NCEP Aerosol Data Assimilation Update:

Improving NCEP global aerosol forecasts using JPSS-NPP VIIRS aerosol products

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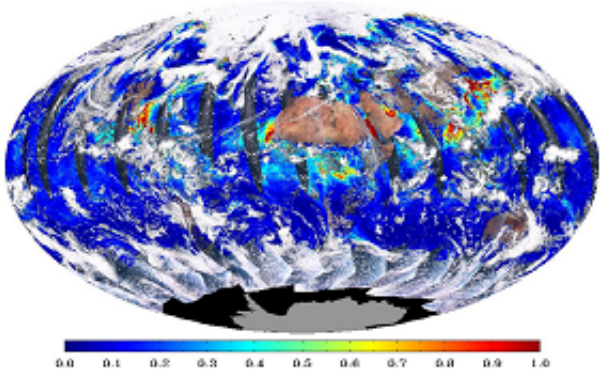
Using satellite data to improve aerosol forecasting

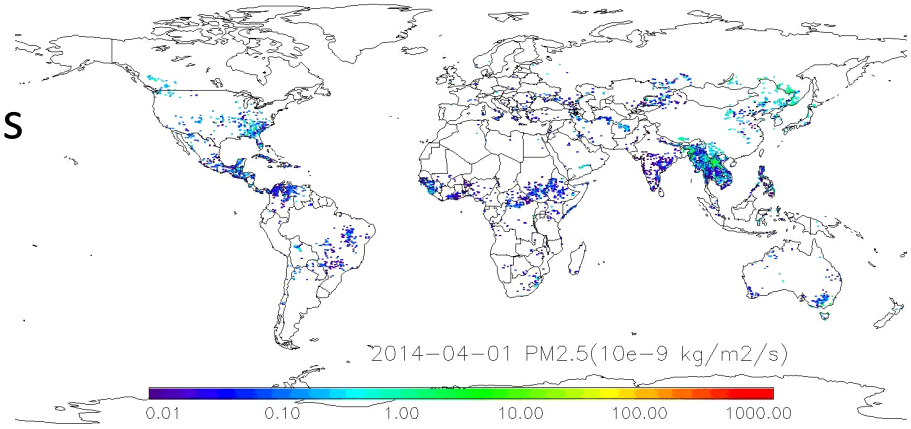
- NCEP's global aerosol forecasting capability has been build upon inter-agency collaboration (NCEP, NASA/GSFC, NESDIS/STAR) and leverage the expertise in other modeling centers (ICAP)
- Satellite observations have been used to improve aerosol products
  - Data assimilation of satellite aerosol observations (in development)
  - Near-real-time biomass burning emissions from satellite observations
  - Routine monitoring of model performance

Aerosol observations from VIIRS



From NOAA/NESDIS/STAR website

Near-real-time biomass burning emissions from multiple satellites



Shobha Kondragunta (NOAA/NESDIS/STAR)

Outline

1. Background – Scope of global aerosol prediction at NCEP
2. The need for aerosol data assimilation
3. Status update in aerosol data assimilation
4. Other aerosol-related activities at NCEP
5. Conclusions

NCEP global aerosol modeling and assimilation

- **Long-term goal**
  - Allow aerosol impacts on weather forecasts and climate predictions to be considered
  - Enable NCEP to provide **quality atmospheric constituent products** serving the stakeholders, e.g., health professionals, policy makers, climate scientists, and solar energy plant managers

- **Phased implementation**
  - Phase 1: Dust-only forecasts (operational)
  - Phase 2: Multi-species forecasts for dust, sulfate, sea salt, and carbonaceous aerosols using NESDIS's NRT GBBEPx smoke emissions (planned FY16 implementation)
  - Phase 3: Aerosol analysis using VIIRS AOD (critical for improving NCEP's aerosol products)

NCEP global aerosol modeling and assimilation –cont'd

- The global aerosol analysis system at NCEP will be implemented with incremental updates
  - The first phase is based on the GSI framework using VIIRS AOD as input observations and the NGAC output as first guess
  - The system will be extended to use multi-sensor and multi-platform aerosol observations and evolve to an ensemble-based system (implementation pathway and timeline uncertain)

- The primary outcomes include:
  - Improved operational global real-time aerosol forecasts. JPSS aerosol information will be assimilated in the NWS operational data assimilation system for the first time.
  - A prototype unified global coupled system with aerosol modeling and data assimilation capabilities.

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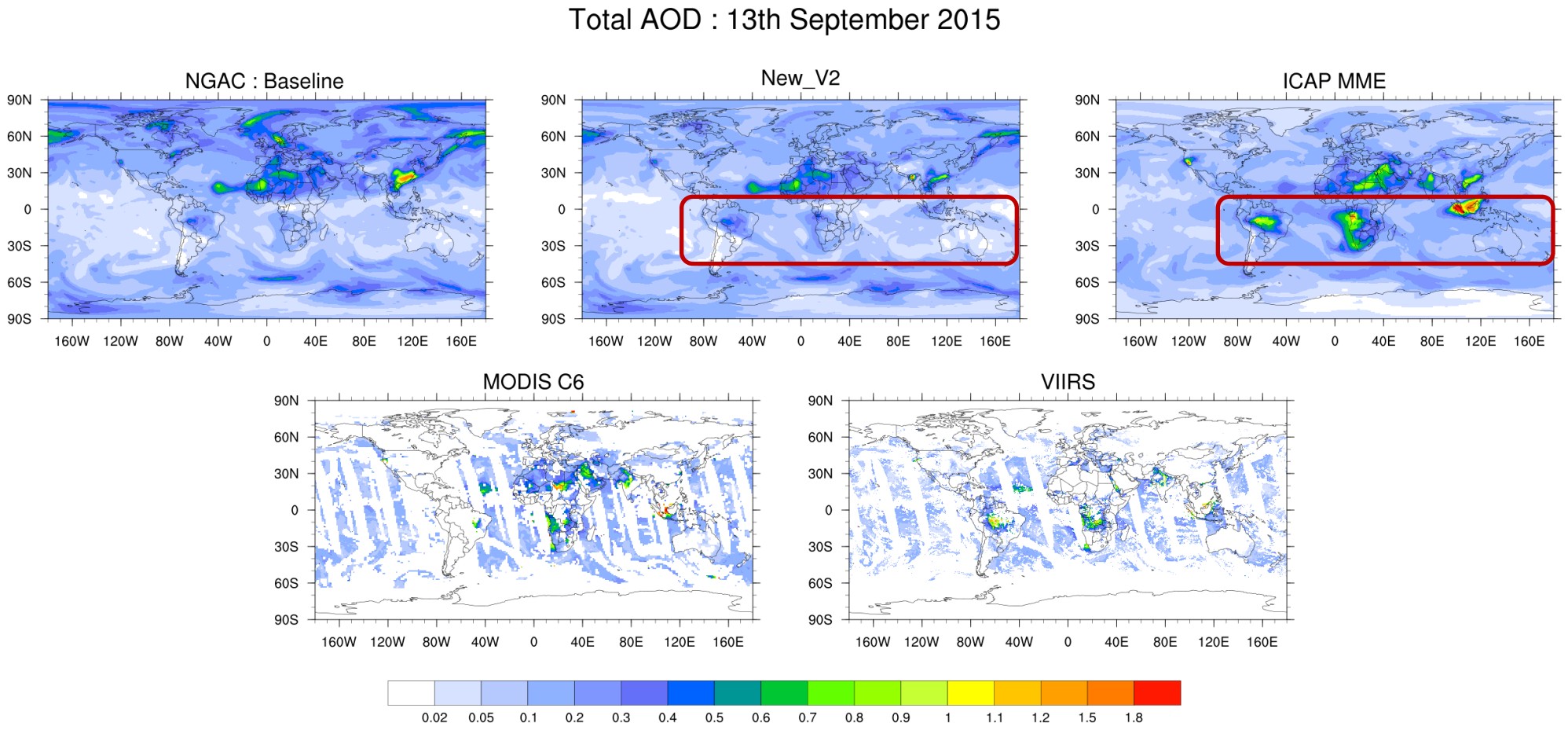
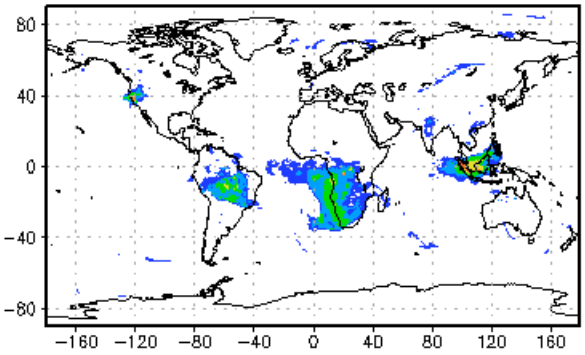
Sept case: Lower AOD in NGAC V2 than ICAP-MME in South America, Africa and SE Asia

