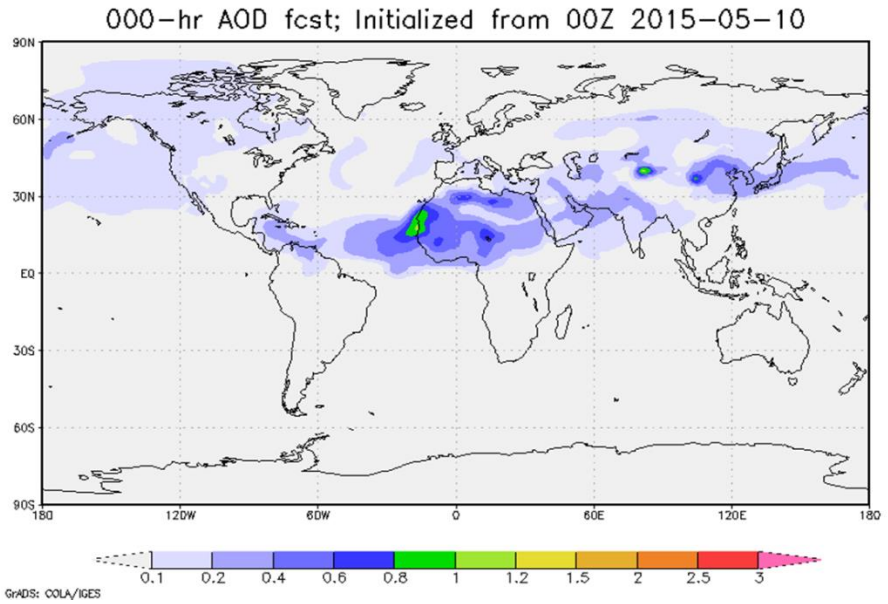
Aerosol and Atmospheric Composition Team Plans

NGGPS Annual Meeting
14 July 2015

Ivanka Stajner
Team Lead



Aerosol and Atmospheric Composition Model Development Team Plan Priorities

- Improve aerosol forecast capability, impacts of aerosol on radiation, microphysical processes and assimilation of observations

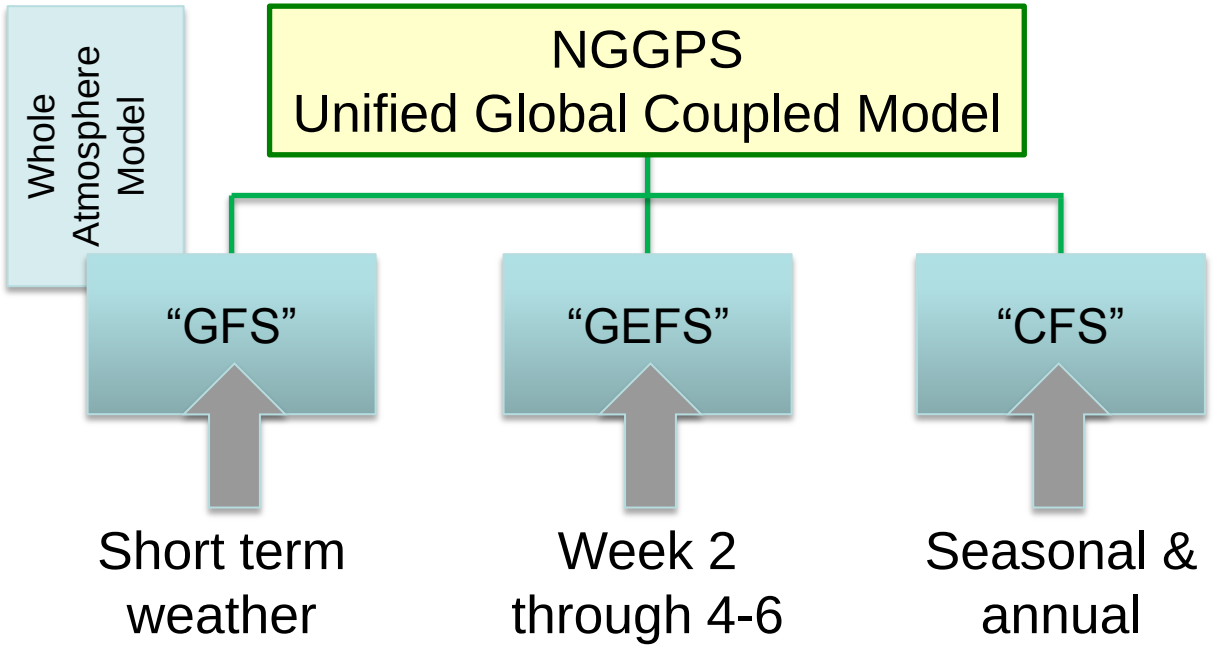
- Improve ozone forecast capability, impacts of ozone on radiation and assimilation of observations

- Integrate with the overall physics package

Aerosol and Atmospheric Composition Model Development Team

- Proposed membership:
- Ivanka Stajner, NWS/OSTI, team lead
- Georg Grell, ESRL
- Arlindo Da Silva, NASA/GMAO
- Doug Westphal, NRL
- Paul Ginoux, GFDL
- Craig Long, NWS/CPC
- Larry Horowitz, GFDL
- Coordination with physics and data assimilation teams:
  - Jim Doyle, NRL
  - Bill Kuo, NCAR
  - John Derber, NWS/EMC
  - Jeff Whitaker, ESRL

Unified Global Model
Operational NGGPS



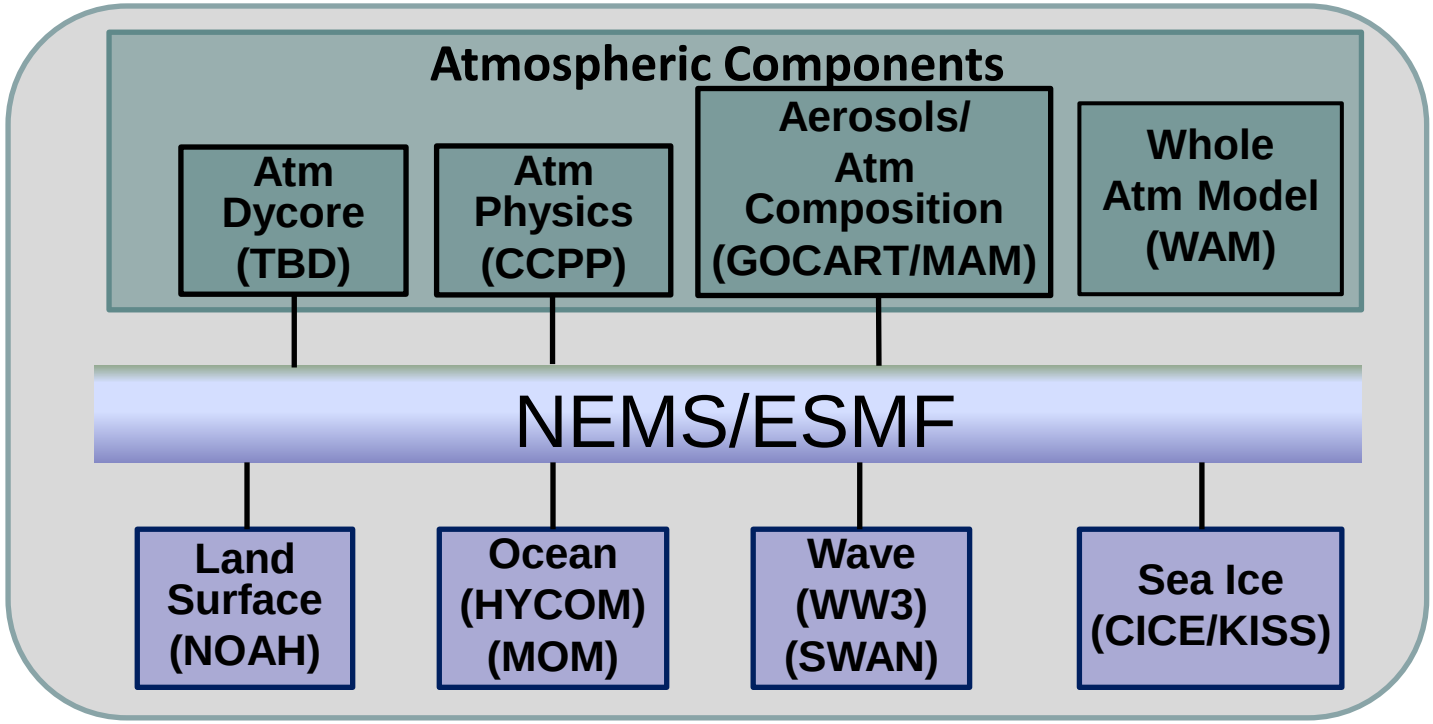
Application
=
Ensemble
+
Reanalysis
+
Reforecast

