NCEP operational Global Aerosol Forecasting System
NGAC Q2FY2017 implementation

EMC CCB meeting

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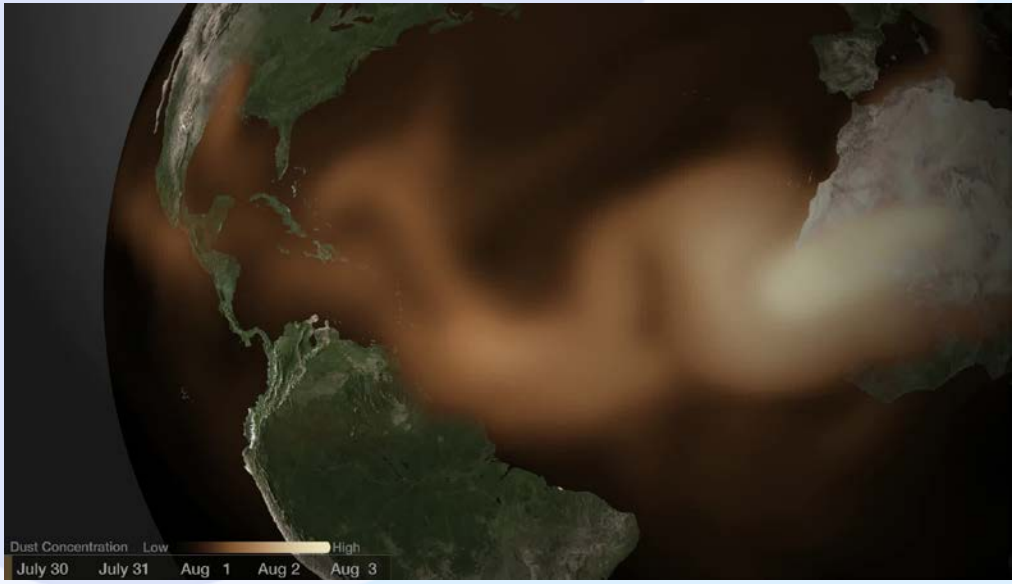
Overview

- Current operational NGAC
- NGAC time line of the project: Quad chart
- Scope of the project
  - Changes and updates since last briefing on March 29, 2016
  - New products
  - Flow chart and resource change
- Implementation planning
  - Model evaluation and verification
  - Downstream application verification

Current Operational NEMS GFS Aerosol Component

Current State

- Near-real-time operational system
- The first global in-line aerosol forecast system at NCEP
- AGCM : NCEP's NEMS GFS
- Aerosol: GSFC's GOCART
- 120-hr dust-only forecast once per day (00Z), output every 3-hr
- ICs: Aerosols from previous day forecast and meteorology from operational GDAS
- Implemented into NCEP Production Suite in Sept 2012.



Ongoing Activities and Future Plans

- Full package implementation (dust, sea salt, sulfate, and carbonaceous aerosols) **FY17**
- Provide lateral boundary condition for downstream regional CMAQ model **FY17**
- Improvement on anthropogenic components
- Aerosol analysis using VIIRS AOD
- Integrate aerosol into FV3GFS
- Provide aerosol information for potential downstream users (e.g., NESDIS's SST retrievals, CPC-EPA UV index forecasts and Solar energy forecast)

NGAC upgrade
Project Status as of: 11/22/2016

G Project Information and Highlights

Leads: Vijay Tallapragada, Jun Wang EMC, Becky Cosgrove, NCO

Scope:

1) Use upgraded NASA GOCART aerosol model and updated NEMS GSM model
2) Extend aerosol species from dust only to multi-species including dust, sea salt, sulfate, organic carbon and black carbon aerosols to provide dust forecast and experimental anthropogenic component forecast using near real global biomass burning emission data GBBEPx
3) Add 12Z cycle forecast

Estimated Benefits:

1) Provide guidance on long range dust aerosol transport and the impact on Particulate Matter (PM) pollution impacting the U.S.
2) Provide dynamic aerosol lateral boundary conditions to regional air quality model
3) Provide multi-species aerosol forecasts to end users for applications such as UV index forecast, SST retrieval and solar energy forecast.

G Scheduling

Milestone (NCEP)	Date	Status
Coordination with SPA team	11/22/2016	Scheduled
EMC testing complete/ EMC CCB approval	11/22/2016	Scheduled
Final RFC submitted to NCO	11/29//2016	Scheduled
Technical Information Notice Issued	12/6/2016	
SPA begins prep work for 30 day test	12/7/2016	
30-day evaluation begins	1/18/2017	
30-day evaluation Ends	2/17/2017	
Management Briefing	2//24/2017	
Operational Implementation	2/28/2017	

G Issues/Risks

Risks:

Mitigation:

G Finances

Associated Costs:

Phase 2 resources: 7 nodes for 30 minutes, 17GB data per cycle

Funding Sources:

R	Management Attention Required	Y	Potential Management Attention Needed	G	On Target

Evaluation from NGACv2 users on Mar 29, 2016

- **Downstream air quality model CMAQ** using NGACv2 as boundary condition shows positive impact. (Jeff McQueen, EMC)

- NGACv2 3D aerosol data improve both accuracy and sensitivity of the **SST physical retrievals**. (Andy Harris and Prabhat Koner, NESDIS STAR)

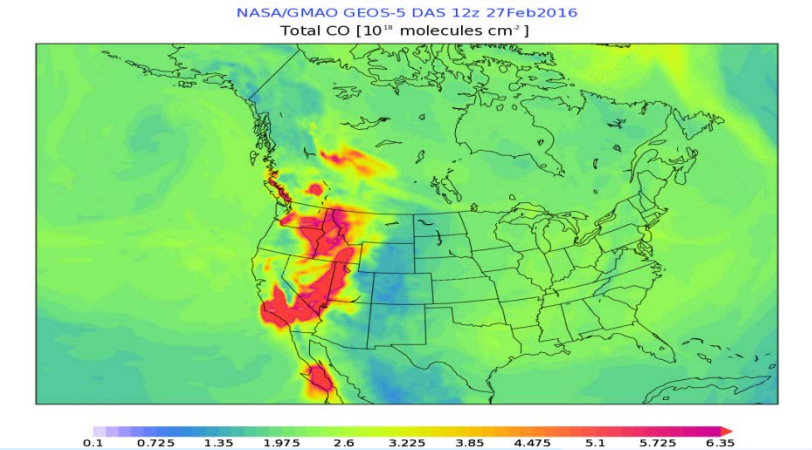
- NGACv2 provides a complete depiction of the aerosol load and the 12Z cycle forecast, this makes it possible for **UV index forecast** to replace current aerosol climatology with the near real time aerosol forecast. (Craig Long, CPC)

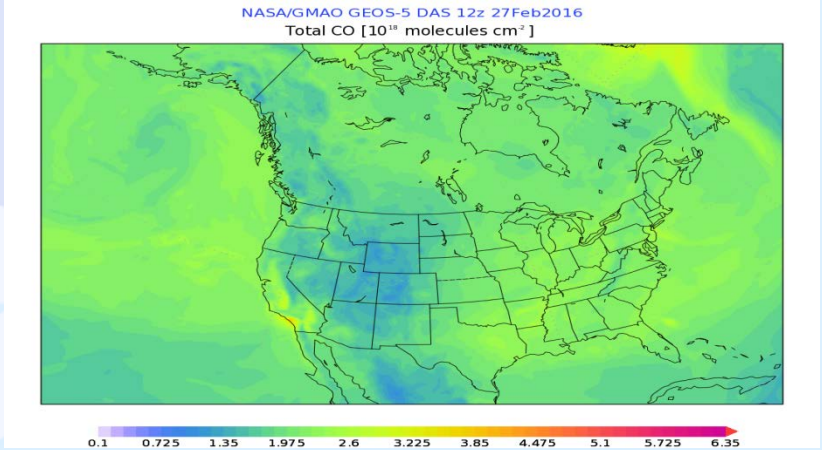
- NRL **ICAP-MME** evaluation noted issues with NGACv2 parallel run:
  - Huge differences relative to ICAP-MME models shown on March 4th NGAC forecast
  - Under/over estimation of smoke in different regions of the world
  - High sulfate values in Europe
  - problems with biomass emission datasets or meteorology fields in NGACV2.0
  - Suggestions include swapping out source functions with those used at NRL and GMAO to see impact of source function or something deeper in the meteorology or microphysics in the atmosphere model

NGACv2 March 4th forecast

- NASA/GMAO confirmed a data problem with satellite Terra from Feb 25 to early March.

http://gmao.gsfc.nasa.gov/news/geos_system_news/2016/elimination_erroneous_biomass-burning.php



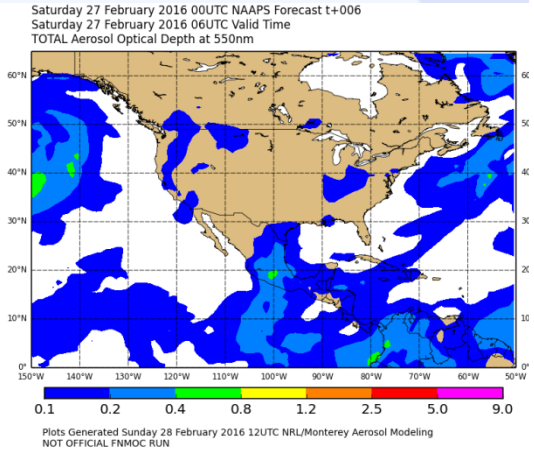


- **NESDIS collaborators confirmed the GBBEPx has unexpected high emissions on February 25 due to Terra malfunction and provided reprocessed GBBEPx biomass emission data**

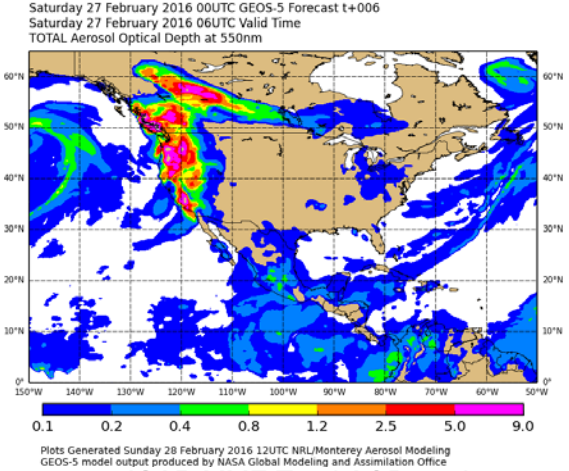
- **NCEP and NESDIS signed up NASA/GMAO operational met data product user list. We will be informed on the satellite malfunction and will regenerate corrected biomass burning emissions and rerun NGAC forecast with the new data.**

