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CONCENTRATIONS OF PM10, PM2.5 AND PM1 INFLUENCED BY SEA-LAND BREEZE CIRCULATION AND ATMOSPHERIC BOUNDARY LAYER IN THE KOREAN MOUNTAINOUS COAST DURING DUSTSTORM PERIOD

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ABSTRACT

The concentrations of 100 nano-particle size to 20ug/m^3 at the eastern coastal region of Korea have been measured by GRIMM aerosol samplers from March 7 through 17, 2004, at two aerosol sampling points in the high mountain (Mt. Taeguallyung; 896m) of upwind side in the west of which Kangnung Meteorological Administration (KMA, called C-point) of Kangnung coastal city adjacent to the East Sea in the east. PM10, PM2.5 and PM1 near the ground surface at C-point until 1200 LST, March 8 before the passage of dust storm were very low with the magnitudes of about 40, 35 and 30ug/m^3, which showed not much different concentrations each other. The maximum concentration of PM10 from March 7 before dust storm occurred near the beginning time of on duty around 0800 LST and off duty around 1700 LST, due to the increase of fuel combustion of vehicles on the street. From the afternoon on March 10 through 16, when the great amount of dust passed through Kangnung coastal city under westerly wind, PM10 concentration reached 340ug/m^3 and PM2.5 and PM1 concentrations were 105ug/m^3 and 60ug/m^3, showing twice higher concentration of PM10 than PM2.5, respectively. The majority of dust transported from China consisted of larger particle size than PM2.5 and PM1. High concentration of particulates was detected at 0900 LST, beginning time of office hour and after the ending time of office hour to 2200 LST at night. Howevere,, the occurrence of low concentration of particulates was found near noon. The transported dust from the upwind side in the west (mountain area) under the westerly wind toward to the downwind side (Kangnung city) were combined with the particulates generated by easterly sea-valley breeze, vehicles, boilers from resident area in the city after sunrise and resulted in the high concentration of particulates at the beginning time of office hour, 0900 LST. For daytime, the upslope wind combined with easterly sea breeze and valley wind drove the dust particles or particulates in the city to be dissipated into the mountain side in the west, resulting in the decrease of particulates at C-point in the coast near noon. The high concentration of particulates occurred again due to the increase of fuel combustion of vehicles at the ending time of office hour and boilers. Under westerly land-mountain breeze toward Kangnung city, returning of particulates floated for daytime near the mountain to the city and emmitted particulates from the city at night increased high concentrations of particulates before midnight with a maximum at 2200 LST and a

shrunken depth of nocturnal surface inversion layer in the city further result in the increase of particulate concentration..

Key Words : PM10, PM2.5, PM1, Duststorm, Sea-Valley Breeze, Land-Mountain Breeze

1. INTRODUCTION

Asian duststorm or called , Yellow Sand and KOSA is quite different from that in other regions of the world such as Sahara and Australian deserts (Reiff et al., 1986; Middleton, 1986). Asian Dust have requently and periodically occurred under strong wind blowing soil in the dried area of the northern China and Gobi desert in Mongolia, and the storms have transported a great amount of dusts to eastern China, Korea, Japan, even north America (Chon, 1994; Chung et al., 2001; Chung and Yoon, 1996; Jigjidsuren and Oyuntsetseg, 1998; Middleton, 1986; Natsagdorj, and Jugder, 1992a). The dust is to make a great contribution to low visibility and air quality in spring in northern Asian countries and even U.S.A.(Carmichael, et al., 1997; Choi and Song, 1999; Chung, et al., 2003; David et al., 2001; Gao et al., Kim, et al., 2001; McKendy et al, 2001; Murayama, 1988). In the recent years, newspaper and TV news reported the diseases of livestock in China, Taiwan, Korea, Japan and Thailand were under the influence of duststorm, which may accompany various bacilli and germ in the countries along the path of the duststorm and caused uncountable thousands of livestock to be killed, due to bacterial disease (KBS TV, 2004; Joong-ang, 2004).

