P13B.14 THE END TO END SEVERE THUNDERSTORM FORECASTING SYSTEM IN AUSTRALIA: OVERVIEW AND TRAINING ISSUES.

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1. INTRODUCTION

Over the last few years the Australian Bureau of Meteorology (Bureau) has been developing systems to cover the range of spatial scales and lead-times involved in the thunderstorm forecasting and warning process. From the medium term (2 days) which is primarily based on mesoscale computer model output, through short term, where the approach shifts towards radar data including the interpretation via radar algorithms and manual viewing of the base data.

In order to utilise these forecast systems in a meaningful way, it is important that first the service requirements and forecast process be well defined and that forecasters have a clear understanding of these. The chosen training approach uses the radar and severe thunderstorm forecast competencies as its core. The competencies embody the scientific knowledge and system skills gained from analysing the forecast process itself. These competencies are the cornerstone of a focused, service-relevant training program that forecasters undertake as an integral part of the introduction of these new systems to Regional Forecasting Centres (RFCs) in Australia.

This paper first describes the end-to-end severe thunderstorm forecasting system as presently used in Australia (see also Richter 2006). It then uses an Australian supercell hailstorm case study to showcase how forecasters use the system outputs to facilitate decision making at various stages of the severe thunderstorm forecast process. In particular, we will attempt to demonstrate that radar-based algorithms add value to the warning decision making process when used carefully in conjunction with the radar base data and other data types. We finally discuss training and assessment issues associated with implementation of the forecast systems.

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2. SYSTEM OVERVIEW

2.1. *Outlook period to 48 hours - National Thunderstorm Forecast Guidance System (NTFGS)*

The NTFGS is a software package that displays those output fields from the 0.125º Australian operational NWP model (Meso-LAPS) that are relevant in diagnosing (severe) thunderstorm potential out to 48 hours from model initialization (Hanstrum 2003). Relevant fields are based on thunderstorm conceptual models relating up-motion, moisture, instability and shear to thunderstorm initiation, development and structure. One of the core elements of the system is a web-based graphical user interface (GUI) referred to as the mesoviewer (Fig. 1). Forecasters can view 3 hourly Meso-LAPS NWP data (Puri et al. 1998) in a way that reinforces the (severe) thunderstorm forecast process.

Algorithms used to determine threat areas for thunderstorms, supercell thunderstorms, tropical squall lines, damaging winds, large hail, tornadoes and heavy convective precipitation potential, utilise an ingredients-based approach. A level of threat at a model grid-point is displayed when the component diagnostics that constitute the threat simultaneously reach pre-determined threshold values. The NTFGS threshold values are based on those found in the literature (for example, Treloar and Hanstrum 2002) and forecast experience. An example subset of the NTFGS threat algorithms and associated ingredients appears in Table 1.

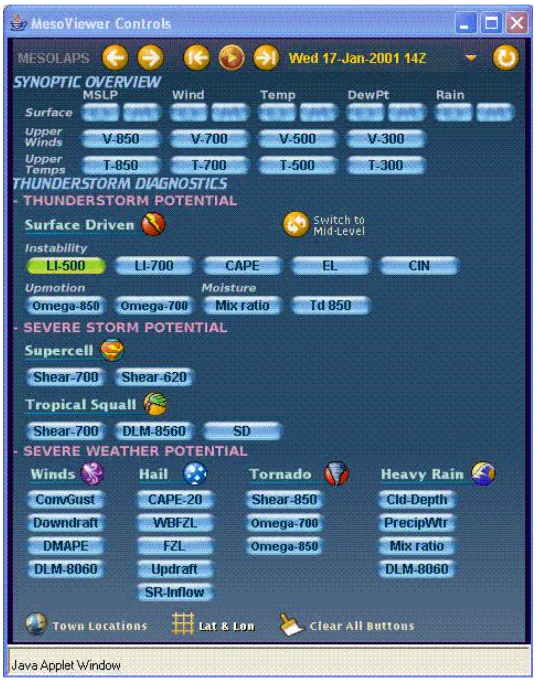

Fig. 1: The mesoviewer GUI of the NTFGS allows forecasters to view 3 hourly NWP fields, threat maps of thunderstorm and severe weather type and the component model diagnostics that constitute the threat.

One of the great strengths of the NTFGS mesoviewer is that it allows forecasters to efficiently overlay and composite model fields and algorithm threat maps. The algorithm ingredients can also be readily viewed. “In an operational setting this guidance can be used to focus the attention of forecasters onto observations in the threat areas to determine whether the signal in the model is also present in the real atmosphere“ (Hanstrum 2003).

Storm type	Algorithm Ingredients
Surface-based Thunderstorm (warm-season, 850 hPa temperature > 12C)	Lifted Index (500 hPa) ≤ -1.0 for lowest 50 hPa mixed layer Low-level ascent > 10 hPa.hr^{-1}. Convective inhibition |CIN| < 25 J.kg^{-1}. Cold cloud depth > 3.0km Updraft reaches –20C or colder (in order that electrification can occur).
Thunderstorm (elevated)	As for surface-based decisions except check for up-motion and instability above the surface up to 500 hPa.
Supercell (warm-season)	Conditions for surface-based convection met and: **Favourable:** Lifted Index (500 hPa) ≤ -4.0 Deep Shear (surface to 2.5-4km) ≥ 30 knots **Very favourable:** Lifted Index (500 hPa) ≤ -5.0 Deep Shear (surface to 2.5-4km) ≥ 35 knots.

Severe weather type	Algorithm Ingredients
Large hail (hail size ≥ 2cm)	Conditions for surface-based convection met and: **Favourable:** 75kts ≤ w < 100 kts WBFZL < 3.5km or w > 100kts WBFZL ≤ 4.2km **Very favourable:** w > 100kts WBFZL < 3.5km Note: updraft, w is both a function of the buoyant energy to –20 C and the storm-relative inflow

Table 1: NTFGS algorithm ingredients and thresholds for storm type threat and severe hail threat. Where
- Lifted Index is the temperature difference between a near-surface parcel lifted dry-adiabatically to saturation and then moist-adiabatically to 500 hPa and the environmental temperature at 500 hPa.
- CIN is the energy needed to lift an air parcel vertically and pseudo adiabatically from its originating level to its level of free convection.
- w is the updraft speed as calculated by

$w=\sqrt{(SRI)^2+(2CAPE_{to-20C})}$, where SRI is the storm relative inflow, storm motion is the 800-600 hPa mean wind and the inflow layer is the lowest 100 hPa AGL and CAPE $_{to\ -20C}$ is the Convective Available Potential Energy of a surface parcel lifted to the -20C level in the atmosphere.
- Wet Bulb Freezing Level (WBFZL) is where the temperature of an air parcel is zero, having been cooled adiabatically to saturation at constant pressure by evaporation of water into it, all latent heat being supplied by the parcel.

