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The impact of assimilating ATOVS 1D-var retrievals over Siberia

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Summary – 1D-var retrievals from ATOVS have been assimilated using 3D-var in an area 30E-130E 50N-70N (corresponding closely to Siberia). For short range forecasts (1-2 days) RMS errors for mean sea level pressure and 500 hPa height over Siberia and the north-west Pacific were reduced by 5-10%. Over the whole northern hemisphere RMS errors fell by around 1%. At longer ranges the impact over the test region was lower, falling to 2% by 3 days and to the hemisphere average of 1% at 4 and 5 days. This gives an estimated improvement in the NWP index of 0.4%. The radiances largely reinforced the existing mean analysis, but mid-tropospheric temperatures were 0.2K lower over most of the test area. The mean temperature at longer forecast range was also lower, but by less than 0.1K and thus a considerable spin-down of mid-tropospheric temperatures over northern Asia was slightly reduced. Because the entire retrieved profile was assimilated the direct assimilation of radiances in 3D-var, anticipated for later in 1999, is expected to benefit similarly from the assimilation of radiances in this region. It is gives encouragement for further improvement in the impact of radiances in the northern hemisphere especially when we begin testing the assimilation over all land regions during 2000.

1. Introduction

The assimilation of ATOVS and TOVS radiances has been shown to have a large positive impact on the accuracy of numerical weather forecasts. Most recently Poulsen et al. (1999) described the overall impact of sounding data on forecast accuracy. At the Meteorological Office the use of TOVS and ATOVS radiance information for assimilation over land has been conservative because of inadequacy in bias correction, quality control techniques, the surface emissivity component of the forward model and the inaccuracy of skin temperature provided by the model background.

Interest has been renewed in making better use of TOVS and ATOVS data over the land by several factors. The major influences are,

- The decline in the radiosonde network
- The threat to our receipt of radiosondes posed by the millennium bug
- Recent experiments at ECMWF showing positive impact from assimilating tropospheric HIRS channels over land
- Higher than average observation – background "O-B" variances for some radiance measurements sensitive to tropospheric temperature over some land areas
- The impact of TOVS and ATOVS is 4-5 times greater in the southern hemisphere than the northern hemisphere

An experiment has been undertaken to investigate the impact of assimilating ATOVS and TOVS radiance information over Siberia. This region was selected for several reasons. The standard deviation of the O-B brightness temperatures is anomalously high in several tropospheric channels. Figure 1 shows O-B standard deviation for AMSU channel 7 peaking at 250 hPa. The largest values of O-B standard deviation are found in the north of Siberia and Canada, Greenland and Antarctica. The anomaly over Siberia is for a low lying region with homogeneous surface emissivity (except during the spring snow melt season). In this region the O-B variance of the low tropospheric channels (which see surface and atmosphere) is frequently less than or equal to that found mid to upper tropospheric channels. The high variances are therefore unlikely to be due directly to surface effects. If the cause of the higher than average variances is larger than average background errors we have more information in the radiances and it is potentially easier to achieve a positive impact than in other regions.

