5.5 Lidar observations of clouds and aerosols

(1) Personnel

Tomoaki NISHIZAWA	(NIES)	- Principal Investigator (Leg-1)
Ichiro MATSUI	(NIES)	- Principal Investigator (Leg-2)
Nobuo SUGIMOTO	(NIES)	- not on board
Atsushi SHIMIZU	(NIES)	- not on board

(2) Objectives

Objective of the observations in this cruise is to study distribution and optical characteristics of ice/water clouds and marine aerosols using a two-wavelength polarization Mie lidar and a high-spectral resolution lidar (HSRL).

(3) Method

(3-1) Mie lidar

Vertical profiles of aerosols and clouds are measured with a two-wavelength polarization Mie lidar. The lidar employs a Nd:YAG laser as a light source which generates the fundamental output at 1064nm and the second harmonic at 532nm. Transmitted laser energy is typically 30mJ per pulse at both of 1064 and 532nm. The pulse repetition rate is 10Hz. The receiver telescope has a diameter of 20 cm. The receiver has three detection channels to receive the lidar signals at 1064 nm and the parallel and perpendicular polarization components at 532nm. An analog-mode avalanche photo diode (APD) is used as a detector for 1064nm, and photomultiplier tubes (PMTs) are used for 532 nm. The detected signals are recorded with a transient recorder and stored on a hard disk with a computer. The lidar system was installed in a container which has a glass window on the roof, and the lidar was operated continuously regardless of weather. Every 10 minutes vertical profiles of four channels (532 parallel, 532 perpendicular, 1064, 532 near range) are recorded. The data was available for following periods:

Leg1) September 26, 2011 - October 25, 2011

Leg2) October 30, 2011 – Nov. 30, 2011

(3-2) HSRL

Vertical profiles of aerosols, clouds, and water vapor are measured with a HSRL. The lidar employs an injection-seeded Nd:YAG laser at 532 and 1064nm in narrower line width than the laser used in the Mie lidar. Transmitted laser energy is more than 100mJ per pulse at both of 1064 and 532nm. The pulse repetition rate is 10Hz. The receiver telescope has a diameter of 30 cm. The receiver has six detection channels: parallel and perpendicular polarization components of lidar signals at 532 and 1064nm, Raman scatter signals at 660nm for water vapor detection, and Rayleigh scatter signals at 532nm using a HSRL technique. APDs are used for 1064nm channels, and PMTs are used for 532 and 660nm. The detected signals are recorded with a transient recorder and stored on a hard disk with a computer. The lidar system was installed in a container having a glass window on the roof, and the lidar was operated continuously regardless of weather. Every 1 minute profiles of six channels are recorded. The data was available for following periods:

Leg1) October 1. 2011 - October 25, 2011

Leg2) October 30, 2011 – Nov. 30, 2011

(4) Results

Temporal and vertical distributions of 532nm lidar signals measured with the two wavelength polarization Mie lidar are depicted in Fig. 5.5-1 for the Leg-1 cruise period and in Fig. 5.5-2 for the Leg-2 cruise period. The figures show that the lidar can detect maritime aerosols in the planetary boundary layer (PBL) formed below 1km, water clouds formed at the top of the PBL, ice clouds in the upper layer and rain falling from clouds, indicating that appropriate lidar measurements could be conducted. Especially, it should be noted that the lidar could detect ice clouds (cirrus) up to very high altitude of 17km since optical and microphysical properties and distributions of cirrus are key parameters for evaluating climate change.

