Validation of a new SAFRAN-based gridded precipitation product for Spain and comparisons to Spain02 and ERA-Interim.

Pere Quintana-Seguí[1], Marco Turco[2], Sixto Herrera[3], and Gonzalo Miguez-Macho[4]

[1]Observatori de l'Ebre, (OE), CSIC – Universitat Ramon Llull. Horta Alta 38, 43520 Roquetes, Spain.
[2]Barcelona Supercomputing Center-Centro Nacional de Supercomputación (BSC-CNS), Carrer Jordi Girona 31, 08034 Barcelona, Spain
[3]Meteorology Group, Department of Applied Mathematics and Computer Science, Universidad de Cantabria, Avenida de los Castros s/n, 39005 Santander, Spain
[4]Grupo de Física Non Lineal, Universidade de Santiago Compostela, Calle Xosé María Suárez Núñez s/n., 15782 Santiago de Compostela, Spain

Correspondence to: Pere Quintana-Seguí (pquintana@obsebre.es)

Abstract. Offline Land-Surface Model (LSM) simulations are useful for studying the continental hydrological cycle. Because of the nonlinearities in the models, the results are very sensitive to the quality of the meteorological forcing; thus, high-quality gridded datasets of screen-level meteorological variables are needed. Precipitation datasets are particularly difficult to produce due to the inherent spatial and temporal heterogeneity of that variable. They do, however, have a large impact on the simulations, and it is thus necessary to carefully evaluate their quality in great detail.

This paper reports the quality of two high-resolution precipitation datasets for Spain at the daily time scale: the new SAFRAN-based dataset and Spain02. SAFRAN is a meteorological analysis system that was designed to force LSMs and has recently been extended to the entirety of Spain for a long period of time (1979/80-2013/14). Spain02 is a daily precipitation dataset for Spain and was created mainly to validate Regional Climate Models. In addition, ERA-Interim is included in the comparison to show the differences between local high-resolution and global low-resolution products. The study compares the different precipitation analyses with rain gauge data and assesses their temporal and spatial similarities to the observations.

The results show that SAFRAN and Spain02 have very similar skill scores, although the later has better scores in general. As expected, SAFRAN and Spain02 perform better than ERA-Interim, which has difficulty capturing the effects of the relief on precipitation due to its low resolution. However, ERA-Interim reproduces spells remarkably well, in contrast to the low skill shown by the high-resolution products. The high-resolution gridded products overestimate the number of precipitation days, which is a problem that affects SAFRAN more than Spain02 and is likely caused by the interpolation method. Both SAFRAN and Spain02 underestimate high precipitation events, but SAFRAN does so more than Spain02. The overestimation of low precipitation events and the underestimation of intense episodes will probably have hydrological consequences once the data are used to force a land surface or hydrological model.

1 Introduction

A good knowledge of the continental water cycle and its quantification is critical for society, mainly because it represents both a resource and a hazard. As a consequence, a better understanding of the continental water cycle is a key problem for climate change impact/adaptation studies, and it has become a strategic topic in national and international climate programs.

For example, the Global Energy and Water Cycle Exchanges Project (GEWEX) is focusing on the global water cycle, whereas the Hydrological Cycle in the Mediterranean Experiment (HyMeX) program is studying the coupled Mediterranean hydrological system and is very interested in the continental water cycle due to its role in the coupled system and also due to the impacts on society. In addition, the European project EU-FP7 EartH2Observe: "Global Earth Observation for Integrated Water Resource Assessment" (eartH2Observe) intends to create a long reanalysis of the global water cycle, whose utility will be tested by comparing it to the higher-resolution products that are available at the national or basin scale (Spain is one of the case studies). In addition, the Spanish project MARCO seeks to improve how regional climate models models (RCM) reproduce hydrometeorological extremes by comparing them to the higher-resolution offline Land-Surface Model (LSM) simulations.

Simulating the continental water cycle is difficult. For example, precipitation is a challenging variable due to its spatial heterogeneity and variability and its time variability. Evapotranspiration is a very complex process that is difficult to measure and depends on the atmosphere, soil and vegetation in a complex manner (e.g., Peters-Lidard et al., 2011; Nasonova et al., 2011; Long et al., 2014).

There are different approaches to simulating the continental cycle. These range from easy-to-calibrate simple water balance models (see, e.g., Orth and Seneviratne, 2015) to the more complex LSMs. LSMs simulate the physical processes at the interface among the soil, vegetation and atmosphere. These models may be run offline, forced by a gridded dataset of screen-level meteorological variables, or online and coupled to an atmospheric model.

The main advantage of using offline LSMs is that they avoid atmospheric model biases because they are forced by gridded observational datasets, but they miss many feedback processes. Such systems have been applied at the global, continental, national and basin scales (Rodell et al., 2004; Decharme et al., 2012; Balsamo et al., 2012; Cosgrove, 2003; Mitchell, 2004; Chen et al., 2007; Habets et al., 2008; Artinyan et al., 2008; Szczypta et al., 2012; Barbu et al., 2014; Martínez de la Torre, 2014) in a wide range of works that include the study of water resources, the initialization of meteorological models and the study of the continental water cycle.

The performance of offline LSM simulations depends strongly on the quality of the meteorological datasets used to force the models. In addition, the non-linear nature of the LSMs, which may amplify the errors, makes it essential to ensure the good quality of the meteorological forcing datasets for land surface and hydrological modeling. Unfortunately, it is not an easy task to build such gridded datasets that include all of the meteorological parameters and reach the spatial (at least 5 km) and temporal (intra-daily) resolutions needed to force an LSM. Meteorological analysis systems such as CANARI (Taillefer, 2002), SPAN (Rodríguez et al., 2003; Navascués et al., 2003; Cansado et al., 2004), MESAN (Häggmark et al., 2000) MESCAN (Soci et al., 2016) or SAFRAN (Durand et al., 1993, 1999; Quintana-Seguí et al., 2008; Vidal et al., 2010; Quintana-Seguí, 2016) are well suited for this task.

Concerning precipitation, which is the variable examined in this paper, there are other interesting reference datasets, which might not be able to force a LSM because they may not have sufficient temporal (they are often daily products) or spatial (they have resolutions that range from 50 to 12 km) resolution; however, they are well known and widely used for other applications such as the validation (see, e.g., Gómez-Navarro et al., 2012; Turco et al., 2013a) and post-processing of Regional Climate Models (Turco et al., 2011; Casanueva et al., 2015) or the statistical downscaling of Global Climate Models (Casanueva et al., 2016).

It is interesting to compare the analysis systems mentioned in the previous paragraph with these daily reference datasets. At the European scale, E-OBS (Haylock et al., 2008) is probably the best known of such products. However, in some countries the station density considered when building E-OBS was very low, thus limiting the capability of that dataset to properly reproduce the climatic variability of those regions. As a result, some products have been developed for specific regions or countries, such as the gridded dataset *EURO4M-APGD* (Isotta et al., 2014) for the Greater Alpine Region and Spain02 (Herrera et al., 2012, 2016) in Spain, which considers a denser station network.

Careful validation of these products should be performed to ensure that they correctly reproduce the important characteristics of the climate of the region under study. The validation should test both the temporal and spatial accuracies of the products not only for the mean values but also for extremes. Some examples of such studies are Ensor and Robeson (2008), who analyzed the statistics of precipitation in gridded products in the USA and found that the interpolation process significantly increased the number of low-precipitation events while greatly reducing the intensity and frequency of heavy-precipitation episodes; Prein and Gobiet (2016), who evaluated many regional datasets in Europe and demonstrated that the differences among them have the same magnitude as the precipitation errors found in Regional Climate Models; Flaounas et al. (2012), who validated the E-OBS dataset in the Mediterranean region and found that those data must be used with care in complex environments such as coastal areas and mountainous regions; Turco et al. (2013b), who compared three different gridded datasets in the great alpine region (E-OBS and two local grids) and found that specific regional products are often more trustworthy than E-OBS; Herrera et al. (2012), who compared Spain02 and E-OBS in Spain and found that the station density severely affects the results; Turco and Llasat (2011), who confirmed the high quality of the Spain02 dataset in northeast Spain; Belo-Pereira et al. (2011), who compared IB02 to global datasets and found that the global products produce better results in Western Iberia than on the Mediterranean side; and Katsanos et al. (2015), who validated the CHIRPS global remote sensing product (Funk et al., 2015) in Cyprus and compared it to E-OBS and local rain gauge data and found that at the monthly scale, the results showed a good correlation between the CHIRPS values and recorded precipitation.

