Study of future changes in drought and soil patterns over Spain using WRF

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Abstract

In recent years, the Mediterranean region has experimented severe drought events causing numerous economic, social and environmental losses. This fact makes necessary to evaluate the potential future changes of drought patterns, especially in vulnerable areas such as Spain. This study explores the projected drought changes using two different drought indices: The Standard Precipitation Index (SPI) and the Standard Precipitation Evapotranspiration Index (SPEI), at different time-scales, and trying to relate them with soil moisture patterns. For that, the Weather Research and Forecasting (WRF) model was used in order to obtain current (1980-2010) and future (2021-2050) climate fields to compute these drought indices.

Results from this study provide a valuable contribution to the understanding of how the increase of the temperature would affect the drought variability that can be used to improve the detection and monitoring of future droughts properly.

Model setup

- ✓ WRF-ARW **v.3.6.1**
- ✓ **2 one-way nesting domains**:
  - EUROCORDEX-0.44
  - Iberian Peninsula (0.088º)
- ✓ **Initial/Boundary conditions:** Bias-Corrected NCAR's CESM
- ✓ **Period of study:**
  - Historical: 1980-2010
  - Future: 2021-2050
  - Scenarios: RCP4.5 & RCP8.5
- ✓ **Parameterization schemes**:
  - Boundary layer : ACM2
  - Cumulus scheme: BMJ
  - Microphysics: WSM
  - Land Surface: Noah LSM
  - Long/short wave radiation: CAM3.0

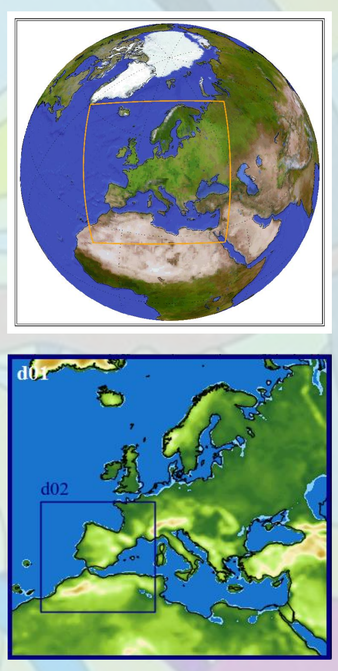


Fig. 1: Domain of study

Drought statistical evaluation

- ✓ Software used to compute drought indices: SPEI R-Package.

$$SPI = f(pr_{monthly}) \qquad SPEI = f(pr_{monthly} - ETo_{monthly})$$

Modified Hargreaves (MH) equation

- ✓ SPEI and SPI were fitted to a log-logistic probability distribution.
- ✓ Time-scales analyzed:
  - 3 months (3-mo) → "Meteorological droughts"
  - 12 months (12-mo) → "Hydrological droughts"
- ✓ Projected changes were analyzed using drought events, i.e. periods in which the index is continuously negative, starting when it falls below -1. Thus, the following drought characteristics were defined:
  - Severity : absolute maximum SPEI/SPI value in a drought event.
  - Duration: nº of months in a drought event.
  - Frequency: nº of drought events in the SPEI/SPI time series.
- ✓ SPEI series were compared with soil moisture content in order to evaluate the relationship between these variables.

