REQUEST FOR AN EMI R&D PROJECT 2027–2029

Country/Organisation:	Türkiye
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Project Title:	Urban Parameterisation in ICON-LAM over Türkiye: A Multi-City Evaluation of TERRA_URB with Satellite-Enhanced External Fields

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]	1500000	1500000	
Graphics Processing Unit Cluster-A	[GBU]			
Graphics Processing Unit Cluster-B	[GBU]			
Accumulated data storage (total archive volume)[2]	[GB]	10000	20000	

[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.

Principal Investigator: Prof. Dr. Yurdanur Ünal

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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).

Motivation and Scientific Plan

Urban areas are home to a great amount of world's population and are among the environments most vulnerable to climate change. The Urban Heat Island (UHI) effect is the temperature excess of city centres over their rural surroundings, and it is one of the most robust signals of human modification of local climate, with documented intensities of 1-5°C in the atmospheric layer and up to 8°C at the surface during warm, calm nights. Accurately representing urban physics in numerical weather prediction and climate models is therefore both a scientific priority and a practical necessity for heat-wave early warning, urban planning, and climate adaptation.

Within the COSMO Consortium and CLM-Community, the TERRA_URB bulk parameterisation scheme (Wouters et al., 2016) has emerged as the operationally mature solution for urban surface-atmosphere exchange in ICON-LAM. Its porting from COSMO to ICON was completed within the COSMO Priority Project CITTÀ, and recent studies have validated TERRA_URB in ICON over Naples at hectometric scale (Cinquegrana et al., 2024) and over Rome and Milan at 1 km resolution (Campanale et al., 2025). Despite this momentum across European cities, the Eastern Mediterranean remains entirely absent from the ICON and TERRA_URB validation record. No published study has applied ICON-LAM with TERRA_URB to any Turkish city.

This project addresses that gap by targeting Türkiye's four large and climatologically distinct cities which are shown in Figure 1. The four cities have been deliberately chosen to constitute a controlled natural experiment across contrasting urban-climatic regimes. Istanbul is a megacity of over 16 million inhabitants, uniquely positioned between the Black Sea and the Sea of Marmara and bisected by the Bosphorus. Its UHI interacts with competing sea-breeze fronts from the north and south, producing convergence zones and Bosphorus-channelled flows that have no counterpart among previously studied European cities (Ezber et al., 2015a, 2015b); air-temperature UHI intensities under calm clear conditions reach 1.7-3.1°C (Ünal et al., 2020). Ankara, by contrast, is a semi-arid inland plateau city at 900 m elevation with no maritime influence whatsoever; its UHI dynamics are controlled purely by land-cover modification, surface moisture deficit, and anthropogenic heat release, making it an ideal thermodynamic control case. Izmir on the Aegean coast, a Mediterranean city shaped by the imbat sea breeze that moderates urban temperatures during summer afternoons, a circulation whose interaction with the growing urban heat dome has never been studied with a physically consistent urban canopy model (Saka & Ünal, 2024). Antalya completes the four-city ensemble by extending the study to the southern Mediterranean coast, introducing a thermally distinct regime characterised by the interplay between strong sea-breeze forcing from the open Antalya Gulf and katabatic drainage flows descending from the Taurus Mountains directly behind the city. This mountain-sea-urban configuration has no counterpart among the other three cities and allows the project to assess TERRA_URB performance under a third coastal archetype, one dominated by orographically constrained circulation rather than strait channelling or gulf geometry. Across these four cities the project systematically asks which urban parameterisation configuration best reproduces UHI intensity, 2m temperature diurnal cycles, planetary boundary layer (PBL) height, and sea-breeze circulation, and to what extent does replacing the default GlobCover-derived impervious surface fields with satellite-derived data reduce model bias.

