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FLASH FLOOD IN MADEIRA ISLAND IN AUTUMN 2012

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I. INTRODUCTION

Madeira (32º75'N and 17º00'W) is a Portuguese mountainous island with the highest peaks above 1800 m (Figure 1), where after the disaster occurred on 20 February 2010, the island has shown to be vulnerable to the flood occurrences suffering significant socio-economical losses. During the autumn and winter seasons the precipitation regime in Madeira is frequently affected by the passage of mid-latitudes systems, such as extratropical cyclones and frontal systems, in opposition to summer season, when the Azores High is the dominant system observed in the North Atlantic (subtropical) Ocean. In the last years some works related to precipitation in Madeira have shown the importance of specific studies related to extreme rainfall events in the island. The analysis of some events with different methods and meteorological data represents an important step for a better understanding of the mechanisms responsible for the genesis and flood occurrences in the Madeira island.

Luna et al. (2011), pointed out that on 20 February 2010, the main process responsible for converting the high moisture content of the southern flow associated with the passage of a frontal system was the orographic lifting imposed by Madeira topography. Couto et al. (2012) linked this southern flow to another structure, known as atmospheric rivers (ARs). They found that the high rainfall amounts observed during the winter 2009/2010 in Madeira's highlands were directly related to the orographic forcing. Their analysis have also identified that the development of precipitation over the island can be intensified by the passage of weather systems like low pressures and cold fronts. Coupled to these frontal systems, the presence of ARs structure was identified, which together with the orographic lifting induced the formation of denser clouds, although with weak vertical development.

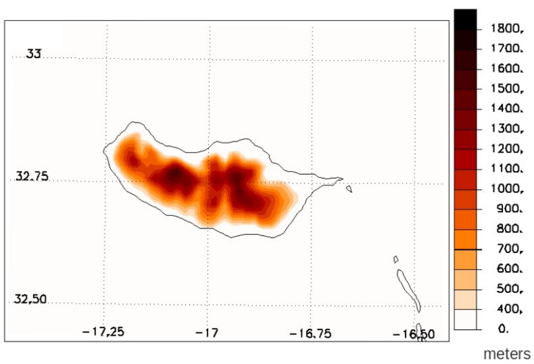

FIG. 1: Madeira's orography (m) obtained from the gtopo30 database with 1 km resolution.

The main purpose of this study is the analysis of a small period of intense rainfall records in Madeira island in autumn 2012 that favoured the occurrence of landslides in some spots of the island, mainly in the Northern region. The main motivation is to identify the different processes leading to the generation of high rainfall amounts in Madeira.

II. DATA AND CASE STUDIES

Rain gauge data provided by the Instituto Português do Mar e Atmosfera (IPMA), as well as radiosonde data obtained from University of Wyoming were analysed for the period between 25 October and 06 November 2012. During this period and based on the rain gauge data analysis, two main events were chosen to be simulated at high resolution (1 km): 30 October and 05 November, when the highest amounts of precipitation in Madeira's highlands and landslides were observed, respectively.

The MESO-NH non-hydrostatic model (Lafore et al., 1998) was used with two different configurations: a single domain at a resolution of 25 km; and a three nested grids with 16, 4, and 1 km resolution. The main characteristics associated to the simulations are presented in Table 1. The initial and boundary conditions, updated every 6 h, were obtained from ECMWF analysis. The total precipitable water obtained from the Atmospheric Infrared Sounder (AIRS) was also used. The AIRS is on board the Aqua Satellite and has a spatial resolution of 13.5 km at nadir. The AIRS data have been useful in the identification of narrow bands (plumes) with high moisture, also known as atmospheric rivers. In this study we considered ARs as a filament with precipitable water above 40 kg/m^2.

Table 1: Configuration of the simulations.

Horizontal resolution	**25 km**	**16 km**	**4 km**	**1 km**
Horizontal dimensions	150x150	60x60	80x80	100x72
Time step	30s	18s	6s	2s
Initial time	28 OCT and 03 NOV at 12 UTC	29 OCT and 04 NOV at 12 UTC	29 OCT and 04 NOV at 18 UTC	29 OCT and 04 NOV at 18 UTC
Run time	60 h	42 h	36 h	36 h
Parameterizations				
Microphysics	ICE3	ICE3	ICE3	ICE3
Convection	KAFR	KAFR	NONE	NONE
Surface	SURFEX	SURFEX	SURFEX	SURFEX
Radiation	ECMWF	ECMWF	ECMWF	ECMWF
Boundary layer	TKE equation	TKE equation	TKE equation	TKE equation

