

GMAO Capabilities for Simulated Observations and OSSEs

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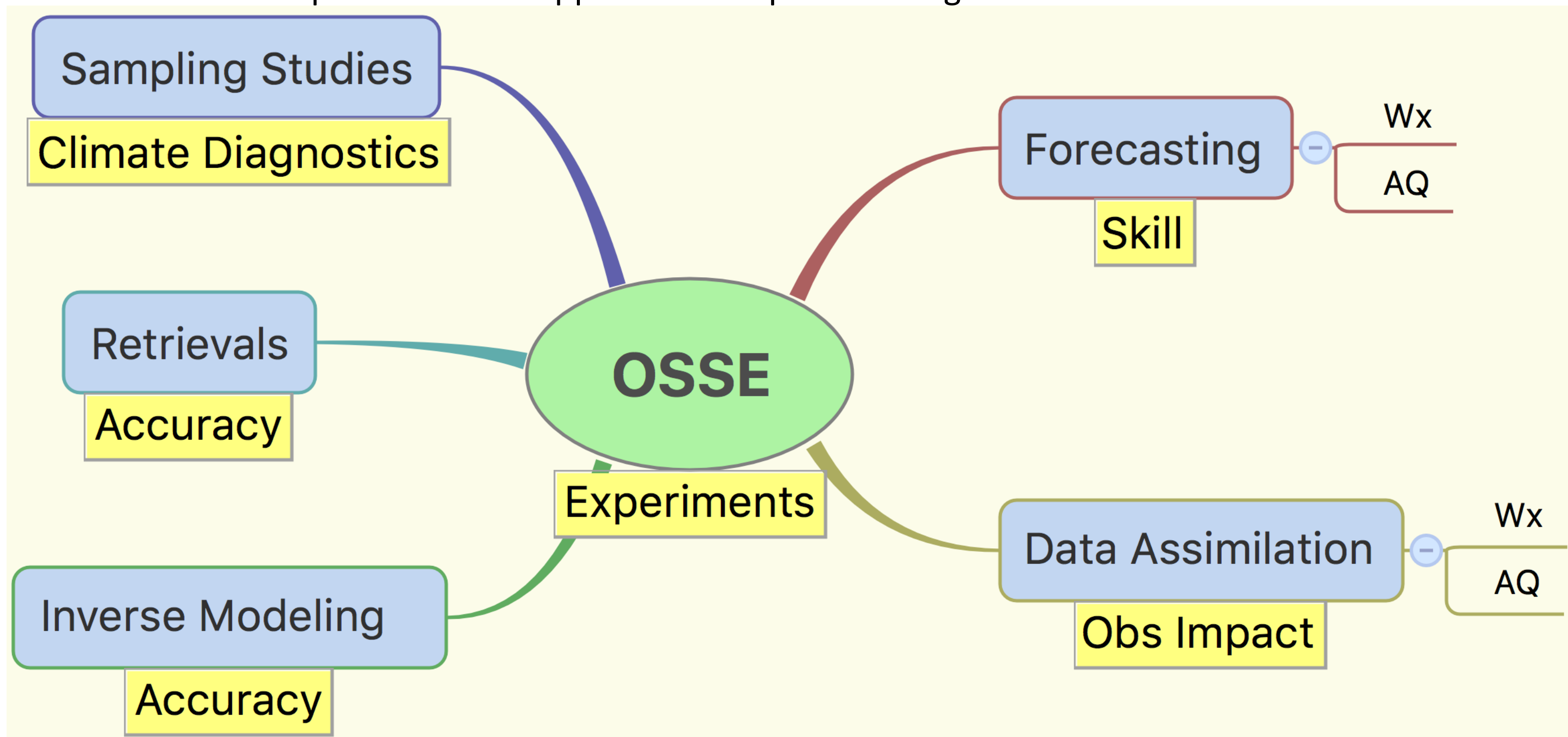
⁴ Jet Propulsion Laboratory

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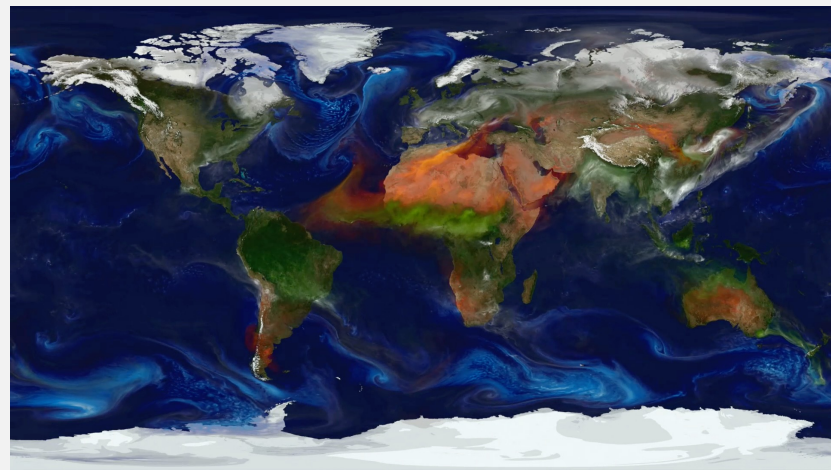
A **framework** for numerical experimentation in which **observables** are simulated from fields generated by an earth system model.

Simulations are performed in support of an experimental goal.



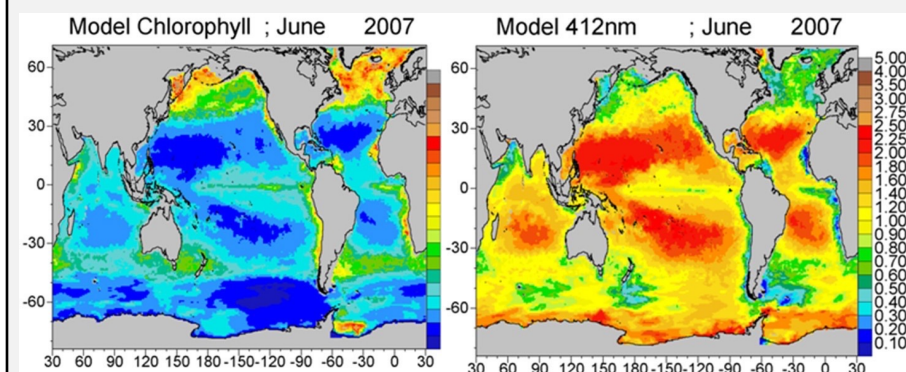
GEOS Nature Run Gridded Atmospheric Profile Properties

- Aerosols (5 species)
- T, P, Winds



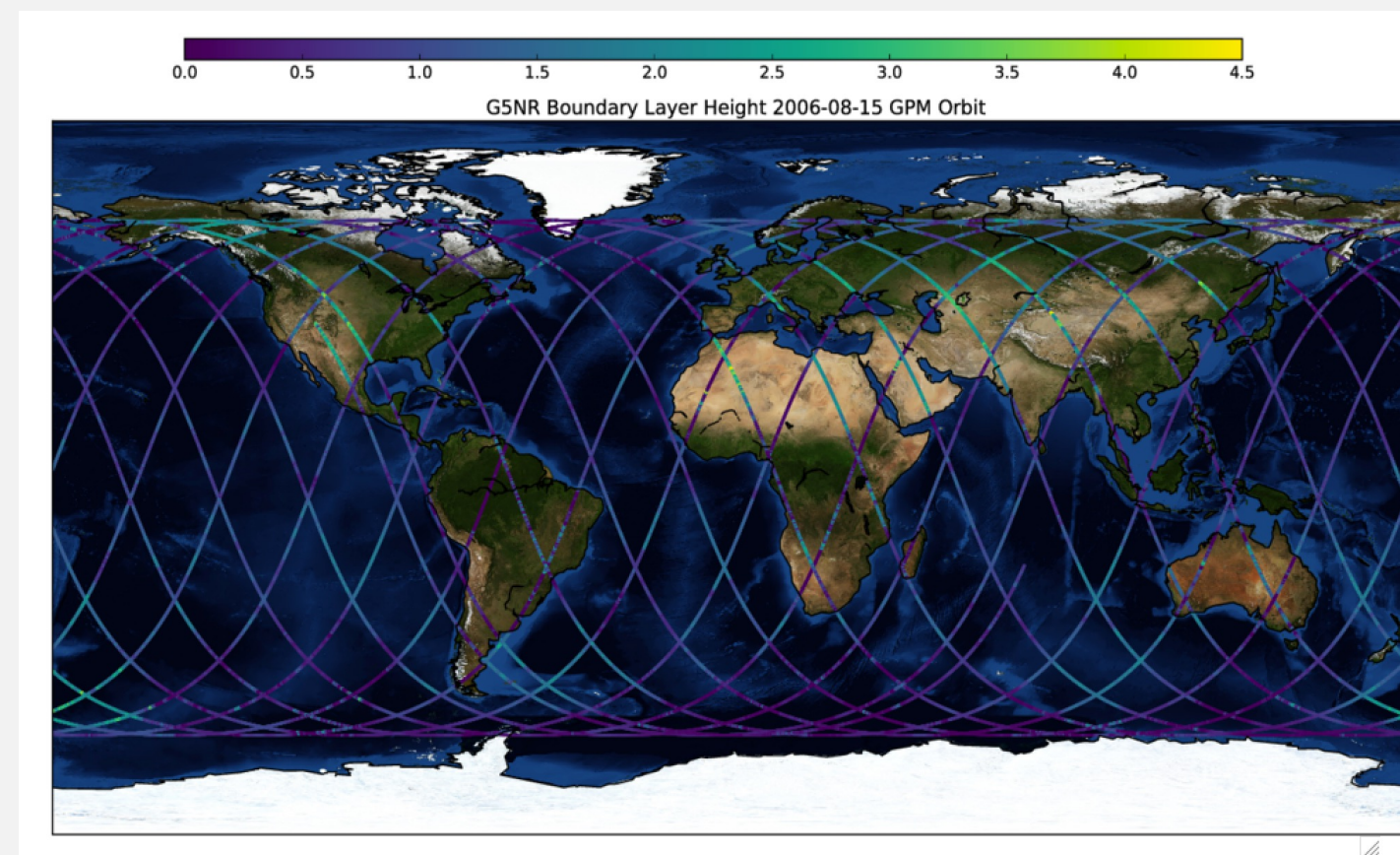
Gridded Land & Ocean Properties

- Water leaving radiance
- Land surface reflectance kernels



Sample the Model Along the Instrument Field of View

- Sun-sensor geometry
- Spectral aerosol optical property profiles (τ_{aer} , ω_{aer} , P_{aer})
- Spectral trace gas optical properties (τ_{Rayleigh} , τ_{abs} , P_{Rayleigh})
- Spectral surface reflectance (glint, glitter)

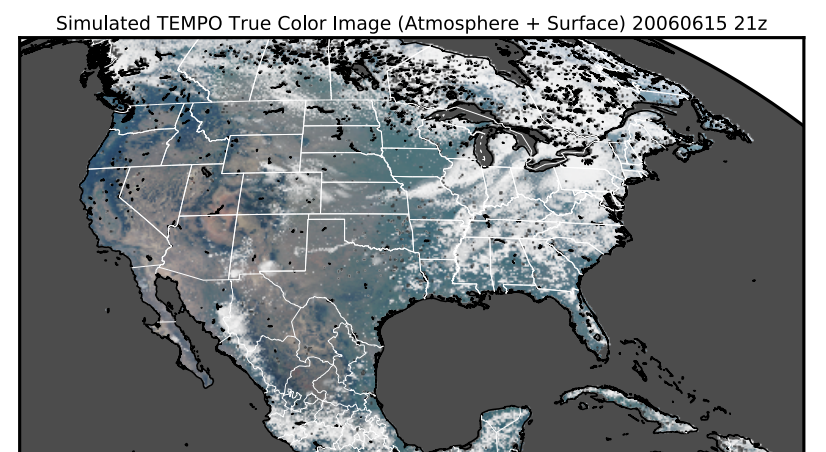


VLIDORT

RTM

Instrument Observables [Satellite L1b]

- Lidar: Attenuated backscatter profiles
- Polarimeter: Polarized TOA radiance (I , Q , U)



