



# GEOS-5 Aerosol Modeling & Data Assimilation: *Update on Recent and Future Development*

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*(1) Global Modeling and Assimilation Office, NASA/GSFC*

*(2) Atmospheric Chemistry and Dynamics Branch, NASA/GSFC*

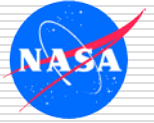
*(3) GESTAR*

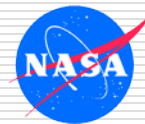
*(4) Science Applications International Corp.*

*(5) Earth Resource Technology*

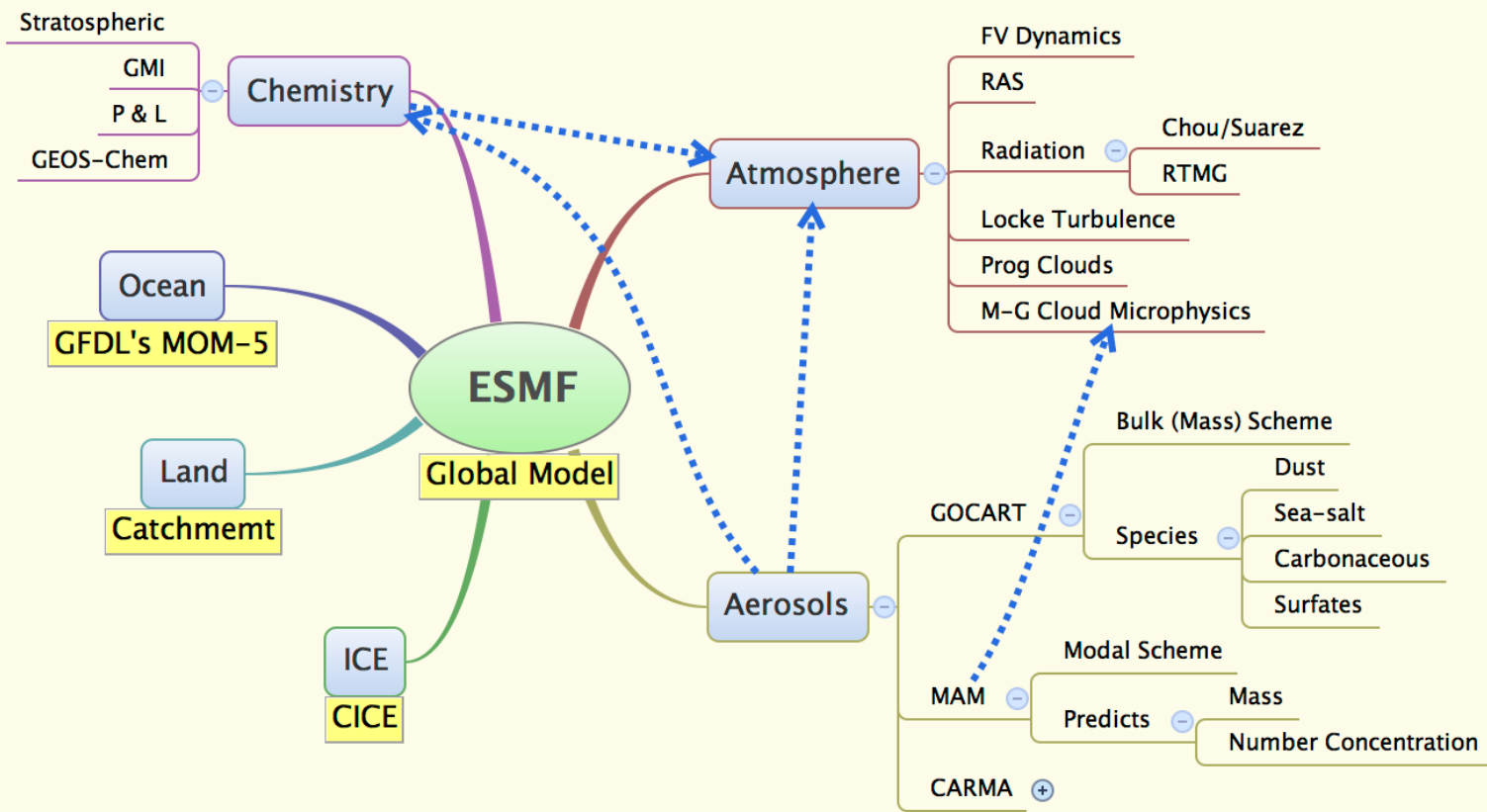
*AEROCENTER Annual Meeting  
GSFC Visitor Center  
Greenbelt, MD, 31 May 2013*

