Study of drought processes in Spain by means of offline Land-Surface Model simulations. Evaluation of model sensitivity to the meteorological forcing dataset

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1. Introduction

- Drought is a hazard impacting all climates and regions of the world. In Spain, its societal impacts may be especially severe, creating water resources related tensions.
- Drought affects different aspects of the continental water cycle, from precipitation, to soil moisture, streamflow, lake volume and piezometric levels.
- The spatial and temporal scales of drought, together with its propagation through the system must be well understood.
- Land-Surface Models (LSM) physically simulate the continental water cycle and, thus, are appropriate tools to quantify soil moisture and other relevant variables and processes.

2. Objectives

1. Are LSMs correctly reproducing how drought propagates through the system?
2. Which are the main sources of uncertainty? Meteorological forcing, model structure, … ?

3. Datasets and models

- **Meteorological forcing datasets**
  - **SAFRAN** (Quintana-Seguí et al 2016, 2017) is a 5 km resolution meteorological forcing dataset.
  - The **FP7 earthH2Observe project** has produced a 0.25° resolution global forcing dataset, based on ERA-Interim and observations.
- **Land-Surface Models (LSMs)**
  - **SASER (SAfran-Surfex-Eaudysée-Rapid)**
    - **SURFEX** (Masson et al., 2013) is a LSM developed by Météo-France. We use the ISBA scheme for natural surfaces in two versions: a simple 3 layered force-restore method (**3L**) and a multilayer diffusion method (**DIF**).
    - The **RAPID** river routing scheme is used within the Eaudysée framework.
    - SASER does not simulate underground water processes.
  - **LEAFHYDRO** (Míguez-Macho et al., 2007), land-surface model which is able to simulate groundwater processes.

Simulations used in this study		Land-Surface Models		
		SURFEX (ISBA-3L)	SURFEX (ISBA-DIF)	LEAFHYDRO
Forcing datasets	SAFRAN (5 km)	SFR 3L	SFR DIF	SFR LHD
	E2O (0.25°)	E2O 3L	E2O DIF	E2O LHD

4. Area of study and study period

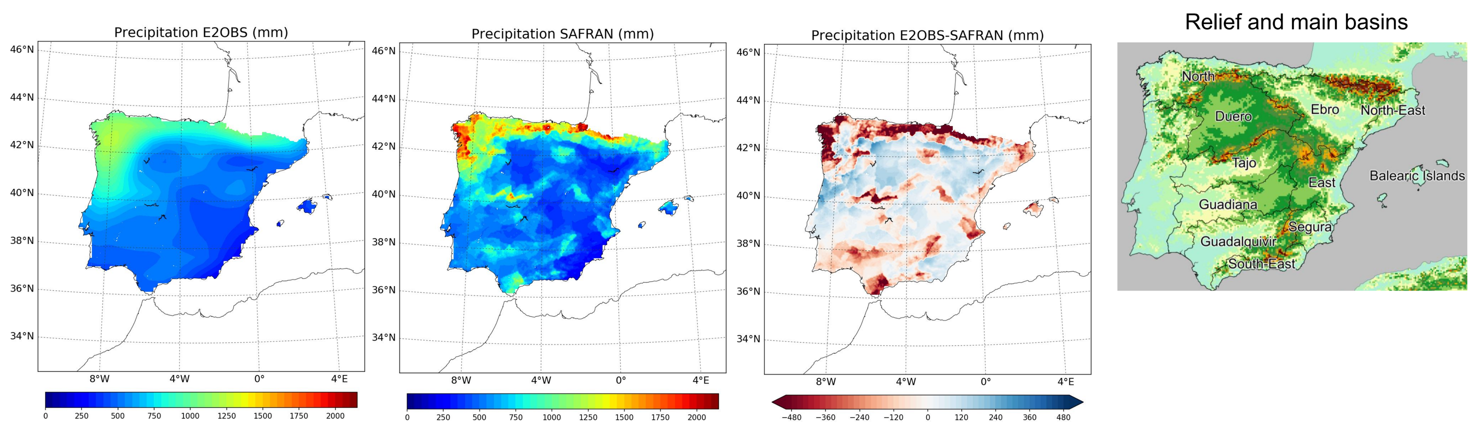
- The area of this study is mainland Spain for the period 1980-2013.

5. Methods

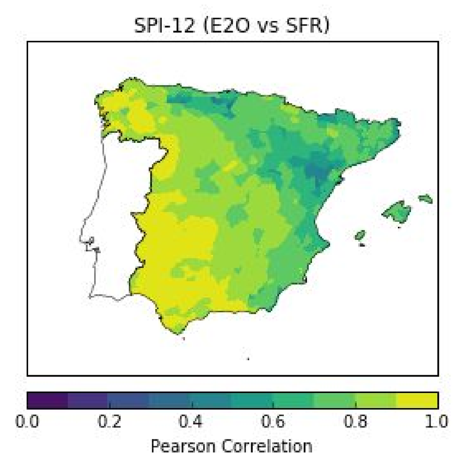
- Drought is assessed by means of standardized indices: SPI (for precipitation), SSMI (for soil moisture), SSI (for streamflow).
- Calculated using a non parametric methodology (AghaKouchack, 2015).
- Drought propagation is studied by correlating one month SSMI or SSI with *n* month SPI for *n* in (1, …, 24).