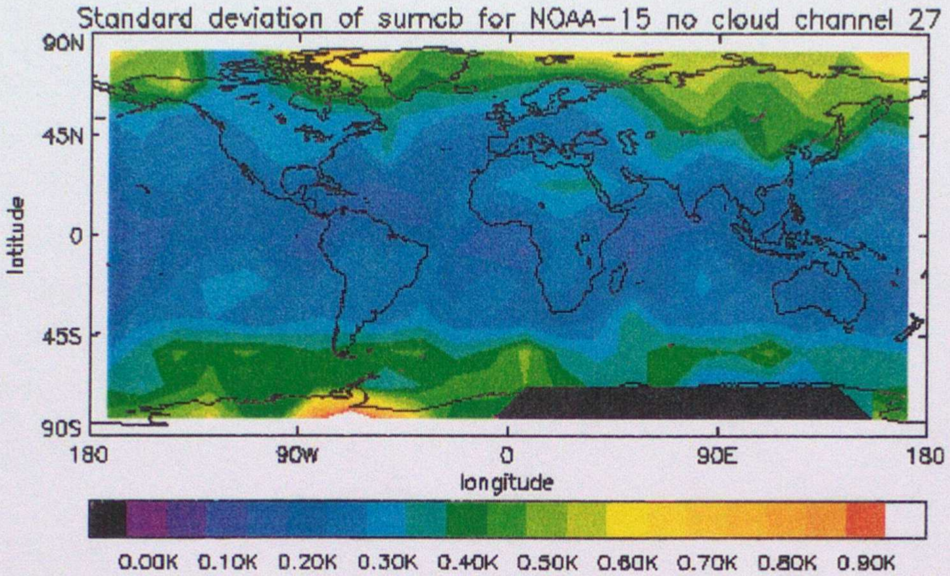

Fig. 1: Standard deviation of O-B for AMSU channel 7, which peaks at 250 hPa. The high values of O-B over northern Asia and the Siberian Ocean would appear to reflect higher background errors.

Another important factor in selecting Siberia as a test bed for assimilation of radiance information over land is the millennium bug or Year2000 problem. There are several regions where continued receipt of radiosonde data after 1 January 2000 can not be guaranteed and Russia is no exception. Repeating advice received from Noyes (pers. comm) verbatim: "…all the message switches in the former Soviet Union are not compliant and the Russians are seeking VCP funding from WMO to upgrade the RTHs. Having ATOVS in our data assimilation system would certainly help counter the risk". The "risk" can be quantified by referring to Bader and Dumelow (1998) who claimed "loss of radiosonde data over Asia could degrade forecasts … over the northern hemisphere as a whole by … about a day for 1-5 day forecasts. However, immediately downstream of the data devoid area, the loss in skill could exceed a day at T+24". The experiment was designed to test whether assimilating ATOVS and TOVS radiance information over Asia improves forecast accuracy when the sondes are present. However the secondary objective was to provide additional robustness against loss of sonde.

Configuration	Channels used over land	Heights assimilated over land < 1,000m	Errors assumed over land	QC checks applied over land
Pre 29/3/99 operational	HIRS 1-3 MSU 2-4 SSU 1-3	Above 100 hPa	As sea.	Gross checks only
Post 29/3/99 operational	HIRS 1-3 MSU 2-4 AMSU 6-14 SSU 1-3	Above 400 hPa	As sea.	Gross checks plus a cloud check on HIRS ch. 3
Siberia experiment 30E-130E 50N-70N	HIRS 1-6 MSU 2-4 AMSU 4-14 SSU 1-3	All heights	As sea.	Gross checks plus a cloud check on HIRS chs. 3-6

Table 1: The use of radiance information in the operational assimilation before and after 29 March 1999 and the experimental setup for Siberia. Note that outside the region 30E-130E 50N-70N the setup for the Siberia experiment is identical to the operational setup since 29 March 99. The post 29 March configuration was used for the experiment control run.

2. Experiment design

The experiment setup is described in Table 1. It is emphasised that the same observational and forward model errors are assumed over the land as over the sea. It is also emphasised that a significant increase in the use of TOVS and ATOVS data over land occurred when 3D-var and ATOVS assimilation went operational on 29 March 1999. Finally it is pointed out that no quality control checks, other than standard OPS missing data/gross limits/1D-var convergence tests are being applied.

3. Results

3.1 Global NWP index

The impact on the global NWP index is naturally small. The change affects the analysis for 2% of the world's surface and 7% of the northern hemisphere extra-tropics and only changes the assimilation from the surface to 400 hPa. Nonetheless the small impact was consistently positive. We focus on impact in the first two weeks because some verification data was lost in the third week. The time series from 12 January to 27 January 1999 are shown in Figure 2 and 3 for mean RMS impact for the northern hemisphere 500 hPa height and mean sea level pressure.

