Using VIIRS AOD to evaluate NEMS GFS Aerosol Component (NGACv2)

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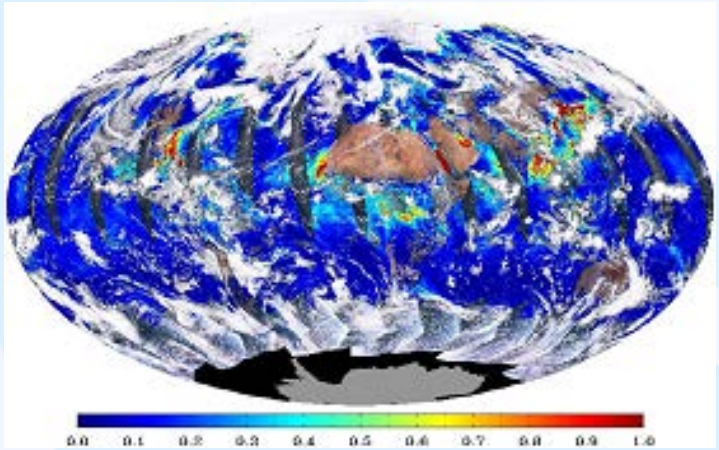
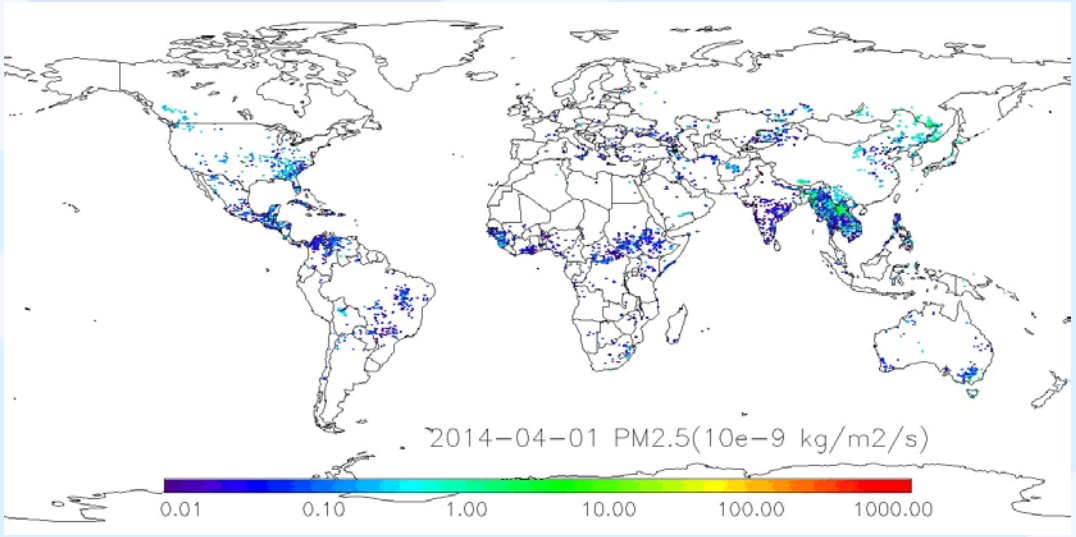
Using satellite data to improve aerosol forecasting

- Satellite observations have been used to improve aerosol products
  - Near-real-time biomass burning emissions from satellite observations
  - Data assimilation of satellite aerosol observations
  - Routine monitoring of model performance (this presentation)

Aerosol observations from VIIRS



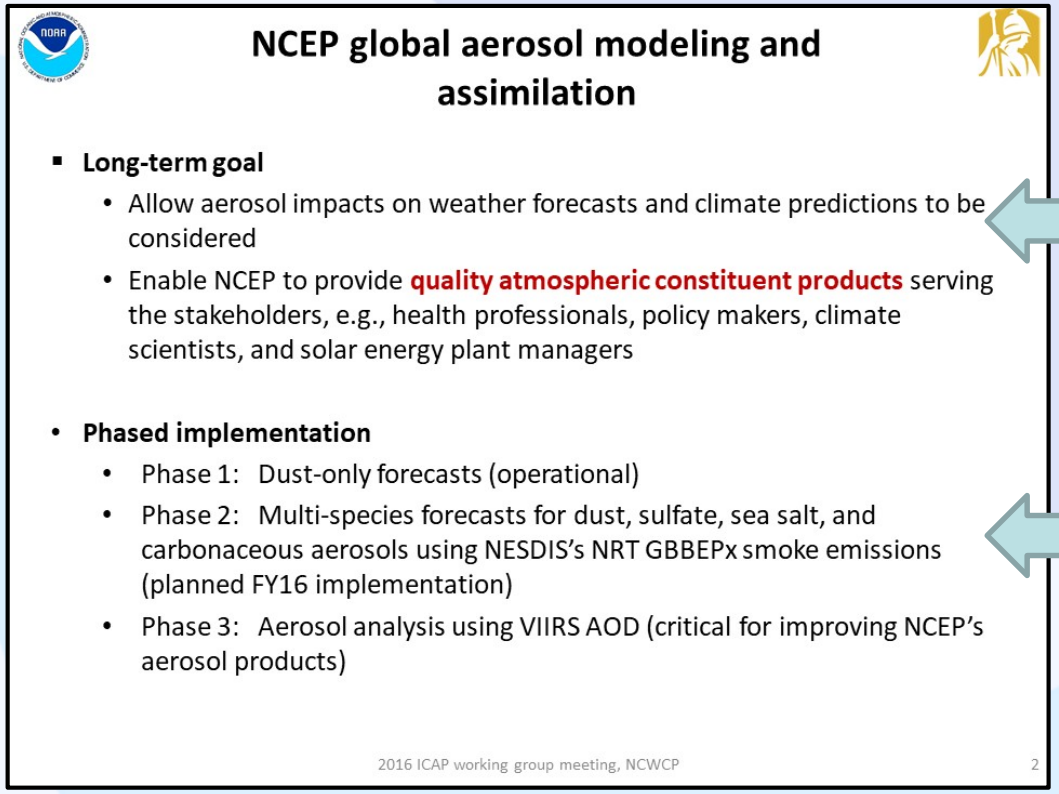
From NOAA/NESDIS/STAR website



Presentation Outline

- Current operational NGACv2 at NOAA
- Verification of NGACv2 AOD products
- Future plans on verification

Overview presented in 2018 ICAP WG meetings



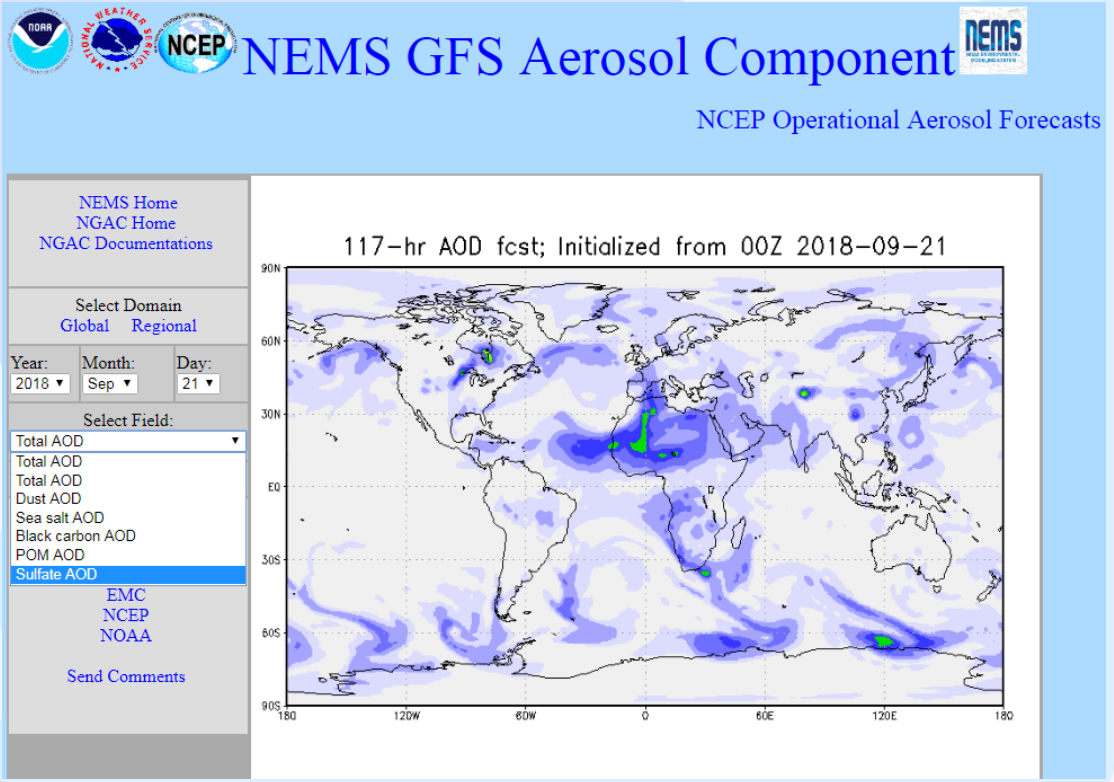
The goals remain the same

- Phases 1 and 2 are implemented (dust-only NGACv1 and multi-species NGACv2)
- Phase 3: implementation is on hold while forecast model is transitioned to FV3GFS-based dynamic core
  - GFS physics except GFDL MP
  - FV3GFS 13 km : Feb. 2019

