Global aerosol forecasting and data assimilation in GFS/GSI

Overview and Progresses

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SPARC Data Assimilation and IPY Workshop, Sept 4-7, 2007

The long-term goal

Where we stands now

Ongoing and near-future activities

Global model with explicit ozone-aerosol chemistry

Parameterized ozone chemistry and climatological aerosol scheme

Incorporate prognostic aerosols in global model

Radiance assimilation providing meteorological and chemical analyses

SBUV/2 v6 ozone assimilation; background aerosols assumed

Assimilation of multiple ozone products; aerosol module added to radiative transfer model

Provide meteorological and chemical LBCs for the regional system

Improved chemical lateral BCs are needed for regional AQ application

Off-line and Lagrangian chemistry modeling

Only the aerosol-related activities will be discussed here.

For ozone assimilation, please see the poster "*Assimilation of multiple ozone products into the NCEP Operational Forecast Model*" by Craig Long and Shuntai Zhou (NOAA/CPC)

NCEP global aerosol forecasting and data assimilation

- **OVERVIEW**
  - Create an integrated operational system for forecasting and monitoring the atmospheric dynamics and chemistry

- **OBJECTIVES**
  - Generate an optimal (accurate and affordable) description of the global distribution of atmospheric aerosols
  - Provide improved air-chemistry forecasts, through improved use of satellite data
  - Respond to the WMO RSMC request for global dust predictions and to NWS/HQ and EPA request for improved aerosol LBCs for CMAQ

NCEP global aerosol forecasting and data assimilation (-continued)

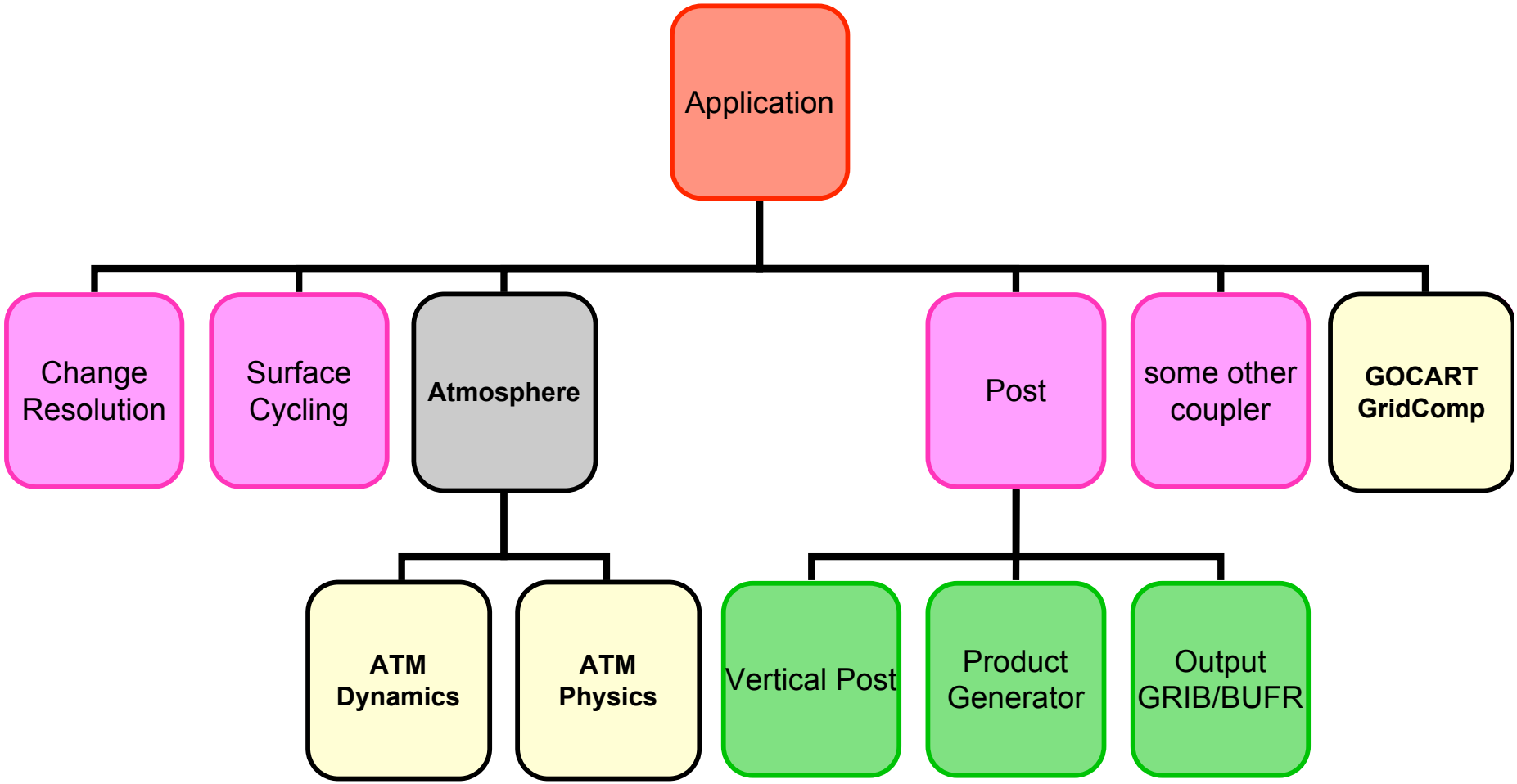
- **APPROACH**
  - Incorporate prognostic aerosols (NASA GOCART) in NCEP Global Forecast System (GFS)
    - Off-line non-interactive
    - In-line interactive
  - Assimilate aerosol measurements (product and then radiance) in NCEP Gridpoint Statistical Interpolation system (GSI)
  - Leverage common modeling framework and shared software development
    - Earth Systems Modeling Framework **(ESMF)**
    - Joint Center for Satellite Data Assimilation **(JCSDA)**

Global Forecast System (GFS)