Kim and Kim (2003) and Kim et al. (2003) explained that particulate matters during Asian Dust event in 2001 and 2002 could be transported toward Seoul city in Korea under strong westerly wind of about 20 m/s. Zhang and Zhong (1985) insisted that about the half of the total quantity of particulate matter are deposited near the source area (30%) and re-distributed on a local scale (20%) and the other half of them are expected to be subject to long-range transport. The transported amount of dust can serve as one of the major particulate matter sources all across the Asia and Pacific regions. An investigate aerosol experiment was performed by many scientific groups in many locations of east Asia of Korea, China and Japan in 2004, but major measurement and researches in Korea have been done at Gosan Supersite of Jeju island in the southern Korea. Except for Gosan, some of scientists personally carried out the measurement of aerosol in the west part of Korea, but no measurement was done in the mountainous coastal region of Korean peninsula.

Thus, the objective of this study is to investigate diurnal aerosol concentration, especially PM10, PM2.5 and PM1, which greatly influenced upon local climate change and human health condition dary and to explain the high concentration time band, considering synoptic and meso-scale motions of atmosphere.

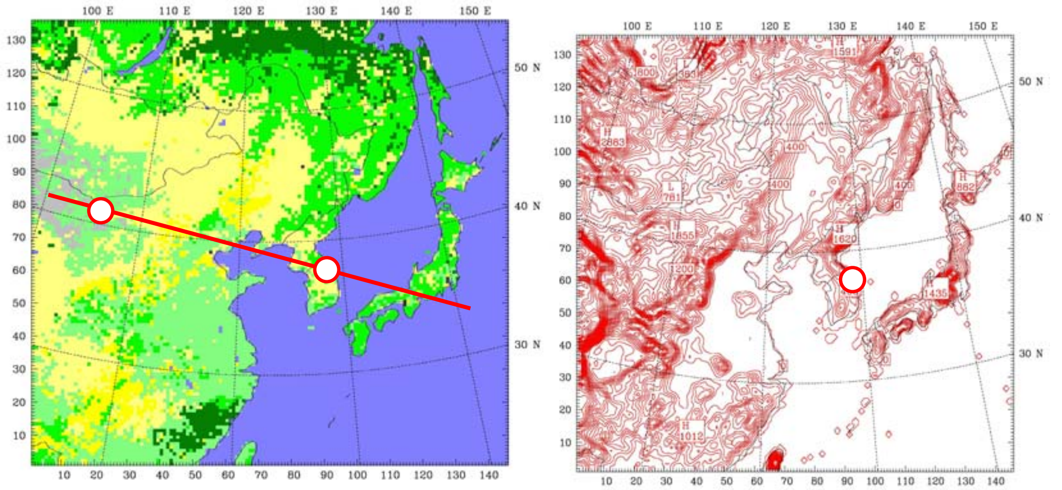
2. MEASUREMENT OF AEROSOL AND TOPOGRAPHY

2-1. Instrument

The concentrations of 100 nano-particle size to 20ug/m^3 at the eastern coastal region of Korea have been measured by GRIMM aerosol samplers from March 7 through 17, 2004, which included dust storm period of China in spring. Two aerosol sampling points were fixed at a measurement point in the high mountain, Mt. Taeguallyung (896m) (called M-point; (37^0 41'N, $128^0$44'E)) upwind side in the west of which Kangnung Meteorological Administration (KMA; $37^0$45'N, $128^0$54'E) of Kangnung coastal city (called C-point) was adjacent to the East Sea in the east.
The GRIMM Model 1107 is an extremely small and portable particle analyzer. The Model 1107 is specifically designed for PM-10, PM-2.5 and PM-1 environmental ambient air analysis using the laser light scattering technology. This technology enables the Model 1107 to make very precise "cut points" for all three PM size classifications. This technique patented system allows the user to collect all three PM fractions simultaneously without changing sampling heads or weighing filters. However, the Model 1107 is the only PM monitor to offer dual technology consisting of both optical and gravimetrical analysis. The Model 1107 incorporates a removable 47 mm PTFE filter which allows the user to verify the optical analysis gravimetrically, as well as providing the option for other chemical analysis on the collected residue.
The 107 Environmental Particulate Monitoring Systems particulate measurements via 900 laser light scattering. Air with multiply particle sizes passes through a flat laser beam produced by an precisely focused laser and several collimator lenses. The scattered light are then detected by a 15-channel pulse height analyzer for size classification. The counts from each size classification are then converted to mass by a well established equation. The data are then presented in the P.S. EPA conventions for PM-10, PM-2.5 and PM-1. The complete 107 system is consisting of the 165 fiberglass housing, the drying temperature control system, the 107 PM dust monitor, sensors for humidity and temperature and the 170M sampling system. Dislays real time data of PM-1 and PM-2.5 and even PM-1 is detected as quickly as every as every six seconds. Sensitivity is from 0.1 microgram/m3 upwards. Stand-alone system is able to be operated directly all times out in the field. No sample pipe heating needed, therefore no loss of VOC's. Auto-zero, self-diagnostic and continuous performance recording are done after each starts.

