

# Uncertainties in Ensembles of Regional ReAnalyses

## Overview and User products

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Grant Agreement 607193

FP7 SPACE 2013-1

# Objective of UERRA

To produces ensembles of European regional meteorological reanalyses of Essential Climate Variables for several decades

To estimate the associated uncertainties in the data sets

To provide more observations for reanalyses

To provide data services and user information

➡ Pre-operational  
Copernicus Climate Change Services



**UEARA**

Uncertainties in Ensembles of Regional ReAnalyses

# Project Partners

**SMHI**



**METEO  
FRANCE**

Toujours un temps d'avance



Koninklijk Nederlands  
Meteorologisch Instituut  
*Ministerie van Infrastructuur en Milieu*

**UEA**

University of East Anglia



**Met Office**

**ECMWF**

**Deutscher Wetterdienst**  
Wetter und Klima aus einer Hand



Meteorologisk  
institutt

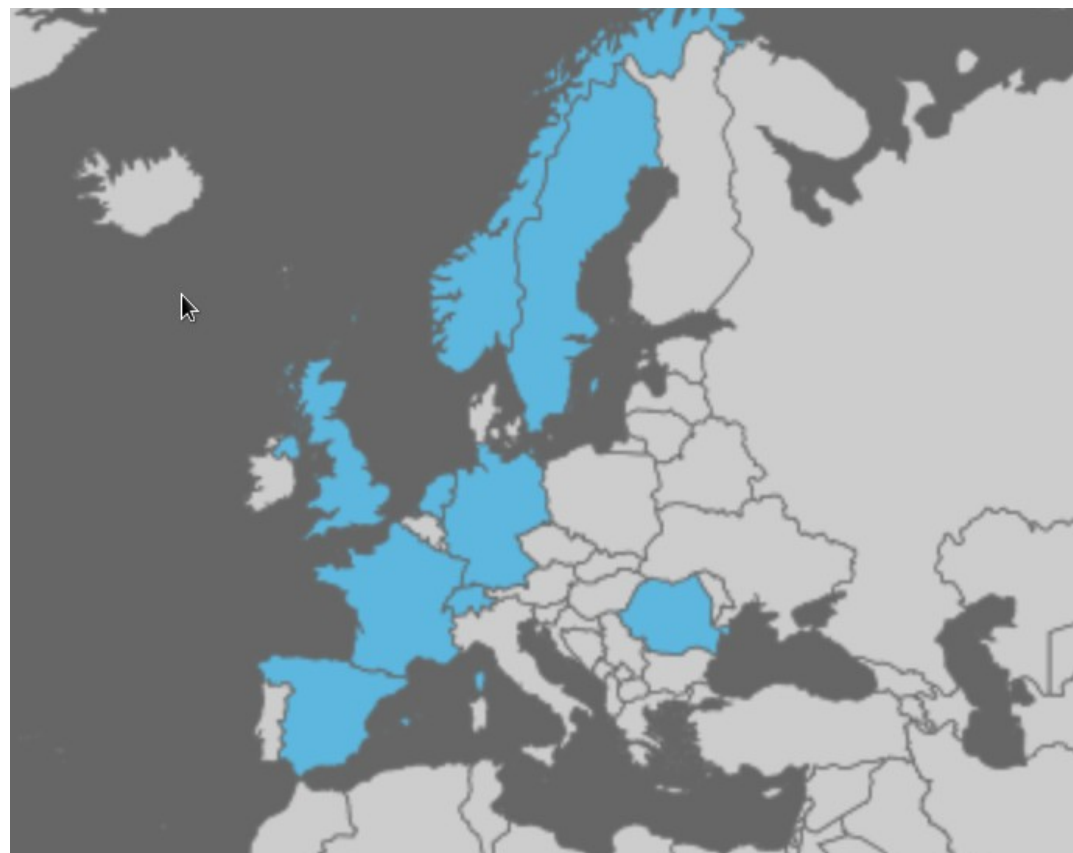


UNIVERSITAT  
ROVIRA I VIRGILI



**universität bonn**

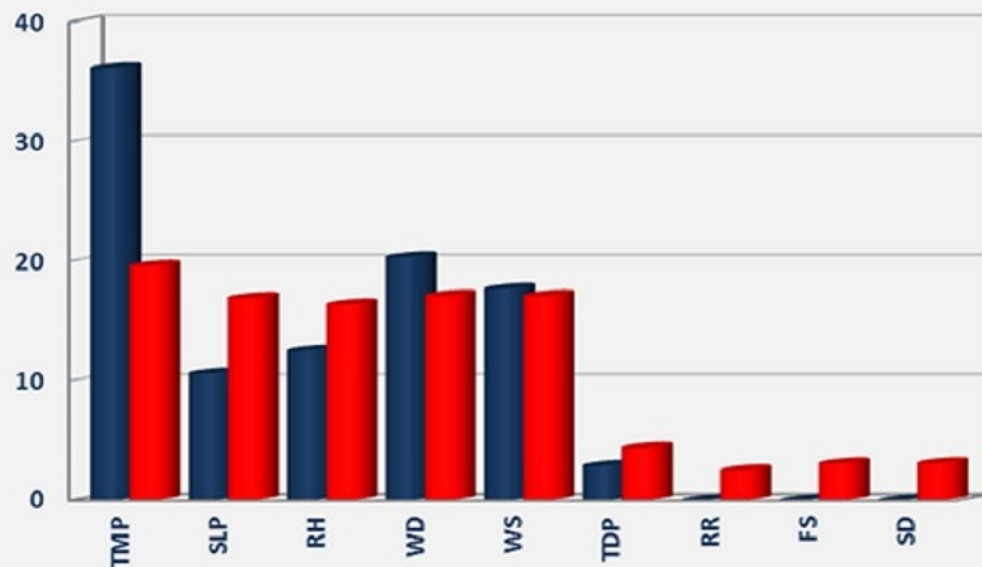
Rheinische  
Friedrich-Wilhelms-  
Universität Bonn



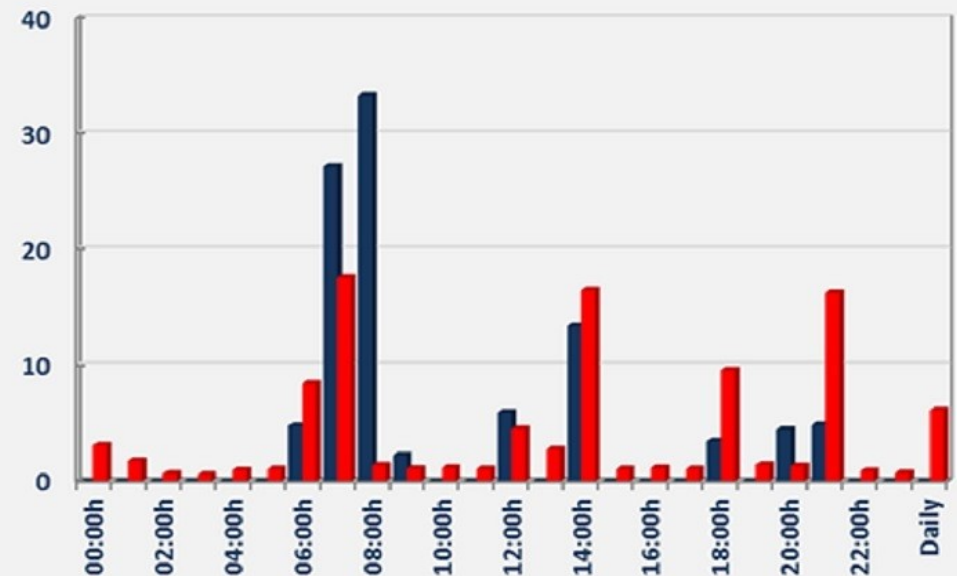
# Data rescue of historical observations

- + *More than 7 M data recovered*
- + *Emphasis on sub-daily scale → observation stream for reanalyses*
- + *Comprehensive quality control and data development (correction, homogenisation)*

