ARL
Air Resources Laboratory
Conducting research and development in the fields of air quality, atmospheric dispersion, climate, and boundary layer

AQ OSSE, Forecasting & Reanalysis
(optimizing assimilation of column AOT & sfc data)

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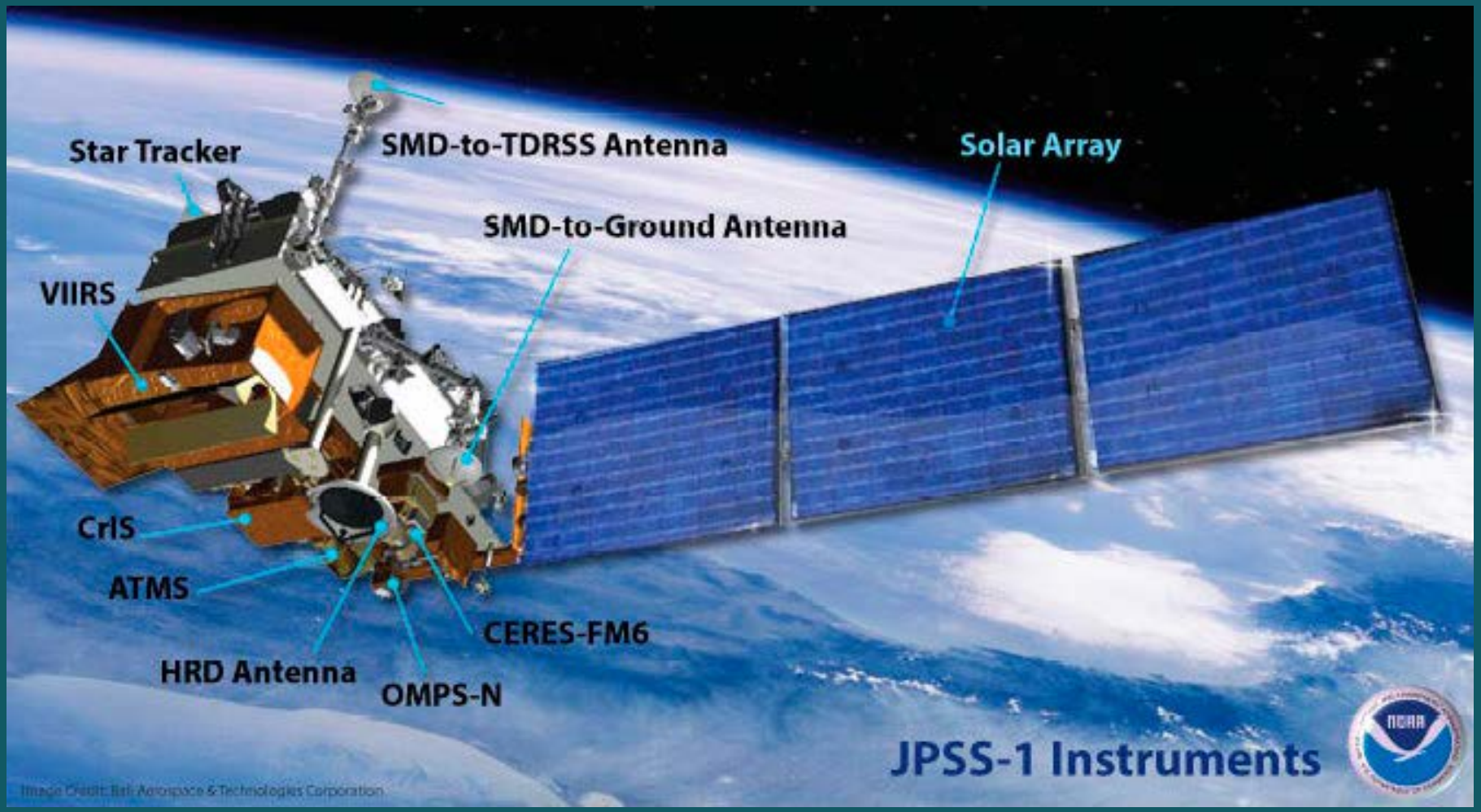
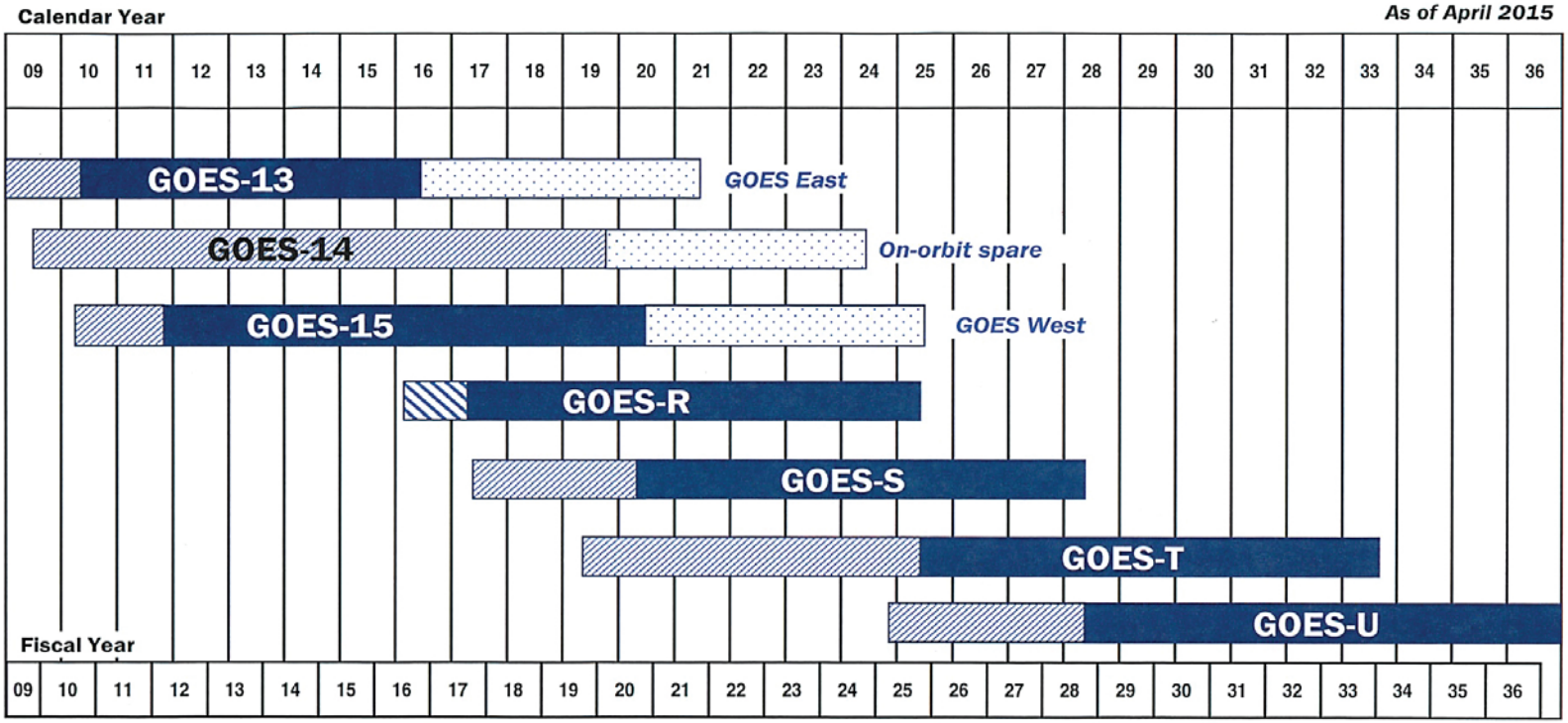
[11] ARL, Atmospheric Turbulence and Diffusion Division, Oak Ridge, TN
[12] Department of Environmental Health, Emory University, Atlanta, GA



