FIT OF ERA-40 ANALYSES TO OBSERVATIONS

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Abstract

The ERA-40 analysis data already available (1958, 1972, 1988-1992) are compared with observations over Central Europe using four different approaches: (i) Exploitation of the analysis feedback (AF) data (TEMP temperature and moisture difference statistics); (ii) comparison of AF statistics with independently analyzed radiosonde data; (iii) comparison of ERA-40 time series with three homogenized Alpine summit station series (ALOCLIM-data); (iv) comparison of ERA-40 time series with homogenized gridded surface data at low levels (ALPCLIM data).

Time series of the differences between ERA-40 first-guess/analysis data and radiosonde observations as available in the AF are known to be useful for finding breaks in individual radiosonde time series. It seems that the main potential drawback of AF data – the dependency of the feedback on the observations to be checked – is not critical in data rich regions like Europe.

This is demonstrated in approach (ii) by contrasting the AF difference statistics with difference statistics generated by an independent analysis method which uses only radiosonde data at neighboring sites. Both methods detect the break and yield the same magnitude of the break. While this result holds for inhomogeneities of a single station it may not be valid if the breaks at different radiosondes are correlated, e.g. when a large country changes the radiosonde type.

The data dependency issue can be completely avoided by using approach (iii). Alpine summit station temperature and humidity values are independent since they are not assimilated into ERA-40. The difference between ERA-40 data and homogenized time series from three summits has a negative trend comparable in magnitude to the observed trend at the summits.

Approach (iv) is similar to (iii) except that it applies to lower levels. The ALPCLIM data selected are homogenized temperature anomaly time series of 86 stations below 1500m MSL, objectively interpolated to a 1x1 grid covering the Alpine region. The difference between ERA-40 (model level 60) temperatures and ALPCLIM 2m temperatures is investigated. The difference series at gridpoints above 1000m MSL shows also a negative trend. The difference series at low level gridpoints shows no trend.

The trends currently found in the differences between these high quality datasets need to be corroborated by longer series as soon as they become available.

1. Introduction

The ERA-40 dataset of global atmospheric analyses and of estimates of various atmospheric fluxes is expected to be of unique quality and will serve as input for a wide range of applications in the geosciences in the next couple of years.

One critical application of the data set will be the detection of low frequency variability signals including trends in the period assimilated. Trend detection requires an extremely high level of temporal homogeneity of the input dataset. While the expected improvement concerning homogeneity has been one of the original motivations for performing reanalyses this property is particularly hard to achieve. In all first generation reanalyses (ERA-15, Gibson et al. 1997) and the NCEP/NCAR reanalyses (NRA, Kalnay et al. 1996, Kistler et al. 2001) several breaks in the time series have been detected. Some of them are reported, for example, in the intercomparison between differing radiosonde datasets, MSU data and reanalyses as performed by Santer et al. (1999). It has been found that the assimilation of satellite data is a particular challenge. Several breaks have been caused by suboptimal use of satellite data.

Most of the errors found in the old reanalyses will be avoided this time. Nevertheless the large amount of changes in the observation input for the ERA-40 assimilation system is still a potential source for inhomogeneities.

This article uses the following approaches in order to assess the temporal homogeneity of the ERA-40 dataset at a relatively early stage of production: (i) studying time series of difference statistics from TEMP-observations over Central Europe, as available in the analysis feedback (AF) data, (ii) comparison of AF difference statistics with difference statistics calculated exclusively from nearby radiosonde observations, (iii) comparing ERA-40 timeseries of temperature and water vapour pressure at 700 hPa with homogenized mountain station data from ALOCLIM (Auer et al. 2001) and (iv) comparing ERA-40 timeseries of temperature at the lowermost (=60th) model level with the ALPCLIM dataset (Böhm et al. 2001). All these comparisons are made over regions that comprise only a small part of the globe. On the other hand, carefully homogenized data are currently available only over rather limited regions.

Atmospheric data assimilation is in a sense similar to separating the wheat (i.e. the final analysis) from the chaff (i.e. the differences between analysis and observations, available as AF data). The AF data may thus be seen only as a by-product of the data assimilation process whose value is not immediately obvious. They are routinely produced within ERA-40 and contain among other information a) quality flags for each observation presented to the assimilation system and b) the differences between analysis or first guess and the observation. Here only the feedback for TEMP observations over Central Europe is studied. In section 2 it is shown that time series of these deviations are quite useful for detecting spurious jumps in the timeseries of the original TEMP observations.

On the other hand feedback data must be used with caution since analysis or first guess data are dependent on the observations to be checked. It becomes clear that in particular the moisture analysis data are affected by biases of individual radiosondes even in regions of high data density. The first guess data are less dependent on such biases. It is attempted to assess this data dependence by comparing the magnitude of jumps as estimated from feedback data with the magnitude as estimated with an objective interpolation method (VERA, Steinacker et al. 2000) based only on observations. VERA uses data from neighboring radiosonde stations in order to generate a synthetic ascent at the location of the radiosonde to be tested (see also Häberli and Steinacker, 2001). First results are discussed in section 2.

In order to avoid the dependency issue ERA-40 series of temperature and water vapour pressure are compared also against time series of Alpine summits. Temperature and moisture information from high altitude stations is rarely assimilated into ERA-40 analyses presumably due to representativity problems at the 6h timescale. The spatial representativity of monthly means is much better. This can also be seen from the fact that it is possible to homogenize mountain station time series by comparing them with neighboring mountain stations (Peterson et al. 1998). Concerning temperature anomalies at 700 hPa the spatial decorrelation distance of monthly means is above 500km (Bica, 2001).

Homogenization of observed time series is a rather tedious task which cannot be automated. It involves interpreting station metadata and good knowledge of the microclimate of the measurement site. The homogeneity of the time series is however crucial for reliable climate trend estimates. Therefore many efforts for homogenizing time series of surface data have been undertaken in recent years. In several studies it has been demonstrated that global trend estimates using unhomogenized data (as the dataset used by the Climate Research Unit (CRU) Jones et al. 1999) are substantially different from typically regional trend estimates based on carefully homogenized data (Böhm et al. 2001). Two examples are the ALPCLIM dataset (Böhm et al. 2001) and the Austrian LOng term CLIMate (ALOCLIM, Auer et al. 2001) dataset. It has been shown that trends from these datasets are about double as high as those from the CRU dataset. The strong trends deserve credence not only because of the careful homogenization of the single series but also due to their consistency. Böhm et al. (2001) have shown that the thickness trend of the 700-1000 hPa layer based on pressure measurements is consistent with the temperature trend based on temperature measurements. Results of comparisons of these homogenized data with ERA-40 data are discussed in sections 3 and 4. Conclusions are drawn in section 5.

