High-resolution simulation of an isolated tornadic supercell in Poland on 20 June 2016

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Introduction

In this work, we analyze a severe storm event, which took place on 20 June 2016, when an isolated tornadic supercell passed through southeastern Poland (**Fig. 1**). The storm was responsible for producing multiple large hail (up to 7.5 cm), severe wind gust events, and a tornado near Sulów (Lubelskie Voivodeship). The peak intensity of the tornado was estimated at F1/T3 in the Fujita/TORRO scale. In this paper, we perform numerical simulations using the Weather Research and Forecasting model to analyze the event, and to evaluate the possibilities of its short-term prediction.

Maximum reflectivity between 1000 and 1900 UTC (10-minute steps)

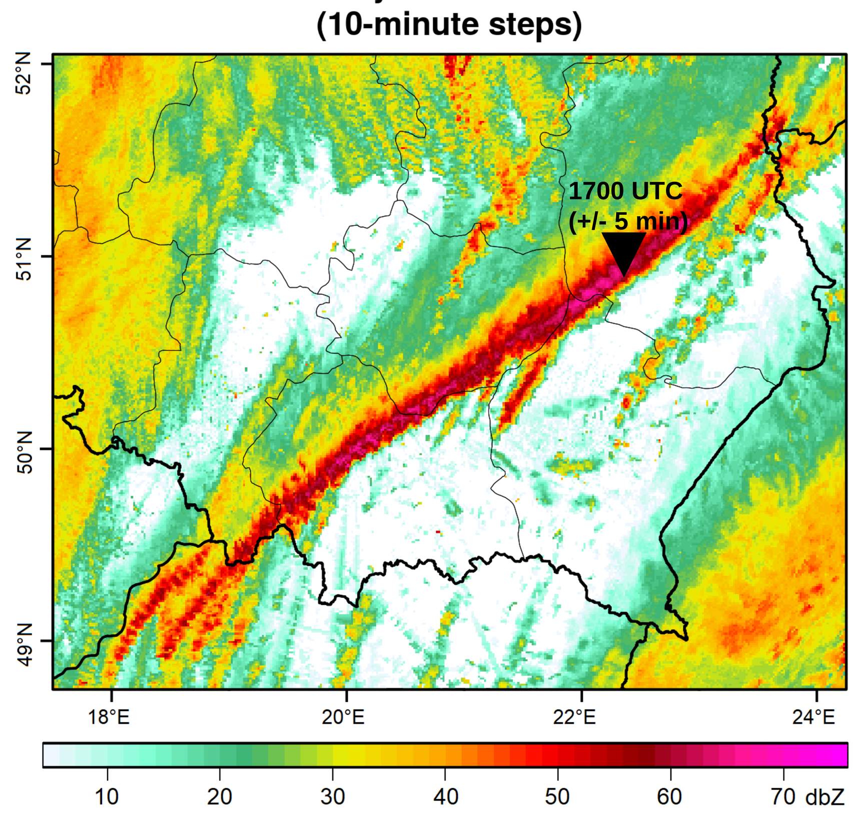


Fig. 1. Maximum reflectivity radar product mosaic from the Polish weather radar data from 0900 to 1900 UTC (source: IMGW), and location of tornado report (black triangle). →

WRF model simulations

WRF 3.9 is used to prepare two downscaling simulations. Three one-way nested domains are defined over parts of Central and Eastern Europe (**Fig. 2**). The physical model's settings are included in **Tab. 1**. One simulation is performed with the basic configuration and is further referred to as the "**WRF_baserun**". The second one additionally includes assimilation of surface and upper air reports from 0000 UTC (WRF model initialization time) and is defined as the "**WRF_assimilation**". For data assimilation, the initial conditions were prepared using the Community Gridpoint Statistical Interpolation System (GSI; Shao et al., 2016). Cross-sections and three-dimensional visualization techniques are also applied, with the use of VAPOR software. Results of simulations are analyzed with the main focus on the tornado event (1700 UTC).

