Evaluating the Accuracy of Weather Predictions for Melbourne Leading Up to the Heavy Rain Event of Early December 2017

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ABSTRACT: *The opening four days of summer 2017 saw Melbourne city recording 73.4 mm of rain, with several places just 60 km to the northeast receiving totals ~200 mm. Prior to the event, on November 30, for the first four days of December, the Bureau of Meteorology predicted median rainfall totals of 25 mm, 30 mm, 20 mm and 1 mm, respectively, for a four day rainfall total of 76 mm. The Bureau also indicated the possibility (with a 25% chance of occurring) of rainfall totals for the first four days, in excess of 70 mm, 80 mm, 50 mm and 8 mm, respectively. This suggested a small (1 in 250 chance) of a four day rainfall total of ~200 mm (should each of these higher amounts be realised). The purpose of this paper is to evaluate the accuracy of the Bureau forecasts leading up to this event, as they prompted warnings of significant flooding across Melbourne. Assessing the probable maximum precipitation for any locality involves assessing whether one may legitimately spatially transfer heavy rainfall events from another place to that locality. Given that the event was characterised by a dominant role being played by dynamical processes, and that ~200 mm fell nearby, it is considered legitimate to propose that there was the potential for an unprecedented four day rainfall total of ~200 mm in Melbourne. A statistical relationship has been established between observed rainfall, and numerical and worded aspects of the next day's forecast. This relationship shows that the contribution from the next day's forecasts for the four days from November-30 is to lift the accumulated percentage variance of the observed rainfall explained by the predictions from 50% to 65%.*

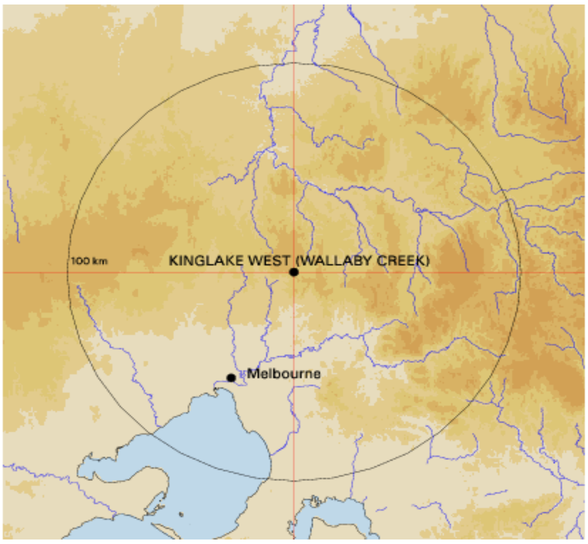
Keywords: *Heavy rain event; Weather forecast accuracy; Melbourne; December 2017*

Introduction

The opening four days of summer 2017 saw Melbourne city recording 73.4 mm of rain, with several places just 60 km to the northeast receiving totals of about 200 mm. Kinglake West (Wallaby Creek) received 205.6 mm (Figure 1).

Prior to the event, on November 30, for the first four days of December, the Bureau of Meteorology (hereafter referred to as the Bureau) predicted median rainfall totals of 25 mm, 30 mm, 20 mm and 1 mm, respectively, for a four day rainfall total of 76 mm. The Bureau also indicated the possibility (with a 25% chance of occurring) of rainfall totals for the first four days, in excess of 70 mm, 80 mm, 50 mm and 8 mm, respectively. This suggested a small (1 in 250 chance) of a four day rainfall total of about 200 mm (should each of these higher amounts be realised). Such a total, had it occurred, would have been unprecedented for the city.

Figure 1 Location of Melbourne and Kinglake West (Wallaby Creek)[1]



The primary purpose of this paper is to evaluate the accuracy of the Bureau forecasts leading up to this event, as they prompted:

- Warnings of significant flooding across Melbourne (the Victorian State Emergency Services sent the following SMS to the Victorian public, "SMS fromVicSES. Flooding is expected across Victoria this weekend. Heaviest rain on Saturday. Check on family & friends. Stay informed http://bit.ly/2g6lcnV");
- Considerable discussion in the media, both during and after the event, as to whether or not the warnings were justified (Figure 2); and,
- Significant discourse relating to the high level of confidence on the part of the Bureau's expectation of a high precipitation event (for example, the forecast storms being rated as a 10 out of 10 http://www.abc.net.au/news/2017-11-30/victoria-weather-heavy-rains-floods-forecast/9209902 drew media commentary).

[1]http://www.bom.gov.au/jsp/ncc/cdio/cvg/av?p_stn_num=088060&p_prim_element_index=0&p_nccObsCode=136&period_of_avg=&normals_years=&redraw=null&p_display_type=enlarged_map

Figure 2 Screen shot of a news item from the Australian Associated Press (AAP) website.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environment

Weather experts say warnings of dire flooding were justified

THERE were predictions in Melbourne of flooding so severe that lives were in danger. So what happened?

AAP DECEMBER 2, 2017 7:55PM

The Rainfall at Kinglake West (Wallaby Creek)

Over the four day period (01-December-2017 to 04-December-2017), 205.6 mm of rain fell at Kinglake West (Wallaby Creek).

