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

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Outline

- Introduction
  - Global aerosol modeling
  - Dual resolution weather-aerosol system at NCEP
- SUNYA-NCEP-STAR R2O project on “Investigation of aerosol effects on weather forecast”
  - Overview
  - Proposed work and deliverables
  - Status update
- Conclusions

Global aerosol modeling at NWP centers

- Aerosol modeling, traditionally serving regional air quality and climate communities, has seen rapid development at several operational NWP centers over the last few years
- Why include aerosols in the predictive systems ?
  - Improve weather forecasts and climate predictions by taking into account of aerosol effects on radiation and clouds
  - Improve the handling of satellite observations by properly accounting for aerosol effects during the assimilation procedure
  - Provide aerosol (lateral and upper) boundary conditions for regional air quality predictions
  - Produce quality aerosol information that address societal needs and stakeholder requirements

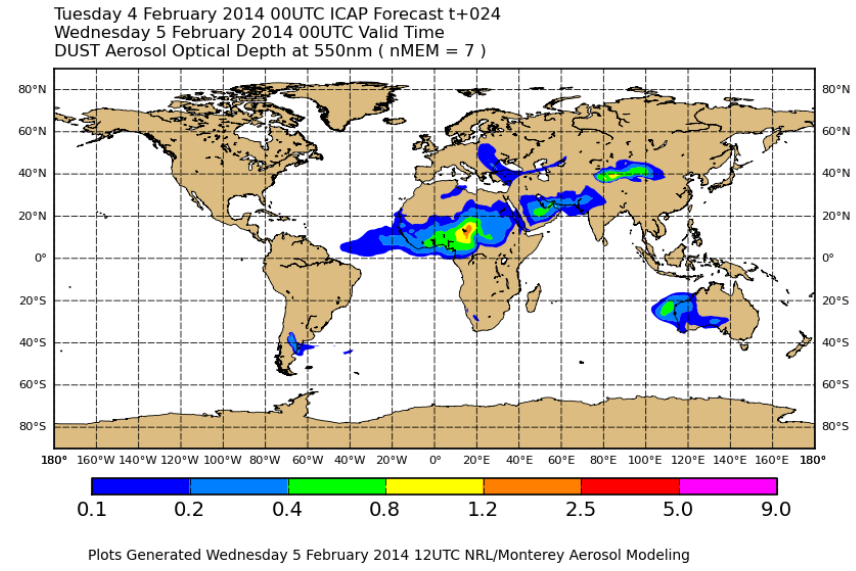
Global aerosol modeling at NWP centers –cont'd

- Aerosol prediction systems are built upon modeling/assimilation methodologies already in place for the meteorological systems.
  - NRL: NAAPS, driven by NOGAPS
  - ECMWF: IFS coupled with LMD
  - GMAO: GEOS-5 coupled with GOCART
  - NCEP: NEMS GFS coupled with GOCART
- Near-real-time smoke emissions from satellites are used. For instance,
  - NRL: FLAMBE (Fire Locating and Modeling of Burning Emissions), fire counts from MODIS and GOES
  - ECMWF: GFAS (Global Fire Assimilation System), FRP from MODIS
  - GMAO: GFED (Quick Fire Emission Dataset), FRP from MODIS
  - NCEP: GBBEPx (Blended Global Biomass Burning Emissions Product – eXtended), FRP from MODIS and geostationary satellites

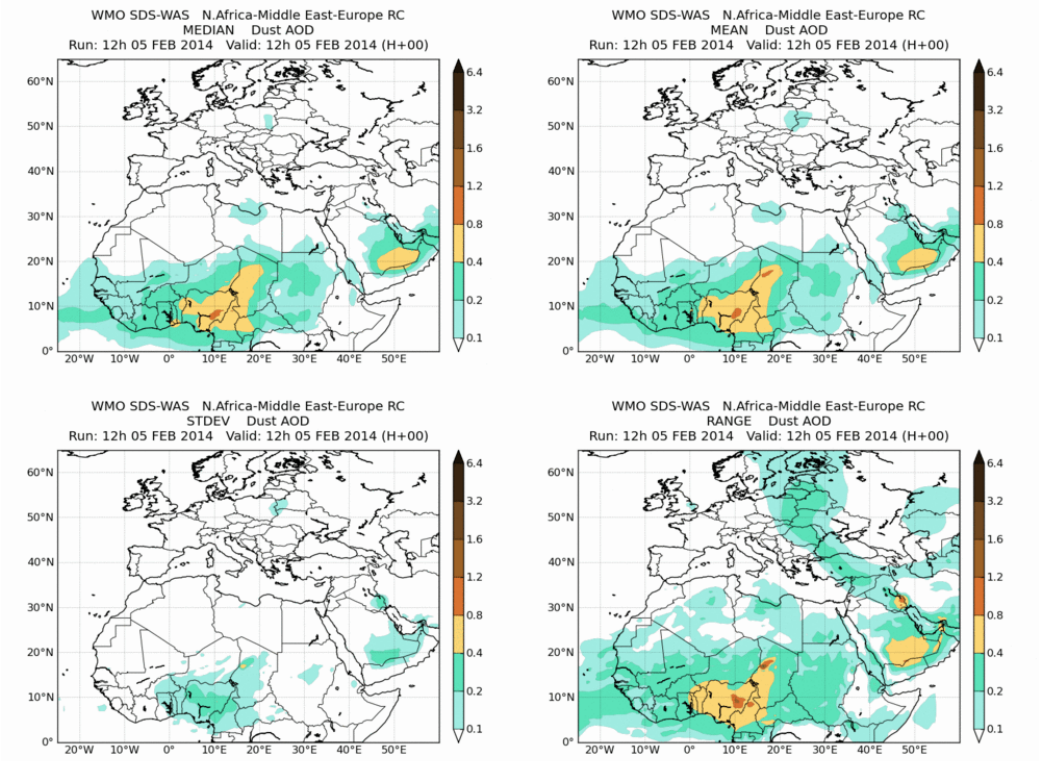
Multi-model Aerosol Ensemble

NGAC dust products contribute global multi-model ensemble (International Cooperative for Aerosol Prediction, ICAP) and regional multi-model ensemble (WMO Sand and Dust Storm Warning Advisory and Assessment System, SDS-WAS)

ICAP global MME. Seven members for dust AOD, including NCEP, NRL, ECMWF, GMAO, JMA, UKMO & BSC.

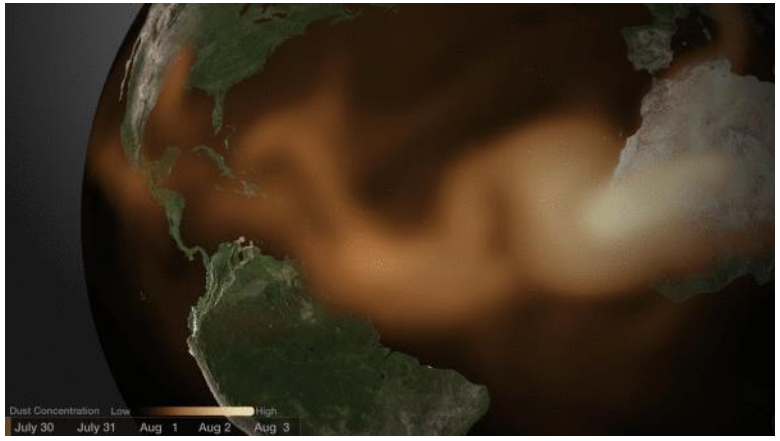


WMO SDS-WAS regional MME. Nine members including 6 global models (NCEP, ECMWF, GMAO, NRL, UKMO & BSC)



