A study on GEO satellite signals in L - to Ka-band affected by Asian Sand Dust

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***Abstract*—**This paper represents an attempt to bring together and analyses the measurement data measured by the Satellite Signal Monitoring Center in Korea and the Korea Meteorological Administration/Korea Meteorological Research Institute in close cooperation with this study team. This paper presents the signal characteristic of GEO satellite operating in frequency range 1 to 20GHz associated with Asian Sand Dust (the so-called Yellow Sand Dust). The downlink signal power (dBm) for L-, S-, C-, Ku-, and Ka-band frequencies from GEO satellites were measured in a clear weather and in Asian Sand Dust weather by the Satellite Signal Monitoring Center. The measured signal power(dBm) were compared to the total number concentration and size distribution of Sand Dust that were measured by the Korea Meteorological Administration/Korea Meteorological Research Institute and the possible correlation between these sets data were analyzed. The results demonstrate that the downlink signal level (dBm) of GEO satellite is attenuated by Asian Sand Dust. Hitherto, merger information has been reported as to the influence of sand dust on satellite communications operating in regions affected by sand dust.

***Index Terms*—**Asian sand dust, scattering, OPC, satellite communications, signal attenuation, signal power.

I. INTRODUCTION

Very few investigators have considered the effects of sand dust on the propagation of satellite communication signal. For example, Chu [1] and Ghobrial [2] examined the attenuation effects of sand storms, and Julius Goldhirsh [3] reviewed and assessed the attenuation and backscatter characteristics of radars operating at L- and S-band. Up until now, the published results have not been found suggesting that sand dust represents an attenuation problem for satellite communications at above 10 GHz. One such a reason maybe that such a dust phenomenon have not been recognized in operation or have been deemed negligible due to infrequent attenuation problems over satellite communication links at these frequencies. This paper focuses on analyzing the possible correlation between the sets of data that have been measured by the measurement equipments and the assessment of attenuation effects of sand dust to satellite communication signal. Therefore, this paper admits that the purpose of this study is not to apply our analysis into the expression of a related theoretical formula [2] [3] [4] [5] [6] [11]. However, the results of this paper will provide useful data and apply this data to prove and analyze attenuation characteristics. Recently the quantity of Asian Sand Dust that flies up into the air in the desert regions of China and Central Asia and comes over the Korean peninsula is seriously increasing in the atmosphere layers during the spring, autumn and winter seasons. For, recently, the diffusion of desert areas in China and Central Asia is very rapidly and widely progressing. This paper analyzes the attenuation effects on satellite communication signals due to Asian Sand Dust by comparatively analyzing the variation states of signal power levels for L-, S-, C-, Ku- and Ka-band frequencies. To do it, we have measured the Number concentration and Particle size distribution of Asian Sand Dust in the atmosphere layer over the Korean peninsula from 10 to 11 Mar 2004 and 30 Mar to 01 Apr 2004, from 07 to 20 Apr 2005 and 30 to 31 July 2005. On the same days, we also have measured the downlink signal power level of 5sets of GEO communication satellites.

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II. THE COMPONENT OF ASIAN SAND DUST

Asian Sand Dust consists of minute sand dust particles that are raised up into the air by a wind or a storm. Origins of Asian Sand Dust are the Taklamakan desert, the sand desert regions of China's western and northwest regions, the Gobi desert and the Asian earth plateau by China' Asian River. The originating factors of Asian Sand Dust are that when a low pressure has occurred in its areas of origin, a cold atmosphere effected by a cold front is heated by a radiating heat on the earth's surface and the atmosphere on the earth's surface is vertically raised up to 3 to 5㎞. At that time, the sand dust is also raised up with the atmosphere. Therefore, the sand dust floats with the atmosphere and disperses in the most adequate height to move a long distance. These particles are transported to Hawaii and the Alaska seacoast, passing through the Korean peninsula and Japan's' island chain by the prevailing westerlies caused by an abrupt air current movement in the atmosphere layer. Throughout the year, Asian Sand Dust mainly appears between March and May in the Korean peninsula, and ⅓~½ of its occurrence frequency is in April. One reason is a particular climate condition enclosing the Korean peninsula in the spring season, March to May, makes this region susceptible to Asian Sand Dust.

