Numerical simulation of tornadic supercell using a convective cloud model

Thomas Rupnig

Introduction

On the 10th of July 2017 a tornadic supercell storm has occoured, south of vienna near the swechat airport. A three-dimensional numerical simulation has been executed in ordert o analyse this supercell storm.

Case Analysis

A supercell Storm formed over lower Austria on the 10th of July 2017 and moved westward. It reached the south of Vienna. Near the Schwechat airport a tornado formed. Tornados often develop from supercell stroms. Supercells contain mesocyclones. As the mesocyclone lowers below the cloud base, cool and moust ai rare taken in from the downdraft region oft he storm. The convergence of warm air in the updraft and cool air create a rotating wall cloud. The rear flank downdraft focuses the mesocyclone's base, causing it to draw air from a smaller and smaller area on the ground. As the updraft intensifies, it creates an area of low pressure at the surface. This pulls the focused mesocyclone down, in the form of a visible condensation funnel. As the funnel descends, the rear flank downdraft also reaches the ground, creating a gust front. The funnel cloud begins causing damage. The system is becoming a tornado.

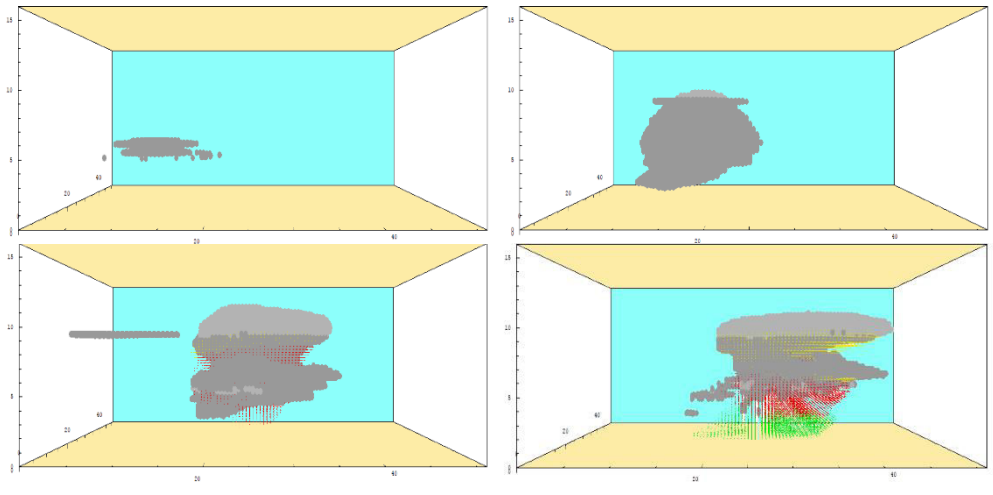

figure 1: formation oft he supercell storm

Method

In order to capture the initiation of supercell storm and evolution of tornado we have conducted also a three-dimensional simulation using a cloud resolving model with fine horizontal grid resolution and small domain which covers the tornadic storm area of 61x61x60 km^3. More detail information about numerical experimental set up and model configurations and parameters are listed in Table1. The cloud model is a 3-D non-hydrostatic, compressible time-dependent, model with dynamic scheme from Klemp and Wilhelmson (1978), thermodynamics proposed by Orville and Kopp (1977), and bulk microphysical parameterization scheme according to Lin et al. (1983). The present version of the model contains ten prognostic equations: three momentum equations, the pressure and thermodynamic equations, four continuity equations for the water substances, and a subgrid-scale kinetic energy equation. More information regarding the cloud model could be found in Telenta and Aleksic (1988), and Spiridonov and Curic (2005; 2010, 2015, 2018), Barth et al. (2007). The cloud model is initialized using a warm ellipsoid thermal bubble with the maximum temperature perturbation of 2.0 °C in the bubble centre as suitable for highly unstable atmosphere to trigger severe convective storm. The initial meteorological conditions were taken from upper air sounding from Wyoming University (attached on Moodle). A three-dimensional (3-D) runs were performed within small domain with size 51x51x20 km^3 that covers the central part of Vienna City area and its southern part where supercell storm and tornado occurred. The horizontal grid length is 250 m, while the vertical resolution is 100m in the PBL layer and 250 at the higher altitudes, respectively. The time step of the model is 1 s and the smaller one is 0.2 s for solving the sound waves. The results are summarized and some of them are exhibited and discussed in the Results Section.

Results

The numerical simulation showed that a strong supercell formed over Austria. In figure 2 below we can see the updrafts and downdrafts. We have got strong updrafts of up to 20m/s and downdrafts of up to 10m/s. After 20 minutes, where the supercell peaked, the cloud was around 13km high and had a width of about 20km. The hail of the supercell storm did not reach the ground.