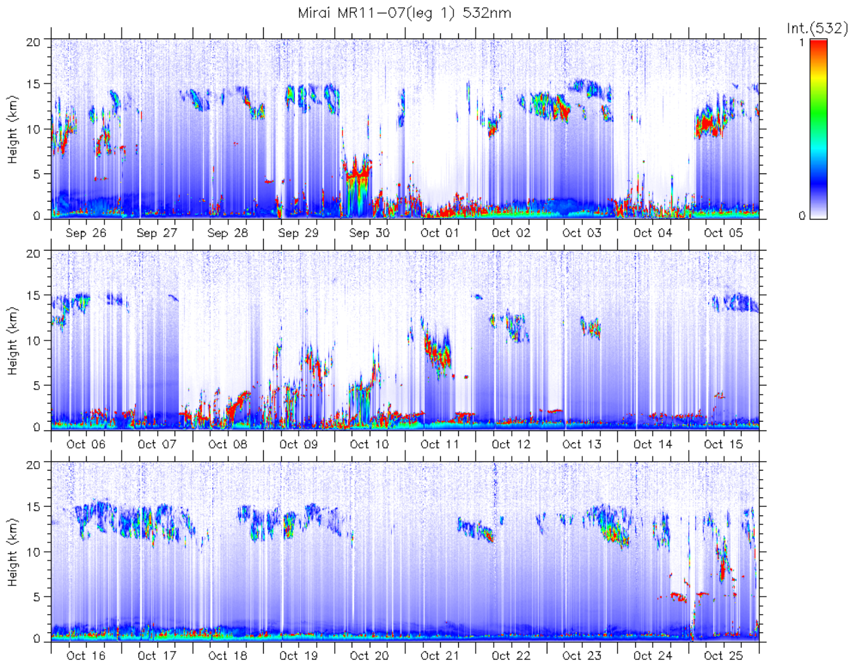

Fig. 5.5-1: Time-height sections of backscatter intensity at 532nm from 26 September 2011 to 25 October 2011 in the Leg 1 cruise.

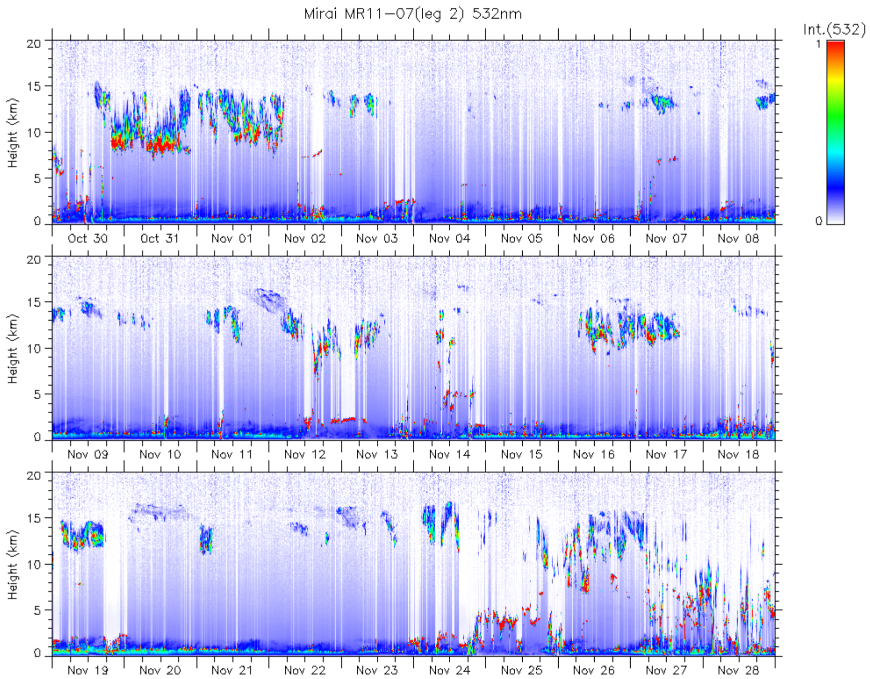

Fig. 5.5-2: Same as Fig. 5.5-1, but from 30 October 2011 to 27 November 2011 in the Leg 2 cruise.

As examples of the HSRL measurements, we show the results on Oct. 5 in the Leg 1 cruise period in Fig. 5.5-3. Total signals at 532nm and 1064nm indicate the existence of maritime aerosols in the PBL formed below 1km, water clouds formed at the top of the PBL, and ice clouds in the upper layer between 10km and 15km. Values of total depolarization ratio at 532nm and spectral ratio of the total signals at 532 and 1064nm (i.e., 1064nm/532nm) for the ice clouds are consistent with results of previous observational studies, indicating that the appropriate lidar measurement could be conducted. The HSRL technique used in this system blocks light scattered by particles (i.e., clouds and aerosols) and transmits light scattered by molecules (i.e., Rayleigh backscatter signals) using an iodine absorption filter and the laser with narrow line width. The signals measured by using the HSRL technique (532nm Ray) decreased in the clouds, indicating that the HSRL system worked well. Raman scatter signals by water vapor (WVraman) were also measured in nighttime (i.e., from 12UTC to 24UTC). We preliminarily compared some vertical profiles of water vapor density derived from the Raman scatter signals with those measured with radio sonde, and we found that the profiles roughly matched.

We further show the results on Nov. 22 in the Leg 2 cruise period in Fig. 5.5-3. The measured signals are appropriate similar to those on Oct. 5. On this day, we could catch optically very thin ice clouds at the altitude of 16km almost all day. Some researchers have reported existence of optically very thin cirrus (called as ‘sub-visible cirrus’). Since optical and microphysical properties of sub-visible cirrus have not known well, we can contribute to improving our knowledge for the sub-visible cirrus.

