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	2024
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	5 M SBU
Data storage capacity	(Gbytes)	-	-	60 000 GB	10 000 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)

The land-surface model in the regional climate model WRF had several problems associated to the correct impact of vegetation on the surrounding atmosphere. The model had cold biases in several areas of central Europe which were not associated to a particular land use type. Furthermore, the model produced low clouds in some areas of western France and Russia that lingered for an unreasonable amount of time. The diagnostics and solution to these problems was possible due to a concerted effort within the WRF community. Additionally, different compilation options led to the emergence of strange surface temperature values in the land-sea interface. All this, lead to a very late start of the planned simulations. These started in earnest in March 2024, with only some diagnostics performed before that.

Additionally, by mistake the majority of the simulations were performed under the ptearth account and not with this account, thus the very small amount of SBUs used.

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

Now that the different bugs have been corrected and the WRF model is performing according to expected, we will pursue the completion of the evaluation run forced by ERA5 and perform the historical run. In doing so, we will consume all the capacity we requested for 2024. Since this project is inserted in an international effort and our simulations are late, we need to run our simulations faster than anticipated, thus we plan to request an extension of resources for next year.

List of publications/reports from the project with complete references

For this special project there aren't yet publications, since the first simulations have just finished. One paper will be submitted in latter in the year 2024.

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.

A new land use dataset for 2015 was prepared for the evaluation runs. This dataset is based on the LANDMATE PFT land cover dataset for Europe 1992-2015 (Version 1.1, doi:10.26050/WDCC/LM_PFT_EUR_v1.1). A protocol was developed in order to translate this dataset into fields appropriate for de WRF model and will be used to translate the transient land use for the historical runs. More details are provided in https://github.com/CORDEX-WRF-community/euro-cordex-cmip6/tree/main/static_data

Although the first simulation is not yet completed, we have already 39 years of results. An extensive evaluation of several varibles will be performed when all the simulations are finished. For each grid point and time scales [daily, monthly, seasonal and yearly], numerous standard statistics will be computed.

For a first glance we began to analyse extreme temperatures and heatwave events. To do this, percentiles of the available near-surface maximum temperature, latent and sensible heat fluxes, and moisture fluxes were computed. Daily percentiles were computed according to the methodology proposed by Zhang et al. (2005), with a 31- and 91-days windows. The method uses a bootstrapping technique to calculate the percentiles to avoid an overestimation of the exceedance rates when the percentiles are employed as thresholds outside the base period used for their estimate. This occurs due to the limited dimension of the base time series, which induces a sampling error in the threshold calculus. The percentiles within a particular year of the base period are calculated by removing the data from that year and replacing it with data from another year, so that the time series keeps its dimension. This is done for all the years except the last, where the percentiles are the average of the percentiles calculated for each year.

In this context a heatwave (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.

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

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.

While temperature is undoubtedly a crucial factor in evaluating the intensity of a HW, the relationship between these extreme events and other variables that can have a feedback effect on their severity is also crucial. 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). As for temperature, both LH and SM were normalised, and the magnitude was computed using equation (2).

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

V represents either LH or SM. 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.

Figure 1 shows the average maximum temperature magnitude across Europe for three percentile thresholds for each season. Since the normalising P_{25} and P_{75} are determined for with *91*-day window, we can ascertain the magnitude of the winter heat waves. These do not pose health hazards, but can have relevant consequences for the hydrological cycle and sectors as agriculture. In winter the very extreme heat waves are mostly concentrated in the Balkan area and around the Alps. The highest magnitudes are found in Summer.

