Advances in knowledge 10 years after the torrential rains in Madeira Island (Portugal)

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1. INTRODUCTION

Back to 20 February 2010

Madeira experienced an event of **extreme precipitation**, with **high impact at the surface**, causing more than **40 deaths** and **damage** estimated at **millions of euros**.

The **greatest impact** was observed in the **southern region**, where flash floods induced numerous landslides.

MADEIRA ISLAND

- It is **located at 32°75'N and 17°00'W**, and it is the largest island of the archipelago with ~740 m² and 250 thousand inhabitants.

- It has an **east-west elongated form**, with a **central mountain chain** and peaks from 1500 m up to above 1800 m eastward, as well as **deep valleys** and **cliffs**.

GOALS

This work intents to show some advancements in knowledge of heavy precipitation events (**HPE**) in Madeira found in the last decade, providing **an understanding** of the main **mechanisms** and **atmospheric conditions** relevant for the establishment of **extreme rainfall over the island**.

2. Couto et al. (2012)

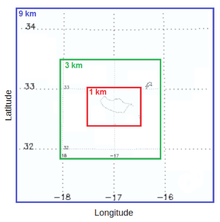
Remote sensing

The **total precipitable water** field was extracted from the AIRS data products, and downloaded for a domain covering the **North Atlantic Ocean.**

Numerical modelling

Meso-NH (*Lac et al., 2018*)

In the first set of simulations, **four experiments** were performed with three horizontal nested domains, and for **4 HPE in winter 2009/10**.



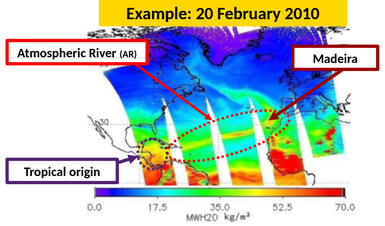
Vertical dimension: 45 levels.
Initial fields: ECMWF analyses.
Standard physical parametrizations package.

The analysis raised two aspects about HPE over the island !!!

1» Large scale

A **cyclone** and **frontal systems** affecting the island.

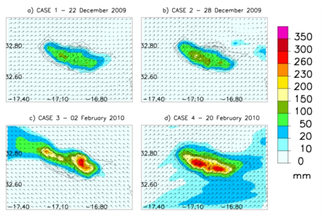
Example: 20 February 2010



ARs coupled to frontal systems

2» Orographic effect

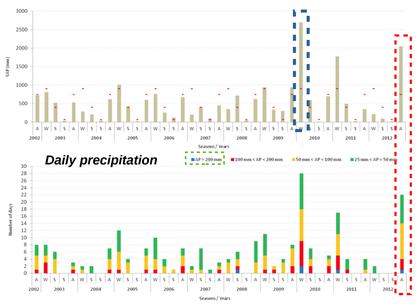
Simulations showed **maximum** of accumulated precipitation in the **highlands**.



Total accumulated precipitation (mm) simulated at 1km. (Source: Couto et al., 2012)

3. Couto et al. (2015)

Seasonal accumulated precipitation



(Source: Couto et al., 2015).

The analysis of the **precipitation** in Madeira highlands **over a 10-year period** showed **dry summers** and the **highest rainfall amounts** in the **winters**, although with some significant events occurring also in autumn and spring seasons.

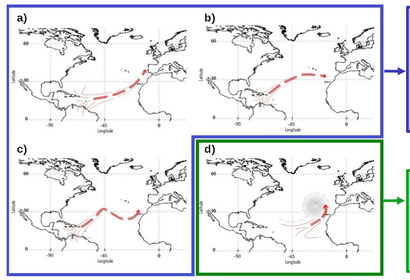
- **From the maximums**

Winter 2009/10:
The wettest in the 10-yr period.

Autumn 2012:
The second wettest period.

Extreme events:
Not so frequent during the period.

Furthermore, it was found that **tropical moisture** transported through the ARs **may reach the island** with **different intensities** and **orientation** during the **winter** seasons (Figure below). However, **for the 10 winter periods**, the **ARs were not the sole factor producing HPE in Madeira.**



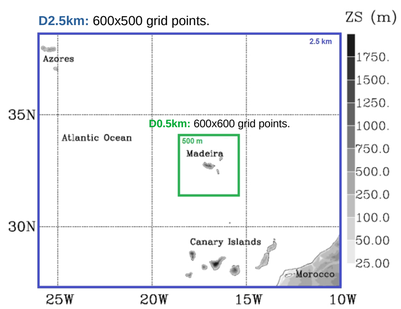
TYPE 1: narrow corridors (few hundred kilometers of width, thousands of kilometers of length), with moisture source in the Caribbean Sea, but with different kind of pathways.

