Strategic Implementation Plan (SIP) for a Community-based Unified Forecast System

Aerosols and Atmospheric Composition *Working Group*

Presented by

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Coordination Meeting for the Unified Forecast System

Strategic Implementation Plan (SIP) Annual Update

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Aerosols and Atmospheric Composition WG Membership

- Gregory Carmichael (U. Iowa)
- Arlindo DaSilva (NASA/GSFC)**
- David Edwards (NCAR)
- Gregory Frost (NOAA/CSD)**
- Paul Ginoux (NOAA/GFDL)
- Georg Grell (NOAA/GSD)
- Larry Horowitz (NOAA/GFDL)
- Yu-Tai Hou (NWS/NCEP)
- Ed Hyer (Navy/NRL)
- Sarah Lu (SUNY-Albany)**
- Craig Long (NWS/NCEP)
- Stuart McKeen (NOAA/CSD)
- Jeff McQueen (NOAA/NCEP)**

- Raffaele Montuoro (NOAA/GSD)
- Rohit Mathur (EPA)
- Mariusz Pagowski (NOAA/GSD)
- Steven Pawson (NASA/GSFC)
- Brad Pierce (UW-Madison/SSEC)
- Ivanka Stajner (NOAA/NCEP) **
- Ariel Stein (NOAA/ARL)
- Rick Saylor, Pius Lee, Daniel Tong, Barry Baker (NOAA/ARL)
- Jun Wang (NOAA/NCEP)
- Li Zhang (NOAA/GSD)

*Co-Chair ***

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- **10.1 Model**
  - FV3GFS/GOCART
    - NUOPC cap included in GSD/GOCART in FV3 framework
    - Detailed testing, improvements to address too strong vertical transport
    - Updated to NASA community parameterizations (sea-salt, sulfate, ocean emissions) and background chemistry fields
    - Tracer transport in physics
    - Model evaluation with ATom-1 field experiment, MODIS, VIIRS, AERONET data using METplus and MONET packages
  - NUOPC cap for CMAQ chemistry developed and synchronized with EPA
  - Implementing a refined stratospheric O3 parameterization in GFSv15.1
  - Implemented NAQFC air quality model upgrade with unified bias correction code for PM2.5 and ozone introducing a new bias-corrected ozone product
  - Implementing the ability to drive dispersion model with HRRR meteorology

