8.2 OVERVIEW OF SYDNEY WEATHER DURING THE FORECAST DEMONSTRATION PROJECT

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1. INTRODUCTION

The World Weather Research Program (WWRP) Sydney 2000 Forecast Demonstration Project (FDP) was conducted over the period 2 September to 21 November 2000. The project involved short-term forecasting systems and associated staff, from Australia, the United Kingdom, the United States and Canada. Most systems continued operating unattended after the formal end of the program. The systems were collocated in the New South Wales Regional Office of the Australian Bureau of Meteorology in Sydney. The project goal was "To demonstrate the capability of modern forecast systems and to quantify the associated benefits in the delivery of a real-time nowcasting service". Other FDP related papers are in this preprint volume. The FDP was conducted over the area shown in Keenan et al. (2001).

Spring, from September to November in the Southern Hemisphere, is a transition period between the influence of the predominantly westerly airstream of the winter months and the easterly airstream of the summer months. It is also the driest season in the Sydney area. Climatologically during this season, there is an increase in the frequency of thunderstorms and severe thunderstorms. Sea breezes also increase in frequency, strength and inland penetration, and cold fronts approaching from the south become more common.

During the Spring and Summer months, thunderstorms tend to develop on the higher terrain in the west and southwest in the late morning, and reach the coast near Sydney in the late afternoon (Matthews and Geerts, 1995). A limited study of radar data (Potts et al., 2000) indicates that their maximum intensity is usually reached on the lowest foothills of the mountains and the coastal plain.

Radar-based severe thunderstorm detection techniques in Sydney have, to date, been based on the manual interpretation of reflectivity structures. These include techniques outlined by Lemon (1980), where the juxtaposition of features such as storm top, mid-level overhang and low-level reflectivity gradient are investigated. The identification of significant storm structures such as a Bounded Weak Echo Region (BWER) in the storm's mid-levels are also utilised. Burgess (1990) suggested this feature is a good indicator of mid-level mesocyclone rotation and therefore supercell structure. Distinctive low-level reflectivity echoes are also assessed, such as a hook or appendage on the storm's rear inflow flank (Forbes, 1980) or those patterns presented by Moller et al. (1990) as representative of the evolution of high precipitation supercells. These latter include a persistent WER notch on the storm's inflow side, persistent high reflectivity levels, strong reflectivity gradients on the inflow flank and above average storm size.

Specific guidance on hail size is provided by locally-developed nomograms (Treloar, 1998). These relate radar measurements of Vertically Integrated Reflectivity and the height of the 50 dBZ reflectivity surface, normalised with the height of the freezing level from upper-air proximity soundings, to four hail size classes. These nomograms were adapted for use in the Canadian Radar Detection System (CARDS) used in the FDP (Burgess et al, 2001).

In the next section we shall discuss the weather during the FDP, then ground and sea clutter problems associated with the Doppler radars. Following that section the major part of the paper concerns forecasting issues, where boundaries develop and how they progress, the development of thunderstorms, their movement and severity, southerly wind changes, and how the data were used to assist forest fire fighting operations.

2. WEATHER DURING THE FDP

The Spring of 2000 was initially unusually hot and dry over the FDP area. During September, maximum temperatures were mostly at least 2ºC above average and rainfall was well below average. Frequent windy periods occurred early in the month and there were several forest fires in the Sydney area. One of these was close to the operational Doppler radar being used by the FDP systems. In October maximum temperatures and rainfall were close to average. November maxima were a little below average but rainfall was well above average.

In the Sydney Metropolitan area, thunderstorms occurred on five days in September, two in October and five in November. The only confirmed severe thunderstorm occurred on 3 November. This supercell thunderstorm, discussed in detail by Sills et al. (2001), produced three weak tornadoes, hail 7 cm in diameter, flash floods and strong surface winds. The paucity of severe thunderstorms during the FDP was unfortunate for the purposes of the Project, restricting the testing of three of the systems. However, days without thunderstorm activity were not devoid of notable features. Interesting days, based on radar

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data during the FDP were classified into the following categories: widespread stratiform rain (8 days); convective <40 dbZ (10); convective >40 dbZ (16); and clear air (15). Clear air days had interesting features such as convective rolls or boundaries.

