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Environmental Analysis in Asian Dust Source Region Using Satellite Remotely Sensed Data

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Abstract : With the negative influences and damage from Asian dust increasing, it's getting important to investigate the climate and soil condition of the source region of Asian dust. There is a high possibility that the desertification and the drastic decrease of plants in China and Mongolia make worse the situation (bad effects of Asian Dust). To detect the movement of Asian dust caused by air circulation, we need to watch the state of the source region to get useful information for the prevention of the dust pollution, and to predict what part of China will become the source region. Therefore, using TOMS aerosol index data, NCEP reanalysis data that is Remote Sensing data from 1981 to 2000 (except 1993~1996, 4 years), for 16 years, examined the relation between the dust occurrence and weather elements.

Dust occurrence appeared much in spring season from March to May in study areas. It had a dry climate during that season as follows : relative humidity about 20~40%, temperature about -5~5°C, precipitation about 33~180 mm, wind speed about 4~10 ms-1. Dust occurrence and weather element annual change in study areas decreased gradually till 1990, but in Gobi desert the incidence of dust occurrence increased since 1997. As a result, found out that the more the precipitation, the less dust occurrence, because the precipitation and surface wind speed had a direct influence on the soil of the source region of dust.

Key Words : Asian Dust, Remote Sensing, TOMS Aerosol Index, Dust Occurrence.

1. Introduction

Recently, the Asian dust, the atmospheric phenomena of the wind carrying yellow dusts occurs frequently because of the rapid industrialization of China and the desertification of north-east Asian countries such as China, Mongolia, which influences on north-east Asia region such as Korea, Japan, etc. The Asian dust is carried mainly by the wind, and spread by turbulence. The Asian dust phenomenon that occurs in every spring season in Korea is a typical example of the long-range transports carrying air pollution material by a wind (Yoon, 1991). The Asian dust phenomenon is an erosion of land surface by a wind at desert regions in China and Mongolia, and at Loess plateau region in Yellow River midstream, which carries and precipitates sands and yellow soil by the strong wind making a mechanical turbulence (Chung, 1986). The Asian dust is commonly

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known that it occurs mostly from March to May after thawing season, the months the strong wind rises according to the weather and climate condition of source region (Chung, 2001).

Though the research on the Asian dust has been performed for a long time, the Asian dust continues to bring negative influences on the ecological environment, the industrial activity, and product manufacture, not to mention human health. New regulation on the source region of Asian dust and the watch system of environmental state of the source region are embossed as an important issue. As the issue has risen as an international matter, Korea is in the progress of the monitoring system construction in conjunction with China and investigation of the source region in China, etc.

Joussaume(1990) performed numerical experiment at all source regions of sand storm all over the world using a general circulation model and presented Takla Makan desert, Gobi desert, Aldous desert and Loess plateau as main source regions in Asian continent. Gao *et al.*(1992) and Shao(2000) suggested that the Asian dust occurred mainly in Asian central region and north-west area of Tibet plateau by analyzing 3 hour interval surface meteorological observation data from 1988 to 1989. Besides, Chun *et al.*(2001) announced the Asian dust occurred in the spring from 1993 to 1995 (3 years) in Yellow River's upper stream region around latitude 40° N, Takla Makan desert region and other dispersed areas to Manchuria in the east.

Obviously, the much Asian dust occurred mainly at Yellow River's upper stream, and other areas including Gobi desert and Takla Makan desert. Also the northeast region of China and Manchuria were discovered as the second source regions of Asian dust(Chun, 2002). Therefore, the source regions of the Asian dust proved through various researches up to now are Takla Makan desert in Talim basin, Gobi desert in Mongolia and the northern area of China, leeward desert and plateau in Altai Mountain in Mongolia, Loess plateau in Yellow River's midstream and inner Mongolian desert in China(Murayama, 1988; Yoon, 1990; Lee, 1993).

The research on the Asian dust is considered as an important issue to understand local climate and atmospheric environment (Jhun, 1999), but the quantitative analysis is still not performed due to the insufficient statistical and environmental data related to dust occurrence in the source region of Asian dust. Accordingly, the dust occurrence in the source region, its soil condition and the alteration tendency of meteorological element ought to be looked into as the first procedure to predict the accurate Asian dust occurrence and its transport.

