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Collection of Submicron Particles with Cloud Droplets Using the New MIT-CFC

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Abstract. Collection efficiency of submicron mineral dust particles by cloud droplets will be examined using the new Massachusetts Institute of Technology - Contact Freezing Chamber (MIT-CFC). Comparison of the collection efficiency of different mineral dust sizes and type will be compared.

Keywords: coagulation process, collection efficiency, mineral dust, MIT-CFC.

INTRODUCTION

Aerosol particles can interact with water droplets. This interaction may result in collision followed by coalescence of the two, which is known as collection or coagulation. The collection process is considered to be an important mechanism for removing aerosol particles from the atmosphere [1]. This process also influences cloud lifetime, precipitation formation and the global radiation budget [2].

Although there have been many experimental and theoretical efforts to better understand the aerosol collection process by water droplets using different instruments and mathematical expressions [e.g.1, 3, 4], most of these studies focus on the drizzle and rain drops sizes [e.g. 1, 3, 5, 6, 7] while only very few studies used cloud droplets sizes [e.g. 2], as can be seen in Table 1.

TABLE 1. Review of different collection efficacy experiments.

Papers	Droplets radius size (µm)	Aerosol radius size (µm)	Aerosol type
Beard [3]	400-850	0.4	$In(Ac)_3$
Kerker and Hampl [8]	940-2540	0.15-0.6	AgCl
Wang and Pruppacher [9]	150-2500	0.25	$In(Ac_3)$
Lai et al. [10]	620, 820, 980	0.15, 0.25, 0.36	AgCl
Leong et al. [11]	56-93	0.58-3.2	MnO_4P_2
Barlow and Latham [12]	270-600	0.2-1	Not provided
Byrne and Jennings [13]	400- 550	0.35-0.88	Not provided
Pranesha and Kamra [14]	1800, 2100, 2400	1.9, 3.8, 6.4	NaCl
Pranesha and Kamra [1]	1500-3500	0.65-6.5	Not provided
Pranesha and Kamra [7]	1800, 2100, 2400	0.95, 1.9, 3.2	Not provided
Vohl et al. [15]	346, 1680, 2880	0.16-0.24	$In(Ac)_3$
Ladino et al. [2]	12.8, 15, 18.2, 20	0.05-0.33	$LiBO_2$

Collection efficiency of aerosol particles by water droplets has been found to be dependent on many factors, for example: the size of the water droplets [1, 10], the

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particle sizes [13] and their density [16], relative humidity of the experiment [4], turbulent fluctuation [17] and on the electric charges of the droplets or even the aerosols [12, 18].

When cloud temperatures are below 0ºC, the collection process can initiate freezing of supercooled droplets in mixed-phase clouds. This process, known as contact nucleation, occurs when an ice nucleus (IN) comes in contact with a supercooled droplet [19]. Contact freezing is thought by some to be the most efficient heterogeneous freezing process [20, 21], but this process is not yet well understood [22]. In order to better understand the contact freezing process, it is important to first understand the collection process of aerosol particles by cloud droplets since it is the initial step in this heterogeneous freezing mechanism.

To our knowledge, very few collection experiments [e.g. 23] used an IN particle type in order to test the collection efficiency by water droplets. It should be mentioned that one possible exception is silver chloride [8]. Although silver chloride can be used in cloud seeding when added to silver iodide [24, 25], there is no evidence that silver chloride can act as an IN alone.

To date, a comprehensive comparisons of experimental studies of the collection efficiency using different aerosol types has not been made as most works used only one type of aerosol (see table 1). Starr and Manson [26] used different spore types but did not compare their collection efficiencies. Even comparisons among similar aerosol types are difficult because of different experimental conditions such as droplet sizes, relative humidity and chamber type as can be seen in the work of Wang et al. [9] and Vohl et al. [15].

EXPERIMENTAL SETUP

In order to study the collection efficiency of submicron aerosol particles by cloud droplets, an experimental setup was constructed. The MIT-CFC (Massachusetts Institute of Technology - Contact Freezing Chamber), is shown schematically in Fig 1A. It should be noted that the ultimate goal of this chamber is to study contact freezing, but at this stage only collection experiments have been performed.

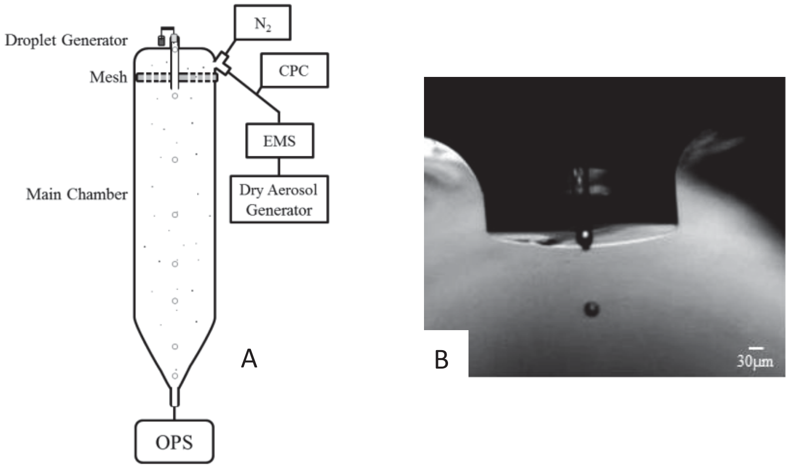

FIGURE 1, MIT-CFC (A) Schematic diagram of a coalescence experiment using MIT-CFC, (B) A 30µm water droplets produced by the Micro drop piezodroppler

