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Quarterly numerical weather prediction model performance summary - April 2004 to June 2005

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Introduction

This summary, covering five quarters during the period from April 2004 to June 2005, continues the series reporting on the performances of numerical weather prediction (NWP) models used operationally in the Australian Bureau of Meteorology.

Verified NWP models and changes during the April 2004-June 2005 period

Local models

During May 2004 the Central Computing Facility (CCF) was relocated and the Bureau's operational NWP models were successfully migrated to the new supercomputer, NEC SX-6. This supercomputer upgrade has provided roughly seven-fold increase in computing power from 256 gigaflops to 1.8 terraflops at peak performance. Concurrently the NWP models run by the Bureau have undergone substantial changes. The assimilation technique used by the Bureau's operational global spectral model, GASP, was upgraded from multivariate statistical interpolation scheme (MVSI) to a generalised multivariate statistical interpolation scheme (GenSI) on 13 May 2004. GenSI is based on an iterative solver algorithm and has the advantage of being able to be easily extended to support direct radiance assimilation, which will be required in the three-dimensional variational assimilation technique (3DVAR). Better quality control of observations and the capability to handle more observation types are other benefits of GenSI. LAPS_PT375, one of the Bureau's limited area models verified in this article, commenced using GenSI assimilation scheme on 8 December 2004.

An upgrade to the Bureau's operational tropical region limited area model, TLAPS_PT375 became effective from 30 May 2005. The new operational system was named TXLAPS_PT375. The improvement included enlargement of the model domain and a new 12-hourly data assimilation cycle which uses GenSI and 1DVAR. A summary of the operational NWP models run by the Bureau and the changes to their assimilation and forecast models during April 2004 and June 2005 is given in Table 1.

Overseas models

During the period covered in this summary, a number of major upgrades to the operational NWP models run by various overseas centres were made. The upgrades were numerous covering the numerics, model physics and the data assimilation component. One important change in data assimilation adopted by many overseas operational centres during the period was the move to four-dimensional variational analysis scheme (4DVAR). The UK Met Office (UKMO) announced an implementation of the 4DVAR data assimilation scheme in their global version of the Unified Model on 5 October 2004; the JMA-run global model (JMAGSM) moved to 4DVAR on 17 February 2005; the Canadian Meteorological Centre (CMC) moved to 4DVAR on 15 March 2005 (which is not part of this summary). The latest upgrade by the CMC brings the number of major operational NWP centres that use 4DVAR assimilation scheme to four, a trend started by ECMWF which commenced its operational 4DVAR assimilation in November 1997.

In addition to the upgrades to assimilation methods there were significant changes to forecast models' resolution in this period. On 31 May 2005

Table 1. Operational NWP models run in the Bureau

Date of change	*GASP*	*LASP_PT375*	*TLAPS_PT375 & TXLAPS_PT375*
Apr 2004	T239L29; 1DVAR & MVSI	0.375° lat/lon horiz grid, 29 vertical levels; 1DVAR & MVSI	0.375°lat/lon horiz grid, 29 vertical levels; MVSI
May 2004	Assimilation scheme changed to GenSI (13/5/2004)	–	–
Dec 2004	–	Assimilation scheme changed from MVSI to GenSI (8/12/2004)	–
Mar 2005	–	Uses QUIKSCAT ocean surface winds	– –
May 2005	–	–	TLAPS_PT375 upgraded to TXLAPS_PT375 with 1DVAR/GenSI (30/05/2005)

NCEP announced an increase in triangular wavenumber truncation from T254 to T382 for its operational global model, the Global Forecast System (abbreviated to GFS, and known as AVN and referred to here as USAVM). The number of vertical levels remained unchanged. JMAGSM's forecast model also underwent a resolution increase: its spectral resolution increased from T213 (quadratic grid) to TL319 (linear grid). Some of the significant changes announced by various operational centres are listed in Table 2.