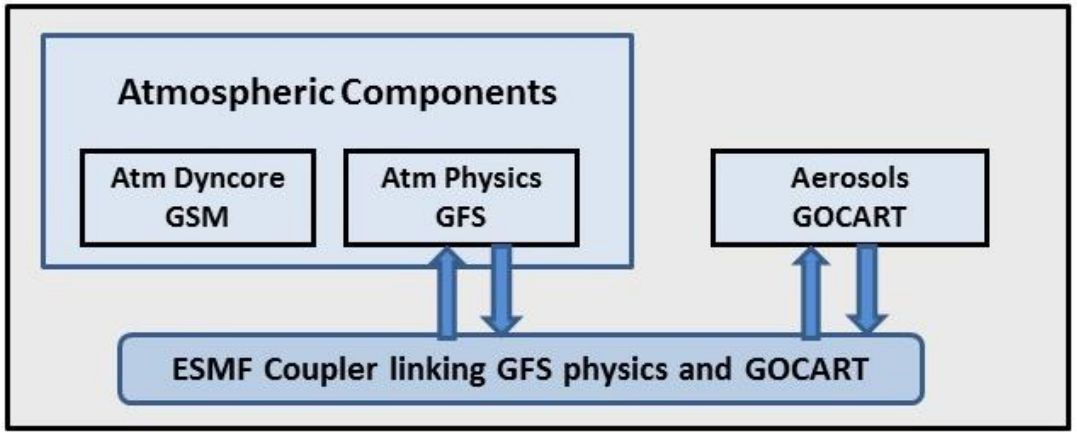
NEMS GFS Aerosol Component

- NCEP's global in-line aerosol forecast system
- Build upon NOAA Environmental Modeling System (NEMS), a common modeling framework using Earth System Modeling Framework (ESMF)
- 5-day dust-only forecast since 2012. Multi-species forecast (dust, sea salt, sulfate, carbonaceous aerosols) upgrade planned in 2016
- Model Configuration:
  - Resolution: T126 L64
  - AGCM: NEMS GFS
  - Aerosol: GOCART



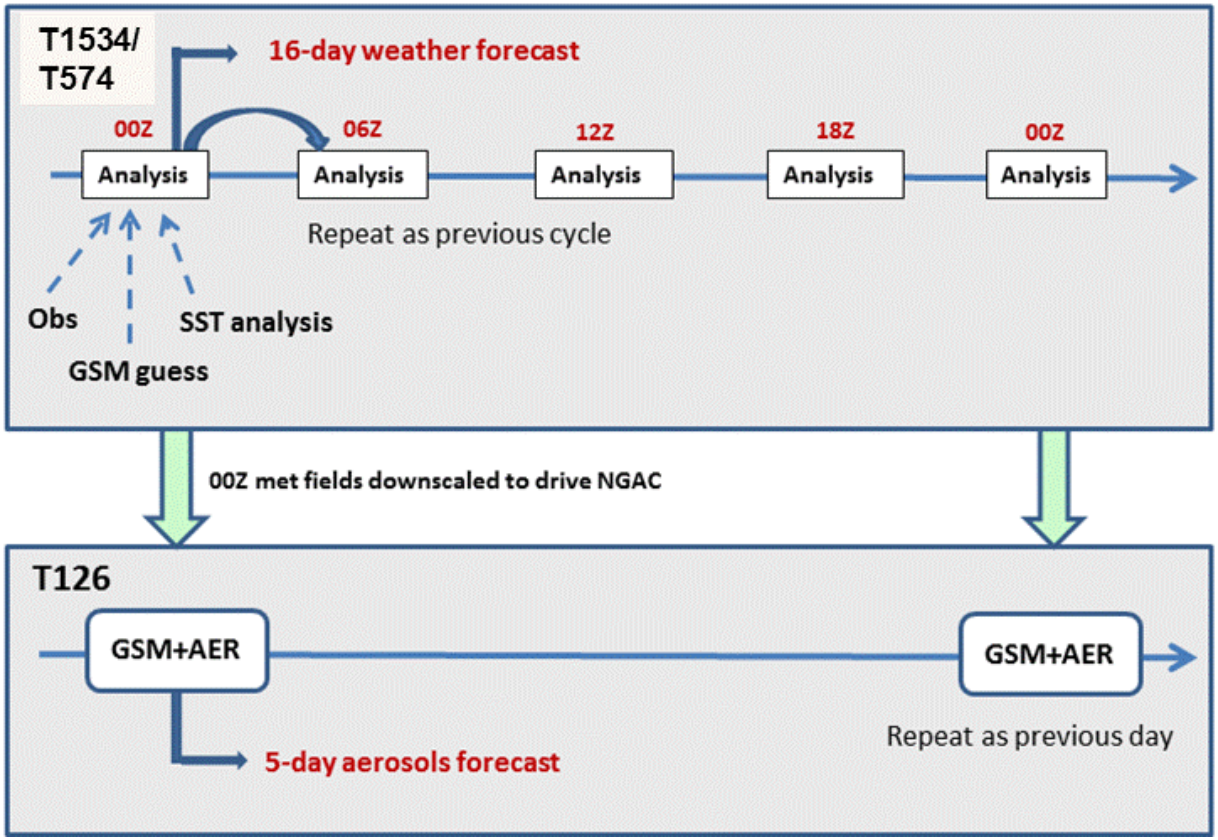
ESMF Earth System Modeling Framework

ATM and AER in NEMS



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 NGAC runs

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

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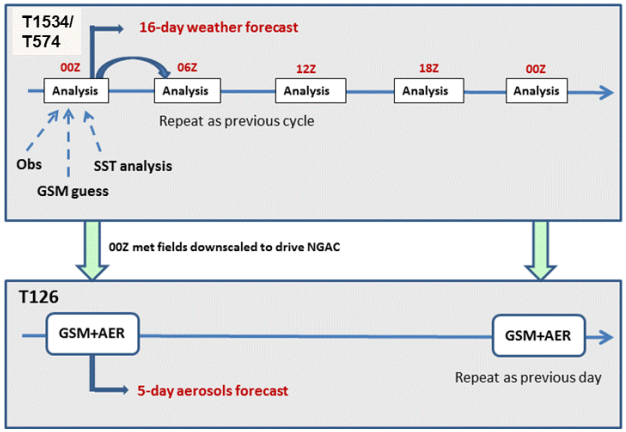
Project Overview

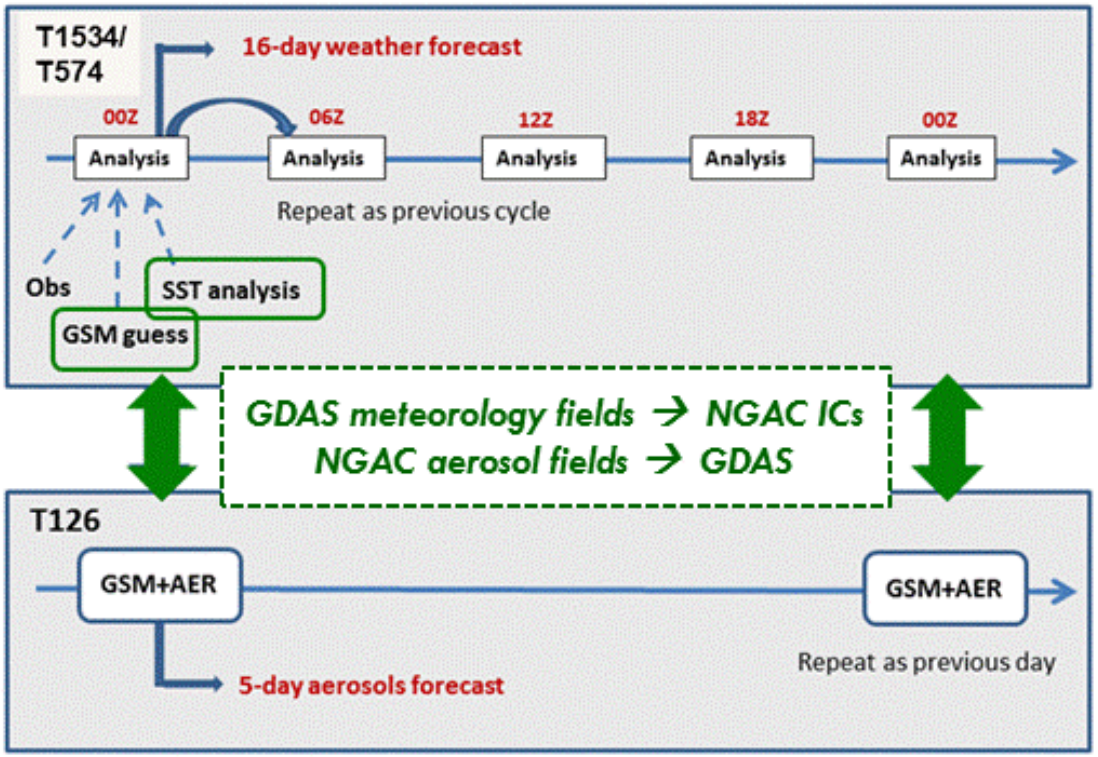
- Objective: Investigate how much complexity is needed to accurately represent the aerosol processes and effectively account for aerosol effects
- Tactical approach:
  - Producing an improved estimates of the temporal an spatial distributions of atmospheric aerosols
  - Aerosol fields from low-resolution 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.
  - Using aerosol fields in conjunction with the forecast model (GSM), the analysis system (EnKF-GSI hybrid), and SST analysis (RTG_SST) to assess the atmospheric response to aerosols

Dual resolution weather-aerosol 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.

