UERRA data user guide

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1. Introduction

1.1 The service

The C3S_322_Lot1 part of the Copernicus Climate Change Service produces and delivers a regional reanalysis (RRA) for Europe including long-term datasets of Essential Climate Variables (ECVs). These datasets can be used in support of adaptation action and policy development as well as contribute to climate services, climate monitoring and research.

The service is implemented in several steps. First, a system developed in the FP7 pre-operational project UERRA (UERRA: Uncertainties in Ensembles of Regional Reanalyses; www.uerra.eu) is used to update the existing RRA in near real time. In combination with the RRA produced already in the pre-operational project, the service offers a consistent RRA from 1961 to near real time.

Moreover, an improved model version will be developed within the service. The model will be used to create a pan-European reanalysis with very high resolution (5.5 km) forced by the global ERA5 reanalysis (RA). The improved system should become operational in the second half of 2019.

![Figure 1: The scheduled time line of production with the different systems.](image)

This document aims to describe the data produced by the first model system (UERRA system), which was developed in the pre-operational UERRA project. The system consists of two parts: the 3-dimensional model version called UERRA-HARMONIE at 11 km resolution and the 2-dimensional MESCAN-SURFEX surface analysis at 5.5 km resolution.

The UERRA-HARMONIE Data Assimilation system is implemented and optimized for the European area with surrounding sea areas (see Figure 2) with a resolution of 11 km and 65 height levels. It is run for the period 1961-present.

The MESCAN-SURFEX 2D-analysis system is used to generate a surface analysis. The system combines downscaled UERRA-HARMONIE reanalysis fields and additional surface observations to make a 2-dimensional analysis with 5.5km resolution over Europe for the period 1961-present.
Figure 2: Model domain of the UERRA systems highlighted with the topography of the UERRA-HARMONIE system where ocean cells are masked in blue.

1.2 Principles of reanalysis systems
Atmospheric reanalysis is a method to reconstruct the past weather by combining historical observations (in situ, surface and satellite remote sensing), with a dynamical model. It provides a physically and dynamically coherent description of the state of the atmosphere. The synthesis is accomplished by assimilating the observational data into a meteorological model and thereby forcing the model to reproduce the observations as closely as possible. The advantage of reanalysis is that they provide a multivariate, spatially complete, and coherent record of the atmospheric state – far more complete than any observational dataset is able to achieve.
The main advantages of reanalyses are (see Verver 2017):

- They provide regularly gridded data, even in places where there are no or few observations;
- They provide a coherent, complete set of variables describing the atmospheric state;
- They provide a reconstruction of the record of past weather since it is constrained by observations.

Weather forecasting is based on an analysis of the current state of the atmosphere and the surface of land and sea. The forecasts are made with mathematical and physical computer models starting from the analysis. The temperatures, winds, pressure, moisture, cloud contents and other variables are mapped at regular points in space and time (Fig. 3).

Figure 3: Schematic representation of a grid for model variables (surface pressure, temperature, u and v wind components and geopotential (Z), Energy and specific moisture content (q)).

Reanalysis uses a weather forecasting model to create a ‘first guess’ of the atmospheric state at a certain time. The first guess is then corrected on the basis of observations. This corrective step, referred to as ‘data assimilation’ (see figure 4), requires statistical knowledge of the forecast error and the observation error. The procedure also uses physical and statistical relationships of the atmosphere when interpreting the observational data. The result of the data assimilation is called the analysis. By repeating this process for a number of time steps the analyses will contain a complete set of values describing the evolution of the atmosphere and the surface over time, also for locations where there are no observations.

This complete estimate of the atmospheric state over time can be of great value to users, for example in assessing impacts of past weather and climate related events, for statistics of the climate in a location or an area or for running other fine scale models or validating climate models.

An important difference between reanalyses and archived weather analyses from operational forecasting systems is that a reanalysis is produced with a single version of a data assimilation system – including the forecast model used – and is therefore not affected by changes in method.
Reanalysis systems differ in the set of observations that are assimilated, the model that is used, and the way the error statistics are estimated and corrections are applied. A variety of reanalysis methods exist as for instance 4D variational analysis (4D-VAR), 3D-VAR (schematically shown in Fig. 4), nudging, and optimal interpolation (OI).

Figure 4: Schematic showing the simulation of the atmospheric state (black line) in the reanalysis, which starts from the analysis (green dots) and resulting in the background (blue dots). Note that the background usually does not coincide with the true observed state of the atmosphere. The source of the figure is unknown.
1.3 The UERRA system
As stated above, the model system that is used during the first phase of the service was designed in the preoperational project UERRA. That is why it is called UERRA system even in the framework of this service. Here, we will briefly mention the main features of the system whereas a detailed technical description can be found in Ridal et al. (2018).
In general, the UERRA system consists of two components. The three dimensional reanalysis based on the UERRA-HARMONIE system as well as the surface reanalysis based on MESCAN-SURFEX.

1.3.1 The UERRA-HARMONIE system
The 3D-UERRA system is based on the HARMONIE Data Assimilation system, which is developed and used within the HIRLAM and ALADIN consortia. The UERRA system is implemented and optimized for the entire European area with surrounding sea areas (see Fig. 2) with a resolution of 11 km and 65 height levels. For the period 1961-2001 ERA40 observations with addition of Swedish and French observations are used. After 2001 conventional data (SYNOP, Ship, Buoys, Radiosondes, Pilot and Aircraft) are used that are operationally available.
The system uses global reanalysis data as lateral boundaries: ERA40 for the period 1961-1979, after that ERA-interim (Fig. 5). Also, the large scales in the regional system are constrained by data from the global reanalysis.

Figure 5: Three different stages of RA: the global reanalyses are used as lateral boundary for the 3D-UERRA regional reanalysis. In turn, these are used as background fields for the 2D surface reanalysis. The amount of observational data used for the RA per area unit increases from the global to the surface reanalysis as indicated by the arrows.
The UERRA system applies the so called 3D variational analysis (3D-VAR). The 3D-VAR method is depicted schematically in Figure 4. At fixed points in time the model state is adjusted based on the observed state, taking into account the statistics of model and observation errors. The UERRA system is run with four cycles per day performing analyses at 00UTC, 06UTC, 12UTC and 18UTC. The forecasts lengths vary between 6 and 30 hours.

1.3.2 MESCAN-SURFEX
The MESCAN-SURFEX system analysis uses the 2D-analysis system MESCAN and the land surface platform SURFEX to generate a coherent surface and soil analysis. The system combines downscaled UERRA-HARMONIE reanalysis fields and additional surface observation (especially for precipitation), to make a high resolution (5.5 km) 2-dimensional analysis over Europe. MESCAN is a surface analysis system using an optimal interpolation algorithm for the 2m-temperature and relative humidity and for the 24h-accumulated rainfall (Soci et al., 2016). SURFEX is a land surface platform, which is driven by temperature, humidity, precipitation, wind and radiative fluxes.

More details regarding the MESCAN-SURFEX system can be found in Bazile et al. (2017).

2. General guidelines for the usage of UERRA data
This section aims to summarize important features of the models and results that the user needs to be aware of when using the UERRA datasets. Although UERRA provides consistent and coherent datasets there are weaknesses and limitations. Some of these are common for reanalyses in general, other are model/version dependent. The user has to decide whether the data is fit for their specific purpose.

Vast amount of data are available from the UERRA system. For the UERRA-HARMONIE system, a complete set of parameters including all available time steps take up ca. 8 TB per model year and hence almost 500 TB for the entire time period. The MESCAN-SURFEX surface analysis is not included in this estimation. However, it needs less storage place than the 3D-reanalysis – in total 47 TB.

For the UERRA-HARMONIE data, the user might choose among more than 50 parameters for different heights and time steps. In addition, the MESCAN-SURFEX analysis offers roughly 30 surface parameters. Detailed descriptions of all parameters are given in section 3.

2.1 Resolution in time and space
2.1.1 Horizontal resolution
As depicted in Fig. 3, all parameters are computed for grid boxes. This means the parameters values reflect a mean over the grid box area. Having a horizontal resolution of 11km for the UERRA-
HARMONIE system implies that each value reflects the mean over an area of $121\text{km}^2$ ($11\text{km}\times 11\text{km}$). This needs to be considered when for instance UERRA data is compared with observation. The resolution of the MESCAN-SURFEX surface analysis is $5.5\text{km}\times 5.5\text{km}$. Hence, a grid box has an area of roughly $30\text{km}^2$.

2.1.2 Vertical resolution
As stated above, the UERRA-HARMONIE system has 65 vertical levels. However, on these so called model levels only a very restricted amount of parameters is stored. The main reason for that is the amount of needed storage space, when all parameters would be stored for all levels. Moreover, the vertical model grid is on hybrid-sigma coordinates, which makes it more complex to use the output.

Therefore, the major part of the data is stored on selected pressure levels. Pressure levels are available at levels between 1000-10hPa with a higher resolution at lower altitudes. In addition, some parameters are stored on height levels. 11 height levels are available which are between 15-500m. One reason to store data additionally on height levels are applications in the wind energy sector. The exact levels both for pressure and height levels are given in section 3 in the corresponding tables.

The UERRA-HARMONIE soil model has 3 vertical levels. The three levels represent approximately the surface, the soil at root depth and the deep soil. Due to the used force-restore scheme in the soil model it is not possible to relate the levels with a certain depth in meter. The MESCAN-SURFEX soil model has 14 vertical levels, which range from the surface to a depth of 12m. The edges between different levels are at 0.01m, 0.04m, 0.1m, 0.2m, 0.4m, 0.6m, 0.8m, 1.0m, 1.5m, 2m, 3m, 5m, 8m, and 12m. Values for a certain level reflect the mean value over the level thickness.

2.1.3 Time resolution
In general, data is stored with hourly resolution for the UERRA-HARMONIE system. However, for many time steps the users have different options to select from and this is no easy choice. The preferred selection might vary for different parameters and the application of the user, respectively. Also, some of the time steps are affected by spin-up issues as explained in the next section.