Unlike previous experimental chambers in which either the droplets or the aerosol passed slowly through a region containing the other type [e.g. 8, 14], in our chamber both water droplets and aerosol pass through the chamber at the same time according to their fall speed while entrained in a nitrogen or air flow.

The droplet generator was placed at the top of the chamber (as can be seen in Fig 1A), two different diameters of water droplets (30 and 60μm) can be produced. The water droplets are generated by a Microdrop piezodroppler (MD-K-130, see Fig 1B for the 30μm diameter droplets size), and contain pure Milli-Q water (18.2 megohm·cm) with 0.08 mg L^{-1} of ammonium sulfate. The dilute ammonium sulfate was used due to its atmospheric relevance as a condensation nucleus and in order to allow us to determine the number of droplets that were collected. While the droplets evaporated during their fall through the dry flow in the chamber, the residual ammonium sulfate particles are those that can be counted.

The aerosols are injected into the main chamber after the droplet, where they pass through a mesh grid (used to straighten the flow), and they move with the flow to the bottom of the chamber. The aerosol and droplets residual counted by an Optical Particle Sizer (TSI OPS, model 3330) which placed at the bottom of the chamber.

PRELIMINARY RESULTS

In order to examine the chamber behavior 750nm PSL particles were used. These particle size distributions were significantly different than the droplets distributions measured at the bottom of the chamber (see Fig 2, thin straight and dotted lines for the aerosol and droplets, respectively). No aerosol-aerosol or droplet-droplet coagulation was observed so this artifact is unlikely in this and future work. We expect coagulation experiments (when both aerosol and droplets were used) to exhibit and increase in the total concentration at sizes ~2.75μm (i.e., the combined size of an aerosol and a droplet residual), as marked by the thick line in Fig 2. A statistically significant increase in this region of the size spectrum was not observed. We anticipate that increase in aerosol concentration and longer experimental time periods will allow for this observation.

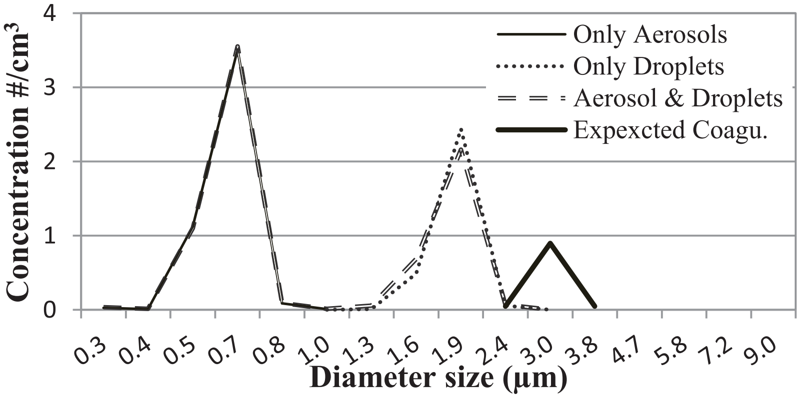

FIGURE 2, Droplets and aerosols distribution as observed form coagulation experiment. The thin straight and dotted lines represent experiments were only aerosol or droplets were used, the dash line represents coagulation experiment when both aerosol and droplets were used. The thick line represents an estimation of the diameter size at which coagulation was expected.

FUTURE WORK

Our next step in the experiment is to use higher relative humidity, in order to maintain the droplets size throughout the CFC. Four dry mineral dust aerosols (Arizona Test Dust, Montmorillonite, Kaolinite and Illite), at three different sizes (500, 750 and 950 nm) will be used. The aerosol will be generated by a dry aerosol disperser and then pass through a BMI Electrical Mobility Spectrometer (EMS, also commonly termed a differential mobility analyzer or DMA) in order to select the size. Before entering the chamber a portion of the aerosol flow will be counted using a BMI Condensation Particle Counter (CPC). A PCVI (Pumped Counterflow Virtual Impactor) will then be added to the chamber before the OPS [27]. The PCVI will allows us to separate the aerosol and water droplets residue from the droplets that collected aerosols, the latter will be examined in the PALMS (Particle Analysis by Laser Mass Spectrometry) instrument in order to differentiate the chemical signatures of both the droplet and the aerosol particles to confirm the collection of the input aerosol particles by the water droplet.

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