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Analysis of the influence of synoptic conditions on precipitation in the Canary Islands.

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Abstract

The present work analyzes the atmospheric synoptic conditions which mainly affect rain episodes over the Canary Islands. The main aims are to assess the reliability of two databases used to determine the weather in the Canary Islands and to study the phenomenological distribution of rain episodes.

To achieve these aims is especially important to keep into account 3 specific features of the Canary Islands. First, their particular location: close to the African continent in a transition area from mild to tropical temperatures affected by the North Atlantic Oscillation (NAO) and the Azores High. Second, the common weather conditions: the archipelago is considered as a dry and very stable area, having over 50 raining episodes per year on average. Third, its steep orography: altitude varies more than 3000m in less than 20km horizontally.

After setting these features, a phenomenological classification is given. A total of 4 atmospheric disturbance phenomena are classified: Deep Atlantic Lows (DAL), Atlantic Surface Lows (ASL), upper Atlantic Lows (UAL) and Troughs (TRO) are the considered phenomena used to characterize the Canary Islands weather. The phenomena which are not possible to include in any of these categories are included in *No detection type* (ND, None).

Using some online resources, such as the AEMET database ARCIMÍS, and Meteo Centre Reanalysis, a set of 104 cases of heavy rain (>30mm episodes) is analyzed to better understand the particular situations in the atmosphere. Furthermore, this type of analysis gives a reliable method to compare the further automatic classification of the phenomena.

After that, the AEMET database is analyzed. This particular database shows the distribution of heavy rain ($> 30mm$) and all the rain ($> 1mm$) in the Canary Islands. These data are further used to compare the reliability of the numerical databases.

Then, Spread and WRF databases are analyzed. Maps of the distribution of the above classification is shown for these two databases. First, 10 and 1mm maps, then, seasonal maps. In this way, both databases are easily compared and furthermore, it is possible to set which are the main phenomena affecting the Canary Islands and their particular location.

Finally, as conclusions: the correspondence between these databases is exposed as well the most important phenomena over the Canary Islands. The correspondence between databases is particularly trustworthy. The most important phenomenon affecting the Canary Islands is DAL and it is prominent during the winter.

Resumen

En la presente memoria se pretende analizar las perturbaciones atmosféricas que dan lugar a las precipitaciones más importantes en las Islas Canarias. Los objetivos principales del trabajo son establecer la fiabilidad de las bases de datos para determinar los fenómenos de precipitaciones así como estudiar la distribución de los episodios de lluvia.

Para lograr estos objetivos es particularmente importante tener en cuenta tres características de las Islas Canarias. Primero, su localización peculiar: cercanas al continente africano en una zona de transición de temperaturas suaves a tropicales, afectadas por la Oscilación del Atlántico Norte (NAO) y por el anticiclón de las Azores. En segundo lugar, las condiciones climáticas generales: el Archipiélago Canario está considerado como un área seca y estable, con una media de 50 episodios de lluvia al año. En tercer lugar, su abrupta orografía: se alcanzan alturas de más de 3000 m en menos de 20 km horizontalmente.

Una vez se han establecido las características anteriores, se proporciona una clasificación fenomenológica. Dicha clasificación contiene 4 casos de perturbaciones atmosféricas: bajas atlánticas profundas (DAL), bajas atlánticas en superficie (ASL), bajas atlánticas en altura (UAL) y vaguadas (TRO). Con estos fenómenos se pretende caracterizar esta situación especial de precipitaciones en las Islas Canarias. Los episodios que no ha sido posible incluir en ninguno de los anteriores fenómenos se han incluido en la catergoría de ninguna detección (ND, None).

Usando recursos en línea tales como la base de datos ARCIMÍS de AEMET y Meteo Centre Reanalysis, se analizan, con el fin de entender completamente las situaciones particulares de la atmósfera para esos fenómenos, un conjunto de 104 casos de lluvias extremas (episodios de más de 30 mm en algún punto). Además, este tipo de análisis proporciona un método fiable para comparar la clasificación automática de los fenómenos.

Después, se analiza la base de datos de AEMET. Usando esta base se estudian las distribuciones de lluvia extrema ($> 30mm$) y de la lluvia total ($> 1mm$). Más tarde estos datos se usan para comparar la fiabilidad de las otras dos bases de datos.

Luego, se analizan las bases de datos Spread y WRF. Se muestran mapas de estas dos bases de datos donde se indican la distribución de los fenómenos clasificados. Primero se analizan mapas de 10 y 1 mm y después mapas por estaciones. De esta forma, se pueden comparar de forma clara ambas bases de datos y además es posible establecer cuáles son los fenómenos que afectan principalmente a las Islas Canarias y dónde están localizados.

Finalmente, a modo de conclusiones se establece que: primero, la correspondencia entre las bases de datos es fidedigna. Segundo, el fenómeno más importante durante los episodios de lluvia es DAL y la estación que deja más lluvias es el invierno.

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1 Introduction.

Las Islas Canarias representan un área climática muy compleja debido a su localización geográfica, cercana al continente africano, y su orografía, que presenta variaciones en altura de más de 3000 m en menos de 20 km horizontalmente. Principalmente, los fenómenos de lluvia se producen por perturbaciones atmosféricas, sin embargo, el relieve juega un papel fundamental y complica la creación de modelos de predicción meteorológica, pues exige que estos contengan gran resolución espacial.
El objetivo principal de este trabajo es el análisis de las distintas condiciones sinópticas que se dan cuando llueve en las Islas Canarias.
Con el fin de cumplir con él, se han estudiado distintas situaciones entre 1995 y 2004.
El análisis se realizó en dos etapas diferenciadas: primero, un análisis visual de 104 casos y después, un análisis automático utilzando el lenguaje de programación Python

From a climatological point of view, the Canary Islands can be considered as a complex area, given their location (located at 28°N, they belong to a transition area from mild to tropical temperatures), close to the African continent, and their orography, with altitude variations of more than 3000 m in less than 20 km horizontally.[1] Mainly the occidental islands, have a very steep orography which requires, at least, 5 km of resolution in numerical models to predict temperature distribution and, particularly, precipitation.[2] Due to their location, within the dust belt, the Canary Islands are also affected by two large sources of soil dust: the desert regions of the Sahara and Sahel.[1]

The North Atlantic Oscillation (NAO) is the dominant mode of winter climate variability over the subtropical North Atlantic precipitation. However, it is still poorly known because of the absence of long and reliable climatic time series in the area, that are usually affected by high noise levels due to the low precipitation rates in the subsidence belt associated with the Azores high.[1]

The Canary Island are a very stable and dry area owing to the influence of the trade wind belt. Northern sides of La Palma and El Hierro are the wettest areas despite it only rains 50 days year, on average.[1] This low rate of rain is a direct consequence of the Azores High. Windward areas exposed to trade winds are are affected by humidity caused by the 'sea of clouds'.

Almost 80% of precipitation is related to atmospheric disturbances, such as Atlantic low-pressure systems or cold air invasions in the upper troposphere,[1] which break the quasi-permanent thermal inversion layer. Furthermore, the local effect of the orography is essential to the development of extreme precipitation (rainfall in Tenerife, Gran Canaria, and La Gomera is directly connected with relief), which usually affects small areas of the islands, being difficult to predict and simulate.

1.1 Aims.

The main aim of this work is to classify the different synoptic conditions which happen when it rains over the Canary Islands.

To achieve this aim a period of 10 years is considered. Different situations over this period allow us to make a proper study: visualizing the specific phenomenon which produced the rain episode, then classifying the different phenomena to achieve precise rain distribution maps.

This particular study is divided into two main parts: first, a handmade and visual analysis in which 104 cases are considered; second, a computerized analysis using Python programming language.

In the first part, the considered cases are analyzed keeping only those in which rain was greater than 30 mm in any point. The points on consideration are fourteen of AEMET stations placed in the Canary Islands, those whose time series contains more than 80% of valid values. This kind of analysis is extremely useful to distinguish and get familiar with the classified phenomena. Furthermore, to verify the reliability of the following method used to classify a large number of rainfall episodes aimed at studying from wet to very heavy rain episodes.

Following this visual analysis, the AEMET database is used to extract some tables where percentages related to each phenomena are exposed. In this way, it is possible to know which fraction of extreme rainfall correspond to each of the classified phenomena. Besides, with the aim of verify the reliability of forecasting, >1 mm rain episodes are also studied.

After that, the cases of rain greater than 10 and 1 mm are analyzed using two numerical databases: Spread and WRF. The first step is to set which disturbance occurred each day (computerized method). Then, maps of 10 and 1mm are outlined. This particular step leads to the obtainment of some maps in which percentages of rain due to each phenomenon are reflected.

This particular methodology is exposed below.

2 Methodology.

Para poder realizar el posterior análisis de datos, se ha tenido que establecer, en primer lugar, qué bases de datos van a utilizarse (base de datos que incluya los datos observacionales así como las bases objetivo del trabajo, es decir, las de las simulaciones numéricas); se usarán las estaciones de AEMET localizadas en las Islas Canarias y los datos obtenidos mediante el modelo WRF (contiene simulaciones generadas a partir de ecuaciones numéricas)[2,5] y SPREAD (una base semi-observacional, que interpola datos de estaciones localizadas en las islas).[6] En segundo lugar, una parte central del trabajo es determinar qué fenómenos son de interés cuando llueve en las Islas Canarias, para lo cual se caracterizan 4 tipos de perturbaciones atmosféricas (bajas atlánticas profundas, bajas atlánticas en superficie, bajas atlánticas a 500 mbar y vaguadas). Se incluye también en la clasificación el caso de que ninguno de los fenḿenos se haya detectado.[1] Finalmente, cuando ya están establecidos estos dos parámetros anteriores, se puede proceder a realizar el correspondiente análisis de las condiciones sinópticas, así como la calidad de las simulaciones numéricas. Para realizar dicho análisis se han establecido dos etapas completamente diferenciadas:

En una primera etapa, se realiza un análisis manual de las situaciones, consultando los mapas reales de AEMET[7] y los mapas de reanálisis de MeteoCenter.[8] En esta etapa se obtiene una tabla de datos que recoge las situaciones sinópticas de cada día considerado (para el caso de lluvia torrencial). Esto sirve como punto de partida para comenzar el análisis automatizado siguiente.

En la segunda etapa, primero se determina la coincidencia del programa que estudia qué fenómenos ocurren en cada caso, comparando la respuesta con el análisis anterior realizado (se obtuvo una coincidencia del 90%) y después se utiliza para sacar esta misma clasificación en los casos de >10 mm (luvia moderada a torrencial) y >1mm (toda la lluvia).[3,4]

The first step to start the analysis is to establish a proper database which, contains accurate data that lends to compare these observational data to numerical simulations run by semi-observational (Spread) and numerical simulation (WRF) databases. Next, a key of this work is to determine which are the interesting phenomena. This step lends to characterize which are the synoptic conditions, and at the same time, study the truthfulness of the numerical database.

Next, the analysis is carried out regarding two parts: the first part consists of a visual interpretation in which some maps are used to point out the atmospheric disturbance conditions of each day. This stage is necessary for the subsequent phase because it allows us comparing real data and numerical simulations.

The next stage consists of an automatic analysis of numerical databases which studies the cases of heavy to very heavy rain (>10mm) and wet to very heavy rain (>1mm),[3,4] distributing the phenomena according to the seasons.

2.1 Databases.

Three different databases are employed:

The first database contains **AEMET's stations**. These stations collect observational data every day of the considered period. To establish quality parameters only 14 of them were studied because they had more than 80% of data during the whole period. This database is the most trustworthy because the observational data are well-calibrated and reflect the totality of rainfall for each day.

Second, the **Weather Research and Forecasting (WRF)** simulations: WRF is a next-generation mesoscale numerical weather prediction system designed for atmospheric research and also forecasting applications.:[2,5] It is operating since 90's and was developed by a cooperative group of the National Center for Atmospheric Research (NCAR), the National Oceanic and Atmospheric Administration (represented by the National Centers for Environmental Prediction (NCEP) and the (then) Forecast Systems Laboratory (FSL)), the (then) Air Force Weather Agency (AFWA), the Naval Research Laboratory, the University of Oklahoma, and the Federal Aviation Administration (FAA).[5] This model is available for scales of tens to thousands of kilometers.[5]

The WRF model if configured using 3 domains.[2] The innermost domain covers the seven islands of the archipelago, located within 26.758 - 30.298 N, 19.438 - 12.628 W, and having 133×79 grid cells[2] to study.

Third, **Spread database** for Canary Islands, which covers the period from 1971 to 2012, using 920 stations (mainly AEMET data but also regional hydrological and meteorological services, and from the national agronomic network).[6] A completed 5×5km spatial resolution grid was calculated based on the reconstructed station series.[6] The comparison between the original data and the model shows a great correlation for the Islands, around Pearson 0.73.[6]

2.2 Description of the considered situations.

The synoptic situation that affect the precipitation in the Canary Islands where studied in a previous work.[1] In the present study, the same types are used and they are summarized in Table 1. The classification of the considered situation is based on the sea level pressure and the geopotential height at 500 hPa in an area surrounding the archipelago.

Phenomenon	Description
Deep Atlantic Low (DAL)	Atlantic low at the surface and 500hPa level.
Atlantic Surface Low (ASL)	Atlantic low at the surface and any other situation no included in DAL
Upper Atlantic Low (UAL)	500 hPa low and any other detection not included in DAL. Mediterranean surface low and Atlantic 500 hPa low. 500 hPa Atlantic low and trough over the Canary Islands.
Trough (TRO)	Mediterranean surface low and trough over the Canary Islands.
No detection (ND, NONE)	None of the previous situations can be detected

Table 1: Phenomena classification.

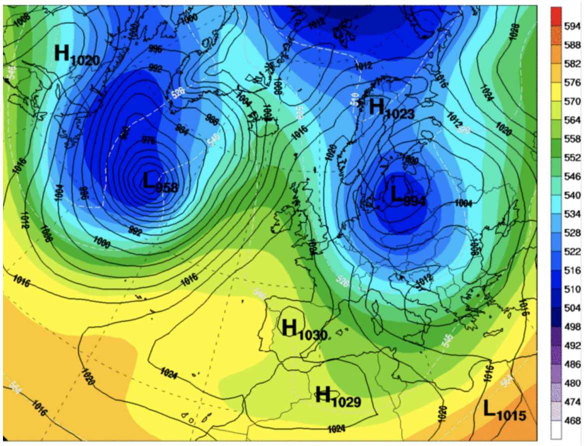
2.3 Visual analysis.

Before beginning to explain what the analysis consists of, some previous considerations have to be set.

