UMBC

National Aeronautics and Space Administration

NASA

Aerosols in Future Reanalysis Products from the GMAO

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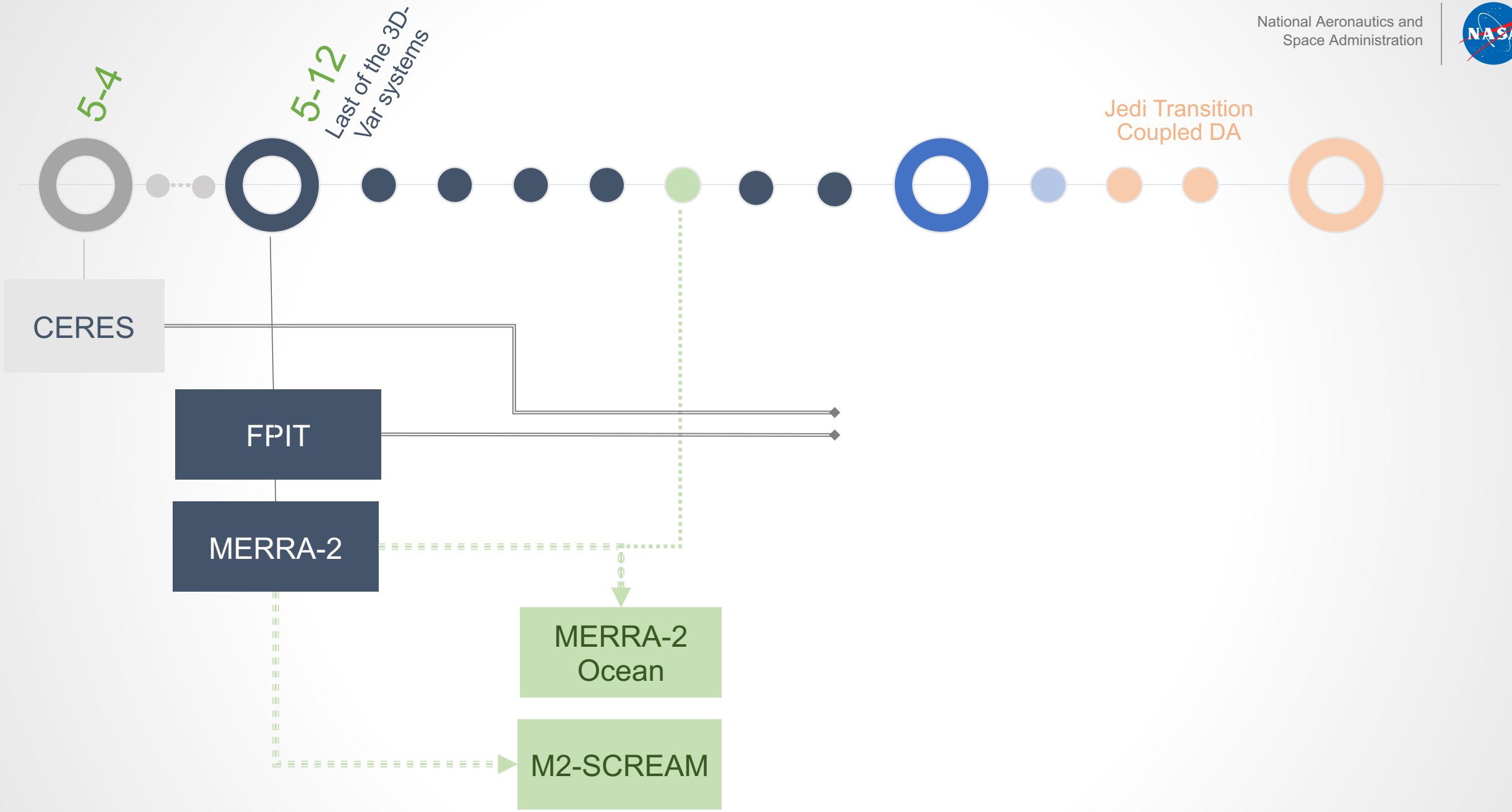
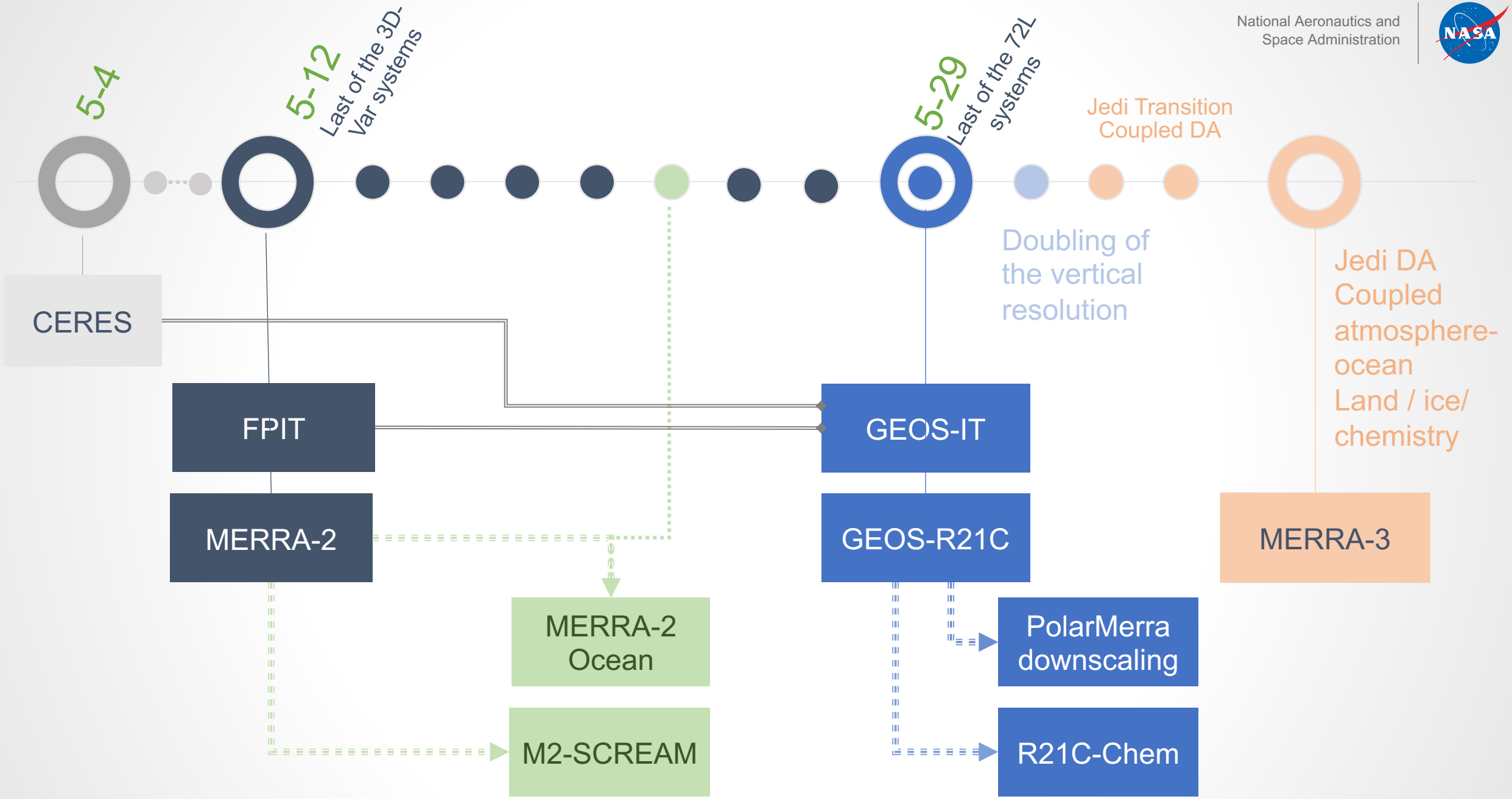

