# PACE Project Science aerosol status and updates

P. Jeremy Werdell (Project Scientist),
Andrew M. Sayer, Kirk D. Knobelspiesse, Meng Gao,
and many more … including L. Remer, O. Torres, R. Levy, C. Hsu,
O. Hasekamp, A. Lyapustin … and more

# NASA Plankton, Aerosol, Cloud, ocean Ecosystem (PACE) mission

PACE will extend **key systematic ocean color, aerosol, & cloud climate data records**.

PACE will reveal the **diversity of organisms fueling marine food webs** & how ecosystems respond to change.

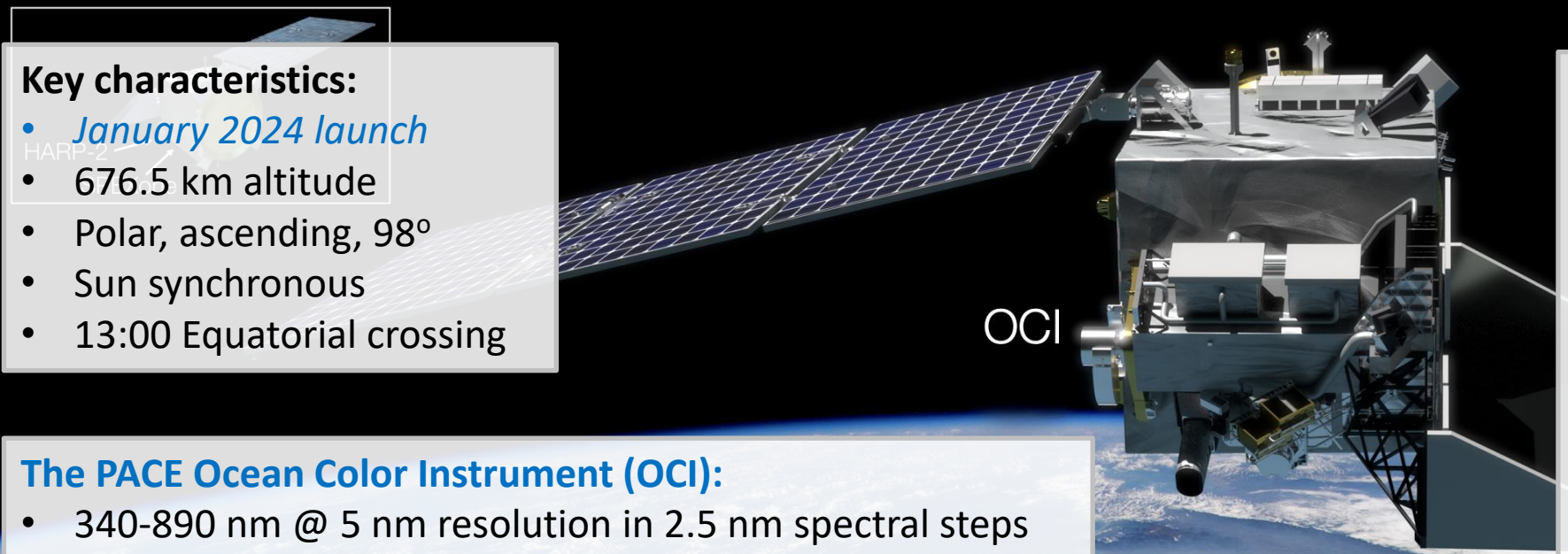
**Looking at the ocean, clouds, and aerosols together** will improve knowledge of the roles each plays in our planet.

**Mission update:**

- *Observatory fully assembled & integrated*
- Mechanical (acoustics, vibration) testing complete
- Thermal vacuum / thermal balance testing complete
- Orbit(s)-in-the-life data flow testing in progress
- Delivery to Kennedy Space Center in November 2023
- 60-day in-orbit commissioning to follow launch

**Key characteristics:**

- *January 2024 launch*
- 676.5 km altitude
- Polar, ascending, 98°
- Sun synchronous
- 13:00 Equatorial crossing




**2 contributed multi-angle polarimeters:**

- **HARP-2 (UMBC)**
  4 visible-NIR bands
  **Wide swath**; 2.5 km @ nadir
  **Hyper-angular**
  *Cloud capabilities beyond OCI*
- **SPEXone (SRON/Airbus)**
  **Hyperspectral** UV-NIR
  **Narrow swath**; 3 km @ nadir
  5 angles
  *Aerosol capabilities beyond OCI*

**The PACE Ocean Color Instrument (OCI):**

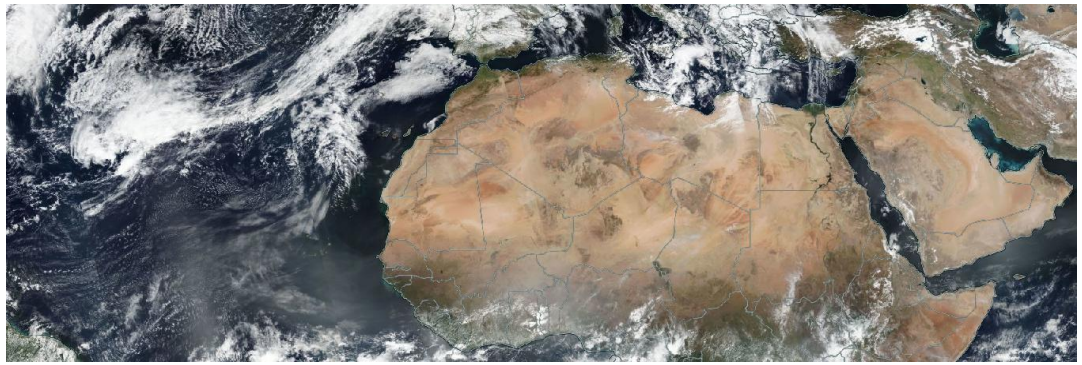
- 340-890 nm @ 5 nm resolution in 2.5 nm spectral steps
- Plus 940, 1038, 1250, 1378, 1615, 2130, & 2250 nm
- 2-day global coverage; 1-km$^2$ @ nadir; ±20° fore/aft tilt
- *Performance driven by ocean color science requirements*

https://pace.gsfc.nasa.gov
@NASAOcean

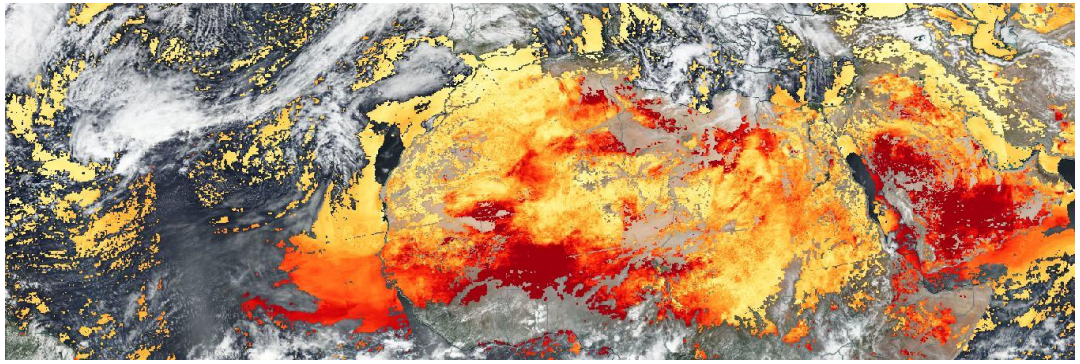
# At-launch OCI aerosol algorithms include heritage Deep Blue and Dark Target

- **Deep Blue** (DB) and **Dark Target** (DT) implemented
  - Based on VIIRS versions of code
  - Output at full (~1 km) resolution
  - Available with <1 day latency from spring 2024
- Post-launch candidates:
  - Remer *et al.* "Unified Aerosol Algorithm" combining DB, DT, and OMAERUV, code delivered, in testing
  - Lyapustin *et al.* MAIAC, code to be delivered