Global spectrum model for operational medium range forecasts

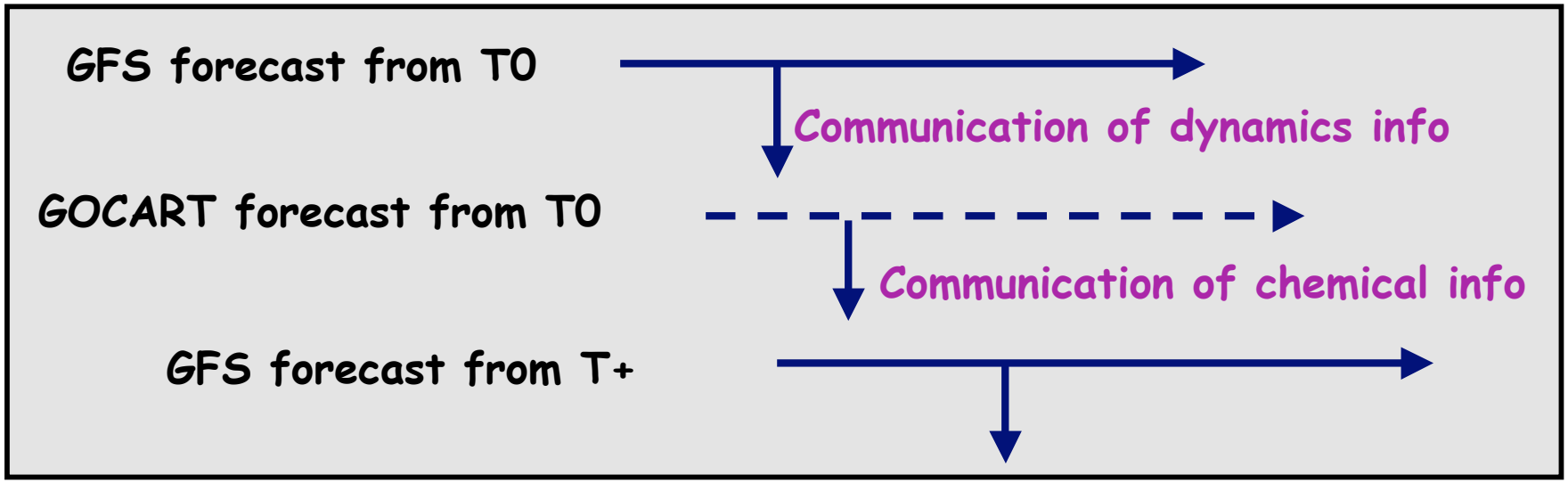
- **RESOLUTION**
  - T382 horizontal resolution (~ 37 km)
  - 64 vertical levels (from surface to 0.2 mb)
- **MODEL PHYSICS AND DYNAMICS**
  - Vertical coordinate changed from sigma to hybrid sigma-pressure
  - Non-local vertical diffusion
  - Simplified Arakawa-Schubert convection scheme
  - MD Chou radiation scheme
  - Explicit cloud microphysics
  - Noah LSM (4 soil layers: 10, 40, 100, 200 cm depth)
- **INITIAL CONDITIONS** (both atmosphere and land states)
  - NCEP Global Data Assimilation System (GDAS)

Earth System Modeling Framework (ESMF) Component Framework

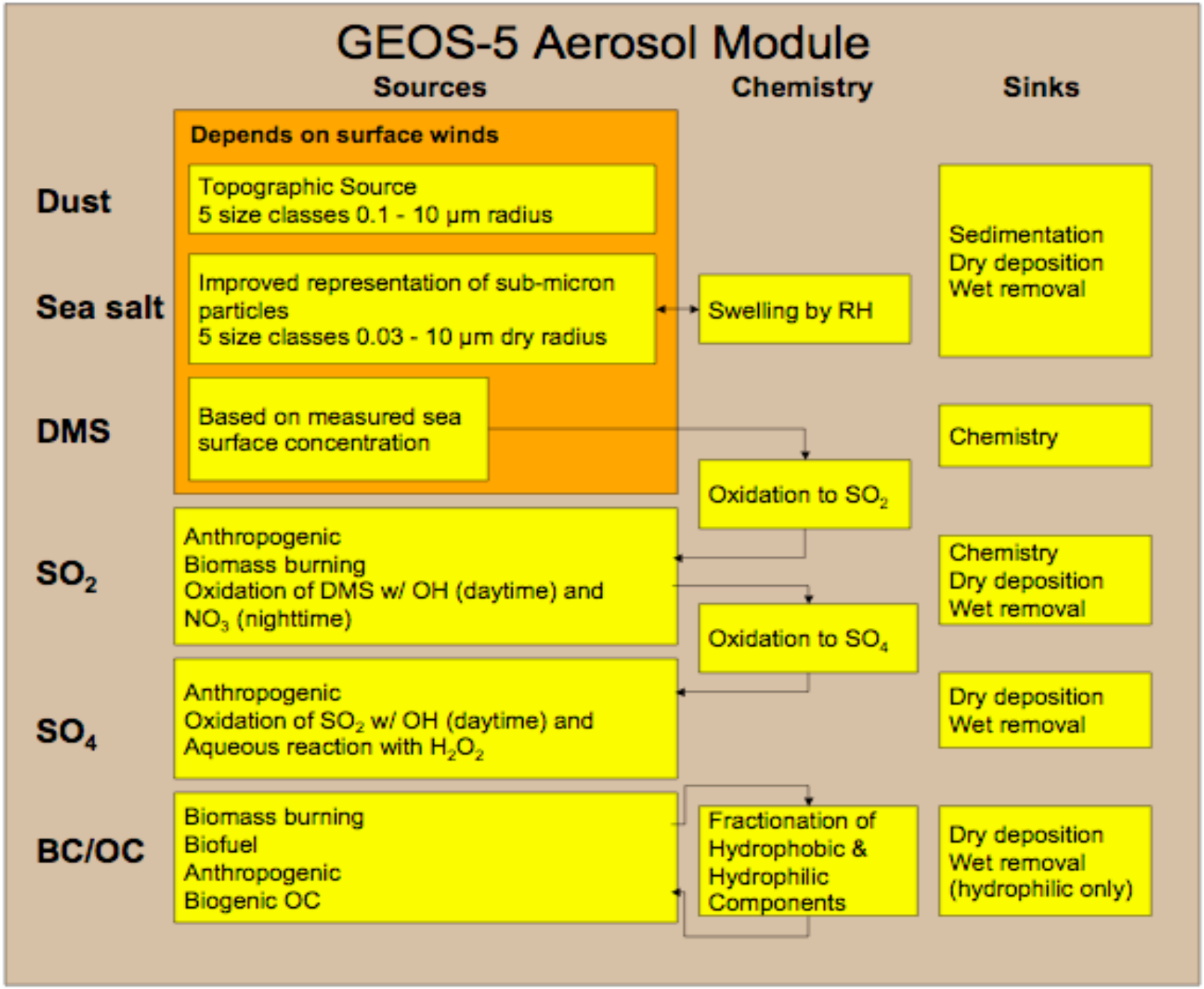


Mark Iredell (NCEP)

