Aerosol Hygroscopicity during the Haze Red-Alert Period in Winter 2016 at a Rural Site of the North China

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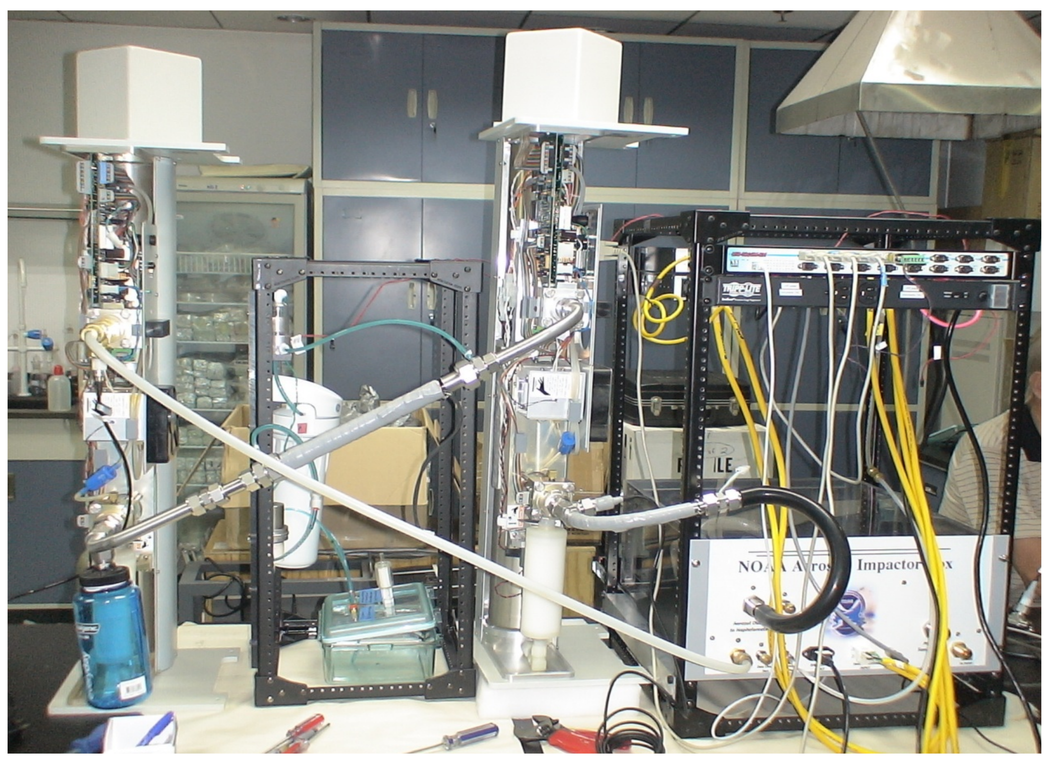
Introduction

Scattering of solar radiation by aerosol particles is highly dependent on relative humidity (RH). Hygroscopic particles take up water and change in size and chemical composition and hence, several key parameters (e.g., scattering coefficient, backscattering coefficient, single scattering albedo and asymmetry parameter) that are relevant to visibility degradation and aerosol radiative forcing. Besides, it is of crucial importance for the comparison between remote sensing and ground based measurements.

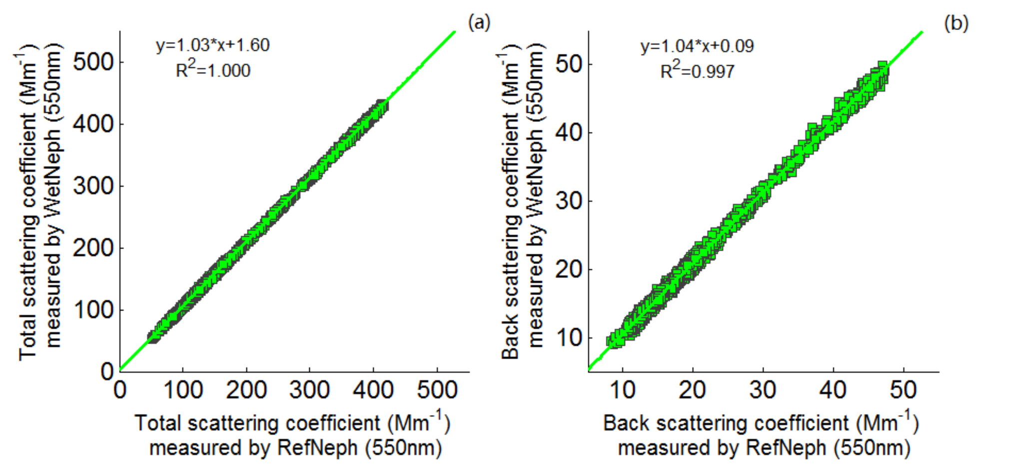
With the rapid development of Chinese economy, the Beijing, Tianjin, and Hebei area has become one of the severely polluted areas in China. Severe anthropogenic pollution would occur in the heating period and the frequency of haze increases. In winter 2016, a number of haze alerts were issued, of which the first haze red alert was from 17 to 22 December. In this study, we focus on the analysis of aerosol optical properties and aerosol hygroscopicity and its relationship to chemical composition, and try to understand the characteristics of aerosols in the North China Plain during this heavy pollution event.

