GEOS-5 Aerosol Modeling & Data Assimilation:

Update on Recent and Future Development

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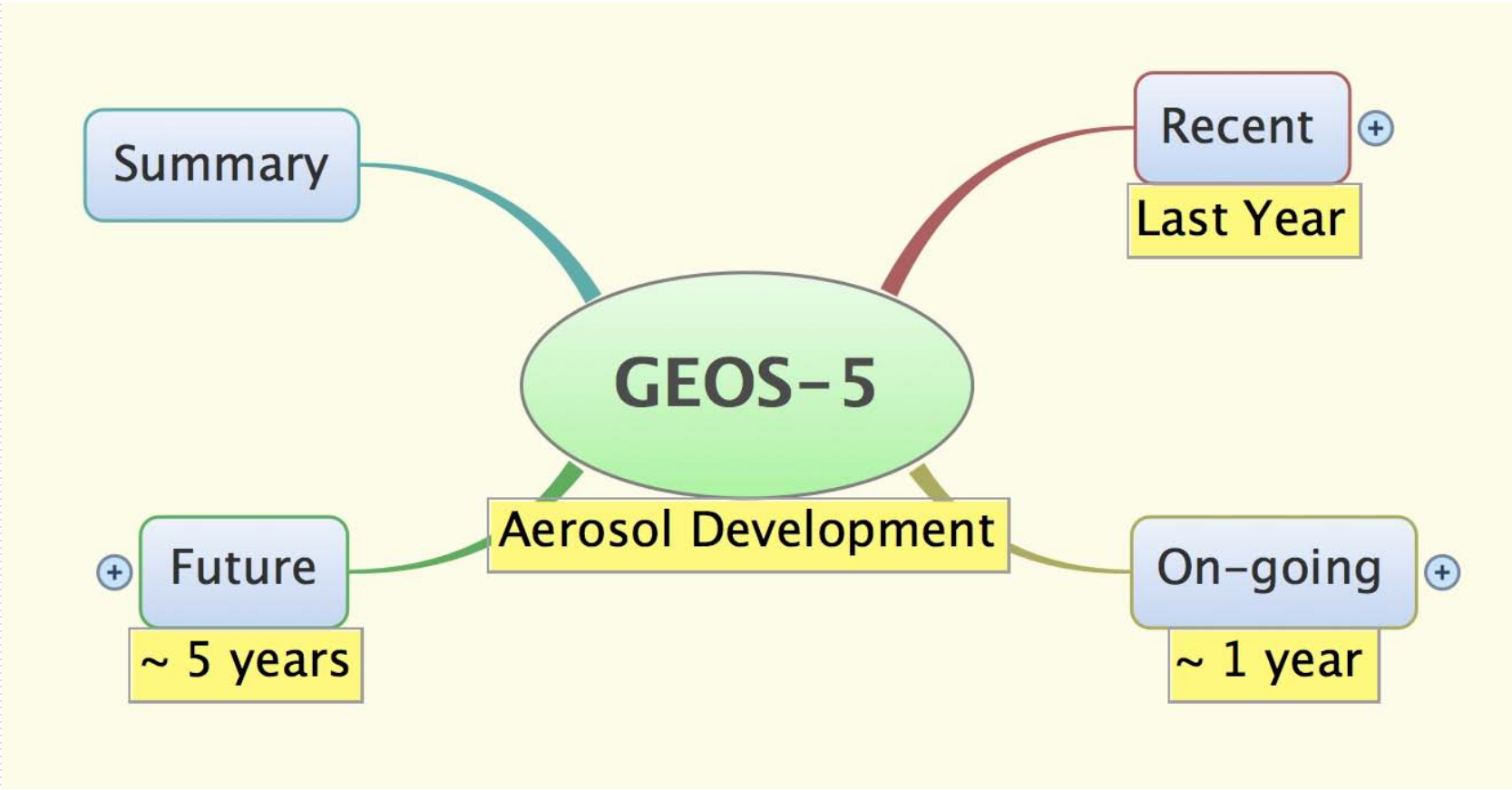
(3) GESTAR

(4) Science Applications International Corp.

