Use of Level-1d ATOVS Radiances in GASP

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1. Introduction

In this study we show that using level-1D ATOVS radiances derived using the European ATOVS and AVHRR Processing Package (AAPP) in the BMRC Global Assimilation and Prediction (GASP) system can significantly improve prediction performance in both the mid-latitudes, in the Southern Hemisphere and the Tropics. For this project we have implemented the GASP assimilation and prediction systems at a resolution of T239/L60, with the uppermost level at 0.1hPa. We have compared the use of NESDIS level-1d ATOVS radiances as available on the GTS with AAPP derived 1evel-1d radiances as obtained via a direct link to the UKMO. There are significant differences between the two data streams particularly with the AMSU-A brightness temperatures. The UKMO data stream from AAPP provides higher spatial resolution of the soundings and also AMSU-B data, which are not sent as part of the NESDIS product on the GTS. The impact of AMSU-B radiance assimilation within this framework is under investigation, as is the extra provision of AMSU-A data from the AQUA satellite. The integration of globally available AAPP ATOVS radiances with the Australian direct read-out AAPP radiances is being developed to enable a unified treatment of radiance assimilation in both the global and regional assimilation systems used in operations in the Bureau of Meteorology.

2. 1DVAR System

The one-dimensional variational retrieval system (1DVAR) used in both the local and global assimilation systems at the Bureau of Meteorology is based on the ECMWF formulation (Eyre *et. al.* 1993). It performs an iterative retrieval of temperature and moisture at the sounding location using a background first guess, interpolated to the 43 level RTTOV-7 forward model. The temperatures and moistures are converted to thickness and precipitable water layers and the corresponding background and analysis errors are calculated for the same quantities. Following Purser (Purser 1990), the analysed increments and analysis errors are scaled dynamically for each sounding, thus allowing the information content to be reflected in the Optimal Interpolation (OI) analysis (Harris *et. al.* 1999). The radiance bias correction (Harris and Kelly 2001) uses background derived bias predictors and a latitudinally varying scan correction.

3. New 60 Level Model

In order to use AAPP derived radiances without the need for extra information or extrapolation, the operational GASP system with a top at 10hPa had to be extended to 0.1hpa. A previous 50 level model with 5 levels above 10hPa, had severe biases in the stratosphere and problems with dynamic stability. It was decided to construct a new 60 level model with 10 levels above 10hPa, and following some work (G. Roff) on model stability and smoothness of level spacing, a spreadsheet technique was devised to interactively produce plots of δ log σ, which was an extremely sensitive measure of the smoothness of level spacing. Beginning with an initial set of levels, the levels were adjusted by hand to produce the very smooth set of levels according to that measure. Figure 1 shows a comparison between the old 50 level model, the initial guess(gr) and the final set in both σ and δ log σ.

Fig 1(a) σ–level vs level.