This study has two objectives. The first is to present a new SAFRAN dataset for Spain, extending the work of Quintana-Seguí (2016) to the whole of Spain and to a period of 35 years (1979/80-2013/14). The second and main objective of this paper is to validate SAFRAN's precipitation and compare the performances of both SAFRAN and Spain02, which is a well-known, high-quality daily precipitation dataset for Spain.

Due to its high quality, ERA-Interim is of special interest in hydrology because it is the basis for other derived products that are tailored for hydrological applications such as WFDEI (Weedon et al., 2014). Moreover, ERA-Interim is a dataset suitable to force LSMs, so it is introduced in the comparison to show how a low-resolution global product compares to local

higher-resolution ones, which is one of the objectives of the eartH2Observe project and, thus, of this paper. In the case of E-OBS, it has not been included for several reasons. On the one hand, E-OBS can be considered a different kind of product in comparison to SAFRAN and Spain02 due to its much lower density of stations and the lower resolution of the final product. On the other hand, E-OBS's station density is especially low in Spain; as a consequence, this dataset cannot correctly reproduce Iberian precipitation regimes, which primarily affects the variability and extremes of precipitation events that are well-known problems reflected in previous studies (e.g., Herrera et al., 2012). Finally, contrary to ERA-Interim, it is not suitable to force LSMs, which is the main objective of SAFRAN.

This document is structured as follows. The study area is presented in Sect. 2, the datasets and methods are described in Sect. 3, the results are shown in Sect. 4 and the main conclusions are summarized in Sect. 6.

2 Study Area

[Figure 1 about here.]

The geographical domain of this study is the peninsular Spain and the Balearic Islands, which is an area located at the cross-roads of the Atlantic Ocean and the Mediterranean Sea. Precipitation in Spain has a marked NW-SE gradient: the northwest is very wet, with a mean precipitation that locally exceeds $2000 \, \mathrm{mmy}^{-1}$, and the southeast is very dry, with some areas that have less than $200 \, \mathrm{mmy}^{-1}$. Following the Köppen classification, most of Spain has a Mediterranean climate, except for some areas in the southeast and the Ebro valley that have a steppe climate. Desert climates can be found in very localized areas of the southeast (AEMET, 2011).

The case of the Ebro valley is interesting. Located in northeastern Spain, with both Atlantic and Mediterranean influences, the region has a low mean precipitation that is caused by the shadowing effect of the surrounding relief. This is an example of the important role of Spain's marked relief on the distribution of precipitation, enhancing it in some areas and decreasing it in others, which in turn has an important effect on runoff generation. This is an added difficulty for gridded precipitation products. Panel (a) of Fig. 1 shows the area of study, its relief and the main river basins. Note that for the sake of simplification, some of the smaller river basins have been grouped.

3 Datasets and Methods

3.1 SAFRAN

The SAFRAN meteorological analysis system (Durand et al., 1993, 1999) was initially created with the objective of forcing the CROCUS snow model (Brun et al., 1989) in the French Alps to improve avalanche prediction. Currently, it is extensively used in a wide range of applications. SAFRAN uses an Optimal Interpolation algorithm (OI) (Gandin, 1966), which combines observations and a first guess (e.g., the outputs of a meteorological model) to produce a gridded dataset of precipitation,

temperature, wind speed, relative humidity and cloudiness. SAFRAN is also able to calculate downward visible and infra-red radiation (Ritter and Geleyn, 1992).

SAFRAN is currently used for operational and research purposes in France (Quintana-Seguí et al., 2008; Vidal et al., 2010; Habets et al., 2008). It is used for research purposes in Spain (Quintana-Seguí, 2016) and Morocco (Szczypta et al., 2015). In

5 Spain, SAFRAN was first implemented and tested in a pilot study for the northeastern Iberian Peninsula using only one year of data (Quintana-Seguí, 2016). We now present an extension of SAFRAN to the whole of Spain and to a period of 35 years (1979/80-2013/14).

One of the main characteristics of SAFRAN is the use of climatically homogeneous zones to divide the space into analysis areas. These zones have irregular shapes and cover an area that is generally smaller than 1000 km^2. They should have a

10 weak horizontal gradient, especially for precipitation. The zones have several vertical levels spaced at 300 m, and SAFRAN estimates the value of the analyzed variable on each level. These values are subsequently horizontally interpolated to a regular grid, according to their altitude. Thus, due to the vertical levels, SAFRAN can account for the variations of precipitation with altitude, using the real gradients at the time of analysis. A downside of the climatically homogeneous zones is that they create artificial discontinuities at the borders of the zones. For precipitation, SAFRAN analyzes daily observations, but all other

15 variables are analyzed every six hours. The data are then time interpolated to the hourly scale using different methods for each variable. It is important to note that for each analysis, SAFRAN uses as much data as possible and that the number of stations used in the analysis thus changes with time; this optimizes the quality of the daily precipitation but makes the dataset untrustworthy for trend analysis. In this article, only the quality of the daily precipitation data is studied. For more details on SAFRAN, please see Quintana-Seguí et al. (2008); Quintana-Seguí (2016).

20 For this study, SAFRAN has been extended to mainland Spain and the Balearic Islands; for this purpose, a new set of climatological zones has been designed. The new zones, which are shown in panel (b) of Fig. 1, also cover Portugal for a possible future extension. The zones have been designed using the experience gathered by Quintana-Seguí (2016). In addition, this newer version of SAFRAN uses ERA-Interim as a first guess for most variables, excluding precipitation (the variable analyzed in this paper), for which no first guess is used. The included rain gauge observations come from AEMET's network

25 (see Sec. 3.5).

3.2 Spain02

Spain02 (Herrera et al., 2012, 2016) is a series of high-resolution daily precipitation and temperature gridded datasets developed for peninsular Spain and the Balearic islands. Version 4 of the product has been produced using the standard EURO-CORDEX grids at resolutions of 0.44, 0.22 and 0.11 degrees and different interpolation approaches (Herrera et al., 2016). To

30 compare Spain02 and SAFRAN, we chose the AA-3D version for this work, which considers the orography to be a co-variable (3D) in the interpolation process and it is areal representative (AA). More specifically, the AA-3D version is constructed by calculating the areal average of the interpolation, which is performed by applying thin plate splines (TPS) with the orography at the monthly scale and ordinary kriging (OK) on the daily anomalies. In fact, this is the same method employed by the widely used European scale product E-OBS (Haylock et al., 2008). As a result, both SAFRAN and the version considered for Spain02

are representative of areas and account for relief in the interpolation process. In addition, Spain02 presents the same problems for reproducing trends as described for SAFRAN due to the station network considered (2756 rain gauges), which prioritizes spatial density over temporal consistency.

Thereupon, we will use Spain02, or SP02, to refer to the AA-3D version of Spain02.

3.3 ERA-Interim

ERA-Interim (Dee et al., 2011) is the current global atmospheric reanalysis produced by the European Centre for Medium-Range Weather Forecasts (ECMWF). It covers the period from 1979 onward. ERA-Interim has a spatial resolution of 79 km (T255).

3.4 Time periods

[Figure 2 about here.]

Figure 2 shows the time periods covered by the SAFRAN and the Spain02 datasets. The latter covers the period from 1971 to 2010, whereas the current 35-year-long SAFRAN dataset has been produced within two projects and can be divided into three sub-periods, as shown in Fig. 2. The central sub-period (labeled SAFRAN1 in the figure) covers the hydrological years (that start in September) from 1995/96 to 2006/07. The other sub-periods (SAFRAN2), which cover the remaining years in the series between 1979/80 and 2013/14, were developed later in another research project.

For each of the SAFRAN sub-periods, a set of randomly selected stations (but guaranteeing the even distribution of the stations) was not used to perform the analysis to obtain an independent validation dataset. Unfortunately, for the SAFRAN1 and SAFRAN2 sub-periods, the same validation datasets were not considered, and a common set of independent stations for the whole 35-year period is thus not available for SAFRAN. Furthermore, Spain02 also has its own set of independent stations. The common set of stations that are independent for both SAFRAN and Spain02 is not useful for validation because there are too few stations that are also poorly spatially distributed. Nevertheless, Spain02 has already been validated with independent data by Herrera et al. (2012, 2016); thus, in this study, the comparisons between SAFRAN and Spain02 are performed using dependent data.