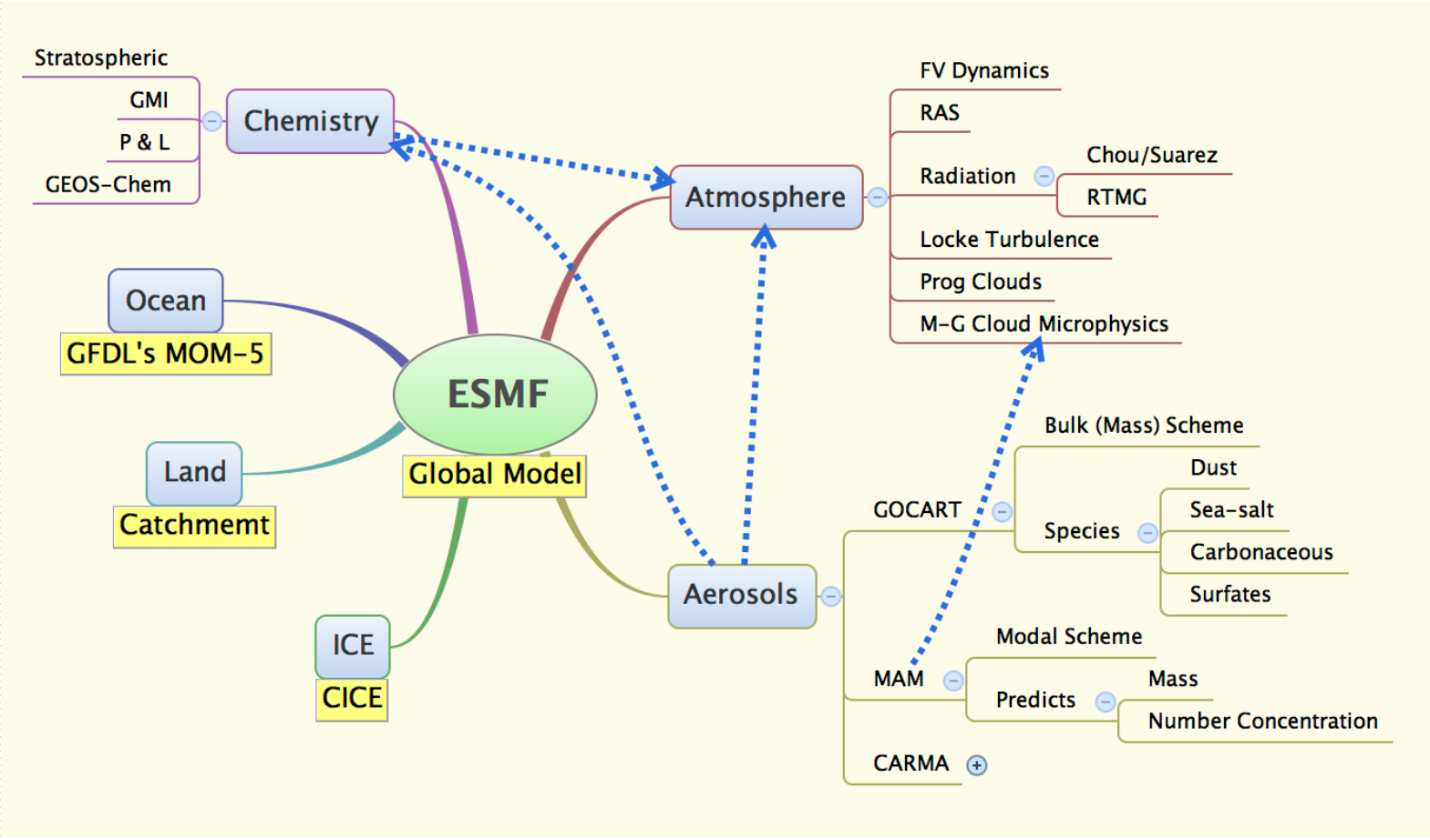
(5) Earth Resource Technology

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

Talk Overview

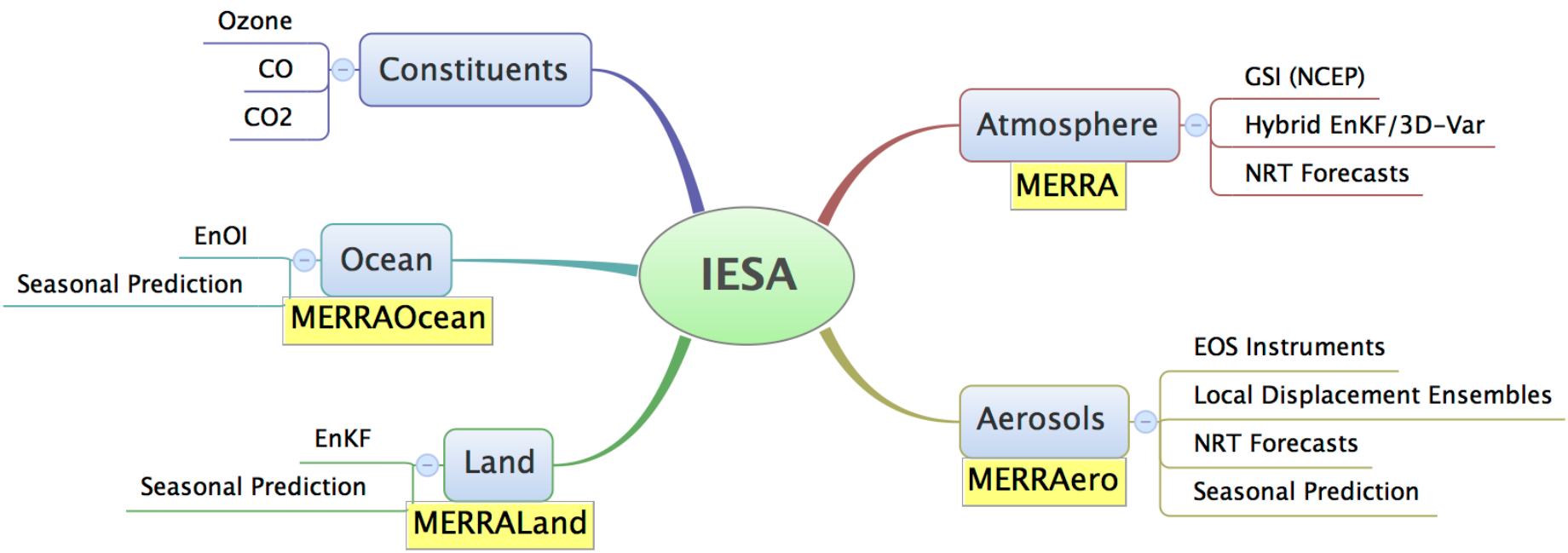


GEOS-5 Earth-System Model



From weather to seasonal to decadal time scales

Integrated Earth System Analysis

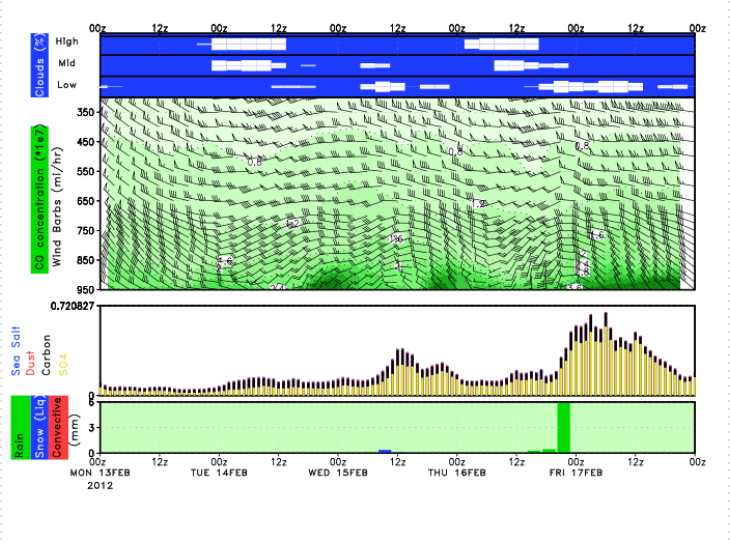


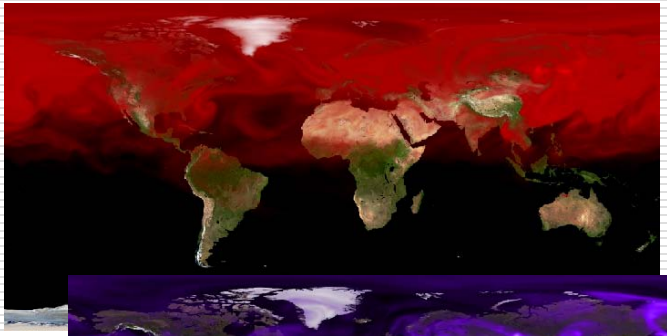
Data Assimilation in GEOS-5

GEOS-5 Forecasting Support

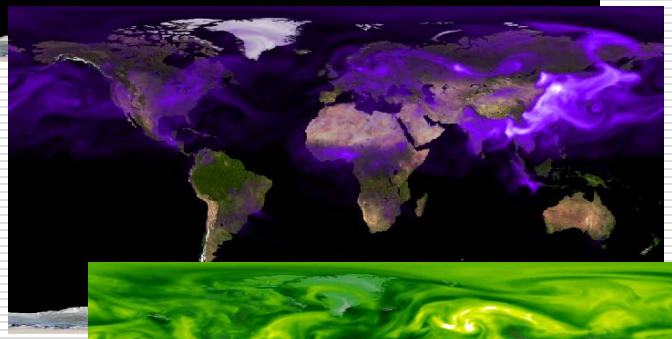
DISCOVER-AQ

- Global 5-day chemical forecasts customized for each campaign
  - O3, aerosols, CO, CO_2, SO_2
  - Resolution: Nominally 25 km
- Driven by real-time biomass emissions from MODIS
- Assimilated aerosols interacts with circulation through radiation