In this study the following ERA-40 data have been used: Experiment version (expver) 245 for 1958, expver 251 for 1972, expver 12 for Sept 1987-Oct 1988, expver 17 for Nov-Dec 1988, expver 18 for 1989-1993. Thus seven years of reanalyses have been investigated. The new runs which use the reprocessed NCEP/NCAR input data (expver 20 for 1958 and expver 30 for 1972) have just started. Statistics from these runs are not yet stable but have been compared with results from expver 245,251.

2. Checking the homogeneity of radiosonde series using analysis feedback data

In data rich regions the weight applied by the data assimilation system to a single radiosonde observation is relatively small. Thus an error at a single observing station will only slightly influence the final analysis. Instead the difference between observed value and analysis will be relatively large.

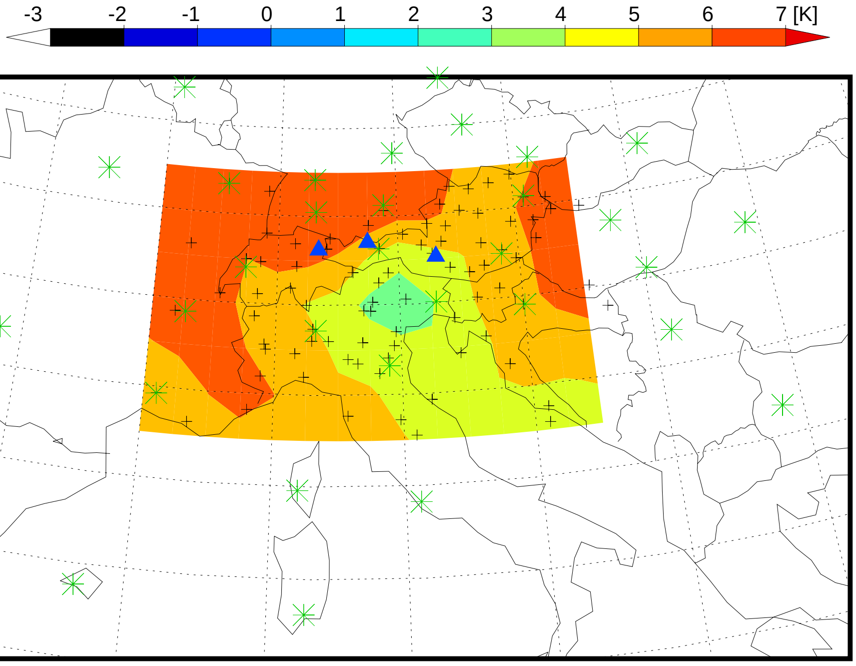

Fig. 1: Overview over the region selected for the intercomparisons. Green stars are radiosonde stations used in this study, Blue triangles are the three Alpine summit stations included in the ALOCLIM dataset. The colored rectangle covers the ALPCLIM area. As an example the monthly mean temperature anomaly compared to the 1901-1998 mean in January 1990 is plotted. The crosses are the stations available for interpolating the ALPCLIM temperature anomalies to a 1x1 grid using a standard optimum interpolation algorithm.

If the error is systematic, e.g. due to a deficiency in the measurement system, one will see a persistent bias in the time series of the difference between observation and analysis. This is known and some experiments have already been made within ERA-40 in order to apply corrections to biased radiosonde data before they are assimilated (see Onogi, 2000; Sokka, 2001, this volume).

In the period 1988-1992 several radiosonde stations in Central Europe (see Fig. 1 for an overview which radiosondes have been investigated using feedback data) have changed their instruments. The resulting breaks in the time series can be detected by looking at the time series of differences between first guess and observations as well as between analysis and observations, as available in the AF. Fig. 2 shows the temperature difference series of the radiosonde station Uccle (Belgium, number 6447), Fig. 3 shows the specific humidity difference series of station Budapest (Hungary, number 12843). These two stations out of several investigated have been chosen since they have breaks right in the middle of the period that has already been assimilated within stream 1. The negative value of the monthly mean difference ERA-40-Uccle in the late 80s may be caused either by a cold bias of the ERA-40 temperature or (with higher probability) by a warm bias of station Uccle. The jump in 1990 is most evident in the stratosphere but can be traced down to below 500hPa in the first guess differences as well as in the analysis differences. The break is more prominent in the first guess difference statistics than in the analysis difference statistics. This fact reflects of course the stronger dependency of the analysis on the (biased) observation compared to the first guess.

The situation is less pronounced but similar for moisture at Budapest which has a moist bias that is particularly strong in the stratosphere (humidity observations from radiosondes are blacklisted there) but can be traced down to below 500hPa.

