Surface Echo Detection in ATLID Observations: A Foundation for Cloud Profile Classification

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Goal: detect opaque clouds and determinate their altitude

Context

Clouds significantly influence the Earth's radiative balance, particularly through their longwave (LW) cloud radiative effect (CRE). Studies using CALIPSO have demonstrated a link between opaque cloud cover, cloud altitude, and the LW CRE observed by CERES (*Vaillant de Guélis et al., 2017; Arouf et al., 2022*).

Motivation

With EarthCARE, we now have co-located lidar (ATLID) and broadband radiometer (BBR) measurements on the same satellite, providing a unique opportunity to better quantify the relationship between cloud properties and their radiative impact. The first step in this process is the accurate identification of opaque clouds and the determination of their altitude, which is the focus of this study.

Approach

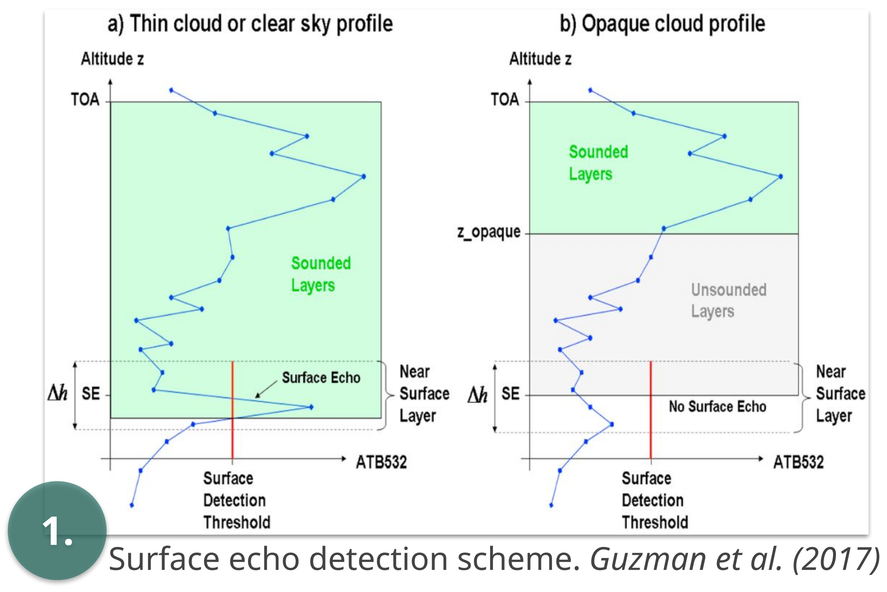
We apply a surface echo detection method based on *Guzman et al. (2017)* to ATLID observations. Profiles where the surface echo is detected are classified as clear sky or thin clouds, while those without a detected surface echo indicate full attenuation of the lidar beam and are classified as opaque clouds. This classification will be essential for linking ATLID cloud observations with BBR radiative measurements.

Method

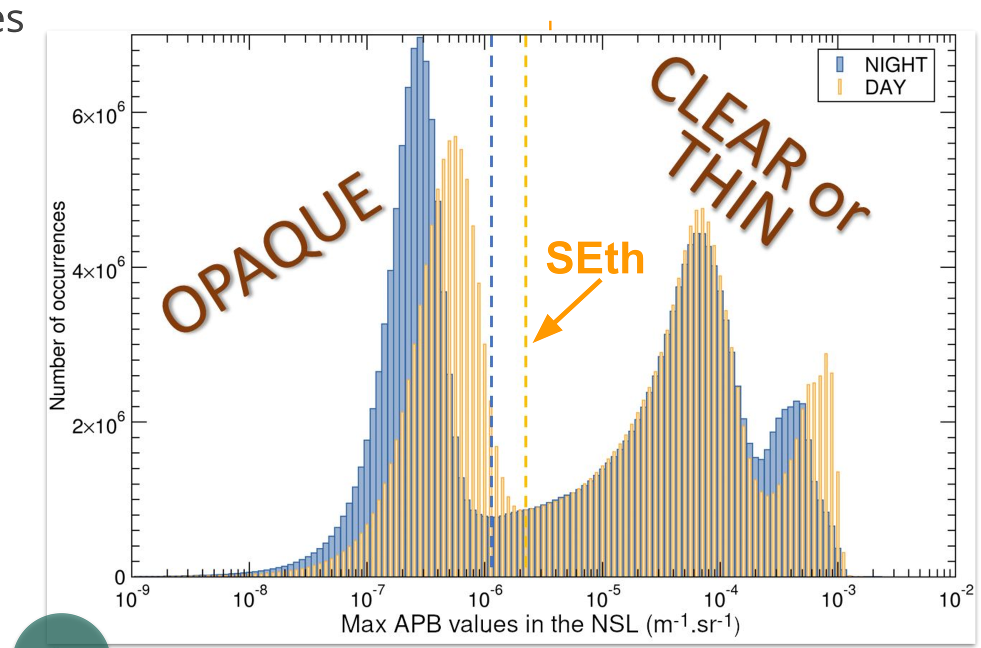
How?

