Status Update on NCEP operational Global Aerosol Forecasting System

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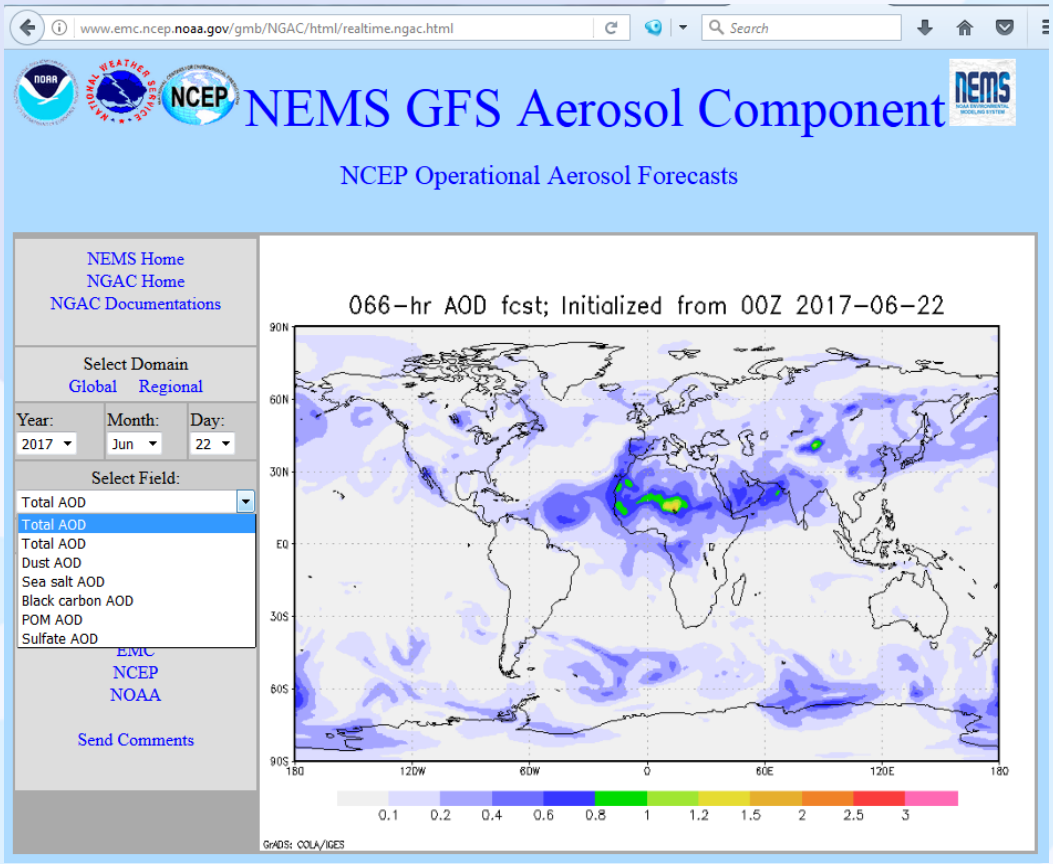
Presentation Outline

- **NGAC implementation in Q2FY2017**
- **Future operational requirements**

Current Operational NEMS GFS Aerosol Component

Current State

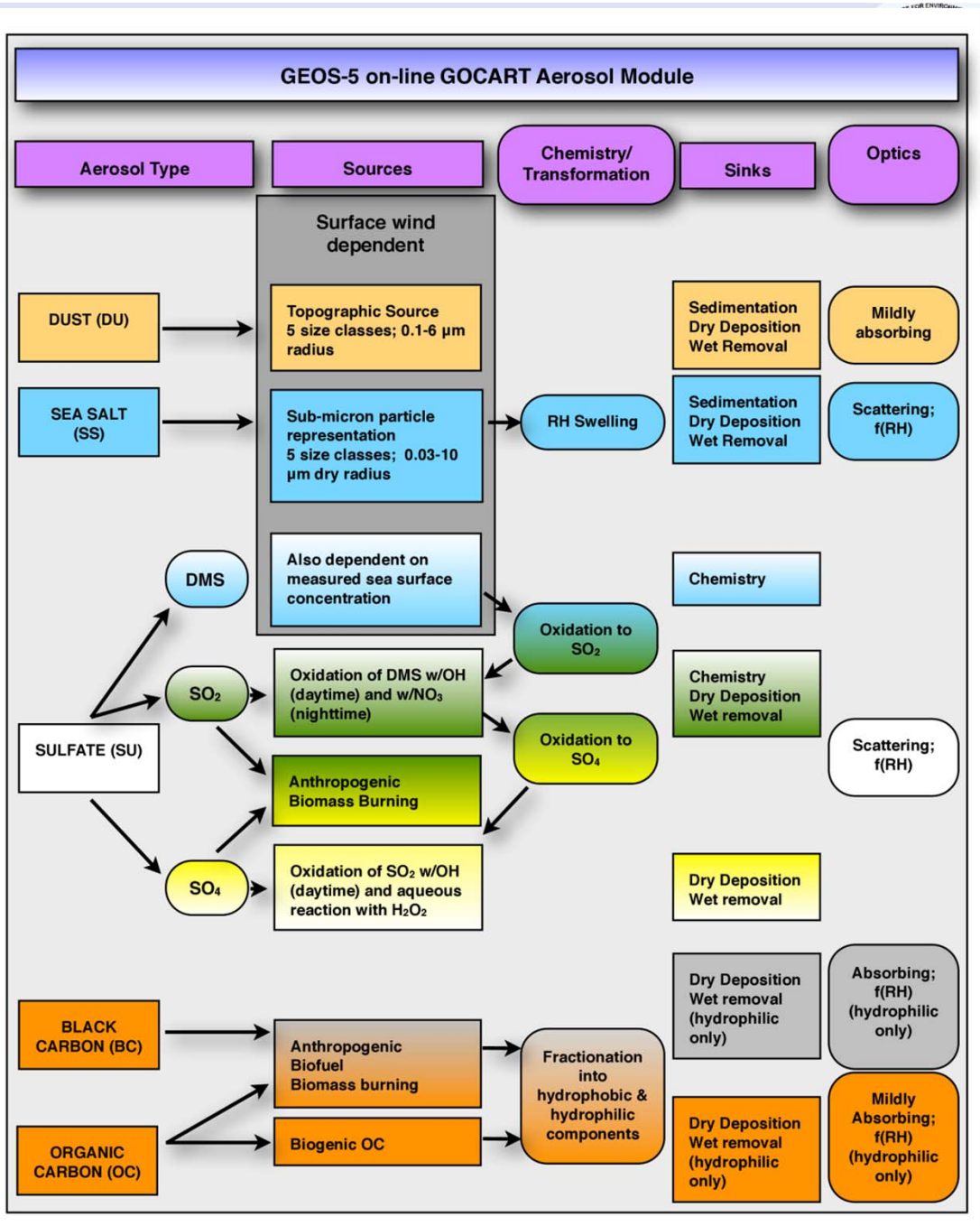
- Near-real-time operational system
- Global in-line aerosol forecast system
- AGCM: NCEP's NEMS GFS
- Aerosol: GSFC's GOCART
- Use near-real-time smoke emissions from satellites (collaborating with NESDIS /GSFC)
- 120-hr multi-species forecast twice per day at 00Z and 12Z, output every 3-hr
- ICs: Aerosols from previous cycle forecast and meteorology from operational GDAS
- Implemented into NCEP Production Suite in March 2017



