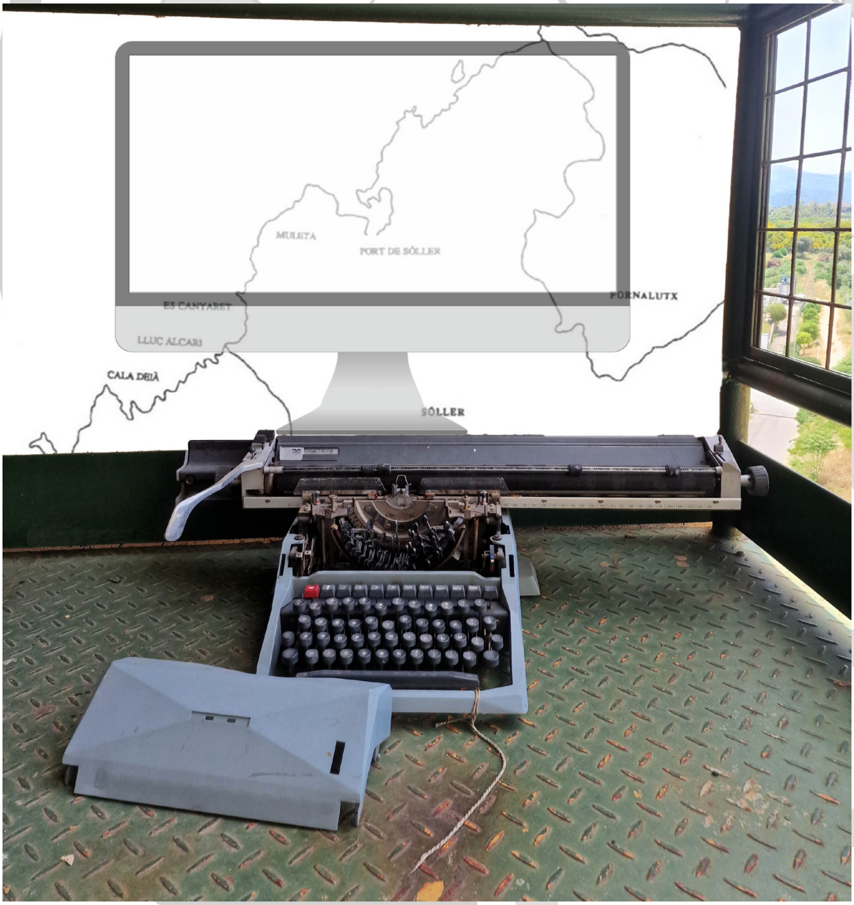
INFORMATION TECHNOLOGIES AND SOCIAL MEDIA: NEW SCIENTIFIC METHODS FOR THE ANTHROPOCENE

Gaetano Sabato, Joan Rosselló (Editors)



Preface by Javier Martín-Vide

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Geographies of the Anthropocene

Information Technologies and Social Media: New Scientific Methods for the Anthropocene

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Editors

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Geographies of the Anthropocene

Open Access and Peer-Reviewed series

The book series “Geographies of the Anthropocene” edited by the International Scientific Publisher “Il Sileno” (Il Sileno Edizioni) will discuss the new processes of the Anthropocene epoch through the various worldviews of geoscientists and humanists, intersecting disciplines of Geosciences, Geography, Geoethics, Philosophy, Socio-Anthropology, Sociology of Environment and Territory, Psychology, Economics, Environmental Humanities and cognate disciplines.

Geoethics focuses on how scientists (natural and social), arts and humanities scholars working in tandem can become more aware of their ethical responsibilities to guide society on matters related to public safety in the face of natural hazards, sustainable use of resources, climate change and protection of the environment. Furthermore, the integrated and multiple perspectives of the Environmental Humanities, can help to more fully understand the cultures of, and the cultures which frame the Anthropocene. Indeed, the focus of Geoethics and Environmental Humanities research, that is, the analysis of the way humans think and act for the purpose of advising and suggesting appropriate behaviors where human activities interact with the geosphere, is dialectically linked to the complex concept of Anthropocene.

The book series "Geographies of the Anthropocene" publishes online volumes, both collective volumes and monographs, which are set in the perspective of providing reflections, work materials and experimentation in the fields of research and education about the new geographies of the Anthropocene.

"Geographies of the Anthropocene" encourages proposals that address one or more themes, including case studies, but welcome all volumes related to the interdisciplinary context of the Anthropocene.
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The volume proposals can be presented in English, Italian, French or Spanish.

The choice of digital Open Access format is coherent with the flexible structure of the series, in order to facilitate the direct accessibility and usability by both authors and readers.

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6. FLOODUP, a citizen science project to increase flood risk awareness and collective knowledge

Montserrat Llasat-Botija[1], *Maria Carmen Llasat*[2]

Abstract

In recent years, there has been a growing demand to strengthen the connection between science and citizens, either through knowledge transfer or through co-participatory and co-creative processes. The goal is to ensure that the benefits of any knowledge gained reflect back on society and, in turn, that citizens become more involved in knowledge generation and more empowered. In this context, this article analyses the importance that this two-way exchange can have when dealing with flooding. To do so, the article focuses on floods in Catalonia (northeast Spain) and on the development of a methodology to encourage this exchange through the FLOODUP application, used mainly as a citizen science tool. This paper presents the adaptive learning-while-doing approach of the FLOODUP project in each of its three phases. The floods in the Maresme county in Catalonia during October 2016 are presented as a case study. In this case, citizen participation through platforms such as XOM, Meteoclimatic and FLOODUP allowed a better diagnosis of the event.