As a consequence, in this study:

1. SAFRAN is validated with independent data for the 1995/96-2006/07 period (SAFRAN1).

2. The other comparisons, which also included Spain02 and ERA-Interim, are performed on a common period (1980-2010, natural years) using dependent stations.

3.5 Station data

Panel (b) of Fig. 1 shows the locations of the daily precipitation stations used for this study, which were provided by the Spanish State Meteorological Agency (*Agencia Estatal de Meteorología*, AEMET). The figure only depicts the 1237 stations

whose time series have at least 90% of the data, which are the stations that were used for our analysis. The triangles correspond to the independent dataset used to validate SAFRAN for the 1995/96-2006/07 time period (249 stations). The smaller dots correspond to the remaining stations, which are used for all other validations (988 stations).

3.6 Comparison measures

5   The methodology used in this paper is based on the approach used by Turco et al. (2013b), with some modifications to account for the hydrological context in which the SAFRAN dataset has been developed.

[Table 1 about here.]

All of the metrics used in this study compare the products with rain gauge data, considering for each station the nearest gridpoints in terms of the Euclidean distance. First, the temporal agreement between the time series is studied using the Relative

10   Mean Absolute Error (MAEr) and the Pearson Correlation (CORR). In a second stage, the spatial agreement is studied using the standard precipitation indicators shown in Table 1. All indices are calculated on an annual scale in the common period (see Sec. 3.4), although some indices have also been calculated for each season (PRCPTOT, R1 and RX1D) or at a monthly scale (PRCPTOT and RX1D) for each river basin (see the river basin map in Fig. 1). Finally, the spatial pattern obtained for each index and gridded dataset is compared to the observations using the correlation (CORR), the variability (relative

15   standard deviation, STDEVr), the relative centered root mean square error (CRMSEr) and the relative bias (BIASr). To make the different indices comparable, the "relative" statistics (STDEVr and CRMSEr) have been normalized by dividing both the CRMSEr and STDEVr by the standard deviation of the observations (the reference dataset). Therefore, a STDEVr of 1 means that the standard deviation of the product is the same as that of the observations. The BIASr is relative with respect to the mean of the observations. The Taylor diagram (Taylor, 2001) summarizes these measures on a single plot, which has been produced

20   to show the seasonal statistics.

4 Results

4.1 Validation of SAFRAN using independent data

[Table 2 about here.]

The first step of our analysis is to validate the new SAFRAN dataset for Spain using independent stations for the period

25   1995/96-2006/07 (SAFRAN1). Table 2 summarizes the results, which show that the mean correlation and MAEr are the same in both data subsets (dependent and independent) for the same time period. The values of the 25th and 75th quantiles of the correlation and MAEr for the independent stations are quite similar, although they are worse than those of the dependent stations, which is an indicator of the robustness of SAFRAN.

4.2 Evaluation of the time similarity

The next step of the analysis is to compare the three studied products (SAFRAN, Spain02 and ERA-Interim) to a common set of observations considering the same period (1980 to 2010).

[Figure 3 about here.]

5   [Table 3 about here.]

Figure 3 shows the correlation and Relative Mean Absolute Error (MAEr) between the three products and the observations. The SAFRAN and Spain02 correlations are very similar, and the main difference is located on the southeastern coast, where SAFRAN has larger correlations. This similarity is also reflected in the statistics of Table 3, with both products having the same mean correlation (0.82) and an almost identical interquartile range (approximately 0.1). As expected, ERA-Interim's
10 correlation is lower. In this case, there is a strong east-west gradient, with the correlations higher in the Mediterranean due to the binary component (rain/no rain) of the precipitation, which is moderately well represented in the reanalysis.

Concerning the MAEr, again SAFRAN and Spain02 show very similar results, as Table 3 corroborates. Spain02's larger errors are mainly concentrated in the southeast, as seen in the correlation, whereas SAFRAN shows a more random spatial pattern. In the case of Spain02, the affected region (close to Murcia) has the highest station density for the entire peninsula, so
15 the interpolation process obtains an areal averaged precipitation value that differs from the local observations of each particular station. This is more relevant when intense local precipitation events occur, which are very frequent in the Mediterranean region, leading to an overestimation of the interpolated values in the surrounding area. The spatially more distributed nature of the SAFRAN's errors points to a close relation with the position of the zone's borders, which produces a homogeneous spatial distribution over the study area. ERA-Interim's errors are higher and quite homogeneous spatially, with the exception of the
20 Mediterranean coast and an area located in the Basque Country (on the eastern side of the Bay of Biscay).

Both SAFRAN and Spain02 (the AA-3D version used in this paper) consider the relief in their algorithms, and the same statistics were thus calculated for a subset of high-altitude stations (located at 1000 m or higher). The results, which are shown in Table 3, do not reflect significant differences between high- and low-altitude stations, with both SAFRAN and Spain02 performing equally well in terms of both correlation and MAEr. The trend of the errors with altitude for all stations was
25 calculated, and it was not significant in any case, not even for ERA-Interim. However, this result does not account for the fact that high-altitude areas are not well represented by observations because there is a lack of stations at the highest elevations.

4.2.1 Evaluation of the spatial similarity by means of precipitation indices

In this section, we evaluate how the different analyzed products are able to reproduce a standard set of precipitation indices. First, the annual cycles of monthly mean and daily maximum precipitation are studied for the eleven river basins shown in Fig.
30 1. The global statistics of each index are then summarized and analyzed.

[Figure 4 about here.]

Figure 4 shows the annual cycle of the maximum daily precipitation (RX1D) for each of the main Spanish river basins. A first look at the figure shows that, as expected, all products underestimate this index and that ERA-Interim is the dataset with the lowest values of RX1D for most basins. Another interesting result is that Spain02 is closer to the observations than SAFRAN, although they are generally close to each other. With respect to ERA-Interim, despite a general underestimation of

5   RX1D, in some cases, it is closer to the observations (e.g., Duero) than SAFRAN and Spain02 or has higher values than either gridded dataset for some months. This is probably due to the relief surrounding these basins (see Fig. 1), which creates a strong rain shadow effect on its leeward side that cannot be reproduced by ERA-Interim because of the coarse resolution.

Concerning the monthly mean (not shown), SAFRAN and Spain02 are closer, with the latter overestimating the monthly precipitation in the east, southeast and Segura basins, especially in autumn, in agreement with the results described in the

10   previous section.

[Table 4 about here.]

[Figure 5 about here.]

Figure 5 shows how both SAFRAN and Spain02 are able to reproduce the spatial patterns and magnitudes for the three indices, although they overestimate the CWD mostly in the high-relief areas and underestimate RX1D, which is a well-known

15   effect of the interpolation process. Concerning ERA-Interim, it misses the effects of the relief, with a strong north-south gradient for the PRCPTOT and CWD indices and a homogeneous spatial pattern in almost all of the study area for RX1D. ERA-Interim is unable to reproduce the intensity of precipitation, which leads to very low values for both PRCPTOT and RX1D.

In addition to Fig. 5, Table 4 summarizes the scores of the three products for the indices defined in Table 1. Both SAFRAN

20   and Spain02 obtain correlations greater than 0.75, with comparable values, whereas ERA-Interim is unable to reproduce the spatial pattern of most of the indices, with several correlations below 0.65. In general, the three datasets nevertheless underestimate indices related to the magnitude and intensity of precipitation (PRCPTOT, SDII, RX1D and RX5D), whereas they overestimate R10, R20 and the frequency of wet days. In addition, there is a common tendency to overestimate CWD and underestimate CDD. There are some exceptions, however, such as the slight overestimation of SAFRAN and Spain02 of

25   PRCPTOT or the overestimation of the CDD index given by SAFRAN. Finally, in terms of variability, there is a general underestimation for the PRCPTOT, SDII, R20, RX1D and RX5D indices, which is as high as 30% for SDII, and an overestimation for the rest, mainly for the CWD index.

[Figure 6 about here.]