The Asian Sand Dust is a kind of soil particle. Its chemical nature is an oxide that consists of Al, Fe, K, Si, Na, Zn and Mg. The greater part of the composition is Al (60%) and Fe (40%). Also, Asian Sand Dust adds a sulphate or a nitrite to the surface of its particles by absorbing gases. For example O2, NOx interact with a particle of sand dust and soil components during movement.

The size of Asian Sand Dust is 1~10μm, smaller than the 1~1,000μm size of sand. So Asian Sand Dust can float in air for a few hours to a few days. The height of Asian Sand Dust is normally between 4Km and/ 6 to 9Km above the earth surface. Asian Sand Dust consists normally of a multi-layer structure, with a lower layer and upper layer. The width of Asian Sand Dust cloud is a range of 2 to 4Km. Fig.5. depict the height of the multi-layer cloud and intensity of backscattering of Asian Sand Dust that has been measured by the LIDAR system

III. THE ATTENUATION FACTOR OF SATELLITE COMMUNICATION SIGNAL

The satellite communication signal is propagated from the earth station to the GEO communication satellite through the earth atmosphere layer. When the satellite communication signal is transmitted by an earth station or communication satellites through the atmospheric layer, it is attenuated by either absorbing or scattering caused by minute particles in the atmospheric layer. Examples of these include oxygen, vapor, rainfall, fog and clouds, snowfall and sleet, free electrons. The Formers' states are rarely varied but the latter states are largely changed by a condition of weather and the atmospheric layer. There are many factors that cause the attenuation effect to satellite communication signals. Of these factors, Rainfall has to be considered the most important attenuation factor to the satellite communication signal, especially when the attenuation effect by rainfall increases rapidly from 10 GHz up to 500 GHz.

IV. THE MEASUREMENT OF ASIAN SAND DUST

A. Signal Level (dBm) Measurement

The downlink signal level of the GEO satellite communication signal have been measured in close cooperation with the Satellite Signal Monitoring Center located in Icheon-Si, Korea. The Center was constructed to monitor the signal transmitted by GEO communication satellites orbiting along longitude 55°E~160°W. The Center has 2sets of 13m Cassegrain antennas to automatically track and monitor 6-band frequencies. This study has measured the downlink signal level of 5-band frequencies operating in the following 5 GEO communication satellites,

- L-Band (Orbit position 105°E, Measurement frequency 1475.22MHz)
- S-Band (Orbit position 80.3°E, Measurement frequency 2491.75MHz)
- C-Band (Orbit position 122°E, Measurement frequency 3760MHz)
- Ku-Band (Orbit position 116°E, Measurement frequency 12730 MHz)
- Ka-Band (Orbit position 116°E, Measurement frequency 20755MHz)

The measurements have been performed 3-times in intervals of 3-hours in 2004 year and of 1-hours in 2005 year in which the phenomenon of Asian Sand Dust is the most strong, during 10-11 March 2004 and 08-20 Apr 2005, the relatively weak during 30-31 March/01 Apr 2004 and 07 Apr 2005, and a clear days during 30-31 July and 23 August 2005.

B. Number Concentration and Dust Size Distribution measurement of Asian Sand Dust

This study utilized the data of a number concentration (PM10) of a minute dust particle and a number size distribution of Asian Sand Dust. These data have been measured by the observation Center of the Korea Meteorological Office and Korea Meteorological Research Institute, respectively, which are located about 40Km from the Satellite Signal Monitoring Center. The minute dust floating or dropping in the atmosphere layer is a kind of solid material the size of which is below 10μm.

The Dust Size Distribution of Asian Sand Dust is classified into 8 parts, including 0.3~0.5μm, 0.5~0.82μm, 0.82~1.35μm, 1.35~2.23 μm, 2.23~3.67μm, 3.67~6.06μm, 6.06~10μm, and 10~25μm.