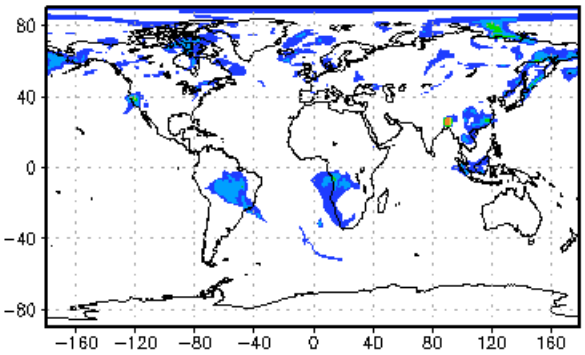


Smoke AOD at 2015-09-13 12z

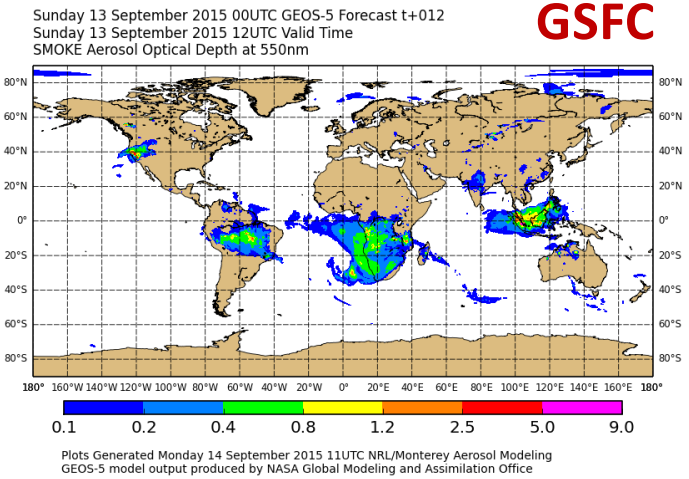
MERRA2



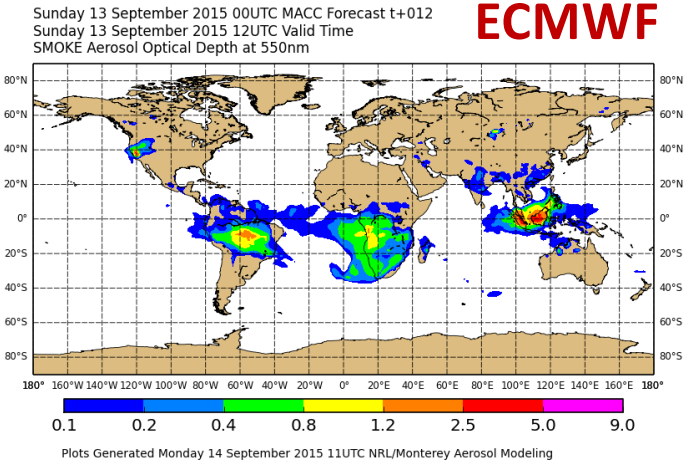
NGAC2



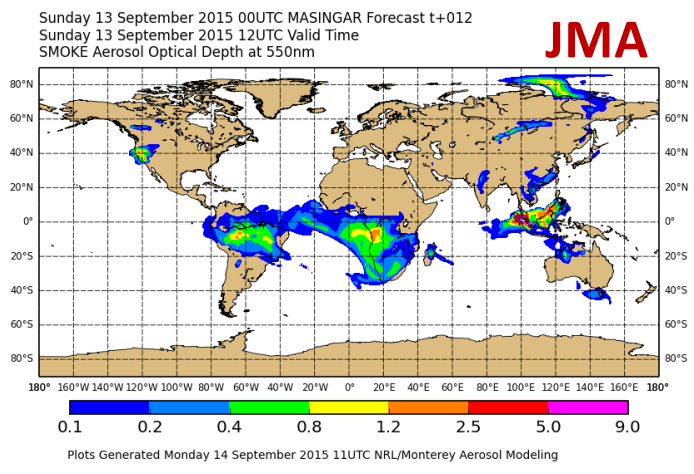
GSFC



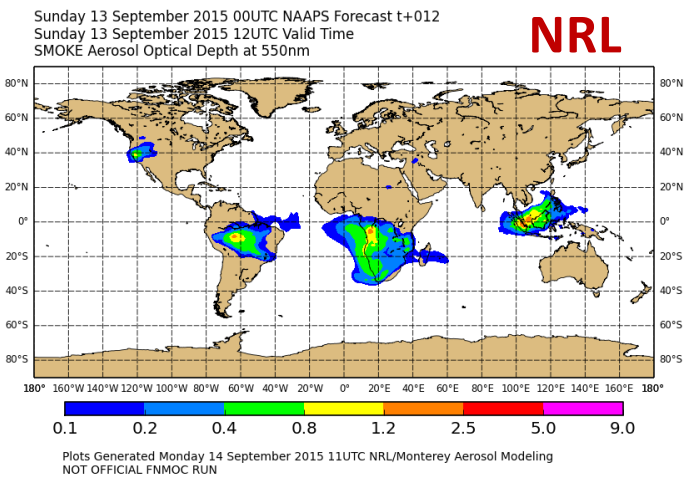
ECMWF



JMA

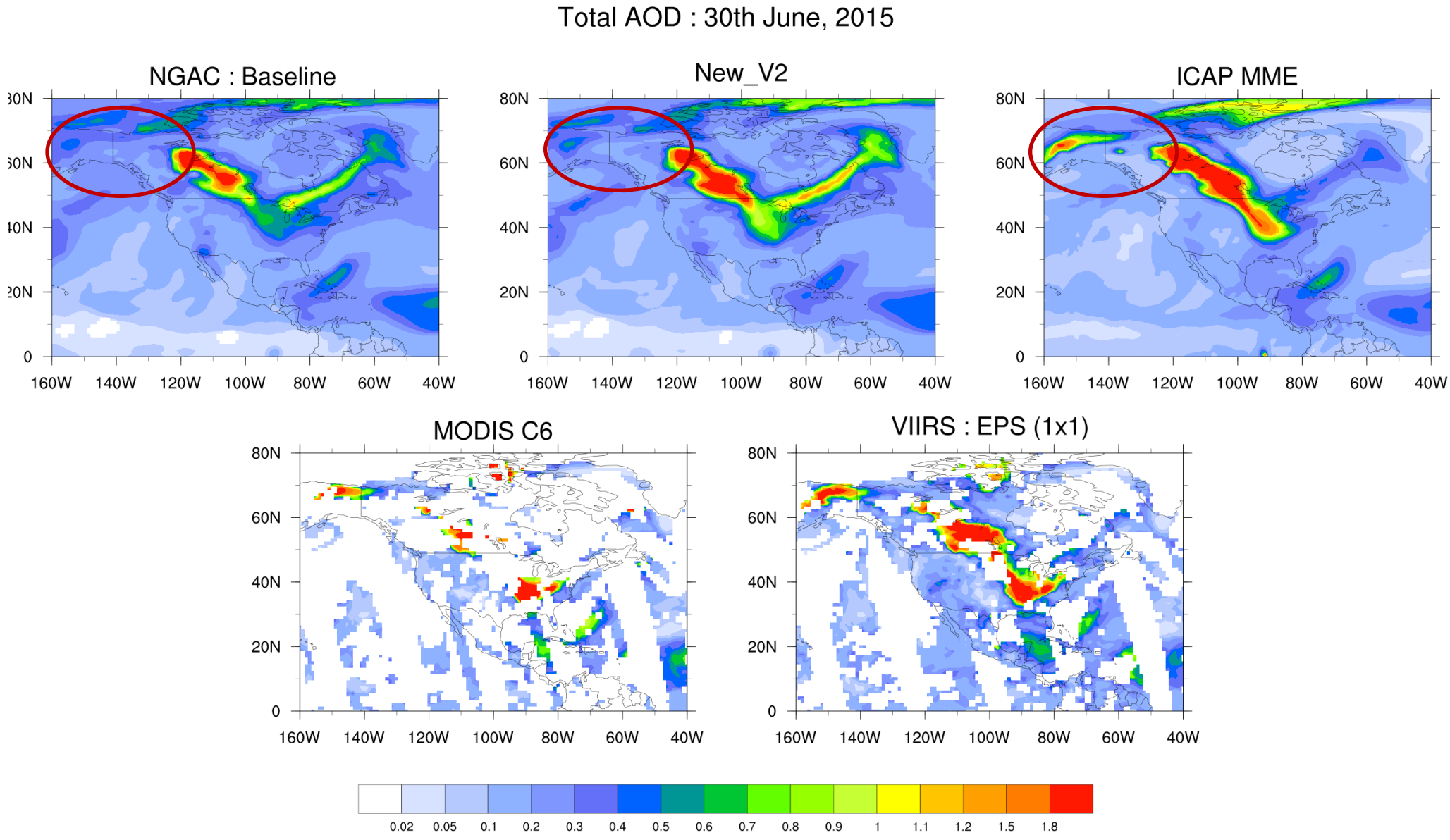


NRL



Smoke AOD in NGAC V2 is lower than ICAP-MME, ICAP member, and MERRA2.

July 2015 case: Lower AOD in NGACv2 than ICAP-MME for the areas affected by Alaska and Africa smoke

