On the Development of Global Aerosol Assimilation at the NCEP and the Use of Satellite-derived Hourly Global Biomass Burning Emissions Product as Source Function in Forecast Model

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Outline

- Motivation
- The development of NCEP GSI global aerosol data assimilation
- The development of NESDIS Global Biomass Burning Emissions Product
- Future tasks

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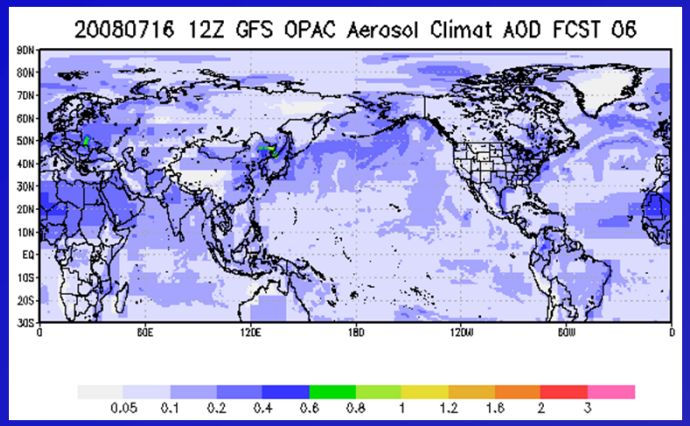
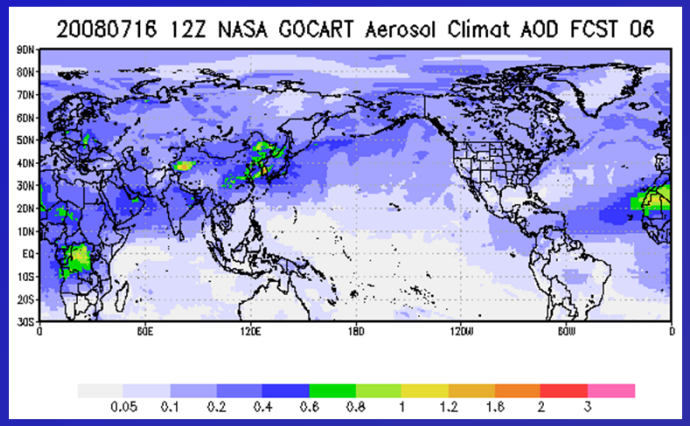
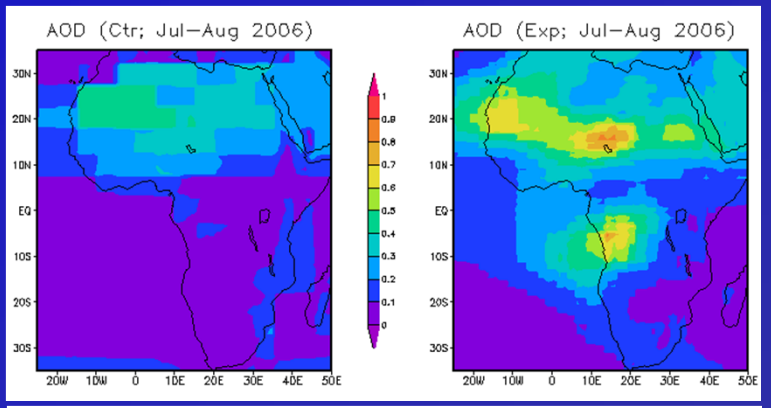
Aerosols Impact on Radiation Budget

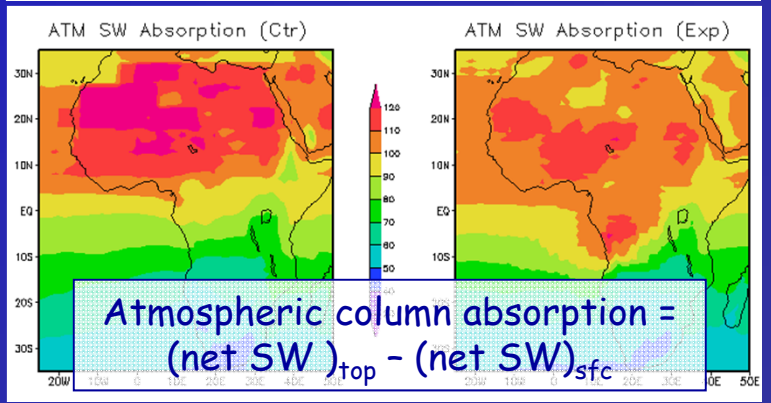
Operational GFS climatology aerosol fields **Ctr**



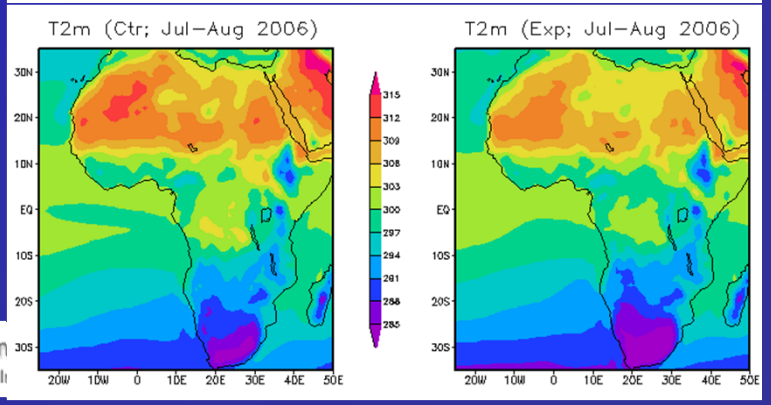
NASA GOCART monthly climatology aerosol fields **Exp**