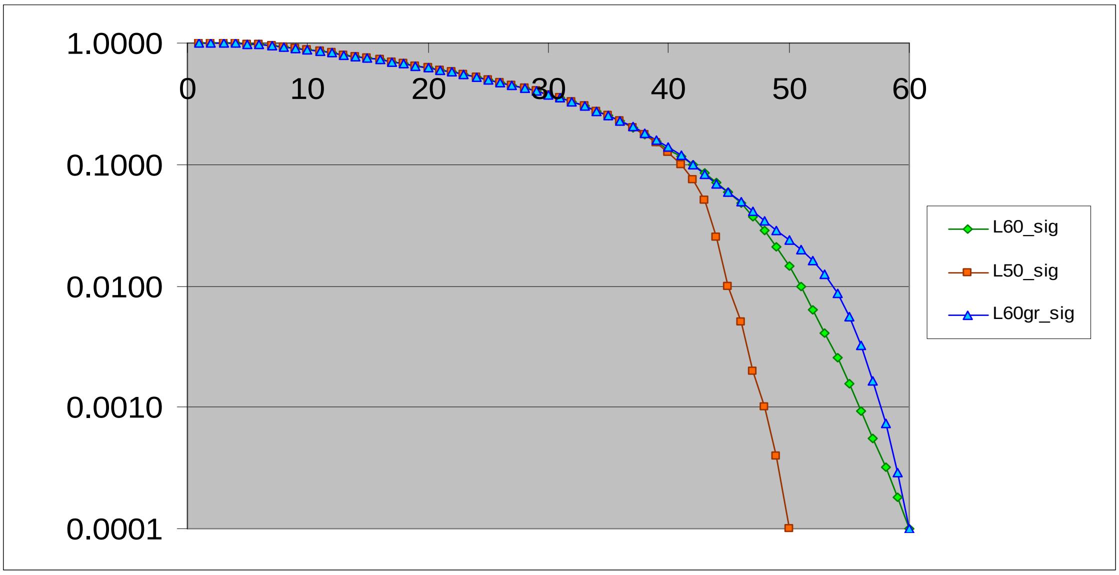
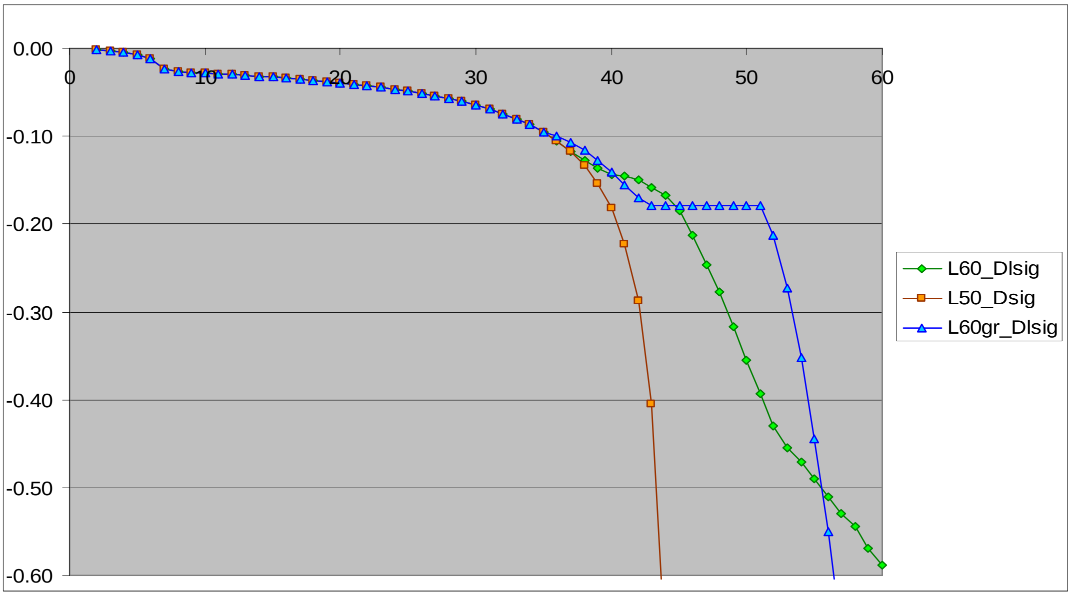


Fig 1(b) δ log σ vs level .



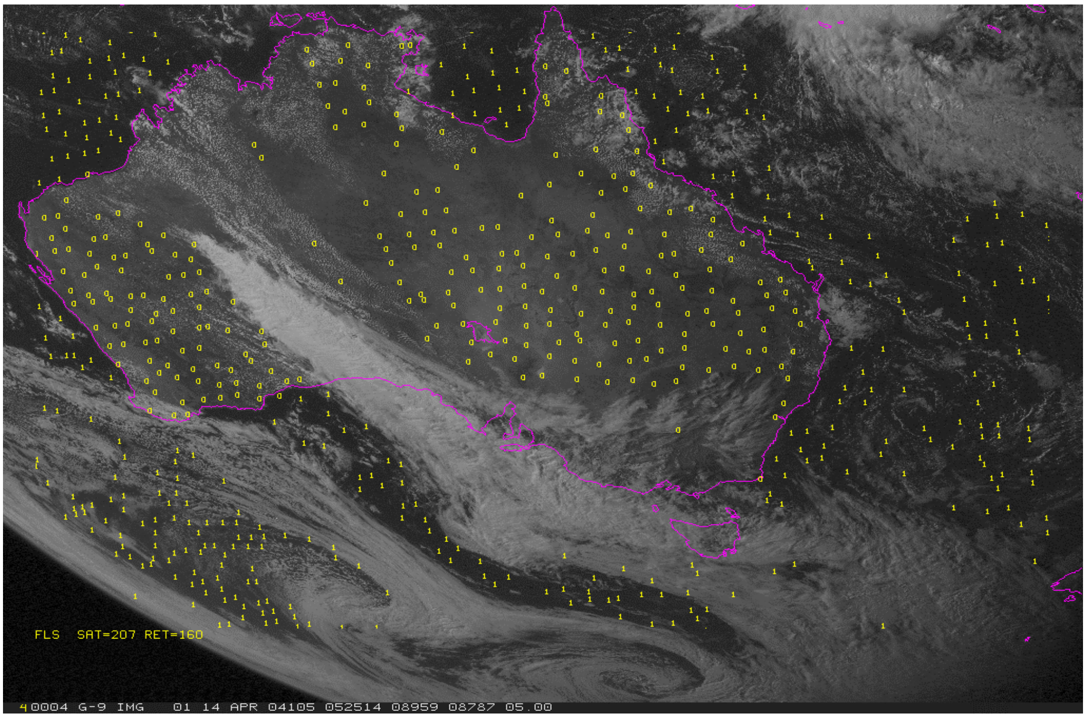
Subsequent trials showed that the new 60 level model was very stable and had much reduced biases in the stratosphere.