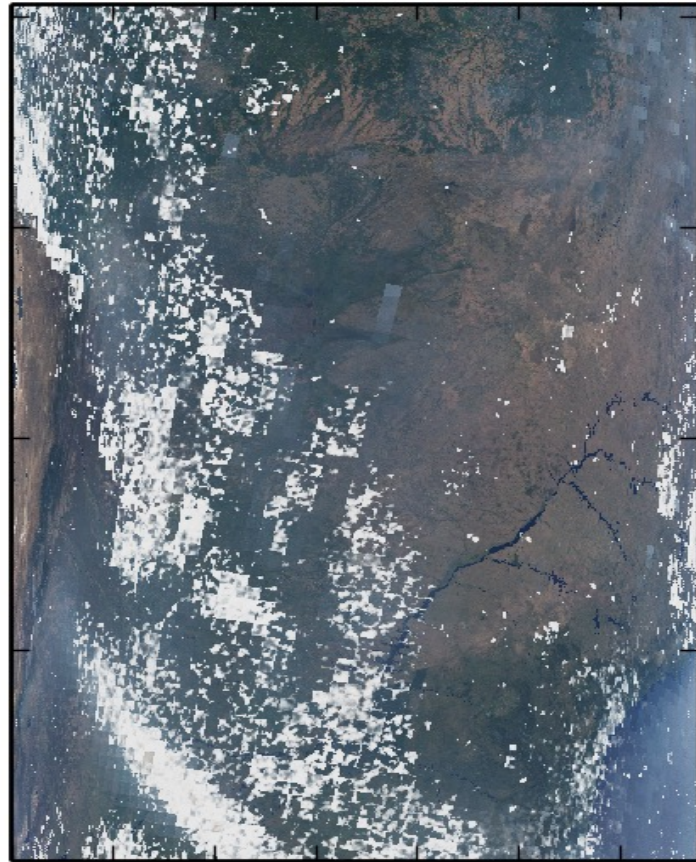
Retrieval Code

Retrieved geophysical parameters

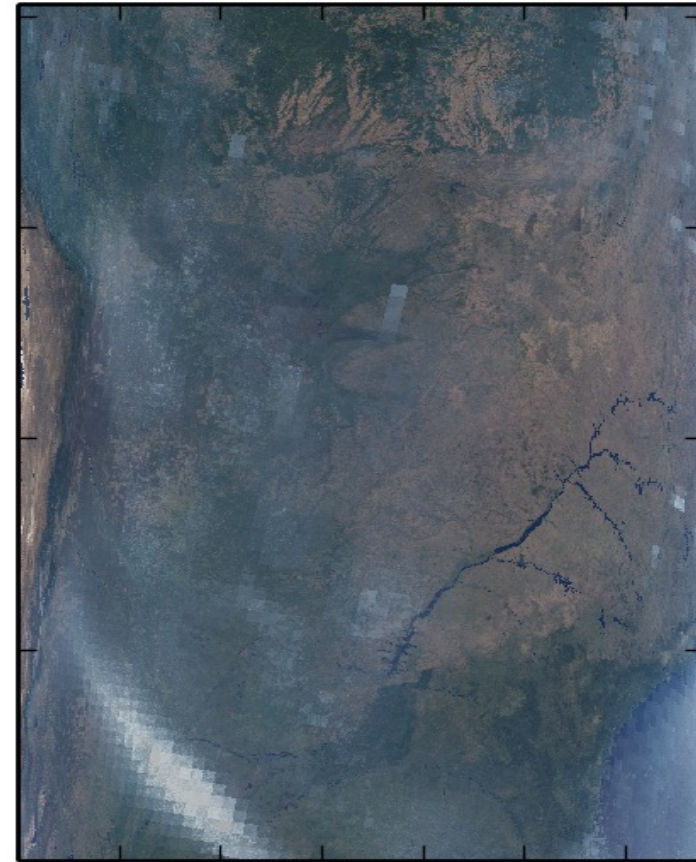
True geophysical parameters

**Retrieval
Assessment**

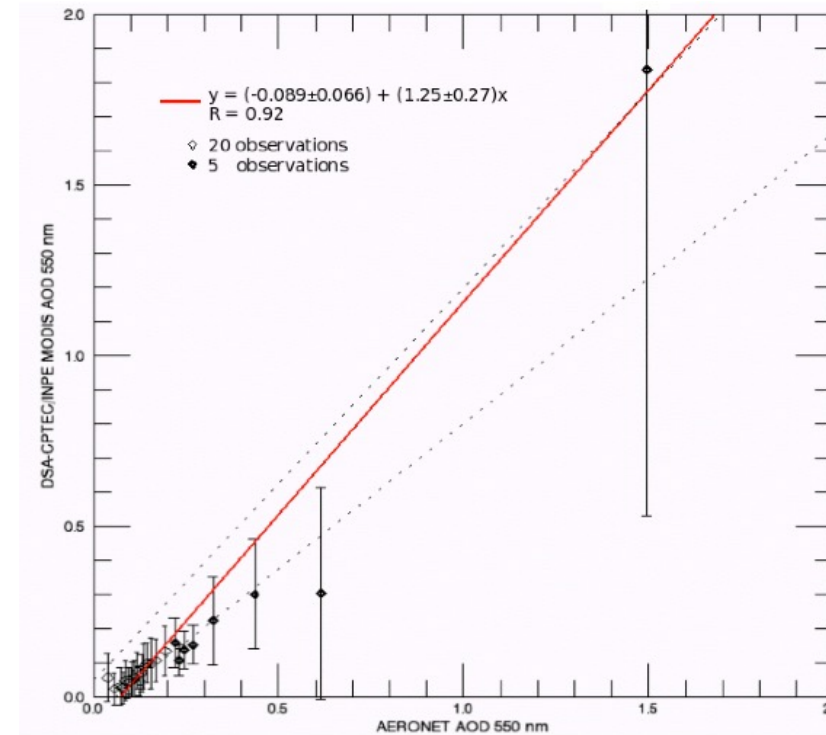
Everything



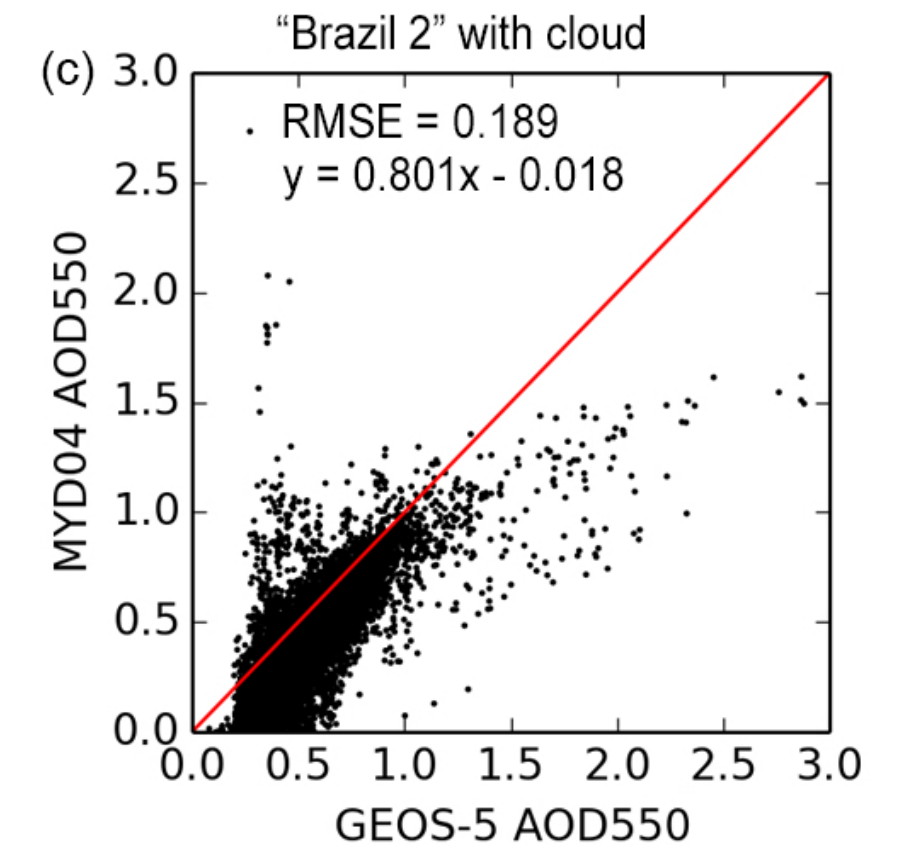
Aerosol and Atmosphere Only



Real Comparison of Retrieved AOD and Observed Ground Truth

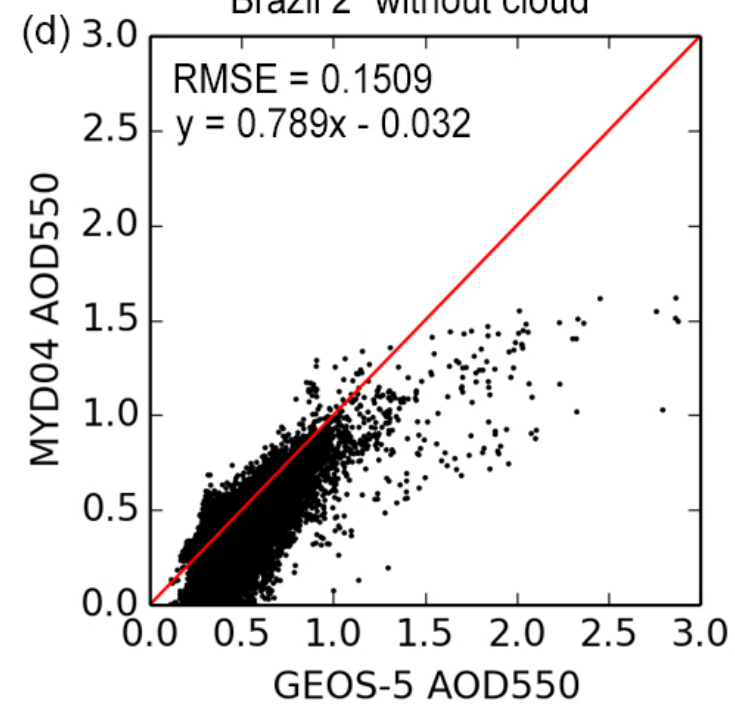


Simulated Comparison of Retrieved AOD and Model Ground Truth

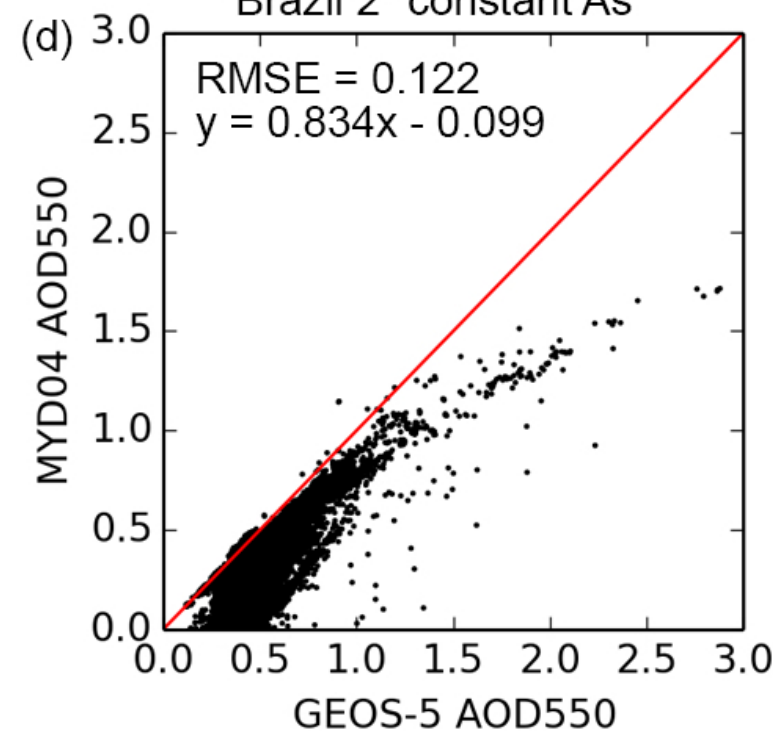


Wind et al., 2013, 2016, GMD

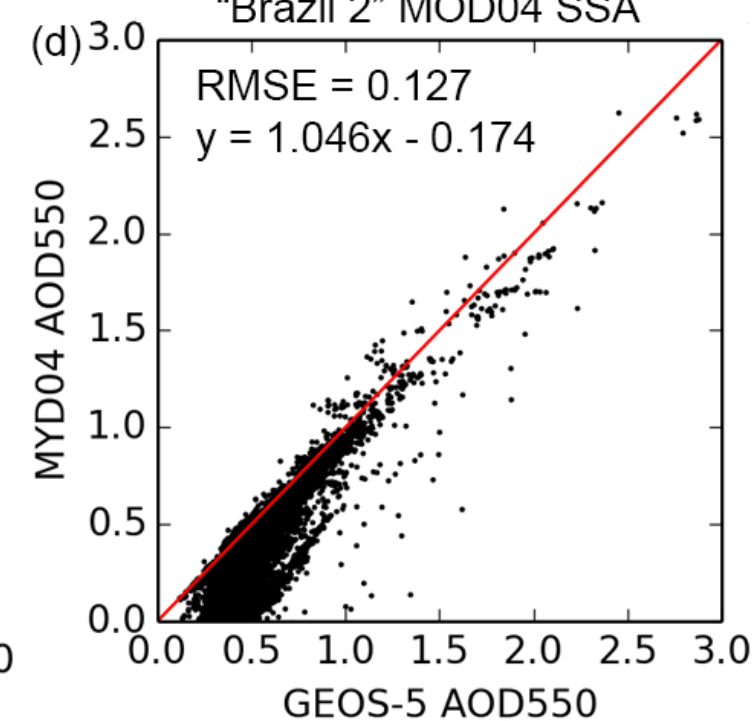
"Brazil 2" without cloud



"Brazil 2" constant As



"Brazil 2" MOD04 SSA

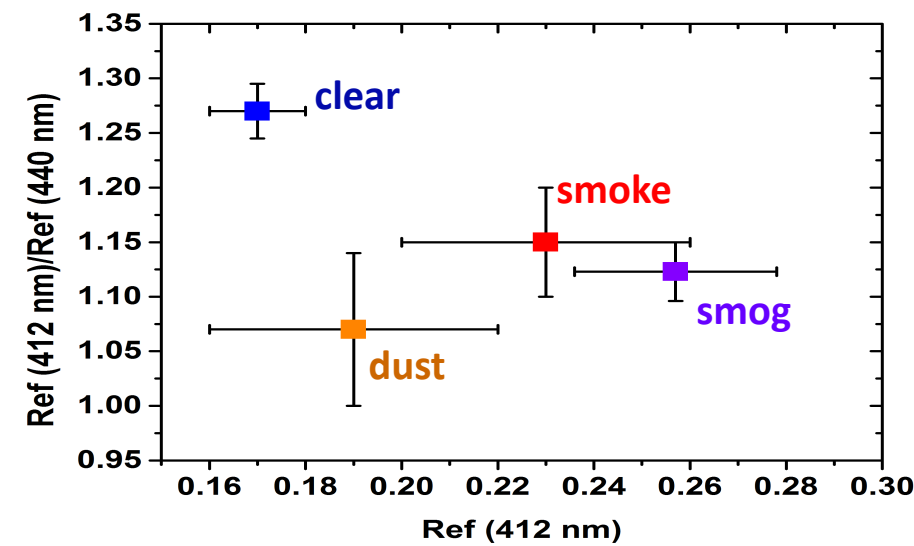


Sensitivity Experiments

Evaluation of whether TEMPO UV-Vis capabilities can augment GEOS-R longwave (2250 nm)

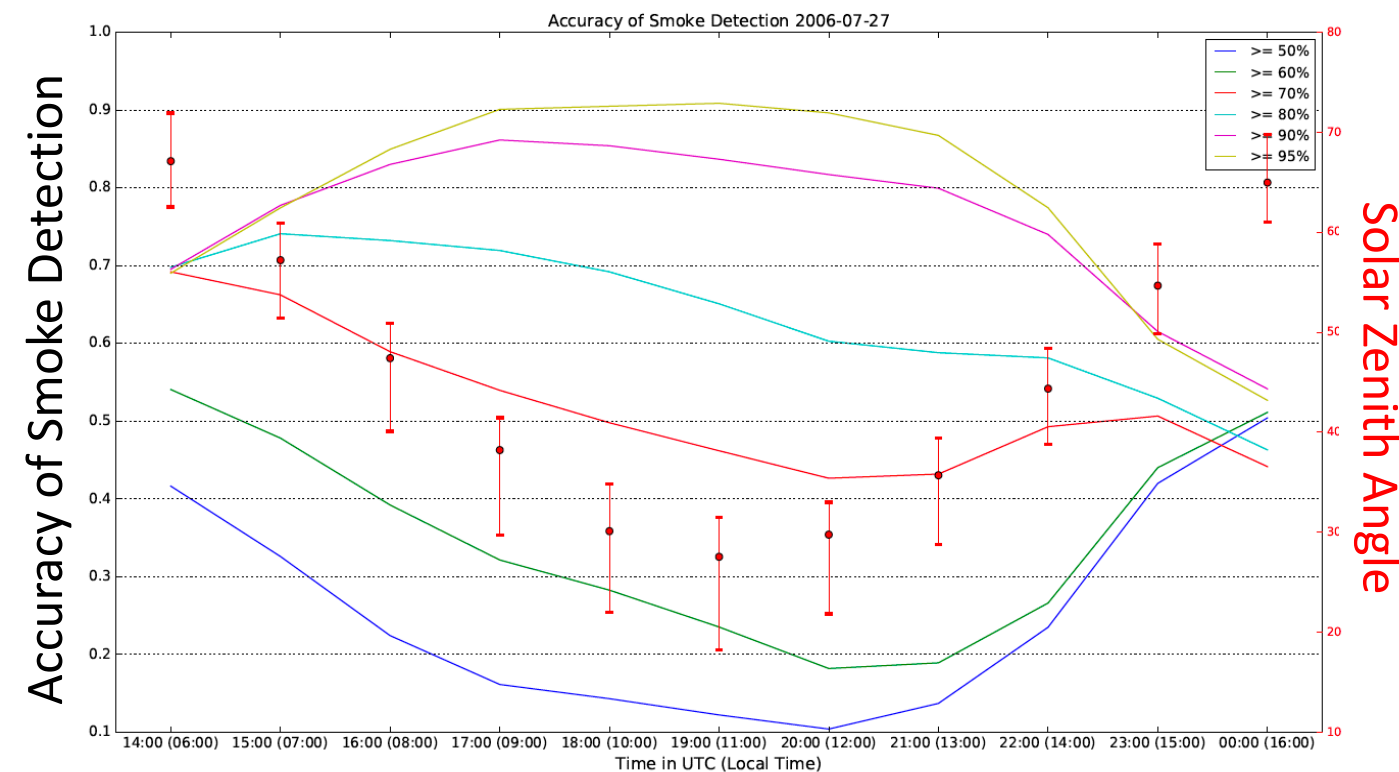
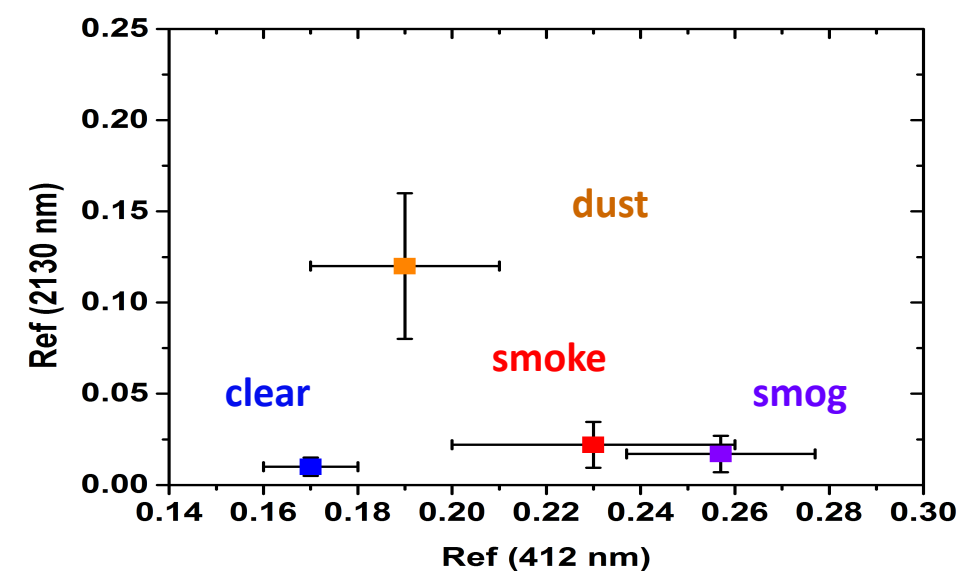
Absorbing Aerosol Index