The Kinglake West (Wallaby Creek) rainfall station has provided observations, almost without interruption, since 1884 (that is, for 133 years). The 205.6 mm four-day rainfall total recorded during the event of December-2017 was the highest such total recorded at the station since 1934 (when 206.7 mm was recorded during a four-day period).

During the rainfall station's 133 years of operation, there have been only three other events with four-day rainfall totals greater than that recorded during the December 2017 event – in 1901 (314.9 mm), in 1891 (270.3 mm) and in 1931 (216.2 mm).

For residents in that area at least, the 2017 event may be regarded as a 'once in a generation event, the like of which few people would have ever experienced'.

The Rainfall at Melbourne

Over the four day period (01-December-2017 to 04-December-2017), 73.4 mm of rain fell at Melbourne.

The various official Melbourne City rainfall stations have provided observations, almost without interruption, since 1855 (that is, for 162 years). The 73.4 mm four-day rainfall total recorded during the event of December-2017 was not unusual – there have been numerous higher four-day totals since records began, the most recent such total being in 2011 (when 90.2 mm was recorded during a four-day period).

The highest recorded four-day rainfall total in Melbourne is 172.5 mm in 1960.

Methodology

Firstly, some background. The World Meteorological Organisation (WMO, 2009) defines Probable Maximum Precipitation (PMP) as:

“The greatest depth of precipitation for a given duration meteorologically possible for a given size storm area at a particular location at a particular time of year, with no allowance made for long-time climatic trends”.

The methodology utilised to establish the PMP for any particular locality involves assessing to what extent one may legitimately spatially transfer heavy rainfall events from another place to that locality. What is taken into account in making such an assessment are (among other drivers) the background atmospheric moisture content and various physical processes (dynamical, orographic) leading to the event.

The question that one attempts to answer here is whether or not it would be legitimate to suggest that one could spatially transfer the heavy rainfall that fell 60 km to the northeast of Melbourne to the city, in which case the warnings would have been would have been more than justified.

Synoptic Situation

Figure 3 depicts the evolution of the surface synoptic situation. It shows that a frontal zone, which was approaching Victoria and New South Wales on 30-November, developed a wave low over Victoria on the 1st of December. The low intensified and moved slowly to the southeast during the subsequent few days. The air mass associated with this development was laden with moisture, dewpoints in excess of 20 deg C being recorded in Melbourne on the morning of the 1st of December.

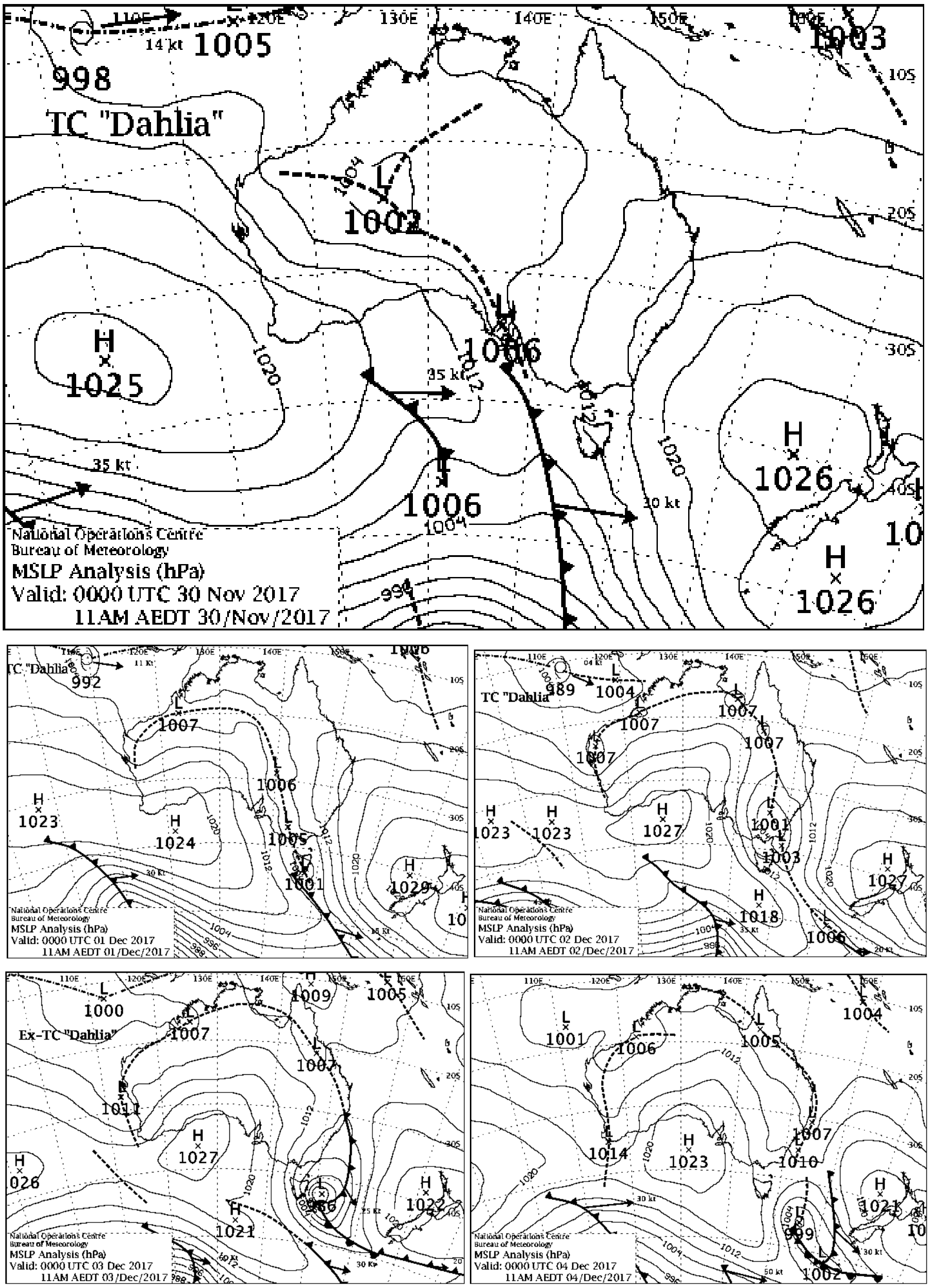
Figure 4 depicts the evolution in the upper atmosphere. It shows that a trough, which was approaching waters to the south of the Great Australian Bight on 30-November, moved eastward whilst amplifying sharply. By the 2nd of December, it had formed a northwesterly maximum wind filament over northern New South Wales, pointing directly into the slack gradient region of the newly developed surface low over Victoria, thereby promoting strong vertical motion of the moist air mass on account of the associated differential vorticity advection.

