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RIDGE ROLLERS: MESOSCALE DISTURBANCES ON THE PERIPHERY OF CUTOFF ANTICYCLONES

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1. INTRODUCTION:

Warm season continental anticyclones are frequently associated with heat waves and droughts (e.g., Namias 1982, 1991; Livezey 1980; Changnon et al. 1996). A less appreciated aspect of continental anticyclones is that mesoscale disturbances evident on the dynamic tropopause (DT, defined as the 1.5 potential vorticity unit (PVU) surface), known as "ridge rollers" (RRs), are often observed to circumnavigate the periphery of these anticyclones (e.g., Bosart et al. 1998, 1999). RRs often originate as fractures from the equatorward ends of northeast-to-southwest oriented PV tails, and move westward along the equatorward periphery of continental anticyclones. As these RRs move poleward and then eastward around the upstream and poleward periphery, respectively, of the anticyclone they may interact with other subsynoptic-scale disturbances embedded in the westerlies on the poleward periphery of the anticyclone. RRs may be associated with convection along the anticyclone periphery with organized mesoscale convective systems (MCSs) occurring on the poleward periphery where the aforementioned upper-level westerly flow, and associated jet-entrance region, provides enhanced ascent and deep-layer shear. A limiting factor on the development of severe MCSs is the presence (or absence) of a moist planetary boundary layer (PBL; e.g., Johns 1993, Wakimoto 2001).

The purpose of this presentation is to document the structure and evolution of heat wave-related continental anticyclones over the US and Australia during July 1995 and February 2004, respectively. Particular attention will be paid to the behavior of RRs and their impact on the mode and severity of convection along the periphery of these anticyclones. The US and Australian cases are contrasted in this paper to show that while RRs are generic to the periphery of warm-season continental anticyclones, their potential impact on surface weather in general and convection in particular is strongly conditioned by the atmospheric stability in the lower and middle troposphere and the thermodynamic structure of the PBL in the anticyclone environment.

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2. DATA AND METHODS:

Analyses and diagnostic calculations prepared in this manuscript were derived from the 32 km North American Regional Reanalysis (NARR; Mesinger et al. 2005) for the US case and the 1.0° Global Forecast System (GFS) analyses for the Australian case. The time-longitude diagram was derived from the 2.5° National Centers for Environmental Prediction and National Center for Atmospheric Research (NCEP/NCAR) Reanalysis (Kalnay et al. 1996, Kistler et al. 2001; Fig. 1). The soundings were obtained from the University of Wyoming webpage (http://weather.uwyo.edu/upperair/sounding.html).

The DT analyses adopted for the synoptic-scale perspective are defined at the 1.5 PVU surface (e.g., Bosart and Lackmann 1995).

3. RESULTS:

a) 10-15 July 1995 US case

Inspection of the 10-15 July 1995 US continental anticyclone shows that energy propagation and associated downstream development beginning just north of the Tibetan Plateau on 4 July resulted in amplification of the 500 hPa height pattern over the US during the period 10-13 July (Fig. 1). This amplification occurred in conjunction with the deepening of a cutoff cyclone over central Canada, resulting in a strong upper-level jet (> 50 m s^{-1} on the DT) along the Canadian-US border (Fig. 2). As RRs moved poleward on the western periphery of the anticyclone, they encountered the upper-level jet entrance region over the north-central US (Figs. 2-3). With ample moist, unstable air present in the PBL (850 hPa θ_e values approaching 360 K), along with an elevated mixed layer (850-500 hPa lapse rates approaching 8 K km^{-1}) the RRs were able to trigger convection (Fig. 3)[1]. This convection quickly became severe in the presence of large CAPE values (approaching 7000 J kg^{-1}; Fig. 4) and moved northeastward, eastward, then southeastward along the poleward periphery of the anticyclone on the poleward edge of the PBL moisture axis.

