Numerical simulation of the formation of precipitation using bin microphysics

Noémi Sarkadi, István Geresdi and Gregory Thompson

INTRODUCTION

The qualitative and quantitative prediction of the properties of precipitation is challenging in everyday forecast, especially in complex cases – in nowcasting.

A mesoscale convective system was formed and moved forward to northern Oklahoma 19-20 June 2007. The storm had a strong convective leading edge and trail stratiform precipitation (Morrison et al, 2012). The research focused on the effect of the melting and that of the evaporation of precipitation elements on the formation of the cold pool.

MODEL DESCRIPTION

Simulations were conducted using the nonhydrostatic Advanced Research Weather Research and Forecasting model (WRF) version 3.4.1 (Skamarock et al. 2008).

Microphysics:

Simulations used a detailed microphysical scheme (Geresdi et al, 2014; Thériault et al, 2015). Four different hydrometeor type was distinguished: ice particles (with the size range: 2.06e-6 — 0.38 m), snowflakes (size between: 2.06e-6 — 7.85e-2 m), graupel particles (size: 3.37e-6 — 5.08e-3 m), water drops [1.56e-6 — 1.02e-2 m; including: cloud water droplets (1.56e-6 — 2.50e-5 m) and raindrops (2.50e-5 — 1.02e-2 m)]. Each type of the different particles were divided into 36 bins. The following microphysical processes were taken into consideration: 1) Diffusional growth of different type of hydrometeors; 2) Melting of solid hydrometeors; 3) Freezing of supercooled water drops; 4) Collision and coalescence of water drops; 5) Self-coagulation of pristine ice crystals results in snowflakes; 6) Self-coagulation of snowflakes increases the mass of snowflakes; 7) Riming; 8) Breakup of water drops; 9) Formation of pristine ice crystals by deposition nucleation; 10) Sedimentation.

Model setup:

The initial conditions followed by Morrison et al (2015). Simulations were integrated for 8 hours. The domain size is 612 × 122 km in the horizontal (1 km grid spacing) and 20 km in the vertical directions (100 sigma levels for model setup).

RESULTS

Figure 1: Simulated horizontal and vertical cross section of radar reflectivity [dBZ] at 4th, 6th and at the 8th simulated hour. Horizontal black line indicates the location of vertical cross sections shown in figures.

