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Verification of the Bureau of Meteorology's seasonal forecasts: 2003-2005

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This report presents verification results for the operational seasonal forecasts issued by the Australian Bureau of Meteorology from 2003 to 2005. It updates the results given in an earlier paper, which describes the methods used for operational verification of these forecasts. The poor performance of the seasonal minimum temperature forecasts in southwestern Western Australia is explored.

Introduction

In a recent paper (Fawcett et al. 2005; henceforth FJB05), a detailed description was given of both the current seasonal forecasting arrangements within the Australian Bureau of Meteorology and the methods used for operational verification of these forecasts. The present article is the first of an intended sequence of regular (if infrequent) contributions to the *Australian Meteorological Magazine*, reporting on the recent performance of the seasonal climate outlooks.

In this article, verification is taken to mean the skill assessment of independent forecasts, as issued operationally. Model verification is used to check how a forecast system is actually performing. This can be for quality control and accountability purposes (for example, the generation of performance indicators for annual reports and the like), but also provides a basis for comparison of different forecast systems as to how they have performed in the recent past. Further, given that many statistically based seasonal climate forecasting systems rely, as does the Bureau of Meteorology's system, on an assumption that the climate is 'stationary' in some generalised sense, model verification can help assess the extent to which such an assumption remains valid.

Data and methods

As indicated in FJB05, the forecasts are issued in the form of the probability of an above median seasonal outcome for three-month rainfall totals and three-month average maximum and minimum temperature. Each month, forecast grids with a 1°×1° resolution are prepared, and verified against a climatology derived from the forecast model's development period (1950-1999). The climatology (or training) period comprises 50 years for the seasons JFM to OND, and 49 years for the seasons NDJ and DJF*. The observational grids are taken from the National Climate Centre's operational Barnes successive correction monthly analyses. These use the whole network for rainfall, but a high-quality sub-network for temperature.

Forecasts for terciles are also derived, and issued through the Bureau's Seasonal Climate Outlook subscription products, but those forecasts are not assessed in this article. The sequence of forecasts assessed here runs from JFM 2003 to DJF 2005-06 (36 forecast periods). This overlaps slightly with the previously reported results (JJA 2000 to JJA 2003 for the above median seasonal rainfall forecasts, and MAM 2000 to JJA 2003 for the above median seasonal maximum and minimum temperature forecasts).

Verification techniques used include per cent consistent rates, LEPS scores and LEPS skill scores, and reliability data. The reader is referred to FJB05 for more detail.

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*JFM = January-February-March, FMA = February-March-April, etc.

Results and discussion

Figure 1 shows the average per cent consistent rate (also called the correct forecast rate in FJB05) for the 36 seasonal rainfall forecasts in the sequence, while Fig. 2 shows the corresponding LEPS skill scores. The southern half of Western Australia and parts of western and northern Queensland have shown the best results for the period, with most of the remainder of the country showing results poorer than the climatological base rates (50 per cent for per cent consistent, 0 per cent for LEPS skill). Over southern New South Wales and northern Victoria, together with scattered small areas across the central and eastern two-thirds of the country, the per cent consistent rates are actually below 35 per cent.

Figure 3 shows the average per cent consistent rate for the 36 seasonal maximum temperature forecasts in the sequence, while Fig. 4 shows the corresponding LEPS skill scores. The seasonal maximum temperature forecasts have been quite successful over the northeastern half of the country, with average per cent consistent rates above 70 per cent. Results for the rest of the country are also quite acceptable, and while there are some regional variations, the results are generally consistent with those previously reported (Figs 7 and 3 in FJB05). It should be noted however that an increasing fraction of these forecasts has increased chances of above median outcomes, suggesting that the global warming signal is now having a substantial presence in these seasonal forecasts.