JPSS-2 3 4 seemed to be lining up

Continuity of GOES Mission

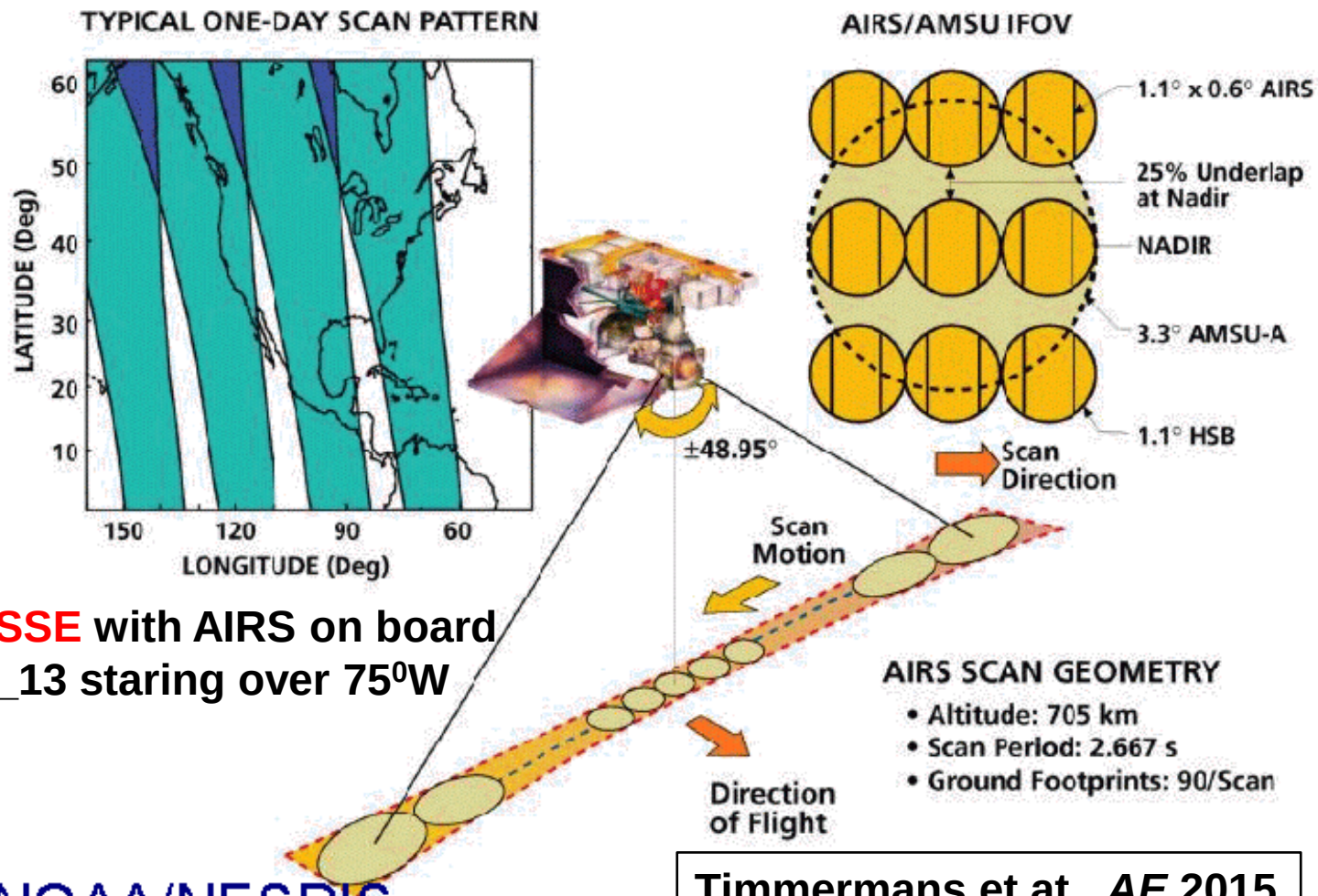


GOES: Geostationary Operational Environmental Satellite

- On-orbit Storage
- Test & Checkout
- Operational
- Fuel-Limited Lifetime

Approved: Stephen Volz 4/21/2015
Assistant Administrator for Satellite and Information Services

Simulation of AIRS Radiance



OSSE with AIRS on board G_13 staring over 75^{0}W

NOAA/NESDIS

Timmermans et at., *AE* 2015

Robert Atlas, *NWP*, Silver Spring, MD Oct29-Nov1, 1979

Preliminary AIRS_G13 impacts (00Z runs)

Domain	Parameter	Level	Anomaly Correlation Forecast Day 1	2	3	4	5	6	7	RMS Error Forecast Day 1	2	3	4	5	6	7
Pac NA	Temperature	250/200 hPa														
		500 hPa														
		850 hPa														
	Wind	250/200 hPa														
		850 hPa														
	Geopotential	250/200 hPa														
		500 hPa														
		700 hPa														
		1000 hPa														
NH	Temperature	250/200 hPa														
		500 hPa														
		850 hPa														
	Wind	250/200 hPa														
		850 hPa														
	Geopotential	250/200 hPa														
		500 hPa														
		700 hPa														
		1000 hPa														

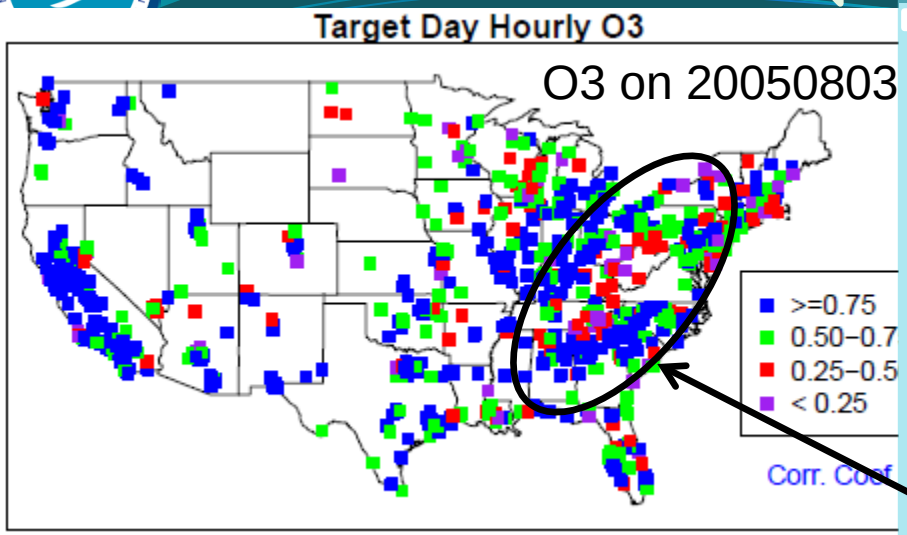
Domain	Parameter	Level	Anomaly Correlation Forecast Day 1	2	3	4	5	6	7	RMS Error Forecast Day 1	2	3	4	5	6	7
SH	Temperature	250/200 hPa														
		500 hPa														
		850 hPa														
	Wind	250/200 hPa														
		850 hPa														
	Geopotential	250/200 hPa														
		500 hPa														
		700 hPa														
		1000 hPa														
Tropics	Temperature	250/200 hPa														
		500 hPa														
		850 hPa														
	Wind	250/200 hPa														
		850 hPa														

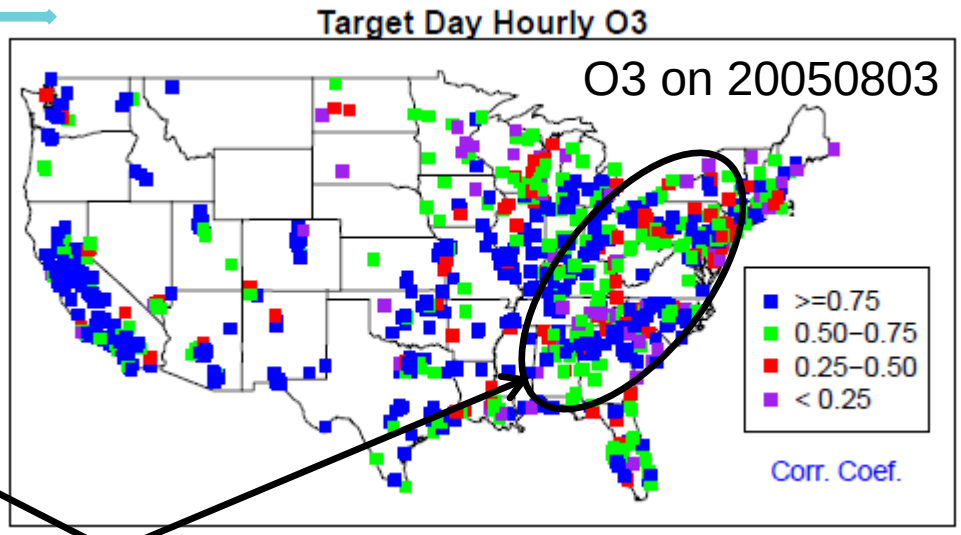
- prs382hwa significantly better than prs382hna
- prs382hwa better than prs382hna, nonsignificant
- no discernible difference
- prs382hwa worse than prs382hna, nonsignificant
- prs382hwa significantly worse than prs382hna

- **Bright Green, Red = statistically significant**
- **Visual interpretation, erred on side of caution (i.e., calling results "significant" only if clear without a doubt)**
- **Separation will be quantitative in a comprehensive scorecard**

