Aerosol Work in GEOS-5

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Outline

- Introduction to GEOS-5 Modeling Environment
- Evaluation of Online GOCART in GEOS-4
- Application of Online Aerosol to Field Missions/Forecasting
- Climate
- GEOS-6

GEOS-5

GEOS-5 [Rienecker et al., 2008] is the **G**oddard **E**arth **O**bserving **S**ystem global climate model and data assimilation system.

- Finite-volume dynamical core [Lin, 2004]
- Relaxed-Arakawa Shubert (RAS) convection scheme [Moorthi and Suarez, 1992; Bacmeister, 2005]
- Chou and Suarez [1994; 2002] and Chou [2003] radiation schemes in solar and IR
- Can run at multiple resolutions: 2.0° x 2.5° → 0.25° x 0.3125° , 72 vertical levels
- Meteorology: Can be run in AGCM, "replay", and forecast modes.
- Aerosols: prescribed or on-line (GOCART aerosol module).

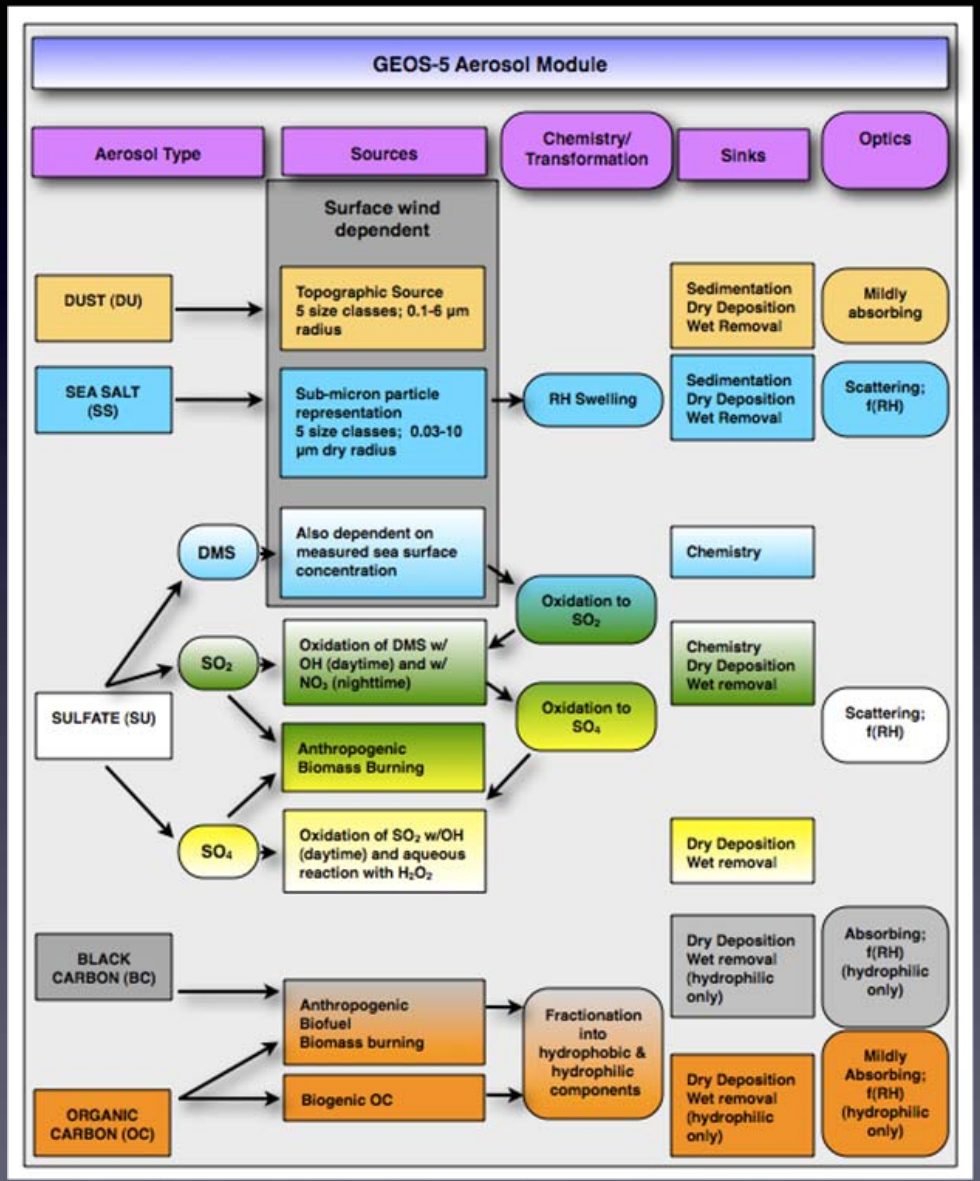
GEOS-5 AGCM

Dynamics:
Finite-Volume Dynamical Core
[Lin, 2004]
Gravity Wave Drag

Column Physics

- **Turbulence** [Lock et al., 2000]
- **Moist Processes**
- **Surface:** (lake, land ice, and land [Koster et al., 2000] and data ocean)
- **Solar/IR Radiation** [Chou & Suarez, 1994;2002; Chou,2003]
- **Chemistry/ Aerosols** GOCART on-line aerosol module or prescribed

Aerosol Module



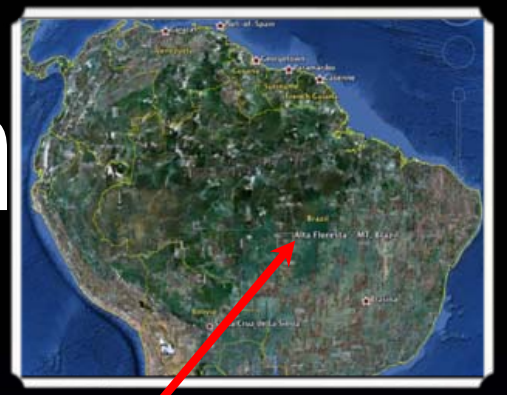
GOCART

- Offline CTM [Chin et al. 2002]
- Online in GEOS-4 [Colarco et al. 2010]

Features

- Sources, transport, dry & wet removal, aerosol optics
- Dust, Sea Salt
  - dynamic (wind-speed dependent) sources
  - particle size distribution
- Carbonaceous
  - black & organic carbon
  - inventory based emissions
  - "aging" by conversion to hydrophilic species
- Sulfate
  - inventory based emissions of SO_2, dynamic DMS
  - sulfate production in aqueous phase, SO_2 reaction with climatological oxidants

