Interreg Sudoe

EUROPEAN UNION

climalert

European Regional Development Fund

CHAPTER 2: Sources of weather data and its usefulness for this project.

INDEX

1. UTILITY OF WEATHER DATA IN THE CONTEXT OF THE PROJECT.

The platform to be created in this project will complement satellite information with weather data for the implementation of the alert applications that are intended to be developed in the field of drought-estimation of biomass, floods and fires. Weather information that can be incorporated can be classified into three large groups: Weather Data Analysis Information; Weather observation (real-time weather monitoring) and prediction. The following briefly describes for utility the information of each of these groups in the three areas of action of the project mentioned above.

1.1. Analysis of meteorological.

The analysis of meteorological data and the generation of climate information from them is fundamental in the field of agroforestry research and planning. The availability of reliable historical data related to meteorological variables such as precipitation, air temperature or solar irradiation, among others, makes it possible to obtain very useful indexes. Although the analysis of meteorological data seems to be limited to researchers or technicians, owners of agroforestry farms, managers of rural communities, associations, municipalities, local or regional entities..., benefit indirectly from this information by becoming users of the models and applications generated from these data.

In the area of flood prevention and warning, the analysis of meteorological data for the generation of climate information allows the implementation of models that make it possible to study the dynamics of the spatial-temporal distribution of water resources. The availability of ten-minute data on rainfall events and flow measurements at short intervals of time (ten-minute, for example), makes it possible to implement highly useful hydrological models for calculating floods. Likewise, the analysis of precipitation records using statistical techniques makes it possible to generate information of interest such as accumulated precipitation excess curves, intensity-duration-frequency curves, studies of the probability of occurrence of dry day spells, etc. The analysis of precipitation intensity records also plays a fundamental role in the study of the selective, recurrent, and progressive loss of the surface layer of the soil due to the action of water, that is, in the study of water erosion. Water erosion represents a serious threat to the agricultural environment, since its effects include the following: reduction of soil thickness, alteration of soil texture, reduction of soil organic matter content, decrease of infiltration rate and water retention capacity of the soil, loss of nutrients, burial of crops, filling of marshes and ponds, etc...The characterization of the erosion of the average rainfall events of an area and their integration with soil information, makes it possible to identify areas more or less vulnerable to water erosion and to apply corrective measures, which can sometimes be related to the modification of traditional land uses.

The study of historical meteorological series (analysis of meteorological data) is of great relevance in the study of drought events and the evolution of soil humidity in the agroforestry field. In this sense the analysis of precipitation data is fundamental. But another factor in the field of estimation of the water balance of the soils is the evapotranspiration. The evapotranspiration is a variable of difficult direct measurement. It is usually estimated by mathematical models that use information from meteorological sensors as input variables. The Penman-Monteith combination equation, modified by Allen et al. in 1998 (PM56), is the reference equation for daily ETo estimation. It requires daily data on air temperature, relative humidity, wind speed, and solar irradiation, or alternatively hours of sunshine. In the absence of any of the meteorological parameters required for the application of PM56, the application of alternative locally calibrated models is recommended. The selection and local calibration of alternative models to PM56 also requires the analysis of data sets of the above-mentioned parameters. To estimate the water deficit, the values of evapotranspiration and daily precipitation are integrated into agronomic models with soil and phenological information. The integration of this information with Earth observation technologies allows improving the operational management of models for estimating the soil water balance and the water deficit of crops, which are relevant for the implementation of drought warning systems. There are different approaches to this integration that will be addressed in later sections of this report. But in any case the development of these soil water balance estimation systems requires the analysis of historical meteorological data (and satellite images). Cultural activities such as planting, soil preparation or fertilization, among others, are conditioned by the state of soil moisture. The above information goes beyond the estimation of drought events. It also allows the establishment of guidelines that generate

1.2. Meteorological Observation.

Monitoring and decision making in the agroforestry field requires the availability of real time weather records. Unlike the line previously developed (analysis of meteorological data), meteorological monitoring directly conditions the daily activity of different agents who have to make decisions based on the meteorological information that reaches them in real time. Sometimes they do not have direct access to this information, but rather it is processed by means of models and applications developed in the field of agroforestry research. The implementation of these monitoring tools usually requires the previous analysis of meteorological records. In other words, the analysis of meteorological data in the field of research enables the generation of applications, which will be used by farm owners and agricultural managers to make decisions based on meteorological data provided in real time, and from predictions of meteorological variables in the short or very short term.

In the area of flood risk estimation the variables related to flow, and surface run-off, are deferred in time with respect to real-time rainfall records. In this way, real-time rainfall monitoring is a useful tool that allows for the anticipation of possible floods or the rise in the level of reservoirs above values that could compromise their stability.

In the area of estimating soil water balances and anticipating drought events, the models used are usually fed by meteorological data recorded in the past. Therefore, this approach would not fall within the scope of meteorological monitoring. However, the availability of real time values from sensors measuring the volumetric content of soil water (TDR, FDR, etc.) or the matrix potential of the soil (tensiometers), would make it possible to make decisions regarding the possible activation of irrigation systems based on updated information. This type of real time monitoring is especially useful in areas where there is a high degree of homogeneity in terms of the physical characteristics of the soil and cultural practices, and where there are no major restrictions affecting the dose and time of application of irrigation.

In the field of fire fighting, real-time information on the values of meteorological variables such as temperature, rainfall, relative humidity or wind speed and direction is of interest for the prevention of the appearance of fires and the monitoring of their evolution once they have been detected. The monitoring of lightning strikes associated with electrical storms is another application of real-time weather monitoring in the field of early detection and mitigation of forest fires. In any case, both the occurrence of natural forest fires and their spread are closely related to the water status of the plant mass. And this, in turn, is correlated with the moisture content of the soil. When the water stress levels of the forest mass exceed a certain threshold as a consequence of the drying up of the soil, there is an increase in the concentration of ethylene in the atmosphere surrounding the plant cover, increasing its flammability. Therefore, monitoring the state of soil moisture through specific applications would be very useful in this field. Remote sensing can play a very important role in the surveillance and detection of forest fires and in the analysis of their effects on the environment. Therefore the integration of real-time meteorological data and satellite images is relevant in the context of this project.

1.3. Weather forecasting.

- Nowcasting (hours)

The applications of very short-term forecasting do not differ greatly from the applications of weather monitoring. The anticipation of certain events or weather conditions is very useful, provided that there is enough time to program strategies that allow efficient adaptation to the forecast conditions. The very short term prediction gives the owner of the agroforestry exploitation a margin of adaptation of a small number of hours, so that it is difficult for him to make some decisions in such a short time. However, the vast majority of the applications of weather monitoring mentioned above can be extrapolated to the very short term forecast. In fact, very short-term weather forecasting has the advantage over real-time monitoring of providing a certain margin of anticipation for decision-making. On the other hand, it is necessary to emphasize that the level of uncertainty inherent in any weather forecast is directly proportional to the size of the time interval that is projected into the future, so that very short-term forecasts turn out to be the least uncertain. And this fact, despite the narrow temporal margin of decision mentioned above, provides a certain security to the decision maker of an agroforestry operation or planning agent of the physical environment.

The use of techniques for very short-term prediction of rainfall events is of great importance in the field of flood warning systems. In this respect, the role of meteorological radars should be highlighted. The integration of hydrological models and information from meteorological radars makes it possible to obtain flow prediction data in the basins, and thus the early detection of possible floods and inundations. Likewise, the techniques for very short term prediction of rainfall events are very useful in the area of management of reservoirs and regulation and irrigation ponds, as they make it possible to anticipate events that could compromise their stability and/or correct operation.

The fight against forest fires is another activity that can benefit from the availability of very short-term weather forecasts. Both the detection of fire outbreaks and the monitoring of their evolution, or the strategies to be followed for their eradication, could benefit from the information provided by very short-term forecasts of variables such as temperature, relative humidity, wind speed and direction or rainfall. In this sense, the prediction of lightning strikes associated with storm precipitation events is obviously of great interest.

- Short-term weather forecast (days).

The prediction of short-term weather variables has traditionally been used in different areas. In the case of the agroforestry area, the owners of the farms have always valued this type of forecast very positively, adapting the programming of their daily activities to the weather forecast. The time horizon of these predictions (days), unlike the case of very short-term predictions, is frankly well adapted to the operating scheme of the agroforestry company, giving the owner of the same a sufficient time margin for the adoption of corrective measures and adaptation to weather conditions. On the other hand, the use of this type of predictions as input variables of agroforestry and hydrological models, opens a very interesting range of applications of the mentioned models. Most of the models currently used provide information on the current state of the system from the accumulation of data collected in the past. This information is used for decision making by different agents. However, the use of short term prediction data as model inputs to obtain forecasts on the future evolution of the systems is not so widespread. The greatest difficulties in using these short-term forecasting data lie in the fact that the degree of accuracy of these data decreases as their time horizon increases. However, the development of probabilistic prediction techniques, in which this level of uncertainty is characterised, and their application to the modelling and programming of activities, opens up a very promising field of development

In the area of flood forecasting, the use of short-term precipitation forecasts makes it possible to detect early events that could lead to flooding. Accumulated rainfall forecasts can be useful provided that they refer to short time intervals. In this sense, the use of probabilistic forecasts of precipitation, average and maximum over short intervals of time, or the probabilistic characterization of the occurrence of different levels of precipitation intensity, is of great interest.

This type of short-term prediction information combined with that from the analysis of the past evolution of soil humidity allows for the anticipation of water stress situations, and therefore the programming of irrigation with some advance notice in the face of possible drought events. The integration of probabilistic predictive information in crop simulation models, also fed with past meteorological data, allows establishing the short-term evolution of biomass accumulation. Likewise, this information is of great interest for the planning of a good number of agroforestry activities. Short-term weather forecasts have conditioned the agroforestry activity since remote times, especially in the case of the detection of adverse weather phenomena with some time in advance.

In the same way, the availability of a combination of probabilistic forecasts of temperature, relative humidity, wind speed and direction, and precipitation, would contribute to the characterization of the risk of forest fires in the short term. Likewise, the knowledge of the short-term evolution of the mentioned variables is of great importance when planning the strategies to be followed once a forest fire has been declared.

- Medium and long term weather forecast (weeks, months).

One of man's great pretensions is to be able to predict the weather rigorously and months in advance. In meteorology, the longer the prediction time, the less reliable the models' forecasts will be. The reason why weather forecasts are losing accuracy is due to the rapid amplification of the inevitable errors and uncertainties of the initial conditions, when we move from reality to the model. This fact makes the applicability of this line of weather forecasting have important limitations. If the levels of uncertainty of medium-term forecasts were reduced to a level similar to that of current short-term forecasts, their field of application would be very similar to that of current short-term forecasts. However, they would have a very clear advantage over the latter in that they would allow for greater anticipation of the measures to be taken. The combination of the information currently available from seasonal or long-range prediction models with the climate data of an area provides a tool of some interest in the context of the present project. The prediction of anomalies of the seasonal averages, and the characterization of the percentage of probability that these anomalies present, allows to reduce the degree of uncertainty inherent to the agroforestry activities and to the management of the territory, making possible the adoption of strategic decisions with a great anticipation. However, as mentioned above, the seasonal forecasts currently available in the latitude of the SUDOE region suffer from a lack of precision compared to short-term predictions.

2. WEATHER DATA SOURCES.

2.1. Agencia Estatal de Meteorología (AEMET).

The State Agency for Meteorology succeeded the then General Directorate of the National Institute of Meteorology in 2008, with more than 150 years of history. It is currently attached to the Ministry of Ecological Transition through the Secretariat of State for the Environment. The purpose of AEMET is the development, implementation and provision of meteorological services under the jurisdiction of the State and support the exercise of other public policies and private activities, contributing to the safety of people and property, and the welfare and sustainable development of Spanish society". As the National Meteorological Service and the State Meteorological Authority, AEMET's basic objective is to contribute to the protection of lives and property through the adequate prediction and monitoring of adverse meteorological phenomena and as a support to social and economic activities in Spain through the provision of quality meteorological services. AEMET has distributed a series of observatories for the measurement of different climatological variables necessary for any type of study or application related to climate. Depending on the measured variables, several types of stations or observatories are distinguished:

- Complete stations.
- Thermometric stations.
- Pluviometric stations.
- Automatic stations.

Weather analysis and monitoring: In the field of weather data analysis and weather monitoring, it is the automatic stations that are of greatest interest in the context of this project. The rapid growth of the network of automatic stations has improved the coverage of the previous networks, providing, in addition, very immediate information although not guaranteed as to the absence of errors, since the data are not subjected to any filtering or validity test in order not to delay their dissemination. They provide historical data, and in real time, of most of the climatological variables: precipitation, temperature, wind, humidity, visibility, pressure, insolation and global radiation, among others. The information that can be consulted associated to each station is the following:

Table 1: Information provided by the stations of the AEMET network

CAMPO	DESCRIPCION
INDICATIVO	Indicativo climatológico de estación
NOMBRE ESTACION	Nombre de estación
PROVINCIA	Provincia de estación
ALTITUD	
COORDENADA X (HUSO 30)	Coordenada X de la estación (UTM/huso 30)
COORDENADA Y (HUSO 30)	Coordenada Y de la estación (UTM/huso 30)
VARIABLES OBSERVADAS	p- PRECIPITACION DIARIA
	T- TEMPERATURA DIARIA
	T- TEMPERATURA HORARIA
	M- PRECIPITACION MENSUAL
	m- TEMPERATURA MENSUAL
	V- VIENTO
	B- PRESION
	H- HUMEDAD
	N- NUBOSIDAD
	I- INSOLACION
	h- TERMOMETRO HUMEDO
	v- VISIBILIDAD
	S- TEMPERATURA SUBSUELO
	e- EVAPORACION PICHE
	E- EVAPORACION TANQUE
	r- RADIACION GLOBAL (HORARIA)
	r- RADIACION GLOBAL (DIARIA)
	d- RADIACION DIRECTA
	d- RADIACION DIFUSA
	G- DATOS QUIMICOS EN GASES
	Q- DATOS QUIMICOS PRECIPITACION
	i- RADIACION INFRARROJA
	U- RADIACION ULTRAVIOLETA
	O- OZONO SUPERFICIAL
	o- CAPA OZONO

AEMET's network of automatic stations consists of a total of 814 automatic observation stations distributed throughout the territory. Figure 1 shows the spatial distribution of the stations belonging to this network. It is a network that provides meteorological data. The frequency of observations has varied over time. Initially almost all variables were measured at standard hours (00:00, 07:00, 13:00 and 18:00 UTC), but nowadays hourly information is available on temperature, precipitation, humidity, wind and radiation.

