URBANISATION AND MAXIMUM TEMPERATURE

Harvey Stern*[1], Belinda Campbell[1], Michael Efron[1], John Cornall-Reilly[1] and John McBride[2]
[1]Bureau of Meteorology, Australia
[2]Centre for Australian Weather and Climate Research

1. INTRODUCTION

1.1 *Background*

The Bureau of Meteorology's (BOM) website (Bureau of Meteorology, Australia, 2010a) explains the large temperature rises that have occurred in some cities thus:

"Particularly at night, cities are usually warmer than their rural surroundings, because of heat stored in bricks and concrete and trapped between close-packed buildings".

The influence of cities on overnight temperatures is well documented. However, their influence on daytime temperatures is less well documented. The current paper expands upon work previously presented on this topic (Stern *et al*., 2010; Bureau of Meteorology, Australia, 2010b).

1.2 *The approach used*

The Australian Data Archive for Meteorology (ADAM) is used to compare trends in maximum temperature (MAXTEMP) at Sydney and Melbourne with those at other (less urbanised) Australian localities. By this means, the relative extent to which MAXTEMP increases in those cities can be attributed to urbanisation, the enhanced greenhouse effect, and other causes, is quantified.

1.3 *Similarity to Torok's (1996) approach*

The approach applied may be compared to that of Torok (1996), whose intention was to identify, and adjust for, "… sudden jumps in time series due to non-climatic changes. It was expected that slight trends over a long period of time would not be detected. However, in practice the method proved to be efficient in the identification of trends in the data due to slow changes over time, such as vegetation growth or urbanisation. Some trends can be made up of a series of small discontinuities of the same sign.

For example, urbanisation can be considered to be a series of abrupt jumps every time a building is constructed or a road sealed, manifesting itself in the record as a slow trend… (As a consequence) the adjustment procedure removed urbanisation signals from the time series".

By contrast, the approach in the present paper is to identify the urbanisation signals, and to preserve them in the time series.

Corresponding author address: Harvey Stern, Bureau of Meteorology, Box 1636, Melbourne, 3001, Australia;
e-mail: h.stern@bom.gov.au

Torok's adjustments have been applied to the derivation of the BOM's high quality data sets (HQDS) (Bureau of Meteorology, Australia, 2010c) and, as would be expected, MAXTEMP rising trends in the Melbourne and Sydney HQDS (with the urbanisation signals removed) are found to be slower than those in the corresponding ADAM data sets (without the urbanisation signal removed).

For closely managed weather observation sites, such as those in the centre of large cities such as Melbourne and Sydney, most of the required adjustments are urbanisation related (rather than site-management related) – although the period 1910-1917 saw Sydney's MAXTEMPs 0.7°C cooler than they otherwise would have been (as a consequence of the instruments being moved).

Cognisant of this, for both localities, sequences of likely MAXTEMPs may be derived for the hypothetical circumstance of the cities not being built where they were, (in the first instance) by using urbanisation-attributed adjustments opposite in sign to those used by Torok. "Opposite", because Torok's, and the HQDS, adjustments lead to a time series based on the assumption of the cities always being where they are).

2. DISCUSSION

2.1 *Comparing city and less urbanised sites*

Sydney and Melbourne MAXTEMP data are compared with other ADAM data sets and are found to be increasing at a faster rate than elsewhere. For example, Sydney's MAXTEMP is increasing at a linear rate that is +0.065°C per decade faster than that of Newcastle, whilst Melbourne's MAXTEMP is increasing at a linear rate that is +0.050°C per decade faster than that of Ballarat (Figure 1).

For both localities, annual MAXTEMP data are statistically modelled over various control periods using MAXTEMP data at surrounding less urbanised stations as input. Thereby, sequences of non-urbanised MAXTEMP can be constructed for the hypothetical circumstance of the cities not being built (Figure 2).

Sydney and Melbourne MAXTEMP data are compared with ADAM data sets for the 73 Australian localities (excluding Sydney and Melbourne) with at least 80 years of MAXTEMP data during the 100-year period 1910 to 2009 inclusive (Figure 3).

2.2 *Synoptic stratification of MAXTEMP data*

MAXTEMPs at Sydney and Melbourne are found to be increasing, respectively, at rates 0.080°C per decade and 0.071°C per decade faster than the average temperature at the 73 sites (Figure 4).

The probabilities of such large differences occurring by chance are <<0.1% in both cases. That the average MAXTEMPs in the two cities have risen at a faster rate than at less urbanised localities is therefore largely attributed to the urbanisation.

Synoptic stratification of 1948-2009 daily Melbourne–Laverton MAXTEMP differences shows that a recent "jump" in the Melbourne series (post Torok's PhD thesis, and therefore not included in the Torok and HQDS adjustments) is due to buildings recently constructed immediately to the south of the Melbourne site.

Synoptic stratification of daily Melbourne and Laverton MAXTEMP data shows that a recent "jump" in the Melbourne series is due to buildings constructed immediately to the south and southeast of the site, with relative rate of MAXTEMP rise being much greater with both anticyclonic (Figure 5) and cyclonic (Figure 6) synoptic types associated with surface southerly and south-easterly flow (Table 1 and Figure 7).

2.3 *Impact of rainfall*

It might be suggested that the recent jump in Melbourne MAXTEMPs may be attributed to the recent decrease in rainfall (Bureau of Meteorology, Australia, 2010d). It is therefore worthwhile considering the relative impact of rainfall on maximum temperature at highly urbanised and slightly urbanised sites, in order to test this proposition. To this end, Laverton and Melbourne data over the 66-year period where data were available for both sites, 1944-2009, were compared:

The overall linear trend at Melbourne is +2.03ºC per century - standard error 0.34ºC. Removing the contribution attributable to the trend in rainfall reduces this by 0.41ºC to +1.62ºC per century - standard error also 0.34ºC);

By contrast, the overall linear trend at Laverton is 1.63ºC per century - standard error 0.38ºC. Removing the contribution attributable to the trend in rainfall reduces this by almost the same amount as for Melbourne ... 0.39ºC (vs 0.41ºC for Melbourne) to +1.24ºC per century - standard error 0.39 ºC.

One therefore concludes that the occurrence of rainfall (or otherwise) has a similar impact on maximum temperature at both the city and less urbanised sites.

3. CONCLUDING REMARKS

As previously discussed, Torok's (1996) approach has the effect of removing urbanisation signals from the series and has the same effect on the Bureau of Meteorology's high quality data sets (HQDS).

However, the current study's approach (using ADAM data sets) has been to preserve the urbanisation signals in the time series.

As a consequence, MAXTEMP rising trends in the HQDS (with the urbanisation signals removed) are found to be slower than those in the corresponding ADAM data sets (without the urbanisation signal removed).