GOCART Module

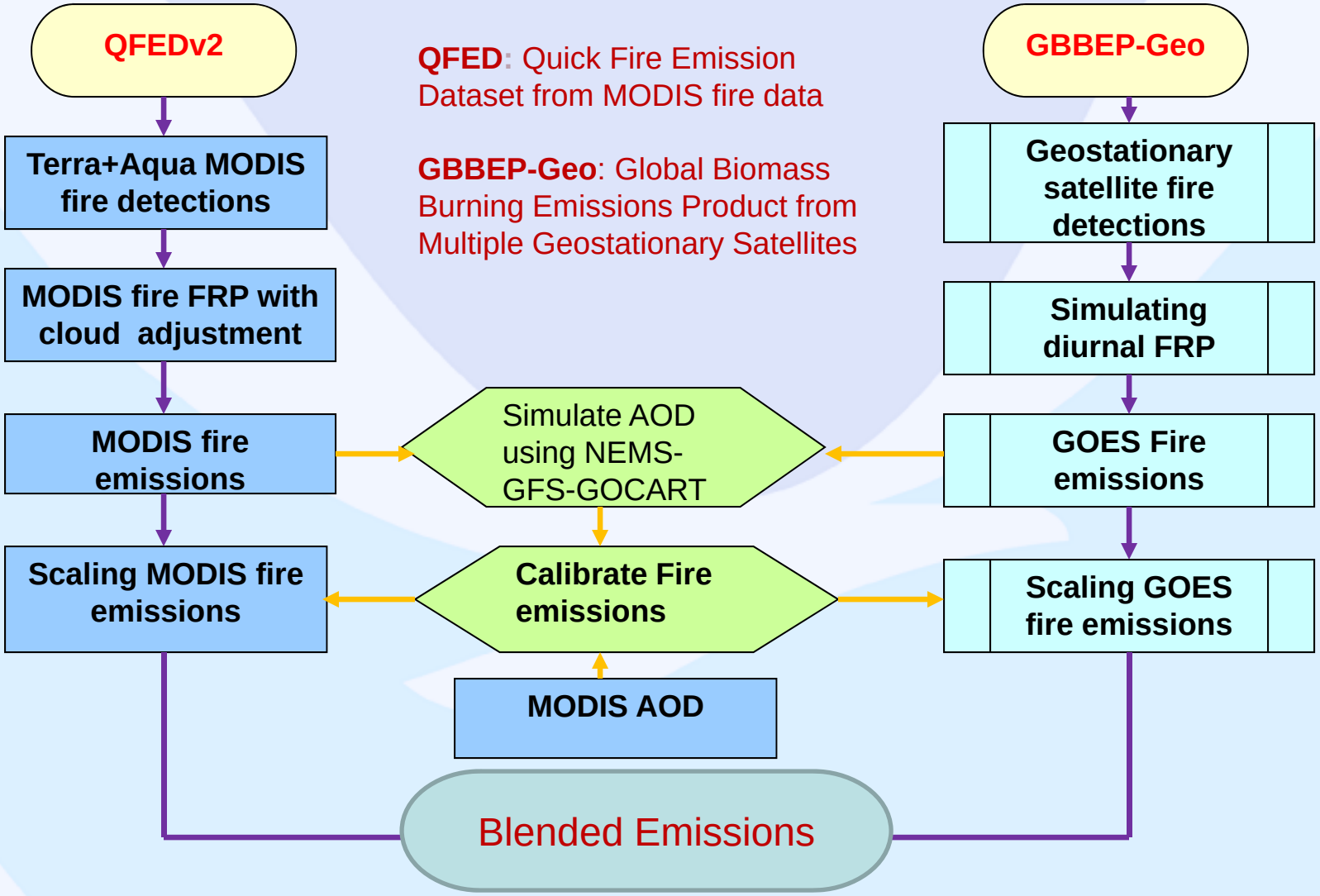
In-line chemistry advantage

- Consistency: no spatial-temporal interpolation, same physics parameterization
- Efficiency: lower overall CPU costs and easier data management
- Interaction: Allows for feedback to meteorology



GOCART diagram provided by Peter Colarco (GSFC)

Flowchart for blended Polar and Geo biomass burning emissions



QFED: Quick Fire Emission Dataset from MODIS fire data

GBBEP-Geo: Global Biomass Burning Emissions Product from Multiple Geostationary Satellites

- Scaling factors are region and biome dependent but static.
- Blended emissions will be generated daily at NESDIS/OSPO for NGAC.
- Scaling factors need to be re-generated only if there is a new satellite replacing an old satellite.

Shobha Kondragunta (NESDIS/STAR)

Q2FY17 Implementation

- **Extend the dust-only system to include sulfate, sea salt, and carbonaceous aerosols**

  - NESDIS - GSFC - NCEP collaborate to develop near-real-time biomass burning emissions GBBEPx
  - Aerosol model was updated to new GOCART version
    - Issues in sulfate chemistry have been identified, prescribed radical/gas distributions and emission inventories have been updated
    - Regional scale factors for OC, BC and SU have been derived from the comparison of GBBEPx and QFED2
  - Atmosphere physics is upgraded to the latest operational GFS physics package:
    - RRTM with McICA radiation package
    - Eddy-Diffusivity Mass-Flux(EDMF) PBL scheme,
    - Land Surface updates: canopy height scheme, soil moisture nudge, roughness length
  - New products to support down stream applications
  - Verification package for monitoring aerosol forecasts
  - **The multi-species aerosol forecast was implemented on Mar 7, 2017**

NGAC Product Suite and Applications

NGAC provides 1x1 degree products in GRIB2 format twice per day

Product files and their contents include:

UV index forecasts **AOD assimilation** **AVHRR SST** **AIRS retrievals**

- **ngac.t$HHz.aod_$CH.grib2, CH=340nm, 440nm, 550nm, 660nm, 860nm, 1p63um, 11p1um**
  - Aerosol Optical Depth (AOD) at specified wavelength from 0 to 120 hour

- **ngac.t$HHz.a2df$FH.grib2, FH=00, 03, 06, ….120, HH=00,12**
  - Total AOD at 0.55 micron
  - Fields from all species: dust, sea salt, carbonaceous aerosols, and sulfate
    - AOD
    - emission, sedimentation, dry deposition, and wet deposition fluxes

Budget, ocean productivity

UV index forecasts

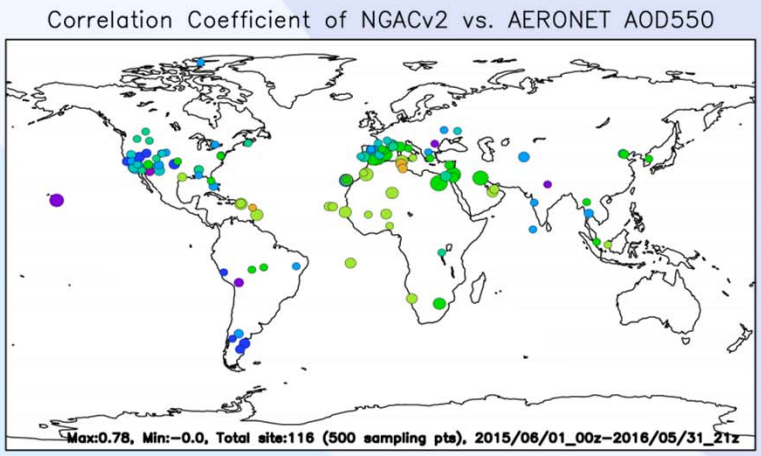
  - Single scatter albedo and asymmetric factor for total aerosols at 0.34 micron
  - *Ångström* Exponent for total aerosols from 0.44 and 0.66 micron

