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# An observational study of the hygroscopic properties of aerosols over the Pearl River Delta region

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## HIGHLIGHTS

- Size-resolved measurement of hygroscopicity of submicrometer particles were done.
- Aerosol hygroscopicity in the Pearl River Delta differs from other megacities in China.
- Aerosol hygroscopicity has a significant diurnal variation, and closely related to air mass origin.

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## ABSTRACT

Hygroscopic growth can significantly affect size distribution and activation of aerosol particles, as well as their effects on human health, atmospheric visibility, and climate. In this study, an H-TDMA (Hygroscopic Tandem Differential Mobility Analyzer) was utilized to measure hygroscopic growth factor and mixing state of aerosol particles at the CAWNET station in Panyu, Guangzhou, China. A statistical analysis of the results show that, at relative humidity (RH) of 90%, for less-hygroscopic particles of 40–200 nm in diameter, the growth factor ($g_{LH}$) was around 1.13, while the number fraction ($NF_{LH}$) varied between 0.41 ± 0.136 and 0.26 ± 0.078; for more-hygroscopic particles, the growth factor ($g_{MH}$) varied between 1.46 and 1.55 with the average equivalent ammonium sulfate ratio ($\varepsilon_{AS}$) ranging from 0.63 to 0.68. The differences in $\varepsilon_{AS}$ among particle of different sizes reveal that more-hygroscopic inorganic salts, such as ammonium sulfate and ammonium nitrate, are of more effective condensation growth for Aitken mode particles. A combined analysis of the probability density function of growth factor (Gf-PDF) and simultaneous meteorological data shows that during clean periods with air masses moving from the north, the particles are more likely to have homogeneous chemical composition, while during polluted or pollution accumulation periods, variations in mean number weighted growth factor ($g_{mean}$) and $NF_{MH}$ become more pronounced, indicating that locally-emitted aerosol particles tend to be in an externally mixed state and contain a certain proportion of less-hygroscopic particles. This study can help improve our understanding of aerosol hygroscopicity and its impact on the atmospheric visibility and environment.


## 1. Introduction

With the rapid development of industrialization and urbanization, atmospheric pollution in Chinese metropolises have become increasingly heavier during the last decades. Increase in atmospheric aerosols has caused deterioration of air quality and more frequent occurrence of hazy phenomena. In addition, changes in aerosol loading may also impact the regional and global climate by altering the radiation balance of the earth-atmospheric system (Chylek and Coakley, 1974).

The effects of aerosol particles on human health, the atmospheric environment and climate are, to a large extent, dependent on the size distribution, chemical composition and the hygroscopic

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properties of particles. The hygroscopic properties of aerosol particles refer to the growth of particles under different moisture conditions. H-TDMA (Hygroscopic Tandem Differential Mobility Analyzer) is the most widely used system to measure aerosol hygroscopicity (Liu et al., 1978). Other systems, including H-DMPS (Eichler et al., 2008) and the tandem/parallel nephelometer (Liu et al., 2008), have also been used sometimes. H-TDMA can measure aerosol hygroscopic growth factor for various particle sizes and under different moisture conditions. It can also provide information on particle mixing states.

Hygroscopicity of submicrometer particles in polluted regions has a significant impact on regional visibility, human health and even climate. But so far, there are not many studies associated with aerosol hygroscopicity measurements, except for a few locations in the United States, Europe and Japan (Baltensperger et al., 2002; Chen et al., 2003; Cocker et al., 2001; Massling et al., 2005; McMurry and Stolzenburg, 1989; Mochida et al., 2006; Adam et al., 2012). Furthermore, few previous observations have exceeded more than a few weeks. An overview by Swietlicki et al. (2008) showed that urban aerosols were generally comprised of hydrophobic, less-hygroscopic and more-hygroscopic particles. Of these, nearly-hydrophobic particles are mainly derived from carbon aerosols emitted from combustion of fossil fuels, such as automobile exhausts. Their basic components are black carbon and insoluble primary organic matters (POM). Less-hygroscopic particles are, in most cases, primary products of aged atmospheric carbonaceous particles, and their primary reactions include vapor condensation and growth through coagulation with other particles. Their main components are moderately transformed combustion particles containing soot, partly oxygenated organic compounds and condensed inorganic matter. In an urban environment, the proportion of nearly-hydrophobic and less-hygroscopic particles within the atmosphere tends to decrease with increasing particle diameter, due mainly to the black carbon from automobile exhausts. More-hygroscopic particles are mainly comprised of inorganic salts (e.g., sulfates and nitrates). As aerosol pollution problems in China have received increasing attention in recent years, short-term aerosol hygroscopicity observations have been carried out in Beijing (Massling et al., 2009), Shanghai (Ye et al., 2011, 2013) and Tianjin (Liu et al., 2011) using H-TDMA.