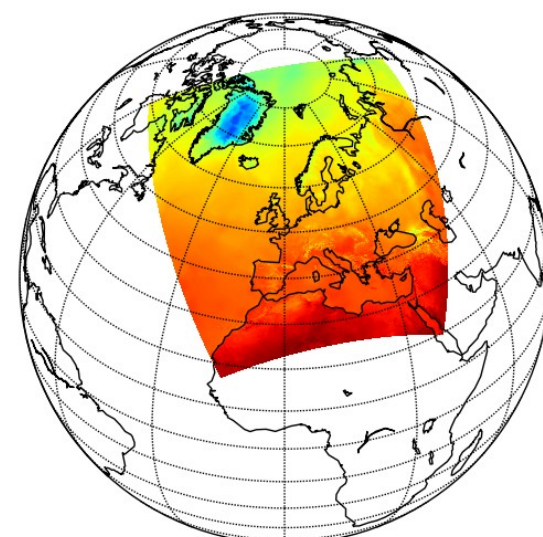
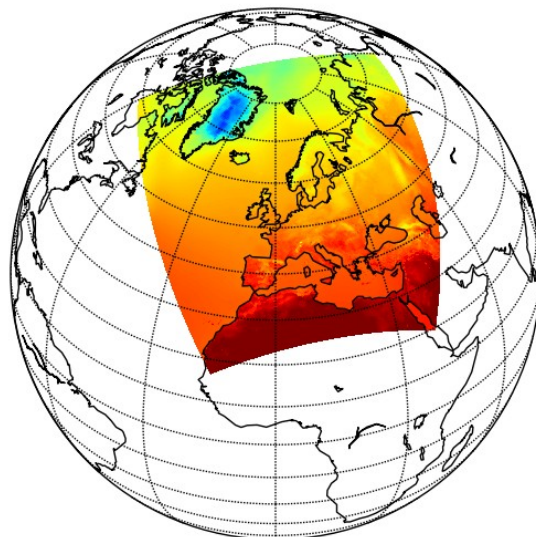
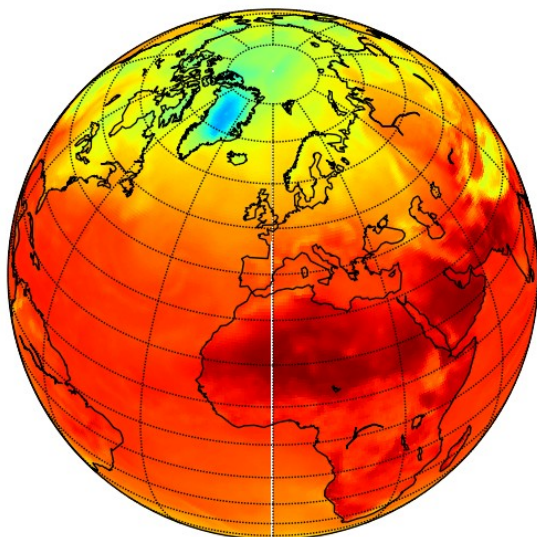
a) Percentage of digitised values by variable for pre-1961 (blue) & post-1961 (red) periods: ~1M & ~5M station values, respectively



b) Digitised values by observing times for pre-1961 (blue) & post-1961 (red) periods: ~1M & ~5M station values, respectively



TMP: hourly temperature; SLP: Sea Level Pressure; RH: Relative Humidity; WD: Wind Direction; WS: Wind Speed; TDP: Temperature Dew Point; RR: precipitation; FS: Fresh Snow; SD: Snow-depth



Forcing from  
global re-  
analyses:

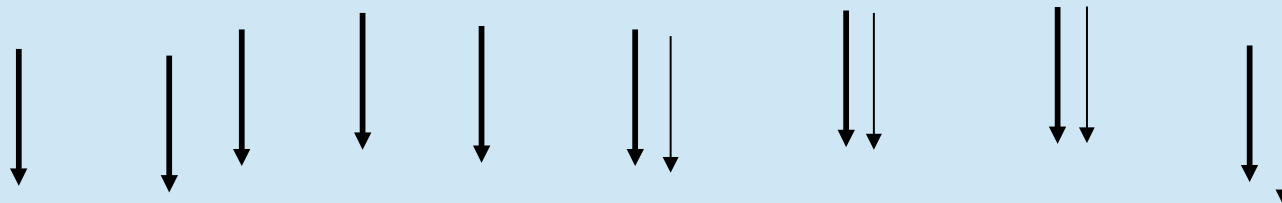
ERA-Interim  
(ERA-40)  
ERA-5 including  
ensembles when  
available

3D Upper air :

- HARMONIE, SMHI
- Unified Model (UM, Met Office
- COSMO, Univ Bonn/DWD
- Ensembles of UM, COSMO (HARMONIE mini ensemble)

2D Surface or cloudiness :

- MESCOAN, Météo-France
- MESAN, SMHI
- 5 year ensemble of MESCOAN
- Surface and hydrological model forced by 2D:  
SURFEX -> TRIP (MF)  
HYPE (SMHI)

