ERA-40 Project Report Series

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ERA-40 Project Report Series No. 15

The radiosonde temperature bias corrections used in ERA-40

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1 Introduction

Historically radiosonde data are the main source of in situ information of the state of the free atmosphere and are commonly regarded as providing reference values when other types of observations are evaluated. The value of the radiosonde data for detection of temporal trends in tropospheric temperature has been addressed by e.g. Gaffen et.al. (2000). In ERA-40 they are especially important before 1973 when no satellite data was available. A comprehensive description of the long-term performance of the radiosonde data used in ERA-40 can be found in Onogi (2000).

In ERA-40 the data have been collected from several different external sources. All data before 1979 were provided by other organisations, mainly NCAR and NCEP. Prior to ERA-40 ECMWF had almost no experience of assimilating data from before 1979. The number of radiosondes has fluctuated between 30000 and 50000 ascents per month globally with the peak number during the years 1970 - 1990. About 75% of the radiosondes cover the northern hemisphere, 15% the tropics and 10% the southern hemisphere.

The radiosondes have some well-known errors, such as the radiation error, and some less well known ones, each of which may depend on different instruments. To make optimal usage of the radiosondes in an assimilation system they consequently have to be bias corrected. Another reason is that radiosonde data does also strongly influence the bias tuning of the satellites (Harris & Kelly, 2001). Bias correction of the temperature of the radiosondes in ERA-40 has been applied after 1979. This report documents and assesses the quality of the radiosondes and the temperature bias correction used in ERA-40.

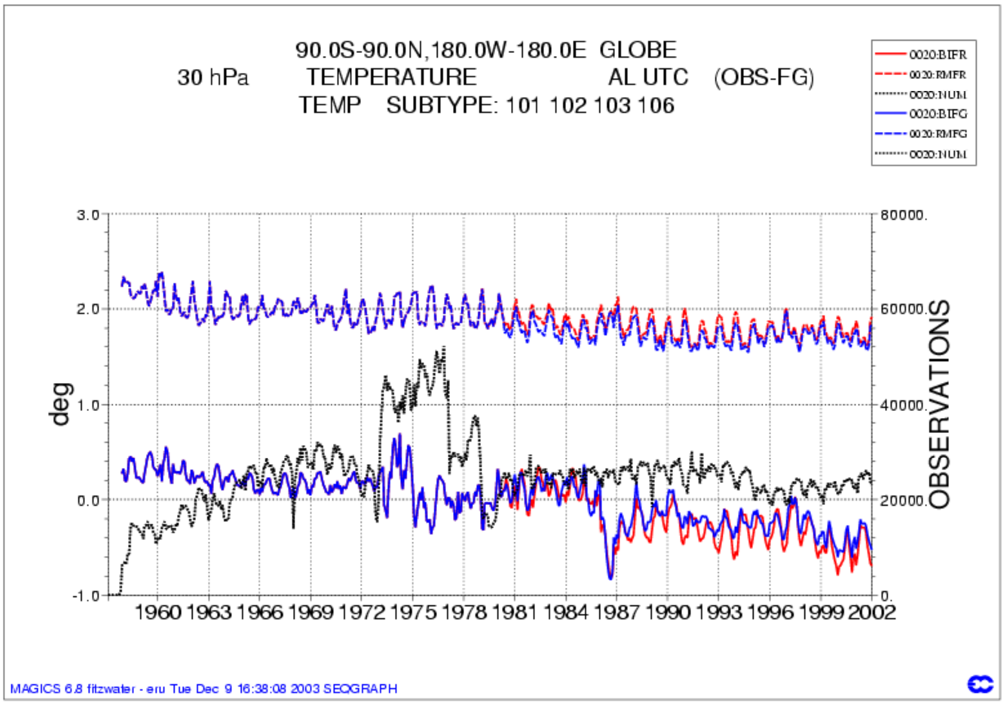
2 General time series

2.1 Temperature

The general quality of the radiosonde temperature observations, as measured by the root mean square error (RMS) of the first guess departure, has increased continuously over the last 45 years. The 500 hPa RMS has steadily decreased from 1.5 degrees in 1957 to 1.0 in 2002 measured over the globe, Figure 1, and similar behaviour is seen for other levels. It is difficult to distinguish the impact from the improvement of the radiosonde measurements, the coverage and the impact of other observation systems such as introduction of satellites; the improvement is due to a combination of all these things. We see that at 500hPa the RMS drops continuously between 1957 and 1970, when we have no impact at all from satellites. The improvement in RMS matches the increased time and space coverage; however there are station groups (not shown) with the same drop in RMS without any increase in coverage, which indicates improved measurements. In the most recent years the low RMS is due to improved background due to the impact of satellite observations even though the radisonde coverage itself has dropped.

The bias however, is much more variable depending on which other observations the radiosondes have to compete with in the assimilation. In the early years the bias is generally smaller than after satellite radiances have been introduced in the assimilation cycle. The first guess is generally colder than the observations up to the nineties when there are a small warming trend in the model at all levels. Towards the end of the period, the first guess has a warm bias at 30 and 250 hPa, and the bias becomes close to zero at 500 and 850 hPa. The absolute value of the bias, globally, is mostly less than 0.4 degrees and never larger than 0.8 degrees.

The number of 500 hPa observations used in the analysis increases from 30000 per month in 1958 to 50000 in 1970. From 1990 the number of observation starts to decrease again and stabilises on 30000 in the beginning of the new millennium. The decrease comes from a general thinning of the radiosonde network and especially over the former USSR. A problem with different data sources and station ID inconsistencies is obvious during 1973-1977 when many soundings were used twice due to their appearing with different station IDs in two different sources. There is however no indication that this causes a significant degradation in departure statistics.



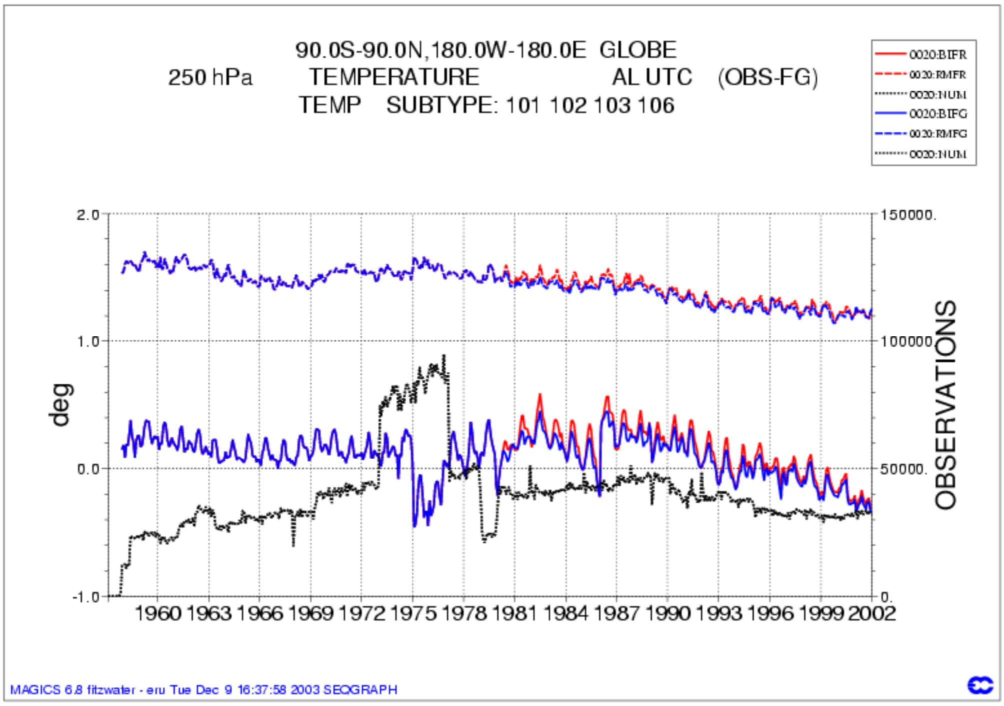
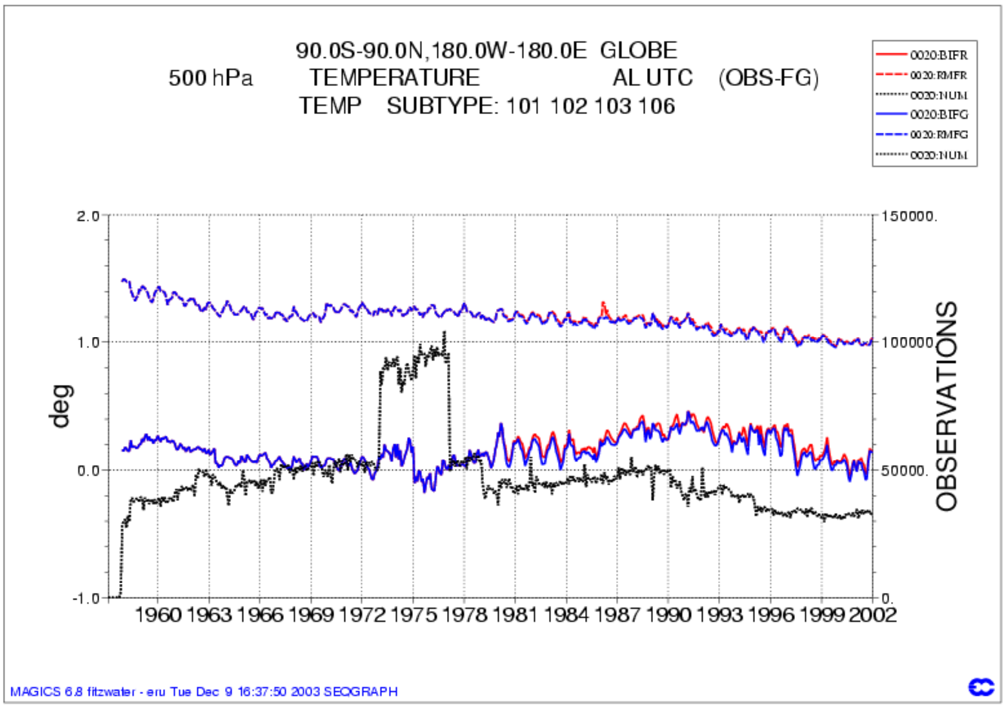


Figure 1 Time series of global temperature first guess departures for 30, 250, 500 and 850 hPa respectively. Dashed line shows the RMS and the solid line is the bias. Blue line means corrected and red uncorrected departures. The black line is number of observations per month.



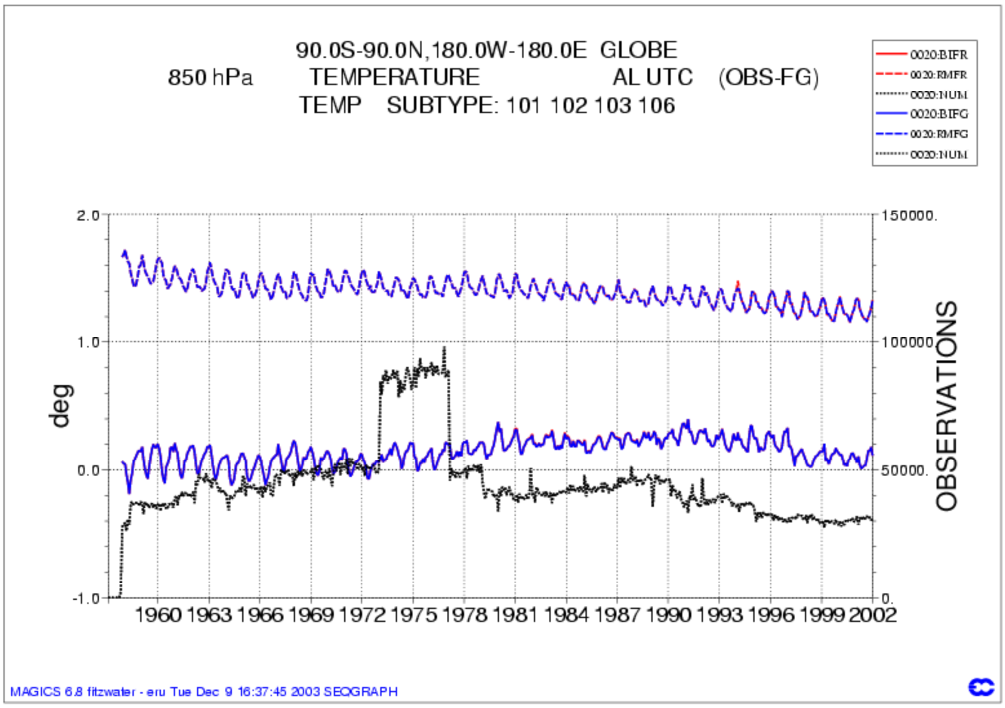
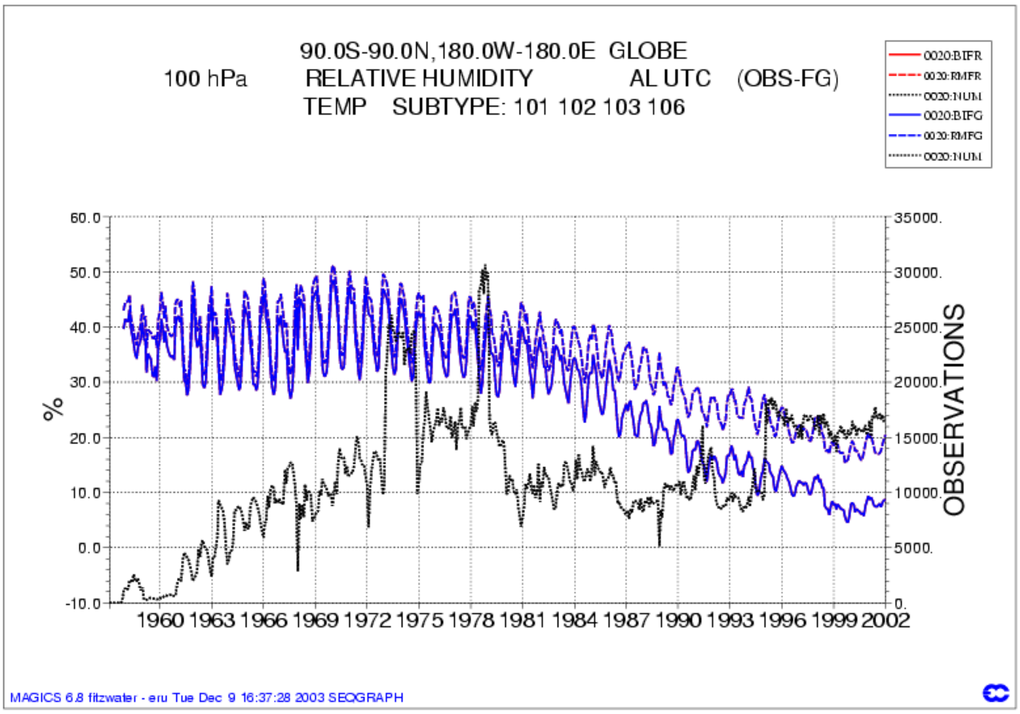


Figure 1 Continued.

2.2 Relative Humidity

The radiosonde relative humidity has not been corrected, even though it known to have errors. The errors have other characteristics than the temperature error and are not as easy to separate from the true value as for the temperature. The time series, however, gives some useful information about the quality of the observations and the assimilation system. There are two things that can be noted from Figure 2. First there appears to be a wet model bias until l965. This turned out in fact to be a dry bias in the one of the radiosonde data sources due to a data-coding problem (Jack Woollen, personal communication). Despite the small bias of less than 10 % the impact on the water budget and the precipitation spin up was clearly noticeable (Betts et.al. 2003).