2.2. *Nowcasting Visualization - 3D-Rapic*

3D-Rapic (Purdam 2007) is a Linux OpenGL display system, written in C++, designed specifically for the display of volumetric (3 dimensional) weather radar data. The display allows the volumetric data to be interactively viewed in a number of different ways (Fig. 2), such as:

- PPI (Plan Position Indicator, constant radar elevation view);
- RHI (Range Height Indicator, constant radar azimuth view);
- Echo Tops (shows the highest echoes that exceed a given threshold. These are colour coded and 3D rendered according to height);
- VIL (a Vertically Integrated Liquid product calculated from the volumetric data to show the mass of water in a column above the earth's surface (units of $kg.m^{-2}$);
- CAPPI (Constant Altitude PPI, assembled from each PPI scan closest to the desired altitude).

A number of different radars and representations may be simultaneously displayed on the display screen. A key feature of the system is the speed and flexibility of use. The user has full control over viewing of the volumetric data.

The system was designed and built by the Australian Bureau of Meteorology and is now used operationally in several southeast Asian countries as well as being the main radar data viewing platform in the Bureau. It contains the necessary communications and database infrastructure to allow data from a number of volumetric and standard surveillance radar sites to be automatically collected, viewed and stored.

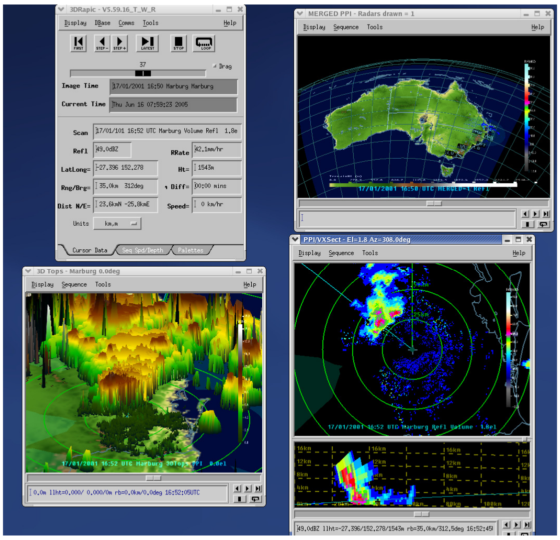

Fig. 2: 3D-Rapic interface showing the main GUI, a merged PPI window, 3D-Tops window and PPI/RHI window.

2.3. *Nowcasting, radar-based algorithms*

TITAN

The Thunderstorm Identification, Tracking Analysis and Nowcasting (TITAN) system (Dixon and Wiener 1993) is a radar-based application that identifies and tracks storm cells and provides short-term forecasts of their movement and size. Thunderstorm detection and forecasts are based on 3-D Cartesian radar data. The application has some geometric logic to deal with thunderstorm mergers and splits and tracks various parameters of the storm cell such as maximum dBZ value, cell top and bottom.

The application was initially developed at the National Center for Atmospheric Research (NCAR), Boulder, CO, USA, and has been integrated with the 3D-Rapic system for use in Australia.

In the TITAN system a 'storm' is defined as a contiguous volume that exceeds thresholds for reflectivity and size. The current reflectivity thresholds used in Australia are 35, 40 and 45 dBZ, which from experience cover most Australian storms, from the tropics to mid-latitudes and winter to summer.

WDSS

The Australian Bureau of Meteorology Research Centre (BMRC) has adapted the Severe Storm Analysis Program (SSAP) of the National Severe Storms Laboratory's severe-weather Warning Decision Support System (NSSL WDSS) for use with Australian radar data, with 3D-Rapic being the primary viewing platform. SSAP consists of severe weather detection and prediction algorithms. The SSAP components currently used in Australia are the Storm-Cell Identification and Tracking (SCIT) algorithm (Johnson et al., 1998) and the cell-based Hail Detection Algorithm (HDA, Witt et al. 1998).

The SCIT algorithm works differently to TITAN in that the radar data is used in its native polar state and a 'storm cell' is defined as the smallest contiguous volume with the largest contiguous reflectivity that exceeds a size threshold, using seven reflectivity thresholds (30 – 60 dBZ in steps of 5 dBZ). In essence it is identifying and tracking individual storm cores, whereas TITAN identifies and tracks the 'whole' storm, defining the exterior of the storm by a reflectivity threshold. Like TITAN, WDSS tracks various cell parameters. The HDA is currently being assessed in the Australian context but initial work indicates similar results to that reported in the USA (Witt et al., 1998).

As new Doppler radars are installed in Australia the Meso-cyclone Detection Algorithm (MDA, Stumpf et al. 1998), Tornado Detection Algorithm (TDA, Mitchell et al. 1998), and Damaging Downburst Prediction and Detection Algorithm (DDPDA, Smith et al. 2004), will be tested and brought online.

2.4. *Forecast Production - Thunderstorm Interactive Forecast System (TIFS)*

The Bureau developed the Thunderstorm Interactive Forecast System (TIFS) (Bally 2004) for interactively producing severe weather warnings and other forecasts from thunderstorm tracks, automatically diagnosed from radar data. TIFS is designed to apply recent advances in radar-based thunderstorm cell detection and tracking techniques to the efficient production of operational forecasts and warnings. The system ingests automated thunderstorm cell detections and tracks, allows graphical editing by forecasters, and produces graphical and text products from the edited data. The text generator uses a simple template filling approach. The graphical products include a map of areas that have been affected by storms, and are forecast to be affected by storms, as well as meteograms for selected locations. It is presently being introduced into forecasting operations in Australia. The current TIFS GUI is shown in Fig. 3.

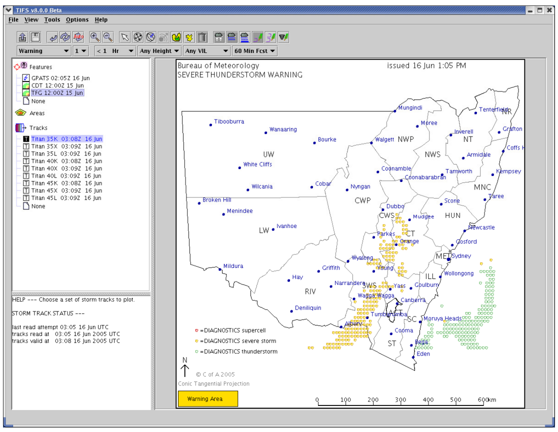

Fig. 3: TIFS GUI with a display of NTFGS thunderstorm forecast guidance over New South Wales.

3. CASE STUDY DISCUSSION

3.1. *Introduction*

The purpose of this case study is to showcase the end to end forecasting system and forecast process.