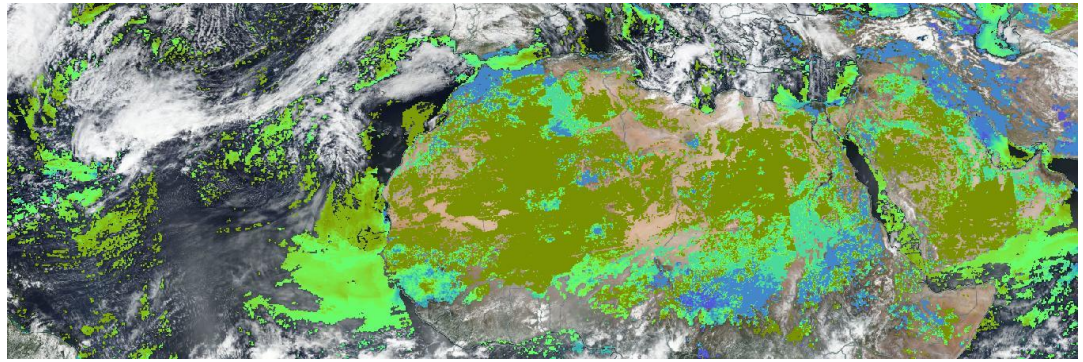
VIIRS
04 Mar 2020

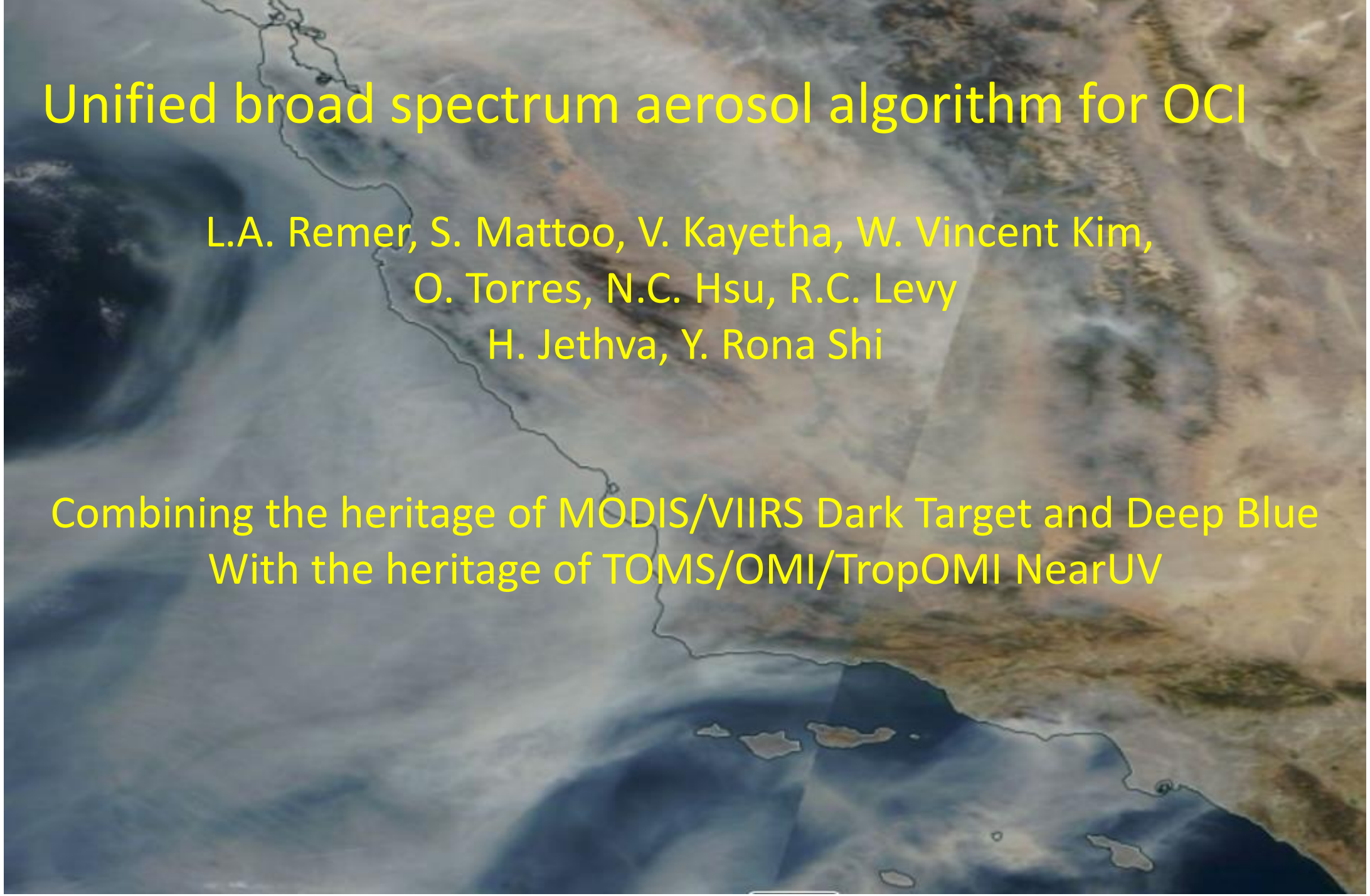


AOD
low high



AE
low high

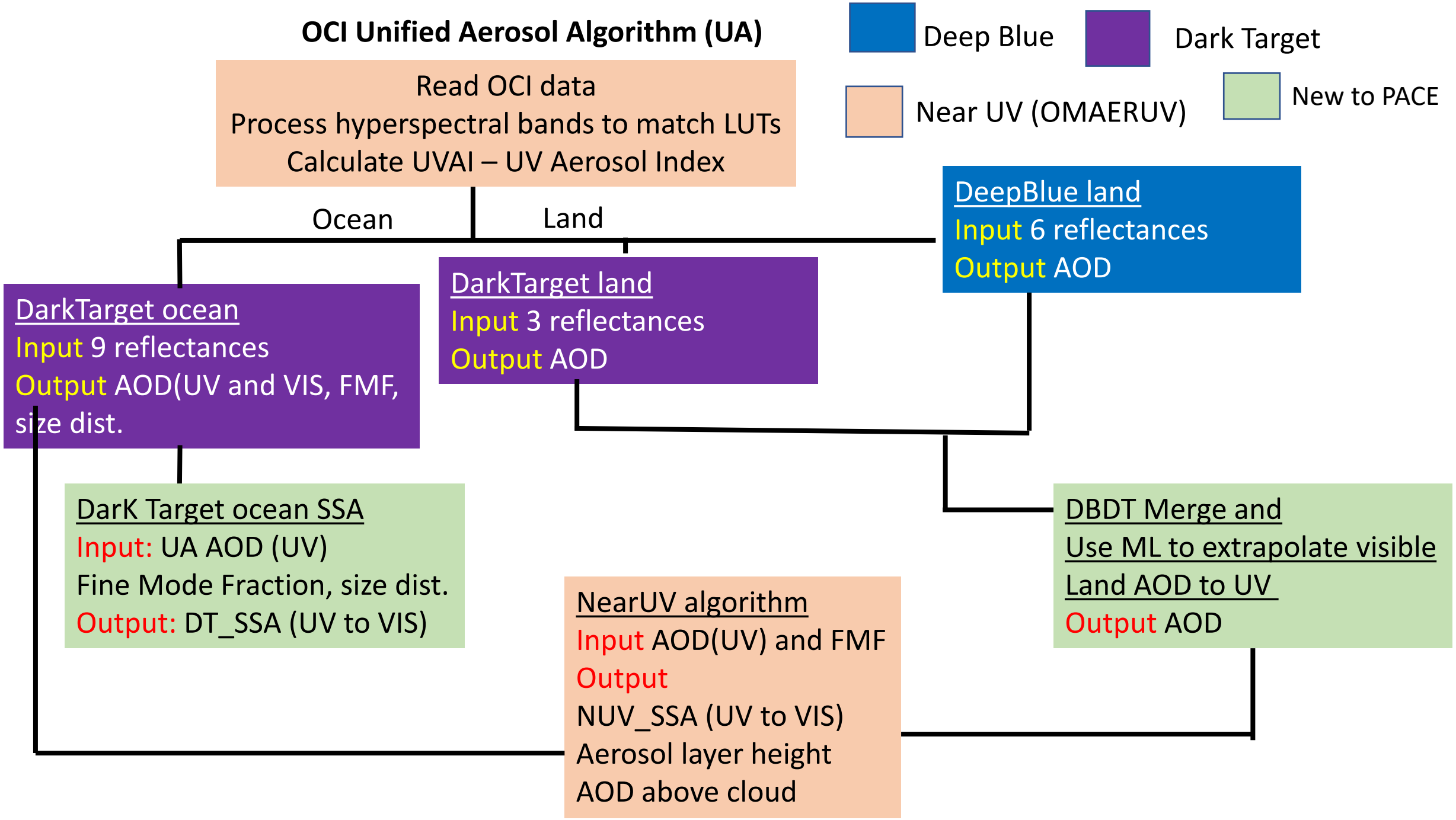


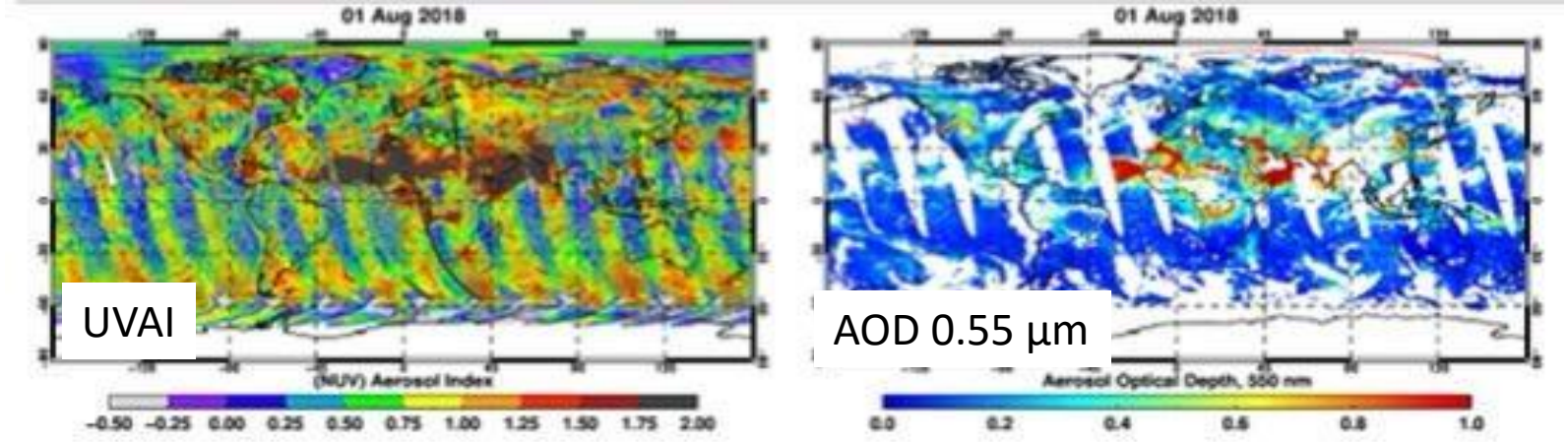


# Unified broad spectrum aerosol algorithm for OCI

L.A. Remer, S. Mattoo, V. Kayetha, W. Vincent Kim,
O. Torres, N.C. Hsu, R.C. Levy
H. Jethva, Y. Rona Shi

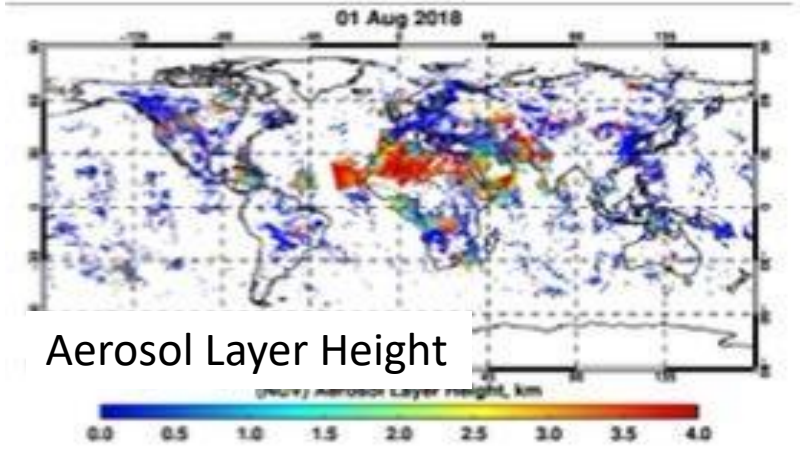
Combining the heritage of MODIS/VIIRS Dark Target and Deep Blue
With the heritage of TOMS/OMI/TropOMI NearUV

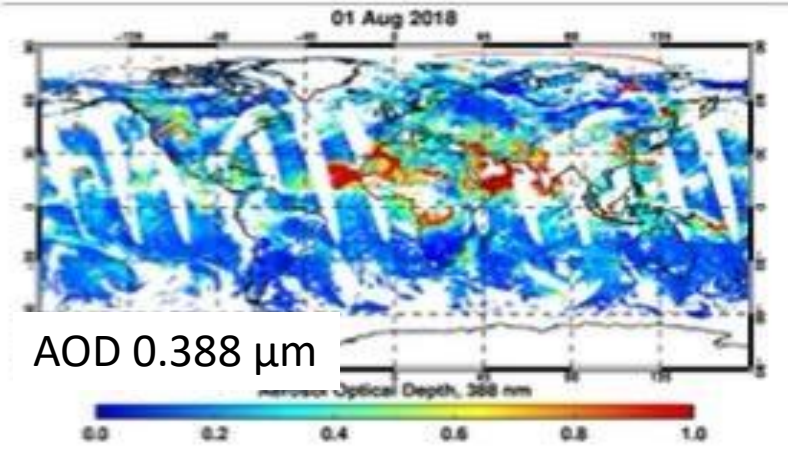

OCI Unified Aerosol Algorithm (UA)
Deep Blue
Dark Target
Near UV (OMAERUV)
New to PACE
Read OCI data
