ACTIVE SENSOR SYNERGY FOR ARCTIC CLOUD MICROPHYSICS

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ABSTRACT

In this study, we focus on the retrieval of liquid and ice-phase cloud microphysics from space-borne and ground-based lidar-cloud radar synergy. As an application of the cloud retrieval algorithm developed for the EarthCARE satellite mission (JAXA-ESA) [1], the derived statistics of cloud microphysical properties in high latitudes and their relation to the Arctic climate are investigated.

1 INTRODUCTION

In recent years, space-borne lidar and cloud radar have been widely used to investigate global three-dimensional cloud properties [2][3]. Advanced research has been performed such as to investigate the relation of clouds to the observed recent-year change in sea ice concentration in the Arctic region [4][5]. Combined use of lidar and cloud radar provides reliable estimate of cloud phase and cloud microphysical properties, which are expected to further help quantify the radiative effect of each cloud phase categories in the arctic that has not been fully done. Still, ambiguity exists in the reliability of low-level cloud detection and cloud-base height estimate from space-borne lidar. In addition, multiple scattering effects on lidar backscattering coefficient and depolarization need to be considered when retrieving water cloud microphysical properties. The main objective of this paper is to use both ground-based and space-borne lidar/cloud radar to complement each other and then use the evaluated liquid and ice-phase cloud microphysics obtained by satellites for the cloud-sea ice interaction studies in the Arctic.

2 DATA AND METHODOLOGY

2.1 Observation data

Here we briefly describe the observation data. In 2013, FMCW 95GHz cloud radar FALCON-A (Chiba University) has been installed at Ny-Alesund, Svalbard and collocated measurement with Polarization Micro-Pulse Lidar (PMPL; National Institute of Polar Research) has been conducted for the first time in the arctic region near Europa. The PMPL data used in this study are obtained with vertical and temporal resolutions of 30m and 300sec, respectively. FALCON-A has 48m and 10sec, resolution. Time-height plot of the observables of PMPL and FALCON-A interpolated to 48m and 300sec resolution obtained in 2013 are shown in Fig. 1. It is seen that major parts of the cloud consist from low depolarization ratio (< 10%) regions, which indicate the presence of horizontally oriented ice particles (2D-ice) or super-cooled water.

For satellite data, Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations (CALIPSO) and CloudSat data are used in this study. The CloudSat/CALIPSO merged data set created at Kyushu University (KU-merged data) was used, which is created by projecting the cloud-masked CALIPSO data onto the CloudSat grid with the same 240m vertical and approximately 1km horizontal resolutions [6]

2.2 Retrieval algorithm

Basically the same cloud mask and cloud particle type classification scheme developed for CloudSat/CALIPSO and EarthCARE are applied to both ground-based and satellite data [6][7]. The retrieval of ice and water cloud microphysics was performed based on the algorithm developed in

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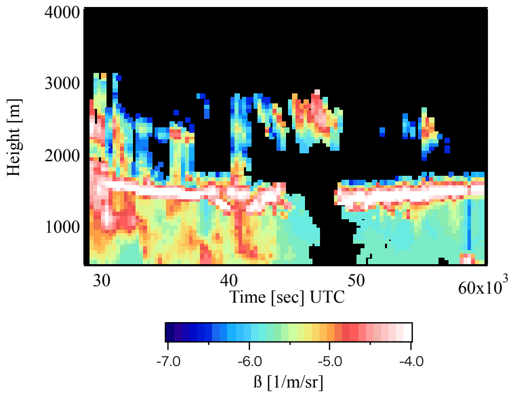
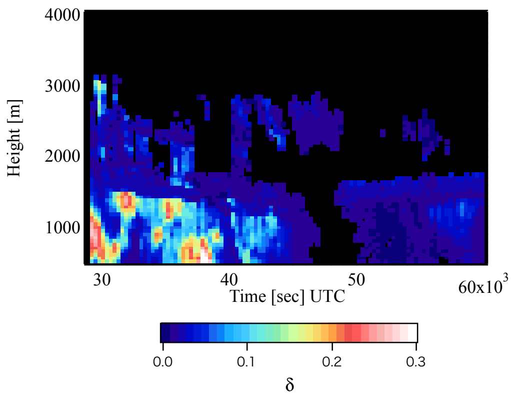
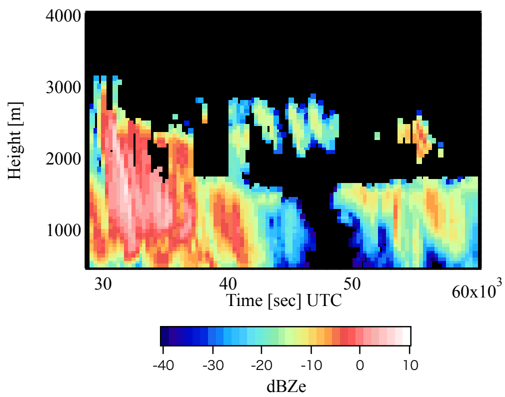
[2][8][9], but with further improvements made in the lidar forward model for liquid phase that accounts for multiple scattering in both backscattering coefficient and depolarization ratio, and also extended to take into account ice and liquid mixture as well as 2-D/3-D ice mixtures [2] within a cloud or within the same lidar and radar grid.



