

Assimilating AURA-derived Trace Gas Retrievals and MODIS AOD into an Operational Multi-pollutant Air Quality Forecast Decision Support System

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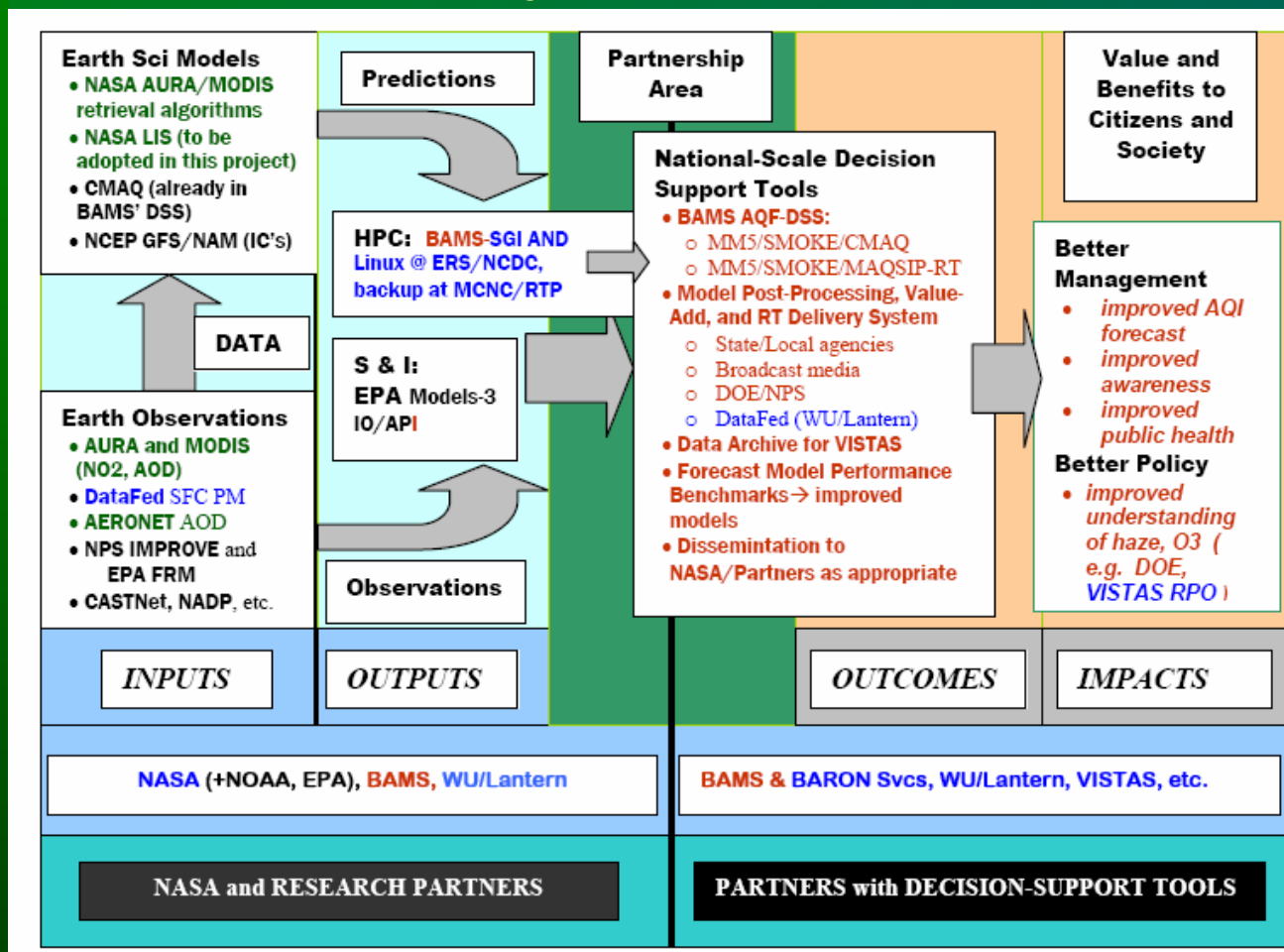
Talk Outline

- Overall Purpose of the Project
- Context of the BAMS Numerical Air Quality Prediction System within Policy/Management Decision Making
- Project Technical Aspects, Plans, and Status
- Summary and Acknowledgments

Overall Purpose

- This project evaluates the potential for AURA/OMI, MODIS, the NASA Land-Information System (LIS), and potentially other NASA-retrieved chemical species observations to:
 - improve operational numerical air quality predictions through design, development, testing and implementation of an advanced operational data-assimilation system using both satellite and ground observations within the operational CMAQ model as deployed at Baron Advanced Meteorological Systems (BAMS)
- for:
 - the benefit of clients that use BAMS' CMAQ guidance in order to inform routine, day-to-day operational air quality forecast decision-making and emissions policy planning; including federal, state, and local agencies, the broadcast industry, RPO's and others

