Locally Received and Processed ATOVS Data in the Australian Region LAPS Data Assimilation and Prediction System

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Introduction

The use of 1DVAR retrievals of ATOVS radiances in the Australian Bureau of Meteorology Local Assimilation and Prediction System (LAPS) has produced a modest improvement in forecast skill over that obtained with NESDIS retrievals and represents an important step towards the unification of the data assimilation schemes employed by the Bureau's local NWP system (LAPS) and global system (GASP). The 1DVAR retrieval scheme was implemented in the 29-level operational LAPS system in September 2002, with 1DVAR retrievals used over the sea and below 100 hPa. NESDIS retrievals are used to extend the first guess profiles above the top of the model (50 hPa).

An extended 50-level version of LAPS, with the model top raised to 0.1 hPa and nested within a similarly extended GASP, is being developed to facilitate the assimilation of locally received ATOVS radiances, processed via the AAPP package. The timeliness of local reception and processing should improve the amount of ATOVS data available to the LAPS system which, operationally, employs an early data cut-off. The vertical extension of both models eliminates the need for NESDIS retrievals and promises a fully unified local/global data assimilation system able to handle radiance data, whether received and processed locally or sent from overseas centres via the GTS, equivalently. The results of experiments conducted to date will be presented below.

The LAPS 1DVAR System

In its standard regional configuration, the operational LAPS system covers a domain extending from 65° south to 17° north and from 65° east to 185° east. A tropical version of the system extends further to the north. Gridpoint spacing is .375° and there are 29 sigma levels extending up to a model lid at (nominally) 50 hPa. A number of higher resolution mesoscale implementations of the system are nested within the regional configuration and use the same starting analysis. Operationally, forecasts are run out to +72 hours in the case of the regional system, and +48 hours in the mesoscale systems. LAPS employs a cold-start data assimilation strategy which runs over two 6 hour cycles, beginning 12 hours before the forecast basetime with an analysis based on a GASP first guess, followed by two further analyses based on LAPS 6 hour forecasts. Operational forecast basetimes are 1200 UTC and 0000 UTC. Lateral boundary conditions are supplied from the most recent available GASP forecast (see figure1.) Because of the requirement to deliver a timely forecast product, the operational system employs a +1 hour data cut-off at the forecast base-time.

