

ERA5-Land: A new state-of-the-art Global Land Surface Reanalysis Dataset

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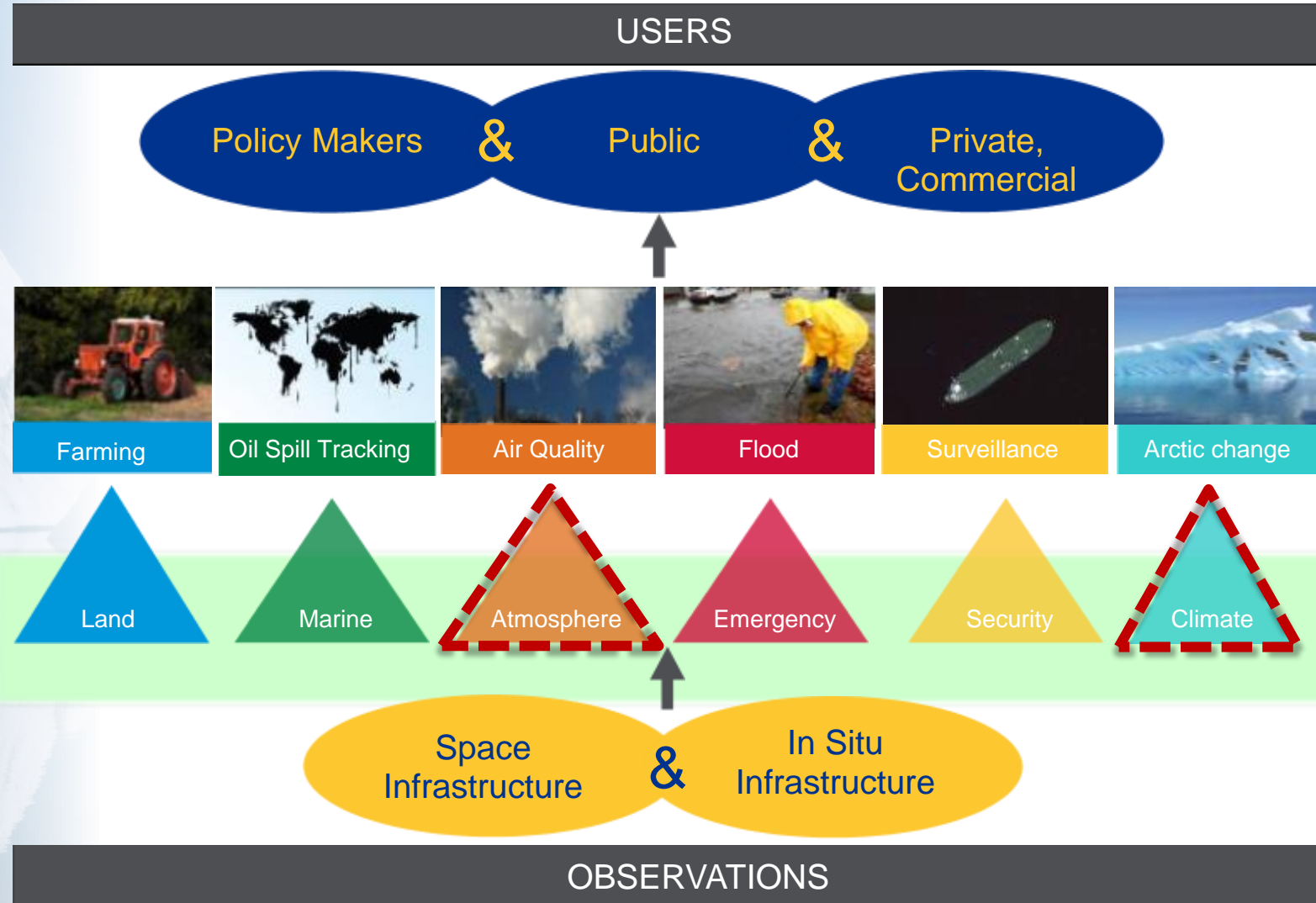
Overview

- Overview of the EU Copernicus Programme and the Climate Change Service
- Introduction to ERA5 reanalysis
- Motivation for a dedicated land-only reanalysis; The ERA5-Land dataset
- Preliminary results based on scout runs
- Future & Summary



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The Copernicus Programme - Services



Different Needs

Examples of areas covered

6 Information Services

Sustainable observation capabilities

ECMWF operates the *Copernicus Climate Change Service (C3S)* and *Copernicus Atmosphere Monitoring Service (CAM5)* on behalf of the European Commission.