b) 7-22 February 2004 Australian case

Inspection of the 7-22 February 2004 Australian continental anticyclone shows a progressive zonal pattern with a strong jet prevailing across southern Australia through 10 February (not shown). Individual short wave troughs embedded in the zonal flow allowed weak cold fronts to reach coastal southern Australia during this period. Downstream development resulted in ridging near 135°E on 13 February, and subsequent troughing near 170°E on 14 February (Fig. 5). This amplification allowed the equatorward portion of the aforementioned trough to cutoff and move westward in the easterlies across northern Australia as a RR on 15 February. Concurrently, the initial anticyclone underwent deamplification as an upstream anticyclone began to amplify near 120°E in response to another bout of downstream development. In response to this amplification, another trough amplified ahead of the second ridge resulting in a trough fracture producing three more RRs. These RRs proceeded to move poleward on the upstream side of the “new” anticyclone, subsequently becoming entrenched in the westerlies (> 75 m s^{-1} on the DT) by 20 February (Fig. 5). Convection appeared to be limited in association with these RRs on the poleward periphery of the anticyclone due to drier PBL conditions (850 hPa θ_e values approaching 340 K), and weaker 850-500 hPa lapse rates (approaching 5 K km^{-1}) when compared to the US case (Figs. 6-7)[1].

4. DISCUSSION:

Both the US and Australian heat wave-producing anticyclones had mesoscale disturbances (RRs) moving along the periphery. These cases are similar in that there was convection associated with the RRs along the equatorward periphery of the anticyclones. These cases differ, however, in that the US case had severe MCSs along the poleward periphery while the Australian case did not.

The differences in convective behavior between the US and Australian cases likely arises because prefrontal northerlies in Australia have a source region over the arid continental interior whereas prefrontal southerlies in the US have a source region over the Gulf of Mexico. Surface evapotranspiration processes in the US can also rapidly moisten the “capped” PBL residing beneath an elevated mixed layer that originated over the higher terrain to the west. Another limiting aspect for the Australian case is the cool oceanic waters (~18°C) along the southern shore that keep the PBL cool, thus limiting instability. These circumstances can change over coastal southeast Australia where pre-disturbance warm, moist north-northeast flow off the warm Coral Sea can set the stage for MCSs to form.

5. ACKNOWLEDGEMENT:

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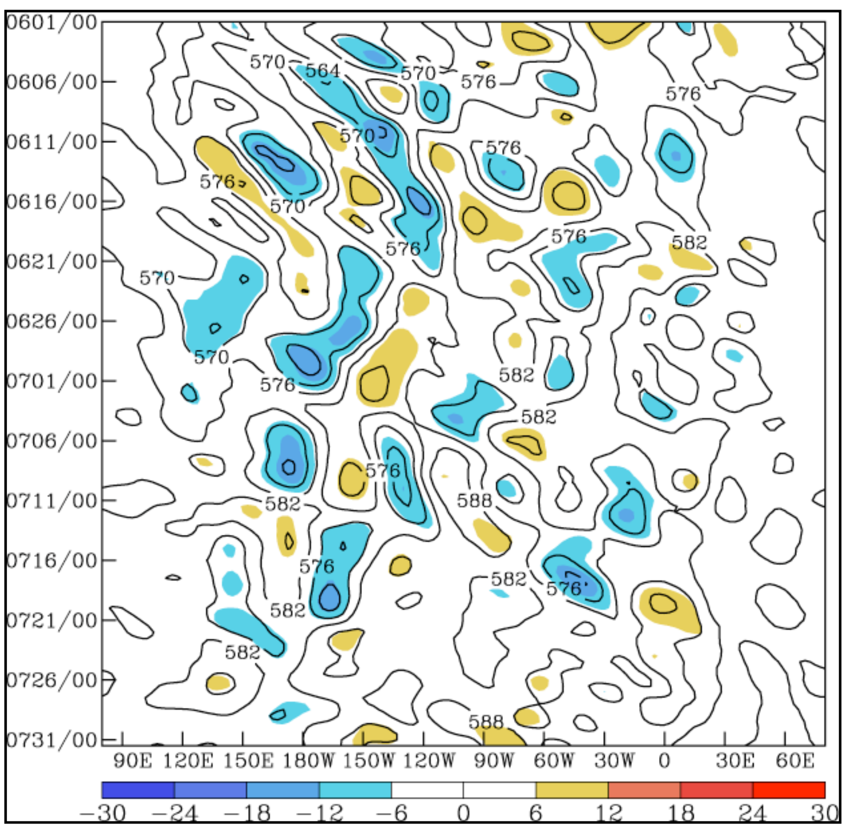