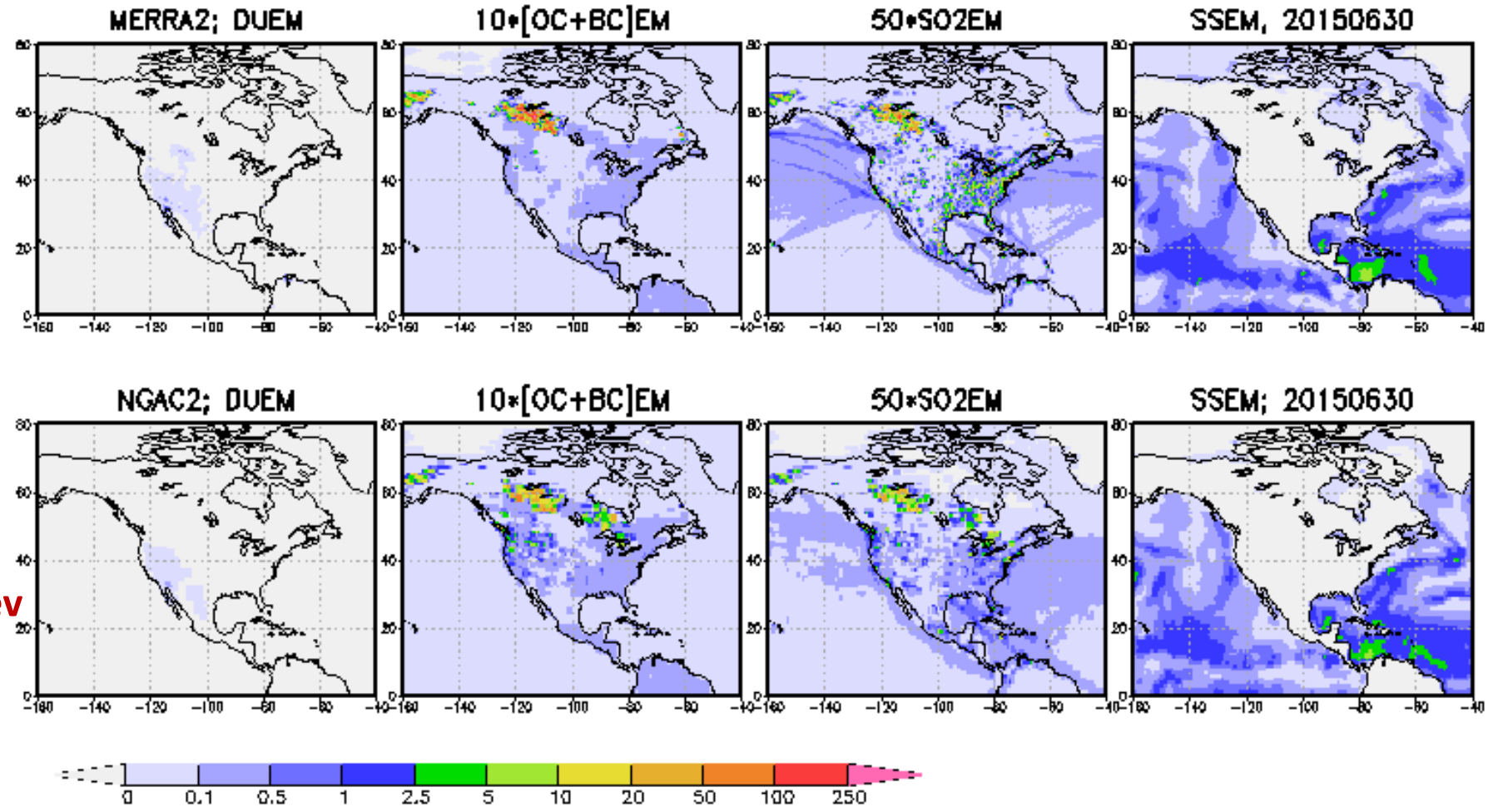


For 2015-06-30

Emissions for DU, OC+BC, SO2, SS for 2015-06-30 12Z

MERRA2

NGACV2_rev

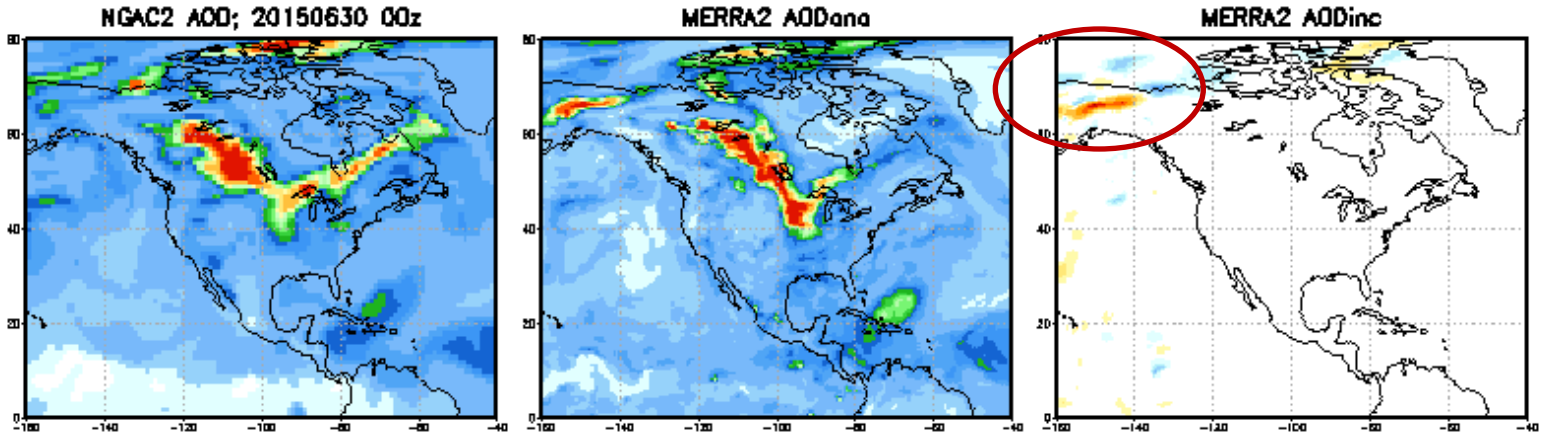


Comparable Alaska smoke emissions in QFED2 (for MERRA2) and GBBEPx (for NGAC v2)

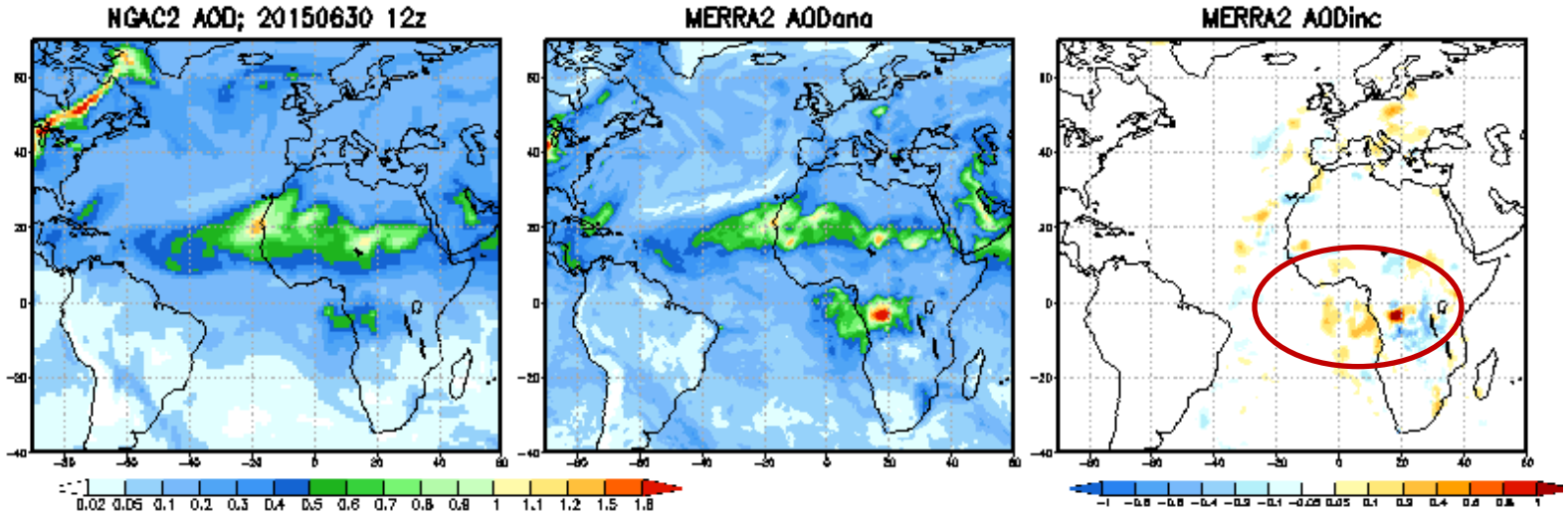
For 2015-06-30

NGAC AOD **MERRA2 AOD** **MERRA2 analysis increment**

00Z



12Z



Comparable smoke emissions between QFED2 and GBBEPx

The AODs differences between MERRA2 and NGACv2 are attributed to analysis increment

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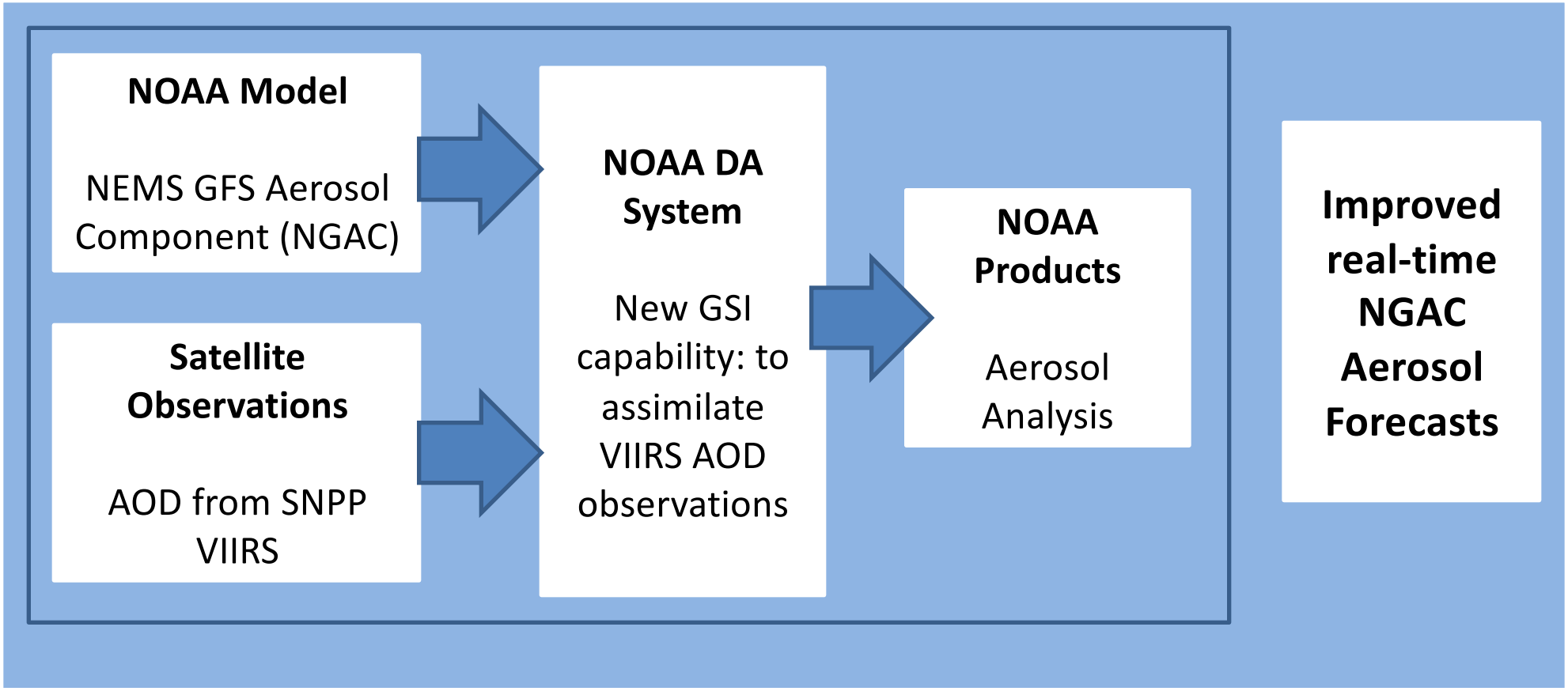
Improving NCEP global aerosol forecasts using SNPP VIIRS aerosol products