Comparison with ICAP forecasts On March 4, 2016

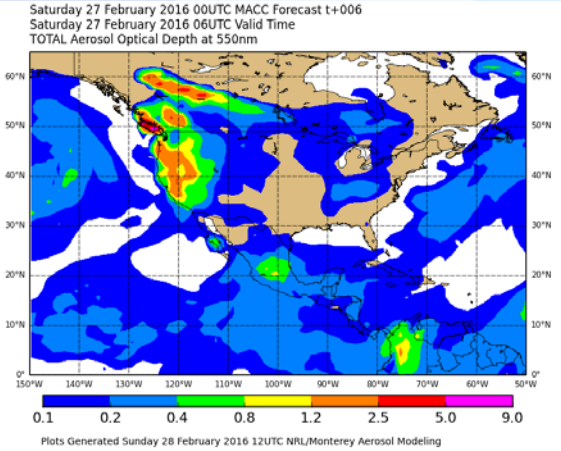
NRL: NAAPS

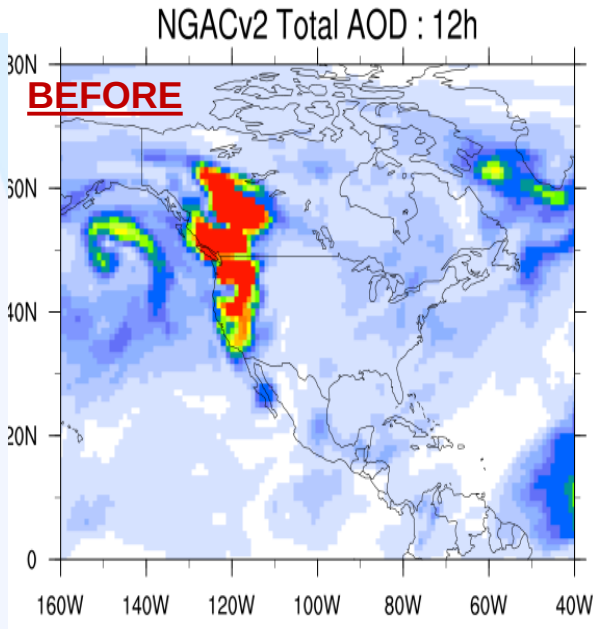


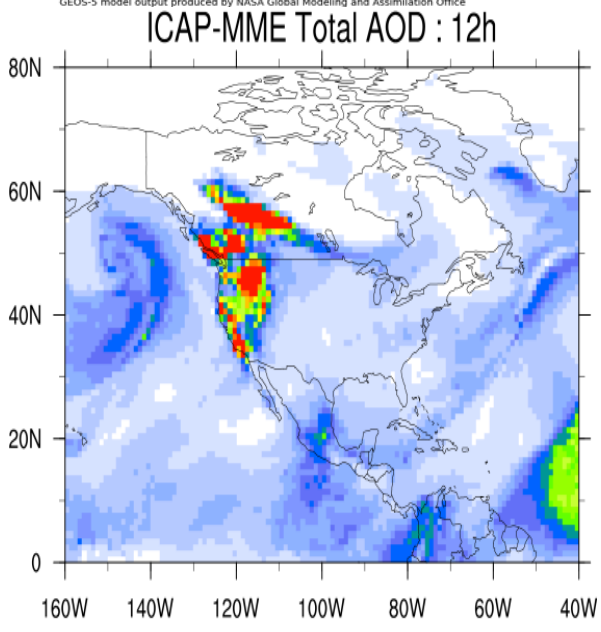
NASA: GOES5

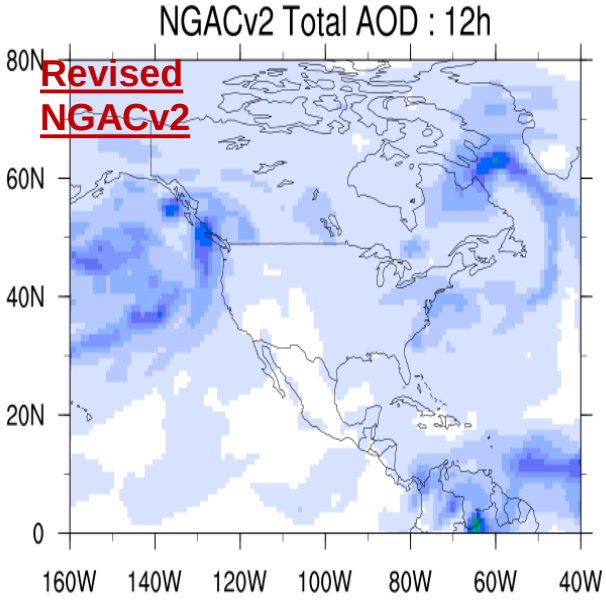


EC: MACC









Identify model and emission issues

- **Review of NGACv2 model source code**
  - NGACv2 GOCART SU component was checked and compared with the latest GEOS 5 (Heracles 5.1 tag). It is confirmed that the two models have same science code.

- **Evaluation of meteorological fields from NGACv2**
  - Meteorological fields from NGACv2 were compared with those fields from high resolution GDAS. It is confirmed that the low resolution NGAC meteorological fields are similar to those from GDAS.

- **3D radical profiles for sulfates**
  - The radical profiles from NGAC V1 are problematic. The units for the radicals are not correct. The 3D radical profiles are generated from the latest GOES5 radical data

- **High sulfate forecasts and emission datasets**
  - Diagnostic experiments using GSFC's QFED2 and NESDIS's GBBEPx (without scaling and without biomass emissions) were conducted. Results show that the high sulfate might have come from the fixed emission datasets
  - All the external emission files in NGAC V2 have been checked and updated to the latest version of GEOS5 except for biomass burning emissions and the dust source functions

Identify model and emission issues Cont.

- **Regional scale factors for biomass emissions**
  - NESDIS compared the GBBEPx with QFED2 and derived regional scale factors for OC/BC/SU
  - Those regional scale factors are applied in the revised NGACv2 model.

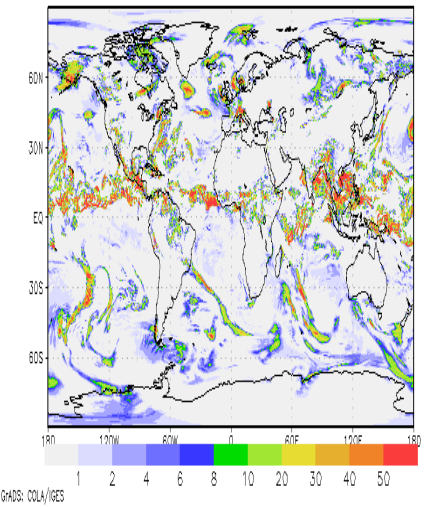
- **False smoke events in North America**
  - There were several false smoke events shown in North America in the smoke season
  - NESDIS made a patch to remove the low quality fire detection data in GBBEPx and implemented the patch into operations in August, 2016.
  - NGACv2 parallel has been updated to use the latest GBBEPx data

- **Impact of revised NGACv2 on downstream users**
  - The revised NGACv2 retrospective runs were generated for 20150601-20160920 and near real-time parallel is started 20160921.
  - The data have been distributed to all the downstream users.
  - CMAQ experiments using NGAC BCs show positive impacts for smoke events compared to using static BCs
  - Solar energy application shows positive impact using NGACv2 660nm AOD

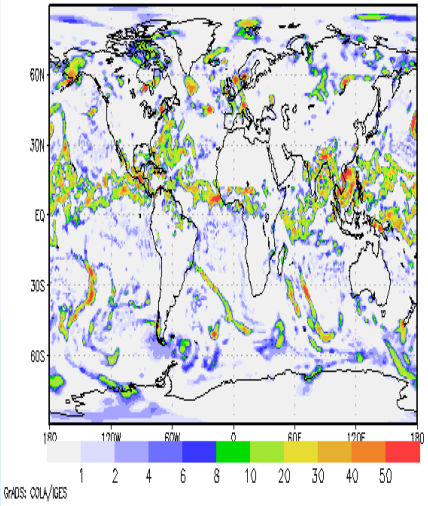
Meteorological field comparison between GDAS and NGAC