Atmospheric column absorption = $(\text{net SW})_{top} - (\text{net SW})_{sfc}$



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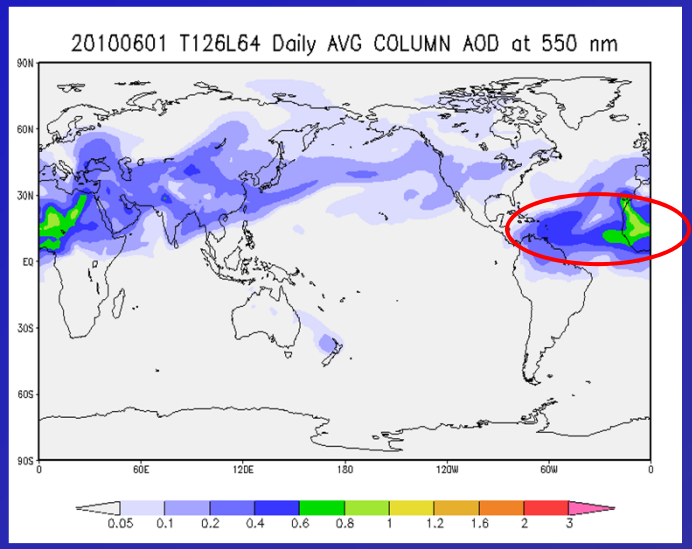
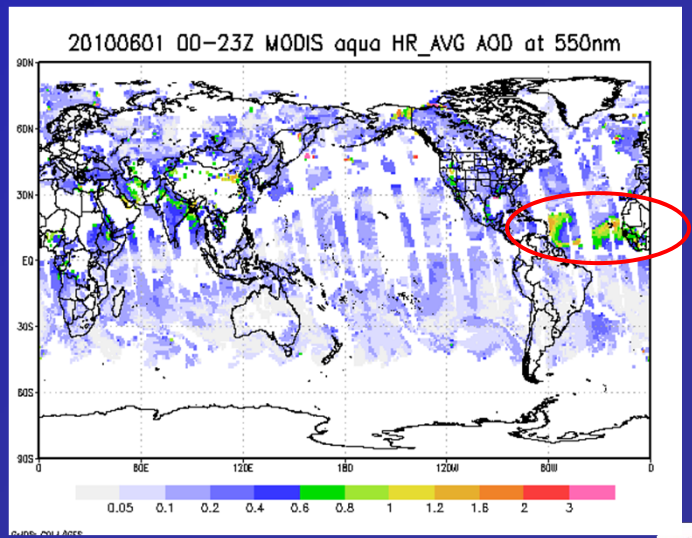
The Forward Model of NCEP GSI Global Aerosol DA

- The National Environment Modeling System (NEMS); Mark Iredell (NCEP)
  - ESMF Based
  - Various physic and dynamic cores from NOAA models (GFS, FIM, NMMB) are available for “select and mix” modeling through the “coupler”
  - Chemical core is based on NASA GOCART and interacted with GFS dynamic and physic cores (NEMS/GFS-GOCART)
- The inline NEMS/GFS-GOCART dust-only simulation produced a good spatial pattern as compared to observed MODIS AOD but the intensity is underestimated





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Goals for NCEP GSI Aerosol DA

- To improve the global aerosol fields simulated by NEMS/GFS-GOCART
  - To improve the performance of NCEP operational weather forecasting systems
  - To improve the performance of NCEP operational National Air Quality Forecasting Capability (NAQFC) on particulate matters (PM) forecasting
- To provide a pathway to study aerosol impacts on radiance retrievals in CRTM (within GSI)