5-4
5-12
Last of the 3D-Var systems
Jedi Transition
Coupled DA
CERES
FPIT
MERRA-2
MERRA-2
Ocean
M2-SCREAM


5-4
5-12
Last of the 3D-Var systems
5-29
Last of the 72L systems
Jedi Transition Coupled DA
Doubling of the vertical resolution
Jedi DA Coupled atmosphere-ocean Land / ice/ chemistry
CERES
FPIT
MERRA-2
GEOS-IT
GEOS-R21C
MERRA-3
MERRA-2 Ocean
M2-SCREAM
PolarMerra downscaling
R21C-Chem

Meteorological Configuration

FPIT

Atmosphere
50km, L72 (C180,L72)
3DVar / Clear-sky
GEOSadas-5.12
2000-onwards
MERRA-2 Obs (no MLS)

GEOS-IT

Atmosphere
50km, L72 (C180,L72)
3DVar / Clear-sky
GEOSadas-5.29 – NLv3
1998-onwards
New/reprocessed (No MLS, No OMPS-LP)
Updated Aerosols + CEDS emissions (GOCART)

- Upgraded model & observing system.
- Target: Instrument teams + CERES.

MERRA-2

Atmosphere
50km, L72 (C180,L72)
3DVar / Clear-sky
GEOSadas-5.12
1980-onwards
MERRA-2 Obs
Precip Correction

GEOS-R21C

Atmosphere
25km, L72 (C360,L72)
Hybrid 4DEnVar / All-sky
GEOSadas-5.29* – NLv3
2000-2025+
New/reprocessed
Updated Aerosols and emissions (GOCART-2G)
OSTIA Reanalysis for SST/SIC BC
Precip Correction (IMERG)

- Upgraded model, DA, observing system, and horizontal resolution

Aerosol Configuration

FPIT

Atmosphere
50km, L72 (C180,L72)
2000-onwards

Species: Dust, Sea Salt, Sulfates, Carbonaceous
Emissions: HFED, QFED, EDGAR/AeroCom
Observing System: MODIS, AERONET (before 2015)

GEOS-IT

Atmosphere
50km, L72 (C180,L72)
1998-onwards

Species: + Nitrates
Emissions: HFED, QFED, CEDS
Observing System: AVHRR, MODIS, AERONET, [VIIRS]