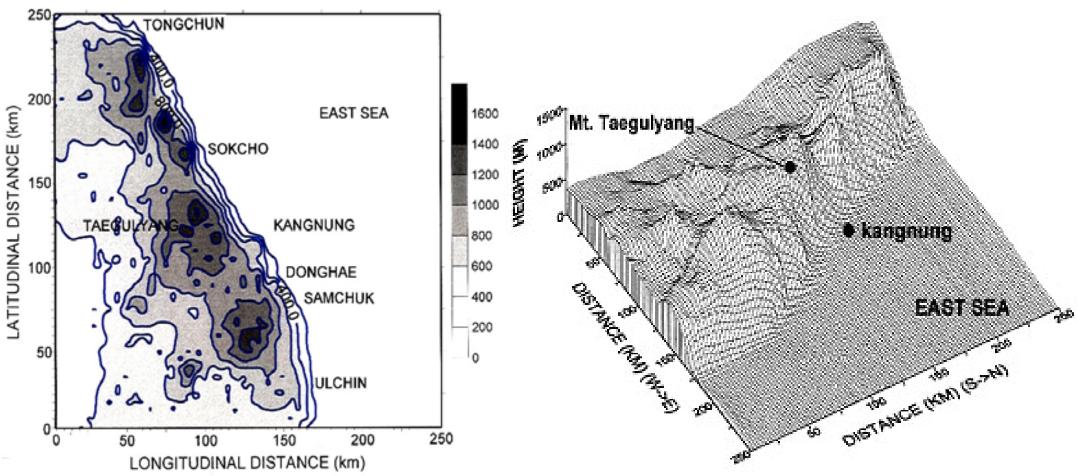
2-2. Topography in study area

The study area is located in the eastern mountainous coastal region of Korean peninsula and two GRIMM aerosol samplers were equipped at the sampling points in the high mountain, Mt. Taeguallyung (896m) (called M-point) upwind side in the west of Kangnung coastal city and Kangnung Meteorological Administration (KMA) of (called C-point) adjacent to the East Sea in the east (Figure 1 and 2). 2.5^0 degree interval terrain date was used for the largest domain and then 1km interval data was used for fine mesh domain, on a straight cutting line from the west toward east, which was major transportation root of dust from the dust storm generation area, China toward Korea like a straight cutting line of Mogolia-Beijing-Seoul-Kyoto-Pacific Ocean like; (10, 90), (130, 40), respectively.



(a) (b)

Figure 1. (a) Land-use data and (b) topography for a coarse domain of a horizontal grid size 27 km. Circles denote duststorm area (China) and Kanunu city (Korea).



(a) (b)

Figure 2. 2D (left) and 3D (right) topographies (circle area shown in Figure 1b) with a horizontal grid size 5 km near Kangnung city (20m above mean sea level; 10 km width) and Mt. Taeguallyung (860 m), Korea.