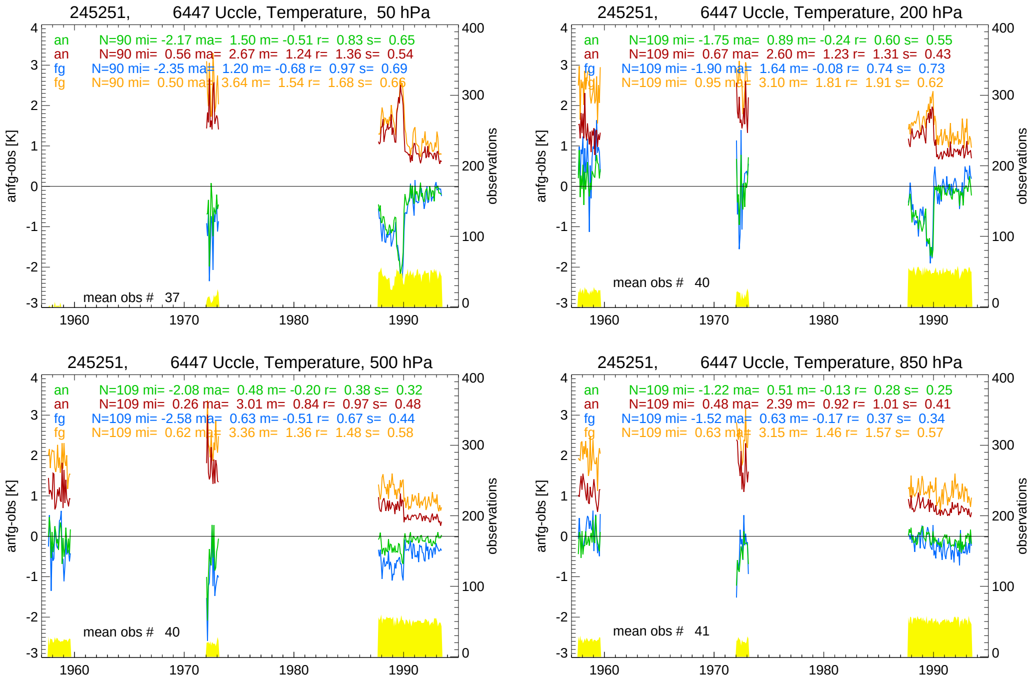

Fig. 2: Time series of temperature differences an-obs and fg-obs from radiosonde station Uccle at selected pressure levels for the periods 1958, 1972, 198709-199306. Experiment runs used: 245 for 1958, 251 for 1972, 12 for 198709-198810, 17 for 198811-198812, 18 for 198901-199306. Green: monthly mean difference an-obs, Blue: monthly mean difference fg-obs, Red: monthly rms difference an-obs, Orange: monthly rms difference fg-obs. The inset statistics (N=number of months, mi=minimum value, ma=maximum value, m=mean, r=rms, s=standard deviation) are calculated from the curves with corresponding color. Filled yellow region: Number of accepted observations (right ordinate). All ascents available in the feedback data have been used. Figures are almost equal when using only nighttime ascents (not shown).

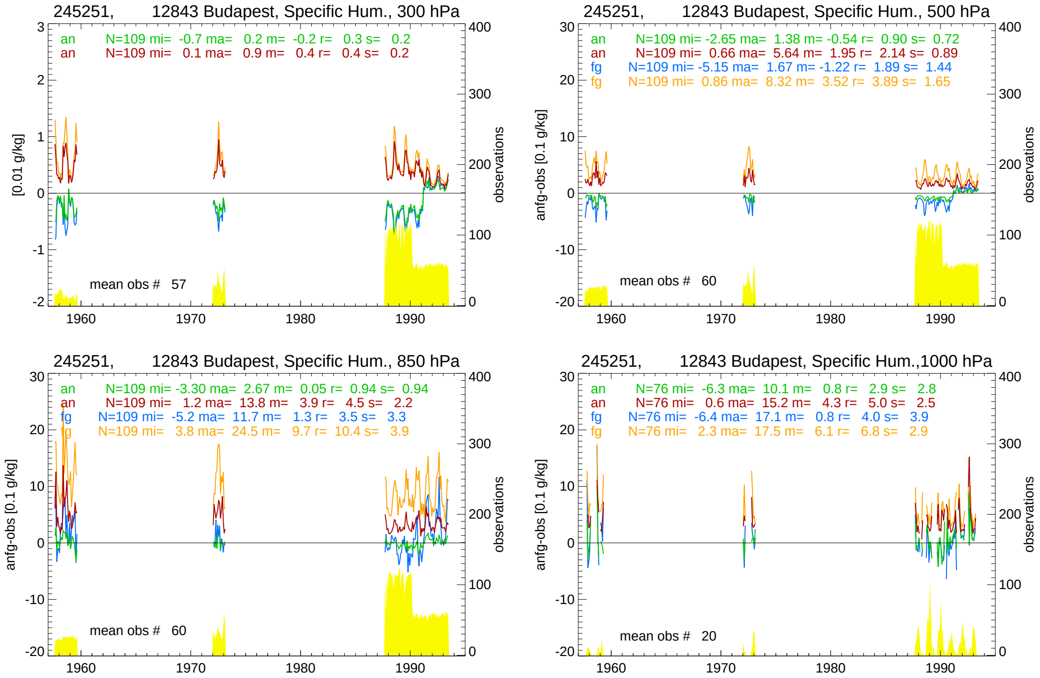

Fig. 3: Time series of specific humidity differences an-obs and fg-obs from radiosonde station Budapest at selected pressure levels. Color coding as in Fig. 2

The problem of data dependency visible in Fig. 2 motivated us to check a radiosonde station with a known break not only with feedback data but also by an independent method that does not use ERA-40 data at all. This method compares the radiosonde series to be tested with a synthetic series generated by horizontal interpolation from neighbouring radiosondes. Provided that the neighbouring radiosondes do not have breaks during the investigated period, e.g. through an instrument change at the same time, their errors can be regarded as strictly independent from the errors at the tested radiosonde. The objective interpolation method used here (VERA, Steinacker et al. 2001) uses thin plate splines on finite elements defined by the radiosonde network. In its most basic form this method yields results that are broadly equivalent to OI. It can, however, be extended to include information about persistent small scale features near orography. Fig. 4 shows time series of the deviation fg-obs and VERA-obs at the radiosonde station Payerne (Switzerland).

It can be seen that both methods are able to detect the break on April 1, 1990 when the instrument has changed at Payerne. Also the magnitude of the break is quite similar and it is concluded that the data dependency issue is minor for temperature in data rich regions like Central Europe. It still remains to be shown that this statement also holds in less densely covered regions and for less well autocorrelated parameters like moisture.

While the feedback information can be used to detect breaks in single radiosondes it is certainly of interest if there is a systematic deviation of ERA-40 first guess or analyses from all 35 radiosonde stations available. Fig. 5 shows that the mean temperature deviations averaged over all 35 stations are quite small in stream 1. In streams 2 and 3 they are noticeably higher. The rms-deviations are significantly lower in stream 1 compared to streams 2 and 3. Interestingly the rms-difference tends to become smaller as stream 1 proceeds.