# Talk Overview

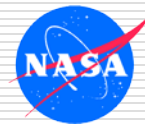




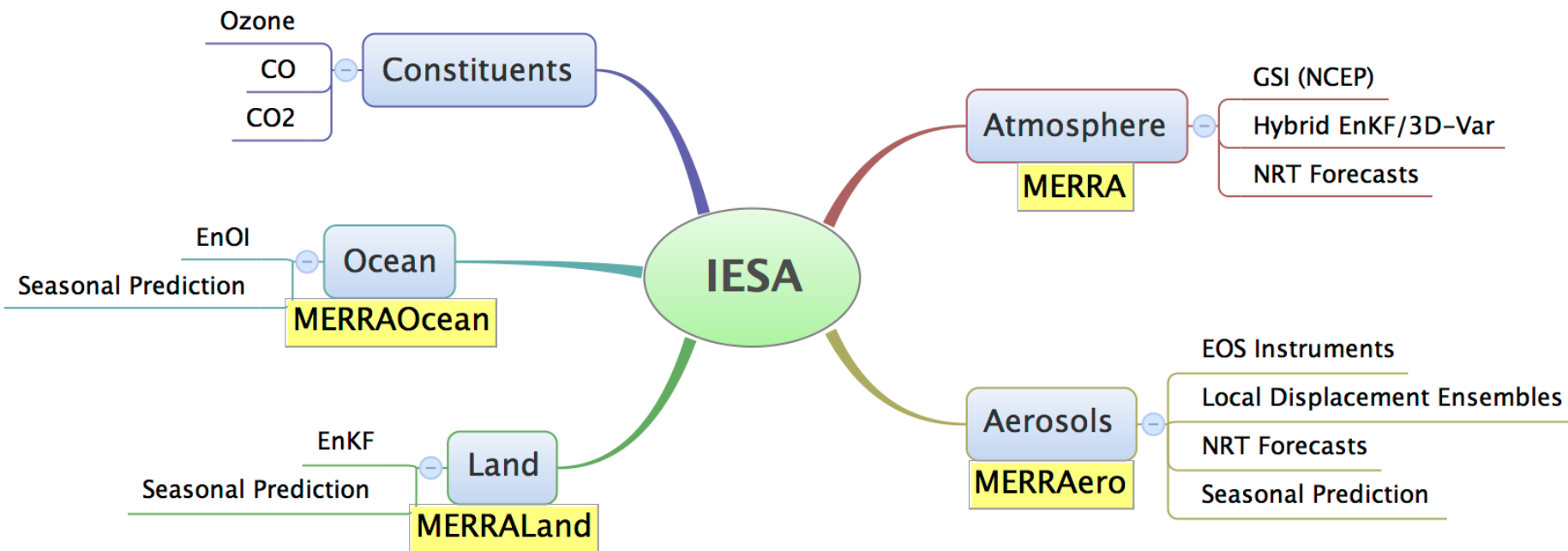
# GEOS-5 Earth-System Model



From weather to seasonal to decadal time scales



# Integrated Earth System Analysis

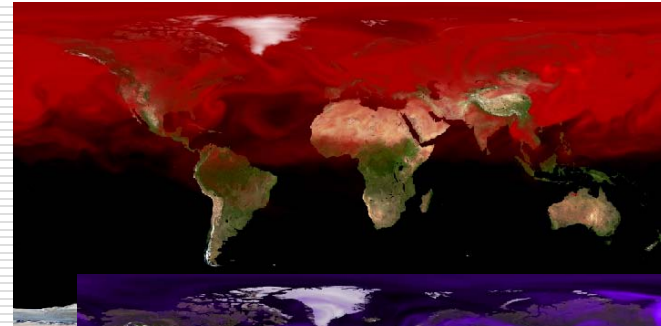


Data Assimilation in GEOS-5

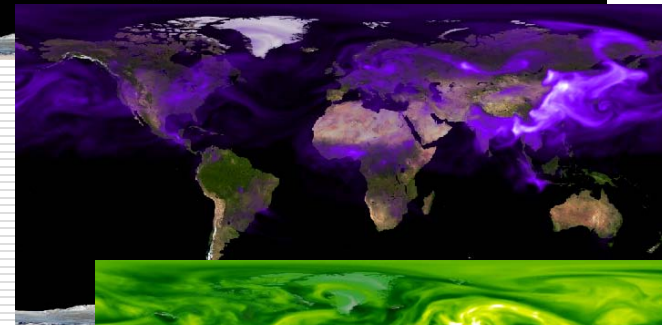
# GEOS-5 Forecasting Support

DISCOVER-AQ

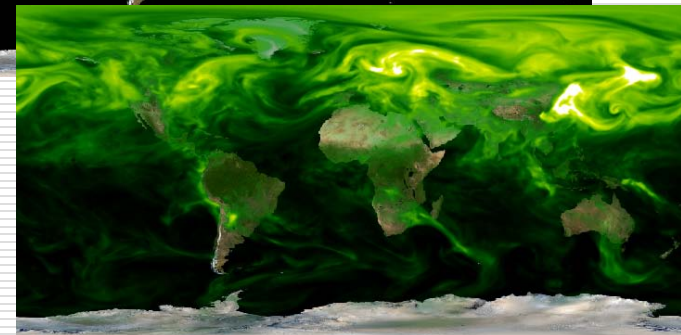
- Global 5-day chemical forecasts customized for each campaign
  - O<sub>3</sub>, aerosols, CO, CO<sub>2</sub>, SO<sub>2</sub>
  - Resolution: **Nominally 25 km**
- Driven by real-time biomass emissions from MODIS
- Assimilated aerosols interacts with circulation through radiation



