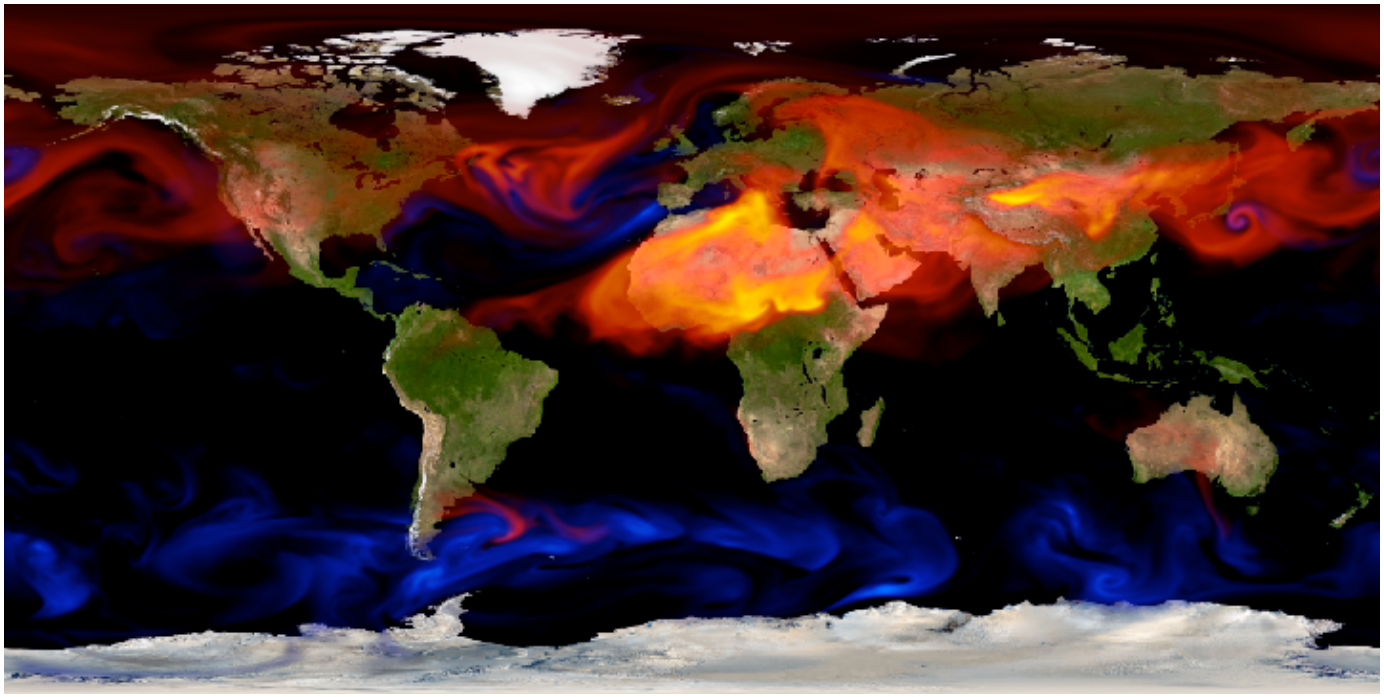
The NEMS/GFS-GOCART System: Overview and Status



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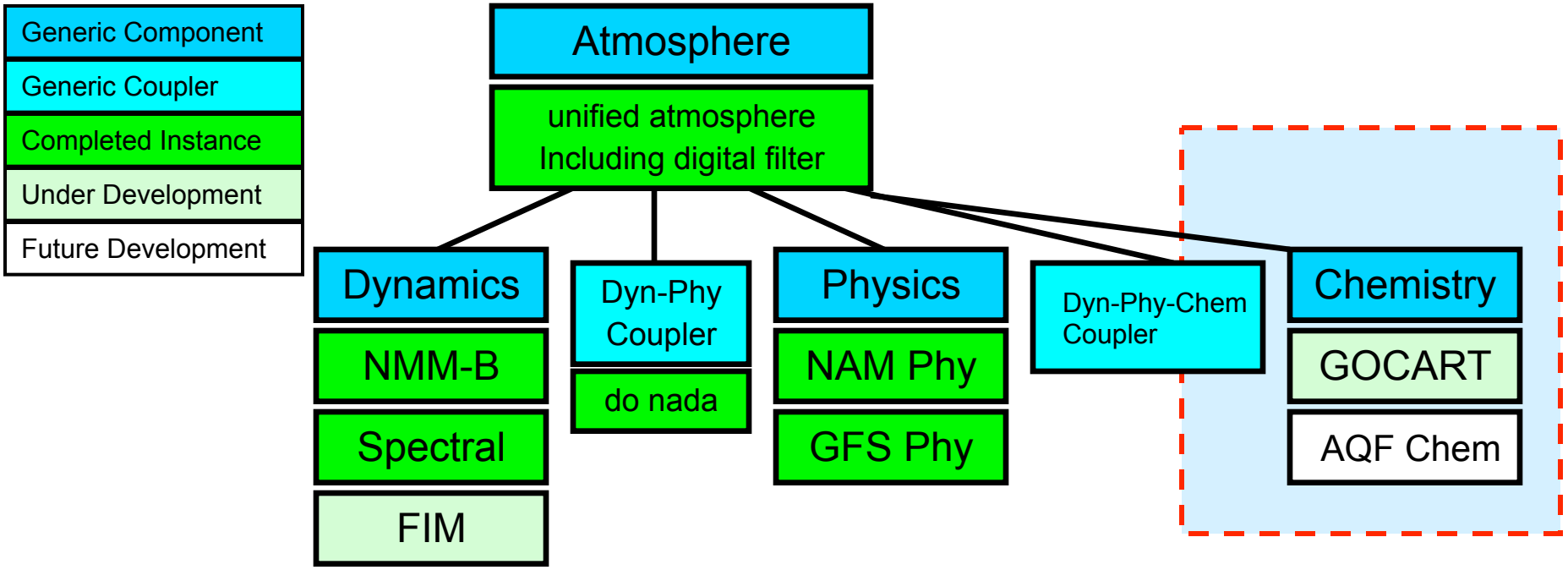
Outline

