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Doppler Radar and Storm Environment Observations of a Maritime Tornadic Supercell in Sydney, Australia

Australian Government
Bureau of Meteorology

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Introduction

During the late morning of 16 December 2015 an EF2 tornado occurred 4 km southeast of Australia's busiest airport – Sydney Airport. This tornado was notable in many ways:

- A relative abundance of observations was available, including the Kurnell C-band Doppler radar located less than 2 km from the tornado path
- The parent supercell tracked over water just off the east Australian coast during its life cycle, apart from when it briefly crossed the Kurnell peninsula when the tornado occurred.
- The tornado passed very close to an Automatic Weather Station (AWS) located on a jetty in Botany Bay at Kurnell which recorded a wind gust of **59.2 m s^{-1} (213 km/h, 115kts, 132mph)** at 10:33 am local time.
- The wind gust measured by the Kurnell AWS is an Australian record outside of a tropical cyclone.
- There were several RFD pulses and strong gate to gate velocity couplets associated with the parent storm prior to the tornado
- Damage from the tornado was extensive with the Insurance Council of Australia reporting it to be the most costly disaster of the Australian 2015/2016 summer, costing insurance companies AU$206m.

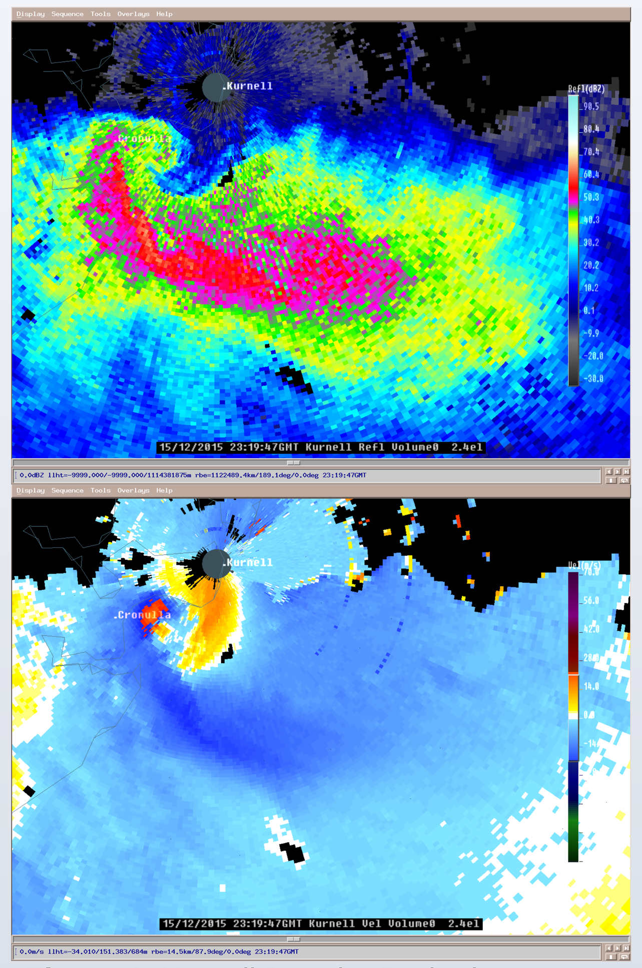

*Figure 1. Kurnell Doppler Radar imagery at 2319 UTC (10:19 am LT) at 0.24° elevation; **a)** PPI reflectivity; **b)** PPI Doppler radial velocity.*

*Figure 2. **a)** Approximate supercell storm track from 2130 UTC 15 December to 0030 UTC 16 December ; **b)** Tornado damage at Kurnell. **c)** Enhanced still frame from video showing tornado (Courtesy of Peter Grassmayr)*