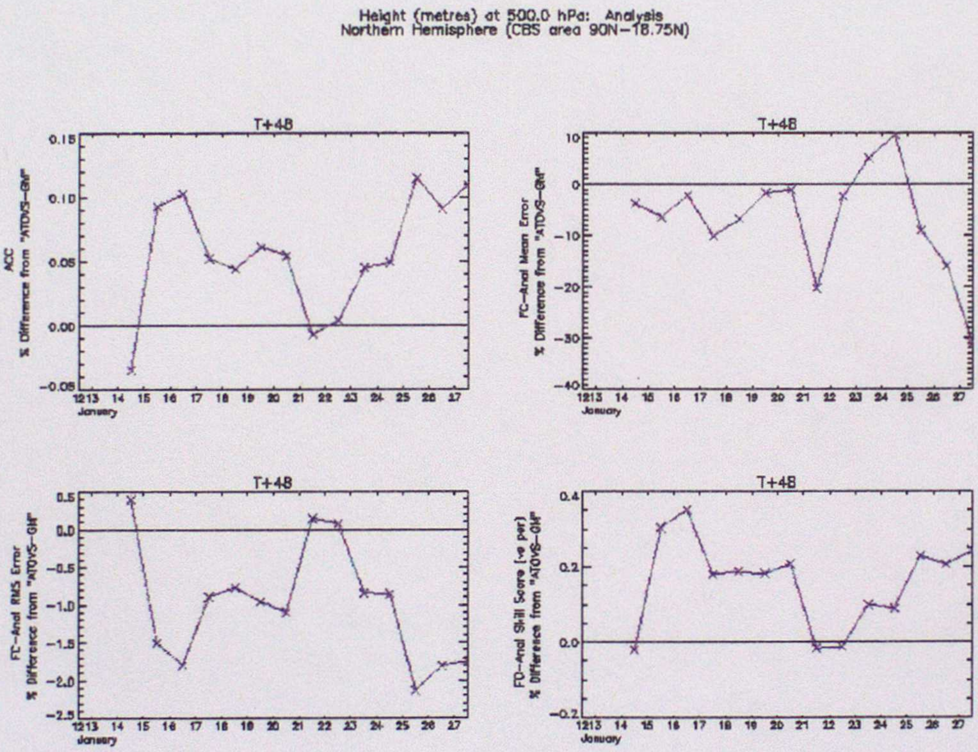

Figure 2: Percentage difference control-trial for NH 500 hPa height. The impact varies from 0-2%.

Overall the skill score for the trial was 83.26 and for the control 83.13 showing a modest 0.13 rise which corresponds to 0.4% for the global NWP index. But it must be emphasised that to achieve such a rise from an assimilation change in a very limited area is not insignificant. Averaged over the whole northern hemisphere the major impact is at longer range: Mean sea level pressure impact at 4 and 5 days account for over half the increase in the index. To study impact at shorter range we need to focus on the area local to the change.

Verification against observations is less positive than verification against analysis with a significant positive impact only being achieved at 4 and 5 forecast range.

Averaged over the whole northern hemisphere there is no significant change in the mean state, mean 500 hPa height bias against analysis falling by around 5-10%. This mostly arises from a reduction in a spin-down of temperature over northern Asia discussed in the next section.

3.2 Regional variation

The global and hemispheric averages show largest impact at longest forecast range and no significant change to the mean state. However we expect the most significant changes to occur at short forecast range near the region where the changes have been made. Figure 4 shows the change in RMSE at day 2 for 500 hPa height. Generally at this forecast range random fluctuations in forecast performance are occurring, these being largest in the southern hemisphere and having short spatial scales. The only coherent feature is the large area of positive impact (blue colours) in the western two thirds of the region where the assimilation change was made and a region of similar size to the east, north-east and south-east of the test region. This is interpreted as a positive impact propogating away downwind from the test region. The magnitude of this positive impact is around 5%, 2% and 1% at 1 day, 2 days and 3 days for 500 hPa height and 10%, 5%, 2% for mean sea level pressure. By days 4 and 5 there is no longer a strong tendency for the test area to have a larger positive impact than anywhere else, although the impact over the Siberian sea remains the largest anywhere. Some small spatial scale negative impacts do occur. The only region where these form any coherent pattern is on the western seaboard of the United States. The reason for this is not known.

