REQUEST FOR A SPECIAL PROJECT 2020–2022

MEMBER STATE: Sweden

Principal Investigator[1]: Semjon Schimanke

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Sweden

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Project Title: Regional Reanalysis Spin Up (RRSUP)

If this is a continuation of an existing project, please state the computer project account assigned previously.	**SP** _____	
Starting year: (A project can have a duration of up to 3 years, agreed at the beginning of the project.)	2020	
Would you accept support for 1 year only, if necessary?	YES X	NO ☐

Computer resources required for 2020-2022: (To make changes to an existing project please submit an amended version of the original form.)		**2020**	**2021**	**2022**
High Performance Computing Facility	(SBU)	55,000,000	25,000,000	
Accumulated data storage (total archive volume)[2]	(GB)	350,000	440,000	

Continue overleaf

[1] The Principal Investigator will act as contact person for this Special Project and, in particular, will be asked to register the project, provide annual progress reports of the project's activities, etc.

[2] These figures refer to data archived in ECFS and MARS. If e.g. you archive x GB in year one and y GB in year two and don't delete anything you need to request x + y GB for the second project year etc.

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Project description

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SMHI, Sweden

1. Introduction

Regional Reanalyses for Europe have been carried out at SMHI in a number of EU FP6 and FP7 projects as well as now as part of the Copernicus Climate Change Service (C3S). A coupled Arctic Reanalysis was performed in the project DAMOCLES with HIRLAM and a European Reanalysis in the EURO4M project, also with HIRLAM and in UERRA most recently. In UERRA SMHI used the ALADIN model and data assimilation within the HARMONIE (HIRLAM ALADIN Regional / Mesoscale Operational NWP in Europe) system. UERRA was a precursor to the operational C3S Service (C3S 322 Lot1, CERRA, Copernicus European Regional ReAnalysis), Regional Reanalysis for Europe. Throughout the various projects, the grid resolutions have improved from 44 km to 22 and 11 km and now in C3S to 5.5 km and with also increased vertical resolution.

The horizontal resolutions have always been several times better than the global ECMWF reanalyses (ERA-40, ERA-Interim and ERA5) and the regional reanalyses have consistently provided more detail and higher accuracy due to better resolved surface properties and better representation in comparison to observations assimilated in the reanalyses. This has been shown in a number of reports (e.g. Ridal et al. 2017 and Ridal 2018) and in comprehensive evaluation of UERRA data against independent information (Borsche et al. 2015 and Kaiser-Weiss et al., 2019)

The global reanalyses have provided the lateral coupling and boundary forcing for the regional systems. Moreover, in EURO4M and UERRA a large-scale constraint, and in C3S a large scale mix, have provided forcing for the largest scales from the global reanalyses. The satellite data were not used in the earlier projects but they are in the current C3S 322 Lot1 service. (To become operational in the autumn of 2019).

The number of years of reanalysis has progressively increased to 55 plus years in UERRA or somewhat less in C3S, but the horizontal and vertical resolutions have virtually doubled in the CERRA system, thereby limiting the number of years to 35 plus years (from the early 80's).

The subsequent reanalysis projects have been carried out over typically 4 year periods but the development of the reanalysis systems, both modelling, data assimilation and observation usage and in particular archiving of the outputs have typically taken 2 of the 4 years, thereby leaving 2 or less years for the actual production of reanalyses.
This situation is not unique to the regional reanalyses, also the global reanalyses have been carried out over limited number of years and within EU projects or the C3S service. Even though the systems are optimised as far as possible, it is only possible to run so many days of reanalyses per day. However, the parallel compute clusters that are used (mainly at ECMWF) allow for a number of reanalysis streams to be run in parallel. Only by running several streams in parallel it is possible to finish the production within a reasonable time frame. And, since the reanalyses are constrained and adapted to observations, it is assumed that complete contiguous runs are not necessary and that the memory of the starting conditions is lost after some time. In the atmosphere this happens

quickly, already after a number of days but the surface conditions impose constraints. In the case of sea surface temperatures they have been prescribed from oceanographic reanalysis data (like OSTIA e.g.) and should not pose a problem in the recent and current regional reanalyses. However, the land surface and particularly the soil properties are another matter and these will be addressed in this special project application.

The surface temperature and superficial soil moisture are adjusted from analysis increments at the 2 metre level in the atmosphere resulting from assimilation of SYNOP observations. The deep soil variables (in the ISBA scheme in the SURFEX soil model) on the other hand, are only slowly adjusted due to exchanges with the levels above and constrained by a climatological value at the bottom lowest level. In Gleeson et al. (2017) they show the spin-up of the superficial soil moisture and deep soil moisture for the MÉRA regional reanalysis for Ireland and the British Isles run at an even higher horizontal resolution of 2.5km. In their Figure 4 one can see an adaptation in the spin-up run compared with the continuous run of at least 4 months for the deep soil. The spin-up run starts from interpolated ECMWF reanalysis data including translation of the soil variables from their soil scheme to the one used in HARMONIE (with the AROME model configuration in the Irish case).