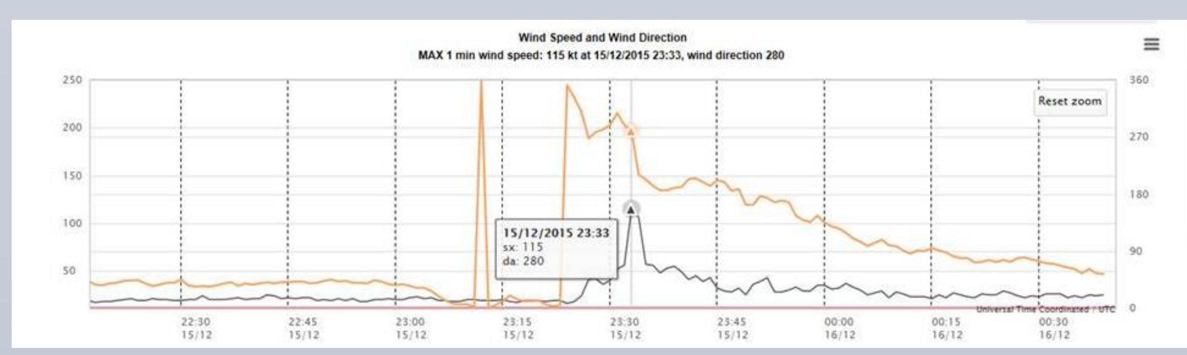

Figure 3. One minute data from Kurnell AWS impacted by tornado. Black line indicates wind speed in knots (using left axis) and yellow line indicates wind direction (using right axis).

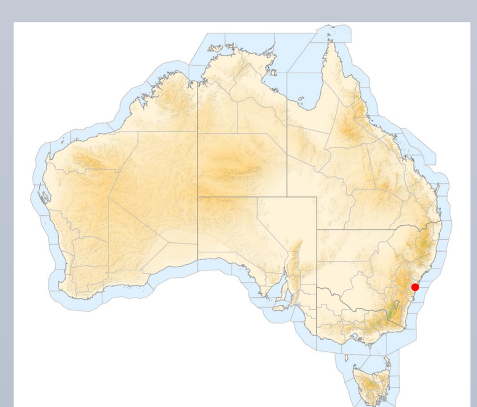

Figure 4. Red dot indicates location of Kurnell

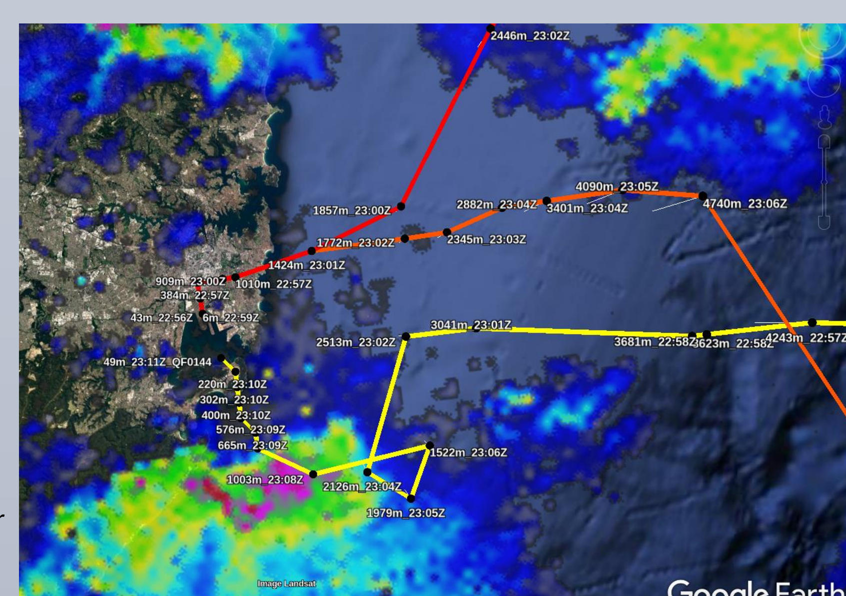

Figure 5 (right). Sydney airport AMDAR flight paths with height and time of data relay and 2306 UTC radar reflectivity overlay; Red 2256 UTC ascending; Orange 2258 UTC ascending; Yellow 2311 UTC descending.

Kinematic assessment of Mesocyclone and Tornado Cyclone

- Dual Doppler winds were derived using Terry Hills S-band Doppler radar (~36km to the north of Kurnell) and the Kurnell radar (1.6km to the east of tornado track)
- The tornado parent cyclone appears as a zone of strong convergence / vorticity in the southwest corner of a ~7 km wide low-level mesocyclone – refer figure 6
- Just prior to tornado formation the storm ingested localised patches of enhanced 0.2-1 km storm-relative helicity (SRH) – refer figure 7
- The key contributor to the overall SRH values appears to be a 'vorticity sheet' within the storm inflow layer where the north-easterly inflow backs to north-westerly – refer figure 8
- AMDAR hodographs confirm very strong spatiotemporal variability in the SRH – refer figure 9

