20^{th} of July 2007 — Explosive Convection over Europe The COSMO Perspective

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1 Introduction

On the 20^{th} of July 2007 an explosive convection weather event has affected a number of European countries: England, Germany, Poland and Ukraine. Severe storms caused extreme floods (Britain and Ukraine) and damaging winds, with a tornado in Poland. For multiscale analysis purpose COSMO-Model simulations with 14 km / 35 levels, 7 km / 50 levels, and 2.8 km / 50 levels (nested) over Europe and Poland have been performed and the 3D history of the giant supercell storm that produced the tornado near Czestochowa has been retrieved. Many synoptic features were correctly reproduced by the model and helped to understand the mechanisms of the case and deduce even such subtle processes like right and left moving wind patterns of tornado convective system. Nevertheless the cloud water convective structures as simulated by the model remains underestimated. One of the fault reasons is that the proper radar assimilation scheme was not adopted, but the second suspicion is that the ageostrophic flow just under the jet stream was not adequately represented. This kind of upper flow caused overriding warm and wet subtropic and even tropic air by the extra cold (arctic) and dry air, thus generating instant upraise of potential instability and explosive convection - the well known mechanism (see Browning, 1985).

2 Understanding the process

On the 12^{th} of July 2007 a deep massive drop of cold arctic air started south of Greenland (see Fig. 1: the temperature field on 300 hPa) to move south-east over north Atlantic towards the British Isles pushing ahead the polar jet branch (see Fig. 2: the air temperature at 20th of July 00 UTC, and the location of the polar jet, Fig.3). These are the key features that control the process on synoptic scale. The polar jet that merges at the moment subtropic jet branch was elongating south-westerly pumping hot and wet tropic air masses towards Europe as seen by temperature field on 850 hPa (Fig. 4). The configuration of isentropic surface 315 K shows the giant hill of cold air related to deep low over south-west Britain as seen via pressure field on 8 km level and embedded jet (Fig. 5). During the next 16 hours the jet was torn out by explosive convection (Fig. 6), still preserving two weakening branches of the main stream: the one towards the British Isles and the second one over Germany and Poland.

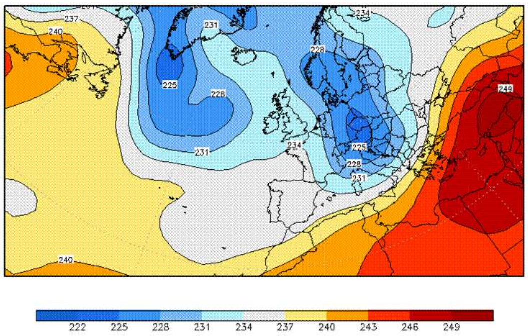


Figure 1: Temperature (K) at 300hPa on 00Z 12 July 2007.

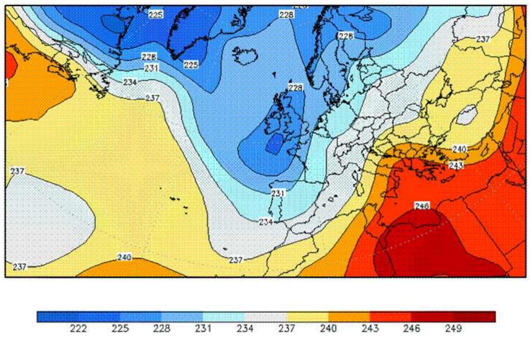


Figure 2: Temperature (K) at 300hPa on 00Z 20 July 2007.

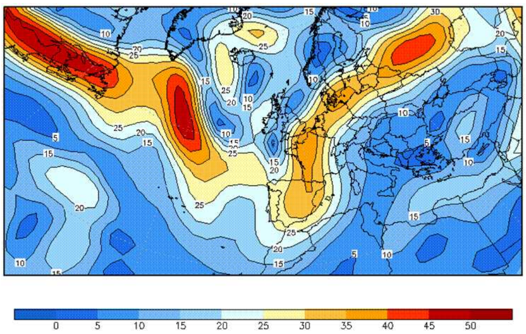


Figure 3: Jet (m/s) at 300hPa on 00Z 20 July 2007.