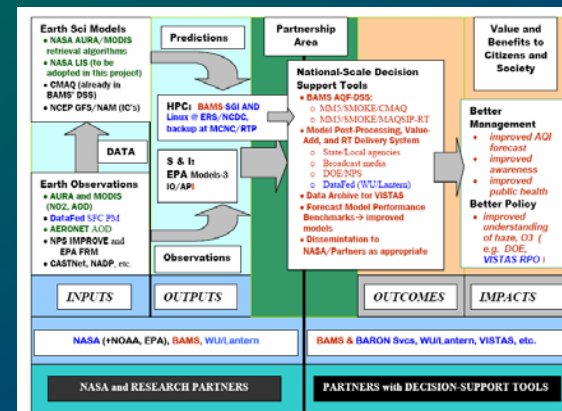
Project Context



Project Context

Application of NASA Earth Science Research Results

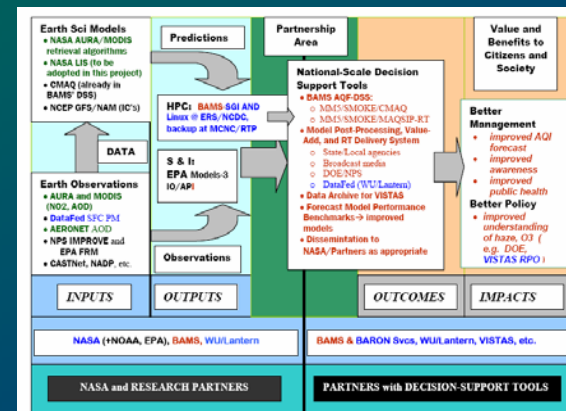
- AURA/OMI Tropospheric NO₂:** The hyperspectral (260 to 500nm) spectrometer OMI (Ozone Measuring Instrument, 2004 to present) on board the EOS-AURA (<http://aura.gsfc.nasa.gov/>) spacecraft is capable of retrieving enhanced versions of traditional TOMS products such as O₃ and aerosols as well as additional trace gas amounts in the troposphere, such as NO₂.
- MODIS AOD Estimates:** The MODIS instrument contains 36 channels, ranging from the visible and mid-infrared to the thermal infrared part of the spectrum. As a result of a newly funded project in the latest EOS re-competition, aerosol information from MODIS over bright surfaces such as desert, semi-desert, and urban regions has been added to the suite of MODIS operational products using the new Deep Blue algorithm (Hsu et al., 2004).
- LIS:** The NASA Land-Information system has been adopted within BAMS as the system of choice for forecasting land-states, including soil-moisture, soil-temperature, surface energy and water fluxes, and runoff. In this project, BAMS will adapt the LIS to provide improved surface relative humidity inputs to CMAQ, reconcile LU/LC classifications, and address subgrid scale effects of numerous kinds, including terrain, LU/LC, and soils. The system will be run in both LDAS and prognostic modes.



Project Context

End Users

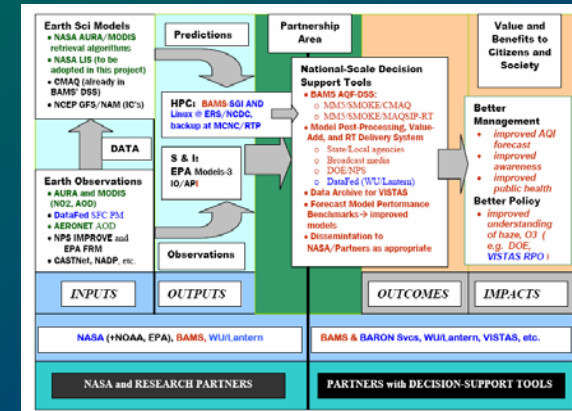
- Federal Agencies including DOE, NASA, various NOAA labs/field-programs, and EPA Regional Offices
- State and local Agencies such as NESCAUM, the Miami-Valley Regional Planning Commission, Pennsylvania DEP, NC DAQ, ADEM, TCEQ etc...
- Regional Planning Organizations for Haze (VISTAS)
- Broadcast Television (over 200 clients nationally)
- GEOSS (we hope)



Project Context

Decision-Making Processes; Management Analyses and Actions

- Issuing of AQ Forecasts, Action Plans, and Health Alerts for Ozone, PM, and regional haze (DOE, EPA, State/Local)
- Assessing the ability of modeling systems to accurately simulate air quality formation and fate through field campaigns (NOAA)
- Improving understanding of regional haze rule making (VISTAS)
- Communicating air quality information and forecasts to the general public (broadcast)
- Broadcast Television (over 200 clients nationally)
- GEOSS (we hope)



