REQUEST FOR A SPECIAL PROJECT 2026–2028

MEMBER STATE: ITALY

Principal Investigator[1]: Valerio Capecchi

Affiliation: Consorzio LaMMA, Laboratorio di Meteorologia e Modellistica Ambientale per lo sviluppo sostenibile & Agenzia Nazionale per la Meteorologia e Climatologia "ItaliaMeteo"

Address: Via Madonna del piano, 10, Sesto Fiorentino, Florence, Italy

Other researchers: *Vieri Tarchiani* – Institute for Bioeconomy of the National Research Council of Italy
Francesco Pasi – Consorzio LaMMA & Institute for Bioeconomy of the National Research Council of Italy
Younoussa Adamou Sayri - National Meteorology Directorate of Niger & Institute for Bioeconomy of the National Research Council of Italy
Thomas Bere - National Meteorology Agency of Burkina Faso & Institute for Bioeconomy of the National Research Council of Italy

Project Title: **A High-Resolution Hindcast for the Sahel Region Based on ERA5 data and the MOLOCH model**

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**ITCAPE	
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 [ ]	NO X

Computer resources required for project year:		**2026**	**2027**	**2028**
High Performance Computing Facility	[SBU]	4.5 M	3 M	3 M
Accumulated data storage (total archive volume)[2]	[GB]	4.5 K	7.5 K	10.5 K

EWC resources required for project year:		**2026**	**2027**	**2028**
Number of vCPUs	[#]			
Total memory	[GB]			
Storage	[GB]			
Number of vGPUs[3]	[#]			

[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.

Continue overleaf.

Principal Investigator: Valerio Capecchi

Project Title: **A High-Resolution Hindcast for the Sahel Region Based on ERA5 data and the MOLOCH model**

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

1. Introduction

The Institute for Bioeconomy of the National Research Council of Italy (IBE-CNR) has long collaborated with the National Meteorology Directorate of Niger (DMN) within the framework of bilateral Niger-Italy programs and multilateral initiatives with the World Meteorological Organization (WMO), for which IBE-CNR serves as one of the Regional Training Centers (RTC).
On this foundation, the "SLAPIS Sahel" trilateral project was submitted to the Italian Cooperation Agency and subsequently approved in 2024 to scale up the SLAPIS approach for early flood warning across the Sirba River Basin and other tributaries of the Middle Niger river.
"SLAPIS Sahel" (https://climateservices.it/progetto/slapis/) is an applied research and training project implemented by the Polytechnic University of Turin in collaboration with:

- The Institute for Bioeconomy of the National Research Council of Italy (IBE-CNR);
- The National Meteorology Directorate (DMN) of Niger;
- The Water Resources Directorate (DRE) of Niger;
- The National Meteorology Agency (ANAM) of Burkina Faso;
- The General Directorate of Water Resources (DGRE) of Burkina Faso.

Among the key objectives of "SLAPIS Sahel" is to enhance numerical weather forecasting capabilities to support early hydrological warning systems. Both DMN in Niger and ANAM in Burkina Faso have decided to develop a numerical weather prediction system based on the Weather Research and Forecasting (WRF) and MOLOCH models, both widely used in research institutes and operational weather forecasting services in Italy and Europe. A secondary goal of the project is to transfer knowledge and tools for the implementation, management, and development of a modelling chain based on the numerical weather models listed above, serving the operational meteorological centres of Niger and Burkina Faso.
In November 2024, two experts from DMN and ANAM started an internship at IBE-CNR, whose aim is to achieve significant progress in the operationalization of NWP models:

- Training;
- Verification of WRF/MOLOCH forecasts for the past rainy seasons;
- Improvement of model parameterisation;
- Production of user guides for both the WRF and MOLOCH model to be used at DMN and ANAM.

2. Scientific goal of the Special Project

Among the above stated general goals, a key objective of the "SLAPIS Sahel" project is to generate a high-resolution, long-term hindcast for the region of interest (see Figure 1). This will be achieved through the dynamical downscaling of ERA5 reanalyses using the MOLOCH model. This initiative builds upon the SPITBRAN 2018-2020 ECMWF Special Project, its continuation (2022-2024), and several ongoing similar projects in Italy (Cavalleri et al., 2024). It has been demonstrated that, despite the hindcast is not assimilating any observations, it provides reliable climate information, particularly regarding precipitation, when compared to regional reanalyses or observational datasets (Capecchi et al., 2023; Cavalleri et al., 2024).
The medium-term objectives of producing this hindcast are twofold:

- To develop a dataset that supports climate services for climatological, agricultural, and above all hydrological applications;

- To provide a reference dataset for training a regional data-driven weather machine learning (ML) prediction model within the Anemoi framework, serving as a foundation for future ML-based climate prediction

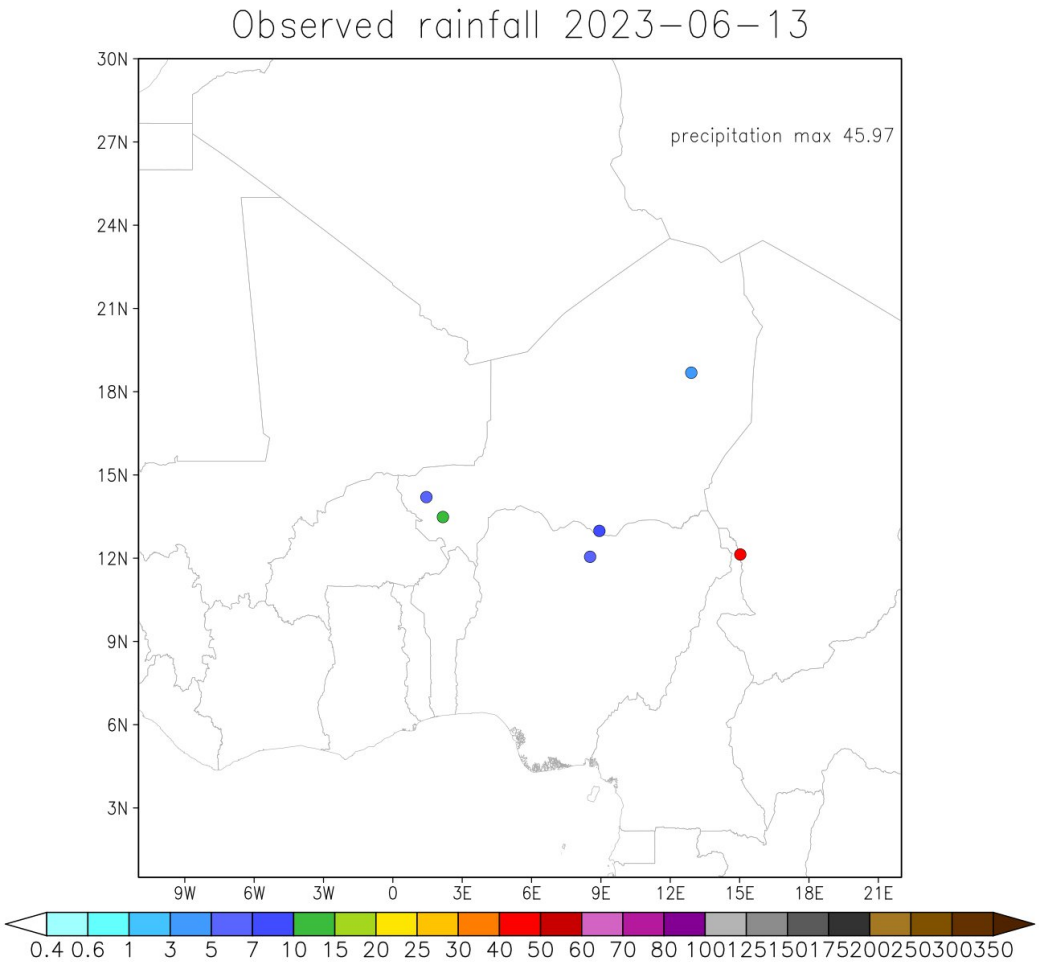

Figure 1: approximate simulation area encompassing the Niger and Burkina-Faso countries

products (following the work by Nipen et al, 2024).
We acknowledge that producing such a hindcast is an ambitious challenge. Despite the fact that increasing resolution and using an explicit treatment of convection *typically* improves the representation of fine-scale atmospheric processes, it doesn't overcome inherent problems such as the model's errors and the uncertainties in the initial/boundary conditions. Nevertheless, we stress the innovative aspect of this activity, which is to assess the feasibility of downscaling ERA5 data across tropical regions and evaluate its reliability. Another innovative aspect of the study is the deployment of the MOLOCH model in the Sahel region. In fact such model is mainly used in mid-latitude regions (Davolio et al, 2020) and to the best of our knowledge no or few attempts have be done to run the MOLOCH model in tropical regions using the explicit treatment of the convection. To justify the use of the MOLOCH model, we underline that it was chosen due to its exceptional simulation speed, which is 2 to 6 times faster (and cheaper in terms of SBUs consumption) than that of other models (Capecchi, 2021) and it is known that the simulation speed is a crucial factor when performing numerical weather simulations over decades.

