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STATUS AND RESULTS OF OSEs

Testing and use of AIRS radiances at ECMWF

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Summary and Purpose of Document

This document briefly describes the OSEs undertaken by ECMWF and their results with a view to the early operational use of the AIRS radiances.

ACTION PROPOSED

The meeting is invited to take into account information contained in this document when discussing the status and results of OSEs.

DISCUSSION

Introduction

1. Radiance observations from AIRS and AMSU-A on AQUA have been received at ECMWF in near real-time since October 2002. As a result of a significant amount of preparation (both technical and scientific) carried out prior to launch using simulated observations, monitoring of the real AIRS radiances started almost immediately after the arrival of the data. The monitoring quickly indicated that the AIRS instrument was very stable, well calibrated and consistent with the expected spectral characteristics. Furthermore, the cloud detection scheme and radiative transfer model (developed before launch) were found to work very well applied to the real AIRS data.

2. The early validation of these two key elements allowed an initial set of 4D-Var assimilation experiments with AIRS to begin. These were performed at lower (T159) resolution and were aimed at establishing the best configuration of the AIRS data usage that could then be tested rigorously at full (T511) resolution. The result was a fairly conservative usage of the AIRS data avoiding parts of the spectrum susceptible to solar contamination and channels sensitive to ozone and surface emission over land. A very simple bias-correction scheme and observation error model were also derived and the data thinned to a horizontal separation of 120 km.

3. The above configuration was then tested at full resolution over the period December 2002 to March 2003 (a total of 100 cases) to gauge the meteorological impact of the AIRS radiances. It was found that the assimilation of AIRS caused a small but consistent reduction in the size of analysis increments near radiosonde locations, and modestly improved the quality of forecasts. These results were sufficiently encouraging that the assimilation of AIRS was included in the operational implementation of the forecasting system upgrade 7 October 2003. Work continues to extend and improve all elements of the initial (conservative) AIRS assimilation scheme and realize more of the potential of this impressive instrument.

Preparation phase

4. The NASA AQUA spacecraft was launched in May 2002 and a subset of radiance data from the AIRS instrument (324 channels from 2378 at 1 sounding location out of 18) have been made available to ECMWF in near real time (NRT) since the end of October 2002. Prior to this date a significant amount of technical development was achieved using simulated AIRS data sets routinely provided by NOAA/NESDIS and some early scientific validation was also performed using a pre-released “focus-day” of data (for 24 August 2002). As a result of this preparation, the processing (i.e. cloud-screening and monitoring) and assimilation impact experiments were able to commence almost immediately following the arrival of the real AIRS data.

Assimilation configuration for AIRS radiances in 4DVAR

5. Following a reasonably comprehensive set of experiments carried out over a one month initial trial period in October/November 2002, an initial configuration for the use of the AIRS radiances in the ECMWF 4D-Var data assimilation system was selected, the key elements of which are summarized below:

- Input radiance data consists of sampled 1/18 locations and 324/2378 channels;
- No assimilation of channels in the O_3 or 4.2 micron band (approximately 100 of the 324 channels);
- Over sea all channels flagged clear (including window channels) are assimilated;

- Over land only long-wave channels peaking above approximately 400 hPa are assimilated;

- Soundings are thinned to a horizontal spacing of 120 km preferentially retaining the clearest;

- Flat (single global number rather than varying) bias correction used for each channel;

- Simple observation error assigned to different blocks of channels (0.6K for dry tropospheric temperature channels away from the surface and stratopause, 1.0K for stratospheric temperature sounding channels and 2.0K window channels and channels sensitive to water vapour).

6. The testing that led to this configuration considered a variety of performance measures including the size of analysis increments, the fit to other observations and forecast impact. The configuration selected is by no means optimal, but rather represents a reasonably safe *baseline* system that could be tested as a candidate for day-1 operational implementation. Many of the data excluded from this configuration clearly convey valuable information, but were considered higher risk options until further work on elements such as cloud detection, modelling land surface emission, ozone and solar radiation could be done. The observation errors are similarly set to conservative levels. While these almost certainly overestimate the true observation errors, no account has currently been taken of inter-channel error correlations and thus some degree of inflation is justified.