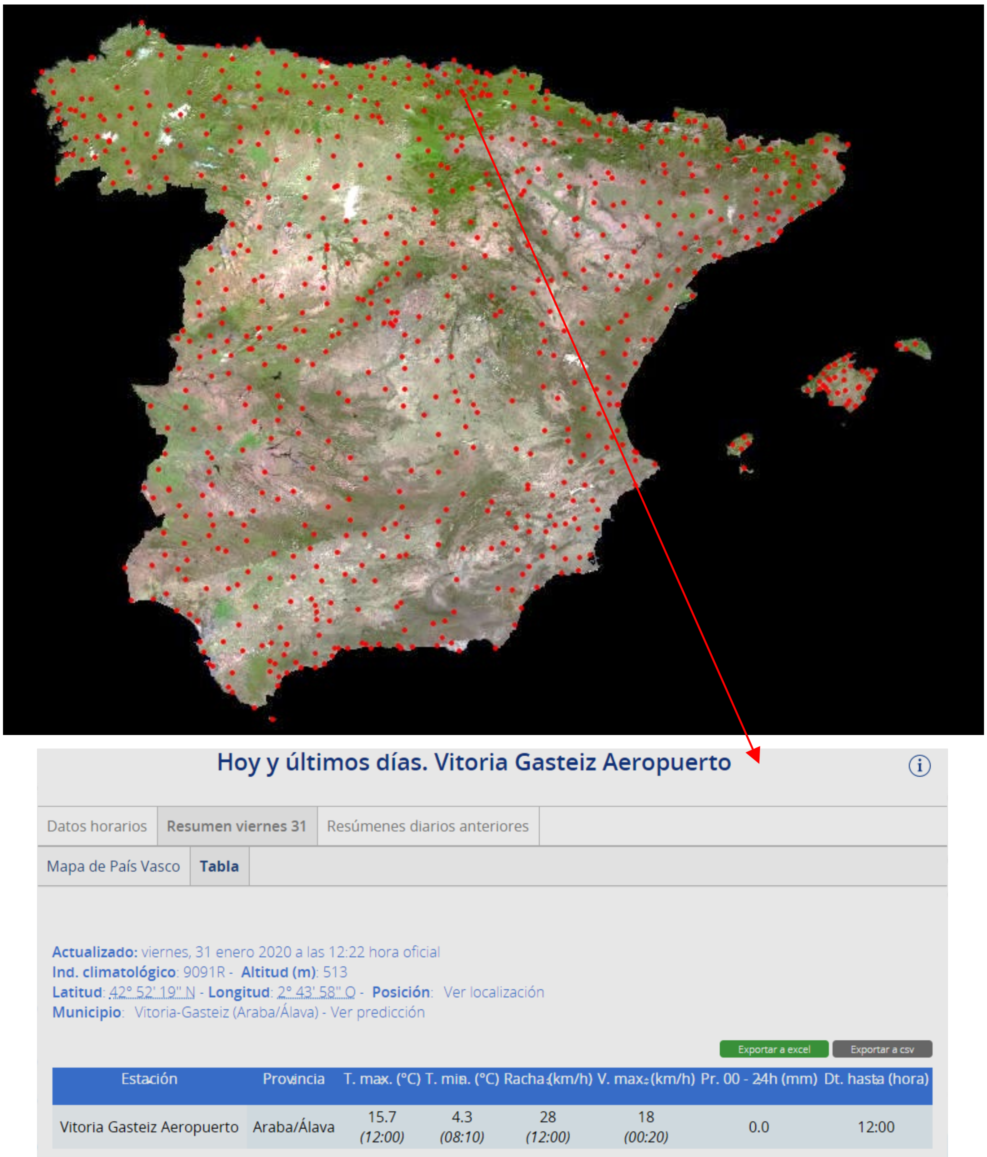


Figure 1. AEMET's network of automatic stations.

Other tools and products in the field of analysis and observation of meteorological data provided by AEMET and of interest in this project

- Monthly monitoring of the climate of the Region of Murcia, by means of a monthly climatological advance, which includes a balance of the hydrological year up to the date of the monthly bulletin. These monthly bulletins are available at: http://www.aemet.es/es/serviciosclimaticos/vigilancia_clima/resumenes?w=1&k=mur

- Meteorological drought monitoring: The SPI (Standardized Precipitation Index) is defined as a numerical value that represents the number of standard deviations of the precipitation fallen throughout the accumulation period in question, with respect to the average, once the original distribution of the precipitation has been transformed into a normal distribution. In this way, a scale of values is defined that is grouped into sections related to the character of the precipitation. This index was designed to account for the different ways in which the precipitation deficit affects the different water resource systems (soil moisture, surface water, groundwater, etc.). Specifically, the SPI was developed by the American researcher Mc Kee in 1993 to be able to quantify the precipitation deficit for different temporal scales and, based on this, to be able to evaluate the impact of the drought on the availability of the different types of water resources. Thus, for example, soil moisture conditions are sensitive to short-term precipitation anomalies (positive or negative), while surface water reserves (reservoirs) and groundwater (aquifers), as well as river flows, respond to long-term pluviometric anomalies. Through the use of the SPI index it is possible to quantify and compare the intensities of the precipitation deficits between areas with very different climates and it has the property that it can be integrated over a wide range of time scales, which makes it possible to use it as an indicator of different types of drought, both those that are of short duration and that produce effects mainly on the agricultural, forestry and livestock sectors, as well as to characterize long-term climatic droughts that lead to hydrological droughts. For the calculation of the SPI for a determined place, it is based on the historical series of monthly precipitations corresponding to the required period, series that is adjusted to the theoretical distribution of probability that is considered convenient, which is then transformed into a normal distribution, so that the average value of the SPI for the place and the chosen period is 0 (Edwards and Mc Kee, 1997). The positive values of the SPI indicate a precipitation superior to the average and the negative values of the same one, a precipitation inferior to the average. Since the SPI is normalized, both wet and dry periods can be represented in the same way, and by applying this index any period can be tracked, whether it has one character or another. The characteristic of a given period (normal, more or less wet, more or less dry) can be determined by the sign (positive or negative) and the absolute value of the SPI (above or below 0), since index values between -1 and +1 characterize a period as "normal" by indicating that one is in the middle of the distribution, which is around the mean, at a distance from it equal to or less than the standard deviation.

  It is said that a "drought" takes place as long as the SPI presents a continuous sequence of negative values, such that these are equal or inferior to -1, although it is considered that the "drought" does not arrive at its end until the moment in which this index returns to take a positive value. This definition allows characterizing each drought according to its duration, intensity and magnitude. The "duration" of a drought is determined by the length of the period in which the SPI values meet the conditions required by that definition. The "intensity" of the drought is determined by the maximum negative value, from -1, that the SPI reaches within the analyzed dry period. Finally, the "magnitude" of a drought is given by the sum of the values of the SPI corresponding to all the months included within the dry period considered. Monthly the maps for all Spain of the SPI of the hydrological year in course are obtained, of the last month, last 3 months, last 6 months, last 12, 24 and 36 months.

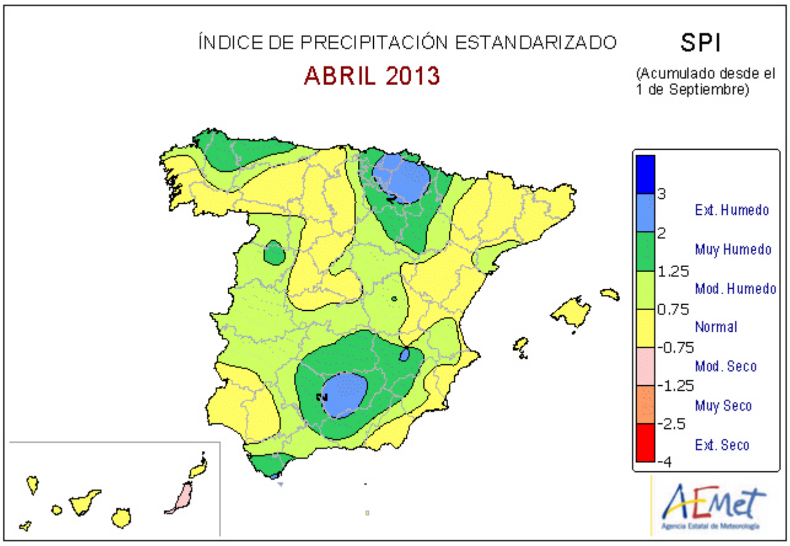


Figure 2. SPI corresponding to the hydrological year from September to April.

- AEMET's water balance. The daily evaluation process of the Water Balance provides parameters related to three variables: precipitation, potential evapotranspiration and soil moisture, and it is elaborated in the Agricultural and Hydrological Applications Service of AEMET. In the water balance updated every 7 days, four maps are presented, showing the geographical distribution, within the national territory - Peninsular Spain and the Balearic Islands, on the one hand, and the Canary Islands, on the other - of the following information:

  - Map 1: Precipitation (mm) accumulated during the last 7 days.
  - Map 2: Potential evapotranspiration (ETo in mm) accumulated during the last 7 days.
  - Map 3: Percentage of soil moisture (Available Water) of the surface layer, with respect to an ADT of 25 mm, on the reference date.
  - Map 4: Percentage of soil moisture (Available Water) of the total layer, with respect to an ADT max (R max), at the reference date.

  The ten-year Bulletin of the National Water Balance for the last three months is also produced and updated every ten days. This bulletin contains summarized information in maps for the whole territory and also in tables that include specific data from the main observatories. The content of the different maps is as follows:

- Map 1: Accumulated rainfall from September 1 to date.
- Map 2: Percentage representing accumulated precipitation from 1 September to date over the corresponding normal value (calculated with reference to the period 1971 - 2000).
- Map 3: Accumulated precipitation during the ten-year period ending on the reference date.
- Map 4: Accumulated evapotranspiration (ETo) from 1 September to date.
- Map 5: Reference evapotranspiration (ETo) accumulated over the ten-year period ending on the reference date.
- Map 6: Percentage of soil moisture (Available Water) of the surface layer, with respect to an ADT of 25 mm, on the reference date.
- Map 7: Percentage of soil moisture (Available Water) of the total layer, with respect to an ADT max (R max), at the reference date.
- Map 8: Variation experienced during the last ten years by the parameter corresponding to the previous map.
- Map 9: Percentage that represents the volume of water stored in reservoirs over the total capacity and weekly variation experienced by this index, grouped in large peninsular river basins as well as in all of them.
- Maps 10 and 11: The content of these maps is variable, representing the average temperature and relative humidity in the first two decades of the month, and in the bulletin of the last day of the month, the monthly rainfall and its percentage with respect to normal values (in the period 1971 to 2000) in the month just ended.

Both the water balance and the ten-year water balance bulletin are available at http://www.aemet.es/es/serviciosclimaticos/vigilancia_clima/balancehidrico.

With reference to the methodology followed for the evaluation of the Water Balance, the following characteristics should be highlighted: The input data for the Balance are: the grid analysis of the HIRLAM numerical weather forecasting model from AEMET with a resolution of 0.05º, the specific data from the synoptic network of Spain, Portugal, southern France and northern Africa, as well as information from the automatic stations that send their data to the AEMET database in real time. The data used in the elaboration of the Water Balance are mostly provisional data and are subject to a later validation. Reference evapotranspiration (ETo) is estimated by the Penman-Monteith method, following the recommendations of FAO document 56 (1998). The maximum value of the soil reserve (R max), as the maximum total available water for plants (TAW= Field capacity - Wilt point), has been estimated at each site as a function of soil texture and type, soil slope, and root depth according to CORINE 2006 land uses. The soil moisture transfer process to the atmosphere is parameterized assuming an exponential extraction process, calculating daily the reserve from the previous reserve, the ETo and the precipitation. The soil moisture reserve is calculated for the R max (TAW max) corresponding to the estimated root depth at each site, and also for a surface layer of the soil corresponding to an TAW of 25 mm.

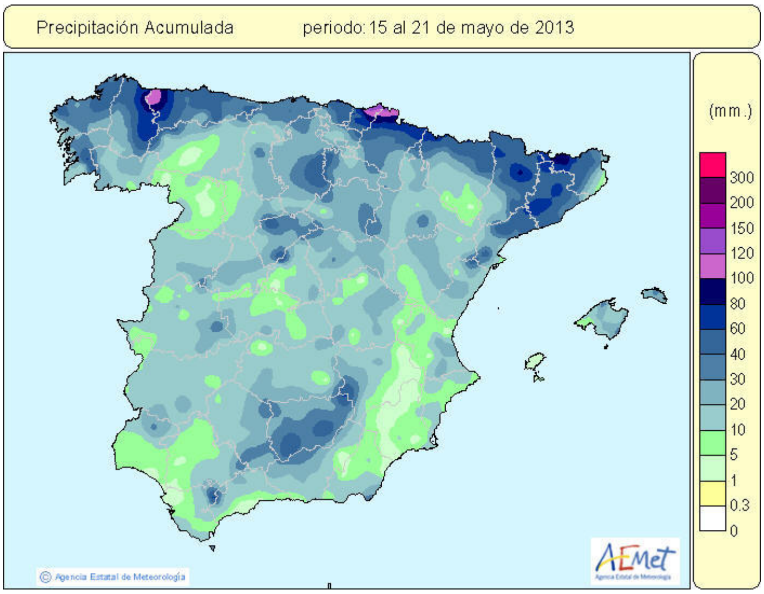


Figure 3. Accumulated precipitation for the last 7 days.

Nowcasting: In the field of very short term forecasting (hours) AEMET has a network of 15 weather radars with doppler capacity. This network provides images of 480 x 480 pixels, with a resolution of 1 km x 1 km for long range products and 0.5 km x 0.5 km for short range products. When the radar scans a region of the atmosphere where precipitation is occurring, the information with the highest meteorological content that we can extract from the radar is the reflectivity factor, related to the distribution of water drop sizes in the scanned atmospheric volume. From this value AEMET provides different derivative products. One of the derivative products provided by AEMET is the accumulated precipitation, although it is difficult to establish a biunivocal relationship between reflectivity and precipitation. For this, AEMET is based on the MARSHALL-PALMER ratio, which is an empirical relationship between reflectivity and precipitation intensity.

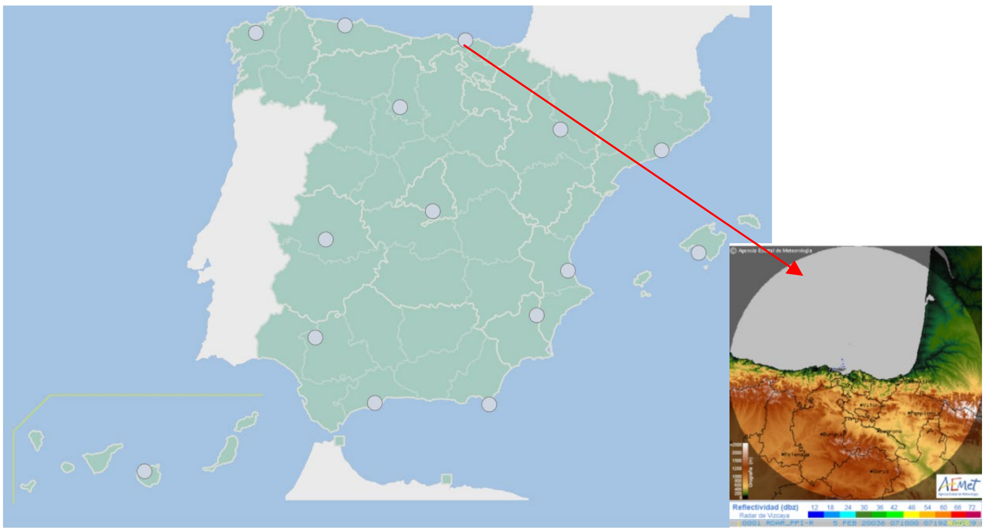


Figure 4. AEMET's radar network.

The accumulated precipitation products generated by AEMET's radars can be of two types, depending on the product taken as a basis for their generation. Regarding the time interval they cover, they can be hourly, daily, or a number of hours such that it is a whole divisor of 24 (for example 6 or 12 hours).

The radar images are shown in the AEMET web site www.aemet.es , being the images of two types:

- Regional Radars cover a geographic area defined by a circle centered on the radar of 240 km radius. The images are in Lambert conical projection, consist of 480 x 480 pixels with a spatial resolution of 1 Km x 1 Km.

  The image shown is the lowest PPI of reflectivity, expressed in dBZ. It represents the projection over the horizontal of the sweep that the radar performs in azimuth while keeping the axis of the antenna elevated 0.5º over the horizontal. This is the radar data closest to the ground and is therefore the most suitable for estimating the precipitation that falls on the ground, although it is also the most affected by orographic blockages. An image is available every 10 minutes.

