Analysis of a first approximation to radar-based precipitation climatology over a highly contrasted land use region

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Abstract: In the present work, a radar-based precipitation climatology (2013-2019 period) is built in order to study changes in precipitation in an area with sharp contrasts in land use. This climatology includes (apart from monthly, seasonal and annual mean) an hourly accumulation study for July and August. The results agree in great measure with the official climatology, apart from some overestimation in certain parts. Inaccuracies possibly as a result of radar beam blocking have been detected. Land use has an apparent effect on high intensity precipitation events in both July and August.

I. INTRODUCTION

In the present study, an area with similar climatic characteristics but differences in land use is examined. The area that fulfill this requirements is found in a large nearly flat region in Catalonia (NE Iberian Peninsula, *FIG.1*). Its land use vary between irrigated and non irrigated areas.

In irrigated areas, moisture prevents temperature to increase, while in non irrigated areas this increase is more rapid, triggering convection more easily. In [1], differences in land use have been found to be the cause of convective precipitation distribution in summer around the bend of the Yellow River in North China. The aim of this study is to analize the behaviour of precipitation in our region at different temporal scales based on weather radar data. As only seven years of data are available, this can only be considered as a first approximation to a high resolution climatology of the area.

To see the differences in precipitation, a fine resolution precipitation map is needed, as convective episodes are developed in a length scale of few kilometers. Current public climatology maps present coarser resolution, based on rain gauges and the experience of climatologists.

Besides fine spatial resolution, finer temporal resolution is also needed in order to study the behaviour of precipitation intensities. These intensities are essential to discover patterns that cannot be detected in usual climatologies.

Usual climatologies show monthly, seasonal or yearly precipitation means over a region, but they do not go below this temporal scale.

Although the study is centered in summer in a small region, an annual, seasonal and monthly precipitation climatology for a larger area is partially shown.

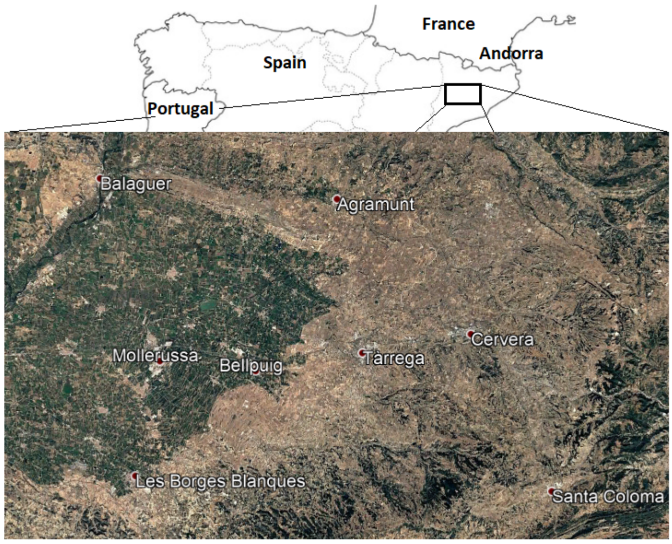

FIG. 1: Area of study.

II. METHODOLOGY

A. Area of study

In order to perform this work, the first step has been to define our area of study. In particular, two areas have been selected (*FIG. 2*). The small one (a) is approximately a rectangle of 20×30 km that encloses a mainly flat region with different use of the land. On the western part (a_W) we can find irrigated fields, while on the eastern part (a_E) fields are not irrigated. This small area a is split by the Urgell Chanel (U), that supplies water to a_W. A larger area (A) of 35×55 km encloses the majority of the plane, with the mountainous area that surrounds it at the north, south and east. This larger area A is

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useful to know how the whole area behaves in terms of precipitation, and to put a in its climatic context.

