Anonymous Referee #1:

Received and published: 19 July 2019

Review of "Iberia01: A new gridded dataset of daily precipitation and temperatures over Iberia"
This paper presents a gridded climatological data product for the Iberian peninsula called "Iberia01" which appears to be a revision of a previous data product called "Spain02", using the same station network and interpolation methods, except including "orography" (elevation?) as covariate in the thin-plate spline step. Iberia01 is compared against a standard (E-OBS), finding more or less similar predictions except in some specific locations for specific climate variables. For precipitation it is found that the higher-resolution Iberia01 predictions show more small-scale variation than the coarse E-OBS product, at least in the case of a specific major precipitation event. The construction and integrity of the dataset appear to be well-done overall, although much of the methods refer to a previously published paper by the same authors. The figures are well-done as well. As a presentation of a new dataset, I think this paper should suffice (with some major revisions, clarifications, etc), although it is not clear whether any of the techniques or analyses are particularly novel.

Interactive comment on Earth Syst. Sci. ***Data Discuss., https://doi.org/10.5194/essd-2019-95, 2019.***

specific lines referenced as (pg:line)

Response: We thank the reviewer for the comments and the time devoted to our paper. Please, see below our point-by-point responses and the changes highlighted as tracked changes in the new version of the manuscript.

Major Issues:

None of the links (p11: 4-6) to the data worked for me. The first sent me to a generic landing page in Portuguese. The second sent me to a site where the data was embargoed and required a login account. The third sent an error message. I assume based on the R code that the third access point requires authentication with Santander and requests via a specialized R function. The AEMET link (pg 10) sent me to another landing page where it was unclear how to find the dataset. Either way, I could not access the data.

Response: We thank the referee for point out this comment. First, the embargo was established in order to prevent the use of the dataset before the publication of the corresponding reference. We have requested to avoid the embargo of the dataset in order to make it publicly available. Second, although this will be the main access point, we are trying to give access to the dataset also through the National services referred in the paper, IPMA and/or AEMET.

The authors state that the E-OBS dataset is taken as a benchmark (4:7) but later claim that the dataset is biased for key variables (6:22). It is not clear in the methods how this assessment is made or quantified.

Response: As the referee has pointed out, E-OBS was defined as benchmark in the current version of the manuscript cause this dataset is considered the reference at European scale. However, as has been reflected in several studies (Belo-Pereira et al. 2011; Turco and Llasat 2011; Flaounas et al. 2012; Herrera et al. 2012 and 2016; Turco et al. 2013; Prein and Gobiet 2016), at national or regional scale E-OBS presents some known biases, mainly in regions with complex orography and/or with low stations' density. To quantify the differences of the spatial pattern for each parameters the following table has been included in the manuscript reflecting several verification parameters considering the nearest grid box of each dataset to the local station observations. In addition, the text has been rewritten accordingly.

Iberia01	**tas**	**RV50Yt**	**pr**	**RV50Yp**	**RR1**
MAE	0.5404	1.6162	0.2888	20.1838	11.2783
BIAS	-0.2099	-1.3145	0.0881	-17.8175	11.2763
RMSE	0.8902	2.9837	0.5651	28.1075	13.6863
Correlation	0.9422	0.7319	0.8496	0.8623	0.4304
E-OBS v17	**tas**	**RV50Yt**	**pr**	**RV50Yp**	**RR1**
MAE	0.8212	2.6219	0.4288	42.4205	10.0718
BIAS	-0.2603	-2.1310	-0.2703	-42.2184	9.9931
RMSE	1.1530	3.9377	0.7510	54.2519	12.5221
Correlation	0.8931	0.5403	0.7508	0.5891	0.4297
E-OBS v17e	**tas**	**RV50Yt**	**pr**	**RV50Yp**	**RR1**
MAE	0.8260	2.6720	0.4357	46.9555	11.4778
BIAS	-0.3341	-2.3033	-0.3021	-46.7663	11.4641
RMSE	1.1811	4.0530	0.7600	58.0514	13.7543
Correlation	0.9047	0.5365	0.7560	0.5659	0.4374

***Table 1:** Comparison between the spatial pattern of the different gridded datasets against the observations for the indices considered.*

Belo-Pereira, M., Dutra, E., and Viterbo, P.: Evaluation of global precipitation data sets over the Iberian Peninsula, Journal of Geophysical Research: Atmospheres, 116, 1–16, doi:10.1029/2010JD015481, 2011.

Flaounas, E., Drobinski, P., Borga, M., Calvet, J.-C., Delrieu, G., Morin, E., Tartari, G., and Toffolon, R.: Assessment of gridded observations used for climate model validation in the Mediterranean region: the HyMeX and MED-CORDEX framework, Environmental Research Letters, 7, 024 017, doi:10.1088/1748-9326/7/2/024017, 2012

Herrera, S., Gutiérrez, J. M., Ancell, R., Pons, M. R., Frías, M. D., and Fernández, J.: Development and analysis of a 50-year high-resolution daily gridded precipitation dataset over Spain (Spain02), International Journal of Climatology, 32, 74–85, doi:10.1002/joc.2256, 2012.

Herrera, S., Fernández, J., and Gutiérrez, J. M.: Update of the Spain02 gridded observational dataset for EURO-CORDEX evaluation: assessing the effect of the interpolation methodology, International Journal of Climatology, 36, 900–908, doi:10.1002/joc.4391, 2016.

Prein, A. F. and Gobiet, A.: Impacts of uncertainties in European gridded precipitation observations on regional climate analysis, International Journal of Climatology, pp. n/a–n/a, doi:10.1002/joc.4706, 2016.

Turco, M., Zollo, a. L., Ronchi, C., De Luigi, C., and Mercogliano, P.: Assessing gridded observations for daily precipitation extremes in the Alps with a focus on northwest Italy, Natural Hazards and Earth System Science, 13, 1457–1468, doi:10.5194/nhess-13-1457-2013, 2013.

Turco, M. and Llasat, M. C.: Trends in indices of daily precipitation extremes in Catalonia (NE Spain), 1951-2003, Natural Hazards and Earth System Science, 11, 3213–3226, doi:10.5194/nhess-11-3213-2011, 2011.

It would be nice to provide some ideas explaining the specific deviations (e.g. along the coast) between Iberia01 and E-OBS in the discussion.