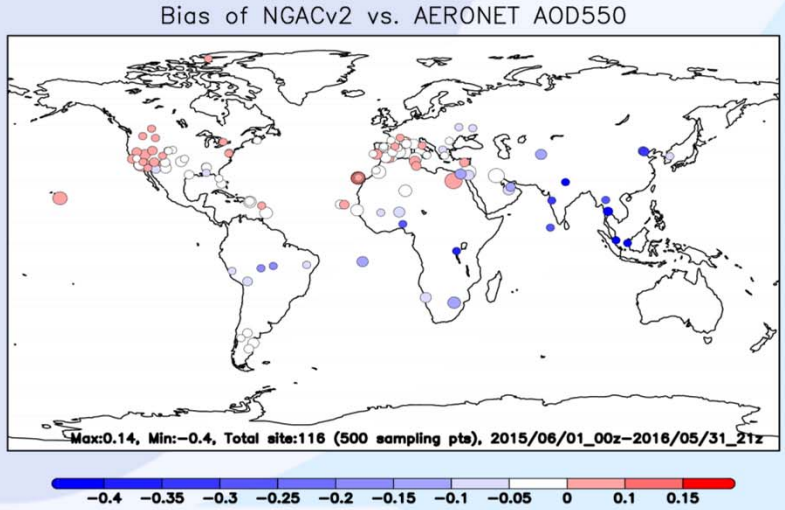
- **ngac.t$HHz.a3df$FH.grib2, FH=00, 03, 06, ….120, HH=00.12** ← **Atmospheric correction**
  - Pressure, temperature, relative humidity at model levels
  - Mixing ratios for aerosol species at model levels

Potential applications for NGAC products are highlighted in red.
New products added by NGACv2 are in pink.