MERRA-2

Atmosphere
50km, L72 (C180,L72)
1980-onwards

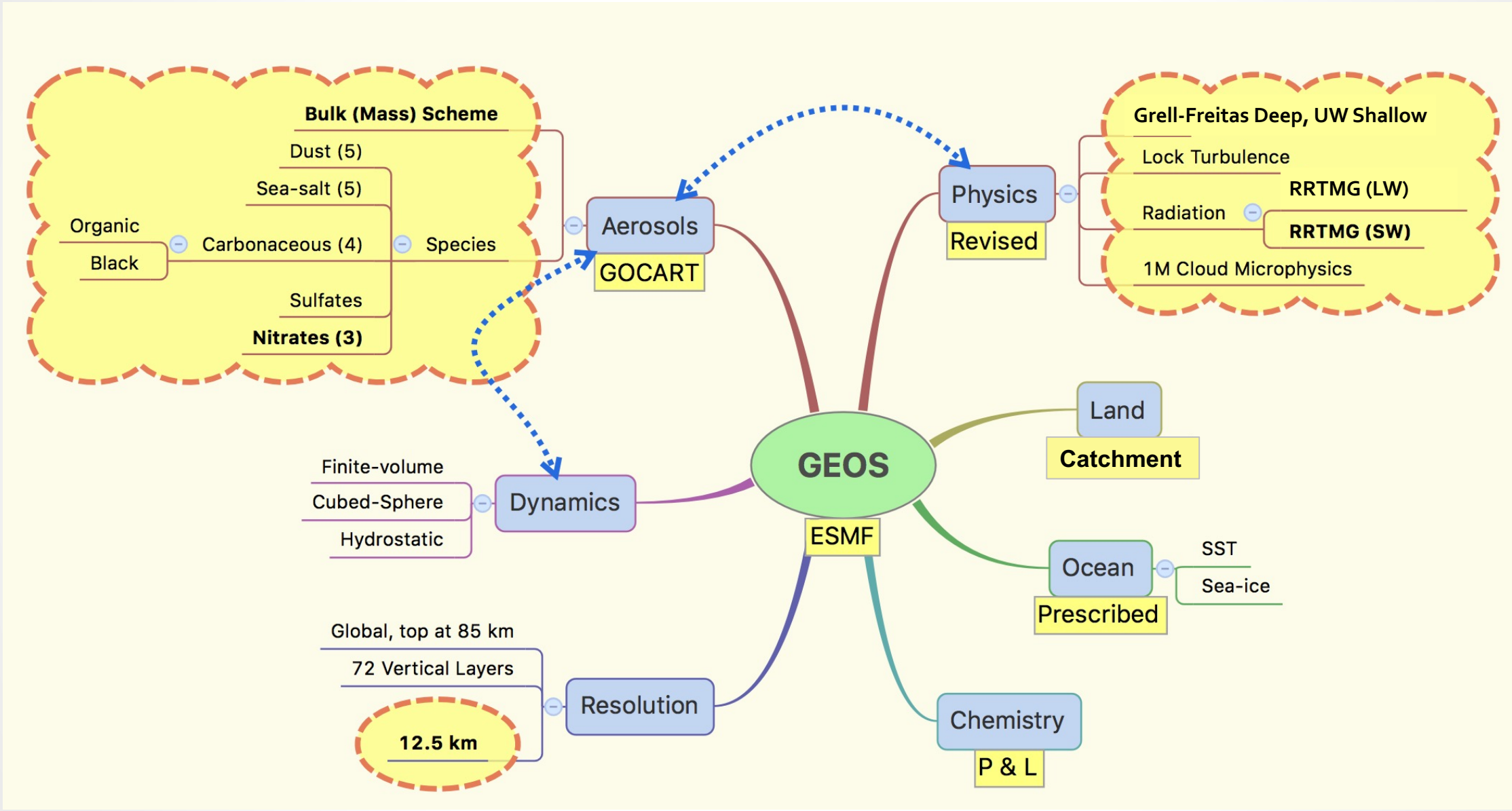
Species: Dust, Sea Salt, Sulfates, Carbonaceous
Emissions: HFED, QFED, EDGAR, AeroCom
Observing System: AVHRR, MISR, MODIS, AERONET (before 2015)

GEOS-R21C

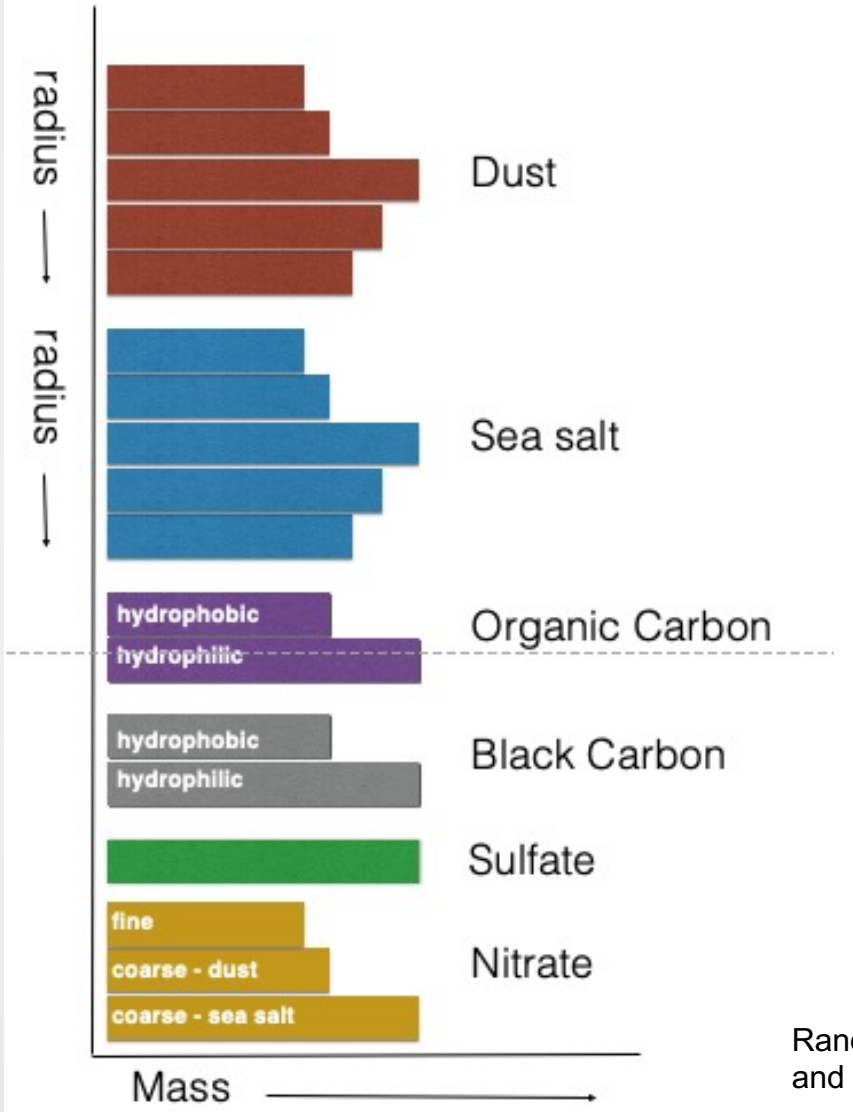
Atmosphere
25km, L72 (C360,L72)
2000-2025+

Species: + Nitrates and Brown Carbon
Emissions: HFED, QFED, CEDS
Observing System: AVHRR, MODIS, AERONET, [VIIRS], [Geostationary]

GEOS-IT Model Configuration



GOCART Aerosol Module and Goddard Aerosol Assimilation System (GAAS)

