# REQUEST FOR A SPECIAL PROJECT 2025–2027


**MEMBER STATE:** Portugal

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**Project Title:** Integrated Physical Numerical Modelling for Assessing Urban Climate Projections over Southwestern European and Brazilian cities

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.) | 2025 | |
| Would you accept support for 1 year only, if necessary? | YES x | NO ☐ |

| **Computer resources required for project year:** | | **2025** | **2026** | **2027** |
|---|---|---|---|---|
| High Performance Computing Facility | [SBU] | 100.000.000 | 100.000.000 | 100.000.000 |
| Accumulated data storage (total archive volume)[2] | [GB] | 120.000 | 240.000 | 360.000 |

| **EWC resources required for project year:** | | **2025** | **2026** | **2027** |
|---|---|---|---|---|
| Number of vCPUs | [#] | | | |
| Total memory | [GB] | | | |
| Storage | [GB] | | | |
| Number of vGPUs[3] | [#] | | | |

*Continue overleaf.*

[1] The Principal Investigator will act as contact person for this Special 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.

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## Abstract

Although urban areas cover a minor fraction of global land (3%), they accommodate more than half of the global population, a fraction that is projected to increase to 68% by 2050 [1,2]. Additionally, cities concentrate infrastructures, that generate more than 75% of global GDP, and are responsible for about 75% of carbon emissions from energy consumption [1]. Furthermore, drastic land-use changes due to urbanisation modulate the local climate [3]. Hence, city-scale climate change adaptation and mitigation strategies play a disproportionately important role, demanding accurate information of urban climate. However, most state-of-the-art global and regional climate simulations do not consider or have highly simplified representations of urban processes, thus misrepresenting local climate variability and extremes [4,5]. This is the case for the CORDEX (Coordinated Downscaling Experiment) ensemble, where the use of urban parameterizations is not standard procedure due to computational constraints [6,9]. This limitation carries major implications since CORDEX is a cornerstone for many climate change studies, impact modelling and for designing adaptation and mitigation strategies [10,11].

The overarching goal of this project is to address the misrepresentation of urban effects in climate models, producing accurate high-resolution information for the XXI on essential urban climate variables, extremes and urban-scale phenomena. This project is focused on Southwestern European cities and the two main Brazilian megacities of São Paulo and Rio de Janeiro (SP-RJ), thereby encompassing different climate settings and climate change challenges. The Weather Research and Forecasting (WRF) model will be used to perform high-resolution km-scale regional climate simulations, also known as convective permitting simulations (~3 km), for specific domains devoted to the selected cities, co-leading the modelling effort of the CORDEX Flag Ship Pilot Study on URBan environments and Regional Climate Change [8]. These runs will be forced by global simulations from the Coupled Intercomparison Project Phase 6 (CMIP6); both historical and future periods are covered, considering different future emission pathways, from high-end to low-end scenarios. The three domains cover Iberia, France, and the region encompassing Rio de Janeiro and São Paulo.


## Motivation

The ongoing rapid urbanisation combined with climate change urges new types of urban climate information that make best use of science and technology [12]. Drastic land-use changes associated with urbanisation are responsible for increased trapping and absorption of solar radiation, reduced evapotranspiration, and reduced night-time cooling in built-up areas, combined with increased heat release due to human activities. As a result, cities typically have warmer air and surface temperatures compared to their surroundings [13,14]. This is the well-known urban heat island (UHI) effect, which has been found over multiple cities across the globe [14,3,4,6,12,15]. The UHI enhances the severity of extreme heat events, resulting in significant increases of morbidity and mortality [12,15,16,17].

Numerical climate models are the best available tools for obtaining information on future climate evolution and its multiple impacts. Earth System Models (ESMs), Global Climate Models (GCMs) and Regional Climate Models (RCMs) reproduce large to medium scale processes [18], thus representing some effects of land-use and land-cover changes. However, these models usually have an overly simplified (or complete lack of) representation of the urban processes [4-7]; a significant shortcoming given the critical importance of accurate quantification of urban climate change and its impacts. Computational power limits GCMs to the use of coarse grid-resolutions (~100 km), inadequate for urban patterns. State-of-the-art multi-model ensembles of RCMs, like CORDEX [8], have resolutions ~10 km, allowing a better simulation of regional climate, but the use of urban parameterizations is not a standard procedure due to its very high computation costs. For example, EURO-CORDEX ensemble was shown to clearly misrepresent urban climate processes [6,9]. This limitation has potentially profound implications, because CORDEX underlies many local climate impact studies and national adaptation and mitigation strategies. Several case studies have revealed significant added value in using km-scale RCMs at ~1km resolutions [19-21] and urban canopy models (UCM) in reproducing the observed urban climate [4], and its extremes [6,15]. However, century long convective-resolving scale RCM simulations with coupled UCM is presently prohibitive computationally; moreover, our proposal is aiming at performing multiple long experiments on the impact of different urbanisation patterns for different models, cities and future emission pathways.