The Optical Particle Counter (OPC), the LIDAR system, has measured the number size distribution of Asian Sand Dust.

V. THE ATTENUATION EFFECT ANALYSIS TO SATELLITE COMMUNICATION SIGNAL

Fig.1 shows the measurement of signal level in 2004 and 2005 year. The results of compare to the maximum signal level on a clear days to the minimum signal level on a sand dust days demonstrate that the downlink signal level(dBm) of GEO satellite are attenuated 1.6dB, 5.8dB, 3.7dB and 8.1dB to S-band, C-band, Ku-band and Ka-band, respectively in 2004 year, 1.1dB, 1.4dB, 0.2dB, 1.8dB and 7.8dB to L-band, S-band, C-band, Ku-band and Ka-band, respectively in 2005 year.

Table 1 show the variation width of signal level(dB) between maximum and minimum level during a sand dust day and a clear day

As Table 2 the variation width of signal level on a sand dust day is generally higher than on a clear day.

Therefore it indirectly shows that Sand dust effect the signal level.

Table 1 Variation width (dB) between maximum and minimum signal level during a sand dust day and a clear day

(a) Variation width (dB) of Signal level in 2004 year

Clarification	L-band	S-band	C-band	Ku-band	Ka-band
very strong Sand dust day	1.1	2.3	0.9	0.4	11.2
strong Sand dust day	1.0	1.9	1.3	2.9	5.5

(b) Variation width (dB) of Signal level in 2005 year

Clarification	L-band	S- band	C-band	Ku-band	Ka-band
very strong Sand dust day	0.7	4.4	1.2	1.6	8.1
strong Sand dust day	0.9	3.1	1.2	0.8	0.9
A clear day	0.4	1.1	0.7	0.4	0.3

Fig 2 shows the measurement of PM10 that is measured in the 8 observation sites located in Korea in 2004/2005. Fig. 2 shows that PM10 distribution very uniform in nationwide even in strong PM days. Its meaning is that the PM10 density effects to all over 5 measurement satellite links at the same time. Fig. 3 shows the relation of the Sand Dust Size Distribution (㎛) to the Number concentration (/㎥) of Asian Sand Dust during the measurement duration in 2004 and 2005year. Fig. 4 shows the total sand dust number concentration in measurement days in 2004 and 2005.

Very strong and strong PM10 day is 11 and 30 March, 2004, and 11 and 20 April, 2005 in Fig. 2 But very strong and strong Sand Dust Number concentration (/㎥) day is 10 and 31 March in 2004 and 07 and 19 April, 2005.

As the analysis was performed of the maximum and minimum signal level during very strong and strong sand dust day and PM10/Number concentration (/㎥) of Asian Sand Dust, the results indicate the following characteristics:

- In data of 2004 year, in the case of L-band, when signal level is minimum, most size of sand dust increased and PM10 also increased. In case of S-band, when signal level is the lowest, all of sand dust size and PM10 increased. In the case of C-band, 0.3~0.5μm size of sand dust increased mainly PM10 also increased. In case of Ku-band, sand dust number concentration over all of sand dust size except 0.3μm and PM10 increased as compared with sand dust number concentration when signal level is the highest. In case of Ka-band, exceptionally sand dust number concentration over all of sand dust size and PM10 decreased as compared with sand dust number concentration when signal level is the lowest
- In data of 2005 year, in the case of L-band, when signal level is minimum, 0.35~6.06μm size of sand dust and PM10 increased. In the case of S-band, sand dust number concentration of all sand dust size and the PM10 increased when signal level is minimum.
- In the case of C-band, sand dust number concentration of 0.3~2.23μm sand dust size and PM10 also increased. In case of Ku-band, sand dust number concentration of all sand dust size and PM10 increased as compared with sand dust number concentration when signal level is the highest. In case of Ka-band, sand dust number concentration of 0.3~3.67 μm sand dust size increased but PM10 decreased as compared with sand dust number concentration when signal level is the highest

