Journal of Quantitative Spectroscopy & Radiative Transfer 218 (2018) 46–53

Contents lists available at ScienceDirect

Journal of Quantitative Spectroscopy & Radiative Transfer

journal homepage: www.elsevier.com/locate/jqsrt

Parameterization of aerosol number concentration distributions from aircraft measurements in the lower troposphere over Northern China

Huige Di*, Jing Zhao, Xuan Zhao, Yuxing Zhang, Zhixiang Wang, Xuewen Wang, Yufeng Wang, Heng Zhao, Dengxin Hua*

School of Mechanical and Precision Instrument Engineering, Xi'an University of Technology, Xi'an 710048, China

A R T I C L E   I N F O

Article history:
Received 1 March 2018
Revised 10 July 2018
Accepted 12 July 2018

Keywords:
Aerosol
Number concentration distribution
Parameterization
Aircraft measurement

A B S T R A C T

To obtain representative models of aerosol size distributions in the vertical dimension, we performed an extensive investigation on aerosol number concentration distributions from 0.1 µm to 3.0 µm based on airborne aerosol measurements, which were measured by a PCASP-100X on 33 flights over Northern China. A multi-modal lognormal size distribution with a base 10 logarithm is applied to fit the measured aerosol size distributions at different altitudes. Most of them can be fitted well by using a tri-modal distribution, while some of the data need to be fitted using a four-mode distribution. As the height increases, the aerosol distributions gradually become monotonous and display double-peak or single-peak lognormal distributions. Vertical variations in aerosol distributions over four days were analyzed and compared to each other. Statistical parameters of aerosol size distributions in the vertical dimension were obtained and analyzed. Relatively stable modal parameters from the ground to a height of 7 km were found for modes 1 and 2. The first and second peaks in the aerosol distributions were found from 0.08 µm to 1.2 µm and from 0.12 µm to 0.4 µm, and their medians were approximately 0.1 µm and 0.3 µm. The standard deviation did not change very much, from 0.05 µm to 0.6 µm and from 0.2 µm to 0.6 µm. The mean particle sizes in modes 1 and 2 were similar and showed an exponential decline with increasing height. Typical modal distributions of aerosol concentrations ranging in size from 0.1 µm to 3.0 µm over the vertical dimension in Northern China are presented along with statistical data. The parameterized formula is also provided in this paper.

1. Introduction

Aerosols are an important source of ice nucleation and coagulation and play a very important role in the formation of ice crystals and aerosol droplets. The size and distribution of aerosols has an important impact on precipitation and climate. Aerosols also have significant environmental effects and have important impacts on the regional environment. The composition of aerosols is complex and varies significantly over time and space. It is one of the most uncertain factors in global climate change research, especially in the vertical dimension. The vertical distribution of aerosols is of critical importance to estimate aerosol radiative forcing and its associated climate impacts [1], and it also plays a role in aerosol-cloud-climate interactions. Well-documented observations of vertical aerosol variations are required for reliable modeling of aerosol radiative properties and their effects on cloud processes [2]. Particle size distributions of atmospheric aerosols have been studied by many scientists, but there have been few studies on the vertical variation in aerosol distributions due to limitations in the observational tools. To date, these distributions are mainly obtained by aircraft measurements [2,3]. A few researchers have also tried to retrieve particle size distributions using multi-wavelength LiDAR [4–6]; however, the complex retrieval algorithm needs be studied further in order to reliably use this LiDAR technology.

A series of airborne measurements of atmospheric aerosols were made over the central United States in the 1980s. Aerosol size distributions ranging from 0.1–16 µm were measured at two altitudes of approximately 1450 and 2450 m above sea level (asl) [2]. Since the 2000s, researchers in China have also carried out aircraft detection of aerosols over some regions and have obtained a lot of observational data [3,7,8]. Sun et al. presented a statistical analysis of 104 flights of airborne aerosol measurements and seasonal vertical variations in aerosol distributions over Shijiazhuang, China. However, there is little research on the statistical results of aerosol modal distributions. Statistical results and parametric analyses of aerosol modal distributions are very important for radiative

* Corresponding authors.
E-mail addresses: dihuige@xaut.edu.cn (H. Di), dengxinhua@xaut.edu.cn (D. Hua).

https://doi.org/10.1016/j.jqsrt.2018.07.009
0022-4073/© 2018 Published by Elsevier Ltd.