The scores shown in Table 4 are summarized in the Taylor diagram. Figure 6 shows a summary of the seasonal statistics

30   of PRCPTOT, R1 and RX1D. In agreement with the results shown in the table, a general pattern in all four diagrams is that SAFRAN and Spain02 are generally close to each other. In addition, the figures show that in general, the results are quite robust across seasons. The only exceptions are R1 in summer, when the distance between SAFRAN and Spain02 increases in favor of the latter, and in autumn, when the distance of RX1D increases, also in favor of Spain02. Another interesting difference is

that in summer, the sign of the bias of PRCPTOT is different for SAFRAN and Spain02. The former has a negative bias, and the latter has a positive one.

5   Discussion

A general analysis of the results shows that SAFRAN and Spain02 have very similar skill scores, although the latter generally has better scores. This means that in Spain SAFRAN's daily precipitation, whose algorithm was designed in the late 20th century, is very close to the precipitation estimated by more recent and more specialized state-of-the-art products. As expected, SAFRAN and Spain02 have better scores than ERA-Interim, and the most important limitation of the reanalysis is its inability to capture the effects of the relief due to its low resolution, as noted in previous studies (see, e.g., Belo-Pereira et al., 2011). However, ERA-Interim reproduces spells remarkably well, in contrast to the difficulties of high-resolution products.

The high-resolution gridded products overestimate the number of precipitation days. This is probably caused by the interpolation method and affects SAFRAN more than Spain02, likely because of the former's use of climatically homogeneous zones. SAFRAN generates precipitation for a whole zone once there is a localized precipitation event in some of the stations within, wrongly assigning the event to unaffected stations. After many occurrences, this process causes an overestimation of the number of wet days for all stations. Similarly, localized high precipitation events may be missed by SAFRAN because it tends to average the values of all stations in a zone. SAFRAN may also completely miss events in zones with few stations, in agreement with Ensor and Robeson (2008). The overestimation of low precipitation events and the underestimation of intense episodes are likely to have consequences when the data are used to force a land surface or hydrological model, and in the future, it will be necessary to investigate how the aforementioned problems affect the quality of LSM and hydrological simulations.

The comparison has shown a known problem of SAFRAN, which is the higher errors that are often found at the borders of the zones (Quintana-Seguí et al., 2008; Quintana-Seguí, 2016). However, Spain02 also has bugs induced by the algorithm, as shown by the higher errors in the Murcia region (southeast). This shows that each algorithm has its own set of limitations, which need to be well documented and explained to the users of the data.

The comparison between the results obtained using dependent and independent data shows that the procedure used to build SAFRAN is robust. Part of this robustness is due to SAFRAN's algorithm, but it is also due to the high density of stations found in the area. Prein and Gobiet (2016) state that "the information content of a gridded dataset is mainly related to its underlying station density and not to its grid spacing". Because the station density in Spain is so high, the algorithms can leverage a lot of information, producing similar results. Thus, Spain, which is a data-rich country, is a relatively easy target for such algorithms. Vidal et al. (2010) and Herrera et al. (2016) have shown that station density has an impact on the resulting SAFRAN and Spain02 datasets. In a future study, it would be interesting to see how differently the results of SAFRAN and Spain02 degrade with station density.

Mountain areas are an exception because the station density in those areas is low and insufficient to reproduce the climatic variability of those regions. Our study has shown that the results of SAFRAN and Spain02 are robust with altitude, as the scores were similar for the stations situated at altitudes higher than 1000 m, but these results do not account for the fact that

the mountain areas are not well observed. This has hydrological consequences because high-altitude areas are the generators of most of the basin's runoff and, thus, of most of the water resources used in Spain. Further inspection of these aspects is necessary in the future. In addition, concerning the relief, it is important to underline that ERA-Interim is unable to reproduce the precipitation regimes of most basins due to its inability to reproduce the effects of the surrounding relief.

5   **6   Conclusions**

SAFRAN and Spain02 have very similar skill scores, although the latter generally has better scores. As expected, SAFRAN and Spain02 are able to reproduce the main characteristics of precipitation in Spain and perform better than ERA-Interim, which has difficulty capturing the effects of relief on precipitation due to its low resolution. SAFRAN is robust because the scores obtained using dependent and independent data are similar. Furthermore, both SAFRAN and Spain02 are also
10   robust with altitude. Era-Interim reproduces spells remarkably well, in contrast to the low skill shown by the high-resolution products. The high-resolution gridded products overestimate the number of precipitation days, which affects SAFRAN more than Spain02, and is likely caused by the interpolation method. Both SAFRAN and Spain02 underestimate high precipitation events, SAFRAN more so than Spain02.

Data availability

15   Four datasets were used for this paper. The SAFRAN dataset for Spain is available for research purposes from the Mistrals-HyMeX database (Quintana-Seguí, 2015). Spain02 v4 is freely distributed for research purposes at the Santander MetGroup THREDDS CATALOG[1]. ERA-Interim is distributed by the ECMWF on its own website[2]. The observational data were obtained from AEMET using the standard forms available on their website[3].

Author contributions.   P. Quintana-Seguí applied SAFRAN to Spain. He gathered the necessary data, obtained and modified the SAFRAN
20   code, wrote the necessary scripts to run it properly, defined the climatically homogeneous zones and performed the product quality assessment. M. Turco and P. Quintana-Seguí designed the validation and comparison methodology. M. Turco performed the analysis and generated the figures that show the results. P. Quintana-Seguí wrote most of the text and generated some figures. M. Turco and S. Herrera provided feedback and improvements to the text. S. Herrera helped choose the right version of Spain02 for this comparison and also edited some figures for publication. G. Míguez-Macho provided feedback which improved the experiment and the document.

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[1]http://meteo.unican.es/thredds/catalog/Spain_CORDEXgrids/catalog.html
[2]http://www.ecmwf.int/en/research/climate-reanalysis/era-interim
[3]https://sede.aemet.gob.es/

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References

AEMET: Atlas climático ibérico/Iberian climate atlas, Agencia Estatal de Meteorología., 2011.

Artinyan, E., Habets, F., Noilhan, J., Ledoux, E., Dimitrov, D., Martin, E., and Le Moigne, P.: Modelling the water budget and the river ows of the Maritsa basin in Bulgaria, Hydrology and Earth System Sciences, 12, 21–37, 2008.

5 Balsamo, G., Albergel, C., Beljaars, A., Boussetta, S., Brun, E., Cloke, H., Dee, D., Dutra, E., Pappenberger, F., de Rosnay, P., Muñoz-Sabater, J., Stockdale, F., and Vitart, F.: ERA-Interim/Land: A global land-surface reanalysis based on ERA-Interim meteorological forcing, Tech. rep., ECMWF, 2012.

Barbu, a. L., Calvet, J.-C., Mahfouf, J.-F., and Lafont, S.: Integrating ASCAT surface soil moisture and GEOV1 leaf area index into the SURFEX modelling platform: a land data assimilation application over France, Hydrology and Earth System Sciences, 18, 173–192,
10   doi:10.5194/hess-18-173-2014, 2014.

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.

Brun, E., Martin, E., Simon, V., Gendre, C., and Coleou, C.: An energy and mass model of snow cover suitable for operational avalanche forecasting, Journal of Glaciology, 35, 333–342, 1989.

15 Cansado, A., Martín, C., Navascués, B., Martin, C., and Navascués, B.: Optimum interpolation new snow depth analysis in HIRLAM, HIRLAM newsletter, pp. 248–252, 2004.

Casanueva, A., Kotlarski, S., Herrera, S., Fernández, J., Gutiérrez, J. M., Boberg, F., Colette, A., Christensen, O. B., Goergen, K., Jacob, D., Keuler, K., Nikulin, G., Teichmann, C., and Vautard, R.: Daily precipitation statistics in a EURO-CORDEX RCM ensemble: added value of raw and bias-corrected high-resolution simulations, Climate Dynamics, doi:10.1007/s00382-015-2865-x, 2015.

20 Casanueva, A., Herrera, S., Fernández, J., and Gutiérrez, J.: Towards a fair comparison of statistical and dynamical downscaling in the framework of the EURO-CORDEX initiative, Climatic Change, doi:10.1007/s10584-016-1683-4, 2016.

Chen, F., Manning, K. W., Lemone, M. a., Trier, S. B., Alfieri, J. G., Roberts, R., Tewari, M., Niyogi, D., Horst, T. W., Oncley, S. P., Basara, J. B., and Blanken, P. D.: Description and evaluation of the characteristics of the NCAR high-resolution land data assimilation system, Journal of Applied Meteorology and Climatology, 46, 694–713, doi:10.1175/JAM2463.1, 2007.

