Update on the NASA GEOS-5 Aerosol Forecasting and Data Assimilation System

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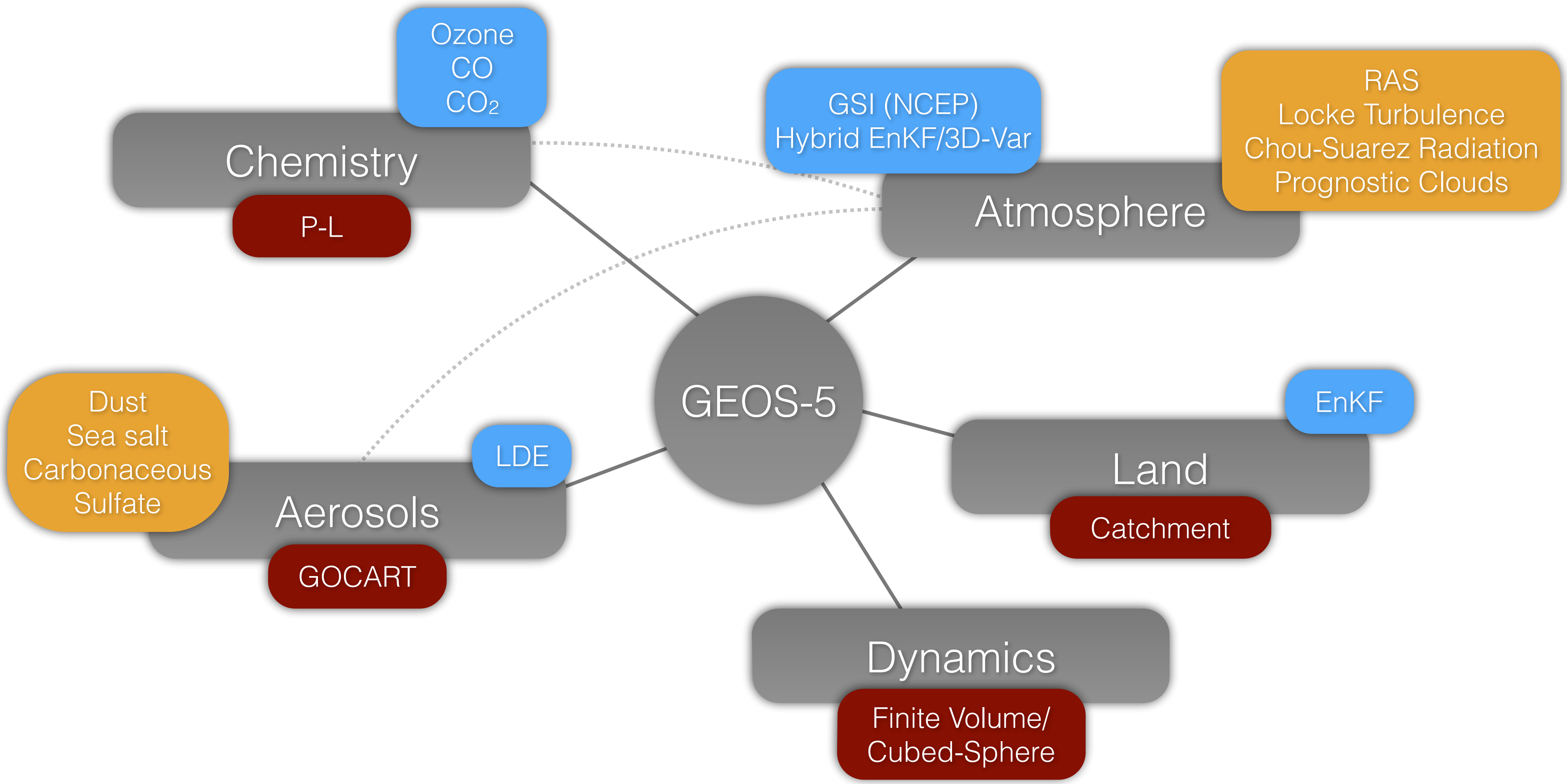
[4]SSAI

ICAP Meeting, Barcelona, Spain, June 16 - 19, 2015

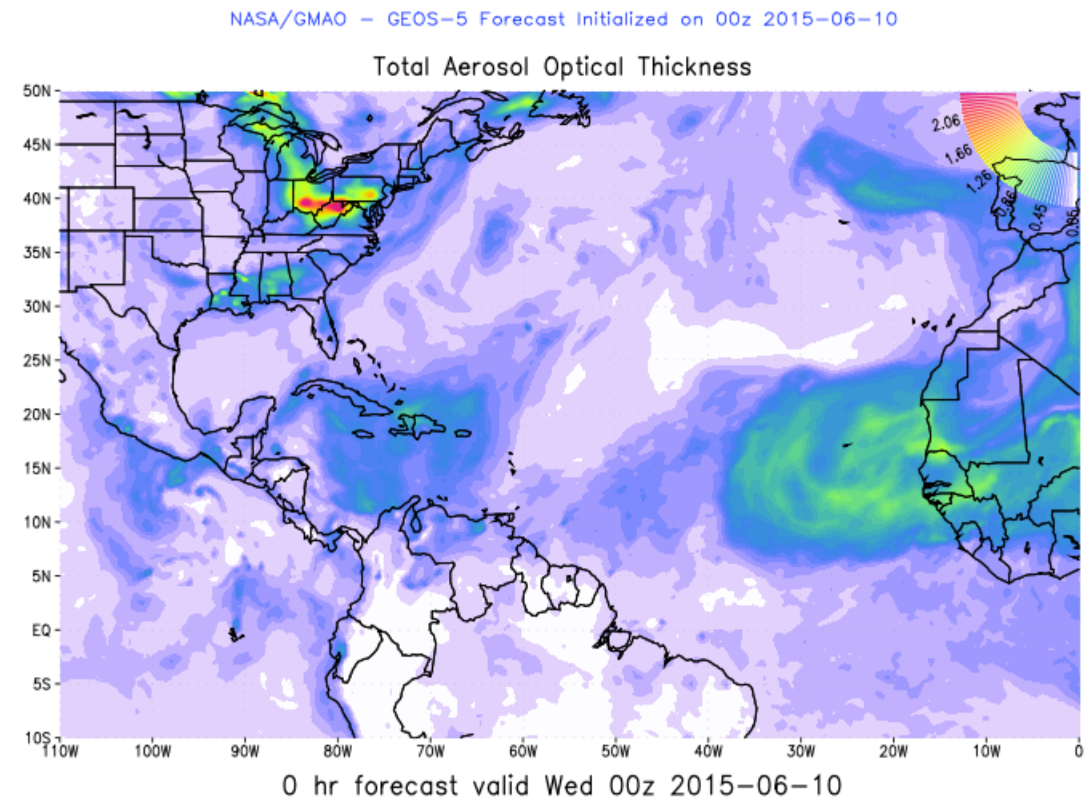
Current NRT Configuration



Global, 25 km, 72 levels, top at 0.01 hPa

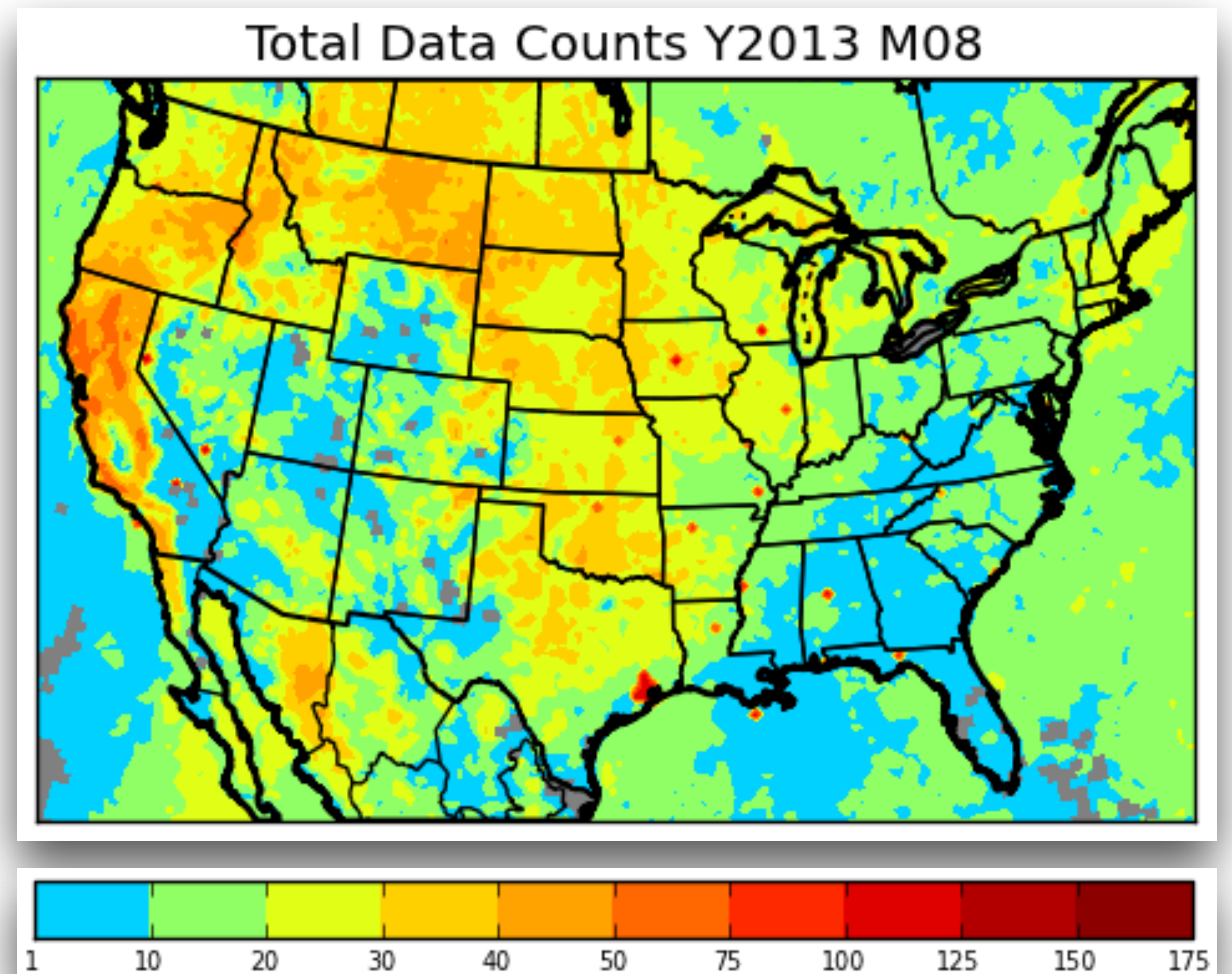
Aerosol Assimilation Products

- 2 x day, 5-day forecasts
- Assimilation of MODIS-derived total aerosol optical depth using local displacement ensembles (LDE)
- NRT MODIS FRP-based biomass burning emissions (QFED)
- Aerosol fields inline with meteorological assimilation
- GMAO provides customized web portals for missions and campaigns



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

Campaign Support SEAC^{4}RS



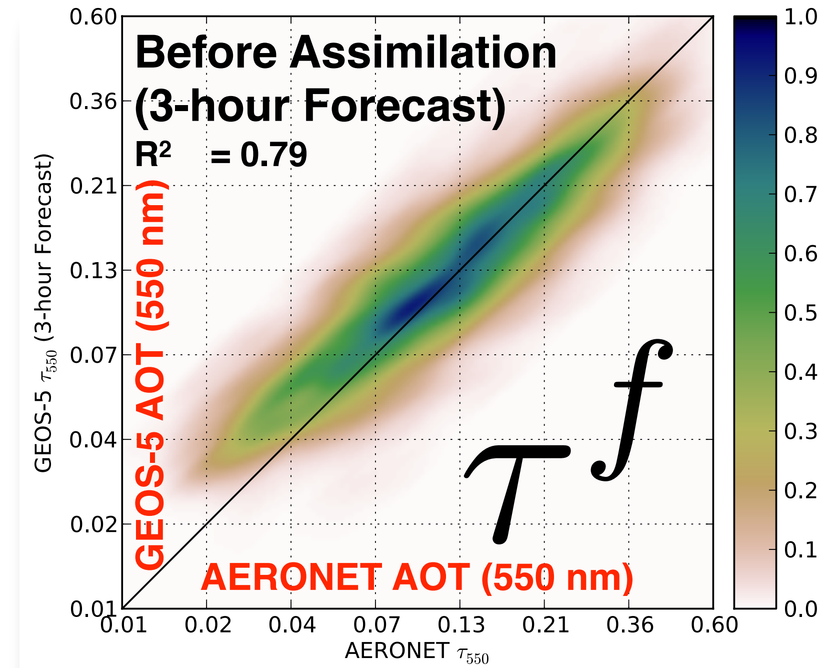
Randles et al., *in preparation*

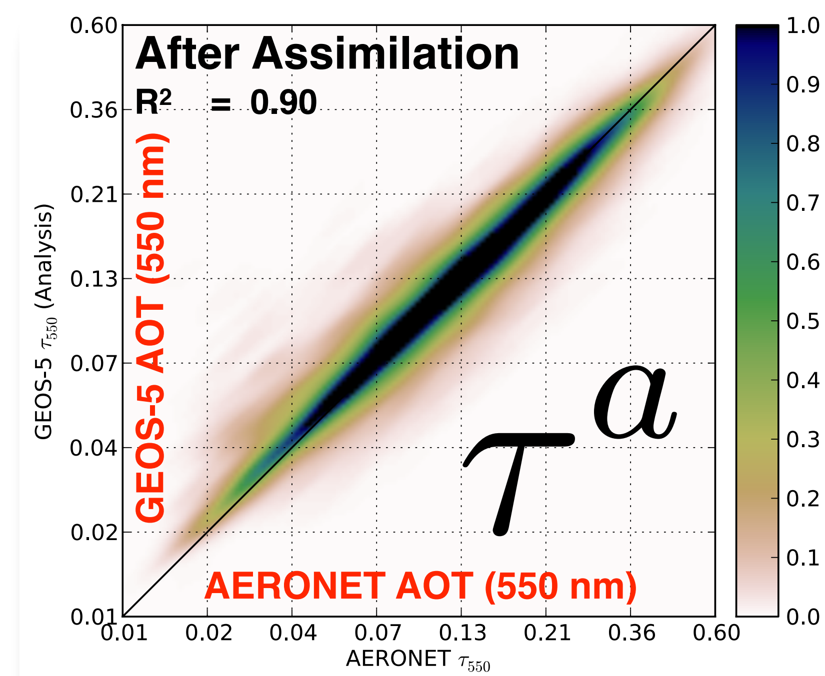
- Airborne atmospheric composition campaign based out of Houston, TX, August - September 2013
- During campaign GEOS-5 and our group provided forecast support
- Post-mission science focuses on the SEAC^{4}RS mini-reanalysis:
  - Replay of analysis meteorology
  - Assimilation of MODIS, MISR, AERONET AOT
  - Smoke "age" tracers to track airmass history