4. REFERENCES

Bureau of Meteorology, *Australia,* 2010a: What cities do to the local climate, web URL: http://www.bom.gov.au/lam/climate/levelthree/cpeople/urban2.htm

Bureau of Meteorology, Australia, 2010b: 13 October 2010, Media Release, "Hot cities", web URL: http://www.bom.gov.au/announcements/media_releases/ho/20101013.shtml

Bureau of Meteorology, Australia, 2010c: Australian high-quality climate site networks, web URL: http://www.bom.gov.au/climate/change/hqsites/

Bureau of Meteorology, Australia, 2010d: Australian Climate Change and Variability, web URL: http://www.bom.gov.au/climate/change/aus_cvac.shtml

Stern, H., Campbell, B., Efron, M., Cornall-Reilly, J., and McBride, J., 2010: Urbanisation and maximum temperature, *Australia - New Zealand Climate Forum 2010,* 13-15 October 2010, Hobart, Australia, web URL: http://www.bom.gov.au/events/anzcf2010/abstract-189.shtml

Torok, S. J. 1993: The Development of a High Quality Historical Temperature Data Base for Australia. PhD thesis, *University of Melbourne, Australia*.

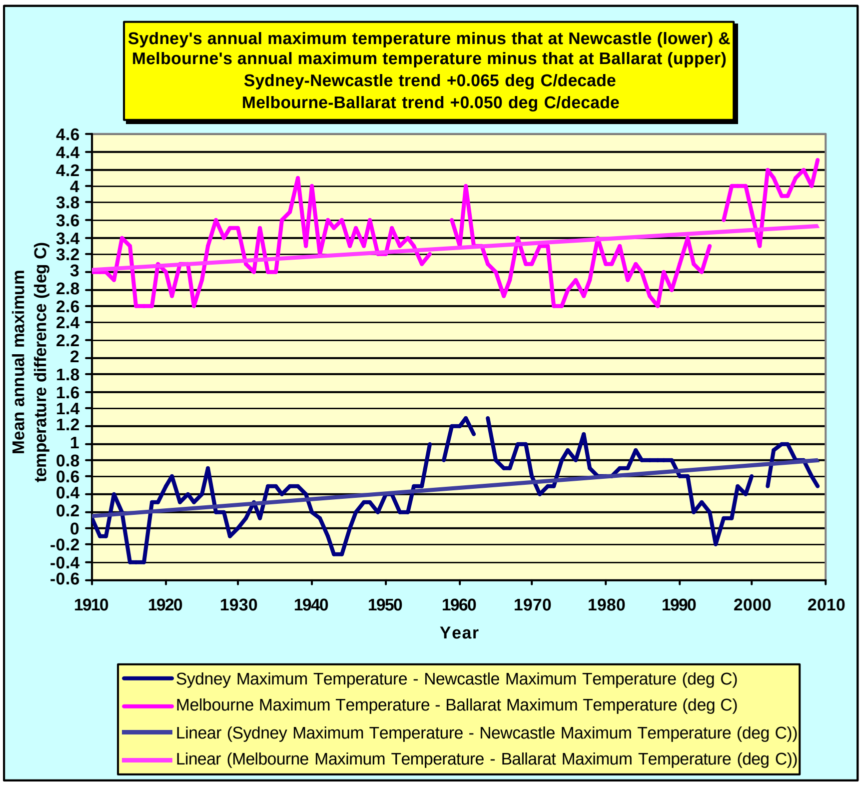


Figure 1 The rate of Sydney's MAXTEMP increase (in comparison with that of Newcastle), the rate of Melbourne's MAXTEMP increase (in comparison with that of Ballarat, and corresponding linear trends.

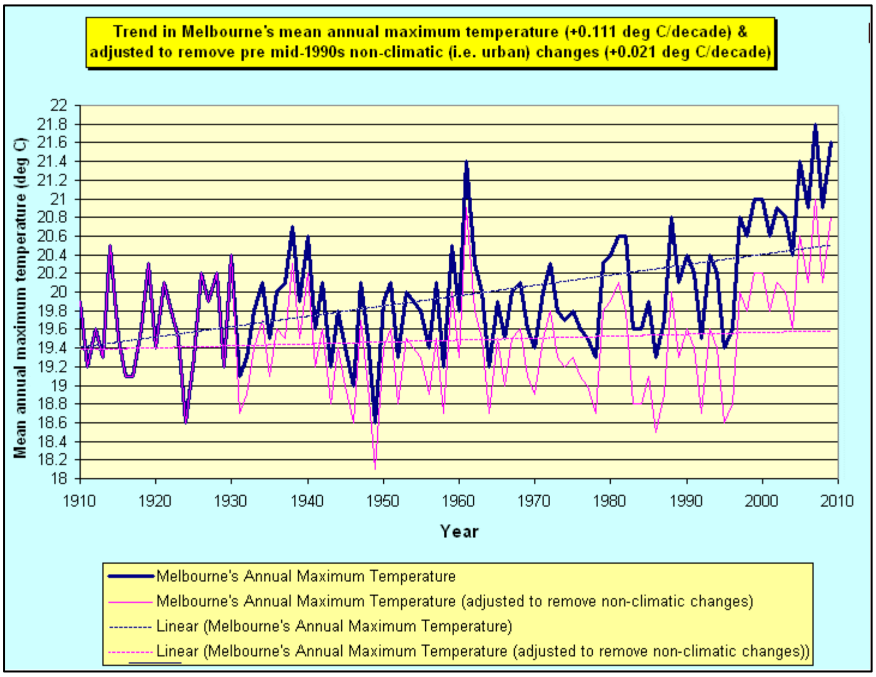


Figure 2 Sequences of Melbourne urbanised and non-urbanised MAXTEMP (in the latter case for the hypothetical circumstance of the city not being built) and corresponding linear trends.

.

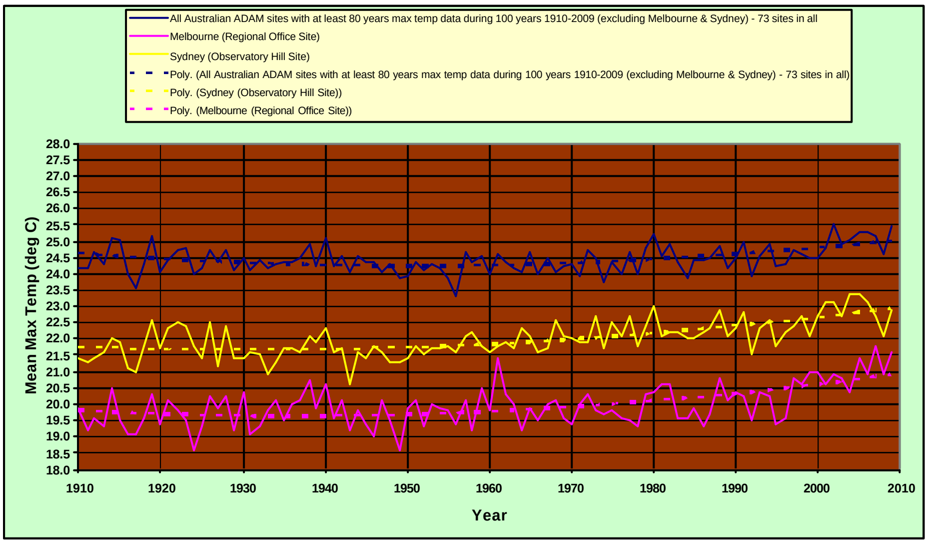


Figure 3 A comparison of the MAXTEMP rise at Sydney and Melbourne with the MAXTEMP rise at other Australian sites, and corresponding polynomial trends.

