Comparison of Cloudsat/CALIPSO cloud observations with ceilometer measurements over the Greenland and Antarctic ice sheets

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Introduction

Clouds play an important role in the polar climates through their influence on the surface energy and mass balance (Bintanja & van den Broeke 1996). Climate models however still struggle to correctly represent cloud macro- and microphysical properties for future climate predictions (Ettema et al. 2010). Improving cloud parameterizations in climate models needs an extensive cloud observational dataset. The harsh polar environment however hampers the ground-based cloud detections. The launch of the Cloudsat and CALIPSO satellites in 2006 marked the beginning of a new cloud observation era. These space-based cloud observations however need to be first validated at the regions of interest before they can be used in a reliable way. This study has set the beginning of a point validation of these satellites at the Summit station, Greenland and the Princess Elisabeth station, Antarctica.

Methodology

Fig. 1: Ceilometers Vaisala CL31 at Princess Elisabeth, Antarctica and CT25K at Summit, Greenland provide ground-based cloud observations

Ceilometer (Fig. 1)
- Robust laser-emitting device for cloud observations
- Present in many polar research stations

Cloud Base Height (CBH) detection algorithm
- Standard algorithms (e.g. built-in Vaisala and THT (Martucci et al. 2010)) fail to detect thin ice layers
- Low backscatter threshold algorithm solves this issue (Fig. 2)
- Noise correction and averaging is an important step

Cloudsat and CALIPSO (Fig. 3)
- CPR radar for penetrating thick clouds
- CALIOP lidar for detecting thin features
- Need to overpass ground stations within radius of 10 km
- Ground observations are compared to satellite observations

