High temporal resolution monitoring of precipitation in the Basque Country

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Abstract

Here we present the main characteristics of the Basque disdrometer network. This network is based on OTT Parsivel disdrometer a laser-based optical instrument for simultaneous measurement of PARticle SIze and VELocity of all liquid and solid precipitation.

In this work, we also present the visualization and analysis tool developed for an easy and intuitive exploitation of disdrometer derived data in real time together with information from the network of rain gauges and remote sensing systems (mainly radar). Such tool allow us to analyze in real and in deferred time all the information available in the territory for precipitation characterization at each

observation point.

Finally, some aspects of interest are introduced in relation to different measurements obtained with the OTT Parsivel disdrometers at different points of the network during some interesting events.

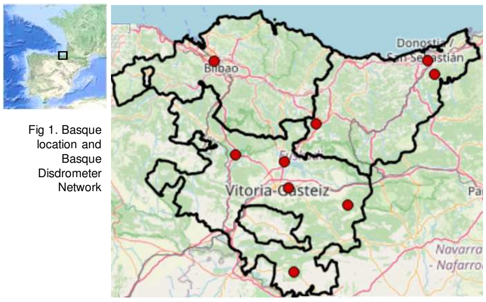


Fig 1. Basque location and Basque Disdrometer Network

Introduction

The reliability of precipitation measurements is a basic requirement since precipitation data represent the fundamental input variables of many scientific applications (hydrologic models, weather forecasting data assimilation, climate change studies, calibration of weather radar, etc.). The scientific community and the National Meteorological Services worldwide are facing the issue of improving the accuracy of precipitation measurements, with an increased focus on retrieving rainfall intensity at a high temporal resolution in order to a better characterization and a precise quantification of the markedly time-varying behavior of precipitation events. In the Basque country case there are two main ways of performing precipitation point measurements; with the pluviometers network that has been developed during more than thirty years (e.g. Gaztelumendi et al 2003, 2018, 2022, Otxoa de Alda 2003), and with the new disdrometer network (see Fig 1, Fig 2 and Fig 3) that is being implemented during these last years.

Those new instrumentation (see Fig 2 and Fig 3) are included in the Basque multipurpose network (e.g. Gaztelumendi et al 2018, 2022), providing information for rain-drop distribution, velocities and other derived quantities on a 1-minute basis for different locations all around the territory.

These disdrometers are equipped with two heads, one of which is an infrared laser emitter and the other a receiver that measures the attenuation produced in the light beam by the particles that pass through it. From this information, size, velocity and typology of the meteors, based on a diameter velocity relationship are derived. Intensity of precipitation, the volume of water per volume of air, visibility or radar reflectivity, among others, are also available (e.g. OTT Hydromet 2018).

The effort to increase the understanding of the precipitation characteristics that affects our territory (e.g. Gaztelumendi et al 2009, Egaña et al 2005, 2007, 2011, 2016) and its quantification through the new network of disdrometers will allow an improvement in impact weather capabilities (e.g. GV 2018, Gaztelumendi et al 2006, 2012) with a better surface precipitation fields characterization integrating new data with that coming from radars (e.g. Aranda et al 2008, Gaztelumendi et al 2008, Hernandez et al 2010) or satellites (Gomez de Segura et al, 2021, Gaztelumendi et al 2021). Many others areas of interest such as edafology, hydrology or climate change at local level, will also be encouraged.

Fig 2. OTT Parsivel Disdrometer

Fig 3. Disdrometers and rain-gauges in Goiain (left) and Arkauti (right)

The Basque Disdrometer Network

OTT Parsivel present weather sensor

The OTT Parsivel present weather sensor (see Fig 3) is a laser disdrometer for comprehensive measurement of all precipitation types (OTT 2022). It captures both the size and speed of falling particles, classifying them into one of 32 separate size and velocity classes. The raw data are used to calculate the type, amount, intensity and kinetic energy of the precipitation, the visibility in the precipitation, and the equivalent radar reflectivity (see Tab 3). The size and speed of every precipitation particle that passes in the measurement area is recorded and from these measurements all relevant meteorological parameters are derived. Complete precipitation measurement including particle size, volume, and intensity are available. Precipitation size and type are each calculated into one of 32 classes, as specified by the World Meteorological Organization (OTT 2016, WMO 2016)

Locations

The first Euskalmet disdrometer (OTT Parsivel class 1) was placed during 2012 in Kapildui, the Euskalmet radar site (see details in Aranda et al 2006), this disdrometer has been working on an experimental basis until 2013. Today, we have eight disdrometers of the same model located in Arkauti, Altube, Iturrieta, Zorrotza (formerly in Deusto), Miramon, Ereñozu, Arrasate, Páganos and Goiain (see Fig 1, Fig 2 and Tab 1).