Current Operational NEMS GFS Aerosol Component (NGACv2)

Current State

- Near-real-time operational system
- Global in-line aerosol forecast system at T126
- AGCM : NCEP's NEMS GFS (spectral model)
- Aerosol: GSFC's GOCART, no DA
- Uses 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 (Wang et al., GMD, 2018)

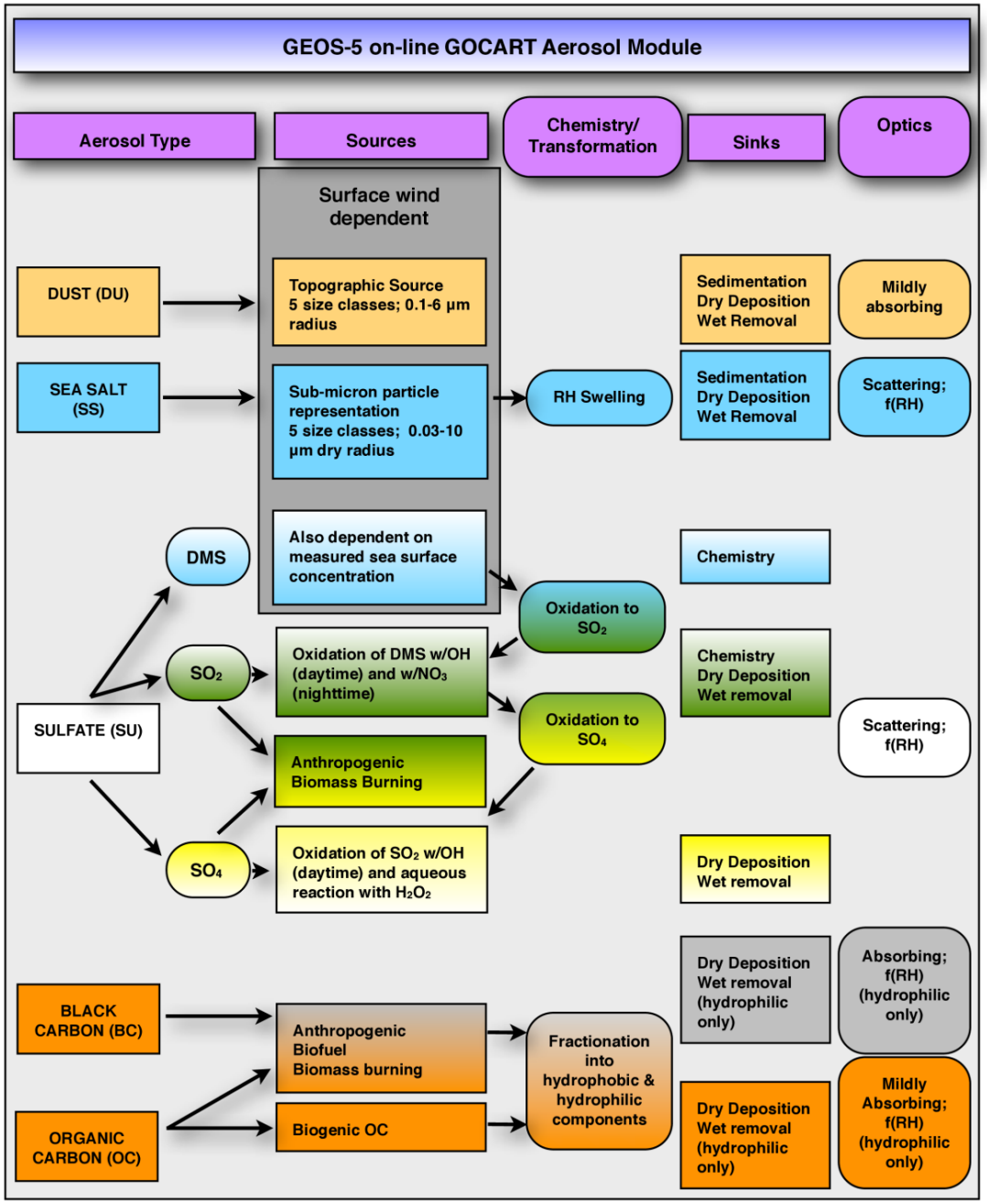


Real time NGACv2 webpage : http://www.emc.ncep.noaa.gov/gmb/NGAC/html/realtime.ngac.html
verification : http://www.emc.ncep.noaa.gov/gmb/NGAC/NGACv2/

GOCART Module

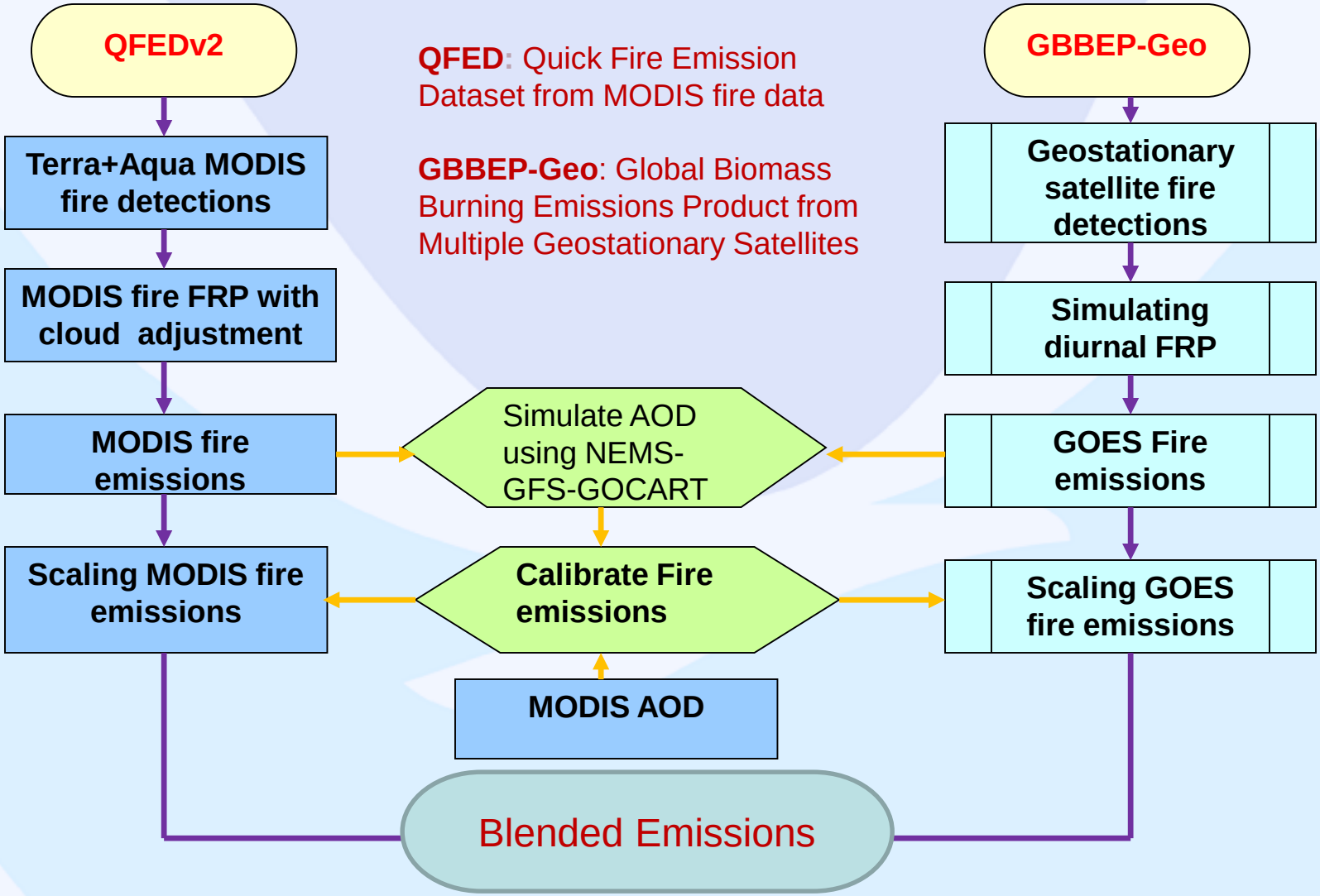
In-line chemistry advantage

- 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 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)