- Introduction
- NOAA Environmental Modeling System (NEMS)
  - Overview and status
  - Proposed enhancements
  - Challenges and issues
- Aerosol-radiation feedback in GFS
  - Impact of aerosols on weather forecasts
  - Impact of aerosols on climate predictions
- Conclusions

NCEP global aerosol forecasting and analysis system

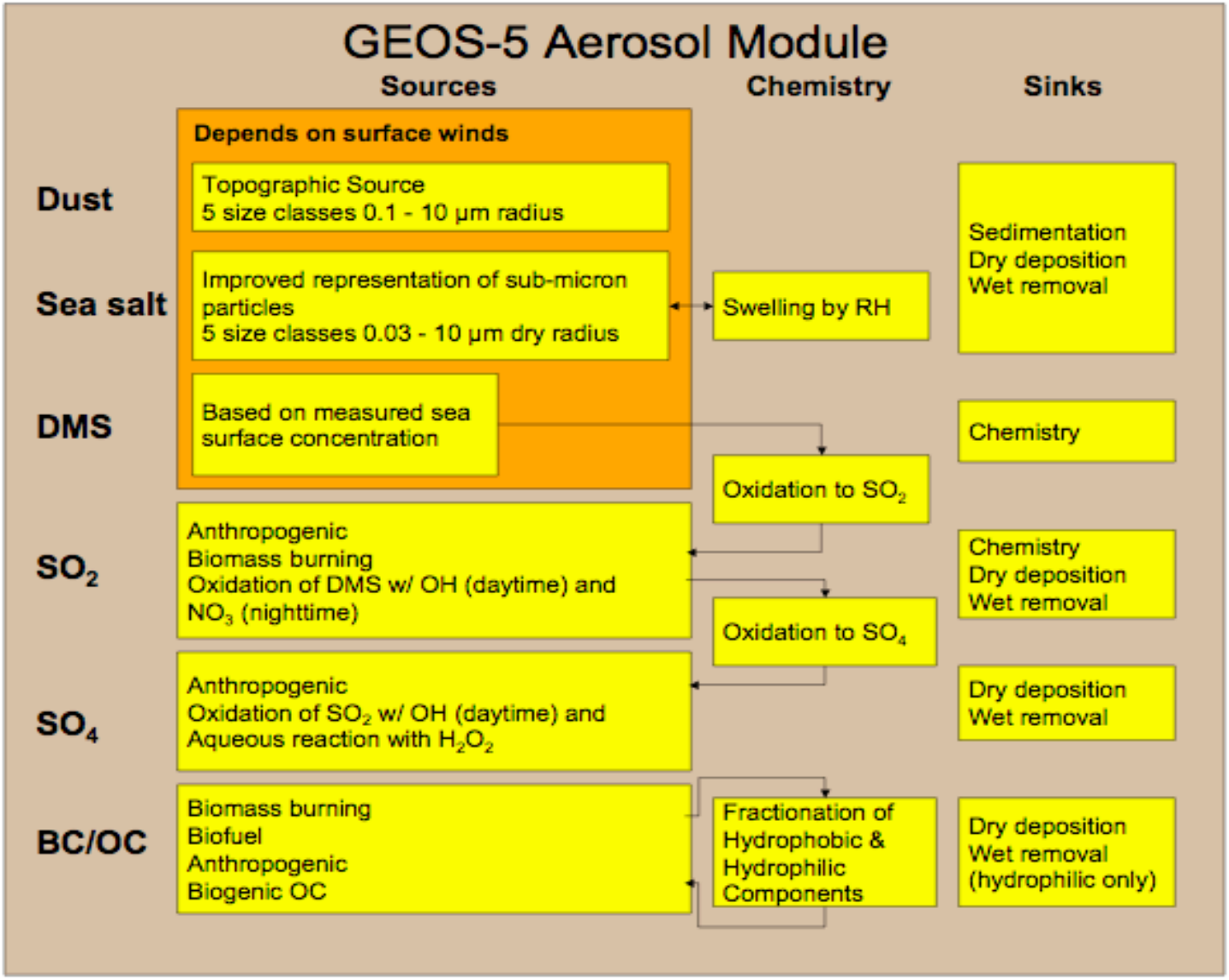
- **Goal**
  - The global aerosol forecasting and assimilation activities aim to extend NCEP's weather-air quality capabilities.
- **Objectives**
  - Potential for improving weather forecasts and climate predictions
  - Providing dynamic LBCs for regional AQF aerosol predictions
  - Support WMO sand and dust storm warning system
- **Phased development**
  - Near-term: develop GOCART CTM, driven by GFS meteorology
  - Long-term: incorporate prognostic aerosols (GOCART) in NEMS/GFS and assimilate aerosol information (AOD and then radiance) in GSI
- **Primary Output**
  - 4D distribution of aerosol concentrations for sulfate, dust, black carbon, organic carbon, and sea-salt
- **Leveraged efforts**
  - Funding from NWS AQ, NOAA-NASA-DOD JCSDA, NASA ROSES, NOAA CTB (Climate Test Bed)
  - Leverage common modeling framework (ESMF) and shared software development (JCSDA)

NOAA Environmental Modeling System (NEMS) Atmosphere Model



- Earth Science Modeling Framework (ESMF) infrastructure
- One unified atmospheric component that can invoke multiple dynamics and physics
- FY2011 operational implementation for NEMS NMM-B (regional applications)
- Developing an interactive atmosphere-chemistry forecast system under NEMS
- The coupler linking GFS and GOCART: unit conversion, vertical index swap, forcing field calculations, potentially re-gridding and mass adjustment

Goddard Chemistry Aerosol Radiation and Transport Model



GOCART parameterizations (excluding transport processes) have been modularized as an ESMF grid component, and have been implemented within GEOS-5 earth system model

Proposed Enhancements

NOAA air quality forecast capability (CMAQ-NAM)

Baseline Conditions: Default static boundary conditions

Expected Outcomes: Provide dynamic aerosol BC for the AQF system, and consequently, improve PM air quality forecasts

