Forecasts of Convective Phenomena Using EPS-based Computation of Universal Tornadic Index

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Abstract

The results from research on COSMO-EPS, carried out at IMWM, are presented. The operational EPS set-up is based on perturbations of soil surface-area index of the evaporating fraction of grid points over land. Usage a Universal Tornadic Index associated with the EPS forecasts system may be helpful in forecasting of severe convection phenomena. This idea was tested in case studies and in long-term evaluation.

1 Introduction

A simple and efficient method was proposed to produce reasonable number of valid ensemble members, taking into consideration predefined soil-related model parameters. Introduced method of obtaining ICs/BCs – time-lagged setup – is another important factor that can add a significant increment to ensemble spread. These features were used to prepare a well-defined ensemble based on the perturbation of soil-related parameters, to be utilized both in operational (forecasting) work and in diagnostic mode. A special approach – using EPS-based forecasts for tornado forecasting – of diagnostic approach is presented here. Small perturbations of selected soil parameter were sufficient to induce significant changes in the forecast of the state of atmosphere and to provide qualitative selection of a valid member of an ensemble (Duniec and Mazur, 2014). Changes of c_soil[*]) had a significant impact on values of air temperature, dew point temperature and relative humidity at 2m agl., wind speed/direction at 10m agl., and surface specific humidity (ibidem). The usage of an idea of time-lagged initial and boundary conditions allowed obtaining a valid ensemble and using it efficiently in an operational mode. Further work is intended to focus on "tuning" ensemble performance and to provide quantitative quality scores. For this purpose the random number generator combined with perturbations of initial soil surface temperature and the dependence of amplitude of perturbation on soil type will be implemented in the COSMO model.While the set of equally weighted time-lagged forecasts improve short-range forecasts, the further progress may also be sought by adopting a regression approach to compute set of weights for different time-lagged ensemble members. EPS runs operationally at IMWM since January, 2016. It covers 4 runs/day, with 48 hours forecasts, 20 members/4 groups (using Time-lagged ICs/BCs; see Duniec G. et al. (2016); conf. Fig.1 below). Amplitude of perturbation of c_soil depends on type of soil (clay, sand, peat etc).

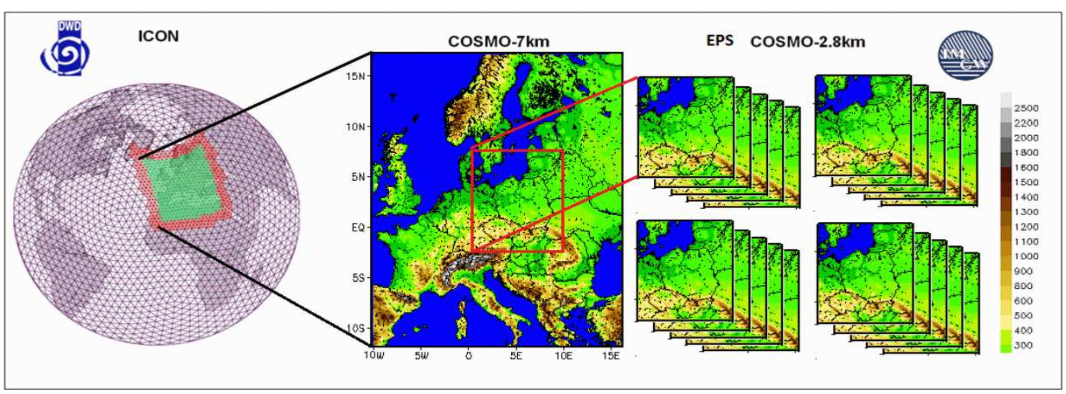

Figure 1: EPS operational configuration *(Duniec et al., 2016)*

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Table 1: Deterministic model(s) – source of ICs/BCs for operational EPS

Model	Grid size NxMxL	Forecast length(h)	Resolution(km)
ICON (DWD)	2949120 triangles	78	13
COSMO v. 5.01	415x460x40	78	7
COSMO v. 5.01*)	380x405x50	48	2.8

**)time lagged ICs/BCs*

2 Details of the deterministic models

Details of the deterministic models configuration are as follows:

Forecasts of air temperature and dew point temperature at 2m agl., surface pressure and windspeed at 10m agl., as well as other fields are available. As a result, plots/chart of EPS mean, spread, probabilities of threshold exceedance are prepared in the routine manner. Results are subsequently stored for further research (e.g. skill-spread relation). In this work a new index to predict severe convection phenomena (especially tornadoes, but also heavy thunderstorms, intensive precipitation episodes etc.) was assessed. This index (called Universal Tornadic Index, UTI) is in general based on a number of predictors related with a strong convection conditions, as follows:

$$UTI = \frac{\frac{CAPE \cdot SRH_{1km}}{200} \cdot \frac{5 \cdot (DLS-20)+(\frac{200-LCL}{10})}{100} + CAPE_{3km} + \frac{SRH_{1km}}{4}}{1000} \cdot \frac{LLS}{12} \cdot \frac{AMR_{500}}{100}$$

whit:

- CAPE being surface based Convective Available Potential Energy,
- CAPE_3km-surface based CAPE released below 3 km agl,
- LCL -Surface based lifting condensation level height,
- AMR_500-average mixing ratio below 500 m,both agl,
- LLS -0-1 km wind shear,
- DLS - 0-6 km wind shear (magnitude of vector difference),
- SRH_1km - 0-1 km storm relative helicity.

Other constrains applied are:

- if SRH_1km<0,then SRH_1km =0;
- if LCL>1500m or CAPE=0 or(convective precipitation amount <2mm/h),then UTI=0

Detailed description of the index and its climatology can be found in Taszarek and Kolendowicz (2013) or Taszarek et al., (2016).

3 Results

Single case, July 14th, 2012 (intensity peak 16:00 UTC). The event – a tornado that passed over the Bory Tucholskie primeval forest – was actually a combination of four tornadoes, with damage track at a distance of 60km, the total length of around 100km. Damaged was 105 buildings, tornado maximum intensity – F3 (Fujita scale), 1 death, 10 injuries, felled 5 km2 of Bory Tucholskie.

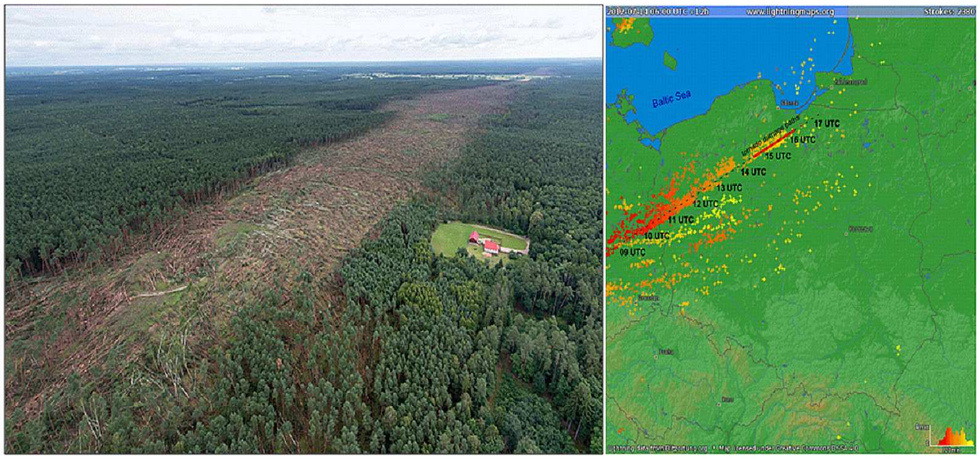

Figure 2: Left – damage track in Bory Tucholskie forest due to tornado of 14 July 2012. Photography: Kacper Kowalski. Right: Lightning captured by the lightning detection network(**www.blitzortung.org**), 0600 to 1800 UTC. Dashed line – radar-based time and position of the thunderstorm. Red line indicate tornado damage paths

Figure 3: UTI forecast, July 14th, 2012, 14:00 to 17:00 UTC. Left: 2.8km deterministic run, right: 2.8km EPS-mean

Long term evaluation – UTI EPS-based thunderstorm forecasts.

Since UTI uses many factors/indicators as predictors (especially CAPE, storm relative helicity, convective precipitation, wind shear etc.) – it can be functional in forecasting not only tornadoes, but other convection phenomena of severe intensity, like thunderstorms (observed with the Polish lightning detection network PERUN). This part was performed with the archive data, starting from 2012. The results are shown in the following figures. Left panel present mean flashrate, right – mean value of UTI for the period of interest.