Figure 6 gives an overview on available time steps. First, there are the four analyses at 00UTC, 06UTC, 12UTC, and 18UTC highlighted in red. These time steps should be of highest quality since the observations are assimilated directly. However, they are available only every sixth hour and not all parameters are available for the analyses (Check tables in section 3 for the availability of the parameters at different time steps). The forecasts are then started from the analyses and the output is saved hourly for the first six hours as indicated by the dark blue in Fig. 6. Whereas the forecasts initiated at 06UTC and 18UTC stop after six hours the forecasts initiated at 00UTC and 12UTC continue until forecast hour 30. However, the output frequency is reduced to three hourly until forecast hour 24 and the last output is then saved six hours later (see blue boxes in Fig. 6).
Due to the forecast lengths, the forecasts are overlapping and for many hours of the day data might be chosen from different forecasts and the analysis, respectively. At 00 UTC and 12 UTC, the users can choose between the analysis and three different forecasts. As shown in Fig. 6, at 12 UTC forecasts are available from the forecasts initiated at 06 UTC (six hour forecast), 00 UTC (twelve hours forecast), and 12 UTC of the previous day (24 hours forecast). However, for other hours of the day (01 UTC, 02 UTC, 04 UTC, …) there is no choice and forecasts are available only from one forecast.

Different forecasts lengths have different strengths and weaknesses. Whereas the short-term forecasts are affected by spin-up issues after the initialization of the model the long-term forecasts might veer away from the real weather due to shortcomings in the model. In general, it is not possible to give a general recommendation for which time steps should be used and the users have to check on their own, which selection gives the best result in their application.

The MESCAN-SURFEX output is essentially hourly except for the driving variables used as input by SURFEX. The analyzed variables are 2m temperature and relative humidity, radiative fluxes and wind with a frequency of 6h and 24h precipitation only available at 6h UTC.

2.2 General limitations of reanalyses

Generally it is challenging for a reanalysis system to correctly reconstruct variables that is very variable in space and time, such as precipitation. For some applications, e.g. in hydrology, it is therefore quite common to correct the precipitation data for a bias. Other variables, like surface temperature, are generally less variable in space and time and easier to reconstruct by the reanalysis system.

Similar to above, results in complex terrain, such as mountainous regions or coastal areas, are generally less reliable than results over a more homogeneous terrain. The models cannot represent the strong gradients that sometimes are caused by the variable terrain.
Figure 7 illustrates this behavior. Here, we show spots in Sweden having the best (blue) and worst (red) correlations between the UERRA-HARMONIE 2m-temperature and observational sites. A total of 853 measurement sites have been investigated and each the 50 with highest and lowest correlation are shown. Clearly, correlations are lowest in the Swedish mountains and along the (east) coast.

Users need to keep in mind, that the reanalysis provides gridded data where each grid box describes the mean over the grid box area. That’s in contrast to observations, which are usually point measurements. In case users need information with a higher horizontal resolution than provided by the UERRA-systems, further downscaling (statistically or dynamically) needs to be considered. For instance, the correlations indicated in Fig. 7 increased when a linear interpolation to the observational site was applied than purely taken the values from the closest grid point.

Partially due to this it is more difficult for a reanalysis system to correctly capture absolute values of extremes than values closer to the mean. This is especially the case for precipitation extremes, where the reanalysis data are highly resolution dependent. This means for example that the number of days with precipitation over a certain absolute threshold value is likely to be less accurate than using a relative threshold such as a 95-percentile value. Also extremes on larger scales, like droughts and heatwaves, are better represented than extremes on smaller scales.

As mentioned earlier, the reanalysis is produced with a single version of data assimilation system/forecast model and is therefore not affected by changes in method. But it is worth noting that some other components of the reanalysis are not consistent over time. For example, the number of available observations is varying over time. Also, the shift of global reanalysis boundary data in 1980 and observation data sources in 2001 will affect the consistency of the time series (see section 1.3.1).
2.3 Model specific issues

In the UERRA reanalyses some problems have been noticed that users need to be aware of. As mentioned above, the amount of data is very large and only part of the data was verified. Hence, often problems are only discovered by the end users. To increase the performance of future reanalysis, we would appreciate if users report known problems. This section lists the issues that are known at the time of writing. If further issues will occur they will be reported via the C3S_322_Lot1 website (https://climate.copernicus.eu/copernicus-climate-change-service-regional-reanalysis-europe).

2.3.1 UERRA-HARMONIE

2.3.1.1 Spin-up issues

Spin-up issues are a general problem for data assimilation and Numerical Weather Prediction systems. However, unfortunately this particular issue is in the UERRA-HARMONIE case somewhat extreme. But, the issue causing the problem is located and the next RRA should not be affected as much by spin-up problems as the current version.

The largest spin-up issues occurs during the first 2 hours of the forecast. It is therefore recommended to primarily use the 6 hourly analysis fields whenever this is possible. Also, it seems that three hourly values can be used without larger restriction. The spin-up problems are most pronounced during turbulent conditions, for example connected to deep low pressure systems, and should therefore be limited in space and time.

These spin-up problems are in some situations causing too high wind speeds for the 1-2 hour forecasts. This is most pronounced in the wind gust but the problem also occurs for the mean wind at 10 meter altitude, see figure 8.

Similar spin-up problems as for the winds can be seen for maximum/minimum temperature. This can in turn cause errors in the cold/warm extremes which affect climate indices such as frost days, tropical nights, ice days and summer days. For instance, Niermann et al. (2017) report that biases for frost days and summer days can be as large as up to 40 days/year when compared with E-OBS data.
Figure 8: 10m wind speed during the storm Gudrun in southern Sweden January 2005. The blue line and dots are hourly observations from station Växjö A. Red line and dots are the hourly UERRA-HARMONIE forecast for the closest grid point. Note the reoccurring leaps in wind speed during forecast hours 1-2.

Then in general there is a spin-up problem for precipitation. Here, it is not recommended to use the first 6 hours of the forecasts. For example, if a user wants to use the 24 hour accumulated precipitation it is thus recommended to use the 30-6 hour forecasts.

2.3.1.2 Archiving issues – relative humidity and cloud cover

Relative humidity: Due to a bug in one of the archiving scripts all relative humidity equal or larger than 100% was set to zero. That issue can be handled by users by setting all zero values to 100%. At least close to the surface there is no risk of setting real zeros to 100 since the humidity is never reaching 0% - not in the model and not in the real world.

For user familiar with CDOs (climate data operators, https://code.mpimet.mpg.de/projects/cdo) this can be done with the following command line:

cdo setmisstoc,100 –setvrange,0.0001,200 INFILE OUTFILE

Cloud cover: The same problem exists for cloud cover so there are large areas archived with 0% that are erroneous. The problem exists for total cloud cover as well as for low, medium and high clouds. Unfortunately, this problem cannot be solved as easily as for humidity since the cloud cover can be zero, which is not the case for relative humidity (in the lower atmosphere). There might be ways to fix this parameter as well. A combination of radiation parameters might be checked to verify
whether the cloud cover is really zero or should be set to 100% instead. However, such a reprocessing has not been tested yet.

The archiving bug was fixed within the Copernicus service and values saved from RRA year 2016 are not affected by this problem.

2.3.1.3 Surface fluxes
For the accumulated surface fluxes of sensible and latent heat values are missing over most of the land area. Whereas the model handles the values correctly, they were ruined in the post-processing. The problem is understood and will be fixed for future production. And, the user is encouraged to use the surface fluxes from the MESCAN-SURFEX system.

2.3.1.4 Radiation/Clouds
For global radiation, there is a general overestimation over Europe. The bias is largest over the ocean parts of the North Atlantic and decreases towards the south. Details regarding global radiation can be found in the UERRA report by Niermann et al. (2017) in section 5.2. It is suspected that the overestimation of global radiation can be a consequence of underestimated cloud cover and investigations are ongoing.

2.3.1.5 Relative humidity/Clouds
Ridal et al. (2018) states that UERRA-HARMONIE produces too much moisture and that this is a known problem for the ALADIN model. The excess of moisture does affect the cloud cover. For instance, the UERRA-HARMONIE re-analysis performs worse than ERA-Interim in situations with low amounts of clouds.

2.3.1.6 Geopotential height
For geopotential height, it seems that some time steps are erroneous. The values seem wrong by a factor of 10,000. The reason for this sporadic error is unknown. Users reported errors for the following days: 1st and 2nd of January 1981, 1st – 4th of August 1981, and 11th of February 1982.

2.3.2 MESCAN-SURFEX
In the MESCAN-SURFEX surface analysis errors have been noticed in the precipitation fields for some areas and time periods, see Figure 9. These errors are most likely due to erroneous observations, which did enter the assimilation procedure. It remains a challenge for the next system to solve this type of weaknesses – especially for “old” and validated data where precipitation is equal to zero for long period. Since the errors are restricted in time and space, the user has to evaluate if the studied time period or region is affected.
2.4 FAQ

- What do you mean with near real-time?
  The production of the UERRA system is delayed by 3-4 month. For instance, in May 2018 we released the RRA for Europe for January 2018. The delay is directly coupled to the production and validation of the global RA ERA-interim, which is used as lateral boundary. Only if this data is released are we able to run the UERRA-HARMONIE system and then MESCAN-SURFEX in a second step.

- Can we use reanalysis data for local applications?
  Reanalysis data are gridded products. The values represent a certain spatial scale which may be hard to compare to a point value that may be obtained from a station. Note that the spatial scale of the data provided is not necessarily the grid spacing of the dataset.

- What’s recommended for the computation of daily/monthly means? Which time steps should be considered?
  Some tests were performed at SMHI regarding 2m-temperature. In one case, the monthly mean was computed from hourly values – the analysis and the first 5 forecasts time steps. In the second case, only the analyses were considered. Consequently each day was represented by 4 values only whereas in case one 24 hourly values were used. However, the mean bias of the monthly means compared to observations was generally somewhat lower when only analyses were used.
  Users should keep in mind that this test was done for 2m-temperature only and that other parameters might behave differently.

