10

THE USE OF CONVECTIVE PARAMETERS BY THE AUSTRALIAN BUREAU OF METEOROLOGY EXTREME WEATHER DESK IN FORECASTING THE 16 DECEMBER 2015 TORNADIC SUPERCELL IMPACTING KURNELL, SYDNEY

James Taylor*, Dean Sgarbossa
Extreme Weather Desk, Bureau of Meteorology, Melbourne, Australia

Harald Richter
Research and Development Branch, Bureau of Meteorology, Melbourne, Australia

1. INTRODUCTION

An independent review of the Australian Bureau of Meteorology (BoM) identified the need for another layer of capability to respond to extreme weather events. In response to the review the Australian Bureau of Meteorology (BoM) Extreme Weather Desk (EWD) was recently established with the aim to provide “a national focus for extreme weather intelligence” and “enhanced severe weather capacity during periods of sustained demand”. A complete process for convection forecasting was trialled by the EWD during the 2015-2016 Australian Severe Weather Season. National forecasts of thunder, large hail, damaging winds, heavy rainfall and tornado were produced internally within the BoM. These are described within this paper along with the use of convective parameters (derived from the literature, the majority of which were developed by the United States National Weather Service Storm Prediction Centre (SPC)) in the EWD forecast process. To complete the process, a daily verification product focussing on continual forecast improvement through verification is described.

The day of the tornadic supercell that affected Kurnell in Sydney Australia is used to illustrate the end to end process used by the EWD. At 10:30 am local time (LT) on Wednesday 16 December 2015 (23:30 UTC 15 December 2015) a supercell thunderstorm moved from the Tasman Sea onto the coast near Sydney airport. An EF-2 tornado was associated with the storm, as assessed from a damage survey, Kurnell C-band and Terry Hills S-band radar data (see figure 1), video footage of the event and a wind gust of 59.2 m s-1 (213 km/h,115 kts, 132 mph) recorded by an automatic weather station located on a jetty in Botany Bay at Kurnell. A companion abstract, “Doppler Radar and Storm Environment Observations of a Maritime Tornadic Supercell in Sydney, Australia” documents the details of the event.

A description of EWD product enhancements that have been implemented following review of the 2015/2016 Australian Severe Weather Season is presented in the concluding remarks and Appendix 4.

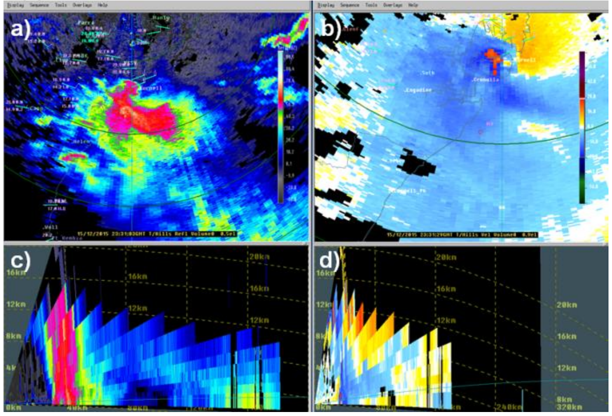


Figure 1. *Radar imagery from the Sydney Terry Hills S-band Doppler Radar valid 23:31 UTC showing* ***a)*** *0.5° elevation PPI reflectivity;* ***b)*** *0.9° elevation PPI Doppler radial velocity;* ***c)*** *RHI reflectivity from the Radar origin due south and;* ***d)*** *corresponding RHI Doppler radial velocity.*

2. EWD CONVECTIVE OUTLOOK PRODUCTS

Eastern regional forecast centres (RFCs) of the Australian Bureau of Meteorology (BoM) produce thunderstorm forecast products for the current day and the following day with areas of “chance” of thunderstorm, “likely” thunderstorms or “likely severe thunderstorms” indicated in a spatial graphical product. At times, cross-border inconsistencies arise between RFC thunderstorm

---

*Corresponding author address: James Taylor, Extreme Weather Desk, Bureau National Operational Centre, Bureau of Meteorology, GPO Box 1289, Melbourne VIC 3001, Australia; e-mail: j.taylor@bom.gov.au

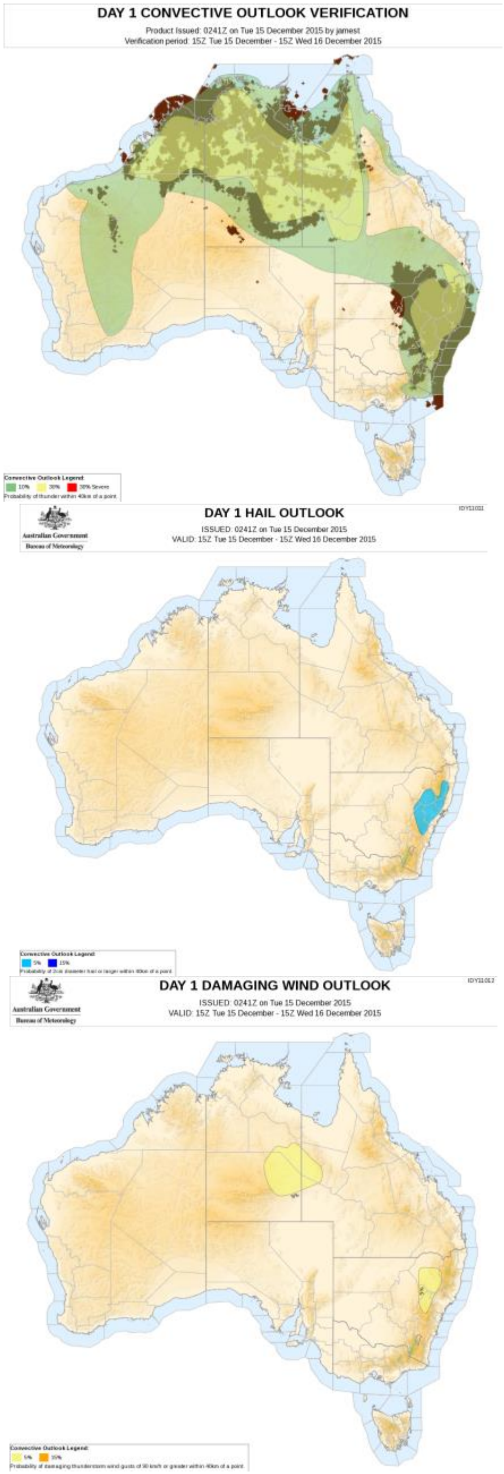


Figure 2. *Examples of EWD Day +1 (next day) graphical hazard outlooks for the period 15 UTC 15 December to 15 UTC 16 December 2015 illustrating the probability within 40 km of a point of (top) thunder probability forecast with observed lightning; (middle) large hail (≥2 cm) and; (bottom) damaging wind gusts (≥90 km/h)*

forecasts due to differing interpretation between forecast offices on a given day of what justifies "chance" or "likely" areas. In an effort to address this, new national convective outlook products were trialled internally within the BoM by the EWD, with spatial thunderstorm risk indicated probabilistically (Figure 2). Probability contours within EWD convective outlooks define the probability of thunder occurring within 40 km of a point within the indicated area (40 km ≈ 25 miles - the SPC spatial range for probability of impact from thunderstorm phenomena such as tornado, large hail or damaging winds).

Figure 2 (top) shows verification of the EWD convective outlook forecast issued at 2:41UTC (1:41pm LT) on 15 December 2015. Brown crosses indicate lightning stroke detection from 15UTC 15 December to 15UTC 16 December (2am to 2am LT) over the forecast region. 15UTC to 15UTC defines the standard forecast “day” across Australia, aligning most closely with local midnight to midnight periods across the various Australian time zones.

The EWD Day +1 convective outlook product (valid the day following the issued day) was defined for the 2015/2016 Australian severe weather season with 3 risk level contours: 10% (green shading) chance of thunder within 40 km of a point; 30% (yellow shading) chance of thunder within 40 km of a point; and 30% chance of severe thunderstorm (red shading) within 40 km of a point.

The convective outlook product was supported by forecasts of probability of severe thunderstorm phenomena: hail greater than 2 cm within 40 km of a point; wind gusts exceeding 25 m/s (90 km/h, 48.6 knots, 55.9mph) within 40 km of a point; rainfall exceeding a 10% annual exceedance probability (analogous to 1 in 10 year average recurrence interval) within 40 km of a point; and tornado within 40 km of a point. Outlook products for Wednesday 16 December for hail and wind are shown in figure 2 (middle) and (bottom).

The graphical forecasts are also supported by a National Convective Outlook Discussion (NCOD) product, providing brief written explanation of the reasoning behind forecast areas. The NCOD for 16 December is included in Appendix 1.

It is no coincidence that these products share similarities with SPC products. The general development of severe thunderstorm science in Australia is constrained by the relative infrequency of reports of severe phenomena associated with thunderstorms in comparison to the US, largely due to the sparsity of Australia’s population. As a result, verification of severe thunderstorm forecasts is challenging. Although climatological factors for

Australian severe thunderstorms differ somewhat to United States severe thunderstorms, the physical processes are similar. As such, US-based research into severe thunderstorm environments is highly useful for recognition of similar severe thunderstorm environments in Australia. By aligning the trial EWD convective outlook products similarly to those of the SPC, the EWD has better potential to take advantage of any SPC forecast process refinements. There would also be advantages if an EWD/SPC forecaster exchange program was able to be developed.

3. EWD CONVECTIVE FORECAST PROCESS

The EWD convective forecast process for the 2015/2016 Australian severe weather season followed the following basic steps:

- Systematic verification of yesterday's convective outlook
- Analysis of current situation.
- Analysis of day 1 (tomorrow) convective situation
- Preparation of products

The verification of yesterday's forecast is an integral step in developing expertise at a national level for convective forecasting. Although reports of severe phenomena associated with thunderstorms are limited, much can be learned through post analysis of the environment and/or remotely sensed data. A daily verification product was developed that included lightning detection overlaid on convective outlook, any reports that were received, assessment of environment where severe thunderstorms may have occurred and analysis of remotely sensed data such as radar or satellite data.

On the day of preparation of the forecast, verification of the previous day's forecast (14 December) was undertaken during the morning (see Appendix 2). The key focus of the verification was the observed thunderstorms not captured within the 10% forecast areas. There were no regions of severe thunderstorm phenomena forecast for Monday 14 December, and since there were no severe weather reports, no detail was recorded in the verification in relation to these complementary products. As the Day +1 convective outlook product corresponds approximately to the +12 to +36 hour forecast period, the preparation of the product tends to rely heavily on analysis of Numerical Weather Predication (NWP) model output. This usually focusses the verification process on how particular NWP guidance may have changed in subsequent model runs. Aside from the well understood benefits to the forecaster of recognition of particular NWP strengths/weaknesses, the documentation of such information can be useful for interaction between forecasters and NWP developers.

Analysis of the current situation on any particular day on the EWD is discussed within the forecast team during a daily national weather briefing undertaken at 22:45UTC (9:45 am LT) in the Bureau National Operations Centre (BNOC). The format of this discussion typically follows a cascading approach, beginning with the BNOC Senior Meteorologist describing systems at the hemispherical scale before focussing in on the synoptic scale. The EWD meteorologist then provides detail on dynamical features that have potential to generate high-impact weather around the continent.

4. CONVECTIVE PARAMETERS

An ingredients-based convective forecast process is utilised within the EWD that promotes an efficient and thorough assessment of the convective environment. Stemming from techniques described in literature as well as best practices from the SPC, the EWD forecaster strategically combines atmospheric ingredients to diagnose areas of risk for significant convective phenomena. This process is aided by the use of composite parameters such as the Supercell Composite Parameter (SCP) and the Significant Tornado Parameter (STP) (Thompson et. al. (2002)). These parameters aim to highlight environments conducive to convective organisation and associated phenomena.

The guidance suite for EWD convective outlook products is organised within the platform (Visual Weather software suite by IBL Software Engineering) used for interrogation of observational and NWP data in a suggested convective forecast process, illustrated in the Ishikawa Diagram in Appendix 3.