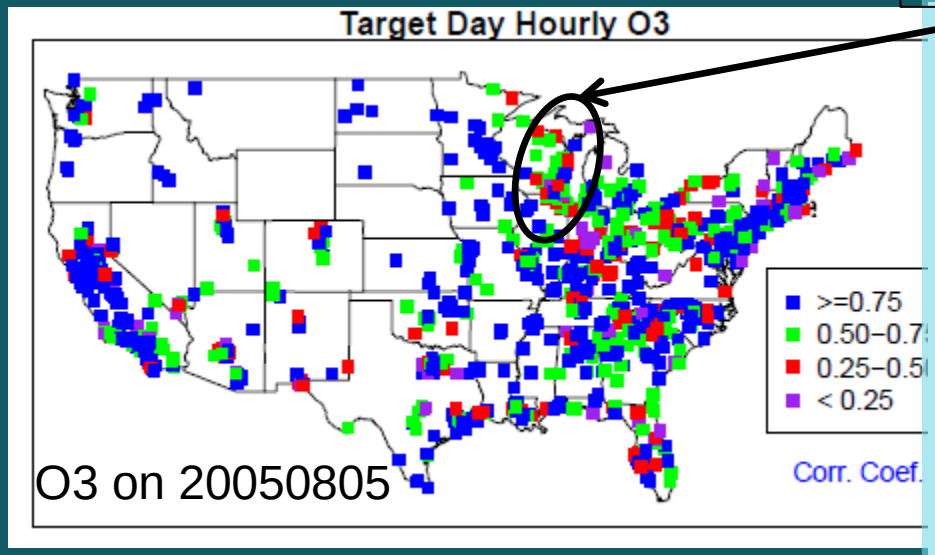
CONTROL- standard GFS

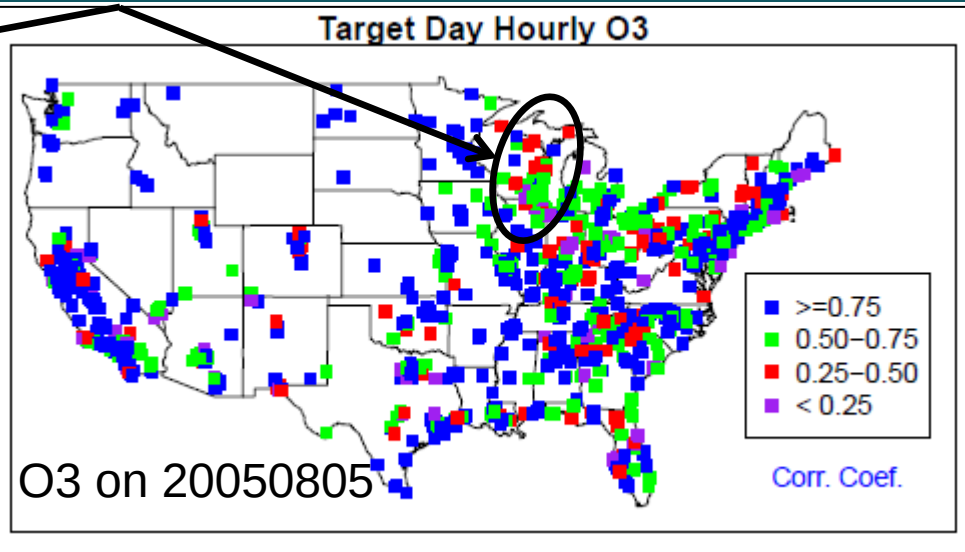
AIRS-assisted GFS





Localized improvement in r & other metrics



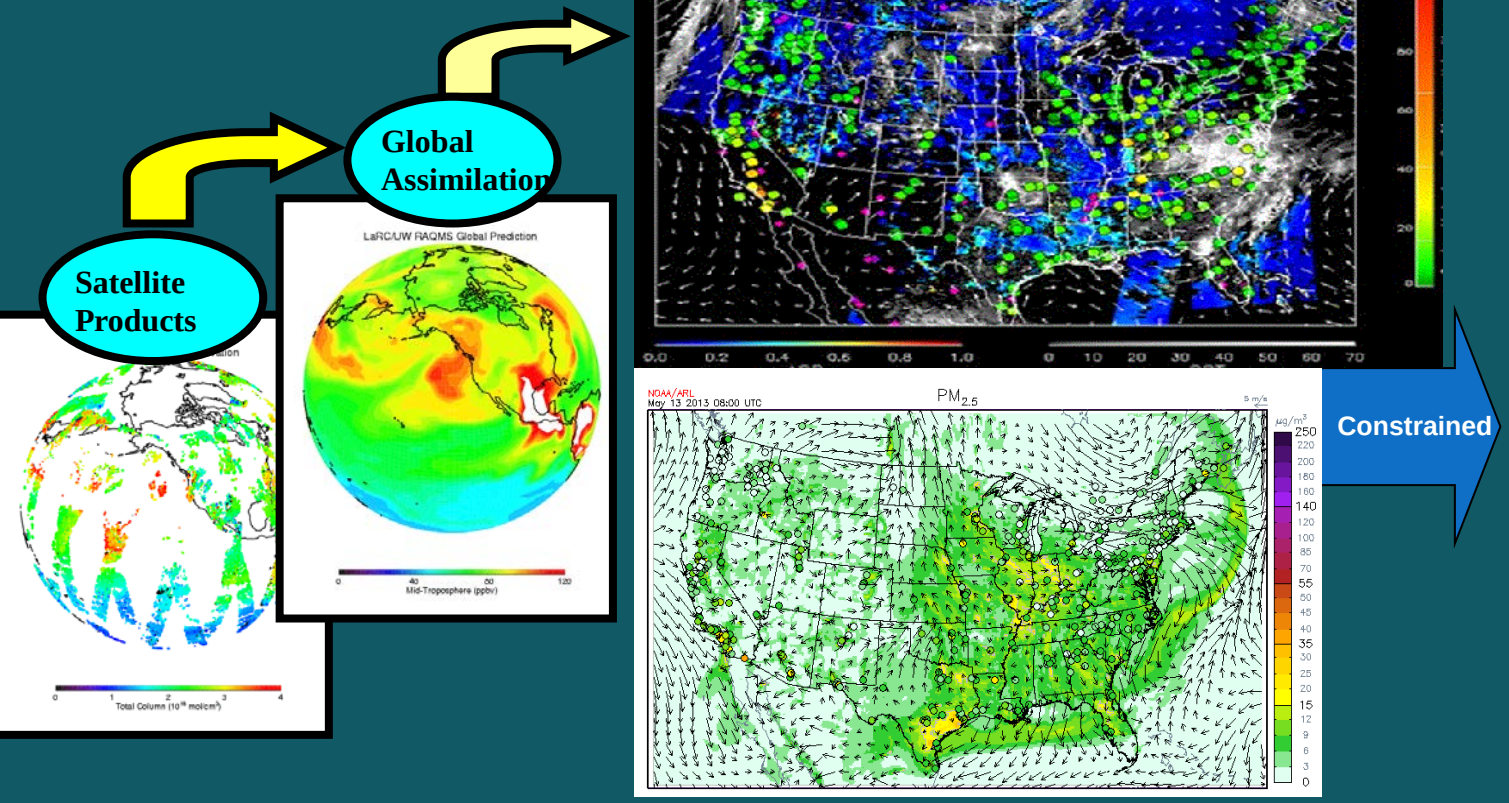


Spatial distribution of correlation coefficient for surface O3 on Aug 3,5 2005

ARL leverages AQAST Project: Air Quality Reanalysis

(*Translating Research to Services*)

Robichaud and Ménard, *ACP* 2014
Ménard et al., *MWR* 2000



+ AQ Assessments
+ State Implementation Plan Modeling
+ Rapid deployment of on-demand rapid-response forecasting; e.g., new fuel type,…, etc.
+ Health Impacts assessments
+ Demonstration of the impact of observations on AQ distributions
+ Ingestion of new AQAST products into operations

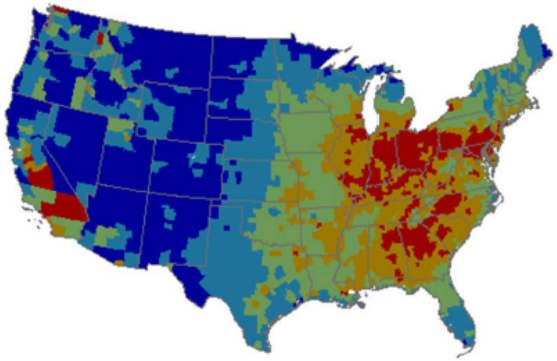
http://acmg.seas.harvard.edu/aqast/projects.html

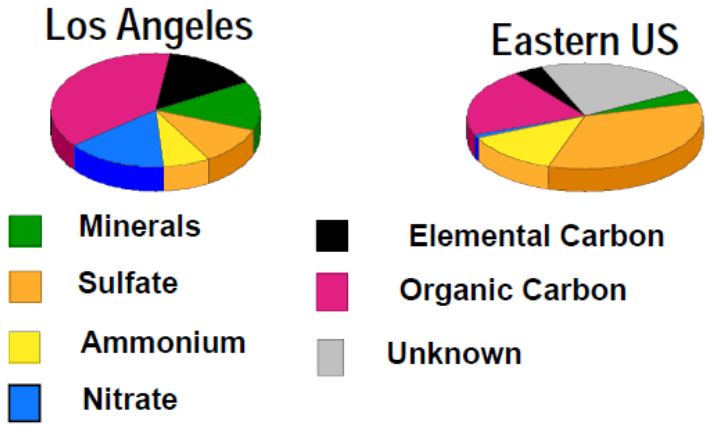
Courtesy: Dan Costa
"New Directions in Air Quality Research at the US EPA"

Public Health Burden of $PM_{2.5}$

(Fann et al., 2011)

