SPECIAL PROJECT FINAL REPORT

All the following mandatory information needs to be provided.

Project Title:	Regional European re-analysis with HARMONIE for UERRA (RERA)
Computer Project Account:	SPSERERA
Start Year - End Year :	2014 - 2016
Principal Investigator(s)	Heiner Körnich Per Undén
Affiliation/Address:	SMHI
Other Researchers (Name/Affiliation):	Richard Mladek / ECMWF Martin Ridal, Jelena Bojarova, Esbjörn Olsson, Ulf Andrae / all SMHI

The following should cover the entire project duration.

Summary of project objectives

(10 lines max)

This project is creating a regional European re-analysis data set from 1961 to present-day with the HARMONIE (HIRLAM ALADIN Regional / Mesoscale Operational NWP in Europe) modelling system. The resolution is 11 km horizontally and 65 levels vertically. A 3-dimensional variational data assimilation is employed. Over a shorter time span of 5 years, a multi-physics mini-ensemble was run with different physical parameterisations. The results from the proposed project are contributing to the European FP7 project UERRA - Uncertainties in Ensembles of Regional Re-Analyses with 12 institutes from 7 EU countries, Switzerland, Norway and an international organisation (ECMWF), coordinated by Per Undén. UERRA will provide long-term datasets of Essential Climate Variables (ECVs) on the European regional scale in order to support adaptation action and policy development. The datasets will contribute to Climate services for Copernicus, climate monitoring and research.

Summary of problems encountered

(If you encountered any problems of a more technical nature, please describe them here.)

- Our model system HARMONIE was not available on the new CRAY-computers in the beginning of 2014. The problem was solved in the second half of 2014.
- Archiving on MARS was not possible from the beginning, since the regional reanalysis data had to be defined in GRIB2 format for the entire UERRA consortium and an archiving strategy had to be agreed upon. The problem was solved in the second half of 2016. The archiving of the reanalysis data to MARS is ongoing now. Currently, it takes 14 days to archive 2 years of data with 2 streams. It is planned to speed up this process in the beginning of 2017.
- Resources for the special project including an extension with 10 million SBUs were used up after Summer 2016. Our UERRA partner UK Met Office helped us by providing additional SBUs allowing us to continue the production during 2016. We are very grateful for this support.
- In a few occurrences, our programs timed out after waiting for ECFS.
- Two cases of insufficient observations from the MARS-archive occurred for the date 1979/01/27 0 UTC and 2005/03/10 18 UTC.
- In the experiments of the 5-year reanalysis mini-ensemble a rather serious bug was discovered after production. It was found that the cost function gradient of the large-scale mixing term, the so-called Jk-term was erroneously calculated and, thus, that the minimization of the cost function did not converge correctly. After the discovery of the error, its effect on the analysis was examined and found to be detrimental, especially in regions with few observations. It was therefore decided to rerun the 5-year reanalyses and also to rerun that part of the long reanalysis that was produced during 2015.

Experience with the Special Project framework

(Please let us know about your experience with administrative aspects like the application procedure, progress reporting etc.)

The special project framework works fine and provides a highly valued possibility to produce results with our modelling system at ECMWF.

Summary of results

(This section should comprise up to 10 pages and can be replaced by a short summary plus an existing scientific report on the project.)

A short summary is given below. For more details the reader is referred to our reports within the UERRA project, available on the UERRA-webpage: http://www.uerra.eu, namely D2.5 and D2.6. The links are given below in the publication list.

The HARMONIE system has been set up over a European domain to produce a long, high resolution re-analysis from 1961 to 2015 covering 55 years. The model domain is shown in Figure 1. The current production status is that 37 years are completed. The reanalysis is produced in several streams. The longest stream of completed data ranges from 2000 to 2015.

