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THE BULADELAH TORNADO AND OTHER SEVERE STORMS OF 1 JANUARY 1970

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THE BULADELAH TORNADO AND OTHER SEVERE STORMS OF 1 JANUARY 1970

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ABSTRACT

Meteorological features associated with an intense tornado and other severe storms on the central and north central coastal districts of New South Wales on 1 January 1970 are discussed. The key factors were an intensifying tropospheric low pressure system over inland New South Wales and extremely high storm mass flux. In a similar circumstance severe storms with probable tornadoes could be expected along the New South Wales coastal areas.

INTRODUCTION

The incidence of tornadic storms along the coastal strip of New South Wales does not appear to be as high as some other parts of Australia e.g. the western slopes of the Great Dividing Range or the agricultural/gold fields belt of Western Australia (see Minor and Peterson, 1979). Evesson (1969) concluded that on average the New South Wales coastal area experiences four tornadoes per year. By contrast the States of Oaklahoma and Kansas (United States) experience 24 tornadoes on average per year and they are usually more intense than the Australian ones. Nevertheless there are numerous documented tornadoes along the New South Wales coastal districts e.g. Dunstan (1956), Zillman (1962), Carr (1964), Evesson (1969), Evesson (1970), Colquhoun (1972), and this probably reflects population concentration in this area.

These documented accounts of tornadoes are indicative of relatively isolated areas of intense instability. By contrast the severe storms which occurred on 1 January 1970 ranged over 350 km and one associated tornado was probably more intense than any ever documented in the Australian meteorological literature.

Although these events occurred many years ago, they are worth examining in the light of more recent research on severe storms, both in Australia and the United States of America. Figure 1 indicates key localities referred to in the text.

DESCRIPTION AND LOCATION

Reports of severe storms were made from a number of locations between Coffs Harbour and Newcastle on 1 January 1970, although with one exception the presence of tornadoes cannot be confirmed. For example:

- at Frederickton (70 km south southwest of Coffs Harbour) a weatherboard house was blown from its foundations and destroyed;

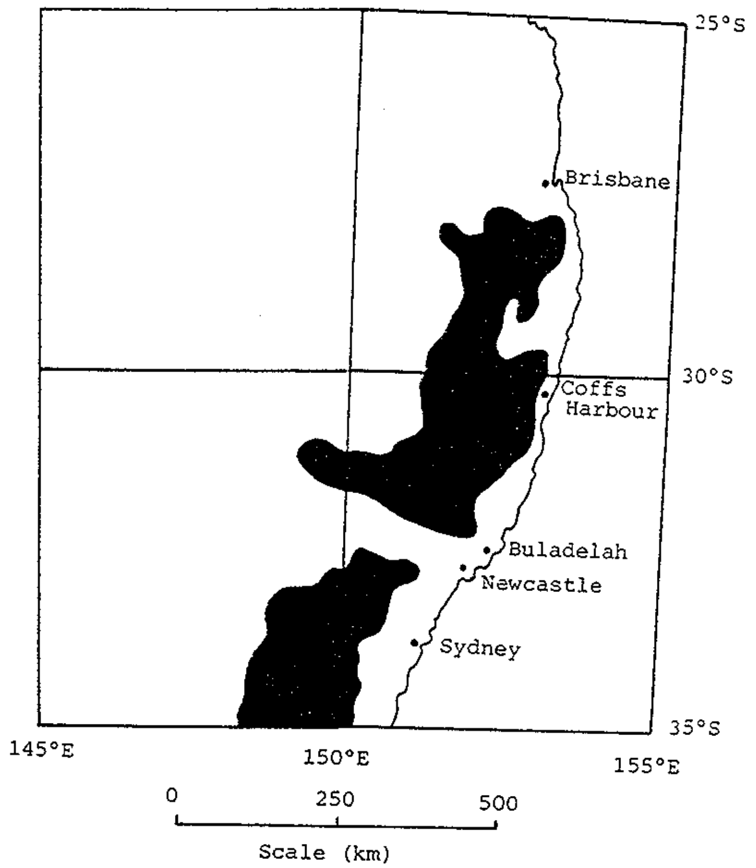


Fig. 1 Locality map. (The shaded area refers to terrain in excess of 700 m above sea level)

- hailstones the size of cricket balls fell at Urunga (25km south-southwest of Coffs Harbour);

- glass doors and windows were broken by hail in the western suburbs of Newcastle. A resident of Jesmond said 'Hailstones the size of eggs tore through the screens with ease. The pressure of the wind and hail was so great that glass doors were bowing inwards and I was pushing them to stop them shattering.'

This damage however pales into insignificance when compared with the havoc that was wrought by a tornado in the Buladelah State Forest (70 km north-northeast of Newcastle). The devastation was incredible. The tornado's path was essentially confined to forested areas and a swathe 22 km long and for the most part between 1 and 1.6 km wide either totally destroyed or debranched over one million marketable trees.

