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Atmospheric Chemistry and Physics Discussions

Diagnosis of dust- and haze pollution-impacted PM10, PM2.5 and PM1 aerosols observed at Gosan Climate Observatory

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- ☆ Methodology and measurement overview
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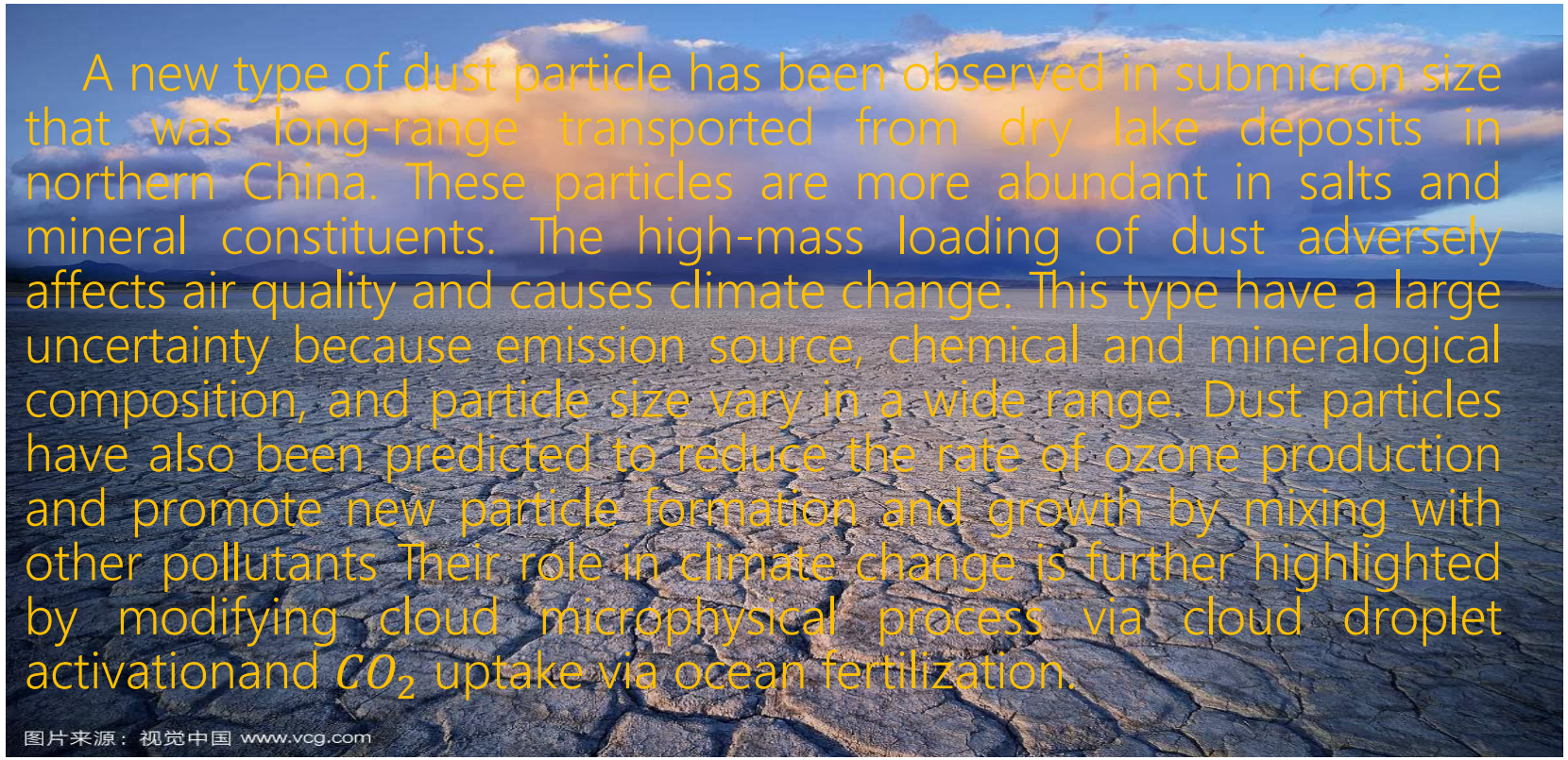
Introduction

Dust particles are dominant atmospheric aerosols and account for more than 60% of the total global dry aerosol mass burden.Dust particles are abundant in coarse mode, which isrepresented by PM10.



