



Climate Change

# Copernicus Regional Reanalysis for Europe

MÉRA workshop, 02/05/2019

Semjon Schimanke et al.





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## What's the service about?

- Operational production of a regional reanalysis (RRA) for Europe in near real-time





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## What's the service about?

- Operational production of a regional reanalysis (RRA) for Europe in near real-time
- Long series of freely available RRA
  - Starting 1961 with a horizontal resolution of 11km/5.5km
  - From the early 1980 with a horizontal resolution of 5.5km (under development)



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## What's the service about?

- Operational production of a regional reanalysis (RRA) for Europe in near real-time
- Long series of freely available RRA
  - Starting 1961 with a horizontal resolution of 11km/5.5km
  - From the early 1980 with a horizontal resolution of 5.5km (under development)
- User support and guidance



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# Overview

1. Introduction to the service
2. The RRA system and available data
3. Data quality
4. Homogeneity
5. Summary



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# 1. Introduction/Background





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# C o p e r n i c u s / C 3 S

- Copernicus is the European Union's earth observation program (<http://www.copernicus.eu/>)



**Atmosphere**  
(CAMS)



**Marine**  
(CMEMS)



**Land**  
(CLMS)



**Climate**  
(C3S)



**Emergency**  
(EMS)



**Security**

- Our service is part of Copernicus Climate Change Services (C3S) (<http://climate.copernicus.eu/>)



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## Service facts

- The service lifetime is 4 years.
- Onset was on 1/9/2017.
- The service is operated together with two subcontractors



Norwegian  
Meteorological  
Institute







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# Time line of service and system details

2017

2018

2019

2020

2021

UERRA system in near real time  
(11km/5.5km resolution)

- 11 km (565x565 grid points), 65 levels
- Surface downscaling analysis 5.5 km (MESCAN-SURFEX)
- Start in 1961 and operational since 2/2018



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# Time line of service and system details

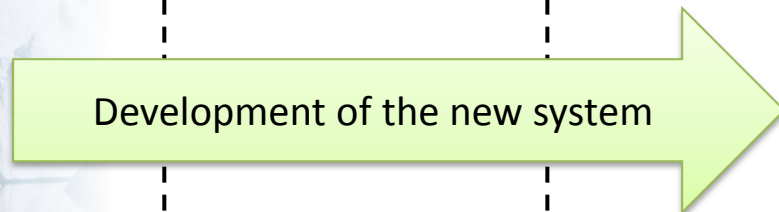
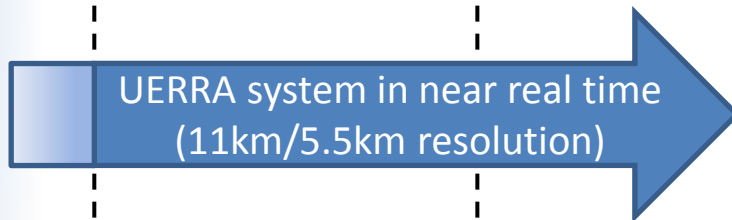
2017

2018

2019

2020

2021



- 11 km (565x565 grid points), 65 levels
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# Time line of service and system details

2017

2018

2019

2020

2021

UERRA system in near real time  
(11km/5.5km resolution)

Development of the new system

New system in operational mode  
(5.5km resolution)

EDA system (10 members at 11km  
resolution)

- 11 km (565x565 grid points), 65 levels
- Surface downscaling analysis 5.5 km (MESCAN-SURFEX)
- Start in 1961 and operational since 2/2018

- 5.5 km (1069x1069 grid points), 106 levels
- Surface analysis at 5.5 km
- Plus 10 ensemble members at 11km
- Will start in the early 1980s



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## Objectives of the service

- Operational production of the RRA for Europe in near real-time
- Develop an enhanced system which should provide data from the early 80's  
In addition, an ensemble at lower resolution
- A comprehensive set of output parameters, ECVs, upper air, surface and soil
- Collaboration and coordination with other reanalysis activities (e.g. Arctic regional reanalysis and ERA5)
- User guidance and support





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## 2. The RRA systems and available data



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FOR THE EUROPEAN COMMISSION



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# The pre-operational FP7 project

- UERRA: Uncertainties in Ensembles of Regional ReAnalysis
- 12 European partners
- Three different RRA plus ensembles
- SMHI's UERRA data is produced for 1961-2015 and it is available through this Copernicus service.



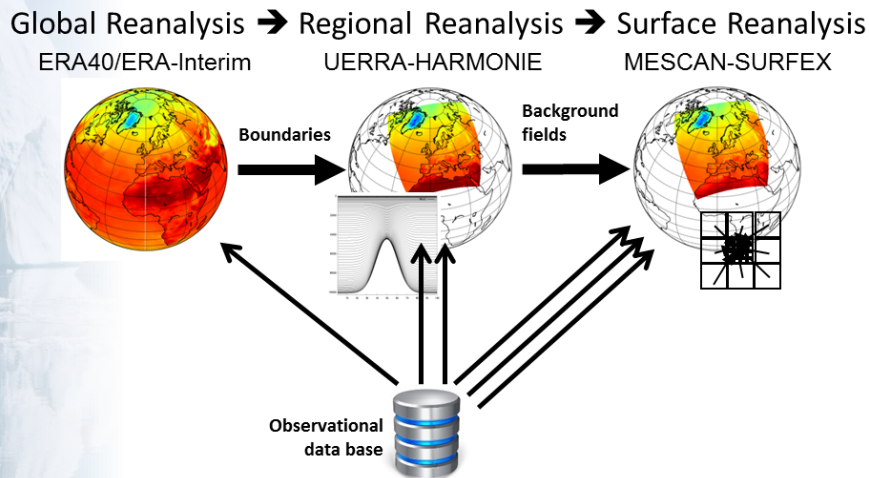
[www.uerra.eu](http://www.uerra.eu)





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# The system



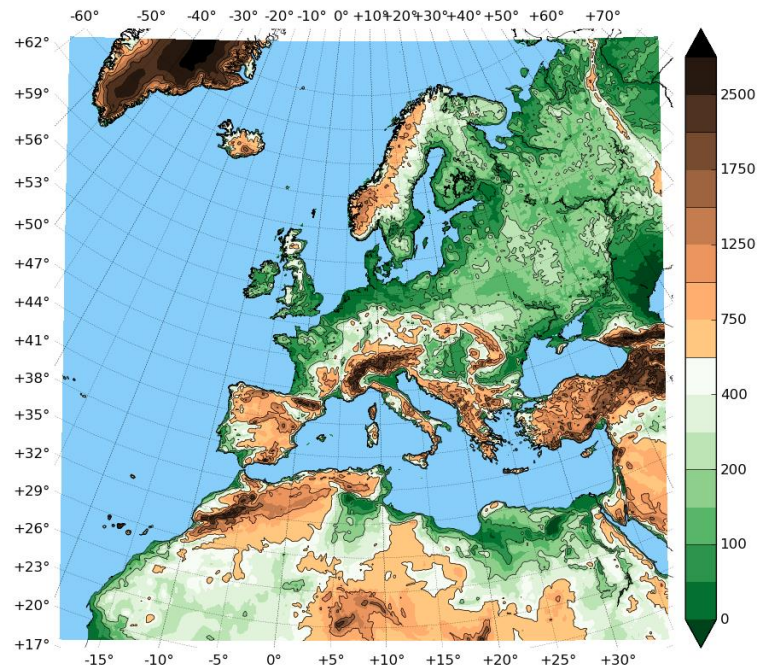
- UERRA system
  - HARMONIE cycle 38h1, ALADIN physics
  - ERA40/ERA-interim as lateral boundary
  - Assimilation of conventional observations
  - 4 cycles per day, forecast lengths 6h and 30h
  - 11km resolution (565x565) and 65 vertical levels
- MESCAN-SURFEX
  - Optimal interpolation (OI)
  - 5.5km resolution



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## Available data

- Modell domain covers entire Europe
- Period 1961-December 2018 with monthly updates
- 31 surface parameters,  
9 parameters on pressure levels,  
7 parameters on height levels,  
4 parameters on model levels  
2 parameters on soil levels
- Additional output from MESCAN-SURFEX (surface and soil)