From 17 to 19 January 2001 a surface trough, aided by a vigorous upper system, produced three consecutive days of severe thunderstorms as it moved from northern New South Wales and through southeast and central Queensland in eastern Australia. The storms were notable for both their severity and their persistence beyond the usual diurnal cycle.

Between 2am and 4am local time [*](LT) on 18 January 2001 a long-lived supercell thunderstorm carved a strip of hail damage across Brisbane's northern suburbs. Reported hailstone diameter sizes ranged from golf ball through to tennis ball. This case study highlights the use of algorithms in aiding forecast decisions during this severe weather event.

3.2. *Outlook, NTFGS – Diagnosing the pre-storm environment*

The potential of the environment to support (severe) thunderstorms and severe weather is routinely assessed on a daily basis in a number of Australian state-based Regional Forecast Centres (RFCs). Forecast products defining the likelihood of (severe) thunderstorms and severe weather for that day are disseminated to various clients (Webb and King 2003, Deslandes 2003). NWP guidance is a particularly important tool for aiding forecaster assessment of the pre-storm environment. Correctly diagnosing the potential of the environment to support (severe) storms and associated severe weather is important for developing effective warning strategies.

We now direct our attention to what threat is revealed to a forecaster by the NTFGS algorithm guidance. We then discuss how an experienced, and well-trained forecaster, might analyse the model data to develop a conceptual model for the overnight dynamic forcing that would be consistent with the initiation of elevated, nocturnal convection. Such a conceptual model can be reinforced by observations. The meso-viewer facilitates easy viewing of the constituent algorithm ingredients.

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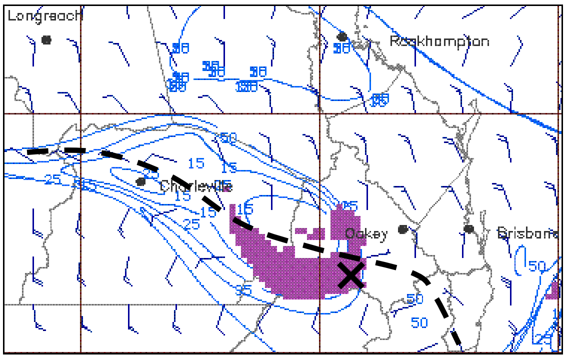
[*] Note that Local time (Eastern Standard Time) = UTC + 10 hours.

Composite maps of NTFGS threat and diagnostic fields valid at +3hours (midnight LT) and +6hours (3am LT) on 18 January are shown in Fig. 4. The +3hour NTFGS threat map (Fig. 4a) indicates the potential for surface-based thunderstorms over the largely unpopulated southern inland region of Queensland. The +6hour forecast (Fig. 4b), valid at 3am, and subsequent forecasts indicate no further overnight threat of surface-based thunderstorms for southeast Queensland.



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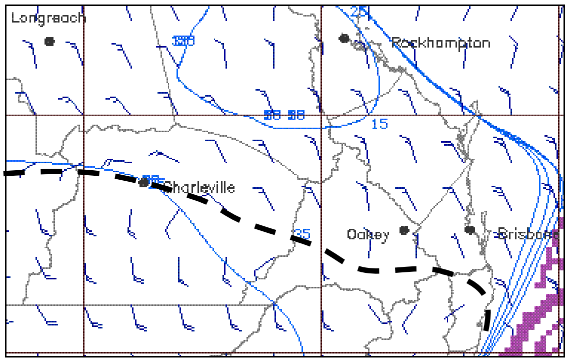


(b)

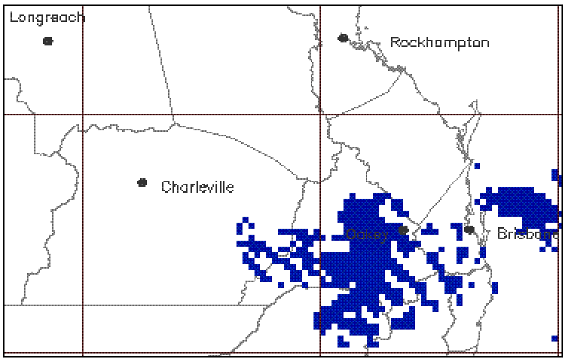
Fig 4: Meso-LAPS forecasts. Vector winds are at σ = 0.9988 (~10m AGL). The thick dashed line delineates the surface trough position. Convective inhibition (CIN) contour interval is 10 J.kg^{-1}. Major towns are included for reference.
(a) +3hr forecast valid midnight LT 18 Jan. Shaded area is surface-based thunderstorm threat as diagnosed by NTFGS. The cross indicates the radar-observed position of convective initiation for the event.
(b) +6hr forecast valid 3am LT 18 Jan.

Note that in the +3 hour model forecast valid for midnight LT on 18 January (Fig. 4a) the surface-based thunderstorm threat area is co-located with the inland portion of a NW-SE aligned trough and also coincides with areas of relatively small CIN magnitude (< 25 J.kg^{-1}).

In the +6 hour forecast valid at 3am LT (Fig. 4b) the convective inhibition (CIN) magnitude for near-surface parcels in the vicinity of the trough increases to values > 25 J.kg^{-1}. This increase in CIN magnitude near the trough is driven by decreases in the model surface temperature (not shown) and is primarily responsible for shutting down the surface-based thunderstorm threat after midnight.

However forecast maps of elevated thunderstorm threat (Fig. 5) show the potential for the initiation and persistence of non surface-based thunderstorms throughout the night over southeast Queensland.

The model-based algorithms indicate no overnight super-cell thunderstorm threat or large hail threat across southeast Queensland (threat maps not shown).



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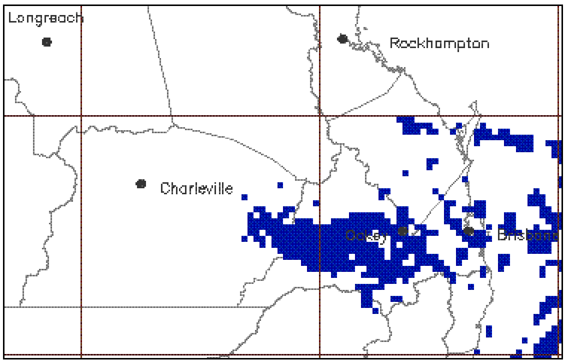
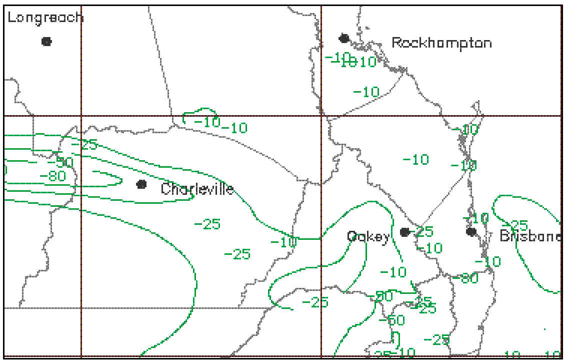


(b)

Fig 5: NTFGS forecasts of elevated thunderstorm threat area. Individual blue squares are centred on model grid points.
(a) +3hr forecast valid midnight LT 18 Jan.
(b) +6hr forecast valid 3am LT 18 Jan.