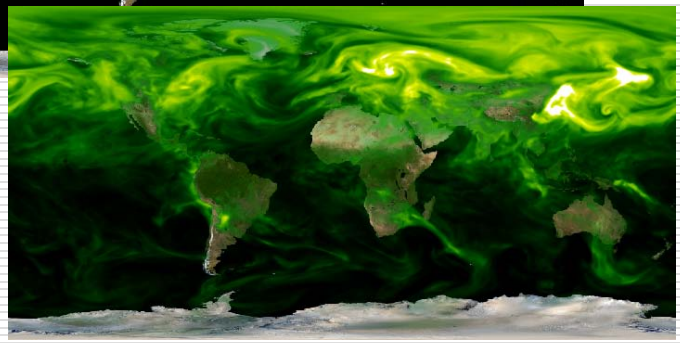




CO



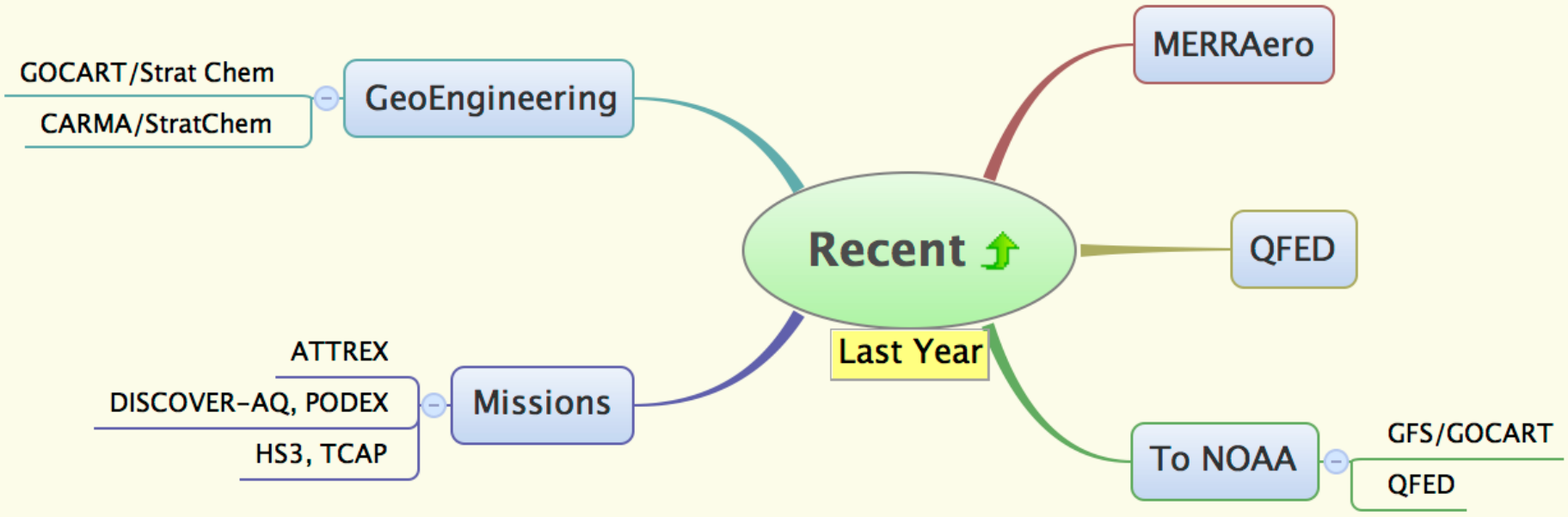
Smoke



SO_4

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

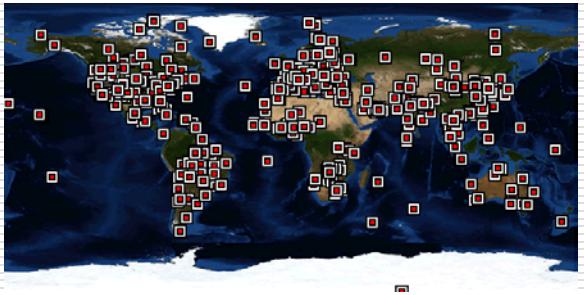
Past Year Highlights

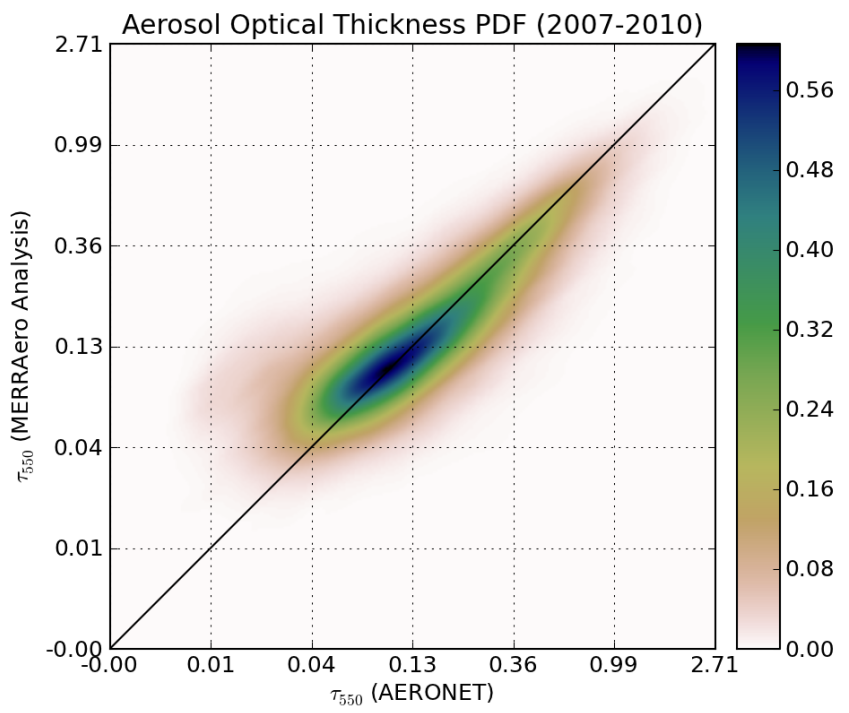


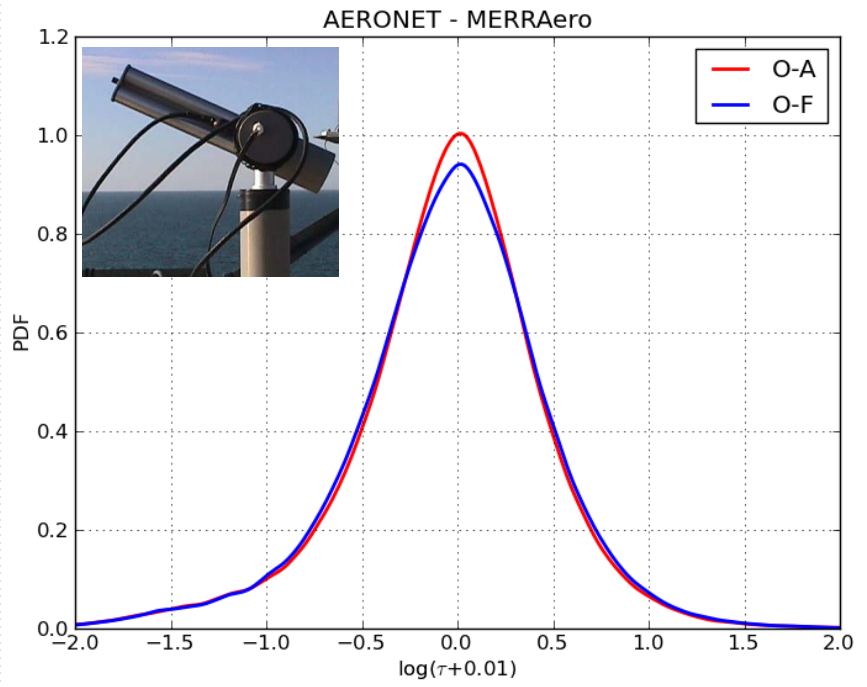
MERR*Aero* Overview

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

AERONET Validation

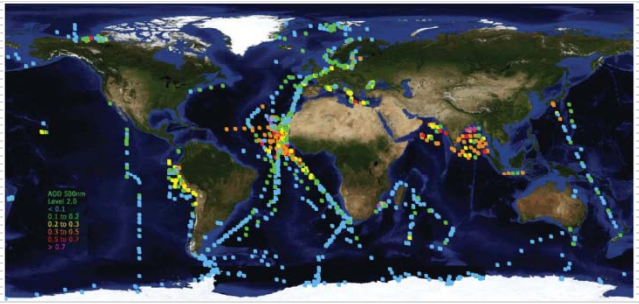




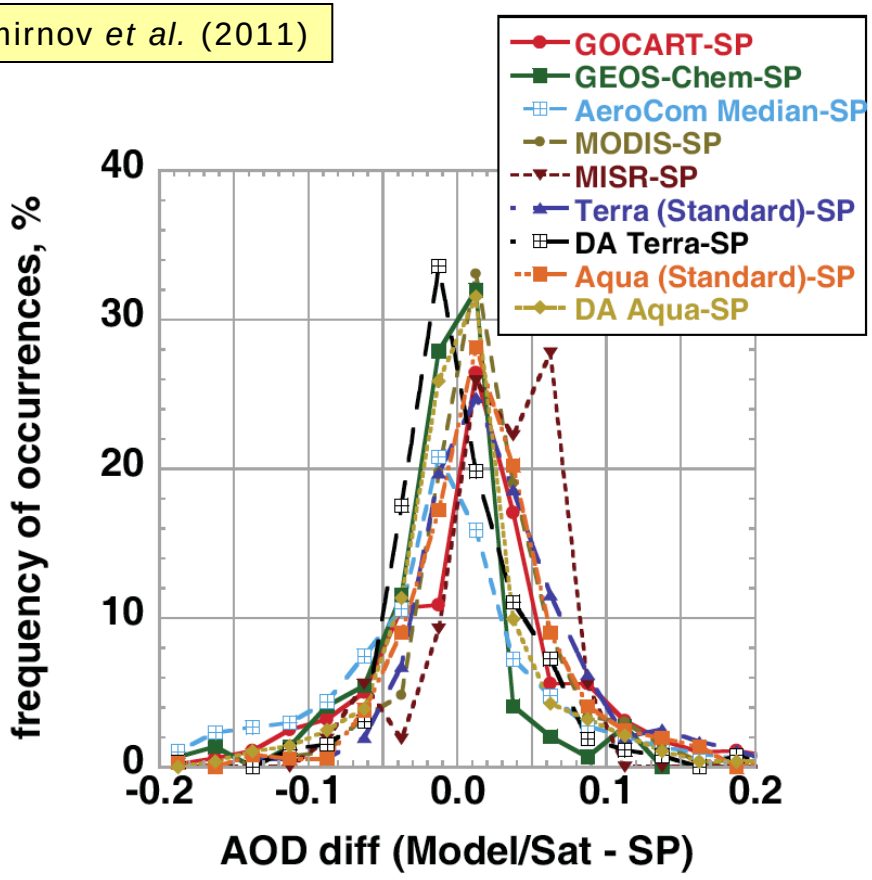


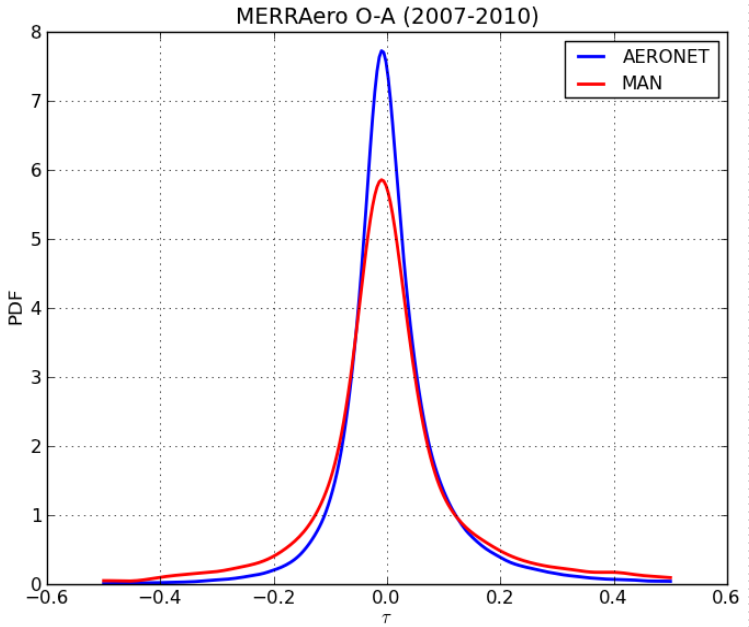
$$\eta = \log(\tau + 0.01)$$

Maritime Aerosol Network