  Also when interpreting the image, the effect of the elevation of the beam with the distance to the radar must be taken into account, which can hide low rainfall.

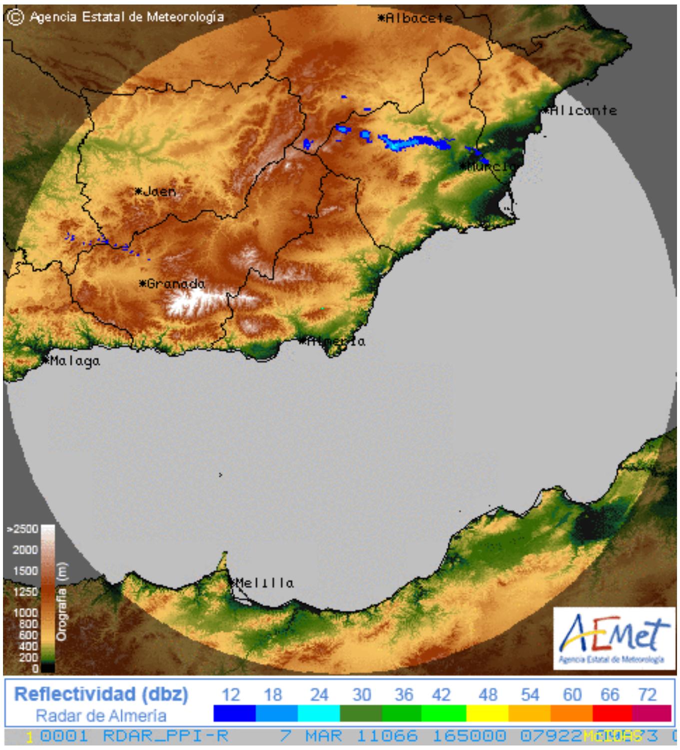


Figura 5. PPI del radar de Almería, disponible en la web de AEMET.

- The radar mosaic that appears in the tab Peninsula and Balearic Islands Composition has been generated by composing the images of the lowest PPI of reflectivity (dBZ) of the radars of the AEMET network, except for the Canary Islands. The image presented here has been remapped to polar stereographic projection. The coordinates of the center of the image are 40 º N and 3 º W, consists of 500 x 500 pixels and its spatial resolution is 3.2 km x 3.2 km. To indicate the areas of effective coverage, a dark gray tone is used to mark the areas that in each mosaic image are not covered by any operational radar. To generate the mosaic image in areas covered by more than one radar, the information provided by the most appropriate radar is chosen taking into account the orographic blocking areas for each radar and the distance of each radar from the area in question. An image is available every 30 minutes. The magnitude represented (Z) is the so-called reflectivity factor, which is what a radar actually measures. This reflectivity factor is the sum of the sixth power of the droplet diameters contained in the volume unit, so its value depends strongly on the distribution of the droplets according to their size. The units dBZ for the reflectivity to which the colour ranges of the images refer correspond to:

Z (dBZ) = 10 x log (Z)

Where the Z value on the right is expressed in linear units of mm/m 3.

As each type of precipitation has its own size distribution, there is no biunivocal relationship between reflectivity and water content. There is also no biunivocal relationship between reflectivity and precipitation intensity, since the droplet fall rate is also involved. It is therefore preferable to represent the reflectivity, which is what the radar actually detects, in the images, rather than the precipitation intensity.

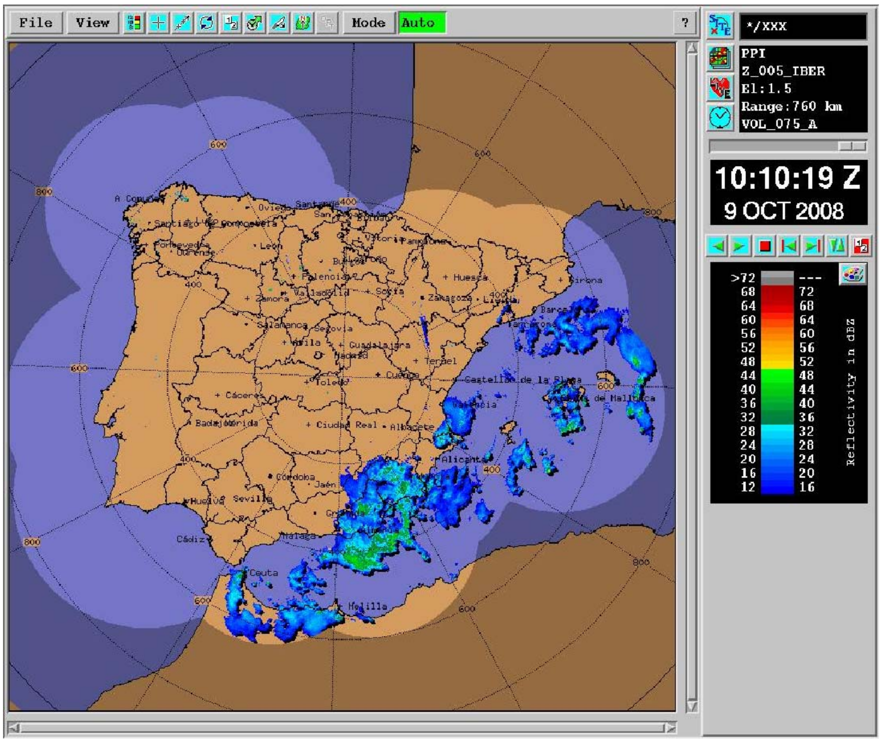


Figure 6. AEMET National Radar Mosaic Composition.

If meteorological satellites can cover large areas of the atmosphere almost continuously and provide information on the upper area and external structure of cloud formations, radars are the appropriate and effective complement, due to their ability to provide information on the internal structure and distribution of precipitation inside the clouds.
Radar observations are essential for the detection, monitoring and prediction of the movement and evolution of severe weather phenomena. In addition, modern processing techniques allow the obtaining of quantitative values of specific elements of great interest such as rain or wind. The way in which a meteorological surveillance radar makes it possible to study the interior of cloud systems and locate the regions where precipitation formation begins, as well as the increase or decrease in its intensity and its movements (both vertically and horizontally) is as follows: The equipment generates frequent long and short energy pulses, with durations of 2 and 0.5 microseconds respectively, in the range of radio frequencies, centimeter wavelengths, specifically 5 cm (C-band).

This energy is concentrated in a very narrow beam by an antenna that performs complete sweeps at different elevations. From one elevation to the next, the antenna may have different rotation speeds, depending on whether it emits long or short pulses. In this way the radar performs a complete volumetric scan of all its surroundings, obtaining information both in the horizontal and in the vertical. The radiated energy interacts with the environment, the clouds and the precipitation (targets), being backscattered back to the antenna (echo); the energy returned depends on the type and size of the elements that make up the cloud. It is negligible for typical cloud droplets (radius of the order of 10 microns) but it is already important for raindrops or precipitation elements (typical raindrop radius 1 mm). From the position in azimuth and elevation of the antenna and the delay time from the moment the pulse is emitted until the echo is received, the radar equipment deduces the location in the space of the targets, and through the intensity of the returned echo it makes an estimate of the amount of precipitation that exists. The processing is doppler, distinguishing between long and short pulse with pulse repetition frequencies of 250 hz and between 900 - 1200 hz respectively. The original ranges and resolutions vary from 240 and 1 to 120 and 0.5 km for long and short pulse respectively.

Products:
- Reflectivity PPI (120 and 240 km ranges)
- Wind PPI (radial component) with 120 km range
- Speed spectrum PPI (turbulence) with 120 km range.
- CAPPIs or horizontal cuts of the volumes generated by the successive explorations. They provide data on reflectivity, precipitation, turbulence and wind speed.
- ECHOTOP is the maximum relative altitude of the echoes with a selectable threshold (12 or 45 dB).
- Maximum altitude is the height of the highest echoes.
- SRI is the surface precipitation intensity, it is used to generate rain accumulation products. It takes into account the height of the isoceros to avoid the bright band effect.
- RAIN1 is the hourly accumulation of rain, either from CAPPI or SRI information.
- RAINN is the hourly accumulation N, obtained from the hourly accumulations (6, 12 and 24 hours).
- VIL is the liquid water content of the vertical column.
- VVP is the wind speed and direction.

Other products are vertical wind profiles (VAD); automatic alarms in specific areas and of different variables by estimation of the evolution in the position of the echoes in the near future (floods, hail, shear, precipitation, severe storms and electrical discharges).
Weather radar HW and SW structure:

- IRIS application software developed by SIGMET
- Software for handling datasets with McIdas, image processing with McIdas application, etc.

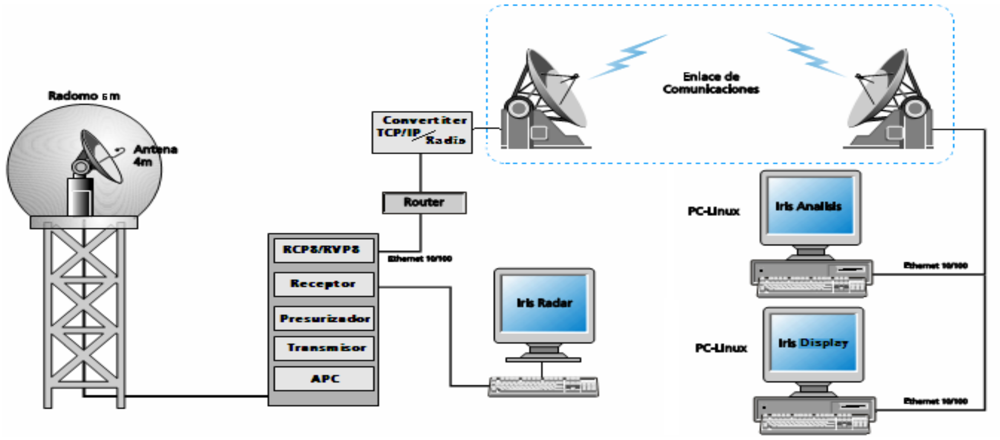


Figure 7. Radar operation scheme of AEMET.

Halfway between monitoring and very short term weather forecasting, it should be noted that AEMET has a terrestrial network for lightning detection that works in the LF/VLF band range, so it is designed to detect cloud-to-ground lightning, which is the most interesting for everyday life, although it can detect marginal cloud-to-cloud lightning. AEMET's lightning network consists of 19 sensors, 14 in the Peninsula, 1 in the Balearic Islands and 4 in the Canary Islands. Thanks to international collaboration, data from sensors in neighbouring countries are also available: Portugal, France, Italy and Morocco, data sets that must be added to the previous ones for the whole process. This product is of interest in the field of very short term prediction of possible fire events.

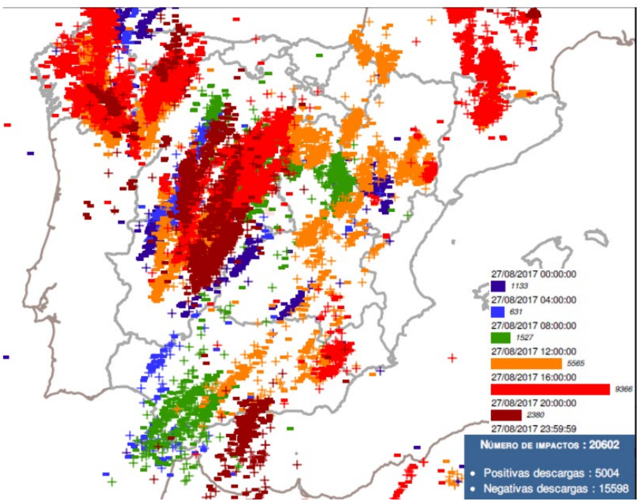


Figure 8. AEMET lightning network.

<u>Short-term weather forecasting:</u> Short-term forecasts (days) and warnings of adverse events are produced using the outputs of the global model of the European Centre for Medium-term Planning (CEPPM), which is an international body to which Spain contributes, through AEMET. These numerical models are used as input for AEMET's limited area models, such as HIRLAM v7.2 with data assimilation (resolution 16 and 5 km) and HARMONIE (in experimentation) with resolution 2.5 km.

The HARMONIE model is the result of the collaboration between the HIRLAM and ALADIN consortiums. It is a non-hydrostatic mesoscale model, which allows convection, with a horizontal resolution of 2.5 km and a maximum range of 48 hours, which uses as contour conditions outputs of the HRP-IFS model of CEPPM.

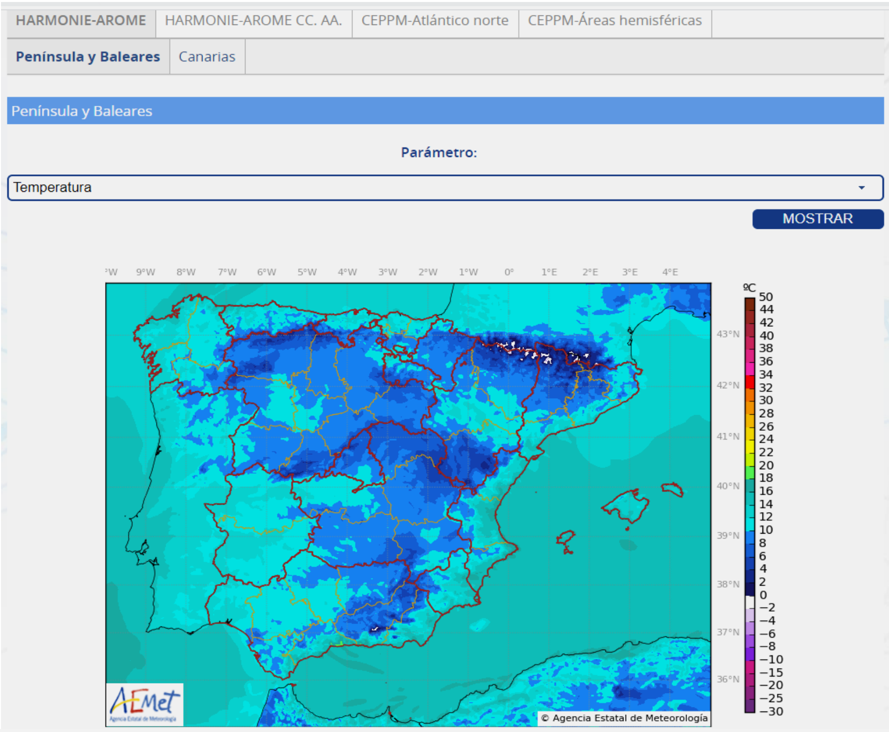
The fields or variables are presented for intermediate areas and for autonomous communities. The intermediate areas are the Peninsula and Balearic Islands, on the one hand, and the Canary Islands, on the other. As regards the Autonomous Communities, an area is presented that covers them completely in all cases. In the case of Canarias, there is a smaller area than the intermediate area.

For the intermediate areas the following variables are shown every three hours:

- Precipitation in the previous three hours.
- Temperature at nominal time (appears by default).
- Pressure at nominal time.
- Cloudiness at nominal time.
- Wind at nominal time.
- Maximum wind gusts in the previous three hours.
- Electrical discharges in the previous three.

For the areas corresponding to the autonomous communities, the following variables are shown every hour:

- Precipitation in the previous hour.
- Temperature at nominal time (appears by default).
- Pressure at nominal time.
- Cloudiness at nominal time.
- Wind at nominal time.
- Maximum wind gusts in the previous hour.
- Electric shocks in the previous hour.



