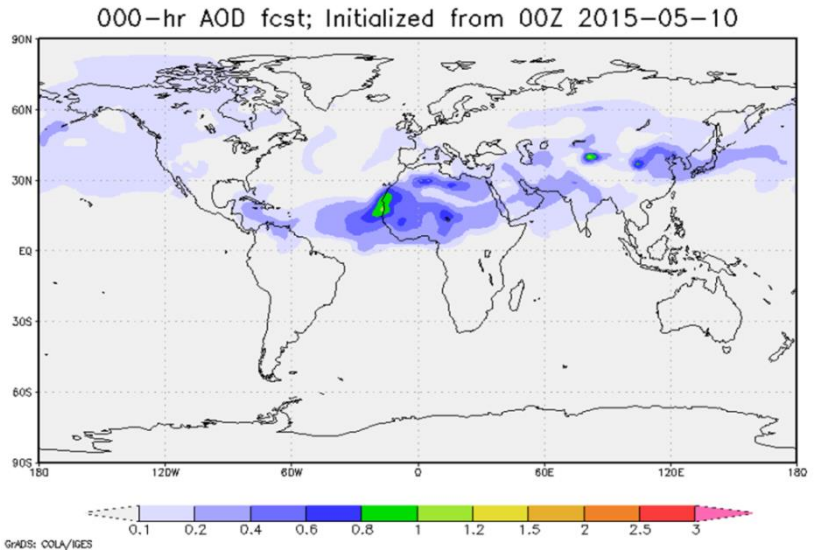
Aerosol and Atmospheric Composition Team Plan

