Finanziato dall'Unione europea NextGenerationEU | Ministero dell'Università e della Ricerca | Italiadomani PIANO NAZIONALE DI RIPRESA E RESILIENZA

multi-Risk sciEnce for resilienT commUnities undeR a changiNgclimate

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1. Technical references

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* PU = Public

PP = Restricted to other programme participants (including the Commission Services)

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0.2	15.04.2026		Final Version

2. Abstract

Task 8.2.3. has produced a compilation/collection of databases that provide a comprehensive quantification of hazard/exposure/vulnerability at a national level. Data are freely available to the RETURN Community and will be published publicly after the end of RETURN activities. In particular, this Report details six key pillars of the impact-oriented climate indicators produced: CoPE, Future Rain, Future E, IDROBOX, DATASCAN, and a suite of various climate indicators developed across all RETURN Climate Spokes. These resources are designed to provide granular, actionable insights into changing earth-system processes, such as convective phenomena, future precipitation trends, and historical hydrometric data. Currently accessible within the partnership, these datasets are slated for full public release at the project's conclusion, forming a core component of the RETURN legacy.

Table of contents

3. Introduction

The purpose of the activities carried out in Task 8.2.3 is to bridge the gap between climate modeling and practical risk management by providing stakeholders with advanced digital tools and high-fidelity data. Understanding climate change impacts on a local scale requires more than global models; it necessitates the downscaling of data and the creation of indicators that reflect actual socio-economic and environmental vulnerabilities. The datasets discussed herein—ranging from multi-model convective ensembles to digitized historical records—serve as the foundation for this mission.

4. Description of the impact-oriented climate indicators

Deliverable 8.2.3 builds on Tasks 8.2.1 and 8.2.2, which identified impact-oriented indicators and assembled the direct observations and indirect reconstructions necessary to provide an extensive characterization of past and present climates. Here we summarize the main impact-oriented indicators developed and assessed.

1. CoPE (Convective Phenomena over Europe). The CoPE dataset is a product of the CORDEX Flagship Pilot Study, focusing on convective phenomena across Europe and the Mediterranean. It utilizes a multi-model convection-permitting ensemble (CPM) to investigate the added value of high-resolution modeling in capturing extreme weather signals. Resolution: Remapped on a regular 3km horizontal grid over Italy. Purpose: To reduce uncertainties in climate change signals related to intense, short-duration convective storms.

2. Future Rain. Future Rain focuses on projecting precipitation patterns under various climate scenarios. It provides high-resolution data essential for urban planning and flood risk assessment. Key Feature: Integration of CPM results to better predict "flashy" rainfall events that traditional models often overlook. Usage: These projections are critical for designing resilient hydraulic infrastructure.

3. FUTURA-E provides a rapid assessment of extreme rainfall changes for specific return periods (T) under the RCP 8.5 scenario. Methodology: It utilizes a stationary frequency analysis based on a SMEV distribution (Simplified Meta-Statistical Extreme Value) applied to an ensemble of 9 convection-permitting models. Functionality: Users can select rainfall durations (1h to 24h) and compare future periods (Near: 2040-2050 or Far: 2090-2099) against the historical reference (1995-2005). Results: Changes are expressed as ratios; values >1 indicate an increase in extreme precipitation. The application includes a "Coherence" parameter (0.5 to 1) to filter cells where a specific fraction of models agree on the trend direction. Spatial Analysis: Analysis can be performed on single cells, user-defined areas, or specific river basins.

4. IDROBOX is an advanced Web-GIS tool for analyzing extreme rainfall at a national scale based on rain-gauge observations. Functionality: It allows for the extraction of Intensity-Duration-Frequency (IDF) curves for the historical climate, applicable to specific geographic points or entire river basins. Hydrological Foundation: The system utilizes regionalized models such as Gumbel, GEV, and the Regionalized Metastatistical Extreme Value Distribution (MEVD-R) and can extract IDF curves at arbitrary points or through the extraction, performed internally, of hydrologic basins based on a specified outlet point.

5. DATASCAN is a massive recovery and digitization effort for historical pluviographic data. Volume: Approximately 83,720 weekly charts (cartellini) have been scanned and digitized. Historical Depth: Covers 23 strategic stations with records starting as early as 1912 and extending through the 1980s, and in some cases, to 2010. Technical Detail: continuous paper diagrams are turned into hourly digital time series based on a semi-automatic algorithm, enabling long-term statistical analysis of climate variability.

6. Impact-Oriented Indicators. A variety of climate impact-oriented hazard indicators were produced by all RETURN Spokes. The indicators are used to track and understand medium- to long-term trends in environmental, social, and economic systems. Grounded in scientific evidence, they quantitatively describe cause-effect relationships within Earth system change processes.