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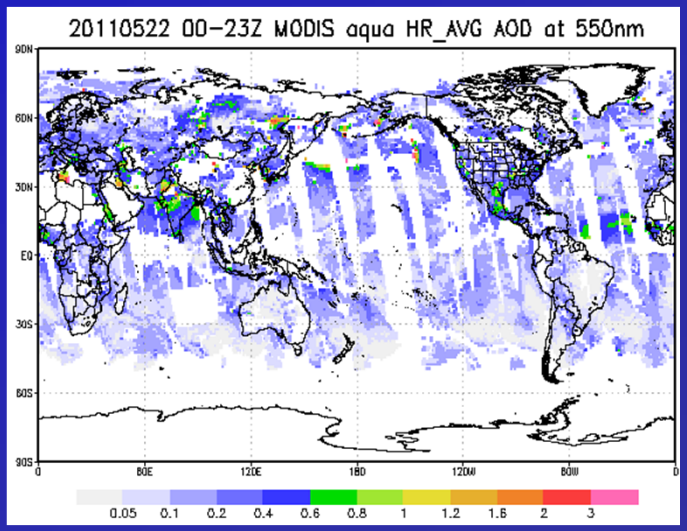
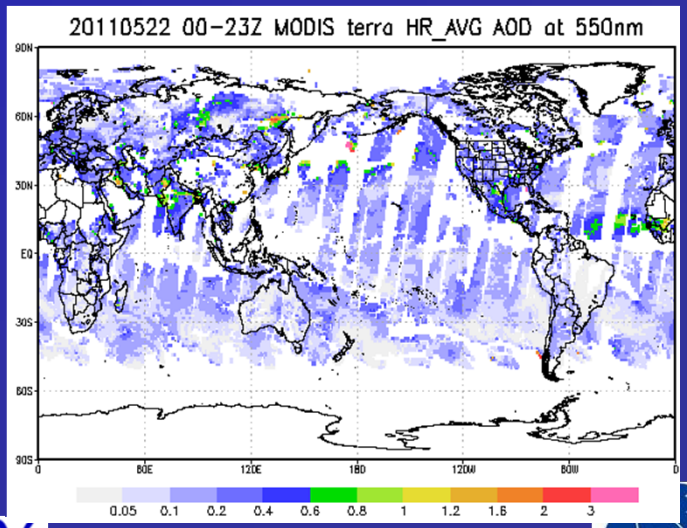
Development of GSI Global Aerosol DA Capabilities

- Add MODIS AOD products in NCEP NCO dataflow
  - MODIS AOD is now operationally pulled by NCEP NCO to NCEP BUFR Tank
- Modify the NCEP GSI to ingest satellite aerosol products
  - Create GSI data structures for aerosol DA
  - Add read-in modules for MODIS AOD fields
- Modify the NCEP GSI to include the model first guess fields (background)
  - Based on NEMS/GFS-GOCART aerosol field output (Sarah Lu)
  - Add NEMS I/O modules for meteorology and aerosol first guess and analysis fields





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"Good data assimilation needs good forward model"

The Uncertainty of Biomass Burning Source Function

- Fires occur randomly and can be of short duration (e.g., agricultural fires induced for land clearing) or long duration (e.g., forest fires).
- The intensity and location of fire can change with time according to environmental conditions as well.
- Therefore, it is difficult to estimate and prescribe the fire emissions both in spatial and temporal scale.
- **Satellite observations provide a choice of "near-real time" and global fire emissions dataset for operational forecasting.**

Global Biomass Burning Emissions Product (GBBEP) for Operational Use in NCEP GFS-GOCART

- Based on satellite observed **Fire Radiative Power** (FRP), **biomass combustion rate** , and **emissions factors**.
- FRP observed from **a constellation of geostationary satellites** (GOES, MetoSAT, and MTSAT) that covers most of the globe at a time scale of 15-30 minutes.
- GBBEP **hourly average** emissions.

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Experiments

- From July 01 to September 30 2010
- Emissions: hourly/daily observed aggregated to 1°x1° gridded emissions
  - **NOAA/NESDIS GBBEP hourly emissions**
  - **NASA QFED v1 daily value with diurnal profile**

NASA Quick Fire Emission Dataset (QFEDv1)

- Based on **MODIS fire counts** onboard Aqua and Terra.
- Correlation between MODIS fire counts and Global Fire Emissions Data (GFED) is used to derive near-real-time daily averaged fire emissions.
- **Daily average** values with option of using diurnal profile.

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NCEP Global Aerosol Modeling Systems

- In-line NEMS/GFS-GOCART is used as the forward model for GSI global aerosol data assimilation development.
- Off-line GFS-GOCART is driven by present operational GFS for real-time dust-only testing since December 2009. It is used in biomass burning simulations for JSDI.

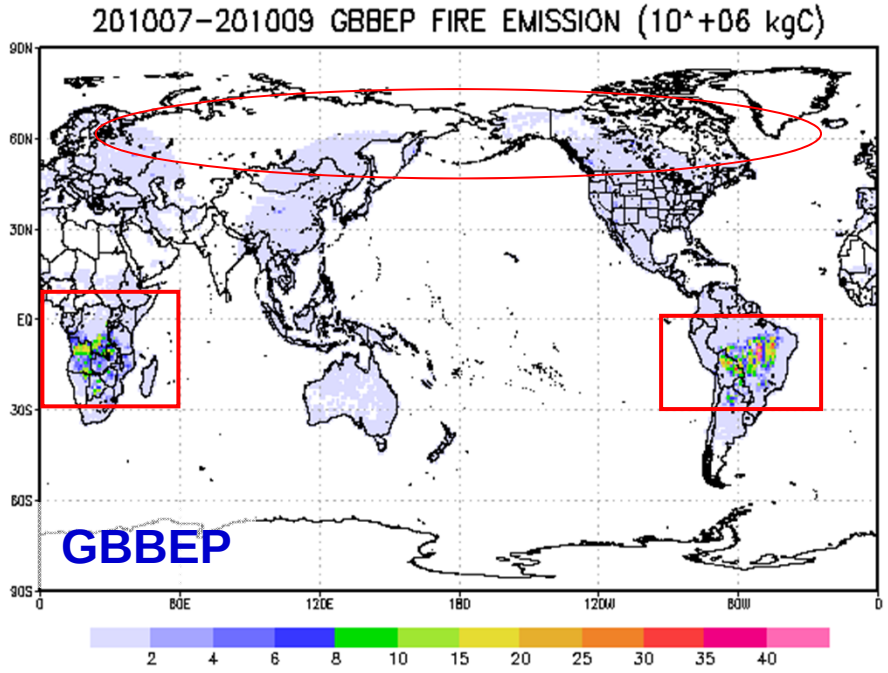
GOCART : NASA Goddard Chemistry Aerosol Radiation and Transport Model
GFS : NCEP Global Forecast System
NEMS : NOAA Environmental Modeling System