Figure 9: Monthly precipitation at station Enköping/Sweden (blue line) and from the closest grid point of the MESCAN-SURFEX surface analysis (red line). Note the two periods where precipitation is underestimated in MESCAN-SURFEX.
- Is the data free and how can it be accessed?
  The UERRA reanalysis datasets (in total more than 700 Tb) are freely available at the MARS archive of ECMWF at https://apps.ecmwf.int/datasets/data/uerra. The full set of variables that are available can be found in https://software.ecmwf.int/wiki/display/UER/Parameters. Details on how to retrieve data from this archive can be found in section 4 of this document.
3. Detailed data description and availability

3.1 UERRA-HARMONIE system

3.1.1 Surface parameters

<table>
<thead>
<tr>
<th>Metadata for UERRA-HARMONIE surface parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Horizontal coverage</strong></td>
</tr>
<tr>
<td>The model domain spans from northern Africa beyond the northern tip of Scandinavia. In the west it ranges far into the Atlantic ocean and in the east it reaches to the Ural. Herewith, it covers entire Europe. See Figure for an overview of the model domain.</td>
</tr>
<tr>
<td><strong>Horizontal resolution</strong></td>
</tr>
<tr>
<td>11x11 km²</td>
</tr>
<tr>
<td><strong>Vertical coverage</strong></td>
</tr>
<tr>
<td>Each surface parameter is valid for one vertical level and three different (near) surface levels exists:</td>
</tr>
<tr>
<td>- surface: atmospheric boundary with the ground or water surface</td>
</tr>
<tr>
<td>- 2m: 2m above the surface</td>
</tr>
<tr>
<td>- 10m: 10m above the surface</td>
</tr>
<tr>
<td><strong>Vertical resolution</strong></td>
</tr>
<tr>
<td>One level only</td>
</tr>
<tr>
<td><strong>Temporal coverage</strong></td>
</tr>
<tr>
<td>1961-01-01 00:00 – close to real time (monthly updates but with a delay to real time of about four months)</td>
</tr>
<tr>
<td><strong>Temporal resolution</strong></td>
</tr>
<tr>
<td>Analysis are available at 00, 06, 12, 18 UTC. The forecast length is depending on the cycle. Cycles initialized at 00 and 12 UTC have forecasts saved at 1, 2, 3, 4, 5, 6, 9, 12, 15, 18, 21, 24, 30. Cycles initialized at 06 and 18 UTC have forecasts saved at 1, 2, 3, 4, 5, 6. Some parameters are saved only until forecast hour six. See section 2.1.3 (Fig. 6) for more details.</td>
</tr>
<tr>
<td><strong>Data type and format</strong></td>
</tr>
<tr>
<td>Gridded data in GRIB2</td>
</tr>
<tr>
<td><strong>Grid</strong></td>
</tr>
<tr>
<td>Lambert conformal conic grid with 565x565 grid points</td>
</tr>
</tbody>
</table>

Table 1: Overview Surface parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>GRIB code</th>
<th>Analysis 0, 6, 12, 18</th>
<th>Forecast 1,2,3,…</th>
<th>Height</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Surface air relative humidity</td>
<td>%</td>
<td>260242</td>
<td>yes</td>
<td>yes</td>
<td>2m</td>
</tr>
<tr>
<td>2. Total column water vapour</td>
<td>kg/m²</td>
<td>260057</td>
<td>yes</td>
<td>yes</td>
<td>vertically integrated above the surface</td>
</tr>
<tr>
<td>3. Total precipitation</td>
<td>kg/m²</td>
<td>228228</td>
<td>-</td>
<td>yes</td>
<td>surface</td>
</tr>
<tr>
<td>4. 10 metre wind speed</td>
<td>m/s</td>
<td>207</td>
<td>yes</td>
<td>yes</td>
<td>10m</td>
</tr>
<tr>
<td></td>
<td>Parameter</td>
<td>Unit</td>
<td>Value</td>
<td>Unit Specificity</td>
<td>Observation Specificity</td>
</tr>
<tr>
<td>---</td>
<td>-----------------------------------------------</td>
<td>--------</td>
<td>-------</td>
<td>------------------</td>
<td>--------------------------</td>
</tr>
<tr>
<td>5.</td>
<td>10 metre wind direction</td>
<td>deg</td>
<td>260260</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>6.</td>
<td>10 metre wind gust speed</td>
<td>m/s</td>
<td>49</td>
<td></td>
<td>yes</td>
</tr>
<tr>
<td>7.</td>
<td>Surface air maximum temperature</td>
<td>K</td>
<td>201</td>
<td></td>
<td>yes</td>
</tr>
<tr>
<td>8.</td>
<td>Surface air minimum temperature</td>
<td>K</td>
<td>202</td>
<td></td>
<td>yes</td>
</tr>
<tr>
<td>9.</td>
<td>Surface air temperature</td>
<td>K</td>
<td>167</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>10.</td>
<td>Skin temperature</td>
<td>K</td>
<td>235</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>11.</td>
<td>Albedo</td>
<td>0-1</td>
<td>260509</td>
<td>yes</td>
<td>only six hours</td>
</tr>
<tr>
<td>12.</td>
<td>Evaporation</td>
<td>kg/m²</td>
<td>260259</td>
<td></td>
<td>yes</td>
</tr>
<tr>
<td>13.</td>
<td>Time-integrated surface latent heat flux</td>
<td>J/m²</td>
<td>147</td>
<td></td>
<td>only six hours</td>
</tr>
<tr>
<td>14.</td>
<td>Time-integrated surface sensible heat flux</td>
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<td>146</td>
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</tr>
<tr>
<td>15.</td>
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</tr>
<tr>
<td>16.</td>
<td>Time-integrated surface net solar radiation</td>
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<td>176</td>
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<td>18.</td>
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<td>%</td>
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<tr>
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<td>%</td>
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<td>26.</td>
<td>Snow density</td>
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<tr>
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<tr>
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<td>31.</td>
<td>Surface roughness</td>
<td>m</td>
<td>173</td>
<td>yes</td>
<td>only six hours</td>
</tr>
</tbody>
</table>
3.1.1.1 Surface air relative humidity
The surface air relative humidity is the modelled humidity valid for a grid point (approximately 11km*11km=121km²) determined for a height of 2m above the surface. The parameter is given % ranging from 0-100. 0% means that the air is totally dry whereas 100% indicates that the air is saturated with water vapour. The saturation is defined with respect to saturation of the mixed phase, i.e. with respect to saturation over ice below -23°C and with respect to saturation over water above 0°C. In the regime in between a quadratic interpolation is applied.
Surface air relative humidity is available for the analysis and the forecast time steps. The value is instantaneous meaning that it is valid for the last time step of the integration at the issued time step.
Please check section 2.3.1.2 Archiving issues when using this parameter.

3.1.1.2 Total column water vapour
The total column water vapour is the vertically integrated water vapour valid for a grid point (approximately 11km*11km=121km²). It is vertically integrated from the surface to the top of the atmosphere. The parameter is given in kg/m².
Total column water vapour is available for the analysis and the forecast time steps. The value is instantaneous meaning that it is valid for the last time step of the integration at the issued time step.

3.1.1.3 Total precipitation
Total precipitation is the amount of precipitation falling onto the ground/water surface. It includes all kind of precipitation forms as convective precipitation, large scale precipitation, liquid and solid precipitation. The amount is valid for a grid box and has the unit kg/m².
The total precipitation is available only for the forecast time steps. It is an accumulated parameter meaning that it is accumulated from the beginning of the forecast. For instance, the 24h-forecast has the accumulated precipitation over 24 hours.

3.1.1.4 10 metre wind speed
The 10 metre wind speed is the wind speed valid for a grid point (approximately 11km*11km=121km²) determined for a height of 10m above the surface. The parameter is given in m/s. It is computed from both the zonal (u) and the meridional (v) wind components by

\[ \text{wind speed} = \sqrt{u^2 + v^2} \]

The 10 metre wind speed is available for the analysis and the forecast time steps. The value is instantaneous meaning that it is valid for the last time step of the integration at the issued time step.

3.1.1.5 10 metre wind direction
The 10 metre wind direction is the wind direction valid for a grid point (approximately 11km*11km=121km²) determined for a height of 10m above the surface. The parameter is given in degrees ranging from 0-360. Here, 0° means a northerly wind and 90° indicates an easterly wind.
The 10 metre wind direction is available for the analysis and the forecast time steps. The value is instantaneous meaning that it is valid for the last time step of the integration at the issued time step.
3.1.1.6 10 metre wind gust speed
The 10 metre wind gust speed is the maximum wind speed since the last post-processing at a grid point (approximately 11km*11km=121km²). It is determined for a height of 10m above the surface. The parameter is given in m/s.
The 10 metre wind speed is only available for the forecast time steps. The value is the maximum since the previous post-processing. For instance, for the first saved time step at forecast 1h it is the maximum wind speed, which occurred between within the first hour of the forecast. For the second saved time step at forecast 2h, it is the maximum wind speed which happened in the second forecast hour, hence between fc1 and fc2. For longer forecasts, the output frequency is reduced. Hence, the maximum over a longer time period is saved. For instance, for the 15h forecast the maximum wind speed is identified within the period 12h – 15h since the last post-processing happened at 12h (12 hours after the onset of the forecast).
Please check section 2.3 Model specific issues when using this parameter.

3.1.1.7 Surface air maximum temperature
The surface air maximum temperature is the maximum temperature since the last post-processing at a grid point (approximately 11km*11km=121km²). It is determined for a height of 2m above the surface. The parameter is given in Kelvin [K].
Surface air maximum temperature is only available for the forecast time steps. The value is the maximum since the previous post-processing. For instance, for the first saved time step at forecast 1h it is the maximum surface air temperature, which occurred between within the first hour of the forecast. For the second saved time step at forecast 2h, it is the maximum surface air temperature which happened in the second forecast hour, hence between fc1 and fc2. For longer forecasts, the output frequency is reduced. Hence, the maximum over a longer time period is saved. For instance, for the 15h forecast the maximum surface air temperature is identified within the period 12h – 15h since the last post-processing happened at 12h (12 hours after the onset of the forecast).
Please check section 2.3 Model specific issues when using this parameter.

3.1.1.8 Surface air minimum temperature
The surface air minimum temperature is the minimum temperature since the last post-processing at a grid point (approximately 11km*11km=121km²). It is determined for a height of 2m above the surface. The parameter is given in Kelvin [K].
Surface air minimum temperature is only available for the forecast time steps. The value is the minimum since the previous post-processing. For instance, for the first saved time step at forecast 1h it is the minimum surface air temperature, which occurred between within the first hour of the forecast. For the second saved time step at forecast 2h, it is the minimum surface air temperature which happened in the second forecast hour, hence between fc1 and fc2. For longer forecasts, the output frequency is reduced. Hence, the minimum over a longer time period is saved. For instance, for the 15h forecast the minimum surface air temperature is identified within the period 12h – 15h since the last post-processing happened at 12h (12 hours after the onset of the forecast).
Please check section 2.3 Model specific issues when using this parameter.

3.1.1.9 Surface air temperature
The surface air temperature is the model temperature valid for a grid point (approximately 11km*11km=121km²) determined for a height of 2m above the surface. The parameter is given in Kelvin [K].
Surface air temperature is available for the analysis and the forecast time steps. The value is instantaneous meaning that it is valid for the last time step of the integration at the issued time step.

3.1.1.10 Skin temperature
The skin temperature is the model temperature valid for a grid point (approximately 11km*11km=121km²) determined for the boundary surface to the atmosphere, both ground and water surfaces. The parameter is given in Kelvin [K].
Skin temperature is available for the analysis and the forecast time steps. The value is instantaneous meaning that it is valid for the last time step of the integration at the issued time step.