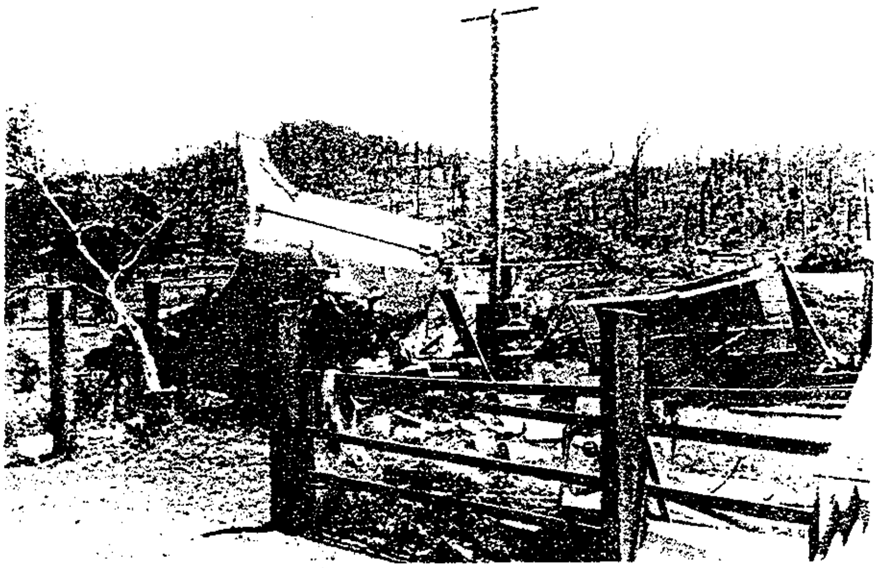
A number of distant eyewitness accounts of the tornado have been combined to give an overall impression. Around noon on 1 January scattered cumulus cloud of only minor development were present over the Buladelah area although larger cumulus clouds were present towards the west and northwest. By 1345 EST cumulonimbus cloud had developed and scud cloud was noticeable in the vicinity of Buladelah. The scud cloud was in some places only about 100 metres above ground level and eyewitnesses watched this cloud being drawn at great speed towards a large cumulonimbus cloud. As the scud approached the cumulonimbus it was drawn up vertically and seemed to form a dense black column of cloud. Debris was noticed spiralling upwards around the tornado funnel. At this time a tremendous roar was heard by a number of residents in the area as the tornado approached. The tornado, which displayed a cyclonic sense of rotation moved south-southeast although its direction varied at different parts of the track. Hail as large as cricket balls fell in the locality. Within 50 km of Buladelah the observed rainfall varied between 5 and 15 mm. Figures 2(a) and (b) illustrate the effects of the tornado.

METEOROLOGICAL FACTORS

Evolution of events till 0900 EST 1 January 1970

During the six days prior to 1 January 1970 a low pressure system was more or less permanently situated in the northern Coral Sea with a moist low-level inflow onto coastal eastern Australia. Low-level northeasterly flow prevailed over New South Wales till 30 December 1969 when a cold front swept over the state bringing much drier air to inland parts. By 0900 EST 31 December 1969 the cold front had moved out into the Tasman Sea, but a fairly slack pressure gradient prevailed over eastern New South Wales. Around this time a low pressure centre, central value 1002 mb, formed over southwestern Queensland. Much further to the southwest a fast moving cold front was oriented almost along the southern coast between the Victoria/South Australia coastal border and the head of the Great Australian Bight, with a deep southerly stream post frontal. Figure 3(a) illustrates the mean sea-level pressure analysis for 0900 EST 31 December 1969.

(a)



(b)

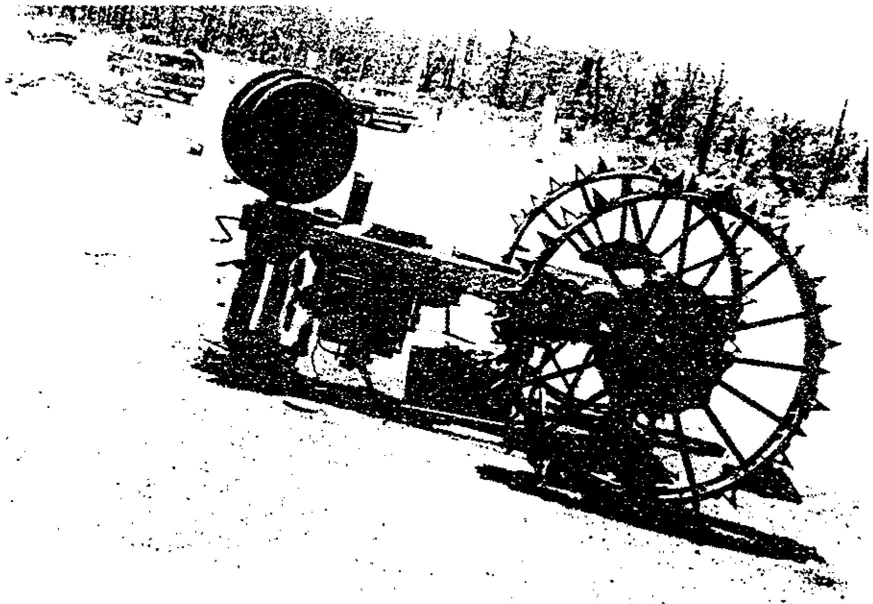


Fig. 2 The effects of the tornado
(a) This photograph shows the type of damage that occurred in a heavily forested area. In the foreground is a totally destroyed caravan
(b) This photograph shows a tractor weighing approximately 2 000 kg that was lifted up, carried through the air and dumped upside down