Figure 1: Time-longitude diagram of 500 hPa height (dam; solid contours) and anomaly (dam; shaded) for the period 01 June–31 July 1995 averaged over 30-50°N latitude. Height anomalies are defined as the 5-day running mean for 1950-2003 subtracted from 2x daily heights. Data source: 2.5° NCEP/NCAR reanalysis.

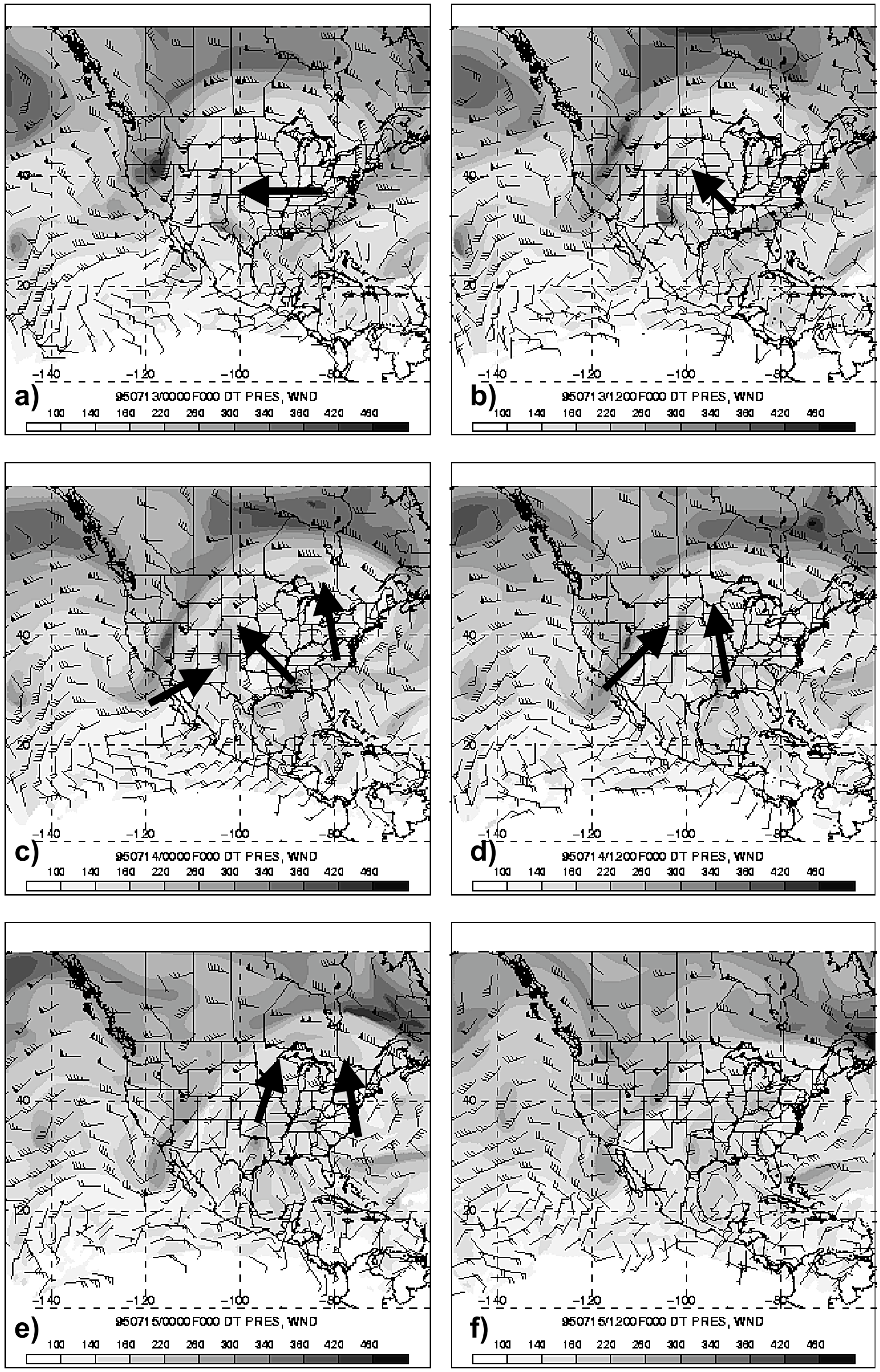

Figure 2: Dynamic tropopause (1.5 PVU surface) pressure (hPa) and wind barbs (full barb=5 m s^{-1}, pennant=25 m s^{-1}) for (a) 0000 UTC 13 July, (b) 