A review of microphysics schemes within WRF model on the example of an isolated tornadic supercell in Poland on 20 June 2016

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Introduction

In the morning of 20 June 2016 an isolated convective cell developed in the northern Slovakia, and under the influence of a strong vertical wind shear reorganized into tornadic supercell. During all track of this structure, increasing lighting activity were observed (Fig. 1.), with the greatest intensity of lightings, hail, rain and wind at the end of structure existing (16-18 UTC). For almost 9 hours, this supercell overcome a route 450 km. In total, 55 reports were noticed in ESWD (European Severe Weather Database) in Poland on 20 June 2016. This thunderstorm produced a hail with maximum diameter up to 7 cm and in the late afternoon a tornado (F1, T3) in the south-eastern Poland (Sulów, Blinów Drugi, Rudnik Drugi, Wola Gałęzowska). On radar scans high reflectivity in the supercell core was observed (with maximum value 65 dbZ) (Fig. 2., Fig. 3).

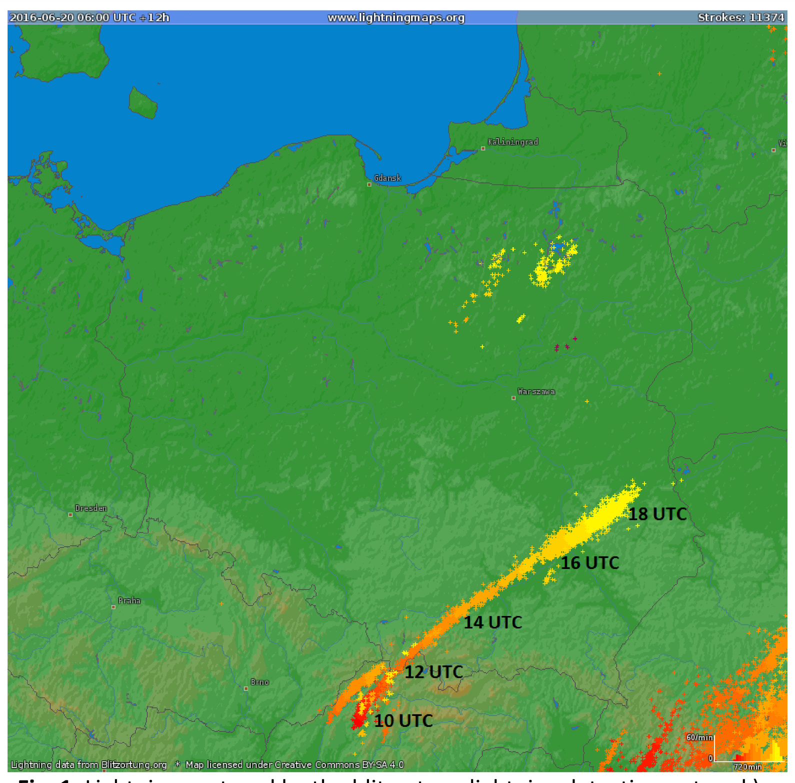

Fig. 1. Lightning captured by the blitzortung lightning detection network) on 20 June 2016 between 06 and 24 UTC.

High thermodynamic instability of troposphere in Sandomierz (south-eastern Poland) at 14 UTC was observed (according to generated atmospheric soundings (Szuster, 2017)). It was evidenced by high values of MUCAPE (2354 J/kg), SRH 0-1 (115 m2/s2), and DLS (36 m/s).
Numerical models are often use to recreate damaging storm events for their analyzing. Much attenton is devoted to importance of microphysics parameterizations. In WRF model, many options of microphysics are available (18) – they take into account different number of variables, sometimes include ice-phase processes or mixed phase processes. Changing of microphysics scheme in model configuration can strongly effect on modeling results, what was investigated by many authors (Rejeevan et al. 2010, Morrison & Milbrandt 2011, Han et al. 2013). Only few cases of storms in Poland were analyzed with using numerical models (Taszarek et al. 2016).