Introduction

AERONET and satellite observations

Atmospheric aerosol

However,it is still a ***big challenge*** to estimate the optical property of main aerosol types especially dust particles in East Asia, because their property is not only dependent on source regions (Huang et al., 2014) but also modified during transport through aging and mixing with pollutants (McFarlane et al., 1992; Von Salzen et al., 2005; Bäumer et al., 2007; Kim et al., 2011).

Using statistical methods analysis five-year measurements of mass, water-solubleions, and carbonaceous compounds for PM10, PM2.5, and PM1. Using mass mode analysis and principal component analysis to gain insight into the effects and significance of mineral dust and haze pollution on atmospheric aerosols.。

Methodology and measurement overview

Aerosol samples were collected separately for PM1, PM2.5, and PM10 onto 37 mm Teflon and Quartz filters (Pall, Corp.) using sharp-cut cyclones (URG, USA) at the Gosan Climate Observatory from 2007 to 2012. Sampling was undertaken for a period of 24 h from 10:00 to 10:00 the next day. A total of sets of samples were collected and analyzed for water-soluble inorganic ions and carbonaceous compounds.

Methodology and measurement overview

Water-soluble species were extracted from the filters into a solution comprising a mixture of 19 mL distilled water and 1 mL methanol. Watersolubleions, including CI^{-}, NO_3^{-}, SO_4^{2-}, Na^{+}, NH_4^{+}, K^{+}, Mg^{2+}, and Ca^{2+} were analyzed viaion chromatography.

Carbonaceous components were measured at the Desert Research Institute using the Interagency Monitoring of Protected Visual Environments TOR protocol.

Methodology and measurement overview

From August 2007 to December 2012, the average PM10, PM2.5, and PM1 mass concentrations of all measurements were 30 μg/m^3, 19 μg/m^3 and 14 μg/m^3.

	PM_{10}		$PM_{2.5}$		PM_1	
	Mean	Mean+σ	Mean	Mean+σ	Mean	Mean+σ
Mass	30	52	19	32	14	25
Cl^-	0.8	1.7	0.1	0.3	0.1	0.2
NO_3^-	2.1	4.1	1.0	2.2	0.7	1.9
SO_4^{2-}	5.5	9.5	4.4	7.5	4.3	7.5
Na^+	1.2	1.9	0.4	0.7	0.2	0.4
NH_4^+	2.8	4.6	2.4	4.0	2.1	3.6
K^+	0.3	0.5	0.2	0.4	0.2	0.4
Mg^{2+}	0.2	0.3	0.1	0.1	0.02	0.04
Ca^{2+}	0.3	0.7	0.1	0.3	0.1	0.2