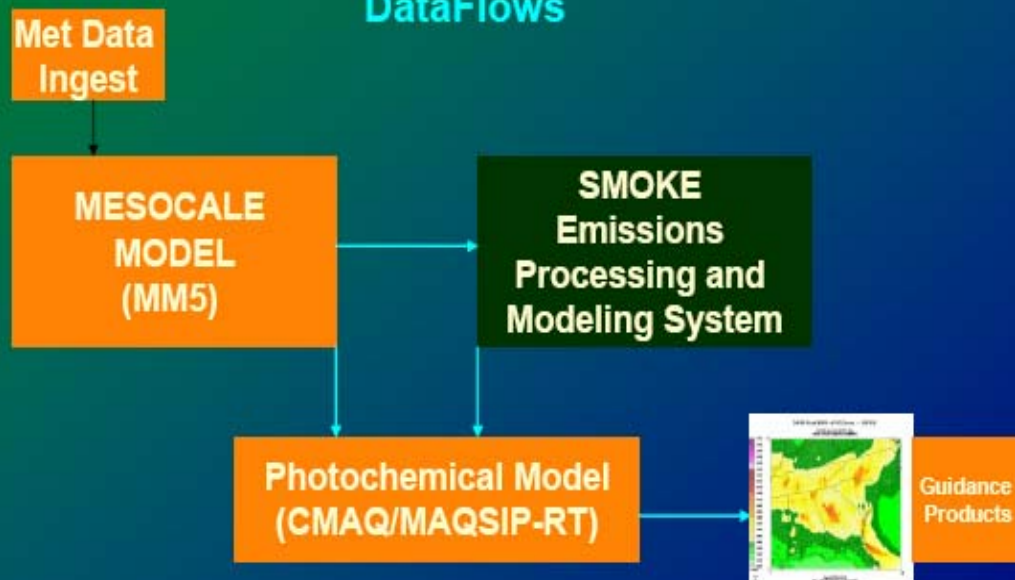
Project Technical Aspects

- **Overview of Systems Configuration**
 - Earth Observations
 - Model Products
 - Data Integration Issues
- **Planned Research and Technical Advances**
- **Validation Activities**
- **Sustaining Operations**
- **Status**
 - Schedule Overview
 - Progress to-date
 - Potential Pitfalls
 - Future Direction and Earth Science Needs

Project Technical Aspects

- **Overview of Systems Configuration**
 - Earth Observations
 - Model Products
 - Data Integration Issues

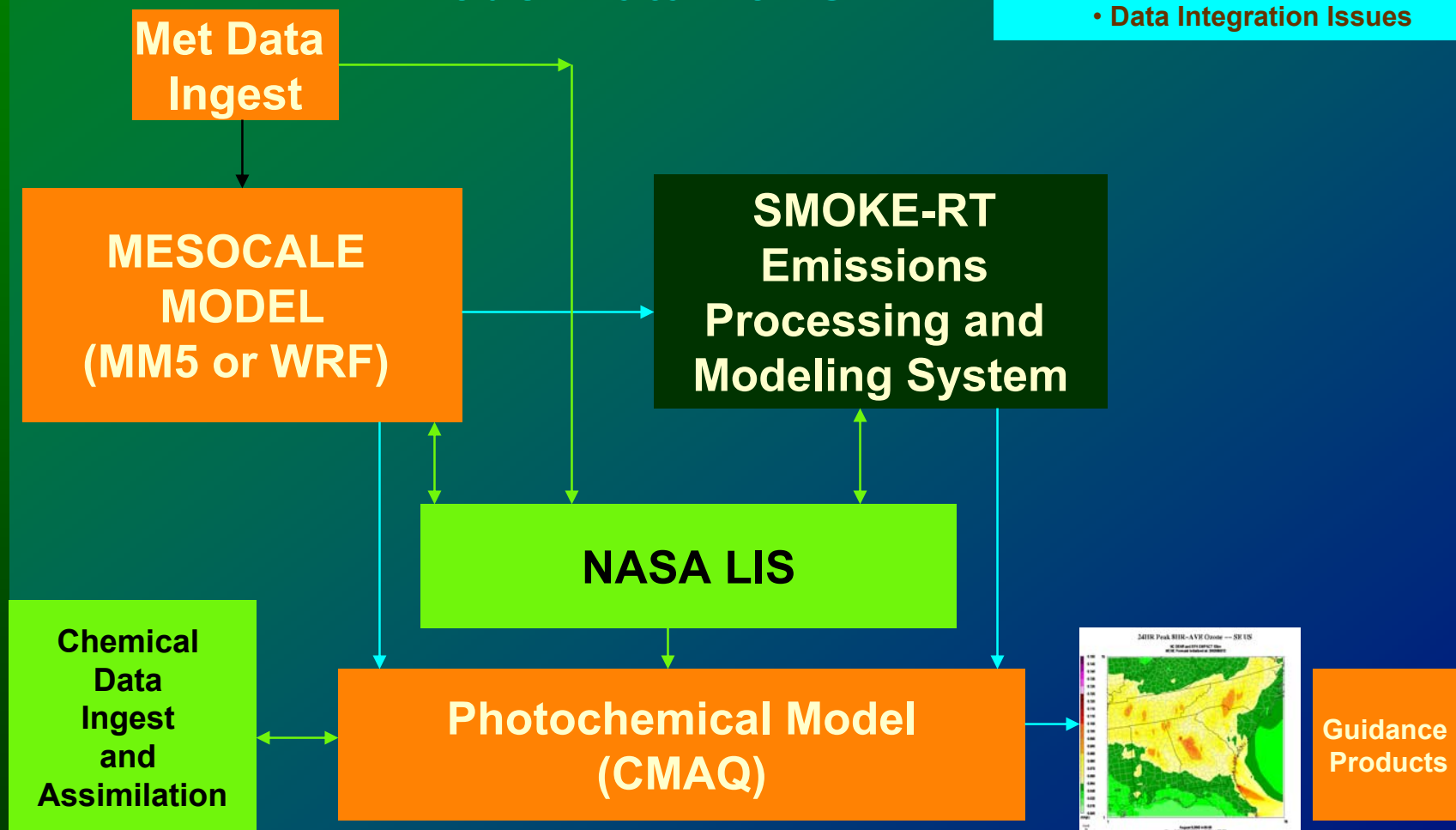
Typical Tripartite Component Model DataFlows