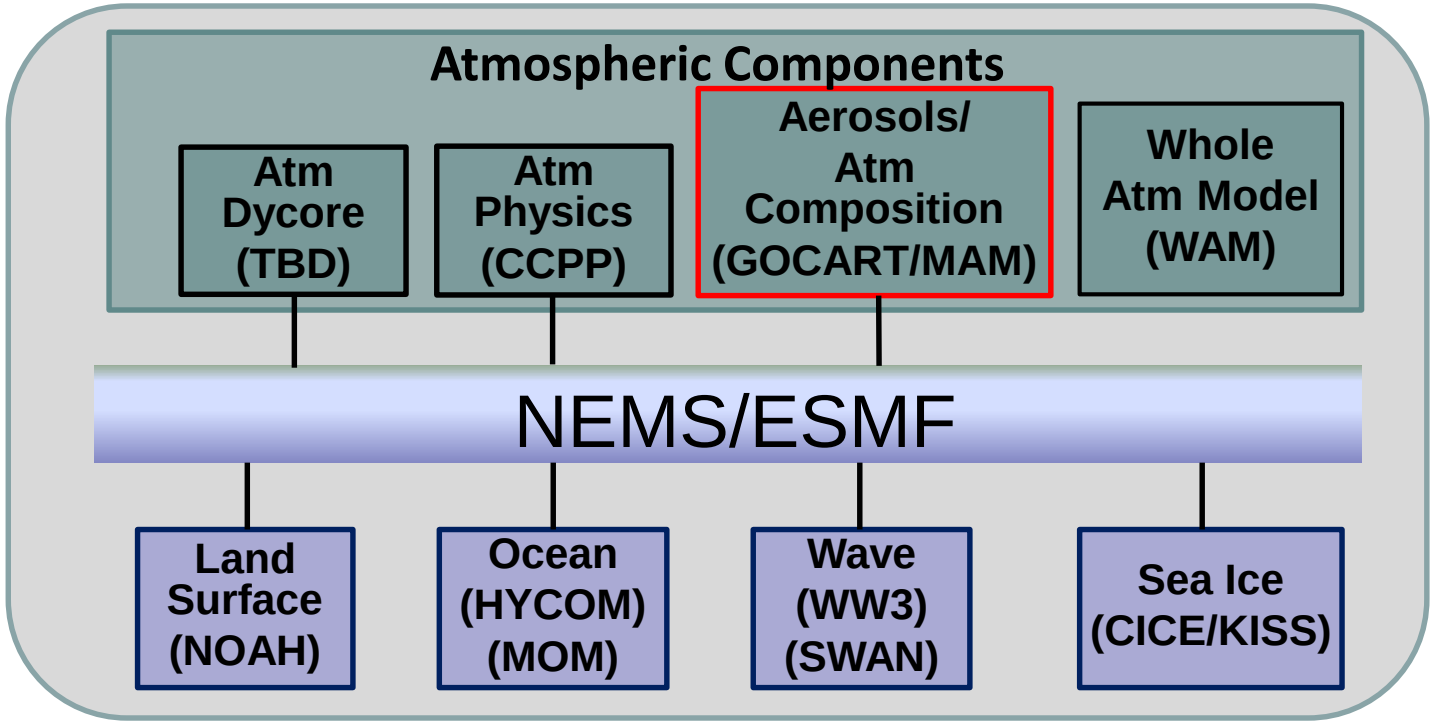
HIWPP/NGGPS Meeting

10 Feb 2016



Ivanka Stajner, Yu-Tai Hou

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

Aerosol and Atmospheric Composition

- Aerosols, e.g. dust, smoke, volcanic ash, sea salt, sulfate, black carbon, organic carbon and anthropogenic aerosols
- Gaseous composition, e.g. ozone, $NO_{X,}$ methane, CO_2
- Aerosol and atmospheric composition effects on radiation, clouds and assimilation of satellite radiances

Aerosol and Atmospheric Composition 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

- Ivanka Stajner, NWS/OSTI, co-lead
- Yu-Tai Hou, NWS/EMC, co-lead
- Georg Grell, ESRL
- Arlindo da Silva, NASA/GMAO
- Doug Westphal, NRL
- Kenneth Pickering, NASA
- Brad Pierce, NESDIS
- Paul Ginoux, GFDL
- Jeff McQueen, NWS/EMC
- Jun Wang, EMC
- Craig Long, NWS/CPC
- Larry Horowitz, GFDL
- Gregory Frost, ESRL
- Stuart McKeen, ESRL
- Ariel Stein, ARL

In coordination with physics and data assimilation teams:

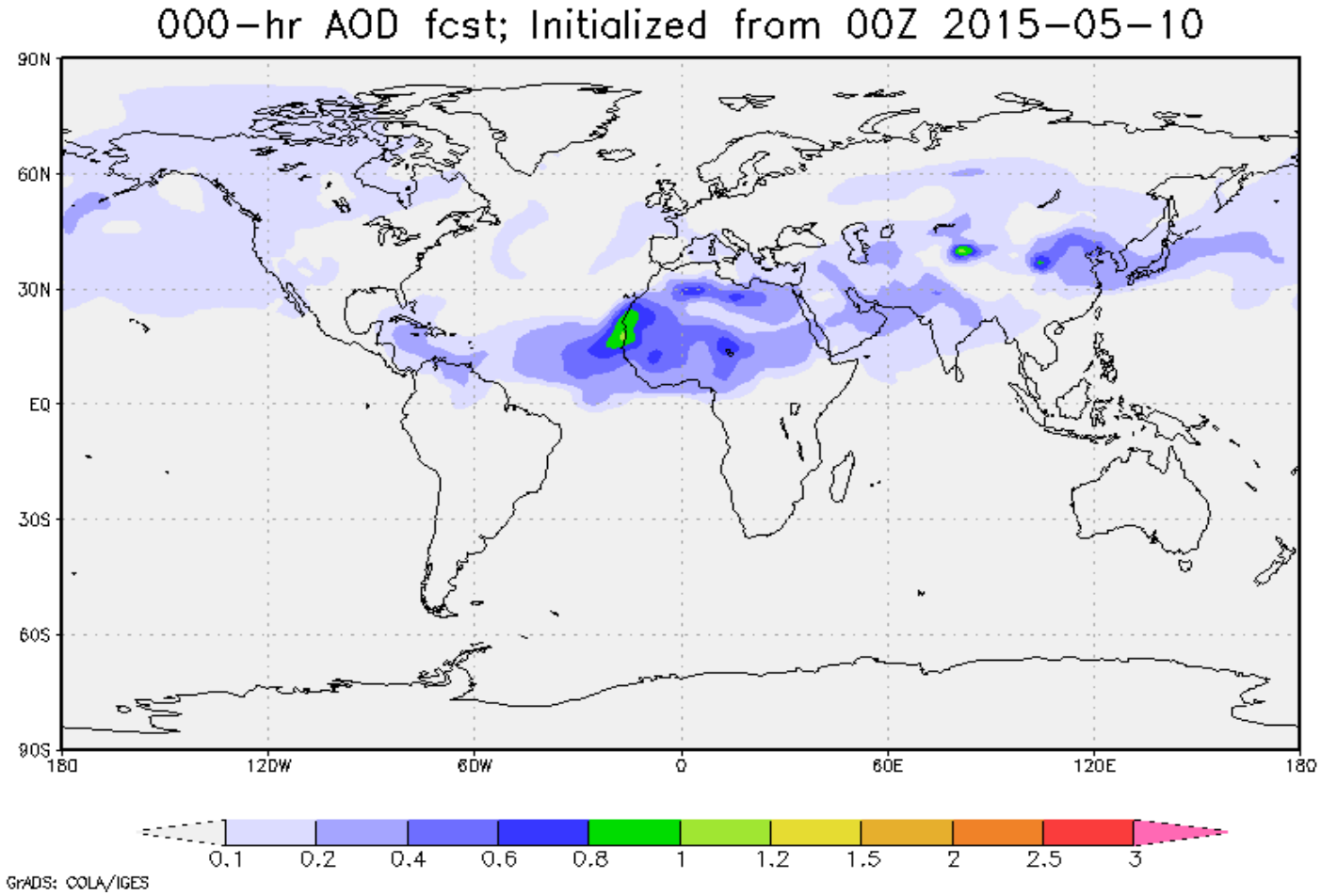
- Jim Doyle, NRL
- Bill Kuo, NCAR
- John Derber, NWS/EMC

