An assessment of the impact of soil initial conditions on drought and precipitation extremes by using a high-resolution regional climate model

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A brief introduction

Soil moisture (SM) is one of the fields with a relevant role in processes involving land-atmosphere interactions, especially in regions such as the Mediterranean Europe, where coupling between those components of the climate system is very strong.

The aim of this study is to address the impact of soil initial conditions on drought and precipitation extremes over the Iberian Peninsula (IP). For this purpose, a dynamical downscalling experiment has been conducted by using the Weather Research and Forecasting model (WRF) along the period 1990-2000. Two one-way nested domains has been considered: a finer domain spanning the IP, with spatial resolution around 10km, nested within a coarser domain covering the EURO-CORDEX region at 50 km of spatial resolution.

Model setup

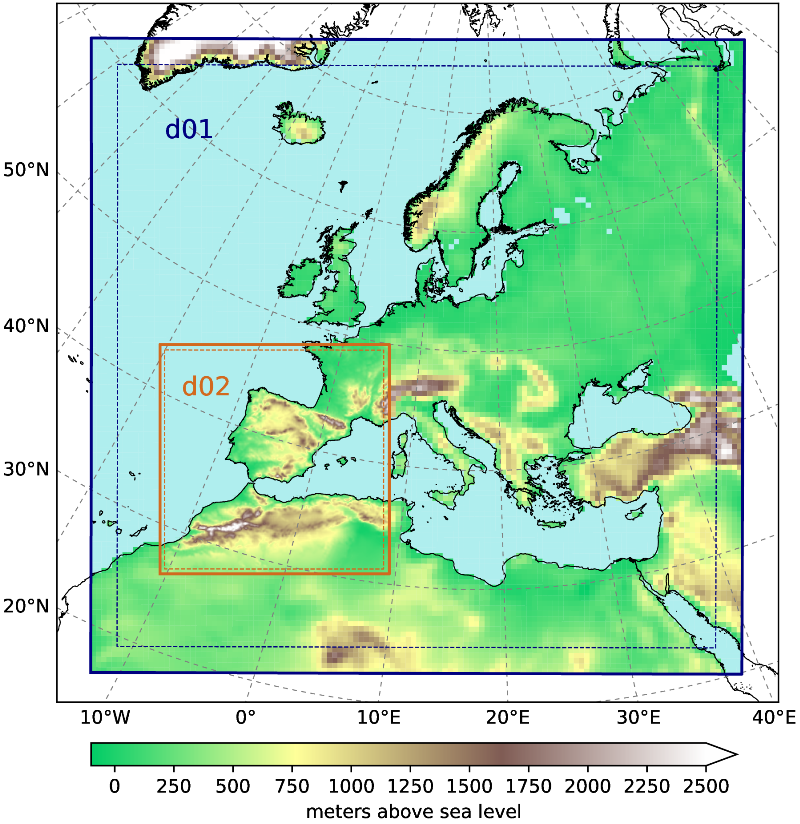


Fig 1. Height (meters) above sea level within the model domains.

- Nested domains:
  d01: EURO-CORDEX (~ 50 km resolution).
  d02: Iberian Peninsula (~ 10 km resolution).
  Nesting procedure: one-way nesting.

- Parametrization scheme:
  Microphysics: WSM3C.
  Long/short wave radiation: CAM3.
  Surface layer physics: MM5 similarity.
  Land surface: Noah Land Surface Model.
  Planetary boundary layer: ACM2.
  Cumulus: BMJ.