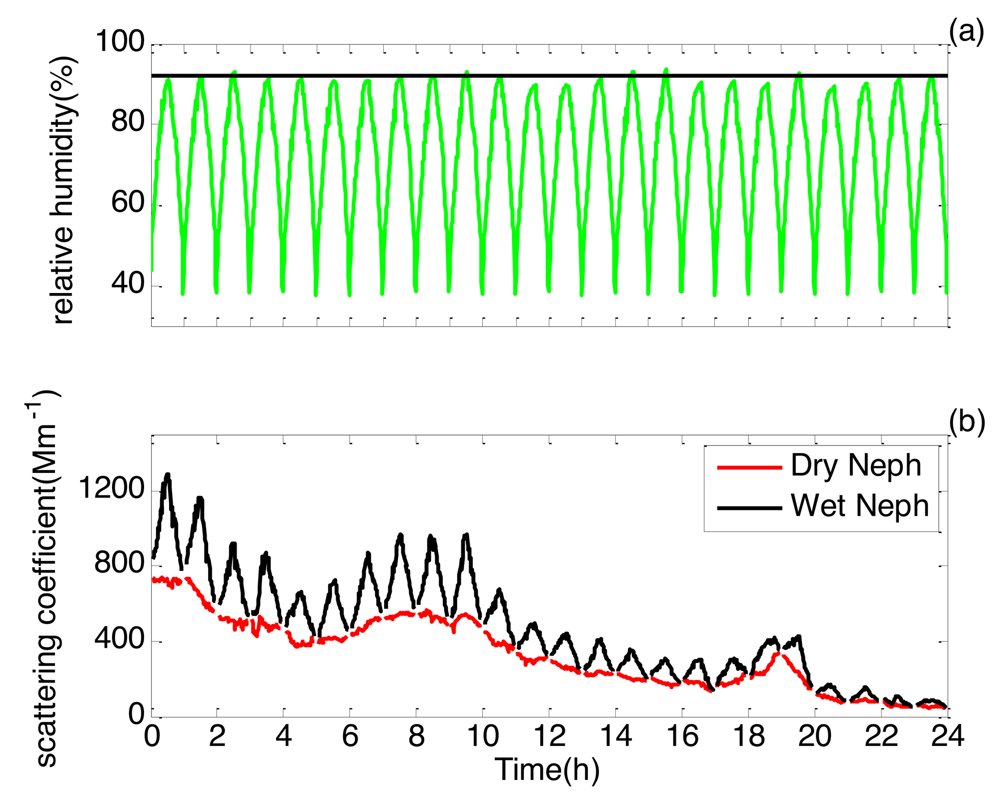
Instruments and Quality control

Aerosol hygroscopicity based on scattering coefficients, f(RH), was measured by a humidification measurement system, which consists of two nephelometers and a humidifier operating in series. RH ranges from <40% to ~90%. RH sensors calibration, nephelometer calibration, zero test and humidification cycle have been done before the measurements.