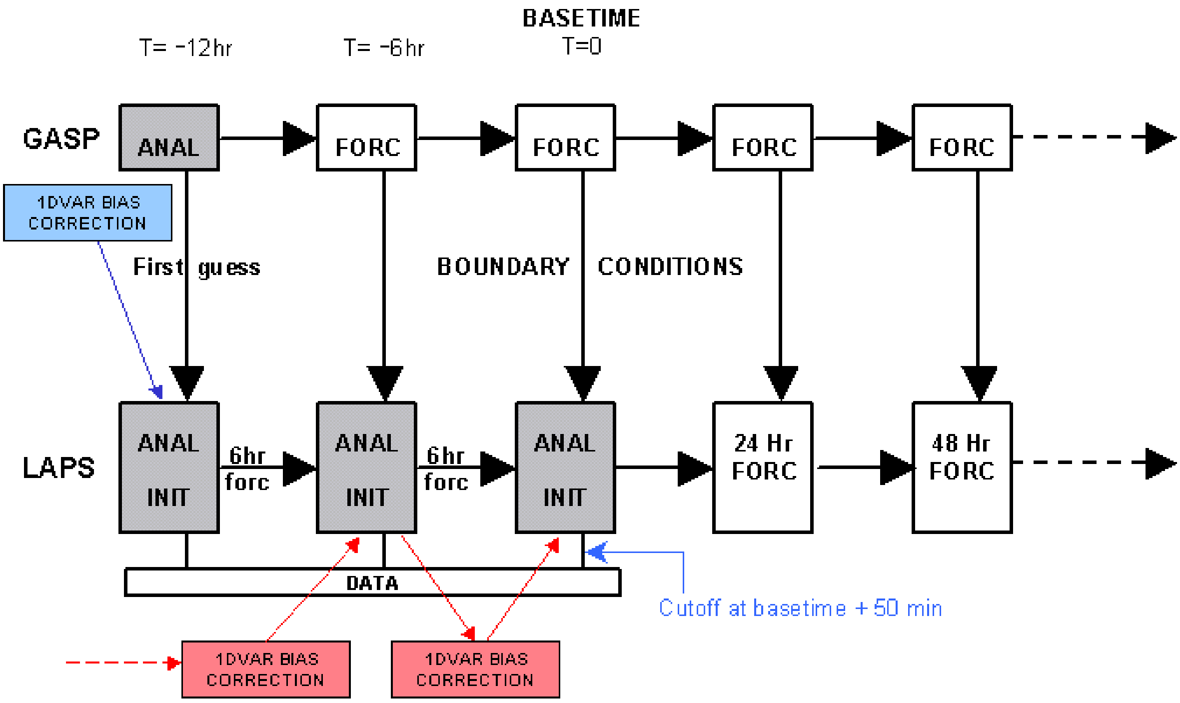

Fig 1: Schematic representation of a LAPS assimilation-forecast cycle

The GASP 1DVAR scheme (Harris and Steinle 1999) was implemented in the LAPS data assimilation cycle with few modifications (Tingwell et al. 2002). The input consists of the NESDIS ATOVS product supplied to the bureau via the GTS. The system computes retrieval error covariance and applies dynamic Purser type scaling (Eyre et al. 1993) to each retrieval which is presented to the OI analysis system in the form of four 1DVAR thickness layers (below 100 hPa) and three precipitable water layers (below 300 hPa). NESDIS thickness layers are used above 100 hPa. NESDIS retrieved temperatures are also used to extend the first-guess profile above the top of the model for use in the forward calculation. Air-mass dependent radiance bias predictors are computed from the first guess (Harris and Kelly 2001). In the LAPS implementation of the scheme, bias predictors generated in the GASP system are employed for the first T - 12 hour retrieval, while the subsequent retrievals, based on LAPS first guesses, employ separate predictors generated by the LAPS system.

Recent Operational Developments The 1DVAR assimilation of ATOVS AMSU-A radiances from NOAA-15 and HIRS and AMSU-A radiances from NOAA-16 was implemented in the operational LAPS suite in September 2002. Pre-implementation trials demonstrated that the system was robust and produced modest positive impact on forecast skill compared to an otherwise identical system that assimilated NESDIS retrieved temperature and moisture profiles (Tingwell et al. 2002). For example, S1 skill scores for 48 hour forecasts of 700 hPa geopotential height typically improved by 0.6 – 0.7 points.

More recently, the 1DVAR system was modified to use the forward model RTTOV 7 (replacing RTTOV 6), thus enabling the assimilation of HIRS and AMSU-A radiances from NOAA-17. This change was implemented operationally in the GASP system in February 2003 and in the LAPS suite in June 2003. Results from one month parallel testing trials showed that in both systems the impact of this change on forecast skill has been neutral.

Current Developments in GASP/LAPS Assimilation

Recent research has focused on the development of a generalized multivariate statistical interpolation scheme (GenSI) which is a major extension of the current operational Optimal Interpolation (OI) based system. This scheme is posed in observation space to allow for more flexibility in the specification of the background error covariances and solves the analysis equation iteratively by a preconditioned conjugate gradient method. It supports both the Australian region and the global domain NWP systems, and allows large volume data selection and the use of extensive data types and improved quality control. It can be readily extended to support 3D radiance assimilation. The software has been implemented to execute both in shared memory and distributed memory computing architectures.