## Present Proposal

The overall objective of this project is to build on cutting-edge km-scale (convective permitting) regional climate simulations to address the misrepresentation of urban effects in climate models and provide accurate high-resolution information on essential urban climate variables, focused on Southwestern European cities and the SP-RJ region. This will allow to depict how climate and extreme event will evolve for the selected cities under different greenhouse gas emissions. This assessment might be relevant to explore the impacts in several indices for livelihood in cities, assisting in designing effective mitigation and adaptation strategies to ensure population safeguard. This km-scale modelling effort is under the framework of the CORDEX Flag Ship Pilot Study on URBan environments and Regional Climate Change (URB-RCC) [8].

## Target questions (TQ)

TQ1: To what extent the new CORDEX Phase II RCMs represent in a better manner the urban climate of the selected cities?

TQ2: To what extent km-scale RCMs incorporating urban parameterizations and new components improve the description of urban climate? What effects do they have on the climate change signal?

TQ3: What are the main urban climate changes under different SSPs?

## Methods

A new set of RCM simulations will be carried out with the WRF model for the EURO and SA CORDEX domains. These simulations will downscale global ERA-5 reanalysis and two global climate scenarios allowing the quantification of urban climate change. The simulations will be performed for a large domain at ~12 km horizontal resolution containing a second smaller domain with 3 km resolution centred on the selected cities.

These will contribute as ensemble members of the coordinated Flagship Pilot Study URB-RCC a EURO-CORDEX initiative supported by WCRP CORDEX international program. The periods covered by the simulations are 2001–2023 forced by ERA5, 2005-2014 for the historical run, and 2046-2055 and 2091-2100 for future climate, forced by the MPI-ESM1-2-HR Earth System Model, in agreement with the new scenarios SSP2-4.5 and SSP3-7.0.

## Workplan

The work will be organized into 3 tasks, with the main objective of performing regional to urban climate simulations, at 3 km resolution, for relevant case studies, in present and future climates. .

Task 1) Performance of km-scale simulations for the present synchronized climate, forced by ERA5 (2001–2023). Relevant variables will be extracted from the raw output as the model results become available. These will be analysed and stored, and the extra output will be discarded. The analysis will be focused on urban climate, and characteristics of extreme events

Task 2) Performance of km-scale simulations for the historical period (2005-2014). For this task, the setup from the previous task is considered, however, the WRF model is forced by the MPI-ESM1-2-HR GCM for a CMIP6 historical period. As in task 1, relevant variables will be extracted from the raw output. A similar analysis to task one will be performed along with an assessment of the differences between the results from the two tasks in order to ascertain the differences between both climates (a historical driven by a GCM and a reanalysis driven past climate)

Task 3) Performance of km-scale future climate simulations for future climates (2046-2055 and 2091-2100) In this third task, the same domain will be pursued but for a future period and therefore the WRF model will be forced by the MPI-ESM1-2-HR GCM results for two decades of the 21st century, in agreement with the new scenarios SSP2-4.5 and SSP3-

7.0. The impact of the cities on the climate change signal will be the primary outcome of this task. The analysis of the changes in land-atmosphere interactions and in the intensity and frequency of extreme events will be pursued.

## Resources

The resources for the tasks are:

2025:

- A total of 23 and 3 years for the first task and part of the second task, respectively.
- Approximately 100.000.000 SBU for the first task and part of the second task.
- Approximately 120.000 of data will be generated for the first and part of the second task.

2026:

- A total of 7 and 15 years for part of the second and part of the third tasks, respectively.
- Approximately 100.000.000 SBU for part of the second and third tasks, respectively.
- Approximately 240.000 of data will be generated for the second and part of the third task.

2027:

- A total of 5 and 20 years for part of the third task.
- Approximately 100.000.000 SBU for part of the third task, respectively.
- Approximately 360.000 of data will be generated for the third task.

The storage will be managed to keep the relevant output of these simulations while temporary testing and extra output will be removed after the analysis.

## References


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