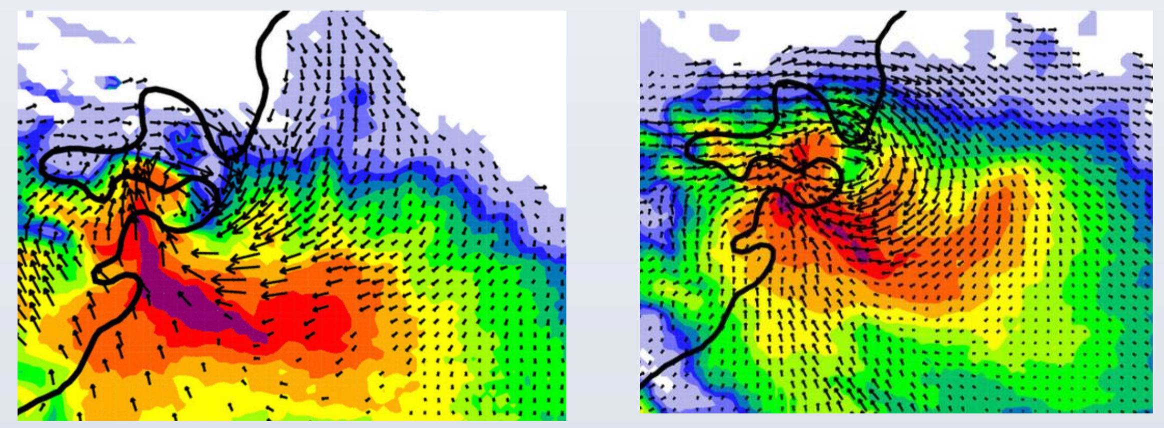

Figure 6. Dual Doppler winds at 2325 UTC at 1.5 km AGL(left) and 2331 UTC at 2.5 km AGL (right). Color fill is the corresponding reflectivity from the Kurnell radar. Winds shown as vectors with increased length corresponding to increased speed.