25 Cosgrove, B. A.: Real-time and retrospective forcing in the North American Land Data Assimilation System (NLDAS) project, Journal of Geophysical Research, 108, doi:10.1029/2002JD003118, 2003.

Decharme, B., Alkama, R., Papa, F., Faroux, S., Douville, H., and Prigent, C.: Global off-line evaluation of the ISBA-TRIP flood model, Climate Dynamics, 38, 1389–1412, doi:10.1007/s00382-011-1054-9, 2012.

Dee, D. P., Uppala, S. M., Simmons, a. J., Berrisford, P., Poli, P., Kobayashi, S., Andrae, U., Balmaseda, M. a., Balsamo, G., Bauer, P., Bech-
30   told, P., Beljaars, a. C. M., van de Berg, L., Bidlot, J., Bormann, N., Delsol, C., Dragani, R., Fuentes, M., Geer, a. J., Haimberger, L., Healy, S. B., Hersbach, H., Hólm, E. V., Isaksen, L., Kållberg, P., Köhler, M., Matricardi, M., McNally, a. P., Monge-Sanz, B. M., Morcrette, J.-J., Park, B.-K., Peubey, C., de Rosnay, P., Tavolato, C., Thépaut, J.-N., and Vitart, F.: The ERA-Interim reanalysis: configuration and performance of the data assimilation system, Quarterly Journal of the Royal Meteorological Society, 137, 553–597, doi:10.1002/qj.828, 2011.

35 Durand, Y., Brun, E., Merindol, L., Guyomarc'h, G., Lesaffre, B., and Martin, E.: A meteorological estimation of relevant parameters for snow models, Annals of Glaciology, 18, 65–71, 1993.

Durand, Y., Giraud, G., Brun, E., Merindol, L., and Martin, E.: A computer-based system simulating snowpack structures as a tool for regional avalanche forecasting, J. Glaciol., 45, 469–484, 1999.

Ensor, L. A. and Robeson, S. M.: Statistical Characteristics of Daily Precipitation: Comparisons of Gridded and Point Datasets, Journal of Applied Meteorology and Climatology, 47, 2468–2476, 2008.

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.

Funk, C., Peterson, P., Landsfeld, M., Pedreros, D., Verdin, J., Shukla, S., Husak, G., Rowland, J., Harrison, L., Hoell, A., and Michaelsen, J.: The climate hazards infrared precipitation with stations—a new environmental record for monitoring extremes, Scientific Data, 2, 150 066, doi:10.1038/sdata.2015.66, 2015.

Gandin, L. S.: Objective analysis of meteorological fields. By L. S. Gandin. Translated from the Russian. Jerusalem (Israel Program for Scientific Translations), Quarterly Journal of the Royal Meteorological Society, 92, 447–447, doi:10.1002/qj.49709239320, 1966.

Gómez-Navarro, J. J., Montvez, J. P., Jerez, S., Jiménez-Guerrero, P., and Zorita, E.: What is the role of the observational dataset in the evaluation and scoring of climate models?, Geophysical Research Letters, 39, doi:10.1029/2012GL054206, 2012.

Habets, F., Boone, A., Champeaux, J. L., Etchevers, P., Franchistéguy, L., Leblois, E., Ledoux, E., Le Moigne, P., Martin, E., Morel, S., Noilhan, J., Seguí, P. Q., Rousset-Regimbeau, F., and Viennot, P.: The SAFRAN-ISBA-MODCOU hydrometeorological model applied over France, Journal of Geophysical Research: Atmospheres, 113, D06 113, doi:10.1029/2007JD008548, 2008.

Häggmark, L., Ivarsson, K.-I., Gollvik, S., and Olofsson, P.-O.: Mesan, an operational mesoscale analysis system, Tellus A, 52, 2–20, doi:10.3402/tellusa.v52i1.12250, 2000.

Haylock, M. R., Hofstra, N., Klein Tank, A. M. G., Klok, E. J., Jones, P. D., and New, M.: A European daily high-resolution gridded data set of surface temperature and precipitation for 1950–2006, Journal of Geophysical Research, 113, D20 119, doi:10.1029/2008JD010201, 2008.

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.

Isotta, F. A., Frei, C., Weilguni, V., Perčec Tadić, M., Lassègues, P., Rudolf, B., Pavan, V., Cacciamani, C., Antolini, G., Ratto, S. M., Munari, M., Micheletti, S., Bonati, V., Lussana, C., Ronchi, C., Panettieri, E., Marigo, G., and Vertačnik, G.: The climate of daily precipitation in the Alps: development and analysis of a high-resolution grid dataset from pan-Alpine rain-gauge data, International Journal of Climatology, 34, 1657–1675, doi:10.1002/joc.3794, 2014.

Katsanos, D., Retalis, A., and Michaelides, S.: Validation of a high-resolution precipitation database (CHIRPS) over Cyprus for a 30-year period, Atmospheric Research, pp. 6–11, doi:10.1016/j.atmosres.2015.05.015, 2015.

Long, D., Longuevergne, L., and Scanlon, B. R.: Uncertainty in evapotranspiration fromland surfacemodeling, remote sensing, and GRACE satellites, Water Resources Research, 50, 1131–1151, doi:10.1002/2013WR014581.Received, 2014.

Martínez de la Torre, A.: Groundwater influence on soil moisture memory and land-atmosphere interactions over the Iberian Peninsula, Phd thesis, Universidade de Santiago de Compostela, 2014.

Mitchell, K. E.: The multi-institution North American Land Data Assimilation System (NLDAS): Utilizing multiple GCIP products and part-ners in a continental distributed hydrological modeling system, Journal of Geophysical Research, 109, 1–32, doi:10.1029/2003JD003823, 2004.

Nasonova, O. N., Gusev, Y. M., and Kovalev, Y. E.: Impact of uncertainties in meteorological forcing data and land surface parameters on global estimates of terrestrial water balance components, Hydrological Processes, 25, 1074–1090, doi:10.1002/hyp.7651, 2011.

Navascués, B., Rodríguez, E., Ayuso, J. J., and Jarvenoja, S.: Analysis of surface variables and parameterization of surface processes in HIRLAM. Part II: Seasonal assimilation experiment, Tech. rep., HIRLAM Technical Repport 59, 2003.

Orth, R. and Seneviratne, S. I.: Introduction of a simple-model-based land surface dataset for Europe, Environmental Research Letters, 10, 044 012, doi:10.1088/1748-9326/10/4/044012, 2015.

Peters-Lidard, C. D., Kumar, S. V., Mocko, D. M., and Tian, Y.: Estimating evapotranspiration with land data assimilation systems, Hydro-logical Processes, 25, 3979–3992, doi:10.1002/hyp.8387, 2011.

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.

Quintana-Seguí, P.: SAFRAN analysis over Spain, doi:10.14768/MISTRALS-HYMEX.1388, 2015.

Quintana-Seguí, P.: Meteorological Analysis Systems in North-East Spain: Validation of SAFRAN and SPAN, Journal of Environmental Informatics, 27, 116–130, doi:10.3808/jei.201600335, 2016.

Quintana-Seguí, P., Le Moigne, P., Durand, Y., Martin, E., Habets, F., Baillon, M., Canellas, C., Franchisteguy, L., and Morel, S.: Analysis of near-surface atmospheric variables: Validation of the SAFRAN analysis over France, Journal of Applied Meteorology and Climatology, 47, 92–107, doi:10.1175/2007JAMC1636.1, 2008.

Ritter, B. and Geleyn, J.-F.: A Comprehensive Radiation Scheme for Numerical Weather Prediction Models with Potential Applications in Climate Simulations, doi:10.1175/1520-0493(1992)120<0303:ACRSFN>2.0.CO;2, 1992.

Rodell, M., Houser, P. R., Jambor, U., Gottschalck, J., Mitchell, K., Meng, C.-J., Arsenault, K., Cosgrove, B., Radakovich, J., Bosilovich, M., Entin*, J. K., Walker, J. P., Lohmann, D., and Toll, D.: The Global Land Data Assimilation System, Bulletin of the American Meteo-rological Society, 85, 381–394, doi:10.1175/BAMS-85-3-381, 2004.