3.1.1.11 Albedo
The albedo is the amount of radiation which is reflected for the given grid point (approximately 11km*11km=121km²). It is determined for the surface to the atmosphere, both for ground and water surfaces. The parameter is given in %. Small values mean that large amounts of the radiation are absorbed whereas large values mean that more radiation is reflected.
Albedo is available for the analysis and the forecast time steps up to forecast hour six. The value is instantaneous meaning that it is valid for the last time step of the integration at the issued time step.

3.1.1.12 Evaporation
Evaporation is the amount of moisture flux from the surface (ground and water) into the atmosphere. It is given as a mean for a grid point (approximately 11km*11km=121km²). The parameter is given in kg/m². By model convention downward fluxes are positive. Hence, evaporation is represented by negative values and positive values represent condensation.
Evaporation is only available for forecast time steps. It is an accumulated parameter meaning that it is accumulated from the beginning of the forecast. For instance, the 24h-forecast has the accumulated evaporation over 24 hours.

3.1.1.13 Time-integrated surface latent heat flux
The surface latent heat flux is the exchange of latent heat (due to phase transitions: evaporation, condensation) with the surface (ground and water) through turbulent diffusion. It is given as a mean for a grid point (approximately 11km*11km=121km²). The parameter is given in J/m². By model convention downward fluxes are positive.
Surface latent heat flux is only available for forecast time steps up to forecast hour six. It is an accumulated (time-integrated) parameter meaning that it is accumulated from the beginning of the forecast. For instance, the 24h-forecast has the accumulated heat flux over 24 hours.
Please check section 2.3 Model specific issues when using this parameter.

3.1.1.14 Time-integrated surface sensible heat flux
The surface sensible heat flux is the exchange of heat (no phase transition) with the surface (ground and water) through turbulent diffusion. It is given as a mean for a grid point (approximately 11km*11km=121km²). The parameter is given in J/m². By model convention downward fluxes are positive.
Surface sensible heat flux is only available for forecast time steps up to forecast hour six. It is an accumulated (time-integrated) parameter meaning that it is accumulated from the beginning of the forecast. For instance, the 24h-forecast has the accumulated heat flux over 24 hours. Please check section 2.3 Model specific issues when using this parameter.

3.1.1.15 Time-integrated surface direct solar radiation
The surface direct solar radiation is the amount of direct solar (short-wave) radiation reaching the surface (ground and water). It is given as a mean for a grid point (approximately 11km*11km=121km²). The parameter is given in J/m². By model convention downward fluxes are positive. Surface direct solar radiation is only available for forecast time steps. It is an accumulated (time-integrated) parameter meaning that it is accumulated from the beginning of the forecast. For instance, the 24h-forecast has the accumulated radiation over 24 hours.

3.1.1.16 Time-integrated surface net solar radiation
The surface net solar radiation is the amount of solar (short-wave) radiation that is absorbed at the surface (ground and water). It is computed

\[
\text{Surface net solar radiation} = \text{surface solar radiation downwards} \times (1 - \text{albedo})
\]

It is given as a mean for a grid point (approximately 11km*11km=121km²). The parameter is given in J/m². By model convention downward fluxes are positive. Surface net solar radiation is only available for forecast time steps. It is an accumulated (time-integrated) parameter meaning that it is accumulated from the beginning of the forecast. For instance, the 24h-forecast has the accumulated radiation over 24 hours.

3.1.1.17 Time-integrated surface solar radiation downwards
The surface solar radiation downward is the amount of solar (short-wave) radiation reaching the surface (ground and water). It is given as a mean for a grid point (approximately 11km*11km=121km²). The parameter is given in J/m². By model convention downward fluxes are positive. Surface solar radiation downwards is only available for forecast time steps. It is an accumulated (time-integrated) parameter meaning that it is accumulated from the beginning of the forecast. For instance, the 24h-forecast has the accumulated radiation over 24 hours.

3.1.1.18 Time-integrated surface net thermal radiation
The surface net thermal radiation is the amount of thermal (long-wave) radiation that is absorbed at the surface (ground and water). It is computed

\[
\text{Surface net thermal radiation} = \text{surface thermal radiation downwards} \times (1 - \text{albedo})
\]

It is given as a mean for a grid point (approximately 11km*11km=121km²). The parameter is given in J/m². By model convention downward fluxes are positive. Surface net thermal radiation is only available for forecast time steps. It is an accumulated (time-integrated) parameter meaning that it is accumulated from the beginning of the forecast. For instance, the 24h-forecast has the accumulated radiation over 24 hours.

3.1.1.19 Time-integrated surface thermal radiation downwards
The surface thermal radiation downward is the amount of thermal (long-wave) radiation reaching the surface (ground and water). It is given as a mean for a grid point (approximately
11km*11km=121km$^2$). The parameter is given in J/m$^2$. By model convention downward fluxes are positive.
Surface thermal radiation downwards is only available for forecast time steps. It is an accumulated (time-integrated) parameter meaning that it is accumulated from the beginning of the forecast. For instance, the 24h-forecast has the accumulated radiation over 24 hours.

3.1.1.20 Mean sea level pressure
The mean sea level pressure is the air pressure reduced to mean sea level valid for a grid point (approximately 11km*11km=121km$^2$). The parameter is given in Pascal [Pa].
Mean sea level pressure is available for the analysis and the forecast time steps. The value is instantaneous meaning that it is valid for the last time step of the integration at the issued time step.

3.1.1.21 Surface pressure
The surface pressure is the air pressure at the surface (ground and water) valid for a grid point (approximately 11km*11km=121km$^2$). The parameter is given in Pascal [Pa].
Mean sea level pressure is available for the analysis and the forecast time steps. The value is instantaneous meaning that it is valid for the last time step of the integration at the issued time step.

3.1.1.22 High cloud cover
The high cloud cover is the percentage of sky covert with clouds in high altitude. It is valid for a grid point (approximately 11km*11km=121km$^2$) and high refers to height above 5000m. The parameter is given in %.
High cloud cover is available for the analysis and the forecast time steps. The value is instantaneous meaning that it is valid for the last time step of the integration at the issued time step.

Please note that there is a problem with this parameter. Check section 2.3.1.2 Archiving issues for more details when using this parameter.

3.1.1.23 Low cloud cover
The low cloud cover is the percentage of sky covert with clouds in low altitude. It is valid for a grid point (approximately 11km*11km=121km$^2$) and low altitude refers to heights below 2500m. The parameter is given in %.
Low cloud cover is available for the analysis and the forecast time steps. The value is instantaneous meaning that it is valid for the last time step of the integration at the issued time step.

Please note that there is a problem with this parameter. Check section 2.3.1.2 Archiving issues for more details when using this parameter.

3.1.1.24 Medium cloud cover
The medium cloud cover is the percentage of sky covert with clouds in medium altitude. It is valid for a grid point (approximately 11km*11km=121km$^2$) and medium altitude refers to heights between 2500m through 5000m. The parameter is given in %.
Medium cloud cover is available for the analysis and the forecast time steps. The value is instantaneous meaning that it is valid for the last time step of the integration at the issued time step.

Please note that there is a problem with this parameter. Check section 2.3.1.2 Archiving issues for more details when using this parameter.

3.1.1.25 Total cloud cover
Total cloud cover is the percentage of sky covert with clouds. It is valid for a grid point (approximately 11km*11km=121km²) and clouds at any height above the surface are considered. The parameter is given in %.
Total cloud cover is available for the analysis and the forecast time steps. The value is instantaneous meaning that it is valid for the last time step of the integration at the issued time step.

Please note that there is a problem with this parameter. Check section 2.3.1.2 Archiving issues for more details when using this parameter.

3.1.1.26 Snow density
Snow density is the snow mass per unit of volume. Hence, the parameter is given in kg/m³. It is given as the mean for a grid point (approximately 11km*11km=121km²). Grid points without snow have missing values.
Snow density is available for the analysis and the forecast time steps up to forecast hour six. The value is instantaneous meaning that it is valid for the last time step of the integration at the issued time step.

3.1.1.27 Snow depth water equivalent
Snow depth water equivalent expresses the snow depth in kg of snow over one square meter [kg/m²]. The unit corresponds to 1 mm of water equivalent. It is given as the mean for a grid point (approximately 11km*11km=121km²).
Snow depth water equivalent is available for the analysis and the forecast time steps up to forecast hour six. The value is instantaneous meaning that it is valid for the last time step of the integration at the issued time step.

3.1.1.28 Snow fall water equivalent
Snow fall water equivalent expresses the snow fall in kg of snow over one square meter [kg/m²]. The unit corresponds to 1 mm of water equivalent. It is given as the mean for a grid point (approximately 11km*11km=121km²).
Snow fall water equivalent is only available for the forecast time steps. It is an accumulated parameter meaning that it is accumulated from the beginning of the forecast. For instance, the 24h-forecast has the accumulated snow fall water equivalent over 24 hours.

3.1.1.29 Land-Sea mask
The land-sea mask is a field that contains, for every grid point (approximately 11km*11km=121km²), the proportion of land in the grid box. The values are between 0 (sea) and 1 (land).
The land-sea mask is constant in time and the field is available for every analysis.
3.1.30 Orography
The orography is the height of the terrain with respect to the model defined globe. Each grid point (approximately 11km*11km=121km²) has one value representing the mean over the grid point domain. The orography is given as geopotential height in meter [gpm].
The orography is constant in time and the field is available for every analysis.