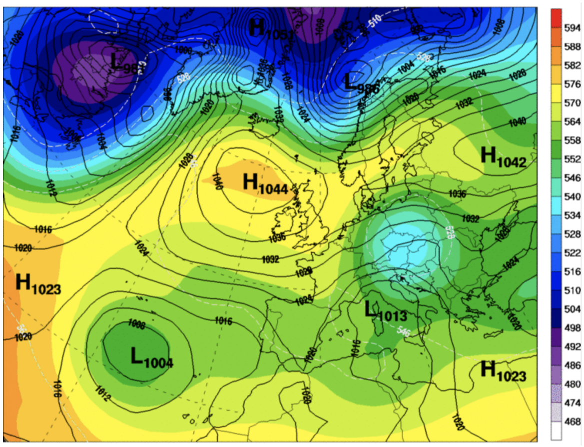
First, as it has been said before, in this cases only situations where the rain was greater than 30 mm, in any station, are considered. Heavy rain condition (>30mm rainfall episodes) is imposed because the sum of cases can be easily evaluated by visual inspection, since it remains 104 situations to assess.

To achieve this part, different maps are consulted. The situation at sea level and 500 hPa are observed in different moments of the same day. The main resources involved were AEMET data and some web pages as AEMET archive (ARCIMÍS)[7] and Meteo Center (UQAM Weather Center) reanalysis.[8] While analyzing each example, a table was created, where the different phenomena and other parameters (date, rain) where included.

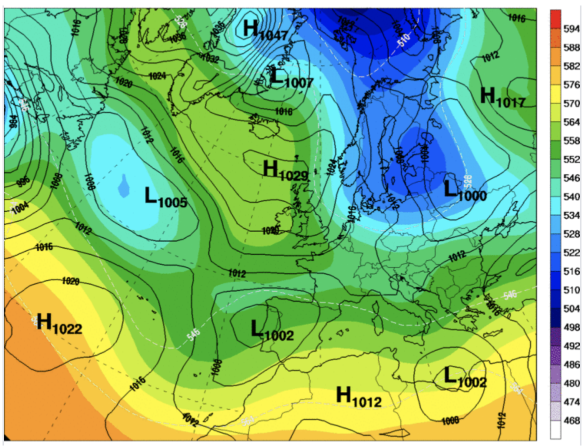
Figure 1 shows different maps representing an example of each of the considered phenomena (Table 1. Figure (a) shows the case of UAL (on 1998/12/06, 54.3 mm): over the Canary Islands it is observed a low pressure over 500 hPa and a trough; despite it is also found a surface low to the west, which could lead to confusion, DAL is completely discarded because the surface low is not the main phenomenon affecting the islands. Figure (b) shows the case of DAL (on



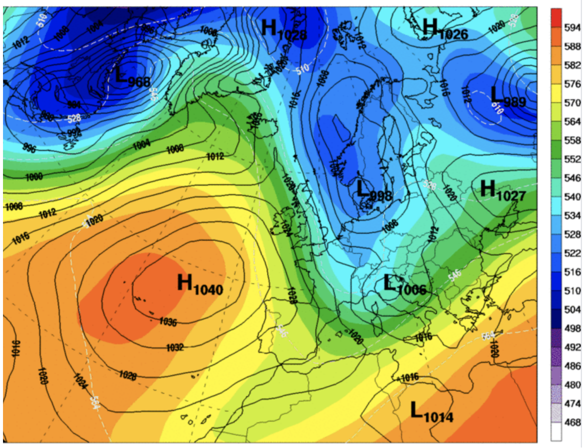
(a) UAL



(b) DAL



(c) ASL



(d) TRO

Figure 1: Different examples of the analyzed situations. a) UAL (1998/12/06) b) DAL (1995/12/12) c) ASL (1997/04/19) d) TRO (1999/11/17). Graphics obtained from MeteoCenter[8]

1995/12/12, 40.4 mm): near to Islands (to the west) it is observed the center of a low pressure at 500 hPa level and a surface low; despite the center is located west, the low-pressure lines are concerning the islands. Figure (c) shows the case of ASL (on 1997/04/19, 30.1 mm), over the Canary Islands a 1012 mbar line is located, and at 500 hPa level a, low is not found. Finally, the figure d) is showing the case of TRO (on 1999/11/17, 35 mm): a trough is located over the Canary Islands.

The same process was done for the remaining cases. To completely determine the kind of phenomenon, it was also checked the previous and the following day maps, in this way the advance of the phenomenon has been analyzed. In some cases, having observed the advance of the disturbance make it possible to discern between one phenomenon, and another.

2.4 Automatic analysis.

This analysis is also divided into different steps. First, a code which determines the synoptic condition was written in Python. It compares different pixels from the extracted maps using the databases. The algorithm detects lows when some conditions are satisfied: being a local minimum in a 3×3 grid, being a value below 1020 hPa for the surface and below 5900 gpm for 500 hPa and having an average gradient over a 5×5 grid.[1] The established parameters follow Table 1. After that, 30mm data are used to compare this automatic classification with the previous analysis (see subsection 2.3), the concordance between the output and the visual analysis was greater than 90%. This great concordance enable us to perform further analysis. Second, another Python code was written. In particular, this allows represent maps and create value tables.The following sections contain tables filled out using these data as well as different maps obtained from the different databases.

The great concordance between hand-analyzed data and the output allow for reaching the next stage. This consisted of taking different rates of rain to make a deeper analysis. To obtain it, the preceding algorithm read the different maps and choose the phenomenon which matches better the Canary Islands grid, then, maps of sections 3.2 are obtained.

2.5 The AEMET database: 30mm analysis.

The next table represents which fraction of rain is related to heavy rain episodes, e.g., the percentage of rain due to >30 mm/day episodes with regard to the total amount.

Station	Percentage of the total (%)
El Hierro (Airport)	57.52
Gran Canaria (Airport)	51.05
Gran Canaria (Valsequillo)	40.23
Tenerife (South Airport)	48.06
Gran Canaria (Las Palmas)	33.39
Tenerife (Güimar)	45.60
Fuerteventura (Airport)	50.05
Tenerife (North Airport)	35.21
Tenerife (Santa Cruz)	55.21
La Palma (Airport)	47.66
Lanzarote (Yaiza)	43.87
Lanzarote (Tías)	35.01

Station	Percentage of the total (%)
Lanzarote (Airport)	45.75
Lanzarote (Tinajo)	42.48

Table 2: Percentage of total precipitation larger than 30 mm/day in each considered station.

Heavy rain episodes in the Canary Islands are particularly uncommon (only 104 cases in a 10-years period) but they represent almost half of the precipitation falling in the Canary Islands. Highly remarkable are the cases of El Hierro (Airport) and Tenerife (Santa Cruz) which lead to rates over 55% of rain. By contrast, Gran Canaria (Las Palmas) and Lanzarote (Tías) are the only stations which collected less than 40% of the total rain due to heavy precipitation events, giving 33.39 and 35.21%, respectively. In general, the occidental islands, which have the most steep orography presents the highest percentage of very heavy rain.

Table 3 shows the percentage of >30 mm rain which corresponds to each considered synoptic situation.

Station	UAL (%)	DAL (%)	ASL (%)	TRO (%)	None (%)
El Hierro (Airport)	6.19	84.51	7.57	1.70	0.02
Gran Canaria (Airport)	4.42	81.16	8.06	5.68	0.67
Gran Canaria (Valsequillo)	16.11	62.40	9.97	8.42	3.11
Tenerife (South Airport)	6.05	75.71	15.90	2.19	0.16
Gran Canaria (Las Palmas)	11.53	66.11	8.48	12.16	1.72
Tenerife (Güimar)	21.69	60.54	8.58	5.82	3.37
Fuerteventura (Airport)	4.71	82.82	5.72	6.19	0.57
Tenerife (North Airport)	6.44	56.40	23.38	10.99	2.80
Tenerife (Santa Cruz)	7.45	69.73	17.97	3.65	1.20
La Palma (Airport)	10.10	77.87	9.80	2.07	0.16
Lanzarote (Yaiza)	10.41	71.55	1.14	16.90	0.00
Lanzarote (Tías)	3.88	75.13	5.93	13.58	1.48
Lanzarote (Airport)	4.97	76.60	7.60	10.64	0.19
Lanzarote (Tinajo)	3.86	70.87	11.99	12.34	0.94

Table 3: Percentage of heavy rain (>30 mm/day) by phenomenon in each station.

DAL phenomenon is the most noticeable disturbance over the Canary Islands when heavy rain episodes occur. The table above shows that this phenomenon brings more than 50% of rain percentage in any station. The lowest percentage of >30mm DAL phenomenon corresponds to

Tenerife (North Airport) with 56.40% precipitation percentage.

It is noteworthy that the three remaining classified phenomenon (UAL, ASL, and TRO) have resembling percentages in each station.

Especially important is to mention that practically all classified phenomenon contribute to heavy rain (>30mm) in the Canary Islands. Tenerife (Güimar) and Gran Canaria (Valsequillo) has the greatest percentage of None-classified phenomenon which corresponds with 3.37 and 3.11%, respectively.

3 Results.

En este capítulo se muestran distintos tipos de resultados basados en la base de datos de AEMET, que contiene los datos tomados de las estaciones meteorológicas situadas en las Islas Canarias. Esta base de datos revelará cuáles son las condiciones sinópticas que afectan mayoritariamente en los fenómenos de lluvia que ocurren en las islas. Para ello, se analizará el caso de lluvias de más de 1 mm. Con esto, se podrá determinar que el fenómeno DAL es la principal situación para que se produzca lluvia en las islas.
Seguido de este análisis, se van a mostrar los estudios realizados con las bases de datos numéricas (WRF y Spread): se pondrá así de manifiesto la concordancia entre estas dos bases de datos, así como la propia concordancia con los datos de estaciones recogidos por la AEMET.

3.1 AEMET database: 1mm analysis.

In a similar construction of the previous analysis, this section starts bringing a table where the percentages of rain corresponding to each particular phenomenon are given.

Station	UAL (%)	DAL (%)	ASL (%)	TRO (%)	None (%)
El Hierro (Airport)	19.59	52.64	11.18	5.52	11.07
Gran Canaria (Airport)	15.56	30.08	7.53	20.42	26.41
Gran Canaria (Valsequillo)	18.36	17.83	10.20	15.17	38.42
Tenerife (South Airport)	16.35	48.69	12.79	13.89	8.27
Gran Canaria (Las Palmas)	18.75	18.99	9.90	19.04	33.33
Tenerife (Güimar)	30.41	21.33	11.15	16.47	20.65
Fuerteventura (Airport)	21.21	41.55	8.00	15.02	14.22
Tenerife (North Airport)	17.53	23.14	15.76	14.39	29.19
Tenerife (Santa Cruz)	30.03	25.29	12.61	18.12	13.96
La Palma (Airport)	16.34	33.98	13.82	10.84	25.03
Lanzarote (Yaiza)	24.05	33.07	8.09	20.36	14.43
Lanzarote (Tías)	18.06	33.90	11.19	14.22	22.63
Lanzarote (Airport)	25.75	33.76	9.92	13.68	16.89
Lanzarote (Tinajo)	22.94	31.50	13.45	13.01	19.10

Table 4: Percentage of rain >1 mm/day by phenomenon in each station.

The table above gives some important results: anew, DAL is the predominant phenomenon, especially important in El Hierro (Airport) and Tenerife (South Airport) whose percentages of rain correspond to 52.64 and 48.69%, respectively.

However, in this particular case of >1 mm rain, UAL, ASL, and TRO are not as resembling as before. The differences among these phenomena have been accentuated. The highest UAL percentage (30.41%) corresponds to Tenerife (Güímar); the highest ASL percentage (15.76%) corresponds to Tenerife (North Airport), and the highest TRO percentage (20.42%) corresponds to Gran Canaria (Airport).

Finally, in this table is remarkable the percentage of None-classified detected phenomenon. Particularly important is the case of Gran Canaria (Valsequillo and Las Palmas) which represent exceptionally high percentages of None-classified phenomenon, leading 38.42 and 33.33%, respectively.

This table will allow the next comparison in further sections because it provides a reliable distribution of almost the total amount of rain in the considered period.

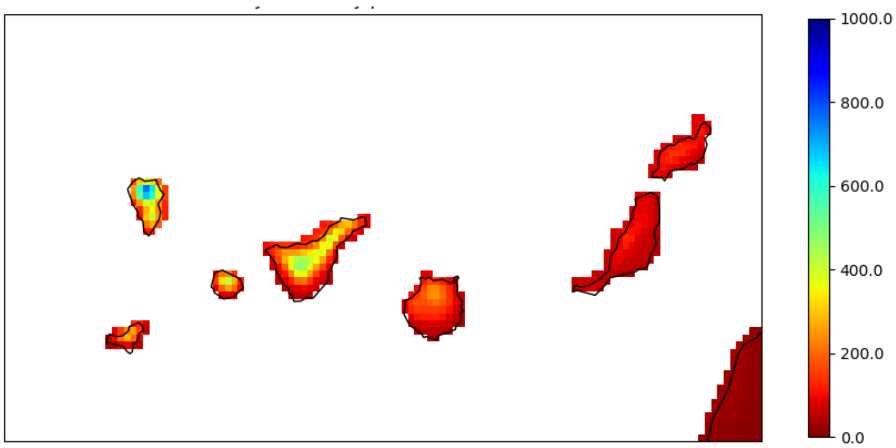
3.2 Numerical database: 1 and 10mm maps.

In this section, 10 and 1 mm maps are exposed. To show the results, the total amount of rain per year and the percentages of rain which are due to each of the characterized phenomena are studied.

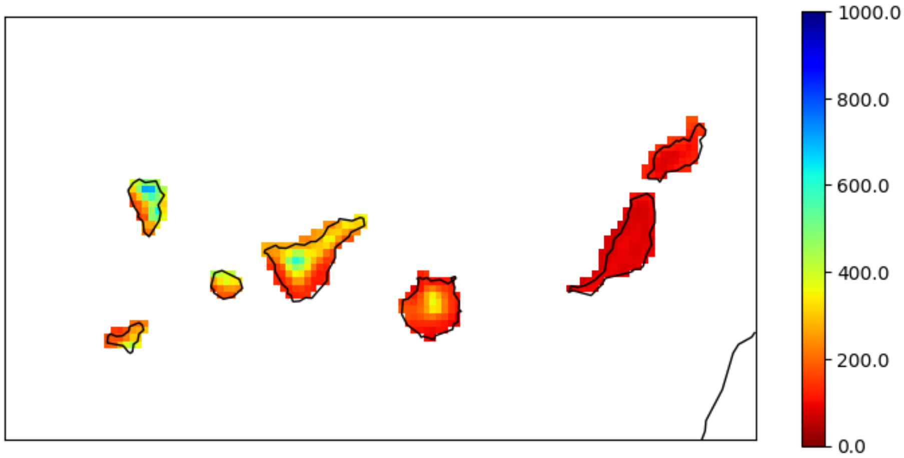
This section will further reveal if the numerical databases can determine precisely the observations collected by AEMET (see sections 2.5, and 3.1).

3.2.1 10mm maps.

The amount of rain corresponding to >10 mm phenomena according to the analysis of both databases is shown in figure 2. This figure shows that Tenerife, La Gomera, and La Palma, especially in the north and central parts of them, are the islands which collected the greatest amount of rain per year. It is evident referring to this chart that the eastern islands are drier than the western. This two aspects, are consequent with the previous knowledge of this work, comparing both of this maps with previous data extracted from AEMET (tables 3 and 4), it is revealed that the western islands accumulate largest amounts of rain in relation to the eastern islands.



