Development of NCEP Global Aerosol Forecasting and Assimilation System: An overview and preliminary modeling results

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1.Introduction

NOAA National Centers for Environmental Prediction (NCEP) is constructing National Environmental Modeling System (NEMS) as its next generation operation system. Earth System Modeling Framework (ESMF) is used in NEMS in order to unify and streamline modeling efforts within NCEP and to enhance the ability to share packages developed elsewhere.

Currently the Global Forecast System (GFS) and the Nonhydrostatic Multiscale Model (NMM-B) have been placed under the NEMS framework. Work is under way to bring in flow-following Icosahedral model (FIM), developed by NOAA Earth System Research Laboratory (ESRL), to the ESMF-based NEMS.

This paper provides a brief overview of NEMS and the efforts to implement NASA aerosol model (GOCART) to NEMS. The adoption of GOCART will enable an aerosol forecasting capability within the NEMS. Note this presentation is focused on the technical aspects of model developments, and the scientific importance and model applications are discussed elsewhere.

2.National Environmental Modeling System Architecture

The ESMF is open source software for building various Earth science applications, such as weather prediction, climate, and data assimilation. It is based on principles of component-based software engineering. The component within an ESMF application may be a physical domain such as the atmosphere or a specific progress/function such as the I/O system. The software that connects the grid components is called a coupler. Couplers take the outputs (export state) from one component and transform them into the inputs (import state) needed to run another component.

Figure 1 shows the architecture of NEMS atmosphere. Dynamic, physics, and GOCART (discussed in the sections followed) grid components run on the same grid in the same decomposition. Besides model dynamics and physics, planned NEMS capabilities include configuration control, concurrent ensemble execution, in-core updating for analysis increments and boundary conditions, data assimilation, post-processor and product generator, and standard operational verification.

3. GOCART Aerosol Module

The Goddard Chemistry Aerosol Radiation and Transport (GOCART) model was developed to simulate atmospheric aerosols (including sulfate, black carbon (BC), organic carbon (OC), dust, and sea-salt), CO, and sulfur gases [Chin et al., 2000, 2002, 2004; Ginoux et al., 2001]. Originally GOCART was developed as an off-line Constituent Transport Model (CTM), driven by assimilated meteorological fields from the Goddard Earth Observing System Data Assimilation System (GEOS DAS). Aerosol sources include SO_2, dimethyl sulfide (DMS), dust, BC, OC and sea-salt emissions from industrial, biomass burning, volcanoes, deserts, ocean, and biogenic sources. Aerosol chemistry uses prescribed OH, H_2O_2, and NO_3 fields for DMS and SO_2 oxidations. Aerosol sinks include wet removal (scavenging and rainout) and dry deposition (gravitational sedimentation and surface uptake).

An ESMF compliant on-line aerosol modeling capability derived from GOCART has recently been developed. GOCART parameterizations (excluding transport processes) have been modularized in a way consistent with the ESMF, and have been implemented within GMAO's GEOS-5 earth system model. The resulting aerosol module, called the GOCART Grid Component (Figure 2), contains aerosol source, sink, and transformation components and is fairly independent from the host atmospheric models.

4.The NEMS/GFS-GOCART system

The NCEP is developing a global aerosol forecasting capability in NEMS by incorporating prognostic aerosols (the NASA's GOCART model) in NEMS GFS core. Extensive code developments have been made. This includes:

- The most recent GOCART source code and relevant utilities (e.g., libraries) have been built at NCEP high-performance computers.

- Emission files for dust, sea salt, OC/BC and sulfate grid components have been mapped to NEMS/GFS native grids and vertical layers
- Software engineering work involves ESMF superstructure (e.g., coupler, import/export states) as well as infrastructure (e.g., grid and data class) have been made in GFS core.
- NEMS I/O module modified for tracer generalization
- The ESMF coupler components that link the GOCART grid component with NEMS/GFS physics grid component have been developed
- NEMS GFS radiation module has been modified to include the radiation-aerosol feedback (direct effect only) for GOCART aerosols.

The phys-to-chem and chem.-to-phys coupler components can be revised to incorporate the on-going and future code changes in NEMS/GFS at NOAA/NCEP and/or GOCART at NASA/GSFC. The linkage through coupler component allows concurrent code development at both ends.