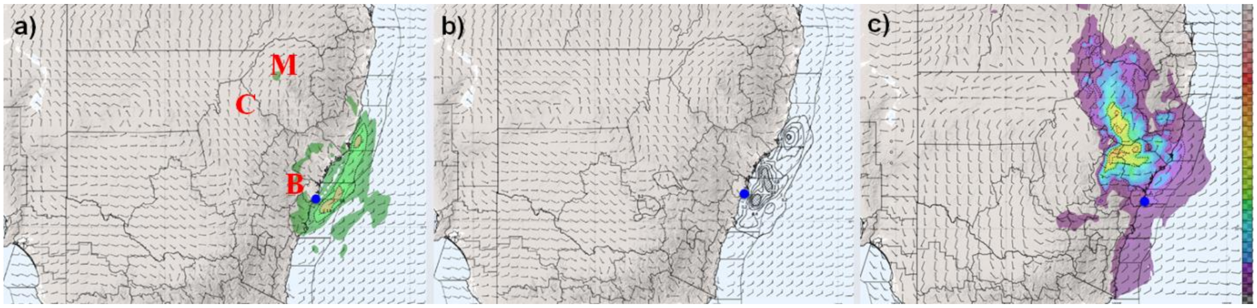


Figure 3. *18 UTC 15 Dec 2015 ACCESS-R derived composite convective parameters over New South Wales (NSW) consisting of **a)** Significant Tornado Parameter, valid 23 UTC 15 December after Thompson et. al. (2002); **b)** Supercell Composite Parameter valid 23 UTC 15 December after Thompson et. al. (2002); **c)** Significant Hail Parameter valid 06 UTC 16 December. Location of the Kurnell tornado is indicated by the blue dot, red letters M, C and B mark the towns of Moree, Coonamble and Blackheath, respectively.*

There were some limitations with the Visual Weather software suite that meant older versions of composite parameters were used, such as the SCP proposed by Thompson et. al. (2003) as opposed to updated SCP presented in Thompson et. al. (2004). The limitations meant that each parameter needed to be subjectively scrutinized by the forecasters. However the process of assessment of each of the composite component parameters helped to develop a greater understanding of the composite parameters strengths and weaknesses.

Examples of STP, SCP and Significant Hail Parameter are shown in Figure 3. The NWP model providing the guidance in Figure 3 is the Australian Community Climate and Earth-System Simulator run on a regional domain (ACCESS-R), developed as a joint initiative between the BoM, Commonwealth Scientific and Research Organisation (CSIRO) in cooperation with the university community of Australia and is based on the UK Meteorological Office's Unified Model (Puri et. al., 2013). The 18 UTC 15 December ACCESS-R run suggested that the environment was conducive to tornadic supercells near Kurnell, NSW (location denoted by the blue dot). However the EWD forecaster believed the threat from marine layer-sourced convection to be low due to convective inhibition associated with the marine boundary layer. Figure 4 illustrates two NWP model soundings at Sydney Airport compared to observed profiles, showing strong capping just hours ahead of the tornadic event. As the SCP, Derecho Composite Parameter and Significant Hail Parameter do not contain any convective inhibition dependence, it is not uncommon to observe large values of these parameters in capped marine boundary layers.

5. DAILY VERIFICATION

The EWD convective outlook products (Figure 2) and NCOD (Appendix 1) indicate that the focus for severe convection in the forecast for 16 December 2015 was the eastern New South Wales (NSW) region. The convective regime was expected to be afternoon surface-based thunderstorms driven by the approaching upper trough and low level convergence likely across the NSW ranges (located approximately 50-100 km west of the NSW coast) combined with high levels of available moisture and steep forecast lapse rates. Although not mentioned in the NCOD, no "red area" was drawn on the convective outlook as the chance of impact within 40km of a point from any severe thunderstorm attributes was assessed to be below 30%.

In terms of the afternoon convection and forecast probabilites of various phenomena, the region of greater than 5-15% chance of damaging winds over northeastern NSW did experience a squall line late in the afternoon that resulted in a gust of 28 m/s (102 km/h) at Coonamble and 32.5 m/s (117 km/h) at Moree. The region of 5-15% chance of large hail did have a report of 3 cm hail at Blackheath during the afternoon. The locations of Moree, Coonamble and Blackheath are shown in Figure 3a.

Figure 4 indicates that the convective inhibition (CIN) from the +36 hour ACCESS-R forecast valid 00 UTC 16 December was 87 J/kg (it should be noted that this would have been less if we had applied the virtual temperature correction) with a similar amount of CIN in the observed 18:42 UTC 15 December Sydney airport sounding. The 22:52 UTC AMDAR indicates that there was next to no CIN in the marine layer ~30 minutes prior to the tornado and the +36 hour European Centre for Medium Range Weather Forecasts (ECMWF) NWP forecast valid 00 UTC 16 December correctly captured this. Subsequent ACCESS-R model runs came into line with the ECMWF as can be seen with the +12 hour forecast soundings based on the 12 UTC 15 December runs shown in Figure 5. Also of interest is how well the 12 UTC 15 December ECMWF and ACCESS-R soundings captured the reduction of CIN at Sydney Airport between 18 UTC to 23 UTC – compare Figure 6 18 UTC +6 hour model forecasts to Figure 5.

The Day +1 forecast probabilities for individual hazards on 16 December were less than 5% for damaging winds, large hail, or heavy rainfall and less than 2% for tornadoes along the central and southern NSW coast (where severe thunderstorms occurred). Given the differences in the convective guidance available for the level of CIN associated with the marine layer, one could argue that this was a reasonable forecast.

Figures 7 suggests that the observed tornadic supercell occurred in close proximity to sharp gradients in the convective parameters, consistent with Cohen (2010) and Thompson et al. (2012). If the forecast for 16 December was updated in the early hours of the same day (note that the EWD is not currently staffed at night), then the reduction in CIN in the available guidance could well have resulted in the probabilities of various severe thunderstorm phenomena being increased.

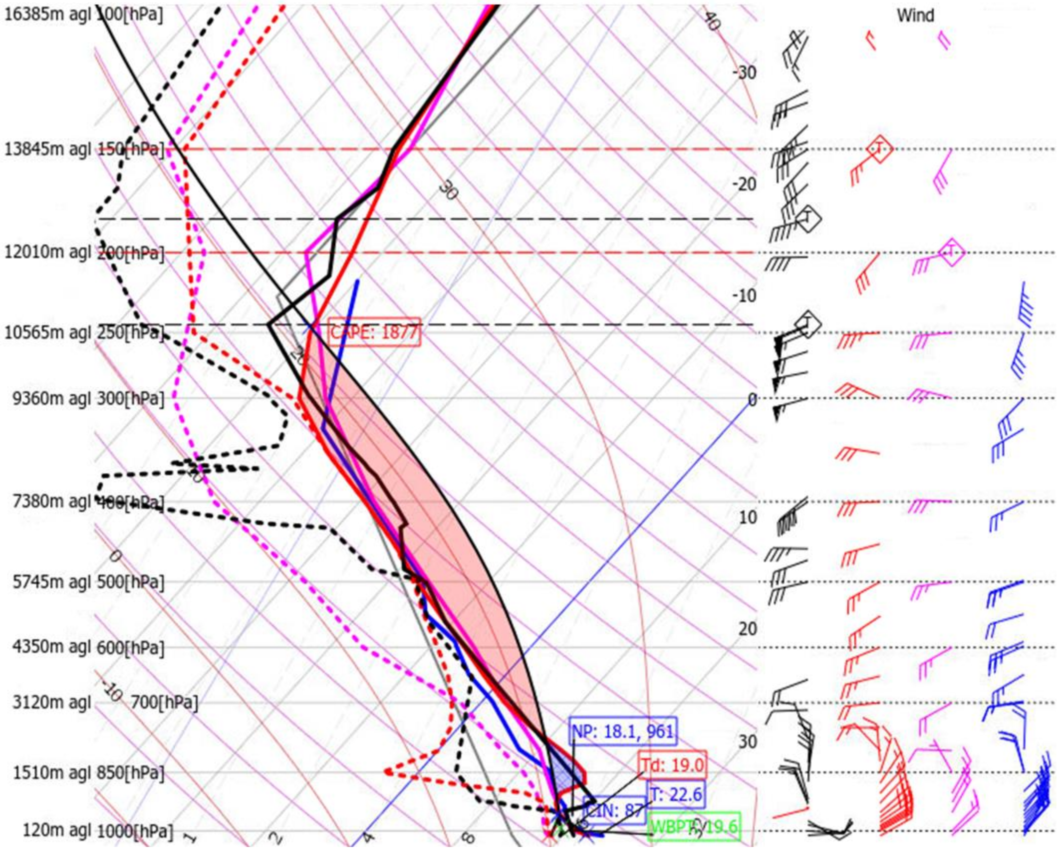


Figure 4. *36-hour model soundings from ACCESS-R (red) and ECMWF (cyan) valid 00 UTC 16 Dec; 1842 UTC 15 Dec observed Sydney Airport atmospheric profile (black) and 2252 UTC 15 Dec Sydney Airport AMDAR (blue).*

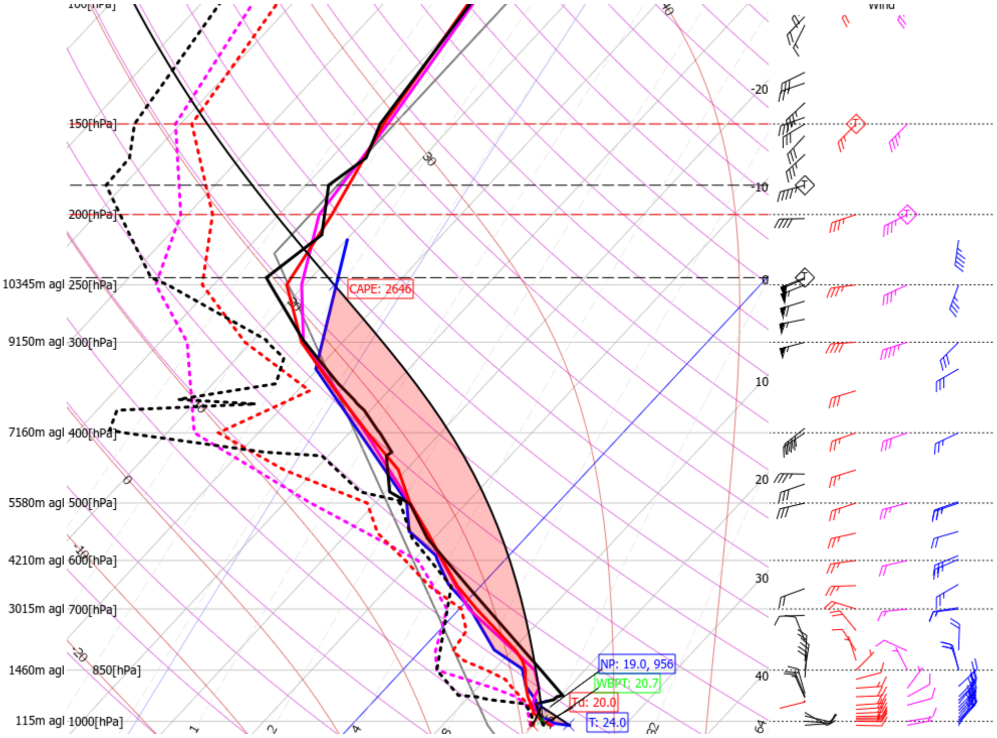


Figure 5. 12-hour model soundings from ACCESS-R (red) and ECMWF (cyan) valid 00 UTC 16 Dec; 1842 UTC 15 Dec observed Sydney Airport atmospheric profile (black) and 2252 UTC 15 Dec Sydney Airport AMDAR (blue).

