# NCEP operational Global Aerosol Forecasting System
# NGAC FY16Q1 implementation

# CCB meeting

Jun Wang, Partha Bhattacharjee, Vijay Tallapragada

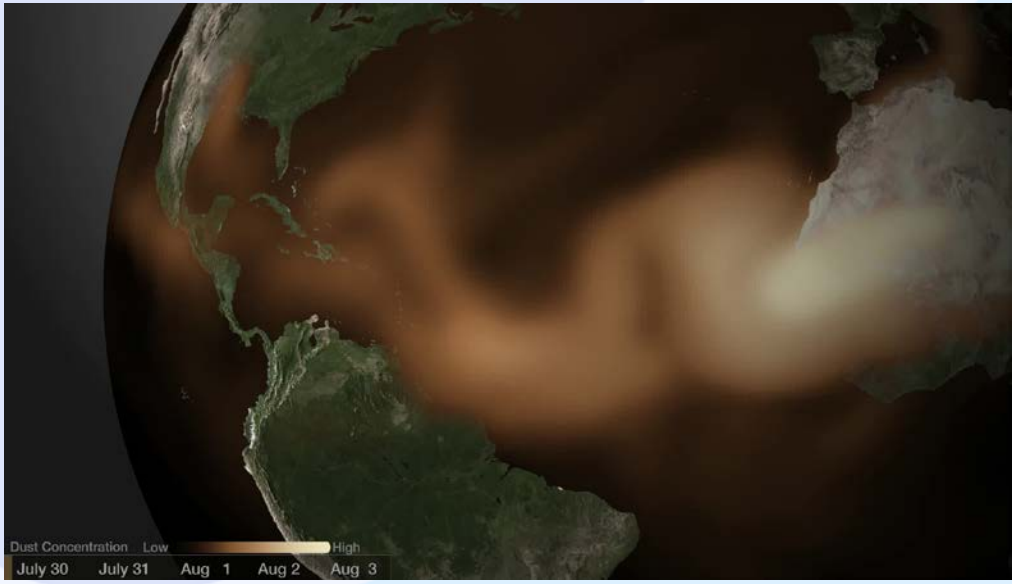
# Overview

- Current  operational NGAC
- NGAC time line of the project: Quad chart
- Scope of the project
  - Changes and updates in the code
  - 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) **FY16**
- Aerosol analysis using VIIRS AOD **FY18 (tentative)**
- Provide lateral boundary condition for downstream regional CMAQ model **FY16**
- Provide aerosol information for potential downstream users (e.g., NESDIS's SST retrievals, CPC-EPA UV index forecasts)

# NGAC upgrade
## Project Status as of: 8/31/2015

## 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 aerosol forecast using near real global biomass burning emission data GBBEPx
3) Add 12Z cycle forecast

**Estimated Benefits:**

1) Provide guidance on long range 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 and sst retrieval.

## G Scheduling

| Milestone (NCEP) | Date | Status |
|---|---|---|
| Initial coordination with SPA team | 07/13/2015 | Done |
| EMC testing complete/ EMC CCB approval | 10/30/2015 | |
| Final RFC submitted to NCO | 11/06//2015 | |
| Technical Information Notice Issued | | |
| SPA begins prep work for 30 day test | | |
| 30-day evaluation begins | | |
| 30-day evaluation Ends | | |
| Management Briefing | | |
| Operational Implementation | | |

## G Issues/Risks

**Risks:**

-Upstream near real time data feed is required.

-NCEP library updates for new fields are required

**Mitigation:**

## G Finances

**Associated Costs:**

Phase 2 resources: 7 nodes for 30 minutes, 14GB data per cycle

**Funding Sources:**

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

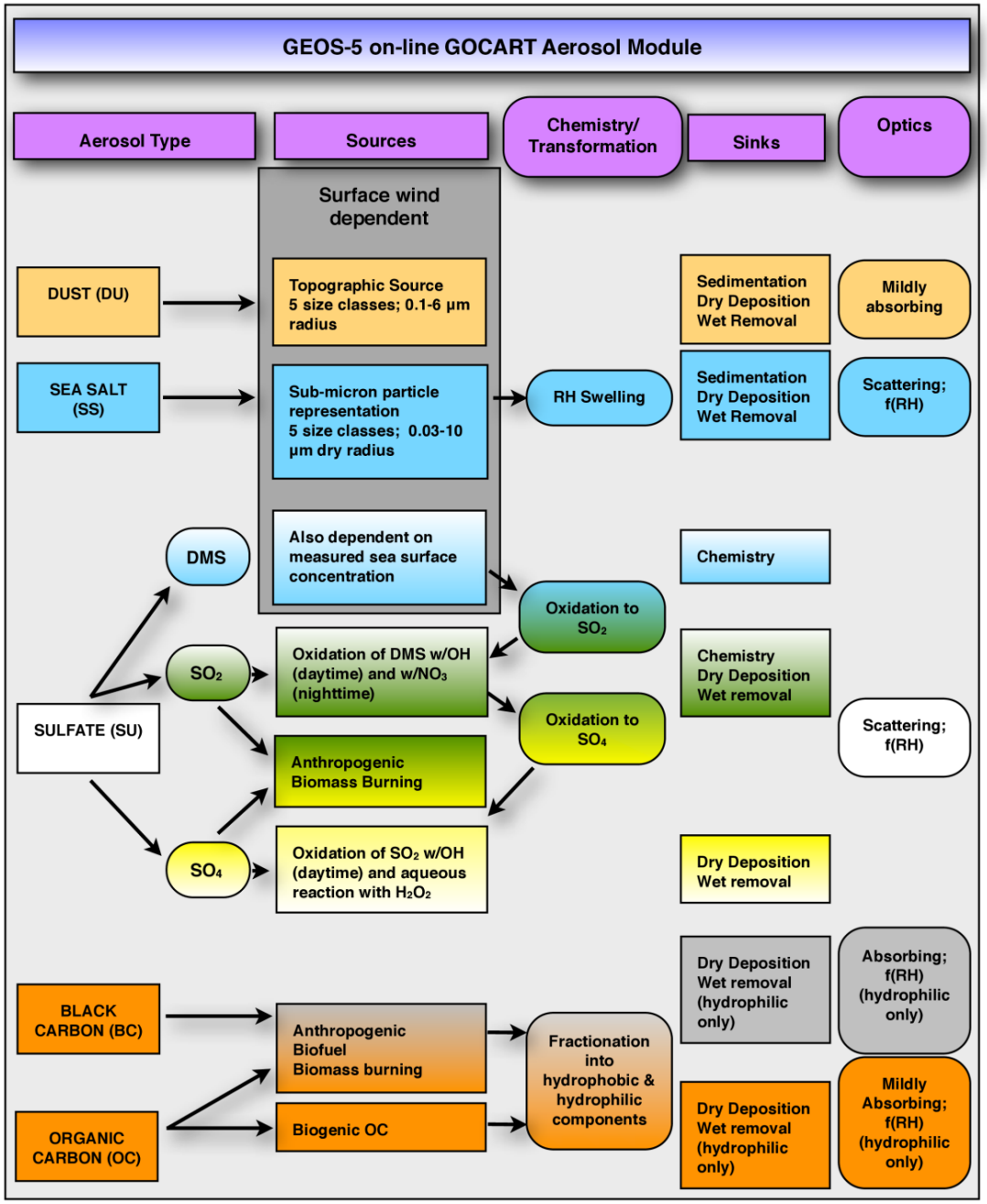
# Q1FY16 Planned Implementation

- 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 ESMF6 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