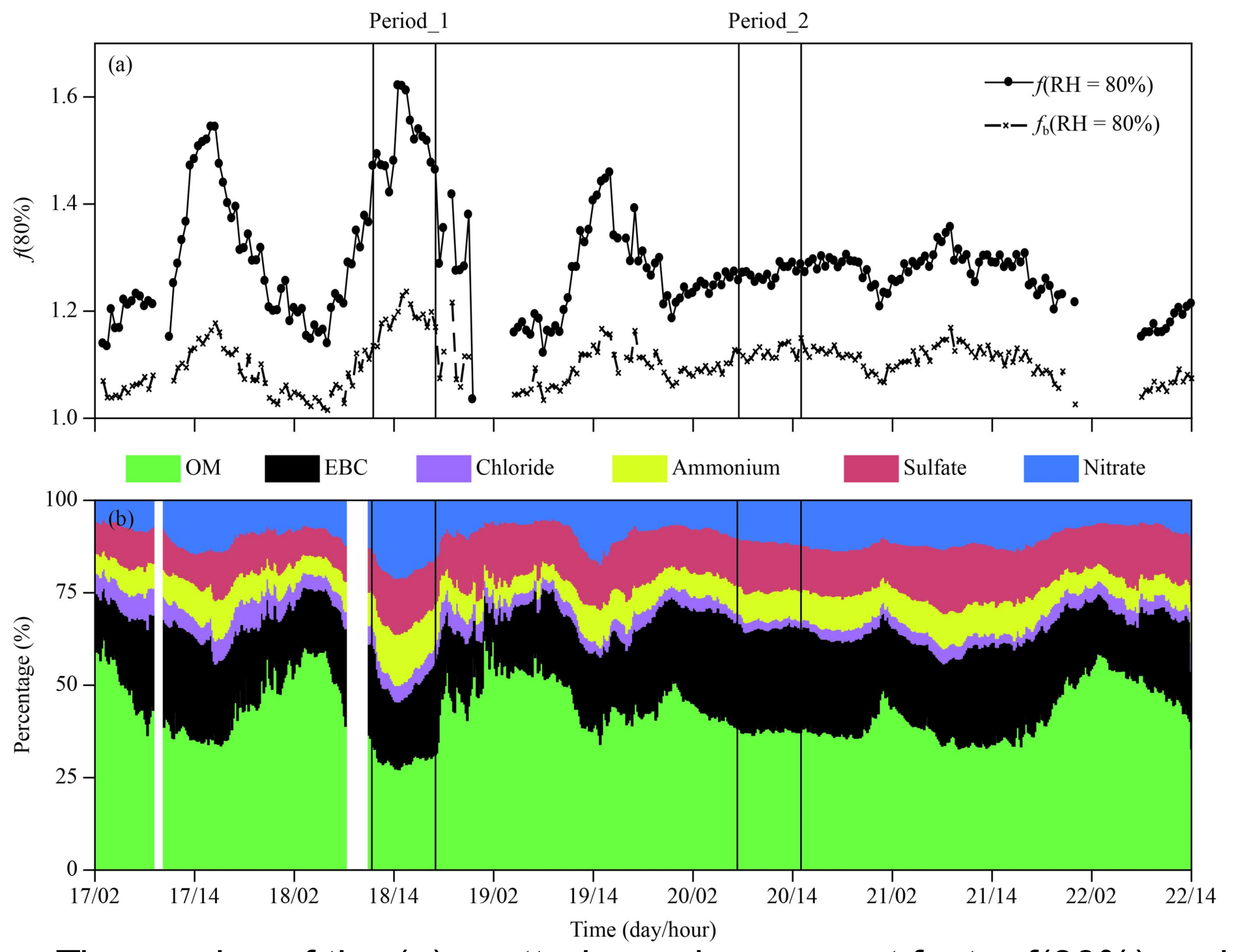


The humidification measurement system was developed through cooperation under the CMA-NOAA Bilateral Agreement

