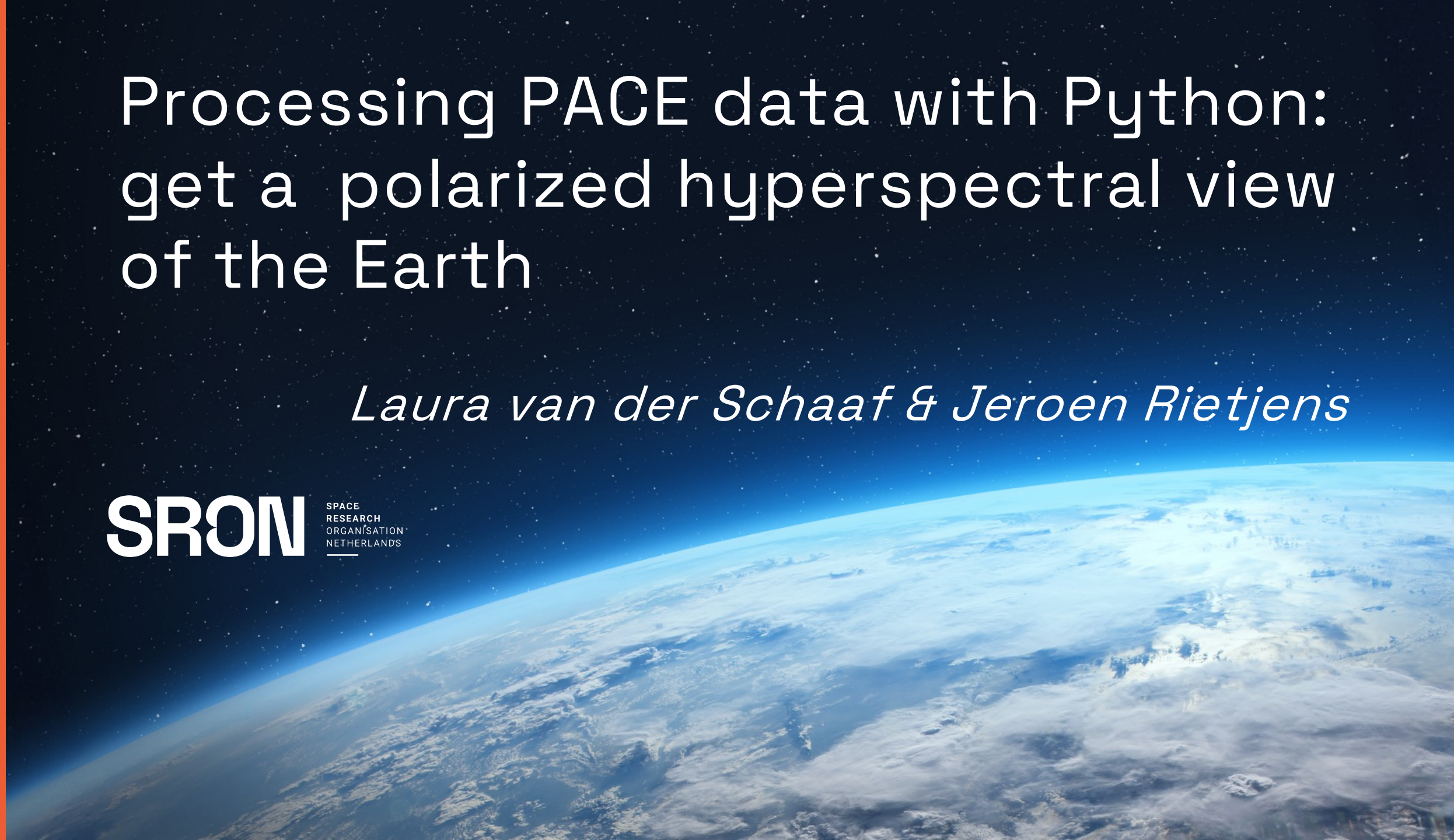
BRINGING ABOUT BREAKTHROUGHS IN SPACE SCIENCE

Processing PACE data with Python: get a polarized hyperspectral view of the Earth

Laura van der Schaaf & Jeroen Rietjens

SRON SPACE RESEARCH ORGANISATION NETHERLANDS



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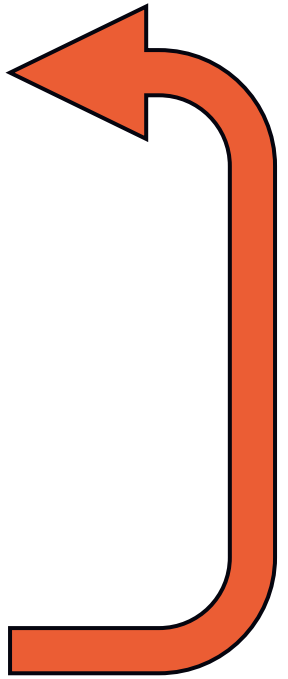
- SRON Space Research Organisation Netherlands (NWO-I)
- ~200 people: (instrument) scientists, engineers, staff
- Scientist using satellite data
  - Earth observation
  - X-ray astrophysics
  - Far-infrared astrophysics
- Satellite instrument requirements definition
- Technology development
  - X-ray & far-infrared detectors
  - Space optics (immersed grating, meta-optics, ..)
  - Coronagraphs for high-contrast imaging
- Satellite instrument development and calibration



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- Instrument scientists
- Laura
  - Data processor development
  - Data processing
  - Data analysis
- Jeroen
  - Instrument development & calibration
  - Instrument performance
  - Operations

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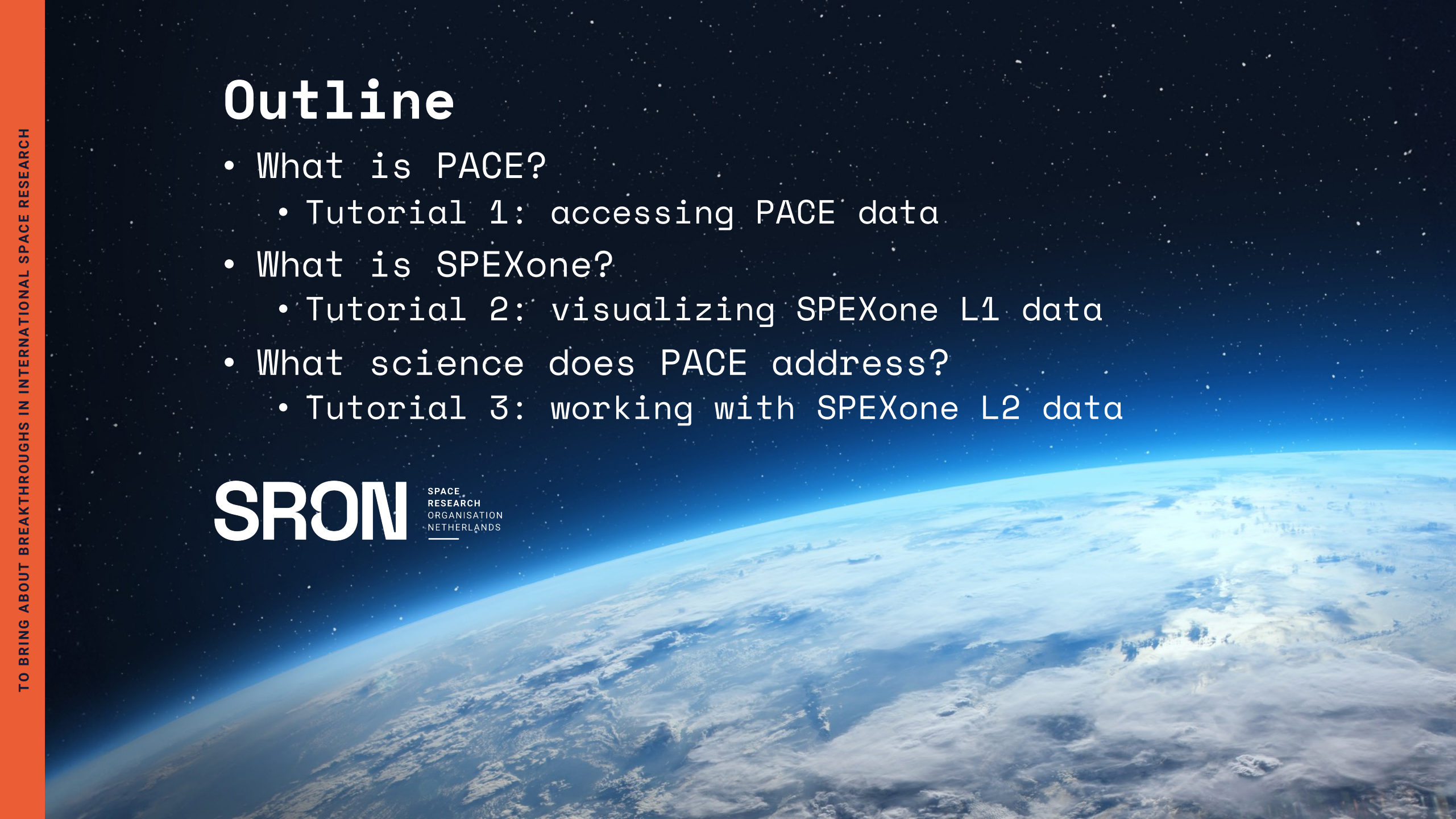

