Análise de Episódios de Precipitação em Portugal

Analysis of Precipitation Episodes over Mainland Portugal

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Understanding the intensity and duration of rain events and other characteristics is important. In this study hourly and daily observations of precipitation at 16 locations over Mainland Portugal were sorted by classes and counted how many data elements are in each class, for consecutive days or hours. The daily precipitation series were divided by wet episodes. The definition of wet episode is a consecutive number of days with precipitation above 1 mm/d, in a given class. This methodology yielded 452 wet episodes. The statistical properties of these episodes were evaluated. The distribution of the daily precipitation showed events up to three consecutive days but it was not possible to establish a link with the precipitation class. For the majority of the stations it was not observed events lasting longer than three days. In all locations it rains for more than six hours. Above this threshold only some stations recorded non-single events that last up to 10 hours. The number of events counted by class diminishes with the increasing duration of the episode and with precipitation class.

1. Introduction

Precipitation is a key variable in the climatic system. Understanding its behaviour can be of the uttermost importance for hydrological processes, water management, agriculture, precipitation, erosivity, runoff studies and landslides and floods, among others.

Located on the south-western part of continental Europe, Portugal's precipitation regime is highly irregular both at the intra-annual time scale and at the spatial scale. This high irregular precipitation regime can be explained by the large-scale circulation features. In wintertime the disturbances associated with the polar front predominated while in summertime the Azores high moves poleward being the prevailing system. Along with the seasonal variability, there is a spatial asymmetry that divides the north region from the south, with the latter being drier giving to precipitation a relevant spatial variability. These patterns are well documented in previous studies made by Corte-Real et al. (1998), Trigo and DaCamara (2000), Goodess and Jones (2002), Santos et al. (2005) and Costa and Soares (2009), to mention a few. The large scale circulation does not explain the interannual variability of Portugal's precipitation: switching between dry and wet years (Haylock and Goodess, 2004, Mourato et al., 2010). This, in part, can be accounted by a relationship with the North Atlantic Oscillation (NAO) (Ulbrich et al., 1999; Rocha, 1999; Antunes et al., 2006; Fragoso and Gomes, 2008).

Due to those irregularities Portugal's precipitation have been of special interest in a future climate conditions once the region may be vulnerable to a change in duration, intensity and frequency of precipitation. A downward trend in the annual and seasonal precipitation was identified (Trigo and DaCamara, 2000; Rodrigo and Trigo, 2007; Durão et al., 2009; Mourato el al., 2010), which had been related to a change in synoptic features over the North Atlantic area (Fernández-González et al., 2012).

In order to provide another insight on the precipitation variability, others authors tried to evaluate the precipitation simulated by different regional climate models, in representing the Portugal's complex precipitation variability (Costa et al., 2010; Soares et al, 2012; Cardoso et al., 2012).

In spite of the importance of the above mentioned studies it may interest to investigate other aspects of precipitation in particular those related with daily precipitation within a particular event context. In Portugal, several studies concerning the occurrence of precipitation events have been conducted. Many investigated precipitation as a case study, either because it was a severe precipitation episode (Brandrão and Fragoso, 1999; Fragoso and Gomes, 2008) or because the event was a trigger to other events. Ramos and Reis (2002) inferred the effects of extreme precipitation episodes on small drainage basins, and Zêzere et al. (1999) on triggering landslides for a particular region. A recent case study from Luna et al. (2011), Fragoso et al. (2012)

and Couto et al. (2012) evaluated the Madeira 2010 exceptional precipitation episode.

The above mentioned studies focused on a singular precipitation episode (hereafter wet episode). In this study, the authors intent to examine a collection of wet episodes that occurred in some cities of Portugal. This characterization of the daily precipitation, with respect to wet episodes, may be an important tool in accessing the features of those episodes. This study motivation is an attempted to classify wet episodes based on the daily circulation patterns and hence add value to precipitation simulations with NWP's models. Also, at this point, the present study is a preliminary analysis that will serve as basis for a more detailed research.

In section 2 are described the datasets and the methodology applied, and then in section 3 the main results are presented. Finally, some final remarks and future work are presented in section 4.