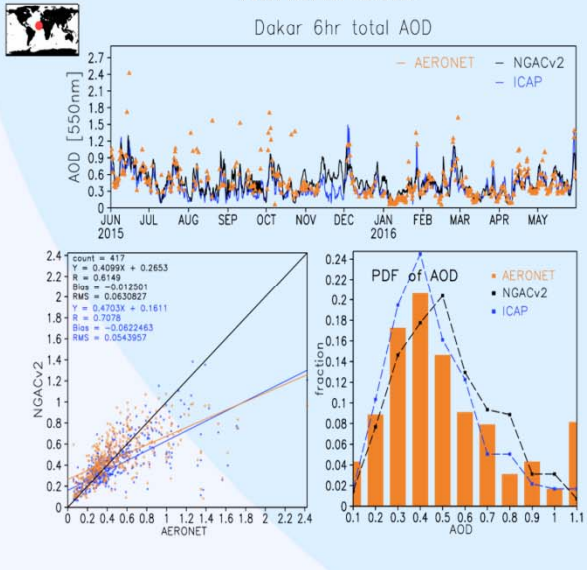
NGAC verification

- Statistics of 2015-2016 NGAC vs. AERONET

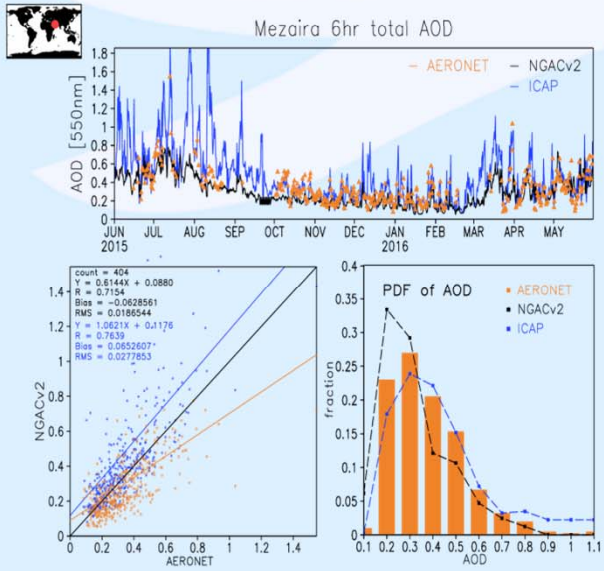




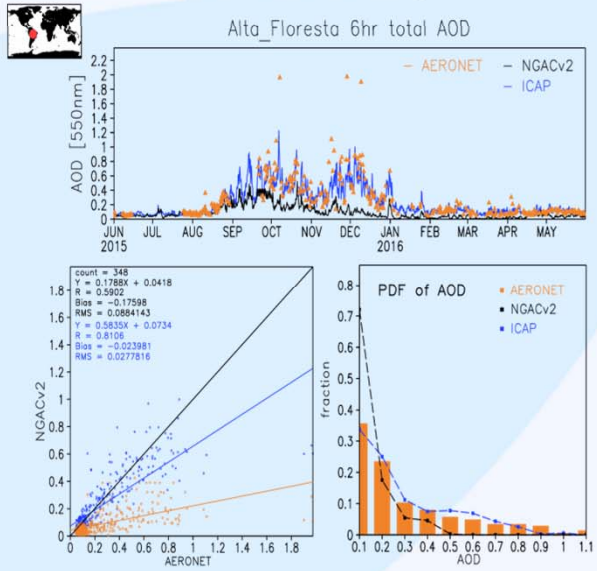
Mineral dust



Arabian dust



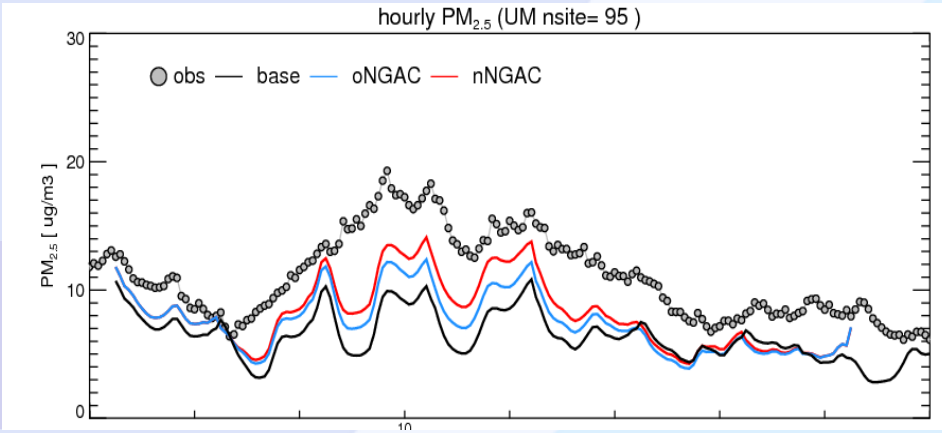
Biomass burning

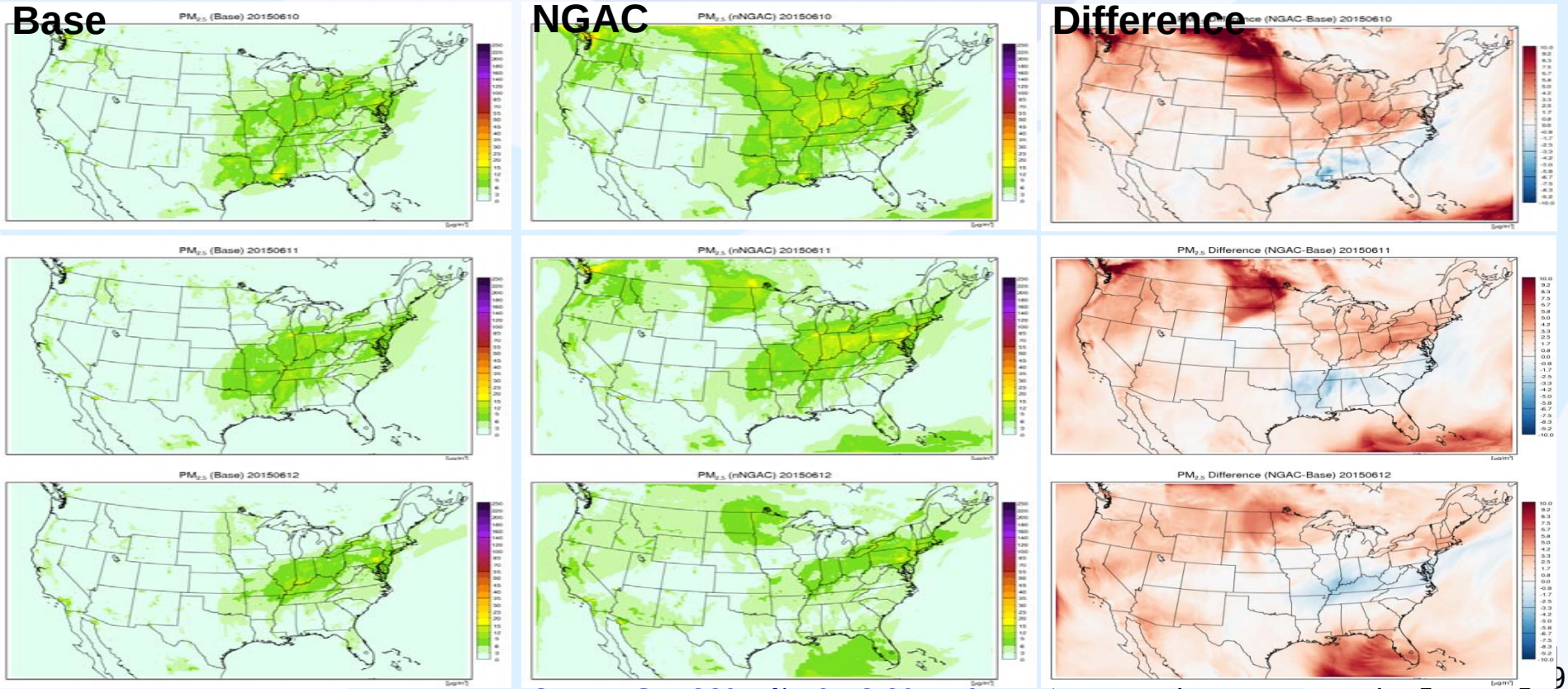


Dynamic LBCs for regional air quality model CMAQ

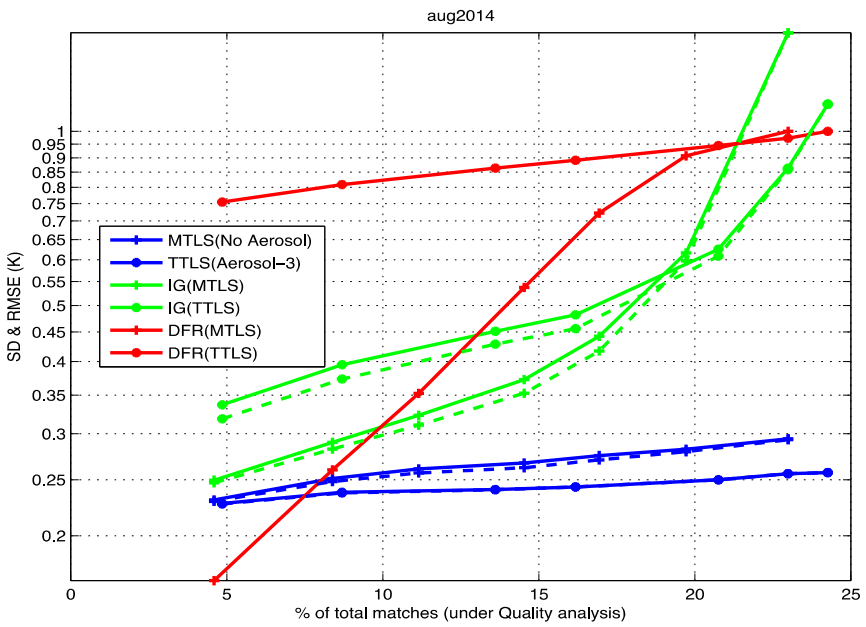
- The inclusion of LBCs from NGACv2 parallel forecast is found to improve PM forecasts.

Analysis of the June 9-12 2015 Canadian fire Surface $PM_{2.5}$ with frontal passages

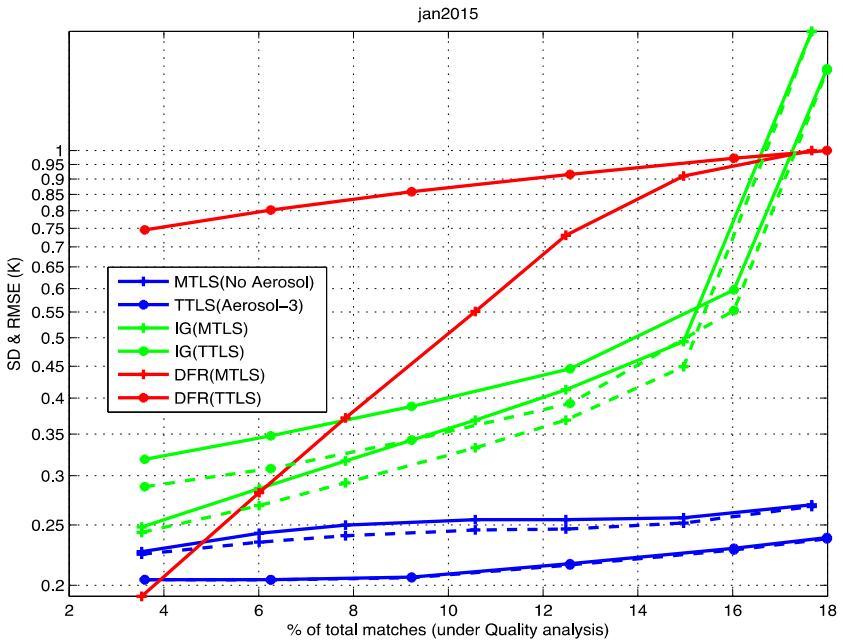




Improving Satellite SST retrieval using NGAC multiple species aerosol forecast



- Retrieval results (night only) for sea surface temperature (SST) are using physical deterministic methods (MTLS and TTLS) from MODIS-AQUA measurement
- **TTLS cannot be implemented without representative aerosol data**