$$AAI = -100[\log_{10}(R_{412}/R_{440}) - \log_{10}(R'_{412}/R'_{440})]$$

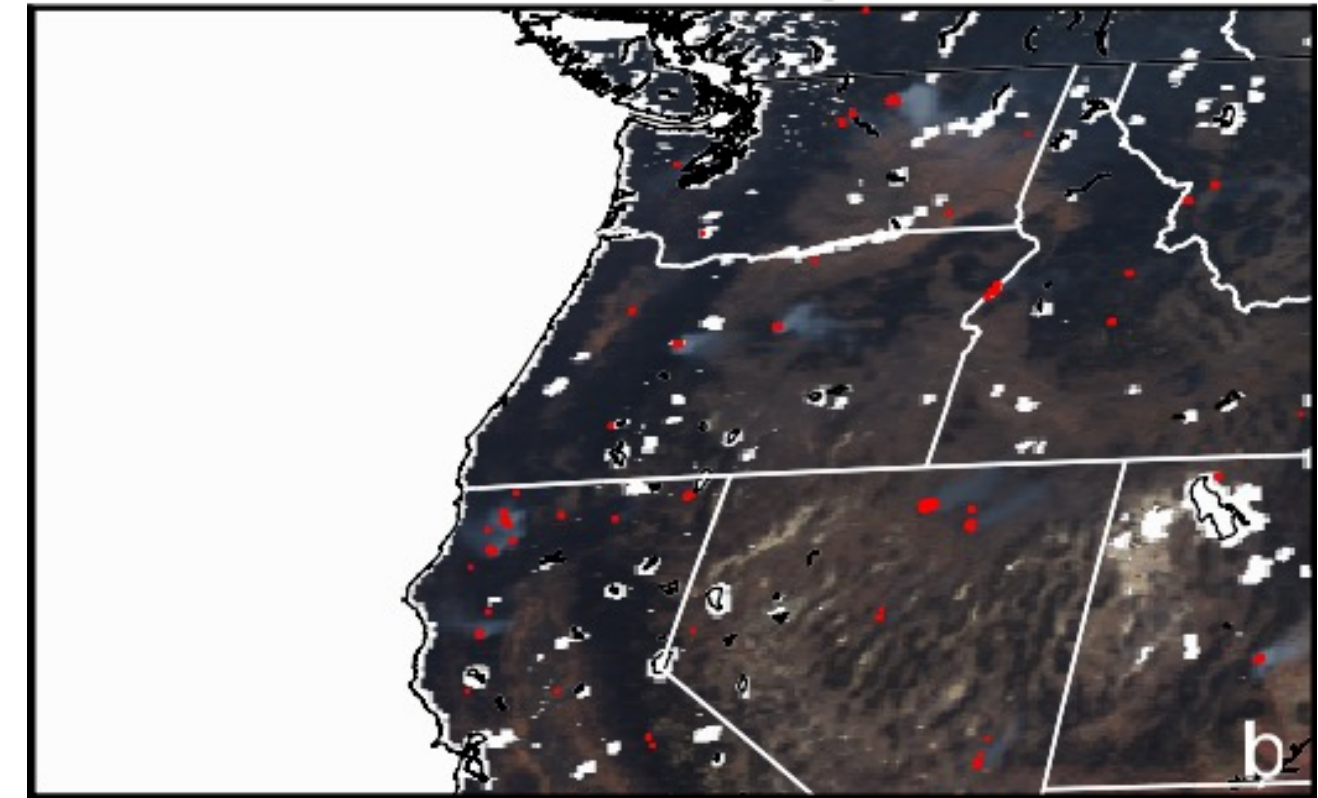


Dust Index

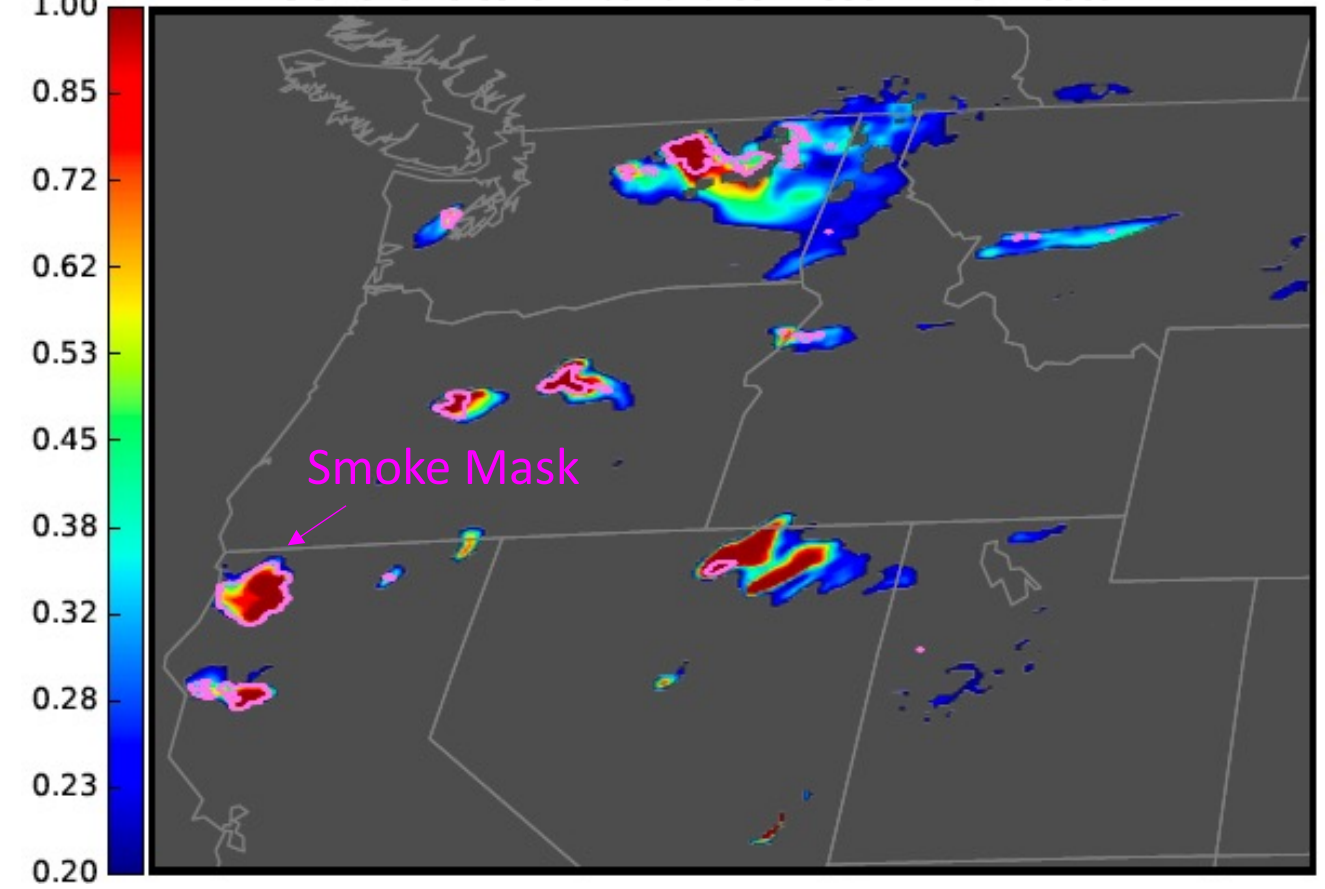
$$DSDI = -10[\log_{10}(R_{412}/R_{2250})]$$



Simulated TEMPO True Color Image 20060727 21z



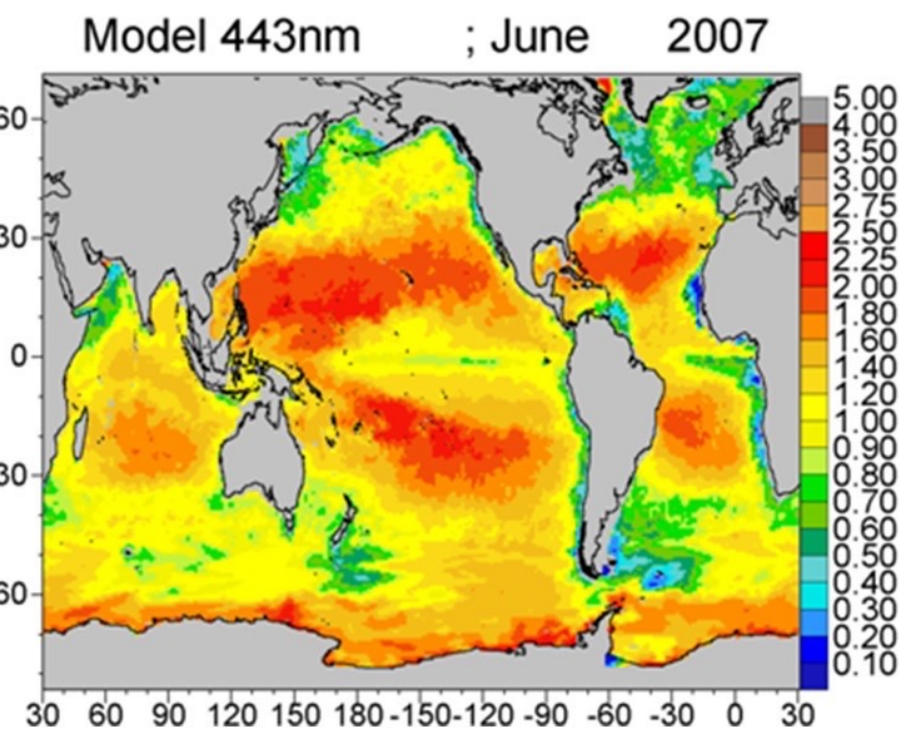
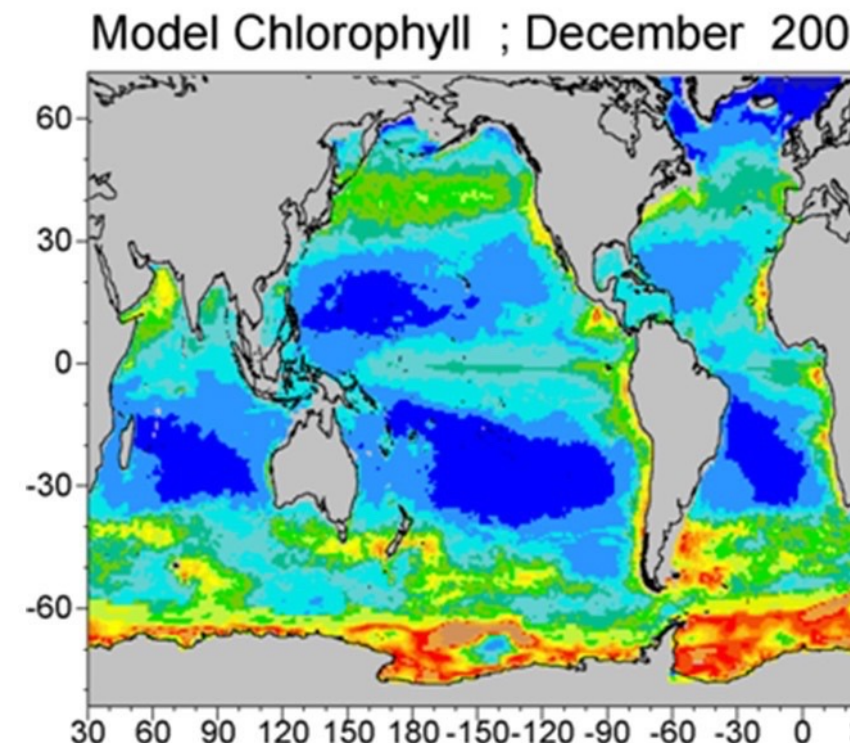
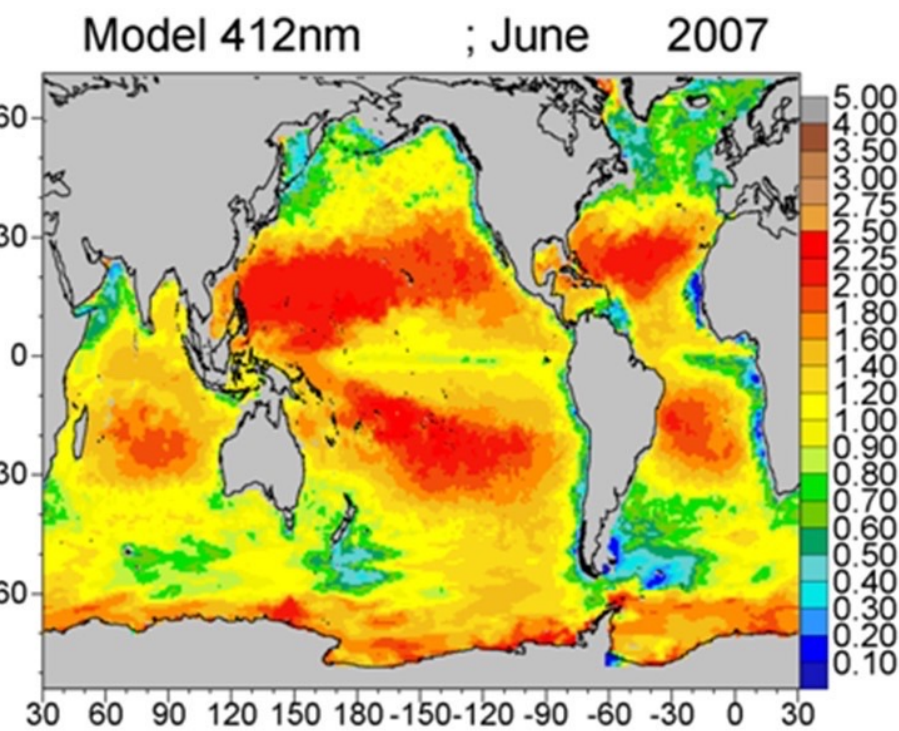
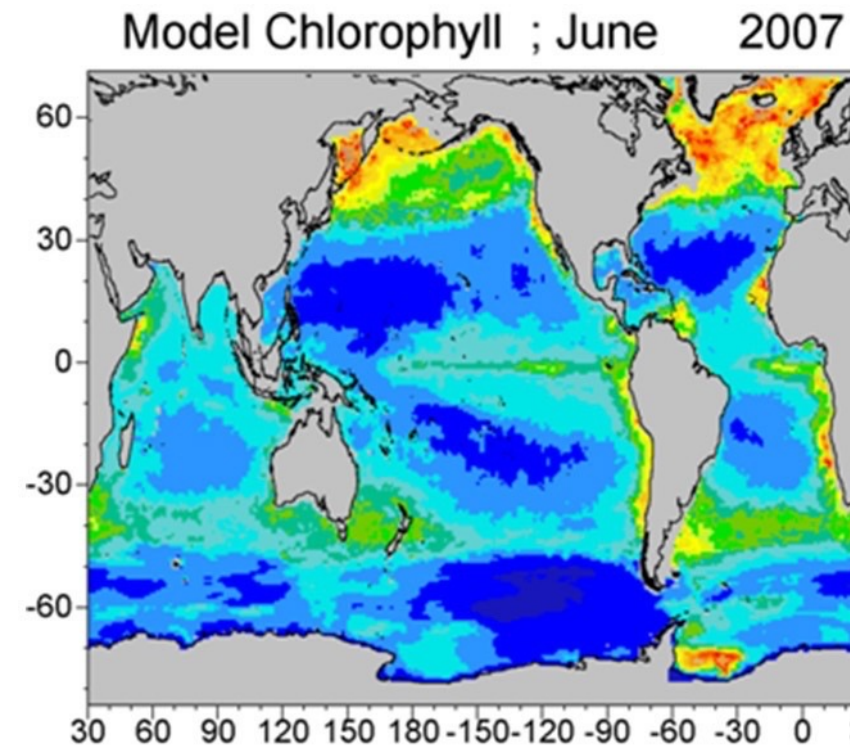
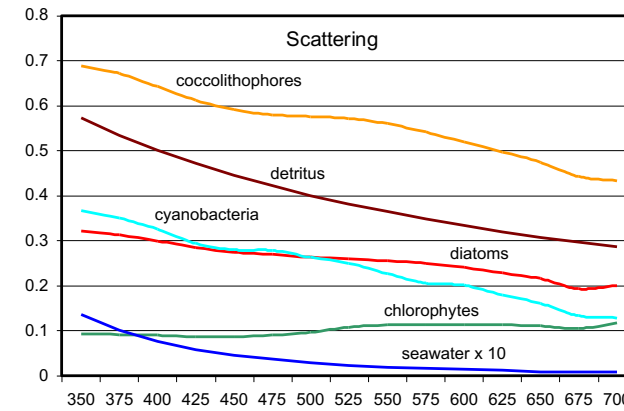
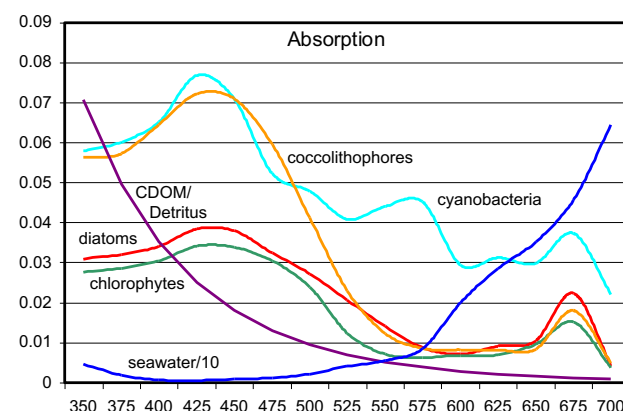
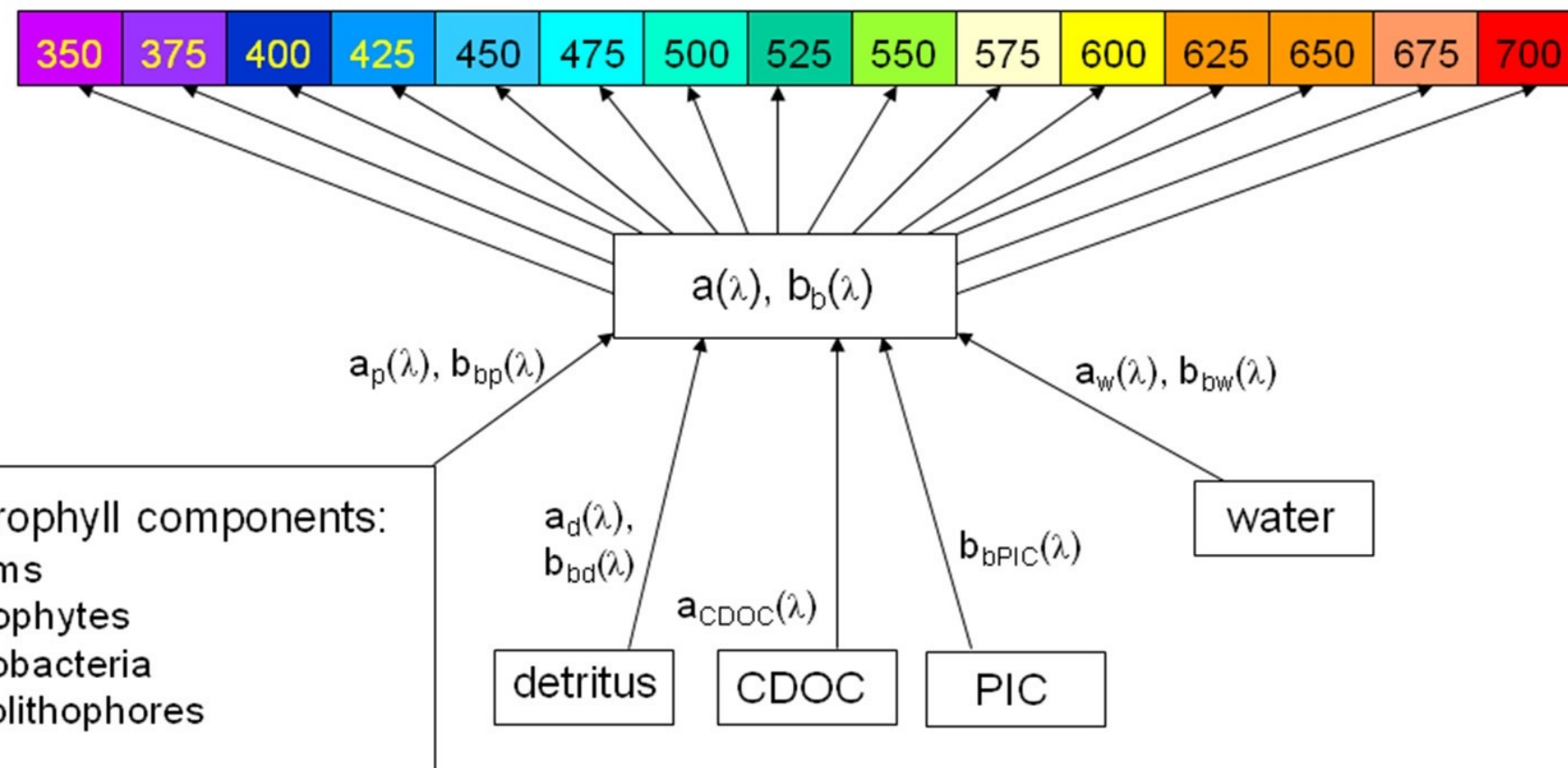
VIIRS Smoke Detection Mask and G5NR 550 nm AOD 20060727 21Z