Parallel trials of the GenSI scheme in both LAPS and GASP have demonstrated a marked improvement in the skill of forecasts based on GenSI analyses over those based on OI analyses. Figure 2 shows the average self-verified MSLP S1 skill score, RMS error and bias for a month of LAPS forecasts based on GenSI analyses (red lines) and OI analyses (green lines). The scores were calculated on a standard verification grid covering the most observation-rich part of the LAPS domain. The GenSI based forecasts were nested within boundary conditions which had been generated from GASP forecasts also based on GenSI analyses. There is clear improvement in forecast skill with the GenSI scheme, increasing with longer forecast intervals to a gain of 2.4 S1 points at +72 hours. RMS errors are also improved and similar gains are seen throughout the vertical domain of the model.

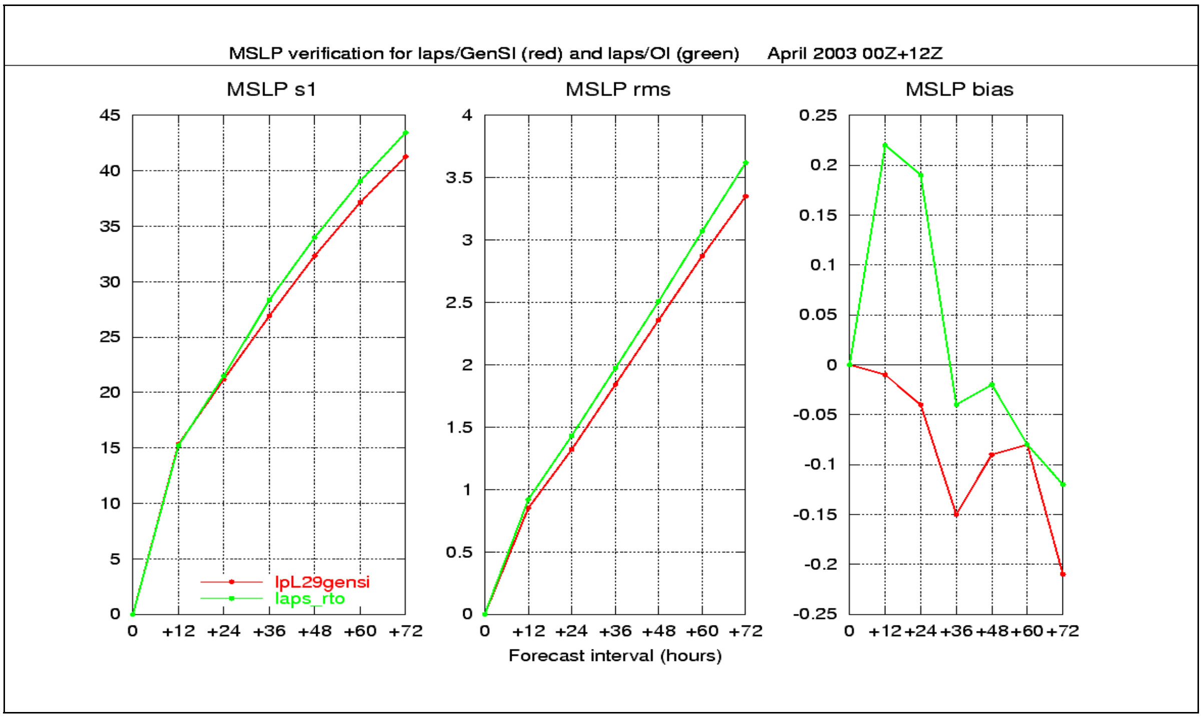

Fig 2: Average MSLP S1 skill score, RMS error and bias for a month of LAPS forecasts based on GenSI analyses (red lines) and OI analyses (green lines). The trial period was April 2003.

A particularly attractive feature of the new scheme is that it provides a single model-independent executable program file which may be used for all configurations of both the global and regional NWP models and thus represents a significant step towards the goal of a fully unified local/global data assimilation system. It is planned to implement GenSI operationally in the first half of 2004.

The Need for Locally Received and Processed ATOVS Radiances

The operational LAPS suite employs an early observational data cut-off (approximately an hour after the forecast base time) to ensure timely generation and dissemination of forecast products. Therefore, timeliness of access to ATOVS data is crucial to the quality of the analyses. Figure 3 shows the NESDIS ATOVS data coverage typically available to the operational LAPS system via the GTS at each of the three analysis times of the cold-start assimilation sequence. For comparison, the data available to the later cut-off GASP system at the corresponding times is shown beneath. We anticipate that the availability of locally received and processed ATOVS level-1D radiance data to the LAPS assimilation system will significantly improve the situation with regard to the final analysis.

