NUMERICAL SIMULATIONS OF MELTING OF GRAUPEL PARTICLES AND SNOWFLAKES

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1. INTRODUCTION

This paper presents results of numerical simulations of melting of graupel particles and snowflakes. The proper simulation of this process near to the surface or above the surface in the melting region is necessary for the correct simulation of the type of the precipitation (e.g. snow, rain, freezing rain etc.). Also the size distribution of the rain drops formed due to the melting affects the formation of the cold pool related to thunderstorms. In most of the numerical models this process is described by using bulk schemes, which can be one-moment, two-moment or multimoment parameterization (Milbrandt-Yau, 2005a,b). In this type of the microphysical scheme and even in most of the detailed microphysical models the basic idea about the melting is that melted water sheds immediately from the surface of the ice core (e.g. Reisin et al. 1996) This assumption is far from the real process. Observation shows that the melted water remains on the surface of both snowflakes (Mitra et al, 1990) and on that of the graupel particles (Rasmussen et al, 1984a,b), and shedding can occur only in the case of the hail/graupel if the size of these particles is above about 1 cm. A numerical model was developed to simulate the melting in the atmosphere.
Verifying of the results of numerical models able to use radar images, where we can discern the different hydrometeor types. Battan and Bohren (1982) noted that when the melting layer was treated like a mixture of water and ice the melting associated with the rapid increases of radar reflectivity.

2. MODEL DESCRIPTION

The calculation was made by using a one-dimensional numerical model. The three different types of the particles (snow, graupel, water drops) are allowed to fall with their terminal velocities.
Two-moments, detailed microphysical scheme (Tzivion et al, 1987) was used to simulate melting, collision between the particles and diffusional growth of the particles. Beside the number concentrations and mixing ratios of the above mentioned parameters, the amount of the melted water in each bin was prognostic variable for both melted snow flakes and graupel particles. The melting rate of the particles was affected by the heat conduction and by the released latent heat of diffusion as it is given in Pruppacher and Klett (2004). Besides these physical processes the heat given by the collected warmer water drops is also taken into consideration (Geresdi, 1992). It is supposed that while the characteristics (shape, density, terminal velocity) of the graupel particles are hardly affected by the melting, these parameters change significantly as the amount of the liquid water increases on the surface of the snow flakes (see eg. Mitra et al, 1990). Because the melting ice particles generally feel high supersaturation in the precipitation zone their diffusional growth can significantly increase the masses of the falling solid precipitation elements. It is supposed that condensed water increases the mass of the melted water.
In our model we considered the following interaction and physical processes: melting of snowflakes, and graupel particles, condensation, deposition, break up of water drops. If the melting rate has exceeded 95%, the melted snowflakes and graupel particles, were transferred to the water drop category.

3. NUMERICAL EXPERIMENTS

In the numerical experiments we examined how melting of snowflakes and graupel particles occurs at different initial conditions. In the first case we analyzed the melting processes at a temperature profile which was given by wet adiabatic lapse rate. In the second case the melting process of graupel particles was simulated at similar environmental conditions as in

the case of the snowflakes. Finally the formation of freezing drizzle was simulated when an inversion layer formed above the surface.
The sensitivity of the melting for the saturation of the environment was investigated in every cases.
At the top of the melting layer a constant flux of the precipitation elements (snowflakes, graupel particles) have been provided.

4. RESULTS OF SIMULATIONS

4.1. MELTING OF SNOWFLAKES

The results show that (i) the relative humidity strongly affects the type of the surface precipitation. In the case of low humidity the melting layer is deeper. (ii) In the positive temperature region the vapor condense on the melted particle, but due to the temperature decrease and the evaporation of the water drops formed by complete melting of the snow the relative humidity increases in the melting region.
(iii) The melting layer getting deeper during the simulation (Fig 1. and Fig 2.). Initially it was about 400 m, and by the end of the simulation it was near to 600 m. The temperature change from the melting at the beginning is the highest at the top of the melting layer (Fig. 3.). The water mixing ratio is changed because of the melting of snowflakes. This change was rapidly, and significant at the first 10 minutes, this can be seen on Fig. 4. The water vapour mixing ratio has also been changing, the change is consistent with the temperature change (Fig. 5.). Fig 6. shows the size distribution of the water drops on the surface at different times. Likewise Fig. 7. shows the size distribution of the melting snowflakes and the size dependence of fraction of the melted water at top of the melting region. While the particles of less than 200 µm melt almost completely, the particles with sizes above one mm remain almost dry.