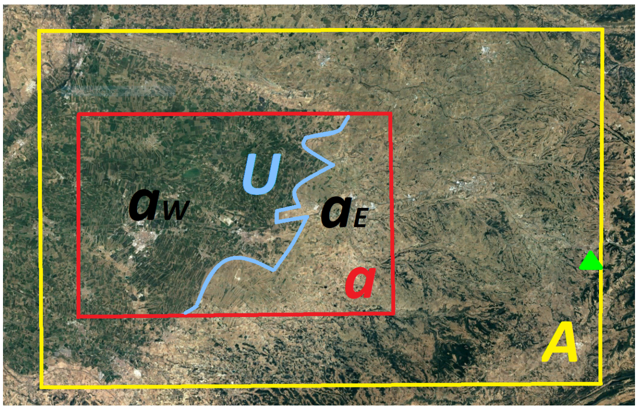

FIG. 2: Location of A, a, a_W, a_E and the Urgell channel (U). The green triangle shows the location of the weather radar from the (XRAD) that is located inside our area of study.

B. Data

Once the areas have been defined, data from the Hydro-meteorological Integrated Forecasting Tool (EHIMI) from the Meteorological Service of Catalonia (SMC) [2] is used as the basis of our analysis. The feature that is used is the Quantitative Precipitation Estimates (referred to as QPE hereafter). The QPE comes from the Weather Radar Network (XRAD) from the SMC. It has a spatial resolution of 1×1 km, grouped in hourly or daily accumulation. This QPE has the peculiarity that it is corrected with raingauges of the Automatic Weather Stations (XEMA) from the SMC [3].

C. Data analysis

To get the climatology of A, daily accumulations have been used in order to build monthly, seasonal and yearly mean for every point of the grid. Daily estimates are good to produce the climatology of the region, but are not capable of describing hourly behaviour of the precipitation i.e. intensity patterns.

Once the climatology is made, the time scale is reduced as well as the area, taking a as the region for hourly accumulation study. Separate calculations are performed in both parts of a (a_W and a_E).

III. RESULTS

A. QPE climatology using daily estimates

Firstly, results based on daily accumulation data of area A are shown.

As can be seen in *FIG. 3*, the area A presents two different precipitation regimes. This mean has been performed over the period 2014-2018, the one with complete data for every month. The first one is the flat area enclosed in a, that presents a quite homogeneous distribution of the precipitation, between 350 and 425 mm. The second regime can be noticed outside the area a, with a gradient that is more pronounced at the eastern extreme, with accumulations ranging between 400 and more than 600 mm. These results are in concordance with climatology, as discussed below. It is worth mentioning that there are several points at the southeast extreme that show a different behaviour than the rest of the grid, probably due to radar beam blocking comig from orography [4] or wind farms that introduce noise [5].

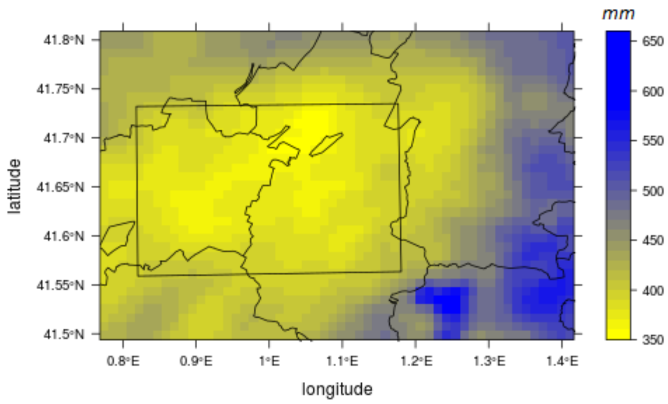

FIG. 3: Annual precipitation mean (mm) over the area A for the 2014-2018 period. Area a (small rectangle) and the administrative limits are shown.

In *FIG. 4* can be seen that the region presents also two regimes concerning summer (JJA), with a drier area at the a region, ranging from 55 and 90 mm and the other outside it, between 65 and 120 mm, with a high precipitation zone at the northern part (note that the legend scale is different from the *FIG. 3*). This mean has been computed for June-July-August (2013-2019). The issue with particular points as in the annual mean study persists at the southeastern extreme (out of scale).

In *FIG. 5* and *FIG. 6*, differences can be noticed between a_W (irrigated) and a_E (non irrigated) that are separated by the Urgell channel, with higher values at a_E in July and vice versa in August (*TABLE I*). Notice also out of scale points probably coming from wind farms and orographic noise.