2. Methods and data

In this study one dataset was used: observed hourly precipitation for 16 different locations over Mainland Portugal (Fig.1), covering the time period from January 2001 to December 2010 provided by the Instituto Português do Mar e Atmosfera (IPMA, http://www.ipma.pt).

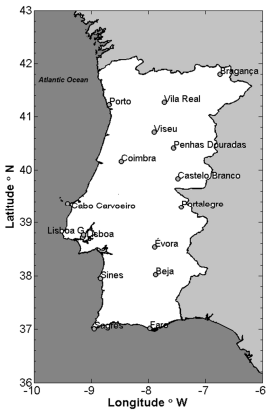

Figure 1. – *Location of the 16 weather stations with precipitation data over Portugal Mainland, used in this study.*

Daily totals from the hourly precipitation were obtained at each location. For each station, the yearly anomalies relative to the 30 yr climatology were calculated. The 30 yr reference period ranges the years 1971 to 2000 and is of 882.1 mm. These series were subjected to a Mann-Kendall test to detect any trend (Sneyers, 1990) whose null hypothesis, H_0, is the absence of any trend. The trend was calculated using the least square linear fitting.

The Gamma function was fitted to the daily precipitation series, taking into account only wet days (days with precipitation above 1 mm/d). The fitness was evaluated using the Kolmogorov-Smirnov test for Goodness of Fit with the null hypothesis that the data comes from a Gamma distribution, against the alternative that it does not come from such distribution.

Following, the daily and the hourly precipitation were organized into classes (intervals, Table 1) and counted how many data elements are in each class, for consecutive days or hours. By doing this one can established how many consecutive days or hours it rained in Portugal in the 2001-2010 time period.

Table 1. Precipitation Classes.

Precipitation Classes (mmd^{-1} or mmh^{-1})
1 to 2
2 to 5
5 to 10
10 to 20
20 to 30
Above 50

To investigate further the behaviour of precipitation, the daily precipitation series were divided by wet episodes. Here, the definition of episode is a consecutive number of days with precipitation above 1 mm/d, in a given class, separated t least by a 24 hour dry period. To narrow down the number of episodes the following criteria we only considered:

1. The ten most intense episodes;
2. The ten episodes with the highest precipitation totals
3. The ten episodes with the longest duration.

This procedure yields a set of 452 precipitation episodes over Mainland Portugal. These rain episodes were analysed.

3. Results

The yearly precipitation series shows that within the decade (2001-2010) there were more dry years than wet marked by negative anomalies throughout of the stations (Fig.2). Although, locations like Porto, Viseu and Coimbra does not follow this pattern, flagging the spatial variability of Portugal's precipitation: the north part of the country being wetter than the south. More, the Penhas Douradas records show marked positive anomalies revealing the orographic characteristics of the station. The Mann-Kendall test was used to detect the series trend. No significant trends were found.