Capital: Vitoria-Gasteiz (altitud: 539 m)
Latitud: 42° 51' 2" N - **Longitud**: 2° 40' 21" O - **Posición**: Ver localización
Zona de avisos: Llanada alavesa

Descargar XML de la predicción detallada de Vitoria-Gasteiz XML

	vie. 31		sáb. 01				dom. 02		lun. 03		mar. 04	mié. 05	jue. 06
	12–18 h	18–24 h	00–06 h	06–12 h	12–18 h	18–24 h	00–12 h	12–24 h	00–12 h	12–24 h			
	13°C	12°C	12°C	17°C	14°C	12°C							
Probabilidad de precipitacion	0%	0%	100%	5%	5%	0%	0%	0%	0%	15%	100%	75%	25%
Cota de nieve a nivel de provincia (m)											1000	900	800
Temperatura minima y maxima (°C)	8 / 17		10 / 18				10 / 18		7 / 19		4 / 11	-2 / 8	-3 / 13
Sensacion termica minima y maxima (°C)	8 / 17		10 / 18				10 / 18		7 / 19		4 / 11	-2 / 8	-3 / 13
Humedad relativa minima y maxima (%)	70 / 90		70 / 90				60 / 85		60 / 85		75 / 95	70 / 95	60 / 90
Direccion y velocidad del viento (km/h)	SO 20	SO 20	SO 10	SO 5	SO 15	SO 10	SO 20	SO 20	SO 20	SO 20	N 10	NE 10	S 10
Racha maxima (km/h)							50						
Sensacion termica (°C)	13	12	12	17	14	12							
Humedad relativa (%)	75	75	85	80	80	85							
Indice ultravioleta maximo	2		2				2		2		2		

Figure 9. AEMET's weather forecasting products.

Future climate scenarios: In the area of future climate projections, the State Agency for Meteorology (AEMET) is the institution responsible for coordinating and developing the projections of the climate models of the PNACC (national plan for adaptation to climate change). The PNACC-Scenarios program is freely available through the AEMET website.

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

According to the IPCC, climate change is now being assessed on the basis of four different scenarios (CPR 2.6, 4.5, 6.0 and 8.5 w/m2 increase with respect to 1765), where the behaviour of temperature and precipitation depends on the radiative forcing imposed by the expected concentration of greenhouse gases at the different assessment times.

The regionalized climate change projections (also called scenarios) provide detailed information on the best estimates of our country's future climate, which are an essential element for carrying out impact and vulnerability assessments in the various sectors that are sensitive to climate conditions, and therefore for designing appropriate policies for adapting to its effects.

Table 2. PNACC data (AEMET,2018).

Método	Modelo	Escenarios	Variable	Periodo	Fichero
Análogos	ACCESS1-0	*HISTORICAL*	*Precipitación*	1961-2000	Descargar fichero (28 MB)
Análogos	ACCESS1-0	*HISTORICAL*	*Tmax*	1961-2000	Descargar fichero (7 MB)
Análogos	ACCESS1-0	*HISTORICAL*	*Tmin*	1961-2000	Descargar fichero (7 MB)
Análogos	ACCESS1-0	*RCP4.5*	*Precipitación*	2006-2100	Descargar fichero (64 MB)
Análogos	ACCESS1-0	*RCP4.5*	*Tmax*	2006-2100	Descargar fichero (17 MB)
Análogos	ACCESS1-0	RCP4.5	Tmin	2006-2100	Descargar fichero (16 MB)
Análogos	ACCESS1-0	RCP8.5	Precipitación	2006-2100	Descargar fichero (64 MB)
Análogos	ACCESS1-0	RCP8.5	Tmax	2006-2100	Descargar fichero (18 MB)
Análogos	ACCESS1-0	RCP8.5	Tmin	2006-2100	Descargar fichero (17 MB)
Análogos	ACCESS1-3	HISTORICAL	Precipitación	1961-2000	Descargar fichero (26 MB)
Análogos	ACCESS1-3	HISTORICAL	Tmax	1961-2000	Descargar fichero (7 MB)
Análogos	ACCESS1-3	HISTORICAL	Tmin	1961-2000	Descargar fichero (7 MB)
Análogos	ACCESS1-3	RCP8.5	Precipitación	2006-2100	Descargar fichero (61 MB)
Análogos	ACCESS1-3	RCP8.5	Tmax	2006-2100	Descargar fichero (17 MB)
Análogos	ACCESS1-3	RCP8.5	Tmin	2006-2100	Descargar fichero (17 MB)

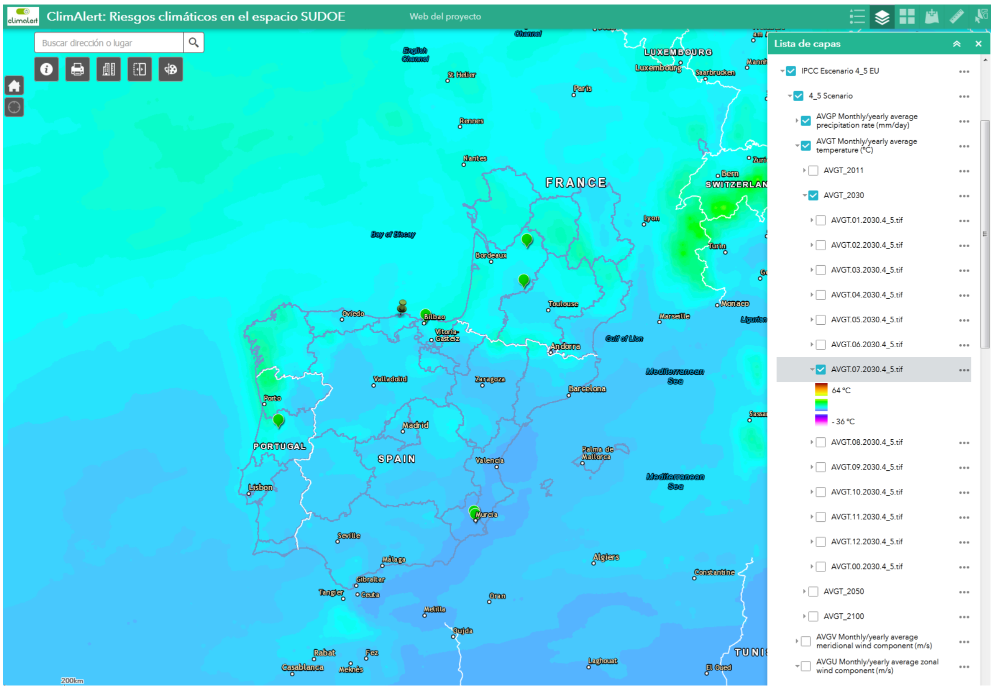


Figure 10. Average annual temperature of July 2030 in scenario 4.5.

The products and meteorological data presented above can be downloaded through the OpenData section of AEMET. AEMET OpenData is a REST API (Application Programming Interface. REpresentational State Transfer) with practically no requirements. It is based on standard protocols (HTTP/HTTPS, json, xml) and allows access from any client, with the only requirement of requesting a KEY API. AEMET OpenData API Key follows the JWT standard. AEMET OpenData allows two types of access: General Access and AEMET OpenData API. Both allow access to the same data catalogue and download of data in reusable formats.

The general access is made through a graphic interface intended for the general public. The interaction with the data carried out by the platform user is punctual and the functionalities of this type are reduced. However, this interaction is carried out by means of friendly interfaces of sequential character that make possible the choice of different options step by step.

AEMET OpenData API allows another type of interaction with the data, mainly oriented to developers and advanced users. This interaction is characterized by the possibility of being periodic and even programmed, from any programming language, without friendly interfaces, with the possibility of self-discovery and allows information reusers to include AEMET data in their own information systems.

The figures show the access portal to AEMET Open Data, and the general access interface (https://opendata.aemet.es/centrodedescargas/productosAEMET?)

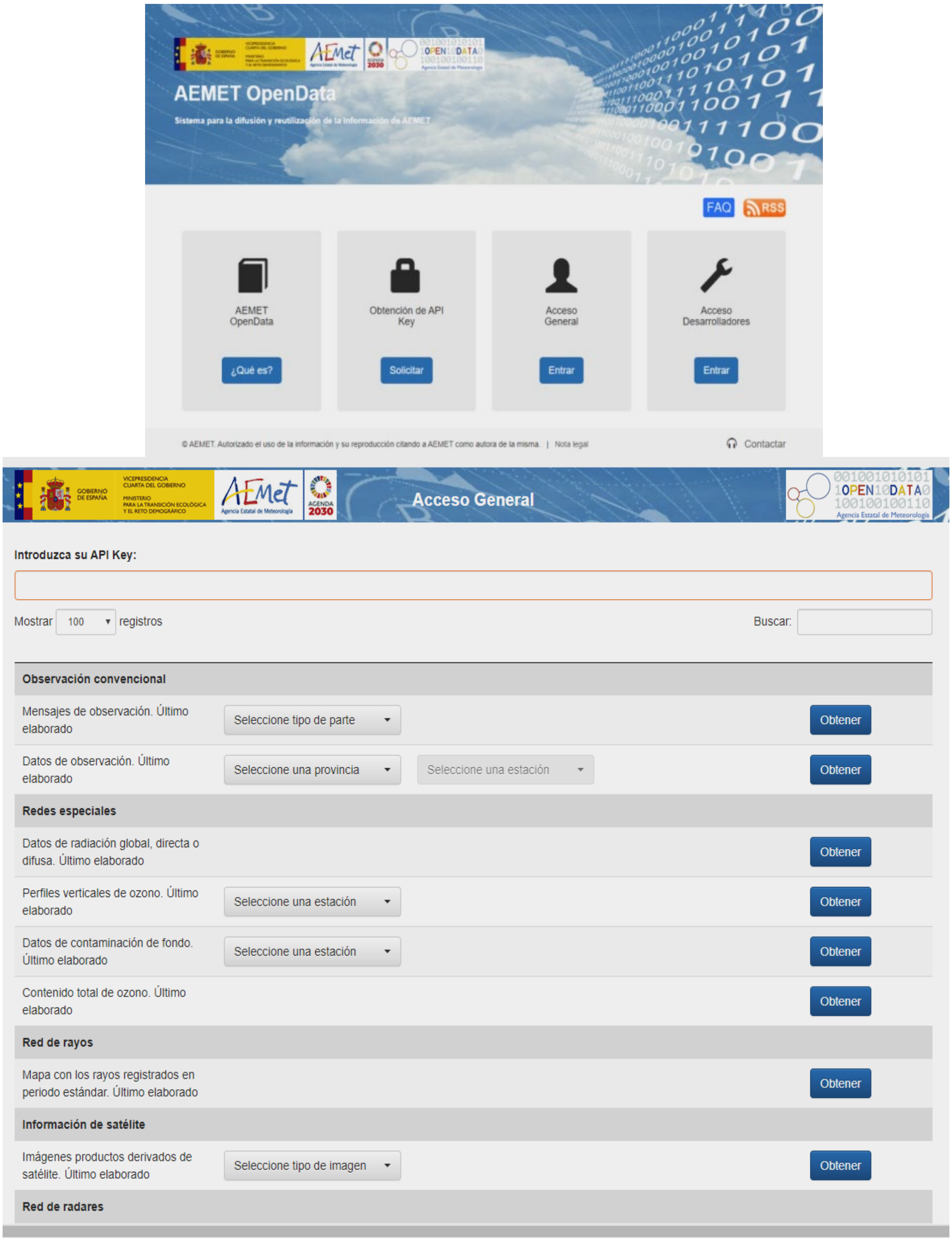


Figure 11. AEMET Open Data.

2.2. Agro-climatic Information System for Irrigation (SIAR) (España).

The Agroclimatic Information System for Irrigation (SiAR) is an infrastructure that captures, records and disseminates the agroclimatic data necessary for calculating the water demand of irrigation areas, which allows for obtaining useful, rigorous and quality information and contributes to better planning, management, handling and control of irrigation operations.

The Agroclimatic Information System for Irrigation is the source of most of the information of a specifically agroclimatic nature that is currently being provided, both by the Ministry and by the Autonomous Communities, and for this purpose the system has been equipped with the following infrastructure:

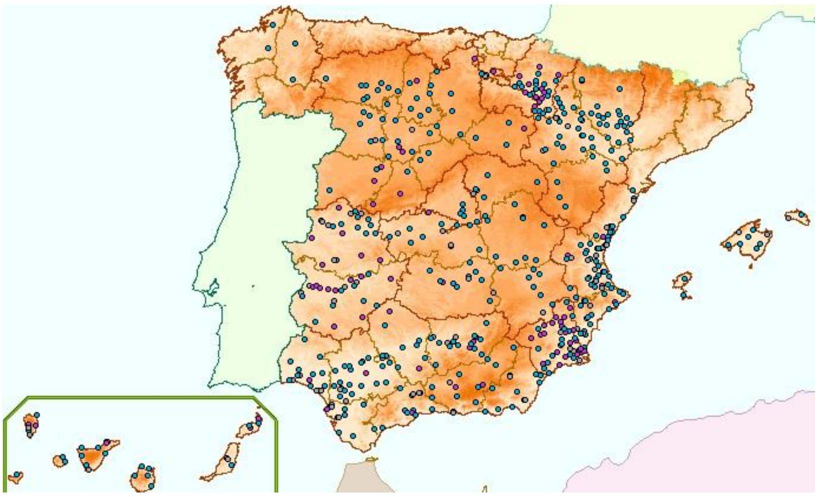
- 468 automatic agroclimatic stations distributed throughout the territory of Spain, which capture the climatic data and transmit the information to the zonal centre. Of the total number of stations, 361 belong to the Ministry and 107 are owned by the Autonomous Communities.

- 12 zonal centres. There is one for each Autonomous Community linked to the Network, each one of them is equipped with the hardware and software necessary for the acquisition, storage and exploitation of the data obtained. From these zonal centres, data from the stations installed in each Autonomous Community are obtained daily and automatically.

- There is a national centre located on the premises of the Ministry, equipped with the technical means for the reception, exploitation and dissemination of all the information collected daily in each of the zone centres. Its task is to store and publish the data at a national level, as well as to exploit and disseminate the information at an institutional level and to coordinate the system in general.

The configuration and location of each agroclimatic station of the SIAR Network have been chosen taking into account the recommendations of the World Meteorological Organization (WMO), the National Institute of Meteorology (INM), the Food and Agriculture Organization (FAO), and the American Society of Agricultural Engineers (ASAE) to obtain the necessary information for the calculation of the representative irrigation needs of the area in which it is located.

The agro-climatic stations are designed to collect the values necessary for the calculation of reference evapotranspiration and rainfall. To this end, each station is equipped with the necessary elements to automatically measure and record the following parameters: air temperature and humidity, wind speed and direction, radiation and precipitation. The average density of the SIAR network is 1 station for every 10,000 ha of irrigated land.



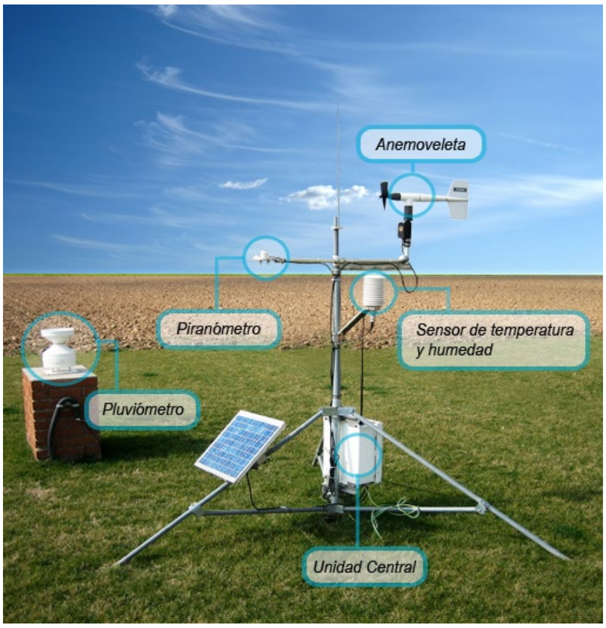


Figure 12. SIAR's network of meteorological stations.