In this study, surveyed the incidence and distribution of dust occurrence in the source regions and vicinities, using aerosol index obtained from TOMS (Total Ozone Mapping Spectrometer) satellite data from 1981 through 1992 for 12 years and from 1997 through 2000 for 4 years, total 16 years, and examined what influences the alterations of surface meteorological elements such as temperature, precipitation rate, relative humidity, wind speed using NCEP(National Centers for Environmental Prediction) reanalysis data.

2. Data and Methods

We performed the data analysis procedure on the Asian dust occurrence and environmental factors as shown in Fig. 1. As shown in Fig. 2, selected study areas and divided the object area including the source region of Asian dust into 3 areas as follows and surveyed the incidence of dust occurrence respectively: [Area 1] 35°N ~ 45°N, 75°E ~ 90°E (Talim plateau and Takla Makan desert), [Area 2] 40°N ~ 48°N, 95°E ~ 110°E (Gobi desert and Mongolia), [Area 3] 34°N ~ 40°N, 105°E ~ 115°E (Loess plateau).

Aerosol index , which was derived from Nimbus-7/TOMS from 1981 to 1992 and the material of Earth

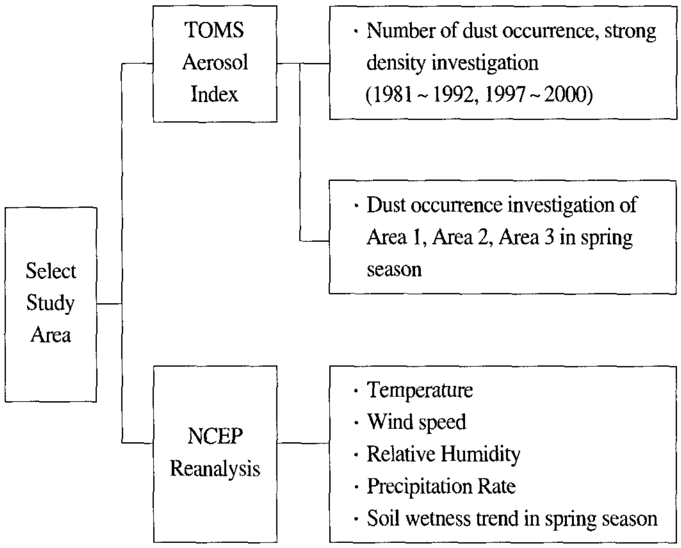


Fig. 1. Study flow of environmental analysis in Asian dust source region.

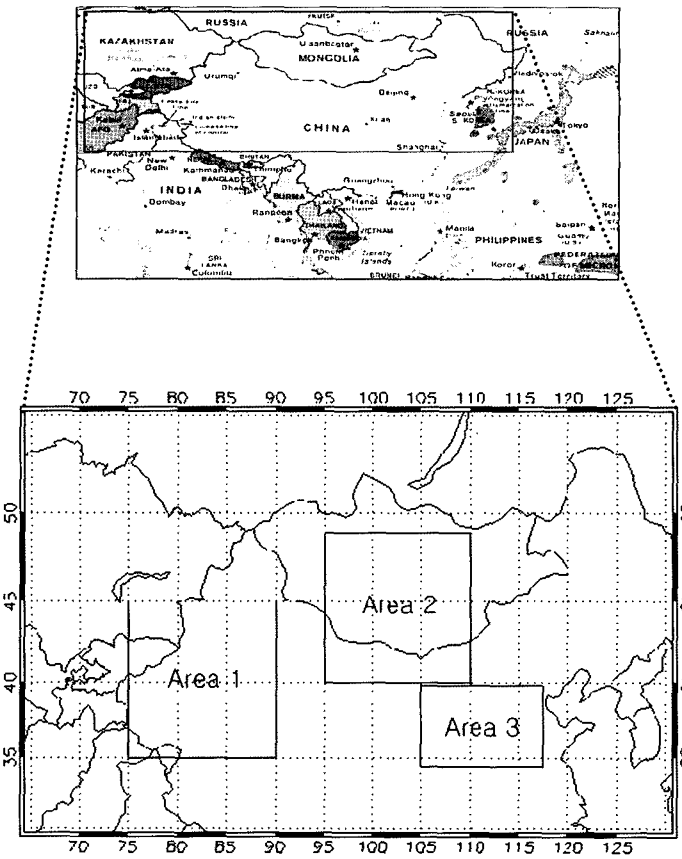


Fig. 2. Study area position.