	PM_{10}		$PM_{2.5}$		PM_1	
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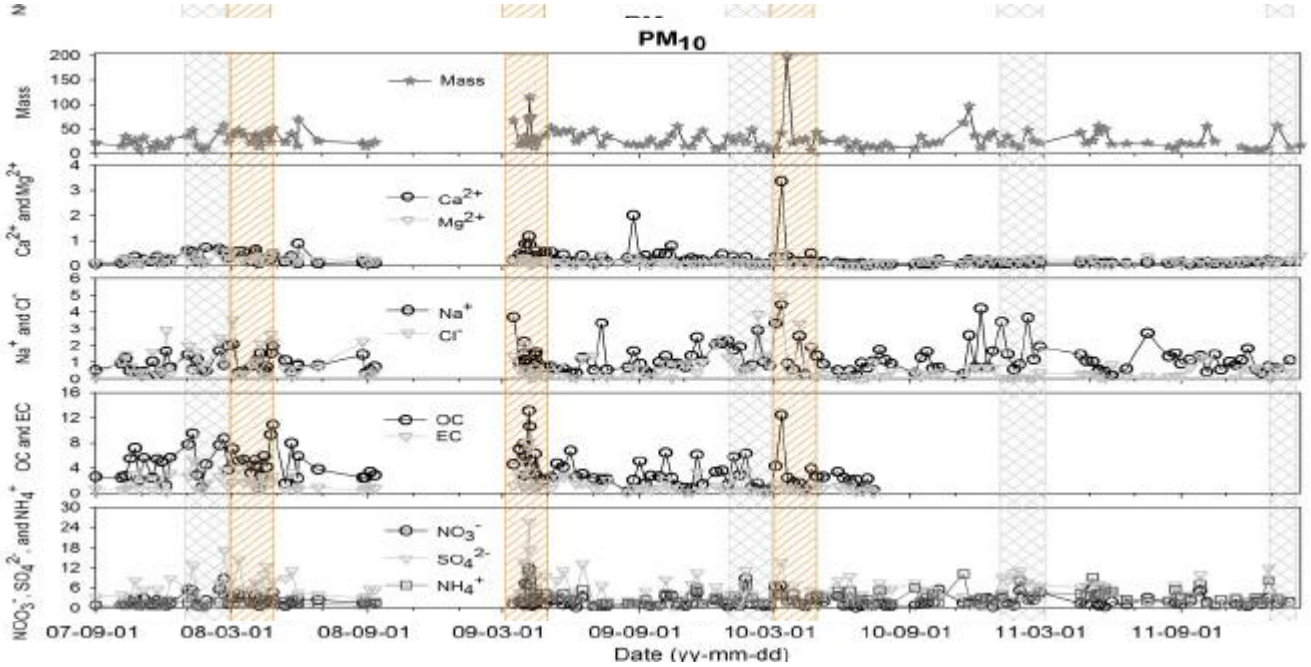
SO_4^{2-}	5.5	9.5	4.4	7.5	4.3	7.5
Na^+	1.2	1.9	0.4	0.7	0.2	0.4
NH_4^+	2.8	4.6	2.4	4.0	2.1	3.6
K^+	0.3	0.5	0.2	0.4	0.2	0.4
Mg^{2+}	0.2	0.3	0.1	0.1	0.02	0.04
Ca^{2+}	0.3	0.7	0.1	0.3	0.1	0.2
OC	4.0	6.6	3.4	5.7	2.6	4.3
EC	1.5	2.9	1.5	2.7	1.2	2.0

As shown on the left, SO_4^{2-} and OC were the most abundant, followed by NH_4^+ and NO_3^-. These four species accounted for 48%, 58%, and 69% of the PM10, PM2.5, and PM1 mass, respectively. Of these species, SO_4^{2-}, NH_4^+, and EC were predominant in PM1, which corresponds to more than 75% of those in PM10.

It is well known that NO_3^- is more abundant in coarse mode particles due to high affinity to soil mineral.