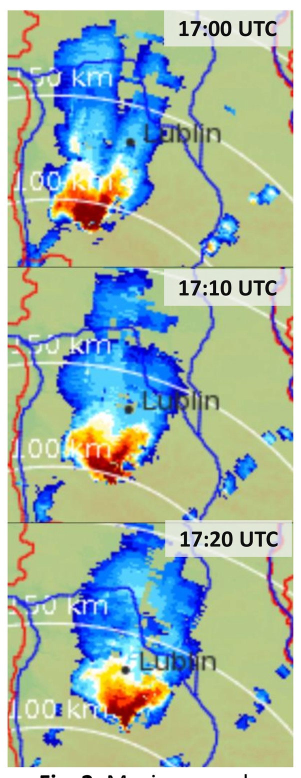

Fig. 2. Maximum radar reflectivity. Source: IMGW.

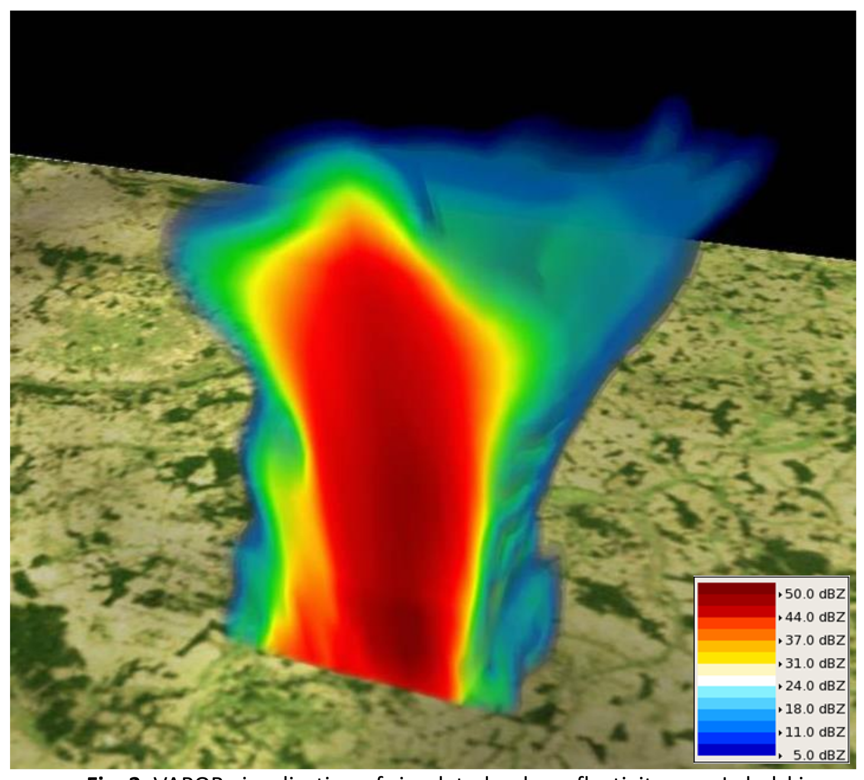
Fig. 3. VAPOR visualization of simulated radar reflectivity over Lubelskie voivodeship at 16:50 UTC.

Data and methods

In this work, WRF model has been used to simulate meteorological conditions, sounding-derived parameters and radar reflectivity over the south-eastern Poland (Fig. 4). In total model was run 4 times with stable configuration, but with using different microphysics schemes. Configuration details were presented in Tab. 1.
Data from 24 meteorological stations located in model domain in Poland area were obtained from SYNOP repots. Radar reflectivity scans were provided by Institute of Meteorology and Water Management in Poland (IMGW). To compare model results, data from atmospheric soundings were also used. This element was generated by a dedicated software (Szuster, 2017). For each surface station sounding from the nearest upper air station was chosen for interpolation (e.g. Fig. 5.).
The main aim of this study is to show how selected microphysics schemes influence on simulation results.