(a) WRF



(b) Spread

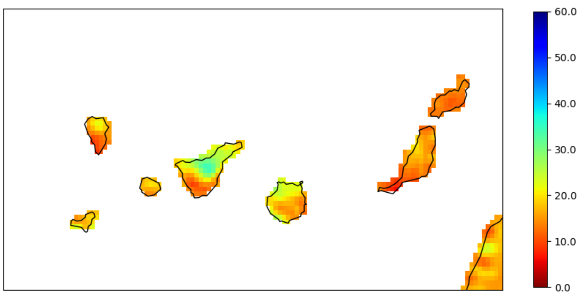
Figure 2: Amount of rain per year which corresponds to >10 mm/day cases according to (a) WRF database, (b) Spread database

On the other hand, the WRF database shows the greatest differences in this amount of rain collected in the highest parts of La Palma, La Gomera, and Tenerife, which generally coincides with the wettest parts. This particular database seems to show more heterogeneous differences between points in a specific island while Spread database shows amounts that are more homogeneous along the islands. It is highly remarkable that in these particular points exist differences of more than 300 mm which is an important amount considering that the highest measure of rain is 800 mm approximately in La Palma.

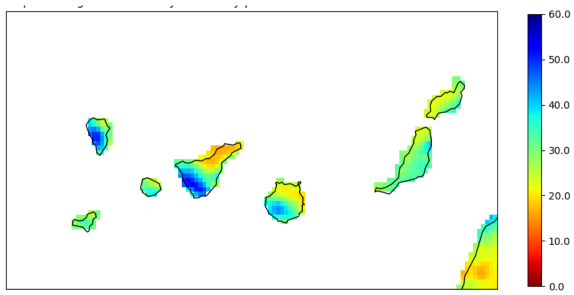
Later sections will show us which of these two databases is more accurate regarding the real data collected by AEMET and also analyzing the behavior of seasons.

3.2.1.1 WRF database.

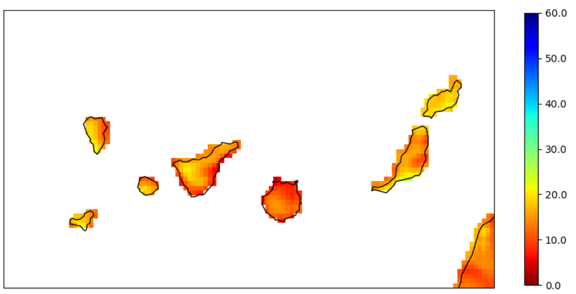
The figure below (Figure 3) shows the percentage of heavy rain (> 10 mm) along the islands which corresponds to each analyzed phenomena (Table 1) studying the WRF database.



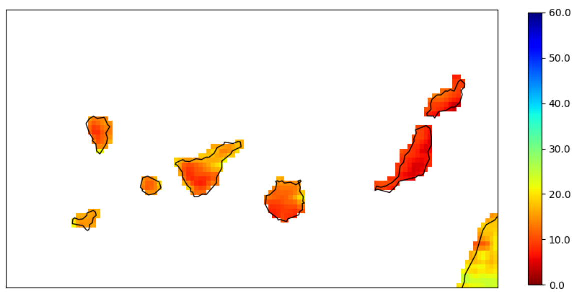
(a) UAL



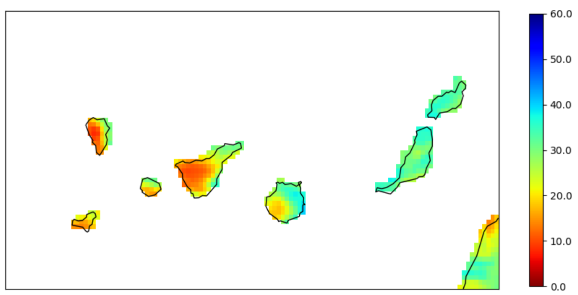
(b) DAL



(c) ASL



(d) TRO



(e) None

Figure 3: Corresponding percentages of the analyzed situations (a-e) and the amount of rain which corresponds to >10 mm/day cases using the WRF database.

On the one hand, in this figure, it is clear that in the eastern islands (Lanzarote and Fuerteventura) DAL and None phenomena mainly sum the total amount of rain (approximately an 80% of the total rain). Besides, Gran Canaria shows a similar behavior: DAL and None phenomena sum around 60% of the total amount, being None phenomenon the most prominent of these two.

On the other hand, the western islands keep a more homogeneous distribution. It is important to highlight the particular cases of Tenerife and La Palma, which again, shows the greatest differences regarding La Gomera and El Hierro.

DAL phenomenon is extremely important in southwest parts of Tenerife and La Palma. This particular phenomenon implies a 60% of the total rain in these mentioned areas. It is also quite important in the southwest part of Gran Canaria. Nevertheless, precipitation due to DAL phenomenon is plentiful in any of the western islands as well as in the eastern islands.

Besides DAL, UAL and None are highly remarkable in Tenerife. In the north of this island, around 20% of rain is due to UAL, in the headland of this island is extremely notable that 20% is due to None phenomenon.

Finally, it is important to emphasize that TRO and ASL phenomena are quite similar along the islands.

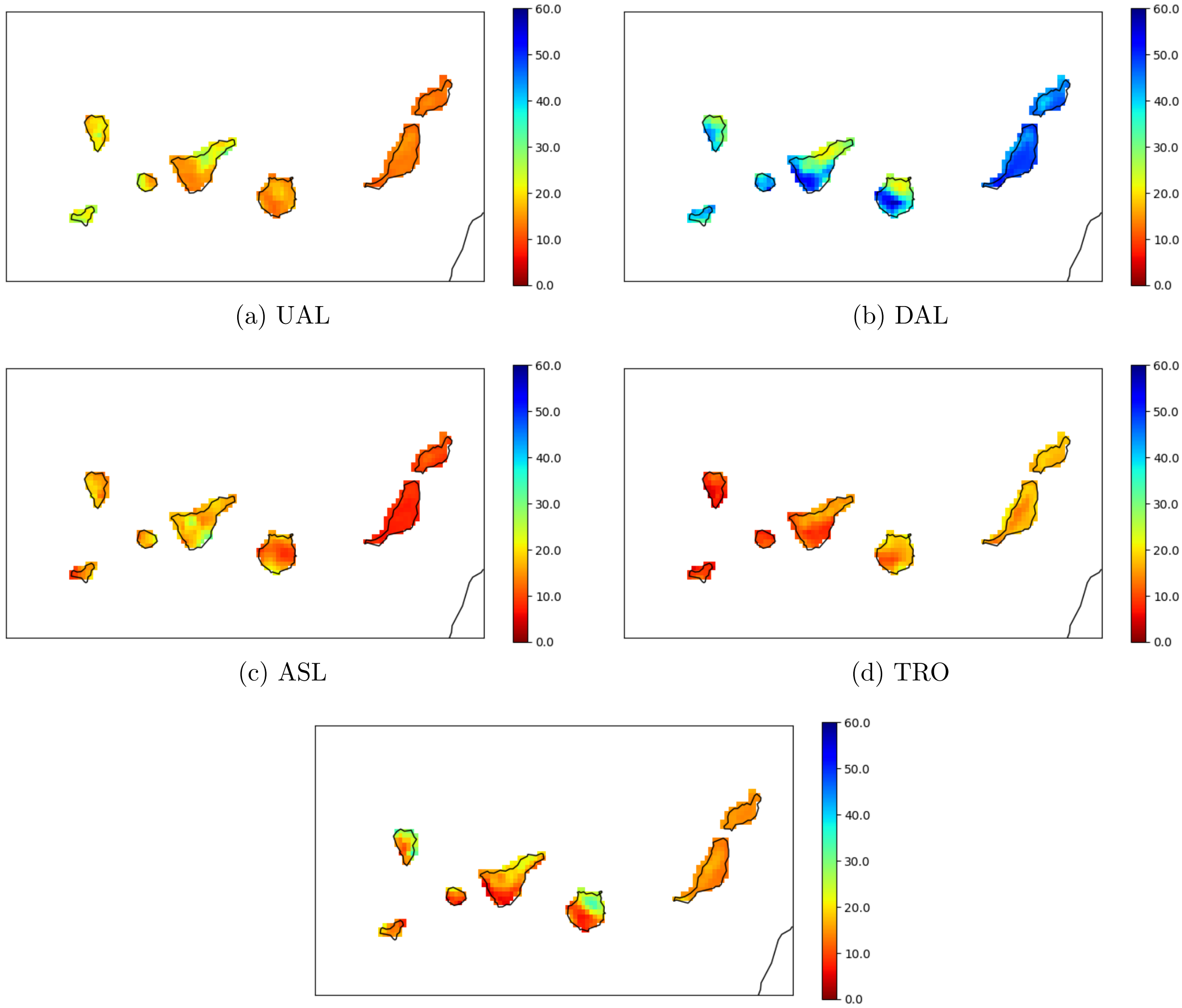
3.2.1.2 Spread database.

The figure below (Figure 4) shows the percentage of rain along the islands which corresponds to each analyzed phenomena (Table 1) studied regarding Spread database. It shows the distribution of heavy rain (>10 mm) related to each analyzed case.

First of all, it is important to point out that the WRF database shows similar results in the distribution of this phenomena. Also, percentages are comparable between both database in rough outlines. A resembling analysis will be carried out.

On the one hand, in the easternmost islands (Lanzarote and Fuerteventura) DAL and None phenomena add up to chiefly the total amount of rain (again, approximately 60% in any point). Besides, ASL phenomenon and UAL also stand out, the first provides the 20 to 30% of the rain of these two islands while the second, provides around 20% of rain in both islands. Finally, the TRO phenomenon only contributes around 10% in each of them. These results are alike regarding the ones showed in the section 3.2.1.1

On the other hand, in the western islands and Gran Canaria, DAL phenomenon is highly remarkable. It is noticeable that southern or central parts of these particular islands collect around 50-60% rain due to DAL. Particularly important are the southern parts of Gran Canaria and Tenerife because are dry areas with few days of rain per year, nevertheless, this shows that only very heavy phenomena are important in these zones. It is outstanding that these two areas also present the lowest None-classified phenomena of all of the Canaries, indicating that a synoptic disturbance is necessary to produce heavy precipitation in these areas.



(a) UAL (b) DAL (c) ASL (d) TRO (e) None

Figure 4: Corresponding percentages of the analyzed situations (a-e) and the amount of rain which corresponds to <10 mm/day phenomena keeping into account the Spread database.

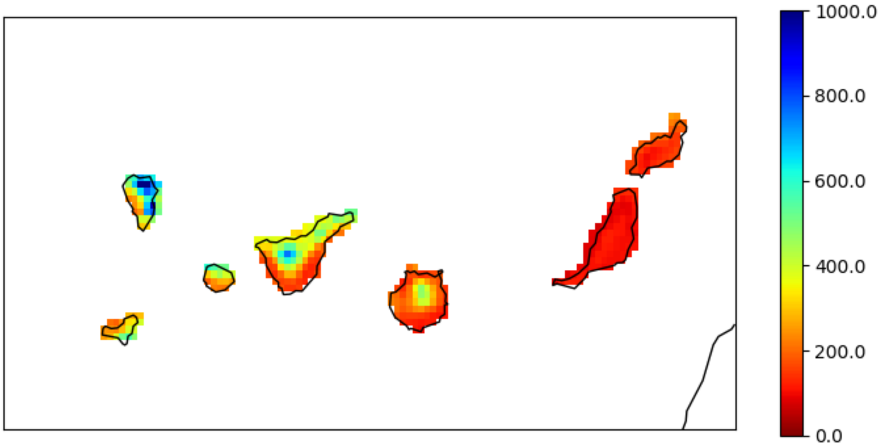
Finally, the ASL, and TRO are quite similar among the islands, again. Especially, the ASL phenomenon in this database is higher than in WRF database in some regions of Gran Canaria and Tenerife. Nevertheless, the other zones are mainly similar in this way.

3.2.2 1 mm maps

In this section and also in the followings a resembling analysis to the one done in the sections above will be carried out.

Keeping the WRF database, the 1 mm phenomena are collected in this subsection. The Figure 5 shows a similar result that the presented for the case of heavy rain (>10 mm/day):

(a) WRF



(b) Spread

Figure 5: Amount of rain per year which corresponds to 1mm phenomena according to WRF database

the greatest amount of rain is collected in the western islands, highlighting again the northern part of La Palma and the central parts of Gran Canaria, Tenerife, La Gomera, and La Palma.

Again, a similar pattern compared to the previous study is shown in this figure. WRF database shows greater amounts of rain per year than Spread, in some areas. It is noticeable than in La Palma there is an area which collects around 1000 mm per year keeping into account WRF database but this same area considering Spread only collects around 400 mm per year. The divergences in the cases of Tenerife and La Gomera are fewer: the highest difference between both databases is around 200 mm (again, greater WRF than Spread quantity).

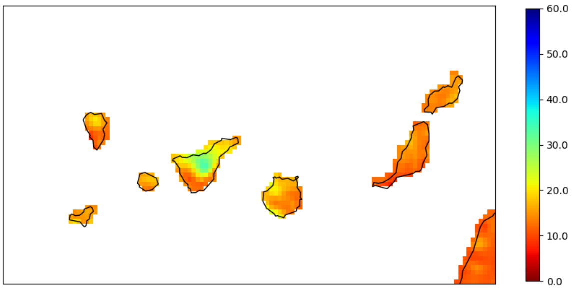
In this case of 1 mm phenomena, also is important the example of Gran Canaria which shows some differences between both databases too.

Considering the examples of Lanzarote and Fuerteventura, it is seen that each of them collect less than 200 mm of rain per year in any of the databases.

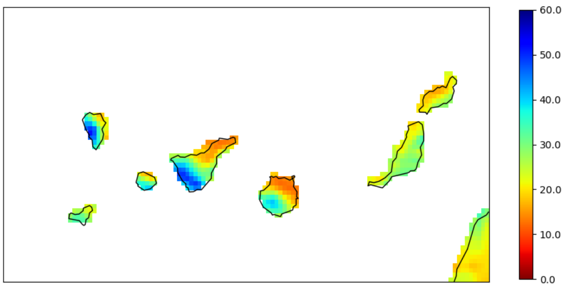
This figure also shows that keeping almost all the rain falling in the Canary Islands (>1mm) the western islands and Gran Canaria represent an important quantity of the rain.

3.2.2.1 WRF database.

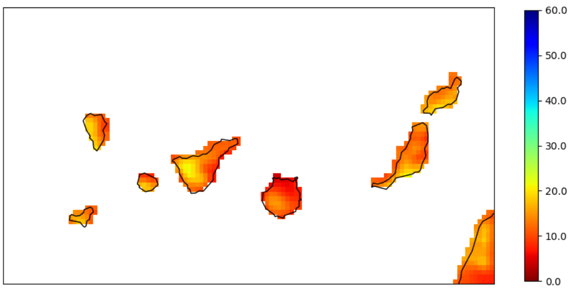
The figure below (Figure 6) shows the percentage of rain along the islands which corresponds to each examined phenomena (Table 1) studied regarding WRF database. It shows the distribution of total rain (>1 mm/day) related to each of the 5 cases carried out.