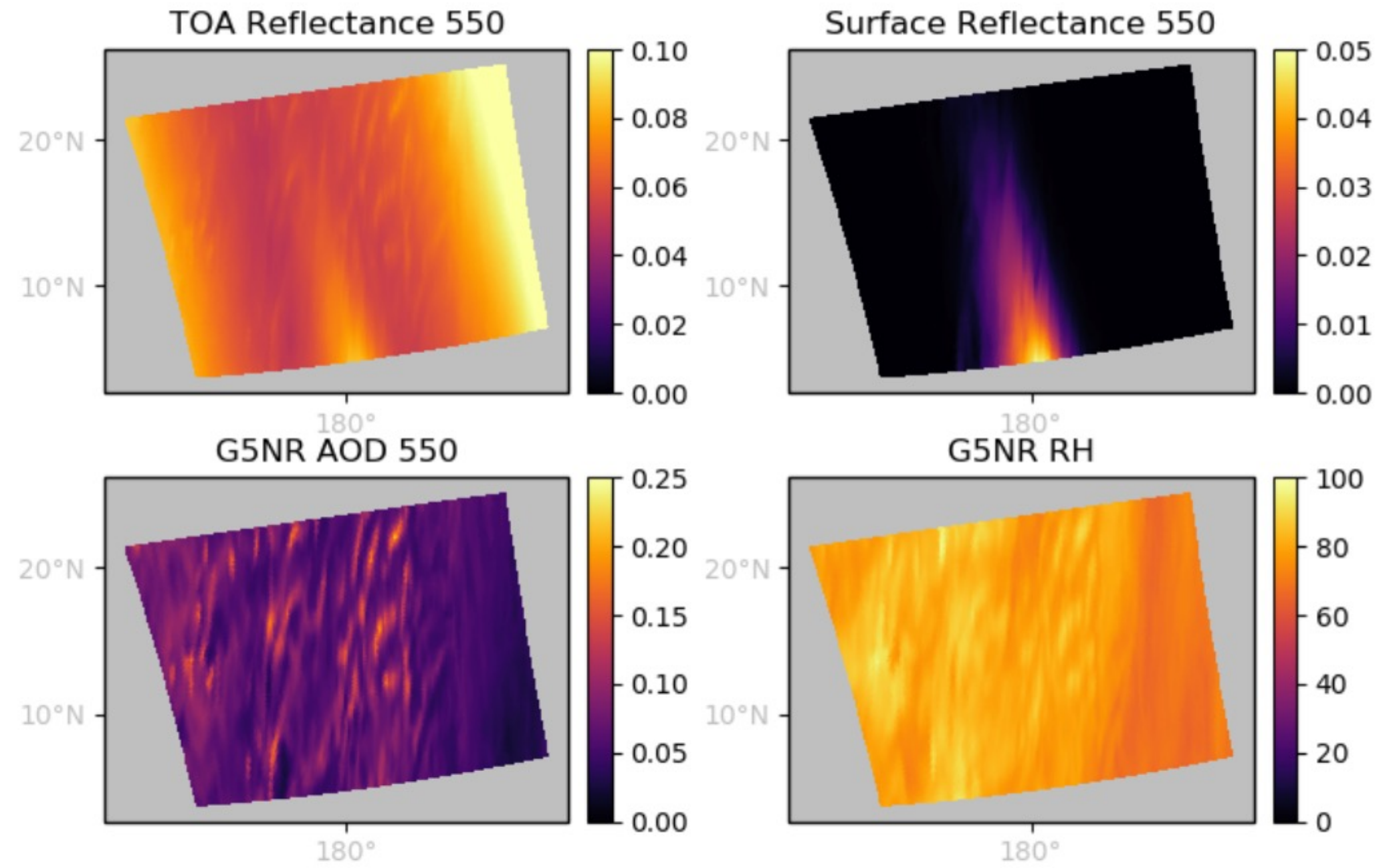
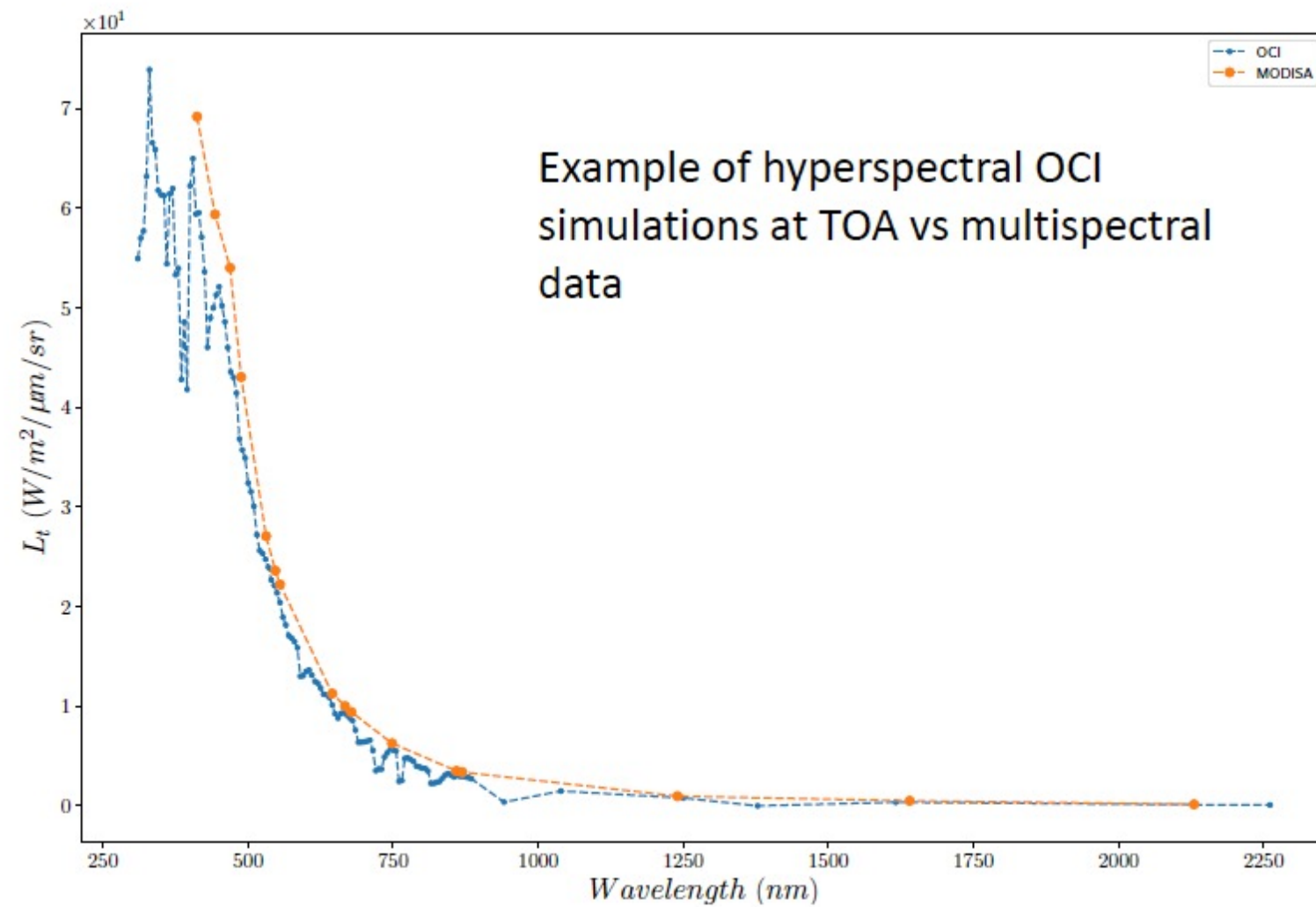
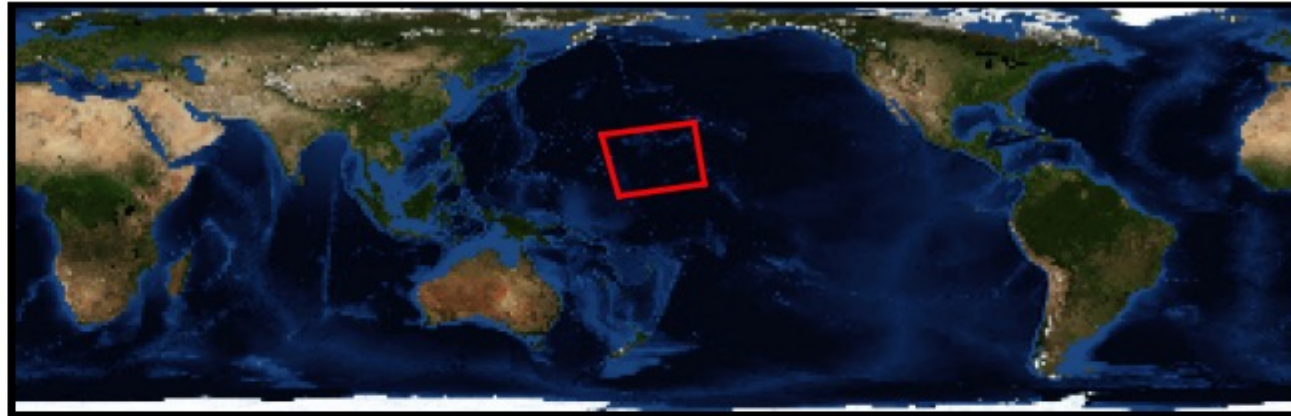


Global Ocean Radiance Simulation

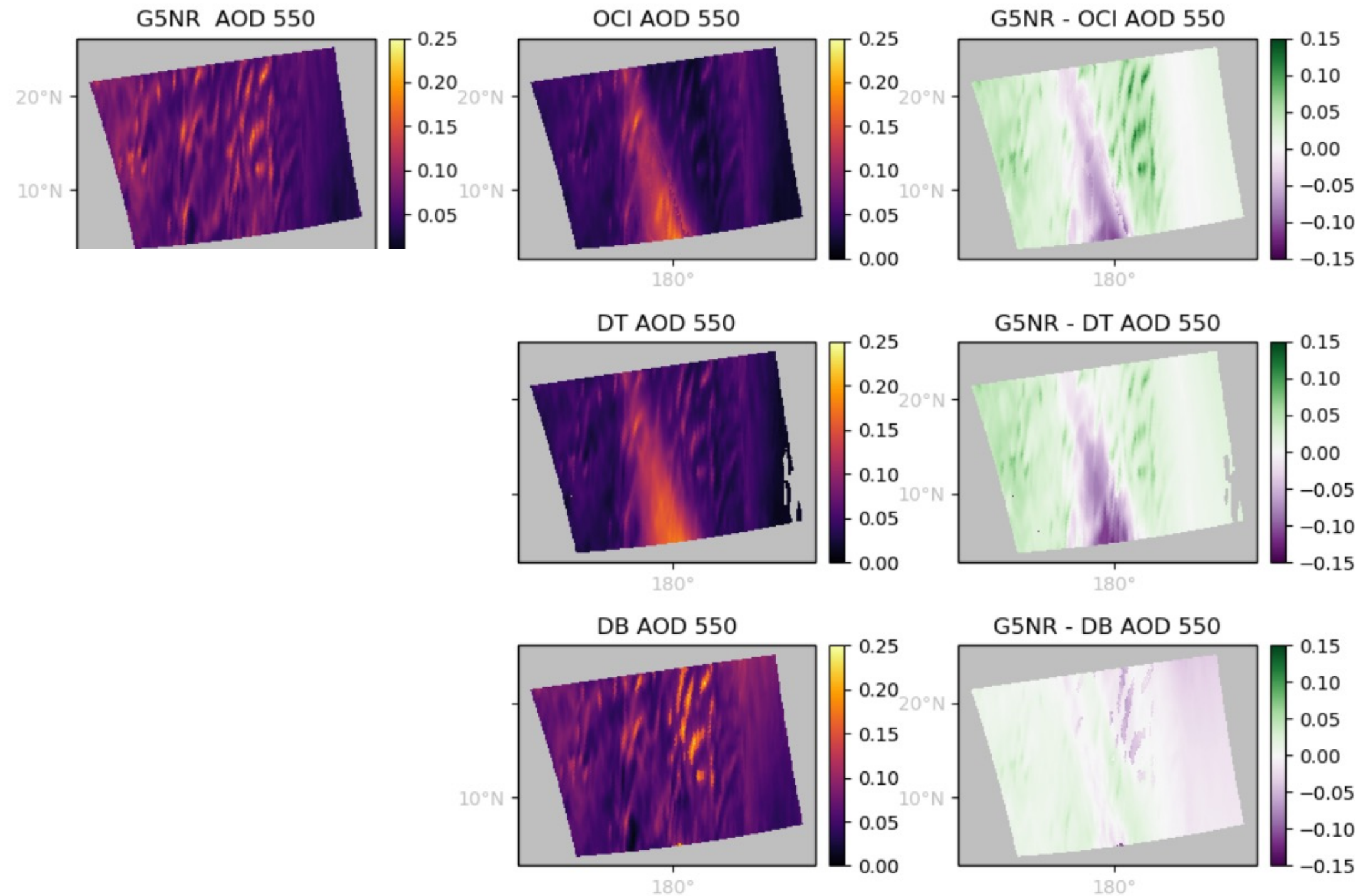
Gregg & Rousseaux, *Frontiers in Marine Science* (2017)