Project Technical Aspects

Modified Component Model DataFlows

- Overview of Systems Configuration
 - Earth Observations
 - Model Products
 - Data Integration Issues

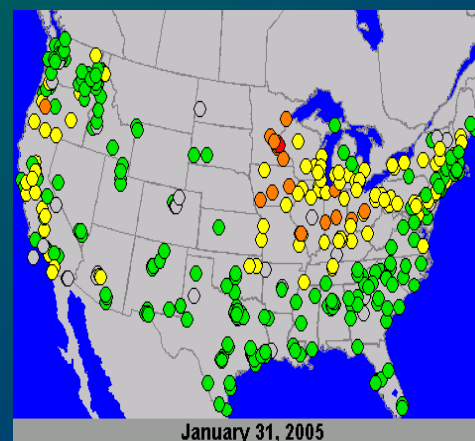
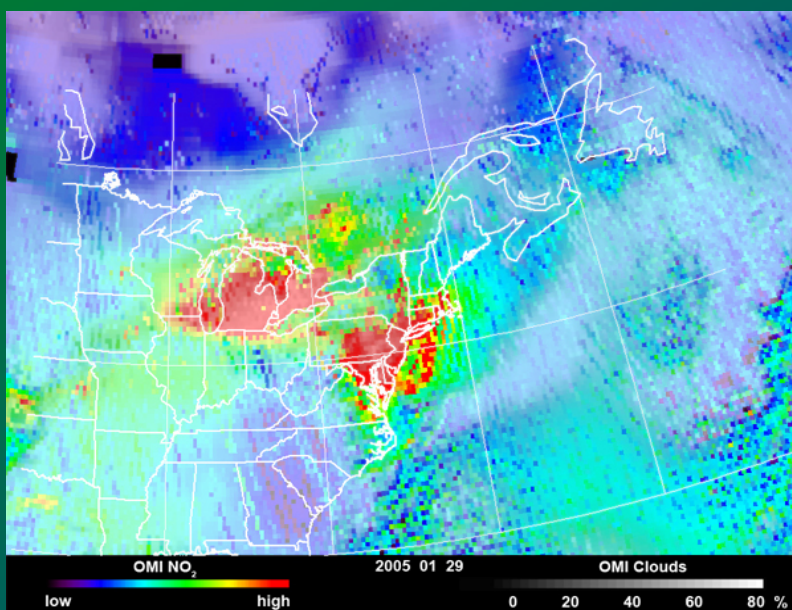


