Soil moisture-atmosphere interactions during the 2020 European Heatwave using RegCM5

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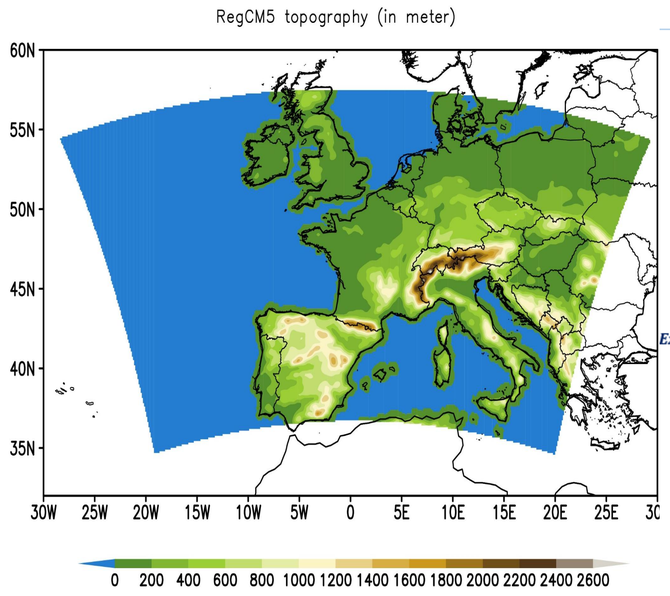
Introduction

The annual recurrence of the European heatwave (HW) has brought renewed attention to the role of climate change in extreme weather events. European HW, such as the 2003 Western European and 2010 Russian incidents, were responsible for 85% of all fatalities resulting from climate-related disasters in Europe from 1970 to 2012, leading to a total of more than 120,000 deaths[1]. The combination of drought and HWs can lead to intensified individual hazards through the coupling of soil moisture and the atmosphere can accelerate the projected impact on ecosystem, social economy, and human health[2]. RegCM version 5 [3] has been dynamical downscaled over FOCI domain (12 km horizontal resolution) with 3 hourly initial and boundary condition from the ERA5 to simulate HW event that occurred in Europe between August 6-11, 2020. This study investigates the sensitivity experiments and coherence in the combination of different dynamical cores (MM5 and MOLOCH) and moisture schemes (SUBEX, Nogherotto-Tompkin and WSM5), with specific focus on role of soil moisture in modulating synoptic pattern and spatio-temporal evolution of extreme heatwave event in the model simulation.

Model domain and description



Model Version	RegCM5
Domain	37°S–58°N; 18°W–20°E
Map projection	LAMCON
Horizontal & Vertical resolution	12 km & 41 sigma-level
Non-Hydrostatic Dynamical core	I.MM5 II. MOLOCH
Radiation scheme	NCAR CCM3
Land surface scheme	NCAR CLM4.5
Resolved scale Microphysics/ Explicit Moisture scheme	I. SUBEX II. Nogherotto-Thompkins (NoTo) III. WSM5
Planetary boundary layer scheme	UW
Ocean flux	Zeng
Cumulus scheme (land +Ocean)	Tiedtke
Cloud fraction scheme	Xu-Randall empirical
Initial & Boundary Condition	ERA5 (3 hourly)

Model setup and list of experiments used in the study

	Dynamical Core	Moisture Scheme
Exp1	MM5	SUBEX
Exp2	MM5	NoTo
Exp3	MM5	WSM5
Exp4	MOLOCH	SUBEX
Exp5	MOLOCH	NoTo
Exp6	MOLOCH	WSM5

Objective

- **To compare the viability of nonhydrostatic (NH) dynamic cores i.e., MM5 and MOLOCH, in RegCM5 with different available moisture schemes (SUBEX, Nogherotto/Tompkins, WSM5).**
- **To simulate HW event (6-11 Aug 2020) and analyse model sensitivity using different moisture scheme.**
- **To assess the role of soil moisture–atmosphere interaction as feedback mechanism.**

Data and Methodology

- The HW episode of 2020 has been selected based FPS URB-RCC, 6-11 August 2020 reported maximum temperatures (Tmax) ~38°C and 8-days long heatwave in Paris [3].
- Dynamical downscaling with the resolution 0.11° x 0.11° was set up in RegCM5 over FOCI domain using 2 NH dynamical core MM5 and MOLOCH and 3 explicit moisture schemes for year 2020.
- Model simulated parameters used in the analysis: maximum temperature (Tmax), relative humidity (Rh), low cloud cover (LCC), soil moisture (SM), surface downwelling shortwave flux (SWF), latent heat flux, sensible heat flux.
- Eobs and ERA5 dataset has been considered as reference used for statistical validation of model through Taylor diagram, ECDF and PDF.
- Soil-atmosphere interaction of HW episode is explained with the help of evaporative fraction (EF), where EF is the ratio of latent heat flux to the sum of latent heat flux and sensible heat flux.

