Current and Future Air Quality Applications of NOAA Operational Satellite Data

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NOAA/NESDIS Center for Satellite Applications and Research

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Background

- Congress mandates…
  - **NOAA must develop and deploy air quality forecast model at NCEP which produces 24 hour ozone and particulate matter forecasts nationwide**

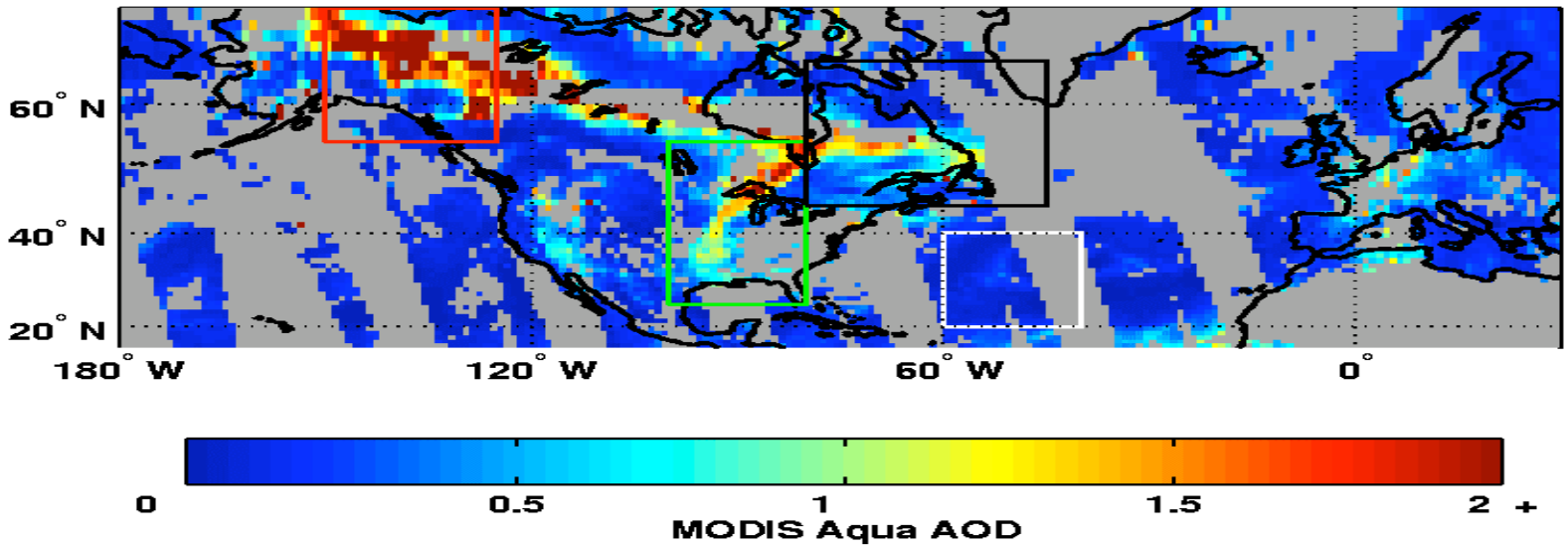
- NOAA acts…
  - **Memorandum of understanding signed between EPA and NOAA to develop and implement an accurate air quality forecast program which includes joint research initiatives**

- NESDIS Role to Meet this Goal
  - Utilize satellite observations of aerosols, ozone and other trace gases to monitor air quality and improve air quality forecast by assimilation of satellite derived air quality products