Response: *We have included a paragraph discussing this point a pointing out to possible reason of the observed differences between both datasets:*

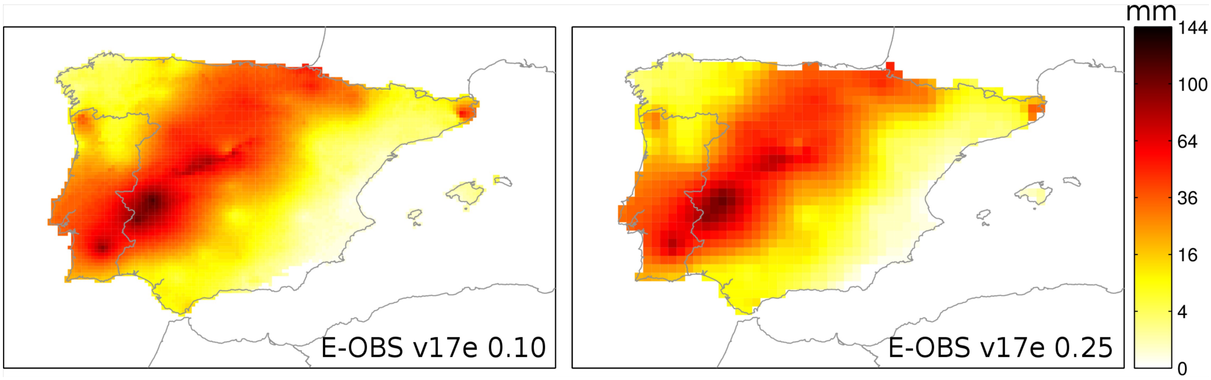
“Note that the complex orography and the influence of both the Atlantic Ocean and the Mediterranean Sea modulate the precipitation over the Iberian Peninsula, leading to particular regimes, as the cold drop in the east coast, that a continental adjustment of the interpolation model is not able to reproduce, even more when a low-dense observational network is considered. In this sense, the large increase of rain gauges considered in Iberia01, when compared with E-OBS, give rise to a much improved precipitation rendering. In the case of temperature, although the observational network considered is similar in both cases, the pattern tends to be more orographic in E-OBS v17 due to the continental adjusment of the interpolation method that overrates this component avoiding regional behaviors. In addition, the contribution of the obersvational network considered in France also has a clear effect on the interpolated value over the Pyrennes and the northeast of the Iberian Peninsula.”

The assessment of resolution for the convective rain event is unsatisfying. First, why do the authors present the 20 km product (v17) and not the 10 km product (v17e) for E-OBS, which seems like a much better comparison?

Second, the authors claim that the difference in resolution for Iberia01 10 vs 3 km resolution does not matter, but this is not quantitatively examined or explained in any way. Are the authors using gestalt, I assume?

Response: *Following the referee's comment we have updated the figure including the high-resolution version of E-OBS (~10 km) but, as can be seen in the following figure, the conclusions have not changed.*

Figure: *Comparison between both resolutions of the E-OBS v17e dataset.*



In addition, we have obtained several parameters to compare the different datasets and resolutions. Table 2 shows the results of the comparison against the observations reflecting that the new dataset performs better than E-OBS v17 for all the parameters considered.
To evaluate the effect of the resolution we have compared both resolutions of each dataset considering the same parameters.

Measure	Iberia ~3 km	Iberia ~10 km	E-OBS v17 ~25 km	E-OBS v17e ~10 km
MAE	3.3861	4.8142	11.0998	10.9936
BIAS	0.2352	0.7046	-1.7382	-1.4243
RMSE	6.5430	8.9360	19.0300	18.7614
Correlation	0.9746	0.9522	0.7625	0.7691

***Table 2:** Comparison between the spatial pattern of the different gridded datasets against the observations.*

To evaluate the effect of the resolution we have compared both resolutions of each dataset considering the spatial pattern and his statistical distribution. In both cases, the Pearson correlation is greater than 0.98 and statistically significant at 95% of significance. Moreover, the hypothesis test applied to compare the mean and the variance of the spatial patterns reflects that both resolutions come from a distribution with the same mean and variance.

Measure	Iberia ~3 km	Iberia ~10 km	E-OBS v17 ~25 km	E-OBS v17e ~10 km
Correlation	0.9855		0.9912	
H (mean)	0		0	
H (std)	0		0	

***Table 3:** Comparison between the spatial pattern of the different resolutions considered to analyse the effective resolution of the gridded datasets.*

When both E-OBS v17 and Iberia gridded dataset are compared in terms of spatial correlation, the Pearson coefficient falls to 0.77-0.78, depending on the resolutions considered, reflecting that E-OBS v17 is not able to reproduce the spatial pattern and that the effective resolution of both datasets is 0.1º and 0.25º for Iberia and E-OBS v17, respectively.

There are numerous grammatical errors, run-on sentences and awkward phrasings throughout. I have noted some below, but not all. The writing is good in terms of logic, but needs a careful proofread (possibly by a native English speaker) before it is publishable.

Response: *We have revised the text following the referee's comment.*

The methods frequently refer to Herrera 2011, 2012. However, more brief descriptions of these methods would be helpful, such as the QC protocols.

Response: *We have extended the description of the quality control procedure in the new version of the manuscript. In addition, two files, one for precipitation and other for temperature, reflecting the observational networks used to build the gridded dataset and their main properties in terms of missing data have been included in the server distributing the dataset.*

Minor Issues:

Where did the 'orography' dataset come from? Isn't this just elevation?

Response: *We have considered the orography given by the Global Digital Elevation Model (GTOPO30) which provides gridded 30 arc seconds (~1 km) elevation for the world (http://webhelp.esri.com/arcgisdesktop/9.3/index.cfm?TopicName=Global_Digital_Elevation_Model_(GTOPO30)).*

The R code (pg 11, line 10) Seems to only calculate and visualize climatologies but doesn't actually do any direct comparisons.

Response: *We agree with the referee and we have clarify this point in the text.*

(6:10) How exactly?

Response: *We have rewritten the sentence to clarify this point and included the corresponding Table with the results:*

"We use this event as an illustrative case study in order to analyze the potential benefits provided by a 3 km gridded version of Iberia01, as compared with the standard 10 km resolution, in terms of the spatial (Pearson) correlation, and the comparison of the mean and variance of the spatial patterns through the Student's t-test and Snedecor's F-test, respectively, for two samples, corresponding to the low- and high-resolution versions of both E-OBS and Iberia01 gridded datasets."

paragraph (6:29ff) move to methods

Response: *We have modified the manuscript accordingly and included this paragraph at the end of the section "E-OBS Gridded Datasets (v17 and v17e)".*

(6:30): "can be considered a realization of" seems like an awkward way to phrase it. Why not 'differs significantly from'?

Response: *We have modified the sentence accordingly.*

(7:2) "thus questioning" – Move interpretations like this to the discussion and flesh them out. I would tend to disagree with this statement as stands.

Response: *We have modified the sentence accordingly.*

Technical issues:

Please remove "In order" from all sentences beginning with "In order to", as this is redundant.

Response: *We have modified the manuscript accordingly.*

(1:9) Run on sentence

Response: *We have rewritten the sentence accordingly:*

"Finally, the possibility to increase the resolution of the dataset using the same interpolation approach is analyzed considering an extreme event of convective precipitation affecting the Iberian Peninsula and the auxiliary very high resolution grid (0.01º), built during the interpolation process to obtain the area-average representativity of the final dataset."

(1:11) omit "As a result"

Response: *We have modified the sentence accordingly.*

(1:15) rephrase

Response: *The paragraph has been completely reformulated:*

"We show that Iberia01 produces more realistic patterns than E-OBS v17 in the case of precipitation for all the indices considered, although both are comparable for temperatures. These differences were assessed using a probabilistic approach based on the E-OBS ensemble. For precipitation, significant differences ---at a 10% level--- between both datasets were found for less than 25% of days over the Iberian Peninsula. For temperature, a very inhomogeneous pattern was obtained, with either a small (in most of the regions) or large fraction of significantly different days. The great uncertainty of the precipitation given by E-OBS ensemble, in which the standard deviation of the ensemble has the same order than the mean value, increases the significance of the results obtained for this variable reflecting the differences between both datasets."