Keywords: Floods, citizen science, resilience, Catalonia, FLOODUP

1. Introduction

According to the EM-DAT database, 951 natural disasters occurred in Europe between 2001 and 2020 related to the weather. 41% of these were floods, which caused 2,142 fatalities, followed by storms (27%) and extreme temperatures (23%). Floods are the type of natural disaster that affect the highest number of people: more than 6.6 million people were affected in

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Europe over this 20-year period (CRED, 2021). The floods recorded in July 2021 in Germany and Belgium caused 200 fatalities and $20 billion worth of damages. In Spain, between 1971 and 2020, the "Insurance Compensation Consortium" (*Consorcio de Compensación de Seguros*, CCS) paid more than €7 billion (updated for 2020) in damages by floods, a figure that represents more than 60% of total insurance claims (CCS, 2021). These numbers show the significance of floods in Europe and their consequences.

The impact of these disasters is related not only to their frequency and to magnitude, which depends on hazard conditions, but also on the vulnerability and exposure (Merz *et al.*, 2021; Kreibich *et al.*, 2017). Consequently, knowledge of these components is very important to improve resilience and preparedness. In recent years, advances have been made in the investigation of these events from different approaches (Barredo, 2010; Petrucci *et al.*, 2019; Blöschl *et al.*, 2019; Di Baldassarre *et al.*, 2013). In particular, the response of the population and their capacity to deal with natural hazards is important to reduce the impact of disasters (Moser, 2014). For this reason, it is so important to improve awareness among the population and engage them in prevention actions. For example, understanding meteorological warnings determines the response of the population; this understanding is not complete if the phenomenon is not well known. On the other hand, it has also been observed that citizen participation improves the response to emergencies, as well as their prevention and recovery, since citizens feel empowered and capable of making proactive decisions. For this reason, greater importance is being given to the participation of the population in coping with natural hazards (Fekete *et al.*, 2021; Starkey *et al.*, 2017).

The content of the paper is structured as follows: Section 2 presents the area of study (Catalonia, northeast Spain) the floods database INUNGAMA in this region, and the spatial distribution of flood events for the 1981-2020 period. Section 3 addresses the application of citizen science to increase flood risk awareness and collective knowledge; Section 4 continues with the presentation of a case study; and lastly, Section 5 presents the conclusions.

2. The importance of floods in Catalonia

2.1. Area of study

Catalonia is in the northeast of the Iberian Peninsula and covers an area of 31,895 km^2 (6.3% of Spain). The French border is located at its northern edge, this is, the Pyrenees Mountain Range, while to the south is the Iberian

Mountain System. This already complex orography is rounded off with the Pre-Coastal Mountain Range and the Coastal Mountain Range, which both lie parallel to the coast. As the population's reliance on agriculture and livestock have reduced, the population inland has decreased, and people have moved to coastal municipalities. Consequently, out of a population of 7,522,596 (IDESCAT, 2016), 3,239,337 inhabitants live in the Metropolitan Area of Barcelona (*Àrea Metropolitana de Barcelona*, or AMB), which covers 636 km^2 and frequently experiences heavy rains. The majority of this population is concentrated in the municipality of Barcelona (1,608,746 people), located between the Besòs river and the Llobregat river, the Coastal Mountain Range and the Mediterranean Sea.

Catalonia is divided into two main large hydrological regions (Fig.1). The first region (16,423 km^2) is within the Autonomous Community of Catalonia (the Catalan government manages it) and includes all the Internal Basins of Catalonia. The second is part of the Ebro Basin (85,534 km^2, and less than 25% is in Catalonia), and is managed by a consortium of regions in different Autonomous Communities under the umbrella of the Spanish government. Although this division between different administrations does not affect the INUNCAT flood prevention and management plan (DGPC, 2017), which depends on Civil Protection, it does hinder the exchange of basin data (flow, precipitation and so on) and communication to the population.

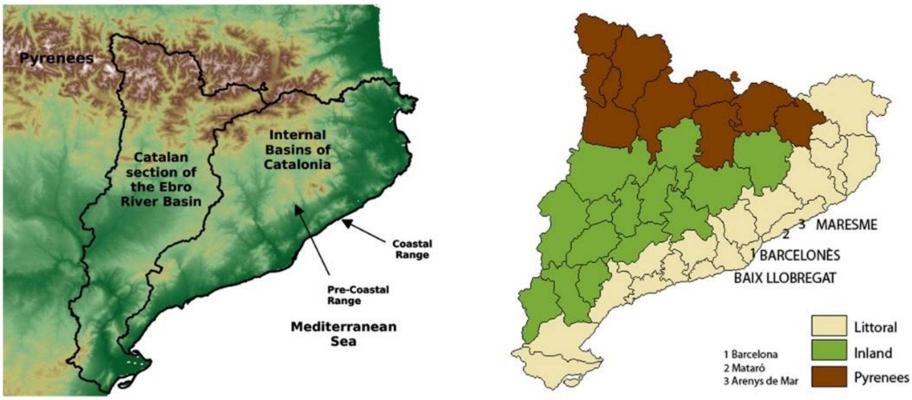

Figure 1 - *Map of Catalonia showing the toponyms and locations cited in the text (Source: Llasat et al., 2014).*

2.2. Floods in Catalonia

The proximity to the Mediterranean Sea, coupled with these orographic characteristics, results in torrential rains developing that result in frequent flash floods and urban floods, mainly in summer and autumn (Llasat et al., 2016). In general, these floods affect the coast, where most of the population lives. The number of residences in flood prone areas and the lack of knowledge of flood risks by a large number of the population are the main reason for economic and human losses. The Spanish public reinsurer, the Insurance Compensation Consortium, paid more than €700 million (values updated to 2020) (CCS, 2021) in compensation for flooding during the 1996–2020 period. Approximately one-third of the flood episodes affected the counties of Maresme, Barcelonès and Baix Llobregat, which belong to the Metropolitan Area of Barcelona (Fig. 1).