Project Technical Aspects

- **Overview of Systems Configuration**
 - Earth Observations

Chemical
Data
Ingest

- **AURA/OMI NO₂ Retrievals:**



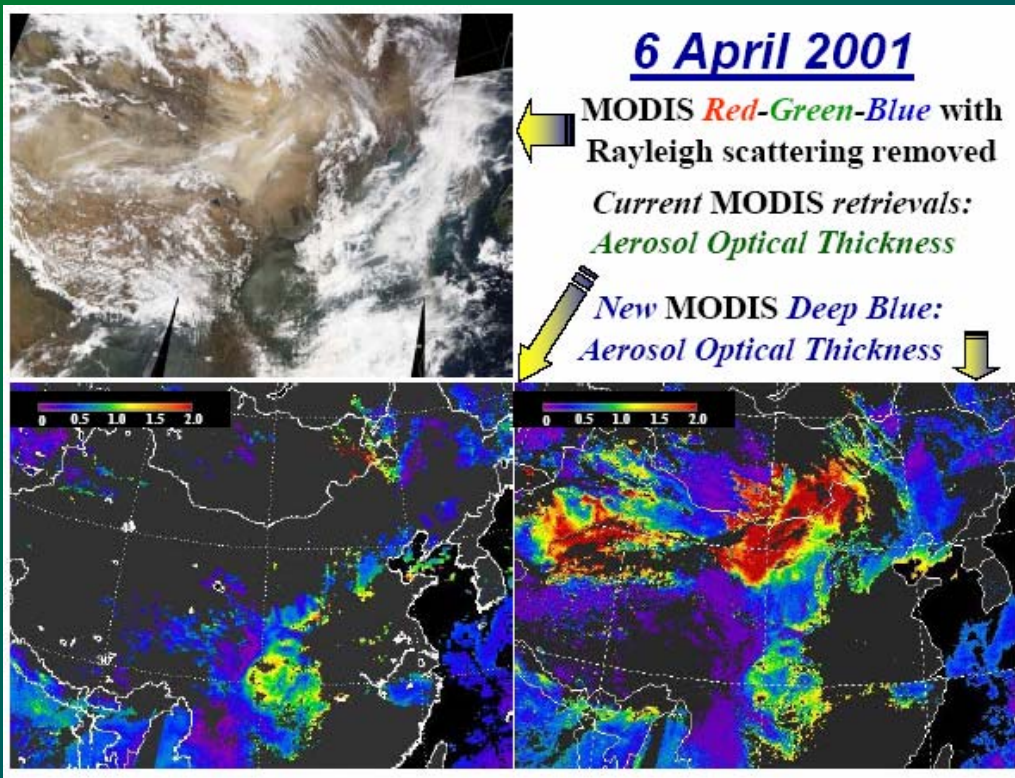
OMI-derived tropospheric NO₂ as seen on January 29, 2005 (left), compared against surface monitor-based PM_{2.5} (right, courtesy EPA AIRNow) data two days later

Project Technical Aspects

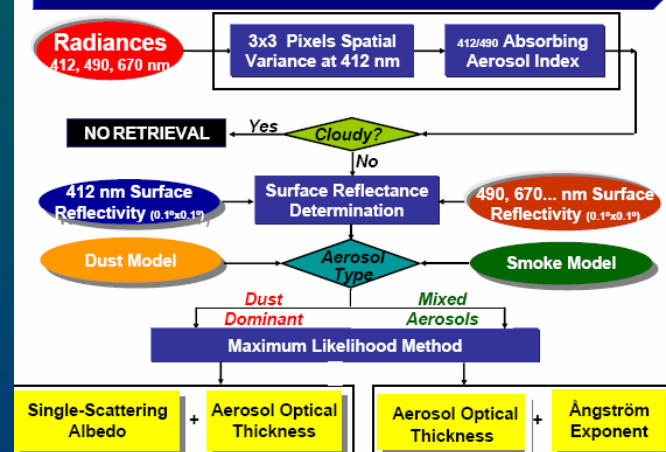
- Overview of Systems Configuration
 - Earth Observations

Chemical
Data
Ingest

• MODIS Aerosol Deep Blue Retrievals:



Flowchart for Deep Blue Algorithm

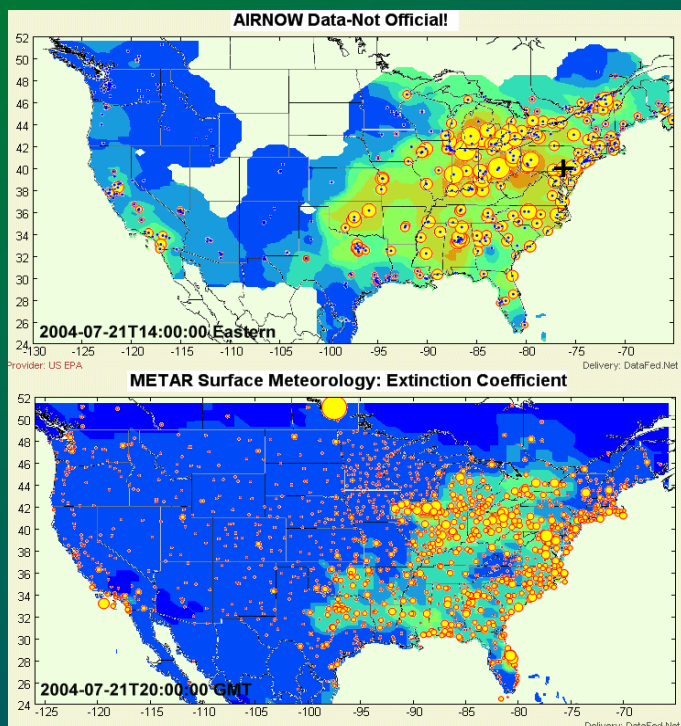


Project Technical Aspects

- **Overview of Systems Configuration**
 - Earth Observations

Chemical
Data
Ingest

•Surface aerosol observations:



Fusion of available PM 2.5 data (top figure) and ASOS-based light extinction data, produces maps (bottom example) of the surface extinction coefficient, aerosol-scale height, and indirectly the PM2.5 concentration over the entire domain