Outline

- What is PACE?
  - Tutorial 1: accessing PACE data
- What is SPEXone?
  - Tutorial 2: visualizing SPEXone L1 data
- What science does PACE address?
  - Tutorial 3: working with SPEXone L2 data

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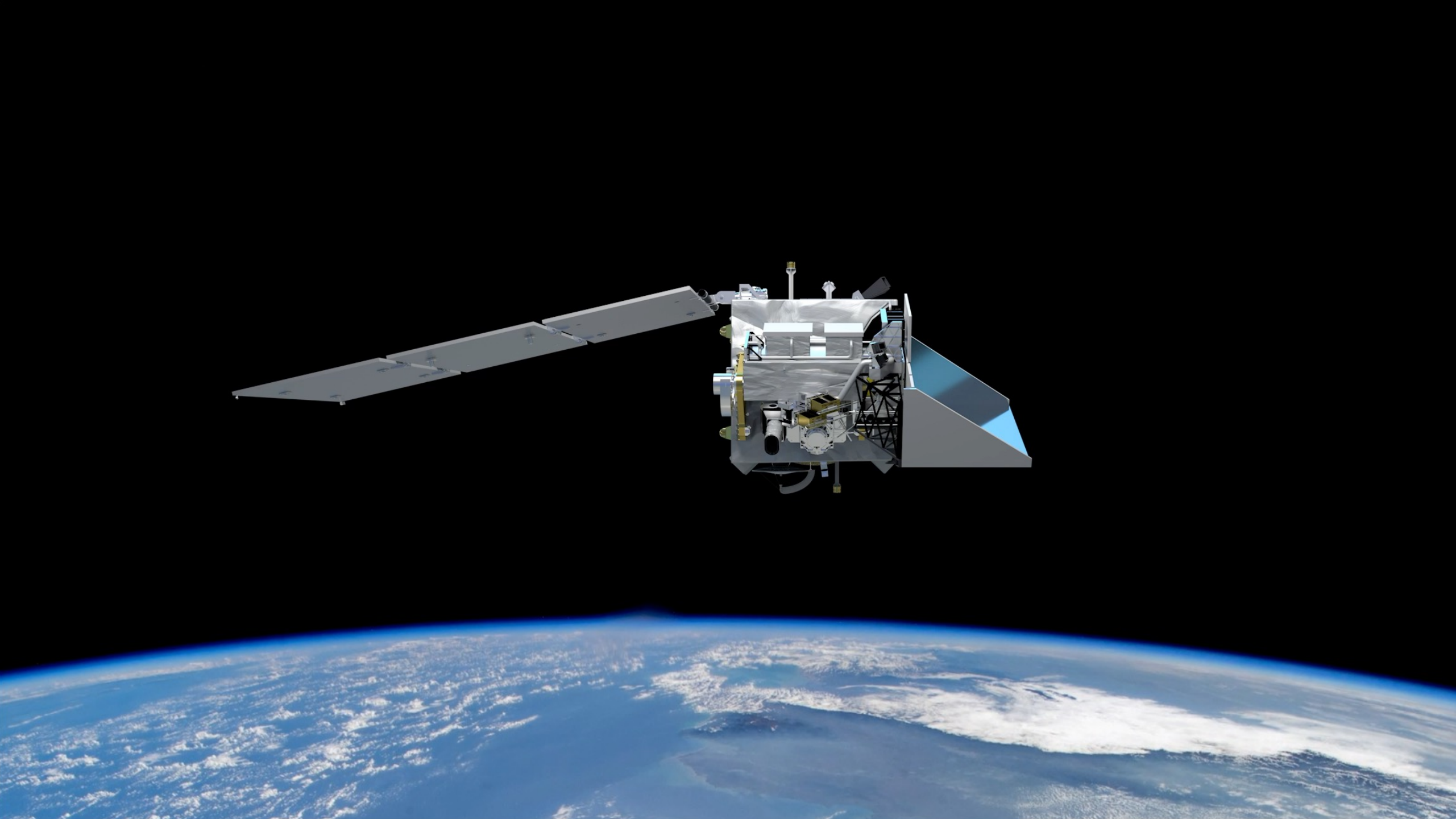
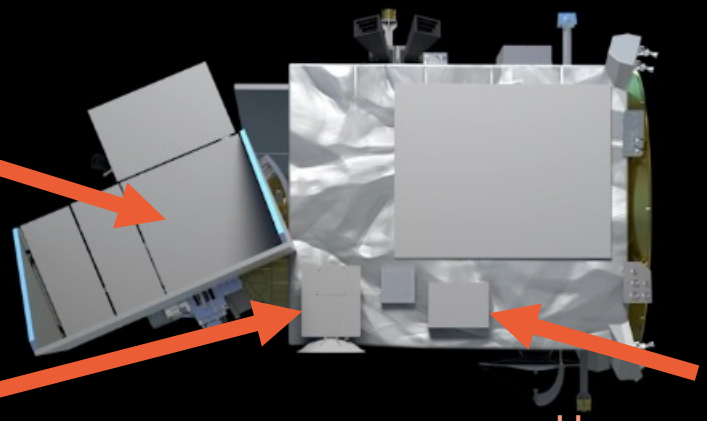


PACE

Plankton, Aerosol, Cloud, ocean Ecosystem

OCI
UV-NIR-SWIR hyper-spectral
imaging radiometer

HARP-2
Hyper-angular wide swath
VIS-NIR-4-band polarimeter

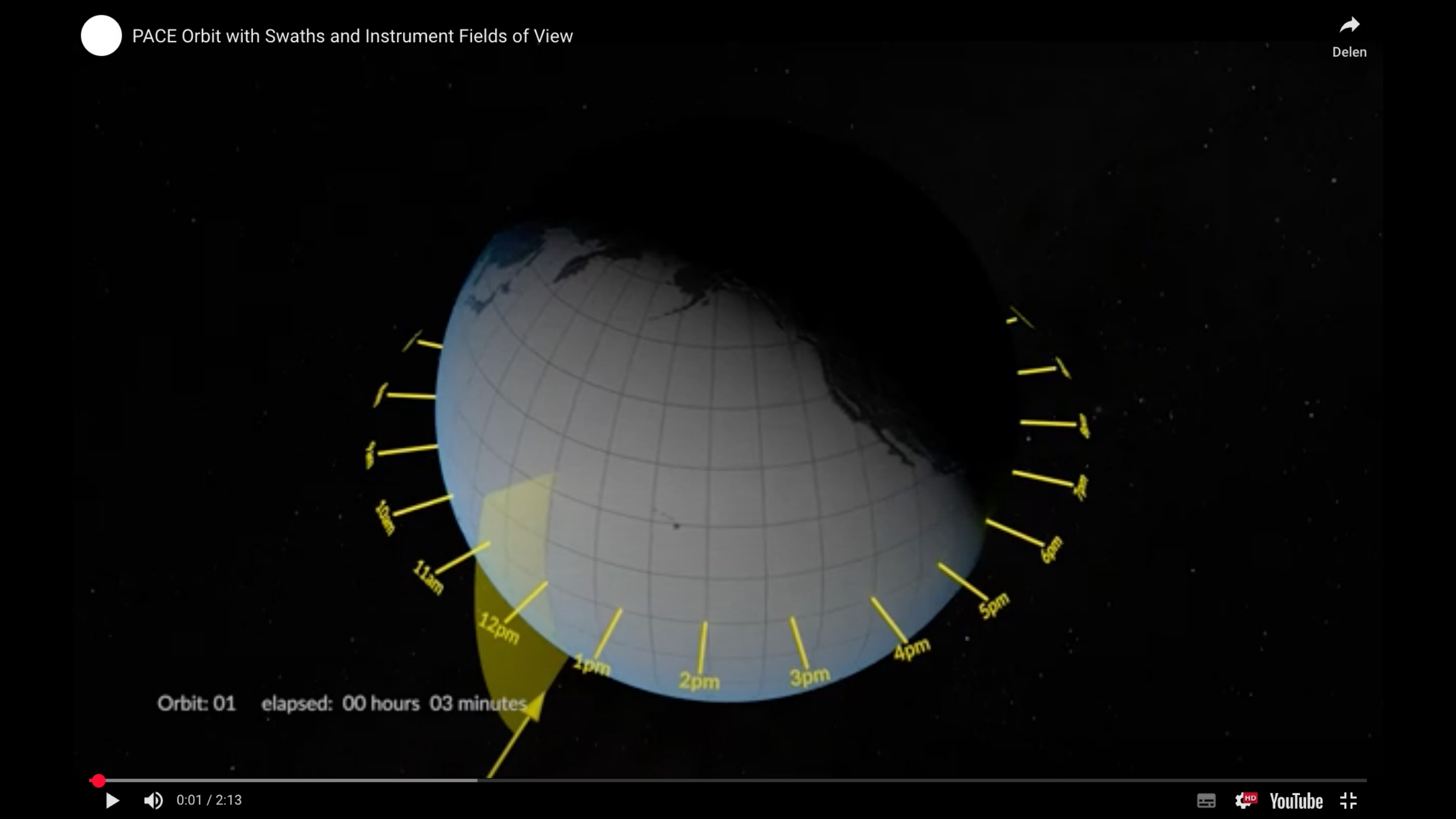


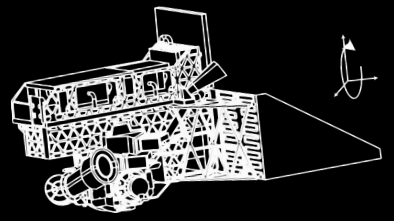
SPEXone
Hyper-spectral UV-VIS narrow swath
5-angle spectropolarimeter