UMBC

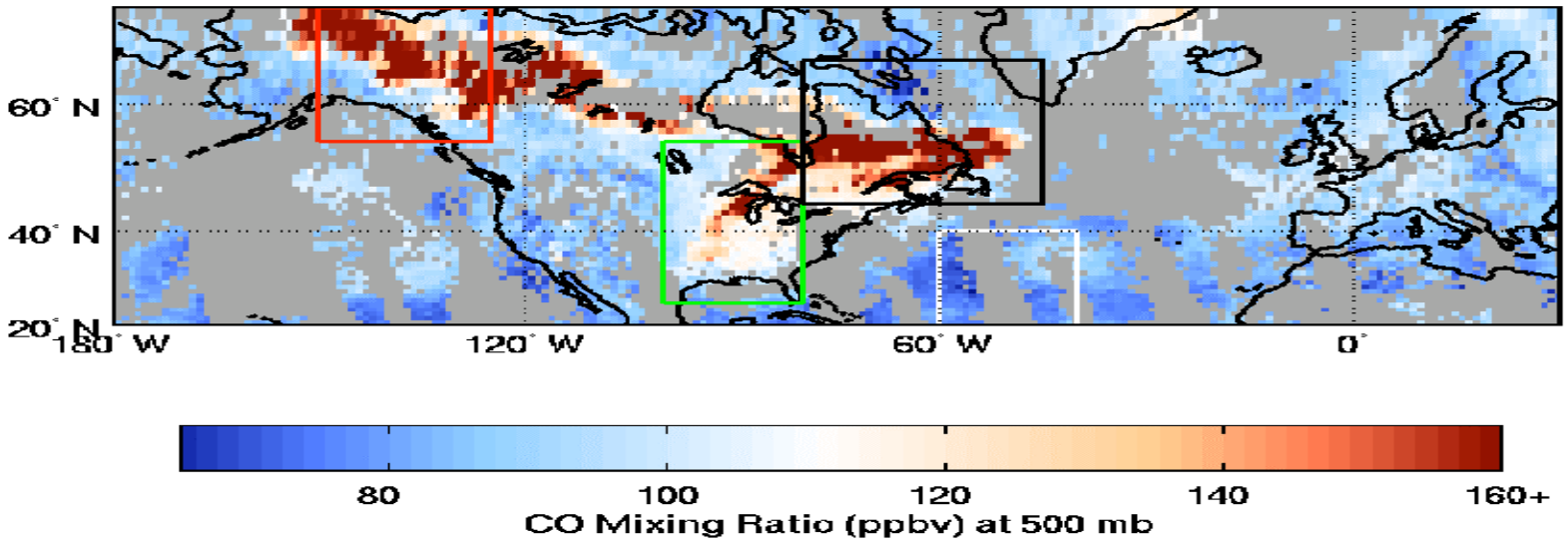
JCET

Local PM MODIS Aqua AOD on 20040718

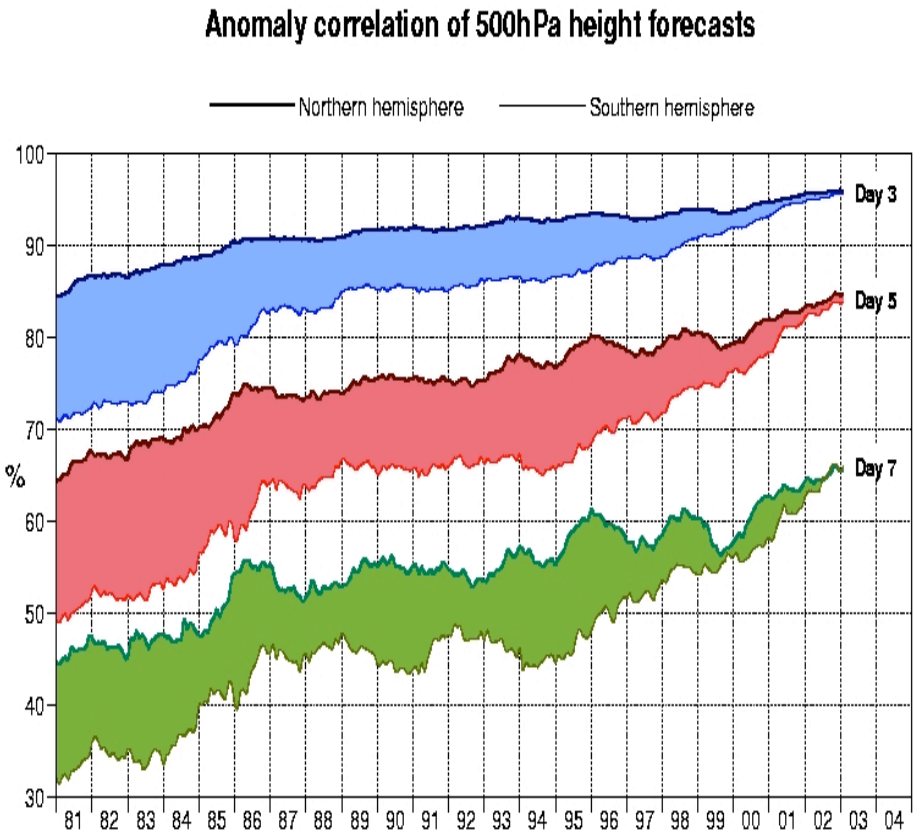


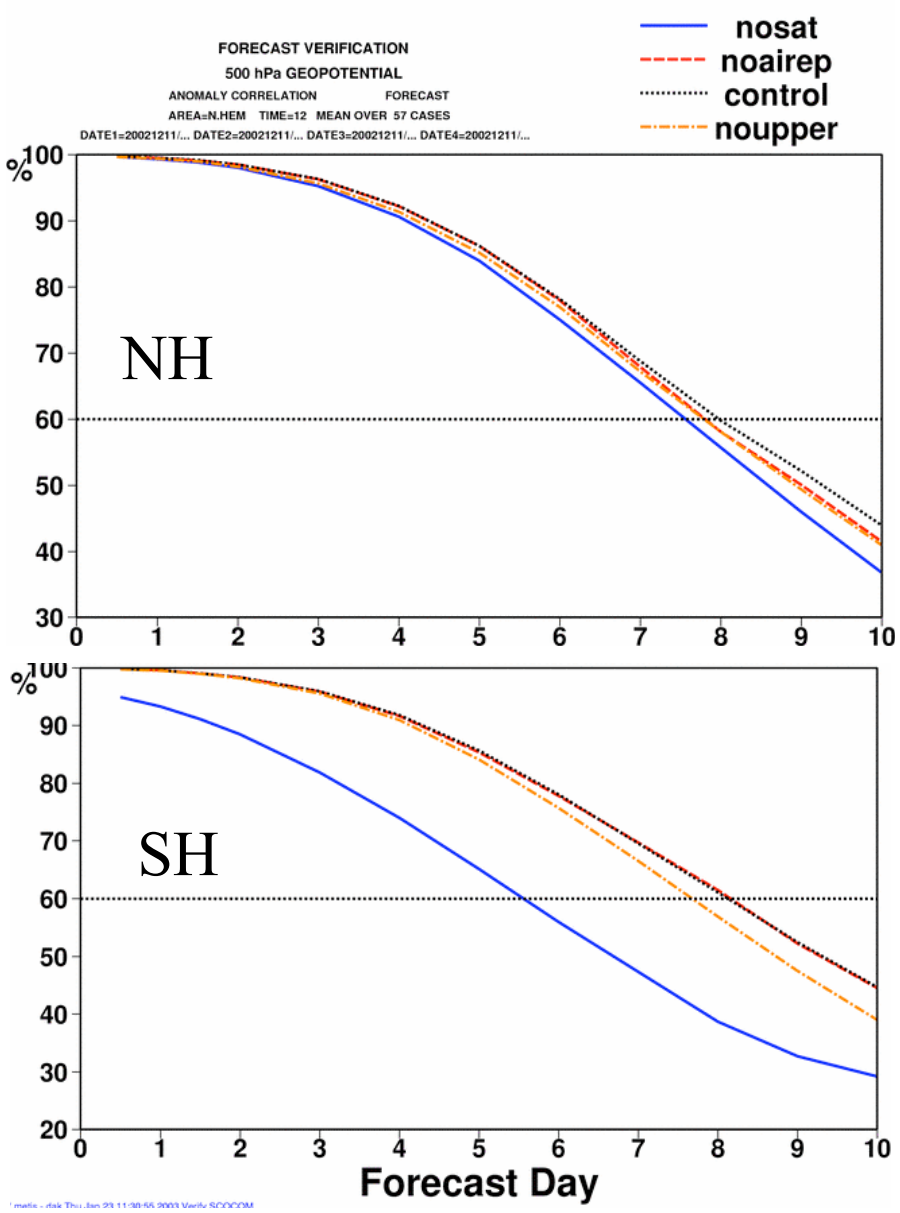
From Wallace McMillan, UMBC

Local PM AIRS CO at 500 mb on 20040718



Evolution of NWP skill in northern & southern hemispheres





Outline

- User Requirements
- Current applications and products
- Future applications and products

NOAA User Community and Requirements for Near Real Time Satellite Products

- EPA, Air quality managers (federal, regional, and local), fire managers, NWS and its field offices, FAA, USFS, academia, industry
  - True color imagery of dust/smoke/industrial aerosols
  - Imagery of volcanic ash/SO2, visibility
  - Quantitative retrievals of O3, SO2, CO, NO2, H2CO, PM2.5, optical depth, aerosol type and composition at hourly temporal resolution and a spatial resolution comparable to air quality forecast models
  - Emissions (particulates and trace gases)
  - Water vapor, temperature, winds, solar radiation
  - Surface characteristics: temperature, moisture, radiative flux, land-use cover, deposition flux, clouds (base and top heights, type and optical depth)

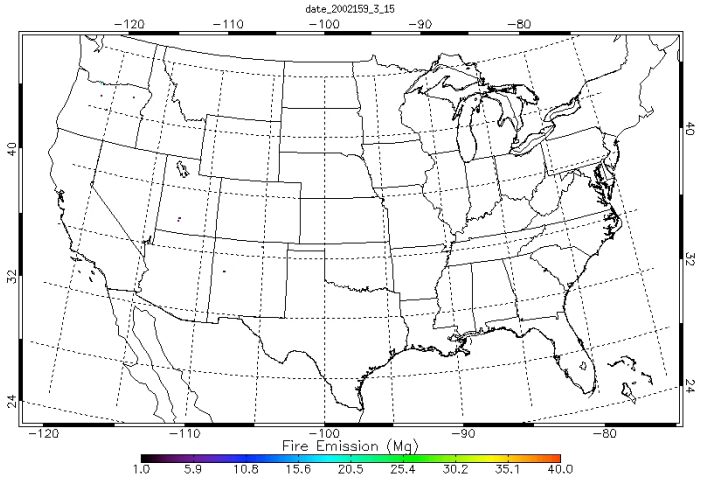
NOAA User Community and Requirements for Near Real Time Satellite Products (Cont.)

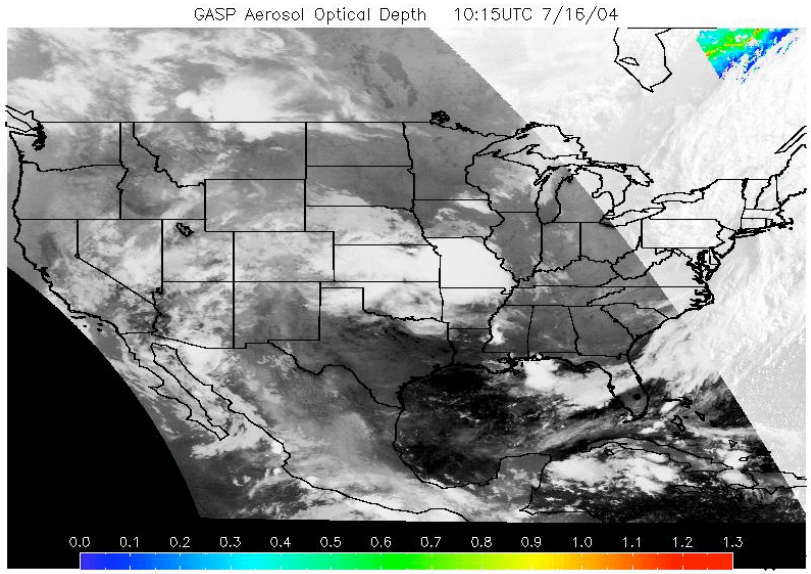
- Build product prototypes to excite the user community at all levels
- Involve users from the algorithm development phase
- User input for sensor requirements
- Data fusion
  - EPA leading the development of a 3D Air Quality Mapping System

Current and Future Products

- Aerosol Optical Depth (AOD) - GOES
- Emissions (Biomass burning) - GOES
- Trace gas (NO_2, SO_2, O_3, H_2CO) from MeTOP GOME-2
- Trace gas (CO, CH_4, O_3) from AIRS, MeTOP IASI and NPOESS CrIS
- Enhanced aerosol products (AOD, particle size, particle type, aerosol height) from GOES-R ABI/HES and VIIRS
- Trace gas (O_3, CO, CH_4) retrievals from GOES-R ABI and HES
- Emissions from GOES-R ABI during biomass burning events

