# Report on NOAA’s Potential Use of GEO-CAPE Measurements of Trace Gases and Aerosols


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With inputs from:

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**Columbia MD**

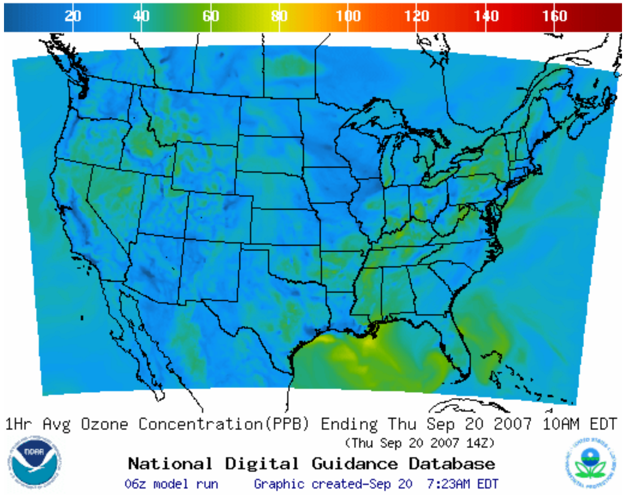
# NOAA's Air Quality Program

**Information for Decision-makers**

Federal Policies

State & Local Management Strategies

**Air Quality Forecasts**




# Satellite Data Applications

- Data assimilation
- Air quality trending
- Sources
- Transport
- Processes
- Air quality forecasting
- Visibility forecasting
- Hazards

# National Weather Service

| Application | Need/Requirement | GEO-CAPE Science Priority |
|---|---|---|
| Data Assimilation | By GEO-CAPE launch, NWS models are expected to evolve to assimilate hourly trace gas and aerosol measurements | 3 |
| Air Quality Trending | NWS interested in additional verification of location, composition, and concentration of chemical species in the atmosphere, for model predictions. | 1 |
| Sources | Interested in synergetic use of GOES-R lightning mapper data with GEO-CAPE NO2 measurements to identify lightning produced NO | 1 |
| Transport | | |
| Processes | Use GEO-CAPE measurements to understand science behind aerosol-water chemistry so the processes are accurately represented in the models | 2 |
| Air Quality Forecasting | GEO-CAPE measurements to help with air quality forecasting at different pollutant levels (low-medium-high) | 3 |
| Visibility Forecasting | Help with particle size discrimination and hygroscopic growth of particles important for visibility | 3 |

# OAR/ESRL

| Application | Need/Requirement | GEO-CAPE Science Question |
|---|---|---|
| Data Assimilation | • Important to understand information content in satellite data and what models need. For example, knowing length scales in horizontal and vertical is important prior to assimilating satellite data | 3 |
| Air Quality Trending | • Important to get aerosols and NO2 from the same instrument as aerosols may impact NO2 and aerosol trend can impact NO2 trend.<br>• Trends in emissions and the effect of those trends on air quality | 1 |
| Sources | • Represent diurnal cycle of mobile emissions in air quality models | 1 |
| Transport | | |
| Processes | • Impact of biomass burning aerosols on cloud formation<br>• Boundary layer physics in the model: primarily guided by surface characteristics and any information on land use/cover, soil moisture etc. are useful.<br>• Regarding clouds in the model, there are conceptual difficulties understanding what is being modeled vs what is observed. Could be useful to have cloud top information and temperature. | 2 |
| Air Quality Forecasting | | |
| Visibility Forecasting | | |

# OAR/ARL

| Application | Need/Requirement | GEO-CAPE Science Question |
|---|---|---|
| Data Assimilation | R&D work related to assimilation | 3 |
| Air Quality Trending | | |
| Sources | • Ammonia emissions are local but impact is widespread.<br>• Dust storm classification.<br>• Biomass burning sources, especially in the western U.S.<br>• For regional modeling, continuous coverage over US is priority followed by areas outside CONUS contributing to air quality issues in the US | 1 |
| Transport | With ozone standard expected to become tighter (lower), more areas in the western U.S. may be in non-compliance. Question is how much of that ozone is local and how much of that due to long-range transport. | 5 |
| Processes | NO2 and ozone should be studied together and a mission with NO2 observations and no boundary layer ozone capability may not be that useful from emissions perspective. | 2 |
| Air Quality Forecasting | | |
| Visibility Forecasting | | |