Verification method

A description of the S1 skill-score, as applied in NMOC, can be found in an earlier article (Skinner 1995). All results have been calculated within NMOC Melbourne, where each of the models was verified against its own analyses. From the large number of objective verification results routinely produced, the statistics presented here cover only the 500 hPa geopotential height and mean sea-level pressure (MSLP) fields over the irregular Australian verification area (Miao 2003). It is noted that this particular verification grid has southerly points that are outside the TLAPS/TXLAPS domains and, hence, the TLAPS/TXLAPS scores are not strictly compatible with those from GASP and LAPS. The results for the 0000 and 1200 UTC base-times have been combined. The results are presented, at this stage, for forecast periods out to a maximum of 192 hours.

Review of performance – April 2004 to June 2005

Local models (GASP, LAPS, TLAPS/TXLAPS)

The intercomparison of the S1 skill-scores of the MSLP forecasts for the three local models is shown in Fig. 1(a). The S1 skill-scores are averaged over the three-month period, April to June 2004 and are shown for various forecast periods ranging from 0 hour to 72 hours. S1 skill-score comparison of the 500 hPa geopotential height forecasts are shown in Fig. 1(b). Similar graphs for the July-September 2004 quarter are shown in Fig. 2(a) and Fig. 2(b); graphs for the October-December 2004 quarter are in Fig. 3(a) and Fig. 3(b); graphs for the January-March 2005 quarter are in Fig. 4(a) and Fig. 4(b); and graphs for the April-June 2005 quarter are in Fig. 5(a) and Fig. 5(b).

GASP clearly outperformed the limited area models in this particular verification in both the MSLP and 500 hPa geopotential height forecasts. This result is thought to be partly due to the advantage of the GASP assimilation which has a longer data cut-off. It is also due to the disadvantage suffered by the limited area models which obtain their initial first guess and boundary conditions from earlier runs of GASP forecasts. Forecasts from earlier runs tend to be poorer than forecasts produced from later runs. One other contributing factor for better-than-expected scores for GASP is that during this period the upgrading to GenSI may have given GASP more skill gain than local models as the local models were less able to take advantage of the new assimilation scheme.

Table 2. Significant changes made to assimilation and forecast models of various overseas NWP centres during the April 2004-June 2005 period.

Date of change	*ECSP*	*UKGC*	*USAVM*	*JMAGSM*
Apr 2004	T511L60; 4DVAR	Unified Model at 0.56° lat/0.83° lon, 38 levels; 3DVAR	T254L64; 3DVAR SSI assimilation scheme	T213L40; 3DVAR
Jun 2004	Introduced two additional 4DVAR analysis/forecast cycles	Assimilates AIRS cloud-free radiance	–	–
Sep 2004	Changes to numerics & 4DVAR; use RTTOV-8	–	–	Assimilates Terra/MODIS & Aqua/MODIS
Oct 2004	–	Implements 4DVAR(5/10/2004); Local retrieval of ATOVS; Improved radiative transfer model for TOVS (RTTOV-7); Improved bias correction for ATOVS over land	–	–
Dec 2004	–	–	–	Radiative transfer model upgraded to RTTOV-7
Jan 2005	–	Parametrisation upgrade related to low cloud, near-surface T (18/1/2005)	–	–
Feb 2005	–	More consistent representation of moist processes within 4DVAR; Assimilation of Aqua-MODIS polar-orbiting satellite data	–	Assimilation upgrade to 4DVAR; increased spectral resolution from T213 to TL319 (17/2/2005)
Mar 2005	–	–	–	Assimilation of Aqua/AMSU-A
Apr 2005	New moist boundary layer scheme, MODIS winds from AQUA activated;	–	–	–
May 2005	–	–	Horizontal wavenumber truncation increased from T254 to T382 (31/5/2005)	–
Jun 2005	Assimilation of rain-affected SSM/I radiance	–	–	–

Global models (GASP, ECSP, UKGC, USAVM, JMAGSM)

The Bureau's own operational global spectral model, GASP and the four global models from overseas NWP centres are operationally used by forecasters. The outputs from the models are also postprocessed to produce various objective guidance products used by users in and outside of the Bureau. Hence their forecast performance is of great interest to the forecasters and other users.