PACE: **OCI + HARP2 + SPEXone:**

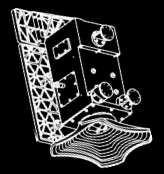
Hyperspectral + Hyperangular + Highly accurate radiometric and polarimetric observations

PACE is yielding unprecedented information content for ocean color, aerosol and clouds

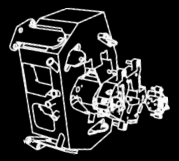

PACE Orbit with Swaths and Instrument Fields of View
Delen
11am
12pm
1pm
2pm
3pm
4pm
5pm
6pm
Orbit: 01 elapsed: 00 hours 03 minutes
0:01 / 2:13
YouTube



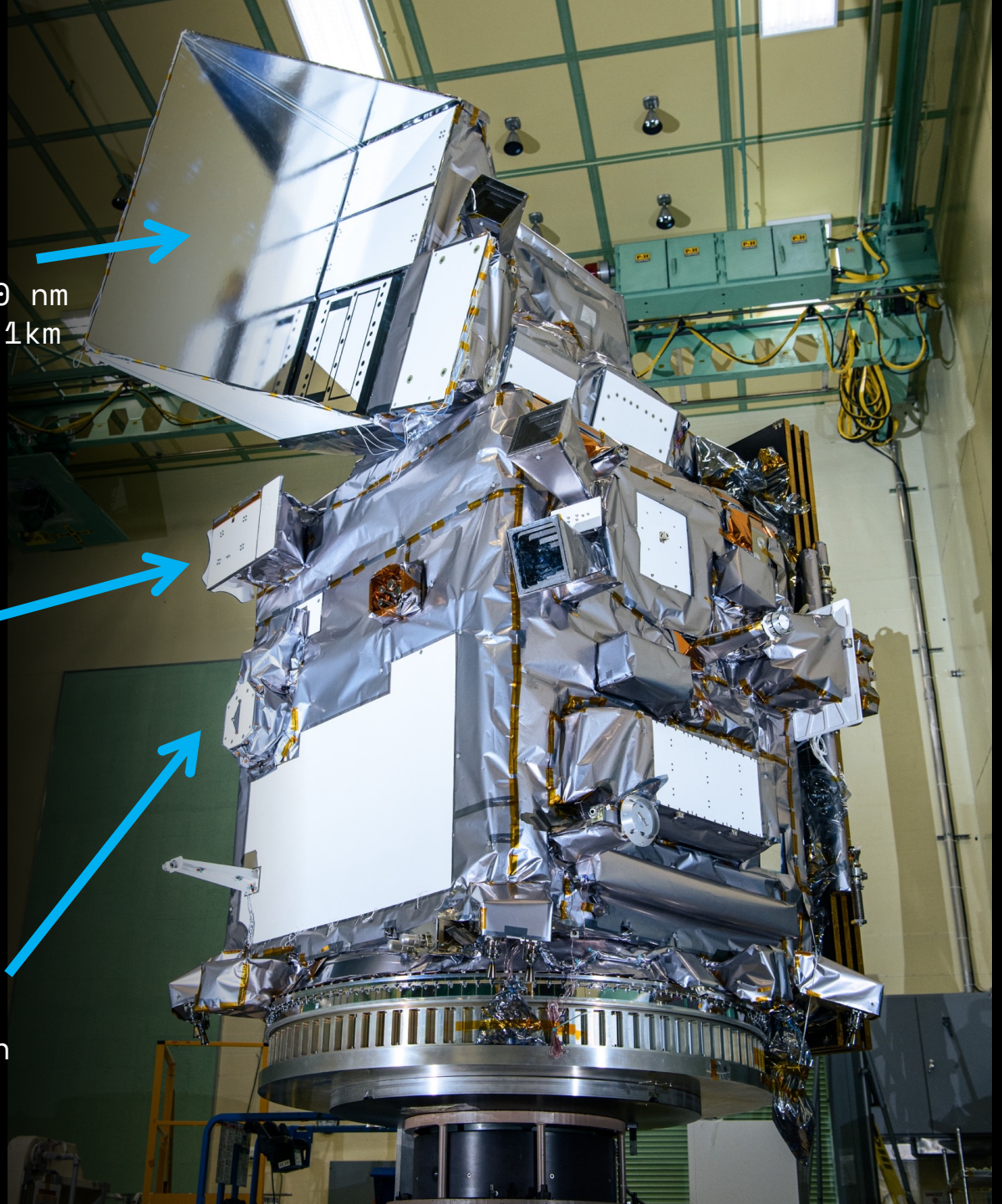
OCI
Radiometer
340-890 nm; 5 nm resolution
7 SWIR-bands between 940-2260 nm
1-2 day coverage; ±20° tilt; 1km



HARP2
Multi-angle polarimeter
440, 550, 670, 870 nm
10-60 viewing angles
wide swath; 5 km resolution



SPEXone
Multi-angle polarimeter
380-770 nm; 2 nm resolution
5 viewing angles
narrow swath; 5 km resolution



Overview of SPEXone data stream – hands-on with notebook 1!

How to decode, calibrate, regrid and analyze data is SRON's responsibility

Getting the data, processing the data, and providing the data to end users such as us in this tutorial is NASA's responsibility

12 to 15 times each day data is downlinked from the satellite to the NASA operations centers on Earth

Combine instrument and satellite data

operations center

L0 (NASA DB)

Decode

L1A (NASA DB)

Calibrate

L1B (NASA DB)

Regrid

L1C (NASA DB)

Analyze

L2 (NASA DB)

It goes on!

Store to your machine for speed up (and in case of little data)

request

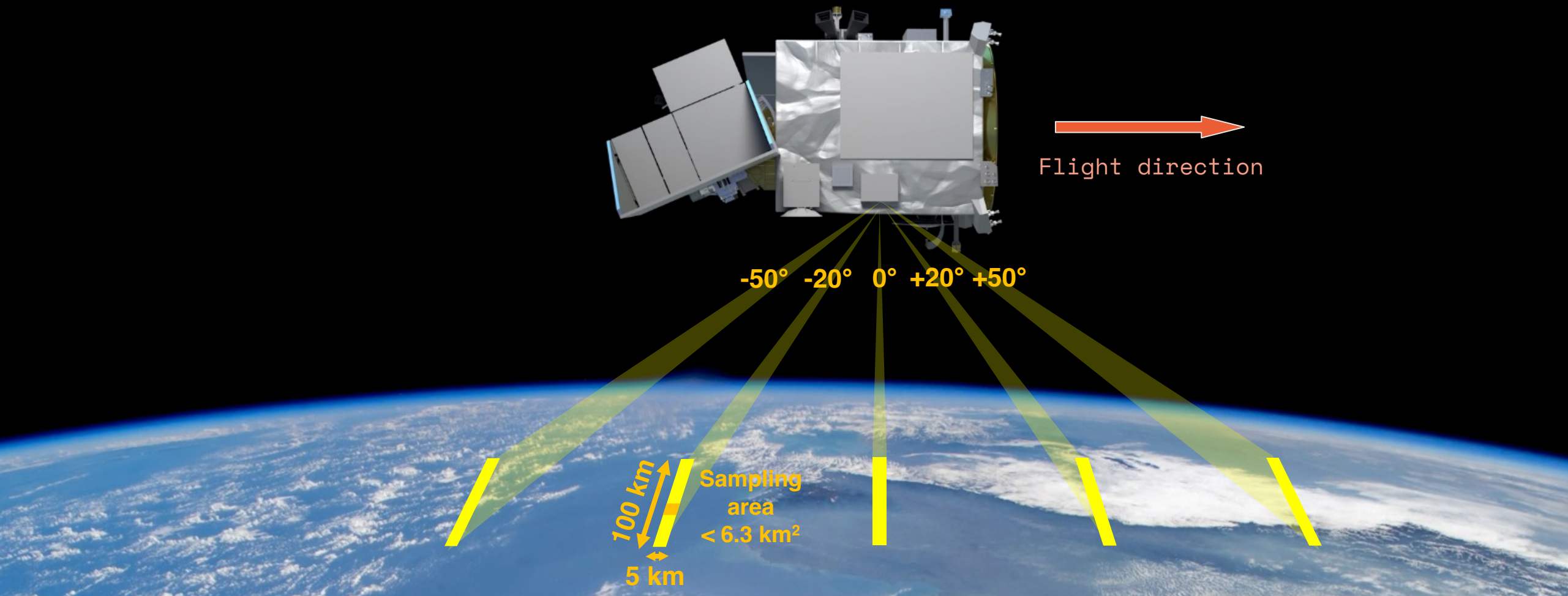
response

Meta data for data selection
Full data for analysis (slow!)