Atmospheric Composition WG Project Milestone Accomplishments

- **10.2 Data Assimilation**
  - Implementing OMPS profile and total column ozone assimilation in GFSv15.1
  - Developed JEDI operator for AOD and interface to 3D-EnVar for FV3GFS-Chem
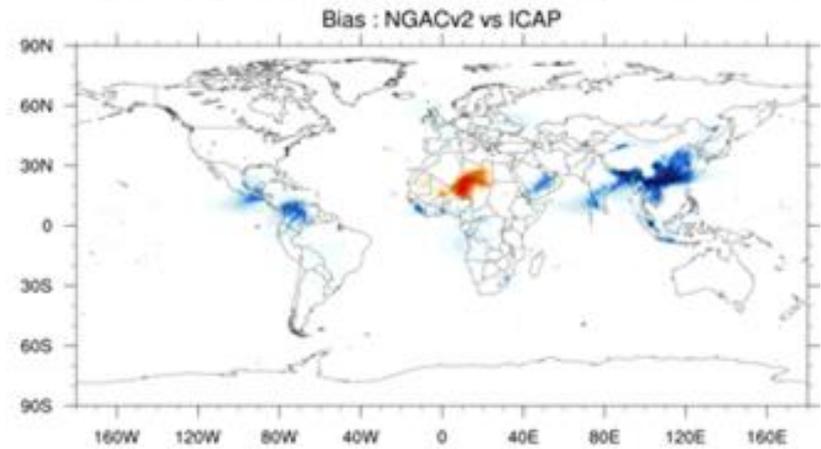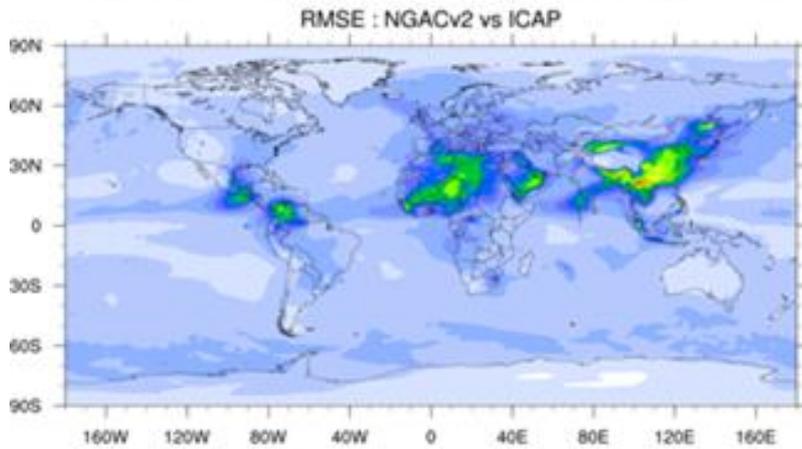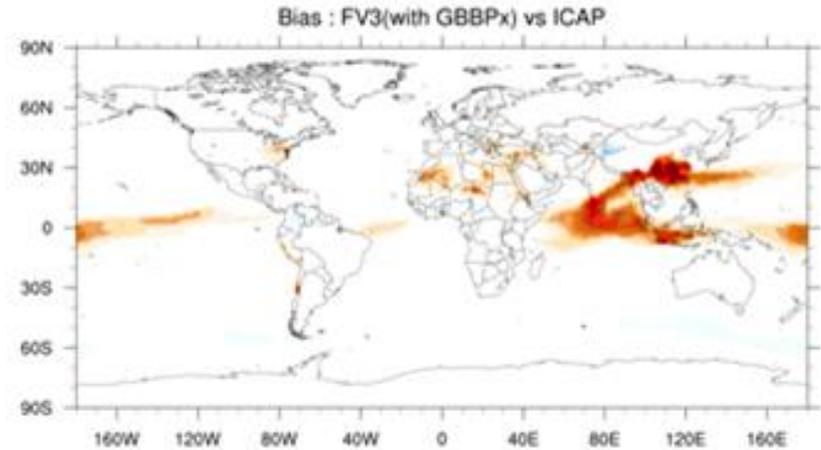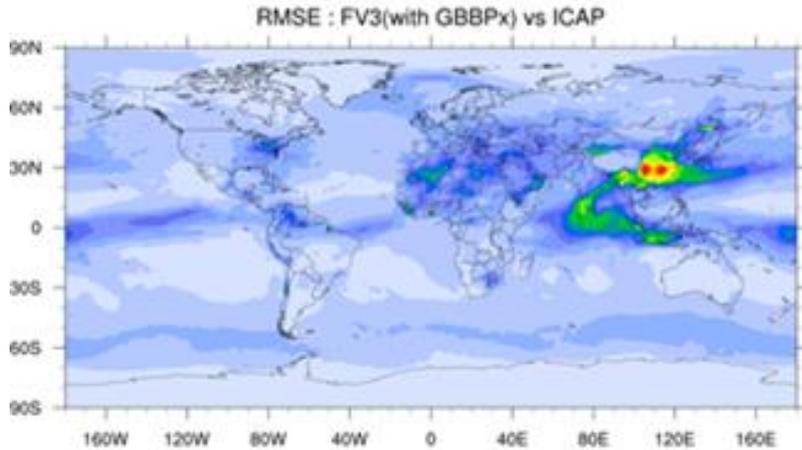 - Developed VIIRS/MODIS AOD DA using GSI-ENKF for FV3GFS-Chem

- **10.3 Emissions**
  - Incorporated NESDIS GBBEPx smoke in FV3GFS-Chem
  - Incorporated ARL Fengsha dust emissions in FV3GFS-Chem
  - Developed complex chemistry emissions input for FV3GFS based on CEDS and/or HTAP inventories

FV3GFS-Chem Evaluation
April 2019 AOD difference vs ICAP

Total AOD at 550 nm differences against the International Cooperative for Aerosol Prediction (ICAP) operational aerosol multi-model ensemble for 25 March to 30 April, 2019.

Project Issues

- **Most issues require cross-working group coordination**
  - Vertical transport issue impacting other planned tasks (investigating contributions from interactions with physics and dynamics)
  - Closer collaboration needed with the DA WG including Aerosol DA plan
  - Consistency of radiative transfer in CRTM and atmospheric model is needed
  - Removing dependency on physics embedded in chemistry suite to couple with GFS physics (eg: PBL: ACM2 for CMAQ)
  - Computing resources for GOCART (3X) and more complex chemistry
  - Plan for reconciling GOCART versions/repository management
  - Verification of Atmospheric Composition
  - Coordination of dispersion capability for UFS
- **Enhancing wider community involvement and coordination on atmospheric composition for UFS**
 - Common infrastructure

The Community Multiscale Air Quality (CMAQ) Modeling System

- **Comprehensive Eulerian Chemical Transport Model**
  - Widely used across the world for air quality assessments, forecasting & research

