SPECIAL PROJECT PROGRESS REPORT

All the following mandatory information needs to be provided. The length should *reflect the complexity and duration* of the project.

Reporting year	2025
Project Title:	Impact of Land-Use Changes on Past and Future Regional Climate over the EURO-CORDEX domain
Computer Project Account:	spptcard
Principal Investigator(s):	Rita Margarida Cardoso
Affiliation:	Instituto Dom Luiz, Faculdade de Ciências, Universidade de Lisboa
Name of ECMWF scientist(s) collaborating to the project (if applicable)	-
Start date of the project:	01/01/2024
Expected end date:	31/12/2026

Computer resources allocated/used for the current year and the previous one

(if applicable)
Please answer for all project resources

		Previous year		**Current year**	
		Allocated	Used	Allocated	Used
High Performance Computing Facility	(units)	35M SBU	6 M SBU	35M SBU	1.5 M SBU
Data storage capacity	(Gbytes)	60 000 GB	10 000 GB	60 000 GB	3 GB

Summary of project objectives (10 lines max)

The project seeks to improve the understanding of the influence of LUC in the main physical mechanisms and systems governing European climate and is integrated in EURO-CORDEX Flagship Pilot Study "LUCAS – Land Use and Climate Across Scales". Land-surface models and, by extension, regional climate models, produce contradicting results even for idealised experiments. Thus, large uncertainties in climate scenarios are associated to land use representation. More realistic simulations of land use/land cover changes may be important towards reducing the uncertainty and inconsistencies in these scenarios. The project seeks to understand how spatial resolution affects the magnitude and robustness of LUC-induced climate changes and how strongly can local LUC attenuate negative impacts of climate change, e.g., extreme events in Europe.

Summary of problems encountered (10 lines max)

After the simulation the finished the CORDEX protocol demands that about 200 variables are extracted cmorised (WCRP-CORDEX/data-request-table: Machine readable data request tables). Although this process does not spend many computing resources it is time consuming. The dimensions of the simulation output files do not allow their transfer out of the ECMWF HPC since the connections between it and the HPC in Lisbon kept failing mid transfer. Thus, all this post-processing was done at the ECMWF HPC. Due to these difficulties in transferring large amounts of data between HPCs, we opted to pre-process the boundary conditions for the future runs in Lisbon. Thus, the resources consumed this year are still limited.

Summary of plans for the continuation of the project (10 lines max)

Now that the boundary conditions for future simulation with the WRF model are assembled and pre-processed we will pursue the future climate simulations for SSP370 and SSP450 scenarios, driven by MPI-ESM1-2-HR. These will encompass the periods (2015-2100) and are an ensemble members of the WRF LUCAS consortium. All simulations within the WRF will use a common namelist and land use parameters and transient land-use changes according to the LUCAS protocol. Outputs will include specific vegetation parameters and selected 3D variables, contributing to coordinated LUCAS ensembles and intercomparisons In doing so, we will consume all the capacity we requested for 2025 and use the allocated storage.

List of publications/reports from the project with complete references

The results from the Evaluation Simulations performed in the past year are being distilled within the consortium and several papers being drafted using the ensemble cmorised variables. Here we present some of the titles of the papers in preparation:

1. Evaluation of Fire Weather Index Performance in EURO-CORDEX Simulations
2. EURO-CORDEX Regional Climate Model Performance in European Mountainous Areas
3. From Means to Extremes: A Comprehensive Assessment of EURO-CORDEX Evaluation Regional Climate Simulations
4. Evaluation of the snow-albedo effect in land-atmosphere interactions in sub-polar and alpine climates in the EURO-CORDEX Evaluation Simulations
5. Atmospheric Rivers in the EURO-CORDEX Evaluation Simulations
6. Assessment of climate trends in EURO-CORDEX Evaluation Simulations
7. Water budget Analysis within the EURO-CORDEX Evaluation Simulations
8. How do land-use changes shape the occurrence of extreme temperatures across Europe?
9. Land Use Changes and Atmosphere Feedbacks in an Evolving Climate

Summary of results

If submitted **during the first project year**, please summarise the results achieved during the period from the project start to June of the current year. A few paragraphs might be sufficient. If submitted **during the second project year**, this summary should be more detailed and cover the period from the project start. The length, at most 8 pages, should reflect the complexity of the project. Alternatively, it could be replaced by a short summary plus an existing scientific report on the project attached to this document. If submitted **during the third project year**, please summarise the results achieved during the period from July of the previous year to June of the current year. A few paragraphs might be sufficient.