Figure 3 shows the mixing ratio of dust aerosols after 45-day T126 L64 NEMS/GFS-GOCART integration, initialized from 2009-07-24 00Z GDAS analysis (for meteorology) and 1.e-9 fixed values (for dust aerosols). The preliminary results are encouraging, as the model integration shows reasonable and realistic dust distribution. However, it also reveals the undesirable feature to transport aerosols (with sparse distributions) in the spectral domain.

5.Conclusions

This paper describes the technical aspects of NCEP's aerosol modeling developments. The GOCART-implementation efforts lead to scientific advances and infrastructure upgrades in NEMS. On the other hand, the chemistry modeling capability provides an opportunity to examine transport characteristics, moisture processes, and physical representation (such as soil moisture from land surface model) in NEMS/GFS.

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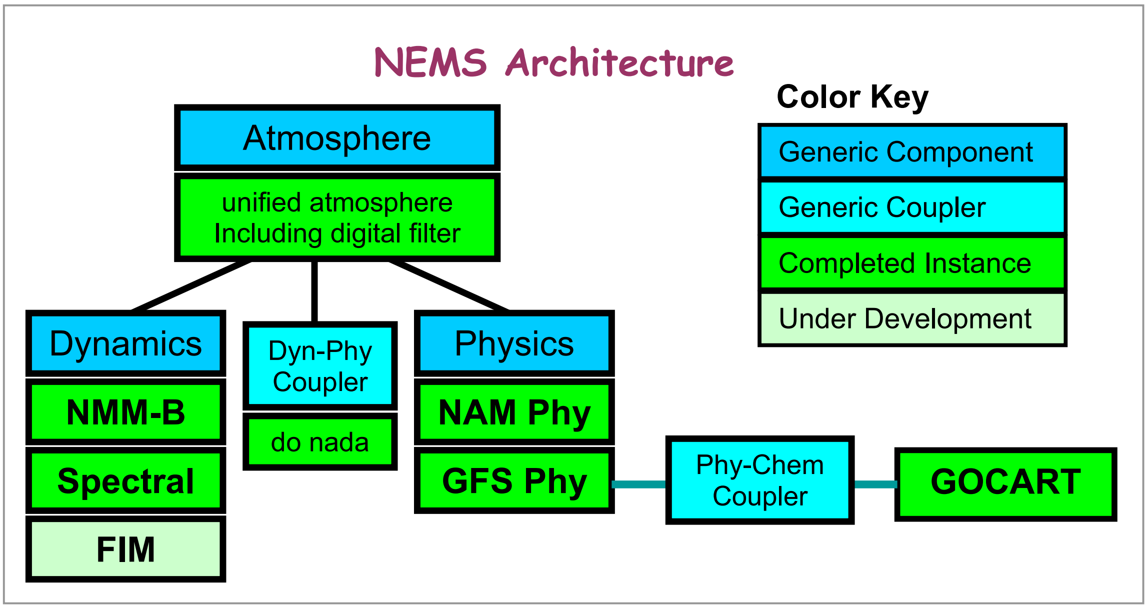

Figure 1. The National Environmental Modeling System architecture.