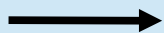


Observations : As complete as possible or improving during the period

NWP model and analysis system remain fixed during the period

Reanalysis quality remains the same or improving

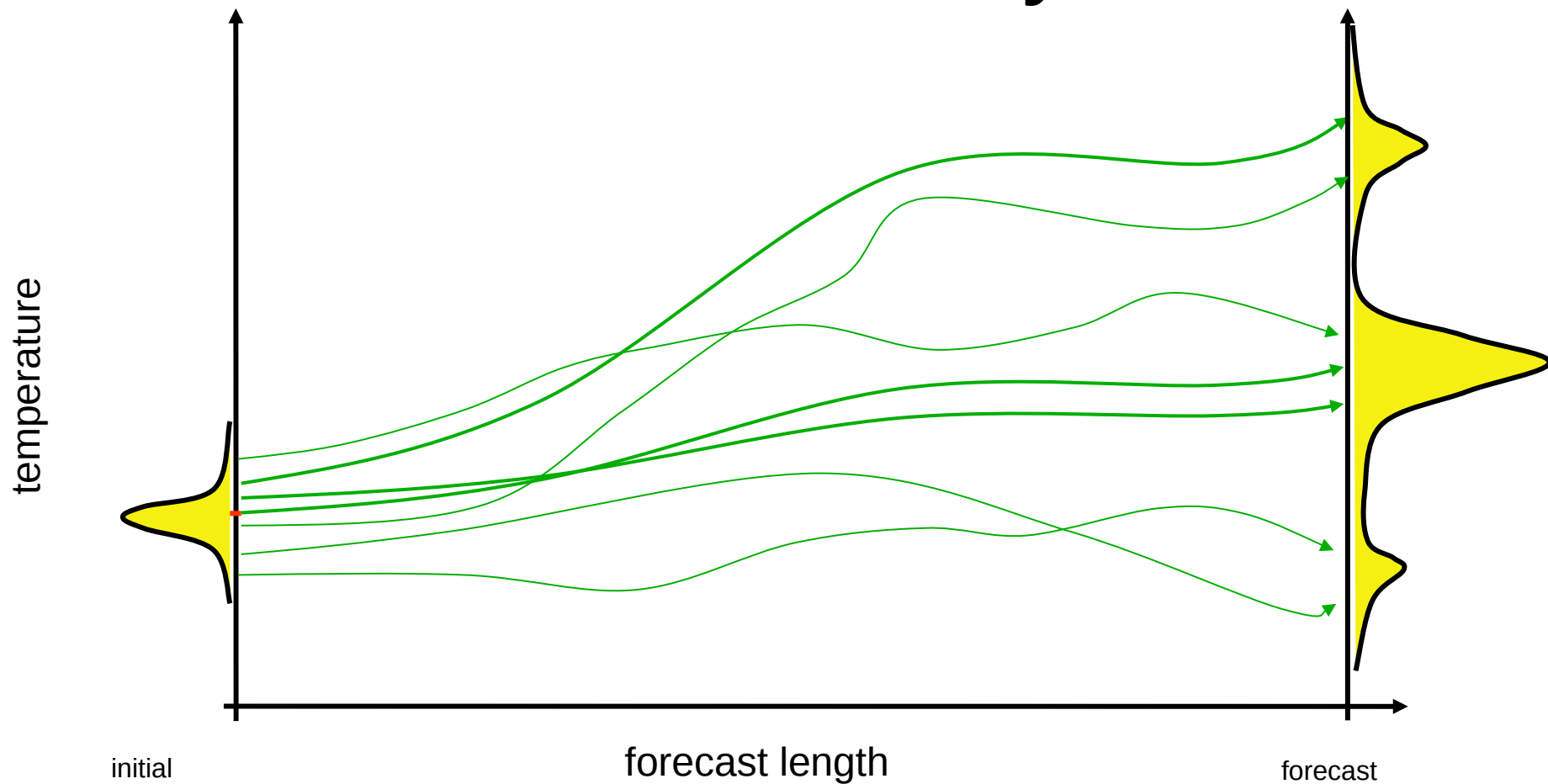
Time : 1961



2014



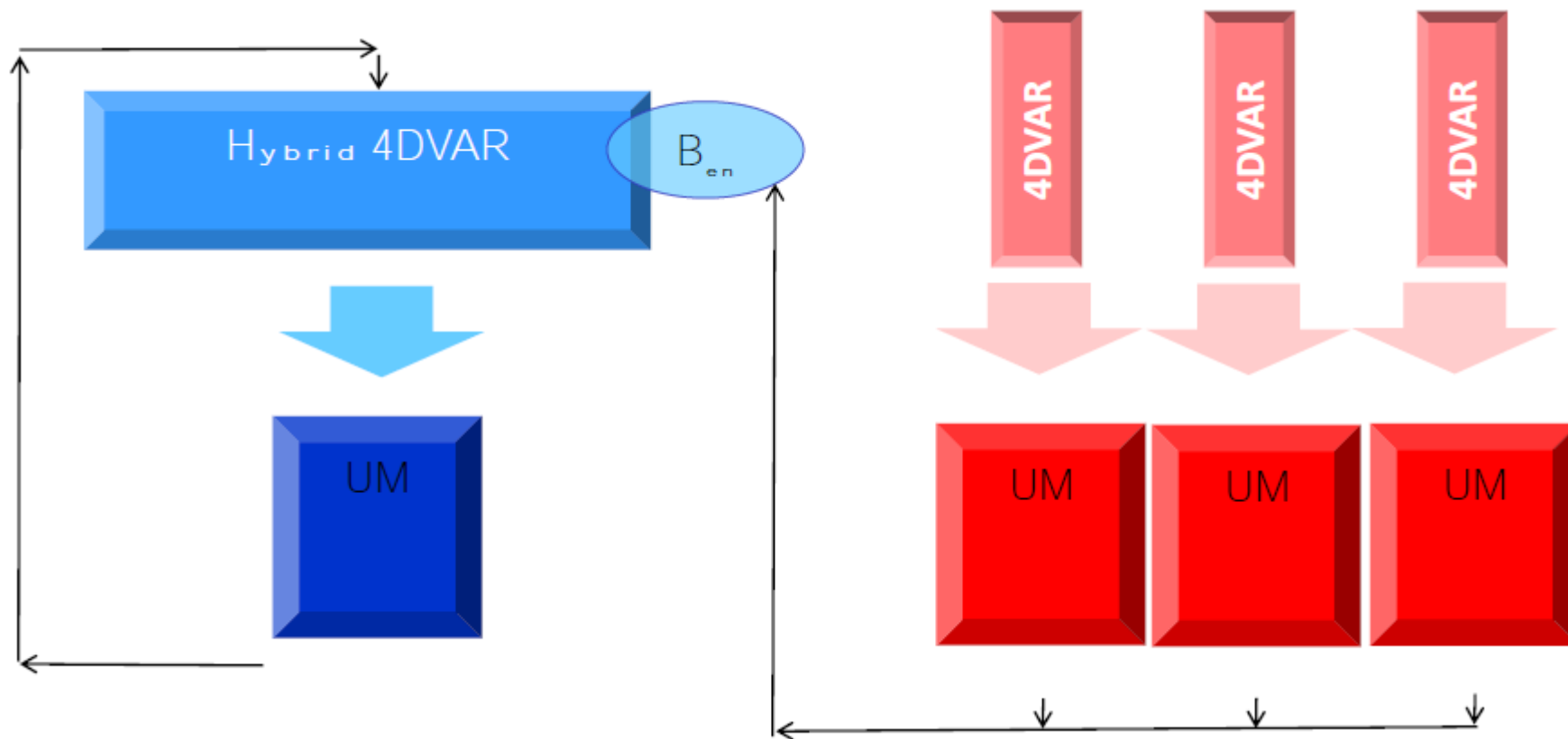
# Ensemble of analyses



the weather development as a  
Probability Density Function (PDF)