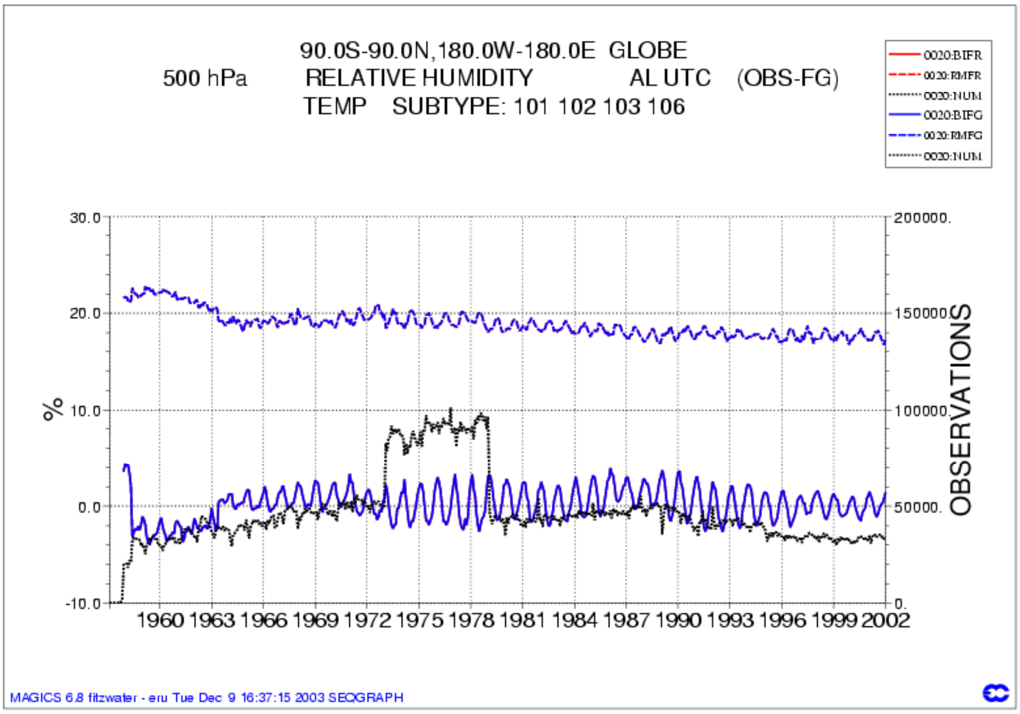
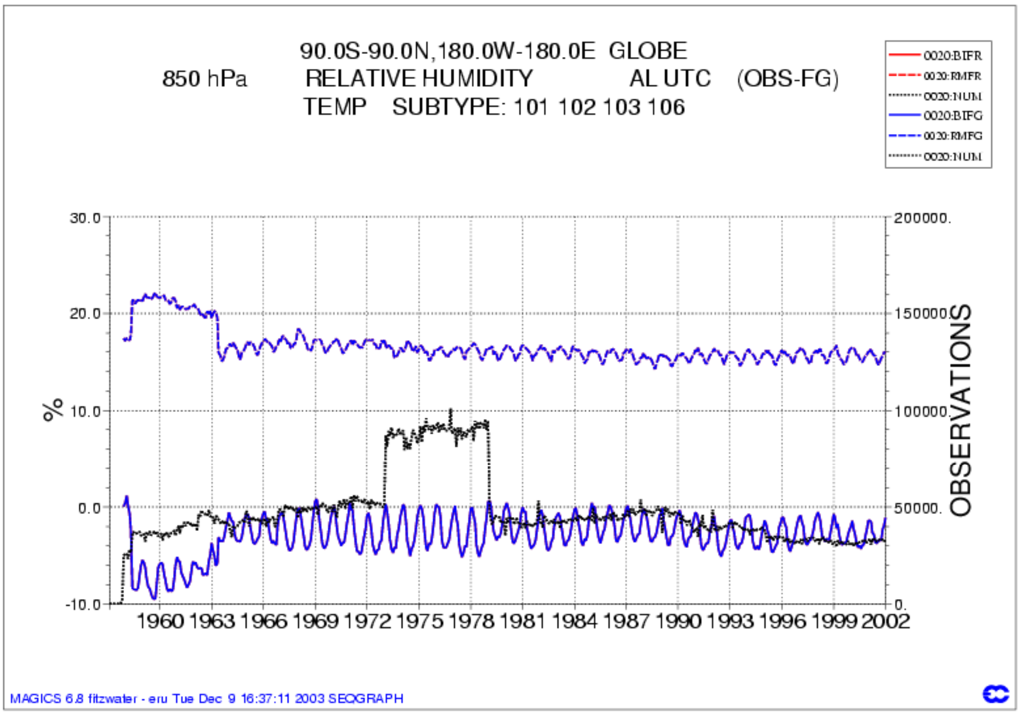


Figure 2 Time series of global relative humidity first guess departures for 100, 500, 850 and 1000 hPa respectively. Dashed line shows the RMS and the solid line is the bias. Blue line means corrected and red uncorrected departures. The black line is number of observations per month.



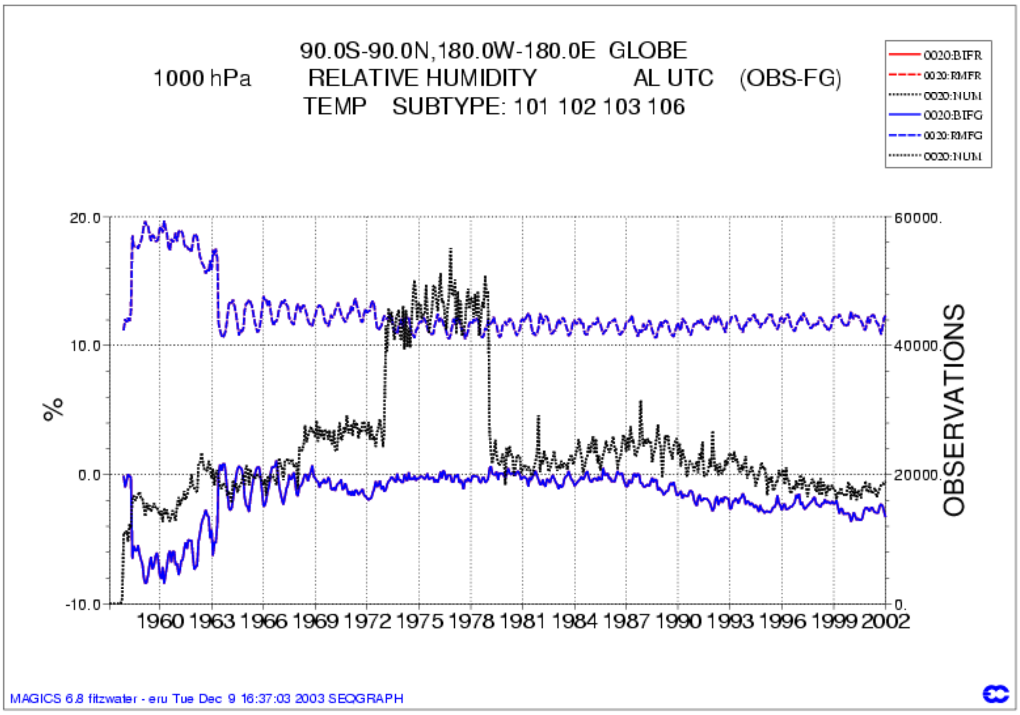


Figure 2 Continued.

The other feature is the decreasing bias at 100 hPa, whereas there are no tendency in RMS and bias at lower levels over the years. The quality of the observations relative to the assimilation system seems to be the same during the period of the lower levels. Since humidity from radiosondes is not assimilated above 300 hPa the model develops its own climate and the bias and RMS are at a constant level of 30 - 40 % until 1979. When satellite information is introduced after 1979 the bias decreases steadily to stabilize at 10% in the late nineties. This has some implications on how high up the relative humidity from radiosondes can be assimilated. It is generally thought that the measurements are too unreliable to be useful. However the figure shows that when the satellites change the model humidity the RMS and bias becomes comparable to what we find in the lower troposphere and it shows that we have some useful information there also.

3 The bias correction method

The background for the radiosonde bias correction used in ERA-40 is described in Onogi (2001). We follow the method described by Bouttier et.al. (1999), which is used operationally at ECMWF. In the operational method each sonde is identified based on the instrument type or the station ID, given that the sonde type for each station is known. The corrections are then based on the characteristics of each instrument. In ERA15 the same principle was used but applied only to a small number of countries where the radiosonde type was known. Statistics were updated every month and calculated from the preceding 12 months statistics (Nomura et.al. 1995, Gibson et.al 1999).

Corrections based on instrument type could not be used in ERA-40 since the instrument type was not reported in the early years. Instead all radiosonde stations are consolidated in 139 groups depending on station id and/or position in order to get a manageable amount of corrections and decent statistics. The groups are defined to represent different countries or areas that are assumed to use similar types of sonde. The groups are identified by intervals of representative station IDs. Since station IDs differ between periods and different sources, and because positions have changed over the years, any possible station has to be mapped to the predefined ID interval for that specific group. The groups cover about 3000 different radiosonde stations. The remaining unidentified stations will be excluded from the statistics and, more important, they will not be corrected. Figure 3 shows the rate of recognition of the TEMP reports over all 45 years. On average 97.5% of the reports have been identified. Land based radiosondes are well covered, and less than 1% of the reports are unrecognized. For the SHIP, DROP and MOBILE reports only 8% have been identified due to the difficulty of adding them to a certain group.

The strong solar radiative heating in the upper troposphere combined with the emitted long wave radiation from the sensor introduces a bias that is a function of the solar elevation. The bias is therefore divided into four different classes of solar elevation: <-7.5, <7.5, <22.5 and >22.5 degrees over the horizon. Since the mean error is subtracted from the correction it becomes independent of any model error as long as the diurnal model error is small, which is the case in the upper troposphere. Another known error is the effect of the length of the wire between the balloon and the sensor. If the wire is to short then the heat capacity of the balloon will affect the measurement. This is especially pronounced in the Chinese radiosondes.

Given the statistics of the first guess departure (bias and RMS) for the four different solar elevation classes over a certain period of at least 12 months the corrections are calculated given a number of constraints. The bias correction procedure for a particular group is described in the following and the effect of each step on its own is shown in Figure 4 - Figure 7.

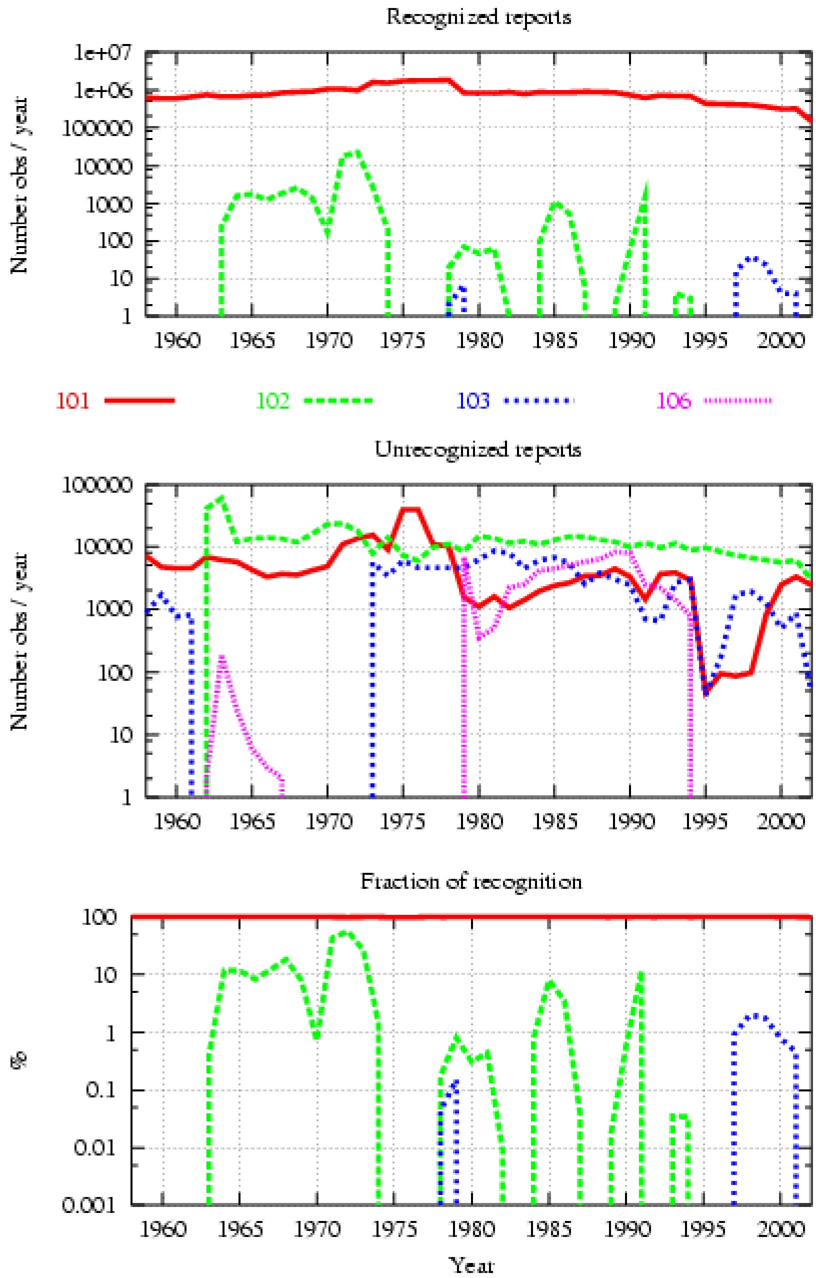


Figure 3 TEMP reports in ERA-40 for different subtypes. Top panel shows reports identified and mapped to a certain group. Middle panel shows unidentified reports. The bottom panel shows fraction of recognition for each subtype. 101 means land based stations, 102 SHIP, 103 DROP and 106 MOBILE.

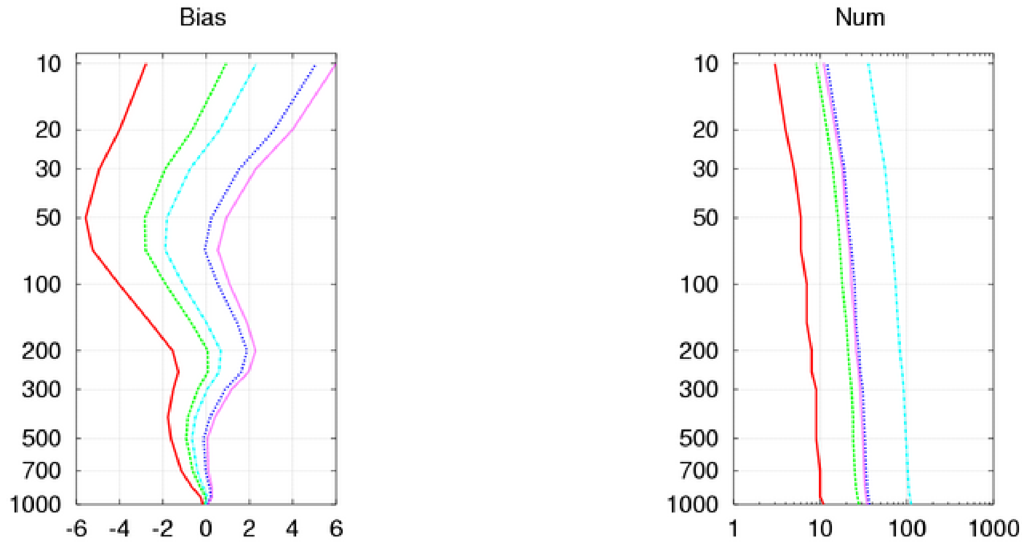


Figure 4 Synthetic radiosonde bias profile. Left is the OBS - FG departure and right is the number of observations for different solar elevations. Red line is the lowest solar elevation and purple is the highest. The mean bias is the cyan line in the middle.

1. Make a cubic spline fitting of each profile and calculate a fitted profile for the mean profile, and make sure that the absolute correction is smaller than the original bias for corrections larger than 0.5 degrees. The fitted profile is assumed to remove irregularities introduced by e.g. uneven statistics. Figure 5a.

2. Limit the average profile to be within 0.0 degrees at 1000 hPa and increase, linearly with ln p, to 2.0 degrees at 10 hPa and remove vertical changes between two adjacent layers larger than 2.0 degrees. Figure 5b.

3. Limit the distance between each solar elevation profile and the average profile to be within 2.0 deg at 10 hPa and 1.0 deg at 1000 hPa. The error is assumed to be within a certain limit, both in absolute terms and in comparison with the mean profile and the neighbouring levels. Figure 5c.

4. If the number of data for each profile is less than 10 or less than 1 % of the total amount of data at that level reduce the correction with the minimum of NUM/10 and NUM/NUMALL. We need a minimum number of ascents to calculate reliable statistics. If we cannot fulfil this we reduce the correction so that we do not introduce erroneous corrections later. Figure 5d.

5. Reduce the correction at each level according to a namelist input. The values used in ERA-40 at standard pressure levels from 1000hPa and upwards was REFRED=0.0, 0.0, 0.2 ,0.4,12*0.8. This means that no corrections were applied below 700hPa and the correction was 80 % above 500hPa. For most cases we only want to correct the upper troposphere. Below 500hPa the errors are assumed to be small as well as influenced by any diurnal cycle in the model error. At upper levels the value of REFRED reflects how much we believe in our correction coefficients. Figure 5e.

6. If only a radiation correction is requested we subtract the mean profile from the corrections. Table 1 shows if and when the correction applied was radiative only or if the average departure was corrected also. The table shows that different corrections were applied on different periods in order to reflect the evolution of different countries' observing system.