Major Milestones:

- Data assimilation grade VIIRS aerosol products
- Prototype GSI VIIRS AOD assimilation system

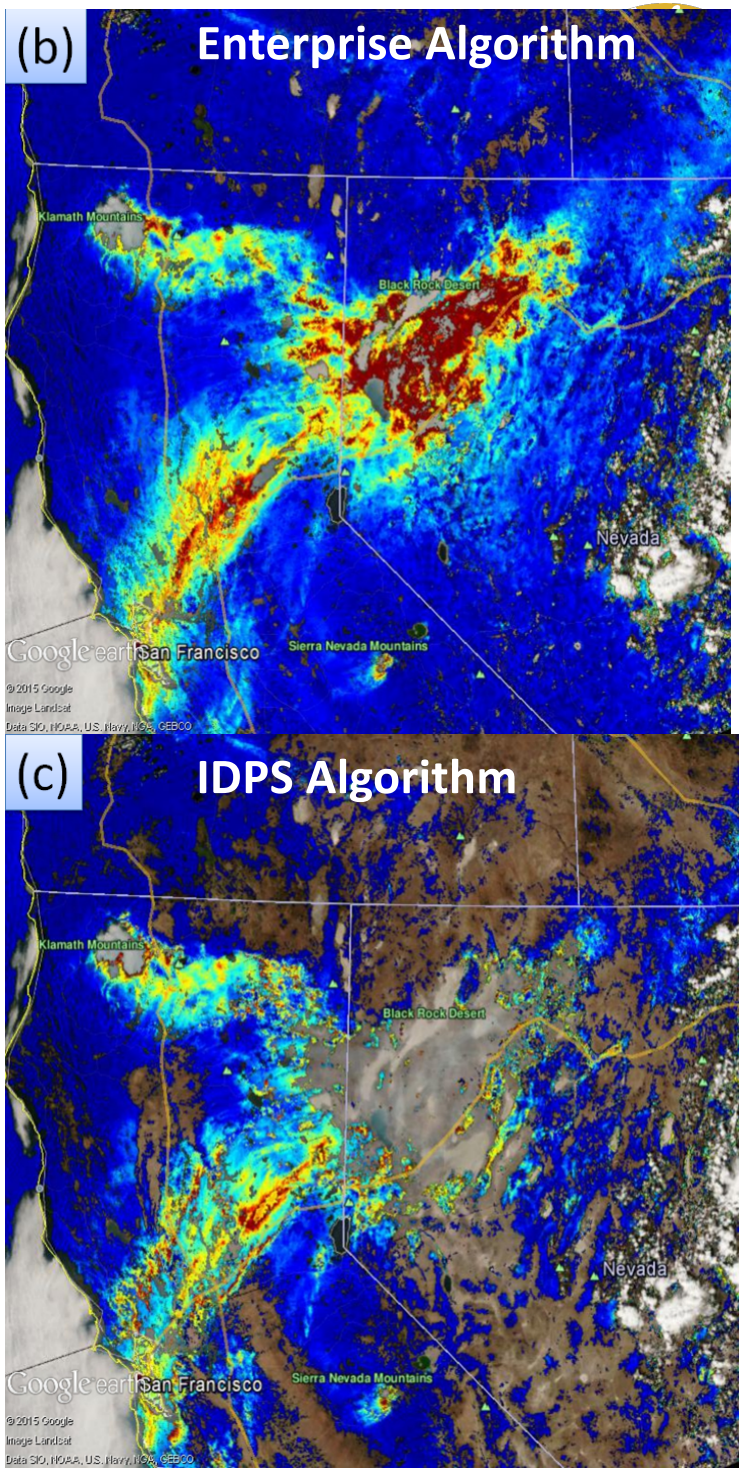
Project Milestones Overview

Task	Description	Milestones/ Deliverables
1. VIIRS quality assurance and bias correction	Conduct VIIRS AOD error analysis and establish VIIRS data screening procedure	DA grade VIIRS AOD products
2. Global aerosol analysis	Develop GSI-based AOD data assimilation system using NCEP's NGAC as first guess and VIIRS AOD as observation input	GSI AOD DA system
3.Benchmark study	Demonstrate the anticipated improvement resulted from AOD DA	Benchmark report

Task 1 VIIRS AOD Quality Assurance and Bias Correction

- VIIRS operational AOD (IDPS version) is well validated and documented. However, the following issues have been documented:
  - Smoke plumes are identified as cirrus cloud
  - Data gaps over bright surfaces
  - Measurement range extends only from 0 to 2 optical depth units

- Enterprise algorithm has been developed to circumvent the deficiencies. This algorithm to be operational in NDE by July 2016
  - Testing and evaluation ongoing



Task 1 VIIRS AOD Quality Assurance and Bias Correction –cont'd

- Obtain AOD and dust/smoke mask products from Enterprise algorithms for select case studies and do model comparison studies

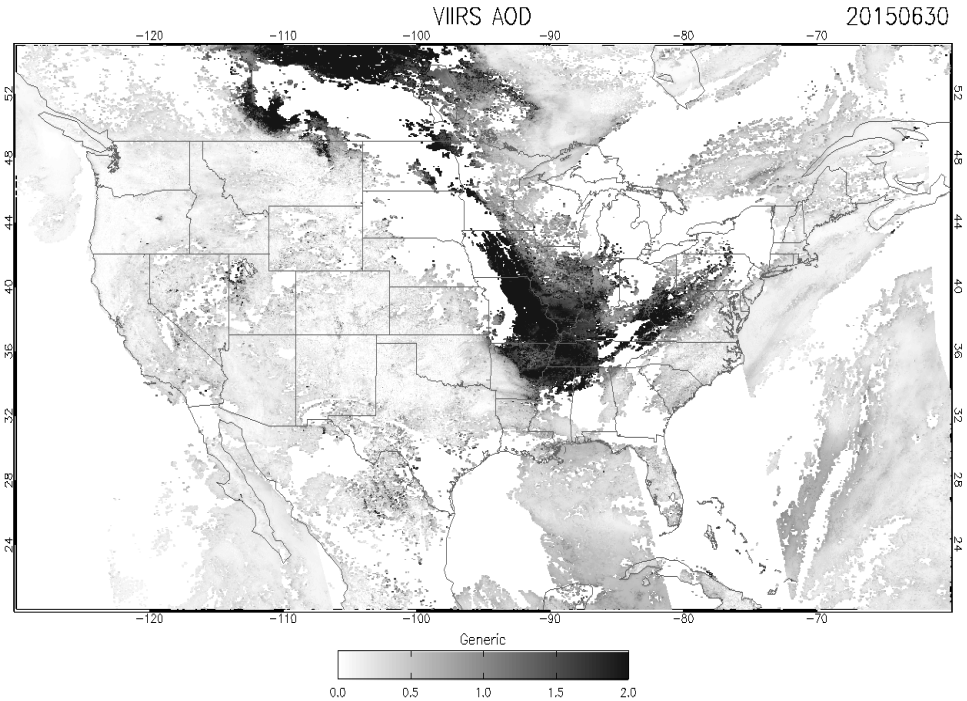
- Identify VIIRS AOD data artifacts and sources of errors and develop data screening procedures if needed

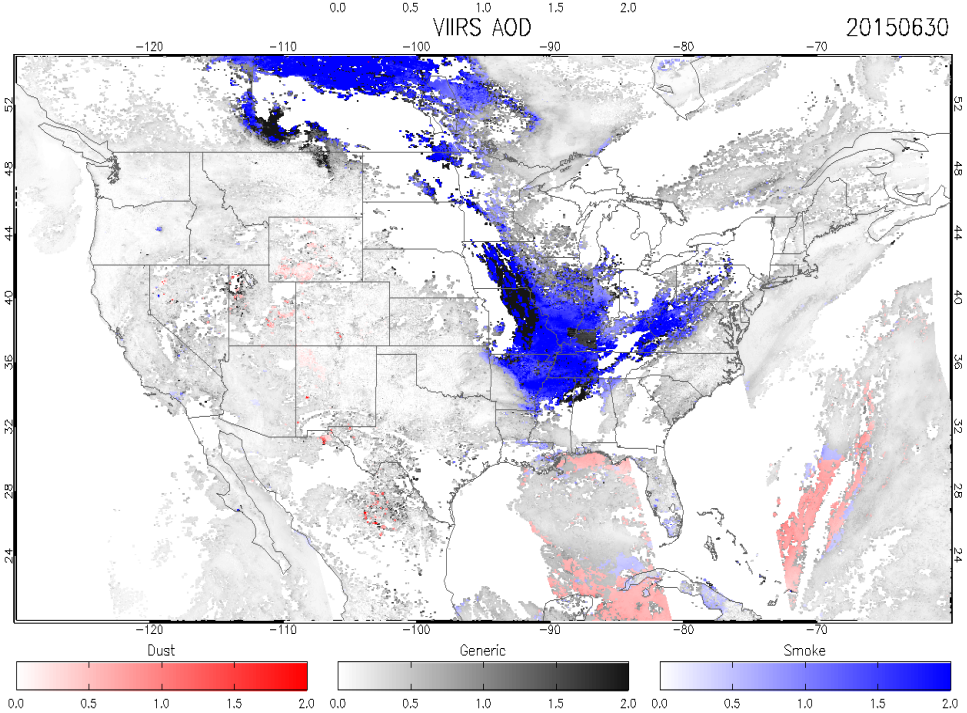
Quick Checkup of VIIRS Aerosol Products

- VIIRS Enterprise Algorithm AOD Product
  - Moderate channel resolution ~750m
  - Daily global coverage with 14-15 orbits