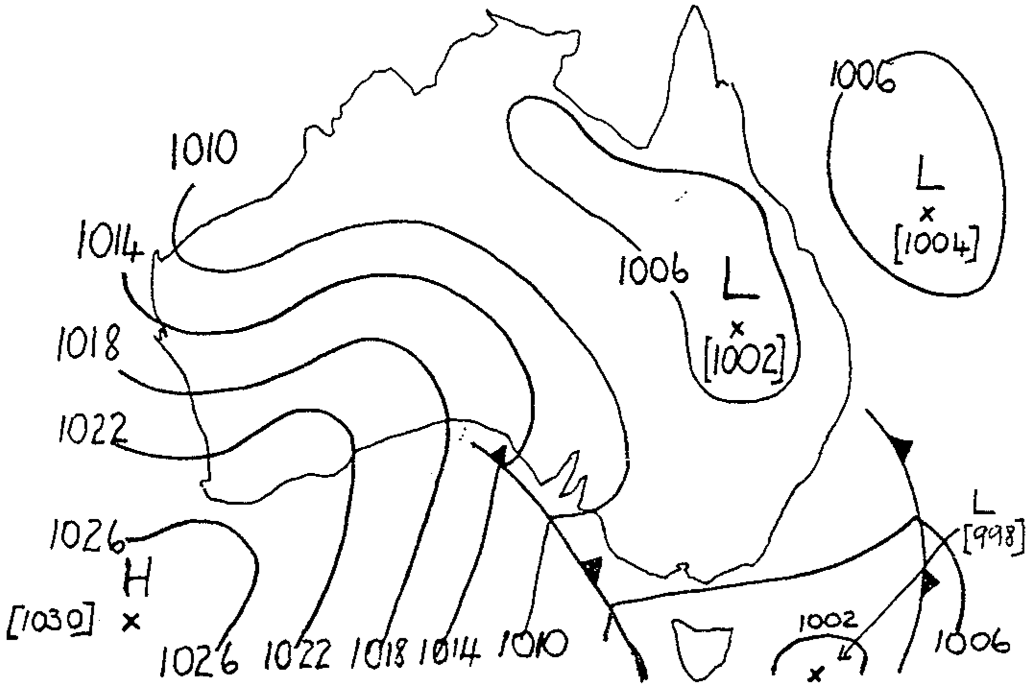


Fig. 3(a) Mean sea level pressure analysis, 0900 EST 31 December 1969

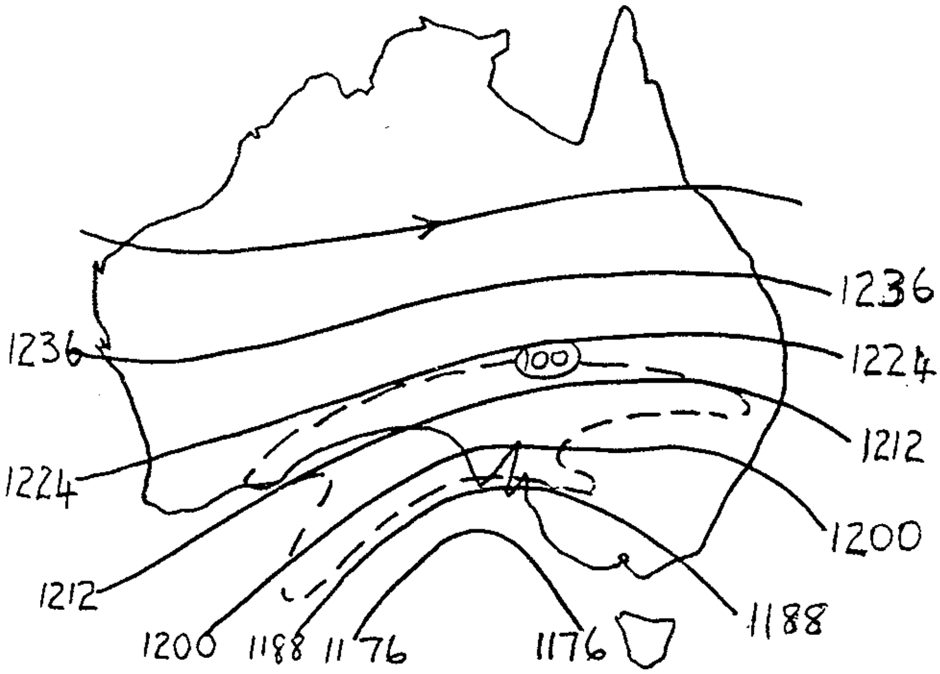


Fig. 3(b) 200 mb analysis, 0900 EST 31 December 1969 (isotach in knots)

A broadscale trough centred near 135°E extended throughout the troposphere with a jet core in excess of 100 kn extending from the Great Australian Bight through Southern Australia to the northern New South Wales coast. Figure 3(b) illustrates the 200 mb analysis for 0900 EST 31 December 1969.

In the following 24-hour period the surface low pressure system deepened to 993 mb while moving south and at 0900 EST 1 January 1970 was centred over central New South Wales. The cold front had advanced northeastwards with its southern extremity situated to the west of the surface low. A pre-frontal trough formed some 500-700 kilometres ahead of the advancing cold front, and frontogenesis had occurred along this trough. Very dry air prevailed for some distance to the west of this new front. A northerly flow prevailed along the central New South Wales coast. Figure 4(a) illustrates the broadscale synoptic pressure analysis for 0900 EST 1 January 1970.