The simulations performed in this special project are part of a wider WRF ensemble for the EURO-CORDEX CMIP6 Land-use changes across scales. The first simulations are now being analysed within the consortium and several proposed papers are now being drafted. The table with the proposed papers can be found in:

euro-cordex/joint-evaluation: Joint evaluation of the CMIP6 downscaling within EURO-CORDEX.

Within these, the following links show four that have been discussed more regularly.

EURO-CORDEX joint evaluation papers

EURO-CORDEX FWI Evaluation - Google Docs

EURO-CORDEX Joint Evaluation "Mountains"

CORDEX-CMIP6_eval_terr-water-budget - Google Drive

Additionally, our team has pursued research on the effects of land-use changes on extreme heat and its feedbacks into the energy and water fluxes. To do that, a new land-atmosphere coupling metric was developed for extreme heat or heat waves. Here we present some of the results that should be published soon.

While temperature is undoubtedly a crucial factor in evaluating the intensity of Heatwaves (HW), the objective of this study is to examine the relationship between these extreme events and other variables that can have a feedback effect on their severity. From the various available variables, we are interested in studying the energy fluxes, specifically latent and sensible heat fluxes (LH and SH, respectively) and the water content, in the form of soil moisture (SM). A HW is a period of at least five consecutive days during which the maximum near-surface temperature exceeds the 85th, 90th, or 95th percentiles computed using a 31-day window. To facilitate the comparison of the intensity of these extreme events across different temporal and spatial scales, we normalized the daily maximum temperature (1) and computed the magnitude of the HWs in question.

$$MT(Tx_d) = \begin{cases} \dfrac{Tx_d - P_{25}}{P_{75} - P_{25}} \; if \; Tx_d > P_{25} \\ 0 \; if \; Tx_d \leq P_{25} \end{cases} \quad (1)$$

Tx_d represents the near-surface maximum temperature whis is above the chosen percentile threshold for the d day. Percentiles P_{25} and P_{75} were computed using the previously described method, with a 91-day window (representing a seasonal value centred on the day).When the maximum temperature is equal to P_{75}, *MT* is equal to one, representing a threshold at a seasonal scale. Thus, whenever $MT > 1$, the extreme event (since the maximum temperature is above an extreme percentile at a monthly time scale) also belongs to the 25th hottest events of that season.

Since extreme heat can lead to an increase of evaporation or LH, if there is enough SM, or can be the result of low soil moisture and evaporation, for both LH and SM, the magnitude was computed using equation (2) to also normlise their intensity.

$$MV(v_d) = \begin{cases} \dfrac{v_d - P_{\mathrm{h}75}}{P_{\mathrm{h}75} - P_{\mathrm{h}25}} \; if \; v_d < P_{\mathrm{h}25} \\ \dfrac{v_d - P_{\mathrm{h}25}}{P_{\mathrm{h}75} - P_{\mathrm{h}25}} \; if \; v_d \geq P_{\mathrm{h}75} \end{cases} \quad (2)$$

V represents either LH or SM. The percentiles P_{25} and P_{75} were calculated in accordance with the methodology outlined in equation (1). It is anticipated that when either LH or SM are situated below or above the seasonal percentiles of 25 or 75, the magnitudes will be below or above the absolute values of -1 (land/vegetation controls the fluxes) or +1 (atmosphere controls the fluxes), respectively. The principal findings can be discerned when all pairs of magnitudes and indexes are integrated into a single entity, namely, the couplings. This integration allows us to represent both variables and relate their distributions directly. Thus a new coupling metric is introduced as the product of both equations and strong land/vegetation atmosphere coupling will be represented by negative values (lower than -1), whilst positive values, greater than one, will indicate week coupling.