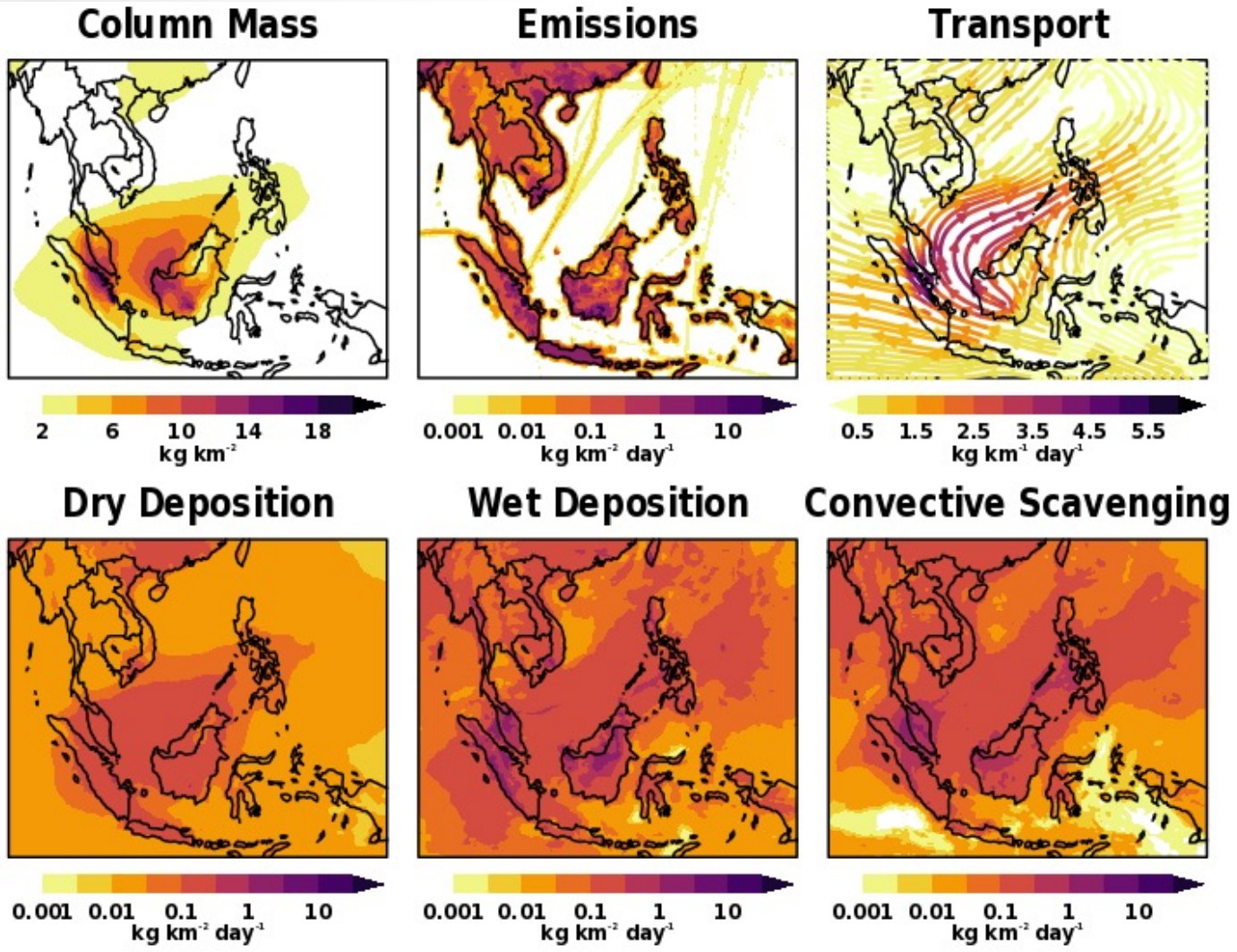


- GOCART treats the sources, sinks, and chemistry of the aerosol tracers
- Transport based on GEOS meteorology
- Dust and sea salt emissions parameterized based on wind
- Carbon, sulfate, and nitrate have anthropogenic and natural sources
- Loss processes = sedimentation, dry deposition, large scale wet removal, convective scavenging

- AOD at 550 nm is assimilated through GAAS every 3 hours
- Aerosol mass is prognostic
- Optical properties (mass extinction coefficient, SSA, Angstrom exponent) determined through look up table as a function of RH and wavelength
- Optics primarily from OPAC (Hess et al., 1998)

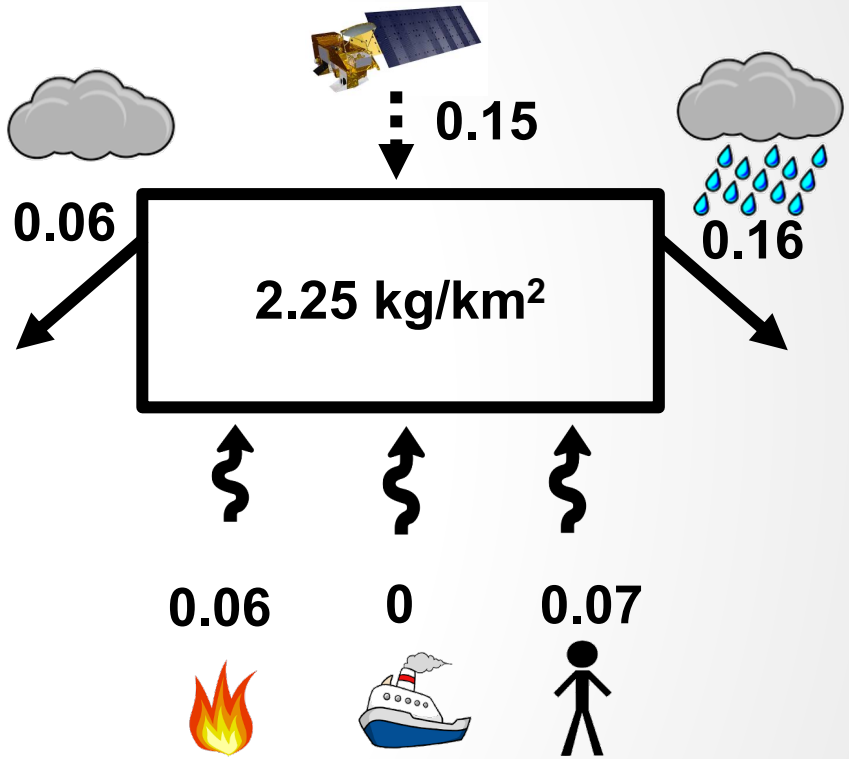
Randles, C. A., and Coauthors, 2017: The MERRA-2 Aerosol Reanalysis, 1980 Onward. Part I: System Description and Data Assimilation Evaluation. *J. Climate*, **30**, 6823–6850, https://doi.org/10.1175/JCLI-D-16-0609.1.