# Climate Prediction Center

- Mission: climate monitoring and seasonal forecasting of temperature, precipitation, drought, fire danger, etc.
- For climate monitoring, needed information includes sea surface temperature (aerosols and clouds interfere)
- Climate change work: includes long-term ozone monitoring in different layers of the atmosphere, especially below the ozone peak near stratosphere-troposphere boundary.  Measurements like TES will be extremely useful.  CPC is interested in understanding if climate change is altering the frequency of stratosphere/troposphere exchange events
- CPC is interested in improving model physics that can help improve seasonal forecasts
- CPC also monitors upper troposphere wave activity.  Westward moving waves either dissipate or intensify to become hurricanes.  When these waves bring dust with them, the dust affects SST, moisture availability and therefore effect the formation of hurricanes.  Therefore, monitoring of dust aerosols over the Atlantic is valuable for CPC
- CPC provides UV Index forecasts and can use GEO-CAPE ozone, aerosols (optical depth, single scattering albedo) in the model.  Having diurnal information of aerosols will be greatly helpful to get more cloud-free observations.

# NESDIS

- Hazards
  - Operational significant events imagery that includes fires, smoke, dust, volcanic ash/$SO_2$ etc.
- Decision support systems such as Hazard Mapping System
  - Users are USFS, USDA, NRL, state and local agencies
- Assimilation into global/regional models to support (R&D) forecasters

