ASSIMILATION OF AMV

J. Paevere, P. Steinle, J. Kepert, C. Tingwell, W. Bourke, Y. Xiao

BUREAU OF METEOROLOGY, P.O. Box 1289K, Melbourne, 3001 Victoria, Australia

ABSTRACT

An 'observation space' assimilation system, GenSI has been developed at the Australian Bureau of Meteorology's Research Centre. The system is designed to provide a unified strategy for global and regional assimilation of most available observing systems in support of the assimilation and prediction systems of the Bureau. The GenSI system performs a sequence of local analyses over grid arrays (~1000 km squares) using all available observations within a scan radius (~3300 km). Spatially dense data such as AMVs are thinned or combined into super-observations. The GenSI system is operational on the Bureau's new supercomputing facility. The new system includes comprehensive use of extensive AMVs plus available ATOVS data, which is currently handled by 1DVAR. The results of parallel trials of the GenSI system for both GASP the global NWP system, and the limited area system, LAPS will be reported. Results relative to current operational performance will be presented together with assessment of impacts, including those of AMVs and scatterometer winds.

1. THE ASSIMILATION SYSTEM

The Australian Bureau of Meteorology implemented the GenSI assimilation system over the global domain in May this year. The previous system, Multivariate Statistical interpolation, MVSI (Seaman et al. 1995) was limited in the quantity of observational data it could handle. Both schemes mesh together a series of local analyses but the GenSI uses observations from a much larger radius for each local analysis. Consequently the differences at the boundaries between local analyses are negligible. Furthermore an iterative solver technique for matrix inversion has eliminated the need to restrict the amount of data used within a local analysis in the new scheme. The removal of limits on the number of observations has allowed the full use of high density atmospheric motion vectors (AMV).

Experiments to test the effect of indiscriminate assimilation of the SATOB data from the GTS have shown little or no gain in forecast skill. Le Marshall and others (Le Marshall, J et al. 2002) have documented the advantages of using high quality AMV in the Bureau's Regional system. However the quality control has been performed locally so only locally derived winds have been used. Using the data transmitted in BUFR format has allowed us to assess the quality of the winds from all the major producers of Atmospheric Motion Vectors, by means of QI and RFF data encoded in the BUFR messages. An important step in obtaining positive impact from GenSI in the global NWP system was to exercise strict quality control of AMV.

Quality thresholds are determined by comparing QI or RFF values of observations against the first guess (6hr forecast) from the local global model, GASP. Diagrams similar to the one below are generated for each channel of each satellite, where the QI from individual observations are plotted against RMS errors from the first guess. A QI threshold is determined where the RMS error falls to the observation error used in the analysis (between 3 and 6 metres per second, depending on level), provided the bias, speed and number of observations is satisfactory. For example in the plots below the thresholds for each channel would be chosen between 85 and 90.