The upper air trough had undergone amplification during this 24-hour period and had cut off at all tropospheric levels between 700 mb and 200 mb. The 200 mb analysis for 0900 EST January 1970 is given at Fig. 4(b). A jet axis around the northern edge of the low extended to coastal areas.

A localised mean sea level pressure analysis for 1200 EST 1 January 1970 is given at Fig. 5. The available temperature and dew point temperature observations indicate the intrusion of very moist air along the central and north cenral coast, and the marked moisture contrast across the leading front.

Radiosonde data

Radiosonde data are available for Williamtown (10 km north of Newcastle) and the proximity of Buladelah to Williamtown is such that radiosonde data for Williamtown at 0900 EST 1 January 1970 can be taken as closely indicative of conditions five hours prior to the tornado. The 0900 EST sounding (Fig. 6) shows the presence of a moist lower layer, capped by a deep drier layer and an inversion separating them. Potential instability existed to the 600 mb level.

The sounding taken at 0900 EST would have undergone major modification by 1345 EST as a result of:

- Low-level heating. The noon temperature at Williamtown had risen to 28°C. However low-level heating to 28°C alone would not initiate convective cloud if other factors remained unaltered.

- Vertical motion. Upper air divergence on the eastward side of the upper trough would have resulted in upward vertical motion and consequent destabilisation, although this is difficult to quantify.

- Advection of high dew point low-level air from the north would enhance the instability.

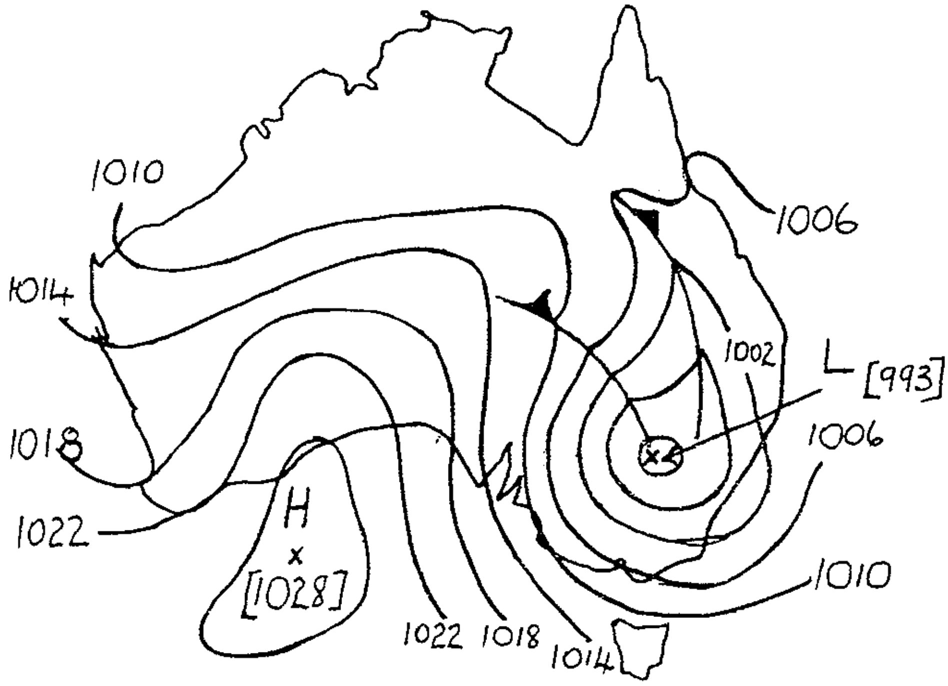


Fig. 4(a) Mean sea level pressure analysis, 0900 EST 1 January 1970

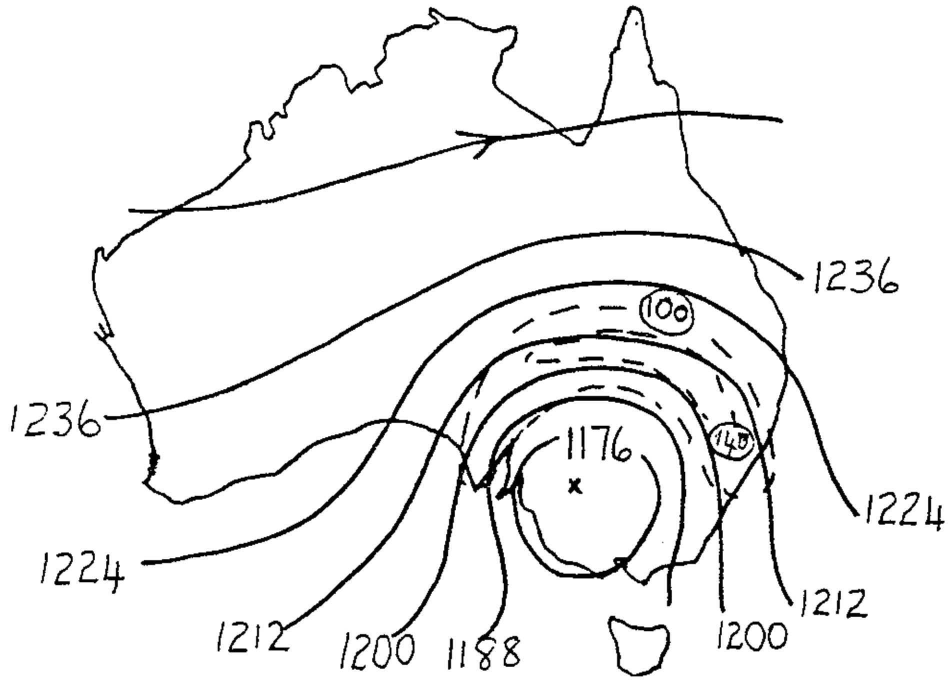


Fig. 4(b) 200 mb analysis, 0900 EST 1 January 1970 (isotach in knots)

