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Deliverable D2.6

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1. Introduction

Within UERRA a long regional re-analysis, from 1961 to present, will be produced using the HARMONIE (HIRLAM ALADIN Regional/Mesoscale Operational NWP In Europe) system. HARMONIE is a complete system for numerical weather prediction that is developed in the HIRLAM (Hi-Resolution Limited Area Model)-consortium. It is built upon the code of the models ALADIN (Aire Limitée Adaptation Dynamique Développement International), AROME (Applications of Research to Operations at MEsoscal) and ALARO (ALADIN and AROME combined model) and developed in collaboration with Météo France and the consortia ALADIN and HIRLAM.

The long HARMONIE re-analysis is run using the ALADIN physics scheme with a horizontal resolution of 11 km. In order to be ready within a reasonable time frame the experiments are run at the European Centre For Medium range Forecasts (ECMWF) facilities in several streams (time periods). Approximately one stream per decade is produced with a four months overlap in order to spin up the model. The model and set up is the same as the ALADIN run described in the UERRA deliverable D2.5 but with a corrected large scale mixing term.

This preliminary report will focus on comparing the first year in the different decades regarding available observations, observation usage and how the model performs compared to the existing global reanalyses ERA-40 (Uppala et al. 2005) and ERA-Interim (Berrisford, 2009). It is important to monitor the model behaviour at an early stage since a long RA consumes a lot of computer power and is very costly to re-run if needed.

2. Model setup

The re-analysis is run using the HARMONIE system cycle 38h1.1. HARMONIE is a script framework that allows for different physics packages, surface schemes or data assimilation schemes. For the long UERRA re-analysis the default setup is used with the ALADIN physics scheme. The basis for the ALADIN setup is the limited area model (LAM) version of the ARPEGE-IFS (Bubnová et al. 1995; ALADIN International Team 1997). It comprises a non-hydrostatic spectral dynamical core with semi-implicit time stepping and semi-Lagrangian advection. In the horizontal resolution used in UERRA, 11km, the model is applied using the hydrostatic assumption. Observations are introduced into the model through data assimilation, both in the upper air and in the surface scheme.

The surface observations are assimilated using an optimal interpolation (OI) method using CANARI (Code for the Analysis Necessary for ARPEGE for its Rejects and its Initialization) and SURFEX (surface externalisée). With SURFEX (Seity et al 2011) the surface analysis is performed in two steps. First CANARI (Taillefer, 2002) finds the analysis increments in each grid point based on observations minus first guess. In the next step a consistent update of the SURFEX surface fields is made based on analysis increments interpolated to all grid points by CANARI. In the UERRA-RA, only synoptic observations are used to analyse 2 meter temperature (T2m), 2 meter relative humidity (RH2m) and Snow Water Equivalent (SWE).

For the upper air data assimilation a three dimensional variational data assimilation (3D-Var) scheme is used. The 3D-Var assimilation scheme creates an analysis by minimising a cost function including observation operators, model and observation error statistics (e.g. Gustafsson et al. 2001, Lindskog et al. 2001 or Brousseau et al. 2008). The background, or model, error describes both spatial correlations and balances between variables. It uses a multivariate formulation based on the forecast errors of the control variables and horizontal spatial homogeneity and isotropy are assumed (Berre 2000). The background error correlations are calculated only once and do not take into account any time dependence (Brousseau et al. 2012) or any heterogeneous information in space (Montmerle and Berre 2010). The observations included are the so-called conventional observations which include synoptic stations, ships, drifting buoys, aircraft observations and radio soundings. No remote sensing data is used.

3. Results

Since the long re-analysis is run in several streams, approximately one stream per decade, there are only a few years run at the early part of the period. Present here is therefore a comparison of the first part of each decade. Interesting parts will be to understand how the number of available observations changes thought the 60 years and if the quality of the model evolves during this time.

Observation usage

The availability of observations has changed dramatically since early 1960, not only in the density and spatial distribution, but also in new observation types that have become available. One example is aircraft data that increases both due to more and more air traffic but also due to a transition from manual to automatic observations.

Figure 1 shows examples of available radio soundings from 1961 (upper right) to 2011 (lower left). It can be seen that the first 10-20 years the number of radio soundings were increasing in number but after that it is more or less constant. During the last years it has even begun to decrease slightly, partly because it is a rather costly observation source.