Fig. 1(a) **MSLP S1 skill-score comparison, for different forecast periods, between GASP, LAPS_PT375, and TLAPS_PT375 (April to June 2004).**

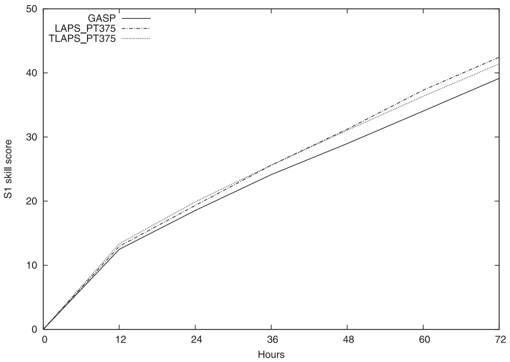


Fig. 1(b) **500 hPa geopotential height S1 skill-score comparison, for different forecast periods, between GASP, LAPS_PT375, and TLAPS_PT375 (April to June 2004).**

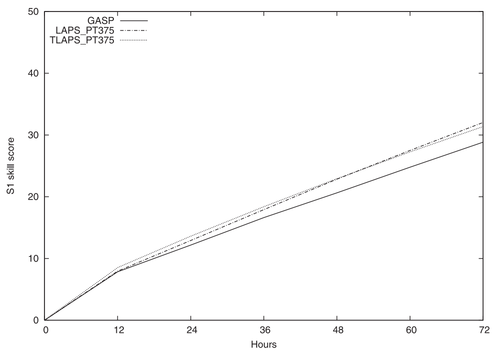


Fig. 2(a) **MSLP S1 skill-score comparison, for different forecast periods, between GASP, LAPS_PT375, and TLAPS_PT375 (July to September 2004).**

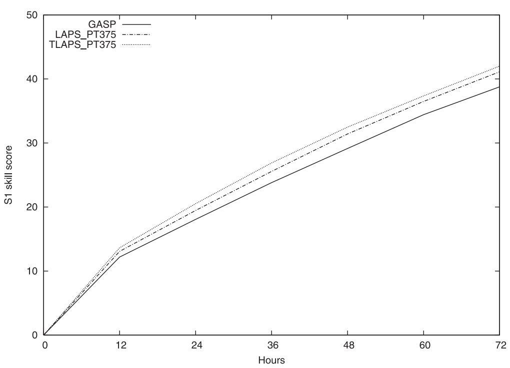


Fig. 2(b) **500 hPa geopotential height S1 skill-score comparison, for different forecast periods, between GASP, LAPS_PT375, and TLAPS_PT375 (July to September 2004).**

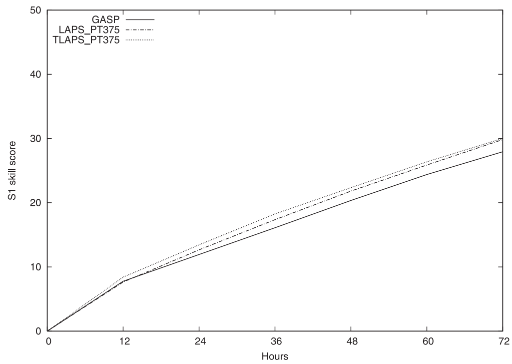


Fig. 3(a) **MSLP S1 skill-score comparison, for different forecast periods, between GASP, LAPS_PT375, and TLAPS_PT375 (October to December 2004).**

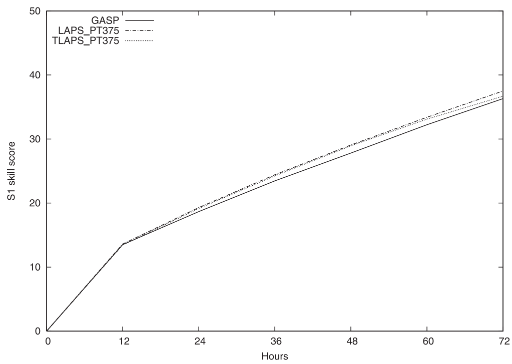


Fig. 3(b) **500 hPa geopotential height S1 skill-score comparison, for different forecast periods, between GASP, LAPS_PT375, and TLAPS_PT375 (October to December 2004).**