3. RESULT AND DISCUSSION

3.1 Aerosol concentration in Kangnung city and Mt. Taeguallyung

PM10, PM2.5 and PM1 near the ground surface at C-point (KMA) of Kangnung coastal city until 1200 LST, March 8 before the passage of dust storm were very low with the magnitudes of about 40, 35 and 30ug/m^3, which showed not much different concentrations each other. The maximum concentration of PM10 from March 7 before dust storm occurred near the beginning time of on duty around 0800 LST and off duty around 1700 LST. Under the weak influence of dust transportation from China into Korean peninsula from March 8 until 1200 LST, March 10, the concentrations of PM10 and PM2.5 and PM1were twice increased over about 50ug/m^3 to 95ug/m^3. From the afternoon on March 10 through 16, when the great amount of dust passed through Kangnung coastal city, PM10 concentration reached 340ug/m^3 and PM2.5 and PM1 concentrations were 105ug/m^3 and 60ug/m^3, showing twice higher concentration of PM10 than PM2.5, respectively.

The majority of dust transported from China consisted of larger particle size than PM2.5. Except for the period from 1800 LST, March 10 through 0300 LST, March 11, when the maximum concentrations of PM10 and PM2.5, PM2.5 and PM1 concentrations still very low, similar to those before the period of dust transportation. It means that the dust transportation from China into Kangnung city could great influence upon the increase of PM 10 concentration in the local area, but not much influence upon PM2.5 and PM1 concentrations. An important thing is that the relatively high concentration of particulates is detected at 0900 LST, beginning time of office hour and after the ending time of office hour to 2200 LST at night. Another thing is the occurrence of low concentration of particulates near noon.

The transported dust from the upwind side in the west (the mountain area) under the westerly wind toward to Kangnung city combines with the particulates generated by easterly sea breeze and valley wind, vehicles, boilers from resident area in the city after sunrise and results in the high concentration of particulates at the beginning time of office hour, 0900 LST. As daytime goes on, the upslope wind combined with easterly sea breeze and valley wind drives the dust particles or particulates in the city to be dissipated into the mountain side in the west, resulting in the decrease of particulates at C-point in the coast near noon.

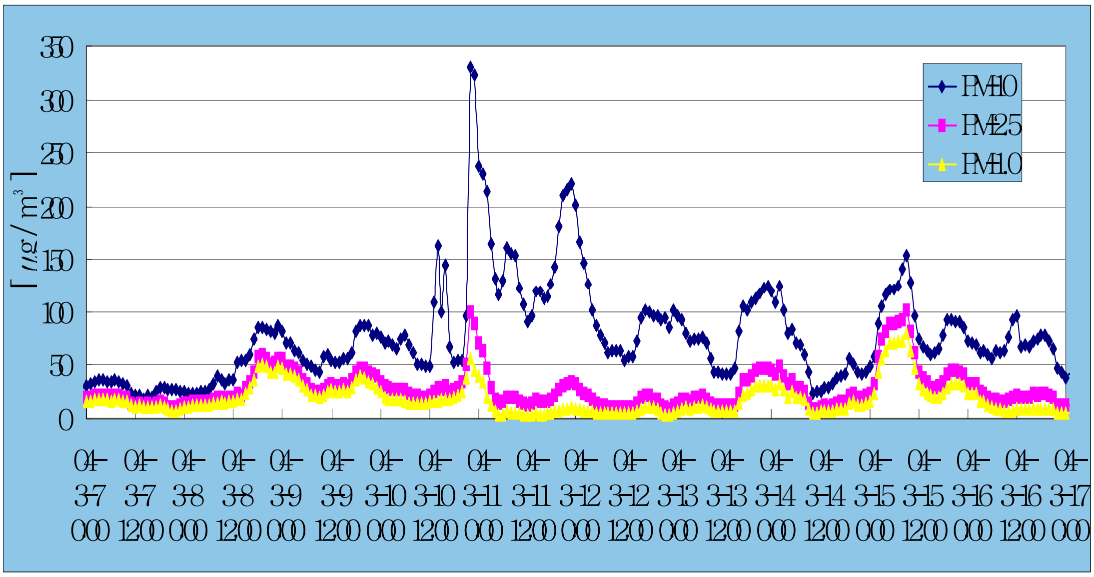


Figure 3. Hourly based concentration (ug/m^3) of PM10, PM2.5 and PM1 at an aerosol sampling point of Kangnung Meteorological Administration from March 7 through March 17, 2004.