# GOCART Module

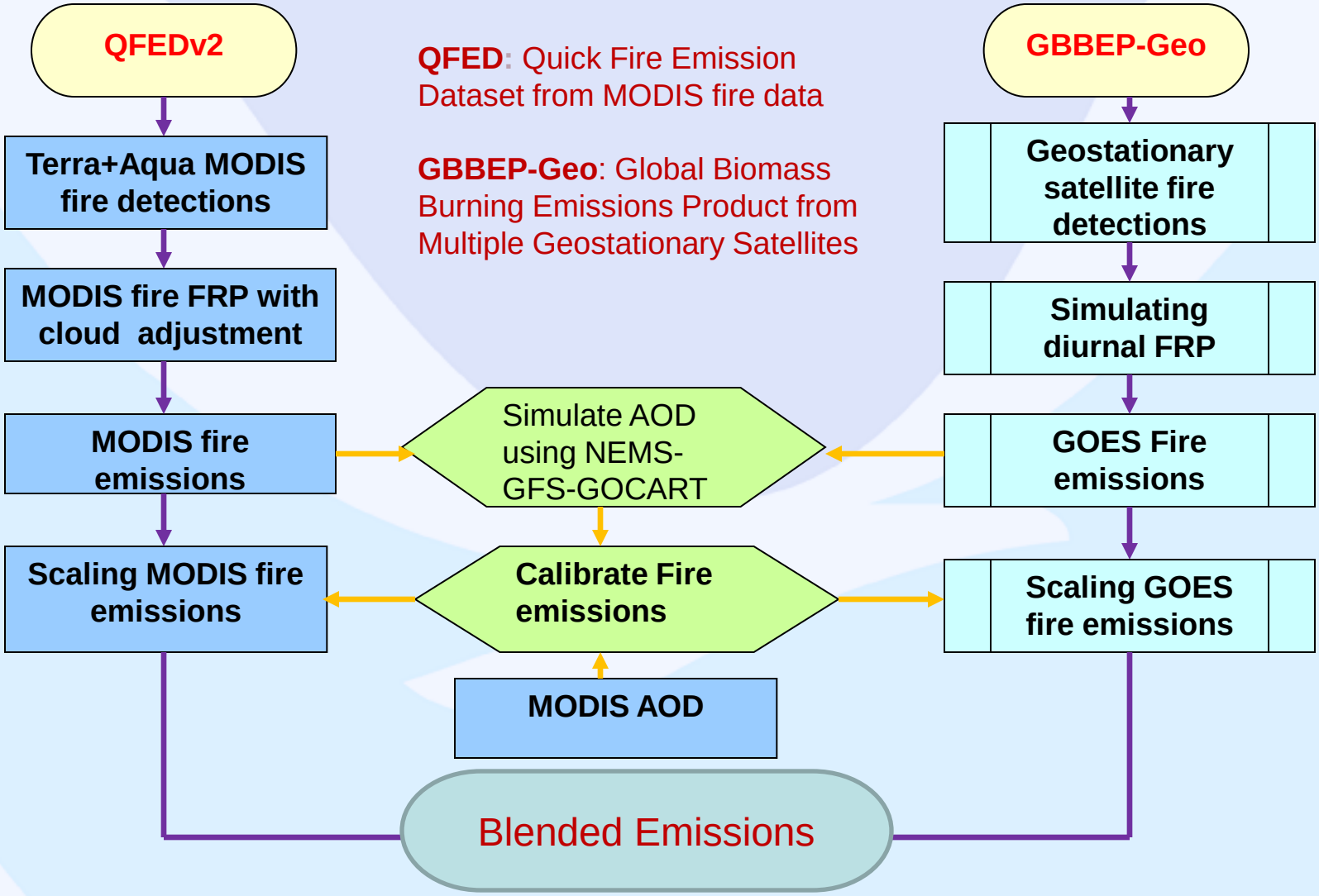
**In-line chemistry advantage**

- 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 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**
  - Total Aerosol Optical Depth (AOD) at specified wavelength from 0 to 120 hour
  - For 550nm, Aerosol Optical Depth all species ← **Multi-model ensemble**

- **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**

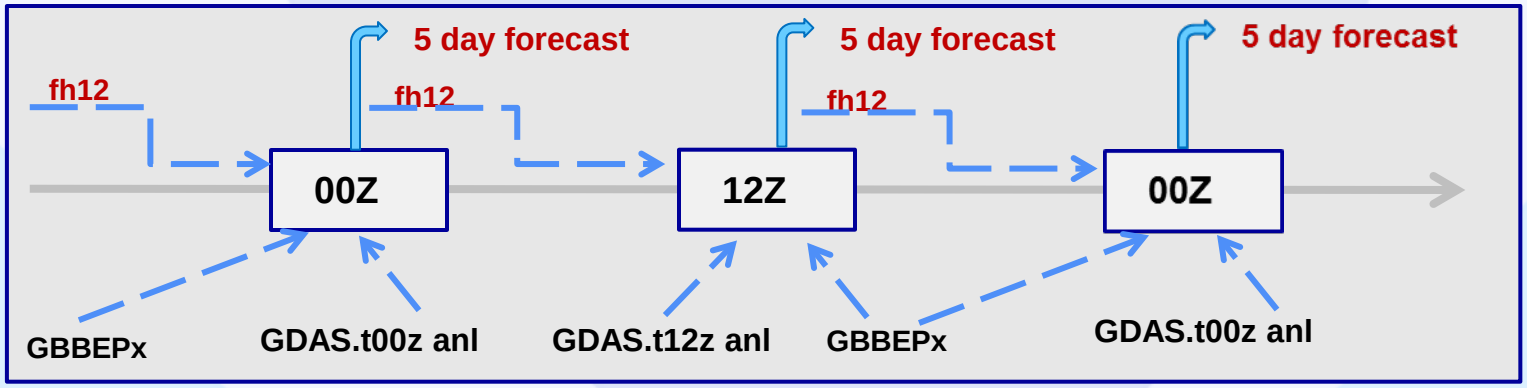
**UV index forecasts**

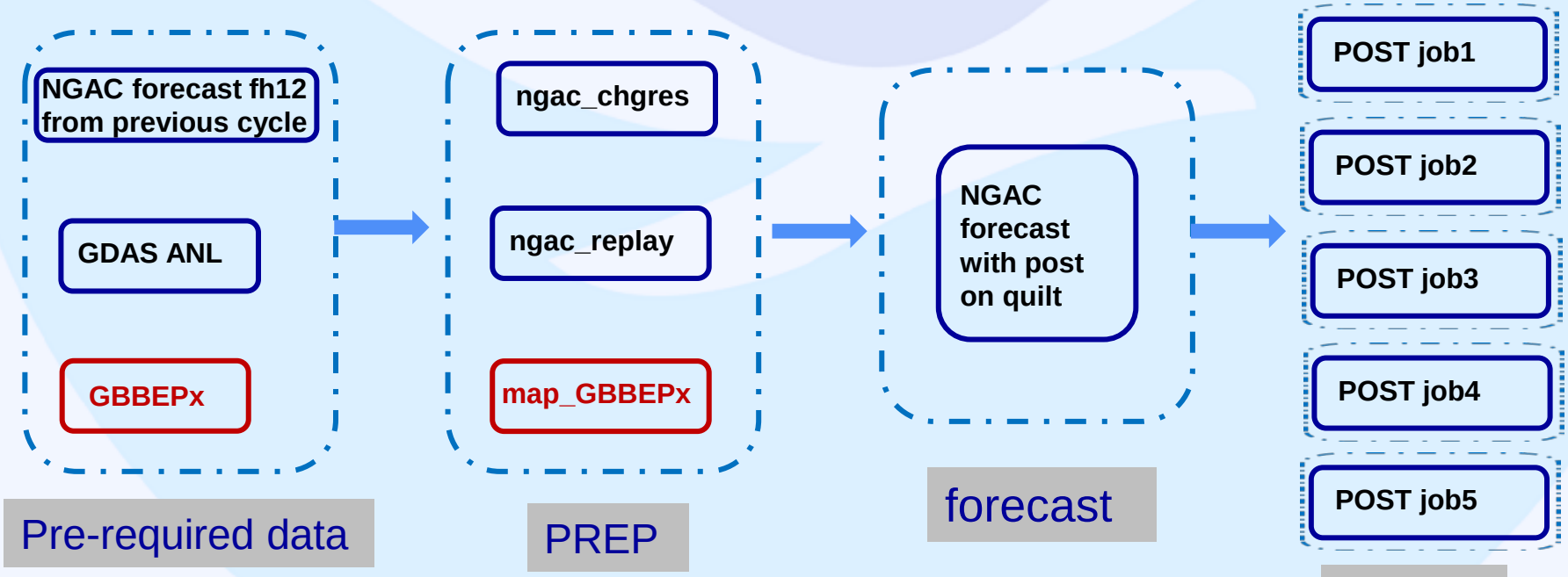
- **ngac.t00z.a3df$FH, FH=00, 03, 06, ….120**
  - Pressure, temperature, relative humidity at model levels ← **Atmospheric correction**
  - Mixing ratios for aerosol species at model levels ← **LBC for regional air quality model.**