- Meteorological fields from NGAC are comparable to those from GDAS

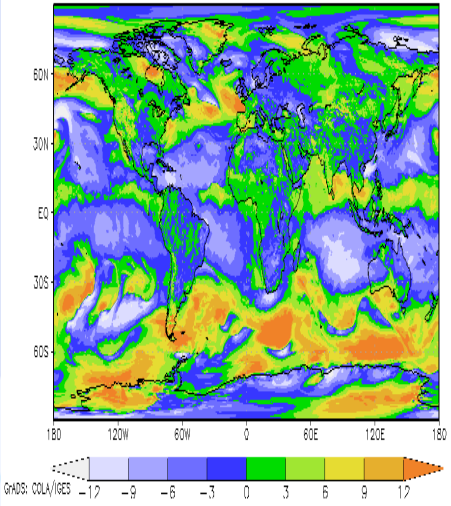
GDAS PRECIP 20150914 fh06



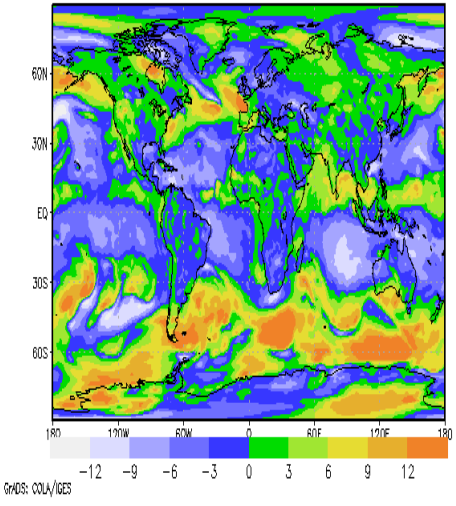
NGAC PRICIP 20150914 FH06



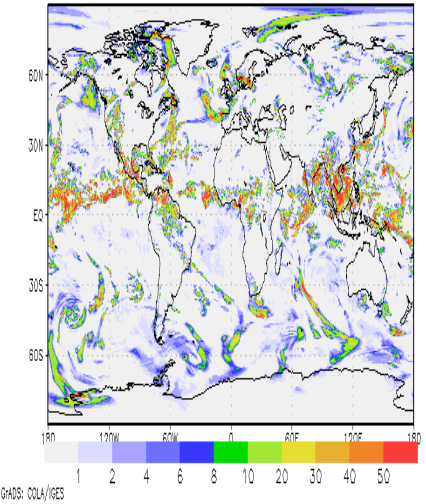
GDAS UWIND 10m 20150914



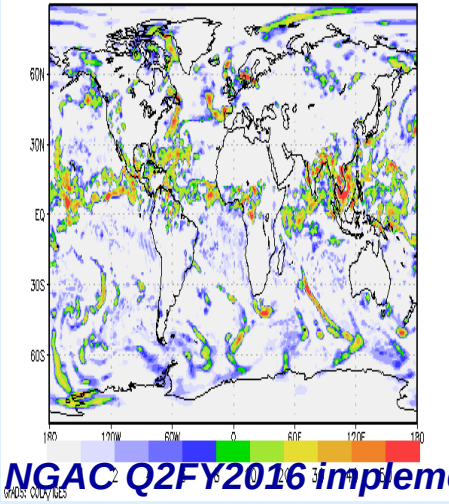
NGAC UWIND 10m 20150913 FH24



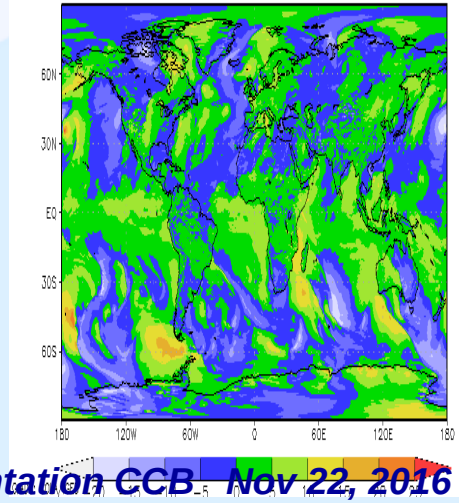
GDAS PRECIP 20150915 fh06



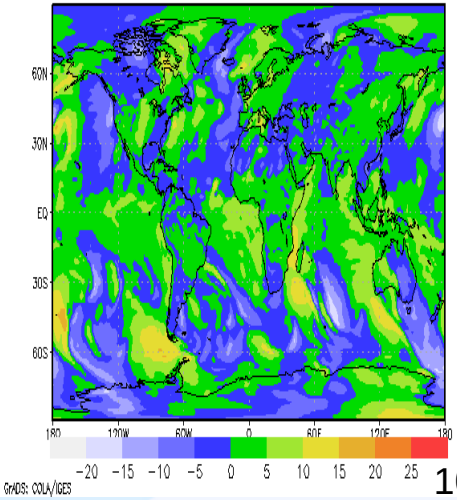
NGAC PRICIP 20150915 FH06



GDAS VWIND 10m 20150914

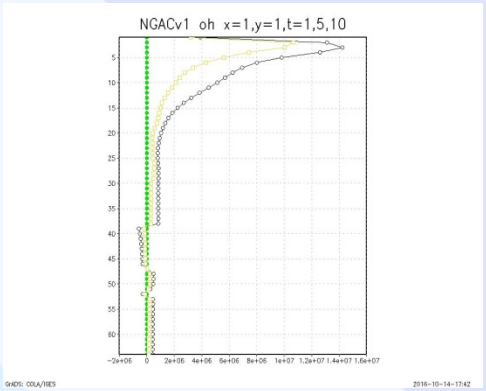


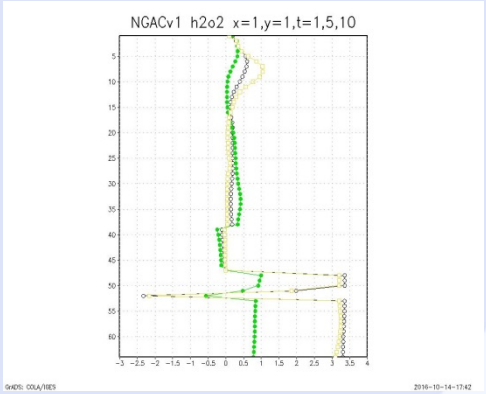
NGAC VWIND 10m 20150913 FH24

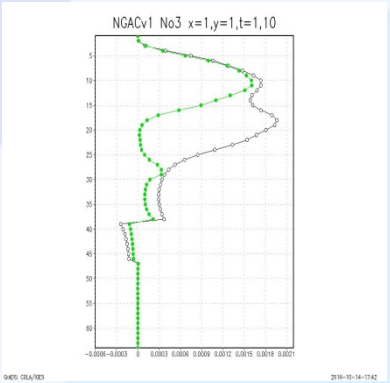


NGACv2: SU radical profiles

NGACv2

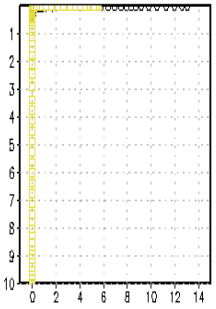




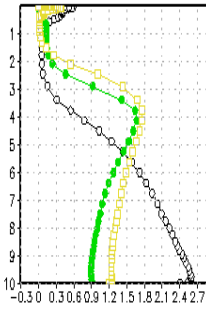


GFSC

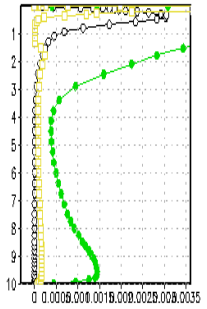
L72; OH x=1,y=1,t=1,5,10, 1.e10



L72; H2O2 x=1,y=1,t=1,5

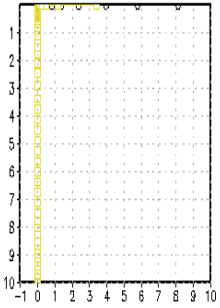


L72; NO3 x=1,y=1,t=1,5,10, 1.e10

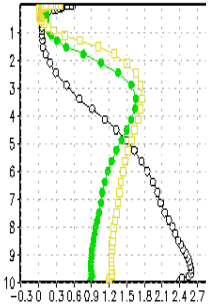


Revised NGACv2

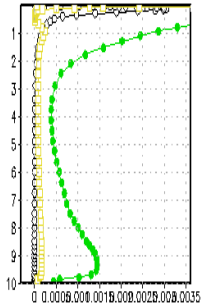
L64; OH x=1,y=1,t=1,5,10, 1.e10



L64; H2O2 x=1,y=1,t=1,5



L64; NO3 x=1,y=1,t=1,5,10, 1.e10



Updated emission files

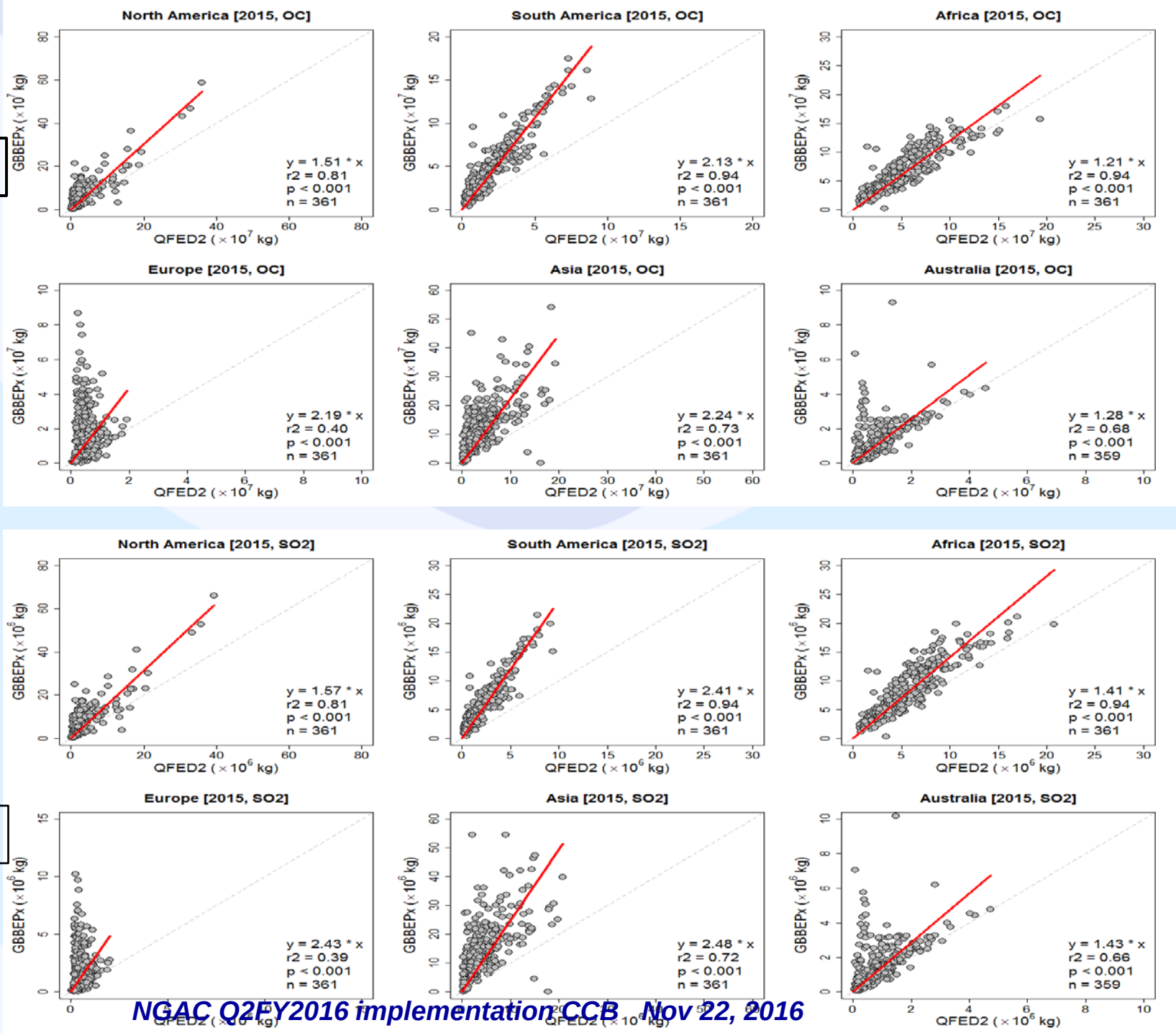
Emissions	NGACv2	Revised NGACv2
Dust	gocart.dust_source.v4a.T126.1971.nc	gocart.dust_source.v4a.xT126.1971.nc
SU_sanl1	bond_streets.anthro_sulfur_src.sfc.T126.2006.nc	EDGAR_v41.nonenergy_SO2_src.sfc.x384_y190.20050703_12z.nc
SU_so2ship	edgar.ship_so2_src.sfc.T126.2007.nc	AeroCom.ship_SO2_src.sfc.x384_y190_t44.19780703_12z_20210703_12z.nc
SU_so4ship	edgar.ship_so4_src.sfc.T126.2007.nc	AeroCom.ship_SO4_src.sfc.x384_y190_t44.19780703_12z_20210703_12z.nc
SU_dmsconc	kettle_chin.dms_sfcconcentration.T126_t12.1971.nc	DMSclim_sfcconcentration.x384_y190_t12.2000.nc
BC_antebc1	bond_streets.anthro_bc_src.sfc.T126.2006.nc	AeroCom.noship_BC_src.sfc.x384_y190_t44.19780703_12z_20210703_12z.nc
BC_ship	edgar.ship_bc_src.sfc.T126.2007.nc	AeroCom.ship_BC_src.sfc.x384_y190_t44.19780703_12z_20210703_12z.nc
OC_terpene	geia.terpene_biogenic.T126_t12.1971.nc	geia.terpene_biogenic.x384_y190_t12.1971.nc
OC_anteoc1	bond_streets.anthro_oc_src.sfc.T126.2006.nc	AeroCom.noship_OC_src.sfc.x384_y190_t44.19780703_12z_20210703_12z.nc
OC_ship	edgar.ship_oc_src.sfc.T126.2007.nc	AeroCom.ship_OC_src.sfc.x384_y190_t44.19780703_12z_20210703_12z.nc

OC

Biomass burning emissions comparison GBBEPx vs QFED2

-regional scale factors are applied in the model

SO2



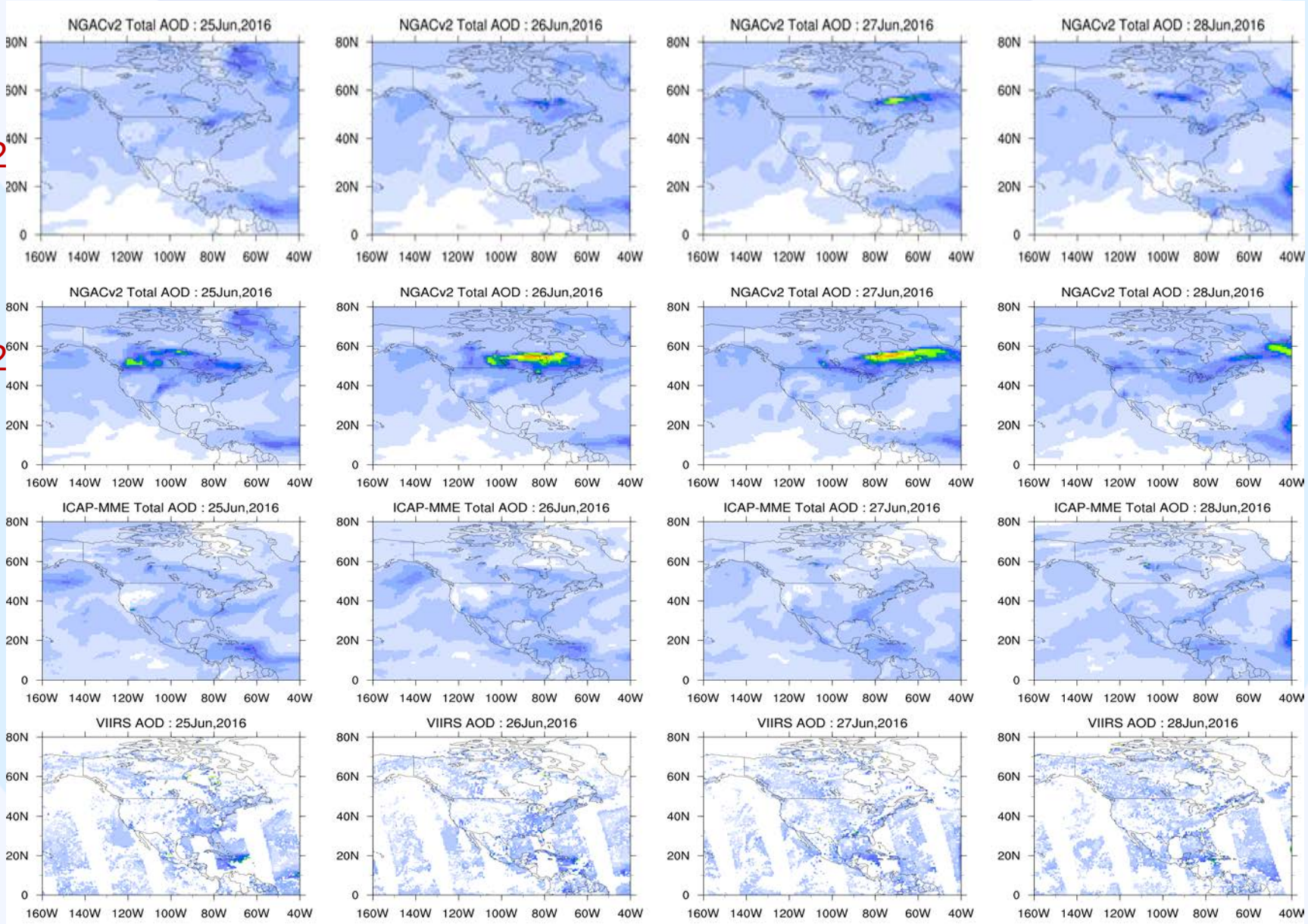
NEDSIS GBBEPx fast track patch implementation