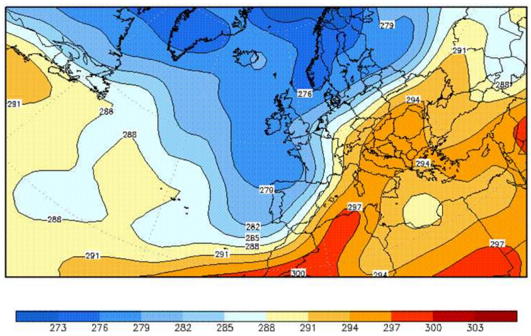


Figure 4: Temperature (K) at 850hPa on 06Z 20 July 2007.

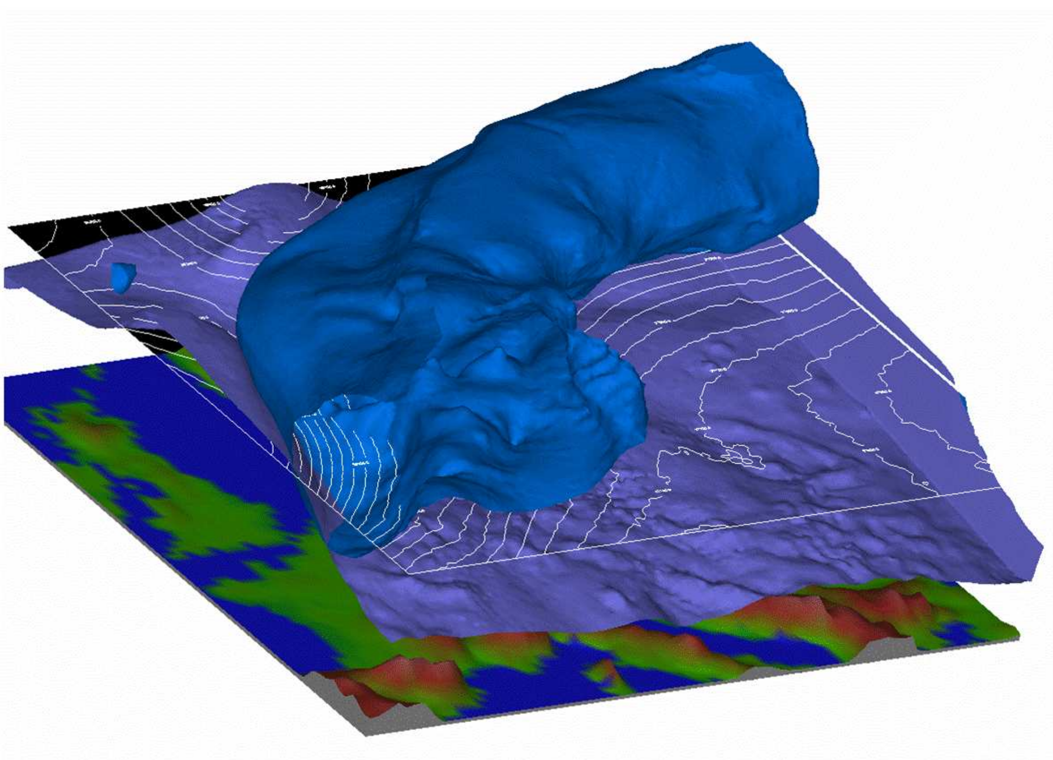


Figure 5: Isentropic surface 315 K and pressure field on 8 km level with embedded jet

