Chienti and Foglia watersheds

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Specific objective	2.2 - Increase the safety of the Programme area from natural and man-made disaster
Work Package Number	5
Work Package Title	Pilot projects
Activity Number	5.1.
Activity Title	Marche Pilot Project
Partner in Charge	LP
Partners involved	PP9 in collaboration with CIMA Foundation (PA Agreement)
Status	Final
Distribution	Public

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1. Introduction

Marche Region through its Functional Centre is in charge to broadcast meteo-hydrological and hydraulic alert to forecast severe event and its effect over regional territories. Thanks to Stream Project, activity 5.1, regional forecast hydrological and hydraulic modelling was updated with new tools in collaboration with the Competence Centre of National Civil Protection CIMA Research Foundation.

2. Hydrological model

Flood-PROOFS (Flood PRObabilistic Operative Forecasting System) is a system designed by CIMA Research Foundation to support decision makers during the operational phases of flood forecasting and monitoring. The goal is to protect the population and infrastructures from possible damage caused by intense precipitation events.

The flood forecasting chain is composed of four main components:

i) the weather forecasts, using different scales meteorological models (global, regional or limited area if available);

ii) rainfall forecasts downscaling in several equiprobable scenarios using RainFARM stochastic model;

iii) observational inputs preparation, in particular rain maps through conditional merging between local ground stations and satellite or radar information;

iv) the distributed hydrological model Continuum (Silvestro et al., 2013), able to estimate river discharge and soil moisture conditions from the meteorological inputs (observation and forecasts).

The operative chain is daily used by the Functional Centre of Regione Marche for flood forecasting.

As part of this activity, CIMA implemented the following:

1. definition, collection and systematization of the information and data needed for forecasting. These data were collected, processed, spatially interpolated and made usable for subsequent analyses and as an input for the modelling.
2. calibration and validation of the Continuum hydrological model on the sections of the regional network with a discharge scale (about 30) with evaluation of the goodness of the relationships in the various hydrological regimes, for all the years of surveying the meteo-hydrological data available on the regional territory.

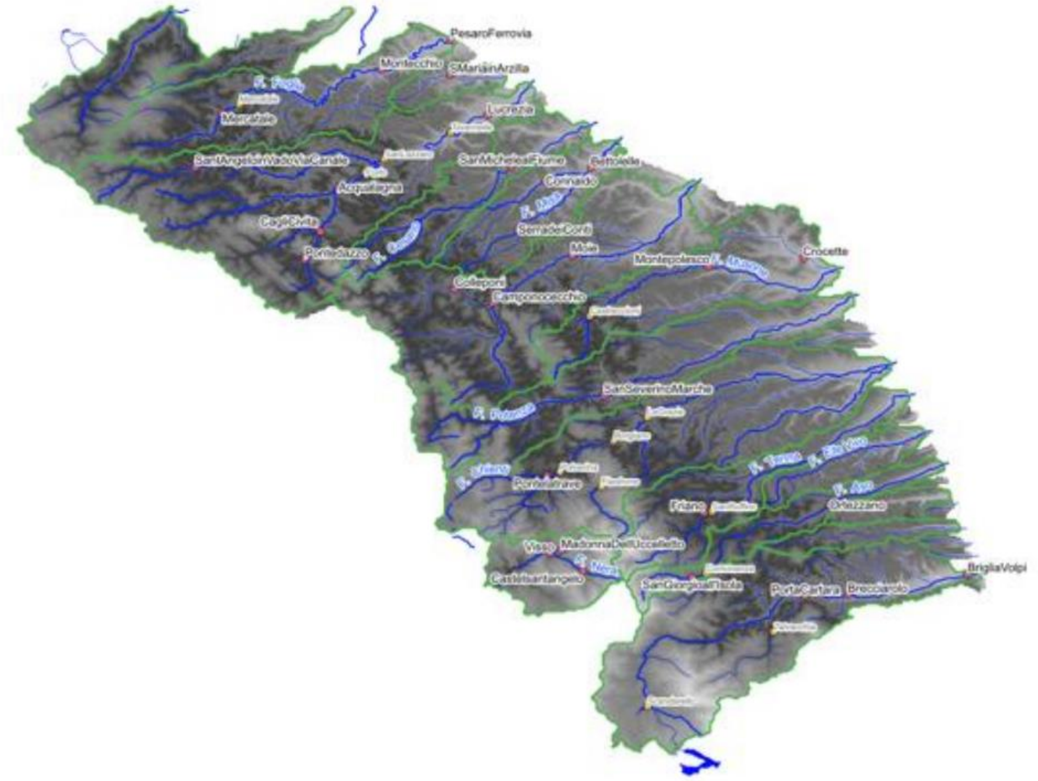

Figure 1. Outlet sections (pink pointers) and dams (yellow pointers) included in the model