OASIM Upwelling Radiance

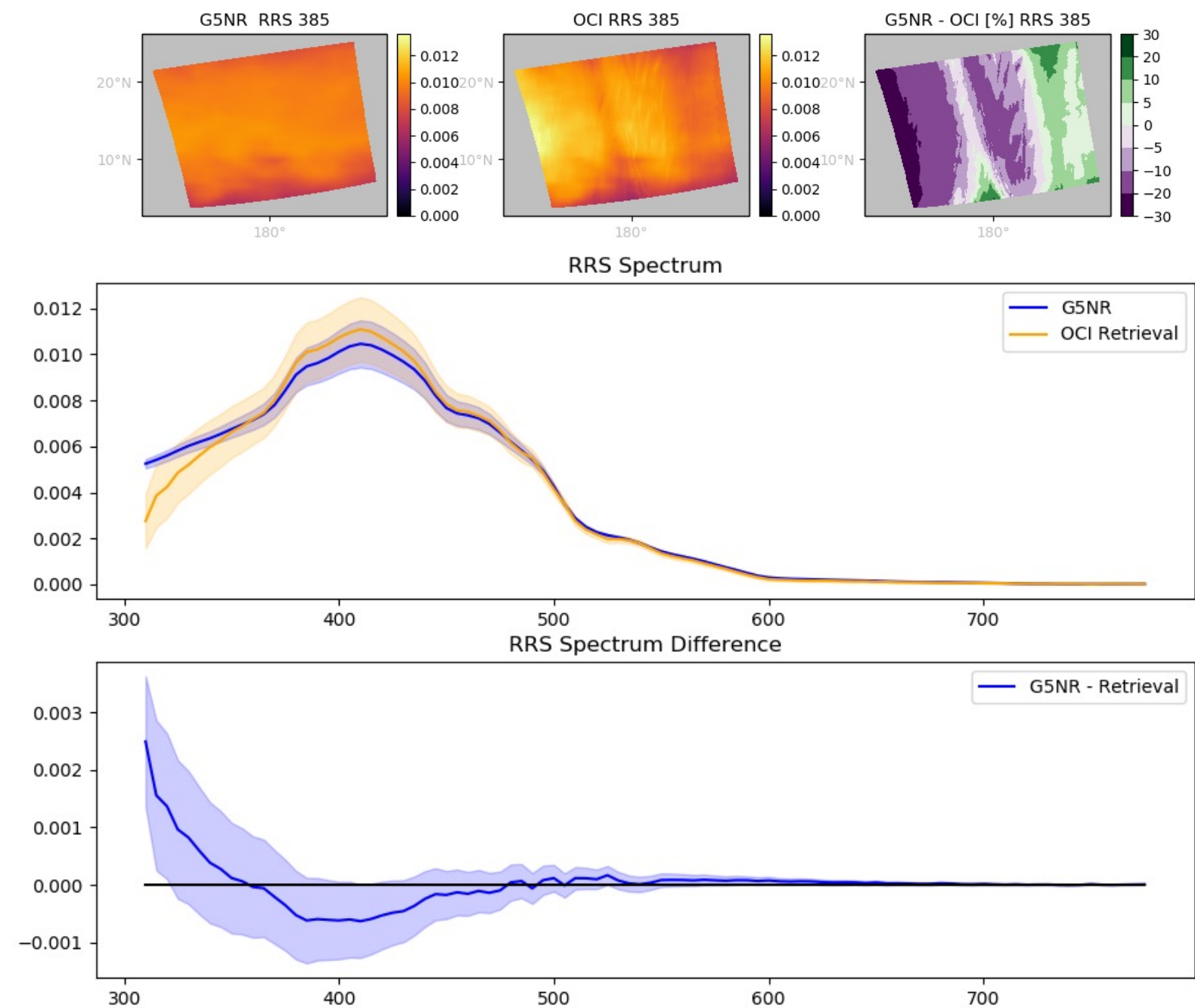




550 nm AOD Retrieval

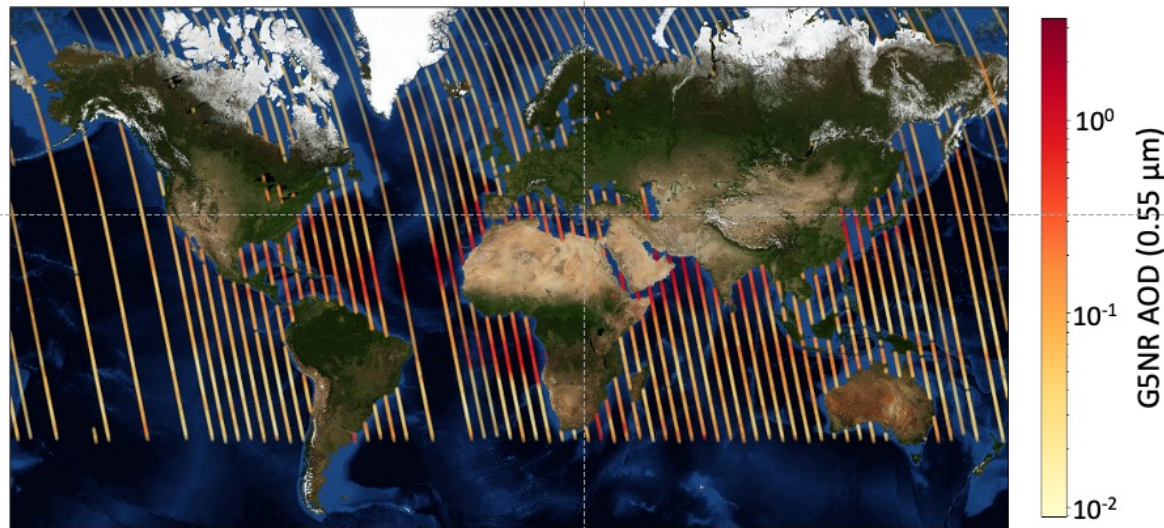


Hyperspectral Water Leaving Radiance Retrieval

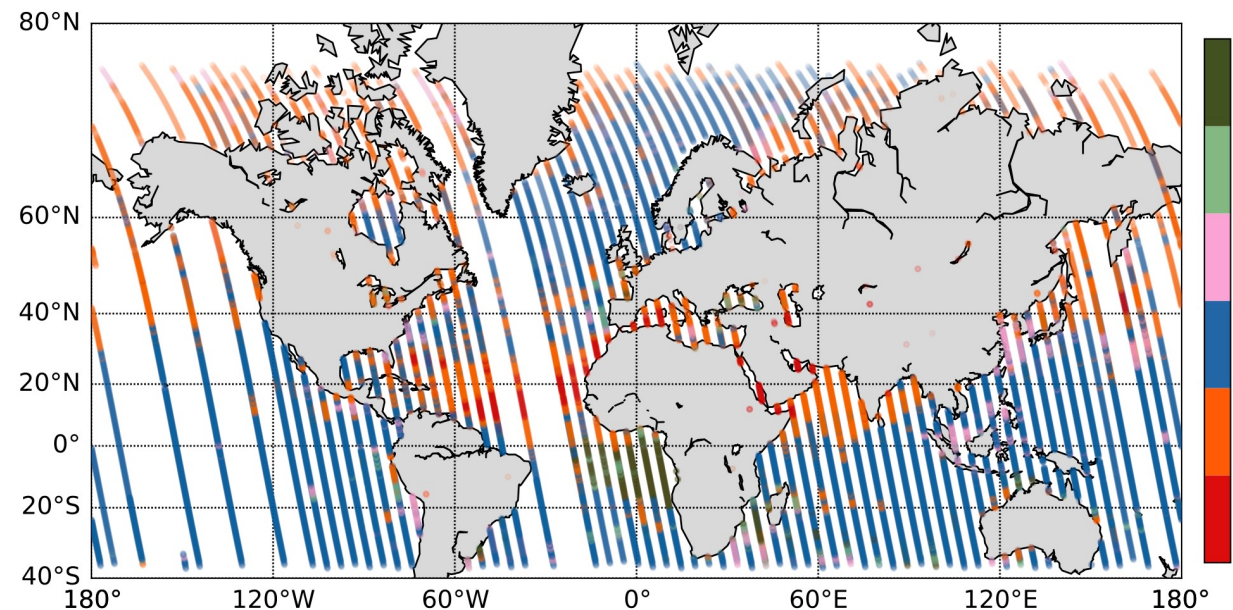


G5NR surface and aerosol fields for 13:30 Sun synchronous orbit

Over 120,000 polarimeter retrievals performed
covering range of AODs and aerosol types in August



0 – Dust | 1 – Polluted Dust | 2 – Marine | 3 – Urban |
4 – BB-White | 5 – BB-Dark



VLIDORT Forward Calculation

Synthetic Polarimeter Measurements (I, Q, U)

10 angles over ± 57 degrees in VZA

8 wavelengths spanning 0.36 μm to 1.6 μm

Simulated Truth

$$I(\text{PSD}, n, k, \text{SPH}, \Theta, V)$$

Noise

$$+ \xi_2 \times I \times 3\%$$

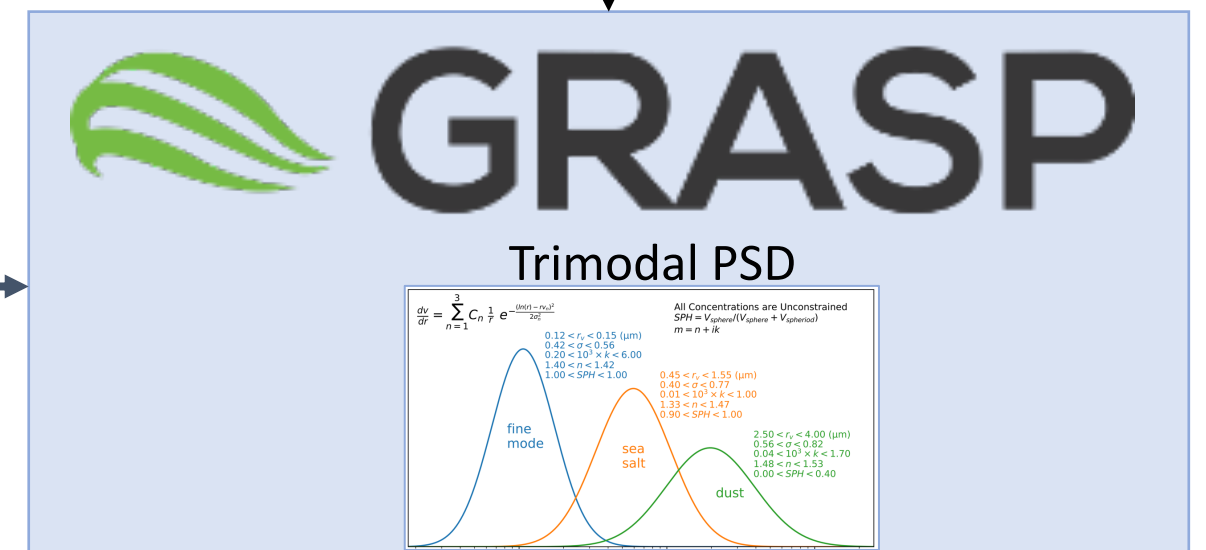
$$Q(\text{PSD}, n, k, \text{SPH}, \Theta, V)$$