# 4D-En-Var

Ensembles of 4D-VAR will be used



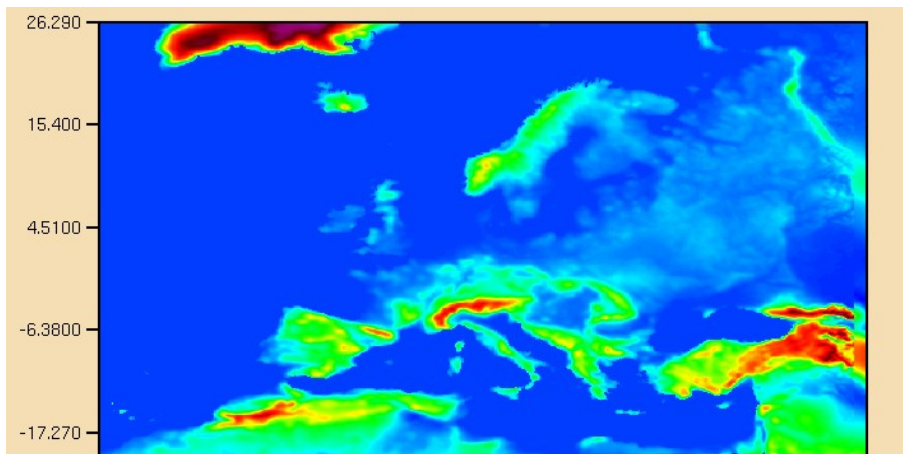


# UERRA

Uncertainties in Ensembles of Regional ReAnalyses

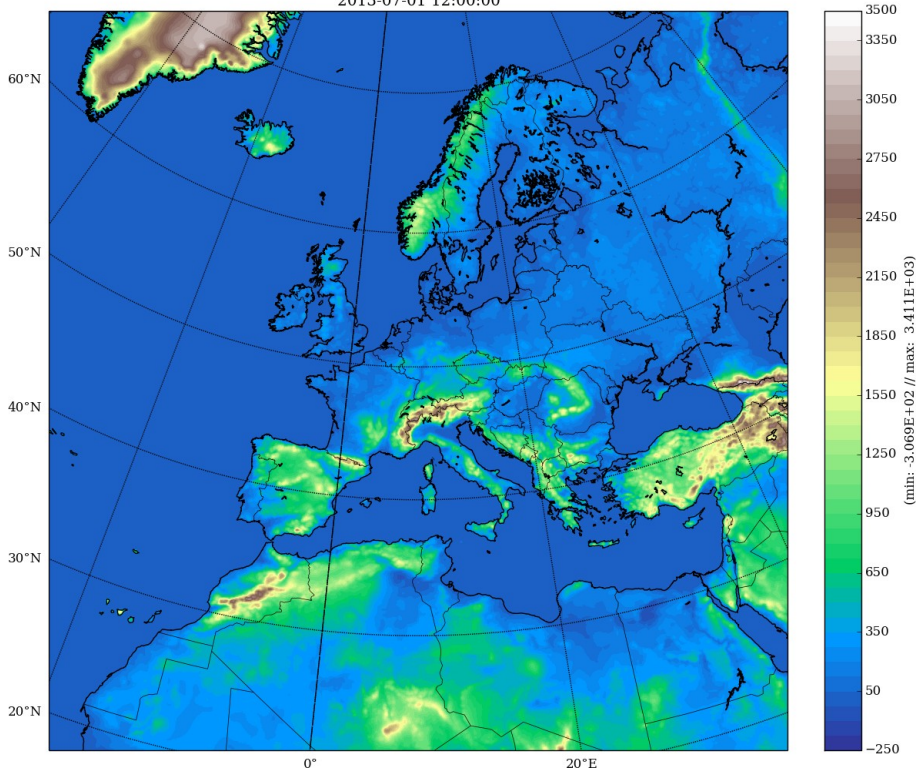
# UERRA Domain & projections

Met Office  
CORDEX  
EU 11 km

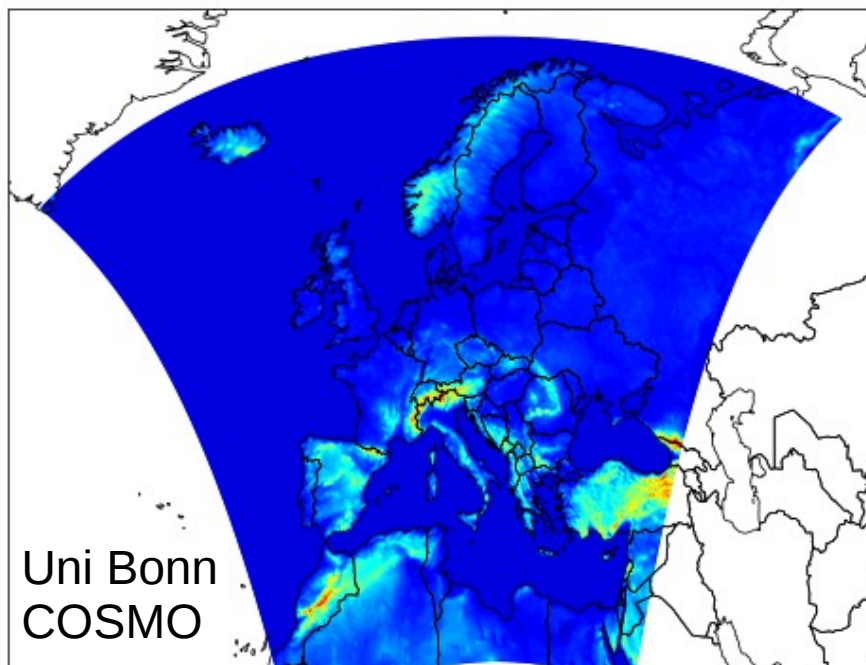


SPECSURFGEOPOTEN  
2013-07-01 12:00:00

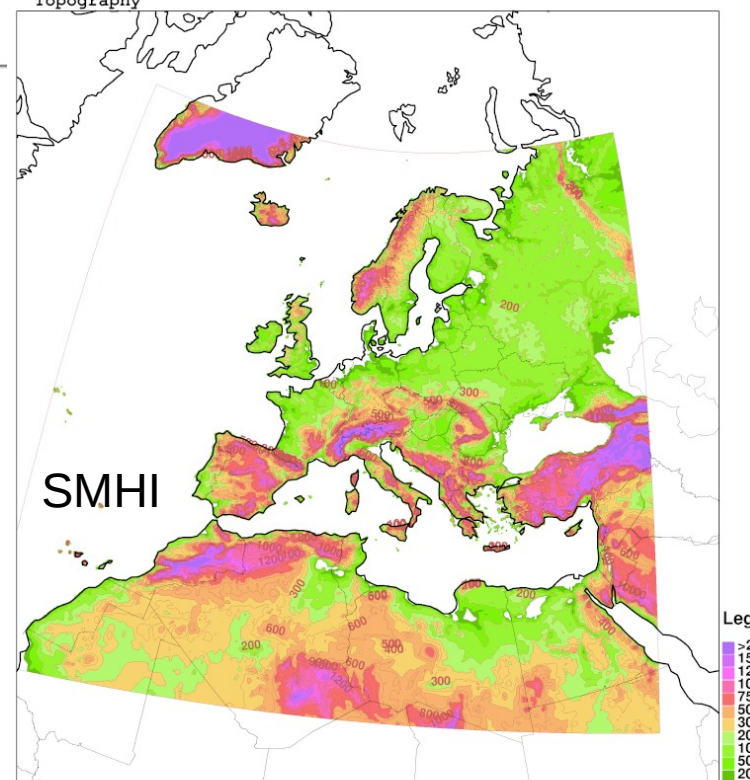
MF



Uni Bonn  
COSMO



Alaro UERRA  
Topography

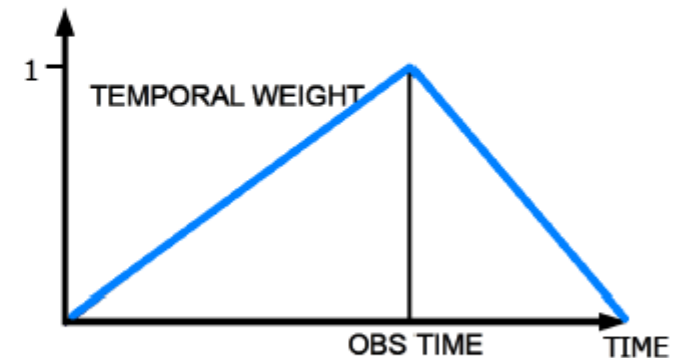
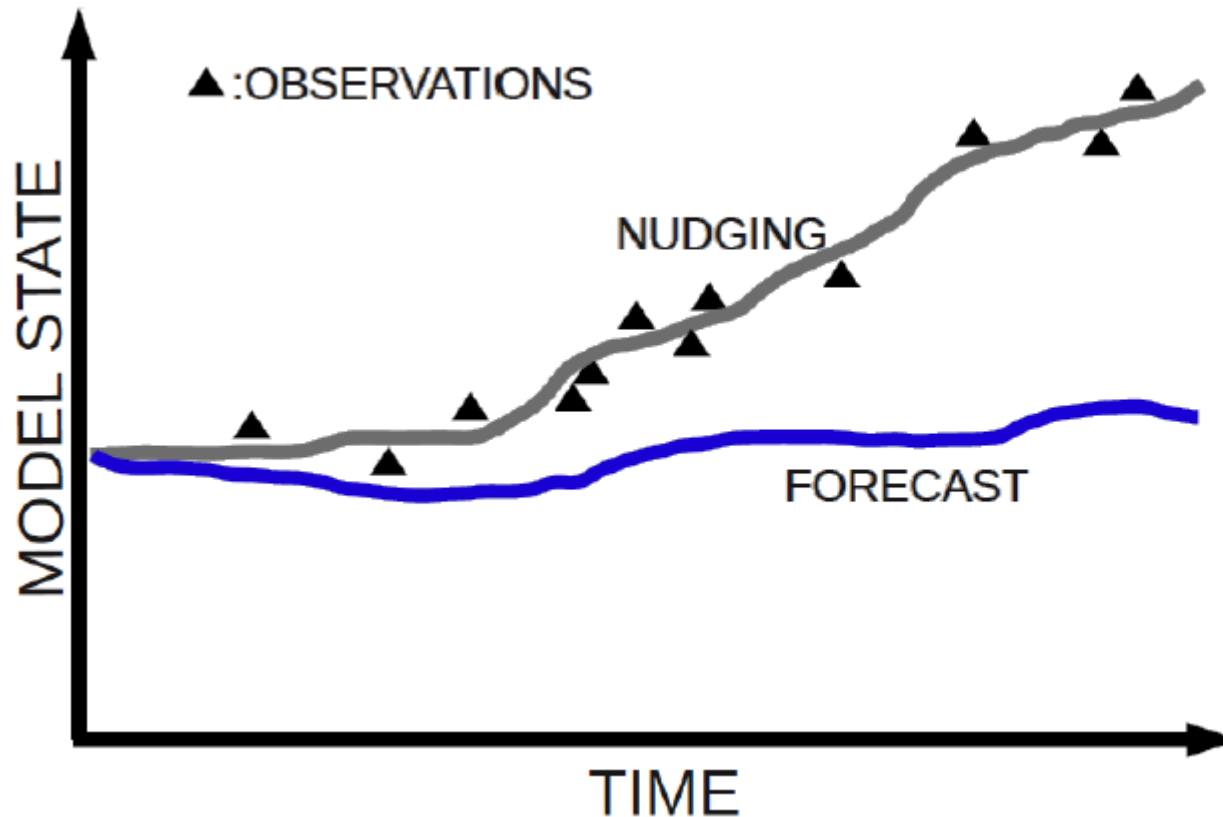


