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Prototype of a high resolution regional reanalysis for Iberian Peninsula an Balearic Islands (IBERA)

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Introduction/Motivation

AEMET has developed a prototype to produce a regional reanalysis for the Iberian Peninsula and Balearic Islands, called IBERA.

The goal is to test its added value compared to other existing reanalysis at global scale (ERA5, 33km) or European scale (UERRA, 11km; UERRA-MESCAN, 5.5km). Apart from the higher resolution (2.5km) there are potential advantages associated to a regional reanalysis. Among them, a better tuning of the HARMONIE-AROME system: to reduce the model biases, to better represent regional effects in error statistics used by the analysis systems and to increase the number of assimilated data. In this work the methods used and some preliminary results are briefly shown. A similar reanalysis was performed for Ireland with very good results (Gleeson et al., 2017)

Reanalysis setup

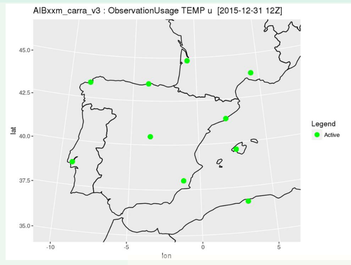
The system is based on the HARMONIE configuration developed for the Copernicus Artic Reanalysis CARRA, carra.beta.2 version which is based on HARMONIE-AROME cy40h1.1. The main modifications introduced for Iberian Peninsula reanalysis are:

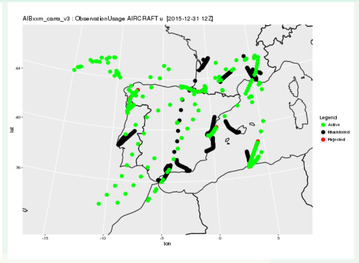
1. **Linear grid at 2.5 km resolution and 65 vertical levels**
2. **SURFEX with 1 patch and Stable Boundary Layer disabled**
3. **Orographic parameterization OROTUR included**
4. **Large Scale Mixing of humidity from the host model in the Fg**
5. **3DVAR background error covariances have been calculated**
6. **Canari structure functions have been tuned and 10m wind analysis has been activated in this surface analysis**

IBERA is driven by ERA5 analysis fields as boundaries every hour. The HARMONIE system is complemented by an offline modified HIRLAM SPAN surface analysis to analyse tmax/tmin and 24-hr precipitation.

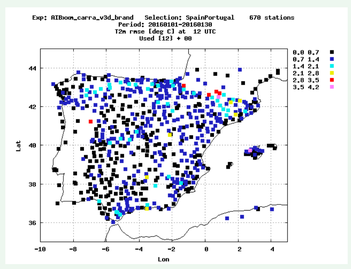
Observations used

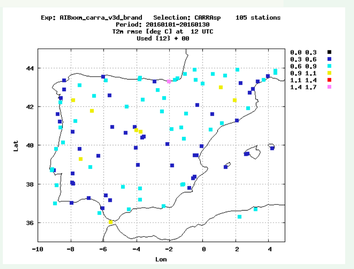
In this IBERA prototype only conventional observations are assimilated by the 3DVar analysis from radiosondes, aircraft, and sea and land surface reports. Large scale information from ERA5 analysis is introduced every 3h with the Large Scale Mixing with ERA5 (LSMIXBC activated).



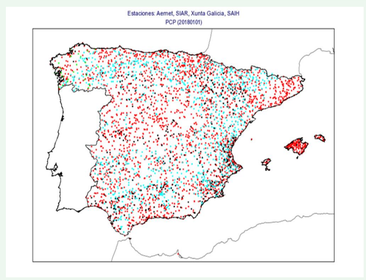


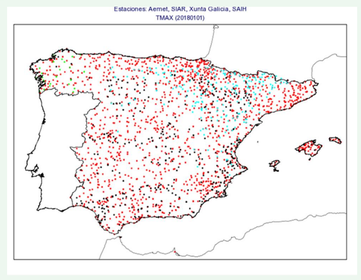
Distribution of upper observations used





However the number of SYNOPs (left) has been substantially increased from the ERA5 observations archived at the ECMWF MARS (right). These data are assimilated by the 3DVAR system (ps, 10m wind) and by the CANARI surface analysis (t2m, rh2m).