The largest increase in number of observations over the 50 years can be seen in the aircraft observations. Before 1980 we have no access to aircraft observations. In 1980 and 1990 all of the aircraft observations were reported manually as AIREP (AIRcraft REPorts) but later more and more are automatic AMDAR (Aircraft Meteorological DAta Relay). The latter together with the increase in air traffic is noticeable not only in the number of observations but also in the distribution of the observations both horizontally and vertically. In Figure 2 the distribution of aircraft observations from July 1980 and July 2000 is shown. It can be seen that in July 2000 there were still many AIREP present together with the AMDAR. The number of available aircraft observations for different altitudes for the same months are shown in Figure 3. Note that the scale on the y-axis is different in the upper (1980) and lower (2000) panels. The difference is rather large between these two months and a constant increase can be seen from 1980 to 2011 for the years produced so far.

The number of SYNOP stations is also constantly increasing during the 50 year period, although not in the same rate as the aircraft observations. Figure 4 shows the distribution of observations for July 1 in 1961 (upper left), 1970, 1980, 1990, 2000 and 2011 (lower right) and it can be seen that already in 1961 there was a rather good coverage over the model domain. There are some areas where observations are missing, e.g. Norway, UK and around the Mediterranean Sea but those are filled in 1970. By the end of the period there is a very good coverage except for parts of Africa.

One way to check if the assimilation is working properly is to compare the first guess (background) and analysis departure, i.e. how much the observations differ from the first guess and from the resulting analysis. If everything is working well the analysis departure should be smaller than the first guess departure. This means that the model has adjusted to the observations. How big this adjustment is will depend on both the background and the observation error and also on the quality of the observations and first guess (forecast). In Figure 5 examples are shown for radio soundings. It shows the first guess departure in blue and the analysis departure in red. The lines with dots are the root mean square errors while the solid lines are the systematic errors (bias). The examples are from the same dates as above, i.e. July in 1961 (upper left), 1970, 1980, 1990, 2000 and 2011 (lower left) and, even though it varies slightly, it can be seen that the general differences between the first guess and observations decreases over the years.