Weather analysis and monitoring: In the context of the present project, the potential usefulness of this network of agro-meteorological stations is limited to the field of data analysis and meteorological monitoring. This CRMS network does not provide very short, short or medium term forecast data. The meteorological data provided by this network of stations can be downloaded both from the website of the Ministry of Agriculture, Fisheries and Food (http://eportal.mapa.gob.es/websiar/Inicio.aspx) and from some of the websites of the Autonomous Communities to which each of the aforementioned regional centres is linked.

Agroclimatic Information of the Canary Islands
http://www.icia.es/icia/index.php?option=com_content&view=article&id=30&Itemid=100008&lang=es

Agroclimatic Information of Castilla-La Mancha
http://crea.uclm.es/SiAR/

Agroclimatic Information of Castilla y León
http://www.inforiego.org

Extremadura Irrigation Advisory Network
http://redarexplus.gobex.es/RedarexPlus/

Murcia Agricultural Information Service (SIAM)
http://siam.imida.es/apex/f?p=101:1:8430615873263931

Advisory Service for Irrigators in Navarre
http://www.intiasa.es/es/comunidad-de-regantes/areas-de-interes/servicio-asesoramiento-al-regante/climatologia.html

Irrigation Technology Service of the Valencian Community
http://riegos.ivia.es/

Other Irrigation Consultancy Centres not belonging to the SIAR network but with similar characteristics.
http://www.larioja.org/agricultura/es/informacion-agroclimatica

In general, downloads through these links do not include automated download applications or protocols, at least not explicitly. However, the automation of the download of these data seems feasible.

2.3. Murcia Agricultural Information Service (SIAM) and measurement networks in the area of the Segura River Basin.

Measurement networks under the responsibility of the CARM (SIAM) in the Region of Murcia (1996-2020)

The IMIDA-SIAM network has been mentioned in the previous section (SIAR), but it is worth mentioning since one of the study areas of this project is the region of Murcia. The service has a total of 51 agrometeorological stations distributed throughout the main irrigation areas of the Region of Murcia. The stations are made up of the following sensors: Temperature, Relative Humidity, Wind, Precipitation, Radiation and Class A Trough Evaporation. The absolute minimum temperature is measured using PT 100 or PT1000 probes, which are located at a height of one and a half metres above the ground, following the guidelines of the UNE 500.520 standard. Wind data are taken at a height of 2 m.

The maps and data of the main variables derived from the SIAM network can be consulted on the geoportal of water (http://geoportal.imida.es/agua/), on the SIAM website (http://siam.imida.es) and on the ClimAlert platform viewer.

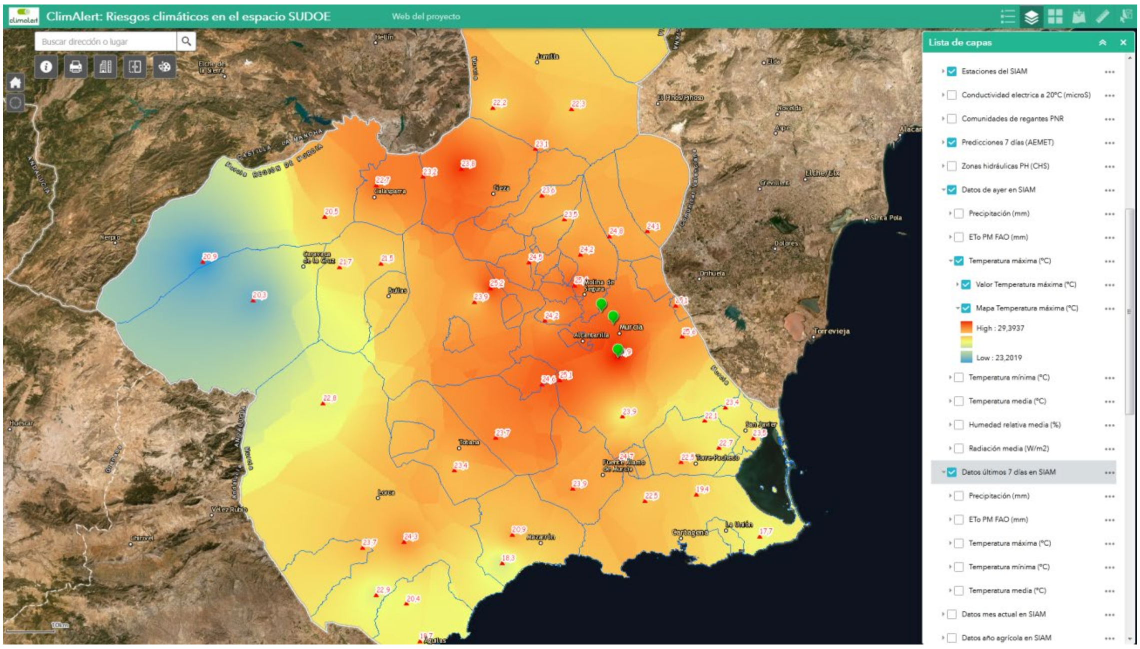


Figure 13. Possible integration of daily data from the SIAM network in the ClimAlert viewer

Table 3. Climatic variables stored in SIAM.

Variable	Descripción
Med	Valor Medio/a
Max	Valor Máximo/a
Min	Valor Mínimo/a
UTMx	Universal Transverse Mercator-ETRS89
UTMy	Universal Transverse Mercator-ETRS89
ABS	Valor Absoluto/a
Días	Número de días utilizados en el informe
UTC	Tiempo Universal Coordinado
DV	Dirección del Viento (º)
DEWPT	Punto de Rocío (ºC)
DPV	Déficit de Presión de Vapor (kPa)
NTANQUE	Nivel de Tanque de cubeta Clase A (mm)
RADACU	Radiación Acumulada (w/m2)
RR	Radiación Reflejada (w/m2)
RADPAR	Radiación Par (w/m2)
T	Temperatura (ºC)
HR	Humedad Relativa (%)
Prec	Precipitación (mm)
ETo	Evapotranspiración de referencia (mm)
RViento	Recorrido del Viento (Km/día)
Rad	Radiación (w/m2)
VV	Velocidad del Viento (m/s)
HSol	Horas de sol (horas)
HORAS0	Horas por debajo de 0 º C (horas)
HORAS7	Horas por debajo de 7 º C (horas)
HF_R	Unidades frio (Método de Richardson) (unidades)
PORCION	Método dinámico de porciones (Método de Fishman et al)
ETO_PM	Cálculo de ETo (Método Penman-Monteith, según la FAO) (mm)

<u>Measurement networks of the CHS (SAIH) in the area of the Segura River Basin.</u>

The Confederación Hidrográfica del Segura (CHS) is the water Authority in charge of the management of the Segura river basin, located in the Southwest of Spain, and it is an autonomous Entity belonging to the State Secretariat for Water and Coast of the Spanish Ministry of Environment.

The main objectives of the Confederación Hidrográfica del Segura can be summarised as follows:

- Estimation of the basin water resources surface and groundwater), with the objective of developing an integrated water management in accordance the social needs and the conservation of nature.
- Improve the means and systems of protection against extreme hydrologic situations, such as floods and thoughts.
- Organise, manage and analyse all the available information about the watershed and make it available to other relevant public bodies and users.
- Protect and improve the water quality within the watershed.
- Manage the public hydraulic area against erosion and events that can affect its quality.
- Satisfy the water demand, by an estimation of present and future water needs, the establishment of use priorities and supporting the development of the different

socio-economic sector depending on the provision of abundant and good quality water resources.

In the field of the hydrological risk monitoring, the CHS has the important role to collect and integrated the data proceeding from different sources, such as the National Meteorological Institute, and the river monitoring network and pass them to other in order to provide the organisations in charge of the civil protection intervention with warnings and real time information about the evolution of an emergency event related to hydrological risk (the rupture of a dam, a flood due to heavy rains, etc.). To perform this task, the CHS counts on an Automatic Hydrological Information System that manages data from the whole river basin and transmits them to the Central Headquarters of the Confederation.

Measurement networks under the responsibility of AEMET in the Segura River Basin.

- Conventional stations, served by altruistic collaborators. They are part of AEMET's pluviometric and climatological network. In the area of the Segura river basin it is made up of 127 stations, which carry out daily rainfall measurements corresponding to the rainfall day. This information is sent monthly to AEMET, which, after a quality control process, integrates it into the Climatological Data Bank (BDCN).
- Automatic weather stations, in the Segura basin AEMET has a total of 39 automatic stations, with ten-minute rainfall measurement. Of these stations, 11 take measurements in "real time", with calls every ten minutes or every hour, depending on the type of station, the rest (28) send the data "on hold" every 4 hours.
- AEMET's meteorological radar is located in the Sierra de la Pila in the town of Fortuna, at an altitude of approximately 1200 meters.

2.4. EUSKALMET (Basque Meteorological Service).

Euskalmet is the Basque meteorological service, created in 1990 and integrated in the Directorate of Emergency Attention and Meteorology (DAEM). DAEM was created as a result of the merger of the Directorates of Emergency Services and Civil Protection, on the one hand, and the Directorates of Meteorology and Climatology, on the other.

In the field of meteorological analysis and monitoring, the Hydro-Meteorological Network of the Basque Country consists of 90 automatic stations connected in real time. They are managed jointly by the Provincial Councils, URA and DAEM. They measure both meteorological parameters and heights (flow rates) of the rivers, as well as physical-chemical parameters of the water in the rivers. The number of sensors connected to each station is very variable, ranging from stations that only measure meteorological parameters to others that measure hydrological parameters. In the case of the more than 50 meteorological stations distributed throughout the territory of the Basque Country, they provide ten-minute data on air temperature, soil surface temperature, relative humidity, precipitation, solar radiation, pressure, average wind speed, maximum wind gust, average wind direction, standard deviation of speed, standard deviation of direction, instantaneous cubic speed and ultraviolet radiation. Not all stations have all sensors.

Regarding very short term forecasting (nowcasting), EUSKALMET has two weather radars. It is a Doppler and dual radar. It scans the entire atmosphere every 10 minutes, one with a radius of 100 km and the other of 300 km. Its main function is to measure the spatial and temporal distribution of precipitation.

EUSKALMET also provides lightning information that corresponds to data collected by the network of Linet sensors available in the Basque Country. In this way, it is possible to relate the electrical discharges with the precipitation information obtained from the Kapildui weather radar, being able to observe in real time how the lightning is located in the storms.

Mesoscale numerical models, not hydrostatic. MOS (Model Output Statistics) is the technique for post-processing the results of numerical weather forecast models using statistics from historical local measurements or current weather measurements. The MOS service substantially improves the accuracy of historical data on temperature, humidity, wind speed and radiation (other variables can be specified on request). The MOS technique combines model results and statistics, using complex numerical models based on the physics of the atmosphere to predict large-scale weather patterns, and using statistical post-processing regression equations to clarify surface weather details.

For downloading meteorological data and products, EUSKALMET makes available on its web site a specific application that allows the user to generate HTML code in order to import data from meteorological stations to a web page.

http://www.euskalmet.euskadi.eus/s07
5853x/en/meteorologia/iframe/castellano/generador.apl

In any case, the most important loan of the meteorological data and products elaborated by EUSKALMET are available through the Basque Government's OPEN DATA portal.

https://opendata.euskadi.eus/sobre-open-data/-/open-data-euskadi/

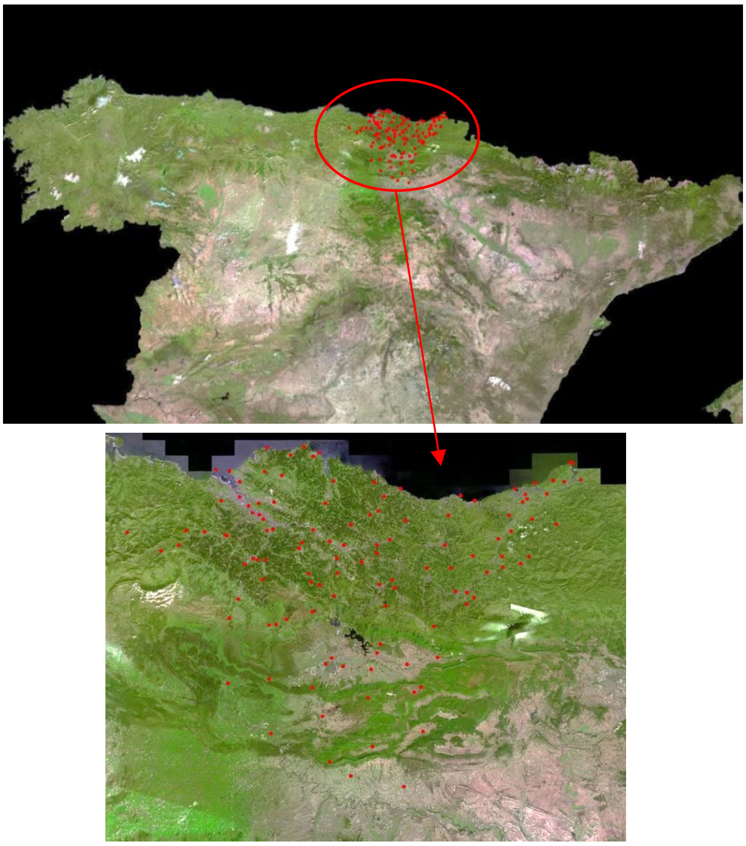


Figure 14. EUSKALMET station network.

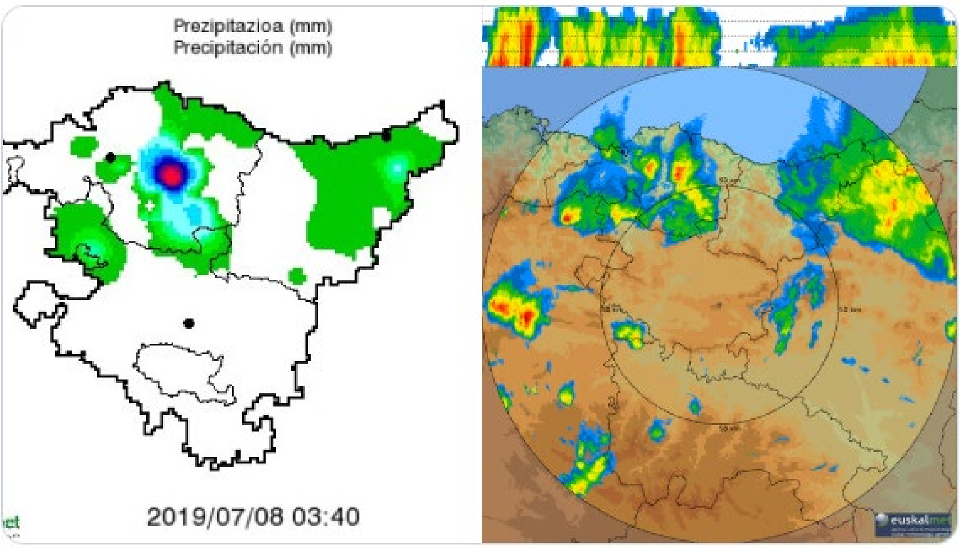


Figure 15. EUSKALMET weather radar products.