The Pearl River Delta (PRD) is one of the three major economic regions in China, and is also one of the four regions suffering the most severe haze in China (Tan et al., 2009; Wu et al., 2005). From October to March, the dry season of PRD region, it suffers the most frequent occurrence of haze. However, there is lack of research investigating hygroscopic growth and the mixing state of submicrometer particles in the PRD. This study uses H-TDMA data from November to December 2011 to analyze variations in hygroscopic growth factor and mixing state for submicrometer particles (40–200 nm) in the core PRD under high humidity conditions (90% RH), and discusses the characteristics of this variation and the related particle aging processes.

## 2. A brief description of the experiments

### 2.1. Measurement site and instrumentation

The field experiments were conducted at the CAWNET station in Panyu, Guangzhou from November 1 to December 29, 2011 (see Fig. 1 for a map of the experimental site). The Panyu Station is located in the center of the PRD region and at the top of Dazhengang Mountain (23°00′N, 113°21′E) with an altitude of about 150 m. Thus it represents the typical atmospheric conditions in the region. This test site is surrounded by residential neighborhoods with no significant pollution sources nearby.

A Hygroscopic Tandem Differential Mobility Analyzer (H-TDMA, see Fig. 2), constructed by Tan et al. (2013), was used to observe particle number size distribution (PNSD), hygroscopic growth factor (*Gf*) and mixing state of aerosol particles. Only a brief introduction to the operating principles and operating modes will be provided here (refer Tan et al., 2013; for more details). During the experiment period, the H-TDMA was placed indoor with room temperature of 25 ± 3 °C. The temperature inside the instrument was 28 ± 1 °C. The aerosol sampling port was equipped with a $PM_1$ impactor inlet and only particles with less than 1 μm in diameter were allowed to enter. Sample aerosol particles first passed through

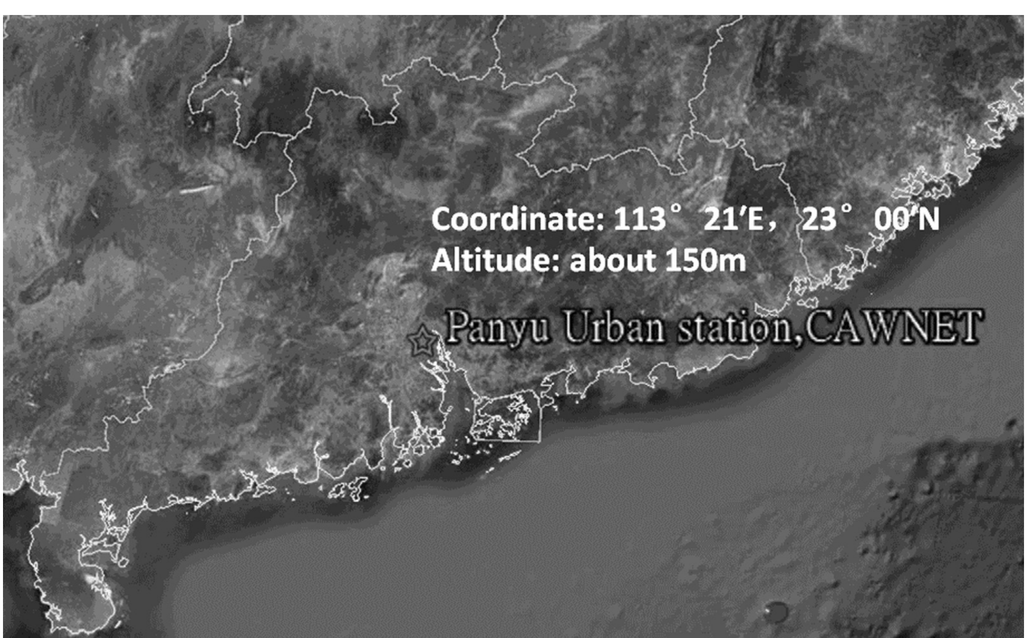


**Fig. 1.** Measurement site.