Performance Measures: The NCEP Air Quality Forecast Verification System and NWS Contingency Exceedance Statistics (threat scores, false alarm ratios, and hit rates)

National Significance: In support of NOAA's mandated responsibility to provide air quality (AQ) information for people at risk and to improve the basis for AQ alerts by providing AQ forecast guidance

End User Community: State and local environmental and public health agencies, the media and public

Proposed Enhancements

NOAA medium range weather forecasts (GFS/GSI)

Baseline Conditions: Climatology-derived aerosol distributions

Expected Outcomes: Provide improved estimates of aerosols in the GFS/GSI, and consequently, improve weather forecasts

Performance Measures: The NCEP GFS Model Performance Statistics (e.g., skill scores, error growth rates, and decay curves)

National Significance: In support of NOAA's core mission to serve society's needs for weather and water information by providing weather forecasts

End User Community: NWS field offices, government agencies, private sector meteorologists, universities, and the public

Challenges for incorporating chemistry component into NEMS:

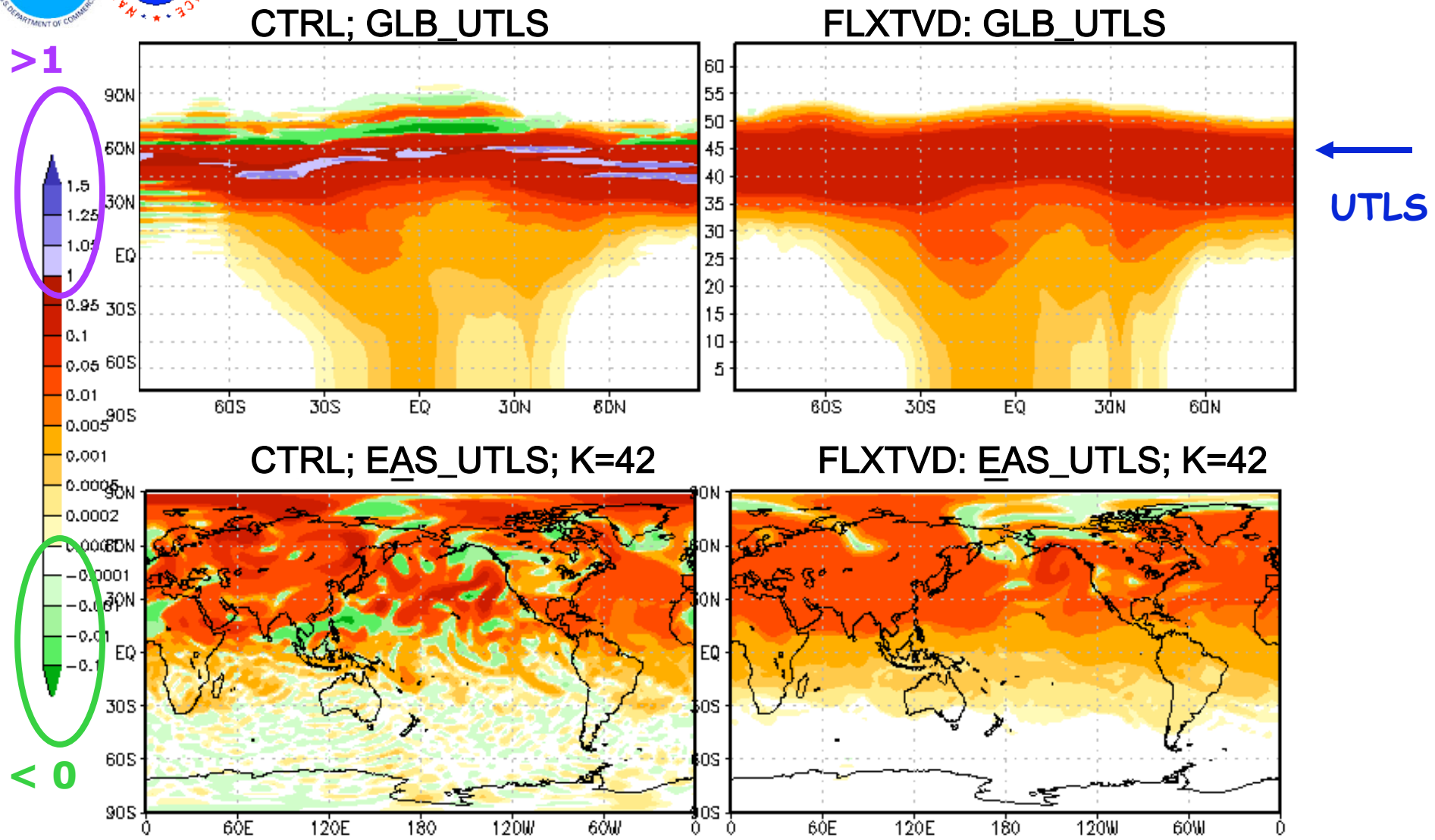
Challenges in chemical weather -an operational NWP perspective

- Weather vs climate applications: Different approaches are needed for climate simulations and NRT forecasts (e.g., IPCC assessment versus AQ forecasts)
- NWP vs CTM modeling: Different focus for the same parameter (e.g., high wind speeds and heavy precipitation for NWP versus stagnant conditions and low intensity rain for CTM)

Challenges for incorporating GOCART into NEMS/GFS

- Needed capabilities in NEMS/GFS
  - Convective transport (already available in RAS)
  - Tracer scavenging in moisture processes
  - Semi-Lagrangian advection scheme
  - Cloud-aerosol interaction
- Code management and coordination
  - The ESMF-based NEMS framework is currently under development and *continues to evolve*
  - NEMS and GEOS-5 employ different ESMF architecture design; ESMF superstructure and infrastructure changes are made in NEMS/GFS in order to bring in GOCART
  - NCEP and GSFC have different code repository with frequent revisions and upgrades
- Resource challenges
  - Code optimization needed
  - The inclusion of 15 passive tracers leads to ~45% increase in run time and the factor of 2.4-2.7 increase in file sizes