SEAC^{4}RS: Aerosol Assimilation Impacts

Observing System	GEOS-5 AOT	Statistics (130°W-60°W, 24°N-55°N)		
		R^2	1000 × stderr	Bias (Obs-GEOS5)
AERONET N = 102,552	Background	0.79	1.25	-0.06
	Analysis	0.9	0.92	-0.02
MISR N = 494,743	Background	0.66	0.9	0.06
	Analysis	0.83	0.58	0.02
MODIS Terra N = 24,504,880	Background	0.72	0.1	-0.12
	Analysis	0.92	0.05	-0.01
MODIS Aqua N = 23,300,505	Background	0.74	0.1	-0.08
	Analysis	0.93	0.05	0

Randles et al., *in preparation*

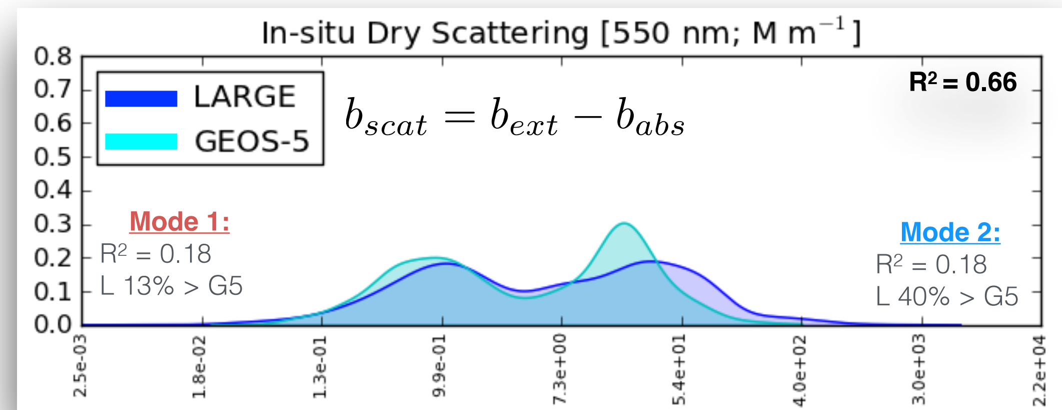


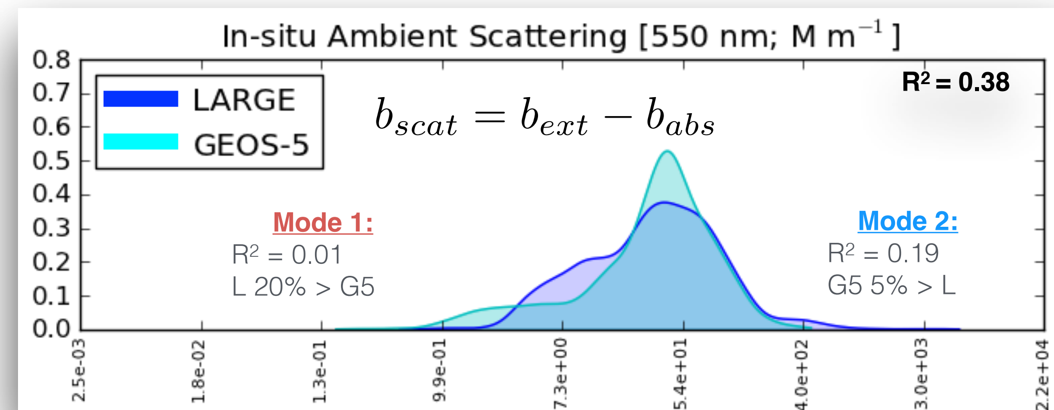


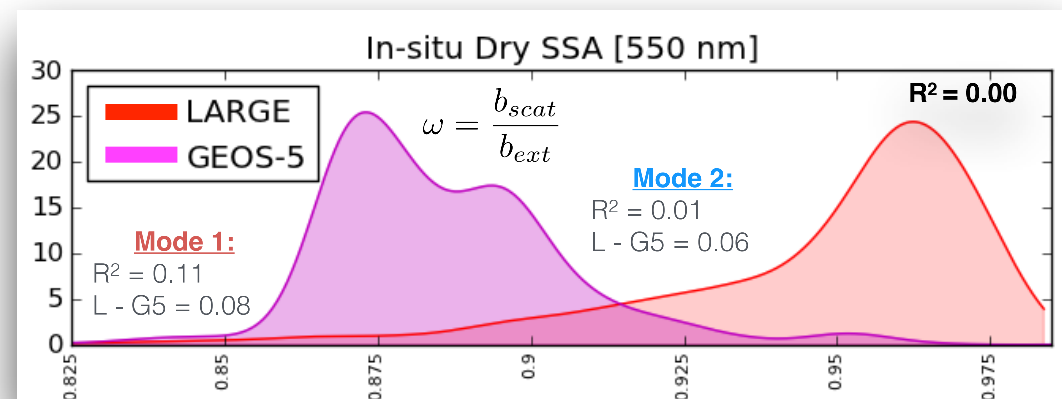
SEAC⁴RS: Campaign Average *in situ* Comparisons