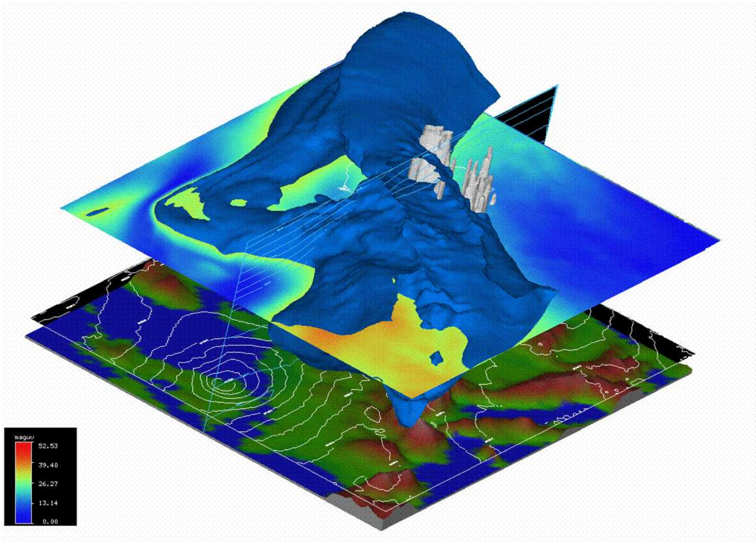


Figure 6: Jet at 30 m/s surface and wind speed on 10.2 km level. Pressure on 1.5 km + radar reflectivity over southern Poland. Vertical cross-section of Potential Temperature – squeezing temperature isopleths represent passage to stratosphere.

3 The model performance – large scale perspective

As the large scale features represented via pressure, horizontal wind and even specific humidity fields were well and satisfactory restored by the model on all resolutions, the cloud water still remains underestimated (see Fig. 7 compared with satellite picture, Fig. 8).

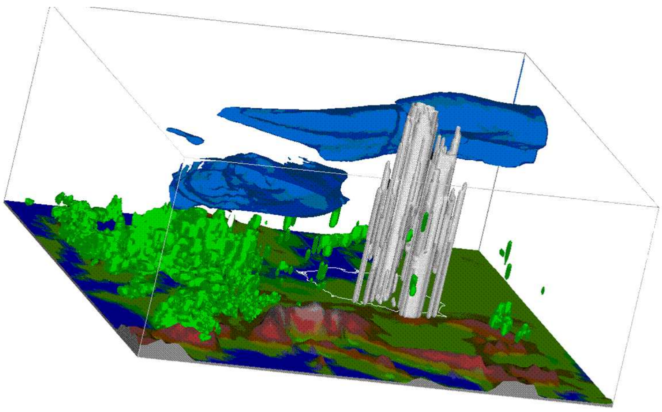


Figure 7: On the 3D picture we have jet-stream (in blue) presented against clouds: a) simulated (for 4h) by model (light green) and b) found by 3 radars (reflectivity in dBZ) over PL (in white). The 2 big white objects are convective complexes, and the one of them near Czestochowa (south-middle Poland) was recognised as a Thunderstorm Supercell – the matter cloud that born tornado beneath. We see the object 30 km wide and 18 km high. Jet-stream and model clouds (cloud water `QC`) are taken from the polish implementation COSMO-PO (Version 4.0, 35 levels / 14 km). However, the modeled cloud water, the radar reflectivity and the respective infrared / thermal satellite band (see Fig. 8) are measured in different units - but all represent clouds and then might be compared, at least visualized, together.