$$CM = \sum MT(Tx_d) * MV(v_d) \quad (3)$$

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The figures show the coupling results for both experiments, either in the form of maps or scatter plots

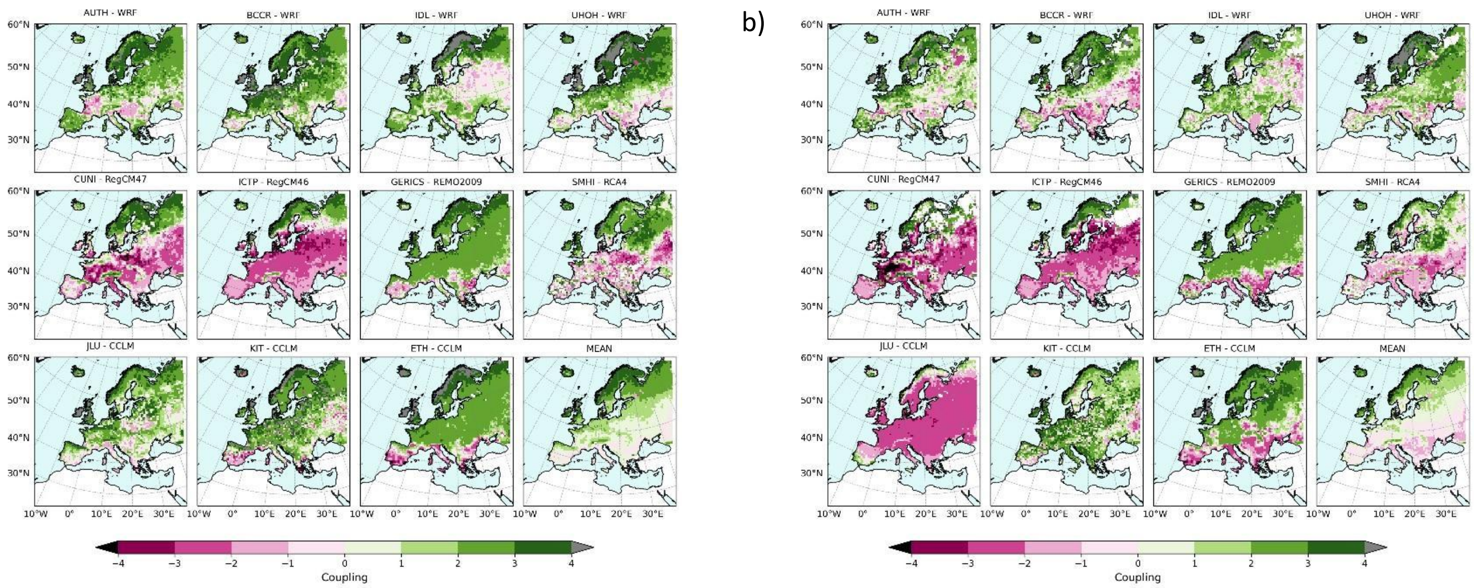


Figure 1 – Summer (JJA) coupling between the magnitude of near-surface maximum temperature and the magnitude of latent heat (Coup(MT,MLH)) in HW for the a) forest and b) grass experiments.