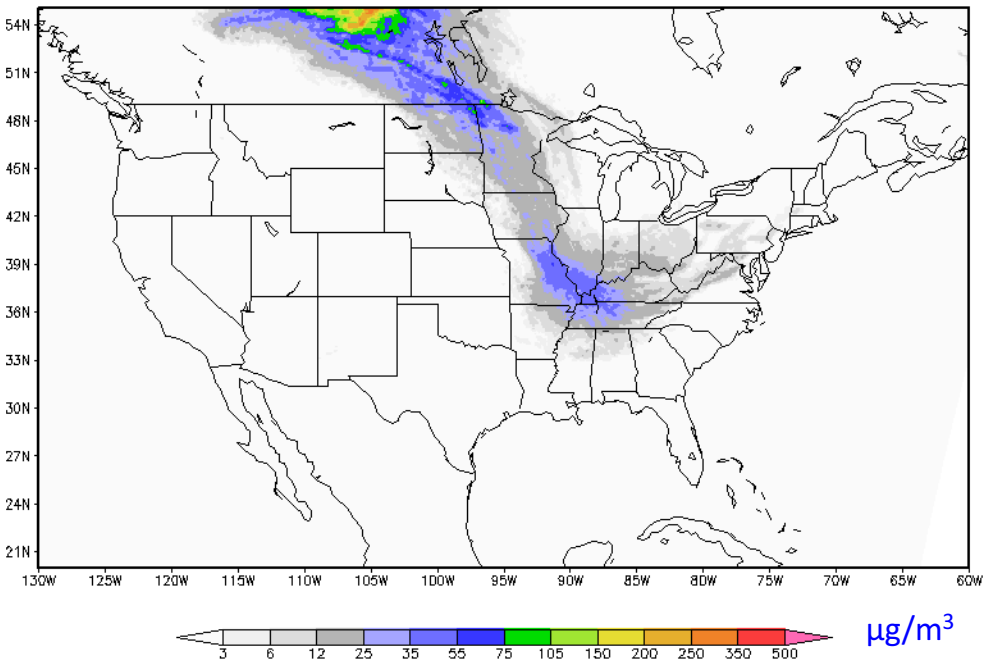
- VIIRS Smoke/Dust Detection Product
  - DAI based algorithm with deep-blue channels
  - Detects dust and smoke plumes

- A few wildfire episodes were selected based on operational HYSPLIT model smoke forecasts
- HYSPLIT smoke forecasts were taken as reference and compared against





HYSPLIT Column Average Smoke Concentration 2015063018



Task 2 Technical/Scientific Progress

- With an older version of GSI/CRTM, NCAR and ESRL assimilates MODIS AOD using WRF-CHEM as first guess
- AOD DA code has been committed to the GSI code repository
- We are extending the new GSI option to use NGAC as first guess and VIIRS as observation input.

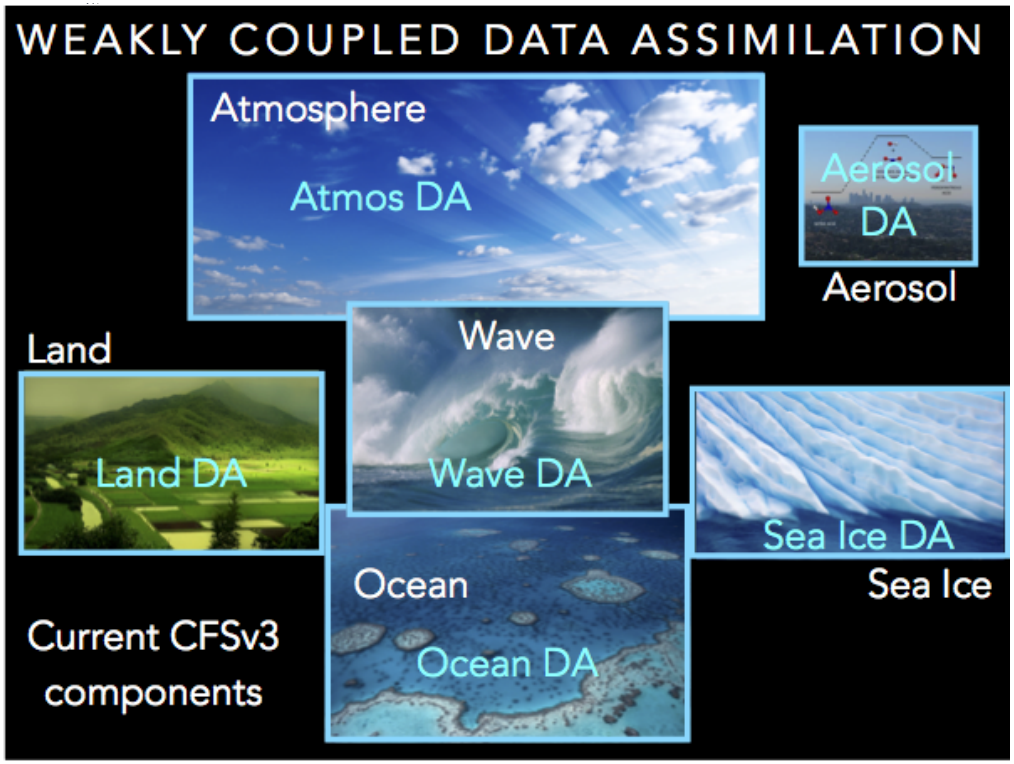
Task 2 Technical/Scientific Progress –cont'd

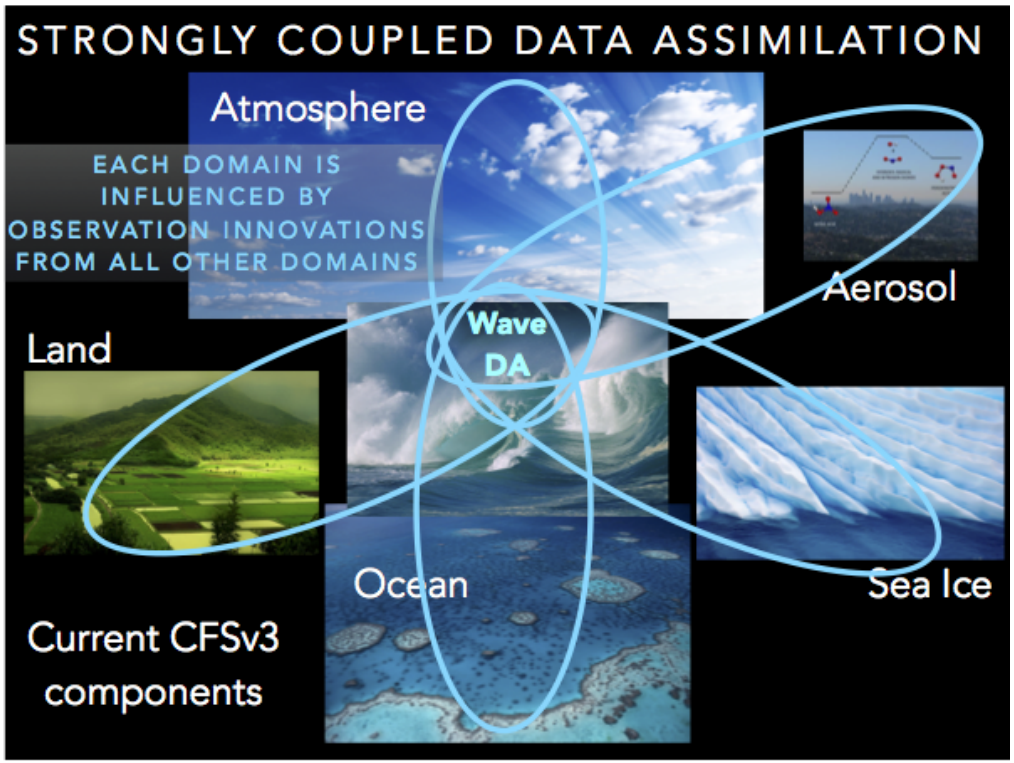
- GOCART interface in GSI:
  - GSI code modified to read in NGAC first guess
- Observation reading interface in GSI:
  - GSI code modified to read VIIRS AOD
  - Observation thinning for VIIRS AOD will be done in reading step.
- Specification of background error
  - Calculated using the NMC method
  - Spatial correlation for GOCART aerosol species
- Specification of observation errors
  - Determined from VIIRS versus AERONET comparisons (VIIRS Cal/Val)
- Observation operator
  - Use JCSDA Community Radiative Transfer Model (CRTM V2.3) as observation operator for VIIRS AOD
  - Forward and Jacobian models
- Synergistic activities:
  - VIIRS AOD from Enterprise algorithm has been encoded in BUFR format and dumped to a development database at EMC

Unified Global Coupled System (UGCS)

- Efforts are underway at NCEP/EMC to develop a fully-coupled ensemble-based DA system for earth system components, including atmosphere, ocean, land, sea ice, wave, and aerosols.