1200 UTC 13 July, (c) 0000 UTC 14 July, (d) 1200 UTC 14 July, (e) 0000 UTC 15 July and (f) 1200 UTC 15 July 1995. Black arrows point to RRs. Data source: 32 km North American Regional Reanalysis (NARR).

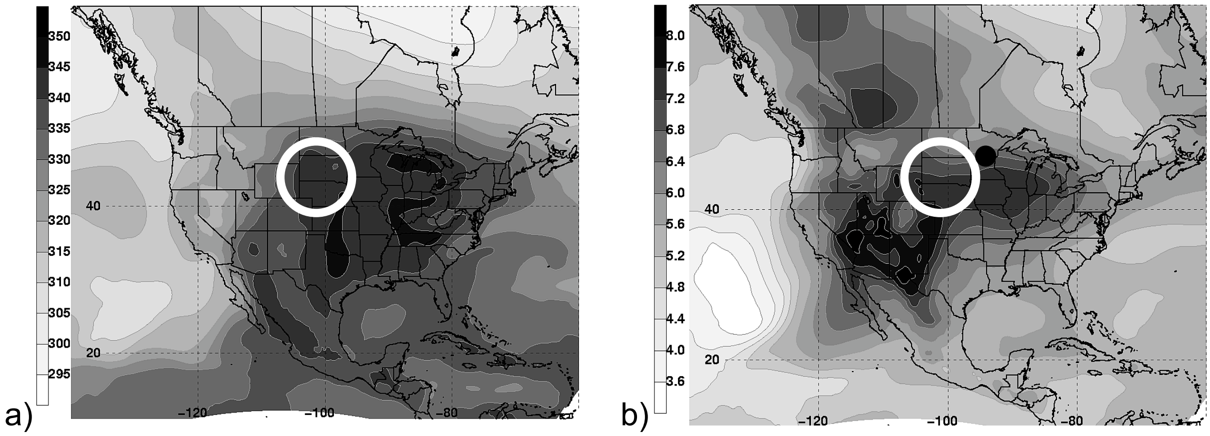

Figure 3: (a) Mean 850 hPa θ_e (K) and (b) 850-500 hPa lapse rate (K km^{-1}) for the period 0000 UTC 13 July–1200 UTC 15 July 1995. White circle denotes equatorward jet-entrance region of 300 hPa jet. Black dot marks location of MPX. Data source: 32 km NARR.