Probe/TOMS from 1997 to 2000, was used to discover the characteristics of dust occurrence in the source region and the continent of China. The data from 1993 through 1996 was excluded in this research due to the difficulty of acquisition. TOMS aerosol index is a daily material whose size of grid is about $1.25° \times 1°$. It consider dust occurred when the reference values to determine the dust occurrence are more than 1.0 for Nimbus-7 or when they are more than 0.7 for Earth Probe(http://toms.gsfc.nasa.gov).

Temperature, precipitation rate, relative humidity, and wind speed considered to look into the relation between dust occurrence and surface meteorological elements were daily mean data (on temperature, wind) and monthly mean data (temperature, precipitation rate, relative humidity, wind) from NCEP reanalysis data on March, April, and May from 1981 to 2000. The size of grid is about $2° \times 2°$ except relative humidity (about $2.5° \times 2.5°$). Meteorological analysis data used in this study came from the temperature values at 2m above from surface, the precipitation rate values on surface, relative humidity values of 1000 hPa, and wind speed values at 10m above from surface. And used soil wetness data from two frequent dust occurring years to analyze the characteristics. It shows the degree of moisture content and dryness.

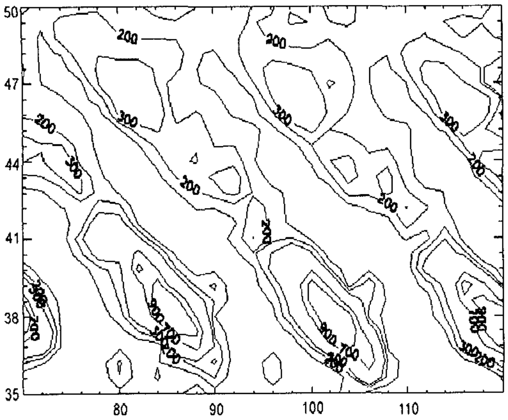
3. Results

Fig. 3. shows the mean distributions of the total dust occurrence days, relative humidity, temperature, wind(wind speed) and precipitation in the spring season (from March to May). The regions that the Asian dust occurs over maximum 900 days for 16 years were are Gobi desert and Loess plateau every longitude 10o in Takla Makan desert area, latitude 35°N ~ 41°N, longitude 70°E ~ 120°E. And similarly, the regions were distributed along the negative inclination angle of 45° (Fig. 3. (a)). The regions that the dust occurs maximum 900 days for 16 years showed similar mean number of dust days(19 days), compared with the mean number of dust days (17 days) from March to May in Takla Makan desert where Jhun(1999) have analyzed. But the number of dust days in Gobi desert and Loess plateau is bigger than the number in this study result. It is because the difference of data between the meteorological information of same interval weather charts from station and the remote sensing data from a satellite travelling an orbit once a day. As it investigate the annual change of the number of dust occurrence days in spring in the study area, the dust occurred the most frequently in 1992, but the least in 2000.