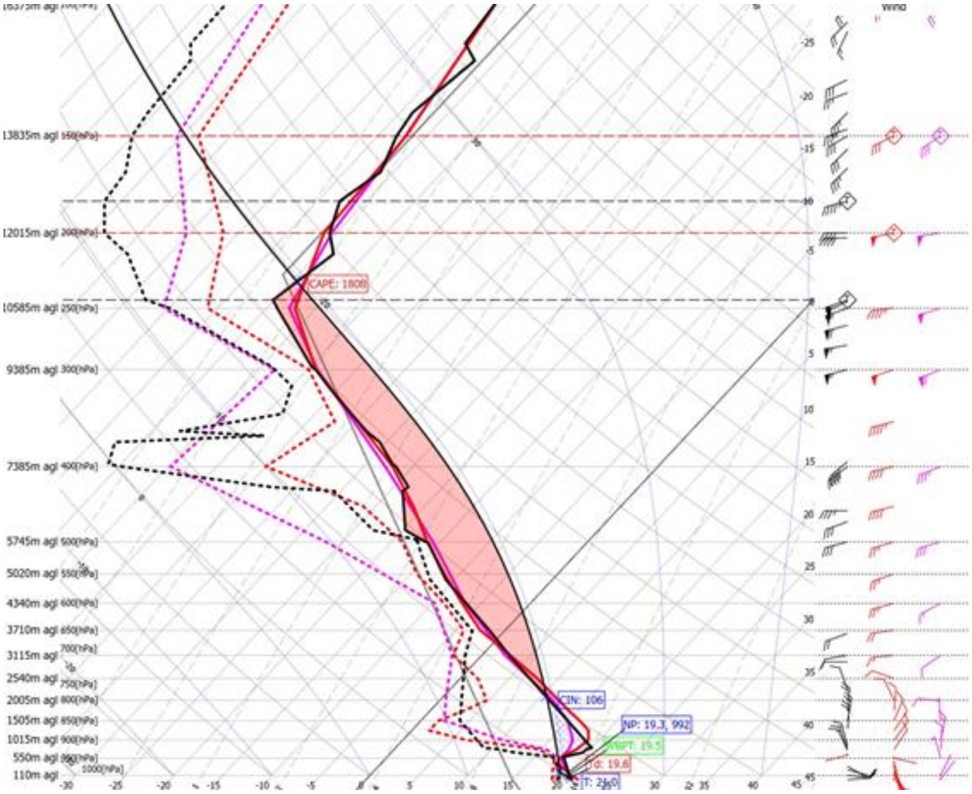


Figure 6. 6-hour model soundings from ACCESS-R (red) and ECMWF (cyan) valid 18 UTC 16 Dec; 1842 UTC 15 Dec observed Sydney Airport atmospheric profile (black).

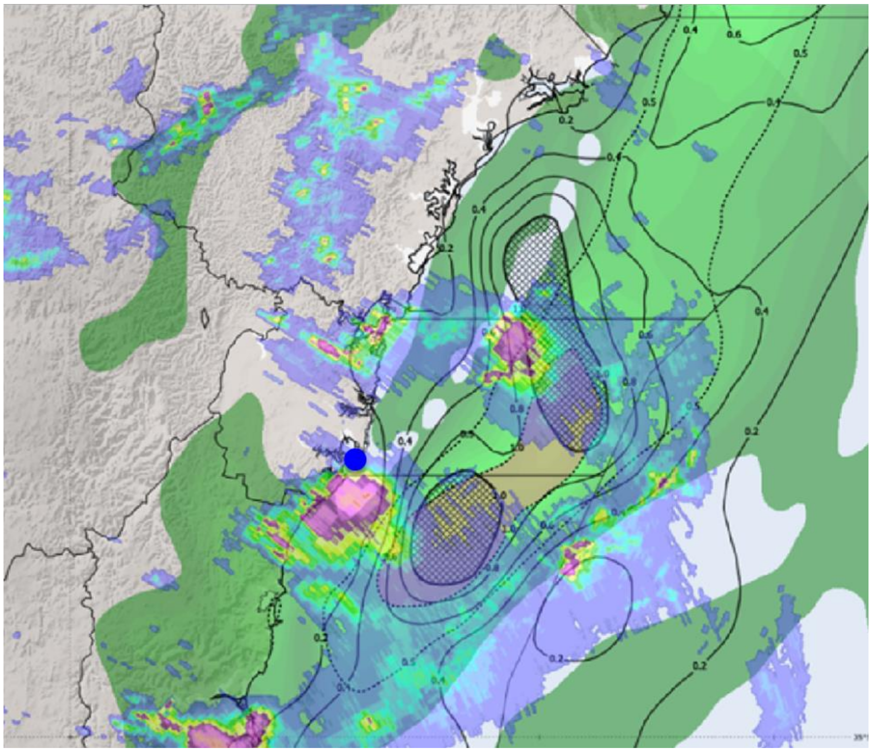


Figure 7. *18 UTC 15 Dec 2015 NWP ACCESS-R forecasts valid 23 UTC of Significant Tornado Parameter (green shading, light brown shading denotes values >1), Supercell Composite Parameter (black contours, cross hatched area denotes values >1) and Kurnell radar reflectivity; Blue dot indicates location of Kurnell, NSW*

6. CONCLUSIONS

This study describes the convective forecast methodology employed by the Extreme Weather Desk from the Australian Bureau of Meteorology for the 16 December 2015 EF-2 tornado just south of Sydney. Parameters designed to highlight storm environments that support severe convection such as the Supercell Composite Parameter (SCP) or the Significant Tornado Parameter (STP) did alert EWD forecasters to the potential for rotating storms 1-2 days in advance of the event, although the severe storms tended to occur at the western periphery of the highlighted area.

A critical element in forecasting the actual tornadic supercell was the erosion of a stout capping inversion on top of a marine boundary layer due to physical mechanisms yet to be established. There was disagreement between the NWP model guidance regarding the presence and strength of the capping inversion a day in advance to the event, which adversely influenced the Day +1 EWD convective outlook for 16 December 2015. Closer to the event however (< 24 hours), NWP model guidance showed increased confidence that the capping inversion would be eroded during the morning hours of 16 December.

The EWD forecast process that includes systematic post-event verification as part of the rostered duties provided the catalyst to further investigate marine layer instability which in turn has increased expertise within the EWD. For instance, the mechanism for the reduction in CIN between 18 UTC to 23 UTC is the topic of ongoing research.

The subjective verification of NWP guidance, thunderstorm guidance and composite convective parameters led to improved skill in forecasting thunderstorms and related hazards during the Australian 2015-2016 convective season. Such a forecast process continues to build expertise on a daily basis within the EWD.

Verification has also been used to refine EWD convective outlook products. Following the 2015-2016 season, the convective outlooks were verified objectively using observed lightning. A bias for under forecasting probability of thunder within 40 km of a point was realised. This prompted the testing of the products against a new definition of probability of thunder within 10 km of a point, which has proven to be far more reliable given the predicted probabilities originally intended for the 40 km radius. The decision to change the service definition from a radius of 40 km to 10 km was made in time for the 2016/2017 severe weather season in Australia.

Another change made for the 2016/2017 season was to make the forecasts of probability of severe thunderstorm phenomena conditional on the occurrence of a thunderstorm. This change was made to allow higher probabilities of severe thunderstorm phenomena to be forecast and will allow a 'probability of severe thunderstorm impact within 10 km of a point' product to be developed in the future. This, and further details on EWD convective outlook service changes for the 2016/2017 season are described in Appendix 4.

7. REFERENCES

Cohen, A. E. (2010). Indices of violent tornado environments. Electron. J. Oper. Meteor, *11*.

Kruper, R.J., Mason M.S., Glanville, M.J.(2016). Technical Note – Kurnell Tornado and Thunderstorm Outflow Events: 16 December 2015. The Australian Wind Engineer Newsletter, *29(1).*

Puri, K., Dietachmayer, G., Steinle, P., Dix, M., Rikus, L., Logan, L., & Bermous, I. (2013). Implementation of the initial ACCESS numerical weather prediction system. *Aust. Meteorol. Oceanogr. J*, *63*, 265-284.

Thompson, R. L., Edwards, R., & Hart, J. A. (2002, August). Evaluation and interpretation of the Supercell Composite and the Significant Tornado Parameters at the Storm Prediction Centre. Preprints. In 19th Conference on Weather analysis and Forecasting and 15th Conference on Numerical Weather Prediction. Amer. Meteor. Soc (pp. J11-J14).

Thompson, R. L., Edwards, R., Hart, J. A., Elmore, K. L., & Markowski, P. (2003). Close proximity soundings within supercell environments obtained from the Rapid Update Cycle. Weather and forecasting, *18(6)*, 1243-1261.

Thompson, R. L., Edwards, R., & Mead, C. M. (2004, October). An update to the supercell composite and significant tornado parameters. In Preprints, 22nd Conf. on Severe Local Storms, Hyannis, MA, Amer. Meteor. Soc. P (Vol. 8).

Thompson, R. L., Smith, B. T., Grams, J. S., Dean, A. R., & Broyles, C. (2012). Convective modes for significant severe thunderstorms in the contiguous United States. Part II: Supercell and QLCS tornado environments. Weather and Forecasting, *27(5)*, 1136-1154.

APPENDIX 1: EXAMPLE OF A NATIONAL CONVECTIVE OUTLOOK DISCUSSION

National Convective Outlook Discussion **for Wednesday 16th December 2015**
Issued Tuesday 15th December 0230Z by JT

The upper trough evident on current WV imagery marching through WA that extends to an upper low over Tasmania is forecast to lie from central NT through NE SA and northern NSW with locally strong upper divergence ahead of the trough. Multiple surface troughs extending from heat lows across the north are likely to continue on Wednesday. There is some uncertainty in the positions of these troughs but generally there will be one through western WA, with another broad trough extending through NE SA to a weak low over northern NSW.

WA: Next upper trough will be approaching the surface trough through western WA. 12Z1412ACCR indicating WBPT in the order of 20 to 23C, the same run of EC has WBPT at least a couple of degrees less. Thunderstorm activity along the trough will be highly likely (at least >30%) if ACCR is correct. Given the uncertainty, only a 10% region has been drawn. If storms do develop along this trough then DMAPE will be >1000 j/kg leading to some potential of damaging wind gusts.

Northern SA and SW NSW: Negative 700 to -20 LI early in the morning, but upper trough likely to have passed through, so it seems like the chance of storms <10% in this region apart from further north where a surface based risk exists in the afternoon.

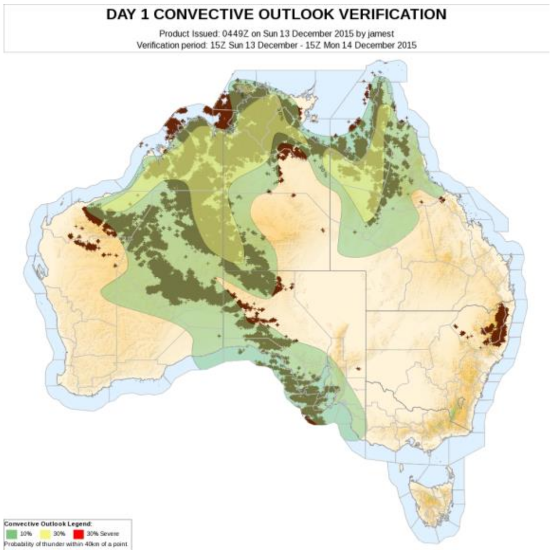
5% damaging wind areas: Positioned ahead of upper trough. Bulk Shear of 20-30 kts allowing for squall line potential.

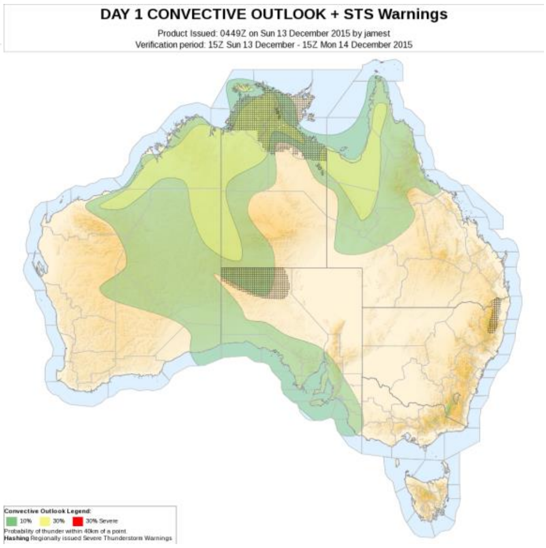
5% heavy rain: Either where deep layer mean (DLM) winds seemed southerly enough that train effect could occur along NSW ranges convergent line, or DLM <10kts. Also paid some attention to the 12Z1412ACCR rainfall guidance. Tropical areas will be at risk but have not included any areas due to lack of shear and high ARIs.

5% Hail: NE NSW Sig Hail parameter not surprisingly (given the SBCAPE, and Bulk Shear) ranges between 0.5 to 1.5 with ACCR having the higher values. Given the approaching upper trough, one could argue for a 15% area, however uncertainty in placement of convergent lines to drive storms prevents certainty in where large hail is more likely. Interestingly the Sig Hail Parameter indicates values in the order of 0.2 (EC) to 0.6 (ACCR) with LCL <1000m over the western Qld region. Given the lack of shear in the region it was thought that probability of large hail was <5%.