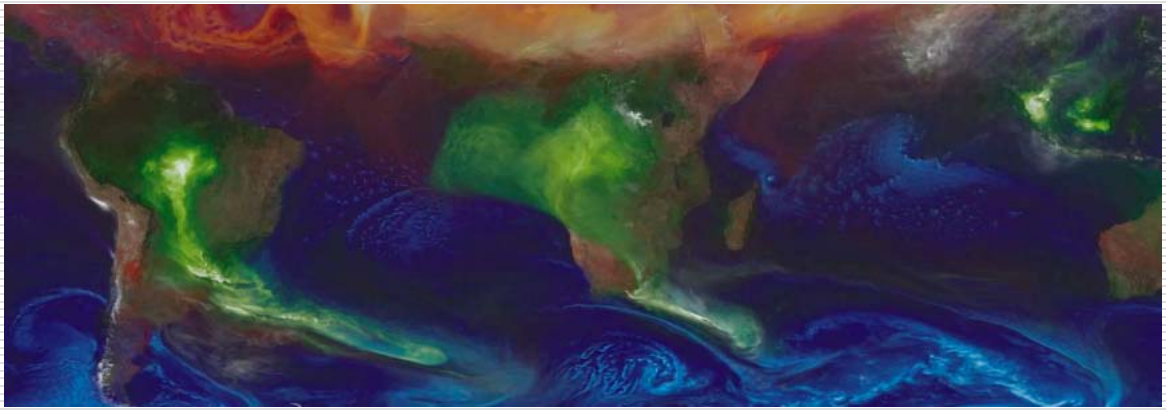
Smirnov *et al.* (2011)





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



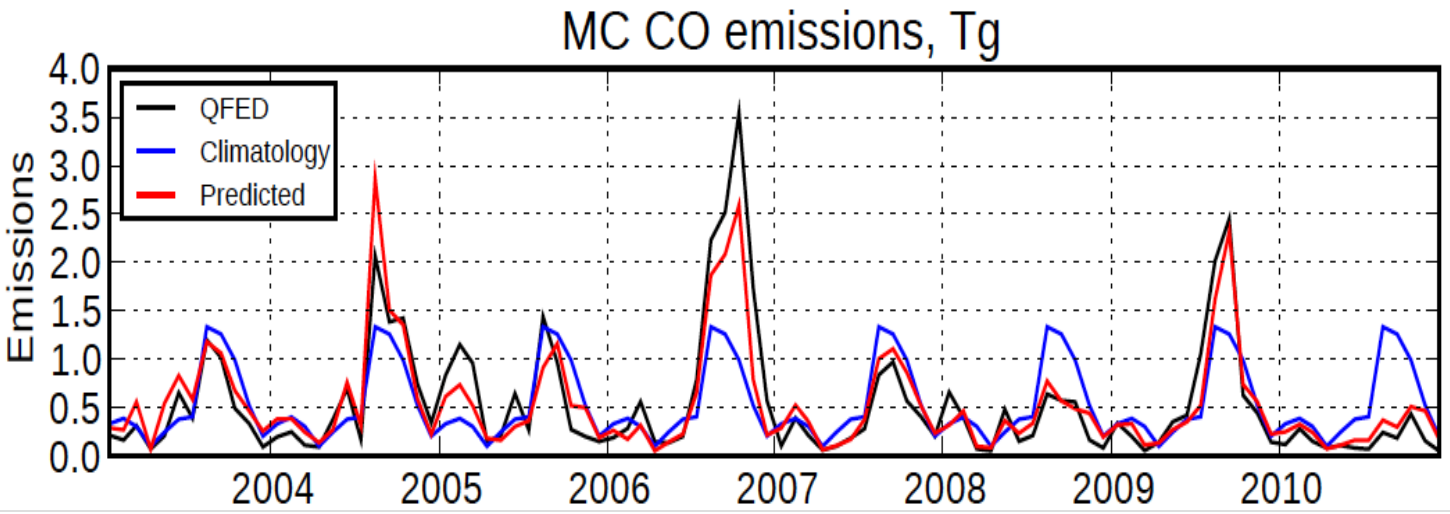
JCSDA: inclusion of geo-stationary information

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:

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



Maritime Continent Example

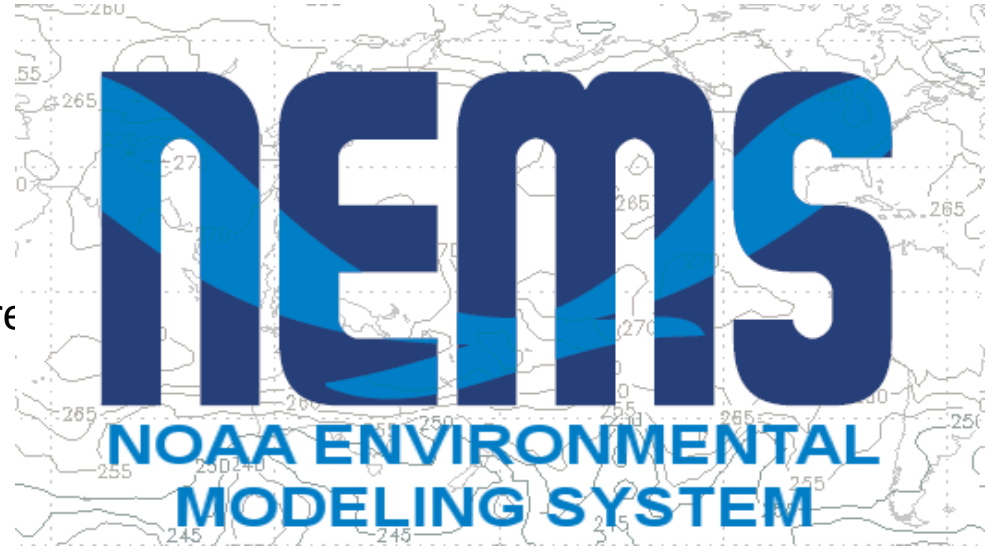
GEOS-5/GOCART Transition to NCEP GFS

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

ESMF Earth System Modeling Framework

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)



