



Global Aerosol Modeling at NCEP

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with acknowledgments to many colleagues and collaborators



Presentation outline

- Global aerosol predictions at NWP centers
- Current Capabilities
- Ongoing activities and future directions
- Concluding remarks



Why include aerosols in the predictive systems?

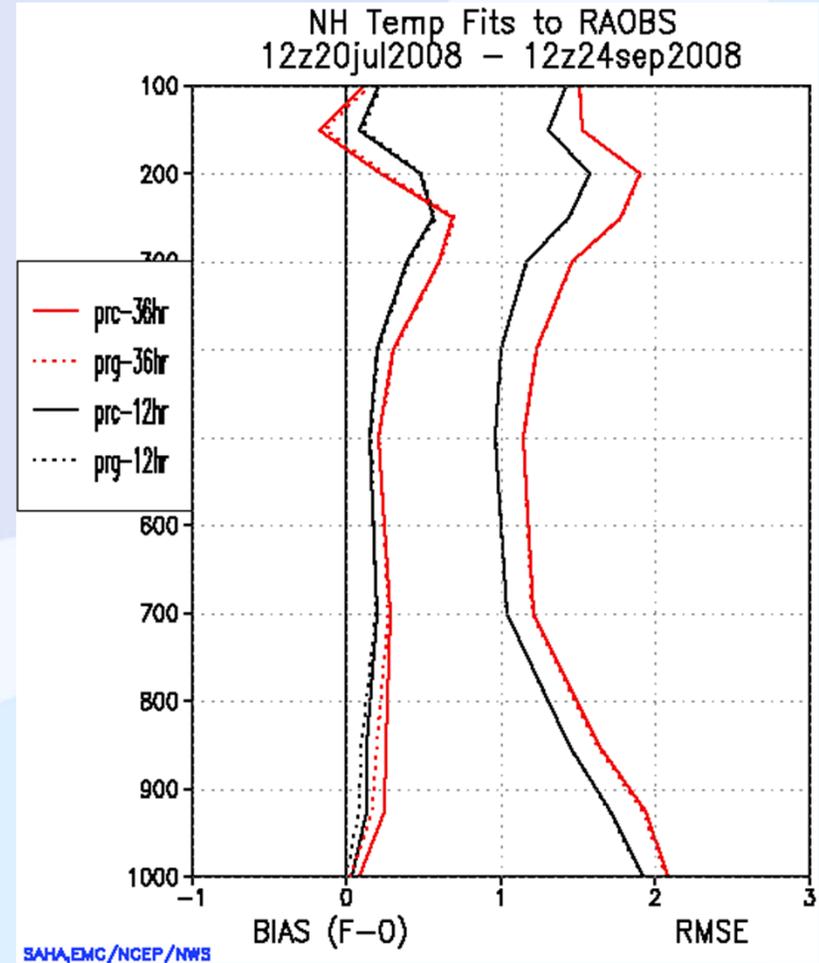
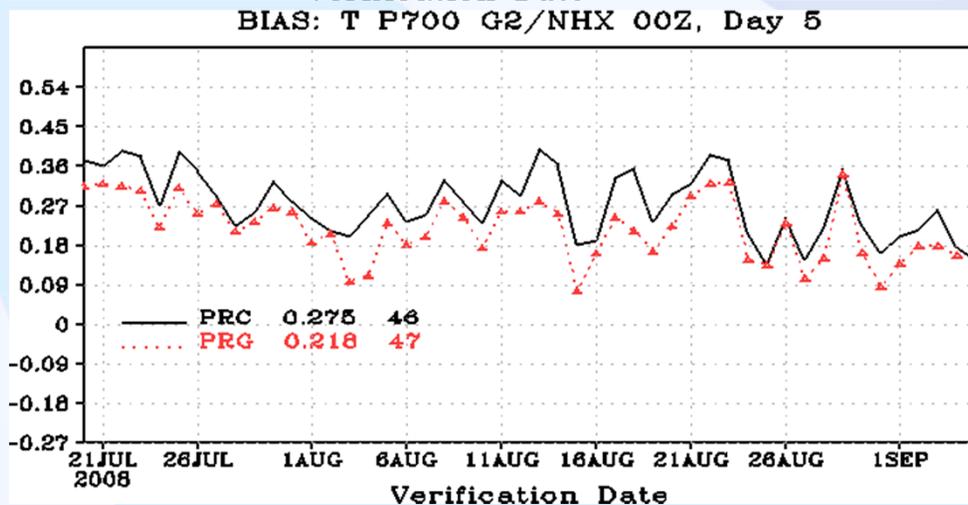
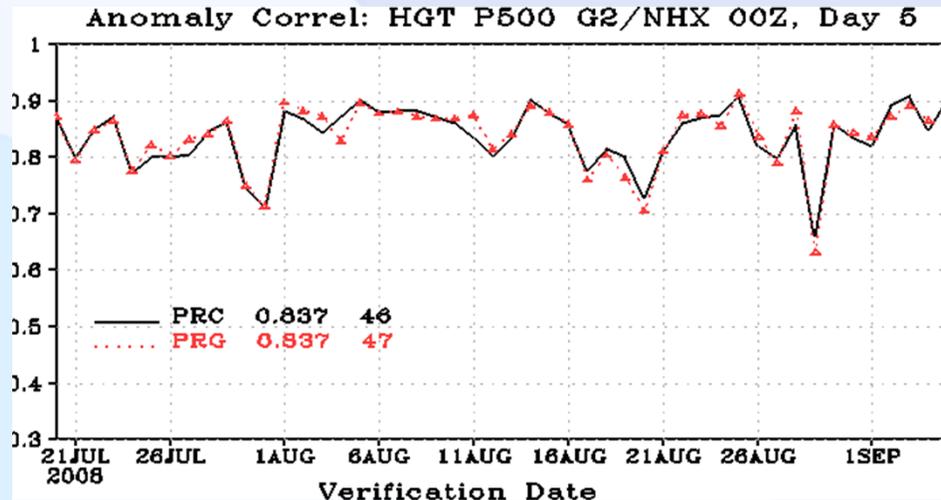
- Improve weather forecasts and climate predictions by taking into account of **aerosol effects on radiation and clouds**
- Improve assimilation of satellite observations by properly accounting for aerosol effects
- Provide aerosol (lateral and upper) boundary conditions for regional air quality predictions
- Produce quality aerosol information that address societal needs and stakeholder requirements, e.g., UV index, air quality, ocean productivity, visibility, and sea surface temperature retrievals.



Global aerosol prediction 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
- Operational aerosol forecasts are now available from several operational and research NWP centers
- Aerosol prediction systems are built upon modeling/assimilation methodologies already in place for the meteorological systems.
 - NRL: NAAPS, driven by NOGAPS
 - ECMWF: MACC, IFS coupled with LMD
 - NCEP: NGAC, NEMS GSM coupled with GOCART
 - GMAO: GEOS-5, GEOS-5 AGCM coupled with GOCART
 - UKMO: MetUM with the Hadley Centre dust scheme

Aerosol-Radiation Feedback: Impact of Aerosols on Weather Forecasts



- T382 L64 GFS/GSI# experiments for the 2008 summer period
- PRC uses the OPAC climatology (as in the operational applications);
- PRG uses the off-line GEOS4-GOCART% monthly dataset