VI. CONCLUSION

This paper analyzed the attenuation effects on the downlink signal of the GEO satellite communication due to Asian Sand Dust. As a result of this work, Asian Sand Dust attenuates the GEO satellite communication signals in the following manner:

The compared results between the maximum signal level and minimum signal level in Asian Sand Dust weather are;

- that, in case of S-band , the maximum signal level is -114.480dBm and the minimum signal level in Asian Sand Dust weather is -116.820dBm in 2004 year and -109.658dBm and -114.078dBm in 2005 year. As a result, about 2.34dB attenuation in 2004 and 4.42dB attenuation in 2005 has occurred to the downlink signal of the GEO satellite communication.
- that, in case of C-band, the maximum signal level is -111.512dBm and the minimum signal level in Asian Sand Dust weather is -116.467dBm in 2004 year and -121.908dBm and -123.490dBm in 2005 year. As a result, about 4.955dB attenuation in 2004 and 1.582dB attenuation in 2005 has occurred to the downlink signal of the GEO satellite communication.
- that, in case of Ku-band, the maximum signal level is -116.031dBm and the minimum signal level in Asian Sand Dust weather is -118.855dBm in 2004 year and -115.997dBm and -118.293dBm in 2005 year. As a result, about 2.824dB attenuation in 2004 and 2.429dB attenuation in 2005 has occurred to the downlink signal of the GEO satellite communication.
- that, in the case of Ka-band, the maximum signal level is -122.949dBm and the minimum signal level in Asian Sand Dust weather is -134.248dBm in 2004 year and -129.581dBm and -137.728dBm in 2005 year. As a result, about 11.299dB attenuation in 2004 and 8.147dB attenuation in 2005 has occurred to the downlink signal of the GEO satellite communication.

In case of Ka-band in 2004 year, the total number concentration of Asian Sand Dust increases, the signal level decrease and the reverse phenomenon also appears. This work did not definitively prove a reason why such a phenomenon occurs strictly in Ka-band. Ka-band is affected by both a small Sand Dust Particle Size and large Sand Dust Particle Size of Asian Sand Dust. As Fig. 5. depicts, Asian Sand Dust consist of both an upper layer that is formed by the small Sand Dust Particle and lower layer that is formed by the large Sand Dust Particle.

Therefore this work supposes that such a unique phenomenon to Ka-band occurs as a result of duct type scattering and reflection caused by a multi-layer Asian Sand Dust. The wavelength of Ka-band is relatively very short compare to other bands. The Ka-band is affected by both the small Sand Dust Particle and large Asian Sand Dust Particle, so a whole range of Asian Sand Dust Particle size affects Ka-band.

The height of small Asian Sand Dust Particles is 4~6Km in the upper layer and the height of large Sand Dust Particles is 2~3Km in the lower layer. Therefore a duct-like barrier exists between the upper layer and the lower layer.

The Asian Sand Dust consists of Al, Fe and Mn. So electromagnetic wave is absorbed, reflected or scattered by Asian Sand Dust. Therefore while Ka-band signal pass through duct-like layer between upper layer and lower layer of Asian Sand Dust, the signals are absorbed, reflected or scattered by an upper and lower layer.