Baseline Evaluation



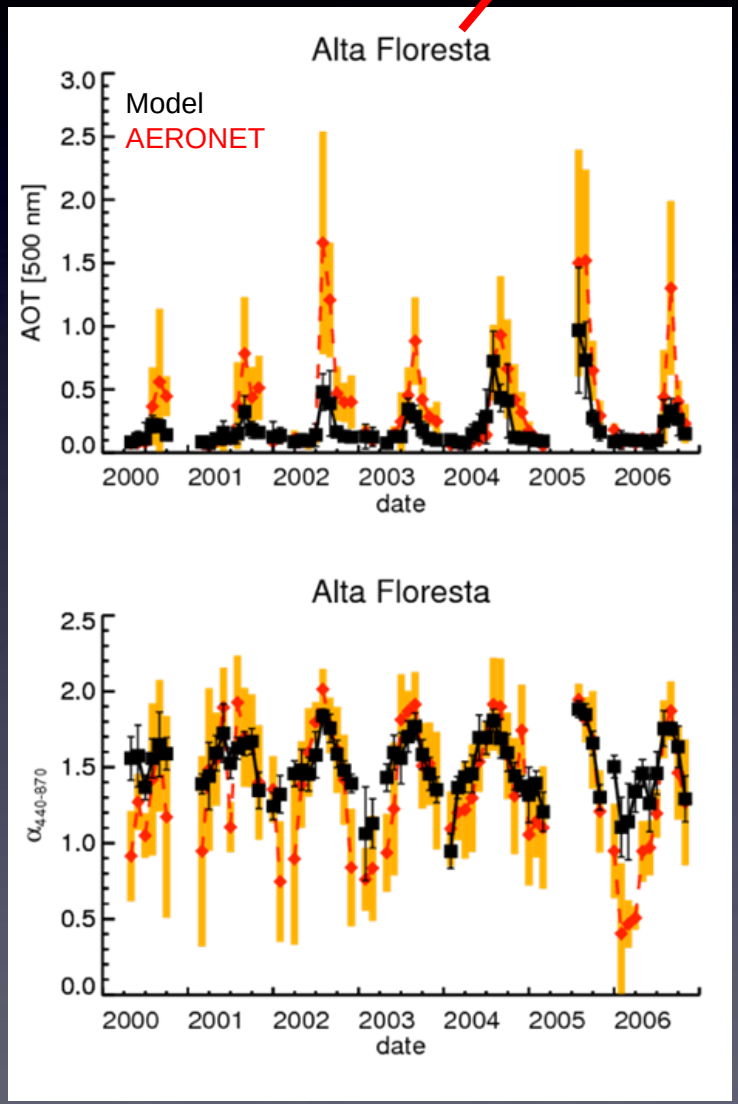
GEOS-4 based evaluation

Optical evaluation

- Models transport mass of aerosol
- Application of “mass extinction efficiency” converts to aerosol optical thickness (AOT)
- Spectral AOT easily comparable to remote sensing instruments; e.g., satellite retrievals, sun photometers

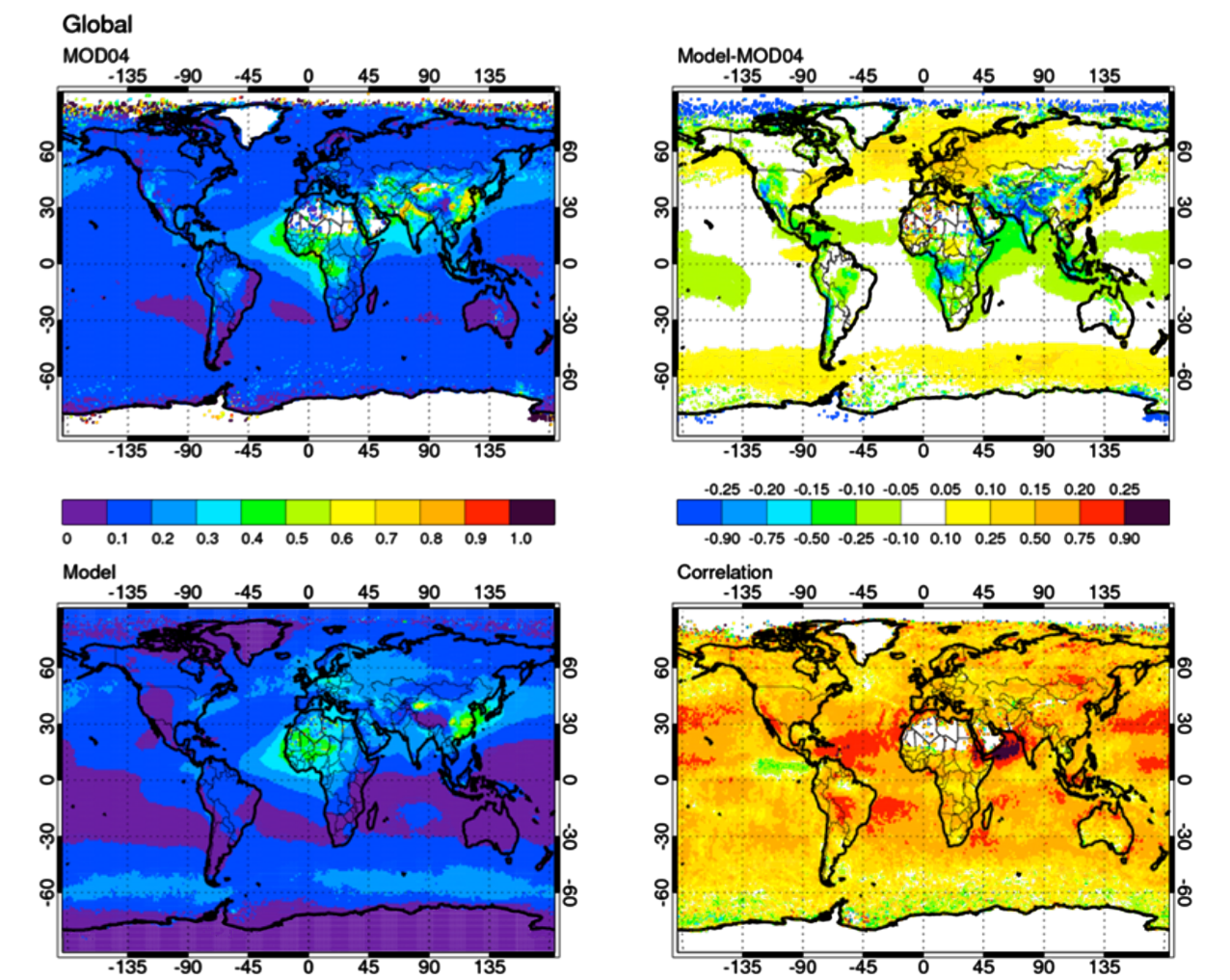
AERONET

- Ground-based sun/sky photometer network [Holben et al. 1998]
- Alta Floresta: Brazil, biomass burning
- Model has seasonality if not magnitude of aerosol signal; reasonable Angstrom parameter
- Errors in emission, particle optics



Colarco et al, “Online simulations of global aerosol distributions in the NASA GEOS-4 model and comparisons to satellite and ground-based aerosol optical depth,” JGR, 2010.