**SST retrieval**

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

# Flow chart of NGACv2



# Resource and time change

- Current NGAC operational: one cycle per day at 00Z
  - NGAC_PREP: 4 pe, 10 minutes
  - NGAC_FCST: 2 nodes, 25 minutes
  - NGAC_POST: 1 pe, 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 pe, 10 minutes
  - NGAC_FCST: 6 nodes, 25 minutes
  - NGAC_POST:
    - 5 jobs
    - each takes 1pe, 30 minutes
  - Disk space: total 14 GB per day

# Implementation Planning

- Implementation dependencies
  - Product generation requirements
    - New aerosol fields are added
    - Changes in NCEP unified post-processor are needed
  - Libraries:
    - Requires NEMSIO and g2tmpl to be updated
    - Both libraries were RFC-ed
  - Data Flow:
    - Streaming of biomass burning emission data GBBEPx onto dcom for NGAC forecast use

# Implementation Planning (Cont.)

- Test completed
  - Prediction model testing
    - NEMS regression tests done
    - Retrospective test from Jul 1, 2014 to Aug 31, 2015
    - Issue was identified in NGACv2_dev and bug was fixed and committed in NGACv2_dev_t4 (frozen code)
  - EMC parallel run starts on Sept. 15 2015
    - Ongoing Monthly and daily evaluation

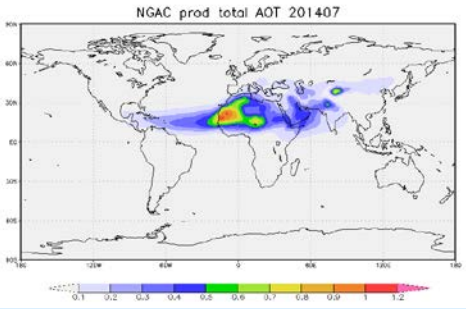
    http://www.emc.ncep.noaa.gov/gmb/NGAC/V2
  - EE meeting was done in July, 2015
- Downstream applications
  - Retrospective and near real time run results were shared with downstream applications
  - Results were presented at NGAC-CMAQ implementation coordinate meeting, CMAQ tests using frozen version of NGAC forecasts as LBC started in Sept, 2015
  - SST retrieval test using NGAC multi-species aerosol forecast started in Sept, 2015

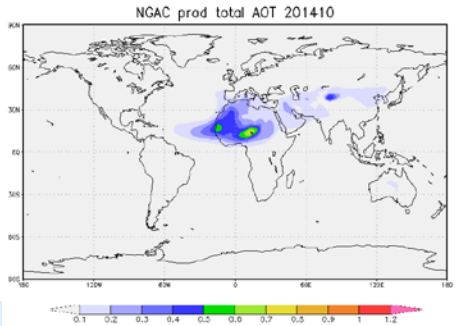
# NGACv2 full aerosol forecasts

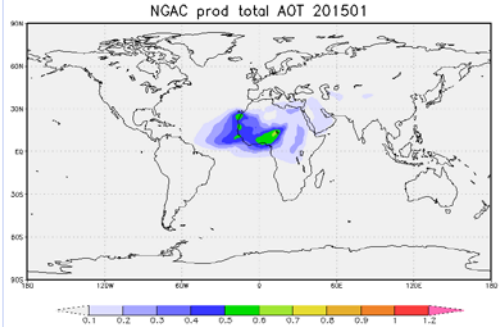
- NGAC has the capability to simulate dust, sulfate, sea salt, and carbonaceous aerosols.
- Near real time GBBEPx biomass burning emission is fed into NGAC
- Results of 1 year NGACv2 forecast parallel run from Jul 2014-Aug 2015 compared with MERRAero

