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PACE polarimetric aerosol and ocean color remote sensing: HARP2 L2 retrievals updates

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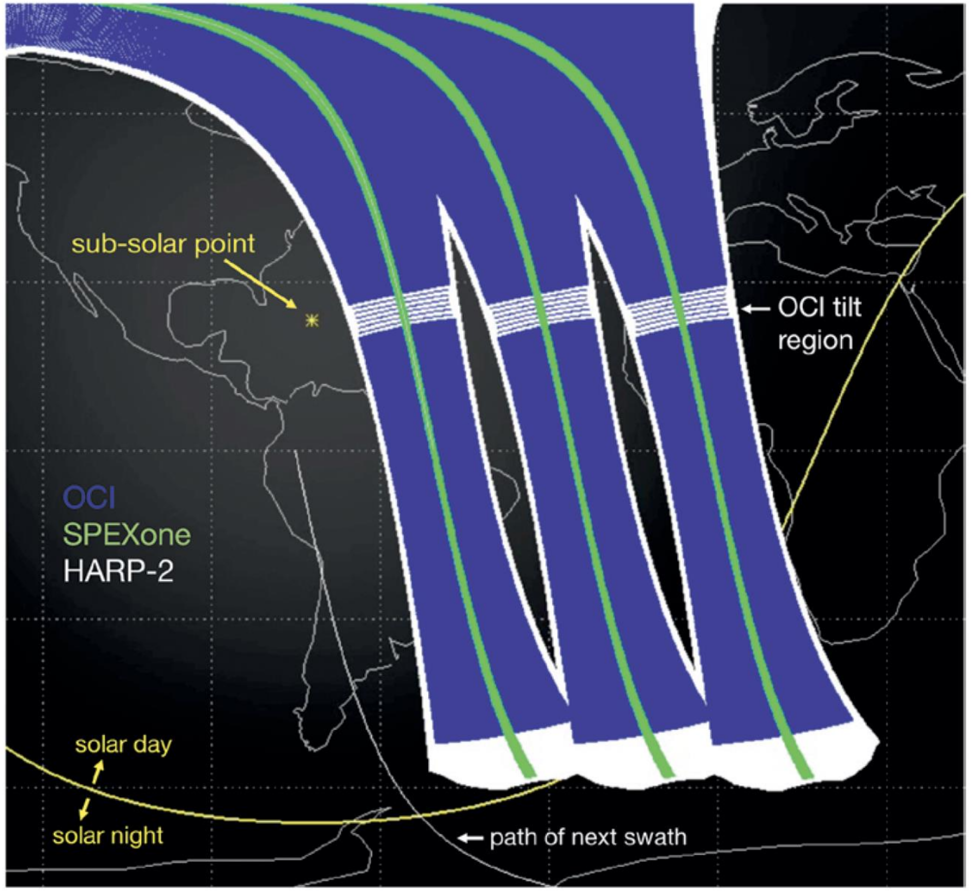
UMBC: P-W. Zhai, X. Xu , V. Martins; SRON: O. Hasekamp

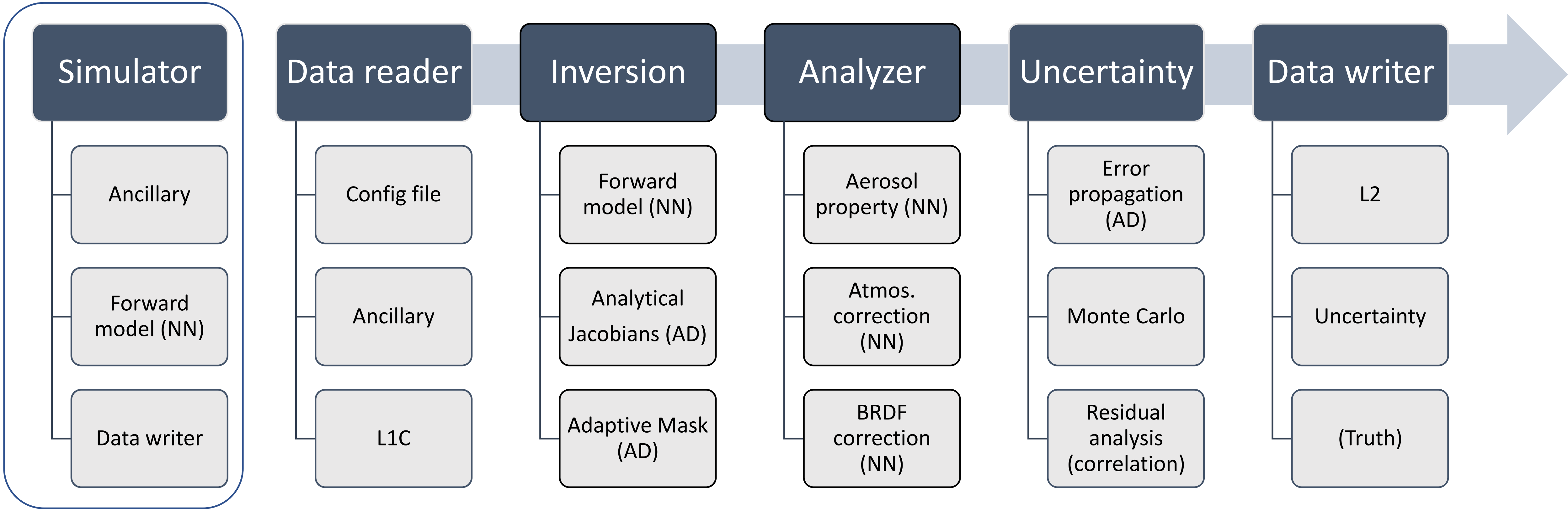
Motivations



PACE orbits, Werdell et al, BAMS (2019)

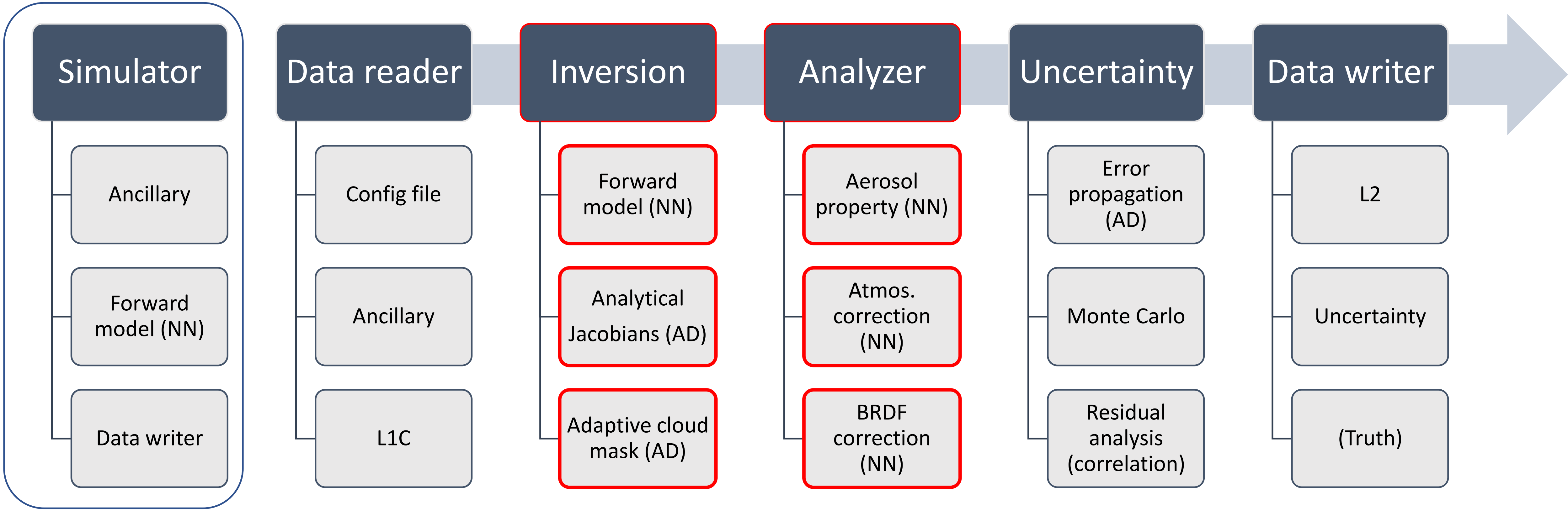
- Conduct simultaneous aerosol and ocean property retrieval based on PACE MAP (HARP2) data.
- Facilitate future synergy on HARP2+ OCI
  - Use HARP2 aerosol to assist OCI atmospheric correction (tested with RSP+ SPEX, Gao et al AMT 2019)
  - Use OCI SWIR band to help HARP2 coarse model aerosol retrievals (tested with AirHARP + RSP SWIR)
- Tackle the computational challenges to process the wide-swath MAP data.