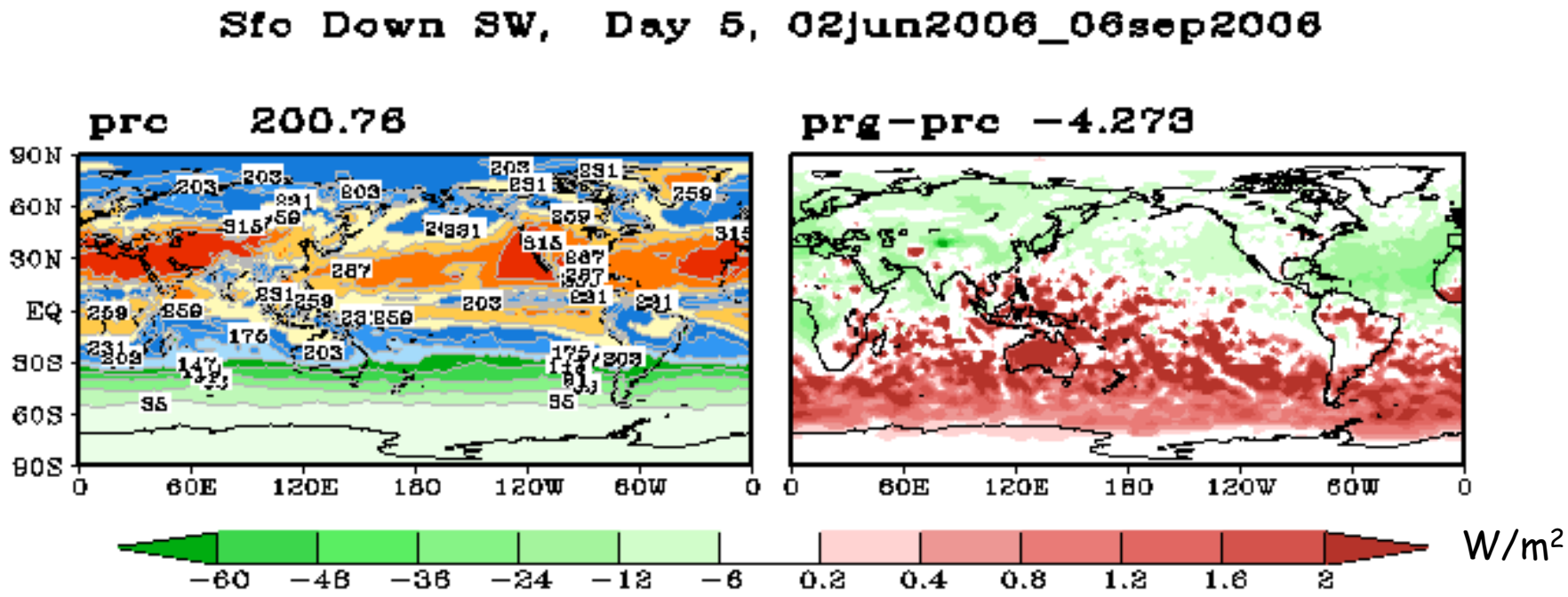
NEMS/GFS tracer experiment



- Flux-limited vertical advection scheme reduces (but does not eliminate) negative tracer values caused by spectral transform.
- Semi-Lagrangian schemes (positive definite advection with mass conserving) are under the development

Impact of aerosols on medium range weather forecasts: Comparisons between forecasts

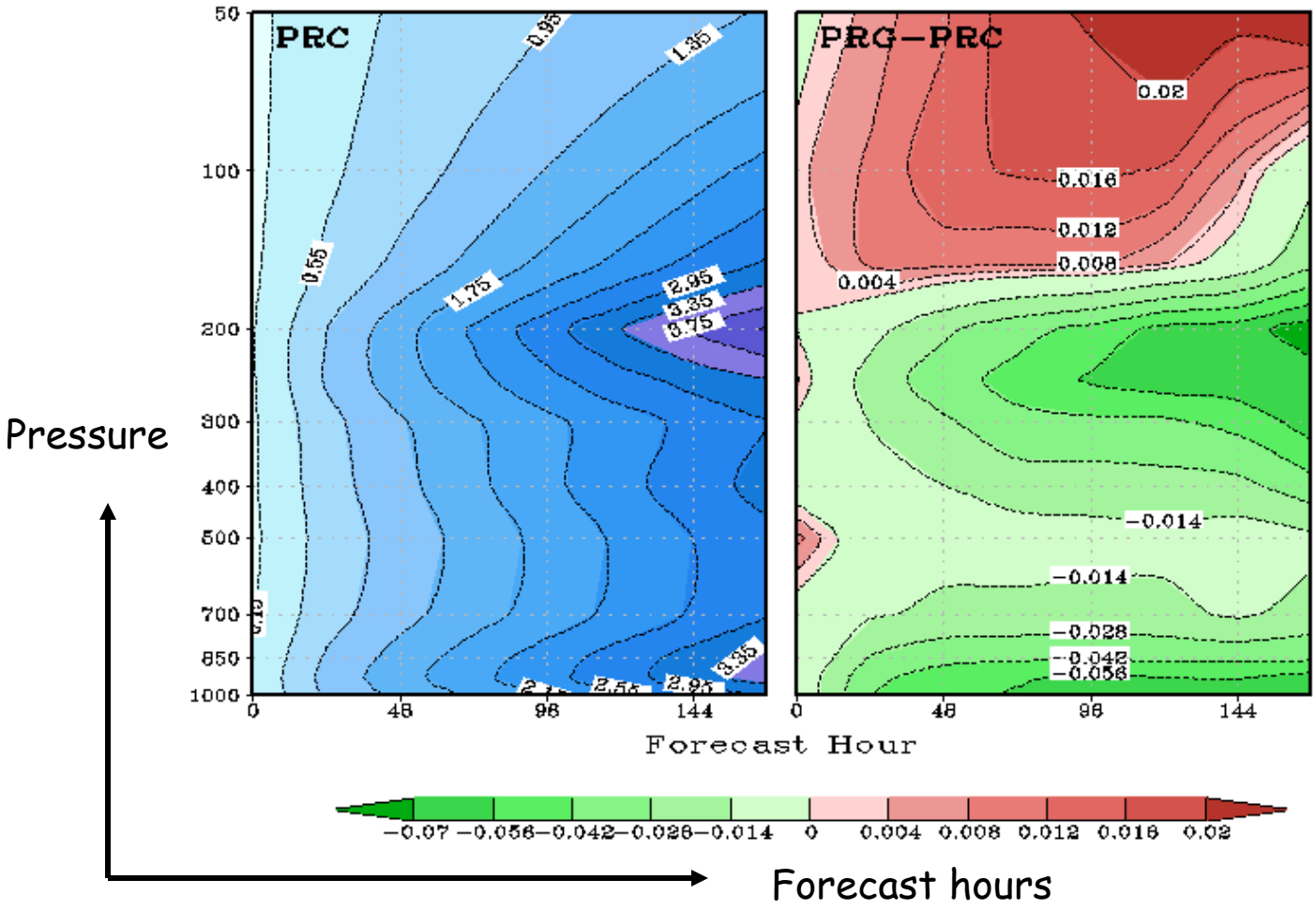
- T126 L64 GDAS experiments (2006-06-01 to 2006-09-07)
- Aerosol scheme configuration: PRC (climatology) and PRG (GEOS4-GOCART)
- The experimental aerosol treatment only impacts the model results via its direct effect on the radiative forcing of the atmosphere