Tab 1. Basque disdrometers location and characteristics.

Location	Code	Date	Type	Data logger	Sotware
Arkauti	D0FC	16/02/2017	Tipo 1	CR1000	V1.17.0
Altube	D0FE	13/05/2018	Tipo 1	CR6	V1.17.0
Iturrieta	D0FA	18/01/2019	Tipo 1	CR6	V1.17.0
		09/02/2021	Tipo 2		V2.11.1
Deusto/ Zorrotza	D0FD	28/12/2018	Tipo 1	CR6	V1.17.0
		02/12/2020	Tipo 2		V2.11.1
		21/12/2021			
Miramon	D0FF	08/10/2020	Tipo 2	CR6	V2.11.1
Ereñozu	D0F9	19/01/2021	Tipo 2	CR6	V2.11.1
Páganos	D0F7	12/02/2021	Tipo 2	CR6	V2.11.1
Arrasate	D0F8	05/05/2021	Tipo 2	CR6	V2.11.1
Goiain	D0FB	12/05/2022	Tipo 2	CR6	V2.11.6

Operational aspects

Disdrometers are connected to a Campbell datalogger model CR1000 or CR6 (Campbel scientific 2013). This connection is made through an SDI-12 interface cable.

The dataloggers are programmed to make a request to the disdrometer every minute, providing the data set measured in that time interval. Through the precipitation intensity field, it is assessed whether it has rained or not and, if so, registered and derived data is stored in different asci files with tabular structure. Three files have been defined (see Tab 2), one for raw data (see Tab 3), one for filed data, and the other for main variables used for surveillance operations.

Campbell´s LoggerNet software is used by Euskalmet for requesting and collecting data from the Basque automatic hydro-meteorological stations network (e.g. Gaztelumendi et al 2003, 2018). The dataloggers connected to the disdrometers are configured in the LoggerNet as if they were just another weather station. In this case, the request for the data contained in the tables is made every minute and not every ten, as is done with the rest of the stations (Otxoa de Alda et al 2003). The data is received via IP through a 4G connection and is stored in file format in two folders on the data server, one for raw data and other one for main variables for each location.

Tab 2. Files and main content.

FILE NAME	FIELDS
CODE_DisData.dat	01: Rain intensity 04: Weather code Table 4677 07: Radar reflectivity 08: MOR visibility 11: Number of particles detected 34 :Kinetic energy 35: Snow depth intensity
CODE_DisField.dat	90: Field N 91: Field v
CODE_DisRaw.dat	93: Raw data

Tab 3. Variables in raw data file.

Nº	Description	Digits	Forms	Range
01	Rain intensity (32 bit)	8	0000.000	mm/h
02	Rain amount since start of device (32 bi)	7	0000.000	mm
03	Weather code according to SYNOP w_aw_a (Table 4680)	2	00	1
04	Weather code according to SYNOP ww (Table 4677)	2	00	1
05	Weather code METAR/SPECI w'w' (Table 4678)	5	+RASN	1
06	Weather code according to NWS Code	4	RLS+	1
07	Radar reflectivity (32 bit)	6	00.000	dBz
08	MOR visibility in the precipitation	4	0000	m
09	Sample interval	5	00000	s
10	Signal amplitude of the laser strip	5	00000	1
11	Number of detected particles	5	00000	1
12	Temperature in the sensor	3	000	ºC
13	Sensor serial number	6	123456	1
14	Firmware IOP version number	4	V1.01	1
15	Firmware DSP version number	4	V1.01	1
16	Current through the heating system	3	0.0	A
17	Power supply voltage in the sensor	4	00.0	V
18	Sensor status	1	0	1
19	Date/time measurement begins	20	01.01.2000 00:00:00	
20	Sensor time	8	00:00:00	
21	Sensor date	10	00.00.0000	
22	Station name	10	XXXXXXXXXX	
23	Station number	4	XXXX	
*24	Rain amount absolute (32 bit)	7	000.000	mm
25	Error code	3	000	
*26	Temperature PCB	3	000	ºC
*27	Temperature in the right sensor head	3	000	ºC
*28	Temperature in the left sensor head	3	000	ºC
30	Rain intensity (16 bit)	6	00.000	mm/h
31	Rain intensity (12 bit)	6	0000.0	mm/h
32	Rain amount since start of device (16 bit)	7	0000.00	mm
33	Radar reflectivity (16 bit)	5	00.00	dBz
*34	Kinetic energy	7	000.000	J/(m²h)
*35	Snow depth intensity (volume equivalent)	7	0000.00	mm/h
*60	Number of all particles detected	8	00000000	I
*61	List of all particles detected(include size and particle speed)	13	00.000;00.000	mm;m/s
90	Field N	223	00.000x	
91	Field V	223	00.000x	
93	Raw	4095	000x	
94	N Characteristic field for weather recogn.	84	0000x	
95	N Characteristic field for weather recogn.	84	0.00x	
96	E Status	55	0000000x	
97	P Status	55	0000000x	
98	T Status	383	00000x	

