



# PACE / EarthCARE Matchups (PEM): An intercomparison library in Python for the NASA PACE and EarthCARE missions

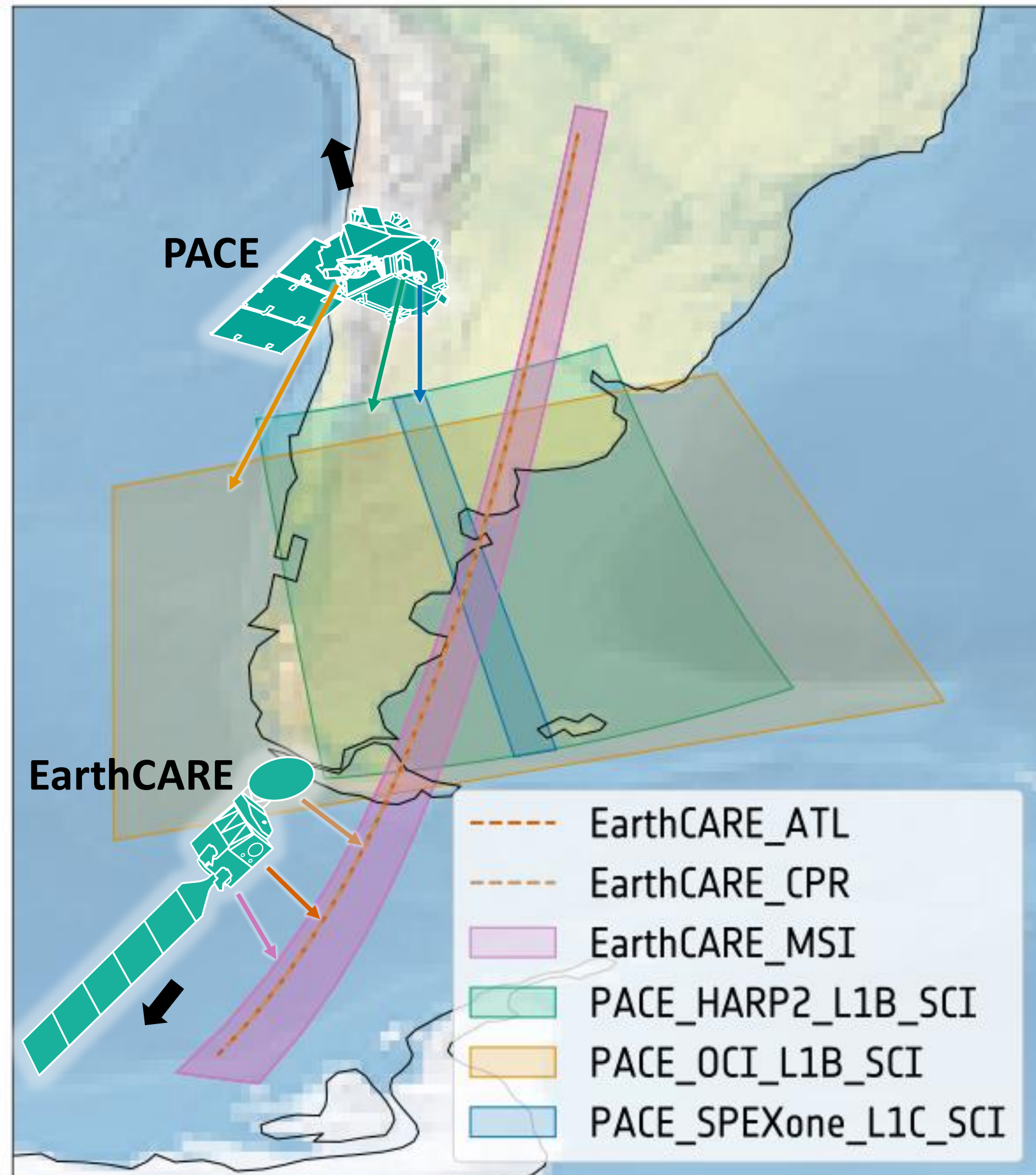


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## PACE + EarthCARE synergy

NASA's Plankton, Aerosol, Cloud, ocean Ecosystem (PACE) mission synergizes with EarthCARE due to its **hyperspectral, hyper-angular, and polarimetric** capabilities. The **higher spatial resolution** of EarthCARE's instruments complements the much **wider swath** of PACE's instruments. PACE and EarthCARE experience regular simultaneous overpasses in the southern mid-latitudes, yielding abundant matchup data for large-scale studies.