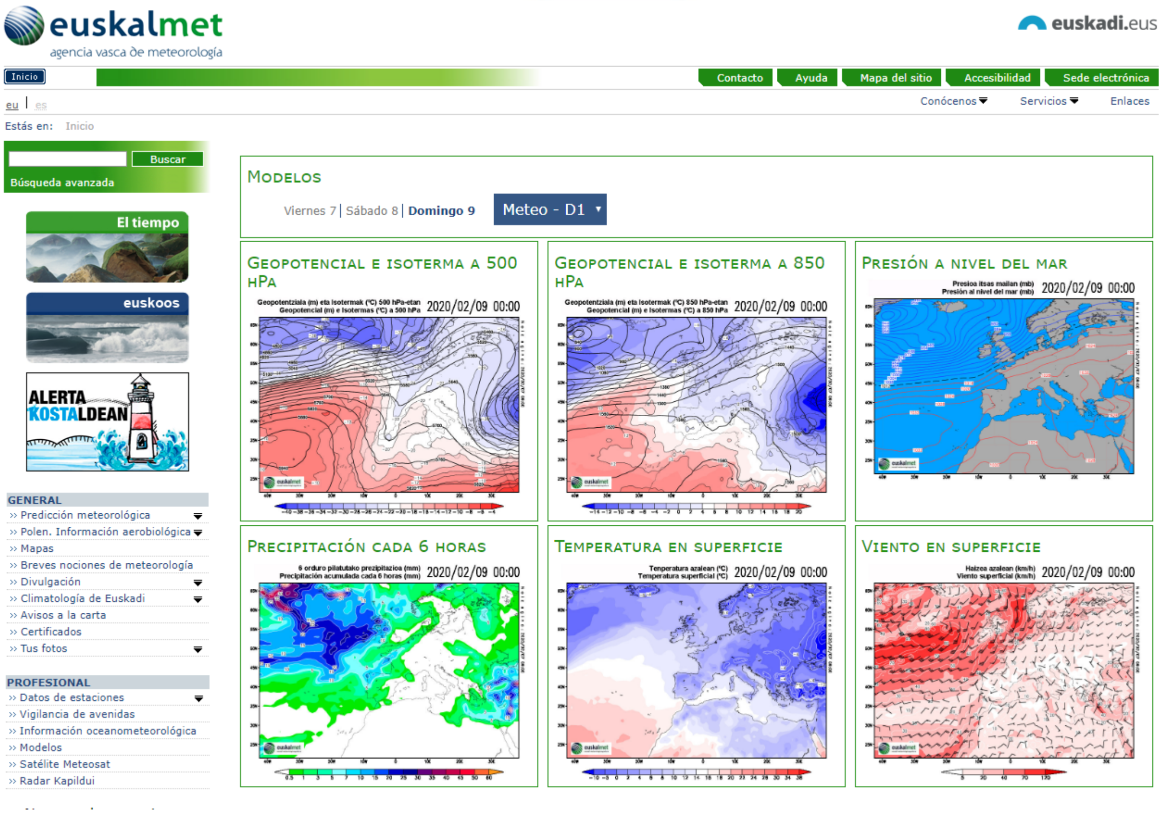


Figure 16. EUSKALMET weather forecasting products.

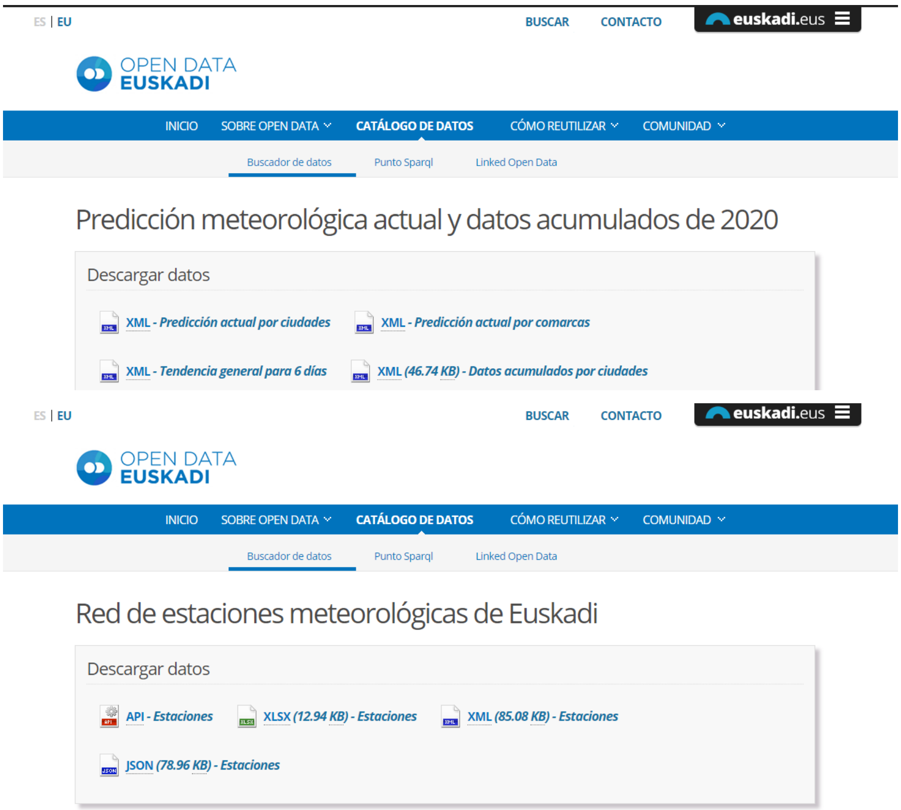


Figure 17. Download of meteorological data through OPEN DATA Euskadi.

2.5. METEOFRANCE.

Météo-France is a French public administrative establishment for meteorology and climatology under the supervision of the Minister of Transport. Since 1993, it has succeeded the National Meteorological Directorate whose origins date back to 1854 with the creation of the meteorological service of the Paris Observatory.

The first mission is to ensure meteorological safety of people and assets. Hence Météo-France provides a warning map of dangerous meteorological events in order to prevent and to take measures of protection. The Meteorological Vigilance system is supplemented in mainland France by marine bulletins and avalanche risk assessment bulletins, and overseas by a cyclone watch and warning system.

The missions of Météo-France focus on:
- Observation and Data network development
- Collect and treatment of the climatological database
- Weather forecast
- Climate projection
- Climate and meteorological research.

The observation data network is composed of**:**

Meteorological stations: The meteorological stations of the Météo-France network are grouped together within the Radome network. 554 stations are installed in mainland France, an average distance of 30 km. They automatically measure the basic parameters (temperature, precipitation, humidity under cover, wind) and some additional parameters such as pressure, soil moisture, radiation, visibility (Table 1). The measurements are continuous and are transmitted regularly. Data are not made available, the annual subscription for 1 station of the Radome network is 376 €/year and 86 000 €/year for the whole network.

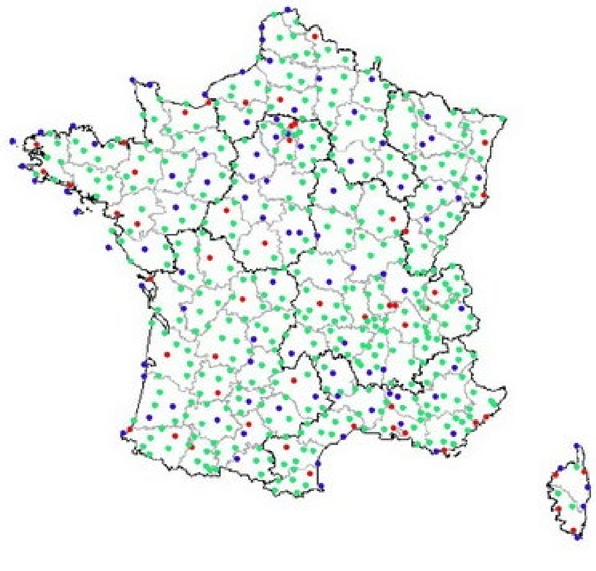


Figure 18. Radome network map of the stations established in Metropolitan France (situation in 31/12/2012) – source Météo-France. Colours define the type of installation (e.g., red points mean the station is located in an airport area).

Table 4. Measured variables of the Radome network

Descriptif	Mnémonique	type	unité
Paramètres standard			
Indicatif INSEE station	numer_sta	car	
Indicatif OMM station	id_omm	int	
Date (UTC)	date	car	AAAAMMJJHHMISS
Point de rosée	td	réel	K
Température	t	réel	K
Température maximale de l'air	tx	réel	K
Température minimale de l'air	tn	réel	K
Humidité	u	int	%
Humidité maximale	ux	int	%
Humidité minimale	un	int	%
Direction du vent moyen 10 mn	dd	int	degré
Vitesse du vent moyen 10 mn	ff	réel	m/s
Direction du vent moyen maximal	dxy	int	degré
Vitesse maximale du vent tmoyen	fxy	réel	m/s
Direction du vent instantané maximal	dxi	int	degré
Vitesse maximale du vent instantané	fxi	réel	m/s
Précipitations dans l'heure	rr1	réel	kg/m²
Paramètres selon instrumentation spécifique			
Température à -10 cm	t_10	réel	K
Température à -20 cm	t_20	réel	K
Température à -50 cm	t_50	réel	K
Température à -100 cm	t_100		K
Visibilité horizontale	vv	réel	m
Etat du sol	etat_sol	int	code
Hauteur totale de la couche de neige	sss	réel	m
Nebulosité totale	n	réel	%
Durée insolation	insolh	int	mn
Rayonnement global	ray_glo01	réel	J/m²
Pression station	pres	int	Pa
Pression au niveau mer	pmer	int	Pa

Part of the Radome network is freely accessible within the framework of international cooperation (62 stations). These stations are part of the SYNOP network (Figure 19). These data are available as geoservices or as archives until 1996.

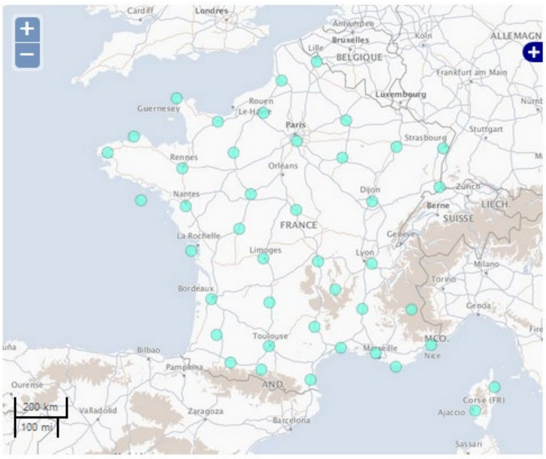


Figure 19. Weather stations located inside the SYNOP network.

- *Hydro-meteorological radars*: 24 weather radars are implanted in the French metropolitan territory, plus 6 others from bordering countries covering 95% of the territory (Figure 20). The installations belong to the ARAMIS network (Application Radar à la Météorologie Infra-Synoptique). C-band (5 cm) radar technology are installed in the north of the country where attenuation by heavy rains remains low, contrast to the south equipped by S-band (10 cm) radar technology. Measurements are updated every 15 minutes throughout the country. Data access is not available only visualisation.

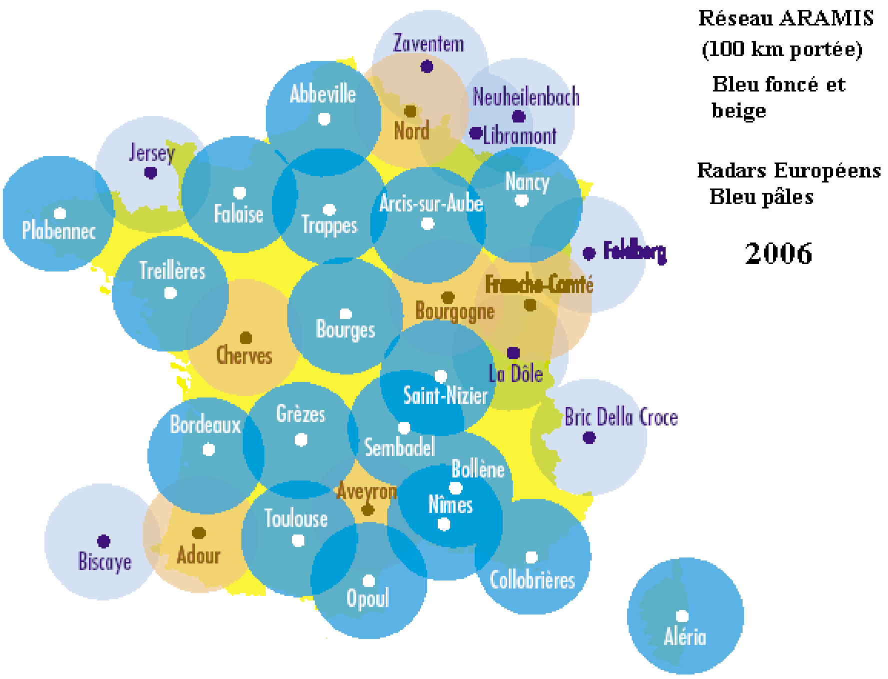


Figure 20. Hydro-meteorological radar located inside the Aramis network

- *Meteorological satellites*: management is shared at European level within the EUMETSAT (European Organisation for the Exploitation of Meteorological Satellites) structure. It is responsible for the establishment, maintenance and operation of European meteorological satellite systems. The data are freely accessible.
- *Lightning detector* via the independent subsidiary Météorage, owned with the company Vaisala. 98% of ground impacts are detected with an accuracy of 100 m thanks to a network of 20 sensors spread over the metropolitan territory (cost not communicated).
- *Hydrological monitoring* : Météo-France offers monthly hydrological monitoring in a free access PDF format. It includes maps of the accumulation, the ratio to normal, of a drought index at the national scale (example on Figure 21). The use of the SWI (Soil Water Index) drought index is based on WHO recommendations.

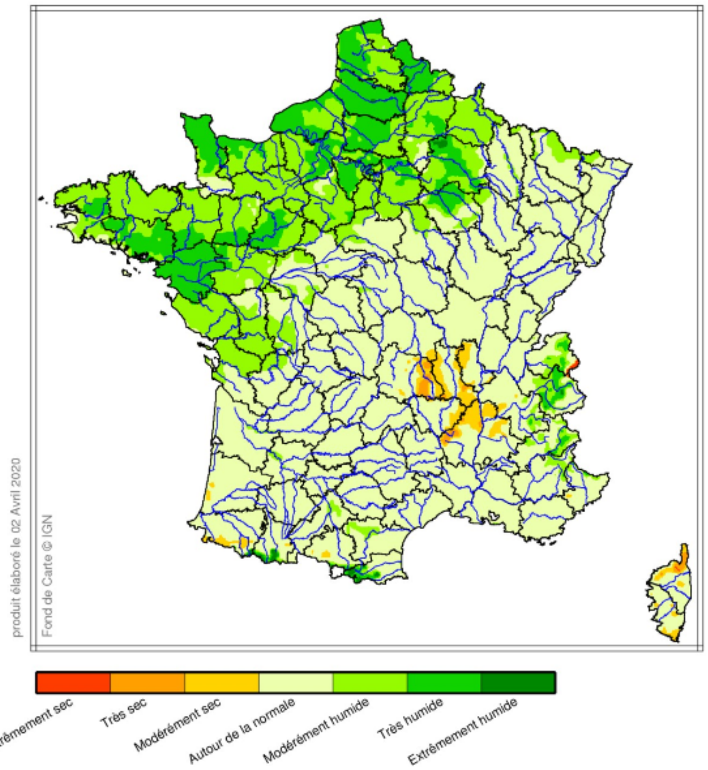


Figure 21. Example of a Soil Water Index map provided monthly by Météo-France

- *<u>Other services</u>*: tide surcharge modelling (no fee). There is no drought index developed by Météo-France.