Surface downward SW fluxes are reduced due to higher aerosol attenuation. Cooler near surface temperature and suppressed PBL depth are found.

Impact of aerosols on medium range weather forecasts: Comparisons between forecasts and analysis

RMS errors of NH temp for 00Z forecasts

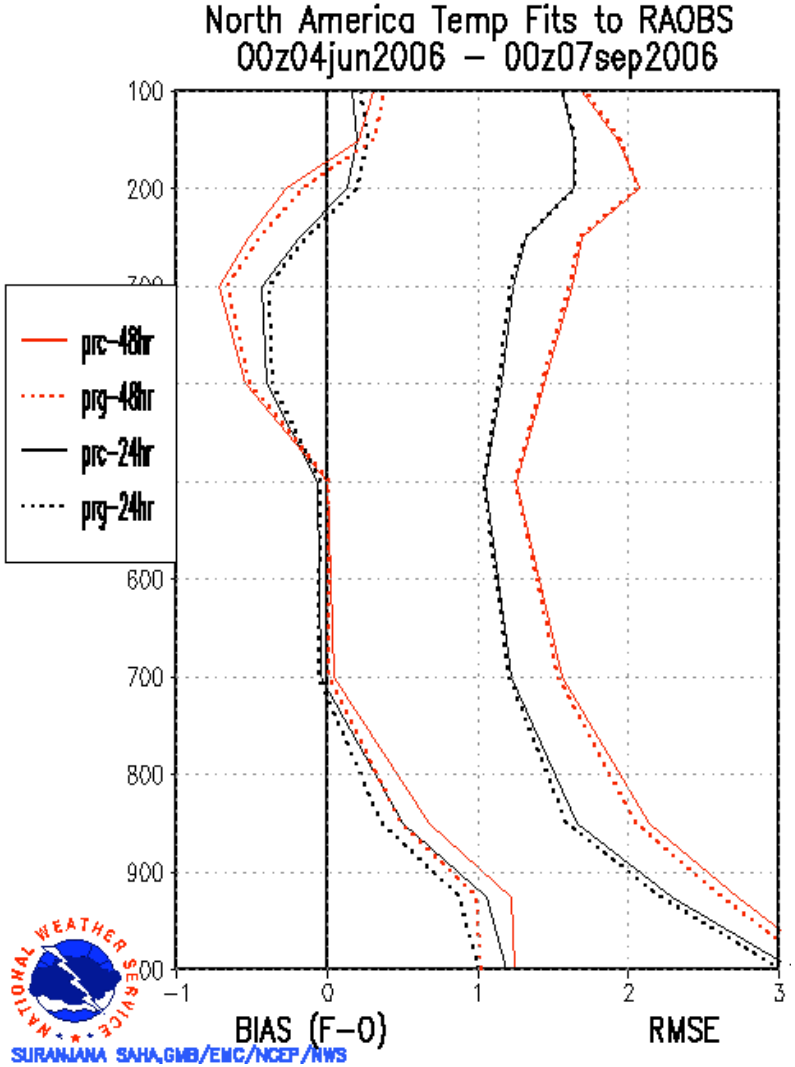