Rodríguez, E., Navascués, B., Ayuso, J. J., and Järvenoja, S.: Analysis of surface variables and parameterization of surface processes in HIRLAM. Part I: Approach and verification by parallel runs, Tech. rep., HIRLAM Technical Repport 58, 2003.

Soci, C., Bazile, E., Besson, F., and Landelius, T.: High-resolution precipitation re-analysis system for climatological purposes, Tellus A, 68, doi:10.3402/tellusa.v68.29879, 2016.

Szczypta, C., Decharme, B., Carrer, D., Calvet, J.-C. C., Lafont, S., Somot, S., Faroux, S., and Martin, E.: Impact of precipitation and land biophysical variables on the simulated discharge of European and Mediterranean rivers, Hydrology and Earth System Sciences, 16, 3351–3370, doi:10.5194/hess-16-3351-2012, 2012.

Szczypta, C., Gascoin, S., Habets, F., Saaidi, A., and Berjamy, B.: Evaluation of the SAFRAN-ISBA-RAPID hydrometeorological chain on a mountainous catchment in a semi-arid region . Case of the Rheraya (Marrakech , Morocco), Geophysical Research Abstracts, 17, EGU2015–14 149, 2015.

Taillefer, F.: CANARI Technical Documentation based on ARPEGE cycle CY25T1 (AL25T1 for ALADIN), Tech. rep., Météo-France, Toulouse (France), 2002.

Taylor, K. E.: Summarizing multiple aspects of model performance in a single diagram, Journal of Geophysical Research: Atmospheres, 106, 7183–7192, doi:10.1029/2000JD900719, 2001.

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.

Turco, M., Quintana-Seguí, P., Llasat, M. C., Herrera, S., and Gutiérrez, J. M.: Testing MOS precipitation downscaling for ENSEMBLES regional climate models over Spain, Journal of Geophysical Research: Atmospheres, 116, doi:10.1029/2011JD016166, 2011.

5 Turco, M., Sanna, A., Herrera, S., Llasat, M.-C., and Gutiérrez, J. M.: Large biases and inconsistent climate change signals in ENSEMBLES regional projections, Climatic Change, doi:10.1007/s10584-013-0844-y, 2013a.

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, 2013b.

10 Vidal, J. P., Martin, E., Franchistéguy, L., Baillon, M., and Soubeyroux, J. M.: A 50-year high-resolution atmospheric reanalysis over France with the Safran system, International Journal of Climatology, 30, 1627–1644, doi:10.1002/joc.2003, 2010.