Percentage of $PM_{2.5}$ related deaths due to 2005 air quality levels by county

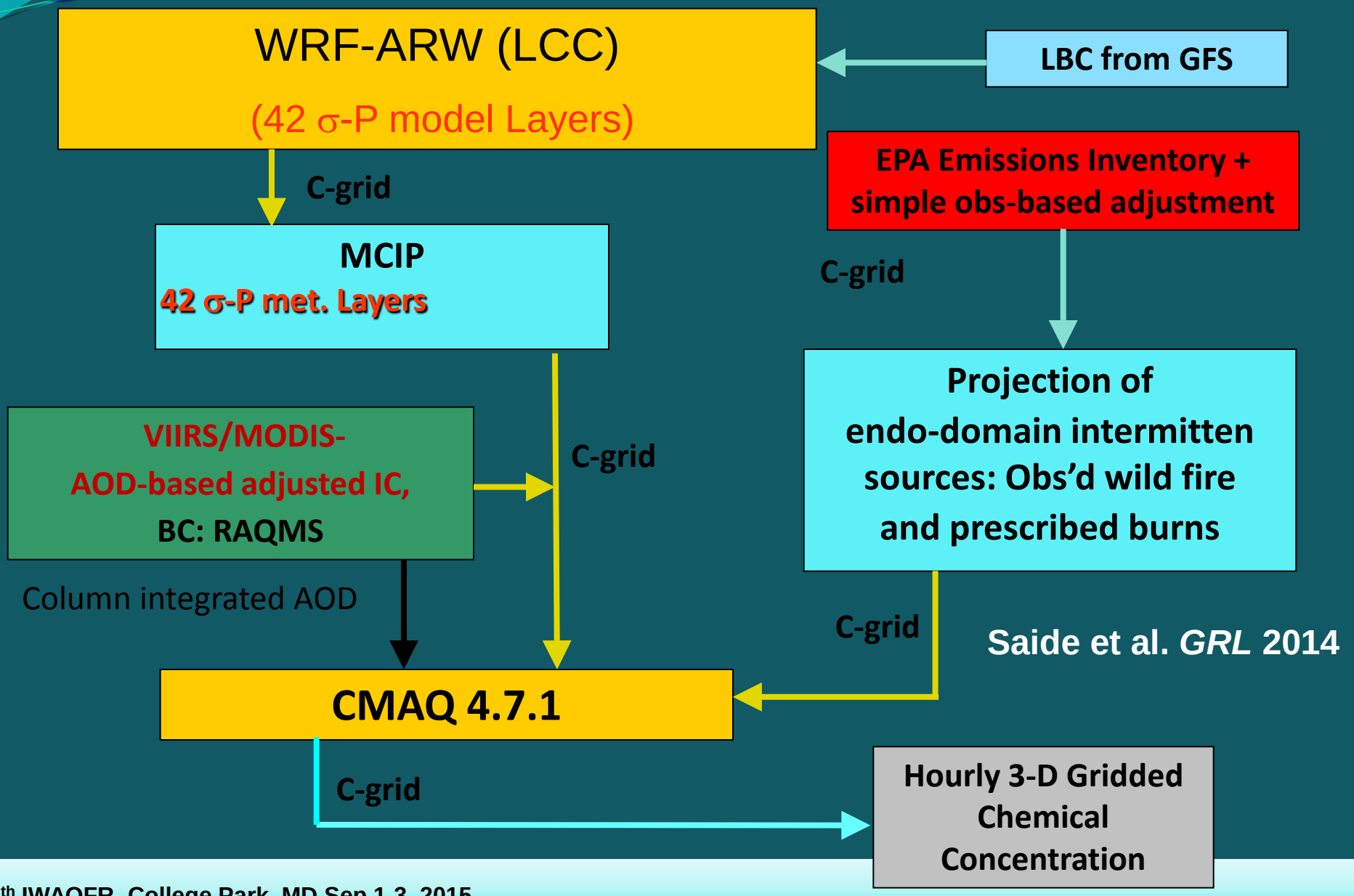


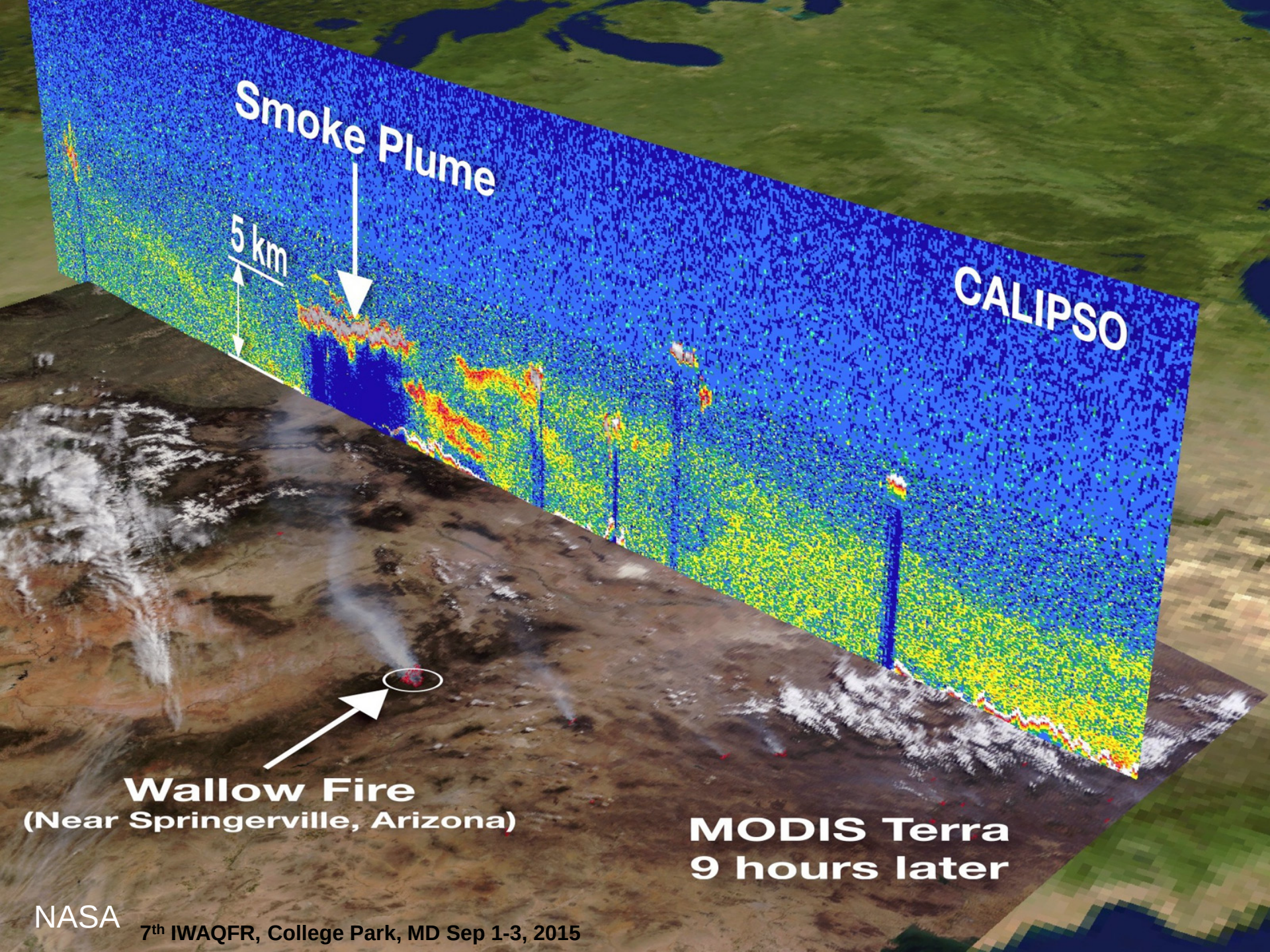


Summary of National $PM_{2.5}$ impacts due to 2005 air quality	
Excess mortalities (adults)[A]	130 to 320,000
Percentage of all deaths due to $PM_{2.5}$[B]	5.4%
Impacts among Children	
ER visits for asthma (<18 yr)	110,000
Acute bronchitis (age 8-12)	200,000
Exacerbation of asthma (age 6-18)	2,500,000

[A] Range reflects use of alternate PM mortality estimates
[B] Population-weighted value using Krewski et al. (2009) PM mortality estimates

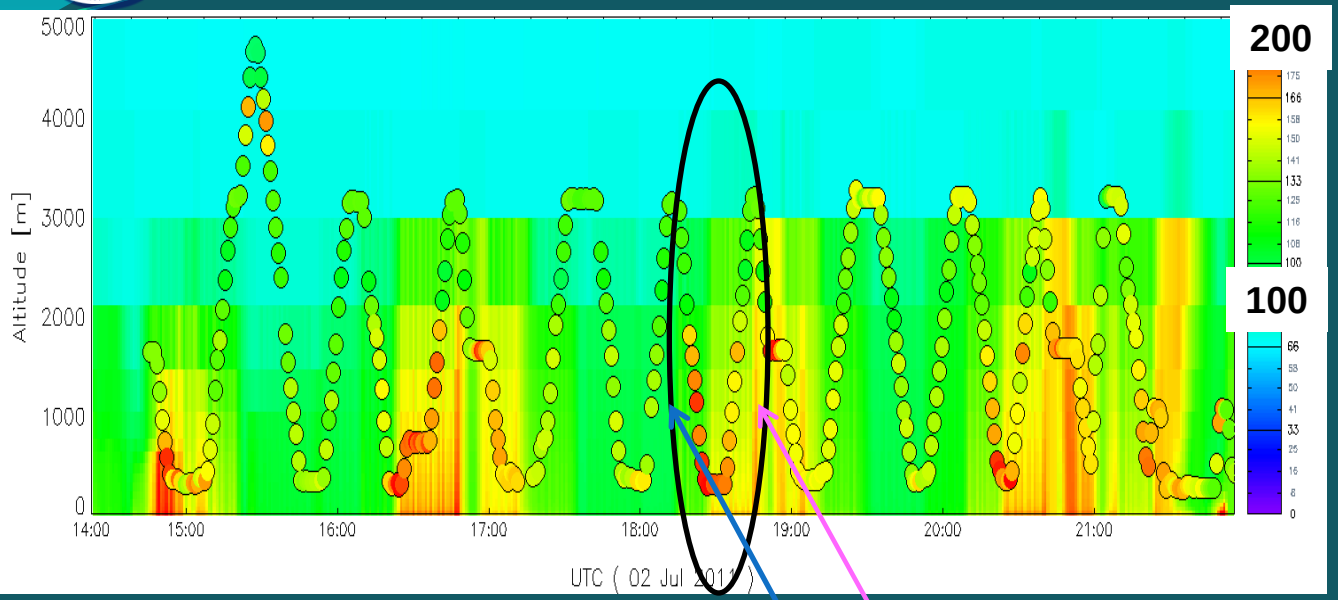
WRF_ARW-MCIP-CMAQ forward model




Smoke Plume
5 km
CALIPSO
Wallow Fire
(Near Springerville, Arizona)
MODIS Terra
9 hours later