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/NGAC/html/realtime.ngac.html

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 v2 NCO 30 day parallel starts February 18, with implementation scheduled by the end of March

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, S. Moorthi 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

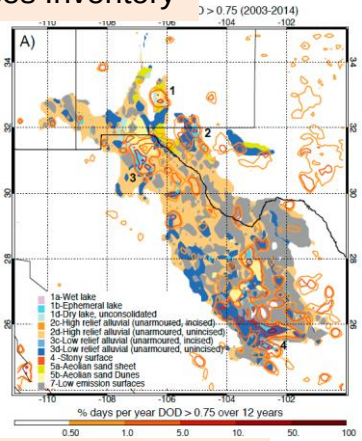
NGGPS Aerosol and Atm Composition Development in Progress

- 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

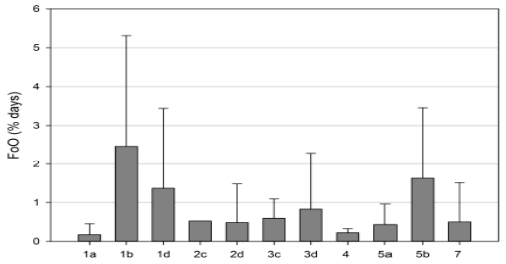
NOAA NGGPS project, PI: Paul Ginoux (NOAA GFDL)

1. Dust Sources Inventory

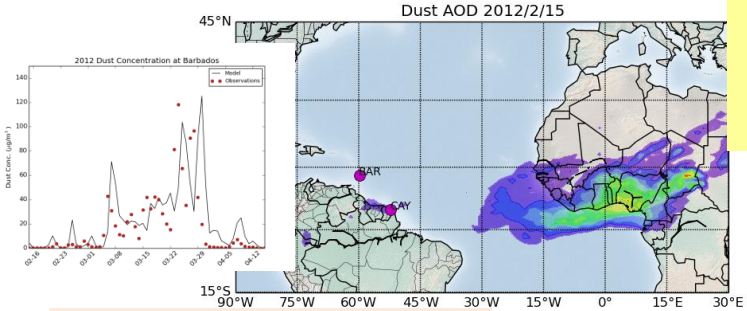


"Do MODIS-defined dust sources have a geomorphological signature?" by Baddock, Ginoux, et al. submitted for publication in Geophysical Research Letters (December 2015).

The highest frequency of dust events detected from MODIS over the Chihuahuan desert is essentially related to ephemeral lakes.

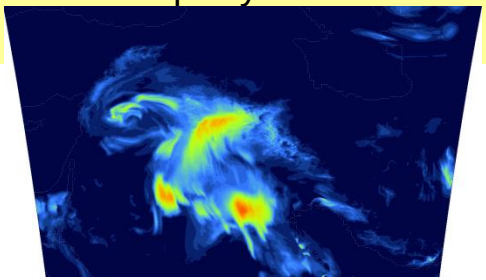


2. Dust Simulation/forecasting



Dust simulation with NMMB:

- 1x1 degree global with different emission schemes (default, Kok, GOCART) and source inventories (Ginoux 2001; 2012) for 2012
- 2x2 km over Middle East to simulate Iraqo-Syrian haboob of September 2015



