

EMI R&D PROJECT FINAL REPORT

All the following mandatory information needs to be provided.

Project Title:	High resolution (1.8 km) atmospheric reanalysis, obtained by dynamically downscaling ERA5 reanalysis with the Italian convection permitting meteorological model MOLOCH
Computer Project Account:	SPITSTOC-2023
Start Year - End Year :	2023- 2025
Principal Investigator(s)	Dr. Paolo Stocchi
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Other Researchers (Name/Affiliation):	Silvio Davolio (Univeristy of Milan and CNR-ISAC) Francesco Cavalleri (CNR-ISAC)

The following should cover the entire project duration.

Summary of project objectives

(10 lines max)

The objective of the SPITSTOC Special Project was the development of a new long-term convection-permitting atmospheric reanalysis dataset over Italy and the Alpine region through dynamical downscaling of the ERA5 reanalysis using the non-hydrostatic MOLOCH model.

The project aimed at overcoming the limitations of existing global and regional reanalyses in representing mesoscale atmospheric processes, convective precipitation, complex topography and local climate variability. Specific objectives included:

1. production of a continuous high-resolution atmospheric dataset covering Italy and surrounding regions at approximately 1.7 km horizontal resolution;
2. generation of hourly meteorological fields for a broad range of atmospheric and land-surface variables;
3. evaluation of the dataset against independent observational products and existing regional reanalyses;
4. demonstration of its applicability to meteorological, climatological and hydrological studies;
5. public dissemination of the resulting dataset through open-access repositories and scientific publications.

Summary of problems encountered

(If you encountered any problems of a more technical nature, please describe them here.)

No major technical issues affected the completion of the project. The main challenge was associated with the very large computational demand required to perform more than three decades of continuous convection-permitting simulations and the corresponding post-processing, quality control and data archiving activities.

The availability of ECMWF computational resources was essential for the successful completion of the project and allowed the production of a unique high-resolution dataset that would have been difficult to generate using standard institutional resources alone

Experience with the EMI R&D Project framework

(Please let us know about your experience with administrative aspects like the application procedure, progress reporting etc.)

The experience with the ECMWF Special Project framework was extremely positive. The availability of reliable HPC resources, efficient data management infrastructure and technical support enabled the successful execution of a computationally demanding long-term reanalysis production effort. The Special Project framework provided the necessary computational environment to perform continuous multi-decadal convection-permitting simulations and contributed significantly to strengthening collaboration between atmospheric modelling, climate and hydrological research activities

Summary of results

(This section should comprise up to 10 pages, reflecting the complexity and duration of the project, and can be replaced by a short summary plus an existing scientific report on the project.)

The main outcome of the project is the production of MORE (MOLOCH Downscaled ERA5 Reanalysis), a new convection-permitting atmospheric reanalysis covering Italy and the Alpine region from 1990 to present at approximately 1.7 km horizontal resolution. As illustrated in Figure 1, MORE is generated through a continuous dynamical downscaling framework in which ERA5 provides initial and hourly lateral boundary conditions to daily MOLOCH simulations over a dedicated Italian-Alpine domain. The dataset includes hourly output for approximately forty atmospheric and land-surface variables, including precipitation, temperature, humidity, wind, radiation fluxes, soil temperature and soil moisture, as well as upper-air variables on selected pressure levels.

The production of MORE required continuous multi-decadal convection-permitting simulations and represents, to our knowledge, the highest-resolution long-term atmospheric reanalysis currently available for Italy and the Alpine region. The dataset provides a physically consistent reconstruction of atmospheric conditions over more than three decades and fills an important gap between coarse-resolution global reanalyses and local observational datasets.

A comprehensive validation framework was developed to assess dataset quality. Precipitation fields were evaluated against the ARCIS and GRIPHO observational datasets, while near-surface temperature was validated using the high-quality UniMi-ISAC observational database. Additional comparisons were performed against ERA5-Land, CERRA, MERIDA-HRES and LAMMA-HINDCAST to benchmark the performance of MORE against existing regional reanalysis products.

Detailed descriptions of the observational datasets, validation methodology and benchmark products can be found in Stocchi et al. (2026).

The results demonstrate that MORE realistically reproduces the spatial and temporal variability of both precipitation and temperature across Italy. The added value of the convection-permitting resolution is particularly evident during summer (JJA), when localized convective precipitation dominates. As shown in Figure 2, MORE substantially reduces biases in precipitation intensity and heavy precipitation statistics compared with coarser-resolution reanalyses, while maintaining a realistic representation of wet-event frequency, particularly during summer convective conditions. The largest improvements are found for precipitation intensity and upper-tail precipitation indicators (p99.9), highlighting the ability of explicit convection to better represent extreme rainfall over complex terrain and coastal regions.

Temperature validation confirms the capability of MORE to reproduce both climatological patterns and long-term variability across Italy. The dataset successfully captures relevant climate indicators, including tropical nights and long-term warming trends, although a moderate cold bias remains in some regions, particularly over complex terrain.

