6^{th} European Conference on Severe Storms (ECSS 2011), 3 - 7 October 2011, Palma de Mallorca, Balearic Islands, Spain

8-year statistical analysis of 3D radar storm tracks

Edouard Goudenhoofdt, Laurent Delobbe
Royal Meteorological Institute, Brussels, Belgium, edouard.goudenhoofdt@meteo.be
(Dated: August 26, 2011)

I. INTRODUCTION

Convective storms can strongly affect human activities by causing heavy rainfall, downburst, hail or tornado. A better understanding of the factors that influence their initiation and development is needed to improve nowcasting techniques. Furthermore, this knowledge is needed for the design of several systems (i.e. satellite communication, hydrological network). Weather radars, which provide volumetric reflectivity measurements at high spatial and temporal resolution, can monitor the precipitation activity of convective storms with good accuracy. Numerous studies have been related to this topic but only a few are based on an objective analysis using several years of high resolution data (i.e. Bellon 2003 ; Saxen 2008; Han 2009 ; Rigo 2010).

II. DATA AND METHODOLOGY

Since 2001, RMI operates a C-Band (5GHz) Doppler radar located in Wideumont (south-east Belgium). The radar performs a 5-elevation scan (0.3, 0.9, 1.8, 3.3, 6.0) every 5 minutes. The volumetric data have a resolution of 1 deg. in azimuth and 250 meter in range (more information can be found in Delobbe and Holleman 2006). The radar data were available 97.6% of the time during the 2003-2010 period considered.

The cell tracker TITAN (Dixon and Wiener, 1993) has been developed for automatic identification, tracking and forecasting of convective cells based on radar reflectivity measurements. The storm identification algorithm defines a convective cell as a 3D region with reflectivity values exceeding a given threshold. The storm tracking algorithm (Figure 1) matches convective storms across two successive radar scans using combinatorial optimisation and can deal with storms that merge or split. TITAN is in constant development by several contributors and is now a broad system with lots of capabilities. In this study, the integrated clutter mitigation technique, which is based on fuzzy logic, has been used to filter the radar data.

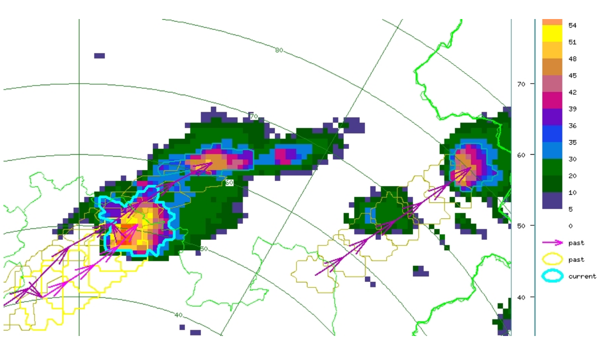

FIG. 1. TITAN : Thunderstorm identification, tracking and nowcasting

III. STATISTICAL ANALYSIS

8-years of volumetric radar data have been processed by the TITAN cell tracking system using a threshold of 35 dBZ. Various information about the identified storms are stored by TITAN such as the centroid position, the volume, the echo-top or the mean reflectivity. For each storm track, aggregated properties are also computed by taking the mean and maximum of the instantaneous properties.

A classification of identified storms, based on several empirical criteria (size, morphology, intensity, distance to closest neighbour) has been developed. Each storm track is then associated with the most frequent type associated with each 5-min part.

The study area is limited to ranges between 20 and 180 km from the radar to ensure that storm cells can be identified. A selection is made on the storm tracks to remove erroneous and shortened storm tracks. A further selection, based on the distance to the radar, is made for properties requiring higher accuracy (i.e. echo-top).

The temporal statistics of convective activity are based on the timeseries of two indices of convection intensity :

- The total number of identified storms (cell count).
- The percentage of convective area in the study area (at 36, 40 and 50 dBZ thresholds).

Figure 2 shows the variation of the convective activity during the year. Most of the convective activity occurs between May and August with the highest activity in July and August. The mean intensity of the convective activity (not shown) peaks in June for 40 and 50 dBZ areas and from June to Augustus for the cell count.

The daily variation exhibits (Figure 3) a maximum activity from 15pm to 17pm UTC, 2 times the minimum activity which lasts from 0pm to 9pm. The mean intensity during convective activity (not shown) is roughly proportional to the activity itself with a slight bias for the maximum which occurs about 1 hour before. The convective episode duration distribution (not shown) tends to be positively skewed with 80% of the episodes lasting less than 5 hours.