- The UGCS-aerosol infrastructure will leverage the variational GSI efforts project (e.g., quality assurance and bias-correction of the VIIRS AOD observations; specification of the observation errors; observation operator implemented in the GSI)





Weak coupling

- Aerosol analysis is combined with the independent analyses from the other system components to produce a coupled forecast.

Strong coupling

- Incorporate innovations from other system components
- Iterative testing of the addition of innovations, e.g., sea surface temperature from the ocean component, soil moisture from the land component, and winds from the atmosphere component.)

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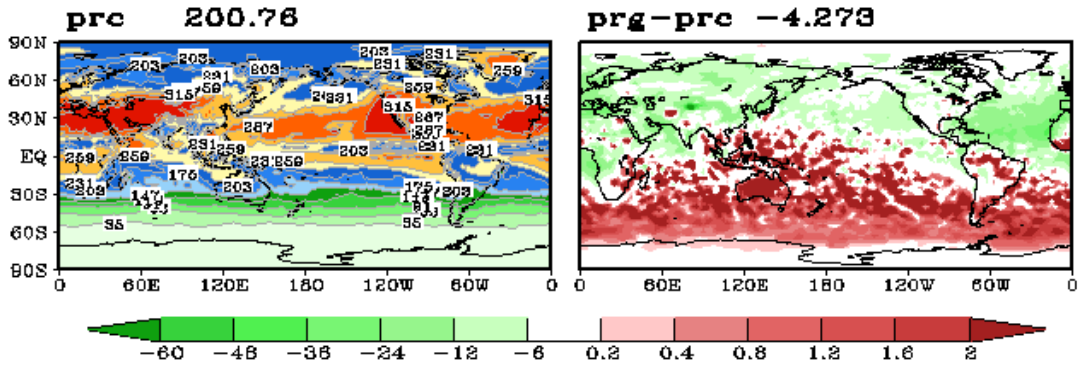
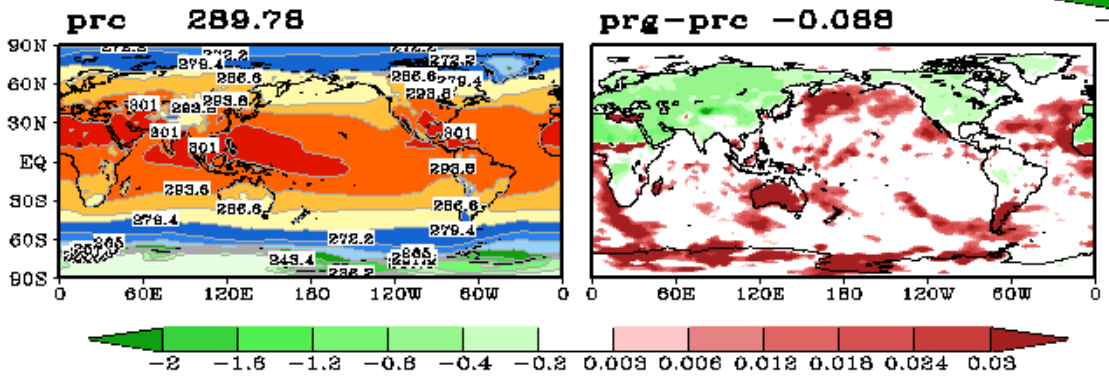
Aerosol-Radiation Feedback: Impact of Aerosols on Weather Forecasts

