Atmospheric Research 150 (2014) 12–20

Contents lists available at ScienceDirect

Atmospheric Research

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

The growth of ice particles in a mixed phase environment based on laboratory observations

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ARTICLE INFO

Article history:
Received 5 December 2013
Received in revised form 10 July 2014
Accepted 11 July 2014
Available online 18 July 2014

Keywords:
Ice crystal
Droplet
Mixed-phase
Cloud

ABSTRACT

This paper describes new laboratory observations about the size evolution of ice crystals and cloud droplets immersed in a mixed-phase cloud. The experiments were performed by using a cloud chamber facility for three temperatures −6 °C, −10 °C and −20 °C, in order to explore the basic crystal growth habits (columns and hexagonal plates). The sizes of the cloud droplets, ice-columns and hexagonal ice-plates were examined for growth times between 50 and 300 s. The results show evidence that after ice crystal nucleation, the cloud droplets reduce gradually their sizes by the evaporation process; while the ice crystals grow as a consequence of the water vapor diffusion process. The ice crystal growths at different temperatures were compared with the results reported by other authors. The experimental data were also compared with a theoretical model of the growth rate of ice crystals. It was observed that the numerical model provides a description of the ice columns' growth in fairly good agreement with the laboratory observations, while it predicts that the hexagonal plates evolve with maximum sizes larger than those observed in the experiments. In general, it has been noted that the results obtained from the model are very sensitive to the parameter that denotes the ratio between the condensation coefficient for the basal face and prism face. It is a critical coefficient that needs to be carefully addressed in cloud modeling.

1. Introduction

Mixed-phase clouds are an important part of the atmosphere and climate system. Detailed knowledge of the microphysical behavior of mixed-phase clouds is important for understanding the ice evolution, the precipitation development, and lifetimes of clouds. Important experimental efforts concerning the understanding of cloud processes have been made in the past few years (Pitter and Finnegan, 2010; Santachiara et al, 2010; Baumgardner et al, 2011, 2014; Cziczo and Froyd, 2014). After formation on ice nuclei, individual ice crystals grow by vapor deposition to a critical size before they can begin the riming process by collection of supercooled cloud droplets (Pruppacher and Klett, 1997; Young, 1993; Shen et al., 2014). Ávila et al. (2009), from laboratory experiments observed that the minimum crystal size necessary for the initial stage of capture and freezing of supercooled cloud droplets by hexagonal plates was around 60 μm diameter and 30 μm width and 60 μm length for columnar ice crystals.

The importance of finding an efficient representation of the ice crystal growth was recognized very early in cloud modeling. Several studies, including in-situ measurements, laboratory work and theoretical calculations, have been carried out in order to find parameterizations of the time evolution of the sizes and mass of the ice crystals as a function of the environmental variables. Ice crystal growth in supercooled cloud conditions has been studied by a number of authors in the laboratory (Mason, 1953; Fukuta, 1969; Ryan et al., 1974,1976; Takahashi and Fukuta, 1988;

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http://dx.doi.org/10.1016/j.atmosres.2014.07.010
0169-8095/