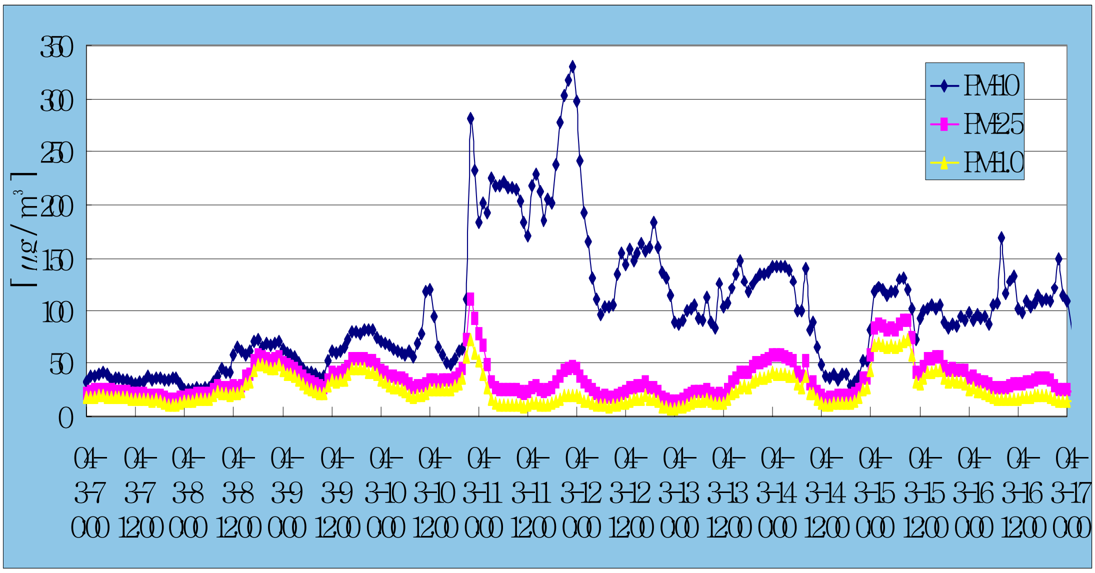


Figure 4. As shown in Figure 4, except for Mt.Taeguallyung (896m) from March 7 through March 17, 2004.

The high concentration of particulates occurred again due to the increase of fuel combustion of vehicles at the ending time of office hour and boilers. These high concentrations of particulates gradually increase before midnight with a maximum at 2200 LST, due to the shrunken depth of atmospheric boundary layer, when the reduction of surface heating of the ground induces the shrunken convective boundary layer and when nocturnal cooling of ground surface generates a shallow depth of nocturnal surface inversion in the city. After sunset, which nocturnal cooling of the ground surface induces the formation of nocturnal surface inversion layer and it showed much shrunken depth of atmospheric boundary layer, compare to the daytime convective boundary layer. Thus, the concentrations of particulates in the early night should much increase than in the daytime.

From 2300 LST, the high concentration of particulates gradually decreased before the beginning of office hour in the next day morning. The reason of the decrease concentration of particulate was due to westerly synoptic wind associated with mountain wind after sunset became relatively strong downslope surface wind toward the coastal city and this surface wind was also associated with land breeze toward the East Sea, resulting in driving the floating particulates to flow in the city into the sea and the decrease of the particulate concentration of 110ug/m^3at 0600 LST, March 11, Kangnung city.

Then, the transported dust from upwind side in the west toward to Kangnung city combined with the particulates generated by surface wind, vehicles, boilers from resident area in the city after sunrise and the high concentration of particulates at the beginning time of office hour, 0900 LST was detected and after that time intensified sea breeze and valley wind drove the particulates into the mountain side in the west again, resulting in the low concentration of particulate of 80ug/m^3at near noon.