PRC: use OPAC climo

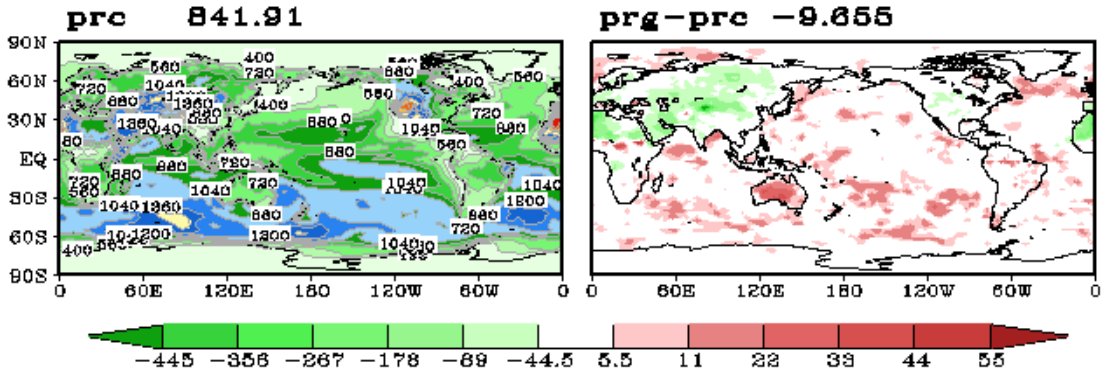
PRG: use off-line GEOS4-GOCART

Surface downward SW fluxes are reduced



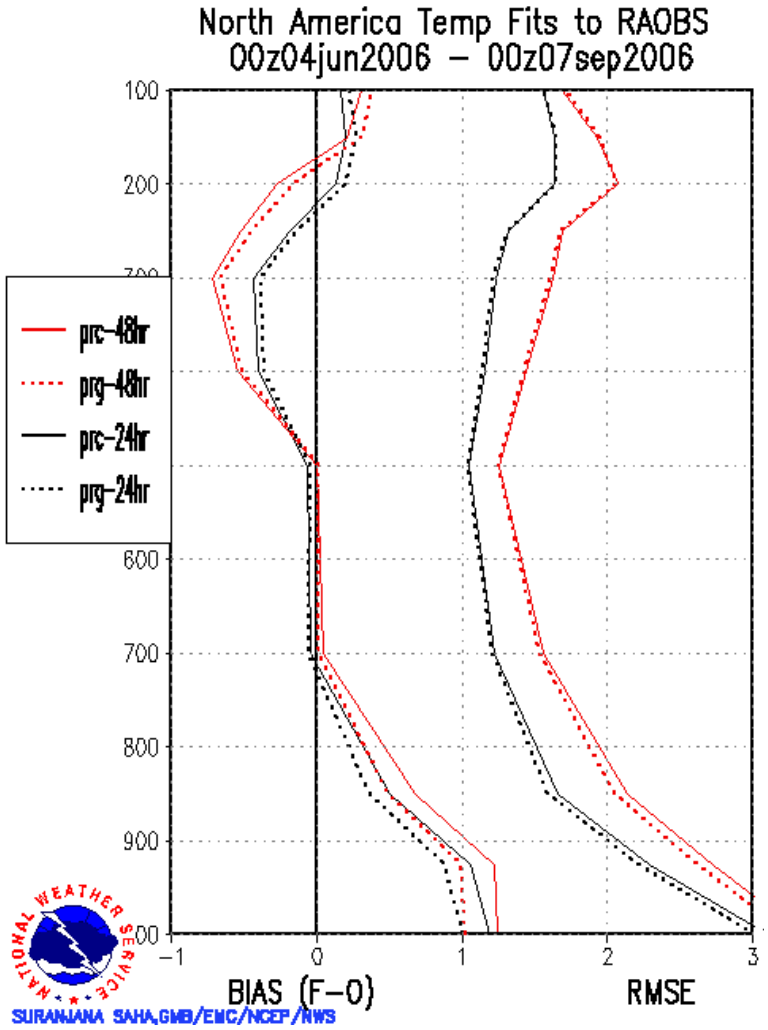


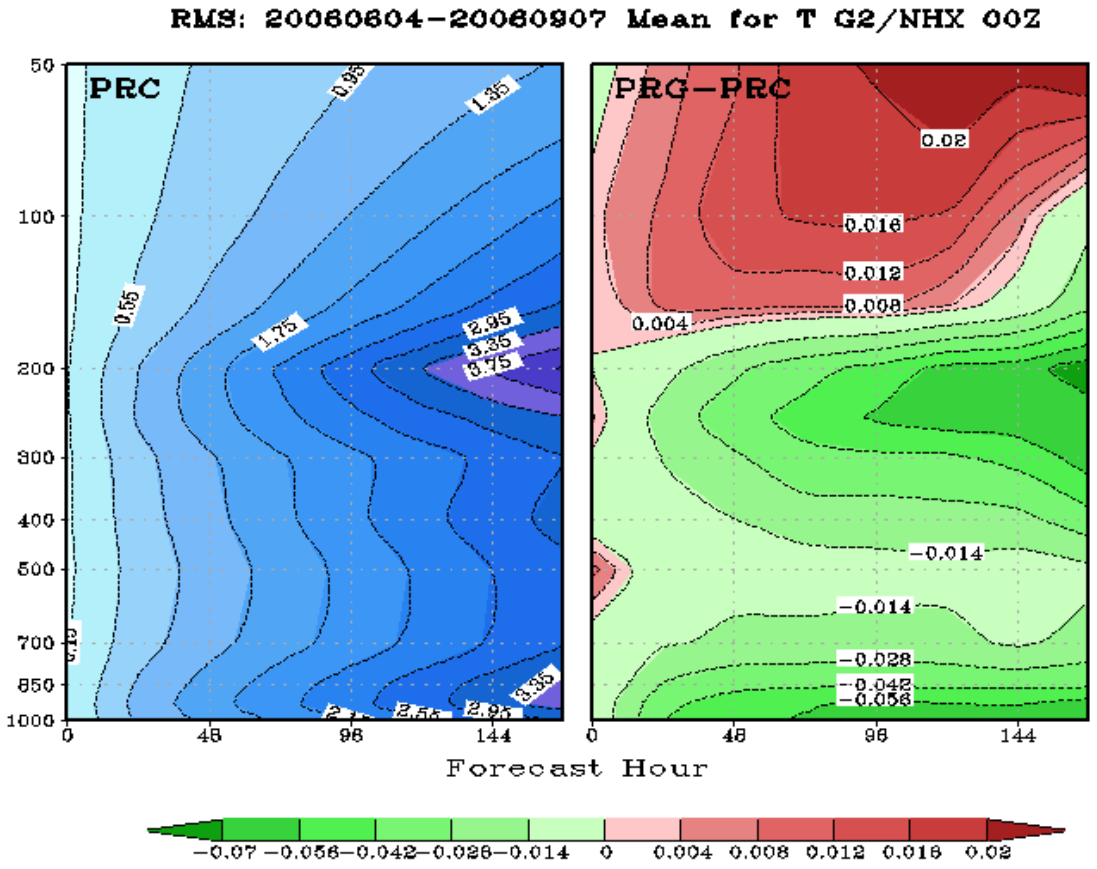
Cooler near surface tempeature



Suppressed PBL depth

Aerosol-Radiation Feedback: Impact of Aerosols on Weather Forecasts

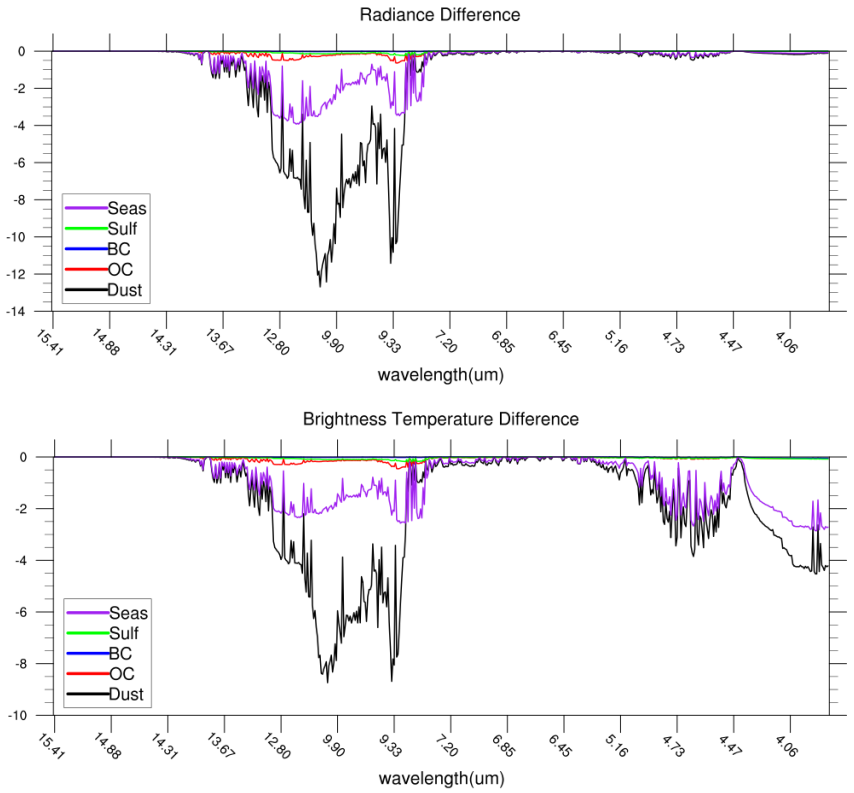




Verification against analyses and observations indicates a positive impact in temperature forecasts due to realistic time-varying treatment of aerosols.

Investigation of aerosol effects on weather forecast using NCEP Global Forecast System

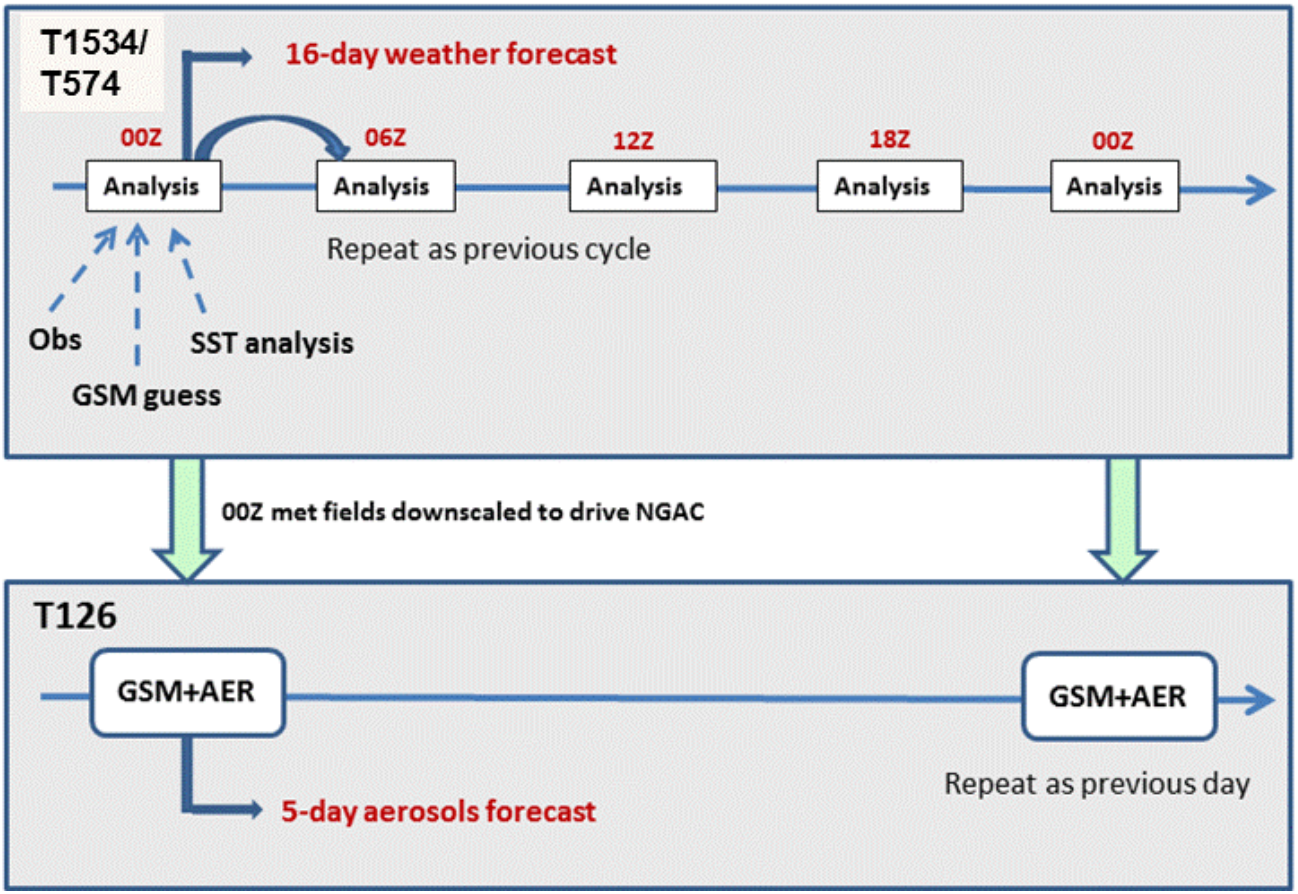
- Overarching goal: Investigating how much complexity is needed to accurately represent the aerosol processes and effectively account for aerosol effects
- Proposed approaches:
  - Aerosol fields from low-resolution NGAC run are fed to high-resolution GDAS, allowing aerosol radiative effects in GSM, physical retrievals in RTG_SST, and aerosol attenuation in hybrid EnKF-GSI to be determined from NGAC forecasts.



Spectral sensitivity of IASI radiance (top) and brightness temperature (bottom) to different aerosols.

