Satellite-Based Detection of Fog and Low Stratus in the Galápagos Islands

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Introduction & Objectives

Precipitation is the only freshwater source for the Galápagos Islands and is therefore essential for both the population and the endemic ecosystem. Drizzle is thought to contribute substantially to freshwater input during the cool season (Jun-Dec), especially at higher elevations (Garua Zone), which are frequently covered by Fog and low stratus (FLS). However, due to the lack of measurements, the impacts of climate change on FLS and precipitation remain uncertain. Monitoring drizzle and predicting changes associated with climate change or large-scale events such as El Niño requires a continuous, high-quality FLS cloud product with high spatio-temporal resolution, as existing products perform poorly at the local scale [1,2]. We therefore develop a locally adapted, physical FLS product based on GOES-16/-19 imagery.

FLS Detection Scheme

Fog and low stratus (FLS) are low stratiform cloud layers containing liquid droplets up to 20 µm in size, and are often responsible for drizzling precipitation [3,4]. The developed FLS detection scheme, applies multiple adopted threshold tests that adapt to local conditions by using moving window calculations to identify pixels in GOES images that match these criteria:

Data

- Based on geostationary satellite data from GOES-16 and -19.
- Full-disk scans every 10 minutes across 16 spectral bands (0.47–13.3 µm), with a sub-satellite resolution of 2.5 km.
- Level-1b (L1b) images and vertical profiles (LVPT) from 2017 to 2026 were obtained from NOAA.
- The data has been radiometrically and geometrically corrected.

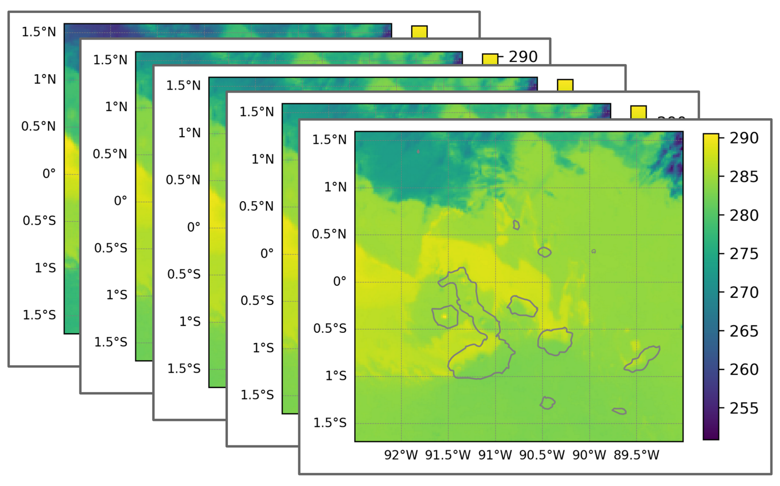

Fig. 1: Example stack of input images

Cloud identification*

- Clear pixels needed as reference pixels.
- From GRR Cloud mask [2].

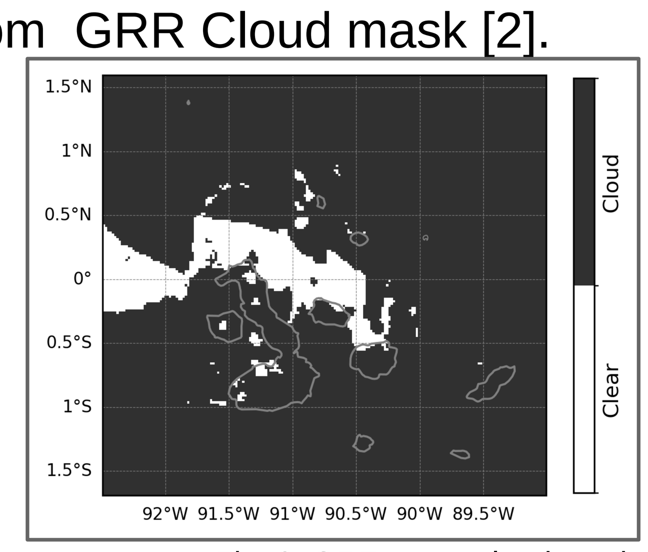

Fig. 2: GRR gross cloud mask.

High-/ mid level cloud test

- 10.3 µm cloud-top temperature thresholds.
- Trade wind inversion temperatures from vertical profiles as thresholds, as they act as a boundary to clouds below.