The nocturnal intensification of inland Australian troughs and associated fronts is a feature noted in previous studies (e.g. Deslandes 1999). Fig. 6 shows maximum values of ascent (between 850-700 hPa) above the nocturnal boundary layer more than doubling between midnight and 3am LT to the west-southwest of Oakey.



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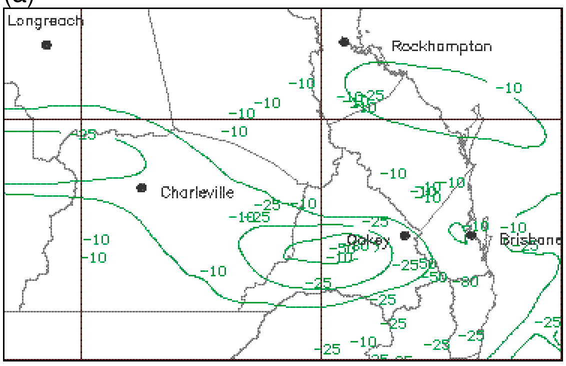


(b)

Fig. 6: Meso-LAPS forecasts. Contours of minimum values of omega (maximum ascent values) in $hPa.hr^{-1}$ in the 850-700 hPa layer. Contour interval is 10 $hPa.hr^{-1}$. Major towns are included for reference.
(a) +3hr forecast valid midnight 18 Jan.
(b) +6hr forecast valid 3am 18 Jan.

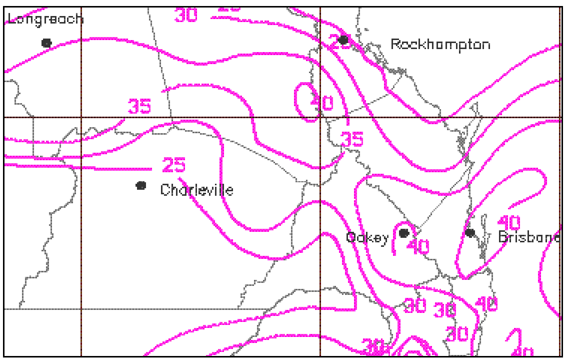
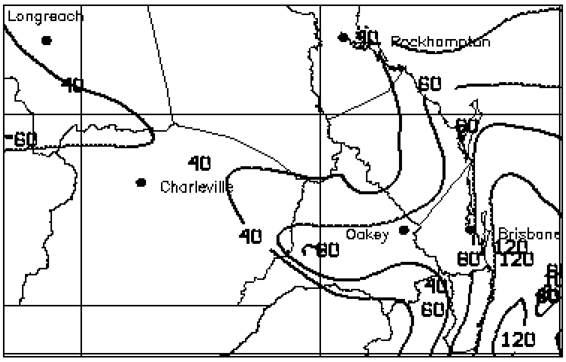


Fig. 7: Meso-LAPS +3hr forecast. Maximum values of shear in the near surface to 2.5-4km layer. Contour interval is 5 knots. Valid midnight LT 18 January. Major towns are included for reference.

Figure 7 shows the + 3hour forecast (valid midnight LT) of near surface to mid-level shear. It is calculated by using the greatest shear value when comparing the 0.9875 sigma level wind and all model winds in the 2.5-4km layer at each grid point. The exclusion of a forecast surface-based thunderstorm threat over southeast Queensland precludes a warm-season supercell threat being painted in the guidance at this time. However the co-location of +3hour forecast of elevated thunderstorm threat (Fig. 5) simultaneously with significantly large values (30-40 knots) of near surface to mid-level shear (Fig. 7) over southeast Queensland warrants further investigation to see whether a significant shear signal might exist in the real atmosphere. Severe convection decisions have since been linked to the non-surface based convection in the operational version of NTFGS.

The exclusion of an overnight forecast surface-based thunderstorm threat over southeast Queensland also precludes a hail threat being displayed in the NTFGS. Nine hour forecasts (valid at 6am LT) of the hail algorithm ingredients of updraft speed and wet-bulb freezing level (WBFZL) height appear in Fig. 8. The threat threshold requirements of updraft speed $\geq$ 75 knots and WBFZL height $<$ 3.5km that (in part) determine a favourable hail environment threat are met over parts of southeast Queensland. In essence two of the three NTFGS hail criteria were met; being strong updraft speed and relatively low freezing level, but the lack of surface-based thunderstorm threat meant that no hail threat was indicated.



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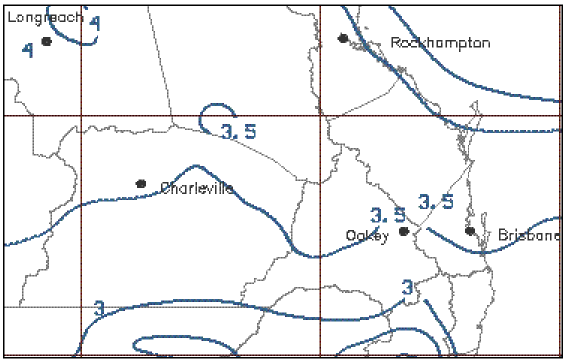


(b)

Fig. 8: Meso-LAPS +9hr forecast. Valid 6am LT 18 January.
(a) Updraft speed (knots) -a function of the buoyant energy to –20 C and the storm-relative inflow.
(b) WBFZL height (km).

In summary then, the NTFGS surface-based thunderstorm threat forecasts indicate the potential for surface-based thunderstorms initiating over inland southern Queensland at midnight LT. However values of low-level ascent three hours later in the forecasts at 3am are not strong enough to maintain lifting of near-surface parcels to their level of free convection (LFC) in the presence of the aforementioned increasing values of convective inhibition (CIN) magnitude. Elevated parcels in the presence of stronger lifting above the boundary layer are able to become positively buoyant and an elevated thunderstorm threat is depicted in the NTFGS algorithm output overnight over southeast Queensland (Fig. 5). These areas also coincide with forecast regions of deep shear, appropriately strong forecast updrafts and low wet-bulb freezing level heights conducive to large hail formation. Elevated supercellular convection has been documented by Davies (2004).