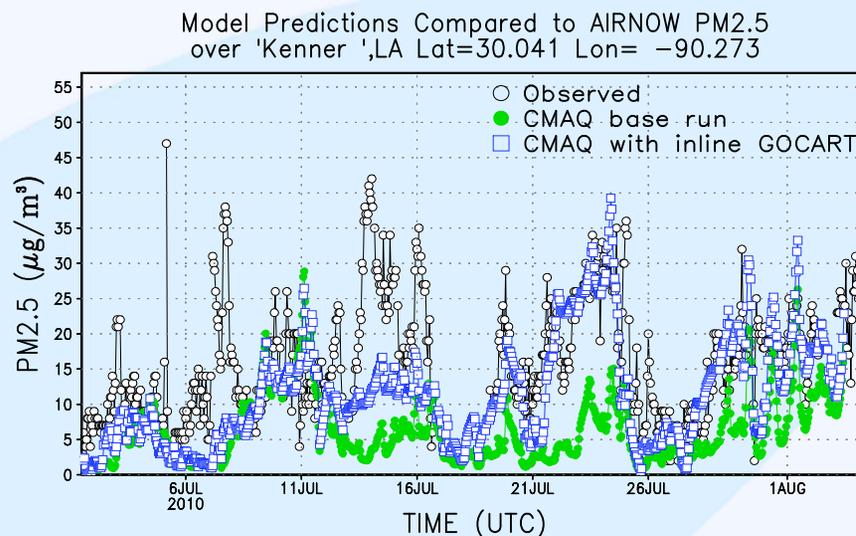
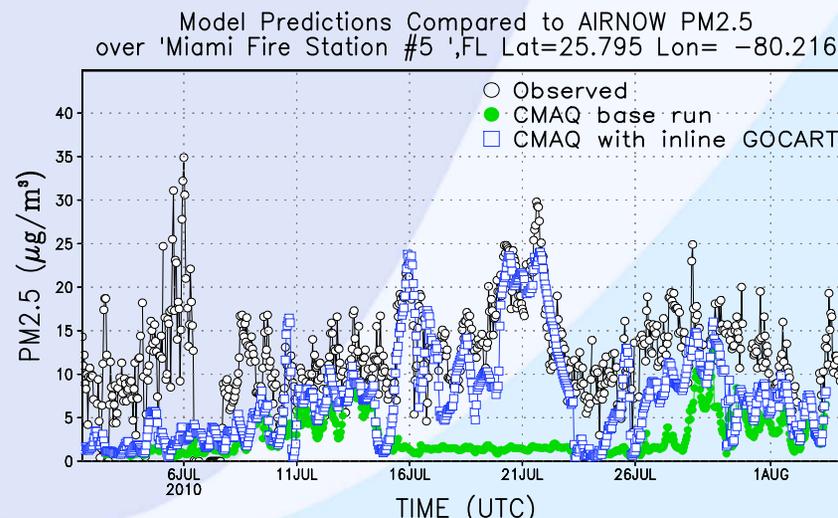
Positive impact in temperature forecasts due to an update in aerosol climatology

Dynamic LBCs for regional models



- Baseline NAM-CMAQ with static LBCs versus experimental NAM-CMAQ with dynamic LBCs from NGAC, verified against AIRNOW observations
- **The inclusion of LBCs from NGAC prediction is found to improve PM forecasts (e.g., reduced mean biases, improved correlations)**

	CMAQ Baseline	CMAQ Experimental
Whole domain July 1 – Aug 3	MB= -2.82 R=0.42	MB= -0.88 R=0.44
South of 38°N, East of -105°W July 1 – Aug 3	MB= -4.54 R=0.37	MB= -1.76 R=0.41
Whole domain July 18– July 30	MB= -2.79 R=0.31	MB= -0.33 R=0.37
South of 38°N, East of -105°W July 18– July 30	MB= -4.79 R=0.27	MB= -0.46 R=0.41





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Global aerosol prediction at NCEP

NEMS GFS Aerosol Component (NGAC)

- NCEP's global in-line aerosol forecast system via NCEP-GSFC collaborations
- Build upon NOAA Environmental Modeling System (**NEMS**) -- a common modeling framework using Earth System Modeling Framework (ESMF)
- Provide 5-day dust-only forecast since 2012
- ICs: Aerosols from previous day forecast and meteorology from operational GDAS
- Model Configuration:
 - Resolution: T126 ($\sim 1^\circ \times 1^\circ$) L64
 - AGCM: NCEP's NEMS GFS
 - Aerosol: GSFC's GOCART