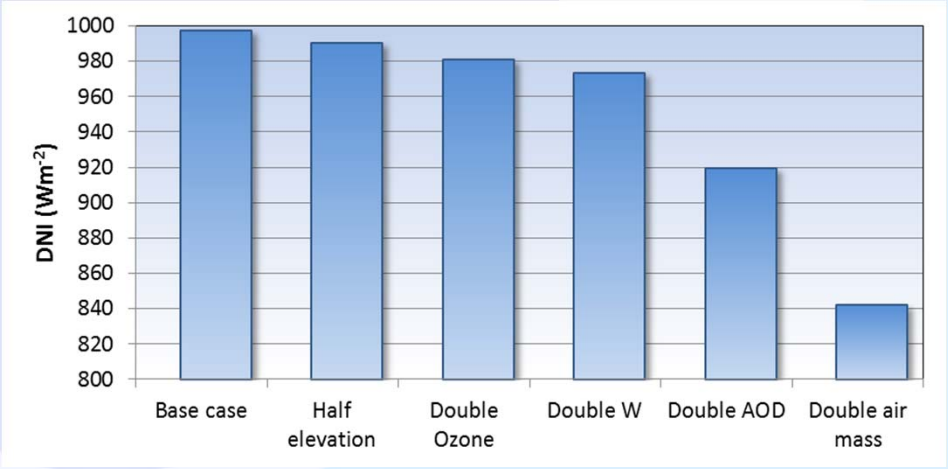


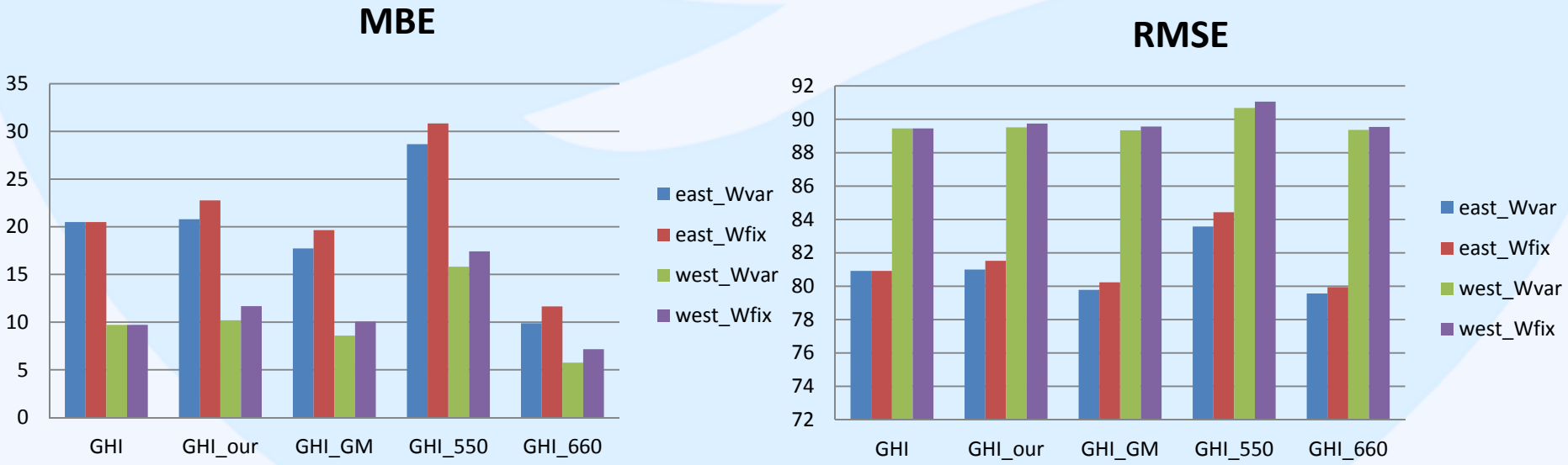
- **There are improvements in SST retrieval on whole data sets using aerosol data, the information content improves drastically.**

Prabhat Koner and Andy Harris

Aerosol impact on solar energy

- Semi-empirical satellite model for solar power shows that Solar power product is sensitive to aerosol
- Using NGAC AOD at 660nm significantly improved the mean bias error in solar power product





Presentation Outline

- Current Operational Configuration
- **Future operational requirements**

Future implementation

- NCEP EMC is in reorganization

- Thirteen NGGPS/Strategic Implementation Plan (SIP) Working Groups have been formed to coordinate the implementation in EMC with input from research community

- Aerosol and Atmospheric Composition SIP WG has identified urgent needs including:

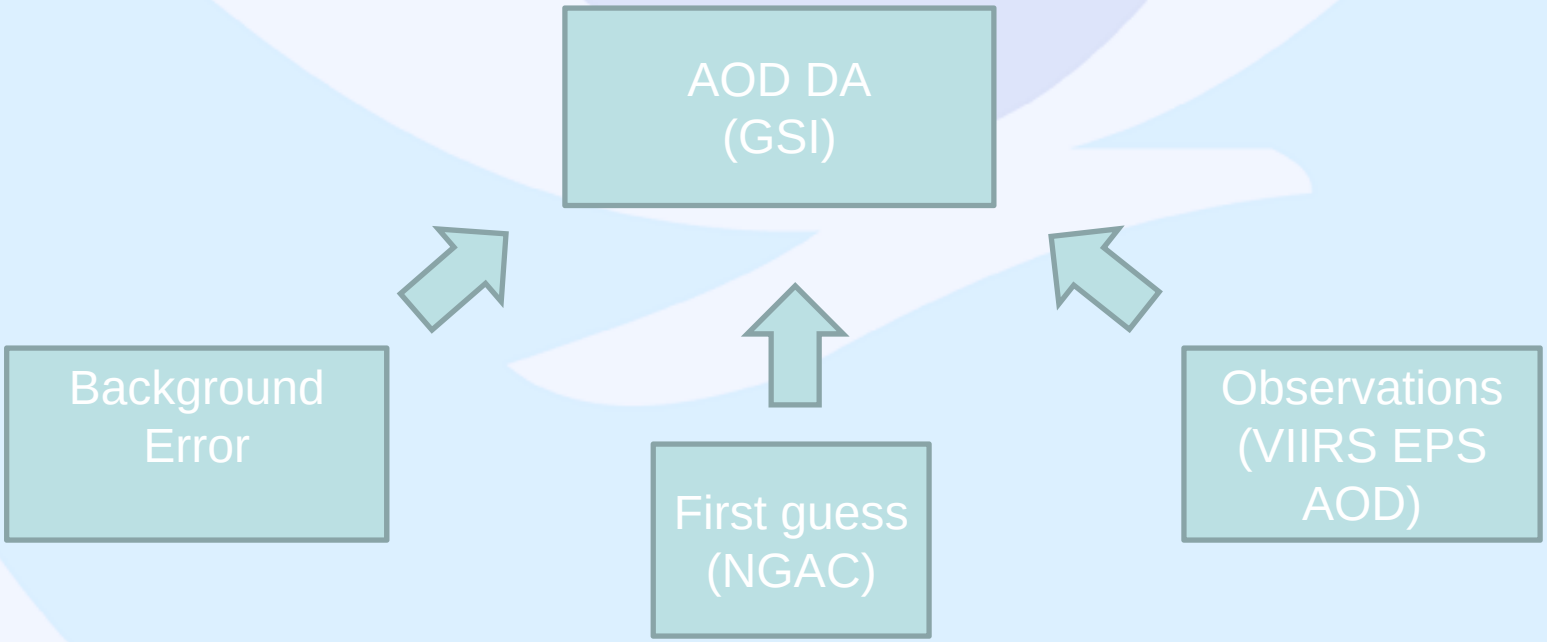
  - A data assimilation system to constrain the atmospheric composition species concentrations and the emissions