Model characteristic	Setting
Model core	WRF 3.7
Grid resolution	1 km
Simulation lenght	12 h, starting at 06 UTC
Time step	10 s
Initial and lateral conditions	0.25° GFS
Cumulus parameterization scheme	Off
Planetary Boundary Layer scheme	YSU (Yonsei University scheme) (Skamarock et al. 2005).
Long and short wave radiation schemes	RRTM (Rapid Radiative Transfer Model) (Mlaver et al. 1997).
Microphysics schemes	**Kessler** (Kessler, 1969) – 3-class schemes with idealized microphysics, no ice processes (mp_physics=1).
	Lin (Chen and Sun, 2002) – 5-class microphysics include graupel; includes ice sedimentation and time-split fall terms (mp_physics=2).
	New Thompson (Ramussen and Thompson, 2005) – 6-class microphysics with graupel; ice and rain number concentrations also predicted (mp_physics=8).
	NSSL – 7-class scheme which constitute a single-moment version of the NSSL 2-moment scheme (mp_physics=19).

Tab. 1. Selected details of simulations and important physical settings.

Fig. 4. Model domain.

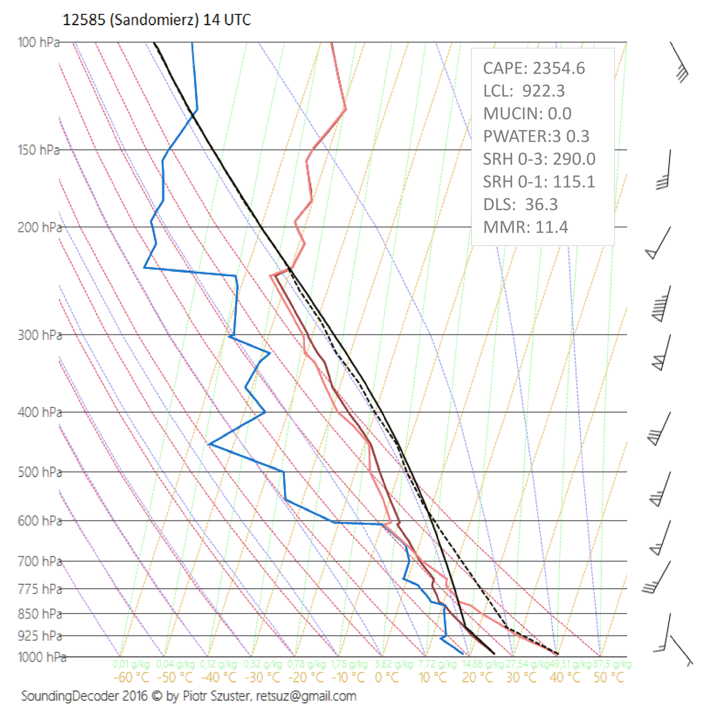

Fig. 5. Example of generated atmospheric sounding.

