COMPARISON CASE BETWEEN CALIPSO LIDAR AND MALS ON M55 GEOPHYSICA DURING RECONCILE CAMPAIGN

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ABSTRACT

We present an example of successful comparison between the measurements of the total and depolarisation backscatter between CALIPSO lidar and two miniature aerosol lidars on high altitude research aircraft M55 "Geophysica". The comparison is performed during one of the flights of M55 in the campaign RECONCILE (EC FP7 GA 236365) [1].

RECONCILE is a 4-year research project dedicated to updated detailed study of the Arctic ozone depletion. A key component in RECONCILE is the field measurement campaigns of coordinated aircraft, balloon and ground-based measurements. The aircraft campaign implemented high-altitude research aircraft M-55 Geophysica and took place from Kiruna Airport, Sweden (Fig. 1). The two backscatter lidars MAL1 and MAL2, probing the atmosphere respectively above and below the aircraft, were part of the research payload of Geophysica.

The measurements from the spaceborne lidar CALIPSO (Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations) within RECONCILE, provided an overall vortex-wide view of the 2009-2010 Arctic PSC season, contributing to the aircraft and balloons flight planning and data interpretation.

The flight with the reported comparison was performed on 20 January 2010.

1. CALIPSO LIDAR

CALIPSO is in a 705-km altitude, 98-degree inclination orbit and is part of the "A-Train" constellation that also includes the Aqua, CloudSat, and Aura satellites [2]. Although PSCs are not one of its primary mission objectives, CALIPSO has proven to be an ideal platform for studying these clouds [3, 4] since its orbit provides extensive coverage (14 orbits/day on average) of the polar regions up to 82 degrees latitude.

The CALIPSO lidar measures elastic backscatter at 532 nm and 1064 nm, with the 532-nm signal separated into parallel and perpendicular polarization components [4]. The lidar pulse rate is 20.25 Hz (one profile every 333 m along the orbit track), and the fundamental vertical resolution is 30 m. However, an altitude-dependent onboard averaging scheme is employed to reduce downlinked data volume.

In the region of the reported comparison, the resolution of the CALIPSO lidar data is 1 km horizontal and 60 m in the vertical

Fig. 1. The research aircraft M55 "Geophysica" taking off Kiruna Airport (January 2010, RECONCILE Campaign)

2. MAL1 AND MAL2 ON M55 GEOPHYSICA

The lidars MAL1 and MAL2 (Miniature Aerosol Lidars Mk1 and Mk2) are elastic backscatter-depolarization instruments, operating at 532 nm [5, 6]. They operate with micropulse lasers, having pulse repetition rates of 4.5-5.5 kHz and are packed each in a single pressurised box having dimensions 510x320x170 mm³ and mass 33.4 kg. MAL1 is installed on Geophysica for upward probing, while MAL2 is installed for downward probing – seen in Fig. 2.

MAL1 and MAL2 are long-term parts of the M-55 payload. Results from campaigns are presented in [6-8].

Fig. 2. MAL1 (left) and MAL2 (right) installed on M-55.

3. RECONCILE FLIGHT ON 20 JANUARY

The RECONCILE flight on 20 January 2010 took place in an Arctic synoptic situation characterised by extremely low vortex temperatures, compared to previous winters. Due to this, considerably more PSCs were observed by CALIPSO, [9], notably in the period 15 December 2009 - 21 January 2010. The consolidated CALIPSO observations show also Type 1a-enh PSCs, i.e. higher number density liquid/NAT mixtures, as most frequent above 18–20 km altitudes, while Type 1a PSCs, i.e. lower number density liquid/NAT mixtures, were most frequent below 18–20 km

The flight of 20 January 2010 was planned for both PSC observation and for coordinated measurements with the CALIPSO lidar. The overlap between the M55 flight path and CALIPSO track took place for an approximately 12-minute period, between 35800-36600s UTC. The overlapping coordinates and the time are illustrated in Fig. 3.

During the overlap, both CALIPSO lidar and the two MAL instruments detected PSC and cirrus. In Fig. 4, the CALIPSO cloud composition "curtain", shows the presence of PSC and cirrus in the collected data.