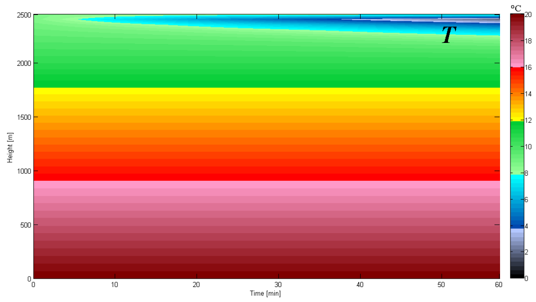

Fig. 1.: Temperature change, y-axis represents the height, x-axis represents the time

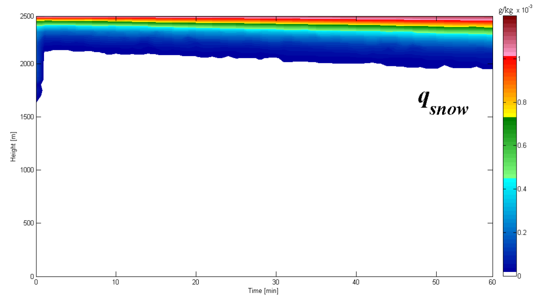

Fig. 2.: Snow mixing ratio change, y-axis represents the height, x-axis represents the time

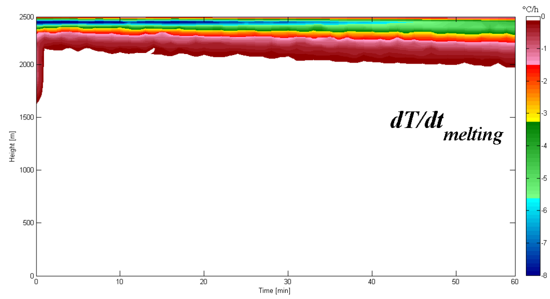

Fig. 3.: Temperature change due to melting, y-axis represents the height, x-axis represents the time

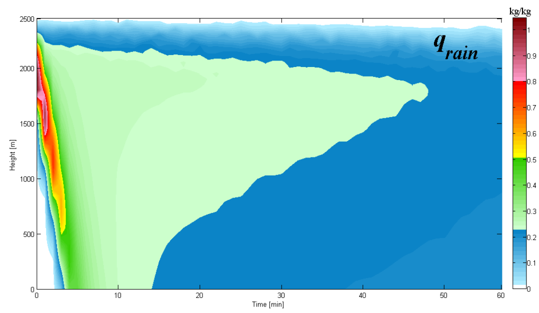

Fig. 4.: Water mixing ratio change, y-axis represents the height, x-axis represents the time

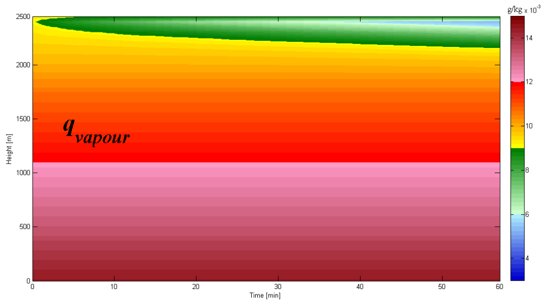

Fig. 5.: Water vapour mixing ratio change, y-axis represents the height, x-axis represents the time

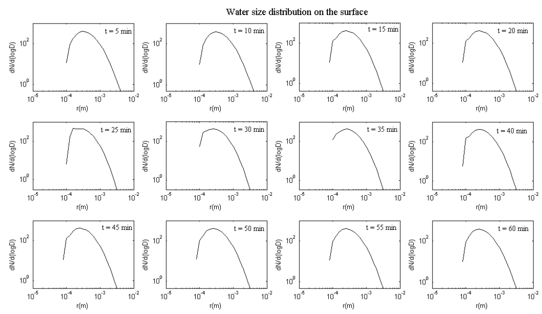

Fig. 6.: Water size distribution on the surface, y-axises represent logarithmic number concentration, x-axises represent the logarithmic radius of water droplets

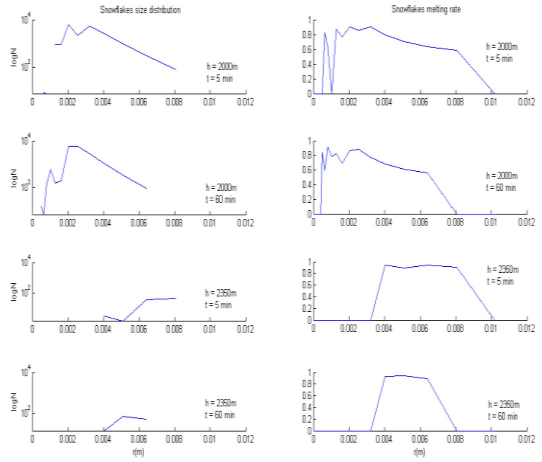

Fig. 7.: Snowflakes size distribution and melting rate on different heights, at different time, y-axises represent logarithmic number concentration, x-axises represent the radius of snowflakes

