ANALYSING MIXING PROCESSES IN TOMOGRAPHICALLY IMAGED FILAMENTS OF ASIAN MONSOON OUTFLOW DURING THE PHILEAS CAMPAIGN USING COMPUTER VISION





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Abstract: Mixing of air masses in the atmosphere is a fundamental contribution to the global circulation. However, mixing processes are difficult to measure, as they require consecutive measurements of the same air masses at different times. The PHILEAS campaign in September 2023 aimed at studying the transport pathways of Asian monsoon air into the UTLS. In a self-matching experiment air masses from the Asian summer monsoon are 3-D tomographically imaged on two consecutive days by our airborne GLORIA instrument across multiple trace gas species. We present a novel computer vision approach, which allows us to classify each type of measured air mass and consequently reveal the mixing processes. This matching experiment was conducted as a demonstration for the Earth Explorer 11 candidate CAIRT, a satellite instrument with a similar measurement principle and capabilities.



◆ The self-matching experiment:

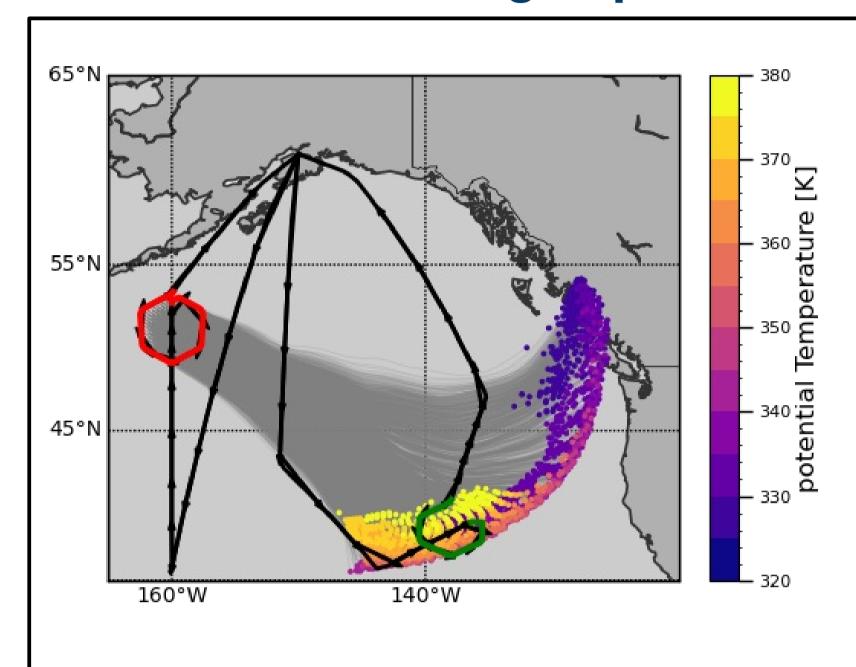
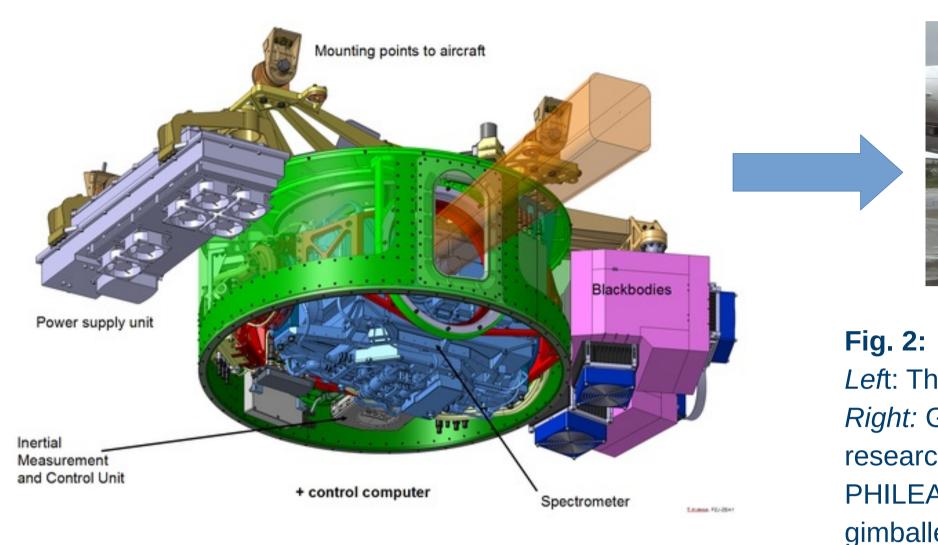


Fig. 1: Self.matching experiment during the PHILEAS campaign. A filament of Asian monsoon outflow is first tomographically measured on the 9th Sept. 2023 UTC (red hexagon, 1) and the outflow of that volume is then revisited on the 10th Sept. 2023 UTC (green hexagon, 2). The outflow from hexagon 1 is indicated until the time of hexagon 2