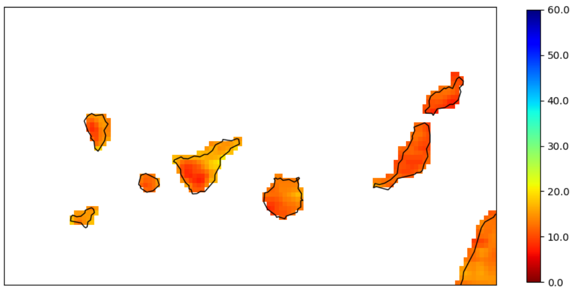
(a) UAL



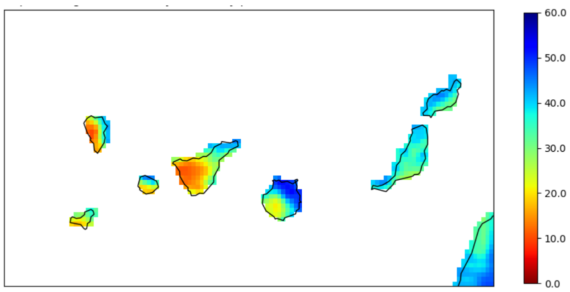
(b) DAL



(c) ASL



(d) TRO



(e) None

Figure 6: Corresponding percentages of the analyzed situations (a-e) and the amount of rain which corresponds to >1 mm/day phenomena keeping into account the WRF database.

First of all, it is important to point out that WRF database shows similar results in both cases of 1 and 10mm.

On the one hand, similarities can be summarized: first, DAL phenomenon has given again the highest percentage of rain: south-west Tenerife and west La Palma lead the percentages with a 60% of rain in each area. Second, UAL is barely noticeable in the central part of Tenerife. Third, ASL and TRO phenomena are again very homogeneous in all points of the map. ASL mainly contributes to the total precipitation of the southwestern areas of the highest islands.

On the other hand, differences are exposed: precipitation related to None phenomenon is higher in this case than in the previous study of 10 mm. Northwest areas of Lanzarote and Fuerteventura present percentages around 40% of this particular phenomena. Besides, Northest parts of Gran Canaria and La Palma exhibit percentages around 60-40%, respectively. Anaga Headland in Tenerife and the north of La Gomera also show percentages around 40% of None-classified phenomena. Finally, some other parts display minor differences which are not necessary to point out.

3.2.2.2 Spread database.

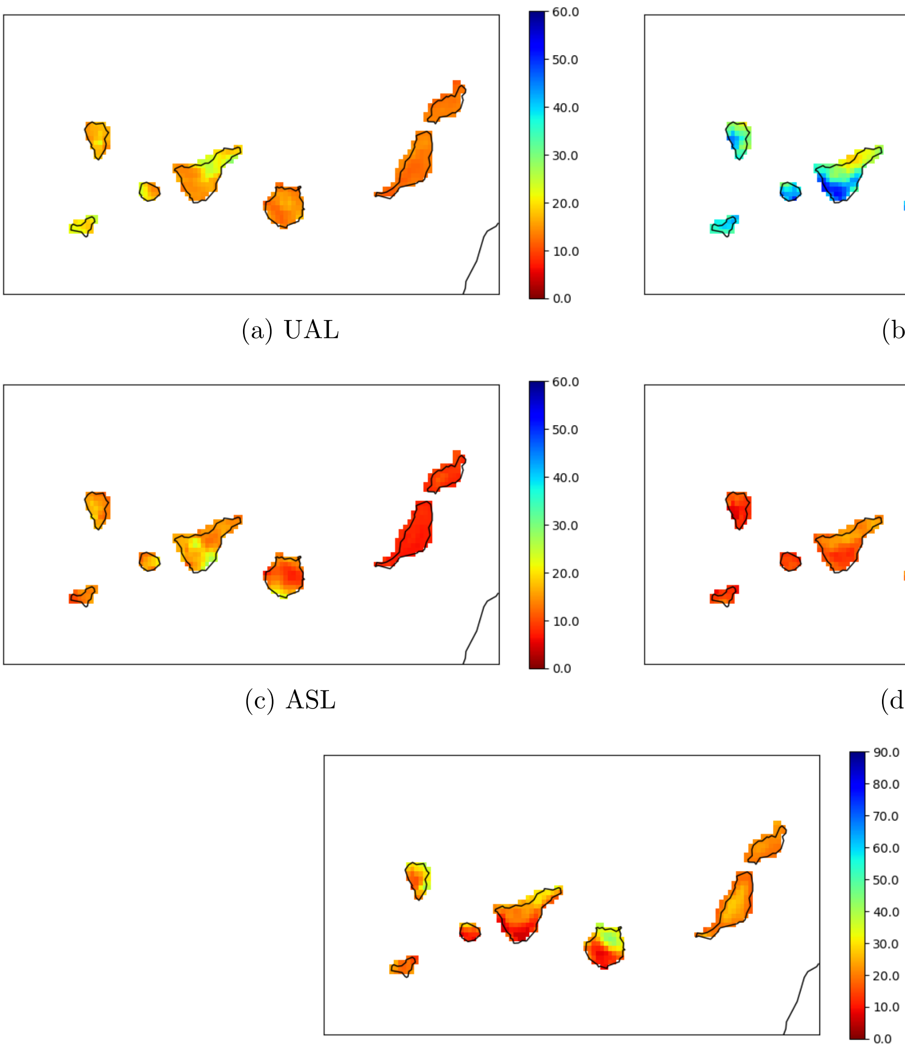
The following figure (Figure 7) shows the percentage of rain along the islands which corresponds to each examined phenomena (Table 1) studied considering Spread database. It shows the distribution of very heavy rain (>1 mm) related to each of the 5 proposed cases.

First of all, it is important to highlight that differences between this case and 10 mm studied done above with this same database shows obvious differences.

Beginning with UAL: in the case of Lanzarote, north Fuerteventura and east Gran Canaria and Tenerife the percentage of this phenomena is, in this particular study, fewer than in the previous one. In the study done before UAL percentage was 30% however in the east part of the island, keeping into account 1 mm cases the percentage is lessen by 10%.

In the second place, it is highly important DAL differences: 10 mm study showed greater percentages of DAL in southwest Gran Canaria, and the middle of La Palma and El Hierro. In these three locations, DAL phenomenon collected around 40 to 50% of the total rain per year, nevertheless, now it only represents 30%.

Finally, it is also important to highlight the None detection case: 1mm phenomena are higher in this case than in the previous one. The most affected regions are the north of Tenerife, Gran Canaria, and La Palma.



(a) UAL (b) DAL (c) ASL (d) TRO (e) None

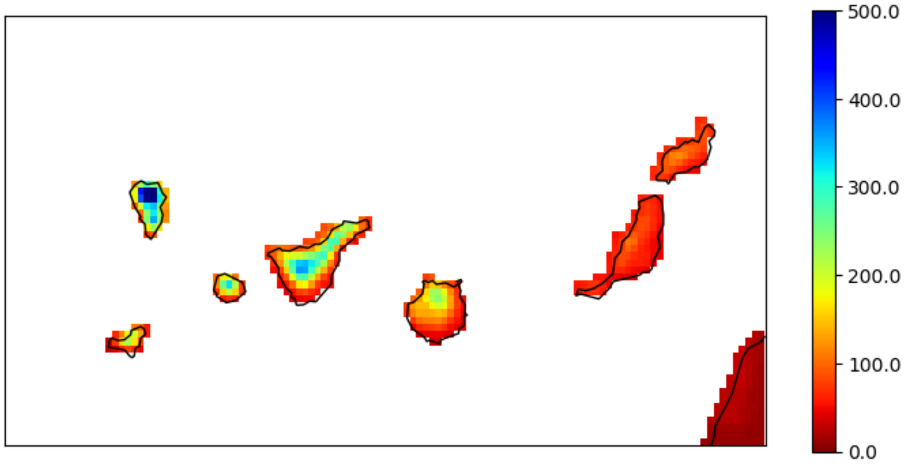
Figure 7: Corresponding percentages of the analyzed situations (a-e) which corresponds to >1 mm/day phenomena keeping into account the Spread database.

3.2.3 Seasonal analysis.

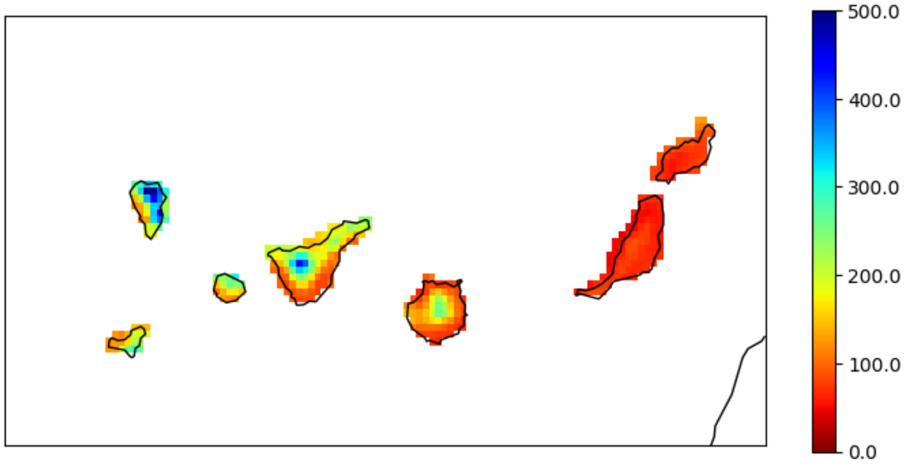
3.2.3.1 Winter Season.

This section studies the distribution of the collected phenomena (see Table 1) for the winter season (December, January, and February).

The aim of this section, as well as the following, is to obtain a phenomenological distribution of rain during a specific season, making possible to specify which are the main phenomena affecting the Canary Islands.



(a) WRF

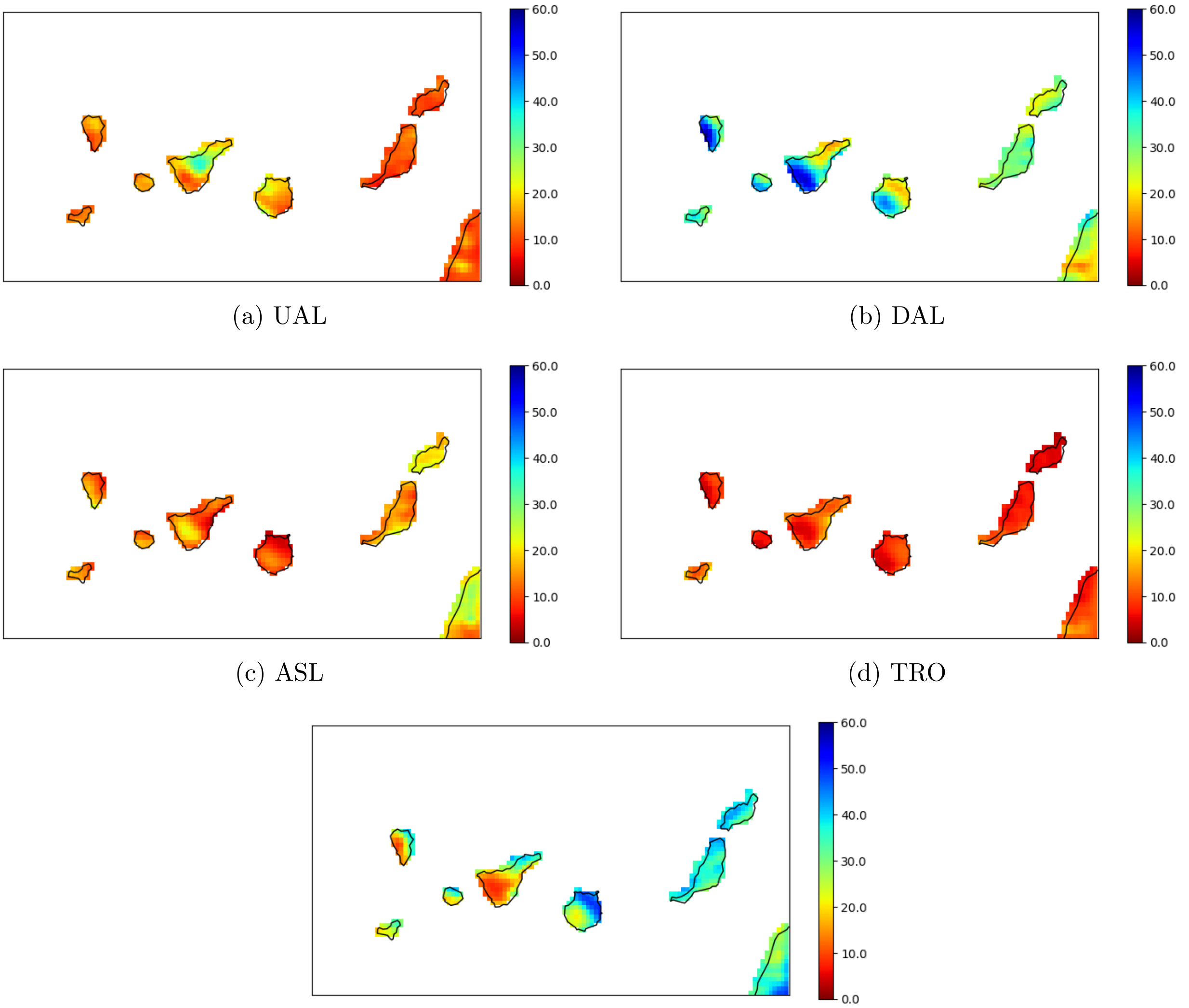


(b) Spread

Figure 8: Amount of rain per year during the winter season which corresponds to 1 mm/day phenomena according to (a) WRF database, (b) Spread database

The figure above (Figure 8) shows the total amount of rain per year during the winter according to both databases. It is evident that both databases show similar results, highlighting the same maximum precipitation areas (northeastern, and middle parts of La Palma, and central Tenerife). Both provide the same amount of rain in each point, roughly, reaching from 400 to 500 mm/year. Both maps agree on pointing out the driest areas in the Canary Islands: Lanzarote, and Fuerteventura having collected a maximum of 100 mm/year, can be considered the driest islands, nevertheless, littoral areas of Tenerife, and Gran Canaria also collected maximum values near 100 mm/year. Especially important is the southwestern area of Gran Canaria where a large area has a peak near to 150 mm/year.