Collection and processing of climatological data: Météo-France is in charge of setting up and managing the national database of past and present climate. These observations are stored and used to produce and feed numerical climate models.

Weather forecasting covers the prediction of the evolution of the atmosphere, the surface ocean and the snowpack. This forecasting is done alongside the study of climate. Model outputs are available free of charge at short notice. The 6-month seasonal forecast remains subject to a fee (annual subscription of 10 000 €). Two numerical models are used to issue the bulletins:

- The Arpège global model (Small/Large Scale Research Action) with a 7.5 km grid over France. The forecasting period is 1 to 3 days.
- Since 2008, the Arome model (Application de la recherche à l'opérationnel à mésoéchelle) has been running on a limited area, including France, with a mesh size of 1.3 km. The calculation readjusts its forecasts every hour based on measurements (stations, satellites, etc.). Reliability of the forecast is also available.

Preparation of climate projections: Météo-France is associated with the Intergovernmental Panel on Climate Change (IPCC) and participates in the preparation of climate projections.

Research: the National Meteorological Research Centre (CNRM) supports Météo-France's research activities in observation, weather forecasting and climate simulation.

Data access summary

Table 5. Data Access and associated cost summary

Products et services	Access conditions / cost
Local meteorological measurements (Radome)	86 000 € / an
Local meteorological measurements (SYNOP)	No fee
6-month seasonal forecast	10 000 €/an
Short term model output (Arpege, Arome)	No fee
Satellite imagery	No fee
Reflectivity animation of the radar mosaic over 3 hours in steps of 15 min.	No fee, only for visualisation
Lightning impact	Cost not communicated
Tide surcharge	No fee

2.6. ACMG (Association Climatologique de la Moyenne-Garonne et du Sud-Ouest/ France).

The Association Climatologique de Moyenne de Garonne (ACMG) was founded in 1959, in Agen, thanks to producers of fruits who wanted to combat frost more effectively. The needs then widened to include all climatic hazards. Since 1964, the ACMG, benefiting from agronomic and meteorological expertise, has been offering technical support services for irrigation management, supplemented in the 2000s by the use of Sentek capacitive probes to measure soil moisture. The subsidiary Agralis Services (SARL) was created in 2003 to meet commercial needs such as the distribution of autonomous measurement sensors (rain gauge, pyranometer, Tinytag, etc.) used in meteorology. It is the exclusive distributor of Sentek capacitive probes in France and French-speaking Africa. These products are accompanied by irrigation advice thanks to the Aqualis.fr platform used as an irrigation assistance tool. This web interface is powered by the measurements of the installed sensors, transmitted via the GPRS telephone network (with operator's fixed price), or via the Sigfox low speed network.

The observation data network is composed of**:**

Meteorological stations (Figure 22): The measurement sites for the basic variables (temperature/rain) are well distributed over the territory of Lot-et-Garonne, overflowing into Tarn-et-Garonne, Gironde and Gers. On these 75 sites, the readings are taken manually every day or using a recorder (Tinytag – Figure 23) with a frequency of 30 minutes (data are retrieved on 3 months basis). These data constitute a rich archive since the birth of ACMG.

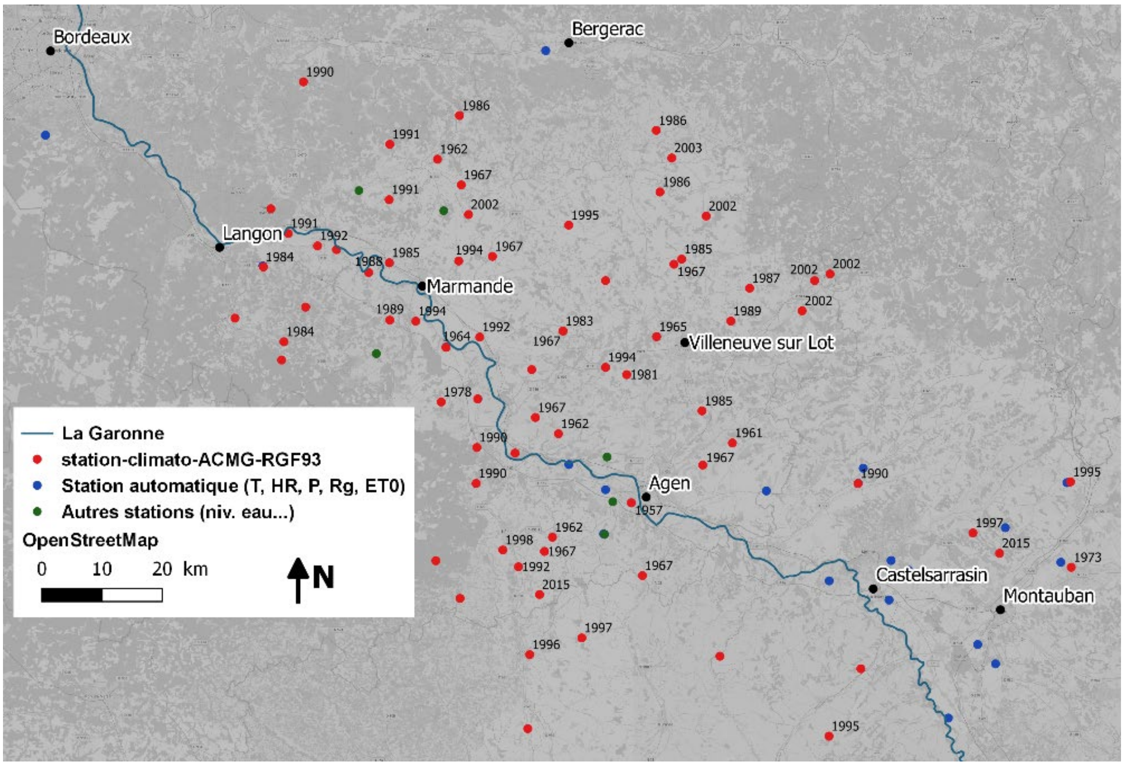


Figure *22*. Presentation of the ACMG's meteorological measurement network

Figure 23. Manual recording of temperature and precipitation accompanied by continuous recording of the temperature under cover by Tinytag

This network continues to be modernized with the implementation of automatic stations with real-time transmission (Figure 24). As part of the spring frost risk prevention aid to farmers, a second fully automated network has been set up since March 2019. Following its success, the network was extended again at the end of 2019/beginning of 2020 in Tarn-et-Garonne thanks to a subsidy from the AEAG (Association d'Etude et de lutte contre les Aléas et la Grêle) support. It will be used as part of ClimAlert in addition to new measurement stations that will include the water level of rivers that can cause rapid flooding in the event of localized thunderstorms.

Figure 24. Automatic station developed in coordination with Agralis Services for measuring temperature in the open air and under cover, precipitation, wind speed, global radiation and atmospheric pressure (blue points in figure. 5)

Hydro meteorological Radar (Figure 25): ACMG is equipped with a C-band hydro meteorological radar (5 cm) installed on Agen Airport since 1995 and which was used at the time to study hailstorms and test the hypothesis of modification of the characteristics of the precipitation by seeding hygroscopic salts such as calcium chloride to accelerate the coalescence. This radar was necessary because the Lot-et-Garonne is located in the middle between several radars distant by more than 100 km which reduces the quality of the observations of convective precipitation occurring in this area. The lowest level observed by radars from Toulouse or Bordeaux is around 4000 m and above. The radar was remanufactured in the early 90s. It is equipped with a scanning and automatic scanning control system which allows the recording of a volume scan over 110 km around Agen in approximately 4 minutes with pixels from 500 m to 1 km depending on the distance from the radar. Thanks to information processing software created by NCAR in the USA and called TITAN it makes possible to detect at altitude areas of formation of zones of very high reflectivity and to follow them to the ground where they generally cause high intensities rain fall and are sometimes accompanied by hail.

Figure 25. Hydrometeorological Radar owned by the ACMG in Agen

TITAN software automatically calculates water slides and tracks thunderstorms before it reaches, for example, an area of a watershed that could be in danger of flooding because the soils are already saturated.

https://ral.ucar.edu/projects/titan/home/whatis_titan.php .
When funding is available, the radar is set to operate when stormy rain events are forecast. Observation and cumulative water slide maps are transferable to any GIS-type viewing platform.

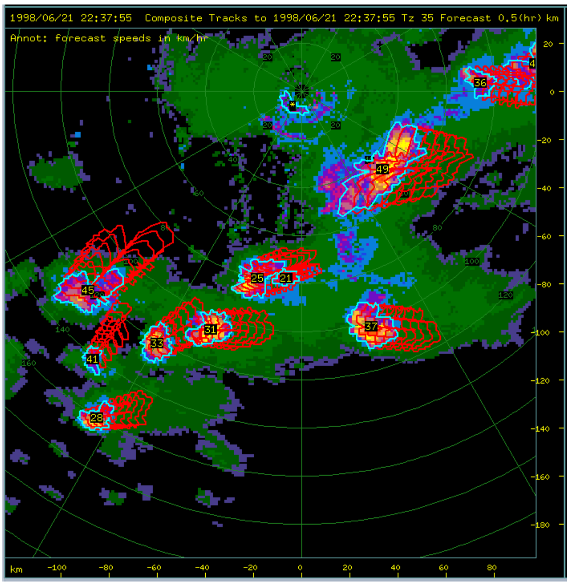


Figure 26. Visualization of a disturbance with the cell propagation thanks to the prediction tool on Titan Software.

2.7. Agro-meteorological network of the Dordogne Chamber of Agriculture.

The first automatic weather stations appeared in the Dordogne in the 1990s to supplement or replace the manual readings of the CDA24 relay farmers (historical since 1960 for certain locations).

At that time, the stations were used by Plant Protection, the Chambers of Agriculture, INRA, agricultural advisers, as well as organisations associated with the agricultural world.

In 1995, the elected representatives and owners of climatic stations decided to create a formula adapted to their needs in order to gain in reliability and time by federating an agro-meteorological agricultural network in the Dordogne.

The network (Figure 27, 28 & 29) brings together all the weather stations in the department and each member benefits from the tools made available. Over the years, this server evolves according to members' ideas, technologies and the needs of the sectors.

Figure 1. Examples of agro-climatic stations installed.

Today the network includes 29 automatic climate stations and 31 agro-climatic stations that are remotely transmitted during the season (irrigation monitoring and control, grassland management monitoring, departmental road services, etc.). The new meteorological stations allow to consult the climatic conditions live. Thus, farmers use Decision Support Tools (OAD) that can operate continuously. Thanks to these D.A.O., phytosanitary treatments are limited and irrigations are controlled. Sustainable agriculture is controlled by the farmer and his adviser.

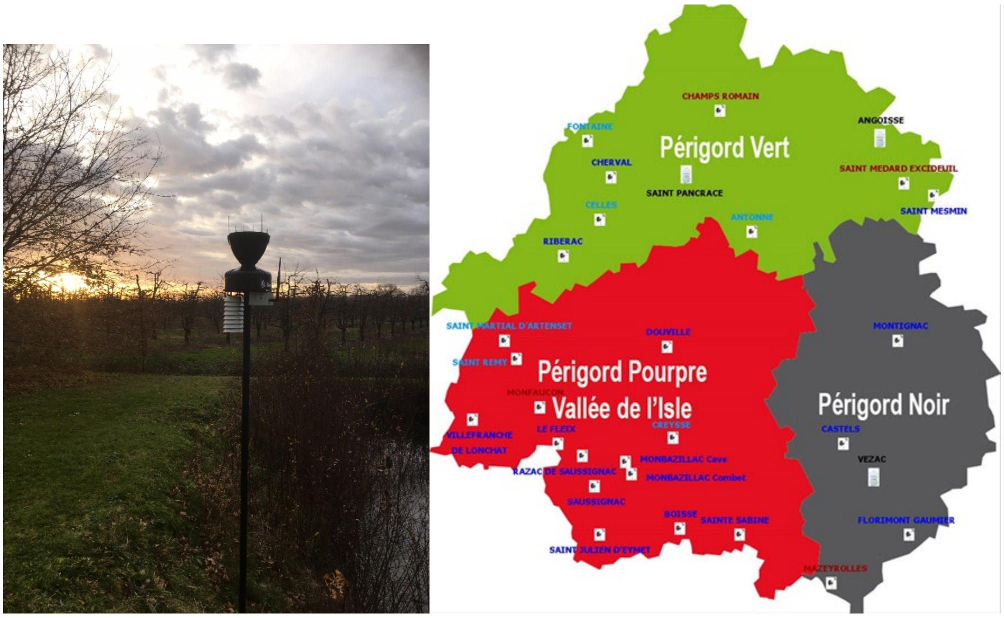


Figure 28. Distribution of the climate network ing the Dordogne department.

Figure 29. Distribution of the Agro-climatic network in the Dordogne department

WHY our network?

- To clarify the effects of climatic factors on biological material, soil and cultivation techniques,

- To provide the farmer with all the information he needs to better adjust his decisions,

- To have a history and carry out frequency modeling studies.

WHICH MISSIONS?

- Collection, validation and dissemination of agro-meteorological data (support to irrigators, OUGC, BSV, OP...)

- Monitoring of stations in the departmental network, hail control network and DRPP stations

- Study of the impact of climate change

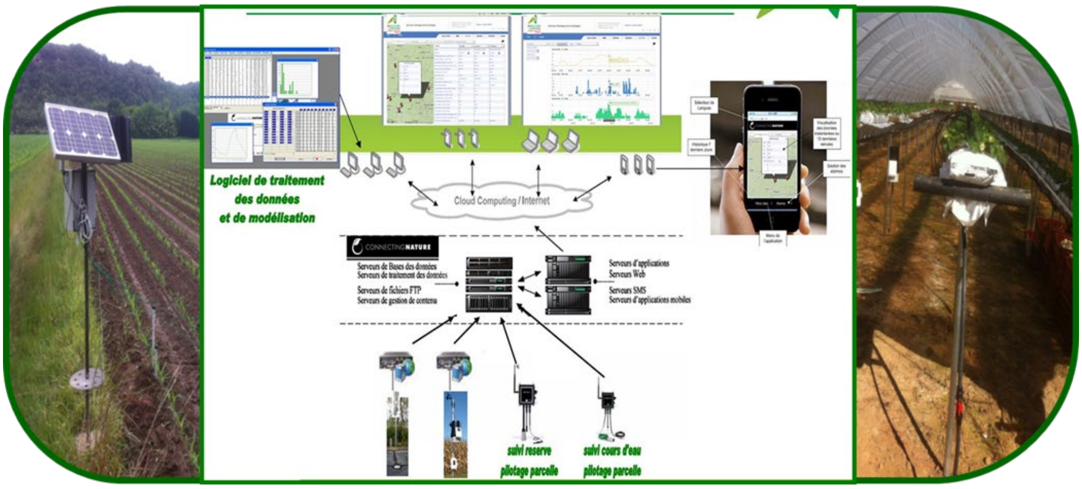


Figure 2. Network structuring: different models and station type.

2.8. Other sources of meteorological data.

Copernicus Emergency Management Service (Copernicus EMS).

Copernicus Emergency Management Service (Copernicus EMS) provides information for emergency response in relation to different types of disasters, including meteorological hazards, geophysical hazards, deliberate and accidental man-made disasters and other humanitarian disasters as well as prevention, preparedness, response and recovery activities. The Copernicus EMS is composed of an on-demand mapping component providing rapid maps for emergency response and risk & recovery maps for prevention and planning and of the early warning and monitoring component which includes systems for floods, droughts and forest fires.
https://emergency.copernicus.eu/

European and Global Flood Awareness Systems (EFAS & GloFAS.)