Dual resolution weather-aerosol system

Operational: One-way coupling



GFS for weather

GFS: OPAC climatology
GSI: Background aerosols
RTG_SST#: No aerosol correction

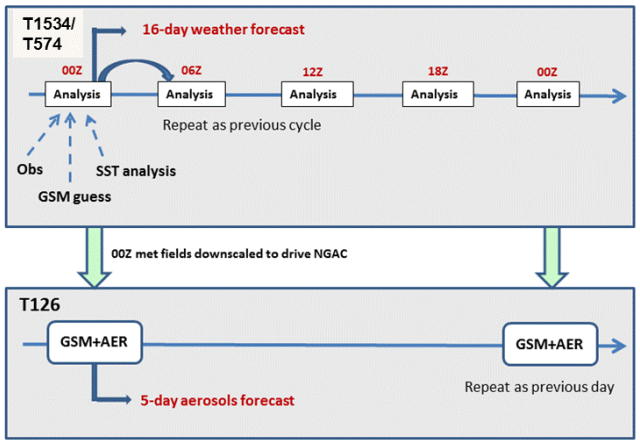
NGAC* for aerosols

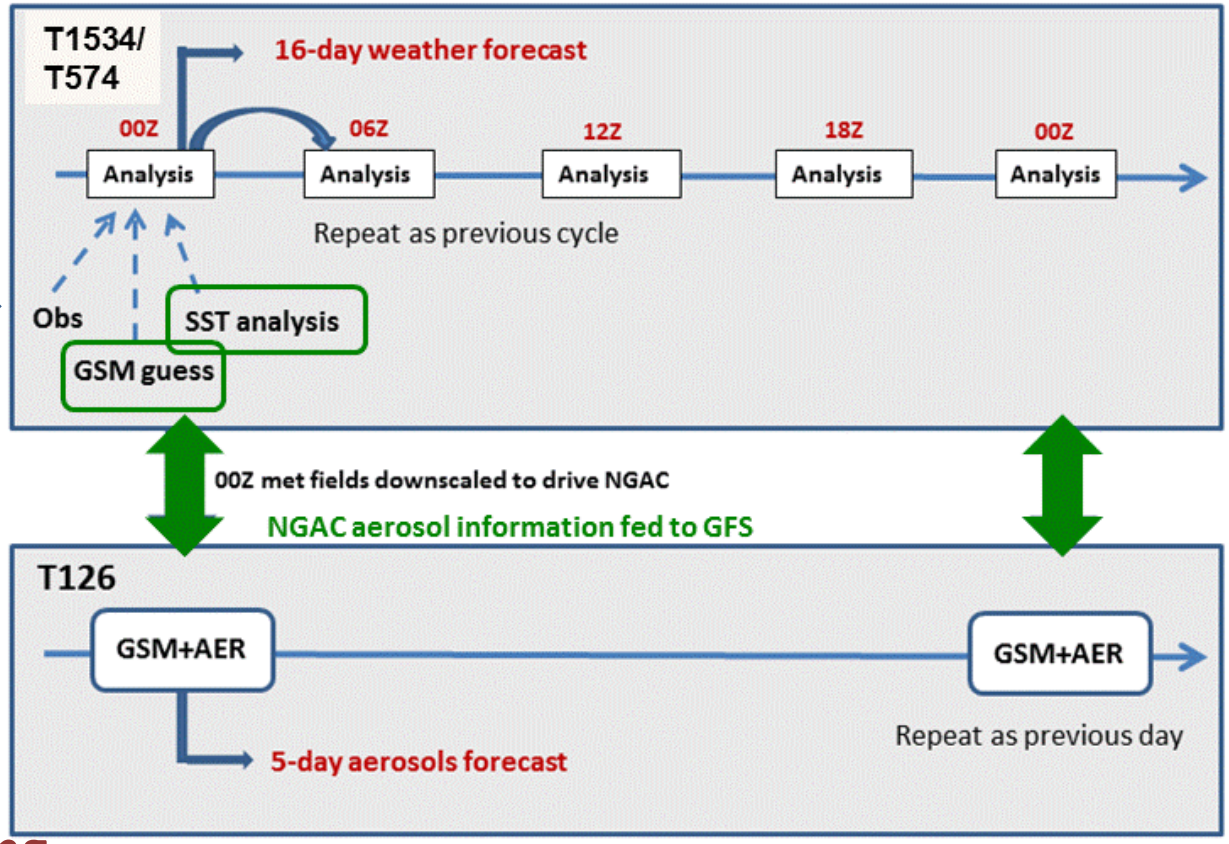
Initial conditions:
ATM: downscaled from GDAS
AER: cycled from NGA runs

#: Real-time Global Sea Surface Temperature
*: NGAC is one version of GSM (in NEMS framework; with the prognostic aerosol option)

Investigation of Aerosol Effects on Weather Forecast using NCEP Global Forecast System

Operational: One-way coupling



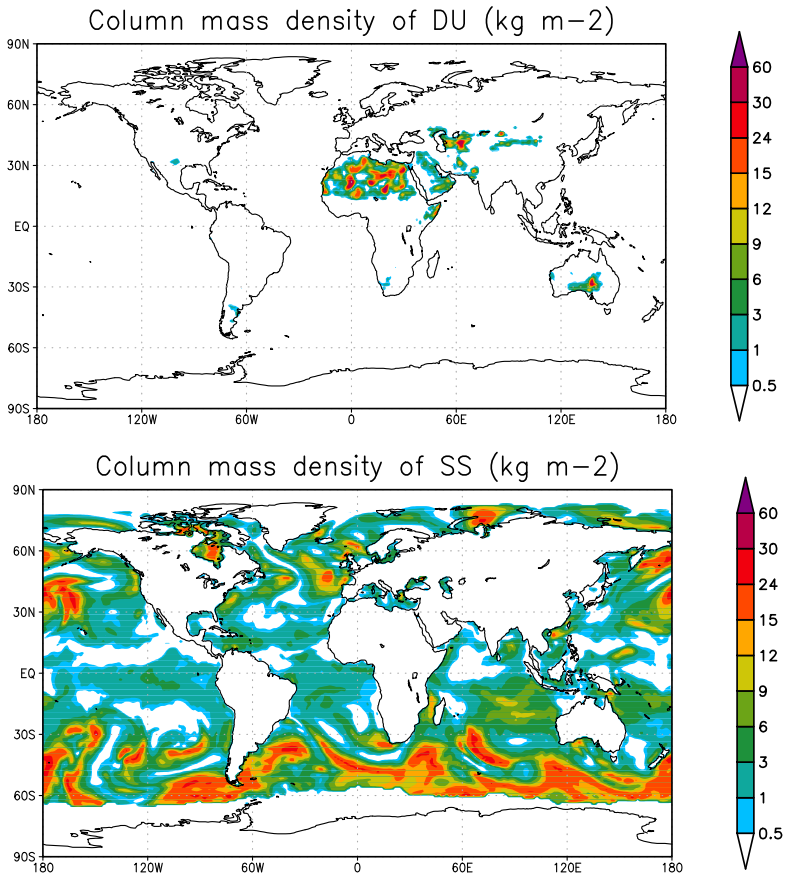


Proposed: Two-way loose coupling

Aerosol fields from low-resolution NGAC run are fed to high-resolution GFS run. This allows aerosol radiative effects in GSM, physical retrievals in RTG_SST, and aerosol attenuation in EnKF-GSI hybrid to be determined from low-resolution NGAC simulations.

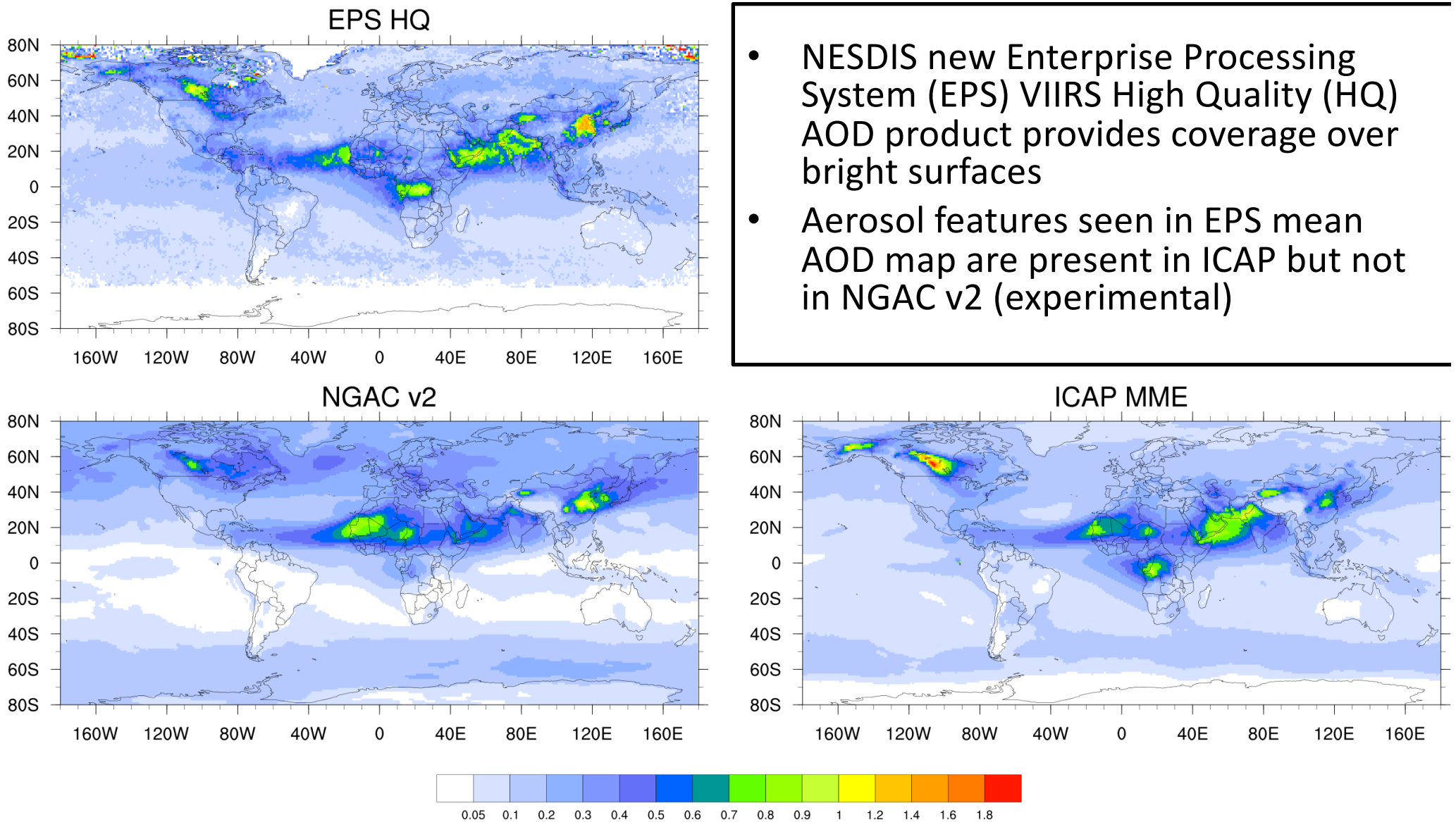
Improving cloud microphysics and their interactions with aerosols in the NCEP global models

- Overarching goal: Improving the representation of aerosol processes, cloud microphysics, and aerosol-cloud-radiation interaction in NCEP global models
- Proposed approaches:
  - Implement GSFC's physically-based aerosol and cloud microphysics package (MAM aerosol scheme and MG cloud microphysics)
  - Tests of the two physics upgrades are conducted individually (uncoupled) initially and will be interactively (coupled)



Dust and sea salt column mass density simulated by Modal Aerosol Model

Concluding Remarks



- NESDIS new Enterprise Processing System (EPS) VIIRS High Quality (HQ) AOD product provides coverage over bright surfaces
- Aerosol features seen in EPS mean AOD map are present in ICAP but not in NGAC v2 (experimental)

Concluding Remarks

- Ongoing efforts:
  - VIIRS AOD data assimilation using GSI and NGAC
  - The prototype system is expected to be ready for testing/fine tuning in Aug 2016
  - Ongoing efforts to investigate the impact of aerosols on NWP and to upgrade the representation of aerosol-cloud-radiation interaction in the model

- Planned activities
  - Ensemble-based DA (UGCS)
  - Assimilate aerosol observations from multiple sources