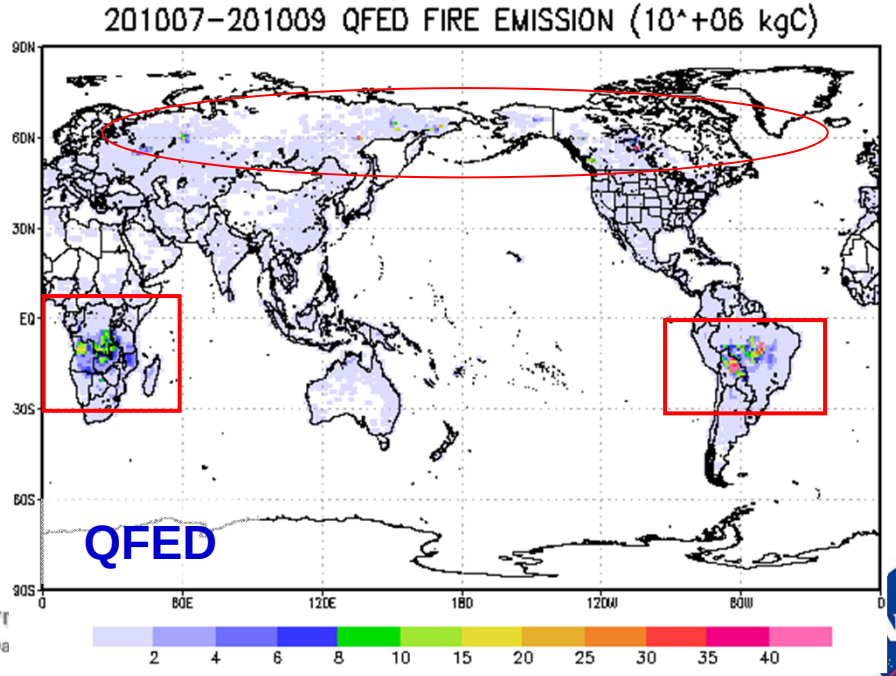

Total Carbon Emissions for GBBEP & QFED (JUL-SEP 2010)

QFED and GBBEP produced similar spatial patterns and monthly variation in total carbon (black + organic carbons) emissions. During the simulated period, both the South America and the Africa had frequent fire activities.

In general, QFED has smaller area of detected fires but with stronger carbon emissions while GBBEP has larger area of detected fires with weaker carbon emissions.

There is a limited spatial coverage for geostationary satellites at high latitudes. Thus, QFED detected more fires in the Russia, the Siberia, and the Canadian Boreal forest.





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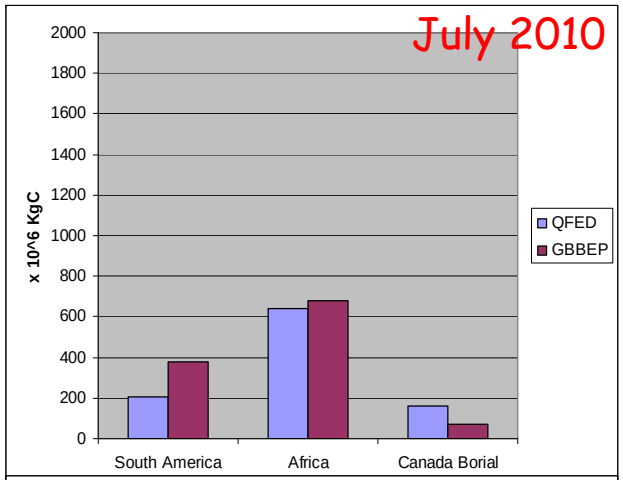
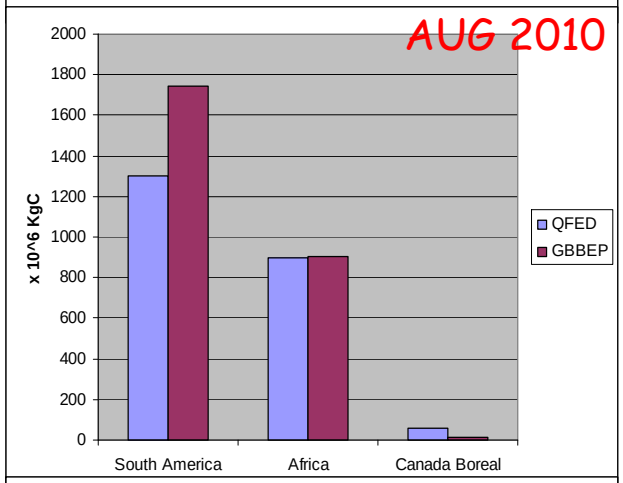
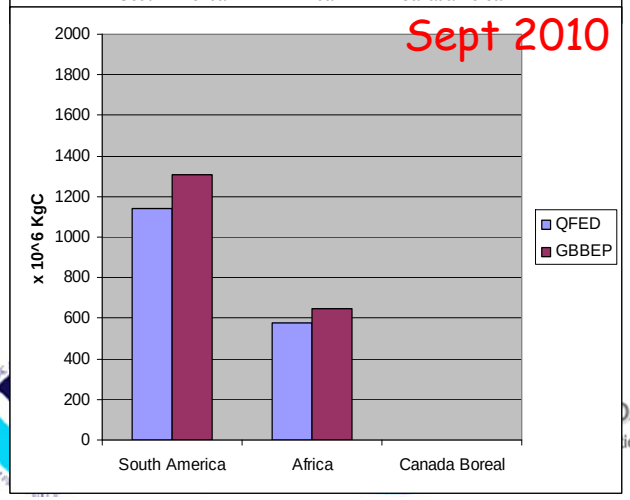
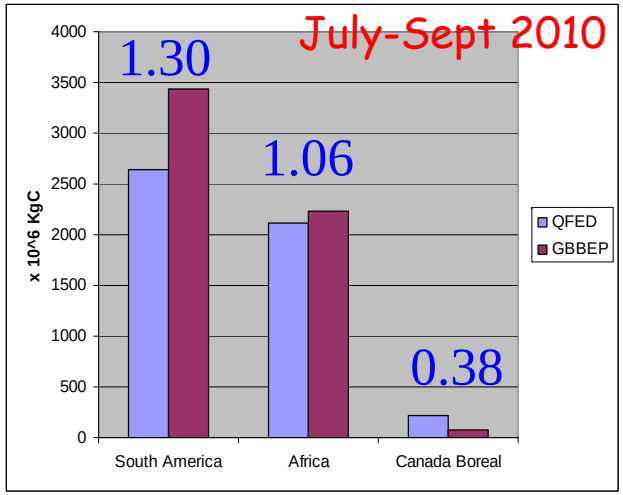
Comparison between GBBEP and QFED

