P474 SYDNEY AIRPORT WIND SHEAR ENCOUNTER - 15 APRIL 2007

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1 INTRODUCTION

At approximately 0923 UTC, 15 April 2007 a Boeing 747 encountered wind shear while attempting to land towards the south on runway 16R at Sydney Airport on the east coast of Australia. The aircraft was about 100 ft above ground level when there was a rapid loss of airspeed and the pilot reported a sensation of being pushed down and sideways. At that time the pilot initiated a wind shear escape manoeuvre as the enhanced ground proximity warning system (EGPWS) sounded a wind shear alert. The aircraft touched down heavily with a maximum vertical acceleration recorded at 2.34g causing the dislodgement of a number of ceiling panels. Three seconds after the initial touchdown the aircraft touched down firmly again and then climbed to go round and make a successful landing several minutes later.

In this study we examine meteorological data and aircraft Flight Recorder data and show the aircraft encountered a decaying dry microburst that developed over the approach end of the runway as a line of high based thunderstorms moved over the airport.

This event has been of interest to airlines in Australia as there are no operational wind shear alert systems in the country. Following from this event a study is currently underway to investigate technology options for a wind shear alert system at Sydney Airport.

2 DATA

The data used in this study includes radar data from the Bureau of Meteorology's Sydney 10 cm weather radar located 45 km south-southwest of Sydney Airport and the Kurnell 5 cm weather radar located 9 km south-southeast of the airport. The Kurnell radar records volumetric Doppler radar data with an update rate of 5 minutes.

One-minute automatic weather station (AWS) data from stations around the Sydney Basin was available together with high-resolution wind data from a network of anemometers located at the runway thresholds on the airport and on the Kurnell Wharf on the south coast of Botany Bay. The high resolution anemometer data is available at 10 second intervals and provides 10 second averages of the wind at each location.

Flight Recorder Data from the aircraft is also presented.

3 WEATHER SYNOPSIS

The mean sea level synoptic weather chart for 0600 UTC (1600 LST), 15 April 2007, (Figure 1) shows a trough across western New South Wales (NSW) separating two high pressure systems, one centred over the Tasman Sea and the other to the west near Adelaide. In association with the passage of a front at higher latitudes the trough moved gradually east and eventually passed through Sydney in the early morning of 16 April bringing a southerly wind change. As the surface trough moved east an upper level trough amplified across the north of NSW with a northwest-southeast orientation. This caused westerly winds in the middle and

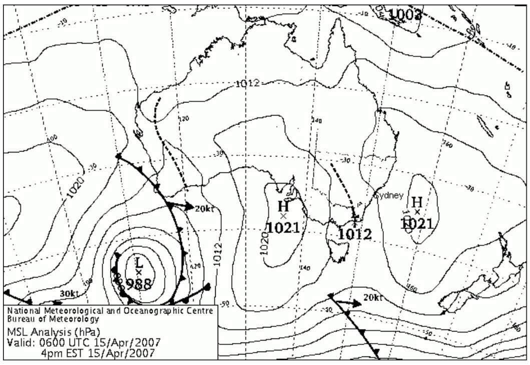

Figure 1. Synoptic weather chart for 0600 UTC (1600 LST) on 15 April 2007 showing surface trough lying across western NSW.

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upper troposphere over Sydney to back to the southwest.

The weather in Sydney on 15 April was initially fine with little cloud and light northwest winds. During the day the wind shifted northeast and strengthened to around 15 knots as a sea breeze became established. Sydney Airport is on the coast and the vertical temperature profile at 0500 UTC (1500 LST) (Figure 2) shows a cool moist boundary layer with an inversion around 1000–1500 ft associated with the sea breeze. Above the low-level inversion the air was warmer and potentially unstable with northwest winds backing to southwest with height. West of Sydney the Great Dividing Range extends north-south with terrain to 1500-3000 ft and the surface winds over the mountains were north-westerly.