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The Climate Change Service (C3S)

The screenshot shows the homepage of the Copernicus Climate Change Service (C3S). At the top left is the Copernicus logo with the tagline "Europe's eyes on Earth" and the C3S logo. To the right are social media icons for Twitter, Instagram, and Facebook, and a "Contact us" button. Below this is a search bar with a "Search" button. A dark red navigation bar contains links for "ABOUT C3S", "NEWS & MEDIA", "EVENTS", "TENDERS", "PRODUCTS", "SERVICES", and "USER SUPPORT". The main banner features a landscape image with a semi-transparent box containing the text "CLIMATE SERVICES FOR YOUR OPERATIONS". Below the banner are three columns: "IN FOCUS" with a "New Job Opportunity" article dated 12 Jan 2017; "MONTHLY MAPS" with a map of average surface air temperatures for December 2016; and "NEWS" with two articles: "Principal Climate Scientist - an exciting new job opportunity at C3S" (12 Jan 2017) and "Report Reassesses Variations in Global Warming" (06 Dec 2016). At the bottom are three boxes for "EVENTS" (13 Nov 2017), "TENDERS" (Deadline 28 Feb 2017), and "PROJECTS" (SWICCA).

*ECMWF operates the **Copernicus Climate Change Service (C3S)** and the Copernicus Atmosphere Monitoring Service (CAMS) on behalf of the European Commission.*

<https://climate.copernicus.eu/>



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ERA5

ERA-Interim is getting old and it is difficult to maintain

ERA5 → New state-of-the-art European Reanalysis, funded within the C3S Copernicus program

- Provides consistent atmospheric, ocean (including waves), cryosphere and land estimates from 1979 to present.
- Land branch: Global estimates of land surface states and surface meteorological forcing
- Higher resolution (~32 km), hourly output, uncertainty estimate.
- Produced in parallel streams
- ERA5 will generate approx. 5 Petabytes of data
- Data is free and accessible, including the observations ingested and how they were used.



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ERA5 Public Release Plan

Recently a two-months *test data set* was made available

- Full resolution, 31km, hourly and 62km-ensemble 3-hourly
- Jan-Feb 2016
- <https://climate.copernicus.eu/climate-reanalysis>

Q2 2017: public release 2010 – 2016

- Includes observation feedback

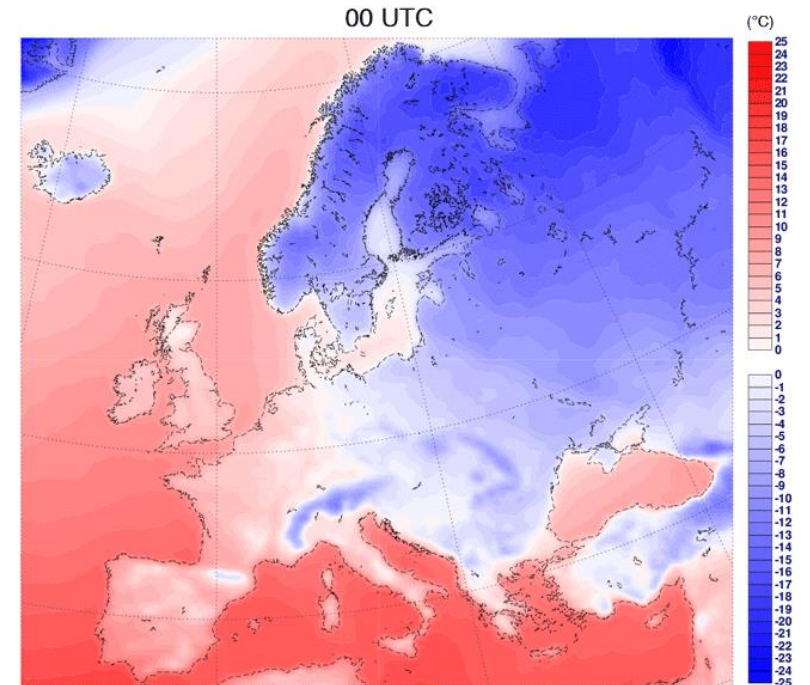
Q3 2017: 2017 – timely updates

- ERA5: Updates with about 2-months delay (final product)
- ERA5T: Updates with short delay (<1 week, preliminary product)