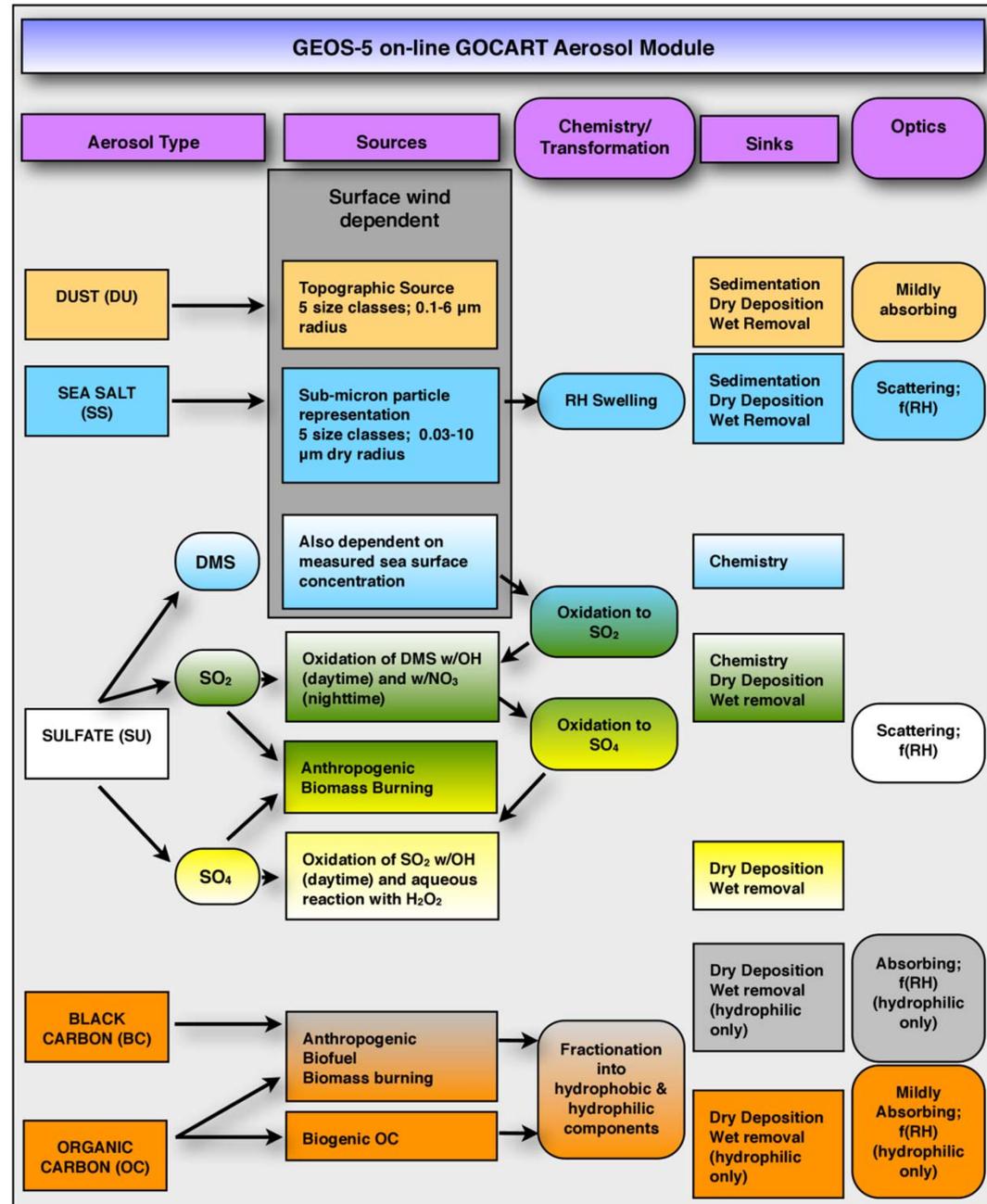


GOCART Module

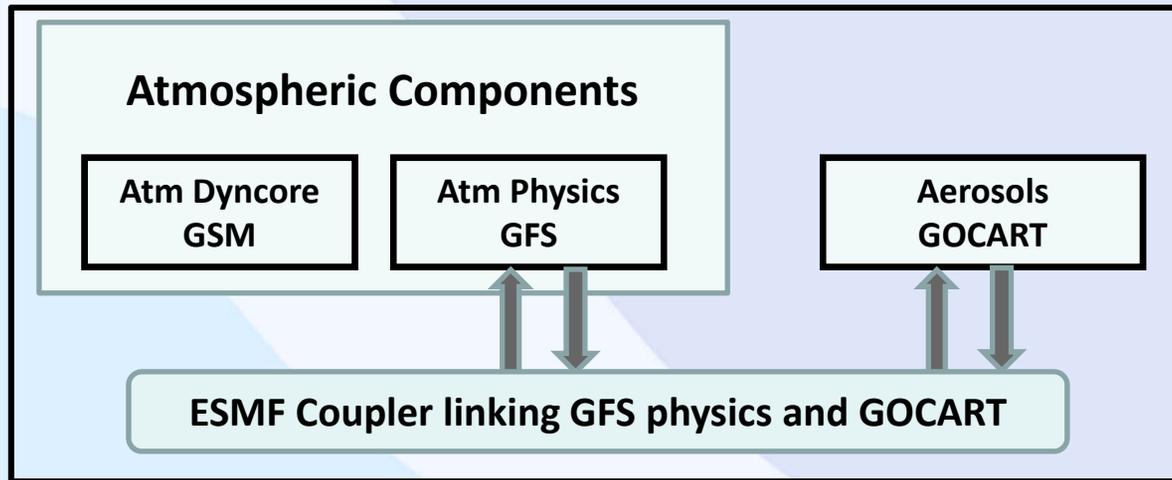
In-line chemistry advantage

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

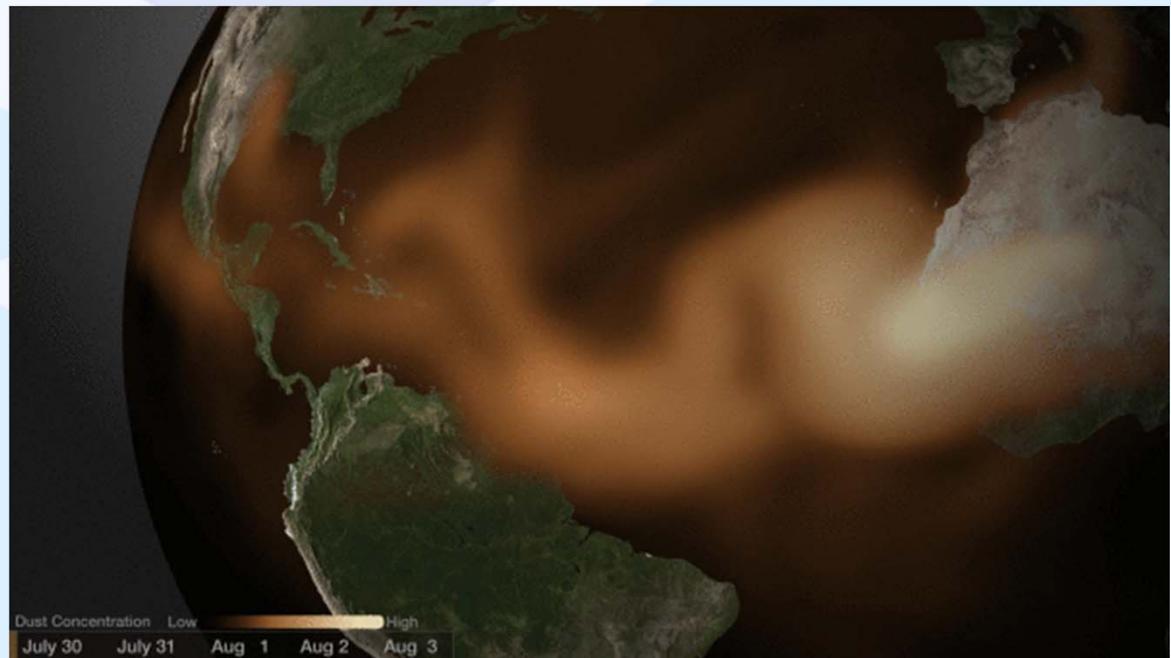
GOCART diagram provided by Peter Colarco (GSFC)



NEMS infrastructure



Massive dust storm sweeps over Atlantic, reported by NBC on July 31, 2013. (The NGAC animation was created by NOAA EVL)



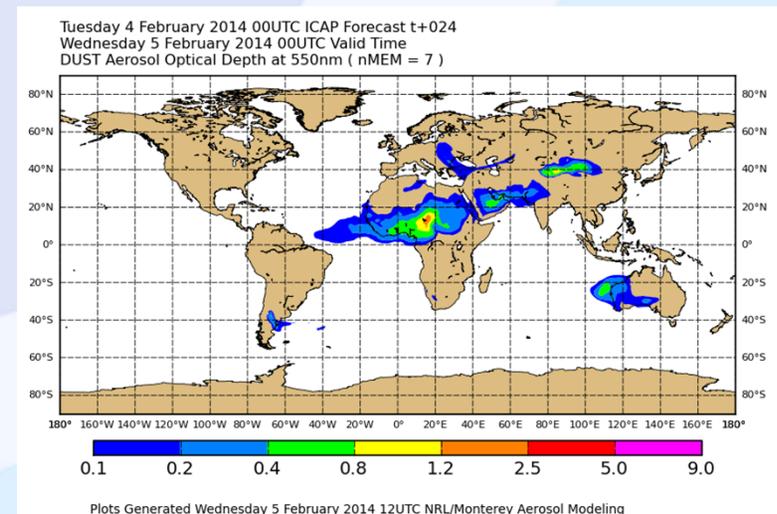
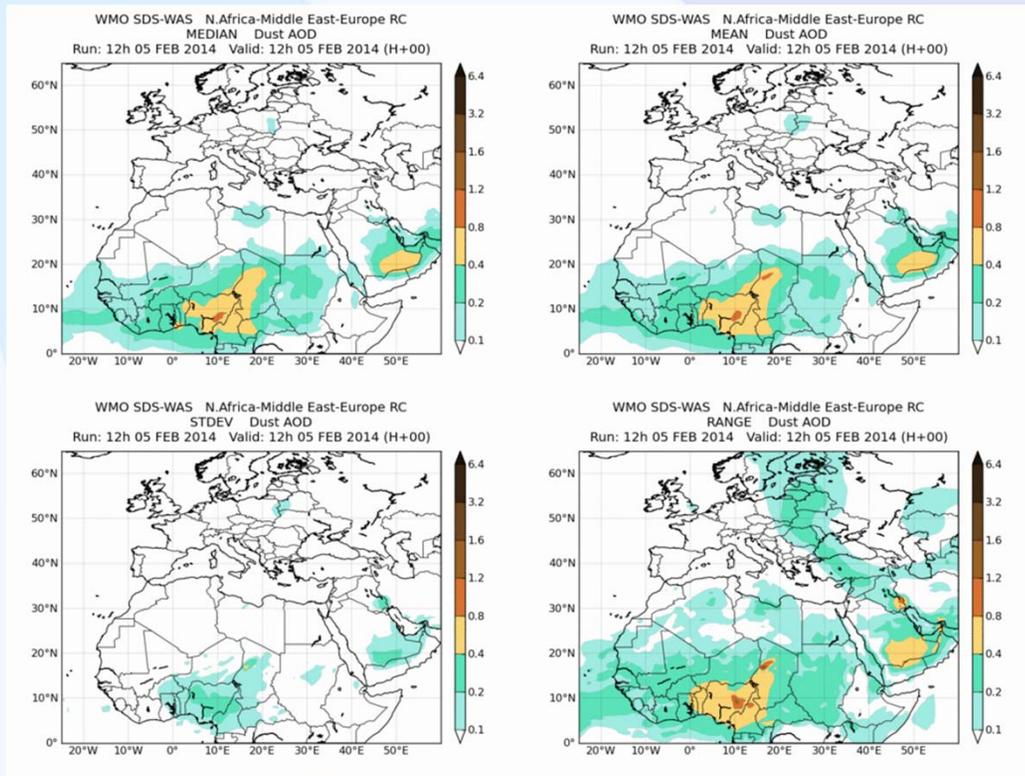
Multi-Model Aerosol Ensemble