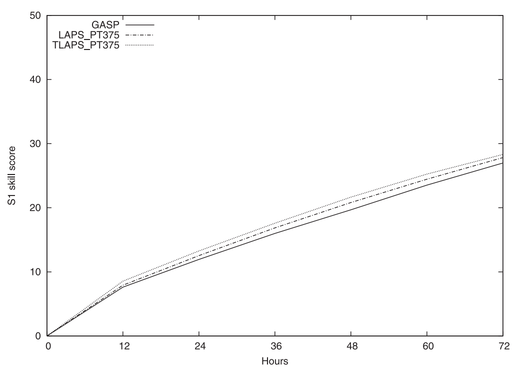


Fig. 4(a) MSLP S1 skill-score comparison, for different forecast periods, between GASP, LAPS_PT375, and TLAPS_PT375 (January to March 2005).

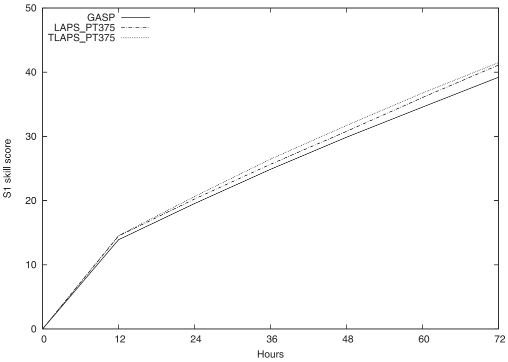


Fig. 4(b) 500 hPa geopotential height S1 skill-score comparison, for different forecast periods, between GASP, LAPS_PT375, and TLAPS_PT375 (January to March 2005).

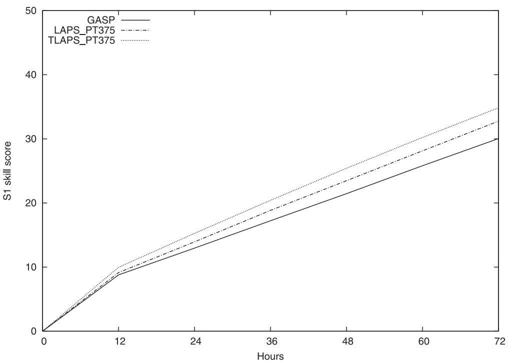


Fig. 5(a) MSLP S1 skill-score comparison, for different forecast periods, between GASP, LAPS_PT375, and TLAPS_PT375/ TXLAPS_PT375 (April to June 2005).

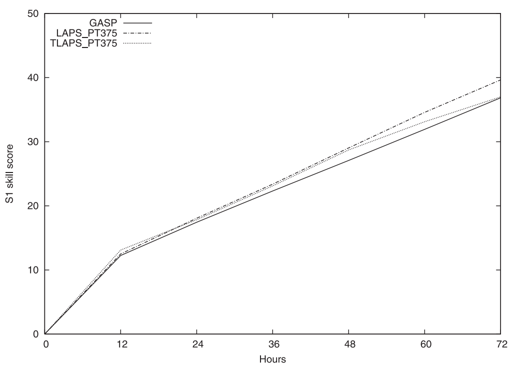
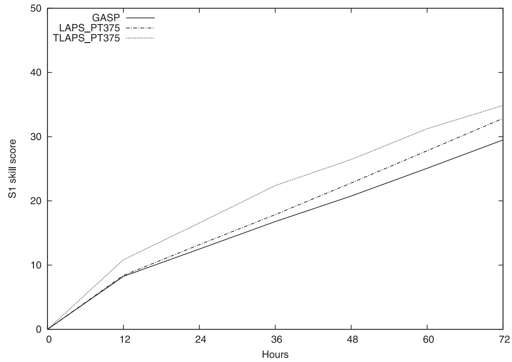


Fig. 5(b) 500 hPa geopotential height S1 skill-score comparison, for different forecast periods, between GASP, LAPS_PT375, and TLAPS_PT375/ TXLAPS_PT375 (April to June 2005).