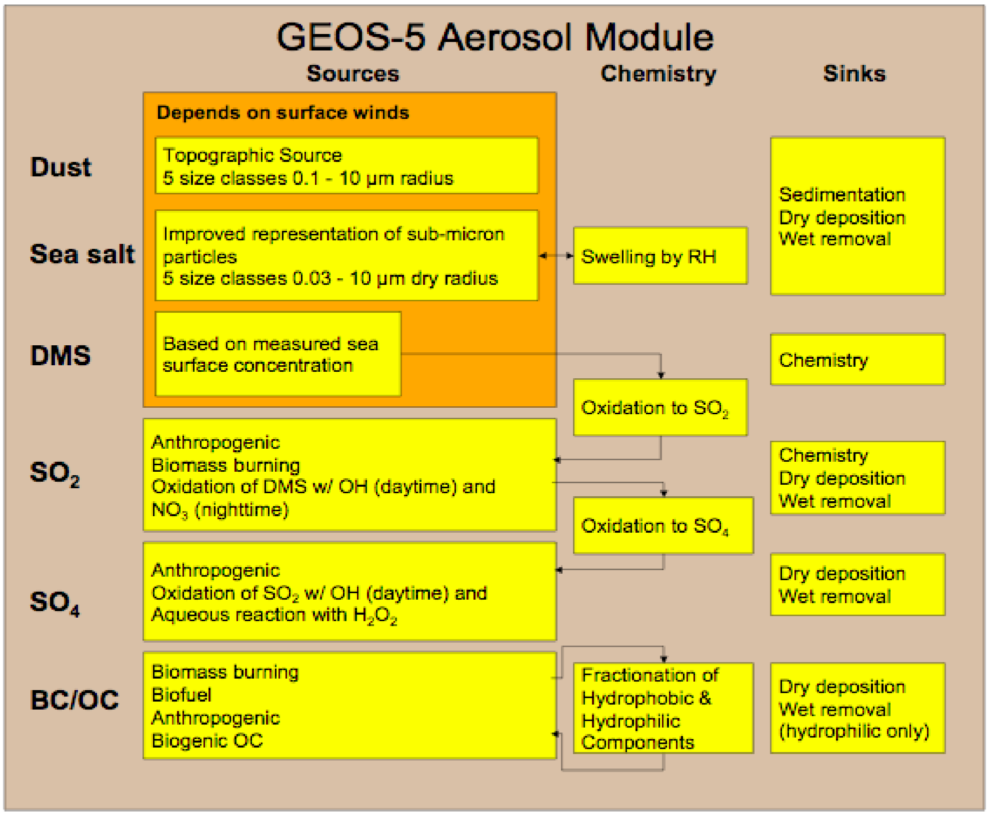

Figure 2. NASA GOCART Grid Component.

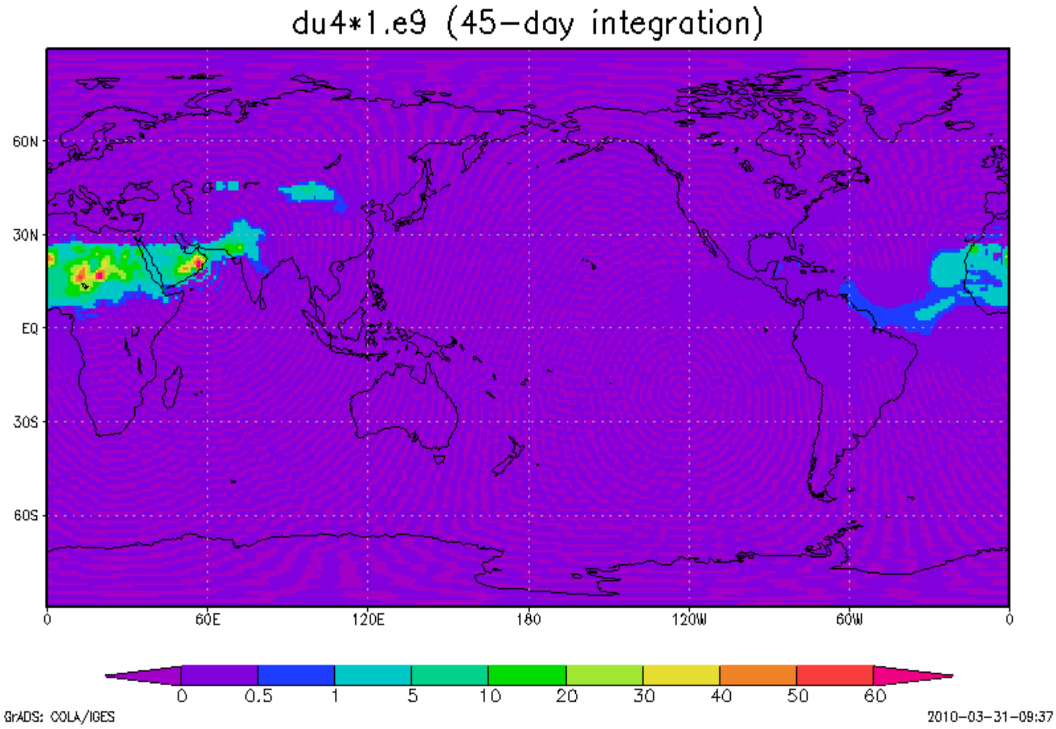

Figure 3. Dust mixing ratios (multiplied by 1.e9, in kg/kg) after 45-day integration.