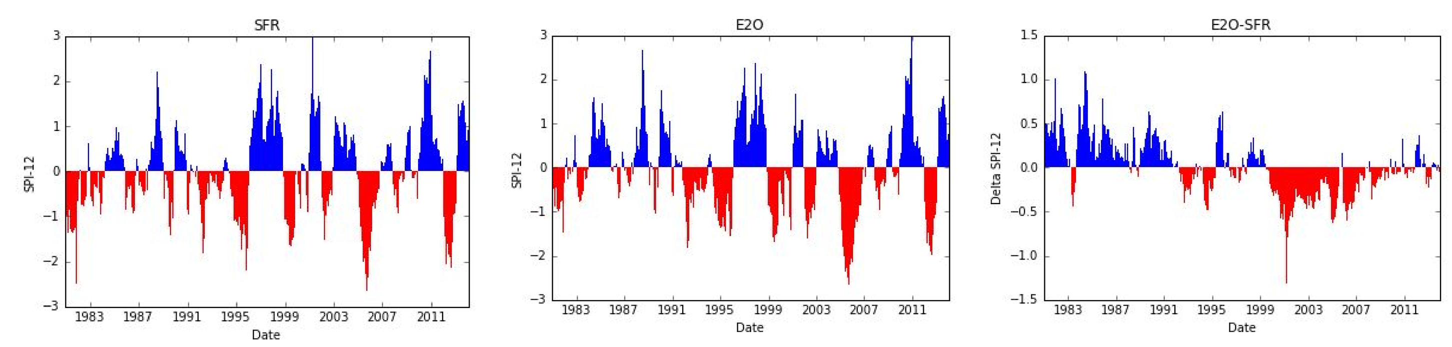
6. Precipitation

- SAFRAN reproduces relief related effects better than E2O, due to the higher resolution and the high number of observation stations used to prepare the dataset.



- E2O and SAFRAN SPI indices correlated well on the west part of the Iberian Peninsula but correlations are lower in the Mediterranean area and in the North.
- Both products simulate similar SPI time series, but they do not present the same trends.



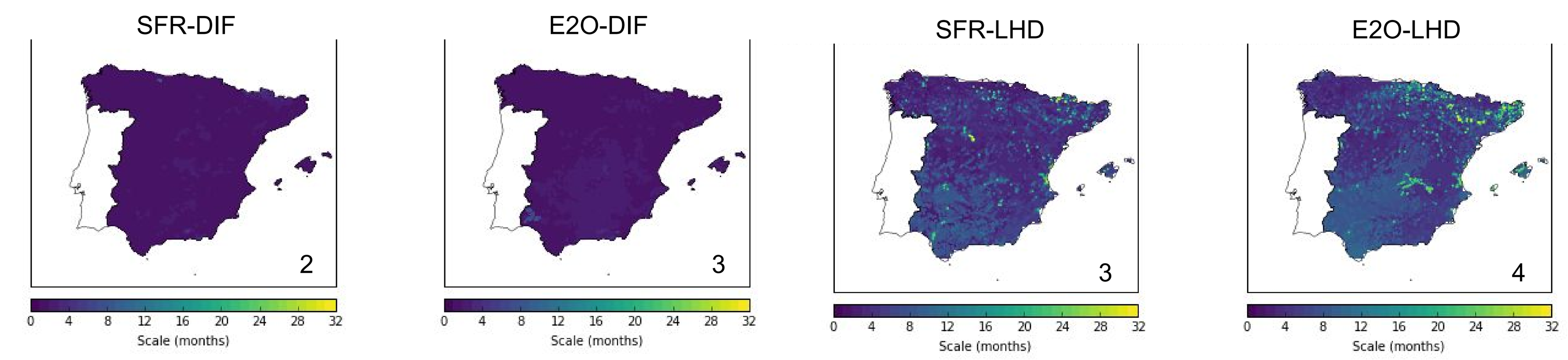


9. Conclusions and perspectives

- Model structure plays a very important role in determining how drought propagates within the system.
- The dynamics and spatial patterns of soil moisture are different between models.
- The same applies for streamflow, where large differences are due to model structure.
- SASER (SURFEX) lacks groundwater processes, LEAFHYDRO could be exaggerating the impact of groundwater on streamflow.
- The forcing dataset also plays a role. The low resolution forcing dataset delays the propagation of drought (+1 month for root zone soil moisture).
- Also, the low resolution dataset is not able to reproduce smaller scale drought patterns.
- This study will be extended by including more forcing datasets and an improved methodology.