Research needs to fit into strategy

1 y	2 y	4 y	**Update cycle**
3 y	20-25 y	1979 - present	**Reanalysis**
6h	6-24h	???	**cycling**
WCOSS	WCOSS	WCOSS ?	**where**

From Hendrik Tolman

NGGPS Prediction Model Components

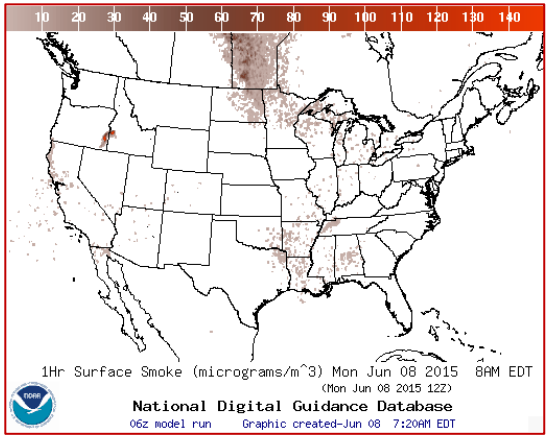


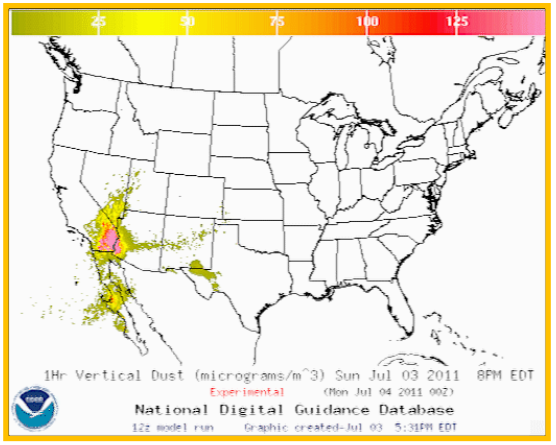
- NGGPS implementation plan development includes an aerosol and atmospheric composition team
- Development of dust/aerosol capabilities is underway by universities and federal labs

NOAA operational predictions of atmospheric dispersion

Routine predictions:

- Smoke predictions nationwide http://airquality.weather.gov/
- Dust predictions over contiguous 48 states (CONUS) http://airquality.weather.gov/
- CTBTO on-demand backtracking capability





Incident support:

- Volcanic ash
- Radiological contamination
- Chemical releases

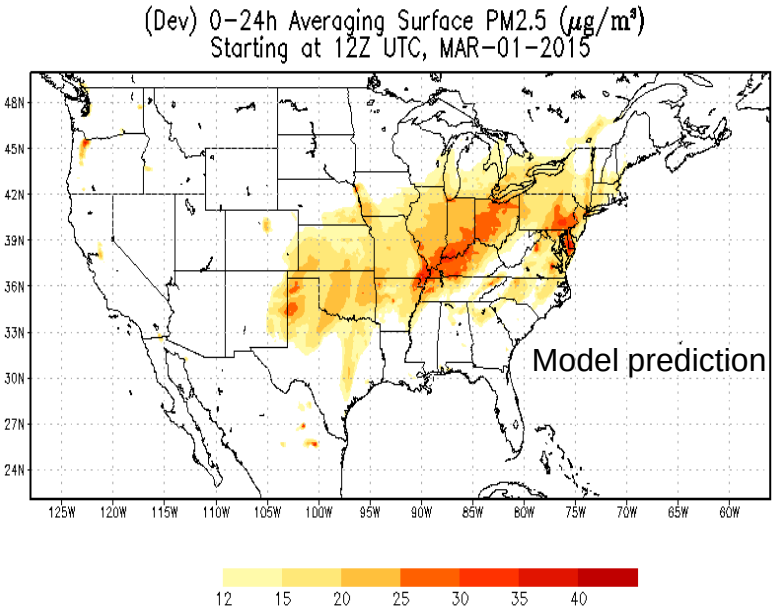
All the above dispersion applications rely on HYSPLIT model.

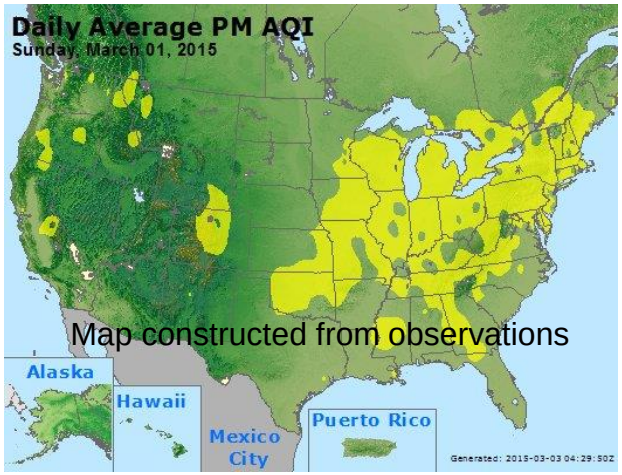
Verification of dust and smoke predictions uses satellite retrievals of dust and smoke.

National Air Quality Forecast Capability: PM2.5 Predictions

Development of fine particulate matter (PM2.5) predictions

- Community Multiscale Air Quality (CMAQ) driven by North American Mesoscale Model (NAM)
- Emissions based on the National Emissions Inventory (NEI), versions 2005 and 2011
- Real time dust and wildfire smoke sources
- Testing of lateral boundary conditions from the global NEMS GFS Aerosol Component (NGAC)
- Exhibits seasonal biases; bias correction procedure in testing
- Verification uses surface PM2.5 observations