NGACv2 Product Suite and Applications

NGACv2 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**

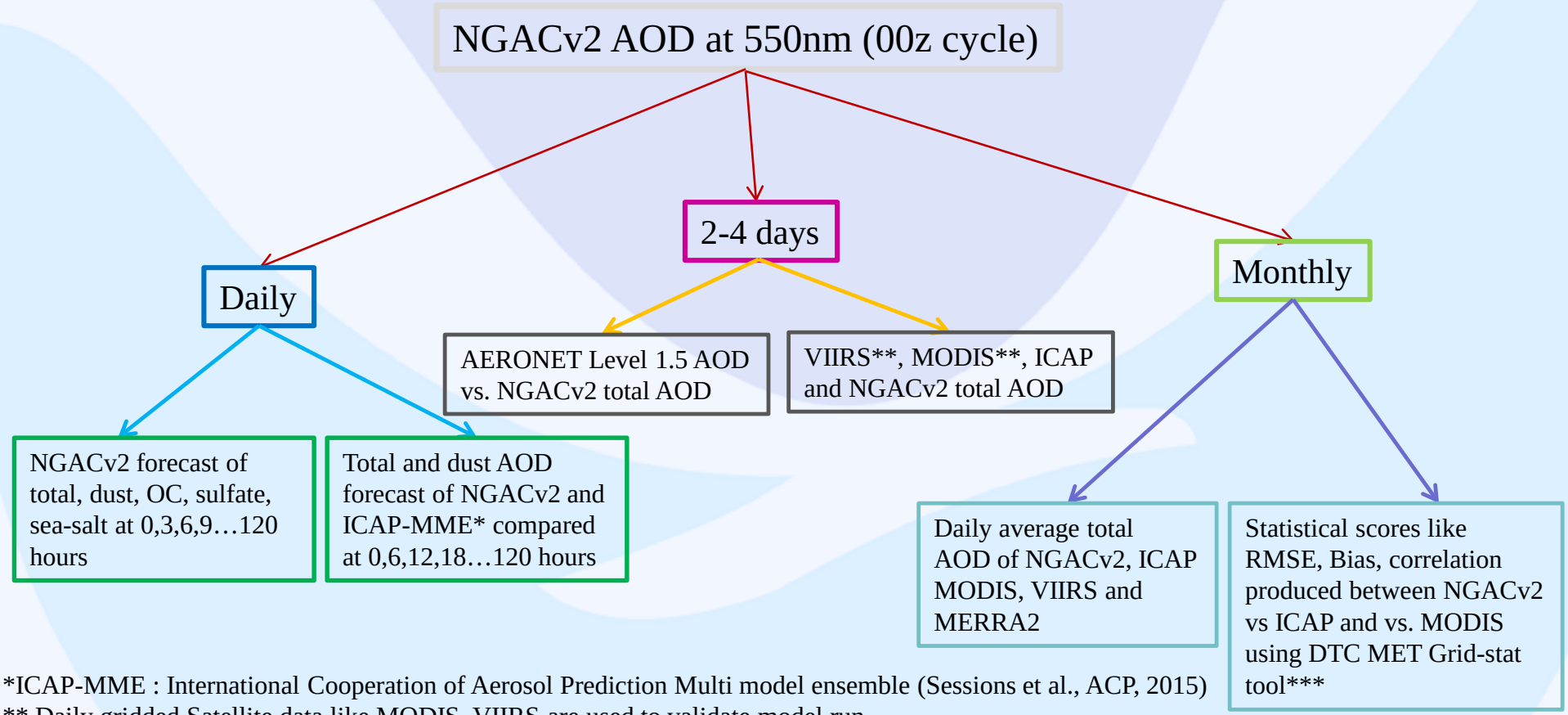
- **ngac.t00z.aod_$CH.grib2, CH=340nm, 440nm, 550nm, 660nm, 860nm, 1p63um, 11p1um**
  - Aerosol Optical Depth (AOD) at specified wavelength from 0 to 120 hour

- **ngac.t00z.a2df$FH.grib2, FH=00, 03, 06, ….120**
  - Total AOD at 0.55 micron
  - PM2.5 and PM10 for total aerosol (WMO request)
  - 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
  - *Ångström* Exponent for total aerosols from 0.44 and 0.66 micron

- **ngac.t00z.a3df$FH.grib2, FH=00, 03, 06, ….120**
  - 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 are in pink.

NGACv2 verification suites



*ICAP-MME : International Cooperation of Aerosol Prediction Multi model ensemble (Sessions et al., ACP, 2015)
** Daily gridded Satellite data like MODIS, VIIRS are used to validate model run
*** currently only covers day-1 forecast skill

Near real-time verification : http://www.emc.ncep.noaa.gov/gmb/NGAC/NGACv2/ covers time-period between 2015 and present

Data for AOD verification

Model based :

- ICAP-MME (from NRL ftp site, data latency is 1-day). Provides total, dust AOD at 550nm 6 hour interval from 0-120 hours (also coarse, fine mode). Data resolution 1 degree.
- ECMWF CAMS : from Copernicus, only 00z cycle. Provides total, dust, OC, BC, Sulfate and sea-salt at 1 degree (3 hours interval from 0-120 hours)
- MERRA2 monthly aerosol extinction at 550nm at 0.5 X 0.625 resolution

Satellite based :

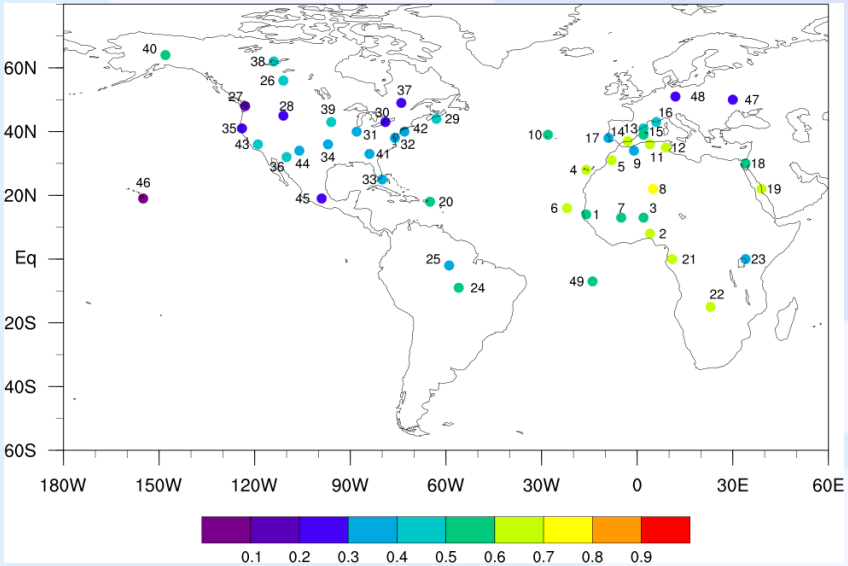
- MODIS daily and monthly collection 6.1 total AOD at 1 degree
- VIIRS AOD at 0.25 degree
- CALIPSO monthly vertical profiles
- Have used MISR, OMI, GOME2 (on METOP-B absorbing aerosol Index) for few case studies

Ground based :

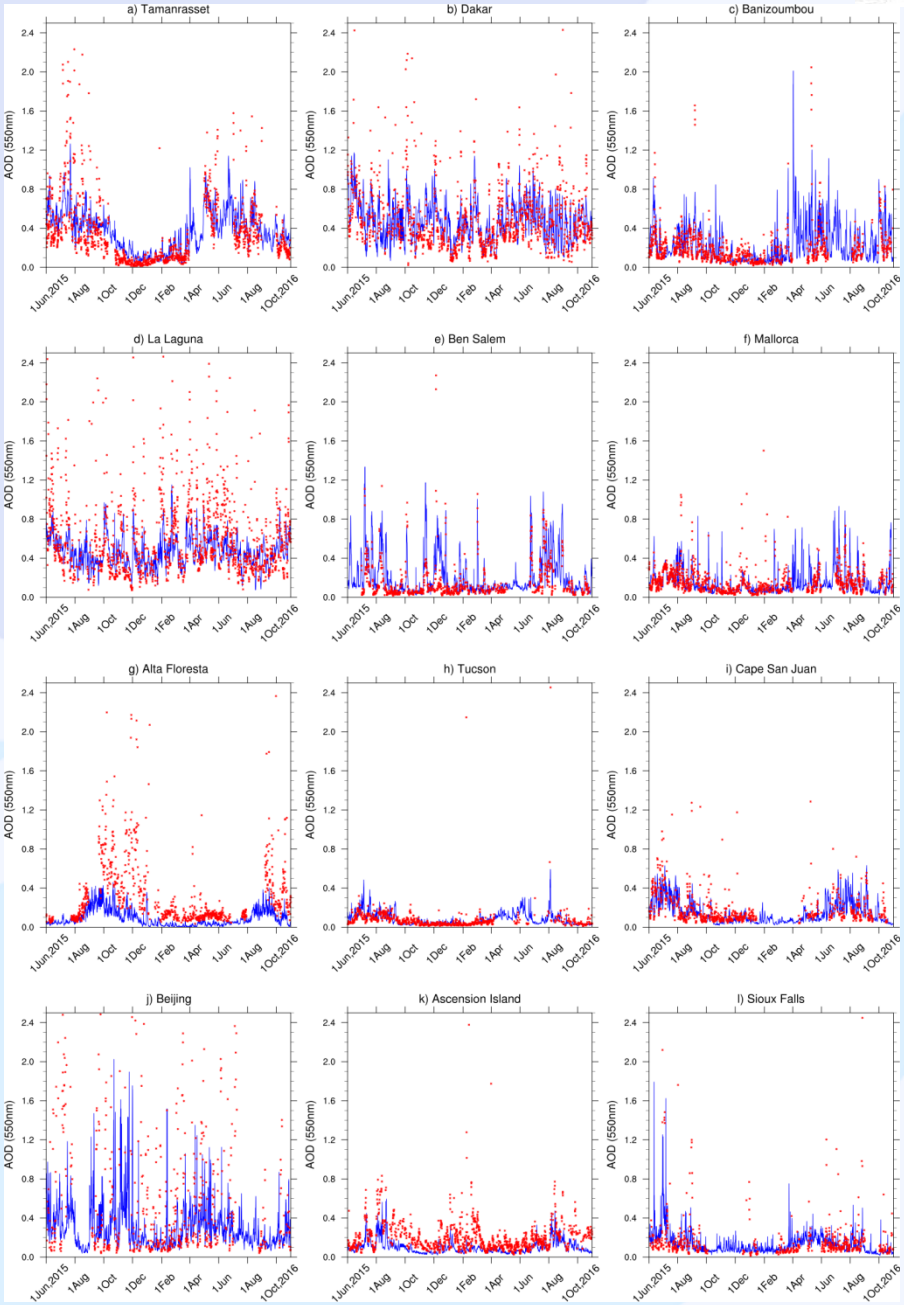
- AERONET level 1.5 over 30 locations
- Use of EPA pm2.5 data to validate model PM forecast → near future