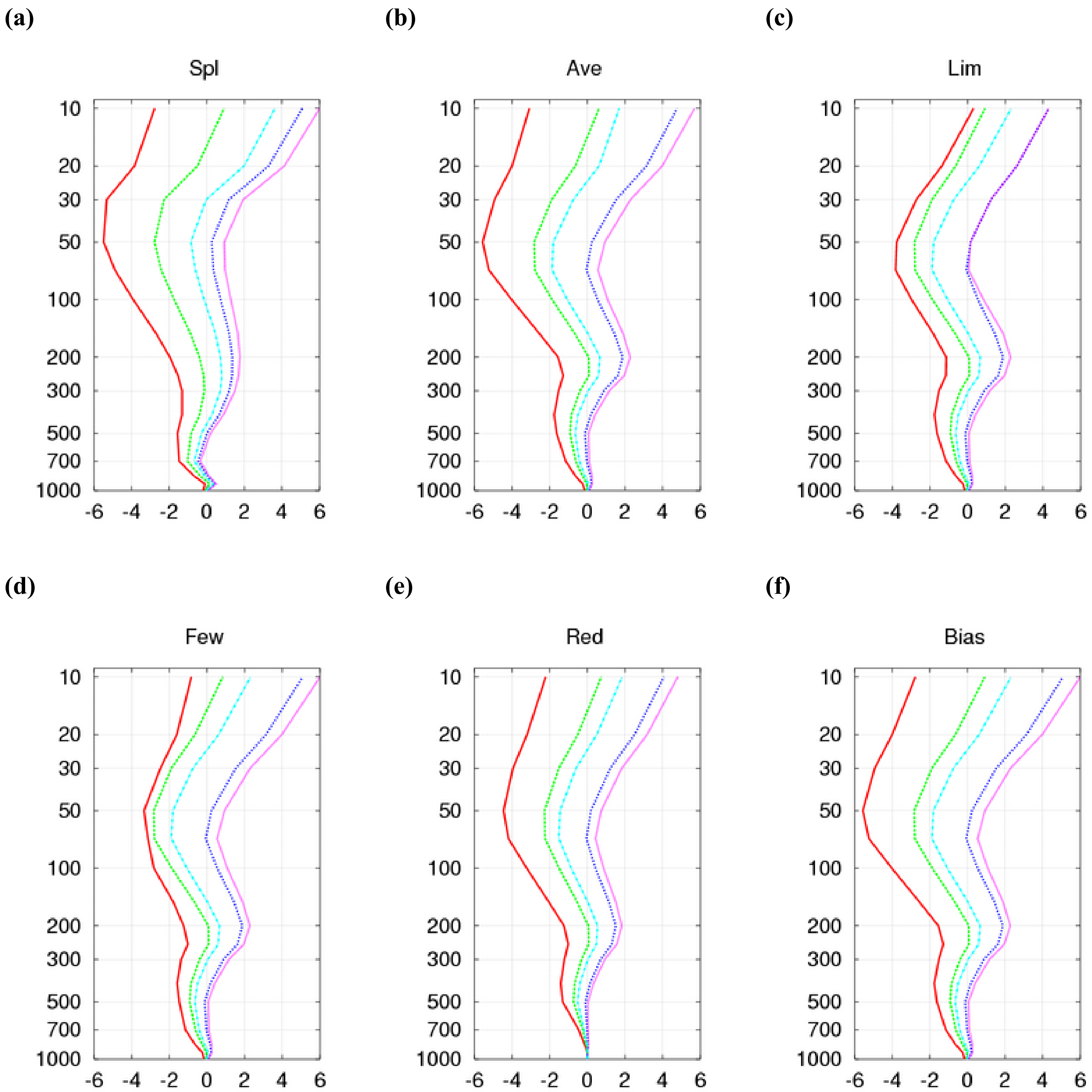


Figure 5 The effect on the profile in Figure 4 for each step in the calculation of the corrections. a) Spline fitting, item 1. b) Adjustment of mean bias, item 2. c) Adjustment of each solar elevation class, item 3. d) Reduction due to few observations, item 4. e) Subjective reduction, item 5. f) Same bias as in Figure 4.

These steps are introduced to ensure that the corrections are realistic and are adjusted to be moderate since the statistical approach was applied for the first time in ERA-40. The effect of each constraint when applied in a sequence can be seen in Figure 6, and the final corrected profile in the top panel of Figure 7. In this particular example the spline fitting shifts the wiggle upward, the limits in step 3 heavily narrow the corrections and step 4 makes sure we don't correct the less data dense profile.

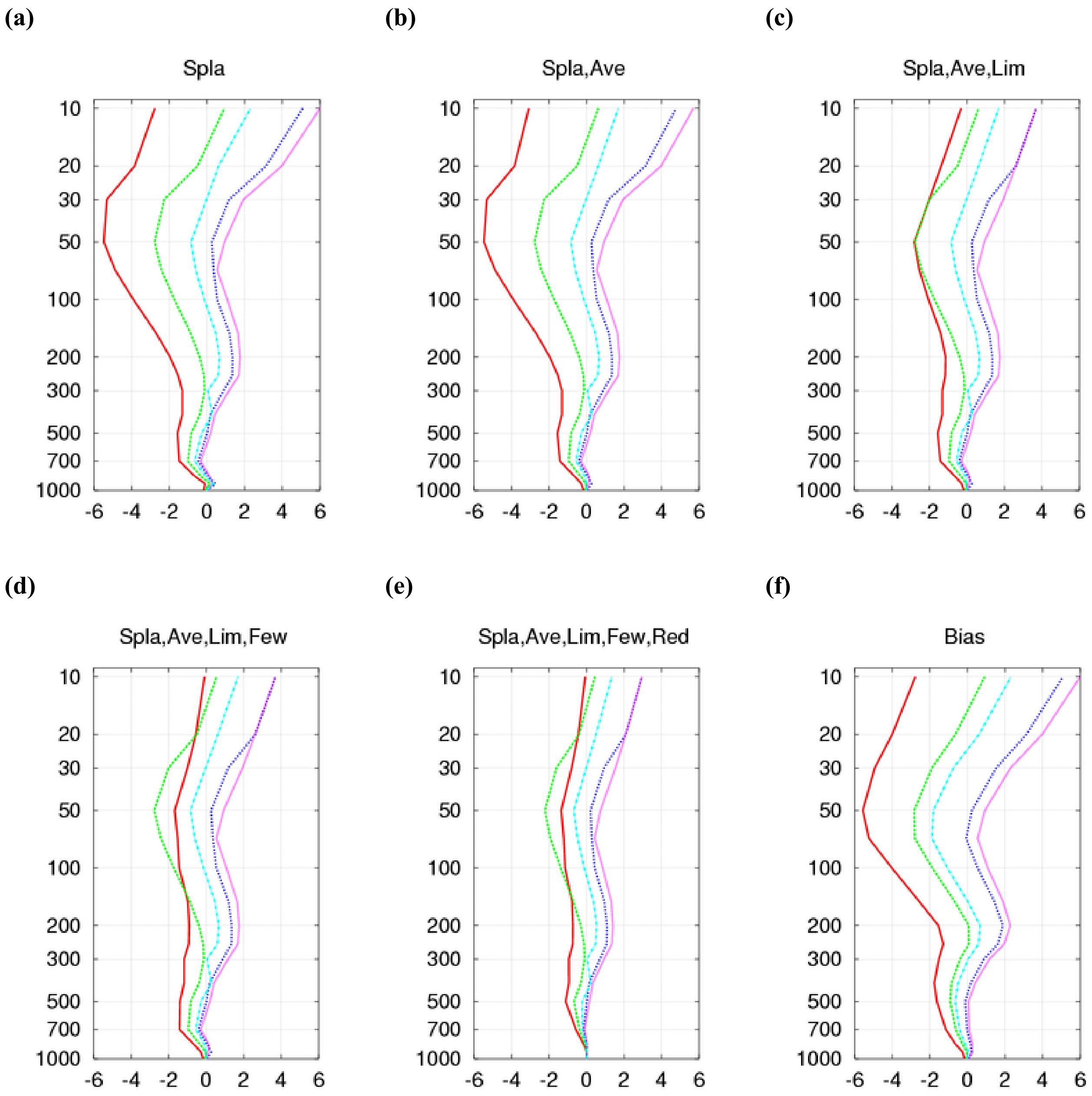


Figure 6 Same as in Figure 5 but for each step in the correction when applied in sequence.

The identification and correction of each radiosonde is then applied in the assimilation step. Observed values between the standard pressure levels are corrected with a linear interpolation of the corrections from the adjacent layers. Corrected and uncorrected departures from the first guess are stored in the feedback files from which new statistics can be calculated. In ERA-40 the corrections were changed when the last 12 months of statistics showed a clear change in the suggested corrections. The behaviour of the bias correction was monitored and the new corrections compared with the former ones. Examples of the monitoring of the bias correction are shown in Figure 8. Since the corrections in ERA-40 always depended on statistics from the former year there was always a lag in the applied corrections. Thus the new corrections were introduced a year after they should have been introduced.

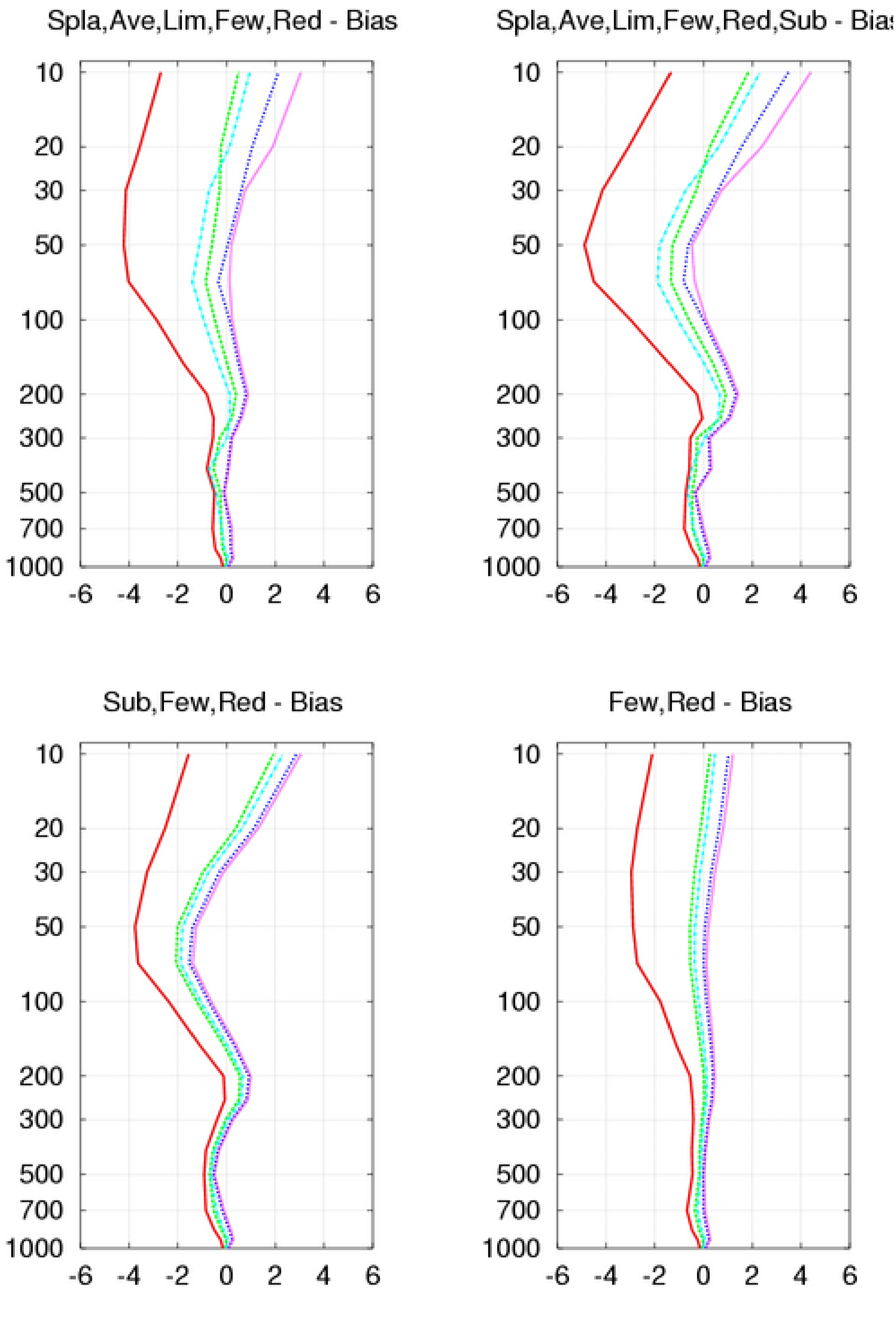
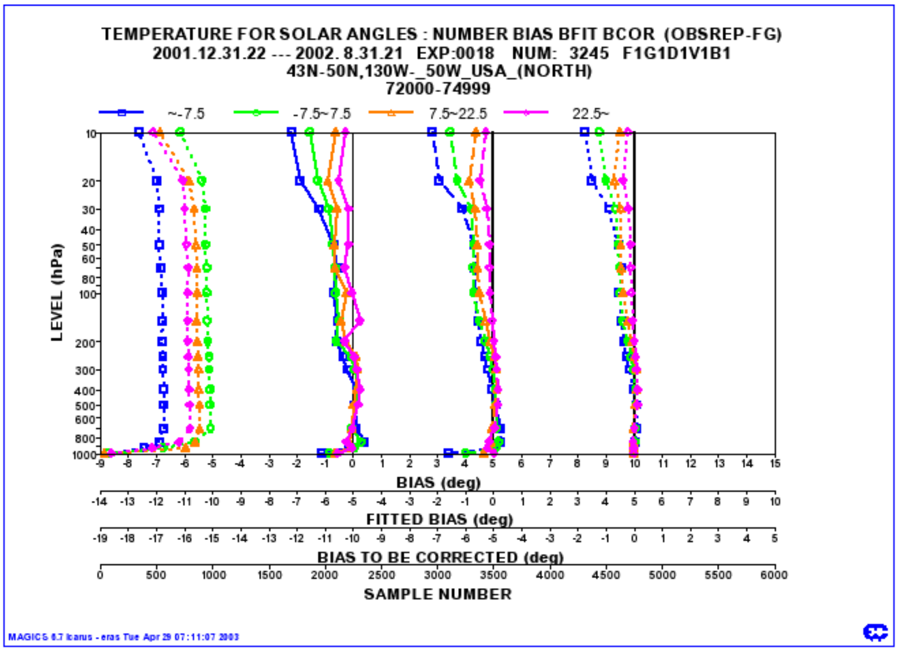


Figure 7 Corrected profiles. Top panel shows the corrected profile with and without removal of the mean bias when the correction in Figure 6 is applied. Bottom panel shows the correction after only step 4 and 5 is applied. See text for discussion.

The bias correction in ERA-40 was turned on at the 00 UTC cycle on the 30th of April 1980. The bias correction table was changed 10 times during the 22 years the correction scheme was active. The dates when the correction tables were updated and detailed list of corrected groups can be found in Table 2 and Table 3. On average 73% of the ascents were corrected during the period. The most data dense groups (USA, Canada, China and former USSR), which count for 50% of the observations, were corrected throughout the period. Not all of the groups had their corrections changed every time the table was updated. Typically a group was updated 3-5 times during the period. As can be seen in the table a large number of groups where never corrected or corrected only during a short period of time. The main reason for this was most often the lack of reliable statistics. Some groups in the Tropics and in the Antarctic were deliberately left uncorrected due to uncertainties in the model performance in these areas.



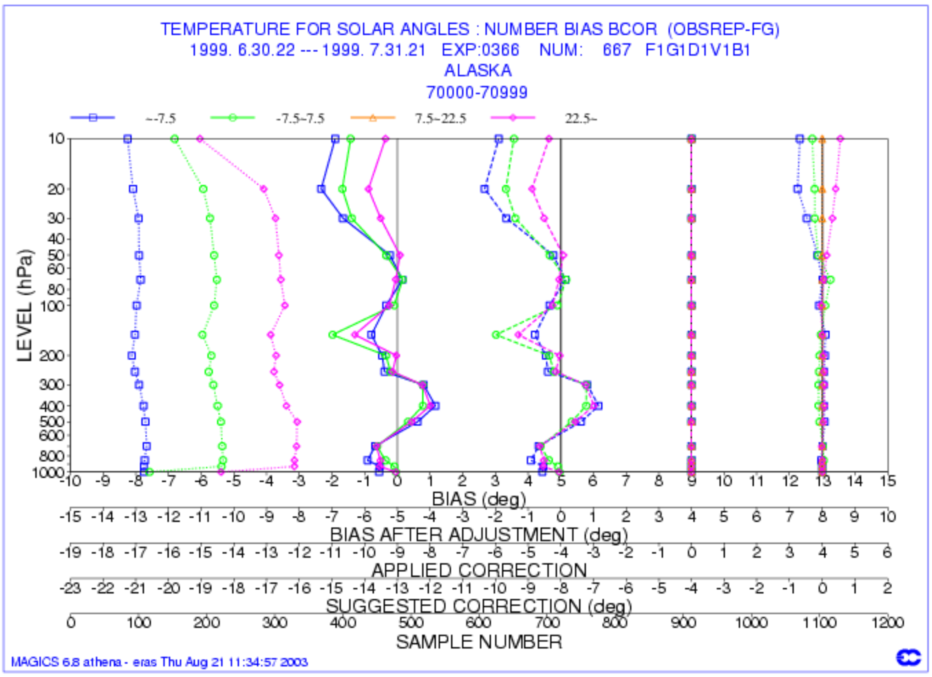


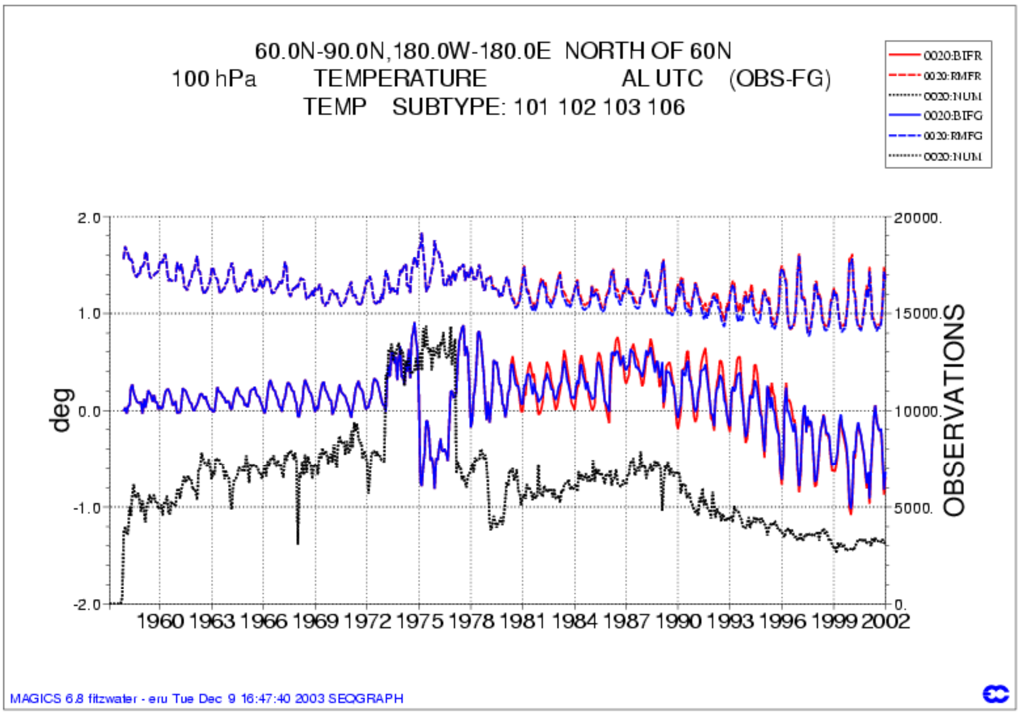
Figure 8 Former and present monitoring. In the top figure the graphs are number of observations, first guess departure, fitted profile, suggested correction. In the bottom figure the graphs are: number of observations, first guess departure, corrected first guess departure, used correction, suggested corrections. The different colours represent different solar elevations.