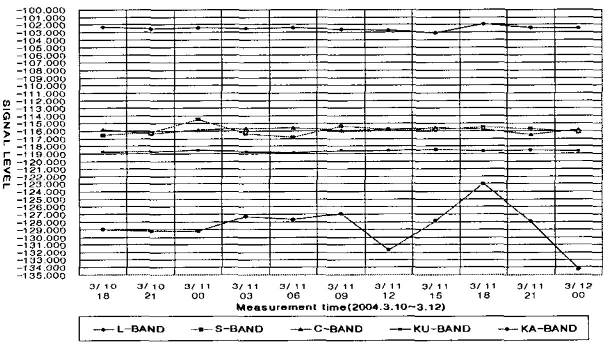
When a satellite communication signal enters into the duct-like sand dust barrier, this study estimates that the signal is integrated to make a bunch of electromagnetic wave in the duct-like sand dust barrier. At this time, if such a sand dust barrier exists in the satellite communication link path, a receiving signal level in a receiver located along the link path will be attenuated because the duct-like sand dust lower-layer acts as a block out curtain to the satellite signal. Therefore in this case the signal level can be decreased rapidly than in a normal situation. On the other hand, if the duct-like sand dusts barrier disappears when sand dust moves away, the integrated electromagnetic wave come down to the receiver antenna directly without any reflection, diffraction or scattering by the upper layer, or any reflecting, diffracting or scattering by the lower layer. In this case, the receiving power in receiver can be increased rapidly than normal situation. This works suppose that such a phenomenon also will happen to the other bands besides the Ka-band by a kind of duct type scattering due to a multi-layer Asian Sand Dust.

Electromagnetic waves are absorbed, reflected or scattered by Asian Sand Dust because the Asian Sand Dust particle consists of Al, Fe and Mn. Therefore this study estimates that when the other bands' signals besides Ka-band pass through duct-like layer between upper layer and lower layer of Asian Sand Dust, they have a mixed and complex nature, combined the duct mode, scatter mode, reflection mode, absorption mode and fading phenomenon, etc.

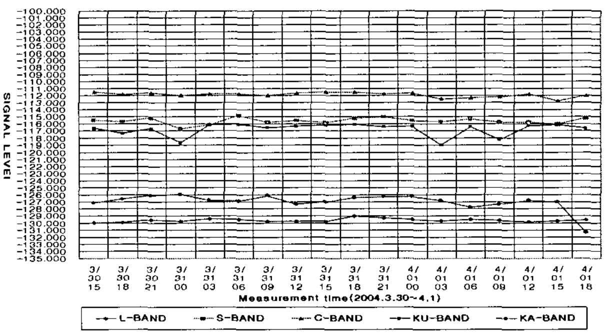
In conclusion, the GEO satellite communication signal is attenuated by Asian Sand Dust (Asian Sand Dust) and the satellite communication signal is also affected by a kind of duct mode fading caused by a multi layer of Asian Sand Dust.

This study anticipates that the results of this paper will greatly contribute to create a theoretical analysis model of the attenuation effect on Satellite communication *signals due to the Asian Sand Dust.*

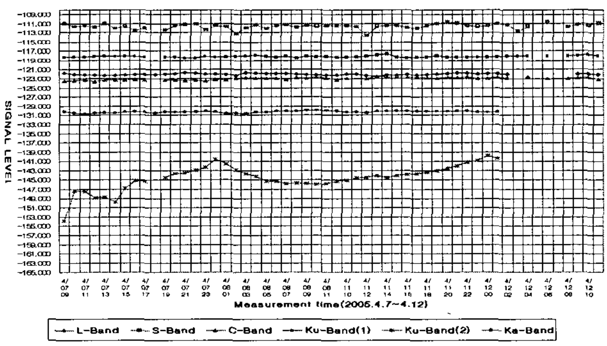
The analysis results of the attenuation relationship between the signal level and the Sand Dust Particle size of Asian Sand Dust are that normally S-, and Ku-bands are affected evenly by the whole Sand Dust Particle size. The L-band is affected by 0.3~6.06 μm Sand Dust Particle size, the C-band by the 0.3~2.23μm and over Sand Dust Particle size, and the Ka-band by the 0.3~3.67μm Sand Dust Particle size.