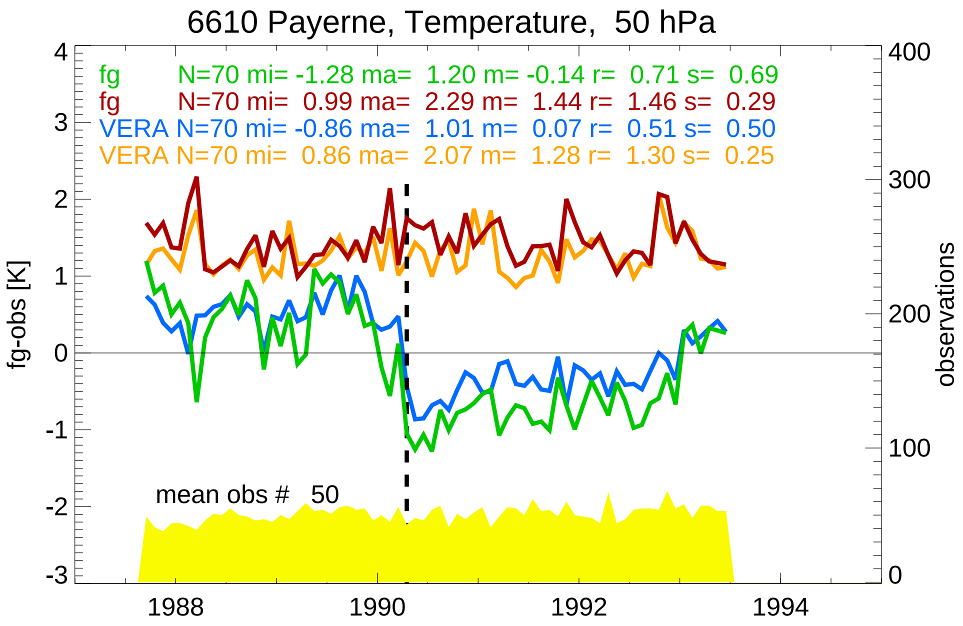

Fig. 4: Time series of temperature differences fg-obs and VERA-obs from radiosonde station Payerne at 50 hPa for the period 198709-199306. Green: monthly mean difference ERA-40 fg-obs, Blue: monthly mean difference VERA-obs (no ERA-40 data involved), Red: monthly rms difference ERA-40 fg-obs, Orange: monthly rms difference VERA-obs (no ERA-40 data involved). Dashed line corresponds to time of instrument change at Payerne. Break is only slightly smaller when using an-obs difference statistics (not shown).

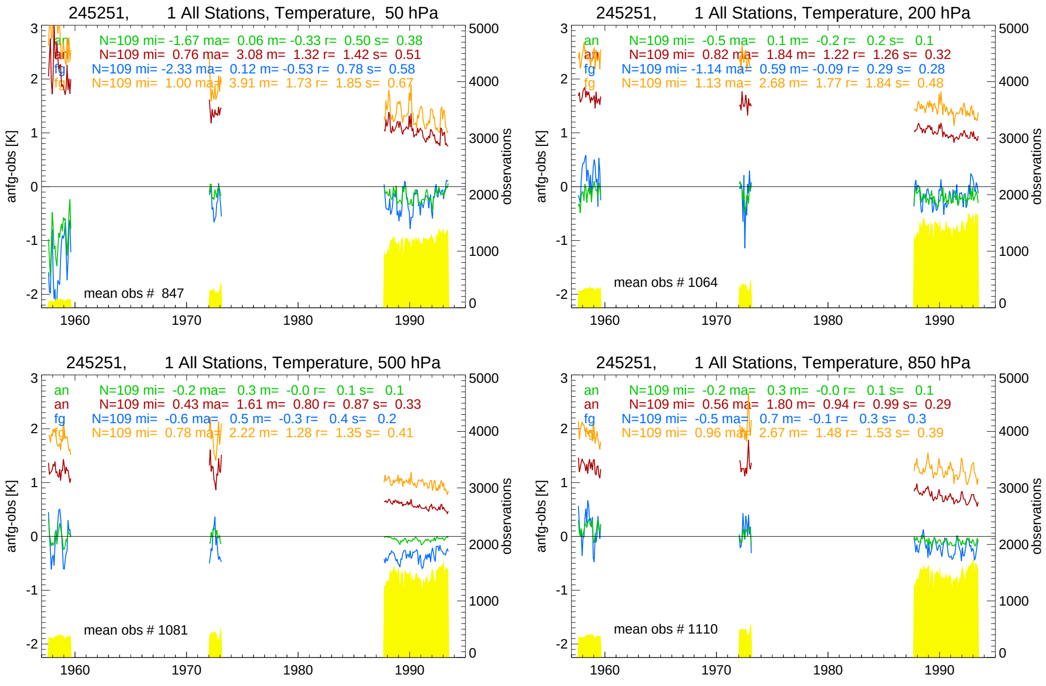

Fig. 5: Time series of temperature differences an-obs and fg-obs averaged over all 35 available radiosondes at selected pressure levels. Color code as in Fig. 2.

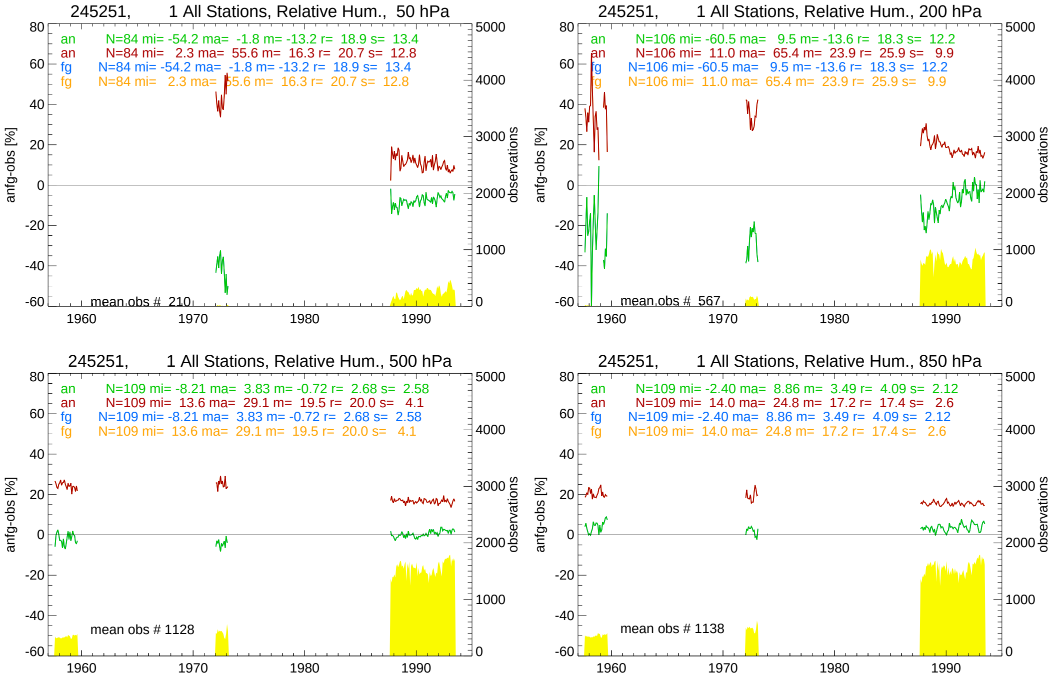

Fig. 6: Time series of relative humidity differences fg-obs averaged over all 35 radiosonde stations. An-obs is equal to fg-obs since relative humidity is blacklisted. The "trend" in the mean humidity deviation in the 90s is due to a cascade of moisture sensor changes at several radiosonde sites at this time.