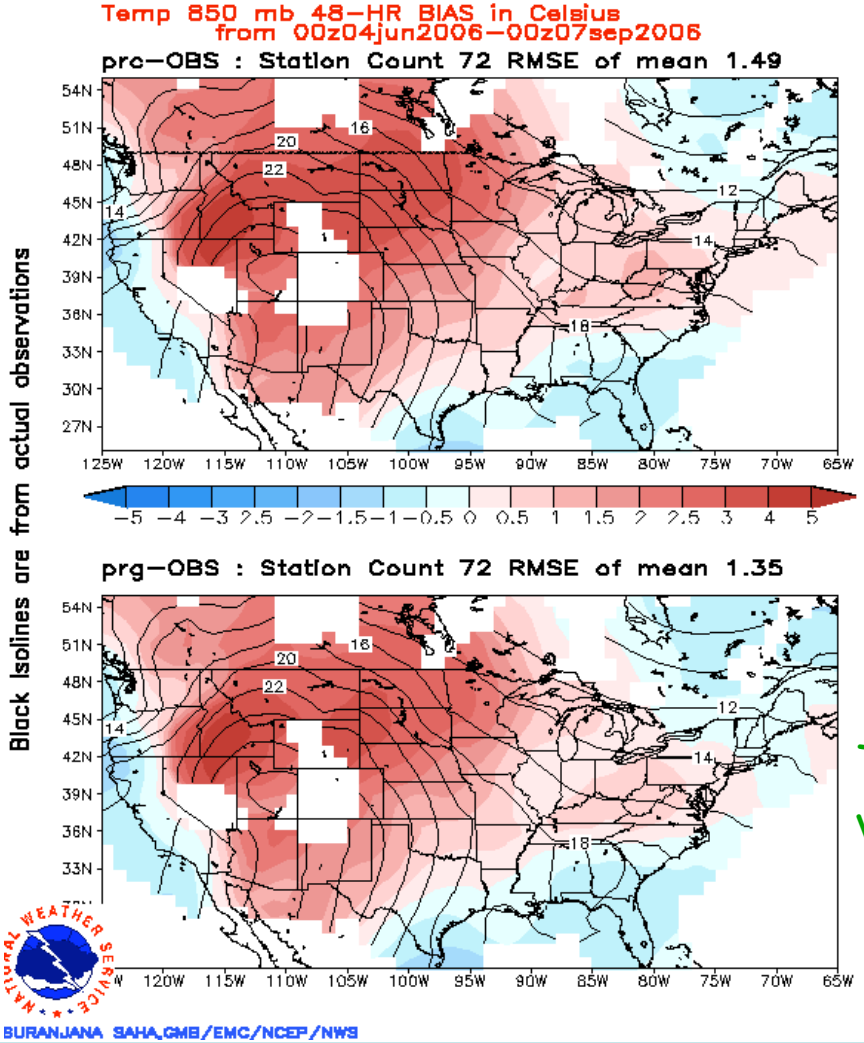
RMSE increased

RMSE reduced

- Improvement in NH Temp forecasts up to 200 mb
- Neutral impact on anomaly correlation for 5-day forecasts of 500 mb heights

Impact of aerosols on medium range weather forecasts: Comparisons between forecasts and observations





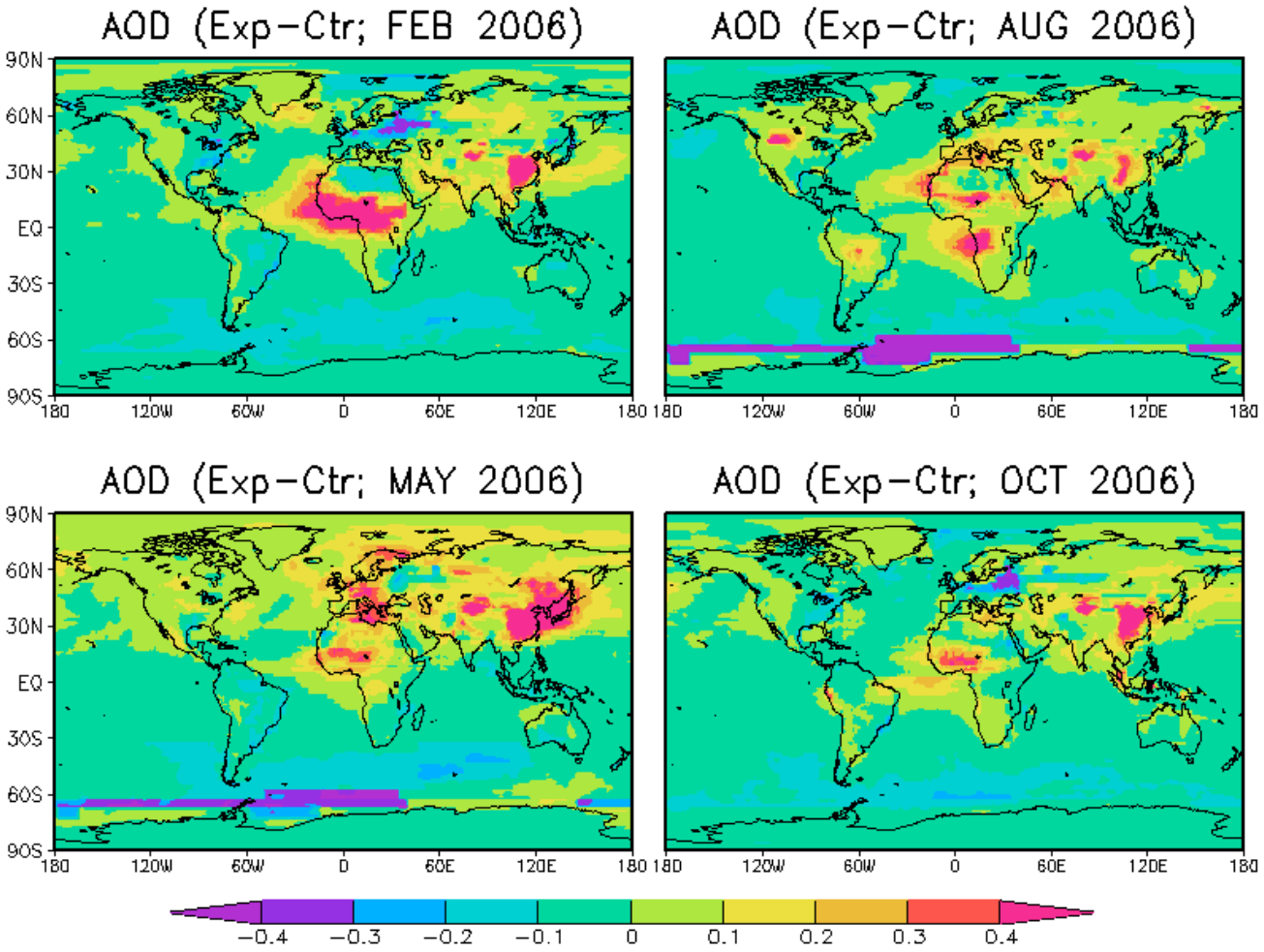
Climo.