APPENDIX 2: EXAMPLE OF THE ROUTINE VERIFICATION APPROACH AT THE EWD

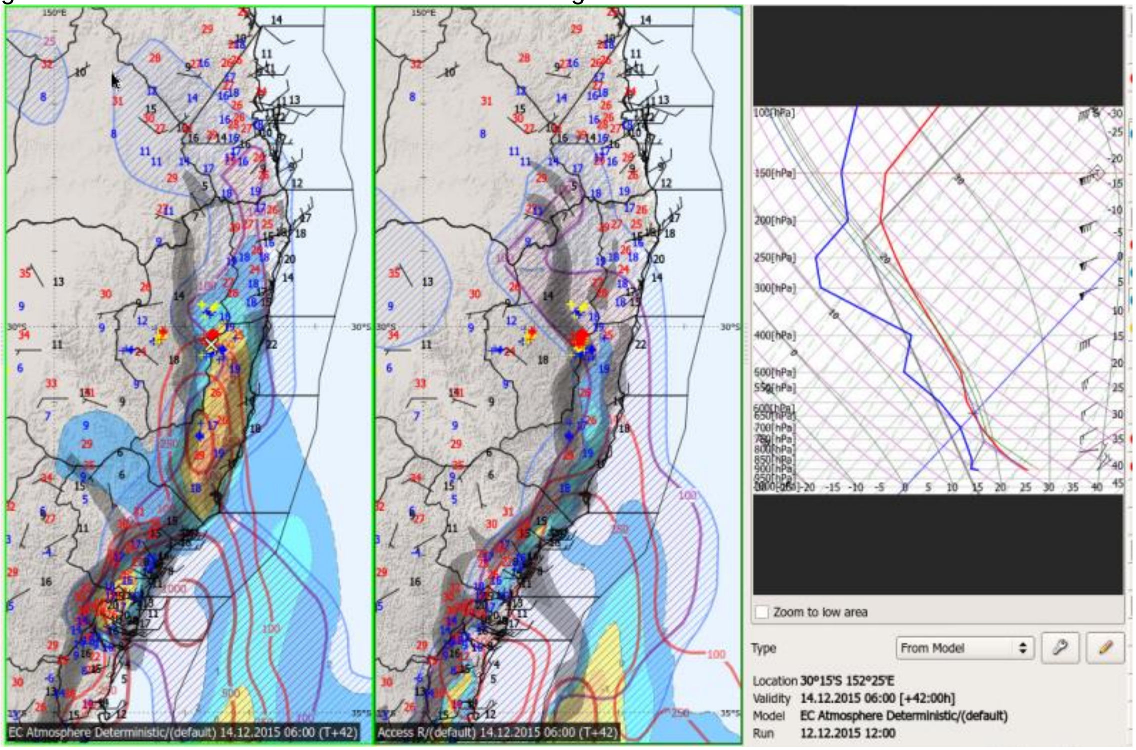
Daily Verification for 14 December 2015





TS forecast assessment:

- Missed storms in NE NSW; Below is 950 to -20C LI (tend to use 950hPa as representative of mixed layer LI) with CAPE and CIN overlayed with EC on left and ACCR on right. EC trace from 12Z1212 guidance used for forecast over missed storm region.

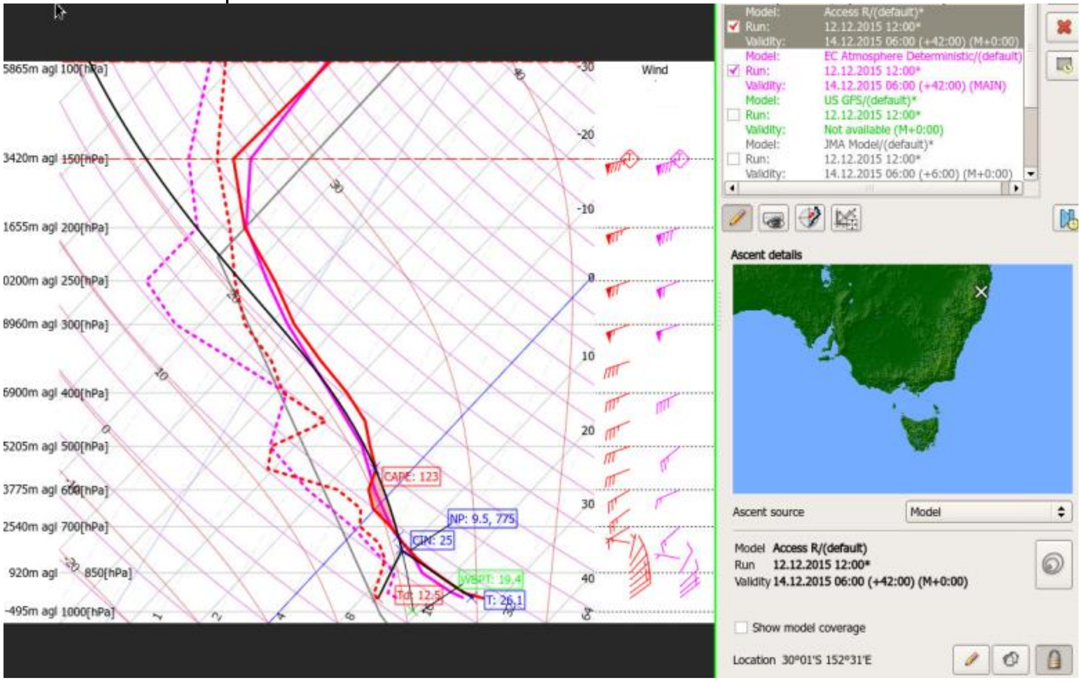


EC Atmosphere Deterministic/(default) 14.12.2015 06:00 (T+42)

Access R/(default) 14.12.2015 06:00 (T+42)

Location 30°15'S 152°25'E
Validity 14.12.2015 06:00 [+42:00h]
Model EC Atmosphere Deterministic/(default)
Run 12.12.2015 12:00

12Z1212ACCR/EC traces (used for forecast) where lightning detected at 06Z1412. Surface conditions of lifted parcel an estimate between ACCR and EC



☐ Model: Access R/(default)*
☑ Run: 12.12.2015 12:00*
Validity: 14.12.2015 06:00 (+42:00) (M+0:00)
Model: EC Atmosphere Deterministic/(default)
☑ Run: 12.12.2015 12:00*
Validity: 14.12.2015 06:00 (+42:00) (MAIN)
Model: US GFS/(default)*
☐ Run: 12.12.2015 12:00*
Validity: Not available (M+0:00)
Model: JMA Model/(default)*
☐ Run: 12.12.2015 12:00*
Validity: 14.12.2015 06:00 (+6:00) (M+0:00)

Ascent details

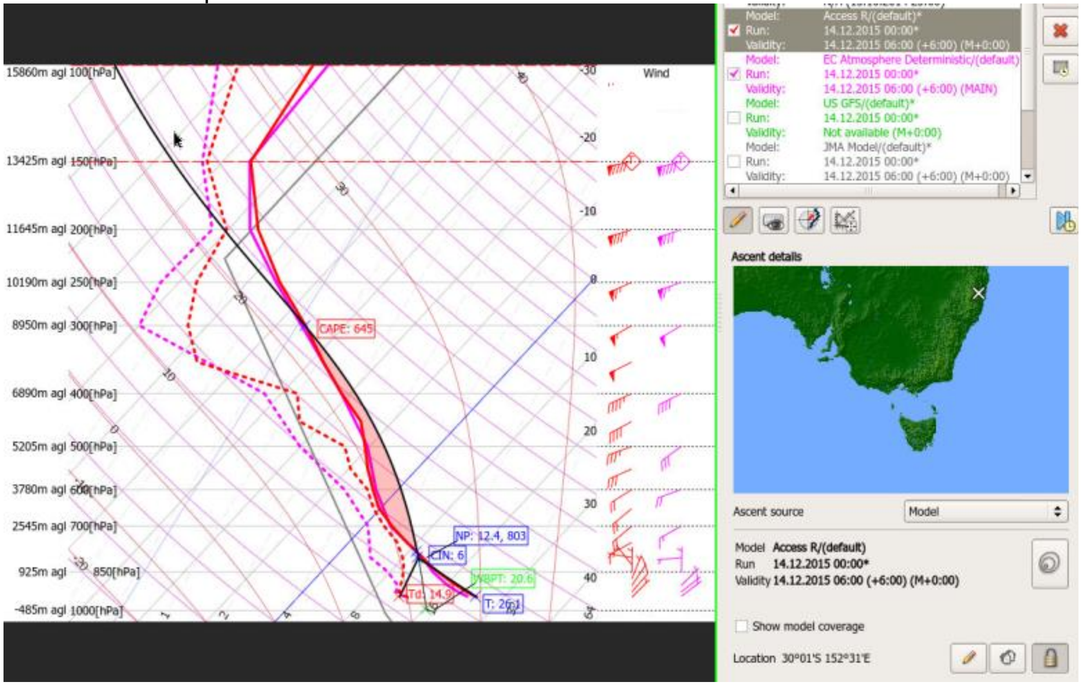
Ascent source: Model

Model Access R/(default)
Run 12.12.2015 12:00*
Validity 14.12.2015 06:00 (+42:00) (M+0:00)

☐ Show model coverage

Location 30°01'S 152°31'E

Same for below but with 00Z1412ACCR/EC guidance which indicated more moisture and less of a middle level hump in the trace.



Model: Access R/(default)*
☑ Run: 14.12.2015 00:00*
Validity: 14.12.2015 06:00 (+6:00) (M+0:00)
Model: EC Atmosphere Deterministic/(default)
☑ Run: 14.12.2015 00:00*
Validity: 14.12.2015 06:00 (+6:00) (MAIN)
Model: US GFS/(default)*
☐ Run: 14.12.2015 00:00*
Validity: Not available (M+0:00)
Model: JMA Model/(default)*
☐ Run: 14.12.2015 00:00*
Validity: 14.12.2015 06:00 (+6:00) (M+0:00)

Ascent details

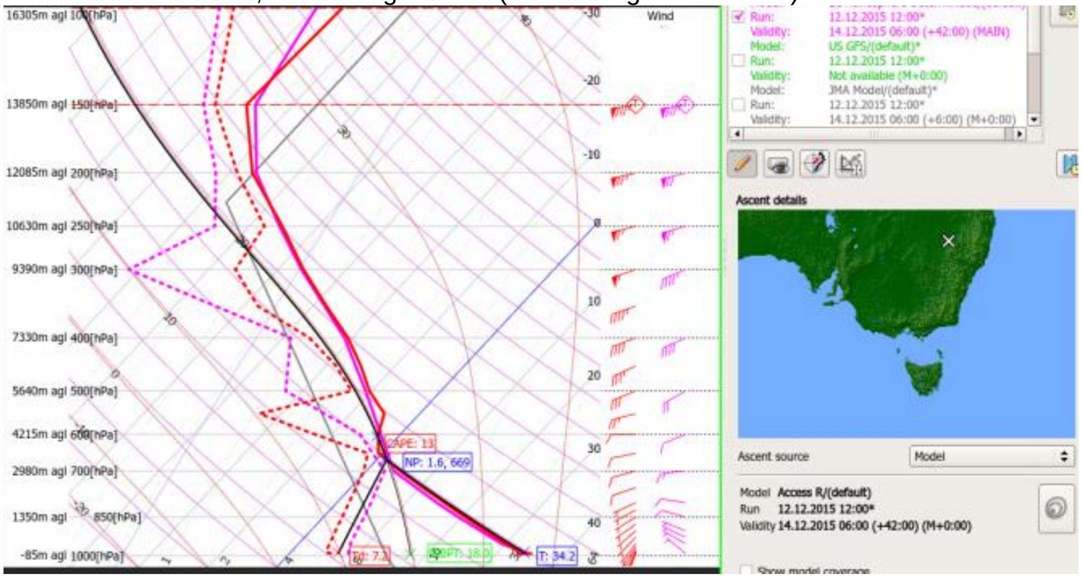
Ascent source: Model

Model Access R/(default)
Run 14.12.2015 00:00*
Validity 14.12.2015 06:00 (+6:00) (M+0:00)

☐ Show model coverage

Location 30°01'S 152°31'E

Same for near Moree, 12Z1212 guidance (no morning Moree trace)