Such a conceptual model, derived from analysis of the model forecasts, is consistent with the observed sounding for Brisbane airport in Fig. 9 (valid 9pm LT on 17 January). Although the distance of the Brisbane sounding from the area of interest near Oakey is about 150km and may not necessarily represent conditions in threat areas over southern inland Queensland, it is the closest actual observation and does reinforce the conceptual model built from the NTFGS output. It is a common forecasting issue in Australia to have no observations near an area of interest, especially at night.

In Figure 9 there is an elevated inversion layer near 850 hPa. Parcels rising from above this elevated inversion level would be significantly buoyant through depth above their LFC and the convective inhibition of these parcels would be less than those parcels rising from below the inversion layer.

Vertical wind shear is important in determining convective organisation and the theory is largely based on the work of Rotunno and Klemp (1985). Tilting of the horizontal vorticity inherent in the ambient shear by a storm updraft leads to a feedback loop between the updraft and the horizontal vorticity with resultant updraft regeneration and propagation. Organised storms lead to increased probability of associated severe weather (Weisman et al. 2000).

In this case the 850-500 hPa layer is taken to be a representative shear layer for convection originating from above the elevated inversion, as deduced from the sounding in Fig. 9. Table 2 shows 850-500 hPa shear values of 28 knots.

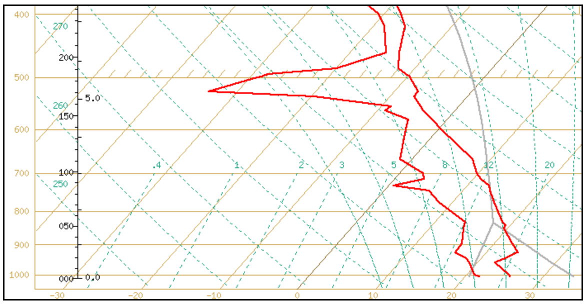


Fig 9: Brisbane observed sounding valid 9pm LT 17 January 2001.

Observed values of shear at midnight over southeast Queensland are computed by coupling upper winds from the observed Brisbane wind flight (valid at 9pm LT January 17) and midnight LT automatic weather station surface winds from Brisbane and Oakey. Observed shear values in Table 2 are consistent with the +3hour model shear forecast (Fig. 7).

Shear	Brisbane	Oakey
Surface – 700 hPa	39 kts	35 kts
Surface – 500 hPa	44 kts	40 kts
850—500 hPa	28 kts	28 kts

Table 2: Shear values at Brisbane and Oakey computed using the 9pm LT 17 January Brisbane wind flight and midnight LT surface observations at Brisbane and Oakey.

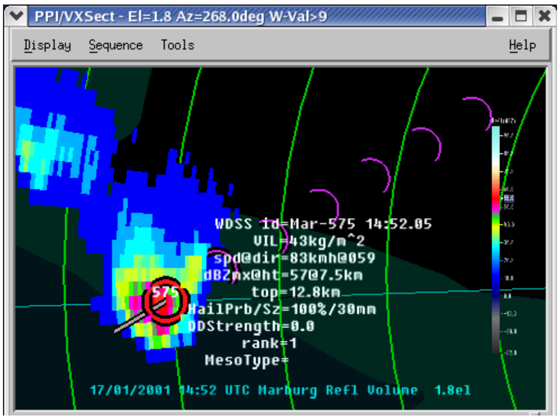
Thus a forecaster who intelligently explored the NTFGS output and had assessed the overnight environment would have been aware of the possibility of elevated severe convection in SE Queensland in the early morning period of 18 January. Now to the monitoring phase.

3.3. *Nowcasting, 3D-RAPIC – Diagnosing storms on radar*

In this section we will primarily demonstrate the current Bureau approach to diagnosing large hail as summarized in Richter and Deslandes (2007). The first detectable echoes, associated with an initiating cell, were evident over southern inland Queensland some 230km to the west southwest of the Marburg 10cm weather watch radar at 14:12 UTC, (12:12am LT). The TITAN and WDSS algorithms greatly enhance the forecaster's ability to be able to diagnose and forecast the evolution of the storm core. For example in the 10 minute period to 14:52 UTC (12:52am LT) WDSS output showed the core rapidly intensifying with maximum values of elevated reflectivity around 7.5km increasing to 57dBZ. Fig. 10a shows the cell at this time. The 1.8° elevation PPI scan is overlain with WDSS past cell track and 10 minute forecast positions of the core out to 60 minutes. The core is forecast to track to the northeast at $83km.hr^{-1}$.

Using a more traditional nomogram approach (Treloar 1998), based on a climatology of hail events, forecasters set the CAPPI level to a threshold height based on the height of the environmental freezing level. Storms displaying 50dBZ reflectivity values through this CAPPI threshold are considered to have a significant likelihood of producing large hail and warrant further analysis using the 3D-Rapic radar display software.

In Fig. 10c the CAPPI display height has been set close to 8km based on the 1100 UTC (9pm LT) Brisbane airport sounding's freezing level height of 4.5km. 50dBZ reflectivity values clearly extend through 8km at 14:52 UTC (12:52am LT) indicating the possibility of severe hail. 3D-Rapic software allows forecasters to quickly and easily view a dynamically generated, simulated RHI scan in real-time simply by dragging a radial through the storm core on the PPI display. The simulated RHI shown in Fig. 10b indicates a strong elevated core of reflectivity extending from 4km through to 12km indicating a powerful updraft. The WDSS Maximum Expected Size Hail (MESH) indicates severe (3cm) hail for the first time (not shown); this reinforces the presence of severe hail indicated by the hail nomogram and inspection of the radar data.



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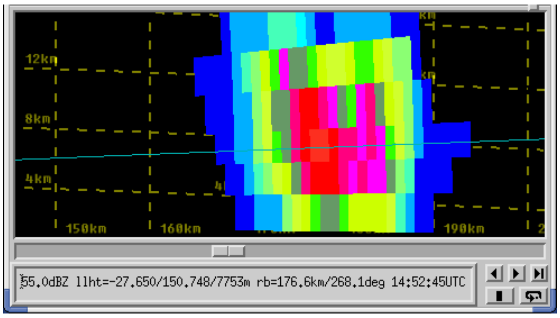

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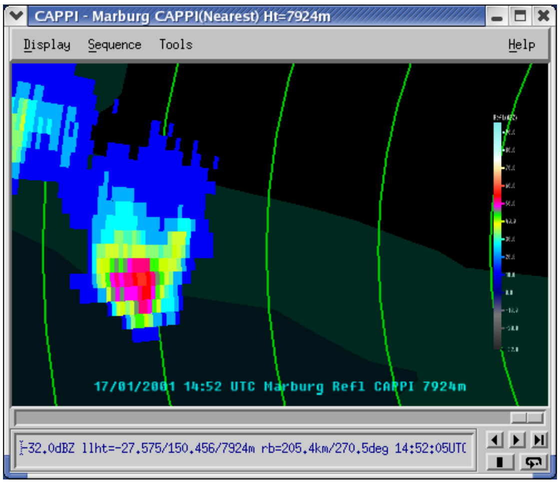