(2:6) expands -> includes

Response: *We have modified the sentence accordingly.*

(2:11-12) reference for this assertion?

Response: *We have included the citation's number of E-OBS in Scopus (1491 citations, in contrast with the 182 of Spain02 (Herrera et al. 2012) and the 94 of PT02 (Belo-Pereira et al. 2011)) in order to justify the assertion. In addition, we have modified the sentence to better clarify its meaning:*
"With more than 1490 citations in Scopus (at August 2019), this is the most used climate reference for European climate studies (e.g. in the Iberian Peninsula, Spain02 and PT02 have more than 180 and 90 citations, respectively)"

(2:14) omit 'the'

Response: *We have modified the sentence accordingly.*

(2:19) 'smooths' awkward term here

Response: We have rewritten the sentence accordingly: *"... , a reduction in the density of stations decreases the variability of both precipitation and temperature with large implications in the representation of extremes."*

(3:6) include 'and' between citations

Response: *We have modified the sentence accordingly.*

(3:15) Run on sentences

Response: *We have modified the sentence:*

"Furthermore, the 0.2º resolution of the Portuguese grid is too coarse for regional climate studies. On the other hand, the lack of temperature grids also hinders a comprehensive analysis of the large inter-annual and spatial variability, characteristic of the Iberian climate. These problems could be solved building a joint grid, using observational station data from both countries."

(3:20) Is this really the first? Seems like there are others, referenced in the same sentence (PT02)

Response: *The Iberia01 dataset is the first gridded dataset built over the Iberian Peninsula, not focused on a greater domain as E-OBS, and reaching the proposed spatio-temporal resolution. Other products have a greater spatial resolution but contain only climatologies or are limited to particular regions of the Iberian Peninsula. We have rewritten the sentence to clarify this point:*

"This represents the first gridded dataset of daily precipitation and temperatures focused on Iberia, and can be considered an update of the PT02 dataset."

(4:8) Replace 'first dataset', 'this one' etc with specific title of each. Confusing

Response: *We have modified the sentence accordingly.*

(5:10) "temperature was built"

Response: *We have modified the sentence accordingly.*

(6:6) Run on sentence

Response: *We have modified the sentence accordingly:*

"To test this possibility, an illustrative example is considered: a convective high-resolution extreme precipitation event occurred on 4-5 November 1997, and characterized by heavy precipitation over most of the Iberian Peninsula."

(6:13) How were clims aggregated?

Response: The climatologies have been obtained averaging the annual values of the indices (tas, pr and RR1). In the case of the 50-years return value the index is representative of all the period, so it is its own climatological value.

(6:14) "the main differences being"

Response: *We have modified the sentence accordingly.*

(6:29) "we used"

Response: We have modified the sentence accordingly.

(9:7) on -> of

Response: We have modified the sentence accordingly.

(9:28) and (9:30) – these sentences are both difficult to understand.

Response: We have modified the sentence accordingly.

“In the case of precipitation (Figure 3, first row), the percentage of outliers considering only the wet-days ranges between 5% and 25% along the Peninsula. For temperatures (Figure 3, second to fourth rows), most of the area shows percentages less than 5% of outliers, with only some regions previously identified (Guadalquivir basin, Pyrenees, etc.) presenting values larger than 50%-60%. In summary, although in most of the domain the temperatures given by Iberia01 are included within the ensemble defined by E-OBS v17e, there are several regions with significant differences that should be considered/treated with caution. Moreover, in the case of precipitation both datasets present significant differences that should be taken into account.”

The sentence “These results are in agreement with the quantile distribution, with the temperature centered around the median, with some underestimation/overestimation in the case of the minimum/maximun temperatures, and the precipitation showing a clear overestimation of the quantiles that increases dramatically when only wet-days are considered.” made reference to a figure that was removed from the final version of the paper, so we have removed also the sentence in the new version of the manuscript.

Iberia01: A new gridded dataset of daily precipitation and temperatures over Iberia

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Abstract. The present work introduces a new observational gridded dataset produced using a dense network (thousands) of stations over the Iberian Peninsula (referred to as Iberia01, Gutiérrez et al. (2019), DOI: http://dx.doi.org/10.20350/digitalCSIC/8641), providing daily precipitation and temperatures for the period 1971-2015 at $0.1°$ regular (and $0.11°$ rotated CORDEX compliant) resolutions. A comparison with both the standard and ensemble version of the E-OBS v17 dataset (at $0.25°$ and $0.1°$ resolutions, respectively) is undertaken in order to assess observational uncertainty in this region. First, a standard comparison is performed for several weather indices, obtaining the differences between both datasets. Secondly, a new probabilistic intercomparison analysis is introduced, using the E-OBS ensemble (v17e) to characterize observational uncertainty and testing the hypothesis that Iberia01 is a realization of the ensemble (i.e. it falls within the observational uncertainty range provided by E-OBS). Finally, the possibility to increase the resolution of the dataset using the same interpolation approach is analyzed considering an extreme event of convective precipitation affecting the Iberian Peninsula and the auxiliary very high resolution grid ($0.01°$), built during the interpolation process to obtain the area-average representativity of the final dataset.

We show that Iberia01 produces more realistic patterns than E-OBS v17 in the case of precipitation for all the indices considered, although both are comparable for temperatures. These differences were assessed using a probabilistic approach based on the E-OBS ensemble. For precipitation, significant differences —at a 10% level— between both datasets were found for less than 25% of days over the Iberian Peninsula. For temperature, a very inhomogeneous pattern was obtained, with either a small (in most of the regions) or large fraction of significantly different days. The great uncertainty of the precipitation given by E-OBS ensemble, in which the standard deviation of the ensemble has the same order than the mean value, increases the significance of the results obtained for this variable reflecting the differences between both datasets.

KEY WORDS: *Observational uncertainty; E-OBS; ensemble; gridded observations; kriging; thin plate splines; extremes; Clime; Precipitation; Temperature*