Mon 1 Jul 2013 00Z +06h  
valid Mon 1 Jul 2013 06Z

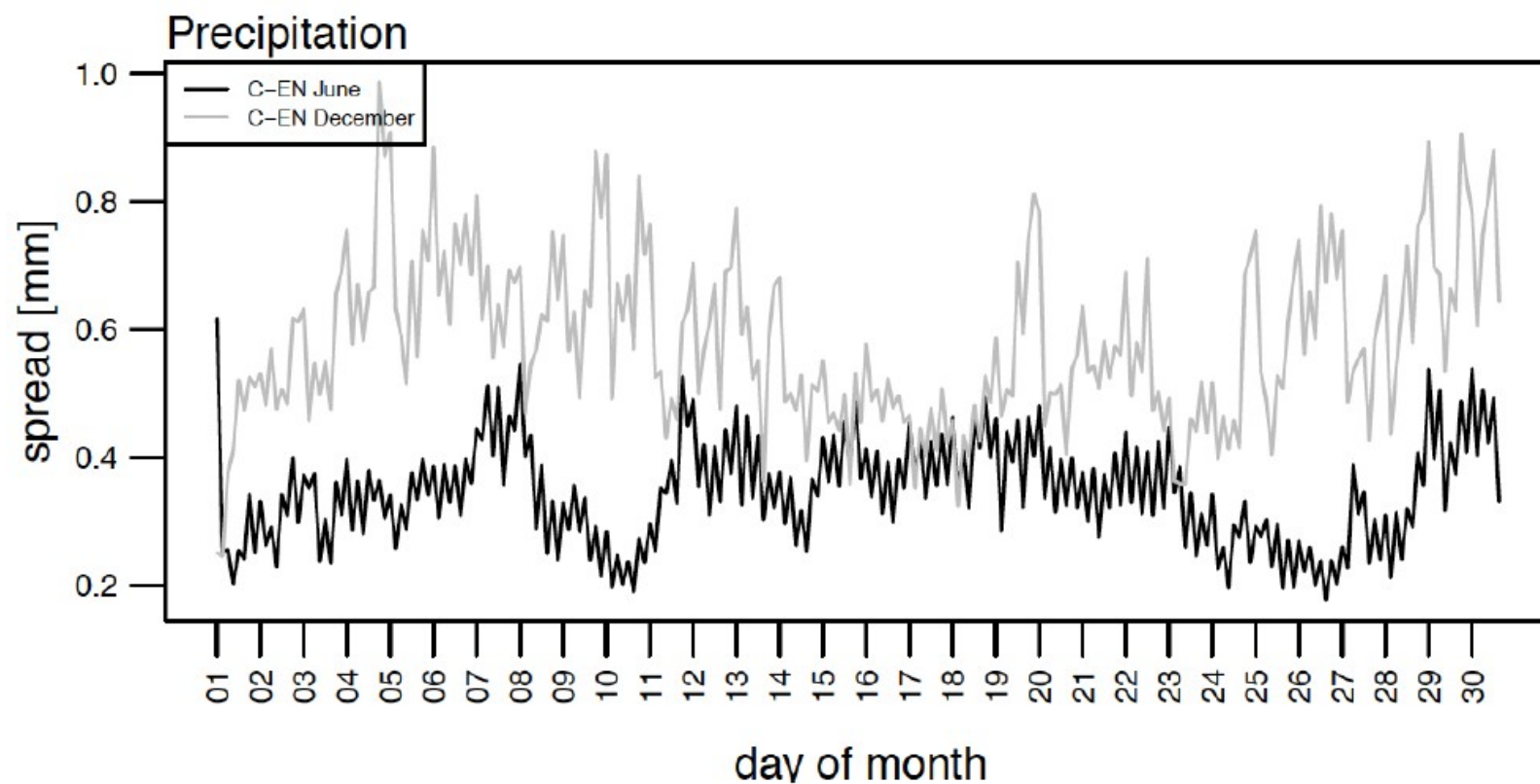
# COSMO University Bonn / DWD

## Ensemble nudging

$$\frac{\partial}{\partial t} \psi(\mathbf{x}, t) = F(\psi, \mathbf{x}, t) + G_{\psi} \cdot \sum_{k_{(obs)}} W_k(\mathbf{x}, t) \cdot [\psi_k^{obs} - \psi(\mathbf{x}_k, t)]$$

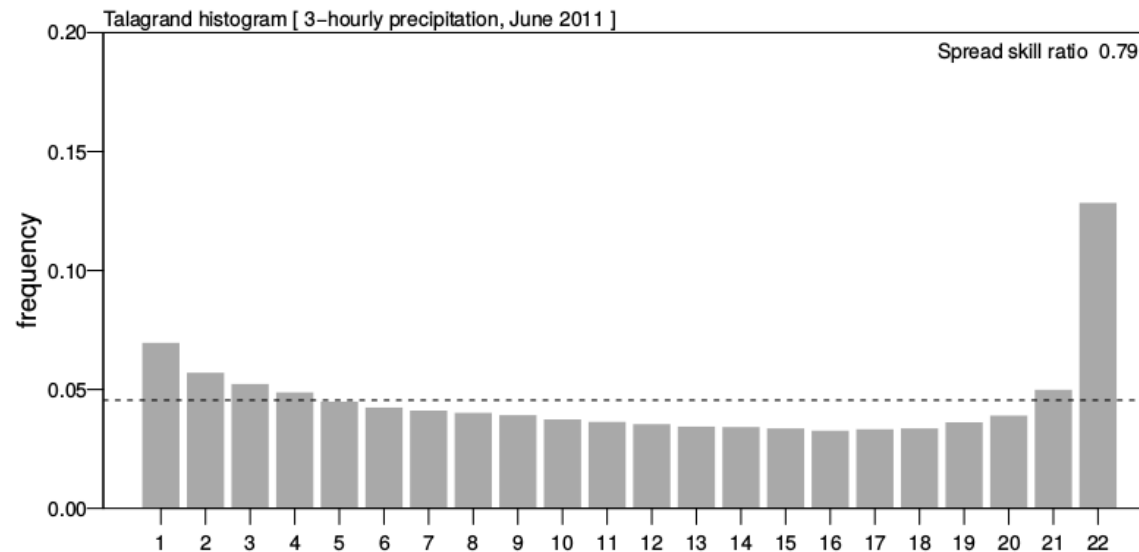


# Spread of the ensemble members around control

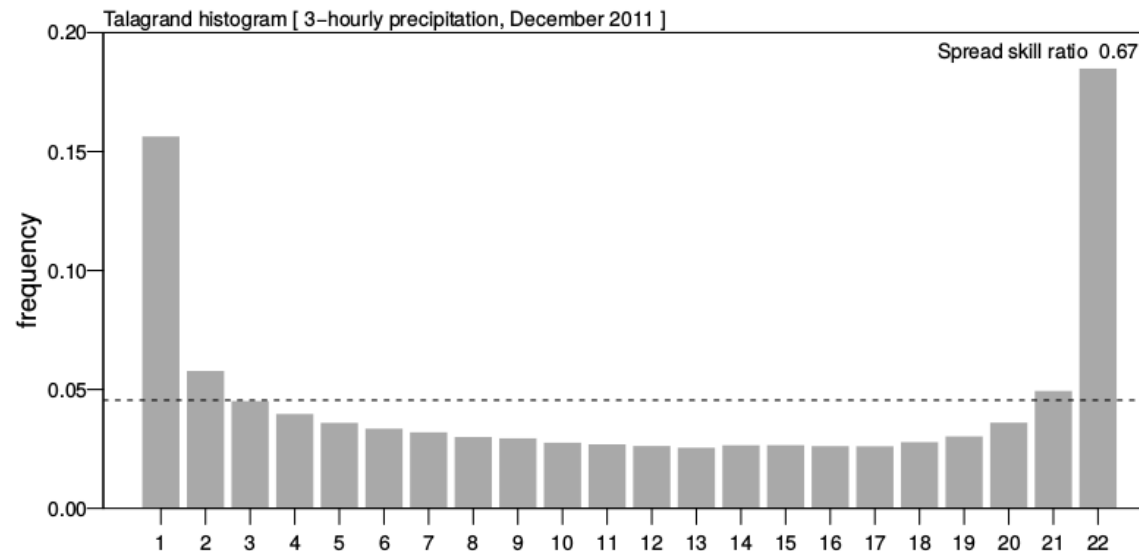


# Analysis rank histogram - validating ensemble quality

June



December

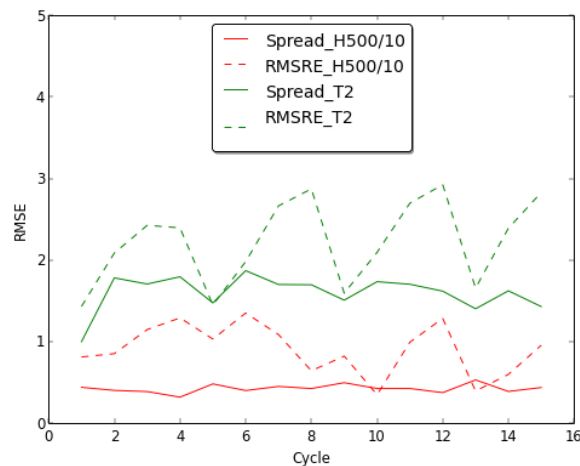




# UERRA – Met Office Initial Results

- Initially with no inflation

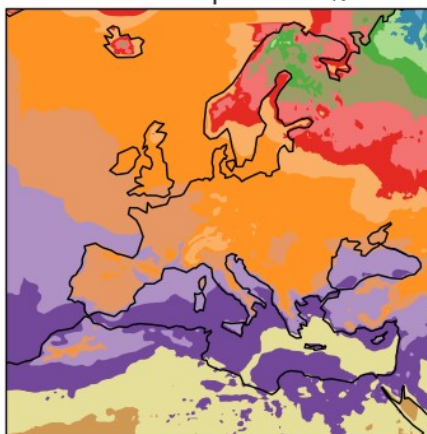
RMS (random) Error and Spread, Europe, T+6 20100215 to 20100225, mi-af552-EG



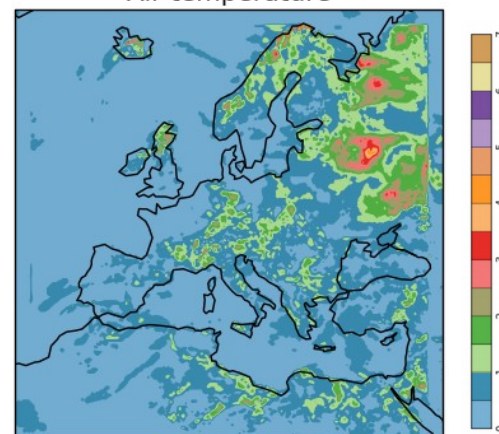
mean

uncertainty

Air temperature/K



Air temperature/K



# 3-D model level fields $u,v,T,q$ , clouds, 2D fields precipitation, surface $p, T, RH$ , snow and more

## Met Office

Hybrid 4D-Var,  
Ensemble of 4D-VARs

1 Control 12 km  
70 levels  
10 (20) members 24 km  
ensemble

ensemble ~1978 -2015

Conventional obs,  
satellite data, precip?