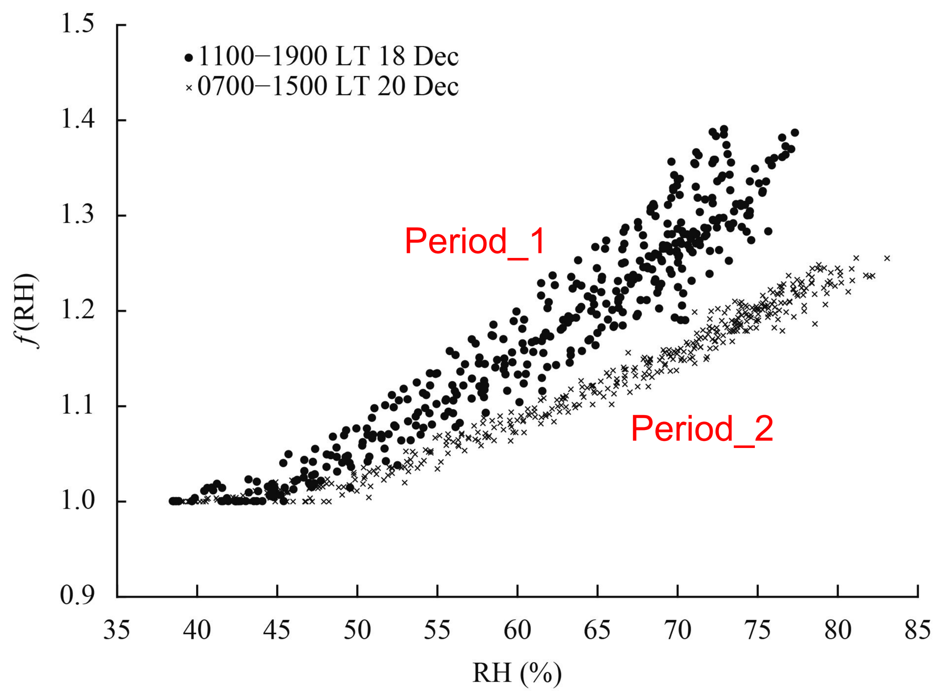




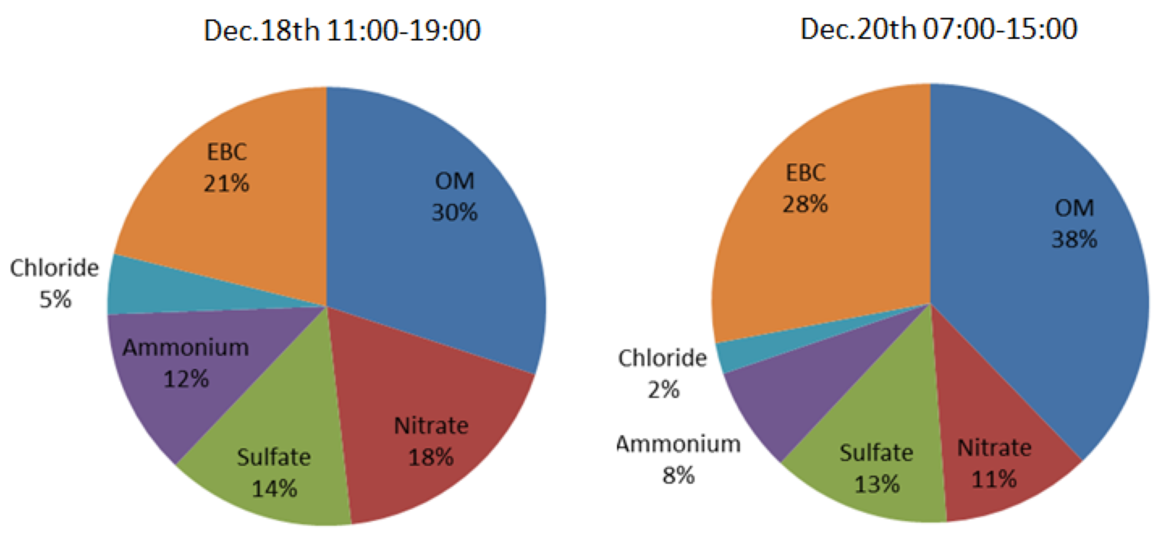
Results



Time series of the (a) scattering enhancement factor f(80%) and backscattering enhancement factor fb(80%), and (b) percentage of mass concentration of aerosol chemical composition. Two periods are defined: period_1 from 11:00 to 19:00 (Beijing Time) 18 December and period_2 from 07:00 to 15:00 20 December 2016.