Forecast impact

7. Forecasts have been run from the analyses that assimilated AIRS radiances and compared to those from the CTRL system. Figure 1 shows forecast error difference maps (AIRS minus CTRL) for 500 hPa height, each system verified using its own analyses and averaged over the first 50 cases of the trial. Blue shading indicates where the AIRS forecasts are better and yellow where they are worse than the CTRL. It can be seen that the assimilation of AIRS has reduced forecast errors at all ranges. The impact is first seen in the short-range (day-3) forecast of the Southern Hemisphere and then in the day-5 forecasts of both hemispheres. The positive signal increases with increased forecast range for the Northern Hemisphere, but becomes marginal beyond day-7 in the Southern Hemisphere (where the situation appears to be more a mixture of good and bad forecasts). No signal is seen in the tropics, but this is due to the choice of forecast variable (i.e. Z500). A positive impact of the AIRS upon the forecasts of tropical temperatures is shown below.

8. Figure 2 shows a larger sample of forecast comparisons (100 cases) displayed as four area-averaged mean forecast scores for 500 hPa geopotential height. However, it should be noted that these have been computed using the operational/CTRL analyses for verification, a choice that may slightly penalize the AIRS system. It can be seen that averaged over 100 cases there is a very small, but very consistent improvement at all ranges in the Northern Hemisphere (the improvement is statistically significant at the 1% level for day-5). For the European area (imbedded in the Northern Hemisphere statistics) the positive impact is marginally clearer, but less significant. In the Southern Hemisphere, only a slight improvement is seen at day-3 (significant at the 5% level) and beyond this no improvement is seen over the CTRL (the negative impact at day-10 was not found to be significant < 10%). The verification of temperature forecasts from the two systems is generally consistent with the height results in the mid-latitudes, but they additionally show a positive impact of the AIRS in the tropical temperatures at 200 hPa (see figure 3). The same statistic for the southern hemisphere shows larger RMS errors when AIRS data are used, but a closer investigation indicates a large systematic difference between the AIRS and CTRL analyses, localized to the edge of the Antarctic continent and not evident at any other level than 200 hPa.

Summary of results

9. The assimilation of AIRS radiances with the baseline system described here shows no adverse effects in the analysis (in terms of the fit to other observations) and slightly reduced analysis increments at radiosonde locations. Overall, the forecast performance of the baseline AIRS assimilation scheme is encouraging, essentially showing a consistent positive impact in most areas and parameters. However, averaged over the 100 cases the impact is small and warrants some discussion. The assimilation configuration is clearly conservative and a variety of further enhancements (many of which are already being tested) has been suggested. However, large improvements over the CTRL may also be limited by the quality of the CTRL system itself. The average level of forecast skill for the CTRL (that currently uses radiances from 3 AMSUA, 2 HIRS, 3 GEOS and 3 SSM/I instruments) is very high and over the period tested was significantly better than forecasts from any other NWP centre. Furthermore, a time series analysis of forecast skill shows that the CTRL system produces very few poor forecasts or “busts”. During the 100-day trial, **no** day-5 forecasts of 500 hPa height scored less that 60% anomaly correlation averaged over either of the hemispheres. Verified over the much smaller European area, still only six day-5 forecasts from the CTRL scored worse than 60%. In four of these cases, the AIRS system improved the forecast by 10% or more (4 AIRS forecasts scored worse than 60% over the period, but the CTRL was never 10% better). Most of the cases where AIRS improves the poor forecasts correlate with when adjoint sensitivity perturbations to the initial conditions (rather than “forced” perturbations) were found to have a large effect. However, the improvements are far less dramatic than those achieved (retrospectively) by the sensitivity perturbations. Usually, cloud was found to obscure many of the sensitive locations (resulting in very few tropospheric AIRS radiances being used). In the one case that was relatively clear (24 Feb. 2003), it appeared that the some of the analysis increments due to AIRS did correlate with the sensitivity perturbations, but many did not. Overall, it is difficult to argue that the assimilation of AIRS is dramatically fixing bad forecasts on any regular basis. It appears more that the assimilation of AIRS (with the current configuration) is having a small, but relatively consistent positive impact upon the forecast skill.