The spatial distribution of convective activity (Figure 4), besides the artificial range effect, reveals a slightly higher frequency on the north of the radar and also on the south west. A

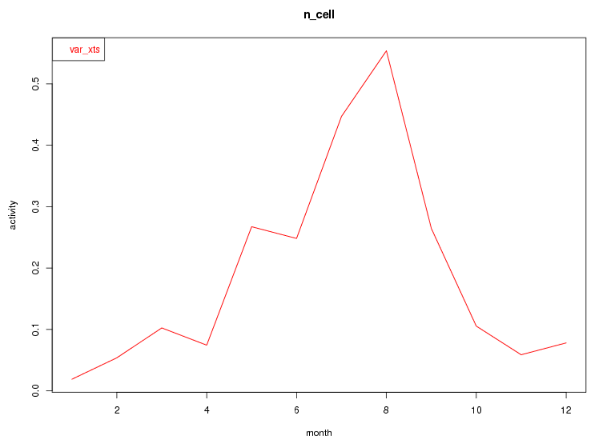

FIG. 2. Mean convective activity for each month

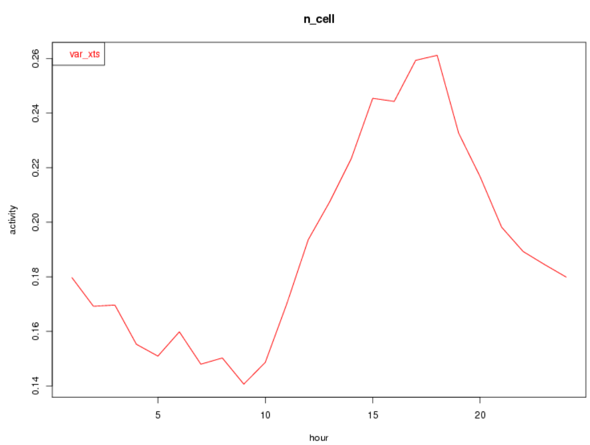

FIG. 3. Mean convective activity for each hour

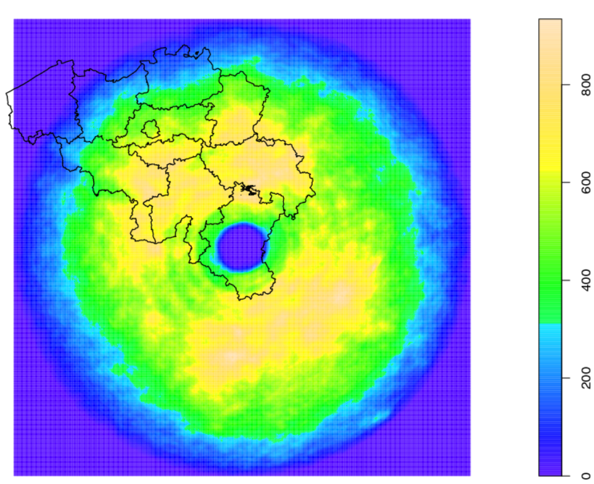

FIG. 4. Spatial distribution of storm count

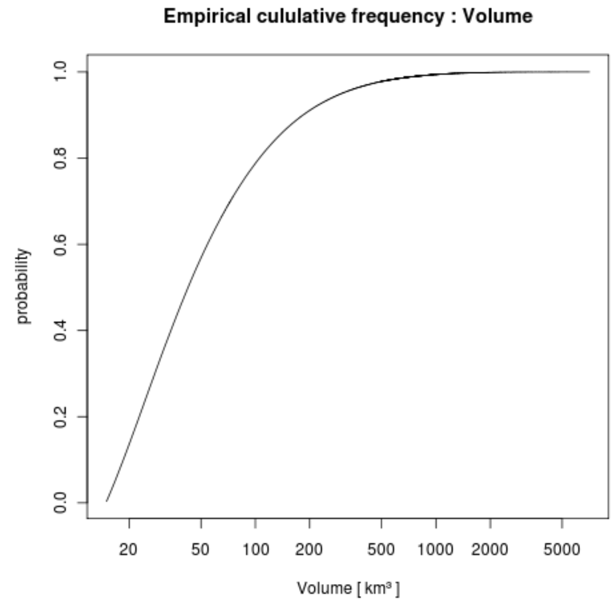

FIG. 5. Empirical cumulative distribution of the instantaneous volume

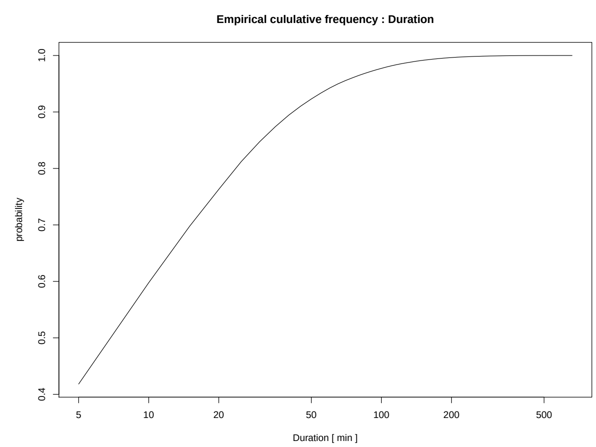

FIG. 6. Empirical cumulative distribution of the duration

possible effect of the local orography should be further investigated.

On figure 5 you can see the empirical cumulative distribution of the instantaneous volume. The volume, echo-top and maximum reflectivity are well described by log-normal models skewed toward lower values. This suggests that intense events are relatively rare.

On figure 6, the empirical cumulative distribution of the duration of simple tracks shows that cells are mostly short lived. Furthermore, their mean speed follow a Weibull distribution and their mean direction are consistent with dominant wind in convective situation.

On figure 7 you can see a significant linear positive relation

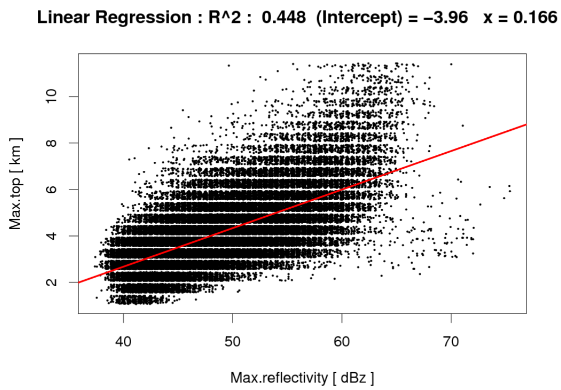

FIG. 7. Scatter plot of maximum echo-top versus maximum reflectivity

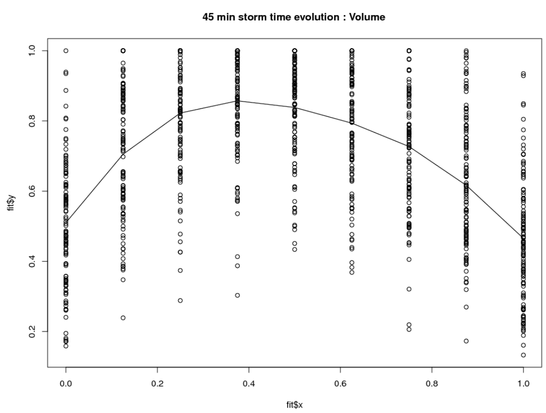

FIG. 8. Mean evolution of storm volume for "isolated strong" type

between the maximum echo-top and maximum reflectivity of storm tracks.

