Available online at www.sciencedirect.com
ScienceDirect
APCBEE Procedia 10 (2014) 246 – 250
Procedia APCBEE
www.elsevier.com/locate/procedia

ICESD 2014: February 19-21, Singapore

Study of the Effects of Acidic Ions on Cloud Droplet Formation Using Laboratory Experiments

Sh. Moradi[a], A. A. Bidokhti[a,*], M. Gharaylou[a], Sh. Jalaie[b] and M. H. Shoushtari[a]

[a]*Institute of Geophysics,University of Tehran, Tehran 14155-6466, Iran*
[b] *Department of Biostatistics, Tehran University of Medical Science, Tehran, Iran*

Abstract

Atmospheric aerosols affect climate of the Earth, scatter sunlight and serve as cloud condensation nuclei (CCN). Yet the reason for many observed events of new aerosol formation is not understood. One of the ideas put forward to explain these events is that the presence of SO_4^{2-} can enhance the formation of aerosols. These sulphate aerosols form partly during the oxidation of the oceanic emission Dimethyl sulfide (DMS) into the atmosphere and partly from volcanoes, plants and soils, fossil fuel combustion, and biomass burning. In this paper, laboratory experiments on warm cloud formation with different acid ion density are presented. The results show that the lifetime of cloud is reduced by increasing density of SO_4^{2-}, but this changes is not significant (significance level, P=0.578), while the cloud concentration is significantly changed with the decreasing of density of SO_4^{2-} (P=0.001). There is also a good significant correlation between cloud concentration with the maximum temperature change, with correlation coefficient, r=0.646 (p=0.004).

Selection and peer review under responsibility of Asia-Pacific Chemical, Biological & Environmental Engineering Society

Keywords: Cloud chamber, nucleation, acidic ions, so_4^{2-} , experiments.

---

1. Introduction

Aerosols are present throughout the atmosphere and affect the climate of the Earth by varying cloud properties [1]. Researches show that the presence of ions may enhance the formation of aerosols [2]. The role

---

[*] Corresponding author. Tel.: +98-21-61118284; fax: +98-21-88009560.
E-mail address: bidokhti@ut.ac.ir.

Selection and peer review under responsibility of Asia-Pacific Chemical, Biological & Environmental Engineering Society
doi:10.1016/j.apcbee.2014.10.047

of ions in the production of aerosols is among the least understood, while being an important, process in the Earth's atmosphere. The nucleation rate is usually proportional to the ion density and the negative ions are important in nucleation [2]. One of the negative ions in the atmosphere is SO_4^{2-}, observed as sea and non sea salts (SS-SO_4^{2-}, NSS-SO_4^{2-}, SO_4^{2-} = NSS-SO_4^{2-} + SS- SO_4^{2-}). NSS-SO_4^{2-} is that fraction of marine SO_4^{2-} aerosol that is not derived from sea water aerosol droplets. NSS-SO_4^{2-} plays a key role in radiation and cloud processes. Hence, it is important to understand the factors affecting its distribution over the oceans. NSS-SO_4^{2-} is a major acidic aerosol species in the atmosphere; over large areas of the world. The pH of aerosols and precipitation is largely controlled by the density of NSS-SO_4^{2-} and ammonium. NSS-SO_4^{2-} aerosol over the oceans has two major sources: the oxidation of Dimethyl-sulfide (DMS) emitted by marine organisms and pollution transported from the continents [3]. Experimental evidence for a microphysical mechanism has been reported in different papers [2, 4, 5, 6 and 7]. However, the role of ion sulfate has not been explored extensively in the laboratory or in field observations. The goal of the current paper is to report some results of the study the effects of sulfate aerosol on the warm cloud formation using laboratory experiments.

2. Experimental methods

The measurements were performed in a 20 litter reaction glass chamber shown schematically in Fig.1. Commercially available sulphuric acid was used to generate SO_4^{2-} for the experiments.

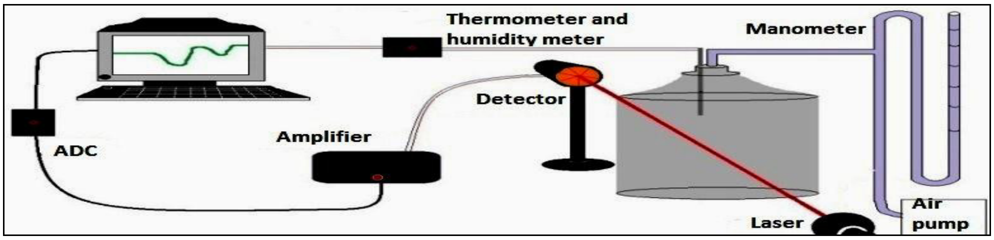

Fig. 1. Schematically figure of the experimental set up.

Table 1. Density of acid was tested and their relevant PH.