Figure 5 shows the average per cent consistent rate for the 36 seasonal minimum temperature forecasts in the sequence, while Fig. 6 shows the corresponding LEPS skill scores. While perhaps not as good as those for seasonal maximum temperature, the seasonal minimum temperature results have exceeded climatological expectations over most of the country and are generally better than those previously reported (Figs 8 and 4 in FJB05). One such area of improvement is

Fig. 1 **Per cent consistent rate for above/below median seasonal rainfall forecasts (36 forecasts: JFM 2003 to DJF 2005-06).**

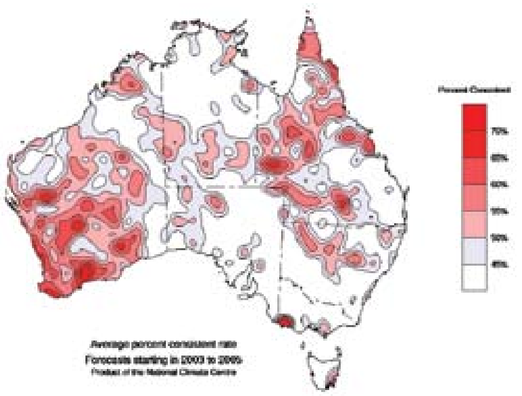


Fig. 2 **LEPS skill scores for above/below median seasonal rainfall forecasts (36 forecasts: JFM 2003 to DJF 2005-06).**

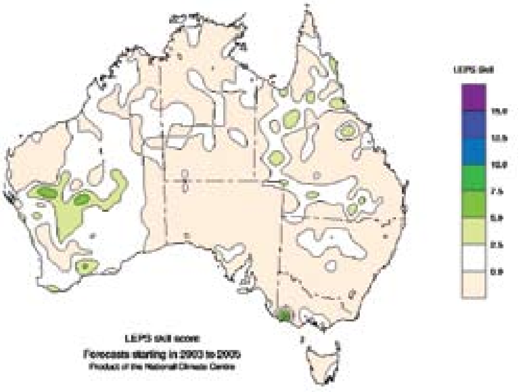


Fig. 3 **Per cent consistent rate for above/below median seasonal maximum temperature (36 forecasts: JFM 2003 to DJF 2005-06).**

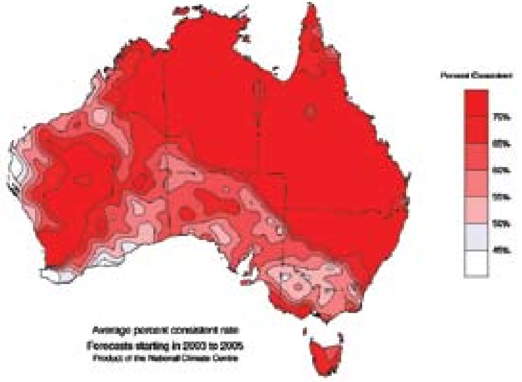


Fig. 4 **LEPS skill scores for above/below median seasonal maximum temperature forecasts (36 forecasts: JFM 2003 to DJF 2005-06).**

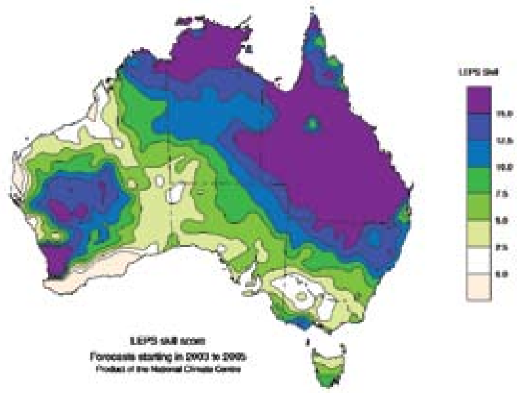


Fig. 5 Per cent consistent rate for above/below median seasonal minimum temperature (36 forecasts: JFM 2003 to DJF 2005-06).

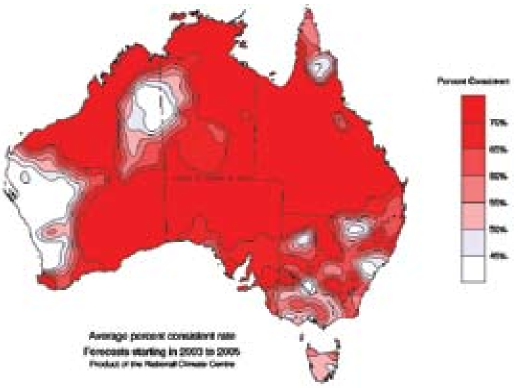
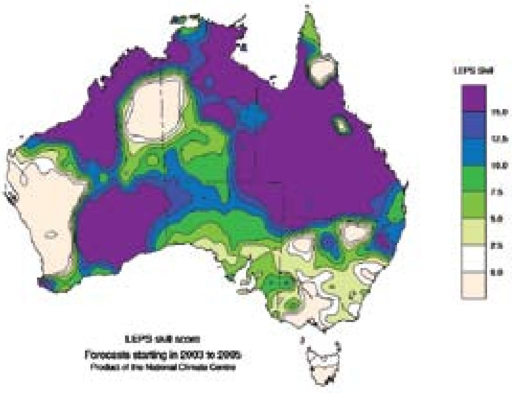


