The Drought Interest Group (DIG):

Increasing severity and duration of droughts in the Iberian Peninsula (1850-2010)

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1. Introduction

The Iberian Peninsula presents a high climate vulnerability caused by its location in the transition area between temperate and subtropical climates. Under climate change conditions, this climate fragility is altered and there are evidences of observed and predicted increases of temperature and decreases in projected precipitation leading to an increase in the evapotranspiration rate. As a consequence, a worsening in drought conditions is expected *(IPCC, 2007)*.

Then, it's necessary to analyse temporal variability of meteorological drought events over Iberian Peninsula to see how the severity and duration of dry/wet conditions have been modified in a multi-decadal perspective.

2. Data & Methods

This study is based on a computation of Palmer's Drought Severity Index (PDSI) in its Self-Calibrated version (Sc-PDSI) using a selection of 24 long temperature and precipitation time series since 1850 over Iberian Peninsula. We used monthly means derived from the Spanish Daily Adjusted Temperature/Precipitation Series (SDATS, SDAPS) adjusted by the Centre for Climate Change C3) for the period 1850-2005 *(Brunet et al., 2006)*, 2 Portuguese time series (adjusted using SNHT) and Available Water Content of the soil (AWC) (Fig.1). In this study, SDATS and SDAPS have been updated to 2010 directly from the AEMET servers (running QC previously and pending of re-homogenisation).

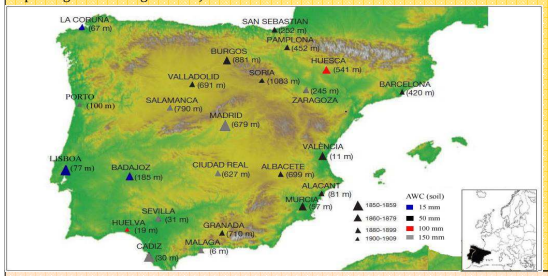

Fig. 1: Map showing the locations, lengths of time series, elevations and AWC of the soil (Adapted from Brunet *et al.*,2007).

When monthly Iberian time series has been created (1850-2010) and its changes of variance corrected, drought index could be applied. The Palmer's Drought Severity Index (PDSI) *(Palmer, 1965)* is based on the supply-and-demand concept of the water balance equation *(Hayes, 1997)* and Palmer's Index values are distributed in 9 categories (Fig. 5). In this way, monthly Sc-PDSI has been computed using monthly Iberian time series to detect wet and dry events for the period 1850-2010. We can differentiate a dry event (in monthly PDSI) as the time period which an undetermined number of consecutive months remain in dry conditions (values below 0 in PDSI). After to have identified all extreme events, the trends of the maximum severity reached for each event, averaged severity and duration in months of dry and wet events have been computed to detect variations in their behaviour across time (at 95% significance level using Mann-Kendall Test).

3. Climate variability

Annual temperature anomalies (reference period 1961-90) show a clear rising trend of 0.1ºC/10 years with a statistically significant linear trend (Fig.2, upper panel). This is consistent with the Spanish temperature increase for the period 1850-2003 *(Brunet et al., 2006)*. Annual precipitation anomalies show a high inter-annual variability and a slight decrease statistically insignificant of -0.41mm/10 years (Fig.2, lower panel).

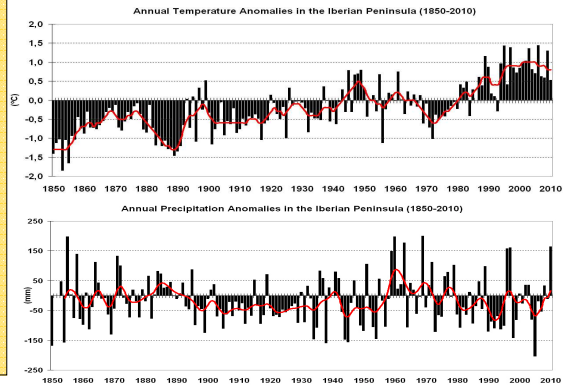

Fig. 2: Annual temperature/precipitation anomalies in the Iberian Peninsula for the period 1850-2010 *(with smoothed by Gauss filter over 10 years)*

4. Results. Drought variability in the Iberian Peninsula

Analysis of Sc-PDSI's variability shows the severity of dry conditions is increasing statistically significant during last decades at a rate of 0.061/decade (Fig. 3). Some studies treated this topic getting similar results (e.g., Brázdil *et al*., 2008 (for Czech Republic), Mavromatis 2007 (for Greece), Briffa *et al*., 2009 (for Europe in summer) and Vicente-Serrano *et al*., 2010 (a few locations around the world). In total, 173 events have been identified for the period (Fig.4), which 86 are dry events and 87 are wet events. The most remarkable extreme events have been validated consulting documental sources provided from official meteorological services which verified these events had occurred. Their severity and duration detected in the drought index are consistent with real situation described in those sources.