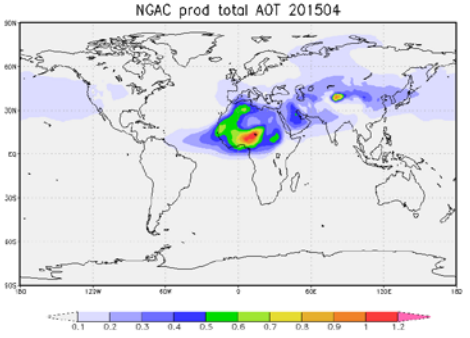
## Total AOD at 550 nm

**NGAC_PROD**

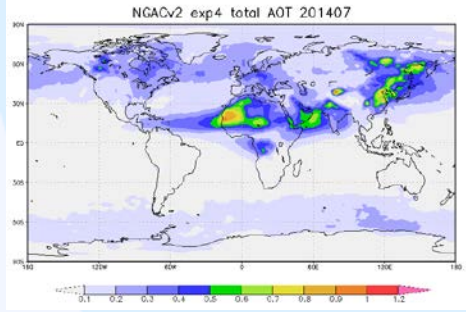


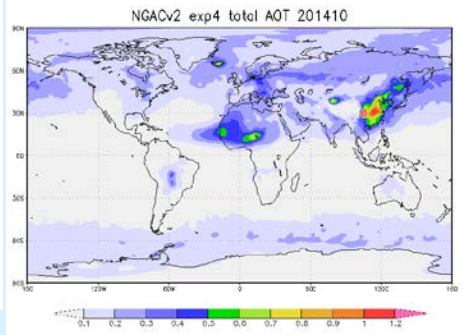


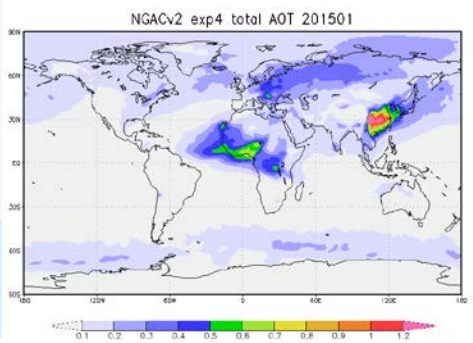


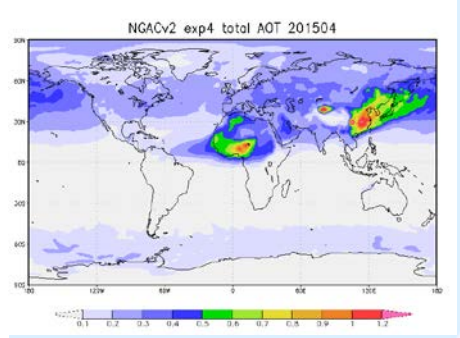



**NGACv2_PARA**

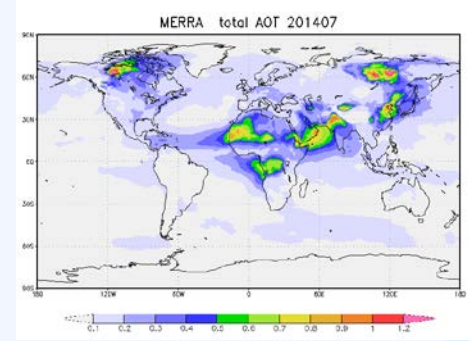


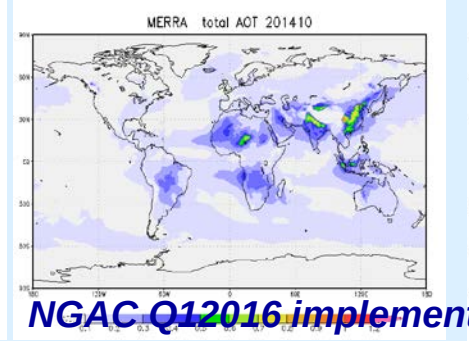


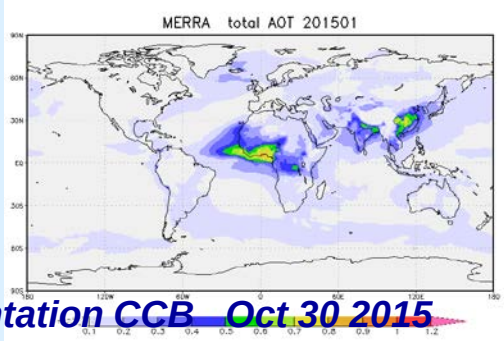


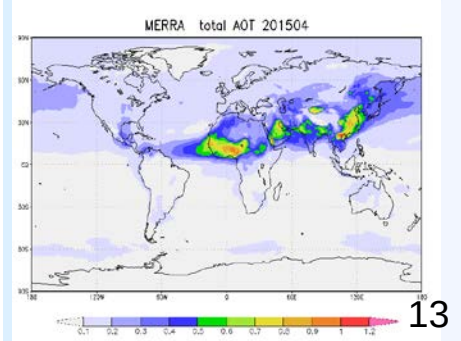



**MERRAero**

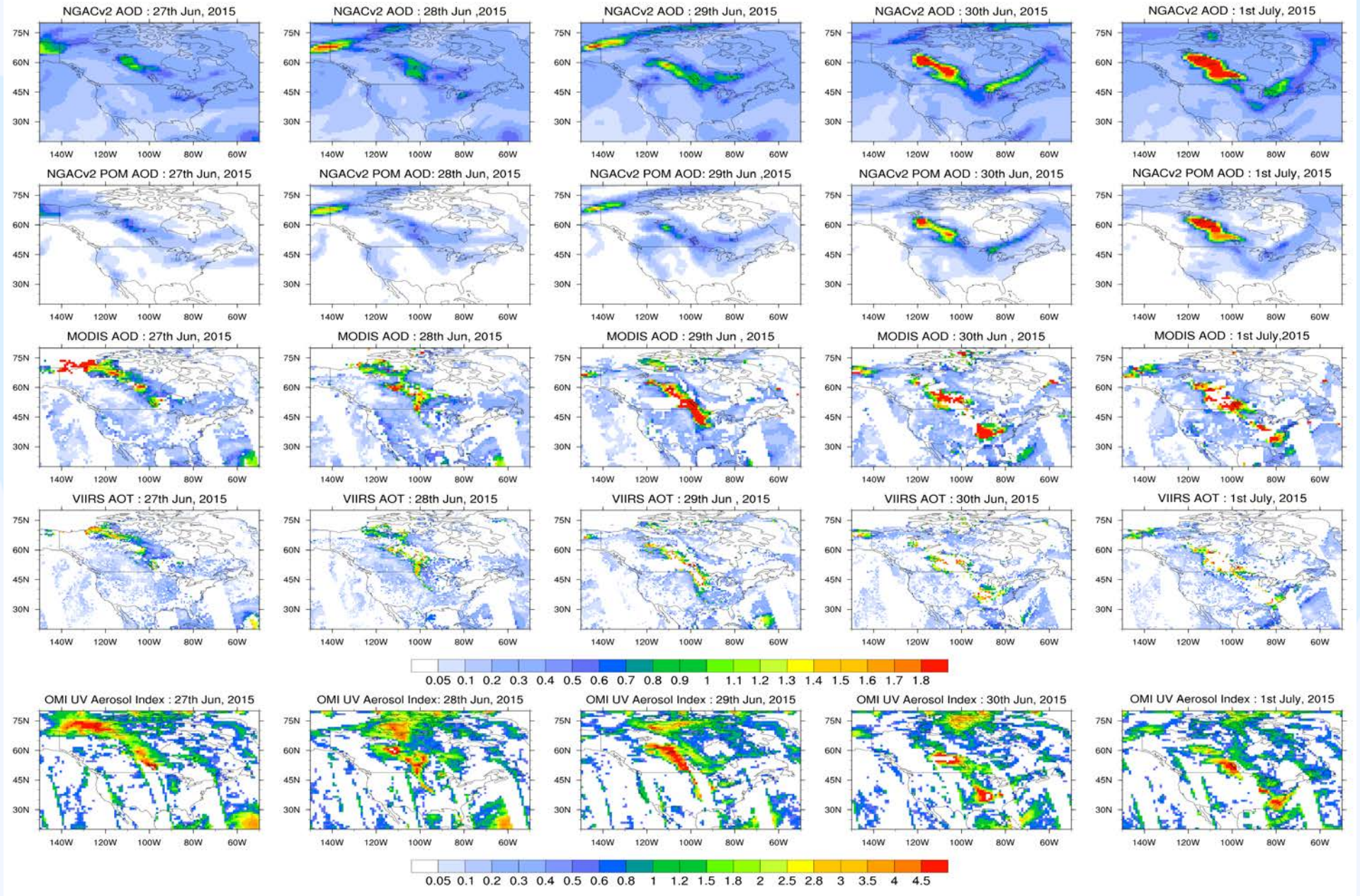






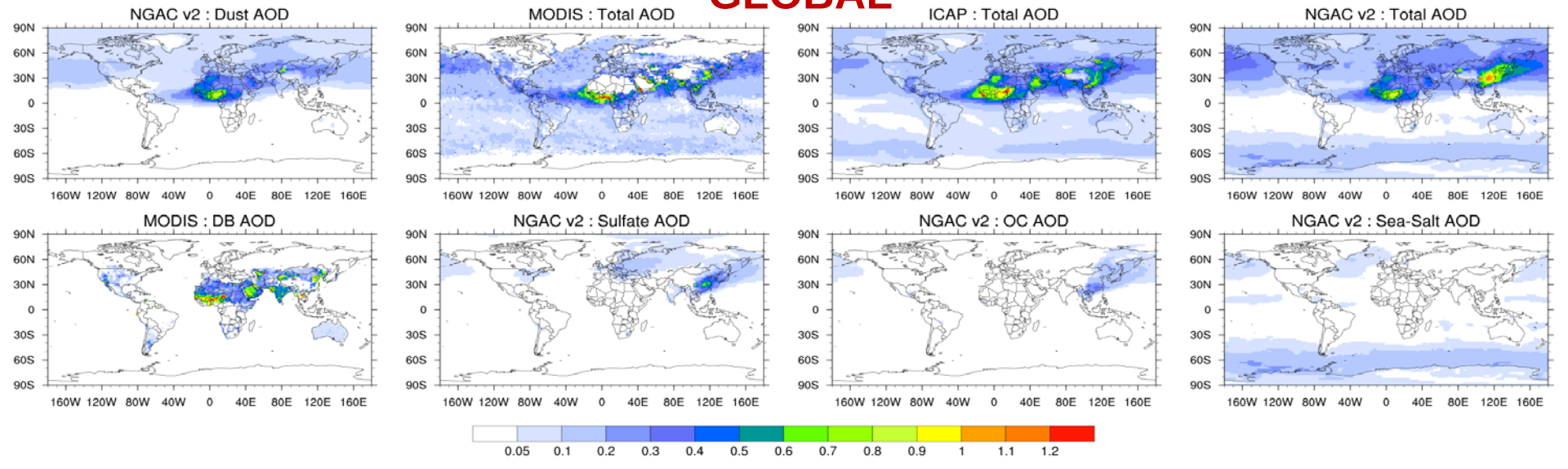


# NGACv2 smoke event Jun27-Jul 1, 2015

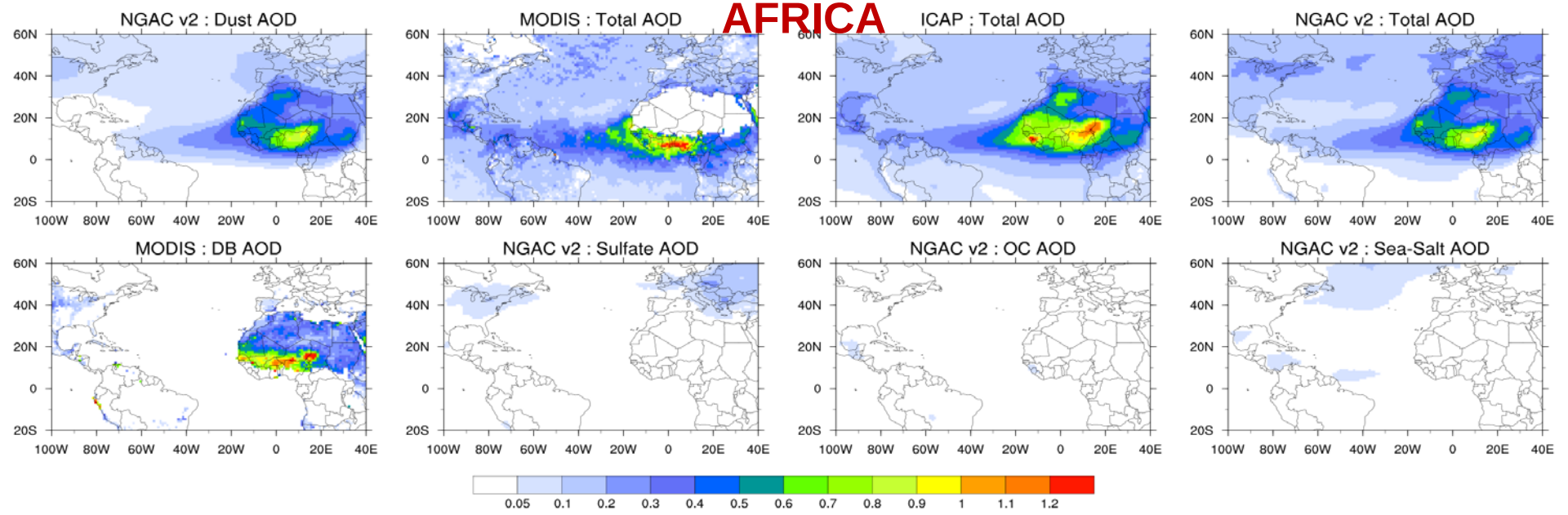


# NGACv2 Monthly mean to Satellite observations and ICAP Apr, 2015

## GLOBAL

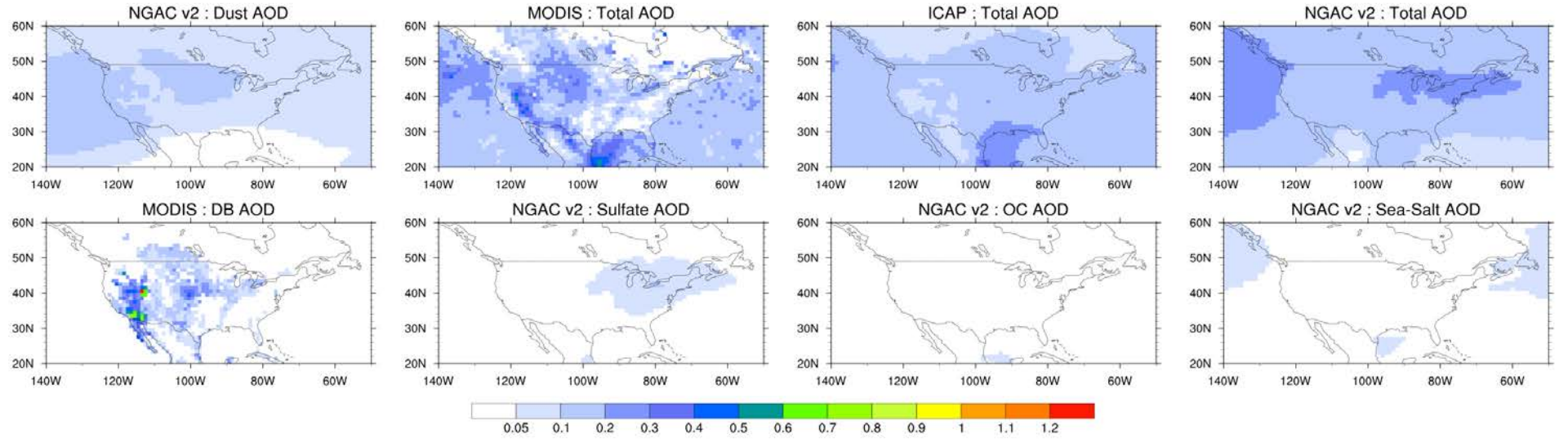