Begin 2018: Release 1979 – 2009:

- Continue ERA5 timely updates
- Continue ERA-Interim for another 6 months

2018: integration of ERA5 back-extension to 1950





Dedicated land reanalysis - added value

- **Motivation for a land-only reanalysis**

- Climate reanalysis does not occur very often.
- Need to bring rapid land model developments to long, consistent time series in a cost-effective way
 - Support hydrological studies addressing global water resources
 - Provide consistent land initial conditions to weather and climate models.
 - Provide dedicated data sets to support and encourage land applications

- **ERA-Interim/Land vs ERA-Interim**

- ❑ **New soil hydrology (Balsamo et al., 2009)**
- ❑ **Snow hydrology (Dutra et al., 2010)**
- ❑ **Vegetation seasonality (Boussetta et al., 2013)**
- ❑ **Bare soil evaporation (Balsamo et al., 2011)**
- ❑ **Precipitation readjustment based on GPCP v2.1**



Dedicated land reanalysis; ERA5-Land added value

ERA-Interim/Land vs ERA-Interim

- ❑ New soil hydrology (Balsamo et al., 2009)
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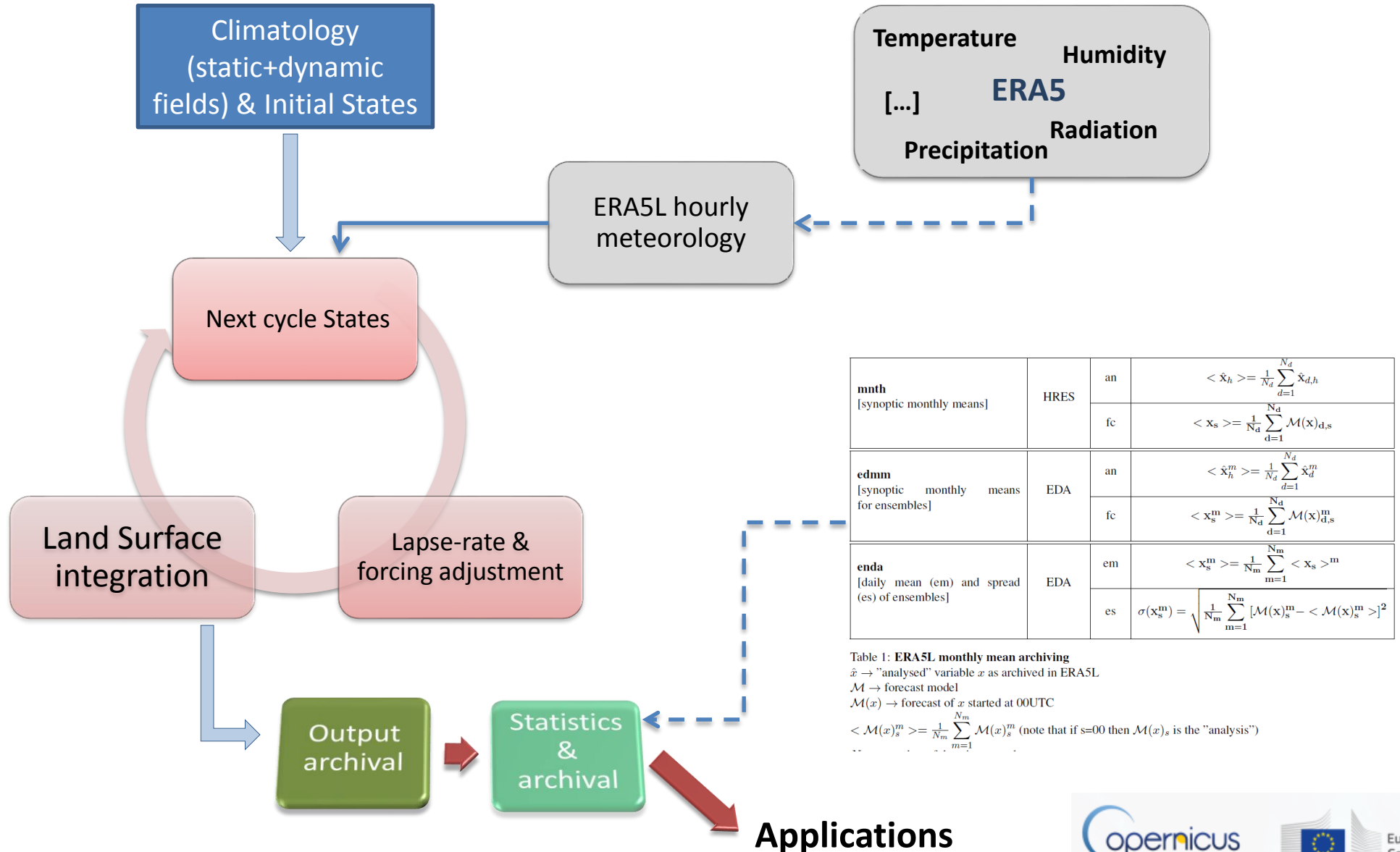
ERA5-Land (v1)