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

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

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





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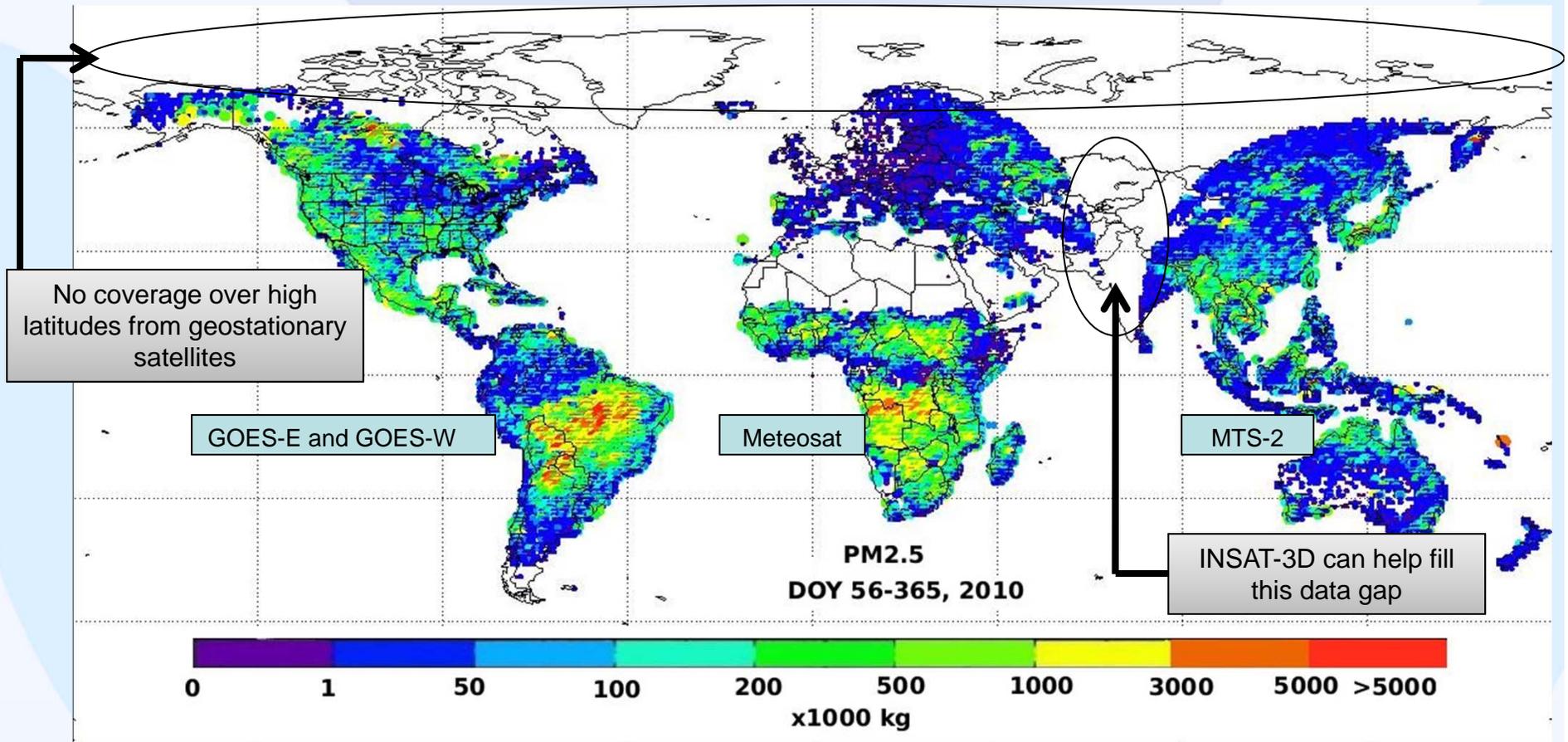


Future Operational Benefits Associated with NEMS GFS Aerosol Component



- Enables future operational global short-range (e.g., 5-day) **multi-species aerosol prediction** (Q1FY16)
- Provides **lateral aerosol boundary conditions** for regional aerosol forecast system (Q4FY15)
- Provides a first step toward an operational **aerosol data assimilation** capability at NOAA
- Allows **aerosol impacts** on medium range weather forecasts (GFS) to be considered
- Allows NOAA to explore **aerosol-chemistry-climate interaction** in the Climate Forecast System (CFS)
- Provides global aerosol information required for various applications (e.g., **satellite radiance data assimilation**, satellite retrievals, SST analysis, UV-index forecasts, solar electricity production)

Annual Global Biomass Burning Aerosol Emissions from Satellite-derived Fire Radiative Power (FRP)



Zhang, X. Y, S. Kondragunta, J. Ram, C. Schmidt, H-C. Huang,
*Near-real time global biomass burning emissions product
from geostationary satellite constellation, JGR, 2012*

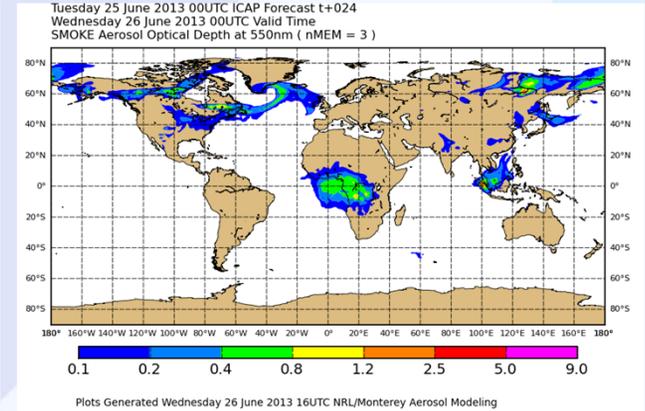
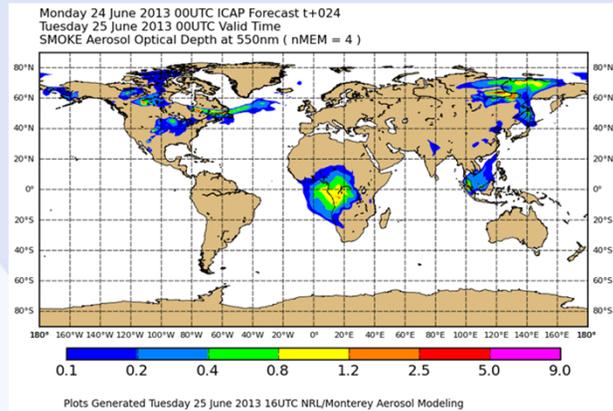
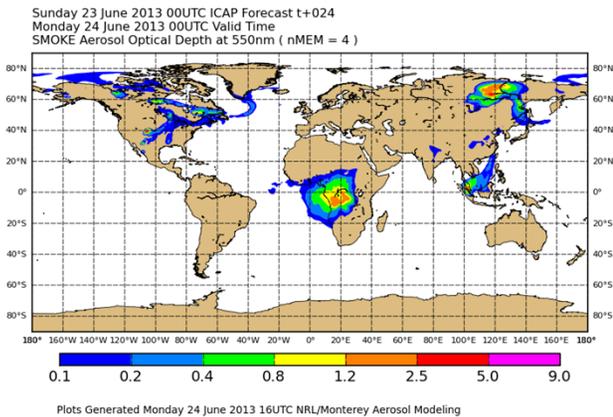
Key:
PM2.5: Particulate mass for particles smaller than 2.5 μm in size
DOY: Day of the Year
Kg: Kilograms

Shobha Kondragunta (NESDIS/STAR)