Retrieval algorithm structure (FastMAPOL)



NN: Neural network
AD: Automatic Differentiation

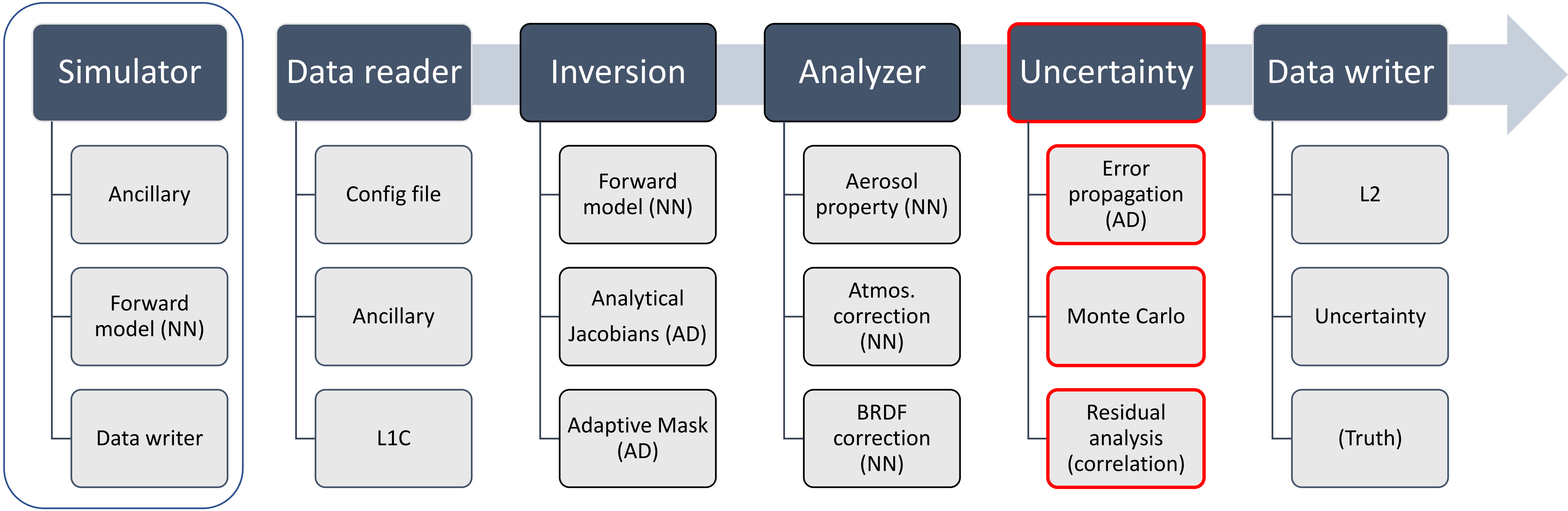
Progress for 2020-2021 (FastMAPOL)



Develop an efficient MAP retrieval algorithm (FastMAPOL):

- Neural network forward model and Jacobians (Gao et al, AMT 2021)
- Adaptive multi-angle data mask to screen cirrus cloud, etc (Frontiers, 2021)
- Atmospheric correction and BRDF correction to derive ocean color (AMT 2021)

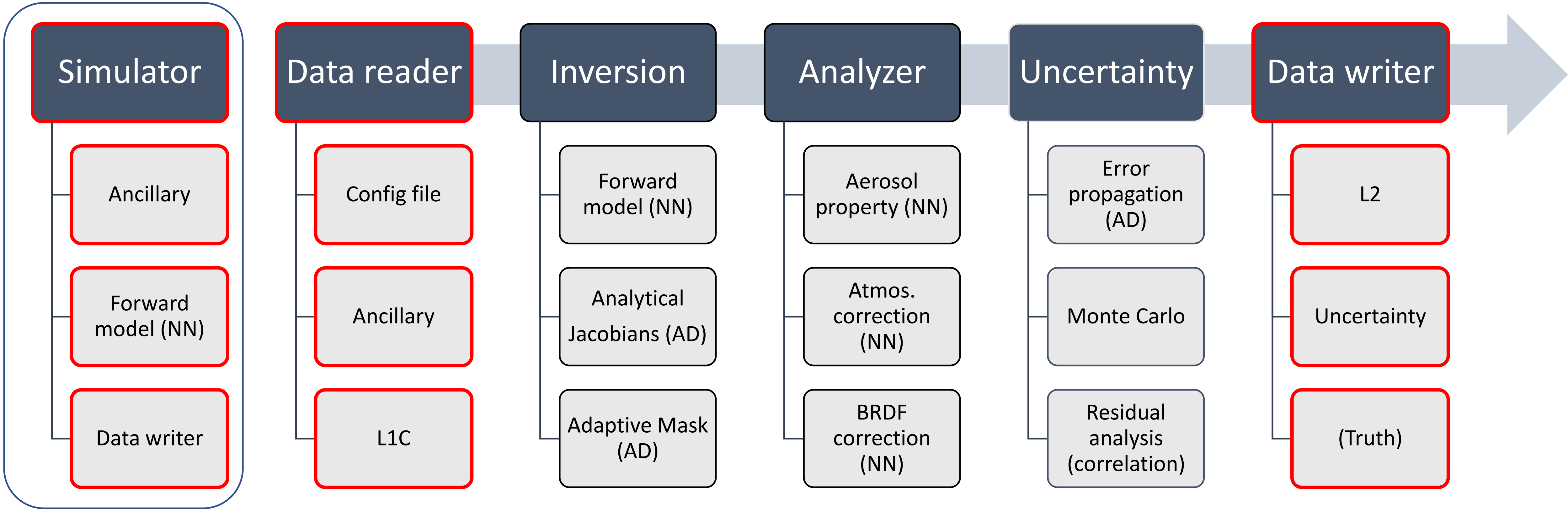
Progress for 2021-2022 (FastMAPOL)



Focus on uncertainty analysis

- Monte Carlo approach to assess error propagation uncertainty (Gao et al, AMT 2022)
- Uncertainty model including angular correlation (AMT 2022, preprint)

Current work (FastMAPOL)



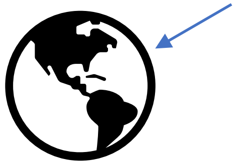
Develop a production version of the code for PACE

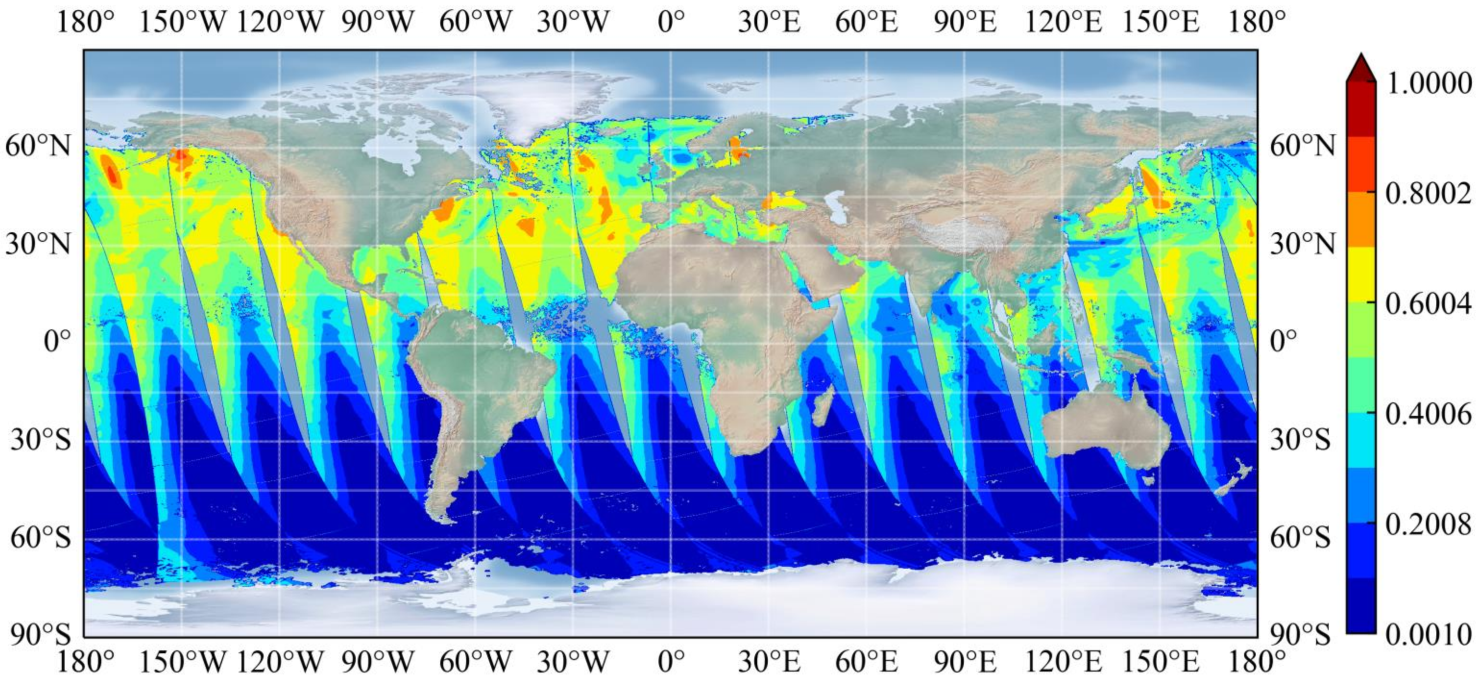
- Simulate global HARP2 L1C data over ocean (DITL: March 21, 2023)
- DITL L2 retrieval and uncertainty analysis

