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The deadliest storm of the 20th century striking Portugal: Flood impacts and atmospheric circulation

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SUMMARY

The deadliest storm affecting Portugal since, at least, the early 19th century, took place on the 25 and 26 November 1967 causing more than 500 fatalities. This work aims to assess the most relevant aspects of this episode. This includes describing the associated meteorological conditions and key hydrological characterisation such as the level of exceptionality of the observed precipitation at different temporal scales, or the estimation of peak discharge values in 20 small river catchments affected. Additionally, from a human impact perspective we provide a full account of all the main socio-economic impacts, particularly the numbers and location of victims (dead, injured, homeless and evacuated).

Based on the sub-daily time series of a representative station, and its Intensity–Duration–Frequency curves, we have found that the exceptionality of this rainfall event is particularly linked to rainfall intensities ranging in duration from 4 to 9 h compatible with return periods of 100-years or more. This range of time scale which are similar to the estimated concentration time values of the hydrographic basins affected by the flash flood event. From a meteorological perspective, this episode was characterised by strong convection at the regional scale, fuelled by high availability of moisture over the Lisbon region associated with a low pressure system centered near Lisbon that favoured the convective instability.

Most victims were sleeping or were caught by surprise at home in the small river catchments around the main Lisbon metropolitan area. The majority of people who died or who were severely affected by the flood lived in degraded housing conditions often raised in a clandestine way, occupying flood plains near the stream beds. This level of destruction observed at the time is in stark contrast to what was observed in subsequent episodes of similar amplitude. In particular, since 1967 the Lisbon area, was struck by two comparable intense precipitation events in 1983 and 2008 but generating considerably fewer deaths and evacuated people.

1. Introduction

Flash floods induced by extreme precipitation events are one of the most life-threatening hazards in western Iberia (Fragoso et al., 2010; Liberato et al., 2012; Trigo et al., 2014). This fact is in line with many other regions of the world, where flooding events represent one the most frequent and costly natural hazards. Moreover, while most floods are originally triggered by favouring meteorological conditions, such as extreme precipitation or early snow melt associated with a heatwave, they are often amplified by undesirable human interference such as urban development and/or vegetation clearing (Smith and Ward, 1998). In particular, humans can alter river catchments in such a way that influences the magnitude and behaviour of floods (Nott, 2006).

Recently, some of us have developed a long-term database of hydrological events for Portugal, since 1865, within the scope of project DISASTER. The DISASTER database comprises 1621 flood cases for the period 1865–2010 that were responsible for a combined death toll of 1012 people and more than 40,000 homeless people (Zêzere et al., 2014). More than half of these fatalities took place in a single event in November 1967.

On 25–26 November 1967 heavy precipitation occurred with unprecedented intensity around the Lisbon metropolitan area,

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soon followed by flash flooding and a burst of landslides in the peripheries of Lisbon (Zêzere et al., 2005) causing significant socio-economic impacts. Without a proper warning system installed, according to Ramos and Reis (2002) 700 people died as a consequence of the floods on the heavily populated metropolitan area of Lisbon. Additionally, almost 900 people lost their homes and several road and train communications were disrupted. The official number of dead people was 495, but at that time the media were strictly controlled by the government and the catastrophe numbers could have been kept lower for political reasons. According to the DISASTER database the death toll reached 522 casualties (Zêzere et al., 2014), while unofficial assessments indicate more than 700 deaths.

It should be noted that most flood occurrences in Portuguese territory fall into two main distinct types, namely: (a) flash floods, usually affecting small river catchments, especially in urban areas (e.g., Ramos and Reis, 2002; Fragoso et al., 2010; Liberato et al., 2012) resulting from short bursts of precipitation and (b) floods in the major river basins, including the international rivers (Tagus, Douro, Guadiana) that are caused by several days (even weeks) of continuous precipitation (e.g., Ramos and Reis, 2002; Trigo et al., 2014).

