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Numerical prediction model performance summary July to September 2000

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Introduction

This summary continues the series comparing the performances of numerical weather prediction (NWP) models.

Models and methods

A description of the Australian verification methods can be found in a previous article (Skinner 1995).

Models are from the National Meteorological and Oceanographic Centre (NMOC) Melbourne and from ECMWF (European Centre for Medium-range Weather Forecasts), NCEP (National Centers for Environmental Prediction), UKMO (United Kingdom Meteorological Office) and JMA (Japan Meteorological Agency).

Four models considered from NMOC, Melbourne, are: LAPS_PT375 (Limited Area Prediction System PoinT 375); MESO_LAPS_PT125 (MESOscale Limited Area Prediction System PoinT 125); TLAPS_PT375 (Tropical Limited Area Prediction System PoinT 375); and GASP (Global Assimilation and Prediction).

Overseas global models included in the comparisons are: ECSP (ECMWF Spectral Assimilation); USAVM (NCEP Spectral model for aviation); UKGC (UK Meteorological Office Grid PE model); and JMAGSM (JMA Global Spectral Model).

Very short summaries of the models can be found in the initial article (Skinner 1995) with references to model updates in subsequent issues.

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All results have been calculated within NMOC Melbourne, where the models were verified against their own analyses. Results are presented for the irregular Australian verification area only (see Fig. 5).

The statistics are a measure of the skill in forecasting geopotential height at 500 hPa or mean sea-level pressure (MSLP). Other field types are not included in these summaries.

The limited area models are run several hours earlier than GASP and this premature data cut-off, particularly for satellite information, adversely affects their skill compared to GASP.

Note that the Australian region verification grid has southerly points which are outside the TLAPS_PT375 grid and easterly points outside the MESO_LAPS_PT125 grid. TLAPS_PT375 and MESO_LAPS_PT125 scores are calculated without these points and are therefore not strictly comparable with those from other models.

Notes on NWP systems

Acronyms

AMSU	Advanced Microwave Sounder Unit
ATOVS	Advanced TOVS
GTS	Global Telecommunication System
HIRS	High-resolution Infrared Radiation Sounder
MSU	Microwave Sounding Unit
NESDIS	National Environmental Satellite Data and Information Service (USA)
NOAA	National Oceanic and Atmospheric Administration (USA)
TIROS	Television Infra-red Observational Satellite
TOVS	TIROS Operational Vertical Sounder

GASP

A major change was made to the analysis of satellite sounding data on 1 August 2000. Instead of using retrievals produced by NESDIS the new scheme analyses the cloud-cleared radiances provided by NESDIS over the GTS from the TOVS (NOAA-14) and ATOVS (NOAA-15) instruments. The radiances estimated from the model first-guess profile of moisture and temperature are compared with the observed values and the profile adjusted using a variational scheme to give a best fit to all the observed radiances. This adjusted profile is then used as the 'retrieval' in the analysis scheme with a weight adjusted for the fact that the first guess has already been used in deriving it. A bias correction scheme is employed to ensure that there are no systematic differences between the observations and the forward radiance calculations from the guess profile.

The technique is known as a one-dimensional variational retrieval (1DVAR). Parallel trials have shown significant improvement in the GASP predictions with this new analysis method (NMOC 2000).

ATOVS

Unfortunately, during the first half of August there were problems with the HIRS instrument on NOAA-15 and neither radiances nor retrievals were available. A change was made within NESDIS so that AMSU-A radiances and retrievals were delivered even if the HIRS data were missing. These problems with NOAA-15 may mean that the full potential of 1DVAR was not achieved, although tests with NOAA-14 data alone have shown significant positive impact. Subsequently, problems developed in channel 14 of the AMSU-A instrument and the analysis of ATOVS radiances in the GASP analysis system was adapted to operate without HIRS or AMSU-14 measurements.

MESO_LAPS_PT125

This model became operational on 16 November 1999 but verification results have not previously been included. An analysis from LAPS_PT375 (Puri et al. 1998), interpolated to the 0.125° latitude/longitude grid, provides the initial conditions. The prognosis component is based on a hydrostatic primitive equation model formulated on sigma levels. The domain is 4.875°N-55°S, 95.0°E-169.875°E and the model is run out to 36 hours twice daily from base times 11 and 23 UTC. There are 29 vertical levels (NMOC 1999). Since the verification area includes grid-points along 170°E, these are missed from the statistics.