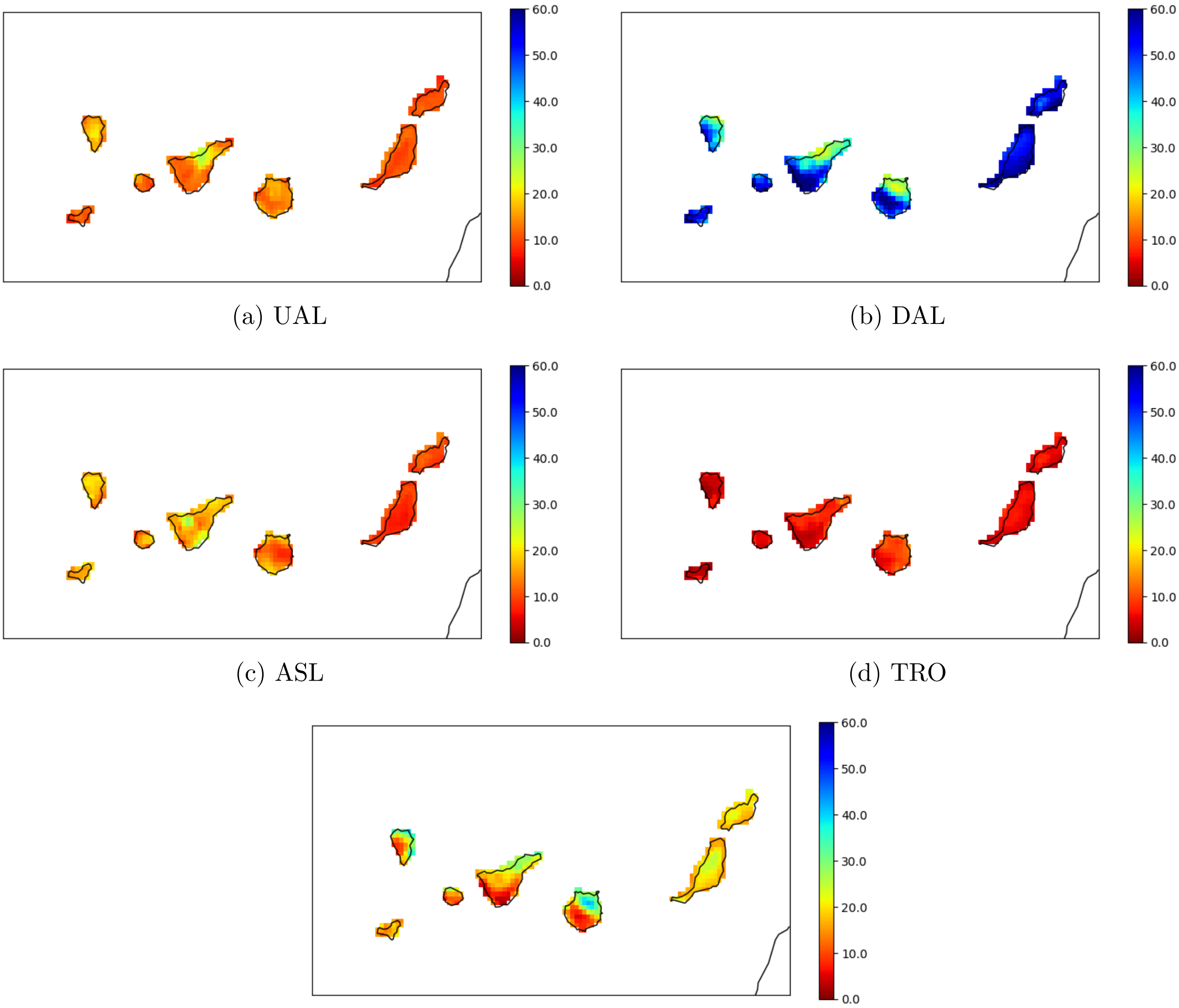
However, minor dissimilarities are set: Spread expects larger areas. La Palma reaching between 400-500 mm/year, and central Tenerife are suppossed to be slightly wetter.



(a) UAL (b) DAL (c) ASL (d) TRO (e) None

Figure 9: Corresponding percentages of the analyzed situations (a-e) which correspond to >1 mm/day phenomena regarding WRF database for winter season.

Figures 9, above, and 10, below, show the percentage of rain along the islands which corresponds to each examined phenomena studied considering each numerical database, WRF (Figure 9) and, Spread (Figure 10), during the winter season.



(a) UAL (b) DAL (c) ASL (d) TRO (e) None

Figure 10: Corresponding percentages of the analyzed situations (a-e) which correspond to >1 mm/day phenomena regarding Spread database for winter season

To begin, the UAL case is analyzed: during the winter season, this phenomenon is quite homogeneous along the islands, collecting less than 20% of rain per year,on average. UAL is particularly important in Tenerife where dissimilarities between both databases come out: a larger expanse of this island has percentages reaching 30% regarding WRF while observing Spread maps, the area is smaller, and percentages on it are above 25%.

Furthermore, the DAL case shows likewise great concordance between both databases: this phenomenon provides a larger amount of rain during the winter. It is particularly important in southern areas of the highest islands reaching almost 60% of the total amount of rainfall. In this specific case, discrepancies between both databases are more prominent: 30% of rainfall in Lanzarote, Fuerteventura, La Gomera, and El Hierro is due to DAL regarding WRF, whereas according to Spread this percentage reaches 60%. Dissimilarities referring Gran Canaria are also noteworthy: the whole island is wetter (reaching 60% maximum in the southwest, and 30% minimum in the northeast) considering Spread, while observing WRF these percentages are lower, having an important area in the southwest not reaching percentages over 20%, the central part reaches about 30%, whereas the wettest area in the island does not reach percentages greater than 45%.

Following, the ASL case is exposed: generally, ASL presents percentages between 20 to 30%. Differences between both databases stand out: regarding WRF, this phenomenon is important in west Tenerife, and Lanzarote, reaching rates slightly over 20%, Fuerteventura also presents minor areas where percentage can reach 20% while the remaining areas, and islands show percentages around 10-15%, on average. Considering Spread, ASL phenomenon is more prominent in the western islands, where some small areas in Tenerife can reach around 30% of rainfall due to this phenomenon. Considering Spread, Lanzarote maintains lower percentages (around 15%) whereas rainfall in Fuerteventura due to ASL supplies less than 15% of the total amount, when Spread database is used.

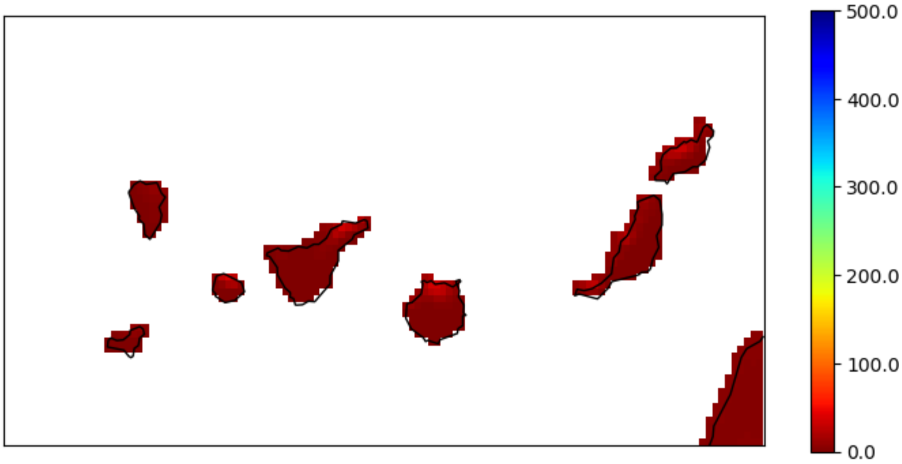
Additionally, the TRO case shows the greatest concordance between both databases: the distribution of percentages of this phenomenon are homogeneous along the islands, having percentages lower than 10%. Few differences between both databases can be outlined: WRF revels unimportant areas where this phenomenon reaches rates about 20% (such as a little area in east Tenerife or El Hierro) whereas Spread continues showing percentages under 10%.

Finally, it is also important to highlight the No detection case which represent significant percentages in some points of the islands. Both databases show similar results in La Palma, and Tenerife; the eastern islands as well as El Hierro, and La Gomera set further differences in both databases. First, west parts of La Palma, and Tenerife have less than 10% of non-classified phenomena, not in the case of central Tenerife where percentages reach 20%, while northeastern areas show rates above 30%. Lanzarote, and Fuerteventura show percentages about 40% regarding WRF whereas those percentages reach 20% as maximum taking into account Spread database. El Hierro, and La Gomera also show higher results in WRF than in Spread, these percentages reach 30% in the first one, and under 20% in Spread. Particularly important is the case of Gran Canaria which has the greatest percentage of None classified phenomena: regarding WRF, percentages in southwestern Gran Canaria get to 30%, and to 50% in the northeastern area; regarding Spread, the island is equally distributed but percentages are lower, not exceeding 20% in the southwest nor 40% in the northeast.

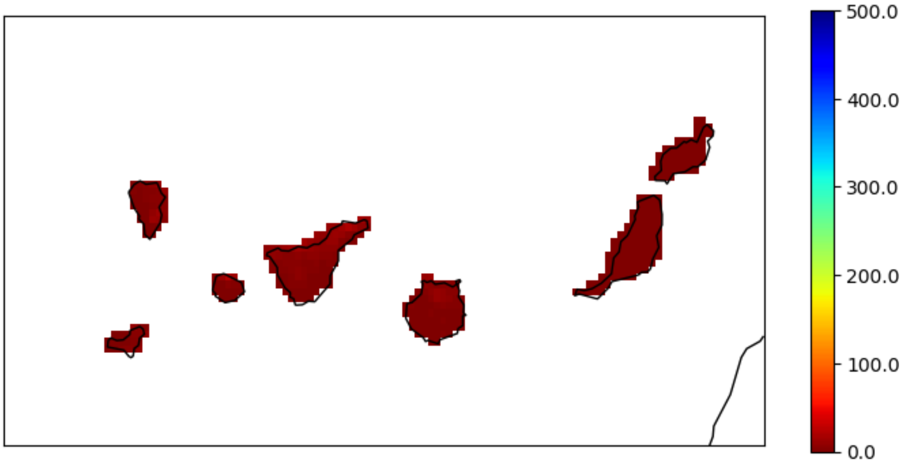
3.2.3.2 Summer Season.

This section studies the distribution of the phenomena collected in Table 1 for the summer season (June, July, and August).

Figure 11 shows the total amount of rain per year during the summer according to both databases. Unequivocally, both databases show the same results. During the summer in the Canary Islands rainfall is beneath 50 mm/year at any point.



(a) WRF

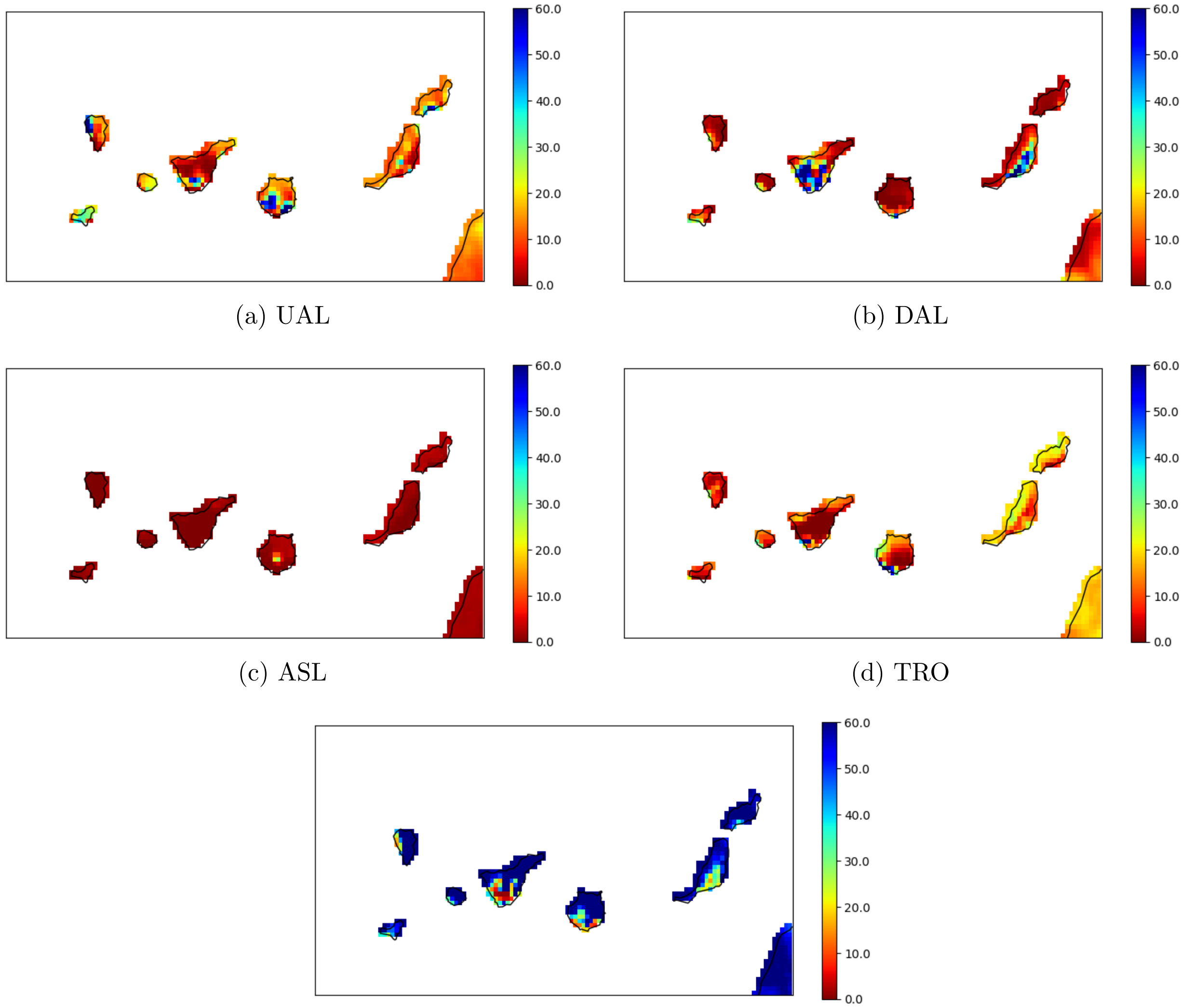


(b) Spread

Figure 11: Amount of rain per year during the summer season which corresponds to 1 mm phenomena according to (a) WRF database, (b) Spread databse

Charts below (figures 12, and 13) show the percentage of rain along the islands which corresponds to each examined phenomena (Table 1) studied considering each numerical database, Spread (figure 13), and WRF (figure 12), during the summer season.