Prototype aerosol forecasting system



- Gridded GFS (under development):
  - Determine aerosol transport processes (advection, boundary layer turbulent mixing and convective transport)
  - Export dynamical info (surface wind, RH, scavenging coefficients, canopy conductance…etc) to GOCART grid component
- GOCART grid component:
  - Determine aerosol source, sink, transformation
  - Export mixing ratios of aerosol species to gridded GFS



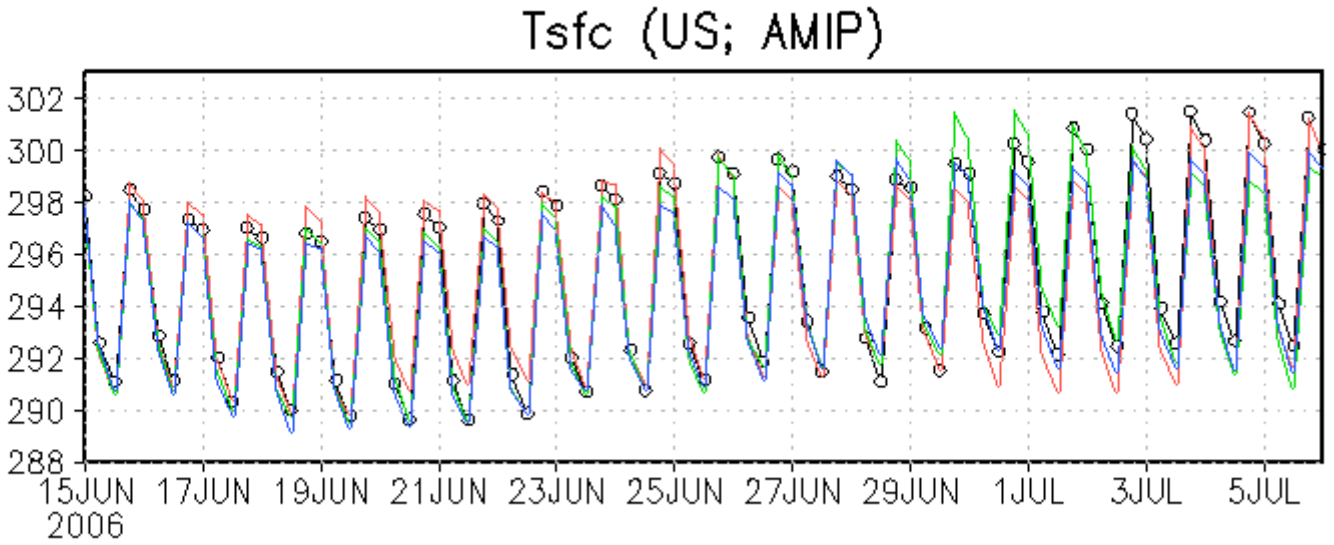
Collaborator: Mian Chin, Code 613.3

Arlindo da Silva (GMAO)

GFS Sensitivity Study

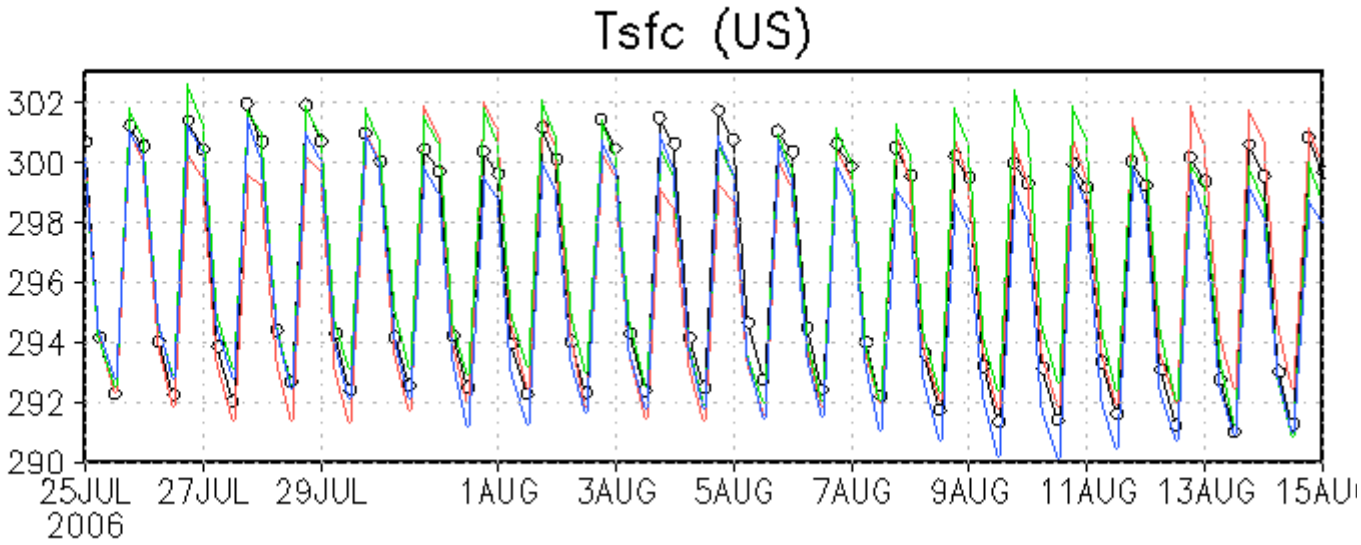
- T126 L64, hybrid coordinate
- AMIP experiment
  - Initialized from 2006-06-01 00Z GDAS analysis
  - 11-week integration (edate = 2006-08-15)
- MRF experiment
  - Initialized from 00Z analysis for the 2006-06 period
  - 5-day forecasts
- Aerosol scheme configuration
  - CTRL: OPAC climatological scheme
  - CLIM: GOCART climatological scheme
  - ANAL: Diagnostic aerosols updated daily
  - PROG: Aerosols as passive tracers updated every 6-hr
- The CLIM run uses GEOS3-GOCART monthly climatology (M. Chin); the ANAL and PROG runs use GEOS4-GOCART 6-hr aerosol analysis (A. da Silva).
- A fully cycled GDAS experiment will be conducted to assess the impact of aerosols on GFS forecasts