WRF vs SYNOP

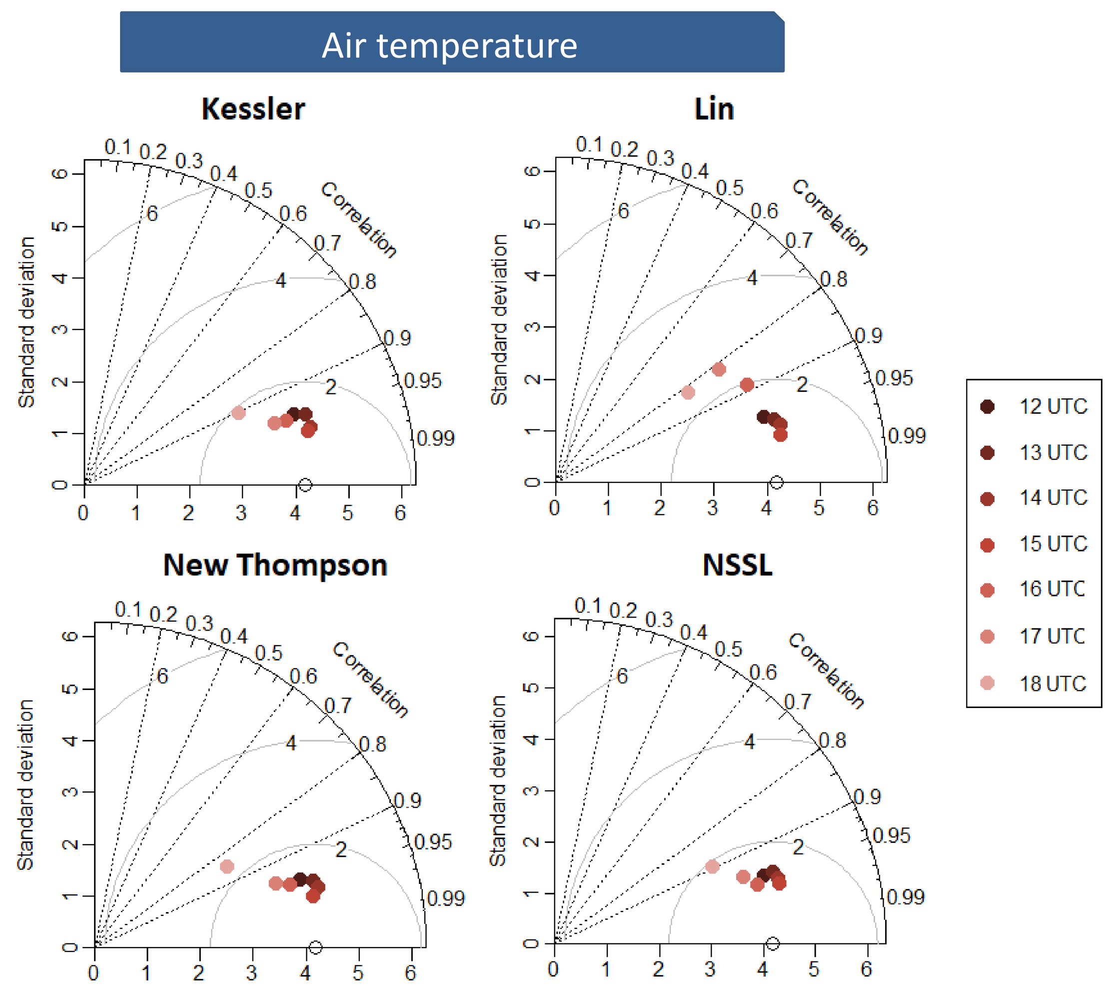

Fig. 6. Taylor diagram for air temperature. Solid grey lines indicate RMSE [°C] values. Presented results show the average from all analyzed stations.