4 Performance of the bias correction

The bias correction should take the observation closer to the unknown, true value of the observation. This often, but not necessarily always, means closer to the model. As seen in Figure 1 the corrected values are generally closer to the first guess over the globe. We also see that the corrections are on average small at most some tenths of a degree. The most corrected area is of course the most data dense area, which is the Northern Hemisphere, Figure 9. If we look at some single areas, Figure 10 and Figure 11, we can see larger corrections. Over the USA we have decreased the seasonal amplitude but over China we have shifted the bias also.

Figure 12 shows the vertical profile for some selected groups of stations over the period 1979 to 2001. The Chinese station has got a radiation and a mean error that should be corrected. From the middle panel we can see that the radiative error has been reduced but the mean error still has got a pronounced peak at 60 hPa. This can be attributed to the spline fitting, Figure 13, applied to the correction. The fitting removes irregularities and may give more realistic corrections, but it cannot handle all curves correctly. The Alaska profile shows a huge radiative error that has been removed without changing the mean profile as is shown in Figure 12. The remaining radiative error is however larger than in the Chinese case. It seems as if the limiting constraints has been too narrow. Figure 14, right column, shows a similar profile for Alaska without this artificial control.

Time series from several station groups shows that the radiative bias is present from the beginning of the period up to the mid eighties with a temperature difference between night time and daytime solar elevations of 1.5 - 4 degrees, Figure 15 - Figure 17. For some stations, such as from the US and Canada the bias is present even up to the very end of 2002. This suggests that a radiative correction should be applied from the very beginning of the assimilation. The year-to-year variations can be significant, especially when instrumentation or methods are changed (as in France 1972, USSR 1976 or Alaska 1996). These changes have to be distinguished from changes due to introduction of new satellites, as in 1979. The former shows up for certain station groups only but the latter should be visible for most of the station groups over the globe.



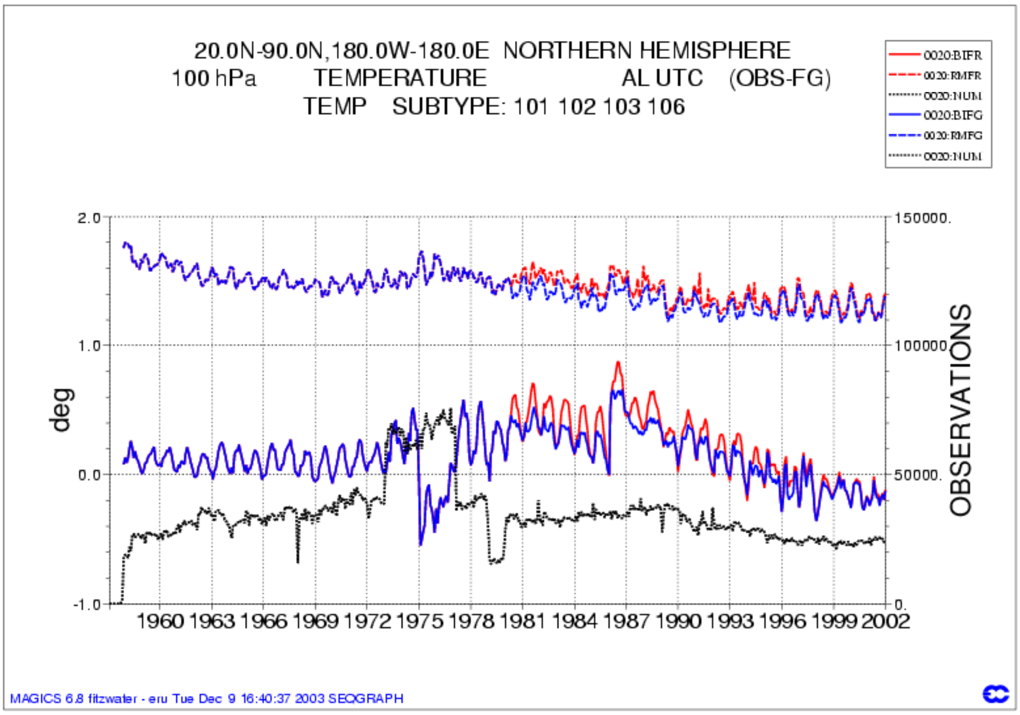
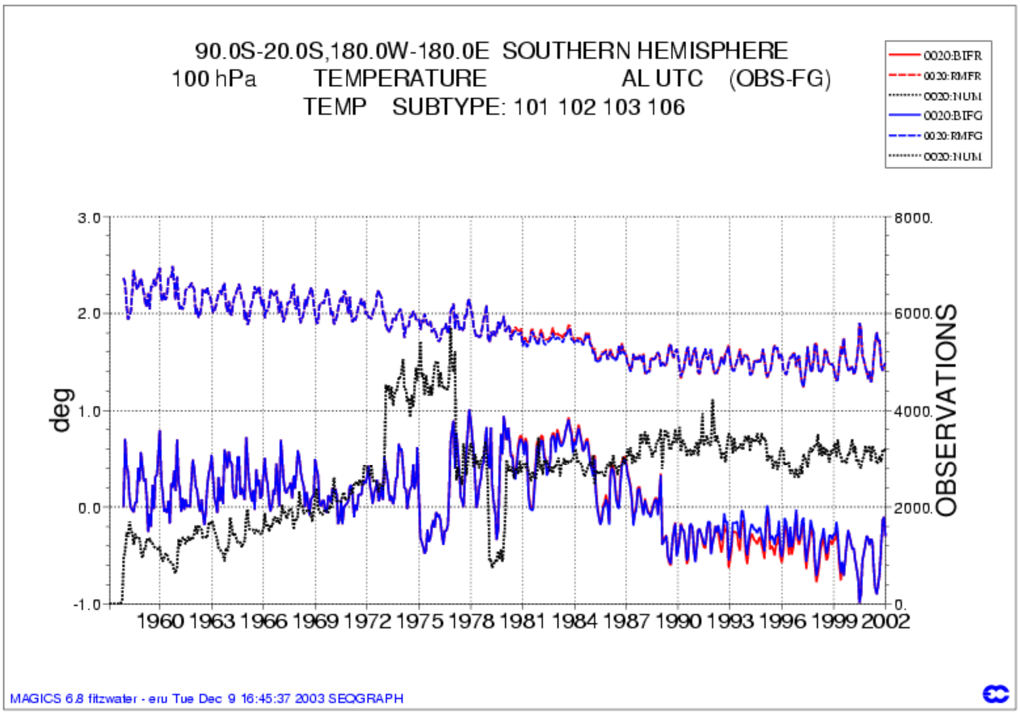


Figure 9 Time series of temperature first guess departures at 100 hPa for different areas. Dashed line shows the RMS and the solid line is the bias. Blue line means corrected and red uncorrected departures. The black line is number of observations per month.



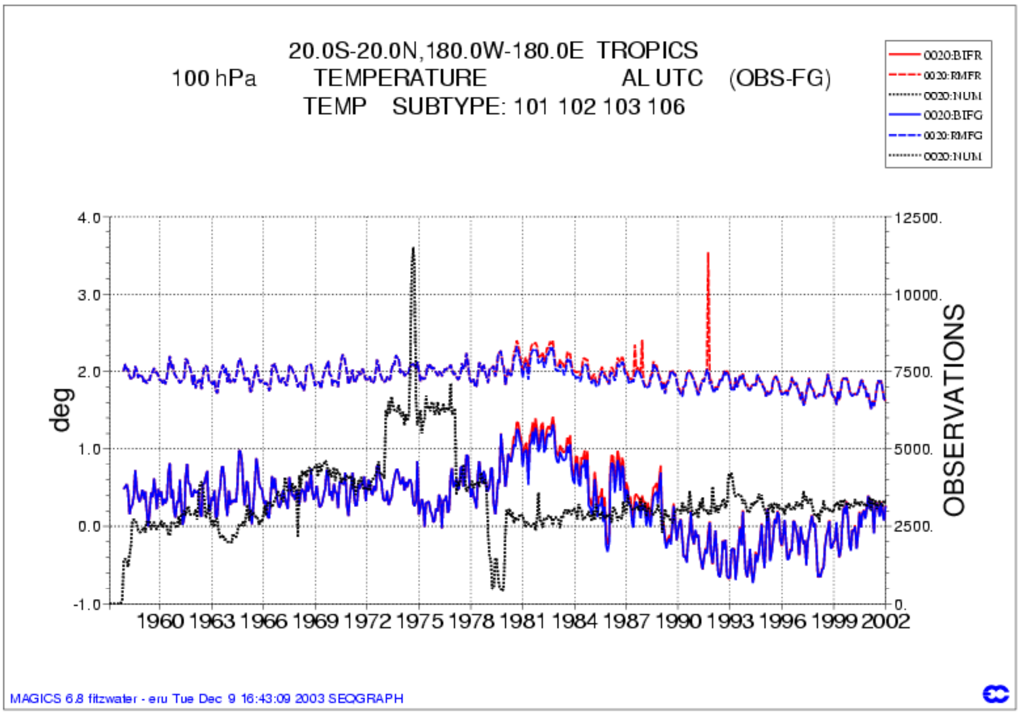
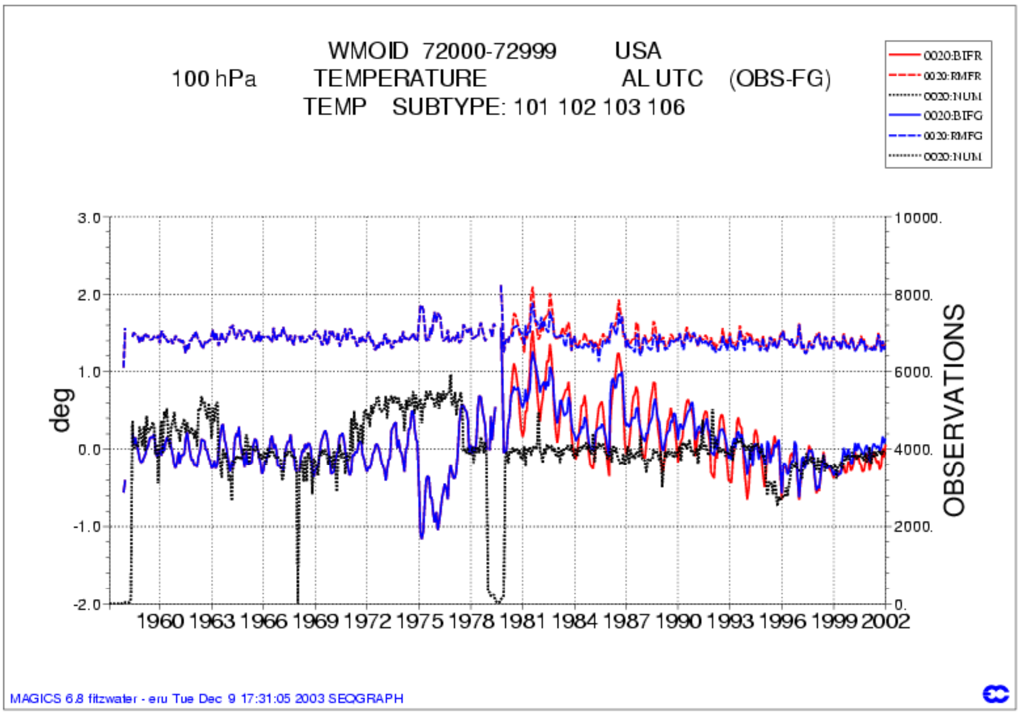


Figure 9 Continued



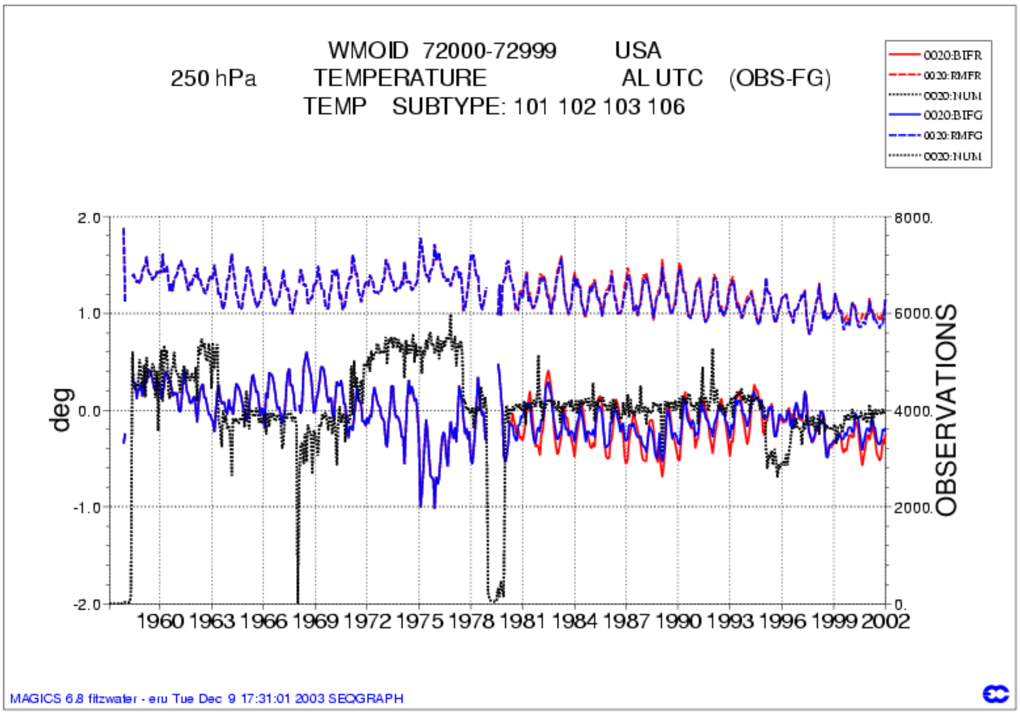
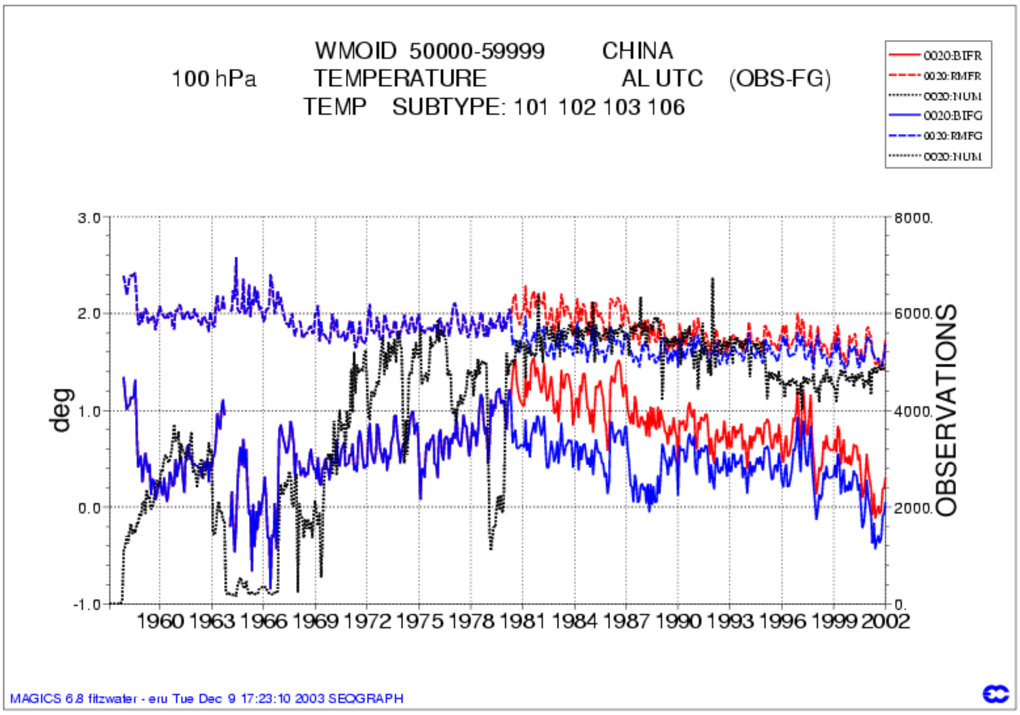


Figure 10 Time series of temperature first guess departures for 100 and 250 hPa over USA. Dashed line shows the RMS and the solid line is the bias. Blue line means corrected and red uncorrected departures. The black line is number of observations per month.