### PACE & EarthCARE Extents 2026-03-16 17:44:40



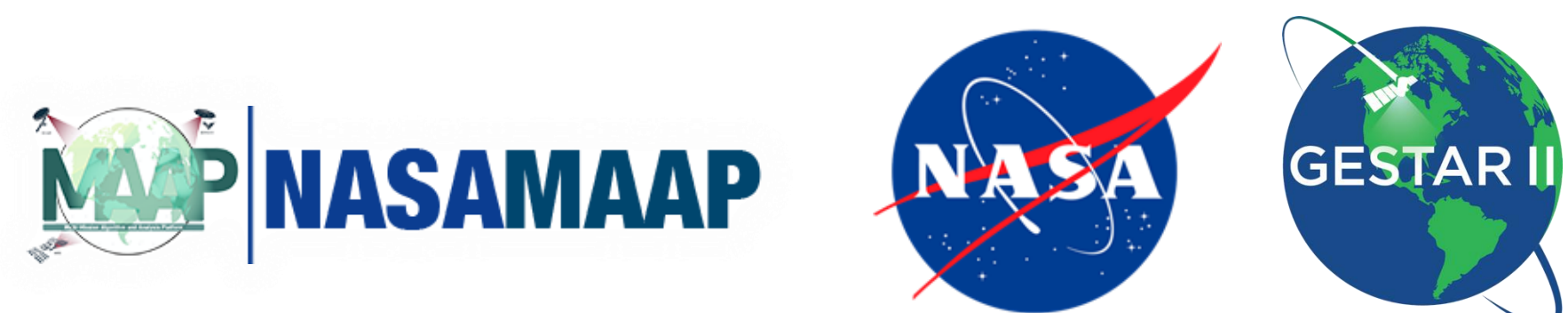
**Figure 1** Extents of PACE and EarthCARE's various instruments for an example overlap scene on March 16th. Note that PACE is in an ascending (daytime) orbit; EarthCARE is in a descending orbit. The HARP2 swath shown here represents the nadir viewing angle; higher viewing angles have varying but generally larger swaths.

## PACE Instruments

- Ocean Color Instrument (OCI)
  - 315-895nm at 2.5nm resolution
  - Select wavelength ranges at 1.25nm
  - 6 bands from 940nm to 2260nm
- Hyper-Angular Rainbow Polarimeter (HARP2)
  - 90 total viewing angles
  - 60 at 549nm, 10 each at 441, 669, 873nm
  - Polarization at 0°, 45°, 90°
- Spectro-polarimeter for Planetary EXploration (SPEXone)
  - 5 viewing angles
  - 385-770nm at 2-5nm resolution
  - DoLP at 10-40nm resolution

## MAAP

The Multi-Mission Algorithm and Analysis Platform (MAAP) is a joint NASA and ESA effort to simplify open science across both agencies. To this end, MAAP brings together data, algorithms, and cloud computing resources. PEM began as a MAAP project, but is built for both MAAP and non-MAAP users, as well as for NASA, ESA, and other users.

