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The application of TITAN for thunderstorm nowcast operations

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Introduction

The Bureau of Meteorology operates a network of conventional, predominately C band, weather radars around the country and these radars provide 10-min low-level surveillance scans and volumetric radar data. These data support forecast and warning operations for the public weather, severe weather and aviation weather services and for hydrometeorological operations.

In recent years there have been moves to upgrade the radar network, to utilise the radar data in a more quantitative way and to develop and implement a nowcast system that provides improved guidance to forecasters and enables the generation of derived products for end users. These developments have resulted largely from the increasing economic impacts of thunderstorms, a recognised need to provide better thunderstorm warning products and a need to streamline the preparation of these products. A Nowcast Applications Server has been developed that integrates several radar data processing applications, including the Thunderstorm Identification, Tracking, Analysis and Nowcasting (TITAN) application (Dixon and Wiener 1993). This application has been used in Australia for a number of years and in this paper we describe its use for the analysis of thunderstorms and for nowcast operations.

The TITAN application

The TITAN application identifies ‘storm’ cells in volumetric radar data and calculates associated parameters. It also tracks the cells and provides a nowcast of their movement. In the data processing the polar volumetric radar data are first converted to a Cartesian coordinate system with a horizontal grid of 460 km $\times$ 460 km centred on the radar, a vertical grid extending from 1 to 20 km, and a grid spacing of 0.75 km in the horizontal and the vertical. The data are then passed to the TITAN application, which identifies a ‘storm’ as a three-dimensional contiguous region in space for which the radar reflectivity, the volume and the height exceed defined thresholds. For most operations in the Bureau the volume threshold for a storm is set at 30 km^3 and minimum top is set at 3 km, giving a minimum area on the order of 3 km $\times$ 3 km. The reflectivity threshold is dependent on the particular application and the system can be run with multiple thresholds. Thresholds at 35 dBZ, 40 dBZ and 45 dBZ are used for operations in the Bureau. At the lower threshold all thunderstorms and more intense convective showers should be captured. For a single convective cell this will define the boundary of the core region of the cell. For larger convective systems the boundary may enclose several cores and associated areas of more intense stratiform precipitation that result from these cores or bridge between them. At the higher threshold only the more intense cells or severe storms will be captured.

The movement of identified storms is determined by minimisation of an objective cost function to achieve a logical match of storms from one time step to the next. The methodology includes procedures for handling merging and splitting of storms, which can occur frequently during convective weather events.

Interpolation of the polar radar data to a Cartesian grid and the identification and tracking of ‘storms’ allows the calculation of a number of associated parameters. This includes storm location, volume, height, area, maximum reflectivity and storm track details. A number of derived parameters are also calculated, including mass, precipitation flux, vertically integrated liquid, hail metrics and severe storm metrics. The rate of change of several of these parameters is also calculated. These parameters are available for analysis purposes or for ‘downstream’ applications that might form part of an integrated nowcast system. Conversion of the radar data to a Cartesian grid also allows for the merging of data from several radars that form part of a network, providing the capacity for the identification and tracking of storms over a wider area.

Analysis of storm characteristics

Applications such as TITAN, that provide objective methodologies for automatically identifying and tracking storm cells observed in radar data, make possible the efficient processing of large volumes of radar data. This enables the analysis of the characteristics of storms in a way that would not be possible otherwise.

Potts etal (2000) examined the radar characteristics of summer time ’30-dBZ’ storm cells in the Sydney area using the TITAN application. This showed the spatial distribution is such that there is a maximum in the frequency and intensity along the east side of the mountains that lie inland from the coast, and characteristics such as storm volume, area and height have a lognormal frequency distribution. To illustrate, Fig 1 shows the frequency distribution of ’30-dBZ’ storm volume for 29 thunderstorm days in the summers of 1995/96 and 1996/97. Fig 1b is a normal probability plot for the transformed volume, ln(volume-k), and this shows a good fit to a lognormal probability distribution.

