Cross-Mission Methodology for Masking Validation: EnMAP cloud mask with Sentinel-5P

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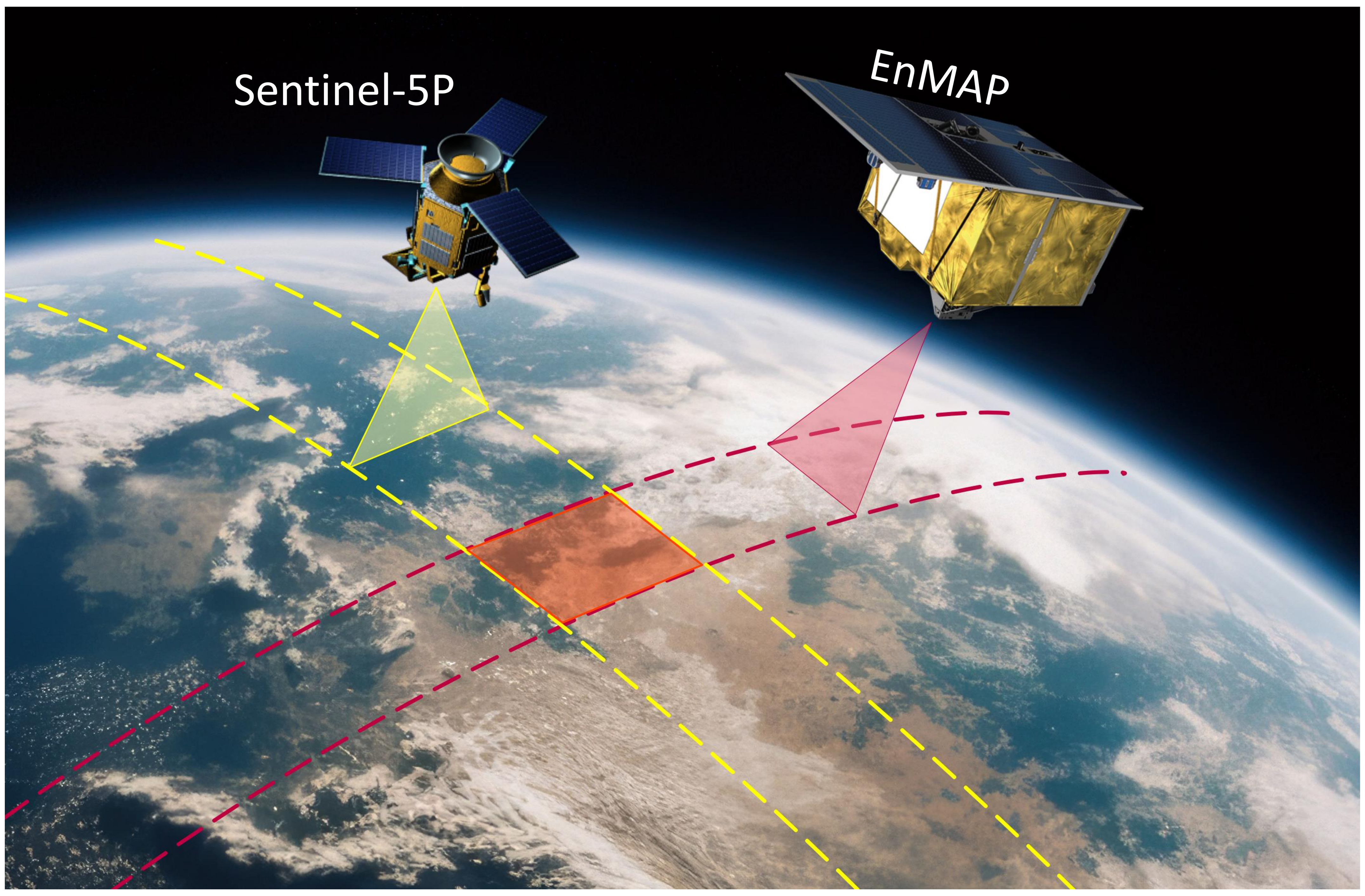

Fig.1 - Illustration of a matching overpass between EnMAP and Sentinel-5P (not to scale). For cloud fraction comparison between the products of the TROPOMI instrument on board Sentinel-5P [1], and the predicted cloud mask from EnMAP [2], only matching overpasses with a small capture time difference should be considered (in the order of seconds), depending on wind speed and cloud altitude.