Proposed Work Plan

- Year-1:
  - Modify GSI/CRTM code to account for GOCART aerosol radiative effects
  - Modify GSM radiation to account for GOCART aerosol radiative effects
  - Evaluate RTG_SST analysis system with the aerosol option incorporated
  - Upgrade GFS parallel scripts to enable two-day coupling
  - Select cases with scenarios of interest (dust outbreak, biomass burning events, and hurricane activities)
- Year-2:
  - Conduct baseline GFS experiments for selected periods
  - Conduct parallel GFS experiments with two-way coupling configuration
  - Diagnose the results from baseline versus parallel experiments
  - Benchmark report

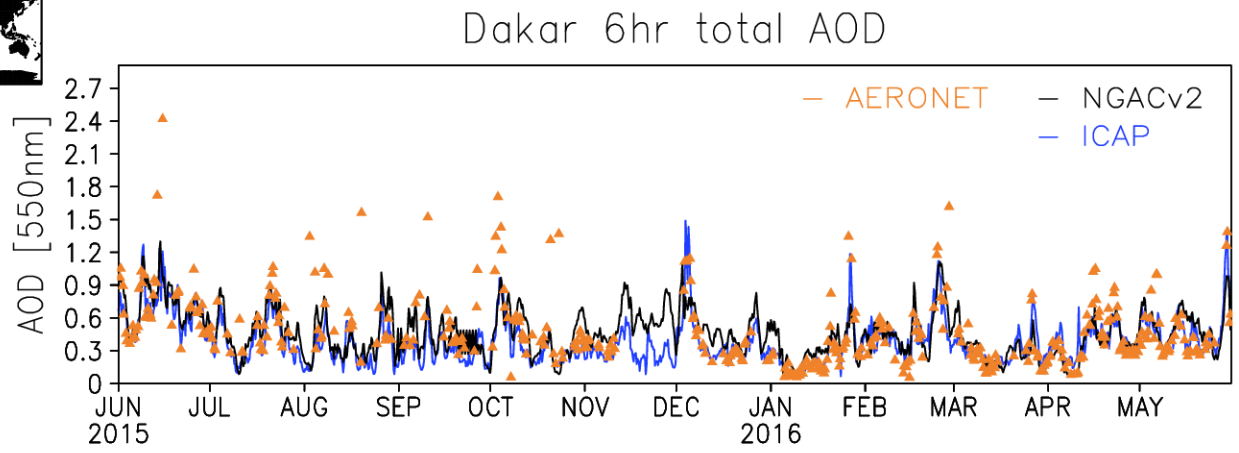
2015-2016 NGAC V2 evaluation

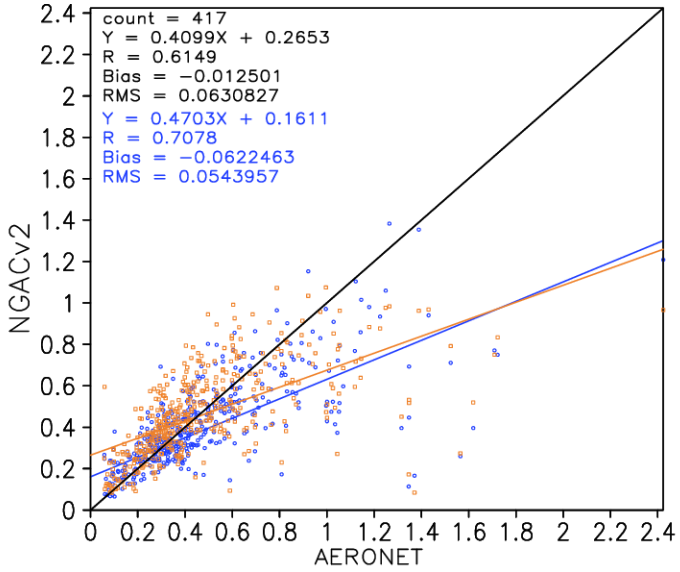
- Rigorous evaluation, diagnosis, and verification of NGAC V2 are needed to ensure that the spatial distribution and temporal variation of NGAC simulated aerosols have reasonable accuracy and are suitable for the aerosol-NWP study.
- We analyzed the results from parallel NGAC V2 for the 2015-2016 period.
- The team evaluates the NGAC simulations with aerosol products from other global models (ICAP-MME and MERRA2), in situ observations from ground-based network (L1.5 AERONET), and aerosol retrievals from satellites (MODIS and VIIRS).

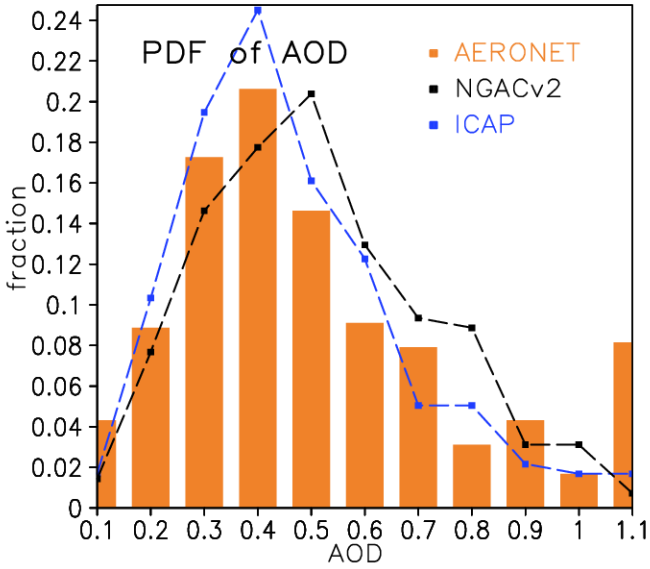
Descriptions of Data

- Data period: 2015/06/01 00Z – 2016/05/31 24Z
- NGAC V2 total AOD at 550 nm
  - NGACv2 parallel run (ngacv2_dev3_t1)
    - Multi-species aerosols (DU, SU, SS, BC, OC)
    - Use satellite-based GBBEPx smoke emissions
- AERONET Level 1.5 total AOD at 550nm
  - AOT_{550} is calculated from AOT at 440nm and 675nm
  - Bin 1-h time window centered at NGAC and ICAP model synoptic output times of 0, 6, 12 and 18 UTC
  - AOD observations greater than 2.5 are not considered
- ICAP-MME total AOD at 550nm
  - 4 members (NRL, GMAO, EMCWF, and JMA)
- Site selection criteria:
  - Sites with available AERONET data count > 500
  - 116 sites (Africa: 23, Arabian: 7, NAmer: 35, SAmer: 13, EU: 26, Asia: 11, Polar: 1)

2015-2016 NGAC V2 evaluation using in situ AERONET observations







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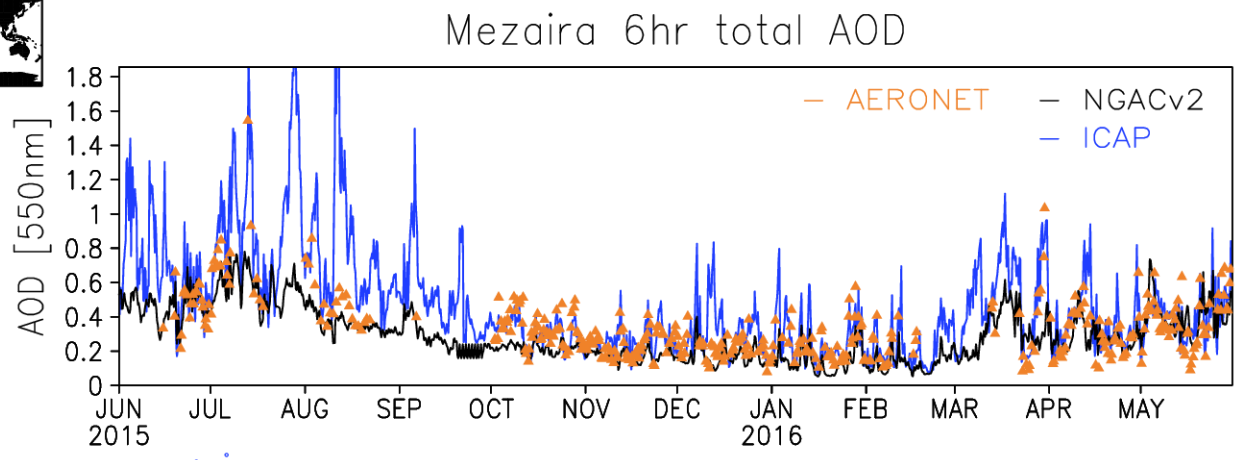

