A-3.2 Studies on Data Utilization Methods for Space-Borne Lidars

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Abstract Space-borne lidars are effective tools for observing global distributions of clouds and aerosols, which play important roles in the radiative processes related to the climate change. This study aims at establishing data reduction algorithms and data utilization methods for space-borne lidars. Data reduction algorithms for deriving distributions and optical characteristics of clouds and aerosols were studied by means of computer simulation. The algorithm was tested using the simulation data generated with a space lidar simulator program based on an atmospheric model and the realistic lidar system parameters. The developed algorithm was also applied to the data of the Lidar In-Space Technology Experiment (LITE) which was carried out by NASA in 1994 with the space shuttle. Data utilization methods for applying space lidar data to climate studies were studied using data from ground-based lidars and a ship-board lidar. Methods for validating space-borne lidar observation and researches combining space-borne lidar data and ground-based (ship-board) lidars were investigated. Applications to validation of climate models were also investigated.

Key Words space-borne lidar, laser radar, cloud, cirrus, aerosol, climate model

1. Introduction

Three-dimensional observation of the global distribution of clouds and aerosols is one of the most important means by which we can better understand the radiative processes related to climate change. Clouds have a large radiative effect that strongly depends on their vertical structure. Aerosols have a radiative effect directly through scattering and absorption, and they also have an indirect effect through the formation of clouds. However, we have insufficient knowledge of the distribution and the characteristics of aerosols, the processes of cloud formation, the vertical structure of clouds, and the radiative feedback of clouds and aerosols. Consequently, these processes are not dealt with precisely in the climate models, which causes uncertainty in the model predictions. Space-borne lidars are among the most effective tools for observing the global distributions of clouds and aerosols as demonstrated by the Lidar In-space Technology Experiment (LITE) and are useful for the validation of climate models and for process studies related to climate change.

The National Space Development Agency of Japan (NASDA) had been developing the Experimental Lidar in Space Equipment (ELISE) for the Mission Demonstration Test Satellite-2 (MDS-2). However, the MDS-2 program was canceled in the review of Japanese space programs after the launch failure of H-II rocket in November 1999. In this study, we studied data reduction methods and data utilization methods originally for ELISE. After the cancellation of ELISE, we broadened the target of the study to include the future programs. NASDA is currently studying the possibility of the joint Earth radiation mission "EarthCARE" with the European Space Agency (ESA). EarthCARE employs a lidar, a cloud-profiling radar (CPR), an imager, and radiometers on the same satellite.

2. Objective

This study aims at establishing space-borne lidar data analysis methods and data reduction algorithms for extracting distribution and optical characteristics of aerosols and clouds. This study also aims at developing methods for utilizing space-borne lidar data in validation of the climate models and in the studies for understanding radiative processes of the atmosphere.

In the space-borne lidar data analysis, we have to consider problems such as low signal-to-noise ratio, limited spatial resolution and coverage, limitation in penetrating optically thick targets, and effect of multiple scattering. We investigated data analysis methods considering these problems to extract the maximum information for application studies.

3. Method

This study consists of the following two parts.

(1) Study on space-borne lidar data reduction algorithms

Data analysis methods were studied for cloud detection and for retrieving optical characteristics of cirrus, stratospheric aerosols, dust layers, and boundary layer aerosols. Data reduction algorithms were developed and tested using the simulated signals. The simulated signals were generated using a realistic 2 dimensional atmospheric model and the lidar parameters for ELISE. All possible noises were simulated numerically. The developed algorithms were evaluated also with the data of the Lidar In-Space Technology Experiment (LITE), which was carried out by NASA in 1994 with the space shuttle.

(2) Study of space-borne lidar data utilization methods

Statistical method for validating cloud and aerosol distributions in the climate models was studied using long-term ground-based lidar data, ship-board lidar data taken in the western Pacific, and the CCSR aerosol climate model.

4. Results

Data reduction algorithms were developed for various targets. The simulation study for ELISE showed that ELISE can observe distribution of most types of clouds, optical characteristics of cirrus, stratospheric aerosols, dust aerosols, and boundary layer aerosols. In the observation of stratospheric aerosols and cirrus, we can apply optical depth constrained algorithm to retrieve backscattering coefficient and lidar ratio (extinction-to-backscatter ratio) at the same time. For the cirrus case, the effect of the multiple scattering was taken into account by introducing a multiple-scattering factor in the lidar equation. The multiple-scattering factors calculated with the Monte Carlo method in subject A-3(3) were introduced. In the observation of boundary layer aerosols, we can apply the two-wavelength method when SNR is sufficiently high.

We applied the developed algorithm to the LITE data and demonstrated the analysis of stratospheric aerosols, cirrus, and boundary layer aerosols.

Statistical analysis of cloud vertical distribution is useful for detecting climate change and consequently for validating climate models. A statistical method for analyzing lidar data was investigated using the long-term data taken with the ground-based lidar at NIES in Tsukuba. The similar method can be applied to space-borne lidar data.

The latitudinal distributions of clouds and aerosols observed with a two-wavelength lidar on board the research vessel Mirai were analyzed. The result showed a two-wavelength lidar can distinguish different types of aerosols. The optical depth calculation by the CCRS aerosol climate model also showed the feasibility of two-wavelength space-borne lidar in observing global distribution of various types of aerosols.

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