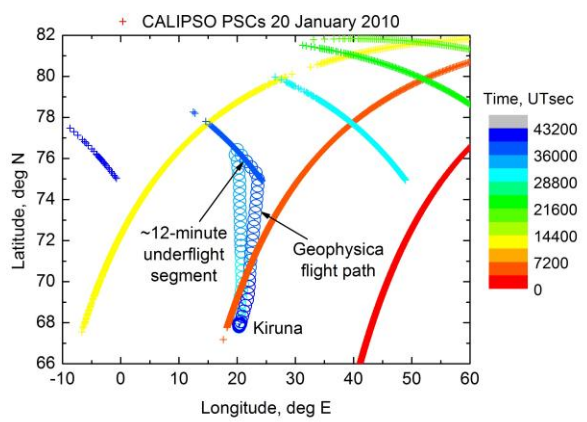

Fig. 3. The CALIPSO orbit tracks and the M55 Geophysica flight path on 20 January 2010 at latitudes and longitudes where the RECONCILE Campaign took place.

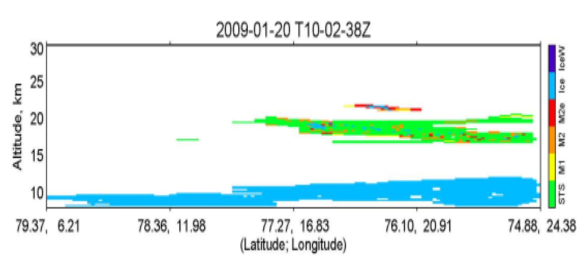

Fig. 4. CALIPSO clouds composition "curtain"; ~10:00 UTC orbit, 20 January 2010

A time-altitude cross-section of the combined MAL1 and MAL2 measurements of backscatter ratio (total), where the overlap period is included, is presented in Fig. 5. The thin black line in the figure is the aircraft altitude. As we see, the MALs measurements also show PSC and cirrus clouds structures, at the altitudes where these were observed by CALIPSO. Figure 6 presents a zoom of the MALs observations of the PSC structure only for the overlap period 35800-36600s UTC.

The depolarisation ratio of the PSC and the underlying cirrus is shown in Fig. 7 (only MAL2, probing down from M55).

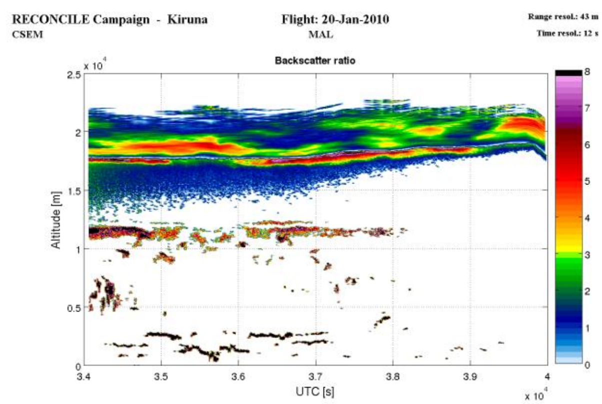

Fig. 5. Time-altitude cross-section of MAL1 and MAL2 measurements on 20 January 2010 – backscatter ratio.

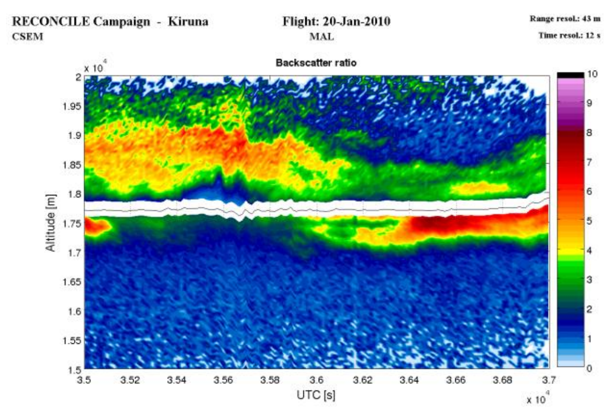

Fig. 6. Time-altitude cross-section of MAL1 and MAL2 measurements on 20 January 2010 – backscatter ratio, zoom around PSC altitudes for the overlap period.

4. CALIPSO-MALS COMPARISON

For the comparison, we present on the same figures, the total backscatter coefficient and its cross-polarized component derived from the measurements of CALIPSO lidar, MAL1 and MAL2, and then averaged for the overall overlap period 35800s – 36600s. These values are plotted together in Figs. 8-11. The altitude resolution is: 60m for CALIPSO lidar and 43m for the two MALs.