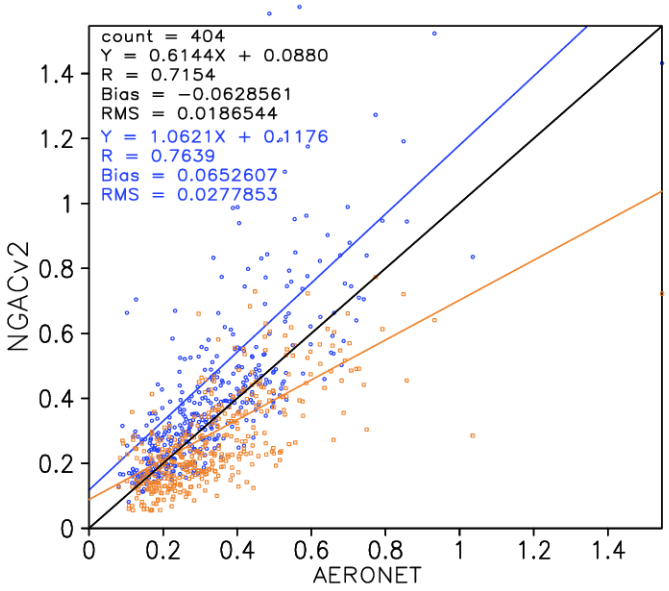

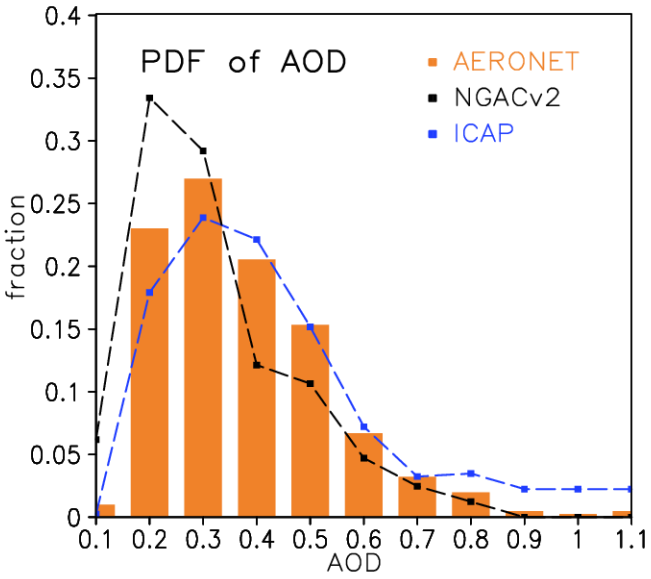

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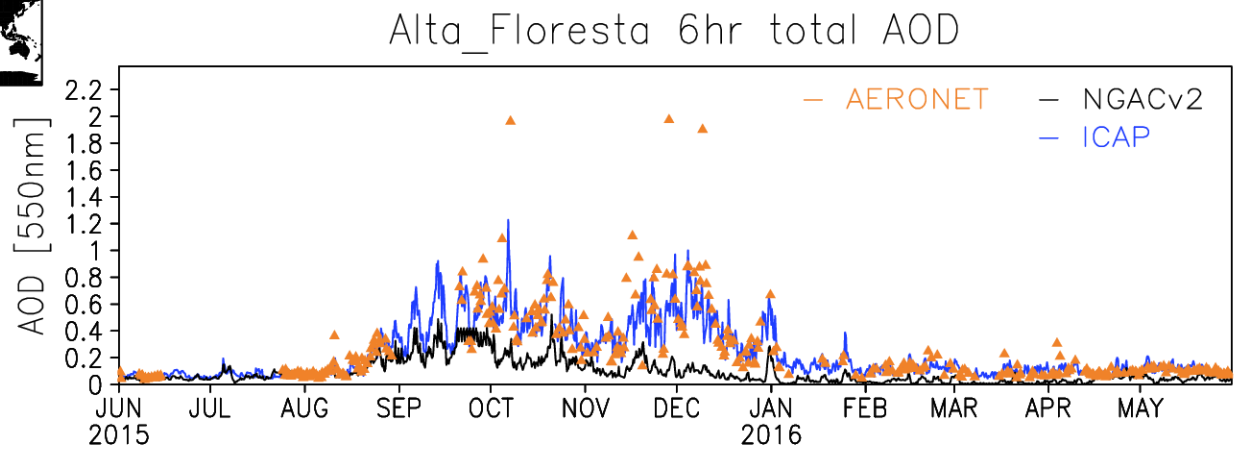