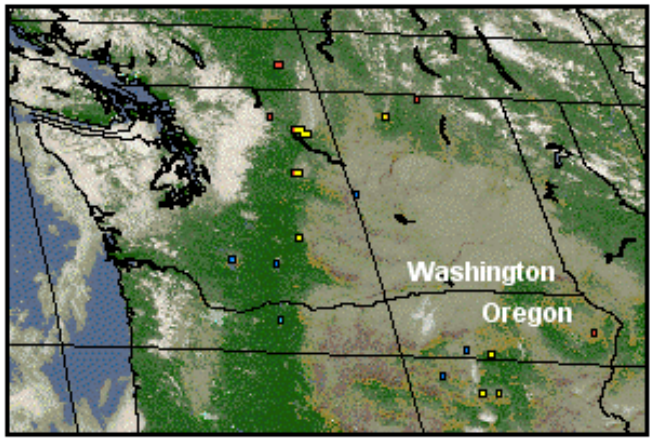
Air Quality Monitoring



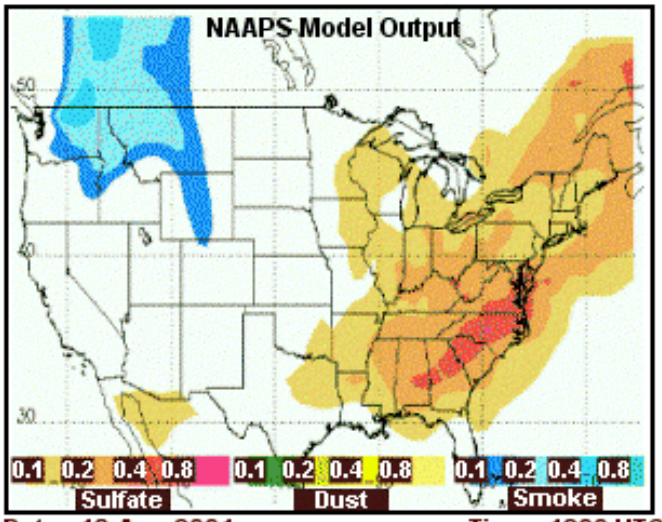


UMBC air quality web page (http://alg.umbc.edu/usaq) which uses these NOAA products and NASA products available through NOAA in near real time to document day to day air quality issues received million hits in the last 17 months

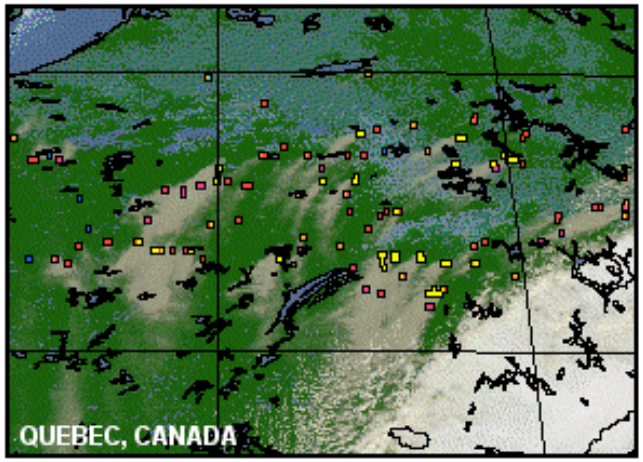
Real-time Assimilation of the Wildfire ABBA Fire Products into the NAAPS Model



Wildfire ABBA Fire Product
Date: 17-Aug-2001
Time: 2200 UTC

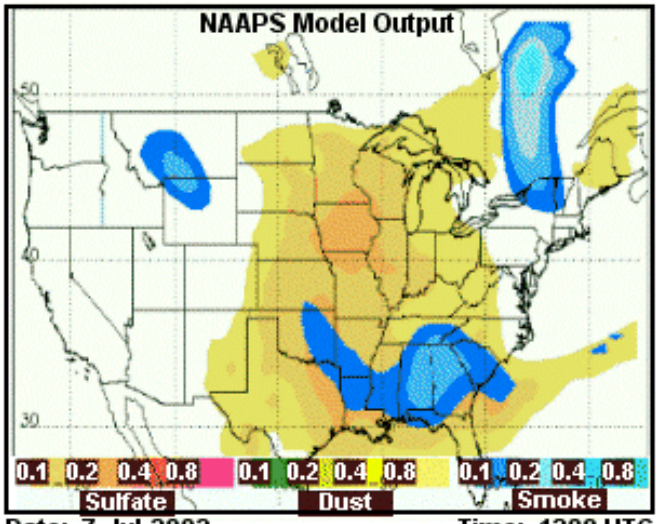


Date: 18-Aug-2001 Time: 1200 UTC



Wildfire ABBA Fire Product
Date: 6-Jul-2002
Time: 17:45 UTC

NOAA/NESDIS/ORA ASPT UW-Madison CIMSS



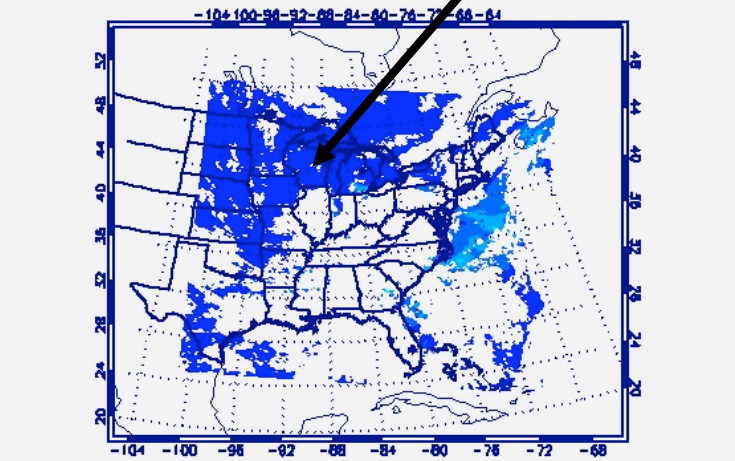
Date: 7-Jul-2002 Time: 1200 UTC

Navy Aerosol Analysis and Prediction System (NAAPS)
Courtesy of Doug Westphal, NRL, Monterey, CA

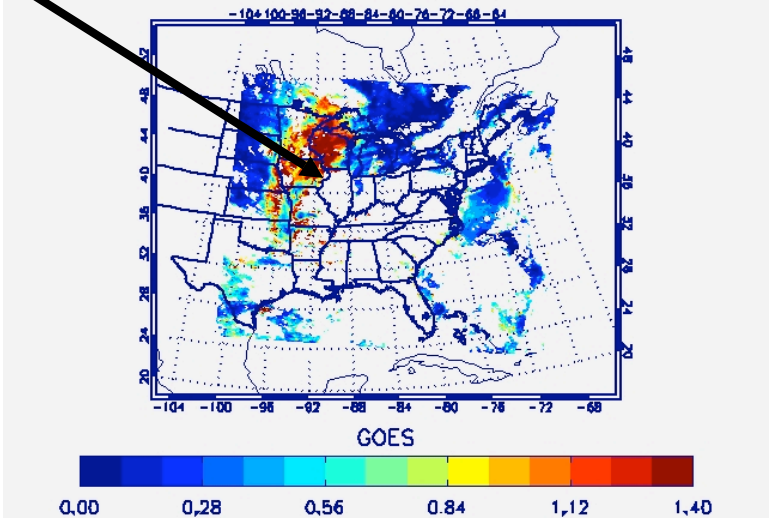
Air Quality Forecast Verification: Evaluation of NWS CMAQ AOD Forecasts using GOES Data

High aerosol loading due to long range transport of smoke from Canadian/Alaskan fires missing in CMAQ forecasts due to static boundary conditions