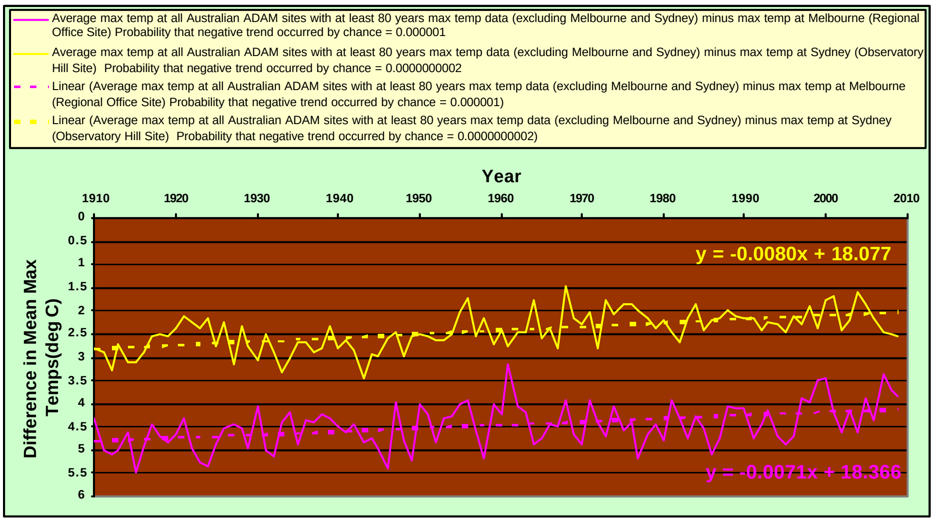


Figure 4 An illustration of MAXTEMP rises at Sydney and Melbourne in comparison with those across the rest of Australia. The (linear) rates of MAXTEMP rise at Sydney and Melbourne are, respectively, 0.080ºC per decade and 0.071°C per decade *faster* than the corresponding rate of MAXTEMP rise at the other Australian sites. The probability of such large differences *occurring by chance* is <<0.1% in both cases.

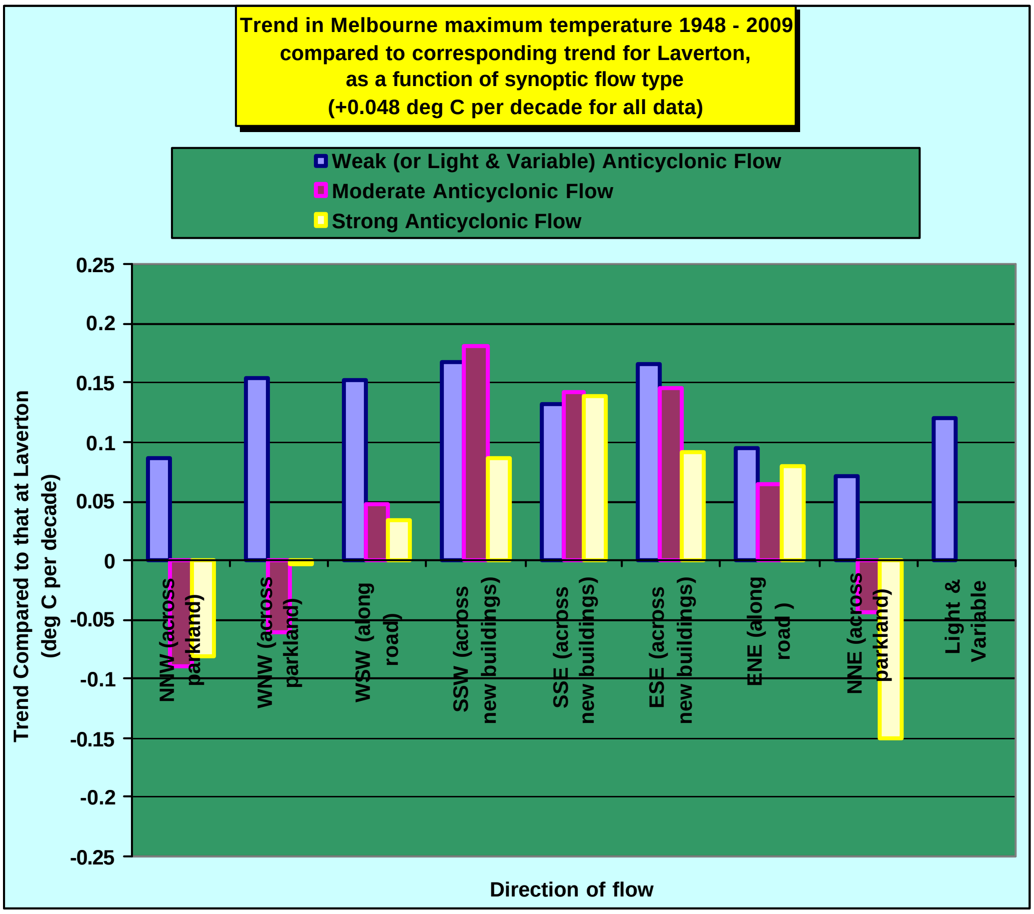


Figure 5 The rate of MAXTEMP rise at Melbourne in comparison with Laverton is greater with anticyclonic synoptic types associated with surface southerly flow across the new buildings than with other synoptic types.