Time-varying

- Warm biases are reduced by ~ 10% in lower atmosphere
- Positive surface SW flux biases are reduced (vrf SURFRAD flux obs)
- North American precipitation verification shows neutral impact (vrf rain gauge obs)
- Storm track errors are reduced (note small sampling sizes, Alberto and Ernesto only)

Impact of aerosols on climate predictions: Climate Forecast System (CFS, GFS coupled with MOM3)

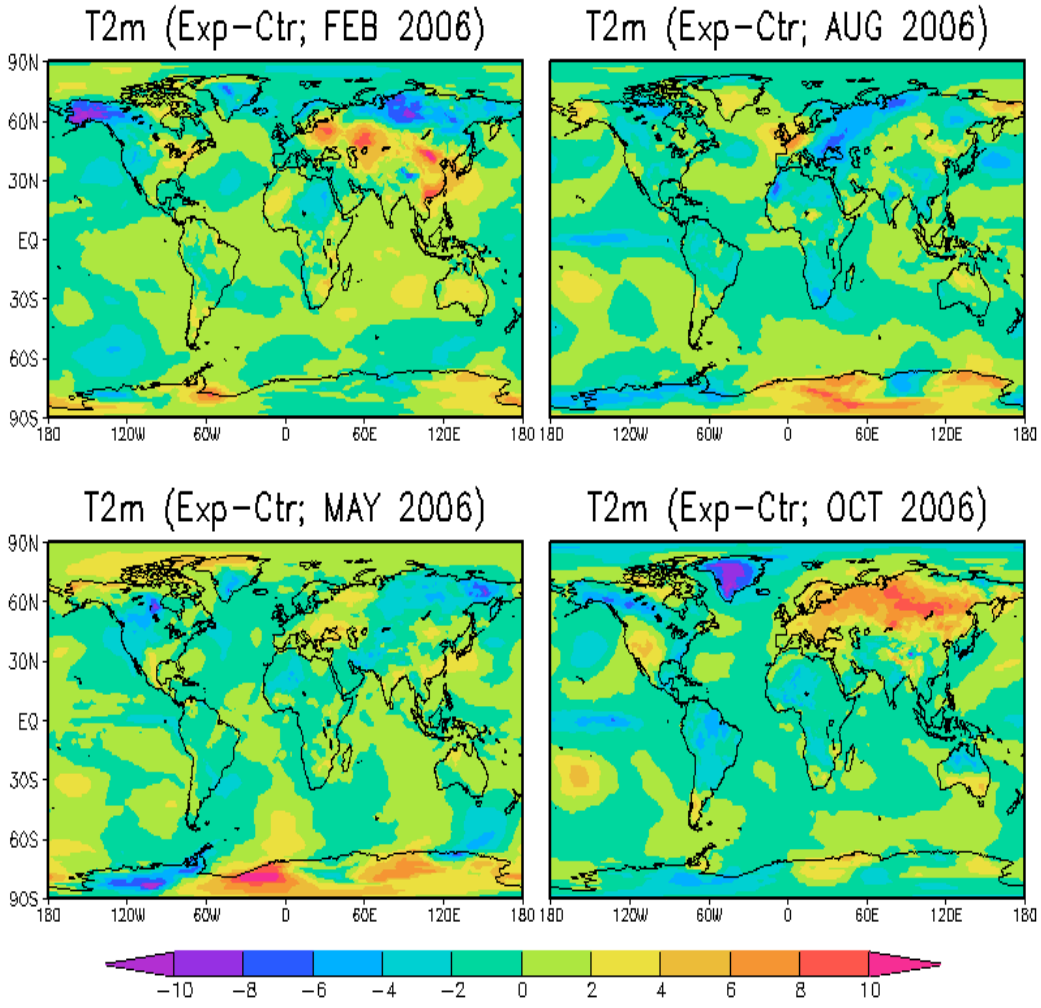
- T126 L64 5-member CMIP experiments (2000/01 to 2007/01)
- CTR uses the OPAC climatology and EXP uses the GEOS3-GOCART monthly data set



The differences in AOD between CTR and EXP runs on different seasons.

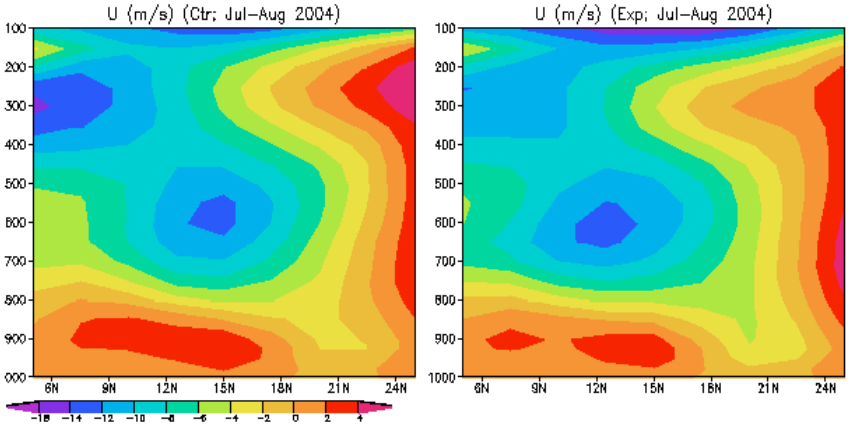
Impact of aerosols on climate predictions: Climate Forecast System (CFS, GFS + MOM3)

- The global impact and regional influence due to different background aerosol loading are examined



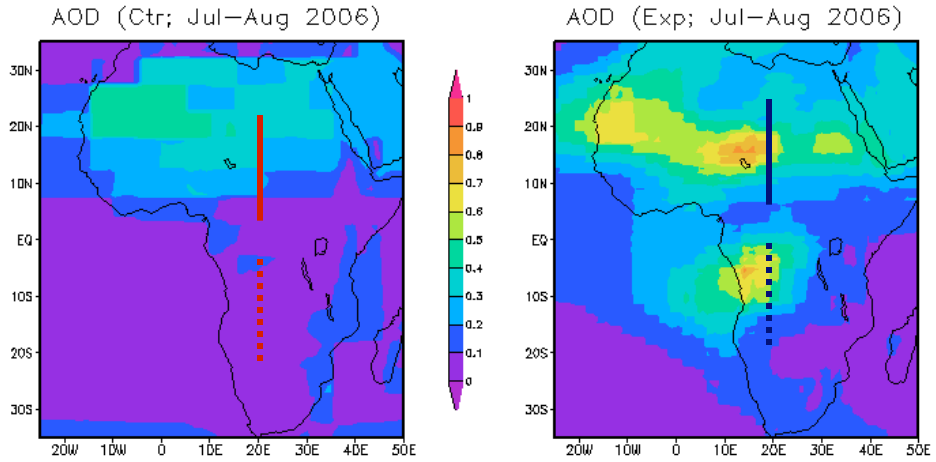
Aerosol direct radiative effect can manifest itself in significant modification of the atmospheric general circulation.