1 Introduction

The availability of high resolution climate data together with an estimate of its uncertainty (observational uncertainty) is of paramount importance for climate studies, from global (Sun Qiaohong et al., 2018) to regional and local scales (Kidd et al., 2011). The first comprehensive gridded temperature dataset was obtained by Jones et al. (1982). This dataset only covered the Northern Hemisphere and produced monthly means at $5°$ latitude by $10°$ longitude grid. Later, this grid was extended to cover the entire globe, with a higher spatial resolution (at $0.5°$ resolution, Jones et al., 1986a, b) and currently includes several variables covering Earth's land areas for 1901-2015 (CRU TS4.0, Harris et al., 2014; Trenberth et al., 2014). However, this kind of resolution is too coarse for regional analysis, which typically requires datasets with tens of kilometres spatial resolution and daily to sub-daily temporal data, in order to differentiate climatic sub-regions and extreme events. In Europe, within the framework of the ENSEMBLES project, the first high resolution continental observational gridded dataset was produced (E-OBS) for daily maximum, minimum and mean temperatures, precipitation (Klein Tank et al., 2002; Haylock et al., 2008; Klok and Klein Tank, 2009) and sea level pressure (van den Besselaar et al., 2011). With more than 1490 citations in Scopus (at August 2019), this is the most used climate reference for European climate studies (e.g. in the Iberian Peninsula, Spain02 and PT02 have more than 180 and 90 citations, respectively). Yet, in some regions, E-OBS relies on a sparse observational network which limits its ability to correctly represent not only mean values, but also the variance and extremes, particularly over complex topography (Klok and Klein Tank, 2009). The Influence of stations density in the quality of gridded products has been analyzed in the last decades by several authors: Rudolf et al. (1994) was able to significantly reduce the precipitation error, from a maximum of 40% to 20%, by doubling the number of stations within a $2.5°$ grid box; Prein and Gobiet (2017) found that in regions with sparse data the uncertainties associated to mean seasonal precipitation could reach 60%; Beguería et al. (2016) found that, in a high resolution observationally based gridded dataset, the density of the underlying observations determines its spatial variance and thus strongly influences climate variability; Hofstra et al. (2010) concluded that, by randomly changing the number of stations in each grid box, a reduction in the density of stations decreases the variability of both precipitation and temperature with large implications in the representation of extremes. Moreover, large temporal differences in the number of stations within each grid box also adds another source of uncertainty since it can change trends of the time series (Hofstra et al., 2009; Frei, 2014; Beguería et al., 2016). Finally, in an analysis of the sources of uncertainty in observationally based gridded datasets, Herrera et al. (2018), highlight that the station density represents the major variability factor, irrespective of the interpolation method. The authors analysed several grids for Spain (complex topography) and Poland (smooth topography) and concluded that the influence of station density is more pronounced in Spain than in Poland due to the large spatial variability and complex orography of the first.

The quality of the station observations is an additional source of observational uncertainty for gridded products. These uncertainties may be reduced by applying quality control procedures and homogenising the time series (Herrera et al., 2012). Precipitation time series also commonly suffer from undercatch associated to windy conditions, which usually results in underestimation of the correct precipitation rate (Frei et al., 2003). Yet in complex topography an increased uncertainty may be associated to the use of these types of corrections (Adam et al., 2006). The areal representativeness of a particular station also poses a challenge. Again, in regions with high terrain gradients, like mountains or coastal areas, surface temperatures are affected by local circulations like sea-breeze, up/down slope breeze associated to night-time radiative cooling in the valleys and to differentiated warming/cooling at sunrise/sunset of the slopes (Whiteman, 1982; Whiteman and McKee, 1982; Whiteman, 1990). Frei (2014) proposed a new interpolation method to tackle the latter, in which the thermal vertical profile of the station surrounding area is considered. Yet, Frei (2014) also acknowledges that the best way to reduce this type of uncertainty is through high station density.

Recently, several national high-resolution grids have been compiled for individual European countries from dense observation networks: SAFRAN analysis at 8km grid spacing covering France at an hourly timestep (Durand et al., 1993; Quintana-Seguí et al., 2008; Vidal et al., 2010), and its recently published extension for continental Spain and Balearic Islands (Quintana-Seguí et al., 2017); PTHBV, a 4km daily dataset for Sweden (Johansson, 2000; Johansson and Chen, 2003); the 5km resolution HYRAS for Germany (Rauthe et al., 2013; Frick et al., 2014); seNorge2 a daily dataset with an 1km resolution for Norway (Uboldi et al., 2008; Lussana et al., 2018); TabsD (MeteoSwiss, 2013a) and RhiresD (MeteoSwiss, 2013b) at 2km for Switzerland; CARPATCLIM a $0.1°$ grid covering parts of nine countries along the Carpathian Mountains (Lakatos et al., 2013) and a $0.11°$ grid for Poland (Herrera et al., 2018).

In the Iberian Peninsula, Herrera (2011) and Herrera et al. (2012) built a precipitation regular grid for continental Spain and Balearic Islands based on 2756 stations (Spain02) following the methodology used in E-OBS. The same methodology was also applied by Belo-Pereira et al. (2011) for continental Portugal using more than 400 stations (PT02). Both grids had a $0.2°$ resolution and a time span of 1950-2003. Recently, Herrera et al. (2015) updated the Spanish grid including precipitation and temperatures (daily maximum, mean and minimum) and enhancing the spatial resolution to $0.1°$ (regular); moreover, they also provided results on a $0.11°$ rotated grid (CORDEX compliant) for the purpose of Regional Climate Model (RCM) evaluation. While the gridding methodology in the PT02 was the same as in Herrera et al. (2012), some discrepancies between the two datasets occurred near the borders, particularly in the northern mountains. Furthermore, the $0.2°$ resolution of the Portuguese grid is too coarse for regional climate studies. On the other hand, the lack of temperature grids also hinders a comprehensive analysis of the large inter-annual and spatial variability, characteristic of the Iberian climate (Esteban-Parra et al., 1998; Muñoz-Díaz and Rodrigo, 2004; Cardoso et al., 2013). These problems could be solved building a joint grid, using observational station data from both countries.

In this paper, we develop an Iberian wide daily regular grid at $0.1°$ resolution, for precipitation and temperatures (maximum, mean and minimum) as well as a $0.11°$ rotated grid (EURO-CORDEX compliant) suitable for model evaluation purposes. This grid is based on a high density network of stations across continental Portugal and Spain and Balearic Islands, with a reasonably stable number of stations for the period 1971-2015. This represents the first gridded dataset of daily precipitation and temperatures focused on Iberia, and can be considered an update of the PT02 dataset. Here, we also introduce the orography as covariate in the interpolation process, which was missing in the initial PT02 and Spain02. The resulting dataset is compared against the most recent version of E-OBS (v17.0, referred to as v17), which includes a new ensemble version (v17e) to assess observational uncertainty and allows for a new probabilistic intercomparisson of these datasets.

The paper is structured as follows: First, in Section 2 a description of the data and methods considered in this work is presented. Secondly, the main results are described (Sec. 3). Finally, the main conclusions and discussions grown from the analysis are detailed in Section 4.

2 Data and Methods

2.1 Observation Network and Quality Control

The present work is based on a dense network of 3847 precipitation stations and over 380 temperature stations from the Spanish Agency of Meteorology (AEMET), the Portuguese Institute for Sea and Atmosphere (IPMA) and the Portuguese Environmental Agency (APA). The final network was obtained applying the same quality control used to build *Spain02* (see Herrera, 2011; Herrera et al., 2012, for a detailed description of the dataset and the corresponding quality control), obtaining the observational network shown in Figure 1(a-b), including 3481 and 276 stations for precipitation and temperature, respectively, with at least 15 (40) years in the period 1951-2015, as defined in the previous works, containing more than the 90% of the precipitation (temperature) data (information about the observational network and their characteristics -location, missing data percentage, etc...- is provided with the dataset Iberia01 in two additional CSV-files). Figure 1(c) shows that there is a clear decline of the number of stations with available data in the last two decades, mainly for precipitation. Therefore, the resulting gridded product is not suitable for historical trend analysis, since biased results could be obtained as a result of the changing number of stations. Moreover, during the period 2009-2014 the are very few precipitation stations in Portugal and, therefore, results should be interpreted with caution in this period. Overall, the spatial distribution of the stations is quite homogeneous over the Iberian Peninsula with a good representation of the orographical gradients, specially for the case of precipitation (see the first column of Fig. 1). Therefore, the orography was included as a covariate in the interpolation process (at a monthly scale) to model and reflect these gradients.