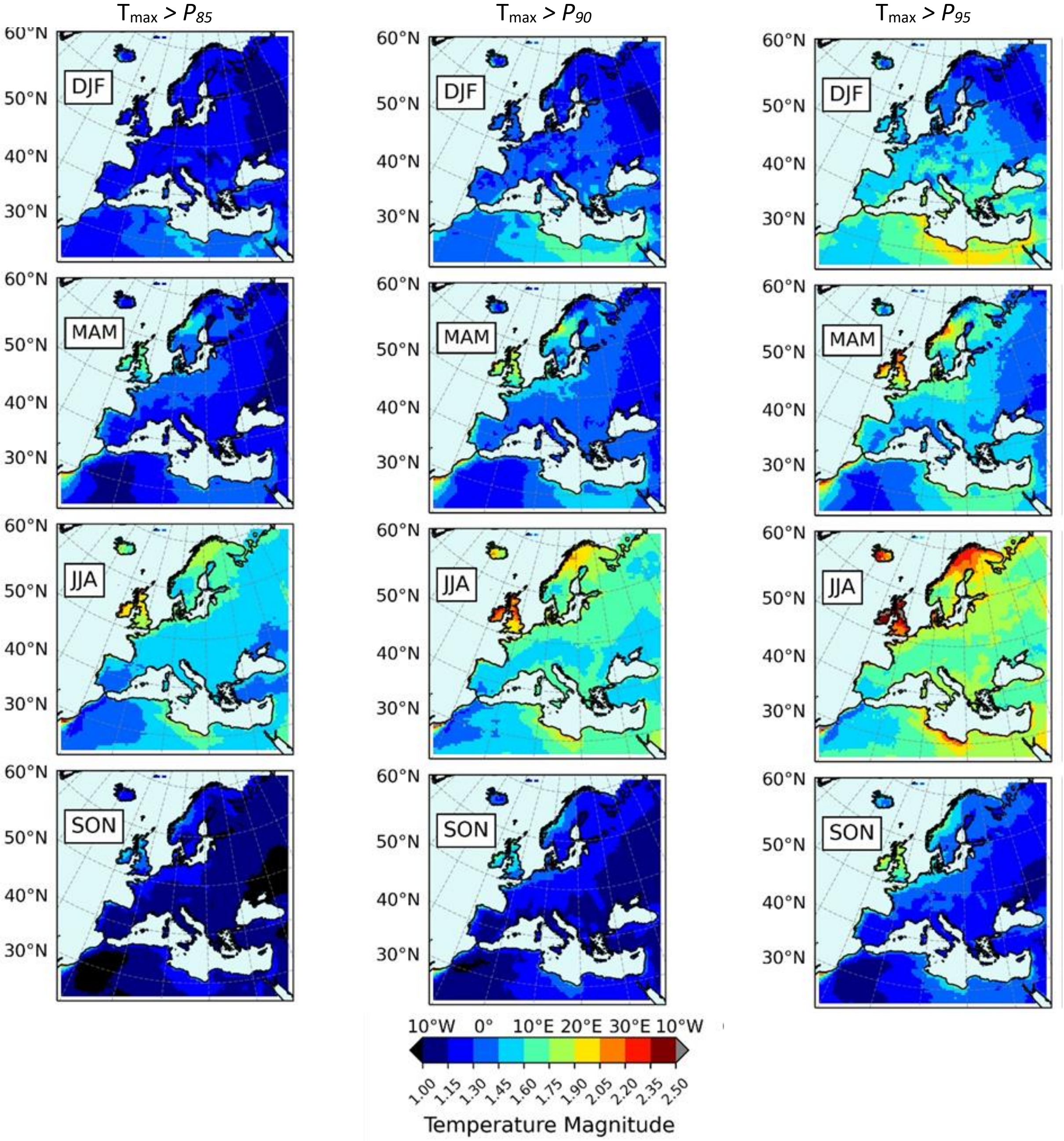

Figure 1: Average maximum temperature magnitude across Europe for three percentile thresholds for each season. Maximum near-surface temperature exceeds the 85th, 90th, or 95th percentiles for more than 5 consecutive days.

Figure 2 is similar to the previous but shows the average magnitudes for latent heat and soil moisture.