A preliminary analysis shows asymmetrical distributions: many points with different per-



(a) UAL (b) DAL

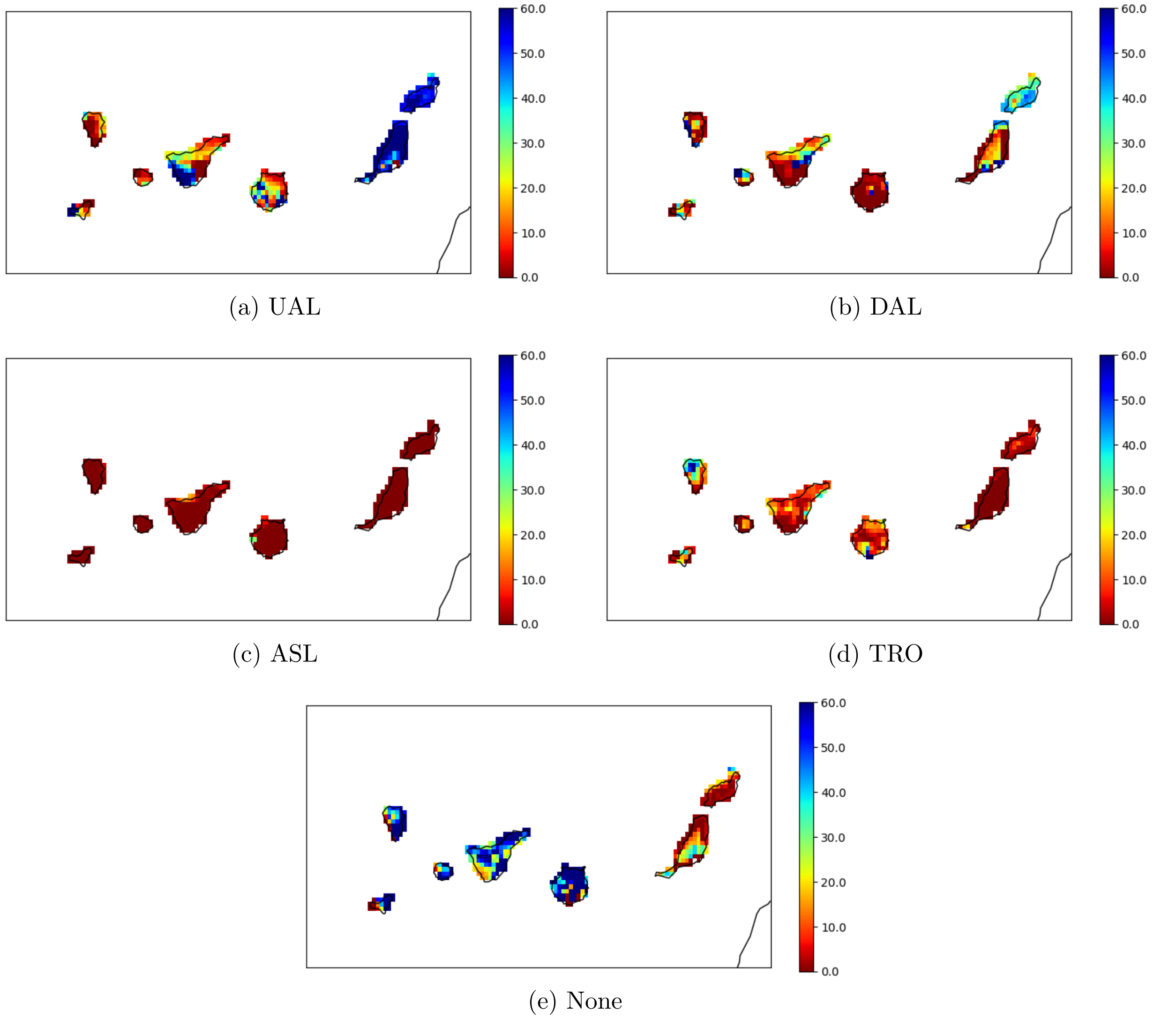
(c) ASL (d) TRO

(e) None

Figure 12: Corresponding percentages of the analyzed situations (a-e) which correspond to >1 mm/day regarding WRF database for summer.

centages in near positions as well as regions where is difficult to establish a global rate. In any case, precipitation during this season is very scarce, which implies that a variation in the percentages of rain due to a particular phenomenon corresponds to a change of only a few litters per day. Despite these conditions some features can be properly established.

During the summer, None phenomena are especially important: having reached percentages of about 60% in almost every point in the islands. Some differences can be outlined regarding Lanzarote, and Fuerteventura: while in WRF these islands maintain the mentioned percentages in the major part, taking into account Spread, these rates are practically null in the same areas, however south part in Fuerteventura show better correspondence between both databases having percentages under 30%.



(a) UAL (b) DAL (c) ASL (d) TRO (e) None

Figure 13: Corresponding percentages of the analyzed situations (a-e) which correspond to >1 mm/day phenomena regarding Spread database for summer.

The second most important phenomenon in summer corresponds to UAL. Again, an uneven distribution is shown: most of the islands have homogeneous percentages, nevertheless, west La Palma, South Tenerife, and South Gran Canaria have very different values in near points, having variations between 20 to 60%, considering WRF. Slightly more homogeneous are Spread charts: controversial points are only located in southwest Gran Canaria. Moreover, databases show a low correlation in the remaining points, especially important are the cases of Lanzarote, and Fuerteventura where percentages reach 15-30% regarding WRF, and 60% in the case of Spread. Western islands also show low correspondence between databases, having higher percentages in almost every point considering Spread database.

DAL phenomenon also shows uneven distributions and low correspondence between databases.

Regarding WRF, DAL phenomenon is especially important in south Tenerife, and east Fuerteventura given that it reaches percentages near 60% in most points; the remaining areas show percentages above 15% in accordance with WRF. Nevertheless, according to Spread, five areas stand out: Lanzarote, where percentages are between 40-45%, middle Fuerteventura, where percentages keep values between 15-30% and some isolated points can reach 60%, north Tenerife, where 30% of rain is due to DAL, on average, and La Gomera and El Hierro, where percentages are uneven, experimenting changes from 0 to 60% along the surface.

TRO case shows more uniform distributions however, great discordance is still significant. Starting with WRF database percentages along the island reach 25% as maximum (only very located points in Tenerife, and Gran Canaria show percentages which can get to 60%). In the case, of Spread percentages are lower in the eastern islands; as maximum 10% of Lanzarote rainfall is due to TRO whereas in Fuerteventura percentages are above 5%. The western islands, as well as Gran Canaria, show less homogeneous distributions but percentages are around 5-15%, only La Palma is needed to be pointed out for the reason that the middle, and northern area can reach rates from 30-60%.

ASL phenomenon is the less significant not reaching percentages above 5% (excepting few, insignificant points in Gran Canaria). In this particular case, both databases show great concordance.

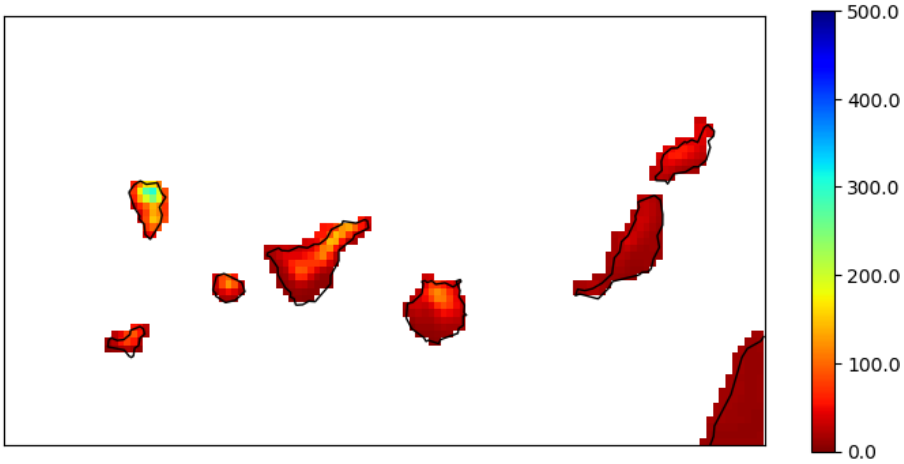
Summarizing, in summer None phenomena are predominant in the western islands, and Gran Canaria and UAL phenomena are primary in Lanzarote, and Fuerteventura in view of Spread, always bearing in mind that precipitation due to each of the phenomena is really scarce.

3.2.3.3 Fall Season.

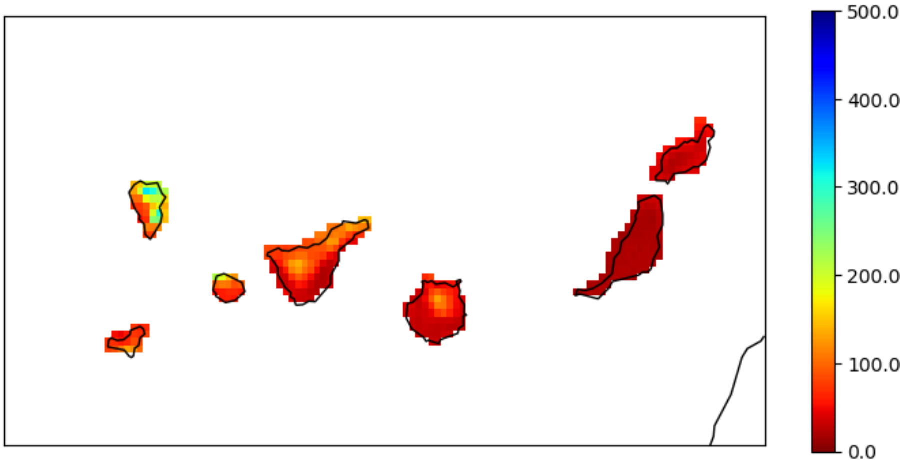
This section studies the distribution of the phenomena collected in Table 1 during the fall (September, October, and November).

The figure below (Figure 14) shows the total amount of rain per year during the fall according to both databases. One, as well as the other, show the same areas of maximum precipitation located in north (WRF), and northeast (Spread) La Palma where rainfall overtakes 200 mm/year. In Anaga Headland, central Tenerife, and in a minor area in north Gran Canaria, regarding WRF, shifted to the center in Spread, rainfall reaches about 150 mm/year. Precipitation in remaining areas and islands is under 100 mm/year.

Charts 15, and 16 show the percentage of rain along the islands which corresponds to each examined phenomena (Table 1) studied considering each numerical database, Spread (Figure



(a) WRF



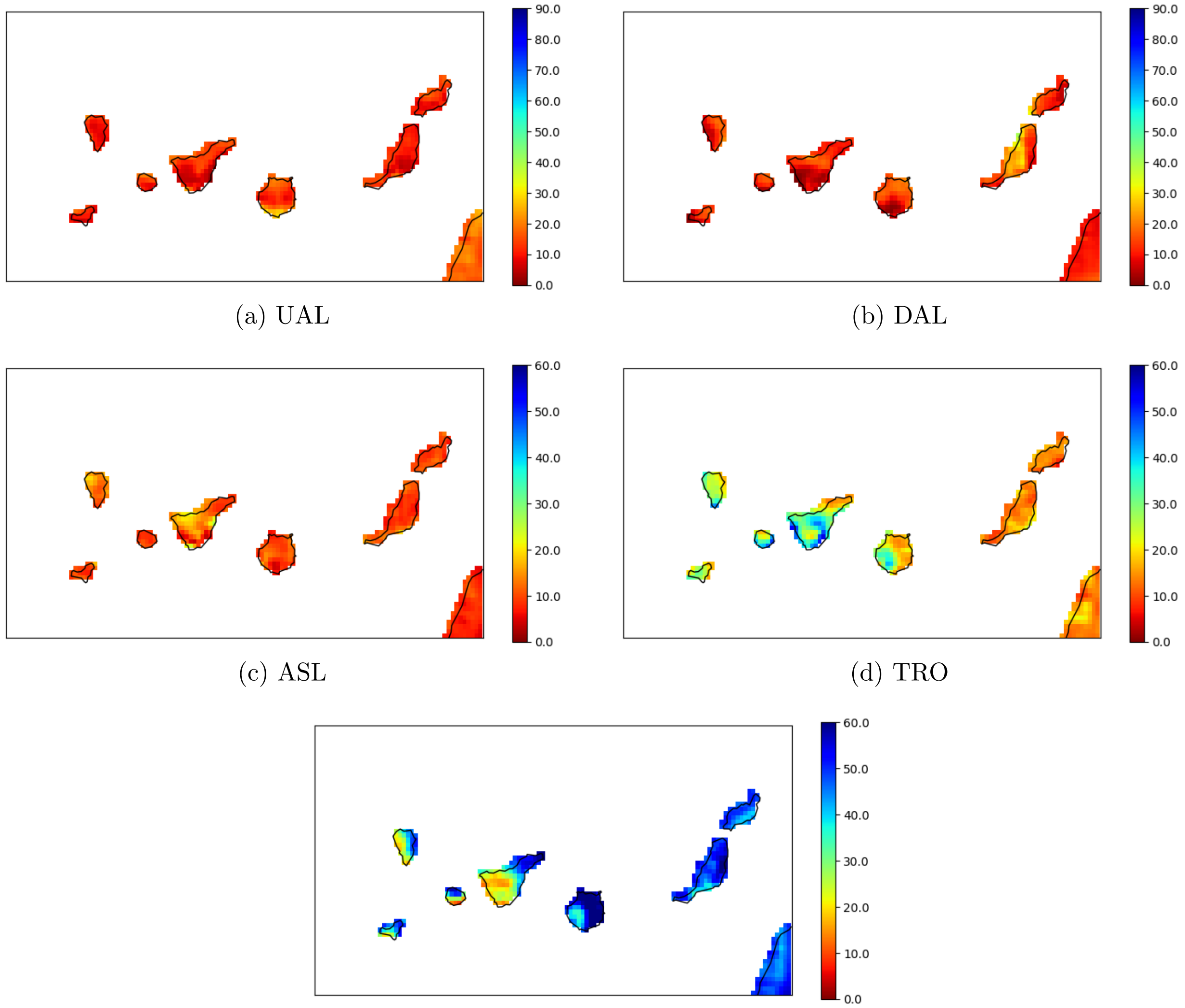
(b) Spread

Figure 14: Amount of rain per year during the fall season which corresponds to 1 mm/day phenomena according to (a) WRF database, (b) Spread databse

16), and WRF (Figure 15), during the fall season.

UAL phenomenon is almost homogeneous, and constant in every island signifying about 15% of the total rain of a year, only a minor extent of south Gran Canaria shows different behavior, entailing 30% of the total rain when the WRF database is analyzed. Nevertheless, the distribution is different studying Spread: the highest percentages are located in El Hierro, La Gomera and center Tenerife where values can signify 30% of the total amount of rain per year; in El Hierro, and La Gomera some isolated points also reach percentages near 50%. Furthermore, La Palma and, remaining areas of Tenerife, and Lanzarote have percentages located between 15 to 20%, percentages in Gran Canaria are about 15% whereas in almost all Fuerteventura these rates do not reach 10%.