Revised NGACv2

NGACv2

ICAP

VIIRS



Changes and updates

- **Changes to source code**
  - NESDIS compared the GBBEPx with QFED2 and derived regional scale factors for OC/BC/SU, those regional scale factors are applied in the revised NGACv2 model

- **External emissions and radical files**
  - The radical profiles from NGAC V1 are problematic. The units for the radicals are not correct. The 3D radical profiles are generated from the latest GOES5 radical data
  - To resolve the high sulfate forecast, diagnostic experiments using GSFC's QFED2 and NESDIS's GBBEPx (without scaling and without biomass emissions) were conducted. Results show that the high sulfate might have come from the fixed emission datasets
  - All the external emission files in NGAC V2 have been checked and updated to the latest version of GEOS5 except for biomass burning emissions and the dust source functions

- **Biomass burning emissions were updated on Aug 20, 2016 by NESDIS**

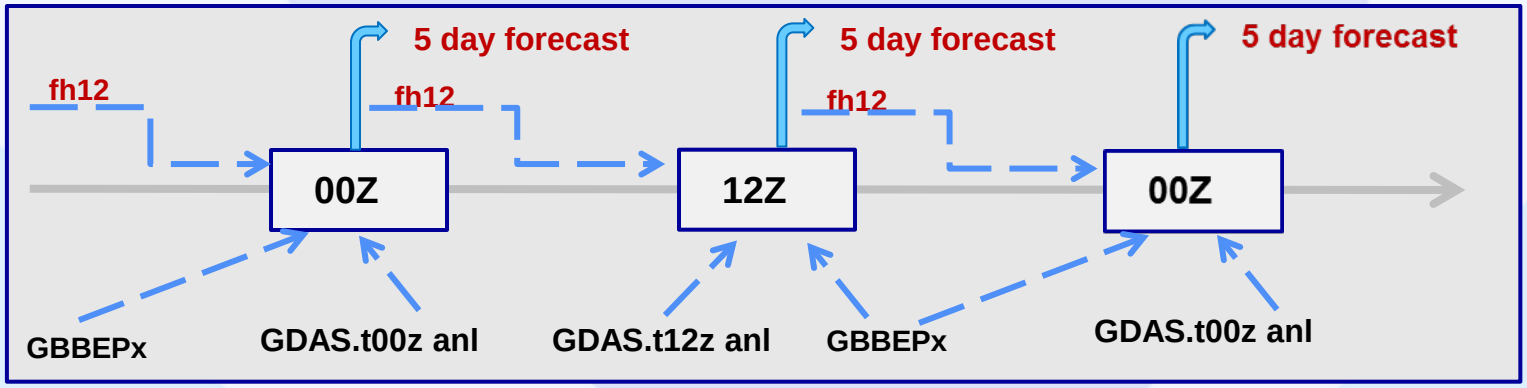
Changes and updates (cont.)

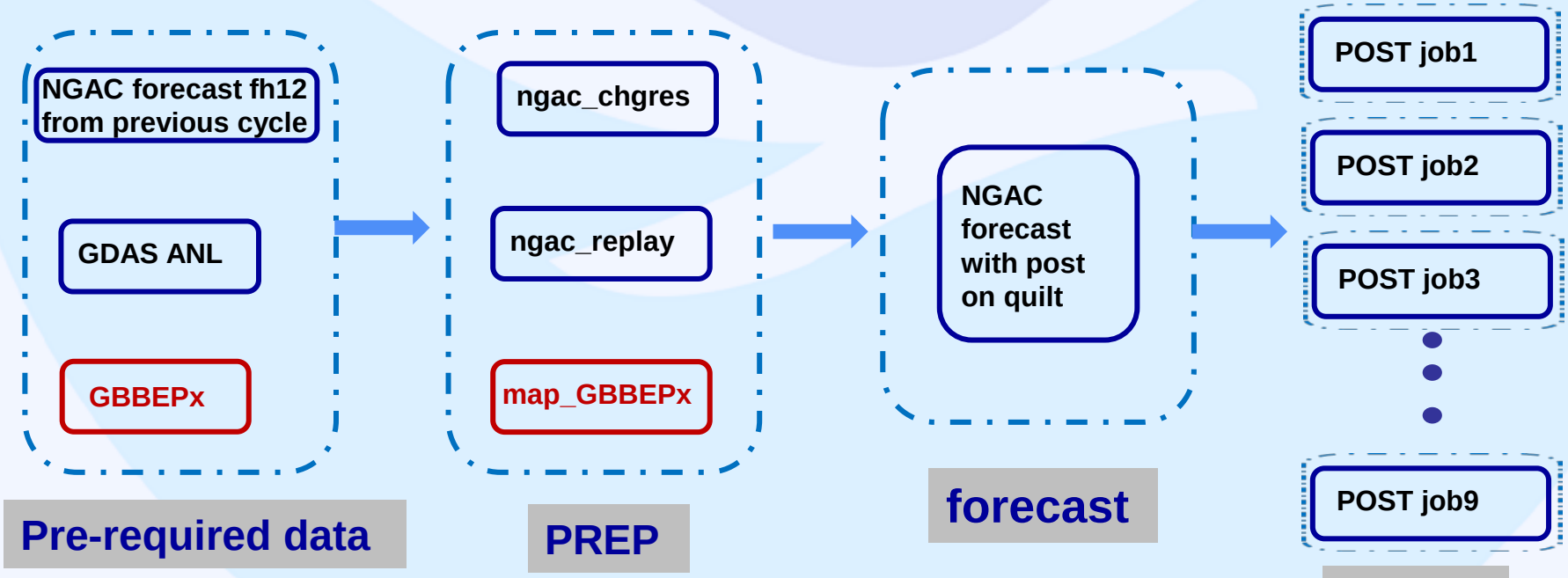
- **Code changes**

  https://svnemc.ncep.noaa.gov/projects/aerosol/branches/nwpara2/ngac.v2.0.0

  - Fix/ngac_fix
    - 3D fields
      - A2_ACCMIP_gmic_MERRA_oh_h2o2_no3.x384_y190_z64_t14.2015.nc
      - AeroCom.aircraft_fuel.eta.x384_y190_L64_t14.2015.nc
    - Surface fields
      - AeroCom.noship_BC_src.sfc.x384_y190_t44.19780703_12z_20210703_12z.nc
      - AeroCom.noship_OC_src.sfc.x384_y190_t44.19780703_12z_20210703_12z.nc
      - AeroCom.ship_BC_src.sfc.x384_y190_t44.19780703_12z_20210703_12z.nc
      - AeroCom.ship_OC_src.sfc.x384_y190_t44.19780703_12z_20210703_12z.nc
      - AeroCom.ship_SO2_src.sfc.x384_y190_t44.19780703_12z_20210703_12z.nc
      - AeroCom.ship_SO4_src.sfc.x384_y190_t44.19780703_12z_20210703_12z.nc
      - EDGAR_v41.energy_SO2_src.sfc.x384_y190.20050703_12z.nc4.nc
      - EDGAR_v41.nonenergy_SO2_src.sfc.x384_y190.20050703_12z.nc4.nc
  - parm:
    - Configure files: BC_GridComp_clim.rc, BC_GridComp.rc, OC_GridComp---full_clim.rc, OC_GridComp---full.rc, SU_GridComp---full_clim.rc, SU_GridComp---full.rc, ngac_config
  - Source code:
    - sorc/ngacv2_fcst.fd
  - Job scripts
    - Scripts/exngac_post.sh.ecf: 9 post jobs

Flow chart of NGACv2.0.1





Resource and time change

- Current NGAC operational: one cycle per day at 00Z
  - NGAC_PREP: 4 tasks, 10 minutes
  - NGAC_FCST: 2 nodes, 25 minutes
  - NGAC_POST: 1 task, 30 minutes
  - Disk space: total 5 GB per day

- NGACv2: two cycles per day at 00Z and 12Z
- For each cycle on phase2:
  - NGAC_PREP: 4 tasks, 10 minutes
  - NGAC_FCST: 6 nodes, 25 minutes
  - NGAC_POST:
    - 9 tasks, 30 minutes
  - Disk space: total 17 GB per day

No change in resource requirements due to additional changes since last briefing on March 29, 2016

Implementation Planning

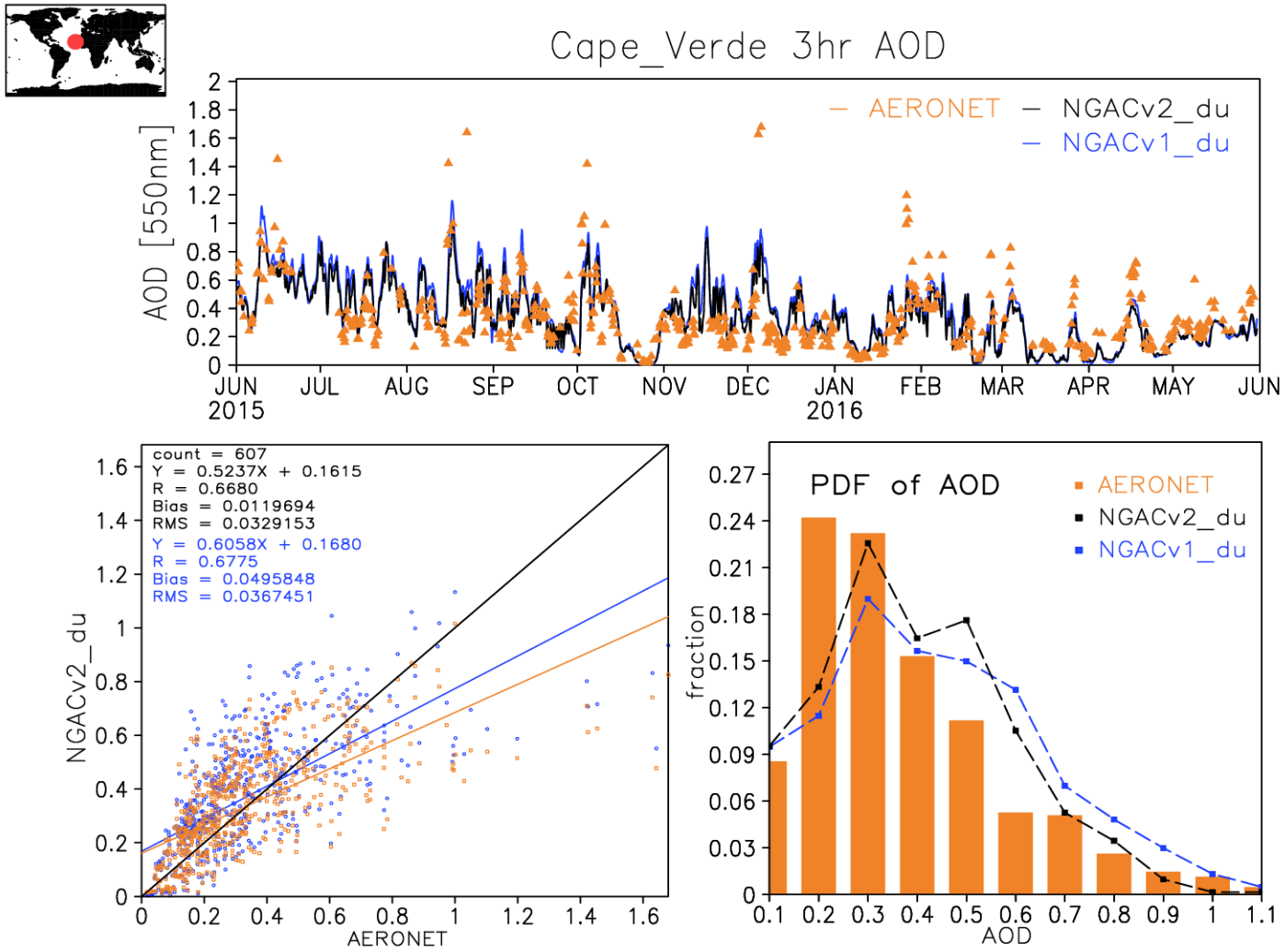
- **Implementation dependencies**
  - Product generation requirements: new aerosol fields are added
  - Library: NCEP post library were RFC-ed