July to September 2000 intercomparisons

Local Models: (LAPS_PT375, TLAPS_PT375, GASP, MESO_LAPS_PT125)

The skill-score at MSLP (Fig. 1(a)) and 500 hPa (Fig. 1(c)) shows GASP is still outperforming LAPS_PT375 and TLAPS_PT375. These are very similar to each other at MSLP but at 500 hPa, TLAPS_PT375 scores better than LAPS in the first 24 hours and vice versa in the period to 48 hours. Root mean square errors at 500 hPa (Fig. 1(d)) show the same tendencies as the skill-scores at this level. At MSLP however, the rms errors (Fig. 1(b)) show TLAPS_PT375 performing better than LAPS_PT375. The snapshot graphs (Fig. 3(a) 3(b)) for MSLP and 500 hPa include monthly averages for MESO-LAPS_PT125 with the data for the other three models. At MSLP, the three LAPS models have very similar scores with only TLAPS_PT375 showing a slight improvement during September. At 500 hPa though, TLAPS_PT375 has the highest score for both July and August although the margin is small. GASP is consistently the best performed of the models over the Australian area.

The superiority of GASP is further demonstrated by the statistics in Table 1 which indicate the relative performance of the models for 24-hour forecasts. For example, GASP in July had the best skill-score 20 times and the worst skill-score only five times. There were three occasions when its score

Table 1. Number of 24 hour forecasts during July to September when each model was (best or equal best)/(worst or equal worst)/(scored 5 points or more worse than the best).

	GASP	*MESO_LAPS_PT125*	*TLAPS_PT375*	*LAPS_PT375*
July (31)	20/ 5/ 3	2/17/ 7	6/ 9/ 7	8/ 9 /6
August (31)	26/ 2/ 0	4/11/13	5/14/ 7	5/11/14
September (30)	20/ 2/ 1	8/ 6/11	6/12/ 6	5/14/12
QUARTER	66/ 9/ 4	14/34/31	17/35/20	18/34/32

Fig. 1(a) Comparison for LAPS_PT375/TLAPS_PT375/ GASP from July to September 2000. S1 skill-scores of MSLP using combined base-times 0000 UTC / 1200 UTC and intervals +12, +24, +36, +48 h over the irregular Australian verification grid.

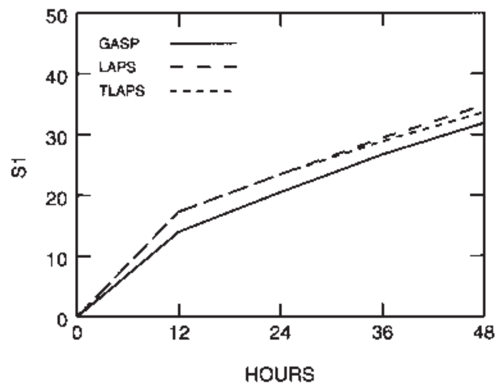


Fig. 1(b) Comparison for LAPS_PT375/TLAPS_PT375/ GASP from July to September 2000. Root mean square errors of MSLP for combined base-times 0000 UTC / 1200 UTC and intervals +12, +24, 36, +48 h over the irregular Australian verification grid.

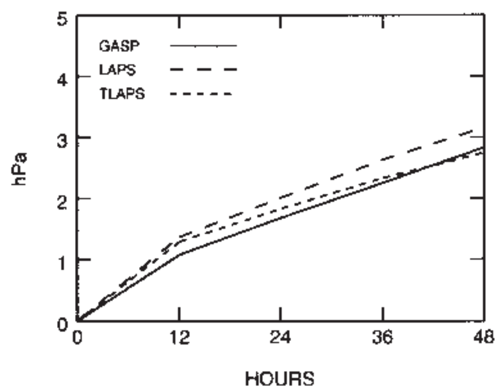


Fig. 1(c) Comparison for LAPS_PT375/TLAPS_PT375/ GASP from July to September 2000. S1 skill-scores of 500 hPa geopotential height (m) for combined base-times 0000 UTC / 1200 UTC and intervals 12, +24, +36, +48 h over the irregular Australian verification grid.