Simulations

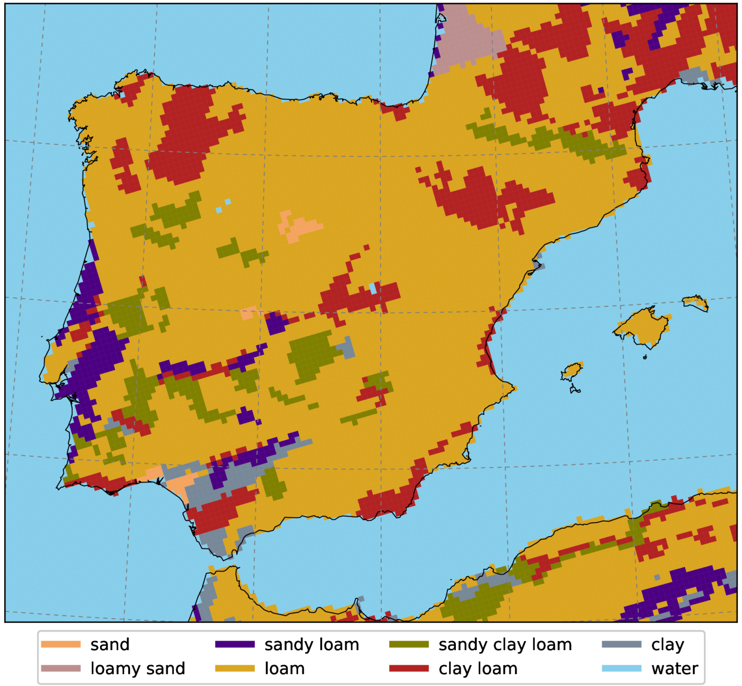


Fig 2. Soil texture map over the Iberian Peninsula.

- Main features:
  Period of study: 10 years, from 1990 to 1999/2000.
  Initial and boundary conditions: ERA-Interim.
  SM initial conditions: wet, dry and very dry.
  Initial dates: 1990-01-01 and 1990-07-01.
  Control simulation: driven by ERA-Interim from 1982 to 2000.

- How have SM initial conditions been calculated?:

$$SMI = -1 + 2\frac{\theta - \theta_{WP}}{\theta_{FC} - \theta_{WP}} \Rightarrow \begin{cases} \theta_{WET} = \theta(SMI = 1) \\ \theta_{DRY} = \theta(SMI = -0.5) \\ \theta_{VERYDRY} = \theta(SMI = -1) \end{cases}$$

SMI: Soil Moisture Index

θ_{FC}: field capacity (for a given texture class)

θ_{WP}: wilting point (for a given texture class)

Methodology

Drought indices:

- Standardized Precipitation Index (SPI):

$$SPI = f(PR)$$

where PR denotes accumulated precipitation, in this study, along 12 months. PR is fitted to a gamma distribution and then transformed to a normal distribution.

- Standardized Precipitation Evapotranspiration Index (SPEI):

$$SPEI = f(PR - PET)$$

where PET identifies accumulated potential evapotranspiration, in this study, along 12 months. Accumulated difference is fitted to a Log-logistic distribution and then transformed to a normal distribution.

Methodology

Precipitation indices:

- Simple Precipitation Intensity Index (SDII):

$$SDII_j = \frac{\sum_{w=1}^{W} PR_{wj}}{W_j}$$

where PR_{wj} denotes daily precipitation amount on wet days w ($PR_{wj} \geq 1$ mm) and W_j identifies the number of wet days in period j.

- Number of days N_j with daily precipitation $PR_j \geq 10$ mm in period j (R10mm).

$$R10mm_j = N_j\left(PR_j \geq 10\,mm\right)$$

- Maximum consecutive 5-day precipitation (R5xDay):

With PR_{kj} as the accumulated daily precipitation along the k 5-day interval in period j:

$$R5xDay_j = max\left(PR_{kj}\right)$$

Methodology

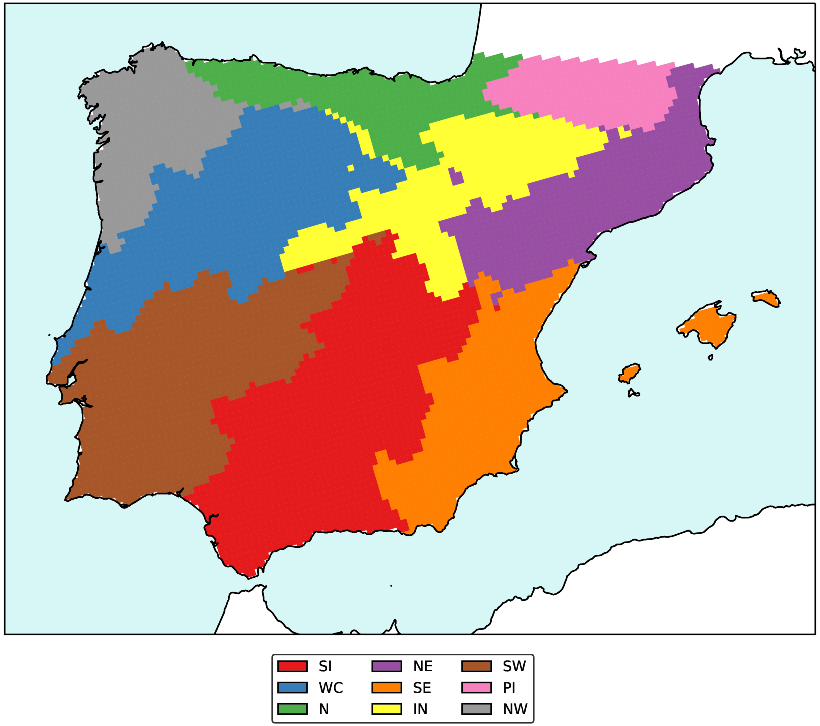


Fig 3. Climate regions for precipitation over the Iberian Peninsula.

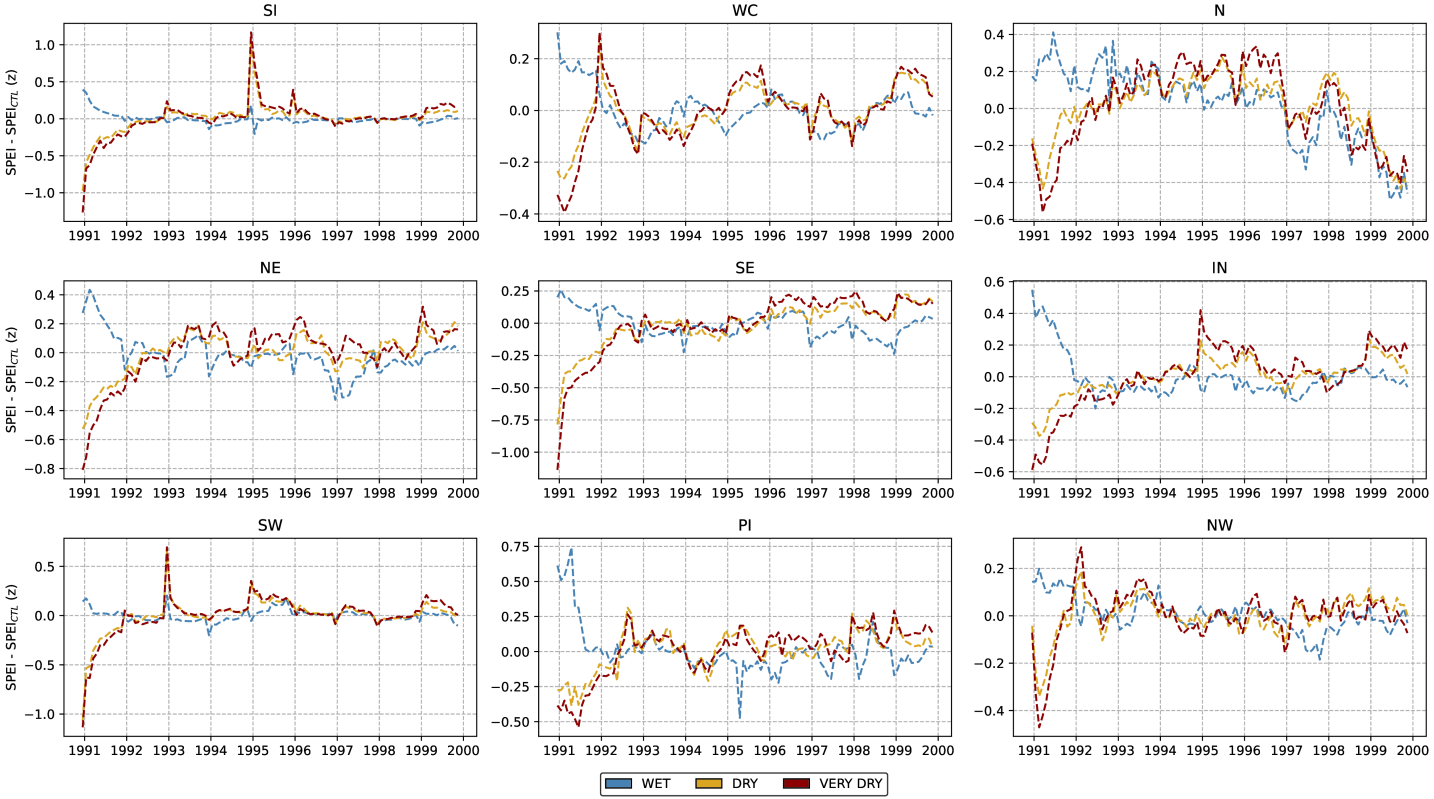
Differences between the 6 sensitivity experiments (3 SM initial conditions x 2 initial dates = 6) and the control run have been assessed over all IP climate regions.