3.1.31 Surface roughness
The surface roughness describes the aerodynamic roughness length (over land). Each grid point (approximately 11km*11km=121km²) has one value representing the mean over the grid point. The surface roughness is given in meter [m].
The surface roughness is available for the analysis and the forecast time steps up to forecast hour six. The value is instantaneous meaning that it is valid for the last time step of the integration at the issued time step.
3.1.2 Parameters on height levels

<table>
<thead>
<tr>
<th>Metadata</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Horizontal coverage</strong></td>
<td>The model domain spans from northern Africa beyond the northern tip of Scandinavia. In the west it ranges far into the Atlantic ocean and in the east it reaches to the Ural. Herewith, it covers entire Europe. See Figure for an overview of the model domain.</td>
</tr>
<tr>
<td><strong>Horizontal resolution</strong></td>
<td>11x11 km$^2$.</td>
</tr>
<tr>
<td><strong>Vertical coverage</strong></td>
<td>11 height levels are available which are between 15-500m.</td>
</tr>
<tr>
<td><strong>Vertical levels</strong></td>
<td>15m, 30m, 50m, 75m, 100m, 150m, 200m, 250m, 300m, 400m, 500m</td>
</tr>
<tr>
<td><strong>Temporal coverage</strong></td>
<td>1961-01-01 00:00 – close to real time (monthly updates but with a delay to real time of about four months)</td>
</tr>
<tr>
<td><strong>Temporal resolution</strong></td>
<td>Analysis are available at 00, 06, 12, 18 UTC. The forecast length is depending on the cycle. Cycles initialized at 00 and 12 UTC have forecasts saved at 1, 2, 3, 4, 5, 6, 9, 12, 15, 18, 21, 24, 30. Cycles initialized at 06 and 18 UTC have forecasts saved at 1, 2, 3, 4, 5, 6. See 2.1.3 (Fig. 6) for more details.</td>
</tr>
<tr>
<td><strong>Data type and format</strong></td>
<td>Gridded data in GRIB2</td>
</tr>
<tr>
<td><strong>Grid</strong></td>
<td>Lambert conformal conic grid with 565x565 grid points</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>GRIB code</th>
<th>Analysis 0, 6, 12, 18</th>
<th>forecast 1,2,3,...</th>
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<td>yes</td>
</tr>
<tr>
<td>2. Wind direction</td>
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<td>3031</td>
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<td>yes</td>
</tr>
<tr>
<td>3. Pressure</td>
<td>Pa</td>
<td>54</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>4. Specific cloud liquid water content</td>
<td>kg/kg</td>
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<td>-</td>
<td>yes</td>
</tr>
<tr>
<td>5. Specific cloud ice water content</td>
<td>kg/kg</td>
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<td>-</td>
<td>yes</td>
</tr>
<tr>
<td>6. Relative humidity</td>
<td>%</td>
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<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>7. Temperature</td>
<td>K</td>
<td>130</td>
<td>yes</td>
<td>yes</td>
</tr>
</tbody>
</table>

3.1.2.1 Wind speed

Wind speed is the wind speed valid for a grid point (approximately 11km*11km=121km$^2$) determined for a certain height (15m-500m) above the surface. The parameter is given in m/s. It is computed from both the zonal (u) and the meridional (v) wind components by

$$wind\ speed = \sqrt{u^2 + v^2}$$

The wind speed is available for the analysis and the forecast time steps. The value is instantaneous meaning that it is valid for the last time step of the integration at the issued time step.

3.1.2.2 Wind direction

The wind direction is the wind direction valid for a grid point (approximately 11km*11km=121km$^2$) determined for a certain height (15m-500m) above the surface. The parameter is given in degrees ranging from 0-360. Here, 0° means a northerly wind and 90° indicates an easterly wind.
The wind direction is available for the analysis and the forecast time steps. The value is instantaneous meaning that it is valid for the last time step of the integration at the issued time step.

3.1.2.3 Pressure
The pressure is the air pressure at a certain height (15m-500m) above the surface valid for a grid point (approximately 11km*11km=121km²). The parameter is given in Pascal [Pa]. The pressure is available for the analysis and the forecast time steps. The value is instantaneous meaning that it is valid for the last time step of the integration at the issued time step.

3.1.2.4 Specific cloud liquid water content
Specific cloud liquid water content is the grid-box mean (approximately 11km*11km=121km²) liquid water content (mass of condensate / mass of moist air) on a height level. It is given in kg/kg. The parameter is only available for forecast time steps. The value is instantaneous meaning that it is valid for the last time step of the integration at the issued time step.

3.1.2.5 Specific cloud ice water content
Specific cloud ice water content is the grid-box mean (approximately 11km*11km=121km²) ice water content (mass of condensate / mass of moist air) on a height level. It is given in kg/kg. The parameter is only available for forecast time steps. The value is instantaneous meaning that it is valid for the last time step of the integration at the issued time step.

3.1.2.6 Relative humidity
The relative humidity is the modelled humidity valid for a grid point (approximately 11km*11km=121km²) determined at a certain height (15m-500m) above the surface. The parameter is given % ranging from 0-100. 0% means that the air is totally dry whereas 100% indicates that the air is saturated with water vapour. The saturation is defined with respect to saturation of the mixed phase, i.e. with respect to saturation over ice below -23°C and with respect to saturation over water above 0°C. In the regime in between a quadratic interpolation is applied. Surface air relative humidity is available for the analysis and the forecast time steps. The value is instantaneous meaning that it is valid for the last time step of the integration at the issued time step. Please check section 2.3 Model specific issues when using this parameter.

3.1.2.7 Temperature
The temperature is the air temperature valid for a grid point (approximately 11km*11km=121km²) determined at a certain height (15m-500m) above the surface. The parameter is given Kelvin [K]. The temperature is available for the analysis and the forecast time steps. The value is instantaneous meaning that it is valid for the last time step of the integration at the issued time step.
3.1.3 Parameters on pressure levels

<table>
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</tr>
<tr>
<td><strong>Horizontal resolution</strong></td>
<td>11x11 km².</td>
</tr>
<tr>
<td><strong>Vertical coverage</strong></td>
<td>24 pressure levels are stored at levels 1000-10hPa.</td>
</tr>
<tr>
<td><strong>Vertical levels [hPa]</strong></td>
<td>1000, 975, 950, 925, 900, 875, 850, 825, 800, 750, 700, 600, 500, 400, 300, 250, 200, 150, 100, 70, 50, 30, 20, 10</td>
</tr>
<tr>
<td><strong>Temporal coverage</strong></td>
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<tr>
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<tr>
<th>Parameter</th>
<th>Unit</th>
<th>GRIB code</th>
<th>Analysis 0, 6, 12, 18</th>
<th>forecast 1,2,3,…</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. <strong>Cloud cover</strong></td>
<td>%</td>
<td>260257</td>
<td>-</td>
<td>yes</td>
</tr>
<tr>
<td>2. <strong>Specific cloud liquid water content</strong></td>
<td>kg/kg</td>
<td>246</td>
<td>-</td>
<td>yes</td>
</tr>
<tr>
<td>3. <strong>Specific cloud ice water content</strong></td>
<td>kg/kg</td>
<td>247</td>
<td>-</td>
<td>yes</td>
</tr>
<tr>
<td>4. <strong>Relative humidity</strong></td>
<td>%</td>
<td>157</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>5. <strong>Temperature</strong></td>
<td>K</td>
<td>130</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>6. <strong>U-velocity</strong></td>
<td>m/s</td>
<td>131</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>7. <strong>V-velocity</strong></td>
<td>m/s</td>
<td>132</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>8. <strong>Geopotential</strong></td>
<td>m²/s²</td>
<td>129</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>9. <strong>Geopotential height</strong></td>
<td>gpm</td>
<td>156</td>
<td>yes</td>
<td>yes</td>
</tr>
</tbody>
</table>

3.1.3.1 Cloud cover
Cloud cover is the percentage of sky covert with clouds. It is valid for a grid point (approximately 11km*11km=121km²) at the corresponding height. The parameter is given in %. Total cloud cover is only available for the forecast time steps. The value is instantaneous meaning that it is valid for the last time step of the integration at the issued time step.
3.1.3.2 Specific cloud liquid water content
The specific cloud liquid water content is the grid-box mean (approximately 11km*11km=121km²) mass of condensate / mass of moist air on a pressure level. The parameter is given in kg/kg. Specific cloud liquid water content is only available for the forecast time steps. The value is instantaneous meaning that it is valid for the last time step of the integration at the issued time step.

3.1.3.3 Specific cloud ice water content
The specific cloud ice water content is the grid-box mean (approximately 11km*11km=121km²) mass of condensate / mass of moist air on a pressure level. The parameter is given in kg/kg. Specific cloud ice water content is only available for the forecast time steps. The value is instantaneous meaning that it is valid for the last time step of the integration at the issued time step.

3.1.3.4 Relative humidity
The relative humidity is the modelled humidity valid for a grid point (approximately 11km*11km=121km²) at the corresponding height. The parameter is given % ranging from 0-100. 0% means that the air is totally dry whereas 100% indicates that the air is saturated with water vapour. The saturation is defined with respect to saturation of the mixed phase, i.e. with respect to saturation over ice below -23°C and with respect to saturation over water above 0°C. In the regime in between a quadratic interpolation is applied. Relative humidity is available for the analysis and the forecast time steps. The value is instantaneous meaning that it is valid for the last time step of the integration at the issued time step. Please check section 2.3 Model specific issues when using this parameter.

3.1.3.5 Temperature
The temperature is the model temperature valid for a grid point (approximately 11km*11km=121km²) at the corresponding height. The parameter is given in Kelvin [K]. Temperature is available for the analysis and the forecast time steps. The value is instantaneous meaning that it is valid for the last time step of the integration at the issued time step.

3.1.3.6 U-velocity
The U-velocity is the zonal component of the wind valid for a grid point (approximately 11km*11km=121km²) at the corresponding height. The parameter is given in m/s. By model convention westerly wind (blowing from the west to the east) are positive. U-velocity is available for the analysis and the forecast time steps. The value is instantaneous meaning that it is valid for the last time step of the integration at the issued time step.

3.1.3.7 V-velocity
The V-velocity is the meridional component of the wind valid for a grid point (approximately 11km*11km=121km²) at the corresponding height. The parameter is given in m/s. By model convention southerly wind (blowing from the south to the north) are positive. V-velocity is available for the analysis and the forecast time steps. The value is instantaneous meaning that it is valid for the last time step of the integration at the issued time step.
3.1.3.8 Geopotential
The geopotential is the potential energy of unit mass at this pressure level relative to the sea level. It is valid for a grid point (approximately 11km*11km=121km²) and it is given in m²/s². The geopotential is available for the analysis and the forecast time steps. The value is instantaneous meaning that it is valid for the last time step of the integration at the issued time step.

3.1.3.9 Geopotential height
The geopotential height is the altitude of the given pressure level in the atmosphere relative to the sea level. It is valid for a grid point (approximately 11km*11km=121km²) and it is given in units proportional to the geopotential. Therefore, the unit is called geopotential meter [gpm]. The geopotential height is available for the analysis and the forecast time steps. The value is instantaneous meaning that it is valid for the last time step of the integration at the issued time step.

Note: The Geopotential and the geopotential height are related by a factor and are thus redundant. Geopotential = Geopotential height / gravitational acceleration (g = 9.81 m/s²) During the UERRA production until 2015 both geopotential and geopotential heights were archived due to an earlier confusion of the two in the design document. In the production since 2016 only the intended one, geopotential, is maintained. However, the geopotential can be computed with the above given formula at any time.