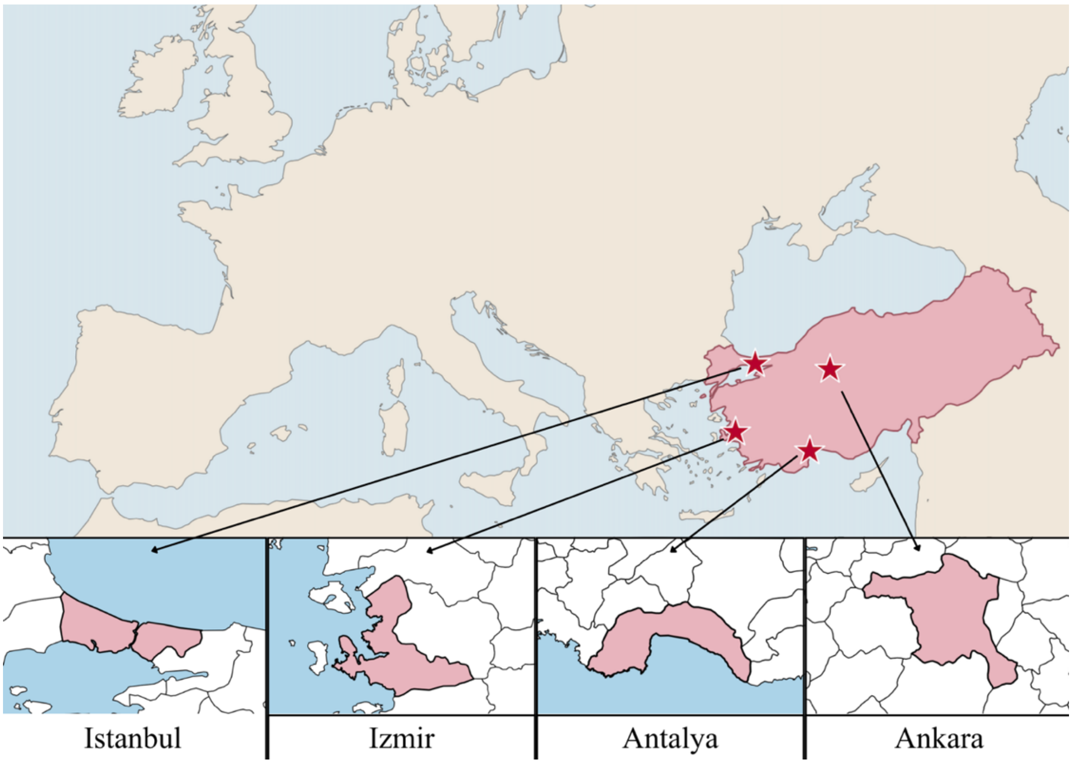

Figure 1. Location of the four chosen cities for the project.

A distinctive feature of this project is the planned integration of satellite-derived urban information into the model external parameter chain. The default impervious surface and land-use fields provided to TERRA_URB through EXTPAR are based on global datasets of limited spatial resolution, which can misrepresent the rapid urban expansion that has characterised Turkish cities over the past two decades. One of the experiments explores the improvement achievable by replacing or refining these fields with higher-resolution earth observation products, combined with a Local Climate Zone classification framework to better constrain the urban canopy parameters. Model output will be evaluated against available surface observations and satellite-derived surface temperature data to assess the added value of each level of urban parameter complexity. Beyond the UHI signal itself, the simulations will be analysed for modifications to mesoscale circulation through changes in sea-breeze onset time, Bosphorus-channelled flow structure, PBL growth, and wind divergence patterns over and downwind of each city. This meteorological dimension is particularly relevant for Istanbul and the two southern coastal cities, where the urban heat dome is known to interact with thermally driven local flows in ways that alter not only temperature but also moisture transport, ventilation pathways, and the timing of convective initiation.