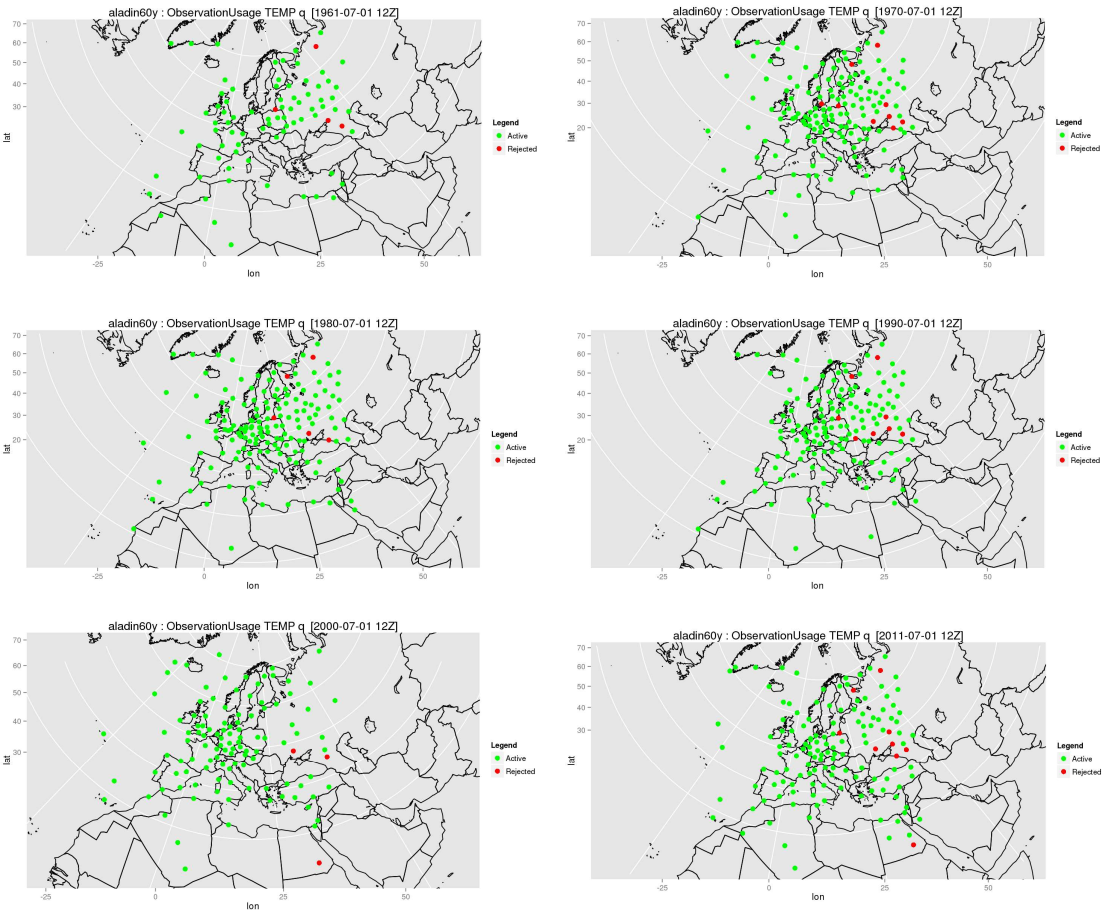


Figure 1. Available radio soundings for different years. Green indicates that the observation is used while red means that it is rejected. Observations are from first of July 1960 (upper left corner), 1970, 1980, 1990, 2000 and 2011 (lower right).

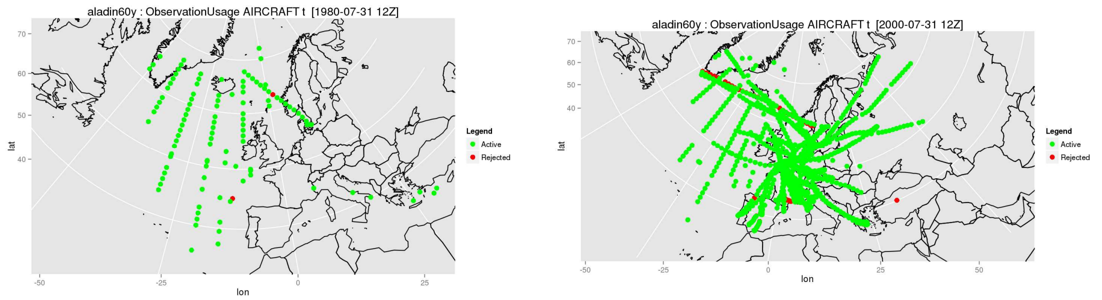


Figure 2. Temperature observations from aircrafts from July 31, 1980 (left) and 2000 (right).