## SMHI/MF

HARMONIE  
3D-VAR

1 member 11 km  
65 levels  
2 members physics (5 y)

deterministic ~1961-2015  
5 years ensemble

Conventional obs,  
Large scale constraint  
from ERA

## Uni Bonn DWD

LETKF and  
Ensemble Nudging

1 Control 12 km  
40 levels  
20 members 12 km  
ensemble

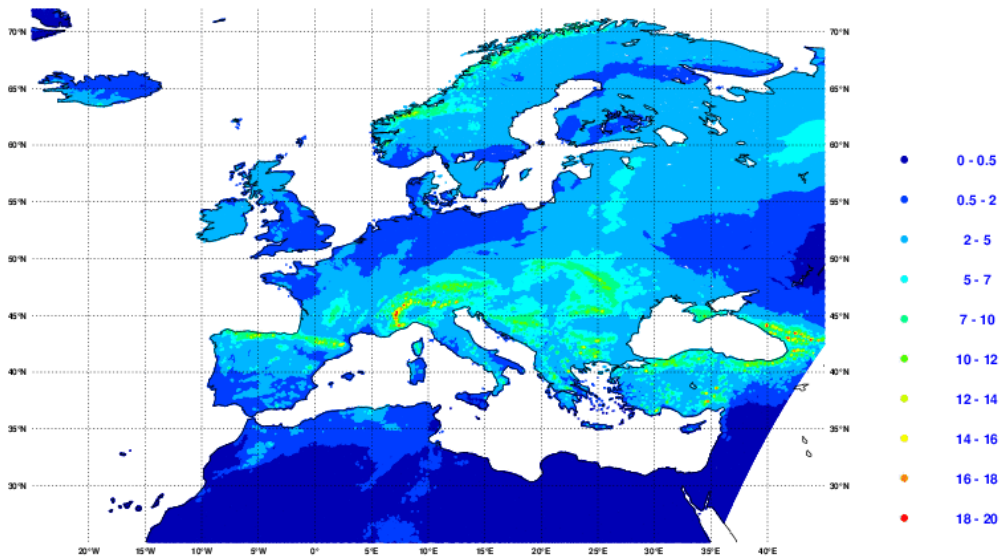
ensemble ~5 years

Conventional obs  
Radar, new in LETKF

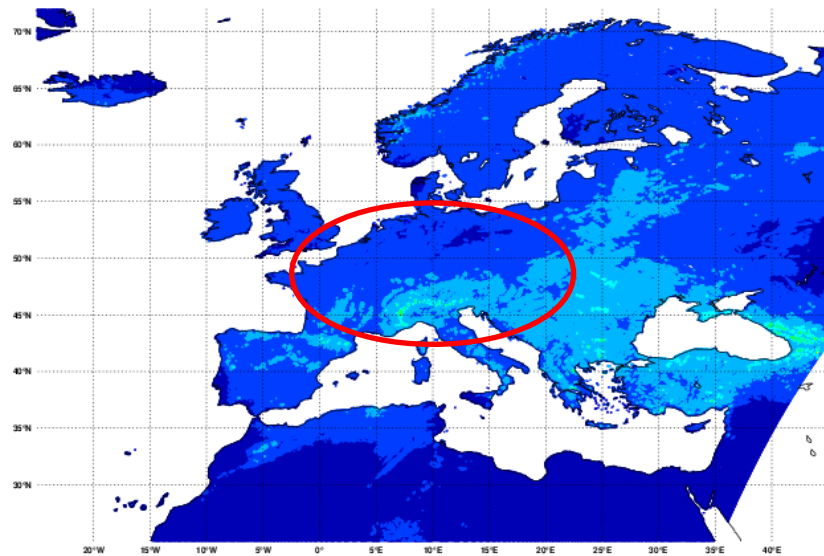
boundary forcing from global ERA reanalyses  
(ERA-40, ERA-Interim, ERA -5, incl. Ensembles, EDA)