In view of the dynamic nature of the atmospheric processes, it is concluded that it would be legitimate to suggest that one could spatially transfer the heavy rainfall that fell in the Kinglake area to Melbourne.

Evaluating the Accuracy of the Predictions

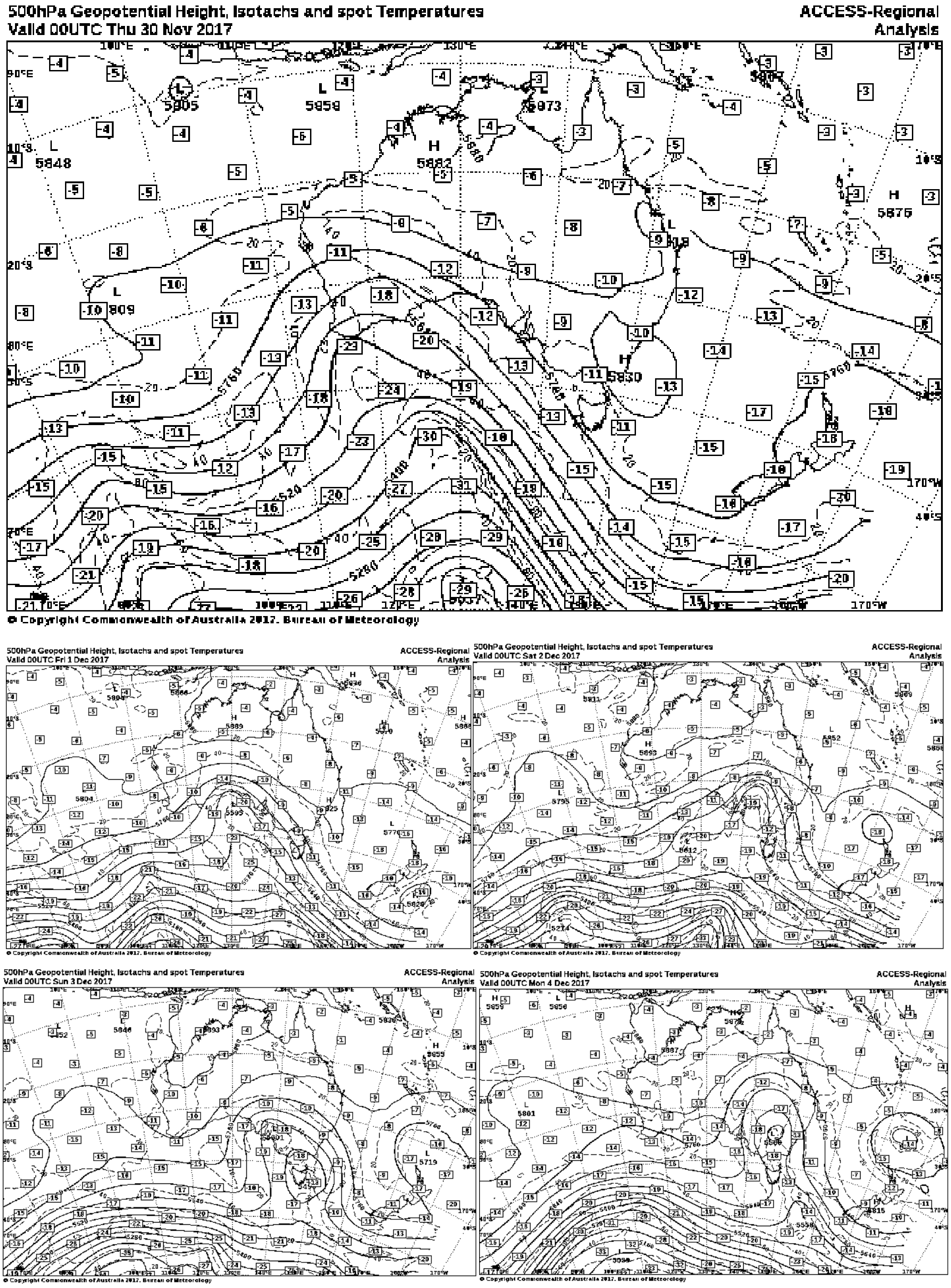
The accuracy of the *rainfall amount predictions* are evaluated from a perspective of calculating their relative impact upon the *accumulated variance* of the *rainfall amount observations* since August 2014.