Sampling Issues



Satellite AOT

- Surface/atmosphere assumptions
- Optical models (assumed aerosol types)
- Some have difficulties over bright surfaces
- Cannot see through clouds

Model AOT

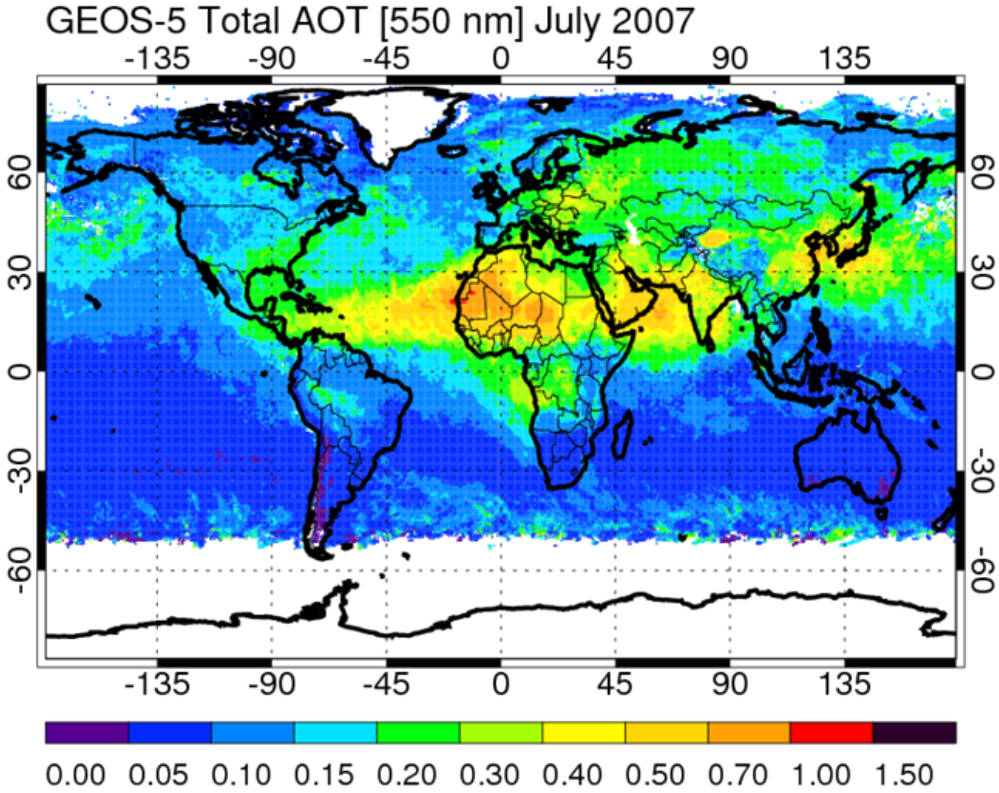
- Based on model aerosol load, environment, optical assumptions
- Compute AOT everywhere

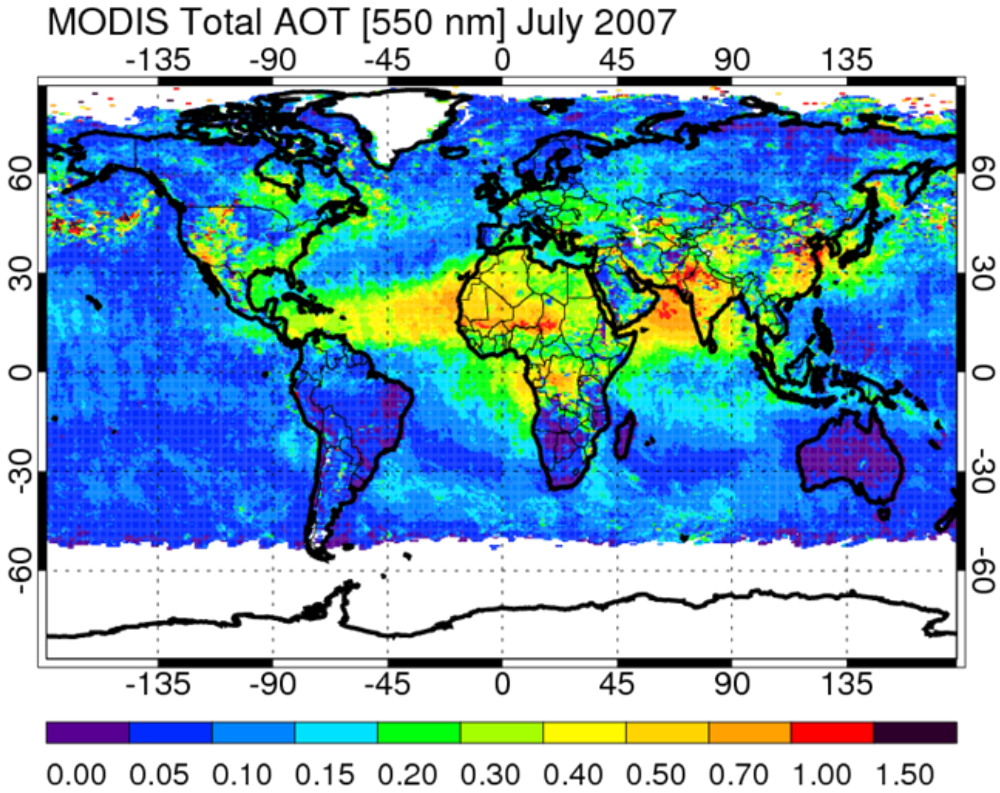
Clear-sky bias

- Satellite sees aerosols in clear-sky conditions
- Screening model results to exclude the cloud cover improves model-data comparison

Colarco et al, “Online simulations of global aerosol distributions in the NASA GEOS-4 model and comparisons to satellite and ground-based aerosol optical depth,” JGR, 2010.

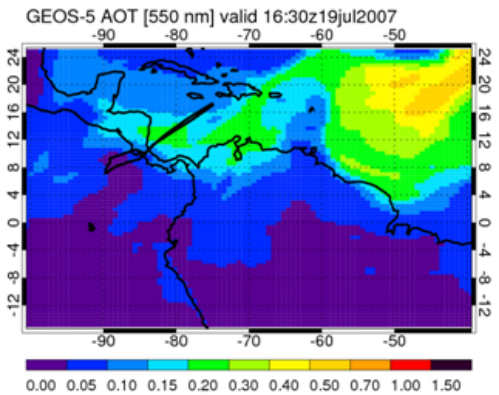
Transition to GEOS-5

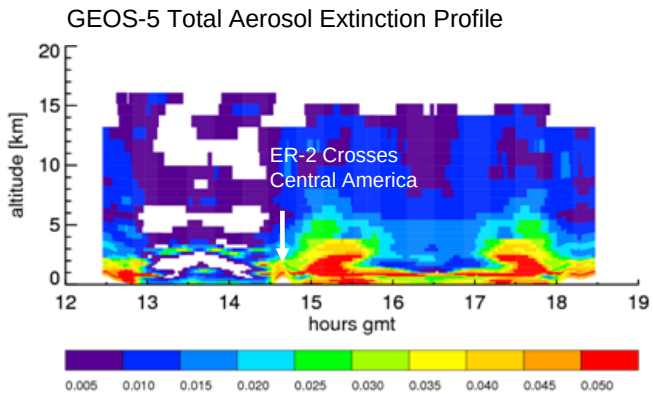


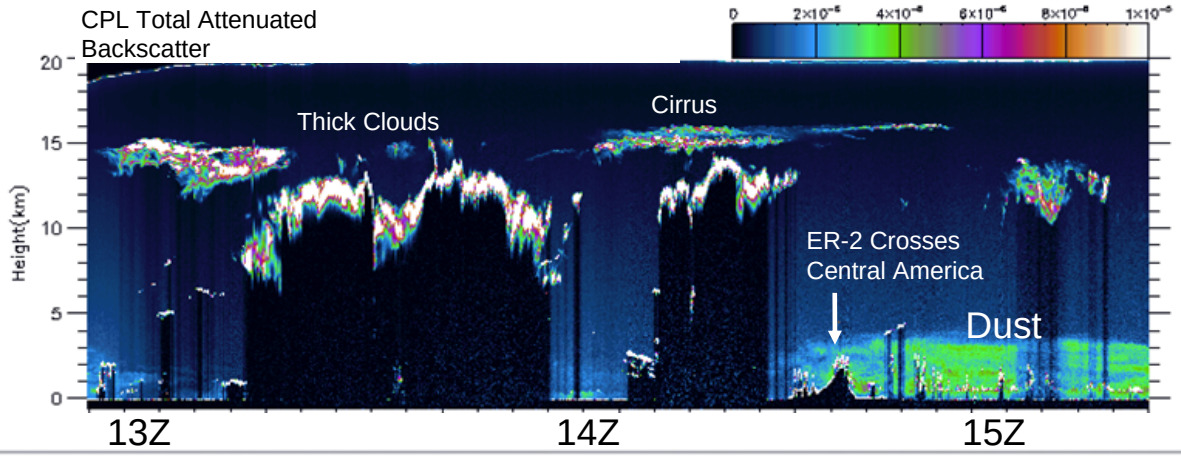


- TC^4 experiment based out of San Jose, Costa Rica, summer 2007
- First field mission deployment of aerosol enabled GEOS-5 system
- Twice daily 5-day forecasts support mission/flight planning