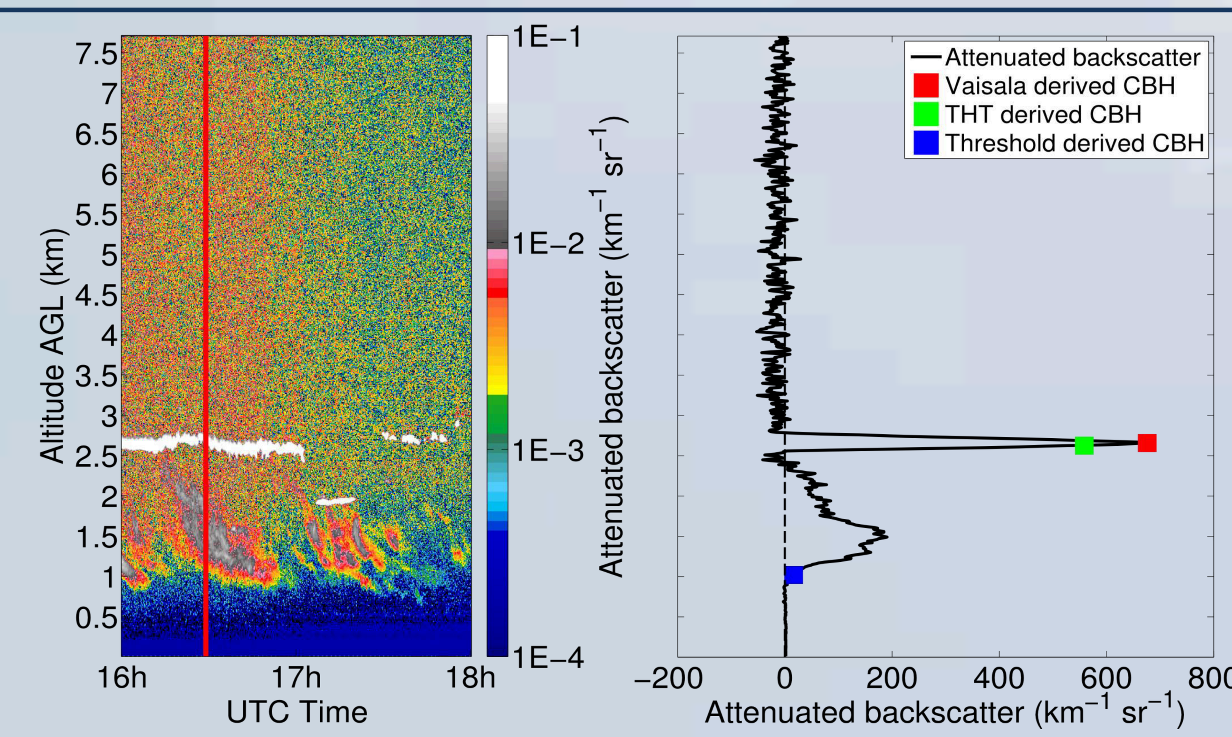

Fig. 2: Detection of thin ice layers by new backscatter threshold CBH detection algorithm: every backscatter value in a noise reduced profile is checked in bottom-up approach until threshold is exceeded (Case: PE, March 8, 2010)

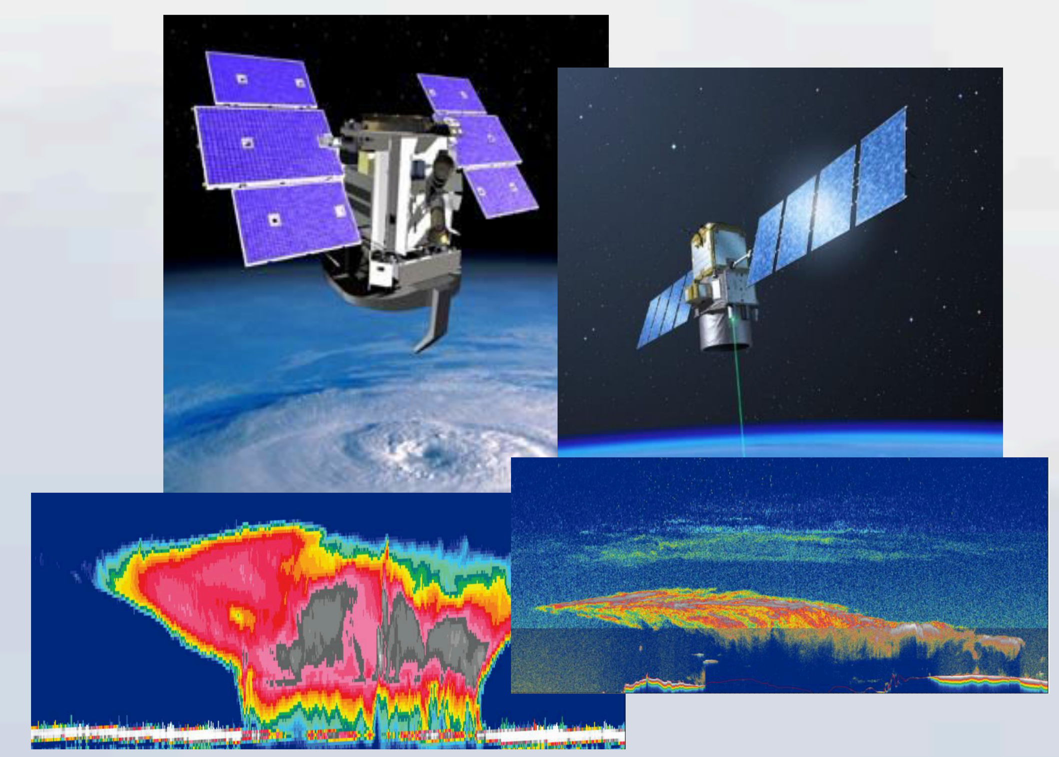

Fig. 3: Cloudsat radar and CALIPSO lidar for space-based cloud observations (Source: Nasa.gov and ccplot.org)

Results

CBH detection algorithm (Fig. 4)
- New algorithm is much more sensitive
- Detection of 'first hydrometeor feature'
- Detection of optically thin ($\delta < 0.1$) ice layers
- Basis for more quantitative comparison

Qualitative comparison with satellites (Fig. 5)
- Overall good agreement
- Ceilometer detects cloud base
- CALIPSO detects cloud top
- In thick clouds, both lasers attenuate
- Cloudsat penetrates thick clouds, but suffers from groundclutter. It misses many important near-surface features