Time series of Tsfc



Ctrl, Clim, Anal, Prog

Wk 3-5

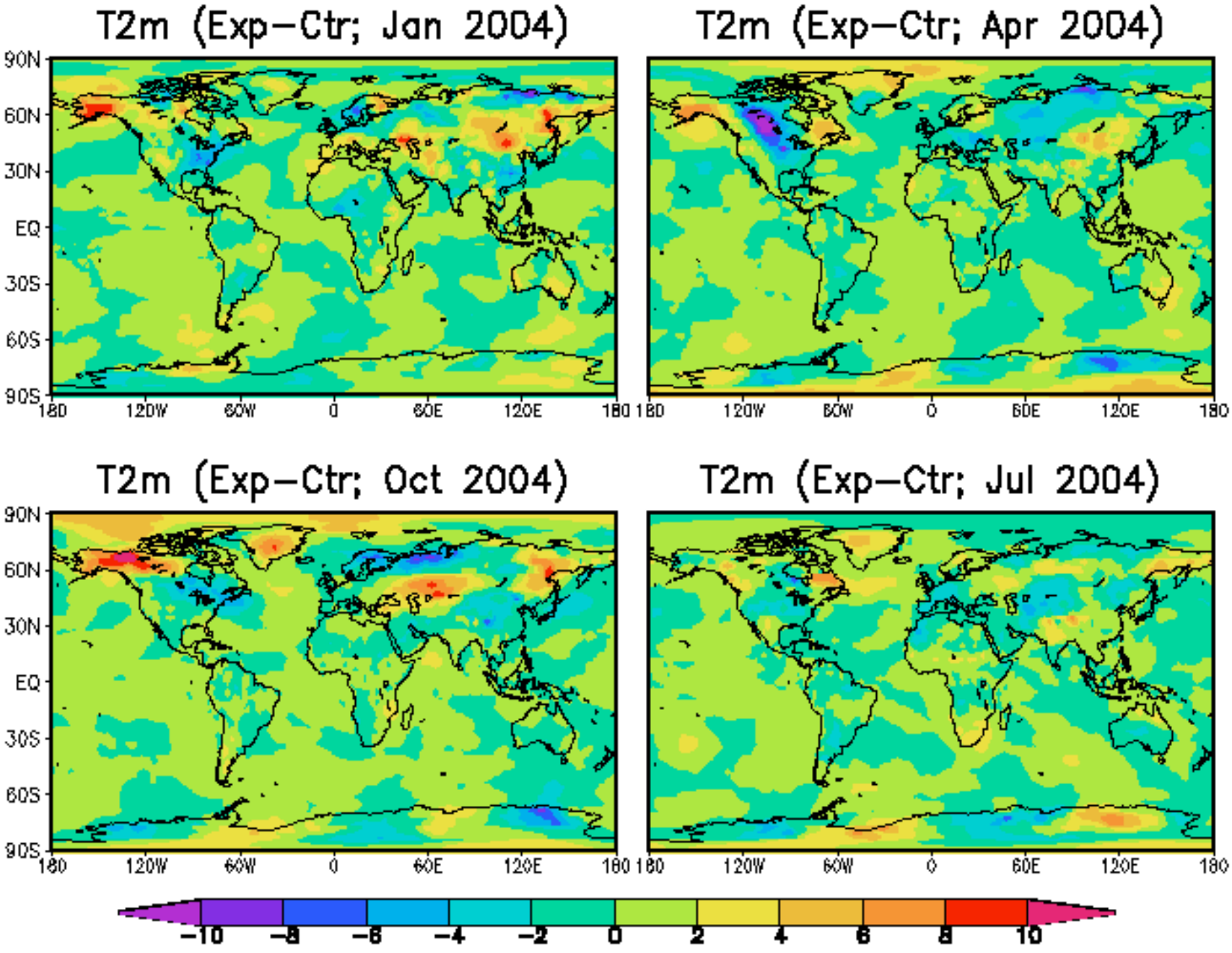


Wk 9-11

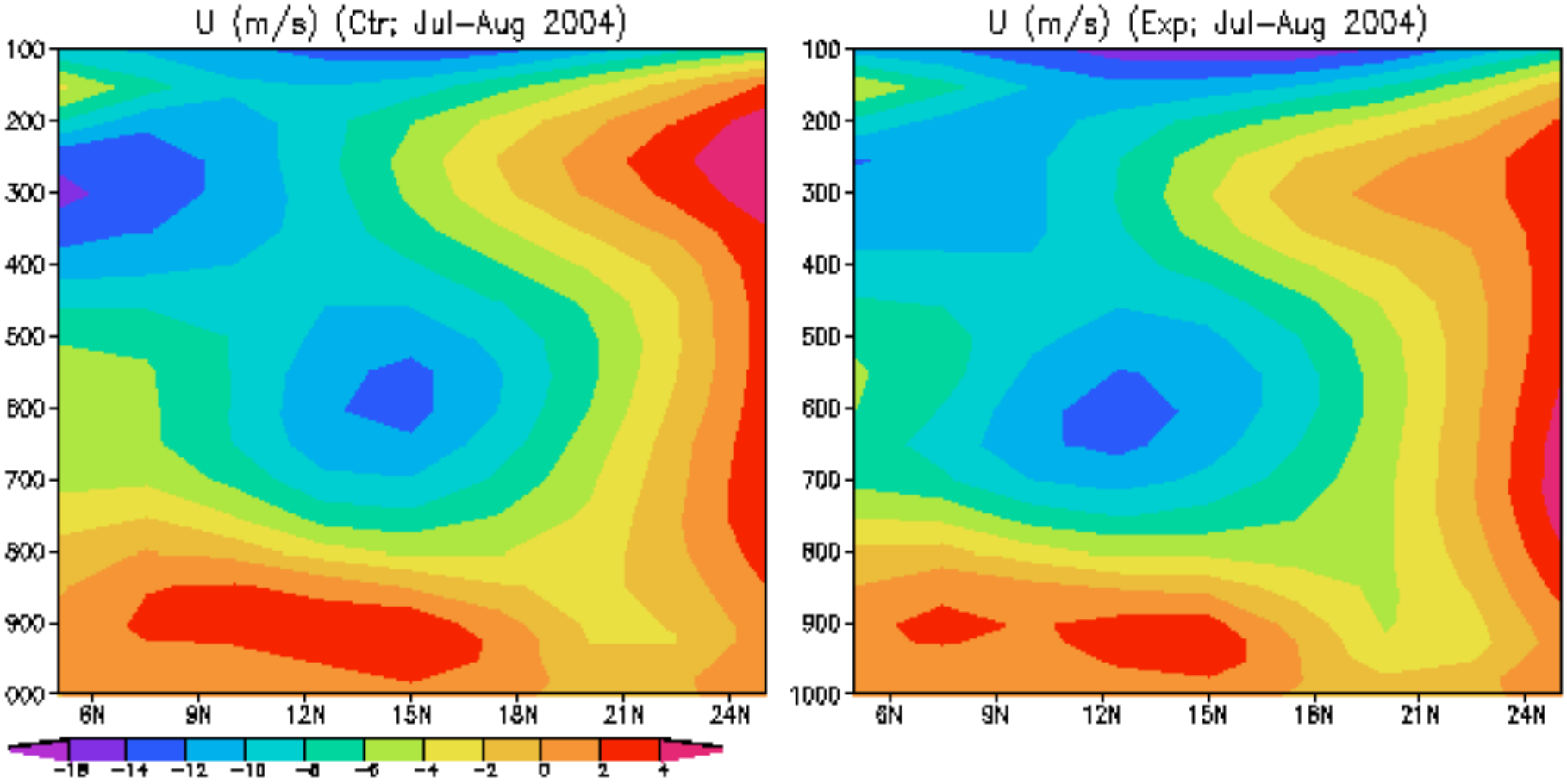
Preliminary CFS results

- **NCEP Climate Forecast System (CFS)**
  - AGCM : GFS
  - Ocean model: GFDL MOM3
- **CFS experiments**
  - 3-year runs (from 2002/01 to 2004/12)
  - Resolution: T126 L64
  - Output every 6 hr
  - Two runs:
    - Ctr: OPAC-based aerosol climatology (5° x 5°)
    - Exp: GOCART aerosol fields (2.5° x 2°; 30 lvl)
- The global impact and regional influence due to different background aerosol loading are examined.

T2m Difference



U-wind Cross Section at 10W



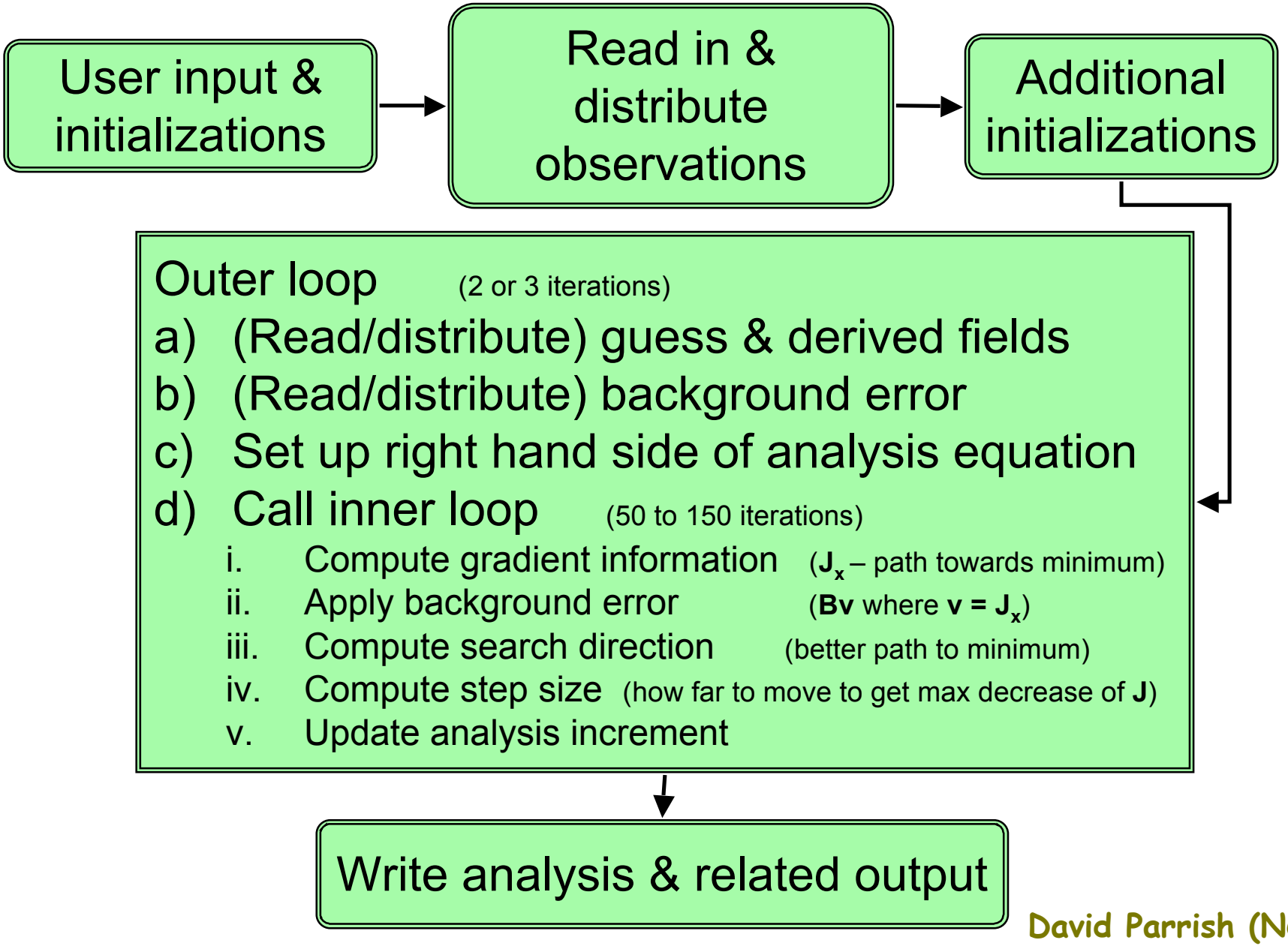
The intensity and location of African Easterly Jet are affected by background aerosol loading (via direct radiative effect)