3. Model Evaluation

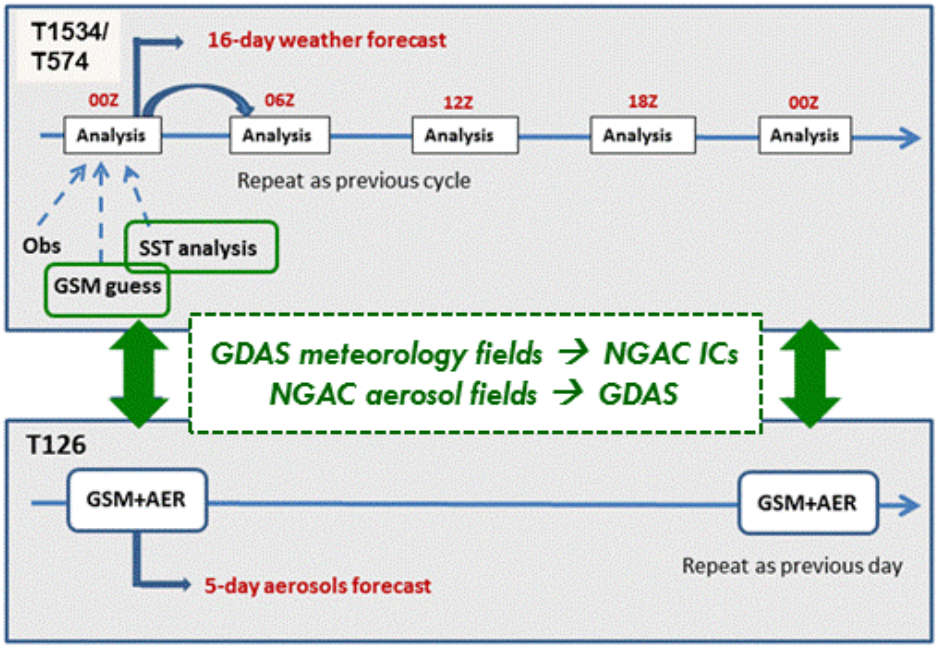
Evaluation and skill scores of each simulations using ground-based and satellite data:

- Oral presentation by Deroubaix, Perez and Ginoux at the American Meteorological Society, New Orleans, January 2016,
- Manuscript in preparation

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

Proposed: Two-way loose coupling



Overarching goal:

- Investigate how much complexity is needed to accurately represent the aerosol processes and effectively account for aerosol effects?

Proposed approach:

- 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 status update:

- Cases of interest (dust and smoke events) are identified.
- GSM radiation code development is in progress.
- New hire came on board SUNYA mid Jan, 2016 and obtained an account at S4 cluster late Jan. His GSI code development on ingesting NGAC aerosols is underway.

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

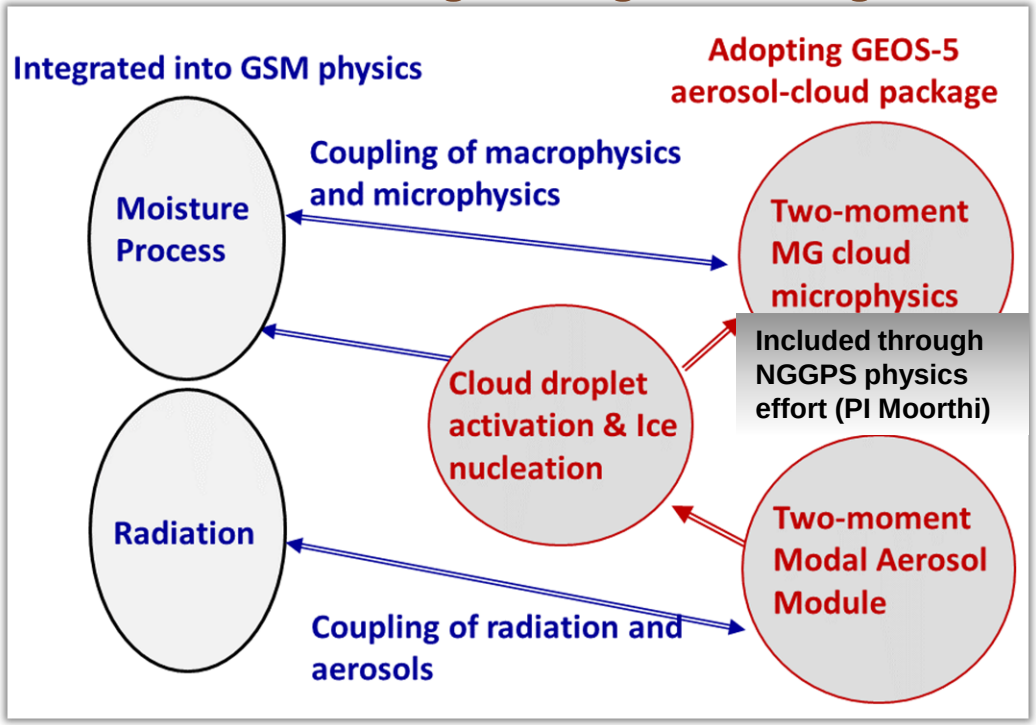
NCEP/EMC: Yu-Tai Hou, Shrinivas Moorthi, Fanglin Yang, Jun Wang