# GOES-R Advanced Baseline Imager

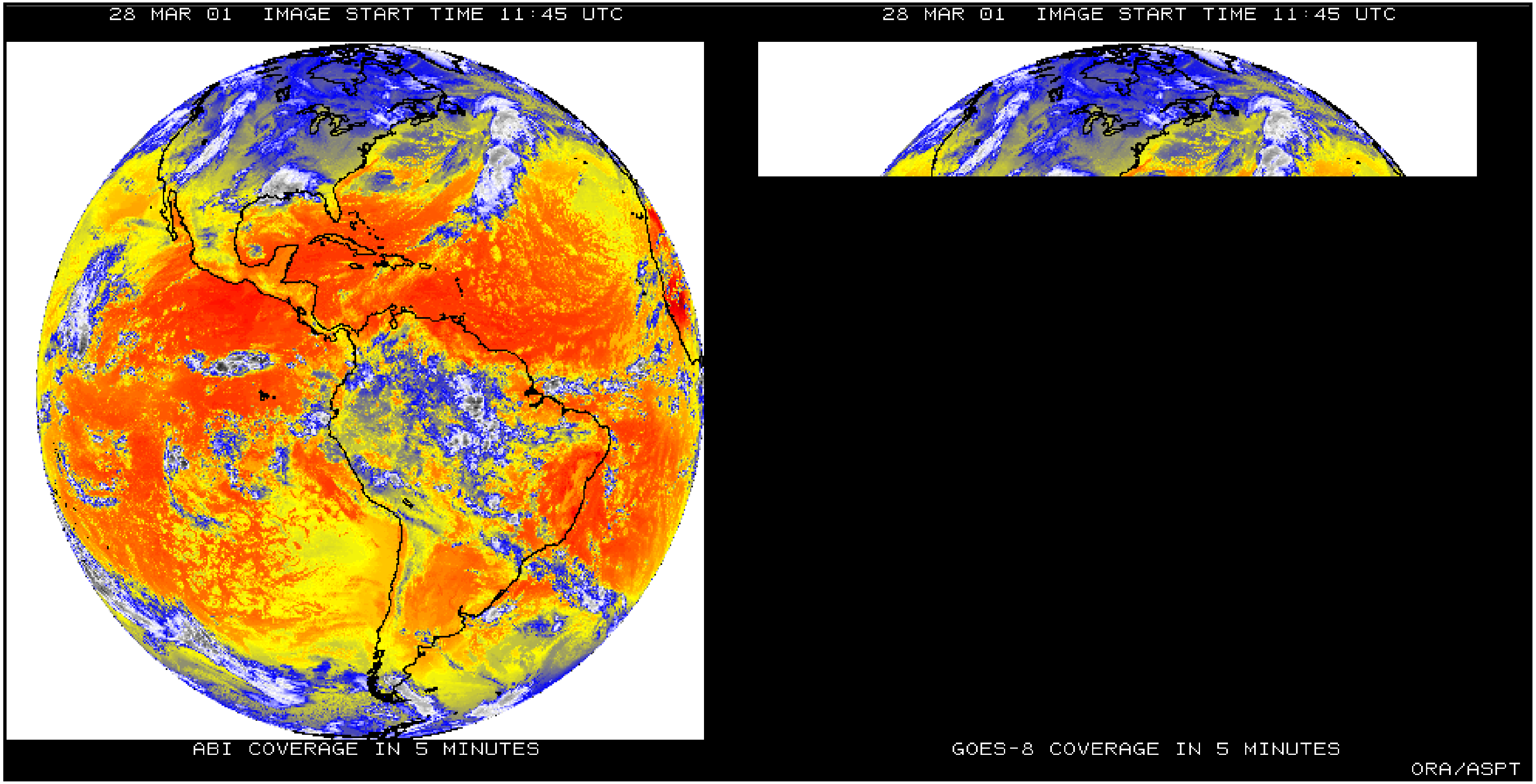
| **Future GOES Imager (ABI) Band** | **Wavelength Range (µm)** | **Central Wavelength (µm)** | **Sample Objective(s)** |
|---|---|---|---|
| 1 | 0.45-0.49 | **0.47** | Daytime aerosol-over-land, Color imagery |
| 2 | 0.59-0.69 | **0.64** | Daytime clouds fog, insolation, winds |
| 3 | 0.84-0.88 | **0.86** | Daytime vegetation & aerosol-over-water, winds |
| 4 | 1.365-1.395 | **1.38** | Daytime cirrus cloud |
| 5 | 1.58-1.64 | **1.61** | Daytime cloud water, snow |
| 6 | 2.235 - 2.285 | **2.26** | Day land/cloud properties, particle size, vegetation |
| 7 | 3.80-4.00 | **3.90** | Sfc. & cloud/fog at night, fire |
| 8 | 5.77-6.6 | **6.19** | High-level atmospheric water vapor, winds, rainfall |
| 9 | 6.75-7.15 | **6.95** | Mid-level atmospheric water vapor, winds, rainfall |
| 10 | 7.24-7.44 | **7.34** | Lower-level water vapor, winds & $SO_2$ |
| 11 | 8.3-8.7 | **8.5** | Total water for stability, cloud phase, dust, $SO_2$ |
| 12 | 9.42-9.8 | **9.61** | Total ozone, turbulence, winds |
| 13 | 10.1-10.6 | **10.35** | Surface properties, low-level moisture & cloud |
| 14 | 10.8-11.6 | **11.2** | Total water for SST, clouds, rainfall |
| 15 | 11.8-12.8 | **12.3** | Total water & ash, SST |
| 16 | 13.0-13.6 | **13.3** | Air temp & cloud heights and amounts |

Based on experience from:

Current GOES Imagers

Spatial resolution: 640 nm at 0.5 km, other visible channels at 1 km, all other channels at 2 km.