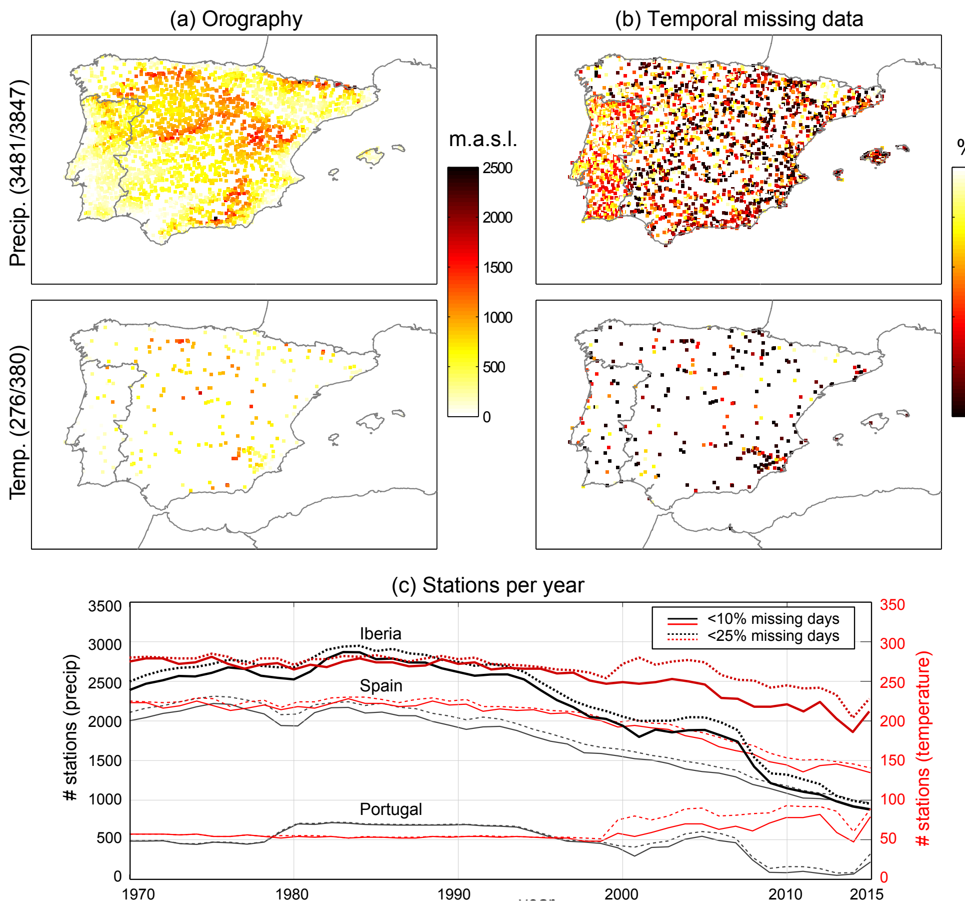

Figure 1. (a) Orography and (b) data availability (percentage of missing days) in the period 1971-2015 for precipitation (top) and temperature (bottom) for the observational networks considered for the interpolation. The numbers on the left of the figure reflect the initial and final number of stations used, once the quality control is applied. (c) Number of stations – considering the Iberian Peninsula, Spain or Portugal – per year for different thresholds of annual missing data for precipitation (black) and temperature (red).

2.2 E-OBS Gridded Datasets (v17 and v17e)

E-OBS (Haylock et al., 2008) is the reference gridded dataset of daily precipitation and temperatures in Europe and has been previously used to analyze the observational uncertainty in the context of the evaluation of regional climate models (see, e.g. Kotlarski et al., 2017). In this study, we use both the standard (v17, 0.2° resolution) and the ensemble (v17e, 0.1° resolution Cornes et al., 2018) versions of E-OBS v17 as benchmark for comparison purposes. In addition to the estimated daily value for each gridbox, the ensembles grid also provides a measure of daily uncertainty, characterized by the standard deviation of the ensemble. E-OBS v17 is used for the sake of comparison with Iberia01 (see Fig. 2) and the E-OBS v17e (the ensemble) is used to assess the observational uncertainty provided by this dataset, and test whether Iberia01 does not differ significantly from the ensemble (i.e. it falls within the observational uncertainty range) with a certain confidence (90%) day by day. For this purpose, the E-OBS ensemble mean (μ) and spread (σ) are used to define a normal distribution $N(\mu,\sigma)$ characterizing observational uncertainty for each grid box and day, and the corresponding Iberia01 values are classified as either inside or outside (values outside the P5-P95 percentile range) the uncertainty range for each grid box and day. Note that outsider values indicate significant differences between both datasets (as characterized by the E-OBS ensemble).

2.3 Weather Indices

To analyze the mean and extreme regimes of precipitation and temperature we use the indicators shown in Table 1. In particular, the 50-year return value for each grid-box was used to characterize the extreme regimes (for the period 1971-2015) obtained by adjusting a Generalized Extreme Value (GEV) distribution to the series of annual maximum of daily values (see Herrera et al., 2015, for a detailed description). In the case of precipitation, both wet-day frequency and rainfall intensity have been considered to properly characterize the mean regime.

Table 1. Precipitation and temperature indices used in this study.

ID	*Indicator*	*Units*
pr	Mean daily precipitation amount	mm/day
RR1	Wet-day ($pr > 1mm$) frequency	%
RV50Yp	50-years return value of daily precipitation	mm/day
tas	Mean daily 2-meters air temperature	deg. Celsius
RV50Yt	50-years return value of the mean daily 2-meters air temperature	deg. Celsius

2.4 Gridding Method

The Iberia01 daily gridded dataset for precipitation and temperatures was built using the previously described observational network and applying the area-averaged 3-dimensional (AA-3D) interpolation method described in previous studies (Herrera, 2011; Herrera et al., 2012, 2015). This interpolation method is an area-averaged method based on ordinary kriging (OK; Krige, 1951; Matheron, 1962) and 3-dimensional thin plate splines (3D-TPS; Craven and Wahba, 1979; Wahba, 1990; Hutchinson, 1998a, b) in a two-step process:

- first, the 3D-TPS is applied to the monthly value considering the orography given by the Global Digital Elevation Model (GTOPO30, https://www.usgs.gov/centers/eros/science/usgs-eros-archive-digital-elevation-global-30-arc-second-elevation-gtopo30?qt-science_center_objects=0#qt-science_center_objects) as covariable;
- second, the daily anomaly is interpolated by applying OK;
- as a result, both the daily anomaly and monthly value are combined to obtain the interpolated daily values

To ensure the area-averaged representativity of the final values, the initial interpolation is done over an auxiliary 0.01° resolution grid and, then, the interpolated results are upscaled (averaged) to the target resolutions, in our case a regular version of 0.10° spatial resolution ($10km$ approx.) and a rotated version matching the grids considered in the EURO-CORDEX project (0.11° and 0.44°). In this work we only describe for simplicity the regular version of 0.10° spatial resolution, although the other datasets are also provided (these datasets will be used in a future paper to evaluate the performance of EURO-CORDEX models over Iberia).