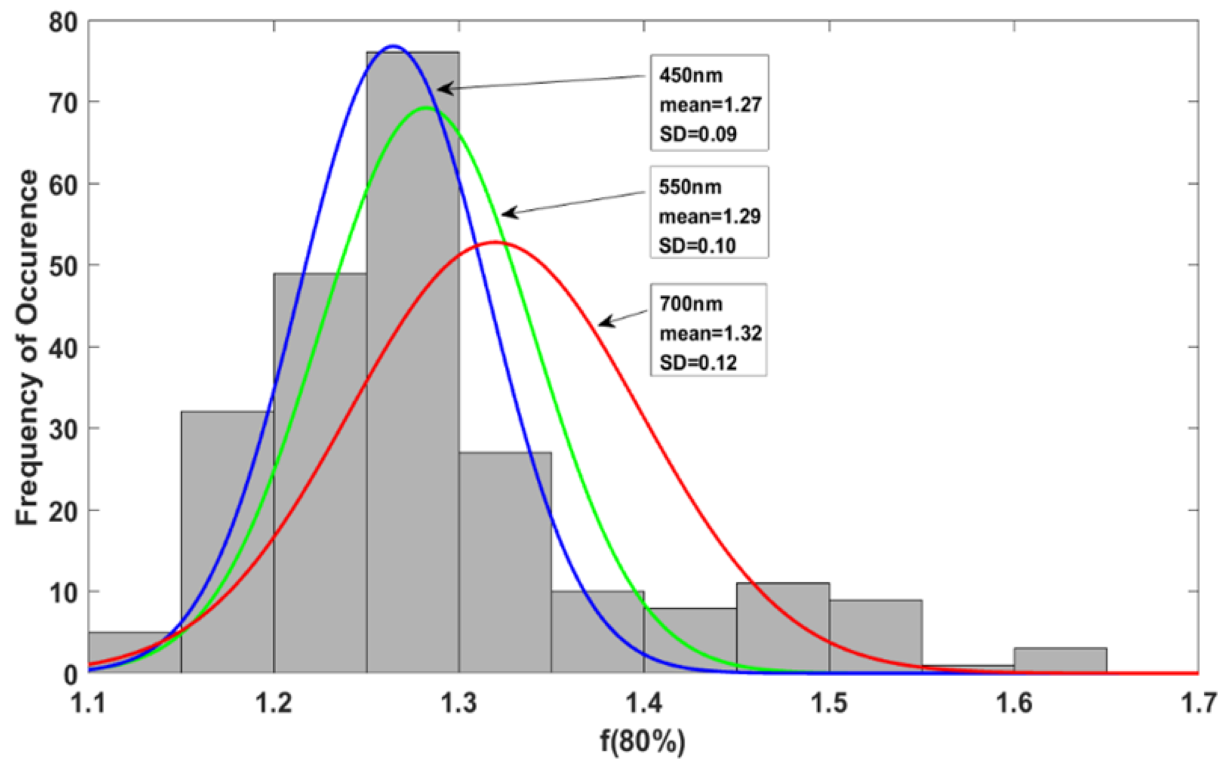
Humidograms of the scattering enhancement factor vs. RH during period_1 and period_2.



Mass fraction of the aerosol chemical composition during period_1 and period_2.

There are similar trends for f(80%) and fb(80%) but with different magnitudes. The f(80%) ranged from 1.12 to 1.62 with an average of 1.29, while fb(80%) varied from 1.02 to 1.24, with an average of 1.10. Both f(80%) and fb(80%) showed a diurnal pattern that peaked in the late afternoon (approximately 1400 LT), especially during the first 3 days. The humidograms in period_2 increased much slower than those in period_1. These suggest that the scattering enhancement factor could largely vary, dependent on the aerosol composition, even during heavy pollution conditions, although the mass fraction of sulfate was quite similar.