A further demonstration of the added value of MORE was provided through the analysis of the catastrophic Emilia-Romagna floods of May 2023. The reanalysis accurately reproduced the meteorological evolution of the two major precipitation episodes and provided an improved representation of mesoscale precipitation structures responsible for localized rainfall maxima. Hydrological simulations forced by MORE also showed improved discharge and soil-moisture estimates at catchment scale, demonstrating the benefits of convection-permitting atmospheric datasets for impact-oriented applications.

The project also resulted in the public release of the dataset through Zenodo, ensuring long-term accessibility, reproducibility and transparency of the generated products. The MORE dataset is publicly available through the Zenodo repository (Stocchi, 2026), while a comprehensive description of the production framework, validation methodology and scientific applications is provided in Stocchi et al. (2026), currently under review in *Earth System Science Data (ESSD)*.

The dataset is designed to be periodically updated and extended, providing a valuable long-term resource for meteorological and climate research, climate services, hydrological applications, climate-

change adaptation studies, extreme-event attribution and future machine-learning developments.

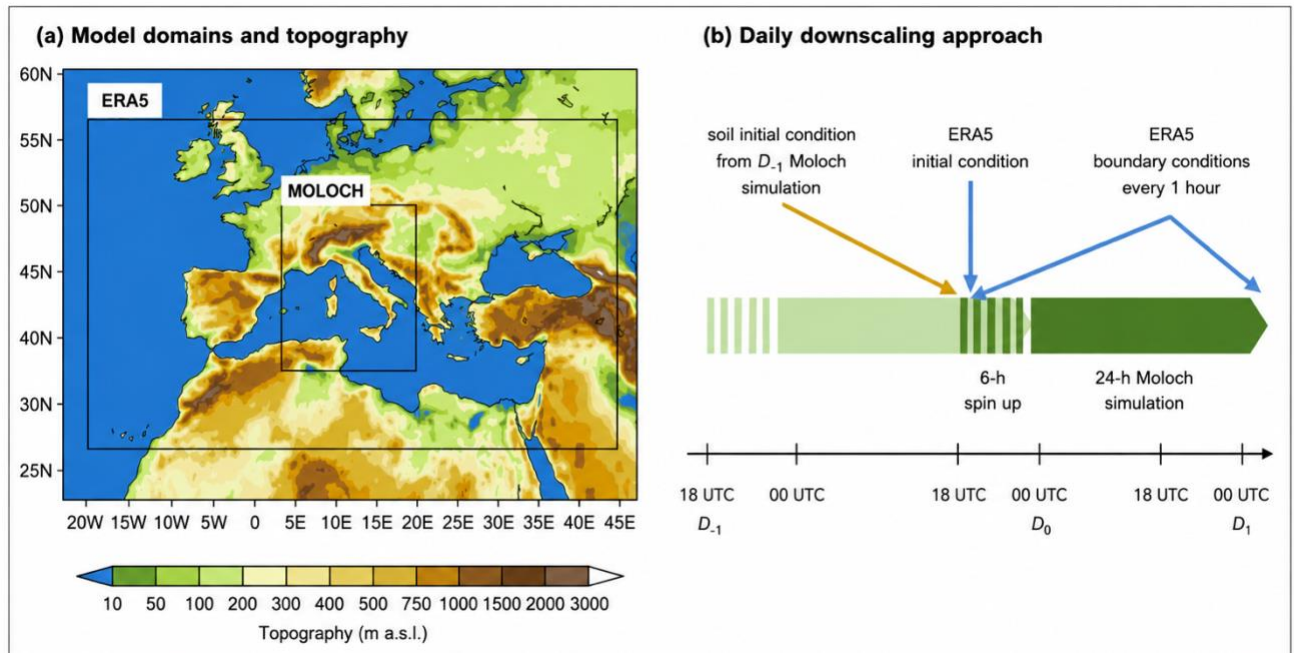


Figure 1. Overview of the MORE production framework. (a) ERA5 forcing domain (outer box) and MOLOCH convection-permitting domain (inner box) used for the generation of the reanalysis dataset. Shading indicates model topography. (b) Schematic representation of the daily downscaling cycle. ERA5 provides atmospheric initial conditions and hourly lateral boundary conditions, while soil variables are inherited from the previous simulation. A 6-hour spin-up period is discarded and the subsequent 24-hour simulation is retained to build the continuous MORE archive.