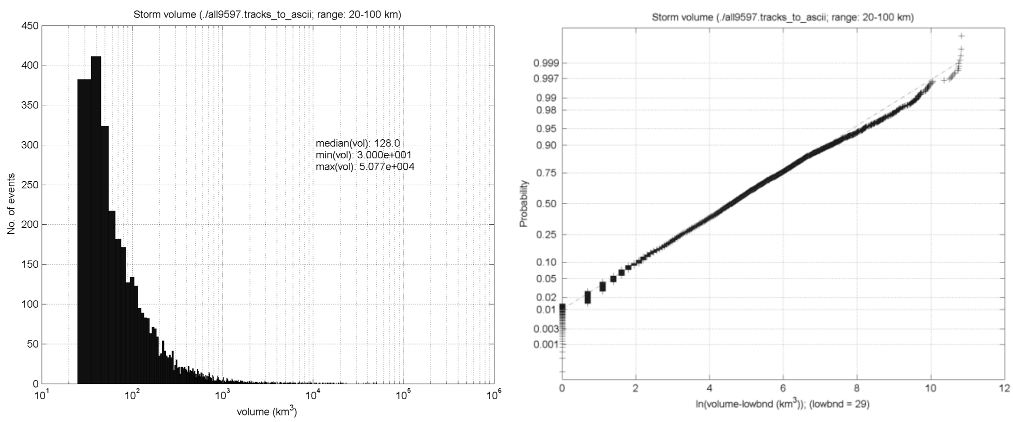

Figure 1. a) Frequency distribution for 30-dBZ storm volume. b) Normal probability plot of ln(volume-k).

May and Ballinger (2005) analysed the characteristics of break-period and monsoon-period thunderstorms in the Darwin area and TITAN was used to identify storms and determine relevant parameters.

The ability to process radar data efficiently and objectively with TITAN has also been of value in the analysis of significant storms events, such as the 14 April 1999 severe hailstorm that developed south of Sydney and moved along the coastal suburbs. The storm was associated with very large hail (up to 9 cm diameter), heavy rain and strong winds and the damage cost was approximately A$2 billion. Fig 2 shows the path of the storm represented by the 49-dBZ reflectivity contour and the storm centroid as identified by TITAN. In the NSW Regional Forecast Centre the operational criteria for classifying thunderstorms as

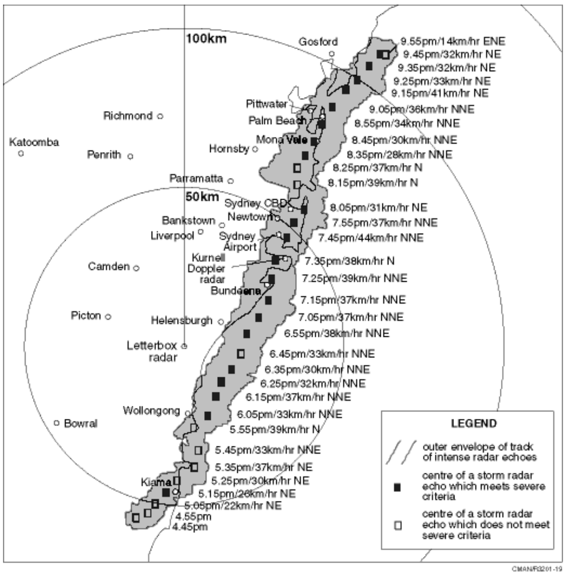

Fig 2. Thunderstorm (49-dBZ) track for 14 April 1999 Sydney severe hailstorm.

severe is when the height of the 49 dBZ reflectivity contour exceeds 8 km and Fig 2 also shows the time steps when this criteria was met.

Nowcast Applications Server

In the year 2000 an international Forecast Demonstration Project was conducted in Sydney as part of the weather support for the Sydney Olympics (Keenan etal 2003, Joe etal 2004, May etal 2004). The Project demonstrated the capability of modern nowcasting systems to deliver end user benefits and provided a major impetus to the development of a nowcasting system in Australia.