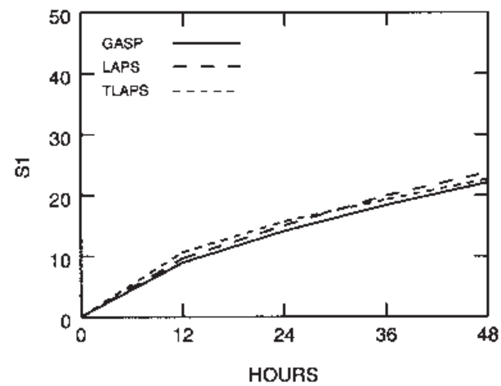
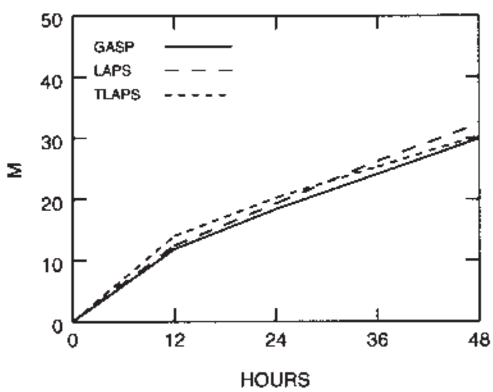


Fig. 1(d) Comparison for LAPS_PT375/TLAPS_PT375/ GASP from July to September 2000. Root mean square errors of 500 hPa geopotential height (m) for combined base-times 0000 UTC / 1200 UTC and intervals +12, +24, +36, +48 h over the irregular Australian verification grid.



was five points or more worse than the best model on that day. Clearly GASP was the most reliable model overall with the highest number of days of 'best' scores, the lowest number of days with 'worst' scores and also the lowest number of 'bad' forecasts. It should be noted that these comparisons of the operational products are influenced by the fact that GASP is run later than the other regional models and therefore has the best data coverage. Also the southern boundary of TLAPS_PT375 does not include the most southerly verification points and the eastern boundary of MESO_LAPS_PT125 also misses some points.

As could be expected, the MESO_LAPS and LAPS_PT375 systems have very similar performance when verified on the coarse verification grid. The MESO_LAPS system provides much greater detail on small-scale variations and topographical effects.

Synoptic overview for 24 h MSLP predictions (local models)

Comments on systematic errors in forecast synoptic features are given below (see discussion on Tables 2 and 3) and the tables provide an overview of performance. Here, the worst forecasts, or those situations where at least one of the local models scored higher

Table 2. Number of occasions during July-September 2000 when errors occurred in each synoptic pattern category in the 24 hour predictions based at 1100 UTC for the local models.

Error pattern	*GASP 92 days*	*TLAPS 88 days*	*LAPS 90 days*	*MESO_LAPS 39 days only*
1. No significant error	12	5	4	3
2. Trough (low) in easterlies				
a. too deep	0	3	2	0
b. too weak	3	6	9	1
c. too fast	3	4	4	2
d. too slow	0	0	0	0
3. Trough (low) in westerlies				
a. too deep	20	13	15	11
b. too weak	29	42	61	27
c. too fast	8	12	13	5
d. too slow	25	17	23	11
4. Ridging				
a. too strong	19	25	20	11
b. too weak	4	4	7	1
c. too fast	10	6	8	2
d. too slow	6	5	6	1

than 30 at 1100 UTC +24 hours, are identified and discussed. Models considered are GASP, TLAPS_PT375, LAPS_PT375 and after 23 August MESO_LAPS. Dates refer to the verifying date of the forecasts.

The first of these, on 8 July, had a complex cut-off low with centres both east and west of Bass Strait. All models had the eastward low too shallow and LAPS_PT375 and TLAPS_PT375 had the western low too deep as well. GASP produced a very good forecast, especially considering that this situation generated the highest scores for the month from the other models. By the following day, the two centres had amalgamated and all models were performing well.

On 12 July, another easterly trough of complex character was developed too slowly, particularly by LAPS_PT375 and TLAPS_PT375. By 13 July, the trough was established in the southern Tasman Sea as the cyclonic part of a blocking situation. At this stage, the models had more trouble with the cradling anticyclone which they all tended to overestimate. The low index nature of the situation continued through 14 July with the cyclonic part becoming split. Details of positioning of this complex system were most difficult for TLAPS_PT375 as it occurred near and partly beyond the model boundaries.

On 3 August, an easterly low at the head of the Bight was captured too quickly in the westerly stream to the south. This affected the scores from LAPS_PT375 and TLAPS_PT375. GASP correctly maintained the low pressure in the Bight.

A different type of error occurred on 19 August, when GASP and TLAPS_PT375 developed a ridge too strongly in the Tasman Sea. LAPS_PT375 showed the same tendency but with smaller errors.

A major low in the Bight on 21 August was badly underestimated by LAPS_PT375 although the position was good. GASP forecast this low pressure well at +24 hours although the situation is also identified as a problem one for the global models at +72 hours (see below).