NGACv2 verification

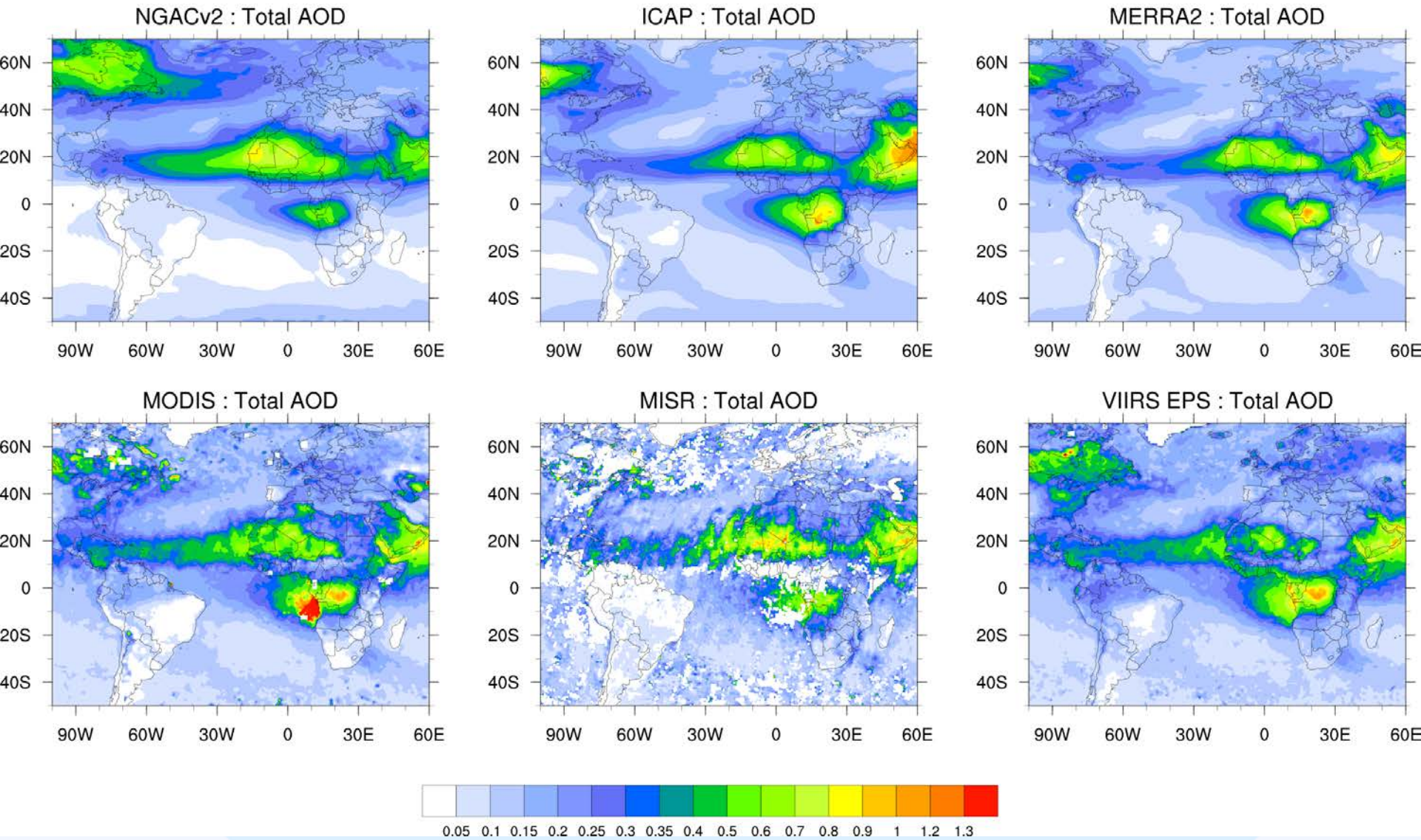
- Statistics of 2015-2016 NGACv2 vs. AERONET



(Bhattacharjee et al., GMD, 2018)