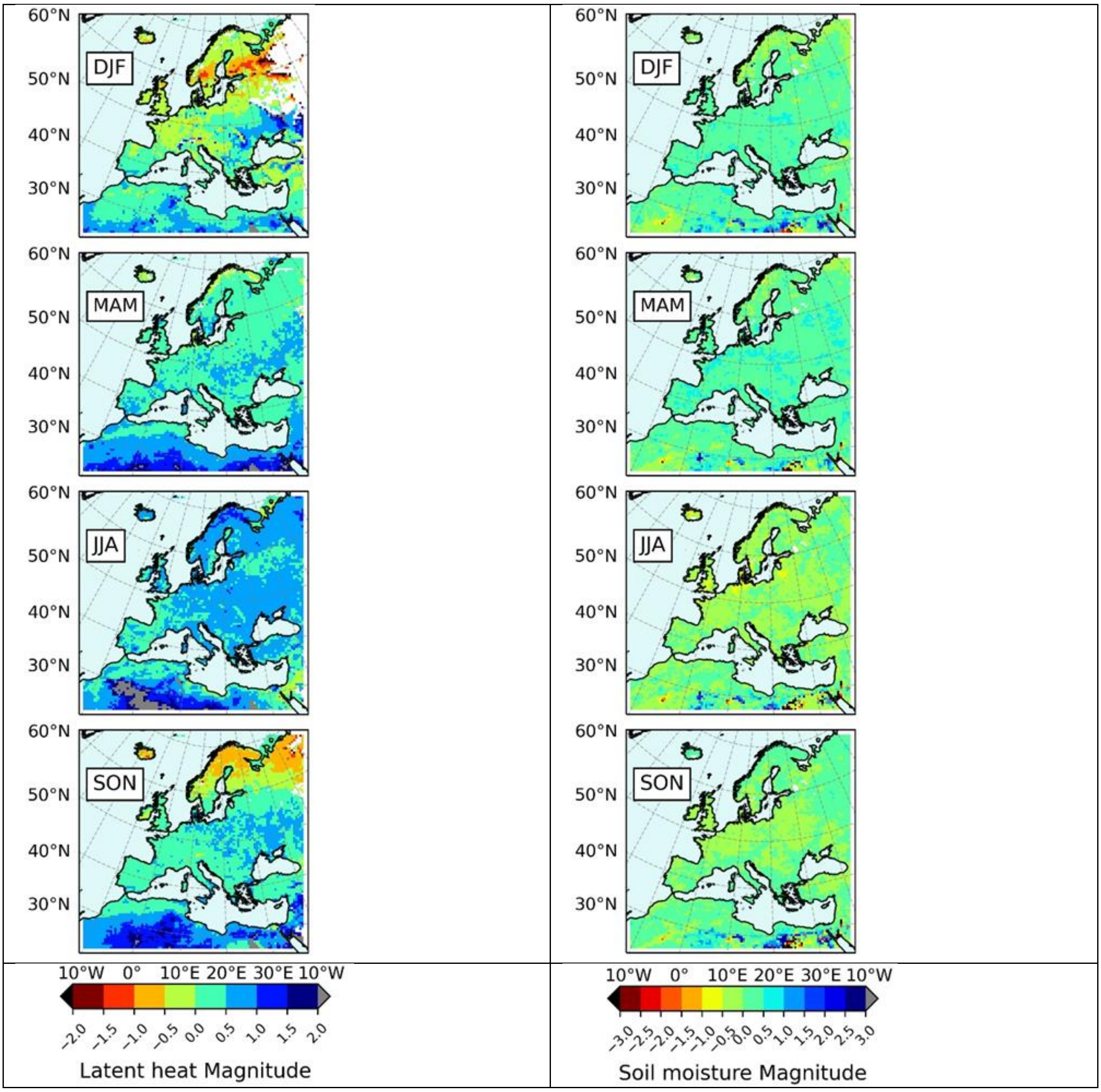

Figure 2: Average latent heat and soil moisture magnitudes across Europe.

Figure 3 shows the spatial distribution of the average heat wave magnitude (severity) across Europe as well as the number of events and their maximum length, for the three percentile thresholds. Since the normalising P_{25} and P_{75} are equal for all thresholds, the severity of the heatwaves incresaes with increasing threshold. The largest severities are found in Scandinavia and in Eastern Europe. Coverlsy the very extreme heat waves have shorter lengths. Here, the Paris 2003 and the Russian 2010 heat waves imprint a strong signal cross all thresholds.