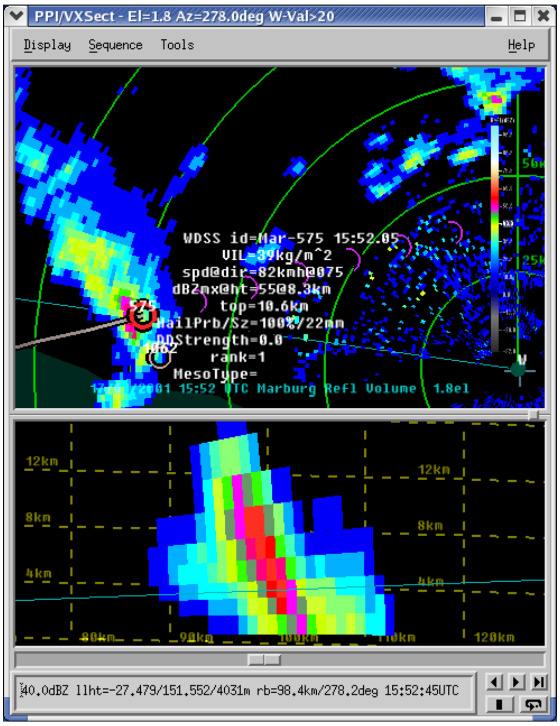
(c)

Fig. 10: 3D-Rapic display at 14:52 UTC (12:52am LT)
(a) PPI display.
(b) Simulated RHI display.
(c) CAPPI set to 8.0km.

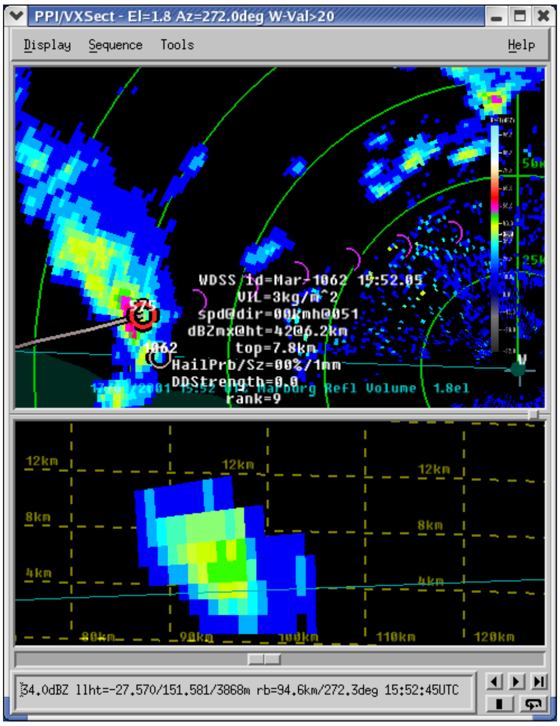
At this stage forecasters must address what type of environment the cell is moving into, whether the storm is likely to persist and whether to issue a Severe Thunderstorm warning for the region using the TIFS forecast preparation software. WDSS forecast tracks also indicate that this storm may enter the Brisbane metropolitan warning area within 60 minutes if it persists on its present track. Such considerations are made difficult by the lack of observations in the vicinity of the storm. It is clear that forecasters coming to the radar at this time without knowledge of the pre-storm environment would be greatly disadvantaged relative to those that had gone through a pre-storm diagnosis similar to that presented in section 2 of this paper.

Over the ensuing hour the cell is tracked as the top-ranked feature by the SCIT algorithm. At 15:52 UTC (1:52am LT) the long cell track path (~95km), is displayed in Fig. 11a. The storm lifetime of 80 minutes is now well beyond the ordinary cell convective time scale of 25 minutes (Doswell 2001). The forecaster now has direct evidence of an immediate storm environment that is capable of supporting long-lived convection.

MESH continues to indicate the threat of severe (2.2cm) hail at this time. WDSS and TITAN forecast tracks show the cell continuing to move northeast through the Brisbane metropolitan warning area. The WDSS SCIT algorithm identifies a weak VIL core on the southern flank of the original core. A close inspection of the radar base data in Fig. 11 indicates the formation of new updrafts, and associated elevated echoes in this area (Fig. 11b). Ten minutes later at 16:02 UTC, or 2:02pm LT, (radar data not shown) the southern most core (WDSS cell 1062) becomes the dominant, top ranked feature in the SCIT table. Over the ensuing 50 minutes this new cell tracks towards the east-northeast while the previous dominant cell (WDSS cell 575) collapses.



(a)

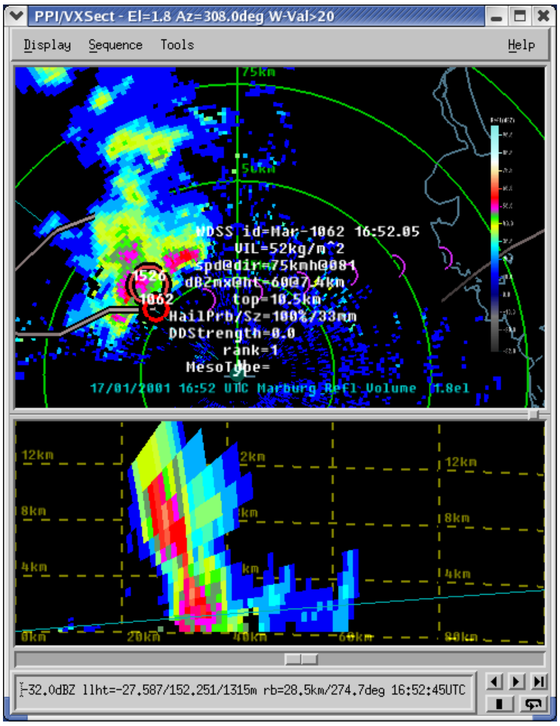


(b)

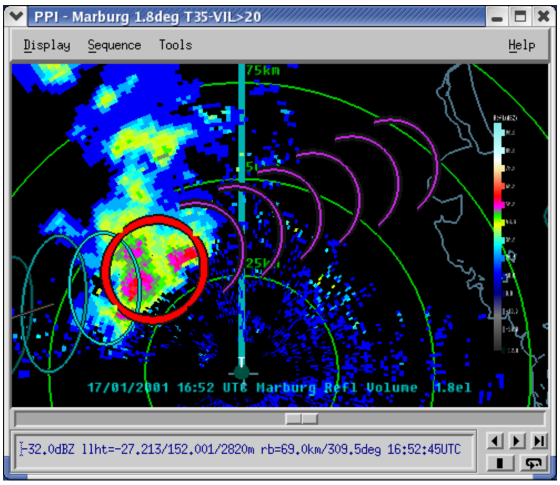
Fig. 11: 3D-Rapic display at 15:52 UTC (1:52am LT)
(a) PPI and simulated RHI display centred on WDSS cell 575.
(b) PPI and simulated RHI display centred on WDSS cell 1062.