Acknowledgement

The work reported in this document was performed in the ECMWF Satellite Section, in particular by Tony McNally, Phil Watts and Jonathan Smith.

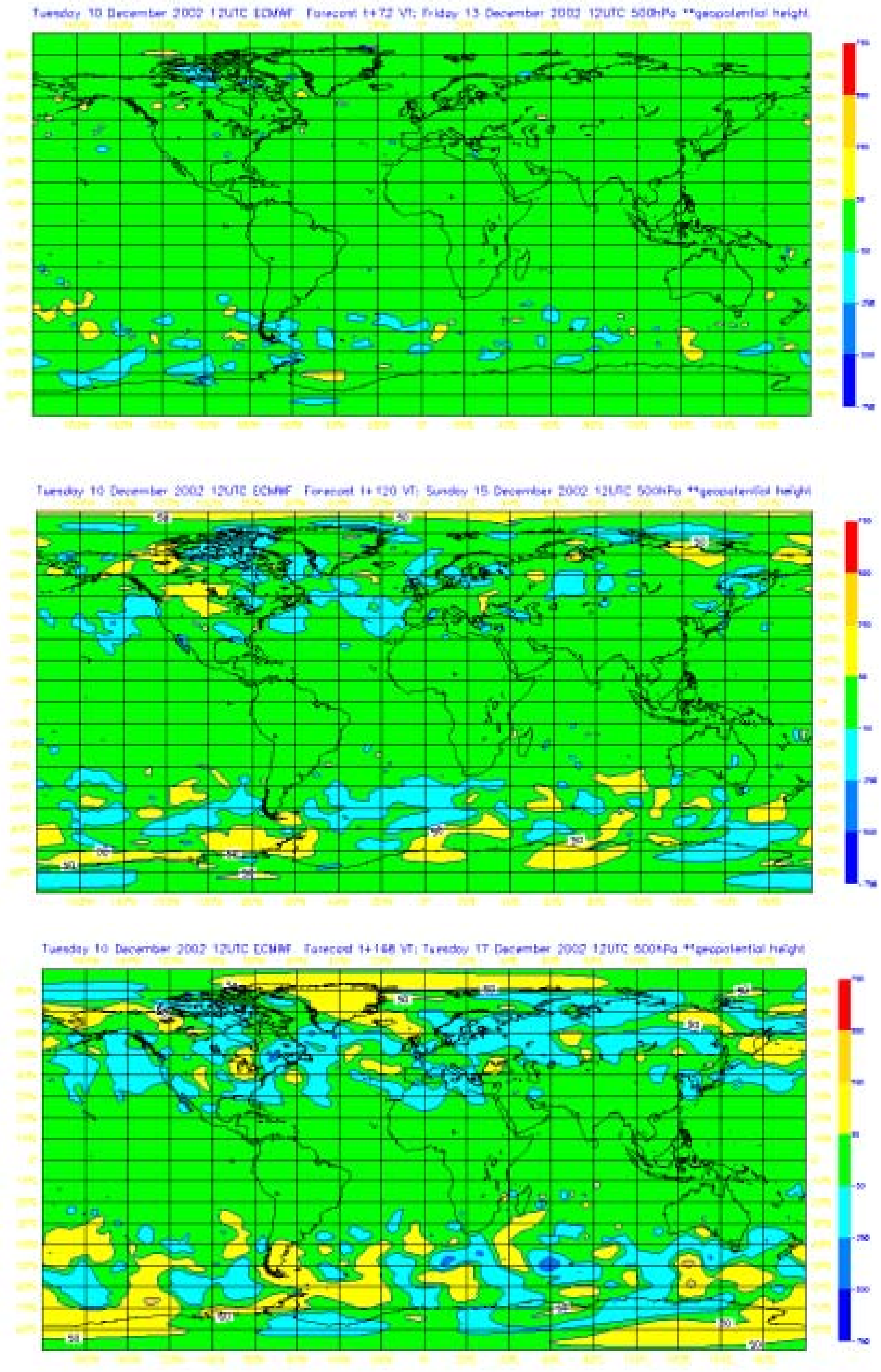
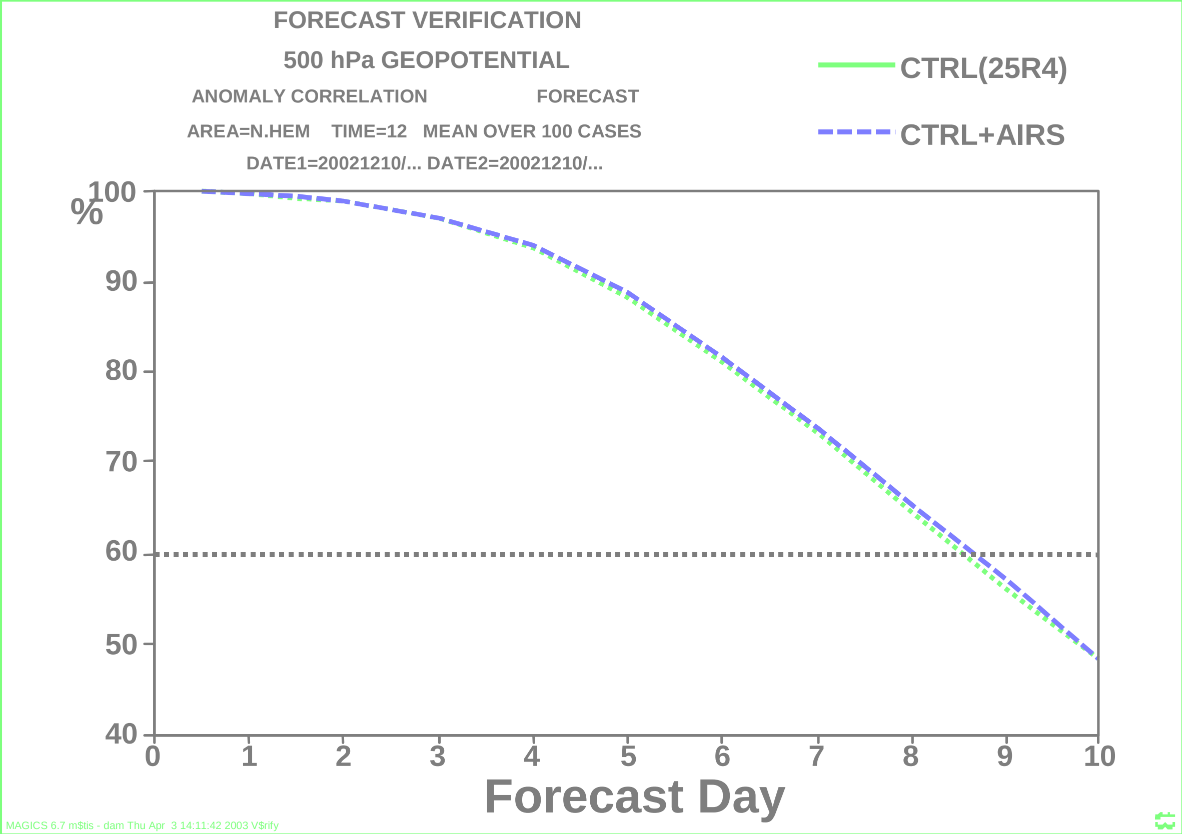