Gridpoint Statistical Interpolation (GSI)

Global/regional analysis system for operational weather forecasts

- **NCEP 3DVAR assimilation system**
  - Implemented with WRF-NMM into the NAM system in June, 2006
  - Implemented for replacement of SSI in the GFS system in May, 2007
- **SCIENTIFIC ADVANCES**
  - Grid point definition of background errors
  - Inclusion of new types of data (e.g., AIRS radiance, COSMIC GPS)
  - Advanced data assimilation techniques (e.g., improved balance constraints)
  - New analysis variables (e.g., SST)
- **CODE DEVELOPMENT**
  - GMAO collaboration through JCSDA
  - Evolution to ESMF

GSI Code - General Flow

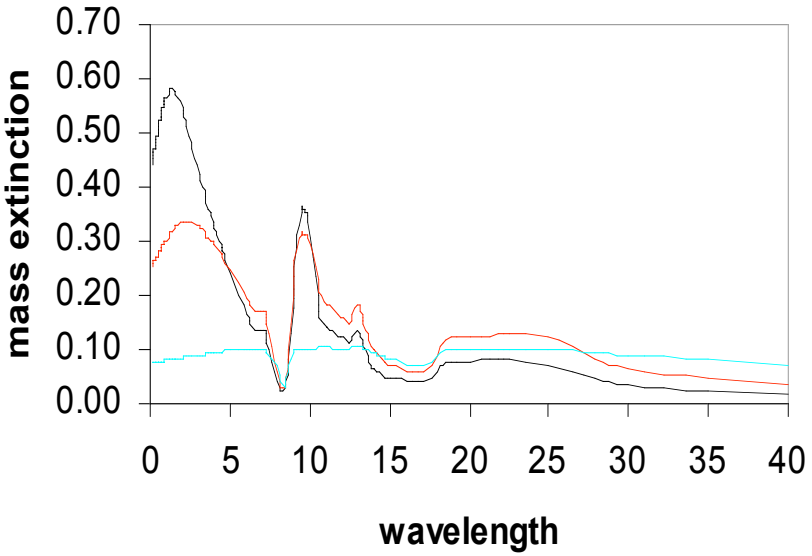


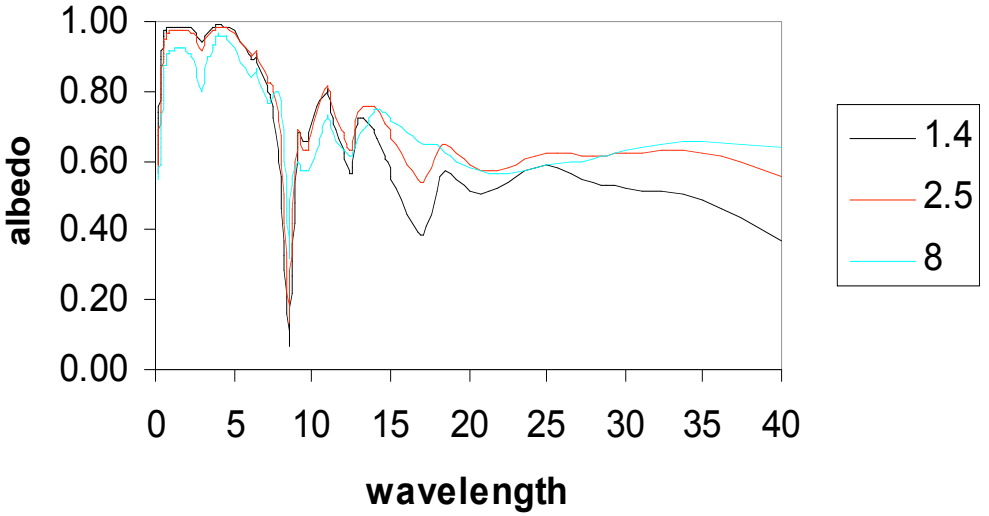
David Parrish (NCEP)

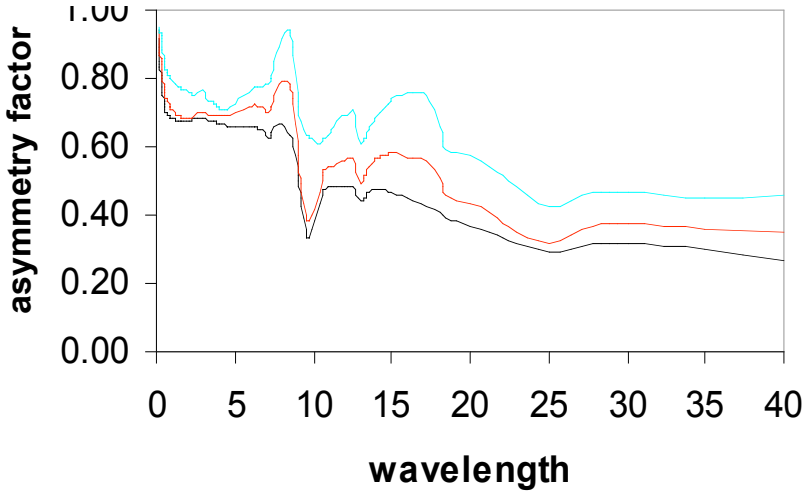
Community Radiative Transfer Model (CRTM)