Fig. 6 shows the timeseries of the relative humidity deviation averaged over 35 radiosonde stations. Relative humidity is used here since differences between analyses/first guess and observations have a much smaller annual variation than have the specific humidity differences. At the 200 hPa level the relative humidity difference has a pronounced trend during the period 1987-1993. The reason is that many radiosonde stations have changed their humidity sensors, thereby significantly reducing the moist bias at high altitudes. The large errors in the moisture measurements from radiosonde are well known and this has presumably been the reason that the moisture observations from radiosondes above 300hPa are blacklisted in the ERA-40 assimilation procedure.

Whereas the data dependency issue is not so important for detecting breaks in single series it is certainly a point of concern when interpreting Figs. 5 and 6. It cannot be excluded that the sum of all radiosondes has a systematic trend that also affects the analyses but is not visible in the feedback data since these are dependent.

3. Comparing ERA-40 series with homogenized summit stations

The data dependency issue can be avoided by comparing the ERA-40 dataset with data that are known to be independent from ERA-40.

The need for homogenization of long term time series of atmospheric parameters has been realized in its full extent in the last two decades. In the countries surrounding the Alps and at a few other places worldwide (e.g. Scandinavia, Moberg and Alexandersson 1997) a lot of efforts have been undertaken in the last decade in order to homogenize the existing long time series which are available in unique density in these regions from the mid-18th century onwards. Two relevant results of these efforts are the ALPCLIM (Böhm et al. 2001) and the ALOCLIM (Auer et al. 2001) datasets.

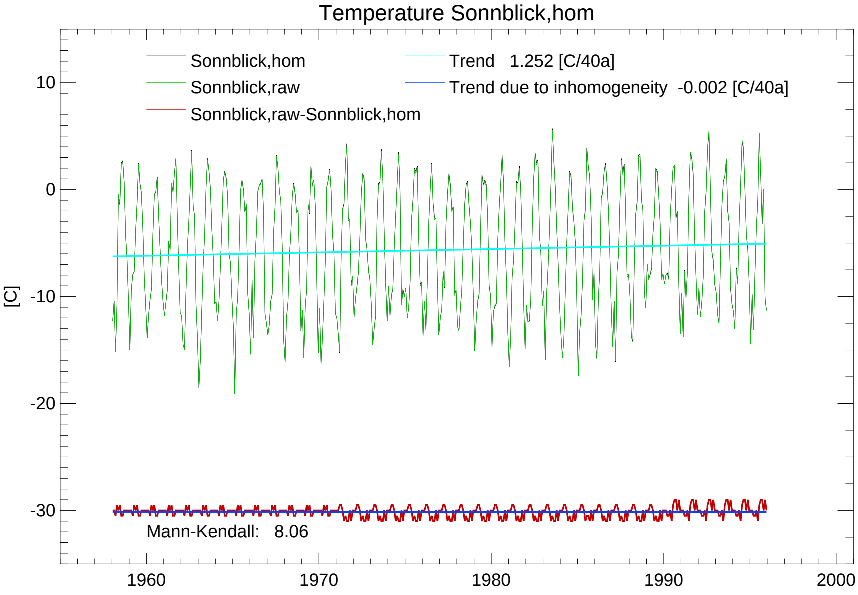

Fig. 7: Homogenized (black) and raw (green) time series of temperature at summit station Sonnblick (3105m). Trend as indicated (light blue line). Red curve is difference between the two time series (note different scale of right ordinate valid for red curve), dark blue line is trend of difference.

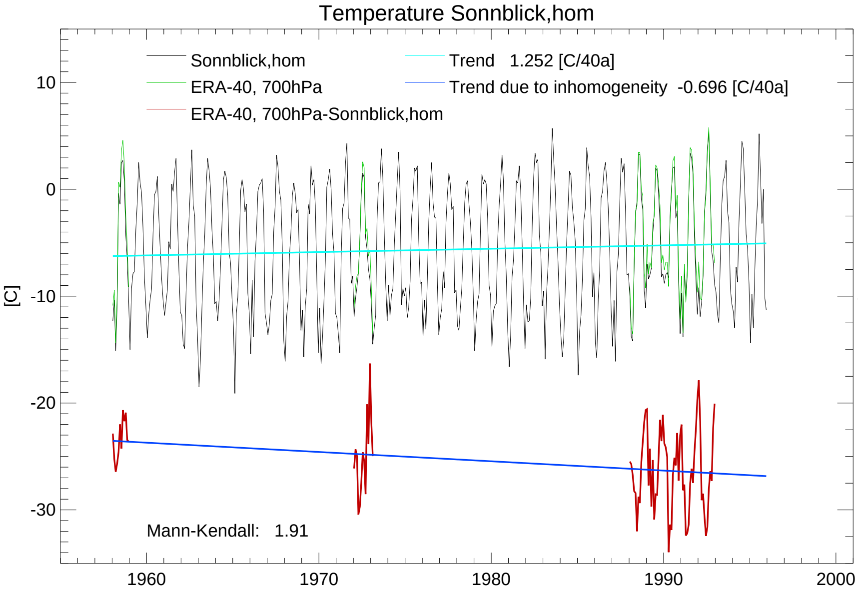

Fig. 8: Black curve as in Fig. 7, green curve is ERA-40 temperature at 700hPa at location Sonnblick. Red curve is difference between the two (again note the different scale of right ordinate valid for red curve). Trend as indicated. Mann Kendall test parameter larger than 1.96 indicates 95% significance of trend.