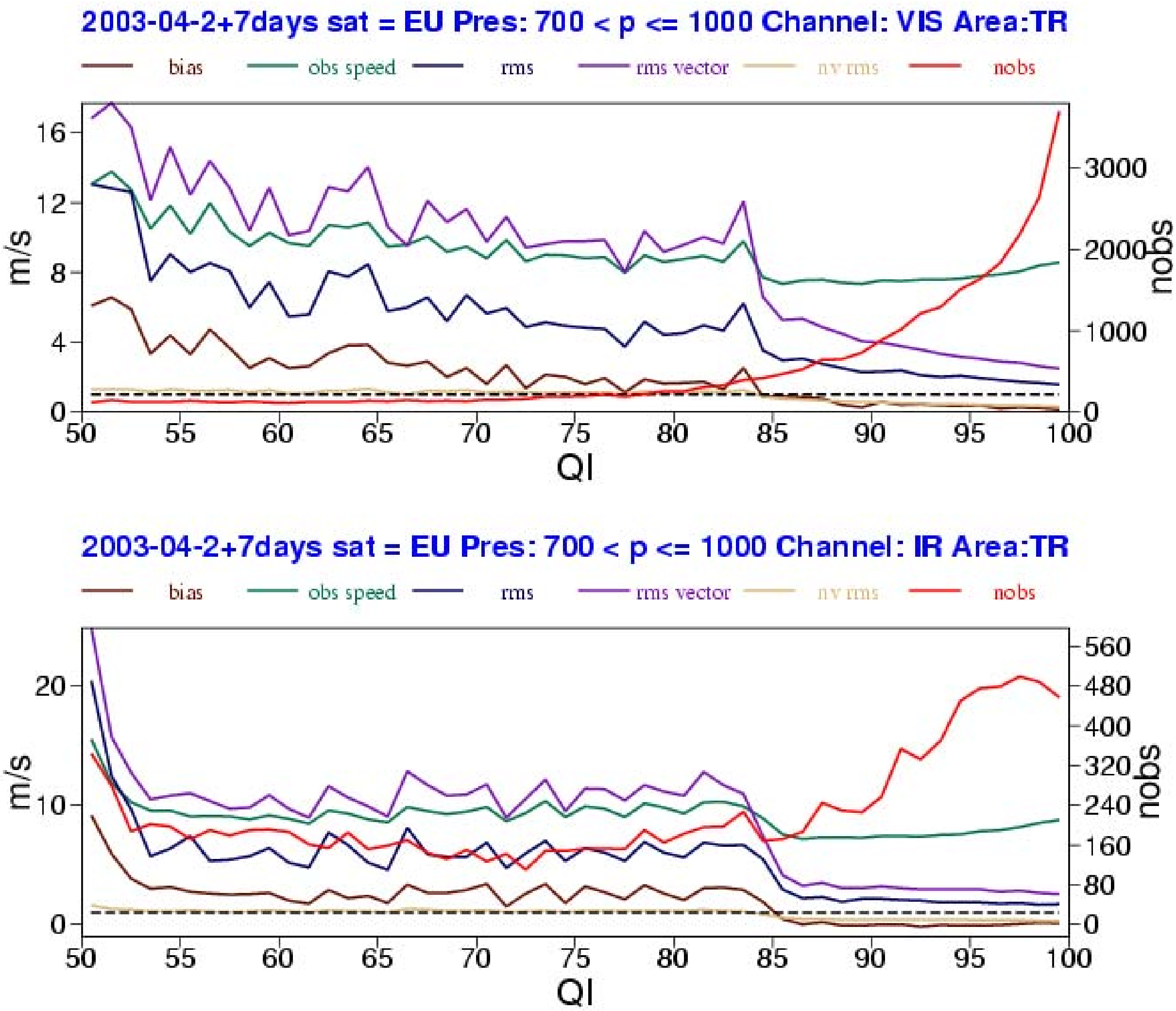


Figure 1. Diagrams of QI values against a range of variables for AMV data received in BUFR format over a seven day period. The rms values are derived from differences from the GASP first guess. The top panel shows the statistics for the visible channel from meteosat over the tropics and the lower for IR. nv rms in brown is the normalised vector RMS error. Note that for the larger errors the number of obs. (nobs) is very low and the QI value is also low.

This threshold information is then incorporated into a table. The observations to be used are selected for each satellite according to quality indicators at three latitude bands over three atmospheric levels for each image type. The assimilation system reads the table of the threshold values and selects data according to these lower limits for acceptable QI values. The data is thinned to a grid of about 100km but the thinning process selects the observation with the highest QI/RFF value in each gridbox. For the trials described here only data from IR and visible channels were selected. Additionally the QI and RFF thresholds were conservative and mid atmospheric data was not used. Below is an example from the table for the Indian Ocean Meteosat. The value 999 indicates that data is not to be selected.

```
52 1   ! ***** IndoEx (Indian Ocean MeteoSAT) ****************
  3                  ! 3 latitude bands
  90 20 -20 -90          ! lat. bands are [90S,20S], [20S,20N], [20N,90N]
  3                  ! divide obs in to 3 layers
  2000 700 400 0         ! layers are [sfc,700], [700,400], [400,top_of_atmos]
    1                ! QI for IR winds
```

```
 87 999  60        !   SHEM
 87 999  85        !   TROP
999 999  60        !   NHEM
2                  ! QI for VIS winds
 87 999 999        !   SHEM
 87 999 999        !   TROP
999 999 999        !   NHEM
3                  ! QI for WV winds
999 999 999        !   SHEM
999 999 999        !   TROP
999 999 999        !   NHEM
4                  ! QI for Multi-channel winds
999 999 999        !   SHEM
999 999 999        !   TROP
999 999 999        !   NHEM
5                  ! QI for WV(clear) winds
999 999 999        !   SHEM
999 999 999        !   TROP
999 999 999        !   NHEM
6                  ! QI for ozone winds
999 999 999        !   SHEM
999 999 999        !   TROP
999 999 999        !   NHEM
7                  ! QI for WV(cloudy) winds
999 999 999        !   SHEM
999 999 999        !   TROP
999 999 999        !   NHEM
```