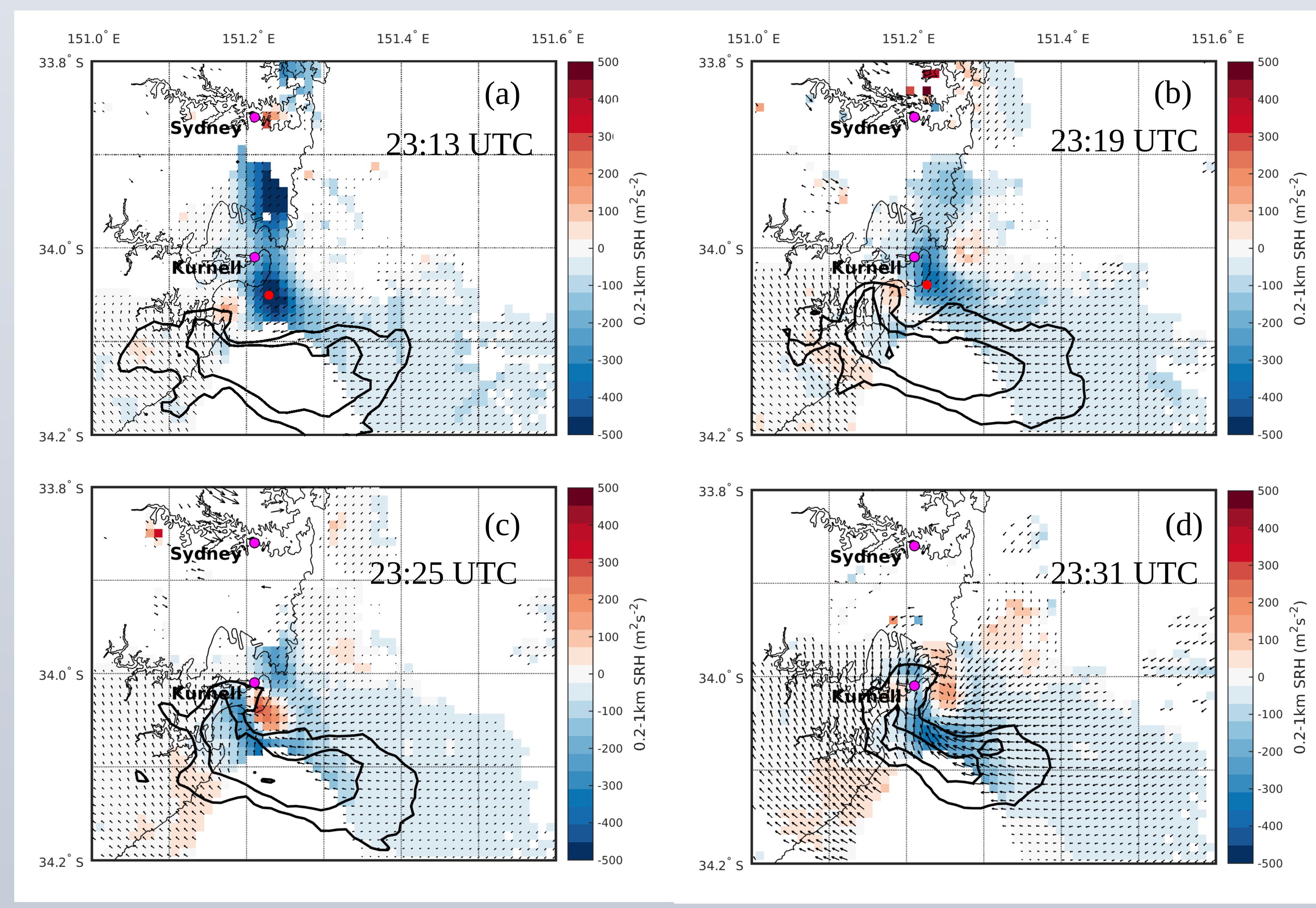

Figure 7: 0.2-1 km AGL storm-relative helicity based on the dual-Doppler derived wind profile (shaded). Wind vectors are shown at 500 m AGL and also derived from dual Doppler. Storm motion (subjectively derived from Kurnell radar data around tornado time) used is 7.5 m s^{-1} towards 19 degrees. Bold contours show 35, 45, 55 and 65 dBZ outlines at 500 m AGL.

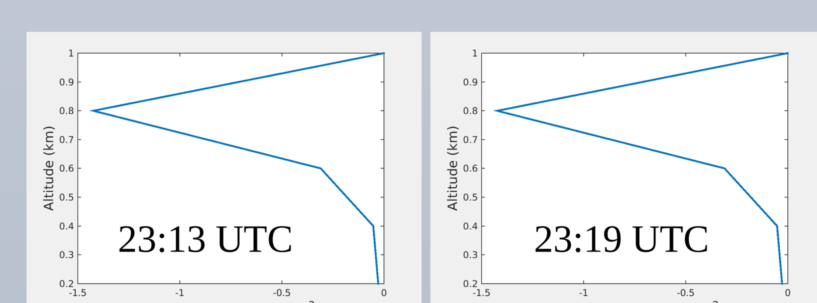

Figure 8: Vertical profile of the streamwise vorticity taken at the locations of the 0.2-1 km SRH maxima (red dots southeast of Kurnell in Figure 7).

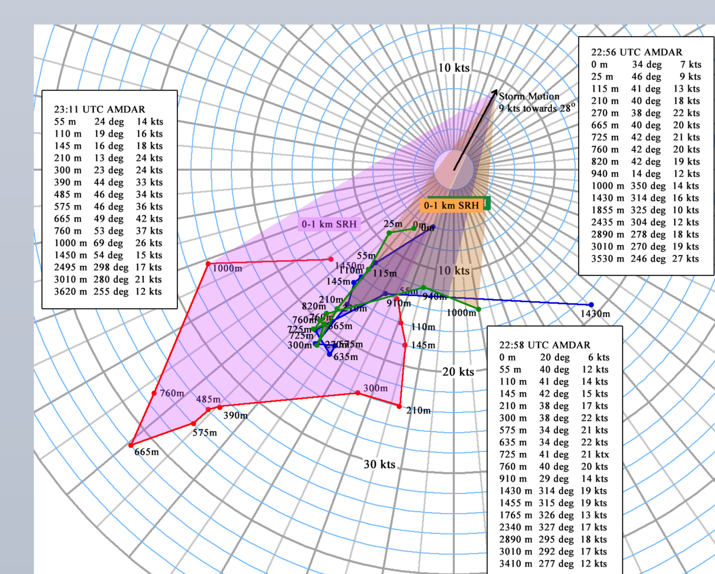

Figure 9: Observed hodographs based on the 22:56 UTC (green), 22:58 UTC (blue) and 23:11 UTC (red) AMDARS shown in Fig. 5.