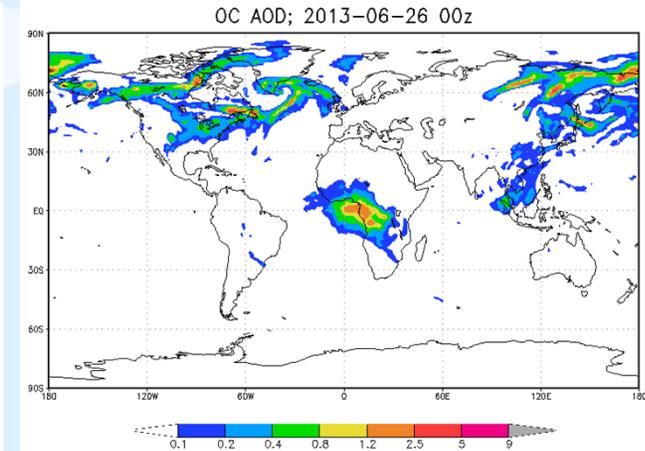
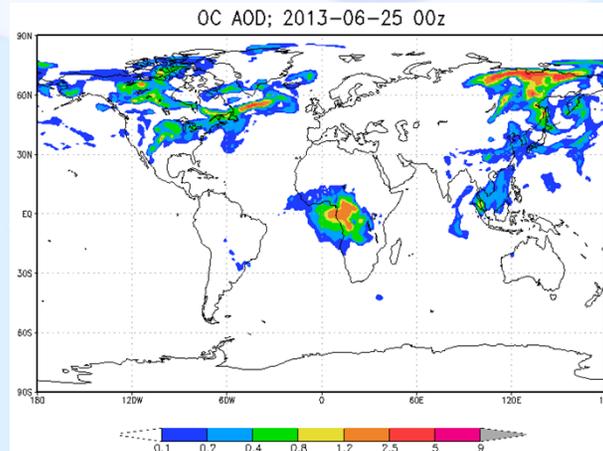
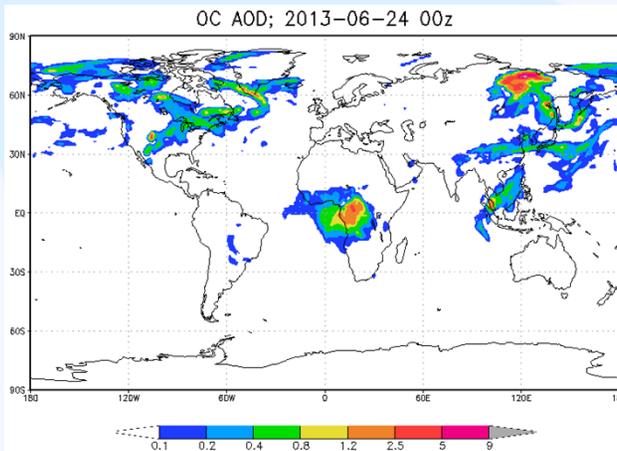
NGAC simulations using GBBEPx



ICAP global ensemble from NRL, ECMWF, GMAO, and JMA



NGAC OC 24hr forecast for Jun 24-26 2013



GBBEPx: Global Biomass Burning Emissions Product from Geo (GBBEP) and Polar (QFED)



NGAC provides 1x1 degree products in GRIB2 format once per day.
Product files and their contents include:

- UV index forecasts** →

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

- AOD assimilation** ↓

 - **ngac.t00z.a2df\$FH, FH=00, 03, 06,120**
 - AOD at 0.55 micron
 - Emission, sedimentation, dry deposition, and wet deposition fluxes
 - Aerosol surface mass concentration ← **Air quality**
 - Aerosol column mass density ← **Budget**

- AVHRR SST** ↙

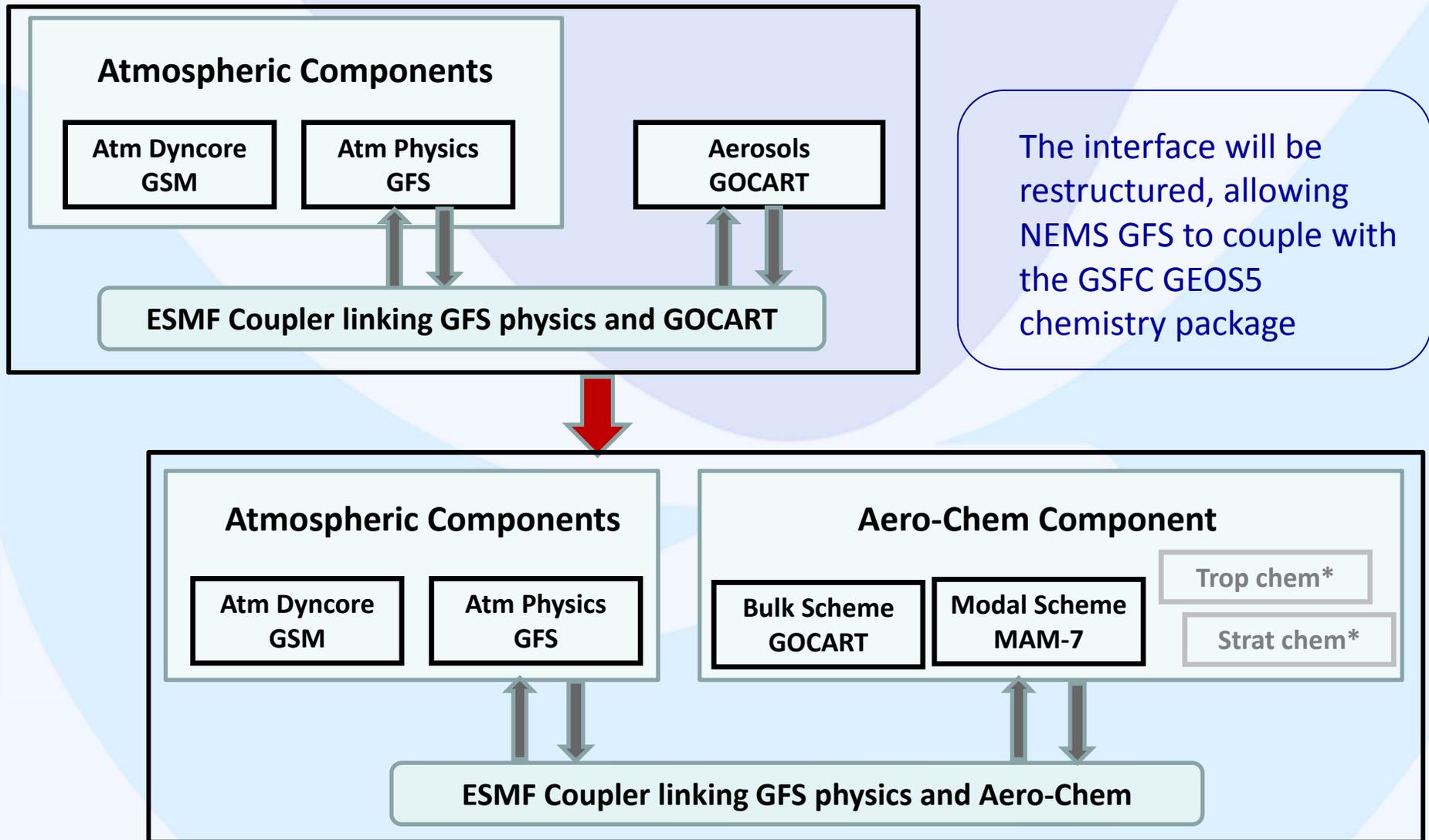
 - **ngac.t00z.a3df\$FH, FH=00, 03, 06,120** ← **Atmospheric correction**
 - Pressure, temperature, relative humidity at model levels
 - Mixing ratios for aerosol species at model levels