SPEXone

Multi-angle spectropolarimetry between 385 - 770 nm using dual beam spectral polarization modulation

5 instantaneous footprints yielding snapshot pushbroom measurements of radiance and polarization



SPEXone

Multi-angle spectropolarimetry between 385 - 770 nm using dual beam spectral polarization modulation

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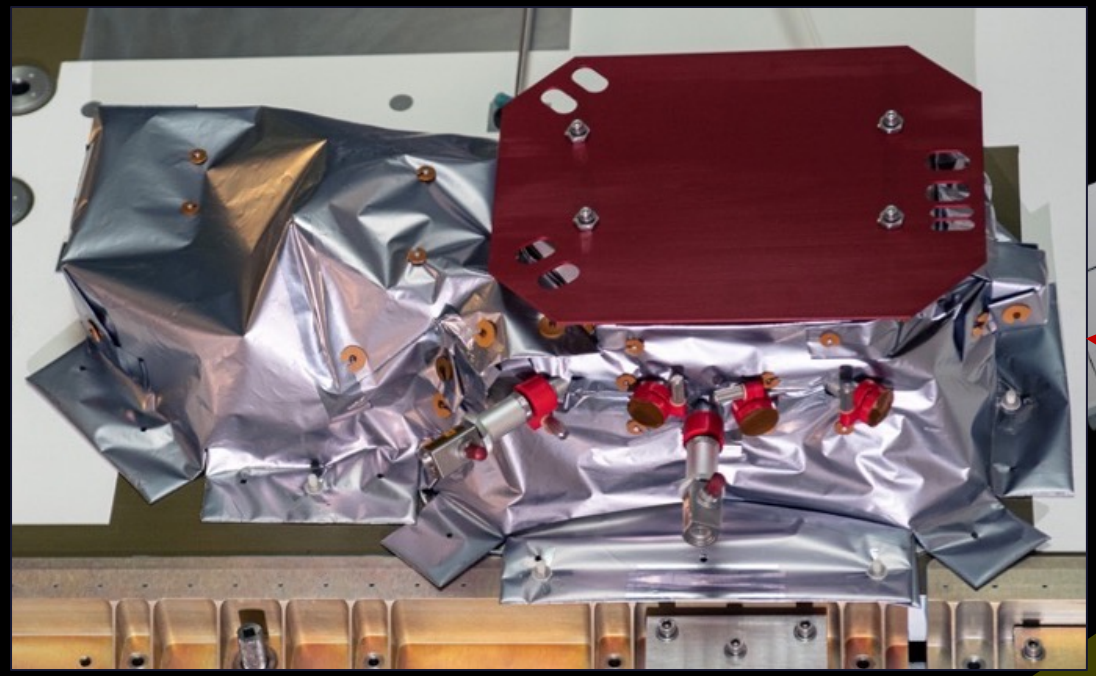
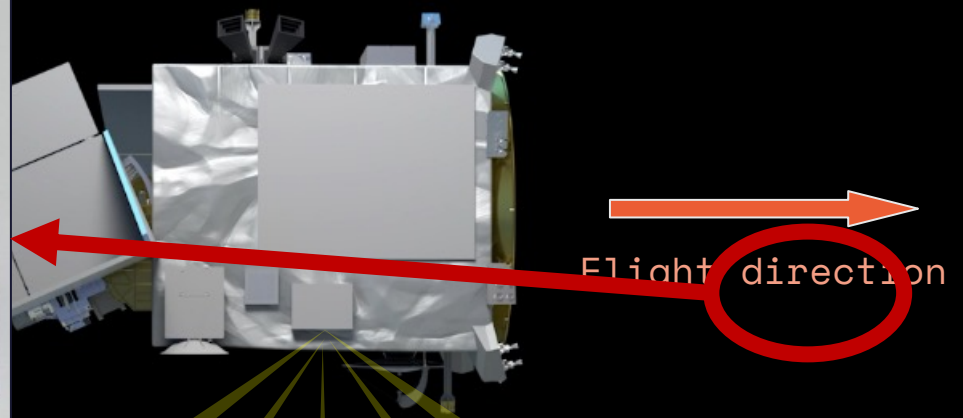