  - Unified Coupling Strategy

NCEP global aerosol data assimilation capability

- NCEP's global aerosol forecasting capability has been build upon multi-institute collaborations (NCEP, NASA/GSFC, NESDIS/STAR, and SUNYA)
- JCSDA supports the R&D efforts aerosol data assimilation capability
  - The development of GBBEPx smoke emissions
  - VIIRS data assimilation using GSI 3dVar system.
- The analysis system will be extended to use multi-sensor and multi-platform aerosol observations and evolve to an ensemble-based system

With GSI/CRTM, NCAR and ESRL assimilates MODIS AOD using WRF-CHEM as first guess. We are extending the GSI option to use NGAC as first guess and VIIRS AOD as observation input.



Scientific/Technical Progress

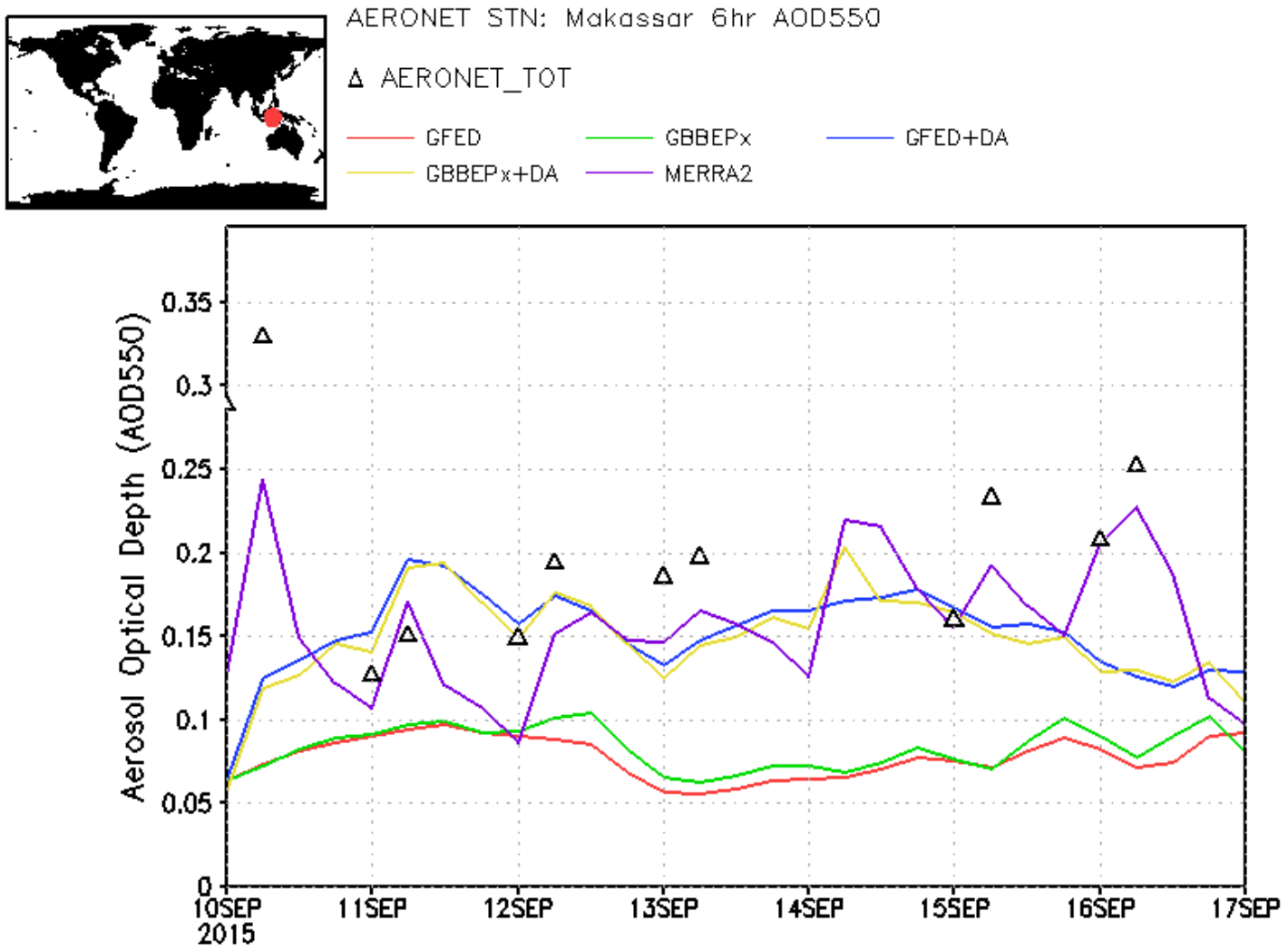
- I/O interface in GSI:
  - GSI code modified to read NGAC first guess and VIIRS AOD
  - Observation thinning for VIIRS AOD is done in reading step
- Specification of background error
  - Calculated using the NMC method
  - Spatial correlation for GOCART aerosol species
- Specification of observation errors
  - Determined from VIIRS versus AERONET comparisons (VIIRS Cal/Val)
- Observation operator
  - Use JCSDA Community Radiative Transfer Model (CRTM V2.2.3)
- Synergistic activities:
  - VIIRS AOD from Enterprise algorithm has been encoded in BUFR format and dumped to a development database at EMC

NGACv2 Experiments

To investigate the effects of aerosol DA on improving aerosol forecasts as well as to document the performance gain resulted from the use of satellite emission information:

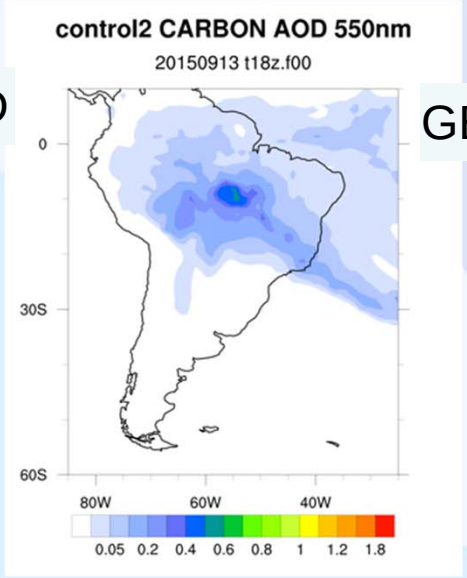
- T126 L64 NGACv2 experiments are conducted using different configuration
  - GBBEPx (NRT smoke emissions), the operational NGACv2 configuration
  - GBBEPx + AOD DA
  - GFED (climatological smoke emissions)
  - GFED + AOD DA
- The experiments cover Sept 10-17, 2015
- The initial condition are taken from EMC's NGACv2 parallel run

Positive impact from AOD DA. With the inclusion of VIIRS data, the errors between NGAC AOD and AERONET AOD are reduced.