Model domain illustrated with model topography and land-sea mask



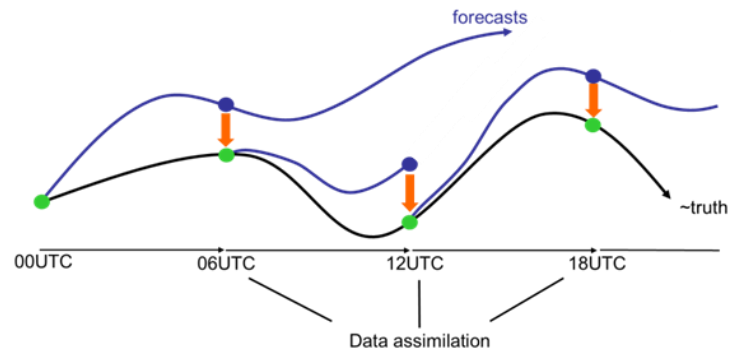


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## Available time steps

		1978-12-02							1978-12-03																											
Forecast starting at		17	18	19	20	21	22	23	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	0	1	2	3
1978-12-02	0 UTC																																			
1978-12-02	6 UTC																																			
1978-12-02	12 UTC																																			
1978-12-02	18 UTC																																			
1978-12-03	0 UTC																																			
1978-12-03	6 UTC																																			
1978-12-03	12 UTC																																			
1978-12-03	18 UTC																																			
1978-12-04	0 UTC																																			
Number of available time steps									4	1	1	2	1	1	4	1	1	3	1	1	4	1	1	2	1	1	4	1	1	3	1	1				

- 4 analysis per day
- Hourly resolution from the forecast model
- Maximum forecast lengths is 30 hours





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# Data access via CDS

<https://cds.climate.copernicus.eu/cdsapp#!/dataset/reanalysis-uerra-europe-single-levels?tab=overview>

The screenshot shows the Copernicus CDS website interface. At the top, there are logos for the European Union, Copernicus, ECMWF, and the Climate Change Service. A navigation bar includes links for Home, Search, Datasets, Applications, Toolbox, and Help & support. The main heading is "UERRA regional reanalysis for Europe on single levels from 1961 to present". Below this, there are tabs for Overview, Download data, and Documentation. The Overview tab is active, displaying a map of Europe with a color scale for "Diff 2m temperature change: Difference 1991-2017 minus 1961-1990". The map shows temperature anomalies across Europe, with a color scale ranging from -0.5 to 1.5. To the right of the map, there is a "Contact" section with the email "copernicus-support@ecmwf.int", a "License" section with the text "Licence to Use Copernicus Products", a "Publication Date" of "2019-02-21", and a "Related data" section listing "UERRA regional reanalysis for Europe on pressure levels from 1961 to present" and "UERRA regional reanalysis for Europe on height levels from 1961 to present".

UERRA regional reanalysis for Europe on single levels from 1961 to present

Overview Download data Documentation

This UERRA dataset contains analyses of surface and near-surface essential climate variables from UERRA-HARMONIE and MISCAN-SURFEX systems. Forecasts up to 30 hours initialised from the analyses at 00 and 12 UTC are available only through the CDS-API (see Documentation).

UERRA-HARMONIE is a 3-dimensional variational data assimilation system, while MISCAN-SURFEX is a complementary surface analysis system. Using the Optimal Interpolation method, MISCAN provides the best estimate of daily accumulated precipitation and six-hourly air temperature and relative humidity at 2 meters above the model topography.

The land surface platform SURFEX is forced with downscaled forecast fields from UERRA-HARMONIE as well as MISCAN analyses. It is run offline, i.e. without feedback to the atmospheric analysis performed in MISCAN or the UERRA-HARMONIE data assimilation cycles. Using SURFEX offline allows to take full benefit of precipitation analysis and to use the more advanced physics options to better represent surface variables such as surface temperature and surface fluxes, and soil processes related to water and heat transfer in the soil and snow.

In general, the assimilation systems are able to estimate biases between observations and to sift good-quality data from poor data. The laws of physics allow for estimates at locations where data coverage is low. The provision of estimates at each grid point in Europe for each regular output time, over a long period, always using the same format, makes reanalysis a very convenient and popular dataset to work with. The observing system has changed drastically over time, and although the assimilation system can resolve data holes, the much sparser observational networks, e.g. in 1960s, will have an impact on the quality of analyses leading to less accurate estimates. The improvement over global reanalysis products comes with the higher horizontal resolution that allows incorporating more regional details (e.g. topography). Moreover, it enables the system even to use more observations at places with dense observation networks.

Contact  
copernicus-support@ecmwf.int

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Publication Date  
2019-02-21

Related data  
UERRA regional reanalysis for Europe on pressure levels from 1961 to present  
UERRA regional reanalysis for Europe on height levels from 1961 to present

- All data is freely available!  
(1961 – 2018)
- Monthly updates ca. four months behind real time
- All you need is to register!
- Almost 500 TB of data





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### 3. Data quality

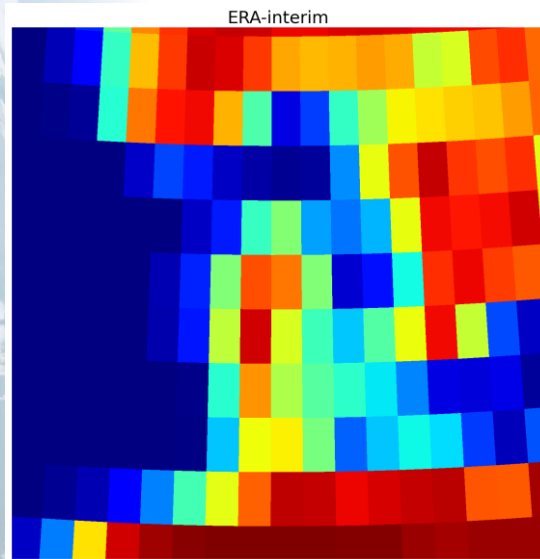




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Added value compared to global RA

## Land-sea masks



~80km



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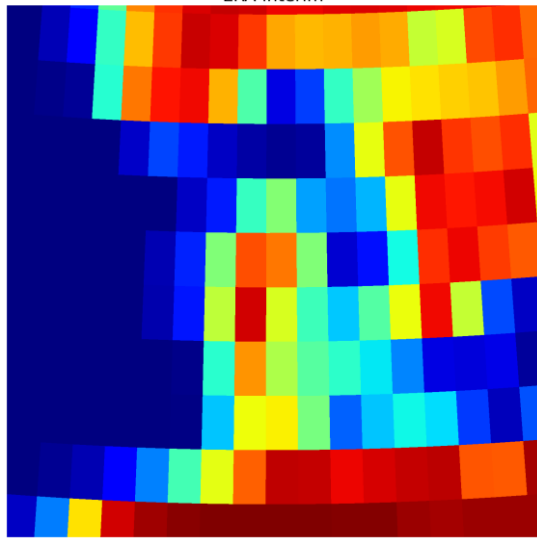


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Added value compared to global RA

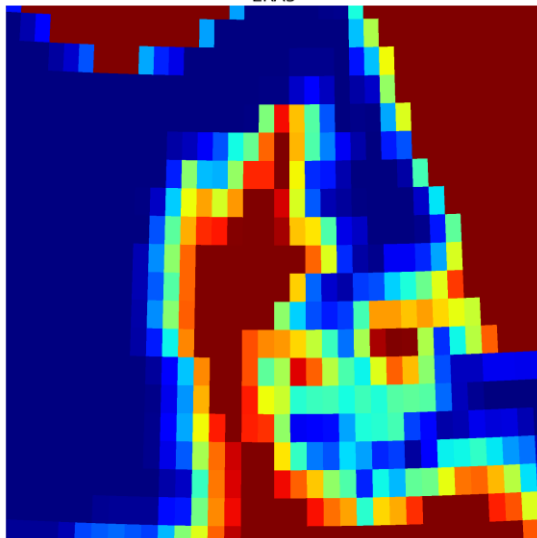
## Land-sea masks

ERA-interim



~80km

ERA5



~31km

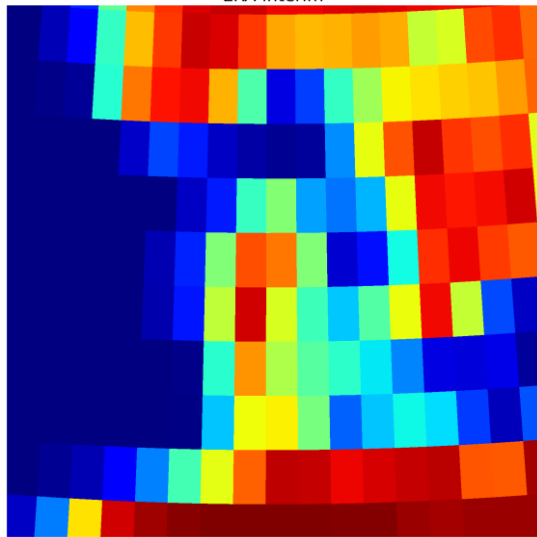


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Added value compared to global RA

