

LATE REQUEST FOR A SPECIAL PROJECT 2026–2028

MEMBER STATE: GREECE

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Project Title: URBAN CLIMATE SIMULATIONS

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.)	2026	
Would you accept support for 1 year only, if necessary?	YES X	NO <input type="checkbox"/>

Computer resources required for project year:	2026	2027	2028
High Performance Computing Facility [SBU]	20.000.000		
Accumulated data storage (total archive volume) ² [GB]	10000		

EWC resources required for project year:	2026	2027	2028
Number of vCPUs [#]			
Total memory [GB]			
Storage [GB]			
Number of vGPU 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.

Principal Investigator:

ELENI KATRAGKOU

Project Title:

URBAN CLIMATE SIMULATIONS

Extended abstract

All Special 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 Special 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 Special Project reports and the use of ECMWF software and data infrastructure will also be considered in the evaluation process.

Requests exceeding 10,000,000 SBU should be more detailed (3-5 pages).

Abstract

In this project we aim to produce a regional climate simulation over Europe in order to assess the impact of urban environment parameterization. The simulation will be performed within the context of the URB-RCC Flagship Pilot Study (FPS). The simulation will use a nested approach, with the outer domain covering the entire Europe while the inner nest will cover a large area of France, with emphasis given over the city of Paris. The Weather Research and Forecasting model (WRF) will be used for the simulation while the most state-of-the-art urban option within the model, the BEP-BEM urban canopy scheme will be implemented. The innovation of this study is the implementation of a detailed dataset of urban characteristics for the city of Paris derived by earth observation methods. The simulation will cover the 10-year period of 2000-2009 including two years for spin off.

Introduction

Climate change is one of the biggest challenges our world is facing today. It has the potential to inflict severe impacts on many aspects of our lives from thermal discomfort to water availability and even property and life losses from severe phenomena. Most of the world population is currently living in urban areas and is projected to further increase substantially in the near future. Moreover, urban environments due to their distinct characteristics can heavily influence the surrounding local climatic conditions while they are also highly vulnerable to changes in the established climate (IPCC, 2023). This makes urban areas a top priority in regional climate impact studies. Unfortunately, urban areas are usually not properly addressed within climate models, one of the most useful tools we have to assess climate change. Most of the approaches rely on crude simplifications of the urban areas usually treating them just as another ordinary land use category or incorporate rudimentary parameterizations to describe the urban environment. For example, even in large, coordinated experiments like those implemented in the EURO-CORDEX framework (Katragkou et al, 2024), many simulations lack a dedicated urban parameterization. Detailed urban canopy models, however, do exist and they are slowly being implemented in regional climate simulations. In the Weather Research and Forecasting model (WRF) (Skamarock et al. 2019), the most detailed urban parameterization is the BEP-BEM urban canopy model (Salamanca & Martilli, 2010). This scheme can take into account many aspects of the urban form (building, roof, road dimensions, thermal and optical properties) and account for various complex phenomena such as shading. Moreover, it can work with the Local Climate Zone (LCZ) approach, where instead of having a single type of urban category the urban grid cells can be diversified among 10 different categories greatly increasing the ability to correctly describe the high spatial variability of the urban environment (Demuzere et al., 2022). Interestingly, many urban characteristics in the BEP-BEM scheme that are accessible in an external file can be updated to better represent the urban area of interest (Brousse et al. 2016). This is the innovation of this study, that it uses a compound dataset of several variables extracted using Earth Observation techniques of urban form to provide a better representation of the city of Paris in long-term regional climate simulation.

The simulation is part of a larger European ensemble under the framework of the URB-RCC Flagship Pilot Study that has been officially endorsed by the World Climate Research Programme (WCRP) Coordinated Regional Climate Downscaling Experiment (CORDEX). After completion, the results will be open to the scientific community.

Scientific plan

We intend to answer the following main scientific question:

Q1: How well does the WRF model describe the climate of Paris when we include a detailed dataset of urban characteristics?

To answer this question we aim to perform a regional climate simulation with the WRF model using a nested approach: covering Europe with a 12km resolution as the outer domain while the inner domain will cover the largest part of France with a resolution of ~ 3km. The simulation will cover the ten year period of 2000-2009 plus two years (1998-1999) of spin up time. We will use the ERA5 reanalysis data (Hersbach et al. 2020) as initial and boundary conditions at 6 hourly intervals, while sea surface temperatures (SSTs) will be updated per 24 hours from the same dataset.

Moreover, integration of this simulation in a wider ensemble of urban climate sensitivity experiments within the FPS will help identify the potential added value our enhanced description of urban characteristics compared to the BEP-BEM parameterization with default values of urban form or less detailed urban parameterizations.

The EO dataset of Paris urban form is readily available and has already been tested using the BEP-BEP scheme in six-month simulations with WRF. Also, all the input files containing ERA5 initial and boundary conditions have been prepared for the entire 10-year period. Therefore, we are ready to begin simulations by the time the computational time is provided.

A manuscript detailing the dataset and some evaluation results of the six-month experiments is in preparation and will be submitted shortly in a scientific journal.

We plan to produce and analyse several essential climatic variables that are particularly impacted by the urban environment: mean, maximum and minimum temperature, surface temperature, wind speed and direction, precipitation amount, cloudiness, Planetary Boundary Layer Height, soil moisture.