4. Comparison between AAPP and NESDIS radiances.

The Bureau of Meteorology has been receiving global AAPP processed level-1d radiances from the Met Office for some time and it is interesting to compare these radiances with those provided by NOAA/NESDIS on the GTS. The NESDIS product comprises both level-1d (AMSU-A mapped to HIRS footprint) radiances and retrievals derived from a database of co-located radiosondes, thinned to 120km resolution. They also contain a cloud detection flag to assist in the use of the HIRS radiances. The operational GASP assimilation system uses the retrieval above 10hPa in the forward calculation and also directly assimilates the retrieval above 100hPa, using the 1DVAR retrieval only below 100hPa.

The AAPP derived radiances do not have any retrieval or cloud information, are at full 30km resolution, and use a different method to map the AMSU-A radiances to the HIRS footprint. Also AMSU-B radiances are provided, which are absent from the NESDIS product. The new 60 level model allows the background to fully specify the first-guess profile, eliminating the need for the retrieval information above the model top, and a –2K window check on HIRS channel 8 is used to detect the presence of cloud. This cloud detection method when applied to the NESDIS radiances agrees with the NESDIS flag 90% of the time, with only 5% called clear when flagged as cloudy. Figure 2 shows the clear radiances detected from NOAA-16 over the Southern Ocean.

Figure 2. Clear HIRS radiances (-2K window check)



When comparing the two radiance datasets it was found that coincident HIRS radiances were identical, but there were significant differences in the remapped AMSU-A radiances. This clearly reflects differences in the remapping algorithms of the processing software. However, when scan bias coefficients are examined for each type of data, it is found that the scan biases are much smaller for the AAPP derived radiances, perhaps indicating a problem with the method used by NESDIS. Figure 3(a) shows a sample of NESDIS brightness temperatures over the Tasman Sea for AMSU-A channel-4 on NOAA-16, and figure 3(b) shows the same, but denser, set of AAPP derived radiances. It can be seen that there are significant differences in the values, especially note the 253.5K value in the NE corner in 2(a) compared to the corresponding 255.6K in 2(b).