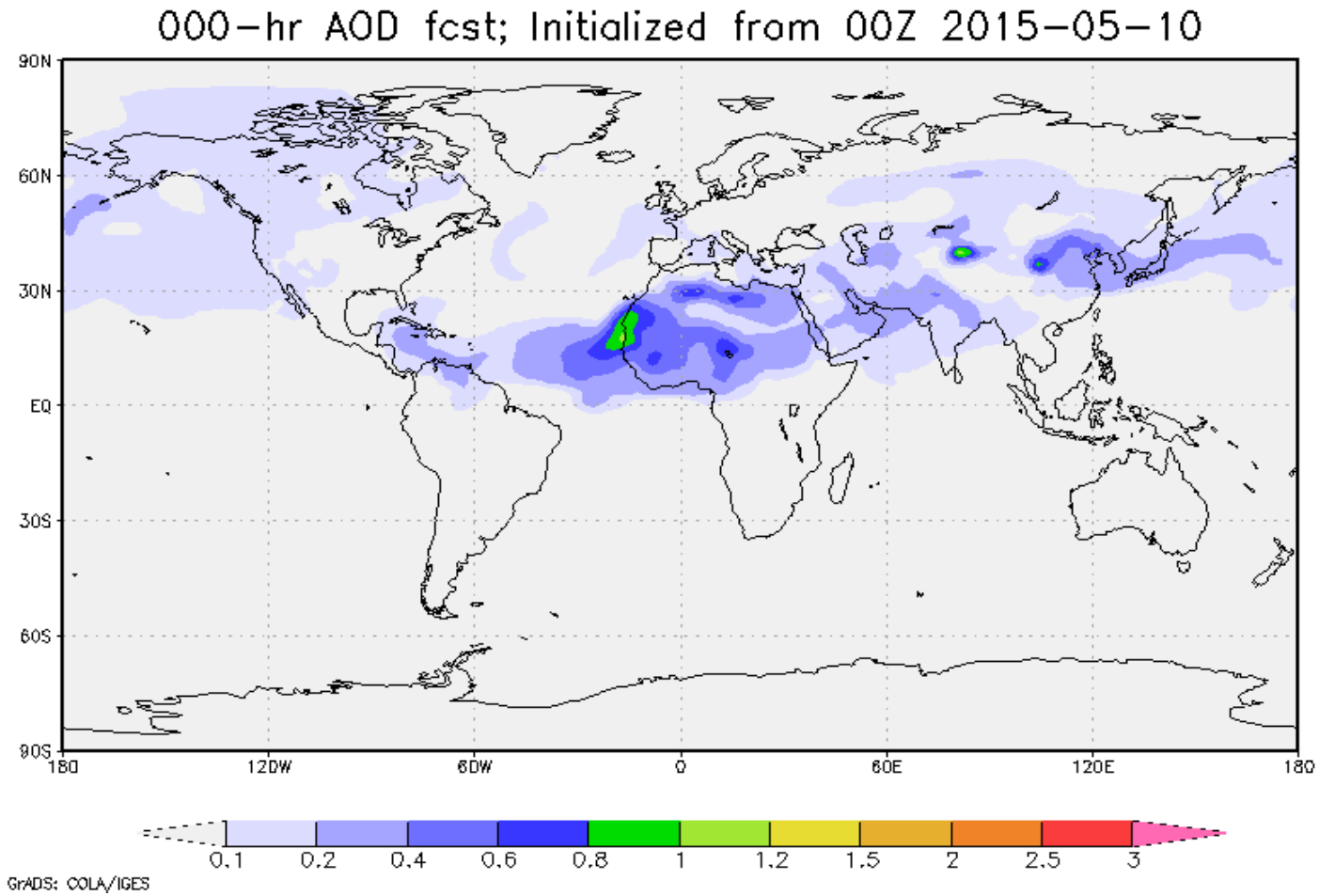


NEMS GFS Aerosol Component (NGAC)

- NGAC is a global in-line aerosol forecast system
- **Goddard Chemistry Aerosol Radiation and Transport (GOCART)** model is the aerosol component model of NGAC
  - Funded mainly by NASA Earth Science programs
- Implementation into NEMS GFS at NCEP was funded by NOAA-NASA-DOD JCSDA and NASA Applied Sciences Program
- Produces 120-hour global dust forecasts

Operational NWS global predictions of dust AOD

NEMS GFS Aerosol Component (NGAC)



Animation from http://www.emc.ncep.noaa.gov/gmb/sarah/NGAC/html/realtime.ngac.html

NGAC Development

- Improve aerosol and volcanic ash forecast capability and aerosol impacts on radiation and microphysical processes

- Near term priorities funded from other sources:
  - Expand to include carbonaceous aerosols, sea salt and sulfate
  - Assimilate aerosol data from the Visible Infrared Imaging Radiometer Suite (VIIRS) instrument

- Produce new aerosol products for downstream application

GFS Ozone Model

- Assimilation of 22 retrieved layers from NOAA-19 Solar Backscatter Ultraviolet Instrument (SBUV/2) version 8 retrievals and total ozone columns from the Ozone Monitoring Instrument (OMI)
- Chem2D parameterization
  - Chemical production and loss
  - Operational implementation uses only two of the four terms
  - Loss of ~1% global total column ozone within first 5 days of forecasts
  - An additional 2%-3% loss by 10-15 days
  - (J. McCormack, T. Hogan, NRL; M. Iredell and C. Long, NCEP)
- No heterogeneous chemistry (i.e. ozone hole) parametrization
- Ongoing project funded by CPO to incorporate remaining two terms to better constrain total ozone budget

Aerosol and Atmospheric Composition Prediction Gaps

- GFS microphysical and cloud parameterization schemes currently do not use predicted aerosols
- Addition of aerosol effects has a potential to improve global precipitation distribution and cloud properties
- Inclusion of anthropogenic aerosols, nitrates and secondary organic aerosols
- Use of predicted aerosols in radiation and assimilation of satellite radiances

Prioritized Areas of Model Development

- Augment current operational aerosol and volcanic ash forecast capability to represent natural and anthropogenic aerosols
  - Size and composition categories
  - Transport
  - Sedimentation
  - Sources
  - Sinks and transformations (nucleation, condensation, coagulation, chemical reactions)
- Improve parameterized ozone sources and sinks
- Gather requirements for forecast of atmospheric composition (over and above aerosols and ozone) and propose advanced system to meet requirements
- Optimize computational efficiency

Coordination and interactions

- Coordination with other Science Working Groups (SWG) and Teams
- Aerosol-radiation processes with Radiation SWG
- Aerosol-microphysics processes for condensation, nucleation, etc. with Microphysics SWG
- Aerosol impact on assimilation of satellite radiances with DA team

NGGPS Aerosol and Atm Composition Development in Progress

- Paul Ginoux (NOAA GFDL)
  - Implementation and Testing of Regional and Global Dust Forecasting
- Sarah Lu (SUNY Albany)
  - Investigation of Aerosol Effects on Weather Forecast using NCEP Global Forecast System – radiative effects
  - Improving Cloud Microphysics and Their Interactions with Aerosols in the NCEP Global Models
- Georg Grell (NOAA/ESRL/GSD)
  - Using Advanced Photochemical and Aerosol Modules to Verify the Applicability of GOCART Aerosol Modules within Global Weather Prediction Models
- Zhanqing Li (Univ. of MD)
  - Evaluating the Impact of Cloud-Aerosol-Precipitation Interaction (CAPI) Schemes on Rainfall Forecast in the NGGPS

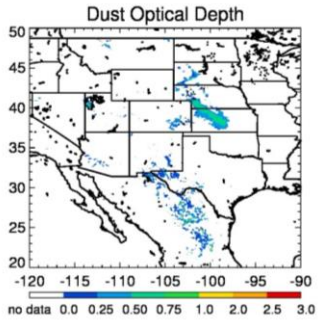
Implementation and testing of regional and global dust forecasting

NOAA NGGPS project

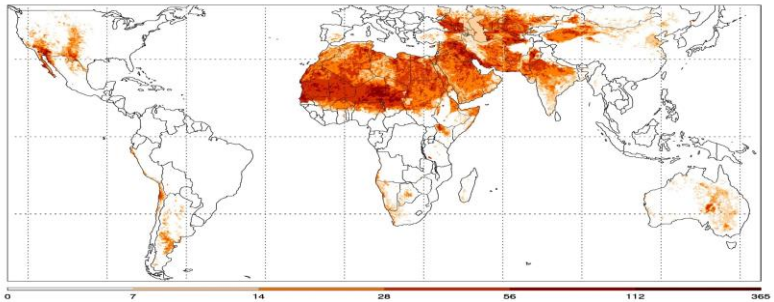
PI: Paul Ginoux (NOAA GFDL)

1. Dust Sources Inventory

Dust detection using MODIS satellite at 0.1° resolution (~10 km) daily for 12 years (2003-2014). Dust source = location of the most frequent dust events (Ginoux et al., Rev. Geophys., 2012). Unique global high resolution dust sources inventory.