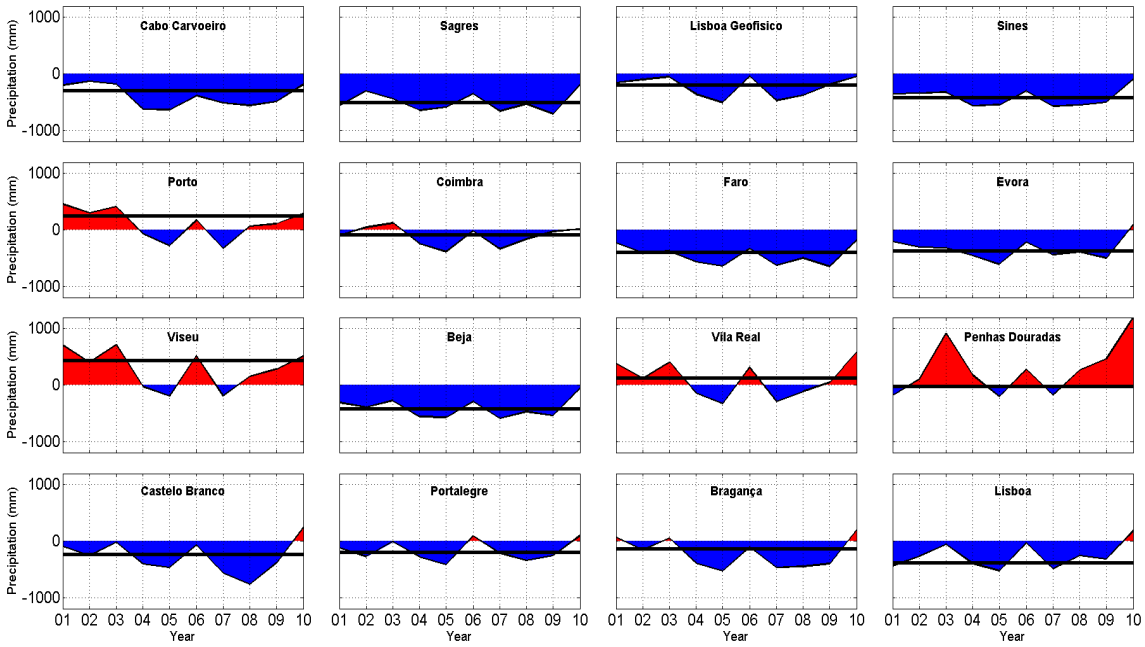

Figure 2. *Anomalies for the yearly total precipitation at the 16 locations. Positive/negative anomalies are depicted by the red/blue shaded areas. The straight line indicates the linear fitting of the series for the 10 yr time period. The anomalies were calculated relative to the 30yr climatological mean of 882.1 mm for the 1971-2000 periods for the whole Portugal region. The Mann-Kendall test was used to test if there is any trend (H0: no trend detected). No significant trends were found.*

The Gamma function was fitted to the daily precipitation series, taking into account only wet days. Since the cumulative distribution function (CDF) for each location behaves similarly, in Figure 3, is presented the CDF for four of the sixteen stations analysed. The fitness was evaluated using the Kolmogorov-Smirnov Test Godness of Fit. Half of the daily precipitation records are less than 10 mmd^{-1} with a median value of about 5 $mm.d^{-1}$. The test results show that the daily precipitation, at each location, are realistic represented by the Gamma distribution which can be useful to fill the gaps in the precipitation series.

Other fits like the log-normal distribution were also tested. It was found that there was no difference fitting the Log-normal and the Gamma distributions.

For each location the daily (Fig. 4) and hourly data (Fig. 5) was organized into classes or intervals.

In all analysed locations the rain events are more common for durations up to two consecutive days, throughout all precipitation classes. For some locations it rains for three consecutive days but it was not possible to establish a link with the precipitation class, except for Porto.

Singular precipitation events in the lower precipitation classes were found for more than three days.

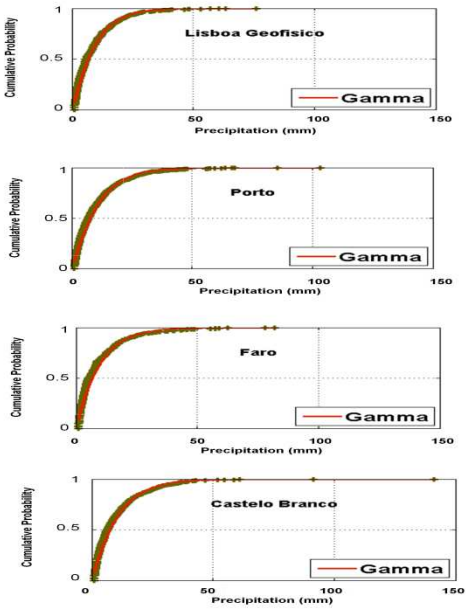

Figure 3*. Cumulative distribution functions for the observed daily precipitation and the fitted gamma distribution (red line).*

The number of events counted by class diminishes with the increasing of the number of days and with precipitation class. In all locations does not rain for more than six hours, with very few locations reaching the 8 consecutive hours and Penhas Douradas reaching the 12 consecutive hours. The

hourly precipitation follows closely the daily distribution pattern: the number of events counted by class diminishes with the increasing of the number of days and with precipitation class.

For each location, wet episodes were identified. These rain episodes were analysed regarding the frequency distribution. The most frequent durations are 2 and 6 days and the most frequent intensities are of 10, 15 and 20 mmd-1. The most frequent duration correspond to precipitation intensities ranges of 15mmd-1 to 30 mmd-1 and from 2 mmd-1 to 16 mmd-1. For these days the total precipitation varies from 35 mm to 60 mm and from 10 m to 93 mm, respectively.