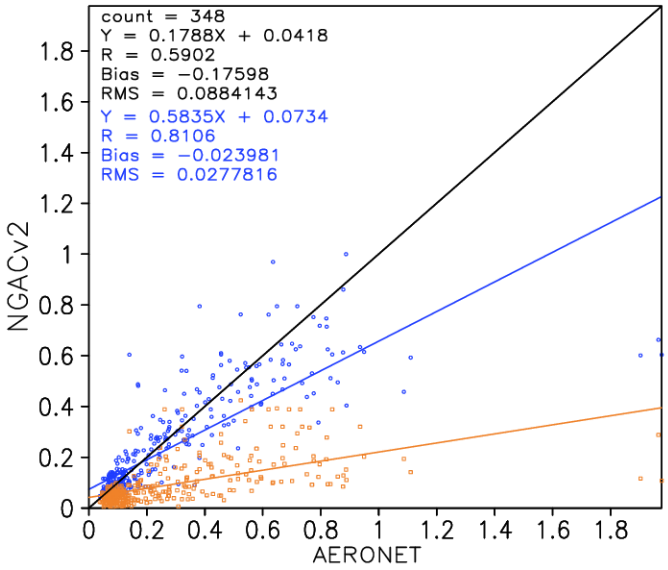

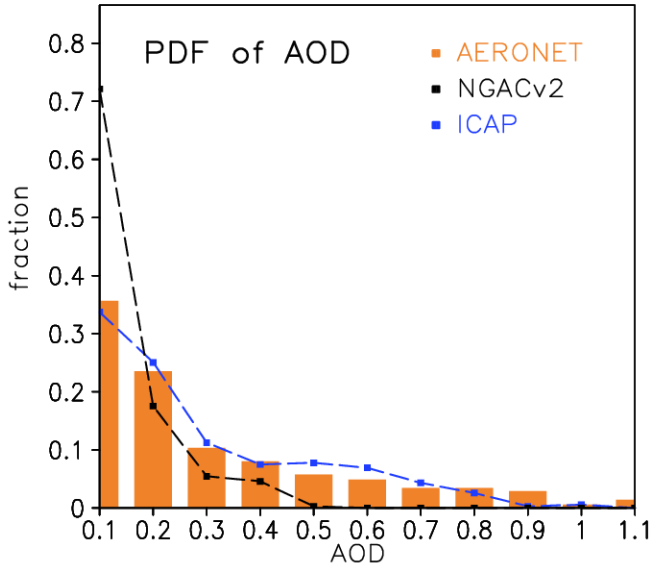

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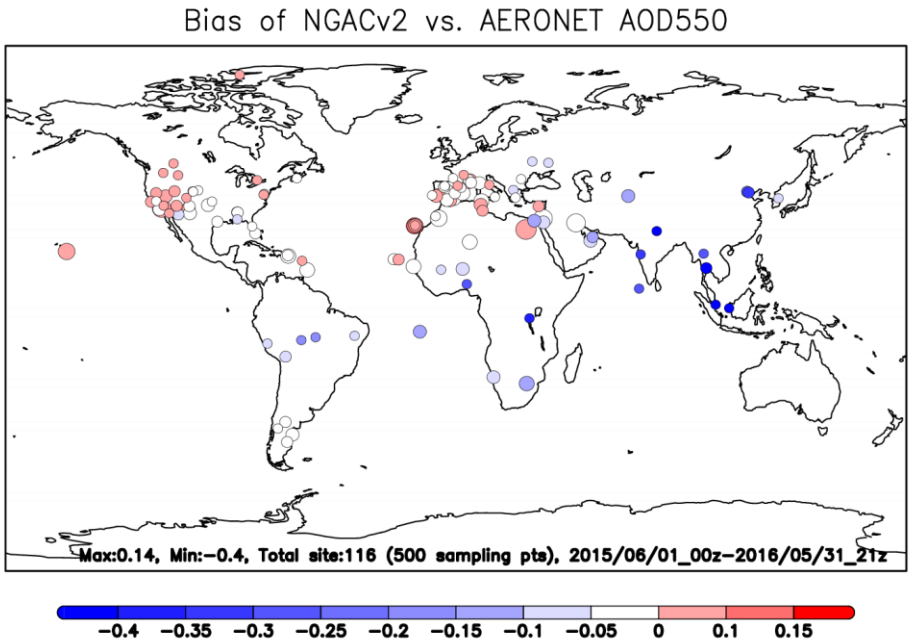
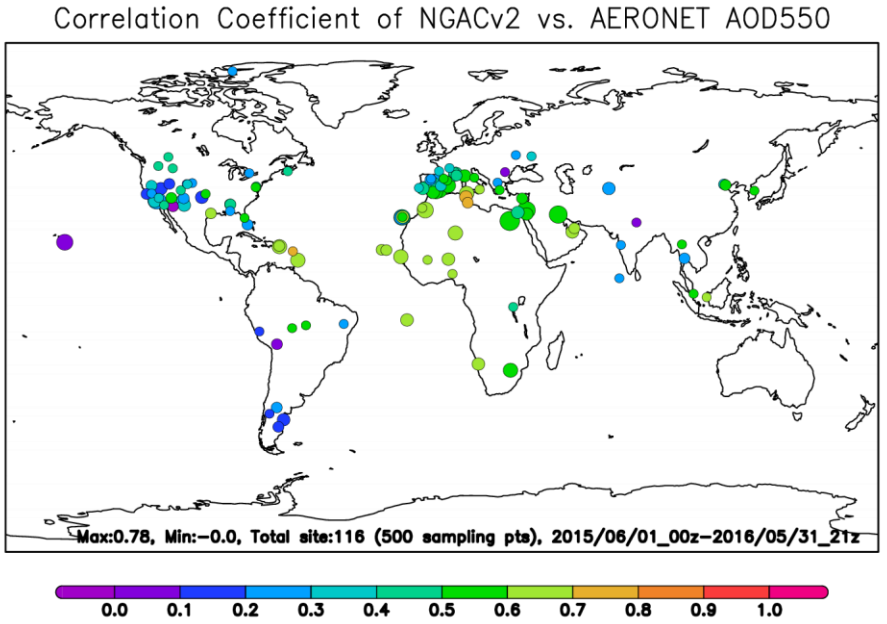
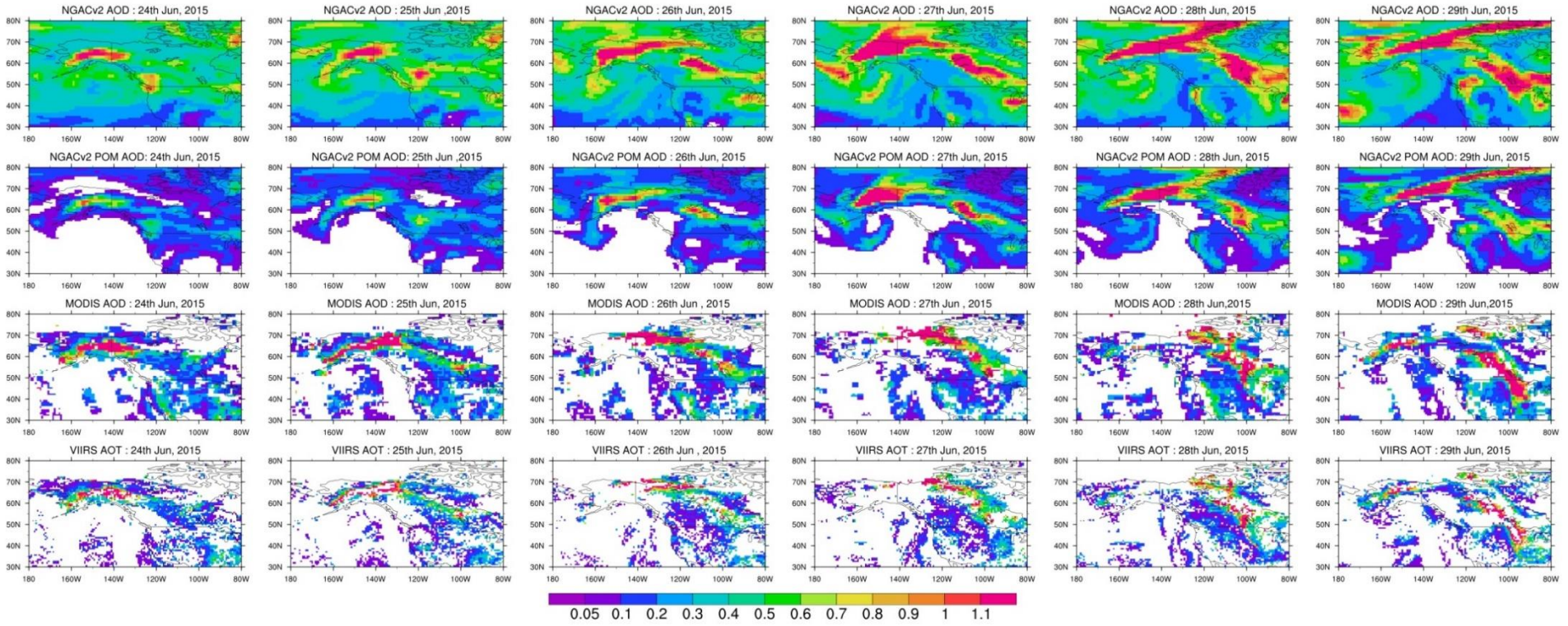




Case selection: Alaska fires (June 2015)



Identify selected cases

Evaluate spatial and temporal distributions of aerosols.

Case selection: Long range dust transport (June 2015)

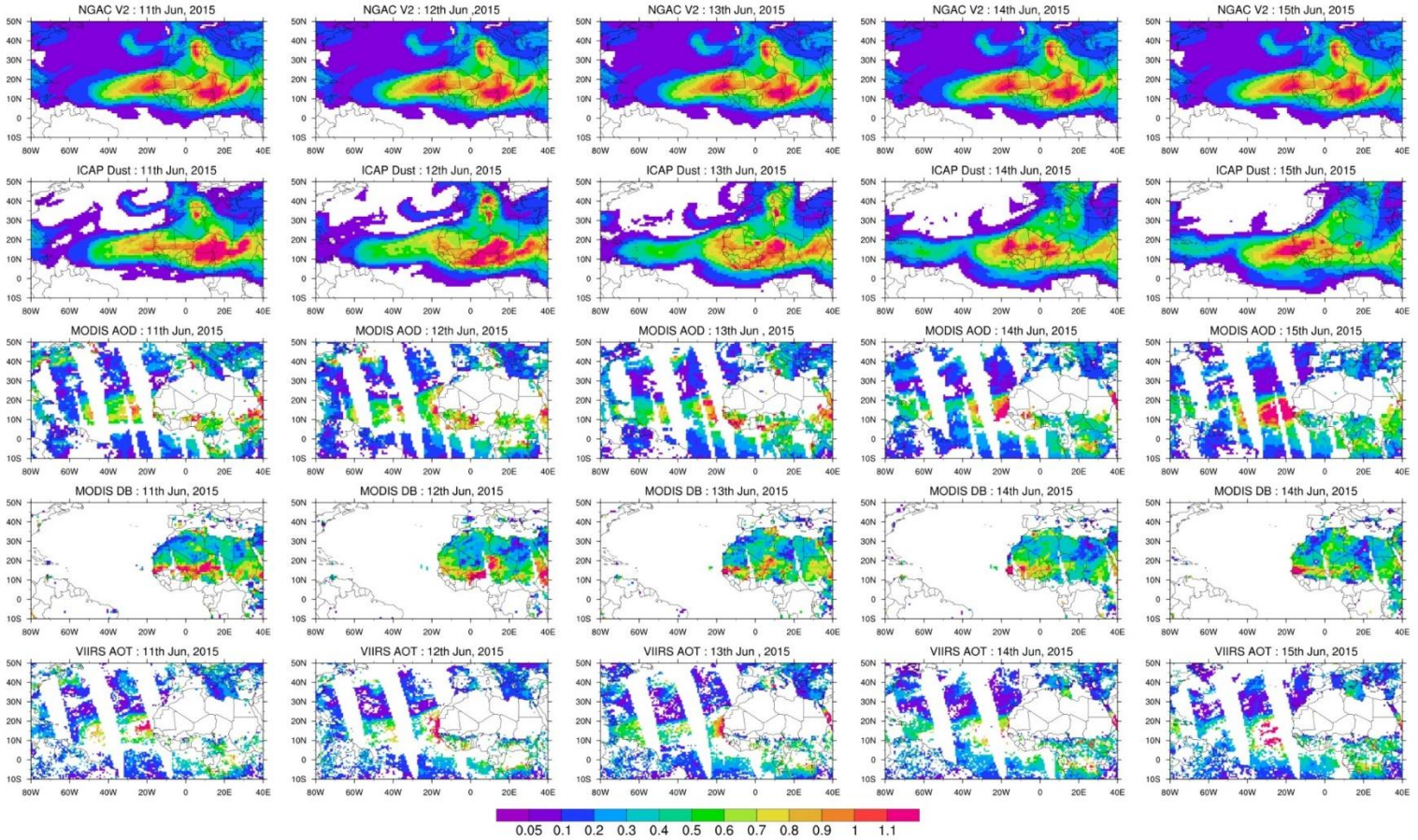
NGAC

ICAP MME

MODIS

MODIS DB

VIIRS



June 18, Joseph Prospero (U Miami) report 1.34 AOD at Barbodos AERONET site

June 23, Judd Welton (GSFC) reported a dust layer near the surface layer at GSFC MPLnet site