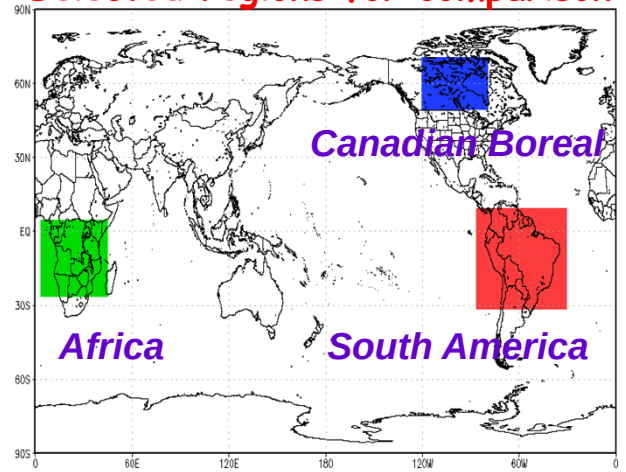








Selected regions for comparison

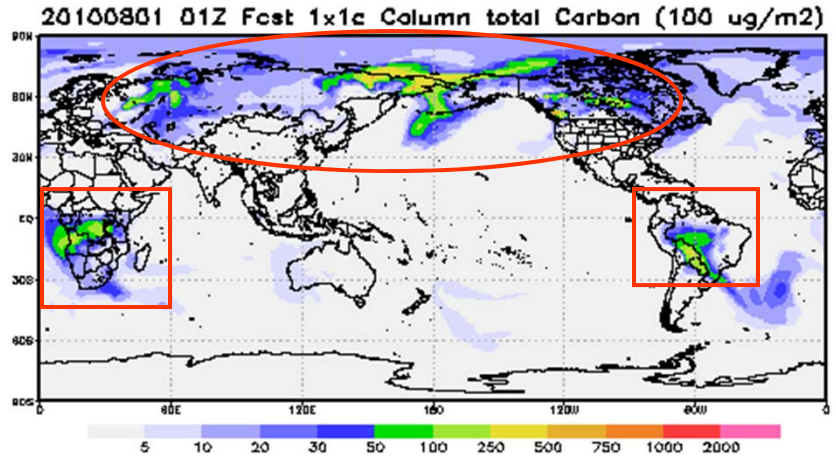


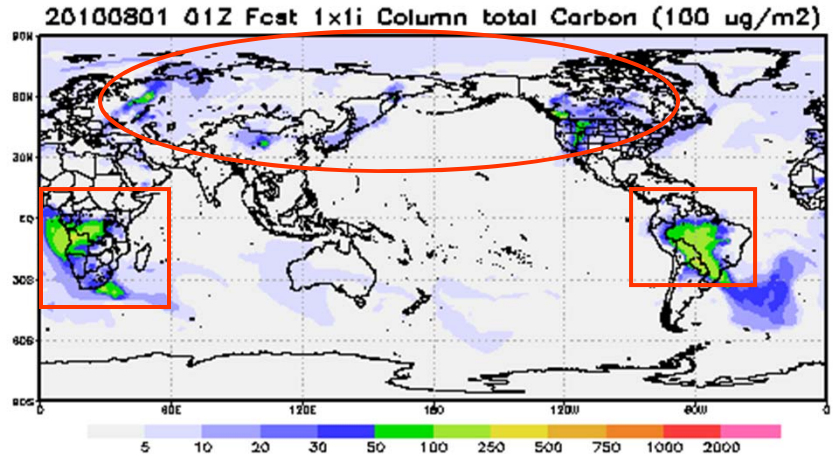
- The GBBEP total carbon emissions were about 30% (in the South America) and 6% (in the Africa) more than that of QFED during the simulated period.
- GBBEP only produced 38% of QFED total carbon emissions in the Canadian Boreal area.

