Australian Government
Bureau of Meteorology

The Meteorology of the Gold Coast floods
29th – 30th June 2005

The wild seas, weather and flooding associated with the Gold Coast flood event were characteristic of a weather phenomenon known as an east coast low. However in this case it was somewhat different in that a well-defined low-pressure system did not form on the surface, as we will show in this report. These systems can rival the impact of a tropical cyclone and occur at any time of the year although they are more common in autumn and in early winter. The first known east coast low struck the far southern coast of Queensland in August 1846 and drove the vessel Coolangatta ashore in the area now bearing its name.

Impact from east coast lows

More notable recent events with some of their effects are listed below

23-25 June 1950. Twenty-Three fatalities 24 hr rainfall totals 636mm (Dorrigo) and 368 mm (Springbrook). Two people drowned in Queensland. Navy ship *Fair Wind* lost with crew of 17. 648-ton freighter *Bangalow* driven ashore at Coffs Harbour. Four lives lost in NSW with 6200 people were left homeless.
July 1965 Wind damage in Brisbane city-floods- 24-hour rainfall totals to 510 mm at Springbrook and 193 mm in 24 hour in the Brisbane Regional Office.
June 1967(a). Four fatalities. Wind gusts to 150 km/hr- major flooding-24 rainfall totals to 621 mm at Springbrook and 282 mm in 24 hour in the Brisbane Regional Office.
June 1967(b). Two fatalities. Culminating event in 1967- winds to hurricane force at Cape Moreton-unprecedented beach erosion on the Gold Coast with houses and sections of roads lost to the sea. 5000 volunteers people dumped 100,000 sandbags to prevent houses washing into the sea.
July 1973. Four fatalities. Vessel *Cherry Venture* driven ashore in hurricane force winds-24 hour rainfall totals to 378 mm.
21/22 May 1981. Three fatalities. Affected most of the east coast with floods and wind damage.
20/23 June 1983. Two fatalities. Floods-24 hour rain totals to 350 mm in 24h at Nambour including 229mm in 4hours.
8 April 1984 Widespread roof damage Gold Coast-floods-24 hour totals to 346 mm.
Five helicopter rescues to stricken yachts.
9/10 May 1987. Four fatalities. Flash Floods Gold Coast with 345 mm in 24 hours at Springbrook.
April 1988. Two events produced floods- 24 hour totals to 302 mm and 337 mm. Crop damage estimated at 100million dollars.
14/18 December 1988. Four fatalities. Severe flooding Gladstone and 4 fatalities SE Qld.
April 1989. Two fatalities. Floods and wind damage- 120 mm in 3 hours in Brisbane.
21/22 February 1992. One fatality. Major flooding and Flash flooding Hervey Bay and Sunshine Coast. 732mm of rain in 24h at Tewantin.
1/5 May 1996. Five fatalities. Wind gusts measured to 65knots significant wave heights reached 6.9metres. Major flooding with 1490mm of rain in 6 days at Springbrook and 1027mm at Mt Glorious in 6 days.

4/5 February 1999. Two men lost in a boat at Breaksea Spit.
8/10 February 1999. Seven fatalities. Major flash flooding Brisbane and the Sunshine Coast. AWS gusts to 63 knots 24 hour rainfall to 404mm at Maleny.
30/31 October 2000. Two fatalities. Flash Flooding between Mackay and Brisbane with two fatalities.
31 January/2 February 2001. One fatality. Storm force winds Cape Moreton and gales at Toowoomba 24 hour rainfall totals to 385mm at Springbrook.
4-7 July 2001. Seven fatalities in long period waves from severe low well offshore.

The development of east coast lows

The development of east coast lows is reasonably easy to understand using an approach suggested in the nineties by Hirschberg and Fritsch (eg 1993) which is consistent with the potential vorticity arguments of Hoskins et al (1985). The low level cyclone develops as an area of strong 200hPa warm temperature advection (associated with a tropopause undulation) moves over the heavy rain area to the east of the developing low pressure system. The tropopause undulation is very easily detected as a warm thermal centre on a 200hPa chart (see below in Figure 1). This heavy rain area is characterized by a warm air advection vertical wind profile close to the 700hPa level. We show this in Figure 1, which uses the May 1996 east coast low event as an example.

At 2300UTC 29 April 1996 a small low was located east of Townsville and by 2300UTC 30 April 1996 it had moved down the coast to be east of Mackay (top right frame in Figure 1). It reached peak intensity near Brisbane between 2300UTC 1 May 1996 and 0500UTC 2 May 1996 with a central pressure of 997 hPa. The warm undulation can be seen to have moved from southwest Queensland to the west of Brisbane as the low developed (left frames Figure 1) with the warm air advection (marked by the bold red arrows) extending over the Brisbane region. In the centre panel the 700hPa charts show warm air advection at this level from the Coral Sea flowing into a cold thermal trough over New South Wales. The surface low forms in the northern region where the two areas of warm air advection intersect.

The development of the June 2005 Low

In contrast to the May 1996 low the tropopause undulation remained in southwest Queensland and northwest New South Wales (left frames in Figure 2) so that the strongest warm air advection tended to remain overland in eastern New South Wales and southeastern Queensland. The 700hPa warm advection region also remained further inland than in 1996. Consequently from Figure 3 the main pressure falls over 29 and 30 June 2005 were over land in New South Wales and southeast Queensland with no major centre evident.

High-resolution mean sea level analyses in Figures 4 (a), (b) and (c) cover the period of the heaviest rainfall in this event. They show a trough system had developed just inland from the coast in Northern New South Wales and extended up to a small low centre just to the north of Brisbane. These charts show that the flow onto the coast was warm and very moist with dewpoints reaching 19-20^{O}C. This was also the period of the strongest winds with gale force northeasterly winds indicated and this was consistent with the largest waves on the wave rider buoys (significant wave heights reaching 5 metres, see Figure 14) around 2300UTC 29 June 2005.

The distribution of the heavy rainfall, mostly east of the mesoscale trough, can be seen from the composite radar image in Figure 5.

Warm air advection and tropical rainfall

(a) Isentropic upslide

Many reports of torrential rainfall in eastern Queensland have shown that such rainfall is associated with winds that back with height. The heaviest rainfall occurred when the winds were mostly in the northeast quadrant between the surface and 500hPa. It can be shown using quasi-geostrophic theory (Figure 2 in Hoskins et al (1978) and Holton (1972, section 3.4)) that warm air advection denotes up motion where the warm air advection is maximized due to the presence of a jet in the layer. Such a wind structure is also associated with upslope flow along isentropic surfaces as long as the isentropic surfaces are not moving faster than the flow (Saucier 1955).

These studies and reports have been documented in Bonell, Callaghan and Connor (2005) and Callaghan and Bonell (2005). For weaker rainfall Connor and Bonell (1998) found that warm air advection, particularly in the layer between 950 and 800 hPa, contributed significantly to trade wind precipitation amounts along the north Queensland coast. In searching through the literature we have found some studies that seem to suggest this process of shear causing isentropic ascent leading to the release of convection: Fritsch et al (1994), Raymond and Jiang (1990) and Raymond (1992).