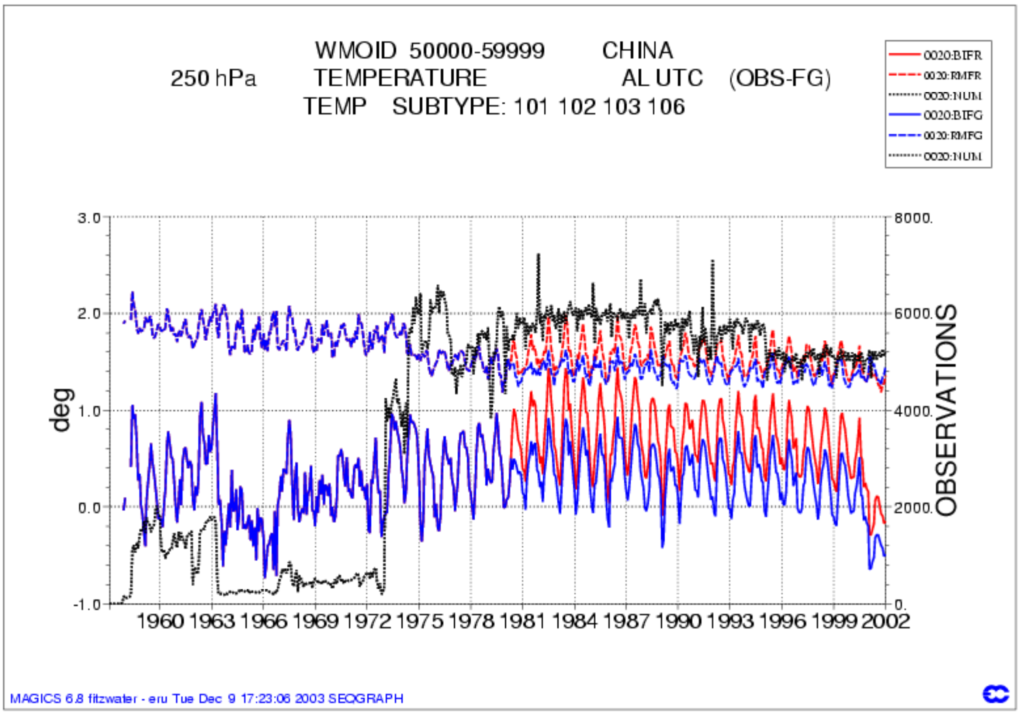


Figure 11 Time series of temperature first guess departures for 100 and 250 hPa over China. Dashed line shows the RMS and the solid line is the bias. Blue line means corrected and red uncorrected departures. The black line is number of observations per month.

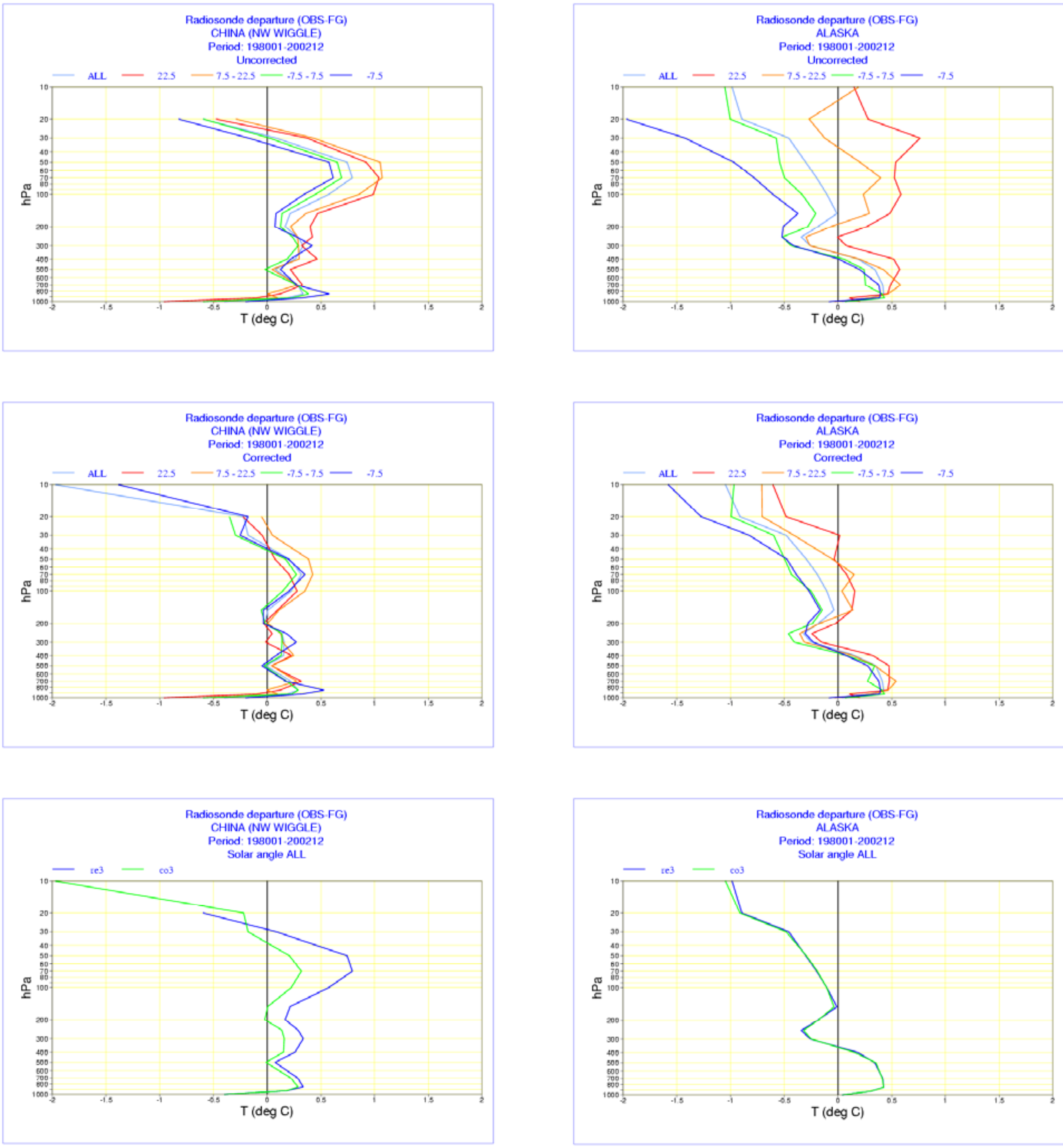


Figure 12 Uncorrected and corrected radiosonde temperature first guess departure from China and Alaska for 1980 - 2002. Top panels are uncorrected departures for all angles. Middle panels are corrected departures. Bottom panels are the uncorrected (blue) and corrected (green) mean departure.

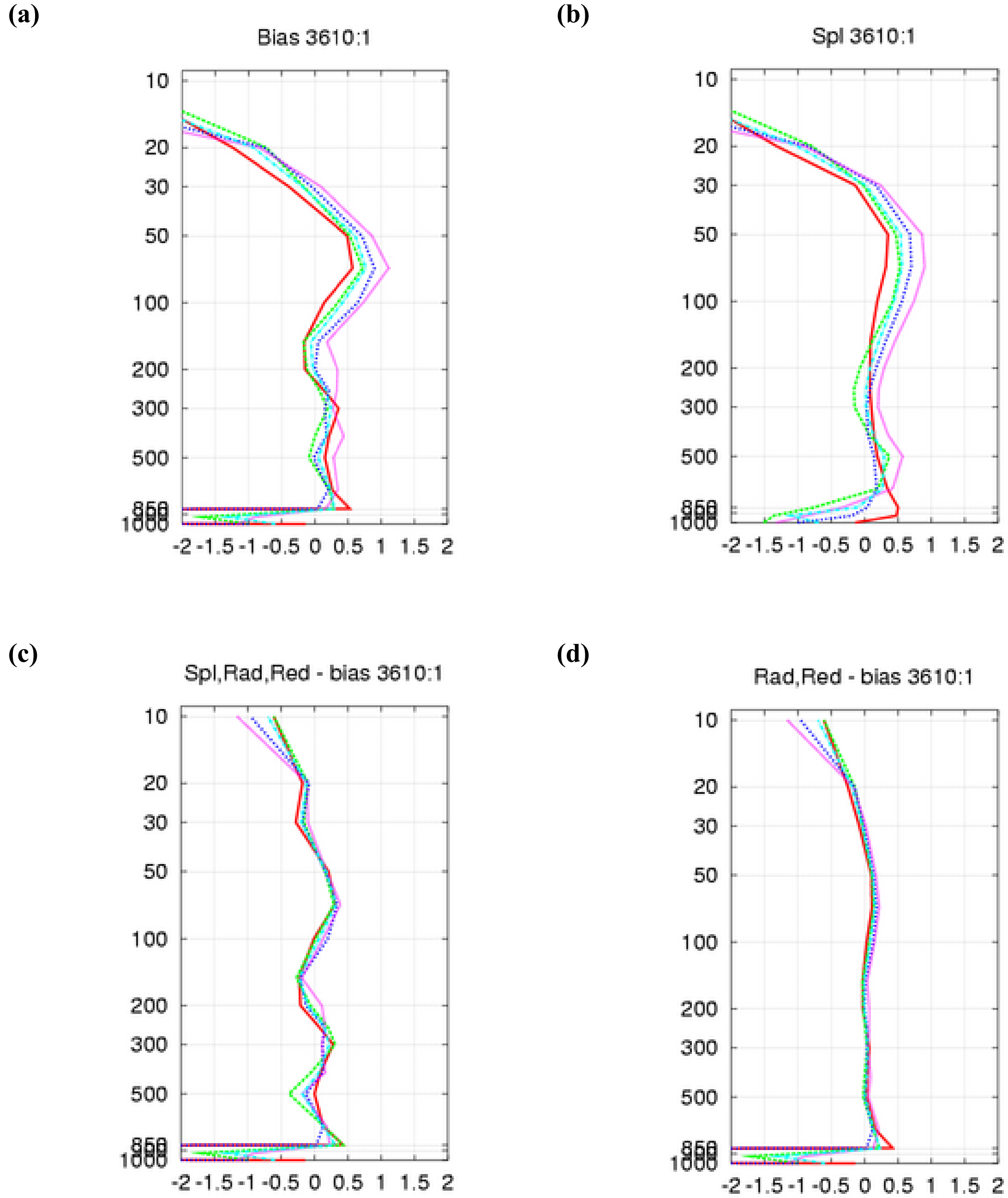


Figure 13 Bias correction over China. From left to right: a) Bias. b) Fitted bias. c) Corrected profile with fitted bias. d) Corrected profile without fitted bias.

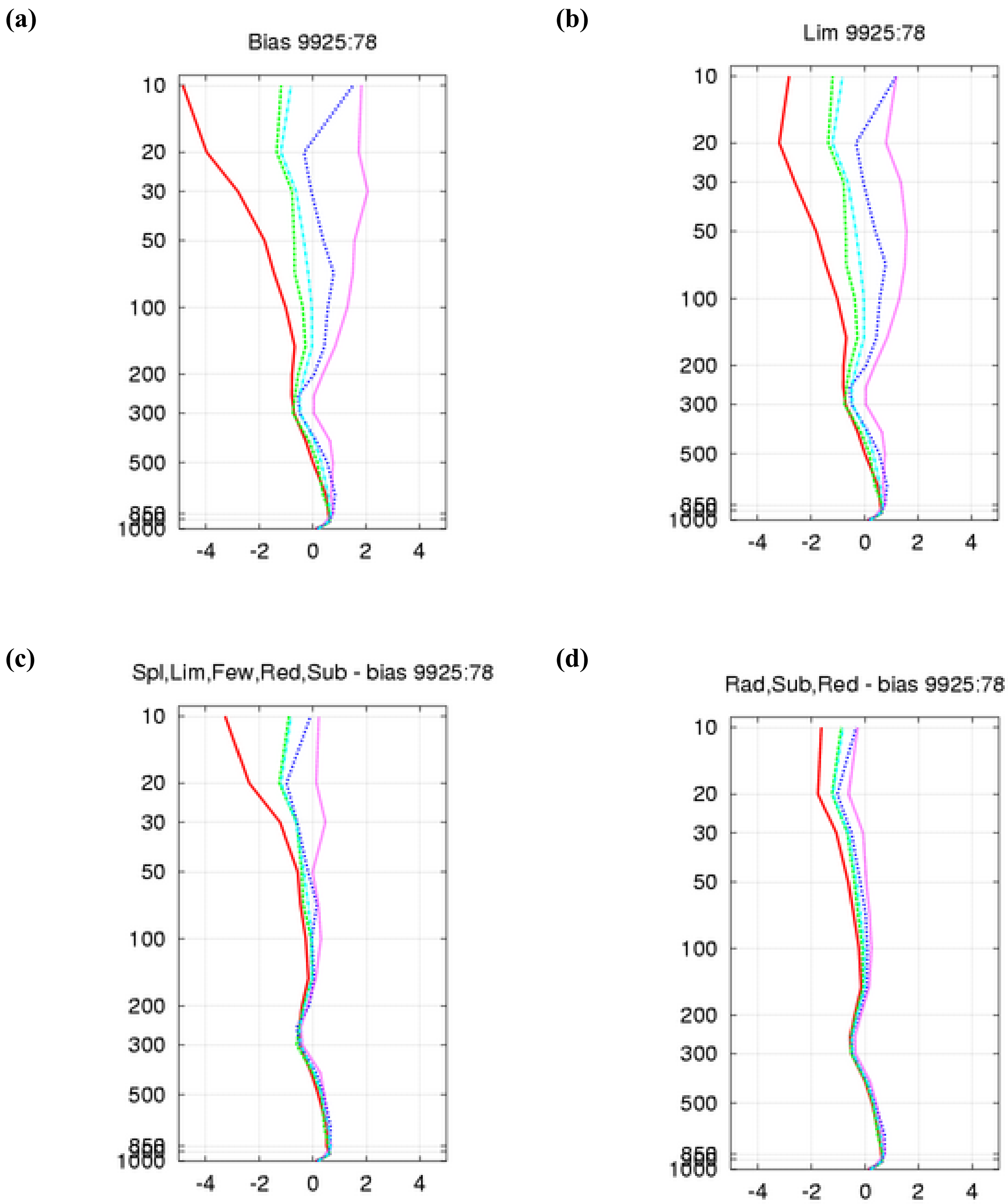
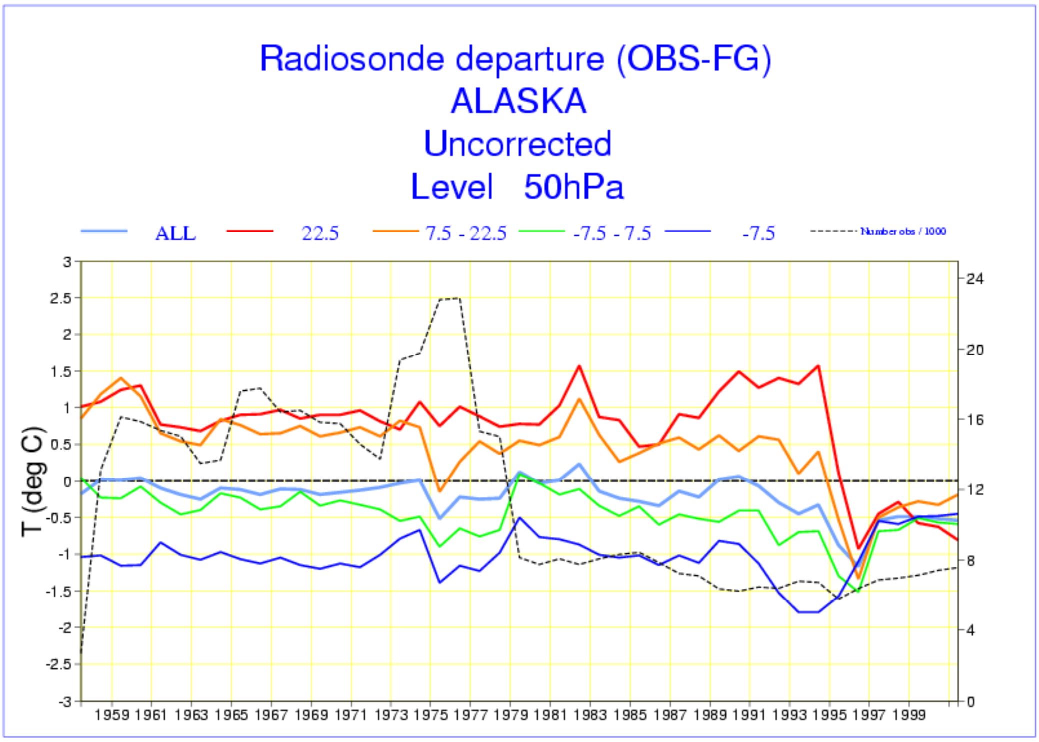


Figure 14 Bias correction over Alaska, with and without limiting factor. a) Bias. b) Limited bias. c) Corrected profile with limited bias. d) Corrected profile without limited bias.