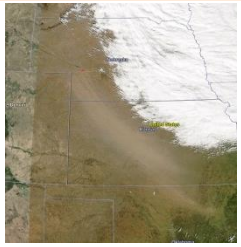


One granule of satellite pixels at a time from regional to global, daily and for 12 years of newly released MODIS data

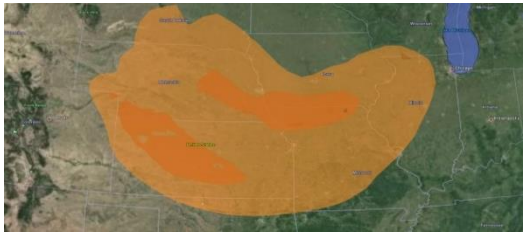


2. Dust Simulation/forecasting

Dust simulation with NMMB for one year (2012), global and CONUS (high resolution)

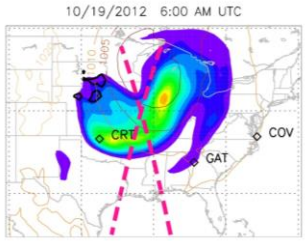


Dust events are frequent in the High Plains, creating deadly accident, shutting Interstate Highways, such as in October 2012.

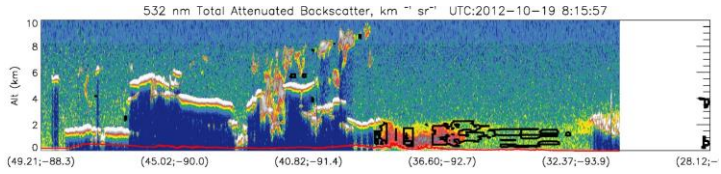


3. Model Evaluation

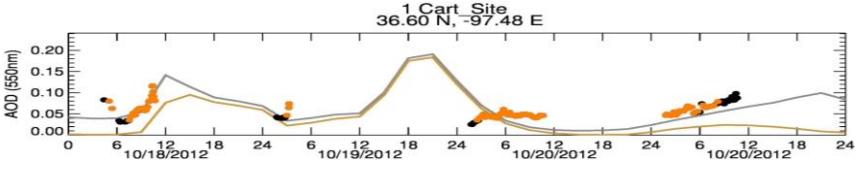
Evaluation and skill scores using ground-based and satellite data

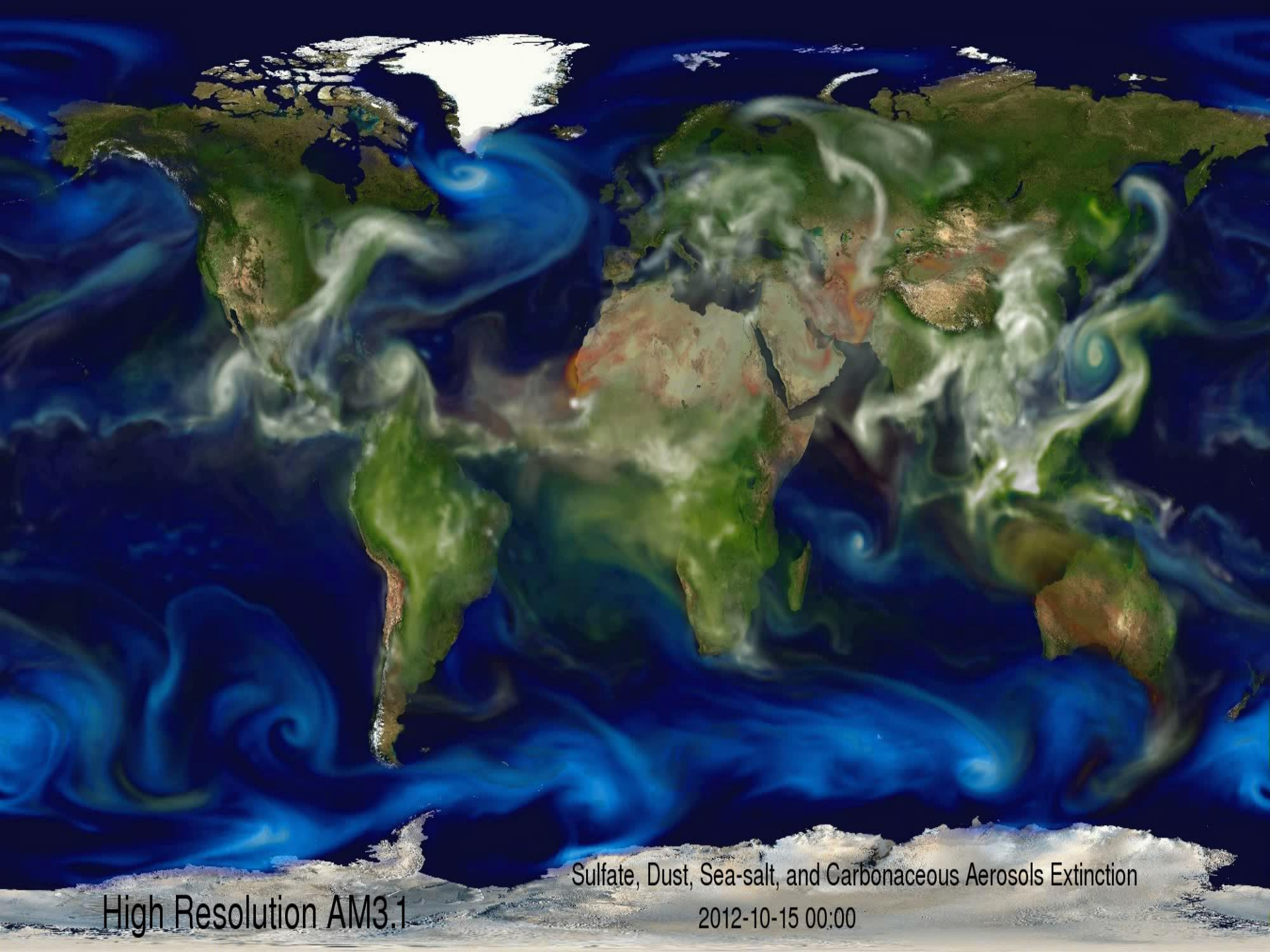


CALIPSO lidar



AERONET sunphotometer




High Resolution AM3.1
Sulfate, Dust, Sea-salt, and Carbonaceous Aerosols Extinction
2012-10-15 00:00

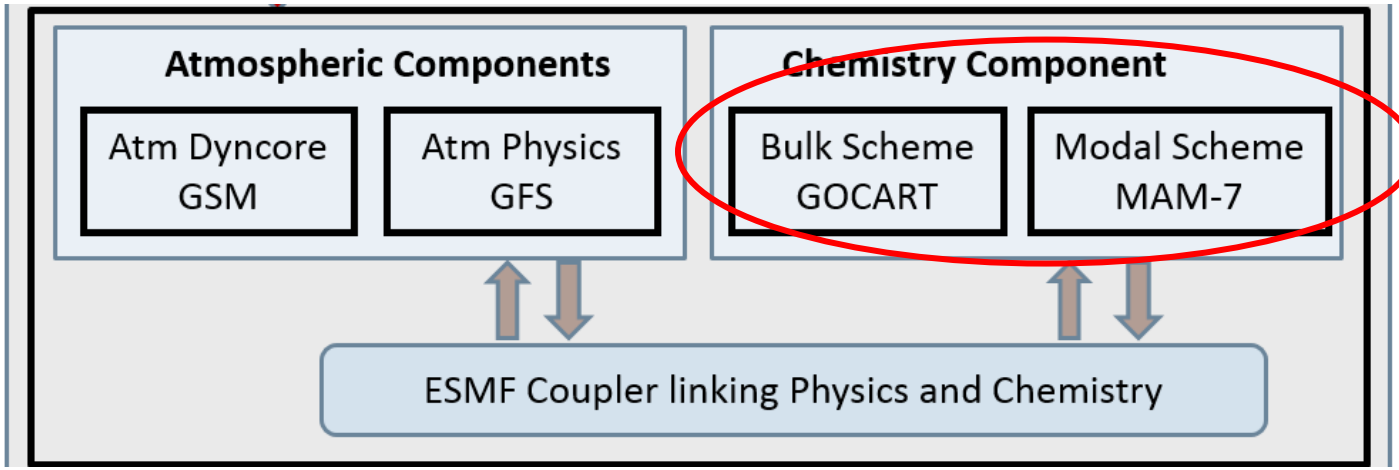
Improving cloud microphysics and their interactions with aerosols in the NCEP global models