CMAQ Forecasts July 17, 2004 17Z



GOES Observations July 17, 2004 17Z



See Kondragunta et al. poster for more details

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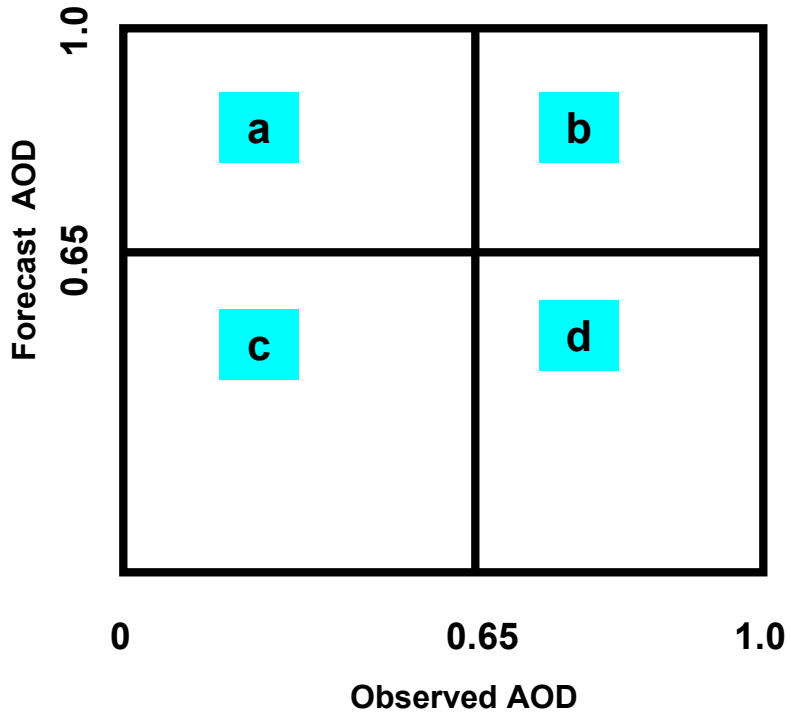
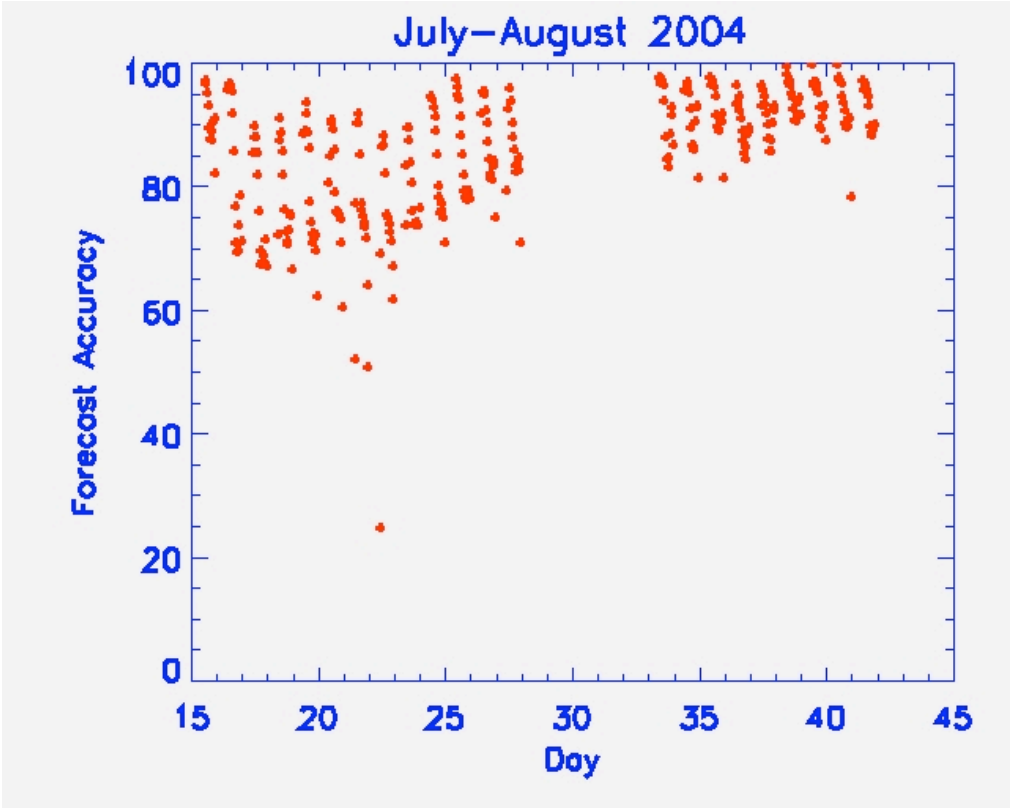
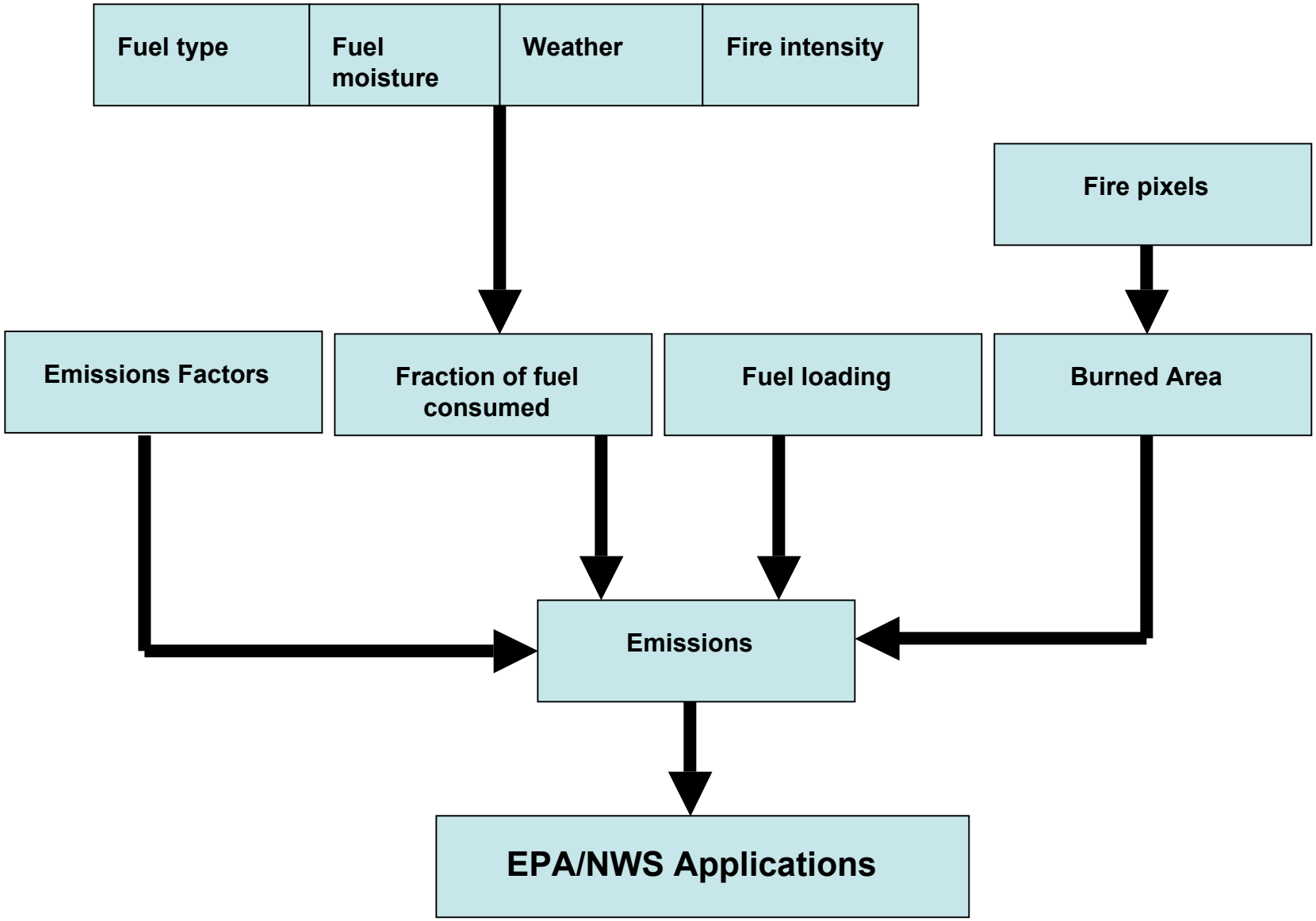