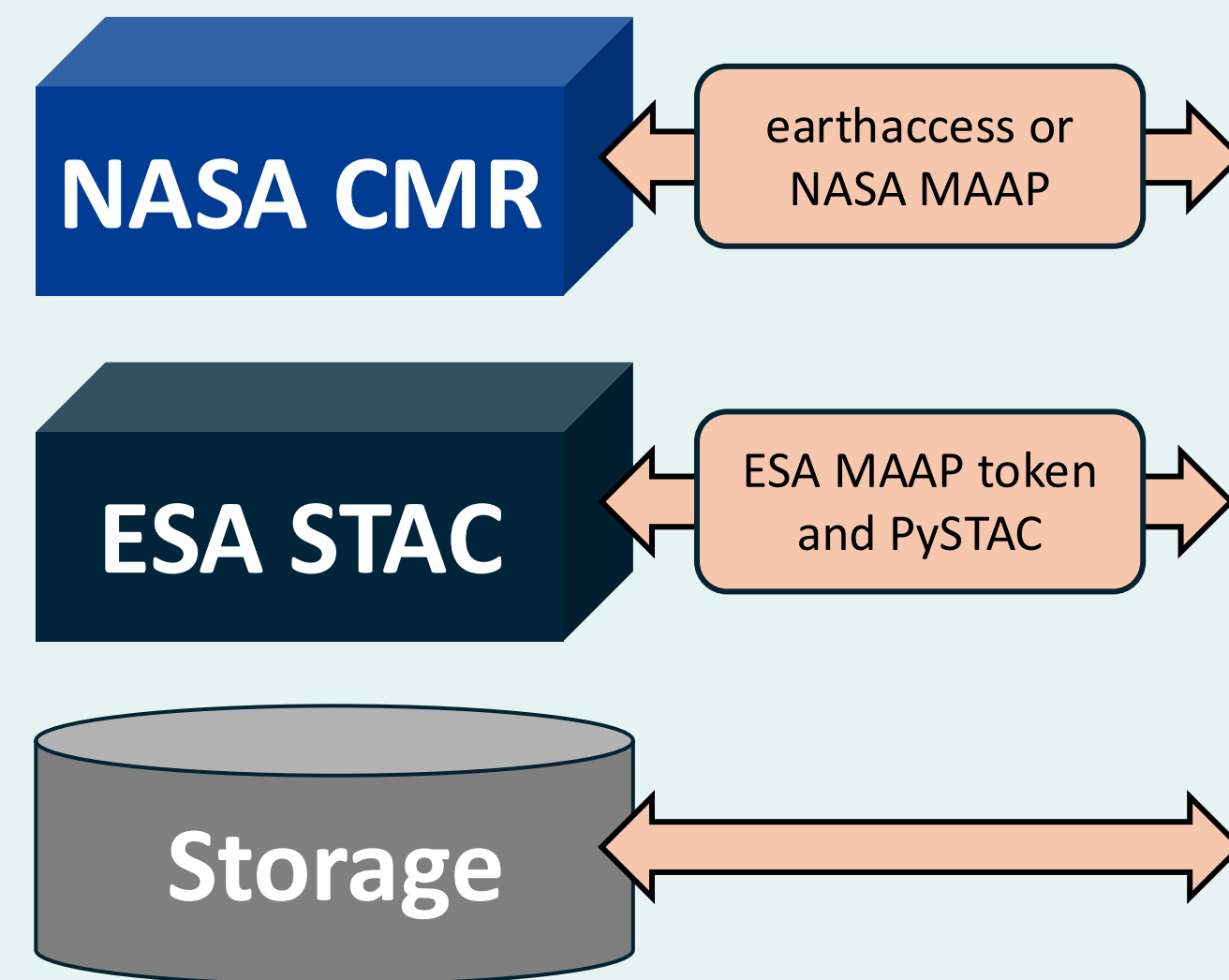


## PACE / EarthCARE Matchups (PEM)

PEM is an open-source Python library designed to simplify scientific comparisons of PACE and EarthCARE data. PEM's goals are to:

- Simplify data acquisition to a few lines of Python
- Support all geolocated L1/L2 PACE and EarthCARE data products
- Produce reproducible results and bolster open-source science
- Deduplicate unnecessary effort on:
  - Reconciling varying metadata formats
  - Solving geospatial bounding box edge cases
  - Efficient interpolation

**Figure 2** Overview of PEM. PEM supports both earthaccess and the NASA MAAP (maap-py) to interface with the Common Metadata Repository (CMR).