Progress toward enhancing dual-resolution weather-aerosol system

- The S4-cluster (NESDIS-funded Supercomputer for Satellite Simulations and Data Assimilation Studies) is the primary platform for code development and experiments in this R2O project.
- S4 provides operational-like environment with access to NCEP SVN (SubVersion) code repository.
- SVN branches have been created for GFS parallel scripts, GSI/CRTM, GSM, and NGAC V2.
- All code changes made in GSM, GSI/CRTM, RTG_SST, and GFS parallel scripts will be committed to NCEP's SVN code repository.

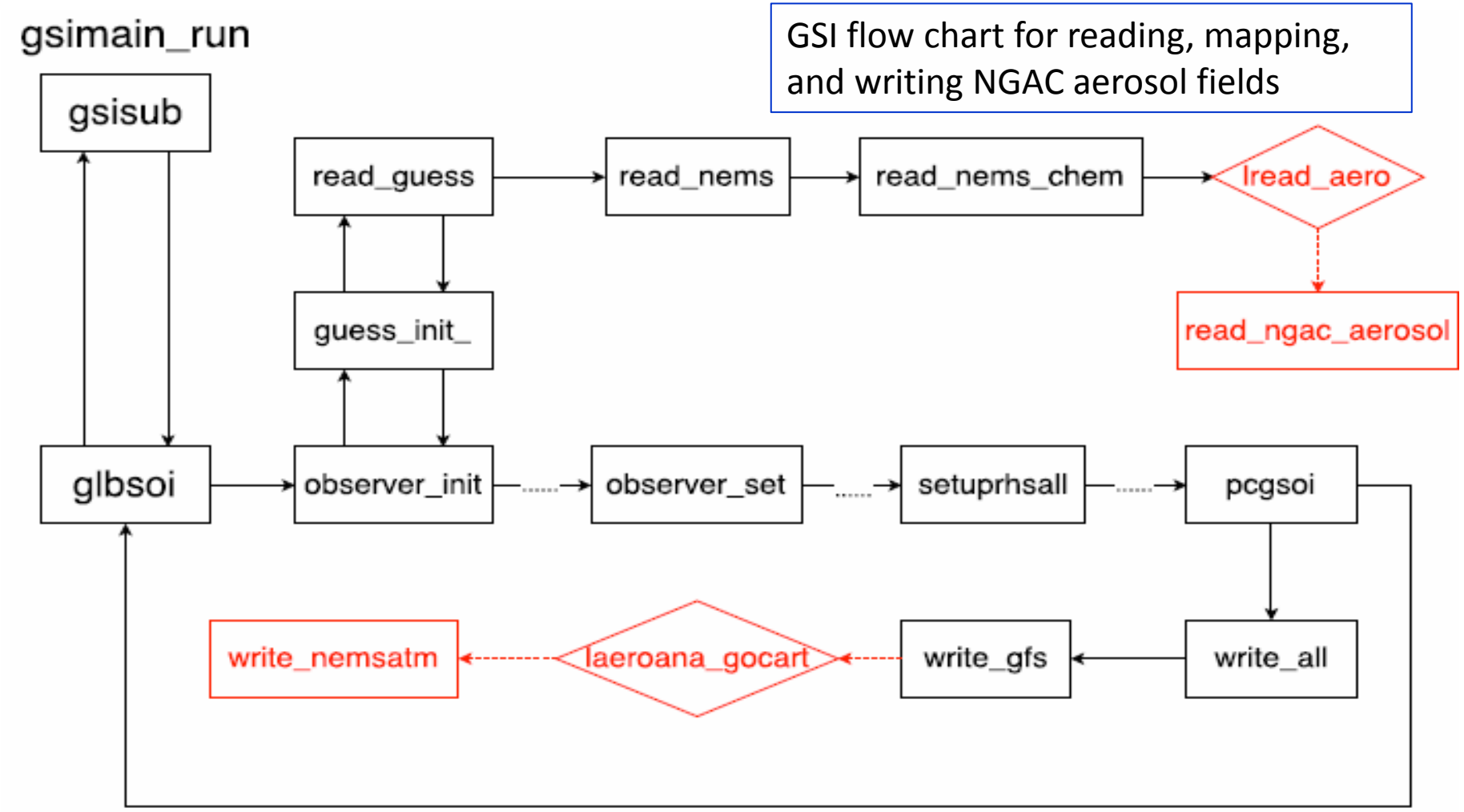
GSM code revision

- New options are being added to GSM radiation package.
  - The default (operational) configuration is to determine aerosol optical properties from Hess et al. climatology.
  - The new options being added are to determine aerosol optical properties from prognostic aerosols (from internal tracer arrays) or prescribed aerosols (from external T126 NGAC output files).
- The Look-Up-Tables (LUTs) for aerosol extinction, single scatter albedo, and asymmetry factor have been updated to use the latest dataset from GMAO, considering non-spherical dust aerosols and hydroscopic growth of non-dust aerosols.
- Work is underway to sync the code with the GSM trunk

GSI code revision

- GSI already has the basic infrastructure to handle aerosol fields. ChemGuess_Bundle allows flexible input of chem-related fields (tracers and aerosols) to GSI. It is controlled by a table named chem_guess added to the anavinfo resource file.
- Following this design, NGAC aerosols are brought into GSI via the ChemBundle. Specifically, code revision is made in GSI to include the new option to read in/write out NGAC aerosols via nemsio module and to fill up ChemBundle with NGAC aerosols.
- Stand-alone GSI and CRTM experiments are conducted to demonstrate the impact of aerosols on radiance and brightness temperature