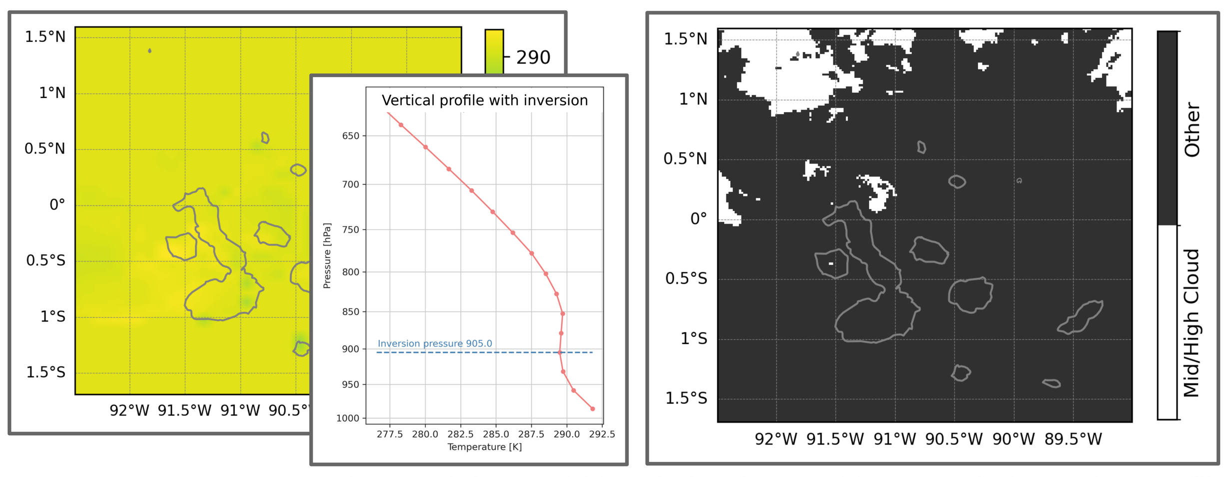

Fig. 3: High- & mid level cloud test with example inversion profile.

Cloud Phase test*

- Eliminate transparent ice clouds.
- Nighttime: split window using 12.3, 11.2, 10.3 and 8.4 µm bands [3,5],
- Daytime: 1.37 µm cirrus band threshold (>0.2).

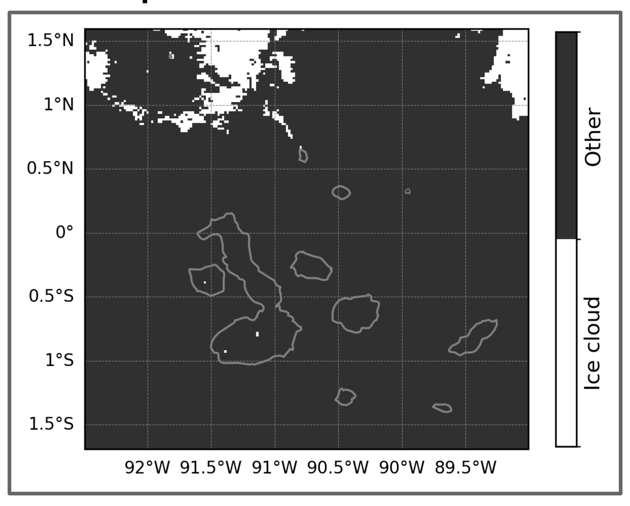

Fig. 4: Cloud-phase / cirrus cloud test.

* Adopted from [2,3,4,5]

FLS test

- Identification by calculating local thresholds for the 11.2 – 3.9 µm band difference [3,4].
- Thresholds are calculated in 50x50 moving windows to adapt to local conditions.