Figure 1 RMS forecast error differences for 500 hPa height AIRS minus CTRL



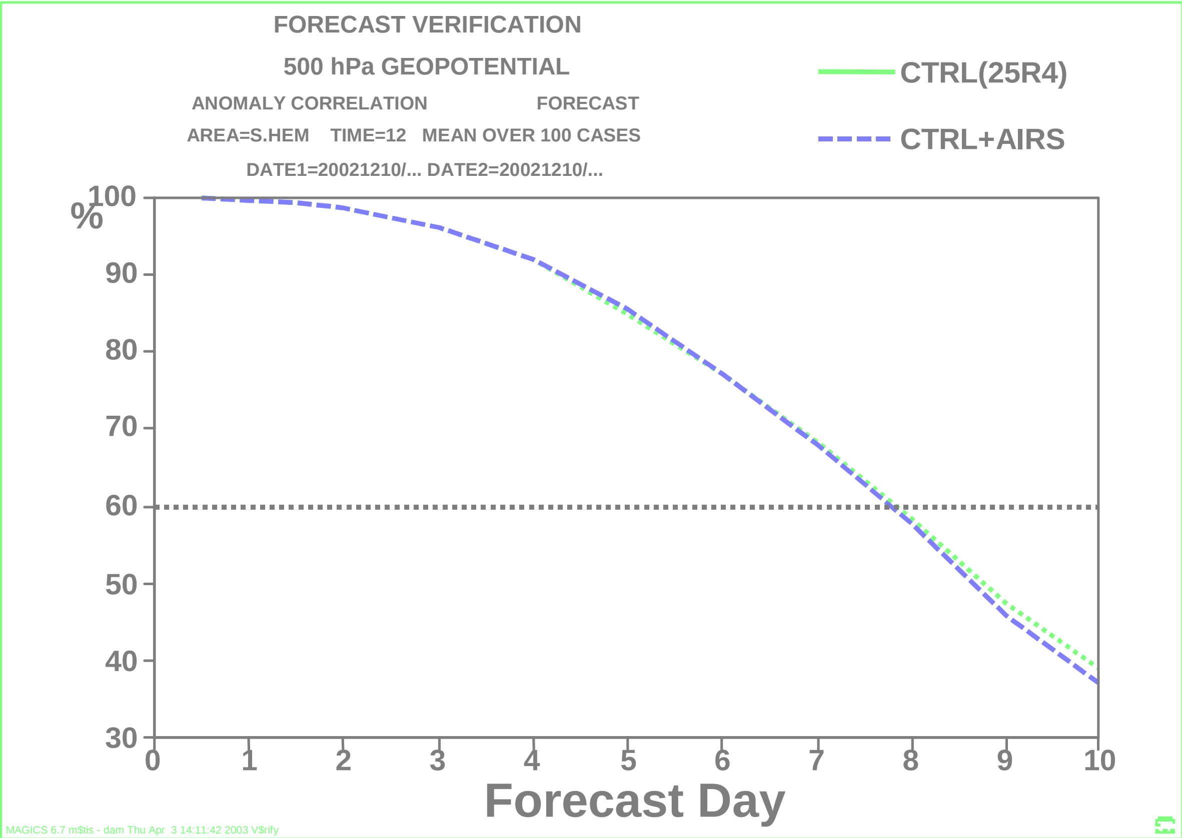
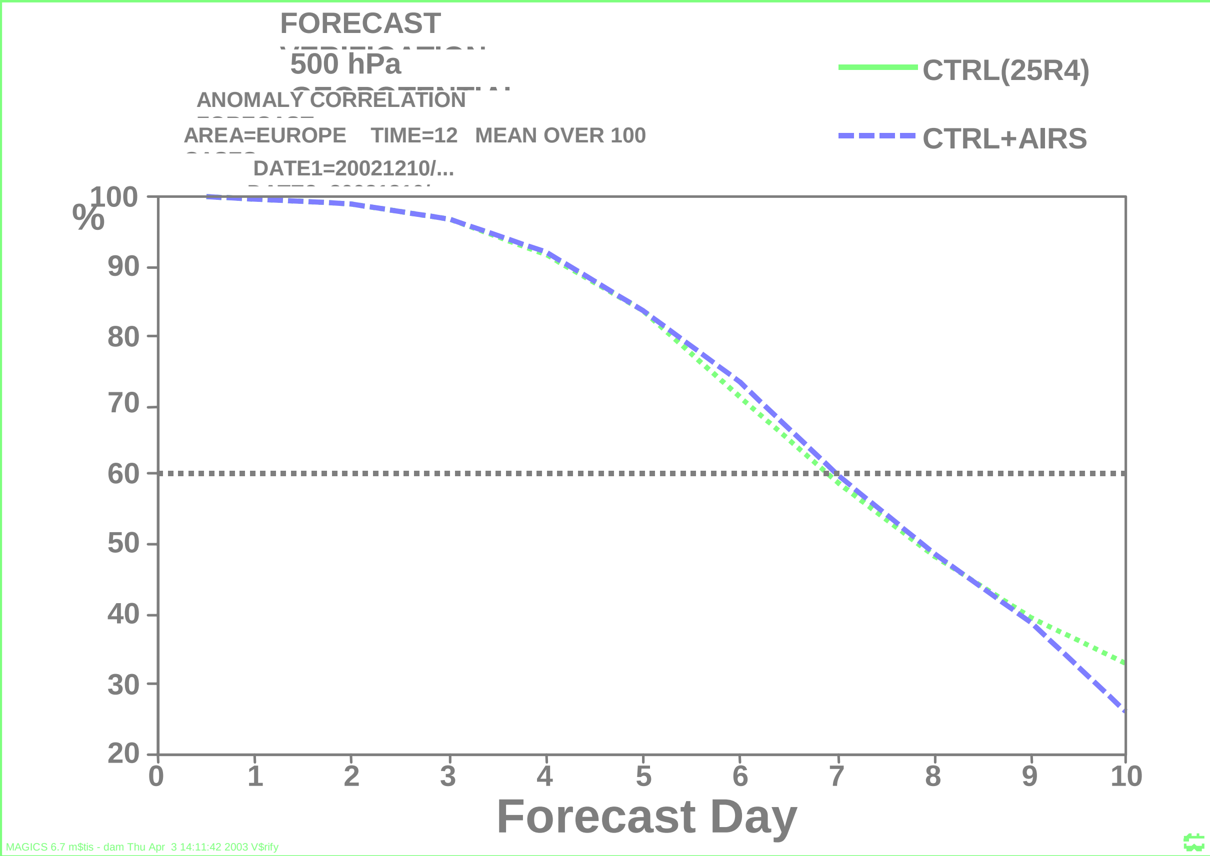