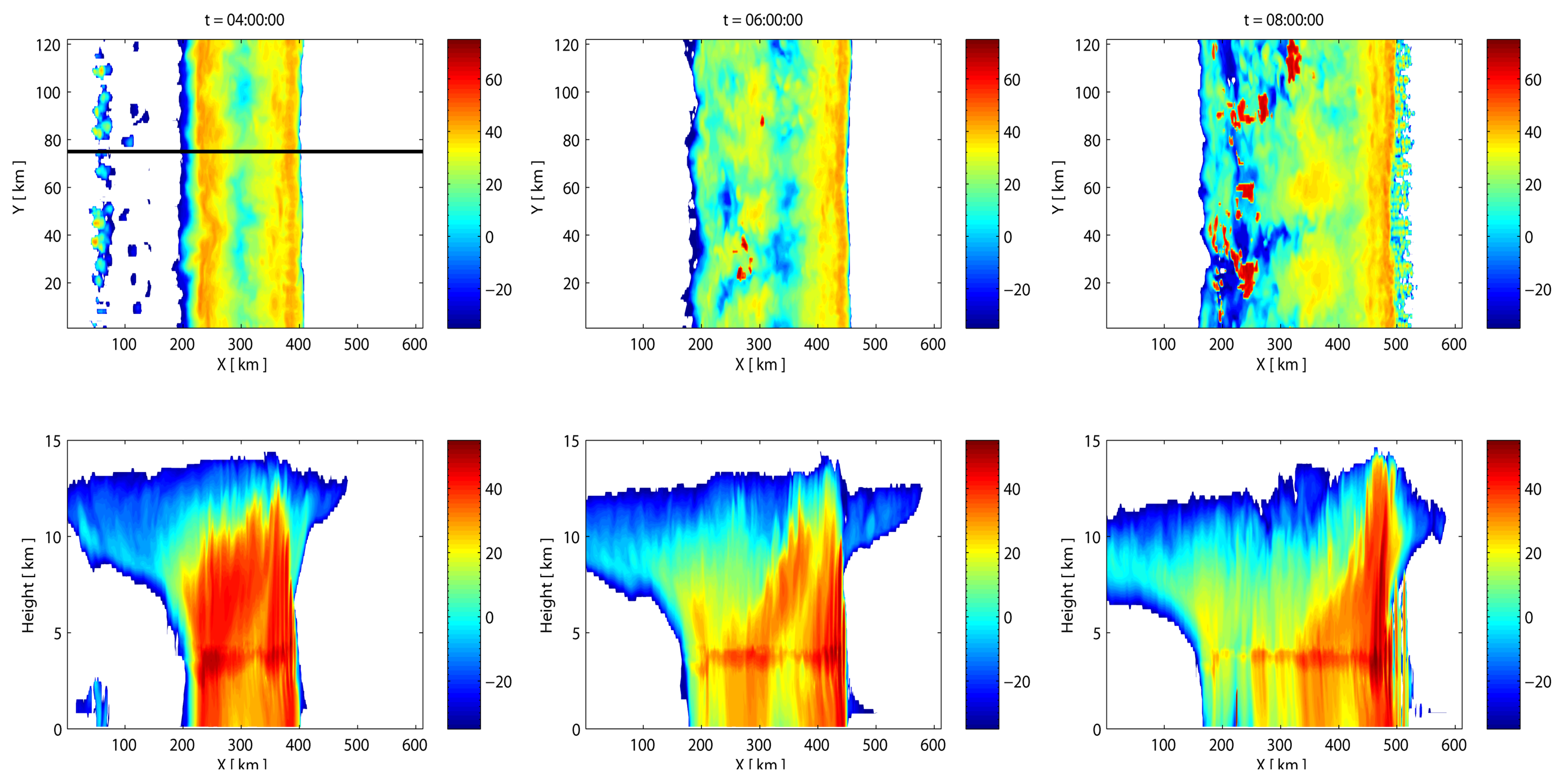
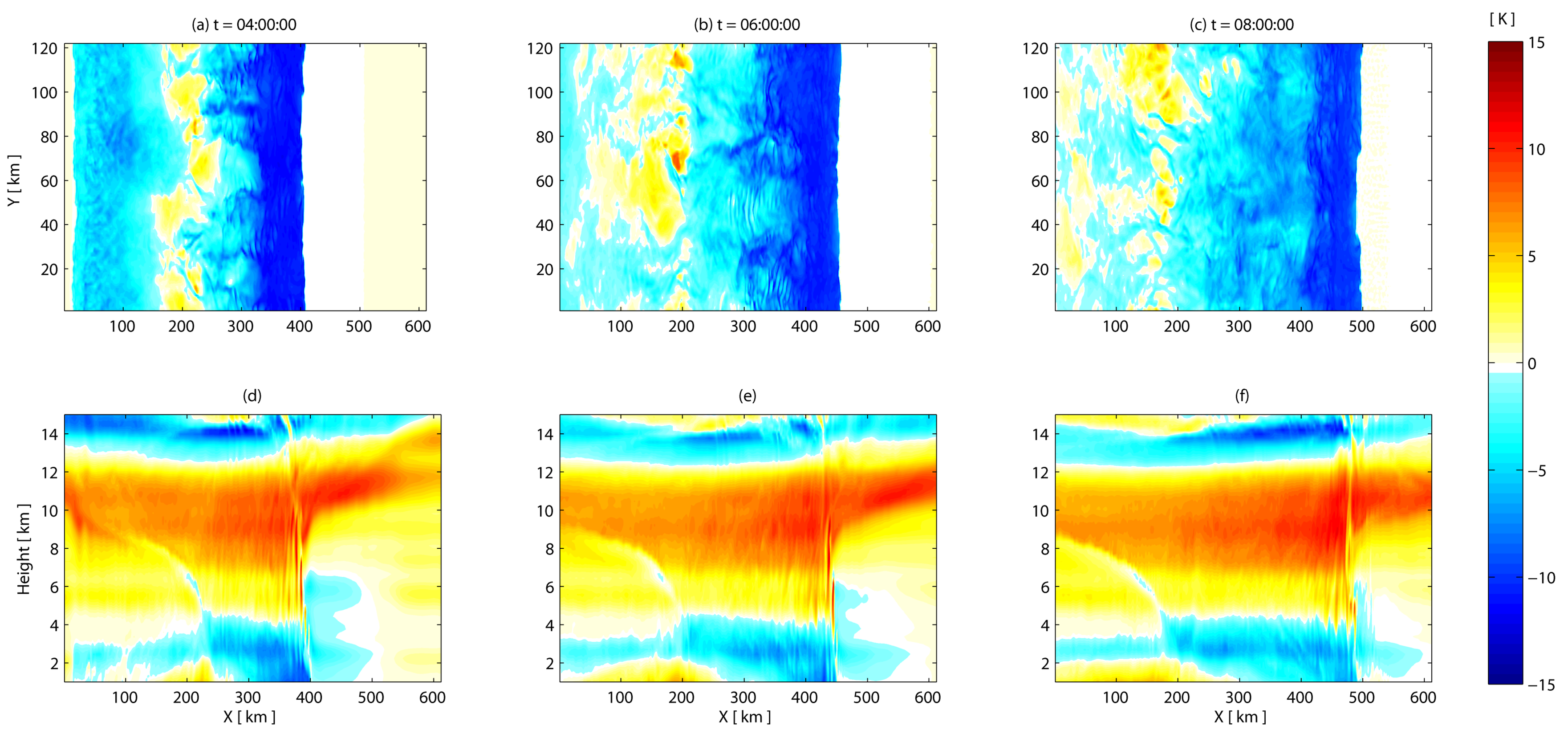