Figure 3 Evolution of the Synoptic Situation (Surface)[2]



[2] Source: http://www.bom.gov.au/australia/charts/archive/index.shtml

Figure 4 Evolution of the Synoptic Situation (Upper)[3]



[3] Source: http://www.bom.gov.au/australia/charts/archive/index.shtml

August 2014 is chosen as the starting point for the evaluation process on account of rainfall amount predictions generated on the basis of two Numerical Weather Prediction (NWP) models being available from that date. The two models are the Global Forecasting System (GFS) model and the European Centre for Medium Range Weather Forecasting (ECMWF) model.

The *accumulated variance* of the *rainfall amount observations* explained by the forecasts is considered utilising two approaches.

Firstly, their relative impact upon the *total* variance explained is considered. The event's impact upon *total* variance explained identifies the extent to which the forecasts accurately established the overall severity of the event.

Secondly, their relative impact upon the *inter-diurnal* variance explained is considered. The forecasts' impact upon the *inter-diurnal* variance explained identifies the extent to which they accurately predicted the temporal variations in the event's severity.

Figure 5 illustrates the impact of the ECMWF model predictions in association with the event upon the *accumulated total variance* of the *rainfall amount observations* since August 2014. It shows that during the four days, from 30-November to 04-December, the impact of the associated predictions was for the accumulated total variance explained to *rise* from 29.7% to 30.7%, a successful outcome, suggesting that the forecasts nicely anticipated the severity of the event.

Figure 5 Impact of the ECMWF model predictions upon the *total* variance explained.

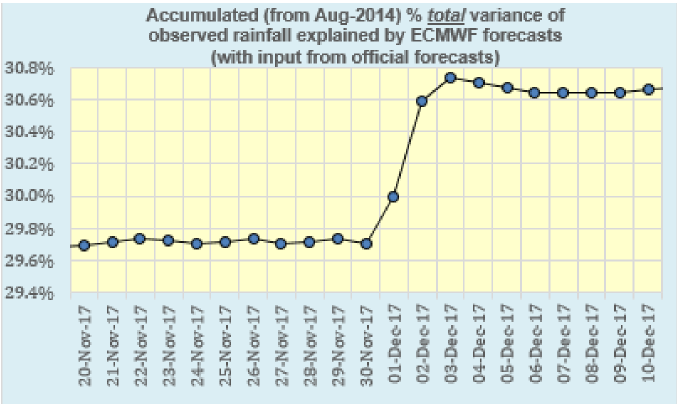


Figure 6 illustrates the impact of the ECMWF model predictions in association with the event upon the *accumulated inter-diurnal variance* of the *rainfall amount observations* since August 2014. It shows that during the four days, from 30-November to 04-December, the impact of the associated predictions was for the accumulated *inter-diurnal* variance (notwithstanding an initial rise from 19.58% to 19.64% between 30-November and 01-December) ultimately to *fall* to 19.54% by the 4th of December, an unsuccessful outcome, suggesting some inadequacy in predicting the temporal variations of the event – nevertheless, the initial rise underlines success at predicting its onset.

Figure 6 Impact of the ECMWF model predictions upon the *inter-diurnal* variance explained

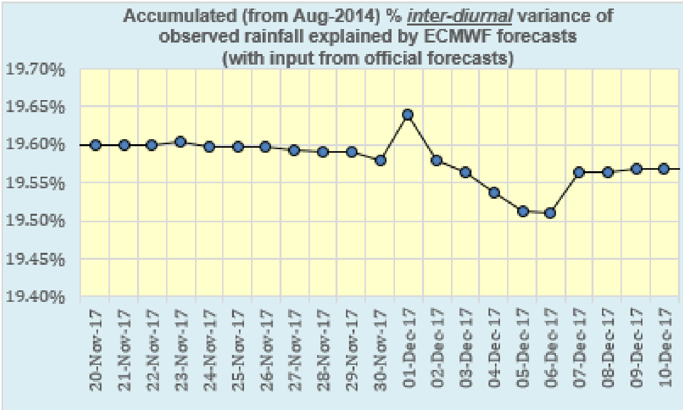


Figure 7 illustrates the impact of the GFS model predictions in association with the event upon the *accumulated total variance* of the *rainfall amount observations* since August 2014. It shows that during the four days, from 30-November to 04-December, the impact of the associated predictions was for the accumulated total variance explained to *rise* from 32.8% to 33.5%, a successful outcome, suggesting once again (as was also the case with the ECMWF model predictions) that the forecasts nicely anticipated the severity of the event..