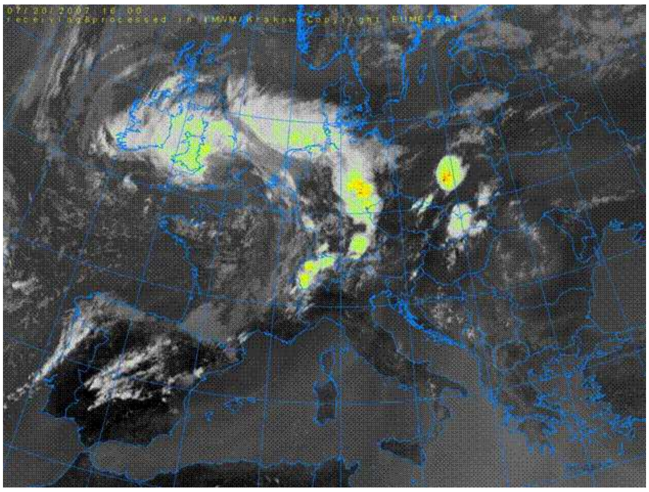


Figure 8: 16Z: Satellite infrared picture. Colored are areas of explosive convection. The picture name is OverShootingTops (OST), also called as *difference image* and represent the difference of brightness temperature of two spectral channels of the satellite Meteosat 9: the channel WV6.2 micrometer (the so called water vapour) and IR10.8 micrometer (infrared). This allows to recognize OverShootingTops (with the difference of brightness temperature > 0) – the most active area of Cb (the strongest updrafts), usually connected with severe thunderstorms with hails. The colors represent: green – still not yet OST (the temperature difference between -3. to 0. C) strong convection reaching tropopause; from yellow to orange to violet - Overshooting tops, cloud tops in stratosphere. The value over +3 (violets) appear very rare. (thanks to Monika Pajek, IMGW – personal communication).

4 The model performance – tornado perspective

The important processes on the tornado forming have been diagnosed as follows:

- upper cold and dry air advection over wet and warm masses,
- lee cyclogenesis in the vicinity of southern Poland mountains,
- the high temperatures growth on the surface,
- the local vorticity transport.

Recognized are five stages of convective situation evolution:

a) decay of previous convective complex; 00-04Z

b) growth and decay of the individual convective cells; 04-10Z

c) creation of convective cluster – the *slow right mover* (the main future supercell body) and the cell *rapid growing left mover* (the future trigger that tornado was generated); 10-14Z

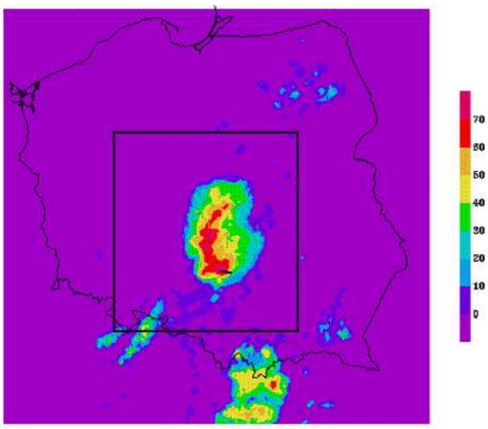
d) The supercell generation by fusion of slow right moving convective complex and the rapidly growing huge Cumulonibus – deduced *left mover*; 14-16Z

e) The mature supercell stage with tornado beneath 16:05 – 16:15Z and huge convective system over Tatry mountains and Slovakia; 16-18Z

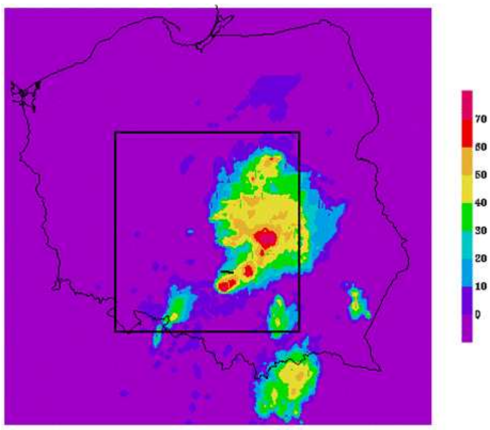
An example of transition from stage d) to e) as seen by different means is enclosed beneath.

4.1 The supercell transition from early to mature stage

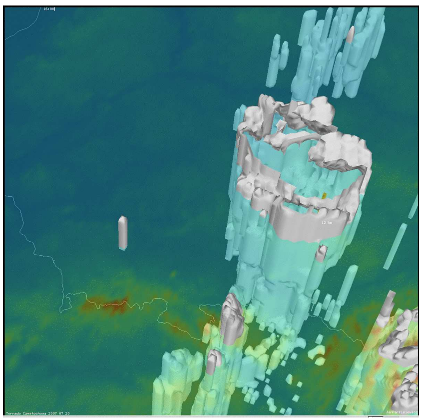
An example of transition from stage d) to e) as seen by different means is enclosed beneath. Here the vertical mean of radar reflectivity (the upper panel) is presented against 3D composite of radar reflectivity and satellite Meteosat 9 picture from HRV high resolution solar channel.