# ABI spatial coverage rate versus the current GOES Imager




ABI coverage in ~5 minutes      Current GOES coverage in 5 minutes

There are two anticipated scan modes for the ABI:

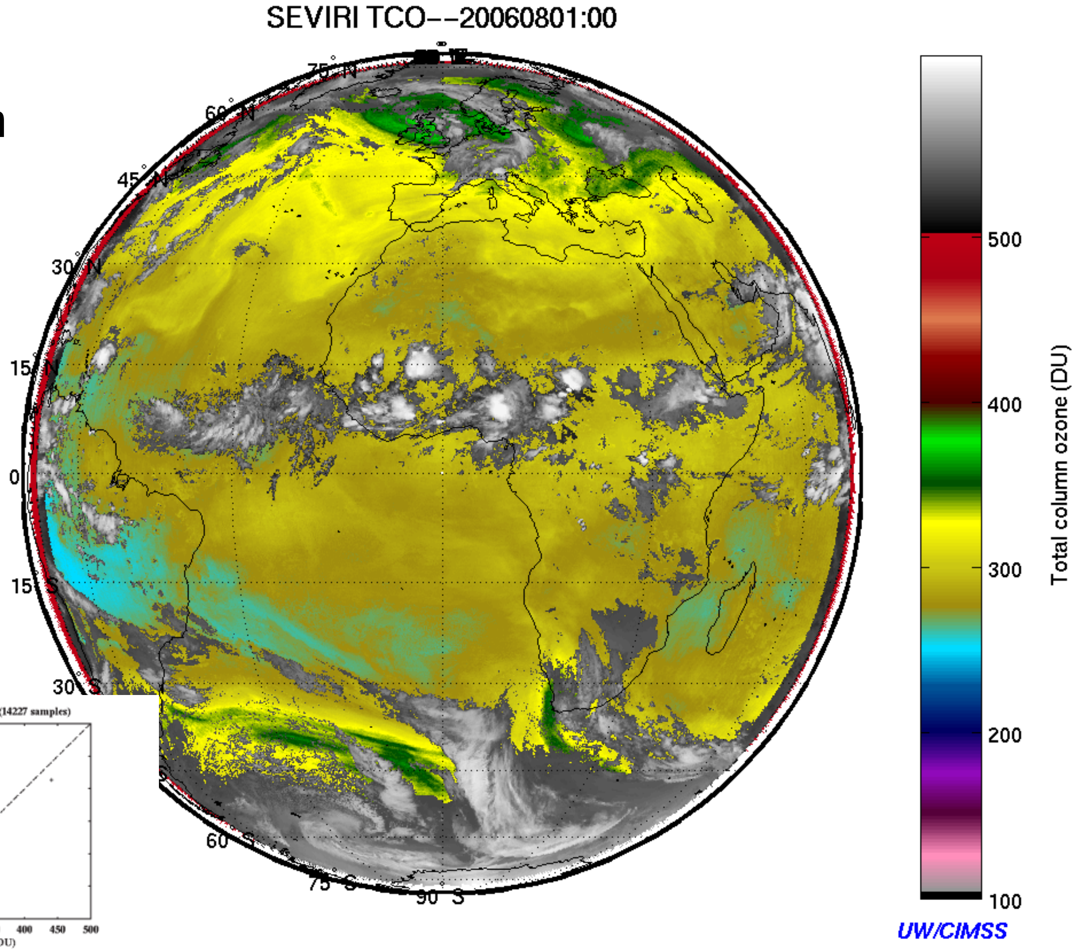
1) full disk images every 15 minutes + CONUS images every 5 minutes + mesoscale.
2) Full disk every 5 minutes.