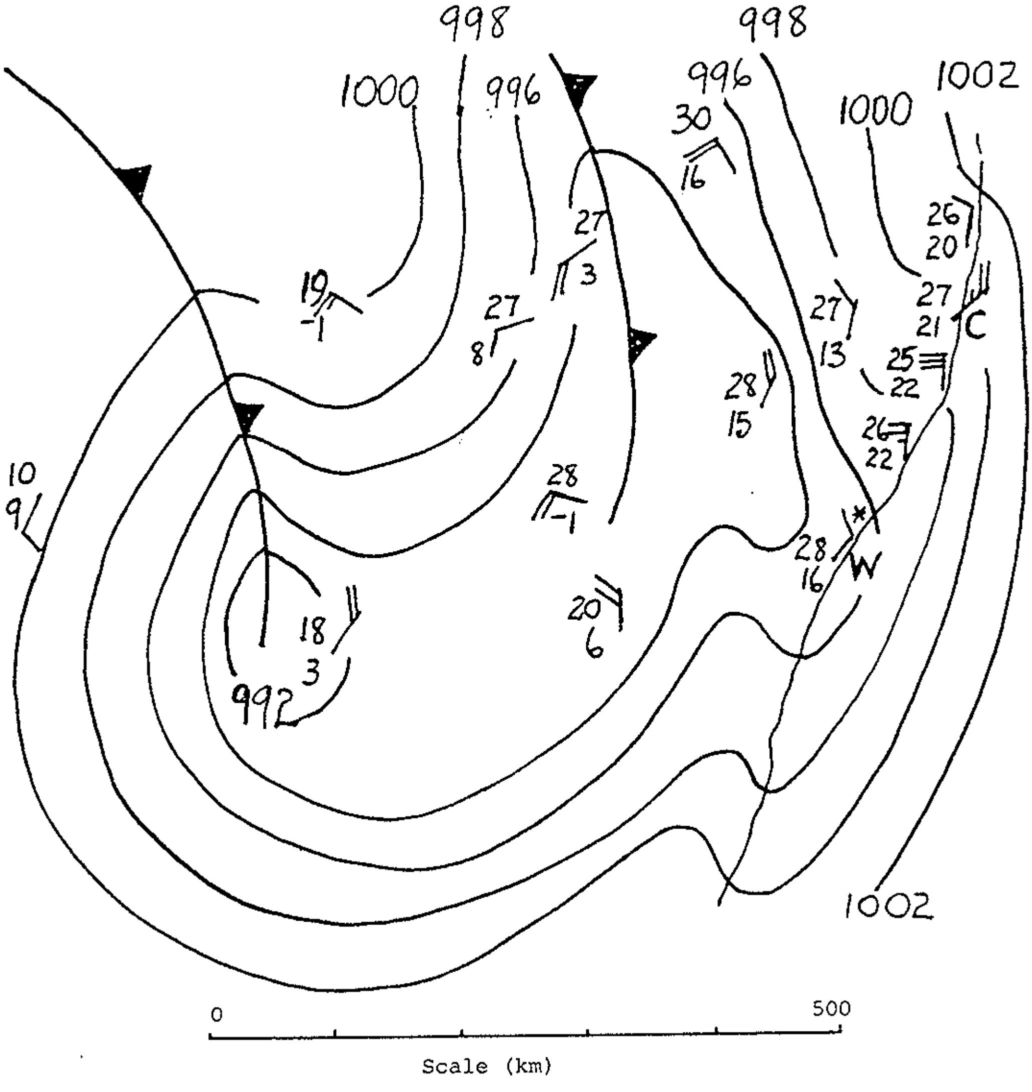


Fig. 5 Localised mean sea level pressure analysis, 1200 EST 1 January 1970. (The Location of Buladelah is indicated by an * while the observations plotted at Coffs Harbour and Williamtown are indicated by C and W respectively. Very moist (dew point 20 to 22°C) low-level air is intruding down the NSW coast while the leading front separates this moist air from very dry air (dew point -1 to 8°C). Moist cooler air follows the second front