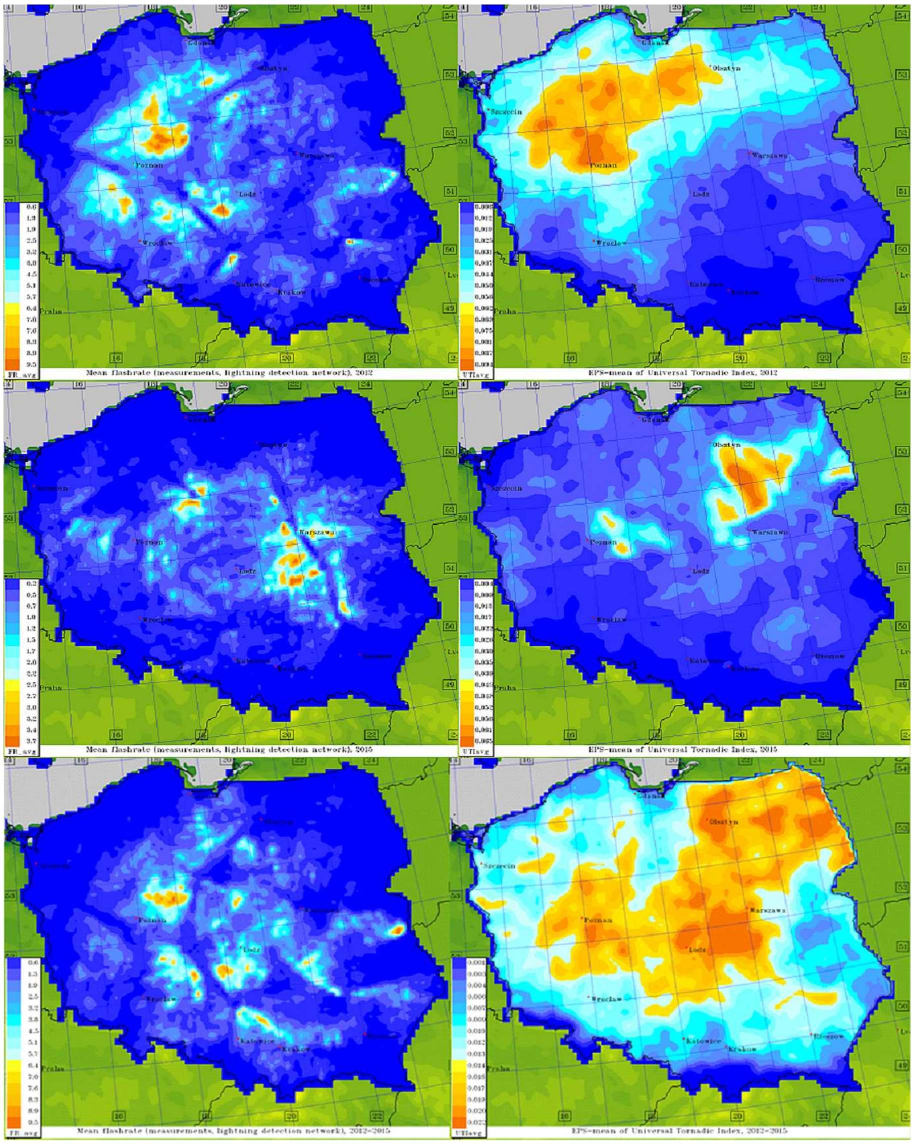

Figure 4: Left – mean flashrate (measurements), average values. Right – EPS-UTI forecasts, average values. Upper charts – year 2012, middle charts – year 2015, lower charts – period 2012-2015.