-50° -20° 0° +20° +50°

100 km

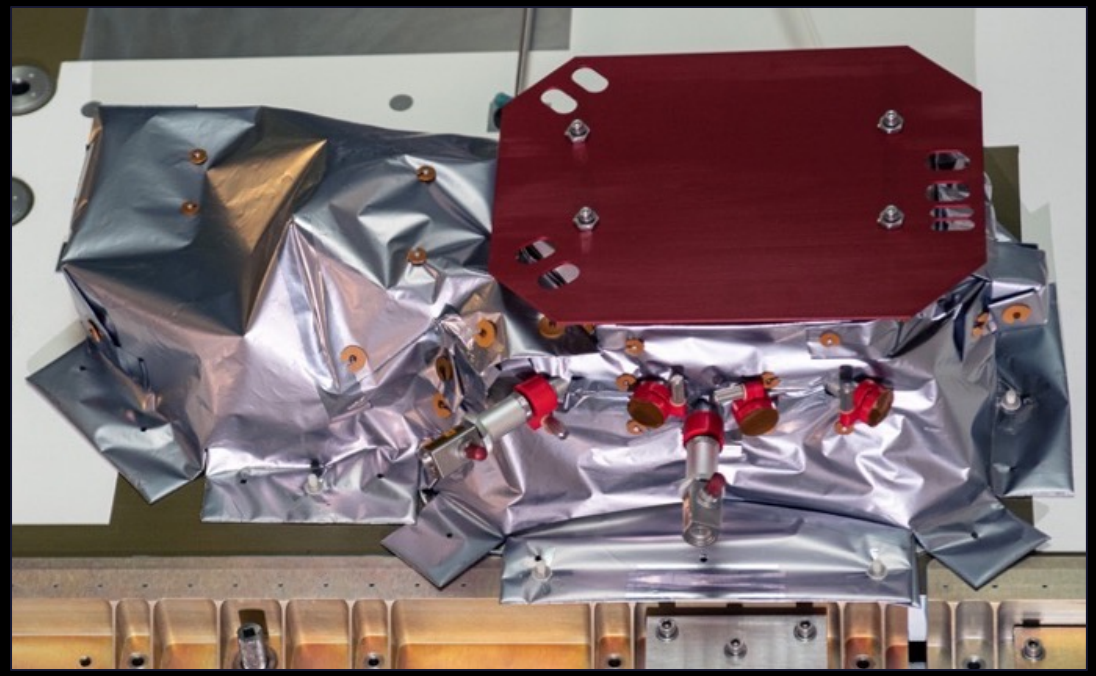
5 km

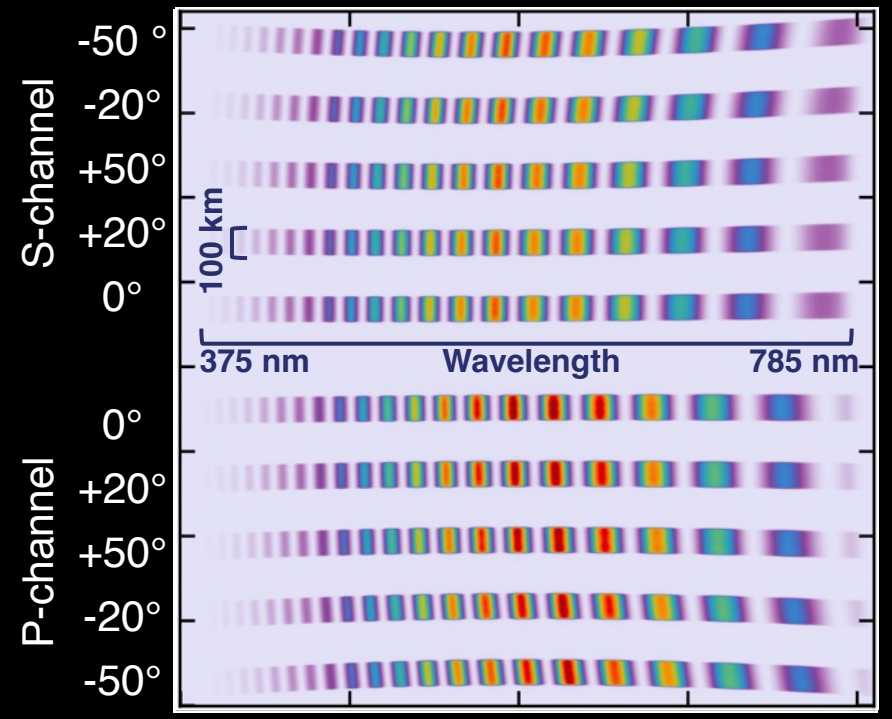
Sampling area < 6.3 km²

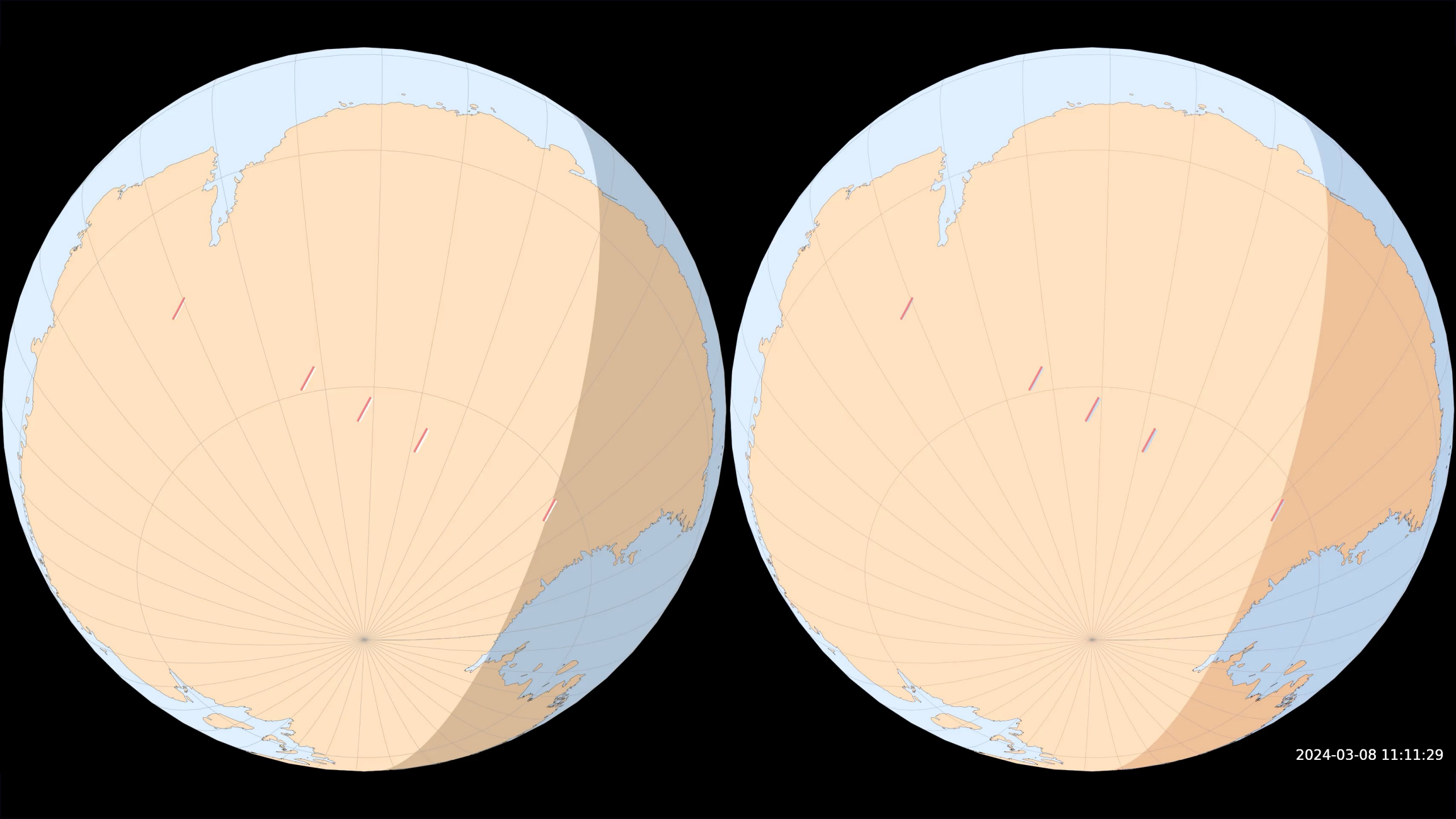
SPEXone

Multi-angle spectropolarimetry between 385 - 770 nm using dual beam spectral polarization modulation

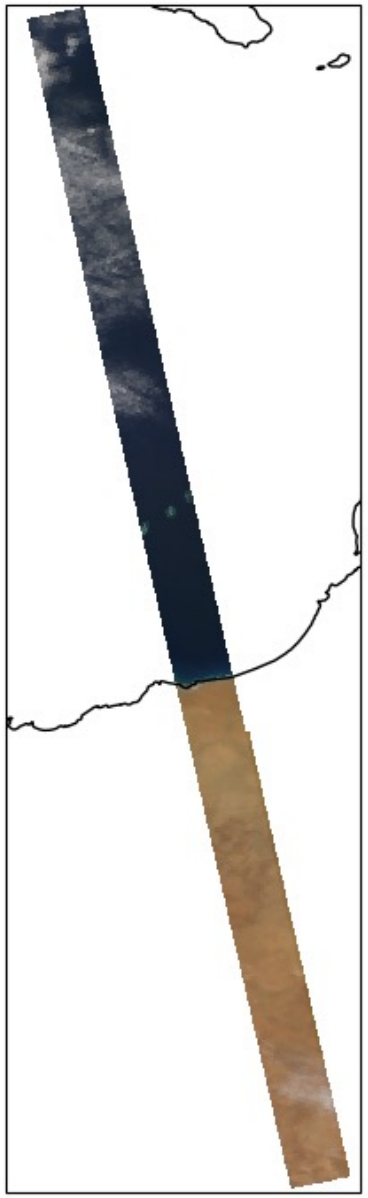
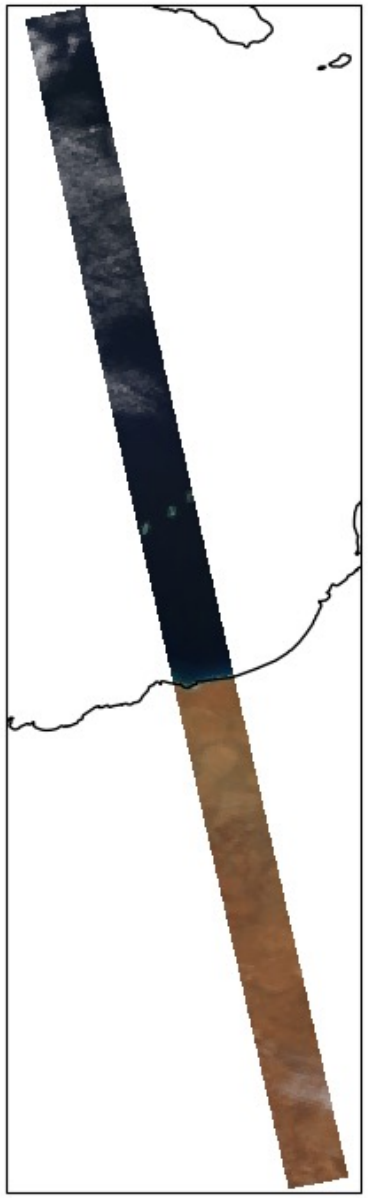
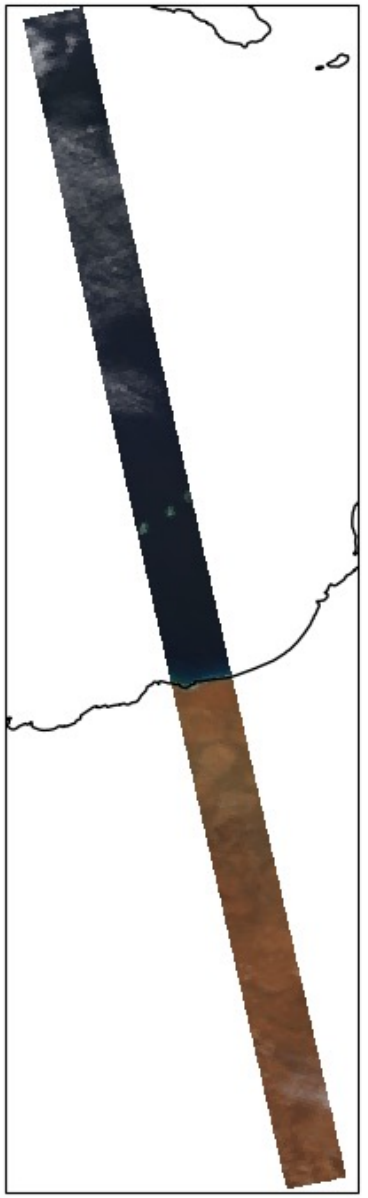
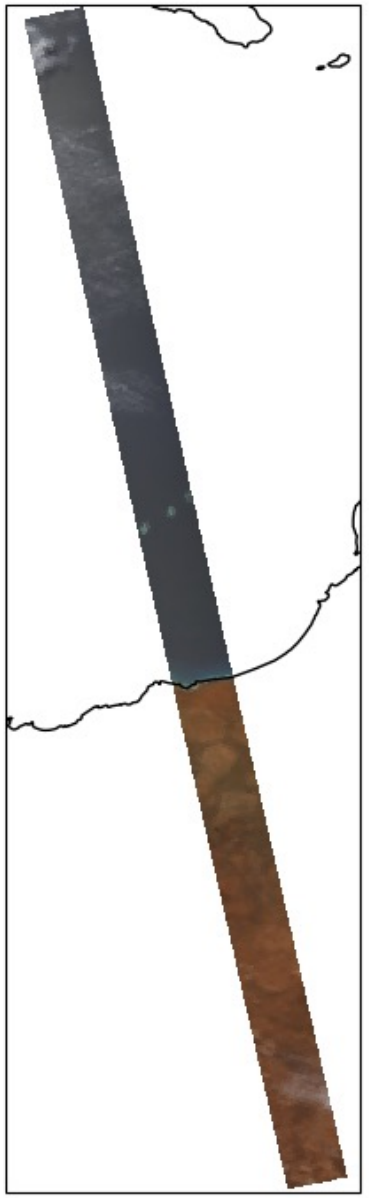
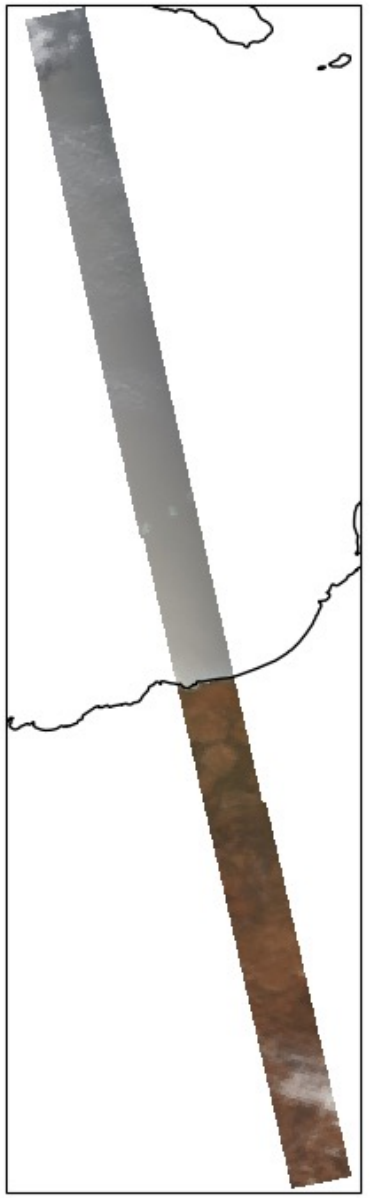
5 instantaneous footprints yielding snapshot pushbroom measurements of radiance and polarization