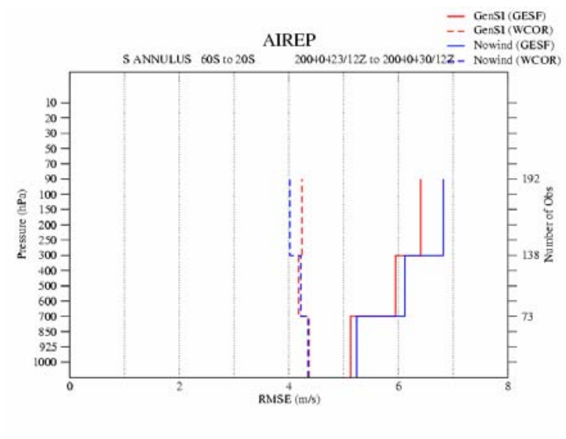
2. TRIALS USING AMV

A series of experiments were conducted to test the system and to gauge the impact of the new observations. A trial (Nowind) was conducted assimilating the conventional data every six hours plus 1DVAR soundings from NOAA15 and NOAA16 but withholding AMV observations. This is compared to analyses using the above plus the AMV from BUFR messages with quality filtering. The analyses were performed at 29 sigma levels on a 240 by 480 horizontal grid. Forecasts to seven days were made from these analyses.

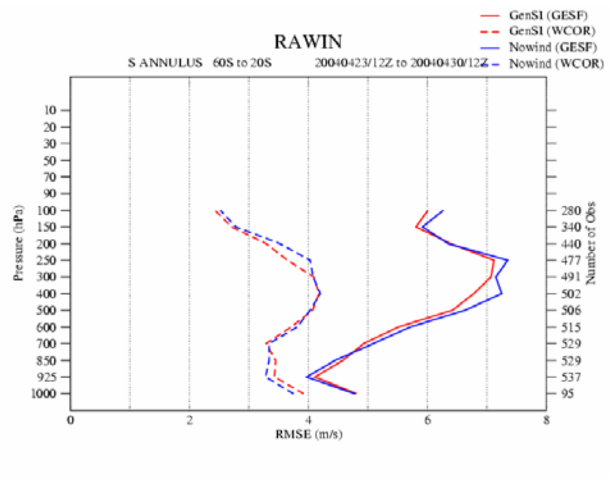
Figure 2 (a) and (b) show the verification of the first guess (GESF) and analysis (WCOR) from the two experiments against RAWIN data and against aireps. In Australia we are particularly interested in the Southern Hemisphere where conventional data, particularly upper air data is very sparse with large data-free areas. GenSI is the trial with the AMV data filtered for quality as described above and Nowind being GenSI with the satellite winds withheld. In both cases the first guess shows larger errors in the mid and upper atmosphere in the Nowind case. In the low levels however the satellite winds do not produce a better result. Contrasting with this positive result is the verification against radiosonde data in Figure 2 (c). Here we see the Nowind trial proving more accurate. Since these verifications are for the southern annulus between 60S and 20S this is probably because of the sparse radiosonde network in the Southern Hemisphere; the observations can be overwhelmed by the dense mass of satellite winds. In this trial only the Mean sea level pressure from synop, ship and drifting buoy data are used. These are used to assess the 1000 hPa geopotential. These data, particularly drifting buoy data over the remote oceans are better fitted when AMV data is assimilated as shown in Figure 2 (d). When verifying the seven day forecast, the AMV data is found to give an improvement in forecast skill in the Southern Hemisphere, but the results are neutral elsewhere. Plots of the anomaly correlation at 500 hPa are shown in Figure 3.