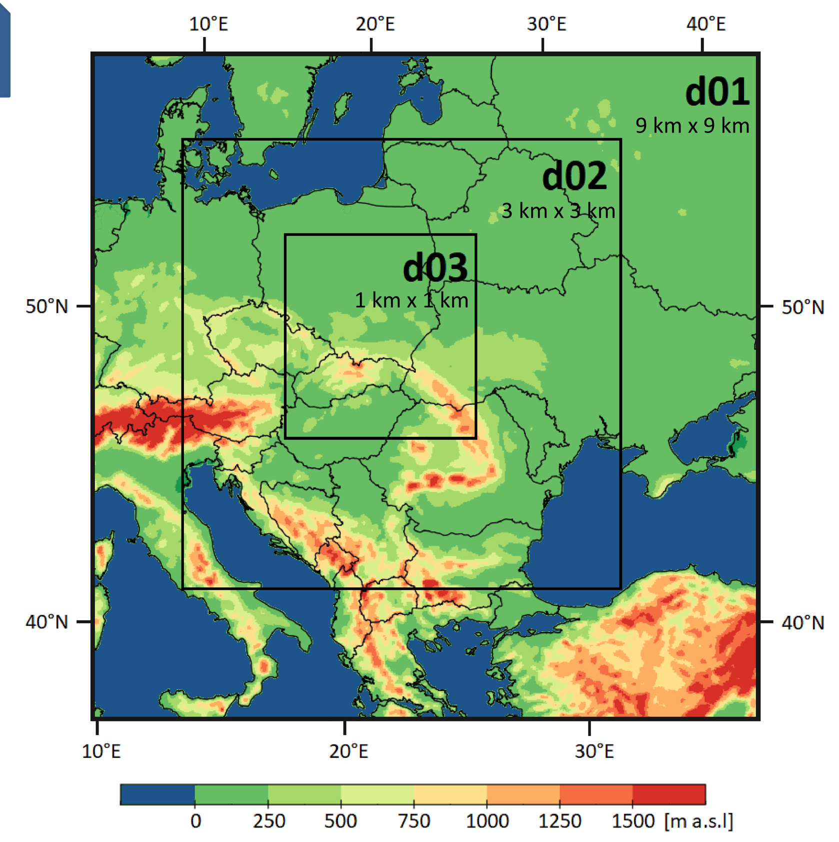


Fig. 2. Three one-way nested domains (d01, d02, d03) over Europe used in model configuration.

Tab. 1. Model configuration details used in simulations.

Model parameters		Parameterizations	
Lateral/boundary conditions	GFS 0.25 deg	**Planetary boundary layer**	YSU (Hong et al., 2006)
Horizontal grid resolution	9, 3, 1 km	**Microphysics**	New Thompson (Thompson et al., 2008)
Time step	45, 15, 5 s	**Shortwave radiaion**	Dudhia (Dudhia, 1989)
Verical Levels	45 (up to 50 hPa)	**Longwave radiation**	RRTM (Mlawer et al. 1997)
Simulation lenght	24 h start at 00 UTC	**Cumulus parameterization**	Kain-Fritsch (Zheng et al. 2015), only for d01 and d02

Simulated reflectivity

The modeled maximum reflectivity is compared with the radar data derived from the POLRAD network (**Fig. 3**). At around 1300 UTC an isolated convective cell passed over the Polish-Slovakian border as evidenced in the observational data and confirmed by the **WRF_assimilation**. Simulated reflectivity fields were also analyzed using 3d visualizations (**Fig. 4**). The cross-sections for the cells in both simulations present a well developed classical supercell structure (Doswell III and Burgess, 1993). In the case of the **WRF_baserun**, two dominant supercells were simulated (marked as „1" and „2"). The analyzed supercell marked as "3" (**WRF_assimilation**) was characterized by the highest reflectivity, but was displaced by approximately 1 h later relative to the radar data.