- The Community Radiative Transfer Model is developed via joint effort of JCSDA (from contributions from NOAA, NASA, and DOD), research institutions and private companies.
- The CRTM is composed of advanced surface emission and reflection models, fast gaseous absorption models, aerosol and cloud optical modules.
- It is used in GSI for global and regional data assimilation as well as applied in GOES-R studies.
- The aerosol module contains the mass extinction, scattering coefficients and detailed phase function for dust, sea salt, organic carbon, black carbon, and sulfate with various effective particle sizes. It also includes a function computing the effective particles size from the ambient humidity.
- The CRTM fully supports aerosol radiance assimilation for the GFS-GOCART system.

Aerosol Optical Properties -- Dust aerosols

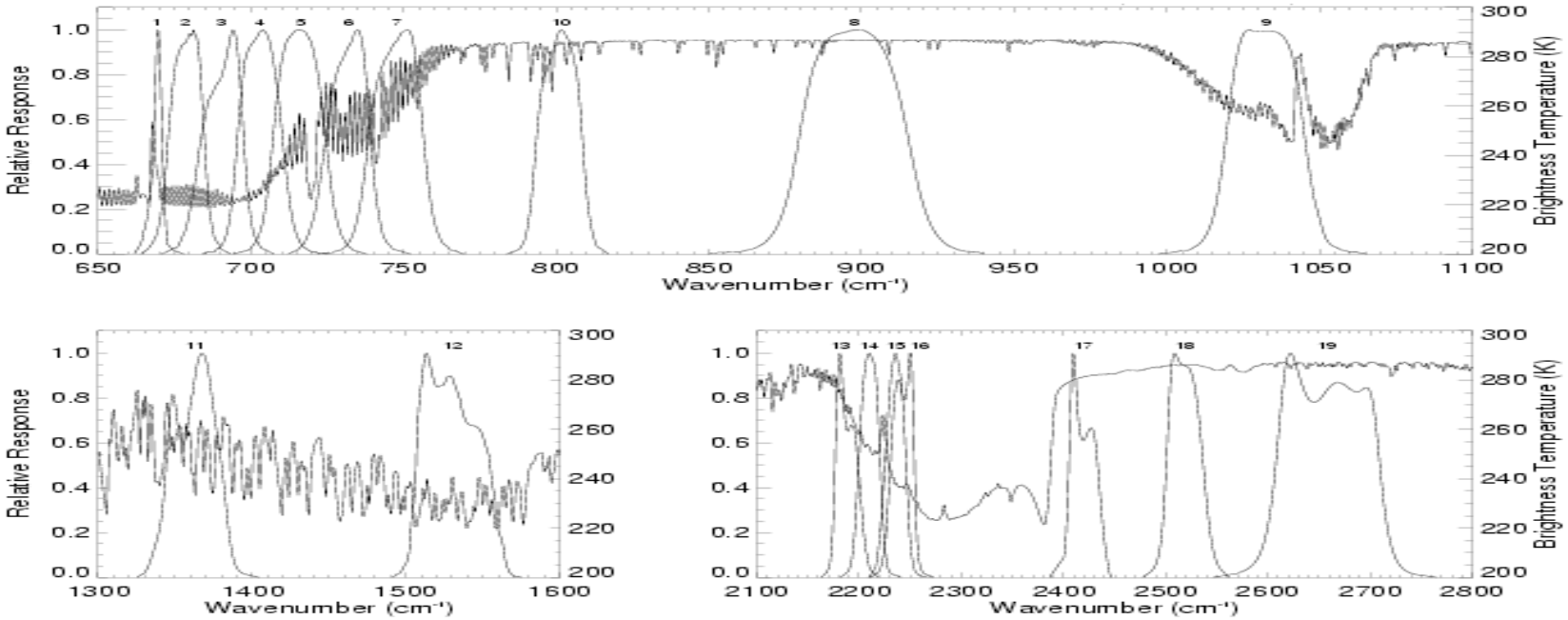






Quanhua Liu (JCSDA)

Aerosol effects on hirs3_n17



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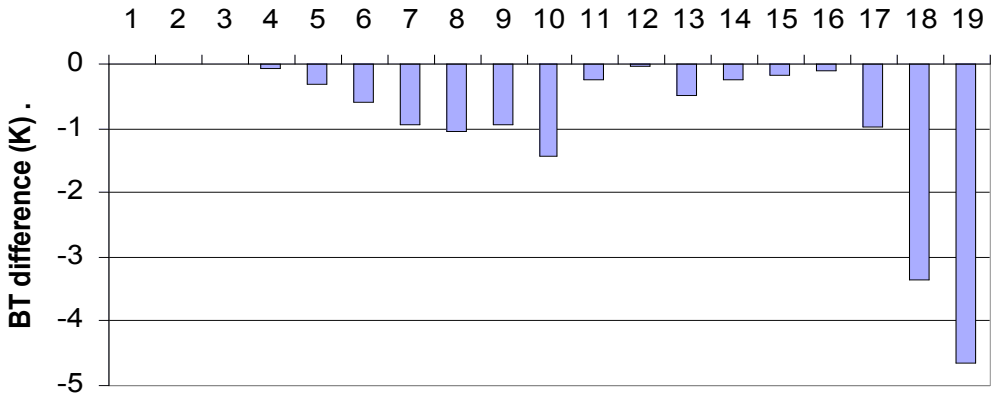


No clouds

0.1 g/m2 OC aerosol at 300 hPa

0.1 g/m2 Dust aerosol at 600 hPa

0.1 g/m2 Dust aerosol at 650 hPa

Quanhua Liu (JCSDA)