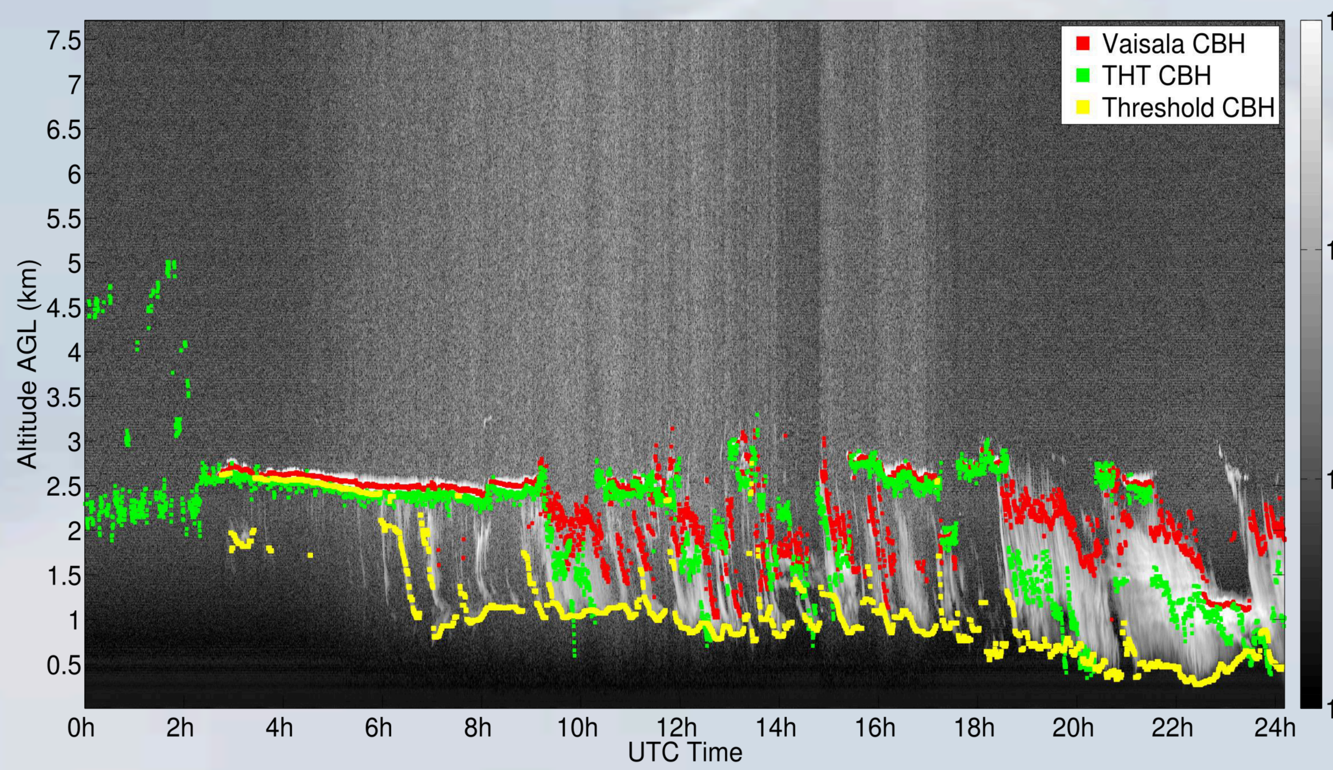

Fig. 4: CBH detection by standard algorithms and new backscatter threshold algorithm. The new algorithm effectively detects lower CBH and optically thinner features (Case: PE, March 8, 2010)