On 24 August, a low south of Western Australia was underestimated by all models and a cut-off in Bass Strait was also underestimated by LAPS_PT375, TLAPS_PT375 and MESO_LAPS. Despite the problem with the WA low, GASP scored well.

On 28 August, all regional models underestimated the strength of a westerly trough in the Indian Ocean. GASP did not have significant errors associated with this system. However, by the following day all models were underforecasting this feature. On the 28 August, a cut-off system in the Tasman was also underestimated by all models and its subsequent south-easterly movement caused errors on the following day.

A southerly trough that was moved too slowly on 23 September, resulted in high scores for LAPS_PT375 and MESO_LAPS. GASP underestimated the strength of another southerly trough on 26 September and it too moved the system too slowly. The tendency to underestimate and move a southerly trough too slowly was again evident on 27 September for a system in the Indian Ocean which affected all models.

Table 3. Number of errors in the three-day predictions from the global models grouped into synoptic pattern categories in the Australian region.

Error pattern	*GASP*	*ECMWF*	*JMA*	*UKMO*	*USA*
1 No significant errors in pattern	1	15	1	4	4
2 Unable to match features	0	0	4	0	1
3 Low in easterlies or cut-off low					
A too linked to westerlies	7	2	8	9	4
B too much in easterlies or cut-off	3	4	1	2	1
4 Trough in easterlies or cut-off low:					
A too deep	9	9	10	8	9
B too weak	16	5	11	10	15
C details of structure	2	8	5	3	7
5 Trough in easterlies over WA:					
A too deep	13	1	1	0	3
B too weak	0	0	1	5	0
6 Trough in easterlies or cut-off:					
A too mobile (i.e. too far east)	18	12	15	18	10
B too slow (i.e. too far west)	11	10	5	12	4
7 Ridging or high pressure system:					
A too strong	37	24	39	47	30
B too weak	12	1	3	4	4
C too mobile	0	0	0	0	0
D too slow	0	0	0	0	0
E latitudinal displacement	0	1	0	0	0
8 A Spurious low or marked over-development	9	5	9	3	4
8 B Missed development of a low or trough	12	4	9	6	6
9 Retaining a low or trough too long	1	0	0	0	0
10 Trough in westerlies basically correct in structure but:					
A too strong	12	10	17	17	10
B too weak	28	13	32	20	23
C details of structure	10	13	7	9	7
11 Low predicted well in intensity but location poor	2	3	2	2	3
12 Trough in westerlies:					
A too mobile	8	11	8	7	7
B too slow	20	7	22	25	16
13 Tropical lows:					
A over-developed	1	0	1	0	0
B missed or too weak	2	1	1	0	0
C mis-located	0	0	0	0	0

The behaviour of the models on these 'bad forecast' days is in line with the generalisations for all situations summarised in Table 2, i.e. for both 'normal' and 'bad' forecasts the models tend to underestimate cyclonic systems and move them too slowly.

An assessment of systematic errors similar to that provided for the global models is shown in Table 2 for 24-hour forecasts based at 1100UTC.

Since the differences between models at this shorter interval is not so marked as at three days, the number of synoptic categories used was simplified. Forecast errors greater than 4 hPa were used to identify the error region which was restricted to the Australian verification area. This region is the same as the one used to produce most of the statistics in this article (Fig. 5).

Note that this summary includes only 39 days data from the MESO_LAPS model. Neither Category 5 for Western Australian troughs nor Category 6 for Tropical Lows had errors during the July to September quarter and were omitted from Table 2.

Given the differences in synoptic categories, Tables 2 and 3 are not directly comparable and both suffer the same weaknesses of subjective judgment and model analysis bias. Even allowing for this, some conclusions and comparisons can be drawn. It is obvious that all the local models had a tendency during this quarter to underestimate the strength of troughs in the westerlies and to move them too slowly (Table 2: Categories 3b, 3d).

GASP also showed this trend in the three-day global comparison (Table 3) where there are 28 occasions of a weak trough (10b), 12 of a missed trough (8b) and 20 occasions when the forecast movement was too slow (12b).