Similar behaviors are found analyzing DAL and ASL cases. Once again, WRF database



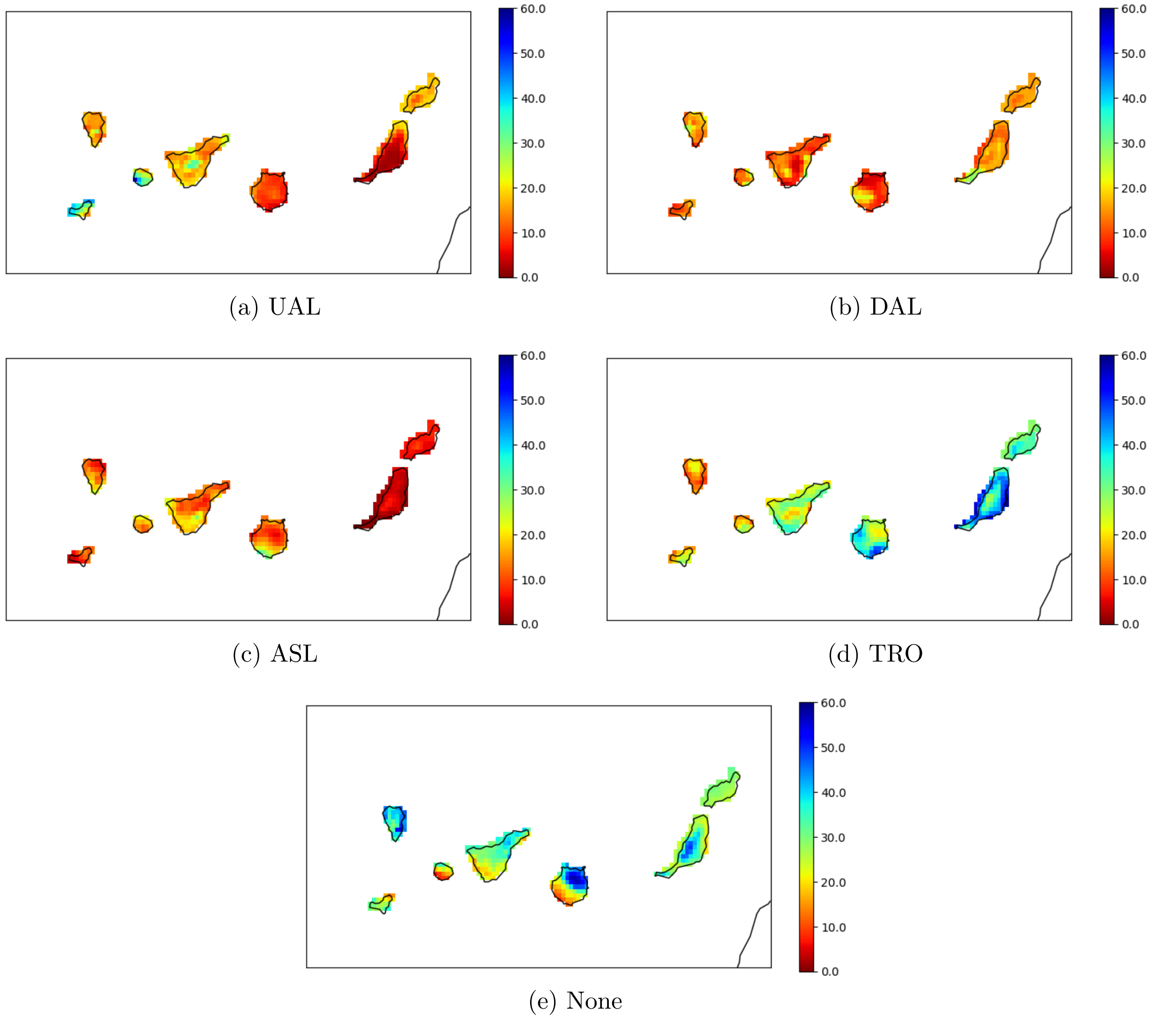
(a) UAL (b) DAL

(c) ASL (d) TRO

(e) None

Figure 15: Corresponding percentages of the analyzed situations (a-e) which correspond to 1 mm/day phenomena regarding WRF database for fall.

shows slightly lower percentages than Spread. Regarding WRF, in fall DAL is outlined in west Fuerteventura, and ASL stands out in northwest La Palma, and Tenerife; these particular cases entail about 20% of the total rain of a year, whereas percentages in remaining areas and islands are homogeneous, and do not reach values above 15%. Nevertheless, considering Spread, some differences can be pointed out: Jandía, in Fuerteventura, reaches the highest percentage due to DAL phenomena reaching an almost constant value of 30%; minor areas in west La Palma, middle Tenerife, and west Gran Canaria, as well as Lanzarote, and remaining Fuerteventura show percentages between 15-25%, while the other areas can only reach rates under 15%. Following with ASL, it can be pointed out that, generally, percentages are about 15% along the islands except for west La Palma. and Tenerife where percentages are to some extent higher,



(a) UAL (b) DAL

(c) ASL (d) TRO

(e) None

Figure 16: Corresponding percentages of the analyzed situations (a-e) which correspond to 1 mm/day phenomena regarding Spread database for fall.

reaching 20% maximum, when WRF database is considered. However, regarding Spread, this phenomena is not as homogeneous: Lanzarote, Fuerteventura, and El Hierro percentages are beneath 10%, in a minor area in south Gran Canaria percentages can reach values about 30%, and in southeast La Palma, La Gomera, and south Tenerife percentages entail 20% of total rain per year.

Rather different is the case of TRO phenomenon: databases show lower correspondence not only regarding the distribution but the values. In any case, both databases show that TRO is relevant for precipitation during fall. Considering WRF TRO phenomena are more frequent in the western islands, and southwestern areas of Gran Canaria having percentages about 30%; besides, some located points in the southwest of Tenerife can reach values near 60%

whereas in northeast Tenerife has values below 20%. The most eastern part of Gran Canaria, as well as Fuerteventura, and Lanzarote have percentages which values fluctuate between 15-20%. Nevertheless, regarding Spread percentages, and distribution of TRO phenomena are quite different. The eastern islands have the highest percentages due to TRO, signifying 40% of the total amount of rain of a year. Besides, Lanzarote littoral and some extent of south Gran Canaria have percentages over 50%. Northeast Gran Canaria, all Tenerife (excepting the central part of Tenerife), south La Gomera, and practically all El Hierro show percentages values about 30%. TRO phenomena in La Palma, central Tenerife, and remaining areas of La Gomera, and El Hierro supply about 15-20% of total rainfall.

Finally, None phenomena again display low correspondence in percentage values but better correlation in distribution than TRO, being also very important for this season. In relation to WRF database, the eastern islands as well as northeast Tenerife, north La Gomera, east La Palma, and north El Hierro have the highest percentages of this phenomenon, reaching over 50% in almost all points. Even so, the remaining areas do not show low percentages but just values between 15 to 30%. Completely different rates are shown considering Spread, the highest percentages are located in central Fuerteventura, northeast Gran Canaria and north littoral in La Palma where values are about 50%. None phenomena in remaining La Palma, and northeast Tenerife supply around 35% of total rainfall. El Hierro, north La Gomera, central, and northwest Tenerife, as well as Lanzarote, and remaining areas of Fuerteventura show percentages about 30%. The left areas only signify rates between 15-20%.

3.2.3.4 Spring Season.

This section studies the distribution of precipitation due to the phenomena collected in Table 1 during the spring season (March, April, and May).

The figure below (Figure 17) shows the total amount of rain per year during the spring according to both databases. Once again, they agree on the areas of maximum precipitation, standing out northeast La Palma where the total amount of rain can entail 300 mm/year. The central area of La Gomera, central Tenerife, and central Gran Canaria show slightly higher percentages than other areas, reaching about 150 to 200 mm/year in accordance with any of the databases.

Figures 18, and 19 represent the phenomenological distribution of rainfall in the Canary Islands, showing the percentage of rain along the islands which corresponds to each of the examined phenomena (Table 1), studied considering each numerical database: WRF (Figure 18), and Spread (Figure 19) during the spring season. Generally, databases show a good

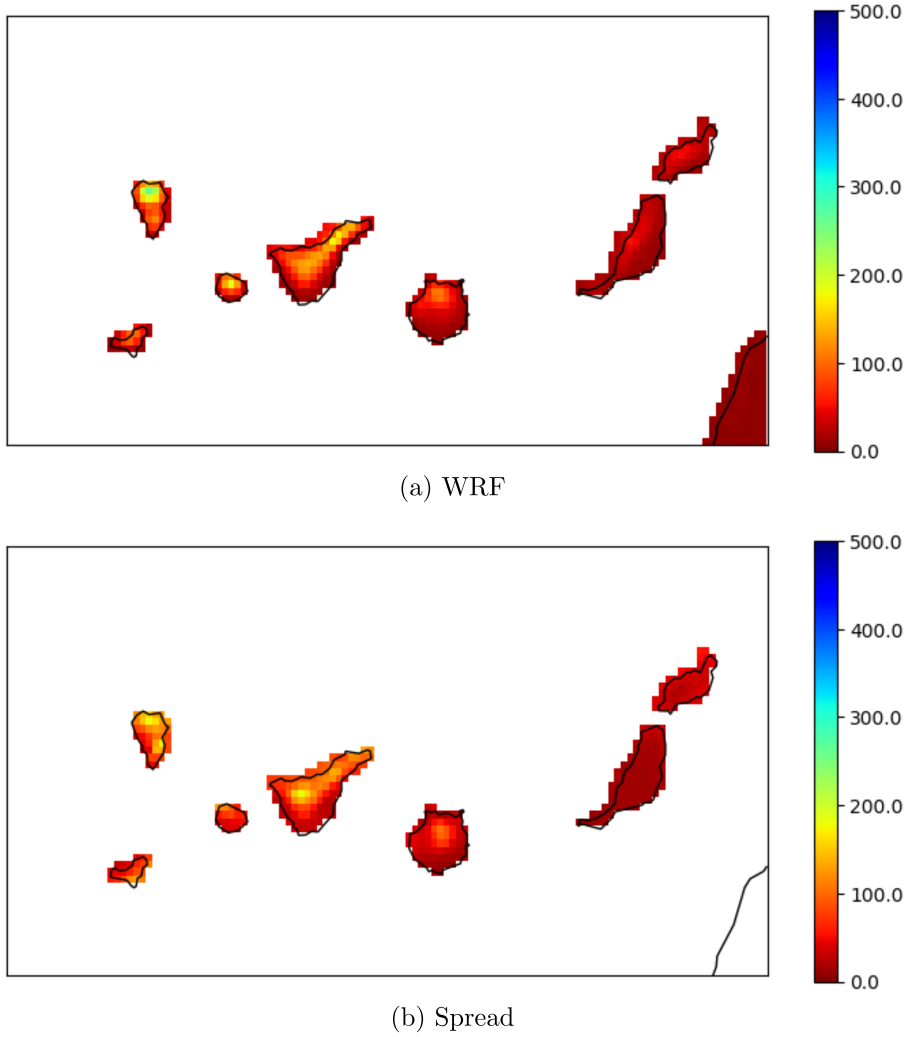
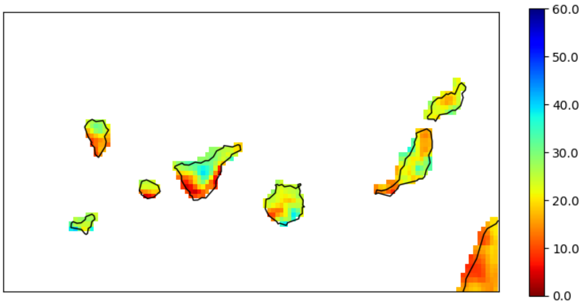


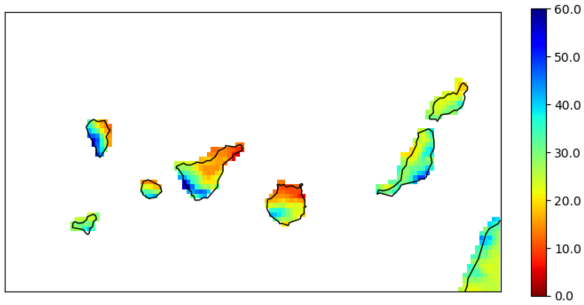
Figure 17: Amount of rain per year during the winter season which corresponds to 1mm phenomena according to (a) WRF database, (b) Spread database

correlation related to distribution, however, percentages have different values along the islands.

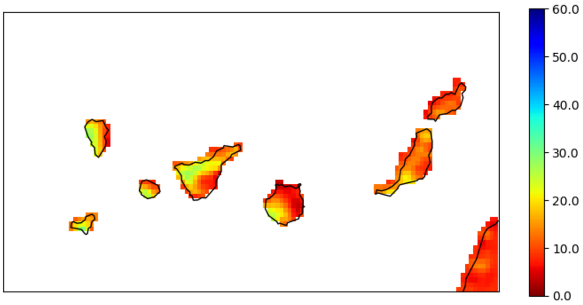
First, UAL phenomenon reaches its highest values, about 35%, in central Tenerife, and southwestern Gran Canaria as well as in some isolated areas of the littoral of some other islands, considering WRF. It entails about 30% of the total amount of rainfall per year in El Hierro, north La Gomera, north La Palma, north Tenerife, northeast Gran Canaria, central Fuerteventura, and south, and northeast Lanzarote. In south La Palma, south La Gomera, south Tenerife, southwestern area of Gran Canaria, south, and northeast Fuerteventura, and north, Lanzarote percentages reach less than 20%. Regarding Spread, percentages have values over 35% (reaching 50 to 60% in some particular and isolated areas) in El Hierro, northeast Tenerife, southeast Gran Canaria, and almost all Fuerteventura. In the remaining areas, percentages are below 20%, having its minimum in Lanzarote, where the values reach 15%, on average.



