8.12 VERIFICATION OF OPERATIONAL THUNDERSTORM NOWCASTS

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1. INTRODUCTION

Severe weather associated with thunderstorms is a significant threat to life, property and the cause of significant economic loss. In Australia, individual thunderstorms have been directly responsible for billions of dollars of damage and the nowcasting of these phenomena represents a significant program activity within the Bureau of Meteorology. The services provided by this activity aim to provide accurate and timely nowcast information to mitigate the potential impact of these storms. The accuracy of these severe weather nowcasts is therefore of considerable interest to meteorologists, the general public and a range of other end users e.g., emergency services, fire fighters, the aviation industry. The accuracy of severe thunderstorm position nowcasts provided by the Bureau of Meteorology, in Sydney Australia is therefore assessed.

The focus is nowcast position accuracy (0-1 h interval), assessing the absolute errors and skill provided by basic nowcast system guidance, the impact of automated system support, and the human, in the derivation of final forecast products.

2. DATA AND FORECAST PROCESS

The Thunderstorm Interactive Forecast System (TIFS), described by Bally (2004) is an interactive nowcast system that has been employed by the Bureau of Meteorology, Australia since 2000 for the production of thunderstorm outlooks and nowcasts in the Sydney area. TIFS produces thunderstorm nowcast products based primarily on radar guidance provided by such systems as the Thunderstorm Identification, Tracking, Analysis and Nowcasting (TITAN) (Dixon and Weiner, 1993). Nowcasters can graphically edit and modify attributes of thunderstorms represented as objects to produce a range of text and graphical warning products. Thunderstorm object attributes that can be modified by the nowcaster include cell existence, location, speed, direction, shape, size and intensity. In this way the nowcasters provide quick routine monitoring and generation of thunderstorm nowcast graphical and text products, without typing, to the public and a range of specialist users.

In normal operation TIFS first ingests TITAN guidance and then employs an expert system to undertake a variety of initial processes. These processes advance storms tracks (accounting for any latency in data arrival), correct for obvious cell tracking errors (usually associated with mis-association of cell tracks, lack of storm history, new cell, etc.) and under-take track filtering (removal of storms below specified intensity thresholds) as shown in Fig. 1. Further graphical intervention by the human is then possible as discussed above. Typical processes would include further track filtering to remove weaker storms not relevant to the forecasts, and if thought appropriate, track modification to account for obvious errors or storm and environmental characteristics not account-ted for previously (e.g., left or right moving track deviations associated with supercells). The severe weather nowcasters aim to enhance the overall forecast process by providing consistent nowcast policy, quality control, and overcome any weaknesses and errors in initial automated guidance.

In this study operational TIFS nowcasts derived from five (ten) minute interval Kurnell (Letterbox) radar volume scans near Sydney for over three years of forecasts from late 2002 through early 2005 are examined. Separate TITAN cell tracks from these two radars are provided to TIFS based on reflectivity thresholds of 35, 40 and 45 dBZ.

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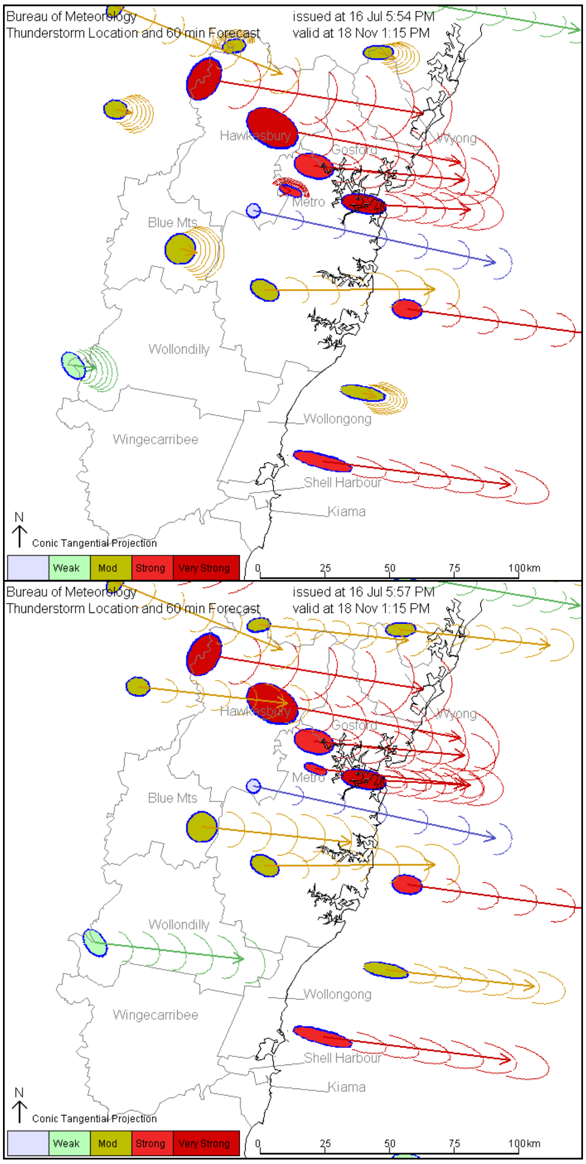