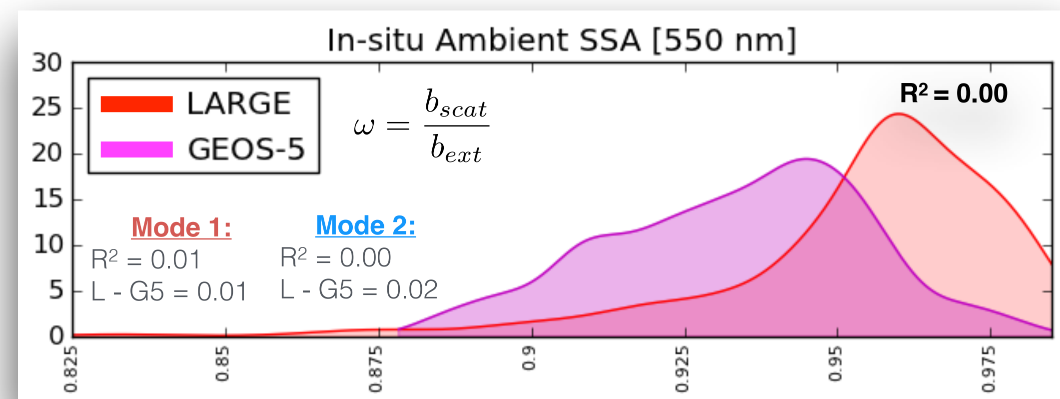
DRY AEROSOL

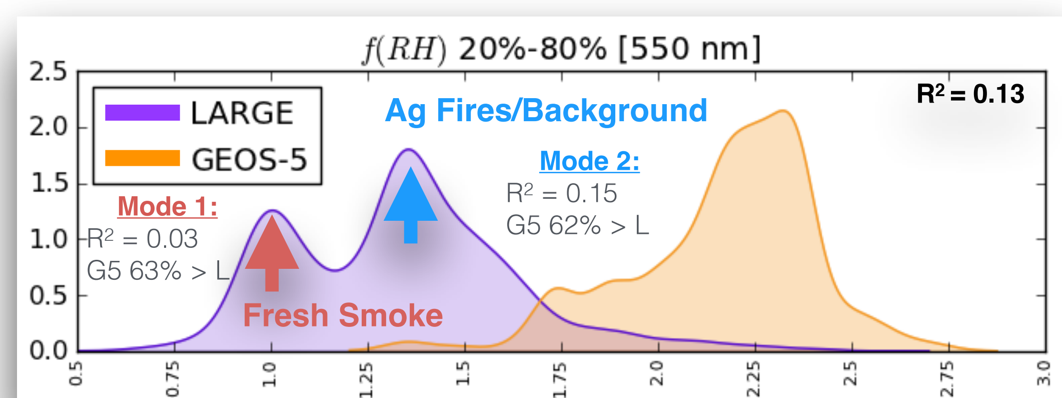
WET AEROSOL

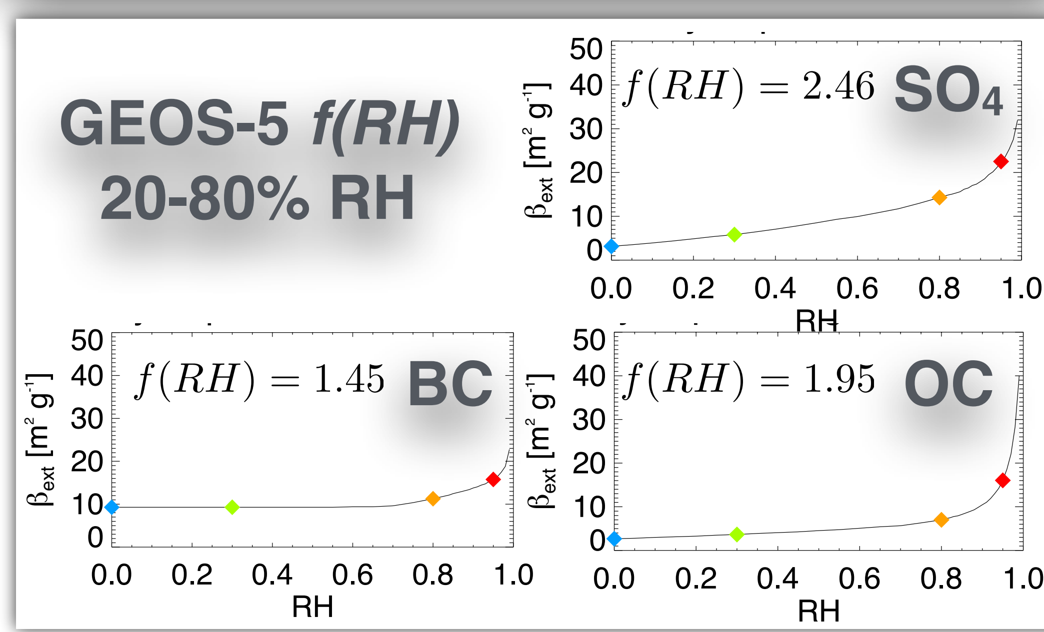








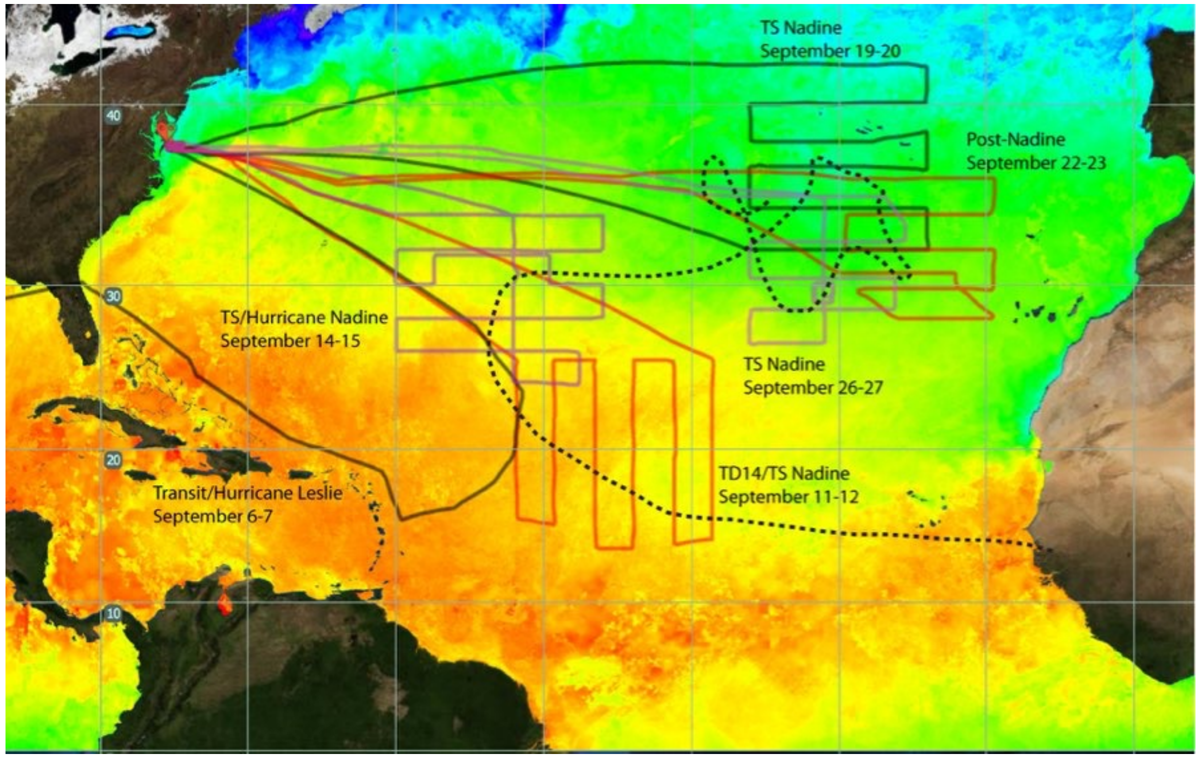




Randles et al., *in preparation*

Campaign Support HS3

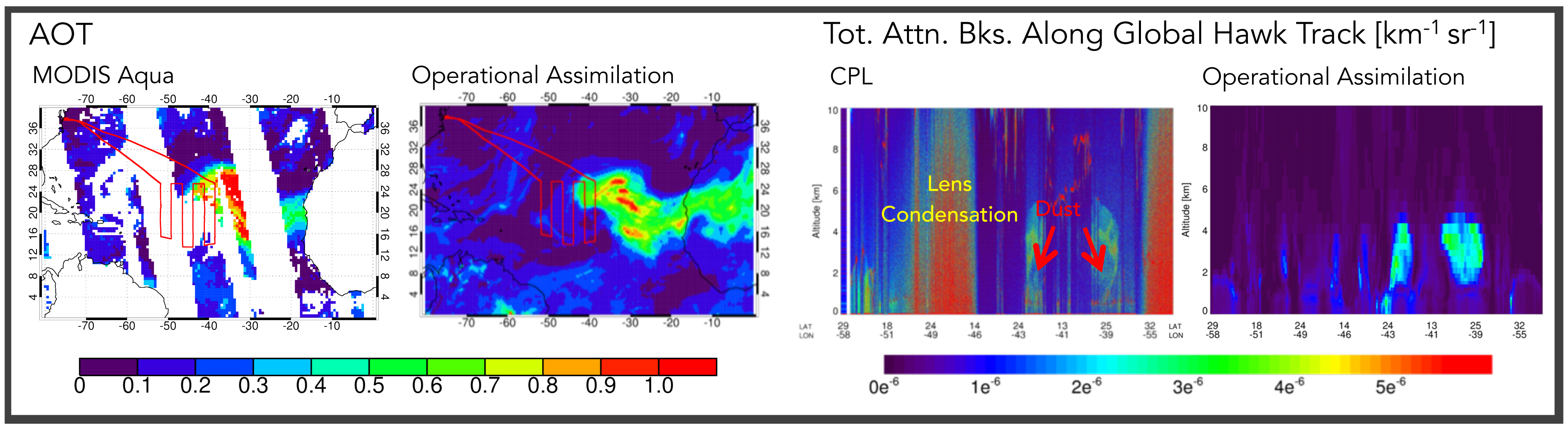
- Global Hawk airborne campaign based out of Wallops, VA, summers 2012, 2013, 2014
- Science goal was to study intensification of tropical cyclones
- During campaign GEOS-5 and our group provided forecast support
- Post-mission science focuses on replay and forecasts to investigate impact of dust on storm system development



2012 HS3 Flight Tracks

HS3 Comparisons to CPL Observations

9/11/12



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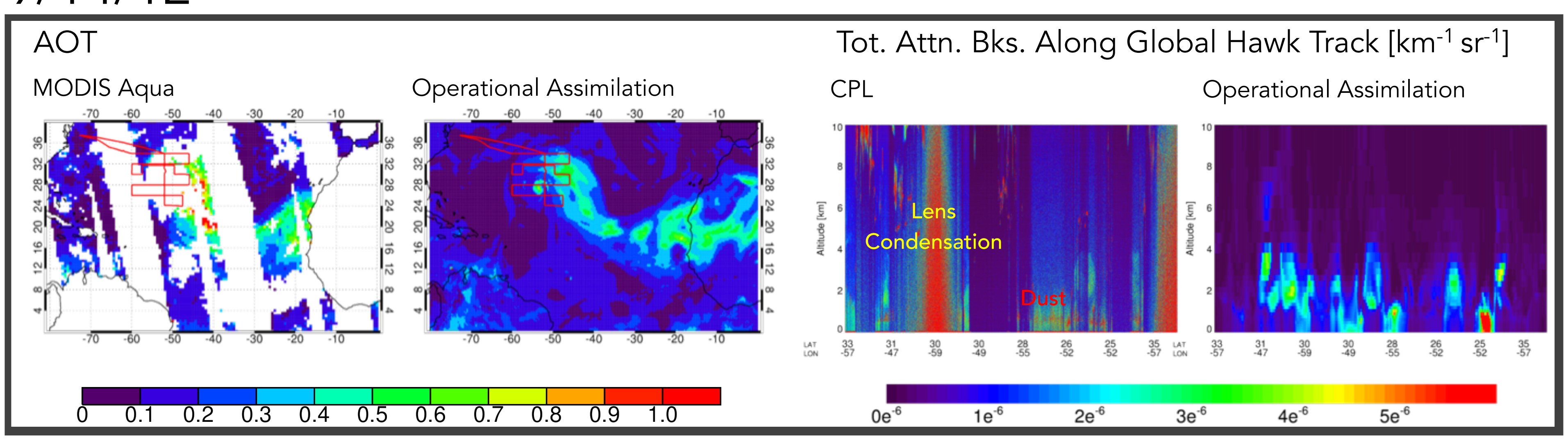


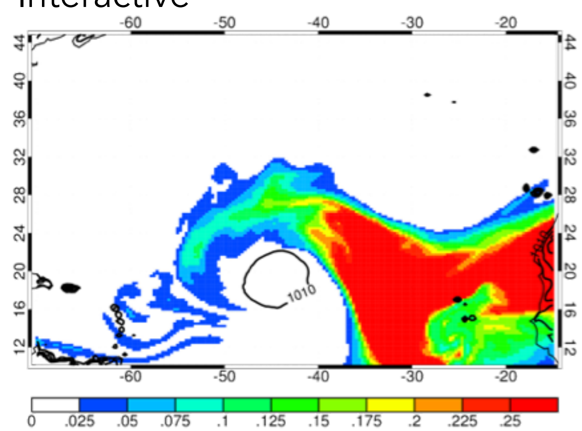
Nowottnick et al., *in preparation*

HS3: Aerosol Radiative Interaction Impacts

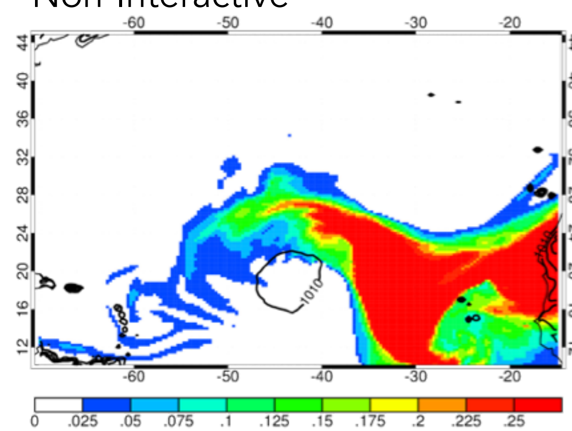
9/12/12 12z

Dust AOT & Surface Pressure [mb]