# Ensemble (6 members) MEAN and SD of 24-h Precip Background and Analysis (June 2010)

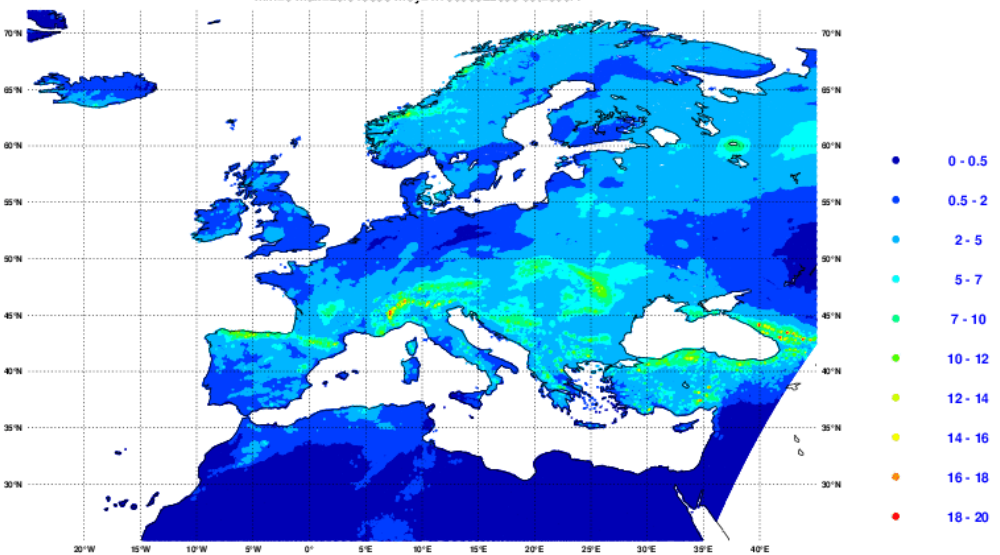
## Ensemble Mean of Background



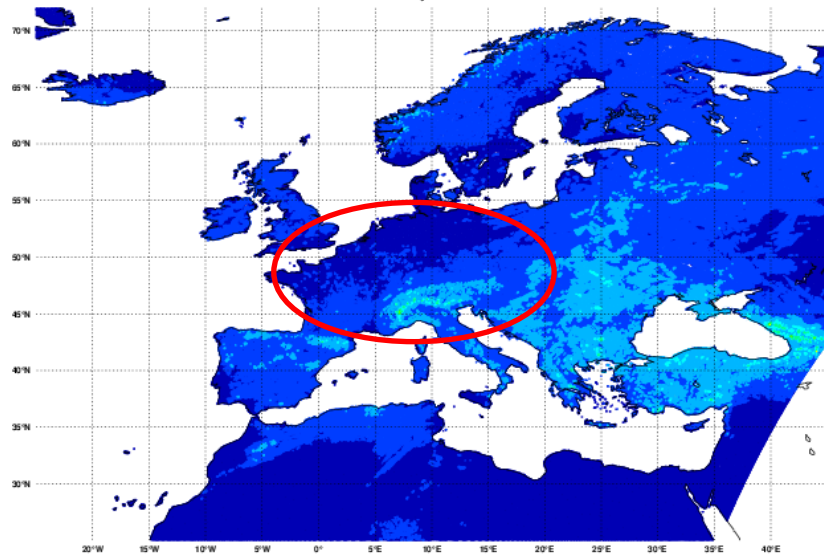
## Ensemble Mean SD of Background



## Ensemble Mean of Analyses

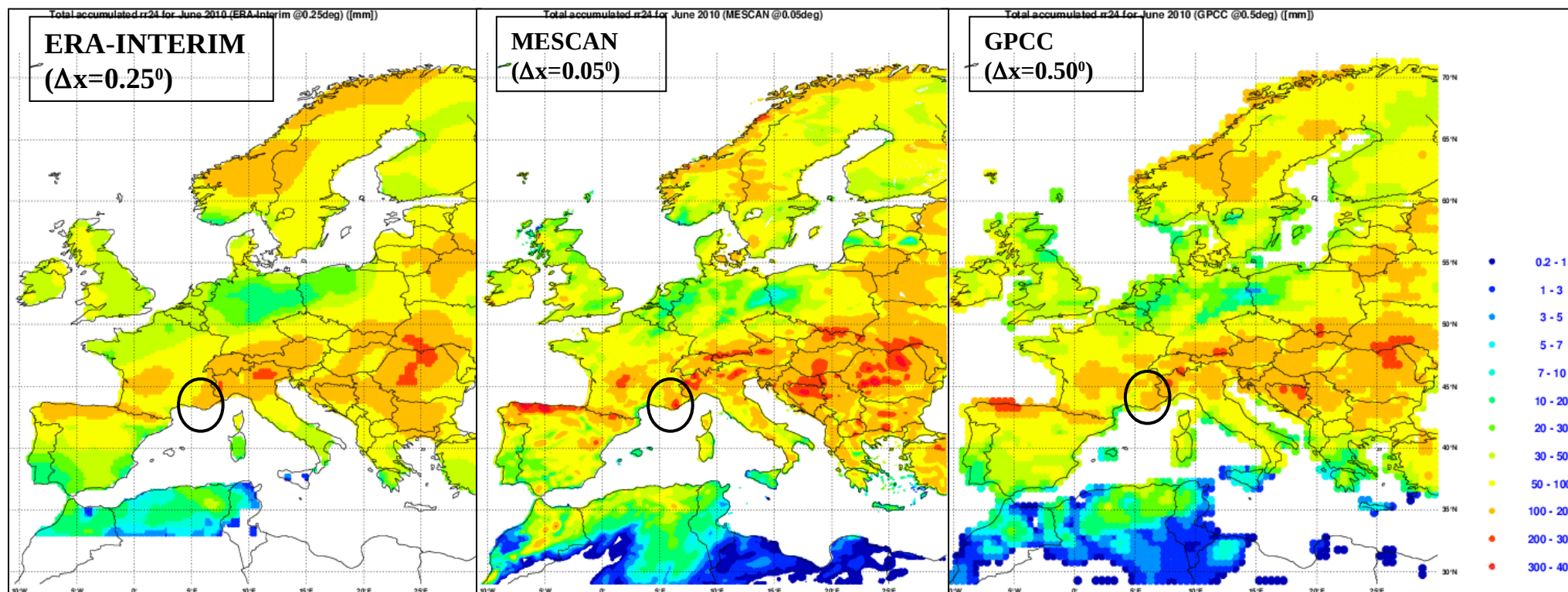


## Ensemble Mean SD of Analyses





# Monthly mean RR24 for June 2010: MESCAN vs ERA-Interim and GPCC



## Issues:

- Observation coverage not dense enough in some parts of Europe!

# MESAN cloud reanalysis SMHI

European cloud cover reanalysis using  
best available data at any given time, 1982 - 2013

Horizontal resolution:

5.5 km MESAN EURO4M (but maybe 22 km HIRLAM EURO4M).

Time resolution:

Hourly for the period 1982– 2013 (2013 not yet available).

Observations:

CMSAF polar orbit AVHRR cloud mask 1982 – 2009.

CMSAF geostationary SEVIRI cloud mask 2004 – 2012.

CMSAF geostationary MVIRI cloud albedo 1983 – 2005

First guess:

EURO4M 22 km HIRLAM 3DVar, 1982 – 2013. Mesan: Optimal Interpolation

Specially adapted B (background) and R (observation) error matrices to take into account orography, land-sea and climatic features

$$x_a = x_b + K(y - H(x_b))$$
$$K = BH^T(HBH^T + R)^{-1}$$

## 2-D surface fields analyses driven by 3D reanalyses

MF/SMHI  
MESCAN

2D advanced  
Statistical  
Interpolation

Downscaled  
ALADIN model  
background

Surface and climate  
stations  
T, Td,  
precipitation

5 km Europe  
T2m, RH, 24 h  
precipitation

1961 - ~2013

SMHI  
MESAN

2D advanced  
Statistical  
interpolation

Downscaled  
3D HIRLAM model  
Climatological  
adaptation background

AVHRR, METEOSAT  
SEVIRI and  
MVIRI

5 km Europe  
Cloud fraction  
**hourly**

~1982 - 2013

SMHI  
HYPE

Hydrological  
physical  
model

ERA, EURO4M and  
UERRA reanalyses  
Precipitation and  
temperature forcing

No input observations  
Validation against  
discharge data

River discharge  
35000 catchments  
Europe, median  
215 km<sup>2</sup>

~1979 - 2010

MF SURFEX  
and TRIP

Surface flux model  
Hydrological physical  
model

MESCAN  
atmospheric  
variables and  
precipitation

No input observations  
Validation against  
discharge data

River discharge  
25 km -> rivers

~1981 - 2010

# Uncertainty estimations

- To evaluate ensemble reanalyses and downscaled reanalyses through **comparison to independent ECV datasets** that were derived independently
- To establish a consistent knowledge base on the uncertainty of reanalyses across all of Europe through a **common evaluation procedure**
  - Extremes, Climate Indices and Indicators of user interest, scales of variability
- To statistically assess the provided information by applying the common evaluation procedure on all data
- User dependent parameters and language adaptation

# Evaluation

## Task 3.1 Coordinated uncertainty evaluation

·D 3.2 Common evaluation procedures (-> data source):

**-A: feedback statistics**

- Data source: radiosonde soundings
- Parameters: T, Ws, RH

**-B: point measurements**

- Data source: station data
- Parametes: Ws, Tmin, Tmax, number of days of threshold exceedance of T and RR

**-C: gridded measurements**

- Data source: gridded data
- Parameters: RR, Tmin, Tmax

**-D: satellite data products**

- Data source: CM-SAF and CCI
- Parameters: global radiation, total cloud cover, swe

**-E: ensemble based comparison**

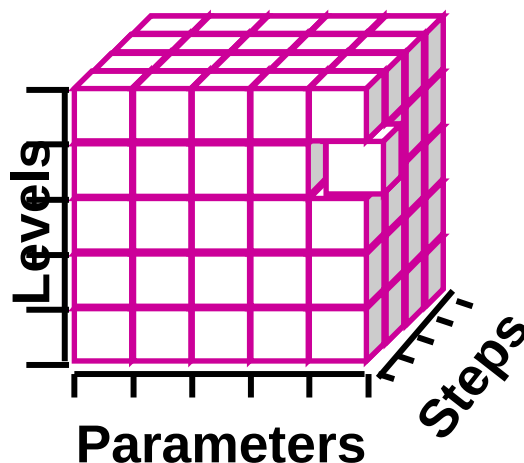
- Data source: WP1 ensemble of gridded data
- Parameters: RR, Tmin, Tmax

**-F: user related models**

# ARCHIVING IN MARS

## Data Services

- + *The common UERRA archive is MARS at ECMWF*  
*Common set of parameters chosen for all models*  
*GRIB2 (some new definitions)*
- + *Data services from MARS and ESGF interface*
- + *Web Map Servers*
- + *Visualisation through Metview and WMS*



# Timeline

2015-2016

**HARMONIE 5 years 2 physics**

**MF MESCAN 5 year 6 member ensemble**

**MESAN hourly cloud analysis 30 years**

2016

**UM Ensemble 4D-VAR 30 years**

2017

**HARMONIE 11 km 3D-VAR -> 50-55 years**

**MESCAN 5.5 km 2D OI -> 50-55 years**

**UM 12 km Hybrid 4D-VAR 35 years**

**COSMO 12 km Ensemble nudging (LETKF?) 5 years**



## Model levels

Store analysis output every six hours at 00UTC, 06UTC, 12UTC, 18UTC for all models. Don't store any forecast fields.