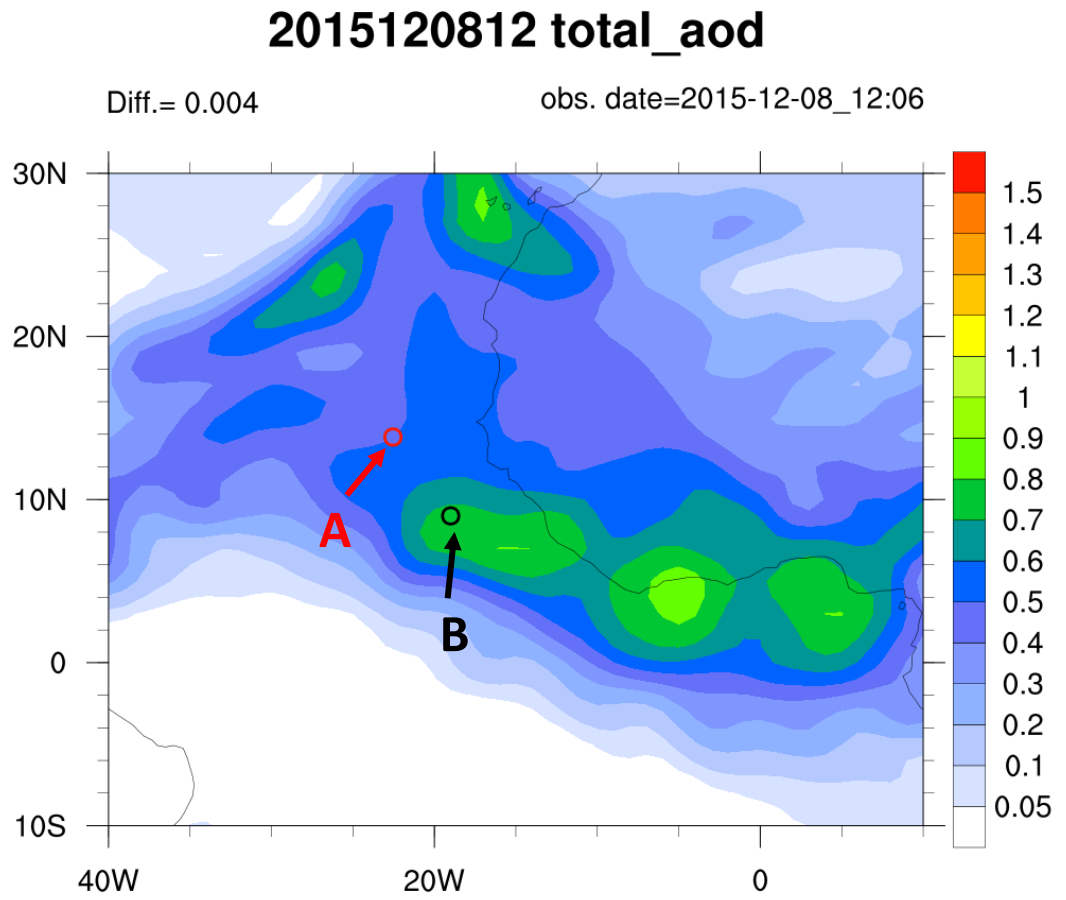
GSI code revision –cont'd



CRTM experiments

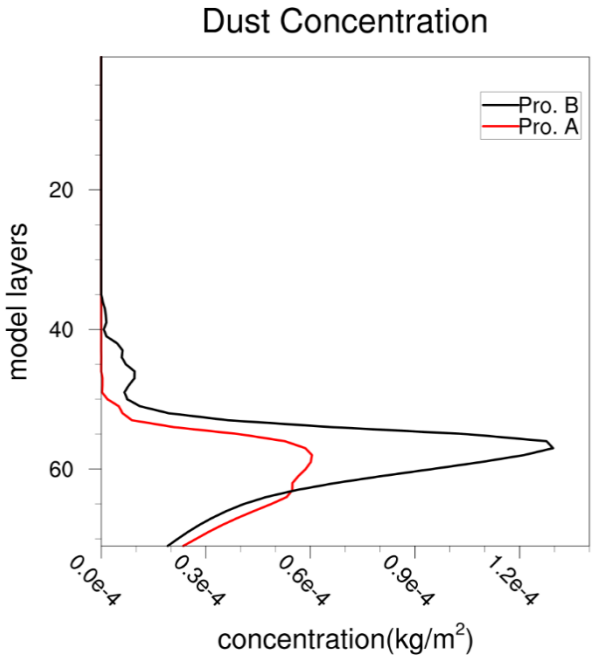
Objective: Understand the impact of dust aerosols on radiance and brightness temperature

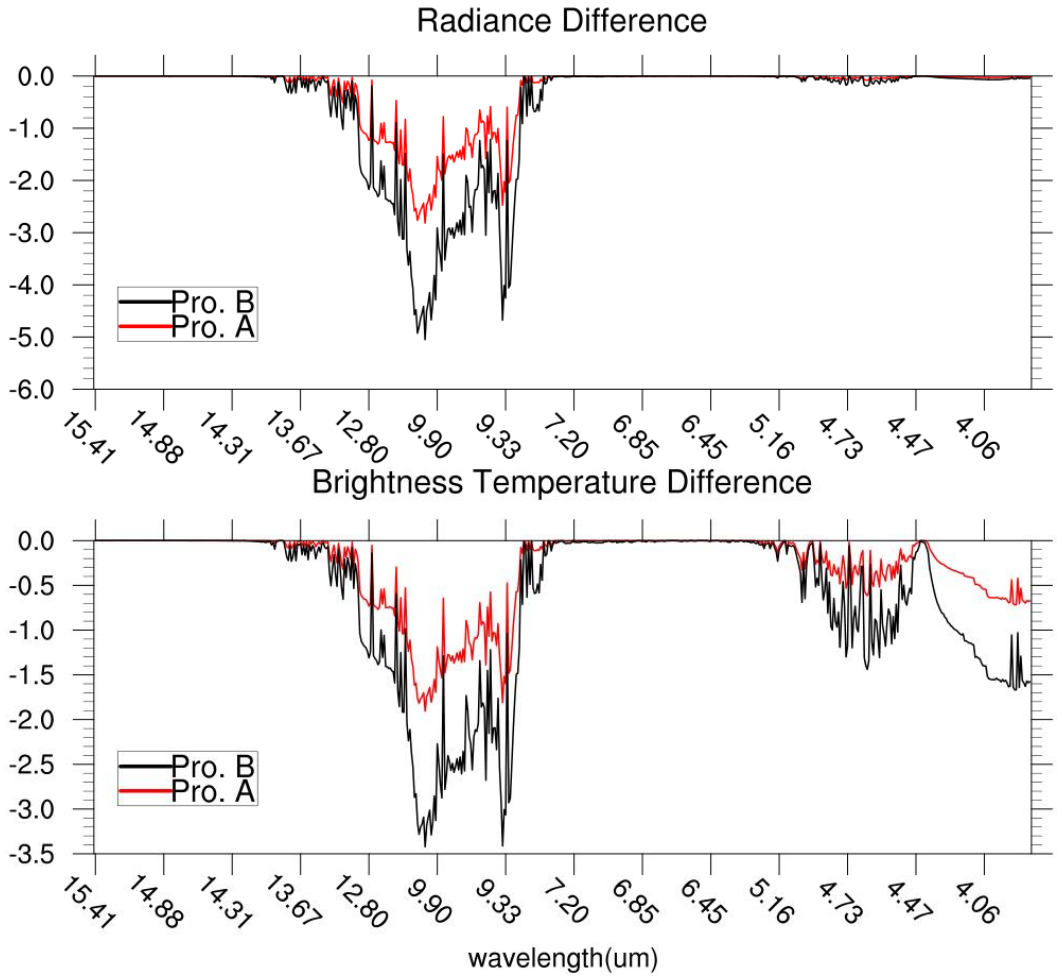
- Time: 20151208 12Z
- Ambient conditions: GDAS 2015120806 6hrs forecast
- Aerosol fields: NGAC 2015120800 12hrs forecast
- Locations:
  - A with AEROSE measurements
  - B with elevated NGAC dust AOD
- Sensor: IASI (iasi616_metop-a)
- Two CRTM runs:
  - Ctrl run (with no aerosols)
  - Expt run (with dust aerosols)



CRTM experiments

Difference (Expt – Ctrl) in radiance [top] and brightness temperature [bottom]