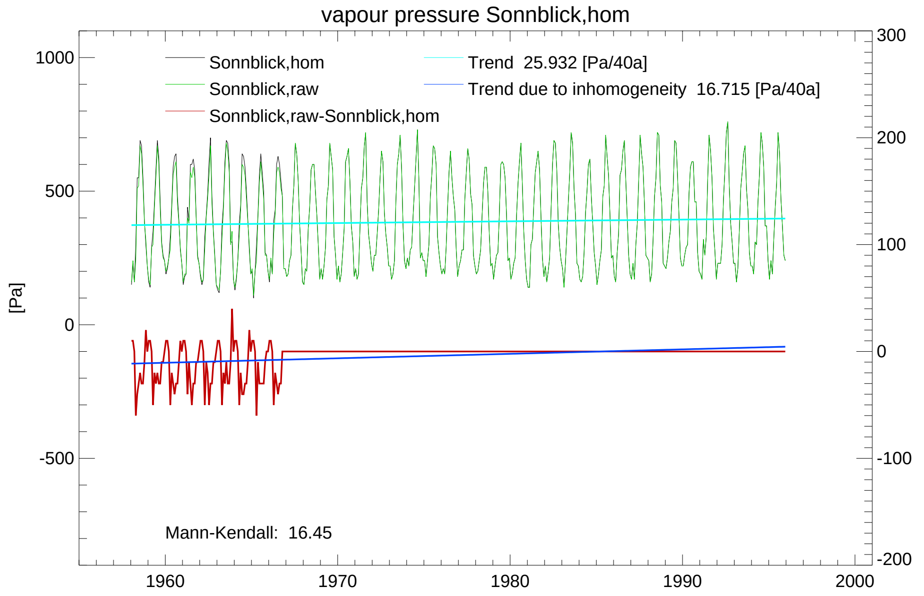

Fig. 9: Homogenized (black) and raw (green) time series of water vapor pressure at summit station Sonnblick (3105m). Trend as indicated. Red curve is difference between the two time series (note different scale of right ordinate valid for red curve).

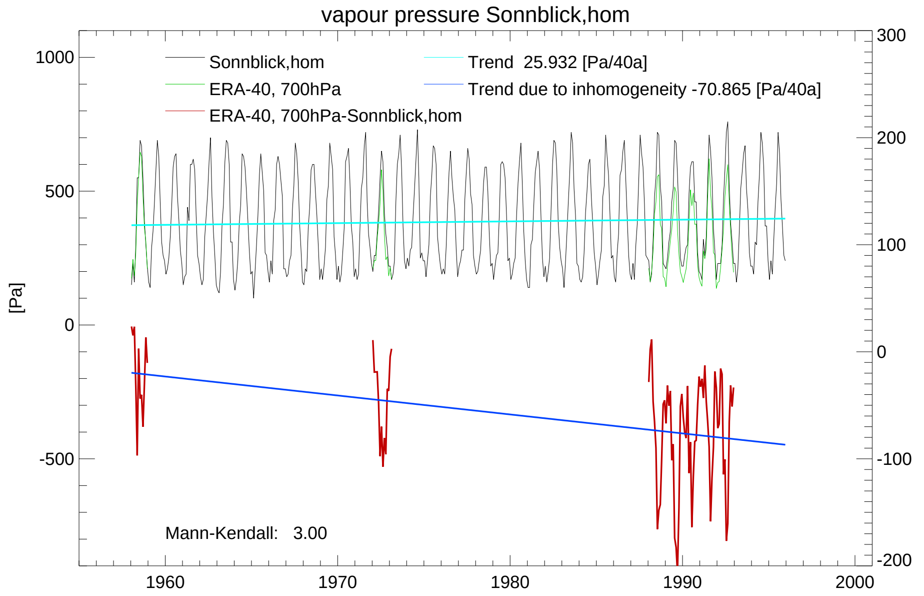

Fig. 10: Black curve as in Fig. 9, green curve is ERA-40 water vapor pressure at 700hPa (calculated from 6-hourly values of relative humidity and temperature at 700hPa) at location of Sonnblick. Red curve is difference between the two (again note the different scale of right ordinate valid for red curve). Trend as indicated. Mann Kendall test parameter larger than 1.96 indicates significant trend.

ALOCLIM contains series of selected climate stations in and around Austria. Homogenized series of monthly mean temperature, water vapor pressure, air pressure and precipitation are provided. For a review of the homogenization methods used see Peterson et al. (1999). This dataset contains three stations on the summits of mountains (see Fig. 1): Sonnblick (3105m), Zugspitze (2960m) and Säntis (2490m). Sonnblick lies slightly above the 700hPa level whereas Zugspitze lies slightly below and the annual mean pressure at

Säntis is around 750hPa. While the comparison of instantaneous point data with analyzed data is inherently problematic due to their rather limited spatial representativity the situation is much better when comparing monthly mean values. The monthly mean temperature has a quite large scale autocorrelation function. This applies in principle also to the monthly mean moisture which is available as water vapor pressure at the ALOCLIM stations.

Fig. 7 shows the homogenized monthly mean temperature series of Sonnblick from 1958-1995 together with the raw (not homogenized) temperature series. The difference between the two series (measured with the scale of the right ordinate) is on the order 0.1K. During the period investigated the temperature at Sonnblick shows a positive trend of 1.3K/40a, similar in magnitude to the other two mountain stations and only slightly higher than the trend at nearby surface stations (see below). In this example the homogenization does only very weakly change the temperature trend.

Fig. 8 again shows the series of Sonnblick, but now compared with the monthly mean temperature at the 700hPa level from ERA-40 at the location of Sonnblick (accurate to within 0.01 degree lat/lon). While there is good overall correspondence between the two series the difference between the temperatures (ERA-40-Sonnblick, red curve) shows a negative trend that is about half as large as the trend detected in the homogenized time series. The annual cycle is caused by the variations in height of the 700hPa level which lies below Sonnblick in winter and above Sonnblick in summer. This variation can be reduced by assuming a standard atmosphere vertical temperature gradient but does only slightly alter the trend in the difference. To calculate trends from 7 years of data is rather risky but done here since the workshop has the aim to find possible spurious trends. The trend found here in the difference is significant at the 90% level according to the Mann Kendall rank correlation test that is widely used for detecting trends (e.g. Schönwiese and Rapp, 1990).

The results for Zugspitze and Säntis are similar except that the trend of the temperature difference is even larger at these stations. It is noted again that the homogenization increment applied to the mountain station series is one order of magnitude smaller than the differences to ERA-40 and alter the trends by less than 0.1 K/40a. The steep trend found in the mountain station series is consistent in sign and amplitude with the increase of the 700-1000 hPa layer thickness that has been observed in the Alpine region.

Similar results are found for the water vapour pressure (*e*) time series. The homogenized monthly mean vapor pressure series at Sonnblick is again first compared with the raw series (Fig. 9) before it is compared with the corresponding series from ERA-40 (Fig. 10). The monthly mean water vapour pressure in ERA-40 has been computed by calculating *e* every six hours from the ERA-40 relative humidity and temperature values at 700hPa and then averaging *e* over one month.