In the period since Sydney2000 the Bureau has developed a Nowcast Applications Server that integrates several radar data processing applications and provides real-time guidance for forecasters and relevant information for ‘downstream’ applications. Specific components of the system include a radar data server, TITAN, the Weather Decision Support System (WDSS) (Eilts 1997), and a quantitative rainfall application known as ‘Rainfields’. Storm parameters determined by the applications and detected features are then made available to display systems and to other applications that generate end-user products.

3D-Rapic

The Bureau of Meteorology’s operational radar data workstation is known as 3D-Rapic. This is a sophisticated application that manages the radar data and allows the display of these data in different ways. It is a primary tool for forecasters in periods when severe thunderstorms are possible.

During severe thunderstorm events there are often many thunderstorms present and the operational forecaster must quickly analyse the volumetric radar data and other relevant information, identify cells that may be associated with severe weather and issue required warnings in a timely manner. Experience has shown there is a need for improved guidance so that storm-cells likely to be associated with severe weather are automatically identified in the radar display. To support this requirement the Nowcast Applications Server provides guidance information identified by the WDSS and TITAN applications that can be displayed in 3D-Rapic. This includes storm intensity information and features such as mesocyclones, hail signatures and damaging downbursts. The forecaster can rapidly identify storm cells likely to be associated with severe weather, determine relevant details and issue associated warnings.

TIFS / ATSAS

The Thunderstorm Interactive Forecast System (TIFS), (Bally 2004), is a graphical user interface that was developed for the generation of graphical and text warning products for thunderstorms. Storm tracks and associated cell features identified by the TITAN and WDSS applications are provided by the Nowcast Applications Server. These data are displayed in the TIFS graphical interface, together with lightning data and selected NWP guidance. Forecasters can then interact with the guidance and generate a range of thunderstorm warning products in a very time efficient manner.

The Automated Thunderstorm Alerting Service (ATSAS) has been developed to provide timely information on the presence of thunderstorms and associated lightning around major airports and enable airline operations managers to manage the risk associated with lightning strikes for ground operations. Systems that support ATSAS take output from TITAN and a lightning sensor and generate end-user graphical and text products that show the location and movement of thunderstorm cells and the presence of lightning near the airport (Fig 3). The products are updated frequently and can be easily understood by airline staff.

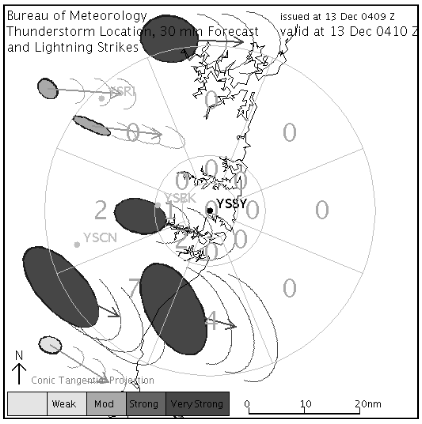

Fig 3. ATSAS product for Sydney Airport for 0410Z, 13 Dec 2004.

Discussion

The TITAN application has been in use in Australia for a number of years and has proved of value for the efficient processing of radar data, the analysis of thunderstorm characteristics and also for real-time nowcast applications.

Nowcast applications like TITAN use the radar data in a more quantitative way and this has significant implications on the operation of the Bureau's radar network. Effective operation of the algorithms is conditional on the data quality and optimal scanning strategies for the radars. This requires careful attention to the range resolution, intensity resolution, radar calibration, the volume scan strategy and appropriate management of radar metadata. Algorithms that identify the presence of hail are very sensitive to reflectivity and this requires accurate calibration of the radar and an intensity resolution that spans the full dynamic range of radar reflectivity. Experience has also shown that storm cell tracking can fail in situations where there are smaller fast moving cells due to difficulties in correlating storms in consecutive volume scans. This is a significantly greater problem at higher latitudes with 10-minute volume scans compared to 5-minute volumes as storms can move a significant distance in 10 minutes.

As previously discussed the data processing for TITAN requires conversion of the radar data to a Cartesian grid. This allows for the merging of volumetric data from several radars that form part of a network and provides the capacity for the identification and tracking of storms over a wider area. Development work in this area is underway.

Acknowledgements

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