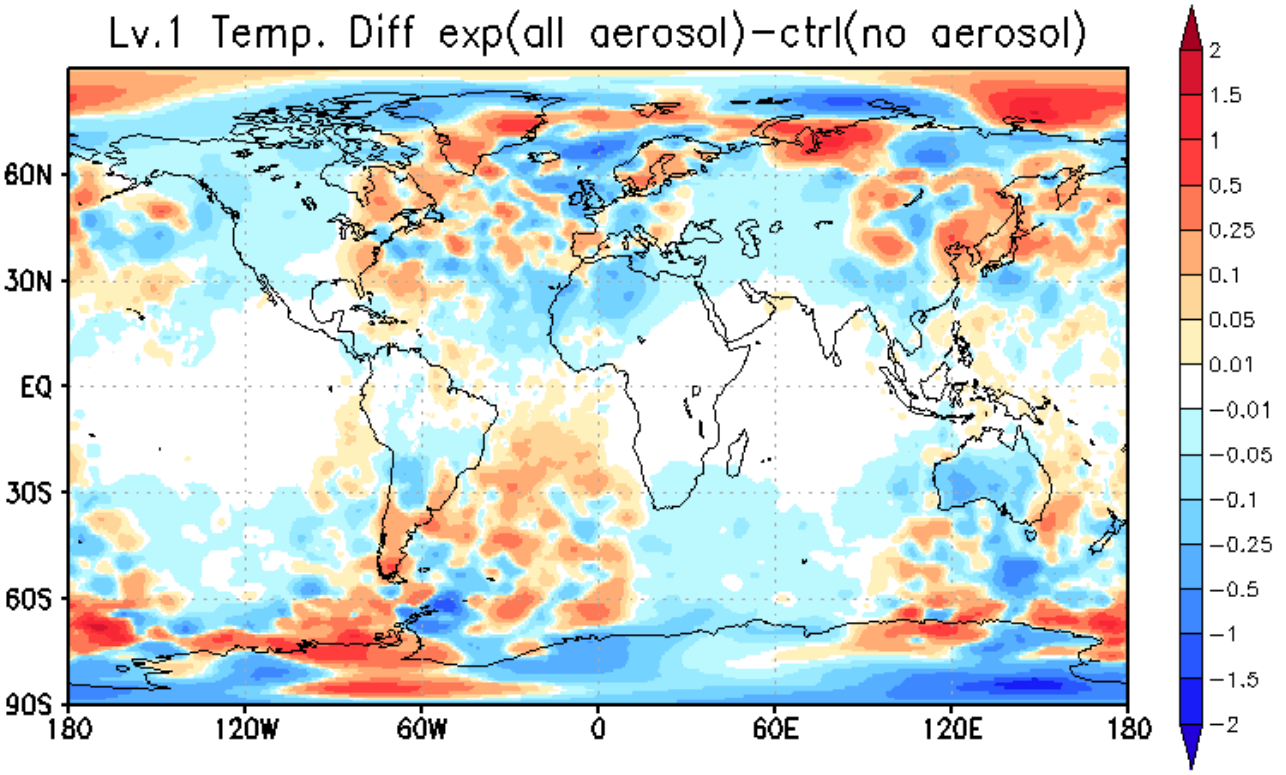




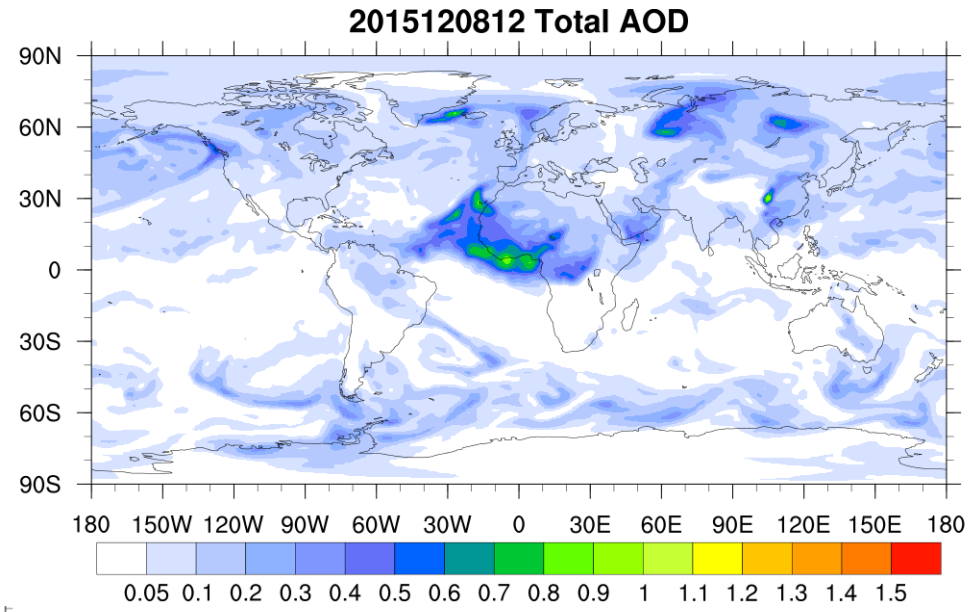
Stand-alone GSI experiments

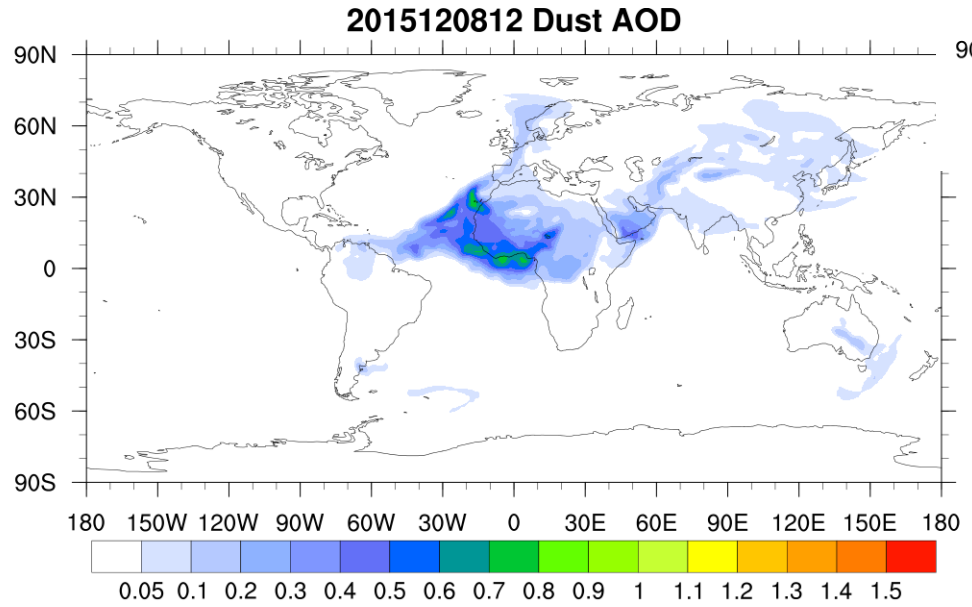
Objective: Investigate the impact of aerosols on meteorology analysis

- Date: 20151208 12Z cycle
- DA method: GSI 3DVar
- Observations: same as operational configuration
- Two GSI experiments:
  - Ctrl: aerosols not considered
  - Expt: account for aerosols from NGAC V2



Stand-alone GSI experiments





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Project Status Update in FFO PI meeting

Project status update in 2015 FFO PI meeting:

- GSM radiation code development in progress
- NCEP's NGAC is evaluated using in situ and satellite observations
- Cases of interest are identified
- New hire has been identified and the paper work is in progress
- HPC account request will be submitted shortly

Project status update in 2016 FFO PI meeting:

- GSM radiation code is modified to use prescribed GOCART fields
- CRTM/GSI code is modified to account for GOCART aerosol fields
- NGAC V2 results are evaluated using in situ and satellite observations as well as aerosols analysis from ICAP-MME and MERRA2
- New hire (Shih-Wei Wei) came on board mid Jan 2016
- Requested and obtained an account at S4 cluster late Jan 2016. All development work is conducted at S4 cluster.

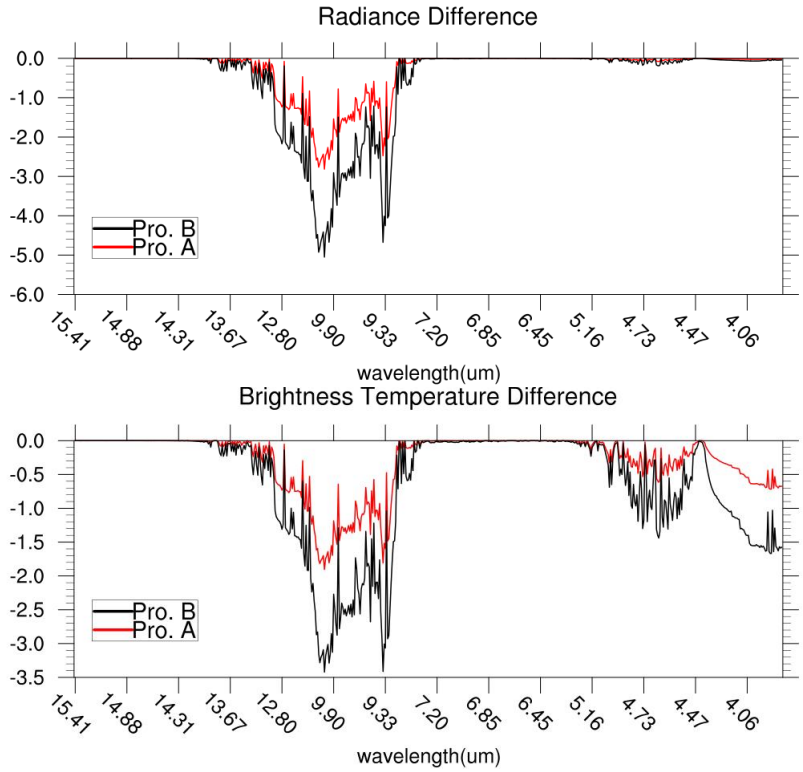
Project Highlight

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

Sarah Lu (SUNY-Albany), Quanhua Liu (NESDIS/STAR), Robert Grumbine (NCEP)

- 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.
- Project deliverables: Flexible aerosol configuration in GDAS parallel scripts

- Aligned with NGGPS efforts to advance physical parameterization and data assimilation
- Transition to operations implementation: All code development will be committed to NCEP SVN code repository, and all tests are conducted under parallel (operational-like) environment



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

Thank You

Suggestions, questions, and comments?