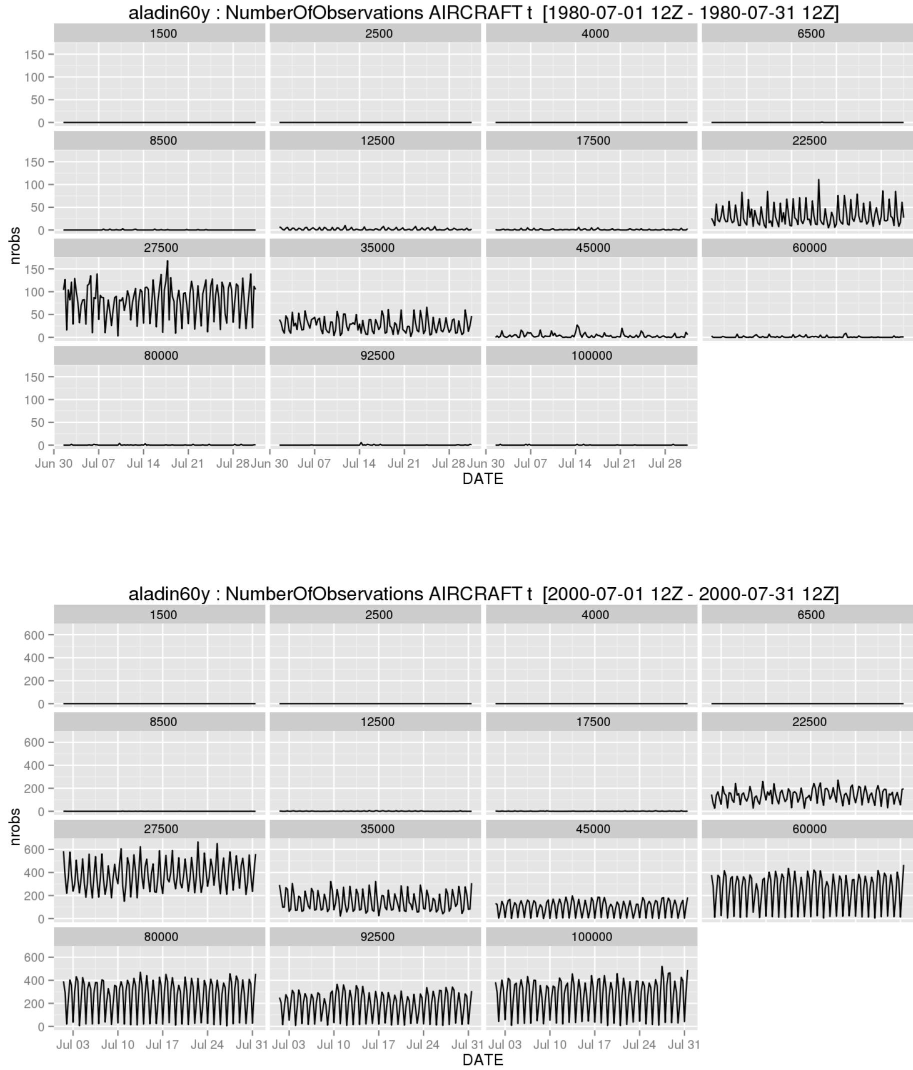


Figure 3. The number of temperature observations from aricrafts in different pressure layers (hPa) for July 1980 (upper) and July 2000 (lower). Not the scale on the y-axis is different.

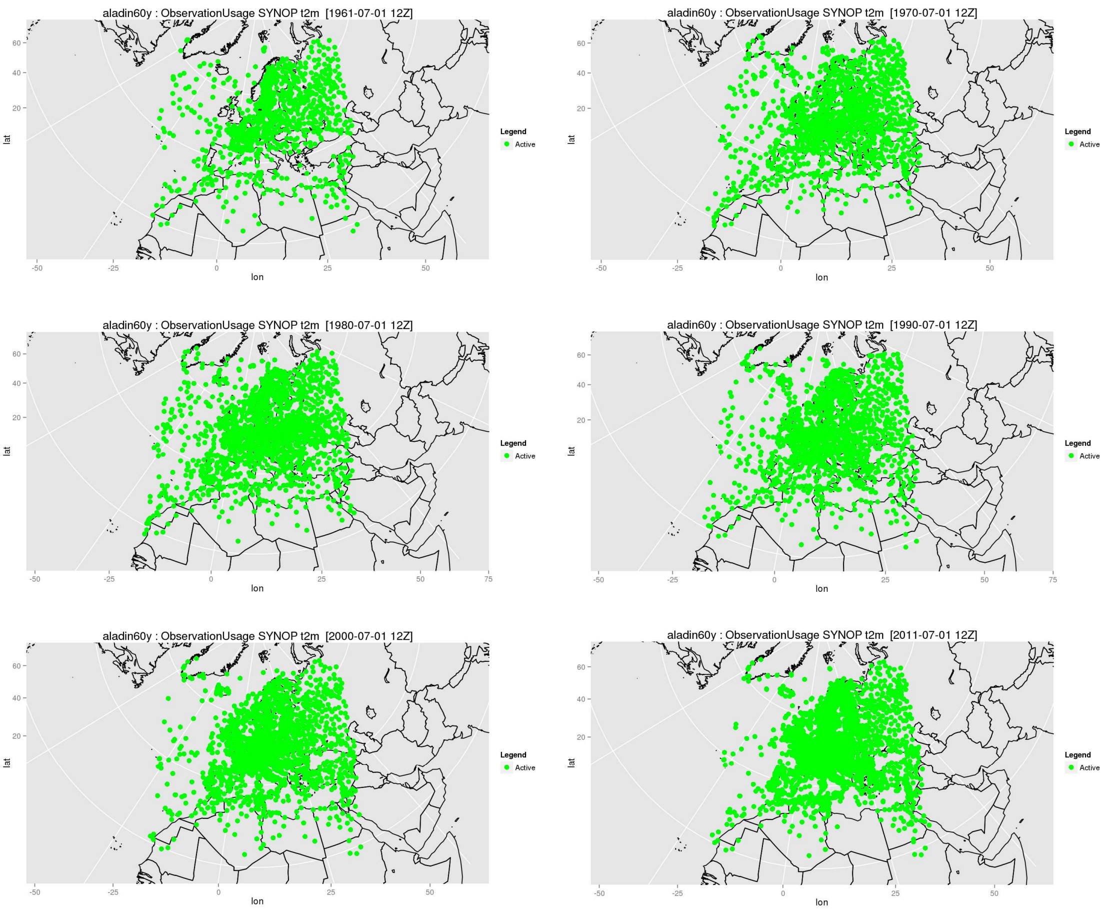


Figure 4. Available SYNOP stations for different years. Green indicates that the observation is used while red means that it is rejected. Observations are from first of July 1960 (upper left corner), 1970, 1980, 1990, 2000 and 2011 (lower right).