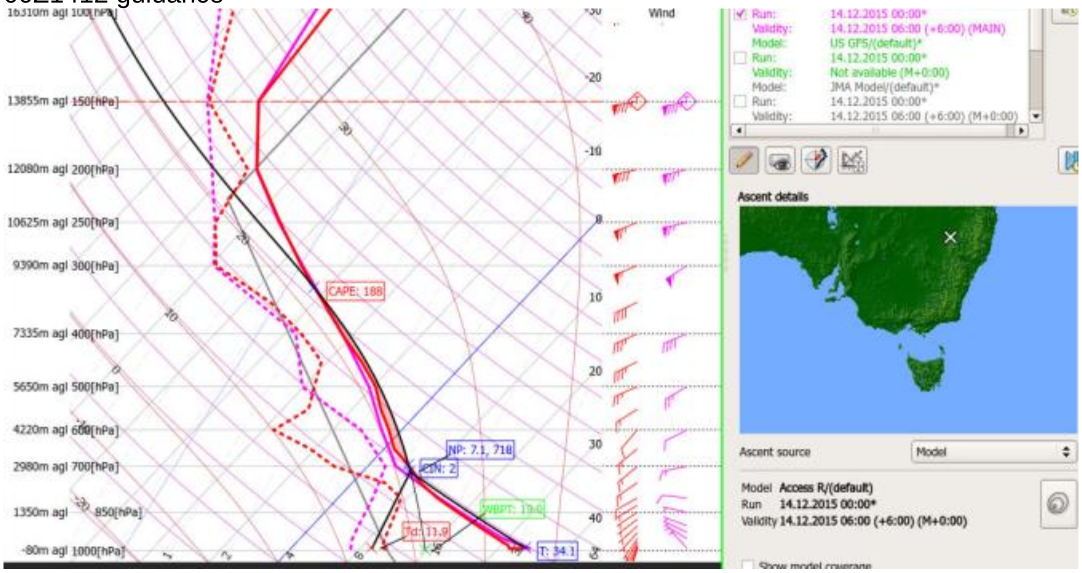
☑ Run: 12.12.2015 12:00*
Validity: 14.12.2015 06:00 (+42:00) (MAIN)
Model: US GFS/(default)*
☐ Run: 12.12.2015 12:00*
Validity: Not available (M+0:00)
Model: JMA Model/(default)*
☐ Run: 12.12.2015 12:00*
Validity: 14.12.2015 06:00 (+6:00) (M+0:00)

Ascent source: Model

Model Access R/(default)
Run 12.12.2015 12:00*
Validity 14.12.2015 06:00 (+42:00) (M+0:00)

☐ Show model coverage

00Z1412 guidance -



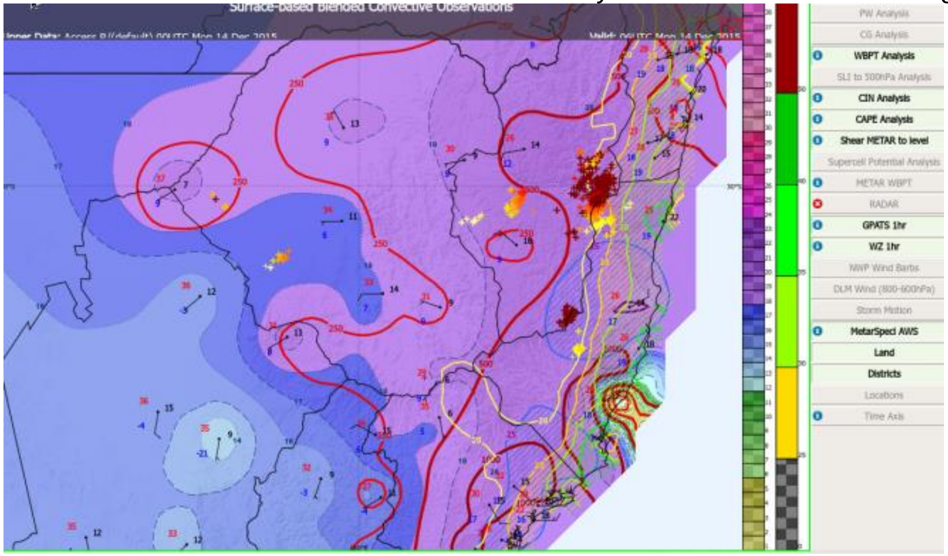
☑ Run: 14.12.2015 00:00*
Validity: 14.12.2015 06:00 (+6:00) (MAIN)
Model: US GFS/(default)*
☐ Run: 14.12.2015 00:00*
Validity: Not available (M+0:00)
Model: JMA Model/(default)*
☐ Run: 14.12.2015 00:00*
Validity: 14.12.2015 06:00 (+6:00) (M+0:00)

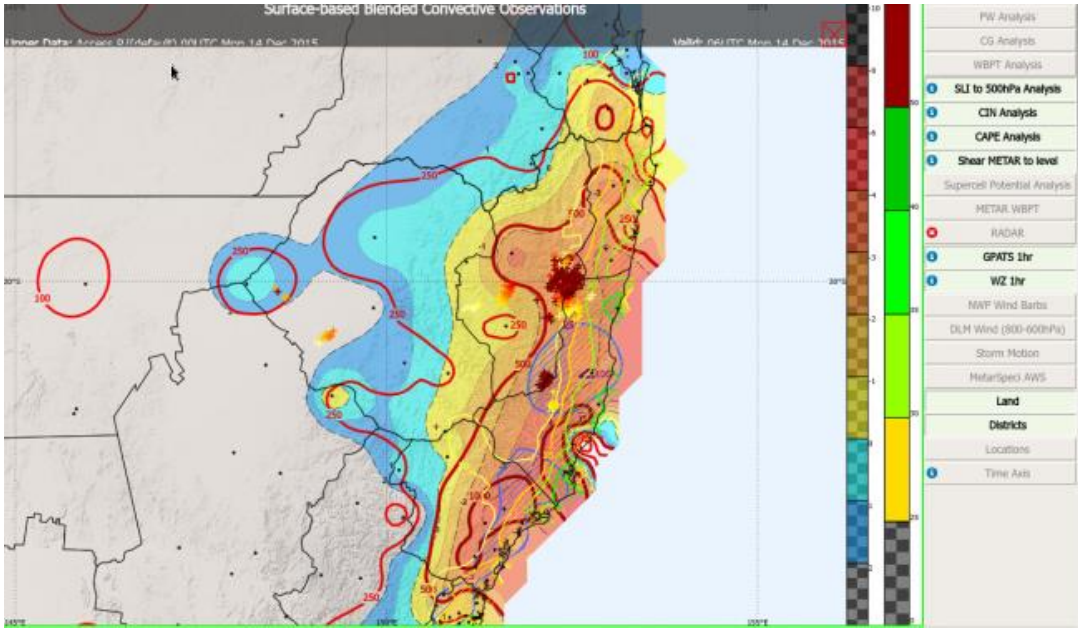
Ascent source: Model

Model Access R/(default)
Run 14.12.2015 00:00*
Validity 14.12.2015 06:00 (+6:00) (M+0:00)

☐ Show model coverage

WBPT needs to be >~19.5C for a storm. Surface obs near lightning indicate WBPT in region 19 at most. Leads one to think that the middle levels may have cooled more than the guidance was aware.

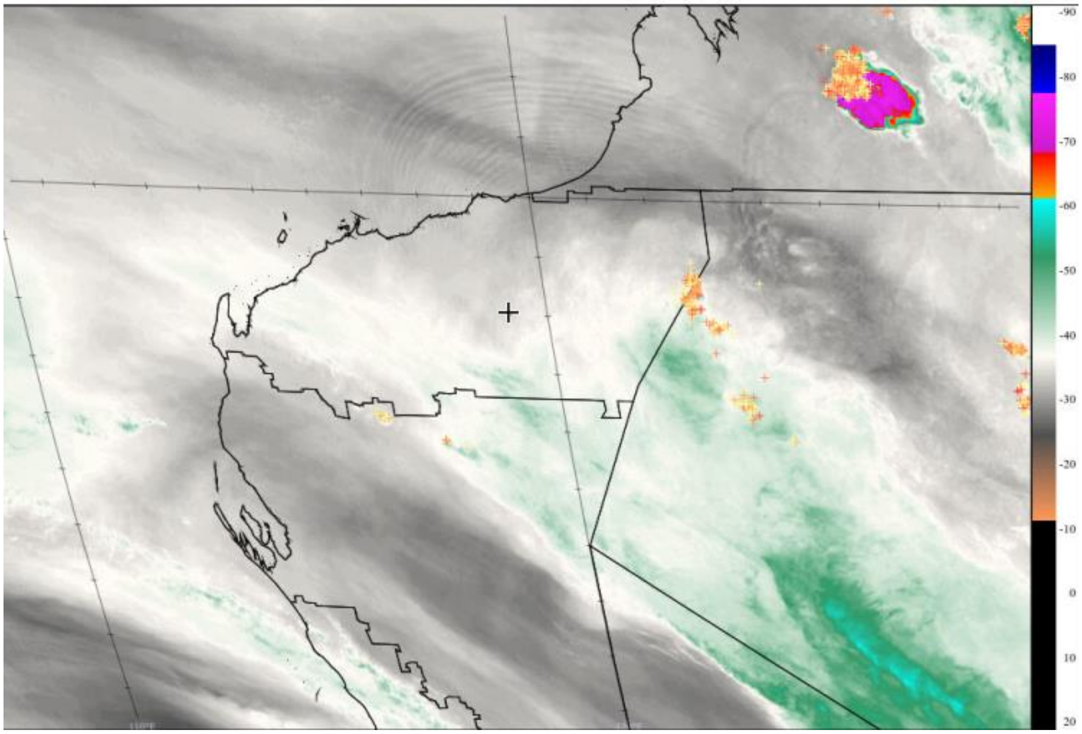


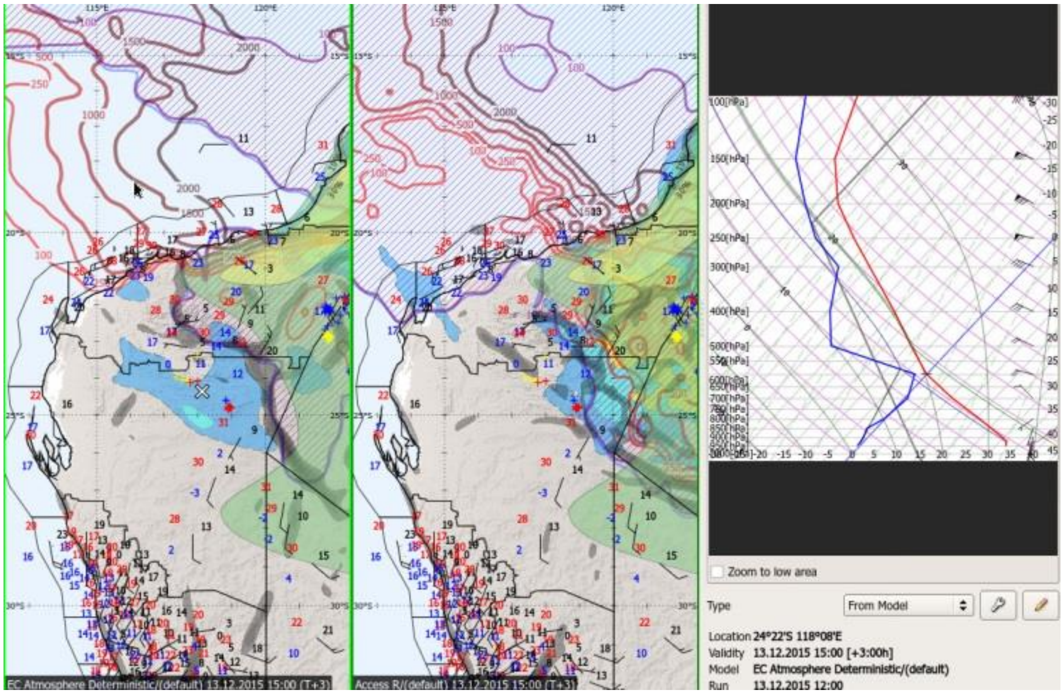


So the later model runs were more onto the chance of storms, given the guidance for the forecast and assessment of the environment, one could argue that these storms occurred in a <10% area at time of forecast issue.

- Missed northern Gascoyne; Appears that weak middle level instability (700 to -20C LI 12Z1312 ACCR/EC below) was realised on the leading edge of the weakening upper trough early Monday. Cannot get back to the 12Z1212 guidance to see if this middle level instability was evident or not.

