NOWCASTING SEVERE STORMS IN THE CENTRAL AREA OF THE STATE OF SÃO PAULO WITH THE AID OF TITAN

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I. INTRODUCTION

Until recently very little was available at IPMet to be deployed as a nowcasting tool, once there was no automatic procedure for detecting and tracking potentially severe cells and to forecast their evolution and displacement. Through a collaborative effort with scientists from the National Center for Atmospheric Research (NCAR), the software system **TITAN** (**T**hunderstorm **I**dentification, **T**racking, **A**nalysis and **N**owcasting; Dixon and Wiener, 1993) was made available to analyze radar data information from both radars operated by IPMet. The implementation in IPMet´s computer system was done with the assistance of NCAR staff that helped with all necessary computer routines to be adapted for direct access to the data format generated by both Doppler radars (Kokitsu, 2005). The results that will be presented here are part of the project validation of the severe events in the central area of the State of São Paulo in compliance with some objectives of the SIHESP (Sistema Hidrometeorológico do Estado de São Paulo) project.

The main objective of the study is to verify the potential of the new tools available with the TITAN system and then to transfer the results to the operational sector of IPMet. Results related to a severe event that occurred on 17 October 1999, causing extensive damage by hail, will be presented as an example.

II. DATA AND METHODOLOGY

The Doppler radars are located at Bauru (Lat: 22.36°S, Lon: 49.02°W, 624 m amsl) and 240 km further west at Presidente Prudente (Figure 1). The main characteristics of the radar are: 2° beam width and ranges of 450 km for surveillance and 240 km in volume scan mode (11 elevations: 0.3° to 34.9°), 1 km radial and 1° azimuthal resolution, and temporal resolution of 15 min or less, recording reflectivity, radial velocity and spectral width.

TITAN was used in the *ARCHIVE* mode and the tracking properties form the base for the analysis here. A TITAN cell was defined by the 40 dBZ threshold for the reflectivity with a minimum volume of 50 km^3, observed at least in two volume scans (15 minutes). For all storms complying with or exceeding the adopted criteria for storm properties, the hail metrics, as well as the forecasting of its evolution, were determined.

Severe Storm Parameter Indicator

Besides tracking and nowcasting the movement of storm cells, TITAN has incorporated algorithms that allow identification of potentially severe storm "signatures", such as hail metrics, to produce probability of hail (POH), based on Waldvogel *et al.* (1979). This implies that hail occurs always when the 45 dBZ reflectivity is present at 1.4 km or more above the freezing level. Another parameter, FOKR (Foote-Kraus) index, also related to hail-producing storms, was developed by Foote *et al.* (2005) and first applied to hail-producing storms in Argentina. Also used for the analysis here is the SSS (Storm Structure Severity) index, developed by Visser (2001) for hailstorms on the South African Plateau.

FIG. 1: Doppler radar network of IPMet (BRU = Bauru; PPR = Presidente Prudente), showing range rings for 240 and 450 km.

III. DISCUSSION AND RESULTS

Storm Overview

The severe event on 17 October 1999 developed and evolved in an environment under the influence of a baroclinic system reaching the State of São Paulo. A squall line with multicellular storm characteristics, showing several intense cells forming ahead of the frontal disturbance, with an extended trailing stratiform area, can be seen in Figure 2.

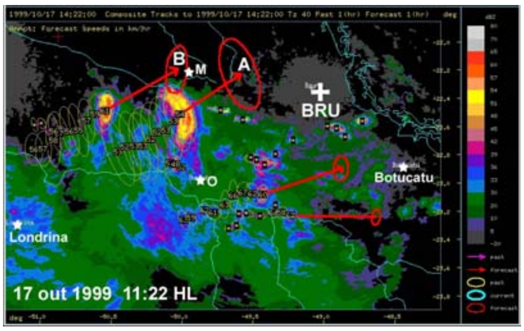


FIG 2: Composite reflectivity field for the Bauru and Presidente Prudente radars, 240 km range, on 17/10/1999, 11:22 LT. The ellipses show the areas in excess of 40 dBZ identified and tracked by TITAN (yellow: past history of the storm; blue: present; red: nowcasting for the next 60 minutes).

Hail Event of 17 October 1999

The most intense cell, labeled A, located south of Marilia (M) at 11:22 LT, is shown in Figure 2 with its trajectory and forecast for the next 60 minutes, highlighting the areas with reflectivities in excess of 40 dBZ. The cell A, that produced the hailstorm had an average speed of 60 to 65 km.h^{-1}, with reflectivities in excess of 60 dBZ, reaching a maximum of between 70 and 72 dBZ and echo top height (10 dBZ) of 13 to 17 km, showing a very intense vertical development. Vertical cross-sections parallel to the direction of movement confirm the existence of tilted updrafts, that sustain and maintain the high reflectivities observed during the lifetime of storm A, with hail falling out at the leading edge of the storm. The storm reached areas north of Bauru, producing severe damage by hail and strong winds at around 13:00 LT.