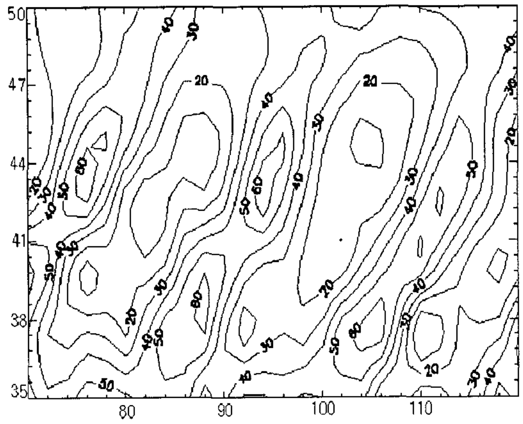
Talim basin, Takla Makan desert and Loess plateau where the Asian dust occurs frequently have a high relative humidity, 50 ~ 60% (Fig. 3(b)) and a low temperature, -10 ~ -5°C (Fig. 3(c)). And the wind speed is strong over 6 ms^{-1} (Fig. 3(d)) and the precipitation is small below 33mm (Fig. 3(e)). Although the number of dust occurrence days is small, the Gobi desert and Mongolian area including the source region of Asian dust record 30 ~ 60% relative humidity is 20 ~ 30% (Fig. 3(b)), temperature is over 5°C (Fig. 3(c)), wind speed is below 4 ms^{-1}(Fig. 3(d)), precipitation is more or less 100 mm (Fig. 3(e)) which is bigger than that of the most frequent dust occurrence regions.

Smirnova(1985) and Lomborenchin(1983) confirmed that the wind speed 7 ~ 9 ms^{-1} causes floating particles of soil to occur rolling phenomenon, and additionally the higher wind speed, wind carries particles more far away, and over 11 ~ 12 ms^{-1} wind starts to raise particles. In this study, the most frequent dust occurrence region, would be influenced directly by the surface wind speed when the wind is strong over 6 ms^{-1}. Also, the precipitation, below 33 mm, is low, which could be considered to be an indirect factor to make dust particles fly off from the soil.

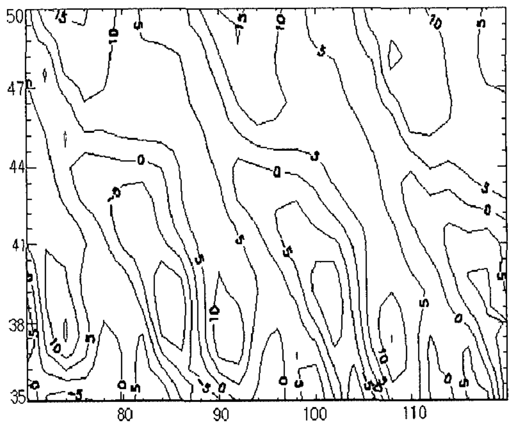
Table 1 shows the monthly mean number of dust



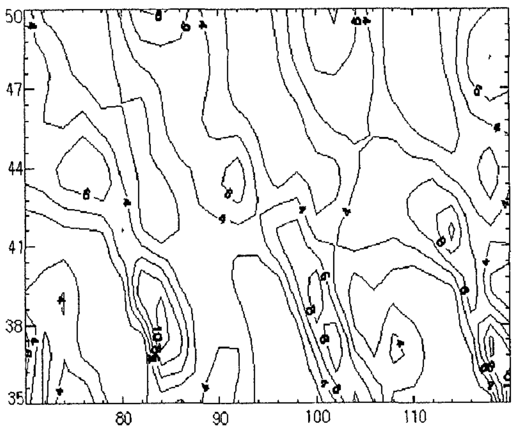
(a) Total occurrence(days)



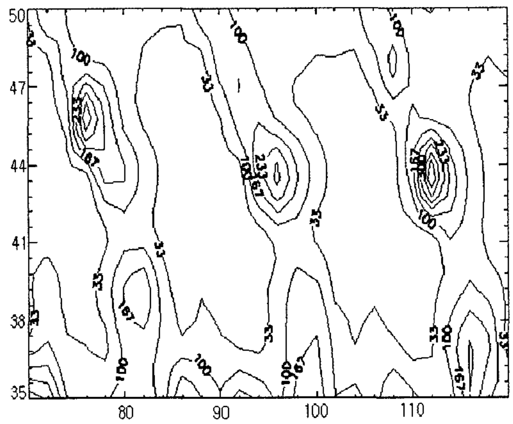
(b) Relative humidity(%)



(c) Temperature(°C)



(d) Wind speed(ms^{-1})



(e) Precipitation(mm)

Fig. 3. Distribution chart of dust total occurrence days, weather elements in spring season.

Table 1. Monthly dust occurrence grid number and percent ratio in Area 1, Area 2, Area 3.

