REQUEST FOR AN EMI R&D PROJECT 2027–2029

Country/Organisation:	Portugal
Principal Investigator[1]:	Rita Margarida Cardoso
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Project Title:	Impact of Land-Use Changes and Urbanisation on Past and Future Regional Climate over the CORDEX-CORE South America Domain

To make changes to an existing project please submit an amended version of the original form

If this is a continuation of an existing project, please state the computer project account assigned previously.	**SP** ………….	
Starting year: (A project can have a duration of up to 3 years, agreed at the beginning of the project.)	2027	
Would you accept support for 1 year only, if necessary?	YES ☐	NO ☐

Computer resources required for project year:		**2027**	**2028**	**2029**
High Performance Computing Facility	[SBU]	80.000.000	100.000.000	80.000.000
Graphics Processing Unit Cluster-A	[GBU]			
Graphics Processing Unit Cluster-B	[GBU]			
Accumulated data storage (total archive volume)[2]	[GB]	90.000	170.000	280.000

[1] The Principal Investigator will act as contact person for this EMI R&D Project and, in particular, will be asked to register the project, provide annual progress reports of the project's activities, etc.
[2] These figures refer to data archived in ECFS and MARS. If e.g. you archive x GB in year one and y GB in year two and don't delete anything you need to request x + y GB for the second project year etc.
[3] The number of vGPU is referred to the equivalent number of virtualized vGPUs with 8GB memory.

EWC resources required for project year:		2027	2028	2029
Number of vCPUs	[#]			
Total memory	[GB]			
Storage	[GB]			
Number of vGPUs[3]	[#]			

Continue overleaf.

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Extended abstract

All EMI R&D Project requests should provide an abstract/project description including a scientific plan, a justification of the computer resources requested and the technical characteristics of the code to be used. The completed form should be submitted/uploaded at https://www.ecmwf.int/en/research/special-projects/special-project-application/special-project-request-submission.

Following submission by the relevant Member State the EMI R&D Project requests will be published on the ECMWF website and evaluated by ECMWF and its Scientific Advisory Committee. The requests are evaluated based on their scientific and technical quality, and the justification of the resources requested. Previous EMI R&D Project reports and the use of ECMWF software and data infrastructure will also be considered in the evaluation process.

Requests exceeding 5,000,000 SBU should be more detailed (3-5 pages).

Abstract
South America hosts some of the most extensive and rapidly evolving land-use and land-cover changes (LUC) on Earth, from large-scale deforestation and agricultural expansion across the Amazon and the Cerrado, to the explosive growth of megacities such as São Paulo, Buenos Aires, Bogotá, and Lima. These transformations modify the land surface's albedo, roughness, evapotranspiration and anthropogenic heat fluxes, altering local and remote climate in ways that remain poorly quantified at continental scale and at the resolution required for impact and adaptation studies. Land use and urbanisation contribute substantially to the overall uncertainty in regional climate projections and, although their impact can rival that of greenhouse gas emissions, they continue to be under-represented in coordinated regional climate ensembles for South America.

This project proposes a new set of continental-scale WRF simulations for the CORDEX South America domain (SAM-22, 0.22°/~25 km, 52°S–19°N, 105°W–17°W), following the CORDEX-CORE protocol – an ERA5-driven evaluation run, a CMIP6 historical run, and future projections under SSP2-4.5 and SSP3-7.0 – using harmonised, transient land-use/land-cover and urban-extent datasets to isolate the biophysical impact of LUC and urbanisation on regional climate. Because the same WRF configuration is already applied by the proposing team to the EURO-CORDEX domain (as part of the ongoing LUCAS Flagship Pilot Study for Europe), this project will deliver a methodologically consistent, cross-continental WRF ensemble. This allows direct, like-for-like comparison of LUC and urbanisation signals between Europe and South America, and contributes new, high-resolution ensemble members to the broader CORDEX-CORE multi-model, multi-domain RCM/GCM ensemble used in international climate change assessments.

The specific objectives are to: (i) quantify the relative contribution of LUC and urbanisation to past climate trends and extremes across South America; (ii) characterise their imprint on the projected climate change signal under two future scenarios; and (iii) deliver a WRF-based dataset directly comparable, domain by domain, with the team's parallel European simulations and with the wider CORDEX-CORE ensemble, supporting both global model intercomparison and regional climate services.

Motivation
Land use and land cover change (LUC) is widely recognised as a major driver of regional and global climate change, modifying local surface properties – albedo, Bowen ratio, and roughness – that govern land–atmosphere mass, energy and momentum exchanges (Pielke et al. 2011;

Mahmood et al. 2014). The magnitude and even the sign of the resulting climate response depends strongly on the scale, type and pattern of the land cover change, and remains one of the largest sources of structural uncertainty in regional climate projections.