Process hyperspectral bands to match LUTs
Calculate UVAI – UV Aerosol Index
Ocean
Land
DeepBlue land
Input 6 reflectances
Output AOD
DarkTarget land
Input 3 reflectances
Output AOD
DarkTarget ocean
Input 9 reflectances
Output AOD(UV and VIS, FMF, size dist.
DarK Target ocean SSA
Input: UA AOD (UV)
Fine Mode Fraction, size dist.
Output: DT_SSA (UV to VIS)
DBDT Merge and
Use ML to extrapolate visible Land AOD to UV
Output AOD
NearUV algorithm
Input AOD(UV) and FMF
Output
NUV_SSA (UV to VIS)
Aerosol layer height
AOD above cloud

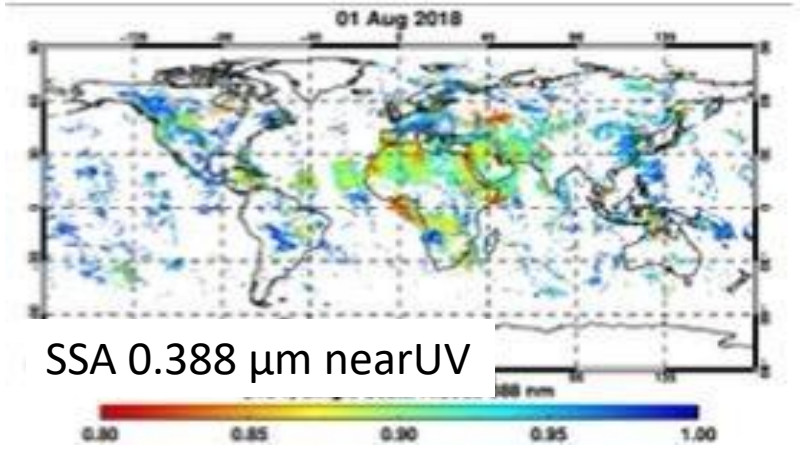


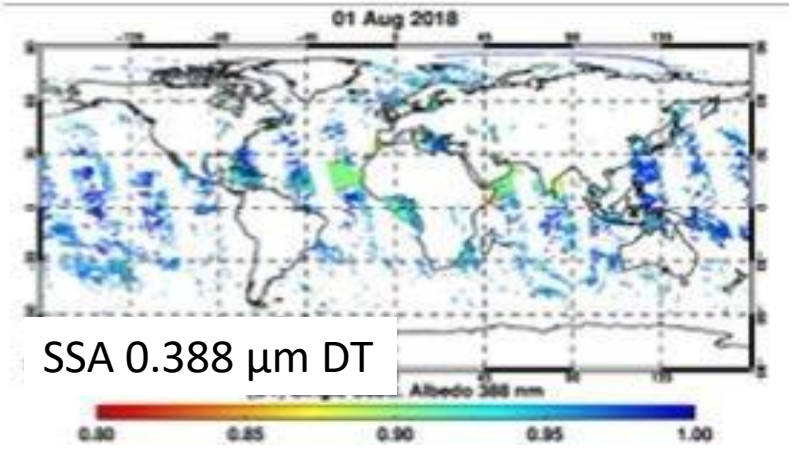







Algorithm applied to collocated VIIRS/TropOMI 01 August 2018

List of products:

AOD

9 wavelengths over ocean (0.354 to 2.25 µm)

5 wavelengths over land (0.354 to 0.67 µm)

New to PACE SSA over ocean (0.354, 0.388, 0.55 µm),

NearUV SSA over ocean and land (0.354, 0.388, 0.48, 0.55, 0.67 µm)

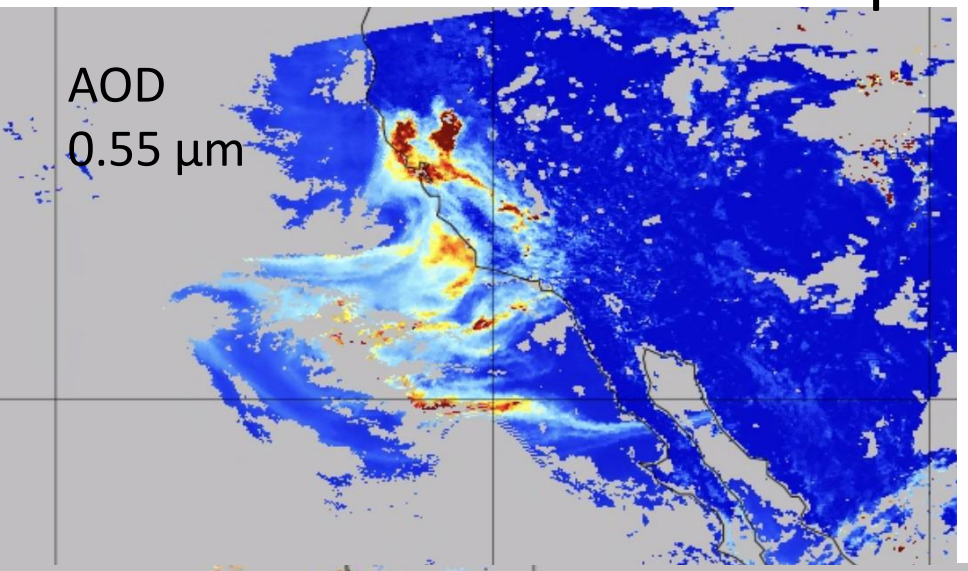
Aerosol layer height

AOD above cloud, when appropriate

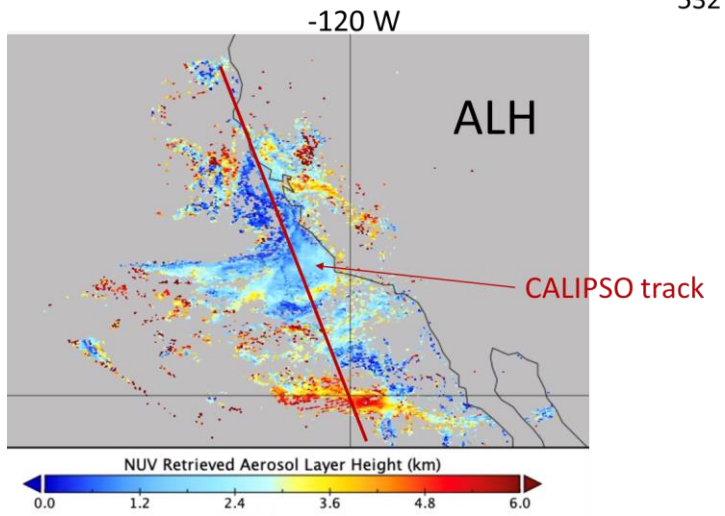
UVAI (UV Aerosol Index)

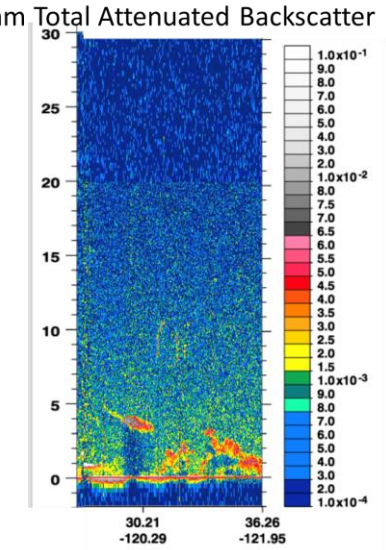
At 7x7 km spatial resolution

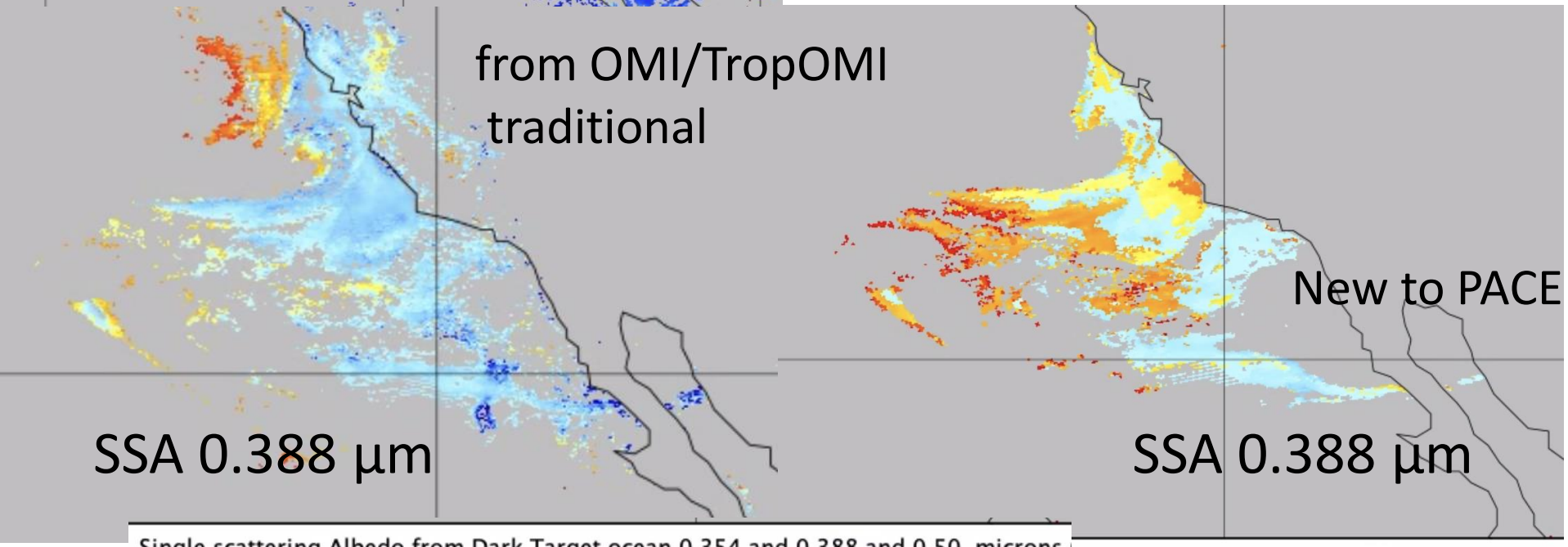
# From collocated VIIRS + TropOMI inputs