- Single stand-alone reintegration of the land component
- No direct assimilation of observations
- Uncoupled run with the atmosphere
 - ❑ Physics of the IFS in cy43r1 (includes all modelling used in ERA-Interim/Land)
 - ❑ Surface dynamical downscaling (allows capturing details associated to processes as topographic forcing)
 - ❑ Daily lapse-rate correction
 - ❑ Uncertainty estimation based on a 10-member ensemble
 - ❑ More customized data set for users in different economic sectors



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ERA5-Land In a simple diagram



Temperature Humidity
[...] ERA5
Radiation
Precipitation

ERA5L hourly meteorology

Climatology (static+dynamic fields) & Initial States

Next cycle States

Land Surface integration

Lapse-rate & forcing adjustment

Output archival

Statistics & archival

Applications

mnh [synoptic monthly means]	HRES	an	$\langle \hat{x}_h \rangle = \frac{1}{N_d} \sum_{d=1}^{N_d} \hat{x}_{d,h}$
		fc	$\langle x_s \rangle = \frac{1}{N_d} \sum_{d=1}^{N_d} \mathcal{M}(x)_{d,s}$
edmm [synoptic monthly means for ensembles]	EDA	an	$\langle \hat{x}_d^m \rangle = \frac{1}{N_d} \sum_{d=1}^{N_d} \hat{x}_d^m$
		fc	$\langle x_s^m \rangle = \frac{1}{N_d} \sum_{d=1}^{N_d} \mathcal{M}(x)_{d,s}^m$
enda [daily mean (em) and spread (es) of ensembles]	EDA	em	$\langle x_s^m \rangle = \frac{1}{N_m} \sum_{m=1}^{N_m} \langle x_s \rangle^m$
		es	$\sigma(x_s^m) = \sqrt{\frac{1}{N_m} \sum_{m=1}^{N_m} [\mathcal{M}(x)_s^m - \langle \mathcal{M}(x)_s \rangle]^2}$

Table 1: ERA5L monthly mean archiving
 \hat{x} → "analysed" variable x as archived in ERA5L
 \mathcal{M} → forecast model
 $\mathcal{M}(x)$ → forecast of x started at 00UTC
 $\langle \mathcal{M}(x)_s^m \rangle = \frac{1}{N_m} \sum_{m=1}^{N_m} \mathcal{M}(x)_s^m$ (note that if $s=00$ then $\mathcal{M}(x)_s$ is the "analysis")



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ERA5-Land versus other reanalyses

	ERA-Int	Era-Int/Land	ERA5	ERA5-Land
Period covered	Jan 1979 – NRT ^(*)	Jan 1979 – Dec 2010	Jan 1979 - NRT	Jan 1979 - NRT
Spatial resolution	~79km / 60 levels	79 km	~32 km / 137 levels	~9 km
Model version	IFS (+TESSEL)	HTESSEL cy36r4	IFS (+HTESSEL)	HTESSEL cy43r1
LDAS	cy31r1	NO	cy41r2	NO
Uncertainty estimate	-	-	Based on a 10-member 4D-Var ensemble at 62 km	Based a 10-member atmospheric forcing at 31 km
Output frequency	6-hourly Analysis fields	6-hourly Analysis fields	Hourly (three-hourly for the ensemble)	Hourly (three-hourly for the ensemble)



