FIRST RESULT OF SODIUM AND IRON LAYERS OVER THE EQUATOR OBSERVED WITH RESONANCE SCATTERING LIDARS

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ABSTRACT

Characteristics of sodium and iron layers in the mesopause region over the equator observed with the resonance scattering lidars installed at Kototabang, Indonesia (0.2S, 100.3E) are reported. Observations of the Na layer have been carried out since August, 2004, and observations of the Fe layer have been carried out since June, 2005. Six simultaneous observations of the Na layer and the Fe layer were performed until August, 2005. The sporadic sodium layer (Nas) and the sporadic iron layer (Fes) were detected in almost every observing opportunity other latitude regions. The occurrence of the Nas layer correlated well with that of sporadic E layer which was observed simultaneously by the ionosonde at Kototabang. On the other hand, the occurrences of the Nas and Fes layers does not correlate with that of the wind shear which has been observed simultaneously by the meteor radar at Kototabang.

1. INTRODUCTION

The resonance scattering lidar is used for observing metal atomic layers such as sodium, iron and potassium that exist around the mesopause region between 80 and 100 km. Since the resonance scattering cross section is very large compared with the cross section of Rayleigh scattering or Raman scattering, the resonance scattering lidar is able to detect a small amount of metal. Metal atomic layers in the mesosphere are an excellent tracer of the atmospheric wave motion in the region between 80 and 100 km. Resonance scattering is observed when laser wavelength is tuned to the resonance-line wavelength of a molecule or an atom.

A sudden formation of a thin sodium layer, superposed in the background mesospheric sodium layers was discovered and this enhanced layer is called the sporadic sodium layer (Nas). Usually, Nas has a thin layer with a width of 1-2 km, lasting for a few tens of minutes to several hours, and the ratio of peak Na density to the normal density is usually from three to five, occasionally, as large as ten[1]. The appearance of such a sudden thin layer is also reported in other metalic atoms, such as Fe and K[2, 3].

In the high latitude observations, a strong correlations between Nas and sporadic E (Es) in the ionosphere occurrence has been observed and it is suggested that a neutral sodium atom is made from sodium ion[4, 5]. It is noteworthy that the correlation between Nas and Es, based on the observations at Hachioji at mid-latitude was also reported[1]. Moreover, in the mid-latitude, correlation of Nas with the wind shear in the mesopause area is also reported[6]. Although regular observations of metal atomic layers such as sodium and iron have been performed between the mid-latitude and the polar regions, there is almost no example of observations in the equatorial area. In order to study the atmospheric structure in the mesopause region over the equatorial zone, we installed a Na lidar in Kototabang, Indonesia (0.2S, 100.3E) in 2004. Simultaneous observations of sodium density and iron density with a Fe resonance scattering lidar were performed in the equatorial area[7]. In this paper, correlation of these lidar data and the sporadic E layer with an ionosonde at the same location is described. Moreover, the Nas observed at Hachioji, Japan (35.6N, 139.4E) and the wind shear observed at Shigaraki, Japan (34.9N, 136.1E) is compared with that observed at Kototabang, Indonesia.

2. INSTRUMENTATION

A block diagram of the lidar system for the mesosphere metal atomic-layer observation, installed in Kototabang is shown in Fig. 1 and specifications of the lidar system are listed in Table 1. The Na resonance scattering lidar consists of a tunable dye laser pumped by a frequency doubled Nd:YAG laser. The Fe resonance scattering lidar consists of a frequency doubled Ti:Sapphire laser pumped by another frequency doubled Nd:YAG laser. The wavelength of dye laser is tuned to the Na resonance wavelength (589 nm) so that the filter transmission intensity of the laser beam may become the maximum using a Na Faraday filter.

The wavelength of the Ti:Sapphire laser is tuned to the Fe resonance wavelength (372 nm) using the wavemeter with 0.1 pm resolution. The receiving system consists of three telescopes each 45 cm diameter. The one with the photomultiplier tube (PMT) which attached a 589 nm interference filter is only for Na observation. The other two with the cut-off filter that cuts the wavelength more than 400 nm are only for ultraviolet wavelengths.