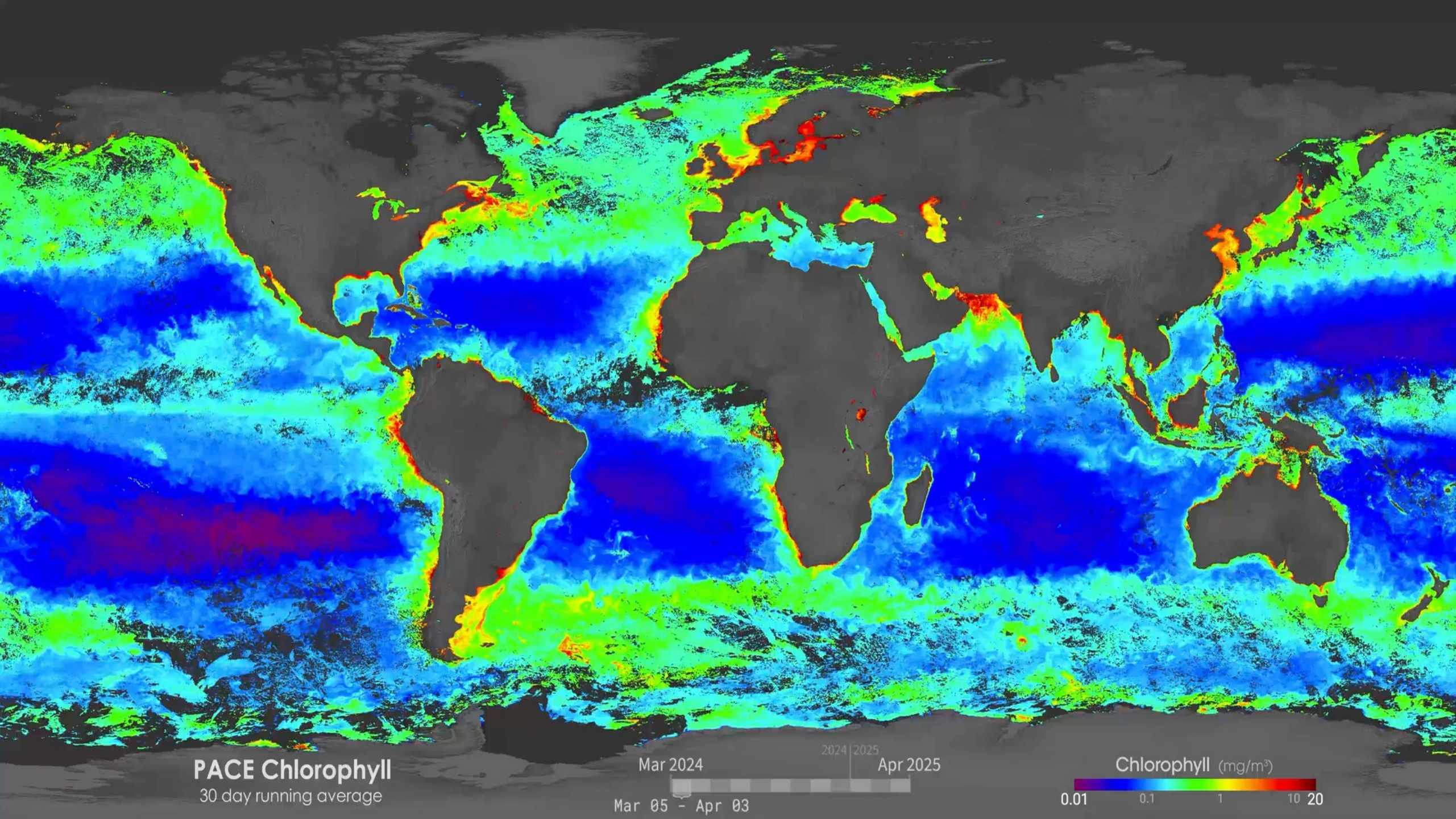


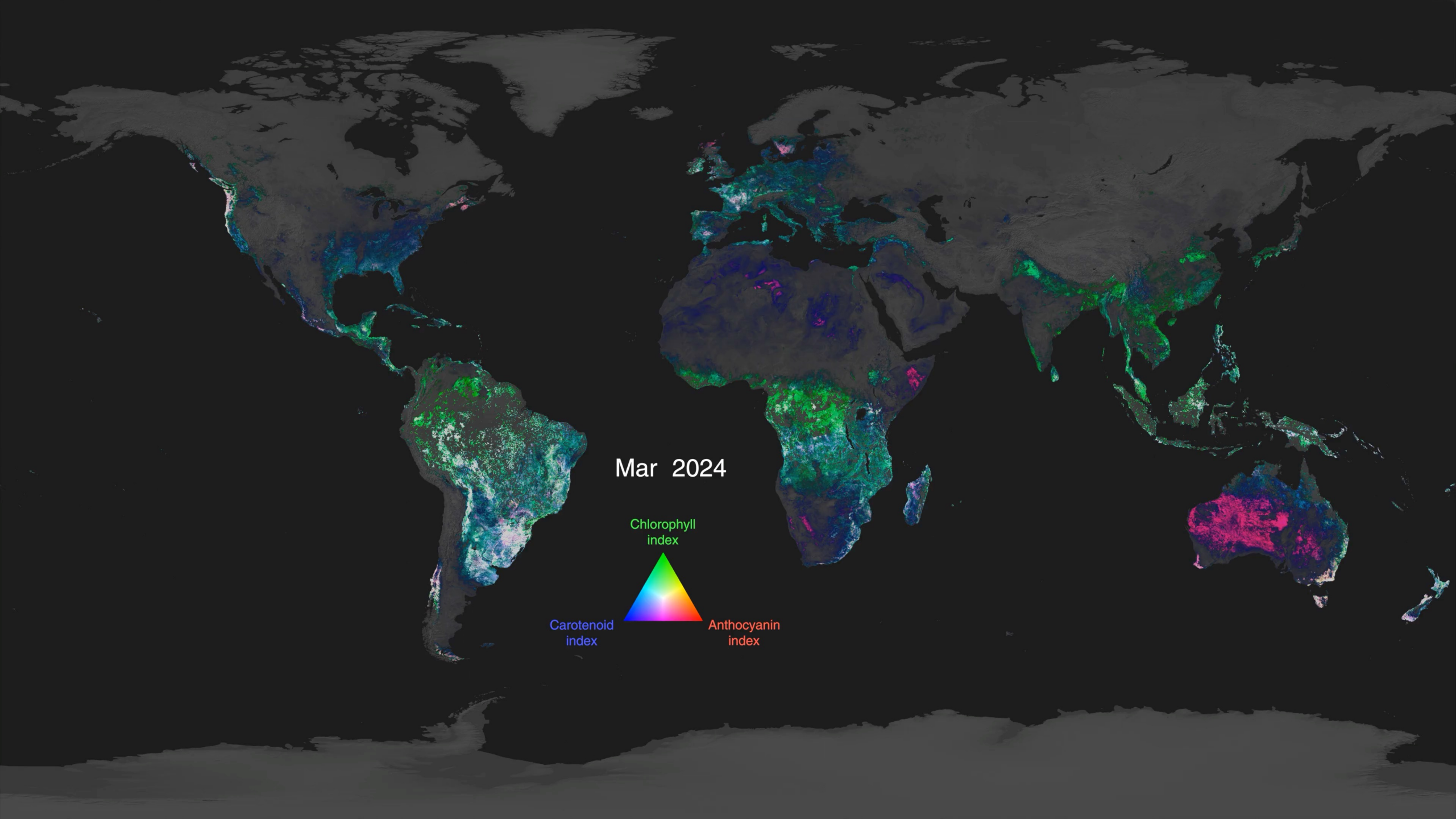



2024-03-08 11:11:29

What do we see? Find out in notebook 2!