At 16:52 UTC (2:52am LT) Fig. 12 shows 2 storm cores indicated by the WDSS algorithms (WDSS cells 1526 and 1062) approximately 30km to the northwest of the Marburg radar. The most intense core displays maximum reflectivity values of 60dBZ to 7.4km. Both TITAN and WDSS forecast tracks (Fig. 12) continue to the east northeast (which is across the northern suburbs of Brisbane). MESH indicates 3.3 cm diameter hail.

Analysis of the RHI display (Fig. 12a) reveals a Weak Echo Region (WER) on the southeast flank of the cell complex which is an indication of a strong updraft (Bluestein et al. 1983).



(a)



(b)

Fig. 12: 3D-RAPIC display at 16:52 UTC (2:52am LT)
(a) PPI and simulated RHI display (along light blue line through cell 1062 in PPI) with WDSS overlay.
(b) PPI display with TITAN overlay.

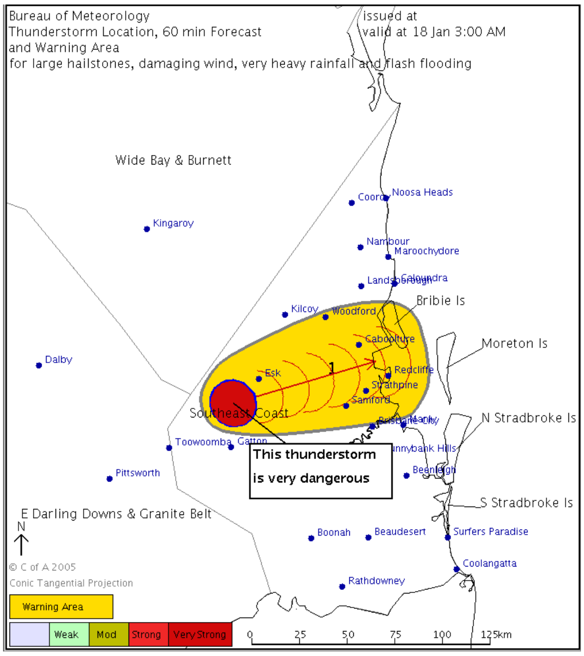
3.4. *Warning preparation - TIFS*

Figure 14 shows a graphical warning and associated meteogram constructed using the TIFS warning preparation software. It is based on the TITAN overlay as displayed in Fig. 12b, i.e. using the 16:52 UTC (2:52am LT) radar image with the TITAN cell advected forward 8 minutes using the current TITAN speed and direction.

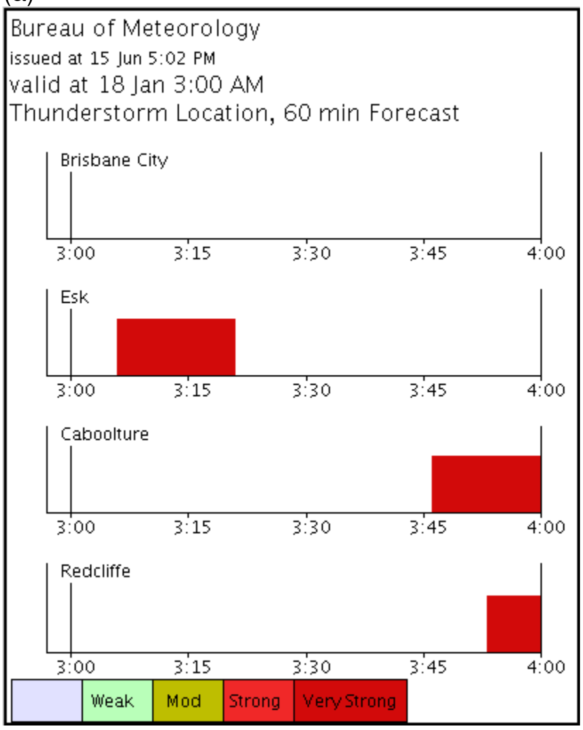
The philosophy behind TIFS is that the forecaster graphically selects and edits guidance to create a warning, TIFS then saves these forecast decisions and automatically generates a range of graphical and text warning products, guaranteeing consistency.

For example in Fig. 14a with the forecaster having decided on the validity of the TITAN forecast track (they have the option to interactively change the forecast track) and adding the warning area, Fig. 14b (a site specific meteogram product) is automatically generated. Text warning products (not shown) are also automatically produced.

Forecaster feedback from Australian forecast offices where TIFS is being used operationally is that the warning preparation time has been significantly reduced while the range of warning products has been increased (Bally 2004). The TIFS infrastructure also allows products to be easily tailored for different clients, while ensuring consistency.



(a)



(b)

Fig. 14: TIFS produced Graphical Severe Thunderstorm warning products. The grading from Weak to Very Strong is for the indicated thunderstorm and is based on simple thresholds.
(a) Threat area map with the severe thunderstorm and its expected track in red and the warning area in yellow.
(b) Site specific Meteogram product where the blocks of red colour indicate the time during which the thunderstorm is expected to affect the given location.

3.5. *The unfolding of the event*

In the ensuing 40 minutes the storm (WDSS cell 1062) displays maximum reflectivity values of 63dBZ to 7km and maximum VIL values of 60kg.m^{-2}. A Bounded Weak Echo Region (BWER) is evident in the 3D-Rapic RHI display at 17:32 UTC (3:32am LT, not shown) whilst the storm is over the northern suburbs of Brisbane. Such reflectivity features are indicative of supercell storms (Doswell 1985). MESH indicates the potential for 3.5 - 4.0cm diameter hail.

By 18:02 UTC (4:02am LT) the cell had moved out over water and from 18:22 UTC rapidly weakened as indicated by the time series of various WDSS cell parameters in Fig. 13.