Interactive

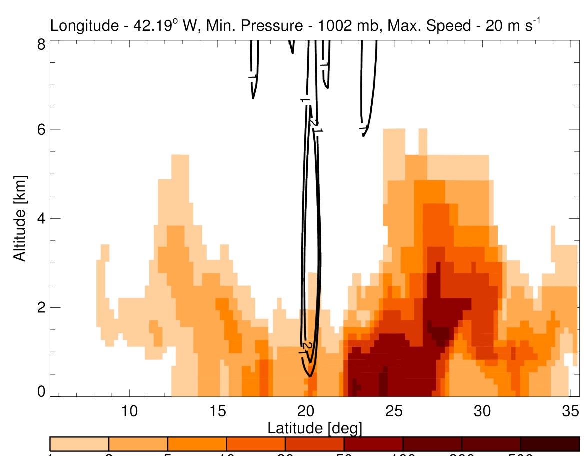


Non-Interactive

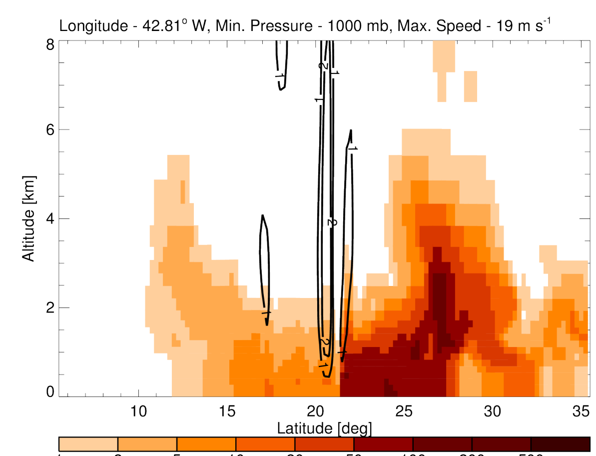


Dust Concentration [μg m^{-3}] & Vertical Velocity

Interactive



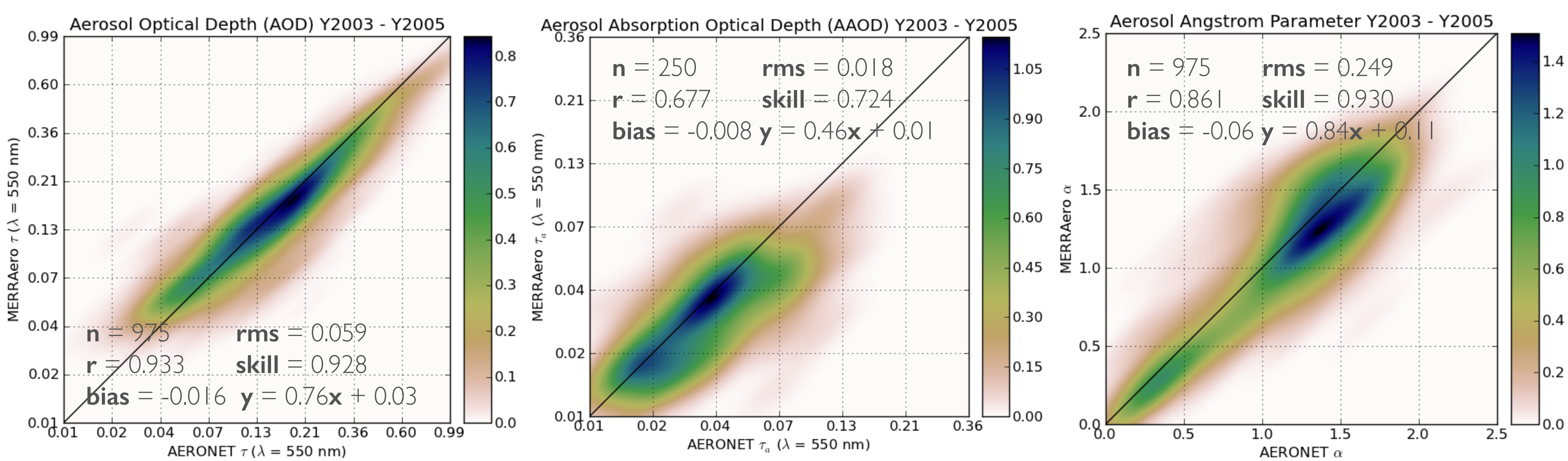
Non-Interactive



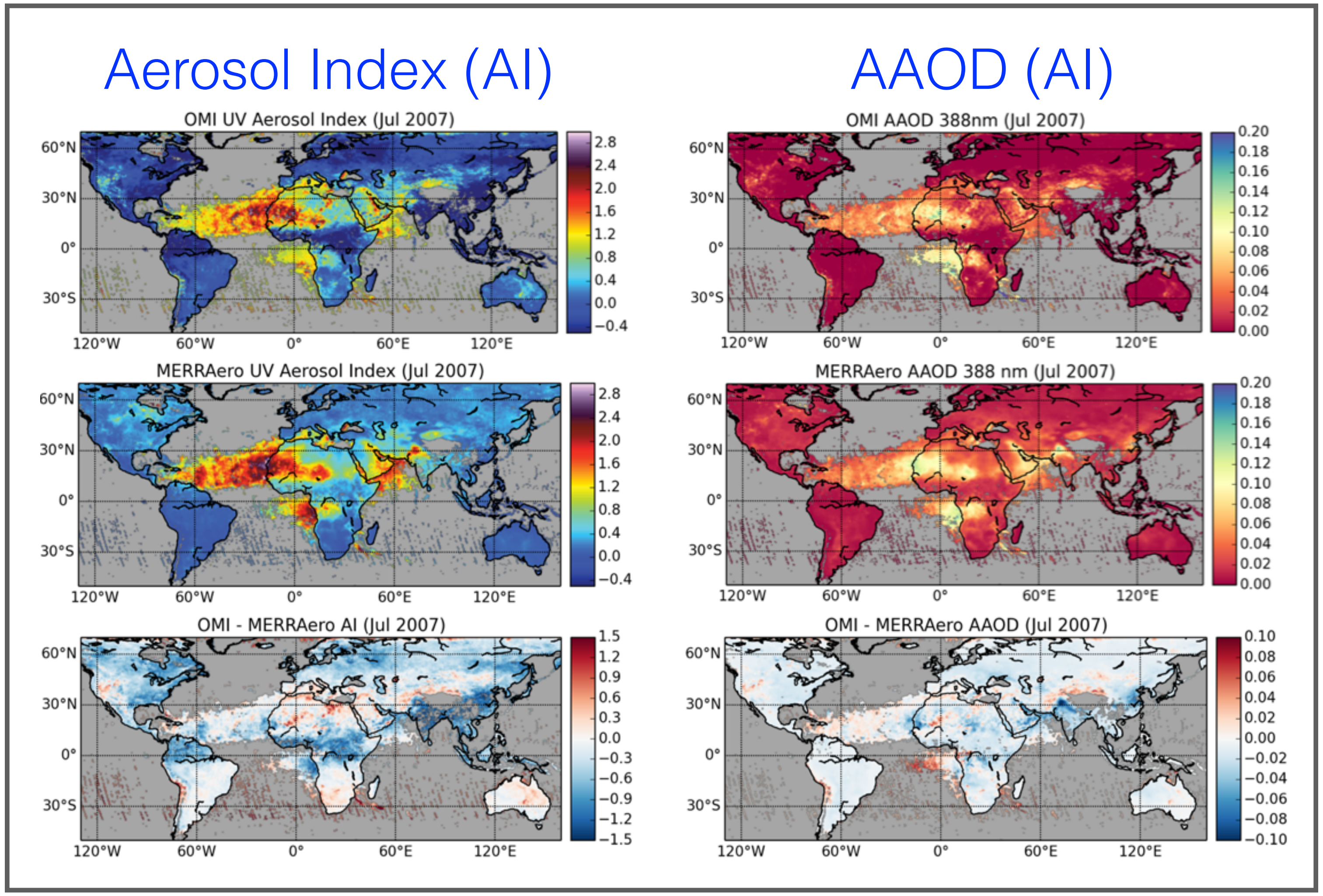
Nowottnick et al., *in preparation*

MERRAero Aerosol Reanalysis

- Aerosol reanalysis based on MERRA meteorological analysis
- 0.5° x 0.625°, 72 vertical levels
- Time period: 2002 - present
- AOT assimilation from QC-ed MODIS over ocean and dark target land observations
- Precipitation imposed from prior data-constrained land surface reanalysis
- Global, high temporal frequency atmosphere and aerosol output



MERRAero: Comparisons to OMI Observations



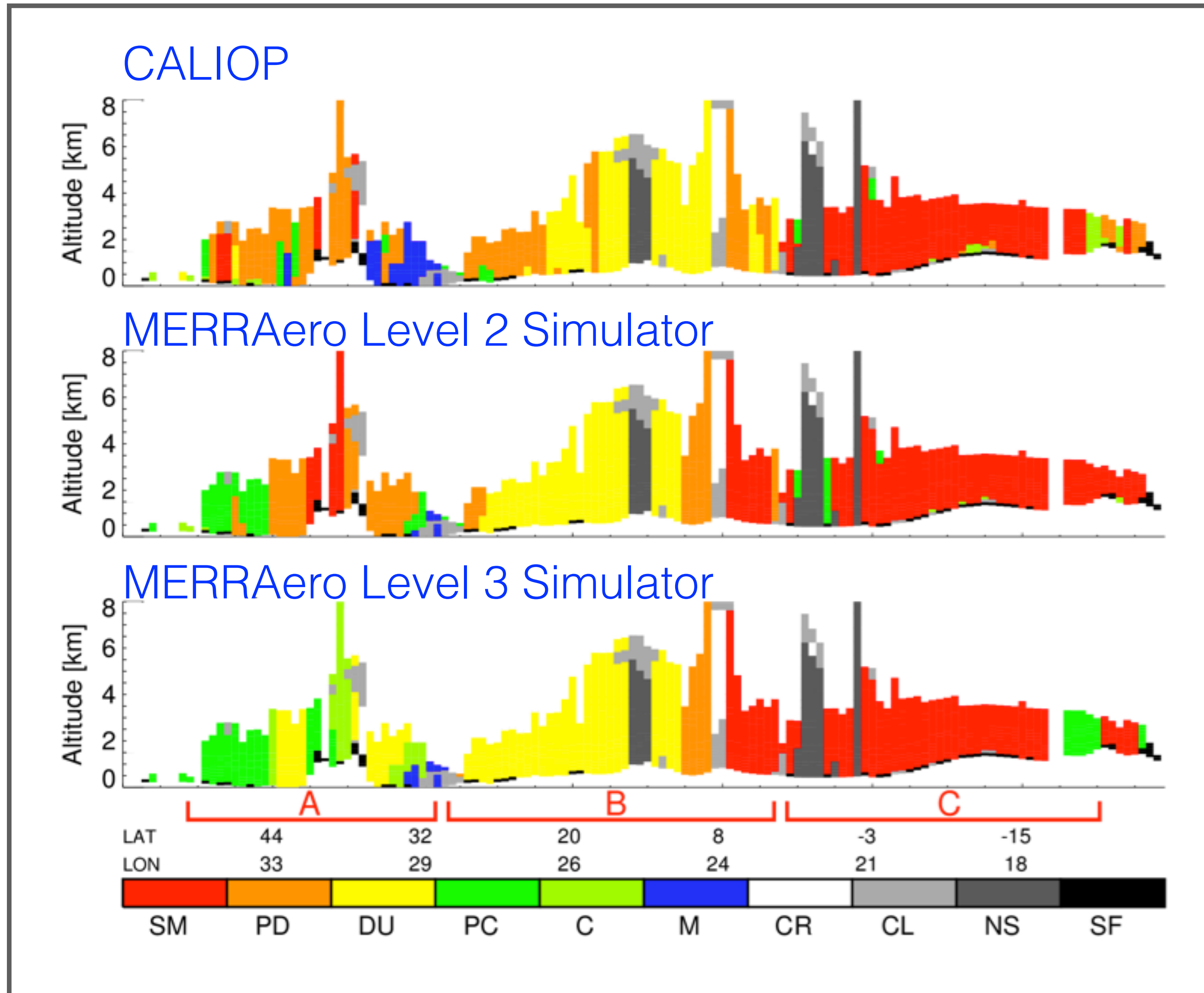
Comparisons of MERRAero and OMI aerosol index (left) and AAOD (right) for July 2007

- From MERRAero aerosol fields we simulate the OMI observed TOA radiances (354 and 388 nm) using VLIDORT
- Comparison of the simulated and observed UV aerosol index provides complementary information to comparison of simulated and retrieved AAOD
- Result is improved confidence in simulated aerosol absorption, as well as refinement of assumed input aerosol optical properties (dust, organic carbon)

Buchard et al., *ACP, 2015*

MERRAero: Comparisons to CALIOP Observations

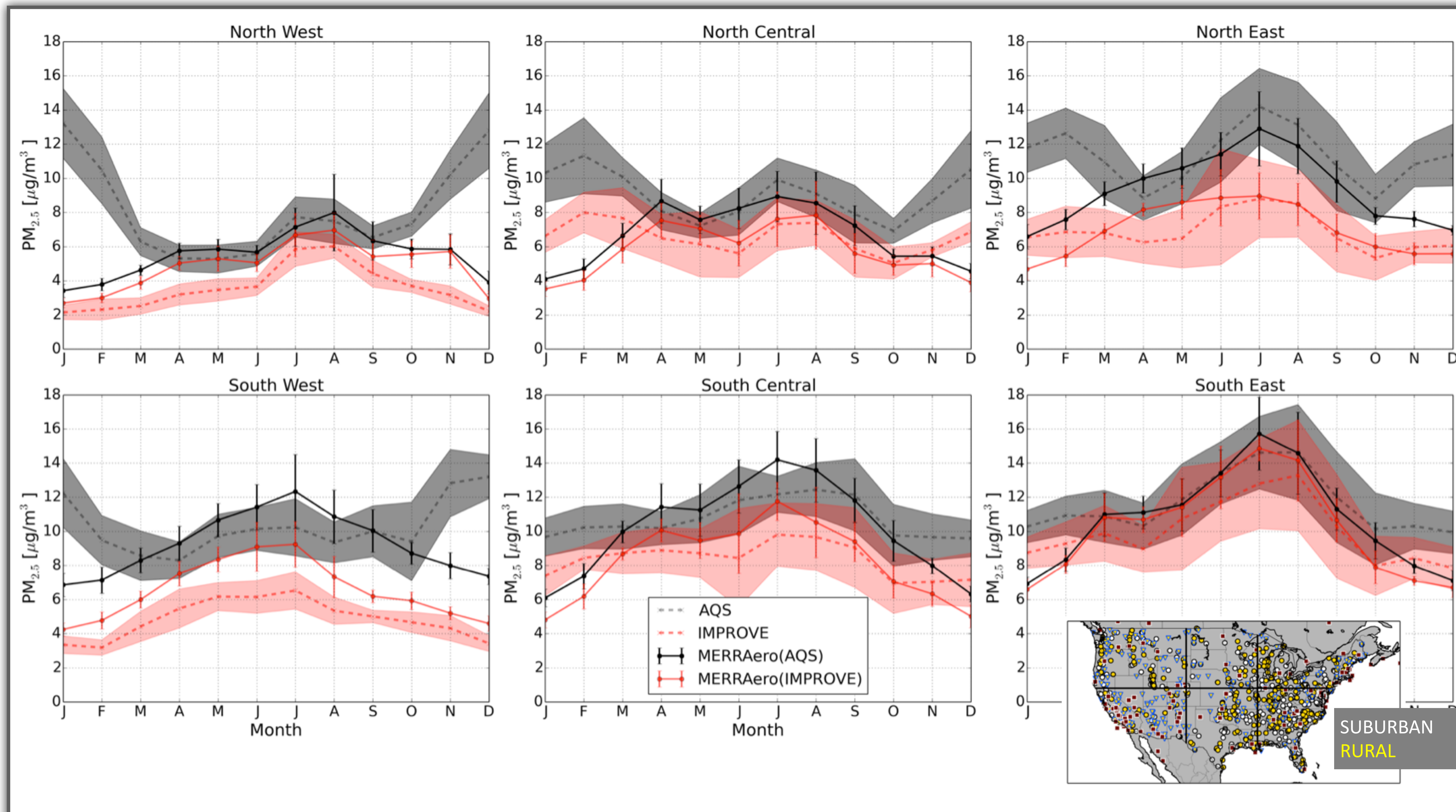
- From MERRAero aerosol fields we simulate the CALIOP 532 nm attenuated backscatter and depolarization ratio
- Simulation of depolarization ratio is possible through inclusion of non-spherical dust optical properties (other species in development)
- Level 2 CALIOP simulator: by simulating the observables we can feed these as inputs to CALIOP VFM algorithm and evaluate aerosol typing
- Level 3 CALIOP simulator: a complementary typing analysis can be performed by using aerosol speciation from MERRAero



Case study evaluation of MERRAero vertical profile with respect to CALIOP observations, July 9, 2009