While some indicators are linked to individual effects, others reflect the combined influence of multiple factors, offering insights into compound hazards. A clear example occurred during the 2023 flood in the Emilia-Romagna Region: prolonged coastal inundation triggered cascading effects on the marine environment, where freshwater flows carrying sediment and pollutants altered oxygen and salinity levels, disrupting both the ecosystem and the local economy for weeks. Inspired by the Italian National Environmental Protection System (SNPA), RETURN identifies and quantifies 15 Climate-Related Impact Sectors at the national scale: Environmental & Geographical: Water Resources, Soil and Land Use, Terrestrial and Marine Ecosystems, Alpine and Apennine Environments, Coastal Zones, and Forests. Socio-Economic: Health, Agriculture and Food Production, Fisheries and Aquaculture, Energy, Urban Areas, Cultural Heritage, Industry and Tourism, and Transport and Infrastructure. Within each sector, a hierarchical framework is defined to ensure scientific rigor: The Impact: The specific climate-related consequence being studied. Impact Indicator: The quantitative metric used for measurement. Parameters and Data Sources: The raw data required for calculation are explicitly listed as a part of the metadata.

5. The RETURN digital ecosystem and publicly accessible databases

The RETURN digital ecosystem is characterized by its interactive Web-GIS architecture, designed to transform complex climate ensembles into accessible, actionable intelligence covering the entire national territory. Rather than providing static maps, the platform provides a dynamic interface where users can tailor visualizations to their specific technical needs through a multi-parameter selection process.

Interactive Data Visualization via Web-GIS. The ecosystem leverages a "query-on-the-fly" approach across its primary products, allowing for a highly granular exploration of climate risks:

Spatial and Administrative Filtering: Users can navigate the national area by selecting specific subregions or river basins. For instance, in applications like IDROBOX, users can identify a basin by selecting the outlet section directly on the map, while FUTURA-E allows for analysis on single cells or user-drawn polygons.

Temporal and Climate Scenario Customization: The platform allows users to toggle between different time horizons. In FUTURA-E, this includes selecting between the "Near" (2040-2050) and "Far" (2090-2099) future periods under the RCP 8.5 scenario.

Event Duration and Return Period Selection: Critical for engineering and civil protection, the Web-GIS enables the selection of event durations (ranging from sub-hourly scales in DATASCAN and CoPE to the standard 1h, 3h, 6h, 12h, and 24h intervals in FUTURA-E). Users can also input specific Return Periods (T)—typically between 2 and 100 years—to visualize how extreme rain quantiles are projected to scale.

Model Ensemble Management: A key innovation of the ecosystem is the ability to select the Climate Model. Users can choose to view results from a single specific model or an ensemble. Through the Coherence parameter, the Web-GIS masks areas where models disagree, allowing users to visualize data only where a set fraction of the ensemble (e.g., 70% or 100%) shows a consistent trend direction.

Visualizing the Datasets. The following snapshots illustrate the integration of these selection parameters within the ecosystem.