Aerosol Lifecycle Example: Black carbon over the Maritime Continent



Black Carbon for 4 August 2019 - 22 September 2019

Regional Mass Budget



- Units for budget terms are kg/km^2/day
- GOCART is coupled with the meteorology and GAAS to provide a full lifecycle of the aerosol
- Extra term in budget for analysis increment
- Budget does not include horizonal transport

Aerosol Emissions for GEOS-IT

National Aeronautics and Space Administration

*Different from FPIT/ MERRA-2

Emission Type	Species	Source	Temporal Resolution	Spatial Resolution
Anthropogenic (+ ship and aircraft)	OC, BC, SO2, SO4, NH3	CEDS (Hoesly et al., 2018)	monthly (Onset-2019) **2020->NRT is a repetition of 2019**	0.5, downscaled to 0.15625
Biomass Burning	OC/BrC, BC, SO2, NH3	HFED (Randles et al., 2016)	Monthly (Onset-early 2000)	0.25 x 0.3125
		QFED v2.5r1 (Darmenov and da Silva, 2015)	Daily **(Persisted from prior day for NRT)**	0.1
Volcanic	SO2	Carn et al. 2017	Daily Eruptive **(Onset-2021)**	Point-sources
			Daily Outgassing	
Dust	DU	Wind driven (Ginoux et al., 2001)	Model	0.5 x 0.625
Sea Salt	SS	Wind driven	Model	0.5 x 0.625
Precursor Gases	H2O2, OH, NO3	MERRA-2 GMI	Monthly	0.5 x 0.625

Aerosol Observing System for GEOS-IT

Data Product	Time Period	
AVHRR NNR	Onset - 20020801_00z	Ocean Only
MODIS Collection 6.1 NNR	20000301-> (Terra)	Gridded to 10km
	20020801-> (Aqua)	
AERONET v3 Level 2	19990101-> NRT production	Land Station AOD
AERONET v3 Level 1.5	NRT production ->	Land Station AOD

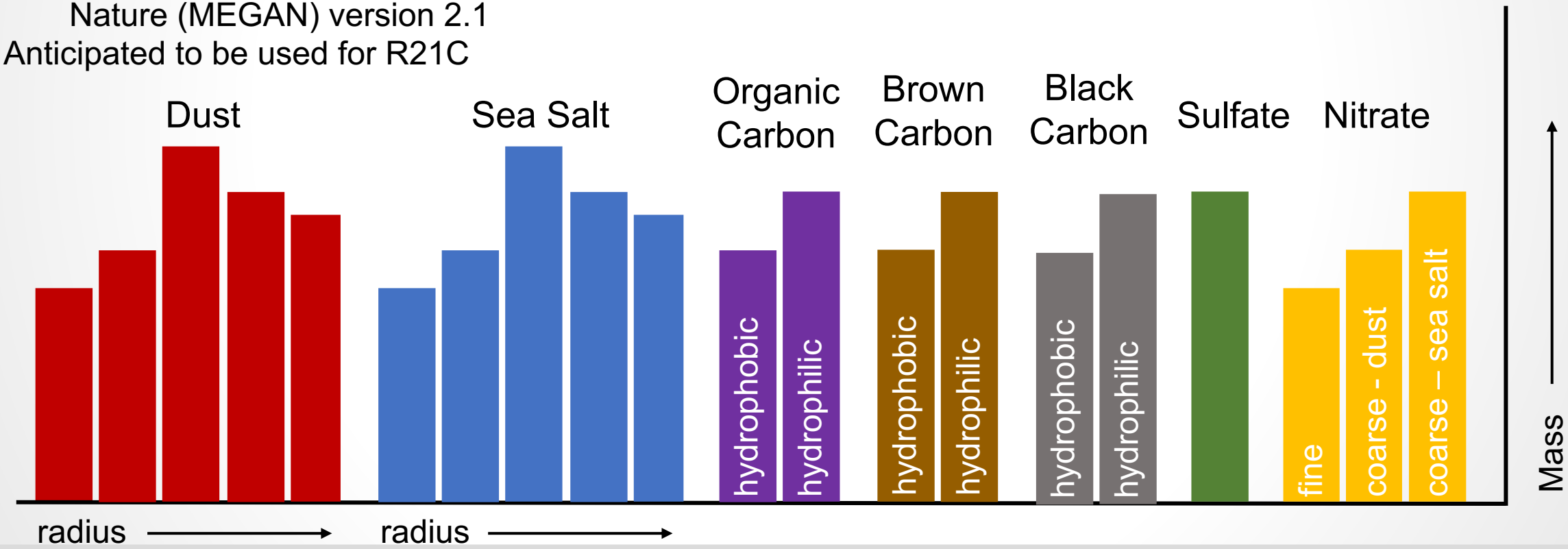
Differences from MERRA-2 and FP-IT: No longer using MISR; AERONET now available for NRT production