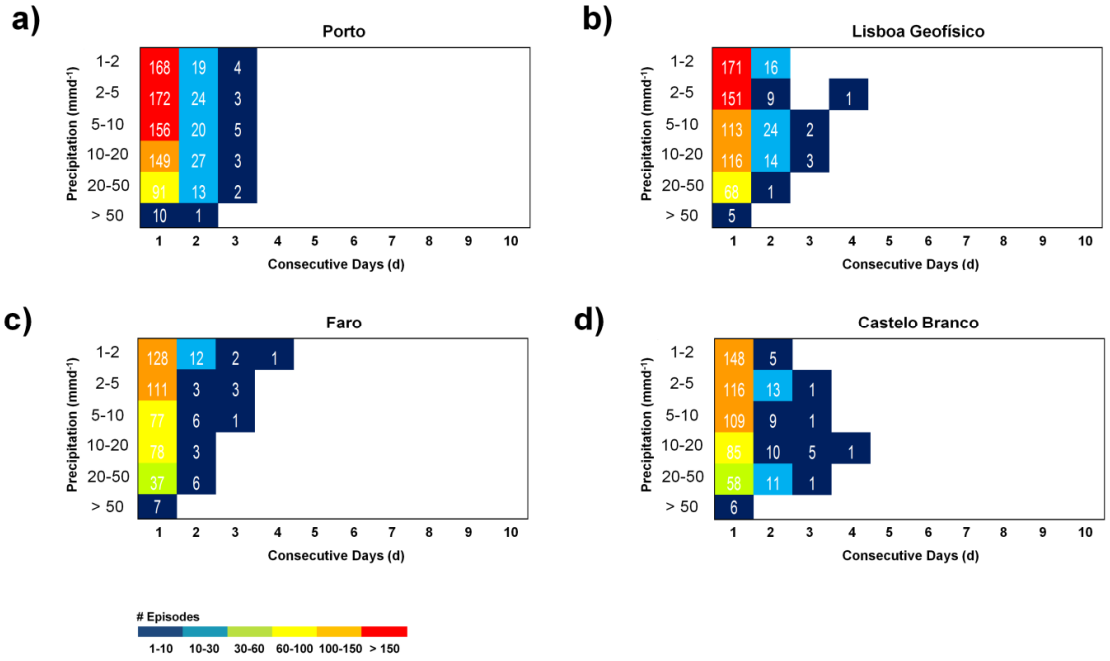

***Figure 4**. Episodes based on daily precipitation, for the following locations scattered over Mainland Portugal: a) Porto; b) Lisboa Geofísico, c) Faro and d) Castelo Branco. The histograms depict the number of consecutive days with precipitation in each of class, defined in Table 1.*