Nowottnick et al., *AMT, submitted, 2015*

MERRAero: Comparisons to PM2.5 Observations

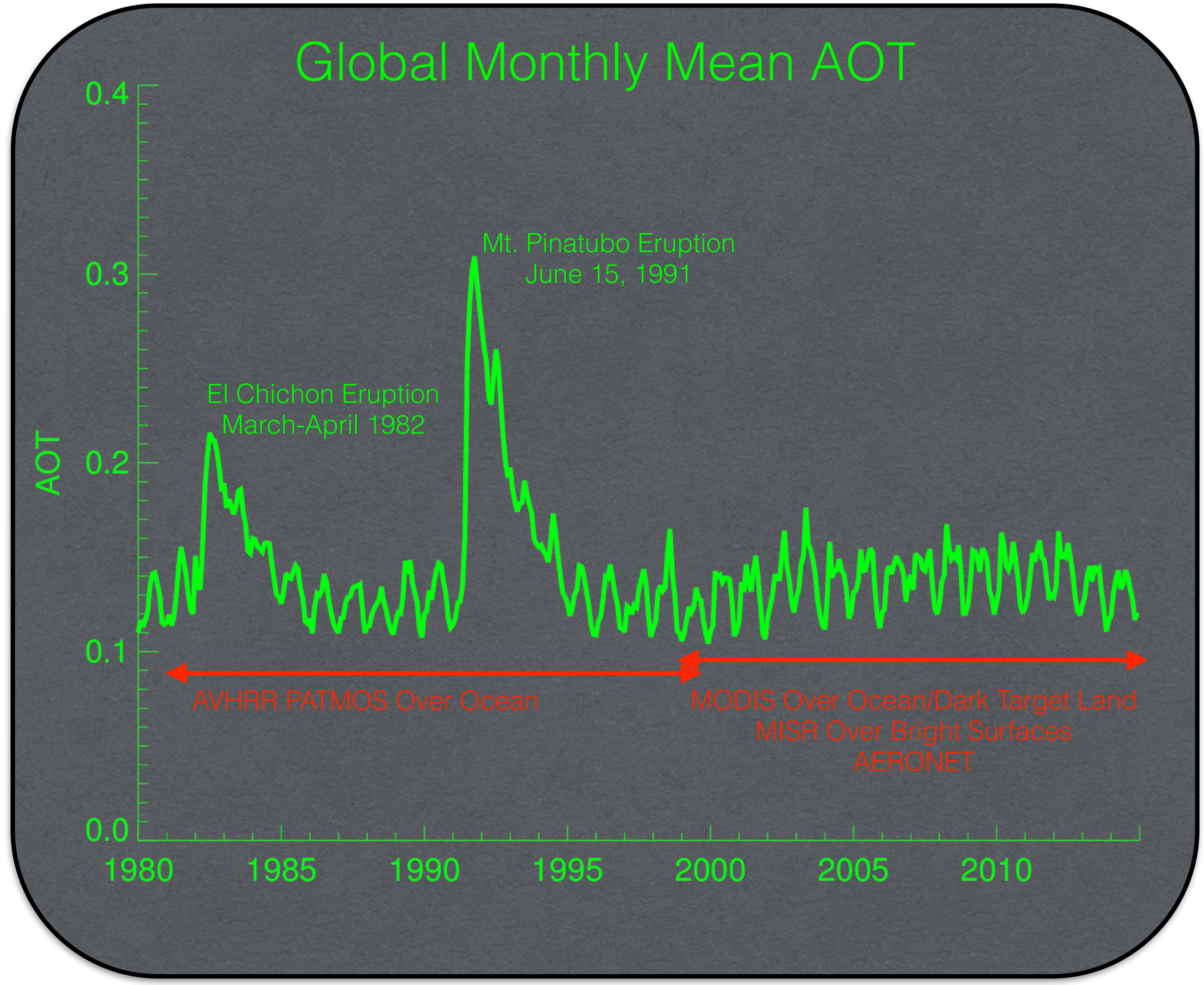


Evaluation of Surface $PM_{2.5}$ in MERRAero

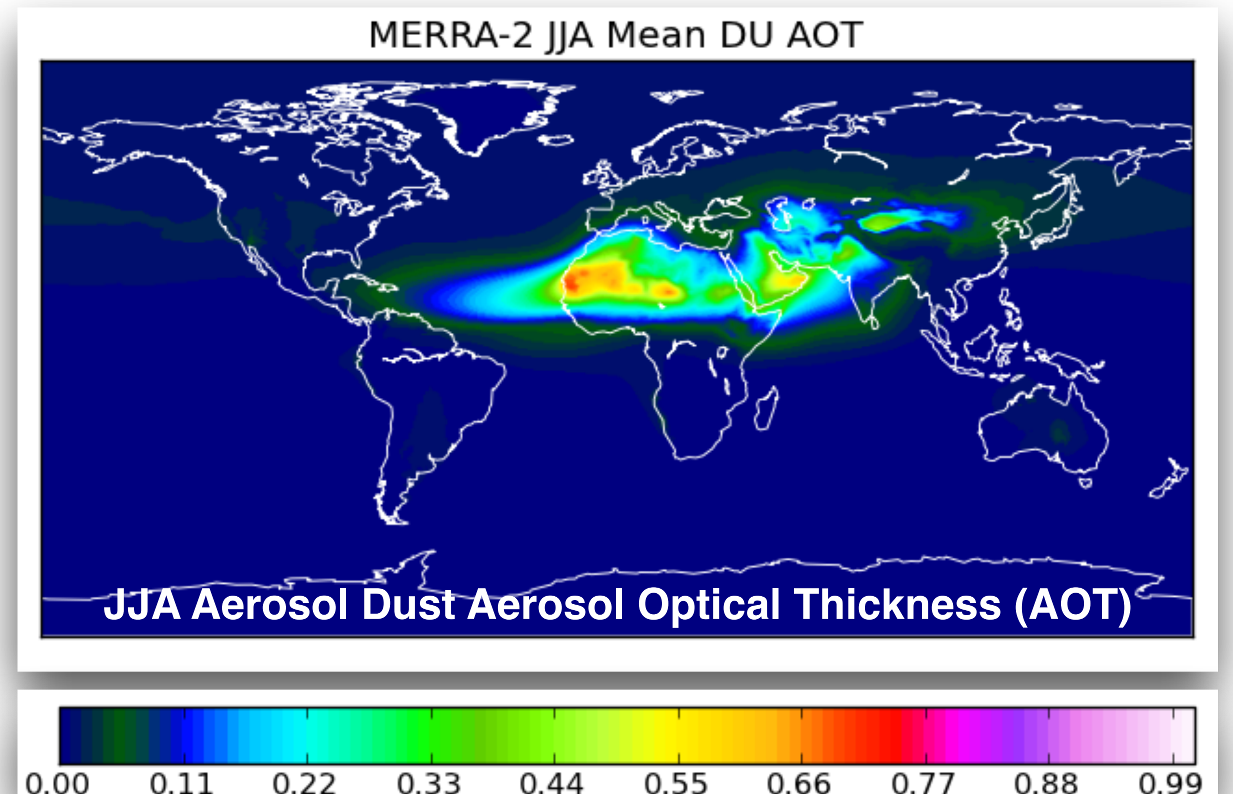
Buchard et al., *Atmos. Env., submitted, 2015*

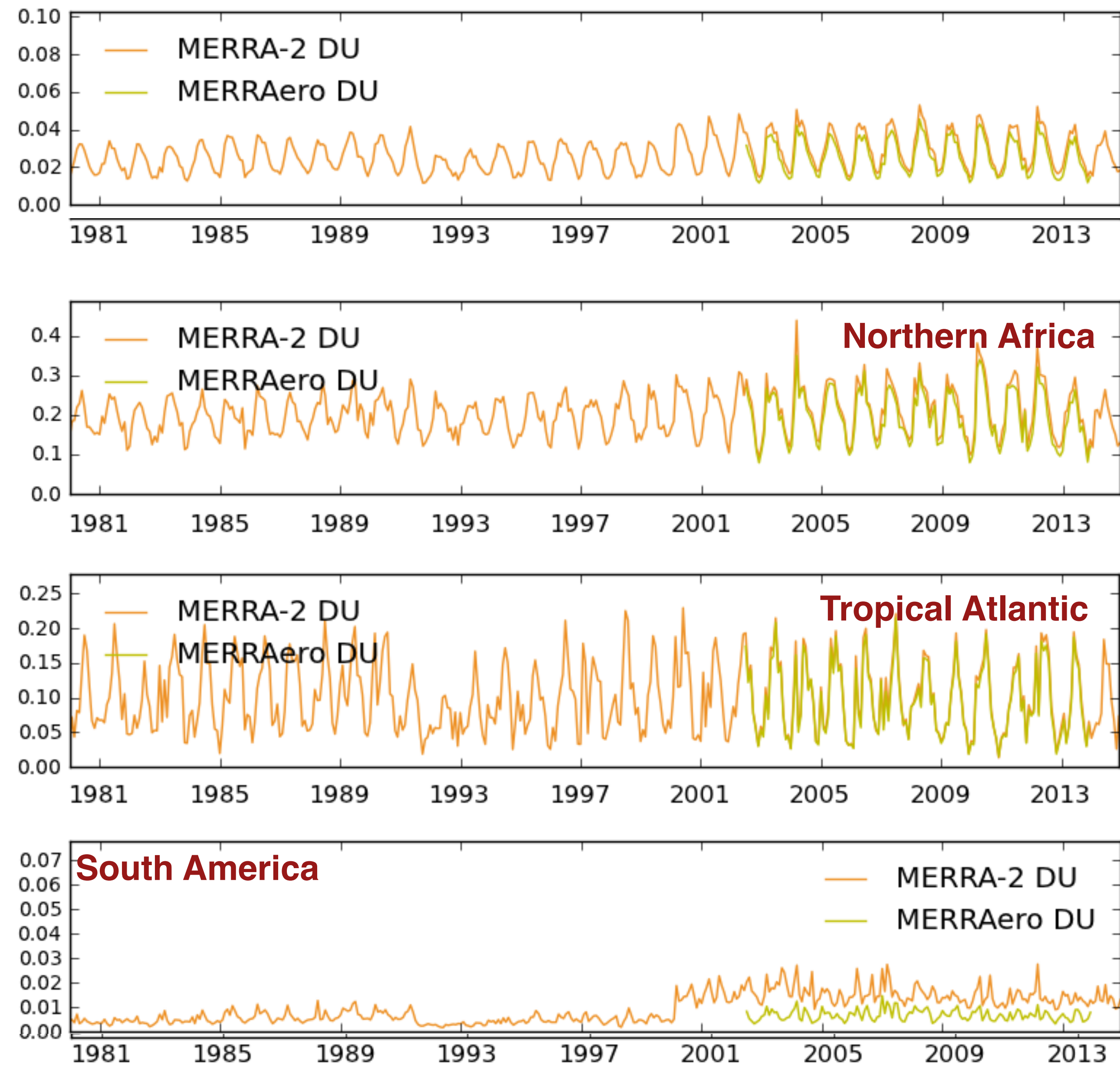
MERRA-2 Aerosol Reanalysis

- Joint atmospheric and aerosol reanalysis
- Updated model and data assimilation system since MERRA
- Updated aerosol emissions
- Time period: 1979 - present
- Global, high temporal frequency atmosphere and aerosol output: 0.5° x 0.625°, 72 vertical levels