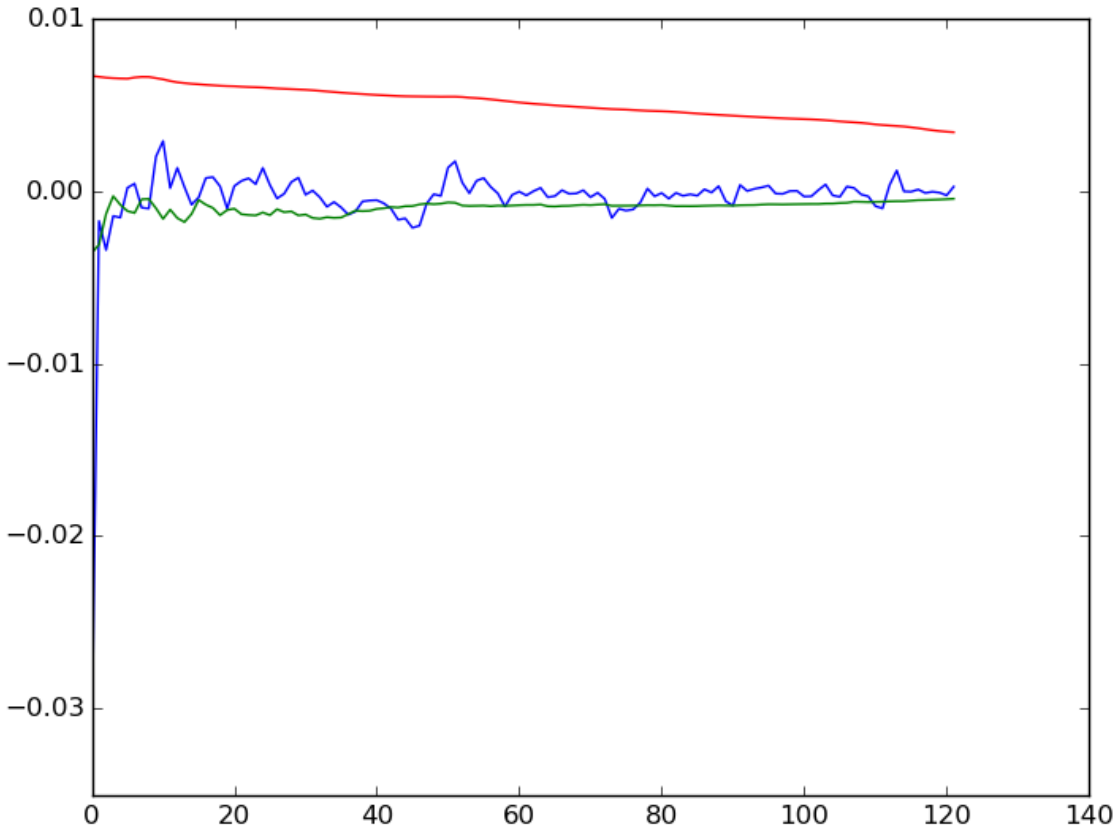

Figure 1. Spin up of soil moisture from UERRA. The spin up is determined from September to December for the years 1989, 1999 and 2005. Blue line represents the soil layer closest to the surface, the green line is the middle layer and the red line represents the deep soil.

In the HARMONIE-UERRA reanalysis a spin-up period of 4 months was used. It was shown by Ridal (pers. Comm.) that for the deep soil moisture it seems that 4 months may be a bit too short. In Figure 1 an example from this investigation is shown where the blue line shows the soil layer closest to the surface, the green line shows the middle layer and the red line represents the deep soil moisture. The top levels are spun up sufficiently but the deep soil is not fully spun up. The spin up

time may also depend on the time of the year. In UERRA, the autumn was chosen to avoid problems of frozen soil in the winter.

2. Questions to be answered and developments

The appropriate length of the spin-up period is important to determine as indicated at least for two reasons.
- No artificial breaks of the reanalysis data should appear between different streams. To avoid breaks, it is obvious that long spin-ups would help. However, that is contradicting with the next point.
- The computing costs of the spin-up runs are additional to the costs of the normal reanalysis production. In particular if many parallel streams have to be run due to production time constraints the computing costs can be significantly though the data of the spin-up periods is usually not made available to the users. Therefore, the intention is to keep the length of the spin-up periods as short as possible with respect to the previous point.