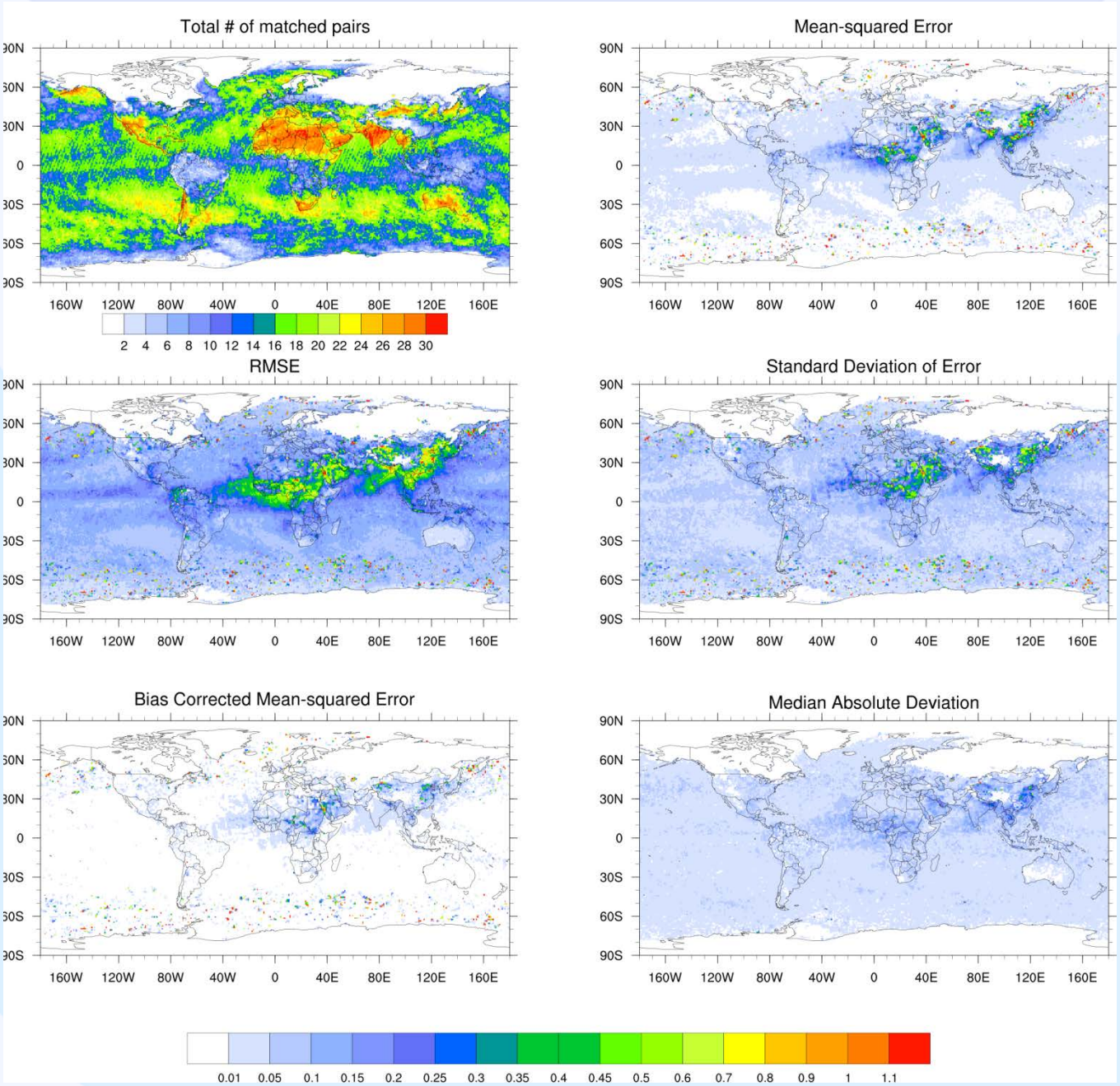


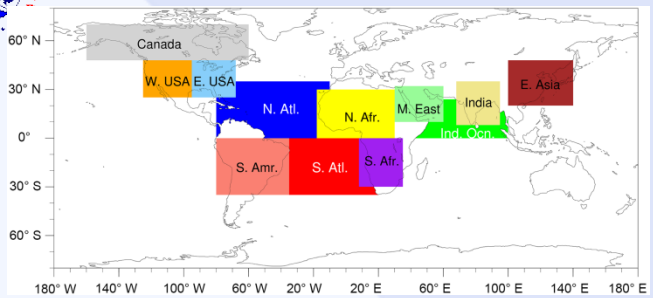
July 2015 : Monthly mean



NGACv2 verification using MET

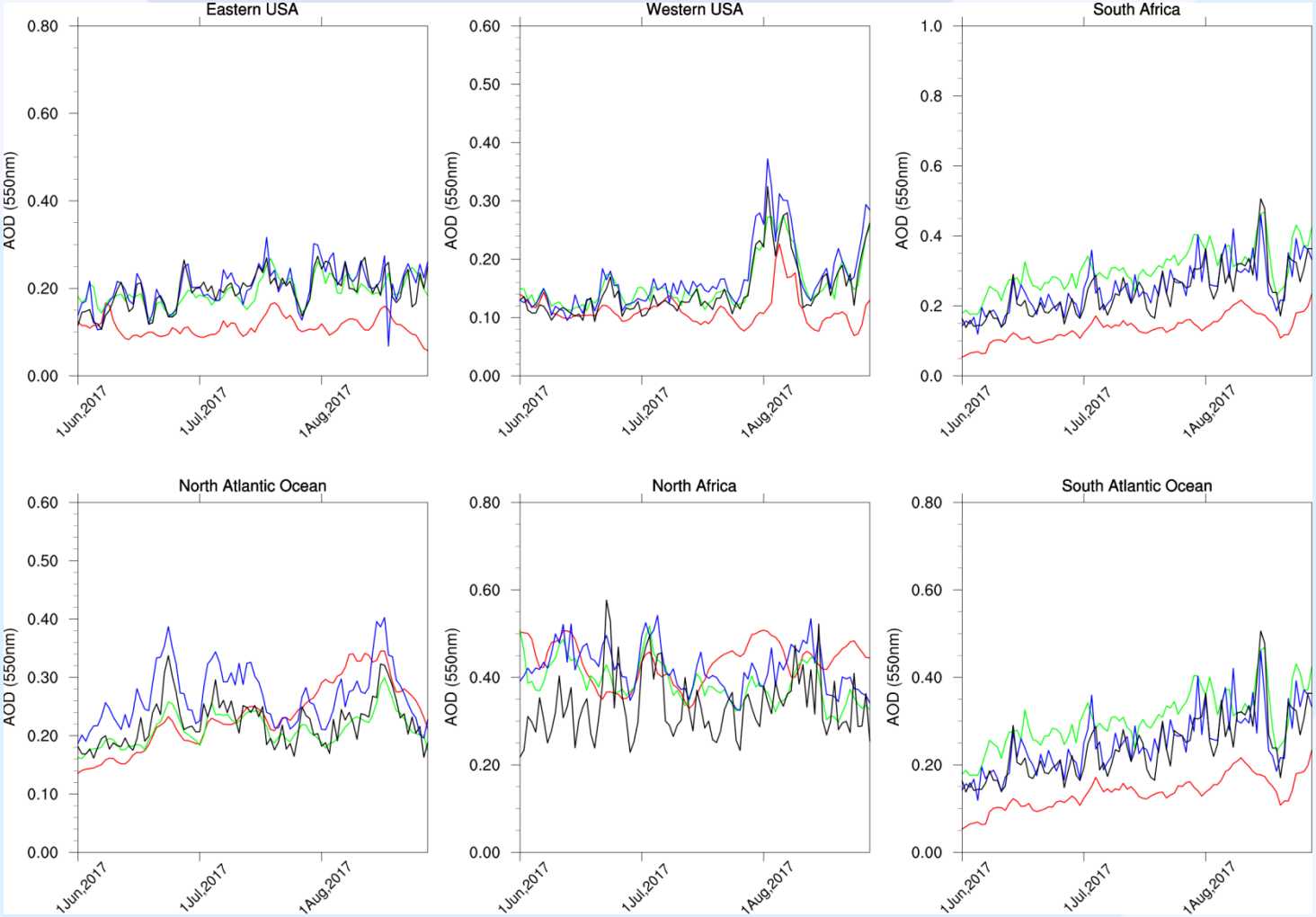
March, 2018





- 0.25 degree gridded VIIRS AOD from ftp site are used

Total AOD : June-July-August 2017

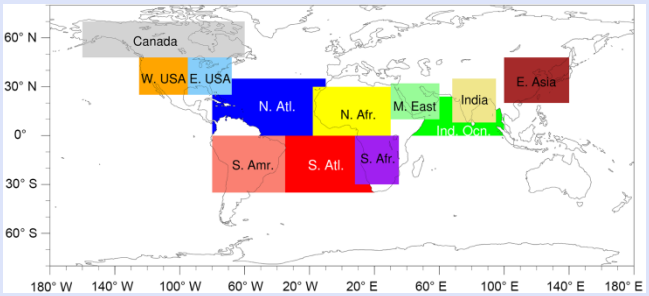


- NGACv2
- ICAP-MME
- MODIS, col6
- VIIRS

Total AOD : June-July-August 2017

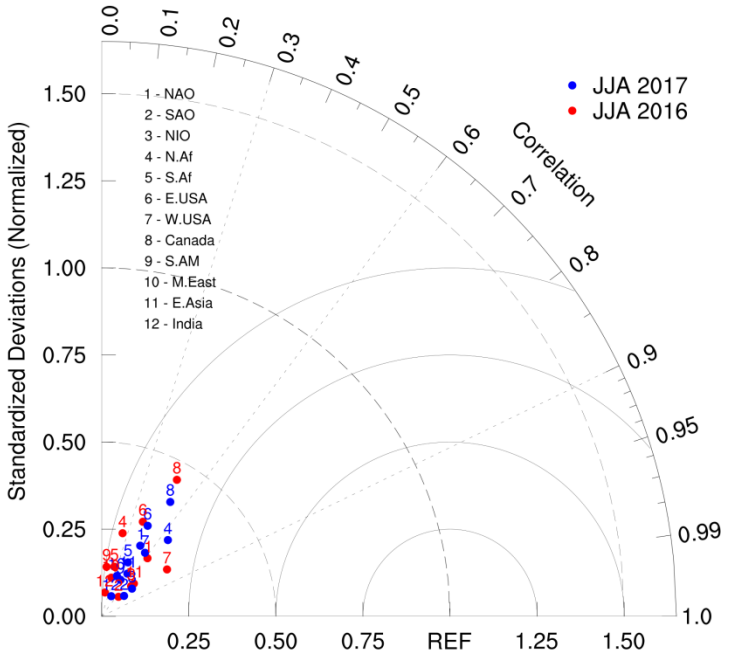
Correlation	NGACv2 vs. ICAP	NGACv2 vs. MODIS	NGACv2 vs. VIIRS
North Atlantic Ocean	0.66	0.48	0.42
South Atlantic Ocean	0.75	0.74	0.73
North Indian Ocean	0.81	0.74	0.71
North Africa	0.81	0.66	0.59
South Africa	0.55	0.44	0.36
Middle East	0.42	0.35	0.28
East Asia	0.66	0.51	0.47
India	0.59	0.43	0.38
South America	0.34	0.17	0.15
East USA	0.61	0.46	0.45
West USA	0.77	0.56	0.52
Canada	0.71	0.52	0.49

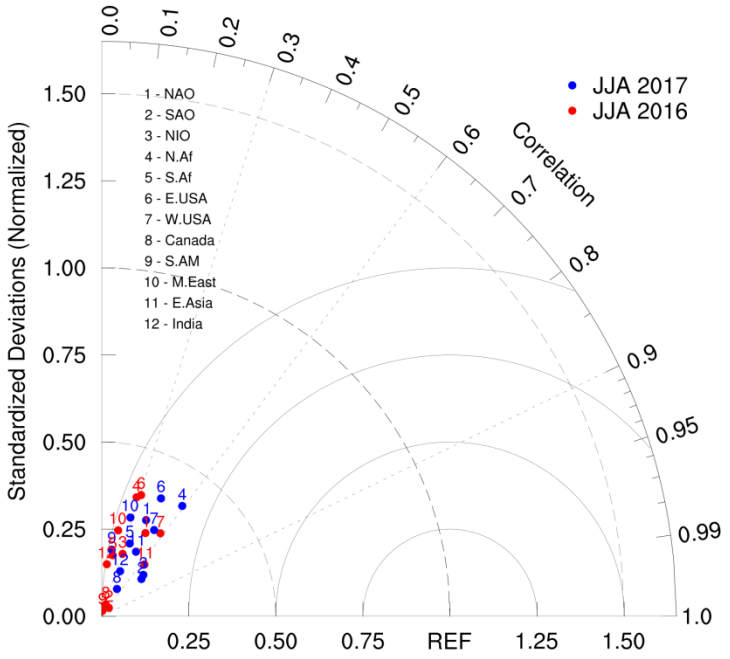
RMSE	NGACv2 vs. MODIS	NGACv2 vs. VIIRS
North Atlantic Ocean	0.07	0.06
South Atlantic Ocean	0.08	0.12
North Indian Ocean	0.27	0.19
North Africa	0.07	0.06
South Africa	0.13	0.11
Middle East	0.14	0.17
East Asia	0.21	0.18
India	0.4	0.19
South America	0.06	0.07
East USA	0.1	0.09
West USA	0.08	0.06
Canada	0.09	0.1