JMA Himawari-8 - valid at Sun, 13 Dec 2015, 16:50 UTC





☐ Zoom to low area

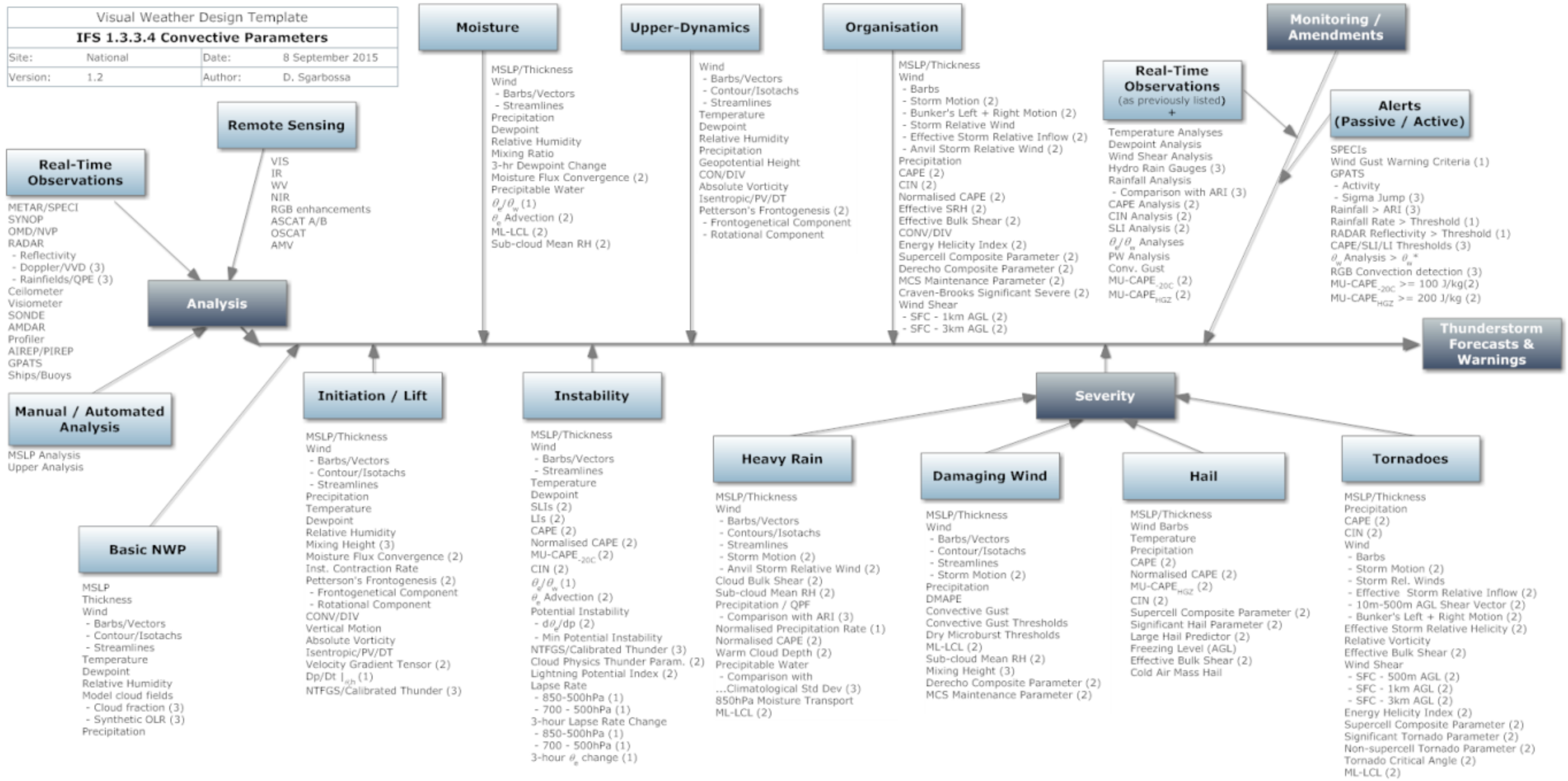
Type From Model

Location 24°22'S 118°08'E
Validity 13.12.2015 15:00 [+3:00h]
Model EC Atmosphere Deterministic/(default)
Run 13.12.2015 12:00

Reports:

- Number of locations recorded between 50-70mm over the eastern Top End including Tindal with 77mm.
- Pidgeon Hole further south recorded 89mm.

APPENDIX 3: ISHIKAWA DIAGRAM ILLUSTRATING THE CONVECTIVE FORECAST PROCESS WITH RESPECT TO GUIDANCE AND DATA.



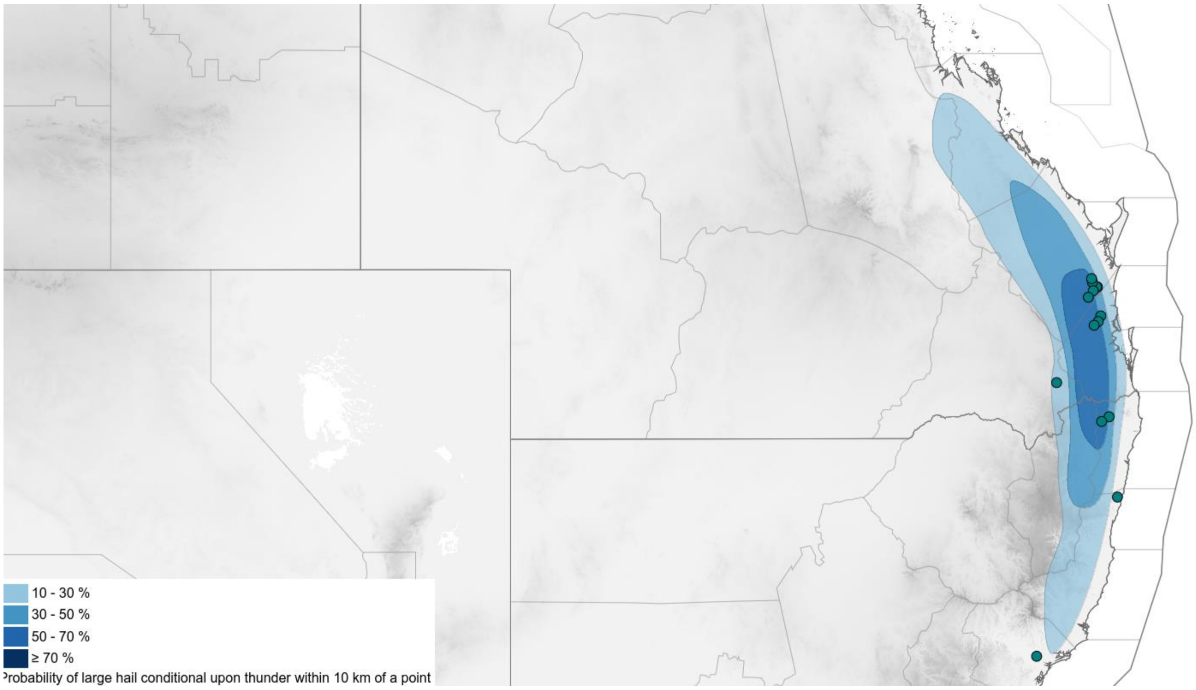
Data Sources		**Parcel Definitions**	
Remote Sensing:	MTSAT-2, AVHRR, Himawari-8, NOAA	SFC (SB-)	2m AGL T and T_d
NWP:	ACCESS-C, ACCESS-R, ECMWF Deterministic, ECMWF Ensemble, USGFS, JMA, UKMO, NextGenFWS, MSAS, NTFGS/Calibrated Thunder	Mixed Layer (ML-)	Mean T and T_d of lowest 100hPa above ground level.
Key		Most Unstable (MU-)	Parcel with largest θ_e in lowest 300hPa above ground level.
(1)	Fields available but maps/templates required	Effective (e-)	Lowest parcel AGL with CAPE >= 100 J/kg and CIN >= -250 J/kg.
(2)	Fields to be calculated as part of IFS Convective Parameters	Effective Most Unstable (eMU-)	Parcel with largest θ_e or CAPE within effective inflow layer.
(3)	Fields unavailable but operationally beneficial.	* CAPE, CIN, LIs calculated for each parcel definition.	

APPENDIX 4

EWD National Convective Outlook Service Changes for 2016/2017 Australian Severe Weather Season

1. Objective verification of convective outlooks issued during 2015-16 showed a systematic bias towards under forecasting the true probability of thunder when defined as 'probability within 40 km of a point'. Forecasts proved reliable when verified using a definition of within 10 km.
2. Changing the service definition (from a radius of 40 km to 10 km of a point) extends the applicability of the products to aviation, particularly the chance of thunderstorms on TAFs.
3. The thunder within 10km definition is arguably a better measure of a person's awareness or perception of a thunderstorm at their location.
4. The 2015/2016 season indicated that probability of severe thunderstorm >30% within 40km of a point was not used often as it denotes a very high level of confidence. The service definition of severe convection attribute outlooks (large hail, heavy rain, damaging wind, tornado) is now 'probability of [severe attribute], conditional on the occurrence of a thunderstorm'. This will allow for further product development as described in point 8.
5. A conditional probability of any severe phenomenon product has been introduced, defined as 'probability of severe phenomena, conditional on the occurrence of a thunderstorm'.
6. This product is consequential of the four individual severe attribute products. It is constructed by taking the maximum probability of the four individual attribute products at any point. For example, a point with conditional probabilities of 10% chance of large hail, 30% chance of heavy rain and 50% chance of damaging wind, will have a conditional probability of severe phenomena of 50%.
7. Objective verification of convective outlooks issued during 2015-16, as well as seasonal climatology of lightning frequency, suggested a need for additional contours to indicate areas of much higher thunderstorm probability than simply '> 30%'. As such additional probability contours have been included in all general and severe convection outlook products to allow for the indication of higher levels of risk.
8. System development work is ongoing towards the introduction of an overall 'probability of severe thunderstorm impact within 10 km of a point' product. This product will be produced by multiplying the 'probability of thunder within 10km' by the 'probability of severe phenomena, conditional on thunderstorm occurrence' at any point. For example, consider a point within a thunderstorm environment characterised by a low-level cap: a low chance of thunderstorm occurrence (10%) but a high chance of damaging winds (50%) if the cap breaks and a thunderstorm does develop:
    - Chance of severe thunderstorm impact:
        = 10% probability of thunder x 50% conditional probability of damaging winds
        = 0.10 x 0.50
        = 0.05 - i.e. 5% chance within 10 km of a point of severe thunderstorm impact

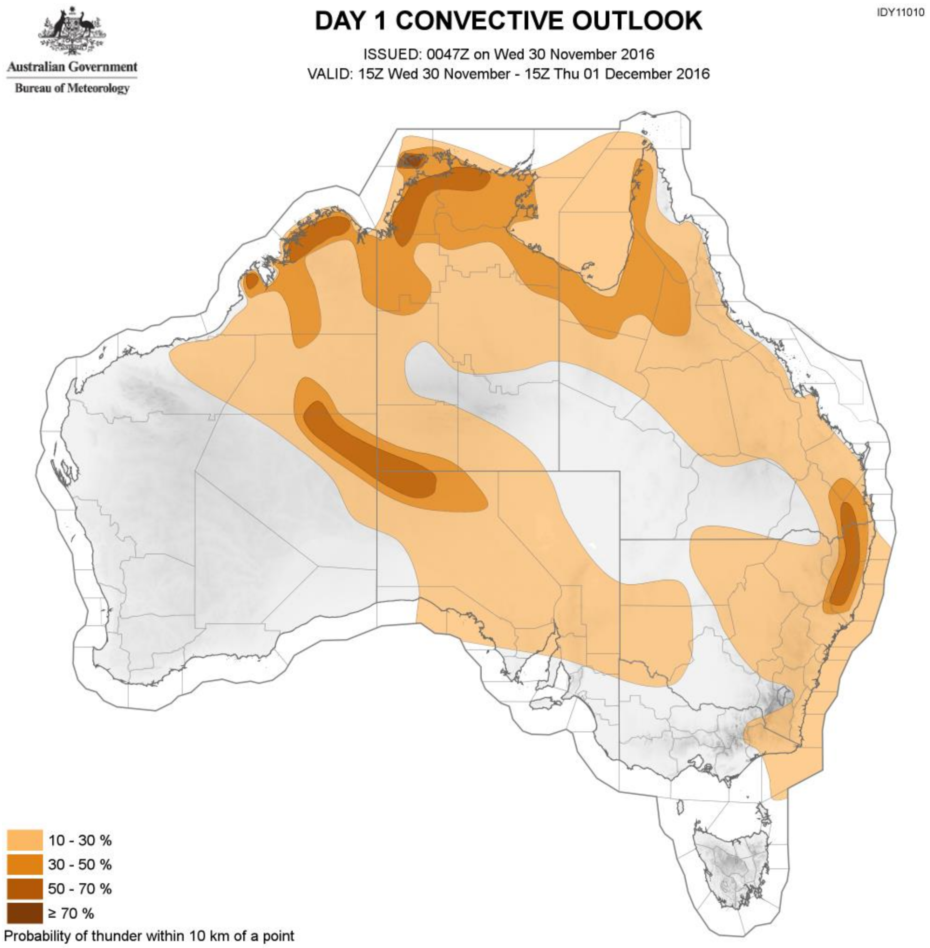
An example of EWD products currently being issued is provided in the National Convective Outlook for Thursday 1 December.
Much development has been undertaken since the 2015/2016 severe weather season which has corrected a number of issues regarding guidance systems in addition to implementing the aforementioned changes to the EWD convective outlook products. Thursday 1 December was an active day for supercell thunderstorm organisation and severe phenomenon, particularly large hail, along the highly populated east coast of Australia. Giant hail (diameters ≥5 cm) was reported in a number of locations across New South Wales and Queensland with the largest hail size of 7 cm reported near Gympie in southeast Queensland. The location of large hail reports are indicated in the following figure as green dots overlayed upon the EWD Large Hail Outlook product.