Fig. 6 LEPS skill scores for above/below median seasonal minimum temperature forecasts (36 forecasts: JFM 2003 to DJF 2005-06).



the central Northern Territory, but the southwest of Western Australia continues to show poor results. A possible reason for this is explored in the Appendix.

Figure 7 shows the time series of area-averaged per cent consistent rates (blue line) and LEPS scores (red line). In each case, the corresponding base rate is shown as a horizontal line in the same colour. The LEPS scores for the above/below median forecasts are scaled so that the LEPS skill scores are calculated by simple averaging*. The green line shows the area-averaged absolute departure from climatology (50 per cent) for the forecast probabilities**. The area-averaging is done across all Australian grid-points.

The seasonal rainfall forecasts have shown little improvement above climatology during the assessment period, and typically are fairly ‘timid’. This reflects the general absence of ENSO events during the period – there was a moderate El Niño event in 2002-03 and another, late developing, weak event in 2006-07. ENSO is the leading known cause of interannual variability in Australian seasonal rainfall, and generates most of the known predictability.

Figures 8 and 9 show the corresponding results for seasonal maximum and minimum temperatures. The temperature forecasts were somewhat more emphatic (on average) than the rainfall forecasts, and as previously indicated it seems likely that global warming has contributed, to some extent, to the success of the temperature forecasts, as measured by the per cent consistent rate and LEPS skill score.

Fig. 7 Australia-averaged LEPS scores (red line) and per cent consistent rate (blue line) for the 36 seasonal rainfall forecasts. The mean absolute forecast departure from climatology (i.e. 50%) is shown in green.

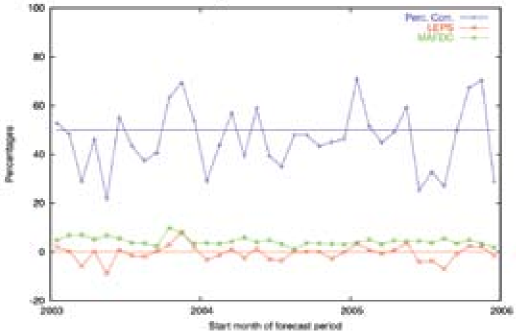
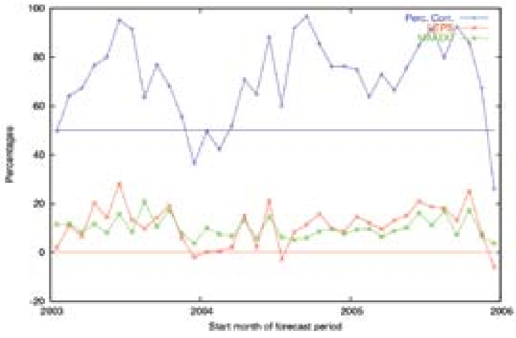


Fig. 8 Australian-averaged LEPS scores (red line) and per cent consistent rate (blue line) for the 36 seasonal maximum temperature forecasts. The mean absolute forecast departure from climatology (i.e. 50%) is shown in green.



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*This can be done for above/below median category probabilistic forecasts, as a special case, but typically not in general.

** There is a relationship between the magnitude of the LEPS scores and the mean absolute forecast departure from climatology (MAFDC); larger (smaller) absolute forecast departures from climatology are on average associated with larger (smaller) magnitude LEPS scores.

Fig. 9 Australian-averaged LEPS scores (red line) and per cent consistent rate (blue line) for the 36 seasonal minimum temperature forecasts. The mean absolute forecast departure from climatology (i.e. 50%) is shown in green.