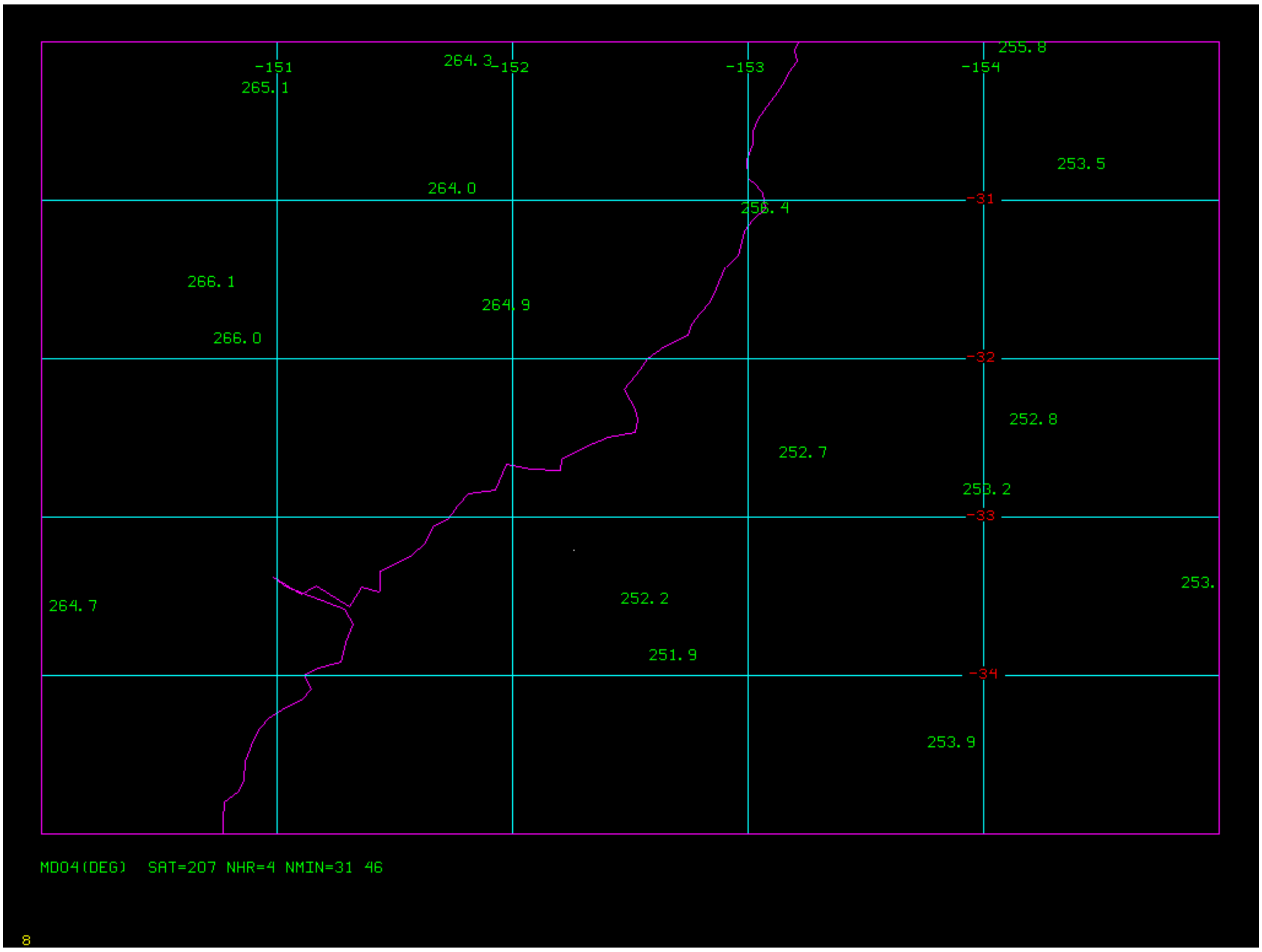


Figure 3(a) NOAA-16 AMSU-A4 (NESDIS)