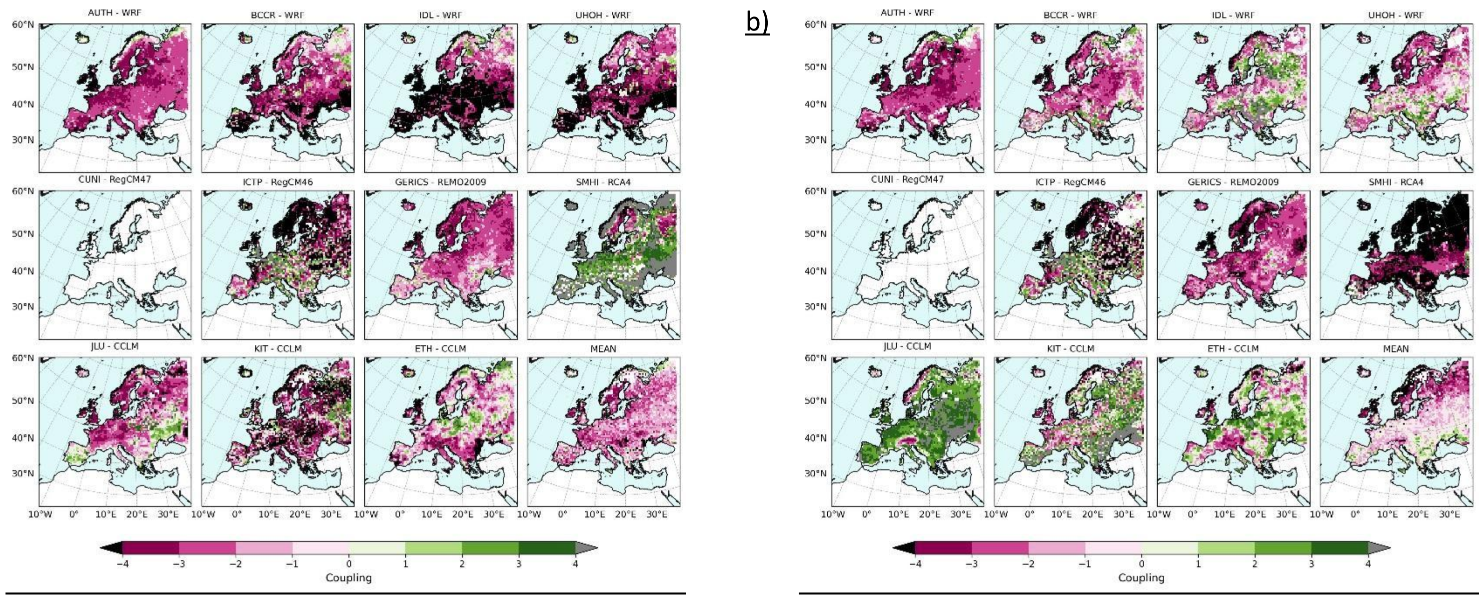
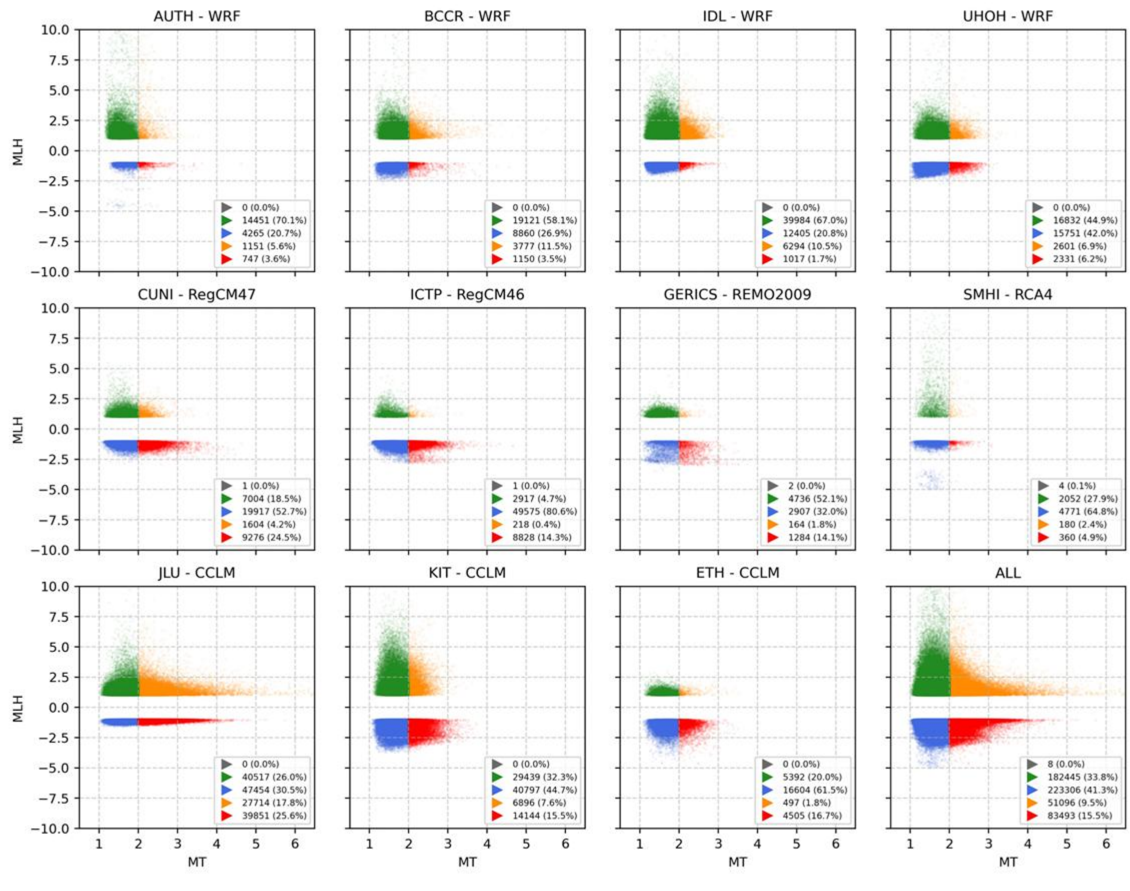