- **Test completed**
  - Prediction model testing
    - NEMS regression tests done
    - Retrospective test from Jun 1, 2015 to Sep 20, 2016
    - Issue was identified in NGAC_v2.0.1 and bugs were fixed and committed in NGACv2_dev3_t1 (frozen code)
  - EMC parallel run starts on Sept. 21, 2016
  - Monthly and daily evaluation of retrospective and parallel run results with Satellite, AERONET and ICAP

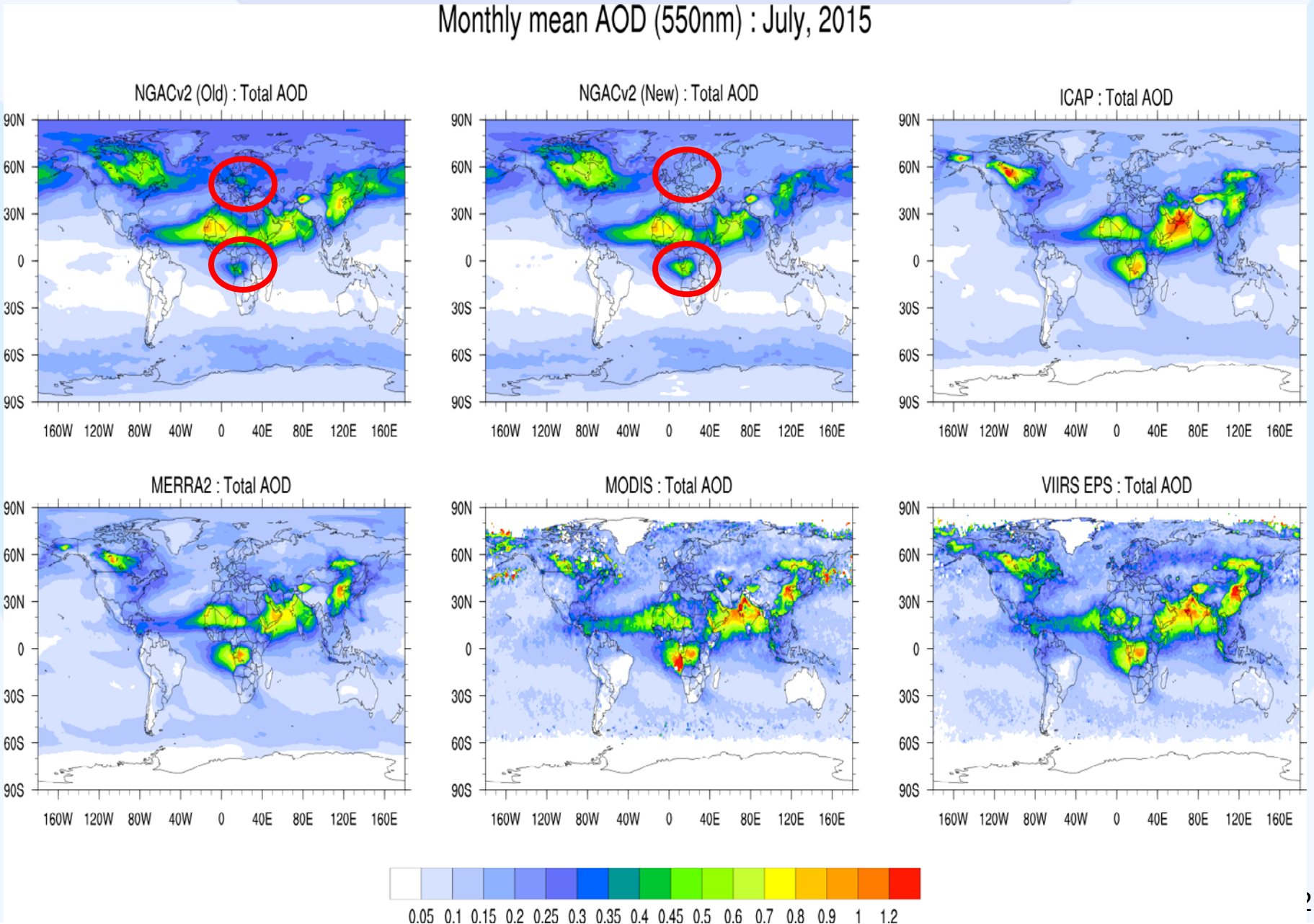
    http://www.emc.ncep.noaa.gov/gmb/NGAC/NGACv2

- **Downstream applications**
  - Retrospective and near real time run results were shared with downstream applications
  - Regional air quality model CMAQ using NGACv2 as boundary conditions
  - SST retrieval test using NGAC multi-species aerosol forecast
  - Solar energy forecast using NGAC 660nm AOD
  - UV index forecast using NGAC 340nm AOD

In-situ statistics



High sulfate forecasts and emission dataset

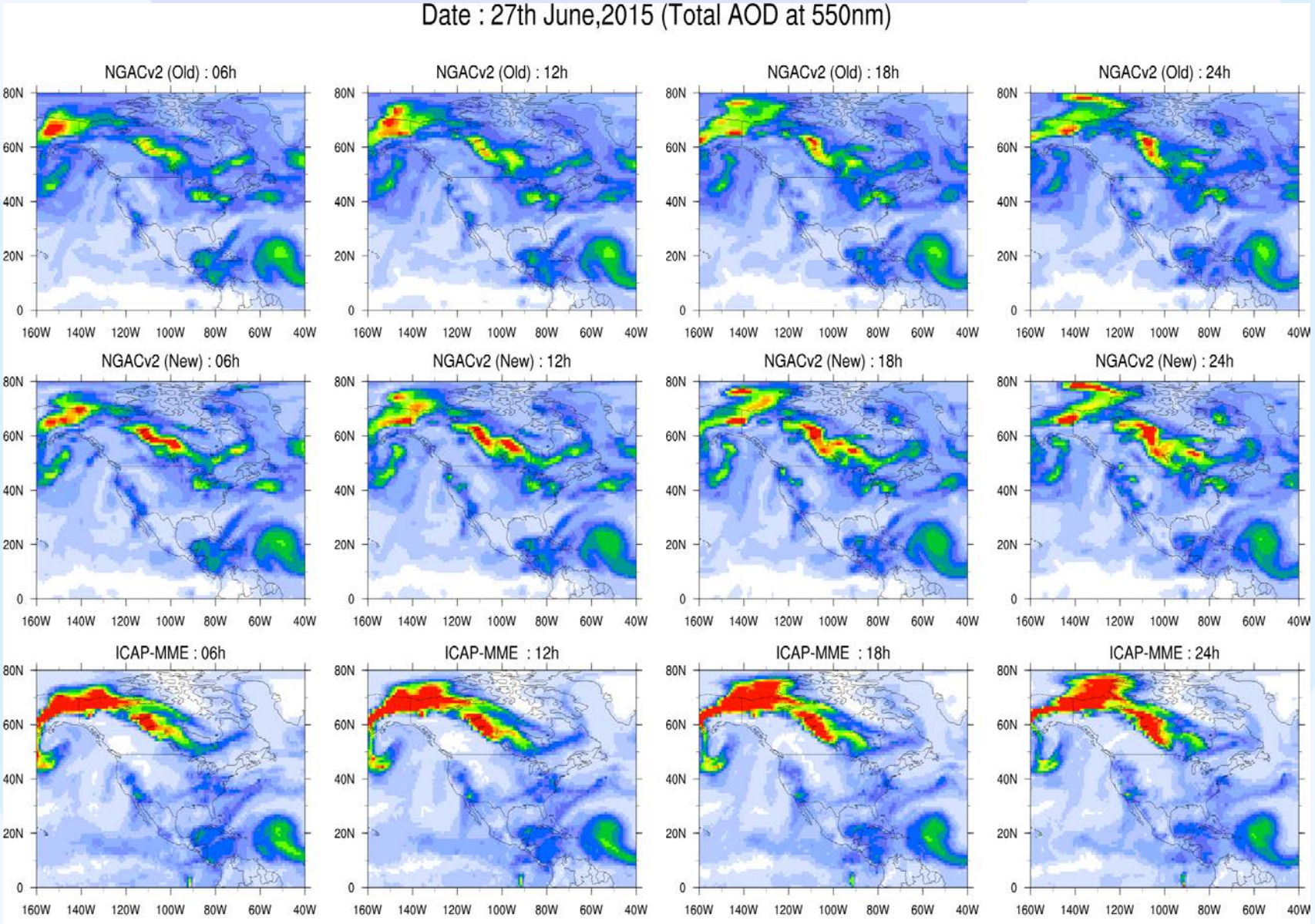


Smoke event on Jun 27-Jul 1 2015

NGACv2

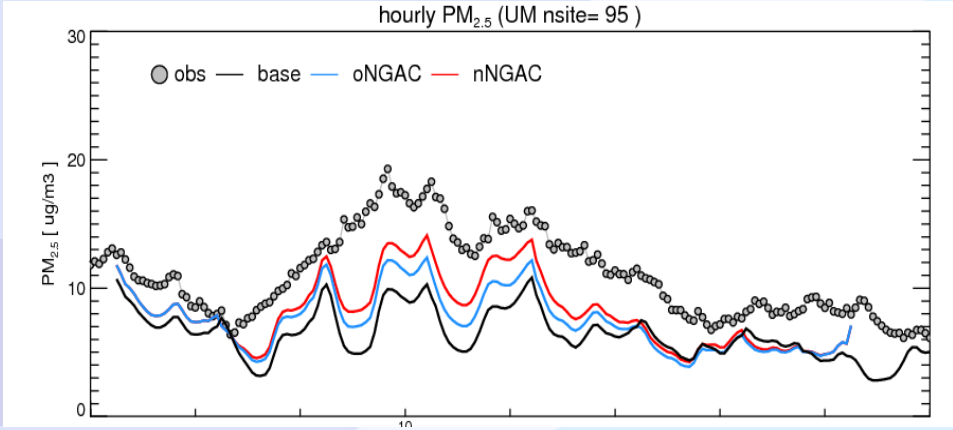
Revised NGACv2

ICAP



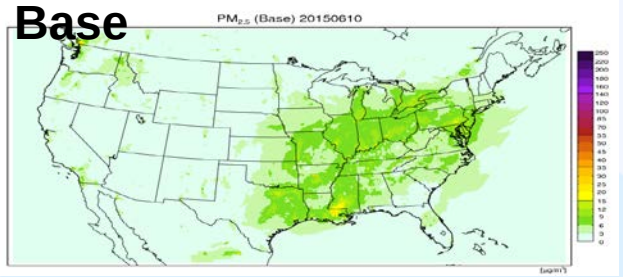
Dynamic LBCs for regional air quality model CMAQ

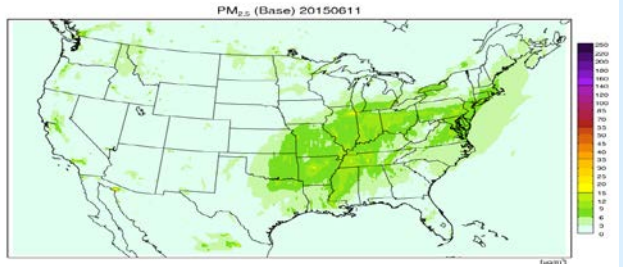
- The inclusion of LBCs from NGACv2 parallel forecast is found to improve PM forecasts.