SUNYA: Sarah Lu, Qilong Min, Sheng-Po Chen

GSFC/GMAO: Arlindo da Silva, Anton Darmenov, Donifan Barahona

NCEP/EMC: Yu-Tai Hou, Shrinivas Moorthi, Fanglin Yang, Jun Wang

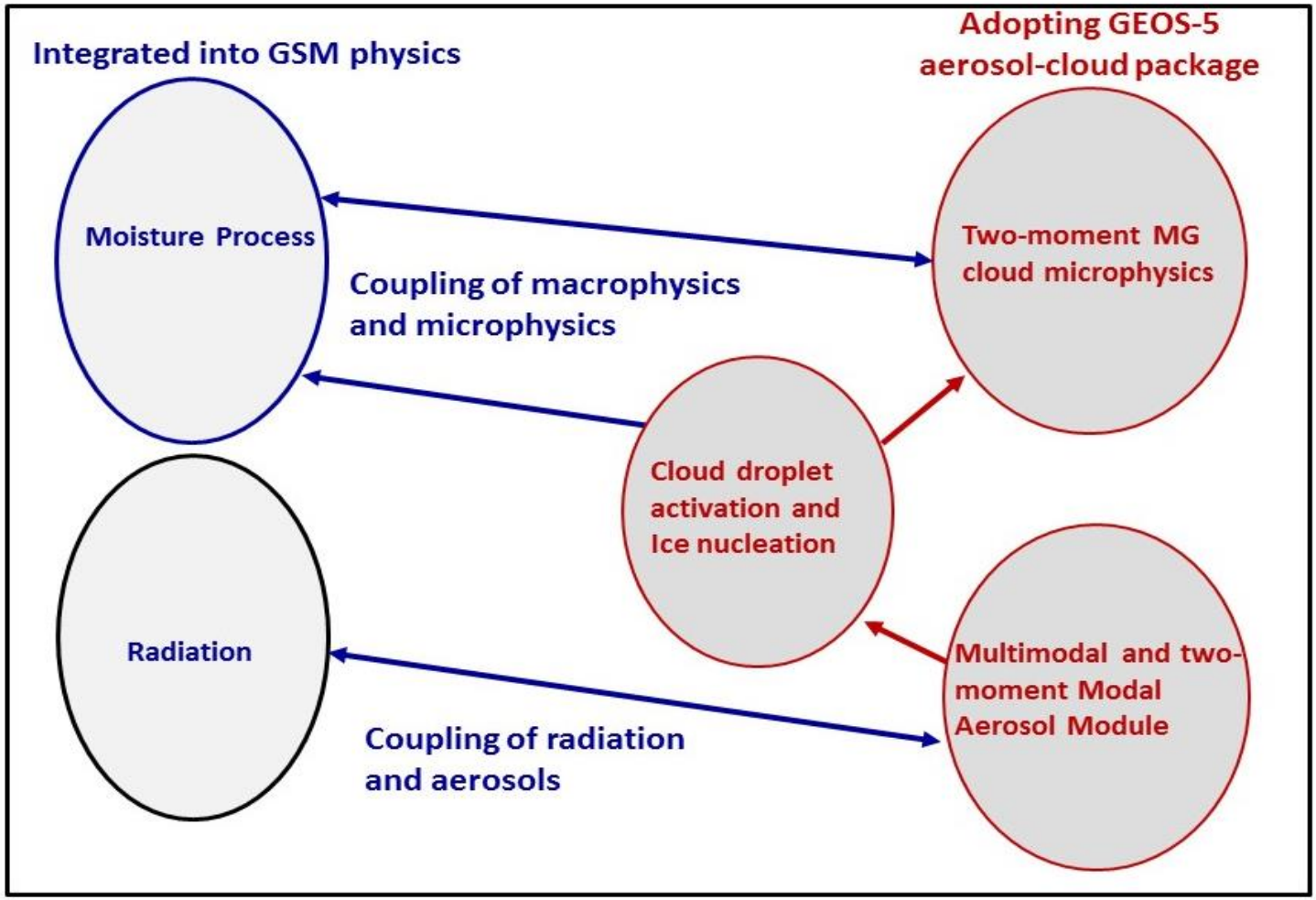
- Objective: Improve the representation of aerosol processes, cloud microphysics, and aerosol-cloud-radiation interaction in NCEP global models
- SUNYA-NCEP-GSFC collaborative effort to upgrade NEMS (NOAA Environmental Modeling System) physics suite by adapting GSFC's physically-based aerosol and cloud microphysics package (which in turn is based on NCAR CAM5)



A choice of aerosol components

Improving cloud microphysics and their interactions with aerosols in the NCEP global models

PI: Sarah Lu



Physically-based aerosol and cloud microphysics package to improve aerosol-cloud-radiation interaction within NEMS

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

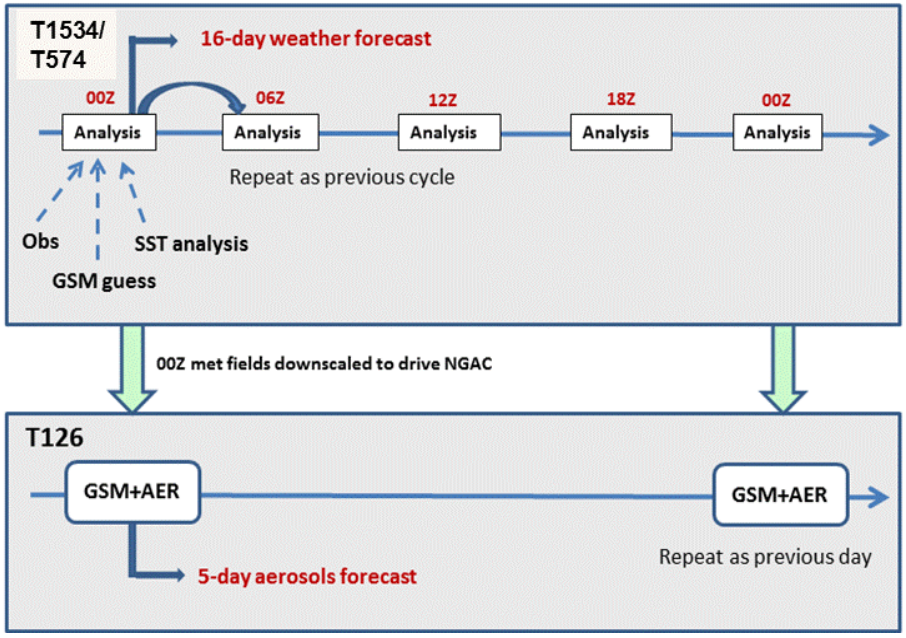
SUNYA: Sarah Lu, Sheng-Po Chen
NESDIS/STAR: Quanhua Liu
NCEP/EMC: Robert Grumbine, Andrew Collard, Jun Wang, Partha Bhattacharjee, Bert Katz

- Objective: Investigate how much complexity is needed to accurately represent the aerosol processes and effectively account for aerosol effects
- SUNYA-NCEP-STAR collaborative effort to explore the optimal (accurate and yet affordable) aerosol configuration for pre-operational testing at NCEP
- Tactical approach:
  - Producing an improved estimates of the temporal and spatial distributions of atmospheric aerosols
  - 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
  - Incorporate flexible aerosol configuration in pre-operational testing at NCEP to foster Research-to-Operation (R2O) and Operational-to-Research (O2R)