PACE HARP2 L1C simulated data (over ocean)

- Simulations:
  - HARP2 L1C grids/geometry: UMBC HARP team/PACE SDS
  - Aerosol and ocean properties: MERRA2, MODIS ocean color
  - Neural network RT simulation (Gao et al, AMT 2021) based on RTSOS (Pengwang Zhai)
- Features:
  - Aerosol fine and coarse mode microphysical properties
  - Open ocean bio-optical model
  - New inputs: aerosol layer height, Ozone, surface pressure
- Data available:
  - https://oceandata.sci.gsfc.nasa.gov/directdataaccess/Level-1C/
- Application:
  - Test data format, geometry
  - Test processing pipeline
  - Evaluate uncertainty

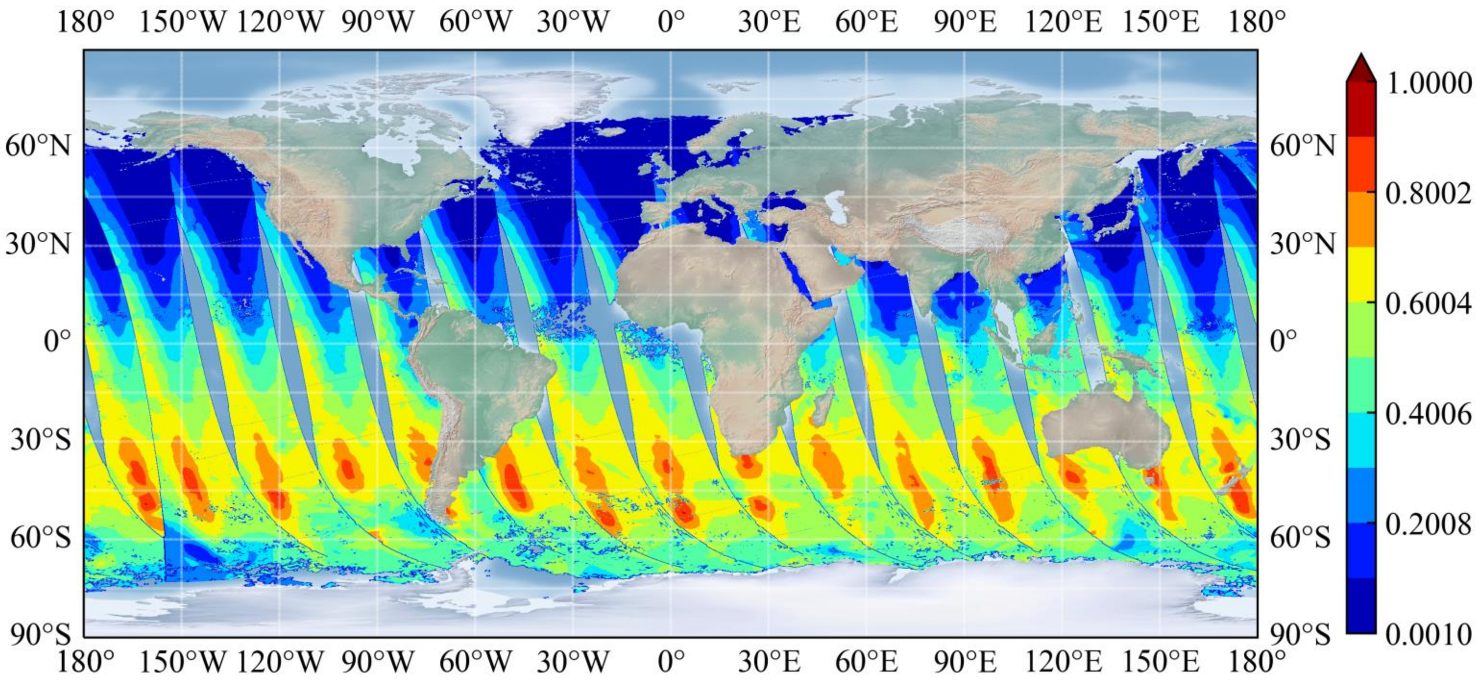
HARP2 L1C DoLP (440nm, view angle: -40.21°)





https://oceandata.sci.gsfc.nasa.gov/directdataaccess/Level-1C/

HARP2 L1C DoLP (440nm, view angle: -42.78°)



https://oceandata.sci.gsfc.nasa.gov/directdataaccess/Level-1C/

PACE HARP2 L2 product (over ocean)

- Simultaneous aerosol and ocean property retrieval
- Product list
  - Aerosol microphysical properties (size, refractive index, AOD, SSA)
  - Wind speed, Chla
  - Rrs (at selected or all available angles)
- Uncertainties of all above products

HARP2 L2 and uncertainty file format (prelim)