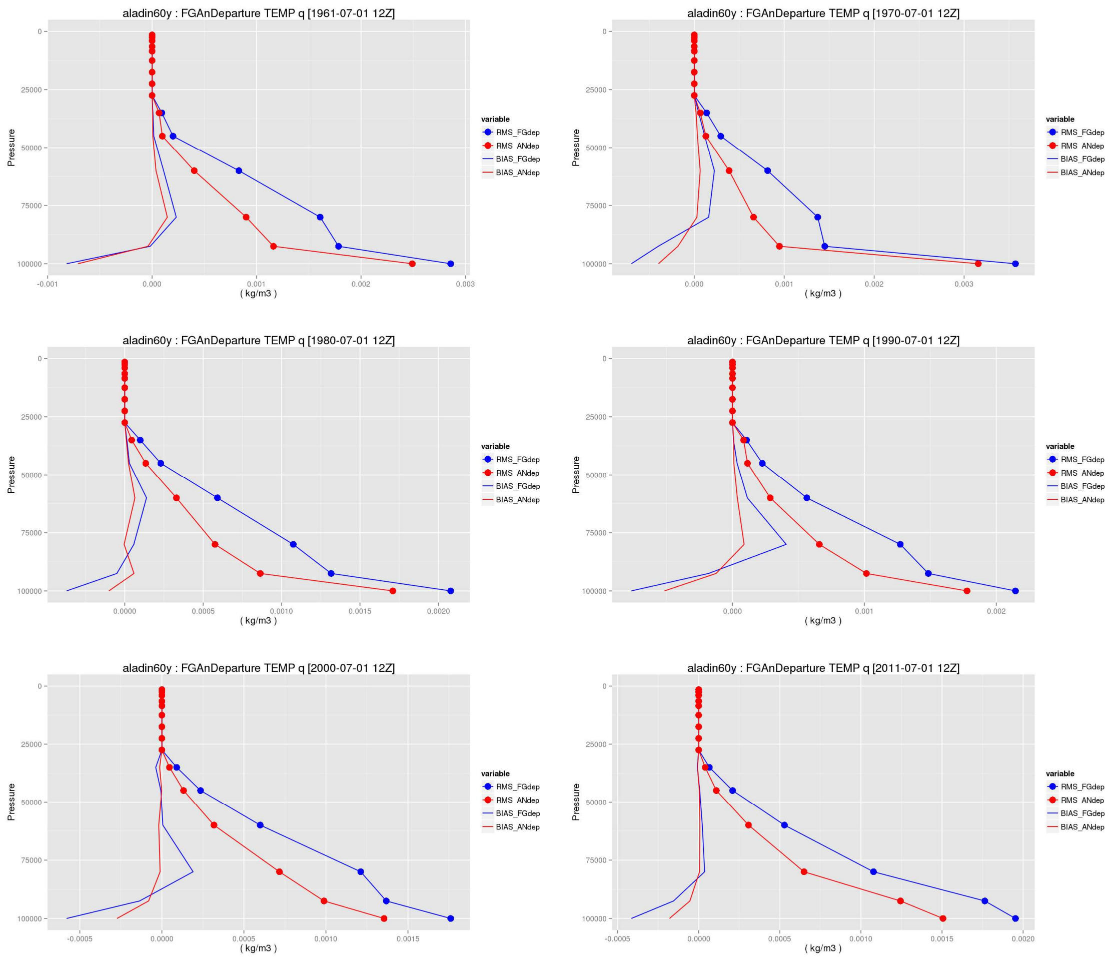


Figure 5. Examples of first guess (blue) and analysis (red) departures for specific moisture for July 1 from 1961 (upper left), 1970, 1980, 1990, 2000 and 2011. Both RMS (line with dots) and bias (solid lines) are shown. Note that the scale on the x-axis changes.