EAR (Equatorial Atmosphere Radar) is a large Doppler radar for atmospheric observation at the equator. It was build in March 2001, in collaboration with the Research Institute for Sustainable Humanosphere (RISH), Kyoto University and the National institute of Aeronautics and Space of Indonesia (LAPAN). The EAR transmits 47 MHz radio wave to the sky, and receives echoes scattered back by atmospheric turbulence. The EAR can observe echoes from ionospheric irregularities at heights more than 90 km [7]. The meteor radar is a radio interferometer and has an effective time and height resolution of 2 km × 1 hour from 80 km to 102 - 3 km altitude. The meteor radar obtains zonal and meridional winds. The wind shear is calculated by taking the difference between zonal or meridional wind velocities of two neighboring heights in the profile. The total wind shear *dV*/*dz* is

$$dV/dz = \sqrt{(du/dz)^2 + (dv/dz)^2} \quad (1)$$

where *du*/*dz* is the zonal wind shear, *dv*/*dz* is the meridional wind shear.

Table 1. Parameters of the resonance lidar system.

	Dye laser	Ti:Sapphire laser
Wavelength	589nm	372nm
Pulse energy	30mJ	13mJ
Laser linewidth	20pm	3pm
Repetition rate	10Hz	10Hz
Range resolution	150m (Min.)	150m (Min.)
Telescope diameter	45cm x 1	45cm x 2

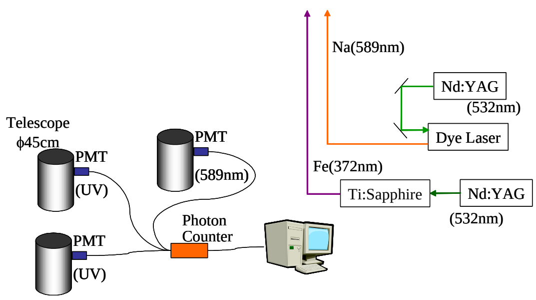

Fig. 1. The block diagram of the lidar system for the observation of the mesosphere metallic atom layer installed in Kototabang.

3. OBSERVATIONS

Six simultaneous observations of the Na layer and the Fe layer were performed until August, 2005. Na layer and Fe layer which were observed by Kototabang are compared. Moreover, ionosphere sporadic E layer (Es) and the meteor-wind distribution were observed with an ionosonde and a meteor radar respectively, which had been installed at the same site as the lidar station. There is no direct relationship to production of the neutral atomic layer and the electron density.

3.1 Lidar observations and Es observation

Fig. 2 shows density distributions of Na layer and Fe layer, and the peak altitude of Es event (E'Hs) with 2 km height resolution on July 30/31, 2005 at Kototabang. Lidar observations were sometimes prevented by cloudy weather conditions. Starting at 1:17 LST, large Nas event appeared at 96 km and continued for 4 hours, with the peak moving downward slightly from 2:00 LST to 3:00 LST. On the other hand, Fes event did not appeare in this night. Although the shape of both atomic layers was the same below 90 km, that was not the same above 90 km. Es event appeared over 110 km at 22:00 LST and moved downward to the Nas altitude at 1:00 LST. However, Es event was not detected after 2:00 LST.

The characteristics of the Nas, Fes and Es events are summarized in Table 2 and altitude distributions of Nas