3. Justification of the computer resources requested

The goal of the project is to perform an hindcast regarding 10 years for each project year, namely the following 10-year long periods: 2001-2010, 1991-2000 and 1990-1981 in the first, second and third year, respectively.
With this programme in mind, resources requested, which builds upon the experience in previous Special Projects, are as follows:

DOMAIN (see the sketch in Figure 1)	SBUs estimated to simulate 1 day	SBUs estimated to simulate a 1-year period	SBUs estimated to simulate a 10-year period	SBUs requested to simulate a 10-year period+10% overhead
~500X400 points	~750	~0.27 M	~2.7 M	~3 M

We emphasize that the 10-year period from 2011 to 2020 is planned to be simulated as part of the Late Request Special Project that was submitted and approved in May 2025. Furthermore, in order to ensure the hindcast remains as up-to-date as possible and closely aligned with the present, we intend to complete the simulation of the 5-year period from 2021 to 2025 during the first year of the Special Project, as soon as the corresponding ERA5 data become

available). Therefore, we request an additional 1.5 million SBUs to perform the simulations required for this recent period.

4. Technical characteristics of the code

MOLOCH is a non-hydrostatic, fully compressible model that uses a hybrid terrain-following coordinate, relaxing smoothly to horizontal surfaces. It is developed at the Institute of Atmospheric Sciences and Climate (ISAC) of the Italian National Research Council (CNR). The latest version of the model is available as GitLab repository: https://gitlab.com/isac-meteo/globo-bolam-moloch. Details about the model can be found in Malguzzi et al. (2006). It was initially developed for research purposes, but today it is being used operationally by various regional meteorological services both in Italy and abroad (Greece and Spain among the others). The microphysical scheme is based on the parameterisation proposed in Drofa and Malguzzi (2004), which describes the interactions of cloud water, cloud ice, rain, snow, and graupel. The MOLOCH model is based on a single Fortran 90 code; it is fully parallelised, applying the domain splitting technique, and is compatible with MPICH2 and OpenMP parallel computing environments. The version released in 2024 will be used in the Project.
The MOLOCH models was successfully compiled and implemented on the ATOS supercomputer during the SPITCAPE 2019-2021 and 2022 Special Projects (see Capecchi, 2021). MOLOCH needs the Intel or GNU Fortran compiler and relies on few additional libraries (namely, the NetCDF and ecCodes libraries); building its executables was proven to be "smooth" enough on several architectures using the Intel Fortran compiler, which produces faster executables than the GNU Fortran compiler.

5. References

- *Capecchi, V. (2021). Reforecasting Two Heavy-Precipitation Events with Three Convection-Permitting Ensembles, Weather and Forecasting, 36(3), 769-790*
- *Capecchi, V., Pasi, F., Gozzini, B. et al. A convection-permitting and limited-area model hindcast driven by ERA5 data: precipitation performances in Italy. Clim Dyn **61**, 1411–1437 (2023)*
- *Cavalleri, F. et al Multi-scale assessment of high-resolution reanalysis precipitation fields over Italy, Atmospheric Research, Volume 312, 2024,107734, https://doi.org/10.1016/j.atmosres.2024.107734.*
- *Davolio, S., Malguzzi, P., Drofa, O. et al. The Piedmont flood of November 1994: a testbed of forecasting capabilities of the CNR-ISAC meteorological model suite. Bull. of Atmos. Sci.& Technol. **1**, 263–282 (2020)*
- *Drofa, O., and P. Malguzzi, 2004: Parameterization of microphysical processes in a nonhydrostatic prediction model. Proc. 14th Int. Conf. on Clouds and Precipitation (ICCP), Bologna, Italy, ICCP, 19–23*
- *Malguzzi, P., G. Grossi, A. Buzzi, R. Ranzi, and R. Buizza, 2006: The 1966 ''century'' flood in Italy: A meteorological and hydrological revisitation. J. Geophys. Res., 111, D24106, https://doi.org/10.1029/2006JD007111*
- *Nipen, TN. et al Regional data-driven weather modeling with a global stretched-grid, https://arxiv.org/abs/2409.02891 (2024)*