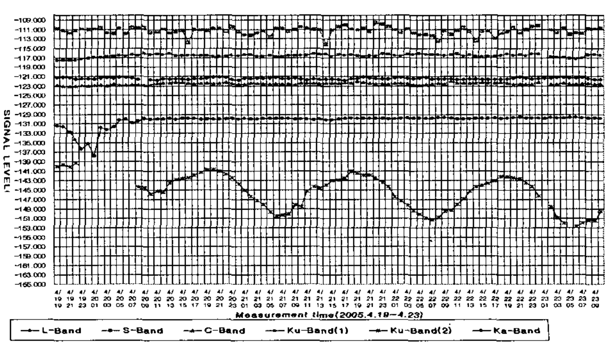
(a) Signal Level on 10-12 March, 2004
(Very Strong Sand Dust day)



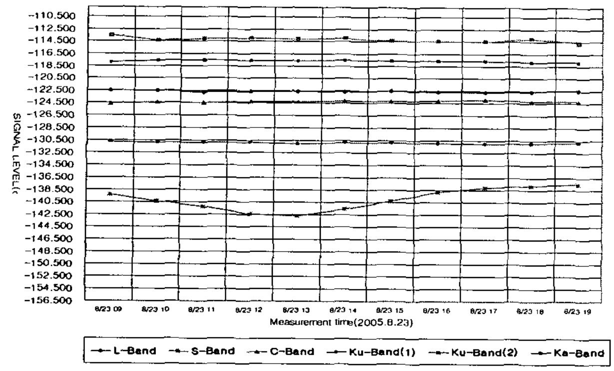
(b) Signal Level on 30-31 March and 01 April, 2004
(Strong Sand Dust day)



(c) Signal Level on 7-12 April, 2005
(Strong Sand Dust day)

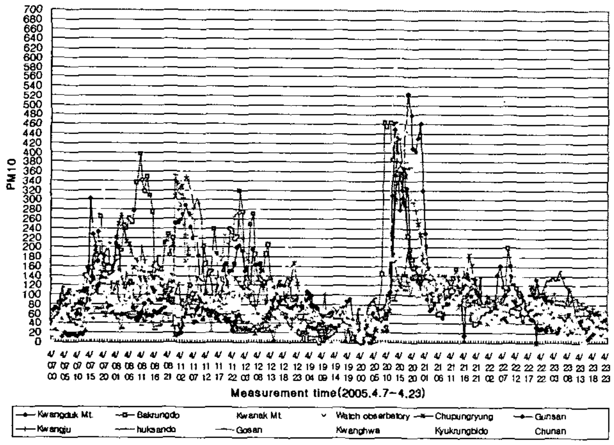


(d) Signal Level on 19-23 April, 2005
(Very Strong Sand Dust day)

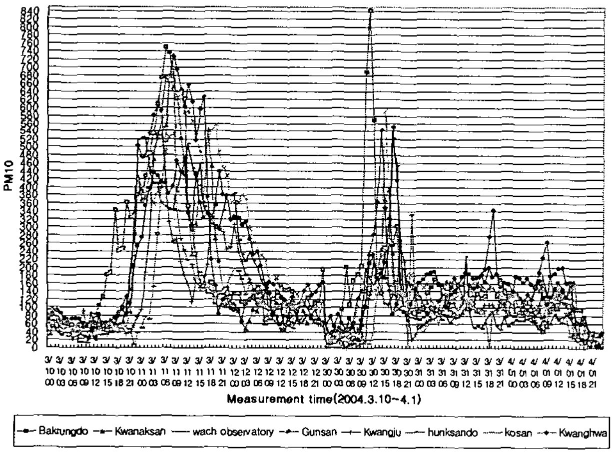


(e) Signal Level on 23 August, 2005 (Clear day)

Fig. 1 Measurement of Signal Level (dBm) in 2004 and 2005



(a) PM10 on 10-12, 30-31 March and 01 April, 2004



(b) PM10 on 7-8, 11-12, 19~23 April, 2005

Fig. 2 Measurement of PM10 in 2004 and 2005 in Korea

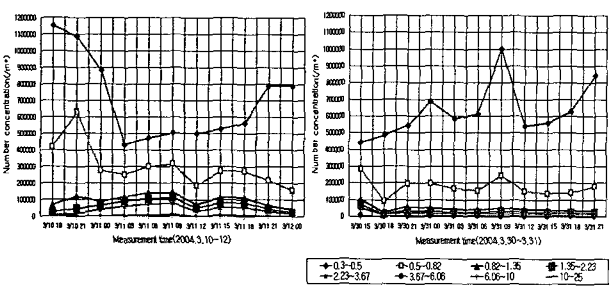


Fig. 3 (a) Asian Sand Dust Size (μm) and Number concentration (/m³) on 10-12, 30-31 March, 2004