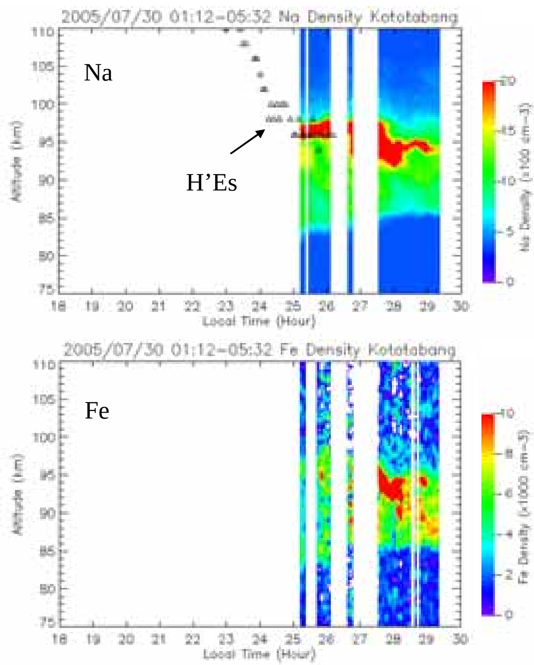

Fig. 2. Density distributions of Na layer and Fe layer, and the peak altitude of Es (H'Es) on July 30/31, 2005 at Kototabang.

events and Fes events at Kototabang and Nas events at Hachioji are shown in Fig. 3. We have a sodium lidar at Tokyo Metropolitan University (TMU) in Hachioji (35.6N, 139.4E). The TMU Na lidar system consists of a tunable dye laser, pumped by a frequency doubled Nd:YAG laser. Although Nas events appeared at various heights between 90 km and above 105 km at Hachioji, Nas events appeared only around 95 km at Kototabang. The Nas event and Es event were correlated, but the Fes event and Es event were not correlated. Nas and Fes appear in the same time and height in many cases above 90 km, however, Fes also appears below 90 km. Several data in a limited period, make it difficult to conclude the general relationship between Nas, Fes and Es. In order to clarify these relations, we will perform these observations continuously.

3.2 Lidar observations and wind shear observation

It was reported that a strong wind shear of the horizontal wind is more likely to accompany the Nas occurrence by the simultaneous observations with the Na lidar at Hachioji (35.6N, 139.4E) and Shigaraki (34.9 N, 136.1E), and the MU radar at Shigaraki from 1992 to 1997[6]. The MU radar is a monostatic pulse Doppler radar operated at 46.5 MHz VHF, constructed at Shigaraki, Shiga, Japan (34.9N, 136.1E). Based on the mesosphere wind profile with time and height resolutions of 1 hour and 2 km observed by the meteor radar from June, 2005 to August, 2005, we investigated the relation between sporadic atomic layer and wind shear over the equator. The event number of Nas and Fes at Kototabang and the event number of Nas in Japan (Hachioji and Shigaraki) to the zonal wind shear and the meridional wind shear is shown in Fig. 4. The appearance of Nas or Fes is checked for every hour, and the event number will be counted if there is Nas or Fes. In Japan, there is no difference between the zonal wind shear and the meridional wind shear, and the event number of the wind shear does not have a peak. On the other hand, in Koto-tabang, the event number of the zonal wind shear is concentrated on the zero wind shear (0 m/s/km) compared with the event number of the meridional wind shear.

Table 2. The characteristics of the Nas, Fes and Es events.

Date	Peak Altitude (km)			Correlation
	Nas	Fes	Es	Nas and Es
24-25 Jun. '05	97	88	95	Yes
30 Jul. '05	96	95	95	Yes
1-2 Aug. '05		88, 93	105-120	
2-3 Aug. '05	95	90	105-120	No
3-4 Aug. '05	95	85, 96	92, 98	Yes
4-5 Aug. '05		96	96-98	
27-28 Aug. '05	95		114-118	No
28-29 Aug. '05	95	93	96-100	Yes

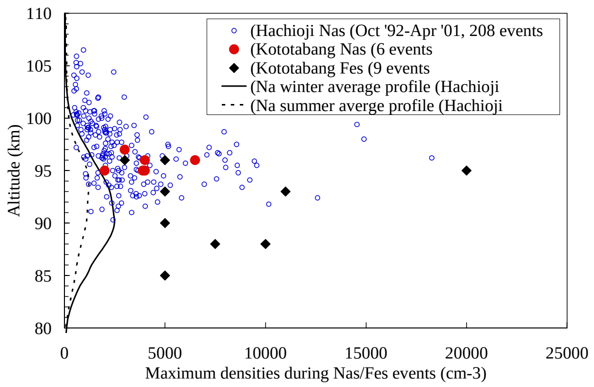

Fig. 3. Altitude distributions of Nas events and Fes events at Kototabang, Indonesia (0S) and Nas events at Hachioji, Japan (35N).