In Figure 2 the 700hPa warm air advection zones indicate such regions of isentropic ascent.

Rainfall Mechanisms and Numerical rainfall prognosis

Dynamically, Mesolaps forecast the lifting mechanisms from Figure 6 where it indicated strong backing winds with height over the Gold Coast at 1800UTC 29 June 2005 which was around the onset time of the heaviest rain. The actual winds at Brisbane (Figure 7) show the strongest warm air advection signal 1700UTC 29 June 2005, which weakened 6 hours later when the rain had cleared Brisbane.

In Figure 8 we compare some of the numerical guidance and this indicates that the Mesolaps forecasts in this events were much superior to the other models and this was also the case with other models not presented in Figure 8. The maximum 24 hour to 2300UTC 29 June 2005 totals forecast for Mesolaps were 160mm whereas the actual falls reached 500mm or more most of which fell in 12 hours.

If we examine the Mesolaps forecast more closely (Figure 9) we see that the model does not forecast the mesoscale coastal trough, which formed along the coast and provided a strong forcing mechanism for ascent. The low level convergence indicated by the model is only from the deceleration of the winds.

Rainfall Analysis

A separate report on the rainfall analysis has been prepared by the Bureau of Meteorology.

Radar imagery

The imagery clearly shows the heavy rain concentrated in a limited area mainly over far southeast Queensland / northern New South Wales. The thunderstorm activity and widespread convection contributed to the extreme rainfall rates over short time periods especially in the

Gold Coast area.

Satellite imagery

The satellite images clearly show widespread deep convection and embedded thunderstorms east of the surface trough and the persistent redevelopment about the Gold Coast, especially between 17z .

Sea conditions

Large waves to 5m were recorded (Figure 14) with erosion and salt-water inundation along coastal areas in southeast Queensland observed. (See Figure 11 below.).
High tide at Gold coast Seaway and Tweed River was at 1600 local time on the 30th (1.28m).
With the wave rider buoy at Tweed reporting 5m with a period of 11secs for the waves, a wave set up of 1.24m is calculated.
HAT[1] for the Seaway is 1.89m, resulting in a tide of around 1m above HAT[1], accounting for the erosion.

Thunderstorm activity

Thunderstorm activity peaked in the southeast Queensland 14^{z} 29th when the mid levels of the atmosphere cooled further, and instability increased. (See Figure 12 below and *CAPE*[2] values as well as GPATS data at Figure 13). The CAPE[2] increased considerably between 11Z and 17Z on the 29th with Total Totals increasing from around 45 to 50 during the period.
Surface Lifted Indices averaged –2.6C (Possible Severe TS).

[1] *HAT – Highest Astronomical Tide*
[2] *CAPE – Convective Available Potential Energy*

Temperatures of around 20^{o}C and high dewpoints of 19^{o}C were prevalent over much of the area, dewpoints increasing from around 14C on 28th. Note the very deep moist layer, which grows significantly in depth between the 11z and 23z flight.

References

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Figures

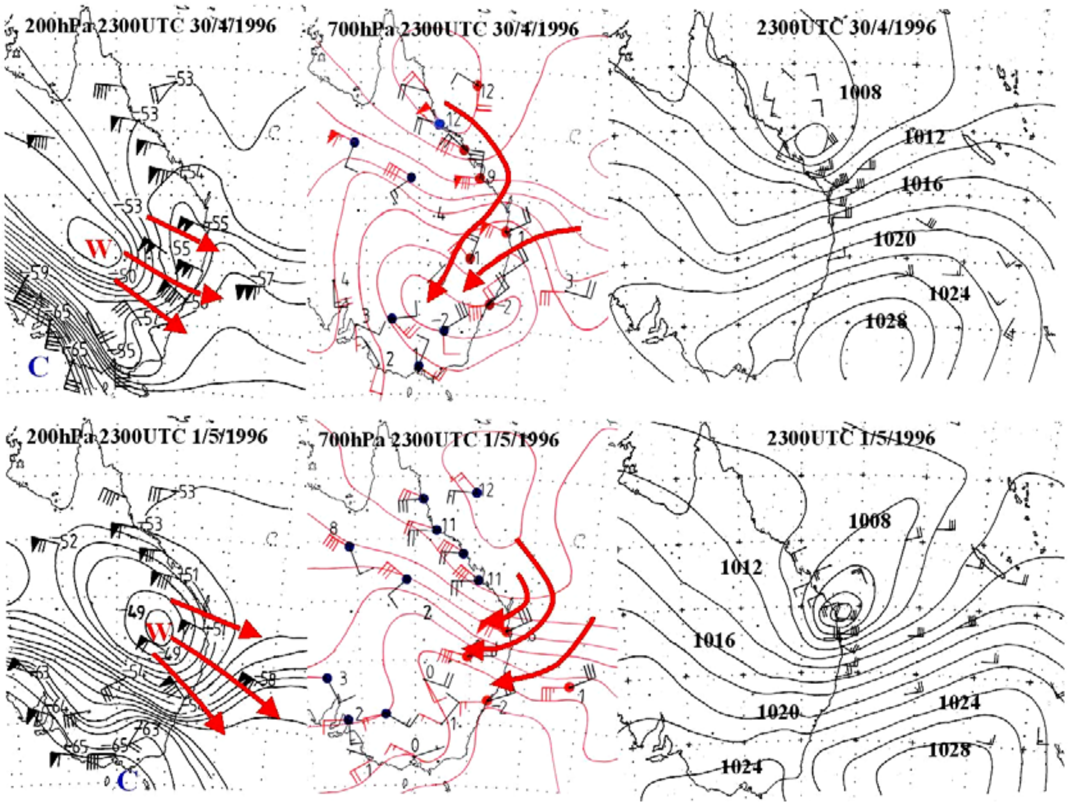


Figure 1…(For the last major east coast low event of May 1996)(Left panels) Temperature and wind at 200hPa with large arrows showing warm air advection.
(Centre panels) Similar for 700hPa except with red plots for 850/500hPa shears.
(Right panels) Mean sea level pressure distribution and surface winds