**User-provided Search Terms**  
(time, time offset, region, etc.)

**PEM Loop:**

- Get & preprocess PACE metadata
- Get & preprocess EarthCARE metadata
- Download, compute masks, and save

**Then:**

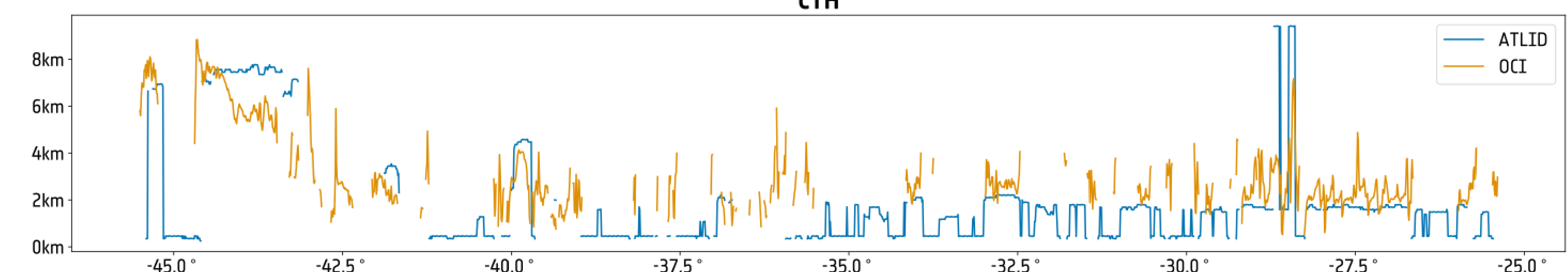
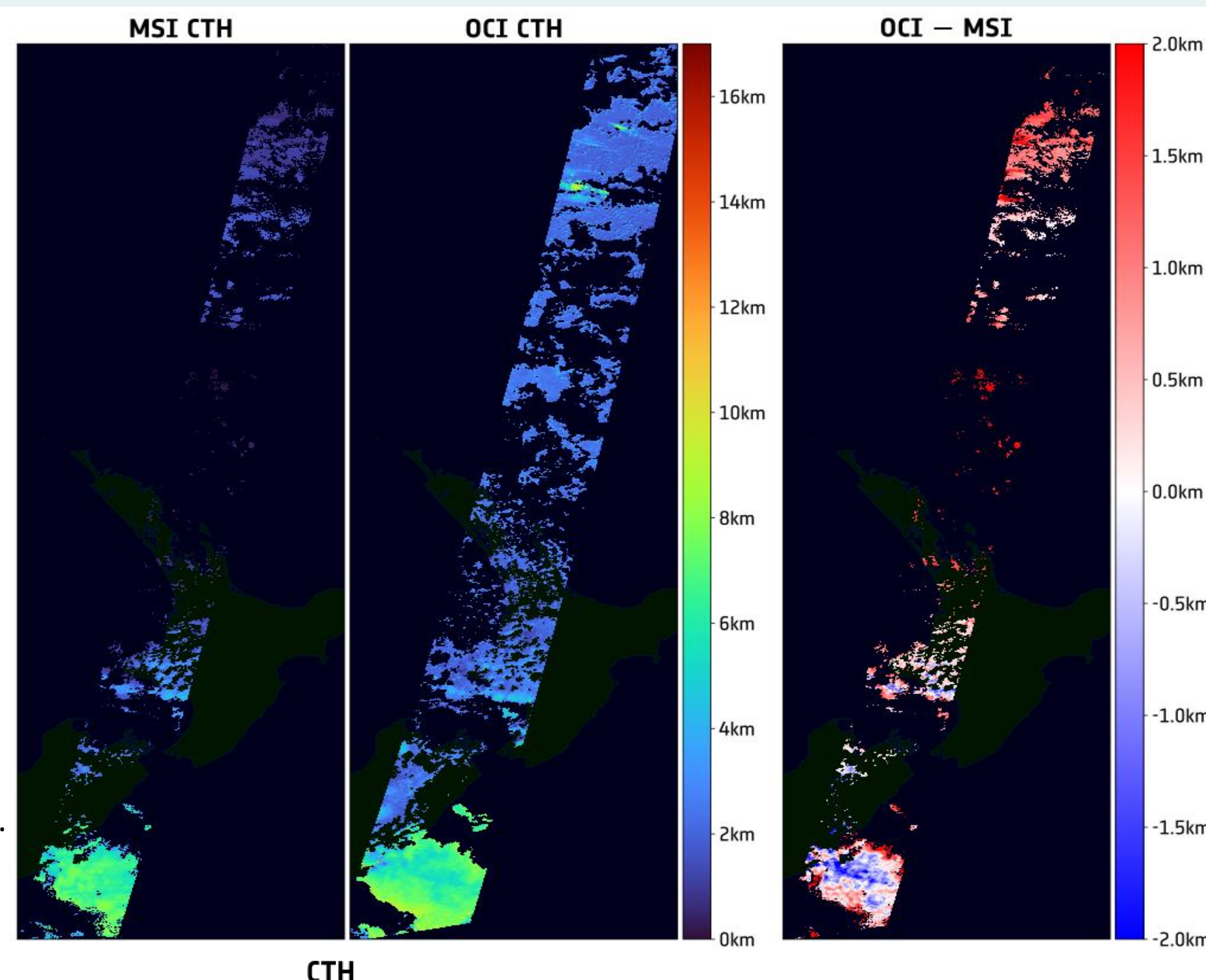
- Plot matchups
- Interpolate
- Comparison, validation, etc.