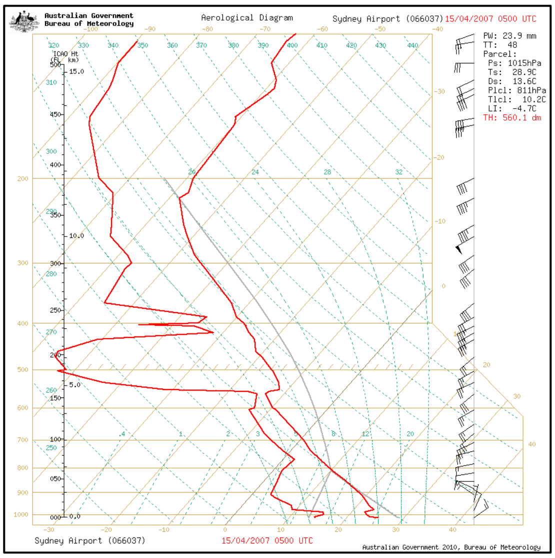


Figure 2. Vertical profile of temperature, dew point and wind (kt) at Sydney Airport (0500 UTC, 15 April 2007).

In situations like this the onshore maritime airflow at low levels and associated inversion typically inhibits the development of convection over coastal areas of Sydney. However, added diurnal heating and convergence over the mountains can result in storm development in a potentially unstable atmosphere. With the west to southwest steering flow these storms will typically move east to northeast over coastal areas of Sydney. In many cases these storms will dissipate when they move off the mountains and over the stable layer on the coast (Potts et al, 2000).

The radar data for 15 April 2007 showed isolated showers and thunderstorms developed over the mountains around 0400 UTC (1400 LST) and moved northeast at 20 knots. Initially the convection decayed as it moved off the mountains but later in the day isolated cells moved across the coast. The convection was high based with a cloud base around 10,000 ft consistent with a mixed parcel lifted from around 900 hPa (3000 ft) in Figure 2. Figure 2 shows relatively dry air below cloud base apart from the cooler layer near the surface.

The cluster of high based showers/storms which caused the microburst at Sydney Airport first appeared on radar to the southwest of Sydney around 0630 UTC and moved across the Airport in the period 0900-1000 UTC. A gust front preceded the storms and this moved across the airport around 0910 UTC bringing southwest winds 15 to 20 knots. Although thunder was heard there was very little precipitation on the ground at the airport and no reduction in visibility as the storm passed over. By 1000 UTC the storm complex had cleared to the east of the Airport and winds had returned to the prevailing northeast direction.

4 MICROBURST OBSERVATIONS

Figure 3 shows a sequence of radar data from the Kurnell Doppler radar and high resolution wind data from the anemometer network on Sydney Airport for corresponding times in the period 0905–0930 UTC.

0905 UTC: The radar data shows the line of storms around 9 km southwest of the airport moving to the northeast around 20 kt. The anemometer data shows northeast winds 10-15 kts over the airport with a southwest wind at the Kurnell wharf associated with the gust front ahead of the line of convection.

0915 UTC: By 0915 UTC the gust front has passed over the airport establishing southwest winds at 15-20 kt across the airport. At this time the wind at Kurnell has shifted northerly 15-20 kt as a convective cell moved over the anemometer.

0920 UTC: By 0920 UTC the leading edge of the line of convection had moved over the airport. The associated radar reflectivity over the airport is 20-40 dBZ though there were more intense cells to the south. The airport anemometer data shows a well defined divergent outflow over the north end of runway 16R associated with the developing microburst. This developed in the previous minute. Due to the low radar reflectivity at low levels the microburst was not observed in the Doppler velocity data.

0921 – 0924 UTC: The microburst is evident in the anemometer data over the north end of runway 16R and was most intense in the period 092101-092201 UTC. At 092201 UTC the aircraft was around 6 km north of the threshold for runway 16R. By 092301 UTC the wind at the threshold of runway 16R has shifted westerly at 12 kt suggesting the centre of the microburst has shifted to the north. At this time the aircraft was 1.3 km north of the runway threshold at an altitude of 210 ft and the aircraft FDR data (discussed in the next section) recorded a wind of 220/15 kt.