NASA

CO (ppb) along the P3 Flight – July 2 2011: AOD_DA case vs. Obs



P3 Three and a half loops:

Beltsville

Padonia

Fairhill

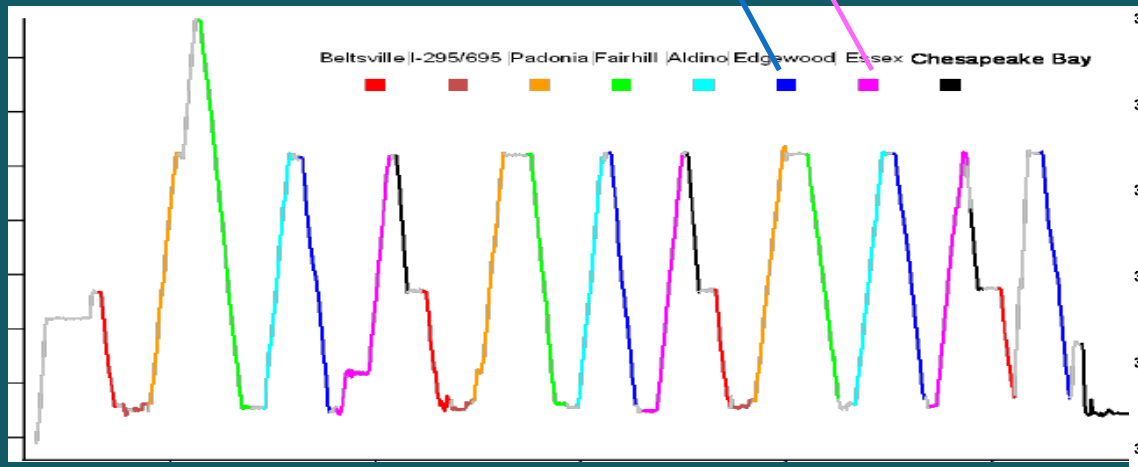
Aldino

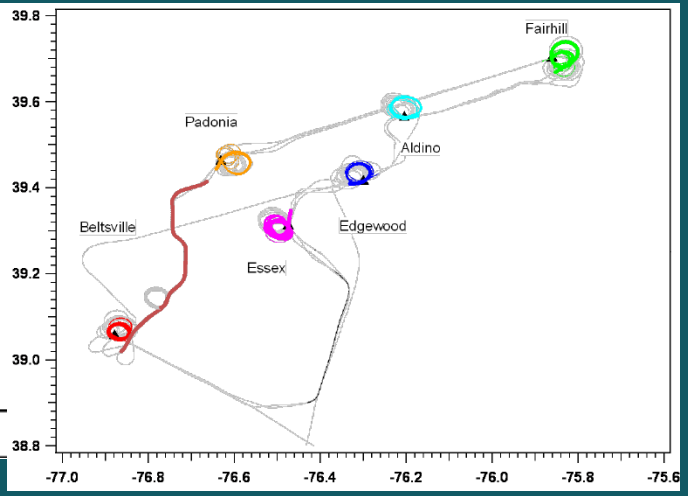
Edgewood

Essex

Chesapeake Bay

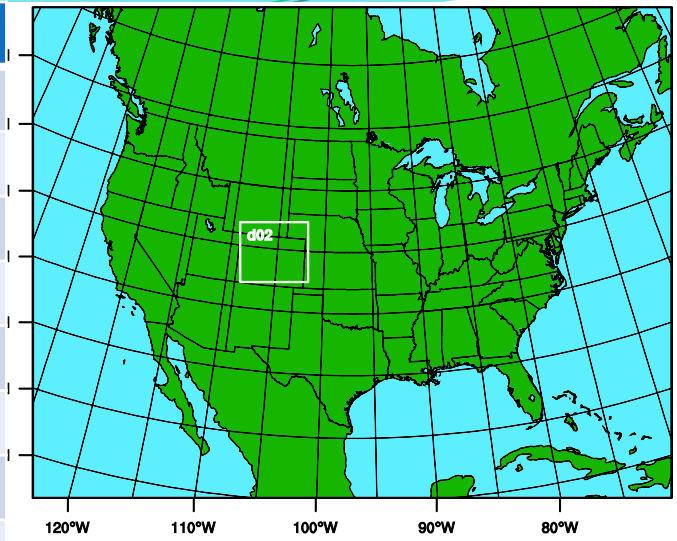
Pickering and Lee, *EM* 2014





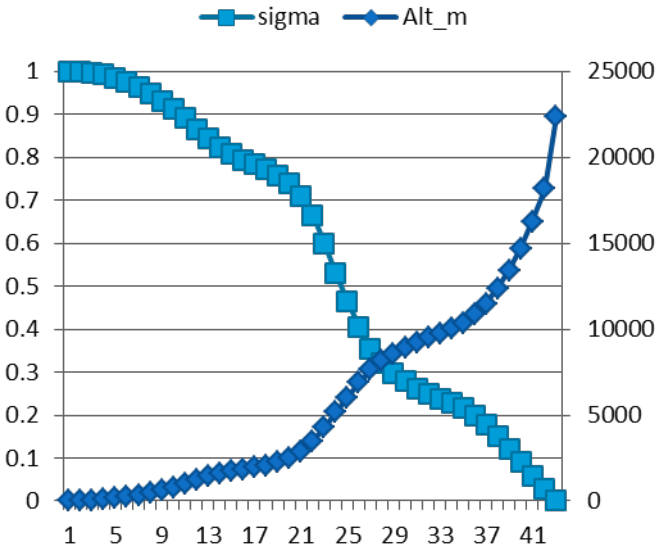
WRF_ARW-MCIP-CMAQ model physics and chemistry options

WRF-ARW	Both North America (12 km) & CONUS (4 km)
Map projection & grid	Lambert Conformal & Arakawa C staggering
Vert. co-ordinate	42 σ-p unevenly spaced levels
advection	RK3 (Skamarock and Weisman (2008))
SW & LW radiation	RRTMG (Iacono et al. 2008))
PBL Physics	Mellor-Yamada-Janjic (MYJ) level 2.5 closure
Surface layer scheme	Monin-Obukhov Similarity with viscous sub-layer
Land Surface Model	NCEP NOAH
Cloud Microphysics	Thompson et al. (2008)
Cloud convective mixing	Betts-Miller-Janjic Mass adjustment