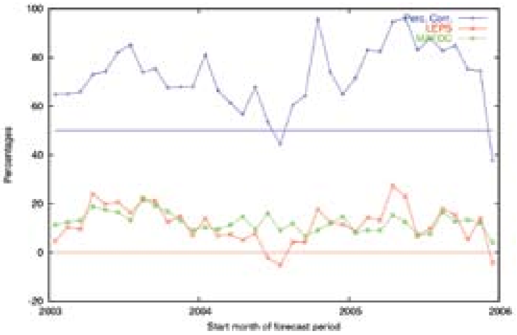

Fig. 10 Reliability data and density function of forecast probabilities, accumulated across all Australian grid-points, for seasonal rainfall (36 forecasts: JFM 2003 to DJF 2005-06).

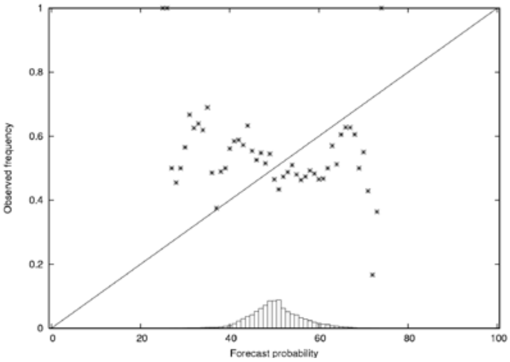

Fig. 11 Reliability data and density function of forecast probabilities, accumulated across all Australian grid-points for seasonal maximum temperature (36 forecasts: JFM 2003 to DJF 2005-06).

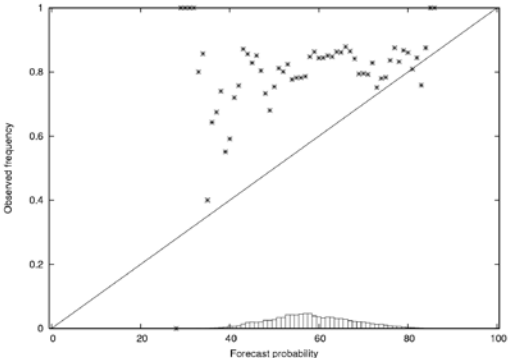

Fig. 12 Reliability data and density function of forecast probabilities, accumulated across all Australian grid-points for seasonal minimum temperature (36 forecasts: JFM 2003 to DJF 2005-06).

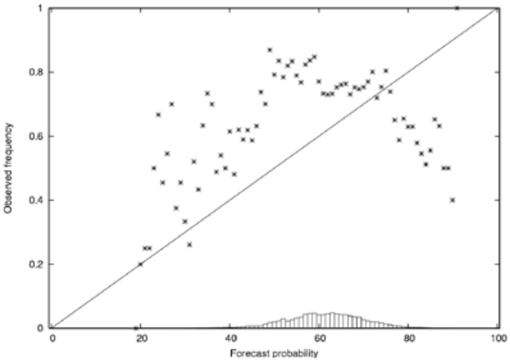

Figure 10 shows the reliability data for the 36 seasonal rainfall forecasts, aggregated across all Australian grid-points. The forecast probabilities have been rounded to integer values for the purposes of calculating the figure. The asterisks show the reliability rate for each forecast probability bin, with the straight line showing the base-line comparison rate of perfect reliability. The boxes indicate the distribution of forecast probabilities. Issued forecast probabilities lie mostly between 40 and 60 per cent, with a slightly heavier upper tail. For forecasts above 50 per cent, above median outcomes have generally occurred less frequently than forecast, while the opposite is the case for forecasts below 50 per cent. These reliability results are closer to the line $y = 0.5$ (the expected result where the outcomes are independent of the forecasts), than the line $y = x$ (perfect reliability), and may be a consequence of the previously mentioned lack of ENSO events in the verification period. Aggregation over the six years' worth of available forecasts (JJA 2000 to ASO 2006; not shown) improves the view of the rainfall forecasts' reliability quite substantially.

Figures 11 and 12 show the corresponding results for the 36 seasonal maximum and minimum temperature forecasts, respectively, again aggregated across all Australian grid-points. For maximum temperature, most of the issued forecast probabilities lie in the 40 to 80 per cent range, with increased chances of above median outcomes much more frequently issued than increased chances of below median outcomes. Generally speaking, above median outcomes have occurred rather more frequently than forecast, suggesting that the regional warming trend associated with the enhanced greenhouse effect (Karoly and Braganza 2005) might be compromising the reliability of the forecast system. There is some consistency between these results and those previously reported (Fig. 13 in FJB05),

Table 1. Linear regression statistics for southwest WA region defined in Appendix. Training period is 1950-1999 (1950-51 to 1999-2000 for NDJ and DJF), forecast period is 2000-2005 (2000-01 to 2005-06 for NDJ and DJF).