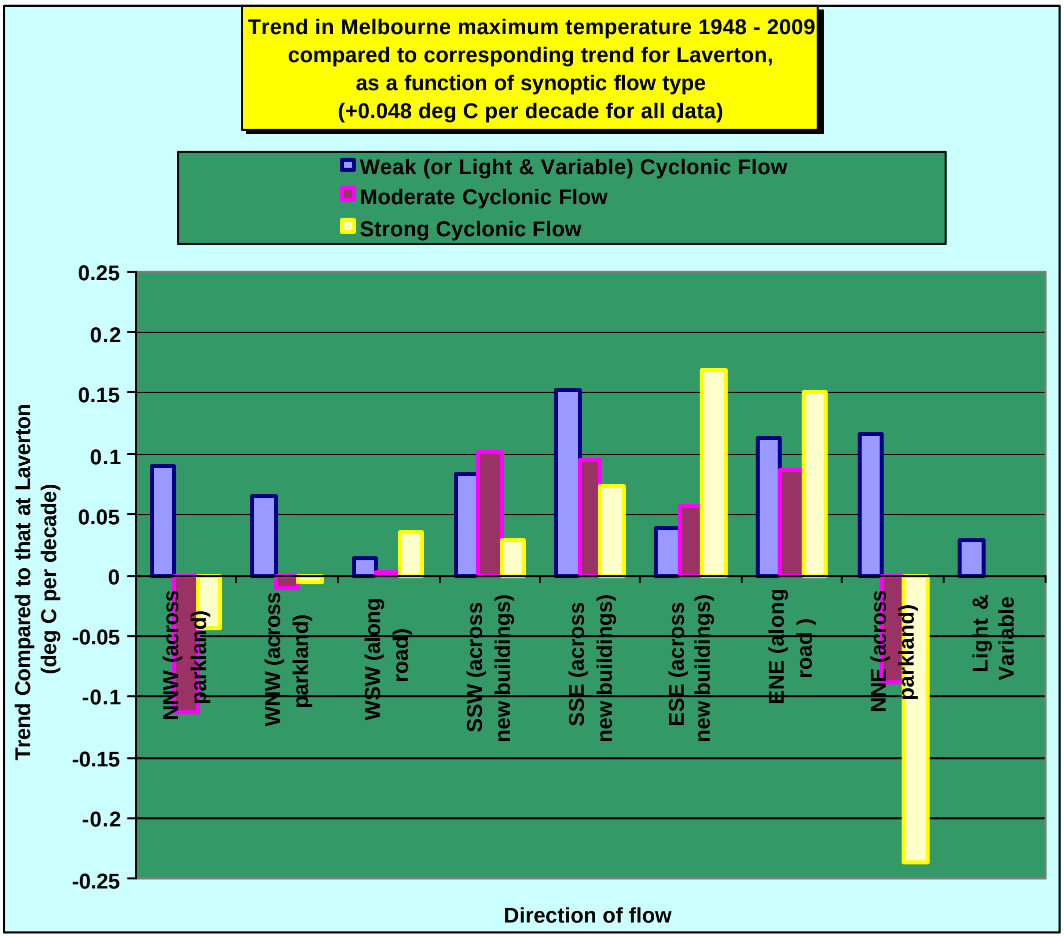


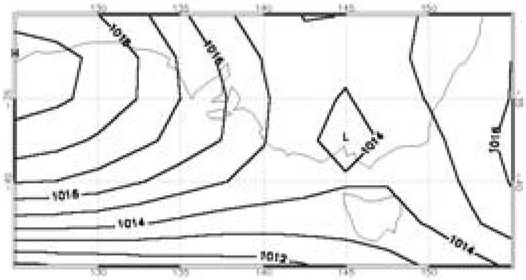
Figure 6 The rate of MAXTEMP rise at Melbourne in comparison with Laverton is greater with cyclonic synoptic types associated with surface southerly flow across the new buildings than with other synoptic types.

Table 1 The curvature, direction and strength associated with the various synoptic types

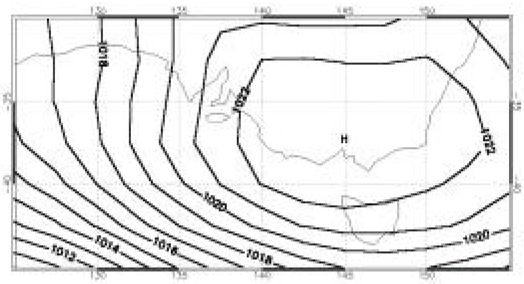
Type	Curvature (Cyclonic/ Anticyclonic)	Direction	Strength	Type	Curvature (Cyclonic/ Anticyclonic)	Directio n	Strength	Type	Curvature (Cyclonic/ Anticyclonic)	Direction	Strength
1	C	Variable	Weak								
2	A	Variable	Weak								
3	C	NNW	Weak	19	C	NNW	Moderate	35	C	NNW	Strong
4	A	NNW	Weak	20	A	NNW	Moderate	36	A	NNW	Strong
5	C	WNW	Weak	21	C	WNW	Moderate	37	C	WNW	Strong
6	A	WNW	Weak	22	A	WNW	Moderate	38	A	WNW	Strong
7	C	WSW	Weak	23	C	WSW	Moderate	39	C	WSW	Strong
8	A	WSW	Weak	24	A	WSW	Moderate	40	A	WSW	Strong
9	C	SSW	Weak	25	C	SSW	Moderate	41	C	SSW	Strong
10	A	SSW	Weak	26	A	SSW	Moderate	42	A	SSW	Strong
11	C	SSE	Weak	27	C	SSE	Moderate	43	C	SSE	Strong
12	A	SSE	Weak	28	A	SSE	Moderate	44	A	SSE	Strong
13	C	ESE	Weak	29	C	ESE	Moderate	45	C	ESE	Strong
14	A	ESE	Weak	30	A	ESE	Moderate	46	A	ESE	Strong
15	C	ENE	Weak	31	C	ENE	Moderate	47	C	ENE	Strong
16	A	ENE	Weak	32	A	ENE	Moderate	48	A	ENE	Strong
17	C	NNE	Weak	33	C	NNE	Moderate	49	C	NNE	Strong
18	A	NNE	Weak	34	A	NNE	Moderate	50	A	NNE	Strong

Figure 7 Weather maps associated with the various synoptic types (next 7 pages)

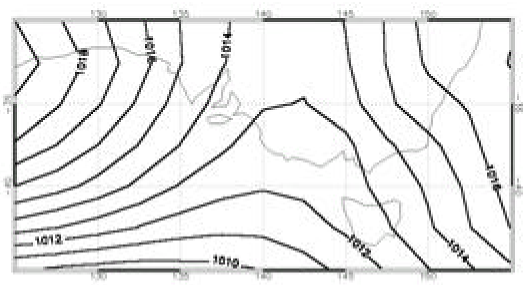
Synoptic Type 1 NCEP Mean Sea Level Pressure Analysis 00UTC



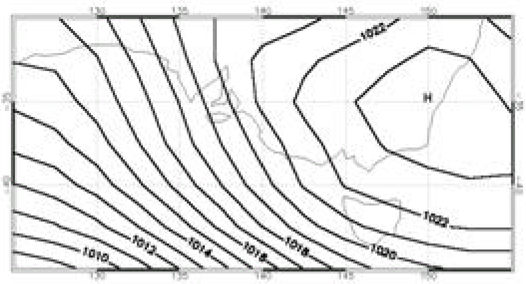
Synoptic Type 2 NCEP Mean Sea Level Pressure Analysis 00UTC