## AFRICA

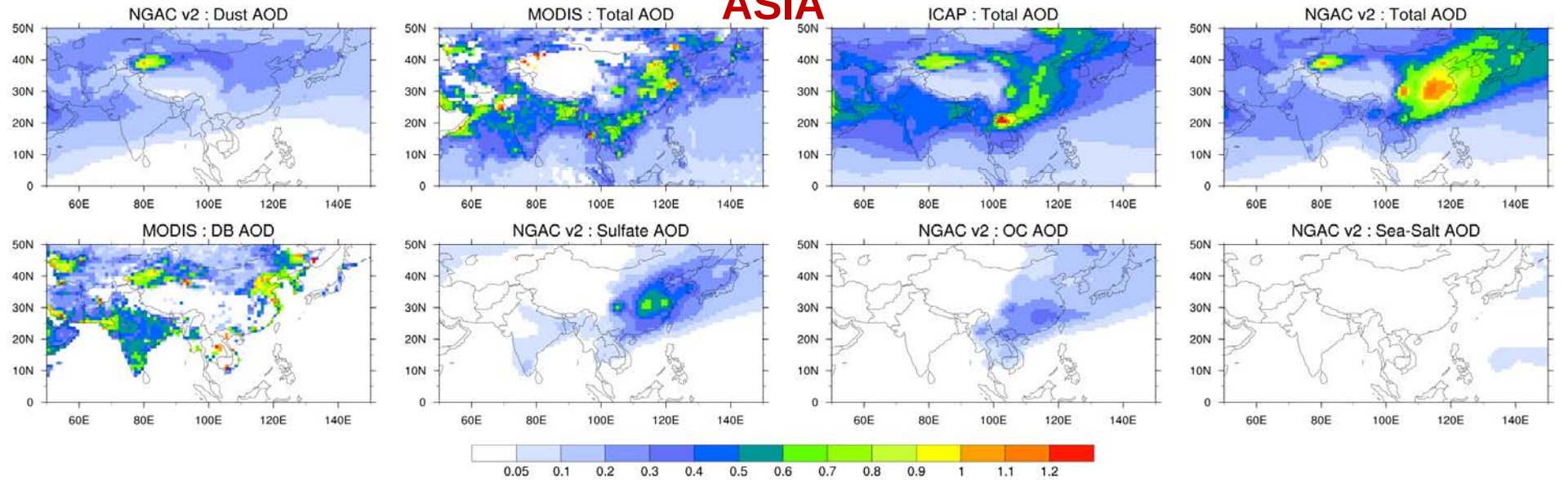


# NGACv2 Monthly mean to Satellite observations and ICAP Apr, 2015

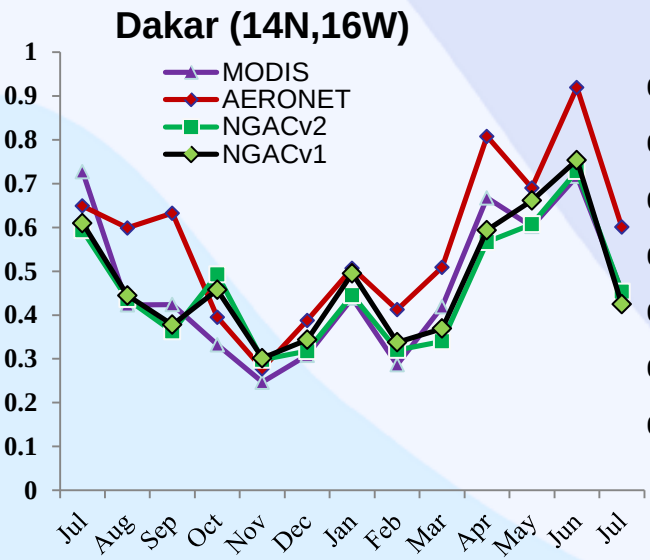
## CONUS

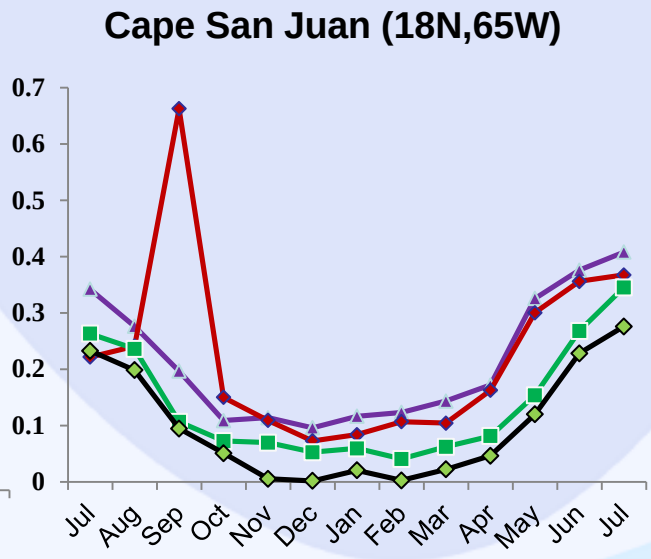


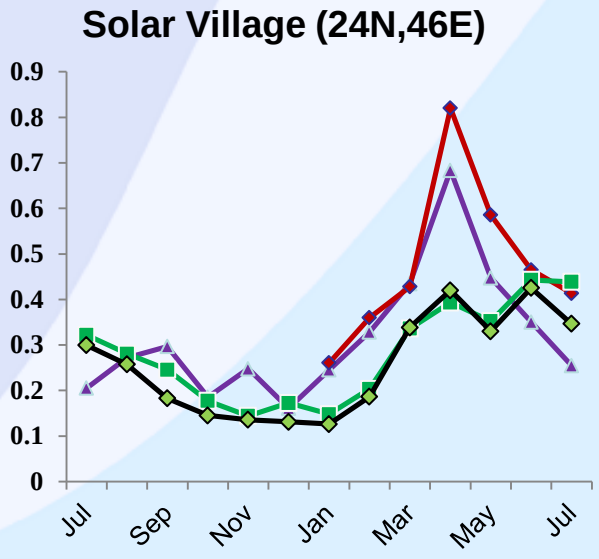

## ASIA

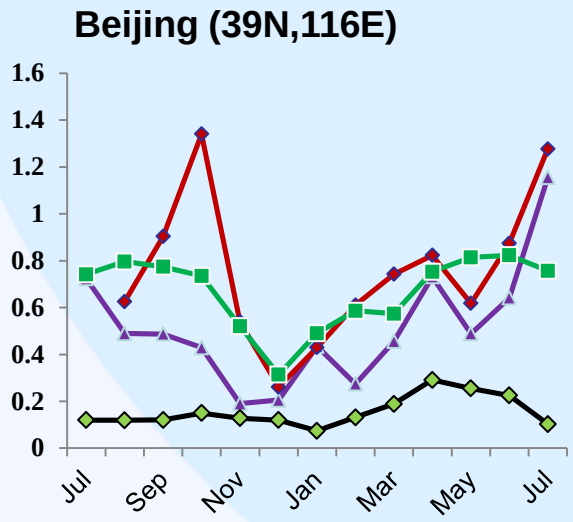


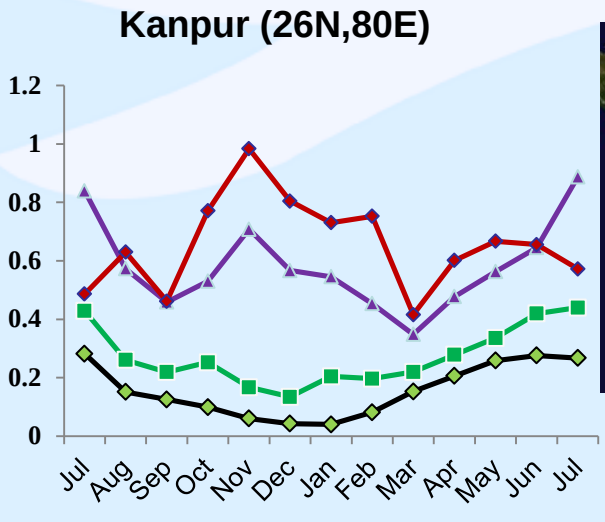
# NGACv2 monthly mean AOD versus AERONET and MODIS



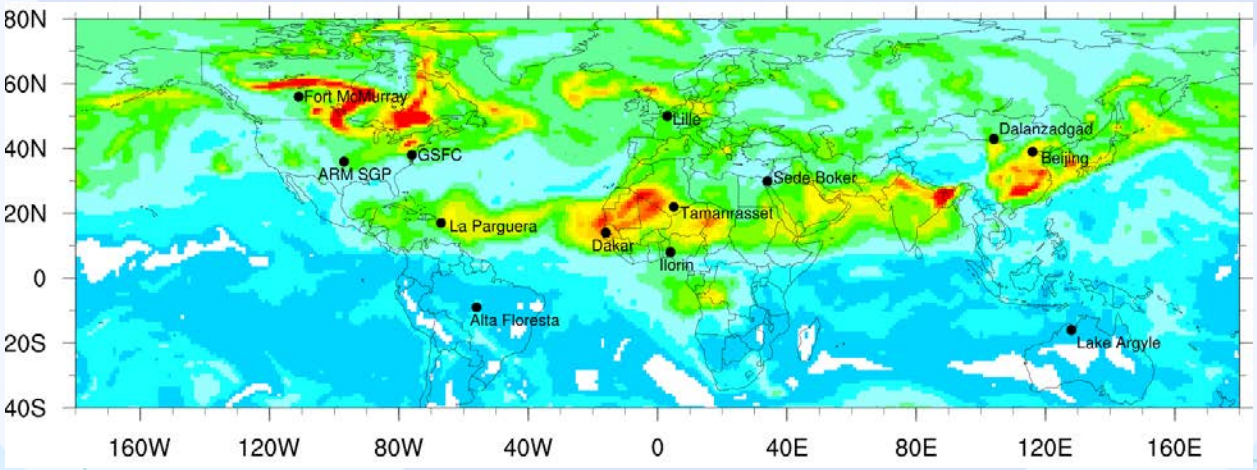





Period: 20140701-20150731

# NGAC Evaluation and Verification




**Dust Dominated AERONET locations 20140701-20150731**

| | RMSE | | Bias | | $R^2$ | |
|---|---|---|---|---|---|---|
| | V2 | v1 | V2 | v1 | V2 | v1 |
| Dakar | **0.433** | 0.382 | **-0.092** | -0.072 | **0.81** | 0.81 |
| La Parguera | **0.2938** | 0.3722 | **-0.049** | -0.087 | **0.68** | 0.72 |
| Tamanrasset | **0.2996** | 0.32 | **0.00268** | 0.0196 | **0.91** | 0.89 |
| Ilorin | **1.144** | 1.216 | **-0.2683** | -0.367 | **0.83** | 0.76 |
| Sede Boker | **0.2055** | 0.1569 | **0.0464** | -0.0058 | **0.68** | 0.61 |
| Dalanzadgad | **0.255** | 0.056 | **0.080** | -0.0055 | **0.48** | 0.64 |

# NGAC Evaluation and Verification

**Smoke Dominated AERONET locations 20140701-20150731**

| | RMSE | | Bias | | $R^2$ | |
|---|---|---|---|---|---|---|
| | V2 | v1 | V2 | v1 | V2 | v1 |
| Fort McMurray | **0.2932** | 0.5371 | **0.02** | -0.1125 | **0.41** | 0.076 |
| Alta Floresta | **1.098** | 1.24 | **-0.251** | -0.292 | **0.08** | -0.122* |
| Lake Argyle | **1.118** | 1.181 | **-0.1748** | -0.202 | **-0.0098*** | -0.065* |