The difference *e*(ERA-40)- *e*(Sonnblick) shows a pronounced annual cycle and is negative – due to the nearby moisture sources at the summit that are too small-scale to be represented in ERA-40. The reason of the steep negative trend of the difference series is less obvious. Streams 2 and 3 seem systematically more humid than stream 1. Again the modifications at the mountain station due to homogenization are much smaller than the differences between ERA-40 and Sonnblick. These results also apply to the other two summit stations.

Table 1 shows that the results found here may also apply to the new ERA-40 assimilations (experiment versions 20,30) but to a weaker extent. The temperatures are consistently warmer in 1958 and 1972 with the new experiments. If this is representative then the trend found in the difference ERA-40-Sonnblick will be reduced but not eliminated.

Experiment	5801	5802	5803	5804	5805	7211	7212	7301
245251	-9.4	-8.1	-12.2	-8.5	0.9	-5.4	-5.3	-8.3
020030	-9.6	-8.2	-12.5	-9.0	0.4	-5.7	-5.4	-8.7

Table 1 Monthly averaged ERA-40 temperature in 700hPa at location Sonnblick (47.05N, 12.95E) for months already assimilated with runs 20/30.

4 ERA-40 temperature series vs. ALPCLIM temperatures

The ALPCLIM dataset contains homogenized time series of surface temperature anomalies at climate stations as well as on a 1x1 grid from 43N/4E to 49N/18E. The homogenized series have not been available for assimilation into the ERA-40 dataset. While the region of comparison is still small compared to the global scale of the analysis it covers at least several gridpoints of the ERA-40 domain.

The ERA-40 temperatures at model level 60 are compared with ALPCLIM-anomalies. Before the comparison the ERA-40 temperatures have been converted into anomalies by subtracting the ALPCLIM 1901-1998 mean temperatures from the ERA-40 temperatures at the 105 gridpoints available. These ERA-40 anomalies have been compared with the corresponding ALPCLIM anomalies and the resulting differences have been checked for possible trends. Fig. 11 compares the anomalies for gridpoints where the ERA-40 model orography is higher than 1000m (12 gridpoints). Consistent with the previous results found for the summit stations there is a positive trend in the homogenized data on the order 1.0K/40a and the trend of the difference ERA-40-ALPCLIM is negative (about 0.5K/40a). Fig. 12 shows a similar comparison for lowland gridpoints (where the ERA-40 model orography is lower than 200m, 18 gridpoints). Again a positive trend on the order 0.8K/40a is found in the ALPCLIM anomalies. There is no trend detectable in the differences between ERA-40 and ALPCLIM anomalies at low levels.

In the new experiments the ML60-temperatures are practically unchanged at gridpoints above 1000m whereas they are warmer at low levels in 1958 (see table 2). It has to be shown yet that these differences are representative.

Experiment	5801	5802	5803	5804	5805	7211	7212	7301
245251 >1000m	-5.6	-3.3	-9.4	-8.1	-3.0	-5.3	-5.2	
020030 >1000m	-5.6	-3.4	-9.5	-8.2	-3.0	-5.3	-4.7	-4.6
245251 <200m	4.5	5.1	0.4	-0.2	1.7	5.1	5.4	-
020030 <200m	5.2	6.1	0.8	0.7	2.3	5.0	5.5	5.4

Table 2 Monthly mean temperature difference between ERA-40 on model level 60 and ALPCLIM over ALPCLIM gridpoints (15 gridpoints where ERA-40 orography is higher than 1000m, 18 gridpoints where ERA-40 orography is below 200m). The large deviation is because the ALOCLIM data are representative for a different height (generally below 1000m) than are the ERA-40 model level 60 data.

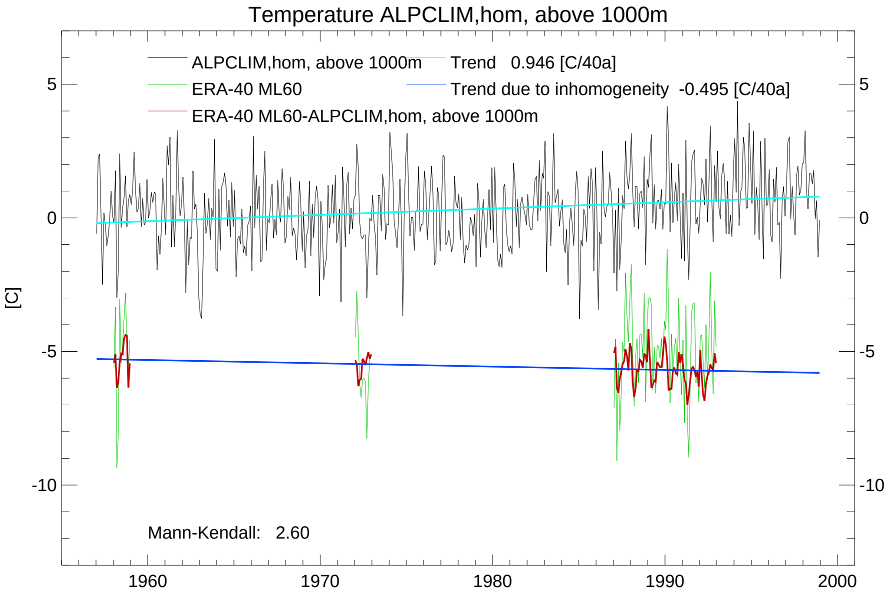

Fig. 11: Black: Homogenized temperature anomalies of temperature at gridpoints where the ERA-40 orography is higher than 1000m, trend as indicated. Green curve: ERA-40 model level 60 temperature minus 1901-1998 ALPCLIM century mean at the same gridpoints – this is the ERA-40 anomaly. Red curve is difference between the two time series (right ordinate applies to red curve).

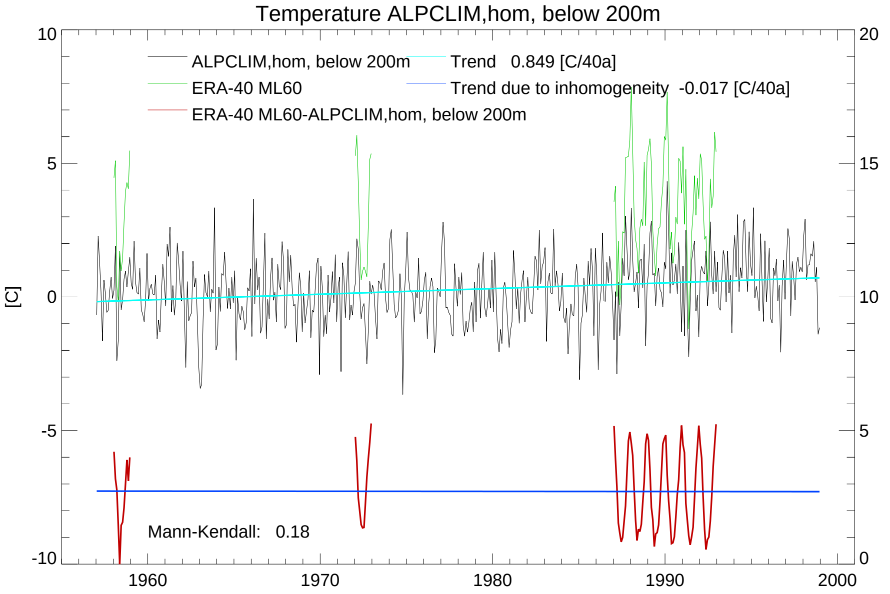

Fig. 12: As Fig. 11 but for lowland (ERA-40 orography below 200m) gridpoints.