0925 UTC: At this time the radar shows reflectivities of 30-40 dBZ over the airport with the cell core just to the east. Based on ceilometer data the cloud base for these cells was 9000 ft with very little precipitation at the ground and no reduction in visibility. There are north to northeast winds around 10 kt at the north end of the airport suggesting the divergent outflow has moved east.

0930 UTC: At 0930 UTC the radar shows the leading edge of a second line of showers/storms approximately 3 km to the southwest of the airport. A gust front ahead of this is evident in the anemometer data with 5-10 kt SW winds at southern anemometers on the airport.

The second line of showers and storms moved across the airport and cleared to the east by 1000 UTC. An east-northeast wind at 15-20 kts was re-established over the airport following the passage of the second line of storms and this eased and shifted north-northwest later in the night.

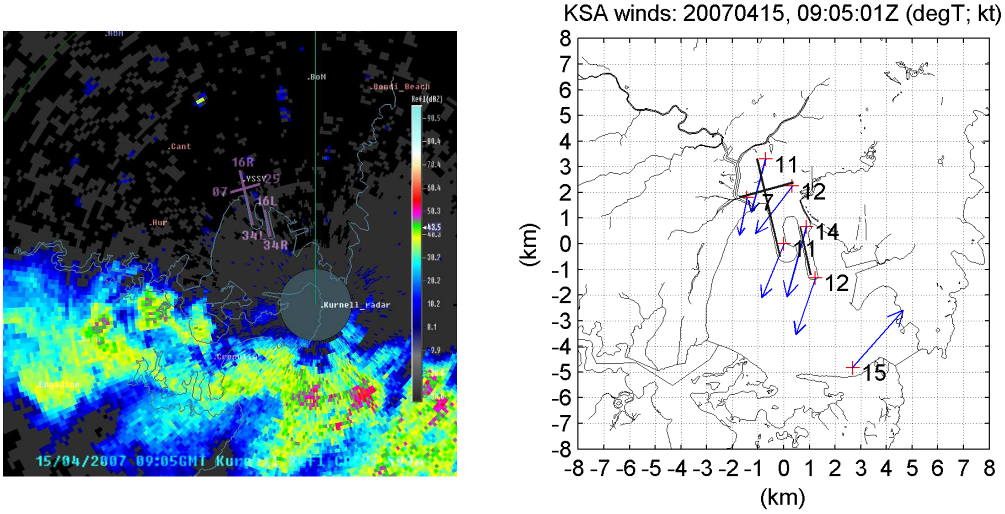
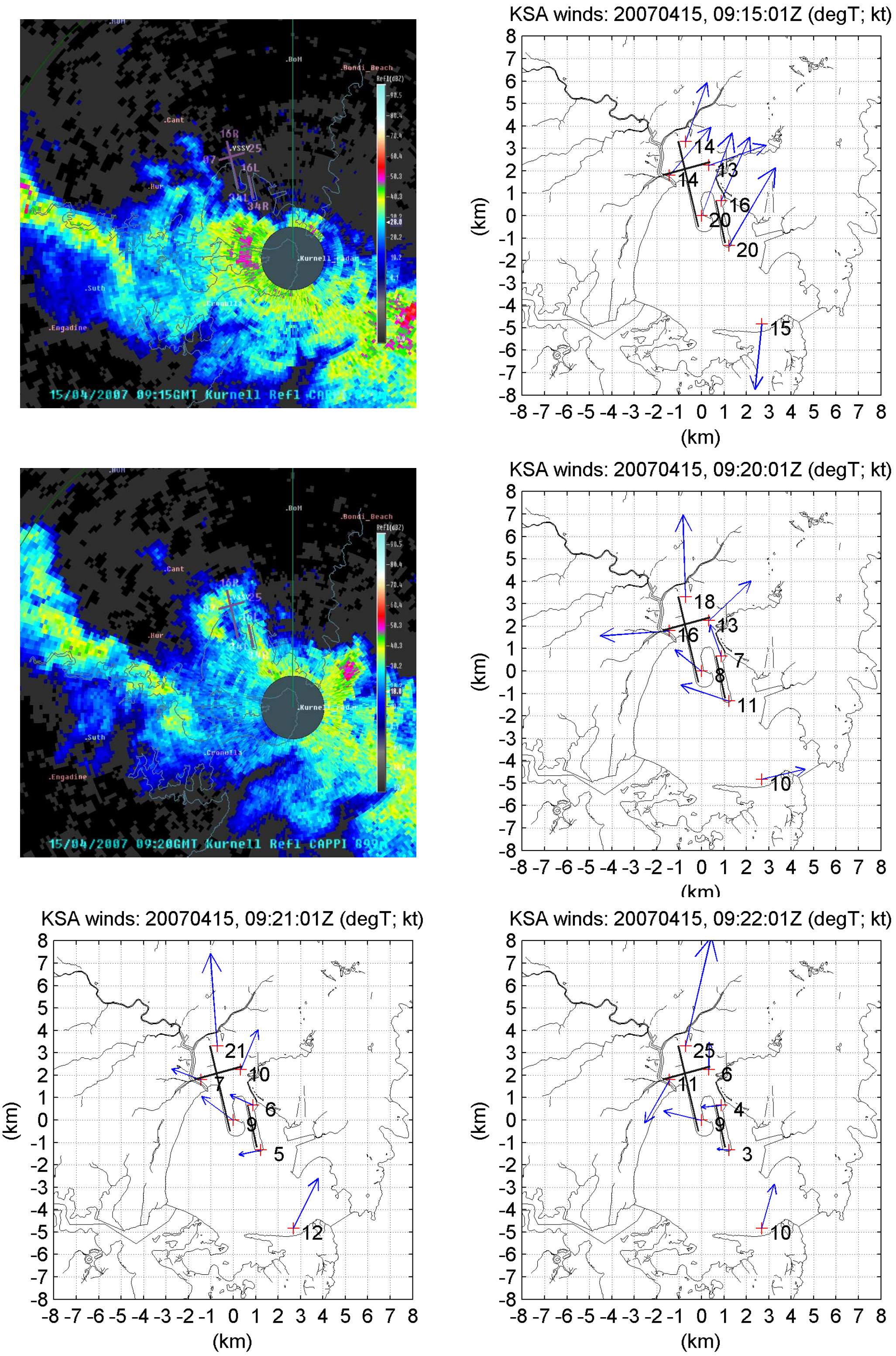