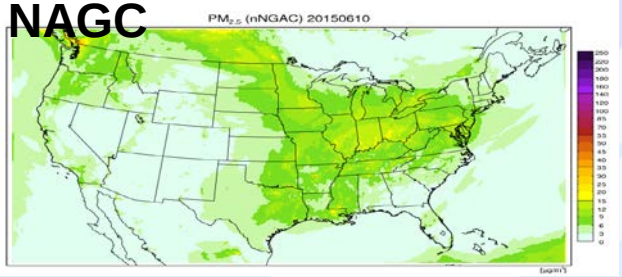
Analysis of the June 9-12 2015 Canadian fire Surface $PM_{2.5}$ with frontal passages

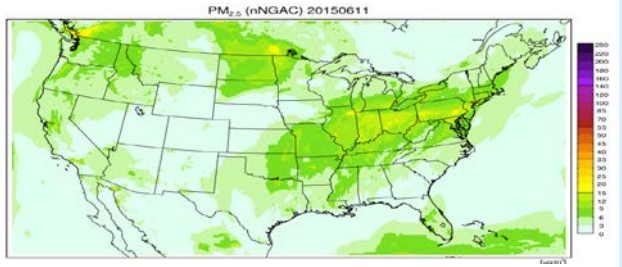
Base

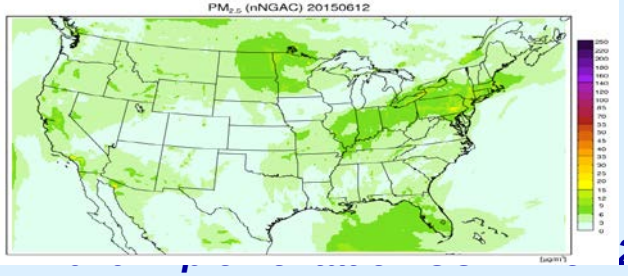




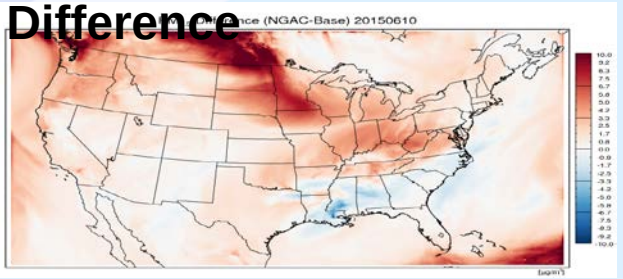
NAGC

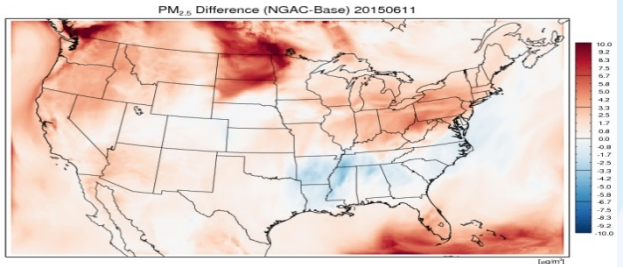


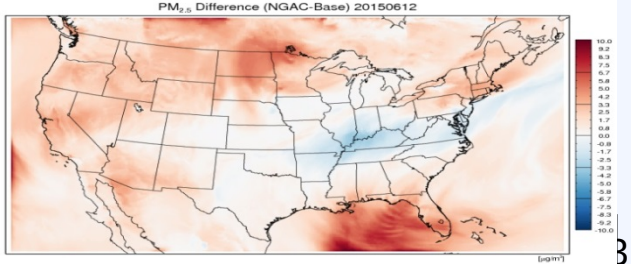




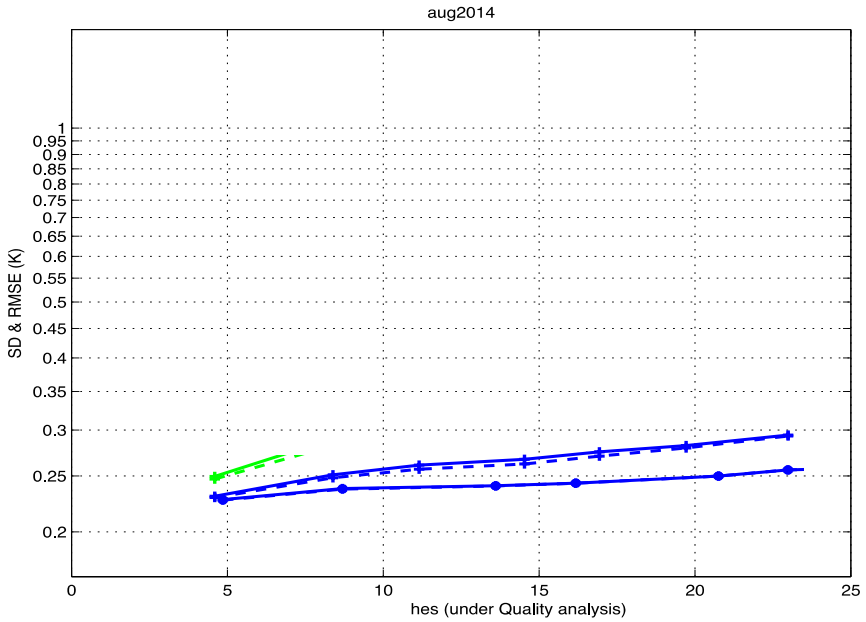
Difference



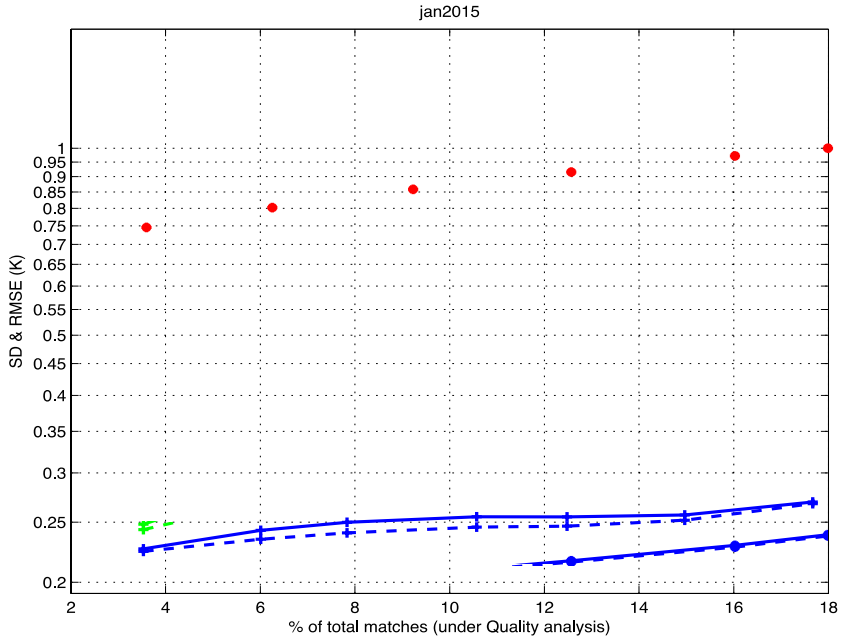




Improving Satellite SST retrieval using NGAC multiple species aerosol forecast



- 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**

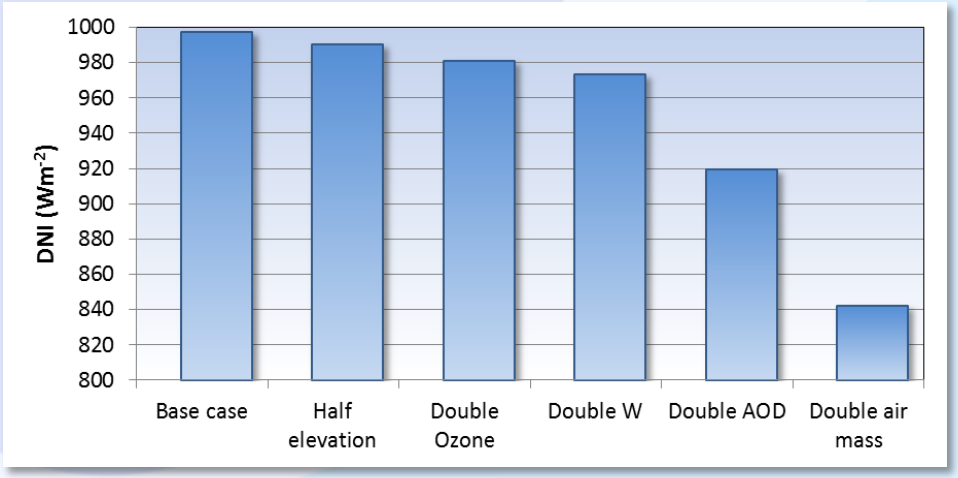


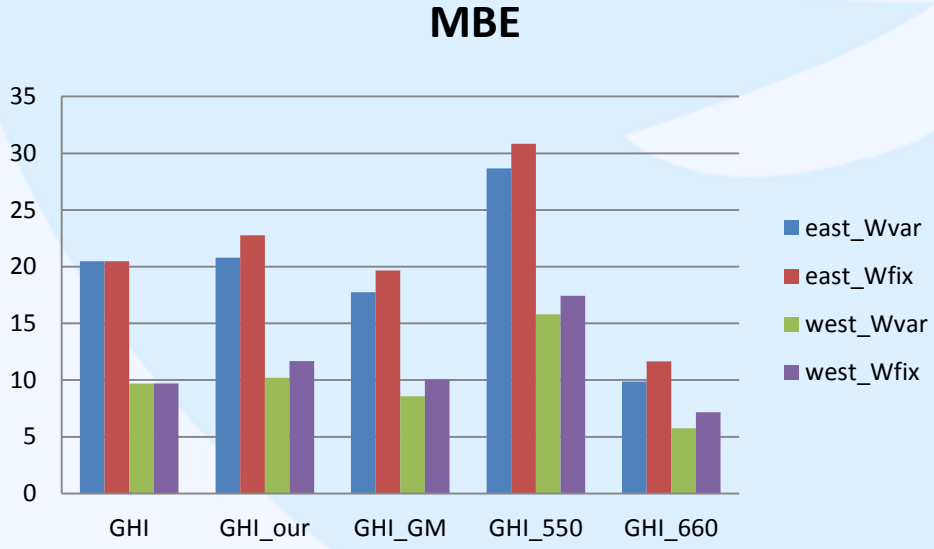
- **There are improvements in SST retrieval on whole data sets using aerosol data, the information content improves drastically.**