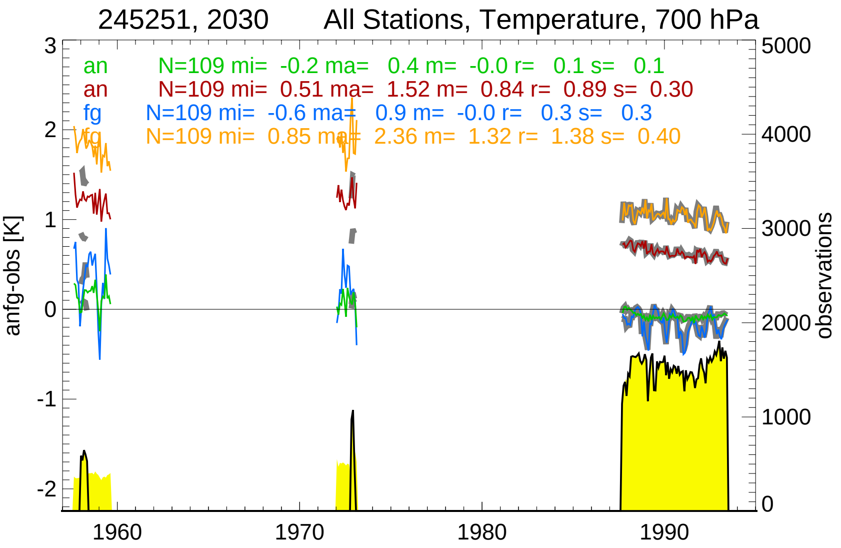

Fig. 13: Temperature difference series as in Fig. 2 for radiosonde stations within the ALPCLIM region (10 stations). The black curves are results from the new experiment runs 20/30. Note the significant decrease of rms-errors in 1958, 1972 as well as the increase of observations in the new runs.

The results of the comparison with ALOCLIM/ALPCLIM data motivate a closer look to the analysis feedback data at 700hPa averaged over all available radiosonde stations (see Fig. 13). First it is found that the rms-difference ERA-40-obs is relatively high in 1958 and 1972 compared to stream 1. The mean deviation is positive in 1958 and 1972 whereas this difference is negative in stream 1.

Performing the same comparison with the new experiment runs 20/30 (grey points in Fig. 13) yields *much* smaller rms-values of the difference ERA-40-obs. The mean differences, however, changed only slightly (see also Table 3). This result together with those from the other comparisons suggests that the too weak positive temperature trend in ERA-40 may be present also when using data from the new experiment runs.

Experiment	**5801**	**5802**	**5803**	**5804**	**5805**	**7211**	**7212**	**7301**	**87-93**
245251 fg	0.1	0.2	0.3	0.5	0.5	0.2	0.1	-0.0	-0.3
020030 fg	0.4	0.4	0.3	0.7	0.4	0.0	0.1	0.1	-0.3
245251 an	0.0	0.1	0.2	0.2	0.2	0.0	0.2	0.0	-0.1
020030 an	0.1	0.1	0.1	0.1	0.0	0.0	0.1	0.1	-0.1

Table 3 Monthly mean analysis and first guess temperature differences ERA-40-obs at 700hPa, averaged over radiosonde stations available (ca. 15 stations). Note positive deviations in all runs of streams 2 and 3 and the negative deviation in stream 1 (87-93).

5 Conclusions

Bearing in mind the advances that have been achieved in various fields affecting the quality of analyzed data and also modeled flux quantities there is little doubt that ERA-40 products will be superior compared to the first generation reanalyses that have been available since a couple of years. While the assimilation scheme is frozen during the fourty years of assimilation temporal inhomogeneities may be introduced into the analyses due to shortcomings in the observation input.

In this article breaks in the time series of radiosonde data over Central Europe have been detected using analysis feedback data. The ability of detecting inhomogeneities in the original time series, at least over data rich regions, suggest that ERA-40 itself provides the basis for the improvement of the observation input that is needed for an even more homogeneous third generation reanalysis in a couple of years.

The use of feedback data for checking radiosondes needs to be complemented with homogenization methods that use entirely independent data and with other quality check methods. It has been shown that an objective interpolation method designed especially for producing analyses near complex terrain (VERA, Steinacker et al. 2000) that uses nearby radiosonde ascents from different countries is also capable to find inhomogeneities in the series of the tested radiosonde (Häberli and Steinacker, 2001).

Another means of checking analysis at least at lower levels is comparison with mountain station data. Comparison with three well maintained summit stations has indicated that the observed warming trend of the order 1.3K/40a at these stations is underestimated by 0.5K/40a when using comparable ERA-40 data, at least with the preliminary assimilation experiments 245/251. A similar result is found when comparing the temperature series of gridpoints above 1000m with the 60th model level in ERA-40. A comparison with homogenized series at gridpoints below 200m shows no differences in the trend.

All the comparisons presented here are preliminary since streams 2 and 3 have been restarted very recently and since the ERA-40 time series is not complete. First results from the new runs (expver 20, 30, 4 months are available) suggest that the trend differences may be weaker with the new runs, probably due to the use of the new radiosonde data reprocessed by NCEP/NCAR. Another limitation of this study is the region of intercomparison which is relatively small for a global analysis. It can well be that the global analyses are unbiased and homogeneous in the global mean and the differences found here are not representative outside the region investigated. Should the differences persist when longer series from streams 2 and 3 become available they provide a challenge for both the reanalysis and the homogenized data sets and need to be explained.

The trend differences found here will undoubtedly change when more data become available. However it does not matter too much if there is a significant trend difference in the series or not. What matters is the capability of the approach used here to detect rather small trend signals.

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