Weedon, G. P., Balsamo, G., Bellouin, N., Gomes, S., Best, M. J., and Viterbo, P.: The WFDEI meteorological forcing data set: WATCH Forcing Data methodology applied to ERA-Interim reanalysis data, Water Resources Research, 50, 7505–7514, doi:10.1002/2014WR015638, 2014.
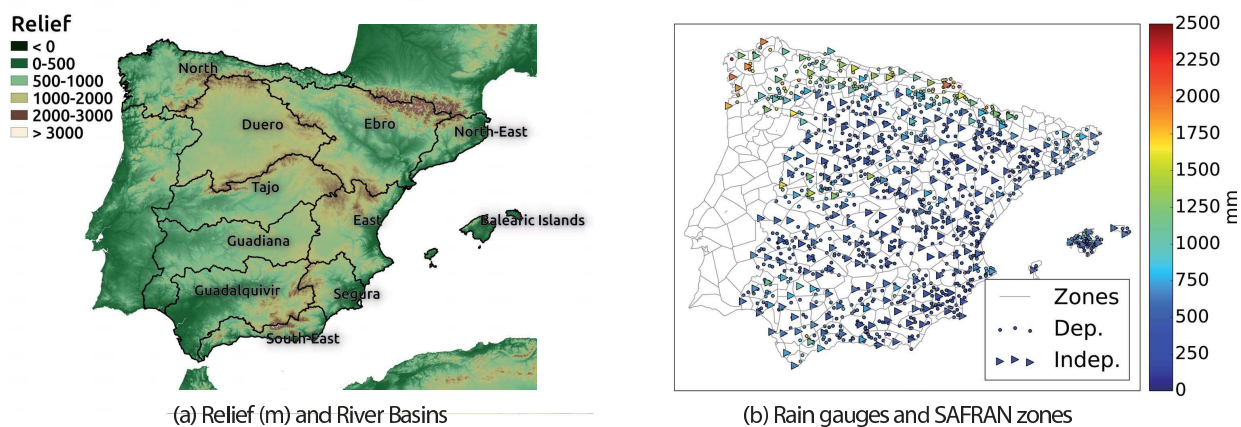
Figure 1. Maps of the study area. The left panel shows the relief and the main river basins of Spain (some smaller basins have been grouped). The right panel shows SAFRAN's climatically homogeneous zones, the rain gauges used for the study and their mean yearly precipitation. The dependent and independent stations are shown as dots and triangles, respectively.
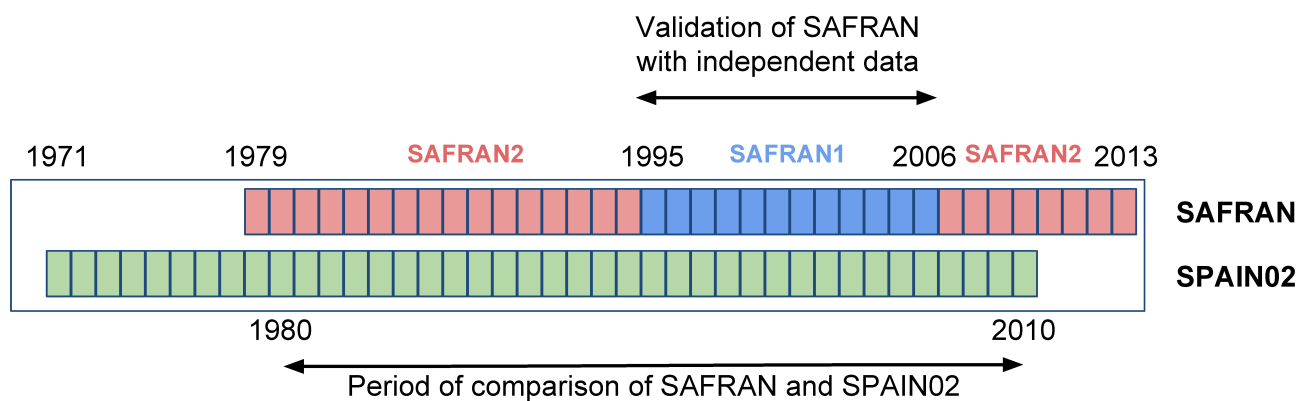
Figure 2. Data availability for SAFRAN and Spain02.
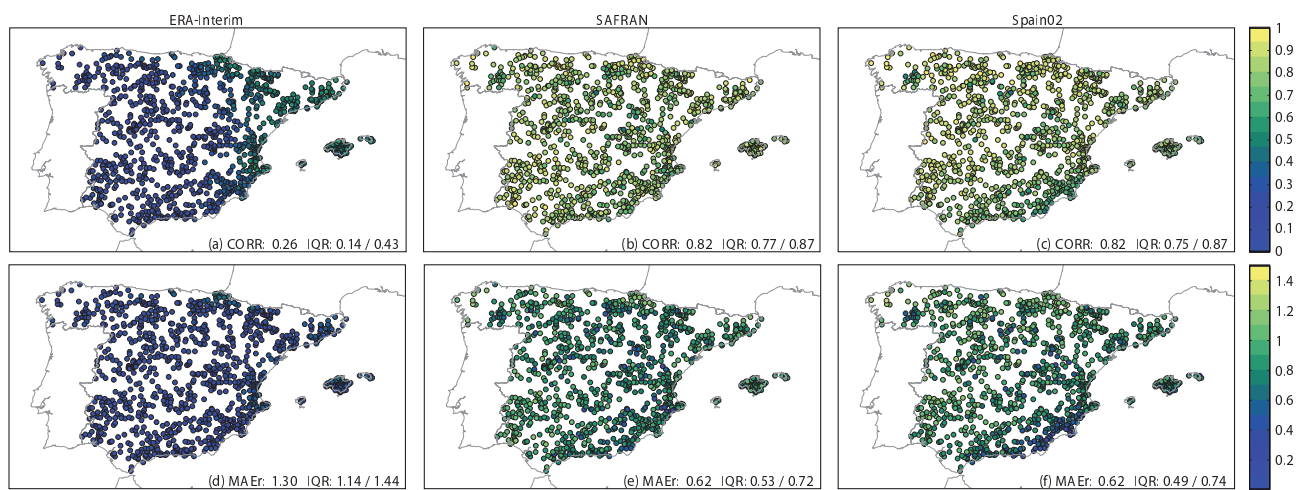
Figure 3. Correlation (a-c) and Relative Mean Absolute Error (d-f) of ERA-Interim, SAFRAN and Spain02, and the observations.
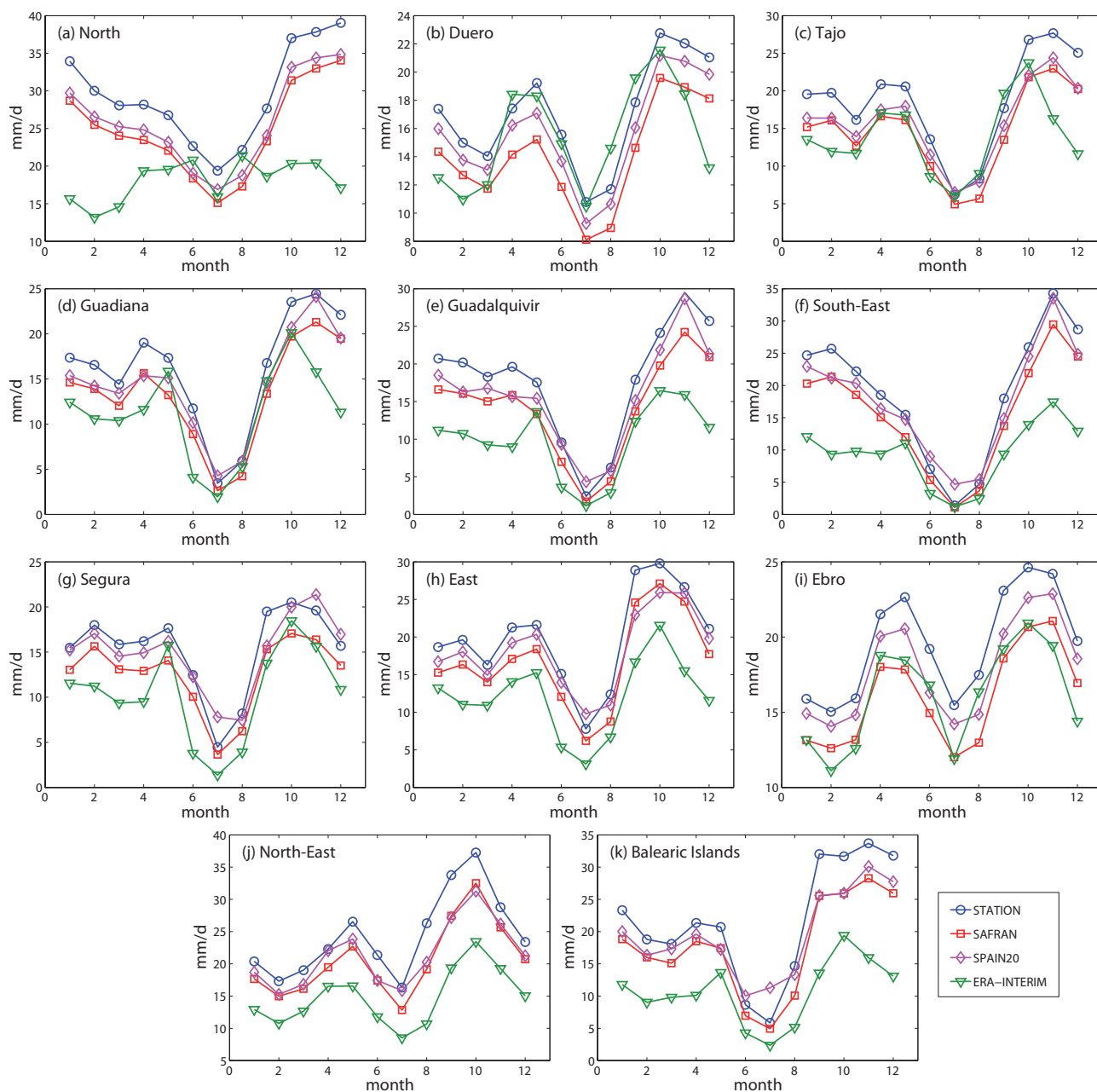
Figure 4. Annual cycle of maximum precipitation in one day (RX1D) for the Spanish river basins. The y-axis range is different for each figure to highlight the differences between datasets.
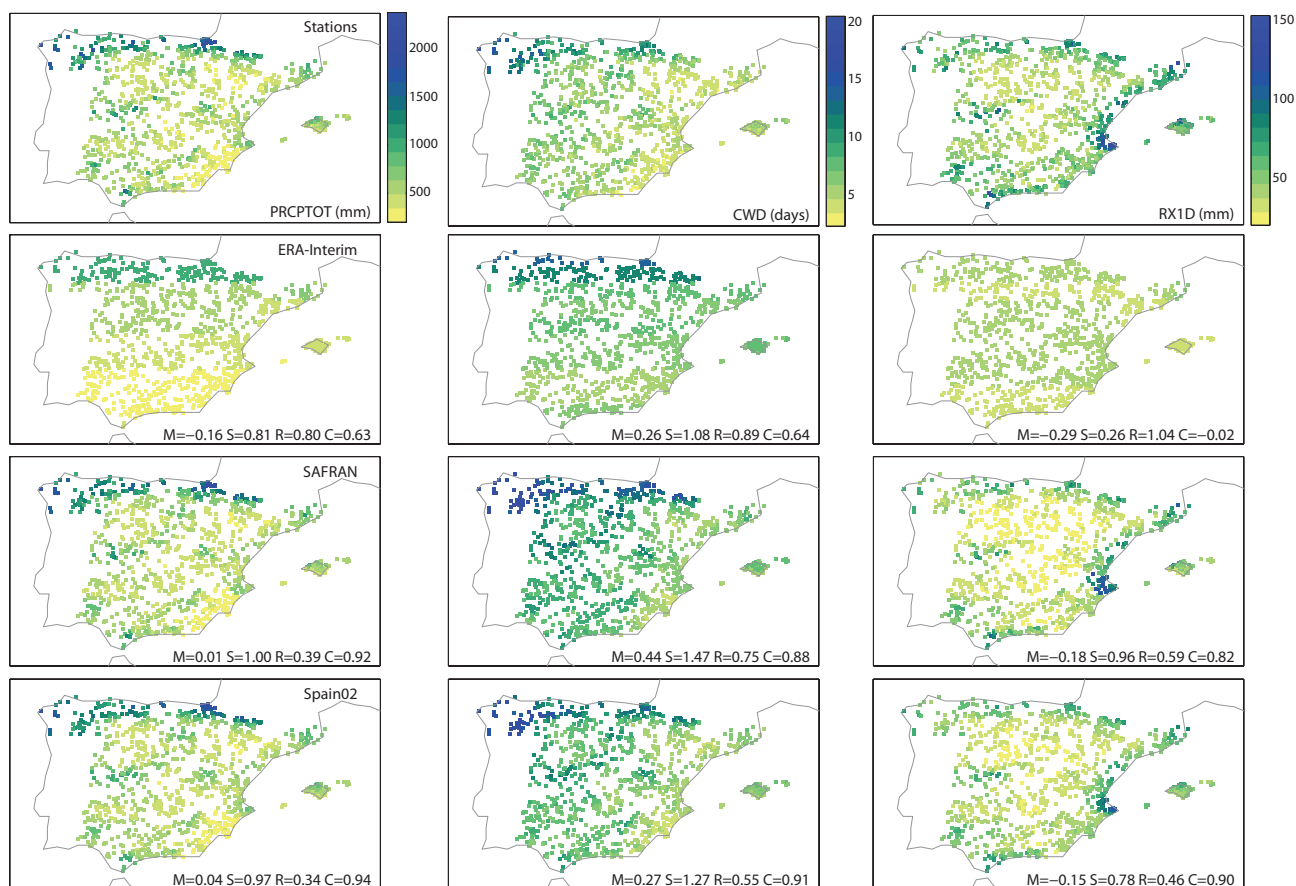
Figure 5. PRCPTOT (first column), CWD (second column) and RX1D (third column) for the stations (first row), ERA-Interim (second row), SAFRAN (third row) and Spain02 (fourth row).
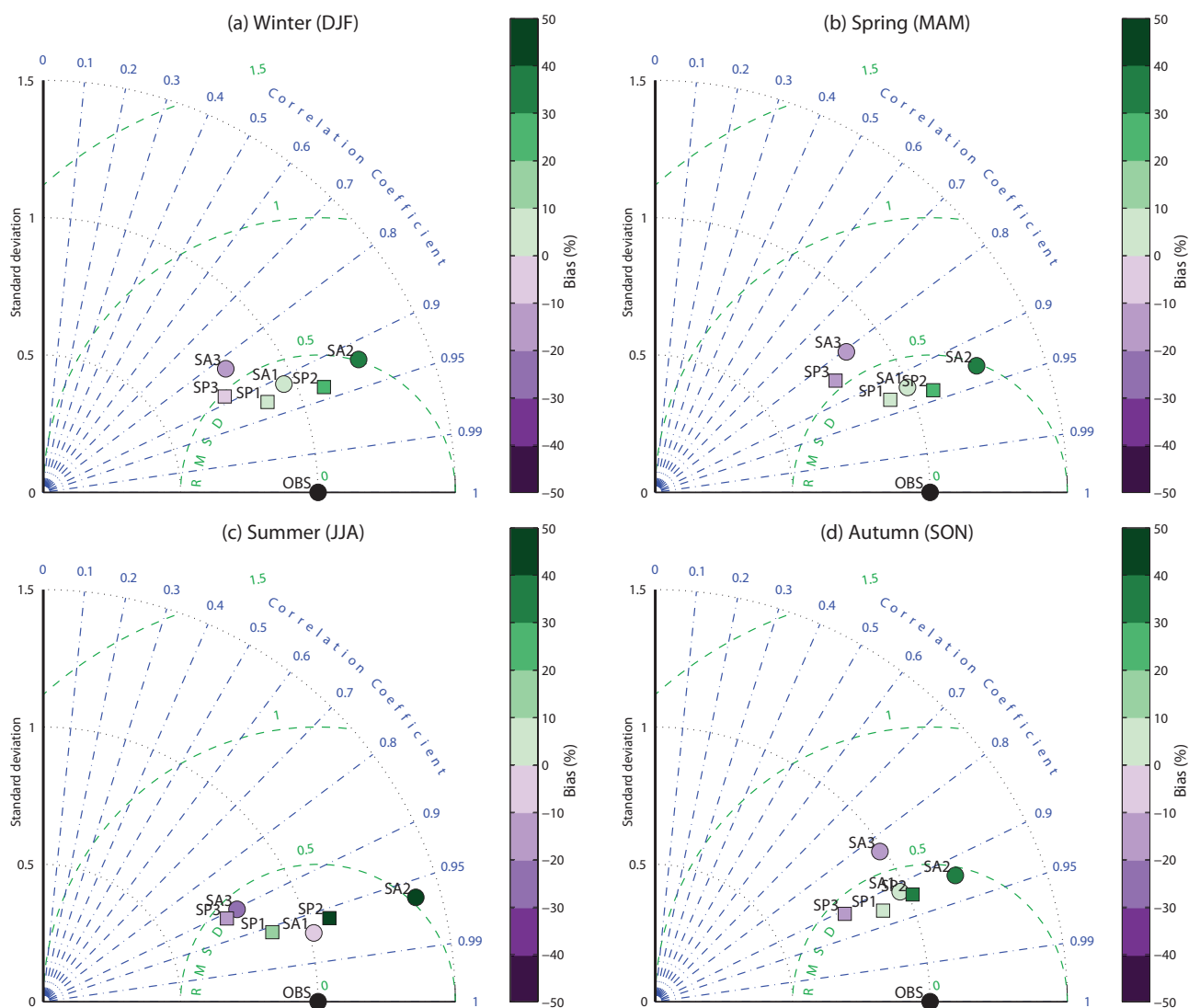
Figure 6. Taylor diagrams for seasonal precipitation climatology over Spain. The points most similar to the station data are closest to the point indicated as OBS. Squares labeled "SP" are used for Spain02, whereas circles labeled "SA" are for SAFRAN. The colors indicate the bias (in percentage with respect to the station data) of the dataset. The numbers correspond to the different indices: 1 = PRCPTOT; 2 = R1; and 3 = RX1D.