The regionalization has been performed by following a multistep approach:

1) Principal Component Analysis for precipitation to get the most important variability modes.
2) Agglomerative Clustering Analysis for rotated loadings to get the optimal number of regions.
3) K-means Clustering Analysis to get the final configuration.

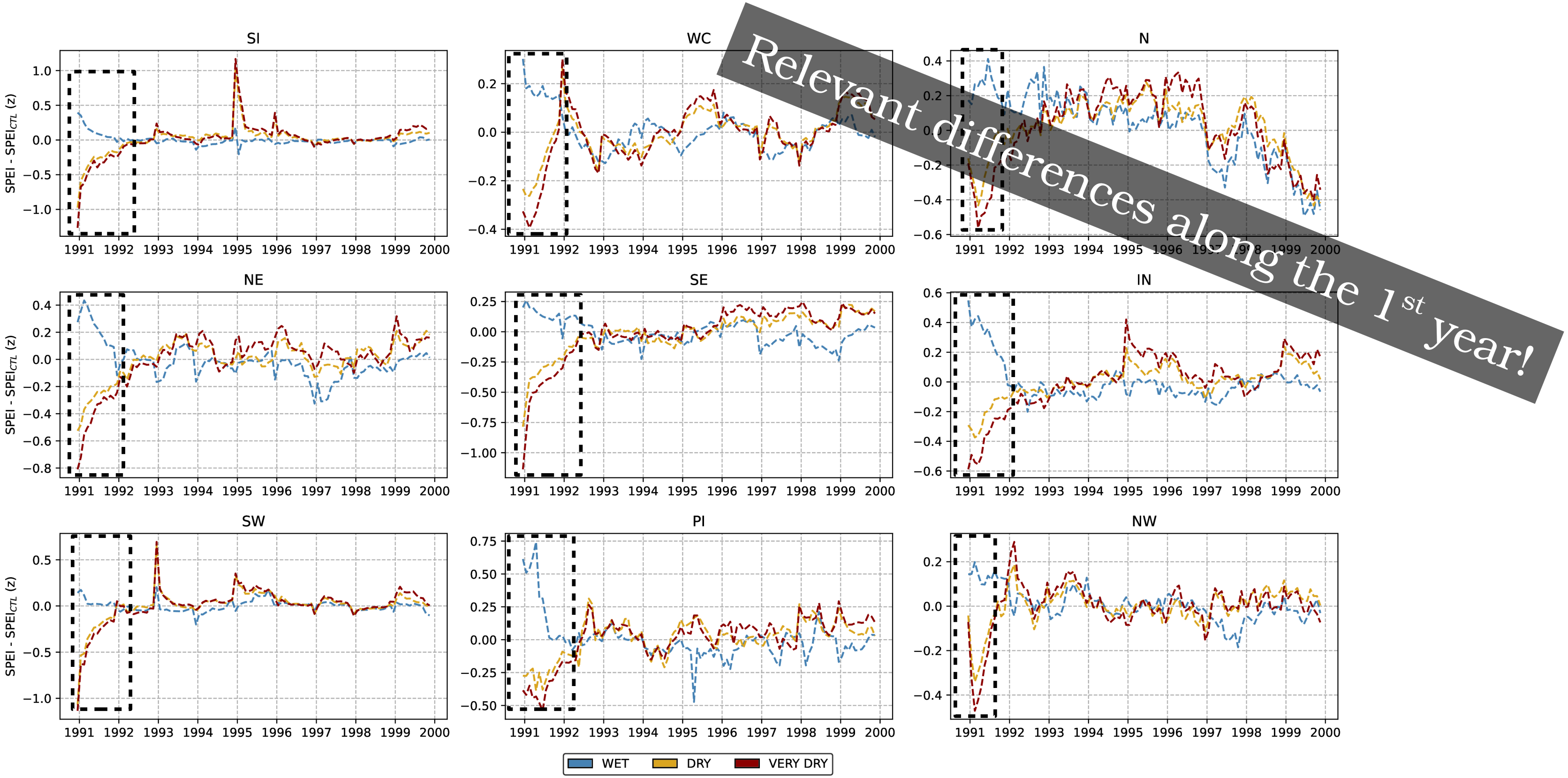
Results

Differences in SPEI with respect to control simulation. Initial date: 1990-01-01.