- AIRS retrievals** ↘

 - **Budget, ocean productivity** ↙

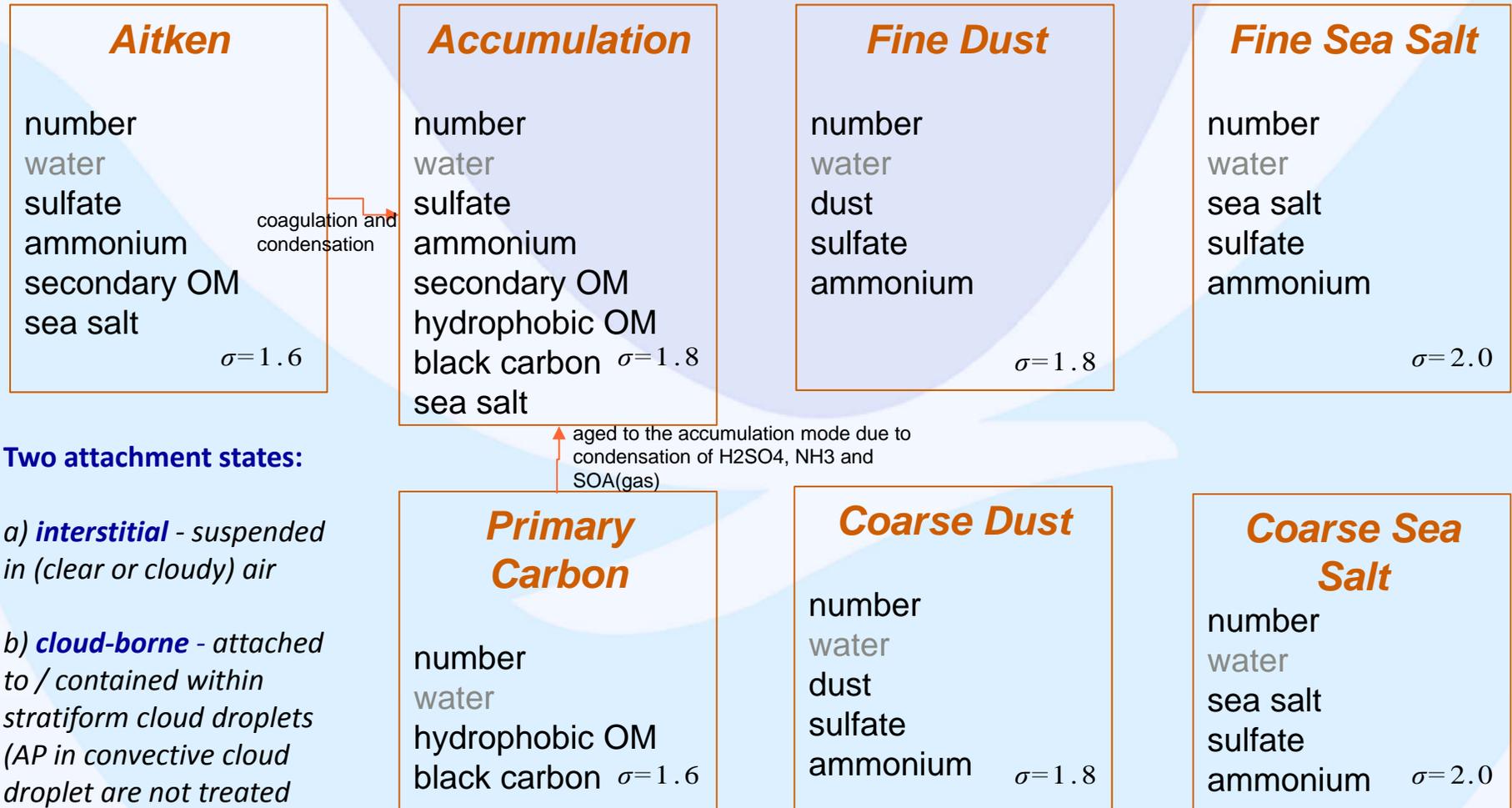
Potential applications for NGAC products are highlighted in red.

Planned Upgrades in NEMS infrastructure



*: compiled as stub lib on-the-fly since NCEP does not port the ozone chemistry code from GSFC

The Modal Aerosol Module (MAM)



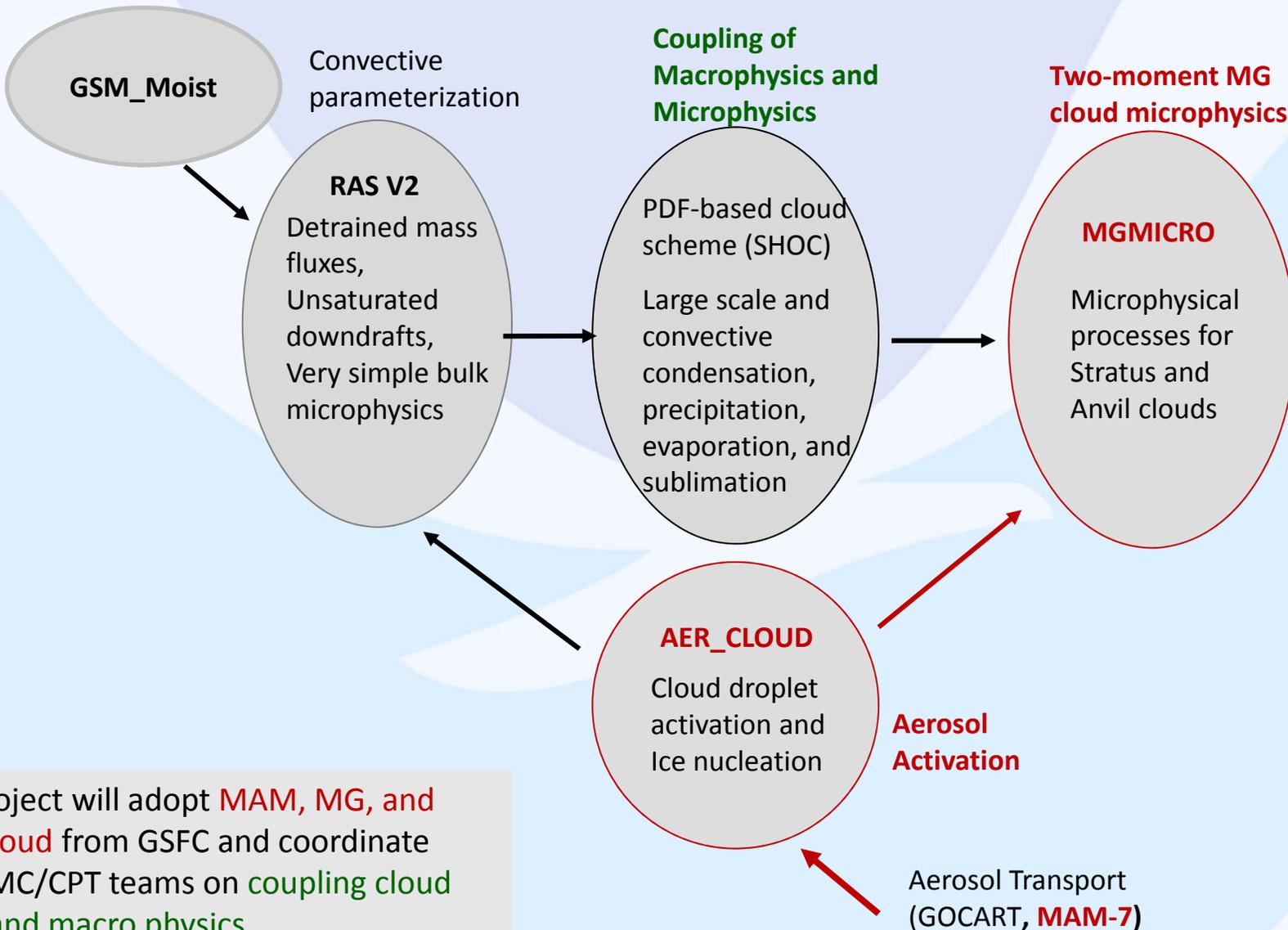
Liu, et al, 2012: Toward a minimal representation of aerosols in climate models: description and evaluation in the Community Atmosphere Model CAM5, GMD, 5,709–739, doi:10.5194/gmd-5-709-2012.

Anton Darmenov (GSFC)

Reanalysis task force workshop, 4-5 May 2015



Adopting GEOS-5 aerosol-cloud package



This project will adopt **MAM, MG, and AER_Cloud** from GSFC and coordinate with EMC/CPT teams on **coupling cloud micro and macro physics**



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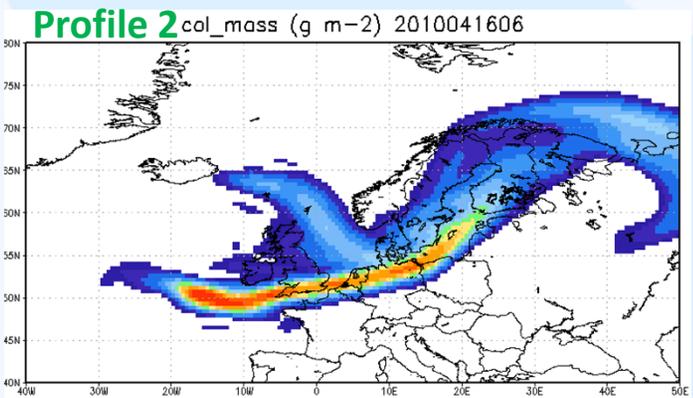
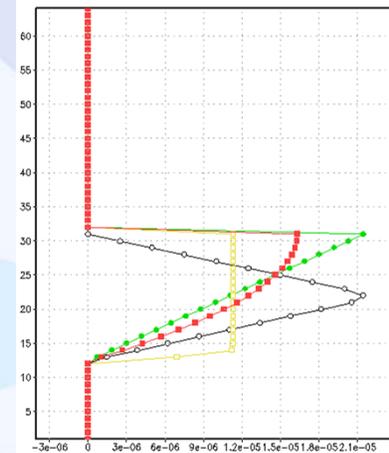
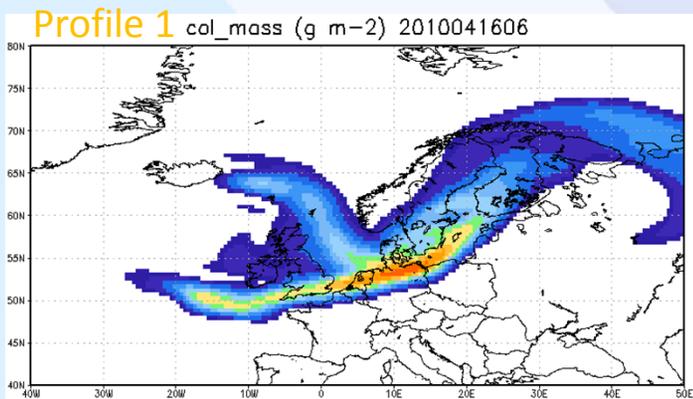
Concluding Remarks