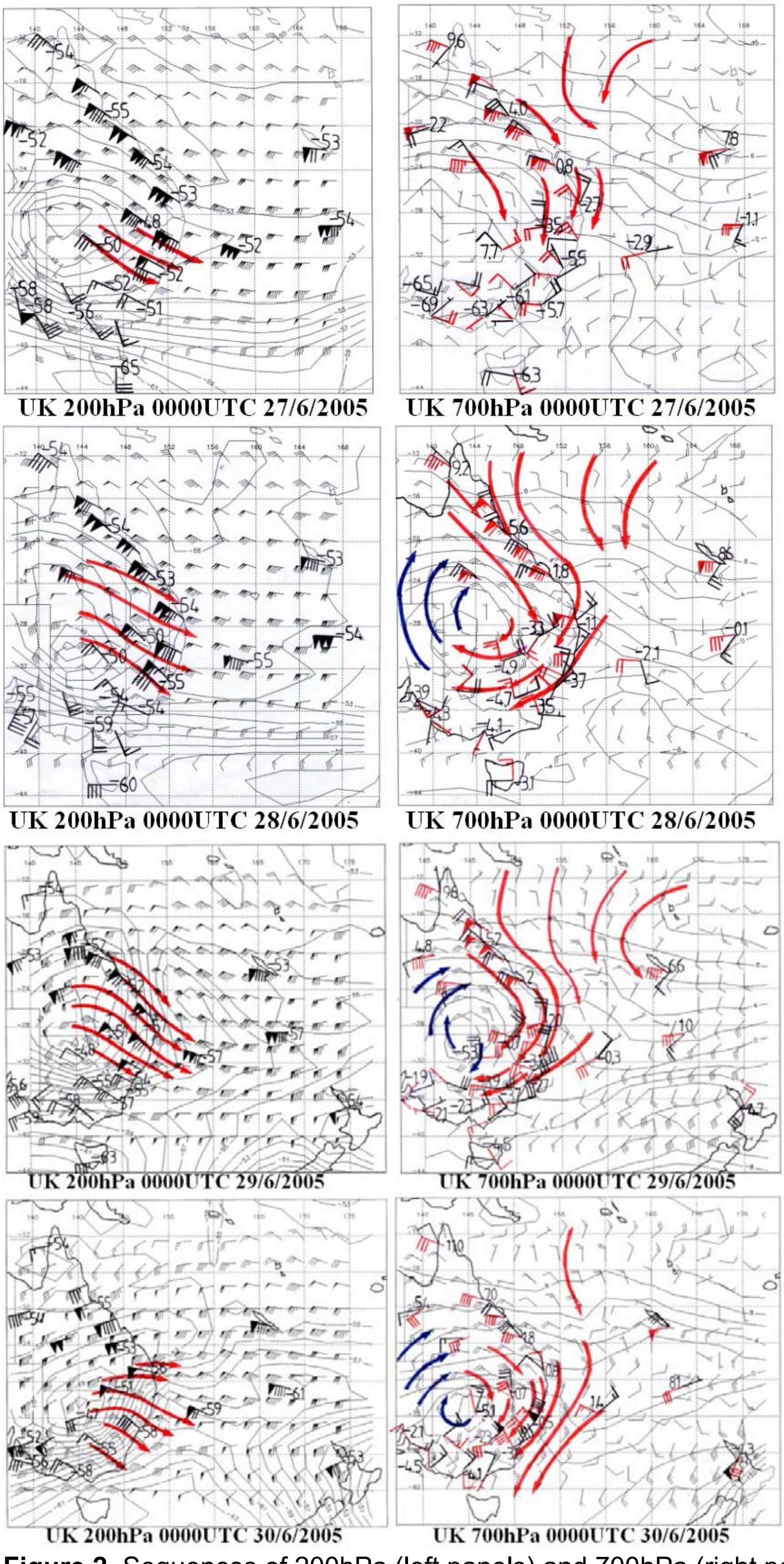


Figure 2. Sequences of 200hPa (left panels) and 700hPa (right panels) leading up to the Gold Coast Floods of 2005 as in Figure 1.

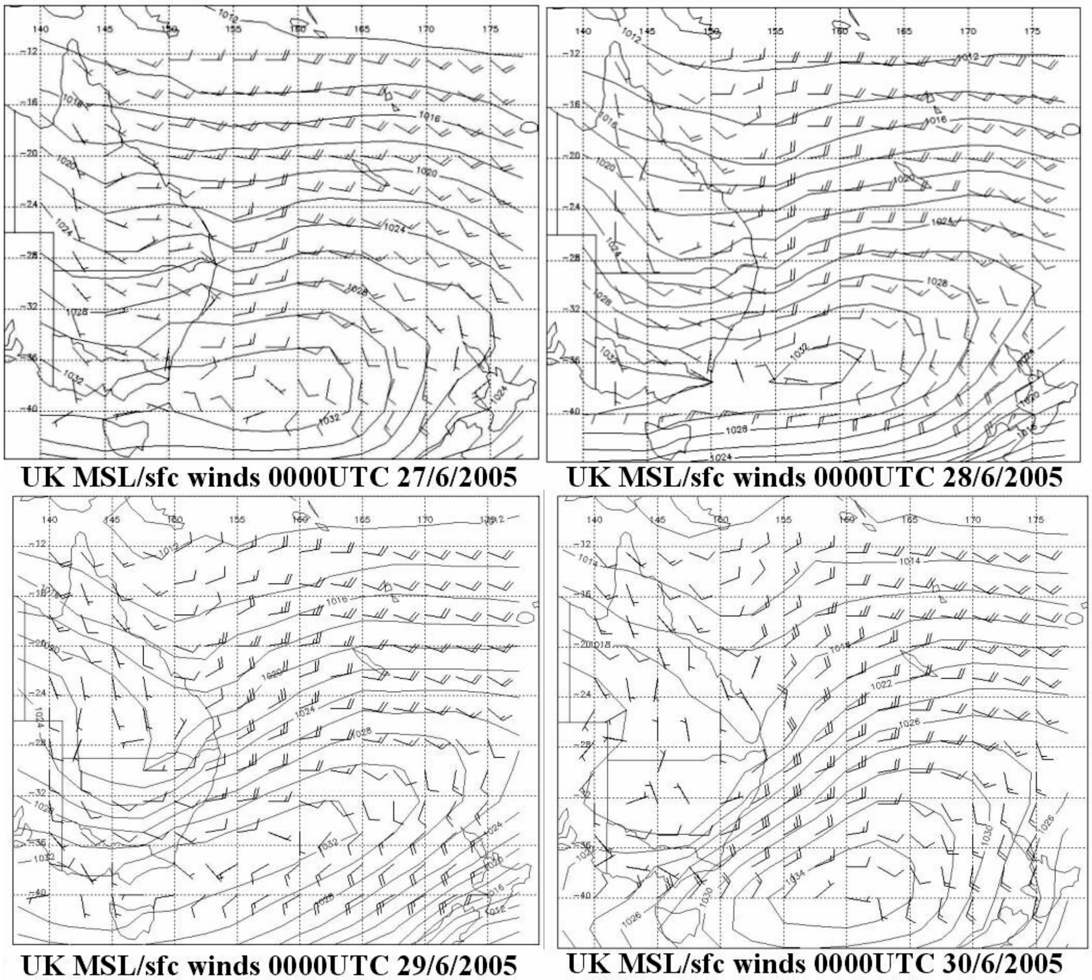


Figure 3. Mean sea level analyses showing pressure distribution and surface winds from the UK model.