Parameter	UM/4DVar UM/En4DVar (MO)	COSMO COSMO/En (HErZ/UB)	Harmonie/V1 Harmonie/V2 (SMHI)
	Analysis	Analysis	Analysis
cloud cover	X	X	
cloud liquid water content (specific)	X	X	
cloud ice content (specific)	X	X	
pressure	X	X	X
specific humidity	X	X	X
temperature	X	X	X
U component of wind	X	X	X
V component of wind	X	X	X

## Pressure levels

**Analysis: six hourly**  
**at 00 UTC, 06 UTC, 12 UTC, 18 UTC (hourly for COSMO) Forecasts : T+1,2,3,4,5,6,9,12,15, 18,21,24,27,30 started at 00 UTC and 12 UTC**  
**T+1,2,3,4,5,6 started at 06 UTC and 18 UTC**

Parameter	UM/4DVar UM/En4DVar (MO)		COSMO COSMO/En (HErZ/UB)		Harmonie/V1 Harmonie/V2 (SMHI)	
	Analysis	Fore- cast	Analysis	Fore- cast	Analysis	Fore- cast
cloud cover	X	X	X	X		X
cloud liquid water content (specific)	X	X	X	X		X
cloud ice content (specific)	X	X	X	X		X
geopotential height	X	X	X	X	X	X
relative humidity	X	X	X	X	X	X
temperature	X	X	X	X	X	X
U component of wind	X	X	X	X	X	X
V component of wind	X	X	X	X	X	X

## Pressure levels

Pressure levels [hPa]
1000
975
950
925
900
875
850
825
800
750
700
600
500
400
300
250
200
150
100
70
50
30
20
10

## Height levels

WP3 suggestion [m]
15
30
50
75
100
150
200
250
300
400
500

– **Height levels  
Analysis:**

**00 UTC, 06 UTC, 12 UTC, 18 UTC,  
hourly for COSMO**

**Forecasts: T+1,2,3,4,5,6,9,12,15,18,21,24,27,30  
00 UTC and 12 UTC, T+1,2,3,4,5,6 06 UTC and 18**

Parameter	UM/4DVar UM/En4DVar (MO)		COSMO COSMO/En (HErZ/UB)		Harmonie/V1 Harmonie/V2 (SMHI)	
	Analysis	Fore- cast	Analysis	Fore- cast	Analysis	Fore- cast
Cloud cover	X	X	X	X		X
cloud liquid water content (specific)	X	X	X	X		X
cloud ice content (specific)	X	X	X	X		X
Pressure	X	X	X	X	X	X
Relative humidity	X	X	X	X	X	X
Temperature	X	X	X	X	X	X
wind speed	X	X	X	X	X	X
wind direction	X	X	X	X	X	X

# Surface levels Analysis:

## 00 UTC, 06 UTC, 12 UTC, 18 UTC

## hourly for COSMO, MESAN, SURFEX

## Forecast: T+1,2,3,4,5,6,9,12,15,18,21,24,27,30

## 00 UTC and 12 UTC, T+1,2,3,4,5,6 06 UTC and 18

### 4.2.1 Precipitation and humidity

Parameter	MF	MES CAN (MF)	SUR FEX (MF)	UM/4DVar UM/En4DVar (MO)		COSMO COSMO/En (HErZ/UB)		Harmonie/V1 Harmonie/V2 (SMHI)	
	For or Bg	Ana	For	Ana	For	Ana	For	Analysis	For
Accumulated total precipitation	X	X		X	X	X	X		X
2m relative humidity	X	X		X	X	X	X		X
Total column water vapour				X	X	X	X	X	X
runoff			X						
drainage			X						

Parameter	MF	MES CAN (MF)	SUR FEX (MF)	UM/4DVar UM/En4DVar (MO)		COSMO COSMO/En (HErZ/UB)		Harmonie/V1 Harmonie/V2 (SMHI)	
	For or Bg	Ana	For	Analysis	For	Analysis	For	Analysis	For
Albedo			X	X	X	X	X	X	X
Clear-sky short-wave downward flux at the surface	Accumulated fluxes and radiation								X
Clear-sky short-wave upward flux at the surface				X	X				X
Clear-sky long-wave downward flux at the surface				X	X				
Direct short-wave radiation flux at the surface	X		X	X	X	X	X		X
Evaporation			X	X	X	X	X		X



Long-wave downward flux at the surface	X		X	X	X	X	X		X
Net long-wave radiation flux at the surface	X		X	X	X	X	X		X
Net short-wave radiation flux at the surface	X		X	X	X	X	X		X
Surface latent heat flux			X	X	X	X	X		X
Surface sensible heat flux			X	X	X	X	X		X
Total short-wave radiation flux at the surface	X		X	X	X	diffuse as separate file not total	dito		X

# Temperature and wind

Parameter	MF	MES CAN (MF)	SUR FEX (MF)	UM/4DVar UM/En4DVar (MO)		COSMO COSMO/En (HErZ/UB)		Harmonie/V1 Harmonie/V2 (SMHI)	
	For or Bg	Ana	For	Analysis	For	Analysis	For	Analysis	For
10m wind speed	X	X		X	X	X	X	X	X
10 m wind direction	X	X		X	X	X	X	X	X
10 m wind gust [in the last 24 hrs   since previous post-processing]				X	X				
Maximum [1.5 m   2 m] temperature since previous post-processing				X	X	X	X	X	X
Minimum [1.5 m   2 m] temperature since previous post-processing				X	X	X	X	X	X
[1.5   2 ] m temperature	X	X		X	X	X	X	X	X
Surface temperature			X	X	X	X	X	X	X

# Surface levels Pressure height

Parameter	MF	MES CAN (MF)	SUR FEX (MF)	UM/4DVar UM/En4DVar (MO)		COSMO COSMO/En (HErZ/UB)		Harmonie/V1 Harmonie/V2 (SMHI)	
	For or Bg	Ana	For	Analysis	For	Analysis	For	Analysis	For
Mean sea level pressure				X	X	X	X	X	X
Surface pressure	X			X	X	X	X	X	X

# Surface levels, clouds

Parameter	MF	MES CAN (MF)	SUR FEX (MF)	UM/4DVar UM/En4DVar (MO)		COSMO COSMO/En (HErZ/UB)		Harmonie/V1 Harmonie/V2 (SMHI)	
	For	Ana	For	Analysis	For	Analysis	For	Analysis	For
	or Bg								
High cloud cover				X	X	X	X	X	X
Medium cloud cover				X	X	X	X	X	X
Low cloud cover				X	X	X	X	X	X
Total cloud cover				X	X	X	X	X	X

## Snow

Parameter	MF	MES CAN (MF)	SUR FEX (MF)	UM/4DVar UM/En4DVar (MO)		COSMO COSMO/En (HErZ/UB)		Harmonie/V1 Harmonie/V2 (SMHI)	
	For or Bg	Ana	For	Analysis	For	Analysis	For	Analysis	For
Water equivalent of accumulated snow depth			X	X	X	X	X	X	X
Accumulated total snowfall				X	X				X
Snow density			X			X	X	X	X
Snow depth			X			X	X	X	X

# Surface levels, Soil

Parameter	MF	MES CAN (MF)	SUR FEX (MF)	UM/4DVar UM/En4DVar (MO)		COSMO COSMO/En (HErZ/UB)		Harmonie/V1 Harmonie/V2 (SMHI)	
	For or Bg	Ana	For	Analysis	For	Analysis	For	Analysis	For
Soil temperature level 1			X (10 cm)	X	X	X	X	X	X
Soil temperature level 2			X (20 cm)	X	X	X	X	X	X
Soil temperature level 3			X (50 cm)	X	X	X	X	X	X
Soil temperature level 4				X	X	X	X		
Volumetric soil water layer 1				X	X	X	X	X	X
Volumetric soil water layer 2				X	X	X	X	X	X
Volumetric soil water layer 3				X	X	X	X	X	X

Volumetric soil water layer 4				X	X	X	X		
Soil water index in the root zone (total and liquid)			X						
Soil water index for the first cm (total and liquid)			X						
Soil water index for 5cm (total and liquid)			X						
Soil heat flux			X						



## Static fields

Parameter	MF	MES CAN (MF)	SUR FEX (MF)	UM/4DVar UM/En4DVar (MO)		COSMO COSMO/En (HErZ/UB)		Harmonie/V1 Harmonie/V2 (SMHI)	
	For or Bg	Ana	For	Analysis	For	Analysis	For	Analysis	For
Land cover (1=land, 0=sea)	X		X	X	X	X	X	X	X
Orography (surface geopot height)	X		X	X	X	X	X	X	X
(Forecast) surface roughness	X		X	X	X	X	X		X



# UERRA user workshop on regional re-analyses

**Where:** Météo France, Toulouse

**When:** 3+4 February, 2016 (noon-noon)

**Topics:**

- Regional re-analyses: qualities and deficiencies
- Sharing experiences and getting advise
- Using uncertainty information
- Evaluation in a user environment; fitness for purpose
- Tips & Tricks & Tools

**Project Website:** [www.uerra.eu](http://www.uerra.eu)



# End

Read more on [www.uerra.eu](http://www.uerra.eu) :

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

Adjoining FP7 Copernicus Projects:  
ERA-CLIM2, CLIPC, QA4ECV, EUCLEIA