Table 1. Climatic mean and extreme indices for precipitation used in this work, based on ETCCDI (http://cccma.seos.uvic.ca/ETCCDI).

Label	Description	Units
PRCPTOT	total precipitation	mm
R1	number of days with precipitation over 1 mm.d^{-1} (i.e. wet days)	d
SDII	mean precipitation amount on a wet day	mm
R10	number of days with precipitation over 10 mm.d^{-1}	d
R20	number of days with precipitation over 20 mm.d^{-1}	d
RX1D	maximum precipitation in 1 day	mm
RX5D	maximum precipitation in 5 days	mm
CWD	consecutive wet days (>1 mm)	d
CDD	consecutive dry days (<1 mm)	d

Table 2. Correlation (CORR) and Relative Mean Absolute Error (MAEr) of SAFRAN compared to independent (Ind.) and dependent (Dep.) observations for the period 1995/96-2005/06.

	CORR			MAEr		
	Mean	Q25	Q75	Mean	Q25	Q75
Ind. Obs.	0.82	0.75	0.86	0.62	0.54	0.75
Dep. Obs.	0.82	0.77	0.87	0.62	0.53	0.72

Table 3. Correlation (CORR) and Relative Mean Absolute Error (MAEr) of the three compared products considering all stations (upper half of the table) and those located at altitudes higher than 1000 m (lower half of the table.

	Correlation			MAEr		
	Mean	Q25	Q75	Mean	Q25	Q75
ERA	0.26	0.14	0.43	1.30	1.14	1.44
SFR	0.82	0.77	0.87	0.62	0.53	0.72
SP02	0.82	0.75	0.87	0.62	0.49	0.75
			>1000 m			
ERA	0.21	0.04	0.36	1.23	1.11	1.43
SFR	0.82	0.75	0.86	0.64	0.55	0.77
SP02	0.82	0.75	0.88	0.61	0.49	0.76

Table 4. Comparison of the performance of ERA-Interim (ERA), SAFRAN (SFR) and Spain02 (SP02) in reproducing indices of mean and extreme precipitation.

	BIASr	STDEVr	CRMSEr	CORR
Total Precipitation (PRCPTOT)				
ERA	-0.16	0.81	0.80	0.63
SFR	0.01	1.00	0.39	0.92
SP02	0.04	0.97	0.34	0.94
Consecutive Dry Days (CDD)				
ERA	-0.01	1.28	0.69	0.85
SFR	0.04	1.04	0.49	0.88
SP02	-0.03	0.91	0.50	0.87
Consecutive Wet Days (CWD)				
ERA	0.26	1.08	0.89	0.64
SFR	0.44	1.47	0.75	0.88
SP02	0.27	1.27	0.55	0.91
Number of Rainy days (R1)				
ERA	0.39	1.66	1.06	0.79
SFR	0.40	1.27	0.50	0.93
SP02	0.30	1.18	0.41	0.94
Mean precipitation of a wet day (SDII)				
ERA	-0.40	0.16	1.03	-0.11
SFR	-0.26	0.68	0.66	0.76
SP02	-0.18	0.67	0.59	0.82
Number of days of $P > 10$ mm (R10)				
ERA	-0.31	0.71	0.78	0.64
SFR	-0.04	1.08	0.40	0.93
SP02	0.05	1.06	0.34	0.95
Number of days of $P > 20$ mm (R20)				
ERA	-0.57	0.25	0.94	0.38
SFR	-0.22	0.94	0.46	0.89
SP02	-0.09	0.94	0.40	0.92
Max. Precip in 1 day (RX1D)				
ERA	-0.29	0.26	1.04	-0.02
SFR	-0.18	0.96	0.59	0.82
SP02	-0.15	0.78	0.46	0.90
Max Precip in 5 days (RX5D)				
ERA	-0.27	0.26	1.01	0.10
SFR	-0.07	0.94	0.54	0.84
SP02	-0.06	0.85	0.42	0.91