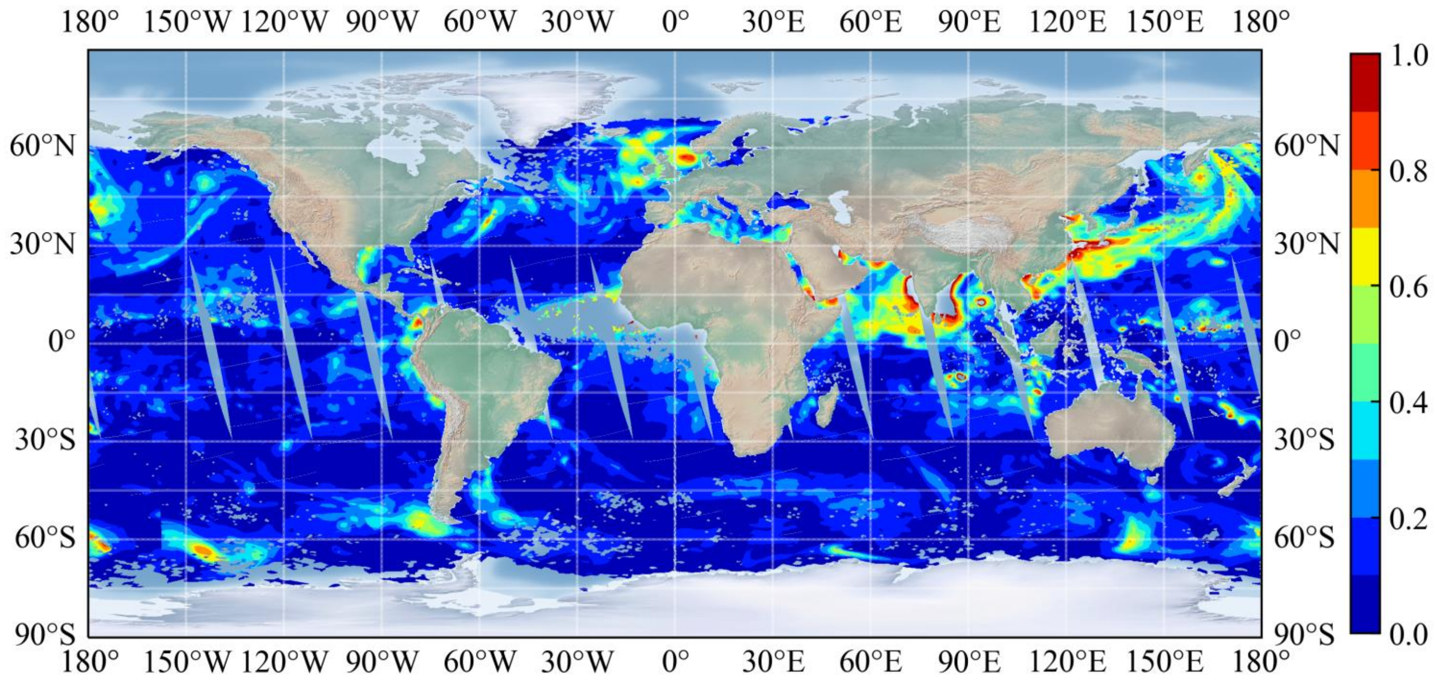
HARP2 L2

Name	
▼ PACE_HARP2.20220321T000500.L2.FM.nc	FastMAPOL
▶ atmospheric_correction	atmospher
▼ geophysical_data	geophysica
alh	aerosol lay
aod	aerosol op
aod_coarse	coarse mo
aod_fine	fine mode
chla	chlorophyll
fvf	fine mode
mi_coarse	coarse mo
mi_fine	fine mode
mr_coarse	coarse mo
mr_fine	fine mode
o3	ozone colu
reff_coarse	coarse mo
reff_fine	fine mode
ssa_coarse	coarse mo
ssa_fine	fine mode
surface_pressure	surface pr
v_mode1	aerosol vol
v_mode2	aerosol vol
v_mode3	aerosol vol
v_mode4	aerosol vol
v_mode5	aerosol vol
veff_coarse	coarse mo
veff_fine	fine mode
wind_speed	wind spee
▼ navigation_data	navigation_
latitude	Latitude
longitude	Latitude
▼ processing_control	processing
chi2	cost functio
nv_dolp	number of
nv_ref	number of
timing	retrieval tir
▼ sensor_band_parameters	sensor_bar
wavelengths	wavelength

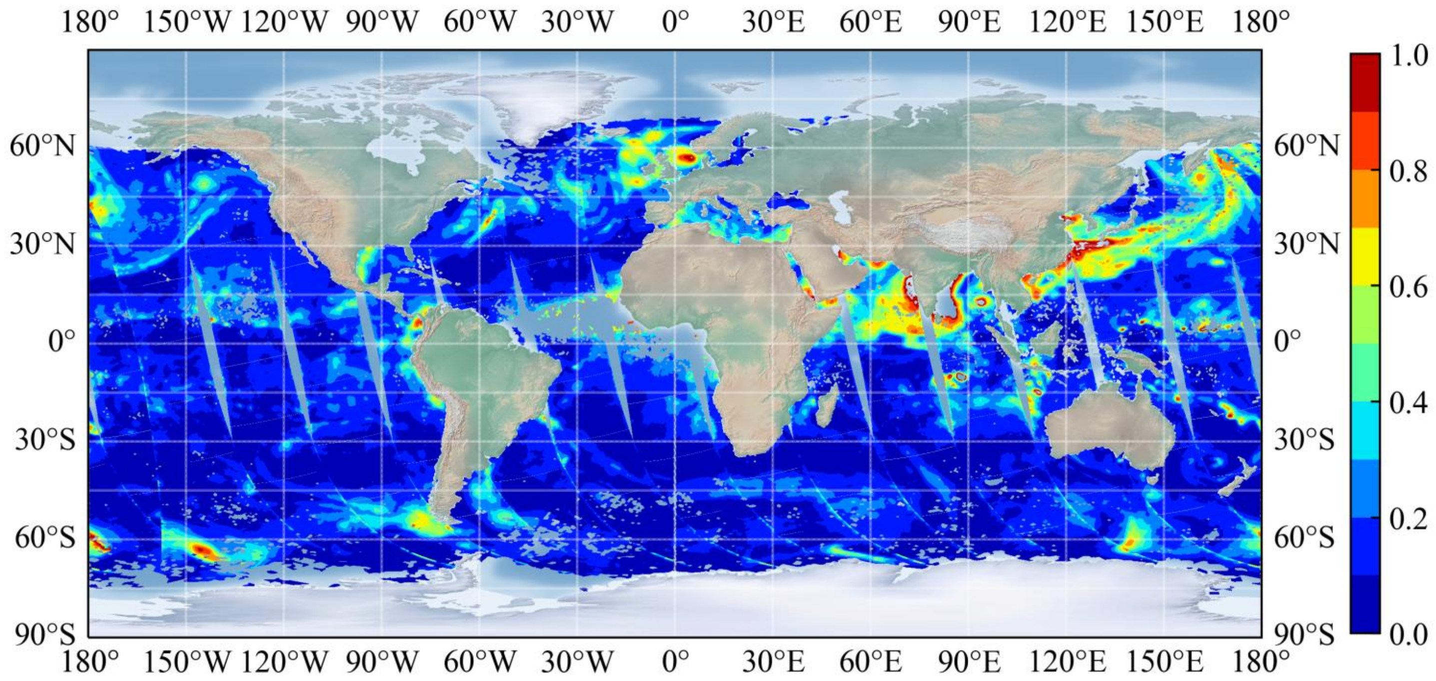
HARP2 L2 UNC (the same format with L2)

Name	Long Name	Type
▼ PACE_HARP2.20220321T000500.L2.FM.UNC.nc	FastMAPOL PACE HARP2 Level-2 Uncertai...	Local File
▶ atmospheric_correction	atmospheric_correction	—
▼ geophysical_data	geophysical_data	—
alh	aerosol layer height	Geo2D
aod	aerosol optical depth	Geo2D
aod_coarse	coarse mode aerosol optical depth	Geo2D
aod_fine	fine mode aerosol optical depth	Geo2D
chla	chlorophyll-a concentration	Geo2D
fvf	fine mode volume fraction	Geo2D
mi_coarse	coarse mode refractive index (imaginary p...	Geo2D
mi_fine	fine mode refractive index (imaginary part)	Geo2D
mr_coarse	coarse mode refractive index (real part)	Geo2D
mr_fine	fine mode refractive index (real part)	Geo2D
o3	ozone column density	Geo2D
reff_coarse	coarse mode effective radius	Geo2D
reff_fine	fine mode effective radius	Geo2D
ssa_coarse	coarse mode single scattering albedo	Geo2D
ssa_fine	fine mode single scattering albedo	Geo2D
surface_pressure	surface pressure	2D
v_mode1	aerosol volume density for submode 1 (Fa...	Geo2D
v_mode2	aerosol volume density for submode 2 (Fa...	Geo2D
v_mode3	aerosol volume density for submode 3 (Fa...	Geo2D
v_mode4	aerosol volume density for submode 4 (Fa...	Geo2D
v_mode5	aerosol volume density for submode 5 (Fa...	Geo2D
veff_coarse	coarse mode effective variance	Geo2D
veff_fine	fine mode effective variance	Geo2D
wind_speed	wind speed	Geo2D
▼ navigation_data	navigation_data	—
latitude	Latitude	Geo2D
longitude	Latitude	Geo2D
▼ processing_control	processing_control	—
chi2	cost function value	Geo2D
nv_dolp	number of angles for DoLP	Geo2D
nv_ref	number of angles for reflectance	Geo2D
timing	retrieval time per pixel	Geo2D
▼ sensor_band_parameters	sensor_band_parameters	—
wavelengths	wavelengths	1D

Truth: AOD(550nm)