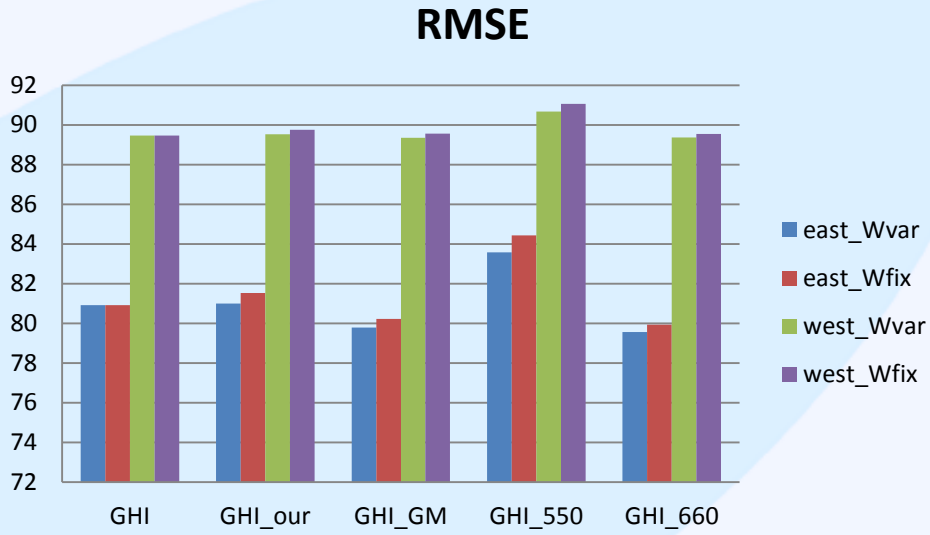
Andy Harris and Prabhat Koner

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







Summary of revised NGACv2 evaluation

- **Model evaluation:**
  - Dust performs well in NGAcv2 after the bug fix and removal process tuning. The long range dust transport of Sahara dust is slightly improved.
  - Sea salt performs normal compared to other models.
  - Sulfate, black carbon and organic carbon performance is improved, but still unrepresentative in north America, sub Saharan and south America region in smoke season.
- **From evaluators:**
  - **NRL's Re-evaluation of NGACv2 experiments**
    - NRL's evaluation of the revised NGACv2 experiments indicated positive improvements in sulfate and sea salt forecasts. The source functions and quality of emission datasets are improved as well. Although fire activity is in the right location, they are still underrepresented. Boreal fires are on par, but South America and equatorial Africa are too low.
    - NRL will continue evaluating NGACv2 forecasts before including them into MME, till then, the aerosol forecast products will be treated as experimental for ICAP community.
    - Overall, the revisions to NGACv2 are satisfactory for NGAC team to proceed with operational implementation
  - CMAQ experiments using NGAC BCs show positive impacts for smoke events compared to using static BCs.
  - Using NGACv2 AOD 660nm significantly improves the mean bias error in solar power forecasts
  - World Air Quality Index Project includes NGAC in it's air quality models.

Acknowledgement

❑ Joint efforts in building global aerosol forecast capability

- ❖ **NEMS team in EMC**: Atmospheric dynamics and physics, code management, framework
- ❖ **SUNY Collaborators** (Sarah Lu, Sheng-Po Chen, Qilong Min): post, verification
- ❖ **GSFC collaborators** (Arlindo da Silva, Mian Chin, Peter Colarco, Anton Darmenov, Donifan Barahona, Atanas Trayanov): science consultation
- ❖ **NESDIS collaborators** (Shobha Kondragunta, Hanjun Ding) and **South Dakota State Univ** (Xiaoyang Zhang): develop biomass burning emission data GBBEPx
- ❖ **DTC MET group** (Tara Jensen): verification
- ❖ **EMC observations process group** (Dennis Keyser and Diane Stokes): implement GBBEPx in NCEP
- ❖ **ICAP working group** (Angela.Benedetti (ECMWF), Jeff Reid(NRL), Michael Schulz(AEROCOM)):global aerosol model development
- ❖ **WMO SDS-WAS experts**

❖ Evaluators:

- ❖ **NESDIS** (Andy Harris and Prabhat Koner): Satellite SST retrieval
- ❖ **NRL** (Jeff Reid and Peng Lynch) and **BSC** (Francesco.benincasa)**:** global and regional aerosol multi-model ensemble
- ❖ **AQ group** (Ivanka Stajner, Jeff McQueen, Jianping Huang, Ho-chun Huang, Jerry Gorline, Perry Shafran, Pius Lee, Li Pan): use NGAC as LBC for regional AQ model CMAQ
- ❖ **CPC** (Craig Long): UV index
- ❖ **SUNY** (Richard Perez and Sergey Kivalov): solar energy

Thank You

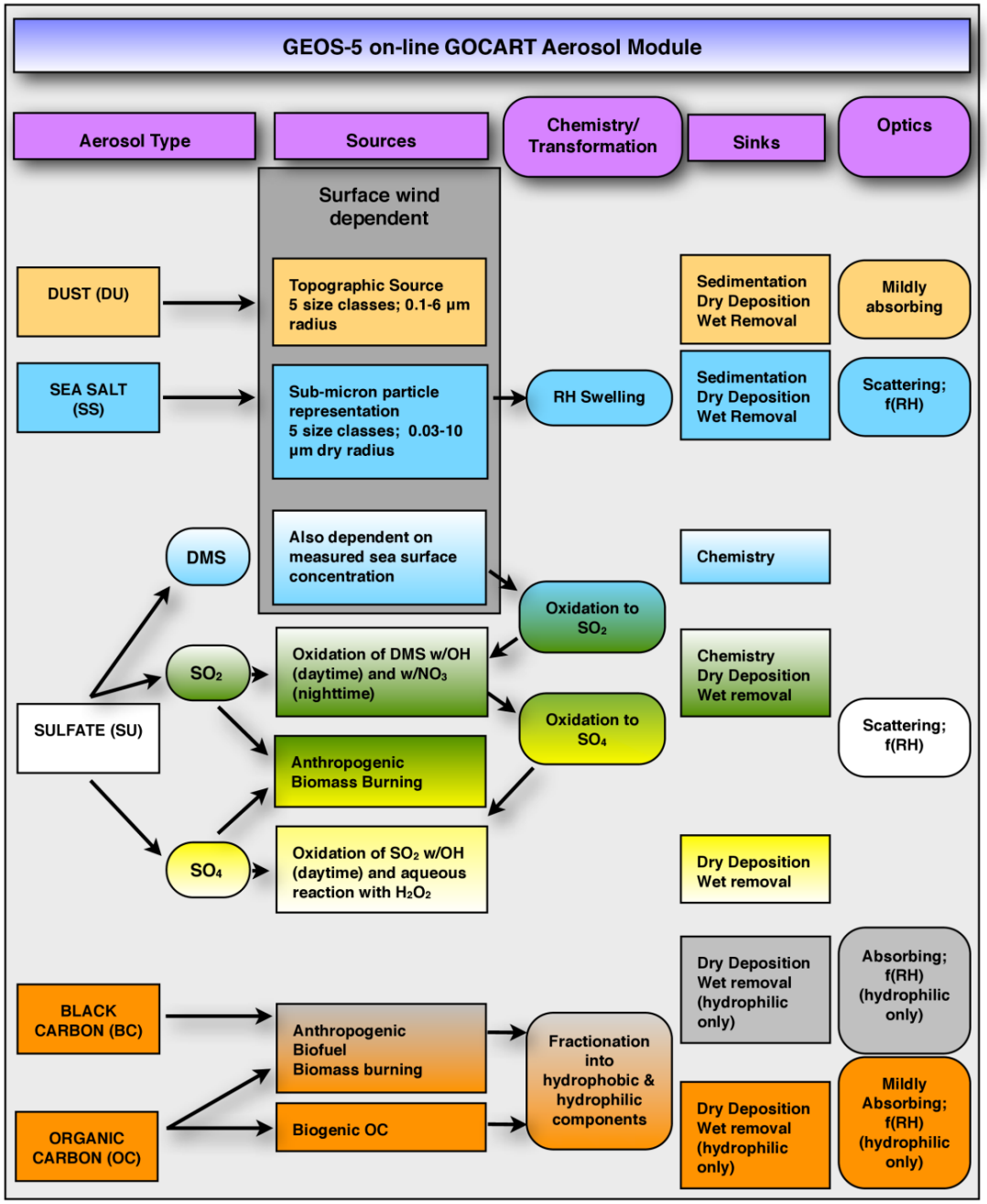
Q1FY16 Planned Implementation

- 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
  - Aerosol model was updated to newer GOCART version
  - 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
  - Bug fix in AOD computation
  - The high latitude build up problem is resolved
  - New products to support down stream applications

GOCART Module

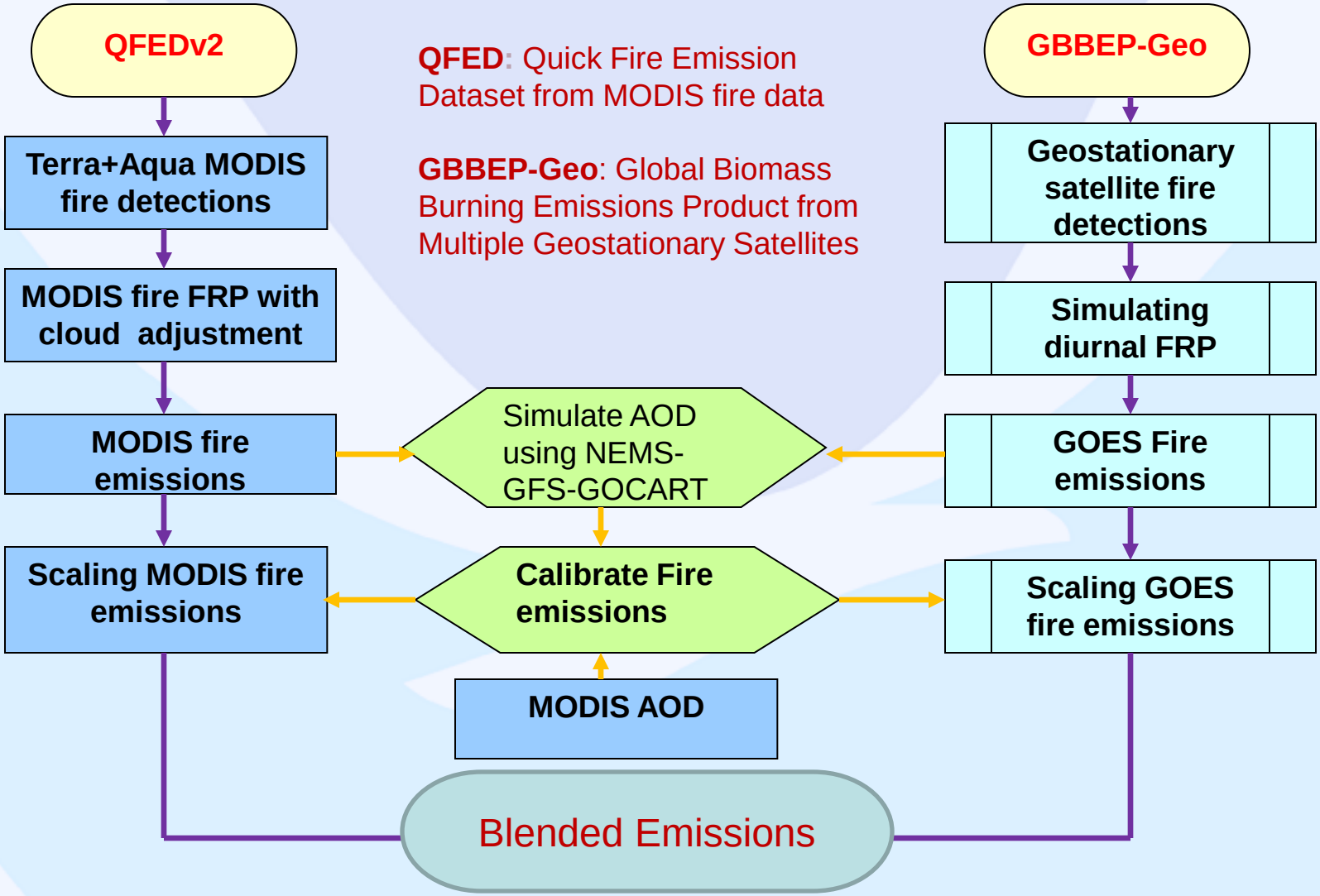
In-line chemistry advantage

- 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



- 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.