Fate of Saharan Dust





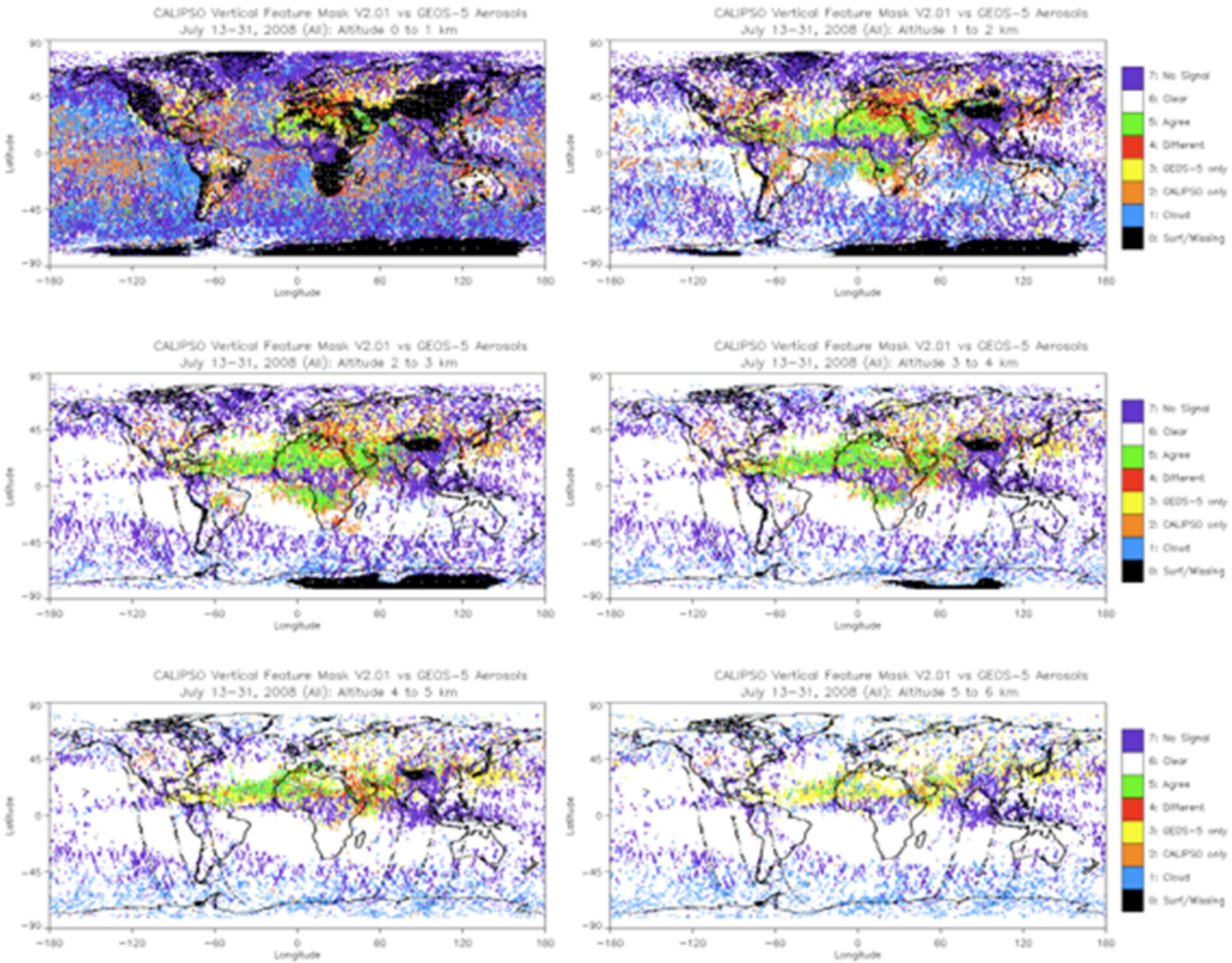


ER-2/CPL samples dust

- Flight July 19, 2007
- Depart San Jose for Pacific
- Turn back over Caribbean
- What controls the apparent barrier to dust crossing Central America?

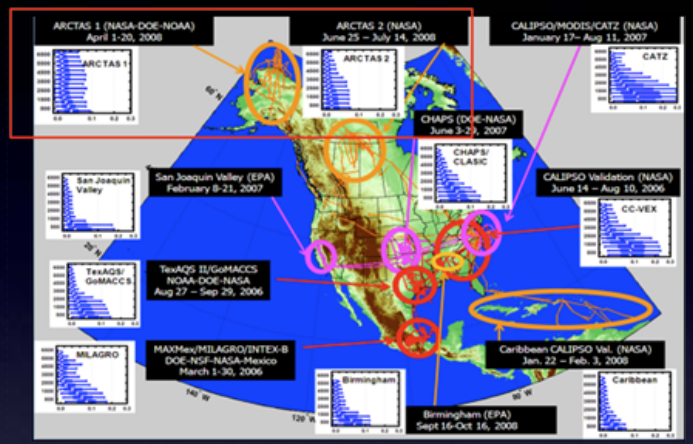
Nowottnick et al, "What is the fate of Saharan dust across the Atlantic?," JGR, in prep.

Aerosol Height Analysis



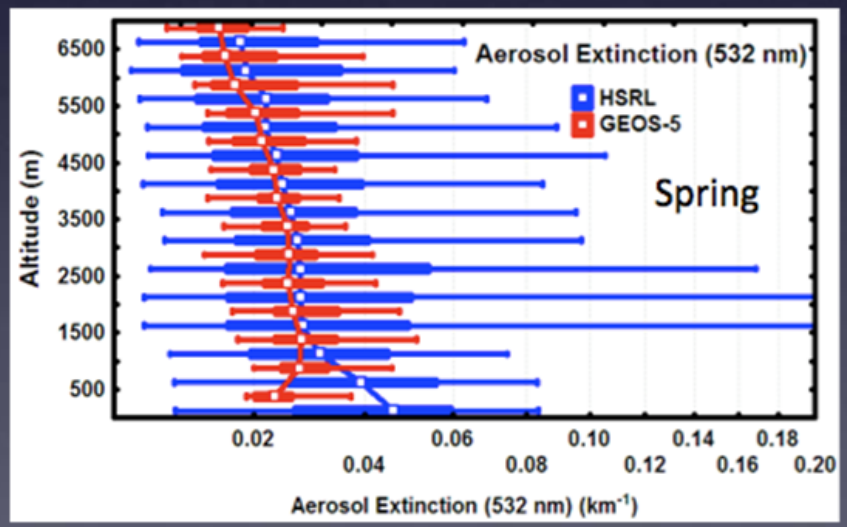
Welton et al.