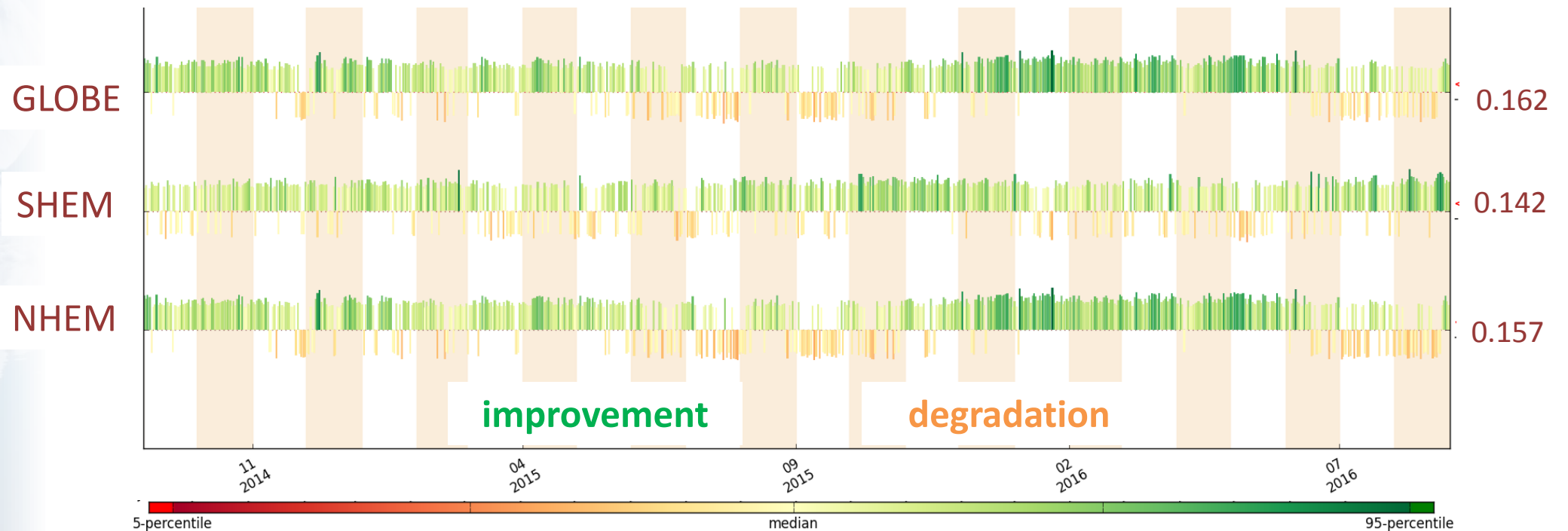
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2 m temperature

- Observations from SYNOP network
- Period: Sept 2014 /to/ Sept 2016

$$\text{abs}[(\text{OBS-FC}^{24\text{h}})_{\text{ERA5}}] - \text{abs}[(\text{OBS-FC}^{24\text{h}})_{\text{ERA5LAND}}]$$

- In general ERA5-Land outperforms ERA5
- South-America, Tropics and Africa obtained the best results
- Seasonal cycle in in Australia → under investigation