Thermodynamic Assessment of Pre-storm Environment

- A firmly capped marine layer at 19 UTC experienced complete removal of the cap during the early morning hours (between 6 am and 10 am LT) – refer figure 10

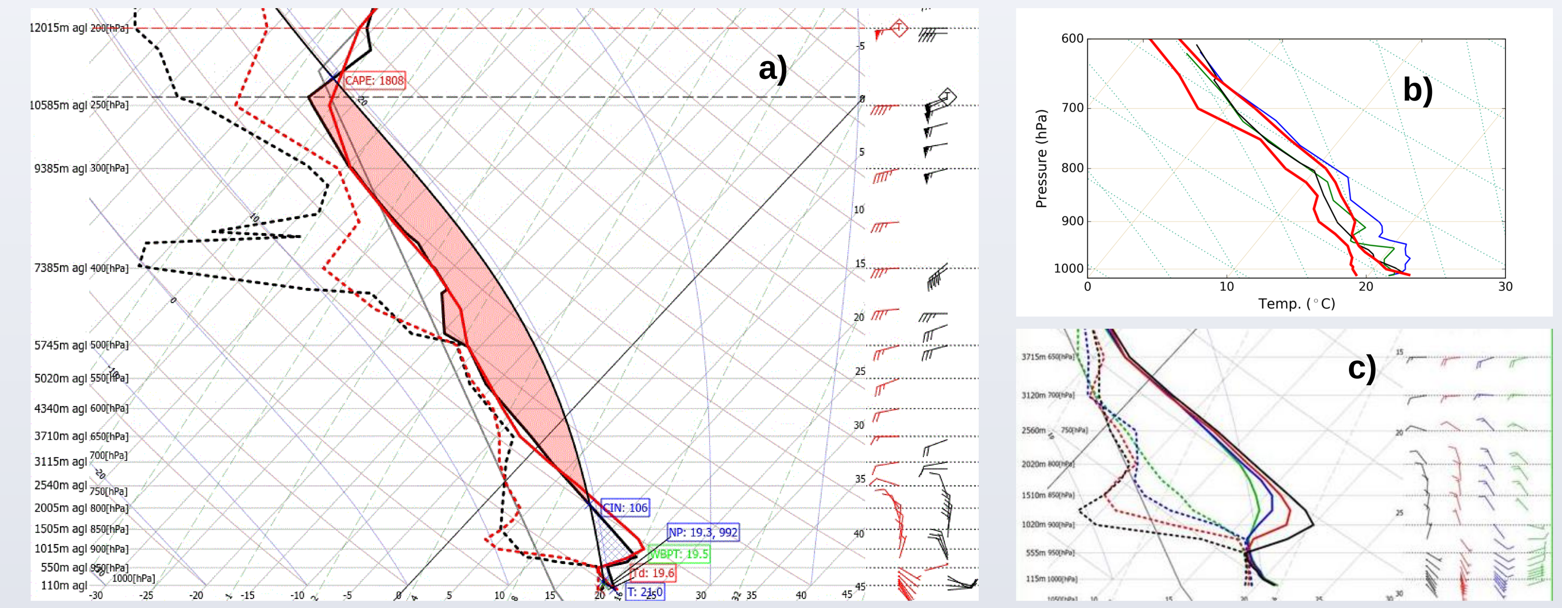

*Figure 10. **a)** 18 UTC 15 December 2015 ACCESS-R (red) model sounding and 19 UTC 15 December observed Sydney Airport sounding (black); **b)** Soundings based on a 6-hour forecast from the 18 UTC ACCESS-R run valid at 23 UTC (red), the 2256 UTC AMDAR (blue), the 2258 UTC AMDAR (green) and the 2311 UTC AMDAR (black); **c)** Hourly soundings at 18 UTC (black), 19 UTC (red), 20 UTC (blue) and 21 UTC (green) based on the 18 UTC run of ACCESS-R indicating the rapid removal of inversion prior to the Kurnell tornado.*