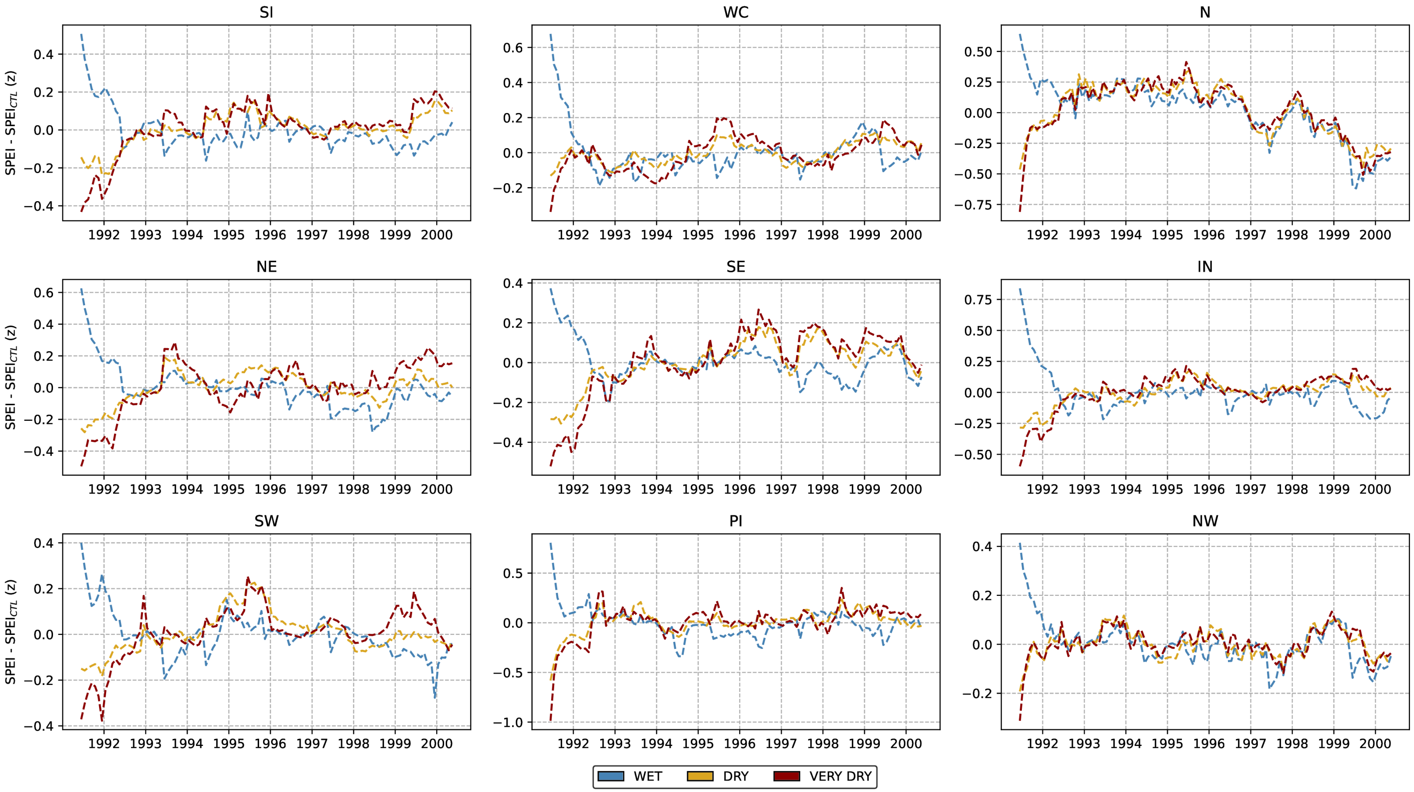
Results

Differences in SPEI with respect to control simulation. Initial date: 1990-01-01.