QFEDv1

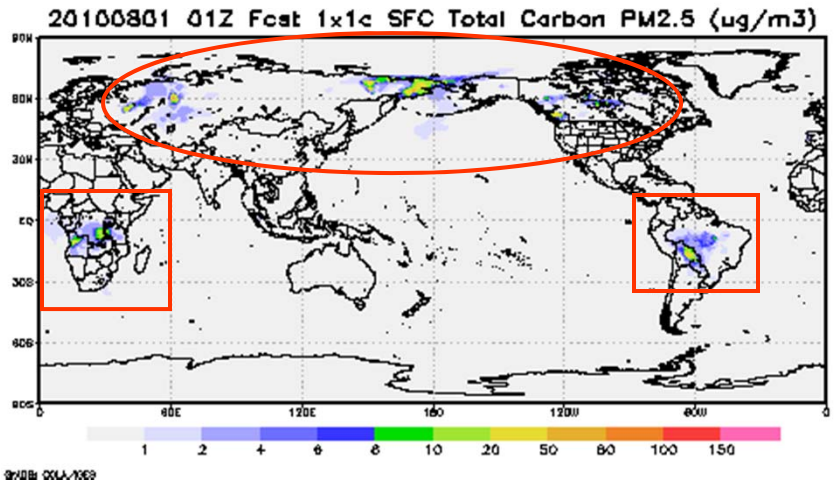
GBBEP

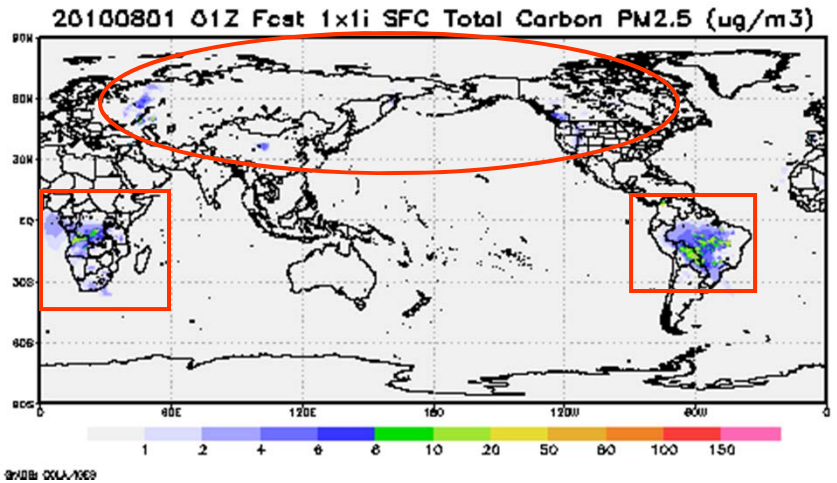
Total Column Conc.





Surface Layer Conc.