Methodology and measurement overview

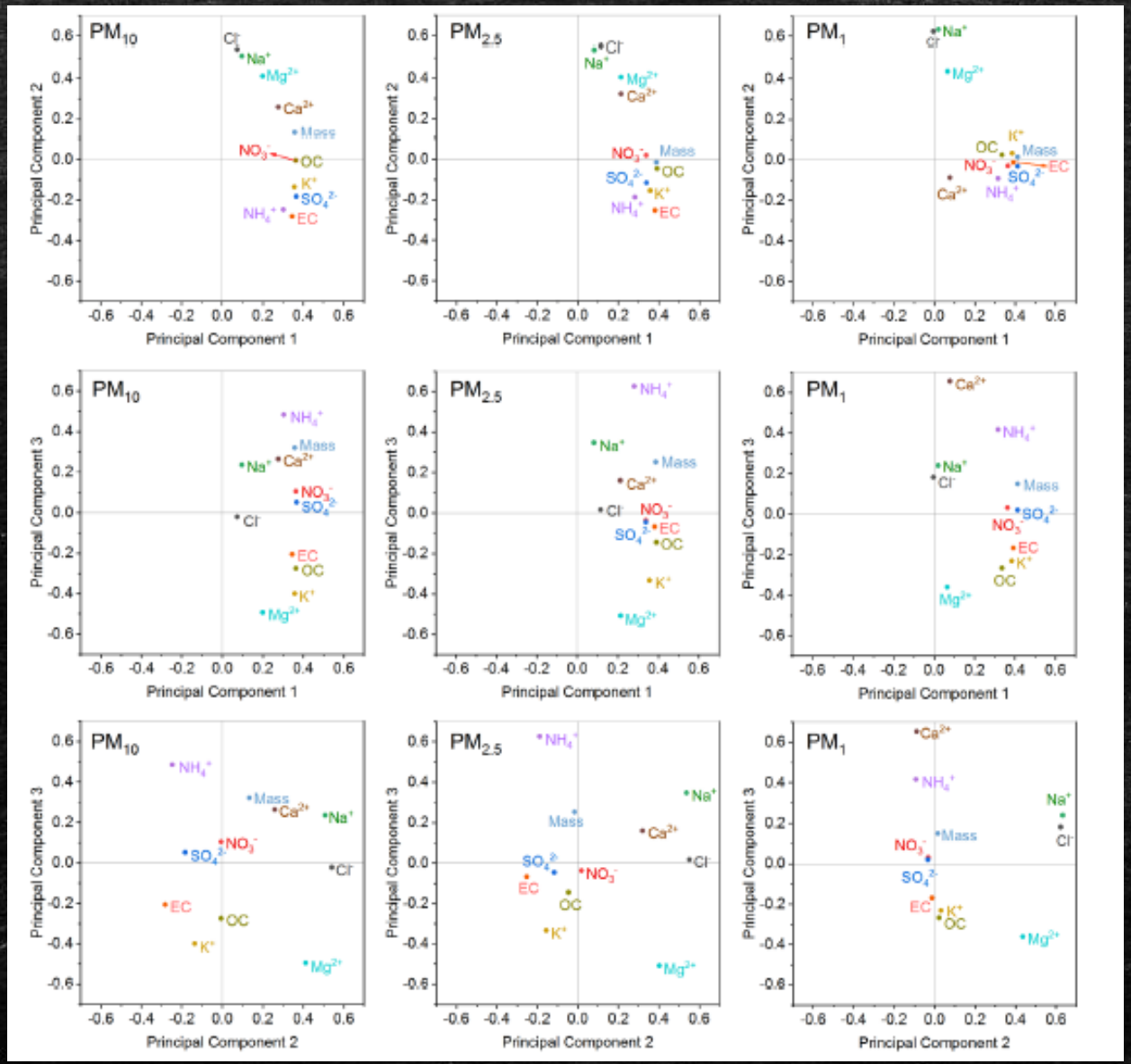
Time-series variations of major constituents of PM10, PM2.5, and PM1 for the entire experiment



Data and results analysis

Principle component analysis (PCA) was conducted for all measured species of PM10, PM2.5,and PM1 aerosols. In PCA analysis, two components are usually selected. In this study, the principle component 1 and 2 accounted for more than 60% of the total variance of PM10, PM2.5, and PM1. The principle component 1(PC1) was composed of high loadings for SO_4^{2-}, NO_3^-, NH_4^+, K^+, OC, and EC, especially in
PM1. These six species contributed almost equally to the PC1, which explained 46% of the total variance. In contrast, the principle component 2 (PC2) explained 16% of the total variance and was characterized by high loadings for Na^+, Cl^-, Mg^{2+} and Ca^{2+}, mainly in PM10 and PM2.5. Interestingly, the principle component 3 (PC3) comprising 9% of the total variance,was associated with high loadings for NH_4^+ and Ca^{2+}, particularly in PM10.These three independent factors explain more than 70% of the total variance.