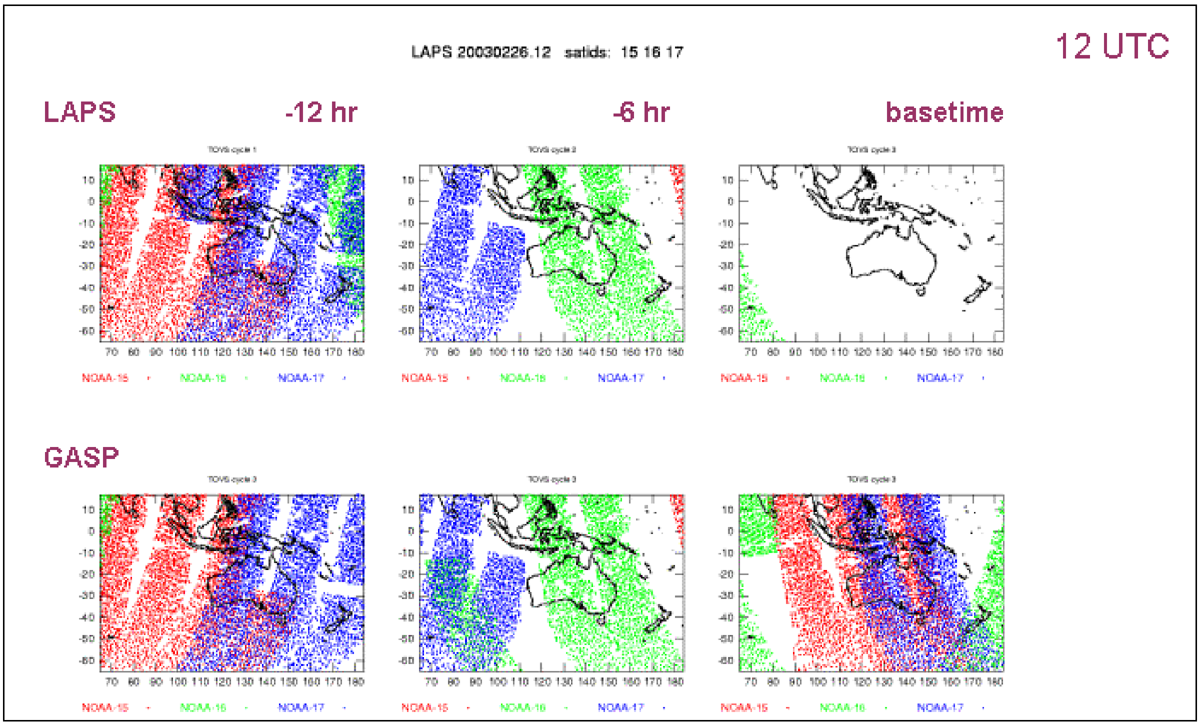

Fig 3: Comparison of ATOVS data coverage in the GASP and LAPS systems for the three analysis times in a LAPS assimilation cycle. Red points represent NOAA-15, green points NOAA-16 and blue points NOAA-17.

To facilitate the assimilation of local radiance data, we have extended the vertical domain and increased the number of vertical levels to 50 in both LAPS and GASP: the new level distribution is plotted in figure 4 alongside the current operational 29 level distributions for both LAPS and GASP. With the 50 level configuration the model lid (nominally 0.1 hPa) is higher than the top level required in the forward model and thus a purely model based first guess may be used in the forward radiance calculation. The need for NESDIS retrieved temperatures to extend the first guess profile is therefore dispensed with and so radiance data unaccompanied by retrieval information (such as locally received radiances) may be assimilated by the 1DVAR system.