4. CONCLUSION

For the dust stsorm period from the afternoon on March 10 through 16, when the great amount of dust passed through Kangnung coastal city under westerly wind, PM10 concentration reached 340ug/m^3 and PM2.5 and PM1 concentrations were 105ug/m^3 and 60ug/m^3, showing twice higher concentration of PM10 than PM2.5, respectively. The majority of dust transported from China consisted of larger particle size than PM2.5 and PM1. High concentration of particulates was detected at 0900 LST, beginning time of office hour and after the ending time of office hour to 2200 LST at night.

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REFERENCES

Carmichael, G. R., Hong, M. S., Ueda, H., Chen, L. L., Murano, K., Park, J. K., Lee,H., Kim, Y., Kang, C., Shim, S., 1997. Aerosol composition at Cheju Island, Korea. J. Geophy. Res., 102(5), 6047-6061.

Choi, S. W., Song, H. D., 1999. Variation of concentration of heavy metal during Yellow sand period of winter season at Taegu area. Bulletin of Envron. Sci., 4(11), 1-13.

Chon, H., 1994. Historical records of yellow sand observations in China. Res. Environ. Sci., 7-6, 1-11.

Chung, Y. S., Yoon, M. B., 1996. On the occurrence of yellow sand and atmospheric loadings. Atmos. Environ., 30, 2387-2397.

Chung, Y.S., Kim, H. S., Natsagdorj, L., Jugder, D., Chen, J. S., 2001. On yellow sand occurred during 1997-2000. J. Korean Meteor. Soc., 37, 305-316.

Chung, Y. .S., Kim, H. S., Jugder, D., Natsagdorj, L., Chen, J. S., 2003. On sand and duststorms and associated significant dustfall observed in Chongju-Chongwon, Korea. Water, Air, and Soil Pollut: Focuss 3: 5-19.

David, M.T., Robert, J. F., Douglas, L. W., 2001. April 1998 Asian dust event: A southern California perspective. J. Geophy. Res., 106(D16), 18371-18379.

Gao, Y., Anderson, J. R., 2001. Characteristics of Chinese aerosols determined by individual particle analysis. J. Geophy. Res., 106 (D16), 18037-18045.

Jigjidsuren, S., Oyuntsetseg, S., 1998. Pastureland utilization problems and ecosystem. Ecological sustainable development. Ulaanbaatar, No.2, 206-212.

Joong-Ang, 2004, The influence of duststorm accompaning various bacilli and germ on Joong-Ang daily newspaper, March 10, 2004.

KBS TV, 2004, Korean Broadcasting Service, 9'oclock news, March 10, 2004.

Kim, H. K., Kim, M. Y., 2003. The effects of Asian dust on particulate matter fractionation in Seoul, Korea during spring 2001. Atmos. Environ., 51, 707-721.

Kim, K. W., Kim, Y. J., Oh, S. J., 2001: Visibility impairment during Yellow Sand periods in the urban atmosphere of Kwangju, Korea. Atmos. Environ., 35, 5157-5167.

McKendry, I. G., Hacker, J. P., Stull, R., Sakiyama, S., Mignacca, D, Reid, K., 2001: Long-range transport of Asian dust to the lower Fraser Valley, British Columbia, Canada. J. Geophy. Res., 106 (D16), 18361-18370.

Middleton, N. J., 1986. A geography of dust storms in southwest Asia. J. Climate., 6, 183-196.

Natsagdorj, L., Jugder, D., 1992a. Statistics method for prediction of dust storms over the Gobi and steppe area in Mongolia in spring. Scientific report, Ulaanbaaatar, pp83.

Murayama, N., 1988. Dust cloud "Kosa" from the east Asian dust storms in 1982-1988 as observed by the GMS satellite. Meteor. Sctell. Cent. Tech., Note, 17, 1-8.

Zhang, Y., Zhong, Y., 1985. The simulation and diagnosis for a strong wind associated with northeast low. Acta Meteor. Sinica, 43, 97-105.