Validating EnMAP cloud mask with TROPOMI cloud fraction product.

The validation of masking algorithms for hyperspectral imagery requires a precise reference, often referred to as ground truth. Currently, most validation exercises for masking algorithms rely on hand-made annotations, but these require significant expertise and labor, as each validation requires the creation of a new dataset.

Additionally, misinterpretation of class definitions often causes overlaps in annotations between classes.

Furthermore, other sources of information such as in-situ measurements, are difficult to obtain on a global scale.

We propose a validation methodology that uses more sensitive and global sources of information, employing physical properties to validate masking products. The main objective is to retrieve reference data from missions specifically designed to sense a particular characteristic of the atmosphere or Earth's surface and use it to validate the masking products of other missions, particularly optical remote sensing.

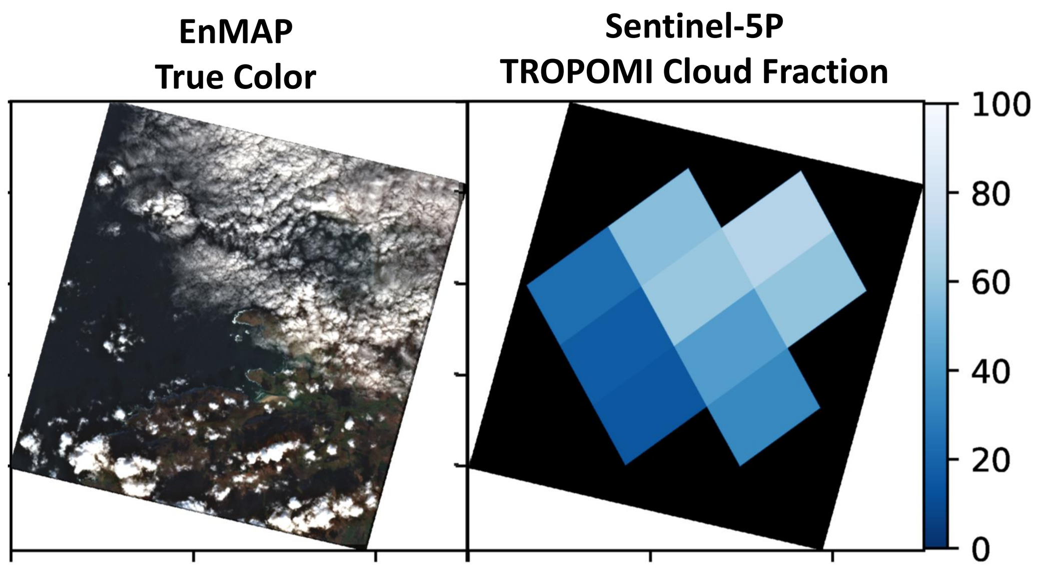

Fig.2 - EnMAP True color $(30 \times 30\ m)$ and TROPOMI cloud fraction product $(5.5 \times 3.5\ km)$ comparison. EnMAP Image: DT0000063937_004 captured on 2024-03-05 12:18:35 UTC.

