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Simulation Study for the Experimental Lidar in Space Equipment (ELISE)

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1. Introduction

A new space lidar system, the so-called Experiment Lidar In Space Equipment (ELISE) is currently being developed at the National Space Development Agency of Japan (Imai et al., 1997; Sasano et al., 1998). This system is to be launched in 2002. Its goals are to demonstrate the feasibilities of some key components of a lidar for long-term orbital operation and to provide scientific data from at least one year observations. The data will be useful for climatological studies.

Prelaunch studies including the development of data analysis algorithms and the simulation for ELISE observations are required by the ELISE system design. A theoretical and experimental study of signal inversion algorithms for space-borne lidar data analysis was conducted (Liu and Sugimoto, 1998). At present, a simulation study is being performed to preestimate the ELISE observation performances and to explore as many applications of ELISE data as possible. In this paper we discuss data analysis for ELISE and describe simulations regarding system calibration and quantitative measurements of the cloud and aerosol.

2. Specification of ELISE

ELISE is a two-wavelength three-channel backscatter lidar. Its major specifications are listed in Table 1. One receiver channel is operated in an analog mode (AN) at 1053nm for day and night observations; another two are operated in a photon counting mode (PC) at 527 nm and 1053 nm for night observations, respectively.

3. Simulation Results

Lidar Return Signals

We used a two-dimension atmospheric model in our simulations. The model atmosphere includes stratospheric and tropospheric aerosols and water and ice clouds. We simulated lidar signals for all three ELISE channels using the system parameters listed in Tab.1. The digitized data sampling processes and the nonlinear response features of data acquisition system were taken into account. Therefore, the generated lidar signals are quite realistic. Figure 1 presents an example of the generated return signals as well as calculated noise-free profiles for three channels. It can be seen that with 527 nm PC channel even the stratospheric aerosol layer can be observed although its backscatter coefficient is small. This shows that this channel has high sensitivity. However, saturation in the simulated cirrus signals near 11 km is also seen in this channel. The other two channels have lower sensitivity. In their signals, a cirrus layer at 10-12 km and a Kosa layer at 3-5 km are detectable.

These generated lidar signals were used as an input in our simulations for the ELISE data analyses.

Table 1 ELISE major specifications

Satellite	
Orbit:	sun-synchronous near-polar
Height:	550±5 km
Ground speed:	6.983 km/s
Measurement	
Direction:	nadir
Vertical resolution:	100 m
Horizontal resolution:	AN: 1.4 km/4.2 km; PC: 1.4 km/21 km
Transmitter	
Laser:	LD-pumped Nd:YLF
Output energy:	84 mJ@1053nm 10 mJ@527nm
Repetition rate:	100 pps
Beam divergence:	0.17 mrad (full angle)
Receiver	
Eff. diameter:	1 m
FOV:	0.21 mrad
Detector:	Si-APD

Calibration

The received lidar return signals with a lidar can be described by the lidar equation:

$$P(r) = \frac{1}{r^2} C \cdot \beta(r) \cdot T^2(r).$$

Here $P(r)$ is the received lidar signal from range r, $\beta(r)$ is the atmospheric backscatter coefficient at r and $T(r)$ is the transmittance from lidar to r. For the calibration of ELISE, the lidar constant C which contains system parameters and other range-independent quantities has to be determined for each channel.

527 nm PC channel can be calibrated with the return signals from 30 - 35 km altitudes where signals can be regarded as only due to molecular scattering. Simulations showed that the lidar constant for the 527 nm channel can be accurately determined with a standard deviation of 2.4 % when 2000 laser shots are