The S1 skill-scores for MSLP and 500 hPa geopotential height forecasts are presented below. The base dates from which forecasts were made were broken down into the same five quarters that were used in the local model comparison in the previous section. Namely, April to June 2004 (Figs 6(a) and 6(b)), July to September 2004 (Figs 7(a) and 7(b)), October to December 2004 (Figs 8(a) and 8(b)), January to March 2005 (Figs 9(a) and 9(b)) and April to June 2005 (Figs 10(a) and 10(b)). ECSP continues to perform best in both measures and this is a trend consistently noted in the previous summary (Stewart 2004). ECSP's relative skill is also clearly evident in the anomaly correlation of MSLP forecasts for each of the quarters shown in Figs 11, 12, 13, 14 and 15.

There were some notable changes in the relative skill among the global models during the period of interest, which coincided with significant assimilation and/or forecast model upgrades at the various operational centres. Starting from the October-December quarter of 2004, UKGC has overtaken USAVM in all three measures used here. This improvement coincides with the use of 4DVAR data assimilation system in the global version of the Unified Model, which began on 5 October 2004. Further gains were made by UKGC when the UKMO reported enhancements to their 4DVAR assimilation package together with a greater data coverage coming from the Aqua-MODIS polar orbiting satellite.

More dramatic gains in S1 skill-score and anomaly correlation were made by JMAGSM following the introduction of the 4DVAR assimilation scheme and increased spectral resolution from T213 to TL319. Its performance over the Australian verification region for the shorter forecast periods now almost equals that of the UKGC and USAVM systems.

Fig. 6(a) MSLP S1 skill-score comparison, for different forecast periods, between GASP, ECSP, USAVM, UKGC and JMAGSM (April to June 2004).

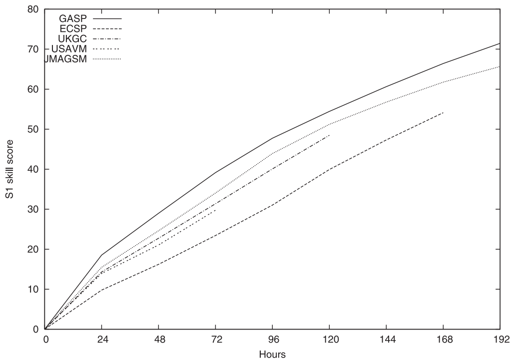


Fig. 6(b) 500 hPa geopotential height S1 skill-score comparison, for different forecast periods, between GASP, ECSP, USAVN, UKGC and JMAGSM (April to June 2004).

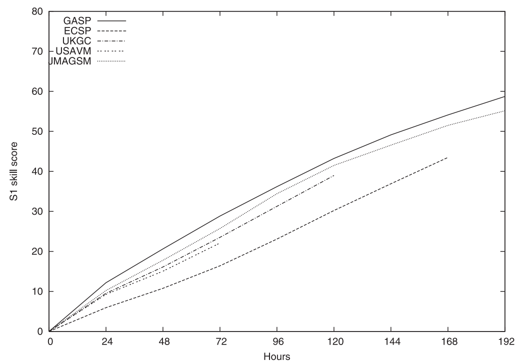


Fig. 7(a) MSLP S1 skill-score comparison, for different forecast periods, between GASP, ECSP, USAVM, UKGC and JMAGSM (July to September 2004).

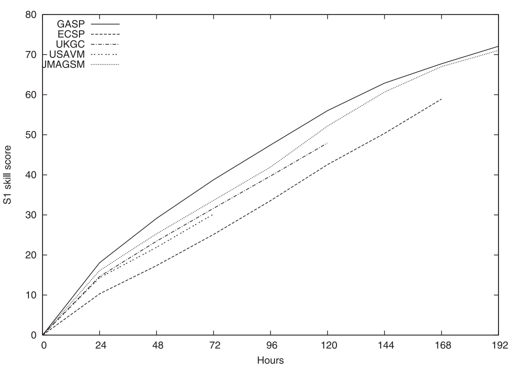


Fig. 7(b) 500 hPa geopotential height S1 skill-score comparison, for different forecast periods, between GASP, ECSP, USAVM, UKGC and JMAGSM (July to September 2004).