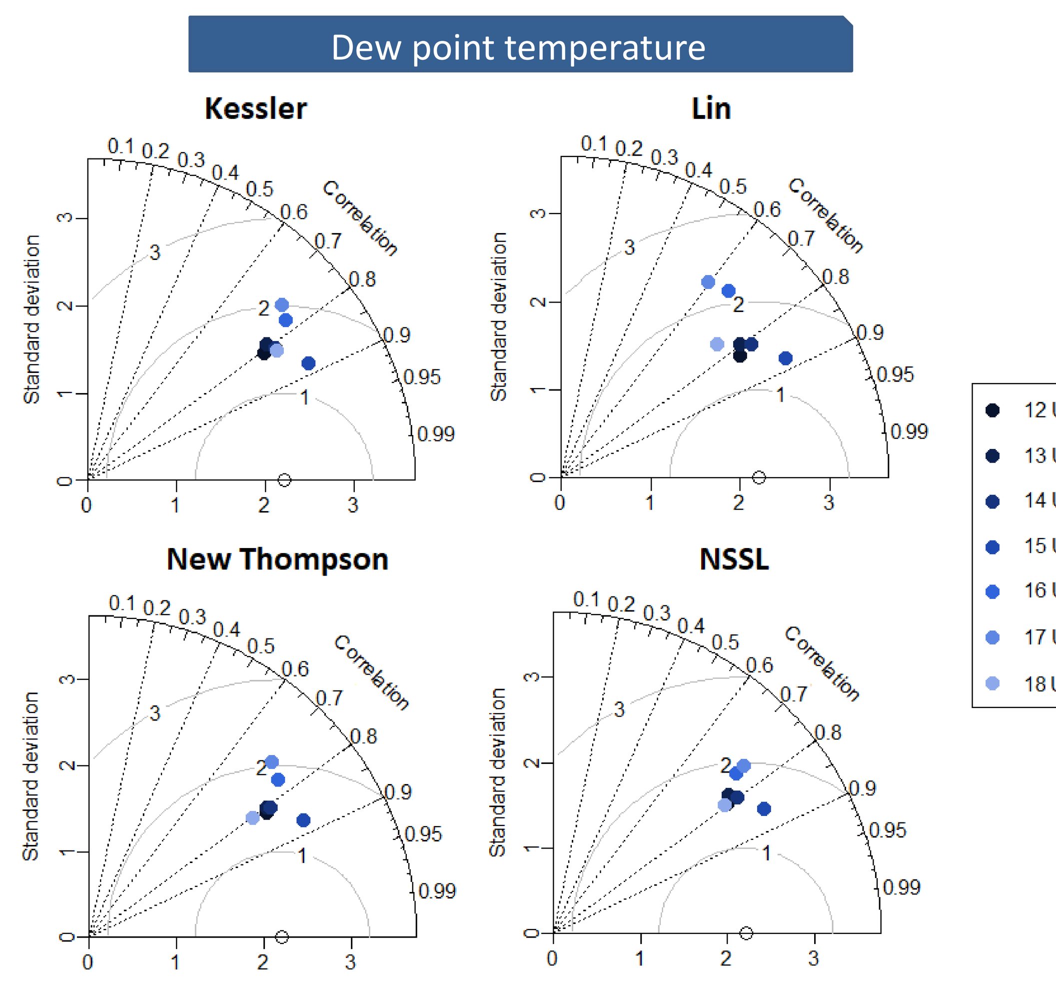

Fig. 7. Taylor diagram for dew point temperature. Solid grey lines indicate RMSE [°C] values. Presented results show the average from all analyzed stations.

WRF vs generated atmospheric soundings

	MUCAPE [J/kg]	DLS [m/s]	Mixing ratio [g/kg]
Kessler	-202.70	-7.75	0.89
Lin	-252.84	-8.02	0.77
New Thompson	-228.45	-7.70	0.85
NSSL	-259.76	-7.69	0.75

Tab. 2. Values of mean error (ME) for selected sounding-derived parameters. Presented results show the average from all analyzed stations.

	12 UTC	13 UTC	14 UTC	15 UTC	16 UTC	17 UTC	18 UTC
MUCAPE [J/kg]	-345.06	-290.03	-328.87	-150.03	-141.20	-69.77	-91.70
DLS [m/s]	-8.63	-7.87	-7.40	-6.97	-8.01	-7.24	-7.75
Mixing ratio [g/kg]	0.60	0.74	0.79	1.083	0.66	0.70	0.82

Tab. 3. Mean error (ME) values of sounding-derived parameters, according to next forecast hours (from 12 UTC to 18 UTC). Presented results show the average from all analyzed stations and testing schemes.