Overarching goal:

- Improve the representation of aerosol processes, cloud microphysics, and aerosol-cloud-radiation interaction in NCEP global models

Proposed approach:

- Adopt physically-based aerosol and cloud microphysics package from GSFC GEOS-5 into NEMS GSM



Project status update:

- NCEP's NGAC is evaluated using in situ and satellite observations to establish the baseline.
- Implementation and tests of the two physics upgrades (MAM aerosol scheme and MG cloud microphysics scheme) are conducted individually (uncoupled) initially and will be interactively (coupled)
- New hire came on board SUNYA late Jan 2015. His HPC (gaea) application is still pending. His NEMS GSM code development is carried out at S4, since July 2015.

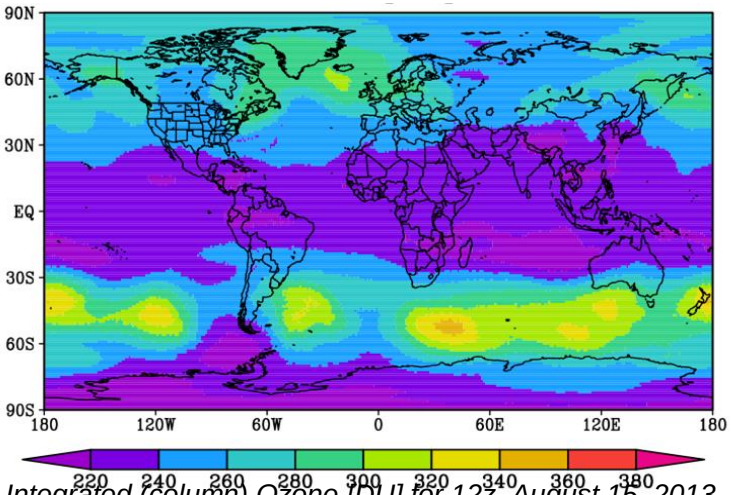
Using advanced photochemical and aerosol modules to verify the applicability of GOCART aerosol modules within global weather prediction model

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

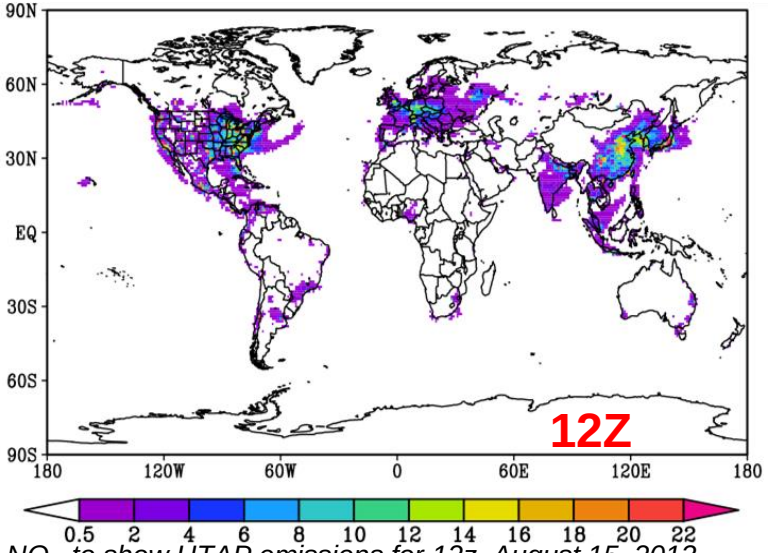
Use chemistry and aerosol packages with different levels of complexity to evaluate interaction of aerosols with radiation and microphysics. Completed chemistry suites:

- Tracer (greenhouse gas or volcanic ash, can be used for any of the other packages)
- Light aerosol package that uses GOCART only
- A medium package (similar to ECMWF),
  - GOCART, RACM gas phase chemistry
  - Inline photolysis
  - Wet and dry deposition
  - Improved dust,
  - Real-time biomass burning,
  - MEGAN biogenic emissions,
  - HTAP anthropogenic emissions,
  - Upper level ozone (above 360k) from GFS/GSI – will run in real-time at 60km resolution

Next: A sophisticated package with even more complexity than what is used in NAQFC