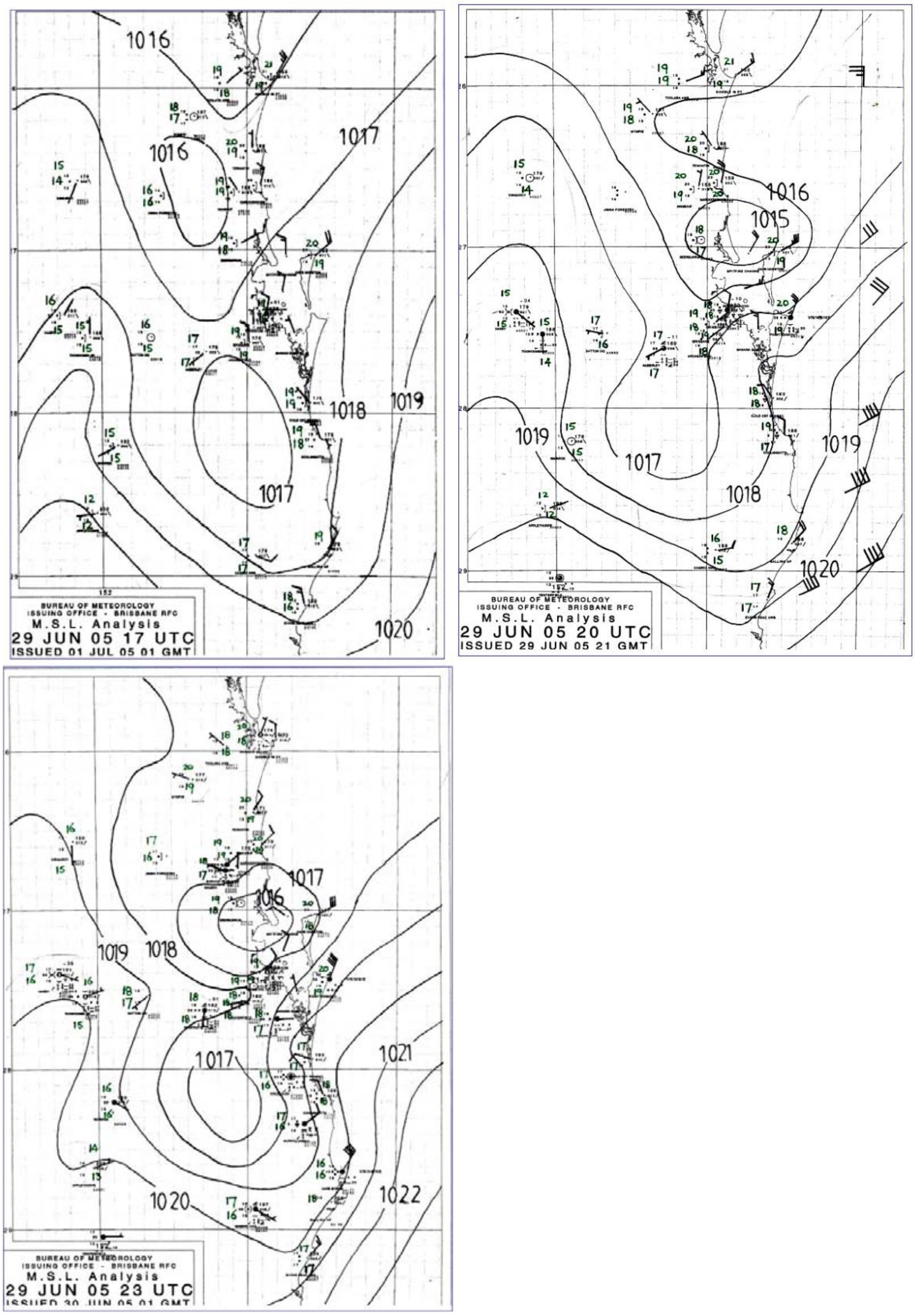


Figure 4. Mean sea level analyses for southeast Queensland and northeast New South Wales. Quikscat winds are plotted in the 200UTC chart. Temperature and dewpoints are highlighted in green.

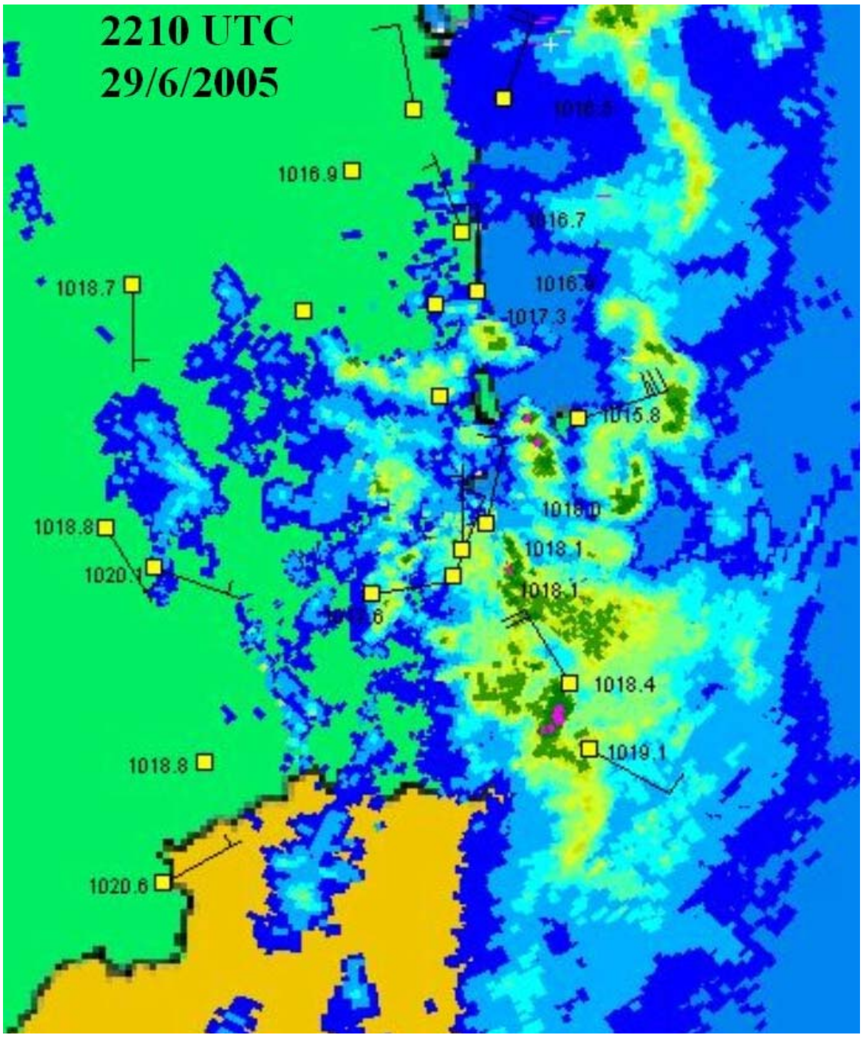


Figure 5. Composite radar image and observations at 2210 UTC 29 June 2005.