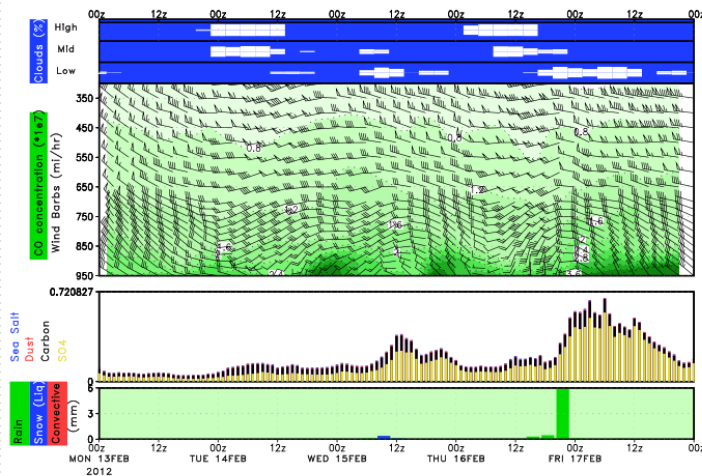
CO



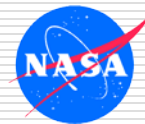
Smoke



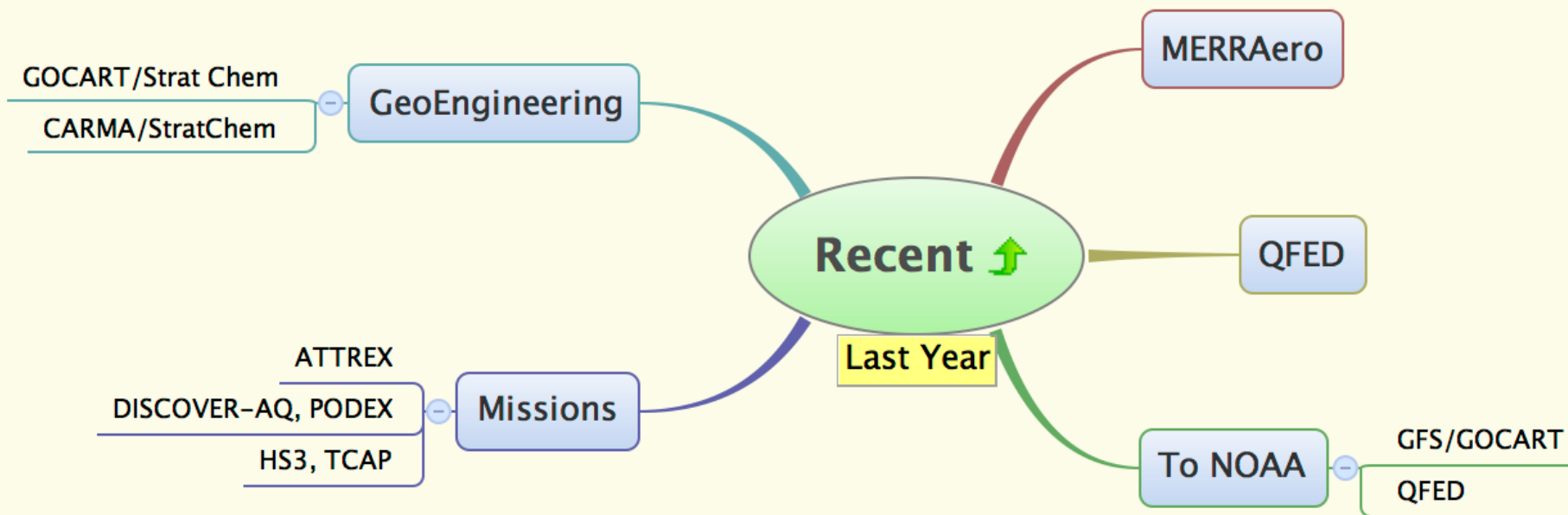
SO<sub>4</sub>

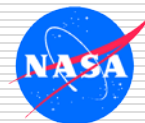


<http://gmao.gsfc.nasa.gov/forecasts/>



# Past Year Highlights

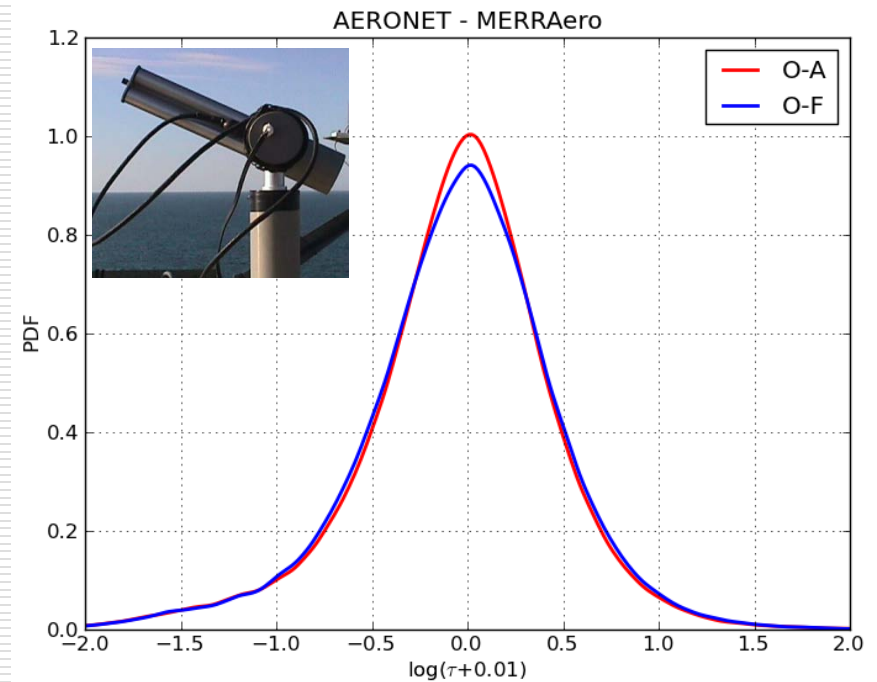
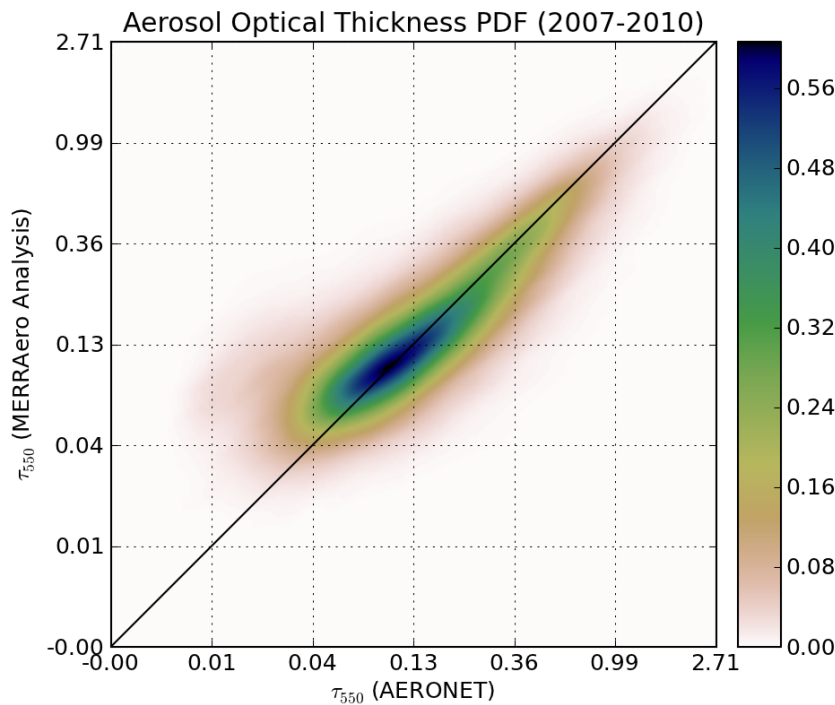
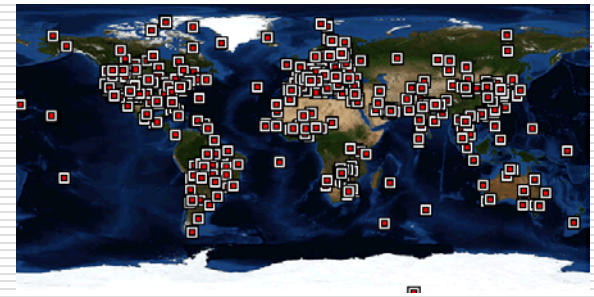




# MERRAero Overview

Feature	Description
<b>Model</b>	GEOS-5 Earth Modeling System (w/ GOCART) Constrained by MERRA Meteorology (Replay) Land sees obs. precipitation (like MERRA <i>Land</i> ) Driven by QFED daily Biomass Emissions
<b>Aerosol Data Assimilation</b>	Local Displacement Ensembles (LDE) MODIS reflectances AERONET Calibrated AOD's (Neural Net) Stringent cloud screening
<b>Period</b>	mid 2002-present (Aqua + Terra)
<b>Resolution</b>	Horizontal: nominally 50 km Vertical: 72 layers, top ~85 km
<b>Aerosol Species</b>	Dust, sea-salt, sulfates, organic & black carbon <sub>7</sub>

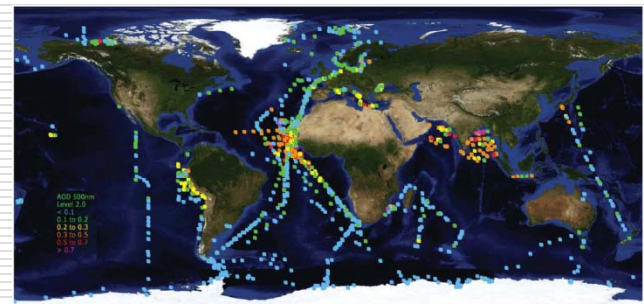
# AERONET Validation



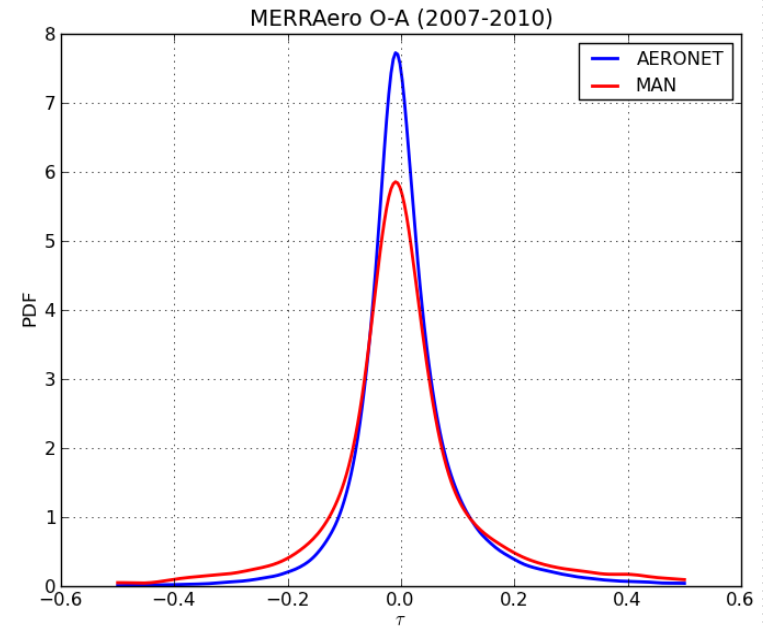
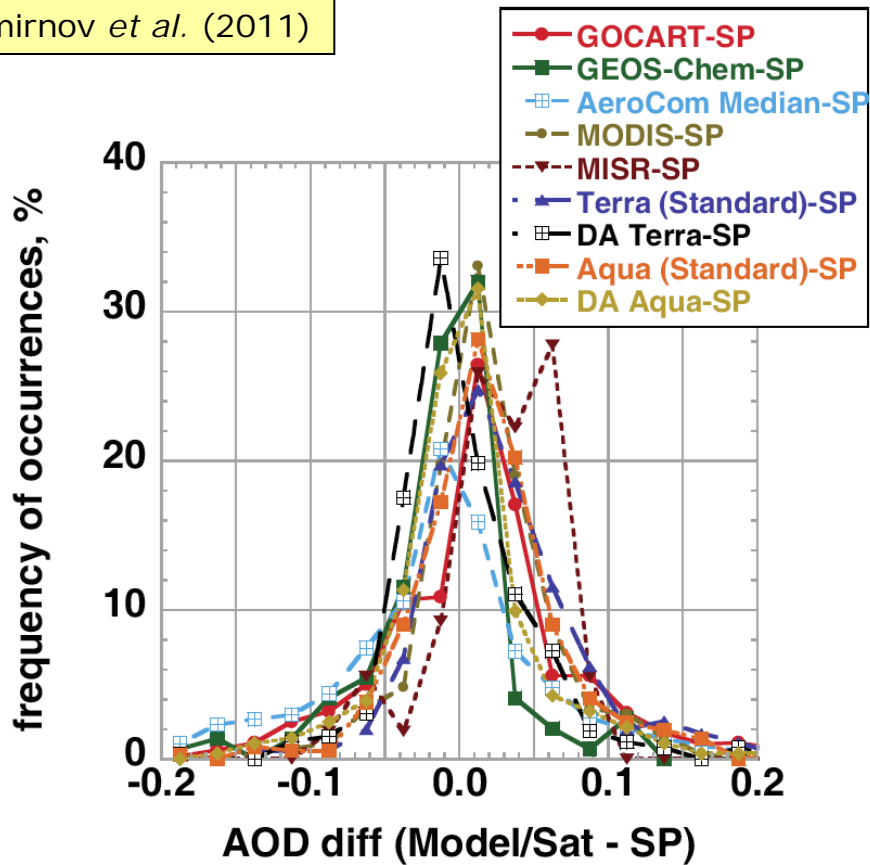
$$\eta = \log(\tau + 0.01)$$



