SPECIAL PROJECT FINAL REPORT

All the following mandatory information needs to be provided.

Project Title:	EURO-CORDEX SIMULATIONS INCLUDING LAND USE CHANGES
Computer Project Account:	**spgrkatr**
Start Year - End Year :	2025 – 2025
Principal Investigator(s)	ELENI KATRAGKOU
Affiliation/Address:	ARISTOTLE UNIVERSITY OF THESSALONIKI, DEPARTMENT OF METEOROLOGY AND CLIMATOLOGY, SCHOOL OF GEOLOGY / 54124, THESSALONIKI, GREECE
Other Researchers (Name/Affiliation):	VASILEIOS PAVLIDIS, STERGIOS KARTSIOS, SOFIA PASCHOU

The following should cover the entire project duration.

Summary of project objectives

(10 lines max)

The project aimed to produce two hindcast simulations over Europe with the WRF model within the EURO-CORDEX framework, especially the LUCAS Flagship Pilot Study (FPS). The two simulations differ only regarding the land use data. The first simulation, the Control, used static land use data while the second simulation, LUC, is a sensitivity simulation that included transient land use changes. Both simulations were forced with ERA5 and covered the period 1980-2010.

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Summary of problems encountered

(If you encountered any problems of a more technical nature, please describe them here.)

During the special project we encountered several issues that lead to a considerable delay of project initialization.

Set up and configuration of the WRF model in the Atos HPC was completed seamlessly without any major issues. Initial tests of the WRF model were successful and the preparation and launch of the Control simulation took place after the first month of project activation. The preparation and initialization of the LUC sensitivity simulation followed shortly within the second month. An initial delay of about two weeks happened due to the need to recreate the input files with transient land use changes in order to accommodate a more precise description of certain land use categories.

Unfortunately, we encountered two additional separate problems that constrained the production flow of the simulations and led to a considerable delay. Firstly, in the early stages of the simulations during quality checking we discovered that the aerosol AOD variable in the WRF output files did not match the expected output, that of the MERRA aerosol. After some testing, we discovered that the initial aerosol input files used in the simulations (through aer_opt=2 in the namelist.input) had the wrong data source. We prepared the correct aerosol files and recommenced the simulations. Overall, this set back led to a delay for about 3 weeks.

A second and more serious problem was encountered shortly after. We discovered that the Leaf Area Index (LAI) variable was not properly updated in the output files of the LUC simulation with transient land use changes. After valuable help from the LUCAS FPS community and extensive testing of the various LAI options, available in the Noah-MP land model we were using within WRF, we realized that a certain LAI option in the Noah-MP was causing the problem. We were utilizing an option (dveg=8) that read the LAI properties from an external file (geo_em) that contains the geographical information and had a fixed in time LAI map (SPOT satellite data) for the year 2015. Thus, the LAI was kept stable despite the incorporation of transient land use. To solve this, we incorporated an option (dveg=3) that uses tabulated values to calculate the LAI according to the land use categories and thus enable the LAI values to differ accordingly. Interestingly, comparison of the correct approach with the older approach indicated considerable differences in several variables. Therefore, we completely restarted the LUC simulation. This led to a delay of about two months.

Despite these delays, we were able to complete within the timeframe of the project (2025) for both simulations a large part of the proposed time span (1980-2020) fully covering the period 1980-2010. Due to the somewhat shorter period completed and the fact that the performance of WRF in the ECMWF HPC was slightly (10-15%) faster than expected, we consumed around 60% of the given computational resources.

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Experience with the Special Project framework

(Please let us know about your experience with administrative aspects like the application procedure, progress reporting etc.)

Experience with the Special Project framework regarding the administrative aspects was overall quite positive. Instructions on the application procedure were clear and the templates of project application and report straightforward to complete. Moreover, process of the application and grant of the computational resources was fast.

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Summary of results

(This section should comprise up to 10 pages, reflecting the complexity and duration of the project, and can be replaced by a short summary plus an existing scientific report on the project.)

Comparison of the produced output of the two simulations shows considerable impacts regarding the inclusion of transient land use changes. We have finished postprocessing of the raw output files for the entire period (1980-2010) our simulations covered and completed an initial analysis of the first five years, 1980-1984, regarding impacts on the basic climatic variables of near surface temperature and precipitation.

Analysis has been performed over the entire European domain as well as over various subregions (over the Prudence regions). We calculated the differences between the two simulations while we have also evaluated them against the E-OBS v31.0e at 0.11° resolution, observational dataset for temperature and precipitation.