4.2. MELTING OF GRAUPEL PARTICLES

Because of the higher terminal velocity the melting process of the graupel particles and its effect on the environmental condition is different from that of the snow flakes. Except of the small graupel particles (< 0.8 mm) all the particles reach the surface. The melting fraction also depends on the size of the particles. The evolved water droplets are smaller than in the case of the melting of snowflakes (Fig. 8.,9.).

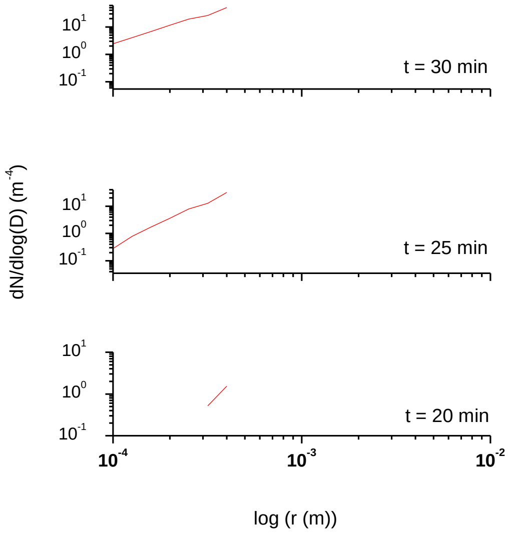

Fig. 8.: Water size distribution on the surface

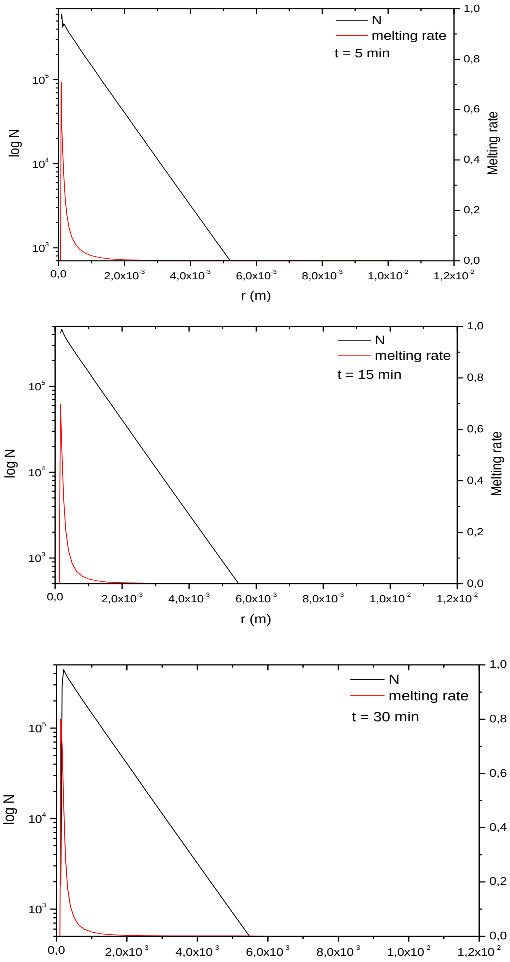

Fig. 9.: Graupel particles size distribution and melting rate, at 2500 m height

4.3. MELTING OF SNOWFLAKES IN THE CASE OF INVERSION LAYER

Studies show that the freezing rain and sleet formation are significantly affected by initial conditions: (i) temperature profile (e.g. max. temperature and depth of the melting layer), (ii) relative humidity.

5. SUMMARY AND CONCLUSIONS

In our studies a detailed microphysics technique is applied to simulate how the snow flakes and graupel particles melt. Numerical experiments were made to investigate how the different environmental conditions affect the melting of the snow flakes and graupel particles.
The calculation shows: (i) The falling precipitation elements can significantly modify the environmental conditions which feedbacks to the melting process. (ii) The new description of melting process (melted water is retained on the surface of the particles) allows to give more correct simulation of the freezing rain formation. (iii) The results are sensitive to the relative humidity in the melting layer.

6. BIBLIOGRAPHY

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Acknowledgements

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