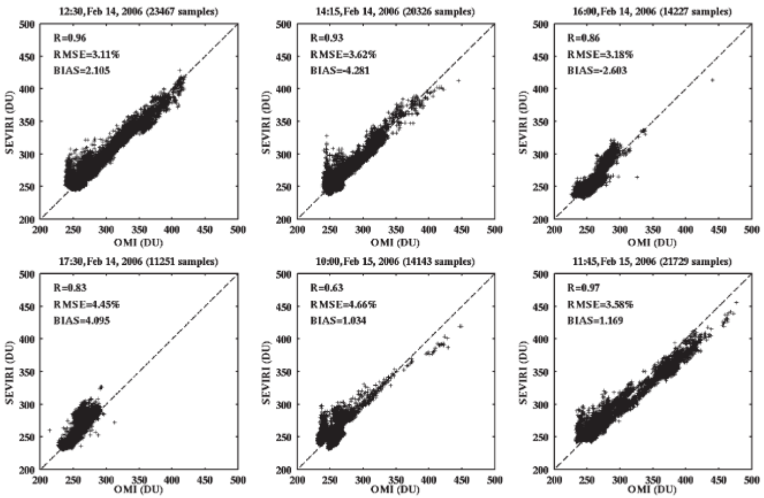
*Slide courtesy of Tim Schmidt*

# What Air Quality Requirements will GOES-R Mission Meet?

- Aerosols over cloud-free atmosphere of vegetated surfaces and water. Quantitative retrievals as well as qualitative imagery. Some promise in UMBC MAIAC algorithm for bright surfaces but needs to be tested
- Fire characterization
- Biomass burning emissions
- Volcanic ash and SO2 (aviation applications)
- Total ozone

