Impact of Soil Moisture Initialization on Temperature Extreme Detection in the context of Regional Climate Modeling

M. García-Valdecasas Ojeda, J. J. Rosa-Cánovas, E. Romero-Jiménez, P. Yeste, S. R. Gámiz-Fortis, Y. Castro-Díez, and M. J. Esteban-Parra

Department of Applied Physics, University of Granada, 18071 Granada, Spain, mgvaldecasas@ugr.es

Abstract

It is well-known that the soil state plays an essential role in the climate conditions at regional scale, especially in those regions with strong land-atmosphere coupling. In this study, the impact of different soil moisture (SM) initial conditions is explored by using a dynamical downscaling experiment. To this end, the Weather Research and Forecasting (WRF) model v3.9.1 was used to generate high-resolution climate simulations driven by the ERA-Interim reanalysis over the Iberian Peninsula (IP). The sensitivity experiment consisted of comparing a control run (CTRL) completed using the ERA-Interim soil moisture (SM) as initial conditions with a set of simulations performed under different SM initializations (very dry, dry, and wet). In this framework, the study focused on exploring the impact of the winter (DJF) soil state on the summer (JJAS) extreme temperatures using two extreme indices: the warm spell index (WSDI), an index related to heat-waves, and the daily temperature range (DTR), which is strongly affected by the soil state.

These results provide valuable information about the impact of the SM initial conditions on temperature extremes, and how long these affect the regional climate in this region. Additionally, these results may provide a source of knowledge about the mechanisms involved in the occurrence of extreme events such as heatwaves, which are expected to increase in frequency, duration, and magnitude under the context of climate change.

Main Model Setup

- ✓ **2 one-way nesting domains:**
  - ➢ **d01:** EUROCORDEX, ~50 km resolution
  - ➢ **d02:** IP ,~10 km resolution
- ✓ **Initial/Boundary conditions:**
  ERA-Interim (ERA) 0.75˚ x 0.75˚
- ✓ **Parameterization schemes:**
  - ➢ Boundary layer : ACM2
  - ➢ Cumulus scheme: BMJ
  - ➢ Microphysics: WSM3
  - ➢ Land Surface: Noah LSM
  - ➢ Long/short wave radiation: CAM3.0

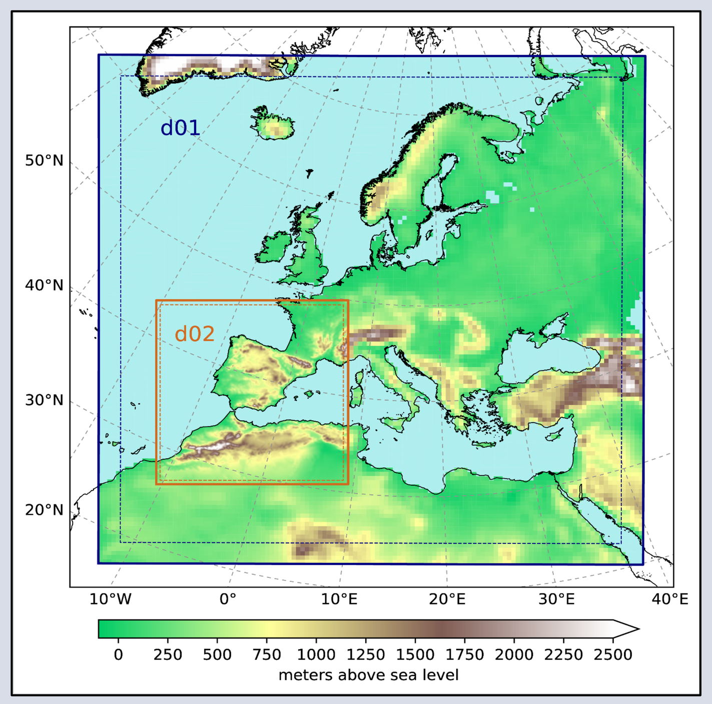


Fig. 1. Domains of study: EURO-CORDEX region (d01) and IP region (do2).