The differences between the two simulations, thus the impact of transient land use changes, can be considerable at grid point level with differences in several cases exceeding 2ºC in temperature and more than 50% for precipitation. Regarding subdomain averages (over the Prudence regions) the impact is generally considerably smaller, with notable exceptions over specific areas and seasons. Overall, regarding both temperature and precipitation, the largest impact is seen in summer.

Specifically, regarding temperature, the differences between the two simulations, thus the impact of transient land use changes, can be considerable at grid point level, even exceeding 2ºC in many cases (Figure 1). This is particularly evident over summer when the largest impact is seen (Table 1), with LUC simulations being considerably colder than CNTRL over the largest part of the domain. In autumn LUC is also colder than CTRL but to a smaller extent compared to summer. In winter and spring there is not a predominant behavior of the impact over the entire domain. Notably LUC in spring is considerably warmer than CTRL (>1 ºC) over a widespread area covering Scandinavia and northeastern Europe.

Considering the temperature bias, both simulations exhibit predominantly negative biases, especially during autumn and winter. Underestimation over 1 ºC and in many areas exceeding 2 ºC is common throughout the domain for these two seasons, while the spatial patterns of the two simulations are very similar. Exceptions are the strong positive bias seen over norther Scandinavia in winter and scattered positive biases mainly over mountainous areas during spring. Interestingly, in summer negative biases in CTRL turn to widespread positive biases in LUC over a widespread region covering western and central Europe. Moreover, in spring a strong negative bias in Scandinavia and northeastern Europe turns to a clear positive bias in LUC. This indicates that the impact of the transient land use changes can considerably modify the biases in certain seasons and over large Areas of the domain.