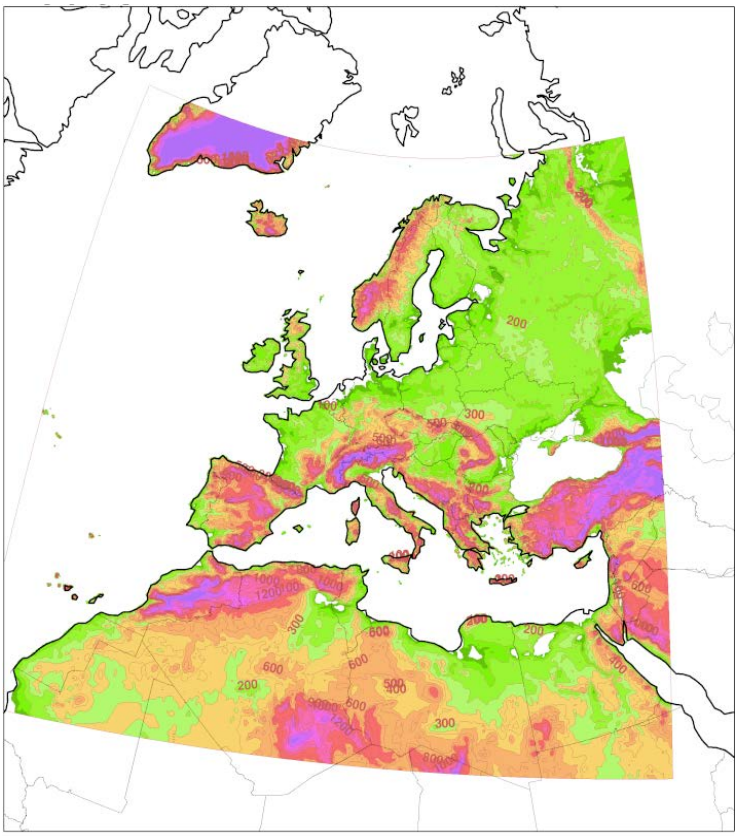

Figure 1: Model topography (shaded) and domain (pale line) for UERRA.

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, as show in Figure 2. Aircraft observations are not available before 1980. Comparing the number of Aircraft observations on different levels from July 1980 and July 2000, it can be seen that the total number of observations in upper levels (225 hPa) has increased from 1980 to 2000 with almost a factor 4. 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, visible in the increased number of observations especially in the lower levels of the troposphere in Figure 2.

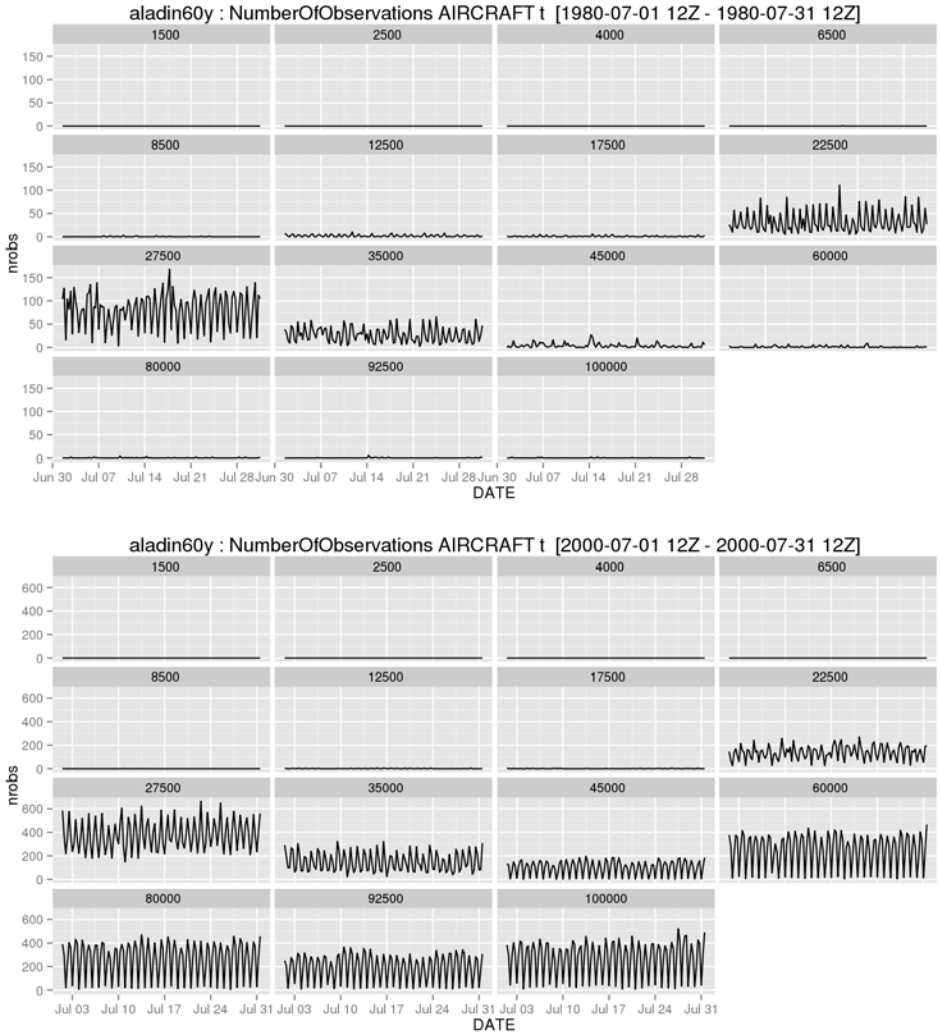

Figure 1. The number of temperature observations from aircrafts in different pressure layers (hPa) for July 1980 (upper) and July 2000 (lower). Note that the scale on the y-axis is different.

The number of available radio sounding also increases during the first 30 years (see Figure 3). 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 are a rather expensive observation type and some countries are reducing the number of launches per day.

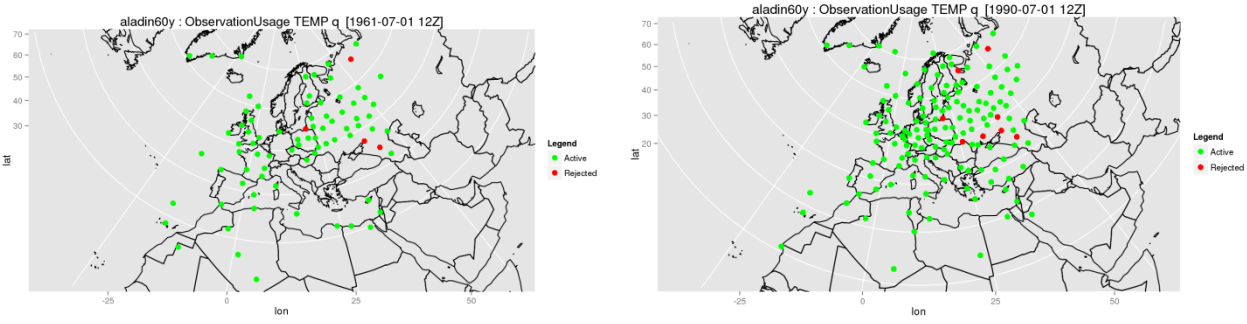

Figure 2. Available radio soundings for July 1961 (left) and July 1991 (right). Green indicates that the observation is used while red means that it is rejected.

The comparison of the first guess and the analysis with the observations confirms that the analysis is closer to the observations. An example is shown for July 1 of 1961 in Figure 4. 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.

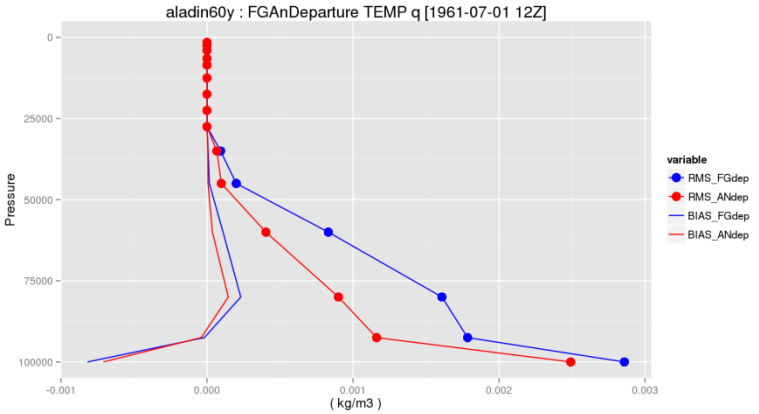

Figure 4. Example of first guess (blue) and analysis (red) departures for specific moisture for July 1 of 1961. Both RMS (line with dots) and bias (solid line) are shown.

List of publications/reports from the project with complete references

The reports of the FP7-project UERRA can be found on the following webpage:
http://www.uerra.eu/publications/deliverable-reports.html

Ridal, M., Körnich, H., E. Olsson and U. Andrae, 2015: Deliverable D2.5: Report of results and datasets of two physics HARMONIE runs for spread estimation. Report of FP7-project UERRA. Available from http://www.uerra.eu/component/dpattachments/?task=attachment.download&id=162

Ridal, M., Körnich, H., E. Olsson and U. Andrae, 2016: Deliverable D2.6: HARMONIE initial production. Preliminary report of the first period of the RA. Report of FP7-project UERRA. Available from http://www.uerra.eu/component/dpattachments/?task=attachment.download&id=186

Future plans

(Please let us know of any imminent plans regarding a continuation of this research activity, in particular if they are linked to another/new Special Project.)

The project UERRA will finish in the end of 2017, covering the years 1961 to present-day. It is desirable that this regional reanalysis will continuously be produced, downscaling the global reanalysis of ECMWF. Therefore, we will apply for a continuation of the project during 2017 and into 2018 in order to ensure near-current date production, until a Copernicus climate service for regional reanalysis is in place. The new special project was granted for 2017 and 2018.