Toward improvement of microphysical processes within the melting layer

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1. Introduction

The melting layer is a frontier left in precipitation physics.

The melting layer plays important roles in the formation of laminar structure of the atmosphere. The cooling due to melting particles can produce deep isothermal layers (Findeisen, 1940). This cooling can lead to a separation of the dynamics above and below the melting layer, and may be important on the large-, meso- and convective-scale phenomena (Atlas et al.,1969; Fabry et al., 1995).

In the melting layer, there appears a layer of enhanced radar-reflectivity, that is, "bright band". The bright band has been considered a source of error in precipitation estimates using spaceborne (TRMM) and ground-based radars. The effect of melting particles on electromagnetic wave propagation is also important in microwave communication.

Although the qualitative explanation of the reflectivity enhancement causing the bright band has been made early on (Ryde, 1946), there is still no consensus after 60 years on a quantitative assessment. Given the large number of factors that may influence the bright band shape, it is not surprising to have so many, often contradictory, explanations of the bright band phenomenon. Since our understanding of the microphysical processes within the melting layer is incomplete, additional efforts must be invested to quantify the mechanisms that satisfy modelers, cloud physicists, and radar meteorologists.

The main purpose of this paper is to present some new physical properties of melting particles observed by using a 2DVD (2-dimensional video disdrometer). This study will improve our understanding of physical processes within the melting layer.

2. Data

We used the two-dimensional video disdrometer (2DVD) (Schönhuber et al., 1997; Kruger and Krajewski, 2002) to measure size, shape, axis ratio (oblateness), canting angle, and velocity of precipitation particles. The 2DVD data were collected over a 6-year period from 2004 to 2008 at Sapporo, and over a 5-year period from 2004 to 2008 at Kanazawa.

3. Melting snowflakes

During melting, the fall velocity of melting snowflakes increases as water accumulation increases their bulk density. Based on their laboratory experiments, Mitra et al. (1990) showed that the fall velocity depends on particle size and its melted fraction.

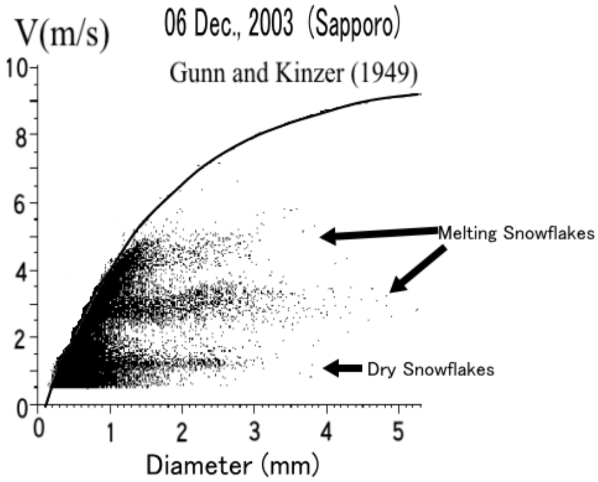

Fig. 1: Velocity-Diameter relationships of dry- and melting snowflakes measured by using a 2DVD at Sapporo on 6 Dec. of 2003.

Figure 1 clearly shows that melting snowflakes weakly depend on parameters such as shape, density, and size of particles as suggested by Matsuo and Sasyo (1981a,b). This result indicates that the most important parameter, that controls a fall velocity of a melting snowflake, is not the melted fraction, but total amount of melting water. This result also indicates that various sizes (and masses) of melting particles with the nearly the same fall velocity can exist together at the same level within the melting layer when these particles originate from snowflakes.

Since the shape of the melting snowflake decides the drag resistance and the ventilation coefficients, the microphysics of melting must be sensitive to the shape of the melting snowflakes. Examples of large melting snow particles observed at Kanazawa on 25 January 2005 are shown in Fig. 2. Large melting snowflakes (we call the typical shape of melting snowflakes the "Mickey Mouse" shape) fell between 00:24 and 00:34 JST, when the surface air temperature ranged from 7 to 8°C. Terminal fall velocities of dry snowflakes do not change with size because their drag resistance increases with size. On the other hand, the melting snowflakes can change their shape and drag resistance. Thus, the fall velocities of large melting snowflakes can be similar to those of raindrops (approximately 8 m s^{-1}).