PACE Chlorophyll
30 day running average
2024 | 2025
Mar 2024
Apr 2025
Mar 05 - Apr 03
Chlorophyll (mg/m³)
0.01
0.1
1
10
20

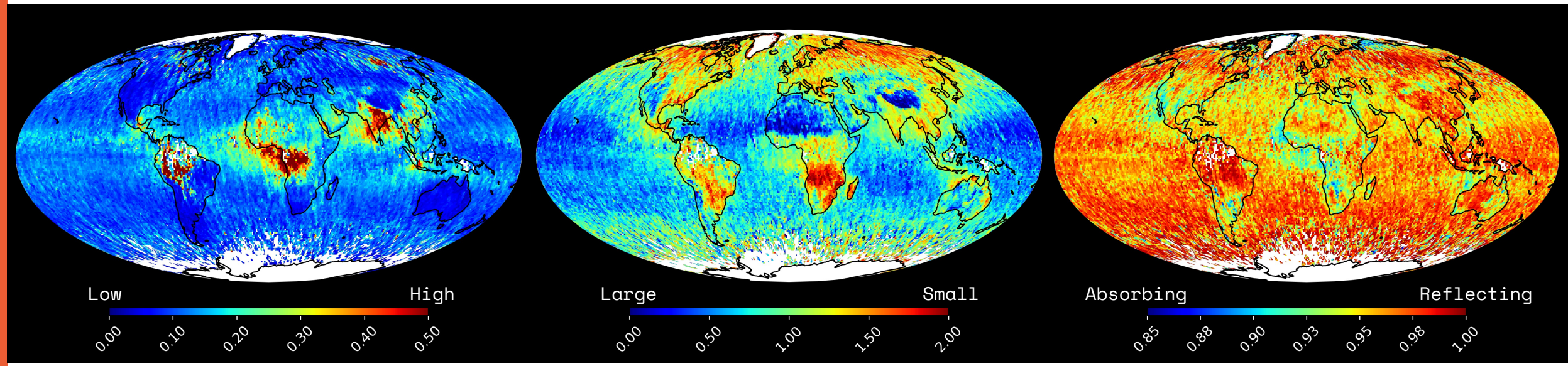

Mar 2024
Chlorophyll index
Carotenoid index
Anthocyanin index

1 year of science data

Aerosol optical depth
(amount of aerosol)

Ångstrom exponent
(particle size)

Single Scattering Albedo
(particle absorption)



Regions with high aerosol:

- Pollution
  - India, SE-Asia, M-America
- Dust
  - Sahara summer
- Biomass burning (BB)
  - Africa, S-America, Canada, Siberia

Patterns in particle size:

- Smallest over BB regions
- Also small over industrial regions
- Large over desert
- Large over (most) remote ocean

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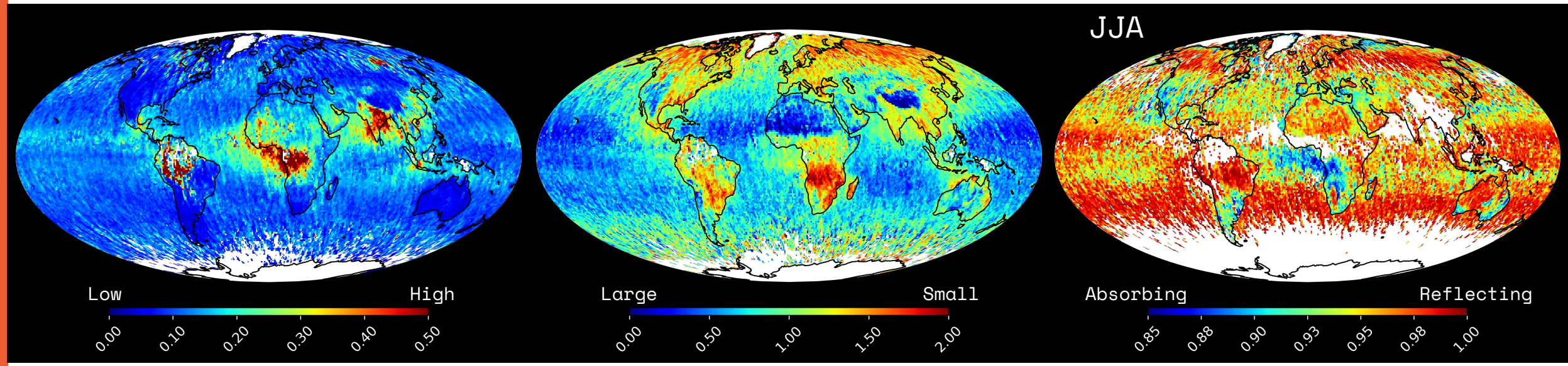
1 year of science data

Aerosol optical depth
(amount of aerosol)

Ångstrom exponent
(patricle size)

Single Scattering Albedo
(patricle size)



Regions with high aerosol:

- Pollution
  - India, SE-Asia, M-America
- Dust
  - Sahara summer
- Biomass burning (BB)
  - Africa, S-America, Canada, Siberia

Patterns in particle size:

- Smallest over BB regions
- Also small over industrial regions
- Large over desert
- Large over (most) remote ocean

Patterns in absorption:

- High for BB in Africa
- High over California
- Much less for BB over Amazone and Siberia
- Low for dust (Sahara)
- Low over ‘clean’ ocean

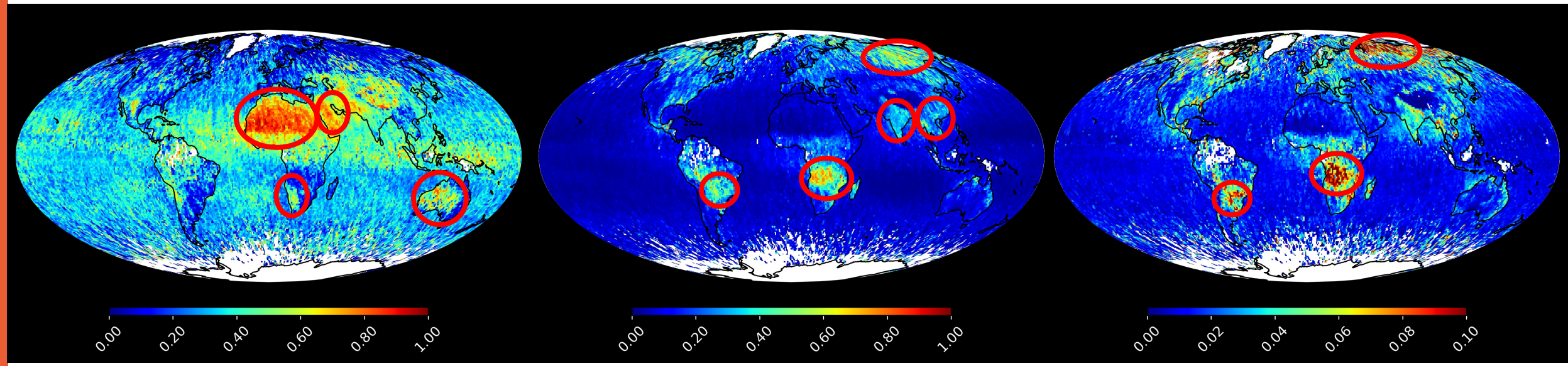
1 year of science data

Dust fraction

Small particles

Non-absorbing (in)organic

Black carbon & brown carbon



Deserts regions:

- Sahara
- Middle-East
- Namibia
- Australia

Industrial and biomass burning regions:

- India & South-East Asia
- Africa, South-America & Siberia

Biomass burning regions:

- Africa, South-America & Siberia

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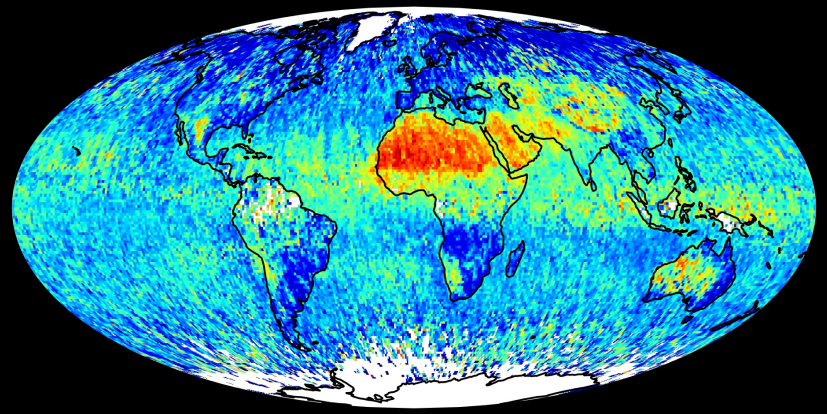
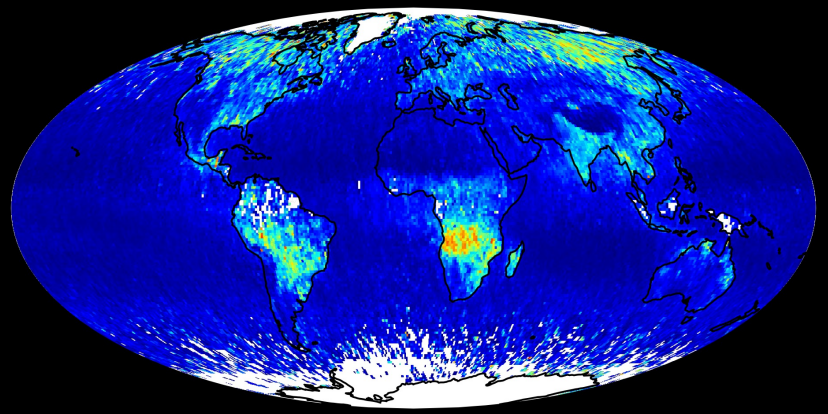
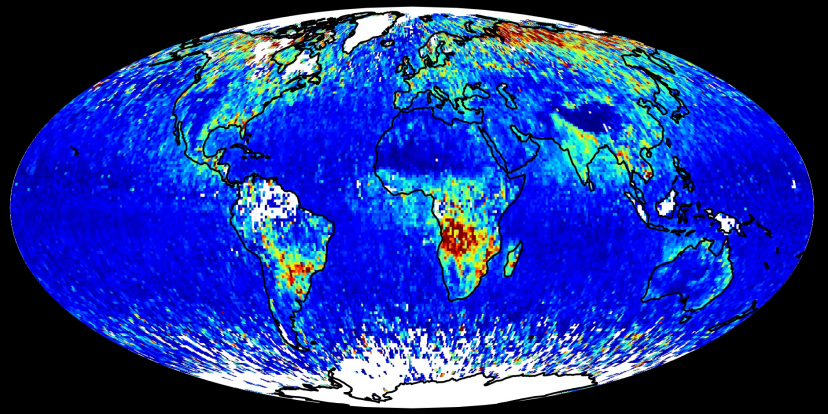
TO BRING ABOUT BREAKTHROUGHS IN INTERNATIONAL SPACE RESEARCH







Explore aerosol products in notebook 3!

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Useful links

- https://pace.oceansciences.org/
- https://pace.oceansciences.org/pace_result_spotlight.htm

- https://pace.oceansciences.org/data.htm

- https://oceandata.sci.gsfc.nasa.gov/
- https://oceancolor.gsfc.nasa.gov/resources/docs/tutorials/

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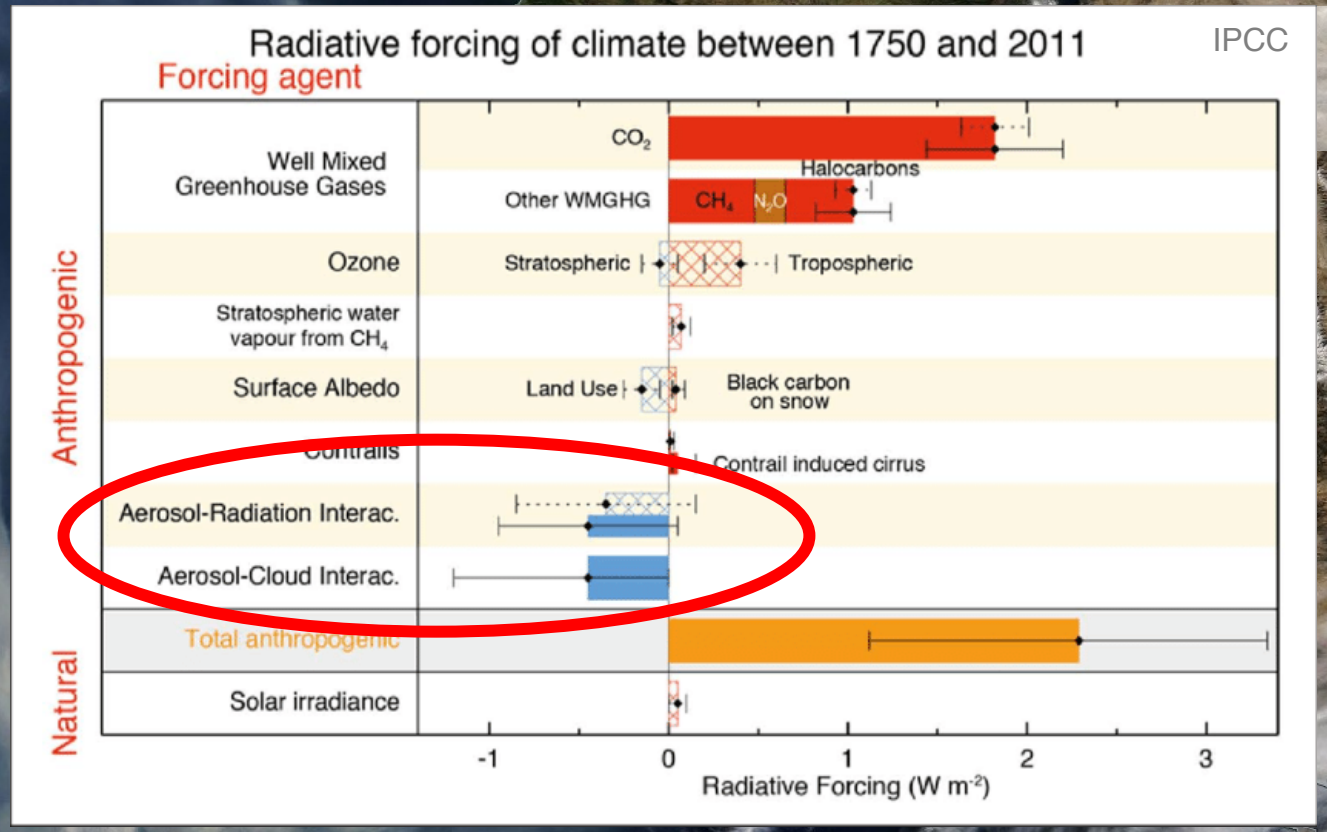
The need for atmospheric aerosol characterization



Climate

Aerosol (in)direct effect on radiative forcing

The need for atmospheric aerosol characterization

Climate

Aerosol (in)direct effect on radiative forcing

Air quality

Human health

The need for atmospheric aerosol characterization

Climate

Aerosol (in)direct effect on radiative forcing

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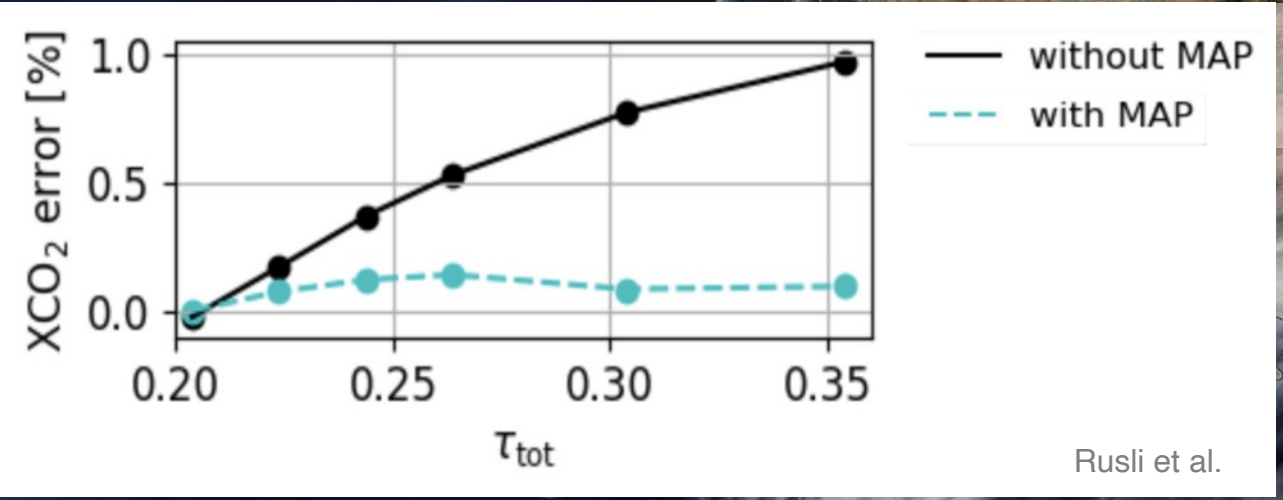

Rusli et al.

Light path correction

Ocean color and trace gas retrievals

The need for atmospheric aerosol characterization

Climate

Aerosol (in)direct effect on radiative forcing

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Light path correction

Ocean color and trace gas retrievals

Multi-angle photo-polarimetry is essential to retrieve relevant aerosol properties: AOT, SSA, refractive index, size, shape, concentration

Mishchenko and Travis, JGR, 2007
Hasekamp and Landgraf, Appl. Opt., 2007
Kokhanovsky et al, AMT, 2010