1. **Determination of the Near-Surface Layer (NSL)**
   a. Read the surface altitude (DEM) for each profile.
   b. Define the NSL as the two layers above and below the detected surface altitude (each layer has a vertical resolution of 100 m).
   c. Identify the maximum Mie Attenuated Backscatter (APB) value within the NSL.
2. **Surface detection threshold**
   a. Distinguish between daytime (☀️) and nighttime (🌙).
   b. Construct a histogram of maximum APB values in the NSL from August 2024 to January 2025.
   c. Identify the surface echo threshold (SEth) to distinguish opaque cloud from clear or thin cloud profile.
   d. To avoid creating a false diurnal cycle and ensure consistency in our data we detect the opaque clouds with the daytime threshold.

	Threshold ($m^{-1}sr^{-1}$)
🌙 (1)	1,26 $\times 10^{-6}$
☀️ (2)	2,24 $\times 10^{-6}$



1. Surface echo detection scheme. *Guzman et al. (2017)*



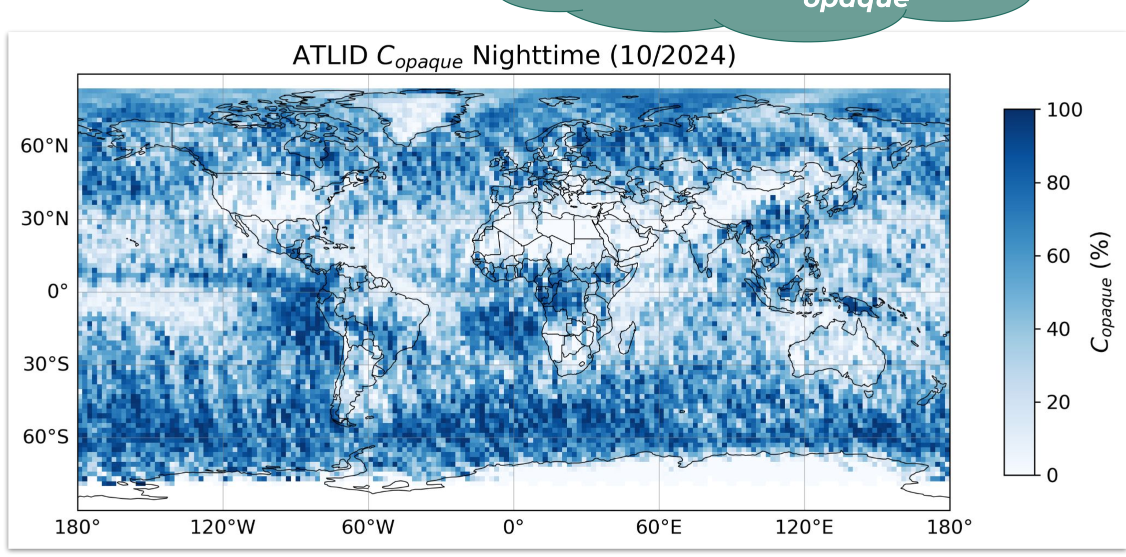
2. Surface detection threshold.

Results I: opaque cloud cover

Consistent?

C_opaque is computed as the percentage of opaque cloud profiles within each 2° x 2° latitude and longitude grid box, ensuring consistency with previous datasets (CALIPSO-GOCCP).

Opaque Cloud Cover (C_{opaque})



Case study: C_{opaque}, October 2024 (nighttime)