Forecasts by GASP of the easterly troughs appears to be much more reliable at 1 day than at three days. However, all the local models showed a tendency to overforecast ridges (Table 2: 4a) a tendency which GASP also had at three days (Table 3:7a)

Global Models: (GASP, ECSP, UKGC, USAVM, JMAGSM)

The averaged performance of the global models over the Australian region at MSLP at combined 0000 UTC and 1200 UTC base times (Fig. 2(a)) shows ECSP as the most skilful followed by USAVM and UKGC and then GASP and JMAGSM. The separate monthly averages at +72 hours (Fig. 3(c)) give more detail for the scores at 1200 UTC and confirm the order of ECSP, USAVM and UKGC. This graph reveals that JMAGSM had a high score (low skill) in August. In July and September, GASP and JMAGSM had similar scores with GASP being the lower (higher skill) in July and JMAGSM in September. The August score resulted in the whole quarter having high values for JMAGSM. Root mean square errors at MSLP (Fig. 2(b)) also show the same relative performances of the models.

At 500 hPa, both skill-score and rms errors (Figs 2(c), 2(d)) again order the models ECSP, USAVM, UKGC, GASP and JMAGSM. Also Fig. 3(d), with scores for individual months at +72 hours, shows JMAGSM with a high score (low skill) in August but with very similar scores to GASP in July and September.

The anomaly correlation (Fig. 4) shows good correlations for ECSP, UKGC and USAVM followed by GASP and JMAGSM. Using 60 per cent as the cut-off correlation for identifying useful forecasts, then ECSP is useful out to 168 hours, GASP to about 130 hours and JMAGSM to 120 hours.

Synoptic intercomparison of global models

As in the previous three editions an attempt has been made to classify errors into broad categories with the aim of identifying systematic biases in the model predictions that may assist forecasters in the use of the model output. This study assessed three-day MSLP predictions from the 1200 UTC global model predictions.

Daily forecast error charts for the period July-September 2000 (i.e. forecast MSLP minus the verifying analysis field from the same NWP system) were produced for each of the models. For the Australian region (loosely defined as between 10° and 40°S from 100° to 140°E and between 10° and 45°S from 140° to 160°E), each case of forecast error exceeding 4 hPa in magnitude was assigned subjectively to a synoptic pattern category as listed in Table 3 based on the dominant characteristic of the error. The categorisation is subjective and can clearly be ambiguous. Use of the system's own analysis is another weakness due to the strong influence of the model on the analysis field in data-sparse areas. Table 3 lists the error patterns used in the classification and the number of cases identified in each category for each global NWP system.

ECMWF had fifteen cases (Category 1) where the forecast error was less than 4 hPa over the full area of interest while all the other models had only a few such cases. On the other hand there were 34 instances when three or more of the models simultaneously had errors exceeding 10 hPa and five instances when this was the case for all five models. These five instances illustrate typical problem areas for the current models. The cases were the three-day forecasts valid for:

- 1 July – a cut-off low of central pressure about 998 hPa analysed over southwest Western Australia was located 5 to 12 degrees too far southeast by all the models.
- 14 July – a secondary low at 32°S 165°E which formed in the north of a cut-off low system over the Tasman Sea was missed completely or only weakly indicated by the models.
- 3 August – a weak low which formed in easterly flow over the head of the Bight was poorly forecast; the models indicated only a weak trough between highs, strongly linked to the westerly flow and too mobile.
- 21 August – a major cut-off low (992 hPa) located over the Bight was either forecast too far to the southeast (as for the 1 July case) or too weak in intensity.
- 5 September – this was a more marginal case involving a low of 975 hPa centred south of Tasmania; most models located the low slightly too far south and underestimated the strength of the cyclonic flow over Tasmania. The UKMO

Fig. 2(a) Comparison for GASP/ECSP/USAVM/UKGC/JMAGSM from July to September 2000. S1 skill-scores of MSLP for combined base-times 0000 UTC / 1200 UTC and intervals +24 h to +192 h over the irregular Australian verification grid.

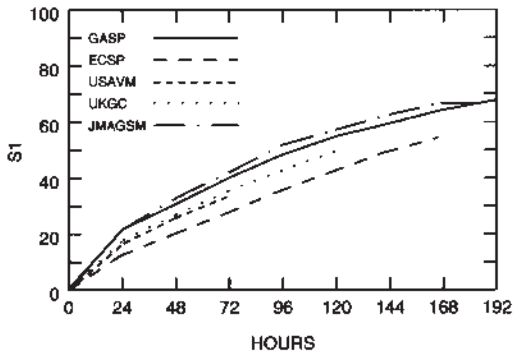


Fig. 2(b) Comparison for GASP/ECSP/USAVM/UKGC/JMAGSM from July to September 2000. Root mean square errors of MSLP for combined base-times 0000 UTC / 1200 UTC and intervals +24 h to +192 h over the irregular Australian verification grid.