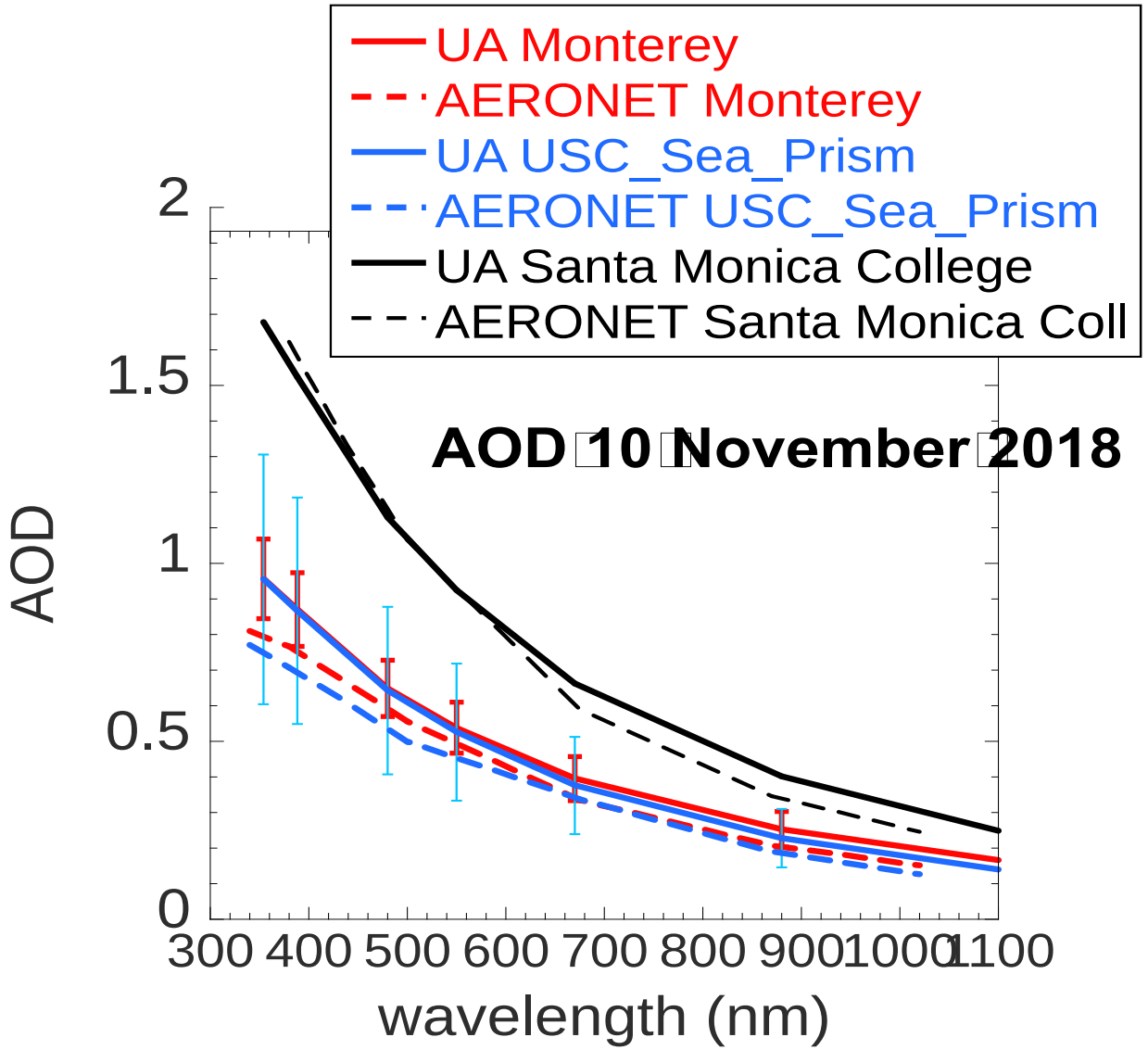

## Aerosol layer height (ALH)

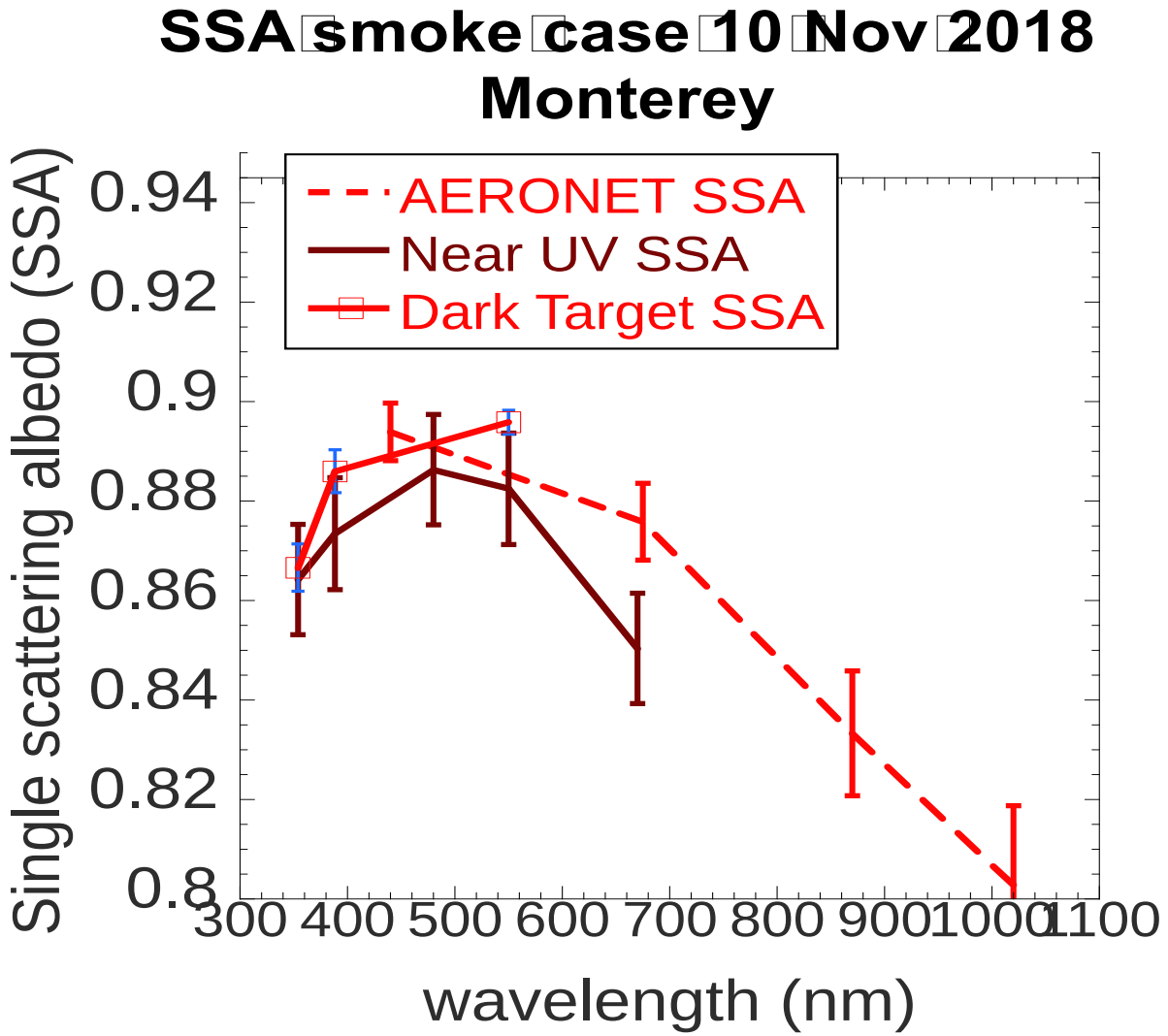


# Comparison spectral AOD and SSA at collocated AERONET sites



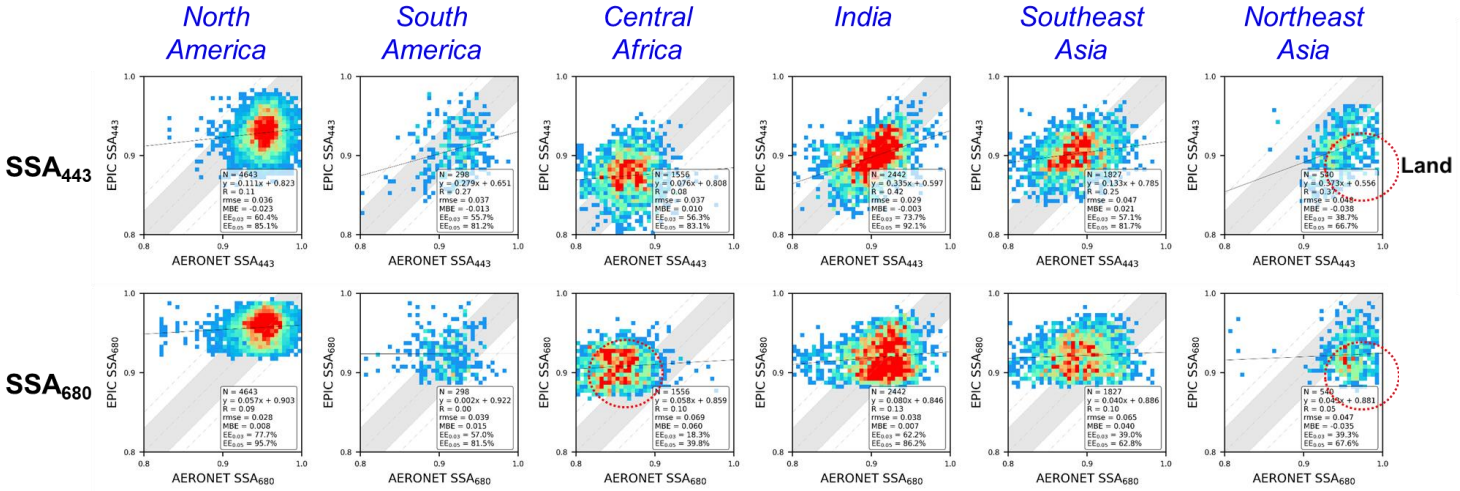
# MAIAC OCI

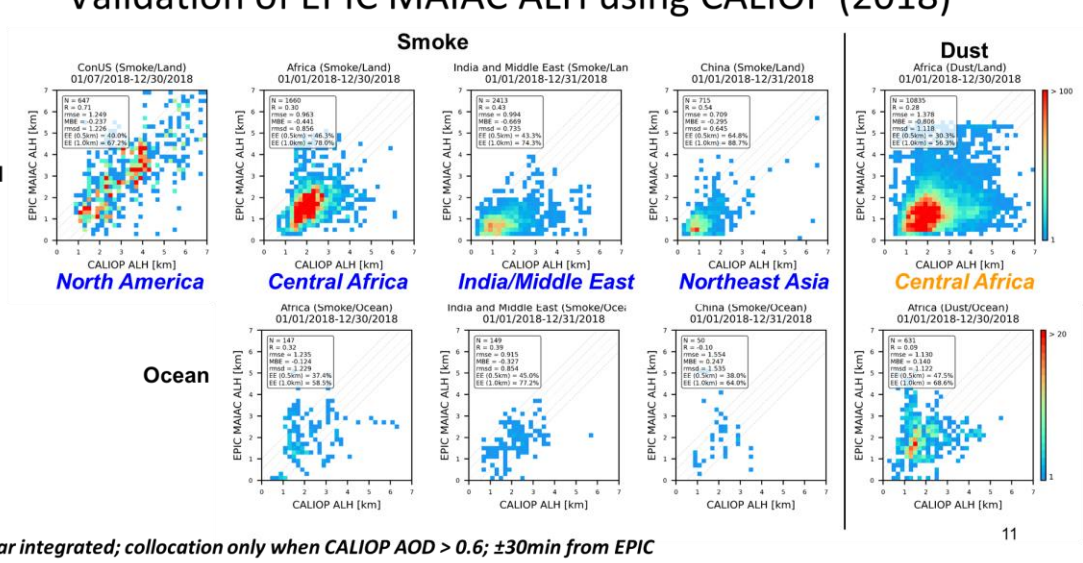
- **MAIAC OCI includes**:

  i) standard processing (AOD, CWV retrieval @ 1km resolution with