Figure 7 Impact of the GFS model predictions upon the *total* variance explained

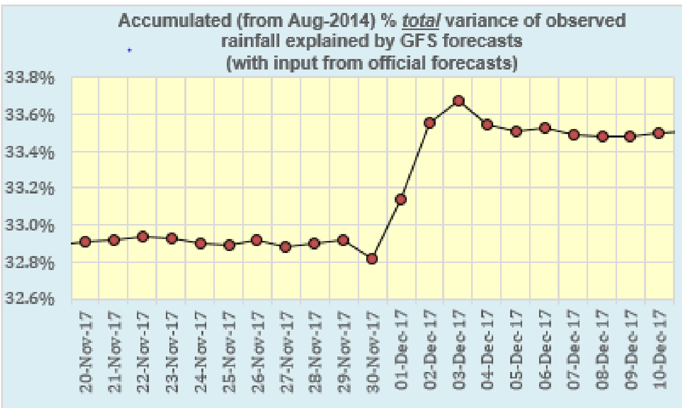


Figure 8 illustrates the impact of the GFS model predictions in association with the event upon the *accumulated inter-diurnal variance* of the *rainfall amount observations* since August 2014. It shows that during the four days, from 30-November to 04-December, the impact of the associated predictions was for the accumulated *inter-diurnal* variance (notwithstanding an initial rise from 24.0% to 24.3% between 30-November and 01-December) to *fall* to 23.8% by the 4th, an unsuccessful outcome, suggesting some inadequacy in predicting the temporal variations of the event – nevertheless, the initial rise underlines success at predicting its onset.

Figure 8 Impact of the GFS model predictions upon the *inter-diurnal* variance explained.

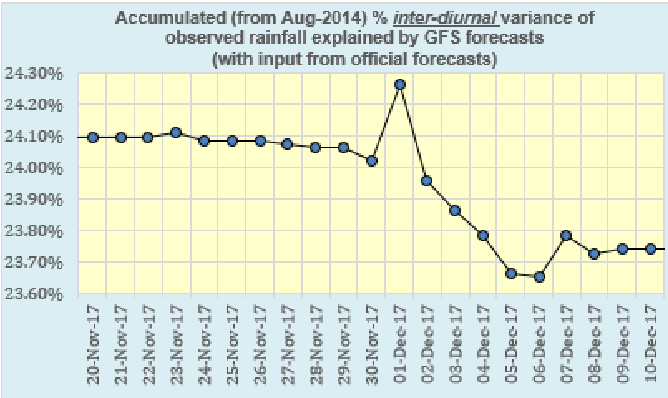


Figure 9 illustrates the impact of the Bureau official predictions in association with the event upon the *accumulated total variance* of the *rainfall amount observations* since August 2014. The set of predictions utilised here, in the absence of Bureau predictions of *expected* rainfall amount are the mid-points of the rainfall ranges (*median* to *25 upper-percentile*) that are issued to the public. It shows that during the four days, from 30-November to 04-December, the impact of the associated predictions was for the accumulated total variance explained to *rise* from 32.6% to 33.4%, a successful outcome, suggesting once again (as was also the case with both the ECMWF and GFS model predictions) that the forecasts nicely anticipated the severity of the event.

Figure 9 Impact of the Bureau official predictions upon the *total* variance explained.

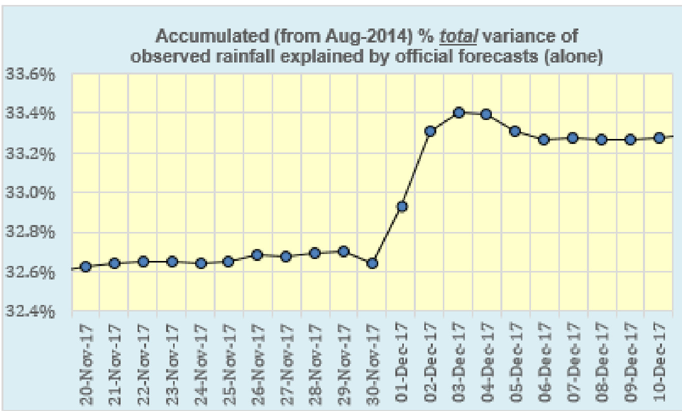
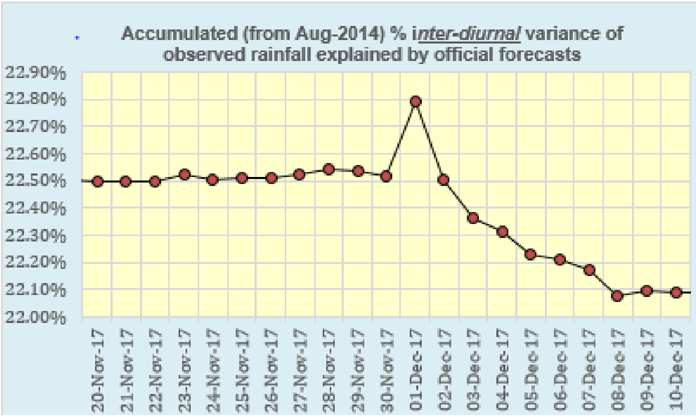


Figure 10 illustrates the impact of the Bureau official predictions in association with the event upon the *accumulated inter-diurnal variance* of the *rainfall amount observations* since August 2014. It shows that during the four days, from 30-November to 04-December, the impact of the associated predictions was for the accumulated *inter-diurnal* variance (notwithstanding an initial rise from 22.5% to 22.8% between 30-November and 01-December) to *fall* to 22.3% by 04-December, an unsuccessful outcome, suggesting some inadequacy in predicting the temporal variations of the event – nevertheless, the initial rise underlines success at predicting its onset.