*Extra fields for type 2 disdrometer

Visualization and analysis tool

The EUSKALMET/TECNALIA Intranet is one of the most relevant applications that supports operational tasks in Euskalmet, particularly in relation to analysis, prediction and surveillance in the Basque Country. This tool is a key point access to all available information and products from models and observations. Images, graphs, tables, maps, texts automatically generated and other human-based products are available for analysis, surveillance, forecast, climate, research, validation, etc.

A particular section was included in the intranet for full consultation of disdrometers data in real time and deferred time, in order to support the monitorization of severe weather and the analysis of past events. Disdrometer section is developed with web methodology, using HTML5 and CSS3 for the visual environment, jQuery for the controls and PHP for the server environment. Openlayers plugin and Geoserver is used for layer management in the map view, and for graphics we use Highcharts capabilities.

In the map (see Fig 3) it is possible to see the location of the disdrometers and choose one selecting the date range. The data will be represented in table format and in different graphs. In both cases it is possible to hide/show the desired available variables. The graph is interactive and allow to see the information details at a temporal point when moving the mouse or using zoom capabilities for a particular area. It is possible to export the graph information in different graphical formats, and to download the data in .csv format with a built-in search button.

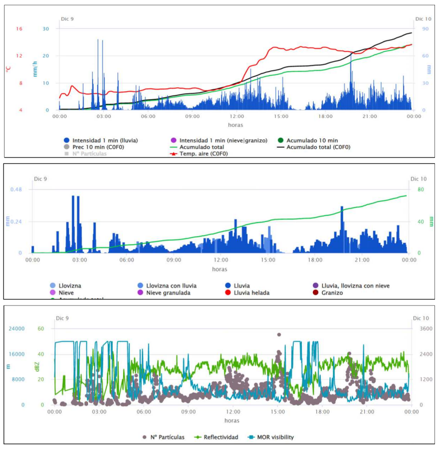


Fig 5. Some graphical examples available in the tool. On top precipitation intensity (mm/hour) and accumulations from disdrometer, heated rain-gauge and temperature in the same site. In the middle one-minute precipitation (mm/min) with category :Drizzle. Drizzle with rain. Rain. Down the number of particles, reflectivity and visibility. Data from Ereñozu, day 09/12/2021, Stratiform and persistent precipitation event

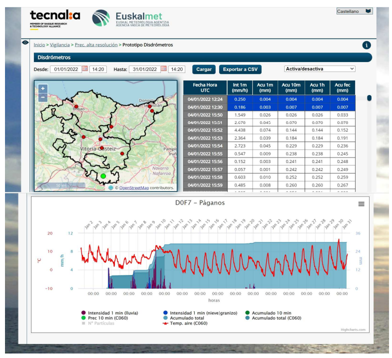


Fig 4. Tecnalia/Euskalmet Disdrometer Tool

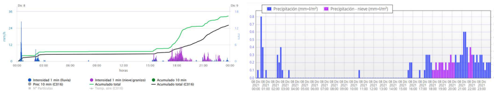
Case applications

Case 1: 08/12/2021 – Snow in Vitoria-Gasteiz

This is a situation of incoming cold air in which the snow level drops during the second half of the day to 500-600 meters. In Vitoria-Gasteiz, it snows heavily from 18 UTC to 20 UTC, and accumulates around 2 cm thick. In Abetxuko (sited in the town), the total accumulated precipitation is 15.9 mm during the whole day, 9.8 mm of which is snow; in Arkauti (sited located in the city's periphery), 11.9 mm are recorded during the whole day, 3.3 mm of which is snow (see Fig 3).