Season	*Coefficient of determination*	*Forecast period mean residual (°C)*	*Training period mean absolute residual (°C)*	*Forecast period mean absolute residual (°C)*
JFM	0.11	–0.37	0.39	0.51
FMA	0.09	–0.30	0.42	0.57
MAM	0.16	–0.24	0.48	1.03
AMJ	0.29	–0.50	0.48	0.86
MJJ	0.25	–0.40	0.49	0.66
JJA	0.25	–0.78	0.56	0.78
JAS	0.21	–0.70	0.53	0.70
ASO	0.27	–0.91	0.49	0.91
SON	0.21	–0.37	0.47	0.41
OND	0.34	–0.51	0.47	0.70
NDJ	0.18	–0.31	0.49	0.46
DJF	0.23	–0.50	0.38	0.60

taking into account the marked shift in the distribution of forecast probabilities towards the warmer side of things. The minimum temperature results are similar to those for maximum temperature, with above median outcomes typically occurring more frequently than forecast.

Appendix

As mentioned above in the discussion of Figs 5 and 6, a large area of southwest Western Australia has consistently shown poor results for the seasonal minimum temperature forecasts across the entire period the National Climate Centre has been issuing these forecasts. It covers a substantial fraction of the principal domain of the second rotated monthly minimum temperature empirical orthogonal function (EOF) of Jones (1998; Fig. 4), and is remarkably consistent with the analogous area of Fig. 8 in FJB05. This area has been investigated for possible changes in the statistical relationships between the forecast predictors and seasonal minimum temperature anomalies.

The area studied comprises all continental grid-points on the 1°×1° grid within the bounds 113.5°E to 117.5°E (i.e., 114, 115, 116 and 117°E) and 23.5°S to 31.5°S (i.e., 24, 25, …, 31°S). The time series of monthly minimum temperature anomalies was calculated from the Bureau's Interactive Data Portal*, with the seasonal anomalies being calculated as the averages of the monthly anomalies. The monthly anomalies obtainable from the Interactive Data Portal are calculated with respect to the 1961 to 1990 period, but this has no impact on the reported results (except possibly at a low level through numerical round-off and truncation effects).

The statistical technique used in the seasonal outlook system is linear discriminant analysis (LDA), but for the current purpose of investigating possible reasons for the poor performance, a different statistical technique (multivariate linear regression) has been adopted.

Linear regressions between the seasonal anomalies and all four sea-surface temperature (SST) predictors (the SST1 and SST2 indices* at lags one and three months) were generated over the 1950 – 1999 training period (50 years of data for all twelve seasons, 1950-51 to 1999-2000 for NDJ and DJF), and the residuals calculated. The regressions were then extrapolated over the subsequent six years (a forecast period of 2000-2005; 2000-01 to 2005-06 for NDJ and DJF). Four statistics were recorded from the regressions; the coefficient of determination (the square of the correlation coefficient; it indicates the fraction of the total variation explained by the regression), the mean residual for the forecast period, the mean absolute residual for the training period and the mean absolute residual for the forecast period. These are given in Table 1. The mean residual for the training period is not listed in the table since it is automatically zero in standard linear regression calculations.

The correlations are fairly weak, with the strongest regression (OND) explaining slightly more than one-third of the variation. The weakest relationship is in FMA, with approximately one-twelfth of the variation explained. The forecast period mean absolute residual (MAR) is higher than the training period MAR in ten of the twelve seasons, with the forecast period MAR being only slightly below the training

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* See www.bom.gov.au/cgi-bin/silo/cli_var/area_timeseries.pl .

* See www.bom.gov.au/climate/ahead/sst_data_table.html for a listing of these values and Fig. 1 in FJB05 for a mapping of the EOFs from which they have been derived.

period in the other two seasons (SON and NDJ). In all twelve seasons, the forecast period mean residual is negative (ranging from –0.24°C in MAM to –0.91°C in ASO), suggesting that the regressions are now predicting seasonal minimum temperatures higher than observed. This suggests that the statistical relationships between the study area's seasonal minimum temperatures and the forecast system predictors are now under some strain.

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