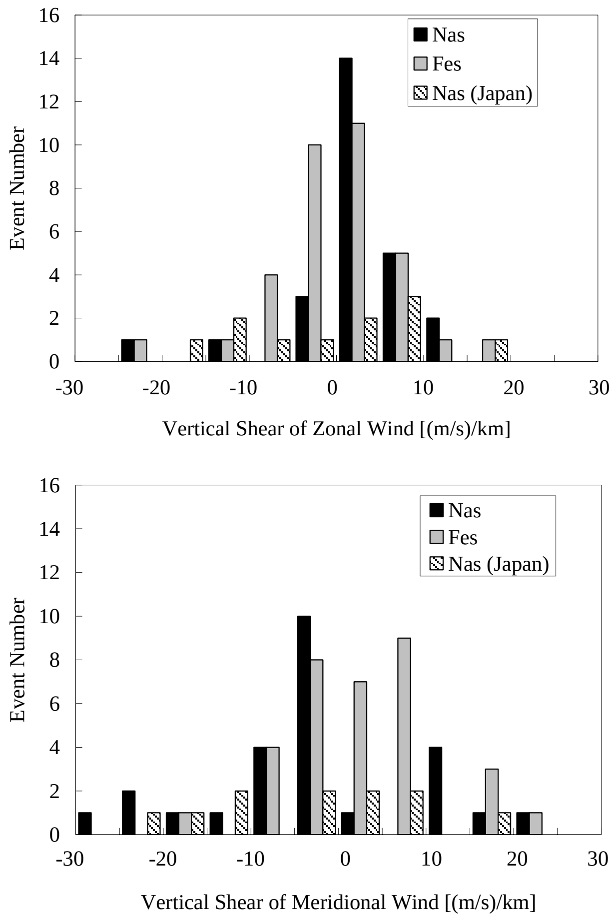

Fig. 4. Distributions of zonal and meridional wind shears at the peak of Nas density and Fes density at Kototabang, and at the peak of Nas density at Hachioji and Shigaraki

(Japan).

Further more, the event number of Nas is concentrated on the zero wind shear compared with the event number of Fes. An Nas event accompanied with a strong wind shear observed by a Na wind/temperature lidar at Haleakala, Maui (20.8N, 156.2W) was also reported[8] and they observed a strong vertical shear of the zonal wind of 42 m/s/km at the altitude of 1 km below a prominent Nas layer. On the other hand, most zonal wind shears were less than ±5.0 m/s/km at the peak altitude of Nas density and Fes density at Kototabang. The standard deviation of the zonal wind shear of Nas events is 7.3 m/s/km and that of the meridional wind shear of Nas events is 12.3 m/s/km. This result is completely opposite to the result of the mid-latitude and the wind shear does not contribute to production of Nas and Fes over the equator. This is an important discovery which indicates that the production process of Nas and Fes at the equator may be differ from the production process at the mid-latitude.

4. SUMMARY

In this study, the correlations between the sporadic atomic layer (Nas and Fes) at equator area and dynamical parameters have been described by means of two resonance scattering lidars, the ionosonde and the meteor radar at Kototabang, Indonesia. Sporadic E layers and wind shears have been investigated at the times and heights of appearance of Nas layers and Fes layers, that were detected by the resonance scattering lidars. Nas events appeared only around 95 km at Kototabang. Nas and Fes events appear in the same time and height in many cases above 90 km. We showed that the Nas event and Es event were correlated. However the Fes event and Es event were not correlated. It is difficult to conclude the general relation among Nas, Fes and Es, because we have obtained several data in a limited period. We are continuing observations and it will be clarified from long-term data in the future.

Almost all wind shears were less than the monthly mean at the peak altitude of Nas density and Fes density at Kototabang. Our observations showed that the Nas event is not influenced by the zonal wind share. This result is different from previous observation over Haleakala (20.8N), suggesting that the existence of different production processes of Nas.

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