ANALYSIS OF THUNDERSTORM CLIMATOLOGY AND CONVECTIVE SYSTEMS, PERIODS WITH LARGE PRECIPITATION IN HUNGARY

Theses of the PhD dissertation

ANDRÁS TAMÁS SERES

EÖTVÖS LORÁND UNIVERSITY
FACULTY OF SCIENCE

PhD SCHOOL IN EARTH SCIENCES
Coordinator of the PhD school: Dr. József Nemes-Nagy, professor, DSc

PROGRAM IN GEOGRAPHY-METEOROLOGY
Coordinator of the PhD Program: Dr. Mária Ottilia Szabó, professor, DSc

Supervisor: **Dr. Ákos Horváth**
Head of the Storm Warning Observatory in Siófok
Hungarian Meteorological Service
Candidate of Geosciences

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Introduction and objective of the study

There is a growing demand of weather forecasting and warning in the industrial society as well as the interest in the statistical-climatological examination of severe thunderstorms has grown rapidly. According to climate researches the number of extremely rainy days in the Carpathian-basin had significantly increased in the last quarter of the 20^{th} century and the frequency of extreme events will continue to increase in the future (*Bartholy* and *Pongrácz*, 2010).

The first Hungarian study on thunderstorm climatology was made by *Héjas* (1898), while mesometeorological researches started at the beginning of the 1960s. Recently thunderstorms and flash floods were examined from dynamical and synoptical aspects; nowcasting methods appeared as well.

We had two main objectives in our research: first to describe the statistical characteristics of severe thunderstorms in Hungary, and second to analyze the meteorological conditions and the structures of systems and periods, which can cause large precipitation between 2004 and 2012.

Methodology

Composite images from Doppler radar reflectivity of the Hungarian Meteorological Service were used. Image resolutions originally were 2 km x 2 km in space, and 15 minutes in time. During our measurement procedure median-filtering was applied for noise reduction and quality upgrading purposes. Using *TITAN method* (*Thunderstorm Identication, Tracking, Analysis and Nowcasting*, developed by *Dixon* and *Wiener* in 1993), the irregular-shaped thunderstorms detected by radars could be characterized by regular, so-called *thunderstorm ellipses*. The main point of identification was as follows: the parameters of the ellipses were determined by the covariance matrix of the isolated, irregular-shaped cluster using the condition that the area of the cluster and the ellipse had to be equal. Two types of thresholds: *the area* ($N_{minlimit}$) and *the reflectivity threshold* ($R_{minlimit}$) were defined. $N_{minlimit}$ referred to the size, while $R_{minlimit}$ determined the strength of a given ellipse. The space distribution of thunderstorm ellipses was analyzed by constructing so-called *thunderstorm-statistic maps* (resolution 18 x 18 km). Using *TREC (Tracking Radar*

Echoes by Correlation) with time step set to 1 minute the lifecycle and track of thunderstorm ellipses could be examined.

The investigation of large precipitation focused on 24-hour periods from 06 UTC to 06 UTC the following day. A period was considered *convective period with large precipitation* when these conditions were satisfied:

1. Two or more stations of the Hungarian rain gauge measurement network reported min. 50 mm precipitation,
2. At least 60% of the forecasted precipitation was convective during the period,
3. There was one or more pixels with min. 50 mm precipitation measured by radar (cells with large precipitation),
4. At least 60% of the radar cells with large precipitation had strong echo (intensity ≥ 40 dBZ).

To check realization of the second condition analyzes and forecasts of the *European Centre for Medium-Range Weather Forecast* were used, while to test the third and fourth conditions TREC and TITAN were applied. The significant mesoscale structures of these precipitation periods were examined and nine combined patterns were created by considering mesometeorological, phenomenological and synoptic perspectives. If more than one convective systems were detected in a 24-hour period, the most significant one was selected.

Programming was done in *C language*; post-procession was made in *Microsoft Excel,* while for visualization *Hungarian Advanced Workstation* system was applied.

Main results

- Annually 158 severe, 103 highly severe and 46 extremely severe stormy days were found and the stormiest month was July. (Stormy days: when at least one severe, highly severe and extremely severe object was detected [with $R_{minlimit}$ = 45, 50 or 55 dBZ]).
- On average 118 severe, 82 highly severe and 20 extremely severe ellipses were detected on a stormy day in the thunderstorm season (period between April and September).

- The daily frequency of ellipses peaked in the late afternoon period (around 17:00 in local time).
- The detected ellipses had maxima in the south-western, north-central and north-eastern parts of Hungary.
- 2625 severe, 597 highly severe and 45 extremely severe long-lived (with lifetime more than one hour) ellipses were found.
- Stronger cells moved faster, and average speed was mostly between 30 to 50 km/h.
- 62 convective periods with large precipitation were found and classified into 9 combined clusters. The maxima of appearances were in June and in 2010.
- The most frequent combined patterns were squall lines with cold front, convective lines along the convergence zones of a (shallow) cyclone and the convective lines with cold front. Periods with squall lines appeared more often than periods with convective lines.
- On average cells with large precipitation appeared in about 0,23% of the total area (which is 564 km^2)

- Periods with squall lines had higher convective activities because greater part of the large precipitation was produced by strong echoes (with reflectivity $\geq$ 40 dBZ).

Summary and conclusions

Our theses shortly present an objective, radar-based analysis on severe convection. The results of our descriptive, multi-year research method can be useful for detecting and forecasting severe thunderstorms. Our work on thunderstorm statistics and synoptical climatology can be extended or upgraded in many ways. In the future satellite and lightning data can be combined with these methods or the results could be further filtered, smoothened and down-scaled. This work can also be extended by involving more hydrological aspects when focusing on regions endangered by flash floods.

Our results suggest that severe and in many times dangerous convective events are quite frequent in Hungary, therefore further examination of these phenomena would be very important for the society and economy as well.

References and publications related to these theses

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