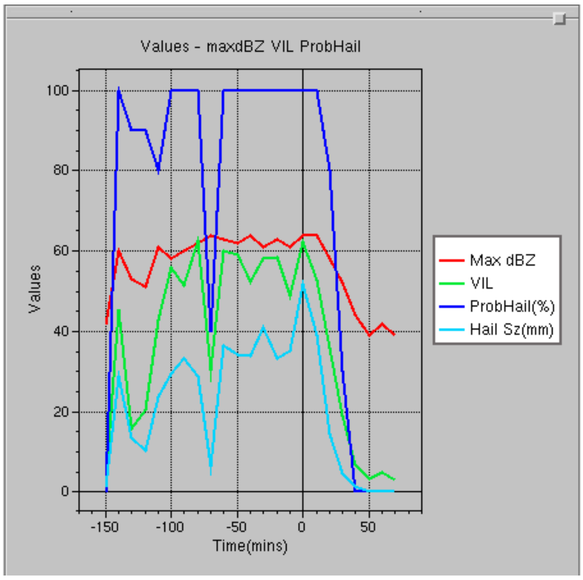


Fig. 13: 3D-Rapic display of a time series of Max dBZ, VIL, Probability of Hail (%) and Hail Size (mm) for WDSS cell 1062 where time =0 minutes is 1822 UTC (4:22am LT)

As indicated in the introduction, between 2am and 4am local time a long-lived supercell thunderstorm carved a strip of hail damage across Brisbane's northern suburbs. Reported hailstone diameter sizes ranged from golf ball through to tennis ball. Some examples are shown in Fig. 14.

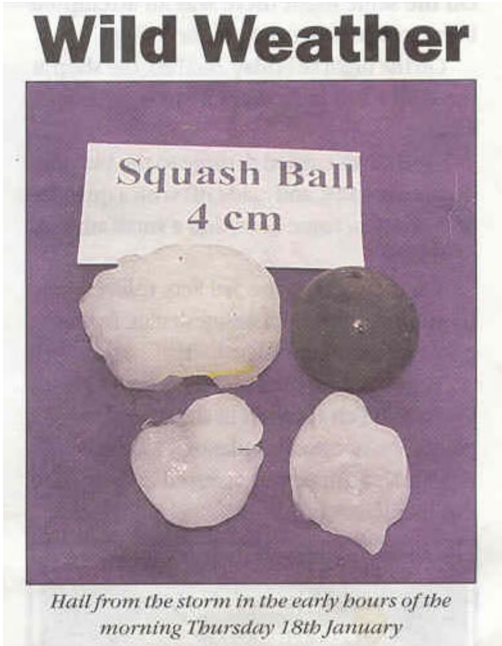


Fig 14: Examples of some of the hail during the event compared with a squash ball.

4. TRAINING AND ASSESSMENT ISSUES

The process of developing the training programs and associated radar-based case studies has also facilitated improvements in the ongoing development of the systems themselves and associated operational service procedures.

The approach to training adopted for this project is rooted in severe thunderstorm and radar competencies (Bell 2003). These competencies are derived as a set of minimal skills and concept knowledge that fully span the actual forecast process. The competency approach ensures that the training resources are highly focused on only addressing the skills and knowledge that forecasters require.

Indiviual training programs are rolled out into the regional forecast offices employing a train-the-trainer model. Regional trainers are brought together and taught by content experts.
The development of training material is carried out by the regional trainers themselves, coordinated through a central workshop forum and follow-up train-the-trainer days to revisit the supporting background knowledge. This methodology has ensured a strong sense of ownership and understanding of the training material by the local trainers. Beyond the training material development, regional trainers have a much stronger understanding of the local office culture and local forecast procedures than centrally based trainers and are directly available to office staff after the official training has concluded.

Training and assessment methods follow a three-tiered structure. Core competencies address the basic capability of using the systems involved (e.g., “which button does what” in the volumetric radar data visualisation software). Training is delivered through hands-on exercises and assessed by means of core competency tick sheets. Meteorological concepts needed to understand radar and thunderstorm behaviour used to be taught through lecture-style ‘powerpoint’ sessions, but are now increasingly rolled into web-based modules that are self-guiding. Concepts are assessed explicitly through web-based quizzes as part of a learning management system. Finally, the application of core competencies and concepts are drawn together in either self-paced case studies or time-synchronised simulations via the displaced real-time simulator (DRTS). Increasingly, the most important form of forecaster competency assessment is carried out through individual DRTS simulations.

The increasing difficulties in releasing operational staff for training and assessment have required training strategies that ensure trainee availability. These strategies include the recall of recently retired staff to backfill operational positions or to target only certain staff (e.g., severe weather sections). In more extreme circumstances, staff cannot be released at all for training. In these cases, training can still be delivered through a combination of self-guided pre-training reading, followed by on-the-job observation, feedback and exercises and an eventual two-way interview.

5. DISCUSSION AND CONCLUSIONS

It is clear from this case study event that radar-based algorithms can support decision making throughout the severe thunderstorm warning process. If forecasters are to make the best possible decisions based on the data at hand it is important that they are able to understand and assess the validity of algorithm output by analysing the (NWP or radar) base-data in the context of observations from the storm environment.

The NWP data provides a dynamically, spatially, and temporally consistent dataset in which to apply conceptual models and interpret observations. Specifically, in this event the National Forecast Guidance System (NTFGS) indicated the potential for elevated, nocturnal convection over southeast Queensland. Despite no overnight supercell or hail threat being indicated by the NTFGS (due to the logic at the time of hail threat with only surface-based convection, since changed), further analysis of the underlying Meso-LAPS numerical model data showed the ingredients for both to be in place overnight throughout southeast Queensland. Forecasters validating the NTFGS algorithm ingredients against sparse observations over southeast Queensland find such signals later existed in the real atmosphere. Senior forecasters prepared for the possibility of overnight severe storms are in a better position to deploy staff appropriately in order to facilitate the issue of severe thunderstorm warnings.

Once storms had formed, the WDSS Hail Detection Algorithm (HDA) indicated that the long-lived cores were likely to be associated with severe hail. The current Australian implementation of the radar-based algorithms have no “knowledge” of the immediate storm environment (apart from the freezing level and –20C height information utilised by MESH within the WDSS HDA). Forecasters must use other data such as observations, coupled with NWP data, to determine whether cells might encounter environments that are conducive to continuing convection and severe weather.

In this particular case the task of using surface observations to assess the buoyancy of the immediate storm environment was made difficult because the storms initiated in relatively data sparse regions. If the updrafts associated with elevated cores over southern inland Queensland were drawing inflow from above the overnight inversion as postulated, then surface observations in the path of the storm cannot be used anyway to assess updraft buoyancy in the immediate storm environment.

Forecasters must exercise extreme radar vigilance during events and analyse the base radar data for storm structure features such as WERs or BWERs that are indicative of self-sustaining, powerful updrafts such as were observed as the storm cores approached and traversed the Brisbane suburbs.

Once forecasters decide to issue severe thunderstorm warnings for an event, the use of the graphical severe thunderstorm warning dissemination software TIFS has been shown to facilitate the timely issuing of consistent graphical and text cell-based warnings.

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