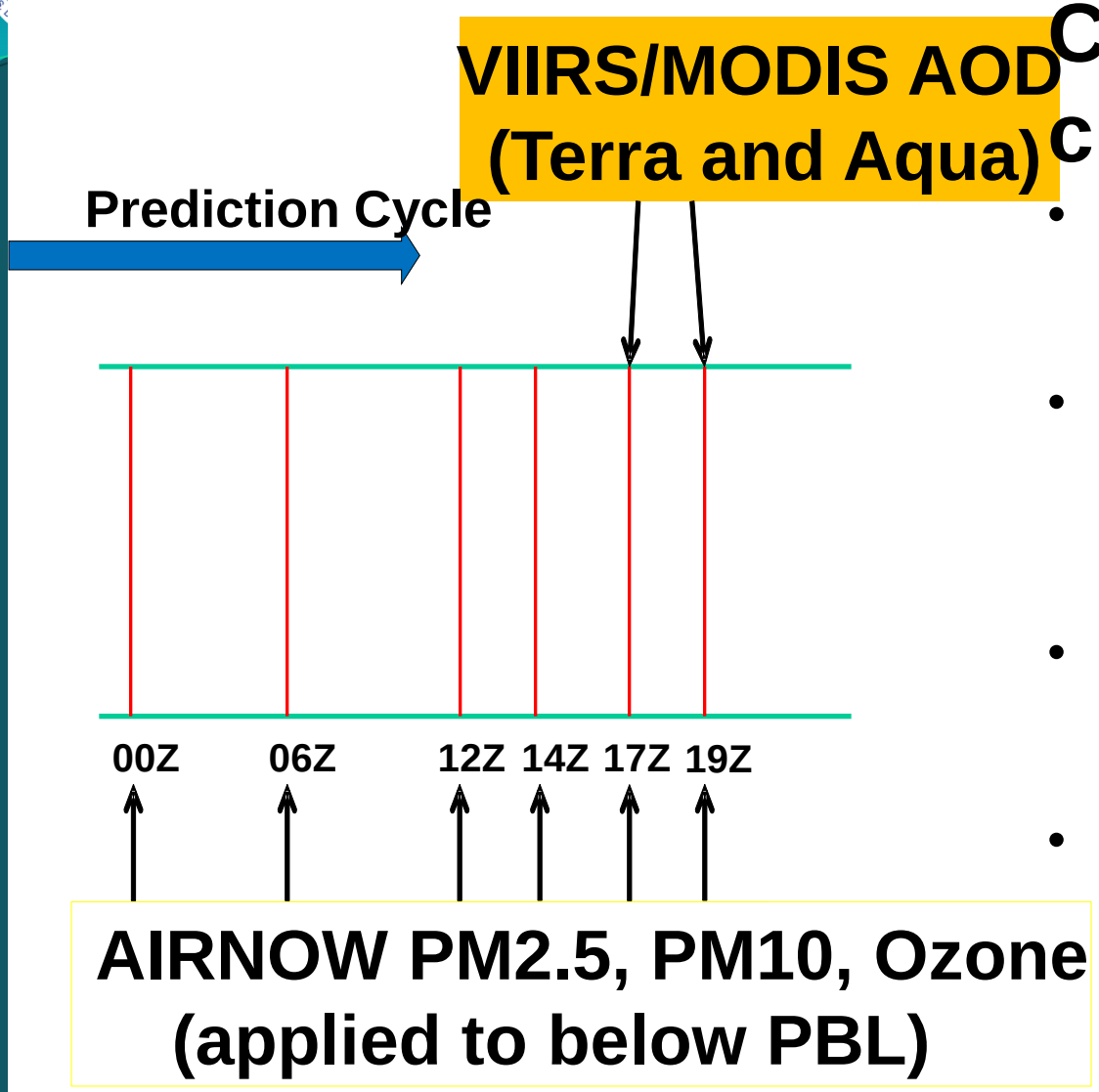
AQ forecast: ^12 km nested to 4 km

CMAQ4.7.1	Both CONUS(12 km) & SENEX (4 km)
Map projection & grid	Lambert Conformal & Arakawa C staggering
Vert. co-ordinate	42 σ-p unevenly spaced levels
Gas chemistry	Cb05 with 156 reactions
Aerosol chemistry	Aero5 with updated evaporation enthalpy
Anthropogenic emission	2008NEI as base year, mobile projected using AQS*, area and off-road used CSPR^, point source uses 2012 CEM data
	WRAP oil and gas emissions data
Biogenic emission	BEIS-3.14
Lateral BC	RAQM (B. Pierce)



42 vertical layers

CMAQ base v5.0.2: cb05_ae5)



- 2008 anthropogenic emission inventory projected to 2011
- NOAA HMS (hazard mapping system) fire emission with Bluesky algorithm
- GOES cloud fraction adjustment provided by U. of Alabama at Huntsville
- RAQMS lateral boundary condition every 6 hours.

Optimal Interpolation (OI)

- OI is a sequential data assimilation method. At each time step, we solve an analysis problem

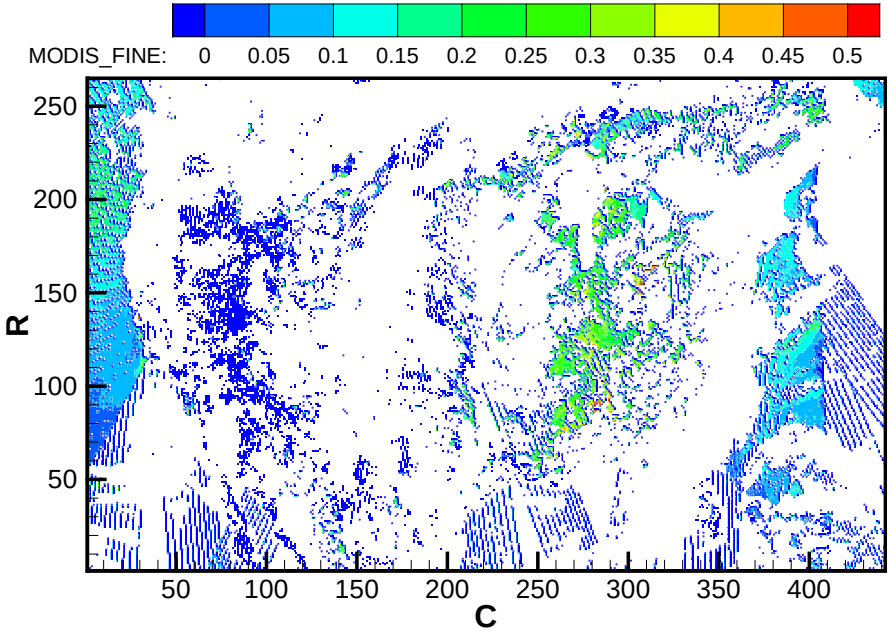
$$X^a = X^b + BH^T(HBH^T + O)^{-1}(Y - HX)$$

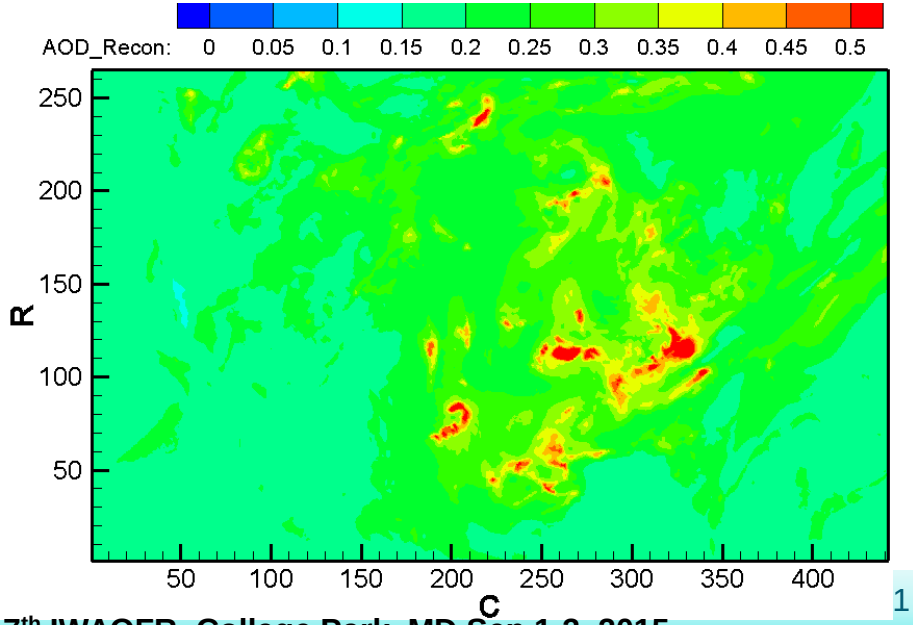
- We assume observations far away (beyond background error correlation length scale) have no effect in the analysis
- In the current study, the data injection takes place at 1700Z daily

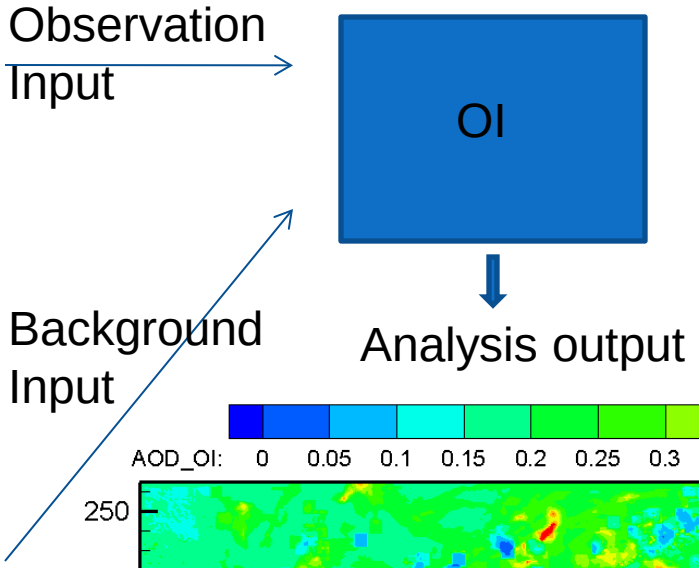
Chai et al. *JGR* 2006

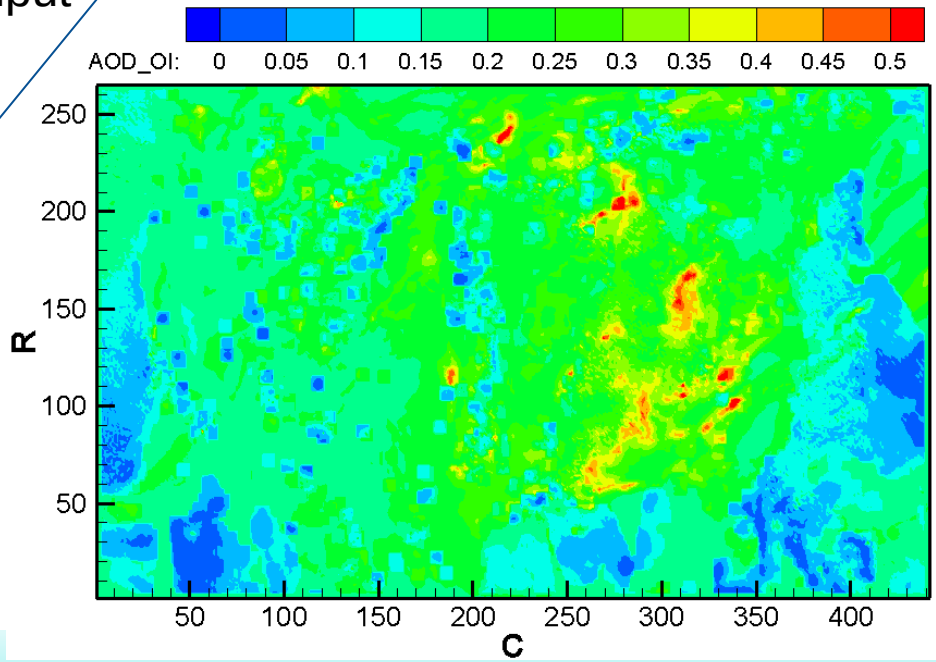
Objective (A): Improve PM forecast

Methodology of OI: Take account for background input; Obs; and physical processes from model