Region \ Month		1	2	3	4	5	6	7	8	9	10	11	12
Area 1	Grid No.	645	3960	15477	20292	23900	18800	11799	10789	11080	4187	3067	1286
	%	0.5	3.2	12.4	16.4	19	15	9.4	8.6	8.8	3.3	2.4	1.0
Area 2	Grid No.	24	381	2242	9172	7375	4563	2445	2249	712	177	104	73
	%	0.2	1.2	7.6	31.1	24.9	15.5	8.2	7.6	2.4	0.6	0.4	0.3
Area 3	Grid No.	2792	4326	6447	10179	6851	3268	1538	918	445	595	425	984
	%	7.2	11.1	16.7	26.3	17.8	8.4	3.9	2.4	1.1	1.5	1.1	2.5

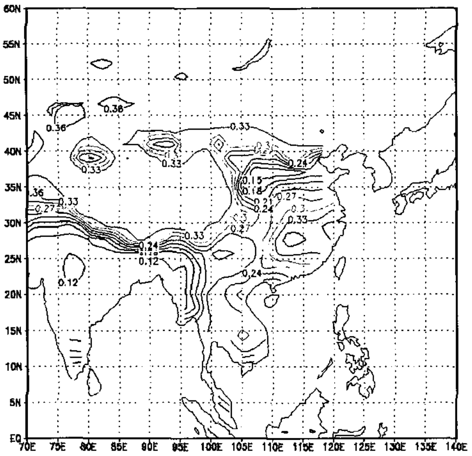
Table 2. Dust strong density grid number and percent ratio in Area 1, Area 2, Area 3.

Region \ Month		March	April	May
Area 1	Strong density grid No. (Dust occurrence grid No.)	1603(15477)	1633(20292)	2242(23900)
	Strong density % (Dust occurrence %)	10.35(12.4)	8.0(16.4)	9.3(19)
Area 2	Strong density grid No. (Dust occurrence grid No.)	79(2242)	185(9172)	83(7375)
	Strong density % (Dust occurrence %)	3.5(7.6)	2.0(31.1)	1.2(24.9)
Area 3	Strong density grid No. (Dust occurrence grid No.)	95(6447)	268(10179)	128(6851)
	Strong density % (Dust occurrence %)	1.47(16.7)	2.6(26.3)	1.86(17.8)

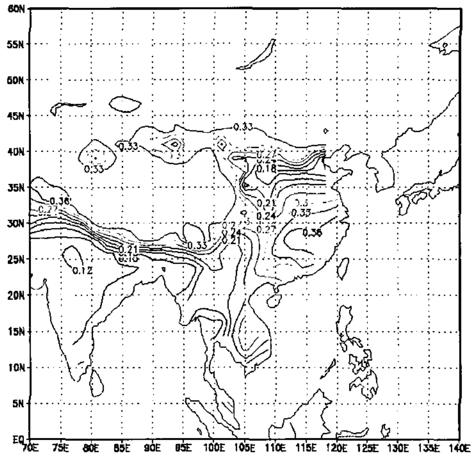
occurrence days in the grid in 1981 ~ 1992, 1993 ~ 2000 for 16 years dividing object area into 3 areas as follows : Area 1, Talim basin and Takla Makan desert, the most frequent dust occurrence regions, Area 2, Gobi desert and Mongolian region including the source region of Asian dust with infrequent dust occurrence, Area 3, Loess plateau. The monthly mean number of dust occurrence in 3 areas records high incidence especially on April and May in a year, and the month with the most frequent dust occurrence and its percentage are May, 19% in Area 1, April, 31.1% in Area 2, and April, 26.3% in Area 3. In particular, the Asian dust phenomenon takes place mainly from March to May in Korea, and the dust occurrence rates in 3 areas from March to May are over 60% in Area 2 and Area 3 which influence Korea directly, and 47.8% in Area 1 which hasn't a direct influence. In this study, we only focus in spring season (from March to May), but in Area 1 and Area 2 the dust occurrence rates on June are higher than that on March. The dust occurrence rates in summer are higher than those in fall and winter. The low dust occurrence rates dominate in winter.