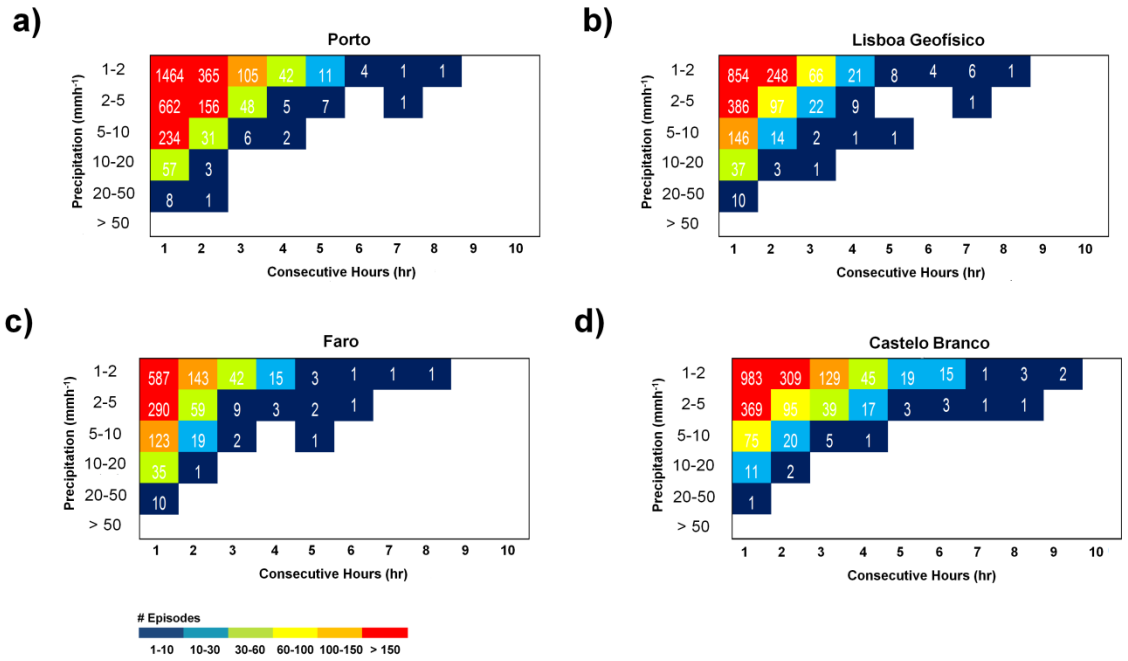

***Figure 5**. Same as Figure 4 but for the hourly precipitation.*

4. Final Remarks

In this study the observed hourly and the daily precipitation for several weather stations, over Portugal, were examined. The observed dataset was provided by the Instituto Português do Mar e Atmosfera (IPMA, http://www.ipma.pt) and consists of 16 different locations over Mainland Portugal, covering the time period from January 2001 to December 2010. The analysis intended to examine a collection of wet episodes that occurred in some cities of Portugal. The hourly and daily precipitation were divided into precipitation intervals and counted how many data elements are in each class, for consecutive hours or days. More, the daily precipitation series were divided by wet episodes. The authors purpose the following definition of episode as a consecutive number of days with precipitation above 1 mmd^{-1}, in a given class, apart at least by a 24 hour dry period. To the best of our knowledge there are no other similar studies, for Portugal, using this methodology.

The distribution of the daily precipitation showed that it is possible to found events up to three consecutive days but it was not possible to establish a link with the precipitation class. For more than three days it was found singular precipitation events for the lower precipitation classes. In all locations it rains for more than six hours, with some locations reaching the eight to ten consecutive hours. The number of events counted by class diminishes with the increasing of the number of days or hours and with precipitation class.

Regarding the wet episodes and due to the characteristics of the synoptic circulation the precipitation episodes identified are a cluster of different storms, leading to wet episodes with different characteristics of intensity and duration.

This study is a preliminary analysis. Is an attempted to classify wet episodes based on the daily circulation patterns that will serve as basis for a more detailed research.

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References

Antunes, S., Pires, O., and Rocha, A. (2006). Detecting spatio-temporal precipitation variability in Portugal using multichannel singular spectral analysis. *Inter. J. Climatol.*, 26(15), 2199-2212.

Brandão, C., and Fragoso, M. (1999). Extreme storms and rainfall erosivity factor in Évora (Portugal). Zeitschrift für Geomorphologie Supplement Volumes, 115, 113-123.

Cardoso, R. M., Soares, P. M. M., Miranda, P. M. A., and Belo-Pereira, M. (2012). WRF high resolution simulation of Iberian mean and extreme precipitation climate. *Inter. J. Climatol.*, doi: 10.1002/joc.3616 (*first published online*)

Corte-Real, J., Qian, B., and Xu, H. (1998). Regional climate change in Portugal: precipitation variability associated with large-scale atmospheric circulation. *Inter. J. Climatol.*, 18(6), 619-635.

Costa, A. C., and Soares, A. (2009). Trends in extreme precipitation indices derived from a daily rainfall database for the South of Portugal. *Inter. J. Climatol.*, 29(13), 1956-1975, doi:10.1029/97JD01012.

Costa, M. J., Salgado, R., Santos, D., Levizzani, V., Bortoli, D., Silva, A. M., and Pinto, P. (2010). Modelling of orographic precipitation over Iberia: a springtime case study. Adv. Geosci, 25, 103-110.

Couto, F. T., Salgado, R., and Costa, M. J. (2012). Analysis of intense rainfall events on Madeira Island during the 2009/2010 winter. Nat. Hazards Earth Syst. Sci, 12, 2225-2240.