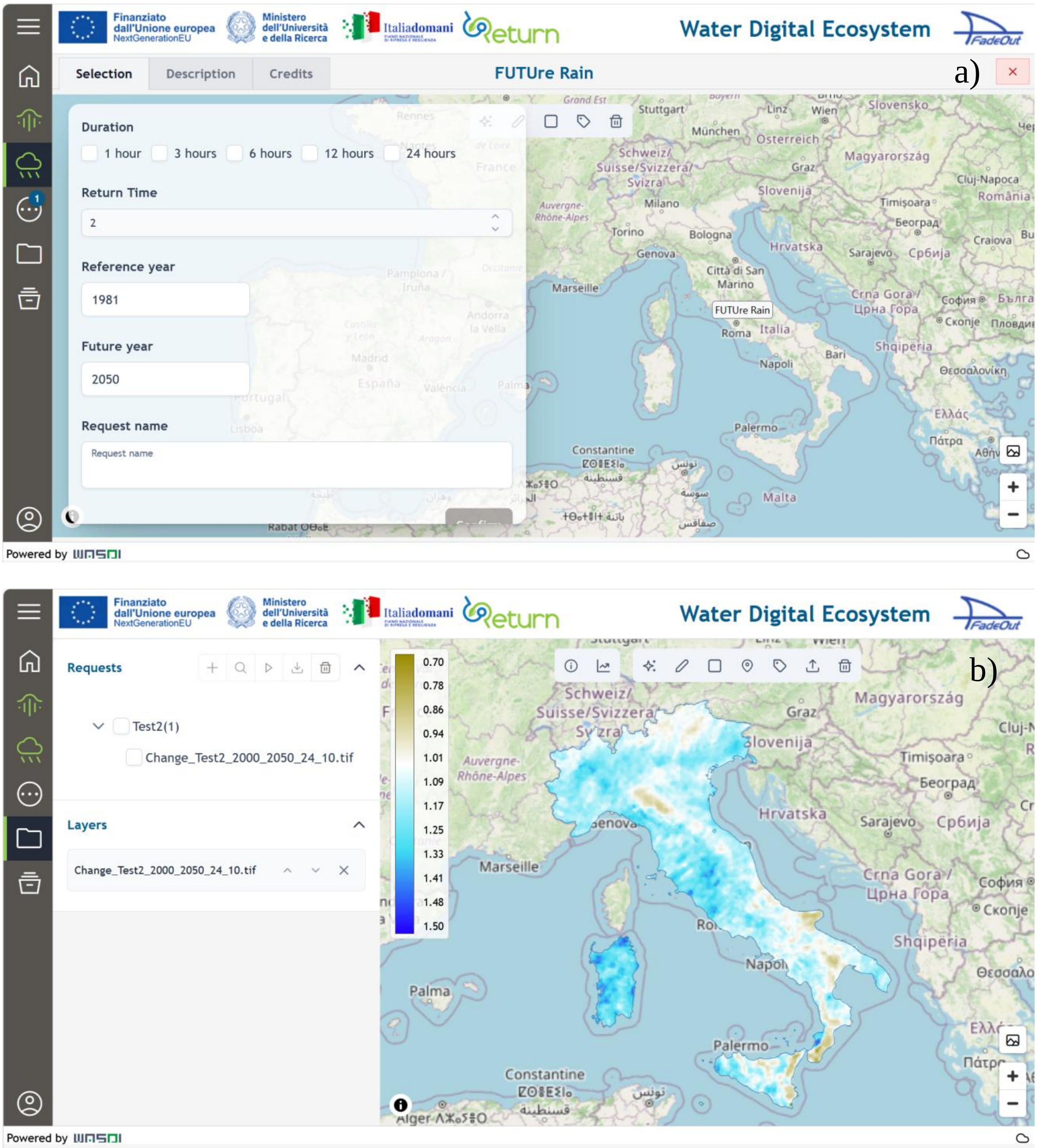

Figure 1. a) FUTURE RAIN interactive control panel, where users select subregions, return periods, event duration and reference and projected years. b) shows the results of a query.

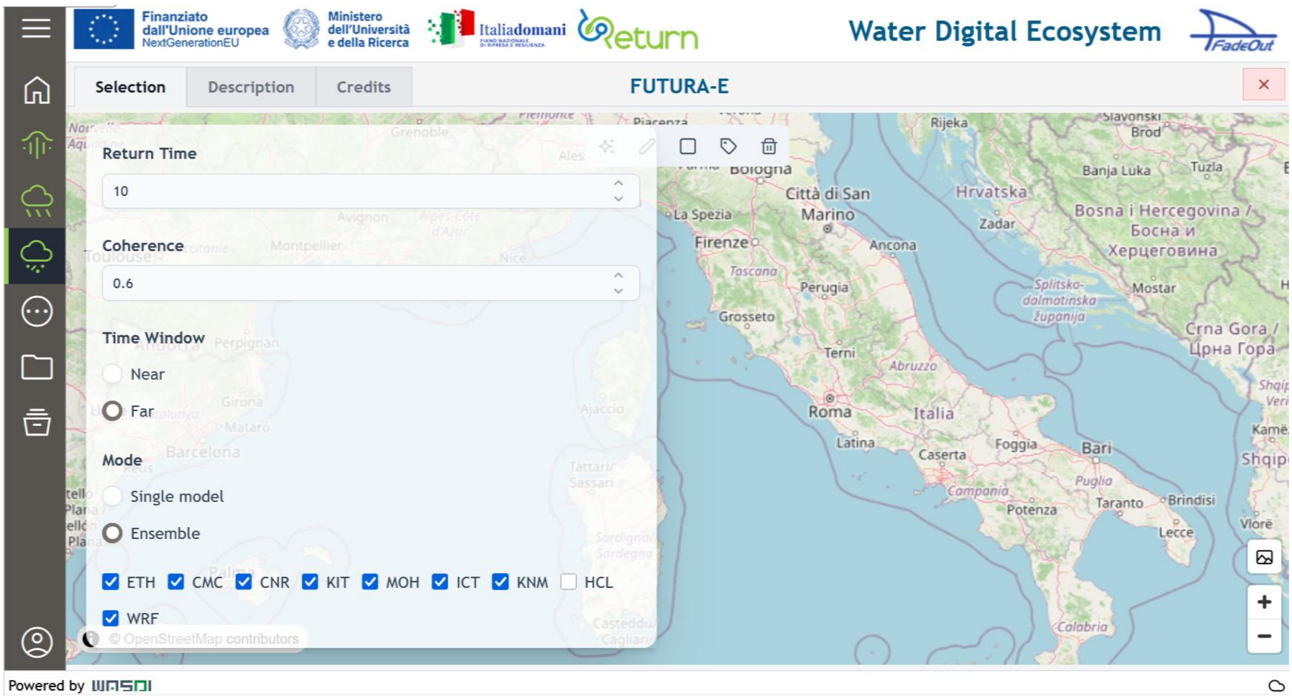

Figure 2. FUTURA-E interactive control panel where users select subregions, return periods, and the coherence threshold to visualize ensemble median variations.