Figure 3. Kurnell radar (CAPPI scans at 3000 ft) and corresponding anemometer data across the Sydney Airport / Botany Bay area in the period 0905-0930 UTC, 15 April 2007. The anemometer data shows wind speeds in knots.



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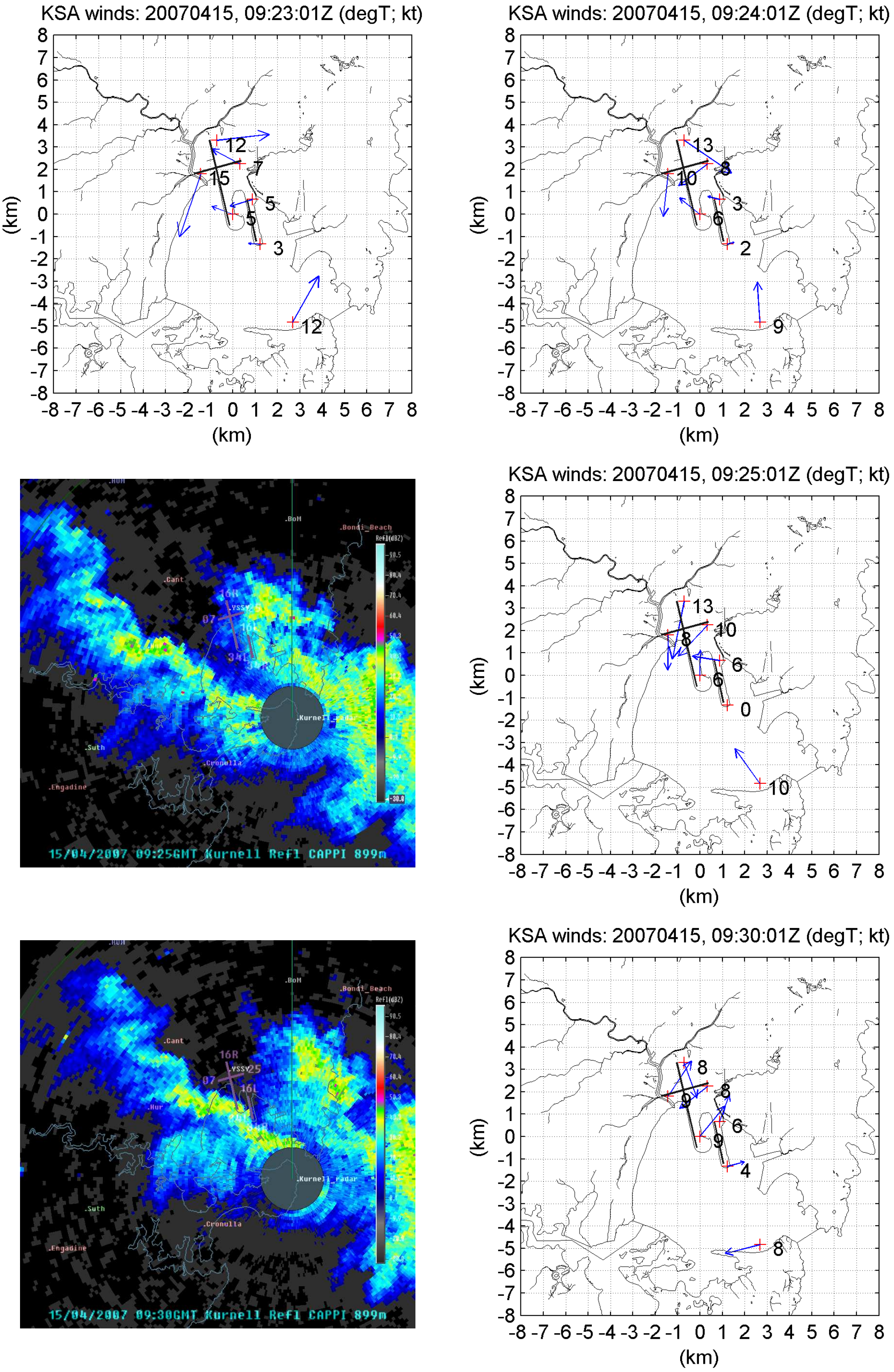

Figure 3. continued.

5 FLIGHT RECORDER DATA

Figure 4 shows the Flight Data Recorder data as the aircraft approached runway 16R, touched down at 092318 UTC and then climbed after aborting the landing. This covers the 3 minute period 09:20:48 – 09:23:48 UTC and shows the radar altitude (ft), the wind direction (degT) and the wind speed (x 10 kt) as the aircraft approached.

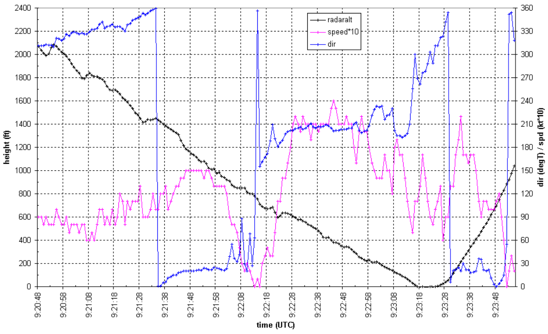

Figure 4. Flight recorder data for period 092048-092348 UTC.