The difference in bias between different groups does also gives useful information. Figure 17 shows the evolution of the observation error in Ireland, UK and France. Apart from the fact that they all have radiative errors there is also a clear shift in the mean bias between the stations. At 100hPa we would expect them to have the same mean bias but there is a two-degree difference between Ireland and France in the sixties and almost one-degree difference between UK and the others countries in the seventies. Consequently there is a need to correct the mean bias as well for many stations. Information of which station group has been corrected for the mean error is given in Table 1.



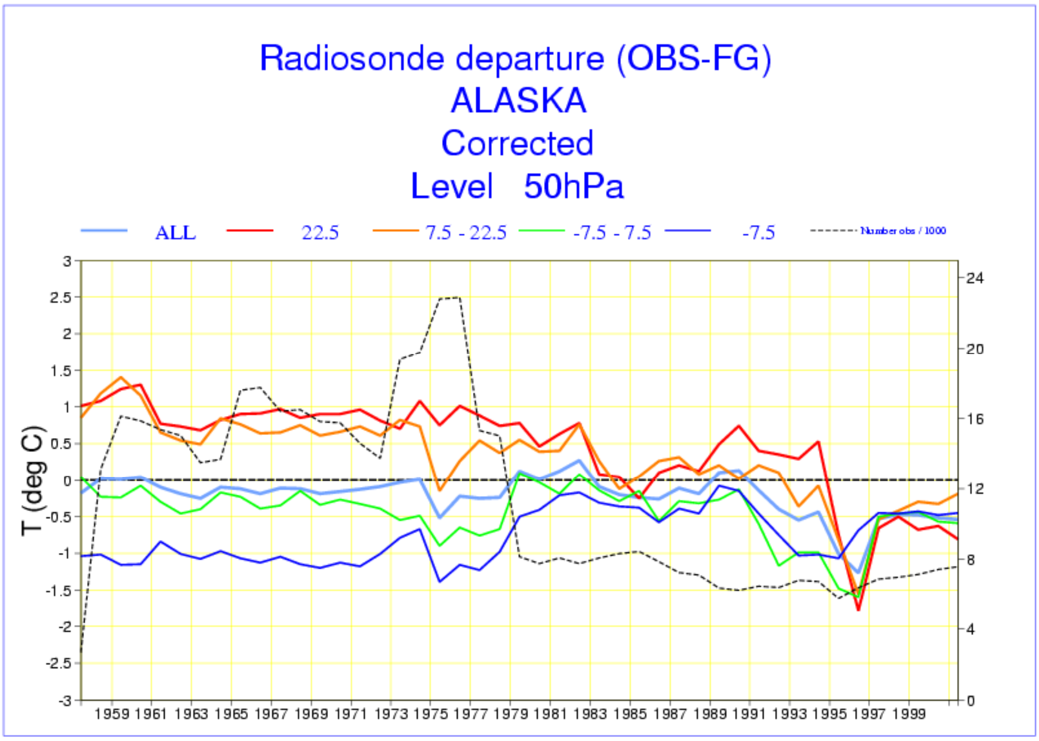
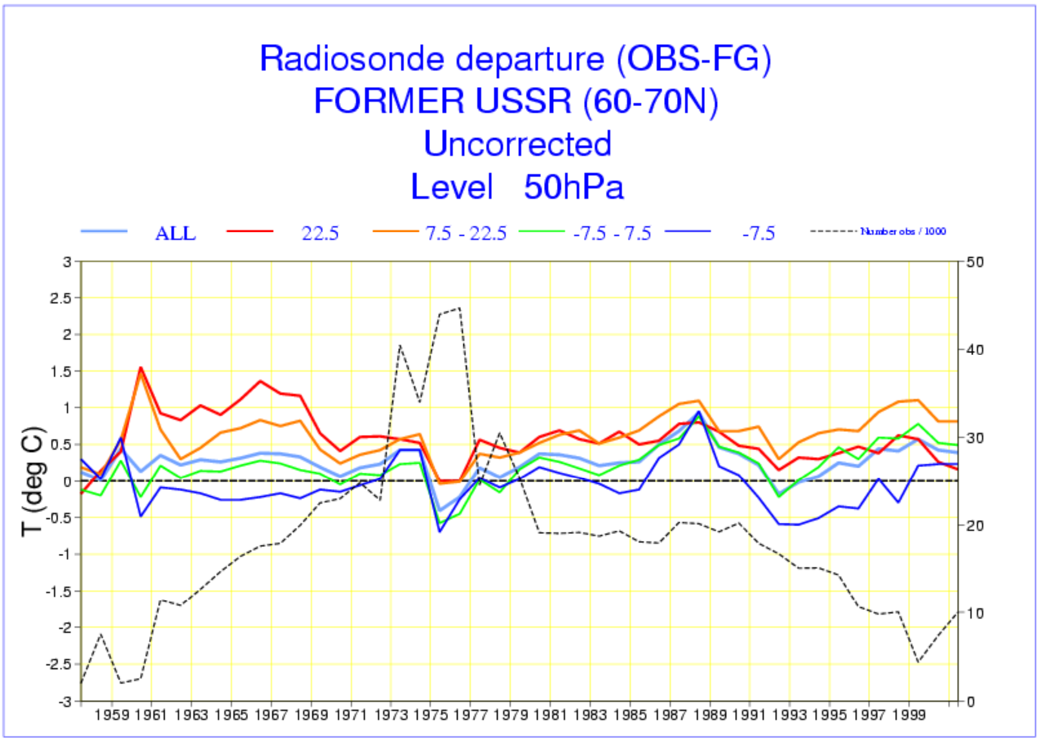


Figure 15 Yearly averages of first guess departures for different solar elevations for Alaska at 50 hPa. Top panel shows uncorrected departures and bottom shows corrected ones. Number of observations is observations per year.



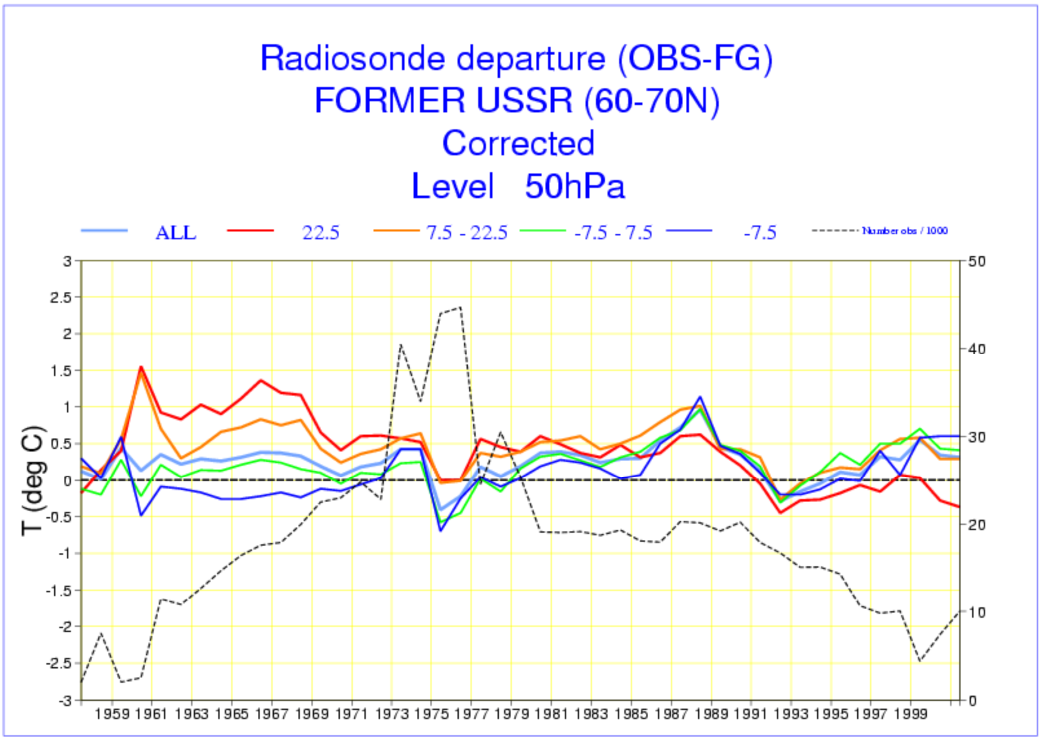


Figure 16 Yearly averages of first guess departures for different solar elevations for former USSR at 50 hPa. Top panel shows uncorrected departures and bottom shows corrected ones. Number of observations is observations per year.

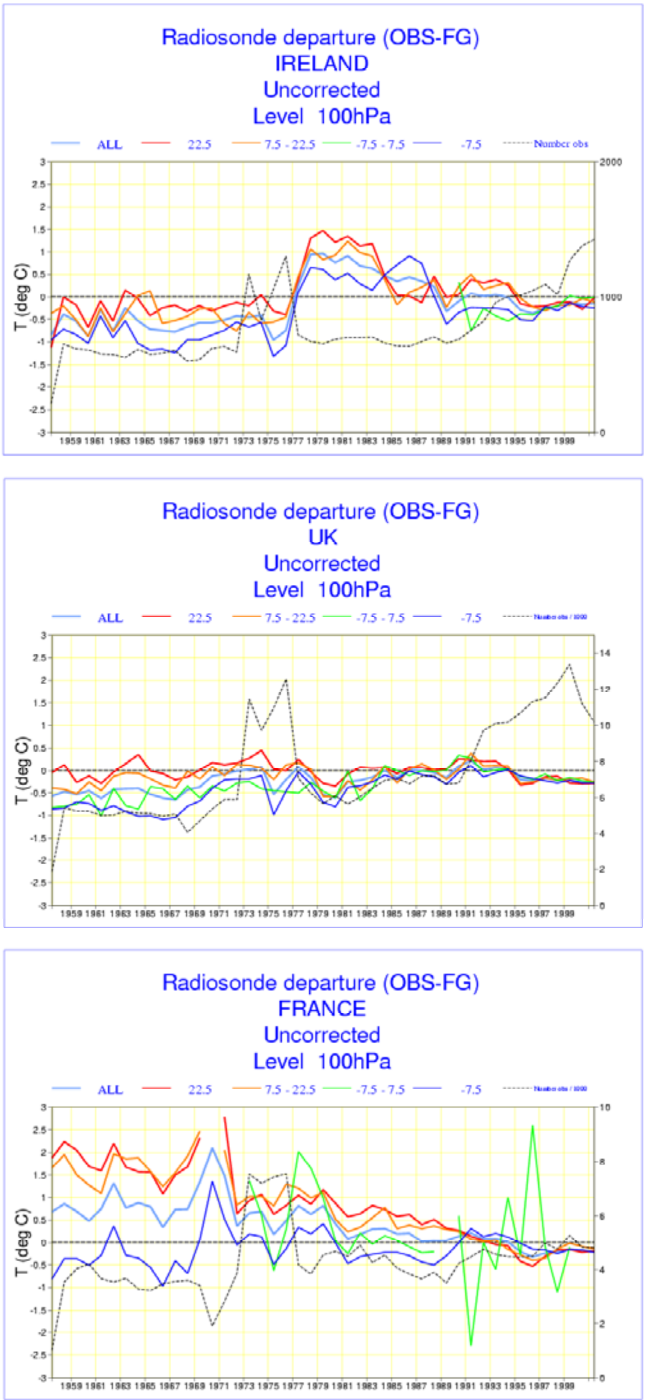


Figure 17 Yearly averages of first guess departures for different solar elevations at 100hPa. From top to bottom: --Ireland, UK and France. Number of observations is observations per year.

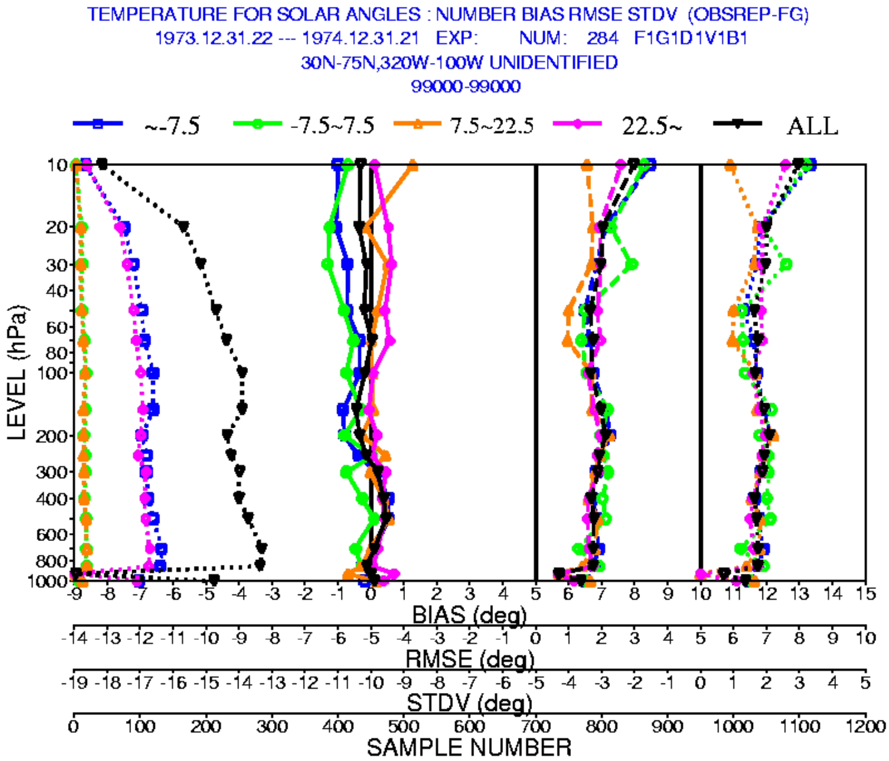
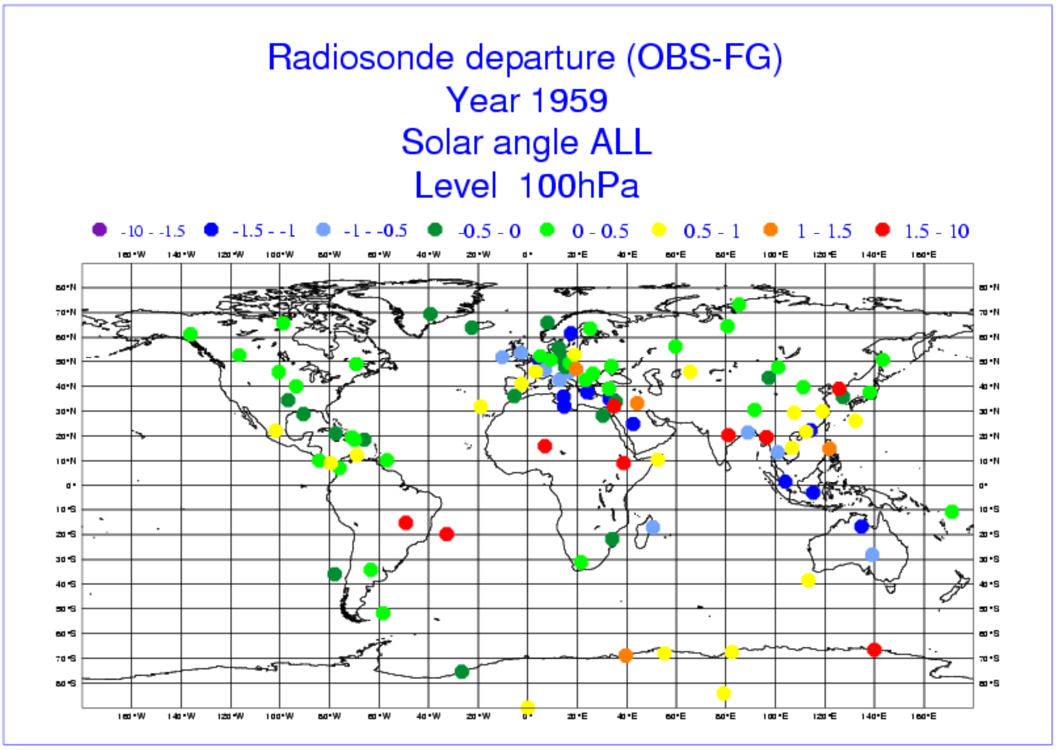


Figure 18 Statistics from unidentified radiosondes over the North Atlantic for 1974.