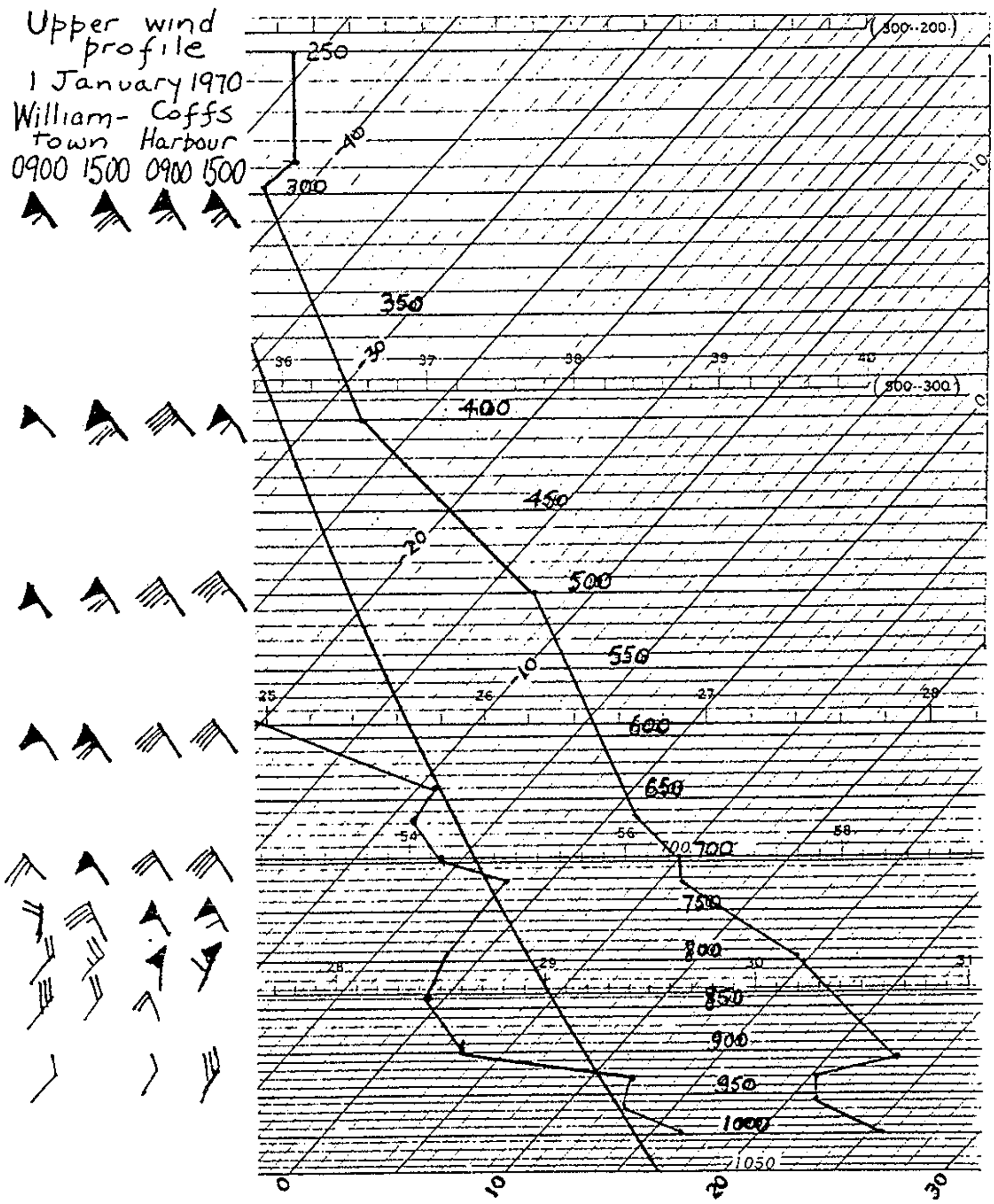


Fig. 6 Radiosonde data, Williamtown 0900 EST 1 January 1970 together with upper wind data for Williamtown and Coffs Harbour, 0900 EST and 1500 EST 1 January 1970

Storm mass flux

Colquhoun (1982) developed a logic sheet for forecasting storms and severe storms. Basically the initial forecast of a storm is made from physical and synoptic considerations, and the intensity of the storm is related to the storm mass flux which is derived from the surface pressure and wind profile. Tentatively he found severe storms (with hail in excess of 2.5 cm diameter or wind gusts exceeding 92 km h^{-1}) required storm mass flux exceeding 100 units and for the most intense storms the flux exceeds 230 units. Assuming the Williamtown 0900 EST low-level winds are representative of those feeding the storm updraft and the 1500 EST winds the storm downdraft, the storm mass flux was calculated at 346 units, a value comparable with those associated with the most severe tornadoes in the United States.

Mositure gradients

Miller (1972) noted that near all tornado and violent storm activity in the mid-west of the United States of America are intense gradients of moisture at all levels from the surface to 700 mb. Fujita (1958), using instrumented aircraft, had measured mixing ratio changes of 5 g Kg^{-1} over a horizontal distance of one kilometre. McCarthy and Koch (1982) proposed a mechanism for the interaction of a dry-line (which separates the dry and moist air), associated topographic features, and their significance in the generation of tornadoes. In the USA the Rocky Mountains act as a westward barrier to the moist air flowing northwards from the gulf of Mexico and the hot dry air originating from the desert to the southwest. The mountain also acts as an elevated heat source for the desert air. As the warmed eastward flowing air subsides in the lee of the mountains, additional warming and drying takes place and a pronounced temperature inversion forms between the low-level moist air and the hot dry air above. The inversion initially inhibits convective development while allowing the build up of very high wet bulb potential temperatures beneath, the resulting potential instabiity being a necessary ingredient for tornado occurrence. The dry line moves east producing convergence ahead of it, vertical motion over it and acts as a trigger mechanism.