WRF vs observed radar reflectivity

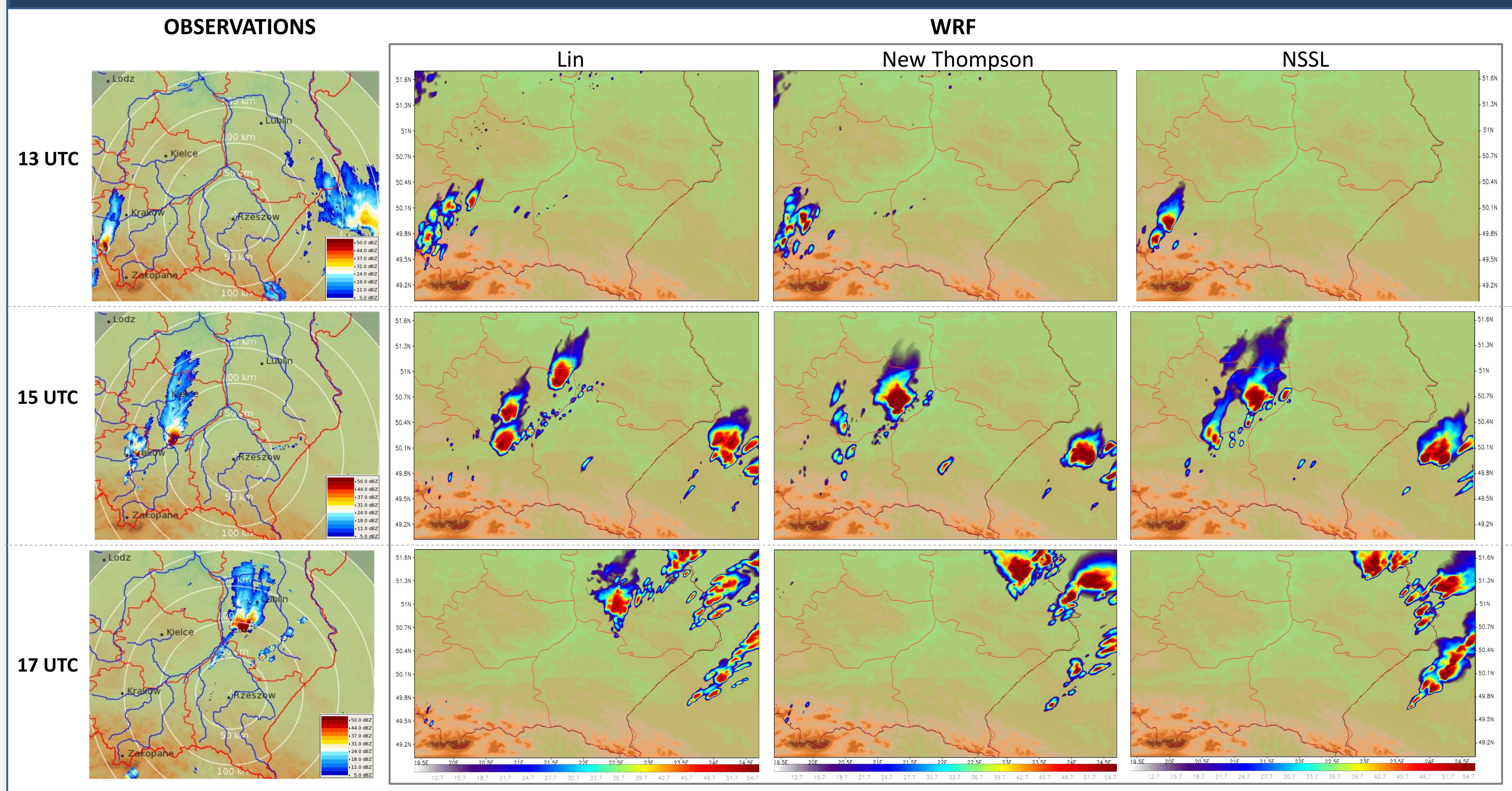

Fig. 8. Observational and simulated radar reflectivity at 13 UTC, 15 UTC and 17 UTC.

Conclusions

Changing of microphysics scheme does not significantly affect on the simulated values of **meteorological elements** of **sounding-derived parameters**.

- Dew point and air temperature:

Further from the start of the simulation, correlations are weaker and values of RMSE unfavorable (Fig 6., Fig. 7). Correlations were higher for air temperature, than for dew point, but worse results of RMSE were obtained for dew point temperature.

- Sounding-derived parameters:

Mean error (ME) values were the smallest for two indices (DLS and mixing ratio) in the case of using NSSL scheme (Tab. 2.). Generally, high values of error occured for DLS (ME equals 7.7-8.0 m/s, when maximum value at this day amounted 40 m/s). In hourly resolution (Tab. 3.) the smallest values of ME occured at 16-17 UTC.

- In **radar reflecivity** analysis (Fig. 8.) singificant differences occured among testing microphysics schemes.

13 UTC: only with **NSSL** scheme, WRF predict organized structure.
15 UTC: **New Thompson** and **NSSL** schemes indicate the occurence of one dominant supercell.
17 UTC: **Lin** scheme predict supercell in right position.

- To indicate the most favorable microphysic scheme for supercells predicting it is necessary to carry out similar studies for other supercell events .