Figure 2: Simulated horizontal and vertical cross section of theta perturbation [K] at 4th, 6th and at the 8th simulated hour.



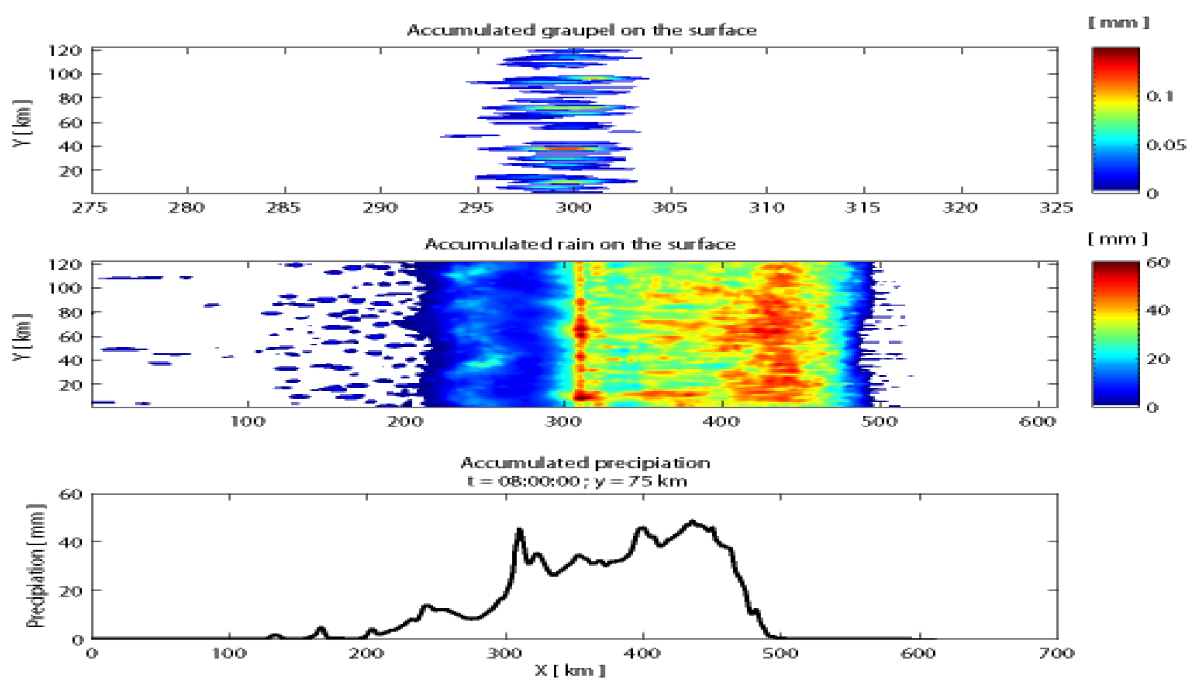


Figure 3: Simulated accumulated graupel (a) and rain (b) on the ground at the 8th simulated hour. (c) Total accumulated precipitation on the surface [mm].

Figure 4: Simulated size distribution of the different type of hydrometeors: (a) snowflakes above the melting level, (b) snowflakes below the melting level, (c) graupel particles and (d) water drops at the 8th simulated hour. Black lines are related to the stratiform region, red lines note the size distributions in the convective region, the dashed lines are related to the melting and riming fractions.