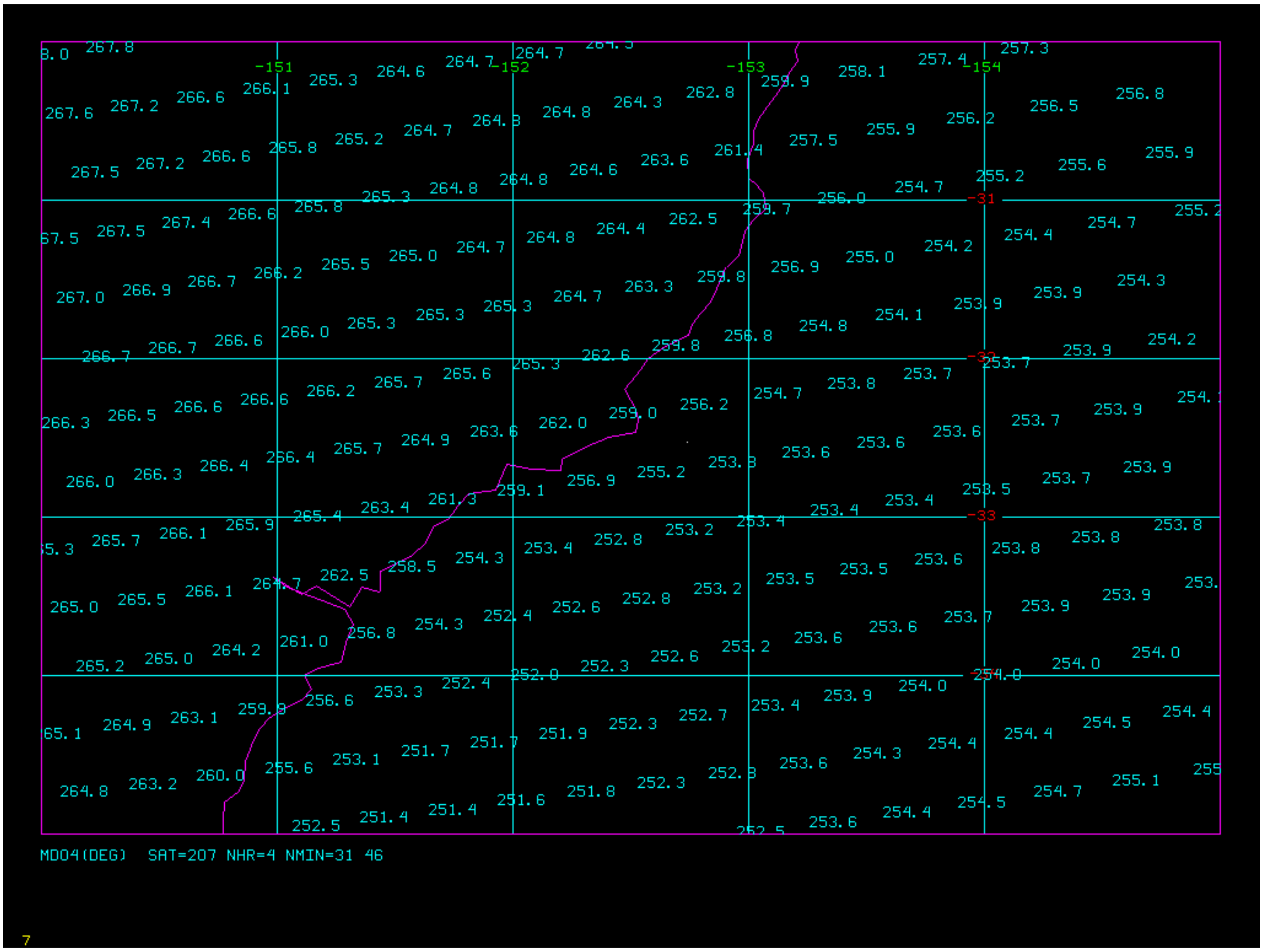


Figure 3(b) NOAA-16 AMSU-A4 (AAPP)

5. Experimental Results

In order to test the use of the different radiance datasets, two T239L60 data assimilation experiments were conducted. In the first experiment, L60_nes, NESDIS radiances were assimilated, but as previously noted, no retrievals were used in the forward calculation. Also due to the improved resolution in the stratosphere, 1DVAR retrievals were assimilated up to 0.4hPa, so that no NESDIS retrievals were used at any stage. AMSU-A radiances from NOAA-15 and both HIRS and AMSU-A radiances from NOAA-16 were used in the experiment.

In the second experiment, L60_1d, AAPP radiances were used in an identical configuration, and in both experiments the 1DVAR retrievals were thinned to the usual optimal resolution of 250km in the OI analysis. In the results that follow, both are also compared to the operational T239L29 GASP system, which uses NESDIS radiances.

Observation fitting statistics were calculated for the six hour first-guess against radiosondes for the three cases. Figure 5 shows the bias and RMS error for geopotential height, averaged over 14 days in September 2004 in the Southern Annulus. Comparing the L60_nes experiment with the operational GASP system shows that the effect alone of extending the model and using only 1DVAR retrievals produces a significant decrease in bias and RMS error. However, when the AAPP radiances are used, the bias is almost completely removed and the RMS error is almost halved again in the upper troposphere. Similar results are also seen in the tropics and northern hemisphere.