Conclusion

We can clearly see how the maximum of updrafts and downdrafts are correlated with the maximum size of the cloud. After 20 minutes, most of the updrafts and downdrafts disapeared. At this point there are still very strong winds, but only horizontally. The simulation of this supercell storm gave a very good insight into the procedure of the growth of this specific mesoscale phenomena over Vienna.

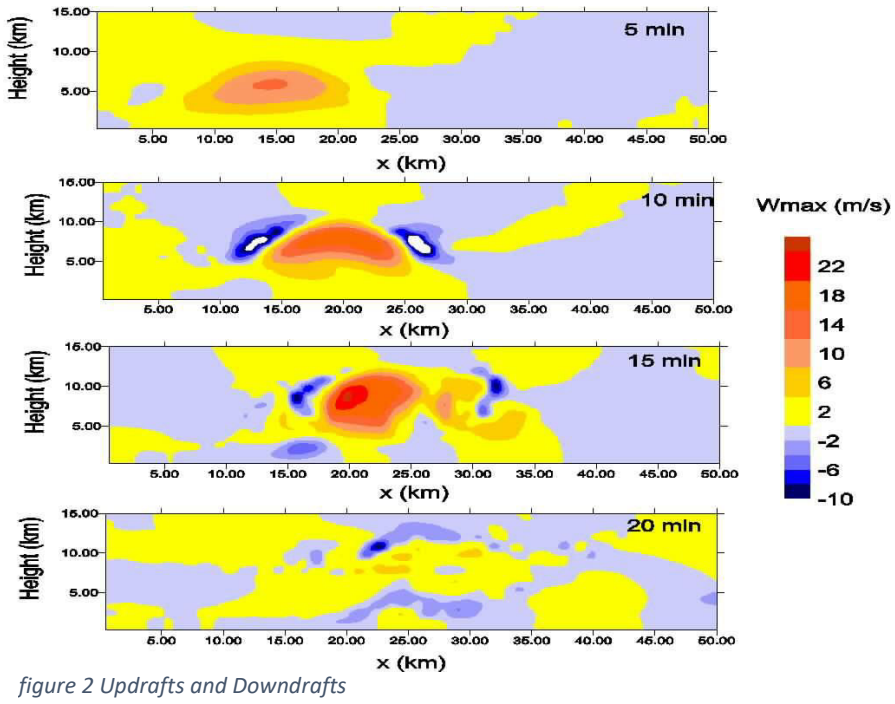

figure 2 Updrafts and Downdrafts

References

Barth, M.C., S.-W. Kim,, C. Wang, K. E. Pickering, L. E. Ott, G. Stenchikov, M. Leriche, S. Cautenet, J.-P. Pinty, Ch. Barthe, C. Mari, J. H. Helsdon, R. D. Farley, A. M. Fridlind, A. S. Ackerman, V. Spiridonov, and B. Telenta, 2007: Cloud-scale model intercomparison of chemical constituent transport in deep convection, Atmos. Chem. Phys., 7, 4709–4731.

Klemp, J.B., R.B.Wilhelmson,1978: The simulation of three-dimensional convective storm dynamics. J. Atmos. Sci. 35, 1070–1096.

Lin, Y.L., R.D. Farley, and H.D. Orville, 1983. Bulk water parameterization in a cloud
model. J. Climate Appl. Meteor. 22, 1065–1092.

Orville, H.D., and F.J.Kopp, 1977: Numerical simulation of the history of a hailstorm,
J. Atmos. Sci., 34, pp. 1596–1618.

Spiridonov V, Dimitrovski Z, Ćurić M. 2010. A Three-Dimensional Simulation of Supercell Convective Storm, Advances in Meteorology. 2010: 15.

Spiridonov, V., and M. Curic, 2015: A Storm Modelling System as an Advanced Tool in Prediction of Well Organized Slowly Moving Convective Cloud System and Early Warning of Severe Weather Risk. Asia- Pac. J. Atmos. Sci., 51(1), 1-15, DOI: 10.1007/s13143-000-0000-0.

Spiridonov, V., and M.Curic, 2018: Evaluation of Supercell Storm Triggering Factors Based on a Cloud Resolving Model Simulation.
Asia-Pac. J. Atmos. Sci., 00(0), 0-00, DOI: 10.1007/s13143-018-0070-7

Telenta, B., and N. Aleksic, 1988: A three-dimensional simulation of the 17 June 1978 HIPLEX case with observed ice multiplication, 2nd International Cloud Modeling Workshop, Toulouse, 8-12 August 1988. WMO/TD No. 268, 277 –285.