Accuracy (%) = (b+c)/(a+b+c+d) * 100

Kondragunta et al., JAM, in review

Deriving near real time biomass burning emissions from satellite fire products



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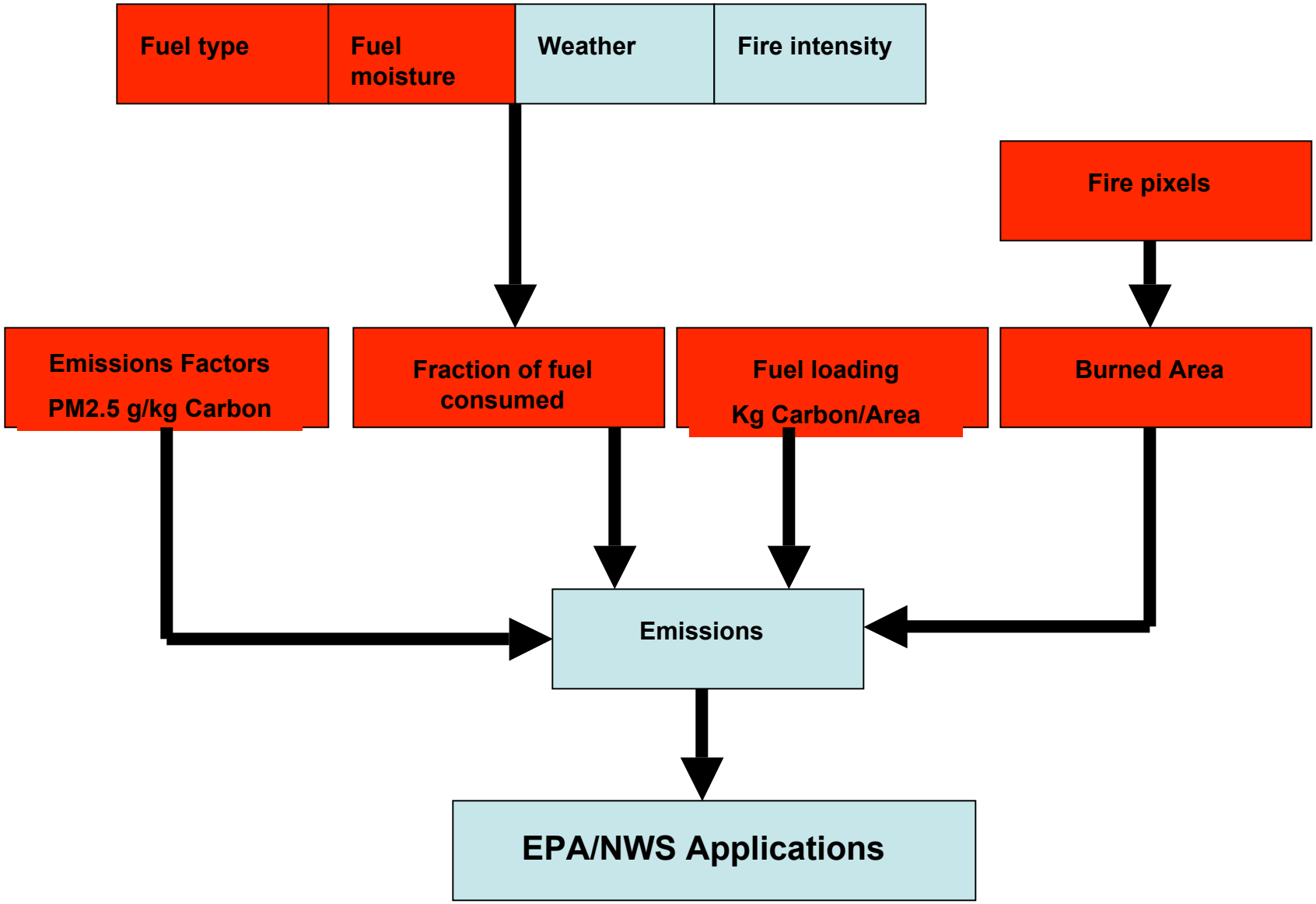


Fuel Load Database Derived from MODIS Data

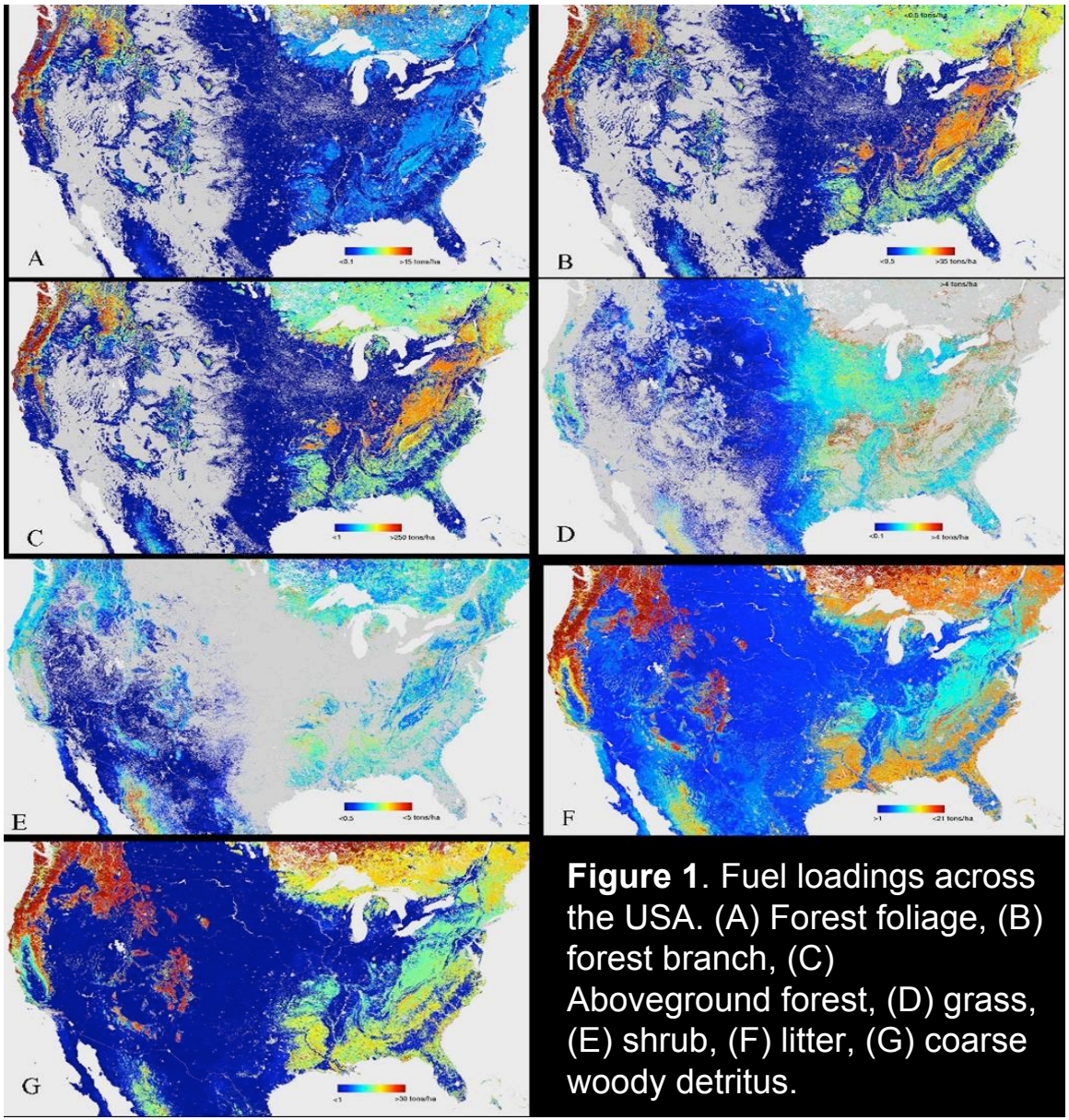


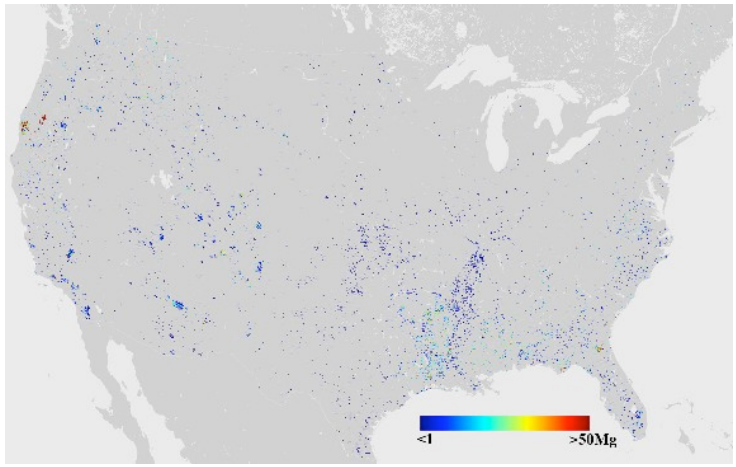
Figure 1. Fuel loadings across the USA. (A) Forest foliage, (B) forest branch, (C) Aboveground forest, (D) grass, (E) shrub, (F) litter, (G) coarse woody detritus.