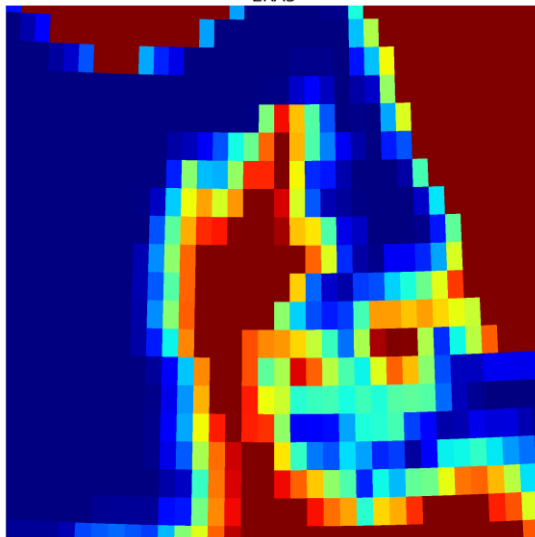
## Land-sea masks

ERA-interim



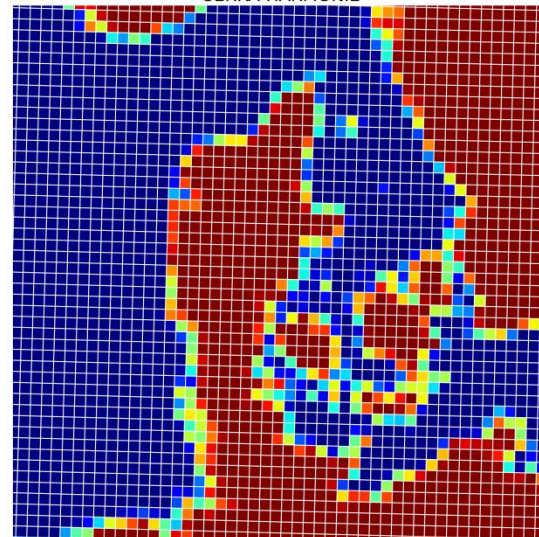
~80km

ERA5



~31km

UERRA-HARMONIE

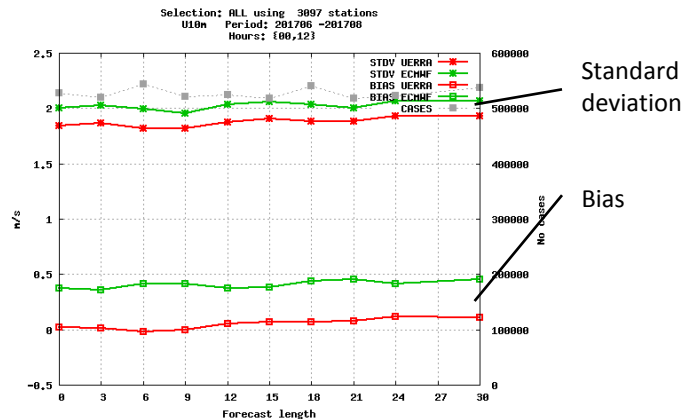


11km



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# Verification



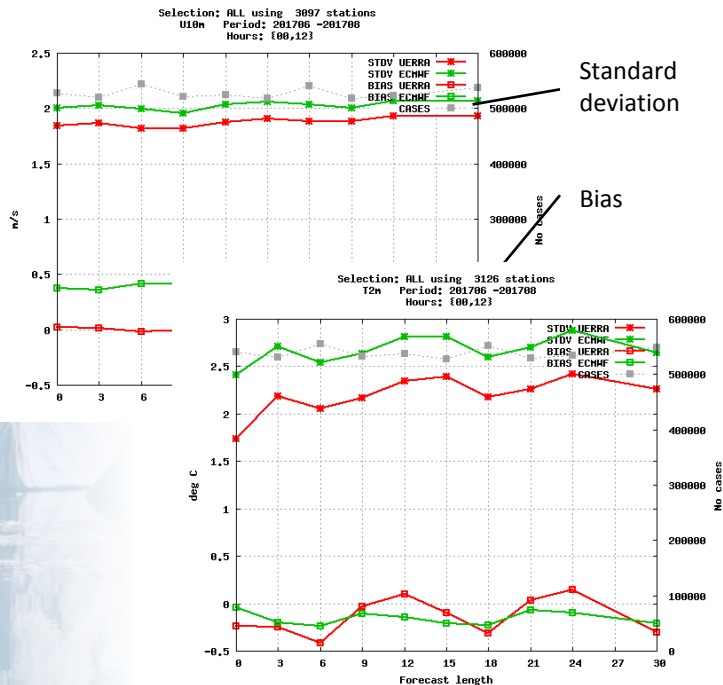
- Verification tools are part of the quality control during the production
- Smaller bias and std than ERA-interim, e.g. T2m, wind speed, precipitation