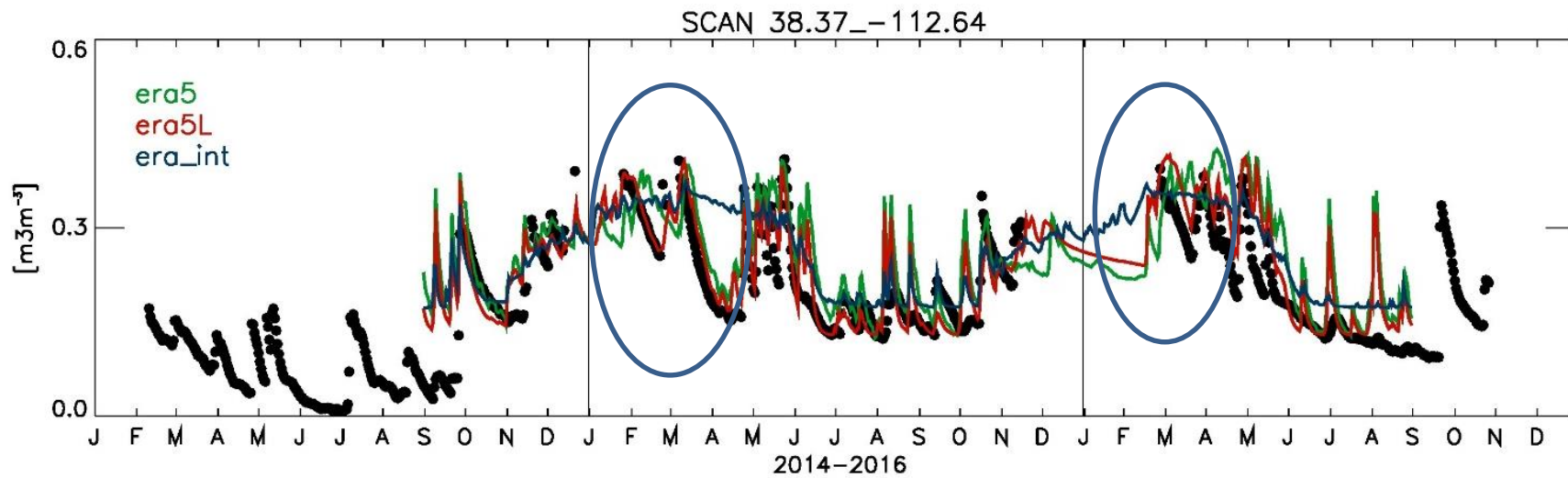
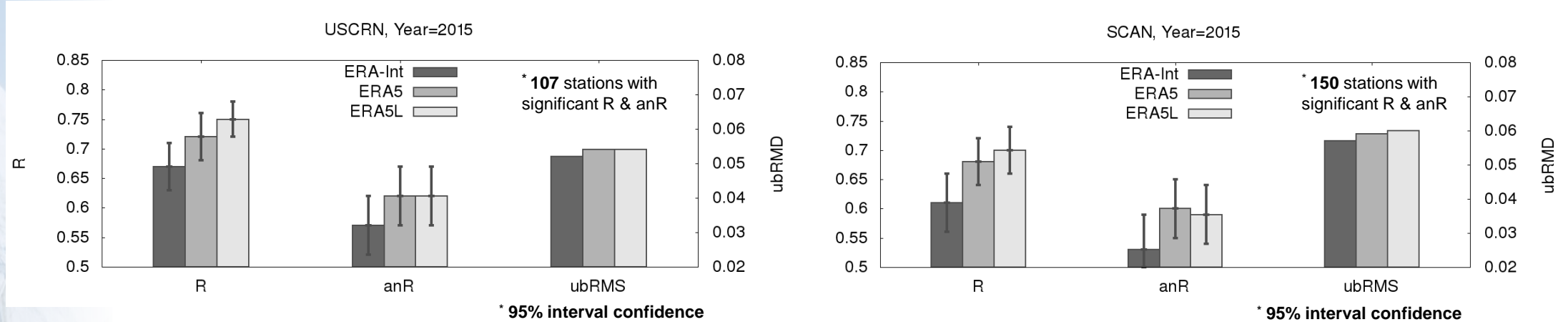




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Soil moisture

Evaluation against in-situ stations from SCAN and USCRN networks (year 2015)