South America is a global hotspot for this uncertainty. Some of the earliest climate model experiments on tropical deforestation were performed over the Amazon (Lean and Warrilow 1989), establishing that replacing forest with pasture weakens the local hydrological cycle, reducing evapotranspiration and precipitation while increasing surface temperature. More recent observational and modelling work has refined this picture considerably: Smith et al. (2023) showed that tropical deforestation causes substantial, previously underestimated reductions in observed precipitation at local to regional scales, while Qin et al. (2025), using a high-resolution WRF configuration with moisture tracers, demonstrated that the precipitation response to Amazon deforestation actually reverses between seasons – increasing in the wet season through enhanced mesoscale circulation, and decreasing in the dry season through the direct loss of evapotranspiration. Such seasonally and spatially contrasting responses can only be resolved with regional climate models run at sufficiently high resolution over the full continental domain, and cannot be captured by coarse-resolution GCMs or by statistical, space-for-time approaches. Beyond the Amazon, the conversion of the Cerrado savanna to cropland and pasture, and the ongoing agricultural frontier expansion in the Chaco and southern Amazon, represent further large-scale LUC processes whose combined regional climate impact has not yet been assessed within a single, internally consistent modelling framework.

At the same time, South America is one of the most urbanised regions in the world, with a large majority of its population already living in cities and continued rapid urban growth projected for coming decades. Urbanisation modifies the surface energy balance through impervious surfaces, reduced vegetation and anthropogenic heat release, generating urban heat islands that intensify heatwaves and amplify health risks. Recent work within the CORDEX Flagship Pilot Study on Urban environments and Regional Climate Change (FPS URB-RCC) has begun to characterise these effects globally, including the representation of megacities in the CORDEX-CORE ensemble (Diez-Sierra et al. 2025) and, specifically for South America, a coordinated assessment of urban–rural contrasts in Buenos Aires, Córdoba and Porto Alegre showing consistent warming, drying and intensified heatwaves over the cities relative to their surroundings (Solman et al. 2026). These studies highlight both the importance of the urban signal in South America and the current scarcity of long-term, continental-scale simulations capable of placing individual city case studies within their broader regional and historical context.

Regional climate modelling of South America poses well-known challenges, including complex topography (the Andes), the diversity of biomes, and the relative scarcity of long, high-resolution, internally consistent simulations compared with, e.g., the EURO-CORDEX domain (Arritt and Rummukainen 2011; Rummukainen 2010). The WRF model has been extensively used and validated as a regional climate model at continental to local scale, including by the proposing team for the EURO-CORDEX domain (Soares et al. 2012), and is increasingly applied across CORDEX domains worldwide. The CORDEX-CORE initiative established a common protocol – a target resolution of 0.22° (~25 km), shared driving GCMs, and harmonised experiment design – to provide consistent, high-resolution regional climate information across the world's most populated continental domains, doubling the resolution of earlier CORDEX simulations and substantially improving the representation of regional climate change signals relative to the driving GCMs (Teichmann et al. 2021; Coppola et al. 2021).

Despite this progress, the existing CORDEX-CORE South America ensemble is based on RegCM and REMO and does not isolate the LUC and urbanisation signal through dedicated transient/static land-use experiments. A WRF-based set of simulations explicitly designed to separate these signals – and run with the same model, physics configuration and methodology already used by the team for Europe – would (i) add an independent, high-resolution ensemble member to the global CORDEX-CORE archive, directly comparable across continents; (ii) provide the first dedicated LUC-attribution experiment for the South American domain at CORDEX-CORE resolution; and (iii) generate continental-scale boundary and validation data that can subsequently support finer-scale, city-level convection-permitting studies of the kind pursued within FPS URB-RCC.

Present Proposal

The overall objective of this project is to identify robust biophysical impacts of land-use/land-cover change and urbanisation on South American climate, across spatial scales from individual cities to the full continent, and across time scales from extreme events to multi-decadal trends. The project extends the WRF-based methodology developed by the proposing team for the EURO-CORDEX domain – within the LUCAS (Land Use and Climate Across Scales) Flagship Pilot Study – to the CORDEX South America domain (SAM-22), with the explicit goal of producing a cross-continentally consistent ensemble. The new generation of WRF, coupling the regional atmosphere with land-surface and hydrological components, will be used to generate high-quality, CORDEX-CORE-compliant climate projections for South America, contributing new ensemble members to the global multi-model, multi-domain RCM/GCM archive and to ongoing international efforts (CORDEX-CORE, FPS URB-RCC) to characterise the role of LUC and urbanisation in regional climate change.