Figure 2 – Summer (JJA) coupling between the magnitude of near-surface maximum temperature and the magnitude of soil moisture (Coup(MT,MSM)) in HW for the a) forest and b) grass experiments.

a)



b)

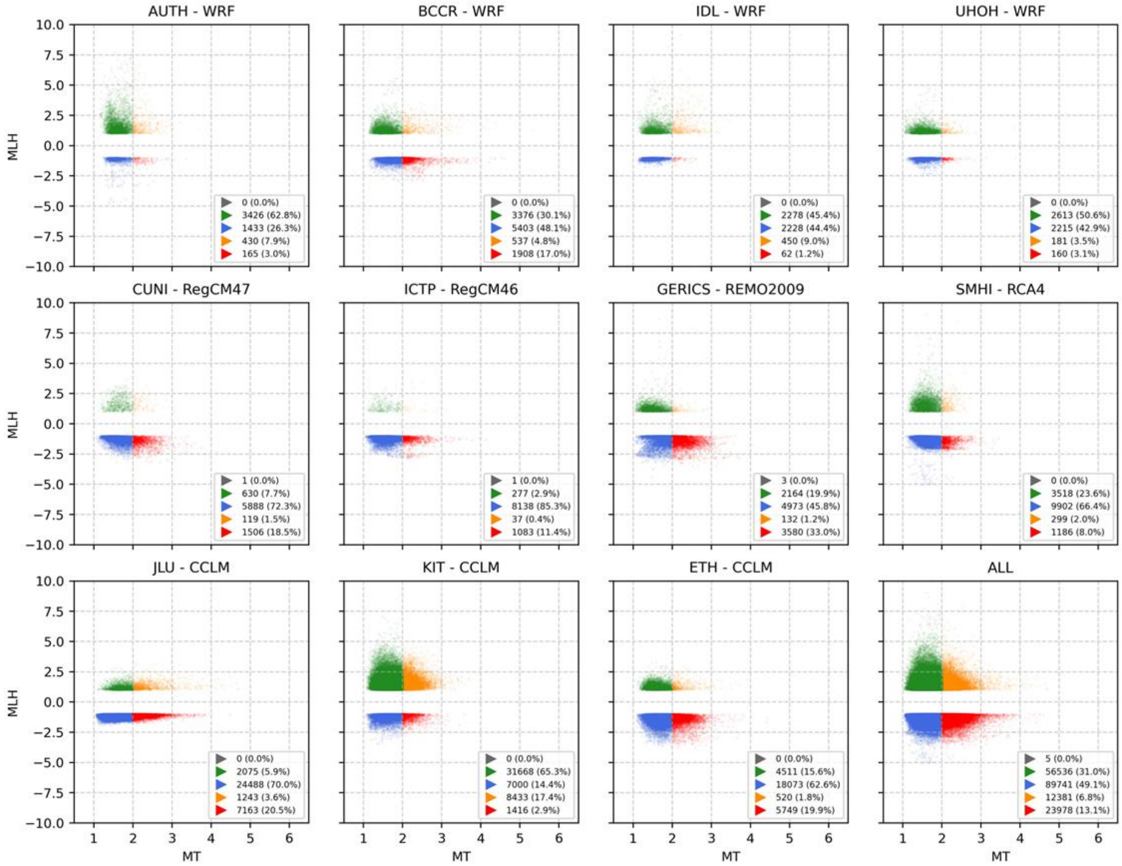