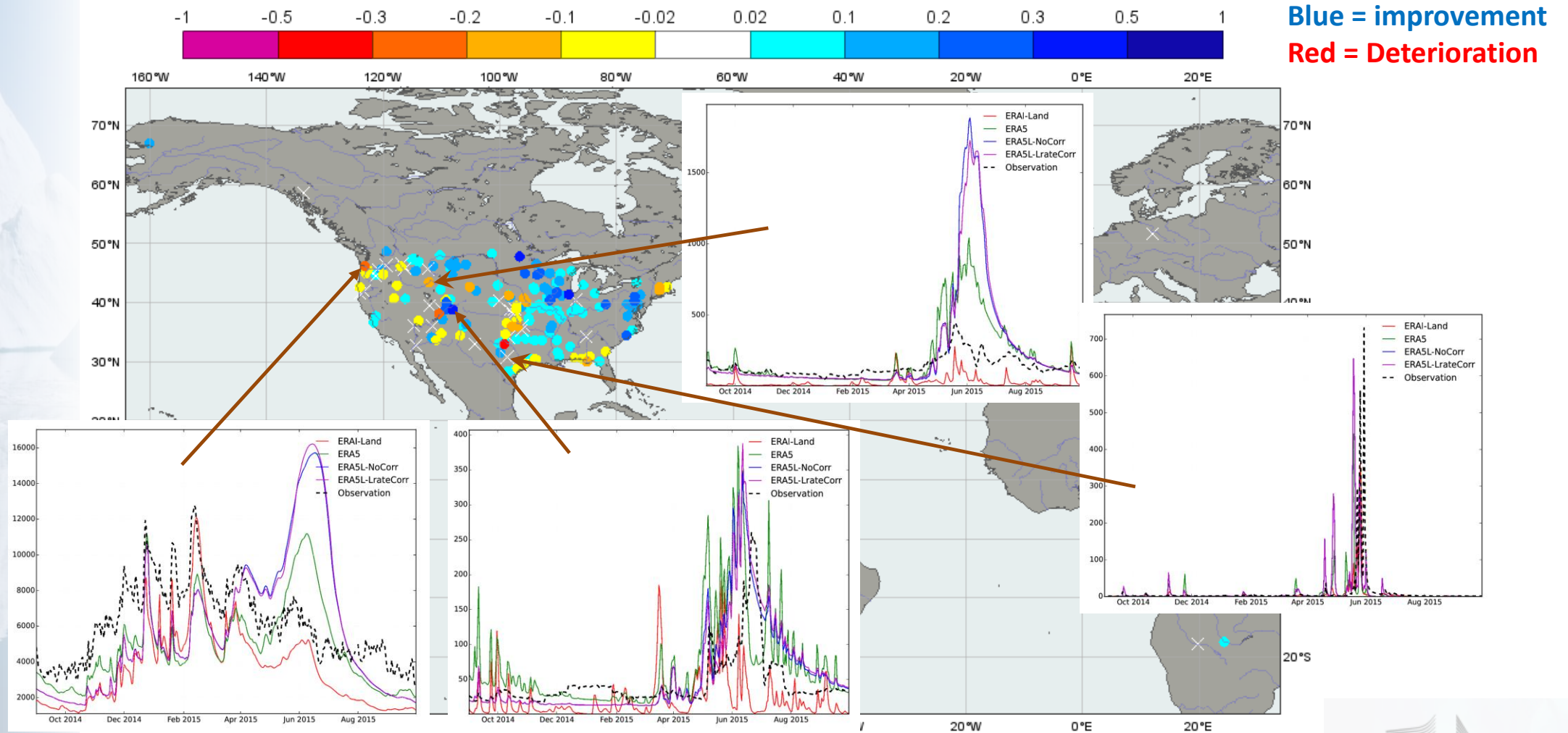




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ERA5/ERA5-Land impact on river discharge

Discharge time series correlation difference ERA5-Land (no lapse rate) vrs. ERA5



- Courtesy of Ervin Zsoter -



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Dedicated land reanalysis ; ERA5-Land (extra-)added value

ERA5L (version 1)

- ❑ Physics of the IFS in cy43r1 (includes all modelling used in ERA-Interim/Land)
- ❑ Dynamic downscaling (allows capturing details associated to processes as topographic forcing)
- ❑ Daily lapse-rate correction
- ❑ Uncertainty estimation based on a 10-member ensemble
- ❑ More customized data set for users in different economic sectors

ERA5L (future versions)

- ❑ Precipitation correction
- ❑ Post-processing of carbon fluxes with BFAS
- ❑ Enhanced ensemble spread through additional perturbations
- ❑ Increased vertical discretization to 10 layers
- ❑ Coupled to an offline data assimilation system