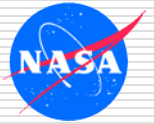
# Maritime Aerosol Network



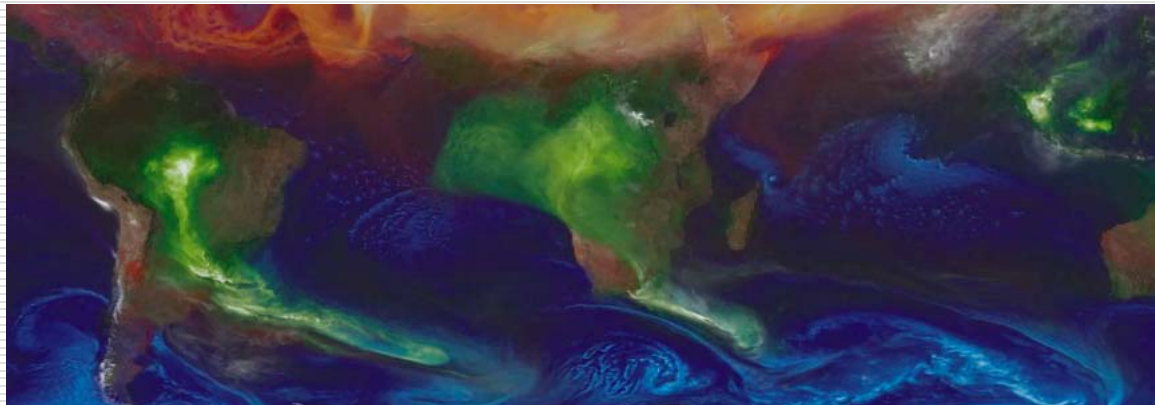
Smirnov *et al.* (2011)



# QFED: Quick Fire Emission Dataset



- ❑ Top-down algorithm based on MODIS Fire Radiative Power (AQUA/TERRA)
- ❑ FRP Emission factors tuned by means of inverse calculation based on MODIS AOD data.
- ❑ Daily mean emissions, NRT (thanks to LANCE)
- ❑ Prescribed diurnal cycle



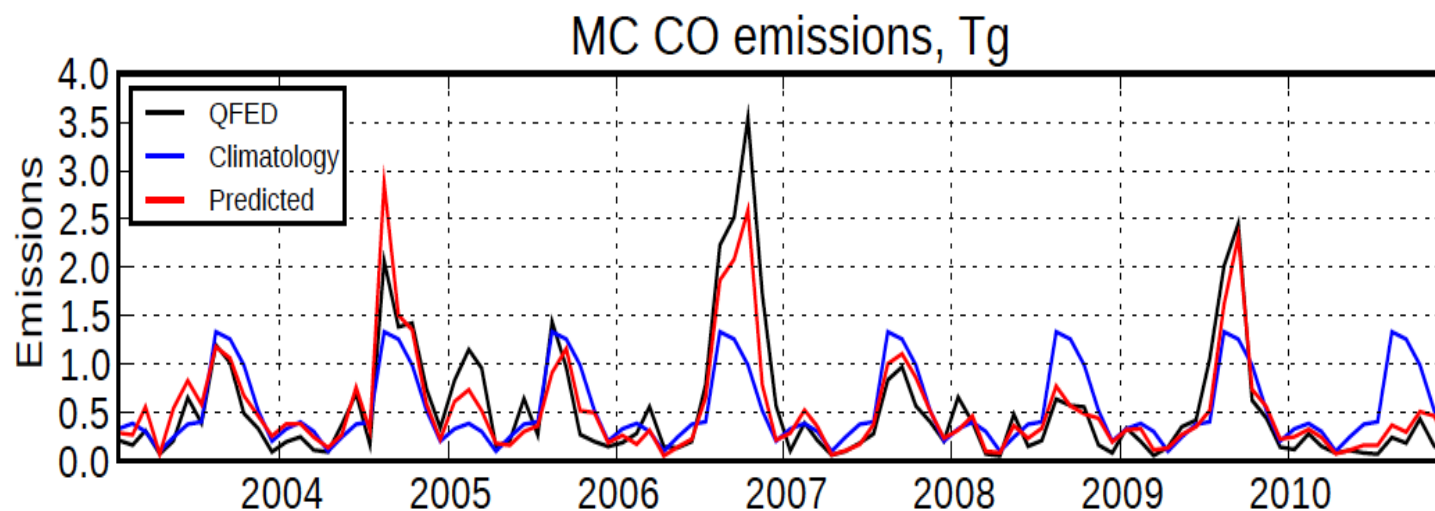
JCSDA: inclusion of geo-stationary information

# Modeling Interannual Variability of Biomass Burning Emissions

- BB emission anomalies respond directly to precipitation and surface humidity conditions
- The normalized Canadian Fire Weather Index captures the *fammability* conditions as a function of surface meteorology

- Parameterization:

$$E = \varepsilon \left( \frac{I}{I_{clm}} \right)^{\alpha_b} E_{clm}$$





# GEOS-5/GOCART Transition to NCEP GFS



Development and operational implementation of the NEMS-GFS Aerosol Component represents a successful three-year “research to operations” project sponsored by NASA Applied Science Program, JCSDA and NWS

Operational September 2013



- Mark Iredell (NEMS team lead)
- Sarah Lu (aerosol modeling)
- Shrinivas Moorthi (physics)
- Yu-Tai Hou (radiation-aerosol)
- Henry Juang (dynamics)
- Jun Wang (I/O and ESMF infrastructure)
- Hui-Ya Chuang (unified post)
- Weiyu Yang (ESMF infrastructure)
- Perry Shafran (verification)