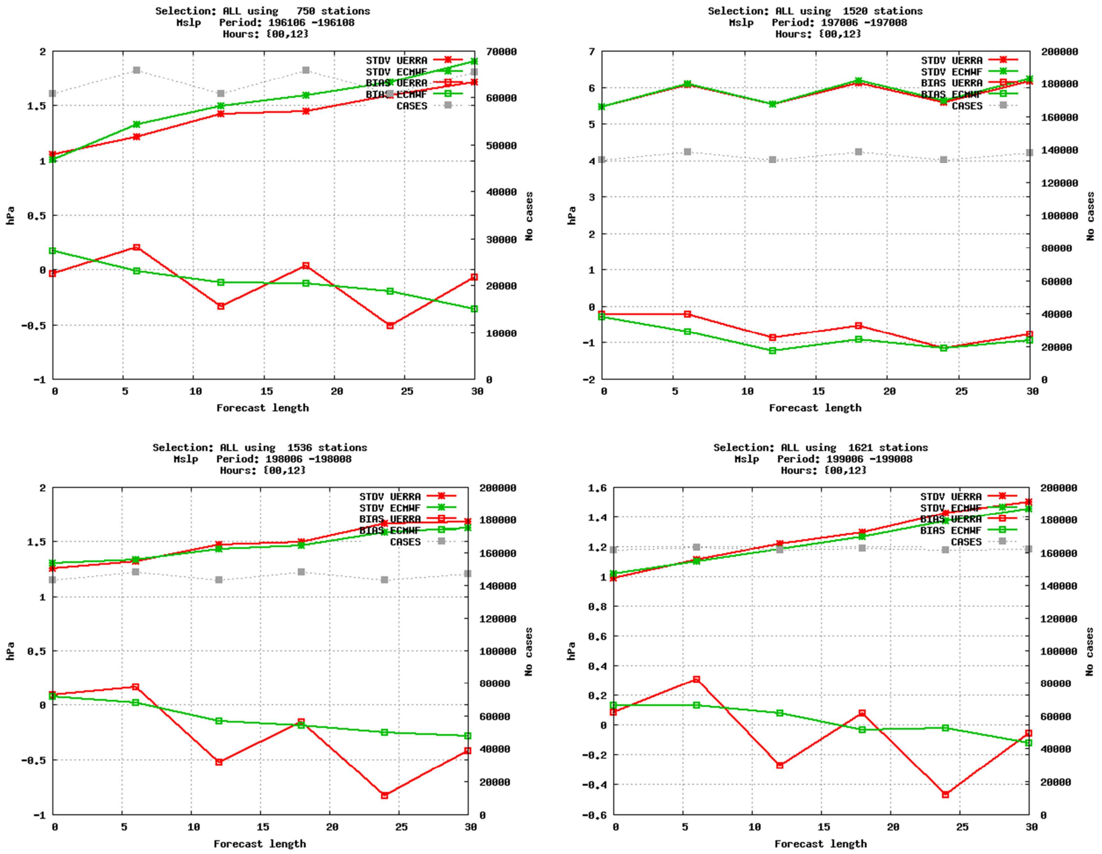
Verification

During the long re-analysis verification is made regularly to make sure the system is healthy. The verification is performed with the HARMONIE verification system. A few examples are shown here for the summer months, June, July and August (JJA), of the same years as in earlier sections, 1961, 1970, 1980, 1990, 2000 and 2011. For comparison the same verification is made against ECMWF re-analysis, ERA-40 before 1979 and ERA-Interim after 1979.

Figure 6 show verification of mean sea level pressure for JJA. It can be seen that for 1961 (upper left) the UERRA re-analysis is slightly better in the standard deviation (STDV) scores. For the other years the UERRA and ERA re-analyses are very similar. The bias is rather small for both but varies in a way for UERRA that is a bit hard to explain.

Figure 7 shows the same thing as Figure 6 but for the 2 metre temperature. Here it is seen that the UERRA re-analysis shows clearly better STDV scores than the corresponding ERA re-analysis. The bias is rather similar for the first two decades, compared to ERA-40, while UERRA is closer to zero for the remaining examples that are compared to ERA-Interim.

Since some parameters are missing in the ERA-40 archives, skill scores for precipitation are not available before 1982. It is however still interesting to compare UERRA precipitation to what is available from ERA-Interim. Figure 8 show the Kuiper skill score for 1990 (upper), 2000 (middle) and 2011 (lower) and it is seen that UERRA shows better precipitation scores for the higher precipitation amounts. This is probably strongly connected to the higher spatial resolution of the UERRA re-analysis compared to ERA-Interim. With a lower resolution the high precipitation amounts will be smoothed.