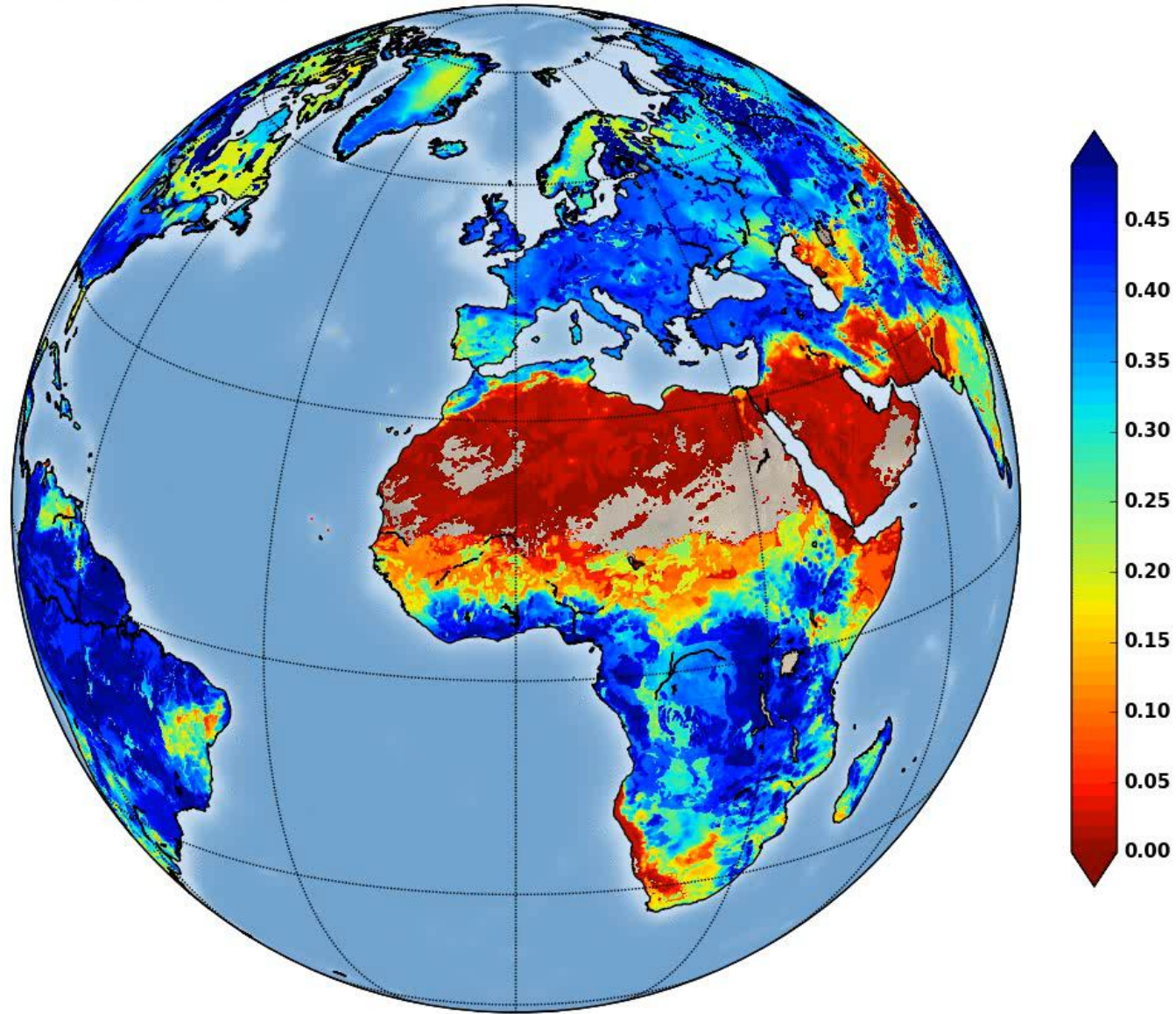
Final remarks

- ERA5-Land is part of ERA5 dedicated-focus reanalysis (ocean, land, chemistry, etc.) and not a separate initiative, therefore will cover the entire duration of ERA5 (e.g. 1950 onwards).
- ERA5-Land is a Copernicus operational product following closely near-term climate (with a short delay) and not only a research product (like was the case for ERA-Interim/Land which a first exploratory land reanalysis, discontinued after 2010).
- ERA5-Land is using methodologies developed by ERA-Interim/Land but has a new concept being the HRES adaptation
 - via a cost-effective resolution enhancement,
 - with the main benefit coming from surface description at a finer grid and a thermodynamic orographic adjustment.
- ERA5-Land does not benefit from the assimilation of surface observations, yet



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01 Apr 2015 00UTC



Thank you!

ERA5-Land (~9 km)