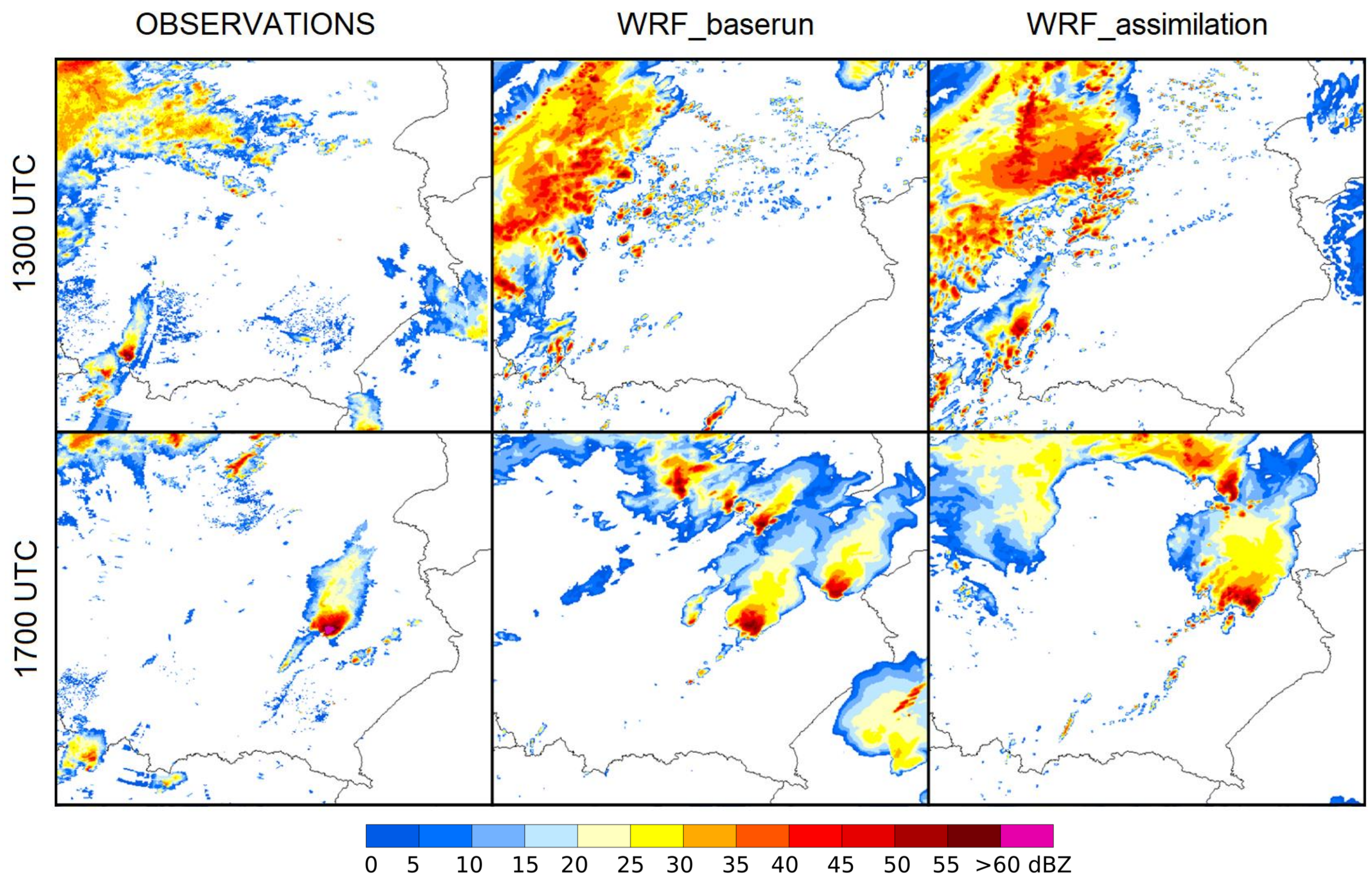


Fig. 3. Observed (OBSERVATIONS) and simulated (WRF_baserun, WRF_assimilation) maximum reflectivity for 13 UTC and 17 UTC over southeast Poland.