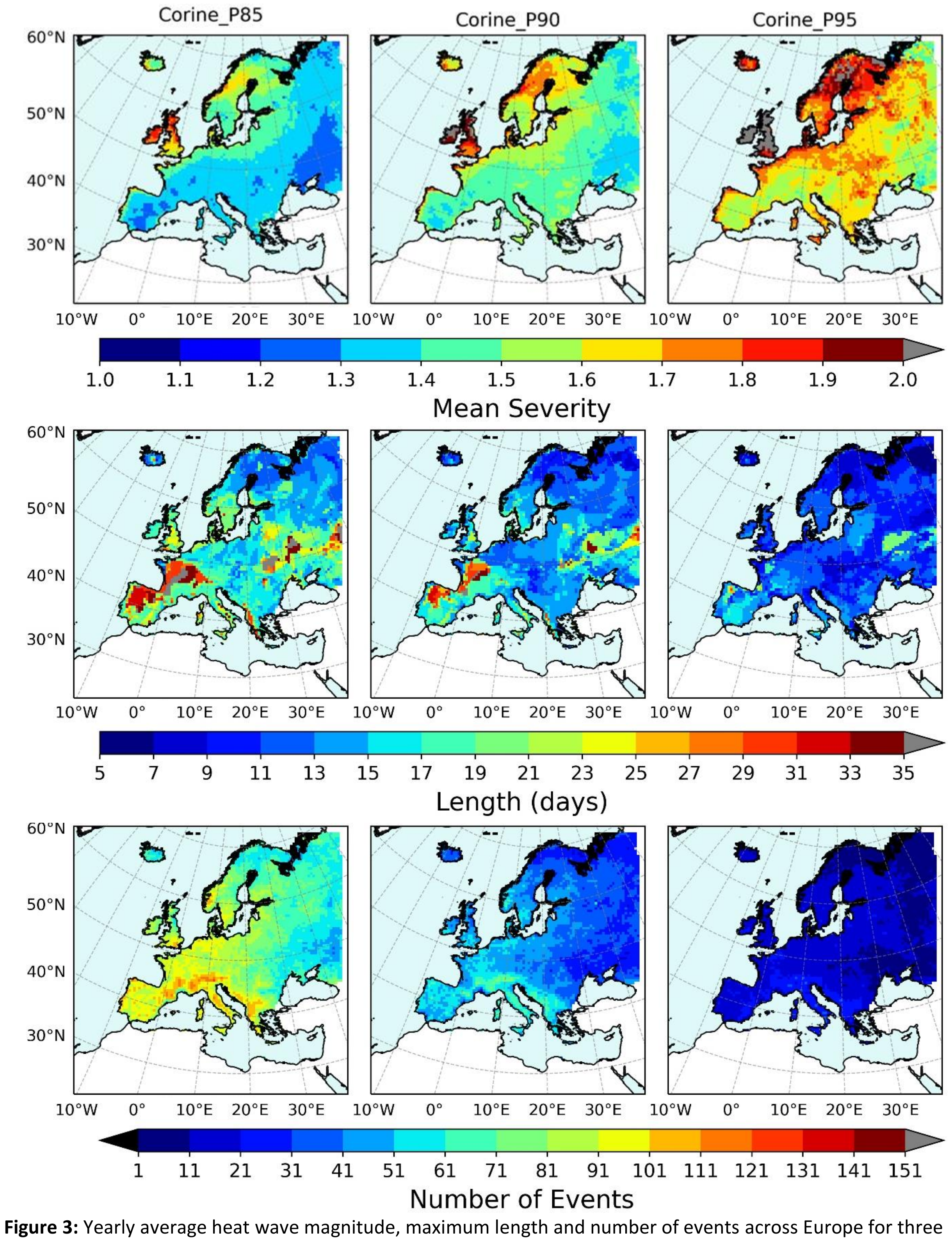

Figure 3: Yearly average heat wave magnitude, maximum length and number of events across Europe for three percentile thresholds. Maximum near-surface temperature exceeds the 85th, 90th, or 95th percentiles for more than 5 consecutive days.

We have updated the WRF model surface configurations and increased our knowledge of the technical requirements associated to this design. Now the historical runs need to be started as soon as the evaluation run finishes (2nd week of July). The time constraints of this project (this is part of the LUCAS FPS and EURO-CORDEX CMIP6 runs) require that the results should be ready as fast as possible. Since we lost 7 months in sorting several bugs in the model, the number of cores needed to perform the simulations has increased from 6 to 10. This implies that our initial HPC SBU request was underestimated. We thus, ask that 50 000 000 SBU be added to the 2024/2025 allocated SBU, i.e. this project's total allocated capacity would be 85 000 000 SBU (35 000 000 + 50 000 000 SBU).