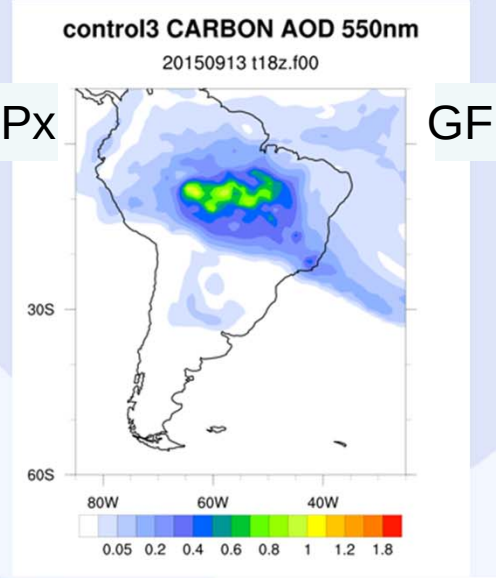


NGACv2 simulations are improved by assimilation of VIIRS AOD and the use of satellite-based smoke emissions.

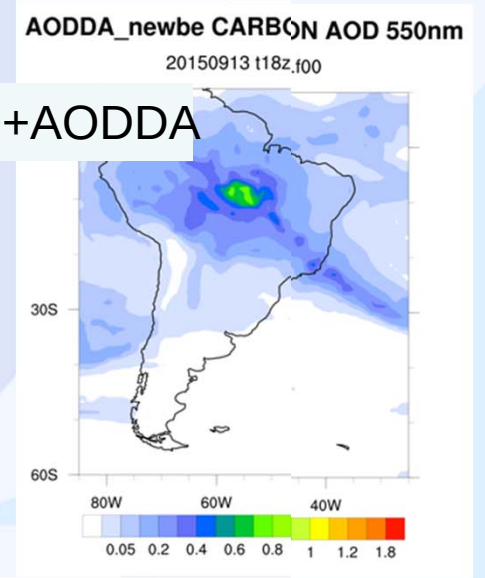
GFED



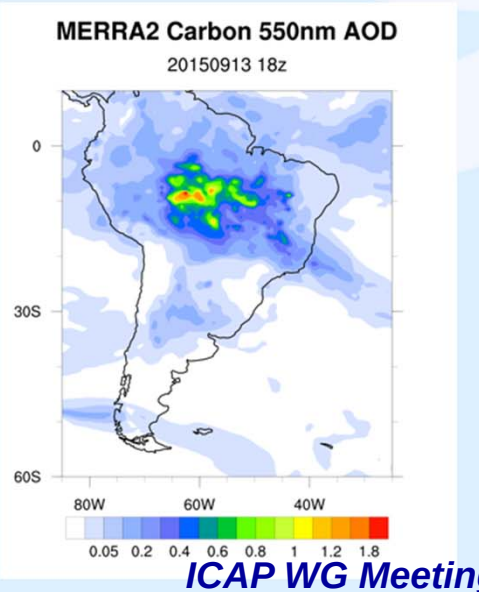
GBBEPx

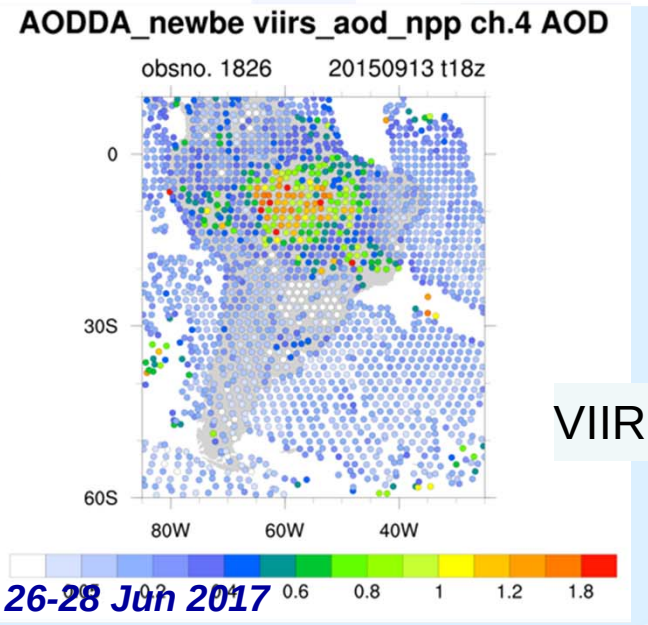


GFED+AODDA



MERRA-2





VIIRS AOD

Summary of NGAC based aerosol DA

- GSI 3DVar aerosol data assimilation system has been extended to assimilate VIIRS AOD using NGAC as first guess.
  - The prototype AOD DA system is being tested and evaluated
  - Ongoing efforts to conduct a benchmark study for an extended time period

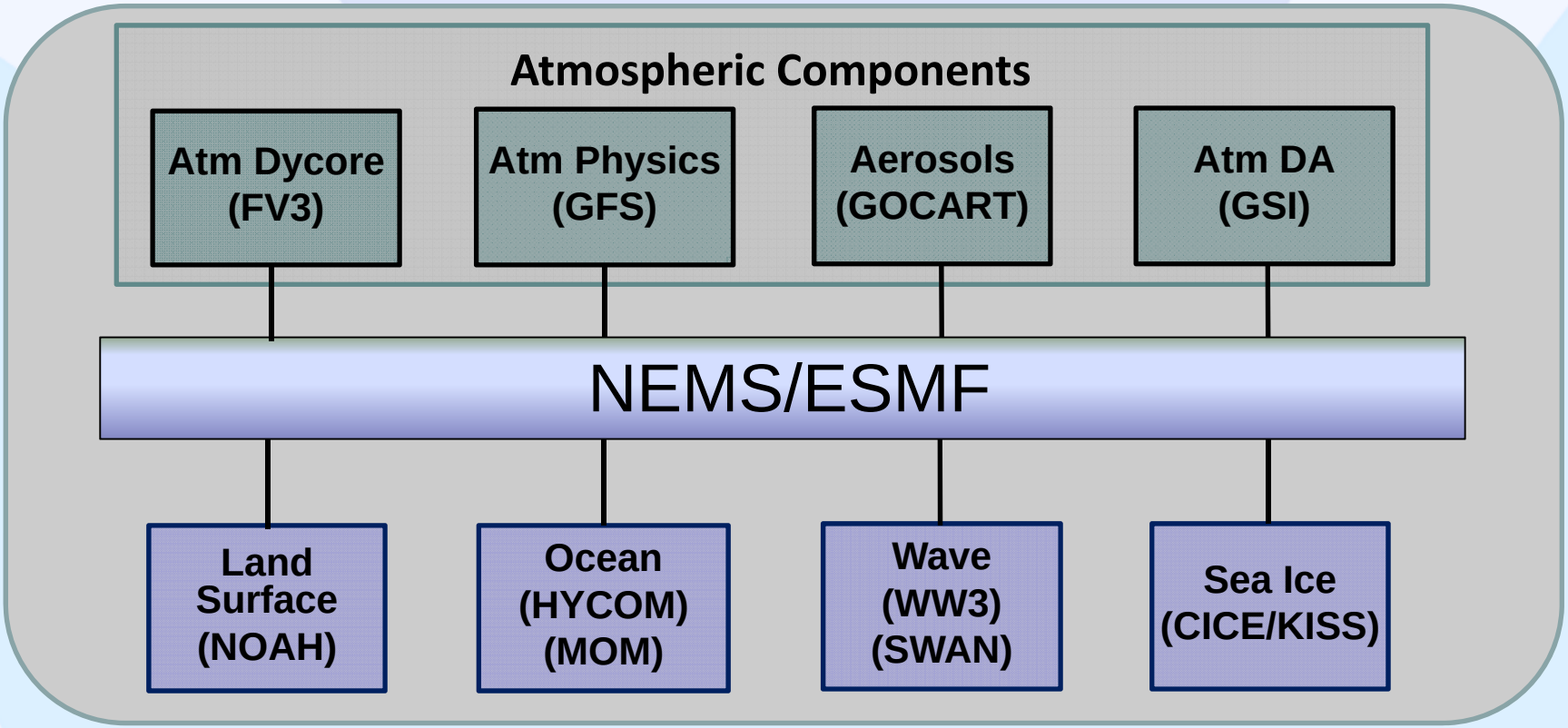
- The assimilation of VIIRS AOD has found to improve NGAC aerosol simulations.