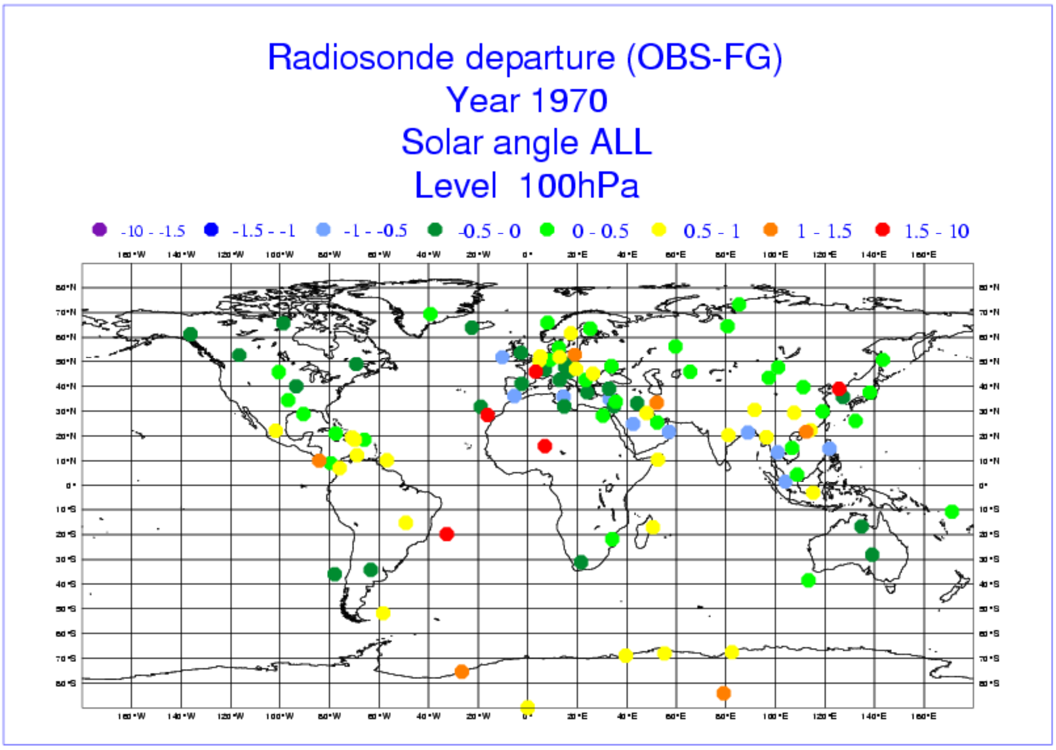
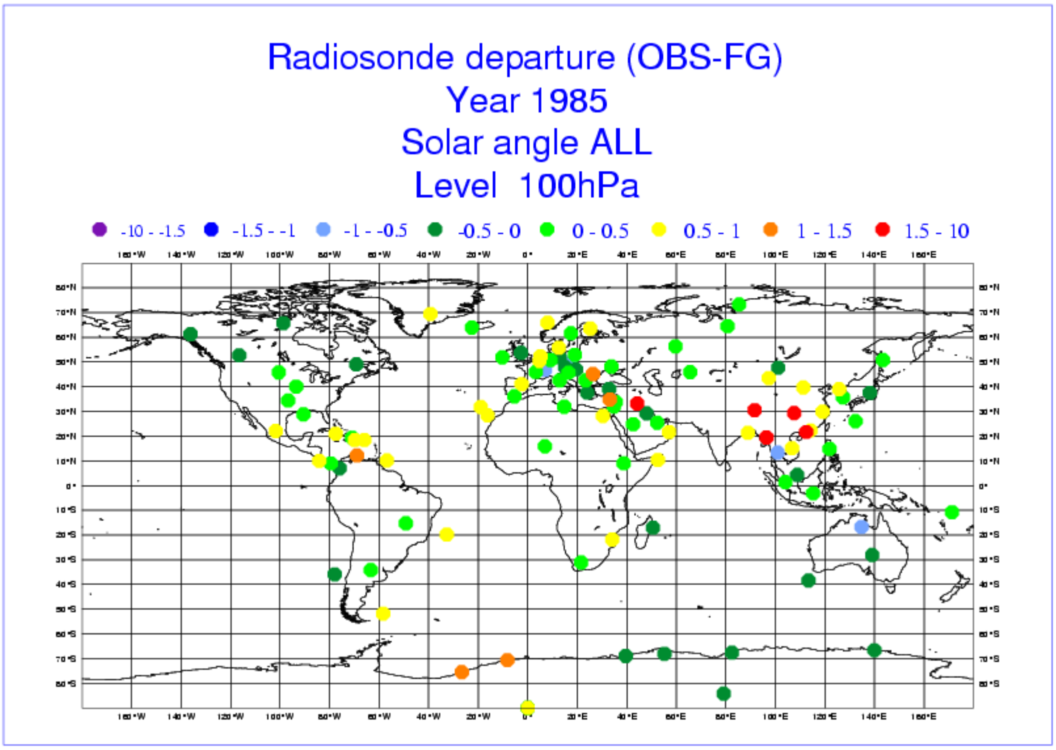


Figure 19 Spatial distribution of yearly first guess departures at 100 hPa. Each point represents one of the groups in Table 3. From top to bottom: 1959, 1970 1985 and 2001 respectively.



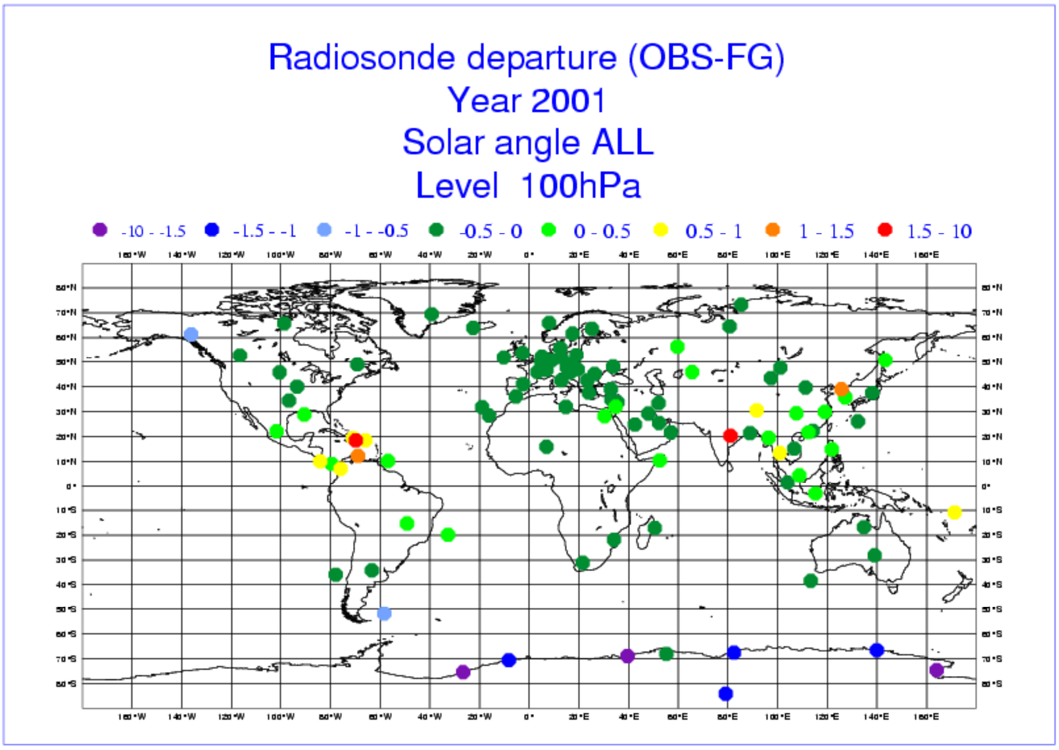


Figure 19 continued.

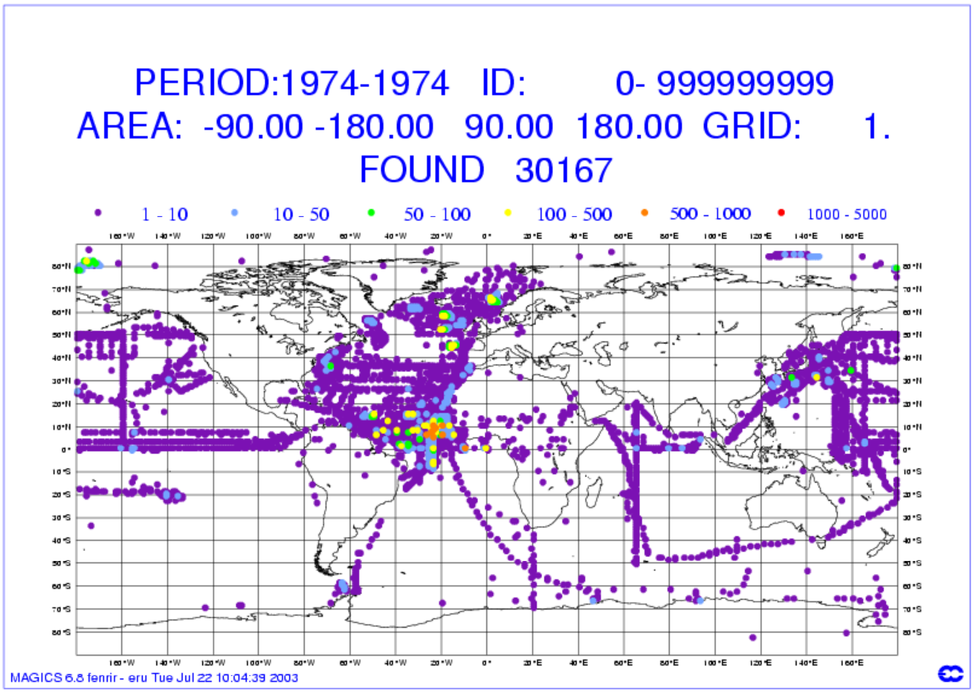


Figure 20 Spatial distribution of unidentified TEMP reports in 1974.

As mentioned earlier the number of radiosondes has fluctuated between 30000 - 50000 ascents per month globally with the peak number during 1970 - 1990. The quality, however, has increased considerably over the years. Maps of the spatial distribution of first guess departures shows a much more coherent structure in 2001 than in e.g. 1959, Figure 19. The radiosonde network over North America seems to be very stable. In data dense Europe the variations between the countries are huge in the beginning but the pattern becomes very coherent in 2001. Over East Asia the improvement is not so dramatic. There are still large variations between different areas. The absolute errors have decreased in general, but some problematic areas remain, such as the Caribbean and East Asia. The switch from a cold to a warm bias of Antarctica is an artefact from problems with the assimilation of satellite radiances over polar regions. The increments from the ERA-40 system is such that it creates an oscillatory vertical profile with a peak at 100hPa. At 50 or 500 hPa (not shown) there is no clear trend in the biases over Antarctica.

5 Discussion

We have seen that the bias correction applied in ERA-40 after 1979 has generally done a good job, but there is of course room for improvement. Some of the performance issues described above could be addressed by the following changes.

With the first guess departure statistics available for all 45 years we have the possibility to produce more comprehensive correction tables for all years. For any future rerun we have the advantage of having all the answers already, although it may be biased towards the version of the assimilation system used in ERA-40. This means that we should calculate new correction tables valid for 1-3 years before any more substantial reruns are performed instead of keeping the old lagged suboptimal tables.

The formation of the different groups seem to be a bit too ambitious since many of the stations in Table 3 are not corrected due lack of reliable statistics. A revision of especially the small groups would be advisable. The low number of recognition of non-stationary radiosondes shown in Figure 3 does also need some further investigation. Although it is a very small part of the total number of radiosondes they are the only information in otherwise data sparse areas in the early years. If we calculate the bias for all unidentified reports over the North Atlantic for 1974 we find that there is some signal in the bias, Figure 18. Figure 20 shows that most of the reports in Figure 18 comes from a few places. The constraints used when calculating the corrections were applied in the first place to keep a conservative line on the corrections when used in the ERA-40 production. If we are to recalculate the corrections we are free to choose time periods and reform groups. As shown in Figure 7, Figure 13 and Figure 14 the constraints may cause more trouble than benefit.

We have only aimed to correct the radiative error in most cases. It is though clear, as shown in Figure 17, that there is a need for a correction of the mean error as well in many cases. This is much more difficult than just adjusting the radiative error since we have to rely much more on the model used. One way is to use the information on the maps in Figure 19 to identify anomalous station groups. If a large area has the same error it is likely to be a model error. On the other hand, if a group deviates significantly from the surrounding groups it is likely that it has an observation error. For the mean biases corrected in ERA-40 no such considerations were made.

The observation error due to radiative cooling or warming is assumed to be a monotonic function of solar elevation. In corrections applied operationally at ECMWF the corrections are therefore forced to that form. In ERA-40 the corrections are purely determined by the bias statistics. For the East Russian group showed in Figure 21 the monotonic assumption seems not to be valid. The error in the solar elevation interval 7.5-22.5 degrees is larger than for elevations greater than 22.5 degrees. This feature occurs in several station groups. The operational method gives an erroneous correction in this case.

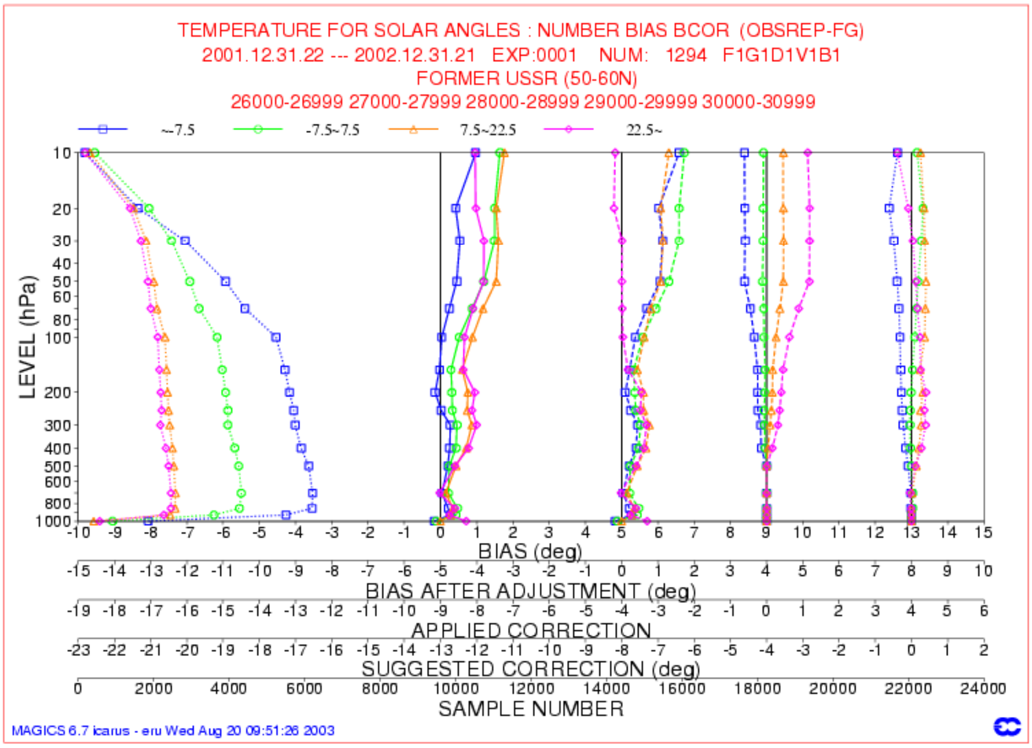


Figure 21 Feedback statistics from ECMWF operational model for 2002. Left panel shows the number of observations for different solar elevations. Second panel shows the uncorrected first guess departure. Third panel shows the corrected departure. Fourth panel shows the corrections applied by operations. Last panel shows the corrections suggested based on the ERA-40 bias correction.

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Table 1 Bias correction switch table for each category used in ERA-40. Flag equal to zero means the full profile was corrected. Flag equal to one means only the radiative errors were corrected. If the actual date was outside the given range or if the time range of the group was set to zero the flag was set equal to zero and the full profile is corrected.