III. RESULTS AND CONCLUSIONS

Intense precipitation was observed in different stations along the period under study in which a maximum daily rainfall amount of 295 mm was measured on 30 October at Areeiro station. On the other hand, isolated landslides were observed in the North of the island on 05 November. The accumulated precipitation simulated in the inner domain (1 km resolution) on each case is shown in Figure 2. For the first case (30 October), the largest amounts were simulated over the central part of the island (Figure 2.a), such as registered in the meteorological stations. In the second case (05 November; Figure 2.b), also in accordance with observations, low precipitation was reproduced over the south part of the island, while the maximum was simulated over the north, where the landslides occurred. In Figure 2, the simulations pointed out the prominent role of orography in the precipitation distribution over the island.

The 25 km simulation (Figure 3) shows that the largest values of water vapor are simulated along a narrow band crossing the North Atlantic Ocean with values above 40 mm. This simulation confirms that the identification of ARs using mesoscale numerical models is possible. The satellite observations allows to identify on October 30 (Figure 4), a band with high precipitable water, showing the passage of an AR over the island in this period with values above 50 kg/m^2. In the second case, heavy rainfall was favoured by the passage of a convective system over the island. The possibility of severe weather development was confirmed from some instability indices obtained from radiosonde observations (not shown here), despite the low CAPE values, which indicates a weak instability environment. Therefore, the moist air at low-levels is lifted enough to attain the instability in some cases.

The rainfall episodes presented in this work represented high-impact in surface, with damages being reported as a consequence of flooding on 05 November. In general, the period was marked by heavy precipitation, mainly on 30 October. The large-scale environment was characterized by the development of an extratropical cyclone near the island, where the frontal structure acting over the archipelago is evident in the first case simulated. A remarkable feature is the fact that in this case, coupled to the cold front, the main moisture source in low-levels was related to an AR structure passing over the island. On 05 November the passage of a convective system over the north region favoured the landslides, however the precipitation was more localized than on the 30 October. The precipitation in the island depends both of local and large-scale environments, and several days with intense precipitation contributed to the landslides on 05 November 2012. The AR observed on 30 October, bringing moist air poleward was important for the flooding occurrence on 05 November, such as it was the precipitation occurred in the days prior to the 20 February 2010 catastrophe.

IV. ACKNOWLEDGMENTS

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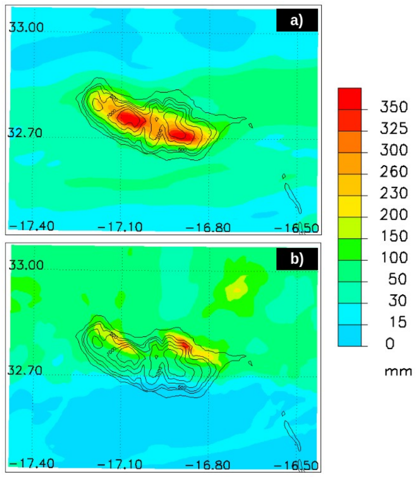

FIG. 2: The shaded areas represent the daily accumulated precipitation (mm) simulated in the inner domain with the MESO-NH model for (a) 30 October 2012, and (b) 05 November 2012. The solid lines represent Madeira orography (m) obtained from gtopo30 database.

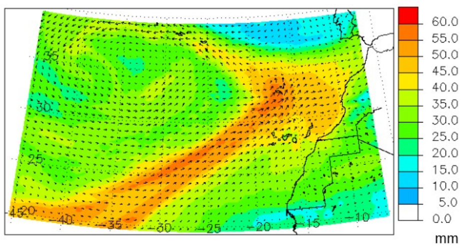

FIG. 3: Thickness of Water Vapor (mm) and horizontal wind vectors at model level 18, approximately 1 km above the surface, both simulated with 25 km resolution for 30 October 2012 at 09 UTC.

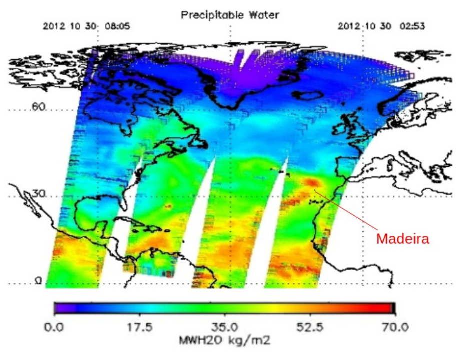

FIG. 4: Satellite image of precipitable water obtained from the AIRS for 30 October 2012 at 08:05 UTC.