REQUEST FOR A SPECIAL PROJECT 2025–2027

MEMBER STATE: Italy

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Project Title: **Re-analysis and Re-forecasting of Extreme Weather Events Using the ICON-LAM Model**

If this is a continuation of an existing project, please state the computer project account assigned previously.	**SP**ITGARB	
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]	900000	900000	900000
Accumulated data storage (total archive volume)[2]	[GB]	400	800	1000

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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Extended abstract

Motivation and work plan

In recent decades, extreme weather events have increased significantly. At the same time, Numerical Weather Prediction (NWP) has made substantial progress thanks to more and better-assimilated observations, higher computing power, and advances in our understanding of dynamics and physics. Despite these advancements, accurately predicting the spatial and temporal precipitation patterns remains a significant challenge.

The aim of the project is to use the most advanced numerical modelling to analyse case studies from the recent past in order to identify critical issues and improve the forecast of future events, not only in cases of heavy precipitation but also for heat waves, strong winds, and other extreme events. The case studies of national interest will be selected in agreement with the Department of Civil Protection, and the results will be shared with the DPC and the regional Centri Funzionali. The ICON-LAM model will be used at high horizontal resolution to re-analyse and re-forecast past extreme events. Different model configurations will be tested using new physical parameterization schemes and various initial and boundary conditions to determine the best configuration for representing severe events on small temporal and spatial scales.

The following simulations are planned to be performed using the ICON-LAM model:

- Runs with different initial and boundary conditions: ICBCS provided by IFS, ICON-EU and ICON-2I analysis.

- Runs with different parameterization schemes for turbulence (free convection, only shallow and deep convection parameterized, etc.), microphysics (single or double scheme).

- Runs with the urban parametrization scheme TERRA-URB activated and different dataset for external urban parameters (GLOBCOVER, ECOCLIMAP, LCZ, etc.)

- Runs at different resolutions: from 2 km to 500 m.

The results will be evaluated to highlight the impact of resolution, parameterizations, data assimilation and initial and boundary condition on the model performance. Temperature, relative humidity, and wind will be compared with observations provided by meteorological stations and/or citizen network (NetAtmo, MeteoNetwork,..) using standard statistic indices (MB, RMSE, etc.). Precipitation will be verified using the fuzzy technique, which compares the data estimated by the national radar mosaic corrected with raingauges with the simulated maps.

Computer resources

A large number of simulations is planned to test all the described configurations, so a relatively large number of Billing Units (900000 Bus per year) is required. To locally store the model output obtained from the ICON numerical experiments in the ECFS system, extensive data storage resources will be utilized.

Technical characteristics of the codes

In the framework of this special project, the following codes will be used:

- ICON-LAM: the icosahedral non-hydrostatic limited-area atmospheric prediction model derived from the ICON global model. This model became operational in DWD's forecast system in January 2015 and has replaced COSMO as the operational model in the COSMO Consortium. Compared to traditional approaches such as the latitude-longitude grid, icosahedral grids provide a nearly homogeneous coverage of the globe. Furthermore, ICON offers a two-way nesting capability, allowing for local refinement of grid spacing within a single simulation. The dynamical core is formulated on an icosahedral-triangular Arakawa C grid. To achieve competitive computational efficiency, time splitting is applied between the dynamical core on the one hand and tracer advection, physics parametrizations and horizontal diffusion on the other hand. ICON uses the more recent FORTRAN2003 standard and a hybrid OpenMP/MPI parallelization leading to a better computational performance on today's CPU architectures. Hybrid parallelization means that the advantages of a coarse-grained MPI parallelization are combined with the advantages of a fine-grained OpenMP parallelization.

- ICON TOOLS: a set of command-line tools for remapping, extracting and querying ICON data files, based on a common library and written in Fortran 90/95 and Fortran 2003. ICON TOOLS provide a number of utilities for the pre- and post-processing of ICON model runs. All of these tools can run in parallel on multi-core systems (OpenMP) and some offer an MPI parallel execution mode in addition.

- TERRA-URB: an advanced urban canopy model integrating urban physics into the TERRA land surface model. The TU scheme is based on the Semi-empirical Urban Canopy Parametrization (SURY), which translates the 3D urban canopy into bulk surface parameters. For each grid cell, TU requires urban canopy parameters such as impervious surface area fraction (ISA), building area fraction (BF), mean building height (H), and height-to-width ratio (H/W) and anthropogenic heat flux (AHF). These urban parameters are provided by local dataset or derived from global LCZ classifications (WUDAPT, ECOCLIMAP, etc.).

- EXTPAR: EXTPAR (External Parameters for Numerical Weather Prediction and Climate Application) is an official software of the COSMO Consortium. It is used to prepare the external parameter data files that are used as input for the COSMO and the ICON model. The code is written in Fortran 90 and Python. The Python scripts use CDO for the most compute-intensive parts. Currently the code is tested regularly using the gcc, NAG, and Intel Fortran compilers. The code is also accelerated in some places with OpenMP parallelization. The code once compiled generates 6 Fortran executables and 9 Python scripts, which can be run simultaneously except for the final extpar_consistency_check.exe, which is used to tie together all the external parameter results into one output file.