Table 2 presents the values of grid points and its percentage on aerosol index, over 3.0 pollution intensity only using TOMS Nimbus-7 and Earth Probe data to examine the contamination level in Area 1 ~ 3 during March through May. Here, the aerosol index over 3.0 means the state we can't see the sun even in daytime. The highly contaminated dust occurs on March in Area 1, which is higher by one and a half times comparing the 12 ~ 19% dust occurrence rate dust with the 8 ~ 10% dust occurrence rate. Nevertheless, the dusts in Area 2 and 3 show low contamination level for their occurrence rate and the dusts with high contamination level appear on March in Area 2 and April in Area 3. As Area 1, desert region, is composed of floatable dust particles without any vegetation, often the strong dust rising phenomenon occurs. And in Area 2 and Area 3, the growth of steppe, vegetation and shrubs after March restrains in some degree the floating of particles from soil.

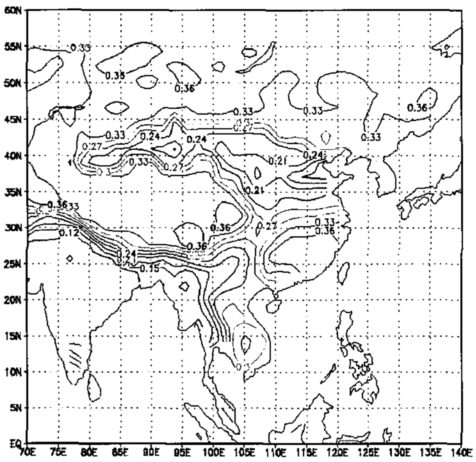
Compared the most frequent dust occurrence year(1992), with the least frequent dust occurrence



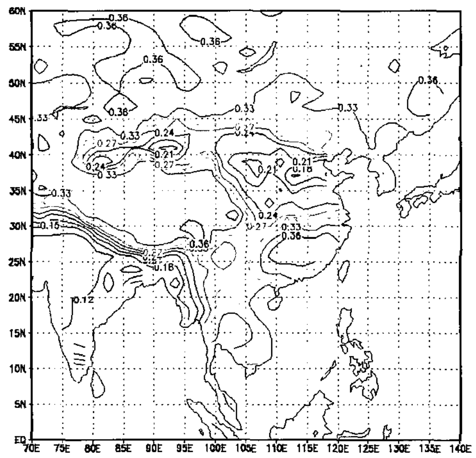
(a) March, 1992



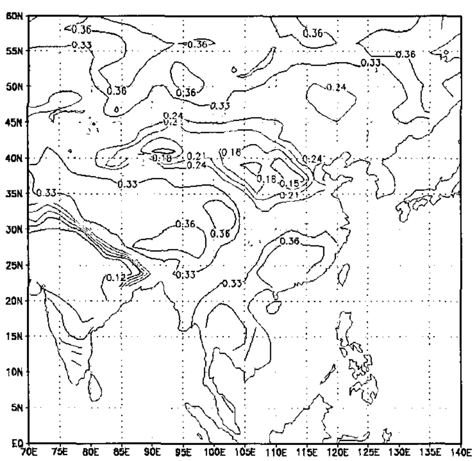
(b) March, 2000



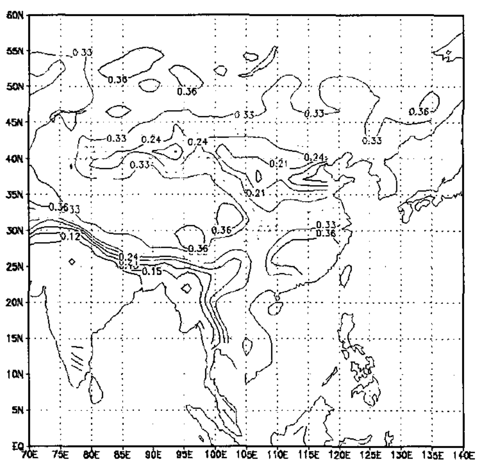
(c) April, 1992



(d) April, 2000



(e) May, 1992



(f) May, 2000

Fig. 4. Distribution of soil wetness in spring season.