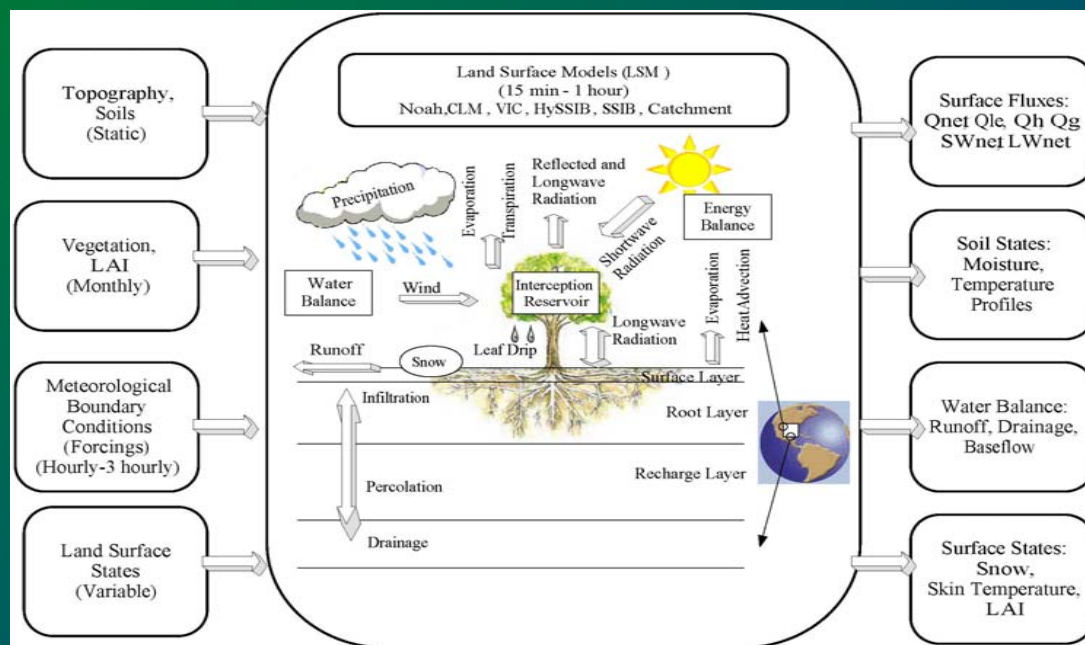
Project Technical Aspects

• Overview of Systems Configuration

• Model Products

NASA LIS

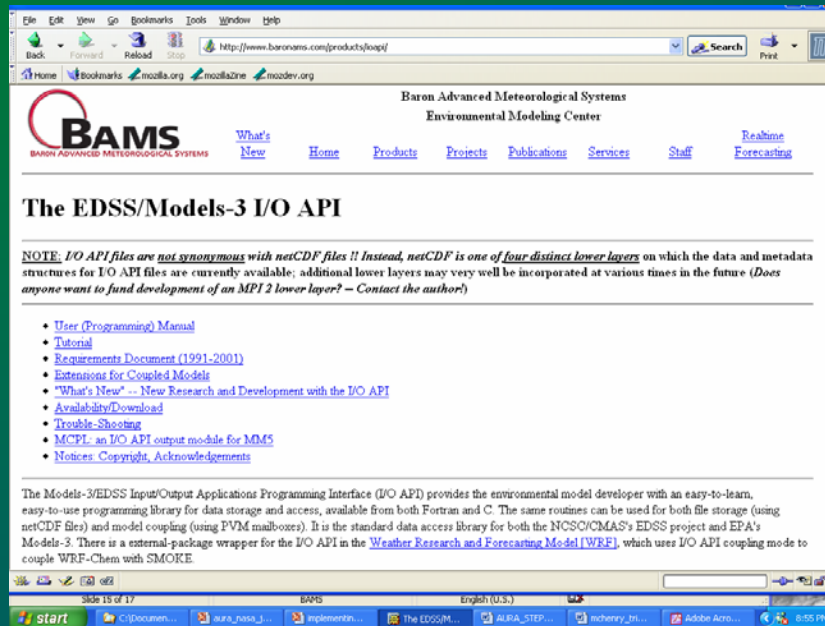
- Improved surface relative humidity
- Harmonization of LU/LC w/ biogenic emissions sub-model



- Other NASA model products, such as global chemistry model boundary conditions, may also be employed

Project Technical Aspects

- Overview of Systems Configuration
 - Data-Integration Issues



- The EPA Environmental Decision Support System (EDSS) Models-3 I/O API (M3IO) will be used as the “common data hub” to resolve mismatches in data types, structures, and metadata
- M3IO is a publically available, well-tested, legacy, applications programming interface in use at hundreds of institutions around the world.
- Development and maintenance continues at BAMS (Carlie Coats)