The analysis of the dynamic of the storms (i.e. how the properties varies during the track life cycle) is particularly interesting for nowcasting purpose. The evolution of storm maximum volume for 45-min duration storm track of type "isolated strong" (Figure 8) shows that the volume grows quickly before a slight decay. Similar results have been found for the other storm properties.

IV. CONCLUSIONS

A long term objective analysis of convective activity in Belgium has been performed. The high resolution volumetric radar data are particularly suited to obtain the statistical and dynamical characteristics of convective storms. The analysis shows that convective storms tend to be more frequent in summer while there is a significant diurnal effect. There is a slight indication that preferred regions for convective activity exist in the study area. Small, weak and short-lived storms are predominant while the intensity of the storms tend to increase when the echo-top increases. Storms tend to reach their maximum intensity quickly before a slow decay.

Those results are particularly interesting for the development of nowcasting techniques. However, the use of a second radar in the vicinity would be useful to validate the results and to detect radar artifacts. The analysis of additional convective storm characteristic derived from other observation systems (lightning information, cloud characteristics observations by satellite, water vapor derived from GPS measurements or different variables derived from NWP models) should complete the study.

V. ACKNOWLEDGMENTS

This research has been supported by the Belgian Federal Science Policy (Research project ACTION 1 MO/34/018).

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