2.5 Effective Resolution

Taking into account the two-step interpolation procedure followed to develop the area-average representative gridded dataset, a natural doubt surges about the possible application of the auxiliary very-high resolution grid (1 km) to build a grid at a resolution higher than 10 km. For instance, the new RCM convective permitting simulations performed in the framework of the CORDEX Flagship Pilot Studies (FPS) reach a resolution of $2-3$ km and, thus, high resolution grids are needed for the evaluation of these projects (Giorgi et al., 2009; Jacob et al., 2014). To test this possibility, an illustrative example is considered: a convective high-resolution extreme precipitation event occurred on 4-5 November 1997, and characterized by heavy precipitation over most of the Iberian Peninsula. This event had great socioeconomic impacts in Portugal (Ramos and Reis, 2002) and Spain (Lorente et al., 2008), and was ranked as the second greatest extreme precipitation event of the Iberian Peninsula (Ramos et al., 2015). We use this event as an illustrative case study in order to analyze the potential benefits provided by a 3 km gridded version of Iberia01, as compared with the standard 10 km resolution, in terms of the spatial (Pearson) correlation, and the comparison of the mean and variance of the spatial patterns through the Student's t-test and Snedecor's F-test, respectively, for two samples, corresponding to the low- and high-resolution versions of both E-OBS and Iberia01 gridded datasets.

3 Results

Figure 2 shows the climatologies of the indices shown in Table 1 for Iberia01 (0.1°) and E-OBS (v17, 0.2° and v17e, 0.1°). In addition, Table 2 shows the differences between the spatial pattern of the different datasets and the observations for each index. The three datasets provide similar results in the case of temperature, with the main differences being located in the South, around the Guadalquivir and Guadiana basins, where the maximum values are attained. In addition, the uncertainty climatology (calculated as the temporal mean of the daily standard deviations of the ensemble values) is also provided for the ensemble version of E-OBS, showing a value around 2.5° in all the territory, with the exception of a number of kernels where the uncertainty is very small, corresponding to the stations used to build the E-OBS grid. Note that the uncertainty climatology is different in Spain and Portugal, with more clear kernels in the first case; this could be due to the different temporal coverage of both networks, with an increase of uncertainty due to days with no observation. Therefore, the uncertainty conveys relevant information on the station network used to build the grid.

In the case of precipitation, E-OBS is not able to reproduce either the mean spatial pattern (pr) or the intensity of the 50-year return value (RV50Yp). E-OBS underestimates mean precipitation by 15 - 20% (mean relative bias, for E-OBSv17 - v17e, respectively), particularly in

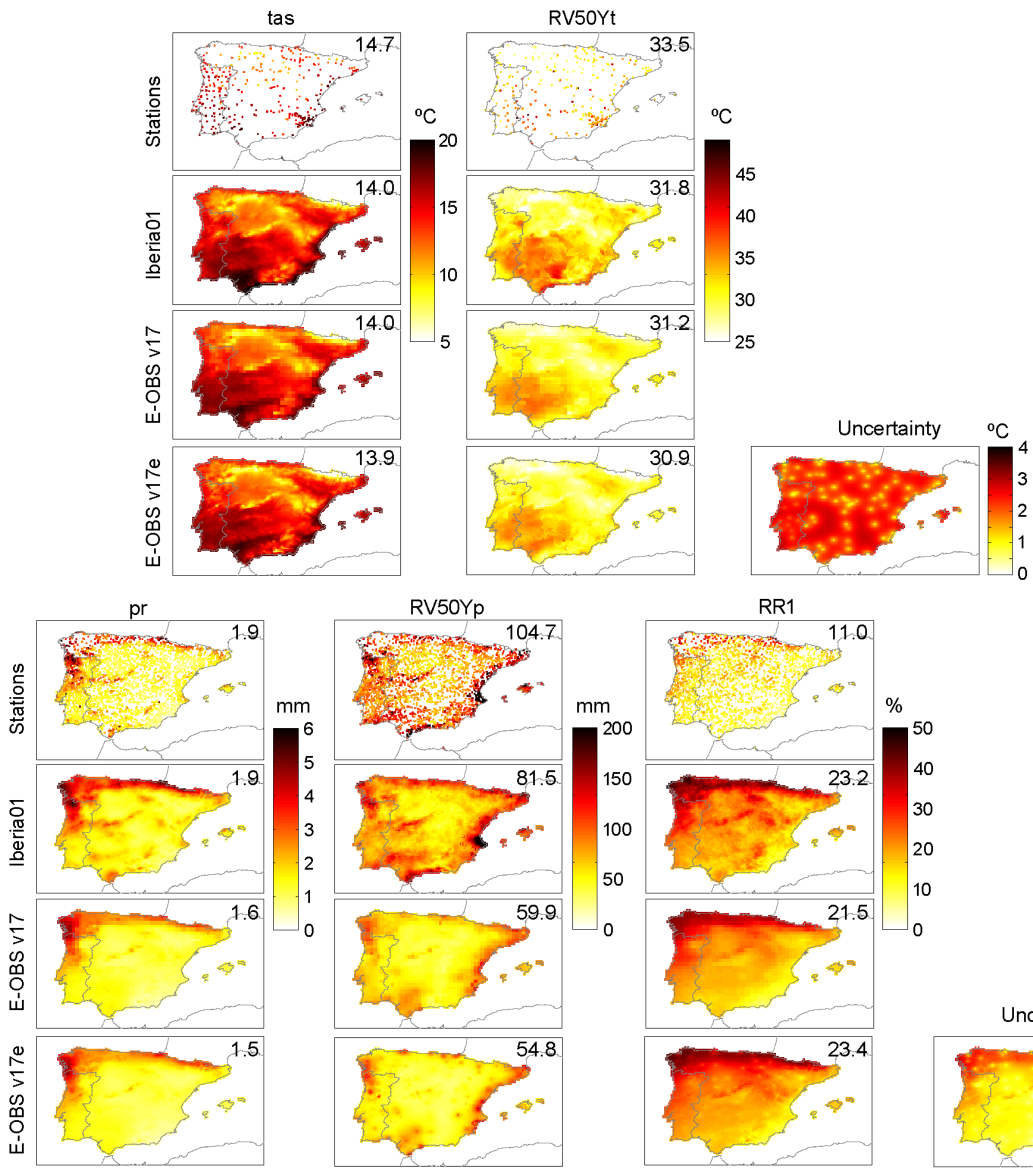

Figure 2. Climatology of the different temperature (top) and precipitation (bottom) indices defined in Table 1, from the stations (local values), Iberia01 (0.1° resolution), E-OBS v17 (0.2°) and E-OBS v17e (0.1°), in rows. The mean daily standard deviation has been included for the latest dataset. The numbers show the spatial mean of each map.

the Central System range of the Iberian Peninsula, and 50-year return values by 42 - 47% (mean relative bias), with some very high biases in some Southern and Mediterranean regions. The case of wet-day frequency is different, since all datasets show a clear overestimation, with Iberia01 showing a more orographic pattern than E-OBS. In this case, the higher resolution of E-OBS v17e provides further spatial detail as compared to the standard v17 one, which is not evident for precipitation intensity. Moreover, the uncertainty (temporal mean of the daily

Table 2. Comparison between the spatial pattern of the different gridded datasets against the observations for the indices defined in Table 1.

