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

https://pace.gsfc.nasa.gov
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

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-km² @ nadir; ±20° fore/aft tilt
- **Performance driven by ocean color science requirements**

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

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
Unified broad spectrum aerosol algorithm for OCI


Combining the heritage of MODIS/VIIRS Dark Target and Deep Blue
With the heritage of TOMS/OMI/TropOMI NearUV
Read OCI data
Process hyperspectral bands to match LUTs
Calculate UVAI – UV Aerosol Index

Ocean

DarkTarget ocean
Input 9 reflectances
Output AOD(UV and VIS, FMF, size dist.)

NearUV algorithm
Input AOD(UV) and FMF
Output NUV_SSA (UV to VIS)
Aerosol layer height
AOD above cloud

Land

DarkTarget land
Input 3 reflectances
Output AOD

DeepBlue land
Input 6 reflectances
Output AOD

DBDT Merge and
Use ML to extrapolate visible
Land AOD to UV

Output AOD

OCI Unified Aerosol Algorithm (UA)

Deep Blue
Dark Target
Near UV (OMAERUV)
New to PACE
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

AOD 0.55 µm

SSA 0.388 µm

New to PACE

Aerosol layer height (ALH)

-120 W

532 nm Total Attenuated Backscatter

Single scattering Albedo from Dark Target ocean 0.354 and 0.388 and 0.50, microns
Comparison spectral AOD and SSA at collocated AERONET sites

AOD 10 November 2018

SSA smoke case 10 Nov 2018
Monterey

Single scattering albedo (SSA)
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(\lambda), 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

Validation of EPIC MAIAC ALH using CALIOP (2018)

1-year integrated; collocation only when CALIOP AOD > 0.6, ±30min from EPIC
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Specification</th>
</tr>
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<tbody>
<tr>
<td>viewing angles</td>
<td>+/-57°, +/-20°, 0°</td>
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<tr>
<td>spectral range</td>
<td>385-770 nm</td>
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<tr>
<td>spectral resolution intensity</td>
<td>2-5 nm</td>
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<tr>
<td>spectral resolution DoLP</td>
<td>15 nm @ 385 nm, 40 nm @ 770 nm</td>
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<tr>
<td>spatial sampling</td>
<td>2.5 x 2.5 km²</td>
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<tr>
<td>spatial resolution</td>
<td>5 x 5 km²</td>
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<tr>
<td>polarimetric accuracy (goal)</td>
<td>0.003</td>
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<tr>
<td>radiometric accuracy (goal)</td>
<td>2%</td>
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<tr>
<td>Signal to Noise Ratio (dark ocean, SZA=70°)</td>
<td>300</td>
</tr>
<tr>
<td>swath</td>
<td>100 km</td>
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</tbody>
</table>
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
SPEXone Aerosol Data Processing: The RemoTAP algorithm

state vector: aerosol and surface properties

Forward Model: Simulate the measurement

measurement: radiance and DoLP

minimize difference

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
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

Thin cirrus correction

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