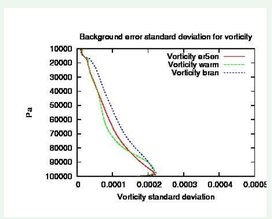


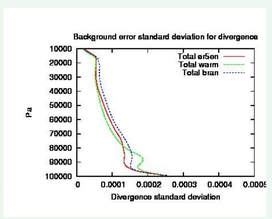


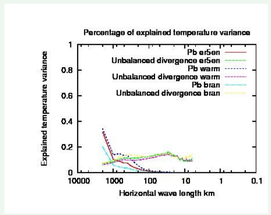
SPAN analysis for precipitation and daily extreme temperatures assimilates observations from the AEMET high resolution climate stations network (red points) and observations from other external networks operated by different Spanish institutions are used for validation (blue, black and green points). These obs. may be assimilated as well in the future.

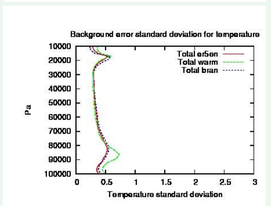
BG error statistics for 3DVar

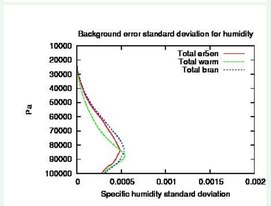
B matrix representing background error covariances for 3DVar, has been calculated in two steps. The first one obtains a B matrix based in a "*downscaled B*" method (ERA5ENDA). ERA5ENDA is then used to create B matrix finally used by IBERA following the BRAND approach (Bojarova and Gustafsson, 2019).

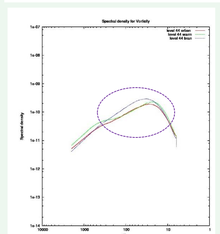












Both B-Matrices are calculated using an ensemble of short-range HARMONIE-AROME model forecasts. The main differences are:

ERA5ENDA method uses a four member ensemble obtained with a dynamical downscaling of 4 ERA5 global ensemble data assimilation members.

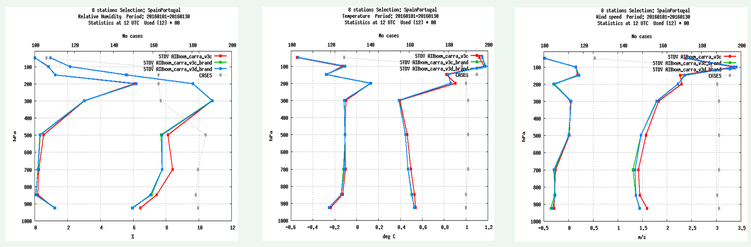
BRAND method uses a 10 member ensemble whose control member is a high resolution 3DVAR and the rest of members are constructed by stochastic perturbation of the analysis control variables in state space. Boundary conditions for this ensemble come also from ERA5 global ensemble.

Figures to the left compare background error covariances obtained with both methods. A previously calculated B obtained through dynamical downscaling of the operational IFS ensemble data assimilation over a different period is also presented (labelled as "warm").

B-BRAND:

- ✓ **higher background error std values.**
- ✓ **larger amplitude of spectral densities at the mesoscale.**
- ✓ **less balanced background errors of different variables.**

Obsfit to the analysis using different B matrices



The Blue and green experiments that use B-BRAND are closer to observations than the red experiment that is based on B-ERA5ENDA. This is consistent with the fact that the background error is higher for B-BRAND than for B-ERA5ENDA.