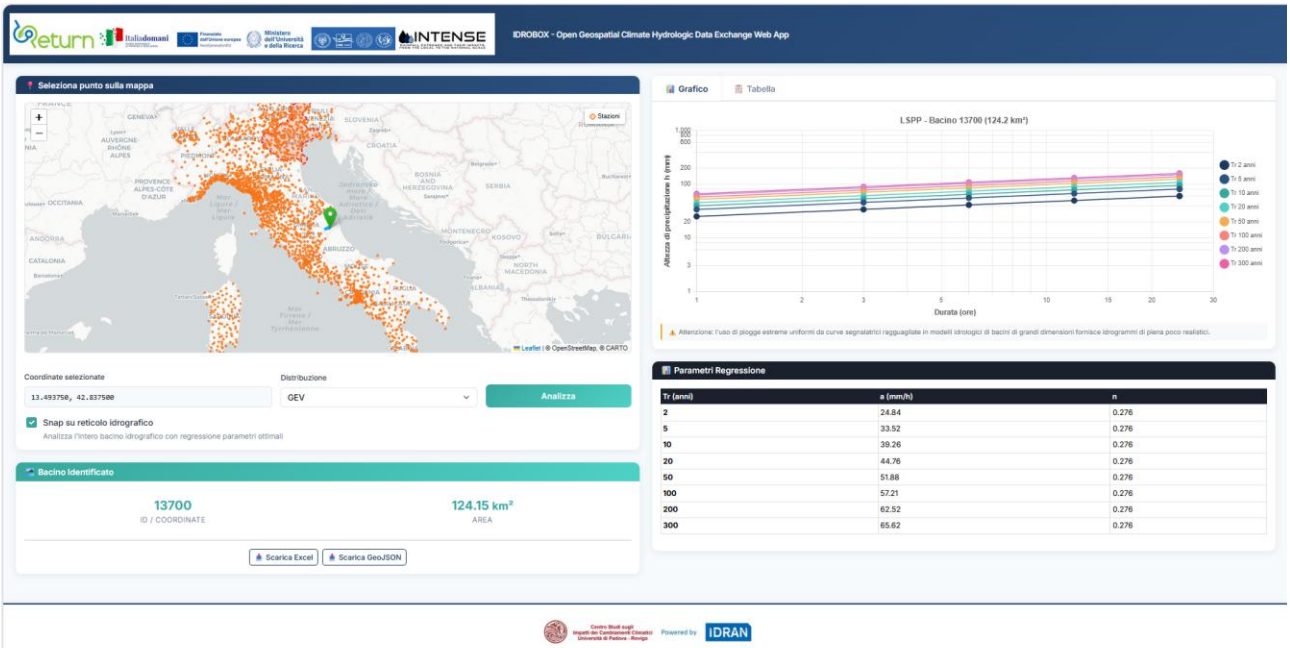

Figure 3. IDROBOX Web-GIS Interface used for consulting IDF curves, where users select specific geographical points or basin outlets to extract historical climate data.

By centralizing these tools, the RETURN project ensures that high-fidelity data from CoPE and digitized historical series from DATASCAN are not isolated but are integrated into a cohesive spatial database (EPSG:4326 - WGS84) ready for GIS analysis and export (e.g., GeoTIFF).

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6. Conclusions

The datasets and indicators produced under the RETURN partnership represent a major advancement in regional climate intelligence for Italy. By bridging the gap between state-of-the-art convective modeling and the preservation of over a century of historical data and by translating physical understanding into impact-oriented climate indicators, the project provides the temporal and spatial resolution necessary for informed policy and resilient engineering.

The integration of systems that modernize access to critical hydrological parameters through an interactive Web-GIS interface offers immediate operational support for territorial planning. The ability for users to customize parameters transforms the platforms from a data repository into a decision-support system. Furthermore, the broad suite of impact-oriented indicators ensures that climate data is translated into actionable insights that account for complex compound hazards and cascading effects.

Upon its full public release, the RETURN digital ecosystem will provide a "one-stop-shop" for climate intelligence, empowering civil protection agencies, local municipalities, and researchers to build a more climate-resilient future based on a comprehensive, scientifically validated foundation of data.