Results

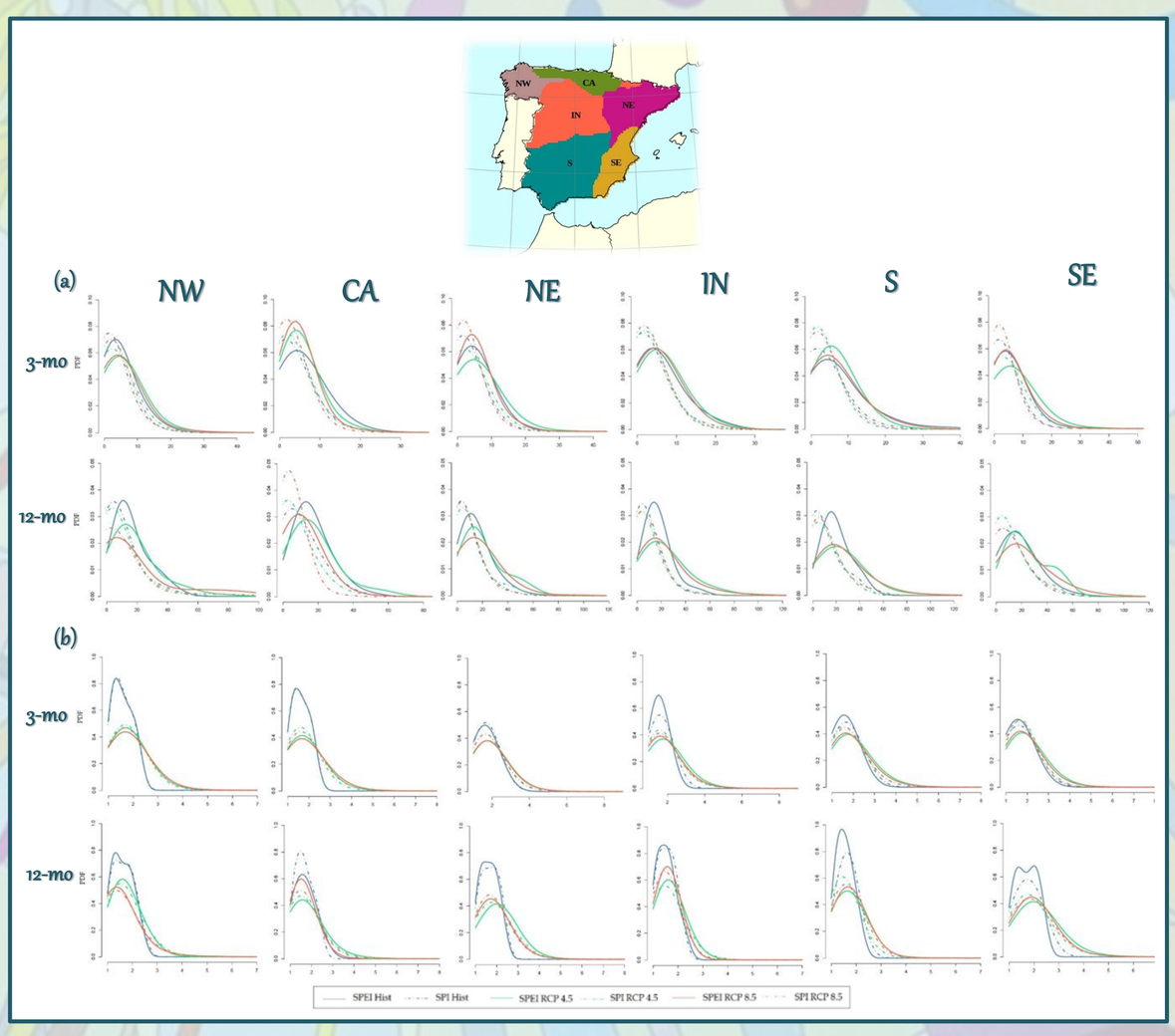
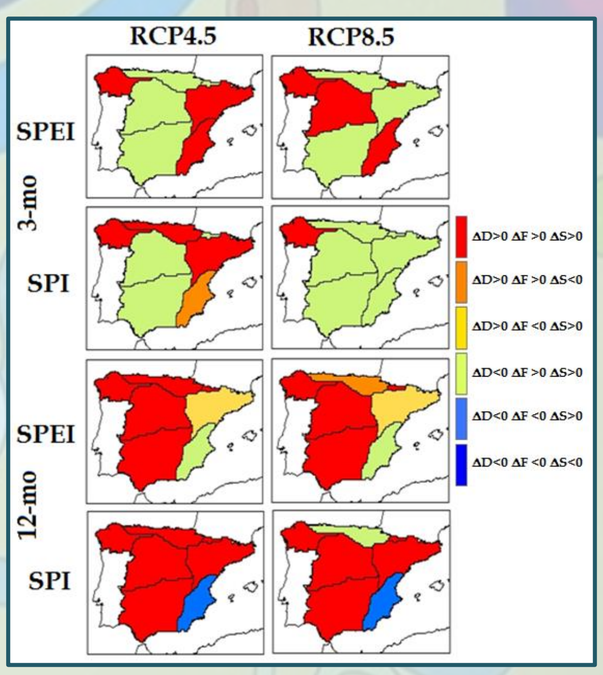


Fig. 2: Probability density functions (PDFs) of current and future droughts (a) duration (months) and (b) severities at 3- and 12-mo SPEI and SPI, for every region.