Fig 1. Example of automated expert system track filtering with TIFS. Cell tracks (a) before and (b) after TIFS expert system track adjustment.

3. ASSESSMENT TIFS TRACK MODIFICATION

3.1 *TIFS expert system track modification*

The impact of the TIFS expert system track modification is assessed by examining cases where the guidance cell speed and direction were set at zero but subsequently modified by the expert system to be non-zero. This does not encompass all modifications. As shown in Fig.2, the expert system had a positive impact on the track errors at all forecast intervals.

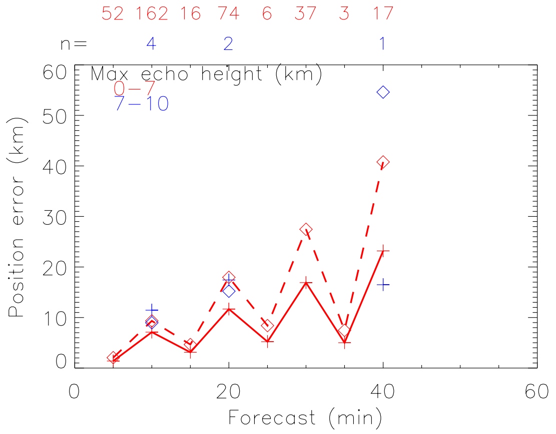

Fig 2. Impact of TIFS expert system track modification, for data from all Sydney radars. Dashed line is before track modification, solid line is after cell track modification. The number of samples in each forecast interval is indicated at the top of the diagram.

Overall, there was a 33% decrease in track error averaged over the available 379 cases. This decrease was statistically significant at the 95th percentile level. In addition the track error was reduced in 73% of the cases in which it was applied.

3.2 *Impact of forecaster filtering of cell tracks*

Forecaster filtering of guidance tracks had a small but overall positive impact on forecast track errors. The track errors with and without filtering are shown for the Kurnell data in Fig.3. In this case the greatest forecaster impact was evident for shallow storms, with the nearly neutral impact for moderate and deep storms. Averaged over cells from all categories,

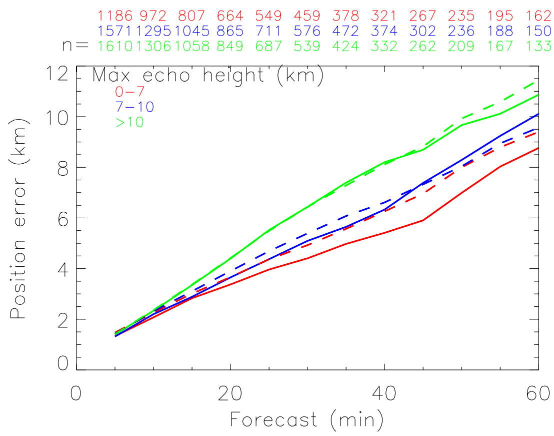

Fig 3. Impact of forecaster filtering of cell tracks within TIFS, for all data from Kurnell radar. Dashed line is without forecaster filtering, the solid line is with forecaster filtering. The sample sizes are given for the filtered samples.

forecast periods, and radars there was a 2.8% improvement in track errors related to forecaster track filtering.