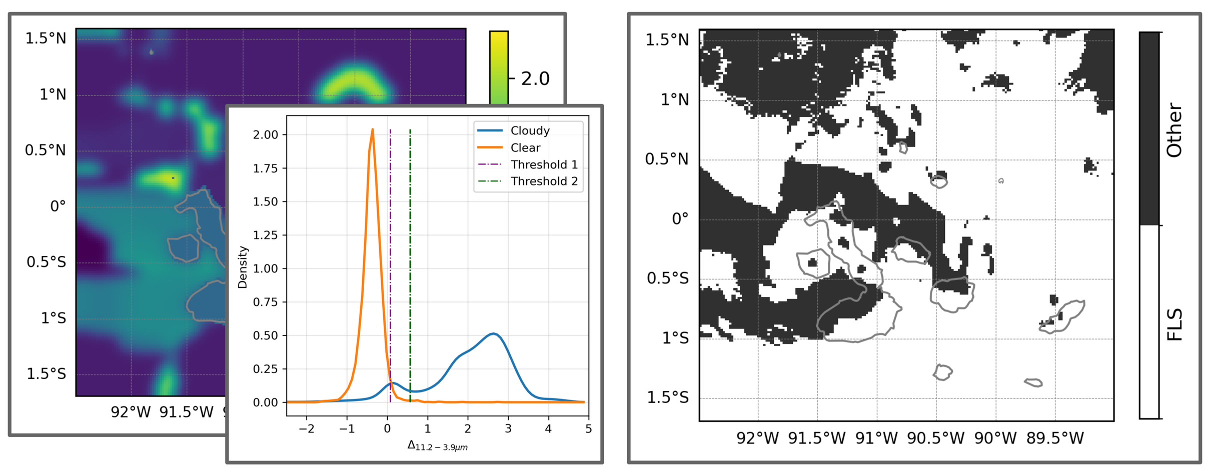

Fig. 5: FLS identification with example threshold detection.

Stratiform test*

- FLS pixels are stratiform when the SD in the 10.3 µm channel do not exceed 2.0 [3,4].

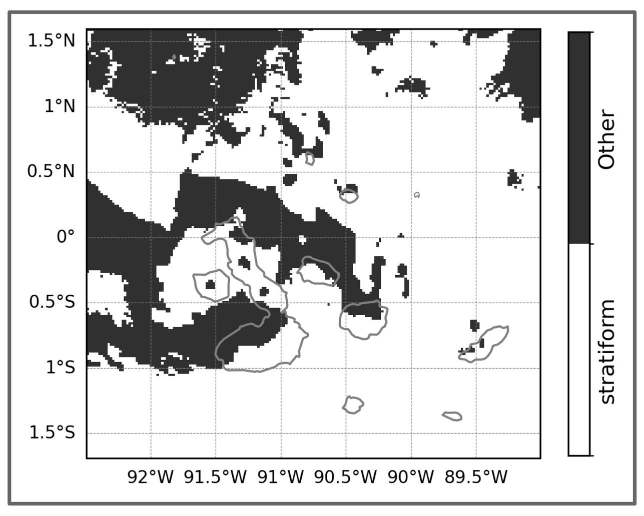

Fig. 6: Stratiformity test.

Final FLS mask

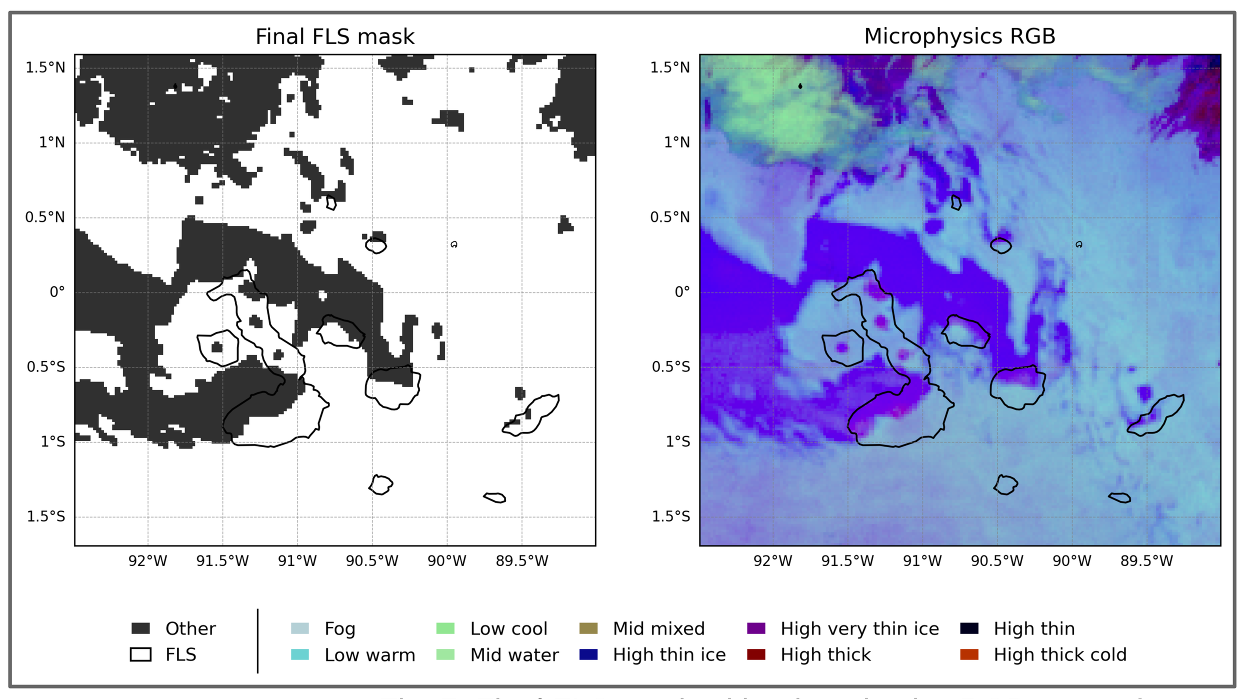

Fig. 7: Final FLS mask with microphysics RGB as a reference.