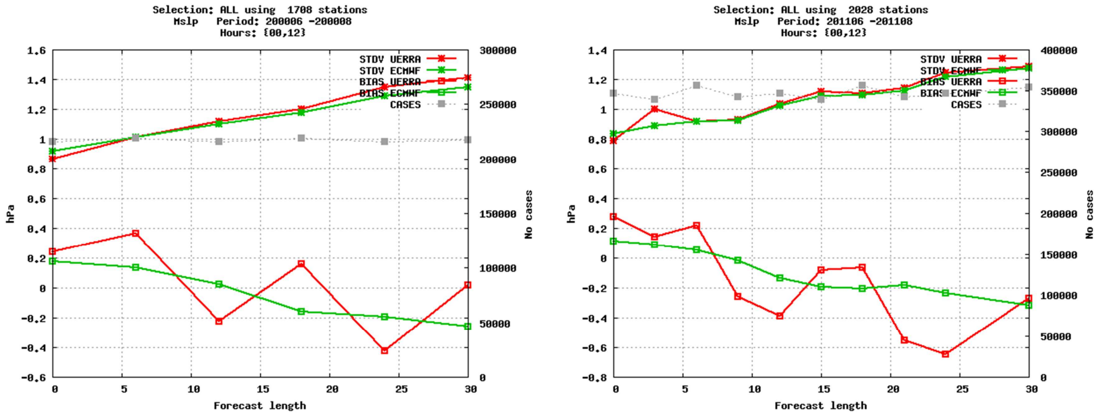


Figure 6. Verification of surface pressure for the UERRA re-analysis (red) and ECMWF re-analysis (green) for the summer months of 1961 (upper left), 1970, 1980, 1990, 2000 and 2011. The upper two lines represent the STDV error and the lower two show the bias.

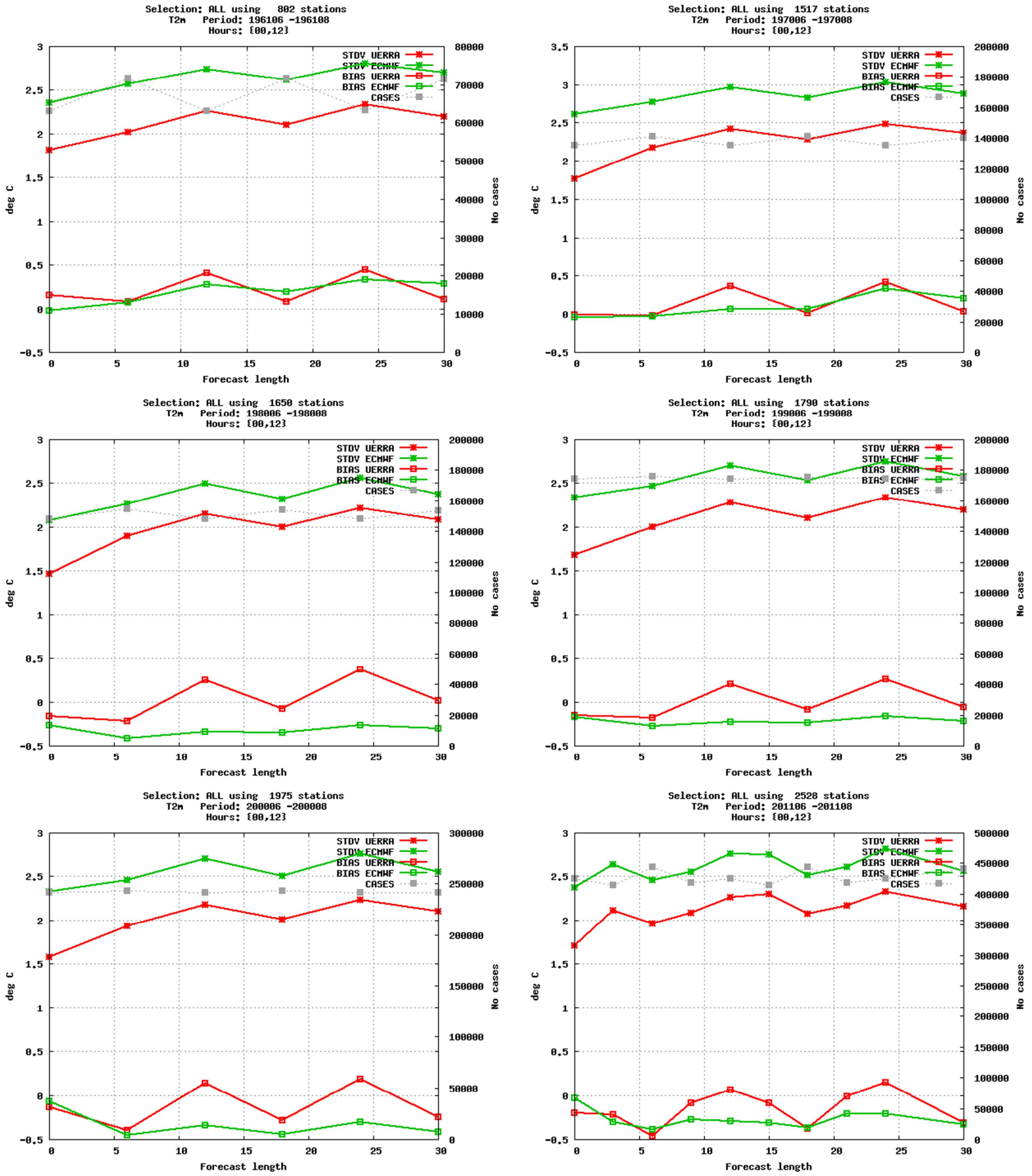


Figure 7. Same as Figure 6 but for 2 meter temperature.