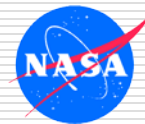


## Collaborators

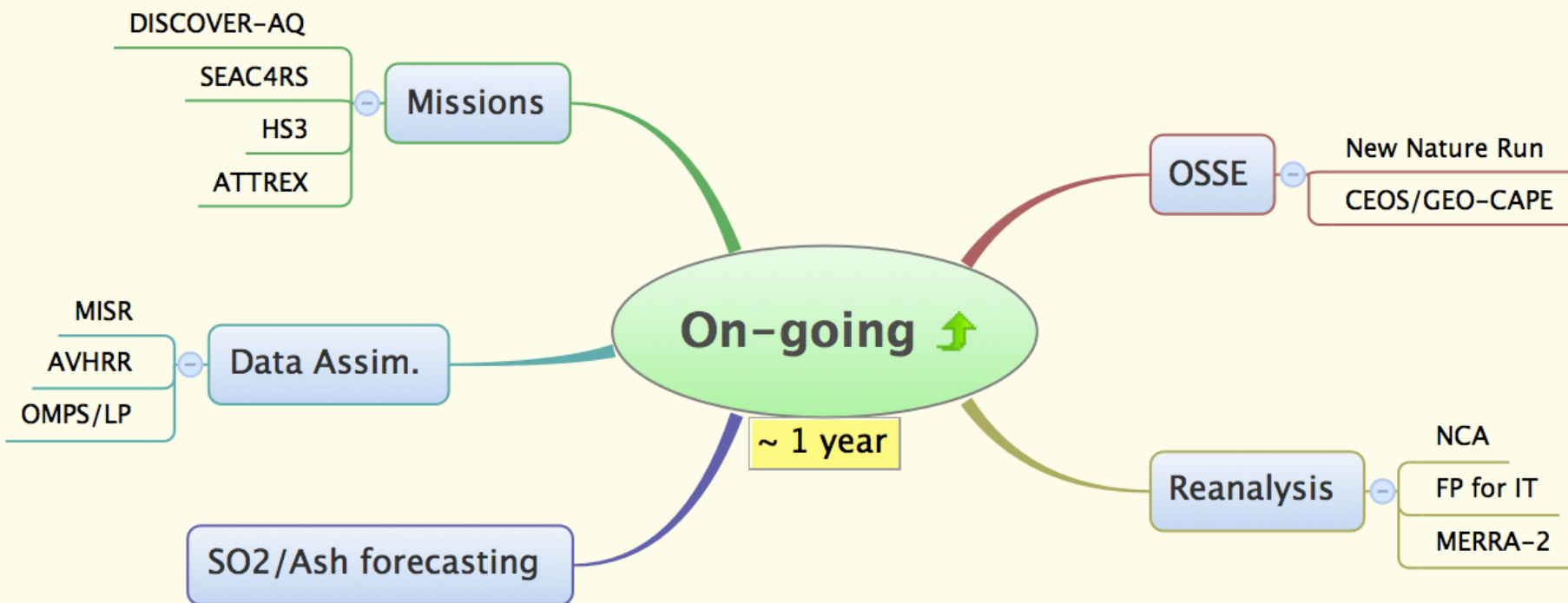
- GSFC** (Arlindo da Silva, Mian Chin, Peter Colarco) for aerosol modeling
- NESDIS** (Shobha Kondragunta and Xiaoyang Zhang) for biomass burning emissions
- NRL** (Jeff Reid, Walter Sessions) for model inter comparison
- ECMWF** (Angela Benedetti, Jean Jacques Morcrette, Johannes Kaiser, Luke Jones) for volcanic ash

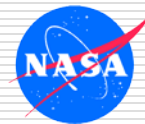
Courtesy: Sarah Lu

- Joint NASA/GMAO, NESDIS/STAR, and NWS/NCEP project to:
  - Develop near real time biomass burning emissions product covering the whole globe from polar and geostationary satellites for NEMS-GFS-GOCART
    - Globally, biomass burning is one of the primary sources of aerosols; burning varies seasonally, geographically and is either natural (e.g., forest fires induced by lightning) or human induced (e.g., agricultural burning for land clearing). Satellites can provide this information on a real time basis.
  - Develop and deploy a global aerosol prediction system that can in the future assimilate satellite-derived atmospheric composition parameters
- Meet Research (NASA) to Operations (NOAA) goals of the JCSDA
  - QFED code transitioned from NASA to NOAA in 2013



# Short Term





# GEOS-5 Reanalyzes

Name	Nominalk Resolution	Period	Aerosol Data	Available
MERRA-1	50 km	1979-present	NONE	now
MERRAero	50 km	2002-present	MODIS C5	now
FP for Inst. Teams	50 km	1997-	MODIS C5	In progress
NCA	25 km	2010-	MODIS C5, MISR	In progress
MERRA-2	50 km	1979-present	AVHRR, SeaWIFS, MODIS C5, MISR	Late 2013/2014

# A global GEO OSSE activity for GEO-CAPE & CEOS

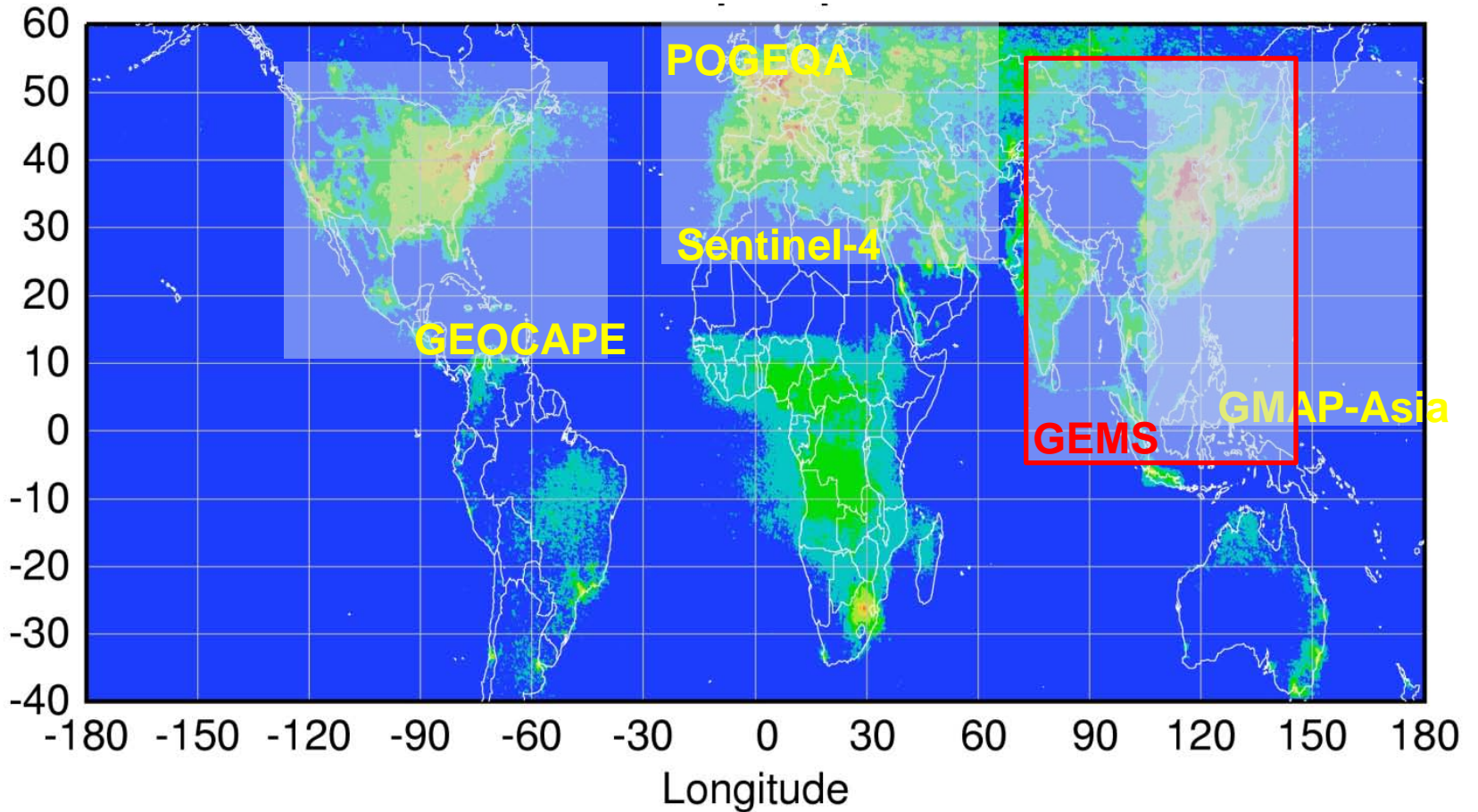


**David Edwards (NCAR) and  
Arlindo da Silva (NASA GSFC)  
with input from the GEO-CAPE SWG  
CEOS/MACC-II OSSE Workshop**