Density of sulfuric acid(PPM)	PH	
333.58	6.8	
450.8	6.35	
647.53	5.6	
1039.98	3.6	
1628.65	3.35	

In order to study the cloud lifetime, cloud concentration and maximum temperature change, five different densities of $H_2SO_4$was added in 1 litre of water at the bottom of the chamber (Table 1). The pressure was increased up to 103 mmHg in the cloud chamber, and then aerosols were allowed to settle to a new steady state for a period of 10-15 minutes. After that the gases was affected under free expansion by opening the chamber valves, this resulted in formation of cloud droplet with a certain density. Cloud concentration was measured by a laser system including a detecting device that detects the opacity of the cloud chamber to laser light; cloud lifetime was estimated by responses of laser system too. A fast response temperature sensor measures the temperature in the chamber. The experiments were repeated for 4 times in each density of acid ion.

We also used the nonparametric statistical analysis methods based on ranking the responses and compare mean of this ranks between groups. In this way ‘Kruscal Wallis’ test was used to compare distributions each of the response variables (namely cloud lifetime, cloud concentration and maximum temperature change) between 5 different density of H_2SO_4, Also to show the repeatability of runs (4 testes) within each experiment group with a specific acid density. The Spearman test was used to determine correlation coefficient between all response variables runs of each experiment.

3. Results

The results show that the cloud lifetime is reduced by the increase of the density of SO_4^{2-} in the chamber, but these changes are not significant (P=0.578), while the cloud concentration is significantly changed with this decrease (P=0.001). In 1039.98 PPM of pure sulphuric acid case study, we have maximum cloud concentration (depicted in table 2). Changes between different tests of the experiments within each density of acid ion were not significant (p>0.05). With increasing cloud concentration, the maximum temperature change also rises.There is a good correlation between the cloud concentration with maximum of temperature change correlation coefficient 0.646(p=0.004). It seems that, in the fourth run larger droplets have been formed; although the cloud has more concentration, but it cleared faster [8]. Also, the maximum temperature change is related to the maximum cloud concentration; because the inner temperature variation of chamber has probably a direct relation with nucleation. It means that in this experiment, an optimum acid concentration for cloud has been deduced.

In the last run, the concentration of cloud is reduced severely that can be concluded that the least concentration of nucleation acid has occurred.

Table 2. The mean ranks, mean and standard error of response variables in different experiments

Acid density (H_2SO_4PPM)	Runs(N)	Lifetime (s)				Cloud concentration (Arbitrary unit, A.U.)					Max temperature change (°C)		
		Mean Rank	Mean	SD		Mean Rank	Mean	SD			Mean Rank	Mean	SD
333.58	4	15.17	151.25	29.95		8.75	0.54	0.024			7.83	1.77	0.03
450.8	4	13.75	143.75	19.23		16.25	0.64	0.02			9.5	1.83	0.07
647.53	4	10.38	109.63	3.73		6.88	0.52	0.015			3.63	1.62	0.05
1039.98	4	9	109.33	7.44		21.5	0.75	0.01			16.5	2.27	0.05
1628.65	4	9.5	111.8	7.31		6	0.48	0.04			9.63	1.85	0.1
		P=0.578				P=0.001					P=0.016		

We show the charts of cloud lifetime in the first run in each density of acid separately and compare visually with together (Fig 2). Note that the detected power of laser is proportional to the concentration of the cloud reversely. And finally the change in the response of the cloud formation was averaged over all experiments. The blue bars in Fig 3 show that the changes in different tests are as a function of acidic ion density, averaged over the five runs. It is seen that the response is remarkably constant over the shown size range.

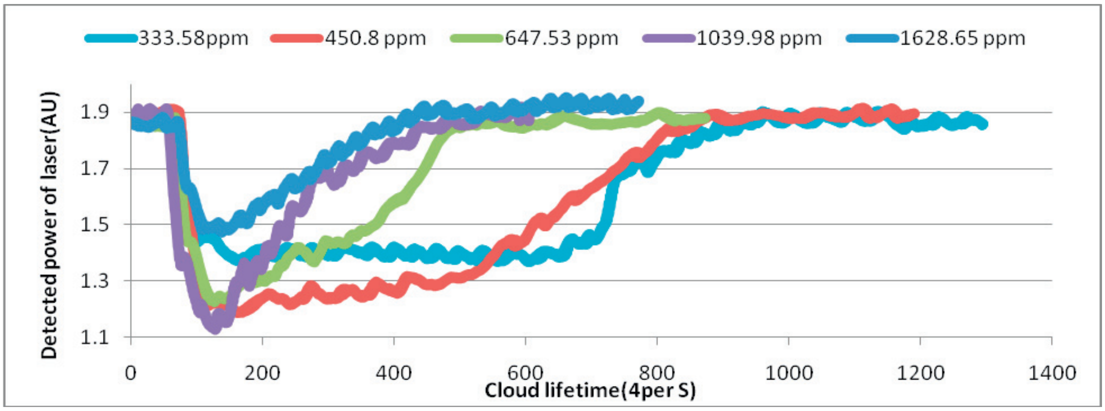

Fig. 2. Comparison between 'cloud lifetime' charts in the first run of each density of H_2SO_4, heavy solid lines show different density of acid, note that detected power of laser is proportional to the concentration of the cloud reversely.