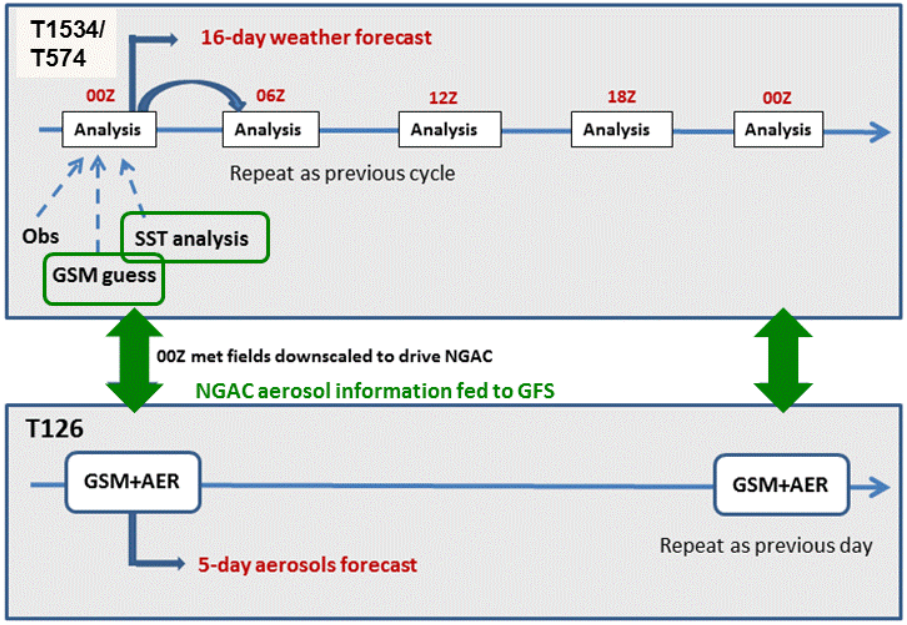
Investigation of Aerosol Effects on Weather Forecast using NCEP Global Forecast System (PI: Sarah Lu)

Dual-resolution weather-aerosol system at NCEP

Operational: One-way coupling



Proposed: Two-way loose coupling



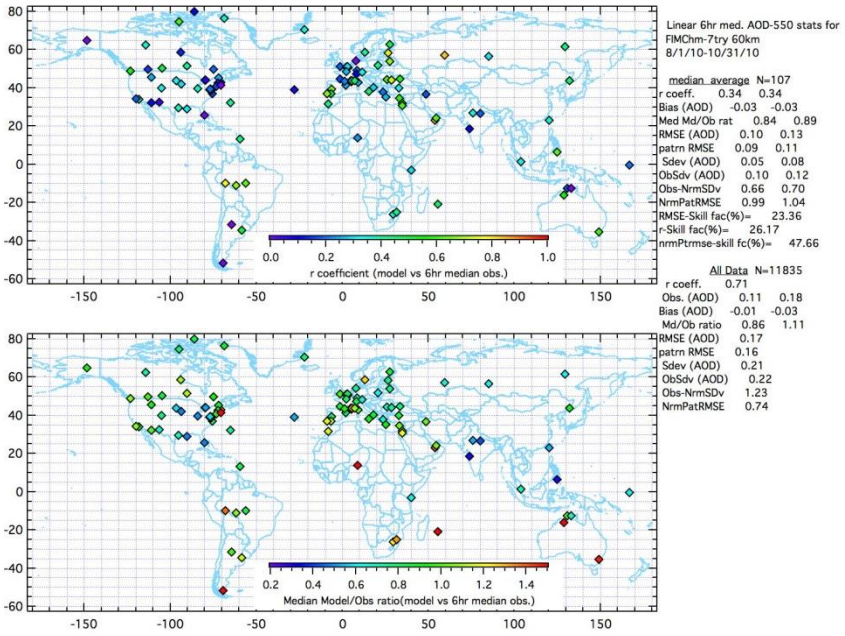
2-way coupling: Aerosol fields from low-resolution NGAC run are fed to high-resolution GFS run. This allows aerosol radiative effects in GSM, physical retrievals in RTG_SST, and aerosol attenuation in EnKF-GSI hybrid to be determined from low-resolution NGAC simulations.

Using advanced photochemical and aerosol modules to verify the applicability of GOCART aerosol modules within global weather prediction mode

Georg A. Grell (NOAA/ESRL/GSD) and Stuart A. McKeen (NOAA/ESRL/CSD)

- Use gas-phase and aerosol chemistry packages with different levels of sophistication in state-of-the-art global modeling systems
- Determine the degree of complexity necessary to estimate the impact of aerosols on numerical weather prediction skill
- Deliverables will include chemistry and aerosol packages for inclusion in any

- For NGGPS this will accelerate development and implementation of weather prediction model components (aerosol models), and improve coupling between the component model systems
- The evaluated chemistry and aerosol packages can be included in any of the



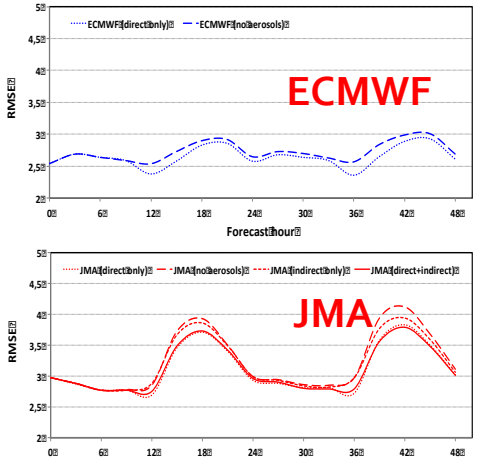
Comparison of AOD predictions using a global modeling system developed at ESRL that includes the simple aerosol approach from the Goddard Chemistry Aerosol Radiation and Transport (GOCART) model.

The evaluation is based on 3 months worth of simulation with a horizontal resolution of about 60km and 64 vertical level. High correlations are most likely near strong signals (forest fires and dust events).

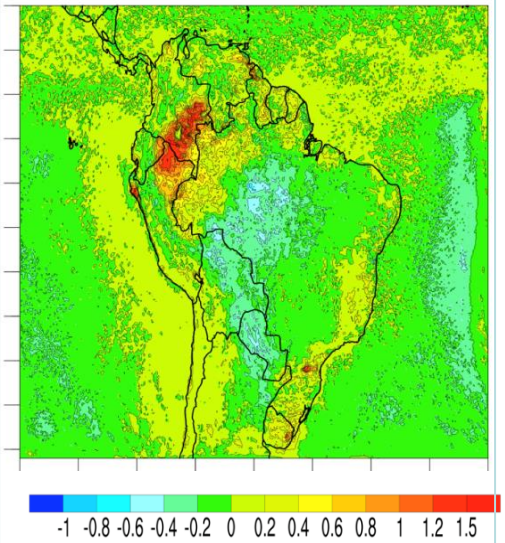
Using advanced photochemical and aerosol modules to verify the applicability of GOCART aerosol modules within global weather prediction mode

- Aerosol impacts on NWP: can this be done with the simple GOCART modules?
- Use chemistry and aerosol packages with different levels of complexity to evaluate interaction of aerosols with radiation and microphysics
  - Very light package that uses GOCART only
  - A medium package (similar to ECMWF)
  - A sophisticated package with even more complexity than what is used in NAQFC

These three chemistry suites may later be included in the NEMS framework and used by any future NGGPS dynamic core



Evaluating the impact of aerosols on Numerical Weather Prediction (NWP): A Working Group for Numerical Experimentation (WGNE) organized by operational centers: Improvement when including aerosols for near surface temperature predictions as shown by this WGNE working group, and a model intercomparison case over Brazil during a field experiment. Examples from 2 operational center models include radiation interaction (direct effect) and microphysics interaction (indirect effect). “No aerosol” runs were done with climatologies



Near surface temperature differences (Temperature at 2m above surface) during mid-morning hours averaged *over twenty 72-hr forecasts*, using convection permitting simulations with a regional model and a sophisticated chemistry package.