B. QPE highlights using hourly estimates

In this part, results in base of hourly accumulation referring to area a are shown.

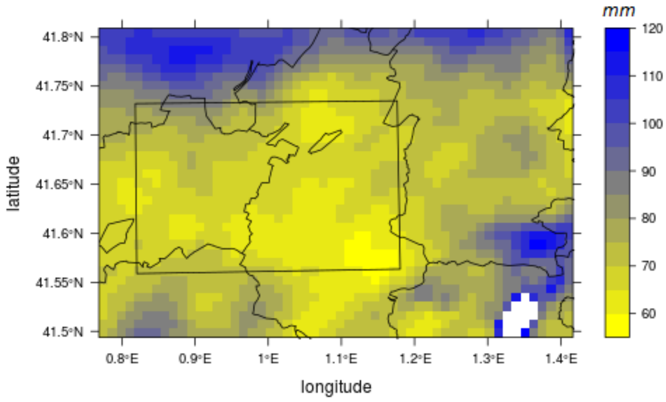

FIG. 4: Summer precipitation mean (mm) over the area A for the 2013-2019 period. Area a (small rectangle) and the administrative limits are shown.

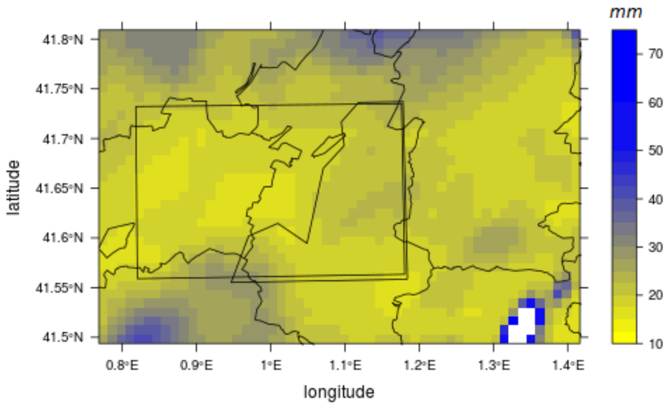

FIG. 5: July precipitation mean (mm) over the area A accfor the 2013-2019 period. Area a (rectangle), the administrative limits and the Urgell channel are shown.

Variable	a_W	a_E
July mean ppt (mm)	18.9 ± 2.2	21.0 ± 2.1
August mean ppt (mm)	25.3 ± 4.8	18.5 ± 1.8

TABLE I: Mean precipitation and standard deviation at a_W (irrigated) a_E (non irrigated) parts of region a in July and August.

For days with precipitation, each non-dry point of the area has been classified as a low, moderate or high intensity precipitation point (between $(0, 0.3]$, $(0.3, 0.8]$ and $(0.8, \infty)$ mm h^{-1}, respectively).

Once all points corresponding to wet days (days with at least one non-dry point) have been summed up, a mean over all points inside the desired area is performed. That is the mean precipitation (spatial mean, not temporal) on a_W as well as on a_E during all the period of study. In addition to the mean, the

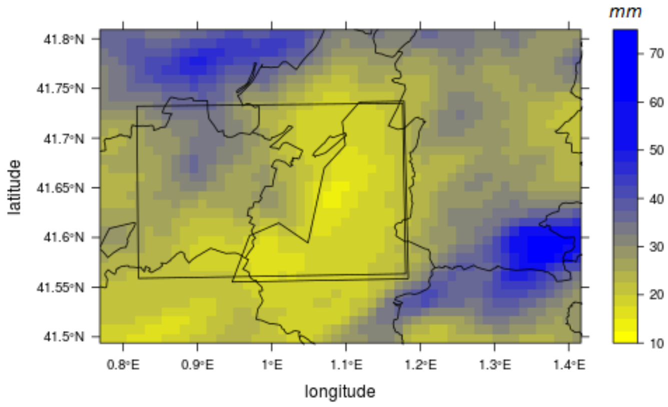

FIG. 6: August precipitation mean (mm) over the area A for the 2013-2019 period. Area a (rectangle), the administrative limits and the Urgell channel are shown.

standard deviation and the percentage of hours with low, moderate and high precipitation rate are given. The results are summarized in *TABLE. II*. Each non-zero hourly data is taken as an episode.