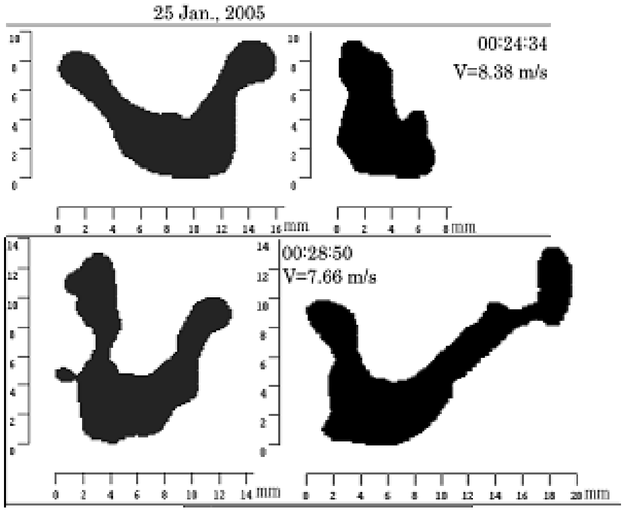

Fig.2: 2DVD images of large melting snow particles observed on 25 January 2005. The time of measurement and fall velocity are also shown.

4. Melting graupels

As shown in Fig. 3, fall velocities of dry graupels increase almost linearly with size (a dotted line). Since the density of melting graupels increases with decreasing size, the difference in fall velocities between dry- and melting graupels increases with decreasing size as shown in Fig.3. The Diameter-Velocity relationship of melting graupels in Fig. 3 can be explained by the theory presented by Matsuo and Sasyo (1981a,b).

Figure 4 shows examples of melting graupels. Aggregation of melting snowflakes occurs within the upper part of the melting layer (Barthazy et al., 1998). This 2DVD images clearly show that graupels can also aggregate with each other within the melting layer.

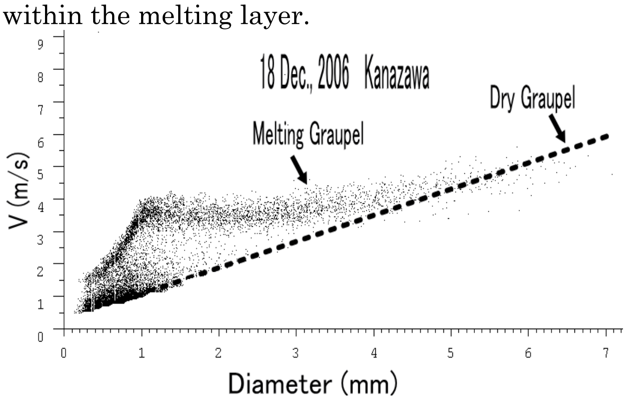

Fig. 3: Velocity-Diameter relationships of melting graupels measured by using a 2DVD at Kanazawa on 18 Dec. of 2006.

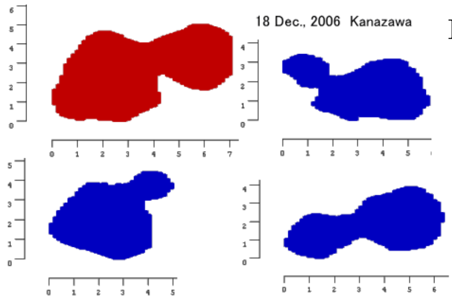

Fig.4: Images of aggregated melting graupels.

5. Concluding remarks

It is believed that observations presented here will help constrain bright band models. Outstanding problems include a more thorough evaluation of the contribution of shape or density effects, aggregation, and breakup of melting particles. We need realistic microphysical and scattering models to satisfy numerical modelers, cloud physicists and radar meteorologists.

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