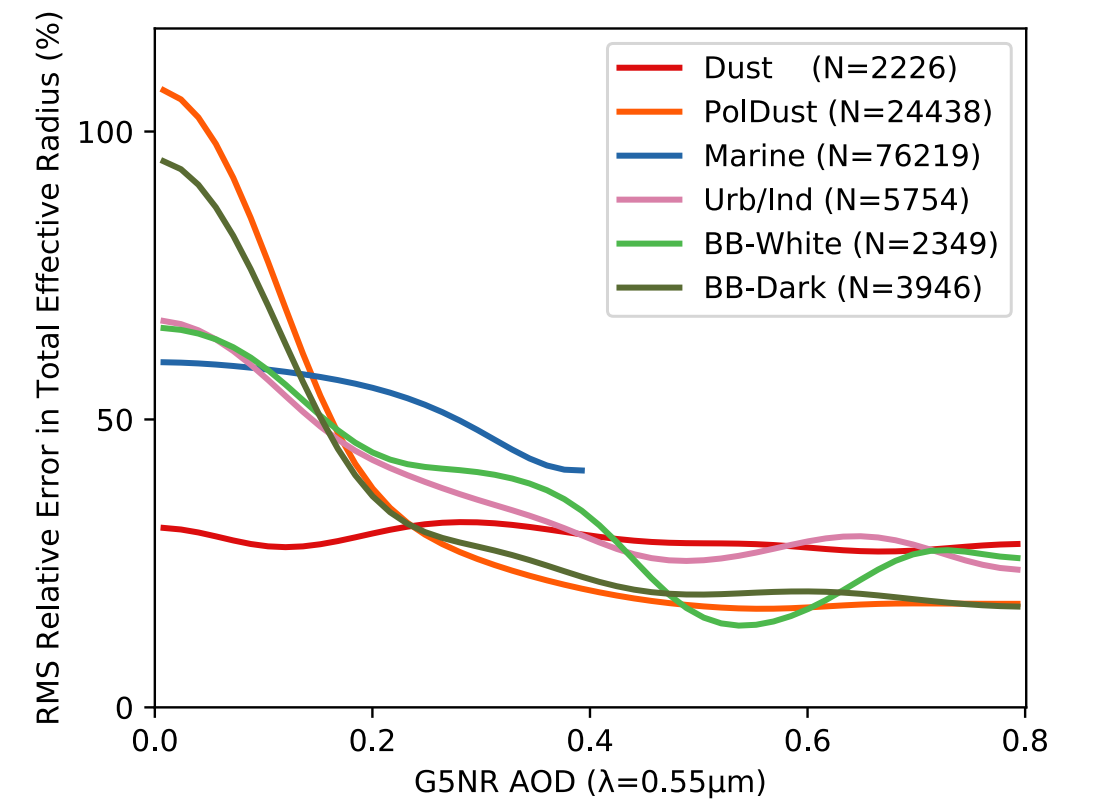
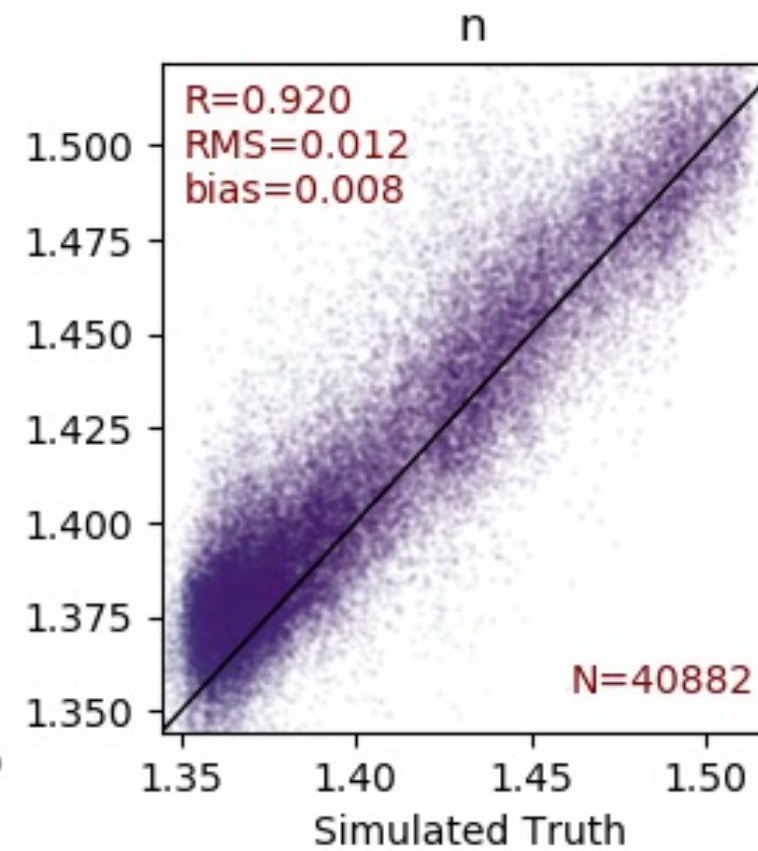
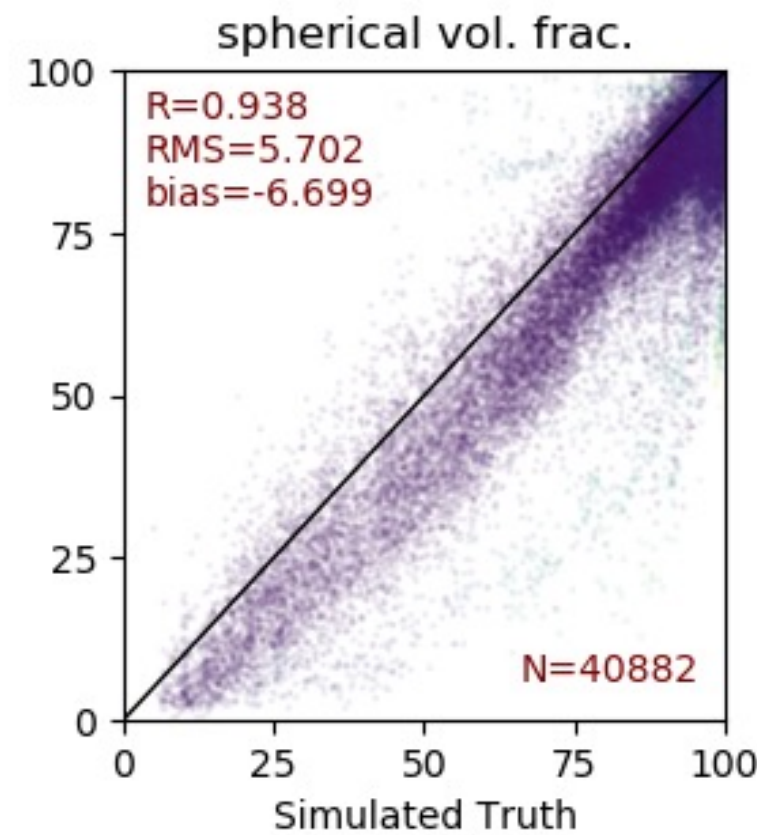
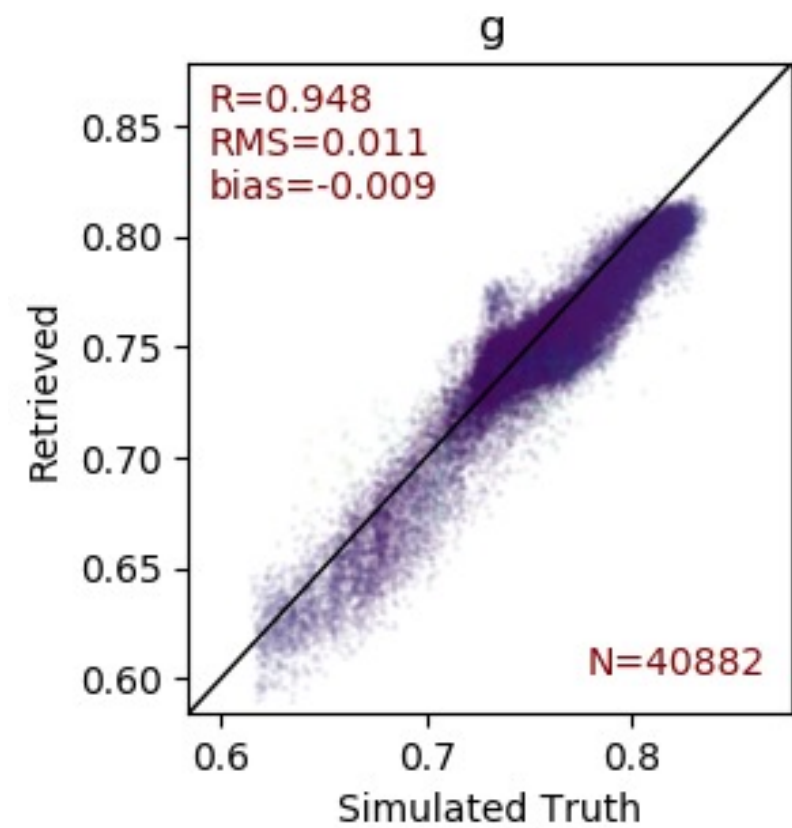
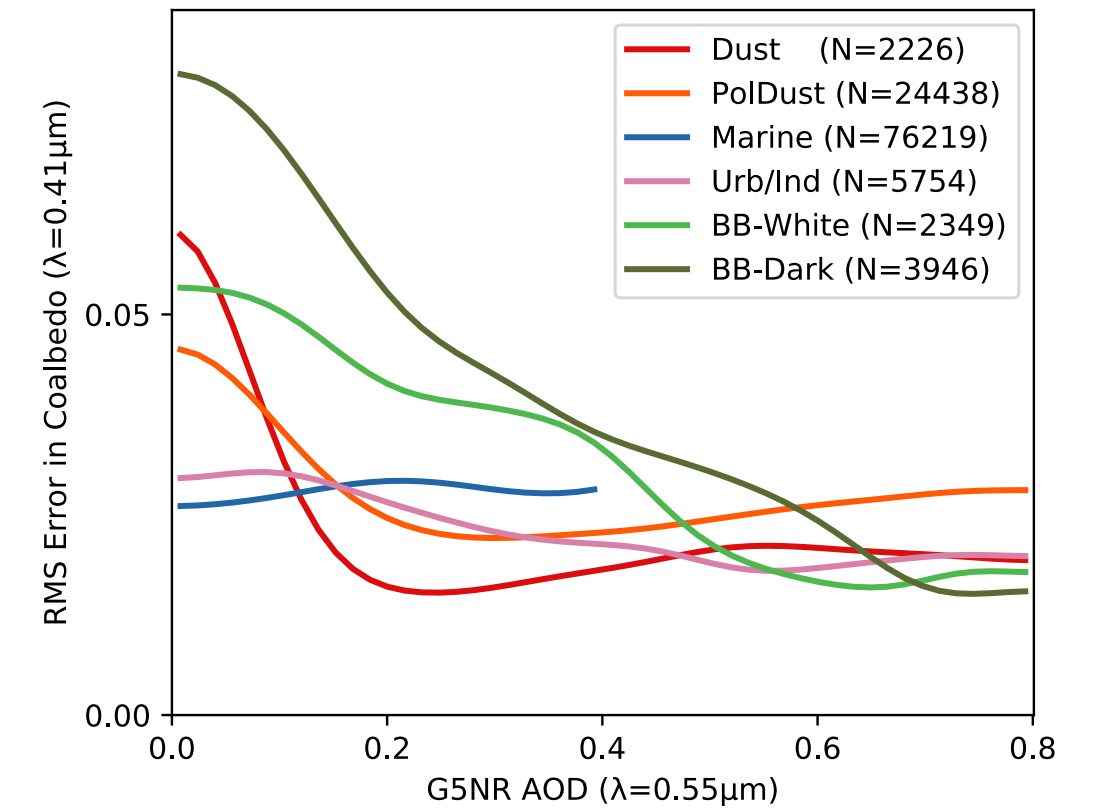
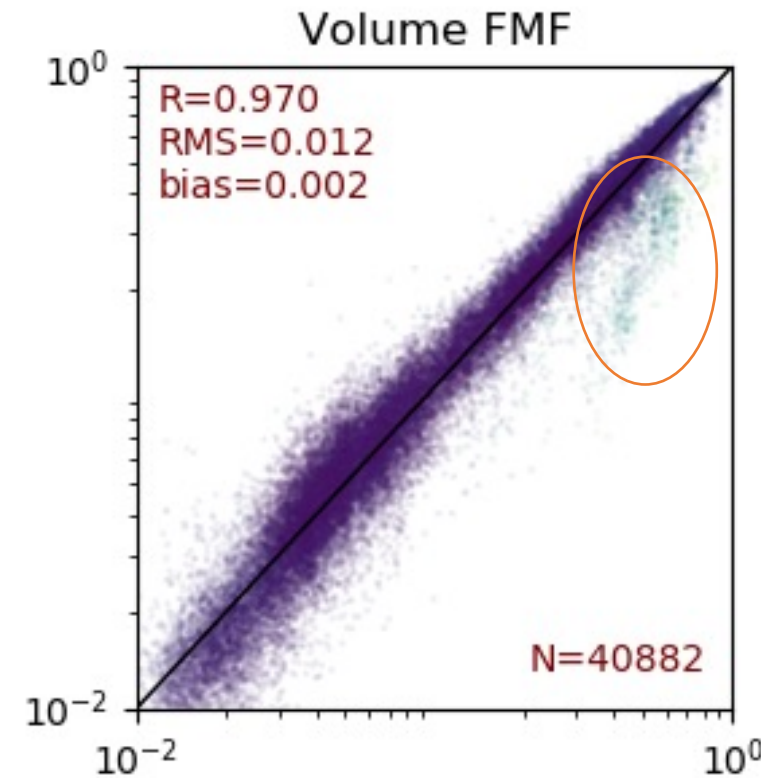
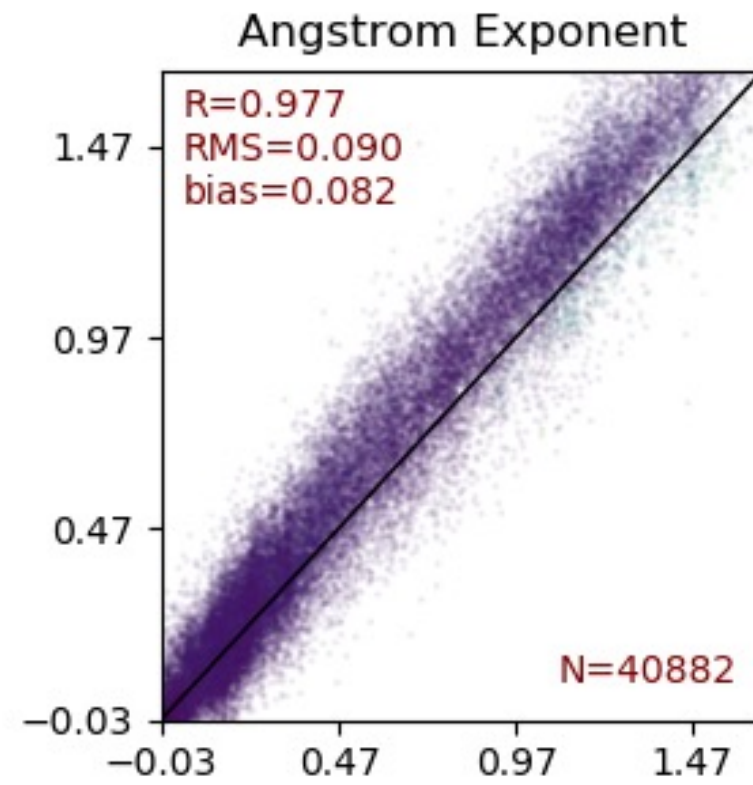
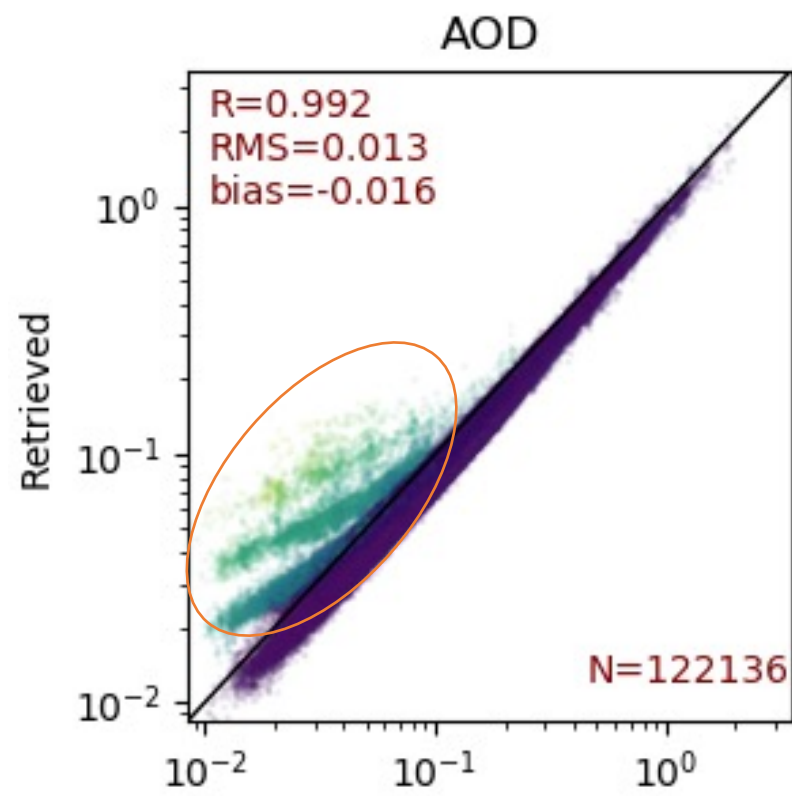
$$+ \xi_3 \times I \times \sigma_Q$$

$$U(\text{PSD}, n, k, \text{SPH}, \Theta, V)$$

$$+ \xi_3 \times I \times \sigma_U$$

Compare AOD, SSA, RI, r_{eff}
(GRASP retrieved vs G5NR “truth”)