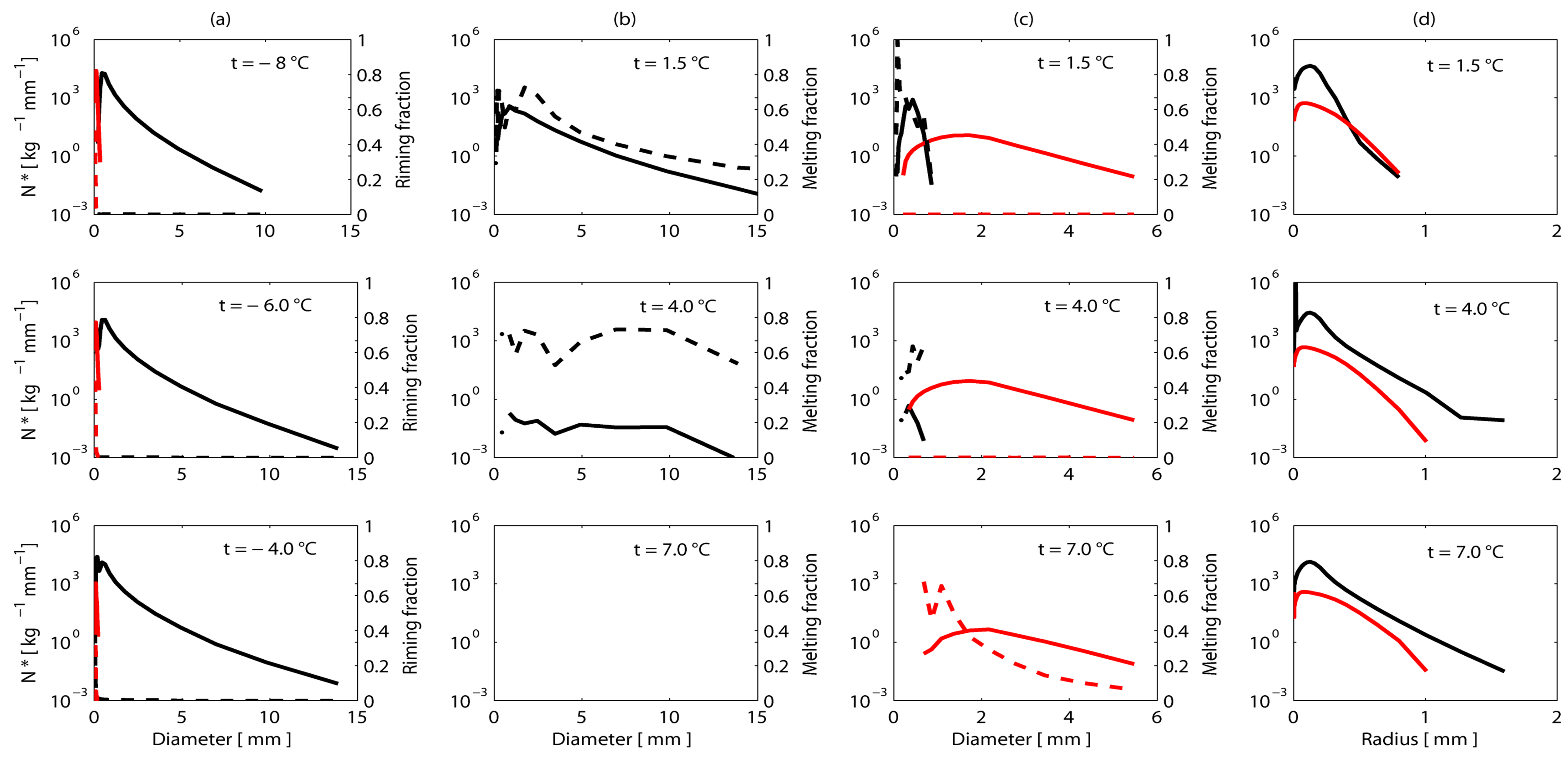