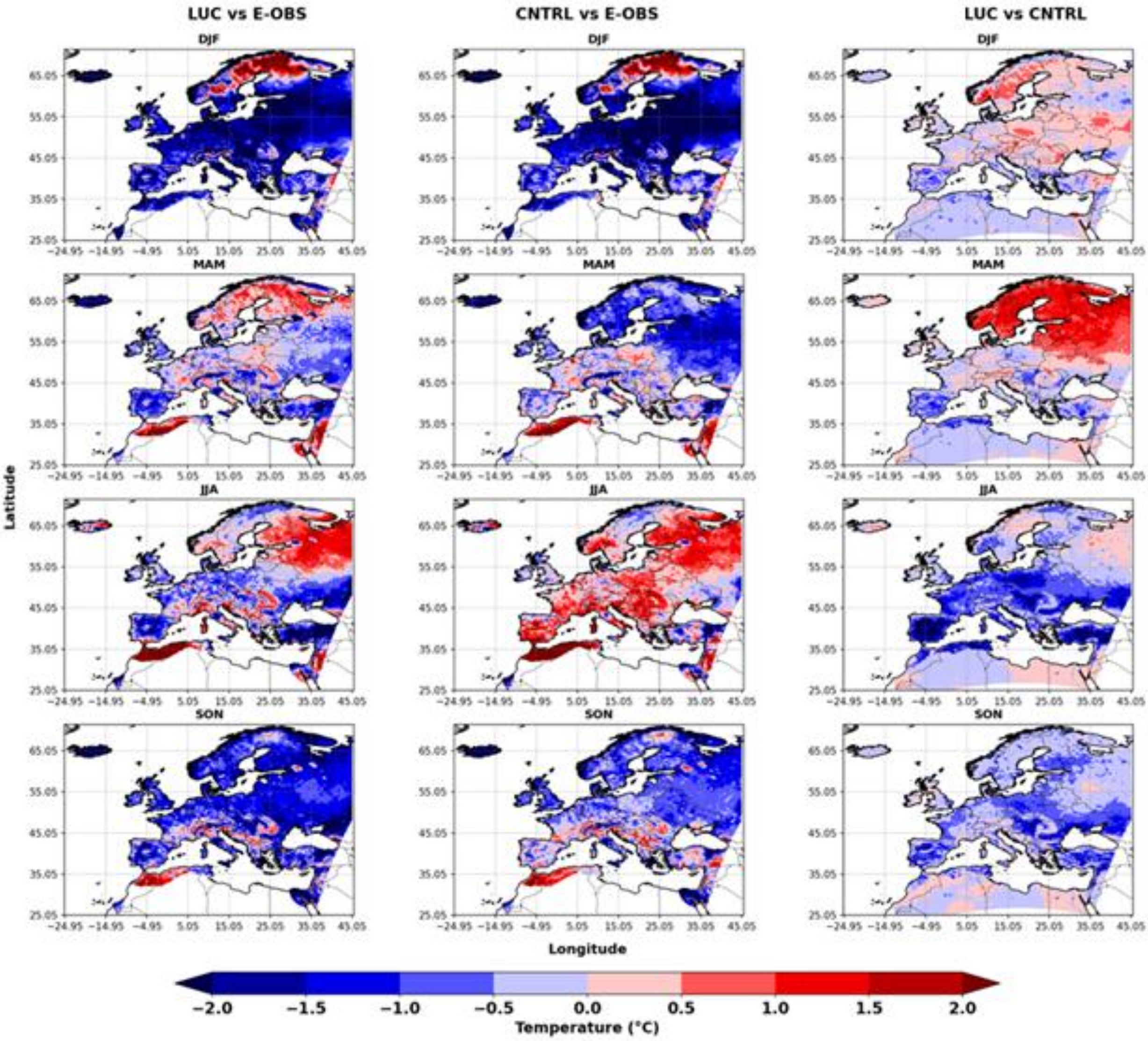

Figure 1:Temperature bias (°C) against E-OBS data for LUC (first column) and CNTRL (second column) simulations. Third column depicts the difference between the two simulations. For all seasons (rows) and the period 1980-1984.

Table 1: Mean seasonal bias of temperature (°C) during summer over various subregions of Europe for the 1980-1984 period. For LUC (first row) and CNTRL (second row) simulations. Third row depicts the difference between the two simulations. AL: Alps, BI: British Isles, EA: Eastern Europe, FR: France, IP: Iberian Peninsula, MD: Mediterranean, ME: Mid-Europe, SC: Scandinavia, GR: Greece

Summer (JJA)									
	AL	BI	EA	FR	IP	MD	ME	SC	GR
LUC vs E-OBS	0.2	-0.5	-0.3	-0.4	-0.7	0.0	-0.6	0.1	-0.6
CNTRL vs E-OBS	0.8	-0.3	0.7	0.5	0.8	0.6	0.3	0.3	-0.1
LUC vs CNTRL	-0.6	-0.2	-1.0	-0.9	-1.5	-0.6	-0.8	-0.2	-0.6

Regarding precipitation, the differences between the two simulations are generally constrained, rarely exceeding 1mm/day at grid point level, while the spatial pattern consists of scattered positive and negative values (Figure 2). During summer, the mean relative differences become more pronounced, reaching 26% over the Iberian Peninsula, 23% over Greece and 15% over France (Table 2).

Compared to the E-OBS dataset, the precipitation bias is predominantly positive across all seasons for both simulations, indicating that the model generally overestimates precipitation. The bias spatial patterns of the two simulations are very similar, indicating that the strong positive bias does not change considerably with the implementation of transient land use change. During spring and summer, the bias reaches approximately 2.5 mm/day, while the relative bias in these two seasons becomes very pronounced over Southern Europe.