Courtesy: Sarah Lu

Collaborators

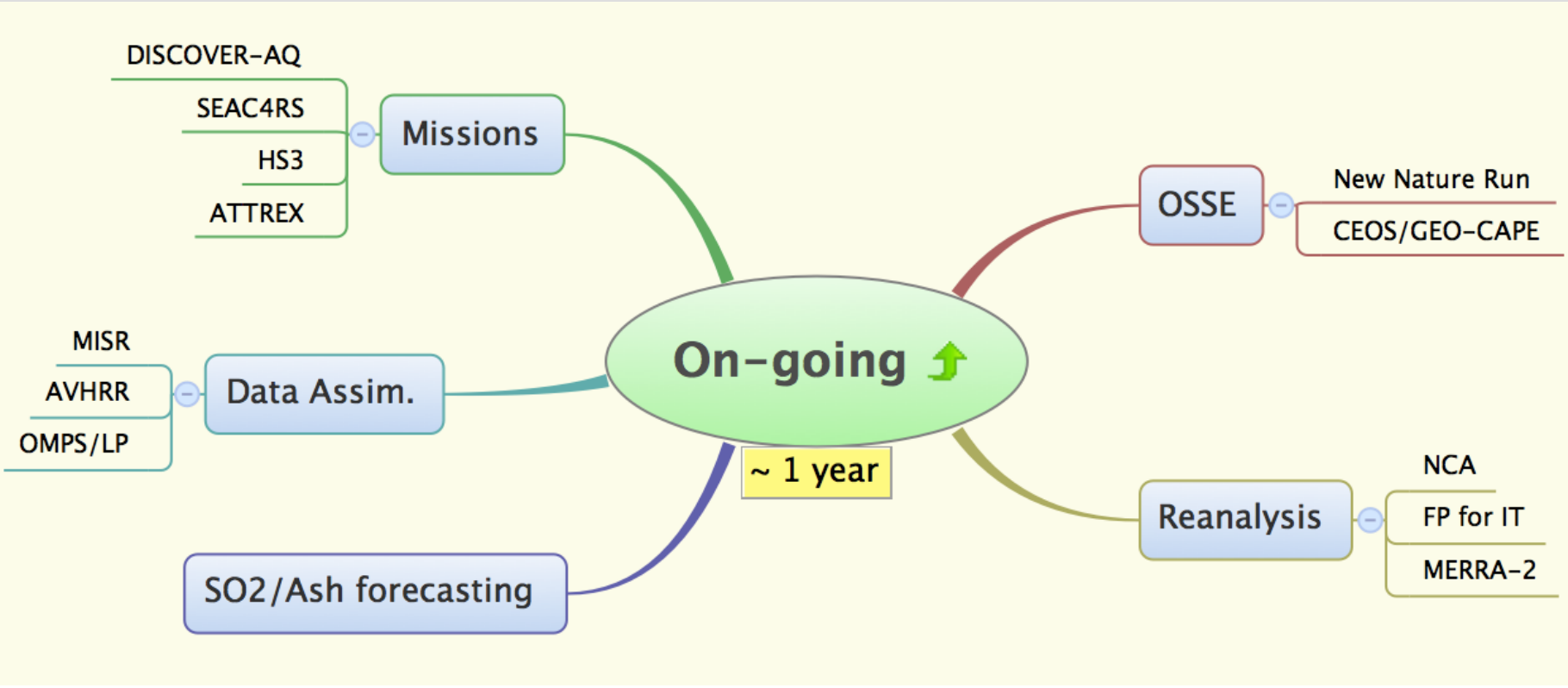
GSFC (Arlindo da Silva, Mian Chin, Peter Colarco) for aerosol modeling
NESDIS (Shobha Kondragunta and Xiaoyang Zhang) for biomass burning emissions
NRL (Jeff Reid, Walter Sessions) for model inter comparison
ECMWF (Angela Benedetti, Jean Jacques Morcrette, Johannes Kaiser, Luke Jones) for volcanic

NOAA/NASA Global biomass burning emissions

- 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

Courtesy: Shobha Kondragunta

Short Term


On-going
~ 1 year
Missions
DISCOVER-AQ
SEAC4RS
HS3
ATTREX
Data Assim.
MISR
AVHRR
OMPS/LP
SO2/Ash forecasting
OSSE
New Nature Run
CEOS/GEO-CAPE
Reanalysis
NCA
FP for IT
MERRA-2

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

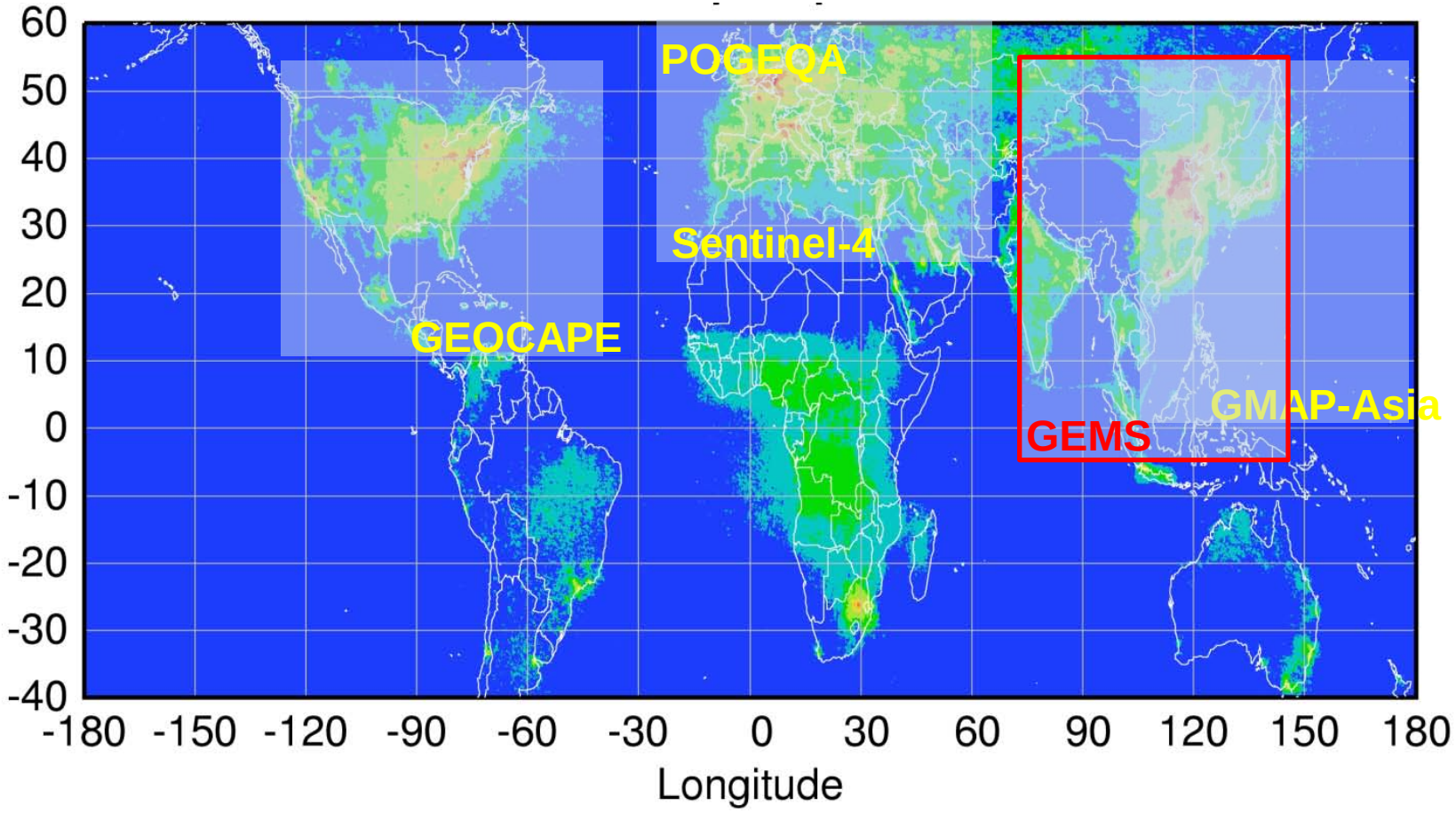
A global GEO OSSE activity for GEO-CAPE & CEOS