3.1.4 Parameters on model levels

<table>
<thead>
<tr>
<th>Metadata</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Horizontal coverage</strong></td>
<td>The model domain spans from northern Africa beyond the northern tip of Scandinavia. In the west it ranges far into the Atlantic ocean and in the east it reaches to the Ural. Herewith, it covers entire Europe. See Figure for an overview of the model domain.</td>
</tr>
<tr>
<td><strong>Horizontal resolution</strong></td>
<td>11x11 km².</td>
</tr>
<tr>
<td><strong>Vertical coverage</strong></td>
<td>65 model levels from the surface to the model top at 10hPa.</td>
</tr>
<tr>
<td><strong>Vertical levels</strong></td>
<td>1, 2, 3, 4,..., 63, 64, 65</td>
</tr>
<tr>
<td><strong>Temporal coverage</strong></td>
<td>1961-01-01 00:00 – close to real time (monthly updates but with a delay to real time of about four months)</td>
</tr>
<tr>
<td><strong>Temporal resolution</strong></td>
<td>Analysis are available at 00, 06, 12, 18 UTC. Forecasts are not saved for the parameters on model levels.</td>
</tr>
<tr>
<td><strong>Data type and format</strong></td>
<td>Gridded data in GRIB2</td>
</tr>
<tr>
<td><strong>Grid</strong></td>
<td>Lambert conformal conic grid with 565x565 grid points</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>GRIB code</th>
<th>Analysis 0, 6, 12, 18</th>
<th>forecast 1,2,3,...</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Specific humidity</td>
<td>kg/kg</td>
<td>133</td>
<td>yes</td>
<td>-</td>
</tr>
<tr>
<td>2. Temperature</td>
<td>K</td>
<td>130</td>
<td>yes</td>
<td>-</td>
</tr>
<tr>
<td>3. U-velocity</td>
<td>m/s</td>
<td>131</td>
<td>yes</td>
<td>-</td>
</tr>
<tr>
<td>4. V-velocity</td>
<td>m/s</td>
<td>132</td>
<td>yes</td>
<td>-</td>
</tr>
</tbody>
</table>
3.1.4.1 Specific humidity
The specific humidity is the mass of water vapor per unit mass of air valid for a grid point (approximately $11\text{km} \times 11\text{km} = 121\text{km}^2$) at the corresponding model level. The parameter is given in kg/kg.
Only analyses are stored for parameters on model levels. The value is instantaneous meaning that it is valid for the last time step of the integration at the issued time step.

3.1.4.2 Temperature
The temperature is the model temperature valid for a grid point (approximately $11\text{km} \times 11\text{km} = 121\text{km}^2$) at the corresponding model level. The parameter is given in Kelvin [K].
Only analyses are stored for parameters on model levels. The value is instantaneous meaning that it is valid for the last time step of the integration at the issued time step.

3.1.4.3 U-velocity
The U-velocity is the zonal component of the wind valid for a grid point (approximately $11\text{km} \times 11\text{km} = 121\text{km}^2$) at the corresponding model level. The parameter is given in m/s. By model convention westerly wind (blowing from the west to the east) are positive.
Only analyses are stored for parameters on model levels. The value is instantaneous meaning that it is valid for the last time step of the integration at the issued time step.

3.1.4.4 V-velocity
The V-velocity is the meridional component of the wind valid for a grid point (approximately $11\text{km} \times 11\text{km} = 121\text{km}^2$) at the corresponding model level. The parameter is given in m/s. By model convention southerly wind (blowing from the south to the north) are positive.
Only analyses are stored for parameters on model levels. The value is instantaneous meaning that it is valid for the last time step of the integration at the issued time step.

3.1.5 Soil parameters

<table>
<thead>
<tr>
<th>Metadata</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Horizontal coverage</td>
<td>The model domain spans from northern Africa beyond the northern tip of Scandinavia. In the west it ranges far into the Atlantic ocean and in the east it reaches to the Ural. Herewith, it covers entire Europe. See Figure for an overview of the model domain.</td>
</tr>
<tr>
<td>Horizontal resolution</td>
<td>$11\times11\text{ km}^2$.</td>
</tr>
<tr>
<td>Vertical coverage</td>
<td>3 levels of the soil model.</td>
</tr>
<tr>
<td>Vertical levels</td>
<td>1, 2, 3</td>
</tr>
<tr>
<td>Temporal coverage</td>
<td>1961-01-01 00:00 – close to real time (monthly updates but with a delay to real time of about four months)</td>
</tr>
<tr>
<td>Temporal resolution</td>
<td>Analysis are available at 00, 06, 12, 18 UTC. Forecasts are saved hourly up to six hours.</td>
</tr>
</tbody>
</table>
### Data type and format

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>GRIB code</th>
<th>Analysis</th>
<th>forecast</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volumetric soil moisture</td>
<td>m$^3$/m$^3$</td>
<td>260199</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>Soil temperature</td>
<td>K</td>
<td>260360</td>
<td>yes</td>
<td>yes</td>
</tr>
</tbody>
</table>

### 3.1.5.1 Volumetric soil moisture
The volumetric soil moisture is the amount of water in a cubic meter soil valid for a grid point (approximately 11km*11km=121km$^2$) in the corresponding soil level. The parameter is given in m$^3$/m$^3$.

The parameter is available for analysis and forecast time steps. The value is instantaneous meaning that it is valid for the last time step of the integration at the issued time step.

### 3.1.5.2 Soil temperature
The soil temperature is the model temperature valid for a grid point (approximately 11km*11km=121km$^2$) at the corresponding soil level. The parameter is given in Kelvin [K].

The parameter is available for analysis and forecast time steps. The value is instantaneous meaning that it is valid for the last time step of the integration at the issued time step.

### 3.1.6 The UERRA-HARMONIE grid description

- Number of points along x-axis: 565
- Number of points along y-axis: 565
- X-direction grid length: 11000 m
- Y-direction grid length: 11000 m

- Projection: Lambert Conformal Conic
- Central meridian: 8
- Standard parallel 1: 48
- Standard parallel 2: 48
- Latitude of origin: 48

- Earth assumed spherical with radius: 6371229 m

- Latitude of first grid point in degrees: 17.612
- Longitude of first grid point in degrees: 341.68
3.2 The MESCAN-SURFEX system

3.2.1 Surface parameters

<table>
<thead>
<tr>
<th>Metadata</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Horizontal coverage</strong></td>
<td>The model domain spans from northern Africa beyond the northern tip of Scandinavia. In the west it ranges far into the Atlantic ocean and in the east it reaches to the Ural. Herewith, it covers entire Europe. See Figure for an overview of the model domain.</td>
</tr>
<tr>
<td><strong>Horizontal resolution</strong></td>
<td>5.5x5.5 km².</td>
</tr>
<tr>
<td><strong>Vertical coverage</strong></td>
<td>Each surface parameter is valid for one vertical level and three different (near) surface levels exists: - surface: atmospheric boundary with the ground or water surface - 2m: 2m above the surface - 10m: 10m above the surface</td>
</tr>
<tr>
<td><strong>Vertical levels</strong></td>
<td>One level only</td>
</tr>
<tr>
<td><strong>Temporal coverage</strong></td>
<td>1961-01-01 00:00 – close to real time (monthly updates but with a delay to real time of about four months)</td>
</tr>
<tr>
<td><strong>Temporal resolution</strong></td>
<td>Analysis are available at 00, 06, 12, 18 UTC. Forecasts are computed up to 6 hours and the output frequency is hourly though some of the parameters are saved only for the six hour forecasts.</td>
</tr>
<tr>
<td><strong>Data type and format</strong></td>
<td>Gridded data in GRIB2</td>
</tr>
<tr>
<td><strong>Grid</strong></td>
<td>Lambert conformal conic grid with 1069x1069 grid points</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>GRIB code</th>
<th>Analysis 0, 6, 12, 18</th>
<th>Forecast 1, 2, 3, 4, 5, 6</th>
<th>Height</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Surface air relative humidity</td>
<td>%</td>
<td>260242</td>
<td>yes</td>
<td>only at 6h</td>
<td>2m</td>
</tr>
<tr>
<td>2. Total precipitation</td>
<td>kg/m²</td>
<td>228228</td>
<td>only available at 6 UTC (24h accumulated)</td>
<td>only at 6h</td>
<td>surface</td>
</tr>
<tr>
<td>3. 10 metre wind speed</td>
<td>m/s</td>
<td>207</td>
<td>yes</td>
<td>only at 6h</td>
<td>10m</td>
</tr>
<tr>
<td>4. 10 metre wind direction</td>
<td>deg (0-360)</td>
<td>260260</td>
<td>yes</td>
<td>only at 6h</td>
<td>10m</td>
</tr>
<tr>
<td>5. Surface air temperature</td>
<td>K</td>
<td>167</td>
<td>yes</td>
<td>only at 6h</td>
<td>2m</td>
</tr>
<tr>
<td>6. Skin temperature</td>
<td>K</td>
<td>235</td>
<td>-</td>
<td>yes</td>
<td>surface</td>
</tr>
<tr>
<td>7. Albedo</td>
<td>0-1</td>
<td>260509</td>
<td>-</td>
<td>yes</td>
<td>surface</td>
</tr>
<tr>
<td>8. Time-integrated surface latent heat flux</td>
<td>J/m²</td>
<td>147</td>
<td>-</td>
<td>yes</td>
<td>surface</td>
</tr>
<tr>
<td>9. Time-integrated surface sensible heat flux</td>
<td>J/m²</td>
<td>146</td>
<td>-</td>
<td>yes</td>
<td>surface</td>
</tr>
<tr>
<td>10. Time-integrated surface direct solar radiation</td>
<td>J/m²</td>
<td>260264</td>
<td>-</td>
<td>only at 6h</td>
<td>surface</td>
</tr>
</tbody>
</table>
3.2.1.1 Surface air relative humidity
The surface air relative humidity is the modelled humidity valid for a grid point (approximately 5.5km*5.5km) determined for a height of 2m above the surface. The parameter is given % ranging from 0-100. 0% means that the air is totally dry whereas 100% indicates that the air is saturated with water vapour. The saturation is defined with respect to saturation of the mixed phase, i.e. with respect to saturation over ice below -23°C and with respect to saturation over water above 0°C. In the regime in between a quadratic interpolation is applied. Surface air relative humidity is available for the analysis and the forecast time steps. The value is instantaneous meaning that it is valid for the last time step of the integration at the issued time step.