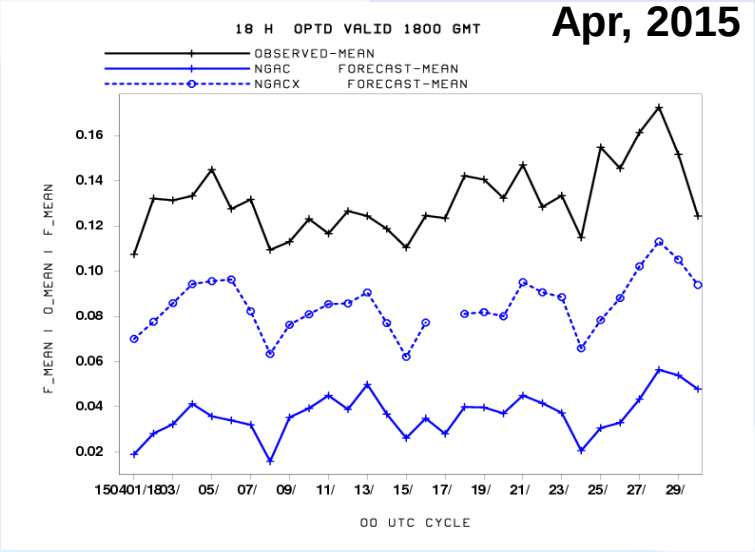
Shobha Kondragunta (NESDIS/STAR)

NGAC Evaluation and Verification

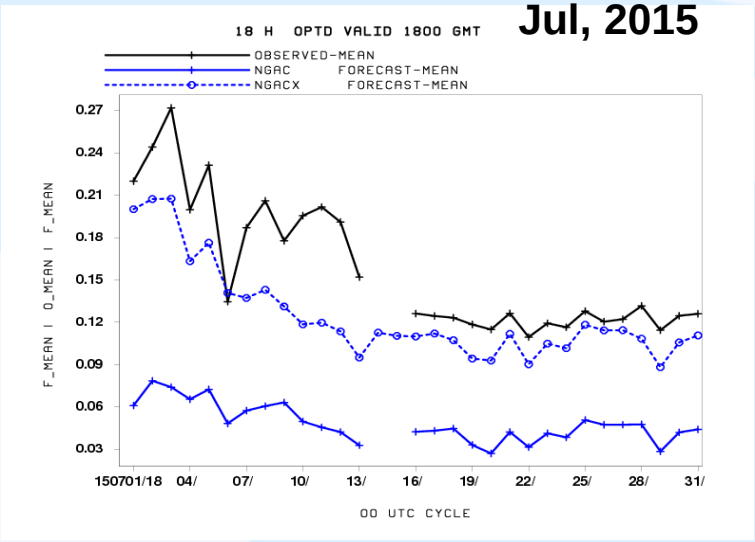
NGAC production vs V2 parallel total AOD against observations at fh18

GLOBE

Apr, 2015

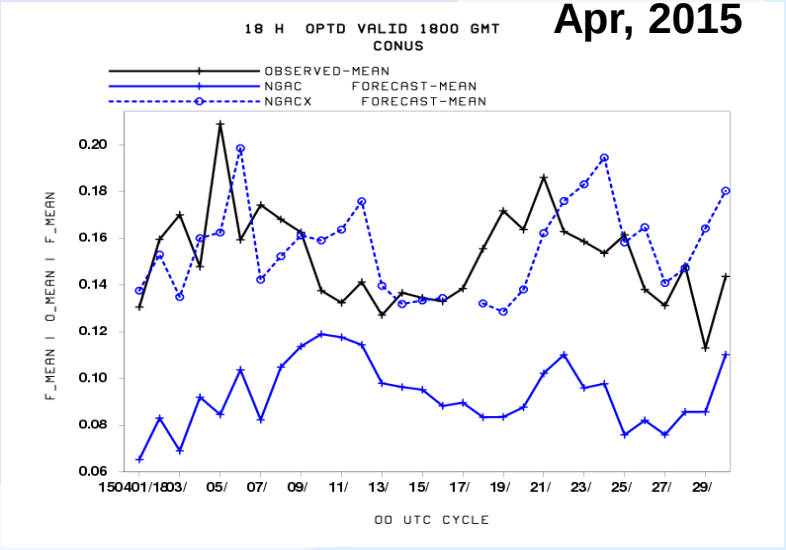


Jul, 2015



CONUS

Apr, 2015



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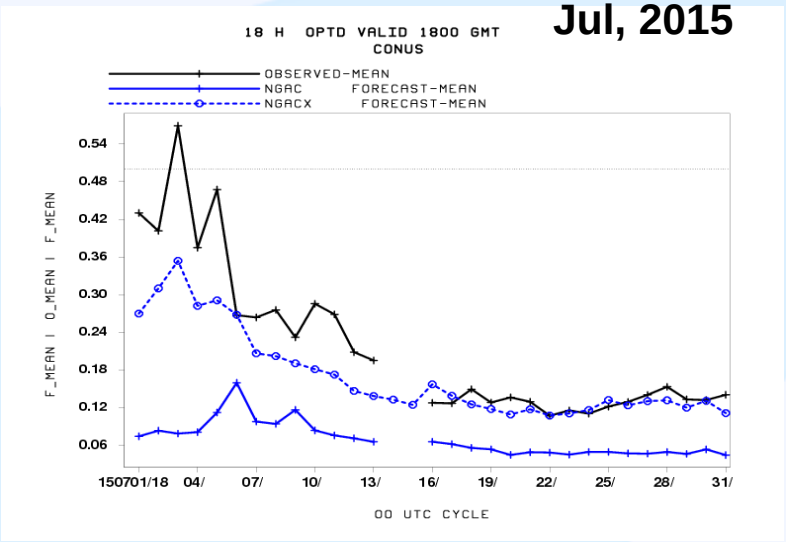
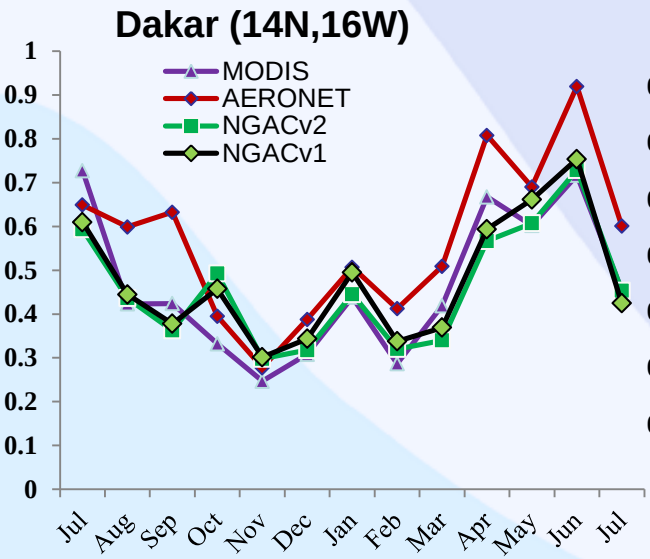
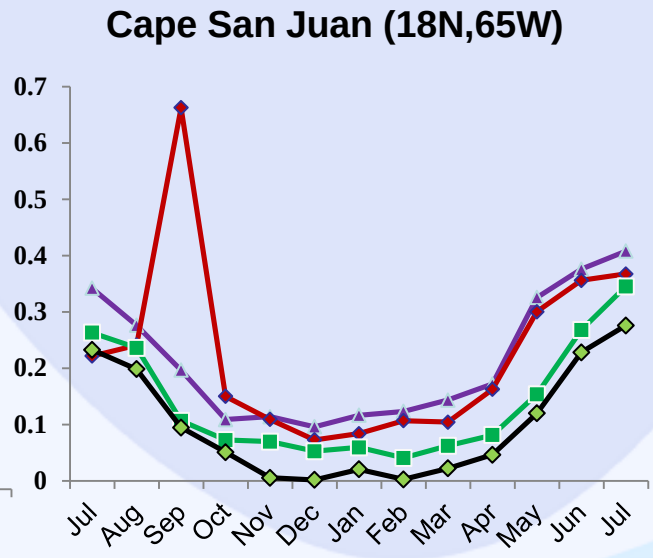
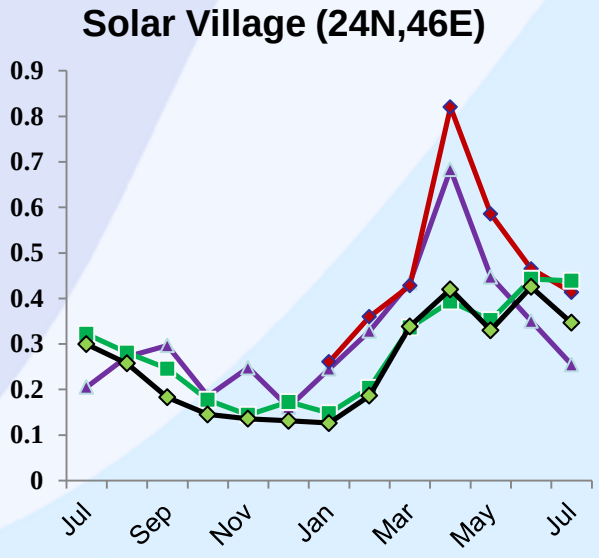
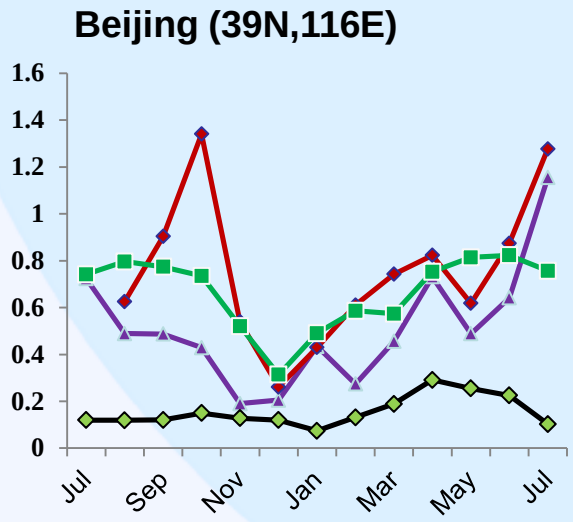


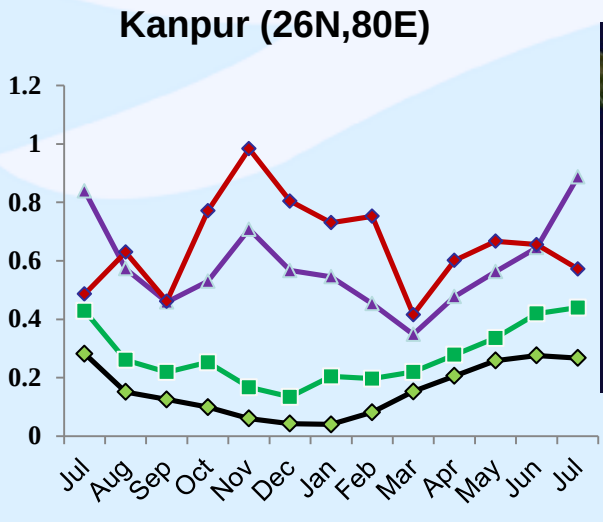
NGACv2 monthly mean AOD versus AERONET and MODIS











Period: 20140701-20150731

NGAC Product Suite and Applications

NGAC provides 1x1 degree products in GRIB2 format twice per day (00Z and 12Z)

Product files and their contents include:

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

- **ngac.t00z.aod_$CH, CH=340nm, 440nm, 550nm, 660nm, 860nm, 1p63um, 11p1um**
  - Aerosol Optical Depth (AOD) at specified wavelength from 0 to 120 hour

- **ngac.t00z.a2df$FH, FH=00, 03, 06, ….120**
  - 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
  - Single scatter albedo and asymmetric factor for total aerosols at 0.34 micron

Budget, ocean productivity

UV index forecasts

- **ngac.t00z.a3df$FH, FH=00, 03, 06, ….120**
  - Pressure, temperature, relative humidity at model levels ← **Atmospheric correction**
  - Mixing ratios for aerosol species at model levels ← **LBC for regional air quality model**

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