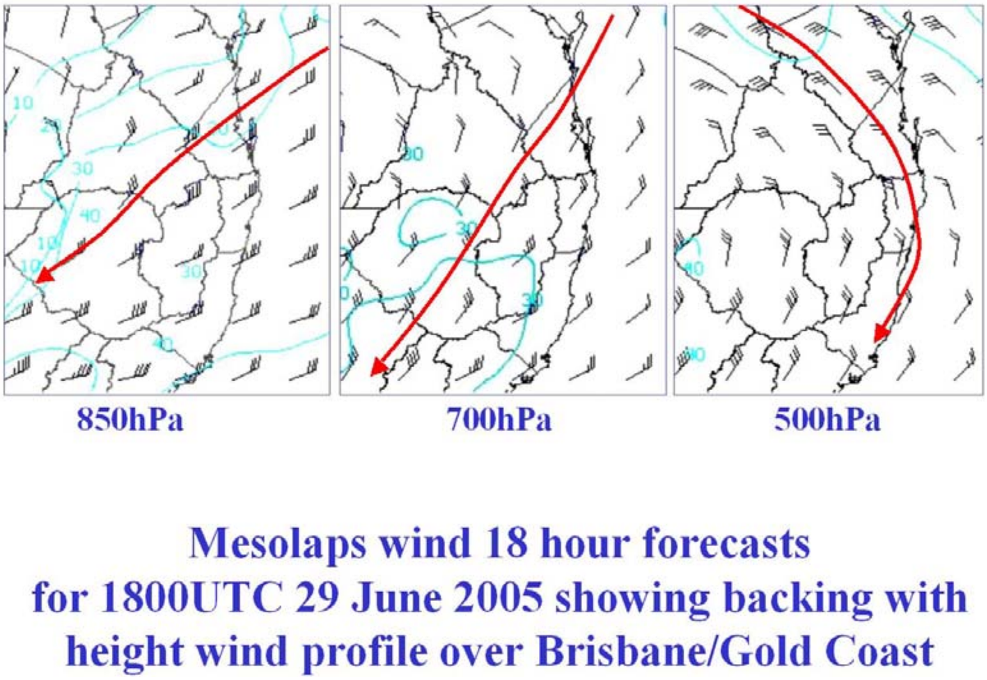


Figure 6. Mesolaps Forecast of vertical wind profile

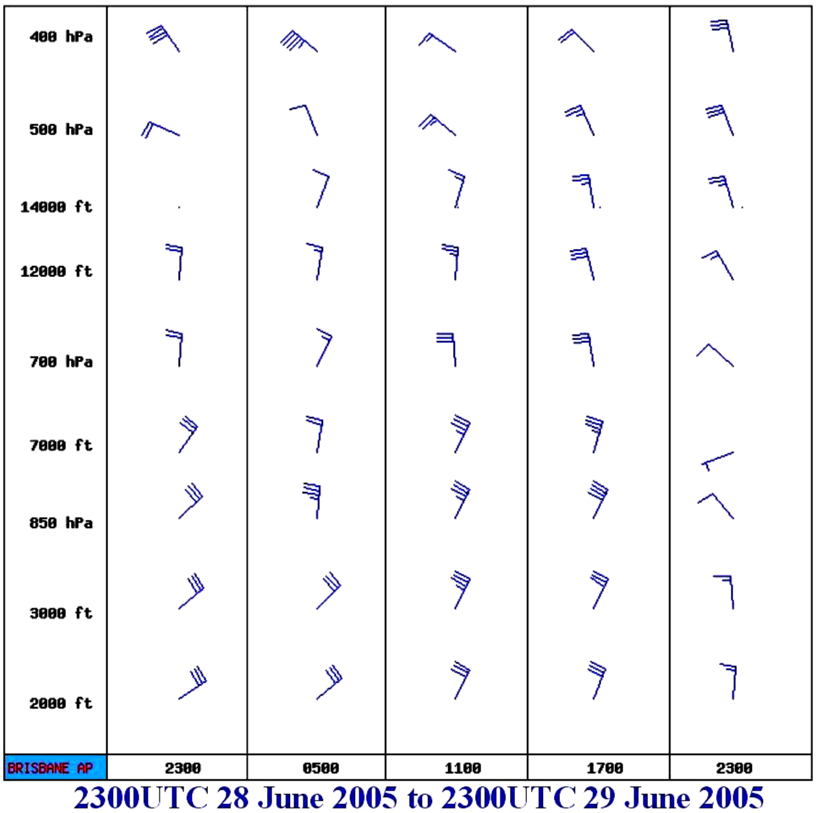


Figure 7. Upper winds at Brisbane Airport.

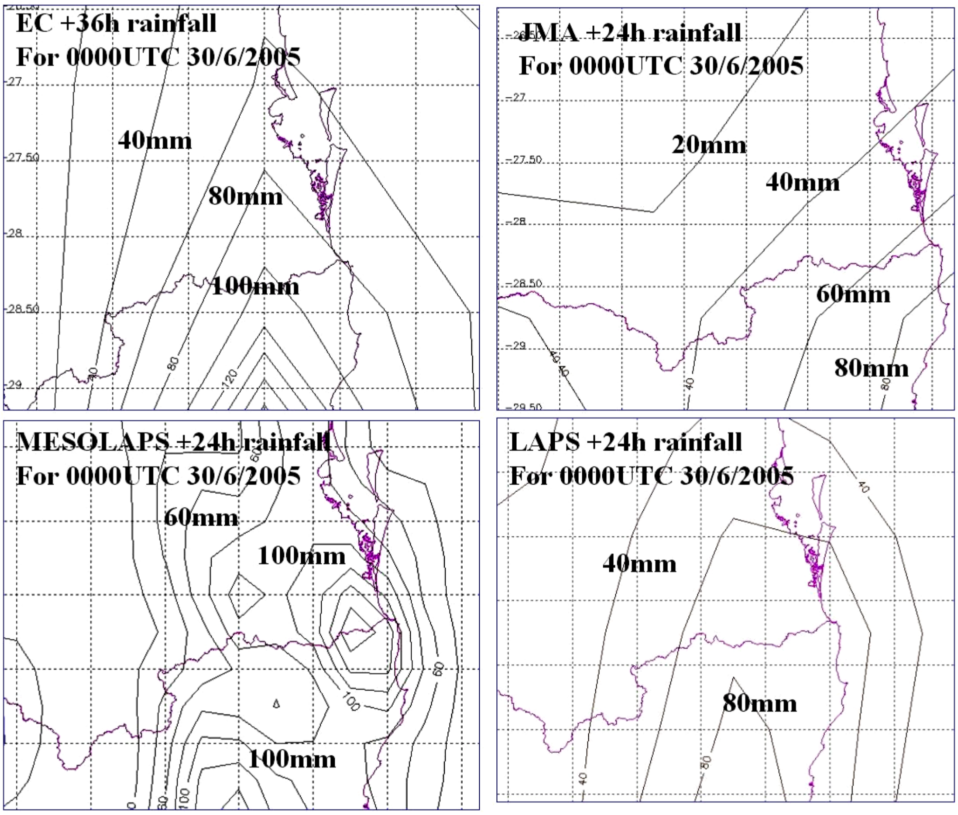


Figure 8. Various numerical rainfall forecasts.