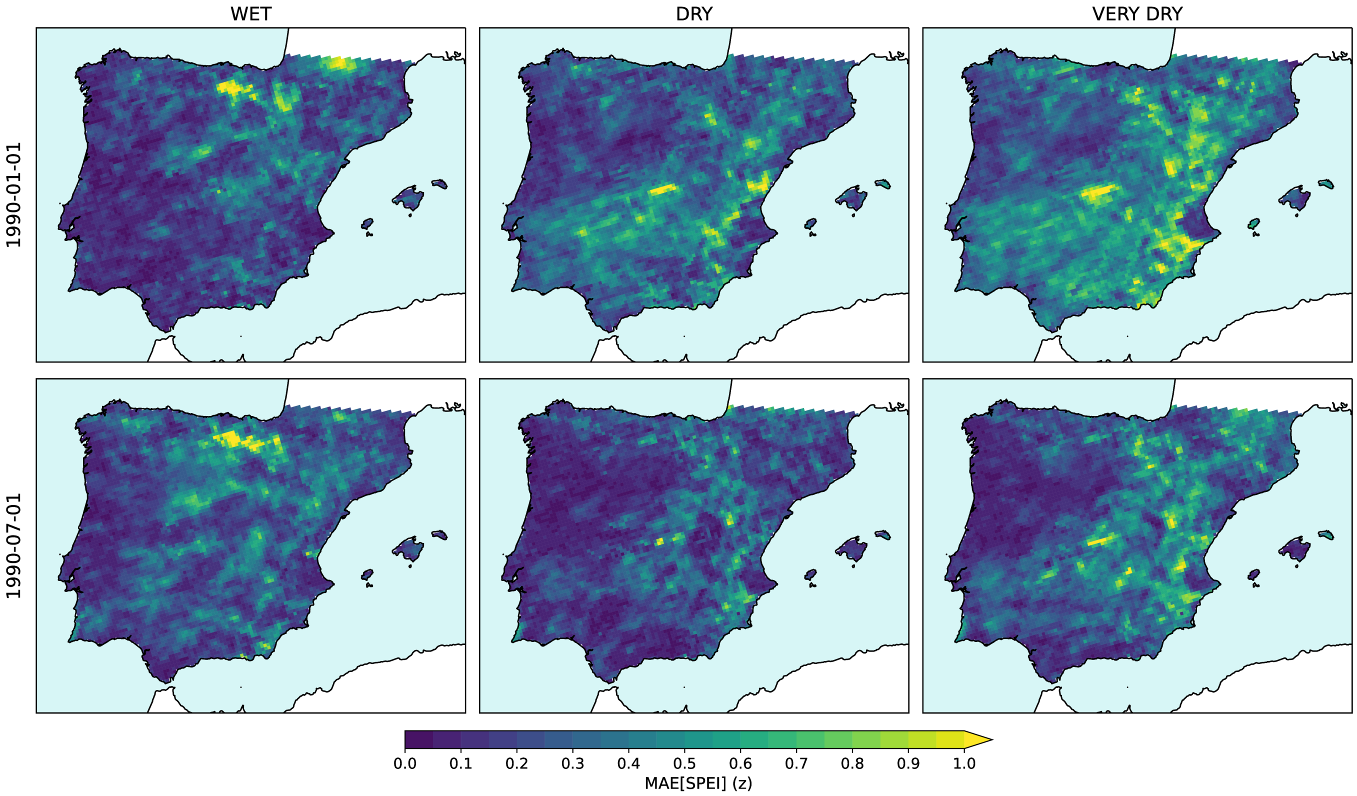
Results

Differences in SPEI with respect to control simulation. Initial date: 1990-07-01.