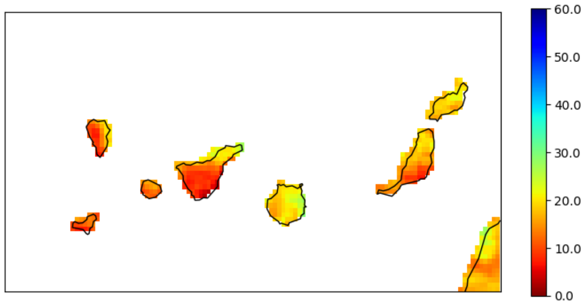
(a) UAL



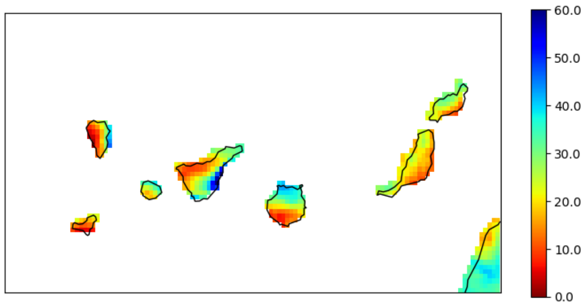
(b) DAL



(c) ASL



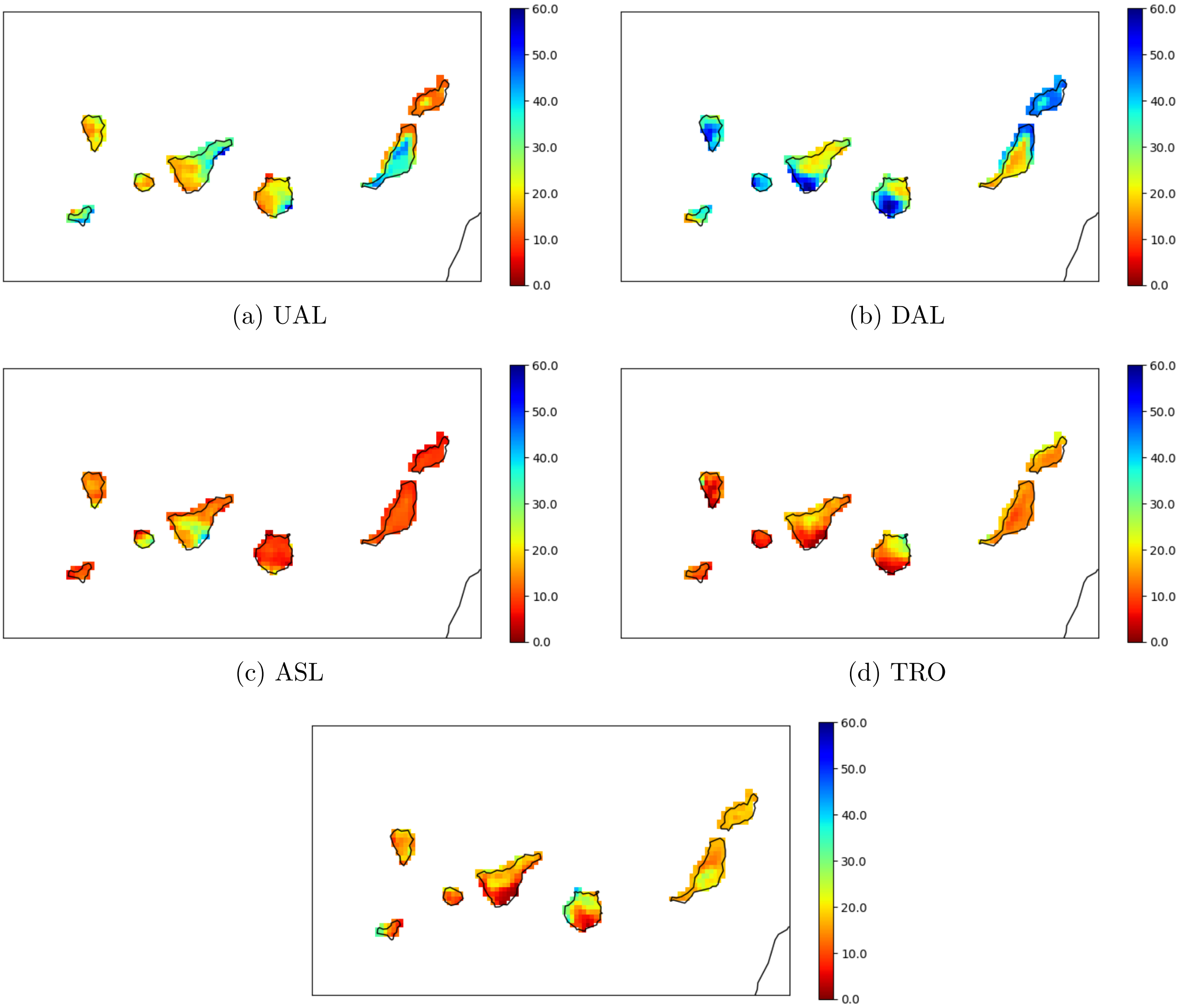
(d) TRO



(e) None

Figure 18: Corresponding percentages of the analyzed situations (a-e) which correspond to 1mm regarding WRF database for spring.

DAL charts also show differences regarding percentages values when considering each database. Generally, both databases show that DAL is highly predominant in El Hierro, west La Palma, La Gomera, southwest Tenerife, south Gran Canaria, north Fuerteventura, and Lanzarote, where percentages reach values between 30 to 50%, considering WRF but 50 to 60% when Spread is considered. These areas do not agree completely between databases, for example, La Palma, and Fuerteventura show some important differences regarding distribution. In the case of La Palma, considering WRF database, east slope presents percentages about 20% whereas, taking Spread database into account, this same area maintains percentages about 40%. In the case of Fuerteventura, WRF chart shows a practically homogeneous distribution along the island having percentages about 30% (some littoral points show different values: in the northwest side



(a) UAL (b) DAL

(c) ASL (d) TRO

(e) None

Figure 19: Corresponding percentages of the analyzed situations (a-e) which correspond to 1mm phenomena regarding Spread database for spring.

percentages entail 20% of rain in some located points; in some points in the southeast side, percentages can entail about 45% of the total rain). However, regarding Spread, Fuerteventura has two divisions: the first one is mentioned above, north, and northeast littoral of Fuerteventura present values between 35 to 50%; the second one, the remaining area which includes the south, and many central points of the islands, where percentages are between 15 to 25%.

ASL figures show again some differences regarding distribution but percentages are better correlated in the agreement points. Generally, ASL phenomenon supplies less than 30% of the total amount of rain, according to both databases. To begin, eastern islands have a great correlation between databases: percentages are about 15-20% along all surface; except for some located points in Fuerteventura, where values are slightly above 20%, and an area in southwest Gran Canaria, where percentages are about 25% when WRF database is taken into consideration. In the case of the eastern islands, Spread database chart shows much more homogeneous distribution than the one conducted by WRF. The case of the western islands is somewhat different. To fix the ideas, considering WRF, the wettest areas by influence of ASL are south El Hierro, west La Palma, southwest La Gomera, and northwest Tenerife; in these areas precipitation due to ASL can entail 30% of the total amount of a year. Nevertheless, when Spread is considered, the wettest areas by influence of the ASL are located in south La Gomera, and northwest to southeast areas in Tenerife (except for the coastal areas where ASL influence is lower) where percentages values are 30%. In the non-mentioned areas, percentages reach values between 20-15%, regarding any of the databases.

Less noticeable differences are shown in the case of TRO, but still, there are some disagreements in distribution. Considering WRF, these phenomena entail a higher amount of rain in Anaga, in Tenerife, and west Gran Canaria, where percentages can reach 30%. Also, these phenomena signify about 20% of total rain in Lanzarote, north Fuerteventura, remaining Gran Canaria, north Tenerife, and east La Palma. In the left areas, values are ranged from 10 to 15%. In the case of studying Spread database, percentages over 30% are only located in a small region in west La Palma, and northeast Gran Canaria, whereas, about 15 to 20% are located in Lanzarote, Fuerteventura, middle-belt Gran Canaria, and north Tenerife. Remaining areas signify less than 15% of total rain during the spring season.

Finally, the None case shows some differences which are needed to be pointed out. In relation to distribution, littoral areas of east La Palma and east Tenerife can also have percentages over 50%, and north Gran Canaria demonstrates values about 40%, regarding WRF; however, the areas, where None is prominent in relation to Spread, are located in east El Hierro, east, and north Gran Canaria. In these last areas, rates values are about 30%. Besides, WRF chart point out east La Palma, north La Gomera, south, and northeast Tenerife, Jandía Natural Park in Fuerteventura, and north Lanzarote as the areas where None cases are highly remarkable, reaching percentages around 30%; the remaining areas can entail less than 20% of rainfall during the season, according to WRF. However, taking into account Spread database, the left areas reach values below 25%, having its minimum (about 15%) in southeast Gran Canaria, south Tenerife, south La Gomera, and east El Hierro.

4 Conclusions.

A partir de lo expuesto en las diferentes secciones de esta memoria, importantes conclusiones pueden extraerse. Una primera conclusión interesante se puede extraer de la sección 2.5: la mayor parte de la lluvia que se recoge en el año es debida a fenómenos extremos. De los fenómenos clasificados (véase Tabla 1), el fenómeno más importante es el que recoge las bajas atlánticas profundas (DAL), que llega a suponer hasta un 80% de las lluvias de alguna de las islas (véase Tabla 3), el cuál también es prominente al analizar la lluvia total (véase Tabla 4), dado que puede alcanzar el 30% de la precipitación de un año. De las secciones posteriores, se puede concluir que la base de datos WRF, que representa un modelo completamente numérico, es posible predecir generalmente (al compararse los resultados con los ofrecidos por la base Spread, una base semi-observacional), cómo se distribuyen las lluvias con respecto a los fenómenos clasificados. Además, de la sección 3.2.3 también se puede extraer que en los meses de invierno suponen la mayor parte de la lluvia de las islas, llegando a alcanzar unos 500 mm/año, durante esta estación; ambas bases de datos presentan gran correlación. Totalmente contrario es el caso del verano, ya que conlleva menos de 50 mm de lluvia al año y es difícil de modelar y predecir; la base numérica WRF, estima que ninguno de los cuatro fenómenos es predominante en las islas, salvo en puntos aislados del sur y este de La Palma, Tenerife y, Gran Canaria y Lanzarote, donde se pueden apreciar zonas en las que los fenómenos UAL y DAL pueden suponer más del 60% de estas escasas lluvias. Curiosamente, el caso del otoño también refleja situaciones en las que los fenómenos None son mucho más abundantes que el resto aunque la base WRF no refleja valores muy consecuentes respecto de la base semi-experimental. Finalmente, en primavera, las situación vuelve a ser estable, reflejando que los fenómenos más abundantes en esta estación son las perturbaciones atlánticas; particularmente, el fenómeno DAL puede llegar a suponer más del 50% de la lluvia de la estación en algunos puntos al tener en cuenta la base de datos de Spread.

A chief result is shown in the discussion made in section 2.5. Despite being considered a dry area, the most decisive rain rates are given when a heavy rain case occurs: having analyzed merely 104 cases in a period of 10 years, the percentages of heavy rain, using AEMET database, show that around 50% (2) of the total rain over the Canary Islands is a result of this aspect. In addition, DAL phenomenon provides a more significant amount of rain per year due to heavy precipitation episodes, around 84.51% in El Hierro (Airport), and 60.54% in Tenerife (Güimar). Among the other phenomena, differences are exceedingly scarce. More curious is the case of None: regarding heavy rain, almost every episode could have been classified according to Table 1; Lanzarote (Yaiza) stands out in consequence of having not a single case unclassified, in contrast, Tenerife (Güimar) has the greatest percentage of None classified cases, which corresponds to a 3.37%.

Another conclusion can be extracted from section 3.1, when total rain related to DAL phenomenon is still quite prominent, however, less significant than regarding heavy rain. This phenomenon provides percentages between 52.64% (El Hierro, Airport), and 17.83% (Gran Canaria, Valsequillo) on the total precipitation rate in the Canary Islands. DAL has diminished in favor of the increase of None phenomenons which are now outstanding. These phenomena in relation to total rain provide around 8.27% (Tenerife, South Airport), and 38.42% (Gran Canaria, Valsequillo).

Analyzing the whole period, and the numerical databases, it is possible to conclude further that DAL phenomena affect lesser extent in northern areas of La Palma, Tenerife, and Gran Canaria, but are entirely important in the southern part of these last two islands because these phenomena represent almost 60% of the total amount of rain. In addition, precipitation due to ASL phenomenon is homogeneous along the islands resulting around 17%. In the other hand, UAL phenomena affect Lanzarote, La Gomera, northern areas of Tenerife, Gran Canaria, and Fuerteventura slightly more than southern parts and the remaining islands, entailing around 25% of total rain. Further, TRO phenomena preserve a homogeneous distribution along the islands, representing 10% of the total rain, where only northern part of Tenerife and Gran Canaria stand out, having percentages close to 20%. Finally, regarding None phenomena, the case of Gran Canaria strikes out given that it represents the largest percentage of None classified phenomena (around 40%); El Hierro, La Gomera, southern Tenerife and southwestern Gran Canaria are outlined as a result of having the minor percentages of None-classified phenomena.

Overall, ASL, UAL, and TRO phenomena despite being homogeneously distributed affect slightly more in northern areas in the case of UAL, southern areas in the case of ASL, and TRO in northeastern areas of the islands, except for Lanzarote, and Fuerteventura. DAL is extremely important in southern areas of the western islands, and Gran Canaria, and it is the predominant phenomenon in Lanzarote, and Fuerteventura.

Further conclusions can be extracted from 3.2.3 in relation with the phenomena which mainly affect during each season. First, it is important to state that generally wet seasons (see sections 3.2.3.1, 3.2.3.3, and 3.2.3.4) maintain good concordance between both databases. Firstly, it is of utter importance to set that the classified atmospheric disturbances (see Table 1) model the real situation in a proper way, because mostly all rainfall can be determined studying these phenomena.

Winter season entails the greatest amount of rain in a year, and it is mostly due to DAL. Nevertheless, UAL, ASL, and TRO are not too important, having values below 20%, mostly.

Besides, None phenomena are quite frequent in the western islands, being able to entail more than 35% of rain in areas such as northeast Gran Canaria. So, generally, winter is well modeled considering only these four phenomena. Although, the numerical database WRF does not completely agree on values with Spread.

Particularly noteworthy is the case of summer. Precipitation is not especially abundant (less than 50 mm/year), and additionally, it implies inhomogeneous distribution, making this scarce rains difficult to predict, and model. Regarding, WRF none of the main phenomena are especially abundant, except for some located points in the east, and south of La Palma, Tenerife, Gran Canaria, and Lanzarote. In these points, UAL, and DAL phenomena can be appreciated because they can represent more than 60% of rain. Nevertheless, None phenomena are dominant in the remaining areas, where they can also represent 60% of total rainfall.

Besides that, fall is not especially good modeled considering only these four disturbances; more than 60% of fall rain is supposed to be collected in the None case when WRF database is considered; whereas, considering Spread, some areas do entail over 50% of total rainfall, but these areas are not the same as those located with WRF chart. Besides, TRO display similar disagreements, different locations regarding the maximum values, and disparity in values. DAL and ASL phenomena are better correlated between database, not being particularly outstanding, but showing values about 15-20%, roughly.

Regarding the spring, DAL case is prominent showing percentages over 40%, and up to 20% in the cases of UAL, and TRO. In contrast, winter, and summer seasons (see sections 3.2.3.1, and 3.2.3.2) are not properly correlated neither reflect a suitable distribution of the main classified phenomena (see Table 1): both seasons have high None percentages. In relation to the winter case, percentages are over 60% in every point whereas in the summer case depends on the database. Focusing on the summer case, percentages of None are around 90% except for located points in eastern areas of El Hierro, and La Palma, and southern areas of Tenerife, and Gran Canaria, regarding Spread. Regarding WRF, percentages are over 40% along the islands excluding the lower half of Tenerife which reaches 20% maximum whereas concentrating on UAL this same area accumulates around 80%.

To sum up, rainfall in the Canary Islands, despite being a dry area, can be caused by extreme precipitations episodes, collecting the maximum precipitation values during the winter. These rainfall events are mostly caused by DAL phenomena. The remaining phenomena during this season are of the same magnitude. Precipitation collected during fall, and spring means as much rain as the pouring rain in winter. During these two seasons, all the phenomena are equally important, roughly. In a general overview, in northeast La Palma, north La Gomera, central, and northeast Tenerife, and central Gran Canaria (these are the areas where maximum amounts of rain are collected) not only DAL is important, but also, UAL which is related to 30% of rainfall in some areas.

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