CANARI and SPAN error statistics

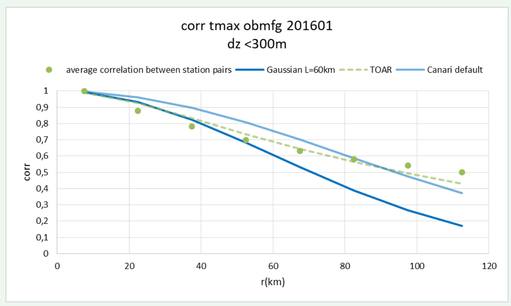
In this IBERA reanalysis prototype, error statistics used by the two surface analysis packages employed (CANARI for 3 hourly t2m and rh2m, and SPAN for daily tmax, tmin and precipitation) have been tuned. Hollingsworth and Lönnberg method is used to calculate structure functions from time series of innovations (ob-fg). The first guess errors autocorrelation model in CANARI is a Gaussian function. In case of SPAN, for daily extreme temperatures and precipitation, a combination of two different scale Third Order Autoregressive functions (TOAR) is used to represent the error's dependence on the horizontal distance. SPAN structure functions are also anisotropic to take into account topographic effects.

CANARI error statistics

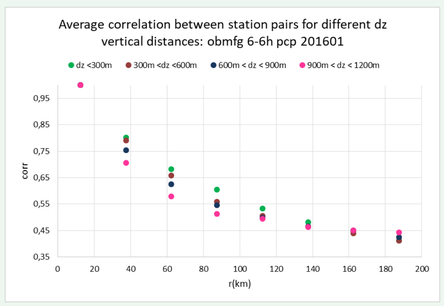
t2m	Default settings	Tuned parameters
L (km)	80	60
Eb(K)	1,6	1,6
E0(K)	1,4	1,2

rh2m	Default settings	Tuned parameters
L (km)	85	60
Eb(%)	18	9
E0(%)	10	6

Tuned structure functions for CANARI are sharper than the default ones. The first guess to observation errors ratio has been also modified.



Upper figure shows the fit of the two autocorrelation models to the empirical correlation found between first guess errors of maximum temperature for stations pairs at different classes of horizontal distance



Upper figure displays the empirical correlations found for first guess errors of 24h accumulated precipitation for stations pairs horizontal distances at different vertical displacement intervals

Analysis of Extreme Temperatures and 24-hr precipitation

Background: The SPAN analysis runs regularly at AEMET to produce 24h precipitation and daily extreme temperatures gridded data at 5.5km resolution assimilating all observations from its climate stations network (Peral et al., 2017). Time series of this SPAN analysis starts in 1951 and lasts until the current year.

SPAN analysis			Obs fit to Fg			Obs fit to analysis		
Param	Resol km	Fg	Bias omf	STD omf	R (ob,fg)	Bias oma	STD oma	R (ob,an)
6-6h ppt	5.5	clim				-0.1 mm	3.5 mm	0.84
6-6h ppt	5.5	MESCAN rean	0.0 mm	5.5 mm	0.71	0.0 mm	3.1 mm	0.91
6-6h ppt	2.5	HARM fo	0.3 mm	5.9 mm	0.69	0.0 mm	3.2 mm	0.91
Tmax	5.5	clim	3.2K	3.1K	0.7	0.0K	1.5K	0.94
Tmax	2.5	HARM fo	0.9K	1.7K	0.92	0.0K	1.2K	0.96
Tmin	5.5	clim	0.5K	3.4K	0.62	0.0K	1.9K	0.89
Tmin	2.5	HARM fo	-0.3K	2.1K	0.86	0.0K	1.5K	0.93