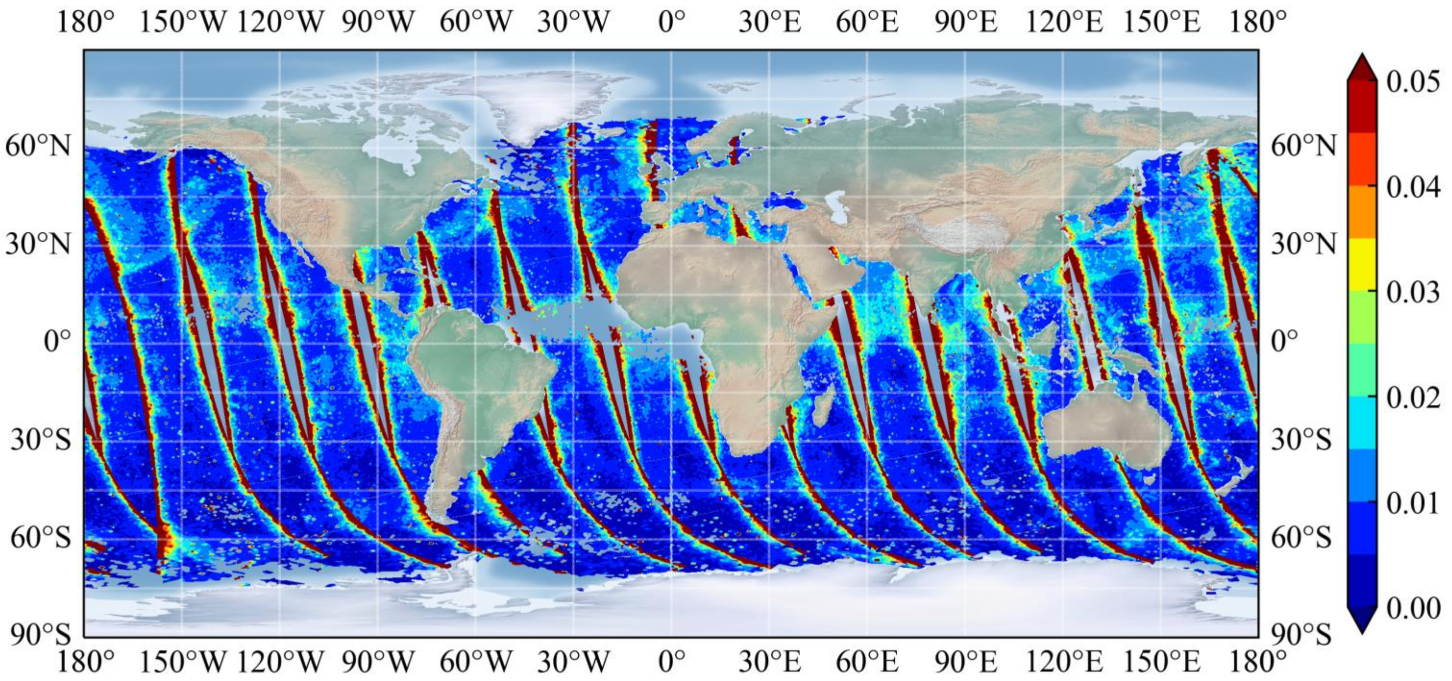


L2: AOD(550nm)

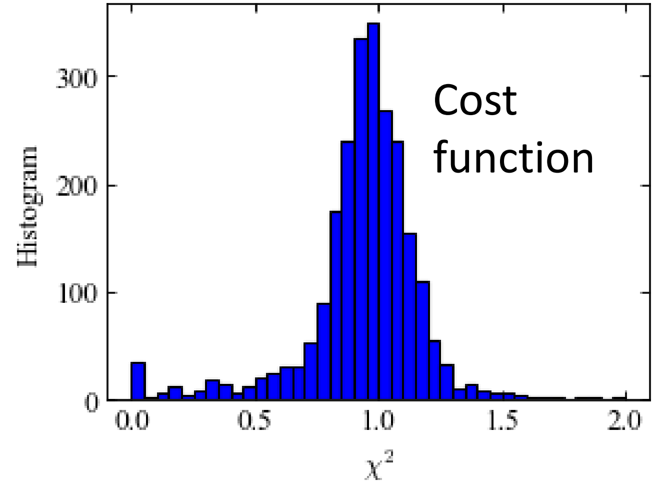


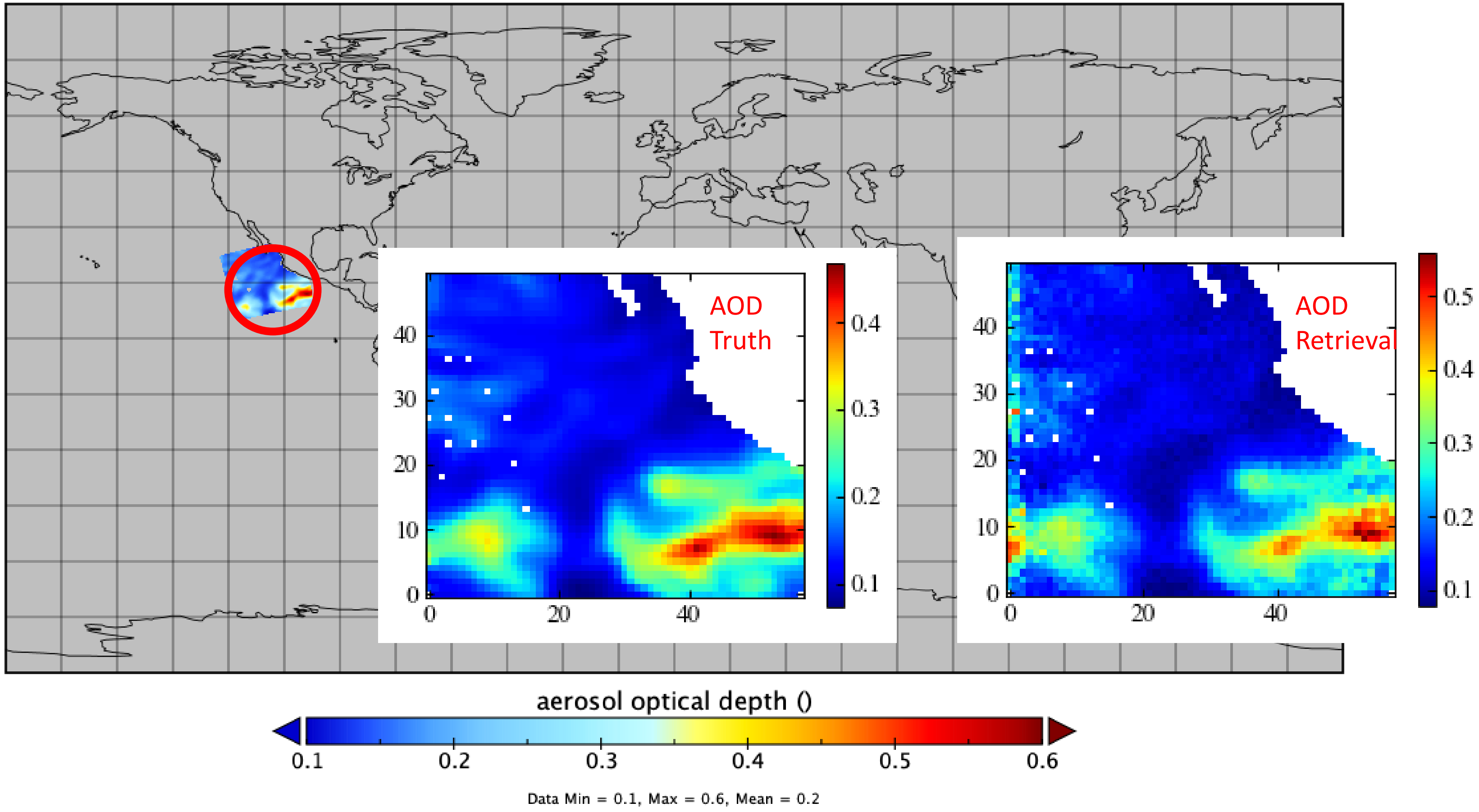
180° 150°W 120°W 90°W 60°W 30°W 0° 30°E 60°E 90°E 120°E 150°E 180°
60°N
30°N
0°
30°S
60°S
90°S
1.0
0.8
0.6
0.4
0.2
0.0

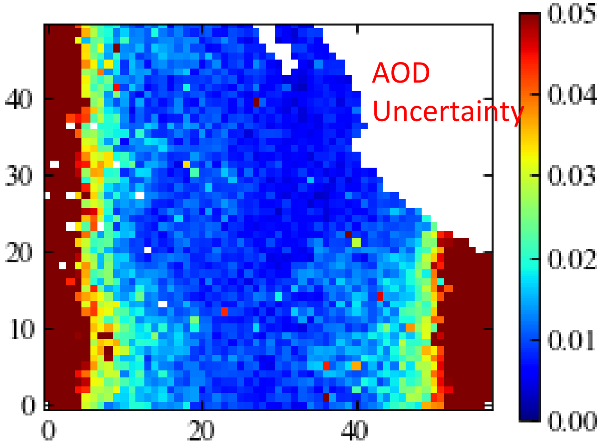
Uncertainty: AOD(550nm)