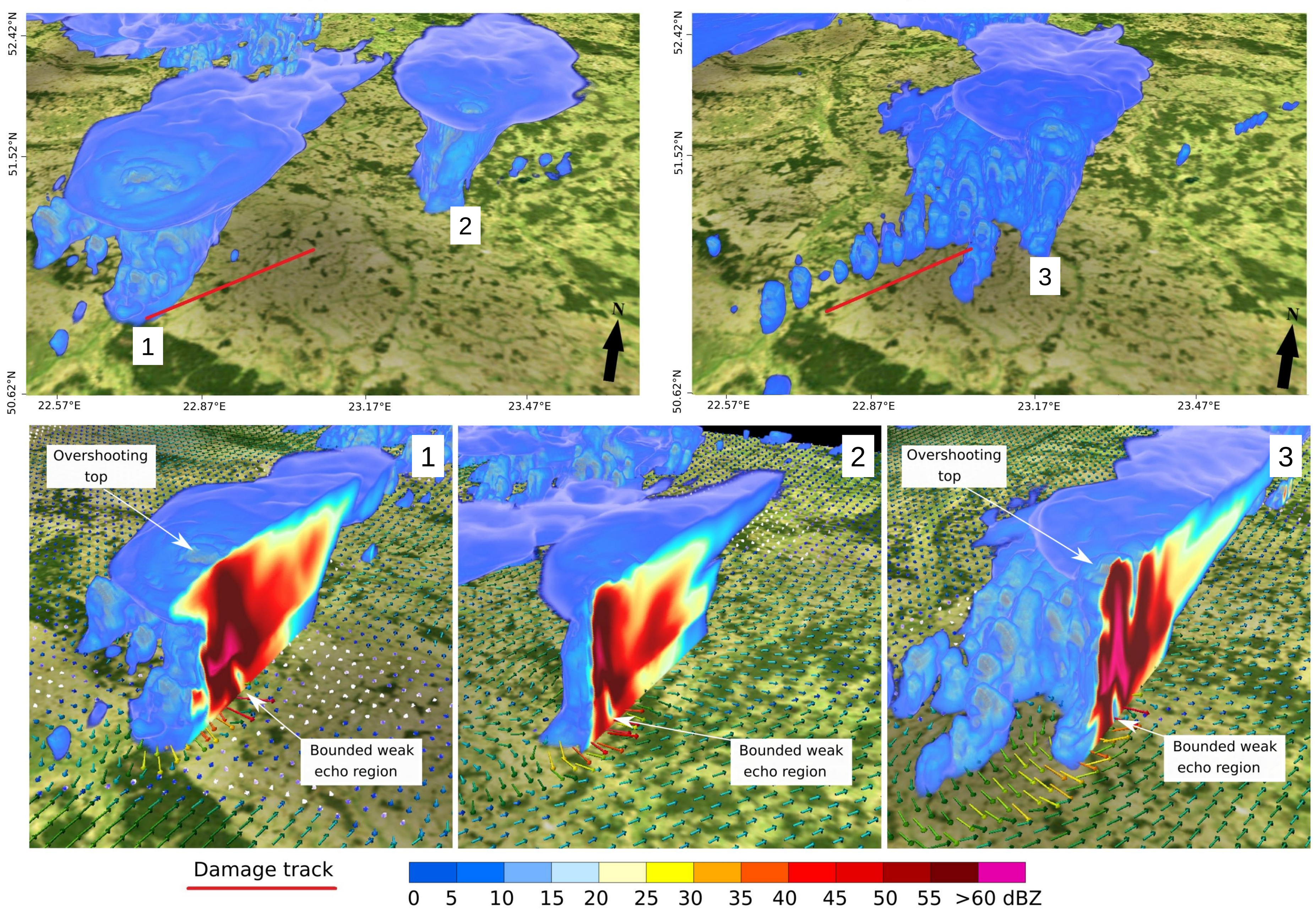