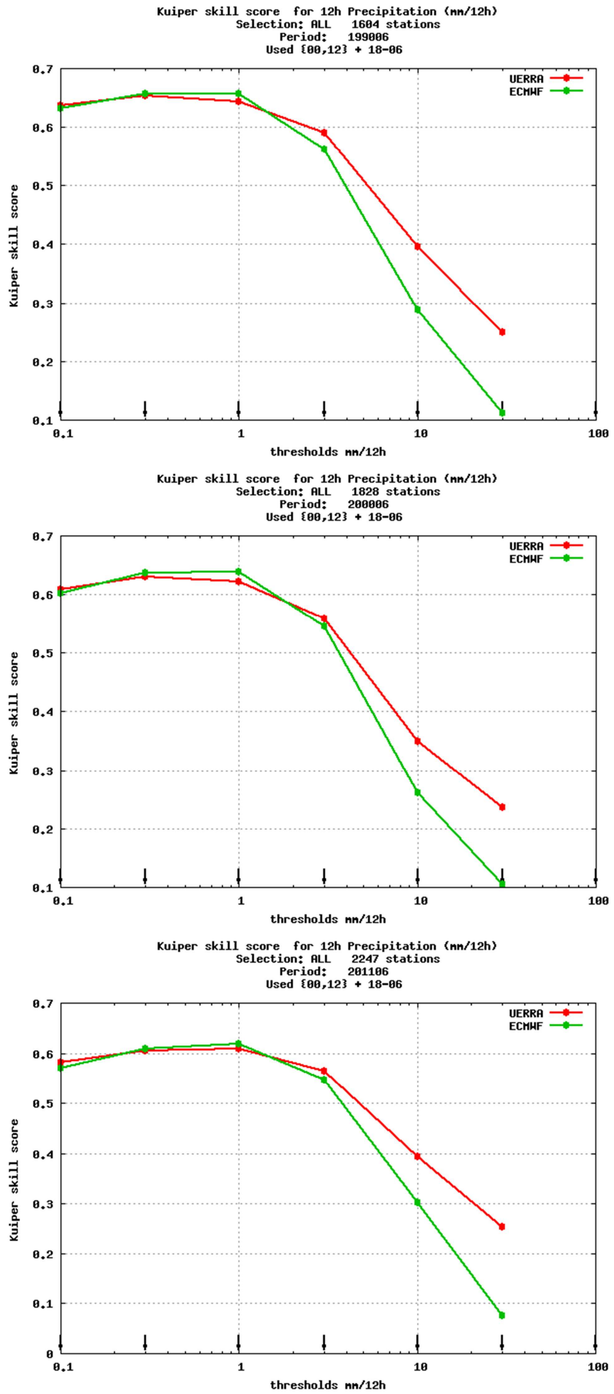


Figure 8. Kuiper skill score for the summer months of 1990 (upper), 2000 (middle) and 2011 (lower). UERRA re-analysis is shown in red and ERA-Interim is shown in green.

4. Summary and conclusions

The HARMONIE system has been set up over a European domain to produce a long, high resolution re-analysis. Two different physics packages, ALADIN and ALARO were evaluated during a 5-year period in a previous study within UERRA. It was determined that the ALADIN package delivered the best results and is therefore used in the long UERRA re-analysis.

In order to be able to produce the re-analysis in reasonable time it is run in several streams, or time periods, with long enough overlap (4 months) to spin up processes and parameters. Currently two to four years has been run for each stream and this report presents a comparison of the first year in each stream.

The observation monitoring shows that the number of available observations, as well as the spatial distribution changes rather much from 1961 until 2011. The most obvious are the aircraft observations, which are not available before 1980. Not only has the air traffic increased since then but the observation technique has also changed from manual at certain times or positions to automatic reports. This leads to a better horizontal distribution as well as vertical information during take off and landing.

The number of available radio sounding also increases during the first 30 years. After that it is more or less constant but during the end of the period it is in fact decreasing slightly. The reason for that is that radio soundings is a rather expensive observation type and some countries are reducing the number of launches per day.

The comparison of the first guess and the analysis with the observations confirms that the analysis is closer to the observations. This means that the data assimilation has adjusted the first guess according to the observations.

The verification of the first periods of the UERRA re-analyses was conducted for numerous near-surface variables as well as for profiles of temperature and wind. The same verification has been performed against the corresponding ERA re-analyses for comparison. For most variables, the HARMONIE re-analysis performs better than or equally good as the ECMWF re-analyses. This is very encouraging and gives hope that a very useful dataset will be produced.

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