Results

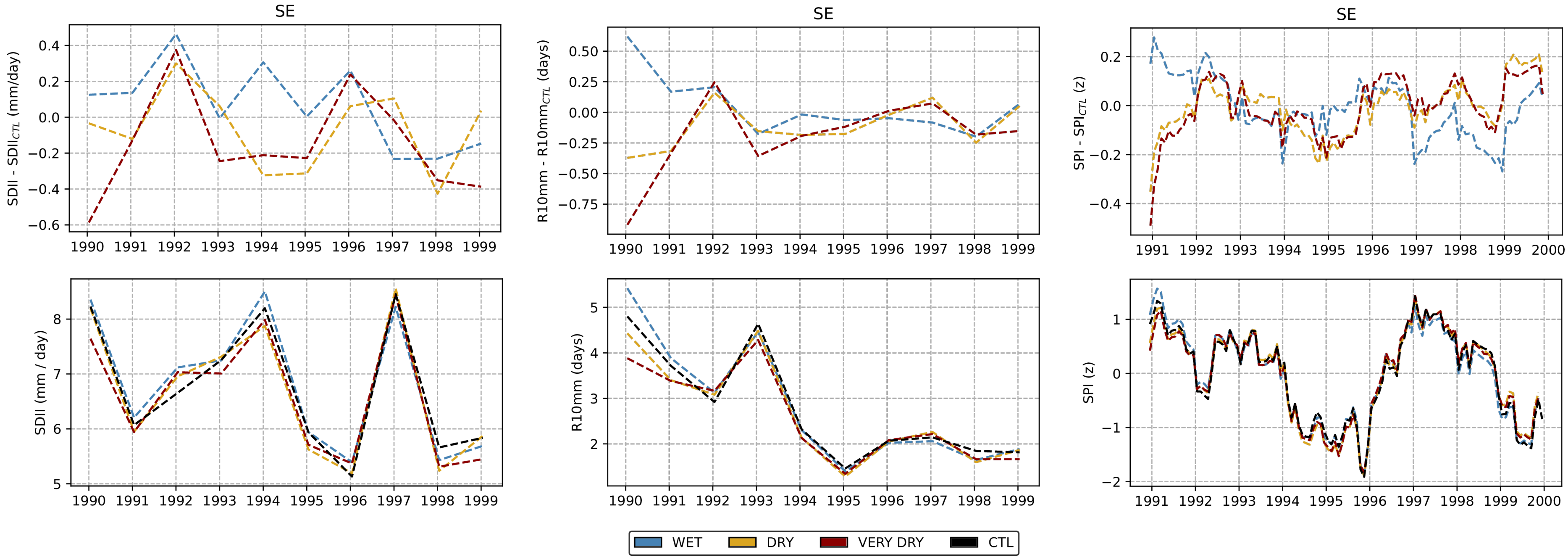
Mean absolute error (MAE) in SPEI along the 1st year with respect to control simulation.



Results

Differences in other indices are not always as noticeable. A few examples for 1990-01-01 as initial date:

Seasonal SDII (MAM) | Seasonal R10mm (MAM) | SPI (monthly)



Concluding remarks

- Among all indices included in this study, the most important differences between sensitivity experiments and the control run are observed for SPEI. MAE values along the 1st year exceed 1 z in some regions.

- The other indices, which only involve precipitation, do not show as remarkable outcomes as SPEI, which incorporates temperature through potential evapotranspiration.

- Likewise spin-up time for SM is larger for drier conditions, MAE along the 1st year in SPEI increases when SM initial conditions become drier.

- The impact of SM initial conditions also depends on the initialisation date. The more different are them from the control soil state at that time, the higher is MAE. For example, MAE values are higher in the VERY DRY experiment when the simulation is initialised on 1990-01-01.

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Thanks for your attention!