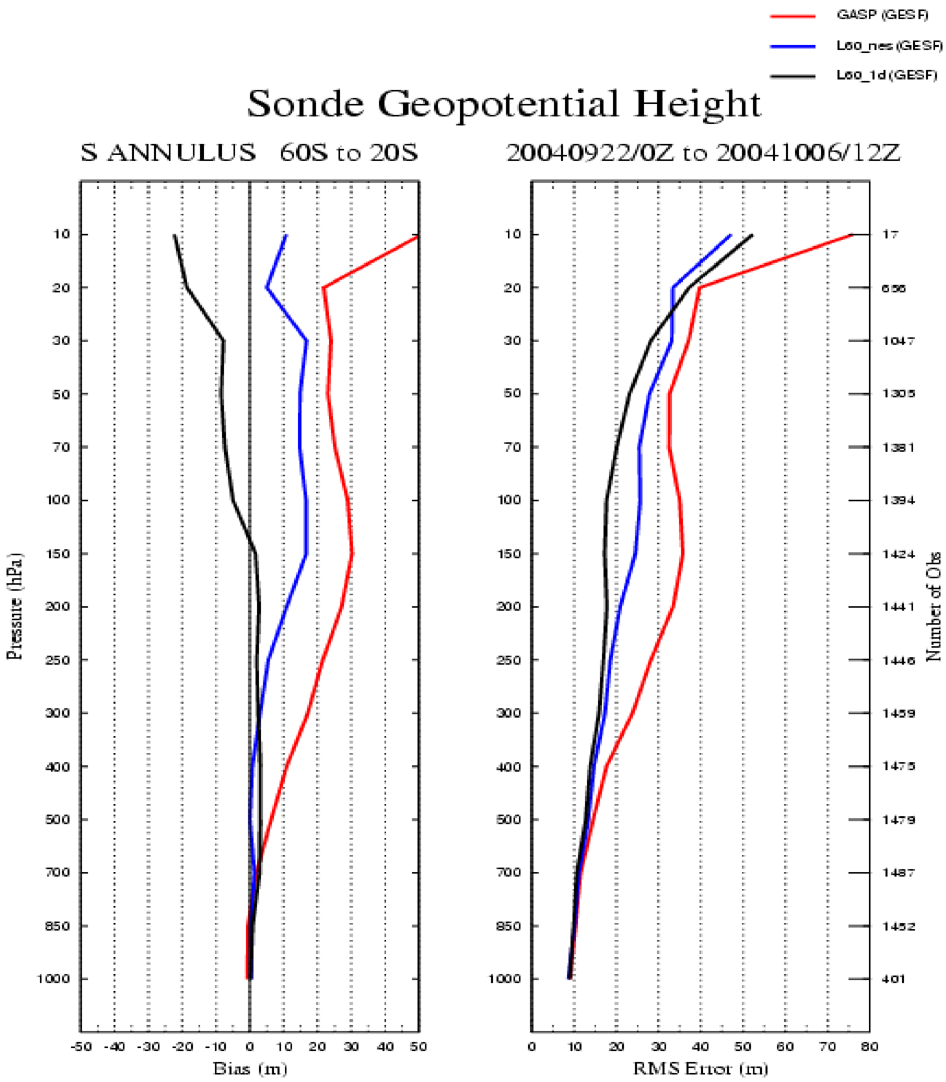


Figure 5. Observed Sonde Geopotential Height minus 6hr First Guess

Forecasts were run over a period of 59 days and verification statistics computed. Overall, both L60 experiments showed significant improvement in the stratosphere, but the L60_1d experiment also showed extra gain over the L60_nes experiment in many regions.