The most significant impact of the forecaster filtering was a 63% reduction in the number of cells passed to the TIFS warnings (from 22,791 to 8,492). Removal of cells not deemed relevant to the essential information to be portrayed in the production of a warning was clearly an important process undertaken by the forecasters.

3.3 *Impact of forecaster track modification*

A very small percentage (1.1%) of track cell locations were actually modified manually by the nowcasters. The results were mixed as shown in Fig. 4. Overall there was a small and insignificant (at the 95th percentile level) deterioration of 2.2% in track error averaged over the 95 available cases. However forecaster track modification did result in an improved track error in a majority (62%) of the cases.

3.4 *Assessment of modification by both the forecaster and expert system*

Using all cell forecasts from both radars some 22,791 cell forecasts were available for examination. The expert system was employed to determine the cell speed and direction in only 572 (2.5%) of cases. The cells were manually modified by the forecaster in only 96 (0.4%) of the cases. This implies that very little additional modification is employed by the forecasters on a day-to-day basis (modification rates varied with the radar and TITAN threshold but ranged from zero to about 4.4% for 35 dBZ storms from the Letterbox radar). These modifications occurred on eleven days with significant events, with warnings issued on eight of these days.

4. OVERALL VERIFICATION and "SKILL" OF CELL TRACKS ISSUED TO THE PUBLIC

Nowcast track errors from all TIFS cell forecasts based on the Kurnell radar are summarized in Fig.5. Errors grow linearly with forecast duration at the rate of 8-10 km h^{-1}, with larger errors observed with the deeper and faster storms. As shown in Fig. 5, storms moving at speeds greater than 40 km h^{-1} have errors averaging about 50% larger than storms moving in the range 0-40 km h^{-1}. Typical track errors are on the order of 30-50% of the storm speed.

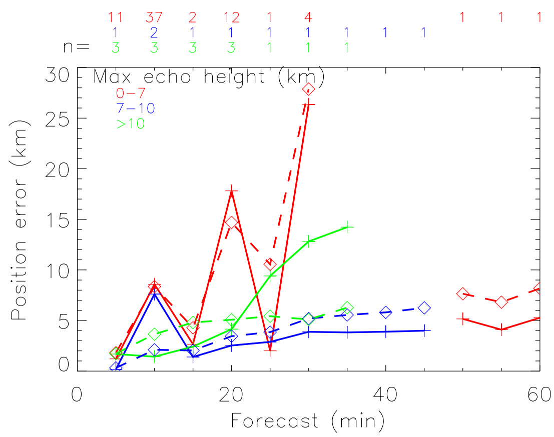

Fig 4. Impact of forecaster modification of cell tracks within TIFS, for data from both Sydney radars. Dashed line is without forecaster modification, solid line is with forecaster modification. Note the very small sample sizes for moderate and deep cells.

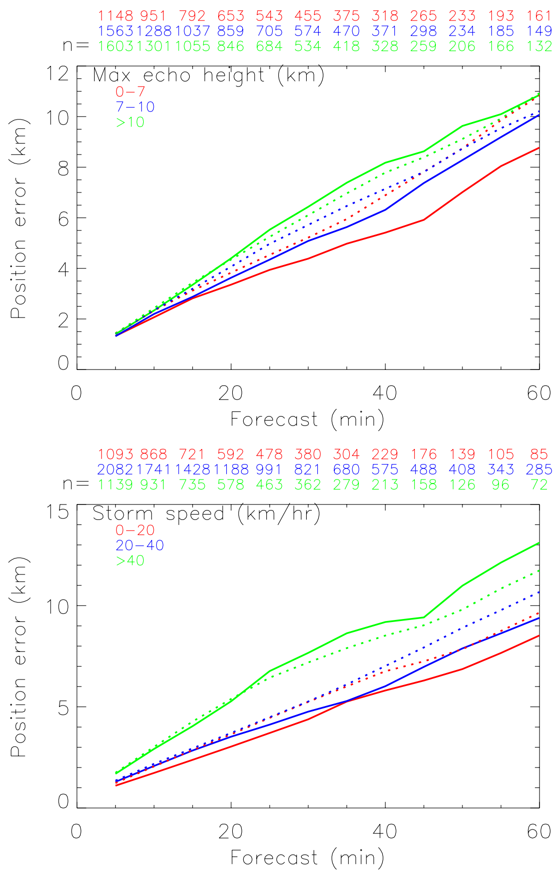

Fig 5. Verification of TIFS track errors issued to the public, for data from Kurnell radar. Solid lines are TIFS forecasts and, dotted lines are extrapolation nowcasts. The top diagram shows stratification based on storm height, the lower diagram shows stratification based on storm speed.