NGACv2 vs. MODIS

NGACv2 vs. VIIRS



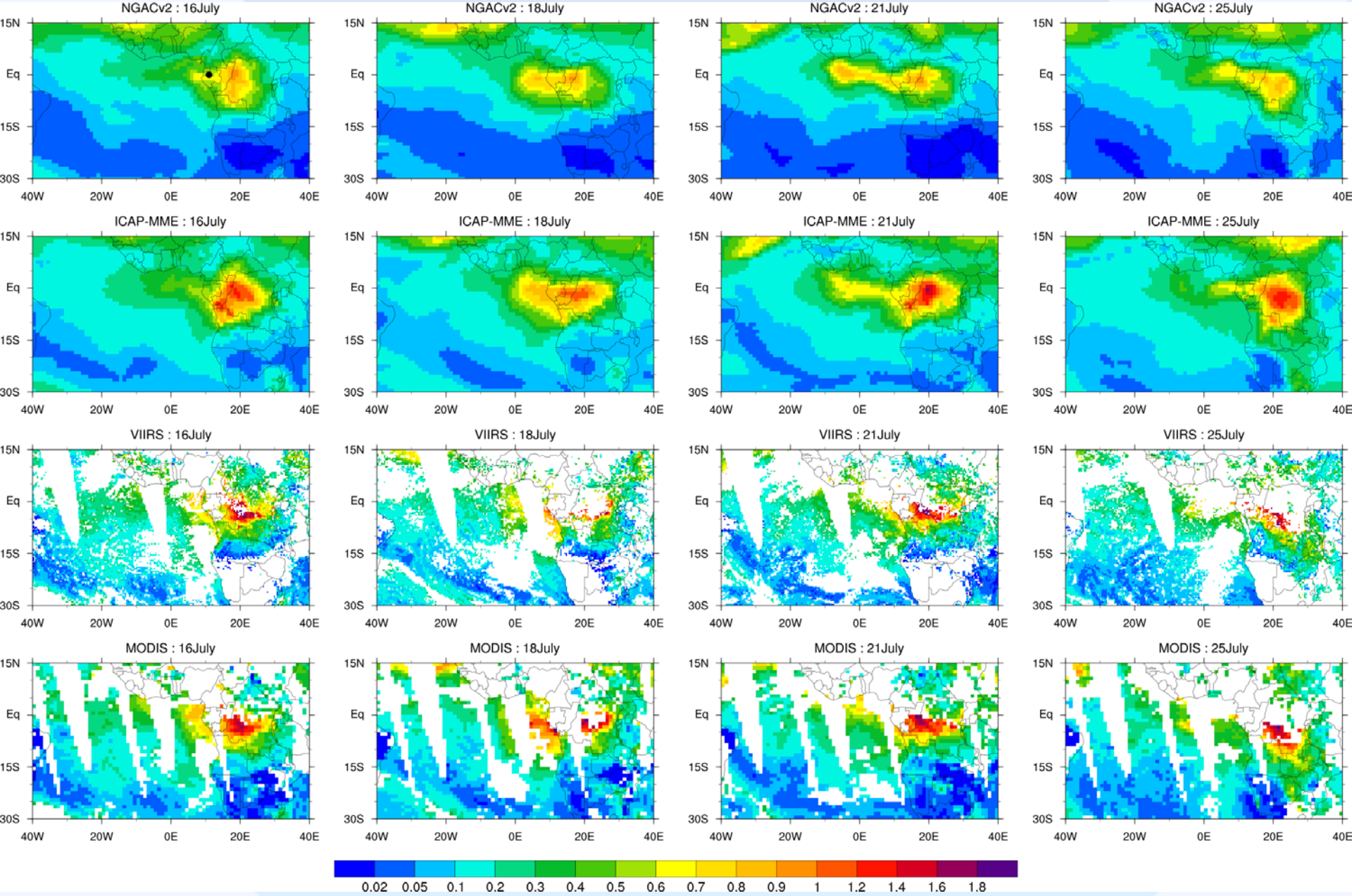


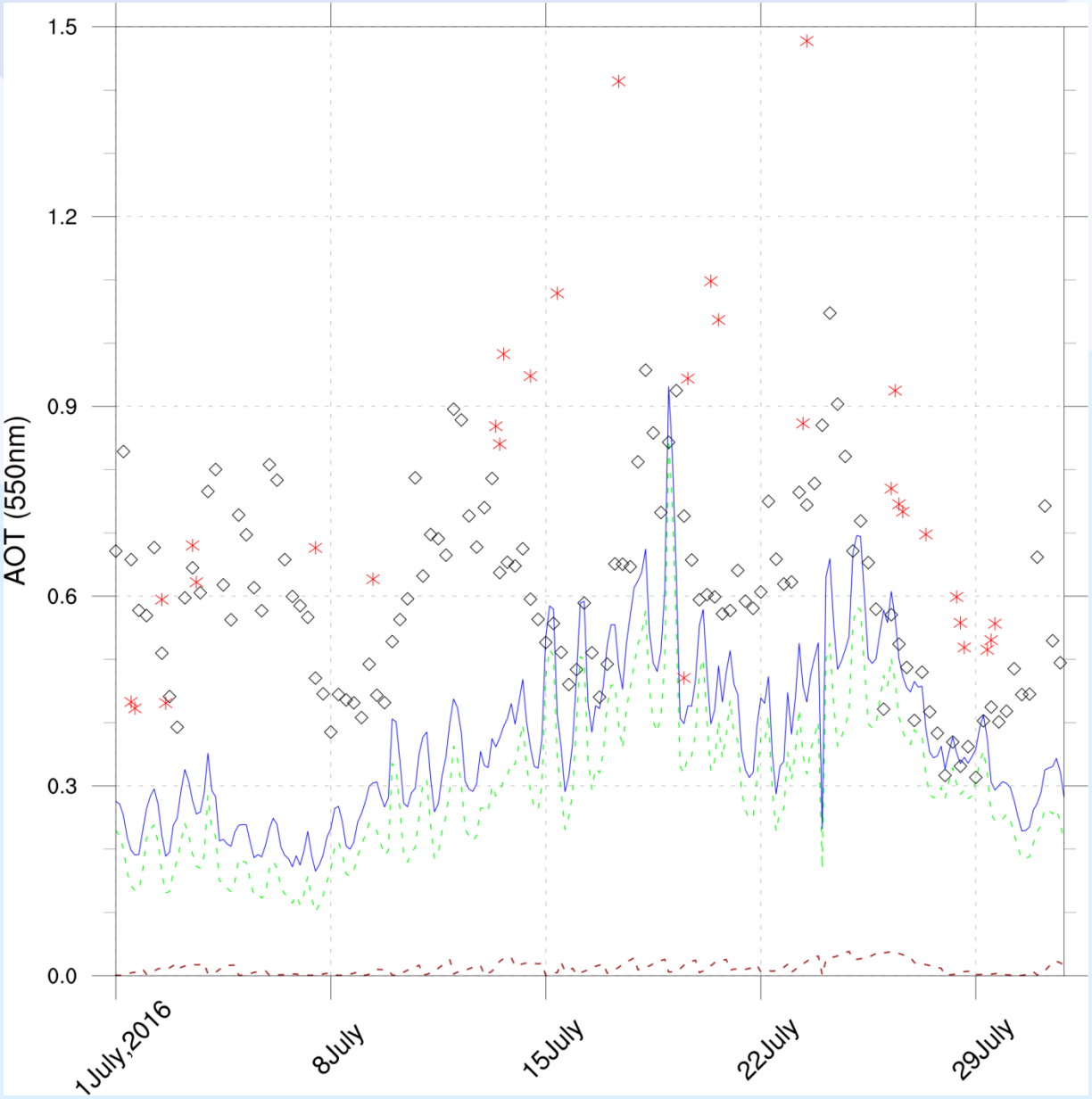
Case studies

Dust outbreaks	Smoke evets
January 31st, 2015 : N. Africa	April 14, 2015 : Siberia
February 2015, W. Africa	24th June, 2015 : Alaska
April 1, 2015 : Asia and Middle East	June 8, 2015 : Canada
May 10, 2015 : W. Africa	May 2016 : Ft. McMurray, Canada
4-11th July, 2016 : W. Africa	August 2016 : California
17-24th July, 2017 : Africa	August 2017 : British Columbia
2-3rd May, 2018 : NW India	