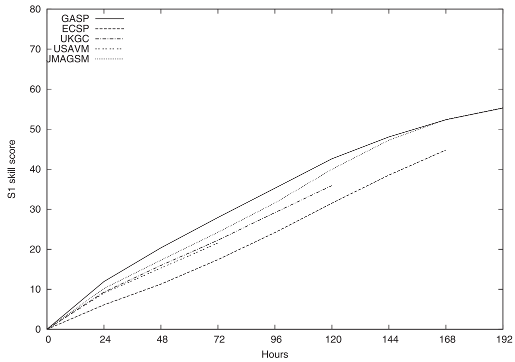


Fig. 8(a) MSLP S1 skill-score comparison, for different forecast periods, between GASP, ECSP, USAVM, UKGC and JMAGSM (October to December 2004).

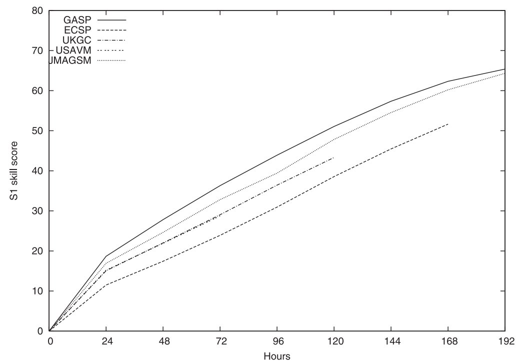


Fig. 8(b) 500 hPa geopotential height S1 skill-score comparison, for different forecast periods, between GASP, ECSP, USAVM, UKGC and JMAGSM (October to December 2004).

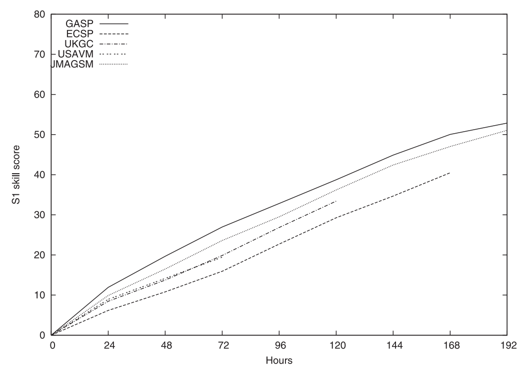


Fig. 9(a) **MSLP S1 skill-score comparison, for different forecast periods, between GASP, ECSP, USAVM, UKGC and JMAGSM (January to March 2005).**

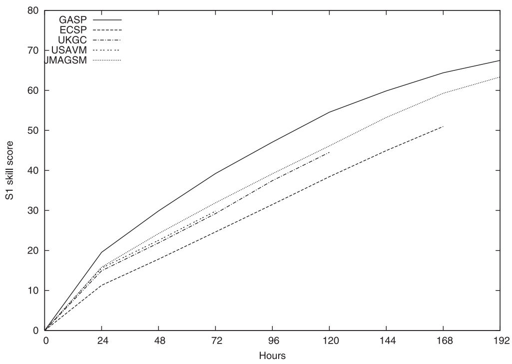


Fig. 9(b) **500 hPa geopotential height S1 skill-score comparison, for different forecast periods, between GASP, ECSP, USAVM, UKGC and JMAGSM (January to March 2005).**

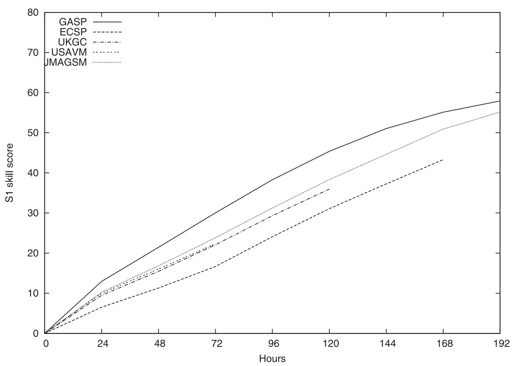


Fig. 10(a) **MSLP S1 skill-score comparison, for different forecast periods, between GASP, ECSP, USAVM, UKGC and JMAGSM (April to June 2005).**