Figure 10 Impact of the Bureau official predictions upon the *inter-diurnal* variance explained.



The work of Clemen (1989) suggests that forecast accuracy can be improved through *combining* multiple individual forecasts automatically via software and, to this end, Engel (2015) documents the Australian Bureau of Meteorology's work towards the development and implementation of *operational* systems that apply multi-model consensus forecasts. Such a piece of software was utilised to generate *experimental* day-to-day predictions out to Day-14 (Stern and Davidson, 2015).

Figure 11 illustrates the impact of the *combined* predictions in association with the event upon the *accumulated total variance* of the *rainfall amount observations* since August 2014. It shows that during the four days, from 30-November to 04-December, the impact of the associated predictions was for the accumulated total variance explained to *rise* from 34.6% to 35.4%, a successful outcome, and *better than any of the individual sets taken separately* - in line with Clemens's (1989) suggestion.

Figure 12 illustrates the impact of the *combined* predictions in association with the event upon the *accumulated inter-diurnal variance* of the *rainfall amount observations* since August 2014. It shows that during the four days, from 30-November to 04-December, the impact of the associated predictions was for the accumulated *inter-diurnal* variance (notwithstanding an initial rise from 24.2% to 24.4% between 30-November and 01-December) to *fall* to 24.0% by the 4th of December, an unsuccessful outcome, suggesting some inadequacy in predicting the temporal variations of the event – nevertheless, the initial rise underlines success at predicting its onset (once again, the outcome was better than that of any of the individual sets taken separately).

Figure 13 depicts the day-to-day *experimental* predictions of rainfall amount out to Day-14, these being those generated between 20-November and 10-December that were based upon the GFS model. The GFS model is shown to have done quite well during the few days leading up to the event, and even indicated the onset of at least some precipitation as far ahead as 12 days prior (albeit, for longer lead times, substantially underestimating the amount).

Figure 11 Impact of the *combined* predictions upon the *total* variance explained.

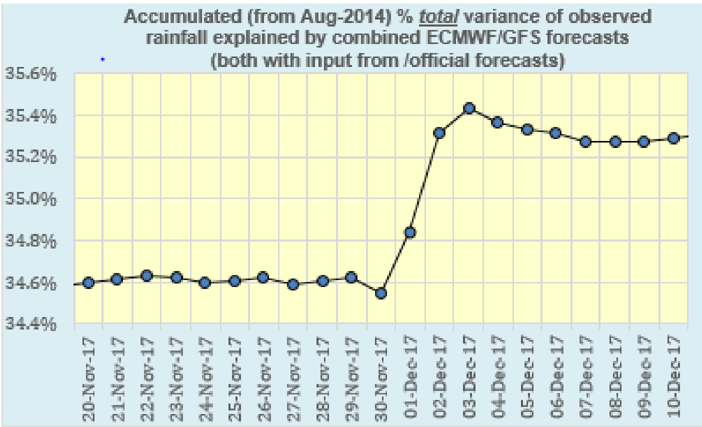


Figure 12 Impact of the *combined* predictions upon the *the inter-diurnal* variance explained.

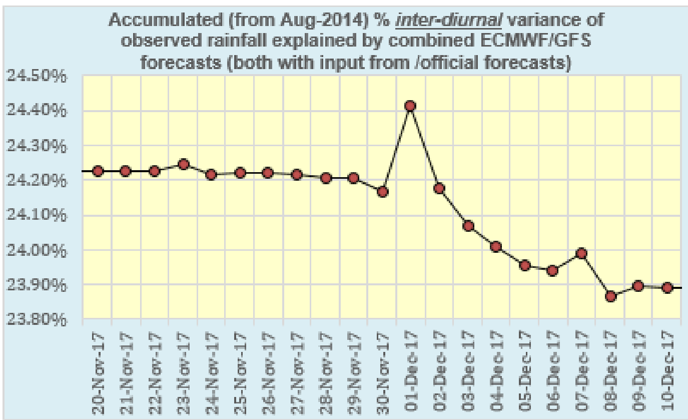


Figure 13 Day-to-day *experimental* predictions of rainfall amount out to Day-14, those generated between 20-November and 10-December, based upon the GFS model