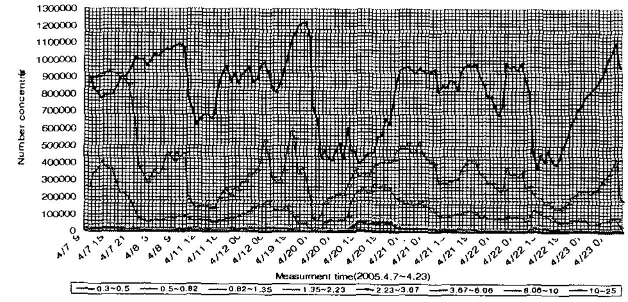
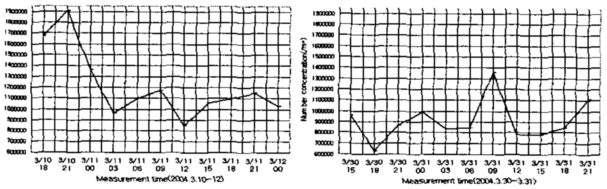
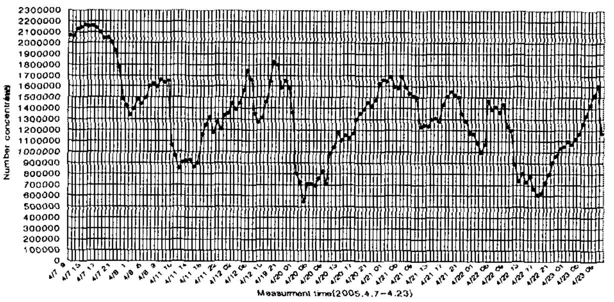


Fig. 3 (b) Asian Sand Dust Size (μm) and Number concentration (/m³) on 7-8, 11-12, 19~23 April, 2005

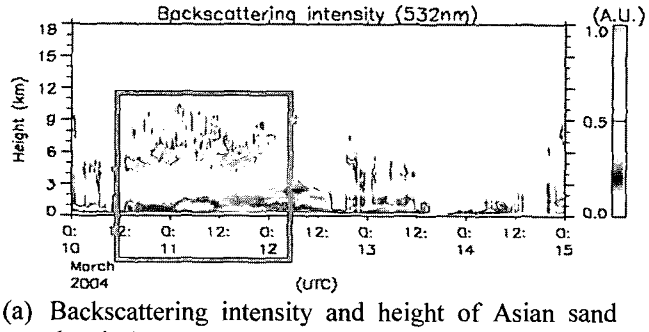


(a) Total Asian Sand Dust Number concentration (/m³) 10-12, 30-31 March, 2004

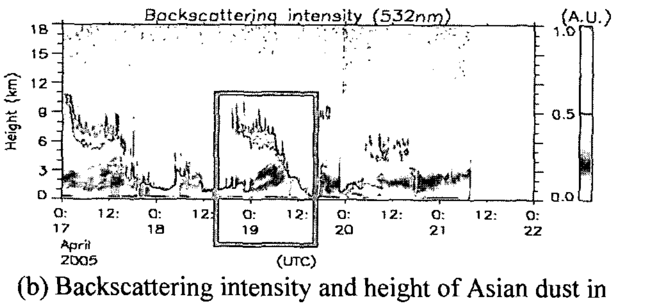


(b) Total Asian Sand Dust Number concentration (/m³) 07-12, 19-23 April, 2005

Fig. 4 Asian Sand Dust total Number concentration



(a) Backscattering intensity and height of Asian sand dust in 2004



(b) Backscattering intensity and height of Asian dust in 2005 year

Fig. 5 Backscattering intensity and height of Asian sand dust

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