climatological regional aerosol models and hyperspectral AC);

  ii) MAIAC-4D - advanced aerosol retrieval {AOD, k(λ), ALH} based on UV-Vis and O2 A,B-bands, and speciation algorithm (volume fraction and mass concentration - BC/BrC for smoke and Hem/Goethite for dust).

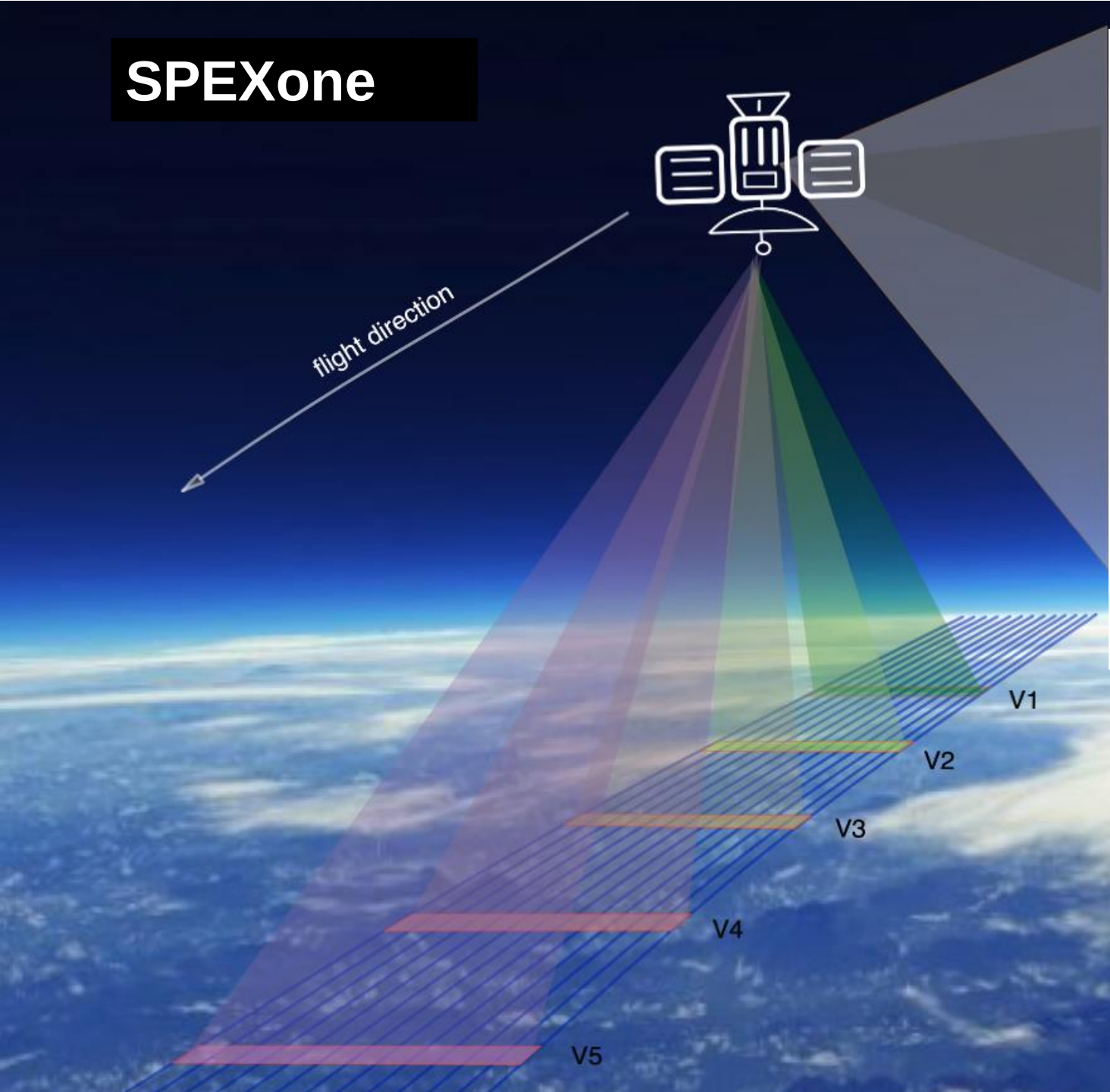
## Assessment of MAIAC-4D using DSCOVR EPIC measurements