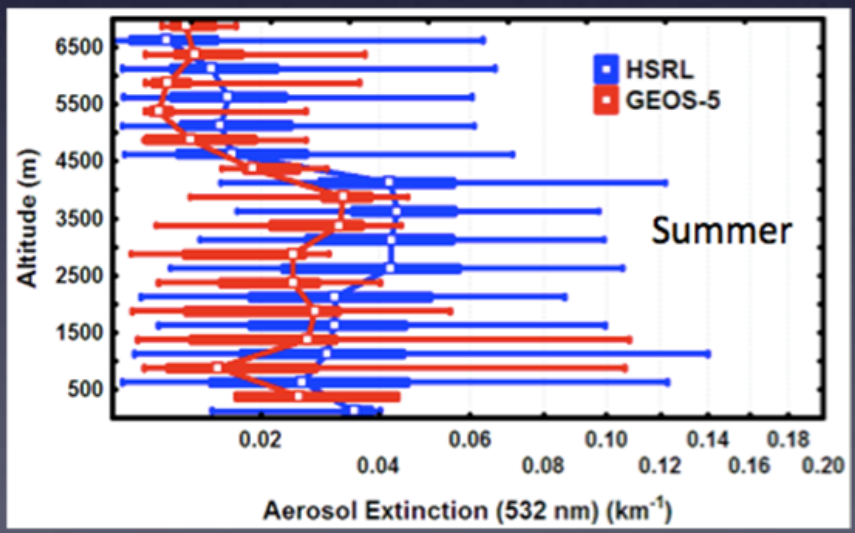
ARCTAS



HSRL deployed on B-200

- 15 science flights, April 2008, Alaska
- 14 science flights, June/July 2008, Canada
- GEOS-5 aerosol extinction profile computed and extracted along B-200 flight tracks
- Comparison to HSRL extinction profile shows generally good agreement

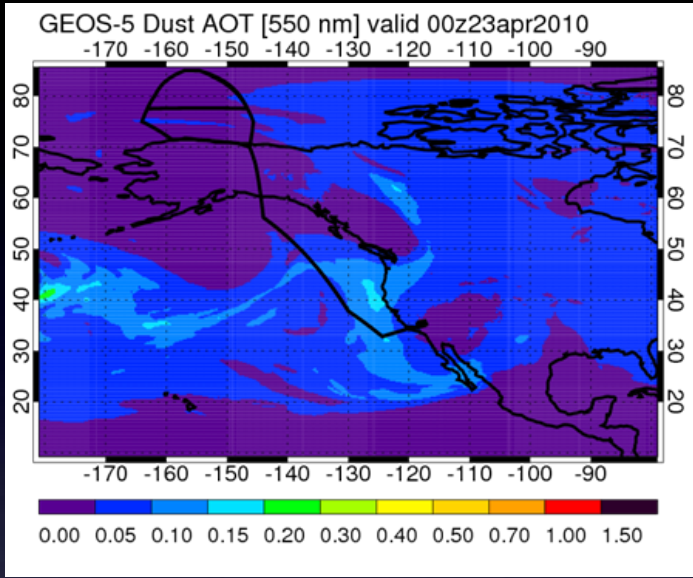


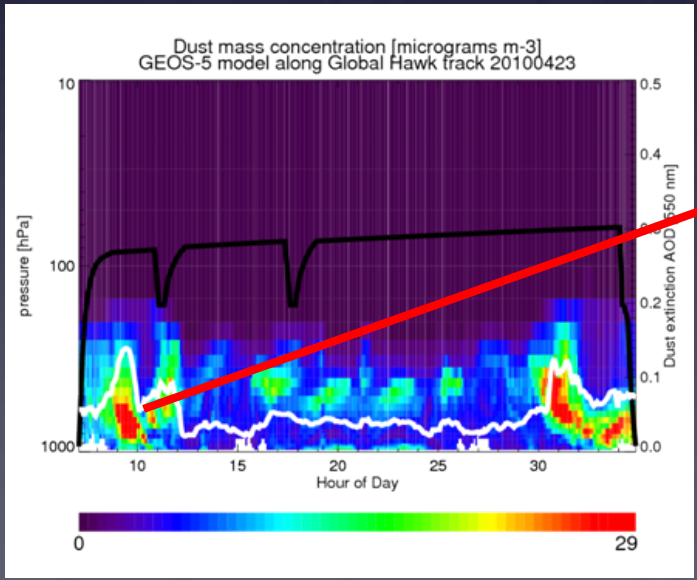


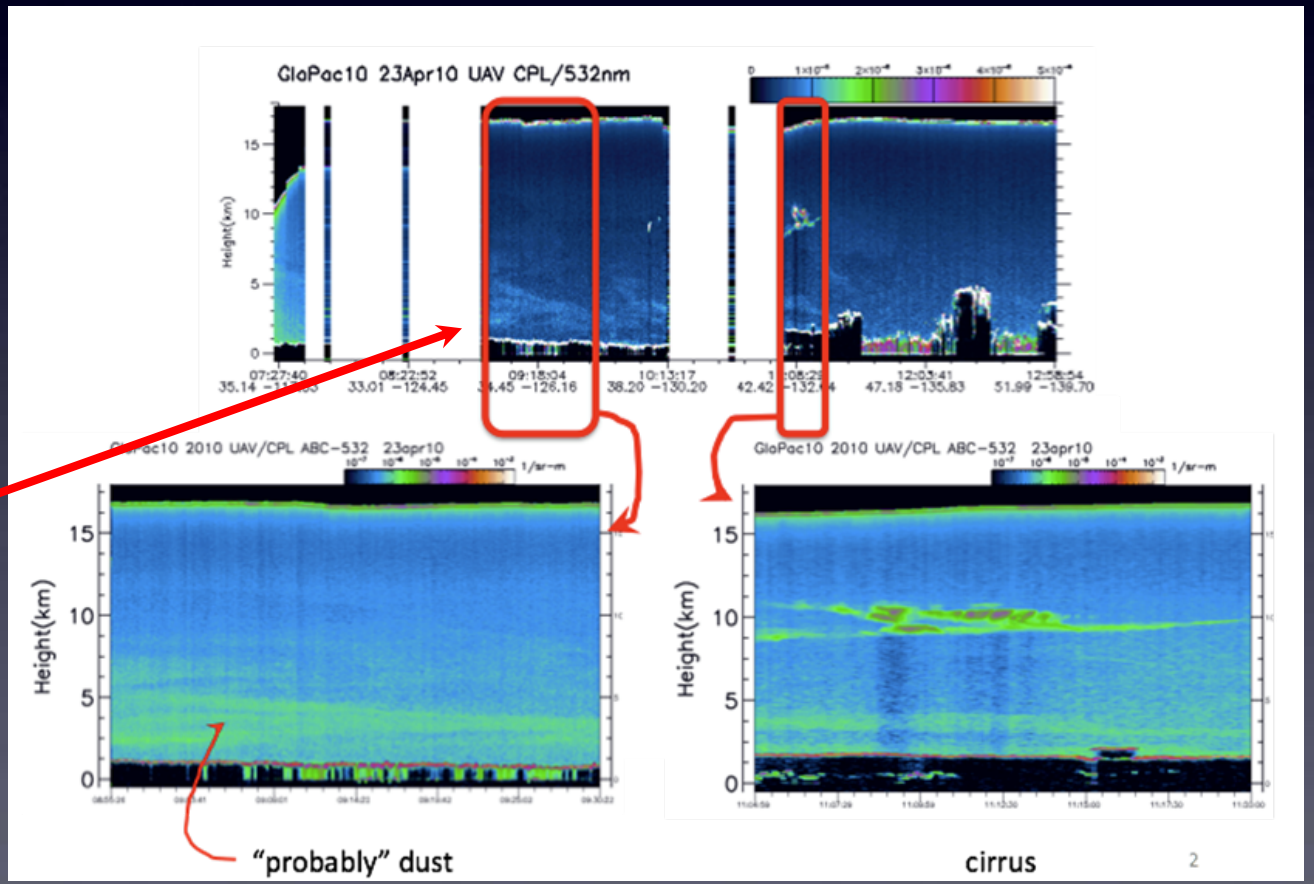
Ferrare et al, "Airborne High Spectral Resolution Lidar (HSRL) Measurements during ARCTAS," Fall AGU 2009.