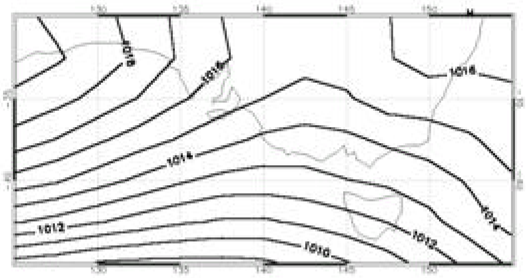
Synoptic Type 3 NCEP Mean Sea Level Pressure Analysis 00UTC



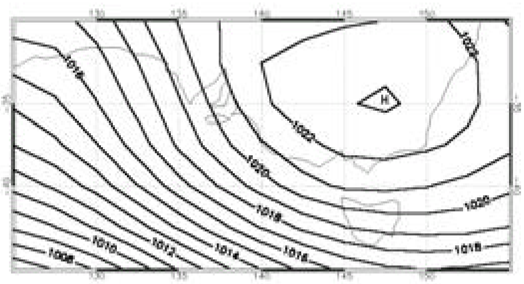
Synoptic Type 4 NCEP Mean Sea Level Pressure Analysis 00UTC



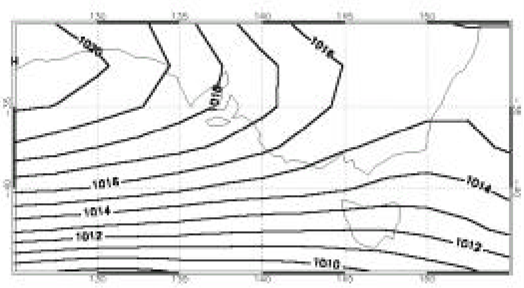
Synoptic Type 5 NCEP Mean Sea Level Pressure Analysis 00UTC



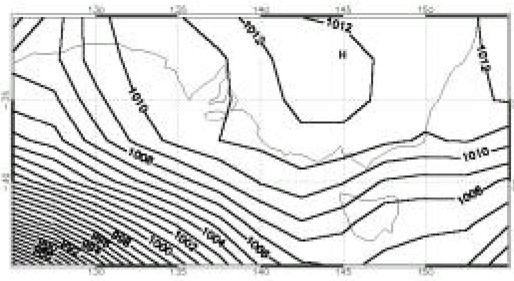
Synoptic Type 6 NCEP Mean Sea Level Pressure Analysis 00UTC



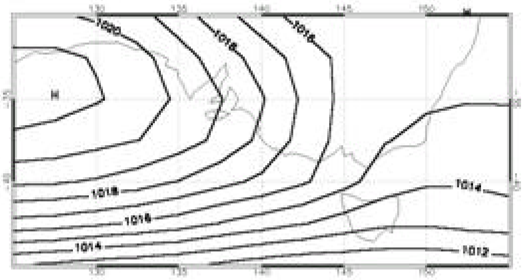
Synoptic Type 7 NCEP Mean Sea Level Pressure Analysis 00UTC



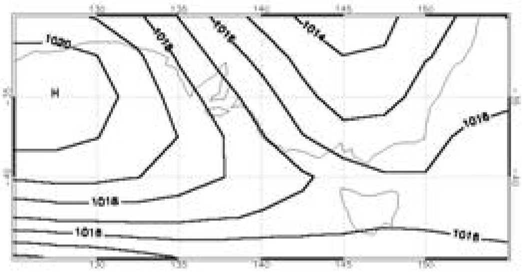
Synoptic Type 8 Member 264 NCEP Mean Sea Level Pressure Analysis 28/12/2001 00UTC



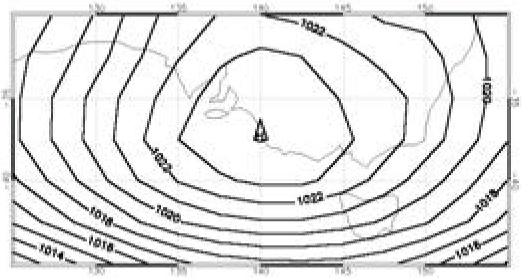
Synoptic Type 9 NCEP Mean Sea Level Pressure Analysis 00UTC



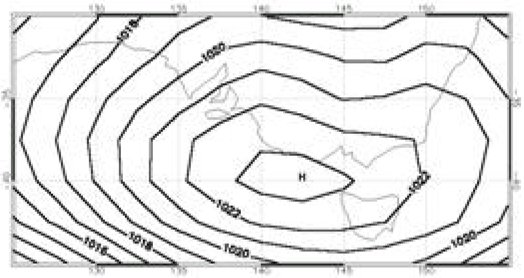
Synoptic Type 13 NCEP Mean Sea Level Pressure Analysis 00UTC



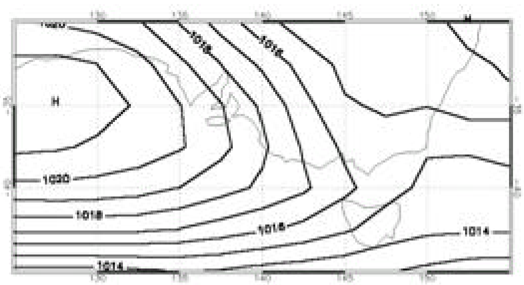
Synoptic Type 10 NCEP Mean Sea Level Pressure Analysis 00UTC



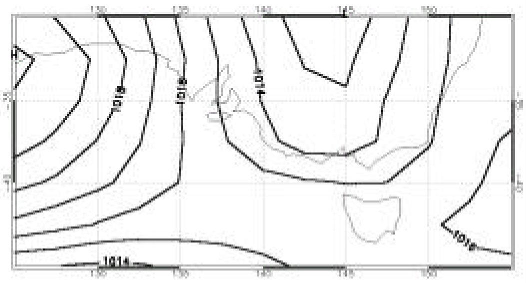
Synoptic Type 14 NCEP Mean Sea Level Pressure Analysis 00UTC



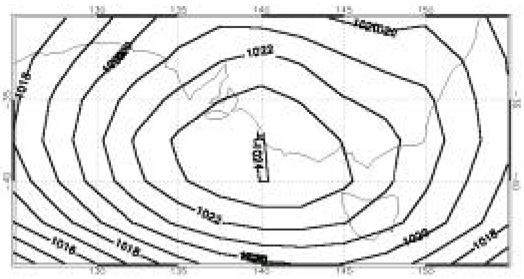
Synoptic Type 11 NCEP Mean Sea Level Pressure Analysis 00UTC



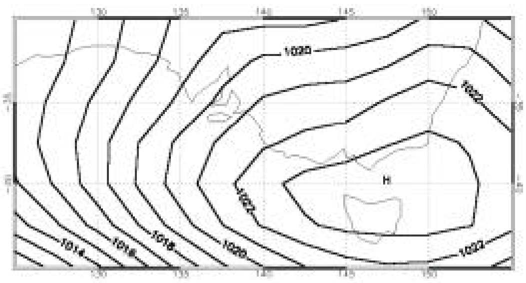
Synoptic Type 15 NCEP Mean Sea Level Pressure Analysis 00UTC



