQ
Central Valley Motivation

NASA/GSFC Giovanni Visualization of AirNow PM2.5 Data, Jan-Feb, 2007.



Main point: PM2.5 is typically very high over the San Joaquin Valley, CA and is highest in the winter in this region.

SURFRAD Products



- Surface radiation budget (SRB)
  - Global, direct, and diffuse downwelling SW (incoming)
  - Downwelling LW radiation (incoming)
  - Total, direct, and diffuse spectral solar irradiance (415, 500, 673, 870, 940, 1625 nm)
  - Up-welling SW and LW radiation (out-going)
  - Up-welling spectral solar irradiance (out-going)
  - Photosynthetically active radiation (PAR), UVB Radiation*
- Aerosol Properties (415, 615, 675, 870, 940, 1625 nm)
  - Spectral aerosol optical depth (τor AOD)
  - Aerosol Angstrom Coefficient (Å)
  - Aerosol Size Distribution
  - Aerosol single scattering albedo (ω_0 or SSA), Asymmetry parameter (*g*)
- Spectral Surface albedo (i.e. mobile SURFRAD, Table Mountain, CO)
- Normalized Difference Vegetation Index (NDVI)
- Meteorology – Temperature, Pressure, RH, wind speed/direction