- Sensitivity experiments suggest NRT estimates of smoke emissions also play a critical role.

Integrate Chemistry Component into FV3-based NEMS Coupled System

- Develop a generic chemistry component in NEMSfv3gfs coupled system
- Include chemistry mechanisms
  - GFS ozone physics (currently a Fortran routine in physics)
  - GOCART and MAM7
  - Reduced ozone chemistry
  - CMAQ
  - GEOS-Chem
- Develop workflow for NEMSfv3gfs chem component
  - Retrospective experiment
  - Special event experiment
  - Regression test

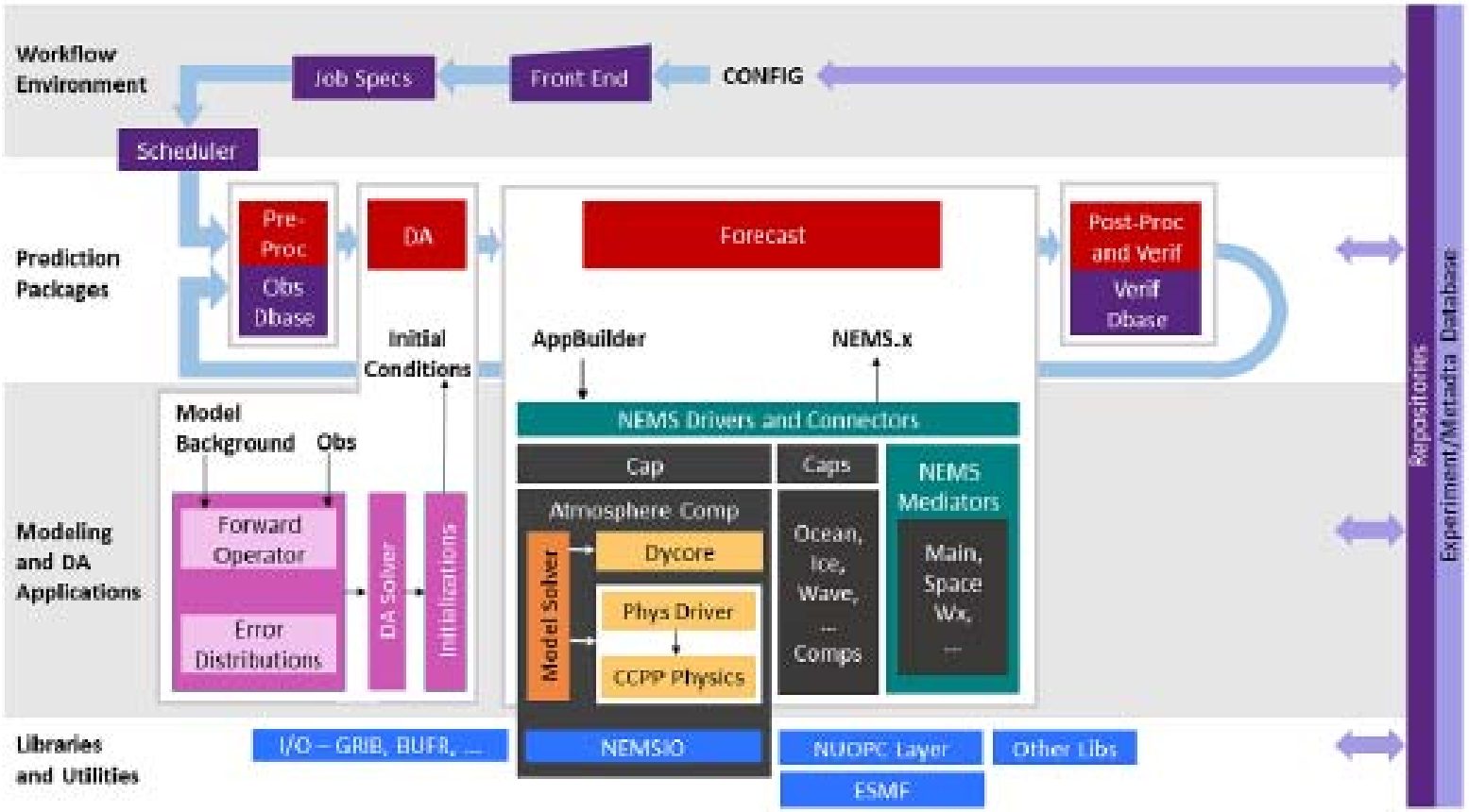
NGGPS Prediction Model Components



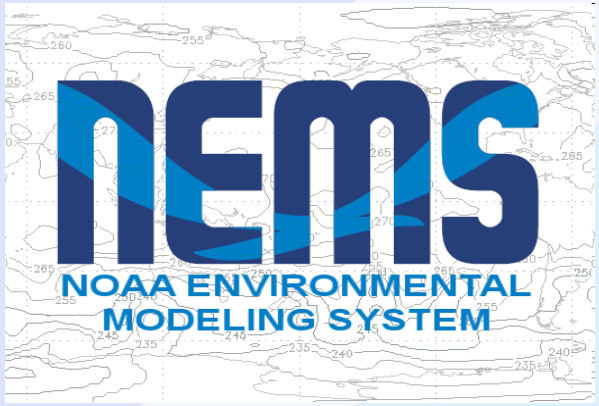
- NGGPS implementation plan development includes an aerosol team
- Development of dust/aerosol capabilities is underway by universities and federal labs

Ivanka Stajner

Unified modeling system architecture for NEMSfv3



Joint efforts in NGAC research and development



NEMS team in EMC:
Atmospheric dynamics and physics
Infrastructure, I/O and post processing
Verification
Documentation

GSFC collaborators (Arlindo da Silva, Peter Colarco, Anton Darmenov, Donifan Barahona, Atanas Trayanov, Mian Chin)

NESDIS collaborators (Shobha Kondragunta, Hanjun Ding, Prabhat Koner, Andy Harris)

South Dakota State Univ (Xiaoyang Zhang)

EMC AQ group (Jeff McQueen, Jianping Huang, Ho-chun Huang, Jerry Gorline)

ARL (Pius Lee, Li Pan)

CPC (Craig Long)

SUNY (R. Perez, S. Kivalov)

ICAP working group

WMO SDS-WAS experts

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Thank You