The total backscatter coefficient at PSC and cirrus altitudes, are presented respectively in Fig. 8 and Fig. 9. Figures 10 and 11 present the cross-polarized component of the backscatter coefficient, respectively at PSC and cirrus altitudes. We also present profiles of the average +/- one standard deviation, (only non-negative values, for CALIPSO measurements).

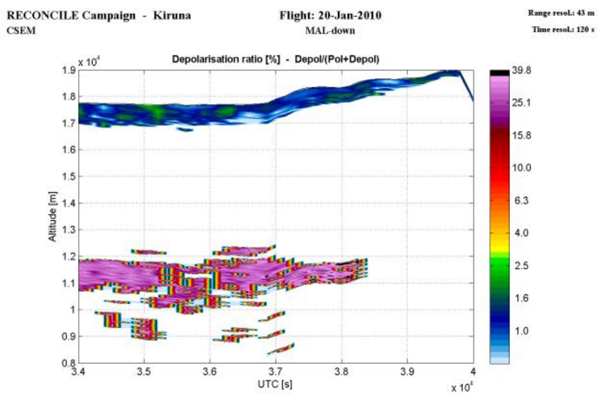

Fig. 7. Time-altitude cross-section of MAL2 measurements on 20 January 2010 – depolarisation ratio.

5. CONCLUSION

We may conclude that the comparison between CALIPSO and MALs lidars is very good. It is best for PSC measurements where this is also achieved for quite low values for the backscatter coefficient and particularly for its cross-polarized component (Figs. 8 and 10). We see some differences at the cirrus altitudes 10.5km-11km and 11.5km-12km, while for the rest of the cirrus altitudes the coincidence is also very good.

One reason for such not-exact coincidence at some of the cirrus altitudes is in the not exact coincidence between the respective probing tracks. Another reason is the different sampling: Along the track for comparison, having a length of approx. 160km, MALs probed practically continuously, while CALIPSO lidar probed with approx. total of 400 pulses, i.e., sampling at 400points. As PSC are more homogeneous than the cirrus and the cirrus looks quite variable in space (and very likely in time, as may be judged from Fig. 5), the comparison at cirrus altitudes is more affected.

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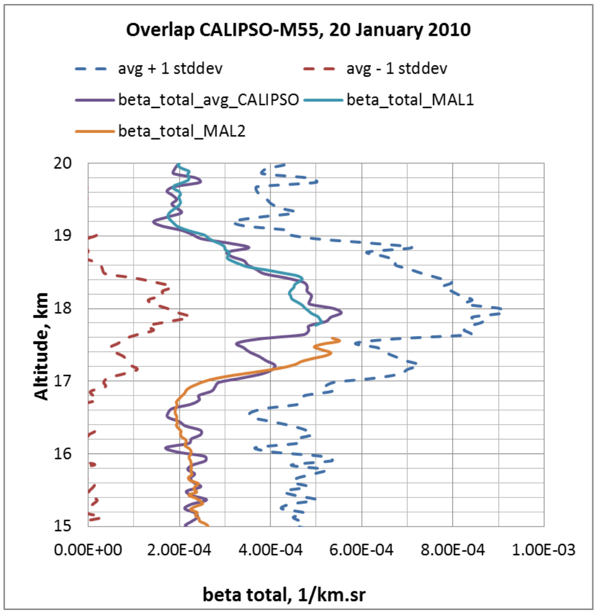

Fig. 8. Profiles of the total backscatter coefficient derived from the measurements of CALIPSO lidar, MAL1 and MAL2, averaged for 35800s – 36600s, flight on 20 January 2010: Comparison at PSC altitudes.