DATE	AMT OBS	FCST Day-1	FCST Day-2	FCST Day-3	FCST Day-4	FCST Day-5	FCST Day-6	FCST Day-7	FCST Day-8	FCST Day-9	FCST Day-10	FCST Day-11	FCST Day-12	FCST Day-13	FCST Day-14
20-Nov-17	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21-Nov-17	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.6	2.4	0.0	0.0	0.0
22-Nov-17	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.1	0.0	0.0	0.0	1.4	1.0	0.0
23-Nov-17	1.0	0.2	0.0	0.6	0.6	2.1	1.3	0.0	0.0	2.2	0.0	0.0	0.0	0.0	1.4
24-Nov-17	0.4	2.4	1.5	1.8	2.3	1.2	0.0	0.0	0.0	3.9	0.0	1.4	0.0	0.0	0.0
25-Nov-17	1.4	4.1	2.8	2.4	2.5	1.6	0.0	0.0	0.0	3.6	2.5	0.0	3.2	3.4	0.0
26-Nov-17	2.8	8.2	7.8	3.6	3.9	3.4	4.3	0.0	0.0	0.0	2.0	0.8	0.0	0.0	1.5
27-Nov-17	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
28-Nov-17	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.5	0.0	0.0	0.0	0.0
29-Nov-17	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.6	0.0	0.0	2.7	0.0	0.0	0.0
30-Nov-17	0.0	0.0	0.0	3.8	6.0	1.9	1.0	0.0	2.4	5.7	5.9	0.0	0.0	0.0	0.0
01-Dec-17	11.8	33.3	26.8	15.6	12.9	8.5	5.9	2.2	2.3	1.8	1.9	2.3	1.9	0.0	0.0
02-Dec-17	48.6	31.8	34.8	23.4	9.0	2.4	0.0	1.0	0.0	4.5	1.5	1.3	0.0	0.0	0.0
03-Dec-17	8.4	10.4	9.3	23.1	15.9	5.5	0.4	0.0	0.0	0.0	0.9	0.0	0.0	0.0	0.0
04-Dec-17	4.6	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.3	0.0	0.0
05-Dec-17	0.0	0.0	0.0	0.0	0.0	4.0	1.6	0.0	0.0	0.0	0.0	0.0	1.2	0.0	0.0
06-Dec-17	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	2.3	0.0	1.7
07-Dec-17	24.2	7.2	5.4	3.8	1.4	2.6	0.7	0.0	0.0	0.0	4.0	1.7	0.0	1.9	0.0
08-Dec-17	1.0	2.0	1.7	3.8	1.3	0.0	0.0	1.1	1.0	0.0	0.0	3.4	0.9	0.0	0.0
09-Dec-17	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7	0.0	0.0	1.8	0.0	0.0	0.8	0.0
10-Dec-17	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.3

The Worded Component of the Predictions

Figure 14 presents the worded précis weather forecasts issued by the Bureau for the first four days of December 2017 between one and seven days in advance. That the Bureau forecasters were very concerned about the possibility of an extreme rainfall event is illustrated by the number of occasions that the word 'heavy' is utilised – in two of the four Day-1 (next day) predictions, in two of the four Day-2 (two days ahead) predictions, in two of the four Day-3 (three days ahead) and in one of the four Day-4 (four days ahead) predictions. Over the entire worded précis weather forecast data set leading up to this event (more than eight thousand predictions over the twelve years from September 2005) the word 'heavy' has only been utilised on eleven previous occasions.

Figure 14 Worded précis weather forecasts issued by the Bureau for the first four days of December 2017 between one and seven days in advance

Date	Day	Amt Obs	Day-1	Day-2	Day-3	Day-4	Day-5	Day-6	Day-7
01-Dec-17	Fri	11.8	HEAVY THUNDERY RAIN DEVELOPING	HEAVY THUNDERY RAIN	RAIN POSSIBLE STORM	SHOWERS	SHOWER OR TWO	SHOWER OR TWO	FEW SHOWERS
02-Dec-17	Sat	48.6	SHOWERS POSSIBLE HEAVY FALLS	RAIN POSSIBLE HEAVY FALLS	RAIN POSSIBLE HEAVY FALLS	A FEW SHOWERS	SHOWER OR TWO	CLOUDY	SHOWER OR TWO
03-Dec-17	Sun	8.4	RAIN EASING	SHOWERS EASING	RAIN POSSIBLE HEAVY FALLS	RAIN POSSIBLE HEAVY FALLS	A FEW SHOWERS	POSSIBLE SHOWER	POSSIBLE MORNING SHOWER
04-Dec-17	Mon	4.6	SHOWERS EASING	POSSIBLE SHOWER	SHOWER OR TWO CLEARING	SHOWER OR TWO	SHOWER OR TWO	POSSIBLE SHOWER	POSSIBLE MORNING SHOWER

A statistical relationship has been established between the subsequent amount of observed precipitation and the words utilised in forecasts. Figure 15 (from Stern, 2018), which illustrates this relationship, demonstrates that the words utilised in the predictions are very much related to expectations of rainfall amount, with the words 'RAIN', 'SHOWERS, 'SHOWER, HEAVY' and 'THUNDER' most highly related.

Figure 15 Multiple-linear regression relationship between the subsequent amount of precipitation (predictand) and the occurrence or otherwise of 16 different words (the VARIABLEs – which are the predictors) utilised in Day-1 précis weather forecasts issued by the Bureau for Melbourne over the twelve years 2005 to 2017. The sixteen different words (predictors) are those that might be included in the forecast. For each of these predictors, a value *1* or *0* is assigned, depending upon whether or not the word appears in the forecast (from Stern, 2018). The "*Coefficients*" are the coefficients in front of the VARIABLEs in the regression equation. The *"tStat"* values relate to the "t Statistic" (the colour bars depict magnitude). The "*P-value*" measures the probability that a *Coefficient* of as large magnitude could arise by chance.