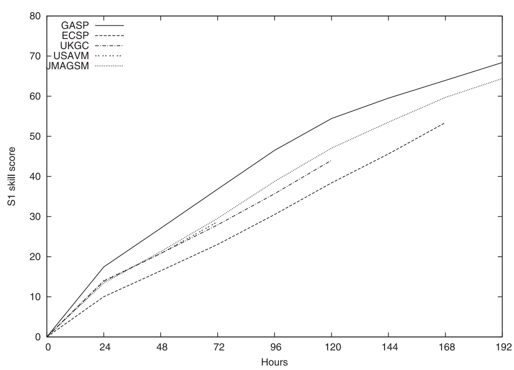


Fig. 10(b) **500 hPa geopotential height S1 skill-score comparison, for different forecast periods, between GASP, ECSP, USAVM, UKGC and JMAGSM (April to June 2005).**

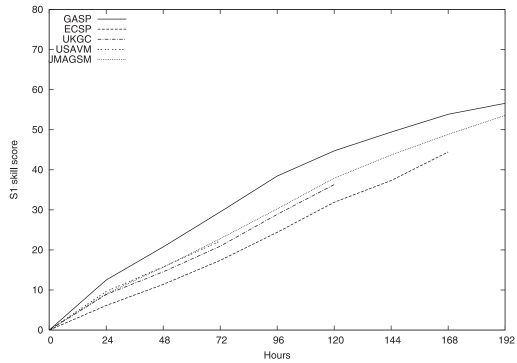


Fig. 11 **Anomaly correlation of MSLP comparison, for different forecast periods, between GASP, ECSP, USAVM, UKGC and JMAGSM (April to June 2004).**

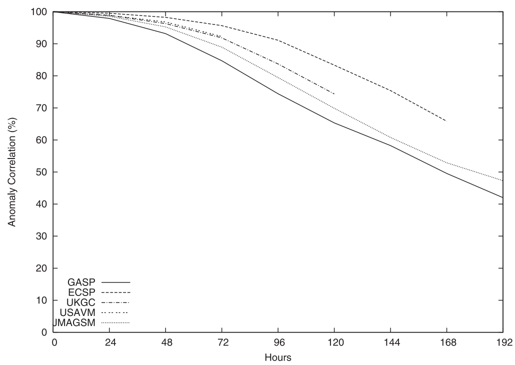


Fig. 12 **Anomaly correlation of MSLP comparison, for different forecast periods, between GASP, ECSP, USAVM, UKGC and JMAGSM (July to September 2004).**

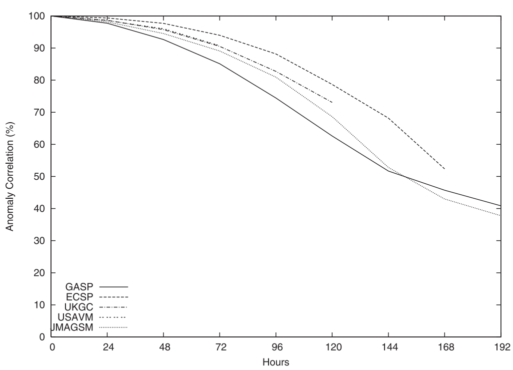


Fig. 13 Anomaly correlation of MSLP comparison, for different forecast periods, between GASP, ECSP, USAVM, UKGC and JMAGSM (October to December 2004).

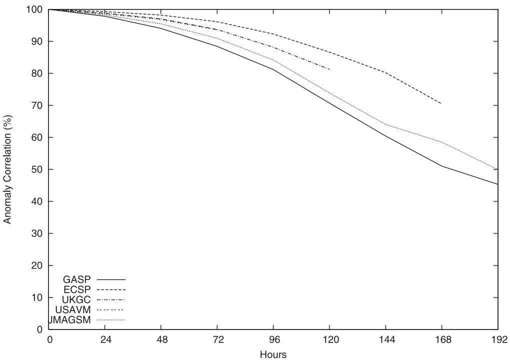


Fig. 14 Anomaly correlation of MSLP comparison, for different forecast periods, between GASP, ECSP, USAVM, UKGC and JMAGSM (January to March 2005).