Compare one granule



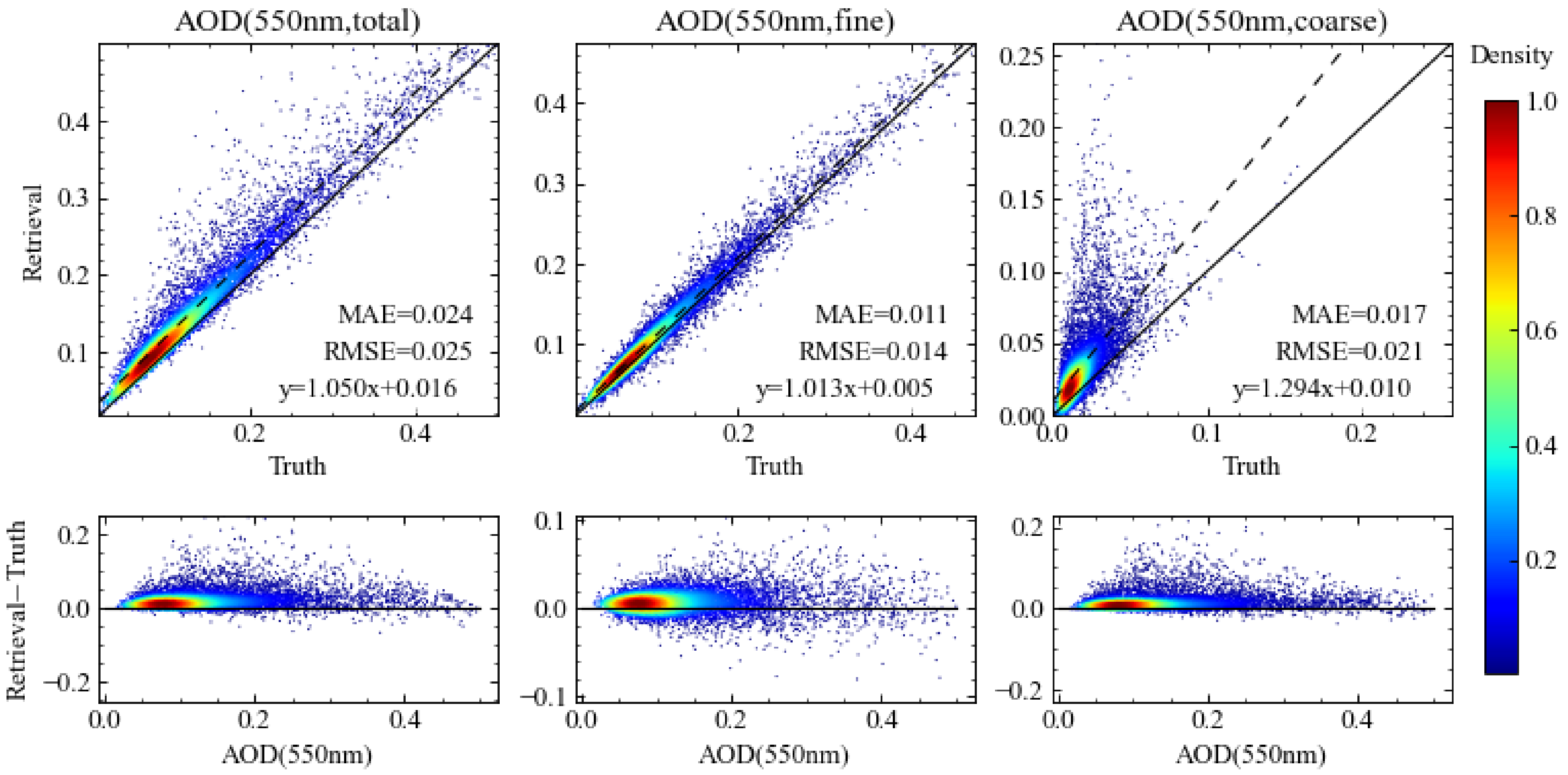




Large uncertainty on image edge (will improve in future L1C data)

Processing is done for every 8 pixels for testing purpose.

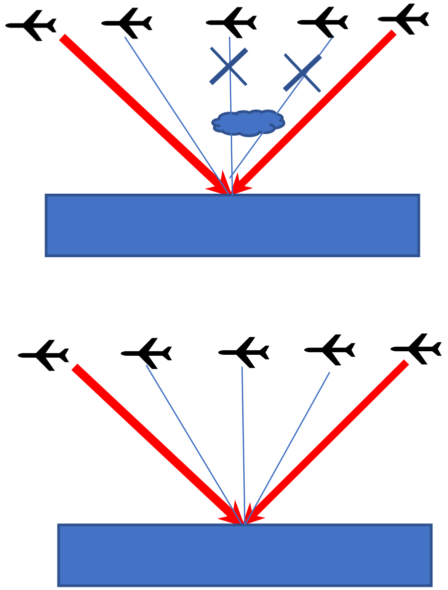
AOD (total, fine, coarse)



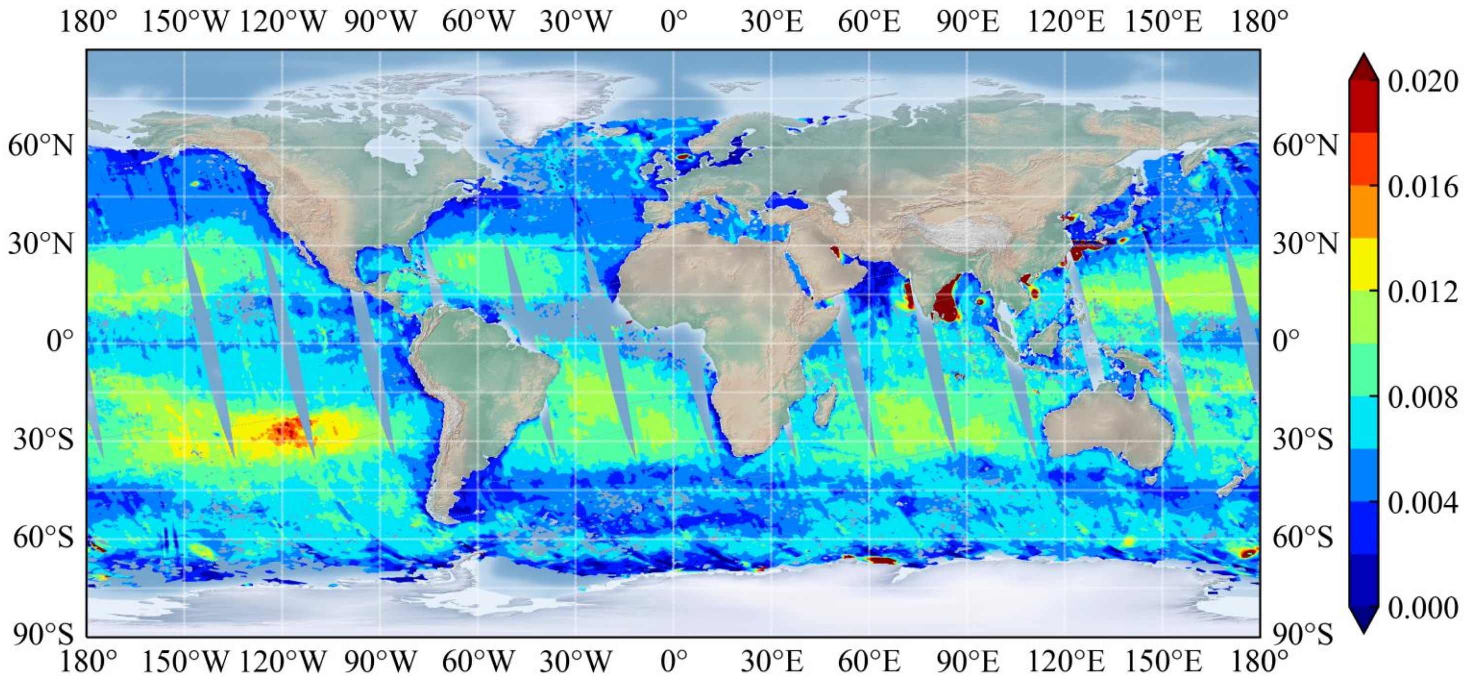
Please see results from synthetic AirHARP data for comparison (AMT 2021, 2022)