Fit to the First Guess/Analysis by 3250/1600 rain/temperature obs. assimilated

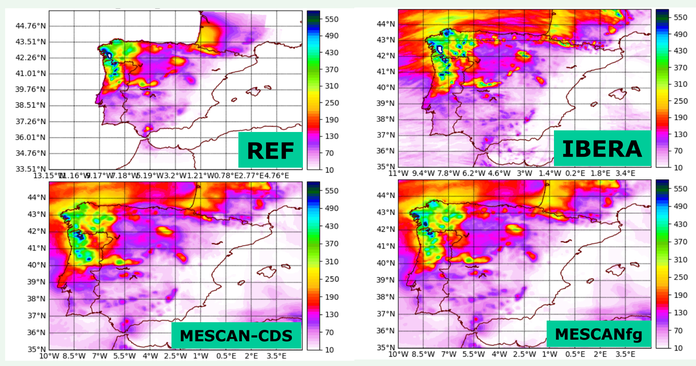
SPAN analysis			Validation against independent obs		
Param	Resol km	Fg	R (ob,an)	STD	Bias
6-6h ppt	5.5	clim	0.85	3.6mm	0.3mm
6-6h ppt	5.5	MESCAN rean	0.87	3.2mm	0.3mm
6-6h ppt	2.5	HARM fo	0.88	3.2mm	0.2mm
Tmax	5.5	clim	0.94	1.4K	0.1K
Tmax	2.5	HARM fo	0.97	1.1K	0.1K
Tmin	5.5	clim	0.89	2.1K	0.9K
Tmin	2.5	HARM fo	0.92	1.8K	0.8K

Assessment of the SPAN analyses using 1200/500 rain/temperature independent observations from AEMET external networks

SPAN 24-hr precipitation analysis applied to different first guess fields (test period January 2016):

- Climatological information (REF)
- HARMONIE IBERA forecasts (IBERA)
- UERRA-MESCAN reanalysis (MESCANfg). Note that this reanalysis does not assimilate the high resolution rain gauge data over Spain

First guess error statistics were tuned separately for the different background fields



Maps above show the accumulated precipitation over January 2016 produced by the SPAN analysis assimilating the same high resolution set of observations and using the different first guesses. The original UERRA-MESCAN reanalysis archived at the Copernicus Climate Data Store is also shown (MESCAN-CDS). Greater detail structures appear in the product based on HARMONIE IBERA. Note that the main differences occur at mountain areas and at Northwestern Spain, the most rainy area this month.

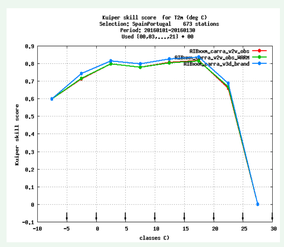
Assessment

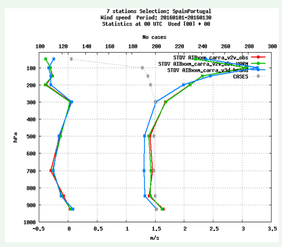
Impact of warm-up and of different background error statistics

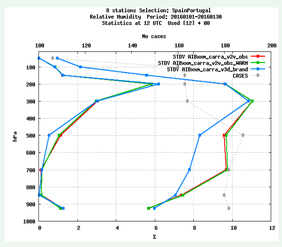
Test period: **January 2016**
Reanalysis experiments:

- Red: Standard Jb without a warmup period
- Green: Standard Jb with a warmup period of 4 months
- Blue: Retuned Jb for the reanalysis and warmup period of 4 months