## 3D Cloud Structure

PEM was borne out of a need to validate the PACE HARP2 3D cloud product, which is in active development.

Here, we show a comparison with the OCI Cloud-Top Height (CTH) product [1]. Note that PEM handles the interpolation of PACE data to both horizontal and vertical reference frames, allowing for easy comparison of passive and active products with several different interpolation schemes.

**Figure 3** Right: the OCI CTH product (CHROMA [1]) is compared with the MSI CTH [2] for a scene over New Zealand. Differences are shown in the third panel. Below: CHROMA is compared with the ATLID CTH [3] in the EarthCARE curtain; the x-axis represents latitude.



### REFERENCES

- [1] Sayer, A. M., Lelli, L., Cairns, B., van Diedenoven, B., Ibrahim, A., Knobelspiesse, K. D., Korkin, S., and Werdell, P. J.: The CHROMA cloud-top pressure retrieval algorithm for the Plankton, Aerosol, Cloud, ocean Ecosystem (PACE) satellite mission, *Atmos. Meas. Tech.*, 16, 969–996, <https://doi.org/10.5194/amt-16-969-2023>, 2023.
- [2] Hünerbein, A., Bley, S., Deneke, H., Meirink, J. F., van Zadelhoff, G.-J., and Walther, A.: Cloud optical and physical properties retrieval from EarthCARE multi-spectral imager: the M-COP products, *Atmos. Meas. Tech.*, 17, 261–276, <https://doi.org/10.5194/amt-17-261-2024>, 2024.
- [3] Wandinger, U., Haarig, M., Baars, H., Donovan, D., and van Zadelhoff, G.-J.: Cloud top heights and aerosol layer properties from EarthCARE lidar observations: the A-CTH and A-ALD products, *Atmos. Meas. Tech.*, 16, 4031–4052, <https://doi.org/10.5194/amt-16-4031-2023>, 2023.