Data and Methodology

SM experiments

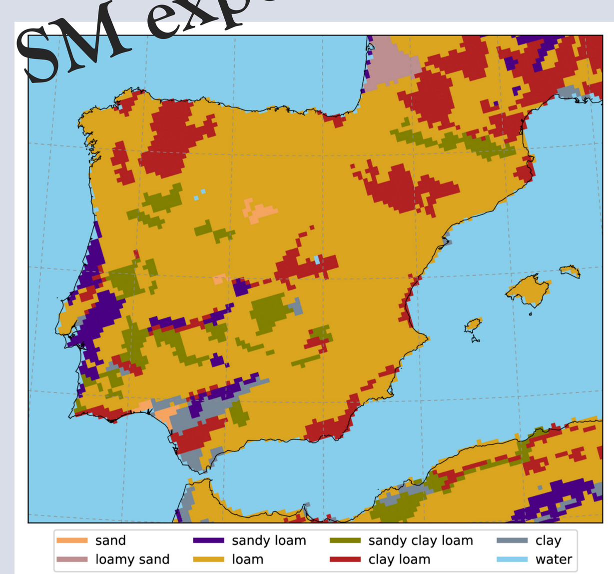


Fig. 2. Soil texture map over the IP.

- **Period of study:** 10 years (1990-1999) starting in 01/01/1990.
- **CTRL simulation:** 18 years (1982-1999) using the ERA SM.
- **Experiments:** wet, dry, and very dry soil conditions.

How have initial conditions for SM been calculated?

Using the WRF soil texture map (Fig. 2), we defined the different soil initial states as:

very dry → SMI = -5 as $\theta_{initial}$

dry → SMI = -2.5 as $\theta_{initial}$

wet → SMI = 5 as $\theta_{initial}$

$$SMI = -5 + 10\,\frac{\theta - \theta_{wp}}{\theta_{fc} - \theta_{wp}}$$

θ: soil moisture; θ_{wp}: wilting point; θ_{fc}: field capacity

Does the Model reproduce the spatial patterns of the extreme temperatures?

The WRF model performance was firstly evaluated by comparing the JJAS (June-to-September) DTR and JJAS WSDI from the CTRL run with those from the E-OBS v20.e datasets. Here, the study period was from 1984 to 1999 in order to ensure the model quasi-equilibrium state.

What effects does the state of the winter soil have on extreme summer temperatures, and how long does it last?

The JJAS DTR and JJAS WSDI were analyzed for the different initialization experiments year-by-year through the differences with respect to the CTRL simulations for different regions. Additionally, to better understand the results, spring (MAM) and summer (JJA) precipitation (pr) and evapotranspiration (E) were analyzed by regions for the first year of simulation.

Preliminary Results

The model evaluation

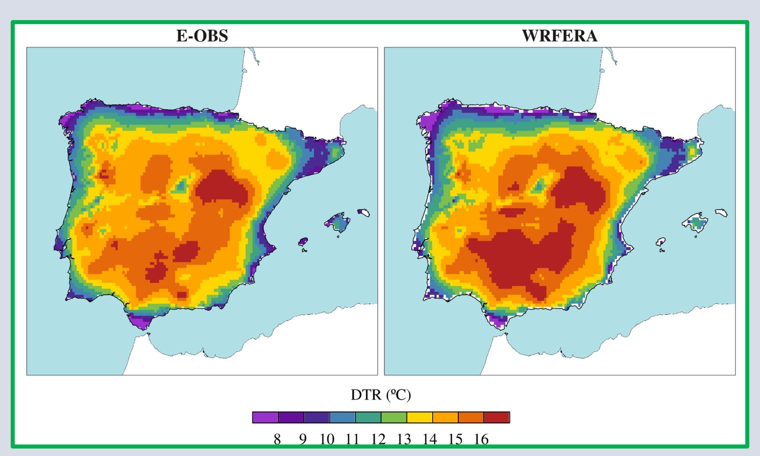


Fig. 3. JJAS DTR for E-OBS and WRFERA for the period 1984-2009.