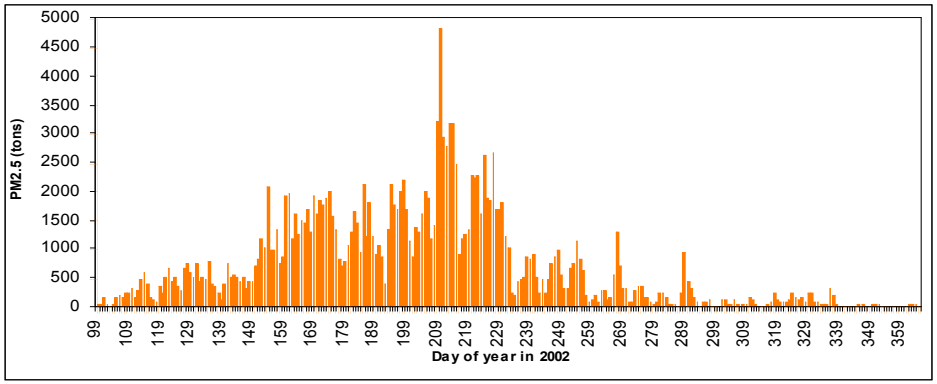
TONS/Hectare

For algorithm details see the poster by Kondragunta and Zhang

2002 PM2.5 Emissions

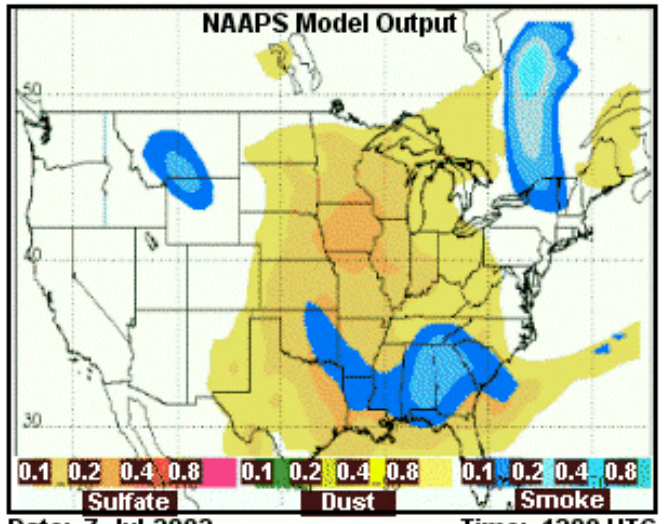
- Inputs
  - Newly developed NESDIS fuel load database
  - WF_ABBA fire location and size
  - Newly developed AVHRR VHI based fuel moisture category
  - Emission factors
- Evaluation of emissions product underway
- NOAA/OAR and EPA to test the impact of assimilation of satellite-derived PM2.5 emissions on predictions
- If NOAA/OAR and EPA work demonstrates the value of satellite-derived PM2.5 emissions, NWS might incorporate this into operational PM2.5 forecasting
- Future work will involve expanding the algorithm coverage to the globe and making the code ready for “operational processing”





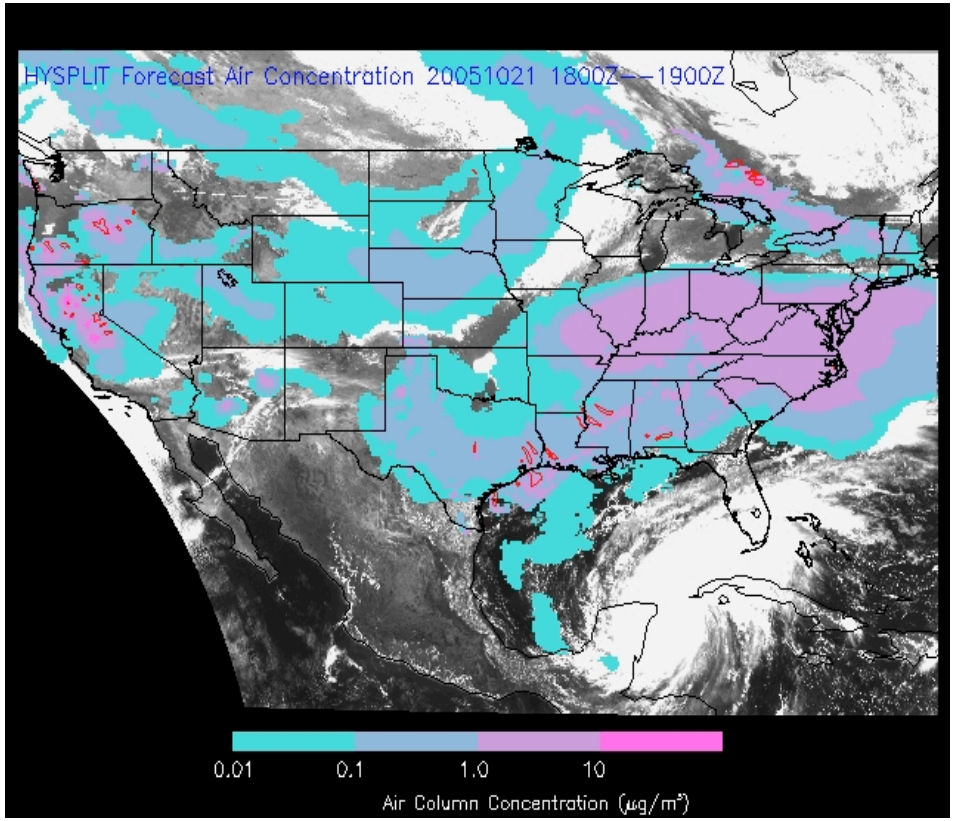
Near Real-Time Assimilation of GOES Fire Products

Navy Aerosol Analysis and Prediction System



Navy Aerosol Analysis and Prediction System (NAAPS)
Courtesy of Doug Westphal, NRL, Monterey, CA

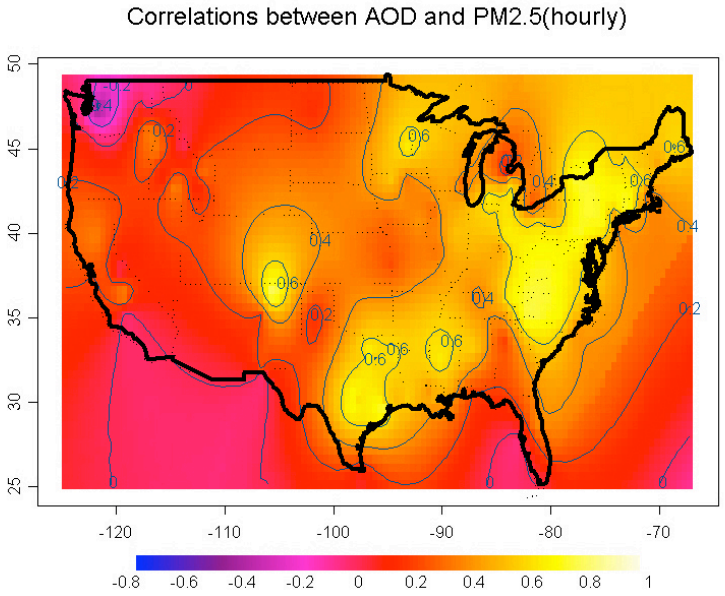
NOAA HYSPLIT Smoke Forecast System



Chemical Data Assimilation Studies

- NESDIS and OAR to conduct satellite chemical data assimilation studies to test the impact on improving air quality forecasts
  - Satellite-derived biomass burning PM2.5 emissions
    - PM2.5 forecasts
  - Satellite-derived AODs
    - Feedback on actinic fluxes/photolysis rates
      - Impact on ozone
      - Impact on secondary organic aerosol formation
    - Improve PM2.5 forecasts
  - Satellite-derived trace gas products
    - NO2 for NOx emissions