— UERRA  
— ERA-interim



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# Verification



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— UERRA  
— ERA-interim

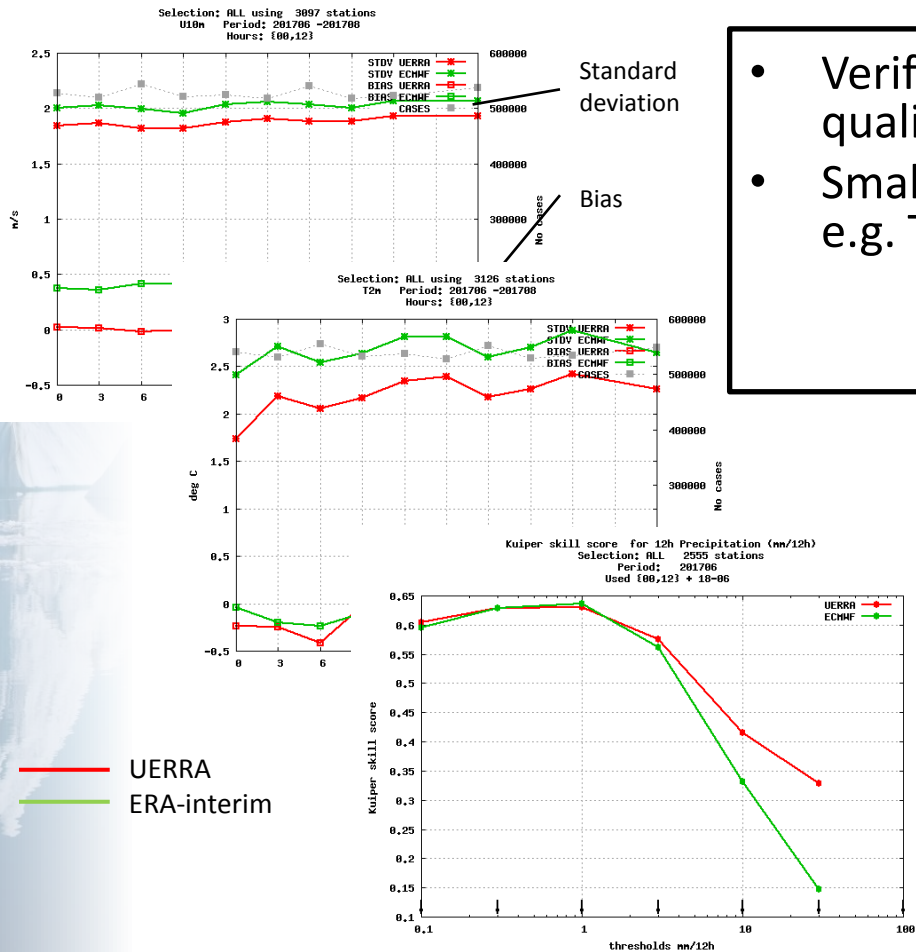




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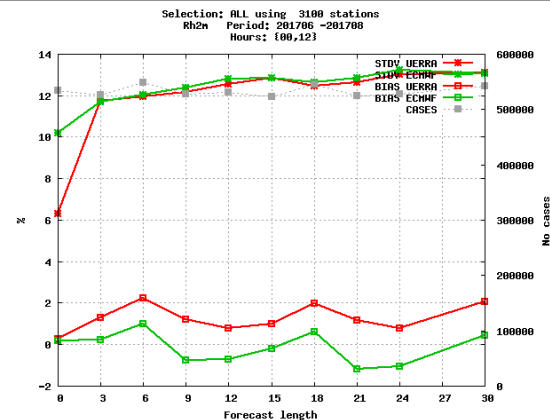
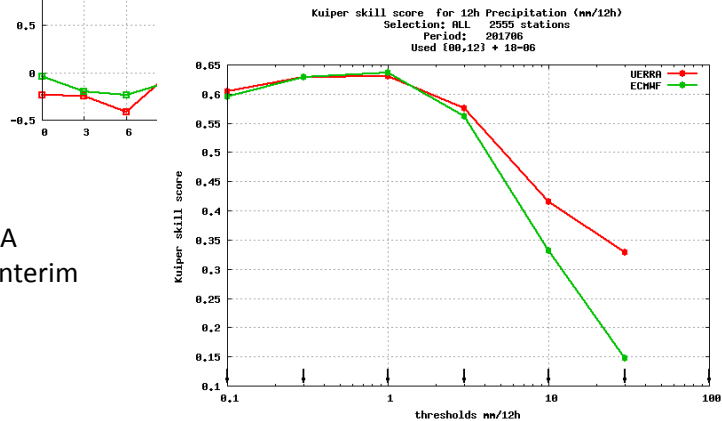
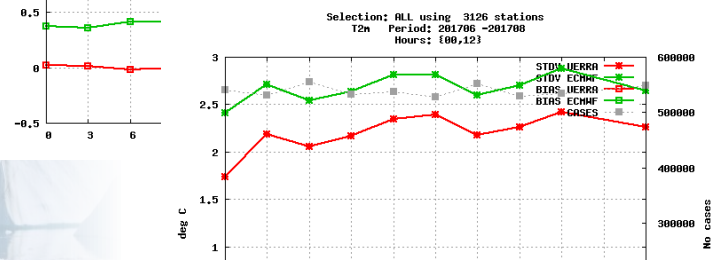
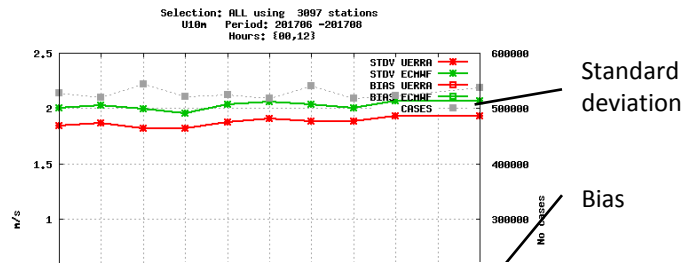




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# Verification

- Verification tools are part of the quality control during the production
- Smaller bias and std than ERA-interim, e.g. T2m, wind speed, precipitation
- Some parameters not better than ERA-interim, e.g. RH2m



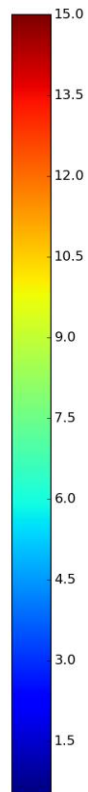
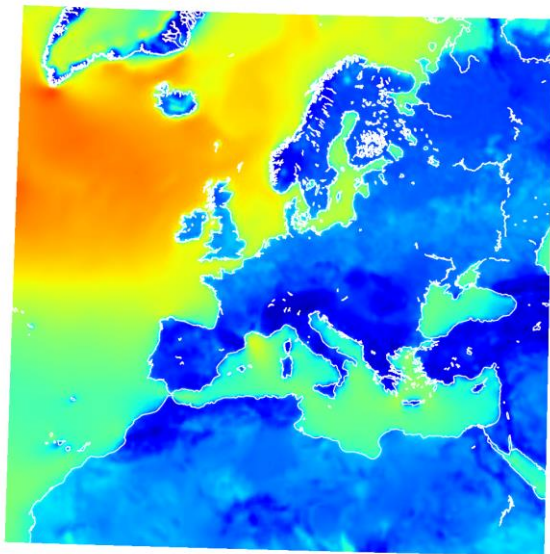


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# DJF wind speed in ERA5 and UERRA

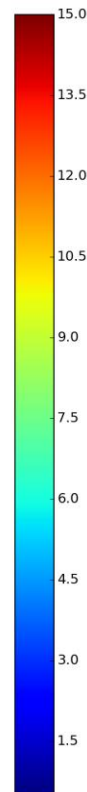
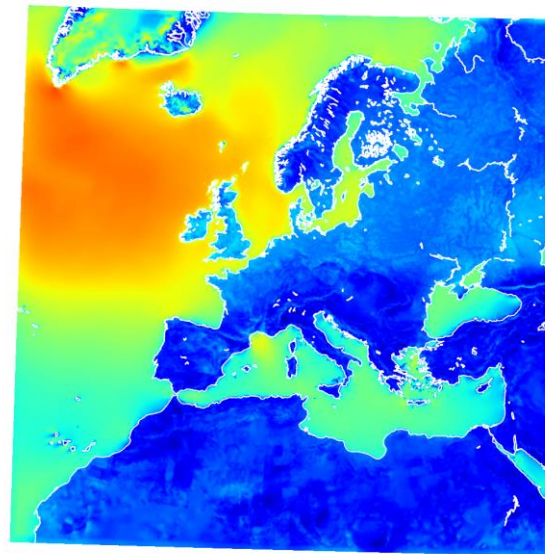
## ERA5

ERA5 DJF windspeed, 2000-2015



## UERRA-HARMONIE

UERRA DJF windspeed, 2000-2015

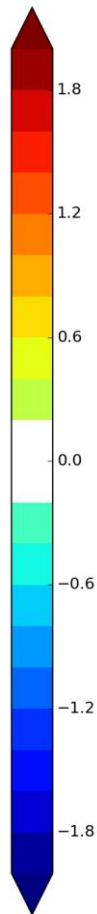
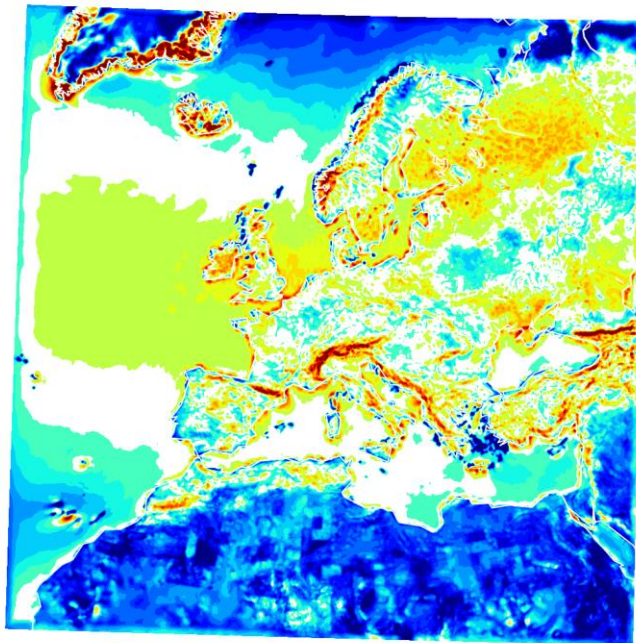