To achieve this, it is necessary to implement an interface that transforms the masking products into physical properties that match the format of the mission products used as a reference.

$$CF_i^{EnMAP} = \frac{p_{cloud}}{p_{total}}(100\%)$$

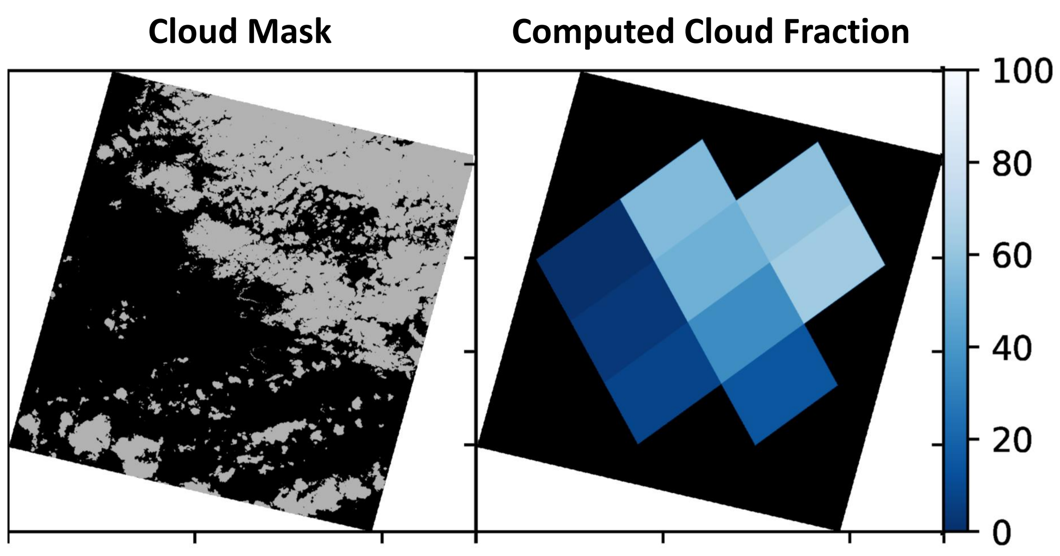

Fig.3 - Cloud mask from masking algorithm (left plot) is transformed into cloud fraction (right plot), matching the spatial resolution and location of TROPOMI pixels.

This work addresses a use case for a spatial feature extraction-based neural network (2D-CNN)[3], trained with a pre-classification from the Python - based Atmospheric Correction (PACO)[4] software developed at the German Aerospace Center (DLR).

The training set comprises 55 scenes with a variety of atmospheric conditions over different Earth surfaces.

The testing dataset consists of matching overpasses between 15 scenes from Sentinel-5P and 105 scenes from EnMAP with less than 180 seconds of capture time difference, resulting in 982 TROPOMI pixels for reference.