3.2.1.2 Total precipitation
Total precipitation is the amount of precipitation falling onto the ground/water surface. It includes all kind of precipitation forms as convective precipitation, large scale precipitation, liquid and solid precipitation. The amount is valid for a grid box and has the unit kg/m². The total precipitation is available for the analysis at 06UTC with accumulated values over 24 hours. For the forecast time steps, total precipitation is available only for the six hour forecast. It is an accumulated parameter meaning that it is accumulated from the beginning of the forecast – hence, accumulated over 6 hours.
3.2.1.3 10 metre wind speed
The 10 metre wind speed is the wind speed valid for a grid point (approximately 5.5km*5.5km) determined for a height of 10m above the surface. The parameter is given in m/s. It is computed from both the zonal (u) and the meridional (v) wind components by
\[
\text{wind speed} = \sqrt{u^2 + v^2}
\]
The 10 metre wind speed is available for the analysis and the forecast time steps. The value is instantaneous meaning that it is valid for the last time step of the integration at the issued time step.

3.2.1.4 10 metre wind direction
The 10 metre wind direction is the wind direction valid for a grid point (approximately 5.5km*5.5km) determined for a height of 10m above the surface. The parameter is given in degrees ranging from 0° to 360°. Here, 0° means a northerly wind and 90° indicates an easterly wind. The 10 metre wind direction is available for the analysis and the forecast time steps. The value is instantaneous meaning that it is valid for the last time step of the integration at the issued time step.

3.2.1.5 Surface air temperature
The surface air temperature is the model temperature valid for a grid point (approximately 5.5km*5.5km) determined for a height of 2m above the surface. The parameter is given in Kelvin [K]. Surface air temperature is available for the analysis and the forecast time steps. The value is instantaneous meaning that it is valid for the last time step of the integration at the issued time step.

3.2.1.6 Skin temperature
The skin temperature is the model temperature valid for a grid point (approximately 5.5km*5.5km) determined for the boundary surface to the atmosphere, both ground and water surfaces. The parameter is given in Kelvin [K]. Skin temperature is available for the analysis and the forecast time steps. The value is instantaneous meaning that it is valid for the last time step of the integration at the issued time step.

3.2.1.7 Albedo
The albedo is the amount of radiation which is reflected at the valid for a grid point (approximately 5.5km*5.5km). It is determined for the surface to the atmosphere, both for ground and water surfaces. The parameter is given in %. Small values mean that large amounts of the radiation are absorbed whereas large values mean that more radiation is reflected. Albedo is available for the analysis and the forecast time steps up to forecast hour six. The value is instantaneous meaning that it is valid for the last time step of the integration at the issued time step. Albedo is defined only over land and has missing values over sea and lakes.

3.2.1.8 Time-integrated surface latent heat flux
The surface latent heat flux is the exchange of latent heat (due to phase transitions: evaporation, condensation) with the surface (ground and water) through turbulent diffusion. It is given as a mean
for a grid point (approximately 5.5km*5.5km). The parameter is given in J/m². By model convention downward fluxes are positive.
Surface latent heat flux is only available for forecast time steps up to forecast hour six. It is an accumulated (time-integrated) parameter meaning that it is accumulated from the beginning of the forecast. For instance, the 6h-forecast has the accumulated heat flux over 6 hours.

3.2.1.9 Time-integrated surface sensible heat flux
The surface sensible heat flux is the exchange of heat (no phase transition) with the surface (ground and water) through turbulent diffusion. It is given as a mean for a grid point (approximately 5.5km*5.5km). The parameter is given in J/m². By model convention downward fluxes are positive.
Surface sensible heat flux is only available for forecast time steps up to forecast hour six. It is an accumulated (time-integrated) parameter meaning that it is accumulated from the beginning of the forecast. For instance, the 6h-forecast has the accumulated heat flux over 6 hours.

3.2.1.10 Time-integrated surface direct solar radiation
The surface direct solar radiation is the amount of direct solar (short-wave) radiation reaching the surface (ground and water). It is given as a mean for a grid point (approximately 5.5km*5.5km). The parameter is given in J/m². By model convention downward fluxes are positive.
Surface direct solar radiation is only available for forecast time steps. It is an accumulated (time-integrated) parameter meaning that it is accumulated from the beginning of the forecast. For instance, the 6h-forecast has the accumulated radiation over 6 hours.

3.2.1.11 Time-integrated surface net solar radiation
The surface net solar radiation is the amount of solar (short-wave) radiation that is absorbed at the surface (ground and water). It is computed

\[ \text{Surface net solar radiation} = \text{surface solar radiation downwards} \times (1 - \text{albedo}) \]

It is given as a mean for a grid point (approximately 5.5km*5.5km). The parameter is given in J/m². By model convention downward fluxes are positive.
Surface net solar radiation is only available for forecast time steps. It is an accumulated (time-integrated) parameter meaning that it is accumulated from the beginning of the forecast. For instance, the 6h-forecast has the accumulated radiation over 6 hours.

3.2.1.12 Time-integrated surface solar radiation downwards
The surface solar radiation downwards is the amount of solar (short-wave) radiation reaching the surface (ground and water). It is given as a mean for a grid point (approximately 5.5km*5.5km). The parameter is given in J/m². By model convention downward fluxes are positive.
Surface solar radiation downwards is only available for forecast time steps. It is an accumulated (time-integrated) parameter meaning that it is accumulated from the beginning of the forecast. For instance, the 6h-forecast has the accumulated radiation over 6 hours.

3.2.1.13 Time-integrated surface net thermal radiation
The surface net thermal radiation is the amount of thermal (long-wave) radiation that is absorbed at the surface (ground and water). It is computed

\[ \text{Surface net thermal radiation} = \text{surface thermal radiation downwards} \times (1 - \text{albedo}) \]

It is given as a mean for a grid point (approximately 5.5km*5.5km). The parameter is given in J/m². By model convention downward fluxes are positive.
Surface net thermal radiation is only available for forecast time steps. It is an accumulated (time-integrated) parameter meaning that it is accumulated from the beginning of the forecast. For instance, the 6h-forecast has the accumulated radiation over 6 hours.

3.2.1.14 Time-integrated surface thermal radiation downwards
The surface thermal radiation downward is the amount of thermal (long-wave) radiation reaching the surface (ground and water). It is given as a mean for a grid point (approximately 5.5km*5.5km). The parameter is given in J/m². By model convention downward fluxes are positive. Surface thermal radiation downwards is only available for forecast time steps. It is an accumulated (time-integrated) parameter meaning that it is accumulated from the beginning of the forecast. For instance, the 6h-forecast has the accumulated radiation over 6 hours.

3.2.1.15 Surface pressure
The surface pressure is the air pressure at the surface (ground and water) valid for a grid point (approximately 5.5km*5.5km). The parameter is given in Pascal [Pa]. Mean sea level pressure is available for the analysis and the forecast time steps. The value is instantaneous meaning that it is valid for the last time step of the integration at the issued time step.

3.2.1.16 Surface runoff
Surface runoff is the lateral water flow occurring at the surface of a grid point (approximately 5.5km*5.5km). The parameter is given in kg/m². Surface runoff is only available for forecast time steps. It is an accumulated (time-integrated) parameter meaning that it is accumulated from the beginning of the forecast. For instance, the 6h-forecast has the accumulated surface runoff over 6 hours.

3.2.1.17 Soil heat flux
The soil heat flux is the energy received by the soil to heat it per unit of surface and time. It is valid for a grid point and has the unit W/m². The Soil heat flux is positive when the soil receives energy (warms) and negative when the soil loses energy (cools). Soil heat flux is only available for forecast time steps. It is an accumulated (time-integrated) parameter meaning that it is accumulated from the beginning of the forecast. For instance, the 6h-forecast has the accumulated surface runoff over 6 hours.

3.2.1.18 Surface roughness
The surface roughness describes the aerodynamic roughness length (over land). Each grid point (approximately 5.5km*5.5km) has one value representing the mean over the grid point. The surface roughness is given in meter [m]. The surface roughness is available for the analysis and the forecast time steps up to forecast hour six. The value is instantaneous meaning that it is valid for the last time step of the integration at the issued time step. The surface roughness is depending on the seasonal variations of the vegetation as well as snow cover.

3.2.1.19 Snow depth
Snow depth is the average snow height for a grid point (approximately 5.5km*5.5km). Snow depth is given in meter [m].
Snow depth is available for the forecast time steps up to forecast hour six. The value is instantaneous meaning that it is valid for the last time step of the integration at the issued time step.

3.2.1.20 Snow density
Snow density is the snow mass per unit of volume. Hence, the parameter is given in kg/m$^3$. It is given as the mean for a grid point (approximately 5.5km*5.5km). Grid points without snow have missing values.
Snow density is available for the forecast time steps up to forecast hour six. The value is instantaneous meaning that it is valid for the last time step of the integration at the issued time step.

3.2.1.21 Snow depth water equivalent
Snow depth water equivalent expresses the snow depth in kg of snow over one square meter [kg/m$^2$]. The unit corresponds to 1 mm of water equivalent. It is given as the mean for a grid point (approximately 5.5km*5.5km).
Snow depth water equivalent is available for the analysis and the forecast time steps up to forecast hour six. The value is instantaneous meaning that it is valid for the last time step of the integration at the issued time step.

3.2.1.22 Snow fall water equivalent
Snow fall water equivalent expresses the snow fall in kg of snow over one square meter [kg/m$^2$]. The unit corresponds to 1 mm of water equivalent. It is given as the mean for a grid point (approximately 5.5km*5.5km).
Snow fall water equivalent is only available for the forecast time steps. It is an accumulated parameter meaning that it is accumulated from the beginning of the forecast. For instance, the 6h-forecast has the accumulated snow fall water equivalent over 6 hours.

3.2.1.23 Percolation
Percolation is the soil total column lateral water flow and bottom soil drainage. It is given as the mean for a grid point (approximately 5.5km*5.5km) and has the unit kg/m$^2$.
Percolation is only available for the forecast time steps. It is an accumulated parameter meaning that it is accumulated from the beginning of the forecast. For instance, the 6h-forecast has the accumulated water flow over 6 hours.

3.2.1.24 Land-Sea mask
The land-sea mask is a field that contains, for every grid point (approximately 5.5km*5.5km), the proportion of land in the grid box. The values are between 0 (sea) and 1 (land).
The land-sea mask is constant in time and the field is available for every analysis.