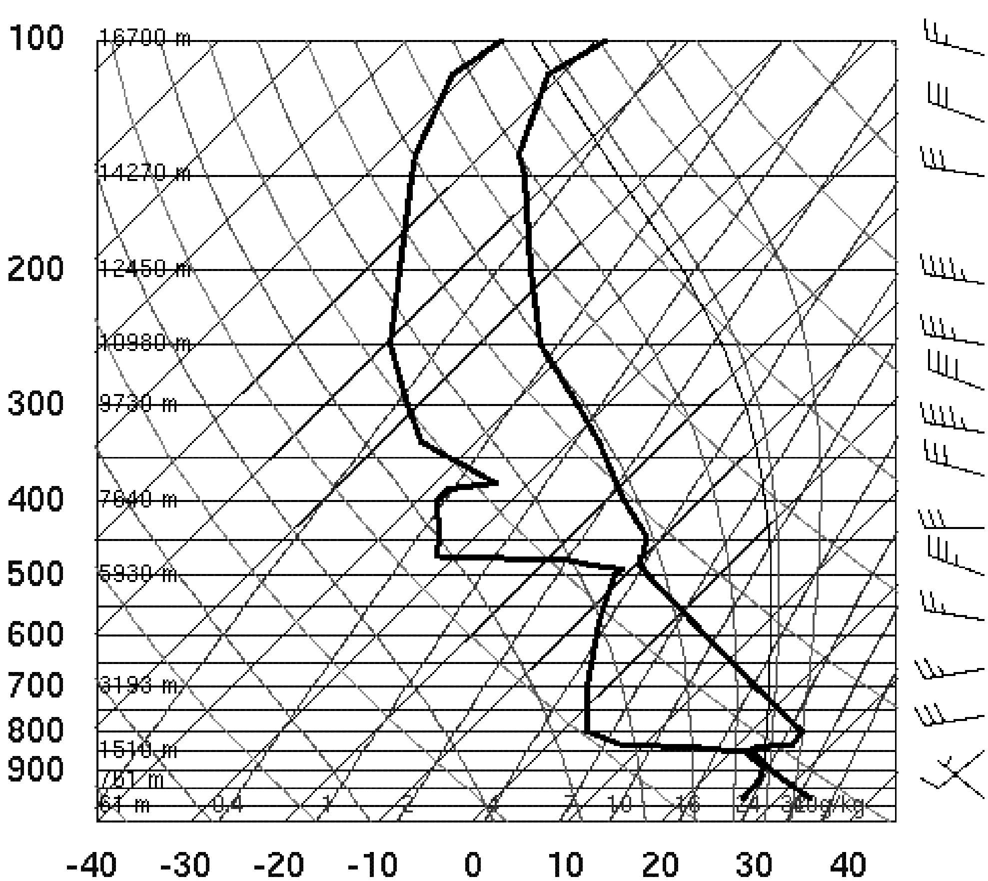

Figure 4: MPX (72649) sounding for 0000 UTC 13 July 1995. Data source: University of Wyoming webpage.