Based on that, the first research question is to find the minimum spin-up length, which ensures that the quality of each stream is more or less indistinguishable from a continuous run. Beside the conduction of the experiments this requires extensive investigations of all model fields, not only of the soil itself.

The spin-up time is believed to depend on the time of year. Usually, it is assumed that autumn should be most favourable to initialize spin-up runs. This will be tested and verified as well. For this purpose we will initialize simulations also in other seasons of the year. These realizations might be compared with data from the operational CERRA data.

A further question and possible way forward could be to enhance the initial soil conditions for the cold start of the spin-up. This could be done by improving the interpolation and interpretation of the initial soil variables from ECMWFs ERA5. Or, another option for the regional reanalysis would be to interpolate variables from the UERRA reanalyses which used the same type of soil scheme as CERRA does (apart from the lake model). Such developments might help to decrease the spin-up period in the future.

3. Experiments and work to be carried out

To answer these research questions, extensive runs of spin-up and maybe continuous reanalyses have to be performed.
Experiments in 2020:
- Two experiments with a spin-up of one year. One might be initialized at a different season than autumn.
- Experiments with different spin-up lengths where the initial conditions are taken from the UERRA fields or ERA5 with improved interpolation/interpretation

Experiments in 2021:
- Spin-up experiments initialized during different seasons of the year. These tests might be combined with results from the improved initial conditions.

Work related to this special project is mainly the evaluation of the output data. The different experiments need to be compared to each other and not only for the soil. Though the soil has the longest time scale there is also feedback to the atmosphere, which should be investigated. For instance, the feedback on heat waves or dry spells should be examined. An important dataset to compare with is the regional reanalysis for Europe, namely the operational CERRA data. These data will be used as a reference to the experiments performed in this special project.

Whereas setting up and running the suggested experiments is only of minor work it will need some effort to create the improved initial fields. Since the UERRA fields are missing some parameters needed for CERRA these fields needs to be merged with data from other sources, e.g. ERA5. Or, when using ERA5 data only, the interpolation and interpretation techniques needs to be improved. For instance, information from additional fields as topography and land-sea-ocean masks needs to be considered.

4. Expected impact from the Special Project

During the preparations of the CERRA production, which took place in the ongoing C3S_322_Lot1 service, we noticed that we have no general understanding of how long spin-up periods are needed. Moreover, we had to conclude that we do not have the needed SBU resources to conduct relevant tests though such investigations seem important. This special project would enable us to perform the needed simulations and investigations. Based on the results, future regional reanalysis productions (inside and outside the Copernicus framework) would benefit from thoroughly examined impact studies of different spin-up length and how these can be optimized. New methods for interpretation, interpolation and combination of different fields will be beneficial for future applications inside the reanalysis production and maybe even beyond.

5. Estimation of computer resources

The model used for the tests is the one developed in the operational C3S service C3S_322_Lot1 (Copernicus Regional Reanalysis for Europe), which is based on the ALADIN model and data assimilation within the HARMONIE (HIRLAM ALADIN Regional / Mesoscale Operational NWP in Europe) system. The domain corresponds approximately to the EURO-Cordex domain. It is setup with a horizontal resolution of 5.5 km (1069x1069 grid boxes) and 106 vertical levels. The used time step is 240s. Though at the time of writing the model configuration is still under development, we have already a good knowledge about the SBU consumption of the setup. Ongoing tests indicate that the cost for producing one year of CERRA output with the new system is about 20 MSBU. Based on this number and the experiment list given above we conclude that the following resources will be needed for this special project:

In 2020:

- Long spin-up experiments, a total of two years: 40 MSBU
- Experiments with improved initial conditions, a total of 9 months: 15 MSBU

In 2021:

- Test on the date of initialization, a total of 15 months: 25 MSBU

References

Borsche M, A. K. Kaiser-Weiss, P. Undén and F. Kaspar, Methodologies to characterize uncertainties in regional reanalyses, *Adv. Sci. Res.*, **12**, 207-218, 2015.

Gleeson, E., E. Whelan and John Hanley, Met Éireann high resolution reanalysis for Ireland, *Adv. Sci. Res.*, **14**, 49–61, 2017, doi:10.5194/asr-14-49-2017

Kaiser-Weiss, A., Borsche, M., Niermann, D., Kaspar, F., Lussana, C., Isotta, F., van den Besselaar, E., van der Schrier, G., Undén, P., Added value of regional reanalyses for climatological applications, *Env. Res. Comm.*, in print, 2019. Article reference: ERC-100061.R1

Ridal M., E. Olsson, P. Unden, K. Zimmermann and A. Ohlsson, HARMONIE re-analysis report of results and dataset. *UERRA deliverable D2.7*, 2017.

Ridal M., Documentation of the RRA system: UERRA. *C3S_322_lot1 deliverable D1.1.2*, 2018.