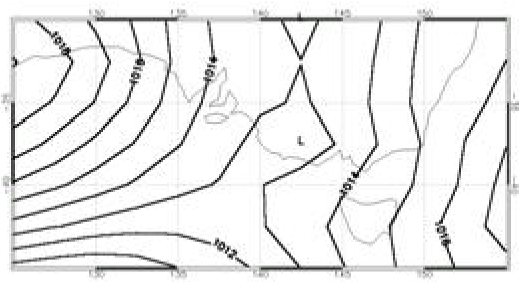
Synoptic Type 12 NCEP Mean Sea Level Pressure Analysis 00UTC



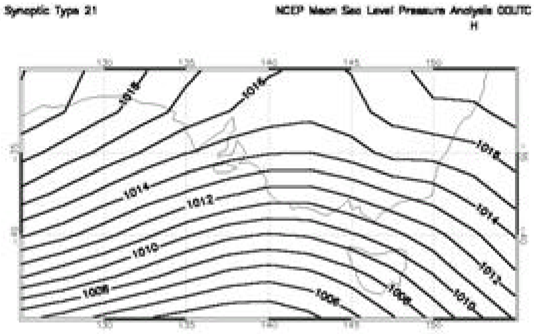
Synoptic Type 16 NCEP Mean Sea Level Pressure Analysis 00UTC



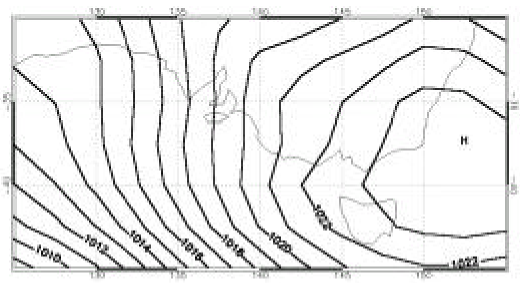
Synoptic Type 17 NCEP Mean Sea Level Pressure Analysis 00UTC



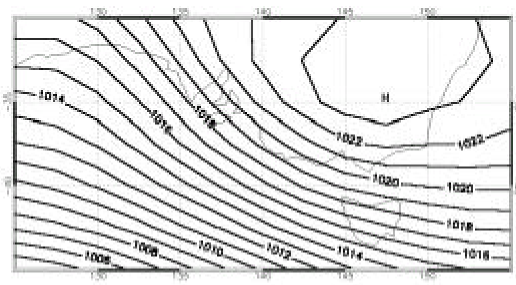
Synoptic Type 21 NCEP Mean Sea Level Pressure Analysis 00UTC



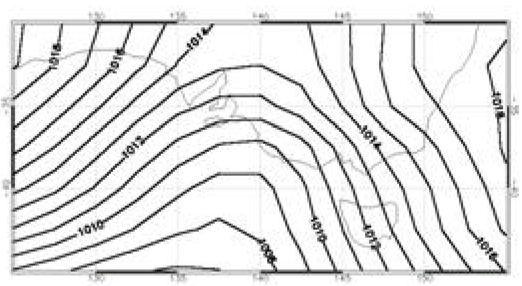
Synoptic Type 18 NCEP Mean Sea Level Pressure Analysis 00UTC



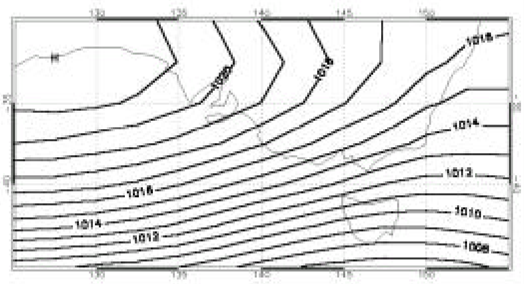
Synoptic Type 22 NCEP Mean Sea Level Pressure Analysis 00UTC



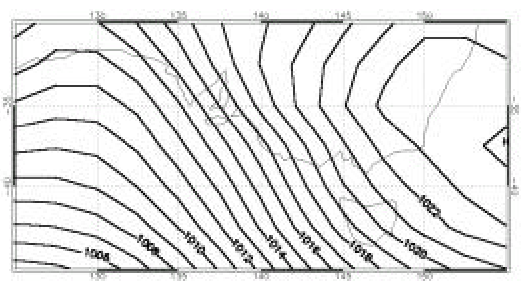
Synoptic Type 19 NCEP Mean Sea Level Pressure Analysis 00UTC



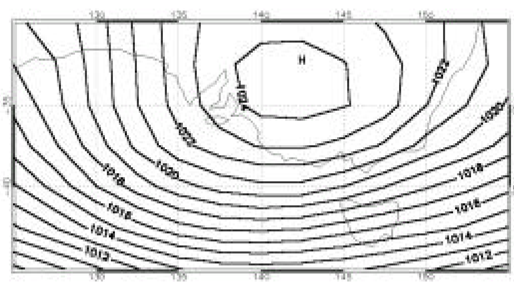
Synoptic Type 23 NCEP Mean Sea Level Pressure Analysis 00UTC



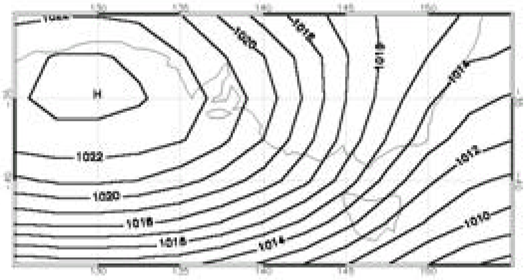
Synoptic Type 20 NCEP Mean Sea Level Pressure Analysis 00UTC



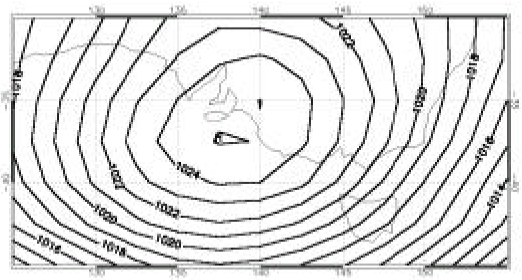
Synoptic Type 24 NCEP Mean Sea Level Pressure Analysis 00UTC



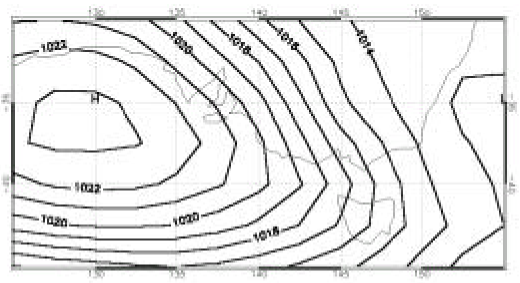
Synoptic Type 25 NCEP Mean Sea Level Pressure Analysis 00UTC