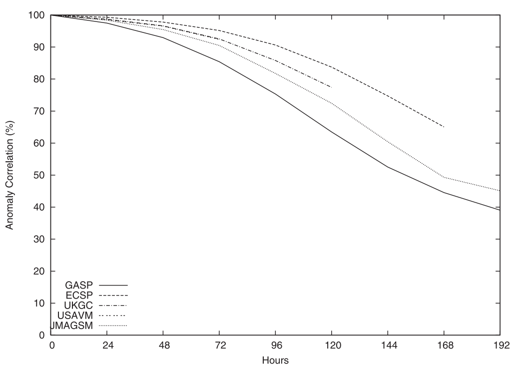


Fig. 15 Anomaly correlation of MSLP comparison, for different forecast periods, between GASP, ECSP, USAVM, UKGC and JMAGSM (April to June 2005).

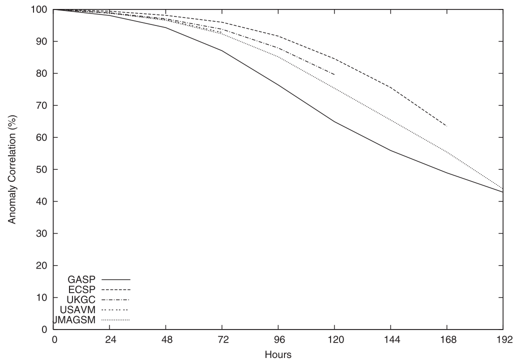
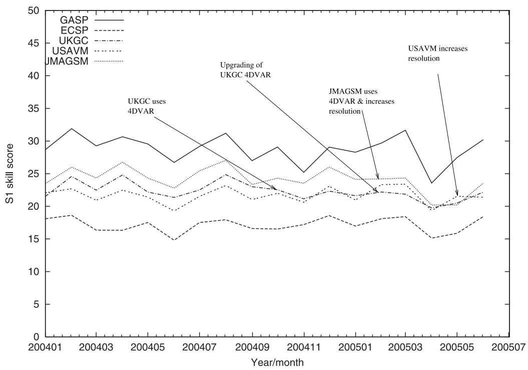


Fig. 16 Monthly-averaged S1 skill score trend for 48-hour MSLP forecasts from GASP, ECSP, USAVM, UKGC and JMAGSM (January 2004 to June 2005).



On 31 May 2005 NCEP announced a resolution increase for the GFS model. Its horizontal wavenumber truncation increased from T254 to T382. The likely impact of this resolution change on performance measures may become clearer later.

To see more clearly the long-term trend in the model skill scores a time series plot of the monthly-mean skill scores is produced in Fig. 16. It shows the average monthly S1 skill scores of 48-hour forecasts made from all base dates falling on each month starting from January 2004 to June 2005. The prominent dates of model upgrades announced by the participating centres are marked on the plot for reference.

Acknowledgments

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References

Miao, Y. 2003. Numerical prediction model performance summary July to September 2002. *Aust. Met. Mag., 52,* 73-5.

Skinner, W. 1995. Numerical prediction model performance summary April to June 1995. *Aust. Met. Mag., 44,* 309-12.

Stewart, P. 2004. Numerical prediction model performance summary January to March 2004. *Aust. Met. Mag., 54*, 83-5.

Web references

For ECMWF: http://www.ecmwf.int/publications/newsletters http://www.ecmwf.int/products/data/technical/model_id/index.html

For UKMO: http://www.meto.gov.uk/research/nwp/publications/nwp_gazette/index.html

For NCEP: http://www.emc.ncep.noaa.gov/gmb/STATS/html/model_changes.html

For JMA: http://www.jma.go.jp/JMA_HP/jma/jma-eng/jma-center/nwp/nwp-top.htm