Integrated (column) Ozone [DU] for 12z, August 15, 2013

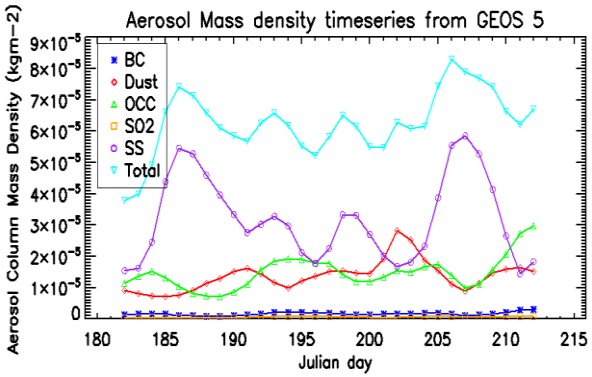


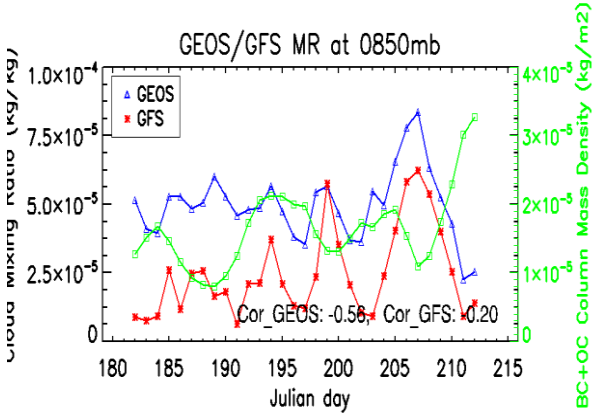
Surface NO_2 to show HTAP emissions for 12z, August 15, 2013

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

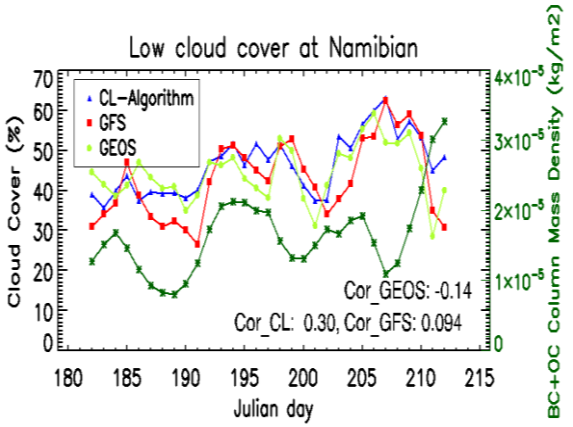
PI: Zhanqing Li, University of Maryland

As the NGGPS will adopt the same cloud and aerosol schemes concerning cloud-aerosol-precipitation interactions (CAPI) as those used in the GEOS-5, we are evaluating the simulations of temperature, cloud water mixing ration, and cloud cover by the GEOS-5 model as a proxy to try to understand its strengths and weakness as soon as possible.