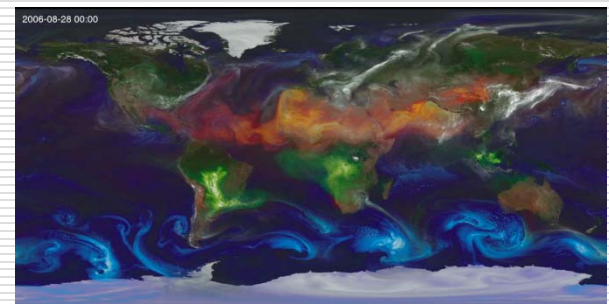


# Geostationary Satellite Constellation for Observing Air-quality



(Richter, 2005)

# GEOS-5 Global 7 km Nature Run



## □ Components

- Atmospheric GCM on cubed-sphere, **non-hydrostatic**
- Prescribed SST, sea-ice
- Constituents
  - Radiatively coupled aerosols
  - Carbon species
  - GMI Combo Chemistry (\*)

## □ Emissions

- Prescribed daily biomass-burning emissions (QFED)
- New dust source function from Ginoux
- Anthropogenic inventories downscaled to 10km

## □ GEOS-5 2013 NR

- Global, 7 km
- Aerosol, parameterized Chemistry
  - ~2 years **simulation**
  - May 2005 – May 2007
- Aerosol, full chemistry
  - ~ 1 month (TBD)
- Availability
  - Free, on-line
  - ~ August 2013

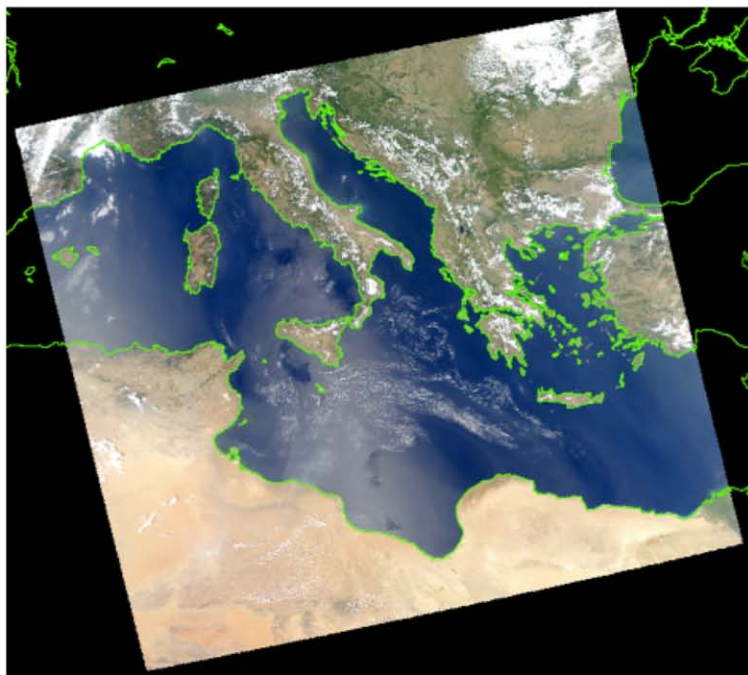
## □ GEOS-5 2016+ NR

- Global, 3.5 km
- Improved model
- Cloud-aerosol microphysics, etc.

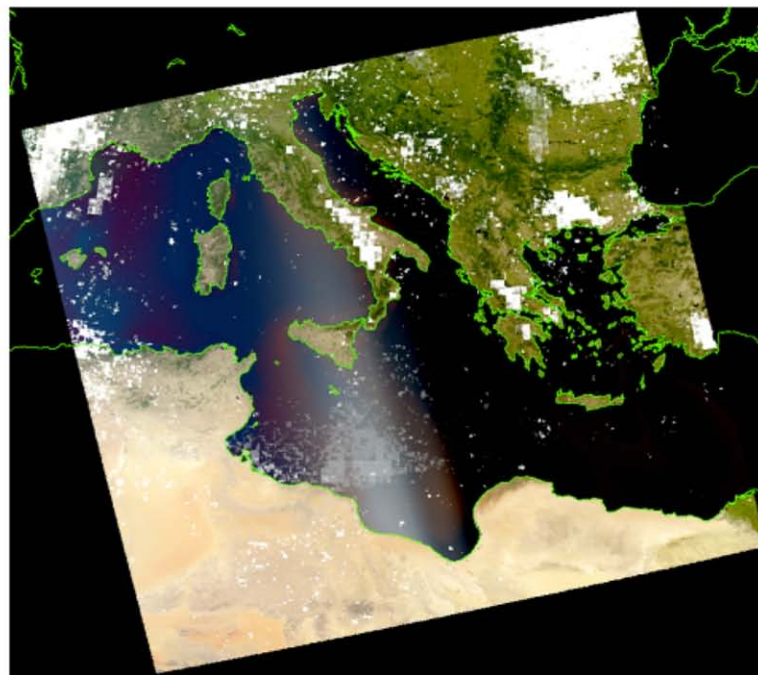
(\*) GMI combo chemistry used for short experiments only.