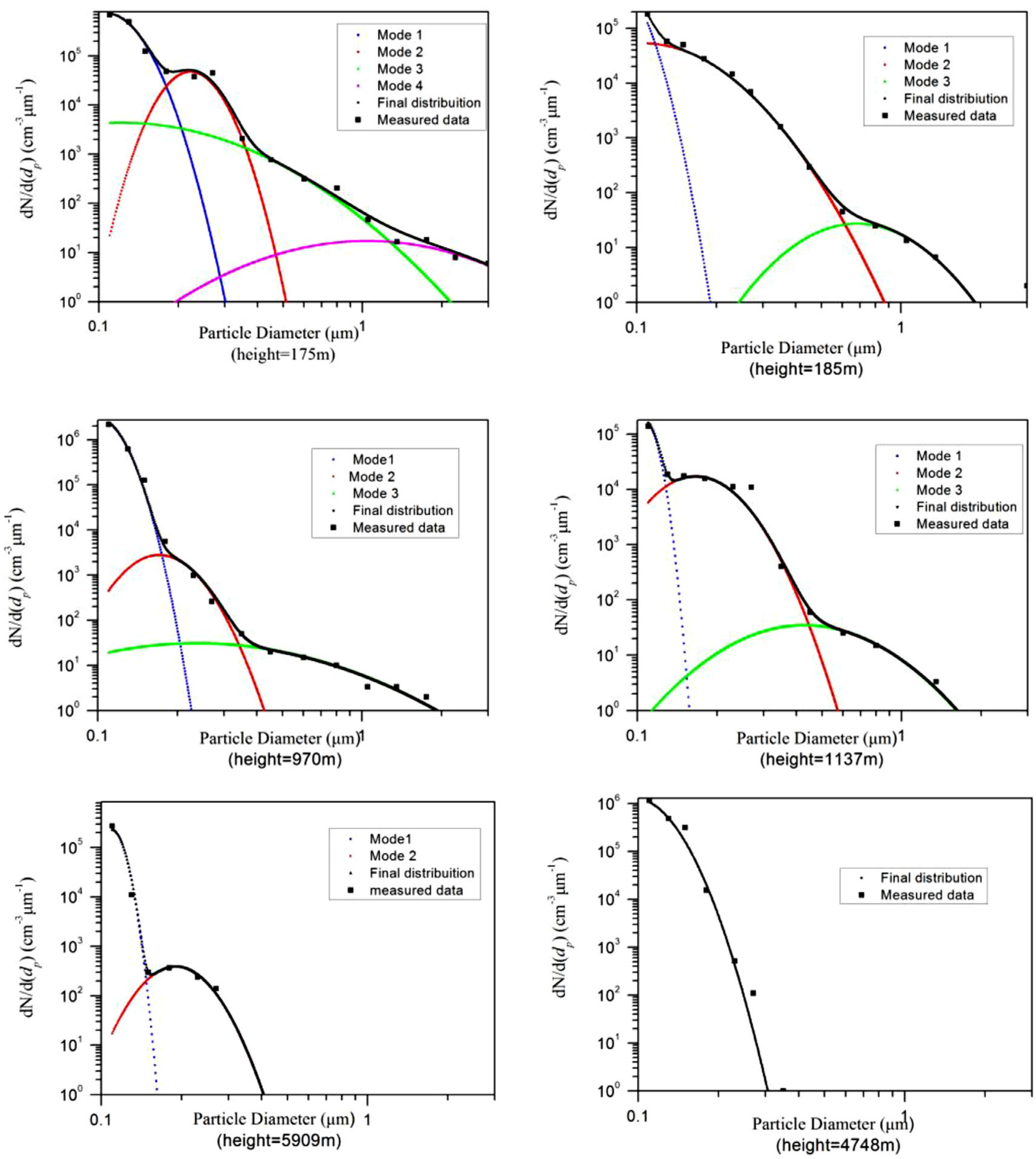

Fig. 1. Fitted results of aerosol concentration distributions at different vertical heights.

transfer properties and can also provide guidance and assistance for remote sensing instruments.

Aerosol measurements were collected over the surrounding areas of Beijing, Northern China from 2005 to 2007 using the airborne Particle Measuring Systems (PCASP-100X, PMI Co. Ltd, USA) belonging to the Weather Modification Office of Hebei Province. The aim of the aircraft measurements was to obtain three-dimensional observational data of first/secondary pollutant transport and secondary contaminants in Beijing and its surrounding areas and to further study the pollution in Beijing and its surrounding areas. Aircraft observational instruments were combined with an artificial rainfall system, and the Particle Measuring Systems were mounted below the wing of the aircraft and in the windward direction. The artificial rainfall broadcasting system was installed on the rear part of the rudder in the downwind direction. Therefore, even if the machine was carried for artificial rainfall it would not affect the measurement results for aerosol it would not affect the aerosol measurement results. Data obtained from 33 flights were used in this study, of which 19 flights were conducted in the spring (March to May) and 14 flights in autumn (September to November). More than 147 vertical profiles were obtained during the 33 flights. The cities in the selected flight range include Shijiazhuang, Xingtai, Handan, Tangshan, Zhangjiakou, Zhangbei, Kangbao, Bohai Bay, and Hengshui lake. The aircraft, operated by the weather Modification Office of Hebei Province, was equipped with a passive cavity aerosol spectrometer probe (PCASP-100X) for aerosols, and a CCN detector for measuring the concentration of condensation nuclei.

Sixty-eight effective vertical profiles from 0.1 km to above 4.5 km were analyzed. The acquisition time of each profile was less than 10 minutes. The measured aerosol concentration distributions were fitted by multi-lognormal distributions or by single-lognormal distributions. Statistical parameters of size distributions in the vertical dimension were obtained. Parameterized solutions for concentration distributions were proposed according to the statistical data.