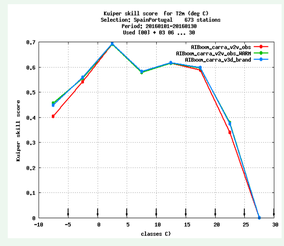
Obsfit to the analysis

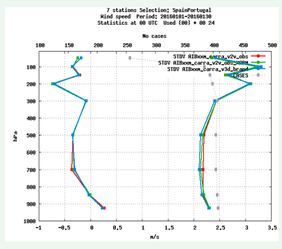


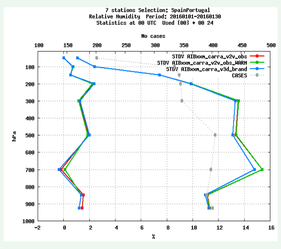


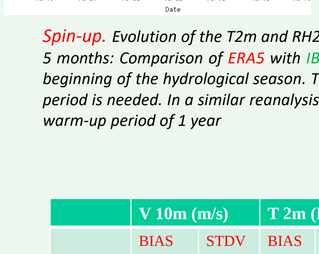


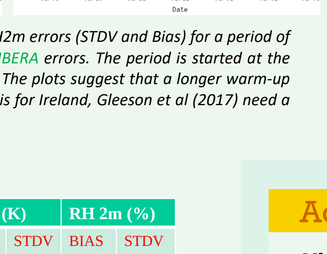
Forecast impact



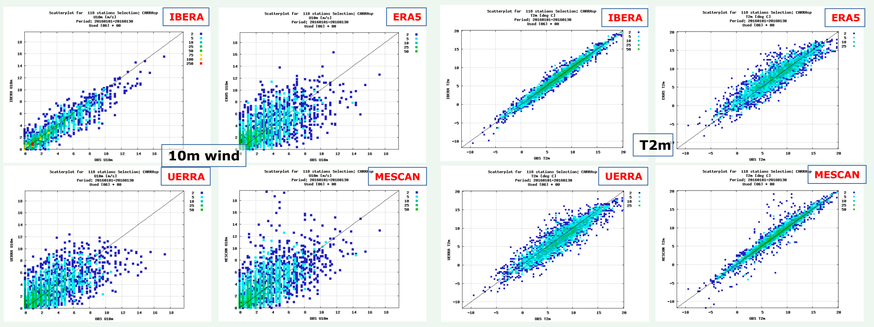








Spin-up. Evolution of the T2m and RH2m errors (STDV and Bias) for a period of 5 months: Comparison of ERA5 with IBERA errors. The period is started at the beginning of the hydrological season. The plots suggest that a longer warm-up period is needed. In a similar reanalysis for Ireland, Gleeson et al (2017) need a warm-up period of 1 year



Closer fit of IBERA to observations compared with other reanalysis

	V 10m (m/s)		T 2m (K)		RH 2m (%)	
	BIAS	STDV	BIAS	STDV	BIAS	STDV
ERA5	0,37	1,00	0,04	1,75	-0,18	9,48
UERRA	0,09	1,97	-0,35	1,58	-0,47	9,94
IBERA	-0,16	0,91	-0,01	0,70	-0,56	3,82

Overall performance compared to other Reanalysis. Test period: January 2026. HARMONIE-AROME IBERA seems to have a clear added value compared to other reanalysis. Note that here we are not using an independent set of obs in the verification: the obs. entered in all the reanalysis.

Acknowledgements

Xiaohua Yang (DMI) has given support to different tasks of this work. Rain gauge and daily extreme temperatures observations used for the assessment of this prototype come from three external Spanish institutions: **D.G. Water and River Basin Authorities, D.G. for Rural Development, Innovation and Agrifood Training (Ministry for Agriculture, Fisheries and Food), and Xunta de Galicia.**

Conclusions

- **AEMET has developed a prototype to produce a regional reanalysis for the Iberian Regional Reanalysis at 2.5 km resolution (IBERA).**
- **It is based on HARMONIE-AROME cycle40h1 in a similar configuration to the CARRA reanalysis but only using conventional observations.**
- **The system benefits from the possibility to reduce model biases for the region, an increased number of surface observations and a better representation of regional effects in error statistics used by the analysis.**
- **The system is enhanced with an off-line surface analysis, SPAN, specially tuned to analyse precipitation and extreme temperatures.**
- **The preliminary tests performed show a clear added value compared to other available reanalysis over the region.**

References

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