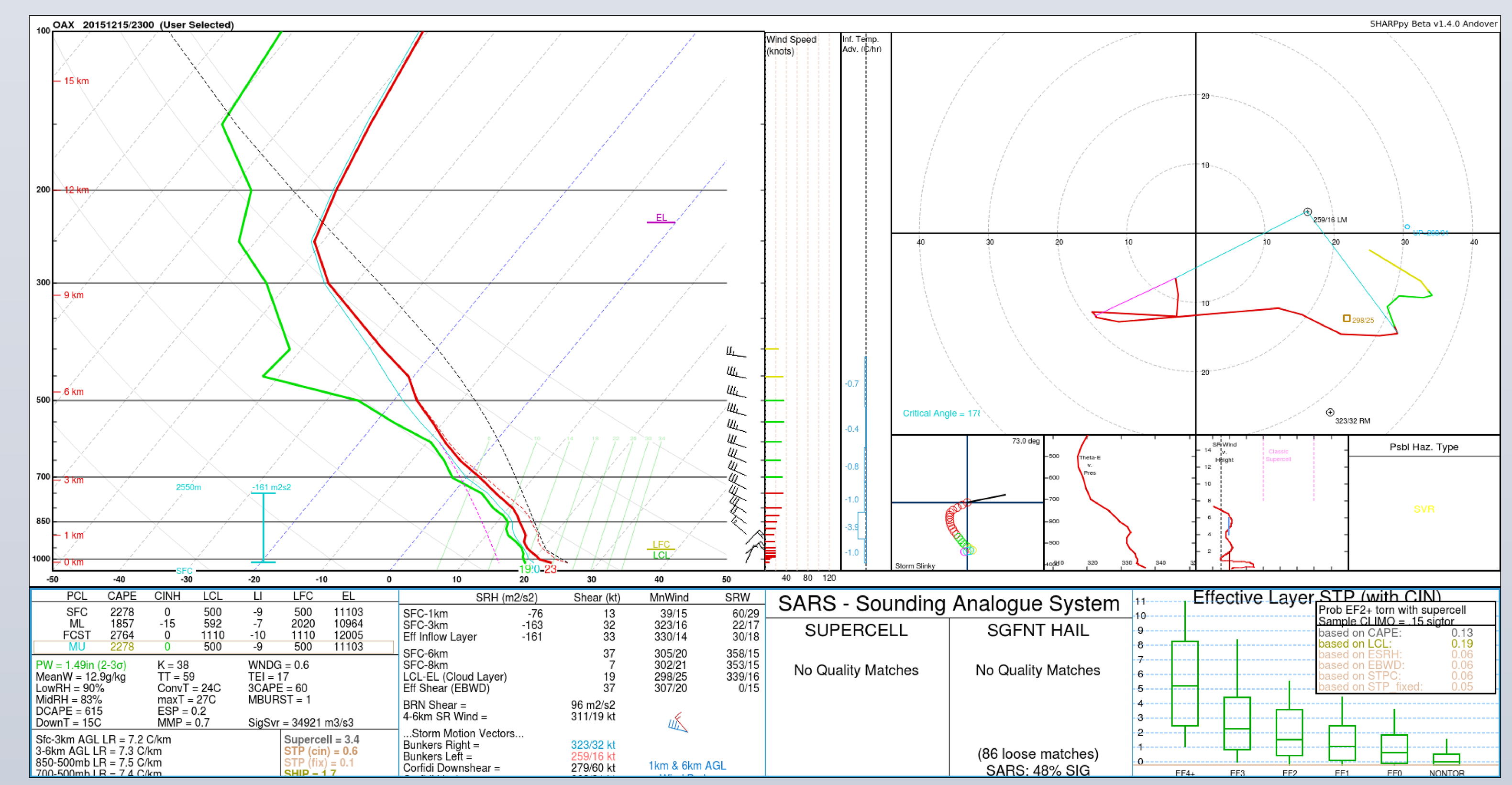

Figure 11. 23 UTC ACCESS-R sounding (18 UTC run) with the hodograph winds derived from the 2313 UTC dual Doppler observations at the location of the SRH maximum (red dot) in Fig. 7a.

Summary and Points for Discussion

- An EF-2 tornado crossed a small Peninsula on 16 December 2015 just 4 km southeast of Sydney Airport
- A wind gust of 59 m s^{-1} was measured as the tornado moved offshore along the northern coastline of the Peninsula
- Small patches of large low-level storm-relative helicity are evident along the eastern coastline of Australia just ahead of the storm and prior to the Kurnell tornado
- In the vertical, these maxima in SRH are dominated by a sheet of large streamwise vorticity along the interface of north-easterly flow (below) and north-westerly flow (above)
- The processes for the cap removal (figure 10) are unclear, but candidates are high-based pre-existing light showers raining into a very dry capping layer and an inland push of easterly flow at 900 hPa, potentially associated with a mesoscale low.