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## DJF windspeed in ERA5 and UERRA

UERRA-ERA5 DJF windspeed, 2000-2015



- Differences mainly smaller than 1m/s
- Differences related to topography/coastline
- General weaker winds over northern Africa and the Norwegian/Barents Sea



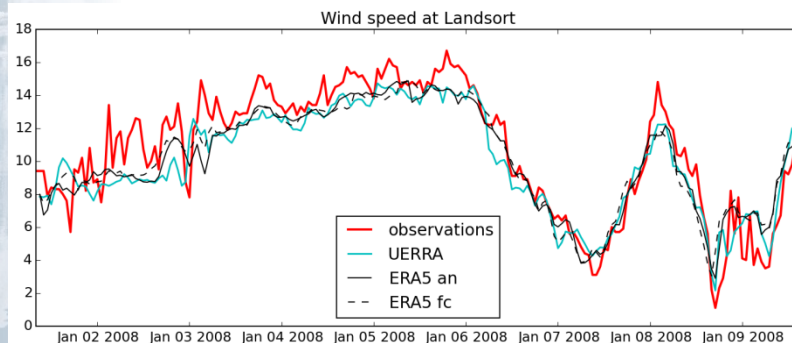
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# Quality of wind speed

## Comparison of wind speed at 24 Swedish coastal stations

	UERRA	ERA5	ERA-int
Mean bias	-0.02	0.01	Not checked
Correlation	0.85	0.85	0.79
RMSE	1.83	1.97	2.36

Based on the period 2000-2015. Hourly data for UERRA and ERA5, 6hourly for ERA-interim



Series of a random sample for visual check.



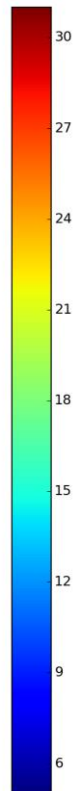
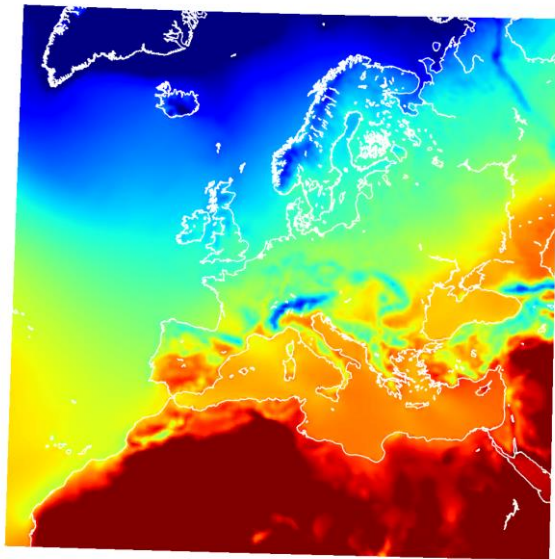


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# JJA 2m-temperature in ERA5 and UERRA

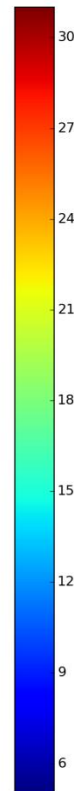
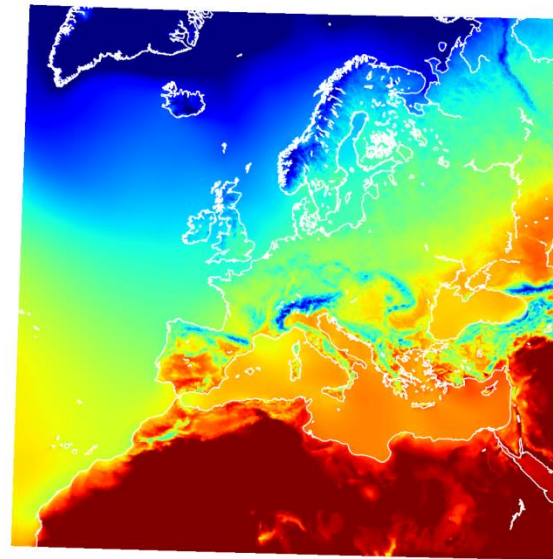
## ERA5

ERA5 JJA T2m, 2000-2015



## UERRA-HARMONIE

UERRA JJA T2m, 2000-2015

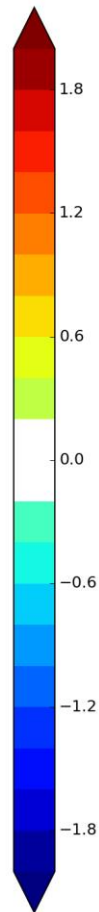
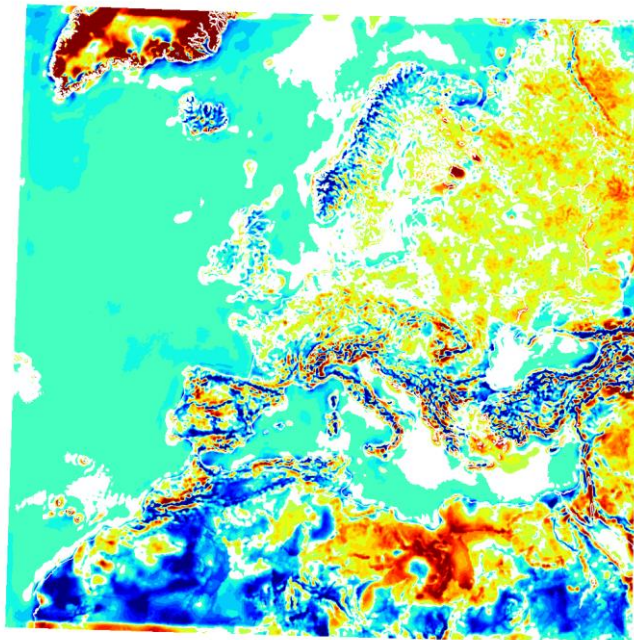




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# JJA 2 m - temperature in ERA5 and UERRA

UERRA-ERA5 JJA T2m, 2000-2015



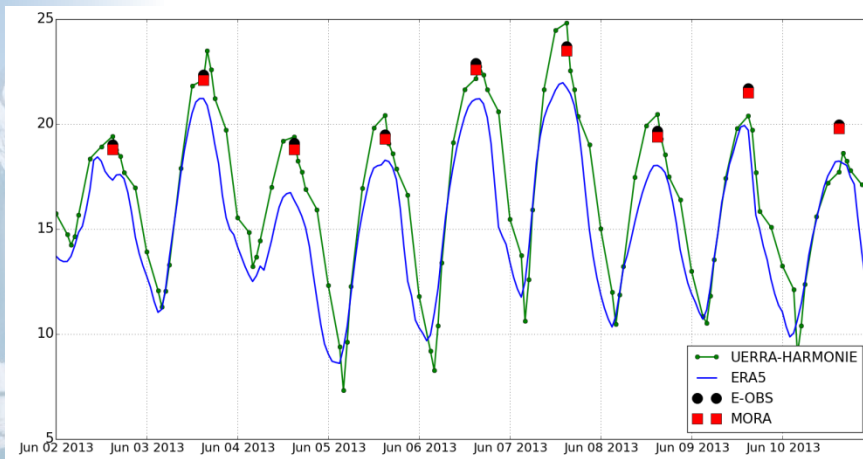
- Small differences over the ocean and flat areas
- Strong effect of topography
- Uncertainty in northern Africa is large



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# T 2 m : Daily cycle and maximum

## Växjö (Sweden)



- Random sample, nine days in June 2013
- Växjö region is quite flat and homogenous
- UERRA-HARMONIE has general higher daily maximum temperatures than ERA5