- **Multiscale**: Hemispheric ☐ Continental ☐ Regional ☐ Local

- **Multi-pollutant & multi-phase**:

  - Ozone Photochemistry
    - NO_x + VOC (biogenic & anthropogenic) ☐ O_3

  - Particulate Matter (PM)
    - Inorganic chemistry & thermodynamics ☐ SO_4^{2-}, NO_3^-, NH_4^+, Na^+, Cl^-, crustals (Fe, Mn, Si, etc)
    - Organic aerosol ☐ primary, anthropogenic/biogenic secondary
    - Geogenic aerosol ☐ wind-blown and fugitive dust, sea salt

  - Atmospheric Deposition: Acidification & Eutrophication
    - Aqueous chemistry, wet & dry deposition

  - Air Toxics
    - Benzene, Formaldehyde, Mercury, etc.

- **Online/Offline configurations** with Atmospheric Dynamics Models
    - WRF-CMAQ 2-way coupled model with aerosol radiative effects
    - Prototype MPAS-CMAQ currently under testing

Simulated Trends (1990-2010) in Ambient $PM_{2.5}$
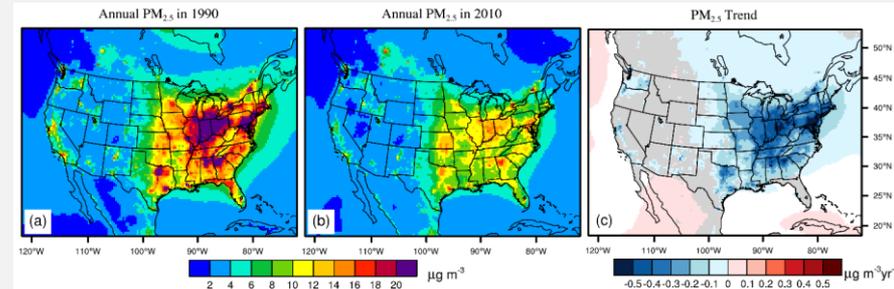
Model updates are periodically released to worldwide users
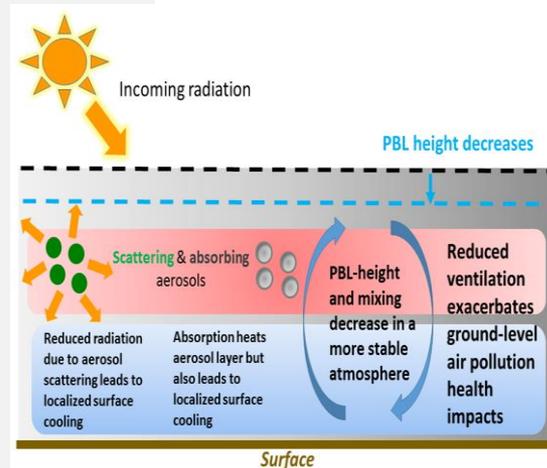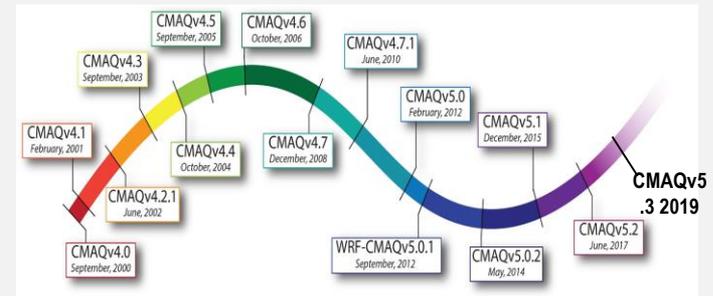
Process-chain interactions between atmospheric chemistry & dynamics are important for representing weather, AQ and health & climate impact assessments

NCAR atmospheric composition modeling

- Currently, global-scale research uses the CAM-chem or WACCM atmospheric models with chemistry as stand-alone or coupled components of the CESM-2 Community Earth System Model

- Regional-scale research primarily uses WRF-chem

- An active new project called MUSICA (Multi-scale modeling infrastructure for Chemistry and Aerosols) will consolidate chemistry and aerosol modules in a single package that will be atmospheric-model agnostic and independent of the particular dynamical core (MPAS or SE)

- MUSICA focuses on enabling a computationally efficient and comprehensive chemistry and aerosol description for whole-atmosphere global modeling, with regional refinement to resolve chemistry at emission and exposure relevant scales

- MUSICA will provide the chemistry component of the NCAR Earth system modeling initiative to enable full feedbacks between the atmosphere, ocean and land