SEVIRI Total Column Ozone Retrievals using ABI Algorithm

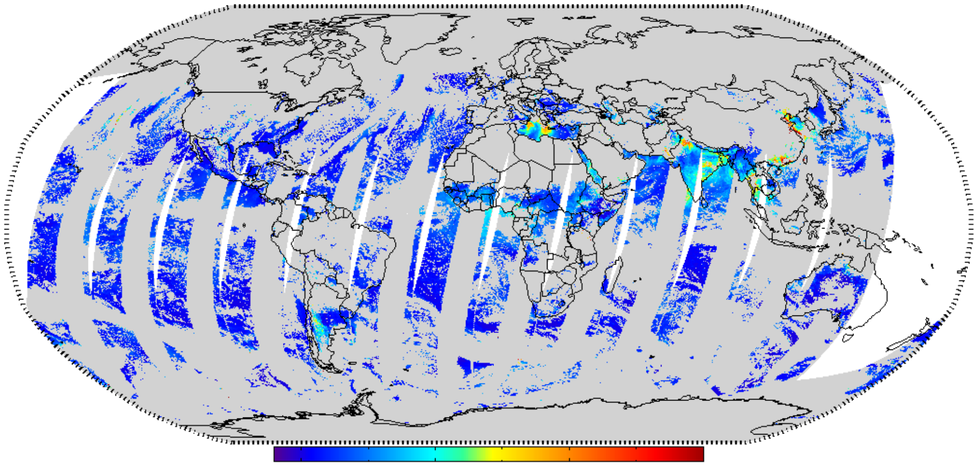


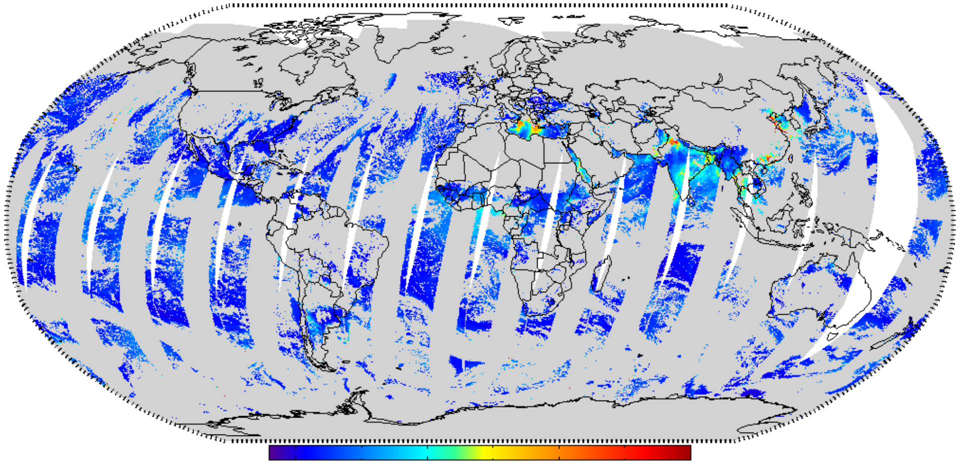

*Jin et al., ITGARS, 2008*

# ABI Aerosol Optical Depth Retrieval

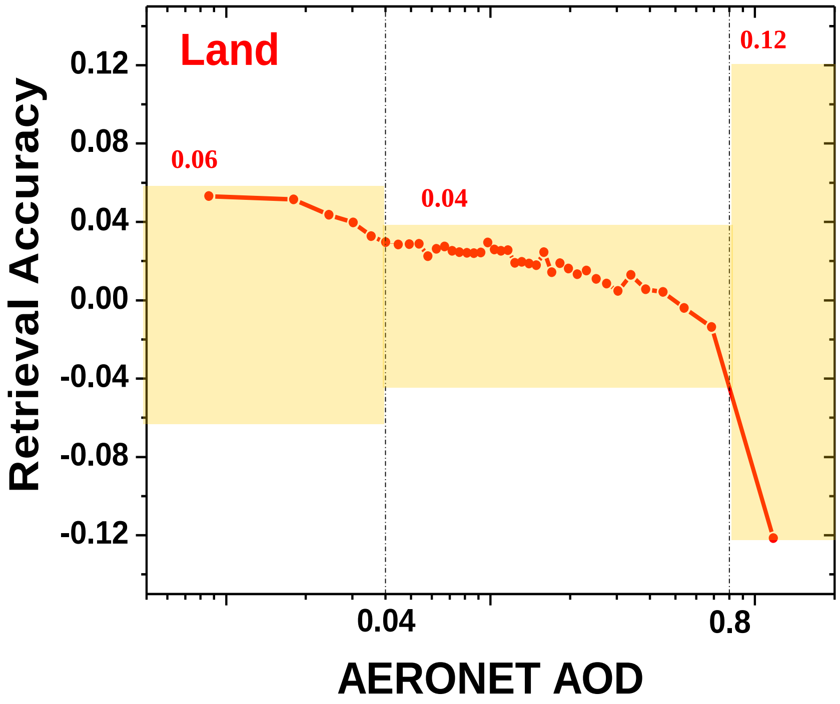
ABI



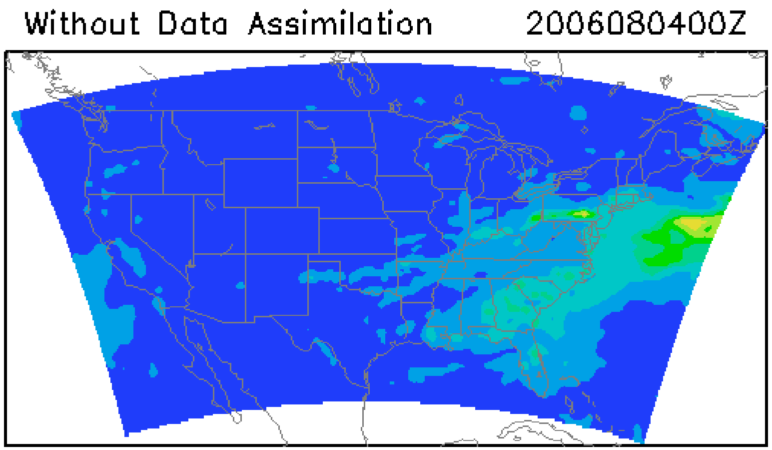
MODIS

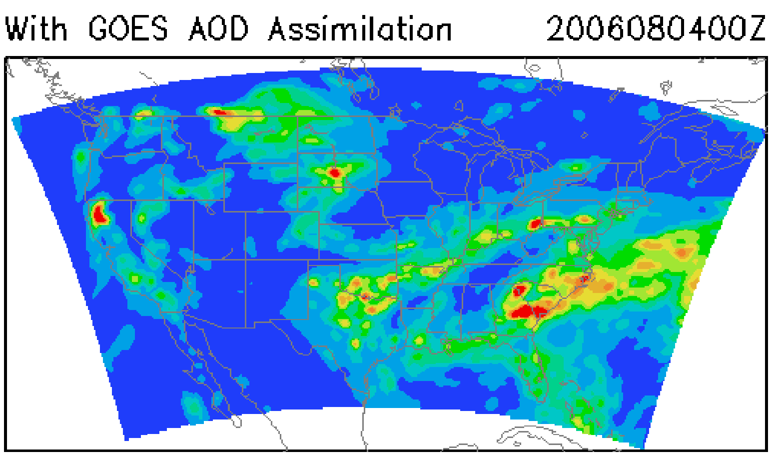


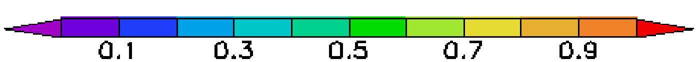
Analysis based on
seven years of retrievals