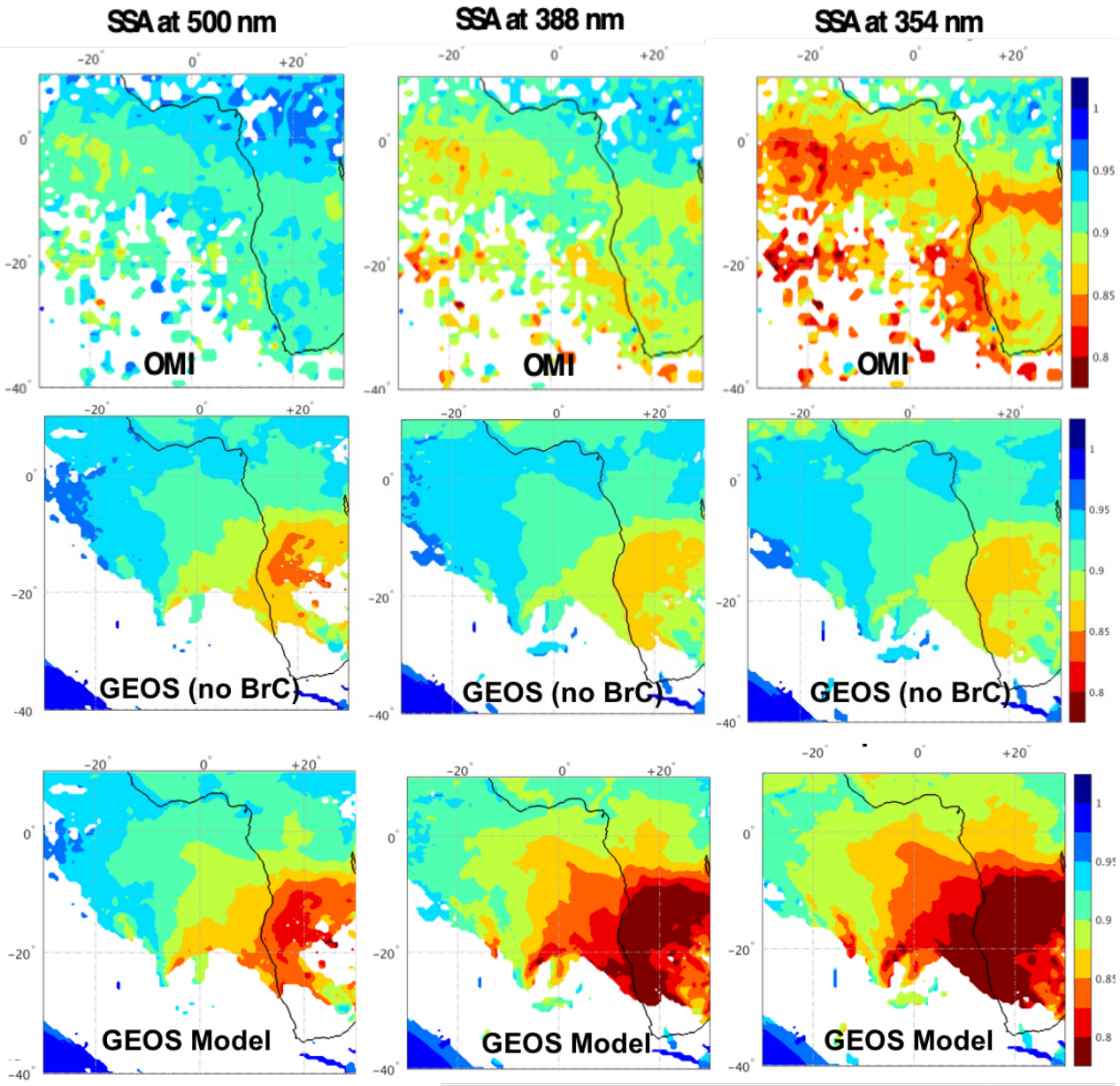
How will R21C differ?

- Non-historical period will use MODIS from MODAPs, not LANCE
- Possible inclusion of VIIRS observations (if pre-processing is complete prior to the onset of production)

GOCART-2G

- A refactoring of the source code to allow for future development, reduce inefficiencies
- Complemented by science updates
  - Introduction of brown carbon and secondary organic aerosol (SOA)
  - Optics table for brown carbon differs from organic carbon for wavelengths smaller than550 nm
  - Re-scaling of organic aerosol to organic carbon ratio for biomass burning emissions
  - SOA from biogenic sources has precursor gases of isoprene and monoterpene emissions calculated online as a function of light and temperature using the Model of Emissions of Gases and Aerosols from Nature (MEGAN) version 2.1
- Anticipated to be used for R21C