Results and Discussion

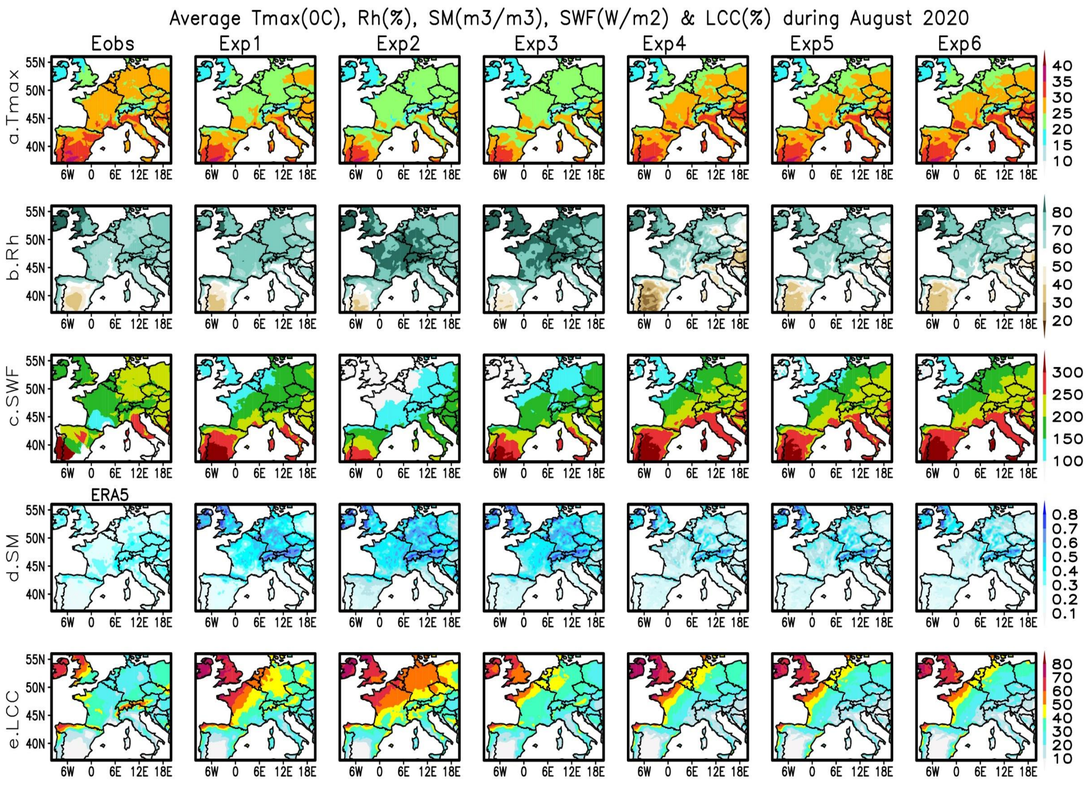


Fig.1 RegCM5 sensitivity experiments for Tmax, Rh, SWF, SM and LCC for August 2020.

Model validation

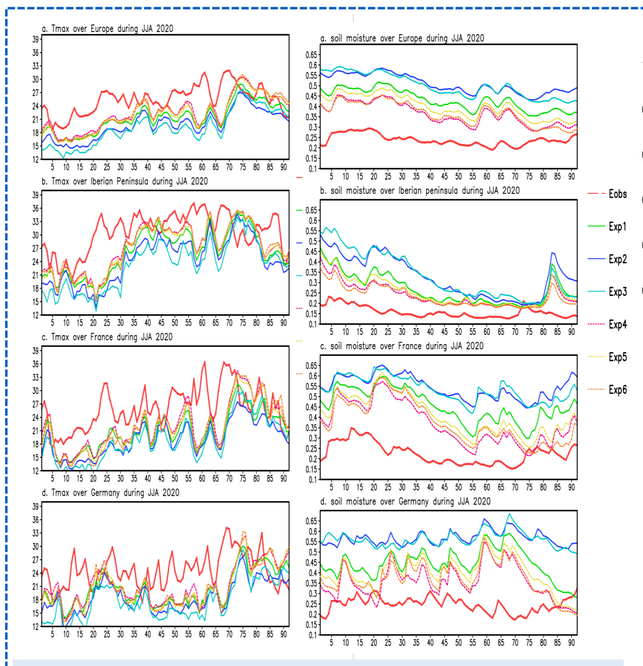


Fig.2 Area averaged daily Tmax (^{0}C) and top layer volumetric SM (m3/m3) over Europe, Iberian Peninsula, France and Germany in summer.