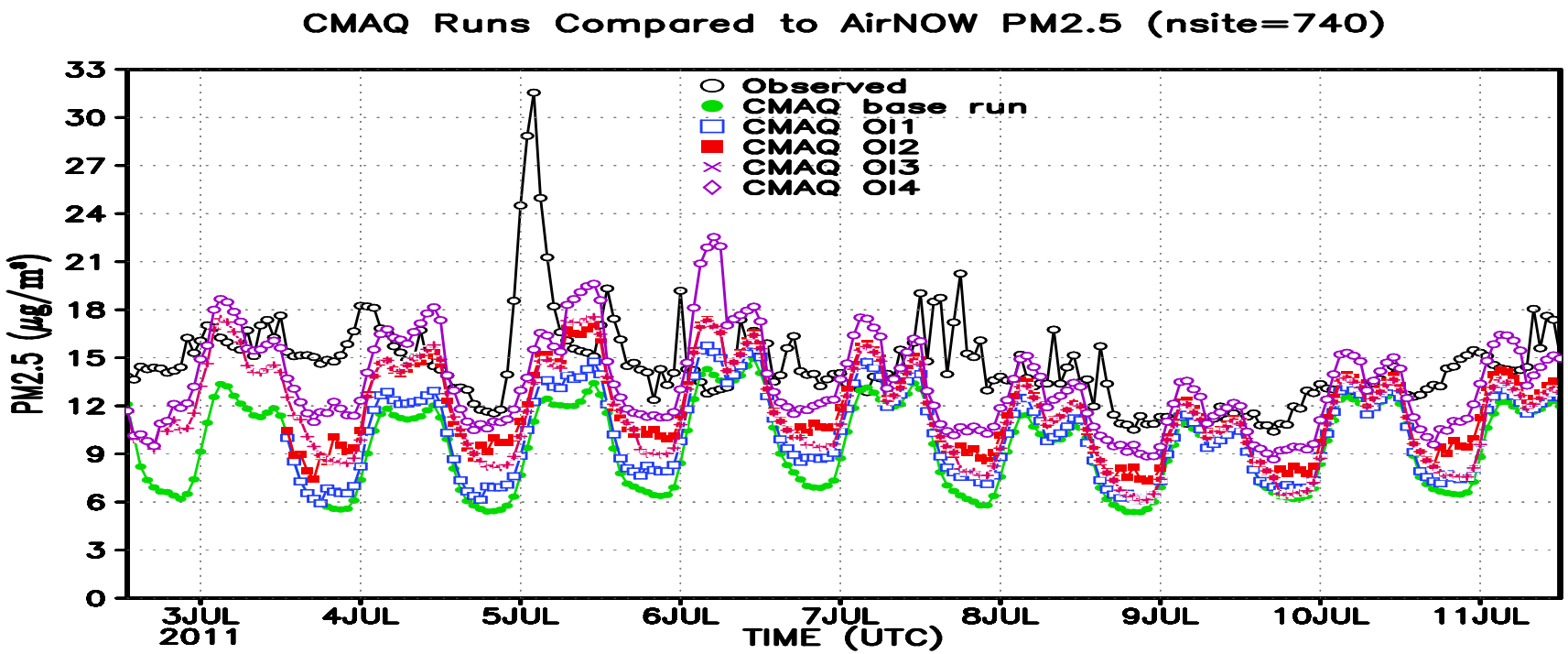




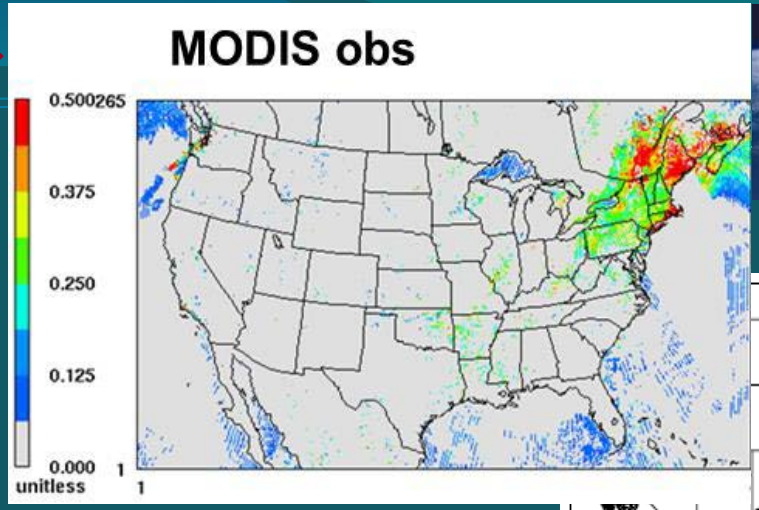


Hourly Statistic Results for CONUS 12Z, 07/06/2011- , 07/07/2011

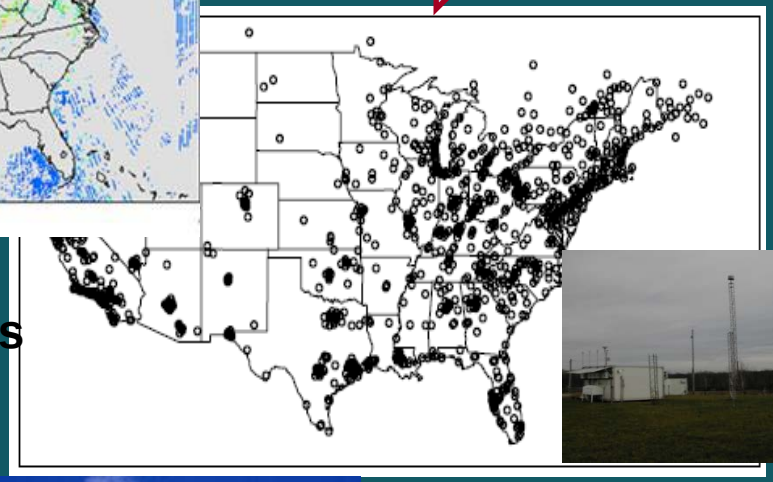
Cases	O_3	PM2.5
Base case	R=0.53 MB=2.54	R=0.23 MB= -7.14
OI1	R=0.56 MB=2.36	R=0.24 MB= -2.63
OI2	R=0.58 MB=1.06	R=0.39 MB= -1.33
OI3	R=0.52 MB=2.08	R=0.36 MB= -1.89
OI4	R=0.56 MB=1.55	R=0.40 MB= -0.11



Lee and Liu, *IEPH* 2014
Pan et. al., *AE* 2014
Kim et al., *GMD* 2015



AIRNow



Cloud-obs Photolysis rates

GOES-MCIP INTERFACE

Cloud transmissivity (calculated from satellite retrieved cloud albedo), cloud top pressure, and cloud fraction are prepared for input to MCIP

MODIFIED MCIP

GOES retrievals replaces MM5 cloud information being passed to CMAQ. Cloud fraction, transmissivity, cloud base and top heights are passed to CMAQ.

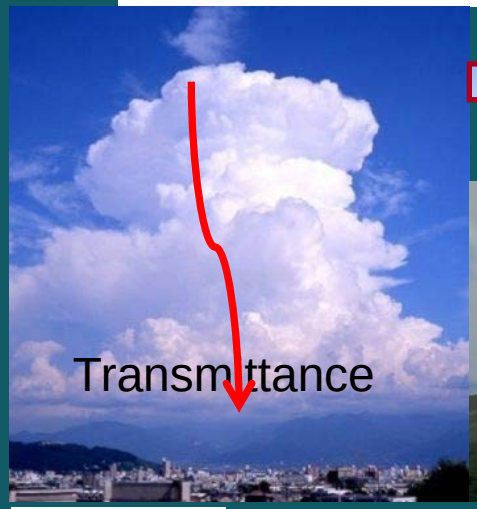
PHOT in CMAQ

In subroutine PHOT, clear sky photolysis rates will be adjusted for cloud cover based on GOES cloud fraction and cloud transmissivity information.

