Cosmic Ray Tracks by the New type of Cloud Chambers

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Abstract. We have fabricated two different types of cloud chambers: a diffusion cloud chamber and a Wilson cloud chamber. These chambers were filled with air and the tracks formed in them by cosmic rays were investigated. Surprisingly, cosmic ray tracks were observed in air containing few aerosol particles. This finding is highly significant and may be useful in future studies of the relationship between solar activity and global cloudiness.

Keywords: cosmic rays and climate, Maunder minimum, cloud chambers

I. INTRODUCTION

Whether cosmic rays affect the global climate is an important unresolved question in geophysics. This question was first posed in a paper by Friis-Christensen and Svensmark published in 1997 [1]. In subsequent papers, Svensmark et al. found a correlation between global cloudiness and the intensity of cosmic rays [2], [3], [4]. According to their analysis, global cloudiness increases when the intensity of galactic cosmic rays, i.e., cosmic rays originating from outside the solar system increases. A clear correlation has also been found between the cloudiness at low altitudes (under 3,200 m) and solar activity. However, no correlation has been discovered between solar activity and the cloudiness at middle and high altitudes. Due to the correlation at low altitudes being so strong, a vigorous debate has ensued in various scientific fields.

Cosmic ray physicists have no difficulty understanding the correlation between the intensity of cosmic rays and cloudiness, since they use cloud chambers to detect cosmic rays, which produce tracks in the chambers by ionization. However, the intensity of cosmic rays appears to be too low to account for number of water droplets in global clouds. Ion pairs induced by cosmic rays probably play only a minor role in accelerating the formation of water droplets. Even if cosmic rays were able to accelerate the formation of a small number of water droplets by ionization, the clouds produced would mask the light of the Sun, thereby reducing the global temperature. Thus, it might be possible to find a reasonable explanation for the correlation found by Friis-Christensen and Svensmark. In the next section, we discuss a scenario proposed by them.

II. THE MAUNDER MINIMUM AND CLOUD FORMATION

During 1645 and 1725, an abnormally low number of sunspots were observed on the solar surface [5]. This phenomenon is known as the Maunder minimum. It coincided with an approximately 2°C drop in the average global temperature. Due to the weakness of the solar magnetic field during this period, the intensity of galactic cosmic rays was stronger than at other periods [6], [7], [8]. Thus, the correlation found by Friis-Christensen and Svensmark would be possible to explain the drop in global temperatures that occurred during the Maunder minimum [9]. The aim of this present study is to find an explanation of the correlation observed by Friis-Christensen and Svensmark.

As a first step towards this goal, we approach the correlation from another point of view. A widely accepted theory by meteorologists is that when warm air ascends to high altitudes, it is cooled and the moisture it contains condenses to form clouds. Both water vapor and aerosol particles (APs) are necessary to form a cloud. This can be easily demonstrated by blowing smoke from a match into a vessel filled with water vapor, which results in the immediate formation of a cloud [10]. In summary, both the water vapor and the APs are necessary for cloud formation [11]. This is the standard theory for cloud formation.

However, the cloud formation process is not so simple: Aitken particles also play an important role. Aitken particles are typically about 20 nm - 80 nm in diameter, which corresponds to the length of a few tens of water molecules. They are so small that they cannot be detected by optical counters. The mass of Aitken particles can be determined by measuring the time that it takes for ionized Aitken particles to drift when they are placed in an electric field. Aitken particles undergo successive collisions with water droplets in air and thereby increase in size until they reach diameters of about 1 μm, which is the size of a large AP. Observations at the Mt. Norikura Cosmic Ray Observatory (altitude: 2,770 m) indicate that Aitken particles in the atmosphere grow from 10 nm to 30 nm in approximately 8 hours [12]. For simplicity, however, we do not consider the role of Aitken particles in this paper. Rather, we regard APs as being the principal source of cloud condensation nuclei (CCN).

In addition, the role of the ions created by cosmic rays is not well understood. There may be other routes through which ions have function as CCN and form water droplets. Do ions accelerate the formation process of CCN? Or do ions increase in size by attracting water particles by themselves, independently of Aitken particles and/or APs? This is a very critical point for understanding the Maunder minimum phenomena. In order to discover the answer to this question, we conducted an experiment using small cloud chambers. In this paper,
after describing our experimental method, we present the results and introduce our future plans.

III. EXPERIMENTAL METHOD

Do ions produced by cosmic rays agglomerate by themselves? Or do they attach to the surface of Aitken particles and/or APs? In order to clarify this point, we fabricated specially designed cloud chambers and used them to conduct experiments.

We prepared two types of cloud chambers: a diffusion cloud chamber and a Wilson cloud chamber. While these cloud chambers are similar to conventional cloud chambers, they differed in that the gas inlet and outlet was located on the outside of the chambers. Figures 1–3 show schematic views and photographs of these diffusion and Wilson cloud chambers.