Summary

- Model development to transition from research to NWS operations improved (more complete, accurate and efficient) representation of atmospheric aerosols and atmospheric composition

- Include impacts of predicted aerosols and atmospheric composition on radiation, microphysics and data assimilation

- Community involvement (model development team, development efforts, models)

- Parallel development, testing and evaluation as NGGPS is built

Questions?

NGGPS Website:

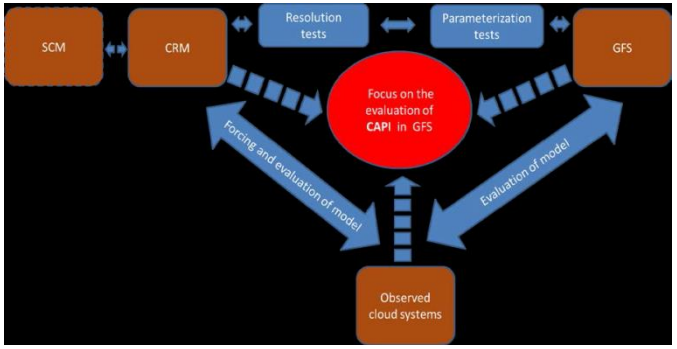
http://www.nws.noaa.gov/ost/nggps

Evaluating the Impact of Cloud-Aerosol-Precipitation Interaction (CAPI) Schemes on Rainfall Forecast in the NGGPS

Principal Investigator: Zhanqing Li - ESSIC, University of Maryland
Co-Principal Investigator: Seoung-Soo Lee - ESSIC, University of Maryland
Co-Investigators: Yu-Tai Hou, Jun Wang, Shrinivas Moorthi - NOAA/NCEP/EMC
Sarah Lu - SUNY Albany

Approach to evaluate schemes:

- Evaluating the performance of the new physical schemes associated with accounting for the aerosol effects that affect rainfall forecasts and cloud simulations through in-depth comparisons with extensive global satellite and ground-based products And observation-based findings



An integrated approach to evaluate the GFS model regarding CAPI by using CRM, SCM, and observations.

- Understanding the causes of discrepancies in simulating clouds and their interactions with aerosol between current and new schemes, and between model simulations and observations by virtue of a high-resolution cloud-resolving model (CRM)

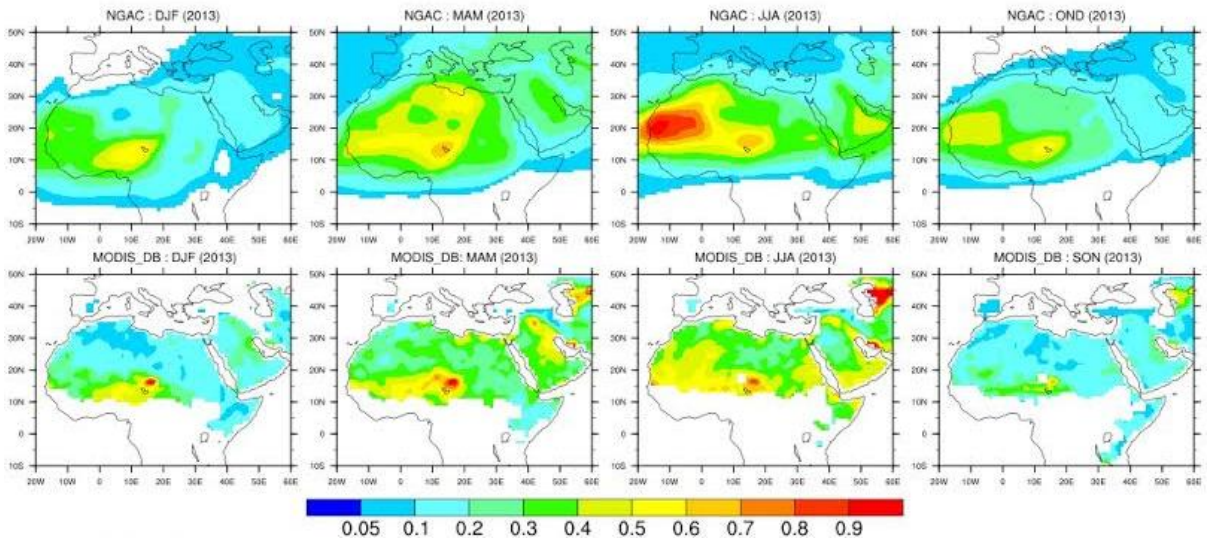
Improving the physical parameterizations of cloud-aerosol interactions allows for efficient, accurate and more complete representations of physical processes and their interactions across scales

Verification: Satellite observations

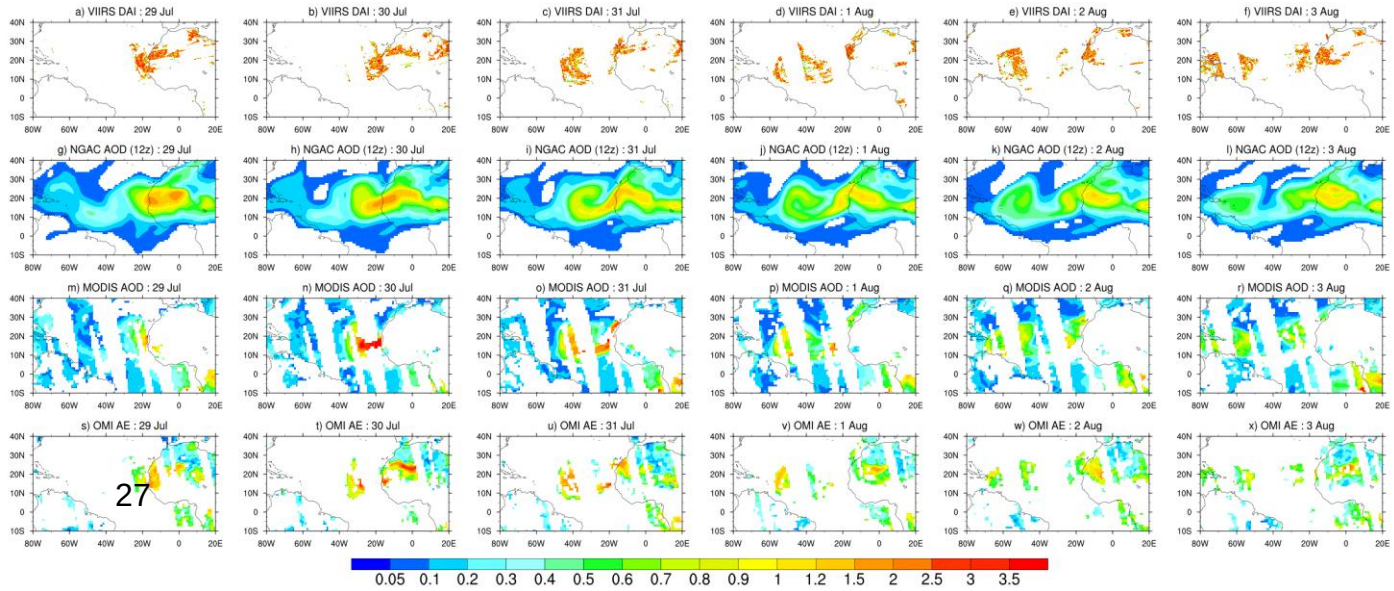
Seasonal variation (2013)

NGAC

MODIS



Case study (Jul 29 – Aug 3, 2013)