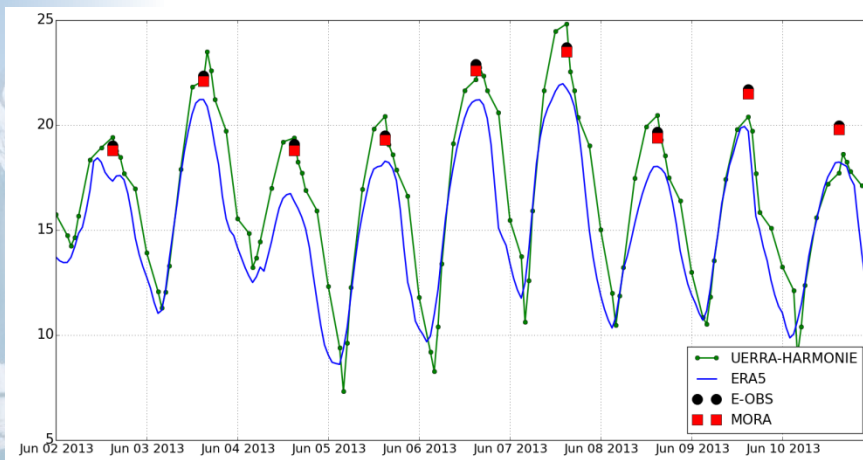




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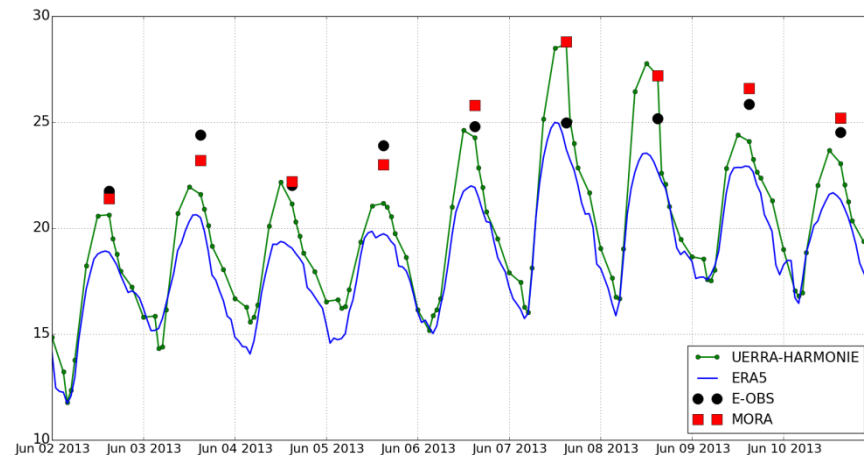
## T 2 m : Daily cycle and maximum

### Växjö (Sweden)



- Random sample, nine days in June 2013
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- UERRA-HARMONIE has general higher daily maximum temperatures than ERA5

### Grazzanise (Italy)



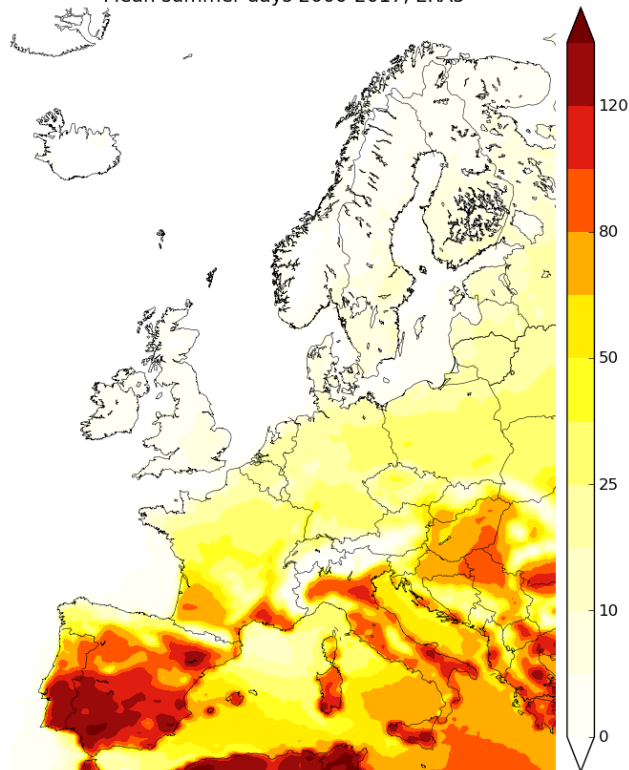
- Grazzanise has a more complex terrain
- UERRA-HARMONIE has general higher daily maximum temperatures than ERA5
- Clear difference between gridded (E-OBS) data and direct measurements



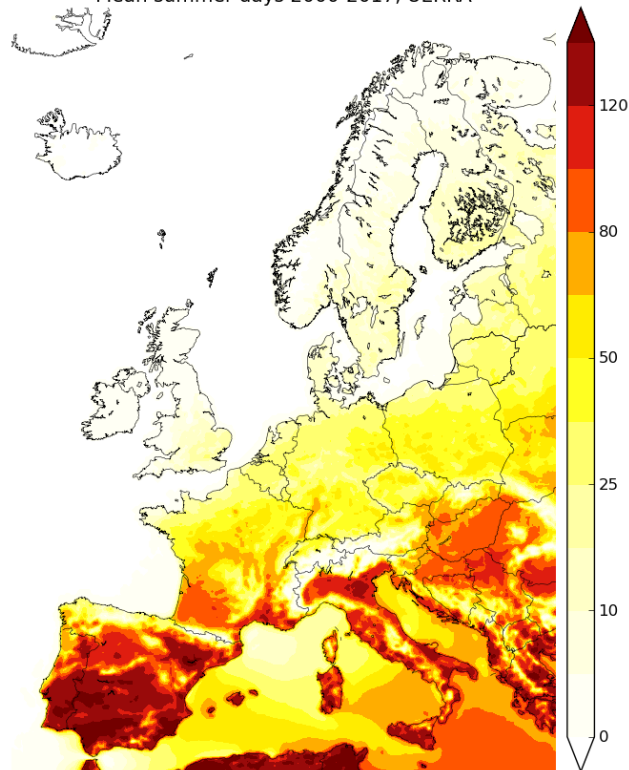
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Summer days =  $T_{max} > 25^{\circ}C$

Mean summer days 2000-2017, ERA5



Mean summer days 2000-2017, UERRA

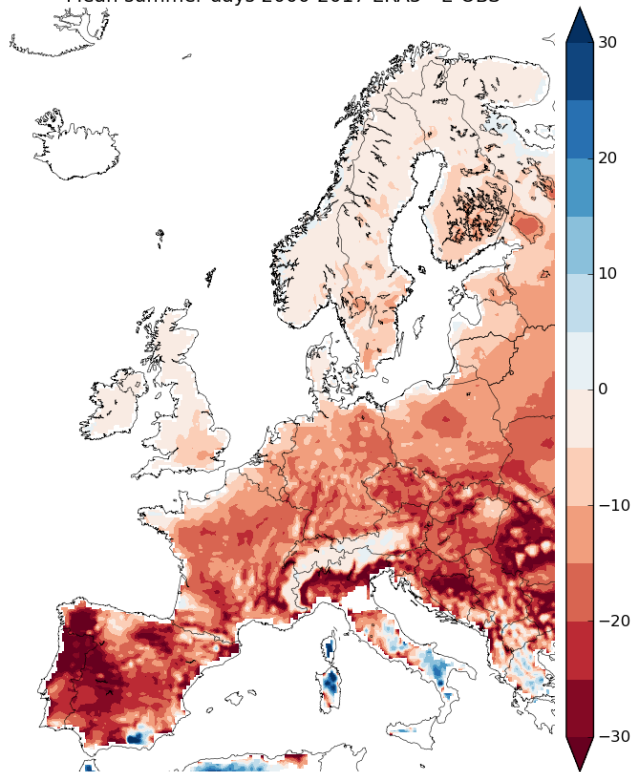




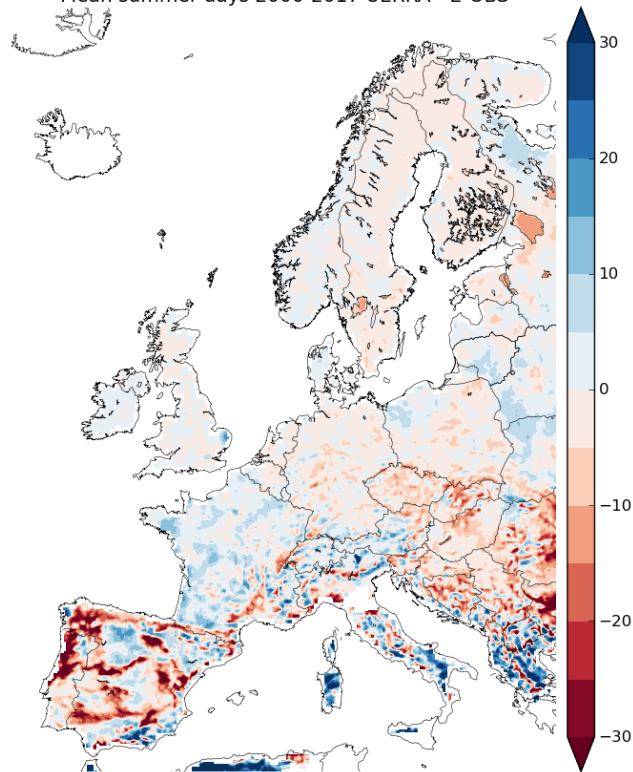
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Summer days =  $T_{max} > 25^{\circ}C$