TYPE 2: This pattern seems to be associated with a cyclonic circulation near the island, and with moisture source in the central to eastern part of the tropical Atlantic ocean.

4. Couto et al. (2016)

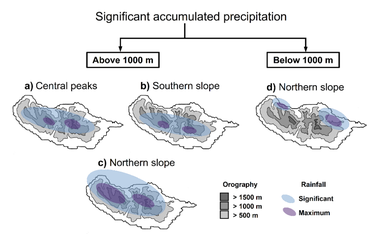
In the second set of simulations, the model was configured with a larger domain of **2.5 km resolution** and an inner domain of **0.5 km resolution**.

» 8 numerical experiments
for 4 HPE in autumn 2012.



Horizontal dimension: Two nested domains.
Vertical dimension: 55 levels.
Initial fields: ARPEGE analyses.

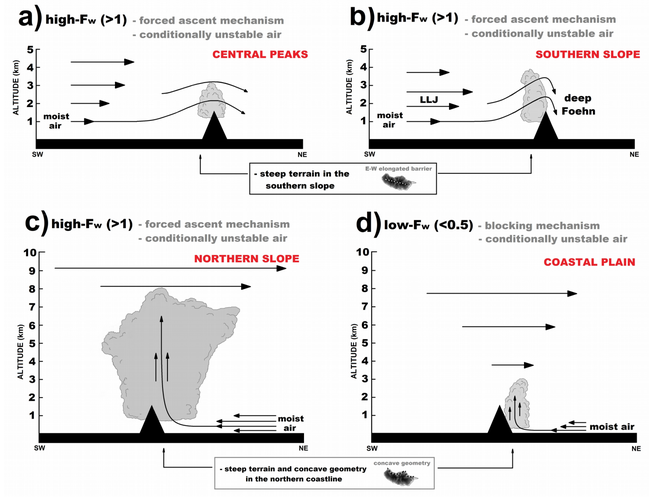
All the significant events in autumn 2012 were simulated confirming the **orographic effect** in the **accumulated precipitation**. The most interesting result found was the occurrence of **maximums values** in **different regions** over the island. For example, over the highlands in the central peaks and southern/northern slopes, or in the coastal plain at lowlands.



Schematic representation of the rainfall patterns over the Madeira verified from the periods simulated (Source: Couto et al., 2016).

5. Couto et al. (2017)

From the simulations of Couto et al. (2016) it was possible to explain the **causes** for the **distinct rainfall patterns**, and the **atmospheric environments associated**. Variations in the **atmospheric environments** (*e.g., airflow, CAPE, PWat, moist Fr number*), jointly with the **orographic forcing** may produce **convection in distinct regions** of the island, resulting in **different rainfall patterns**.



Schematic representation of some features identified in the four situations examined. The vertical cross-sections have a SW-NE orientation,and the elements drawn are the vertical wind profile over the windward region, and the orographic effects created in response to this flow, namely producing convection over the island (Source: Couto et al., 2017).

6. Conclusions

Ten years later, the advances in the understanding of significant precipitation in the Madeira is evident. In order to understand the events, it should be kept in mind that **Madeira** represents a **three-dimensional obstacle** and the **physical processes** over there **are initiated in function of the airflow dynamic**, mainly because it may **go around** or **above** the island. The studies show how different events may occur, since the **formation** or **enhancement** of the **precipitation** over the island **is totally dependent on the geographic aspects** and **atmospheric conditions** associated with each precipitating event.

Acknowledgements

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References

Couto FT, Salgado R, Costa MJ (2012) Analysis of intense rainfall events on Madeira Island during the 2009/2010 winter, *Nat. Hazards Earth Syst. Sci.,* 12, 2225–2240. https://doi.org/10.5194/nhess-12-2225-2012.

Couto FT, Salgado, R., Costa, M.J. and Prior, V. (2015), Precipitation in the Madeira Island over a 10-year period and the meridional water vapour transport during the winter seasons. *Int. J. Climatol.*, 35: 3748-3759. https://doi.org/10.1002/joc.4243.

Couto FT, Ducrocq V, Salgado R, Costa MJ (2016) Numerical simulations of significant orographic precipitation in Madeira Island. *Atmos. Res*. 169: 102– 112. https://doi.org/10.1016/j.atmosres.2015.10.002.

Couto FT, Ducrocq V, Salgado R, Costa MJ (2017) Understanding significant precipitation in Madeira island using high-resolution numerical simulations of real cases. *Q.J.R. Meteorol. Soc*., 143: 251-264. https://doi.org/10.1002/qj.2918.

Lac C, and Co-authors (2018) *Geosci. Model Dev.*, 11, 1929–1969. https://doi.org/10.5194/gmd-11-1929-2018.