Using Satellite Measured AOD as a Proxy for Surface PM2.5 Monitoring

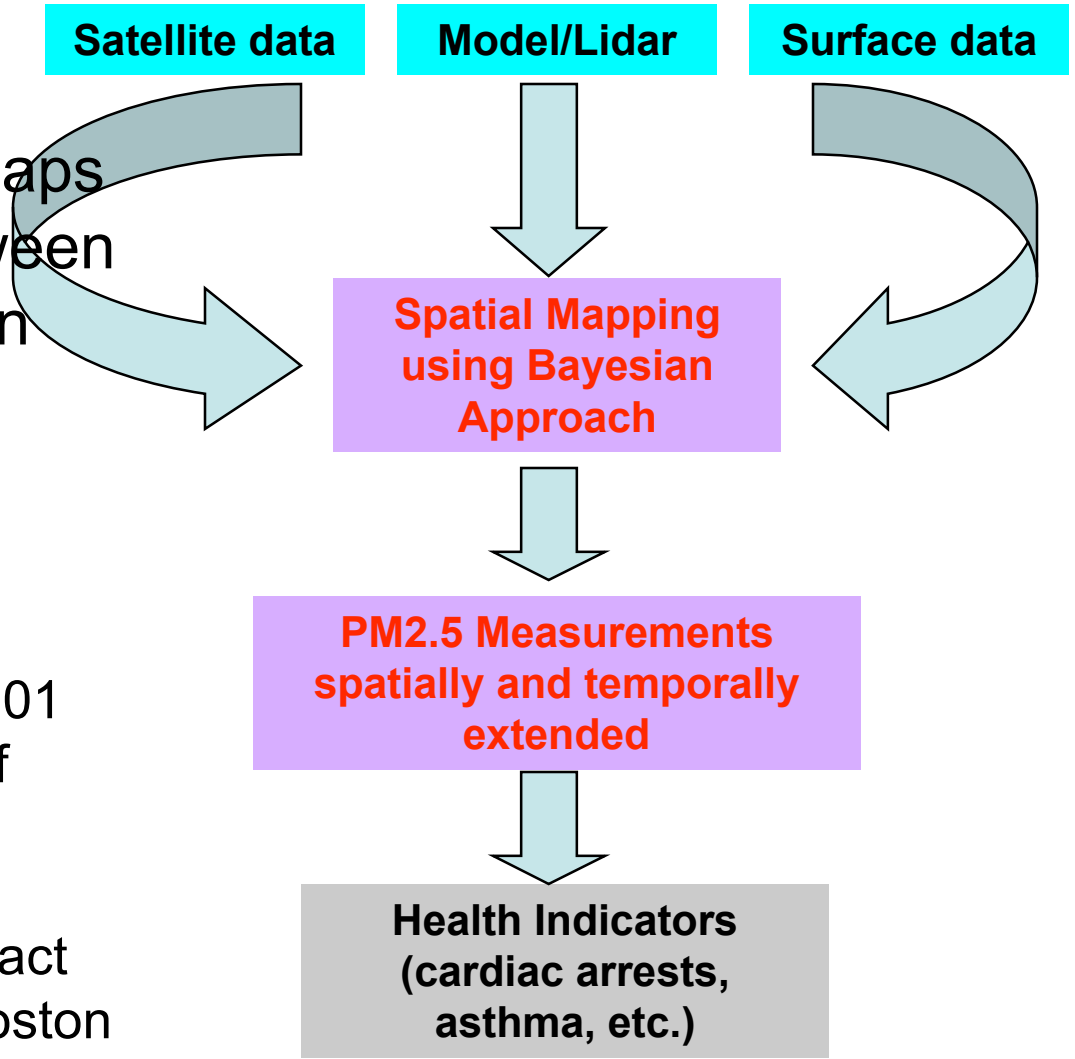


- **Seems like a possibility in the eastern U.S.**
- **Why doesn't it work over the mid-west and west?**
  - **Aerosol type different?**
  - **Aerosol always above the PBL?**
  - **Relative humidity?**
  - **Are current satellite retrieval algorithms inadequate? *Bright surfaces and/or clouds ruining the game?***
- **Is multi-sensor data integration the only way out?**

Engel-Cox et al. 2004

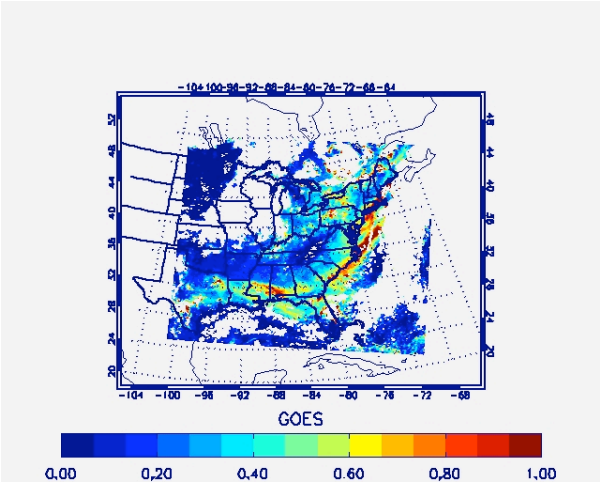
Three Dimensional Air Quality Mapping System

- Understand the mechanisms behind AOD/PM2.5 correlations
- Fill temporal and spatial gaps to study the linkages between poor air quality and human health
  - GEOSS effort led by EPA
  - NESDIS an active co-investigator
  - Initial study will focus on 2001 data. In future, ten years of GOES AOD data will be integrated with ground observations for health impact studies in New York and Boston

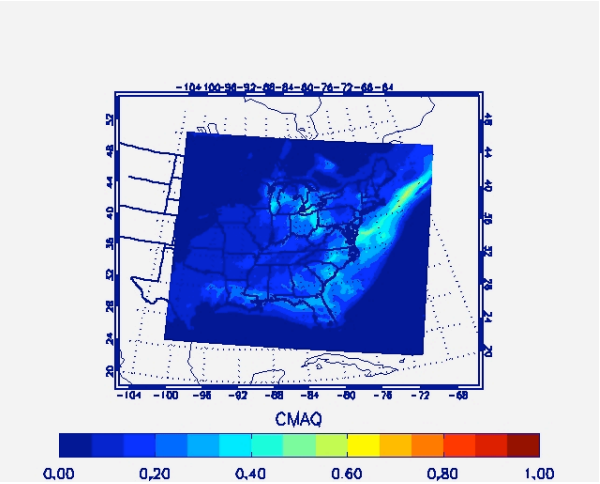


Limitations of Current Satellite Data

GOES Observed AOD (smoke aloft + sulfate haze in PBL)



CMAQ Forecasts (sulfate haze in PBL)



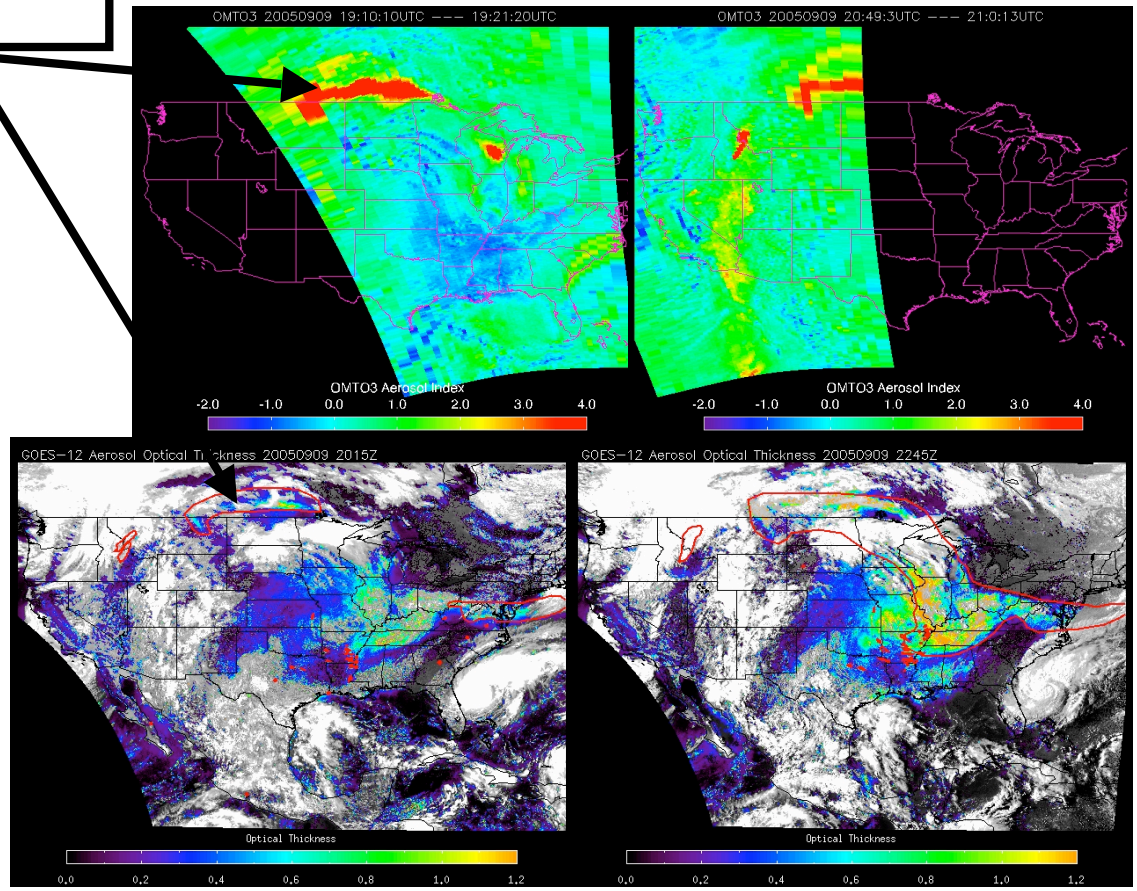
- **Observed AOD much higher than forecast AOD due to mixing in of smoke with sulfate. Model did not have smoke**
- **GOES AOD product cannot distinguish smoke from urban pollution**
  - **Ability of sensors such as OMI and GOME-2 to separate AOD into absorption and scattering optical depths will be very useful for model applications**

Limitations of Current Satellite Data (Cont.)