3. CLUTTER PROBLEMS

Sydney is a topographically complex area. This is exacerbated by the location of the Kurnell Doppler radar near the coast (Fig. 1.) and close to a suburban location. Therefore both ground and sea clutter are serious quality control issues. For manual analysis, the forecasters disregard the sea clutter. The automated algorithms either masked the off shore regions or rejected sea clutter signals because of the lack of height continuity. Occasional anomalous propagation produced spectacular sea clutter echoes with intensities exceeding 30 dBZ and with distinct wave features out to ranges beyond 100 km. The Blue mountains west of Sydney show clearly on the radar data. Some of the clutter is removed from the radar data stream using filtering techniques, but there is inevitably some leakage. Particular problems were posed because of the dual pulse repetition rate using on this radar. In the radar operation, a single set of filters is used for both pulse rates, and thus have different effective widths, and this produces some spoking in the reflectivity images. The worst case for wind data quality was when strong low level winds, approximately twice the Nyquist velocity for the individual radar beams, combined with intense clutter over the Blue Mountains. In this case the velocity data was extremely noisy and basically unusable.

4. FORECASTING ISSUES

One of the major issues facing forecasters is whether thunderstorms that develop on the mountains and move towards the Sydney area will intensify or decay. The importance of low-level boundaries is well known in relation to thunderstorm development and intensification. Other factors affecting storm longevity include the direction in which they translate, the potential buoyancy of the boundary layer air and the change in the vertical wind shear encountered by the storm. These are discussed by Wilson et. al. (1998).

The importance of boundaries during the FDP was not confined to thunderstorms. The safety of people near forest and grass fires and efficient operations at Sydney Airport were also dependent on accurate timing of boundaries. Boundaries were seen to develop both within the FDP area and externally before moving into the area. Significant boundaries within the area developed due to seabreezes, the convergence of anabatic winds near mountain ridges, the outflow from precipitation areas, and the development and progression of pressure gradient winds that displace the offshore or onshore flow. The most important external boundaries are cold fronts.

The Doppler data revealed the complexity of position of the sea breeze front. In weak sea breeze situations, its inland penetration could vary considerably and be influenced by even relatively low terrain. Stronger sea breezes, such as on 5 October (Fig.1), achieved deep inland penetration. Being closest to the coast, the Kurnell radar was first to detect sea breeze fronts.

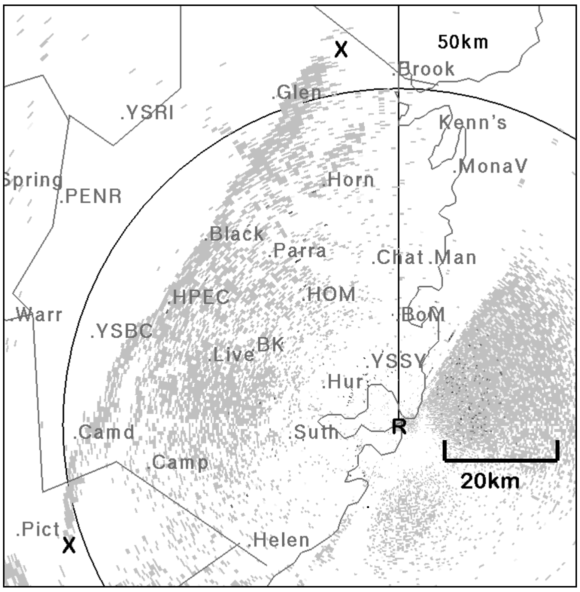

FIG. 1. Kurnell radar reflectivity image on 5 October 2000. The sea breeze is penetrating 30-40 km inland as marked by the X's. The radar is at R. The echoes to the east of the radar are sea clutter.