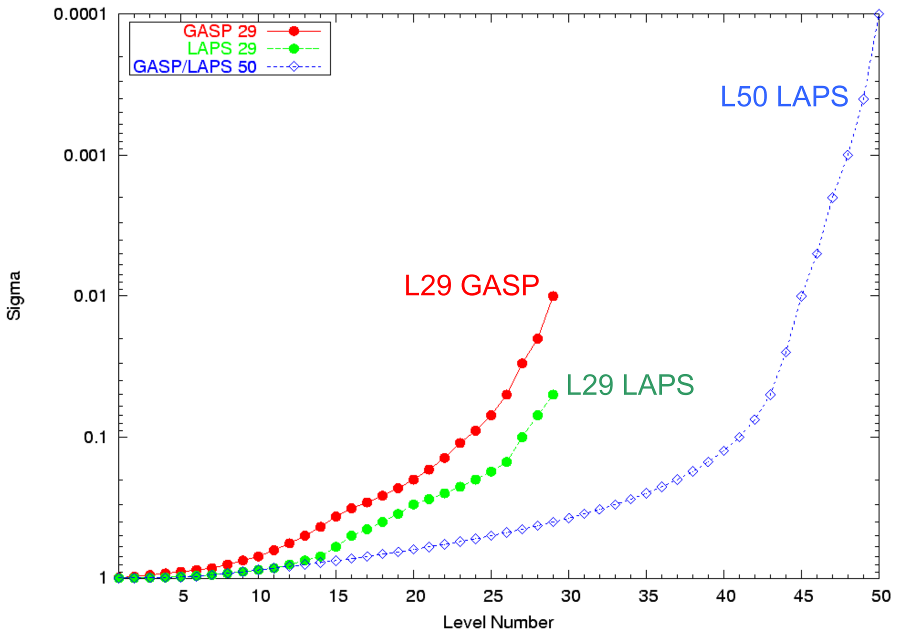

Fig 4: The new 50 level distribution plotted alongside the current operational 29 level distributions for both LAPS and GASP

Trials of 50 Level Systems

We have begun a series of trials of the 50 level configurations of both GASP and LAPS to test the performance and robustness of the models under the new configuration. To date only NESDIS radiance data has been assimilated in these trials. Initial and ongoing trials of the GASP system with the proposed 50 vertical levels and a comparatively low (T79) horizontal resolution (Harris et al. 2002) demonstrated both robust model performance and improved forecast skill with both OI and GenSI analysis schemes. Extension of these trials to the full operational horizontal resolution of T239 required some adjustment of the stratospheric model dynamics – in particular the introduction of Rayleigh friction and an increase in horizontal diffusion – in order to dissipate stratospheric noise. The model time-step was also reduced to avoid occasional CFL violations. With these modifications the T239L50 configuration of GASP, employing GenSI analysis, has run reliably for trial periods of more than one month.

Forecast verification results are shown in figure 5 in which S1 skill score, bias, RMS error and anomaly correlation data are plotted for MSLP and 200 hPa geopotential height. Data for the T239L50 trial are shown as solid lines and that from the corresponding period for the operational T239L29 configuration are shown as broken lines. The verification data shown were calculated for the Australian region and the trial period was April 2003. We note that the impact of the vertical extension to GASP on forecast skill is essentially neutral in the Australian region over the forecast period required to provide boundary conditions for LAPS. Our trials of the 50 level configuration of LAPS have therefore been nested within boundary conditions provided by the T239L50 GenSI GASP system.