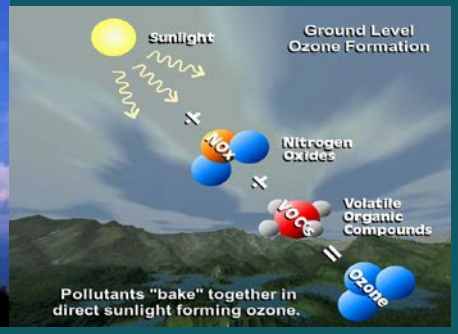
Interpolated in between.

Cloud Base According to Lifting Condensation Level

$$T_c = B / \ln\left[\frac{A\varepsilon}{wp_0}\left(\frac{T_s}{T_c}\right)^{2/\kappa}\right]$$



Isoprene & PAR



Tong et al. *AE* 2015

Summary

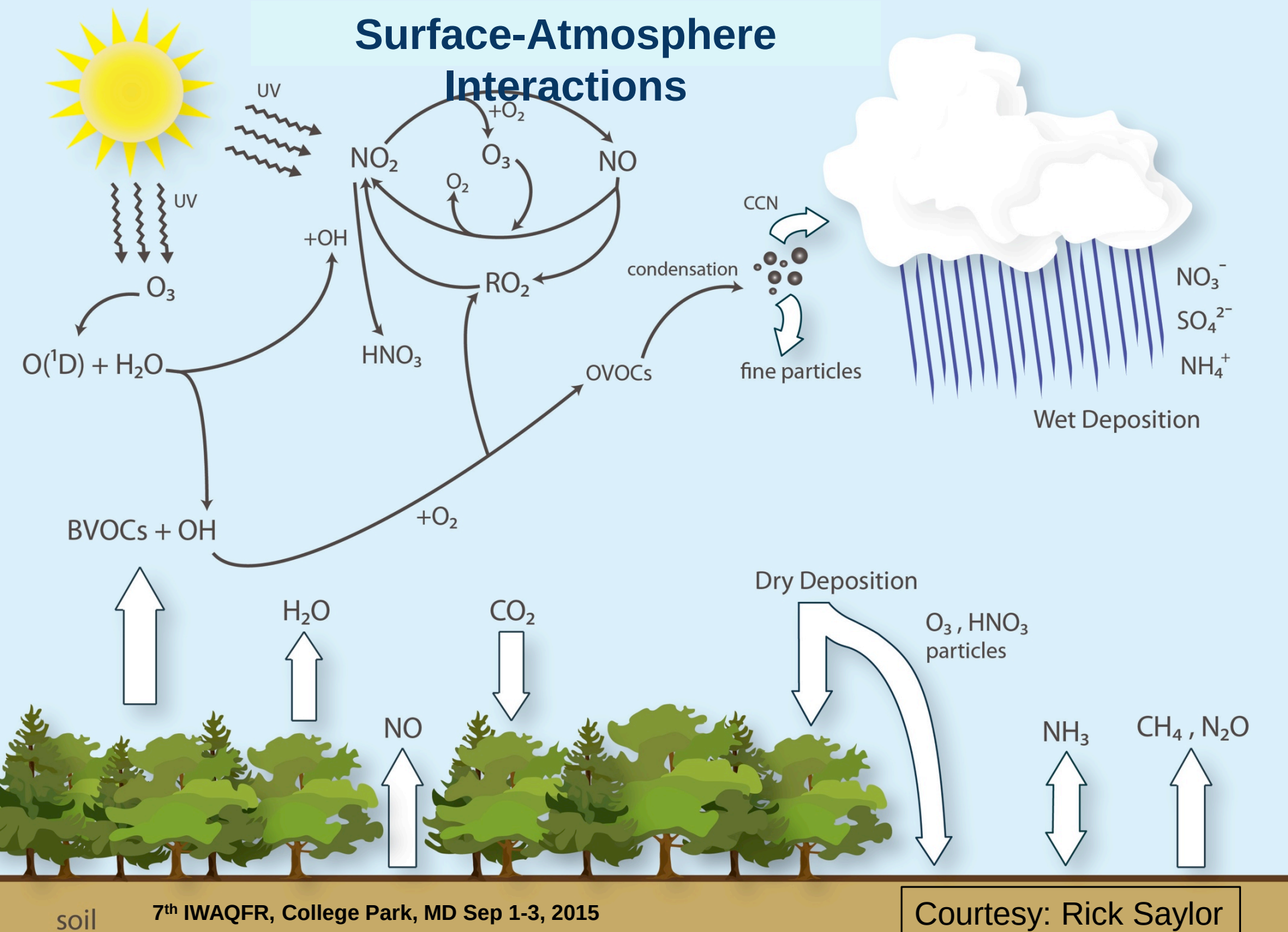
- NOAA Service: Chemical Re-analyses
  - Translate Science to Service
  - Protect life, environment and economy
  - Benefit NAQFC

- Observation System Simulation Experiment: an AQ prospective
  - Preliminary test with AIRS on GOES

EXTRA SLIDES

Contact:
Pius.Lee@noaa.gov
http://www.arl.noaa.gov/

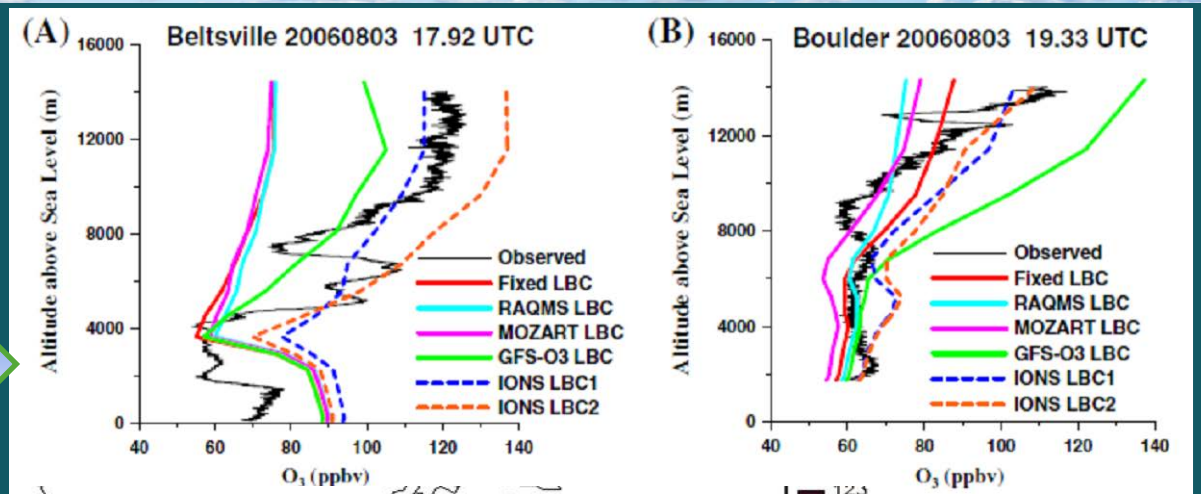
Surface-Atmosphere Interactions



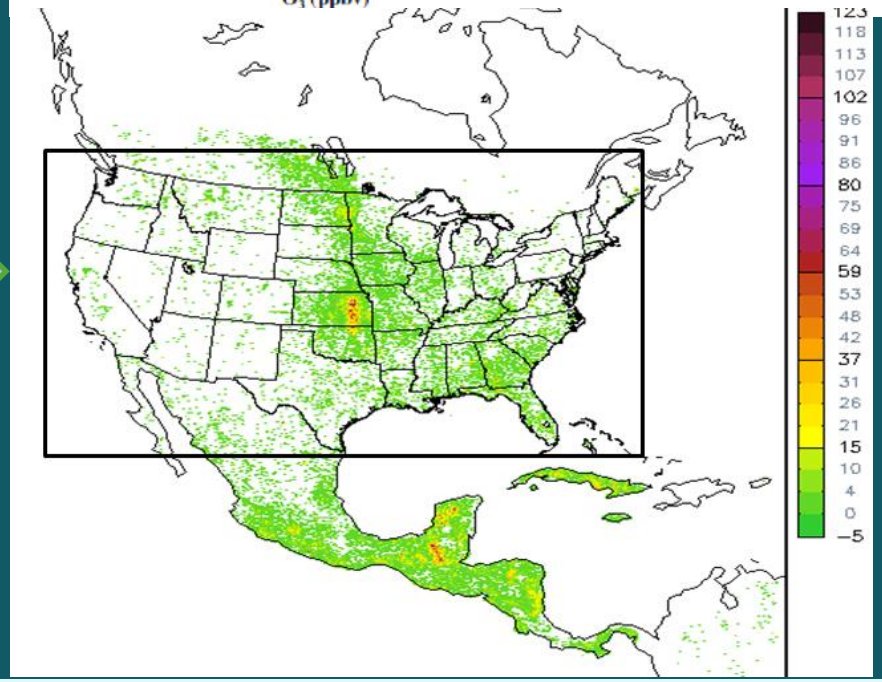
Courtesy: Rick Saylor

Next data set
To be include
In data assimilation?

MLS & MODIS AOD from global Model: e.g., RAQMS



Exo-domain as well as endo-domain wild fires & prescribed burns



Tang et al., *EFM*, 2009