# Improved Aerosol Predictions with Satellite Data Assimilation



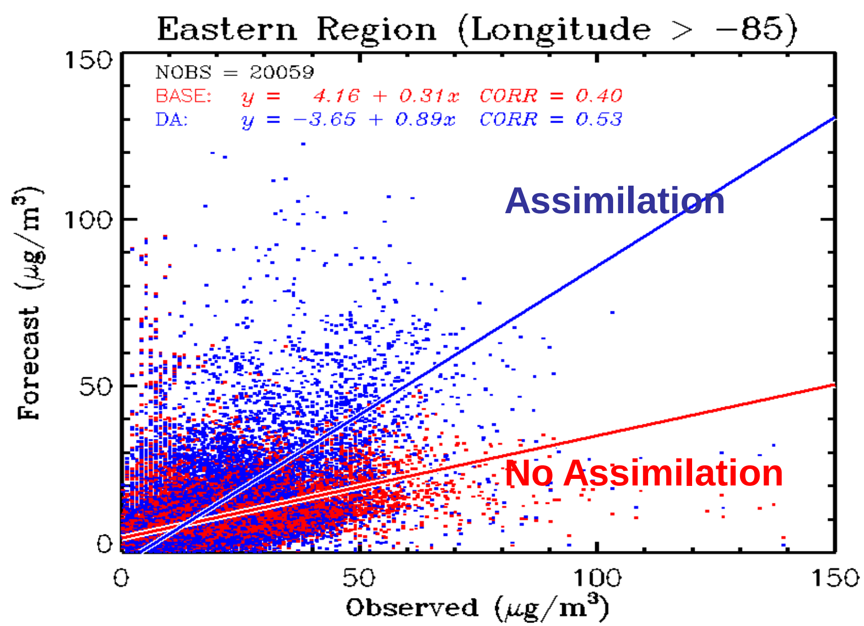




**AOD**

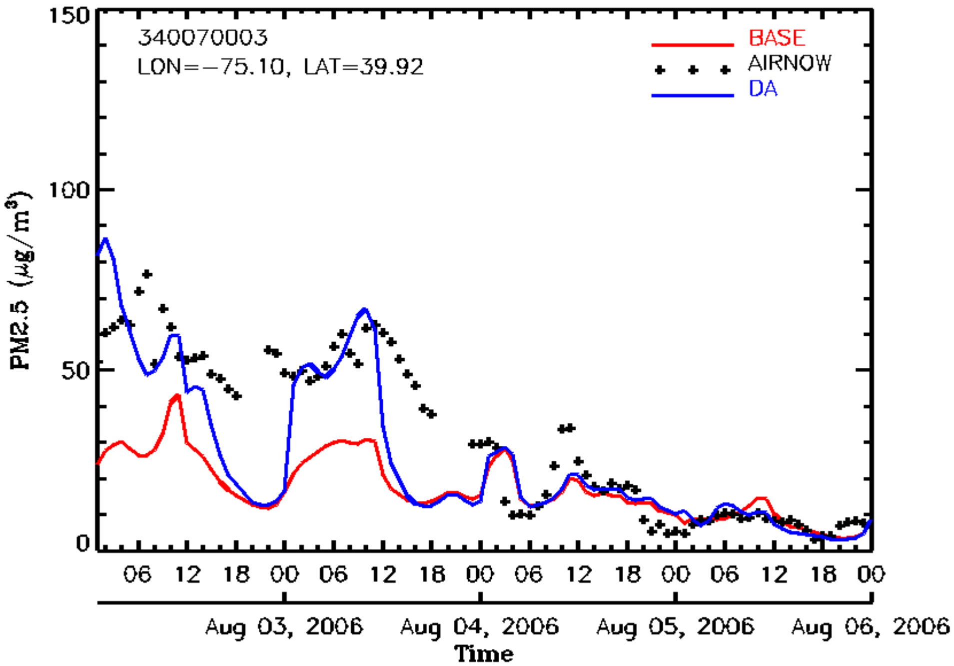
- **Assimilation (Cressman analysis) of GOES Aerosol Optical Depth (AOD) in a NOAA-EPA Weather and Research (WRF)/Community Multiscale Air Quality (CMAQ) model test runs shows improved aerosol predictions for an east coast pollution episode where aerosols were well mixed in the boundary layer**