Iberia01	*tas*	*RV50Yt*	*pr*	*RV50Yp*	*RR1*
MAE	0.5404	1.6162	0.2888	20.1838	11.2783
BIAS	-0.2099	-1.3145	0.0881	-17.8175	11.2763
RMSE	0.8902	2.9837	0.5651	28.1075	13.6863
CORR	0.9422	0.7319	0.8496	0.8623	0.4304
E-OBS v17	*tas*	*RV50Yt*	*pr*	*RV50Yp*	*RR1*
MAE	0.8212	2.6219	0.4288	42.4205	10.0718
BIAS	-0.2603	-2.1310	-0.2703	-42.2184	9.9931
RMSE	1.1530	3.9377	0.7510	54.2519	12.5221
CORR	0.8931	0.5403	0.7508	0.5891	0.4297
E-OBS v17e	*tas*	*RV50Yt*	*pr*	*RV50Yp*	*RR1*
MAE	0.8260	2.6720	0.4357	46.9555	11.4778
BIAS	-0.3341	-2.3033	-0.3021	-46.7663	11.4641
RMSE	1.1811	4.0530	0.7600	58.0514	13.7543
CORR	0.9047	0.5365	0.7560	0.5659	0.4374

standard deviations of the ensemble values) is of similar magnitude to the mean value (also with kernels of small uncertainty corresponding to stations) reflecting a large uncertainty for this variable.

Figure 3 shows the percentage of significantly different days for each gridbox, variable and season. For precipitation (first row), only Iberia01 wet-days were used in order to minimize the effect of the different wet-day frequencies. The differences for this variable exhibit a homogeneous spatial pattern over the Peninsula with values around 10% in general; this is due to the large uncertainty of the daily E-OBS ensemble spread (see Fig. 2). Regarding the temperatures, most of the spatial pattern presents values close to zero, reflecting the similarity between both datasets for these variables. However, some local differences are found particularly for the mean (second row) and maximum (third row) temperatures, with the greatest values reached in the Pyrenean and Central ranges and the south coast of the Iberian Peninsula, in agreement with the differences shown in Figure 2. In this case, the ensemble uncertainty is in agreement with the differences between these two datasets found in Figure 2.

To explore the possibility to increase the resolution of the Iberia01 grid, we consider the extreme event occurred the 4-5 November 1997 and compare the resulting values of the 0.1° grid with a higher resolution 0.03° one developed using the auxiliary 0.01° grid generated in the interpolation process. Tables 3 and 4, Figure 4 show the results obtained for the extreme event indicating that an increment of the Iberia01 resolution beyond 10 km has no clear impact in the effective resolution of the precipitation pattern. In particular, in spite of the clear improvement of both versions of Iberia01 w.r.t. E-OBS v17e for all the parameters considered (see Table 3), there are only slight differences between both versions of Iberia01 when compared with observations.

Moreover, as it is reflected in Table 4, the spatial correlation between both resolutions is greater than 0.98 for both datasets, and any significant — at 5 % level — difference is found for the mean and variance of the spatial pattern according to the applied hypothesis test for two independent samples, the Student's t-test and Snedecor's F test for the mean and the variance, respectively.

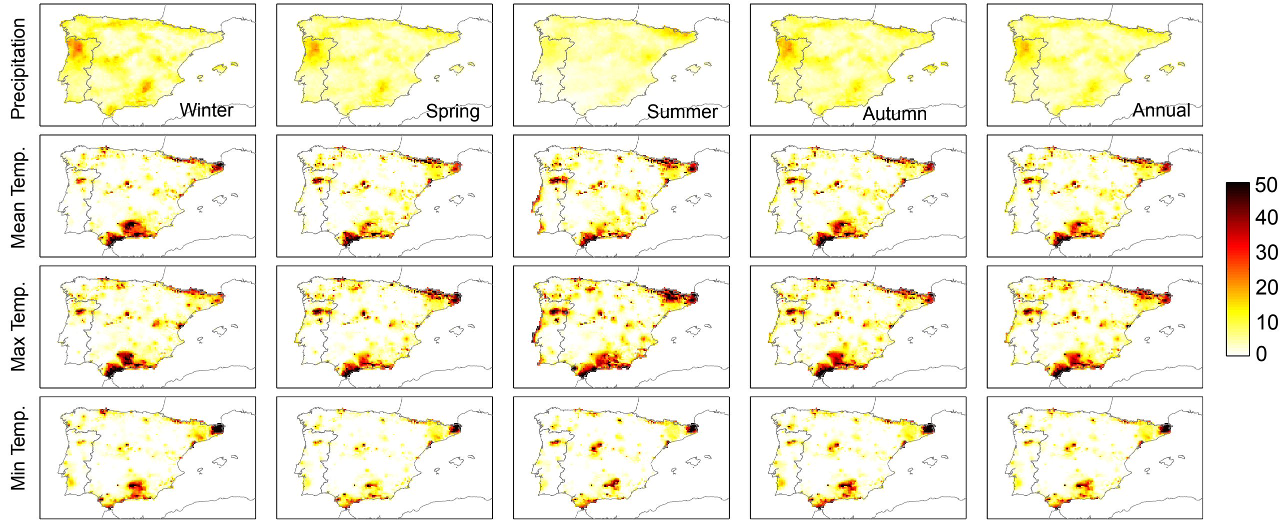

Figure 3. Percentage of significantly different days between Iberia01 and E-OBS v17e for each gridbox, variable and season, defined as the Iberia01 daily values outside the the $P5 - P95$ percentile interval of the normal distribution given by the E-OBS ensemble, in the period 1970-2015 for wet-days (first row), and mean (second row), maximum (third row) and (fourth row) minimum temperatures.

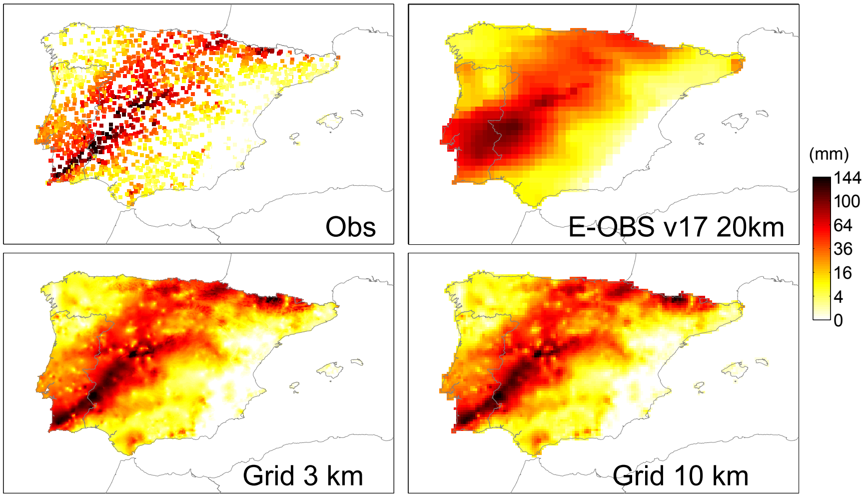

Figure 4. Daily precipitation of the 4-5 November 1997 observed and given by E-OBS v17e, and a 3 km and 10 km version of Iberia01.