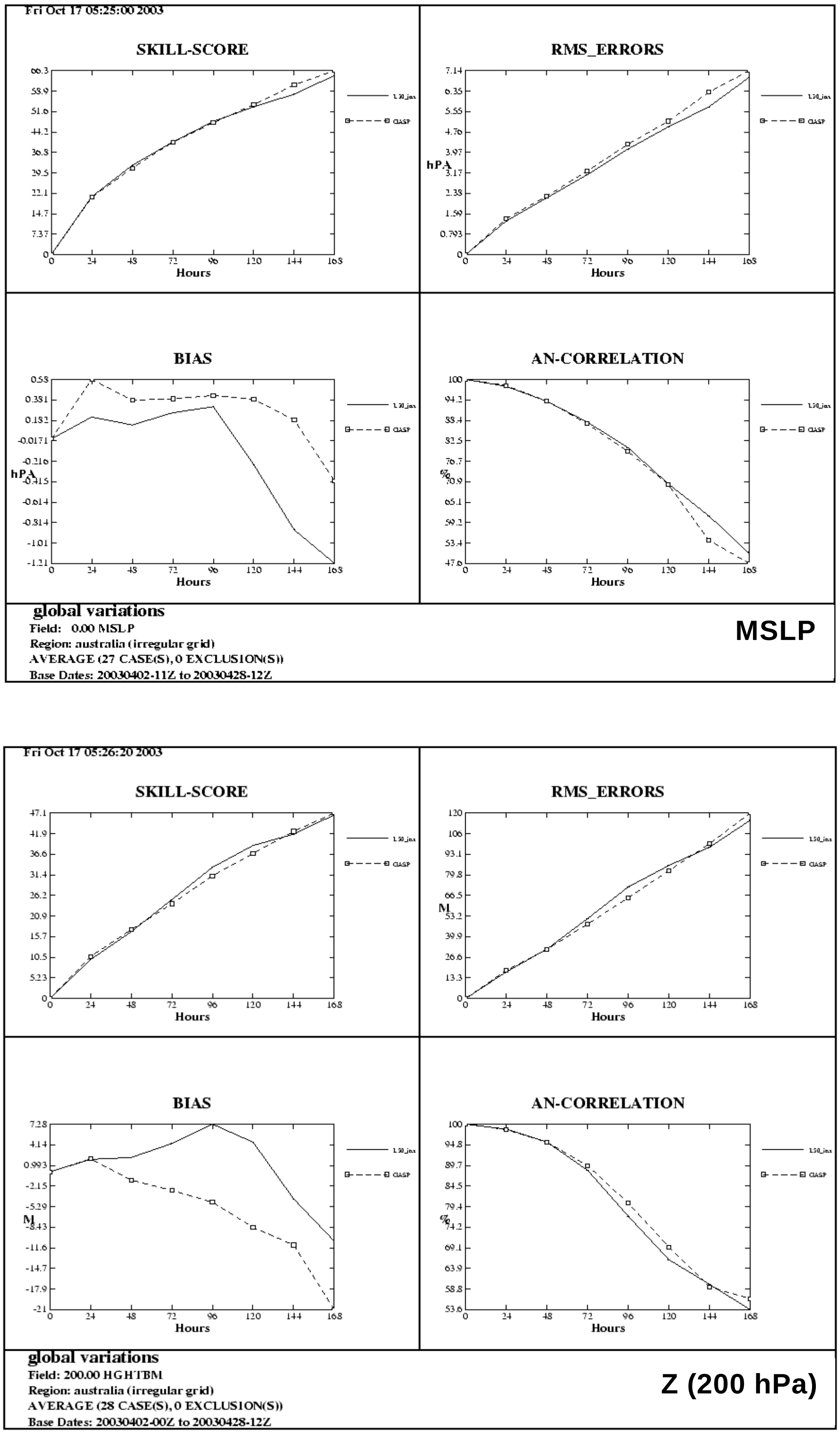

Fig 5: S1 skill score, bias, RMS error and anomaly correlation data, plotted for MSLP and 200 hPa geopotential height. Data from the GASP T239L50 trial are shown as solid lines and that from the corresponding period for the operational T239L29 configuration are shown as broken lines.

Verification results for a preliminary two week trial of the 50 level configuration of the LAPS system are shown in figure 6 (red lines) and compared to results from the operational 29 level configuration of

LAPS calculated for the same period (green lines). Both configurations used GenSI analysis. Shown are S1 skill score, RMS error and bias for MSLP and geopotential height at 500 hPa and 200 hPa, calculated on the standard verification grid. These results indicate modest gains to forecast skill in the upper troposphere with the extension of LAPS to 50 levels.