Observed vs Predicted Surface PM2.5 (µg/m$^3$) Concentrations

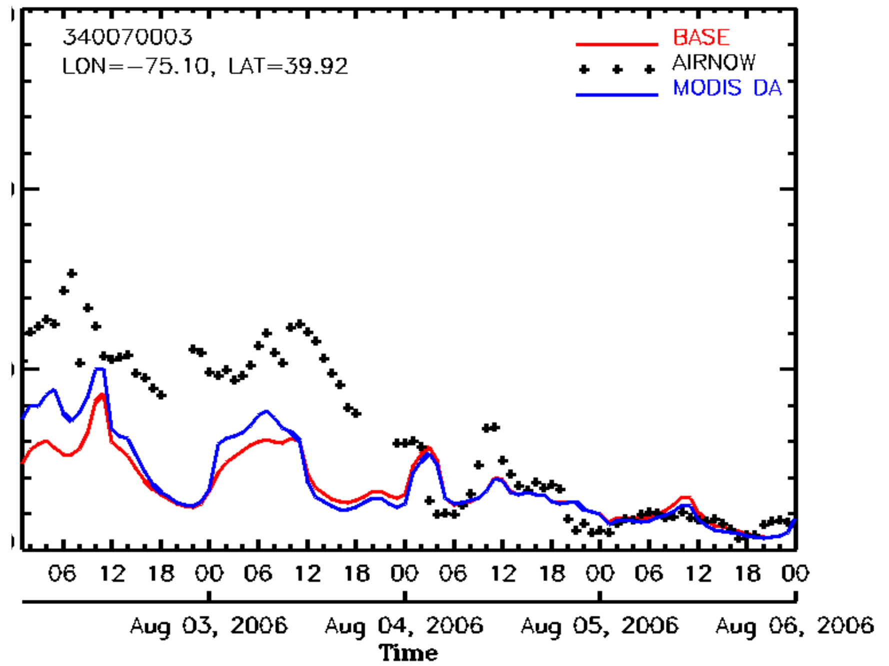


# Time Series of PM2.5 concentrations

GOES AOD Assimilation




MODIS AOD Assimilation




- WRF-CMAQ assimilation test runs are reinitialized every 24 hours with satellite AOD observations. GOES has a 10-hr observational window during which hourly mini-cycling is used.
- Both GOES and MODIS assimilation improve surface PM2.5 predictions. GOES has a bigger impact than MODIS due to hourly cycling.
- Loss of information around 18 UTC in base case as well as assimilation run was determined to be due to boundary layer dynamics

# Areas of Cooperation

- Chemical data assimilation (ARL as a lead) to improve air quality predictions
  - Current products from OMI and GOME-2 in preparation for GEO-CAPE
  - GEO-CAPE proxy data/OSSEs etc.
    - NESDIS/STAR has built two simulators: simulator for aerosol retrievals based on MODIS derived products as truth (provides radiances from visible to near IR using 6S), WRF-CHEM simulator for aerosol retrievals (provides radiances from visible to thermal IR using CRTM)
- Model emissions
  - Improving diurnal variation in the model to improve predictions
- Resources will be an issue to initiate and carry out the R&D work