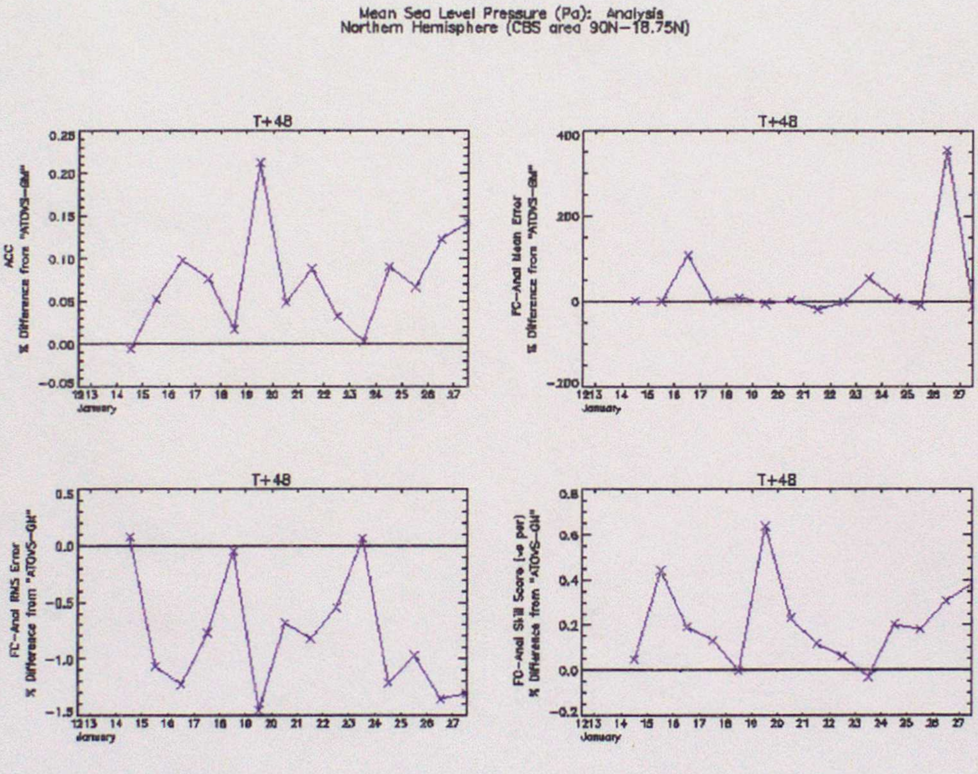

Figure 3: Percentage difference control-trial for NH pmsl. The impact varies from 0-1.5%.

The mean change in temperature over Asia in experiments switching on radiance assimilation over Asia at ECMWF was around –1K over a large area (Saunders 1998). This gave an improved fit to radiosondes. The impact of assimilating TOVS and ATOVS 1D-var retrievals over Siberia in the Meteorological Office analysis was to cool the lower troposphere by around 0.2K as seen in Figure 5. The T+6 was cooled by a similar amount but subsequent forecasts were only cooled by 0.1K or less. As the tendency in the control was for the mean temperature in this region to get colder in the first 48 hours of the forecast the trial showed a slightly lower spin-down of temperature. This results in the modest improvement of the bias of the forecast measured against its own analysis of 5-10% (the control bias was around –1m) seen in Figure 2. There was no significant bias for pmsl at T+48 (hence the percentage difference in Figure 3 is meaningless) but larger biases in the control run at longer range were reduced in the trial.