We used purified air and nitrogen manufactured by the Sumitomo Seika Chemicals Co. which had very low levels of APs in them (less than one AP per liter according to the manufacturer). In general, there are high quantities of APs in the air. Table I shows the number of APs per liter measured in the air in the laboratory and outside the building. These APs were measured by using the optical particle counter. In Table I, the number of aerosols per liter is presented as a function of AP size.

We investigated the formation of tracks by cosmic rays in the purified gases. Ethanol was placed in the bottom of the glass flask and also at the top of the flask. First, we passed gas through both chambers until the total amount of gas passed through each chamber exceeded five times the volume of the chamber. According to our calculations, this process increased the purity of the gases by a factor of 160 (i.e., 6 × 10⁻³).

We cooled the diffusion cloud chamber by putting solid CO₂ at the base of the glass flask and waiting approximately 30 min until the vessel had cooled down and a saturated layer had formed, which was capable of producing cosmic ray tracks. For the Wilson cloud chamber we just lowered the piston and expanded the volume; this formed a supercooled region. We have recognized the cosmic ray tracks by the naked eye, being illuminated the cloud chamber by the photo diode.

IV. PRELIMINARY RESULTS

Surprisingly, cosmic ray tracks were observed in the semi-purified air in the same way that they were observed in the contaminated gas that contained a high concentration of APs. We are currently unable to explain this observation. It appears that ion pairs generated large droplets without the assistance of APs. Is there a previously unconsidered third route to make CCN? Do ions form water droplets by themselves? Our experimental results suggest that this is possible.

However, there are several questions concerning the quality of our experiment. Even although we used pure air, the purification process was not perfect. Some APs might remain not only on the chamber wall but also in the gas itself. The baking of the chamber wall is not easy.

Even if the air contained a small amount of APs, ion pairs may form to the large water droplets. Furthermore, we did not measure the amount of Aitken particles in the semi-pure air. The air might have been relatively free of Aitken particles, but it is unlikely that there were no Aitken particles present. It is unclear role ethanol vapor plays. Does it behave like Aitken particles in the flask for ions?

Therefore we have conducted another experiment using the diffusion cloud chamber. The chamber was filled with the pure air after the evacuation inside the chamber by the vacuum pump. Neither any track nor fog was seen. However when we installed a ring fulfilled with a plenty of the Ethanol on the top side of the flask, clear tracks of cosmic rays and fogs were seen even in the “pure” air.

V. COMMENTS AND DISCUSSIONS

Finally we would like to remark on the formation process of the cloud. In the old bibliographies [13], the formation process of water droplet in cloud chamber has been given. The ions formed by the passage of cosmic rays in the chamber will attach a water molecule and grow up by the following process. Water droplet has a trend to form a cubic shape to minimize the surface tension (σ). However it is said that in case there is an electric charge on the water vapor, Coulomb force of the electric charge is able to weaken the surface tension. By the balance of force between the electric force and the surface tension , the other water vapor can attach on the charged water vapor and grow up to large size of water droplet (≥100nm). The process could be described by the following equation: RT/Mln(P/P∞) = 2σ/ε + dσ/dr - ε²/8πr³ ε.

The authors find several such examples in the plasma physics, however we are a little bit skeptical for the application of above explanation to the formation process of cloud. Because the electric charge is a unit at the beginning and such statistical electric field could act to the molecular orbit of electrons effectively? We know of course the water molecule has a electric dipole moment, but from a gross feature of view , they are neutral in charge. The Aitken particle may have an important role in the formation process of cosmic ray tracks.

Ions generate cosmic ray tracks in the cloud chamber. This is the discovery by Sir Wilson. He investigated cosmic rays using Wilson cloud chamber. Initially, he observed plenty of fogs in his cloud chamber. However, after expanding the cloud chamber repeatedly, he saw cosmic ray tracks.

In the initial stages, the water droplets were formed by attaching to APs inside the chamber. However, it is unclear whether the tracks of cosmic rays were formed with the assistance of Aitken particles or APs that were left in the cloud chamber. If this had been true, Sir Wilson was lucky to see cosmic ray tracks [14]. To confirm this point, we need to conduct another experiment using a vessel that has been fulfilled by the purified air.
TABLE I: Number of Aerosols in side Air. The number of APs per liter measured in the air inside the laboratory and outside the building. The data are given as a function of the size of the APs.

<table>
<thead>
<tr>
<th>Size of Aerosols</th>
<th>&gt; 0.3 μm</th>
<th>&gt; 0.5 μm</th>
<th>&gt; 0.7 μm</th>
<th>&gt; 1 μm</th>
<th>&gt; 2 μm</th>
<th>&gt; 5 μm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outside</td>
<td>399,447</td>
<td>35,578</td>
<td>7,907</td>
<td>2,822</td>
<td>884</td>
<td>87</td>
</tr>
<tr>
<td>Inside</td>
<td>175,698</td>
<td>14,107</td>
<td>3,634</td>
<td>1,558</td>
<td>675</td>
<td>71</td>
</tr>
</tbody>
</table>

We plan to investigate the cloud formation process by using a vacuum chamber and report the results at the conference in Lodz.

VI. ACKNOWLEDGEMENTS

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REFERENCES