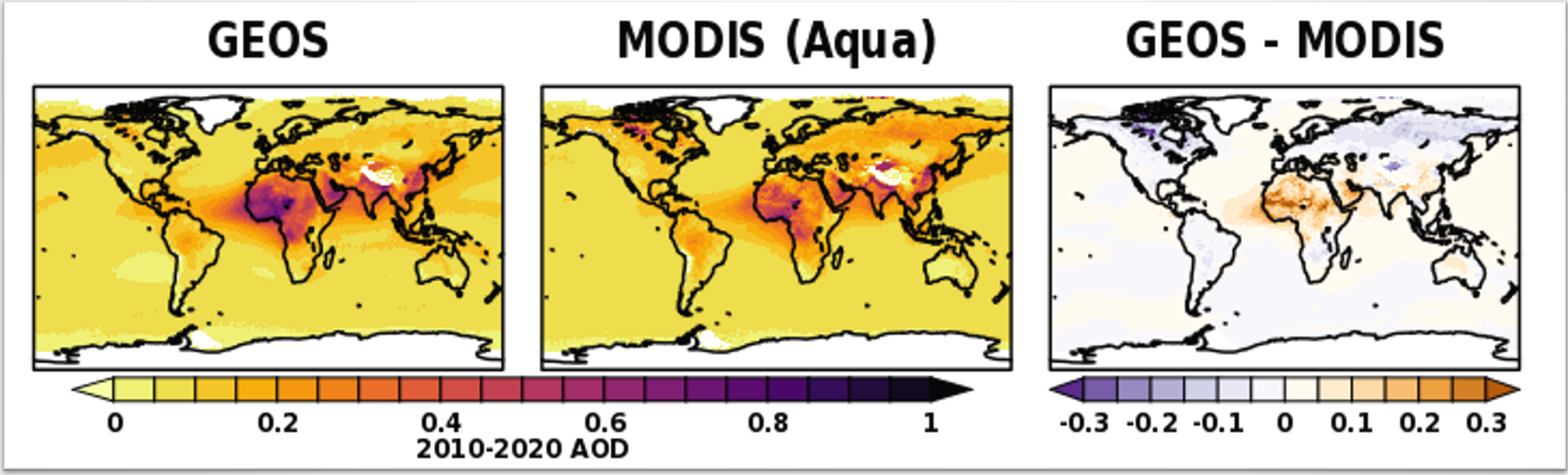




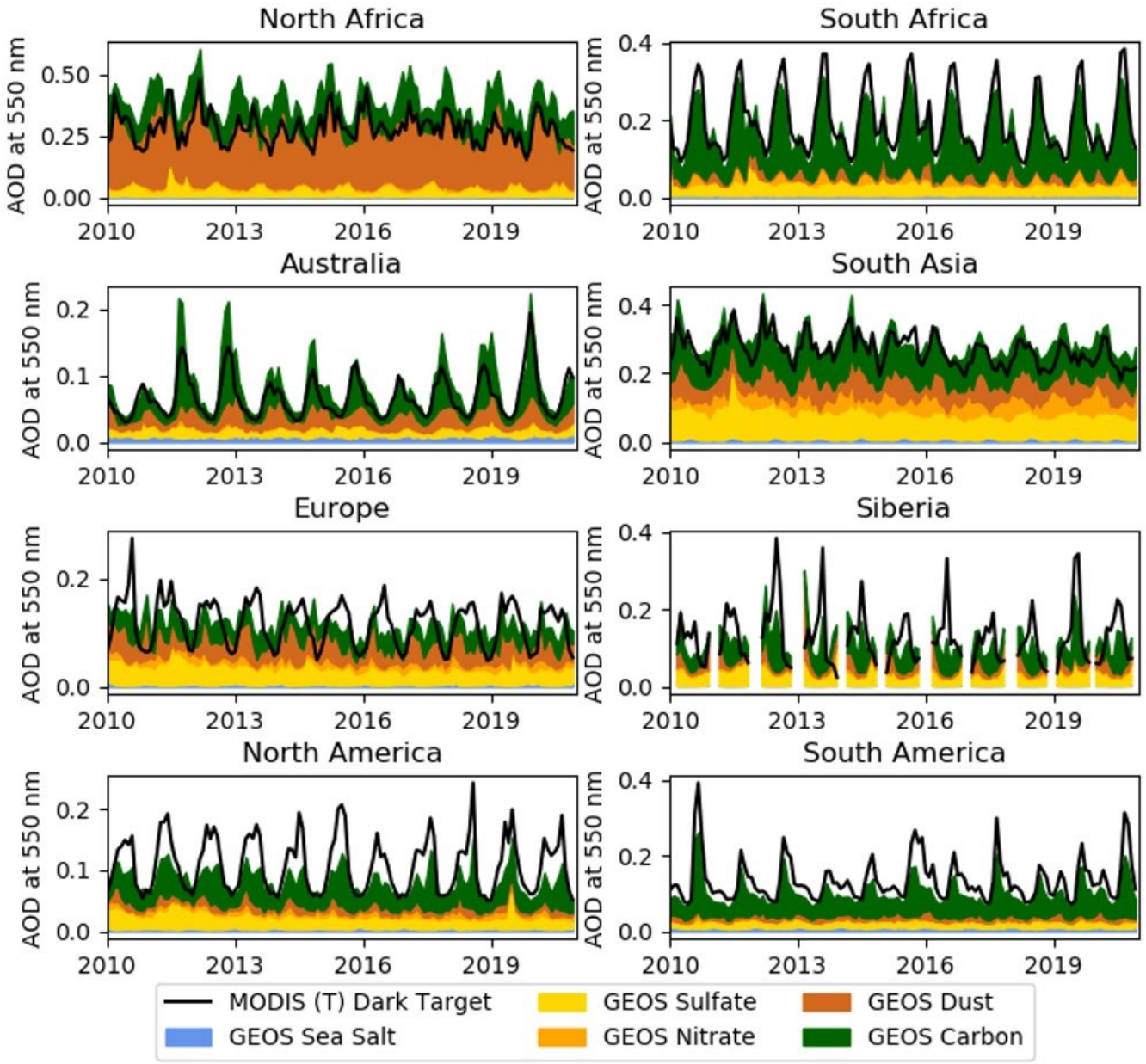
Benefits of Brown Carbon

- Anthropogenic organic carbon has different optical properties from organic carbon emitted through biomass burning
- The figure on the left gives us a glimpse of the current state of the GEOS model (with and without BrC inclusion) with respect to the spectral contrast in OMI (onboard Aura satellite) retrieved aerosol absorption (or Single Scattering Albedo, SSA).
- The differences in SSA distribution and magnitudes partly demonstrate the motivation for our present work as we focus on regions dominated by biomass burning aerosols.
- To this end field observations, e.g. during ORACLES (over southern African BB outflow region), FIREX-AQ (over northwestern and southeastern US) can help us understand and fill the gap between the model and satellite observations.