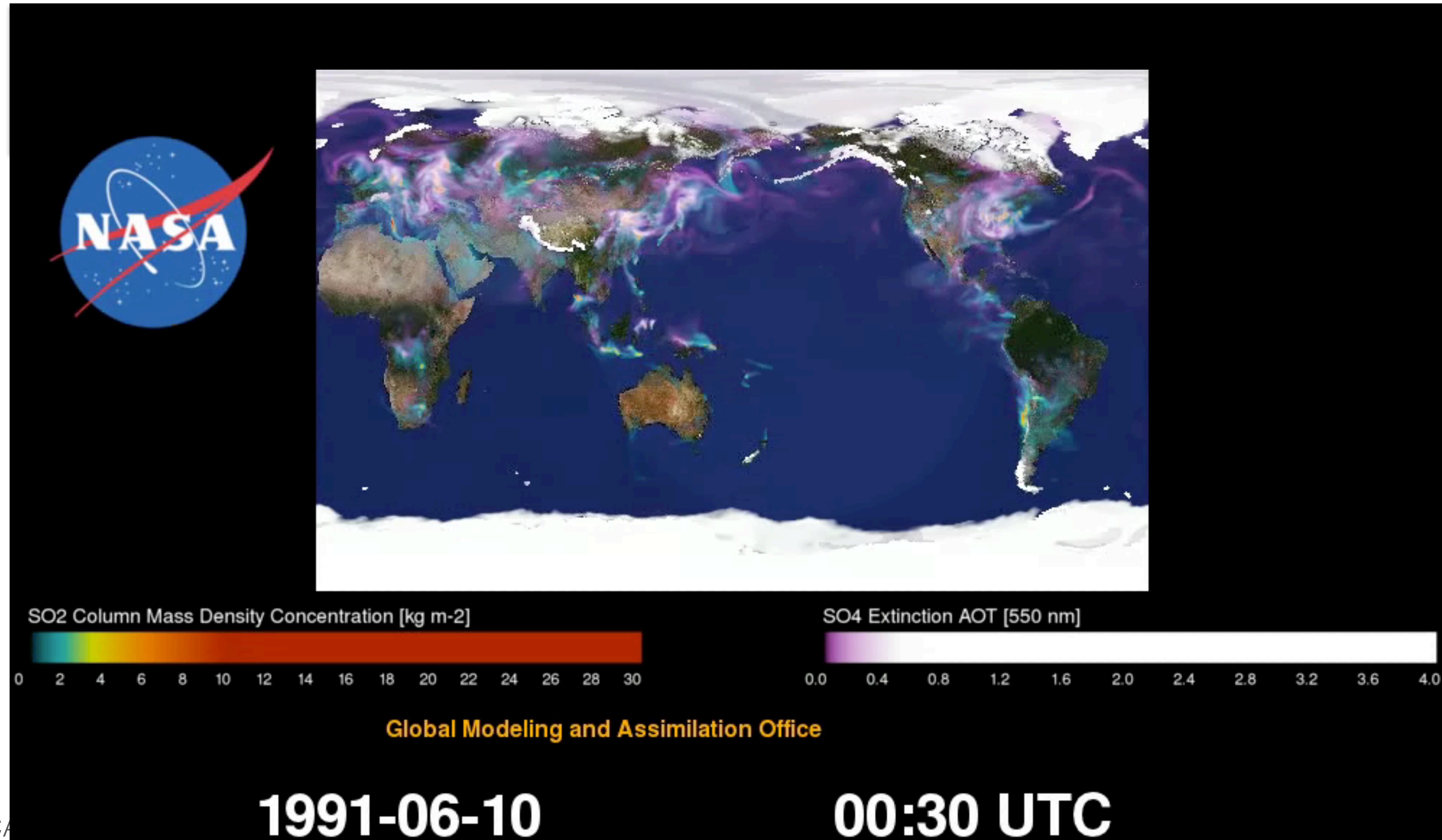


MERRA-2 Aerosol Reanalysis

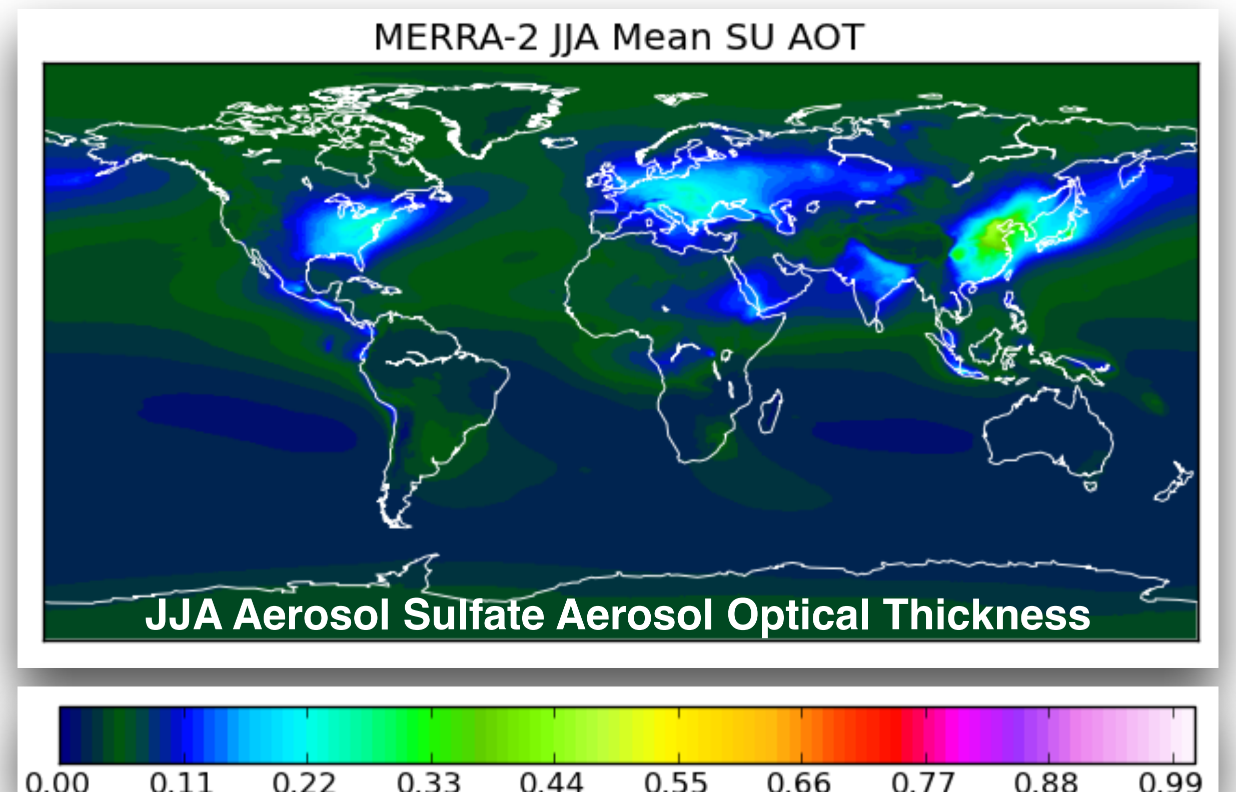


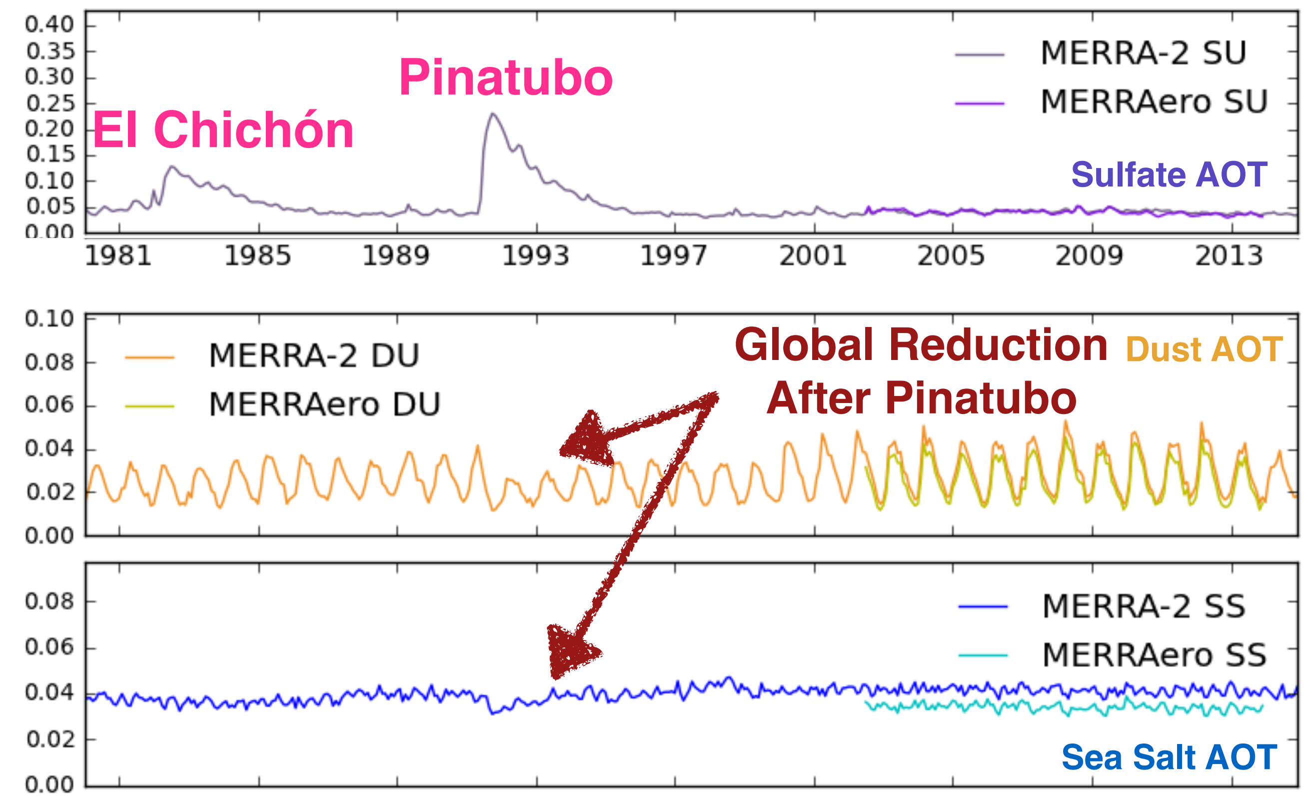


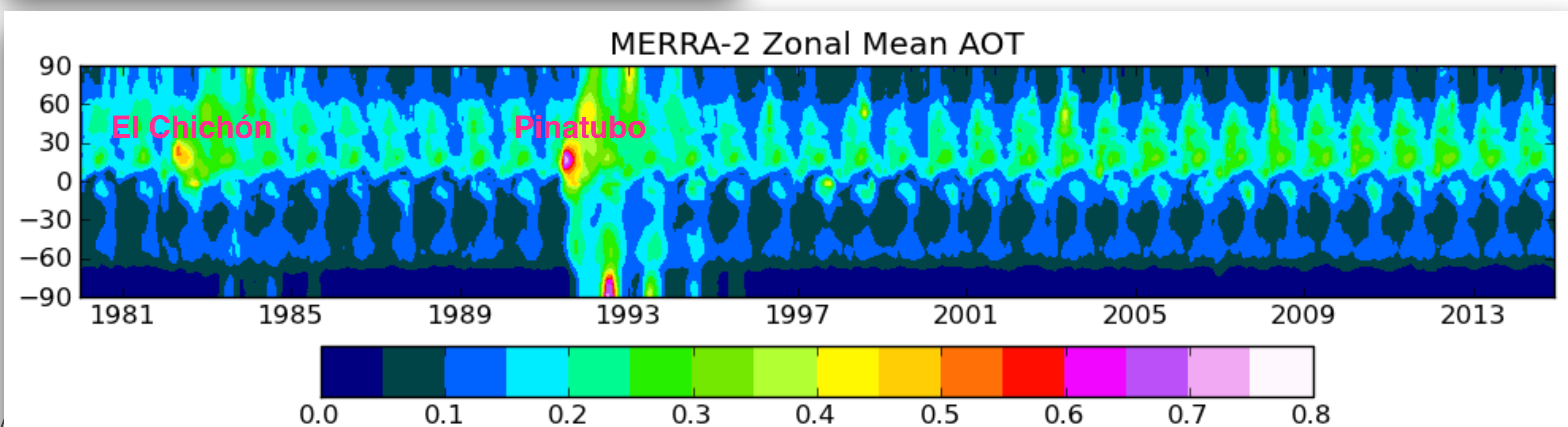
MERRA-2 Aerosol Reanalysis



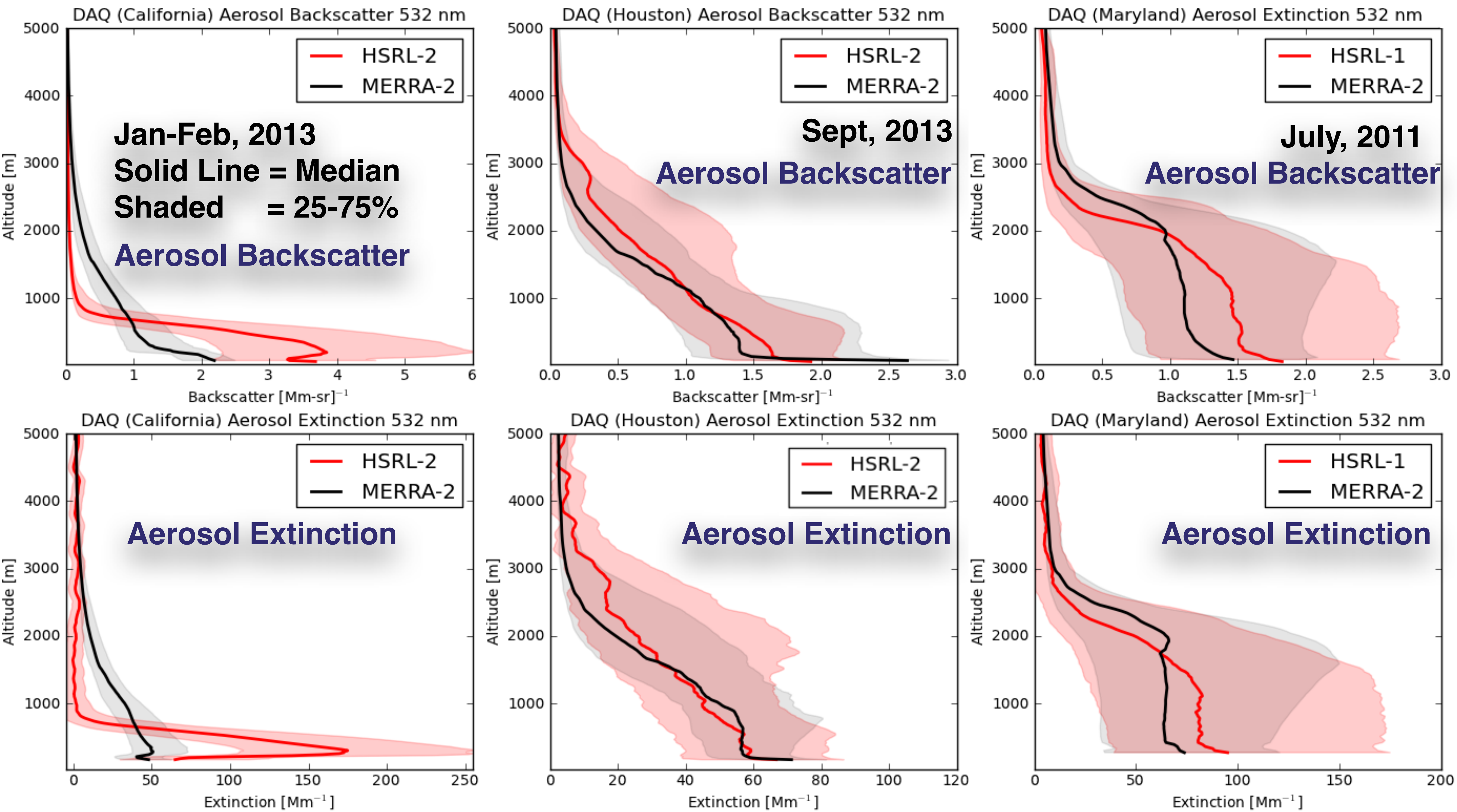
MERRA-2 Aerosol Reanalysis



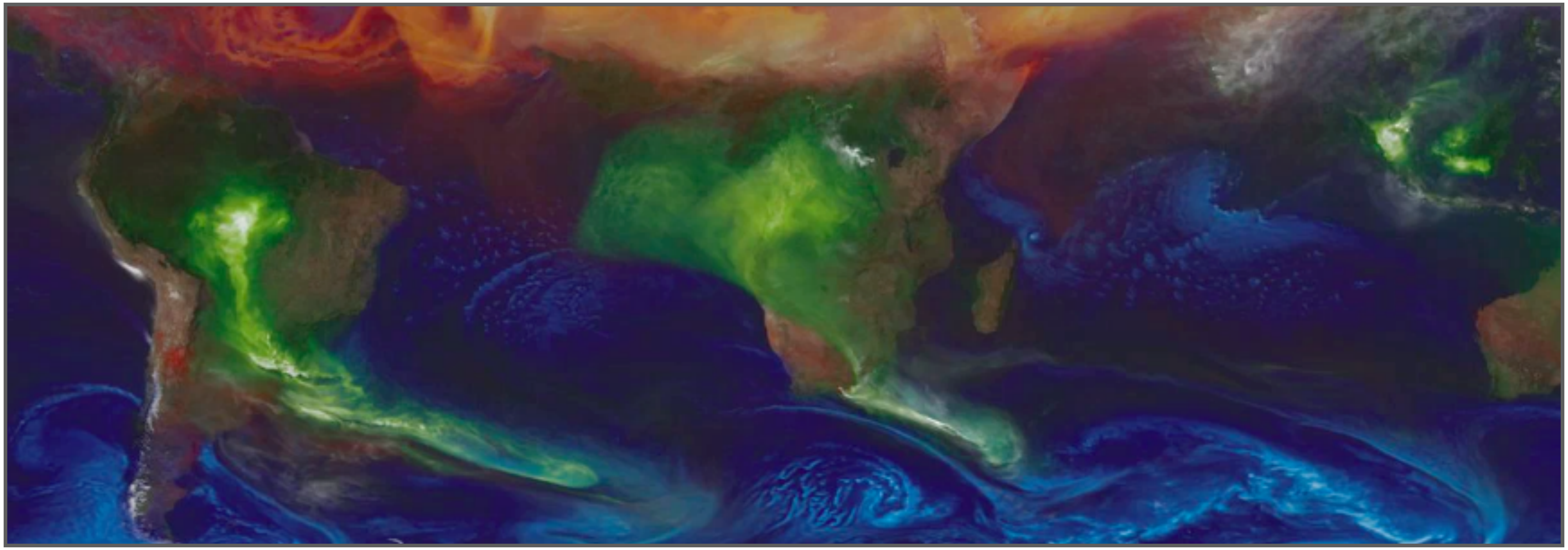




MERRA-2 Aerosol Reanalysis

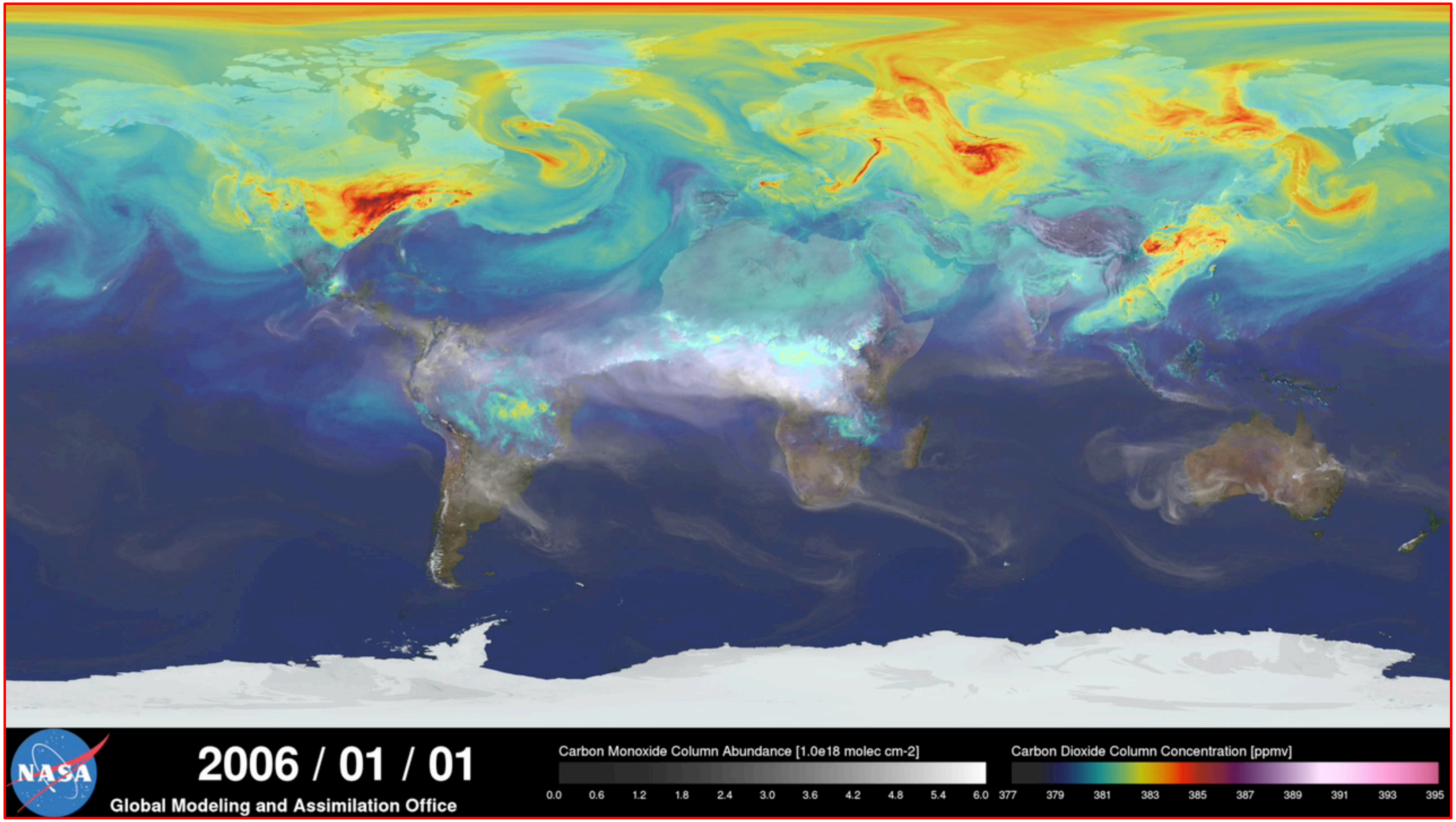


MERRAero-2



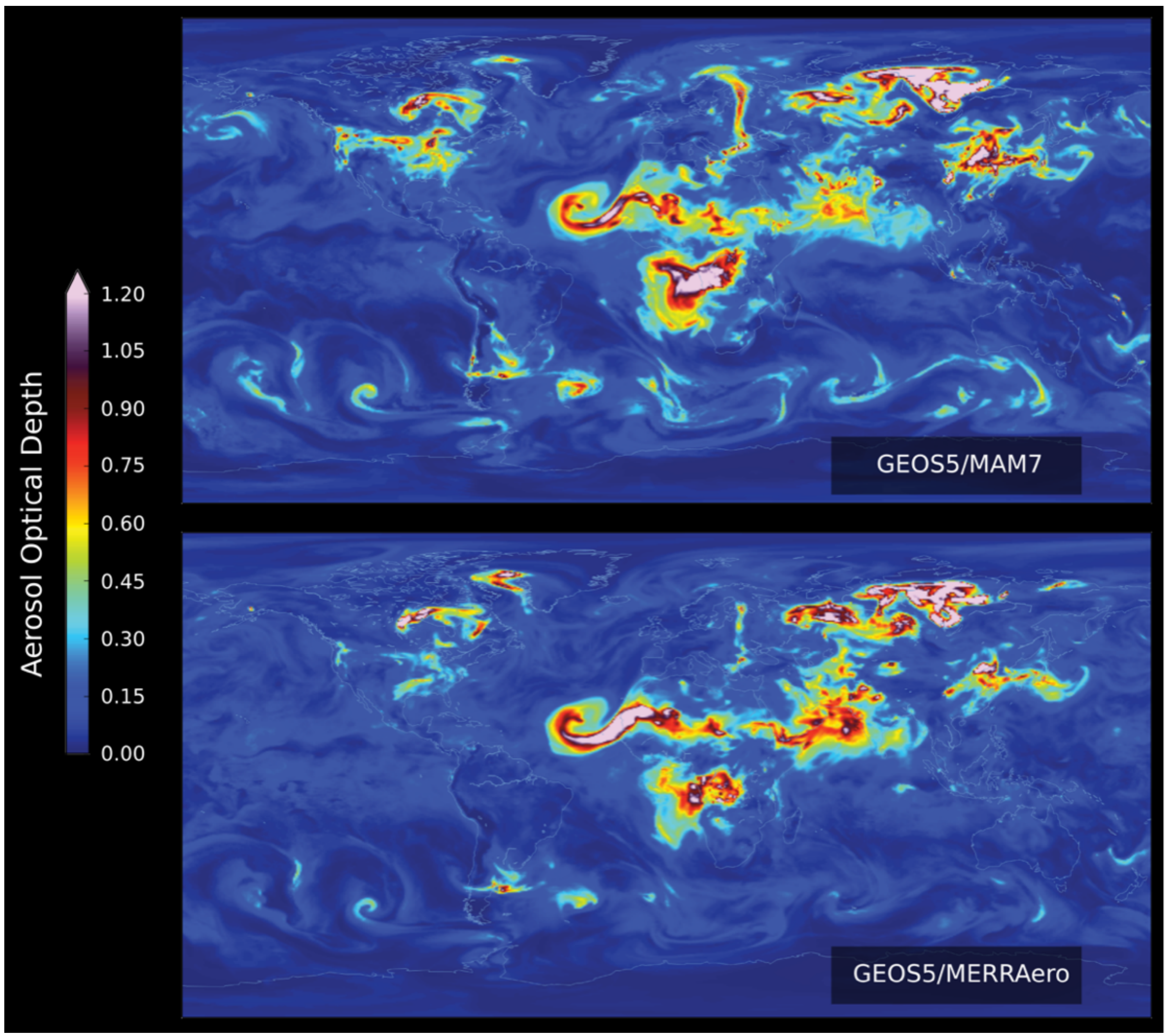
- MERRA-2 version of the model
- Global 12.5 km replay of EOS period (2000 - present) using MERRA-2 meteorology
- Assimilation of MODIS, MISR, and AERONET
- Availability late 2015

GEOS-5 Nature Run



7-km GEOS-5 "Nature Run" simulation of CO & CO_2

Modal Aerosol Microphysics



- Current GOCART aerosol scheme is mainly bulk aerosol mass; limited information on composition (carbonaceous) and size (dust and sea salt)
- Limited utility for aerosol-cloud interaction: need particle size and composition
- MAM-7 - Modal Aerosol Model, in collaboration with U. Wyoming and PNNL
- Resolve aerosol composition across seven modal groups
- Bring in additional processes: SOA, nitrate
- Bonus features: simplified chemistry mechanisms (KPP-based "achem" component; aerosol-cloud interaction via NCAR 2-moment cloud scheme; more sophisticated aerosol-radiation interactions

Modal Aerosol Microphysics

Aitken

number
water
sulfate
ammonium
secondary OM
sea salt

$\sigma = 1.6$

coagulation and condensation

Accumulation

number
water
sulfate
ammonium
secondary OM
hydrophobic OM
black carbon
sea salt

$\sigma = 1.8$

Fine Dust

number
water
dust
sulfate
ammonium

$\sigma = 1.8$

Fine Sea Salt

number
water
sea salt
sulfate
ammonium

$\sigma = 2.0$

aged to the accumulation mode due to condensation of H2SO4, NH3 and SOA(gas)