As the aircraft descended it experienced northwest winds around 10 kt shifting to the northeast below 1400 ft and increasing to 15 kt as it encountered the sea breeze. When the aircraft reached 800 ft the wind shifted from northeast to south-southwest and increased to around 20 kt. At this time the aircraft was around 4 km north of the threshold for runway 16R and the observed wind change is consistent with the aircraft descending through the upper boundary of the gust front that passed across the airport earlier.

When the aircraft was at 100 ft (092310 UTC) and 0.6 km from the runway threshold the wind rapidly shifted from 190/18 kt to 280/12 kt and the aircraft recorded an airspeed loss of 28 kt in a period of 7 seconds. The observed wind change reported by the aircraft is consistent with the wind at the threshold of runway 16R where the wind had shifted to 280/11 kt. The pilot initiated a go-round at this time with the aircraft touching down heavily before climbing.

As the aircraft climbed the observed wind is reported as 020/18 kt consistent with the presence of the divergent outflow.

6 DISCUSSION

Low altitude wind shear and its impact on aviation is well understood and the ICAO Manual on Low-level Wind Shear' (ICAO 2005) presents considerable detail on the topic. It describes wind shear as "a change in wind speed and/or direction in space, including updrafts and downdrafts" which can result from a number of meteorological factors including sea breezes, cold fronts, strong low level winds, terrain, gust fronts and convective downdrafts.

Experience has shown that low-altitude wind shear presents a significant risk to aviation during the landing/take-off phase when the airspeed and ground clearance are near critical. Furthermore, wind shear associated with convective activity, and particularly the microburst, presents the greatest threat to aircraft operations and these phenomena have been the cause of a number of major aircraft accidents involving passenger aircraft (National Research Council, 1983). There have been detailed investigations of these events and a number of scientific studies aimed at gaining a better understanding of their characteristics and the factors that cause them (Wilson et al 1984, Hjelmfelt 1988).

Fujita (1981) defined a microburst as a downdraft associated with a sudden outflow of damaging horizontal winds at the surface with a horizontal extent less than 4.0 km. In a study of microburst characteristics using Doppler radar Wilson et al (1984) refined this by classifying a convective downdraft as a microburst when the distance between the maximum radial outflow regions in the initial stages is ≤ 4km and the velocity differential is ≥ 10 m/s (20 kt). They described the evolution of a typical microburst as illustrated in Figure 5 and found the lifetime of a microburst is of the order of 5-15 minutes. A further finding was that in many cases there may be no rain at the surface associated with a microburst.

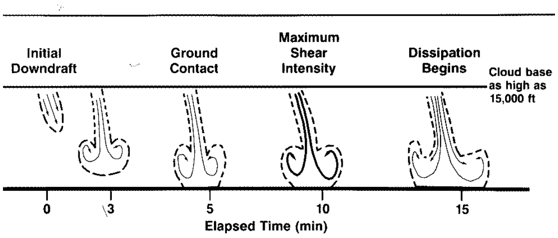

Figure 5. Evolution of typical microburst (Adapted from Wilson et 1984)

Based on these criteria, the divergent outflow evident in the anemometer data over the north end of runway 16R in the period 091951-092300 UTC can be defined as a ‘dry’ microburst. From the anemometer data the lifetime of the event was at least 3:10 minutes and it is likely the lifetime was a little longer but after 092300 UTC the centre of the microburst was outside the airport anemometer network and the divergent outflow was not so clearly evident. The wind observations recorded by the aircraft Flight Data Recorder are consistent with the surface observations and with a microburst encounter. The observations suggest that the microburst was weakening when the aircraft encountered it at 092310 UTC.

A simple analysis of the vector difference between the observed winds at two anemometers showed the maximum divergence occurred at 092151 UTC when the wind at the thresholds of runways 16R and 07 was 190/30 kt and 040/14 kt respectively. This corresponds to a vector difference of 43 kt (22 $m.s^{-1}$) over a distance of 1.7 km and equates to a divergence of $12.9x10^{-3}$ s^{-1}. This is significantly greater than the threshold of 10 $m.s^{-1}$ at ≤4 km used by Wilson et al (1984) to define a microburst (equating to a divergence of $2.5x10^{-3}$ s^{-1}), and the mean velocity difference reported by Hjelmfelt (1988) of 24 $m.s^{-1}$ over 3.1 km (equating to a divergence of $7.74x10^{-3}$ s^{-1}).