Floods in Catalonia are usually surface water floods, which means rainfall-related floods (Bernet et al., 2017), including pluvial floods but also flooding from sewer systems, small open channels, diverted watercourses or groundwater springs (Falconer et al., 2009). The presence of the coastal mountain range encourages heavy rainfall to develop which in turn results in flash floods and urban floods. They take place in ungauged catchments or in urban environments where there are no measurement stations. Therefore, there is usually no hydrological information on these floods. This lack of information and the need for this information in order to reconstruct historical events is one of the main reasons to call on citizen contribution.

Despite the fact that flash floods are usually local and do not cause significant damage, in some cases they can be catastrophic. The most severe flooding episode in Catalonia took place on 25 September, 1962, in the Besòs river basin, in Vallès Occidental county, to the west of Barcelona. There were 815 casualties and more than €600 million (adjusted to 2020) in direct losses, which were the result of heavy rains (212 mm in less than 3 hours) that led to river floods to levels not seen in 200 years (Martín-Vide & Llasat, 2018), and were also caused by high levels of exposure and vulnerability. It was also the result of an over occupation of flood zones by migrants that arrived in Catalonia in large numbers from other Spanish regions to work at the booming textile industry, the absence of flood prevention and management plans, and the poor weather forecasting tools at the time. Compared with the flood event of 10 June, 2000, under similar hazard conditions, there was a considerable improvement both in exposure (less population density due to the textile factories closing down), and vulnerability (improved protection and flood prevention plans and early warning system, together with the creation of Civil Protection) (Kreibich *et al*., 2017). However, a field visit to residents who currently live near the rivers that flooded in 1962 shows that they no longer feel at risk due to floods, and vulnerability has again increased (the "levee paradigm" that creates a false feeling of security, Di Baldassare et al., 2018). On the other hand, a post-event analysis carried out recently (Martín-Vide & Llasat, 2018) that includes more observations, has shown that initially estimated discharges were 2 to 4 times greater than the approximate rainfall-based water discharges. This fact justifies the benefits of collecting more information from pictures, witnesses, and so on. This flood event is an example of the dual benefits of the application of citizen science to floods: greater risk awareness, better events reconstruction.

An analysis of historical floods since the 14th century shows a growing trend in so-called extraordinary floods in Catalonia (Llasat *et al*., 2005, 2014; Barrera-Escoda & Llasat, 2015). This trend, which began in the mid-19th century, has mainly been attributed to greater occupation of potential flooding areas and to the alteration in land use. Future scenarios show an increase in flood damage (Cortès *et al*., 2019), which is partially justified by the increase in short but heavy rainfall events (Llasat *et al*., 2021). The last catastrophic floods recorded in Catalonia, known as storm "Gloria", were a good lesson for the population on how climate change could produce more severe compound events than in the past (Canals & Miranda, 2020). The problem, however, is that we are in a so-called liquid society (Bauman, 2000), in which news and events are easily forgotten. One of the objectives of FLOODUP is to awaken historical memory on what floods meant for the region historically and what measures have been developed and can be applicable to mitigate their impact.

2.3. INUNGAMA database

In addition to post-event analysis through surveys (Ruin *et al*., 2014), press and internet plays a major role to collect risk data. Press is also very useful for the reconstruction of episodes and for the completion of serial episodes (Bayés Bruñol *et al*., 2003; Llasat *et al*., 2009b; Petrucci, 2012). Press reports and other sources such as insurance companies or official reviews allow us to fill in data when there is not enough instrumental information. They are also useful to compare with available information, and to have a detail of flood impacts through photographs and videos. The media is the best source when there is interest in creating a systematic database with all the floods recorded over a long period in a broad region, including floods that occurred in ungauged catchments, as it contains daily and continuous information over long periods. For episodes prior to the presence of newspapers, it is possible to resort to historical archives.

In 2000, a historical flood database began to be created by the GAMA team in the context of the European SPHERE project (Benito *et al.*, 2004) using criteria to classify floods based on damage descriptions (Llasat *et al.*, 2005). This criterion is applied in the present paper. The compiled information comes from historical archives (for the oldest events), press news, technical reports, and scientific articles with a view to collecting sufficient rigorous information to characterise flood events and their impacts, as well as to analyse trends in the context of risk change. The result was INUNGAMA, a flood database in ACCESS connected to a GIS (Geographical Information System), which in 2007 contained 217 flood episodes for the 1901-2000 period (Barnolas & Llasat, 2007). A posterior analysis of the systematic period 1981–2010 (Llasat *et al.*, 2014) showed that, from 219 floods recorded across the region on this period, 11% of them were catastrophic, 53% were extraordinary, and the rest only produced minor damages. The reader can find more information about the classification criteria and methodology in Llasat *et al.* (2013, 2016). INUNGAMA is part of the Mediterranean database on catastrophic floods, FLOODHYMEX (free access in https://mistrals.sedoo.fr/?editDatsId=1150&datsId=1150&project_name=MISTRALS). This database is updated continuously. Figure 2 shows the number of catastrophic flood events recorded on a municipal scale over the last 40 years. The maximum frequency corresponds to the coastal region where the three components of risk, hazard, vulnerability, and exposure are at their highest (Llasat *et al.*, 2016).