1. *Monthly variations*

A clear difference in the intensity episodes can be noticed between July and August. In July, low intensity events represent around 40 percent of the total episodes and high intensity episodes around 30 percent, while in August the percentages are reversed. Moderate precipitation rate presents no relevant temporal variations. High intensity episodes account for more than the 75% of the total precipitation accumulation regardless of the area (a_W or a_E) or the month (July or August). The moderate and the low intensity episodes complete the table, being the former accumulation more than twice the latest.

The last point to be mentioned in this section is that July presents around 25 more overall hourly precipitation episodes than August (165 vs. 140) and a greater overall accumulation (~ 210 vs. ~ 150 mm) (*TABLE II*).

2. *Spatial variations*

Regarding the spatial variations of the precipitation, no noticeable changes can be reported in the low nor the moderate rates. Looking at high intensity, no changes in the percentage of high intensity episodes can be seen, but an important difference in total precipitation shows up: 24 mm more on the non irrigated side in July and 42 mm more on the irrigated side in August.

	July				August			
	irrigated (a_W)		non irrigated (a_E)		irrigated (a_W)		non irrigated (a_E)	
intensity	ppt (mm)	episodes (%)	ppt (mm)	episodes(%)	ppt (mm)	episodes (%)	ppt (mm)	episodes (%)
low	8.8 ± 1.4	42	8.6 ± 1.0	42	7.8 ± 0.9	30	7.8 ± 0.8	27
moderate	21.5 ± 2.9	26	21.1 ± 2.2	26	19.5 ± 2.3	27	20.2 ± 3.1	28
high	168.1 ± 23.9	32	192.1 ± 23.9	32	145.5 ± 34.4	43	103.0 ± 23.1	45

TABLE II: Total mean precipitation (spatial mean) over region a during July and August from the 2013-2019 period and percentage of episodes for each intensity class. A separation is made in terms of land use.

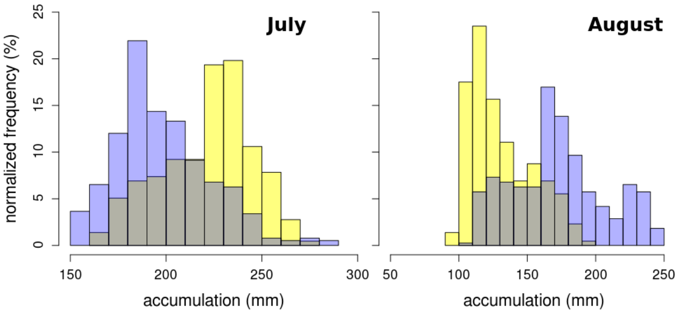

FIG. 7: Histogram of the total accumulation in the 2013-2019 period over a_W (irrigated, in blue) and a_E (non irrigated, in yellow), normalized (percentage of points). In grey, the intersection between the histograms of a_W and a_E.

The results that are detailed in *TABLE II* are partially graphically represented in *FIG. 7* in terms of overall precipitation of each point.

IV. DISCUSSION

A. QPE climatology assessment

As one aim of this work is to obtain a climatology of precipitation of an area inside Catalonia, the first step to be done is to look at the current published climatology of the area. The used official climatology is the Climatic Atlas of Catalonia [6].

According to it, the central and western part of the big region A presents a minimum (350 to 400 mm) and the northern, southern and eastern the higher values, reaching 450 to 500 mm (not shown). The results in our work fit these specifications in general, but more detailed resolution is reached (*FIG. 3*).

Regarding summer climatology, the pattern differs in a way that we have found a 55 mm minimum at the region a southeast corner, while [6] locates the minimum at the a western part, between 40 and 60 mm (not shown), where we found more than 60 mm. In general, an overestimation is detected, being more important at the northern part of A. At this region, our climatology (*FIG. 4*) gives around 100 mm, while the atlas does not exceed 80 mm.