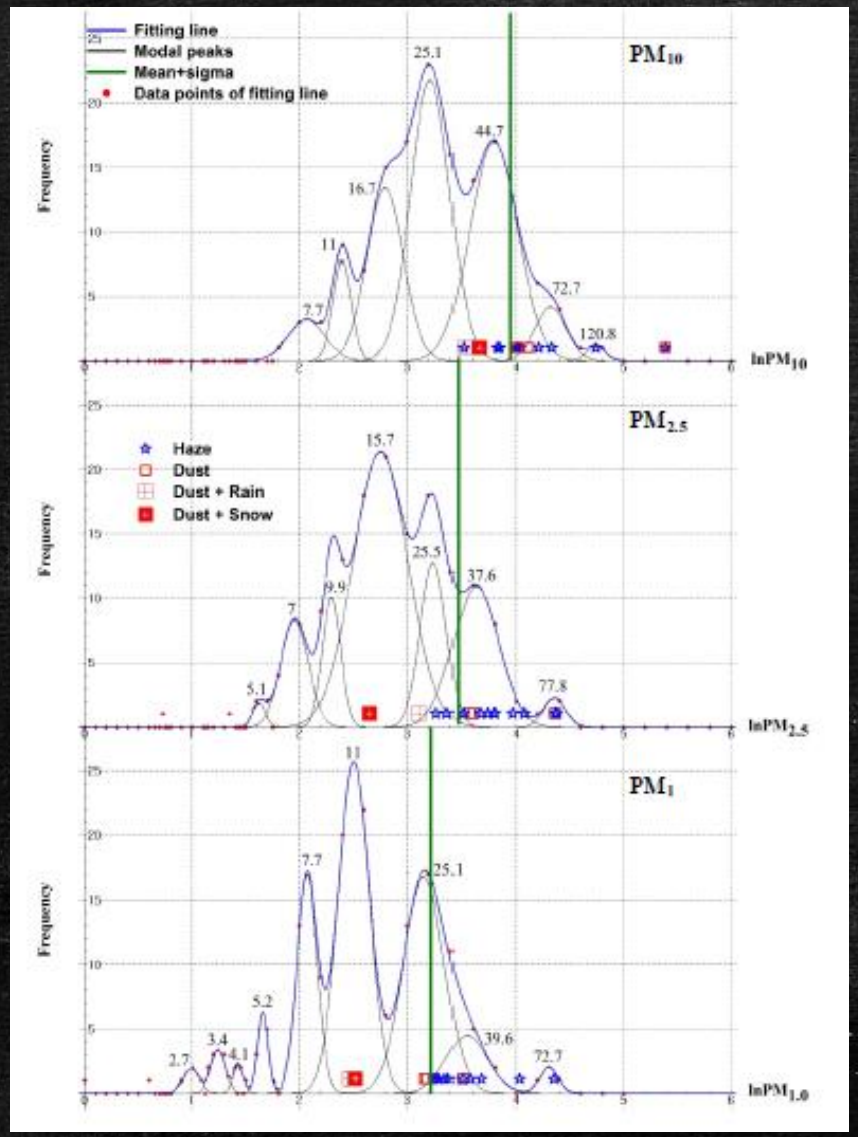
Principal component analysis results for all measured substances in PM10, PM2.5 and PM1



Data and results analysis

As the most abundant species, SO_4^{2-} and NO_3^- concentrations were highly correlated with PC1 loadings for all three-size particles, confirming that the PC1 represents the influence of anthropogenic pollution sources. In saline dust, the concentrations of Ca^{2+}, Na^+, and Cl^- were enhanced concurrentlywith OC sub-component (Zhang et al., 2014; Shang et al., 2018; O'Dowd et al., 2004; Griffithet al., 2010). The sea-salt contribution of Ca^{2+} was estimated to be 12% in PM2.5 and 19% in PM10, assuming that sodium was derived solely from sea salt. In this study, the measurements of water-soluble ions demonstrate that the contribution of sea salt species was found to reach the maximum in summer when aerosol loading is at its minimum under influence of marine air. Thus, the PC2 represents the impact of dust particles including alkaline soils. NH_4^+ concentration was moderately related to PC3 loadings in PM2.5 and PM10. In particular, a relatively good correlation of $NH_4^+$with Ca^{2+} in PM10 indicates the agricultural influence due to fertilizer use.

Frequency distributions of PM10, PM2.5 and PM1 mass concentrations for all measurements.



The mean concentrations of the three types of particulate matters were higher than their median and main-mode concentrations and the standard deviations were comparable to the median concentrations. These results show that mass concentrations varied in a wide range due to high concentration events.

Data and results analysis

At GCO, the five-year measurements of aerosol mass and chemical composition reveal that the top 10 % of PM10, PM2.5, and PM1 mass was affected by dust or haze plumes. anthropogenic pollution is a main driver for enhanced PM1 and PM2.5 mass concentrations if their concentrations are greater than the 90th percentile.

Conclusions

1.For the entire period, PM2.5 accounted for 63% of PM10, while PM1 comprised 74% of PM2.5 on average.

2.The multiple regression using the three PC loadings shows that the anthropogenic pollution accounted for 99 % and 63 % of PM1 and PM10 mass variation, respectively. The effect of soil dust was the largest on PM10 (36%) and not negligible on PM2.5 (~10%).

3. The mainmode was commensurate with the median concentration and the mean + σ was comparable to the concentration of the 90th percentile. It indicates that the average mass concentration is highly susceptible to high-concentration episodes. Consequently, the mean+σ is suggested as a robust criterion that determines the substantial impact of soil dust or pollution plumes on PM10, PM2.5, and PM1.

Thank you for your attention