GloPac

- First deployment of NASA Global Hawk aircraft
- Long-distance, long-duration (up to 30 hour) flights

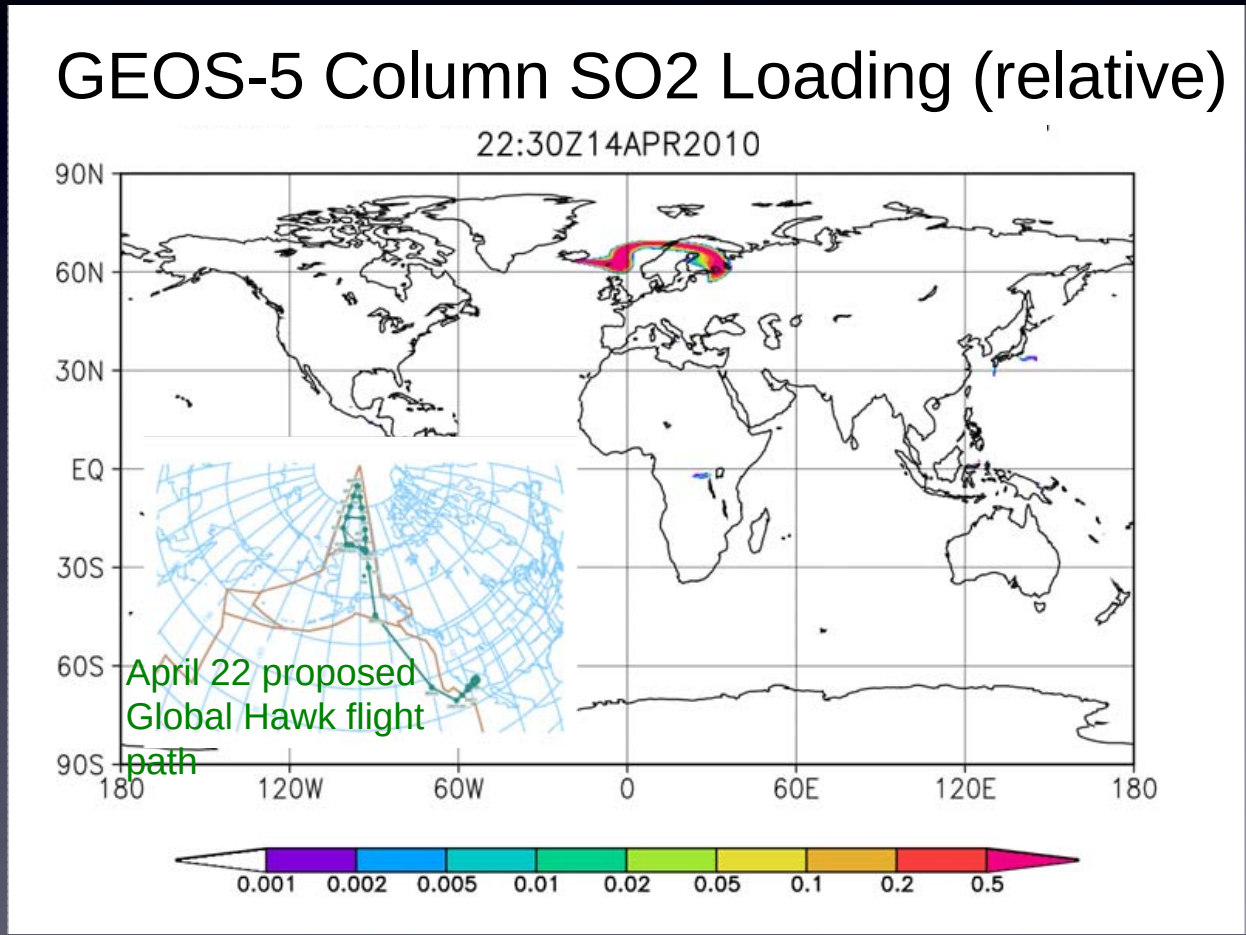




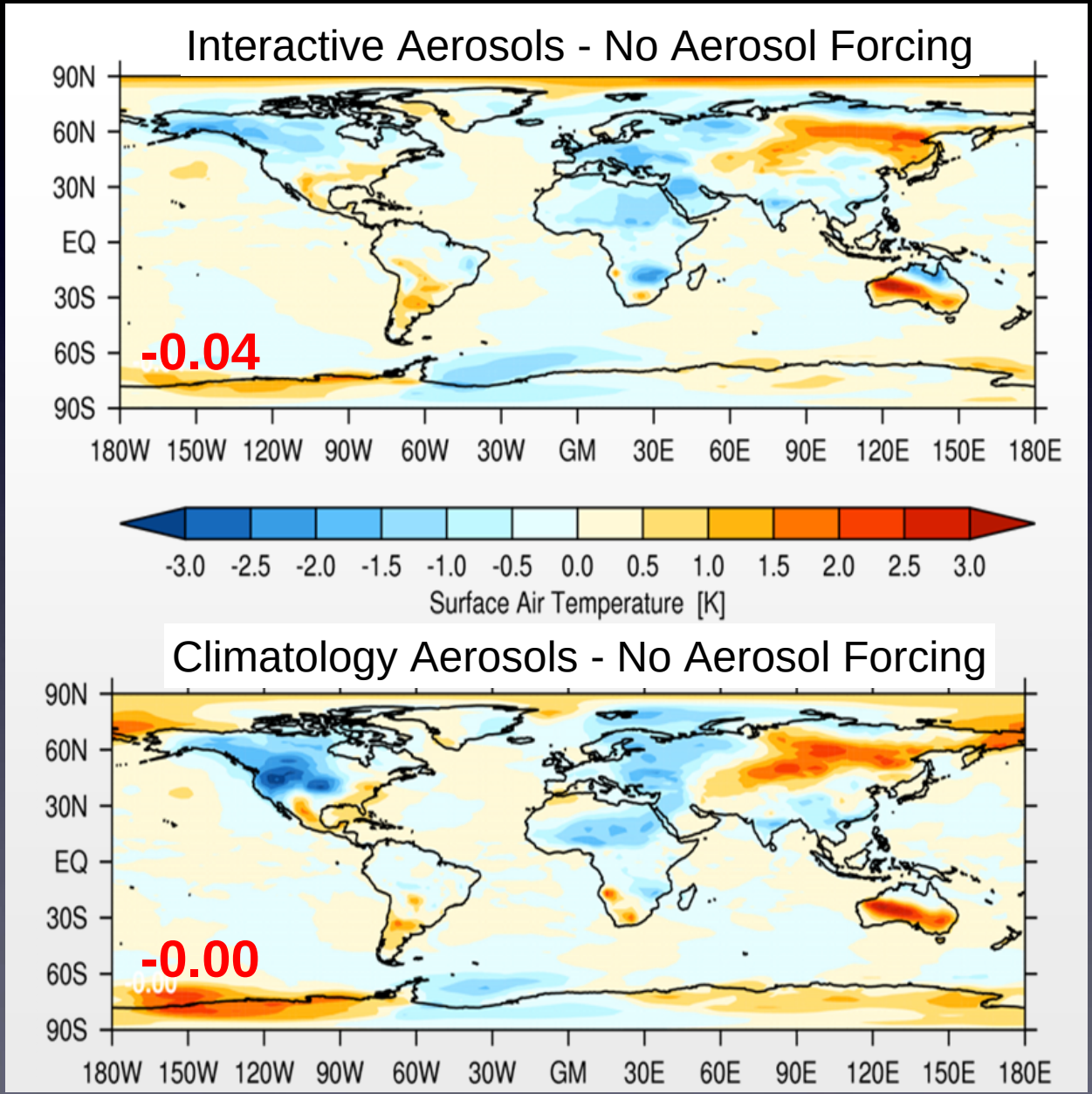


Eyjafjallajökull Eruption

- A major eruption occurred on April 14, with minor ones over the next several days
- The NASA Global Hawk aircraft was projected to fly in the Arctic north of Alaska on April 22
- *Would the Global Hawk intercept air masses containing aerosols from the eruption?*
- The NASA GEOS-5 model was deployed in support of the Global Hawk mission