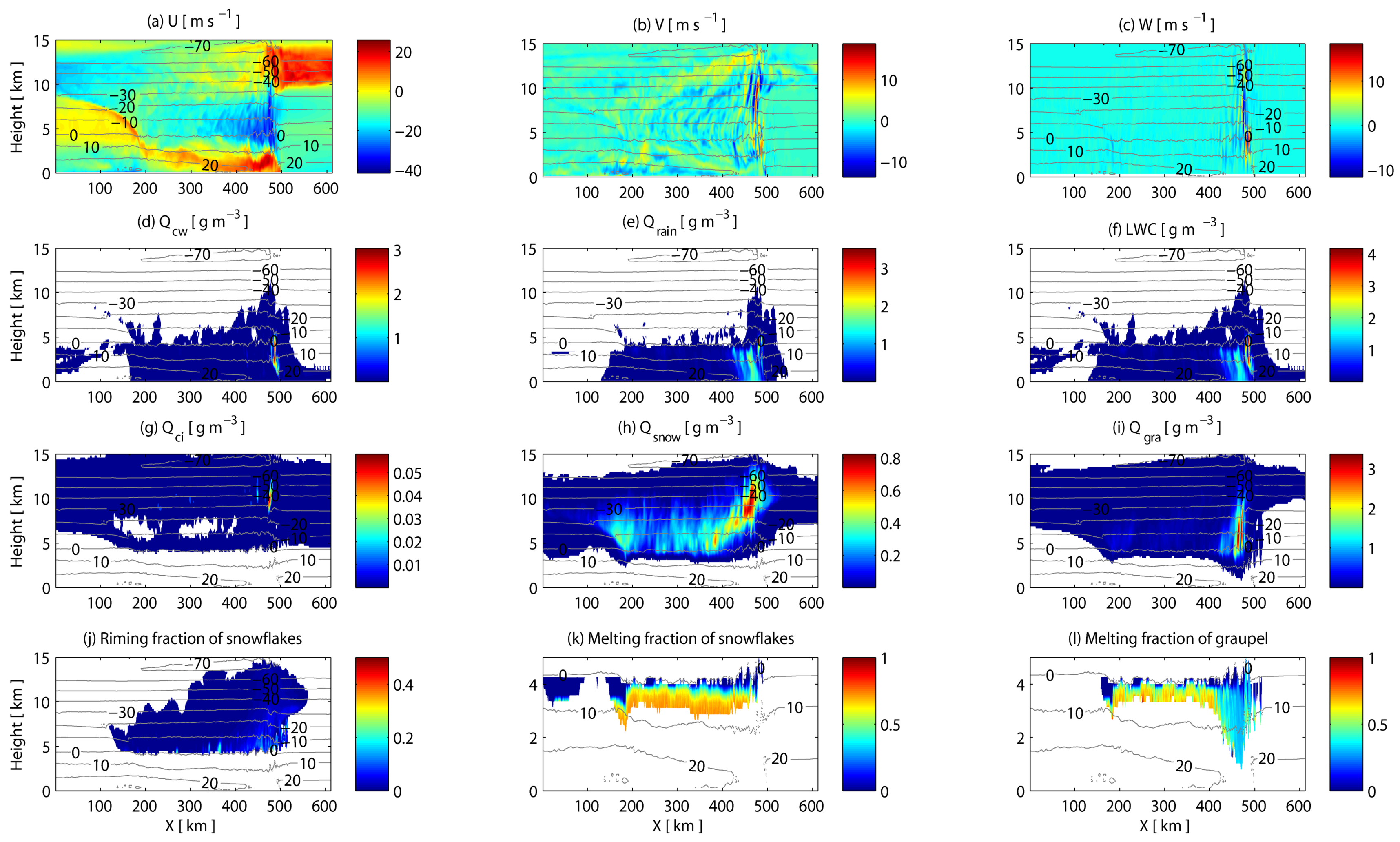