In Australia there have been previous studies of microburst events and several aviation safety incidents associated with wind shear. Chappel and Hanstrum (1998) describe two dry microburst events at Alice Springs Airport on 2 November 1996 and discuss the implications for aircraft operations over inland Australia. Potts (2002) provides details on other meteorological studies and also presents details on two air safety incidents where aircraft encountered wind shear.

The analysis presented here again illustrates the complex winds and small space and time scales that can occur with thunderstorms and this includes storms that may appear less intense. The short lead time for such events means that only automated systems can effectively detect any associated wind shear on the relevant approach or departure flight corridor and provide timely and appropriate warnings.

In Sydney operational forecasters suggest that 60-80 percent of storms will be associated with moderate to heavy rain at the surface (personal communication). Pilots well understand the risks of wind shear associated with these storms and will generally delay landing or departing when present. For this event the cluster of convection was high-based, the radar reflectivity was not high and there was very little rain at the ground yet a relatively intense short-lived microburst developed. The risk to aviation from such ‘dry’ microbursts is increased as there may be no visual cues indicating the presence of wind shear on the flight path. This event suggests the incidence of ‘dry’ thunderstorms in Sydney, and the associated risk of ‘dry’ microbursts, may be higher than previously thought.

7 CONCLUSIONS

At approximately 0923 UTC, 15 April 2007 a Boeing 747 encountered a decaying dry microburst while attempting to land on runway 16R at Sydney Airport on the east coast of Australia. At an altitude of 100 ft the aircraft lost 28 kt of airspeed in a period of 7 seconds and the approach was aborted. Flight control was maintained but the aircraft touched down heavily before climbing to make a successful landing several minutes later.

In this report we present an analysis of meteorological data associated with the event, including Flight Recorder Data from the aircraft.

This case highlights the challenge in quantifying the level of risk to aviation from wind shear. Thunderstorms will be associated with convective downdrafts but the frequency of microbursts and the period they may affect the flight corridor for a given runway requires appropriate observing networks or systems. This event was not observed in the Doppler radar data and the availability of the high resolution wind data for Sydney Airport demonstrates the utility of these data for this purpose.

The wind shear encounter discussed in this paper supports the conclusion in Potts (2002) that “wind shear associated with convection, namely gust fronts and microbursts, present a risk to aircraft operations in Australia”.

8 REFERENCES

Chappel, L.C. and B.N. Hanstrum, 1998: A severe dry microburst over central Australia. Sixth Australian Severe Storms Conference, Bureau of Meteorology, Melbourne, Australia.

Fujita, T.T., 1981: Tornadoes and downbursts in the context of generalized planetary scales. J.Atmos.Sci., 38, 1511-1534.

Hjelmfelt M.R., 1988: Structure and life cycle of microburst outflows observed in Colorado. J.Appl.Meteor. 27, 900-927.

ICAO, 2005: Manual on Low-level Wind Shear. ICAO Doc 9817-AN/449., pp219.

National Research Council, 1983: Low altitude wind shear and its hazard to aviation. National Academy Press, Washington DC., 161pp.

Potts R.J., 2002: Low altitude wind shear at major Australian airports and the risks to aviation. Preprints 10th Conf. on Aviation Range and Aerospace Meteorology, 13-16 May 2002, Portland, Oregon. Amer. Met. Soc.

Potts, R.J., T.D.Keenan and P.T.May, 2000: Radar Characteristics of Storms in the Sydney Area. Monthly Weather Review, 128, 3308-3319.

Wilson J.W., R.D. Roberts, C. Kessinger and J. McCarthy, 1984: Microburst wind structure and evaluation of Doppler radar for airport wind shear detection. J Clim Appl Met., 23, 898-915.