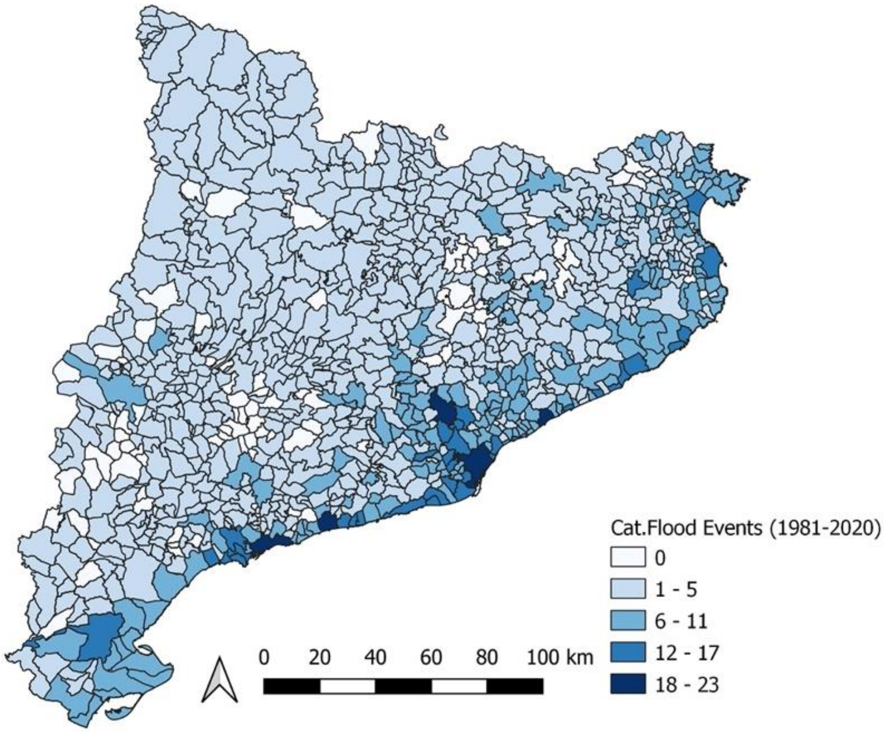

Figure 2 - *Map of the number of catastrophic flood events that have affected each municipality of Catalonia from 1981 to 2020.*

It should be said, however, that despite the systematic search for information, there are still notable uncertainties about the date, location, and damage of the floods, which can be reduced with the collaboration of the population.

3. The application of citizen science to increase flood risk awareness and collective knowledge

3.1. Citizen science

Over the last few years, new technologies have developed that allow the emergence of collaborative and participatory projects in which citizens contribute to scientific research, for example through their data and observations, in what is known as "citizen science" (Paul *et al*., 2020; Vohland *et al*., 2021). The concept of citizen science is very broad and there are different definitions for it. The "Green paper of citizen science" (EC & SC, 2013) defines it as follows: "*Citizen Science refers to the general public engagement in scientific research activities when citizens actively contribute to science either with their intellectual effort or surrounding knowledge or with their tools and resources*". The European Commission (2016) defines it as a "*scientific work undertaken by members of the general public, often in collaboration with or under the direction of professional scientists and scientific institutions*" (European Commission, 2016). Muller et al. (2015) synthetises the work of different researchers and concludes that "*Citizen science is a form of collaborative research involving members of the public: volunteers, amateurs and enthusiasts. It can be thought of as a form of animate crowdsourcing – or 'participatory sensing' – when it actively involves citizens collecting or generating data. Hardware sensors can be used by citizens to collect data, but citizens themselves can also be classified as 'virtual sensors' by interpreting sensory data".*

With these definitions in mind, citizen science comprises a broad series of activities and practices with the common thread of non-specialist citizens taking part, in an active and meaningful way, in tasks in a scientific project. In Spain, there are an increasing number of projects of this nature, as shown by the Observatory of Citizen Science (Ibercivis, 2021) and the Citizen Science Office of Barcelona (Ajuntament de Barcelona, 2021). Along these lines, the review paper by Buytaert et al. (2014) shows how citizen science can be applied in hydrology and water resources and, contains some mentions of how it can be applied in relation to flash floods.

Citizen science presents an opportunity to increase the information available, improve awareness, prevent flood risk, and mitigate its impact.

3.2. FLOODUP

FLOODUP is a citizen science project developed by the authors with the aim of improving the awareness among the population about natural hazards (mainly floods) and climate change, while increasing the information available to researchers (Llasat-Botija *et al*., 2019).

The aim is to create, in a collaborative way, a map of the main impacts of natural hazards and climate change, as well as areas for improvement and ways communities are adapting. To achieve these objectives the main tools developed have been a Mobile Application (Floodup) and an online platform. Through this App, users can provide information on observed phenomena and the damages caused; observations of bad practices or places that could be particularly affected in the case of floods or other natural hazards; observations related to adaptation, such as traditional local prevention measures, protection infrastructure, or new proposals such as Nature Base Solutions. (Llasat *et al.*, 2020).

The citizen science projects are dynamic and must adapt and evolve attending the social and scientific challenges. Considering that this book deals with new scientific methods for the Anthropocene related with Information technologies and social media, the following paragraphs show the three phases of FLOODUP, with the challenges and lessons learned. The FLOODUP project started in 2014 with the support of the Spanish Science and Technology Foundation (FECYT, FCT-14-8681). At first, it focused on flooding, but now it has been expanded to a wide range of hydrometeorological phenomena (droughts, storms, landslides, etc.), and includes a category of "other" to accommodate several other phenomena that participants wish to send for research purposes.

3.2.1. Start of the project (2015-2017)

The project was founded with the aim of being a scientific dissemination project with a component of citizen science. During this phase, the first mobile application was developed and launched, alongside a website, a flood educative dossier, and numerous educational activities and pop-up campaigns.

The first version of the app (2015-2017 period) was downloaded by more than 1,100 people but only 27% (330 people) registered on the app. Profiles of registered users were analysed. 70% of them were men, while 23% were women, and the remaining 7% were institutions and entities. As for their origin, 74% of users came from Spain. 5% of all registered users were citizens of other European Union countries (Germany, Italy, France, Hungary, Slovakia, Bulgaria and Austria), while 8% were from countries outside the EU (mainly countries from South America like Colombia, Argentina, Perú, Uruguay or México, but also people from Nigeria, Burkina Faso, India, Indonesia, Malaysia, Saudi Arabia, Kazakhstan and Canada). The origin of the remaining users is unknown (Fig. 3). As for users from Spain, Catalonia had the greatest share of users out of all the Autonomous Communities, with 46% of the total number of users.