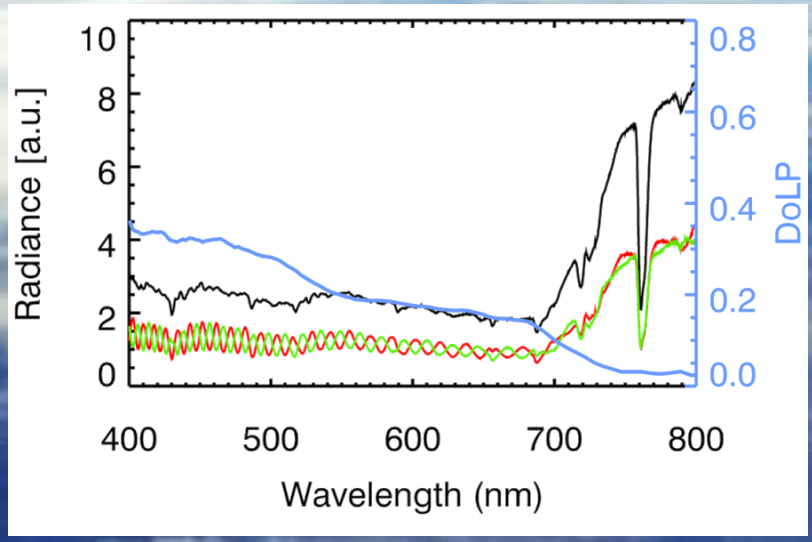




*1-year integrated; collocation only when CALIOP AOD > 0.6; ±30min from EPIC*

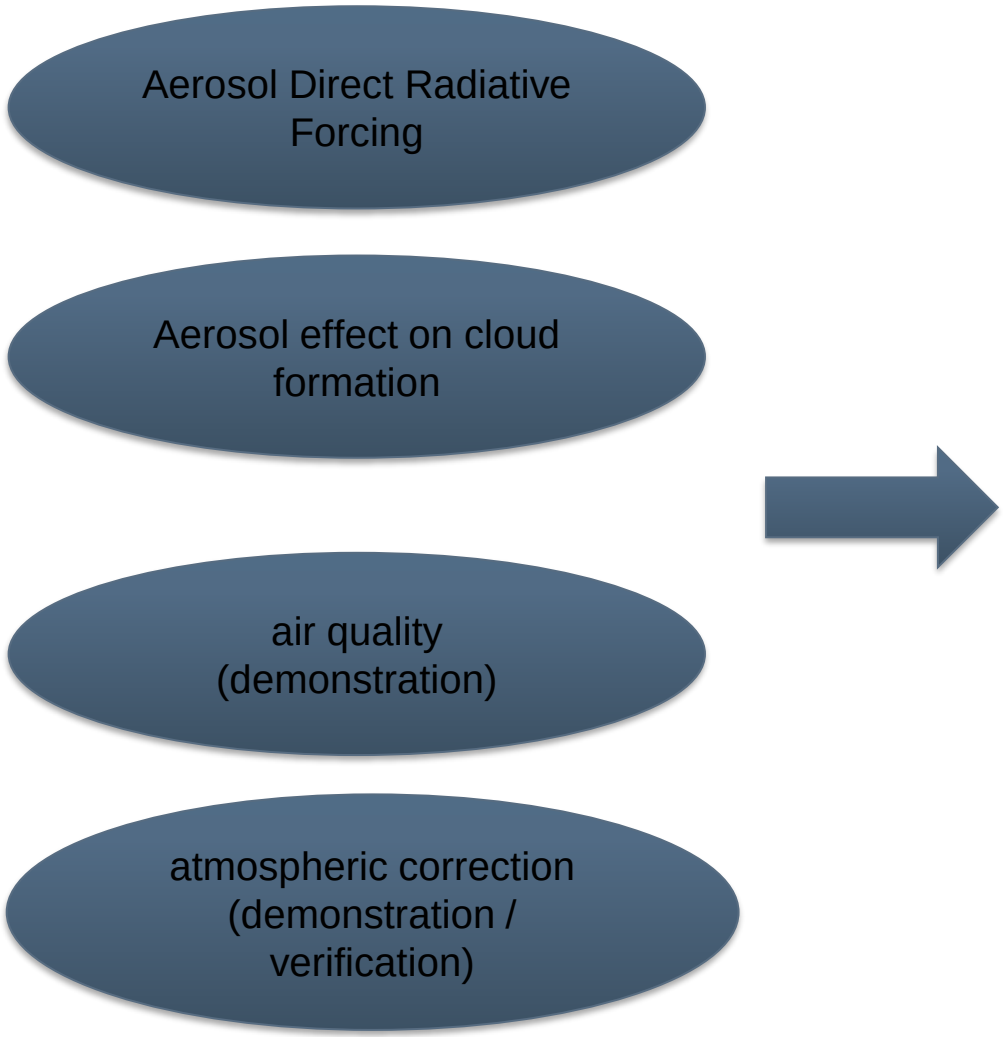
# SPEXone




| Parameter | Specification |
|---|---|
| viewing angles | +/-57°, +/-20°, 0° |
| spectral range | 385-770 nm |
| spectral resolution intensity | 2-5 nm |
| spectral resolution DoLP | 15 nm @ 385 nm<br>40 nm @ 770 nm |
| spatial sampling | 2.5 x 2.5 $km^2$ |
| spatial resolution | 5 x 5 $km^2$ |
| polarimetric accuracy (goal) | 0.003 |
| radiometric accuracy (goal) | 2% |
| Signal to Noise Ratio (dark ocean, SZA=70°) | 300 |
| swath | 100 km |



# SPEXone Aerosol Products




**Level-2 Products**

**Aerosol Optical Depth (fine/coarse/total)**
expected accuracy: 0.03 or 10%
**Single Scattering Albedo**
expected accuracy: 0.02-0.03
**Effective radius** (fine / coarse)
expected accuracy: 10%
**Effective variance** (fine / coarse)
expected accuracy: 50%
**real refr. index** (fine/coarse/total)
expected accuracy: 0.03
**imag. refr. index** (fine/coarse/total
expected accuracy: 1 x $10^{-3}$ or 15%
**Aerosol layer height**
Expected accuracy**:** 500 m
**Particle shape**

**Derived Products**

**Cloud Condensation Nuclei (CCN) proxy**
**Direct Radiative Effect**
**Chemical composition**

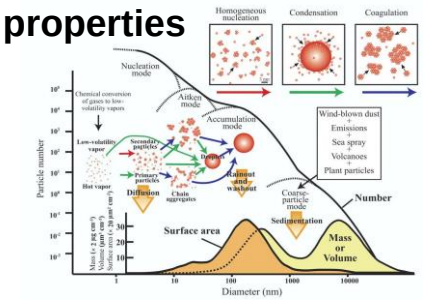


Hasekamp et al., JQSRT, 2019

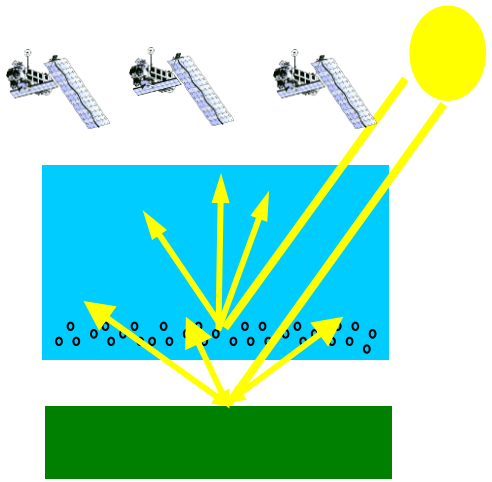
# SPEXone Aerosol Data Processing: The RemoTAP algorithm

minimize difference

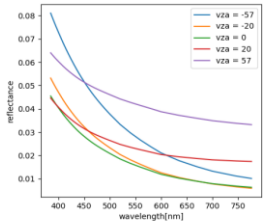
**state vector:**
**aerosol and surface properties**

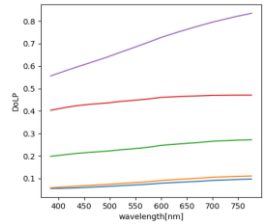



**Forward Model:**
**Simulate the measurement**



**measurement:**
**radiance and DoLP**




update till optimal agreement

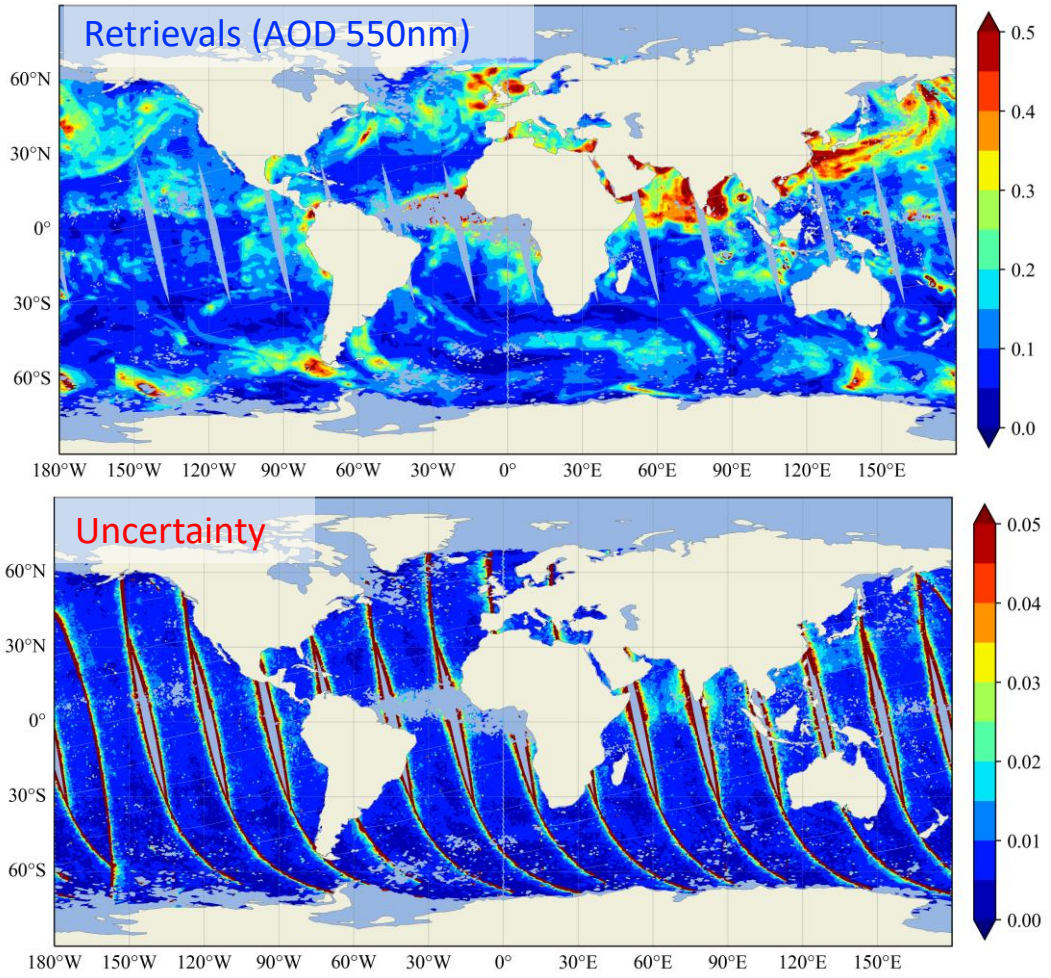
RemoTAP: REMOte sensing of Trace gas and Aerosol Products