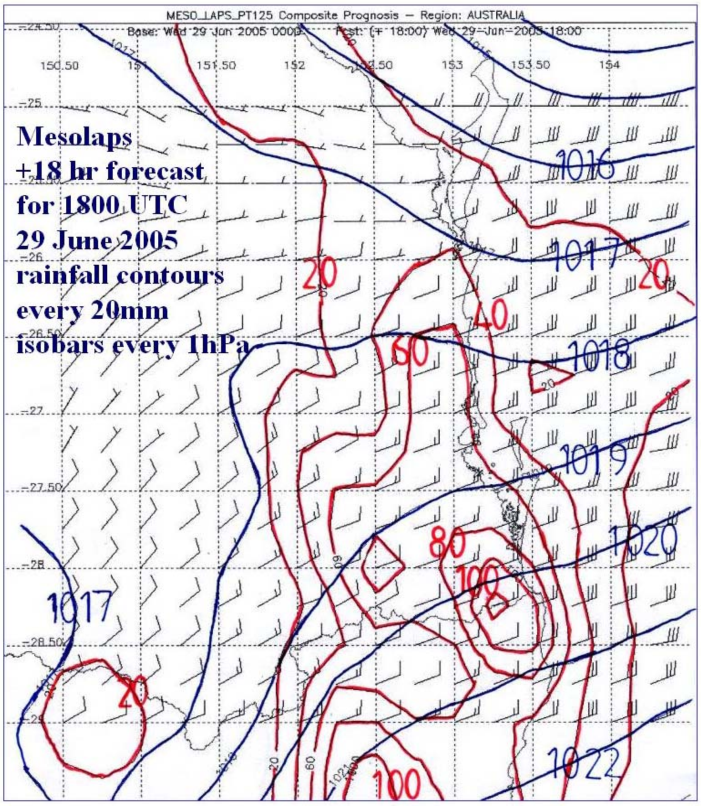
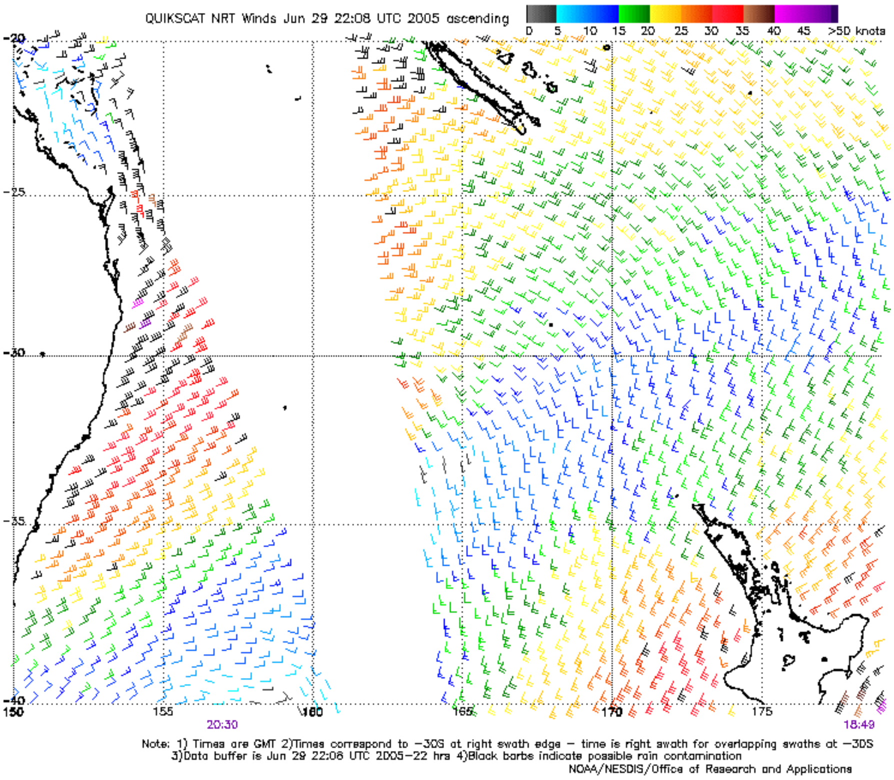


Figure 9. Mesolaps forecasts for surface winds, pressure distribution and cumulative rainfall (mm) for 1800UTC   29 June 2005.