CEOS
Committee on Earth Observation Satellites

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

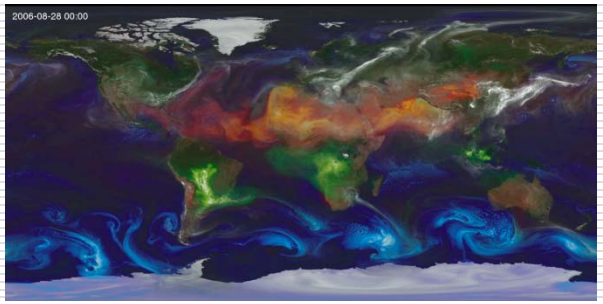
NCAR NATIONAL CENTER FOR ATMOSPHERIC RESEARCH
is sponsored by the National Science Foundation

Geostationary Satellite Constellation for Observing Air-quality



(Richter, 2005)

GEOS-5 Global 7 km Nature Run



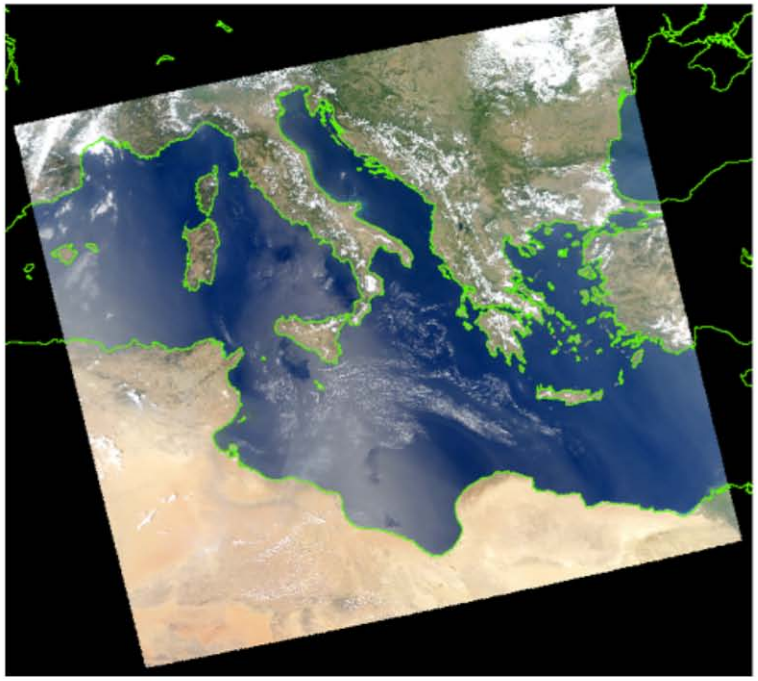
- **Components**
  - Atmospheric GCM on cubed-sphere, **non-hydrostatic**
  - Prescribed SST, sea-ice
  - Constituents
    - Radiatively coupled aerosols
    - Carbon species
    - GMI Combo Chemistry (*)
- **Emissions**
  - Prescribed daily biomass-burning emissions (QFED)
  - New dust source function 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.

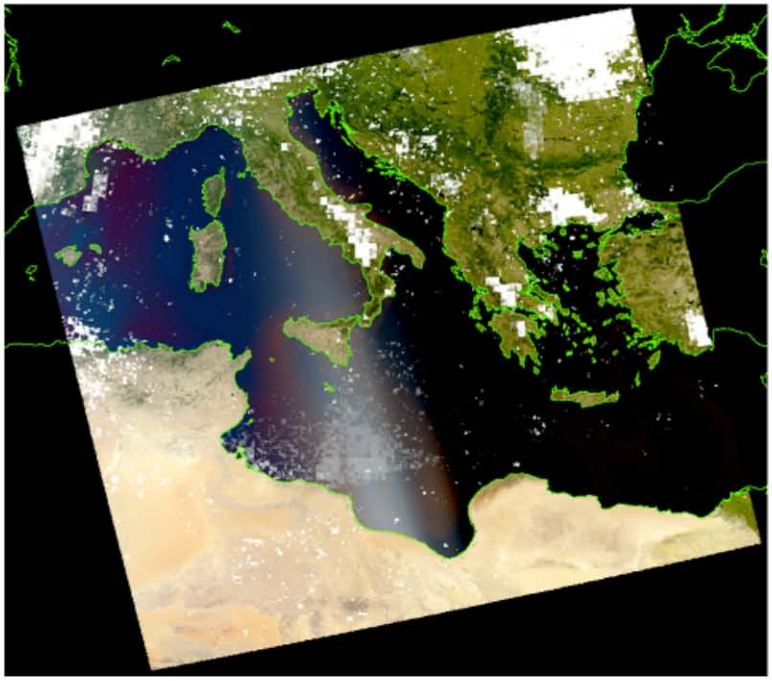
(*) GMI combo chemistry used for short experiments only.