Multi-angle ocean color analysis (Prelim)

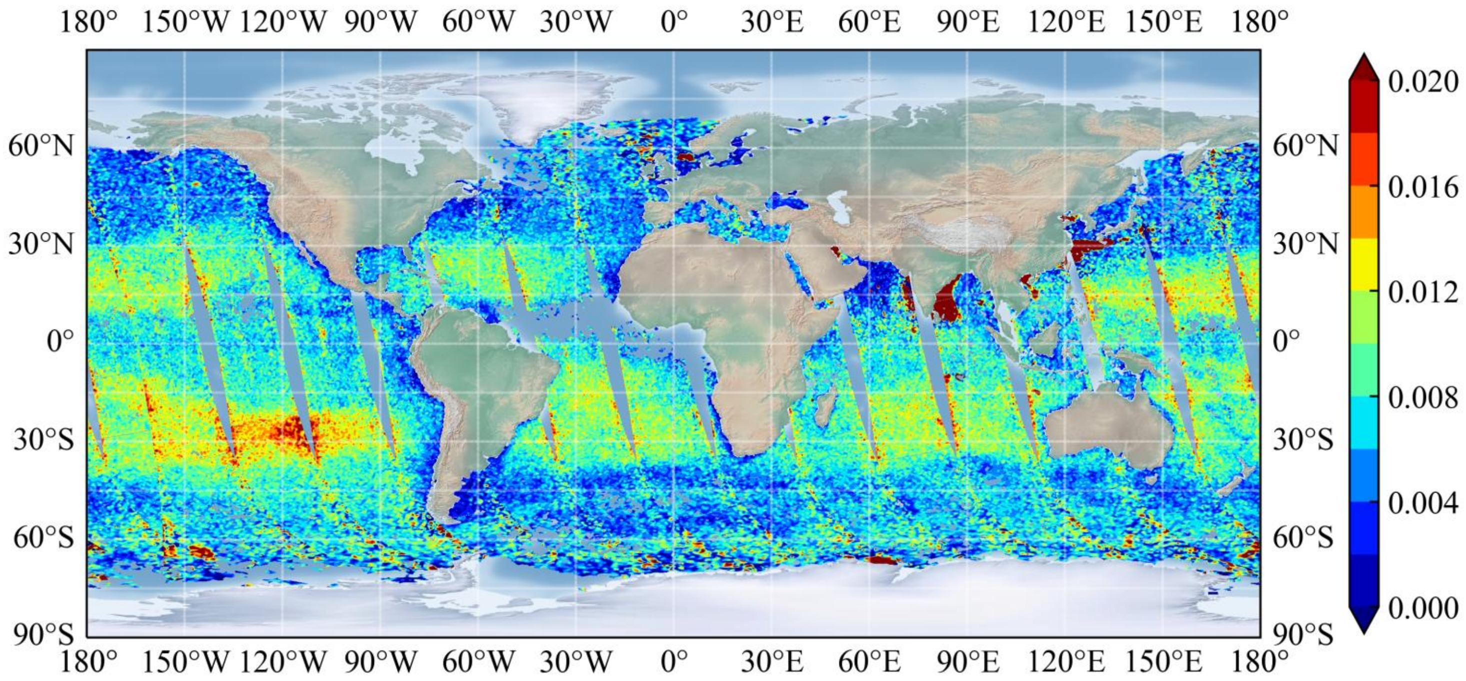
- Conduct multi-angle atmospheric correction and BRDF correction
- Application:
    - Increase ocean color data coverage (Gao et al, Frontiers 2021)
    - Evaluate multi-angle ocean color signal
    - Mean value may help reduce noise.
    - Variance may be used as metric for BRDF correction.
- Challenges:
    - Depend on the measurement uncertainty model
    - Need evaluate angular uncertainty correlation
    - May relate to water properties from real data?



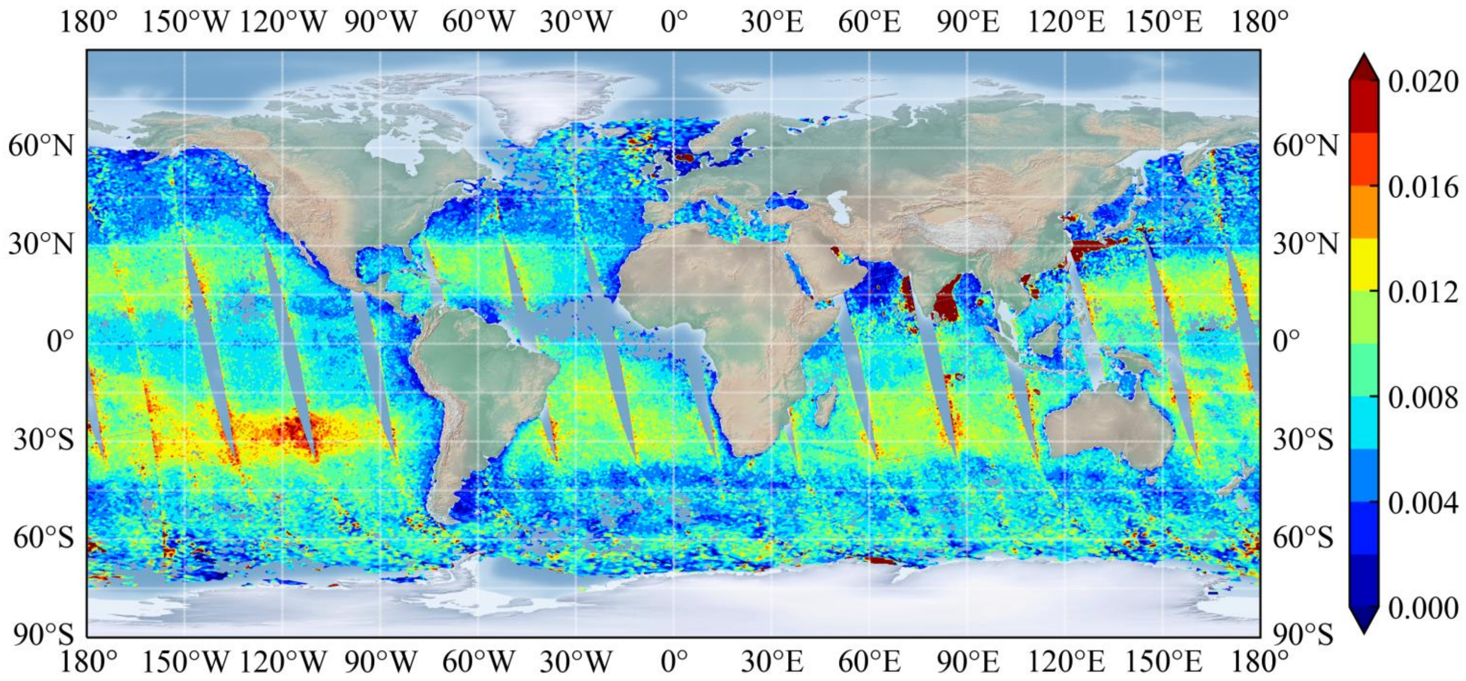
Truth (Rrs@440nm)