EWD Large Hail Outlook product for Thursday 1 December with large hail reports denoted by green dots.

Large hail reported from Kyogle, NSW.

National Convective Outlook for Thursday 1 December 2016
Issued 12:00 pm AEDT Wednesday 30 November 2016



Middle level instability associated with the upper trough currently moving across SA will be over central parts of NSW by 15Z, providing a risk of storms in the area that will advect east and clear during the morning. There is also a similar risk over eastern Victoria in the morning. Middle level storms again a reasonable chance across southern parts of SA early on Thursday, however unlike this morning, the supporting upper feature is not as strong. Directional divergence ahead of an upper trough associated with an approaching cold front could well be enough to support storms in the area.

Most of the rest of the forecast is associated with surface based storm potential in the afternoon, although there is likely to be some persistent overnight convection in parts of the tropical areas.

Note that the capping of the seabreeze along the southern NSW eastern ranges is quite low, however it is more likely that the lifted air will be the drier westerly, as such it is a low risk of storms after the morning middle level instability clears.

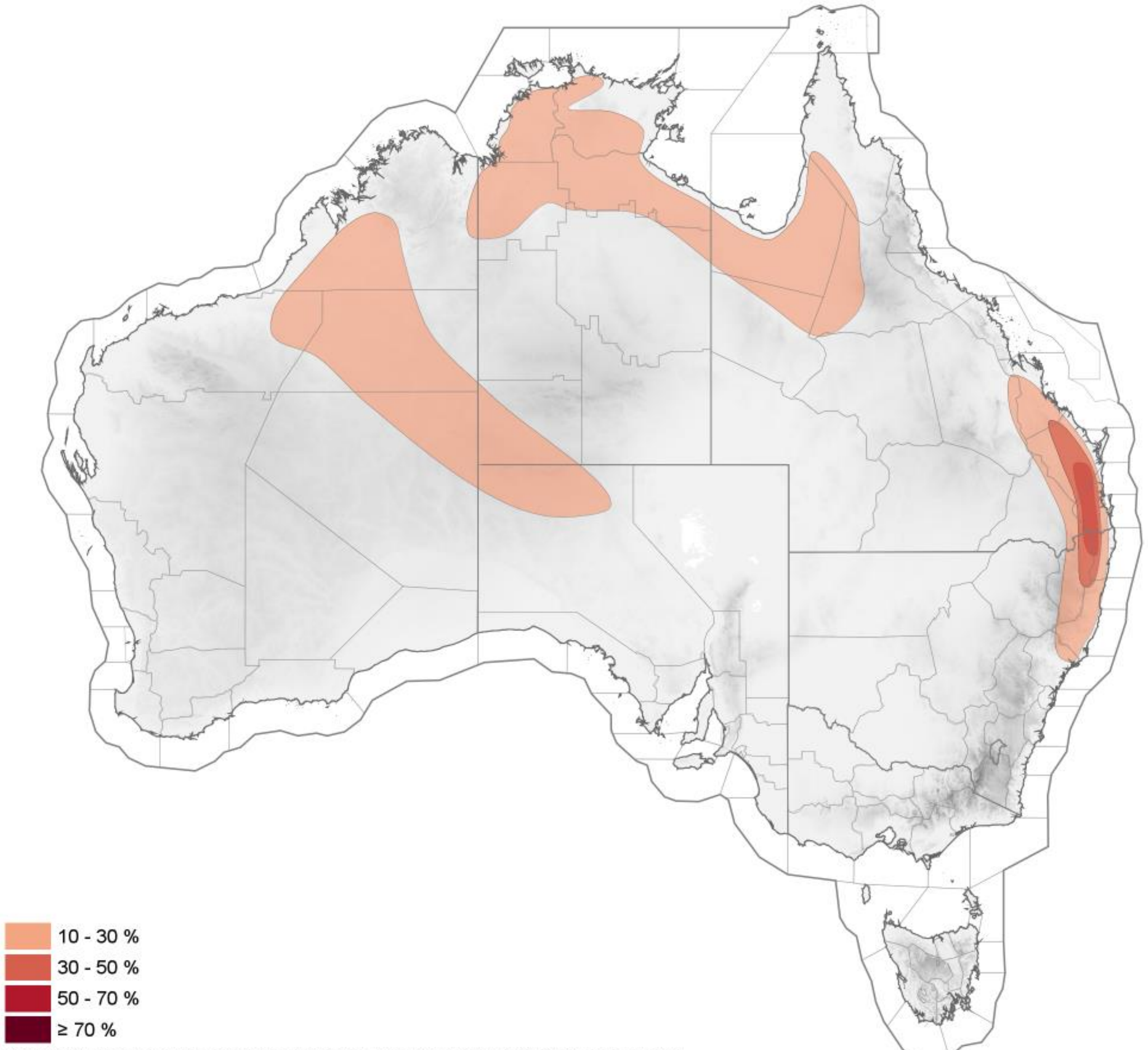
Also note that the 12Z2911EC indicates afternoon instability over northeastern Tasmania but this is not supported by the 12Z or 18Z2911ACCR. As such the area is thought to be <10% chance of storm within 10km of a point.

IDY11014

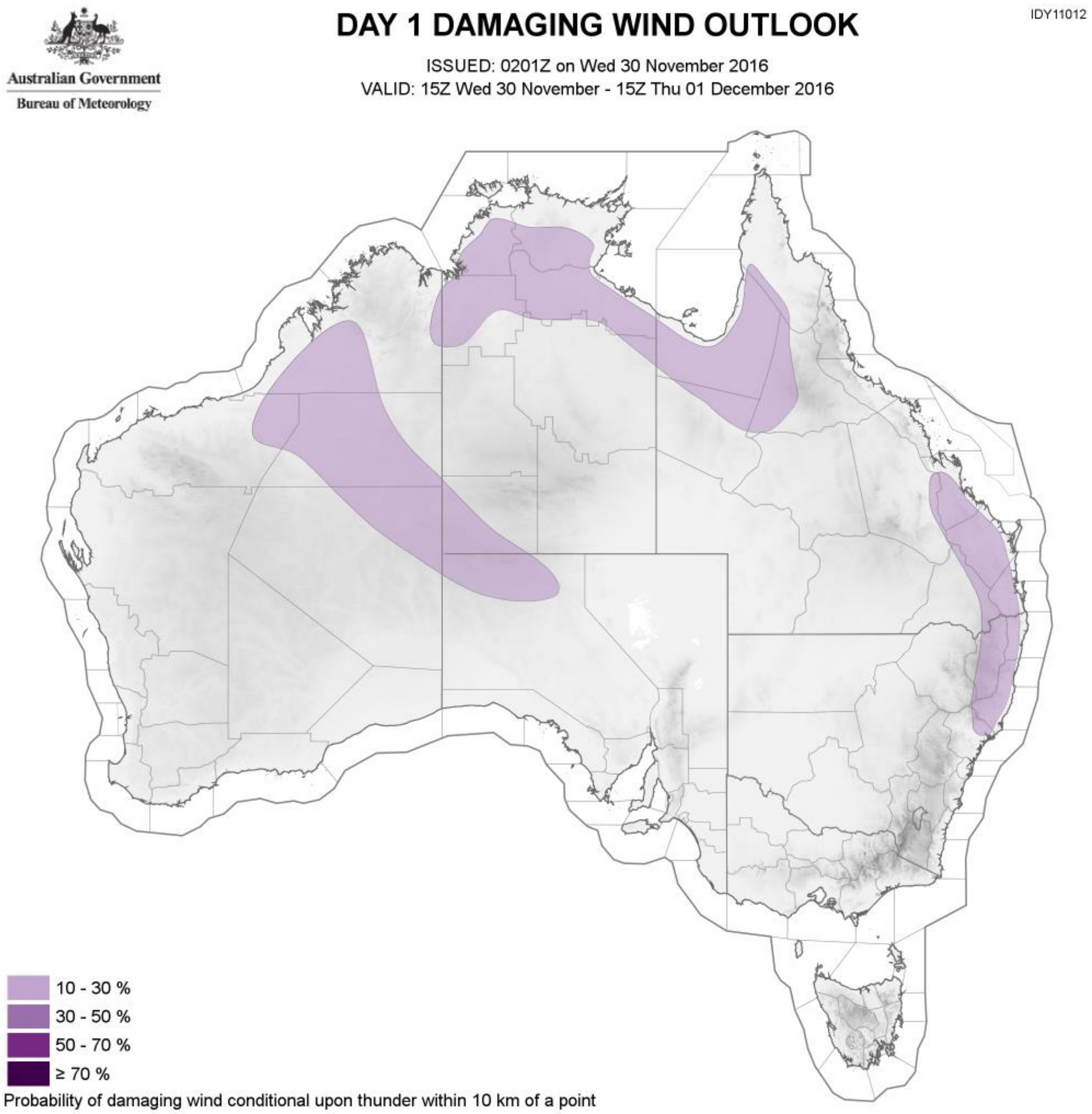
Australian Government
Bureau of Meteorology

DAY 1 SEVERE CONVECTIVE OUTLOOK

ISSUED: 0313Z on Wed 30 November 2016
VALID: 15Z Wed 30 November - 15Z Thu 01 December 2016