Project Technical Aspects

• Planned Research and Technical Advances

- The Modified Component Model DataFlows shown above constitute the major research activities and comprise the planned technical advances:
 - An operational *chemical* data-assimilation module (with perhaps several sub-modules) will be designed, developed, tested, validated, and placed into operations at BAMS
 - Design of the DA module will account for typical errors in the measurements as well as the models in order to “optimize the interpolation,” starting with a background component aerosol and NO₂ state fields from the previous CMAQ forecast cycle
 - The final DA module algorithms are in the planning stage and will be the key technical “inventions” of the project
 - OI, 3D-VAR, Bayesian approaches are all possible
 - Combination of data-sources (surface, satellite) is critical

$$T_m' = T_m + K(T_o - H T_m)$$

Project Technical Aspects

• Validation Activities

An array of “with” and “without” tests will be performed offline using the baseline system as the control. The improved system will be tested on a set of representative episodes including

- (1) winter-time haze;
- (2) summertime haze; and
- (3) summertime ozone.

Within these categories, further differentiation will be made between

- (1) smoke and/or dust driven events,
- (2) sulfate driven events;
- (3) nitrate driven events; and
- (4) events that involve long-range transport from outside the domain.

This array of typical events will be run with and without NO₂ and AOD assimilation.

An independent set of tests will be done with the LIS to determine the improvement in surface relative humidity forecasts. Objective measures of forecast performance will be used to quantify the results.

The project expects between a 10% and 25% improvement in objective forecast skill as measured by a variety of both threshold and discrete forecast metrics for at least some forecast situations that are not currently well handled (dust, smoke, black carbon)

Project Technical Aspects

• **Plan for Sustaining Operations**

- Planned series of project demonstrations
- Cross-fertilization with other NASA sponsored AQ Applications (e.g. 3D AQS; Blue-Sky RAINS); and other Federal Agencies as possible
- Modifications to current business model
- Maintaining and Enhancing Current Clientele
- Collaboration with DataFed
- GEOSS
- International Opportunities

Project Technical Aspects

- **Status**
 - Schedule Overview

- Year 1: Design Specification, System Configuration, and Rapid Prototyping of Improved DSS
- Year 2: Verification, Demonstration, and Validation of Enhanced DSS
- Year 3: Final Validation, Benchmarking, and Integration into Sustained Operations

Project Technical Aspects

- **Status**
 - Progress to-date

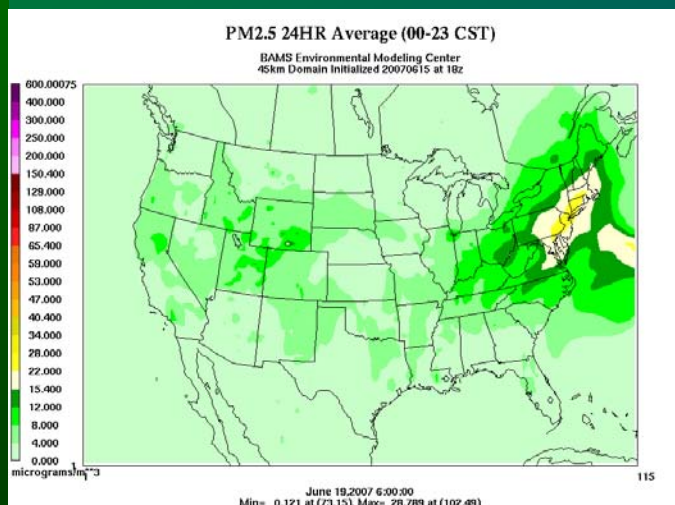
- Year 1: Project is in the early phases;
was funded on January 1, 2007
- Kickoff meeting was held at PI institution
- PI attended NASA-based ESIP Federation Meeting
- BAMS has acquired and installed ingest and development computer
- NASA/GSFC is preparing to begin supplying MODIS data
- NASA/GSFC is researching real-time availability of AURA NO₂ data (may be delayed)
- CAPITA/Lantern sub-contract in place; they are now beginning work
- Investigator meetings are being held in parallel
with the current meeting this week

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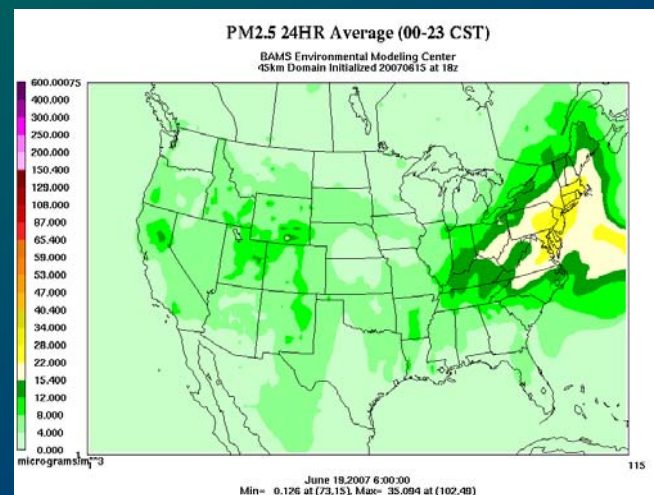
Project Technical Aspects