- Operational global aerosol forecasts are now available at NCEP
- Efforts are under way to upgrade aerosol model and improve the aerosol-cloud-radiation interaction in NCEP global models
- The prognostic aerosol capability provides a first step toward aerosol data assimilation and aerosol reanalysis and enables NCEP to provide aerosol forecast products to serve a wide-range stakeholders, such as health professionals, aviation authorities, policy makers, climate scientists and solar energy plant managers
- With further development, NEMS GFS can be used for modeling and assimilation of reactive gases (including ozone) and aerosols (including volcanic ashes) on a global-scale.

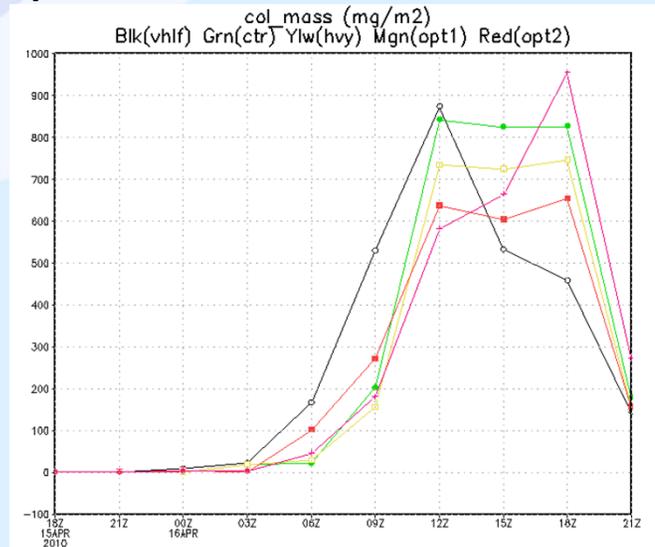
Volcanic Ash Modeling



- NGAC dust module has been modified to forecast volcanic ashes.
- Results from the prototype ash system are qualitative, as the focus is on plume transport pattern.
- The 2010 Eyjafjallajokull eruption event provides an unique opportunity to test the model's capability and limitation.



Time series of column mass over Leipzig (51.4N, 12.4E) by NCEP/NGAC, using different plume profile specifications



Ashes arrived over Leipzig at 5 UTC and peak at 12-15 UTC (Lidar retrieval)



Thanks.
Questions and Comments?



Backup Slides

Reanalysis task force workshop, 4-5 May 2015

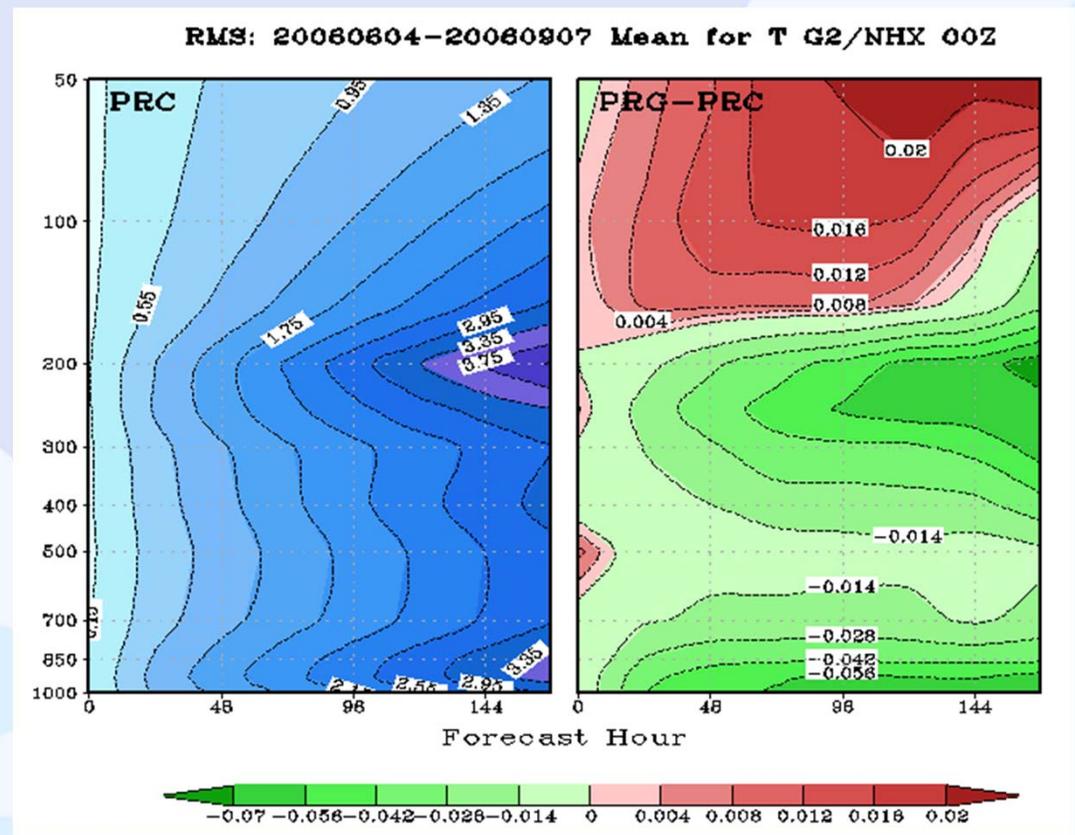
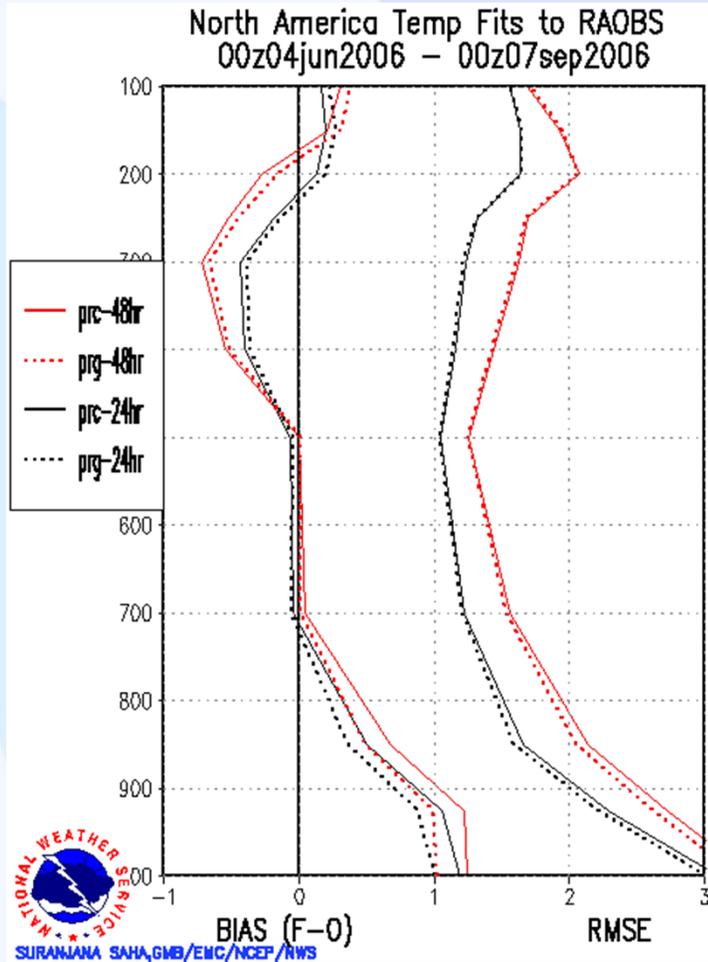