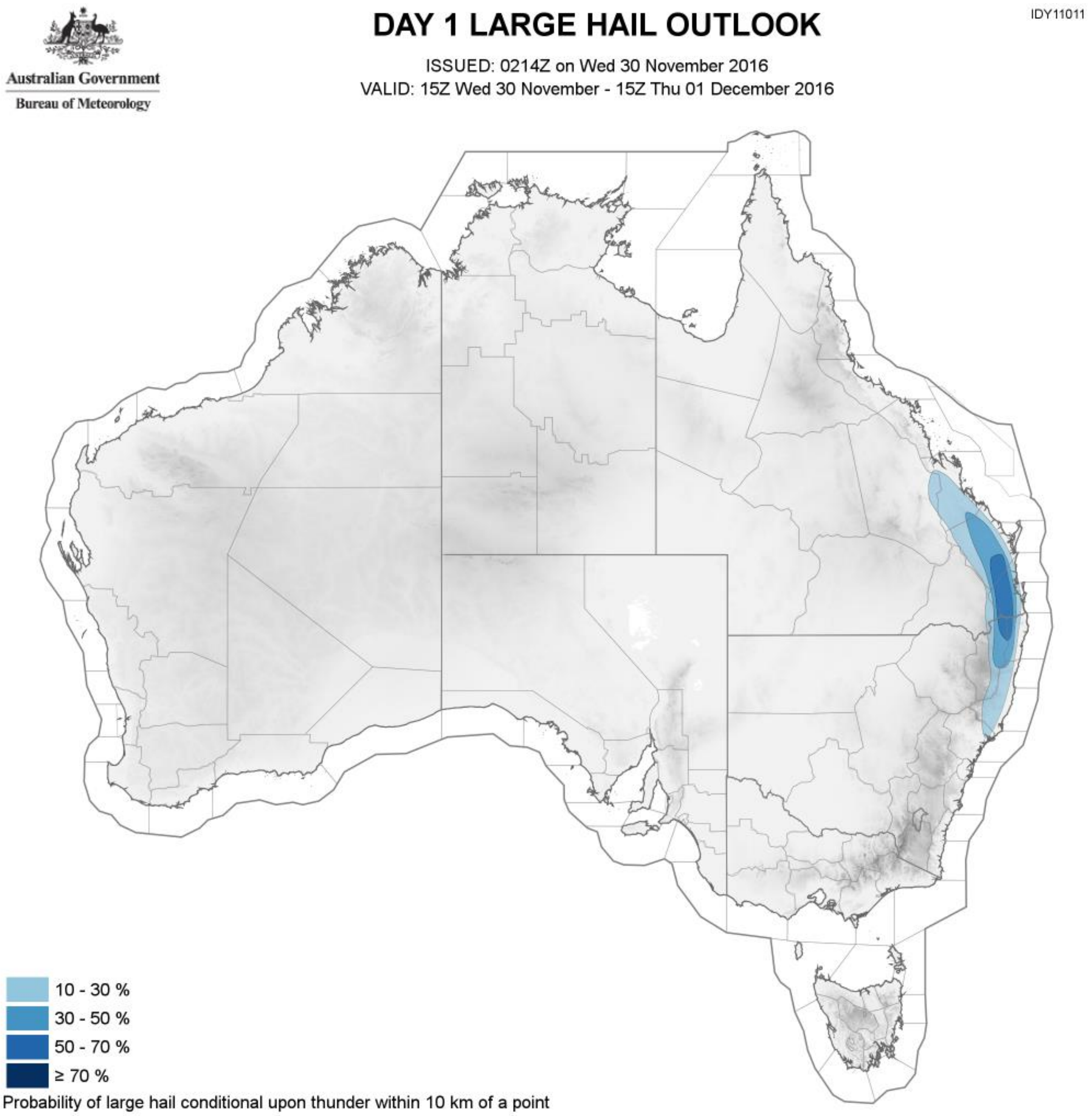


Probability of severe phenomena conditional upon thunder within 10 km of a point

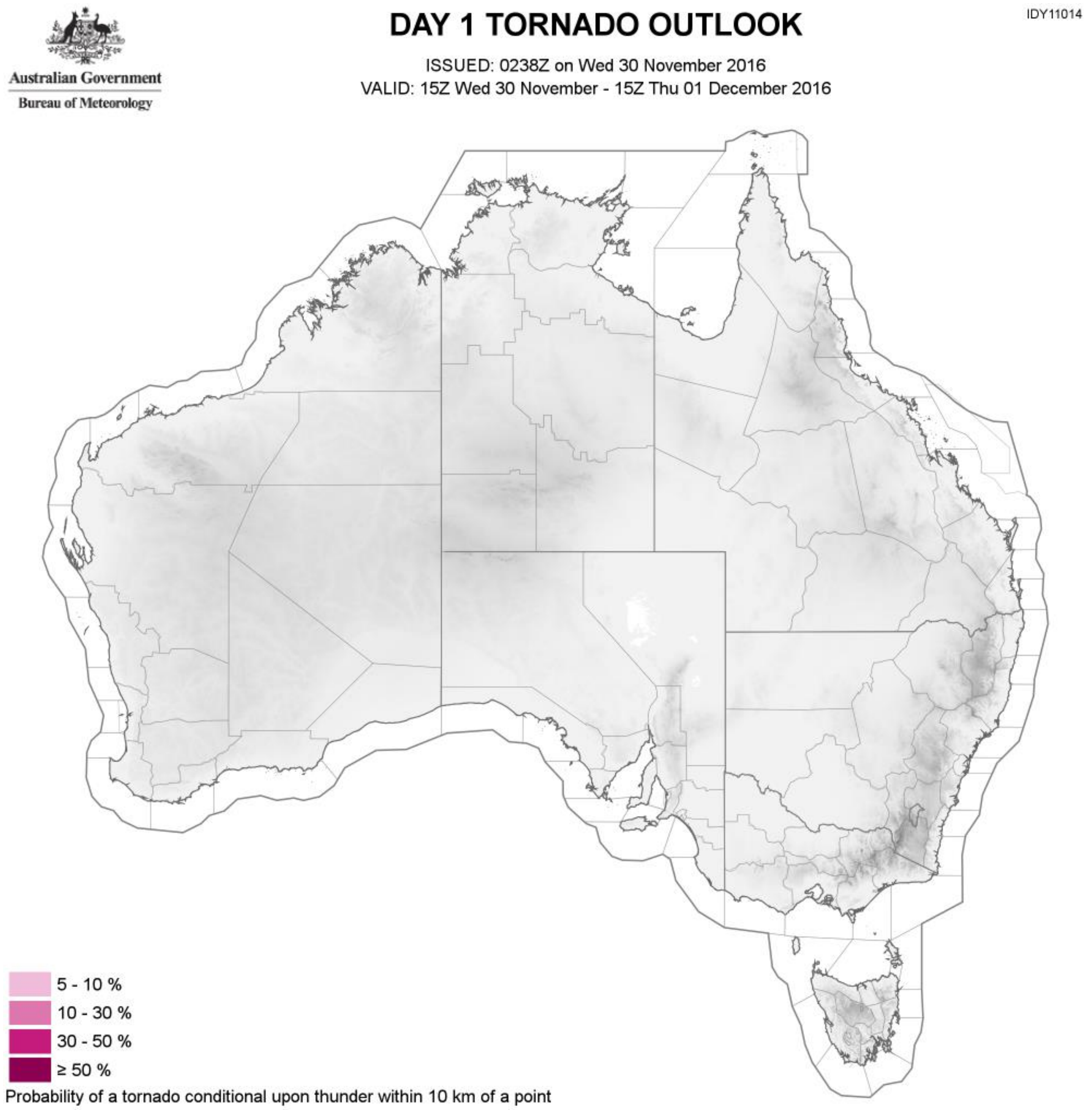


With 0-3km SRH in excess of -200m2/s2 over parts of NE NSW/SE Qld, and CAPE >2000 j/kg, it is not surprising that the supercell parameter in 12&18Z2911ACCR is >2 and as high as 3.5 in places. The question will be how well capped the northeasterly airmass is that is opening the hodograph to drive the large SRH. ACCR indicates that further from the coast the CIN is < ~100j/kg and given the convergence across the Divide, this could be broken and storms may live longer than expected into the higher CIN air near the coast if they are well organised. With DLM winds generally westerly at ~30 kts, they will be perpendicular to the convergent line, however if a storm veers far enough left there will be potential for boundary riding in places – the 12Z2911ACCR/EC indicate that this could happen in the north of Qld’s SE district. So in terms of convective mode, expecting most storms to blow up then weaken as they reach the higher capped air. However there seems to be very good potential for a couple of intense supercells in the afternoon. Given the convective mode, the chance of impact at a point is assessed as only 10%.

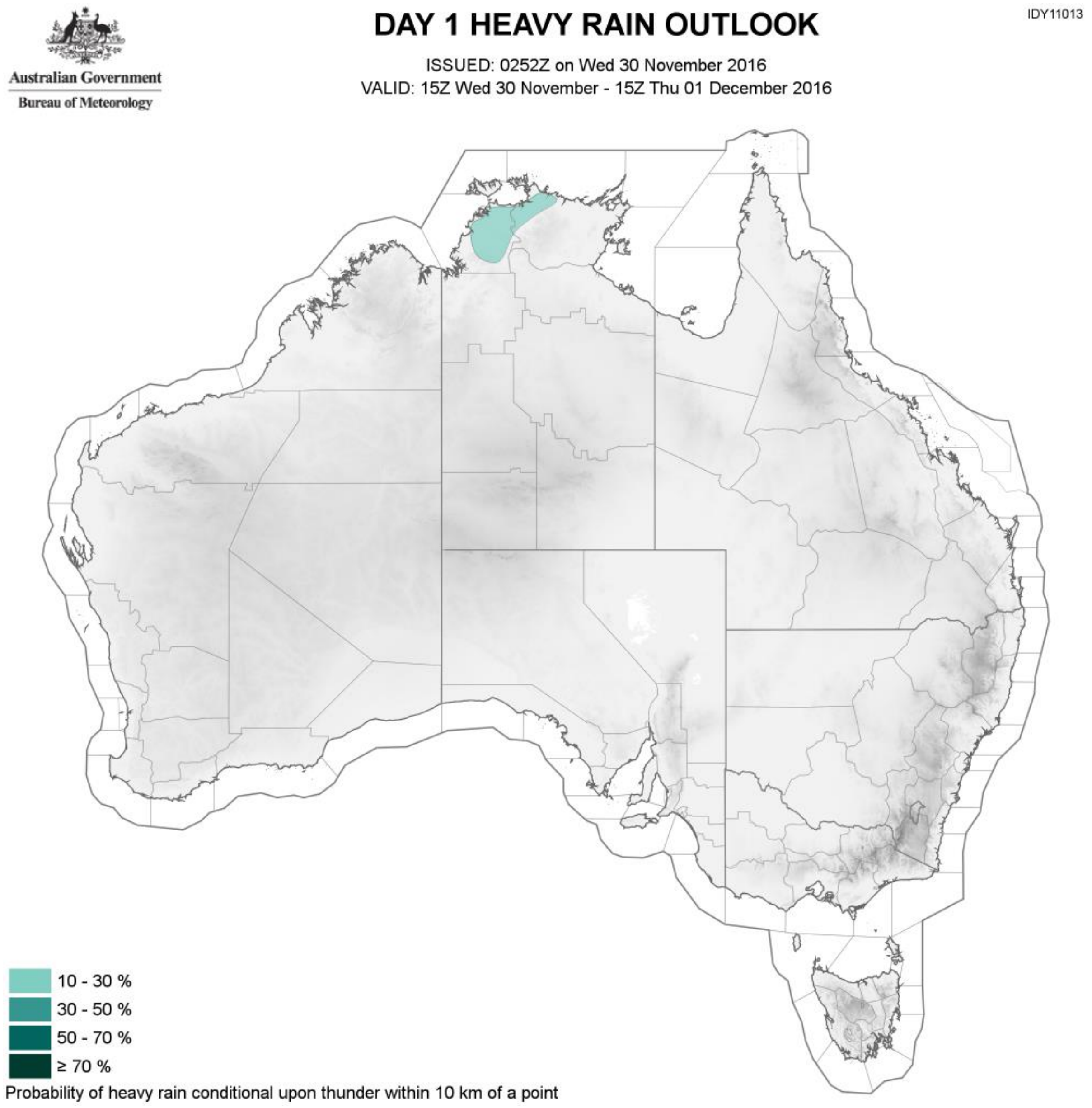
The other areas are drawn where 12Z&18Z2911ACCR has DMAPE ~700-1200j/kg, CAPE >500j/kg and reasonable indication of middle level dry slot and EC has some consistency. However, one may argue that cold pool driven outflow could produce damaging wind gusts (given the height of cloud bases) elsewhere across the interior of the continent.



Large hail seems quite likely with storms along the ranges of northern NSW and southern Queensland given the steep lapse rates below the freezing level, CAPE>2000 j/kg and the potential for at lease a few supercells. It is possible that the 50% area is a bit overconfident given the forecast convective mode (discussed in wind description), however given the CAPE profile, it is thought that even short lived storms that dissipate in higher CIN air closer to the coast will still have time to produce large hail.



The LCL looks to be too high to justify a tornado area in NE NSW or SE Qld. The LCL does reduce to near 1000m closer to the coast but CIN will be >250j/kg reducing the potential for supercell longevity if they steer into this region. Interestingly the critical angle is ~90 degrees in northwesterly flow due to the upper west to southwesterlies in the wake of the upper trough that moves through in the morning. This would help supercell development, but the high LCL reduces the chance of tornado. Of course, given the very strong updraughts, non-supercell tornadoes will be possible along the Divide but the chance of occurance is still thought to be <5% within 10 km of a point.



Heavy rain will be a risk with any long lived supercells in NE NSW/SE Qld, however the risk of impact at a point will be quite low due to the forecast convective mode and Deep Layer Mean (DLM) winds ~25-30 kts. As such no area drawn.