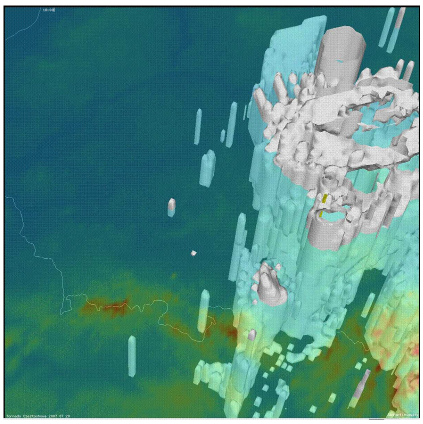
(a) Radar reflectivity on 16Z 20 July 2007.



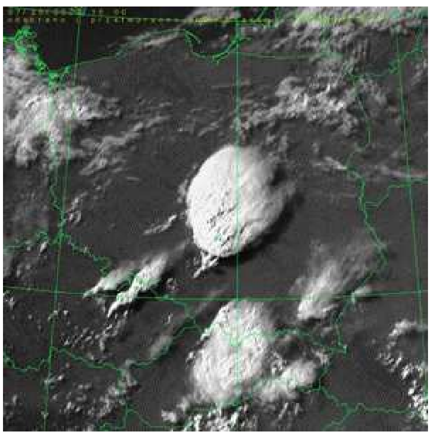
(b) Radar reflectivity on 18Z 20 July 2007.



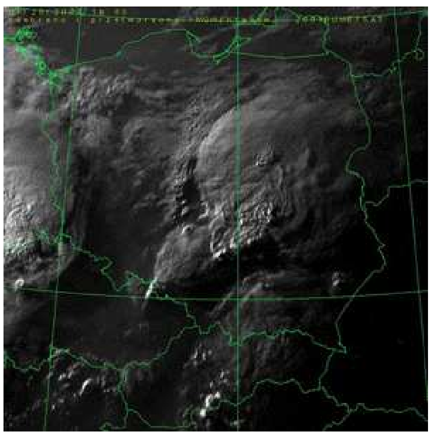
(c)



(d)



(e)



(f)

Figure 9: Supercell transition from early (16 UTC, left column) to mature stage (18 UTC, right column).

4.2 An example of restored tornado related features

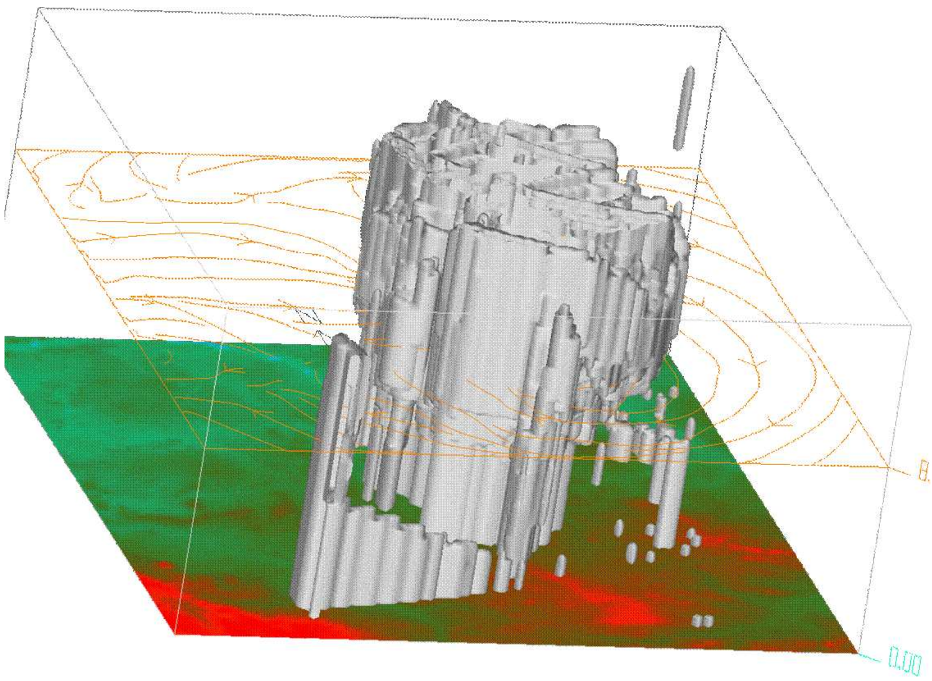


Figure 10: 16Z: Restored 3D supercell structure of the *right mover* type. On the 3D radar reflectivity composite the streamlines of relative motion are super imposed. These relative streamlines depending on the height and must reflect the horizontal vorticity field as taken from the COSMO-PO (Version 4.0 50 levels / 2.8 km). Vertical extent of the domain is 15 km.