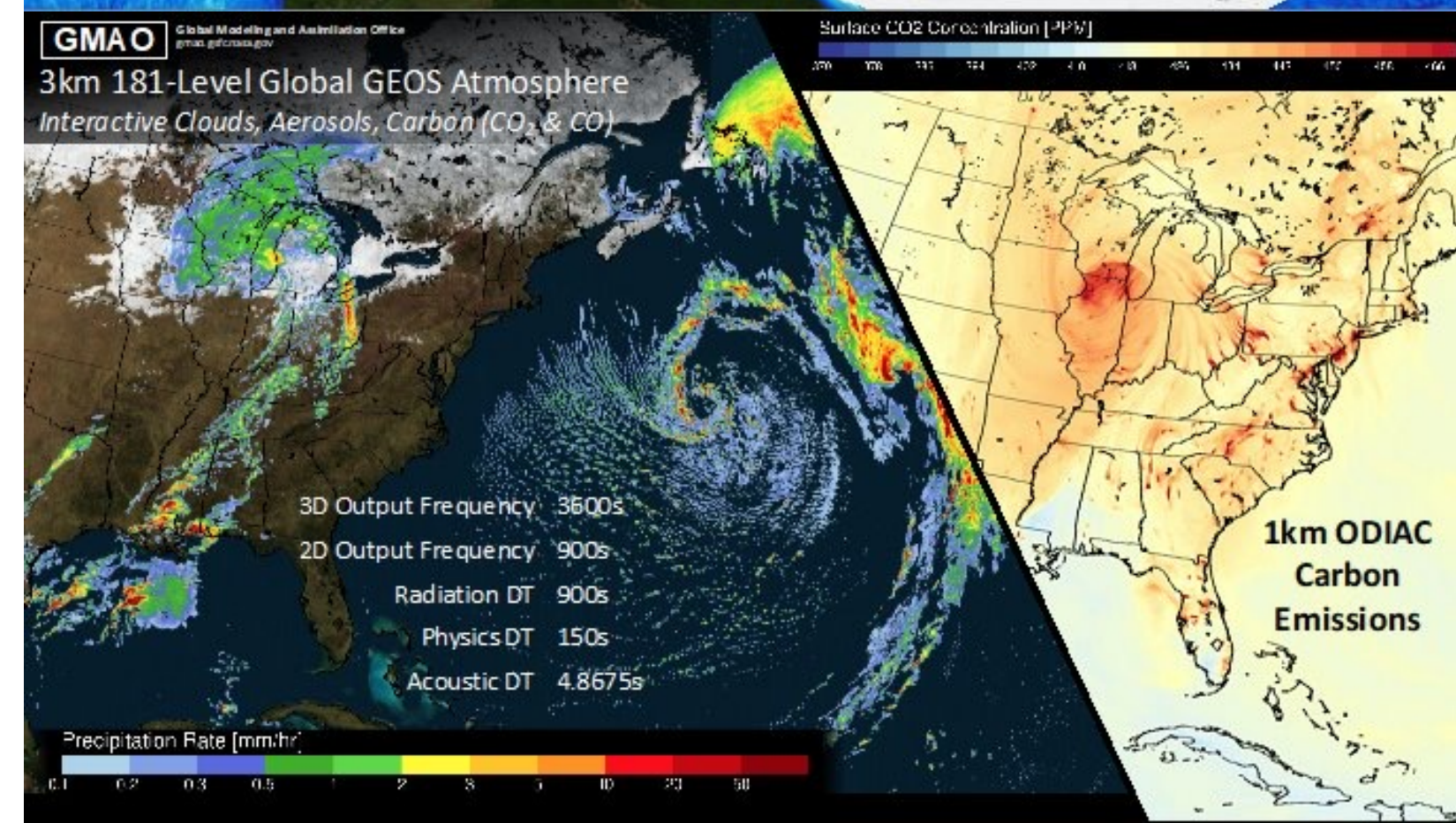
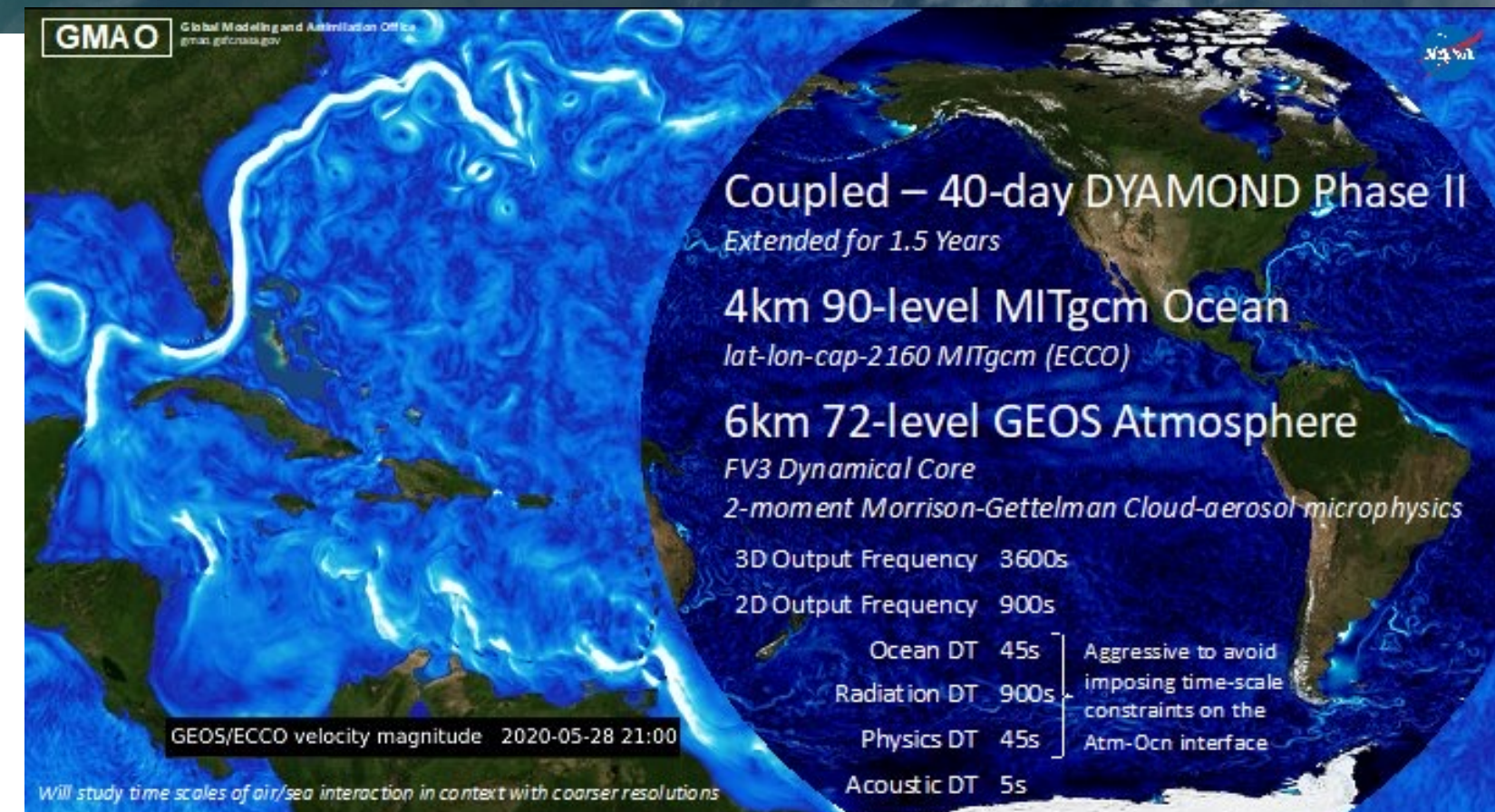
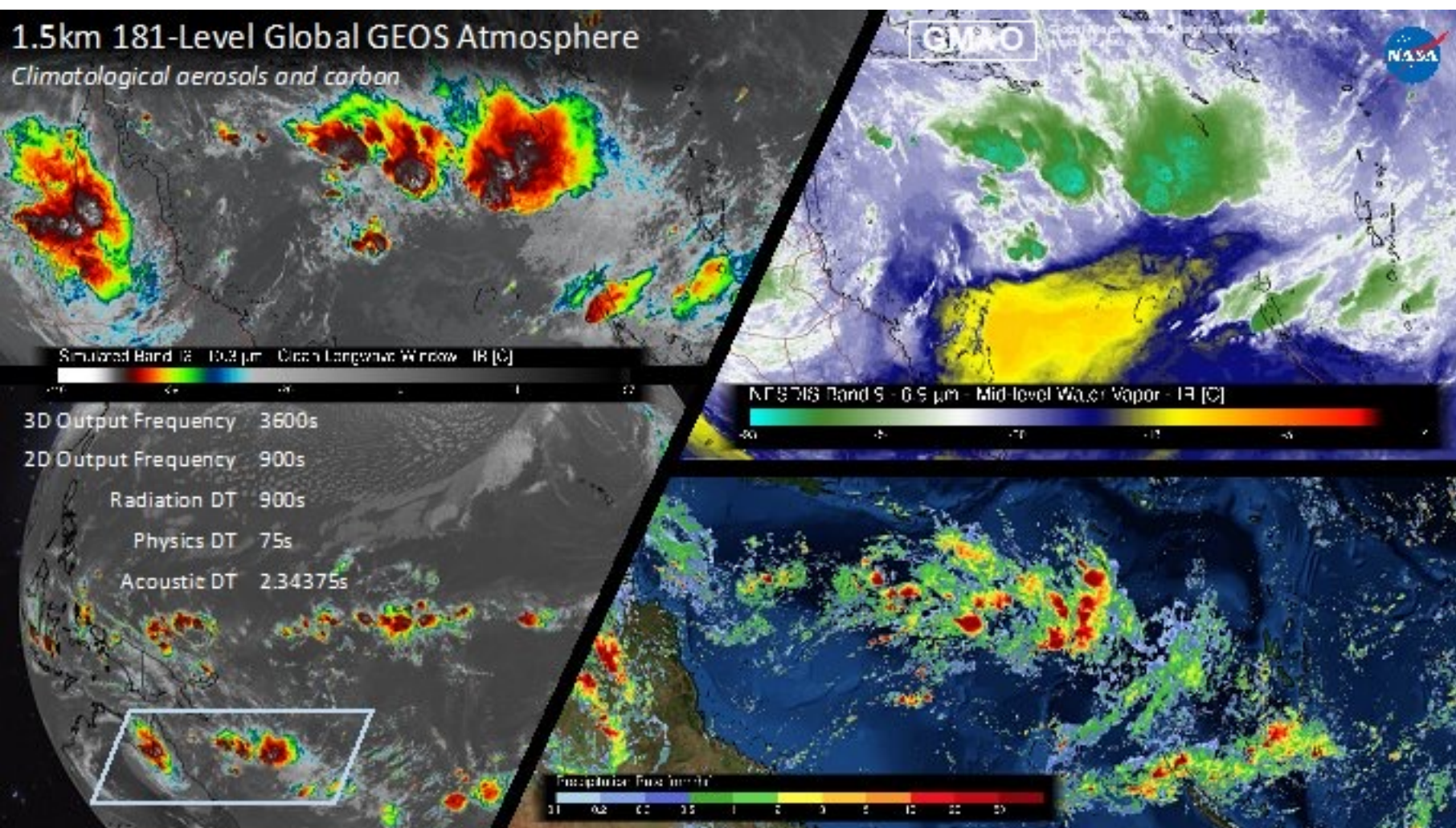
- The GEOS 7 km Nature Run has served us well over the years, but lack of realistic cloud properties has been a road block
 - Cloud downscaling algorithms lacked realism at km scale
- Land surface reflectance is not prognostic and limited to observed climatology of specific channels
 - e.g. MODIS, TOMS

DYAMOND Runs Phase II

Configuration	Total Cores - "System"	Throughput	Data Volume
Coupled Atm-Ocn 6km 72-Level Atm 4km 90-Level Ocn	8,160 Intel Xeon Haswell processor cores "Pleiades" NASA-NAS	3 Simulated Days / Wallclock Day	0.3 Petabytes
Atmosphere+Aerosols 3km 181-Level Atm	39,360 Intel Xeon Skylake processor cores "Discover" NASA-NCCS	7 Simulated Days / Wallclock Day	2.0 Petabytes
Atmosphere 1.5km 181-Level Atm	39,440 Intel Xeon Skylake processor cores "Discover" NASA-NCCS	1.5 Simulated Days / Wallclock Day	1.3 Petabytes

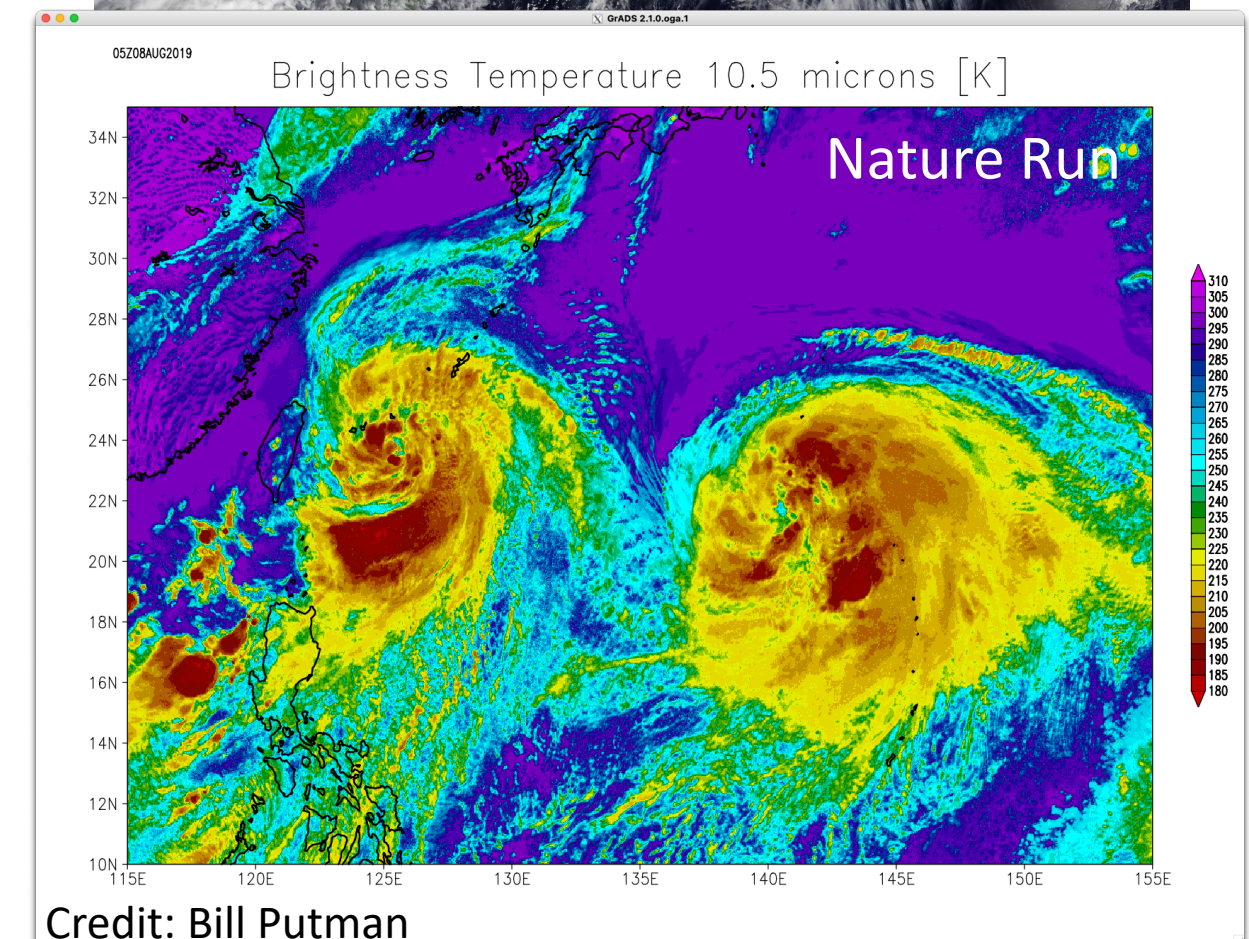
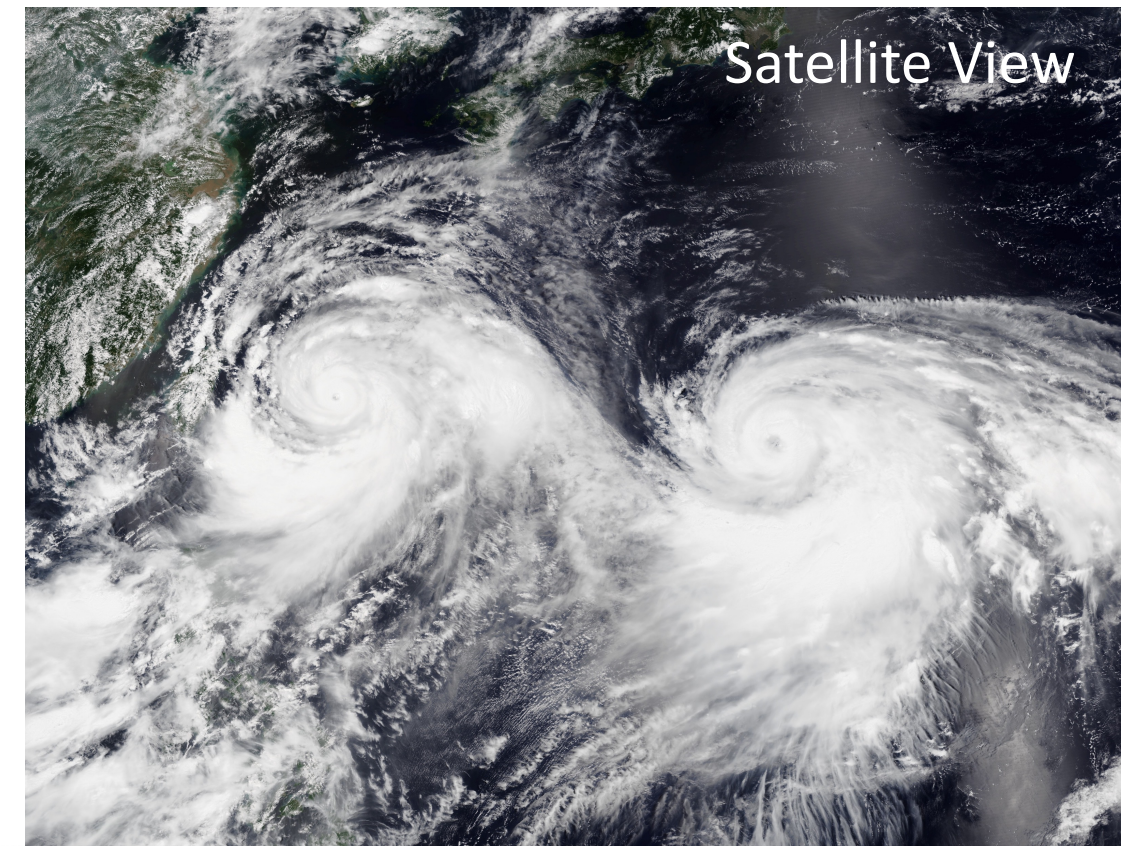
Credit: Bill Putman