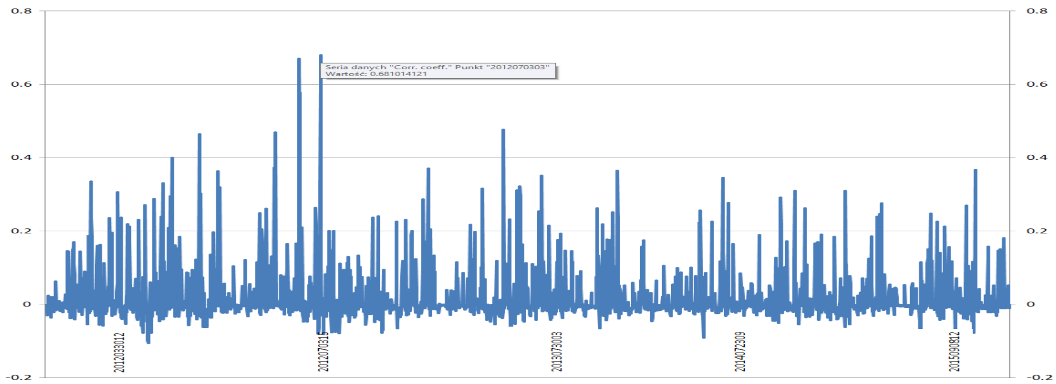

Figure 5: Correlation coefficient UTI vs. FR, consecutive values 2012-2015 (overall avg. 0.1). Best correction attained for July 3rd, 2012, 03:00 UTC (heavy storm over central and northern Poland).

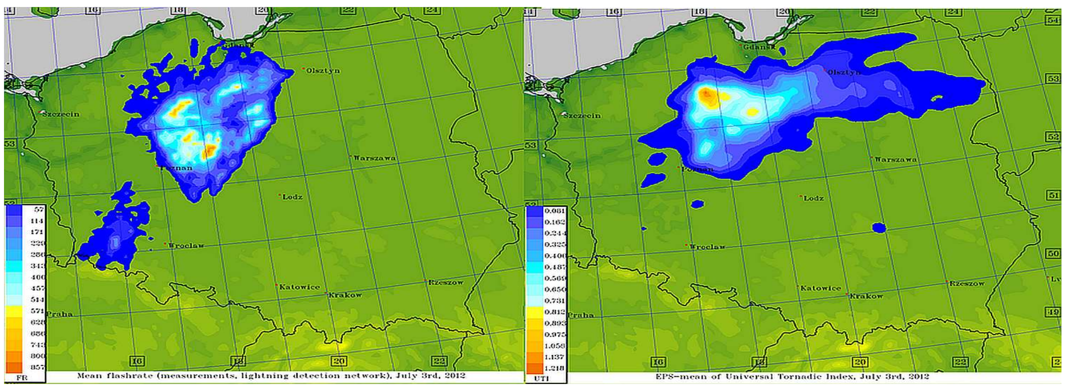

Figure 6: Left – mean flashrate (measurements). Right – EPS-UTI forecasts. July 3rd, 2012, 03:00 UTC

4 Conclusions

A relatively simple method of forecasting extreme convective phenomena has been proposed. This method uses Universal Tornadic Index as an indicator of the occurrence of a convective phenomenon. Since it utilizes many factors (CAPE, storm relative helicity, convective precipitation, wind shear etc.) – it can be useful in forecasting not only tornadoes, but also thunderstorms or squalls. Application of EPS in CP scale based on time-lagged ICs/BCs allows improving forecasts (especially due to the removal of false alarms). The research was carried out using archive data, starting from 2012. The noteworthy correlation between significantly higher EPS-UTI values and occurrence of thunderstorms was established.

Model forecasts with a spatial resolution of 2.8km and initial conditions – results of deterministic model with a resolution 7km – were used for the study. Additional filters (precipitation amount, CAPE threshold value etc.) were used. The use of numerical forecasts of meteorological model may be supportive of severe convective storm prediction. EPS-mean value of UTI is comparable with the ones calculated in a deterministic run(s), however significantly less amount of "noise signals" is observed. Thus, one can expect (in operational mode) decrease of FAR/increase of POD.

References

[1] Albergel, C., de Rosnay, P., G. Balsamo, G., Isaksen, L., Munoz-Sabater, J., 2012: Soil Moisture Analyses at ECMWF: Evaluation Using Global Ground-Based In Situ Observations. *J. Hydrometeor*, 13, **1442-1460**.

[2] Aligo, E. A., Gallus, W. A. and Segal, M., 2007: Summer Rainfall Forecast Spread in an Ensemble Initialized with Different Soil Moisture Analyses. *Wea. Forecasting*, 22, **299-314**.