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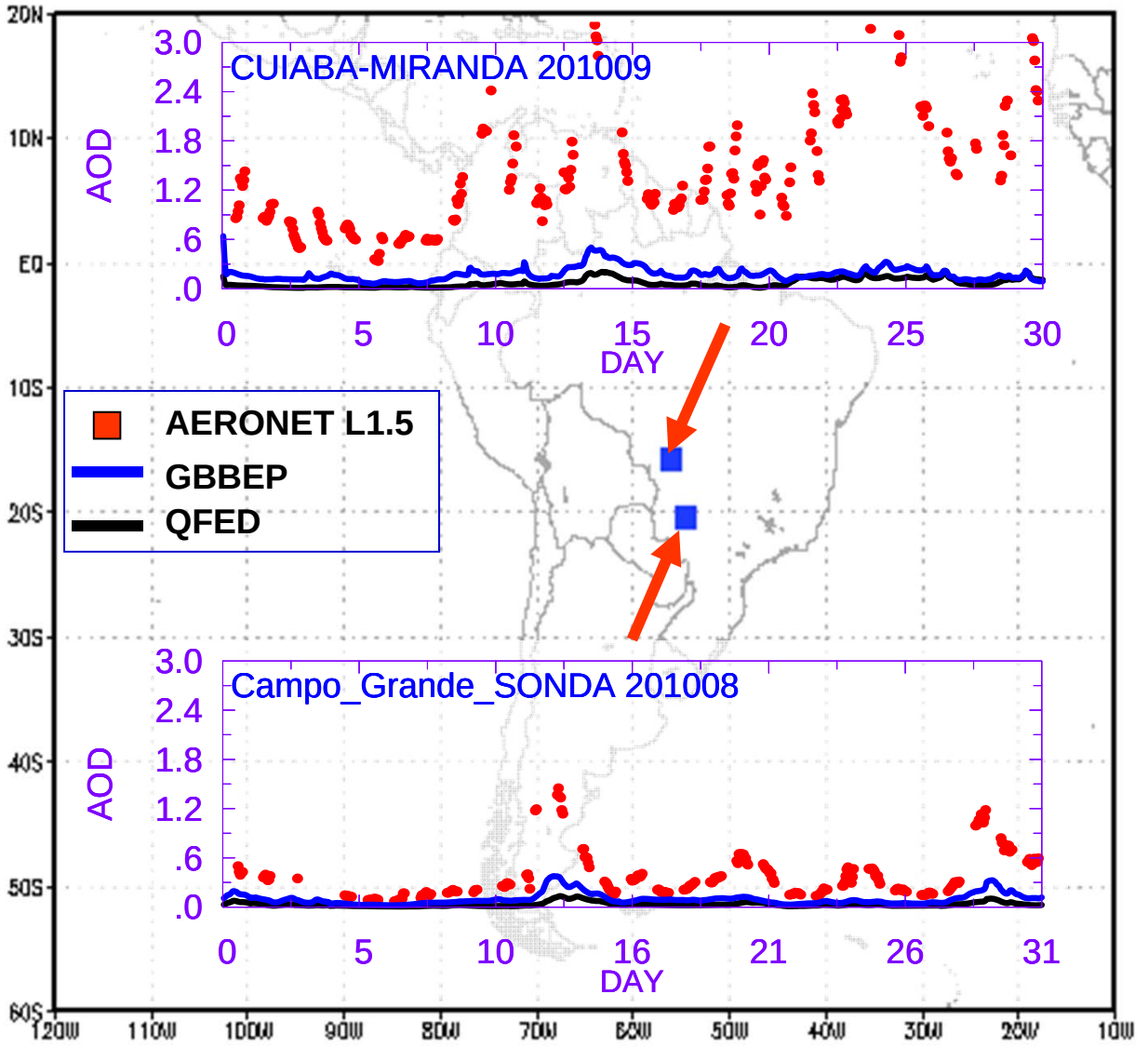
The comparison between observed and modeled AOD

1. Both model-derived AOD using GBBEP and QFED were much smaller than AERONET observed AOD
2. It is because satellite detected fire appeared only in a small viewing area (e.g., 1 km^2), and the derived carbon emissions were quickly diluted in a model grid that has a much larger area (global 1°x1°).
3. Reid et al. (JSTARS, 2010) and Yang et al. (JGR, 2011) found that biomass burning emissions have to be scaled by a factor of 3 in the models.
4. **The occurrences of fire event match well with the jump of observed AOD.**



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Future Tasks

- **GSI Global Aerosol Data Assimilation**
  - Obtain the statistics for error covariance matrix of aerosols
  - Develop capability to assimilate aerosol observations (AOD)
  - Conduct global aerosol data assimilation
  - **Study impact of aerosol assimilation on NAQFC aerosol forecast**
  - **Study impact of aerosol assimilation on global weather forecast**
- **Global Biomass Burning Emissions Product (GBBEP)**
  - Run in-line NEMS/GFS-GOCART and compare the results with offline GFS-GOCART simulations
  - Run NAQFC with forecasted NEMS/GFS-GOCART dust and biomass burning aerosols LBC and evaluate the runs


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Acknowledgement

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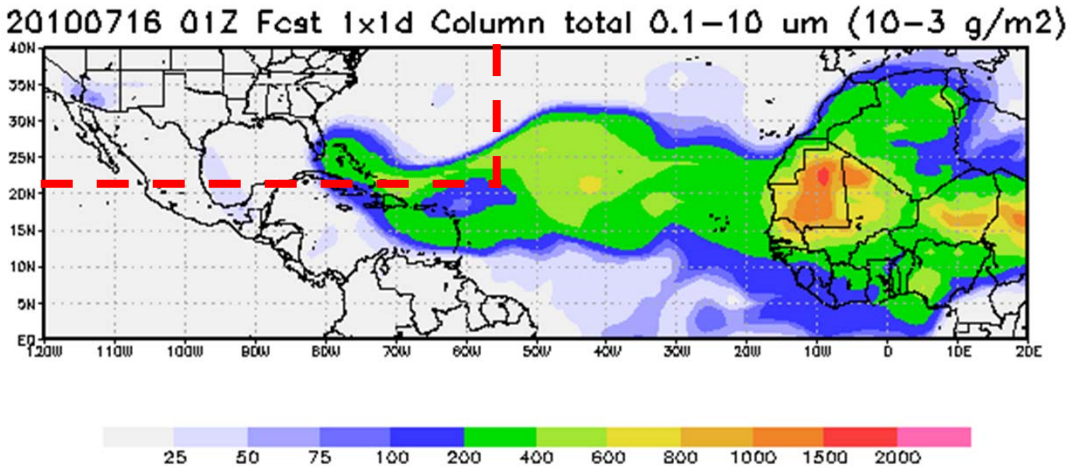
Support Operational CONUS Air Quality Forecasting Efforts at NCEP