VIIRS dust mask

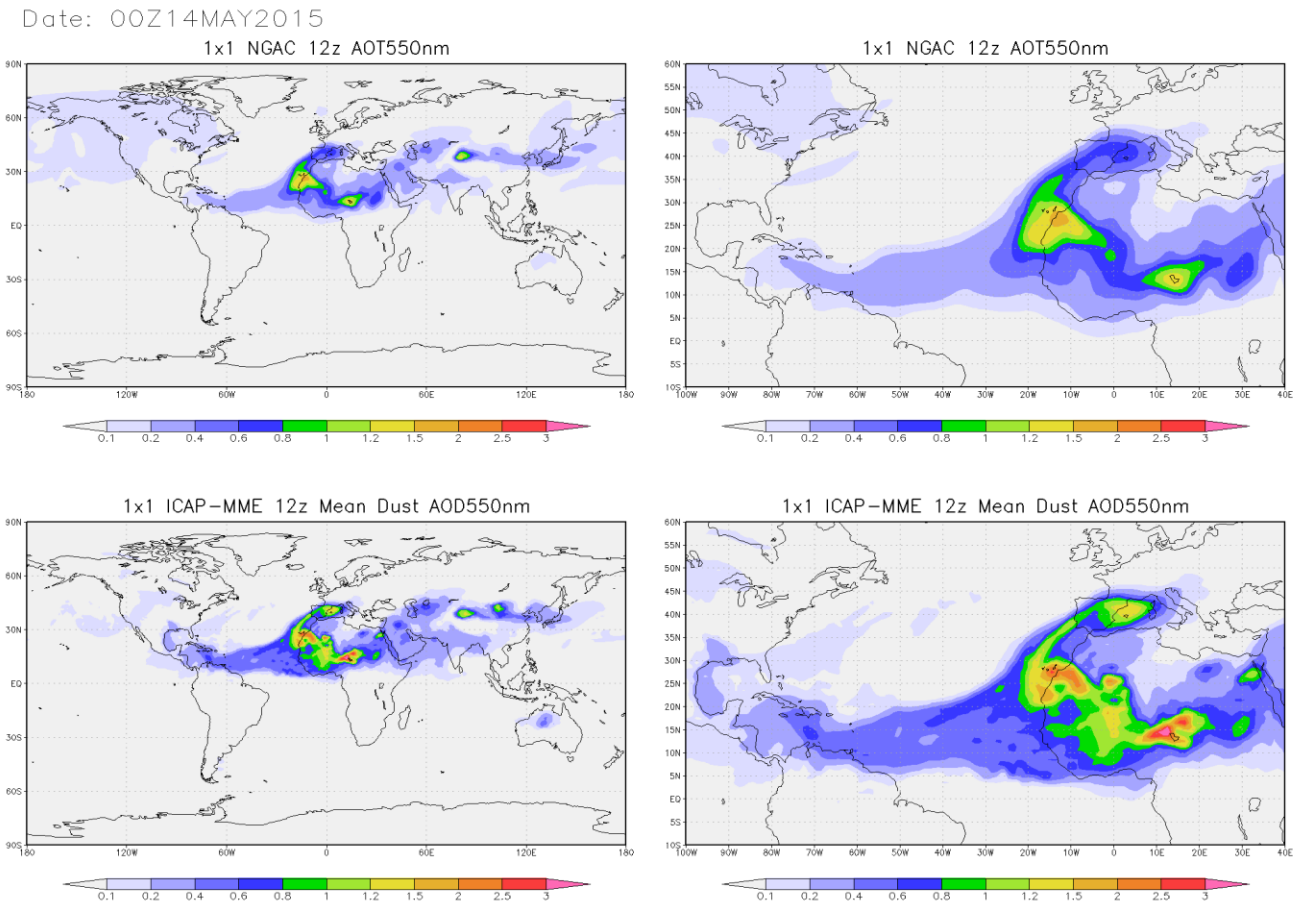
NGAC

MODIS

OMI

27

Global multi-model ensemble comparisons



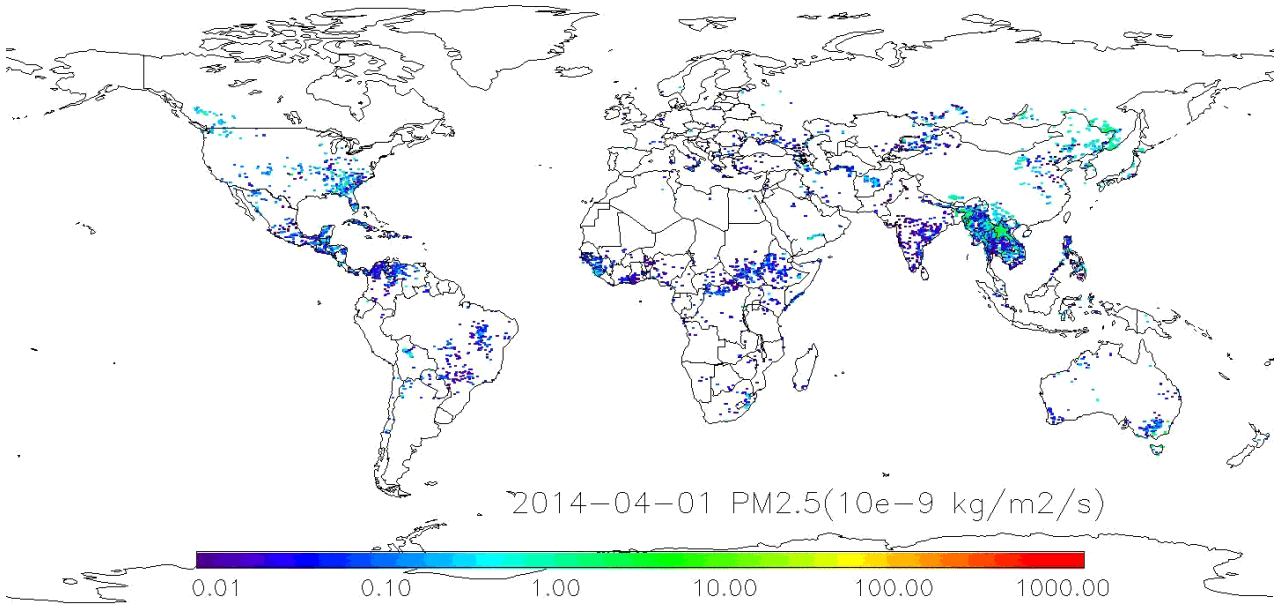
NGAC

ICAP MME (7-members)

ICAP is a global aerosol forecasting working group for aerosol forecast centers and data providers. NCEP leverages collaborations with other recognized world experts in operational aerosol forecasting

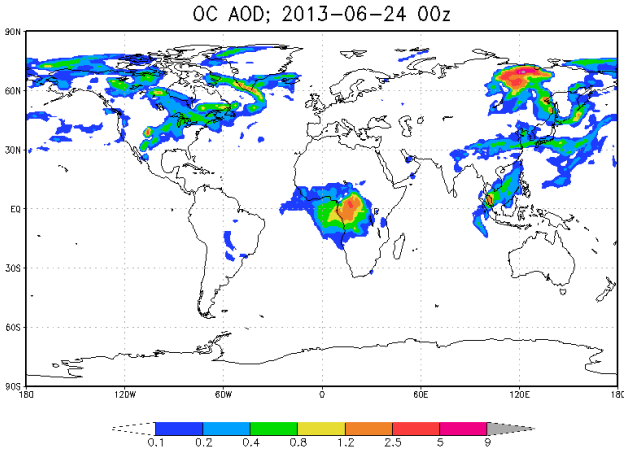
Q1FY16 upgrade: Multi-species forecast using near-real-time smoke emissions from satellites

Temporal and spatial variation in smoke emissions from GBBEPx



GBBEPx: Global Biomass Burning Emissions Product-eXtended, blended from Geo (NESDIS's smoke products) and Polar (GSFC's smoke products)

NGAC Organic Carbon AOD



ICAP smoke AOD MME