PERIOD	FLAG	GROUP
000- 000	0	NORWAY
194101-198612	1	SWEDEN
000- 000	0	FINLAND
194101-198812	0	UK
194101-198812	1	IRELAND
194101-199012	0	ICELAND
000- 000	0	GREENLAND
194101-198312	1	DENMARK
194101-198712	1	NETHERLANDS
194101-198412	1	BELGIUM
194101-199912	1	SWITZERLAND
194101-197212	0	FRANCE
197301-199012	1	FRANCE
194101-198212	1	SPAIN
000- 000	0	GIBRALTAR
194101-198612	1	PORTUGAL
194101-197512	0	GERMANY (EASTERN)
000- 000	0	GERMANY (WESTERN)
194101-199612	1	AUSTRIA
194101-197012	0	CZECH SLOVAKIA
194101-197212	0	POLAND
194101-197712	0	HUNGARY
194101-199912	1	FORMER YUGOSLAVIA
194101-199912	0	ROMANIA
194101-196912	0	BULGARIA
194101-198612	1	ITALY
000- 000	0	MALTA
194101-197712	1	GREECE
194101-198912	0	TURKEY
199001-199912	1	TURKEY
000- 000	0	CYPRUS
194101-196912	0	RUSSIA (70-80N)
194101-196912	0	FORMER USSR (60-70N)
197001-199912	1	FORMER USSR (60-70N)
194101-196912	0	FORMER USSR (50-60N)
197001-199912	1	FORMER USSR (50-60N)
194101-196912	0	RUSSIA (FAR EAST)
197001-199912	1	RUSSIA (FAR EAST)
194101-196912	0	FORMER USSR (UKR,BEL,MOL ETC)
197001-199912	1	FORMER USSR (UKR,BEL,MOL ETC)
194101-196912	0	FORMER USSR (MIDDLE ASIA; KAZ ETC)
197001-199912	1	FORMER USSR (MIDDLE ASIA; KAZ ETC)
194101-198512	0	FORMER FRENCH DEP. IN ARABIA
194101-199412	1	ISRAEL
000- 000	0	FORMER BRITISH DEP. IN ARABIA
000- 000	0	SAUDI ARABIA
000- 000	0	KUWAIT
000- 000	0	IRAQ
000- 000	0	IRAN
194101-199912	1	AFGHANISTAN
194101-190012	0	OMAN YEMEN
000- 000	0	PAKISTAN BANGLADESH ETC.
000- 000	0	INDIA

000- 000	0	MONGOLIA
000- 000	0	HONGKONG
194101-199912	1	NORTH KOREA
194101-199812	1	SOUTH KOREA
194101-197012	0	JAPAN (MAIN LANDS)
197101-198012	1	JAPAN (MAIN LANDS)
194101-197012	0	JAPAN (SOUTH ISLANDS)
197101-198012	1	JAPAN (SOUTH ISLANDS)
000- 000	0	MYANMAR
000- 000	0	THAILAND
194101-198712	1	MALAYSIA
000- 000	0	SINGAPORE
194101-199912	1	FORMER FRENCH DEP. IN SE ASIA
194101-199912	0	CHINA (NW WIGGLE)
194101-199912	0	CHINA (NORTH)
194101-199912	0	CHINA (25-35N,80-95E;TIBET)
194101-199912	0	CHINA (MIDDLE INLAND)
194101-199912	0	CHINA (25-35N,115E-)
194101-199912	0	CHINA (-25N,105-125E)
000- 000	0	FORMER SPANISH DEP. IN AFRICA
194101-199912	1	FORMER FRENCH DEP. IN AFRICA
000- 000	0	FORMER BRITISH DEP. IN AFRICA
000- 000	0	FORMER PORTUGUESE DEP. IN AFRICA
000- 000	0	FORMER ITALIAN DEP. IN AFRICA
194101-199912	1	EGYPT SUDAN
000- 000	0	ETHIOPIA ERITREA
194101-199112	1	SOUTH AFRICA AND SURR. COUNTRIES
194101-199612	1	ALASKA
194101-199512	1	40N-57N,145W-100W CANADA (SOUTH WEST)
194101-199512	1	40N-57N,100W- 50W CANADA (SOUTH EAST)
194101-199512	1	57N-90N,145W- 50W CANADA (NORTH)
194101-199612	1	24N-32N,120W- 70W USA (FAR SOUTH)
194101-199612	1	32N-37N,130W- 50W USA (SOUTH)
194101-199612	1	37N-43N,130W- 50W USA (MIDDLE)
194101-199612	1	43N-50N,130W- 50W USA (NORTH)
194101-199212	1	MEXICO
194101-199212	1	COUNTRIES (1) IN MIDDLE AMERICA
000- 000	0	CUBA
000- 000	0	HAITI DOMINICA
000- 000	0	COUNTRIES (2) IN MIDDLE AMERICA
194101-199012	1	PUERTO RICO
000- 000	0	PANAMA
000- 000	0	COUNTRIES (3) IN MIDDLE AMERICA
194101-199112	0	CURACAO AND BONAIRE
000- 000	0	COLOMBIA,VENEZUELA,ECUADOR,PERU,BOLIVIA,PARAGUAY
000- 000	0	BRAZIL
194101-198812	1	CHILE
000- 000	0	ARGENTINA
000- 000	0	FALKLAND ISLANDS
000- 000	0	ANTARCTICA (SOUTH AFRICA)
000- 000	0	ANTARCTICA (GERMANY)
000- 000	0	ANTARCTICA (USA)
000- 000	0	ANTARCTICA (UK)
000- 000	0	ANTARCTICA (FORMER USSR)
000- 000	0	ANTARCTICA (JAPAN)
000- 000	0	ANTARCTICA (AUSTRALIA)
000- 000	0	ANTARCTICA (FRANCE)
194101-199612	1	USA PACIFIC ISLANDS
000- 000	0	(FORMER) UK DEP. IN PACIFIC ISLANDS

000- 000	0	(FORMER) FRENCH DEP. IN PACIFIC ISLANDS
194101-196712	0	NEW ZEALAND
196801-198812	1	NEW ZEALAND
194101-198712	1	AUSTRALIA (NORTH(23S-),ISLANDS) PAPUA NEW GUINEA
194101-198712	1	60S-23N,110E-170E AUSTRALIA (SOUTH)
000- 000	0	INDONESIA
194101-199912	1	PHILIPPINE

Table 2 Years when the bias correction tables were updated. Detailed information about what was changed is found in Table 3.

DATE			
19791101	19820101	19830101	19870201
19910326	19920414	19961104	19990610
19991101	20010101		

Table 3 Representative groups in the bias correction. 0 means uncorrected, 2 means new correction, 1 means same correction. The last column gives the fraction of number of corrected profiles for the period May 1980 to August 2002.

STATION \ YEAR	80	82	83	87	91	92	96	99	99	01	%
NORWAY	2	2	1	1	0	0	0	0	0	0	37.
SWEDEN	2	1	1	0	0	0	0	0	0	0	32.
FINLAND	0	0	0	0	0	0	0	0	0	0	0.
UK	2	2	1	2	2	1	2	0	0	0	85.
IRELAND	0	0	0	0	2	1	2	0	0	0	50.
ICELAND	2	1	1	2	2	1	2	0	0	0	87.
GREENLAND	0	0	0	0	0	0	0	0	0	0	0.
DENMARK	0	0	2	0	0	0	0	0	0	0	17.
NETHERLANDS	2	1	1	0	2	1	1	0	0	0	76.
BELGIUM	0	0	2	0	0	0	0	0	0	0	15.
LUXEMBOURG	0	0	0	0	0	0	0	0	0	0	0.
SWITZERLAND	0	0	0	0	2	1	1	0	0	0	51.
FRANCE	2	2	1	1	2	2	0	0	0	0	75.
SPAIN	2	1	0	0	0	0	0	0	0	0	12.
GIBRALTAR	2	1	1	1	0	0	0	0	0	0	39.
PORTUGAL	2	1	1	1	0	0	0	0	0	0	41.
GERMANY (EASTERN)	0	0	0	0	0	0	0	0	0	0	0.
GERMANY (WESTERN)	2	1	1	1	0	0	0	0	0	0	39.
AUSTRIA	2	1	1	1	2	1	2	0	0	0	83.
CZECH SLOVAKIA	2	1	1	1	0	0	0	0	0	0	39.
POLAND	0	0	0	2	0	0	0	0	0	0	9.
HUNGARY	2	1	1	2	0	0	0	0	0	0	50.
FORMER YUGOSLAVIA	2	1	1	1	2	1	0	0	0	0	84.
ALBANIA	0	0	0	0	0	0	0	0	0	0	0.
ROMANIA	2	1	1	2	2	1	1	0	0	0	93.
BULGARIA	0	0	2	0	0	0	0	0	0	0	21.
ITALY	2	1	2	0	0	0	0	0	0	0	23.

MALTA	0	0	0	0	0	0	0	0	0	0	0.
GREECE	0	0	0	0	0	0	0	0	0	0	0.
TURKEY	2	2	1	2	2	1	2	2	1	1	100.
CYPRUS	0	0	0	0	0	0	0	0	0	0	0.
RUSSIA (70-80N)	0	0	0	0	0	0	0	0	0	0	2.
FORMER USSR (60-70N)	2	1	1	1	2	1	1	1	1	1	96.
FORMER USSR (50-60N)	2	1	1	1	2	1	1	1	1	1	96.
RUSSIA (FAR EAST)	2	1	1	1	2	1	1	1	1	1	96.
FORMER USSR (UKR,BEL,MOL ETC)	2	2	1	1	2	1	1	2	1	1	96.
FORMER USSR (MIDDLE ASIA; KAZ ETC)	0	0	0	0	2	1	1	1	1	1	37.
FORMER FRENCH DEP. IN ARABIA	0	0	0	0	0	0	0	0	0	0	0.
ISRAEL	2	1	1	1	2	1	2	0	0	0	90.
FORMER BRITISH DEP. IN ARABIA	0	0	0	0	0	0	0	0	0	0	1.
SAUDI ARABIA	0	0	0	0	0	0	0	0	0	0	3.
KUWAIT	0	0	0	0	0	0	0	0	0	0	0.
IRAQ	0	0	0	0	0	0	0	0	0	0	0.
IRAN	2	0	0	0	0	0	0	0	0	0	3.
AFGHANISTAN	0	0	0	0	2	1	0	0	0	0	2.
OMAN YEMEN	0	0	0	0	0	0	0	0	0	0	0.
PAKISTAN BANGLADESH ETC.	0	0	0	0	0	0	0	0	0	0	0.
INDIA	0	0	0	0	0	0	0	0	0	0	1.
MONGOLIA	0	0	0	0	0	0	0	0	0	0	0.
HONGKONG	0	0	0	0	0	0	0	0	0	0	0.
MACAU	0	0	0	0	0	0	0	0	0	0	0.
NORTH KOREA	2	2	2	2	2	1	1	1	1	0	100.
SOUTH KOREA	2	1	1	1	2	1	1	1	1	1	99.
JAPAN (MAIN LANDS)	2	2	0	0	0	0	0	0	0	0	17.
JAPAN (SOUTH ISLANDS)	2	2	0	0	0	0	0	0	0	0	17.
MYANMAR	2	1	1	0	0	0	0	0	0	0	57.
THAILAND	0	0	0	0	0	0	0	0	0	0	0.
MALAYSIA	0	0	0	0	2	1	1	1	1	1	67.
SINGAPORE	0	0	0	0	0	0	0	0	0	0	0.
FORMER FRENCH DEP. IN SE ASIA	0	0	0	0	2	2	1	1	1	0	61.
CHINA (NW WIGGLE)	2	1	1	2	2	1	1	1	1	1	100.
CHINA (NORTH)	2	1	1	2	2	1	1	1	1	1	100.
CHINA (25-35N,80-95E;TIBET)	2	1	2	2	2	1	1	1	1	1	100.
CHINA (MIDDLE INLAND)	2	1	1	2	2	1	1	1	1	1	100.
CHINA (25-35N,115E-)	2	1	1	2	2	1	1	1	1	1	100.
CHINA (-25N,105-125E)	2	1	1	2	2	1	1	1	1	1	100.
FORMER SPANISH DEP. IN AFRICA	0	0	0	0	0	0	0	0	0	0	0.
FORMER FRENCH DEP. IN AFRICA	2	1	1	1	2	1	1	0	0	0	88.
FORMER BRITISH DEP. IN AFRICA	0	0	0	0	0	0	0	0	0	0	0.
FORMER PORTUGUESE DEP. IN AFRICA	0	0	0	0	0	0	0	0	0	0	0.
FORMER ITALIAN DEP. IN AFRICA	0	0	0	0	0	0	0	0	0	0	0.
EGYPT SUDAN	2	2	1	1	0	0	0	0	2	1	50.
ETHIOPIA ERITREA	0	0	0	0	0	0	0	0	0	0	0.
FORMER BELGIUM DEP. IN AFRICA	0	0	0	0	0	0	0	0	0	0	0.
EQUATORIAL GUINEA	0	0	0	0	0	0	0	0	0	0	0.
LIBERIA	0	0	0	0	0	0	0	0	0	0	0.
SOUTH AFRICA AND SURR. COUNTRIES	0	0	0	0	2	2	1	0	0	0	51.
ALASKA	2	2	1	1	2	1	2	0	0	0	88.
40N-57N,145W-100W CANADA (SOUTH WEST)	2	2	1	1	2	2	2	2	1	1	100.
40N-57N,100W- 50W CANADA (SOUTH EAST)	2	2	1	1	2	1	2	2	1	1	100.
57N-90N,145W- 50W CANADA (NORTH)	2	2	1	1	2	1	2	2	1	1	100.
24N-32N,120W- 70W USA (FAR SOUTH)	2	2	1	1	2	1	2	2	1	1	100.
32N-37N,130W- 50W USA (SOUTH)	2	2	1	1	2	1	2	2	1	1	100.
37N-43N,130W- 50W USA (MIDDLE)	2	2	1	1	2	1	2	2	1	1	100.
43N-50N,130W- 50W USA (NORTH)	2	2	1	1	2	1	2	2	1	1	100.
MEXICO	2	2	1	1	2	1	2	0	0	0	91.

COUNTRIES (1) IN MIDDLE AMERICA	2	2	1	1	2	1	1	0	2	1	98.
CUBA	0	0	0	0	0	0	0	0	0	0	0.
HAITI DOMINICA	2	1	1	2	0	0	0	0	0	0	58.
COUNTRIES (2) IN MIDDLE AMERICA	2	2	1	1	0	0	0	0	0	0	63.
PUERTO RICO	2	1	1	1	2	1	1	2	1	1	87.
PANAMA	2	1	2	1	0	0	0	0	0	0	50.
CLIPPERTON	0	0	0	0	0	0	0	0	0	0	0.
ANGUILLA	0	0	0	0	0	0	0	0	0	0	0.
SAINT KITTS AND NEVIS	0	0	0	0	0	0	0	0	0	0	0.
COUNTRIES (3) IN MIDDLE AMERICA	0	0	0	0	0	0	0	0	0	0	1.
DOMINICA	0	0	0	0	0	0	0	0	0	0	0.
SAINT VINCENT	0	0	0	0	0	0	0	0	0	0	0.
GRENADA	0	0	0	0	0	0	0	0	0	0	0.
ARUBA	0	0	0	0	0	0	0	0	0	0	0.
CURACAO AND BONAIRE	2	1	2	2	2	1	1	0	2	1	99.
COLOMBIA,VENEZUELA,ECUADOR,PERU, BOLIVIA,PARAGUAY	2	1	1	1	0	0	0	0	0	0	40.
SURINAME	0	0	0	0	0	0	0	0	0	0	0.
BRAZIL	0	0	0	0	0	0	0	0	0	0	5.
CHILE	2	1	1	1	2	1	1	0	0	0	86.
URUGUAY	0	0	0	0	0	0	0	0	0	0	0.
ARGENTINA	0	0	0	0	0	0	0	0	0	0	0.
FALKLAND ISLANDS	0	0	0	0	0	0	0	0	0	0	0.
ANTARCTICA (ARGENTINA)	0	0	0	0	0	0	0	0	0	0	0.
ANTARCTICA (SOUTH AFRICA)	0	0	0	0	0	0	0	0	0	0	0.
ANTARCTICA (GERMANY)	0	0	0	0	0	0	0	0	0	0	0.
ANTARCTICA (USA)	0	0	0	0	0	0	0	0	0	0	0.
ANTARCTICA (FINLAND)	0	0	0	0	0	0	0	0	0	0	0.
ANTARCTICA (UK)	0	0	0	0	0	0	0	0	0	0	0.
ANTARCTICA (FORMER USSR)	0	0	0	0	0	0	0	0	0	0	0.
ANTARCTICA (POLAND)	0	0	0	0	0	0	0	0	0	0	0.
ANTARCTICA (URUGUAY)	0	0	0	0	0	0	0	0	0	0	0.
ANTARCTICA (CHILE)	0	0	0	0	0	0	0	0	0	0	0.
ANTARCTICA (CHINA)	0	0	0	0	0	0	0	0	0	0	0.
ANTARCTICA (SPAIN)	0	0	0	0	0	0	0	0	0	0	0.
ANTARCTICA (FORMER USSR)	0	0	0	0	0	0	0	0	0	0	0.
ANTARCTICA (KOREA)	0	0	0	0	0	0	0	0	0	0	0.
ANTARCTICA (INDEA)	0	0	0	0	0	0	0	0	0	0	0.
ANTARCTICA (JAPAN)	0	0	0	0	0	0	0	0	0	0	0.
ANTARCTICA (AUSTRALIA)	0	0	0	0	0	0	0	0	0	0	0.
ANTARCTICA (FRANCE)	0	0	0	0	0	0	0	0	0	0	0.
ANTARCTICA (ITARY)	0	0	0	0	0	0	0	0	0	0	0.
ANTARCTICA (NEW ZEALAND)	0	0	0	0	0	0	0	0	0	0	0.
USA PACIFIC ISLANDS	2	1	1	1	2	1	2	0	0	0	89.
(FORMER) UK DEP. IN PACIFIC ISLANDS	2	1	1	1	0	0	0	0	0	0	44.
(FORMER) FRENCH DEP. IN PACIFIC ISLANDS	2	1	1	1	0	0	0	0	0	0	34.
TOKELAU	0	0	0	0	0	0	0	0	0	0	0.
DETACHED ISLANDS	0	0	0	0	0	0	0	0	0	0	0.
NEW ZEALAND	2	1	1	1	2	2	1	0	0	0	89.
DETACHED ISLANDS	0	0	0	0	0	0	0	0	0	0	0.
AUSTRALIA (NORTH(23S-),ISLANDS) PAPUA NEW GUINEA	2	1	0	0	2	1	1	0	0	0	76.
60S-23N,110E-170E AUSTRALIA (SOUTH)	2	2	2	0	2	1	1	0	0	0	78.
INDONESIA	2	1	1	1	0	0	0	0	0	0	26.
PHILIPPINE	2	1	2	2	2	1	1	0	0	0	62.