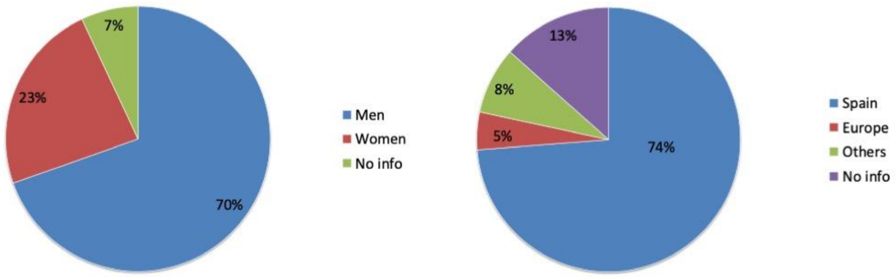

Figure 3 - *Profile of users registered in the FLOODUP app according to gender (left) and origin (right).*

Over 700 contributions were collected through the different channels in its first phase. Through the app, 263 observations were uploaded and validated, out of which the most important share (59%) were connected to flood observations, followed by the category of "other phenomena" (23%), in which a significant proportion were storms and hail. The rest covered other observations (8%), vulnerable areas (5%) and historical flood memory (5%). 47 episodes of flooding (3 located outside Spain) and 35 episodes of other phenomena were identified too. Most observations were images of events (heavy rain, floods, etc.) that were going on at the time, although events from previous years were also uploaded. This information was useful in completing some episodes of the INUNGAMA database. Another result of this first phase was the information collected on the October 2016 flood event (see Case Study).

In summary, the main objective of the project in this phase was educational, with a citizen science component, and it was more heavily focused on floods. At the time, there was a great growth in science education apps. Two lessons were learned in particular: the need to register is an obstacle to app use, and the importance of developing educational activities to increase the project's impact.

3.2.2 Intermediate phase (2017-2019)

During this phase, the project evolved, with citizen science taking centre stage. The app did not operate during this phase, but alternative channels were tested to encourage participation. With the goal of detecting potential improvements to create a new version of the app, a participatory campaign was launched. Relevant methodology to carry out the project in secondary schools was designed during this phase. The main objective was to gather information about floods in local neighbourhoods and raise awareness about natural hazards and climate change. A physical flood model that could be taken to schools and workshops such as Science Fairs was developed (Fig. 4). In collaboration with the flood management entity in Barcelona, BCASA, some materials were developed to explain the risk of flooding and flood management in the city.

Figure 4 - *Physical flood model.*

Another key activity in the second phase were workshops with elderly people. These workshops, held in the city of Barcelona, worked on a map of the environment, and gathered information on specific areas that were the most frequently flooded, with proposals from citizens on green areas and other measures that could reduce the flood risk. Around 40 observations were collected, of which more than 50% were about flood events. Most people remembered the events were the most recent or the most catastrophic, such as the 1962 event. The rest of the observations corresponded to “aspects to improve” (20%) such as problems related with the drainage system or the design of public squares, and “good practices” (25%) such as green spaces or rain gardens.

The pop-up campaigns continued, and the project participated in the FORCES project of the Barcelona Education Consortium. The project became a member of the Barcelona Office of Citizen Science (https://www.barcelona.cat/barcelonaciencia/es/ciencia-ciudadana). This gave a remarkable boost to the project. In summary, this phase was characterised by links with other citizen science projects through the Office of Citizen Science. The citizen science component became more important and begun to be linked with research projects carried out by the group. The educational component was not lost, and was reinforced using citizen science as an educational strategy. The most important point learnt from this phase was the importance of collaborating with other projects, not only to learn but also to establish synergies between projects. It could be seen that workshops are a good strategy to collect information, but that they require physical supports such as models or maps.

3.2.3 Third phase (2019-present)

A new app has been developed in the context of the PIRAGUA project (EFA210/16 Interreg V Spain-France-Andorre Programme POCTEFA 2014-2020, EU) and a Twitter project profile has been launched (Fig. 5). In this phase FLOODUP has been included in the Observatory of Citizen Science in Spain (https://ciencia-ciudadana.es/proyecto-cc/floodup/) and in the European portal EU-CITIZEN.SCIENCE (https://eu-citizen science/project/173).

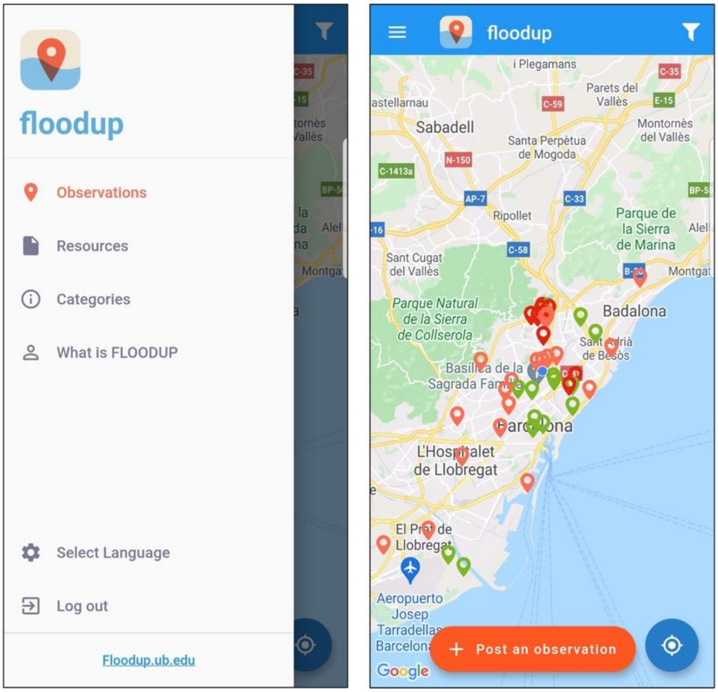

Figure 5 - *Floodup app menu and Home screen.*

In the new version, the phenomena that can be collected through the app has been expanded beyond floods. Some of these, such as extreme temperatures, are phenomena that have significant media coverage and a high social interest as we have seen in previous studies (Llasat *et al.*, 2009a). Currently, the app has almost 300 registered users. As for the twitter profile (@floodup_UB), which was launched in September 2019, it has already accumulated more than 190 followers and has published more than 390 tweets (between tweets and re-tweets).