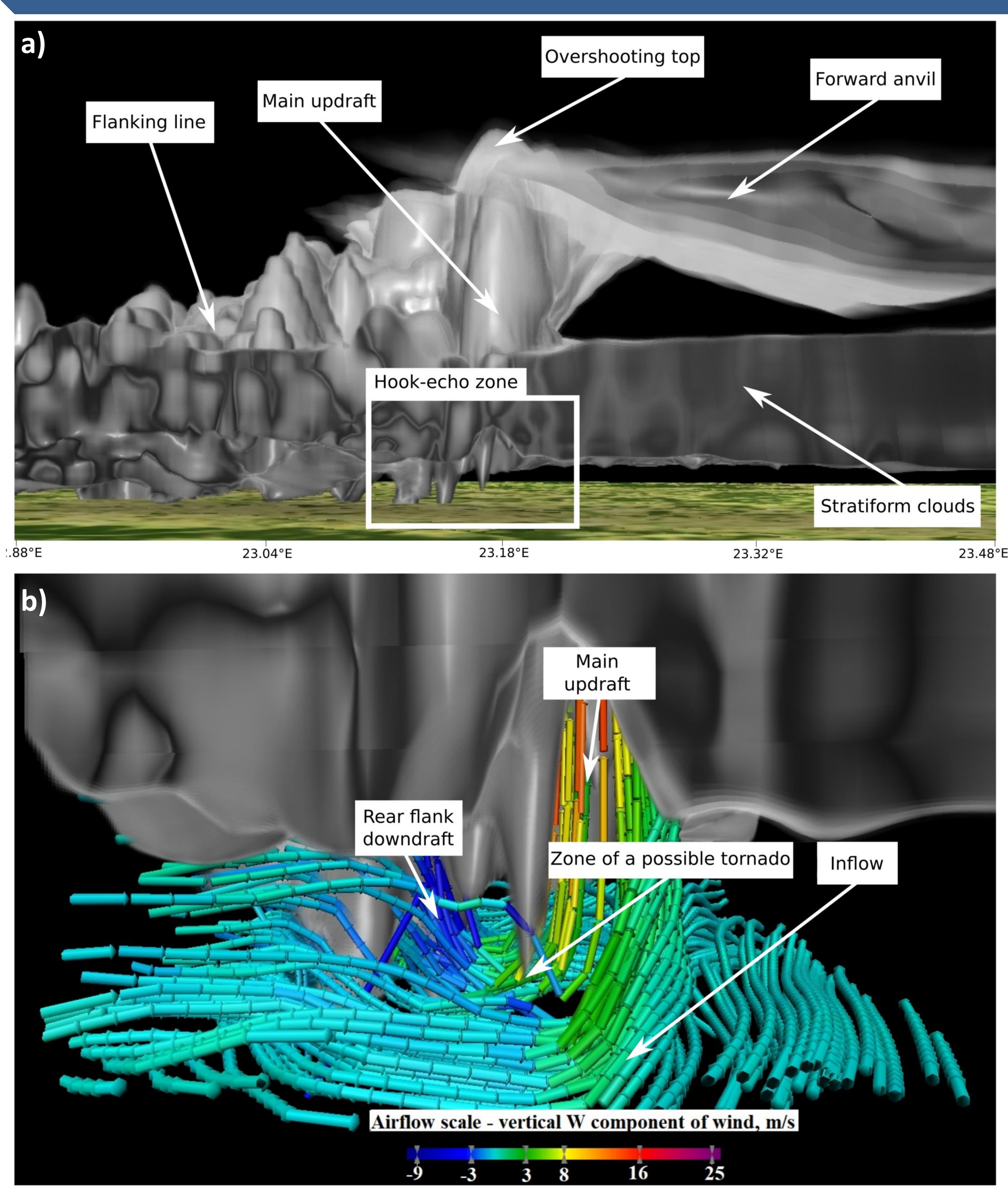