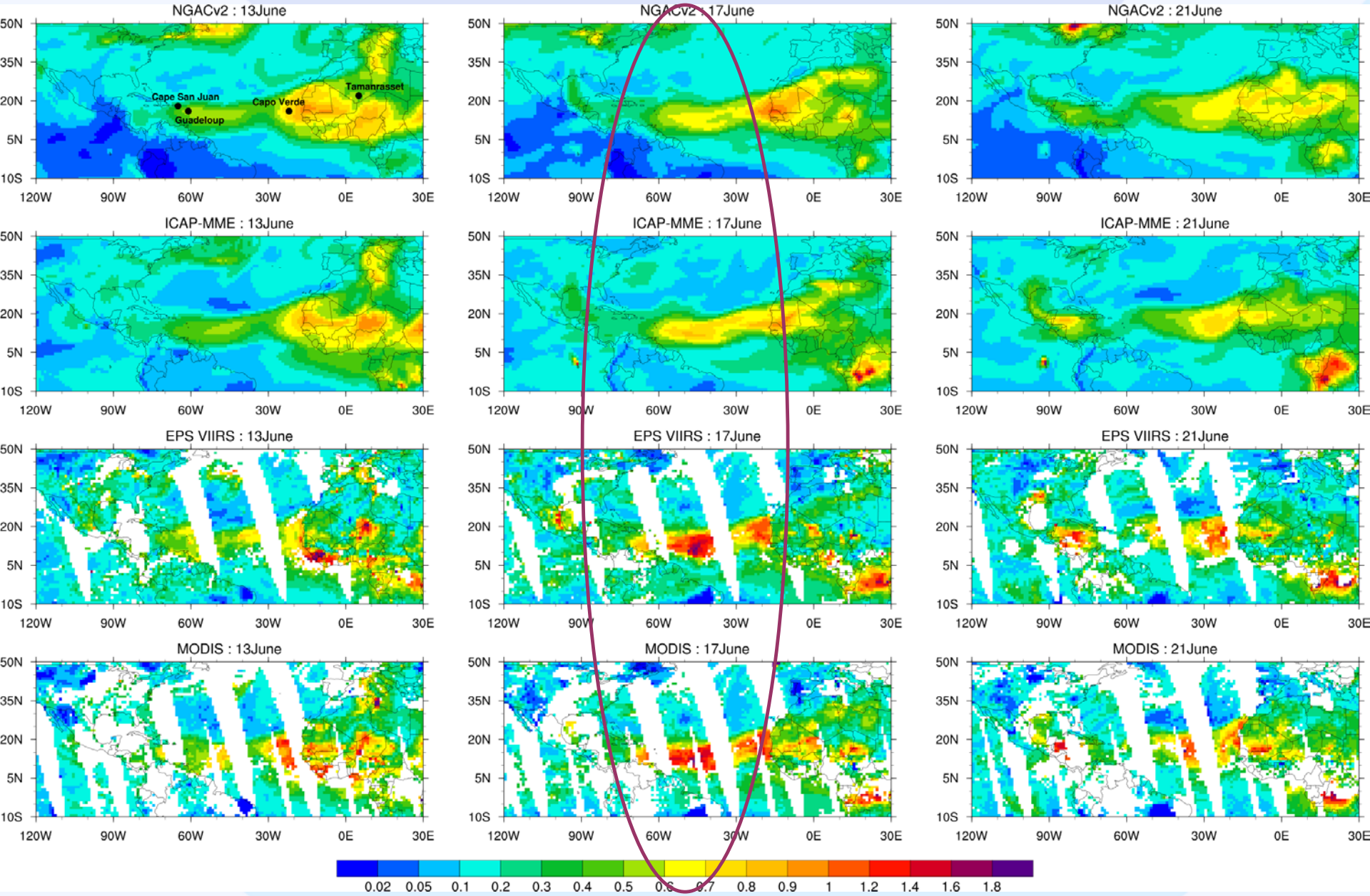
- extensively evaluated model simulations against global dust and smoke events before implementation

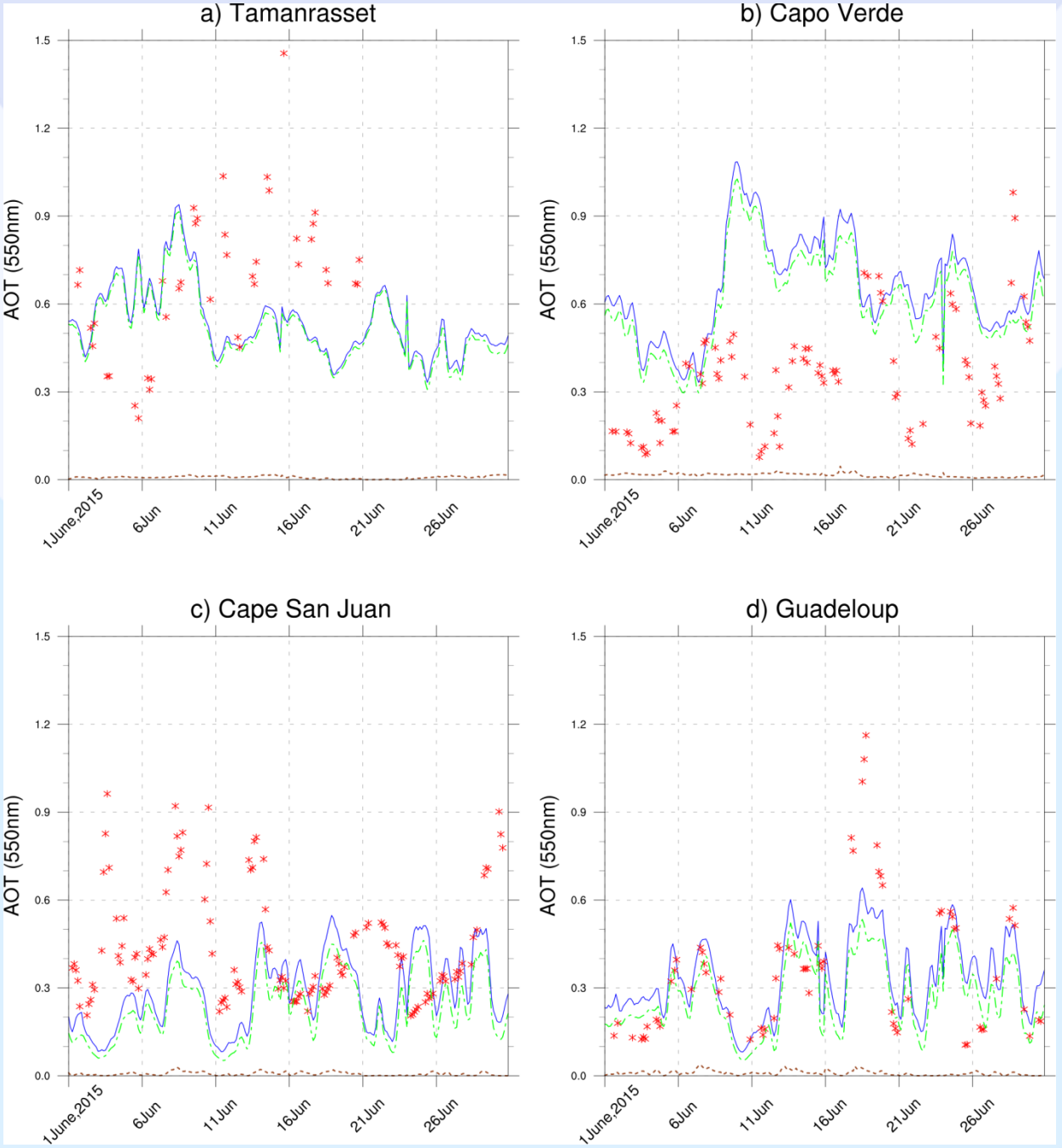
Forest fire over South Africa (2016)



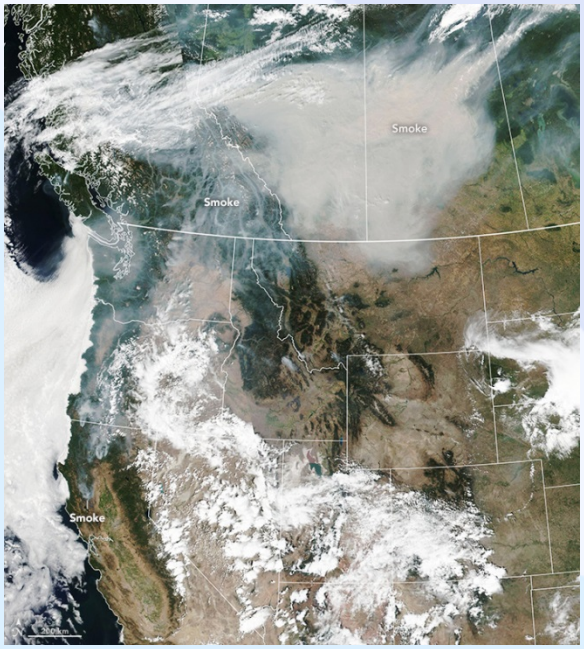

AERONET
OC AOD
Total AOD
ICAP total AOD
BC AOD
AOT (550nm)
1.5
1.2
0.9
0.6
0.3
0.0
1July,2016
8July
15July
22July
29July