1.5km 181-Level Global GEOS Atmosphere
Climatological aerosols and carbon

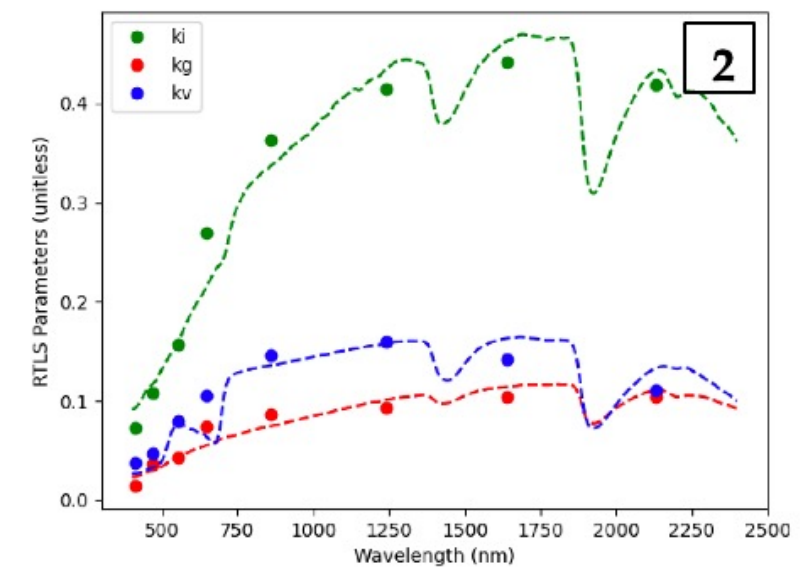
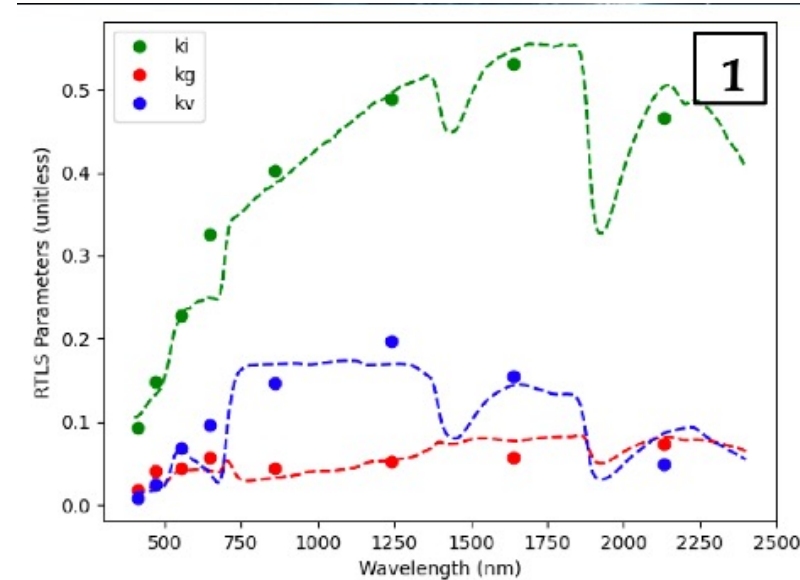


Storm Resolving Nature Run

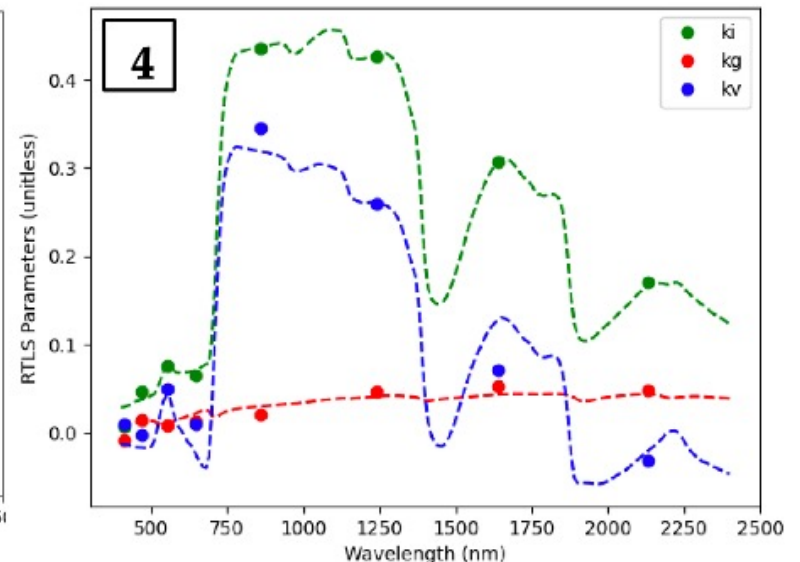
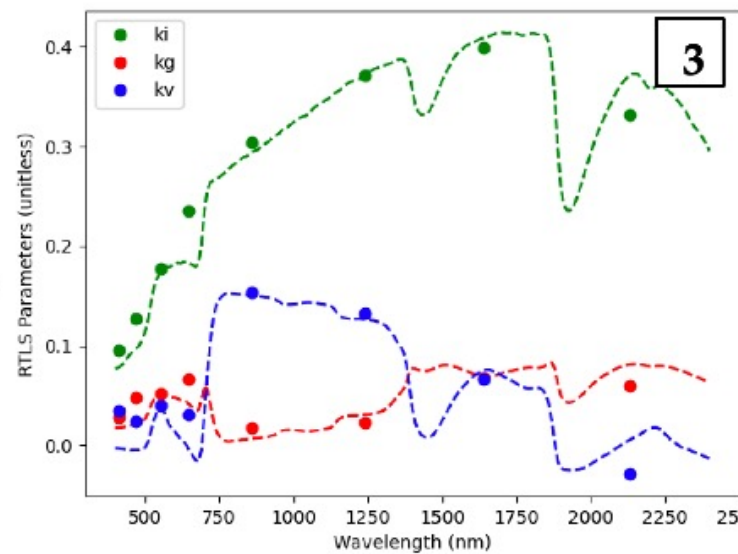
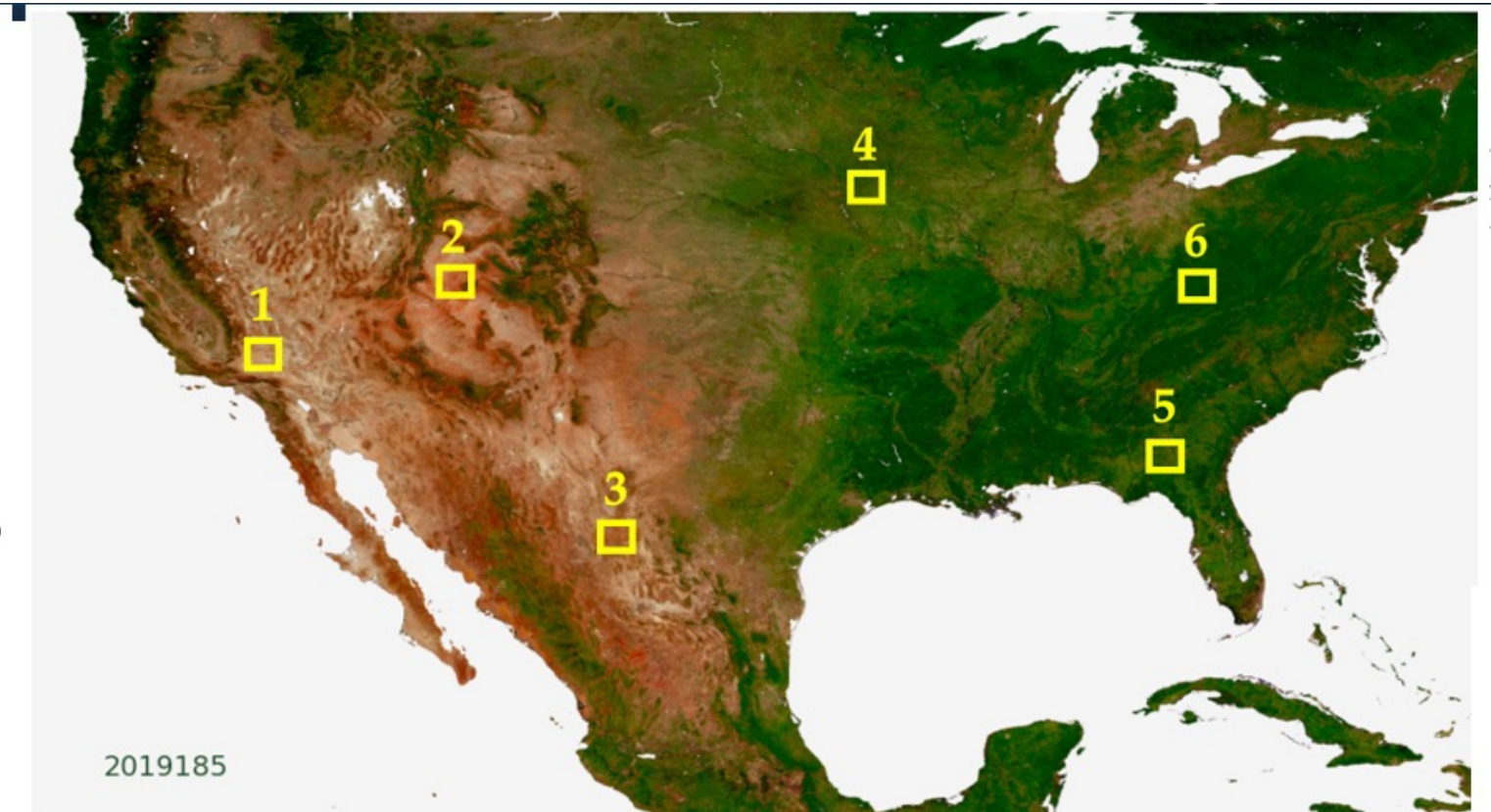
- Traditional I/O based approaches for Nature Run generation are not practical.
 - 1-km model requires exabytes of storage for 1 year simulation
- Developing two-phase workflow for generating Nature Run datasets
 1. Model is spun up in a run with limited output except for frequent checkpoints and browse products
 2. Model is run from checkpoints with on-line sampling of geophysical variables at user specified observation locations
 - Flexible API for custom geo-location samplers, allowing maximum flexibility: ground stations, aircraft trajectories, satellite swaths



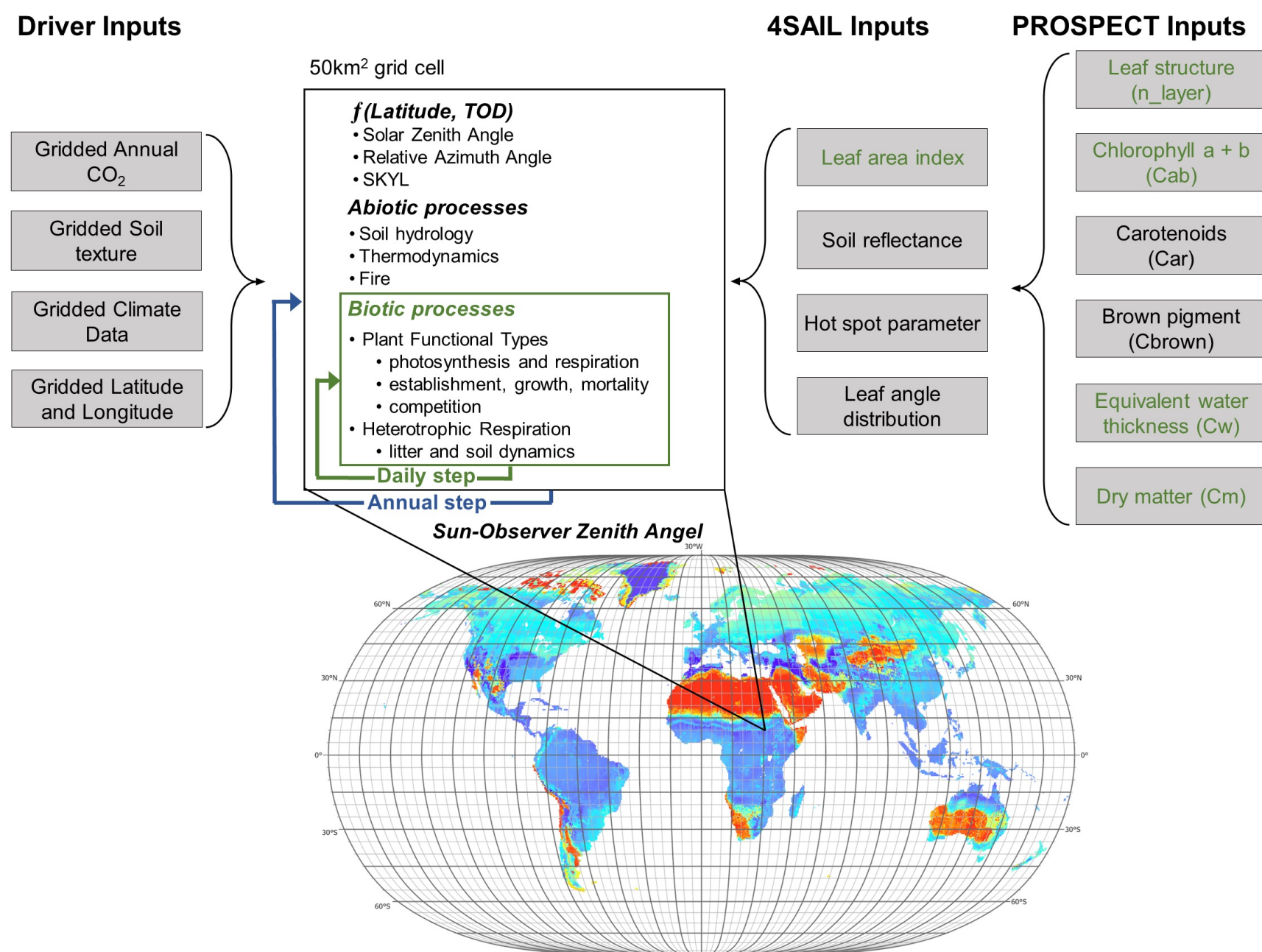
- Hyperspectral Surface BRDF (RTLS) parameters are generated based on the corresponding MODIS (MCD19) products and the Aster/ECOSTRESS spectral library
- The data are provided on geographic grids from 60°N to 60°S and 180°W to 180°E at a 0.01x0.01 degree spacing.
- The data have been generated for every 8-day period for Year 2019.
- Each pixel includes the RTLS parameters for 213 spectral bands from 380 nm to 2500 nm at a 10 nm spectral resolution.



Credit: Weile Wang (ARC)



LPJ-Prosail



- Simulates global dynamic surface reflectance data for spaceborne imaging spectroscopy missions.
- Dynamic global vegetation model, *LPJ* + canopy radiative transfer model, *PRO4SAIL*.
- Gridded input variables drive process-based vegetation dynamics of **10 plant functional types** and downstream biogeochemical and hydrological cycling.
 - Atmospheric Inputs: CRU, MERRA-2 or km-scale Nature Run (in progress)
 - HWSD or USDA global soils
 - CO_2
 - LUH v2 land use change data
- Variables cross-walked between LPJ and PROSAIL (green in the diagram) to estimate globally-gridded, top-of-canopy reflectance data at the same time step as LPJ.
- Reflectance (Level 1) data products:
 - Globally-gridded top-of-canopy reflectances for **1980-2021**.
 - Daily or monthly time step
 - 0.5° globally gridded
 - 400-2500nm @ 10nm

- The GMAO OSSE framework based on the 7 km GEOS Nature Run has been the basis of several retrieval algorithm evaluation studies
- The simulated observations have allowed us to:
 - Test hypotheses for mechanisms that can explain known retrieval biases
 - Evaluate the synergy between instruments
 - Demonstrate the feasibility of heritage retrieval algorithms on new sensors
 - Exercise retrieval algorithm software before launch
 - Derive global statistics of the accuracy of a multi-angle polarimeter retrieval
- Next generation km-scale cloud resolving Nature Runs will allow for demonstrating cloud effects
 - New I/O paradigm will enable easier handling and sharing of this very large dataset
- Collaboration with the SBG team's developments of hyperspectral and prognostic land surface reflectance will further the realism of our simulated observations and bring the observation simulator closer to a true Earth system digital twin