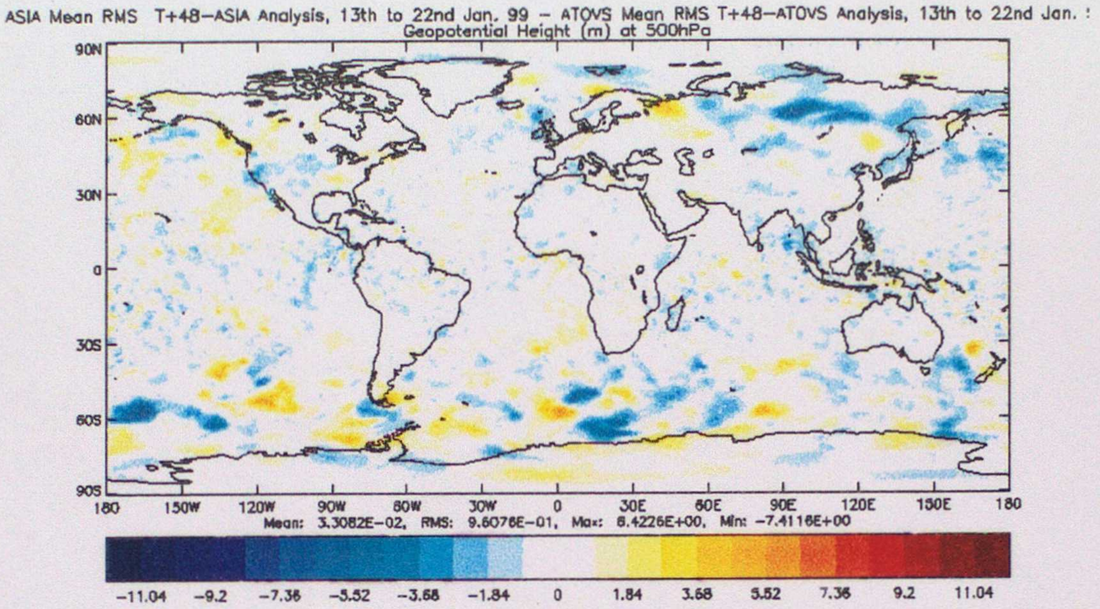

Fig. 4 Difference of RMSE for T+48 500 hPa height for control and trial. Blue colours indicate a lower RMSE for the trial. The impact in and downwind of the trial is a 5% reduction in RMSE.

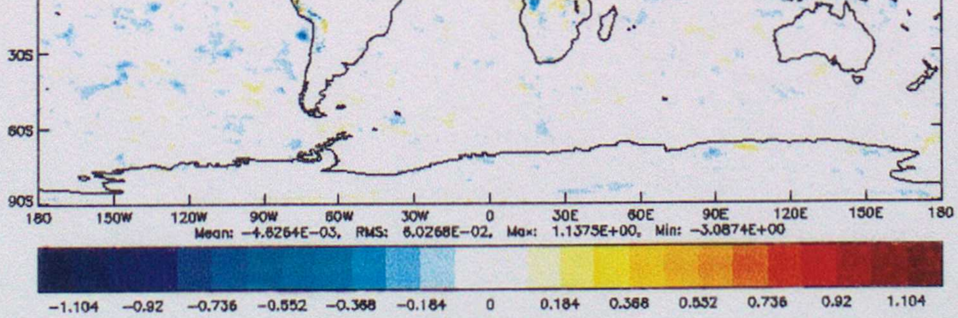

Fig. 5 Difference in mean temperature at 850 hPa for trial-control. Blue colours indicate a colder temperature in the trial. The temperature of the lower troposphere is around 0.2K colder in the trial than in the operational.

4. Conclusions

The assimilation of ATOVS and TOVS 1D-var retrievals in 3D-var at all heights in an area corresponding roughly to Asia has a modest (0.4%) improvement in the estimated global NWP index. However close to the region where the change was made the impact was 5-10% reduction in RMSE for pmsl and 500 hPa height at T+24. This impact gradually propagates across the entire northern hemisphere to give a mean impact of around 1-2% reduction in RMSE for the northern hemisphere as a whole. Impact south of 20N is neutral. The change to the mean values of temperature, pmsl and 500 hPa height was small (-0.2K for temperature) but did slightly reduce spin-down in temperature over Asia in the early part of the forecast. Similar small improvements in bias were seen for 500hPa height and pmsl. As the temperature retrievals were assimilated at all heights the tested assimilation of 1D-var retrievals was as close to direct radiance assimilation as possible. However the sensitivity of the analysis to direct radiance assimilation over land may be different and the impact over Asia will have to be carefully monitored. No study was made of the assimilation of humidity over land, the channels most sensitive to humidity not being used in 1D-var.

The following recommendations are made:

- ATOVS and TOVS 1D-var retrievals over Siberia be included in the "summer upgrade package".
- Quality control is applied to identify emissivity/skin temperature errors or missed cloud over land.
- An emissivity analysis is introduced to allow assimilation of radiance information over all land regions.
- The bias correction method is redesigned to be robust over high land.

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