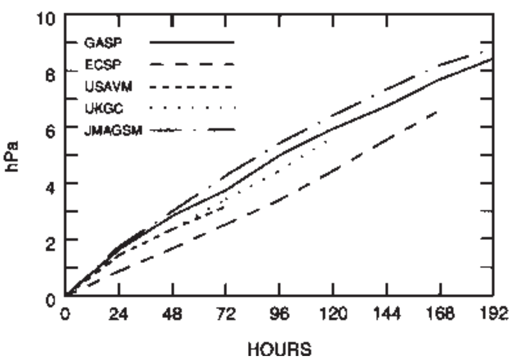


Fig. 2(c) Comparison for GASP/ECSP/USAVM/UKGC/JMAGSM from July to September 2000. S1 skill-scores of 500 hPa geopotential height (m) for combined base-times 0000 UTC 1200 UTC and intervals +24 h to +192 h over the irregular Australian verification grid.

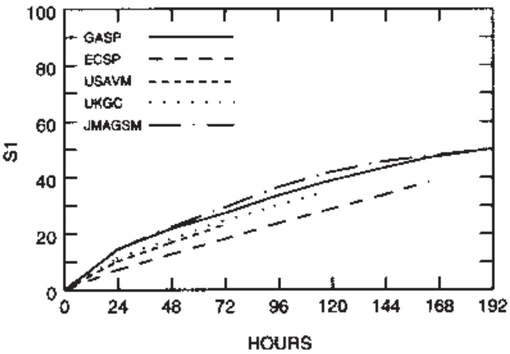
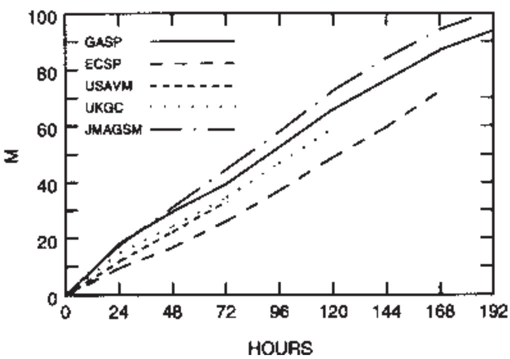


Fig. 2(d) Comparison for GASP/ECSP/USAVM/UKGC/JMAGSM from July to September 2000. Root mean square errors of 500 hPa geopotential height (m) for combined base-times 0000 UTC / 1200 UTC and intervals +24 h to +192 h over the irregular Australian verification grid.



forecast of the flow was excellent but it overestimated the strength of the associated upstream ridge.

There were several instances during the quarter of complex troughs over the region. These generally caused problems in the predictions. One such example occurred during the period 7-9 August when a complex trough over the Bight intensified as it moved east to become a double-centred low over the Tasman.

From 19-29 August there was a blocking high centred south of 50°S in eastern Australian to Tasman Sea longitudes and a slowly evolving low to its north. The model predictions failed in the detail of the cyclonic component of the system. Similar patterns occurred on several occasions during the three months but were of shorter duration.

A third example occurred from 23-26 September with a weak trough in easterly flow over the continent. The models consistently predicted an intensification of this feature, which did not eventuate.

Problems occurred in the details of features in strong westerly flow, such as a secondary low south of Western Australia on 7 September.

Comments on particular synoptic features

Cyclogenesis. GASP and JMA again had the most cases in the category (8b) of missed or seriously under-forecast developments, but the problem was less marked than for the April-June period. All the models had some serious misses. One case common to all the models, although weakly captured by ECMWF, was the development of a low over the

Fig. 3(a) Monthly S1 skill-scores of MSLP for LAPS_PT375/TLAPS_PT375/GASP/MESO_LAPS from July to September 2000 for base-time 1200 UTC and interval +24 h over the irregular Australian verification grid.

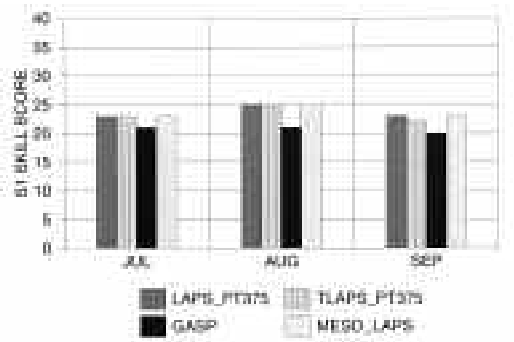


Fig. 3(b) Monthly S1 skill-scores of 500 hPa geopotential height (m) for LAPS_PT375/TLAPS_PT375/GASP/MESO_LAPS from July to September 2000 for base-time 1200 UTC and interval +24 h over the irregular Australian verification grid.