Relative BIAS (%) - 2001 - 2016 - JJA

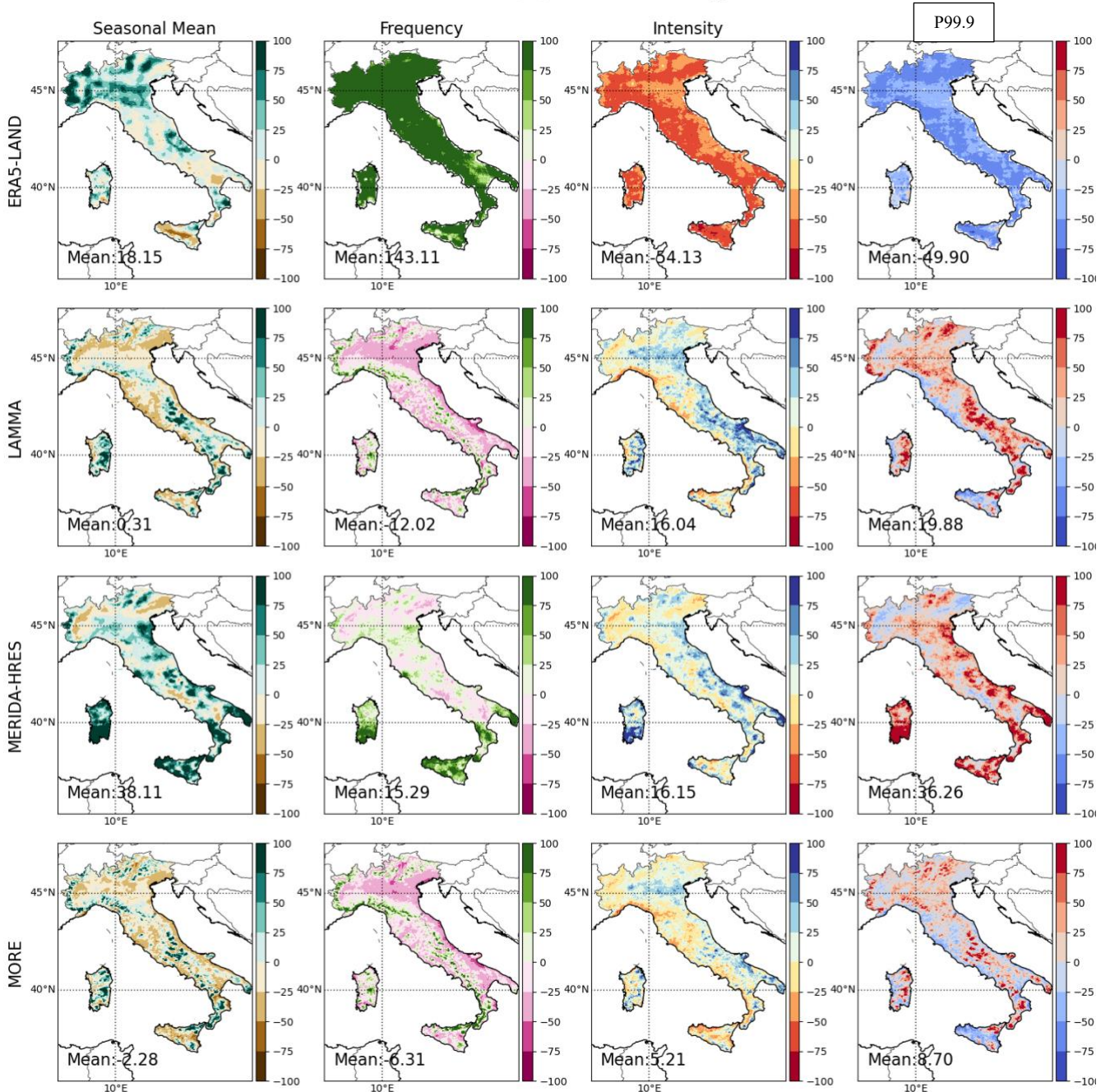


Figure 2. Relative bias (%) of seasonal mean precipitation, wet-hour frequency, wet-hour intensity and heavy precipitation index (p99.9) during summer (JJA) for ERA5-Land, LAMMA-HINDCAST, MERIDA-HRES and MORE against the GRIPHO observational dataset (2001–2016). MORE exhibits reduced biases in precipitation intensity and extremes compared with coarser-resolution products, highlighting the benefits of convection-permitting downscaling for representing summer convective precipitation over Italy.

List of publications/reports from the project with complete references

Stocchi, P., Cavalleri, F., Tariq, M., Brunetti, M., Camici, S., Mastrangelo, D., Di Sante, F., and Davolio, S.: MORE, a new convection-permitting reanalysis dataset over Italy and Alpine region: Validation and application in weather, climate and hydrology, *Earth Syst. Sci. Data Discuss.* [preprint], <https://doi.org/10.5194/essd-2025-789>, in review, 2026

Dataset

Stocchi, P.: *MORE – MOLOCH Downscaled ERA5 Reanalysis Dataset over Italy and Alpine Region (Version 1.0)*. Zenodo. <https://doi.org/10.5281/zenodo.18470948>, 2026

Future plans

(Please let us know of any imminent plans regarding a continuation of this research activity, in particular if they are linked to another/new EMI R&D Project.)

Future activities will focus on the operational extension of MORE to the most recent years, further evaluation of additional atmospheric variables and the integration of the dataset into climate-impact and attribution studies.

Particular emphasis will be placed on the use of MORE for the analysis of extreme events, hydrological applications, convection-permitting climate services and the development of machine-learning approaches for weather and climate downscaling. The dataset is also expected to support future national and international projects addressing climate resilience, climate adaptation and high-resolution climate information services.