The radar at Badgery's Creek (YSBC in Fig. 1.), being sited well inland, was the most useful in locating boundaries that formed over the mountains in the west of the project area. On 23 October, storms developed over high terrain in the convergence between anabatic winds, which was clearly visible in the Doppler data. One storm was quasi-stationary for more than two hours.

Outflow boundaries were relatively rare during the FDP period. On 26 September, a supercell thunderstorm developed well to the northwest of the FDP area. It produced a gust front that moved into the area. Storms developed late in the evening when a wind shift from the ocean interacted with this gust front. The most notable outflow boundary day was on 3 November. Outflows were evident from most storms and their interaction was important in the formation of new cells. The most severe storm moved along the sea breeze front, contrary to the direction it could be expected to move based on the wind field in which it was embedded.

Boundaries caused by the displacement of onshore or offshore flows by the gradient wind occurred on several days. Usually, the displacement of an onshore flow causes a temperature rise and stronger winds. These changes are of particular interest to firefighters and affected some serious wildfires that occurred during September. The mesoscale automatic weather station network (mesonet) and radar data, used together, allowed forecasters to provide accurate information when briefing firefighting agencies on the timing and strength of wind changes. On a number of occasions gusty westerly winds were seen to develop at high elevations to the west of Sydney and eventually extend further east. The eastern boundary of the westerlies was seen when looping radar imagery as a fine non-continuous line, identified by forecasters by the uniform eastward movement and further located using the mesonet. Fire agencies were able to remove personnel from the fireground prior to the onset of dangerous fire weather conditions following advice from forecasters after timing one of these fine lines.

There were seven marked cold fronts during the FDP period, all visible on radar. Three of these, on 21 September and 10 and 27 October produced gusts at Sydney Airport sufficiently strong to be called southerly bursters (Colquhoun et al., 1985). Wind changes on 27 October were particularly interesting as the sea breeze retrogressed, being displaced by the pressure gradient wind during the late afternoon, prior to the arrival of the southerly burster. The most complex cold front, which did not reach burster strength, was on 8 October. The wind change to the south was accompanied by a rise in temperature. About 40 minutes later the wind strengthened and the temperature fell by about six degrees. The temperature and dewpoint temperature changes in the first 40 minutes of the onshore flow were indicative of two roll vortices in the head of the change, with the first rotating in a counter clockwise sense when viewing a north/south vertical cross-section from the west. Figure 2 shows and example of a southerly change affecting the FDP area on 15 October.

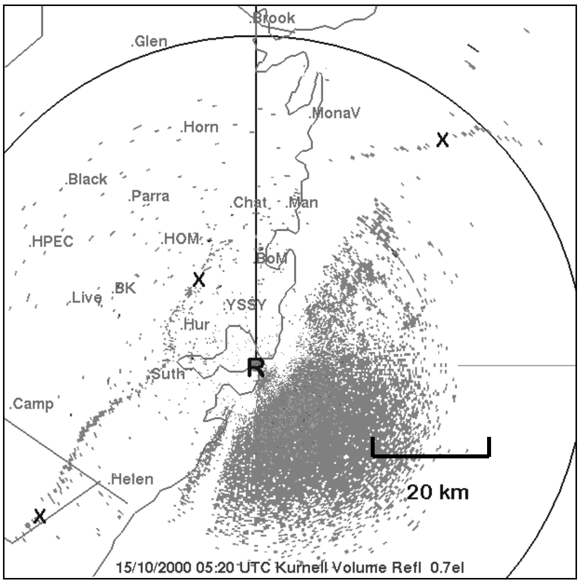

FIG. 2. Kurnell radar reflectivity image showing a southeasterly change affecting the FDP area extending between the three points marked X. The radar is located at R.

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