MODIS Level 1/2 Simulator

a) Actual RGB composite



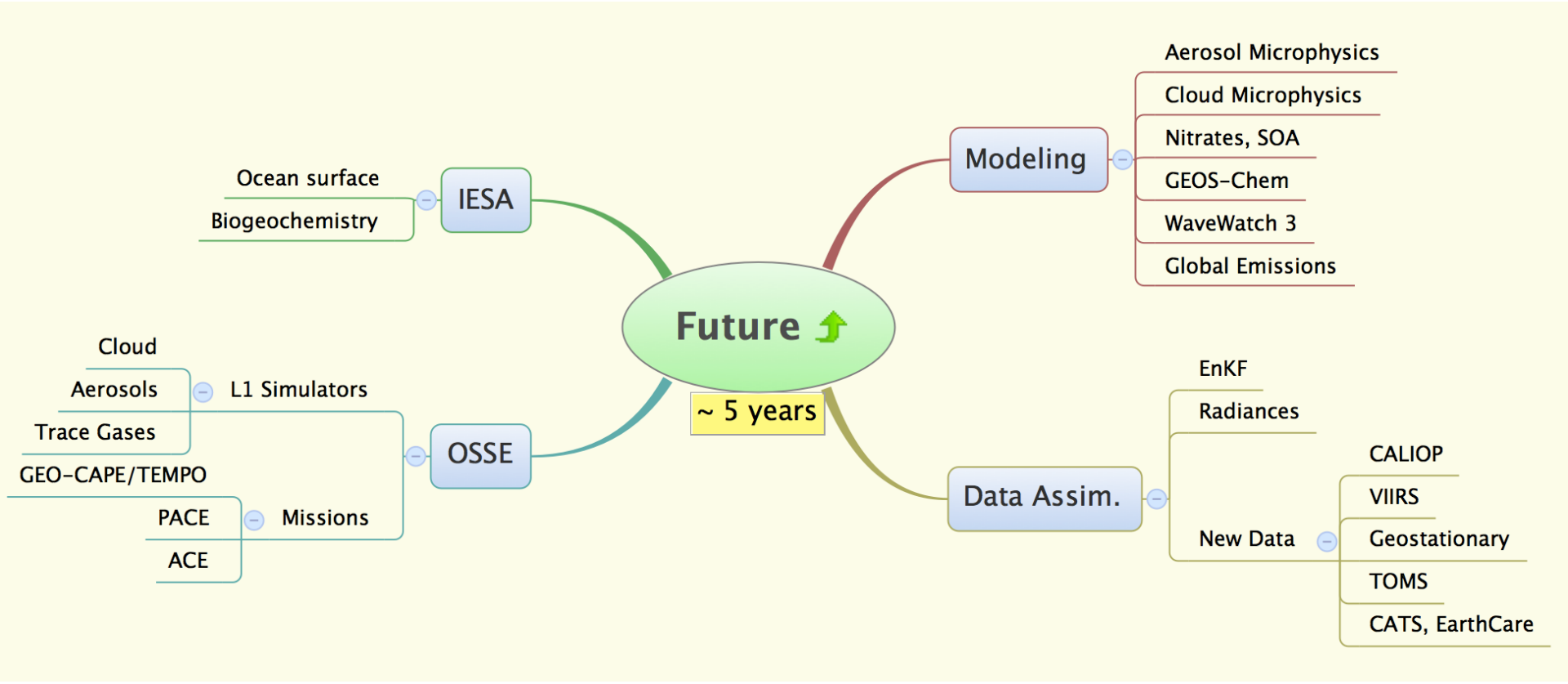
b) Simulated RGB composite



Example: no aerosols

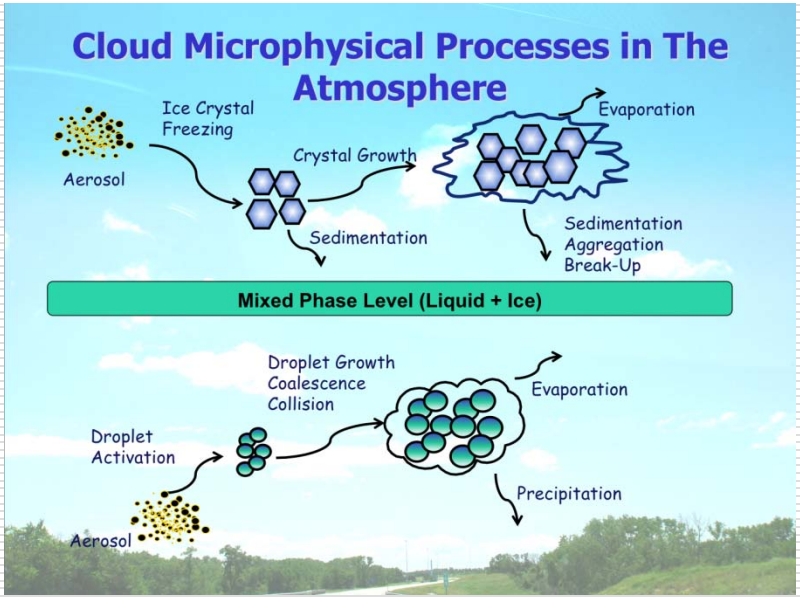
With Gala Wind, Steve Platnick

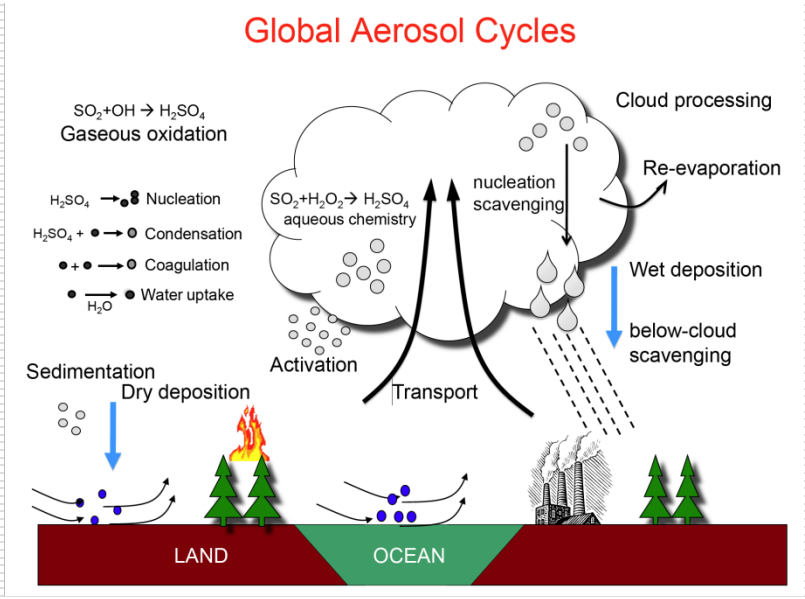
Mid- to Long-Term



Aerosol-Cloud Interactions

New Cloud Microphysics **Requires Aerosol Microphysics**

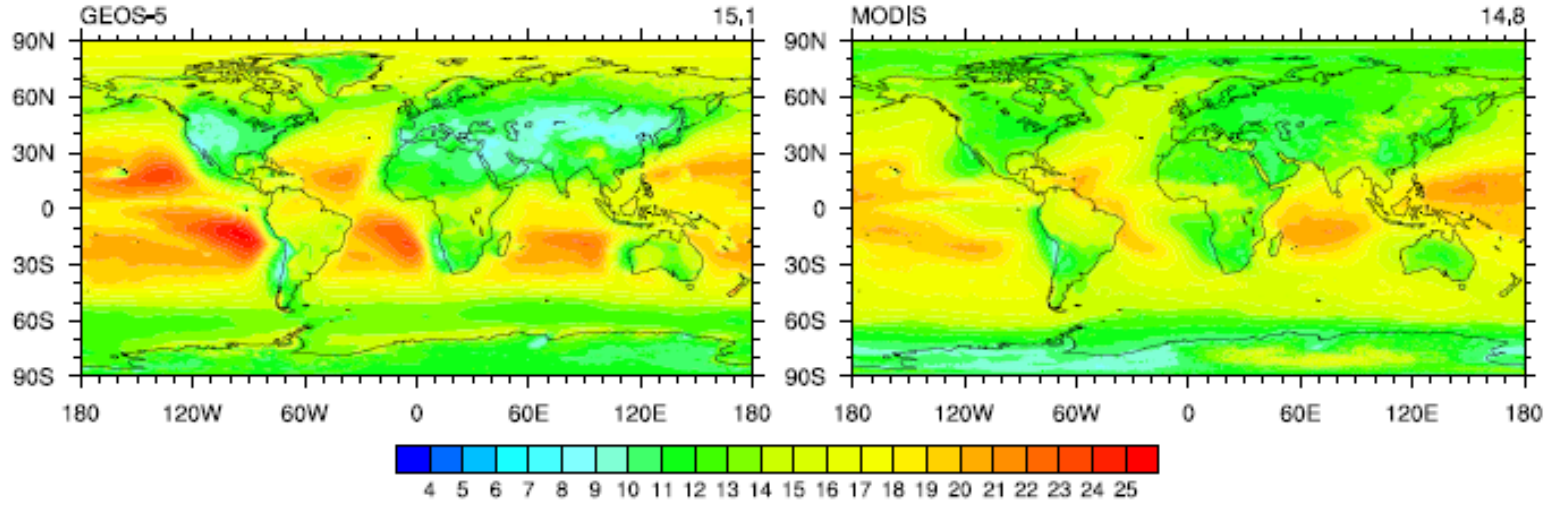




Prediction of aerosol mass & number

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.



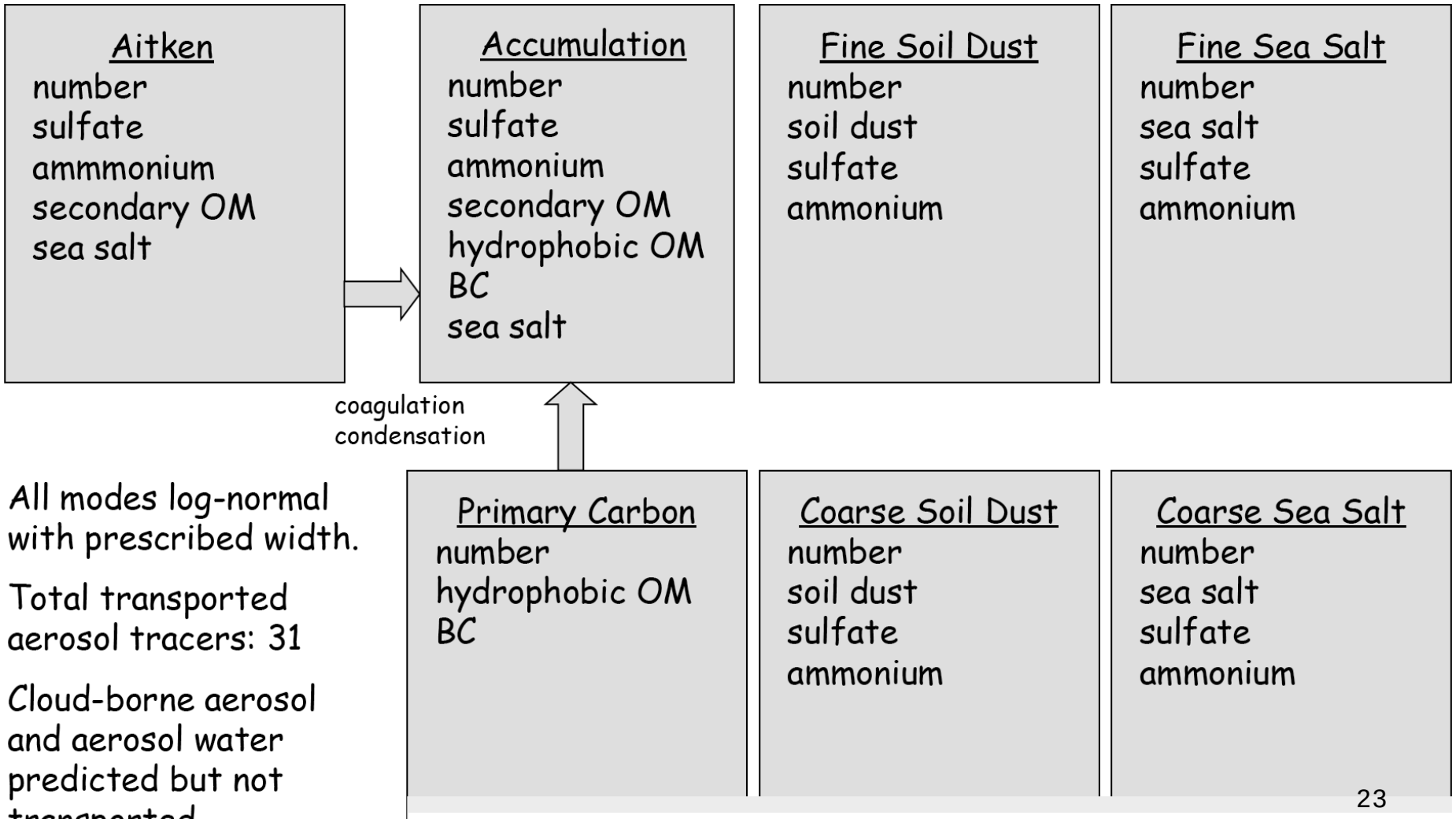
Annual Mean Cloud Droplet Effective radius (μm)