VARIABLE	*Coefficients*	*t Stat*	*P-value*
CONSTANT	0.1417	5.43	3.0E-08
RAIN	2.0797	42.15	0.0E+00
SHOWERS	0.9540	19.16	5.8E-79
SHOWER	0.4994	14.27	1.8E-45
HEAVY	2.5934	9.42	3.4E-21
THUNDER	0.5546	8.24	1.1E-16
DRIZZLE	0.4940	5.64	8.9E-09
EASING	0.3008	4.93	4.3E-07
BECOMING	0.0888	1.64	5.0E-02
FOG	-0.0260	-0.42	3.4E-01
CLOUD	-0.0696	-1.70	4.4E-02
FINE	-0.1144	-3.13	8.7E-04
LATE	-0.1515	-3.99	3.3E-05
CLEARING	-0.1670	-4.11	2.0E-05
CHANCE	-0.2616	-5.42	3.2E-08
FEW	-0.4505	-8.19	1.6E-16
LITTLE	-0.8675	12.10	1.9E-33

A statistical relationship has also been established between the subsequent amount of observed precipitation and the official LOW amount in the Bureau forecast – lo (which is the median amount), the official HIGH amount in the Bureau forecast – hi (which is the 25 percentile), the official

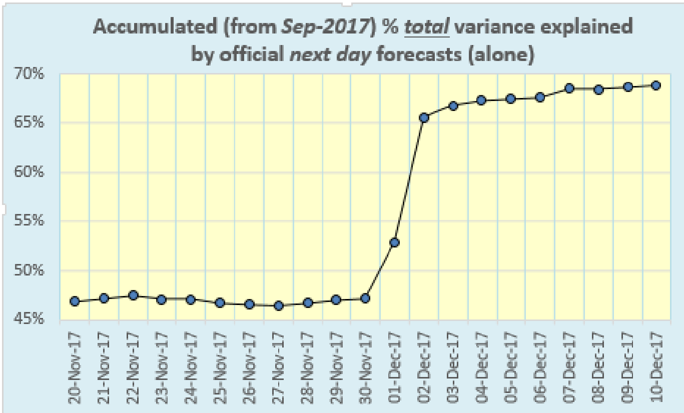
Probability of Precipitation (PoP), and the number of days ahead for which the forecast is valid - d. This relationship is illustrated in Figure 16.

Figure 16 Multiple linear regression relationship between the subsequent amount of precipitation (predictand) and 15 predictors, namely, the Official LOW amount given in the forecast, which is the median amount (lo) expected, the Official HIGH amount given in the forecast, which is the 25 percentile amount (hi) expected, the Official Probability of Precipitation (pop) given in the forecast, the number of days ahead (d), and combinations (products) thereof (utilising predictor enveloping as per Stern, 1994). The multiple linear regression relationship is derived on Day-1 to Day-7 forecast data over the seven years to September 2017. The term *Coef* refers to the coefficients in front of the *Predictor*s in the regression equation. The *"tStat"* values relate to the "t Statistic" (the colour bars depict magnitude).

Predictor	Coef	t Stat
const	-0.0071	-0.28
lo	-0.7282	-2.55
hi	0.3065	4.75
pop	-0.0009	-0.30
lo*hi	0.4238	4.21
lo*pop	0.0082	1.73
hi*pop	0.0075	3.72
lo*hi*pop	-0.0053	-4.39
d	0.0348	5.60
d*lo	0.0717	1.06
d*hi	0.0204	1.37
d*pop	0.0018	2.40
d*lo*hi	-0.0724	-2.98
d*lo*pop	0.0001	0.08
d*hi*pop	-0.0017	-3.31
d*lo*hi*pop	0.0007	2.05

Using that relationship to interrogate *next day official* predictions *from September 2017* – admittedly looking at a different set of forecasts, and for a much shorter period, than those *Day-1 to Day-7* predictions *from August 2014*, on which Figures 5 to 12 are based - one finds a very positive impact from the *next day* forecasts for the four days from November 30. That impact is to lift the accumulated percentage total variance of the observed daily rainfall totals (from 30 September) explained by the individual next day official predictions (issued on November 30, and December 1, 2 and 3) from just under 50% to just over 65% (Figure 17), and underlines just how successful the Bureau's short term official forecasts were.

Figure 17 Impact of the individual *next day official predictions* upon the *total* variance explained



Summary

The opening four days of summer 2017 saw Melbourne city recording 73.4 mm of rain, with several places just to the northeast receiving totals of about 200 mm. The Bureau forecasts leading up to this event prompted warnings of significant flooding across Melbourne and, both during and after the event, considerable discussion in the media as to whether or not the warnings were justified. Specifically for Melbourne, the forecasts nicely anticipated both the onset and the overall severity of the event, notwithstanding some inadequacy in predicting its temporal variations. Furthermore, in view of the dynamic nature of the atmospheric processes driving the event, it is concluded that it would be legitimate to suggest that one could spatially transfer the extreme rainfall that fell in the Kinglake area to Melbourne, justifying both the warnings that were issued and the terminology that was utilised in the forecasts.

Before closing, it is worthwhile to observe that interestingly, at a workshop conducted as part of the American Meteorological Society's 98th Annual Meeting in Austin, Texas – *(In) consistency in a social media world: communication reflections of the 2017 hurricane season* – the issue of how sharing conflicting model information may promote inconsistent messages about uncertainty was addressed (Amer. Meteor. Soc., 2018). Relevant to this event, is the reference in the introduction to the mixed sources of available advice. Inconsistency in the messaging can result in residents that are in danger, not taking the ameliorating actions that they need to take. The point was made at the aforementioned workshop that, where meteorologists identify that there is a substantial risk of an impending extreme event, the message delivered, both by forecasters and public officials, should be unambiguous.

To the credit of those involved in this case, it was.

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