The Australian Great Dividing Range is much lower than the Rocky Mountains but it would still ennance low-level moisture gradients in a favourable situation. In eastern Australia the rising terrain would tend to inhibit the westward penetration of the low-level moisture and in fact shunt it southwards thereby developing a boundary separating the moist and dry air. On 1 January the front which developed over New South Wales had much lower dew point temperatures to the west. The marked contrast between the dew point temperature at coastal localities and places some 200 and 300 km inland can be seen from Fig. 5.

Composite analyses

After researching many tornadoes in the USA, Miller (1972) classified tornado situations into five synoptic types. These are composite patterns involving features from the surface to the 500 mb level. In one of these patterns (his synoptic type E) a major feature is a deep surface low. The position of the surface low and other significant synoptic features relative to the tornado threat area, and transposed for the southern hemisphere, is given in Fig. 7. The Australian upper wind and radiosonde network in this area is inadequate to resolve the detail required to precisely delineate a threat area as in Fig. 7. However, many of the features of Miller's composite analysis are clearly present at 0900 EST 1 January 1970. The tornado/severe storm is south of a region of very strong low-level wind (see Fig. 6, particularly the strength of the winds at Coffs Harbour), while the cold front and surface low are in favourable localities. Evidence for a warm front is difficult to discern. Also on 1 January 1970 the 500 mb jet flow would be considerably further westward than would be expected from Miller's pattern.

Air mass soundings

Miller (1972) identified three air mass type soundings associated with tornadoes. His type 1 air mass sounding bears some resemblance to that measured at Williamtown at 0900 EST 1 January 1970. The median type 1 air mass sounding, based on 230 soundings of tornadoes is shown in Fig. 8. At Williamtown on 1 January 1970 the inversion is stronger than for Miller's (1972) tornado sounding. However, the depth of moisture is much less.

A comparison is made in Table 1 of characteristics of Miller's (1972) type 1 air mass and features of 1 January 1970 situation.

AN ANALOGUE SITUATION

Holcombe and Moynihan (1978) discussed a tornado with track length 51 km which struck the Brisbane Metropolitan Area on 4 November 1973. There are many similarities between this situation and that of 1 January 1970. A developing mean sea level low pressure system over inland New South Wales was associated with very strong low-level winds over northern New South Wales. Two frontal systems were associated with the low, the first separating very moist and dry low-level air.

In the upper troposphere a jet stream extended over northern New South Wales. These features are illustrated in a composite chart (Fig. 9).

This situation then is quite analogous to that of 1 January 1970. The major difference is that on 4 November 1973 the mean sea level pressure centre was much further southwards from the tornado area and the associated strong low tropospheric winds were basically westerly rather than with a substantial northerly component. In these ways the synoptic situation of 4 November 1973 also differed from Miller's type E pattern.

CONCLUDING REMARKS

Although the synoptic situation over New South Wales on 1 January 1970 was relatively rare, it provided optimum conditions for severe storms and tornado genesis along the coastal strip. Severe storms were observed over a wide area and one intense tornado occurred; if it had passed over a populated area clearly a major disaster would have occurred.

TABLE 1 COMPARISON OF MILLER'S TYPE 1 AIR MASS AND 1 JANUARY 1970 SITUATION

CHARACTERISTICS OF MILLER'S (1972) TYPE 1 AIR MASS	FEATURES OF 1 JANUARY 1970 SITUATION
a. The temperature lapse rate is conditionally unstable in the strata above and below the inversion or stable layer.	a. Conditionally unstable lapse rate is present above and below the inversion level.
b. The moist content is stratified with the lowest layer having a relative humidity over 65 per cent and surface dew points over 13°C. Very rapid drying is evident in the inversion (subsidence type) and above the top of the inversion the relative humidity tends to increase slightly, then more rapidly above 550 mb.	b. The relative humidity in the lowest layer varied between 50 and 56 per cent. The surface dew point temperature within 50 km of Buladelah varied between 16 and 19°C. Rapid drying is evident above the inversion with the relative humidity increasing to the 720 mb level.
c. Winds increase with altitude with a narrow stream in the dry air above the inversion having a component of at least 55 kmh^{-1} perpendicular to the wind flow in the warm moist air.	c. At Williamtown NNE winds do increase with altitude, but show no turning till above the 850 mb level. Winds at Coffs Harbour show turning, but the magnitude of the component is much less than in the US case.
d. The air from the surface to 400 mb is conditionally unstable and has a negative Showalter Index. The Lifted Stability Index is about -6 on the mean sounding. The Vertical Totals Index is 28, the Cross Totals 26 and Total Totals 54.	d. Two layers of conditionally unstable air are evident. the Showalter Index +4, the Lifted Index -3.5, the Vertical Totals Index 31, the Cross Total 13 and the Total Totals 44.