Figure 2a Mean anomaly correlation of 500 hPa height for the Northern and Southern hemispheres averaged over 100 cases (10 Dec 2002 to 19 March 2003)



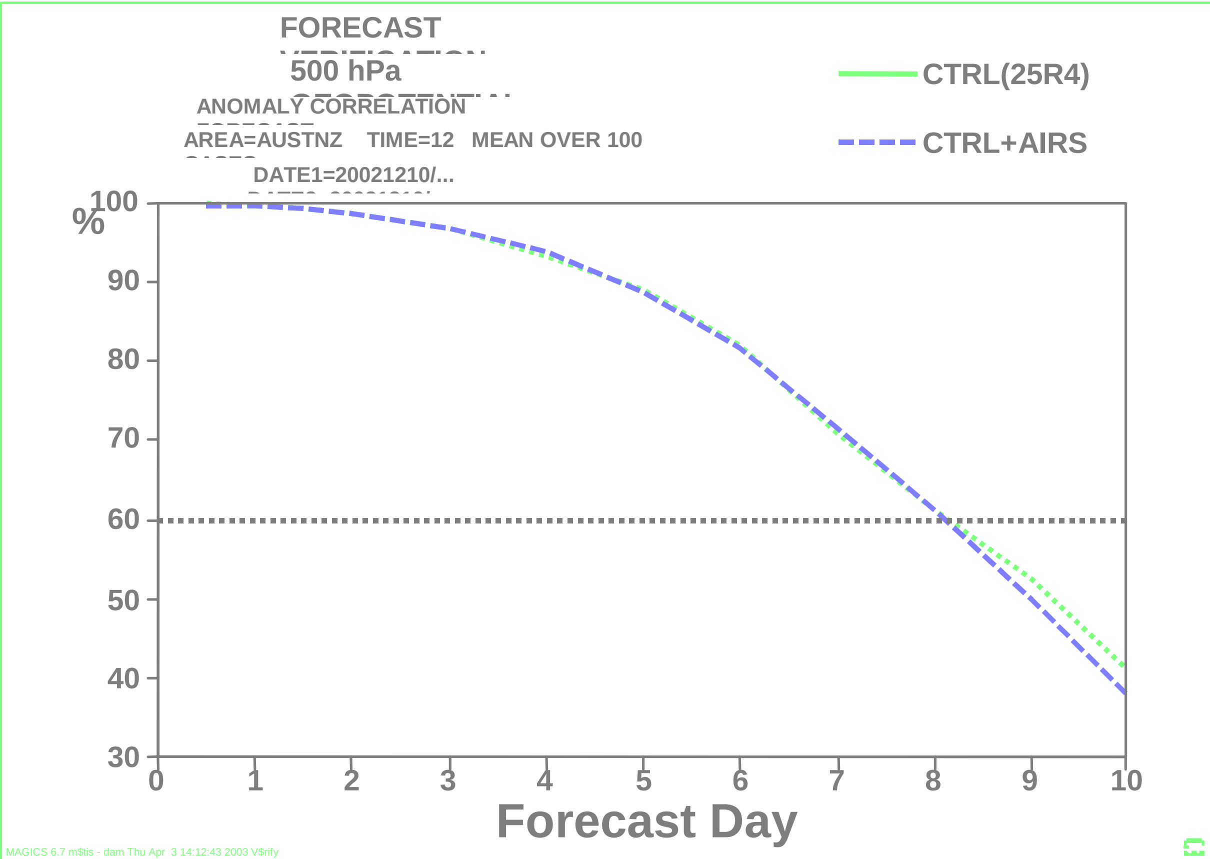
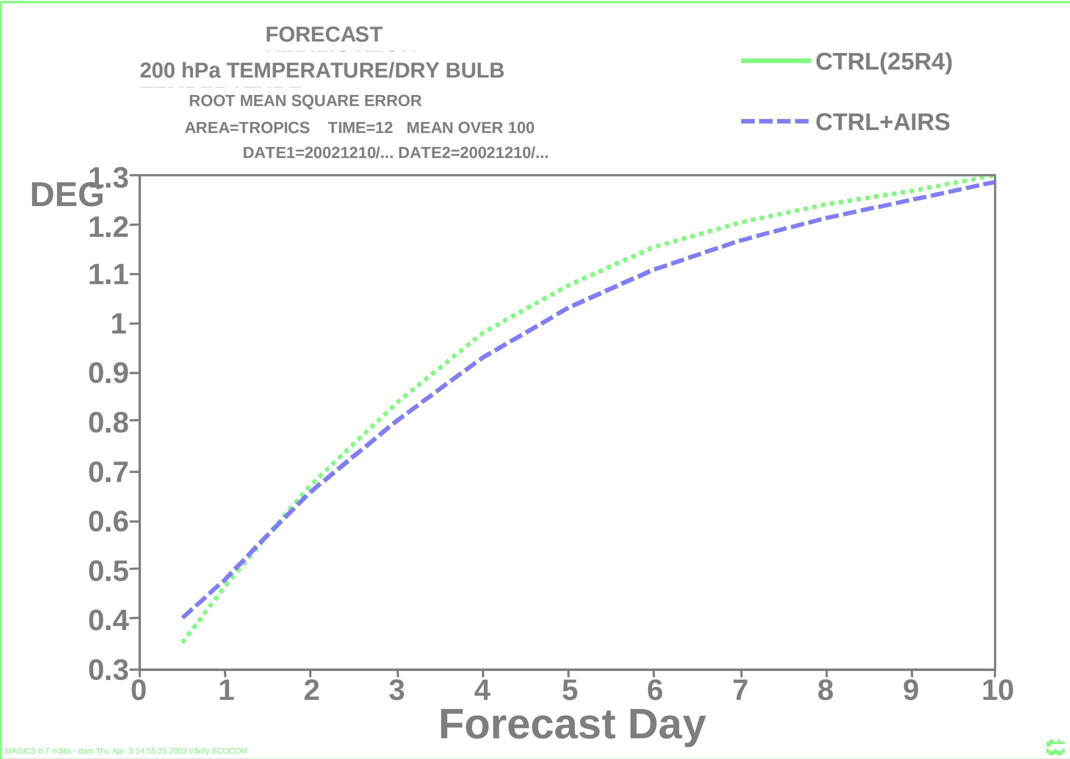


