Measurements of Near-Infrared Radiative Properties of Laboratory Generated Water Ice Clouds at High Spectral Resolution

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Abstract

Cirrus clouds are known to have a significant impact on climate, yet large uncertainties remain in the radiation budget due to clouds and their radiative properties. We present results of preliminary laboratory experiments designed to measure near-infrared scattering phenomena at high spectral resolution in the vicinity of water vapor absorption features at 1.37 μm. In addition to the fundamental importance of determining the radiative properties of ice clouds, these experiments characterize the effects of ice particles on the performance, precision and accuracy of an in situ near-infrared spectrometer, the JPL Laser Hygrometer (JLH). JLH scans across a strong water vapor absorption line at 1.37 μm wavelength in an open path sample cell to measure atmospheric water vapor. The DC-8 mounted JLH is shown in figure 1.

The extent of radiative interference effects of ice crystals on JLH measurements within cirrus clouds is quantified here.

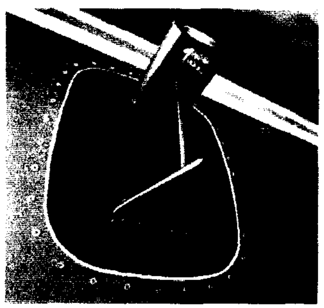

Figure 1 The JPL Laser Hygometer (JLH) is mounted on the fuselage of the NASA DC-8 aircraft. The instrument shown has an optical path length of 50 cm. Other versions have path lengths of up to 1120 cm.

Procedure

An ice cloud was generated in the UCLA cloud chamber, the schematic layout of which is shown in figure 2, cooled to below -41°C, the homogeneous nucleation temperature of water. The chamber is a corrosion resistant steel box with a volume of approximately 1.35 m³, which is roughly cubical. The steel chamber is surrounded by Styrofoam, which is approximately 0.2m thick. The assembly is enclosed in a plywood outer shell. A 30 by 30 cm window on the top of the chamber exposes the top of the ice cloud for study. The chamber is cooled by placing dry ice directly on the top of the stainless steel box in a 15 cm gap between the top of the steel box and the plywood. This method is very effective at cooling the chamber fairly evenly with only a few degrees temperature gradient between top and bottom. When a cloud is formed it's top surface lies at the level of the window and is stable due to the sharp temperature difference between cloud and room atmosphere

Data and Results

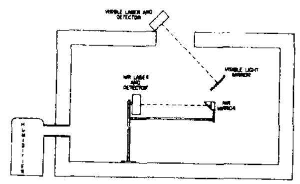

figure 2 Schematic representation of the UCLA cloud chamber. JLH is completely submerged in the chamber to eliminate effects of room air water vapor absorption.

The cloud is formed by injecting water droplets generated by a commercial household humidifier which generates the droplets ultrasonically.

The droplets freeze into droxtals, with a mean size of 7 μm diameter, upon contact with the cold air. Light attenuation was measured simultaneously by JLH placed inside the chamber and by a visible (red) diode laser and detector. To extract any meaningful data, the microphysical properties of the ice cloud and the particle concentration at each moment in time needed to be measured.

Following the procedure of Barkey et al., 2000, replicas of ice crystals were made immediately before and after reflectance measurements were made. This was accomplished by allowing a sample of crystals to fall upon a laboratory slide coated with a partially dissolved layer of acrylic. As the solvent evaporated, replicas of the crystals were made in the acrylic

A sample is shown in figure 3. The replicas were studied microscopically to determine size distribution. By measuring the amount of visible laser light extinction, and using the derived ice crystal size distribution, an estimate was made of the particle concentration as a function of time.

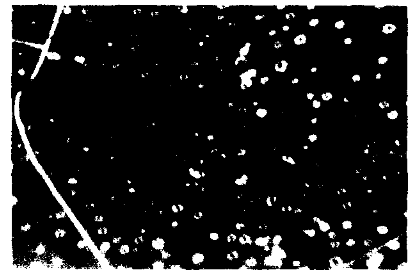

figure 3 Photomicrograph of droxtals sampled from the UCLA cloud chamber during the reported experiment. The left to right dimension of this image is 200 μm.

Theory

By measuring the amount of NIR laser light extinction, and using the measured ice crystal size distribution, a determination can be made of the particle concentration at any time. This is done by calculating an extinction coefficient, ßext, from a measurement of the laser extinction and the equation:

$$I / I_0 = e^{-\beta ext\, N L}$$

Where I is the measured intensity of the NIR beam after passing through the ice cloud, I_0 is the measured intensity in the absence of cloud, L is the path length through the cloud, and N is the particle concentration.

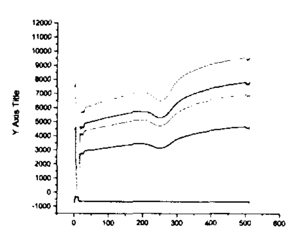

figure 4 Laser detector power vs frequency at several times during ice cloud dissapation for the case where NIR laser beam travels a short distance through room air. There is substantial absorption at 1.37μm

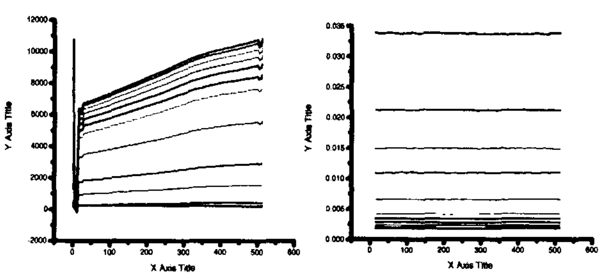

figure 5 Right - Laser detector power vs frequency vs time for case where NIR laser beam is completely submerged in the ice cloud.
Left - Absorption coefficient, ß, as a function of frequency.

Data and Results

The experiment was conducted with the JLH in two different orientations. An inital series of experiments were conducted with the JLH NIR laser beam originating from outside the cloud chamber and parallelling the path of the visible red laser. The results of this method are shown in figure 4 where it can be seen that, even for the short path length through the room air above the cloud, there is substantial attenuation at the 1.37μm absorption line.

Conclusions

- We have demonstrated a technique for measuring NIR extinction by laboratory ice particles (up to 3.5 m^{-1}).
- The ice crystal generated in the cloud chamber were droxtals with a mean maximum size of 7 μm.
- We have demonstrated that the extinction coefficient, ß, is independent of wavelength over the wavelength range we are studying.
- Using the observed sample size distribution, we are able to calculate particle concentration from NIR extinction.

Acknowledgements

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