Two relevant actions can be highlighted in this phase: some projects carried out with high school students, and post-event flood campaigns. The last campaign was devoted to providing information about a flood event that took place in October 2019, sharing information with citizens and develop a co-participative project. In terms of the school projects, the curriculum dossier for the schools has been expanded, and seven projects have been carried out in schools. Students have contributed to this project by uploading observations made if a rainfall event was recorded near the school during the project, good practices and problematic areas in the neighbourhood; they also measured the rain collected and gathered information from local residents through questionnaires. The results have scarcely been homogeneous and, in some cases are not at all representative. This led us to debug projects to make them easier to implement as well as more systematic. However, these activities helped students to feel part of the project of characterizing a neighbourhood in terms of flooding and valuing the importance of their observations.

In summary, during this phase a new version of the mobile application was launched and continues to evolve as a school project. The project is no longer limited solely to floods and has expanded to climate change. In relation to the context, it is necessary to highlight the national and international tendency to give more importance to citizen science with new lines of public funding. During this stage, large events have followed in quick succession (storm Gloria, the Covid pandemic, etc.) with a strong impact on society. Finally, concepts such as the climate emergency are emerging, and the SDGs have become popular. An important learning point from this phase has been that post-event campaigns should be conducted as close as possible in time to the event, in order to take advantage of mobilisation and citizen's recent memory.

4. Citizen participation in a case study: the Maresme flood event in October 2016

The first study in Spain of an adverse meteorological phenomenon considering information from social networks, was that of the snowfall of March 2010 (Llasat *et al*, 2010). In this case, social networks were used as a source of information to learn about the different types of population response to an extreme weather event. Along the same lines, the article by Oliver *et al*. (2021) focused on tweets collected during three campaigns to assess the population's perception of coastal risks and climate change. In both cases, the citizens were not aware of participating in the process, rather they were the object of study. In the episode analysed below, the citizens consciously sent the information, which made it possible to improve the diagnosis of the episode. Most of them provided rainfall data through the network of volunteer weather observers (XOM) of the Meteorological Service of Catalonia (SMC), and the METEOCLIMATIC network that compiles a large number of the meteorological observations sent by professional and amateurs observers, while a few provided images and descriptions through FLOODUP.

Between 12 and 14 October 2016, there was intense rainfall that had a particularly significant impact on the Maresme region (Fig. 6), where most of the streams overflowed. On 12 October, the rain began to fall on the southern part of the region and soon spread along the littoral counties. During the afternoon and evening, the heaviest rains affected the centre and northeast of the Catalan coast, leaving the rest of the territory with more representative rainfall. The next day, 13 October, the rain became more widespread everywhere, without exception. Finally, on 14 October, the rain disappeared gradually from west to east. Figure 6 shows how cumulated precipitation in 72 hours was over 100 mm in all the coastal counties between the Barcelonés county and France, with a very localised maximum above 200 mm in the southern part of the Maresme county. Most of this precipitation was recorded in a very short time, giving rise to flash floods that caused damages estimated at some €7.4 million euros, and one death.

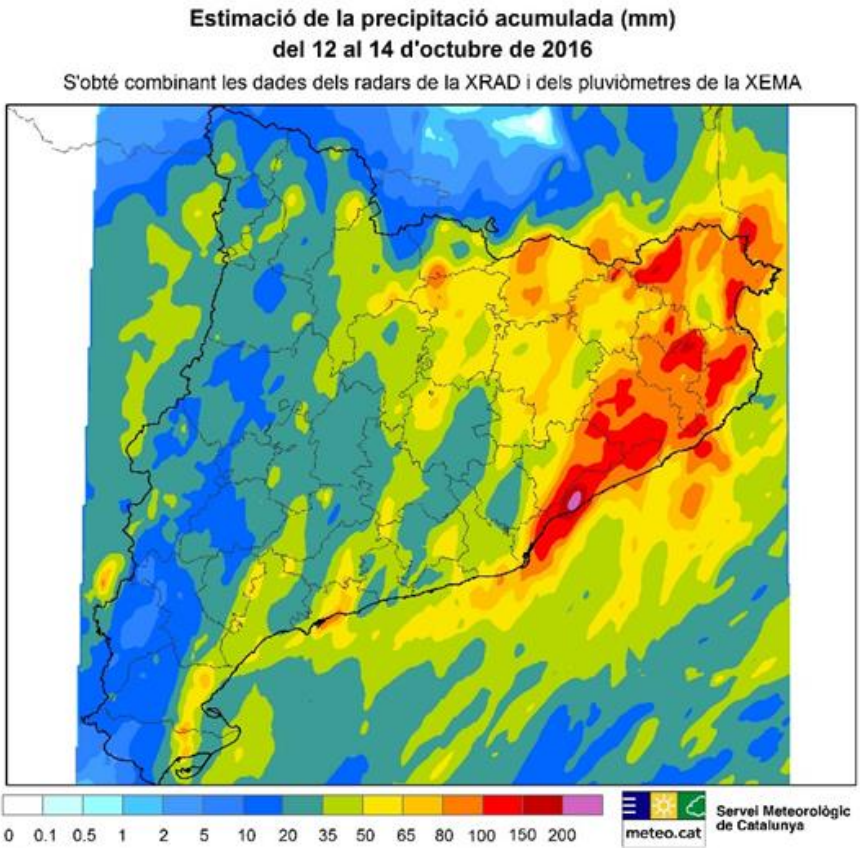

Figure 6 - *Cumulated rainfall in Catalonia between 12 and 14 October 2016 (Source: SMC).*