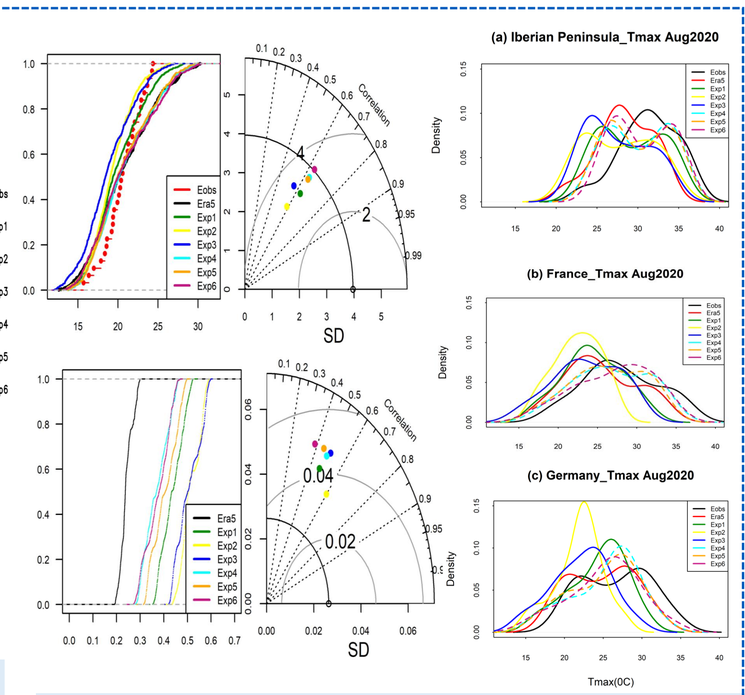


Fig.3 Taylor diagram, E(CDF) and probability distribution of Tmax (^{0}C)and SM (m3/m3).

- Heatwaves are primarily caused by inherent atmospheric fluctuations, but external atmospheric factor (such as SM) intensifies the severity of heatwave.
- In the observation, major regions are affected by HW seen by a dry climate, that is lower EF and SM.
- In RegCM5 there is overestimation of SM and EF which might be possible reason for delayed HW episode.

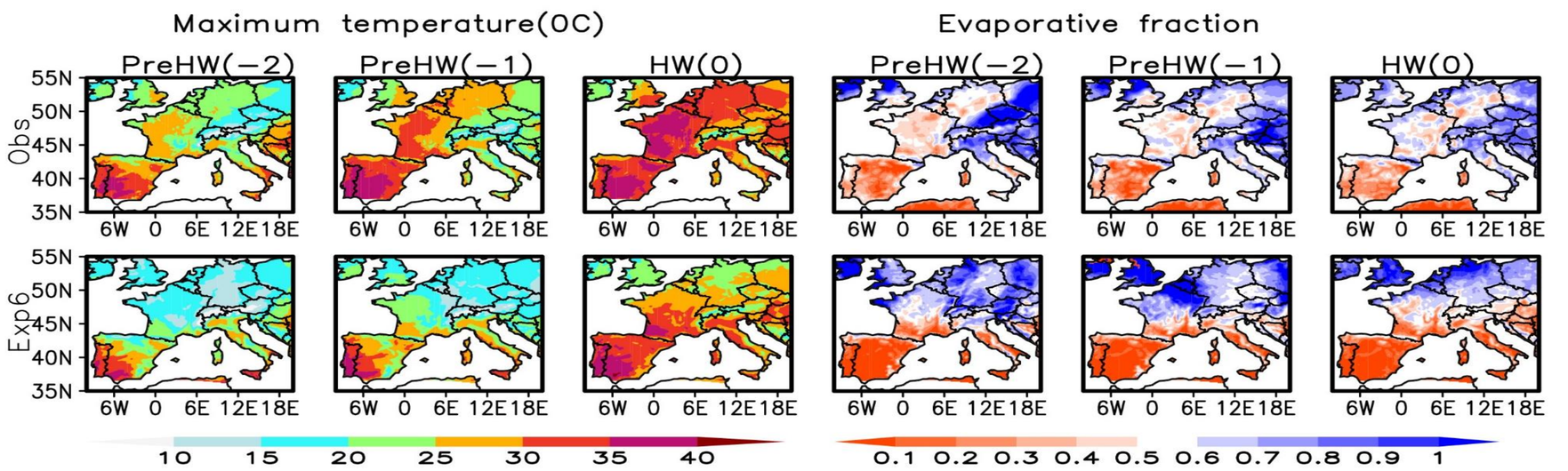


Fig.4 Observation vs Exp6 of Tmax and EF before 2 days; HW(-2), before 1 day; HW(-1) and during HW (6-11 Aug 2022).

Conclusions

- **The intercomparison between the model experiment shows that the effect of dynamical core is more prominent than explicit moisture schemes for simulating heatwave event.**
- **RegCM5 with MOLOCH core is better in simulating Tmax than MM5 core due to the overestimation of LCC, Rh and SM compared to observation.**
- **All experiments showed 2-3 days lagged response of HW episode, however they captured the peak intensity. The reason might be explained by the high EF, SM and LCC during August 2020.**
- **Exp6 has better skill in simulating the Tmax in terms of intensity and duration of the event.**
- **Thus, there is a major role of SM in RegCM5 in simulating the onset HW events.**

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References

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