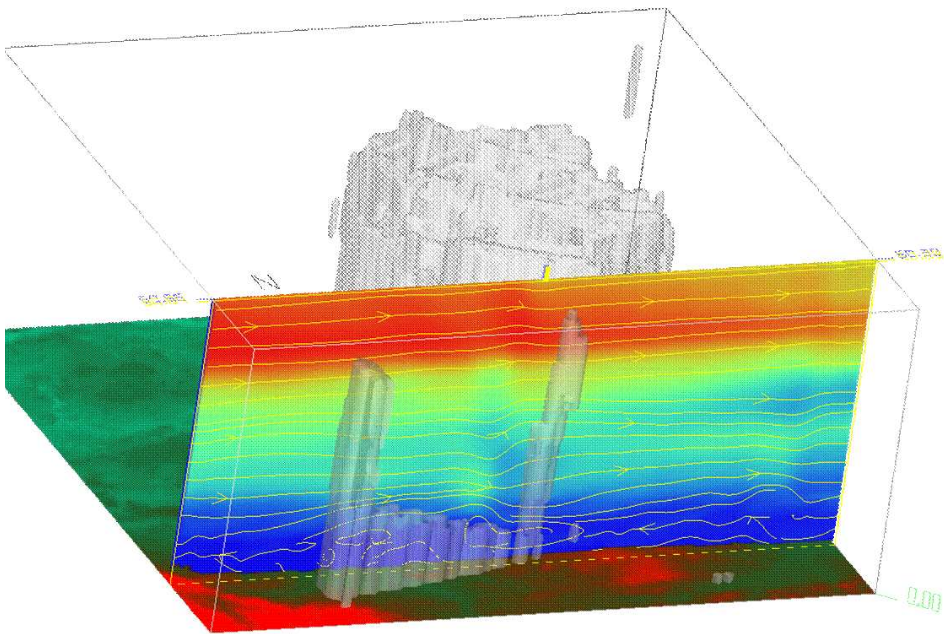


Figure 11: The supercell cross section with streamlines and wind speed as the background. The characteristic typical wind jump and related vortex tube trace as simulated by the COSMO-Model high resolution 2.8 km / 50 levels nested model.

5 Towards a conclusion

Just after K. Browning et al. (2002): *Local severe weather events often occur in association with convection organized on the mesoscale within larger-scale weather systems. Observing, understanding and predicting such events is difficult because of the multiscale nature of such events.* Despite the *difficult nature* of the searched event the COSMO-model shows its capability to cope with the case. All basic features related to pressure, wind, temperature and even specific humidity fields were satisfactory restored. The problem occurred with convective cloud water structures. It is not allowed (e.g. from aviation point of view) to treat big convective objects (like suppercells) stochastically. The overtaking time could be squeezed but reasonable foreseen effect of several hours for suppercells (and possibly 1 hour for tornados) should be performed by the model – at least to keep it as a challenge. The easiest obvious truism would be to quote Browning's conclusion: *Improving the resolution of the model and assimilating more mesoscale observational data will increase its ability to produce very-short-range forecasts of these important features.* Concerning heavy precipitation and explosive convection it was shown that non-orographic effect of upper cold and dry air advection over wet and warm air masses is equally important to be properly represent by the model resolution.

References

Browning, K. A., 1985. Conceptual models of precipitation systems. *The Meteorological Magazine*, **No. 1359, Vol. 114**, pp. 293-319.

Browning, K. A., Panagi, P., Dicks, E.M., 2002. Multi-sensor synthesis of the mesoscale structure of a cold-air comma cloud system. *Meteorol. Appl.*, **9**, pp. 155-175.