The XOM collaboration and fieldwork through the app allowed us to collect over 200 observations on the effects of the episode, most of them in the Maresme region (Fig. 7, 8). Throughout the episode, XOM members made some 50 warnings about rain intensity, rough sea conditions and windstorms, amongst others. More than 480 tweets, 71 posts on Facebook and 8 posts on Instagram were posted in connection with this episode. With the help of FLOODUP, visual information concerning this episode was also obtained. The Maresme region is crossed by numerous streams in the Coastal Range. They are characterized by their steep slope, they only carry water when heavy rains occur, and they can cause serious damage since they all run through urban areas (Fig. 7). Since these are ungauged catchments, rainfall data and observations of water level and impacts are very useful to reconstruct the event. In this event, the images showed how the water height and speed was important and affected communication infrastructure, (highway, roads, streets, etc.) as well as partially destroying the sewer network (Fig. 8).

Figure 7 - *Photo of the flooded area in Vilassar de Mar (Source: Twitter FLOODUP).*

Figure 8 - *Damages to the pavement caused by floods in Vilassar de Dalt (Source: FLOODUP).*

According to the official rainfall network of SMC (XEMA), 256.5 mm were recorded in Cabrils over the three-day period (234.1 mm in 24h, Fig. 9) but the big difference in comparison with other nearby stations cast doubts about accuracy. Citizen collaboration through the XOM corroborated this value, as they recorded 290.5 mm (257 mm in 24 hours) and 200.3 mm (176.2 mm in 24 hours) in Vilassar de Mar and Teià, respectively (Fig. 9). METEOCLIMATIC also corroborated this information, with maximum cumulated precipitation of 296.2 mm and 223.6 mm in Vilassar de Mar and Premià de Mar, respectively. The maximum intensity was recorded in Cabrils by a XEMA station with 84.4 mm in 30 minutes, showing the extraordinary magnitude of this rainfall event.

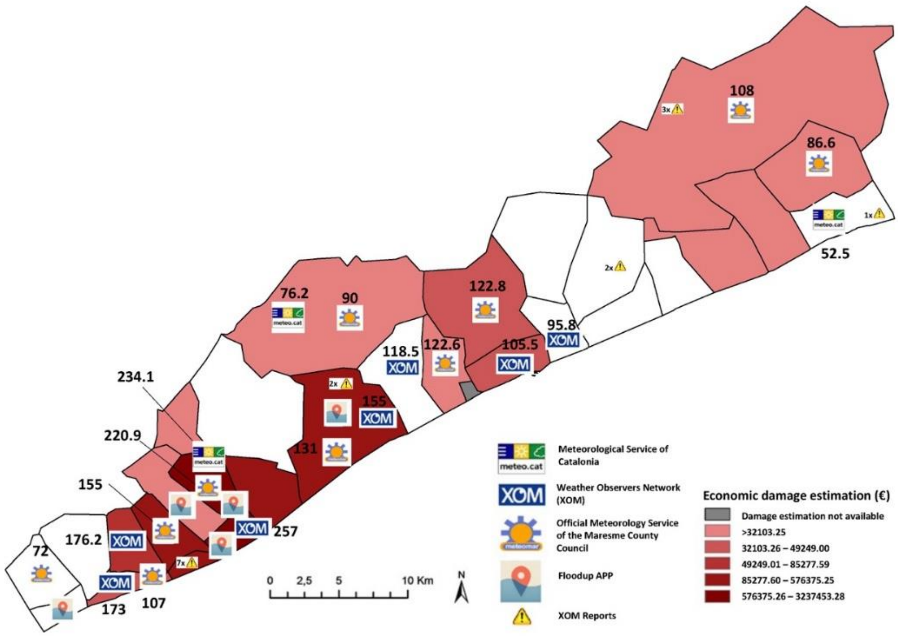

Figure 9 - *Map of the Maresme episode with the available information. The municipalities are coloured according to the economic losses as estimated by each Town Hall concerned. Precipitation (mm) refers to 24 h. (Source: Llasat-Botija et al., 2019).*

FLOODUP allowed 342 impacts to be identified. The study by Cortès *et al.* (2018) showed that, in Catalonia, it is possible to obtain a relationship between accumulated precipitations over 24 hours and the likelihood of serious damage estimated by the Insurance Compensation Consortium (CCS). In the case of October 2016, the correlation between CCS compensations for flood damages in each municipality and the maximum daily precipitation registered is 0.7. Taking into account that other factors also influence the amounts paid (Cortès *et al*., 2018), we can consider this correlation relevant. Figure 10 shows the relationship between the compensation paid by the CCS to each municipality, the estimate made by the city council and the total rainfall of the event. It is observed that the city council estimates a higher amount than the CCS. This is not unusual, because there are some urban assets that are not covered by CCS. The relationship between rainfall and damages is adjusted to an exponential law, in which from a certain value of the cumulative total precipitation (between 150 and 200 mm) economic damage quickly increases. Teià (3) stands out for having a high precipitation, but their damages were below the curve (lower population density, more resilient buildings due to high GDP). Pictures collected through FLOODUP highlighted the largest accumulation of water in Premià de Dalt (4) and

Premià de Mar (5), located downstream, despite the apparently low rainfall recorded in situ. Although the high water level could be the result of rainfall in the upper part of the basin, data provided by four METEOCLIMATIC stations located in Premià de Mar show accumulated values above 200 mm, that also justify the floods in situ. The picture from Vilassar de Mar (1) (Fig. 7), downstream of Cabrils (2), allows us to see the stream overflow and helps us to understand the tremendous scope of the damage. The gap from the curve shown in the cases of Vilassar de Mar and Premià de Mar is justified by the high vulnerability of both villages because they are crossed by the national road, the railway track, and are at the mouth of the streams that overflowed.