Time series of five different aerosol and total aerosol column mass



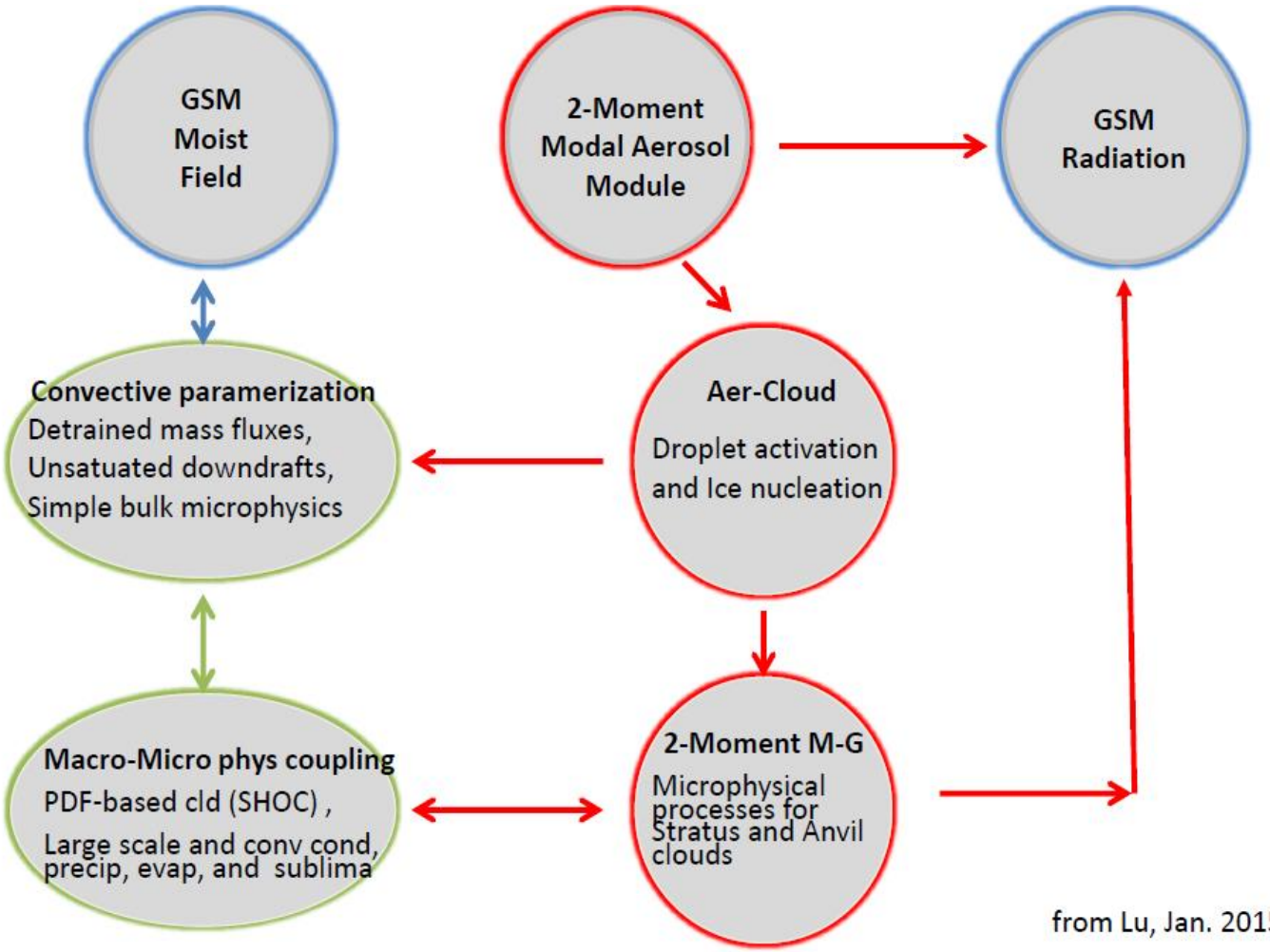
Comparison of time series of cloud water mixing ratio from GEOS-5 and GFS

Comparison of time series of low cloud cover from the GEOS-5, GFS, and the CL algorithm using MODIS data in July 2014.

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
- Coordination with other programs (CPO, R2X)

Adopting GEOS-5 Aerosol-Cloud Package



from Lu, Jan. 2015

Aerosol-Cloud-Radiation Processes Three MAPP-CTB projects

1) **PBL-Convection-Clouds** (Steven Krueger, University of Utah & Shrinivas Moorthi NCEP/EMC (2014-2017)

- Based on Assumed PDF method with a Simplified High-Order Closure (SHOC) scheme to bring in advanced TKE-based PBL scheme, and the Chikira and Sugiyama (C-S) cumulus convection scheme for deep convection.

2) **Cloud-microphysics Interacts with Aerosols and Radiation** (Sarah Lu, SUNYA and Yu-Tai Hou NCEP/EMC (2014-2017) co-funded by NGGPS

- Adapting the Aerosol-Cloud-Microphysics component from NASA GEOS-5 to the NEMS/GSM-GFS. The aerosols part contains an upgraded GOCART bulk aerosol scheme and the Modal Aerosol Module (MAM) aerosol scheme. The cloud-microphysics part is a modified Morrison-Gettleman's double-moment scheme, which is being included through an NGGPS-funded physics effort (PI Moorthi).

3) **PBL-Convection-Clouds** (Chris Bretherton, University of Washington and Jongil Han NCEP/EMC (2014-2017)

- Follow-on the project co-lead by Hualu Pan in 2010-2013. Focus on development of TKE-based Eddy-Diffusivity Mass-Flux (EDMF) scheme and the Cloud-Layers Unified by Bi-normals (CLUBB) scheme. In its extended development stage, an upgrade of cloud-microphysics based on WSM6 scheme is also tested.