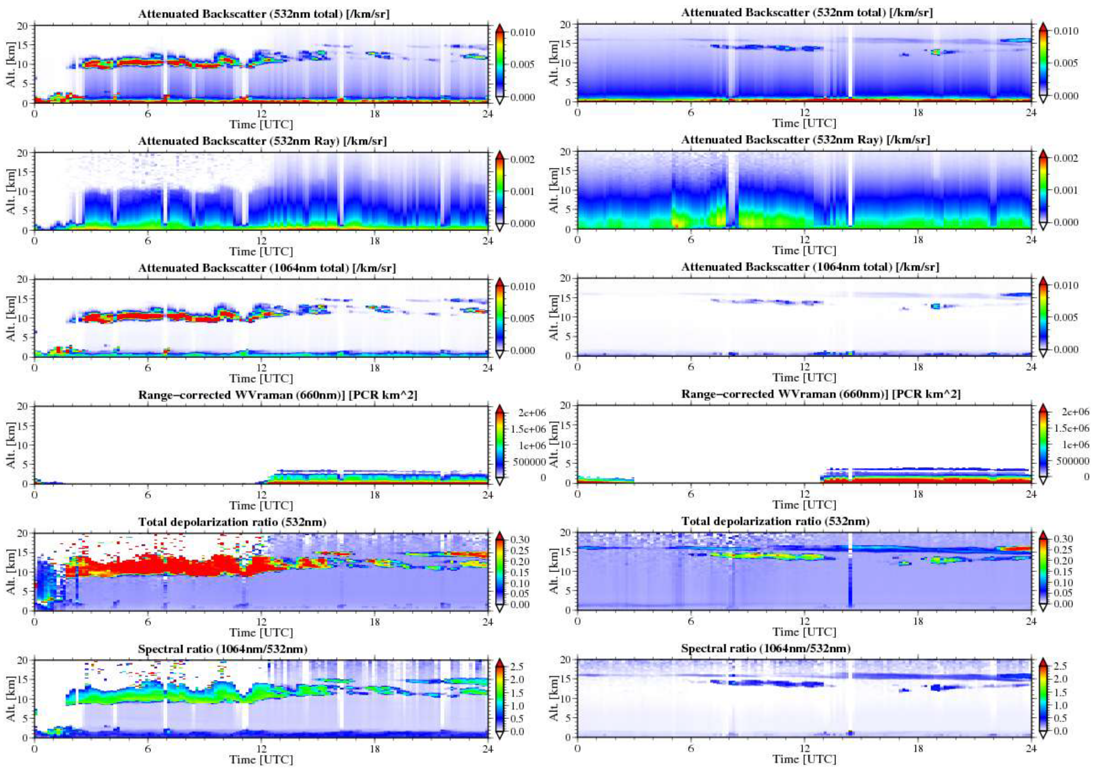

Fig. 5.5-3: Time-height sections of total attenuated backscatter coefficient at 532nm (532nm total), Rayleigh attenuated backscatter coefficient at 532nm (532nm Ray), total attenuated backscatter coefficient at 1064nm (1064nm total), water-vapor Raman scatter signals (WVraman), total depolarization ratio at 532nm, and spectral ratio of total attenuated backscatter coefficients (1064nm/532nm). [Left figure] 5 October, 2011 in the Leg 1 cruise. [Right figure] 22 November, 2011 in the Leg 2 cruise.

(5) Data archive

Contact NIES lidar team (nsugimot/i-matsui/shimizua/nisizawa@nies.go.jp) to utilize lidar data for productive use. The following parameters are / will be available.

Mie lidar

- raw data
    - lidar signal at 532 nm
    - lidar signal at 1064 nm
    - depolarization ratio at 532 nm
    - temporal resolution 10min/ vertical resolution 6 m
- processed data (plan)
    - cloud base height, apparent cloud top height
    - phase of clouds (ice/water)
    - cloud fraction
    - boundary layer height (aerosol layer upper boundary height)
    - backscatter coefficient of aerosols
    - particle depolarization ratio of aerosols

HSRL

- raw data (plan)
    - lidar signal at 532 nm
    - lidar signal at 1064 nm
    - depolarization ratio at 532 nm
    - depolarization ratio at 1064 nm
    - Rayleigh backscatter signal at 532nm
    - Raman backscatter signal at 660nm
    - temporal resolution 1min/ vertical resolution 3.75 m
- processed data (plan)
    - extinction coefficient at 532nm
    - backscatter coefficient at 532nm
    - backscatter coefficient at 1064nm
    - depolarization ratio at 532nm
    - depolarization ratio at 1064nm
    - water vapor concentration

(6) Acknowledgments

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