- Current atmospheric composition data assimilation (DA) focuses primarily on DART (EnKF) for integration with CESM global modeling, and WRFDA (4Dvar) for regional scale aerosols

- Future atmospheric composition DA will integrate with MUSICA with the goal of Earth-system cross-scale coupled capability using ensemble, variational and hybrid approaches as appropriate

- Collaborations with other community DA projects such as JEDI are being explored

ACOM   NCAR   NSF

GMAO Capabilities, Using the FV3-Based GEOS System

Mature options:

- GOCART aerosol modules: aerosol assimilation and prediction; feedback (direct effects)

- Organization of emissions using HEMCO, combining inventory, satellite-constrained, and interactive options

- Gaseous chemistry – transition to GEOS-Chem mechanism; daily production using "GEOS-CF"

- Multi-variate GSI-based constituent assimilation, applied to carbon cycle and stratospheric composition

Emerging options:

- Predictive emissions modules, especially for biomass burning

- Simplified (and hence cost-viable) gaseous chemistry for full air quality prediction

- Multi-variate assimilation to include reactive tropospheric chemistry with emissions constraints

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Surface ozone [ppbv]

GEOS-FP surface ozone "analysis" in October 2017
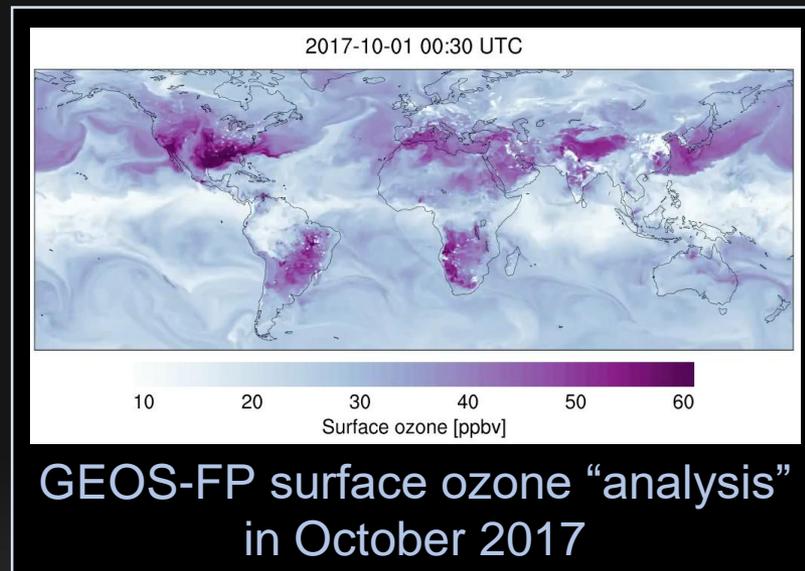
Atmospheric Composition WG near term tasks

- **10.1 Model:**
  - Inclusion of aerosol component in GEFSv12
  - Work to identify and resolve vertical transport issues
  - Reconciling scavenging schemes with NASA version
  - Evaluate and tune ARL FENGSHA dust scheme
  - Air Quality CMAQ model extended to 72h, driven by GFSv15 meteorology with bias correction post-processing

- **10.2 Data Assimilation**
  - Update CRTM for GOCART and CMAQ aerosols and unify with UPP
  - Testing 3D-Var, ENKF for AOD DA. Migrating towards JEDI

- **10.3 Emissions**
  - Test plume rise with NESDIS GBBEPx FRP
  - Test anthropogenic emissions for more complex chemistry

- **Infrastructure**
  - FV3GFS-Chem code optimization

- **Verification (METplus/MONET)**
  - Include field experiment & aerosol AOD data (VIIRS, MODIS, AERONET, GOES)
  - Evaluation of FV3GFS/GOCART experiments with ATom-1 field experiment

Atmospheric Composition WG Team Coordination and Dependencies

- <u>System Architecture WG:</u> NUOPC cap couplers for GOCART and CMAQ
- <u>Verification WG:</u> MET based verification started; need MONET compatibility, evaluation protocol and test plan for adoption of new capabilities for the full system and for AAC component
- <u>Post-processing WG:</u> Extension of NCEP post for atmospheric composition parameters and meteorological variables for offline models

- <u>DA WG:</u>
  - Coordinate a plan for aerosol DA development/T2O
  - GSI, JEDI coordination on coupling atmospheric composition with meteorological variables; *CRTM and UPP coordination*
- <u>Physics, LSM WG:</u>
  - Ensure physics consistency with chemistry modules
  - Include tracers in transport, deposition and interactions with physics
  - Emissions from the surface - coupling with land and physics