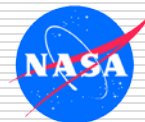
# MODIS Level 1/2 Simulator

a) Actual RGB composite

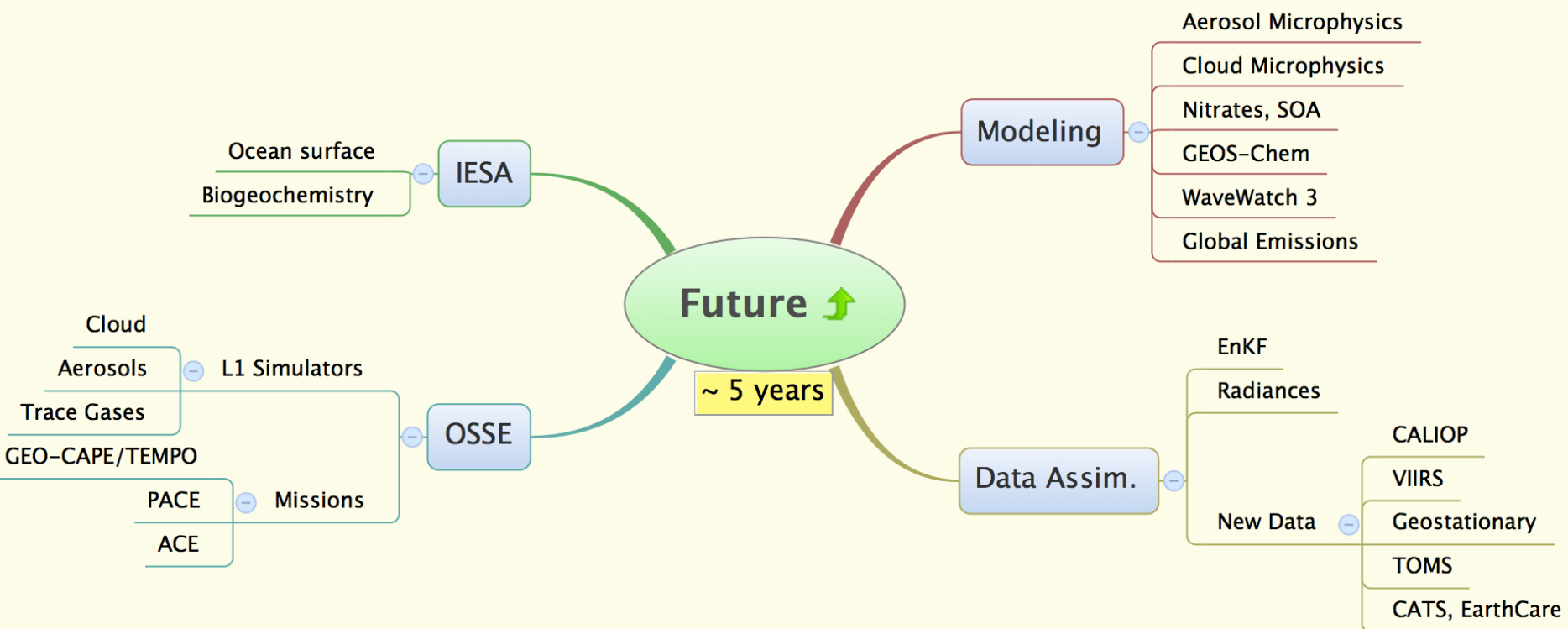


b) Simulated RGB composite





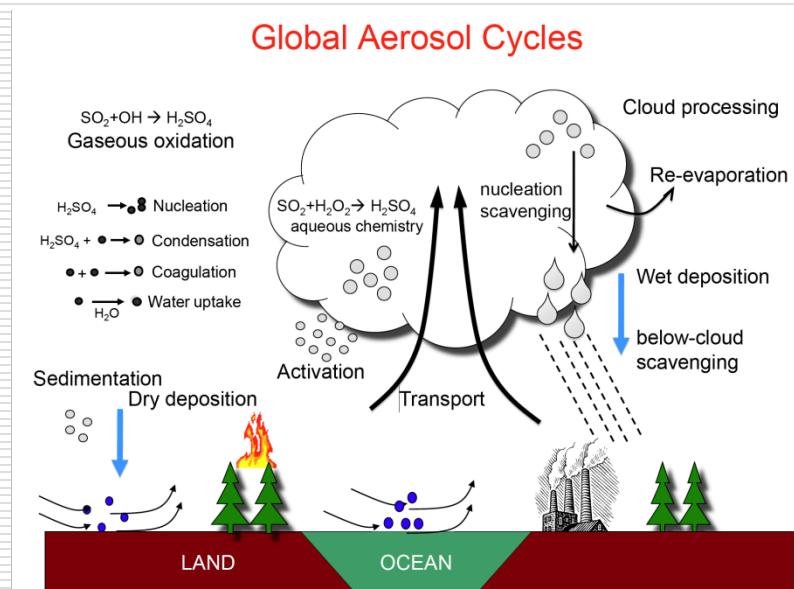
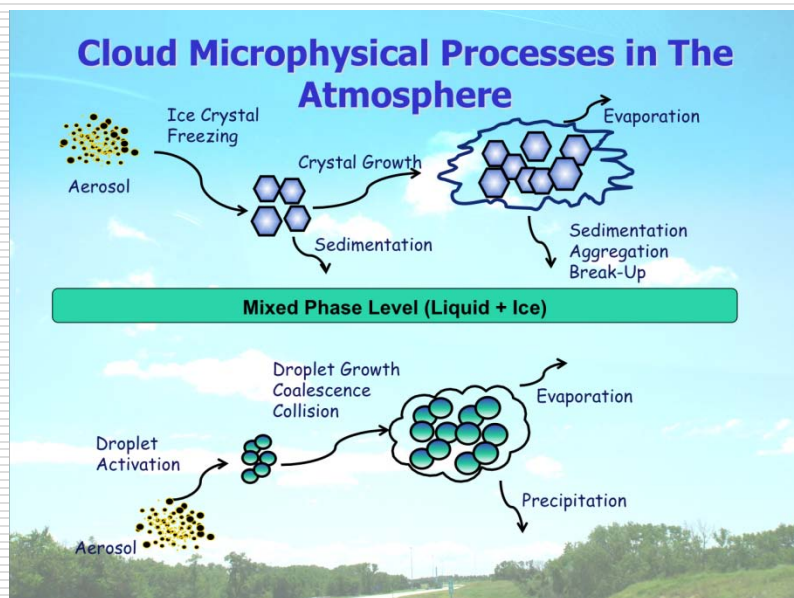
# Mid- to Long-Term



# Aerosol-Cloud Interactions

## New Cloud Microphysics

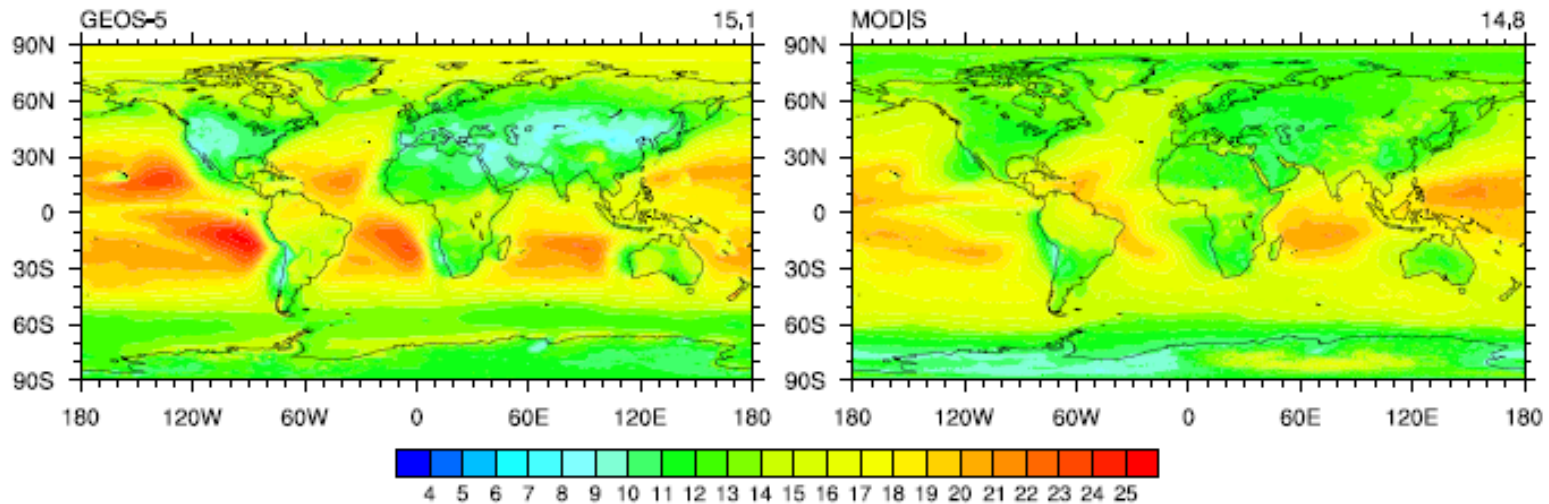
## Requires Aerosol Microphysics



Prediction of aerosol mass & number

# New Cloud Microphysics

- Two-moment cloud microphysics for stratus and convective clouds (Morrison and Gettelman, 2008, Barahona et al. 2013).
- Explicit ice nucleation (Barahona and Nenes, 2009) and CCN activation (Fountoukis and Nenes, 2005) coupled to GOCART aerosol.
- New cloud fraction scheme.



Annual Mean Cloud Droplet Effective radius ( $\mu\text{m}$ )

- Great improvement in the representation of liquid and ice water content.
- Effective sizes are explicitly calculated accounting for aerosol effects.
- More realistic cloud fields (cloud water path, cloud fraction, optical thickness).