References:
Lu et al., Frontiers Rem. Sens., 2022
Fu et al., AMT, 2018; 2022
Fan et al., Rem. Sens., 2019
Hasekamp et al., JGR, 2011
Hasekamp and Landgraf, AO, 2008

# In-house polarimetric retrievals implemented for HARP2

FastMAPOL

- Lead: Meng Gao
- Joint aerosol and ocean retrieval
- Fast neural network radiative transfer forward model
- Reasonable pixel-level uncertainty estimates for all quantities
- Validated with AirHARP and synthetic global HARP2 data
- Updates for spheroidal dust and land surfaces in the works




**Main products**

Complex refractive index (fine/coarse)

Aerosol effective radius & variance

Layer height

AOD

SSA

Wind speed

Chlorophyll a

**Research products**

Multi-angle cloud mask

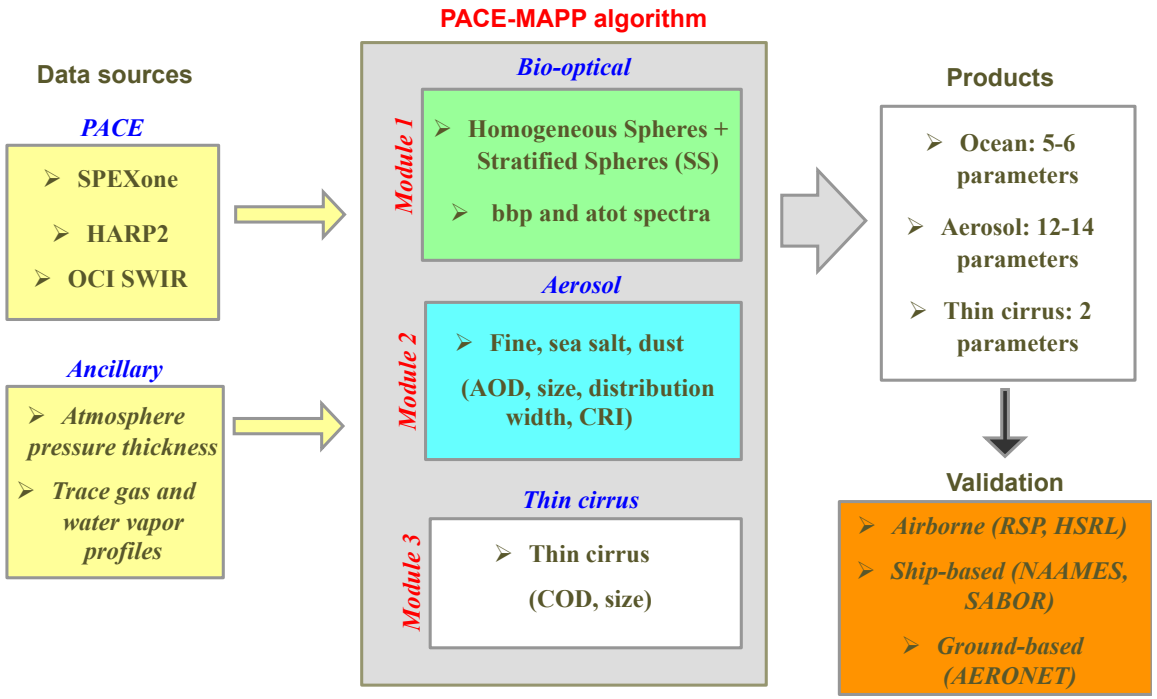
Multi-angle water leaving signal

https://doi.org/10.5194/egusphere-2023-1843

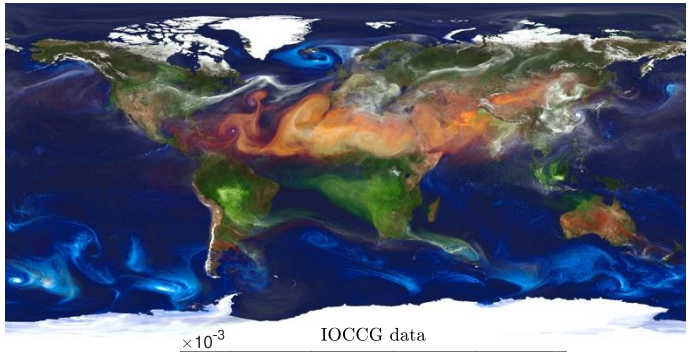
# …and PACE-MAPP from the Science Team (Snorre Stamnes/LaRC)

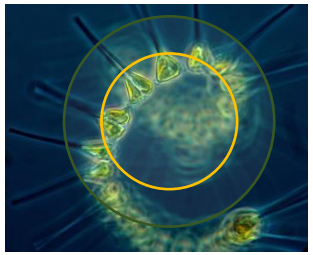
***PACE-MAPP will produce accurate aerosol optical and microphysical properties, and ocean properties, using SPEXone, HARP2, and OCI (SWIR channels)***

- ***coupled atmosphere-ocean vector radiative transfer model***
- ***accurate but fast Lorenz-Mie and T-matrix LUTs***

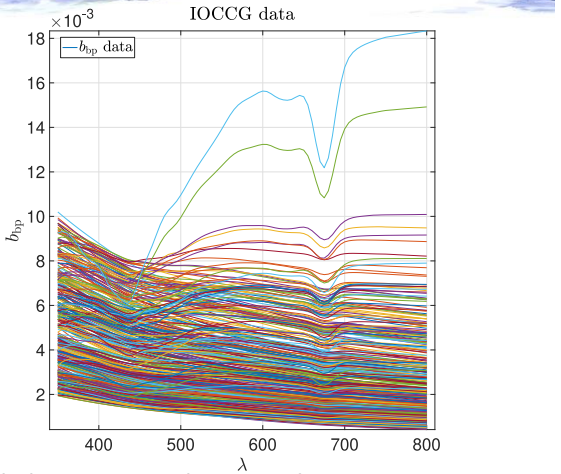



*Aerosol VIS-NIR-SWIR properties: fine mode (absorbing), sea salt, and dust*





*Bio-optical model has a mixture of uncoated and coated spheres*




*Collaborate with PACE bio-optics/geochemistry scientists on coastal zones/challenging regions*

*Thin cirrus correction*

# For more info…

- Next PACE science team competition is out on NASA ROSES!
  - A.38 PACE SAT, due date **Dec 5**
- All data will be freely available in NetCDF4 format
- Questions about PACE aerosol (or cloud) data?
  - Andrew Sayer (andrew.sayer@nasa.gov) for OCI
  - Kirk Knobelspiesse (kirk.d.knobelspiesse@nasa.gov) for polarimetry
  - Meng Gao (meng.gao@nasa.gov) for FastMAPOL
- Find simulated & proxy data here: https://oceancolor.gsfc.nasa.gov/data/pace/test-data/