Dünkeloh, A., and Jacobeit, J. (2003). Circulation dynamics of Mediterranean precipitation variability 1948–98. *Int. J. Climatol.*, 23(15), 1843-1866.

Durao, R., Pereira, M. J., Costa, A. C., Côrte-Real, J. M., and Soares, A. (2009). Indices of precipitation extremes in Southern Portugal–a geostatistical approach. Nat. Hazards Earth Syst. Sci, 9, 241-250.

Fernández-González, S., del Río, S., Castro, A., Penas, A., Fernández-Raga, M., Calvo, A. I., and Fraile, R. (2012). Connection between NAO, weather types and precipitation in León, Spain (1948–2008). *Inter. J. Climatol.*, 32(14), 2181-2196.

Fragoso, M., and Tildes Gomes, P. (2008). Classification of daily abundant rainfall patterns and associated large-scale atmospheric circulation types in Southern Portugal. *Inter. J. Climatol.*, 28(4), 537-544.

Fragoso, M., Trigo, R. M., Pinto, J. G., Lopes, S., Lopes, A., Ulbrich, S., and Magro, C. (2012). The 20 February 2010 Madeira flash-floods: synoptic analysis and extreme rainfall assessment. Nat. Hazards Earth Syst. Sci, 12, 715-730.

García, J. A., Serrano, A., and De la Cruz Gallego, M. (2002). A spectral analysis of Iberian Peninsula monthly rainfall. *Theoretical and Applied Climatology*, 71(1-2), 77-95.

Goodess, C. M., and Jones, P. D. (2002). Links between circulation and changes in the characteristics of Iberian rainfall. *Inter. J. Climatol.*, 22(13), 1593-1615.

Haylock, M. R., and Goodess, C. M. (2004). Interannual variability of European extreme winter rainfall and links with mean large-scale circulation. Inter. *J*. Climatol., 24(6), 759-776.

Luna, T., Rocha, A., Carvalho, A. C., Ferreira, J. A., and Sousa, J. (2011). Modelling the extreme precipitation event over Madeira Island on 20 February 2010. Nat. Hazards Earth Syst. Sci, 11(2437-2452), 2011.

Mourato, S., Moreira, M., and Corte-Real, J. (2010). Interannual variability of precipitation distribution patterns in Southern Portugal. *Inter. J. Climatol.*, 30(12), 1784-1794.

Ramos, C., and Reis, E. (2002). Floods in southern Portugal: their physical and human causes, impacts and human response. Mitigation and Adaptation Strategies for Global Change, 7(3), 267-284.

Rodrigo, F. S., and Trigo, R. M. (2007). Trends in daily rainfall in the Iberian Peninsula from 1951 to 2002. *Inter. J. Climatol.*, 27(4), 513-529.

Rodriguez-Puebla, C., Encinas, A. H., Nieto, S., and Garmendia, J. (1998). Spatial and temporal patterns of annual precipitation variability over the Iberian Peninsula. *Int. J. Climatol*., 18(3), 299-316.

Santos, J. A., and Corte-Real, J., Leite, S. M. (2005). Weather Regimes and their Connection to the Winter Rainfall in Portugal. *Int. J. Climatol*., 33–50.

Soares, P. M., Cardoso, R. M., Miranda, P. M., de Medeiros, J., Belo-Pereira, M., and Espirito-Santo, F. (2012). WRF high resolution dynamical downscaling of ERA-Interim for Portugal. Climate Dynamics, 39(9-10), 2497-2522.

Sneyers, R. (1990). On the Statistical Analysis of Series of Observations. Tech. note 143, WMO No. 415, Geneva, 192 pp.

Trigo, R. M. and C. C. DaCamara (2000) Circulation weather types and their influence on the precipitation regime in Portugal. *Int. J. Climatol*., 20, 1559-1581.

Ulbrich, U., Christoph, M., Pinto, J. G., and Corte-Real, J. (1999). Dependence of winter precipitation over Portugal on NAO and baroclinic wave activity. *Inter. J. Climatol.*, 19(4), 379-390.

Zêzere, J. L., de Brum Ferreira, A., and Rodrigues, M. L. (1999). The role of conditioning and triggering factors in the occurrence of landslides: a case study in the area north of Lisbon (Portugal). Geomorphology, 30(1), 133-146.