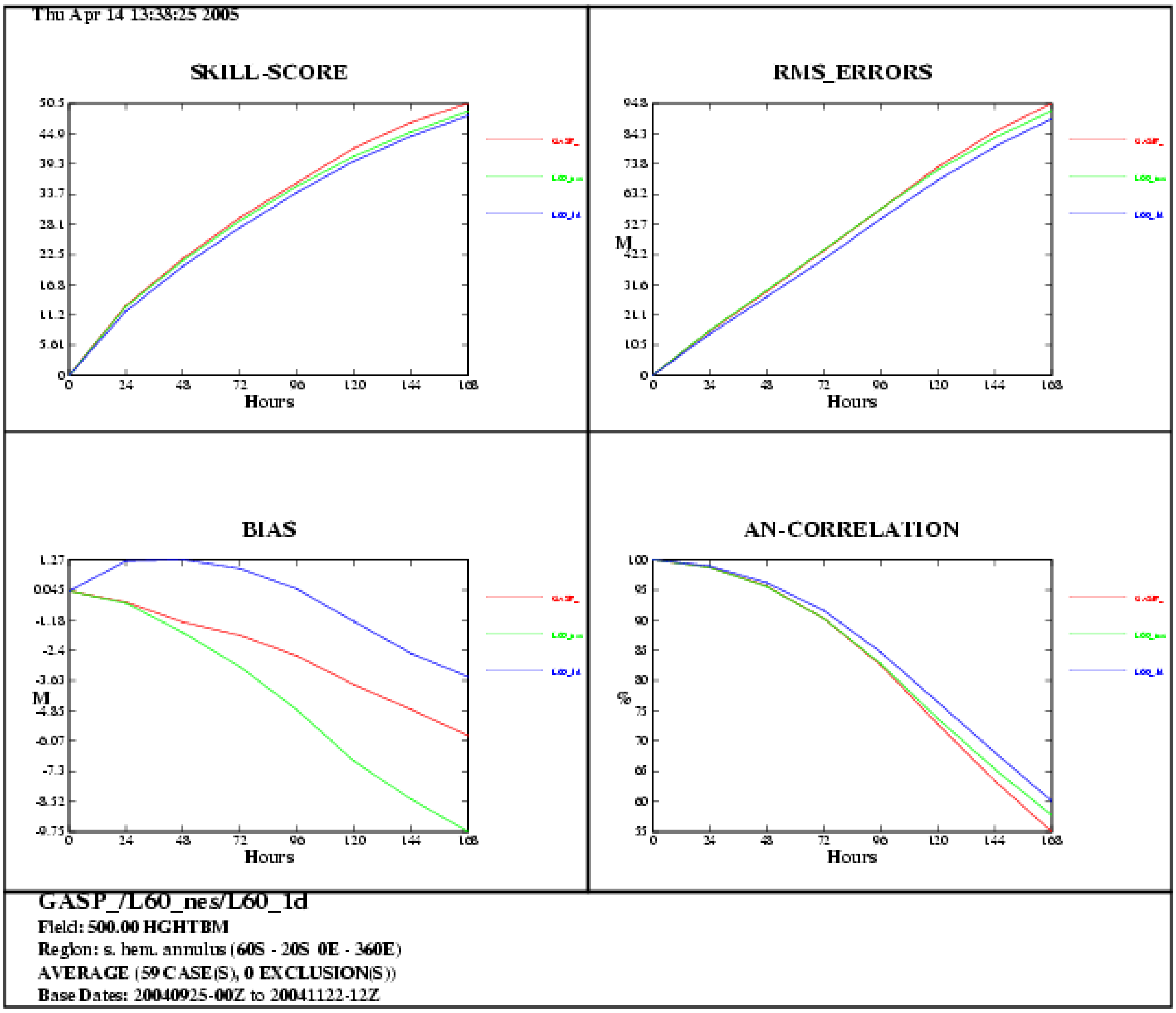


Figure 6. 500hPa Geopotential Verification Scores over the Southern Hemisphere

Forecast skill was improved with the increase in vertical resolution and the removal of NESDIS retrievals, both in the forward modelling process and the actual assimilation, while still using the NESDIS radiances. However, Figure 6 shows that the use of the AAPP radiances has a larger effect. This agrees with the results of the observation fitting statistics. The gain may be due to the different method of mapping the AMSU-A radiances in the two products.

6. Further Work

While the above improvement in forecast skill is to be welcomed, the data stream from the Met Office offers data from the AMSU-B instruments, which is not provided in the NESDIS product. Also HIRS and AMSU-B data is available from NOAA-17 and AMSU-A data is also available from the AQUA satellite. Experiments have been performed using both NOAA-17 HIRS and AMSU-A radiances from AQUA, showing further improvement in forecast skill. The use of the AMSU-B data is a subject of current investigation.

7. Conclusion

The above results confirm that using higher vertical resolution with a model top at 0.1hPa provides a much better background guess profile than the current operational GASP system. This enables the direct use of radiances without the need of extra retrieval information, which allows the use of data from many platforms. Also it appears that the level-1d data, which is produced by the AAPP processing package, is of higher quality than that of the NESDIS level-1d product, possibly related to the microwave mapping methods used.

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