Saharan dust storm , 2016

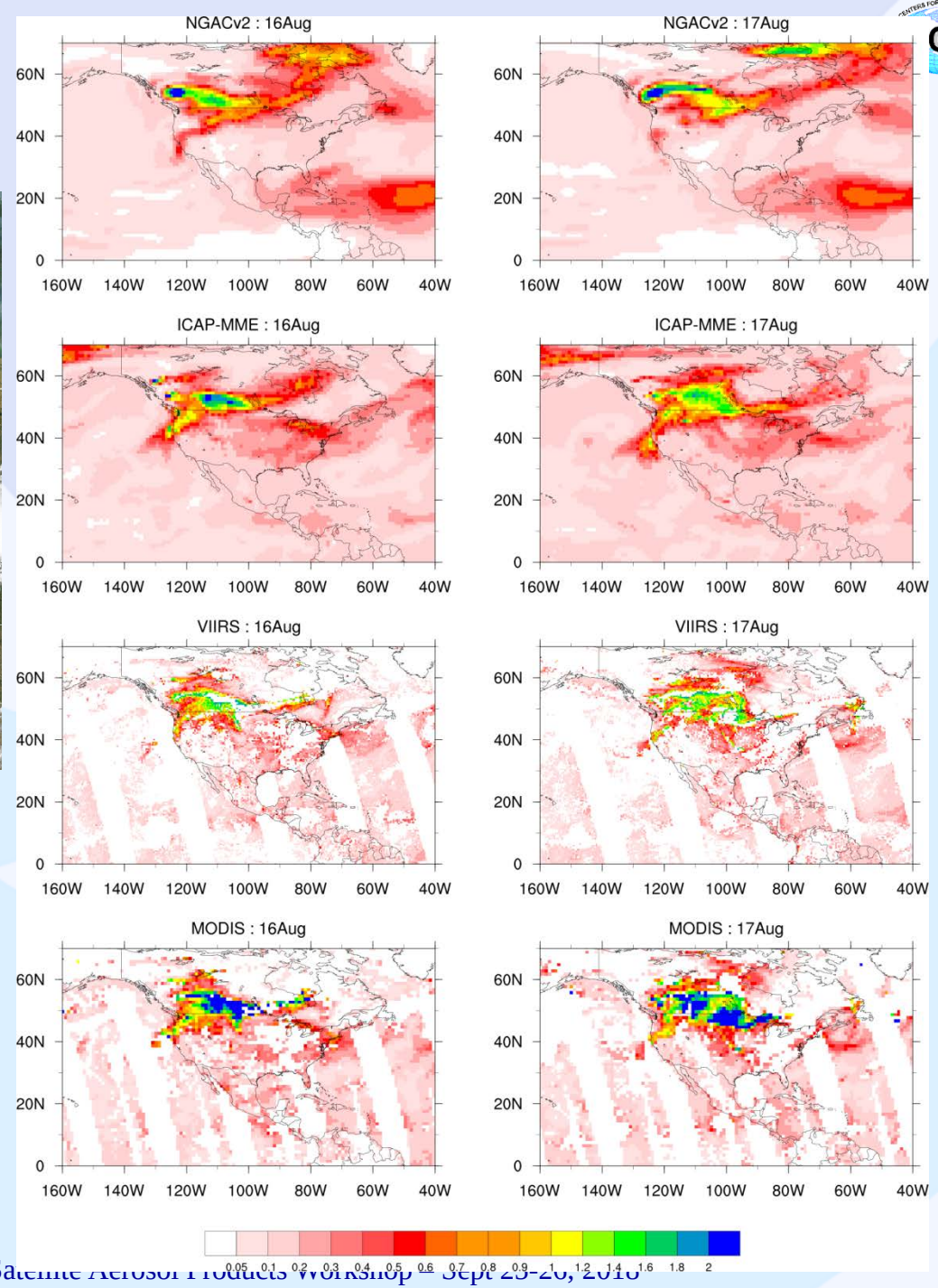



a) Tamanrasset
b) Capo Verde
c) Cape San Juan
d) Guadeloup
AOT (550nm)
0.0
0.3
0.6
0.9
1.2
1.5
1June,2015
6Jun
11Jun
16Jun
21Jun
26Jun
* AERONET
Dust AOD
Total AOD
OC AOD

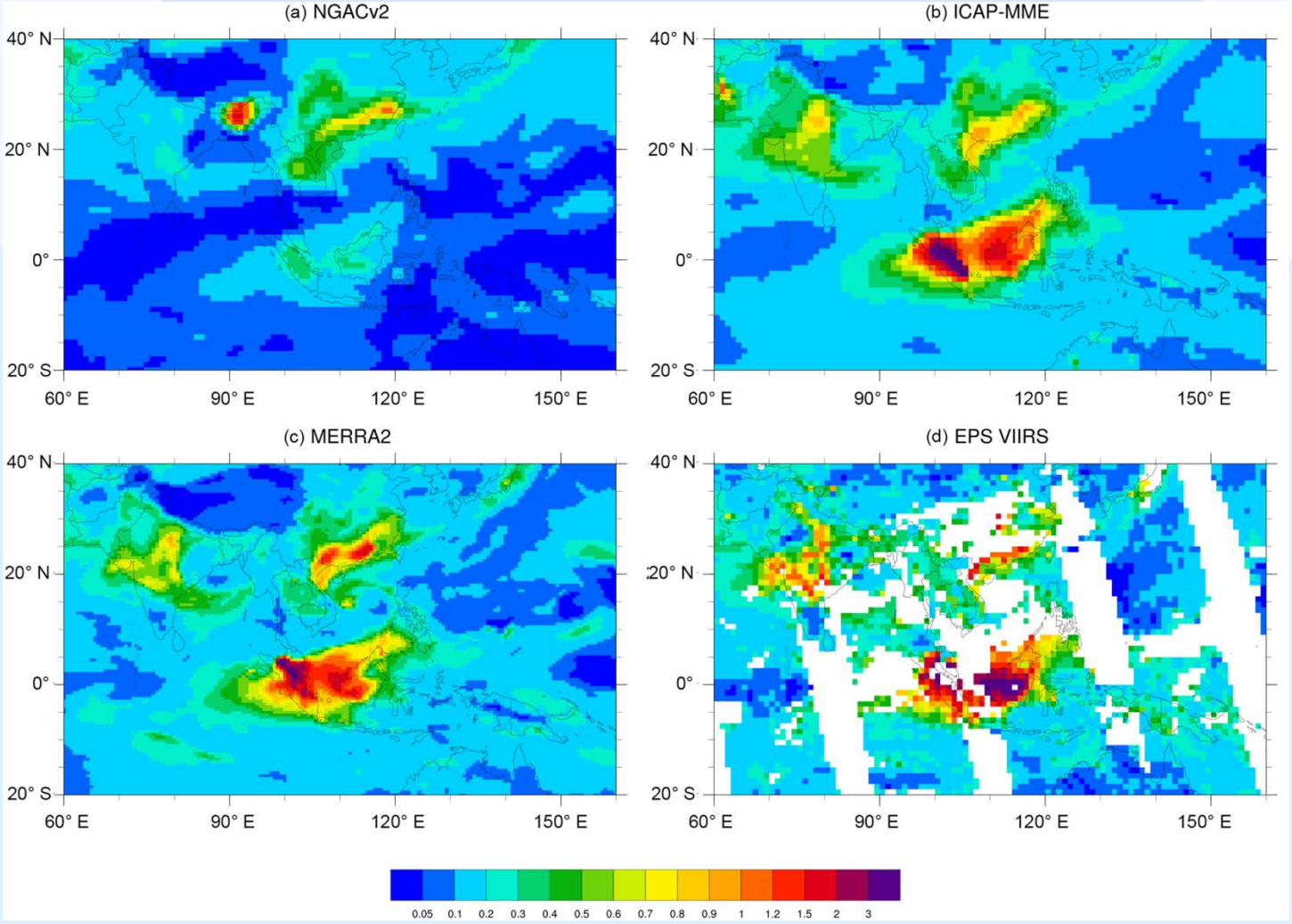
Canadian forest fire, 2018



https://earthobservatory.nasa.gov/images
(15th August, 2018)



Indonesian fire, 2015



- Model underestimates high AOD over SE Asia
- MERRA2 aerosol analysis increment (analysis – model first guess) shows 0.6-0.8 increase in AOD at 06:00z DA cycle

Conclusions

- Evaluations with satellite aerosol products are critical to current and future operational aerosol models run at NWS/NCEP. Using case studies, monthly and long-term statistics helped us to understand some of the biases (in terms of model, emission or absence of DA).
- NGACv2 able to simulate smoke events over Africa, USA, Canada with reasonable success.
- Some improvements of model simulations over Asia, but largely underpredicts AOD over India and China.
- Knowledge learned from implementing NGACv2 will help us to better understand and evaluate finer resolution GSDChem (with FV3 dynamics) in future.
- Limitation in model evaluation in terms of using total AOD with observations. Any species based satellite/observational AOD data set available to better comparison with model results ?
- Collaboration with DTC MET group to read VIIRS AOD in progress and also to implement some object based verification