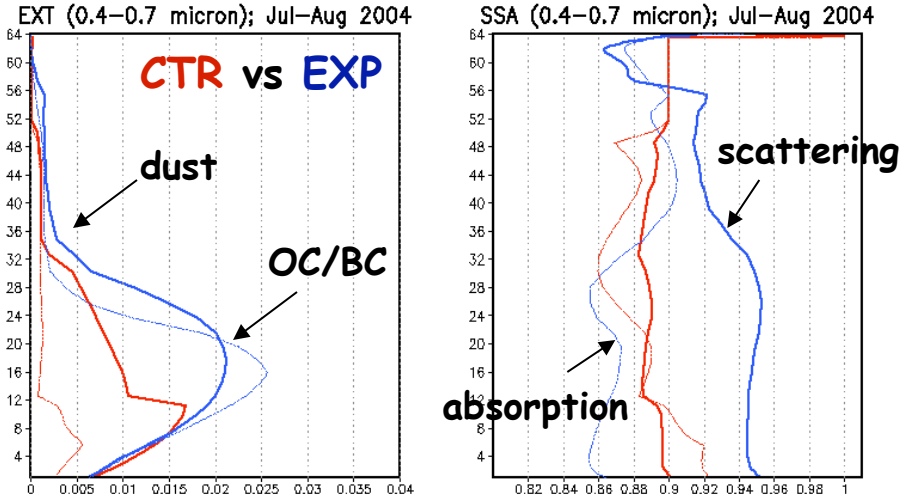
U-wind cross section at 10W



The intensity and location of African Easterly Jet are affected by aerosol loading

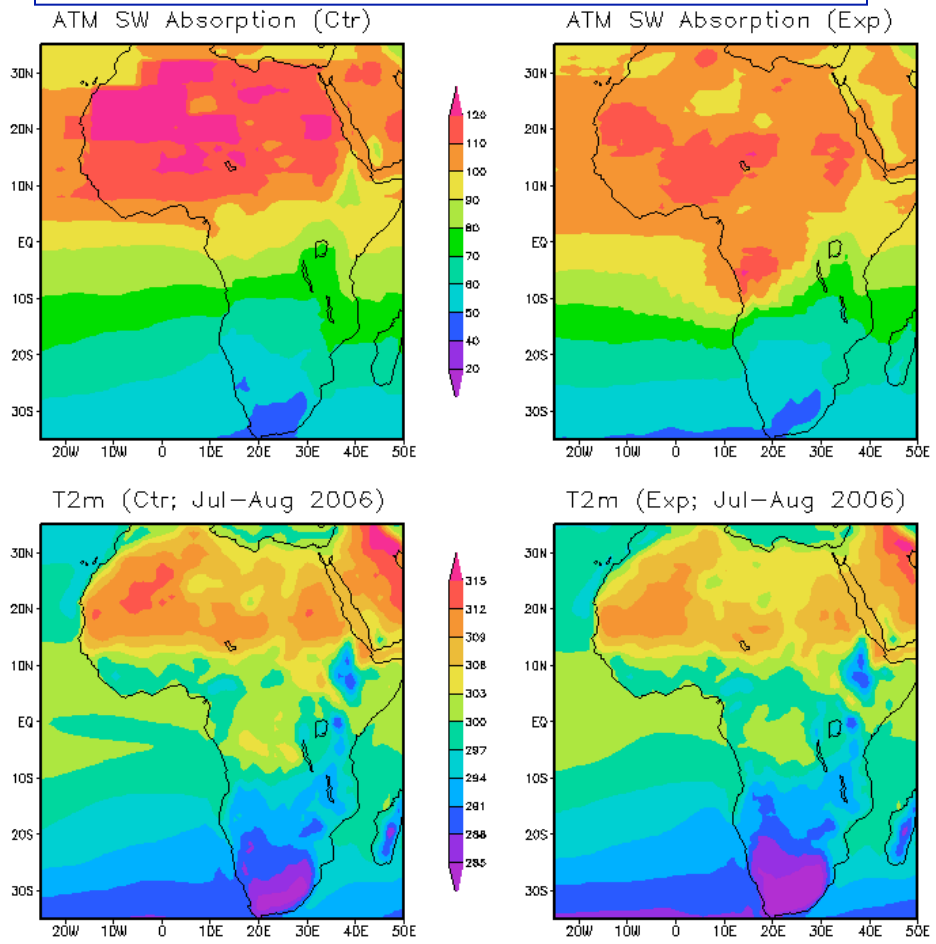
Impact of aerosols on climate predictions: Climate Forecast System (CFS, GFS + MOM3)





Region 1 (20E; 5N to 25N; dust aerosols)
Region 2 (20E; 20S to Eq.; OC/BC aerosols)

Atmospheric column absorption=
(net SW)top – (net SW)sfc



Information on vertical structure and chemical composition is important

In Conclusion

- **NEMS chemistry modeling**
  - NCEP is developing NEMS as next-generation weather forecast system
  - NEMS R&D efforts continue in interactive atmosphere-chemistry modeling system: NMM-B + Chem* and GFS-GOCART
  - Leverage common modeling framework (ESMF), shared software development (JCSDA), and research collaborations
  - The chemistry modeling efforts will lead to scientific advances and technical upgrades in the NEMS

- **Aerosol-radiation feedback:**
  - GFS/GSI experiments show a neutral-to-positive impact on medium range weather forecasts due to realistic time-varying treatment of aerosols.
  - CFS CMIP experiments indicates aerosol direct radiative effect can manifest itself in significant modification of the atmospheric general circulation.

*: Please see the poster "Progress on NEMS/NMMB-AQ Development" by Youhua Tang

Thank You

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