Mean summer days 2000-2017 ERA5 - E-OBS



Mean summer days 2000-2017 UERRA - E-OBS





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## 4. Homogeneity





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# H o m o g e n e i t y

## Risks for inhomogeneity

- Switch of lateral boundary data
  - 1961-1978 ERA40
  - 1979-        ERA-interim

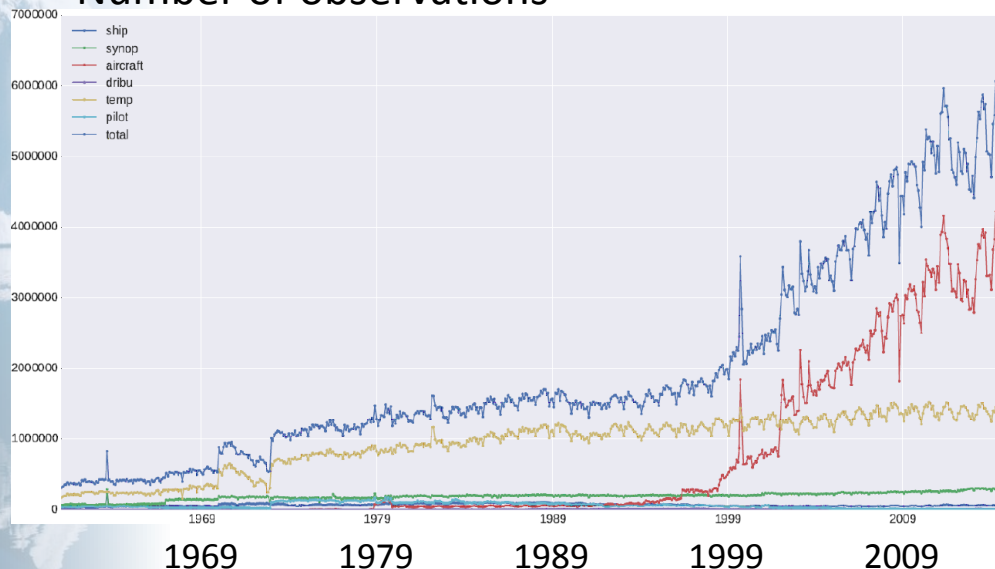




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# Homogeneity

## Number of observations



## Risks for inhomogeneity

- Switch of lateral boundary data
  - 1961-1978 ERA40
  - 1979- ERA-interim
- Increasing numbers of observations in time, especially aircraft data



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# Homogeneity

Investigations of the forecast skill (differences between fc30 and fc6):

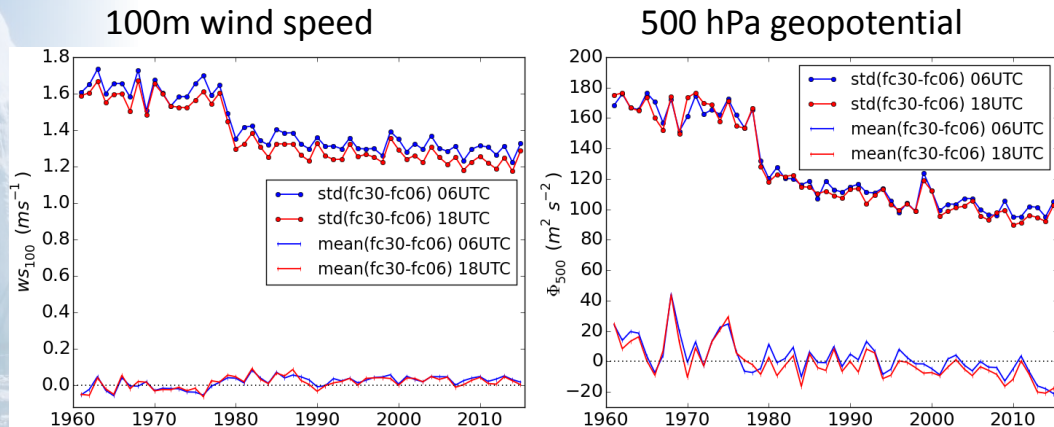
- Forecast skill effects accuracy of the first guess and has herewith consequences on the data quality





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# Homogeneity



Yearly averages of the standard deviation and mean of the forecast difference fc30-fc06 during winter (DJF).

Left: 100m wind speed. Right: 500 hPa geopotential. Curtesy Adam von Kraemer.

Investigations of the forecast skill (differences between fc30 and fc6):

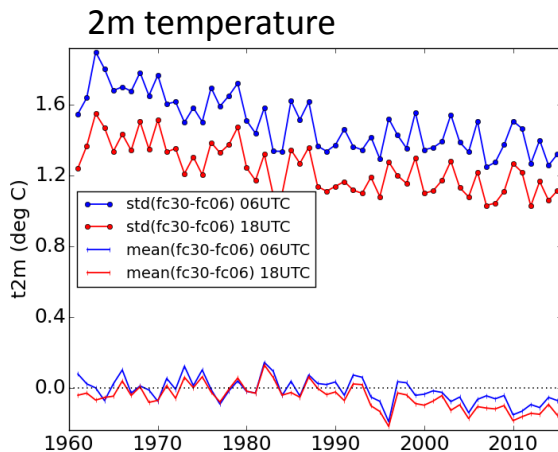
- Forecast skill effects accuracy of the first guess and has herewith consequences on the data quality
- Increase of quality with the switch to ERA-interim and increasing numbers of observations (upper air)





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# Homogeneity



Yearly averages of the standard deviation and mean of the forecast difference fc30-fc06 during winter (DJF).

Curtesy Adam von Kraemer.

Investigations of the forecast skill (differences between fc30 and fc6):

- Less change of quality for surface parameters
- Surface parameters are less affected due to a more constant number of surface observations throughout time



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# User support

**Reanalysis - Overview**

Atmospheric reanalysis is a method to reconstruct the past weather by combining historical observations 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 main advantage of reanalyses is that they provide a multivariate, spatially complete, and coherent record of the atmospheric state – far more complete than any observational dataset.

Another advantage is that reanalyses are produced with a single version of a data assimilation system – including the forecast model used – and is therefore not affected by changes in method.

More information about reanalysis is available in the ["Reanalysis" lesson](#).

**UERRA data user**

Issued by: SMHI / S. Schimanski  
Date: 31/05/2018  
Ref: C3S\_322\_Lot1.4.1.2\_UERRA  
Official reference number service

**Reanalysis for Europe**

This part of the Copernicus Climate Change Service aims to produce and deliver a regional reanalysis (RRA) for Europe. The service will be implemented in several steps. First, a system developed in the JRC pre-operational public project will be used to update the existing RRA in near real time. In combination with the RRA produced already in the pre-operational project, the service will offer a consistent RRA from 1980 to near real time.

However, an improved model version will be developed within the service. The model will be used to create a semi-forecast reanalysis with very high resolution (2.5 km) forced by the global ERA5 reanalysis (ERA5). It will use a full set of both observations and satellite information that adds quality which being reanalysis contained in time, high resolution surface observations will be added for the sake of surface energy flux. A set of the project is a comprehensive set of physical parameters to be derived for air, surface, height levels in the boundary layer for energy applications, conventional pressure levels and more. Finally, a set of diagnostic tools will be provided for the climate data store at every hour of the model integration. Uncertainty estimates of the output parameters and RRA will be provided in a variety of forms from an Ensemble Data Assimilation, which will have a somewhat lower horizontal resolution than the control deterministic RRA.