Moreover, several urban specific variables (e.g. urban canopy wind, roof-road temperature, green roof temperature) will be stored and analysed. Variable postprocessing will take place on-site, ensuring the minimization of data transfer. We plan to employ a fortran based postprocessing tool that has already been successfully tested in the ECMWF HPC. Assessment of the simulation will use a variety of gridded observational and satellite products with emphasis given on observational data from a set of around 50 stations of Meteo-France.

We plan to complete the 10-year simulation within the year of 2026.

The time plan of the simulations is as follows:

Month1: Setup of the WRF model in the ECMWF HPC system and initial conditions data transfer.

Month2-8: Completion of the 10-year WRF simulation

Month3-8: Post processing and data transfer

Justification of computer resources

Computer resources

We aim to perform one 10-year simulation covering the period 2000-2009 as well as two years of initial spin-up time (1998-1999), therefore a total of 12 simulated years. Based on our experience with the ECMWF HPC system as well as other HPC systems we plan on using 256 cores and expect the required time for each simulated month to be around 28-30 hours. For a total of 12 simulated years (144 months) the required real time is around 4300 hours (15.552.000 sec). By using 256 cores we estimate around 1.100.000 core hours (3.9 x10⁹ core secs) of computational time. Thus, the expected SBU amount is around 19.000.000. We intend to complete the entire simulated period within the current year thus we request 20.000.000 SBUs for year 2026.

Storage required

WRF model output is quite heavy. One year of the proposed nested simulation approach requires around 6TB of space. However, we intend to post-process the model output data on site thus greatly reducing storage requirements. We estimate that one year of post-processed data requires around 500 GB. Thus, for the full 10-year period we estimate a need of around 5TB for the post-processed data. The required space for the driving data is around 1-2 TB. We intend to post-process the produced raw model data after the completion of each simulated trimester thus we do not expect the presence in the storage of more that 3-4 months of raw data (~2 TB). Therefore, a request of 10 TB of space.

Technical characteristics of code to be used

We plan on using the WRF climate model with the ARW core, specifically v4.5.1 for the planned simulation. The WRF-ARW code is written in Fortran with some supplementary programs that are written in C to perform file parsing and file construction. The necessary libraries are netCDF, MPICH, JasPer, Libpng, and Zlib. We are more than ten years of experience with the WRF model and have compiled and used various versions of the model in different HPC environments. Specifically, we have compiled and used the above WRFv4.5.1 in the ECMWF HPC for long-term climate simulations within the project “EURO-CORDEX SIMULATIONS INCLUDING LAND USE CHANGES”.

References

- Brousse, O., Martilli, A., Foley, M., Mills, G., and Bechtel, B. (2016). WUDAPT, an efficient land use producing data tool for mesoscale models? Integration of urban LCZ in WRF over Madrid, *Urban Clim.*, 17, 116–134, <https://doi.org/10.1016/j.uclim.2016.04.001>
- Demuzere, M., Kittner, J., Martilli, A., Mills, G., Moede, C., Stewart, I. D., Van Vliet, J., & Bechtel, B. (2022). A global map of local climate zones to support earth system modelling and urban-scale environmental science. *Earth System Science Data*, 14(8), 3835–3873. <https://doi.org/10.5194/essd-14-3835-2022>
- Hersbach, Hans, Bill Bell, Paul Berrisford, et al. 2020. “The ERA5 Global Reanalysis.” *Quarterly Journal of the Royal Meteorological Society* 146 (730): 1999–2049. <https://doi.org/10.1002/qj.3803>.
- IPCC, 2023: Summary for Policymakers. In: *Climate Change 2023: Synthesis Report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* [Core Writing Team, H. Lee and J. Romero (eds.)]. IPCC, Geneva, Switzerland, pp. 1-34, doi: 10.59327/IPCC/AR6-9789291691647.001
- Katragkou, E., Sobolowski, S. P., Teichmann, C., Solmon, F., Pavlidis, V., Rechid, D., Hoffmann, P., Fernandez, J., Nikulin, G., & Jacob, D. (2024). Delivering an improved framework for the new generation of CMIP6-driven EURO-CORDEX regional climate simulations. *Bulletin of the American Meteorological Society*. <https://doi.org/10.1175/bams-d-23-0131.1>
- Salamanca, F., & Martilli, A. (2010). A new Building Energy Model coupled with an Urban Canopy Parameterization for urban climate simulations-part II. Validation with one dimension off-line simulations. *Theoretical and Applied Climatology*, 99(3–4), 345–356. <https://doi.org/10.1007/s00704-009-0143-8>
- Skamarock, W. C., J. B. Klemp, J. Dudhia, D. O. Gill, Z. Liu, J. Berner, W. Wang, J. G. Powers, M. G. Duda, D. M. Barker, and X.-Y. Huang, 2019: A Description of the Advanced Research WRF Version 4. *NCAR Tech.Note NCAR/TN-556+STR*, 145 pp. [doi:10.5065/1dfh-6p97](https://doi.org/10.5065/1dfh-6p97)
- URBAN FPS website, https://ms.hereon.de/cordex_fps_urban/index.php.en , last accessed 04/03/2026