Benchmarking our Current Modeling Capabilities



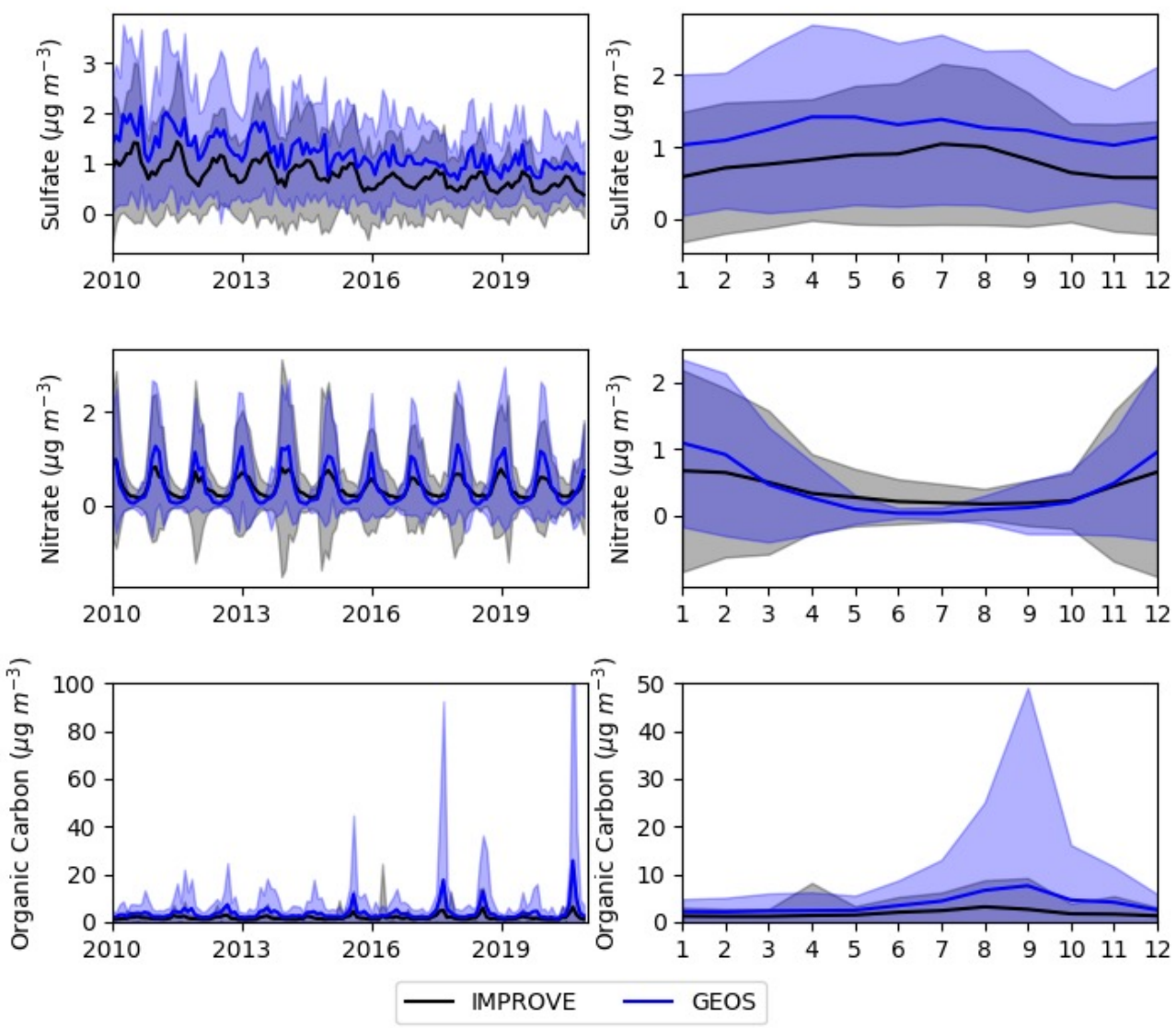
- 10+ year model run constrained to MERRA-2 meteorology
- No observational constraint for aerosols
- MODIS is an independent observation
- What should future development focus on?
- Overestimated AOD in North Africa linked to excessive dust
- Seasonal underestimation in the Americas, Siberia due to deficiencies in carbon



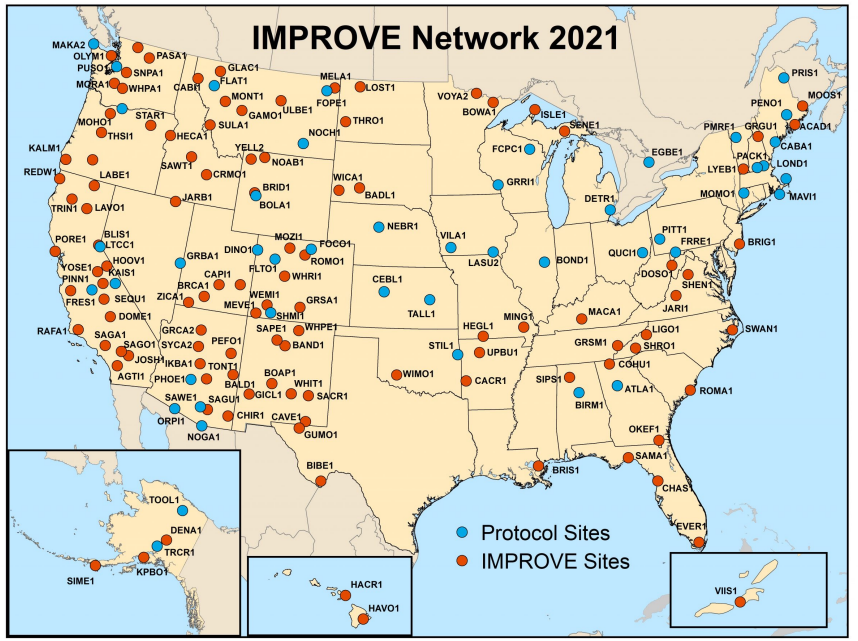
Timeseries of AOD

- No AOD Assimilation
- GEOS generally captures the seasonal cycle of AOD around the globe
- Good agreement in South Africa, Australia, South Asia
- Overestimate of dust (North Africa) and underestimate of smoke (Siberia, Americas)
- Europe warrants further evaluation

Surface Aerosol Concentration in the United States



- No AOD Assimilation
- IMPROVE is a collection of air quality sites, typically located in National Parks
- Shading is +/- 1 standard deviation
- GEOS has too much aerosol mass; amplified seasonal cycle for nitrate



http://vista.cira.colostate.edu/Improve/improve-program/

Summary

- GMAO is currently working on configuring two retrospective products: GEOS-IT and R21C
- Aerosols will be constrained in both products using AOD at 550 nm from AERONET and MODIS
- GEOS-IT will have 6 aerosol species while R21C will have seven (+ brown carbon)
- Sources and sinks of aerosols are controlled by GOCART, transport is coupled to meteorology
- Current aerosol configuration performs well however work is needed to reduce African dust and increase extinction from biomass burning aerosol

Ongoing Development

- Work is underway to assimilate AOD from additional satellites – GOES, Himawari, and VIIRS
- Leveraging progress made in the JCSDA-Joint Effort for Data Assimilation Integration (JEDI) framework, the GMAO is working on transitioning its aerosol data assimilation scheme to a hybrid ensemble-variational scheme, including observations of multi-wavelength AOD