- 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).

Courtesy: D. Barahona

7-Mode Modal Aerosol Module (MAM)

ESMF Component Derived from CAM5 Implementation
In Collaboration with Xiaohong Liu, Steve Gahn (PNNL)



All modes log-normal with prescribed width.

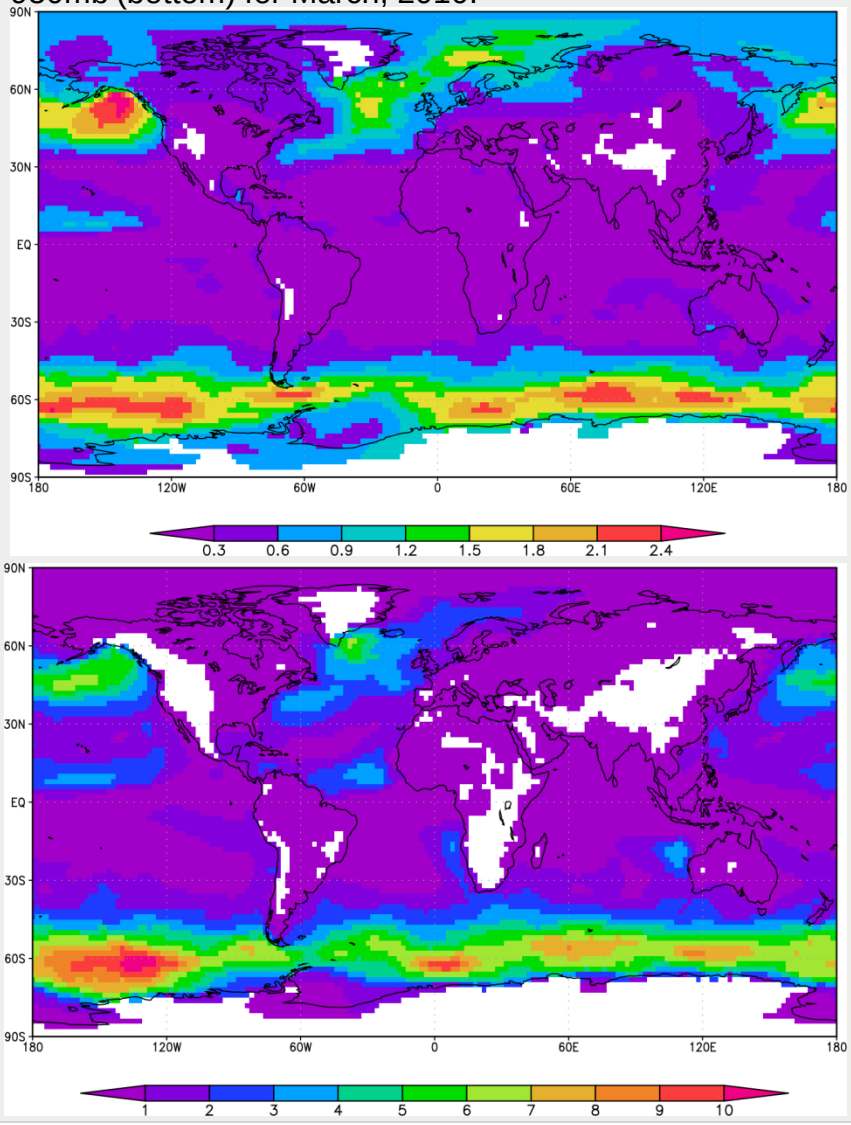
Total transported aerosol tracers: 31

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

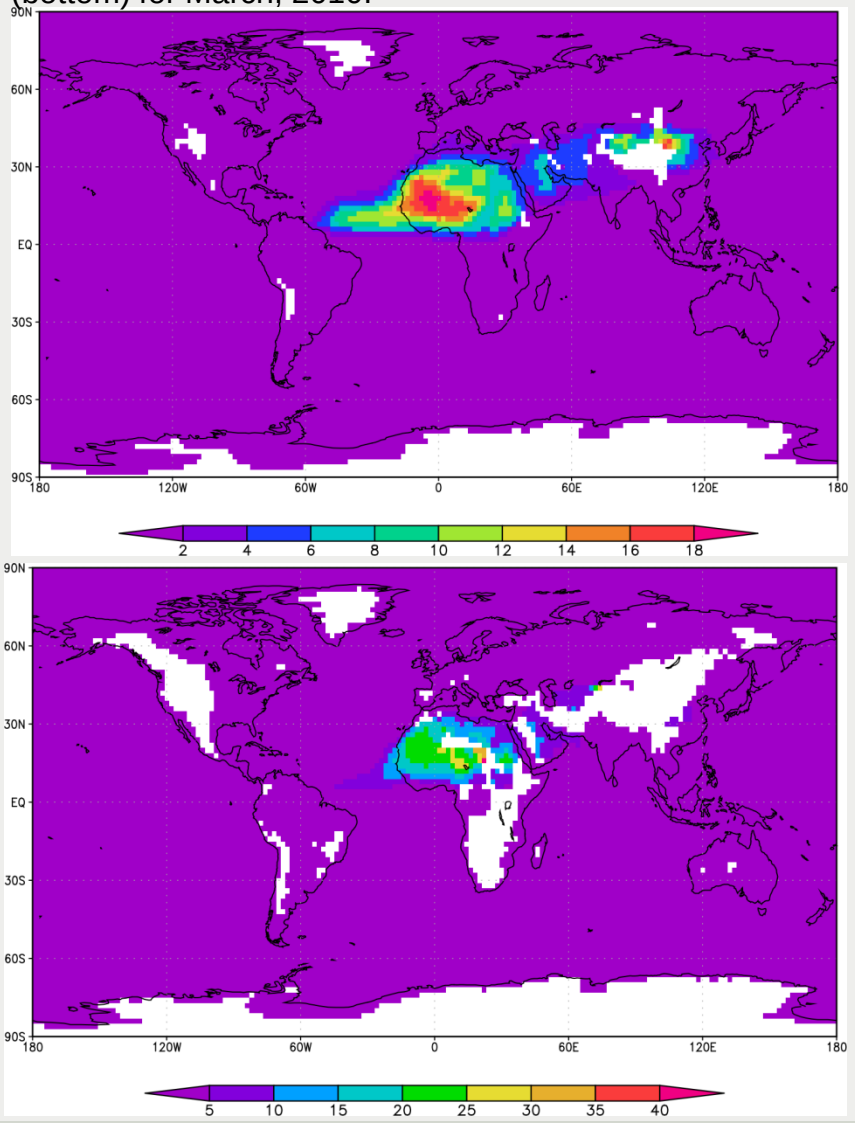
Courtesy X. Liu

Number concentration

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



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



Summary

- 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 synthetizing the information content of models and satellite data
  - OSSEs for supporting future NASA observing mission
- Close collaboration between modelers and data producers is key.