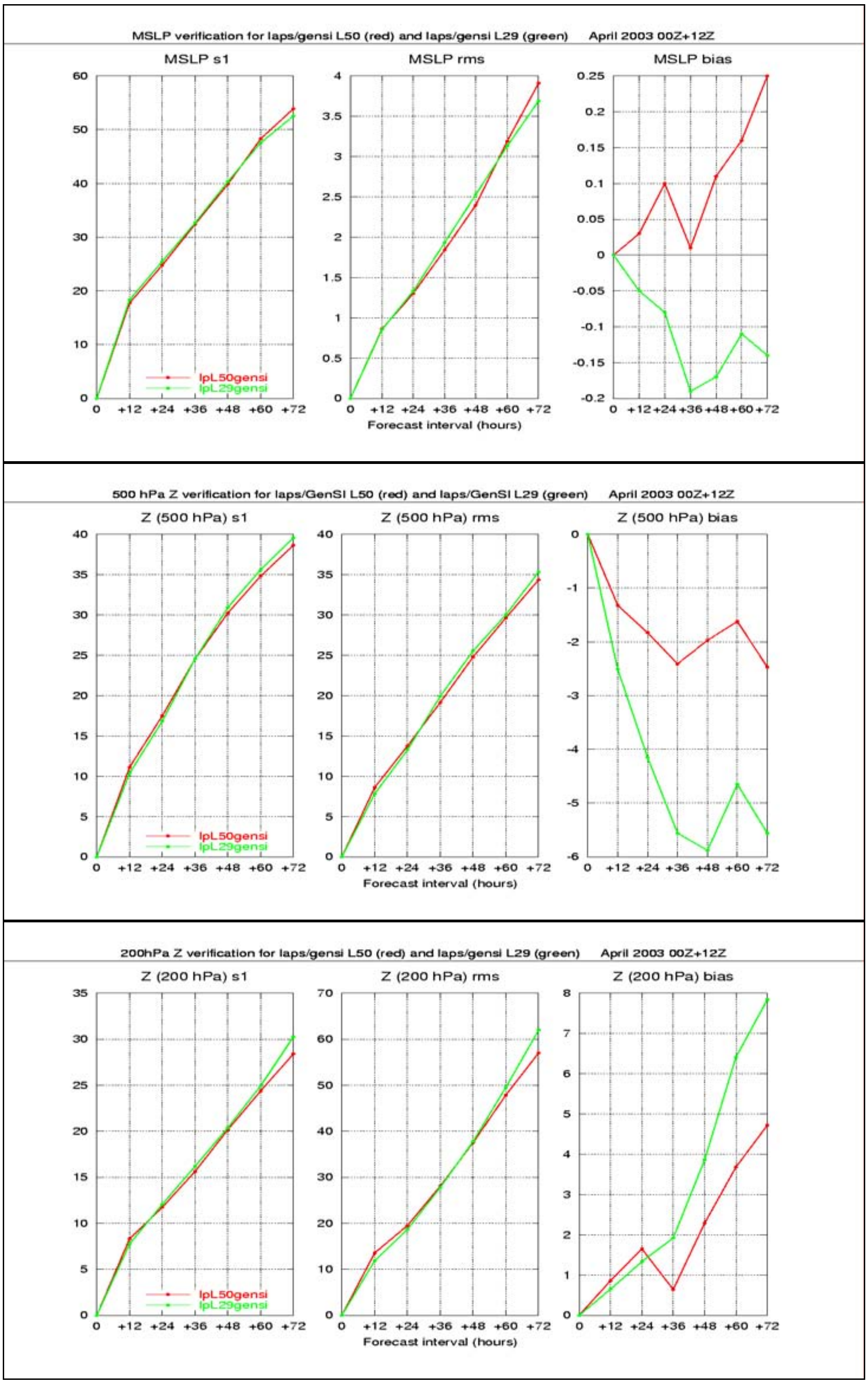

Fig 6: S1 skill score, RMS error and bias for MSLP and geopotential height at 500 hPa and 200 hPa for the 50 level configuration of the LAPS system (red lines) and the 29 level configuration (green lines).