The overall skill of these forecasts is assessed by computing the mean cell motion observed for the previous hour as a benchmark (dotted lines in Fig. 5). A minimum of ten samples over the previous hour was required to define a no-skill motion. For the shallow and moderate depth storms, and the slow to moderate moving storms, the TIFS nowcasts are approximately 10% more accurate than the benchmark, at least beyond about 20 minutes. For the deep (> 10 km) and fast moving storms the nowcasts are marginally less accurate than the extrapolation benchmark.

TITAN, which provides the guidance to TIFS, employs a weighted average of past storm motion to provide its nowcast. As discussed only a small percentage of guidance track nowcasts were actually amended by the forecasters. This means that any skill relative to the TITAN tracks is likely to be marginal at best. The results in Fig. 5 do indicate that optimization of the blending process for fast and deep moving storms needs further consideration. Typically fast moving storms are harder to track automatically and may show anomalous behaviour.

TIFS track errors are relatively uniform in space but some there are small systematic biases evident in Fig. 6. On average the TIFS nowcasts are biased slow and to the right of the storm motion, i.e., to the south and west. The trend is consistent over the 60 minute forecast interval.

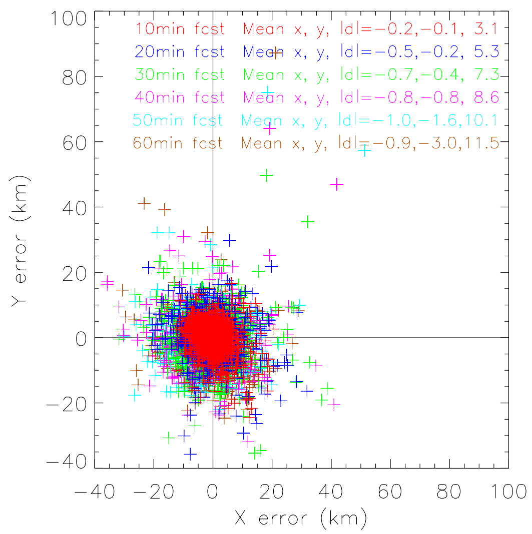

Fig 6. Spatial distribution of TIFS track errors from both Sydney radars.

5. SUMMARY

This study has examined the accuracy of thunderstorm track errors generated by TIFS in Sydney, Australia. These are operational thunderstorm nowcasts based on guidance provided by TITAN and potentially modified by both expert system and human intervention. The results show that in the busy storm warning environment guidance track nowcasts are used in the vast majority cases with little human intervention. When track adjustments are made they typically involve changing forecast cell locations in significant storms.

The most frequent human intervention is quality control and optimizing the form of the product. In the overwhelming number of cases this does not include modification of track locations. Reducing the number of tracks presented in the final product is an important activity aimed at clarifying the overall threat. This “filtering” process based on the expert system and the human did provide a small improvement in the track errors. Human intervention to specifically adjust cell track locations did not decrease the average track error.

The TIFS tracks showed some skill relative to the benchmark extrapolation employed herein for shallow and moderate depth storms. For fast moving and deep storms there was some overall degradation in skill. This probably reflecting the more “anomalous” or non-persistent flank motion associated with deep supercell storms and difficulties in effectively tracking fast moving storms.

6. REFERENCES

Bally, J. 2004: The Thunderstorm Interactive Forecast System: Turning automated thunderstorm tracks into severe weather warnings. *Wea. Forecasting*, **19**, 64-72.

Dixon, M.J. and G. Weiner, 1993: TITAN: Thunderstorm Identification, Tracking, Analysis and Nowcasting - A radar based methodology. *J. Atmos. Oceanic Technol*., **10**,785-797.