The most important snowfall of the day can be seen in the disdrometer information (Fig 3) between 18 UTC and 20 UTC, accumulating around 7-8 mm in the form of snow, with reflectivities between 20 and 40 dBz, with accumulations in 10 minutes at the moment of maximum intensity slightly above 1 mm, with a maximum minute intensity of 10.9 mm/h (18:27 UTC). Visibility is reduced to 125 m at the moments of maximum intensity of the snowfall, with an increase in the number of particles (in this case snowflakes) reaching 986 per minute.

Fig 3. Arkauti precipitation data: disdrometer (left) and heated rain-gauge (right)

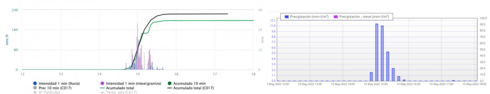


Case 2: 15/06/2022 – Vey heavy storms in Donostialdea

Convective nuclei form in the north-east of Gipuzkoa during the afternoon. Between 16:00 and 18:00 very heavy thundershowers occur, also with hail and very strong gusts of wind, especially affecting the area of Donostialdea. The intensity of the downpour in this area exceeded 30 mm/h, making it very heavy (Miramon 33.3 mm/h, Lasarte 27.3 mm/h, Oiartzun 15.8 mm/h). These showers caused problems in Donostia, with streets, some ground floors and commercial premises flooded by water, and damage in some areas such as the velodrome and the Anoeta mini-stadium.

The showers are intense and rain and hail are mixed. The intensity of the showers (registered in Miramon, see Fig 4) at the worst moment presents precipitation intensities in 1 minute of 186 mm/h, with accumulated in 1 minute of 3.1 mm and accumulated in 10 minutes of 15.1 mm and in 1 hour 29.4 mm. The maximum reflectivity corresponding to this instant is 57.5 dBz , 9591 particles are counted and visibility of 133 m are registered. The total accumulated precipitation during episode is 29.6 mm with the disdrometer and 33.6 mm in the rain-gauge.

Fig 4. Miramon precipitation data: disdrometer (left) and heated rain-gauge (right)



Remarks and Conclusions

✓ A network of OTT Parsivel disdrometers has been deployed in different points of the territory, providing high temporal resolution information on precipitation and others parameters. This network, currently with 9 disdrometers, will be extended in the future.

✓ The OTT Parsivel is a laser-optical disdrometer that measures the size and velocity of hydrometeors with a sampling output is 1 min, providing the rain rate, radar reflectivity factor and other rain parameters. Those variables are computed from drop size distribution, the number of drops in a 32x32 size versus fall velocity matrix.

✓ Data adquisition and query tools have been developed so that data can be conveniently exploited for analysis and monitoring. These data interfaces on the operational intranet are designed in an evolutionary way according to the needs of the different users .

✓ The exploitation of raw data and droplet distributions is carried out in the R environment and is currently not available in the analysis and monitoring tool. These capabilities will be included in the next intranet tools version.

✓ Through the network of disdrometers we can analyse the distribution of precipitation intensity with a high temporal resolution, which contributes to obtaining detailed information on the characteristics and type of precipitation, which undoubtedly improves the monitoring, surveillance and tracking of adverse situations of precipitation and/or snowfall, as well as storms. It is also of great interest to obtain the type of hydrometeor, especially in storm situations to differentiate rain from hail, and in situations of incoming cold air to differentiate rain from snow.

✓ It is possible to obtain the parameters a and b that relate precipitation intensity to reflectivity, depending on the type of situation, which could improve certain radar products, especially those oriented towards hydrology, i.e. products that are derived from the Marshall-Palmer relationship in general, and thus obtain higher quality quantitative precipitation estimation fields.

✓ Although the main orientation of disdrometers network is the surveillance and monitoring in real time of severe phenomena (like most of the instruments currently present in the multipurpose network), it is managed according to standards with the aim of continuity so that it can contribute to the future detection of possible signals of climate change on a local scale.

Acknowledgements

The authors would like to thank the Department of Security of the Basque Government and particularly to the Directorate of Emergencies and Meteorology for operational service financial support. We also would like to thank all our colleagues from DAEM, EUSKALMET, and TECNALIA for their daily effort in promoting valuable research and services for the Basque Society. Local climate potential applications studies has been partially cover in the context of LIFE-URBANKLIMA2050 project.

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