Dry events accustom to be more severe and longer than wet events in average and note that the driest and longest events occurred during the last two decades coinciding with the warmest years of the time series and, in general, less precipitation than normal.

Otherwise, maximum and averaged severity of dry events show a statistically significant increases at a rate of 0.1 in PDSI values every 13 dry events (in the case of maximum severity), and the averaged severity does it every 28 dry events. Therefore, the duration of dry events is increasing statistically significant a month every 7 dry events, so droughts are longer and more severe currently than before.

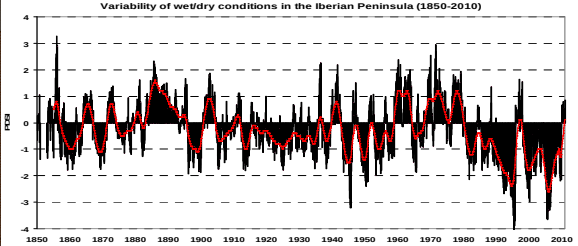

Fig. 3: Fluctuations in 12-month Sc-PDSI in the Iberian Peninsula for the period 1850-2010 *(with smoothed by Gauss filter over 5 years)*

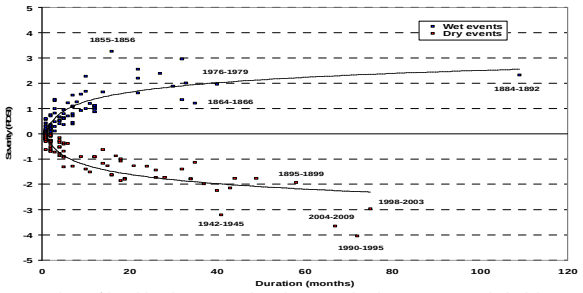

Fig. 6: Behaviour of detected dry and wet events according to the maximum index value (maximum severity) related with the duration of each event. Most remarkable wet and dry events are shown as well and black lines draw logarithmic trends.

A joint analysis between severity and duration gives us an idea about the magnitude of each event, for this reason it's better to study them together. The behaviour of detected dry and wet events according to maximum severity related with its duration is shown in Figure 6. The accumulative character of droughts has been identified by noting that when the duration of dry event increases so does the severity in a direct relation of 0.9 (Pearson's Coefficient) and drawing a logarithmic distribution.

CATEGORIES	PDSI value
Extremely wet	≥ +4
Severely wet	≥ +3 to < +4
Moderately wet	≥ +2 to < +3
Slightly wet	≥ +1 to < +2
Near normal	> -1 to < +1
Slightly dry	> -2 to ≤ -1
Moderately dry	> -3 to ≤ -2
Severely dry	> -4 to ≤ -3
Extremely dry	≤ -4

Fig. 5: Classification of PDSI categories defined by Palmer (1965)

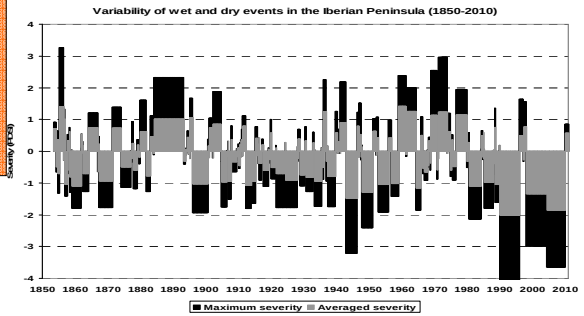

Fig. 4: Dry and wet events detected in the Iberian Peninsula (1850-2010). Black bars refer to the maximum monthly index value (maximum severity) recorded for each event, meanwhile grey bars indicate the average index value for each event. The duration in months for each event is represented in the x axis: bars' widths are proportional to duration.

5. Conclusions and further work

The obtained results confirm the magnitude of meteorological droughts (severity and duration) is worsening significantly in the Iberian Peninsula during last decades, while wet events don't present significantly variations. The analysis conducted in this study suggest that, under the temperature increases and precipitation decreases projected for the Mediterranean basin *(IPCC 2007)* drought conditions are very likely to worsen in the future in the Iberian Peninsula *(Dai A., 2011)*. This study can improve when all series are re-homogenisated using better methods (HOME results). It would be interesting to build a joint drought duration and severity distribution using copulas.

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6. References

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