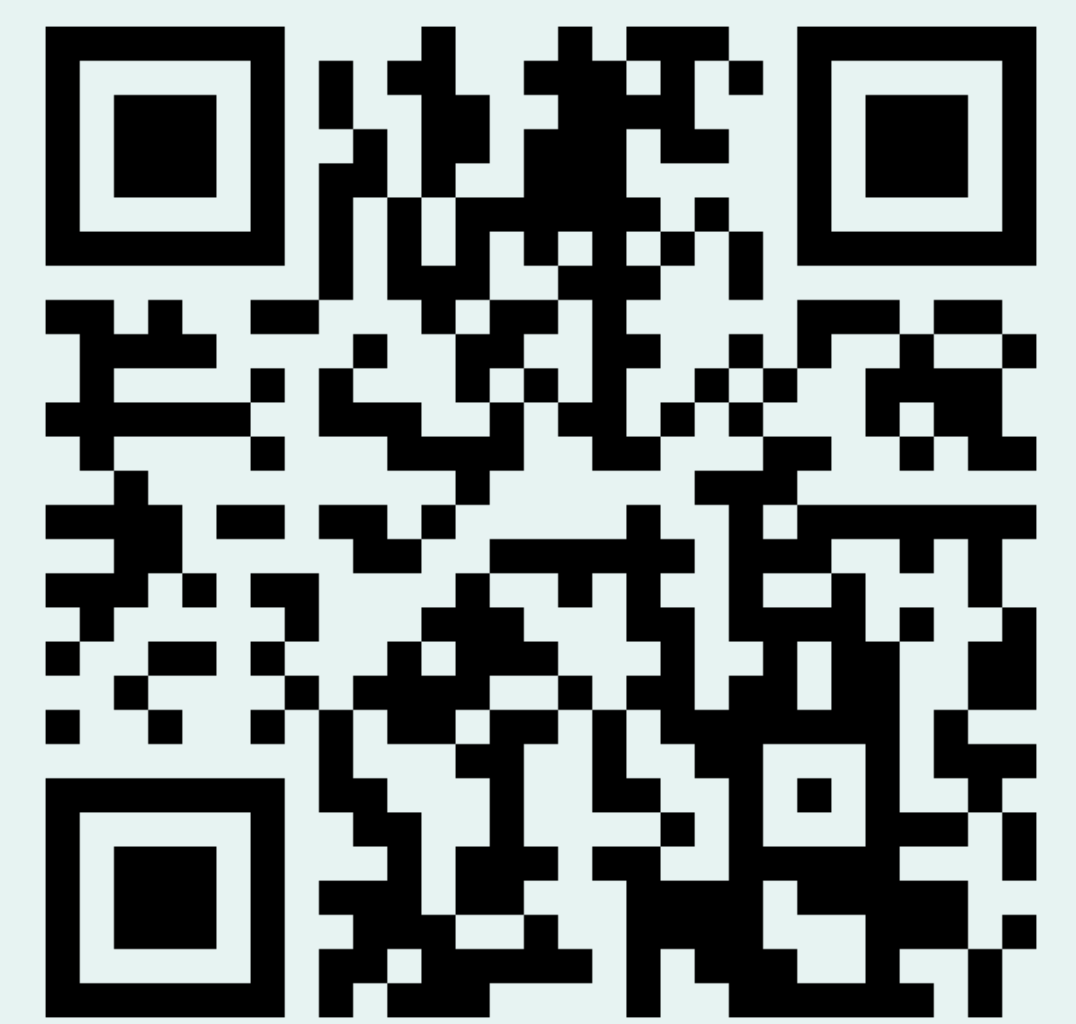
## Getting Matchups

Using PEM is simple. In the following code snippet, we provide the PACE and EarthCARE products we'd like to compare, the time range, and optional additional arguments to the `get_matchups` function:

```
matchups = get_matchups(
    shortname_pace="PACE_OCI_L2_CLOUD",
    shortnames_earthcare=[
        "ATL_CTH_2A",
        "AM_CTH_2B",
    ],
    temporal=(TIME_START, TIME_END),
    bbox=BBOX, # bounding box (optional)
    limit=5, # results limit (optional)
    ..., # (more options)
)
```

Matchups are automatically downloaded and saved. This includes the associated PACE and EarthCARE files, as well as a mask representing their overlap. Matchups can also be loaded from storage later.

PEM is open source. Code and instructions can be found on Github using the QR code or link. Bug reports and PRs are greatly appreciated!



[github.com/seanremy/pace-earthcare-matchups](https://github.com/seanremy/pace-earthcare-matchups)

## EarthCARE 2026 Science and Validation workshop

8–12 June 2026 | Rhodes House | Oxford, UK

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