Figure 2b Mean anomaly correlation of 500 hPa height for Europe and Australia / New Zealand averaged over 100 cases (10 Dec 2002 to 19 March 2003)



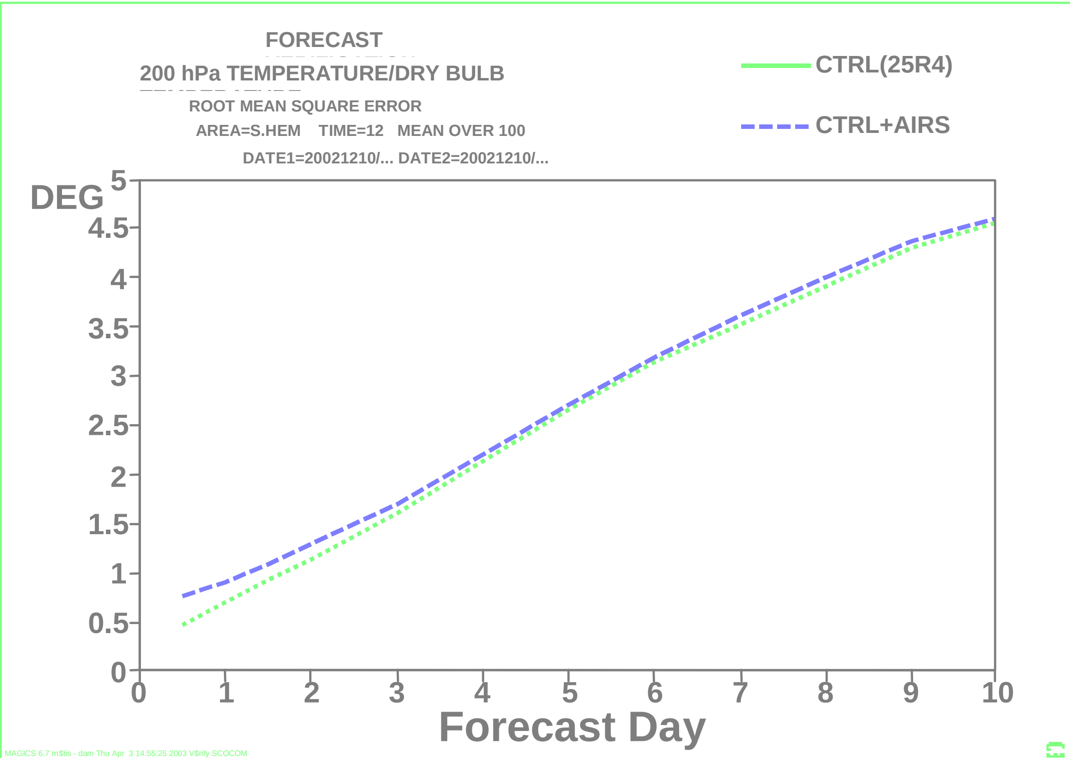


Figure 3 RMS temperature errors at 200 hPa for the Tropics and Southern hemisphere averaged over 100 cases (10 Dec 2002 to 19 March 2003)