The European and Global Flood Awareness Systems (EFAS & GloFAS) provide complementary flood forecast information to relevant stakeholders supporting flood risk management at national, regional and global level.

The forecasts are derived using in-situ and satellite data as well as hydro-meteorological models and aim at facilitating users with a wide range of added value (medium-range lead time, probabilistic, river basin wide, flash flood indicators etc.) flood forecast products.

http://www.efas.eu/

http://www.globalfloods.eu/

The European Flood Awareness System (EFAS) is one service of the Copernicus Management Service CEMS. It is designed to support preparatory measures for flood events across Europe, particularly in large trans-national river basins.

To provide information on upcoming flood events, EFAS relies on a hydrological forecasting chain

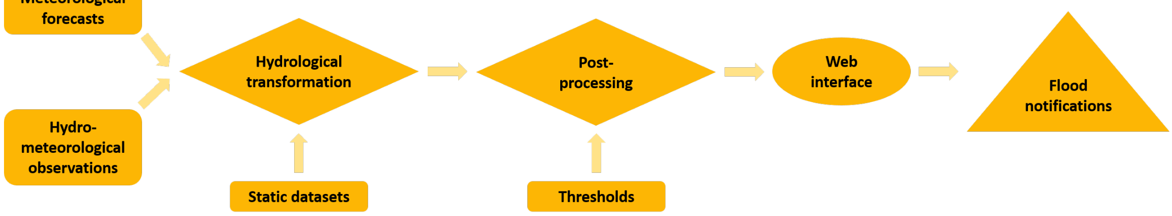


Figura 31. The EFAS hydrological forecasting chain.

There are key elements in the EFAS production chain: the meteorological forcing and land surface data; the hydrological models; and the EFAS forecasts and products.

The meteorological forcing data are all the information necessary to produce hydrological simulations.

- Historical hydro-meteorological time series records: they are used to calibrate the hydrological model, and to define the flood thresholds used to derive EFAS products. They are collected and managed by the JRC with contributions from MDCC, HDCC EFAS (Meteorological and Hydrological Data Collection Centres) and COMP (EFAS Computation Centre).
- Real-time hydro-meteorological observations: they are necessary to define the starting points of the hydrological forecasts, also called initial conditions. They are collected from national agencies and quality checked by the EFAS Meteorological and Hydrological Data Collection Centres (MDCC and HDCC respectively) before being transferred to the EFAS Computation Centre (COMP).
- Meteorological forecasts: they are used to provide the future meteorological input to the hydrological models. Both deterministic (i.e single realisation from a single numerical weather prediction system) and ensemble (i.e. multiple realisations - also called ensemble members - from a single numerical weather prediction system) forecasts are used in EFAS, obtained from a range of providers.

The land surface data are all the information necessary to set-up and implement the hydrological models.

- Land surface data: they include land surface information and model parameters. They are prepared in advance by COMP, with contribution from the JRC (Joint Research Centre of the European Commission).

EFAS products are produced by COMP and can be viewed through the EFAS mapviewer under the categories 'Flood summary' and 'Flash Flood'.

To respect Member States authorities regarding flood warnings, some EFAS forecasts and products are only accessible to EFAS partners in real time. However, archived EFAS forecasts and products older than one month are freely accessible under specific terms and conditions. To learn more on EFAS data restrictions and terms and conditions, visit the data access pages.

https://www.efas.eu/efas_frontend/#/home

https://www.efas.eu/training

https://www.efas.eu/publications-on-efas

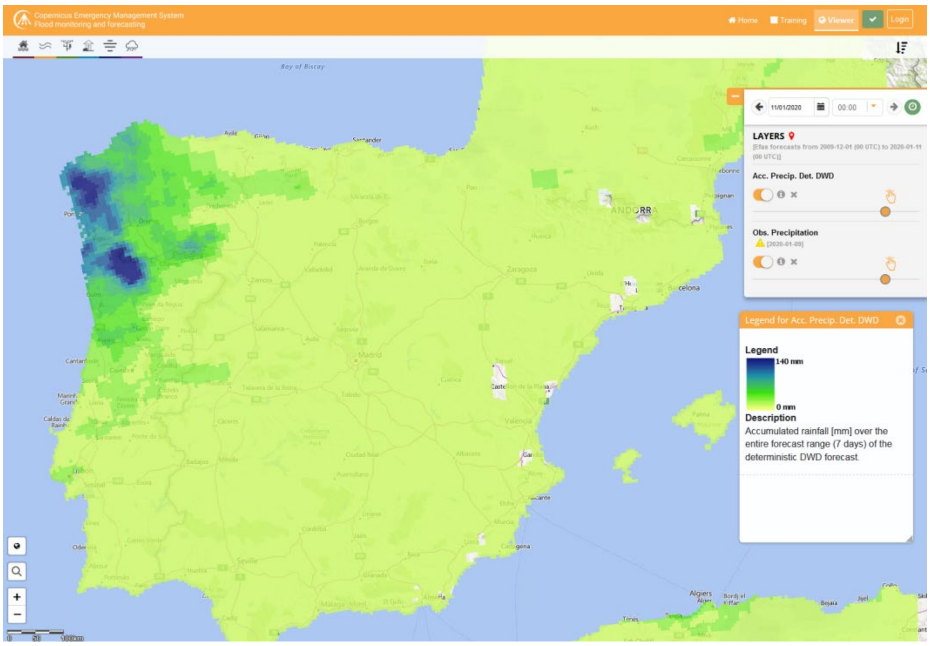


Figura 32. Visualización de la previsión de lluvia del día actual en visor EFAS.

EFAS collects near-real-time water level and river discharge observations including, where available, the national/regional thresholds from a large number of data providers. The information is displayed in the "National flood monitoring" layer in the EFAS map viewer. Note that gauging station density might not be the same as at the national/ regional level and that, depending on the data provider, a different number of threshold levels might exist. The monitoring of flood extent for specific events based on satellite data is available in the rapid mapping component of the CEMS.

To calculate the flood forecasts EFAS needs the hydrological initial conditions for LISFLOOD (Distributed Water Balance and Flood Simulation Model) which are derived from forcing LISFLOOD with gridded, near real-time meteorological observations. A large-number of in-situ meteorological data is collected from various data providers and interpolated to a regular grid. The interpolated grids for daily accumulated precipitation and daily average temperature are available in the map viewer and are important for verifying the quality of the initial conditions for the hydrological model. Furthermore, a 24-hour accumulated observed precipitation information based on SYNOP (Surface Synoptic Observations) stations is also available.

To support the interpretation of the flood forecasts EFAS displays also two key hydrological variables, soil moisture and snow water equivalent that might trigger or increase the risk of flooding. These maps are simulated using near real-time interpolated meteorological observations to run LISFLOOD and are also used as initial conditions for the flood forecasts. For hydrological variables, soil moisture and snow water equivalent, their respective anomalies are calculated to compare the simulations with the "normal" situation. Where available, the user can compare these maps also with values derived from satellite observations.

Copernicus Climate Data Store (CDS).

The CDS is an easy-access archive for all kinds of climate-related data. Retrieving relevant information and manipulation of the data can be done through the toolbox. It is available openly to the general public.

The CDS is the recommended and easiest way to access EFAS data and all relevant metadata information; users can select the type of data and dates of the time series they want to download. All archived EFAS data is in the form of raw hydrological time series outputs, and accessible to all. The data is currently available as GRIB2 or NetCDF. The data is available for anyone to use under a Copernicus data license.

Copernicus Climate Data Store
EFAS historical simulations
EFAS forecasts

IFS (Integrated Forecast System- ECMWF)

The comprehensive Earth-system model developed at ECMWF in co-operation with Météo-France forms the basis for all our data assimilation and forecasting activities. All the main applications required are available through one computer software system called the Integrated Forecasting System (IFS).

The European Centre for Medium-Range Weather Forecasts (ECMWF) is an independent intergovernmental organisation supported by 34 states based in Reading. ECMWF is both a research institute and a 24/7 operational service, producing and disseminating numerical weather predictions to its Member States.

The Integrated Forecast System (IFS) is a global numerical weather prediction system jointly developed and maintained by the European Centre for Medium-Range Weather Forecasts (ECMWF) based in Reading, England, and Météo-France based in Toulouse.

The following variables are shown every six hours for the North Atlantic area:

Surface:
- Precipitation in the previous six hours.
- Pressure at nominal time (appears by default).
- Temperature at nominal time.
- Cloudiness at nominal time.
- Wind at nominal time.

850 hPa:
- Temperature and geopotential in the same graph

500 hPa:
- Temperature and geopotential in the same graph

300 hPa:
- Wind and geopotential in the same graph

For the hemispheric areas the following variables are shown every twelve hours:
- Surface and geopotential pressure at 500 hP.

Tabla 6. Variables ECMWF suministrados por AEMET

ECMWF

Formato : GeoTiff
SRS : EPSG:4326

Descripción de los ficheros

Nombre del fichero	typeOfLevel level	Name	Formato	Parámetro	centre
019-10-2T18:00:00+00:00_130_300.tif	isobaricInhPa 300	Temperature	GeoTiff	130	
019-10-2T18:00:00+00:00_130_500.tif	isobaricInhPa 500	Temperature	GeoTiff	130	
019-10-2T18:00:00+00:00_130_850.tif	isobaricInhPa 850	Temperature	GeoTiff	130	
019-10-2T18:00:00+00:00_131_300.tif	isobaricInhPa 300	Velocidad del viento	GeoTiff		
019-10-2T18:00:00+00:00_131_500.tif	isobaricInhPa 500	Velocidad del viento	GeoTiff		
019-10-2T18:00:00+00:00_131_850.tif	isobaricInhPa 850	Velocidad del viento	GeoTiff		
019-10-2T18:00:00+00:00_131_300_direcc_viento.geojson	isobaricInhPa 300	dirección del vieno	GeoJSON		
019-10-2T18:00:00+00:00_131_500_direcc_viento.geojson	isobaricInhPa 500	dirección del vieno	GeoJSON		
019-10-2T18:00:00+00:00_131_850_direcc_viento.geojson	isobaricInhPa 850	dirección del vieno	GeoJSON		
019-10-2T18:00:00+00:00_151__press.geojson	superficie	Mean sea level pressure	GeoJSON	151	
019-10-2T18:00:00+00:00_156_300_geopotencial.geojson	isobaricInhPa 300	Geopotential Height	GeoJSON	156	
019-10-2T18:00:00+00:00_156_500_geopotencial.geojson	isobaricInhPa 500	Geopotential Height	GeoJSON	156	
019-10-2T18:00:00+00:00_156_850_geopotencial.geojson	isobaricInhPa 850	Geopotential Height	GeoJSON	156	
019-10-2T18:00:00+00:00_164_4326.tif.tif	surface 0	Total cloud cover	GeoTiff	164	
019-10-2T18:00:00+00:00_165__direcc_viemtp_10m.geojson	surface 0	dirección del viento a 10 m	GeoJSON	165	
019-10-2T18:00:00+00:00_165_modulo.tif	surface 0	Velocidad del viento a 10 m	GeoTiff	165	
019-10-2T18:00:00+00:00_167_4326.tif.tif	surface 0	2 metre temperature	GeoTiff	167	
019-10-2T18:00:00+00:00_228_6HH_6HH.tif	surface 0	Total precipitation 6 horas precedentes	GeoTiff	228	

Meteorological Archival and Retrieval System (MARS).

MARS is the main repository of meteorological data at ECMWF. It contains petabytes of operational and research data, as well as data from Special Projects. Access to the MARS archive requires an account with ECMWF. Read the MARS documentation for more information.

Users can browse the Archive catalogue (describing archive data that ECMWF can distribute) or the complete MARS catalogue (authorization required) from dedicated server. Users can select which part of the data that they would like to download in terms of area, dates, forcing model, time step, variables etc. Whilst the MARS archive offers a huge flexibility for download, it requires some basic programming skills to retrieve the data and might not be suitable to all. It is possible to find the Copernicus FAS data here: https://apps.ecmwf.int/mars-catalogue/

EFAS partners who have access to the real-time information on the EFAS-IS map viewer can also have direct access to the forecast data through a password protected ftp. This enables the users to get a sub-sample of the operational data as a direct ftp transfer. The operational data are saved for 30 days on the ftp then moved automatically to the MARS and CDS archives.

https://confluence.ecmwf.int/display/COPSRV/Ftp+service

OPERA: Radar Programme of EUMETNET

EUMETNET is a grouping of 31 European National Meteorological Services that provides a framework to organise co-operative programmes between its Members in the various fields of basic meteorological activities. These activities include observing systems, data processing, basic forecasting products, research and development and training.

Odyssey, the OPERA Data Centre, generates and archives composite products from raw single site radar data using common pre-processing and compositing algorithms.

Odyssey creates 3 composite products:

- Instantaneous Surface Rain Rate
- Instantaneous Max Reflectivity
- 1 Hour Rainfall Accumulation

The composites cover the whole of Europe in a Lambert Equal Area projection. They are updated every 15 minutes, and issued ca. 15 minutes after data time. In the rain rate composite each composite pixel is a weighted average of the valid pixels of the contributing radars, weighted by a quality index, the distance from center of the pixel and an exponential index related to inverse of the beam altitude. Polar cells within a search radius of 2.5 km of the composite pixel are considered. Measured reflectivity values are converted to rainfall (mm/h) using the Marshall-Palmer equation. Rainfall accumulation is simply the sum of the previous four 15-minute rain-rate products. In the maximum reflectivity composite each composite pixel contains the maximum of all polar cell values of the contributing radars at that location. Composites are available in two formats: BUFR and HDF5. Each file has two fields: the data field and the quality field.

The members of OPERA and EUMETNET may use the composites for their official duties without a separate licence. The OPERA products are also available under license to 3rd parties:

- For national weather service's not participating in OPERA which want to use the products to support their public weather service, contact info@eumetnet.eu
- For a research and education licence, contact info@eumetnet.eu
- For a licence to exploit the products commercially, contact one of the ECOMET members contact points or send a mail.

Spanish Drought Indexes Database (CSIC).

The database of drought indexes of Spain offers historical information that can be updated on the drought conditions, according to different drought indexes, at a spatial resolution of 1.1 km and a weekly spatial resolution (4 weeks per month). The calibration period of the indices is 1961-2014. The detailed technical information on the indices can be consulted in: Vicente-Serrano SM, Tomás-Burguera M, Beguería S, Reig-Gracia F, Latorre B, Peña-Gallardo M, Luna Y, Morata A, González-Hidalgo JC. A High Resolution Dataset of Drought Indices for Spain. Data, 2 (3): 22 (2017).

You can select the drought index to download, the time scale (in the case of SPEI, SPI and SPDI) and the date of interest to modify the information shown in the map.

Figure 33. Viewer of the sequia database (CSIC).

The drought index database for Spain is available under the Open Database License. All the rights on the individual contents of the database are authorized under the Database Contents License (free download in NetCDF format).

https://monitordesequia.csic.es/

EMS Drought Observatory (EDO &GDO).

The EMS Drought Observatory (DO) provides drought-relevant information and early-warnings for Europe (EDO) and the globe (GDO). Short analytical reports (Drought News) are published in case of imminent droughts.

EDO and GDO build on open web services and connect drought data providers and users from global to regional levels.

http://edo.jrc.ec.europa.eu/edov2/php/index.php?id=1000
http://edo.jrc.ec.europa.eu/gdo/php/index.php?id=2001