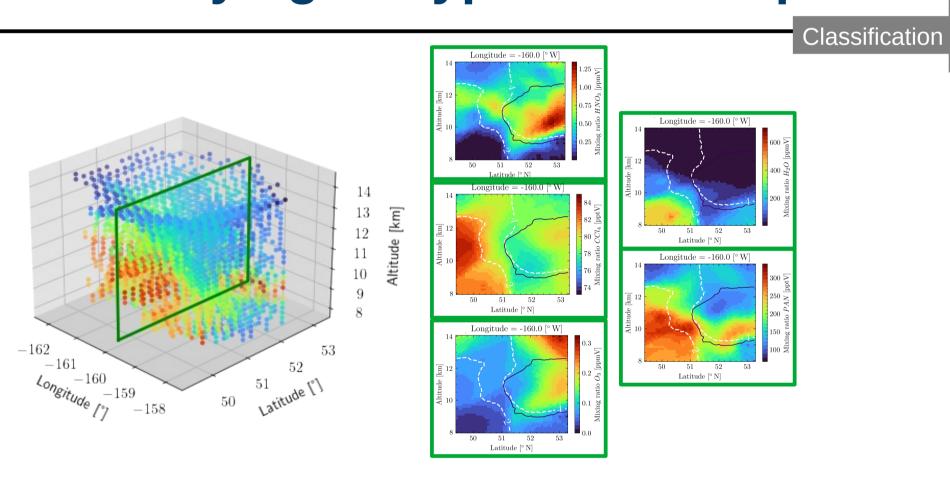


Left: The IR limb observer GLORIA. Right: GLORIA mounted underneath the research aricraft HALO during the PHILEAS campaign. The instrument is gimballed and can be panned in flight.

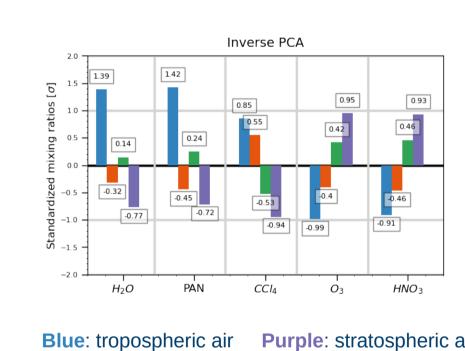
Capable of measuring multiple trace gas species from IR emission. For 3-D tomoraphic retrieval:

H₂O, PAN, CCl₄, O₃, HNO₃

Classifying air types via Computer Vision:



nterpretation First hexagon PCA Second hexagon PCA



The problem:

- What does monsoon air look like in reality?
- How many types of air have we observed?
- What does the geometry look like?

The approach:

- Condense all the information of the wide array of observed trace gases into subspace
- Train a Gaussian Mixture Model on the resulting clusters

The product:

- Classification accurately reflects the spatial structure
- Inverse transformation return the chemical composition of each cluster, allowing physical interpretation

Main results from this analysis:

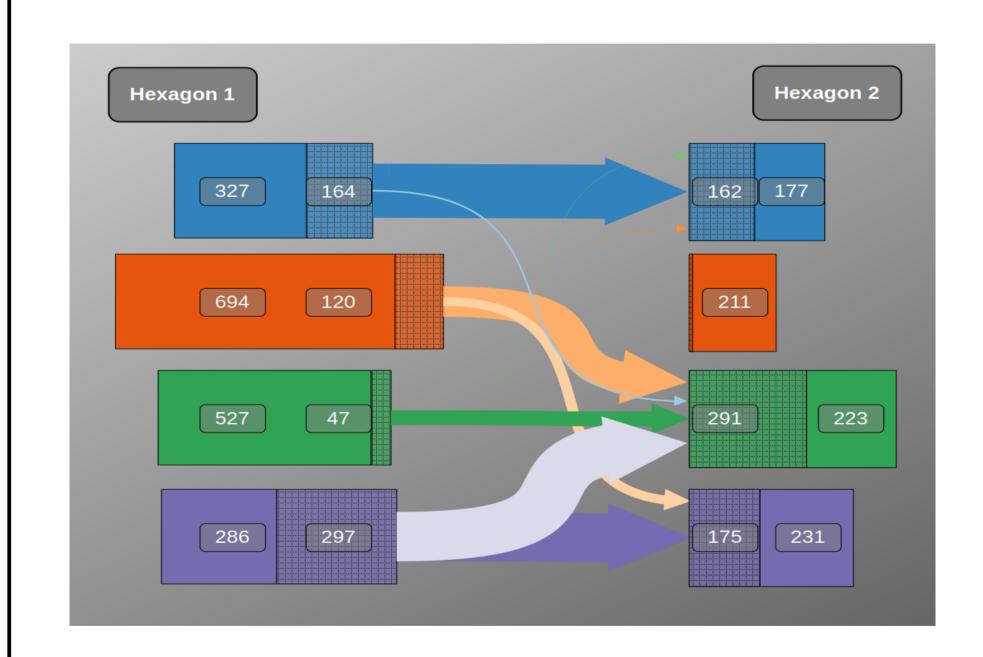


Fig. 3: Observed class transitions due to mixing. Twice measured air parcels are shown hatched. Transition arrow size is consistent in scale.