- Forecasts carried out in the field showed that while the Global Hawk would intercept air masses from the eruption, the plume would be quite dilute and at lower altitudes than the aircraft



Climate



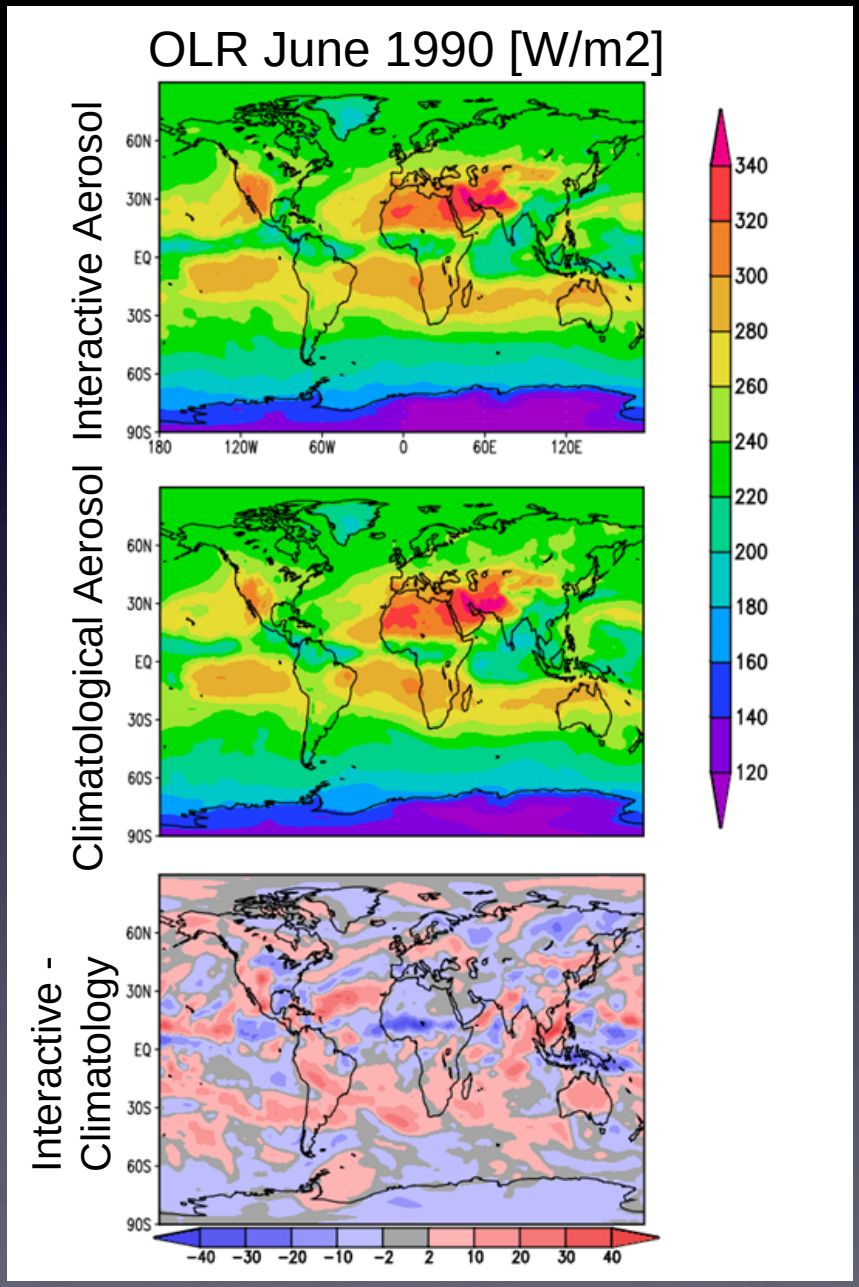
Options for running the AGCM

- No aerosol forcing
- Climatological aerosols
- Fully interactive aerosols

What is the difference in model climate between climatological and interactive aerosol forcing?

- Runs for 2003 (SST forcing, emissions), 2 x 2.5
- Climatological aerosols based on interactive run