- **Status**
 - Progress to-date

- VISTAS RPO has supplied CMAQ annual run data and observations for case study selection and implementation from "final" 2002 base run
- BAMS has implemented VISTAS-developed update to CMAQ to improve secondary organics forecasts which were previously severely underforecast



Old (left)



New (right)

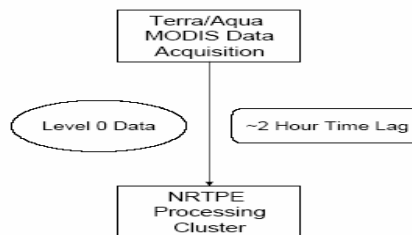
Three-day forecast for June 19

Project Technical Aspects

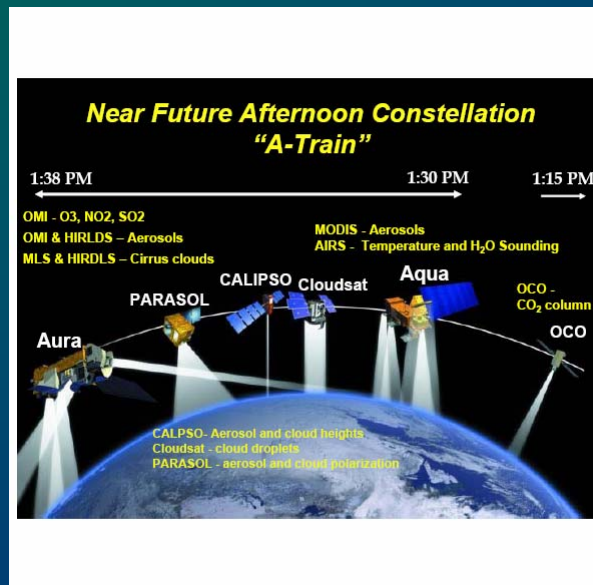
- **Status**
 - **Potential Pitfalls**

- **Polar orbit of MODIS (Terra; Aqua) presents challenges over the US**

Data Acquisition and Transfer for NRT Processing



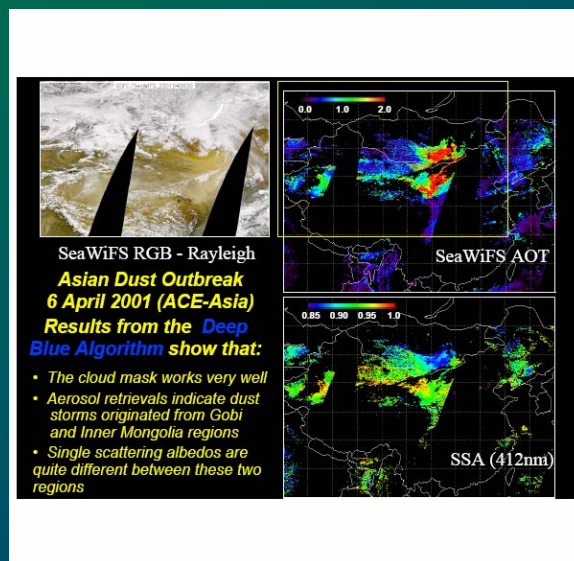
- Terra Crosses Equator at ~10:40 Local Standard Time, North to South
- Last Terra US Granule at ~2100 GMT
- Last US Terra Granule to NRTPE at ~2300 GMT
- Aqua Crosses Equator at ~13:40 Local Standard Time, South to North
- Last Aqua US Granule at ~2300 GMT
- Last US Aqua Granule to NRTPE at ~0100 GMT the Next Day



Project Technical Aspects

- **Status**
 - Potential Pitfalls

- A satellite/surface DA module attempting to account for complexity of aerosol “states” and NO₂ has not been tried in routine real-time operations
 - NO₂ assimilation may be very tricky given “stiffness” of reaction
 - Cloudy skies may present problems



Project Technical Aspects

- **Status**

- **Future Direction and Earth Science Needs**

Remembering that the goal is to produce reliable operational air quality forecasts at scales that are high-resolution enough to provide high quality forecasts to *local* citizenry, and to guide current and future public policy in light of health costs to citizens:

Any improvements in three-to-five dimensional observations of chemical species will help!!

- Can you imagine that Charney, et al. could have developed NWP *without* routine surface and upper air met observations?

Acknowledgements

- **Rudy Husar** (Center for Air Pollution Impacts and Trends Analysis, Wash U., St. Louis)
- **Christina Hsu, Jay Herman** (NASA Goddard)
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- **Mike Abraczinskas** (VISTAS RPO)
- **Carlie Coats; Jeff Vukovich; Jesse O'Neal** (BAMS)

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