3. ASSIMILATION OF SCATTEROMETER DATA

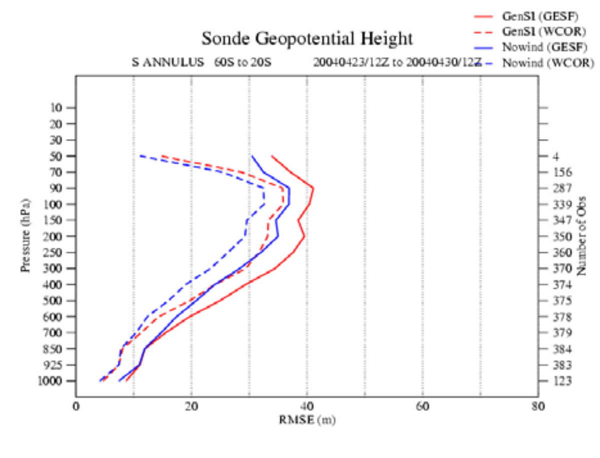
Quikscat data was next incorporated into the assimilation. Whereas the trials described earlier were conducted at 29 levels, extra levels were required close to the surface to provide a more accurately resolved planetary boundary layer suitable for scatterometer data. Trials were conducted with 33 vertical levels for Quikscat data in addition to the data in the earlier trials. A complementary trial was run with the same settings but with Quikscat withheld. Results from these experiments are shown in Figures 3 and 4. The first guess errors are generally smaller with Quikscat assimilated when compared to aireps and rawins. However the gains are small when compared to those achieved assimilating AMV. In this experiment the scatterometer data makes little difference when verified against radiosonde geopotential height. Verification against the Southern Hemisphere drifting buoys showed a small impact.



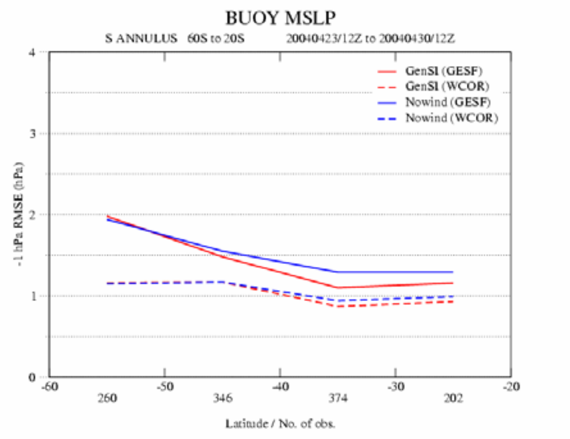
(a)



(b)



(c)



(d)

Figure 2. Verification of first guess 6hour forecast (GESF solid line) and analysis (WCOR dashed line) are shown for GenSI (the trial with AMV assimilated) in red and Nowind (AMV withheld) in blue. 2(a) shows RMS errors against aireps, 2(b) errors against rawin data, 2(c) against geopotential height from radiosondes and 2(d) against mean sea level pressure from drifting buoys.

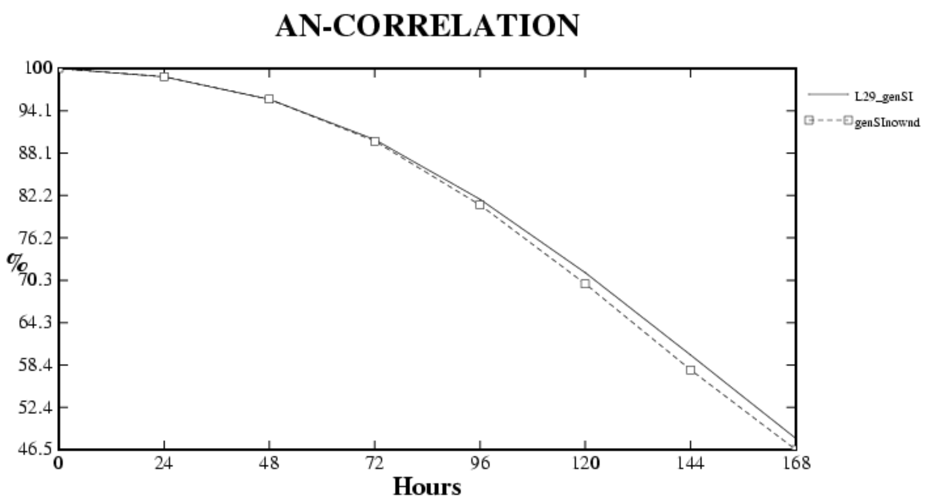


Figure 3. Anomaly Correlation: 500hPa Geopotential Height forecasts from 12Z base time over the Southern Annulus (60S – 20S) for the period 20040203 – 20040420. L29_genSI, the solid line uses quality controlled AMV. GenSInownd, the dashed line with open squares is the equivalent system with winds withheld.

However, when the forecasts out to seven days are verified against their analyses there appears to be no gain in skill. The likely explanation is that these trials incorporated “PAOBS”, the synthetic mean sea level pressure observations created after manual intervention in the analysis over the Southern Hemisphere. The analysts had access to the Quikscat data and thus some information from the data is incorporated implicitly.