An interesting comparison arises when dealing with July and August. In July, as in summer, an overestimation exists specially at the A south-western corner. The minimum that appears in the literature at the center and western part of a (not shown) can be clearly seen, but we found other minimums at other locations (*FIG. 5*). It has to be mentioned that at the eastern part of a, a local maximum is located. This could be due to the difference in land use (irrigated vs. non irrigated at a_W and a_E respectively). To take a closer look to this region, *TABLE I* shows that in July both sides differ in the mean accumulation of precipitation in one standard deviation.

In August, the trend (drier at the center and wetter at the extremes) is more pronounced, also with an overestimation of the precipitation at the north and at the southeast (50-60 mm vs. 20-30 mm from the literature). A clear change in the precipitation trend is seen with respect to July, with higher values at a_E compared to a_W, as it is detailed in *FIG. 6* and *TABLE I*. In this case, differences between both sides are greater than in July, of more than one standard deviation. This fact enhances the possibility that the differences in land use is behind this behaviour. Although the behaviour is the opposite from July, there is a clear distinction between both sides.

Regarding radar beam blocking, as has been mentioned in the *results* section, in the southeastern part, the QPE suffers a bias, due to the blocking of several wind farms [5] and orography [4]. This blocking introduces a bias that produces overestimated values in this region. The affected region is relatively small, so it does not inhibit us to get a good overall climatology over the big area A.

B. Hourly QPE assessment

Relevant findings referring to the temporal distribution of precipitation in a are presented. As shown in *TABLE II*, intensity patterns change between July and August. In July, low intensity periods represent more than 40 percent of the precipitation episodes while high rate events represent around a 30 percent, regardless of the irrigated or the non irrigated region. There are also no relevant differences between regions in August, but the percentages of low and high rate precipitation are reversed (~ 40 for high and ~ 30 for low intensities).

Regarding spatial distribution of precipitation, this aforementioned reversal in intensity patterns has no effect on the total accumulation in low nor moderate intensity episodes, remaining constant over both months and regions. The difference shows up at the total accumulation in high intensity episodes. Such difference consists of significantly more precipitation on a_W than on a_E in July and more precipitation at a_E than at a_W in August. This may be related with the different use of land (irrigated vs. non irrigated). This difference in high intensity patterns can be related with [1], but only applies in the case of July. Although the accumulation in August does not agree with [1], the percentage of episodes seems to do so, experiencing a small (non statistically significant) increase in the moderate and high intensity episodes at the non irrigated area a_E (27+43 (a_W) vs. 28+45 (a_E)).

Although the results are clear, conclusions about high intensities have to be taken cautiously, because accumulation is very sensitive to events with high radar reflectivity, such as hailstorms. A smaller impact with daily accumulation based climatologies has also to be taken into consideration.

V. CONCLUSIONS

Despite rain gauge based climatologies are computed with a longer period of study than ours, we can affirm that our results have good quality comparing them to the official climatology. This radar-based climatology possesses a spatial resolution that can not be reached by any rain-gauge network alone so fine patterns of precipitation have been found at monthly scales. Some of these fine patterns differ from the established climatology (e.g. accumulation on irrigated area in August).

An overestimation of accumulated precipitation has been found for summer, being greater at the north, east and south regions of A, where the orography is more complex. In this sense, wind farms and orographic radar beam blocking is an element to take into in account if an improvement of the accuracy of QPE at the southeastern part of A is wanted.

Concerning the small area a, a different behaviour for intensity patterns have been found for July and August. This different behaviour does not have any relevant dependency on land use. On the other hand, the accumulation in high intensity episodes does present dependency in land use, being the pattern in July the opposite than in August.

Further studies on daily precipitation regimes and hourly evolution in summer are encouraged, as the sun plays an important role in triggering convective storms. A validation of the present radar-based climatology using rain gauges data could serve as a good way to adjust possible bias in the climatology itself, as well as possible bias in the QPE issued from the EIHMI tool.

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