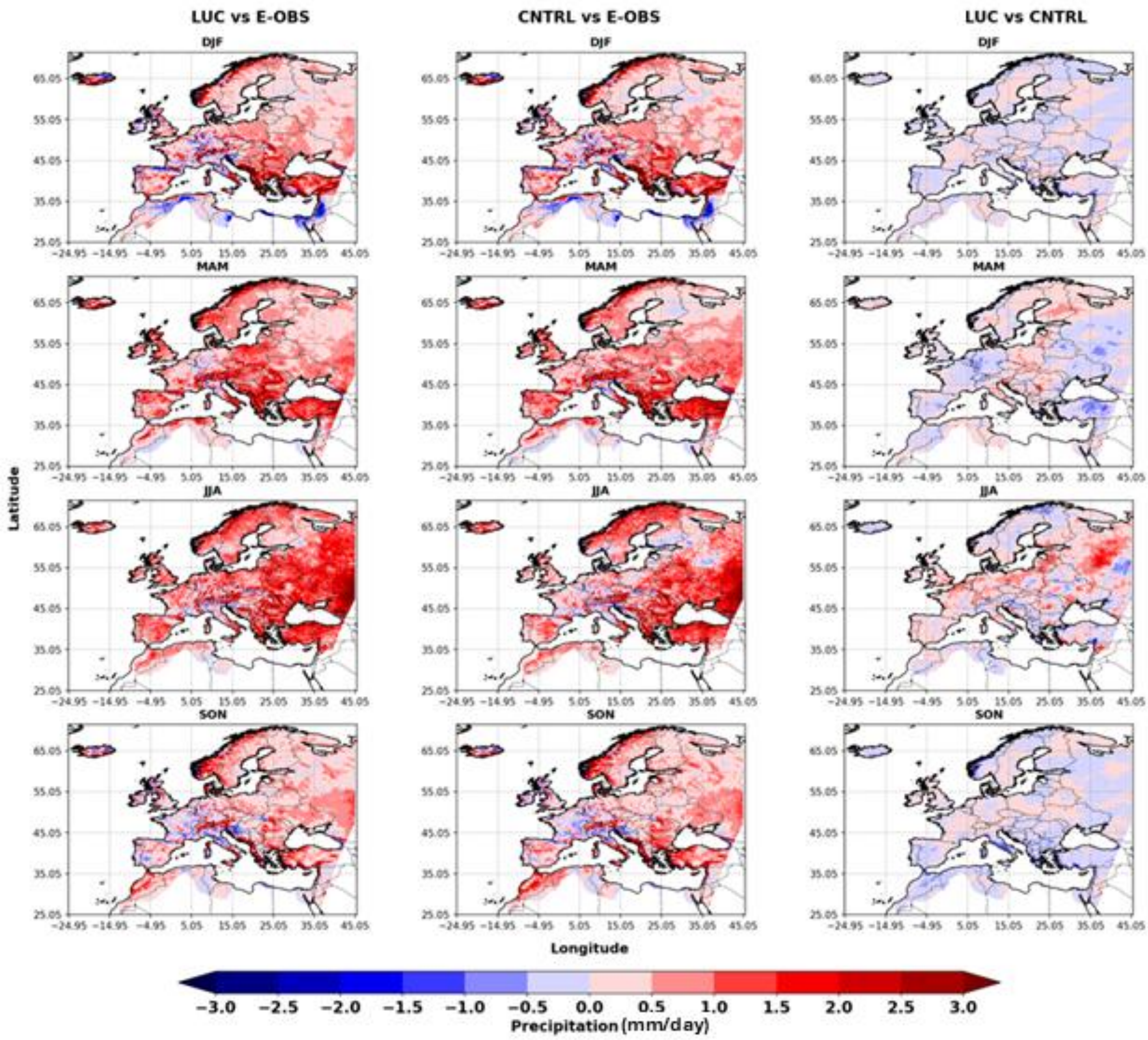

Figure 2: Precipitation bias (mm/day) against E-OBS data for LUC (first column) and CNTRL (second column) simulations. Third column depicts the difference between the two simulations. For all seasons (rows) and the period 1980-1984

Table 2: Mean seasonal bias of precipitation (mm/day) and relative bias (% in parenthesis) during summer over various subregions of Europe for the 1980-1984 period. For LUC (first row) and CNTRL (second row) simulations. Third row depicts the difference between the two simulations. AL: Alps, BI: British Isles, EA: Eastern Europe, FR: France, IP: Iberian Peninsula, MD: Mediterranean, ME: Mid-Europe, SC: Scandinavia, GR: Greece

Summer (JJA)									
	AL	BI	EA	FR	IP	MD	ME	SC	GR
LUC vs E-OBS	0.56 (18.6%)	0.65 (34.8%)	1.10 (51.7%)	0.51 (28.4%)	0.76 (183.6%)	0.84 (341.5%)	0.78 (36.9%)	0.74 (35.0%)	1.20 (584.9%)
CNTRL vs E-OBS	0.46 (16.5%)	0.37 (19.6%)	0.92 (43.5%)	0.23 (12.9%)	0.56 (130.5%)	0.81 (315.8%)	0.40 (18.7%)	0.63 (30.3%)	1.19 (404.2%)
LUC vs CNTRL	0.10 (3.2%)	0.28 (13.2%)	0.19 (6.8%)	0.28 (14.5%)	0.19 (25.5%)	0.03 (12.7%)	0.39 (15.8%)	0.11 (5.6%)	0.01 (22.2%)

We are currently in the process of expanding the analysis, incorporating the entire time period and additional variables of interest.

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List of publications/reports from the project with complete references

Future plans

(Please let us know of any imminent plans regarding a continuation of this research activity, in par ticular if they are linked to another/new Special Project.)

Since we have shown that the impact of transient land use change can be considerable in recent-past hindcast simulations, we are considering extending the research both in historical and future period simulations under certain SSPs scenarios. This endeavour would be valuable since it could help to more accurately identify the true signal of climate warming. In this case we would definitely consider applying for another Special Project.

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