Ongoing activities and future directions



- Improving the representations of cloud microphysics, aerosol processes and **aerosol-cloud-radiation interaction** in GFS/CFS by adopting GSFC's physically-based cloud/aerosol package
- **Explore resources versus complexity**: How much complexity is needed to accurately represent the aerosol processes and effectively account for aerosol effects?
- **Observation-based diagnosis package** is needed to examine whether the model with improved aerosol-cloud package better captures the aerosol/cloud properties and the processes relevant to aerosol-cloud-radiation interactions.
- Efforts are now underway to develop an **aerosol data assimilation** capability in the hybrid EnKF-GSI system
- **Downstream applications**, e.g., providing LBC for regional AQ model; providing 3D aerosol fields for SST retrievals ...etc

Aerosol-Radiation Feedback: Impact of Aerosols on Weather Forecasts



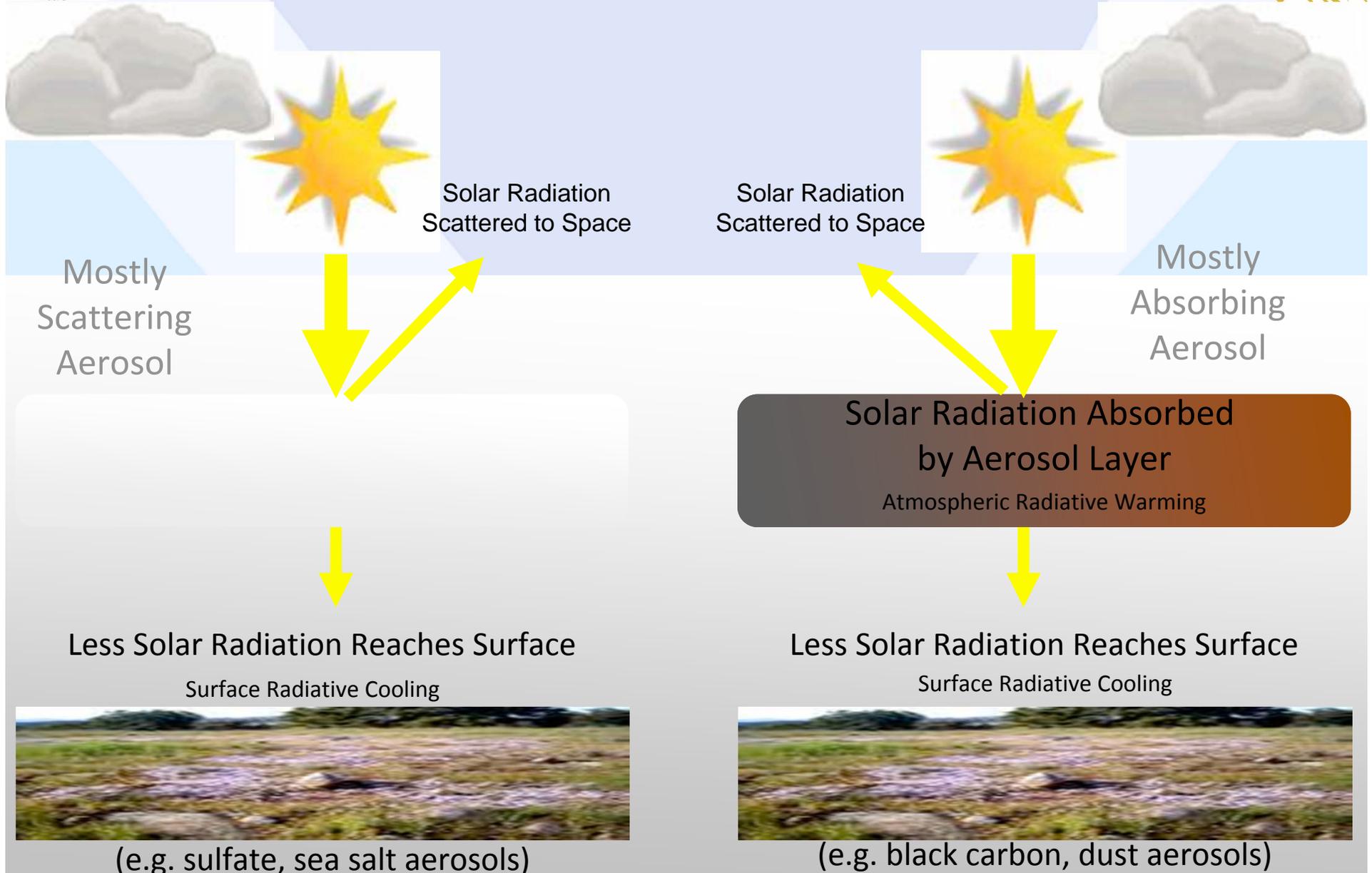
Verification against analyses and observations indicates a positive impact in temperature forecasts due to realistic time-varying treatment of aerosols.

- T126 L64 GFS/GSI# experiments for the 2006 summer period
- PRC uses the OPAC climatology (as in the operational applications)
- PRG uses the in-line GEOS4-GOCART% dataset (updated every 6 hr)

#: 2008 GFS package
%: In-line GEOS4-GOCART

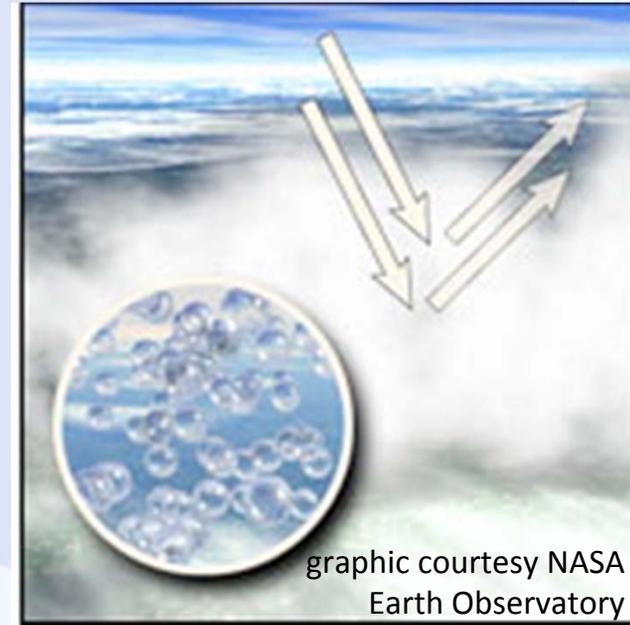
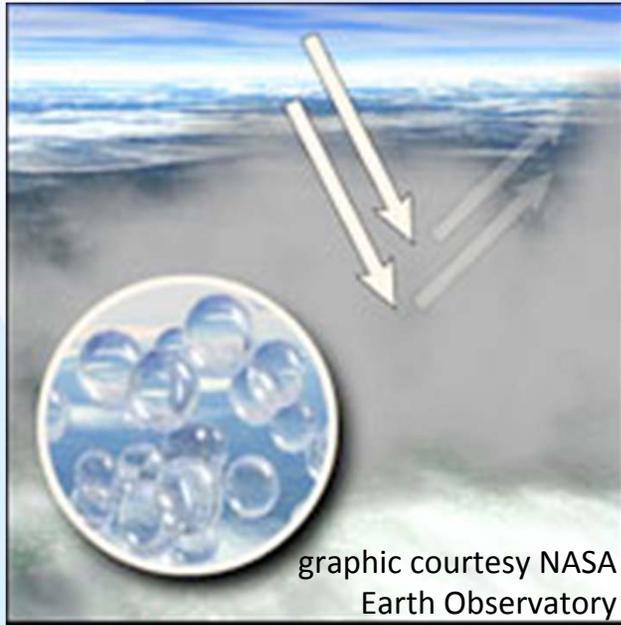


Aerosol Direct effect





Aerosol INDirect effect



Larger cloud droplets,
less reflective cloud.

Less Aerosols

Twomey Effect

Smaller cloud droplets,
more reflective cloud.

Increased Cooling by Clouds

More Aerosols

Albrecht Effect

Larger cloud droplets,
droplets rain out easier,
clouds dissipate quicker.

Smaller cloud droplets,
droplets rain out less,
longer-lived clouds.