Numerical simulation of tornadic supercell using a convective cloud model

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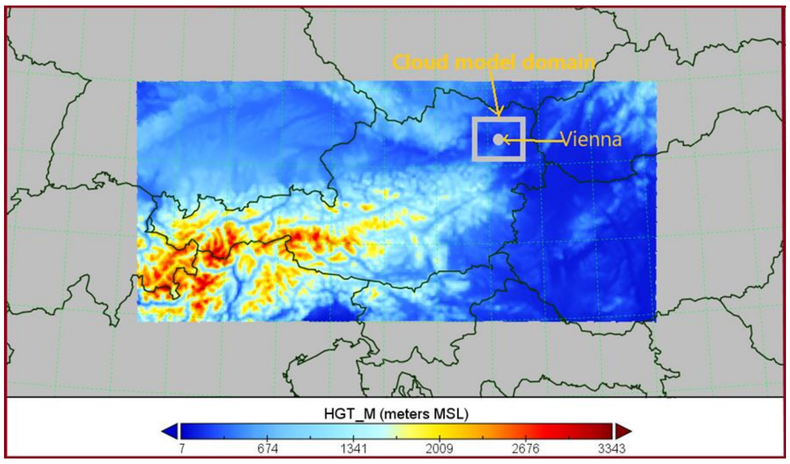
Introduction

On July 10th 2017 a supercell above eastern Austria developed, which caused a tornado near the Airport of Schwechat. In order to analyse this mesoscale phenomena and to understand the physical processes of the event, a convective cloud model was used, to simulate the supercell.

Tornado near the Airport of Schwechat, Austria on 10.7.2017



Cloud model domain for the simulation of the supercell

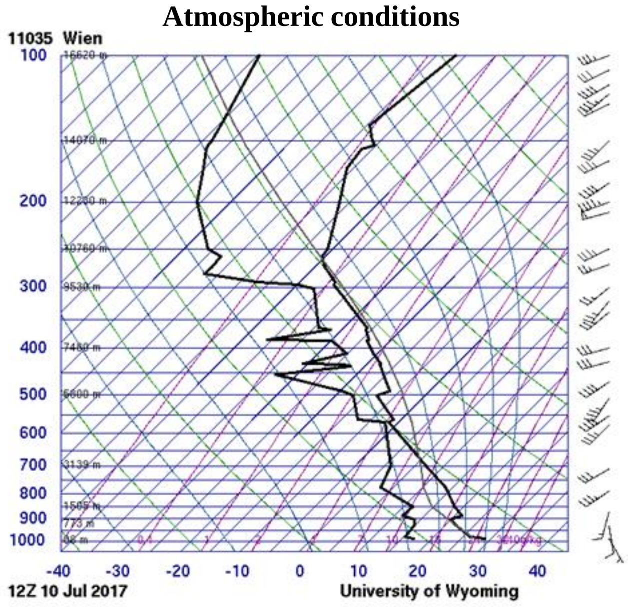
Methods

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 area of 61x61x60 km3. 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), Barth et al. (2007).

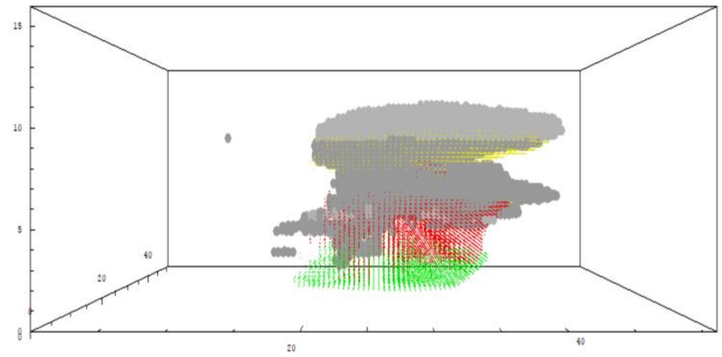
The cloud model is initialized using a warm ellipsoid thermal bubble with the maximum temperature perturbation of 2.0 C in the bubble centre as suitable for highly unstable atmosphere to trigger severe convective storm. The initial meteorological conditions were taken from upper air sounding from Wyoming University (attached on Moodle). A three-dimensional (3-D) runs were performed within small domain with size 51x51x20 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 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.

Atmospheric conditions

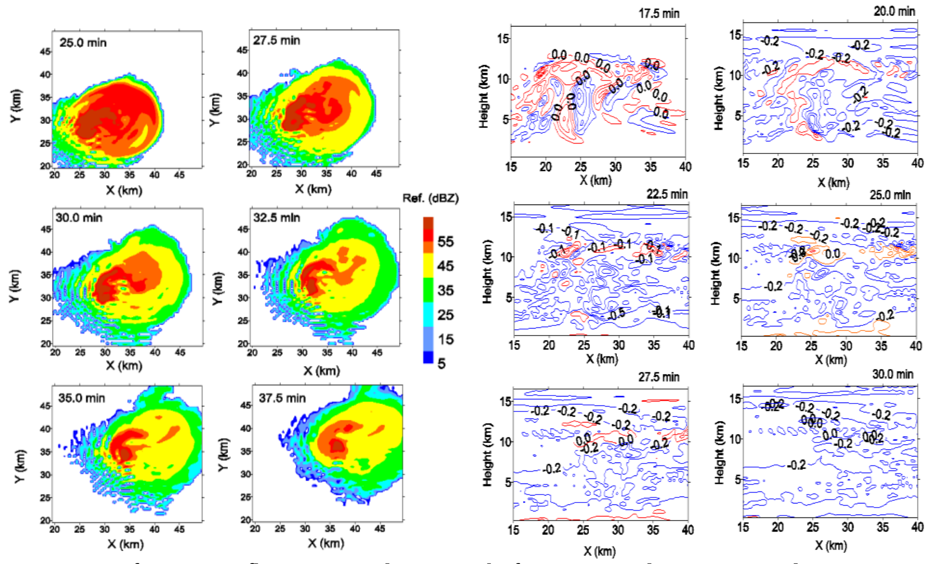


Results

The cloud model simulation showed a detailed development of the supercell. In reflectivity simulations the characteristic hook echo can be observed and the vertical vorticity simulation depicts positive vorticity in the back of the supercell, which, due to the expansion of this area near the ground, indicates the development of a tornado.



Cloudmodel simulation of the supercell



Left Figure: reflectivity simulation; Right figure: vertical vorticity simulation

Conclusion

The numerical cloud model did perform well on this mesoscale phenomena. It was able to reproduce in detail the formation of the supercell and development of the tornado.

References

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.