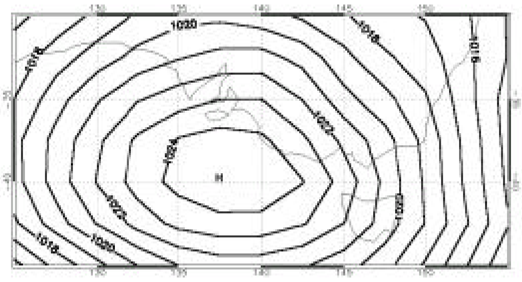
Synoptic Type 26 NCEP Mean Sea Level Pressure Analysis 00UTC



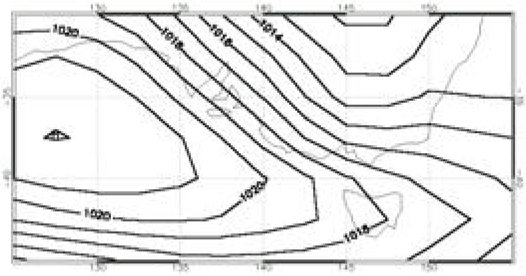
Synoptic Type 27 NCEP Mean Sea Level Pressure Analysis 00UTC



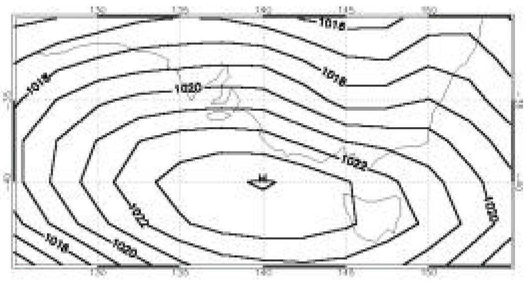
Synoptic Type 28 NCEP Mean Sea Level Pressure Analysis 00UTC



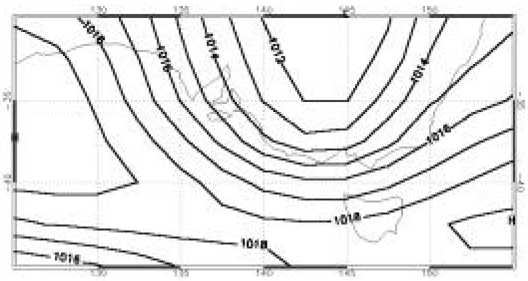
Synoptic Type 29 NCEP Mean Sea Level Pressure Analysis 00UTC



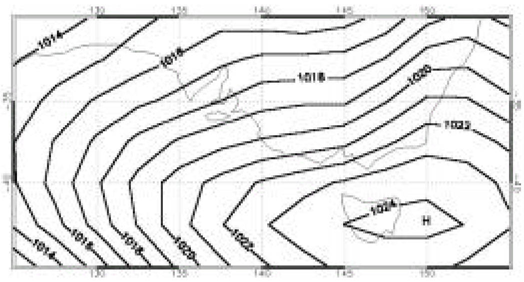
Synoptic Type 30 NCEP Mean Sea Level Pressure Analysis 00UTC



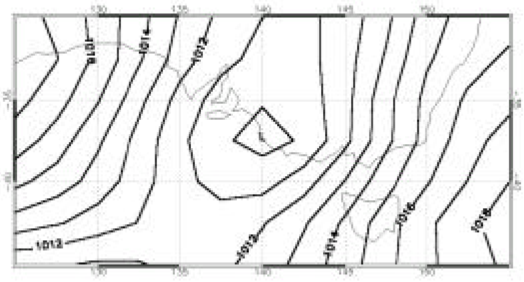
Synoptic Type 31 NCEP Mean Sea Level Pressure Analysis 00UTC



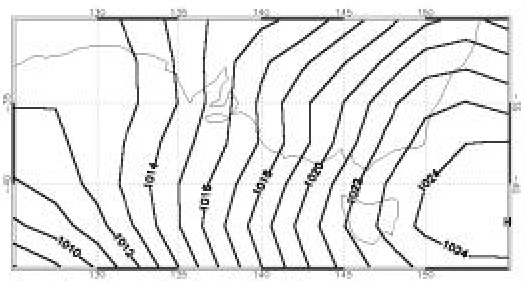
Synoptic Type 32 NCEP Mean Sea Level Pressure Analysis 00UTC



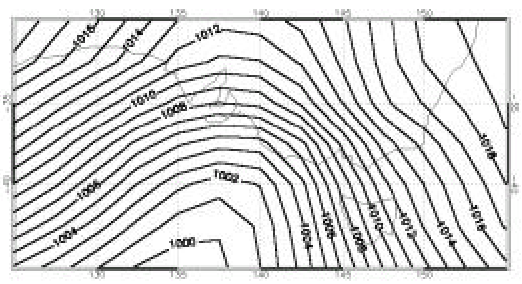
Synoptic Type 33 NCEP Mean Sea Level Pressure Analysis 00UTC



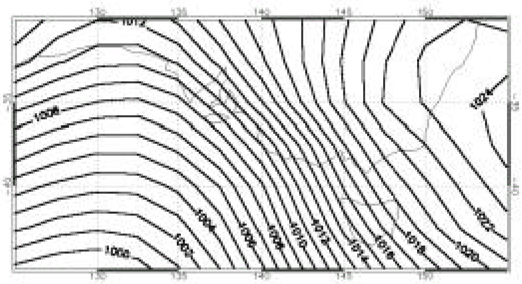
Synoptic Type 34 NCEP Mean Sea Level Pressure Analysis 00UTC



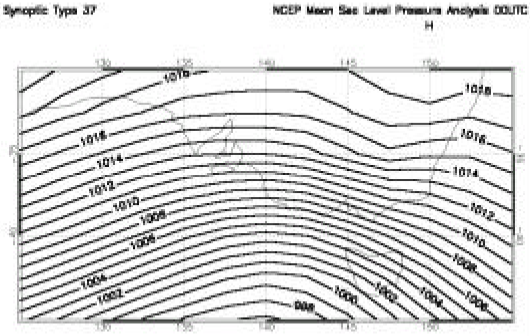
Synoptic Type 35 NCEP Mean Sea Level Pressure Analysis 00UTC



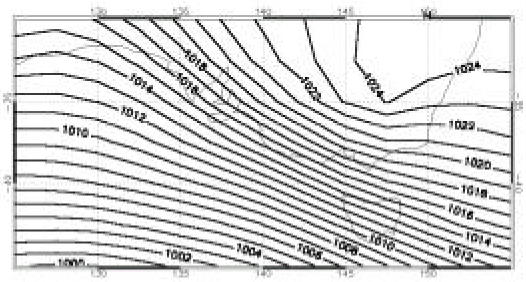
Synoptic Type 36 NCEP Mean Sea Level Pressure Analysis 00UTC



