Japan Geoscience Union Meeting 2012
(May 20-25 2012 at Makuhari, Chiba, Japan)

MIS26-P08 Room:Convention Hall Time:May 23 17:15-18:30

Laboratory experiment for verification of cloud condensation nucleation by cosmic rays

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Ion-induced nucleation of condensed particles has been suggested as one of mechanisms for correlation between the solar activity and the global climate change. The idea is that ions, which are produced by atmospheric ionization of cosmic-ray particles, promote growing-up of aerosol particles, then create cloud condensation nuclei and provide the increase of cloud amount. Recently some experiments have been planned or on progress in order to verify this scenario. We are also trying to verify independently of the other experiments. In a talk, we will explain our experimental method, report the progress and discuss the future prospect.

The galactic cosmic-ray flux reaching the earth is modulated by change in interplanetary magnetic field due to the solar activity. It was the start of the controversy that change in cosmic-ray intensity measured by neutron monitors on ground correlated well to the change in low cloud amount in the earth's atmosphere. Although there are many subjects to be examined such as method of cloud measurement, interpretation of cosmic-ray data and bias for the correlation, it would be valuable to investigate the relation between the ionizing radiation and cloud nucleation in laboratories under controlled conditions. We have introduced the air with some constituents simulating the real clean atmosphere into the chamber, which can be sealed or evacuated in order to reproduce the reactions in the atmosphere, and created a near-natural situation by irradiating with Sr-90 beta-rays and exposed to UV light, and measured ions and aerosol particles in the chamber. Assuming sulfuric-acid aerosols are the most effective to develop the size of aerosol particles, we have tried to create sulfuric-acid molecules based on sulfuric dioxides in air. Then water molecules condensate on the sulfuric-acid molecules and develop their size and, if exceeding the critical size, they can grow up to cloud condensation nuclei.

Our system consists of a gas mixing apparatus, a reaction chamber with ionizing radiation and UV radiation, and measuring instruments. The gas mixing apparatus mixes pure dry air, wet air involving water vapor, oxygen-based ozone and nitrogen-based sulfuric dioxide. The concentrations of these gases were controlled by changing the flow rates of the components. Typical total flow rate was 5 L/min. The reaction chamber is a cylinder of 40 cm in diameter and 60 cm in length and the volume is about 75 L. With a flow of 5 L/min, all gases in the chamber should be exchanged in 15 min. assuming the gas flow is uniform in the chamber. In the reaction chamber, the mixed gas is irradiated by beta rays and exposed to UV radiation. One can change the amount of irradiation by putting thin (0.1 mm thick) SUS plates between the chamber window of 0.2 mm thick and the radiation source. The UV window is made of quartz and a mercury lamp with light of 254 nm can be set at the window. No control of light yield was done. Considering the creation of sulfuric acid molecules, we first exposed the air with sulfuric dioxide, water vapor and ozone to the UV light. Then we irradiate the gas with beta rays and measure the change of products, that is, concentrations of ozone and sulfuric dioxide, densities of ions and condensed particles with a size larger than 2.5 nm, and temperature and relative humidity. We will report the results of measurements under several conditions.

Keywords: cosmic rays, solar activity, global climate, atmospheric ionization, aerosol, cloud formation