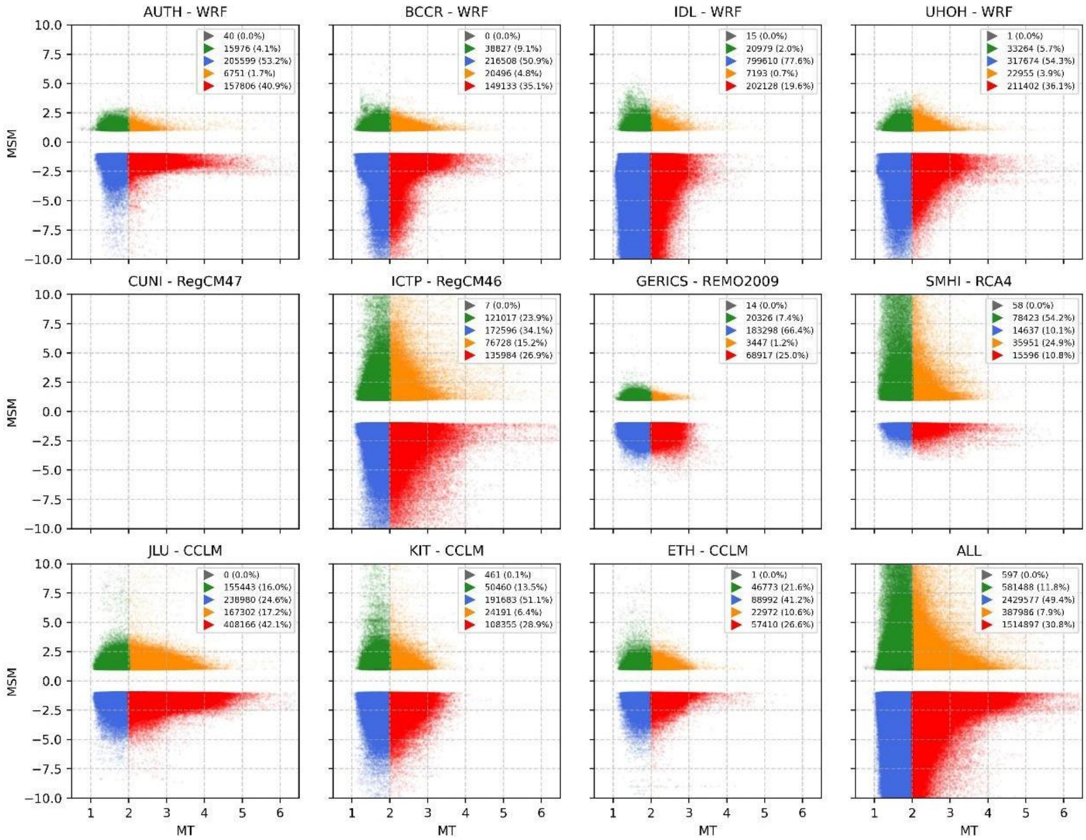


Figure 3. – Southern Europe Summer (JJA) coupling between the magnitude of near-surface maximum temperature and the magnitude of latent heat (Coup(MT,MLH)) in HW for a) forest and b) grass experiments.