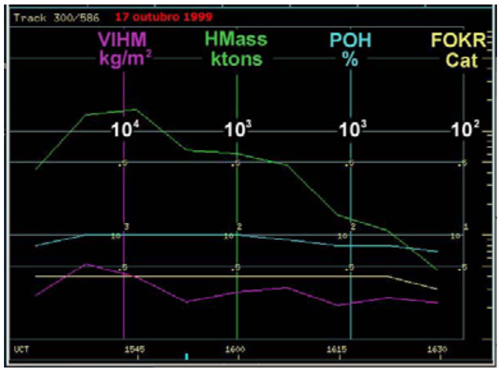
The temporal evolution of the hail severity parameters for cell A can be seen in Figure 3, with the observations covering 30 minutes before and 30 minutes after the observed hail fall, from 12:30 to 13:30 LT. The temporal evolution for variations of the indices relating to hail metrics, such as VIHM (hail from VIL max), probability of hail (POH) and the FOKR index are shown in Figure 3. The index POH, related to the probability of hail reaching the ground, shows values very close to and even reaching 100%, from 12:37 LT to 12:59 LT. At 12:30 LT, the FOKR index reaches a number 4 category, in a classification that spans from 0 to 4, persisting until 13:15 LT, when a slight decrease in value can be seen, but still showing category 3 and 4 during the continuous movement of the storm towards the northeast sector. According to the classification by Abshaev (Foote *et al.*, 2005), the categories 0 and 1 are considered non-hail producing storms, while category 3 and 4 are hail producing storms, and the category 4 can produce 5 to 6 times more damage on the ground than category 3. The SSS index (not shown here) also exhibits a severe volume and top structure classification, with magnitudes for the index of 8 and 9, indicative of the presence of intense updrafts, important and needed for the formation and maintenance of the hail that was observed later on at the surface.

Storm Cell Tracking and Forecasting Verification

The TITAN system has a statistical module to allow the verification of the storm cell tracking and forecasting. The forecasting results can be evaluated using the performance indices, such as the Critical Success Index (CSI), which varies from 0 to 1, being desirable to have values close to 1, once this index is defined as a function of the probability of detection (POD) and of the false alarm rate (FAR). The results for the evaluation of the 17/10/1999 event are summarized in Figure 4, considering forecasting times of 15, 30, 45 and 60 minutes. The values for the probability of detection and movement of the storm cell exceeding the 40 dBZ threshold and life span greater than 15 minutes are around 70 to 74 %, having a false alarm rate of 46 to 56%. The CSI varies from 38 to 55%, for a forecasting period of 60 and 15 min, respectively. Considering the period of 30 minutes for issuing an alert for a severe storm, the performance of the forecast, represented by the CSI index, is around 45%, with the capacity for the identification and tracking by TITAN being in excess of 70%, considering the threshold adopted here.

IV. CONCLUSION

A new forecasting tool especially developed for direct application in nowcasting and implemented at IPMet was applied here for the analysis and evaluation of a severe event that occurred in the central State of São Paulo. The results produced by this preliminary analysis have demonstrated the potential use of TITAN severity indices to support the issuing of severe weather warnings within the 240 km range of the two Doppler radars operated by IPMet. The analysis will be extended to include more cases and to improve the radar bulletins issued routinely for the public in general and the local Civil Defense Authorities in particular.



12:30 **13:30**

FIG 3: Temporal evolution of TITAN severity indices (POH, FOKR, etc) from the hail-producing cell observed on 17/10/99.

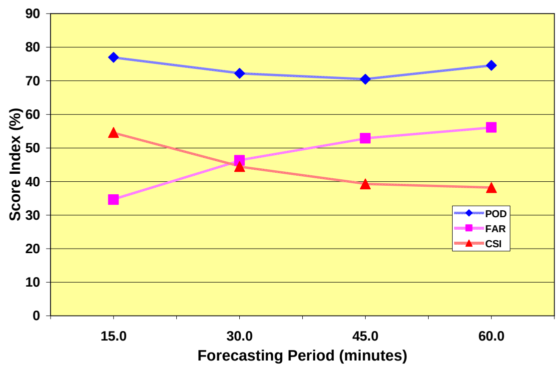


FIG. 4: Evaluation indices for the performance of the storm cell forecasting observed by the Bauru Doppler radar on 17/10/1999.

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