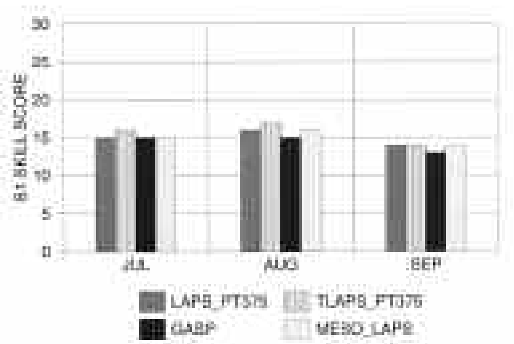


Fig. 3(c) Monthly S1 skill-scores of MSLP for GASP/EC/UK/US/JMA from July to September 2000 for base-time 1200 UTC and interval +72 h over the irregular Australian verification grid.

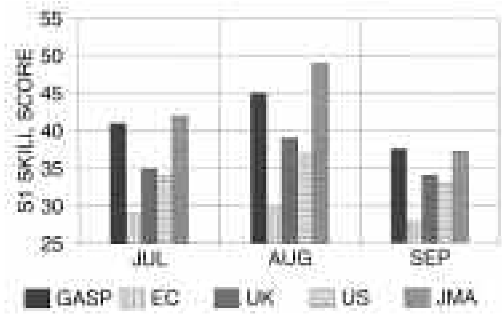
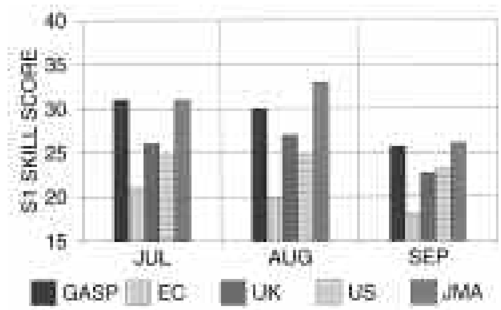


Fig. 3(d) Monthly S1 skill-scores of 500 hPa geopotential height (m) for GASP/EC/UK/US/JMA from July to September 2000 for base-time 1200 UTC and interval +72 h over the irregular Australian verification grid.



western Bight on 20 August; this case was a precursor to the case of a common major error noted above.

Except for ECMWF and JMA, the models again showed a preponderance of under-developed systems rather than over-developed systems, but this characteristic was less marked than in the previous quarter.

Troughs and lows in easterly flow. As noted above, events with cut-off lows occurred commonly during the period and were generally associated with prediction errors. Except for ECMWF the predictions all linked such features too much to the westerlies and often moved such systems too rapidly to the east. The US and GASP systems also tended to under-forecast the intensity of such systems. The character of the ECMWF predictions in this quarter are in marked contrast to the previous quarter, making it difficult to draw conclusions about systematic behaviour.

For the particular case of troughs over Western Australia (category 5), GASP continued its bias of over-predicting this feature. The other models show a much lower frequency of errors in this region although UKMO had 5 occasions of significant under-prediction.

Extratropical lows or troughs in the westerlies. For mobile westerly troughs where the structure and location were acceptable, the intensity tended to be under-estimated by all models, although only marginally so in the case of ECMWF and UKMO. A general tendency to under-estimate the strengths of troughs in the westerlies is consistent with the patterns in previous quarters.

Fig. 4 Anomaly Correlation of MSLP for GASP/ECSP/USAVM/UKGC/JMAGSM from July to September 2000 for combined base-times 0000 UTC / 1200 UTC over the irregular Australian verification grid.