a)



b)

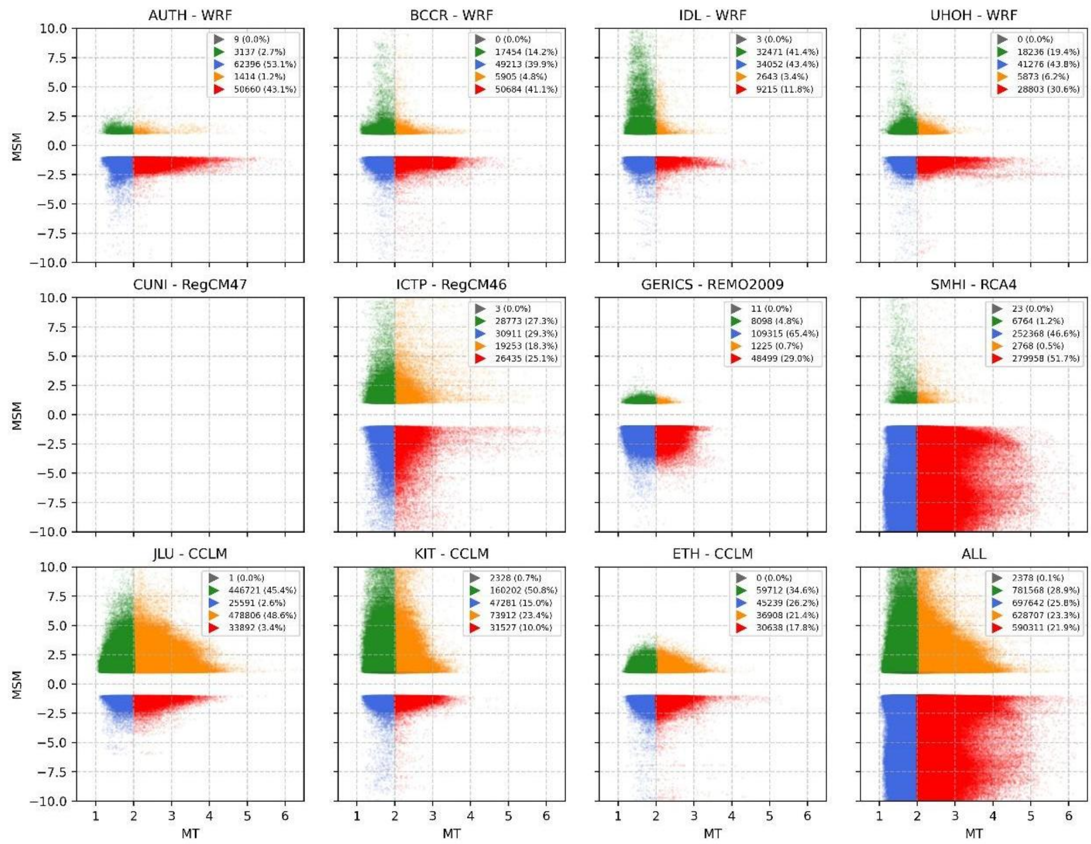


Figure 4 – Summer (JJA) coupling between the magnitude of near-surface maximum temperature and the magnitude of soil moisture (Coup(MT,MSM)) in HW for the a) forest and b) grass experiments.

Conclusions

The *new coupling metric* is versatile and exposes the coupling between the atmosphere and the soil under extreme temperature events. It is built with normalised variables and can thus be used to compare different regions or scenarios.

Although there is a large uncertainty in the results, in the ensemble mean *Afforestation* shows weak coupling between temperature and latent heat in northern and central Europe, with transition zone in the northern part of the Mediterranean. While the *extreme deforestation* experiment exhibits strong coupling in southern Europe, with the transition zone in central Europe. These effects intensify during heat wave episodes. *Afforestation* has lower soil-atmosphere coupling than *deforestation* due to the forests ability to source water from deeper layers of the soil and transfer this moisture to the atmosphere through evapotranspiration.