**Mixed aerosol to relatively clean AERONET locations 20140701-20150731**

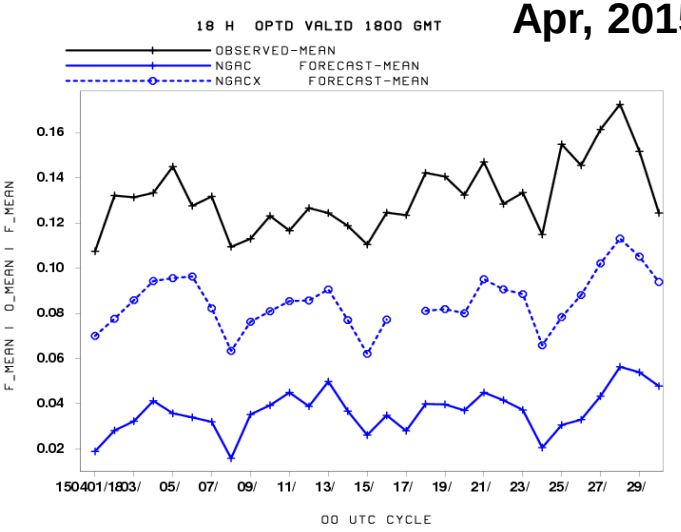
| | RMSE | | Bias | | $R^2$ | |
|---|---|---|---|---|---|---|
| | V2 | v1 | V2 | v1 | V2 | v1 |
| Beijing | **0.704** | 1.656 | **-0.143** | -0.606 | **0.334** | 0.012 |
| Lille | **0.2862** | 0.5522 | **0.052** | -0.1411 | **0.177** | 0.106 |
| GSFC | **0.339** | 0.633 | **-0.06** | -0.152 | **0.074** | 0.148 |
| ARM SGP | **1.385** | 1.551 | **-0.124** | -0.219 | **0.047** | 0.035 |

# NGAC Evaluation and Verification

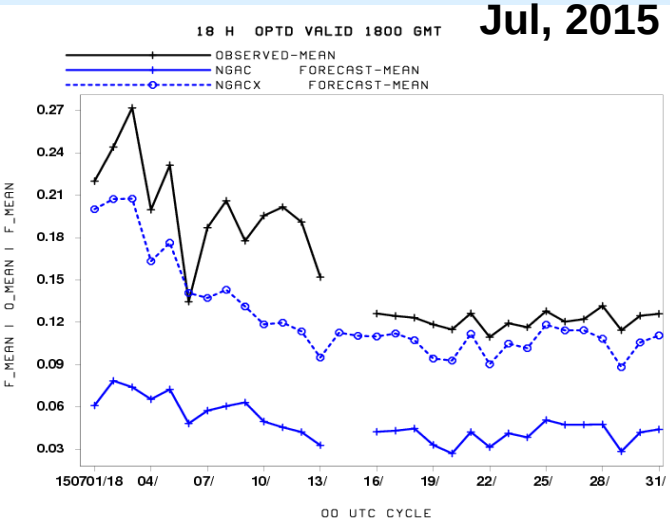
## NGAC production vs V2 parallel total AOD against observations at fh18