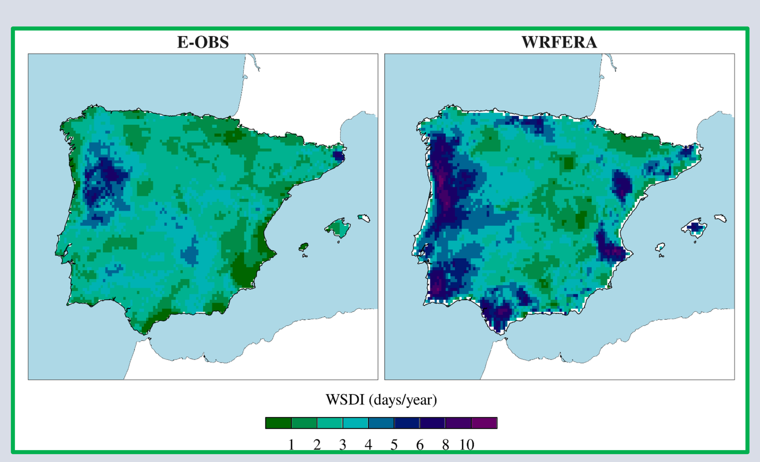


Fig. 4. JJAS WSDI for E-OBS and WRFERA for the period 1984-2009.

Effect of Soil-state on extreme temperatures

Fig. 5. Regions of study.

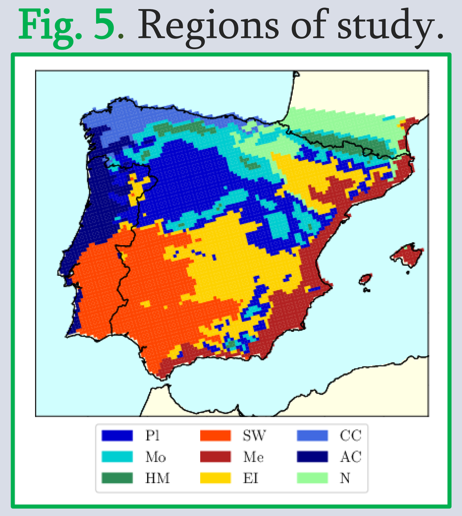
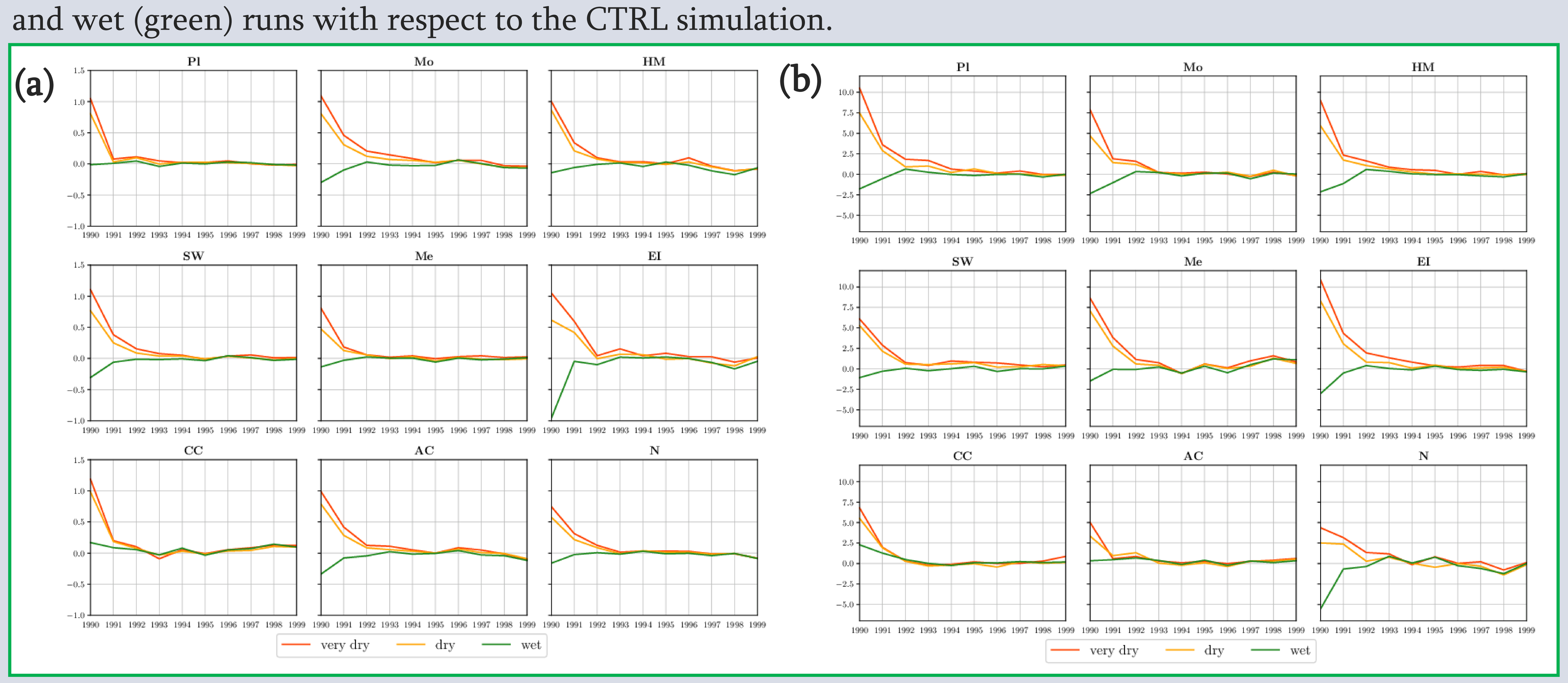