- No automatic identification of particle type
  - Dust/smoke/sulfate/organic/other aerosol types
- No particle composition and shape
- No vertical information of aerosols and trace gases
- Unable to see through clouds

Using Advanced Sensor Capabilities to Our Advantage: Applicability of OMI Aerosol Index Data in Improving Hazard Mapping System Smoke Analysis

GOES AOD product shows clouds mixed in with smoke aerosols. OMI can do a retrieval when aerosols are mixed in with clouds



OMI data courtesy of NASA

- In the HMS, analysts use fire locations and visible imagery to draw smoke plumes. When plumes are removed from the source (fires), analysts have difficulty differentiating smoke from other aerosols
- NWS funded NESDIS/STAR to assess (QA/QC) the analyst drawn smoke plumes so they can be used in verifying HYSPLIT smoke forecasts
- GOES AODs (physical retrieval rather than interpretation) are being used to evaluate the HMS analysis. However, GOES cannot differentiate between smoke and non-smoke aerosols either
- OMI Aerosol Index can identify smoke from urban/industrial haze but cannot differentiate between smoke and dust

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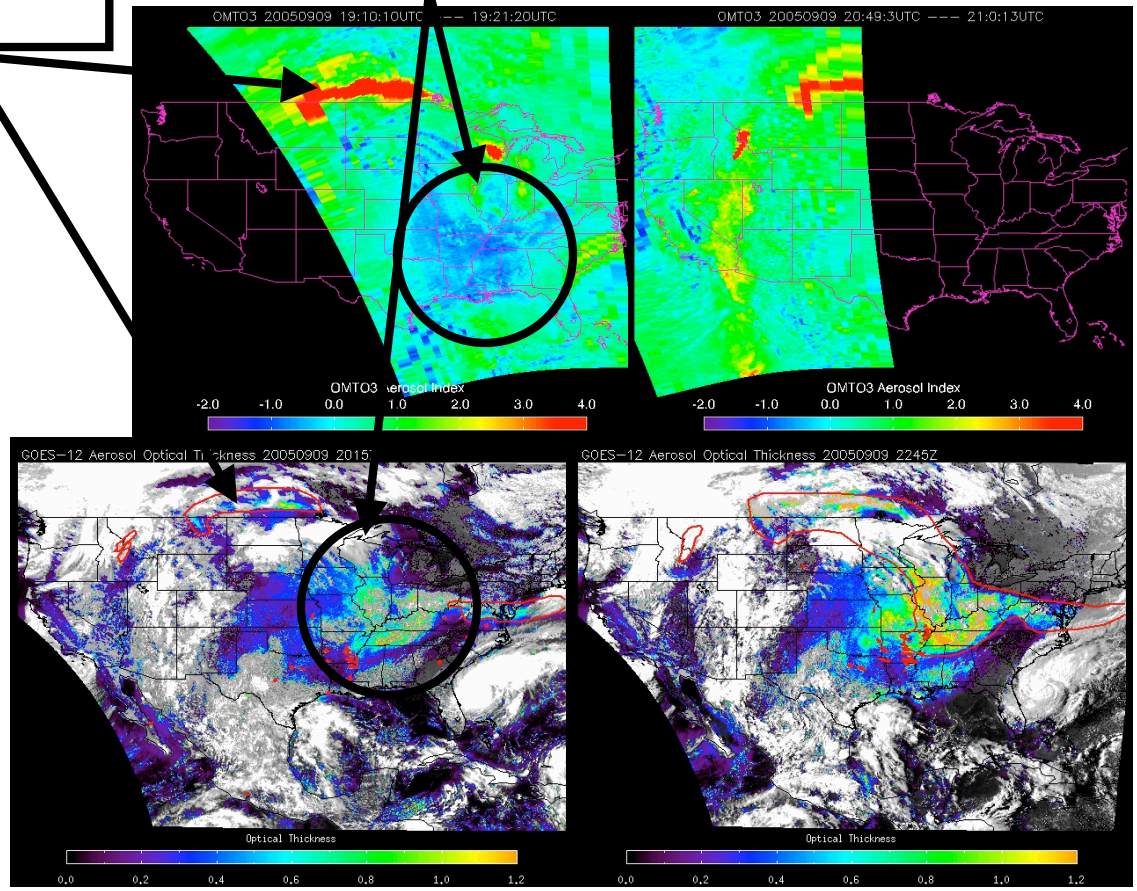
OMI says this is scattering type of aerosol. So did the analyst as he did not draw a plume there



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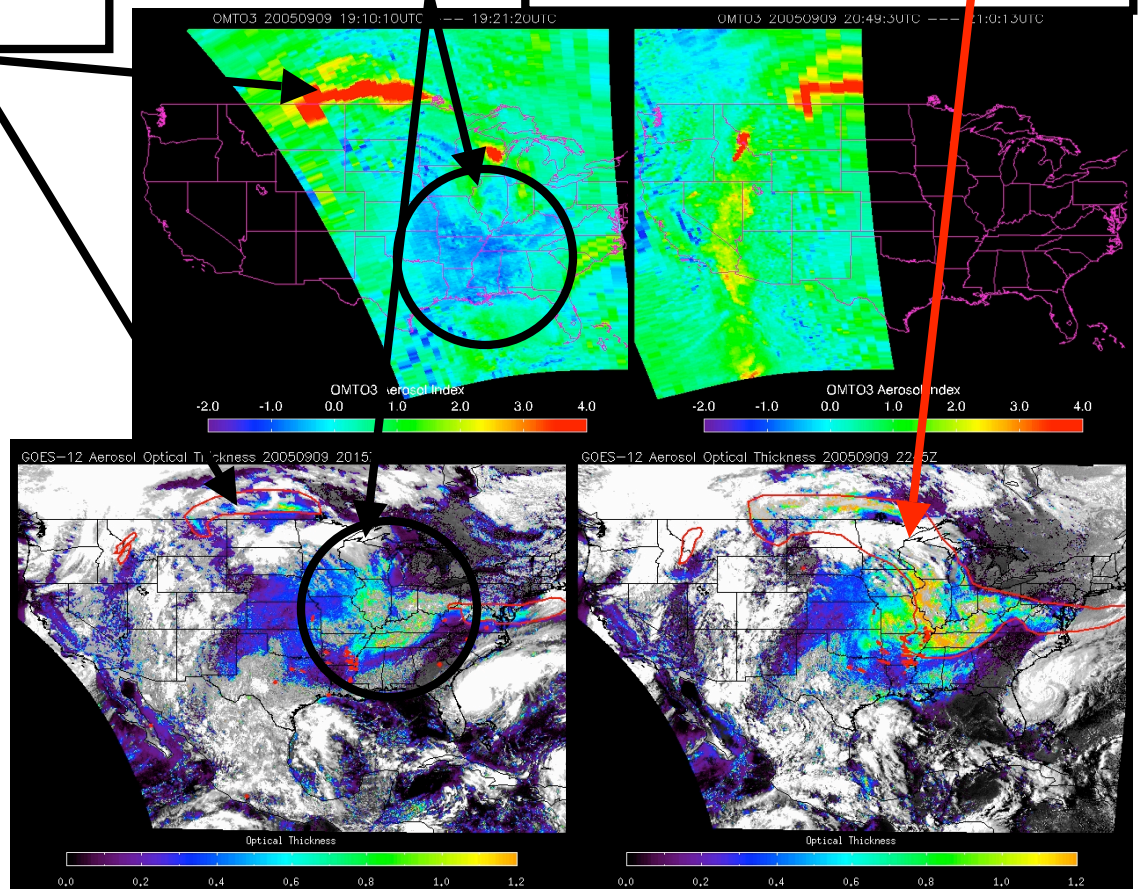
OMI says this is scattering type of aerosol. So did the analyst as he did not draw a plume there

Few hours later analyst draws a big plume. Is this all smoke? It is unfortunately after the OMI pass, so cannot conclusively say. But OMI has a big potential to help analysts with these interpretations



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Near Real Time Air Quality Products from MeTOP GOME-2 at NOAA/NESDIS

- **Algorithm development to begin in 2006**
- **OMI DOAS algorithms will be employed, tested, and implemented**
- **Products will be made available in NRT in 2008**
- **Products will be available at 40 X 40 km^2 spatial resolution**

Product	User	Application
NO2	EPA NWS	• Assessments •Constrain NOx emissions in air quality forecast model •Verification of precursor forecast fields
H2CO	EPA NWS	• Assessments •Constrain isoprene emissions in air quality forecast model •Verification of precursor forecast fields
Ozone	NWS	• Ozone forecast improvements
Aerosol optical Depth (absorption vs scattering)	EPA NWS NESDIS	• PM2.5 Monitoring •PM2.5 and ozone forecast improvements •Hazard Mapping System
Volcanic SO2	NESDIS	• Hazard Mapping System

GOES-R AQ products at 5 minute refresh rate over the Americas

- *Aerosol optical depth*
- *Aerosol size*
- *Aerosol type*
- *Biomass burning emissions*
- *Carbon monoxide*
- *Fire size and location*
- *Height of aerosol layer*
- *Methane*
- *Ozone*

NPOESS and METOP will provide the same up to six times per day but with global coverage

See Kondragunta and Goldberg poster for details

Conclusions

- NESDIS is currently meeting several user needs
  - Active collaboration with NOAA line offices (OAR, NWS), universities, other federal agencies (EPA, NASA, USFS), and international agencies (ISRO, IMD)
- MetOP, NPOESS, GOES-R sensors will meet additional requirements not met by current sensors
- New science and sensors will be the drivers for further enhancements and improvements

Products Timeline