Primary Carbon

number
water
hydrophobic OM
black carbon

$\sigma = 1.6$

Coarse Dust

number
water
dust
sulfate
ammonium

$\sigma = 1.8$

Coarse Sea Salt

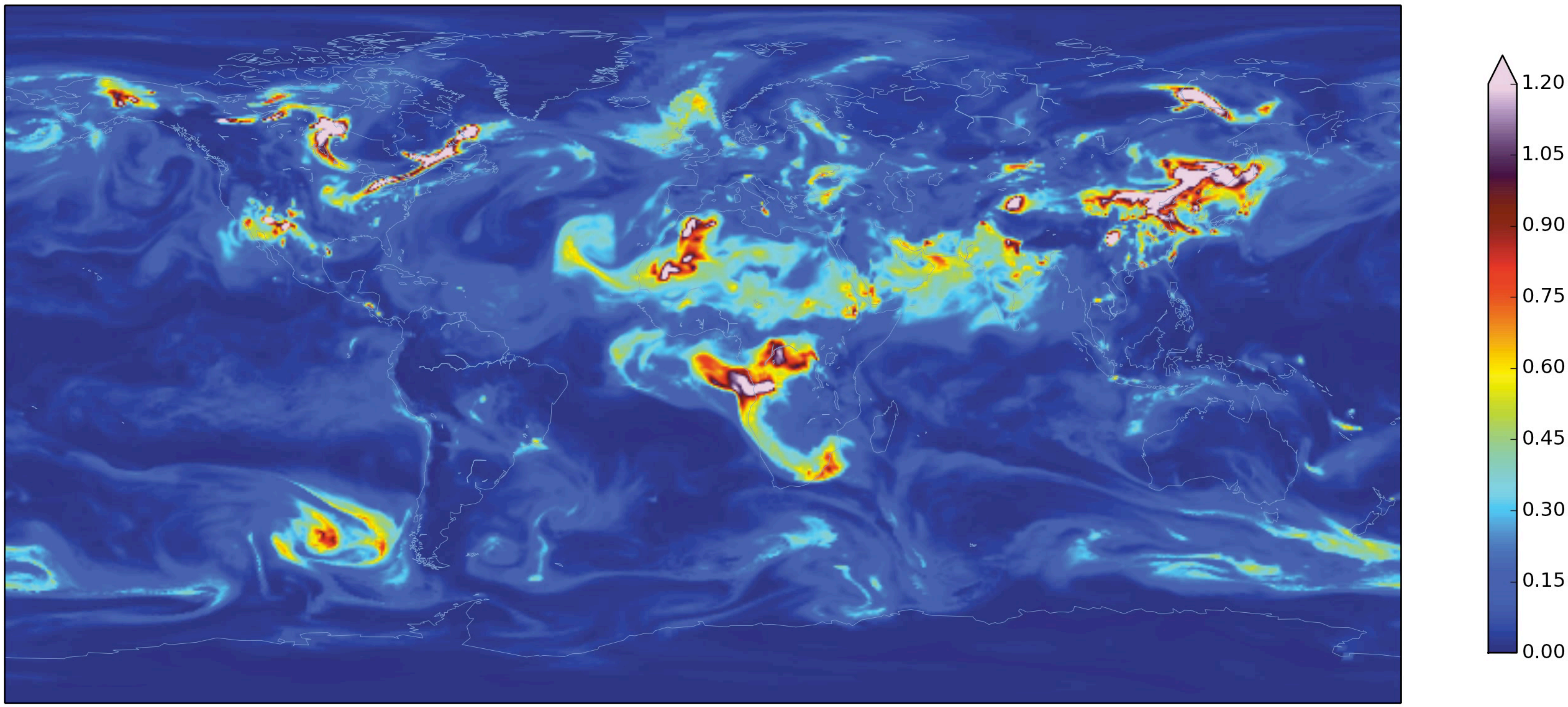
number
water
sea salt
sulfate
ammonium

$\sigma = 2.0$

Aerosol components

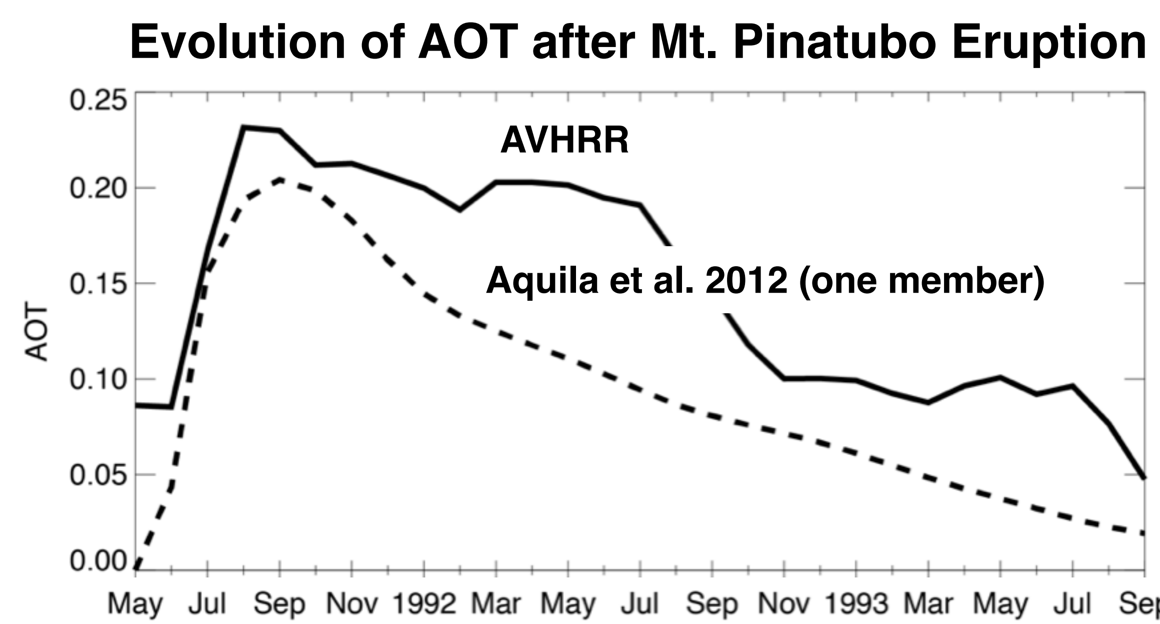
- Sulfate
- Ammonium
- Black carbon
- Dust
- Sea salt
- Primary organic
- Secondary organic

Modal Aerosol Microphysics



Stratospheric Aerosols and Sectional Aerosol Microphysics

- How are stratospheric aerosols (and changes in their loadings) perturb climate? How will climate change following next Pinatubo-like volcanic eruption? What does background state of stratospheric aerosol look like?
- Observations: OMPS-LP, GOMOS, OSIRIS, SAGE-ISS …

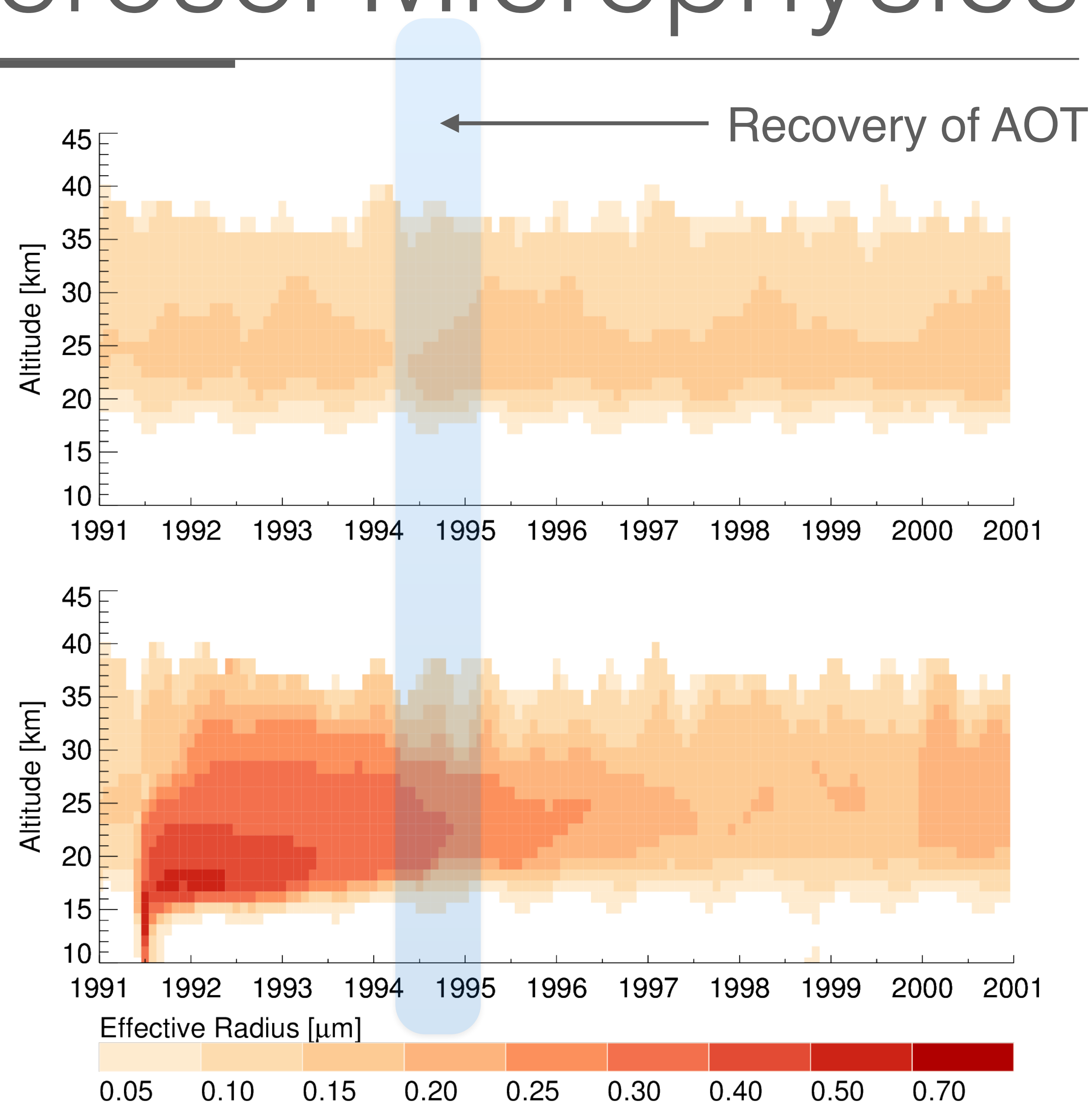


- Introduced mechanisms for production of background stratospheric aerosol from OCS oxidation
- Coupled this mechanism to CARMA sectional aerosol microphysics scheme

Stratospheric Aerosols and Sectional Aerosol Microphysics

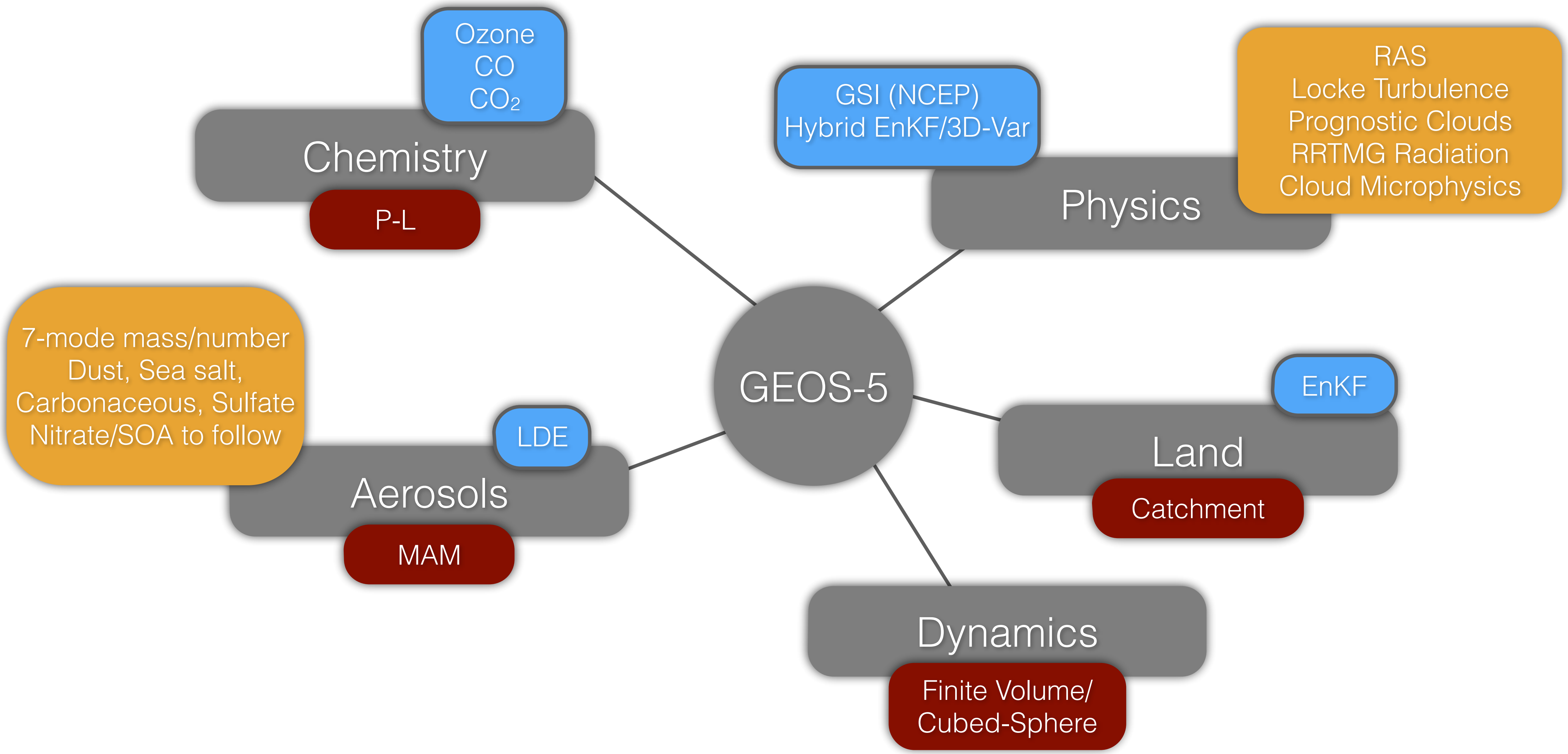
CARMA simulation that sees only sulfate produced from OCS oxidation

CARMA simulation that sees all sources of sulfate production



Zonal mean particle effective radius at 0° latitude

Late 2015 NRT Configuration



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