**Global Reanalysis → Regional Reanalysis → Surface Reanalysis**

ERA5 boundary → Background fields → Observational data

**Figure 1:** Three different stages of reanalysis: Left) the Global Reanalysis ERA5 will be used as boundary condition, middle) a 3D Regional Reanalysis, and right) a 2D Reanalysis for the near surface. The amount of observational data used for the RRA per area unit increases from the global to the surface reanalysis as indicated by the arrows.

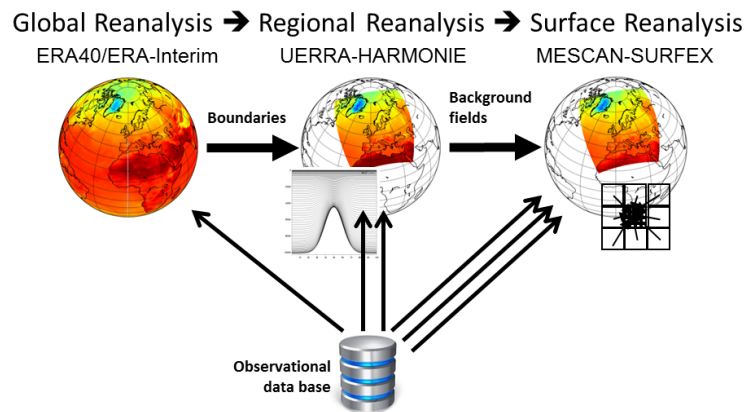
- User guide
- Homepage  
<https://climate.copernicus.eu/regional-reanalysis-europe>
- Git server with example scripts  
[https://git.smhi.se/C3S\\_322\\_Lot1/C3S\\_322\\_Lot1\\_user\\_examples](https://git.smhi.se/C3S_322_Lot1/C3S_322_Lot1_user_examples)
- Training material  
<https://climate.copernicus.eu/user-learning-services>



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## Summary

- The service offers:
  - Based on the RRA from the FP7 UERRA project, hourly data at 11km resolution from 1961 to near real time for Europe
  - A comprehensive set of output parameters for the surface, the upper air, and the soil
  - User guidance and support
- Data quality improves compared to global products
- Some inhomogeneity due to the change from ERA40 to ERA-interim







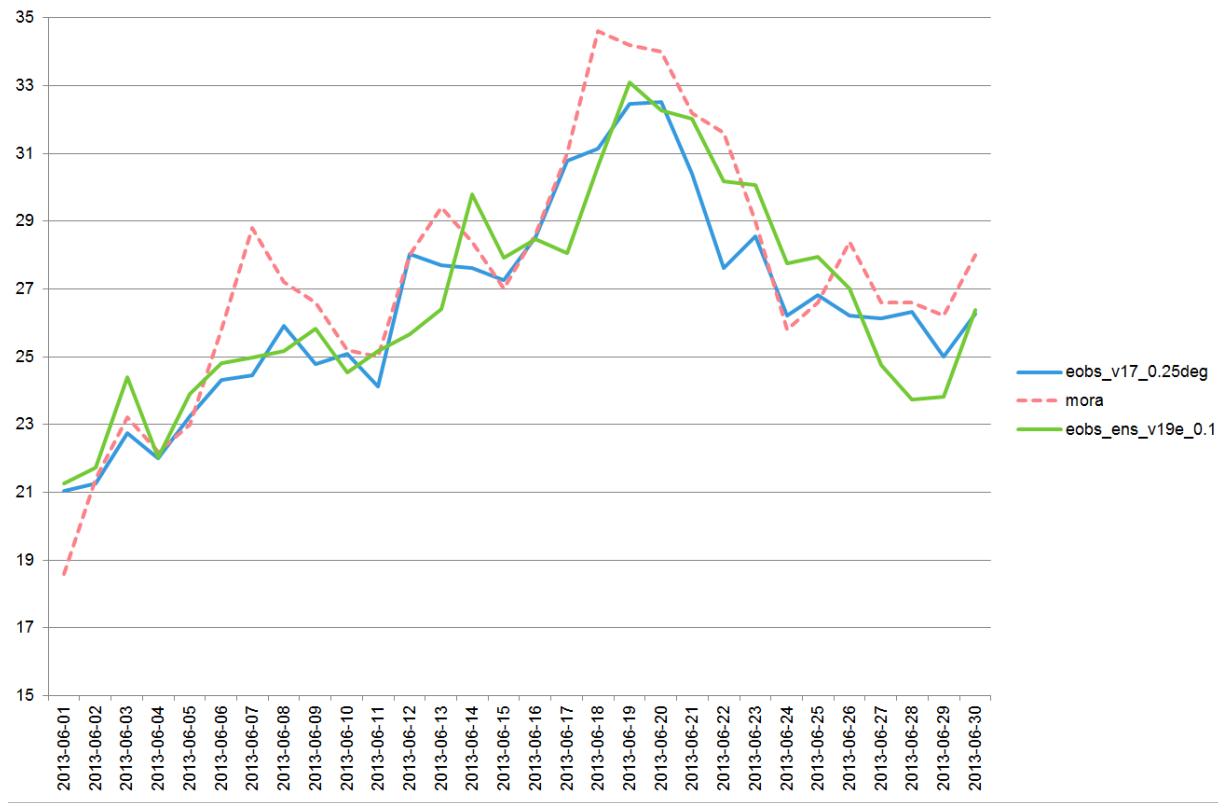
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Back-up slides...





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## Model systems: differences

UERRA system	New system
HARMONIE cycle 38h1 (ALADIN physics)	HARMONIE cycle 40.1h/42 (ALADIN physics)
SURFEX 7.3	SURFEX 7.3 with updates from SURFEX 8.0
ERA40 and ERA-interim as LBC	ERA5 as LBC
4 cycles per day	8 cycles per day
No satellite data	Satellite radiances, e.g. IASI, MSU, AMSU
---	Usage of ERA5 ODB files, e.g. blacklisting information
---	More obs-data, e.g. GBGNSS

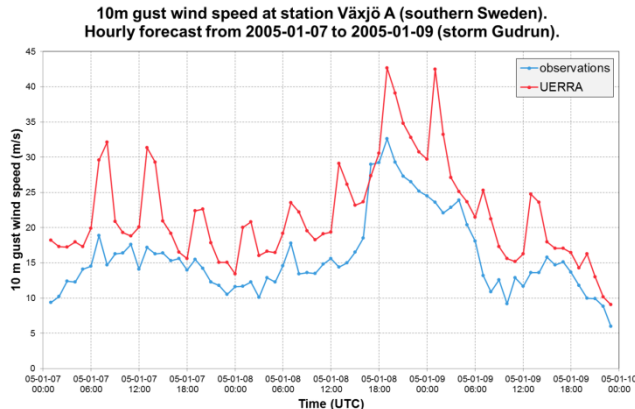




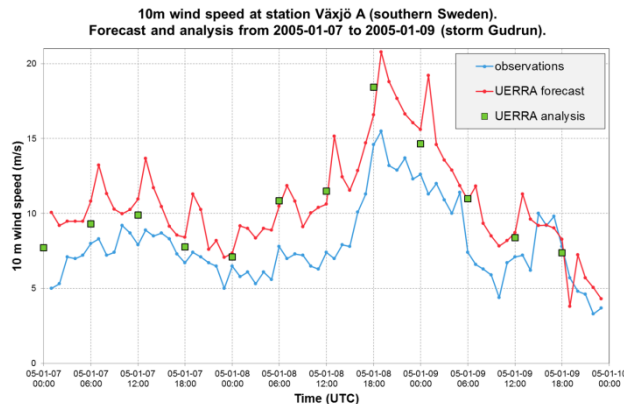
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# Known short comings

Gust wind speed



10m wind speed



## Windspeed during Gudrun

- Wind at a station in southern Sweden during a major storm
- Shown are fc1-6 (and fc0)

➔ Clearly unrealistic jumps

➔ Affected are forecasts lengths 1h and 2h