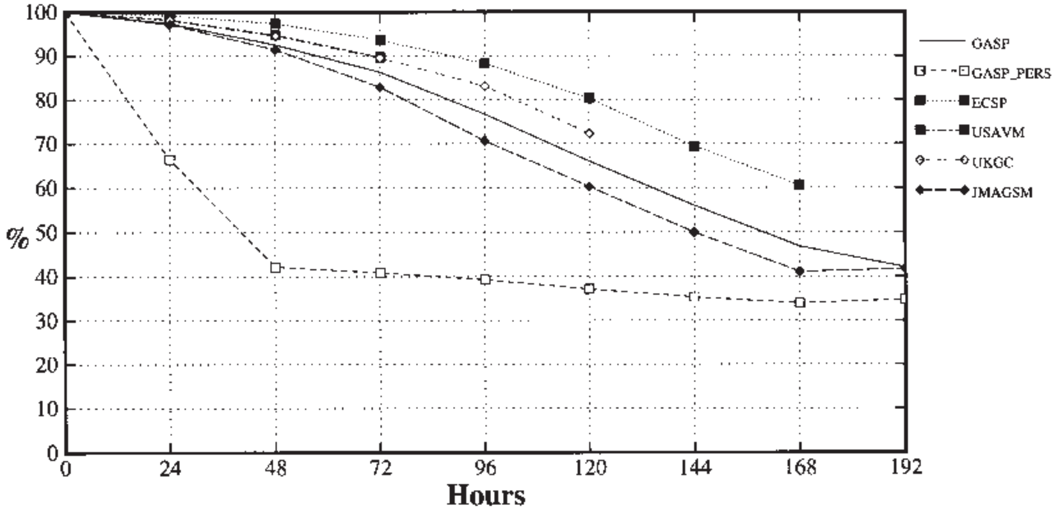
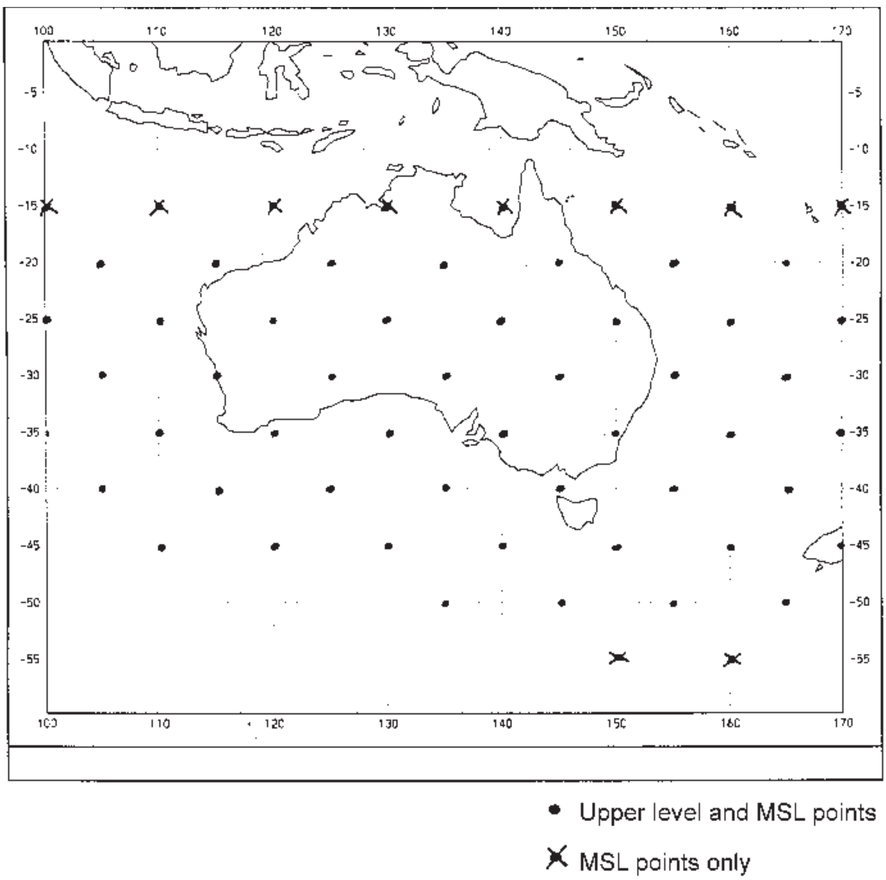


Fig. 5 Australian verification grid. Upper levels use 48 points while MSLP field verification uses 58 points.



Except for ECMWF, predicted speeds of movement for westerly troughs were again biased towards being too slow as in the previous three quarters. Except for the January-March quarter, ECMWF has shown a bias toward moving the westerly troughs too fast, although it is marginal in this quarter.

Ridging and high pressure systems. All models again showed a clear tendency to over-predict the extent of high pressure systems and ridging. A counter-example though occurred on 24 July when all models under-estimated strong ridging to the south of Western Australia and the development of strong southerly winds over the Bight as far south as 55°S. The model predictions did not capture this meridional pattern and all favoured south-westerly flow. ECMWF again showed the fewest problems overall with ridging and UKMO had the most cases. UKMO occasionally gave forecasts of strong central pressures that were outliers in the ensemble. One such case was 1 August when UKMO forecast a high of 1038 hPa over the Tasman, at least 4 hPa higher than the other predictions and 8 hPa higher than in the verifying analysis.

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