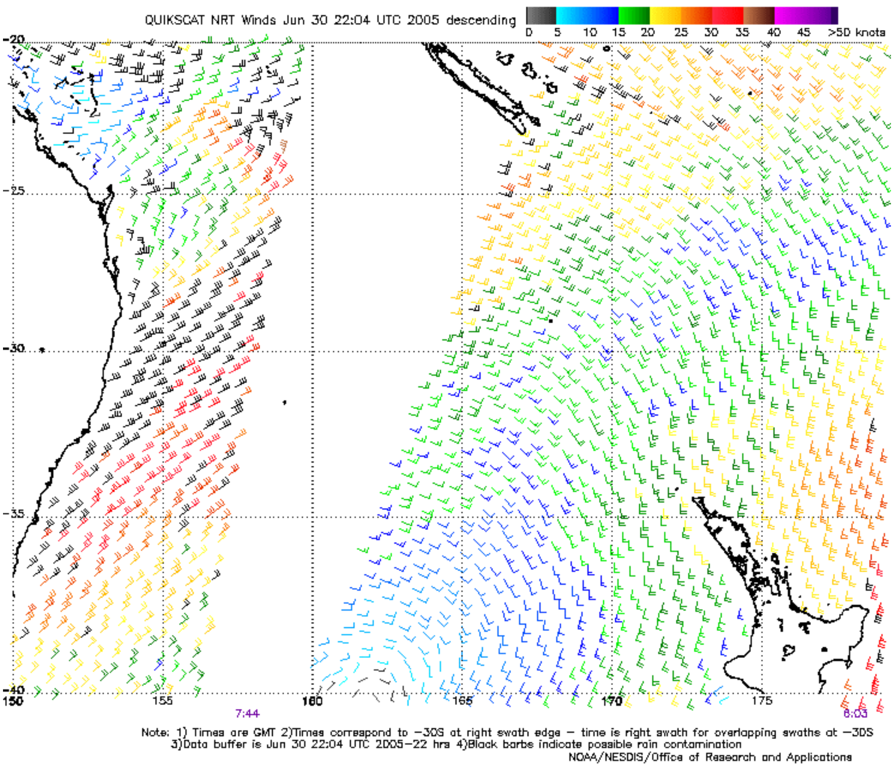
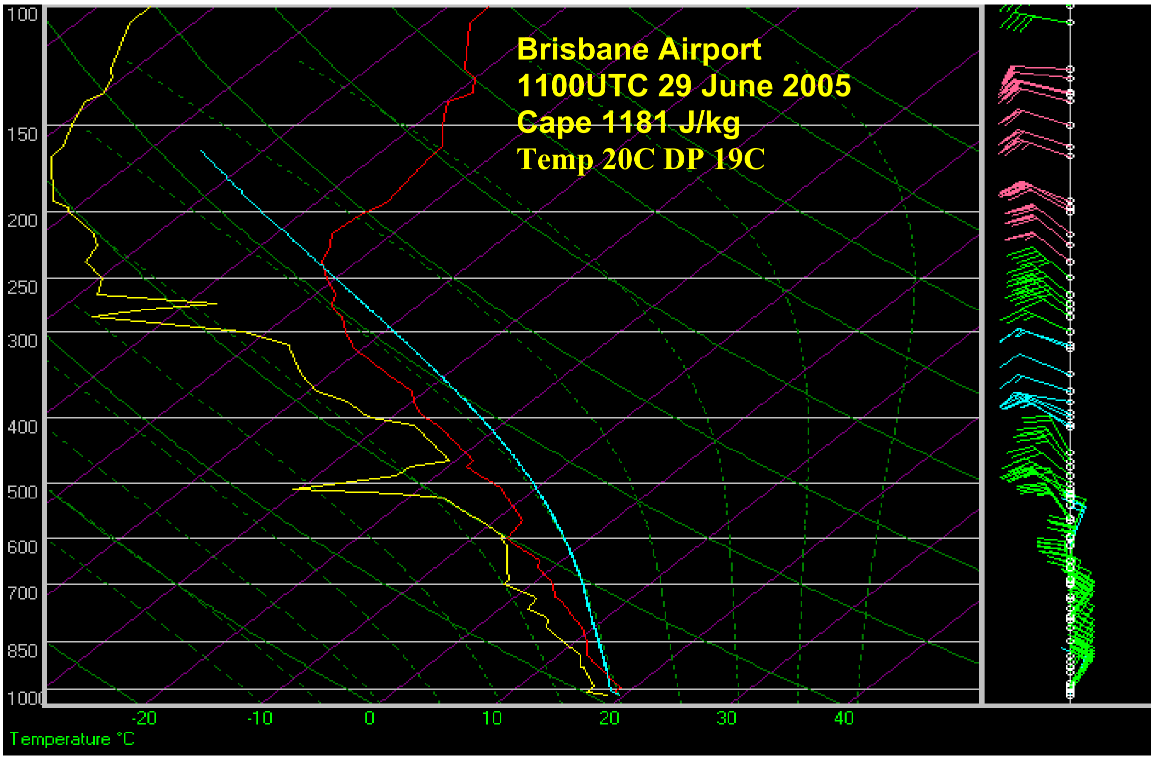


Figure 10: Quickscat images showing gale force winds offshore from Southeast QLD.