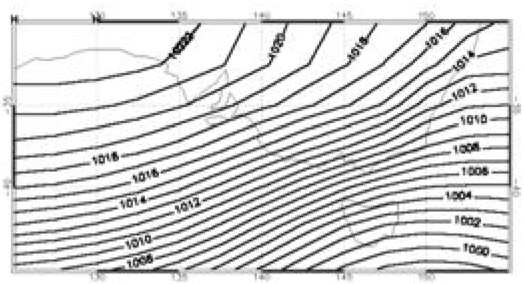
Synoptic Type 37 NCEP Mean Sea Level Pressure Analysis 00UTC



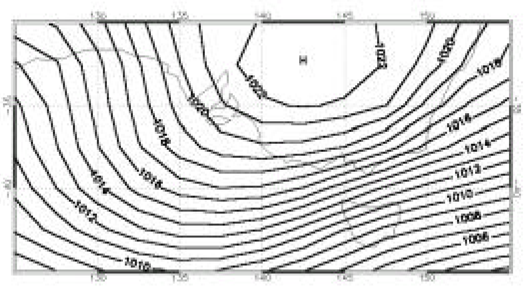
Synoptic Type 38 NCEP Mean Sea Level Pressure Analysis 00UTC



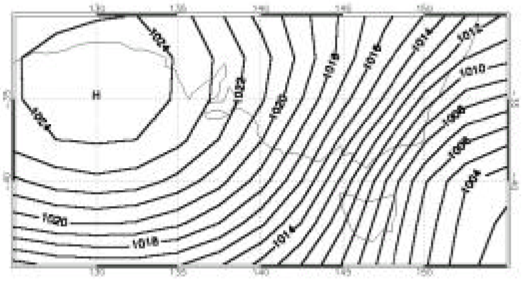
Synoptic Type 39 NCEP Mean Sea Level Pressure Analysis 00UTC



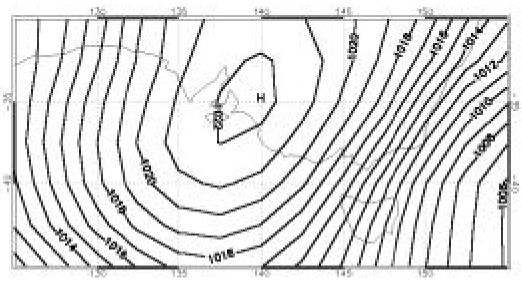
Synoptic Type 40 NCEP Mean Sea Level Pressure Analysis 00UTC



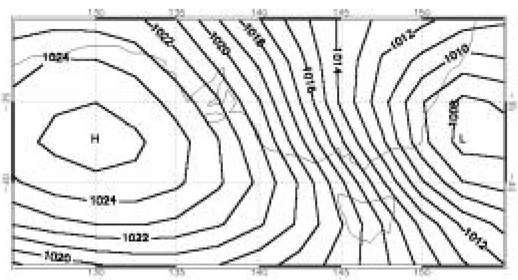
Synoptic Type 41 NCEP Mean Sea Level Pressure Analysis 00UTC



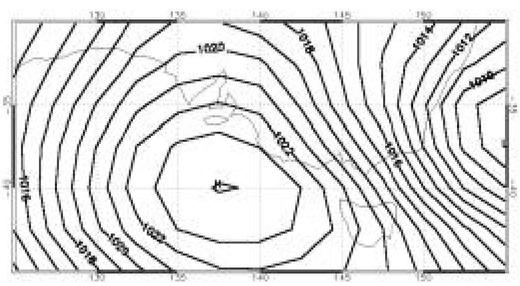
Synoptic Type 42 NCEP Mean Sea Level Pressure Analysis 00UTC



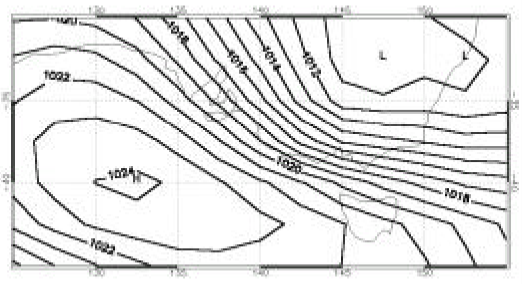
Synoptic Type 43 NCEP Mean Sea Level Pressure Analysis 00UTC



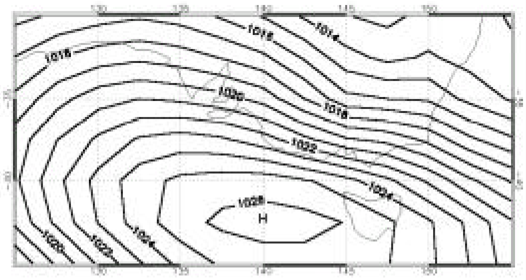
Synoptic Type 44 NCEP Mean Sea Level Pressure Analysis 00UTC



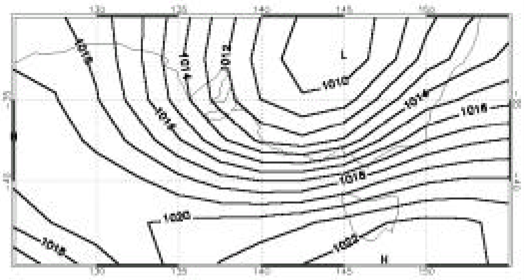
Synoptic Type 45 NCEP Mean Sea Level Pressure Analysis 00UTC



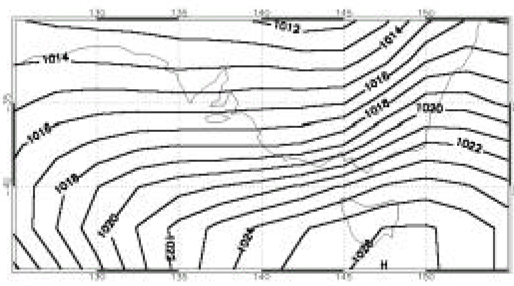
Synoptic Type 46 NCEP Mean Sea Level Pressure Analysis 00UTC



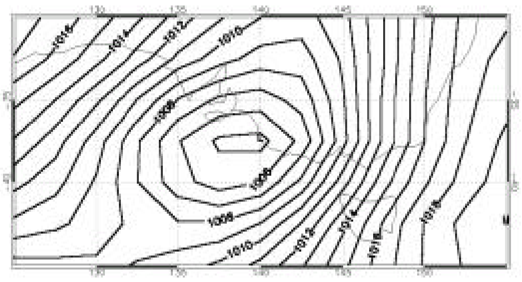
Synoptic Type 47 NCEP Mean Sea Level Pressure Analysis 00UTC



Synoptic Type 48 NCEP Mean Sea Level Pressure Analysis 00UTC



Synoptic Type 49 NCEP Mean Sea Level Pressure Analysis 00UTC



Synoptic Type 50 NCEP Mean Sea Level Pressure Analysis 00UTC