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Chemical characterization and source apportionment of atmospheric submicron particles on the western coast of Taiwan Strait, China

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ABSTRACT

Taiwan Strait is a special channel for subtropical East Asian Monsoon and its western coast is an important economic zone in China. In this study, a suburban site in the city of Xiamen on the western coast of Taiwan Strait was selected for fine aerosol study to improve the understanding of air pollution sources in this region. An Aerodyne high-resolution time-of-flight aerosol mass spectrometer (HR-ToF-AMS) and an Aethalometer were deployed to measure fine aerosol composition with a time resolution of 5 min from May 1 to 18, 2015. The average mass concentration of PM_1 was 46.2 ± 26.3 μg/m^3 for the entire campaign. Organics (28.3%), sulfate (24.9%), and nitrate (20.6%) were the major components in the fine particles, followed by ammonium, black carbon (BC), and chloride. Evolution of nitrate concentration and size distribution indicated that local NO_x emissions played a key role in high fine particle pollution in Xiamen. In addition, organic nitrate was found to account for 9.0%–13.8% of the total measured nitrate. Positive Matrix Factorization (PMF) conducted with high-resolution organic mass spectra dataset differentiated the organic aerosol into three components, including a hydrocarbon-like organic aerosol (HOA) and two oxygenated organic aerosols (SV-OOA and LV-OOA), which on average accounted for 27.6%, 28.8%, and 43.6% of the total organic mass, respectively. The HOA was shown to correspond to primary combustion sources, while the LV-OOA and SV-OOA were identified to be closely associated with more aged and fresher secondary organic aerosol (SOA), respectively. It was revealed that regionally-transported SOA dominated the OA in Xiamen. The relationship between the mass concentration of submicron particle species and wind further confirmed that all major fine particle species were influenced by both strong local emissions in the southeastern area of Xiamen and regional transport through the Taiwan Strait.

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Introduction

Submicron particles, whether natural or anthropogenic, originate from emissions of primary particulate matter and secondary particulate matter from gaseous precursors (IPCC AR5). Submicron particles are crucial air pollutants in the urban environment and they have important effects on human health, visibility and climate change, the adverse health effects are of special concern in metropolitans (Baklanov et al., 2016). Organics contribute a large fraction to the submicron particles and are poorly understood (Zhang et al., 2007). Apportioning organic species into their sources and components correctly is a critical step towards enabling efficient control strategies and model representations (Ulbrich et al., 2009). Submicron particles are a complicated mixture of various species, it is essential to have a deep understanding of the chemical identification and source apportionment.

Although many studies focused on submicron particles in atmosphere were carried out in Yangtze River Delta region, Pearl River Delta region and Beijing–Tianjin–Hebei region (Feng et al., 2009; Huang et al., 2012, 2013, 2014; He et al., 2011; Hu et al., 2016), there are few studies about the Taiwan Strait. Both the west and east sides of the Taiwan Strait are mountainous and coastal terrain that make it a special channel for the airmass transportation in eastern China. The area around the Taiwan Strait is mainly influenced by subtropical East Asian Monsoons and the special climatic conditions such as sea-land breeze and high RH (Deng et al., 2014). The west side of the Taiwan Strait is an important economic zone in China like Pearl River Delta (PRD) and Yangtze River Delta (YRD). There are many important industrial and densely populated areas on both the west and east side of the Taiwan Strait, which can emit large amount of particulate pollutants transported through the Taiwan Strait along with the airflow. Xiamen (24°36′N, 118°03′E) is one of the most important metropolitan in the west side of the Taiwan Strait economic zone with an area of 1573.16 km^2 and a population of 3.81 million. Like many other cities in China, Xiamen also suffers a big problem of air pollution with the rapid development of economy and urbanization. The industrial plants in Xiamen, including coal-fired power plants, ceramic plants, porcelain products and textile industry, can be the potential emission sources for air pollution. So the submicron particle pollution in Xiamen, to the west side of the Taiwan Strait, is not only under the influence of local emissions, but also obviously affected by regional sources transported along the coast.

Although some studies have been taken on the properties of submicron particles in Xiamen, but the chemical characteristics and source apportionment was rarely studied. The result in Zhang et al. (2012) show an annual average concentration of $PM_{2.5}$ of 86.16 $\mu g/m^3$ during June 2009 to May 2010, focusing on a long lasting period. Zhang et al. (2013) showed that the average mass concentration of $PM_{2.5}$ of the period before, during and after hazy from Dec. 25, 2010 to Jan. 1, 2011 were 88.80 ± 19.97, 135.41 ± 36.20 and 96.35 ± 36.26 $\mu g/m^3$, respectively, focusing on the chemical compositions, light extinction and metropology in Xiamen. Some other previous studies showed that organic matter and sulfate were the most abundant components of fine particles in Xiamen, followed by ammonium and nitrate (Wu, 2015; Yan et al., 2015).

High-resolution time-of-flight aerosol mass spectrometer (HR-ToF-AMS, Aerodyne, US) is a very useful instrument to measure the chemical composition and size distribution of non-refractory species. This paper reports the size resolved chemical characterization measured by an HR-ToF-AMS, coupled with an Aethalometer to measure black carbon aerosol, and the results of factor analysis for organic aerosol source apportionment with the high-resolution of the organic mass spectra in the air in Xiamen in May 2015, aims to have a further understanding of the chemical composition and variation of submicron particles in Taiwan Strait region.

1. Experimental methods

1.1. Sampling site description

The sampling site was located in the Institute of Urban Environment, Chinese Academy of Sciences (IUE, CAS) in the Jimei District, and was a suburban site close to the Xinglin Bay. Since this site was located roughly at the geometric center of the Xiamen territory and in the downwind area of urban Xiamen during the sampling period, it could serve as a good receptor site of various pollutant sources in this region, reflecting not only urban emissions but also industrial emissions. The campus and its surroundings were mostly covered by subtropical plants. Two local roads are about 100 m far away to the northwest and northeast, respectively. The field campaign was conducted from 1 May to 18 May 2015. The average ambient temperature was 24.3 ± 2.9°C. In winter, the air quality in Xiamen can be greatly influenced by the air mass transported from the more polluted northern inland, so the local emissions in this region cannot be obviously observed. While in summer, the air quality is quite good due to the abundant precipitation and the clean air mass from the sea, which makes summer not an ideal choice for air pollution research. Therefore, the spring time, as a transition season, was selected for this study.

1.2. HR-ToF-AMS measurement and data process

An Aerodyne High-Resolution Time-of-Flight Aerosol Mass Spectrometer (referred as AMS) was deployed in an air monitoring station in the campus of IUE, CAS with a $PM_{2.5}$ cyclone inlet set up on the roof of the station to remove coarse particles and lead the airflow into the room with a flow rate of 10 L/min. The detailed principles of the operation of AMS were described in previous publications (DeCarlo et al., 2006; Canagaratna et al., 2007). During the campaign, the AMS was operated in a cycle of 2 ion optical modes (V and W), including 2 min V-mode to obtain the UMR mass concentration and size distribution of the non-refractory species (organics, SO_4^{2-}, NO_3^-, NH_4^+ and Cl^-); 2 min W-mode to obtain high-resolution mass spectra of organics. The inlet flow rate calibration, ionization efficiency (IE) and particle size calibration was conducted at the beginning and the end of the campaign with the method described in previous publications (Jayne et al., 2000; Jimenez

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