Aerosol and Atmospheric Composition FY 16 Team Plan Short-term Priorities

- Development of aerosol verification package to include the following evaluation datasets
  - Composition (from surface, field measurements)
  - MODIS, VIIRS , AHI , ABI AOD
  - Particle size distribution (from AERONET measurements)
  - CALIPSO (expedited product plume height)
  - Deposition (for coupled system verification)
- Comparison of real-time biomass burning emission approaches: GBBEPx (NESDIS), QFED (GSFC), and GFAS (ECMWF)
- Gaseous (ozone) chemistry for stratosphere and troposphere (use 3d production and loss rates with diurnal cycle from retrospective CTM runs)

Aerosol and Atmospheric Composition FY 16 Team Plan Long-term Priorities

- Determine interface for inclusion of aerosol and atmospheric composition components into NGGPS
- Intercomparison of aerosol model approaches for aerosol component (GOCART, MAM)
- Gaseous (ozone) chemistry for stratosphere and troposphere
  - consider available approaches of varying complexity (climatological production and loss rates, reduced mechanism, full chemistry) e.g RAQMS-reduced, AM3, MOZART, RAQMS, GMI
  - recommend several approaches as potential candidates for evaluation
  - evaluate impact on the meteorological forecast skill

Aerosol and Atmospheric Composition FY 16 Team Plan Long-term Priorities

- Assimilation of AOD data from additional satellites (combined MODIS/VIIRS, AHI, ABI)
- Assimilation of ozone/precursor data from OMI, OMPS (nadir and limb), CRIS, IASI and additional satellite data
- Plume injection height for fire emissions (leverage FIREX, JPSS fire and smoke initiative, NASA NRL efforts; validation datasets CALIPSO, MISR)
- Forecast impact assessment and coordination with Physics and Data Assimilation Teams:
  - Data assimilation of meteorological variables
  - Aerosol and ozone radiative impacts
  - Aerosol-microphysics interactions

NGGPS Aerosol and Atmospheric Composition Three Main Points

- One Major Accomplishment:
  - Included Modal Aerosol Model (MAM-7) and two moment Morrison and Gettleman microphysics into NEMS GSM and tested separately
- One priority focus effort for FY16:
  - Include aerosol radiative effects in GSM
- One most important issue or coordination need:
  - Close coordination with physics (radiation and microphysics), data assimilation and dynamical core (tracer transport: conservation, computing needs)

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

The Modal Aerosol Module (MAM)

A modal aerosol module (MAM, Liu et al., 2012) has been developed for the Community Atmosphere Model version 5 (CAM5), the atmospheric component of the Community Earth System Model version 1 (CESM1).

MAM is capable of simulating the aerosol size distribution and both internal and external mixing between aerosol components, treating numerous complicated aerosol processes and aerosol physical, chemical and optical properties in a physically-based manner.

Aerosol components

- Sulfate
- Ammonium
- Black carbon
- Dust
- Sea salt
- Primary organic
- Secondary organic

Aerosol modes

- Aitken
- Accumulation
- Primary carbon
- Fine sea-salt
- Fine dust
- Coarse sea salt
- Coarse dust

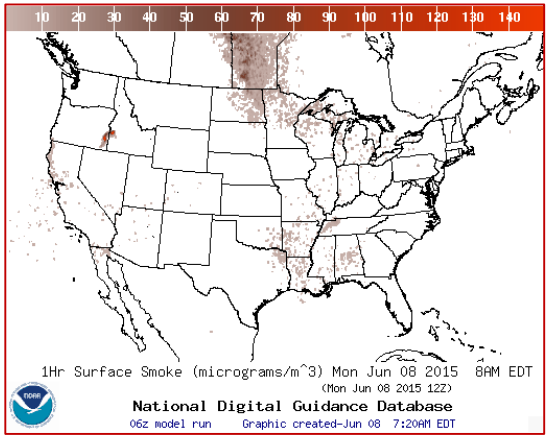
Aerosol microphysics

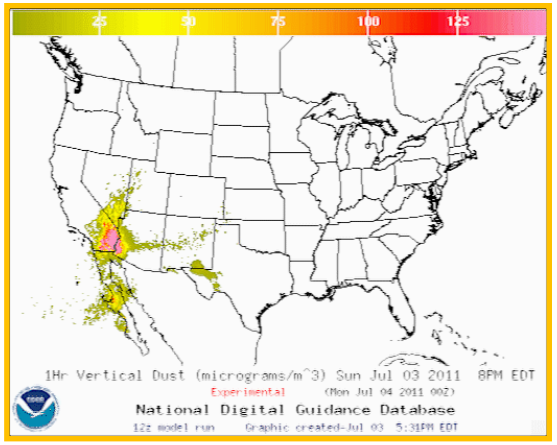
- Nucleation (H2SO4-NH3-H2O and BL nucleation)
- Coagulation (intra- and intermodal of AIT, ACC, PCM)
- Condensation(H2SO4, NH3 and SOA(g))
- Gas-aerosol exchange

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