Overall, this was the deadliest storm in Portugal during the 20th century and the deadliest natural hazard since the 1755 Lisbon earthquake, not accounting heat waves. Nevertheless, to the best of our knowledge this extreme hydro-meteorological episode was never studied in detail. Part of this apparent negligence to assess such an extreme event may be due to the unfavourable political context of the time. However, we should recognize three additional factors that have contributed for the inexistence of an in-depth analysis of such extreme event both in the Portuguese and international literature until now: (1) the absence of a dynamic meteorological and hydrological research community, (2) the unavailability of a high resolution precipitation dataset covering the entire territory and (3) the inexistence of a list of places with the affected people and socio-economic impacts. These last two limitations were overcome to a large extent in recent years. Firstly, a comprehensive list of people affected (fatalities, injured, displaced, evacuated and disappeared) has been obtained through the DISASTER database (Zêzere et al., 2014). Secondly, a new high density daily precipitation gridded dataset developed by the Portuguese and Spanish meteorological offices is particularly appropriate for this study and was already used to rank extreme precipitation events in Iberia (Ramos et al., 2014).

The aim of this work is to evaluate and characterise the impacts of the November 1967 floods, but equally to probe the atmospheric circulation conditions associated to such an extreme event. To achieve these goals, the following objectives must be addressed:

(1) To determine the spatial distribution of precipitation anomalies using a recent high resolution dataset for Portugal.
(2) To characterise the impacts and spatial distribution of flash floods in Lisbon and 14 surrounding municipalities around the Lisbon area.
(3) To assess the role played by the large-scale atmospheric circulation.

2. Datasets and methodology

2.1. Historical sources

The main historical data source used here corresponds to the recent dataset of flooding and landslide events that took place in Portugal since 1865 (Quaresma, 2009) and aggregated within the scope of DISASTER project (Zêzere et al., 2014). The main objective of the DISASTER project was precisely to construct a database on hydro-geomorphologic disasters that have occurred in Portugal in the last 150 years, based on information available within several daily Portuguese newspapers. The DISASTER database provides detailed information on each individual hydro-meteorological case including; (1) its location, (2) type (flood or landslide), (3) occurrences date, (4) date of the corresponding newspaper publication and (5) involved rescue entities. Additionally, this database often makes available further contextual information for each event and the nearby affected town/region, including the number of (i) human fatalities, (ii) people injured, (iii) people disappeared, (iv) homeless people, (v) people evacuated as well as the overall socio-economic costs.

The DISASTER database was used to extract the DISASTER cases of the November 1967 event. A DISASTER case is a unique hydro-geomorphologic occurrence – flood or landslide –, which independently of the number of affected people, caused casualties, injured or missing, evacuated or homeless people, and is related to a unique space location (Zêzere et al., 2014). A DISASTER flood event in the database is a set of DISASTER cases sharing the same trigger which can have a widespread spatial extension, thus including floods of different rivers (Zêzere et al., 2014). In addition, the flood of a unique river can affect different places and be considered as different flood cases.

Usually, press data does not provide complete and specific information about the space location of DISASTER cases, but this was not the case of the November 1967 event. This event was reported in three different editions of the 'Diário de Notícias' that were published on the 26 November 1967 giving very detailed descriptions and photos of damages, which were useful for the georeferencing process. Therefore we were able to georeference with a point shapefile all the reported DISASTER cases that caused casualties, injured or missing, evacuated or homeless people during the November 1967 event. The precision of DISASTER cases location of this event has two classes depending on the quality of the case description in the newspapers: (i) location based on local toponymy/name of the street (accuracy associated to 1:10,000 scale); (ii) location based on local geomorphology and river path, as they were at the time of the flash flood (accuracy associated to 1:25,000 scale).

2.2. ECMWF reanalysis

We have used the ERA-40 European Centre for Medium-Range Weather Forecasts (ECMWF) Reanalyses (Uppala et al., 2005), namely the geopotential height fields, temperature, wind, divergence data and the specific humidity at all pressure levels. In addition, mean sea level pressure (SLP) and total column water vapour (TCWV) for the Euro-Atlantic sector (100°W-50°E, 0°N-70°N) were also utilized. These fields were extracted for November 1967, at full temporal (six-hourly) and spatial (T159; 1.125° regular horizontal grid) resolutions available, to analyse large-scale meteorological conditions associated with the extreme event.

2.3. Precipitation datasets

To characterise the distribution and spatial extent of this extreme event we have used 'IB02' the most comprehensive database of daily precipitation available for mainland Portugal (PT02, Belo-Pereira et al., 2011) and Spain (SPAIN02, Herrera et al., 2012). The 'IB02' database spans from 1950 to 2008, with a spatial resolution of 0.2° latitude/longitude grid. This database is based on a dense network of rain gauges, combining with a total of more than eight hundred stations over Portugal, and two thousand over Spain all quality-controlled and homogenized. This large number of stations is crucial to allow meaningful regional assessments of