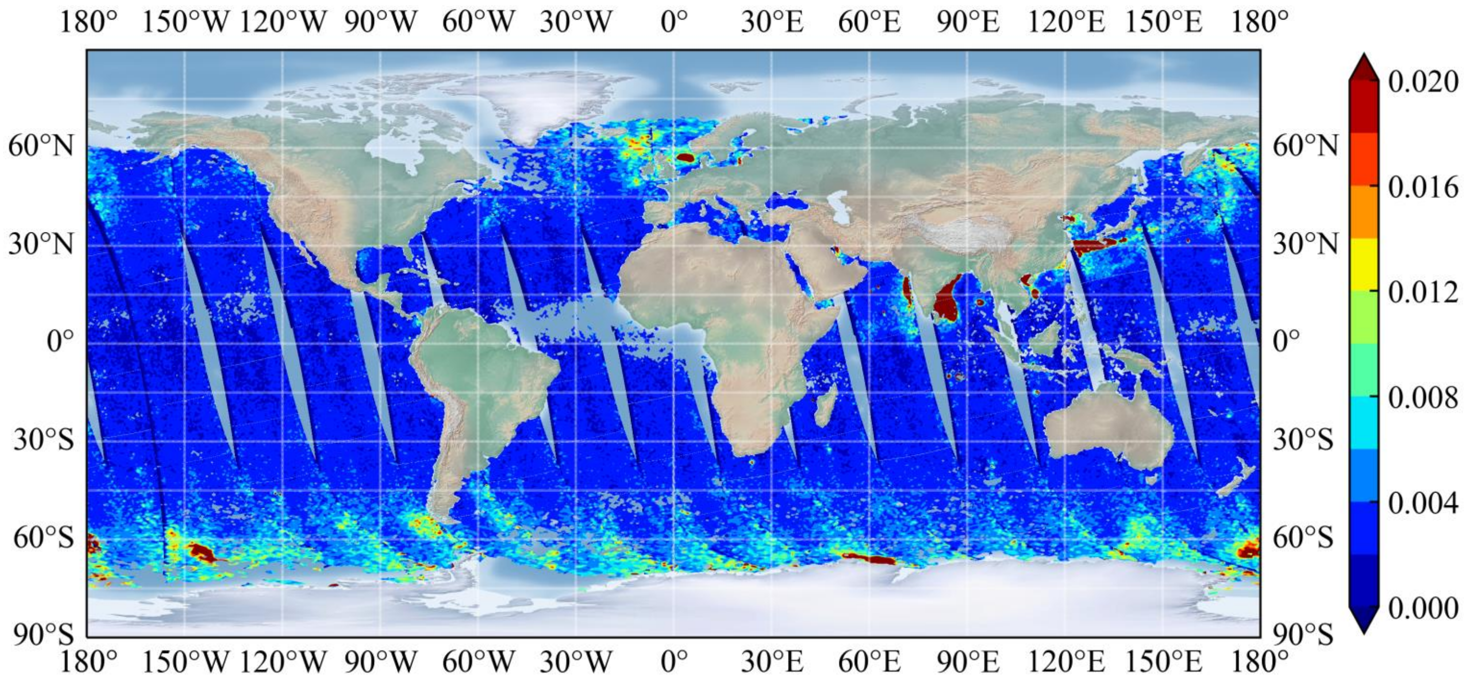
L2 (Rrs@440nm)


180° 150°W 120°W 90°W 60°W 30°W 0° 30°E 60°E 90°E 120°E 150°E 180°
60°N
30°N
0°
30°S
60°S
90°S
0.020
0.016
0.012
0.008
0.004
0.000

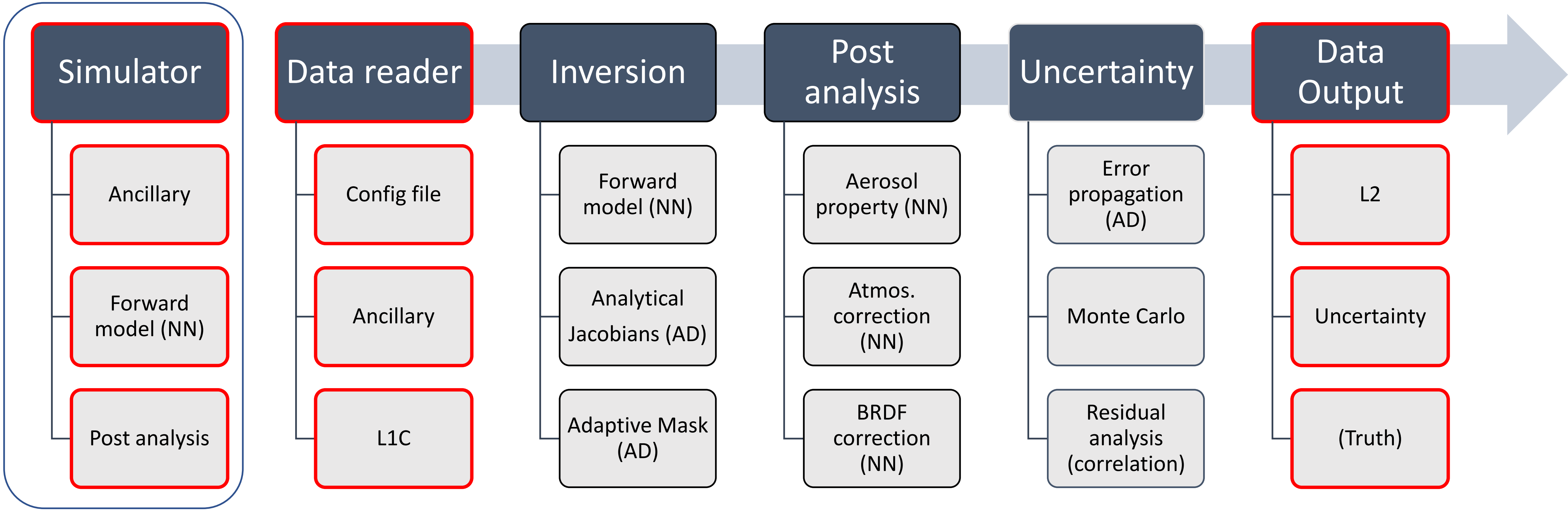
L2 angular mean (Rrs@440nm)



L2 angular standard deviation (Rrs@440nm)



Plan for 2023



Continue DITL test and uncertainty analysis

- Plan to improve aerosol model for simulation and retrieval
- Plan to improve water bio-optical model (global a,bb, etc?)

Related publications (2021-2022)

- Gao, M., K. Knobelspiesse, B. A. Franz, P.-W. Zhai, B. Cairns, X. Xu, and J. V. Martins. 2022. **"The impact and estimation of uncertainty correlation for multi-angle polarimetric remote sensing of aerosols and ocean color."** Atmospheric Measurement Techniques, (preprint) [10.5194/egusphere-2022-1413]
- Aryal, K., P.-W. Zhai, M. Gao, and B. A. Franz. 2022. **"Instantaneous photosynthetically available radiation models for ocean waters using neural networks."** Applied Optics, 61 (33): 9985 [10.1364/ao.474914]
- Gao, M., K. Knobelspiesse, B. Franz, P.-W. Zhai, A. Sayer, A. Ibrahim, B. Cairns, O. Hasekamp, Y. Hu, V. Martins, J. Werdell, and X. Xu. 2022. **"Effective uncertainty quantification for multi-angle polarimetric aerosol remote sensing over ocean."** Atmos. Meas. Tech., 15 (16): 4859–4879 [10.5194/amt-15-4859-2022]
- Ibrahim, A., B. Franz, A. Sayer, K. Knobelspiesse, M. Zhang, S. Bailey, L. McKinna, M. Gao, and P. J. Werdell. 2022. **"Optimal Estimation Framework for Ocean Color Atmospheric Correction and Pixel-level Uncertainty Quantification."** Applied Optics, Vol. 61 No. 20: [10.1364/ao.461861]
- Zhai, P.-W., M. Gao, B. A. Franz, et al. 2022. **"A Radiative Transfer Simulator for PACE: Theory and Applications."** Frontiers in Remote Sensing, 3: [10.3389/frsen.2022.840188]
- Gao, M., K. Knobelspiesse, B. A. Franz, P.-W. Zhai, V. Martins, S. P. Burton, B. Cairns, R. Ferrare, M. A. Fenn, O. Hasekamp, Y. Hu, A. Ibrahim, A. M. Sayer, P. J. Werdell, and X. Xu. 2021. **"Adaptive Data Screening for Multi-Angle Polarimetric Aerosol and Ocean Color Remote Sensing Accelerated by Deep Learning."** Frontiers in Remote Sensing, 2: [10.3389/frsen.2021.757832]
- Gao, M., B. A. Franz, K. Knobelspiesse, P.-W. Zhai, V. Martins, S. Burton, B. Cairns, R. Ferrare, J. Gales, O. Hasekamp, Y. Hu, A. Ibrahim, B. McBride, A. Puthukkudy, P. J. Werdell, and X. Xu. 2021. **"Efficient multi-angle polarimetric inversion of aerosols and oceancolor powered by a deep neural network forward model."** Atmospheric Measurement Techniques, 14 (6): 4083–4110 [https://doi.org/10.5194/amt-14-4083-2021]