Figure 11: Webcams images at Duranbah, Kirra and Snapper on Gold Coast



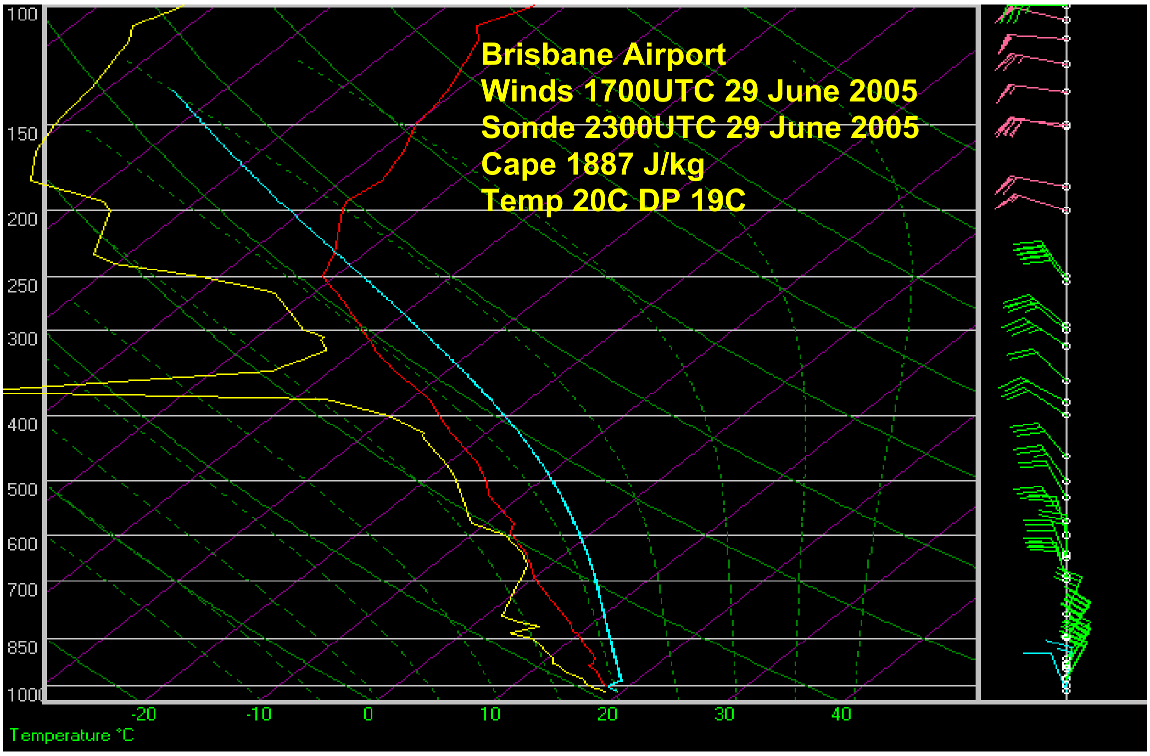


Figure 12: Brisbane Airport temperature and winds

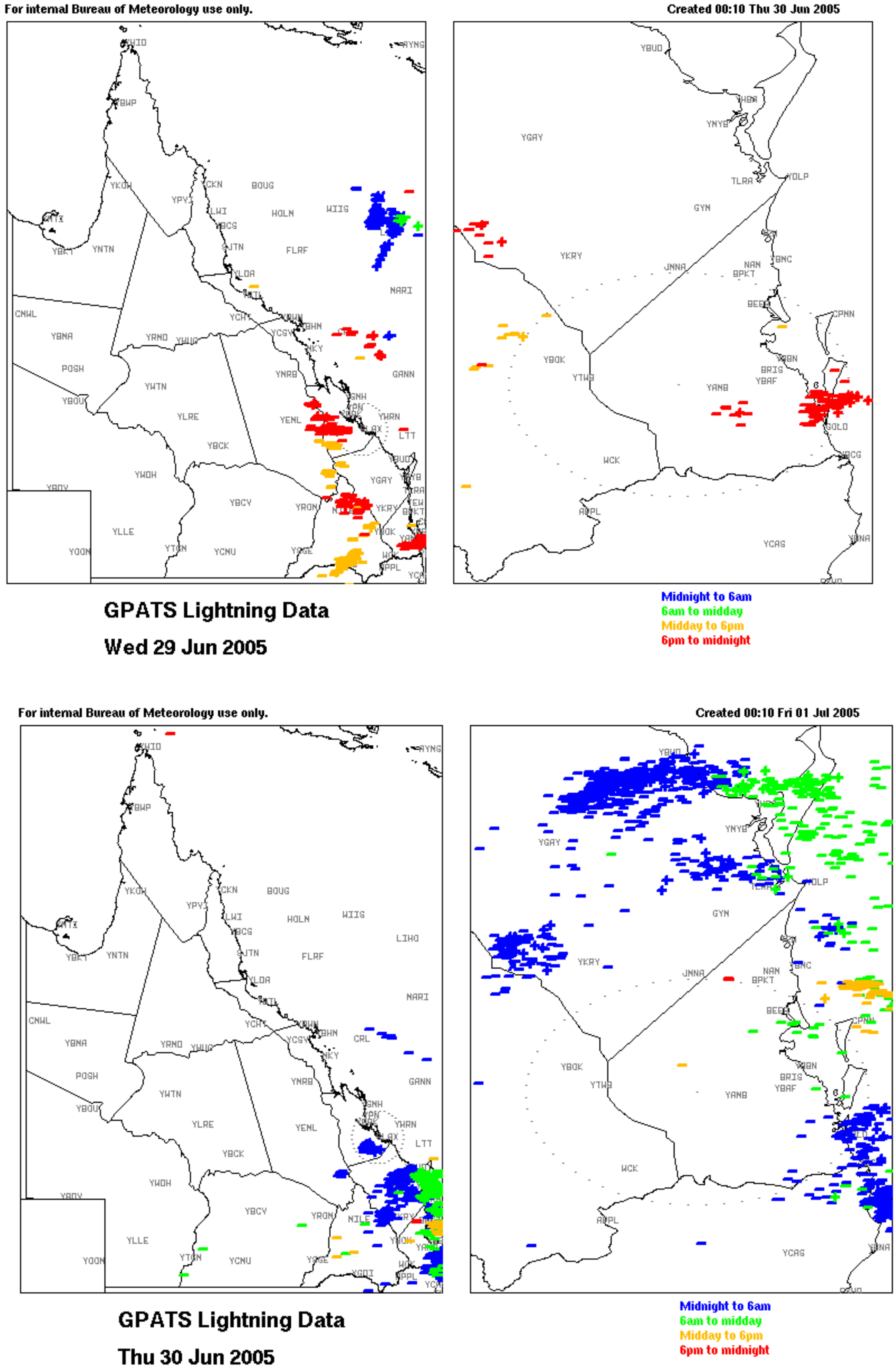


Figure 13: GPATS Lightning data for 29th/30th June

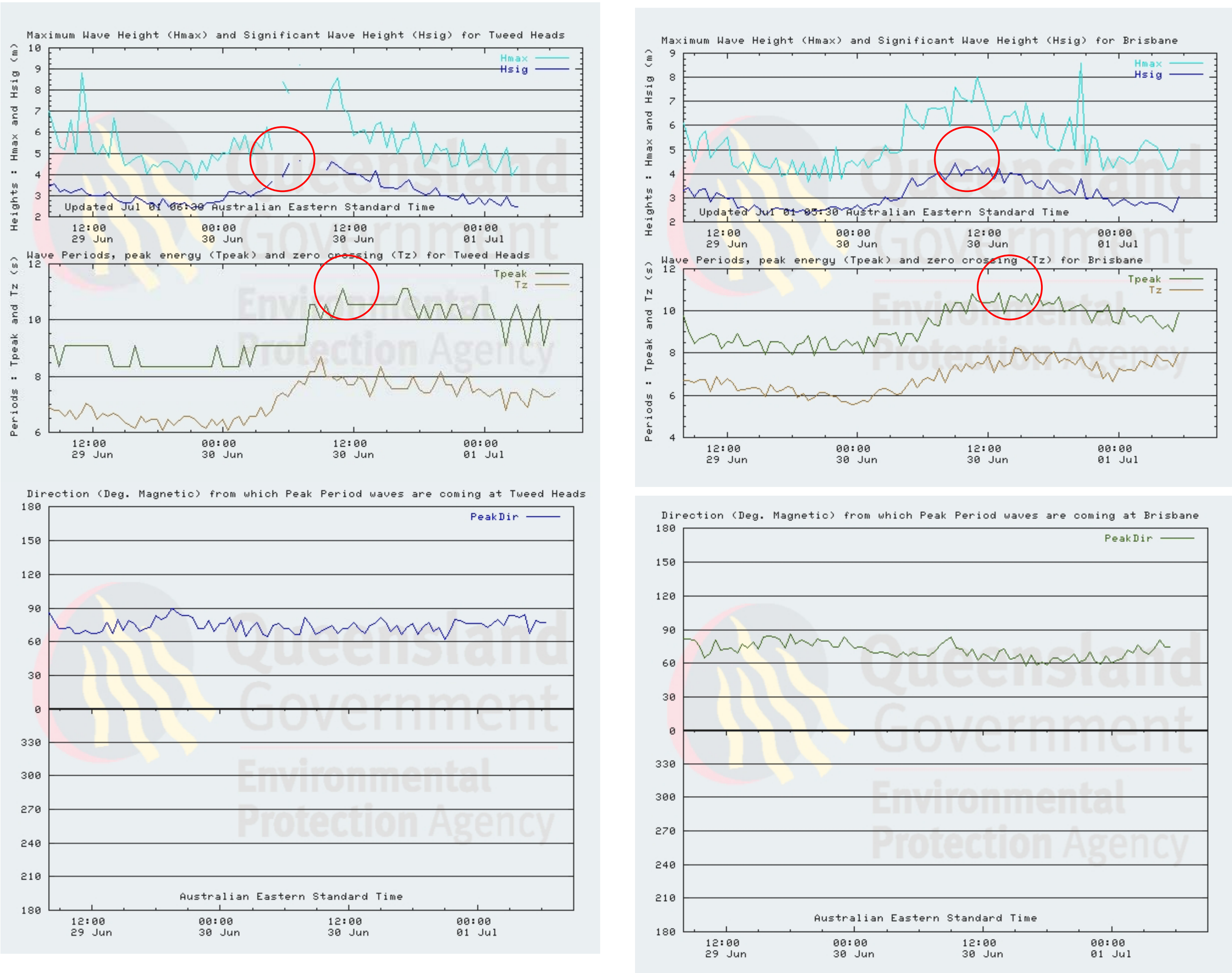


Figure 14: Buoy data for Tweed River and Brisbane with peak waves and periods circled