Chemistry - Climate



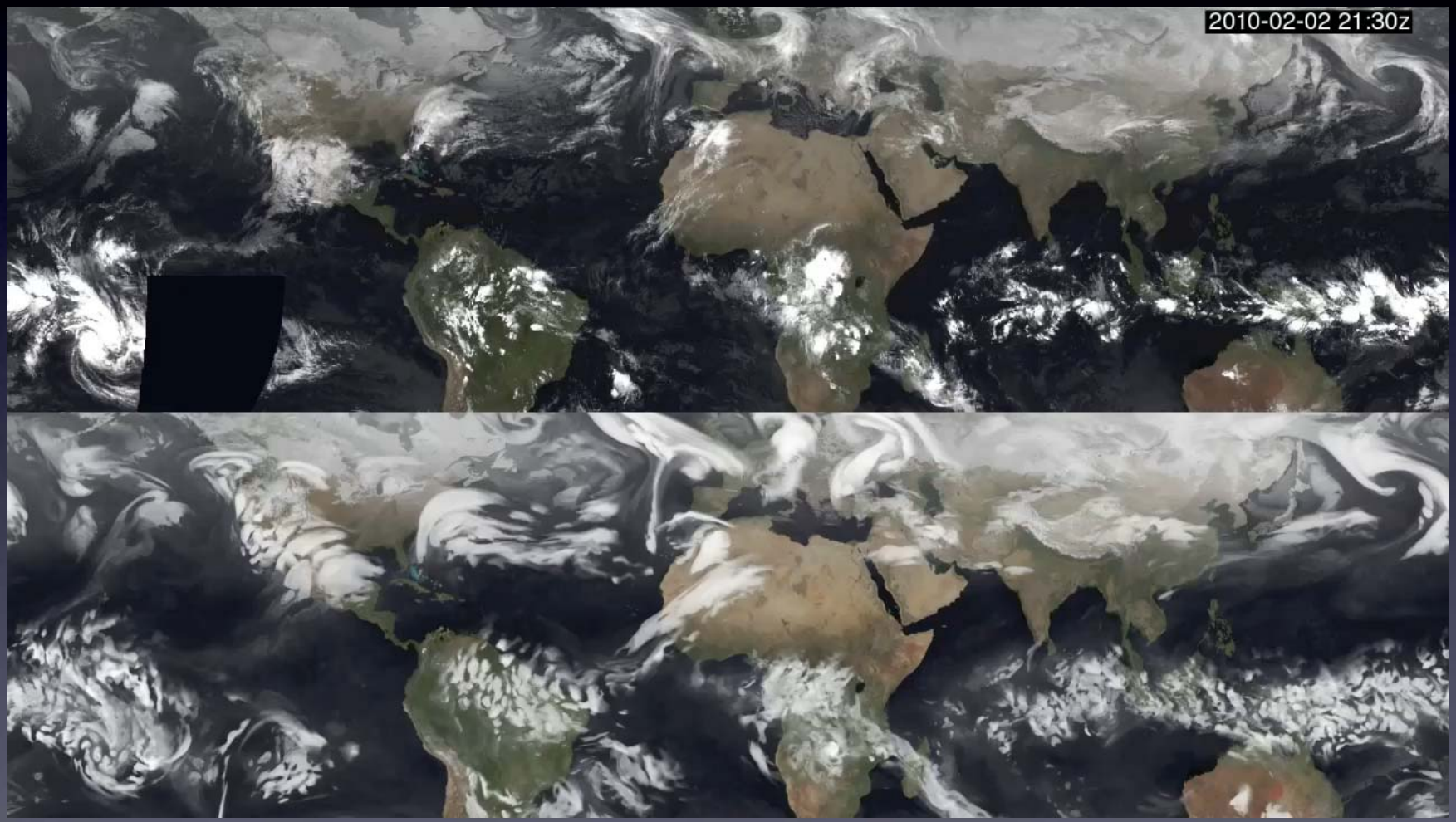
Large, experienced chemistry modeling group at GSFC

- Heritage in stratospheric chemistry
- Group is building around UTLS, dipping toes in tropospheric chemistry
- Using GMI chemistry mechanism in trop.

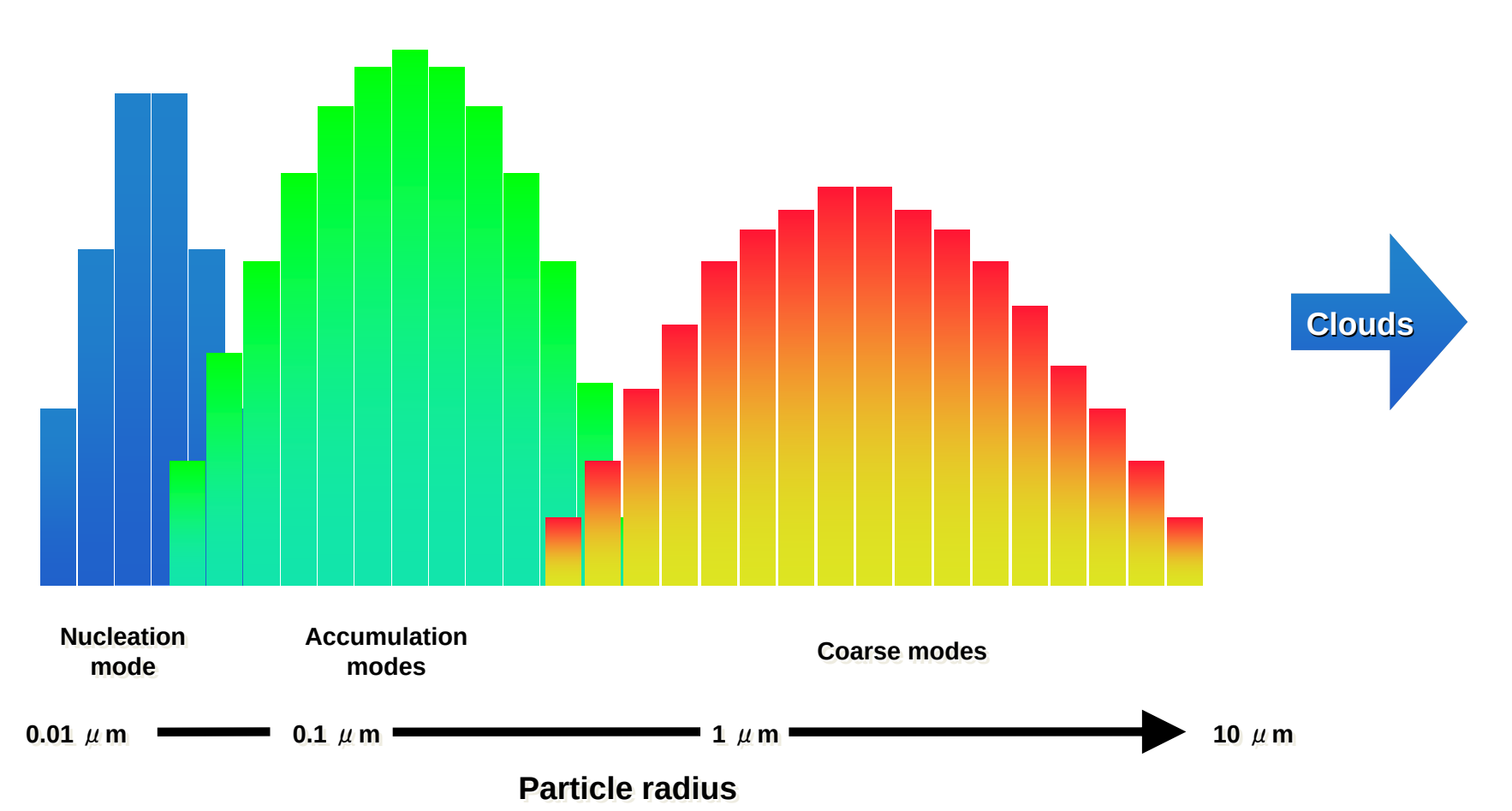
Interactive GOCART

- For example, sulfate mechanism in GOCART requires offline oxidant fields
- Introduce a two-way coupling: oxidants from GMI to GOCART, aerosol from GOCART to GMI (photolysis, surface area)

Future Dynamical Core



Future Aerosol Cores



- Modular nature of code permits trying different aerosol cores
- MAP project involves inclusion of CARMA sectional aerosol microphysical model
- Need this evolution in sophistication to get to clouds, climate

GEOS-6

- Non-hydrostatic dynamical cores to run at global ~1/8˚ resolution; 91 levels
- Model becomes “cloud permitting;” relaxed-RAS
- Morrison/Gettelman cloud microphysics; Nenes ice microphysics
- 4D-Var data assimilation
- RRTMG radiation scheme

Summary

- Aerosol development going on in much larger GCM development
- Same model is run for climate/assimilation/hindcast/forecast problems
- Involvement in field mission activities provides detailed case study analysis opportunties