Results II: comparison of ATLID with CALIOP/GOCCP

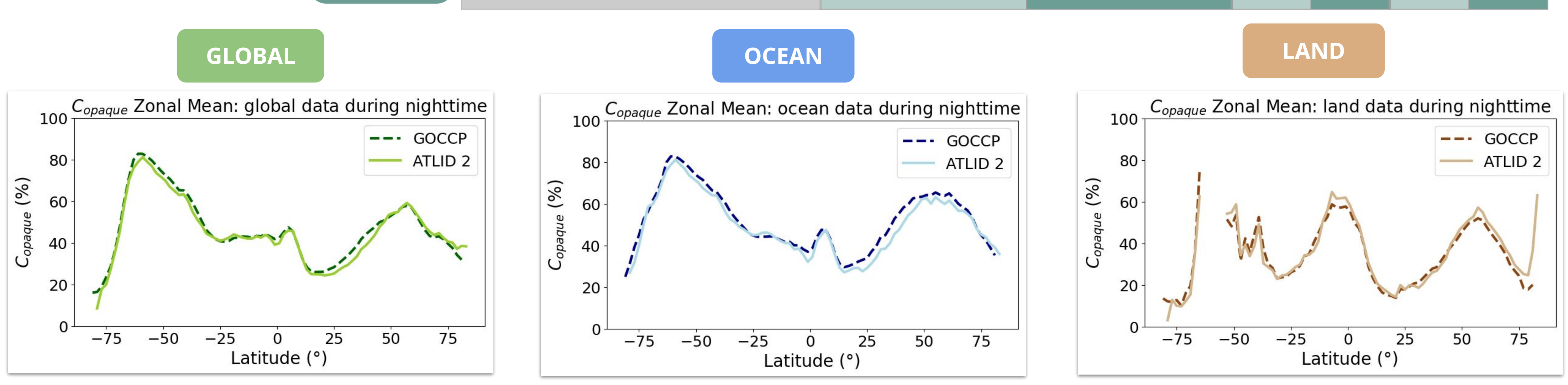
The table presents the mean C_{opaque} values derived from GOCCP (GCM Oriented CALIPSO Cloud Product) observations between 2008 and 2018, alongside the mean ATLID estimates for **October–December** 2024.

Preliminary results indicate that our ATLID data processing underestimates opaque cloud cover compared to CALIOP. This underestimation is further illustrated in the figures, which show the zonal means of C_{opaque} for both datasets.

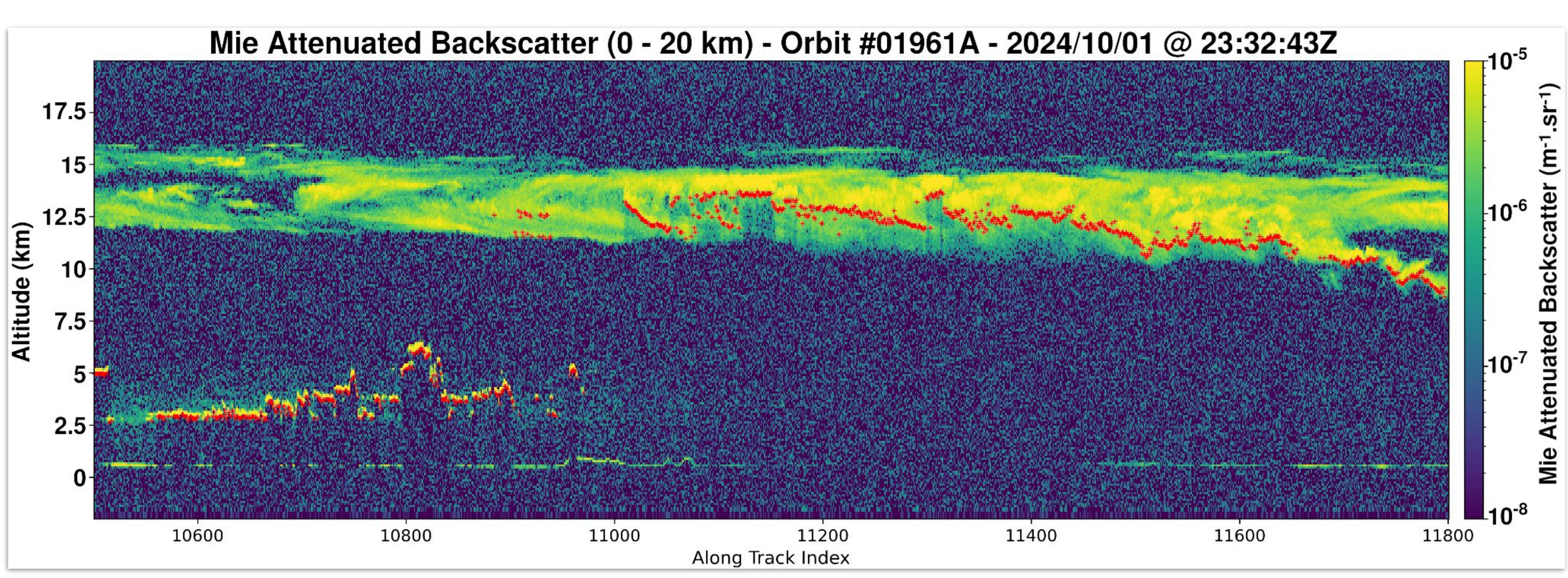
In this initial analysis, these differences exceed CALIOP's interannual variability, indicating the need for further investigation.