Note that the interpolation method, independently of the target resolution, is calibrated to reproduce the spatial dependence of the mean field of the target variable, which is usually greater than the grid resolution (1° approximately in this case). Therefore, the effective resolution of purely interpolated gridded products is limited by this spatial value, which define the size of the kernels used for the interpolation process. As a result, in order to properly evaluate the convecting permitting CORDEX simulations, other approaches like regional reanalysis (e.g.

Table 3. Comparison between the spatial pattern of the different gridded datasets against the observations.

Measure	*Iberia01 3 km*	*Iberia01 10 km*	*E-OBS v17 (25 km)*	*E-OBS v17e (10 km)*
MAE	3.3861	4.8142	11.0998	10.9936
BIAS	0.2352	0.7046	-1.7382	-1.4243
RMSE	6.5430	8.9360	19.0300	18.7614
CORR	0.9746	0.9522	0.7625	0.7691

Häggmark et al., 2000) or methods combining interpolation and analysis as the proposed by Quintana-Seguí et al. (2017) and Peral et al. (2017), among others, should be used.

Table 4. Comparison between the spatial pattern of the different resolutions considered to analyse the effective resolution of the gridded datasets.

Measure	*Iberia01 3 km vs. Iberia01 10 km*	*E-OBS v17 (25 km) vs. E-OBS v17e (10 km)*
CORR	0.9855	0.9912
t test (H)	0	0
F test (H)	0	0

4 Conclusions and Discussion

In this work a new gridded dataset for the Iberian Peninsula and the Balearic Islands based on a quality-controlled and dense station network has been described and compared with E-OBS v17, considering both the standard and the ensemble version of this product, to reflect and analyze the observational uncertainty related with both datasets.

On the one hand, Iberia01 is able to reproduce the spatial pattern and intensity of both the mean and extreme regimes of precipitation and temperature, in terms of the weather indices defined in Table 1, including extreme events as the one occurred the 4-5 November 1997 shown in the Figure 4. For the weather indices considered, E-OBS v17 tends to underestimate the extremes and soften the spatial pattern of precipitation, in agreement with other previous studies (Herrera et al., 2012). It is however more similar to Iberia01 in the case of temperature indices, with the main differences appearing in the Guadalquivir and Guadiana basins, and the Pyrenean range. In addition, both datasets present large differences for wet-days (see Figure 2), with E-OBS v17 identifying less than the 70% of the observed wet-days all around the Peninsula and falling up to the 40% in Summer. Note that the complex orography and the influence of both the Atlantic Ocean and the Mediterranean Sea modulate the precipitation over the Iberian Peninsula, leading to particular regimes, as the cold drop in the east coast, that a continental adjustment of the interpolation model is not able to reproduce, even more when a low-dense observational network is considered. In this sense, the large increase of rain gauges considered in Iberia01, when compared with E-OBS, give rise to a much improved precipitation rendering. In the case of temperature, although the observational network considered is similar in both cases, the pattern tends to be more orographic in E-OBS v17 due to the continental adjusment of the interpolation method that overrates this component avoiding regional behaviors. In addition, the contribution of the obersvational network considered in France also has a clear effect on the interpolated value over the Pyrennes and the northeast of the Iberian Peninsula.

On the other hand, considering the ensemble version of E-OBS, E-OBS v17e, an experimental framework to evaluate the observational uncertainty has been defined, analizing if Iberia01 falls inside the ensemble given by E-OBS v17 and, then, if it could be considered a realization of the ensemble. In this case, we conclude that both datasets could be used indistinctly. First, note that the spread of the ensemble for precipitation has the same order of the mean value reflecting a large uncertainty for this variable, and questioning in this particular case the practical utility of this measure of uncertainty, in contrast to the one obtained for temperatures. In the case of precipitation (Figure 3, first row), the percentage of outliers considering only the wet-days ranges between 5% and 25% along the Peninsula. For temperatures (Figure 3, second to fourth rows), most of the area shows percentages less than 5% of outliers, with only some regions previously identified (Guadalquivir basin, Pyrenees, etc.) presenting values larger than $50\% - 60\%$. In summary, although in most of the domain the temperatures given by Iberia01 are included within the ensemble defined by E-OBS v17e, there are several regions with significant differences that should be considered/treated with caution. Moreover, in the case of precipitation both datasets present significant differences that should be taken into account.

The Iberia01 dataset (Gutiérrez et al., 2019, DOI: http://dx.doi.org/10.20350/digitalCSIC/8641) is publicly available through the climate services portals of:

– IPMA: http://www.ipma.pt/pt/oclima/servicos.clima/

– AEMET: http://www.aemet.es/es/serviciosclimaticos/cambio_climat/datos_diarios

5 Code and data availability

All the datasets used in this work are publicly available. The Iberia01 dataset (Gutiérrez et al., 2019, DOI: http://dx.doi.org/10.20350/digitalCSIC/8641) is publicly available through the climate services portals of:

- IPMA: http://www.ipma.pt/pt/oclima/servicos.clima/
- DIGITAL.CSIC Open Science: http://hdl.handle.net/10261/183071
- Santander User Data Gateway (UDG): http://meteo.unican.es/tds5/dodsC/Iberia01/Iberia01_v1.0_010reg_aa_3d.ncml

The E-OBS v17 dataset is remotely available through the KNMI's THREDDS Data Server http://opendap.knmi.nl/knmi/thredds/e-obs/e-obs-catalog.html and the ensemble version E-OBS v17e is available through the Copernicus' Climate Change Service http://surfobs.climate.copernicus.eu/dataaccess/access_eobs.php.

The R code to obtain the climatologies of the different indices used in this analysis for Iberia01 and E-OBS v17 dataset is publicly available from the GitHub repository of Santander Meteotology Group: https://github.com/SantanderMetGroup/notebooks

Author contributions. Herrera S., Gutiérrez J.M. and Soares P.M. conceived the study; Gutiérrez J.M., Soares P.M., Cardoso R.M., Espíritu-Santo F. and Viterbo P, obtained and processed the Spanish and Portuguese observational datasets; Herrera S. implemented the code to make the interpolation and the analysis, and built the dataset and figures of the paper; Herrera S., Soares P.M., Gutiérrez J.M. and Cardoso R.M. wrote the manuscript and all the authors revised the results.

Competing interests. The authors declare that there are not any competing interest.

Acknowledgement. This work was partially funded by the Spanish Government R&D Programme (Exp. CGL2010-21869 and CGL2010-22158-C02). Pedro M.M. Soares and Rita M. Cardoso wish to acknowledge the SOLAR (PTDC/GEOMET/7078/2014) project and the funding by the project FCT UID/GEO/50019/2019 - Instituto Dom Luiz.

The authors are grateful to the Portuguese Institute for Sea and Atmosphere (IPMA) and the Portuguese Environmental Agency for providing the needed observational data. The authors are also grateful to AEMET for providing the necessary data to do this work. We acknowledge the E-OBS dataset from the EU-FP6 project ENSEMBLES (http://ensembles-eu.metoffice.com) and the data providers in the ECA&D project (http://www.ecad.eu). We acknowledge the E-OBS dataset from the EU-FP6 project UERRA (http://www.uerra.eu) and the Copernicus Climate Change Service, and the data providers in the ECA&D project (https://www.ecad.eu)

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