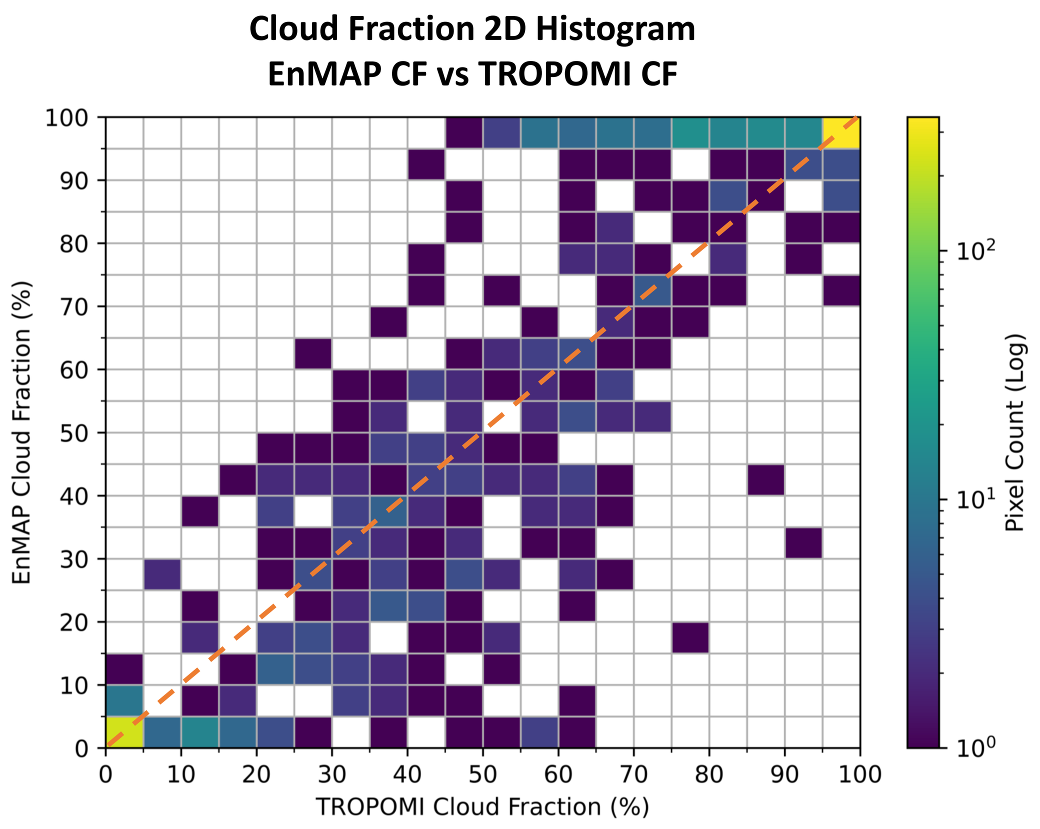

Fig.4 - 2D Histogram for cloud fraction comparison and distribution visualization of currently available samples. Most of the pixels cluster around the case of clear sky (0%, 0%) or full cloud coverage (100%, 100%).

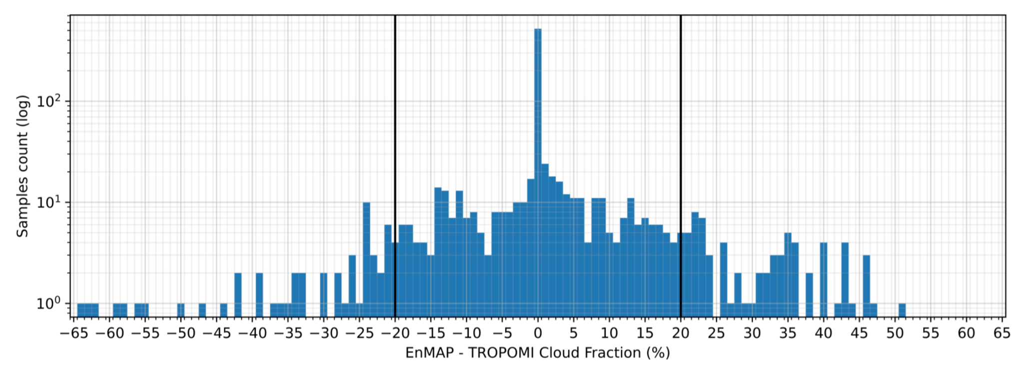

Fig.5 – Histogram of differences between computed and reference cloud fraction.

Conclusions

This approach performs validation of an EnMAP cloud mask with highly sensitive and global sources of information, as in the case of TROPOMI, a mission designed to retrieve trace gases and cloud properties; however, the large spatial resolution and the radiometric cloud fractions of TROPOMI makes both cloud products not completely comparable. The algorithms for cloud fraction retrieval should be exhaustively studied to explain potential systematic bias in the reference data. This methodology could be applied with other highly sensitive sources of information for other masks (snow, vegetation, water, etc.).

[1] D. G. Loyola *et al.*, "The operational cloud retrieval algorithms from TROPOMI on board Sentinel-5 Precursor," *Atmos. Meas. Tech.*, vol. 11, no. 1, pp. 409–427, Jan. 2018.
[2] T. Storch et al., "The EnMAP imaging spectroscopy mission towards operations," Remote Sensing of Environment, vol. 294, p. 113632, Aug. 2023.
[3] M. E. Paoletti, J. M. Haut, J. Plaza, and A. Plaza, "Deep learning classifiers for hyperspectral imaging: A review," Dec. 01, 2019, Elsevier B.V.
[4] R. de Los Reyes et al., "PACO: Python-Based Atmospheric COrrection," Sensors (Basel)., vol. 20, no. 5, p. 1428, Mar. 2020.

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