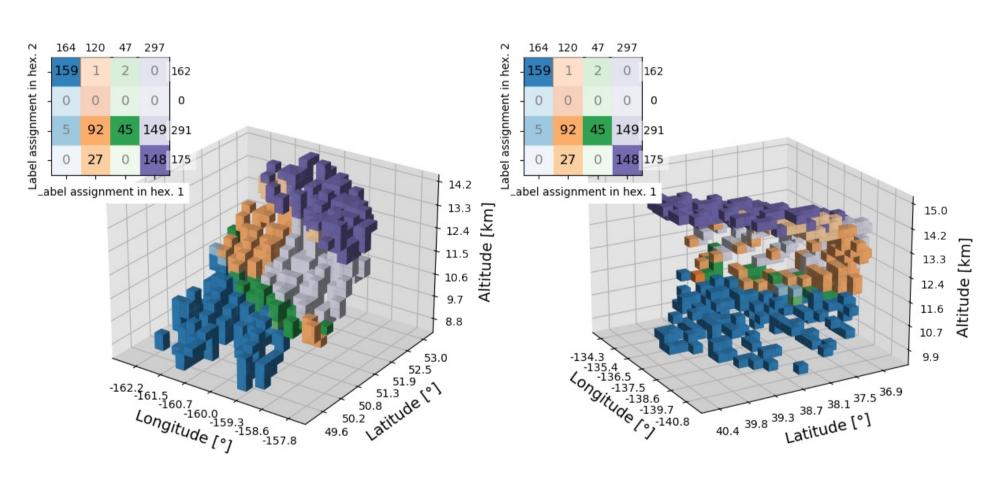


Fig. 4: Spatial resolution of mixing processes from hexagon 1 (left) into hexagon 2 (right). Color-code is consistent with Fig. 3.

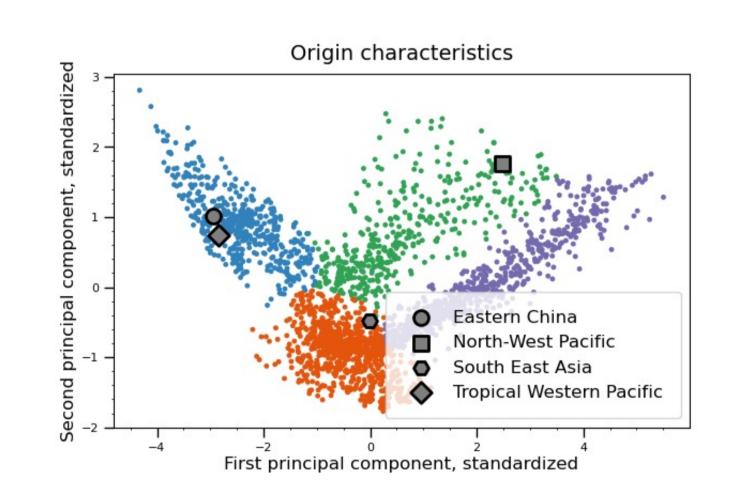
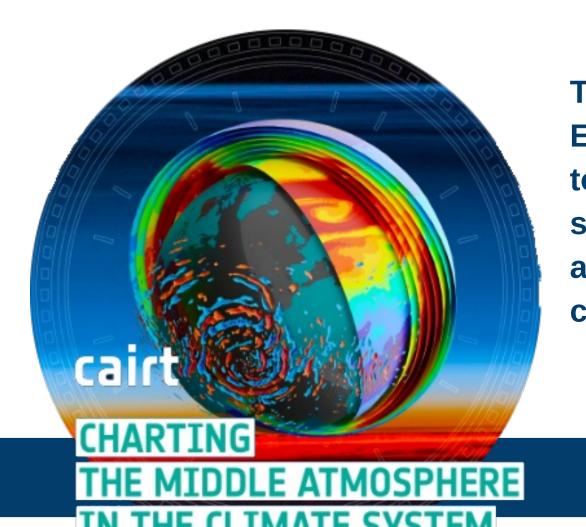


Fig. 5: Connecting air types to regions of origin. Characteristic points are derived by weighting all measurements by their origin tracer concentration. Different regions of origin show distinct characteristics.



The GLORIA instrument is the demonstrator for the ESA Earth Explorer 11 candidate CAIRT. It would be capable to perform similar 3-D tomographic measurements of the same trace gas species over a much larger altitude range and with global coverage, among many more capabilities. Find out all about CAIRT here:



