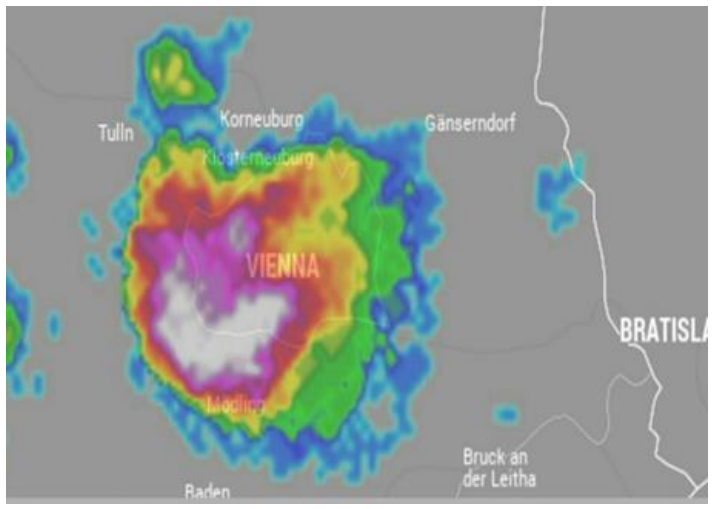
Numerical simulation of tornadic supercell using a convective cloud model

David Hinger
Universität Wien

Introduction

On the 10th of July 2017 a supercell developed over the area of Vienna. This supercell caused a Tornado near the Airport of Schwechat. The event was simulatetd with an convective cloud model, to make a good analysis of the supercell possible.

Tornado near the Airport of Schwechat on 10.7.2017



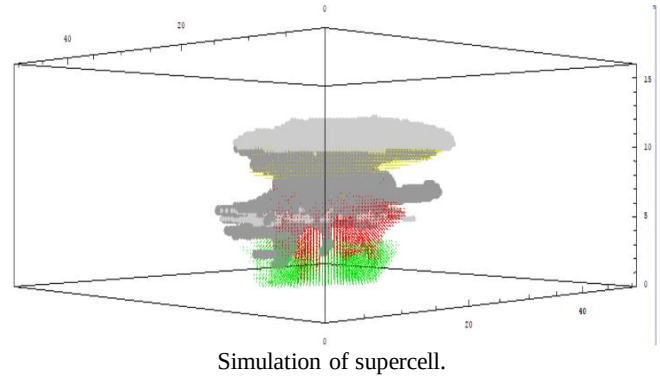
Observed rainfall of supercell.

Methods

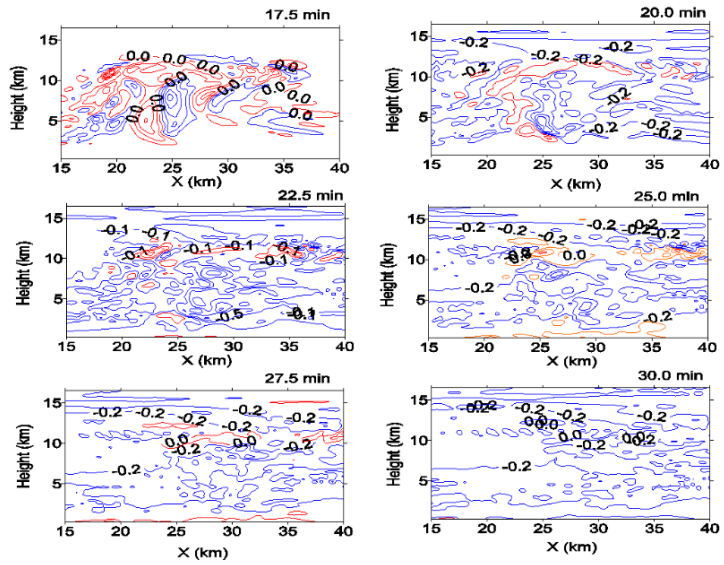
In order to capture the initiation of supercell storm and evolution of tornado we have conducted also a three-dimensional simulation using a cloud resolving model with fine horizontal grid resolution and small domain which covers the tornadic storm of 61x61x60 km³. The cloud model is a 3-D nonhydrostareaatic, 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), 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. A three-dimensional (3-D) runs were performed within small domain with size 51x51x20 km³ 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 1s and the smaller one is 0.2s for solving the sound waves. The results are summarized and some of them are exhibited and discussed in the Results Section.

Results

The simulation of the supercell shows a very detailed development process. The simulation of the vertical vorticity shows a vertical corridor of positive vorticity in the back of the supercell. The corridor goes near to the ground and indicates an establishment of a Tornado.



Simulation of supercell.



Simulation of vertical vorticity in supercell

Conclusions

The numerical convective cloud model, worked really good for this case. It brought a clear and detailed depiction of the forming of a supercell and the development of the Tornado.

Bibliography

1. 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.
2. Klemp, J.B., R.B.Wilhelmson,1978: The simulation of three-dimensional convective storm dynamics. J. Atmos. Sci. 35, 1070–1096.
3. 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.
4. Orville, H.D., and F.J.Kopp, 1977: Numerical simulation of the history of a hailstorm, J. Atmos. Sci., 34, pp. 1596–1618.
5. Spiridonov V, Dimitrovski Z, Ćurić M. 2010. A Three-Dimensional Simulation of Supercell Convective Storm, Advances in Meteorology. 2010:15.
6. 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.
7. 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 (in press).
8. 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.