Figure 5: Vertical cross sections: (a) U-wind, (b) V-wind, (c) W-wind component [m s^{-1}] and the mixing ratios [g m^{-3}] at the 8th simulated hour: (d) cloud water, (e) rain water, (f) total liquid water, (g) cloud ice, (h) snowflakes and ice particles, (i) graupel particles and (j) riming rate of snowflakes, (k) melting rate of snowflakes and (l) melting rate of graupel particles. Gray lines note the temperature in °C.



CONCLUSIONS

A numerical simulation of a real squall line using bin microphyisical scheme was made. The melting of the solid hydrometeors (snowflakes and graupel particles) were tested. The formation of a cold pool and the radar reflectivity pattern were investigated.

Simulaton shows:

- In the stratiform region the model overestimated the precipiation (related to this the radar reflectivity) associated with the intensive melting of snowflakes (Fig 1c, Fig 3b).
- The model is able to reproduce the bright band considering the size dependent melting fractions (Fig 1b).
- Formation of the cold pool behind the leading edge is spreading around 100 km.
- The modeled size distributions show that the formation of the graupel particles are related to the intense convective regions (Fig 4c).
- The liquid water droplet median volume diameter is 3 mm (Fig 4d).

REFERENCES

Geresdi, I., Sarkadi, N. And Thompson, G., 2014: Effect of the accretion by water drops on the melting of snowflakes. Atmos. Res. 149, 96-110.

Morrison H, Tessendorf S. A , Ikeda K. and Thompson G., 2012: Sensitivity of a Simulated Midlatitude Squall Line to Parameterization of Raindrop Breakup. Mon. Weather Rew. 140, 2437-2460.

Morrison H, Milbrandt J. A, Bryan G. H, Ikeda K, Tessendorf S. A. and Thompson G., 2015: Parameterization of Cloud Microphysics Based on the Prediction of Bulk Ice Particle Properties. Part II: Case Study Comparisons with Observations and Other Schemes. J. Atm. Sci. 72, 312-339.

Skamarock W, Klemp J, Dudhia J, Gill D, Barker D, Duda M, Huang X.Y. and Powers, J., 2008: A description of the advanced research WRF version 3. Technical Report. NCAR Techn. Note NCAR/TN-475 + STR (113 pp.)

Thériault J. M, Milbrandt J. A, Doyle J, Minder J. R, Thompson G, Sarkadi N. and Geresdi I., 2015: Impact of melting snow on the valley flow field and precipitation phase transition. Atmos. Res. 156, 111-124.

ACKNOWLEDGEMENTS and CONTACT

Participation was sponsored by the CAMPUS HUNGARY Program.

Contact information:

Noémi Sarkadi: sarkadin@gamma.ttk.pte.hu
University of Pécs, Hungary

István Geresdi: geresdi@gamma.ttk.pte.hu
University of Pécs, Hungary

Greg Thompson: gthompsn@ucar.edu
NCAR Research Application Laboratory, Boulder, CO