Fig. 4. Vertical cross-section of the 3D-computed reflectivity of simulated supercells from WRF_baserun and WRF_assimilation at 1700 UTC over southeastern Poland. The dimensions' scale ratio (X:Y:Z) is 1:1:3. Vectors represent 10m AGL winds.

High-resolution visualization of the supercell



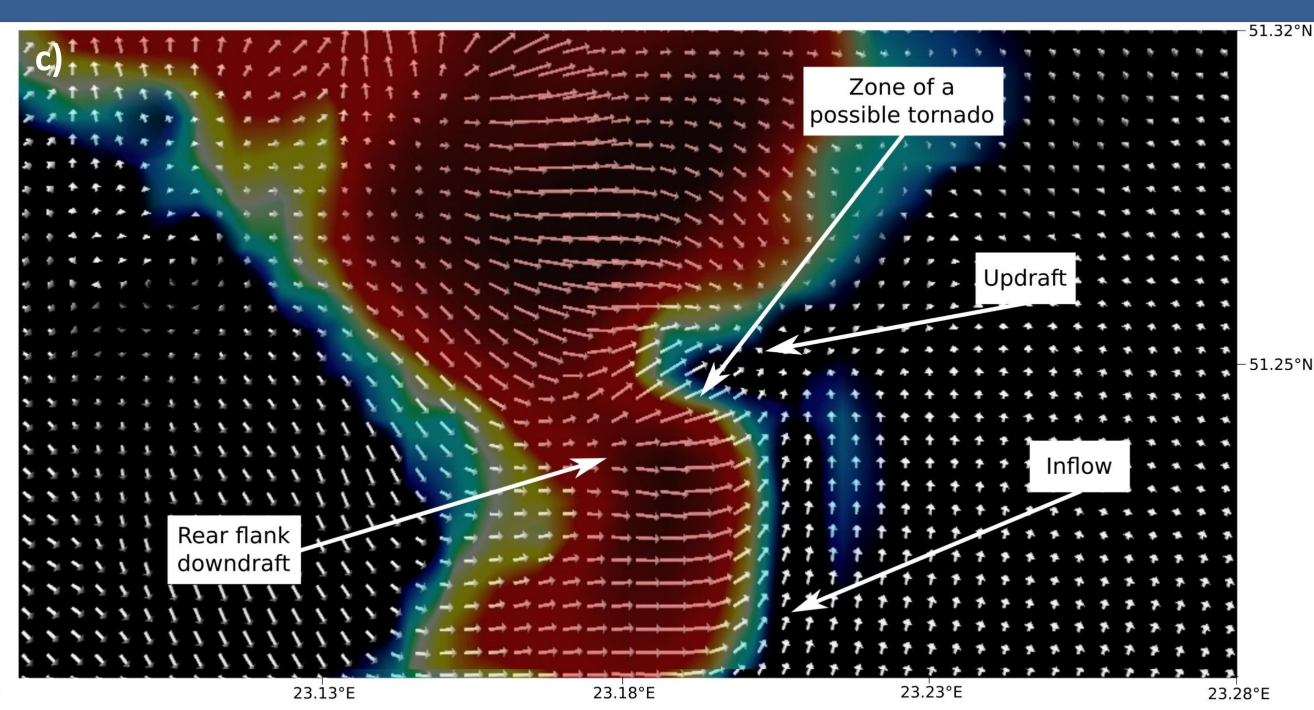


Fig. 5. 3D-computed water vapor mixing ratio of supercell simulated in WRF_assimilation for 1700 UTC facing north: a) side view, b) zoomed side view including 0–200m AGL airflow with vertical W component (colored), and c) horizontal projection of 1 km AGL simulated reflectivity and 10m AGL wind vectors.

In **Fig. 5**, the supercell from simulation WRF_assimilation is presented in a water vapor mixing ratio parameter (**a**). The zoomed area of a "hook-echo" zone shows a southwesterly surface inflow entering the narrow, strong updraft and descending air within the rear flank downdraft on its western side (**b**). A top view of the 1 km AGL reflectivity and 10m AGL wind vectors displays a bounded weak echo region indicating updraft location, westerly winds from rear-flank downdraft, and the inflow area (**c**). In agreement with the conceptual models (Doswell III and Burgess, 1993; Markowski and Richardson, 2009), a possible tornado location can be depicted between the updraft zone and rear-flank downdraft, as indicated in **Fig. 5b**.

Conclusions

Prepared high-resolution downscaling simulations within GFS 0.25 deg. initial conditions, provide evidence that NWP models can successfully predict supercells and indicate their lifecycle with a high accuracy. From two model runs we proved that assimilation of observational data such as surface synoptic reports and atmospheric soundings, may increase the quality of the simulation.

High-resolution visualizations showed that numerical simulation with assimilated observational data had successfully sampled the wind field environment conducive to tornadic formation. In general, as shown in previous studies, our findings confirm that assimilation methods are crucial to capturing extreme convective events in a proper manner.

It is very important to highlight that given the resolution of the grid (1 km), model is incapable of resolving the tornadic process and thus, simulating a tornado itself. Our analysis indicates that a simulated storm had a favorable wind field and was capable of producing a tornado.

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