Target questions (TQ):

The main target questions this proposal aims to contribute to are:

TQ1: What is the relative contribution of land-use/land-cover change (deforestation, agricultural expansion) to regional climate trends across South America in the recent past?

TQ2: How does urbanisation modify near-surface temperature, humidity, wind, and extreme heat in South American megacities and their immediate surroundings?

TQ3: How does the 0.22° (~25 km) CORDEX-CORE resolution affect the magnitude and robustness of the simulated LUC and urban signals relative to coarser regional and global simulations?

TQ4: How large is the contribution of LUC and urban expansion to projected future climate trends and extremes (droughts, heatwaves, heavy precipitation) under SSP2-4.5 and SSP3-7.0?

TQ5: How comparable are the biophysical impacts of LUC across the South American and European continents when simulated with the same regional model (WRF) and methodology?

TQ6: How does this WRF-based South American ensemble compare with the existing RegCM/REMO CORDEX-CORE ensemble for the same domain, and what added value does it provide to the multi-model archive?

Methods

A new set of continental-scale RCM simulations will be carried out with the WRF model for the CORDEX South America domain (SAM-22: 52°S–19°N, 105°W–17°W, 0.22°×0.22° horizontal resolution, ~25 km), following the CORDEX-CORE experiment protocol. The simulations will downscale ECMWF's ERA5 reanalysis for an evaluation period (1980–2020), and the CMIP6 GCM MPI-ESM1-2-HR for a historical period (1960–2014) and for two future scenarios, SSP2-4.5 and SSP3-7.0 (2015–2100), mirroring the experimental design already adopted by the team for the EURO-CORDEX domain. Each experiment will be run in paired transient/static land-use and urban-extent configurations – using harmonised, time-evolving land-use/land-cover and urbanfraction datasets for South America – in order to isolate the LUC and urbanisation signal from the climate change signal driven by greenhouse gas forcing alone. The model will use the same physics configuration, including an urban canopy scheme, as the team's EURO-CORDEX WRF setup, to ensure direct cross-continental comparability of the resulting LUC and urban signals. Output will follow the CORDEX data and metadata standards for publication on the Earth System Grid Federation (ESGF), and selected city-scale diagnostics will be made compatible with the urban/rural masking framework developed under the CORDEX FPS URB-RCC.

Workplan

The work will be organised into three tasks, mirroring the structure successfully adopted for the team's parallel EURO-CORDEX project: simulations with transient and static land cover/urban extent will be performed and evaluated for the current climate, the recent historical period, and future climate, for the South America domain.

Task 1. The contribution of LUC and urbanisation to current climate. A new set of continental-scale simulations, with and without land-use/urban change, will be performed for the CORDEX South America domain with WRF, downscaling ERA5 over 1980–2020 (41 years). Model setup and efficiency testing will be performed before the start of the production runs. Relevant variables will be extracted from the raw output as results become available, analysed and archived, while non-essential output is discarded. The analysis will focus on land–atmosphere interactions, the urban heat island signal in major cities, and the development and characteristics of extreme events (heatwaves, droughts, heavy precipitation).

Task 2. The contribution of LUC and urbanisation to historical climate. For this task, the setup from Task 1 is retained, but WRF is forced by the MPI-ESM1-2-HR GCM for the CMIP6 historical period (1960–2014, 55 years). As in Task 1, relevant variables will be extracted and analysed, together with an assessment of the differences between the reanalysis-driven and GCM-driven results, to characterise the additional uncertainty introduced by the driving GCM.

Task 3. The contribution of LUC and urbanisation to future climate. The same domain will be pursued for the future period 2015–2100 (86 years), with WRF forced by MPI-ESM1-2-HR under the SSP2-4.5 and SSP3-7.0 scenarios. The impact of LUC and urban expansion on the climate change signal will be the primary outcome of this task, with particular attention to changes in the intensity and frequency of extreme events and to the evolution of the urban heat island under continued urban growth.

Resources

Task 1 (current climate, 1988–2025): A total of 76 simulated years, approximately 50,000,000 SBU and 70,000 GB of archived data.

Task 2 (historical climate, 1960–2014): 110 simulated years, approximately 70,000,000 SBU and 90,000 GB of archived data.

Task 3 (future climate, 2015–2100, two scenarios): 86 simulated years, approximately 160,000,000 SBU and 120,000 GB of archived data.

Tasks 1 and 2 are planned for the first project year and a half, and Task 3 for the remaining year and a half, in line with the staged HPC allocation requested above. Only the relevant analysed output of these simulations will be retained long-term, while temporary testing data and extra diagnostic output will be removed after analysis.

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