C_{opaque} (%)	GLOBAL ☀️	GLOBAL 🌙	OCEAN ☀️	OCEAN 🌙	LAND ☀️	LAND 🌙
GOCCP	40,30 ± 0,46	46,08 ± 0,48	47	52	33	34
ATLID 2 (2,24 $\times 10^{-6}$ $m^{-1}sr^{-1}$)	39,63	44,68	45	50	35	35

Zonal Means of C_{opaque}



Results III: altitude where the LiDAR is Fully Attenuated

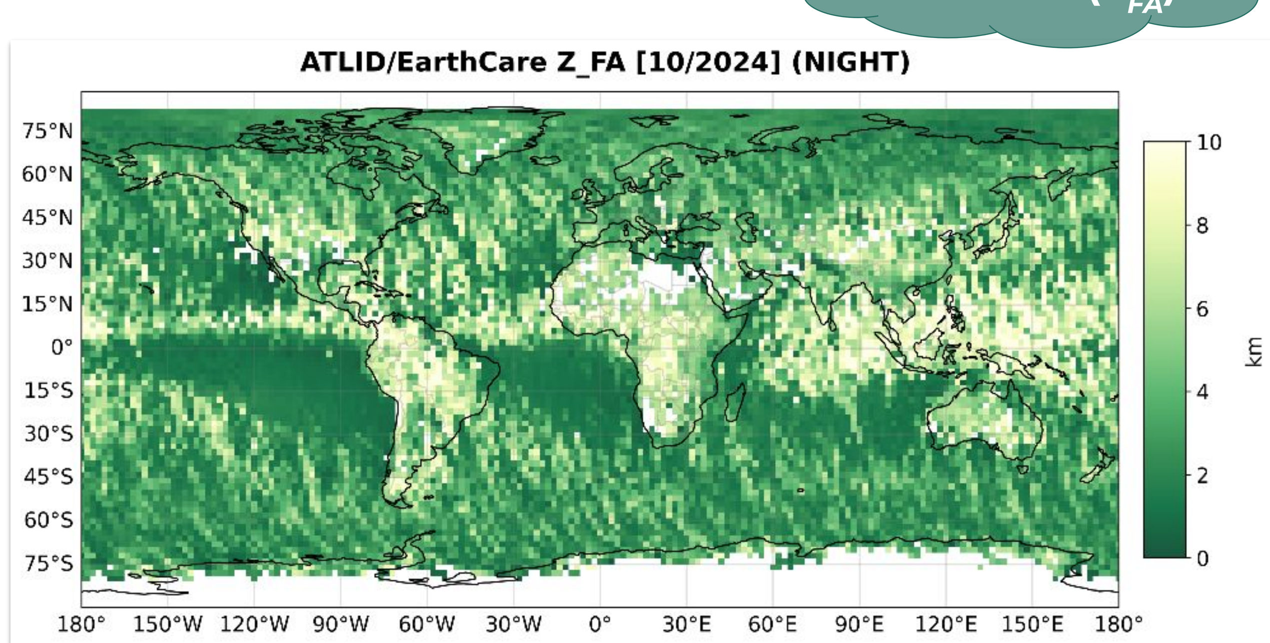


Case study: LiDAR curtain example with the determination of the altitude where the lidar is fully attenuated (Z_{FA}) in red crosses (+).

The latitude where the lidar is fully attenuated (Z_{FA}) is determined by scanning upward from the surface level to locate the first altitude where the signal exceeds an opaque cloud detection threshold (3 $\times 10^{-6}$ $m^{-1}sr^{-1}$).

These preliminary results show patterns that are consistent with those observed by *Arouf et al., 2022* for GOCCP.

Opaque Cloud Altitude (Z_{FA})



Case study: Z_{FA}, October 2024 (nighttime)

Conclusions and perspectives

Despite instrumental differences, ATLID and CALIPSO-GOCCP exhibit consistent opaque cloud detection.

Next steps:

- **Surface Echo Refinement:** Improve the treatment of the profiles where there's inconsistencies between the Digital Elevation Model (DEM) and the surface echo. Histogram analysis of the Above Surface Layer to better separate thin clouds from clear sky.
- **Polarization for Noise Reduction:** Leverage polarization data to filter aerosols and refine thin cloud accuracy.
- **Cloud Radiative Effect (CRE):** Cross-referencing ATLID with the broadband radiometer (BBR) will help assess the link between cloud properties and their radiative impact, a first with co-located instruments.

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2nd ESA-JAXA EarthCARE In-Orbit Validation Workshop
17–20 March 2025 | ESA-ESRIN | Frascati (Rome), Italy

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