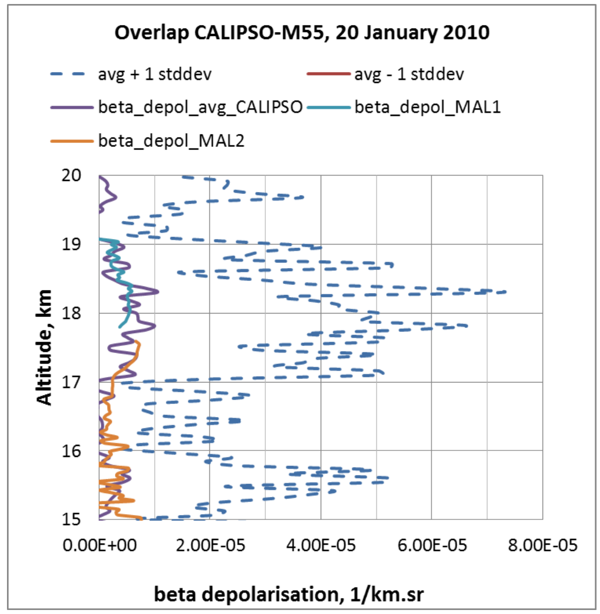

Fig. 10. Profiles of the cross-polarized component of the backscatter coefficient derived from the measurements of CALIPSO lidar, MAL1 and MAL2, averaged for 35800s – 36600s, flight 20 January 2010: Comparison at PSC altitudes.

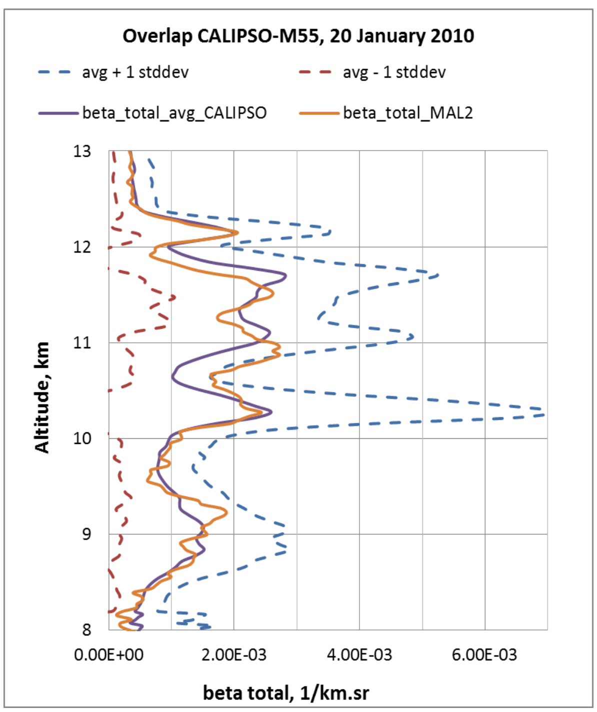

Fig. 9. Profiles of the total backscatter coefficient derived from the measurements of CALIPSO lidar, MAL1 and MAL2, averaged for 35800s – 36600s, flight on 20 January 2010: Comparison at cirrus cloud altitudes.

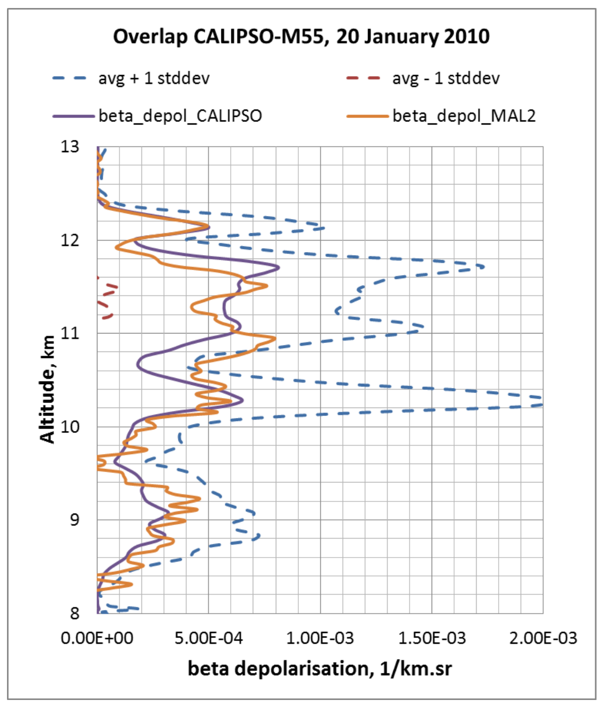

Fig. 11. Profiles of the cross-polarized component of the backscatter coefficient derived from the measurements of CALIPSO lidar, MAL1 and MAL2, averaged for 35800s – 36600s, flight 20 January 2010: Comparison at cirrus cloud altitudes.