Results and Discussion

POD	FAR
0.719	0.142
Accuracy	**Precision**
0.649	0.857
F1-score	**Missed %**
0.782	28.08

Tab. 1: Performance metrics of the FLS mask.

- The FLS cloud mask performs well when validated against weather station at Cerro Crocker, which measures visibility (Fog is detected, when measured meteorological optical range drops below <1km).
- Retrieved fog occurrence matches expected patterns, with higher frequencies on windward and lower frequencies on leeward sides of the volcanic islands.
- Retrieved fog occurrence is ~5% lower than weather station observations on average.

  → The FLS mask does not exclusively detect ground fog, and upper cloud layers can obscure fog/low stratus in satellite observations, which lead to differences to ground truth observations.
- Limited number of local weather stations measuring meteorological optical range limit validation with ground truth measurements
- **Next steps:** 1) Detect ground fog from local camera images using image segmentation,

  2) Train a machine learning model with extracted spectral FLS signatures from the FLS mask and the image segmentation output to detect ground fog.

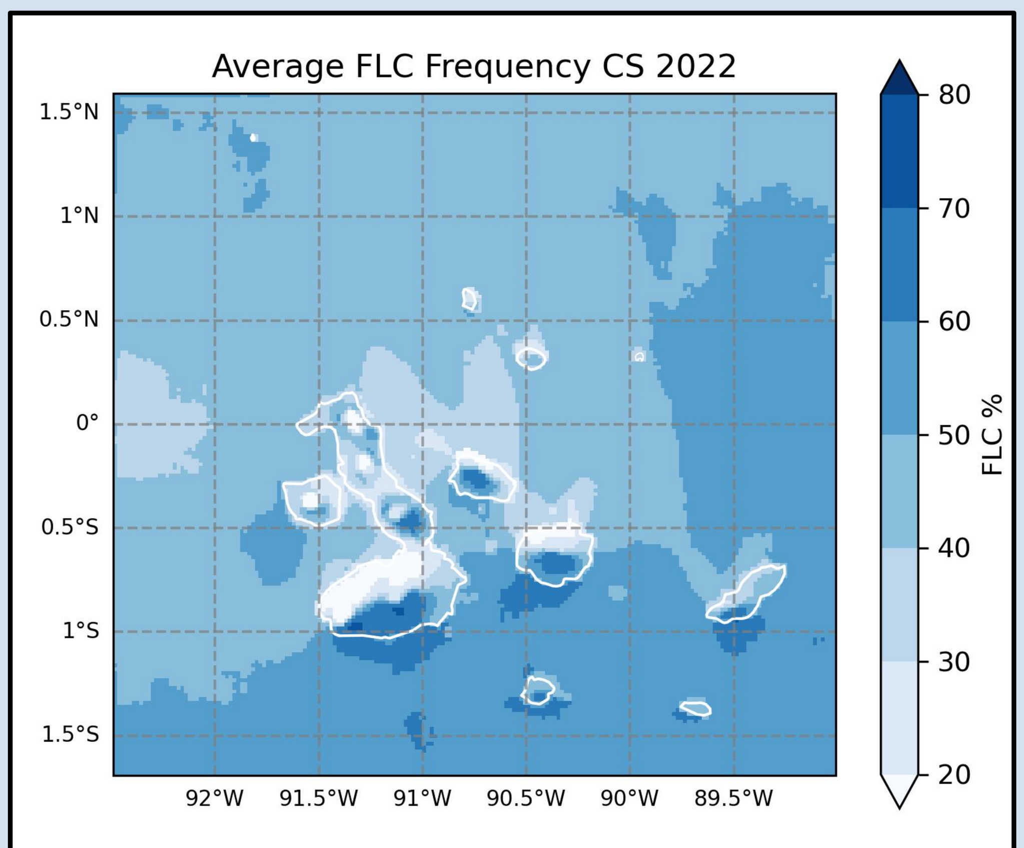

Fig. 8: FLS frequency for the cool season 2022.

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Acknowledgments

The work was carried out within the DARWIN project (Dynamics of Precipitation in Transition: The water source for the Galapagos Archipelago under climate change), is kindly funded by the Research Foundation of Germany (DFG) under the grant number BE 1780/60-1. The authors would like to thank the Charles Darwin Foundation, the Galapagos National Park Service and Ministry of Environment, Water and Ecological Transition of Ecuador for their institutional support.