3.2.1.25 Orography
The orography is the height of the terrain with respect to the model defined globe. Each grid point (approximately 5.5km*5.5km) has one value representing the mean over the grid point domain. The orography is given as geopotential height in meter [gpm].
The orography is constant in time and the field is available for every analysis.
3.2.2 Soil parameters

<table>
<thead>
<tr>
<th>Metadata</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Horizontal coverage</strong></td>
</tr>
<tr>
<td><strong>Horizontal resolution</strong></td>
</tr>
<tr>
<td><strong>Vertical coverage</strong></td>
</tr>
<tr>
<td><strong>Vertical levels as depth of the considered layer in meter [m]</strong></td>
</tr>
<tr>
<td><strong>Temporal coverage</strong></td>
</tr>
<tr>
<td><strong>Temporal resolution</strong></td>
</tr>
<tr>
<td><strong>Data type and format</strong></td>
</tr>
<tr>
<td><strong>Grid</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>GRIB code</th>
<th>Analysis 0, 6, 12, 18</th>
<th>forecast 1,2,3,...</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Liquid non-frozen volumetric soil water</td>
<td>m³/m³</td>
<td>260210</td>
<td>-</td>
<td>yes</td>
</tr>
<tr>
<td>2. Volumetric soil moisture</td>
<td>m³/m³</td>
<td>260199</td>
<td>-</td>
<td>yes</td>
</tr>
<tr>
<td>3. Soil temperature</td>
<td>K</td>
<td>260360</td>
<td>-</td>
<td>yes</td>
</tr>
<tr>
<td>4. Volumetric wilting point</td>
<td>m³/m³</td>
<td>260200</td>
<td>yes</td>
<td>-</td>
</tr>
<tr>
<td>5. Volumetric transpiration stress-onset</td>
<td>m³/m³</td>
<td>260211</td>
<td>yes</td>
<td>-</td>
</tr>
</tbody>
</table>

3.2.2.1 Liquid non-frozen volumetric soil water
The liquid non-frozen volumetric soil water is the amount of liquid water in a cubic meter soil valid for a grid point (approximately 5.5km*5.5km) in the corresponding soil level. The parameter is given in m³/m³. The parameter is only available for forecast time steps. The value is instantaneous meaning that it is valid for the last time step of the integration at the issued time step.

3.2.2.2 Volumetric soil moisture
The volumetric soil moisture is the amount of water in a cubic meter soil valid for a grid point (approximately 5.5km*5.5km) in the corresponding soil level. The parameter is given in m³/m³. The parameter is only available for forecast time steps. The value is instantaneous meaning that it is valid for the last time step of the integration at the issued time step.

To interpret soil water and to compare different models the Soil Wetness Index (SWI) is used:

\[
\text{SWI} = \frac{\text{soil_water} - \text{wilting_point}}{\text{field_capacity} - \text{wilting_point}}.
\]
3.2.2.3 Soil temperature
The soil temperature is the model temperature valid for a grid point (approximately 5.5km*5.5km) at the corresponding soil level. The parameter is given in Kelvin [K].
The parameter is only available for forecast time steps. The value is instantaneous meaning that it is valid for the last time step of the integration at the issued time step.

3.2.2.4 Volumetric wilting point
The volumetric wilting point corresponds to the soil water content at which plants wilt and can no longer recover. It is given for a grid point (approximately 5.5km*5.5km) in the corresponding soil level. The parameter is given in m³/m³.
The parameter is only available for the analyses.

3.2.2.5 Volumetric transpiration stress-onset (soil moisture)
The volumetric transpiration stress-onset (or volumetric field capacity) corresponds to the soil water content after the soil has been saturated and allowed to drain freely. It is given for a grid point (approximately 5.5km*5.5km) in the corresponding soil level. The parameter is given in m³/m³.
The parameter is only available for the analyses.

3.2.3 Grid

Number of points along x-axis: 1069
Number of points along y-axis: 1069
X-direction grid length: 5500 m
Y-direction grid length: 5500 m

Projection: Lambert Conformal Conic
Central meridian: 8
Standard parallel 1: 50
Standard parallel 2: 50
Latitude of origin: 50

Earth assumed spherical with radius: 6371229 m

Latitude of first grid point in degrees: 20.292
Longitude of first grid point in degrees: 342.514
4. Data access

The UERRA reanalysis datasets (in total more than 700 Tb) are freely available from the Copernicus Climate Data Store (CDS) at https://cds.climate.copernicus.eu/. After registration there are several options to download and visualize the data. An introduction to the CDS and the CDS Toolbox is available as a lesson in the Copernicus User Learning Services at https://uls.climate.copernicus.eu/group/learning/browse-lessons?packageId=1148.

The options for data access are:

1) Download the data via a form in your web browser.
2) Use CDS Toolbox to write and execute an extraction script.
3) Install the python package cdsapi and get the data directly onto your computer.

Each of these options is further described below. Please note that at the time of writing only the UERRA-HARMONIE analysis data are accessible via the CDS web form and Toolbox (option 1 and 2 above). To access all the data, including for example MESCAN-SURFEX analysis and UERRA-HARMONIE forecasts, you need to use the CDS API (option 3). Also note that the data are currently only available in GRIB format.

Option 1 is very straightforward; just choose one of the UERRA datasets available in the CDS from: https://cds.climate.copernicus.eu/ cdsapp#!/search?type=dataset&text=uerra then click the "Download data" tab in the browser, fill in and submit the form. Below the form are also buttons for showing the corresponding Toolbox request (see option 2 below) and API request (see option 3 below). The result of these requests will be one GRIB or NetCDF file.

Option 2 is mainly aimed at further processing of the data in the CDS Toolbox. This involves writing some code in the CDS Toolbox editor. You can take this code from the Toolbox request generated in option 1 above. As mentioned this method is mainly for using data in the CDS Toolbox, but you could also use it to download data. There is an example retrieval script at (logging in required) https://cds.climate.copernicus.eu/toolbox-editor/examples/01-retrieve-data.

Option 3 is the preferred method for downloading larger amounts of data. This option also provides access to all data, including forecast data and the MESCAN-SURFEX analysis data. To use this method you need to install the python package cdsapi on your computer. This is described at https://cds.climate.copernicus.eu/api-how-to.

After installing the CDS API you can execute python scripts to retrieve UERRA data. In section 4.1 and 4.2 are examples for retrieving the UERRA-HARMONIE 2m temperature 6 hour forecast and the MESCAN-SURFEX 24 hour precipitation analysis. Note that the example in 4.1 is retrieving data that is listed in CDS and therefore uses a slightly different syntax than the unlisted data retrieved in 4.2. The request in 4.1 is based on code generated by the CDS web form (see option 1 above). The request syntax in 4.2 is based on the ECMWF MARS retrieval system. These requests can for example be generated via web forms available at https://apps.ecmwf.int/datasets/data/uerra/
The scripts in section 4.1 and 4.2 are also available for download via the open GitHub at https://git.smhi.se/C3S_322_Lot1/C3S_322_Lot1_user_examples.

### 4.1 CDS API example, CDS-listed UERRA-HARMONIE analysis

```python
#!/usr/bin/env python

import cdsapi
import calendar

c = cdsapi.Client()

def retrieve_uerra_eswi():
    """
    A function to demonstrate how to iterate over several years and months etc
    for a particular UERRA request for origin SMHI.
    Change the variables below to adapt the iteration to your needs.
    You can use the variable 'targetFile' to organise the requested data in files as you wish.
    In the example below the data are organised in files per month.
    """
    yearStart = 2015
    yearEnd   = 2015
    monthStart = 1
    monthEnd   = 12
    for year in list(range(yearStart, yearEnd + 1)):
        for month in list(range(monthStart, monthEnd + 1)):
            numberOfDays = calendar.monthrange(year, month)[1]
            targetFile = "ofile_%04d%02d.grb" % (year, month)
            requestDates = ["{:02}".format(i) for i in range(1, numberOfDays+1)]
            requestMonth = '{:02}'.format(month)
            requestYear = '{:04}'.format(year)
            uerra_eswi_request(requestYear, requestMonth, requestDates, targetFile)

    def uerra_eswi_request(reqYear, reqMonth, reqDates, target):
        """
        A UERRA request for 2 metre temperature every 6th hour.
        Origin SMHI, surface level, analysis fields.
        Request cost per day is 4 fields, 1.8 Mbytes.
        """
        c.retrieve('reanalysis-uerra-single-levels',
                    {'model': 'harmonie',
                     'variable': 'ts2m',
                     'year': reqYear,
                     'month': reqMonth,
                     'day': reqDates[0],
                     'format': 'grib'})
```

4.2 CDS API example, CDS-unlisted MESCAN analysis

#!/usr/bin/env python

import cdsapi
import calendar
c = cdsapi.Client()

def retrieve_uerra_lfpw():
    '''
    A function to demonstrate how to iterate efficiently over several years and months etc
    for a particular UERRA request for origin Meteo France.
    Change the variables below to adapt the iteration to your needs.
    You can use the variable 'target' to organise the requested data in files as you wish.
    In the example below the data are organised in files per month.
    '''
    yearStart = 2015
    yearEnd = 2015
    monthStart = 1
    monthEnd = 12
    for year in list(range(yearStart, yearEnd + 1)):
        for month in list(range(monthStart, monthEnd + 1)):
            startDate = '%04d%02d%02d' % (year, month, 1)
            numberOfDays = calendar.monthrange(year, month)[1]
            lastDate = '%04d%02d%02d' % (year, month, numberOfDays)
            target = "ofile_%04d%02d.grb" % (year, month)
            requestDates = (startDate + "/TO/" + lastDate)
            uerra_lfpw_request(requestDates, target)
A UERRA request for total precipitation every 24 hours at 06 UTC.
Origin Meteo France, surface level, analysis fields.
Request cost per day is 1 field, 2.2 Mbytes.

```python
c.retrieve('reanalysis-uerra-complete',
  {
    'class':'ur',
    'stream':'oper',
    'type':'an',
    'dataset':'uerra',
    'origin':'lfpw',
    'date': requestDates,
    'expver':'prod',
    'levtype':'sfc',
    'param':'228228',
    'time':06
  },
  target)

if __name__ == '__main__':
    retrieve_uerra_lfpw()
```
5. References/Further reading

5.1 References

- Ridal, M.; S. Schimanke; S. Hopsch (2018): Documentation of the RRA system: UERRA, deliverable D322_Lot1.1.1.2 in the scope of the Copernicus service C3S_322_Lot1, available via Copernicus

5.2 Further reading

Within the UERRA project, many reports were written describing the system and the data. It is recommend to have a look at these documents if you are looking for something specific. The collection of UERRA deliverables can be found here: http://www.uerra.eu/publications/deliverable-reports.html

For users, the reports listed below might be of specific interest:
- Deliverable 2.14: Reanalysis uncertainty evaluation
- Deliverable 3.8: User friendly synthesis report on evaluation and uncertainty of regional reanalyses
- Deliverable 4.5: Indices based on reanalysis data, including uncertainty information
- Deliverable 7.2: Training material on the use of reanalysis in climate services

You will find an overview of current atmospheric reanalyses activities at https://reanalyses.org/index.php/atmosphere