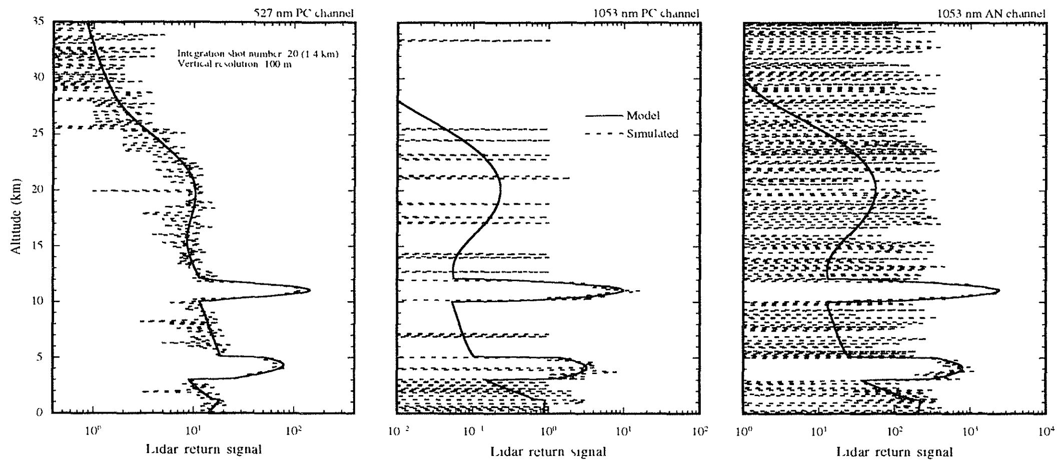

Fig.1 An example of simulated lidar return signals for three ELISE channels for a model atmosphere.

integrated which corresponds to an observation time of 20 s and a horizontal distance of ~140 km.

The lidar constant of 1053 nm PC channel can be determined relatively with 1053 nm and 527 nm PC channel signals from 30 -35 km altitudes. According to our simulations, when 2x10^5 laser shots (~14000 km horizontal distance) are integrated the lidar constant of 1053nm PC channel can be determined with a standard deviation of 5.6 %.

For the 1053 nm AN channel, the lidar constant can be relatively determined from the ratio of integrated 1053 nm AN and PC channel signals from cirrus clouds or some dense aerosol layers. Since the signals from cirrus clouds or dense aerosol layers are much stronger than the molecular scattering signals from 30 - 35 km altitudes as used in 527 nm and 1053 nm PC channel calibrations, a better accuracy for the 1053 nm AN channel calibration can be obtained with much fewer laser shots.

Retrievals of Optical Properties

Retrieval simulations of the cloud and aerosol optical properties were conducted for ELISE using the lidar data analysis algorithms summarized and discussed by Liu and Sugimoto (1998).

As shown in Fig.1 the 527 nm PC channel is suitable for observations of the stratosphere. With integrated 527 nm signal optical properties of the stratospheric aerosol can be retrieved. This channel can also provide observations of tropospheric aerosols and molecules as long as they are not hidden by dense clouds. The molecular signals can be used as a reference in the data analysis for some thin clouds such as cirrus. Although cloud signals may cause saturation of data acquisition in this channel, the scattering signals above and below the clouds can be used to determine their transmittances. Thus, their effective optical depths can be retrieved.

1053 nm PC and AN channels are designed to mainly observe clouds and dense aerosols. It was shown that from the signals of these two channels optical properties of thin clouds can be retrieved. For the modeled cirrus both the effective extinction and the backscatter and the effective lidar ratio can be iteratively retrieved when the effective optical depth determined from PC 527 nm signals is used as a constrain.

Aerosol optical properties can be retrieved from 527 nm PC channel signal and 1053 nm PC or AN channel signal using two-wavelength data analysis algorithms. An example of the modeled Kosa data analysis showed that the lidar ratio, backscatter and extinction at 527 nm might be retrieved.

4. Conclusion

Our simulations show that with three channels operated at two wavelengths ELISE can offer not only the global observation of cloud and aerosol structures but also the quantitative measurements of cloud and aerosol optical properties. The following experiment objectives can be expected with ELISE:

(1) Cloud: cloud structures including PSCs; cirrus optical properties; cloud cover rate.
(2) Stratosphere: aerosol backscatter and its wavelength dependence; large-scale aerosol distributions.
(3) Troposphere: aerosol optical properties; long-range aerosol transportation; PBL height and structure.

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