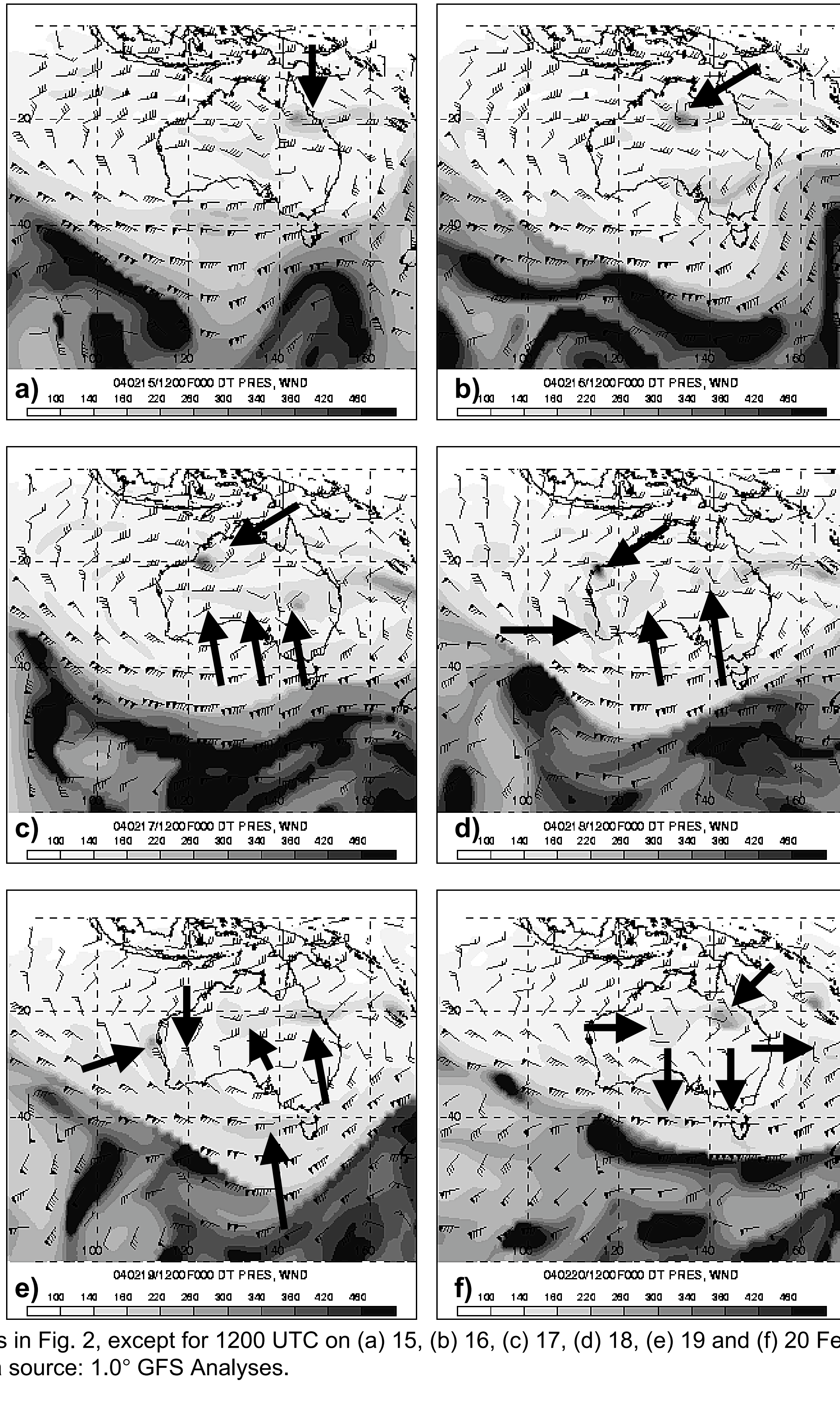

Figure 5: As in Fig. 2, except for 1200 UTC on (a) 15, (b) 16, (c) 17, (d) 18, (e) 19 and (f) 20 February 2004. Data source: 1.0° GFS Analyses.