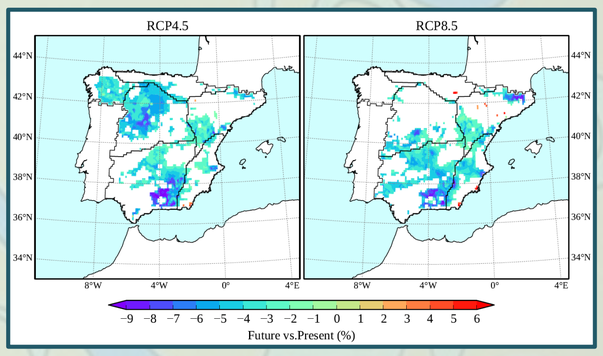


Fig. 4: Projected changes for soil moisture content in percentage. White areas indicate that changes are not significant using a two-sided Wilcoxon rank sum test, at 95% confidence level.

Fig. 3: Classification of regions based on averaged projected changes for drought duration (ΔD), frequency (ΔF) and severity (ΔS) for every region and for both drought indices and time-scales.

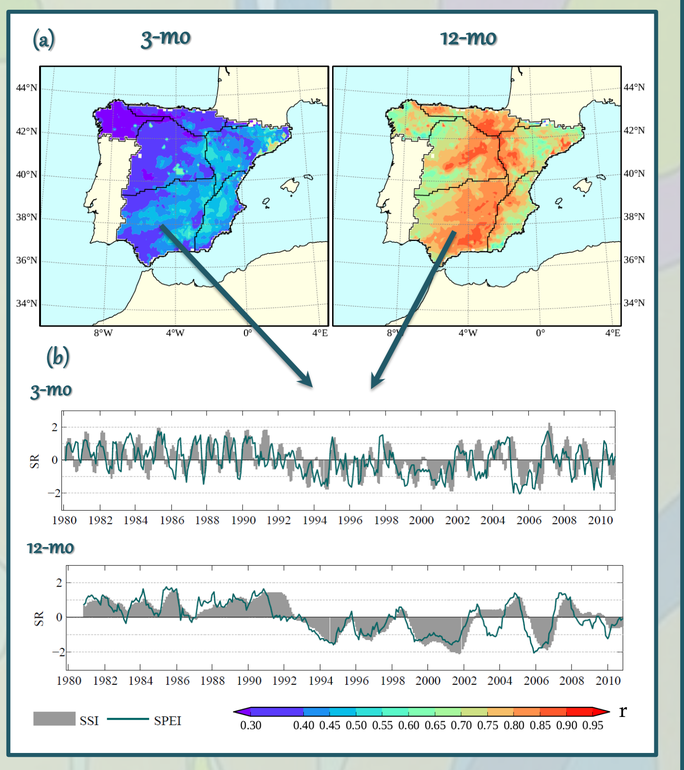


Fig. 5: (a) Correlation coefficients between simulated SPEI at 3-mo and 12-mo time-scales and soil moisture content (SSI) series for 1980-2010 period. (b) Time series of SPEI and normalized soil moisture content for South region.

Concluding remarks

- ✓ Results show an increase in the severity and duration of droughts in most regions, being larger when SPEI index is used to define drought events. This fact confirms the relevance of taking into account the temperature to detect future drought events. Projected changes also show a significant decrease of soil moisture content.
- ✓ Correlation analysis between SPEI and soil moisture, at different time-scales, show a relationship between them which is more significant at higher time-scale.
- ✓ There is a good agreement in the sign of projected changes for severity, duration and frequency for meteorological droughts. Conversely, the projected changes for hydrological droughts do not agree in sign in most regions.
- ✓ The RCPs scenarios show similar results for the period of study (2021-2050). Future works will include analyses for the period 2071-2100 in order to estimate the uncertainties between these two indices in a period where the differences between RCPs scenarios could be more significant.

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