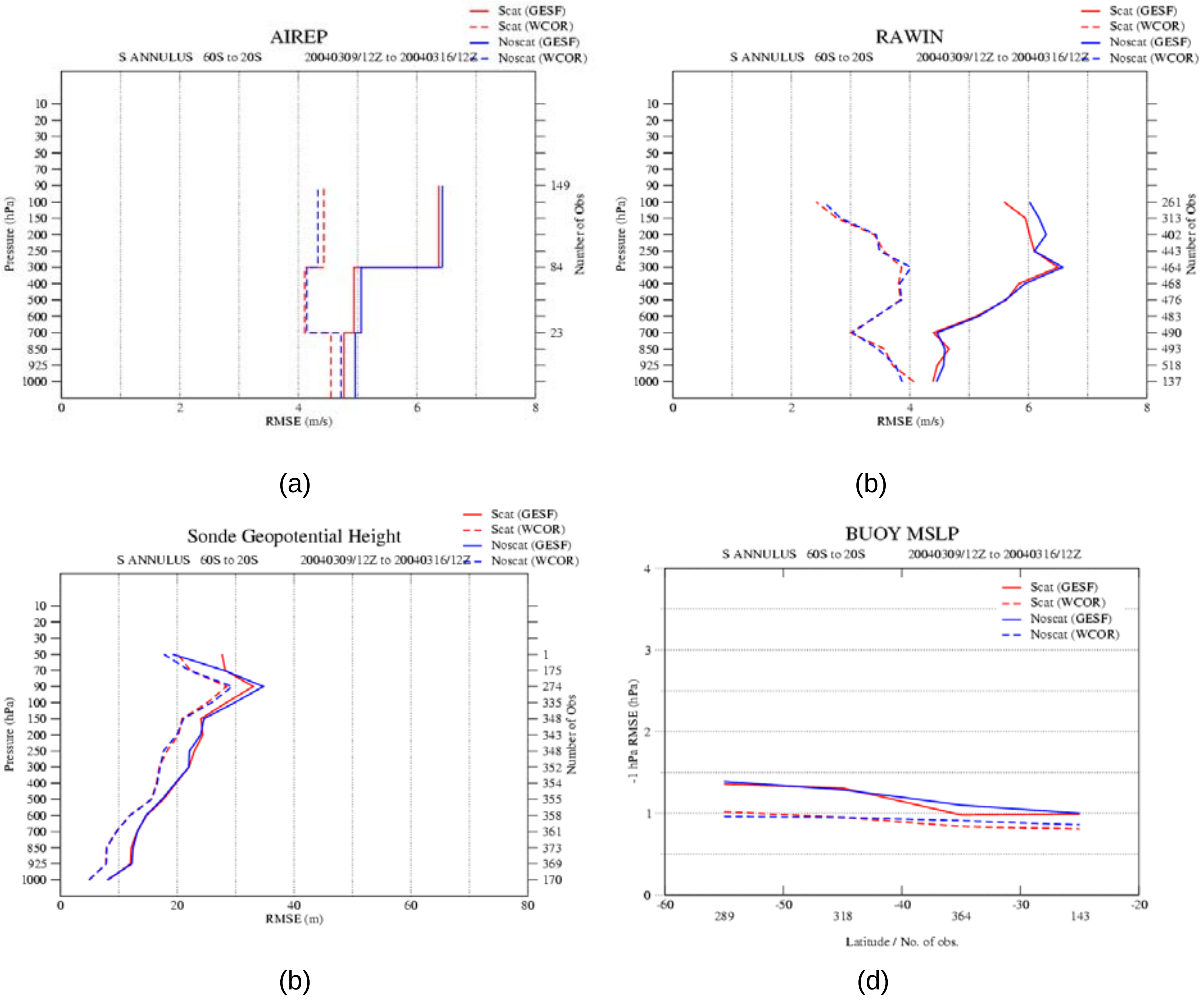


Figure 4. Verification of first guess 6hour forecast (GESF solid line) and analysis (WCOR dashed line), as in Fig. 2 are shown for Scat (the trial with AMV and Quikscat assimilated) in red and Noscat (Quikscat withheld) in blue. 4(a) shows RMS errors against aireps, 4(b) errors against rawin data, 4(c) against geopotential height from radiosondes and 4(d) against mean sea level pressure from drifting buoys.