Table 1. Relative differences (%) between the very dry, dry, and wet simulations and the CTRL one in terms of precipitation (pr) and actual evapotranspiration (E). In columns, the values for spring (MAM) and summer (JJA) are shown for each region.

	Pl		*Mo*		*HM*		*SW*		*Me*		*EI*		*CC*		*AC*		*N*	
	MAM	JJA	MAM	JJA	MAM	JJA	MAM	JJA	MAM	JJA	MAM	JJA	MAM	JJA	MAM	JJA	MAM	JJA
pr																		
very dry	-11	-27.6	49.7	45.3	213.3	245	-31.7	-86.5	-1	-69.1	-19.3	-60.2	18.3	11.3	-31.2	-50.8	39.9	37.3
dry	19.1	34.3	96.7	148.7	307.8	454.5	-12.2	-78.8	36.2	-45	4	-25.8	57.2	87.7	-5.4	-15	75.8	130.2
wet	39.7	697	124.9	1334	361.3	2871	15	46.5	71.5	288	29.3	364.7	84.7	966.1	18	357.1	106.4	1247
E																		
very dry	-42.8	-53.5	-26.4	7.7	-15.2	99.2	-45.7	-86.3	-56.8	-70.5	-51.6	-71.4	-10.2	-23.4	-35.6	-52.3	-14	-3
dry	-34.5	-39.2	-22.3	25.2	-20.1	103.4	-34.5	-81.4	-51.3	-63.4	-43.3	-62.4	-8.3	-9.9	-28.4	-38.5	-8.7	13.1
wet	-10.6	107.4	-6	228.7	-20.8	294.8	0.8	12.8	-26.9	33.6	-11.2	53	0.5	158.8	-8.3	93.8	11.8	241.3

Fig. 6. (a) JJAS DTR (ºC) and (b) JJAS WSDI (number of days) differences for very dry (orange), dry (yellow), and wet (green) runs with respect to the CTRL simulation.



Concluding Remarks

- ➢ **WRF represents quite well the spatial patterns of the DTR, but shows more difficulties to adequately capture the WSDI behavior.** The model tends to overestimate WSDI, especially for the Plateau region.
- ➢ **The lower the soil moisture in winter, the greater the WSDI and DTR, in general**. The latter is accompanied by a lower surface evapotranspiration rate during spring that remains in summer except for mountainous regions. However, for wet initial conditions, the spring evapotranspiration rate is also lower than in the CTRL simulations, being much higher during winter.
- ➢ **SM has a strong impact on the occurrence of heat-waves in summer,** and it can remains for several years (3-4) in most of the IP, at least for very extreme SM conditions.
- ➢ **The effects on the DTR are also notorious,** but in most of the regions, these disappear in two years.
- ➢ **The results show a major impact on the dry and very dry simulations**, which is likely due to the fact that these initial conditions are more different from the actual one during winter.
- ➢ The results for the dry simulation suggest a **potential negative soil moisture-precipitation** feedbacks in some regions of the IP, which is also shown for mountainous regions under very dry soil initial conditions.

ACKNOWLEDGEMENTS: This work has been financed by the project CGL2017-89836-R (MINECO-Spain, FEDER). The WRF simulations were performed in the Picasso Supercomputer at the University of Málaga, member of the Spanish Supercomputing Network.