### GLOBE

Apr, 2015

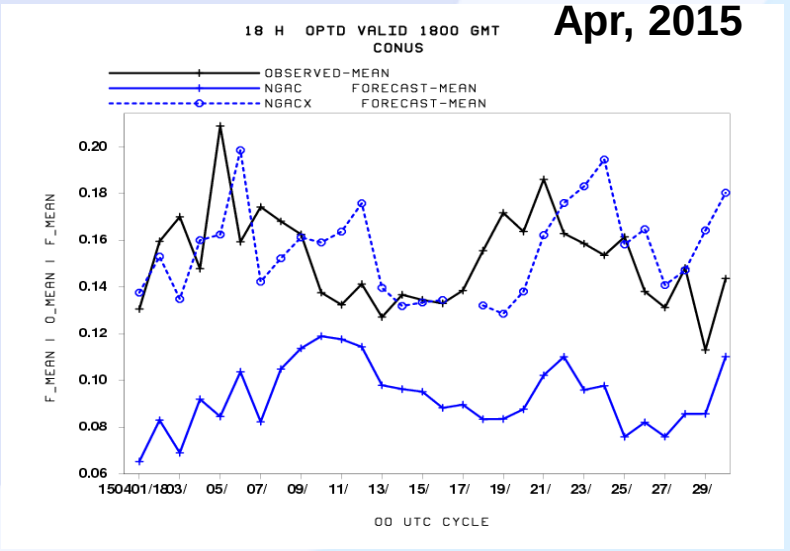



Jul, 2015

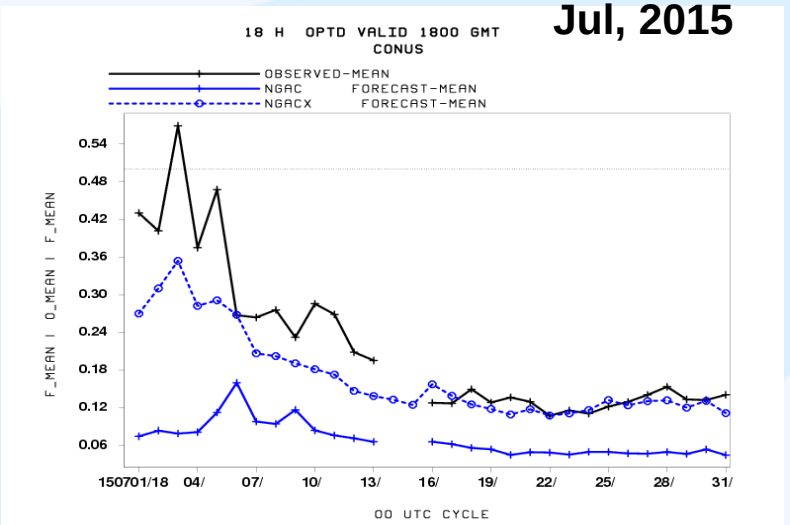



### CONUS

Apr, 2015

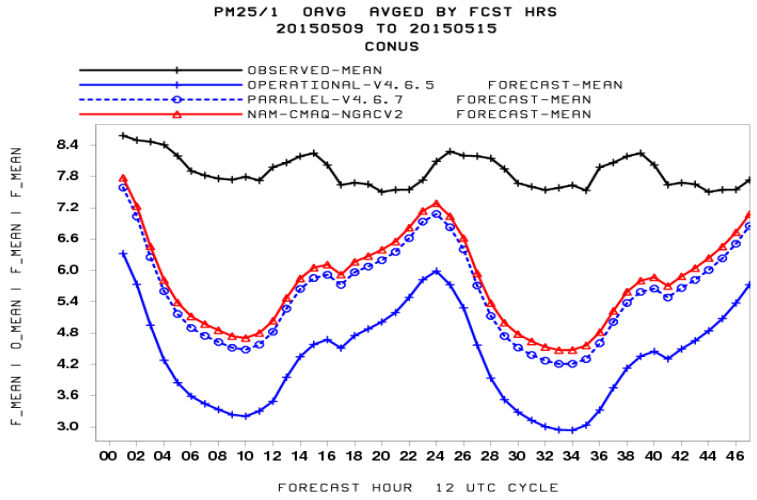



Jul, 2015

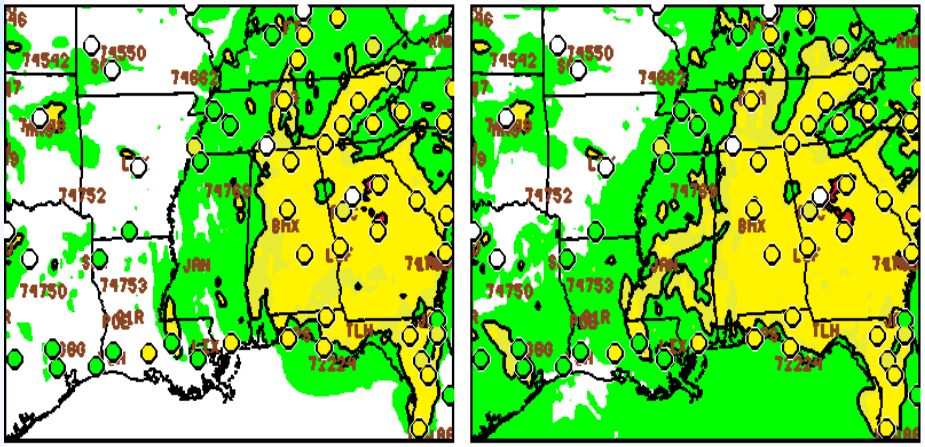


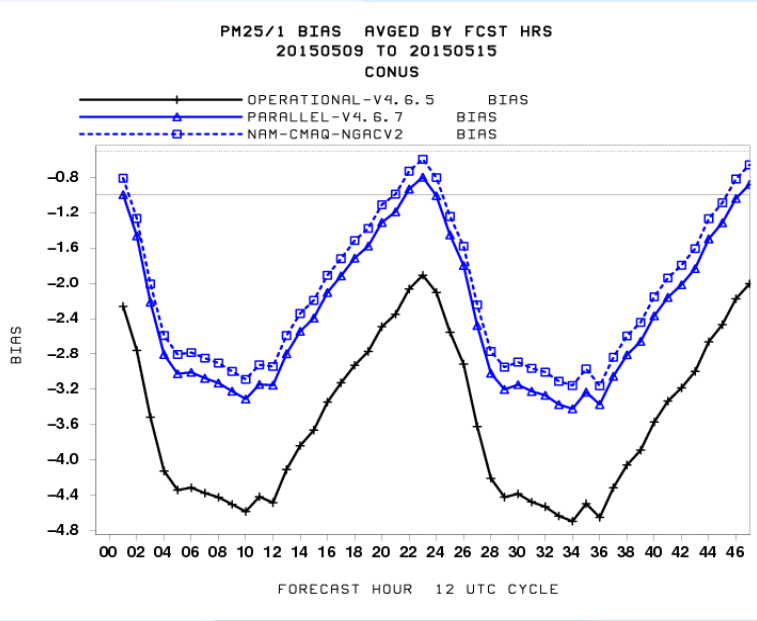
# Downstream application test: Dynamic LBCs for regional models

- Operational NAM-CMAQ using static LBCs versus experimental NAM-CMAQ with dynamic LBCs from NGACv1 and from NGACv2.
- The inclusion of LBCs from operational NGAC forecast is found to improve PM forecasts, and it is in CMAQ Q12016 implementation. Initial tests show that using NGACv2 forecast as LBC further improves CMAQ PM forecast.

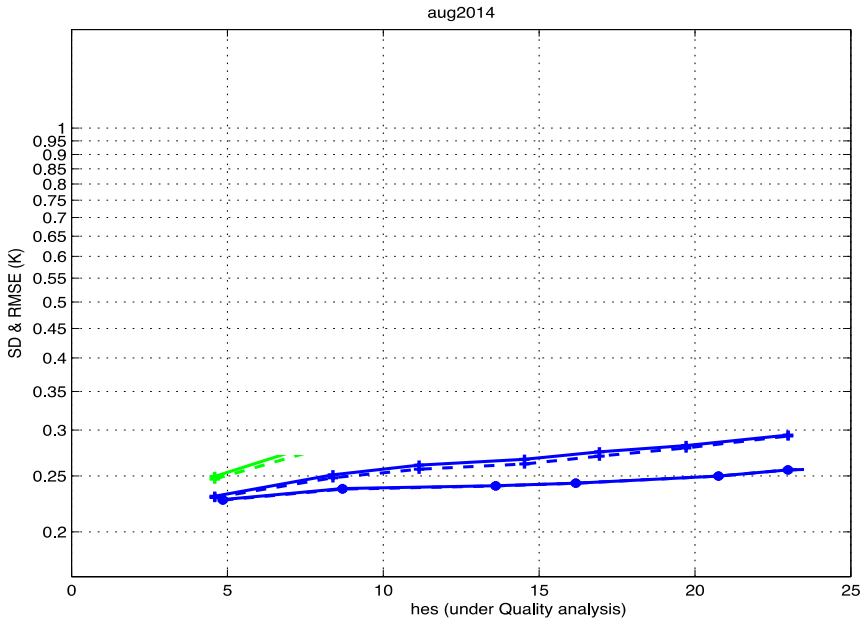



## Dust event on 201505100-20150515

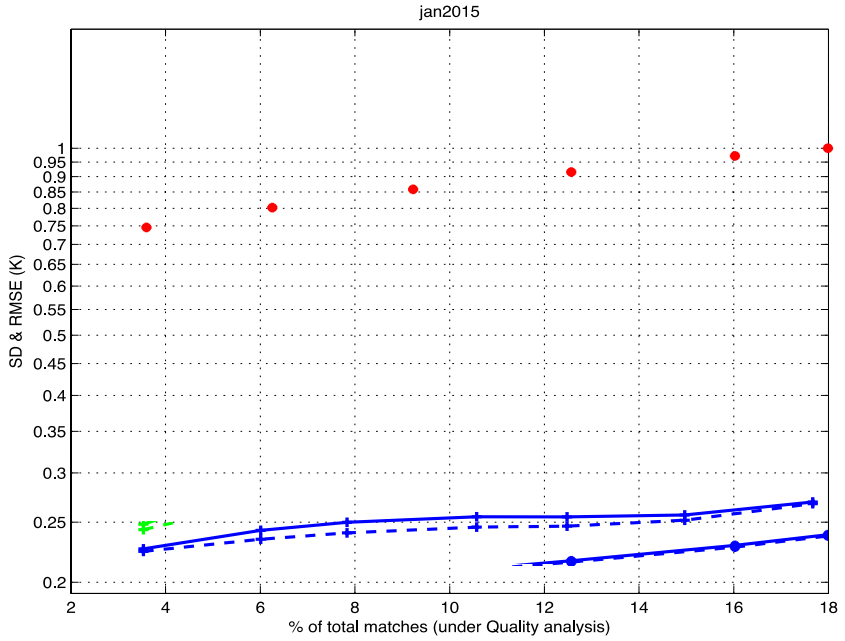


# Improving Satellite SST retrieval using NGAC multiple species aerosol forecast




- 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

# Summary

- In NGACv2, new capability of multiple aerosol species global aerosol forecast is added and new aerosol information products are generated
- Model evaluation shows that NGACv2 has comparable forecast skills for dust and improved aerosol forecast at smoke dominated region and mixed aerosol dominated region compared to current operational. On CONUS, EMC Forecast Verification System shows NGACv2 performed better than current NGAC operational.
- Downstream application CMAQ tests and external user test for SST retrieval show positive impact.
- EMC is ready to hand off the code for implementation

# 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): model development, post, verification
- ❖ **GSFC collaborators** (Arlindo da Silva, Mian Chin, Peter Colarco, Anton Darmenov, Donifan Barahona, Atanas Trayanov): GOCART model
- ❖ **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 package
- ❖ **EMC observations process group** (Dennis Keyser and Diane Stokes): implement GBBEPx in NCEP
- ❖ **ICAP working group** (ECMWF, UKMET, JMA, NRL, GSFC, AEROCOM, satellite and in-situ data providers on AERONET, MPLNET, MODIS, VIIRS): global aerosol model development, aerosol data
- ❖ **WMO SDS-WAS experts:** model inter-comparison

- ❖ **Evaluators**:
  - ❖ **NESDIS** (Prabhat Koner and Andy Harris ): Satellite SST retrieval
  - ❖ **NRL** (Jeff Reid and Peng Lynch) and **BSC** (Francesco.benincasa)**:** global and regional aerosol multi-model ensemble
  - ❖ **WFO at Miami:** dust transport
  - ❖ **AQ group** (Ivanka Stajner, Jeff McQueen, Jianping Huang, Ho-chun Huang, Jerry Gorline, Perry Shafran, Pius Lee): use NGAC as LBC for regional AQ model CMAQ
  - ❖ **CPC** (Craig Long): UV index

# Thank You