4. THE REGIONAL SYSTEM

GenSI is also being tested over the Limited Area Prediction System, LAPS (Puri et al. 1998). Trials have been conducted using both Quikscat data and BUFR encoded AMV. Results are shown in Figure 5. Although some gain over the current operational runs were seen when measured by S1 skill score, which is basically a measure of the gradient, a bias in both mean sea level pressure and in geopotential height produced larger rms errors than the current operational system. Gains over the current system are difficult to achieve because the existing system uses locally derived cloud drift winds that are quality controlled and only high quality data is used. If we assume that the data is of similar quality to those used in the GenSI system then Quikscat data may be producing the differences. The matter is currently being investigated.

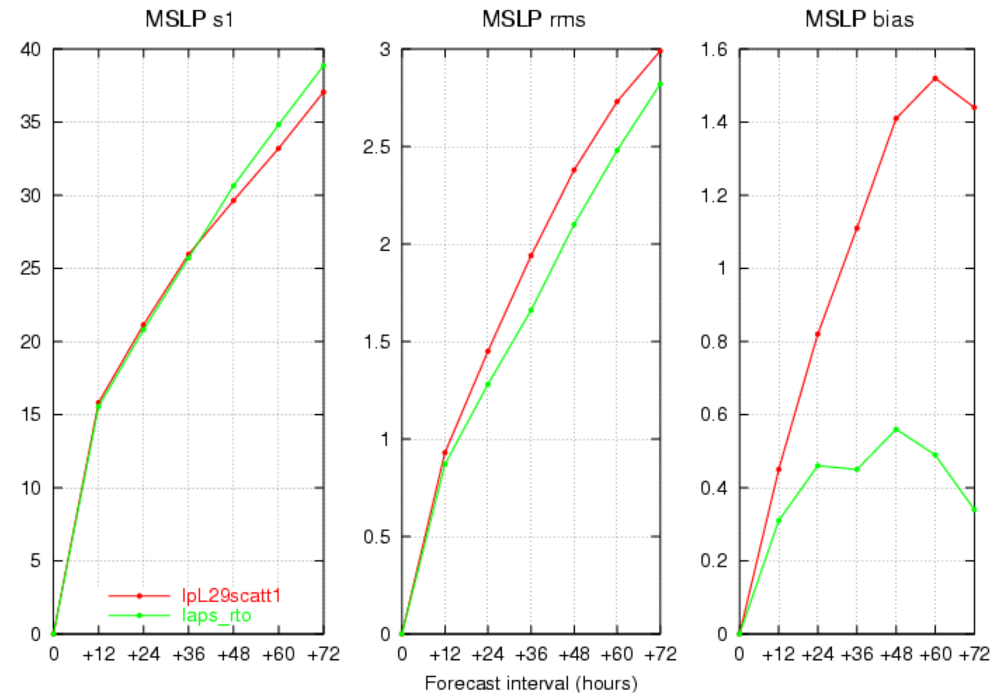


Figure 5. lpL29scatt1 in red is the GenSI trial over the Australian Region using BUFR winds and Quikscat data. Laps_rto in green is the operational run for the same January – February 2004 period. Plots from the left are of S1 skill score, RMS error and Bias for Mean Sea Level Pressure.

5. CONCLUSION

The use of GenSI has allowed the use of larger volumes of data. Over the global domain, assimilation of AMV leads to better analyses over the Southern Hemisphere where there are large areas devoid of conventional data. Forecasts out to seven days benefit from these improved analyses. When Quikscat data are added, there is a small gain in the accuracy of the analysis in the GASP system. Over the limited domain of the regional system a brief trial in which Quikscat data are assimilated yielded results that are inconclusive. Compared to the current LAPS system the trial produced a larger positive bias in MSLP but appears to give a better representation of the pressure gradient. Overall, with careful quality control, the assimilation of AMV and Quikscat data can lead to more accurate analyses and better forecasts.

6. REFERENCES

Holmlund, K. et al. 2001. “Enhanced Automatic Quality Control Applied to High-Density Satellite-Derived Winds”, *Monthly Weather Review*, **129**, pp. 517-529

Seaman, R., et al. 1995. “Evolution of the Bureau of Meteorology’s Global Assimilation and Prediction System. Part I: Analysis and Initialization”. *Australian Meteorological Magazine*, 44, No. 1, pp. 1-18.

Le Marshall, J., et al. 2002 “The estimation of high density atmospheric motion vectors and their application to operational numerical weather prediction “. *Australian Meteorological Magazine*. Vol. 51, no. 3, September 2002. pp. 173-180

Puri, K, et al 1998. “The new BMRC Limited Area Prediction System, LAPS”. *Aust Met. Mag*., 47, 203-223