(a.)



(b.)

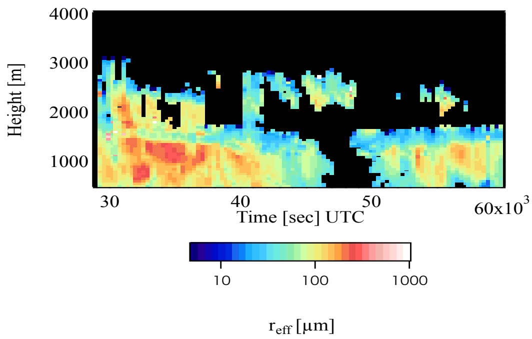


(c.)

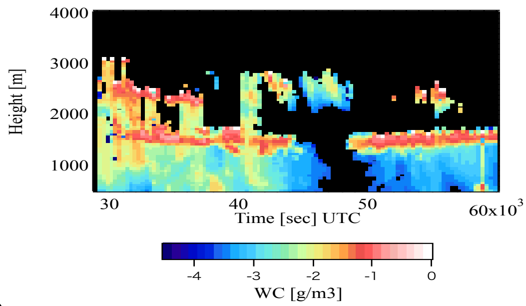
Fig. 1 Time-height plot for the (a.)(b.) attenuated backscattering coefficient β and depolarization ratio δ at 532nm obtained by PMPL, and (c.) radar reflectivity factor obtained by Falcon-A.

3 RESULTS

Comparison of the vertical cloud frequency of occurrence obtained by ground-based and space-borne lidar/radar measurement was performed during satellite overpasses within the observation period 2013-2015. The cloud frequency of occurrence below (above) 2km obtained by CALIOP (PMPL) tended to underestimate the PMPL (CALIOP) value when fully attenuated pixels where not considered in the statistics. The agreement was improved after developing a new cloud mask scheme to identify fully attenuated pixels [10][11]. On the other hand, there was an overall agreement between the cloud radars when attenuation due to wet Radome is taken into account.



(a.)

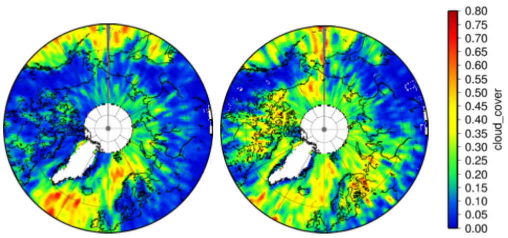


(b.)

Fig. 2 Time-height plot for (a.) the retrieved effective radius (r_{eff}) (b.) total ice and water content (WC).

The microphysical properties retrieved for the ground-based observation are shown in Fig.2. The effective radius r_{eff} and total water content within the thin layer with high backscatter coefficient and low depolarization ratio located around 1.5km were around 20~30 μm and 10^{-2}~10^{-1} g/m^3, respectively. The particle types of the layers are identified as mixture of super cooled water and ice partictles. The ice particles falling out of this region have r_{eff} around 100 μm and ice water content of 10^{-3} g/m^3. Similar features were also seen in the satellite retrieval data.

The cloud properties obtained by satellite data in the Arctic (latitude > 65 degrees) were partitioned into low-level, mid-level and high level. The water cloud coverage and its variability obtained by CALIOP was the largest at low-level throughout the year. The maximum and minimum water cloud coverage appears around May/ September and July, respectively. Relation between the seasonal variability of low-level water cloud coverage to the sea ice concentration obtained from the passive microwave radiometer Aqua/AMSER-E during the period 2006-2010 showed similar tendency as indicated in previous studies [4]. The retrieved water and ice cloud microphysical properties will be further analyzed to estimate their radiative effects in future study.



(a.) (b.)

Fig. 3 Cloud coverage of water cloud in the 0.5-1.5km altitude range obtained from CALIOP data in (a.) july and (b.) September 2008

4 CONCLUSIONS

Ground-based lidar and cloud radar data obtained at Ny-Alesund were used to evaluate vertical cloud properties retrieved from CloudSat/ CALIPSO satellite data during overpasses in the period 2013-2015. Cloud frequency of occurrence observed by both platforms showed overall agreement with each other when fully attenuated pixels were removed from the statistics. Water cloud microphysics was retrieved by taking into consideration the multiple scattering effects on lidar backscattering coefficients and depolarization ratio. Mixed phase condition was also analyzed by extending ice cloud microphysics retrieval scheme. The retrieved cloud microphysical properties will be used to investigate their radiative effects in the Arctic. The algorithms used in the studies will be adapted for the high spectral resolution lidar ATLID, and Doppler cloud profiling radar CPR onboard EarthCARE.

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