Table 1 (Cont'd)

CHARACTERISTICS OF MILLER'S (1972) TYPE 1 AIR MASS	FEATURES OF 1 JANUARY 1970 SITUATION
e. Tornadoes in this type of air mass most frequently occur in families and their paths are commonly long and wide compared to tornadoes occurring in other types of air masses. The tornadoes are more numerous in later afternoon, but occur at any time of the day and night, and are usually accompanied by wide-spread destructive winds and large hail. Individual tornadoes have a rather straight path and move rapidly at an average speed of about 60 km $^{-1}$, although exceptions to these characteristics are frequently reported.	There was evidence of likely tornadic activity at other localities along the mid north coast of NSW (e.g. Frederickton, Urunga). Large hail was reported from Newcastle suburbs. The general direction of movement was to the southeast, although there were variations from this.
f. Sky conditions preceding the occurrence of tornadoes in this type of air mass begin initially with reports of morning stratus followed by temporary clearing and then reports of the development of middle cloudiness. Surface temperature reports are abnormally high for the season and time of day or night, and the dew point often rises very rapidly one to four hours before the storm causing the air to be very oppressive. As the storm passes, the temperature drops very rapidly and returns to normal. The surface pressure tendency drops slowly for several hours, rises briefly, then as the storm reaches the station falls rapidly. As the storm pases, the surface pressure rises rapidly and in a few minutes returns to normal.	The observations at Buladelah are too infrequent to describe a cloud sequence. However between 0300 and 0600 EST cloud, base 2000 ft was observed at Williamtown. This cleared by 0900 EST. Only minor vertical cloud development was observed around noon and the very low scud cloud was observed almost simultaneously with the cumulonimbus. No temperature, dew point temperature or pressure data are available for Buladelah. However at Williamtown the noon temperature was close to normal for January. The dew point temperature fell 3°C to 16°C in the three hours prior to 1200 EST. The surface pressure fell steadily 3.5 mb (corrected tendency -2.5 mb in the three hours to noon).

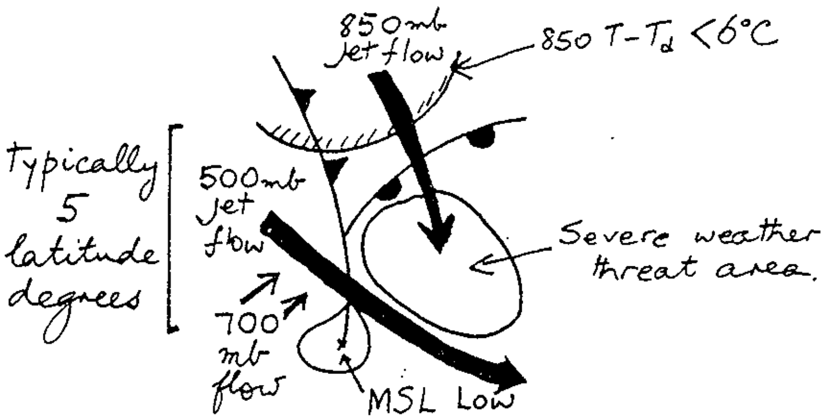


Fig. 7 Type E tornado/severe thunderstorm producing synoptic (after Miller, 1972)

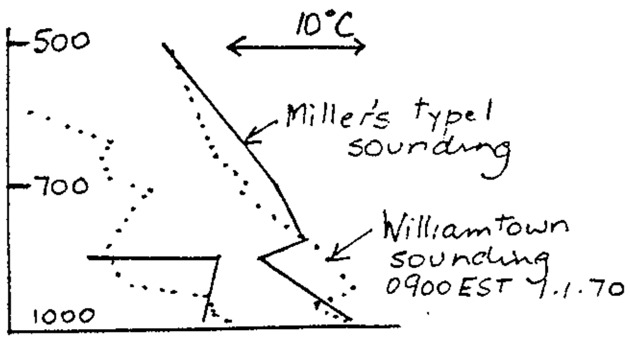


Fig. 8 Comparison of Miller's Type 1 sounding and that for Williamtown 0900 EST 1 January 1970

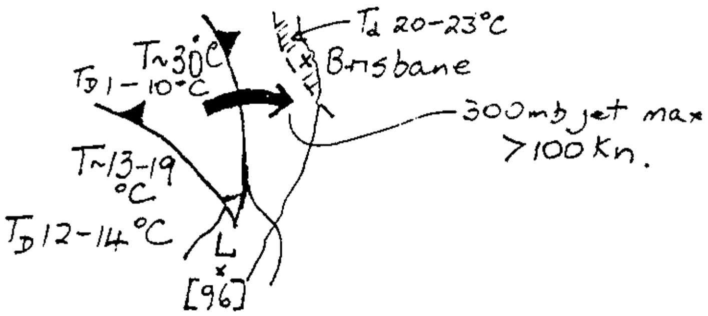


Fig. 9 Composite chart showing significant features associated with a tornado at Brisbane on 4 November 1973

From a synoptic viewpoint, the situation showed many similarities with one associated with tornadoes in the USA and another tornado situation in Brisbane. However, the air mass sounding was somewhat at variance with soundings for similar situations in the USA. The storm mass flux, which also takes into account physical considerations, was of a magnitude normally associated with intense storms.

The relative infrequency of events such as these renders their forecasting difficult. The very low inland mean sea level pressure provides some initial indication so that it would seem appropriate that this be built into an alert phase of an automated system. Routine calculations of storm mass flux in potentially unstable situations would also be very helpful.

ACKNOWLEDGMENTS

I am grateful to Mr John Colquhoun for making available data collected after the events and for his many helpful comments.