Summary and Future Plans

Preliminary results from tests of the 50 level GASP and LAPS configurations are encouraging, although there may well be further work to do to optimise the stratospheric model dynamics, radiation physics and cloud microphysics. A robust 50 level configuration of GASP and LAPS will then form the basis for testing the 1DVAR assimilation of locally received ATOVS radiances.

The system we envisage for the reception and processing of ATOVS radiance data is shown schematically in figure 7. Current work towards the operational implementation of local reception and processing of radiance data by the Bureau of Meteorology Space Based Observations Section is nearly complete. Data will be processed via AAPP to level 1D, encoded into BUFR format and stored in the Bureau's Real Time Database. It is also planned to receive global ATOVS radiance data from the Met Office, also processed via AAPP to level 1D. These data sources will then provide the input to a fully unified 1DVAR system for GASP and LAPS which will assimilate local and remotely processed ATOVS radiances equivalently, regardless of source.

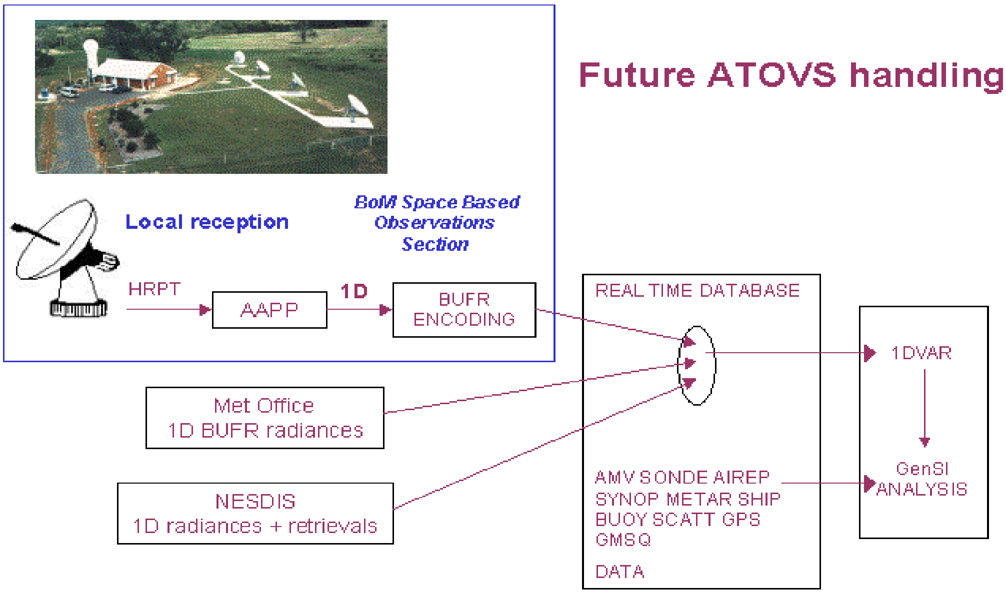

Fig 7: Schematic diagram of the reception and processing of ATOVS radiance data.

NESDIS radiance data will continue to be received and utilised, although its optimal use in combination with data processed via AAPP, and the possible cross-calibration issues that may arise, will require investigation. We also plan to extend the 1DVAR system to assimilate AMSU-B data in the near future. A longer term goal is the production of a unified 3DVAR GASP/LAPS assimilation system.

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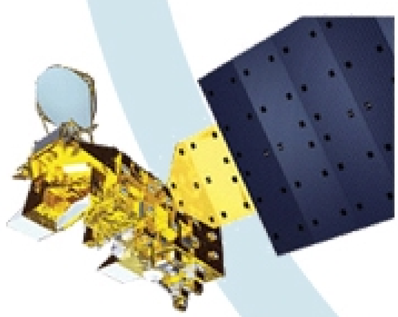

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