Distribution of f(80%) at different wavelengths

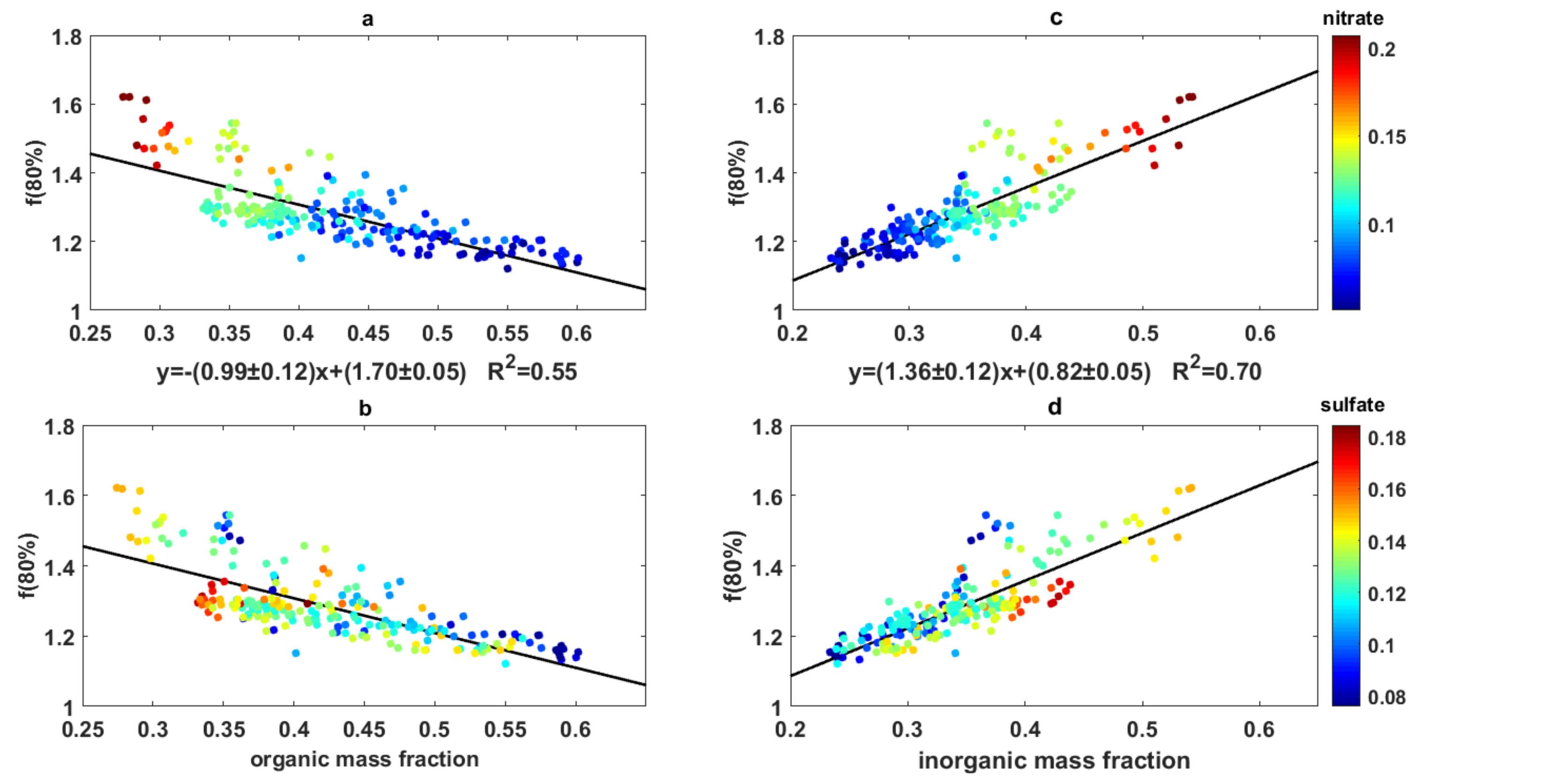


Only ~2% shift to higher *f*(80%) values with a larger standard deviation was observed as the wavelength increased, which is similar for the backscatter enhancement factors. Therefore, only slight spectral dependency of *f*(RH) was observed during the red-alert period.

Histogram of *f*(80%, 550 nm) overlaid with the Gaussian curves based on the statistics for *f*(80%, 450 nm), *f*(80%, 550 nm), and *f*(80%,700 nm).

The Relationship of f(RH) and Chemical Composition

(a) and (c) colored by nitrate (b) and (d) colored by sulfate



✓f(80%) increases with inorganic mass fraction, but decreases with organic mass fraction
✓f(80%) shows clearer relation with nitrate fraction than sulfate fraction

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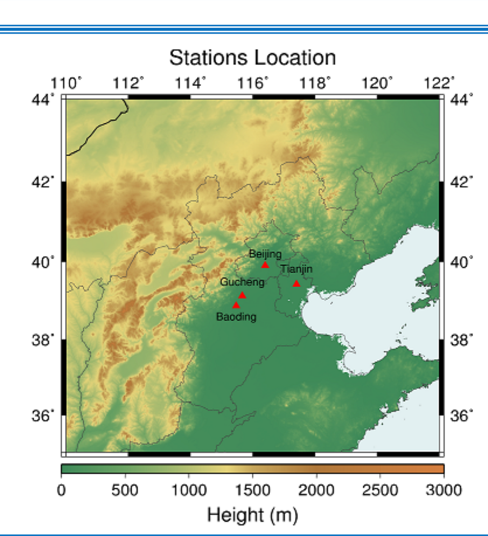

Gucheng station (39°08′N, 115°40′E; 15.2 m a.s.l.), which is located in Dingxing county, Hebei Province. The site is approximately 110 km southwest of Beijing, 130 km southwest of Tianjin, and 35 km northeast of Baoding, and is surrounded by farmland and sporadic villages.