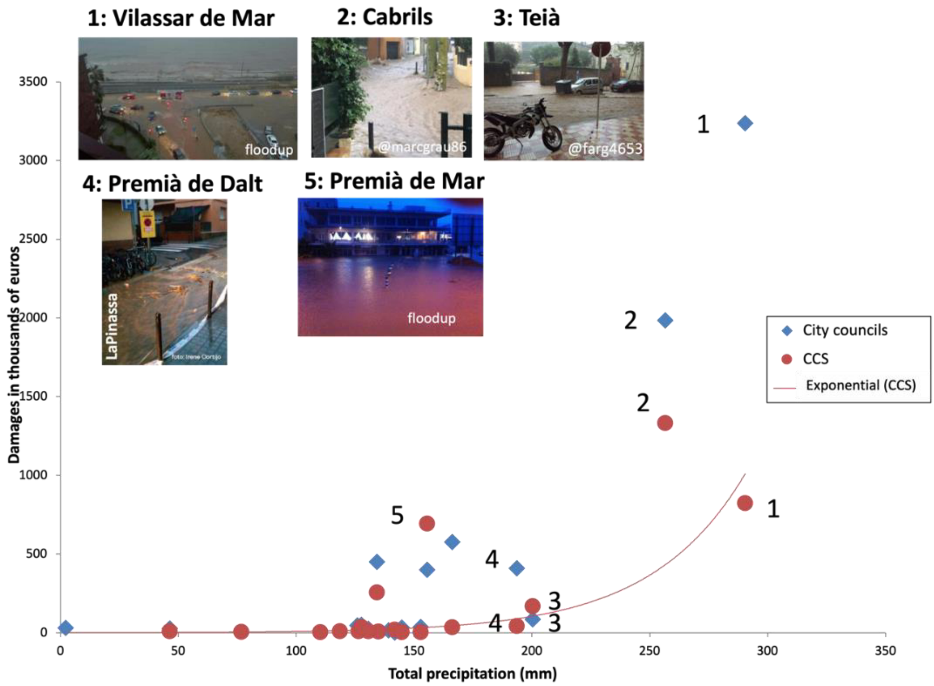

Figure 10 - *Relationship between the economic assessment of damages made by the Municipalities and the amounts paid by the CCS (€) with the total precipitation in the municipality (mm). (Source: Llasat-Botija et al., 2018).*

5. Conclusion

Throughout this paper, the FLOODUP project has been presented as a tool to improve flood risk awareness and available information for research. It has been observed that hands-on and participatory activities promote greater engagement among the population in helping to protect and prepare for natural hazards. It is also an opportunity for citizens to participate closely with researchers and provide help. A close follow-up and respectful relationship can allow us to build a lively and enriching community for all.

The use of technology such as the app or Twitter allows for fluid and almost real-time communication. It also makes it possible to share information among the population. However, there are some issues to be taken into account. The low percentage of registered users once the app gets downloaded shows that registration and privacy management are sensitive aspects in this type of project. Other obstacles to participation have been identified. The first is related to the time and location of the event in relation to the collaborator's coordinates. The second issue is associated with technological difficulties and barriers (for example, not having enough free space on mobile phones to save images). A third issue to be taken into account is recognition of citizen participation. In this case the project has difficulties due to competition with the media, especially regional TV broadcasters, which also collect images. The expectation that citizen contributions will appear on the weather news on TV, makes it the main channel where photographs are sent by citizens. Finally, a fourth question to take into account is the complexity of developing and maintaining tools like the mobile application.

Citizen science is an important source of information to increase available data—especially from remote or under-reported locations—, to identify differences in the distribution of impacts through more detail, and to validate meteorological observations. In relation to weather and hydrological information, the case study presented (October 2016) shows the usefulness and importance of having "weather stations and observation points" distributed across the territory, especially when it comes to episodes with concentrated precipitation both in terms of time and space, as large variations can occur from one point to another nearby. This type of network of volunteer observers is highly appreciated and is an important asset to the existing network of official stations. Pictures and videos can also contribute in a useful way to hydrological modelling or to understanding damages thanks to the visual and detailed information provided by citizen observations.

Finally, a project such as FLOODUP should be coherent and rigorous in its objectives and applications, while being flexible enough to adapt to social and technological changes over time and taking into account the comments and suggestions of the participants.

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The development of technology during the Anthropocene has affected science and the ways of "doing science". Nowadays, new technologies help scientists of several disciplines by facilitating knowledge and how to manage it, but also allow for collaborative science, the so-called "Social Science", where everyone can be a scientist and be involved in providing data and knowledge by using a computer or a smartphone without being a specialist. But is it really that simple? Actually, the daily and integrated use of different digital technologies and sharing platforms, such as social media, requires important reflections. Such reflections can lead to a rethinking of epistemologies and scientific paradigms, both in human geography and social sciences. This volume titled "Information Technologies and Social Media: New Scientific Methods for the Anthropocene" includes 10 chapters exploring some changes related to the way to do science with a multidisciplinary approach. From classroom experiences to the use of Citizen Science, from Artificial Intelligence use to how Social Media can help researchers, the book reflects on the ICT influence during the last few decades, exploring different cases, complementary perspectives and point of views.

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