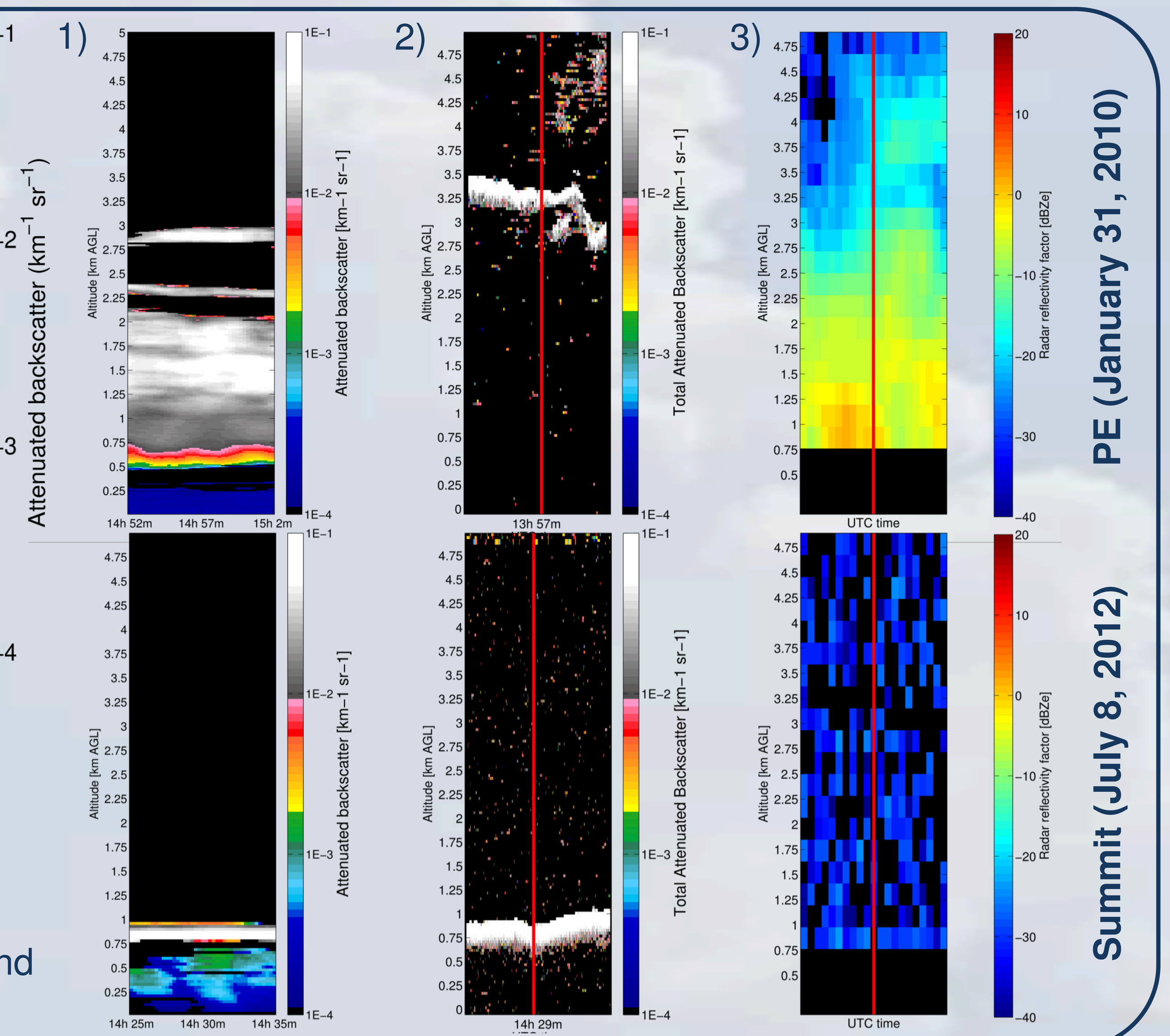

Fig. 5: Qualitative comparisons between ceilometer (1) and Cloudsat (3) / CALIPSO (2) for a PE and a Summit case.

Discussion and conclusion

The ceilometer's bottom-up and CALIPSO's top-down approach should perhaps be rather used in an integrating way instead of a validating way. Using the new backscatter threshold CBH detection algorithm, the ceilometer effectively detects the cloud base, while CALIPSO detects the cloud top. The usability of Cloudsat for these purposes is still under question. Most cloud features occur near the surface, where Cloudsat suffers from ground clutter. This study has focused on (i) preparing the ground-based observations by noise reduction and developing an improved CBH detection algorithm and (ii) on setting up a dataset with combined ground-based and satellite-based observations. We did a first qualitative comparison to point out opportunities and problems of the satellite observations for the detection of clouds over the ice sheets. A more quantitative approach is carried out in the near future.

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