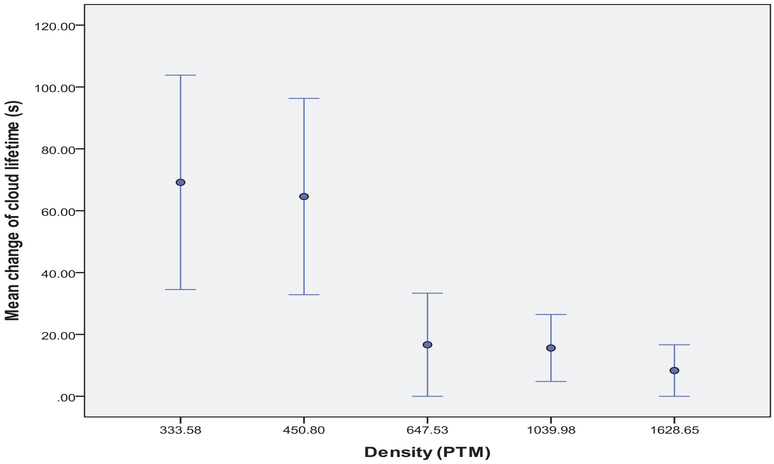

Fig. 3. Mean +, - 2 Standard error of cloud lifetime changes in different runs as a function of H_2SO_4 density in the chamber

4. Summary and conclusions

A clear physical understanding of atmospheric particle nucleation mechanisms is critical in assessing the influences of aerosols on climate and climate variability. To study the role of SO_4^{2-} in an experimental examination, we tested five different density of H_2SO_4 in a cloud chamber. For each experimental test, the lifetime, the cloud concentration and maximum temperature changes were measured. The mean lifetime, mean and standard error of the cloud concentrations in each variable and the changes in them over four tests within each density separately were collected. Also Kruscal Wallis test (a nonparametric statistical analysis method) has been done to compare distributions of each of them in different density of H_2SO_4. The Spearman test was used to determine correlation between the response variables and show there is a good correlation between cloud concentration and maximum temperature change. Moreover, comparison of the cloud characteristics was done to show the repeatability of tests (4 tests) in each experiment with a specific acid density. The results show that cloud lifetime is not dependent on the density of acid ion (333.58 to 1628.65

PPM) probability, while there is a significant increase in the cloud concentration with the increase of acid density in the chamber. So cloud concentration can be affected by ion density. This result is supported by Katz and Svensmark studies [2, 7, and 9]. Also this research illustrates that as the ion density increases up to a certain value, the cloud concentration increases, after that by adding density of the acid ion, the cloud concentration decreases. We have the best cloud concentration in the chamber for 1039.98 PPM. The results presented here may provide an important missing piece of the puzzle as to how SO_4^{2-} may affect climate change.

Acknowledgements

The support of the University of Tehran is greatly acknowledged.

References

[1] Forster, P., Ramaswamy, V., Artaxo, P., Berntsen, T., Betts, R., Fahey, D. W., ... & Van Dorland, R. Changes in atmospheric constituents and in radiative forcing. *Climate change* 2007; *20*.

[2] Svensmark, H., Pedersen, J. O. P., Marsh, N. D., Enghoff, M. B., & Uggerhøj, U. I. Experimental evidence for the role of ions in particle nucleation under atmospheric conditions. *Proceedings of the Royal Society A: Mathematical, Physical and Engineering Science* 2006; *463*(2078), 385-396.

[3] Prospero, J. M. The chemical and physical properties of marine aerosols: An introduction. *Chemistry of Marine Water and Sediments* 2002; 35-82.

[4] Pedersen, M. B., J. O. P., U. I., S. M. Paling, and H. Svensmark, Aerosol nucleation induced by a high energy particle beam. Geophysical Research Letters 2011; 38 L09805.

[5] Kirkby, J., Curtius, J., Almeida, J., Dunne, E., Duplissy, J., Ehrhart, S., Franchin, A., Gagn´e, S., Ickes, L., K¨urten, A., et al., Role of sulphuric acid, ammonia and galactic cosmic rays in atmospheric aerosol nucleation. *Nature* 2011; *476*(7361), 429-433.

[6] Sullivan, R. C., Moore, M. J. K., Petters, M. D., Kreidenweis, S. M., Roberts, G. C., & Prather, K. A. Effect of chemical mixing state on the hygroscopicity and cloud nucleation properties of calcium mineral dust particles. *Atmospheric Chemistry and Physics* 2009; *9*(10), 3303-3316.

[7] Svensmark, H., Enghoff, M. B., and Pedersen, J. O. P. Response of Cloud Condensation Nuclei (> 50 nm) to changes in ion-nucleation. *arXiv preprint* 2012;*1202.5156*.

[8] Shoushtari, M. H., Naji, F. and Bidokhti, A. A. A laboratory study of role of ions in warm cloud formation. *Journal of the earth and space physics* 2013; In Press.

[9] Katz, J. L., Fisk, J. A., Chacrov, V. M. Condensation of a supersaturated vapor IX. Nucleation on ions. *J. Chemical Physics* 1994; 101, 2309-2318.