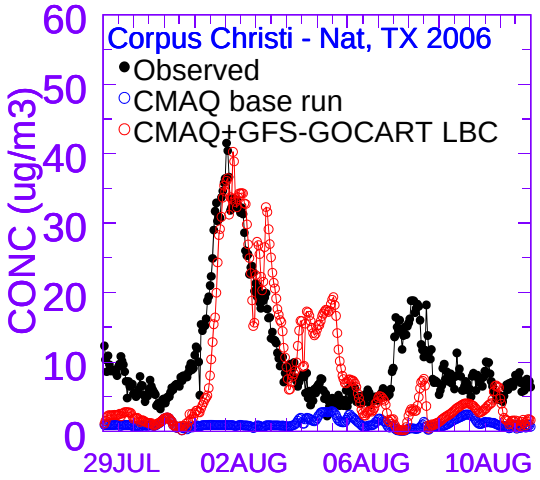
Sahara Dust Intrusion to CONUS During Summertime

Sahara dust intrusion Episodes in July 2010; impact on the Gulf Coast and South Atlantic Coast states.



The GFS-GOCART aerosol simulations provide dynamic LBCs to National Air Quality Forecast Capability (AQFC) to identify the intrusion due to long range transport.

Offline GFS-GOCART dust simulation during 2006 TEXAQS with LBC coupling CMAQ shows that the timing of dust episode is well simulated and the improvement of CMAQ PM forecast is significant.



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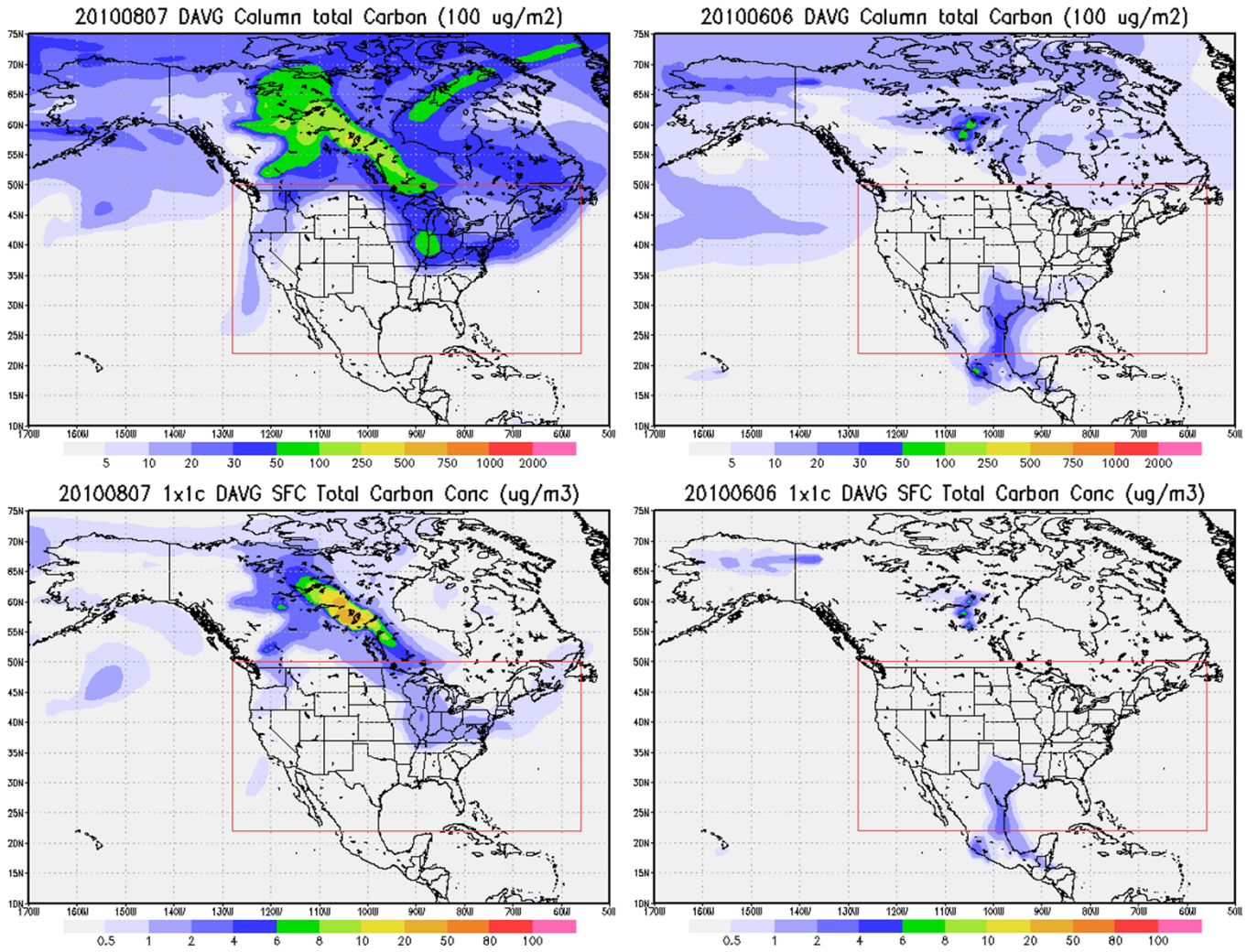
Long-Range Transport impact on CONUS PM Forecasting



Canadian Boreal Fire **Mexican Fire**

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