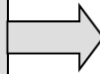
# 7-Mode Modal Aerosol Module (MAM)

ESMF Component Derived from CAM5 Implementation

In Collaboration with Xiaohong Liu, Steve Gahn (PNNL)

## Aitken

number  
sulfate  
ammonium  
secondary OM  
sea salt



## Accumulation

number  
sulfate  
ammonium  
secondary OM  
hydrophobic OM  
BC  
sea salt

coagulation  
condensation



## Fine Soil Dust

number  
soil dust  
sulfate  
ammonium

## Fine Sea Salt

number  
sea salt  
sulfate  
ammonium

All modes log-normal  
with prescribed width.

Total transported  
aerosol tracers: 31

Cloud-borne aerosol  
and aerosol water  
predicted but not  
transported.

## Primary Carbon

number  
hydrophobic OM  
BC

## Coarse Soil Dust

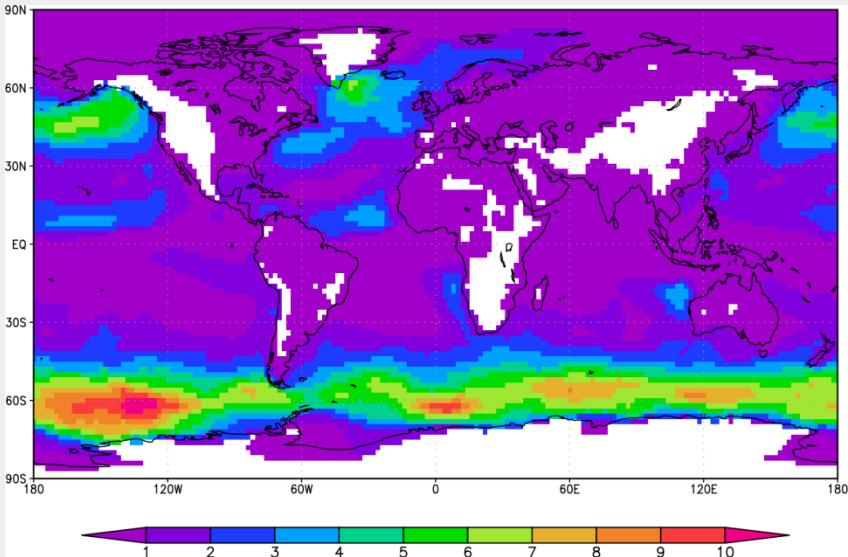
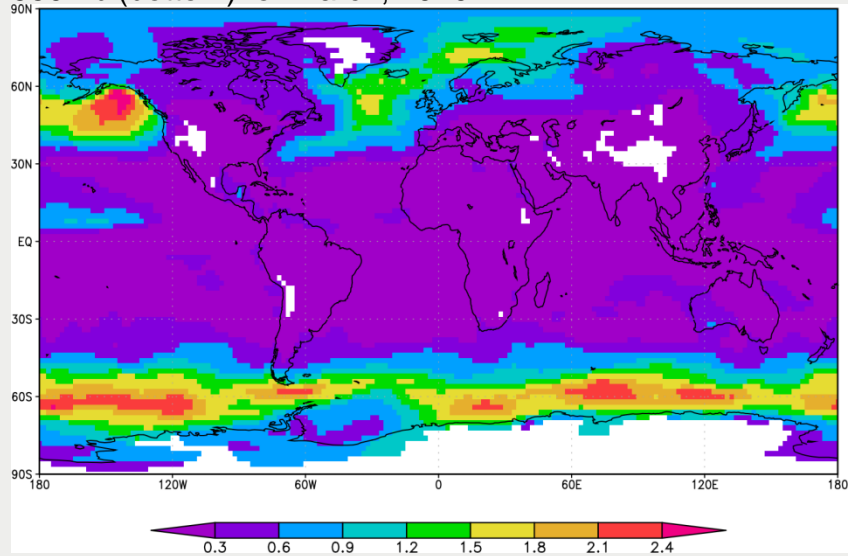
number  
soil dust  
sulfate  
ammonium

## Coarse Sea Salt

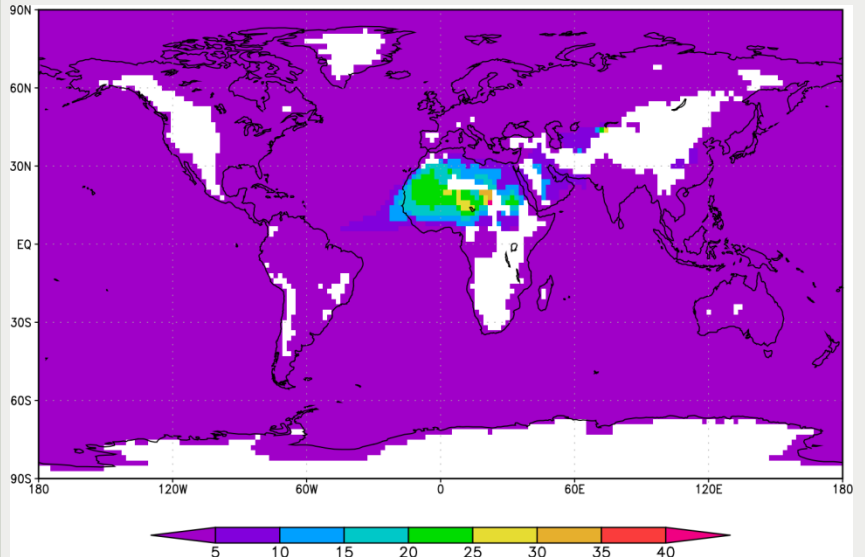
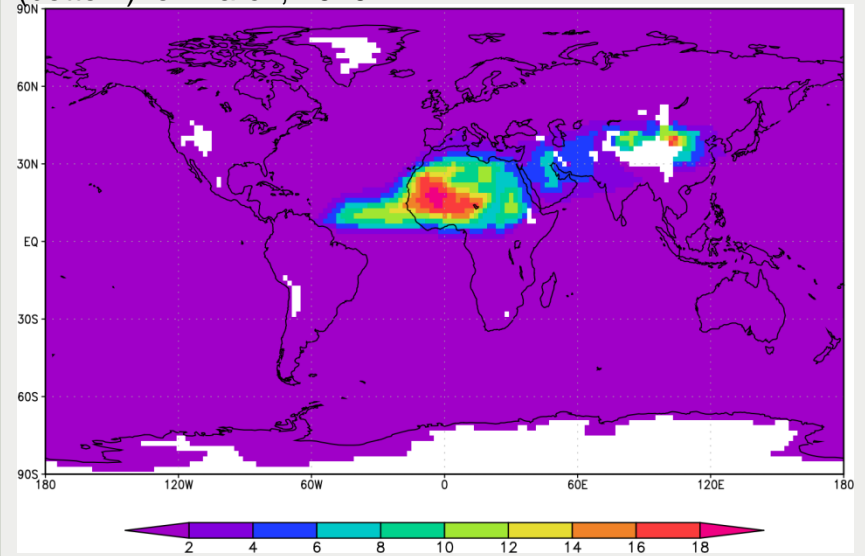
number  
sea salt  
sulfate  
ammonium

# Number concentration

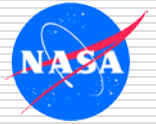
Number concentration (cm<sup>-3</sup>) of aerosol particles in the fine sea-salt mode. Monthly mean values at 850mb (top) and 950mb (bottom) for March, 2010.



Number concentration (cm<sup>-3</sup>) of aerosol particles in the fine dust mode. Monthly mean values at 850mb (top) and 950mb (bottom) for March, 2010.







# Summary

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- Aerosols are an integral part of the GEOS-5 modeling and data assimilation systems
- General framework: *Integrated Earth System Analysis* (IESA)
- Capabilities
  - Prediction from weather to decadal scales
  - Assimilated datasets for synthesizing the information content of models and satellite data
  - OSSEs for supporting future NASA observing mission
- Close collaboration between modelers and data producers is key.