Aerosol Data Assimilation

- Goal: Configure an aerosol assimilation system with the flexibility to incorporate assimilation techniques of varying complexity and the extensibility for the inclusion of additional current or future aerosol instruments
- Planned phased deployment:
  - Incorporation of GOCART prognostic aerosols into GFS
  - Refinement of the GFS-GOCART system
  - Benchmark studies of global aerosol simulations
  - Incorporation of aerosol module into CRTM
  - Estimations of background errors (using NMC method)
  - GSI modification for aerosol assimilation
    - Univariate assimilation of MODIS aerosol retrievals
    - Multi-variate assimilation including aerosol sensitive channels (jointly assimilation of MODIS/OMI radiance)

Data Availability

- NCEP is receiving MODIS level 1 product and OMI AI in real time
- GOES column integrated AOD product is available
- Potential data sources
  - OMI-like aerosol retrievals produced by the GOME-2, UV+ VIS
  - AIRS (Advanced Infrared Radiation Sounder), IR
  - MLS (Microwave Limb Sounder), stratospheric aerosol, MW
  - Future Sensors: GOES-R ABI, NPOESS VIIRS, CrIS, OMPS
- Challenges:
  - Inability of satellite retrievals to identify aerosol specification and vertical structure

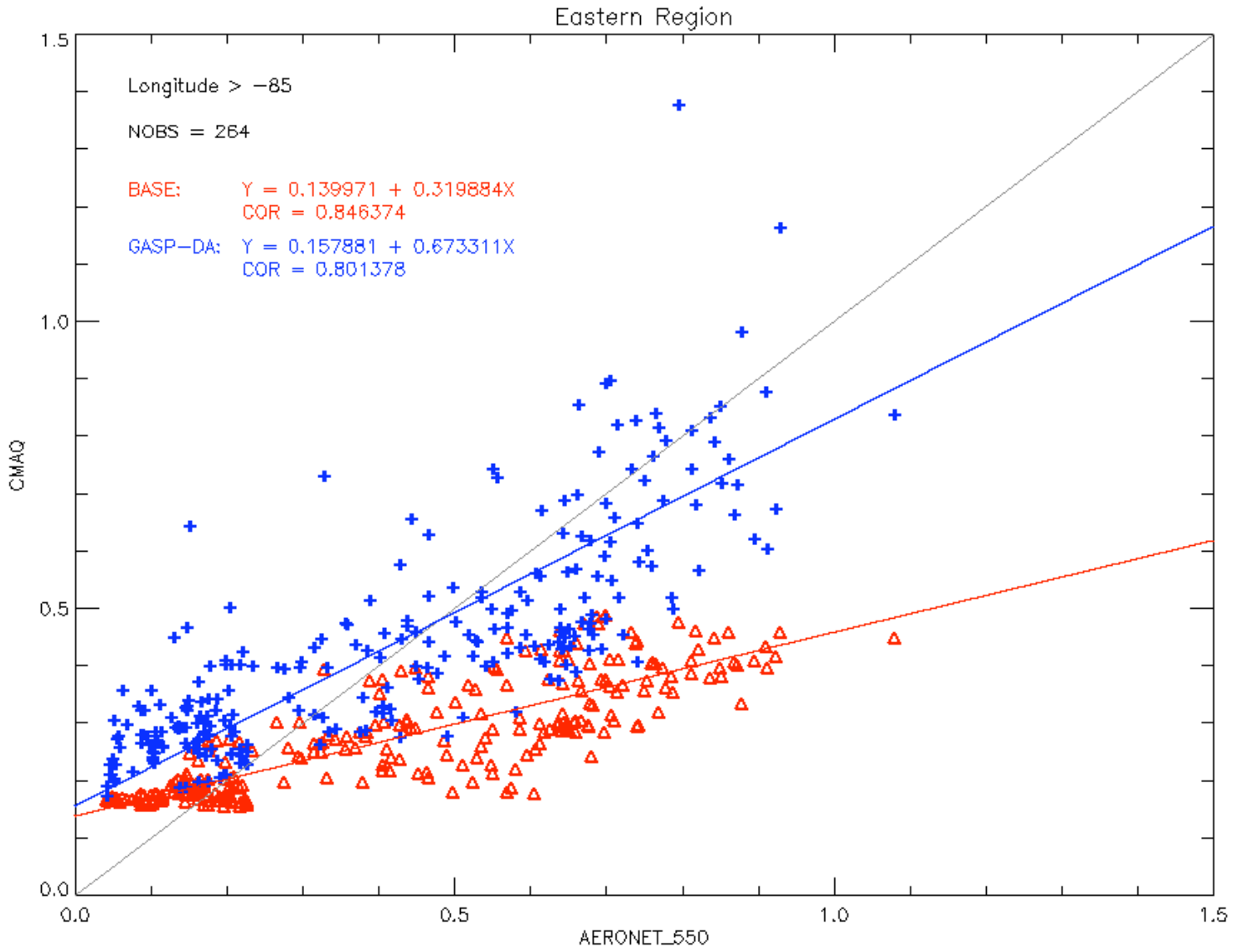
Conclusions

- NCEP recently initializes the efforts to develop global aerosol forecasting and assimilation capability in GFS/GSI via the NCEP-GSFC collaborations.
- This project enables the use of NASA earth science results (GOCART model and MODIS/OMI measurements) to enhance NOAA environmental forecasting capability.
- Logistics for research-to-operation
  - Resources:
    - R& D efforts needed to add new analysis variables in GSI
    - The number of transported tracers is increased from 3 to 21.
  - Communication path (NRT)
  - Data format (BUFR)
  - Operation transition protocol

Discussions

- Chemical data assimilation using GSI are in progress or planned. These include but are not limited to:
  - OMI total and profile ozone assimilation (G. Long, CPC)
  - MLS ozone data assimilation (I. Stajner, GSFC)
  - Regional ozone assimilation for WRF-CHEM (G. Grell, OAR-GSD)
  - Regional GOES ozone assimilation for UH-CMAQ (B. Pierce, NESDIS-CIMMS)
  - Aerosol data assimilation for CMAQ (S. Kondragunta, NESDIS-ORA)

10-day CMAQ simulations
Base run vs assimilation run using GOES AODs



S. Kondragunta & Q. Zhao (NESDIS)

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Thank You