The experimental design adopts the 14 simulation days plus 7-day spin-up each, a summer and a winter case. ERA5 reanalysis provides 6-hourly lateral boundary conditions and daily SST updates. If ERA6 becomes available during the project period, it could also be tested as an alternative boundary condition source, allowing a direct comparison with the ERA5-driven simulations. All runs are performed in hindcast mode. Four experiments are conducted for each city and season:

Exp. ID	Urban param.	LCZ input	Satellite data	Purpose
EXP-1 CTRL	Off (default)	No	No	Baseline
EXP-2 URB	TERRA_URB (default UCPs)	No	No	Basic TU effect
EXP-3 LCZ	TERRA_URB + LCZ UCPs	Yes	No	LCZ-derived UCP gain
EXP-4 SAT	TERRA_URB + LCZ UCPs	Yes	Yes	Satellite-derived UCPs and validation

EXP-4 (highlighted) is the centrepiece of the project. The 32 ICON-LAM runs (4 experiments × 3 cities × 2 seasons) are designed to be analysed as a structured ensemble, with each incremental step isolating the contribution of a specific modelling improvement. Cities and their planned resolutions are configured as follows:

City	Climate archetype	Key process
Istanbul	Megacity, dual-sea, Bosphorus	Sea-breeze, the effect of Bosphorus
Ankara	Continental highland plateau	Pure thermodynamic UHI
Izmir	Aegean coastal, open gulf	Imbat sea-breeze, UHI feedback
Antalya	Mediterranean coastal	Mountain-valley, sea-breeze, UHI three-way interaction

All of the four cities will be simulated at high resolution (under 2km) which is appropriate for urban boundary-layer dynamics. The expected scientific outputs include the first peer-reviewed ICON-LAM + TERRA_URB evaluation for Türkiye, a quantified incremental assessment of urban parameter complexity from four experiment levels, a comparative analysis of four fundamentally different coastal and continental urban UHI regimes, and a replicable methodology for extending the ICON urban modelling framework to the Eastern Mediterranean.

Technical Characteristics of the Code

The ICON (ICOsahedral Nonhydrostatic) model is an open-source Fortran 90 code developed jointly by DWD and MPI-M. The limited-area configuration ICON-LAM is used throughout this project with the standard NWP physics package. ICON uses an unstructured icosahedral-triangular horizontal grid with a terrain-following hybrid sigma-pressure vertical coordinate, and avoids the pole problem of lat–lon grids that imposes severe computational constraints at high resolution. In this project the global ICON grid has 2,949,120 triangles at ~13 km effective resolution; the LAM nests are refined to under 2km for all the four cities with 60 vertical levels and enhanced resolution in the lowest 2 km.

Urban physics are provided by TERRA_URB activated within TERRA, the ICON land-surface model. TERRA_URB implements a tile approach in which each grid cell is partitioned into an urban fraction, defined by the impervious surface area fraction ISA, and a natural fraction. Within the urban tile, semi-empirical corrections modify roughness length, albedo, heat capacity, emissivity, and the diurnal anthropogenic heat flux profile. In EXP-3 and EXP-4, LCZ-derived 2D fields for building plan area fraction, mean building height, and height-to-width ratio replace the globally hard-coded SURY morphological constants. All external parameters are pre-processed with EXTPAR; the Sentinel-2 ISA and LCZ-derived fields are inserted as standard NetCDF4 replacement fields, a procedure documented and successfully applied by Campanale et al. (2025). The code is parallelised with MPI and OpenMP and has been benchmarked on ECMWF HPC infrastructure by the COSMO Consortium partners with whom this project collaborates.

Justification of Computer Resources

The experimental design comprises 32 ICON-LAM hindcast runs, 4 experiments × 4 cities × 2 seasonal case periods, each covering 14 simulation days plus a 7-day spin-up. All four cities will be simulated in very high resolution (under 2km) with 60 vertical levels and hourly output throughout. Since the simulations will be performed at very high resolutions, they will require a relatively large number of Standard Billing Unit (SBUs). At these resolutions and domain sizes, the combined computational cost of the full run matrix, together with the allowance for model setup, EXTPAR customisation, and iterative debugging expected in the first year, amounts to approximately 3,000,000 SBU in total, requested in two equal annual allocations of 1,500,000 SBU. Storage of 20 TB (10 TB first year and 10 TB for the second year) on ECFS accommodates hourly output from all very high-resolution runs.

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