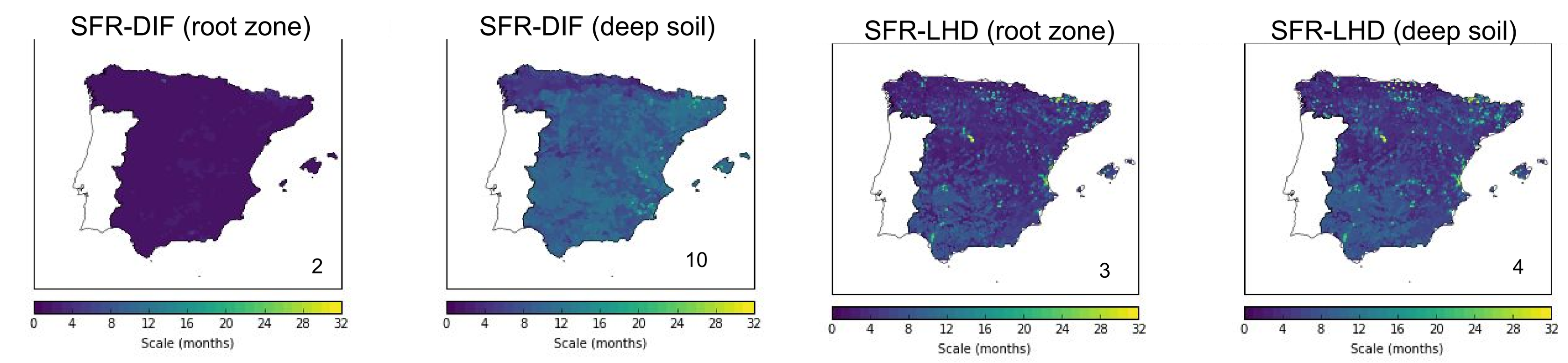
7. Soil Moisture

- Maps: n of maximum correlation between SPI-n and root zone SMSI-1.
  - Number in the lower right corner: same value but for the aggregated time series.



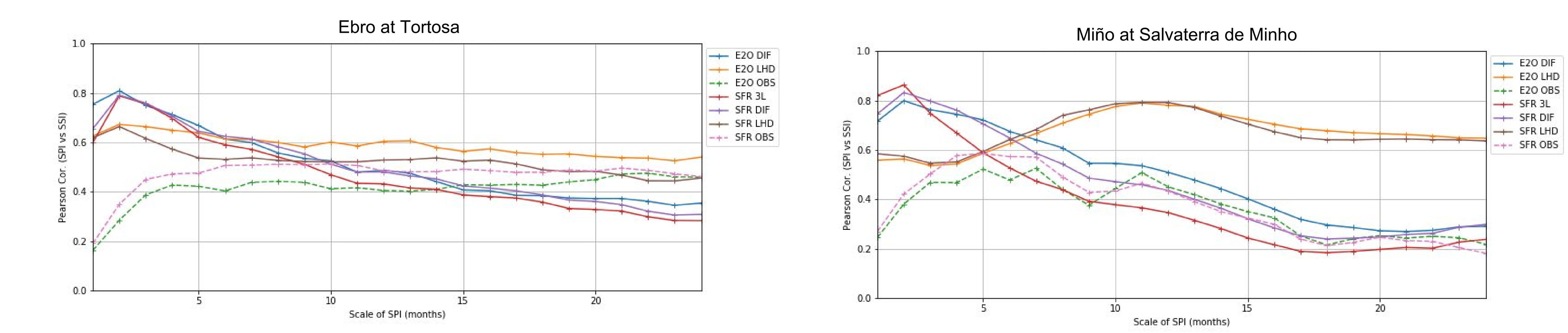
- The spatial patterns are very different between models (SURFEX is very homogeneous).
- SURFEX's soil moisture is more reactive to precipitation than LEAFHYDRO's due to the lack of groundwater processes.
- The forcing doesn't change the spatial pattern but it does change the temporal dynamics: On average, E2O introduces a 1 month delay compared to SFR.

But, how different is the behaviour of the root zone compared to the deeper soil?



- Very different hydrological behaviour of the different layers of the soil for each model.
  - SFR-DIF has a very slow deep soil.
  - LEAFHYDRO is spatially more heterogeneous.
- Groundwater and lateral processes are the main reasons for the differences.
- Different model structure leads to very different behaviour! In the future we should check how reality behaves.

8. Streamflow



- Two examples of two very different rivers are shown.
- The figures show the correlation of SPI-*n* and SSI-1 for *n* in 1, …, 24.
- Observations serve as a reference. However, the observations reflect the managed river and the models do not simulate management (dams, canals, irrigation, …).
- SURFEX (DIF and 3L) has high correlations with precipitation at short time scales.
- LEAFHYDRO has high correlation at larger time scales, which might be due to groundwater processes inducing memory to river flow.
- The forcing dataset has a measurable effect, but it seems that model structure is more critical.

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