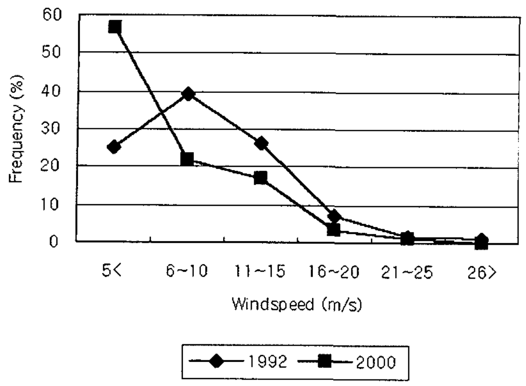


Fig. 5. Frequency of surface wind speed.

year(2000). Fig. 4(a) ~ (f) shows the soil wetness in 0°N ~ 60°N, 70°E ~ 140°E in the spring (March ~ May). The soil wetness is 20 ~ 30% low in study areas (35°N ~ 50°N, 75°E ~ 120°E). Especially, the soil wetness in Area 3 in the spring is below 20% that means serious dryness. As the result shown in Fig. 4, the tardy growth of vegetation by moisture deficiency in soil and the formation of strong floating particles are involved in the dust occurrence. Specially, with the fact that the soil wetness value in Loess plateau is lower than that of Takla Makan desert or Mongolia, Gobi desert, a large number of dust occurrence in Loess plateau may produce a direct effect on Korea. Fig. 5 expresses the frequency of surface wind occurrence in every 5 ms^{-1} in 3 areas. The winds below 5 ms^{-1} emerged frequently in 2000, and the 6 ~ 10 ms^{-1} winds that raise dust particles appeared often for about 18% more in 1992(about 40%) than in 2000(about 22%). Consequently, the main factor of frequent dust occurrence during research period is the large quantity of dust particles by the moisture deficiency and absence of vegetation in soil as the first, and wind speed over 6 ms^{-1} as the second.

4. Conclusions

In this study, using TOMS aerosol index investigate for the characteristics of dust occurrence in the source region of Asian dust and the continent of China.

The regions that the Asian dust occurs over 900 days for 16 years are Gobi desert and Loess plateau every longitude 10° in Takla Makan desert area, latitude 35°N ~ 41°N, longitude 70°E ~ 120°E. And similarly, the regions are distributed along the inclination angle of 45°. Talim basin, Takla Makan desert and Loess plateau where the Asian dust occurs frequently have a high relative humidity(50 ~ 60%) and a low temperature (-10°C ~ -5°C). And wind speed is strong(over 6ms^{-1}) and precipitation is small(below 33 mm). Although the number of dust occurrence days is small, the Gobi desert and Mongolian area including the source region of Asian dust record 30 ~ 60% relative humidity, over 5°C temperature, below 4 ms^{-1} wind speed, 100 mm precipitation, which are higher than that of the most frequent dust occurring regions.

The monthly mean number of dust occurrence days in the following 3 areas records high on April and May in a year : Area 1, Talim basin and Takla Makan desert, the most frequent dust occurrence regions, Area 2, Gobi desert and Mongolian region including the source region of Asian dust with infrequent dust occurrence, Area 3, Loess plateau. The over 3.0 contamination level dust occurs on March in Area 1, which is higher by one and a half times comparing the 12 ~ 19% occurrence rate dust with the 8 ~ 10% rate of occurrence. But the dusts in Area 2 and 3 show low contamination levels for their occurrence rate, and the dusts with high contamination level appear on March in Area 2 and April in Area 3. Compare the most frequent dust occurring year, 1992, with the least frequent dust occurring year, 2000. The average soil wetness value was below 30%, especially in 1992, the soil wetness was below 18% in Area 3(Loess plateau) so that there was a great deal of floating dust particles. And the surface wind over 6 ~ 10 ms^{-1} occurred by 20% more in 1992 than in 2000.

Up to now, the statistical method applying the past field survey data and documents has been used at the environment study about Asian dust's source region, but the more effective method utilizing satellite remote survey data that provide broad observation data and information in a short time will be applied at the environment study about Asian dust in the future.

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