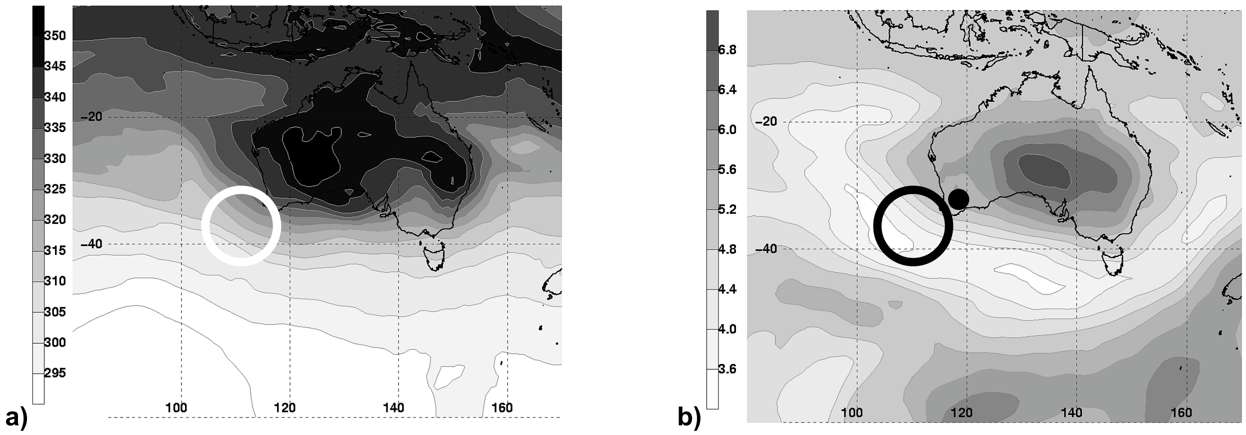

Figure 6: As in Fig. 3, except for the period 0000 UTC 14–0000 UTC 22 February 2004. Circles denote equatorward jet-entrance region of 300 hPa jet. Black dot marks location of YPAL. Data source: 1.0° GFS Analyses.

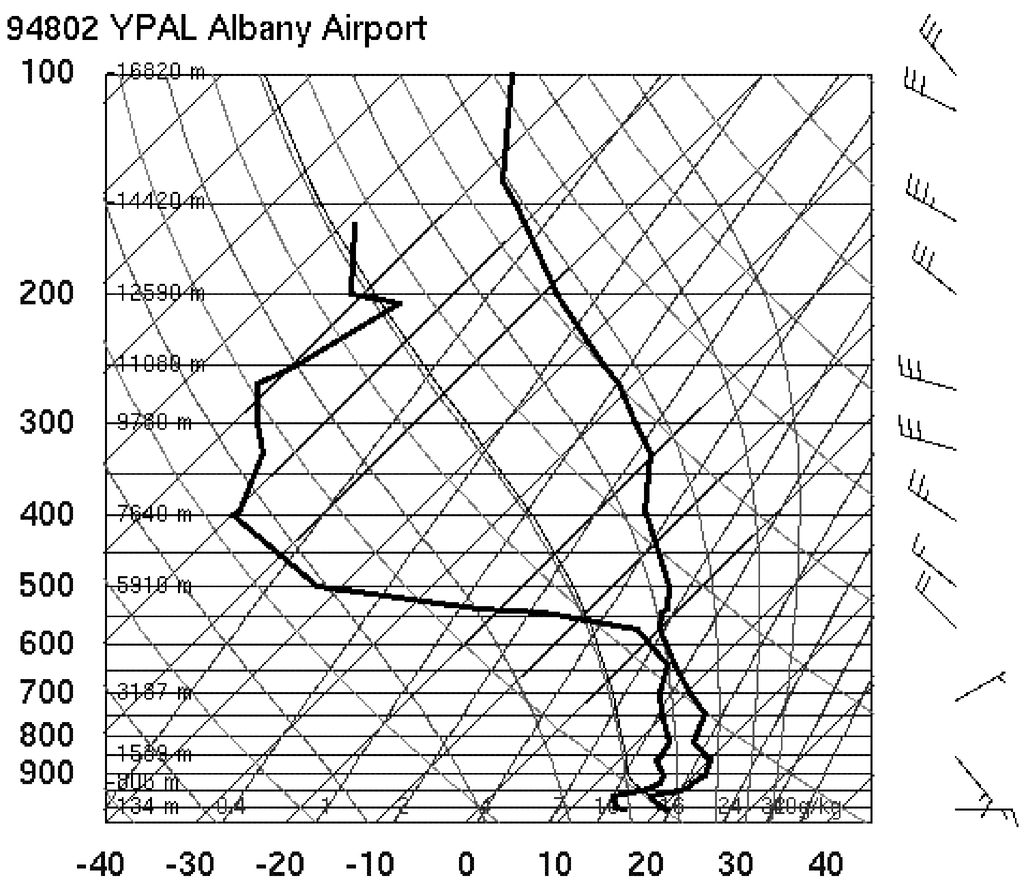

Figure 7: YPAL (94802) sounding for 1200 UTC 16 February 2004. Data source: University of Wyoming webpage.