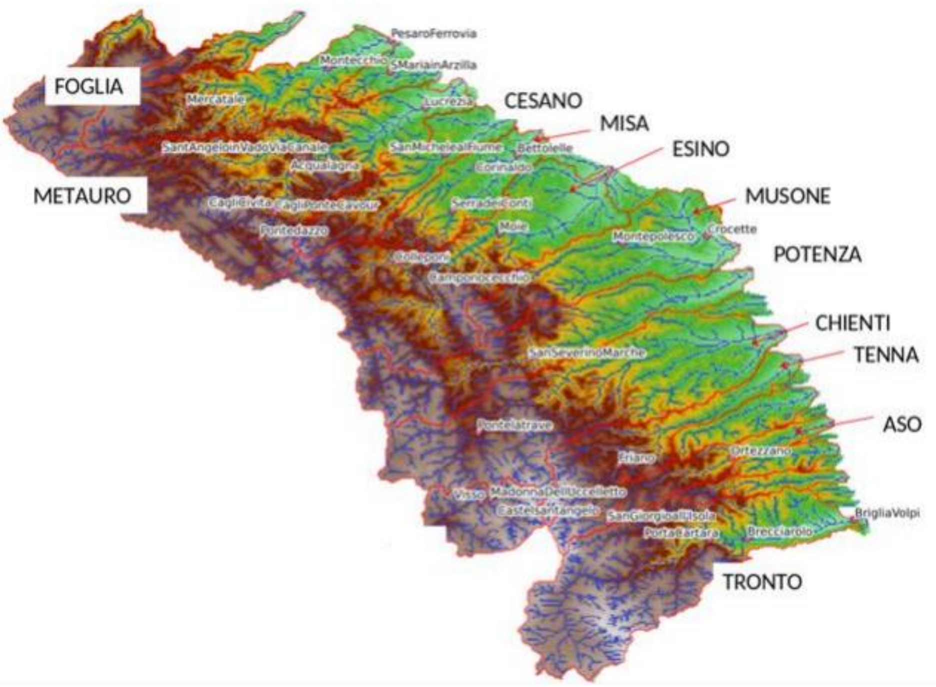

Figure 2. Calibrated basins

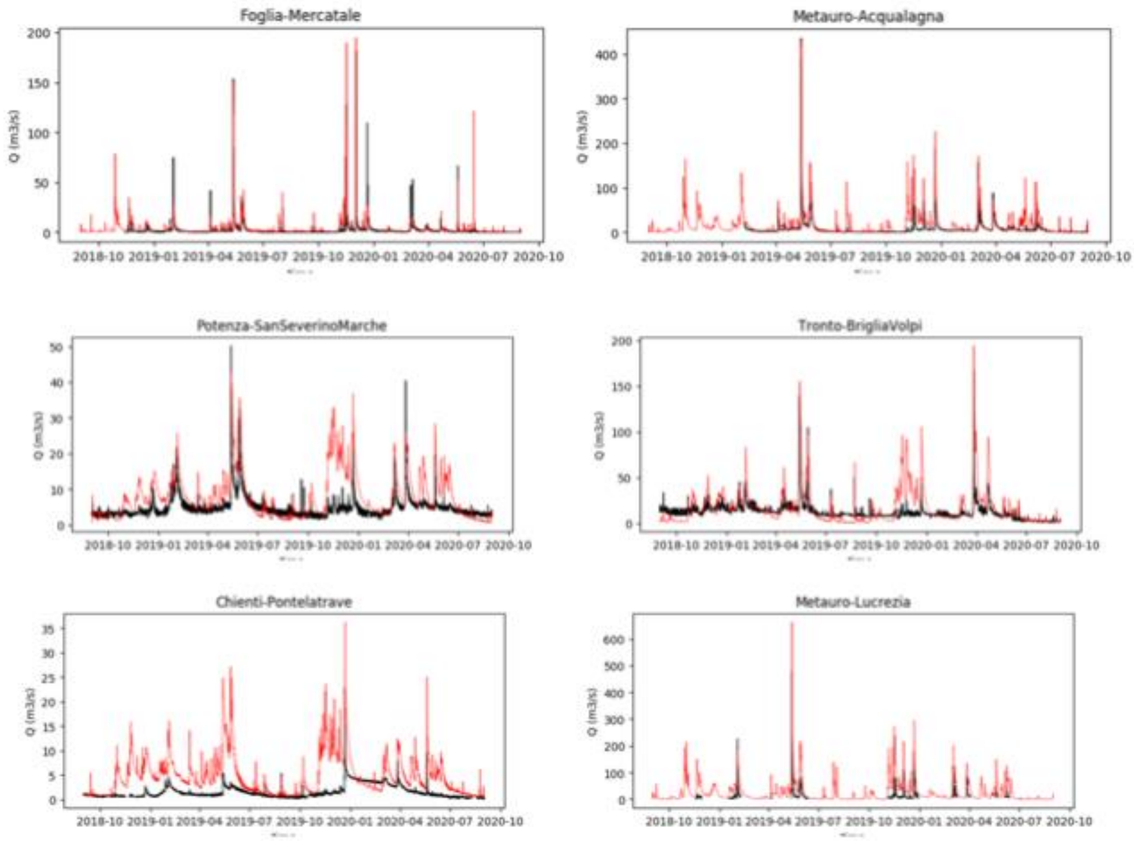

Figure 3. (Black) observed vs (red) modelled discharge values over the calibration period

3. Implementation of a 2D opensource hydraulic model on the Foglia and Chienti basins and creation of scenarios for assigned flow useful for forecasting purposes.

The activity consisted in the implementation of a bidimensional hydraulic model, TELEMAC-2D, on the Foglia and Chienti rivers, in the computation of a set of hazard maps for different return periods and in the creation of an abacus of flood maps using an interpolation algorithm. The abacus is used in the Flood-PROOFS forecasting chain to forecast flood scenarios.

The hydraulic model used in the present study is the two-dimensional hydrodynamic model TELEMAC-2D, developed to simulate free surface horizontal flows in two dimensions, neglecting the vertical component of speed (http://www.openTELEMAC.org).

The output provided by the model is the dynamics in time and space of the tie rods and speeds from which maps of maximum tie rod and maximum speed can be obtained, and the flow scales in defined sections.
The elaboration of the cartographic layers for hydraulic modelling (DEM and buildings) was realized in GIS environment. The DEM used has a spatial resolution of 1 meter. This product was produced by "Ministero dell'Ambiente e della Tutela del Territorio e del Mare" during the project "Piano Straordinario di Telerilevamento".
Sizes and dimensions of the bridges were measured during the filed survey campaign (see Annex for details).

The peak discharge values for different return periods (5, 10, 20, 30, 50, 100, 150, 200, 500 years) were provided by the "Regionalizzazione delle portate massime annuali al colmo di piena per la stima dei tempi di ritorno delle grandezze idrologiche" available at link https://www.regione.marche.it/Regione-Utile/Protezione-Civile/Progetti-e-Pubblicazioni/StudiMeteo-Idro#Studi-Idrologici-e-Idraulici.

Standard-shaped design hydrographs were created for each return period and used to feed TELEMAC-2D and create the hazard maps.

A very important activity to increase the accuracy of the hydraulic modelling was the field survey campaign conducted from 6th to 10th of April 2021 through also APR.
It aimed at:

- Detecting and measuring bridges in the area of interest, bridges are not included in the DEM.
- Check the quality of the available DEM.
- Check the status of the levees.

This campaign allowed us to build a more accurate mesh that leads to more reliable and accurate hydraulic modelling. The triangular mesh is the core of the implementation of the hydraulic model. It is the representation with irregular triangular elements of the area of interest. In this way the domain is described according to the location and elevation by a finite point in tri-dimensional space.

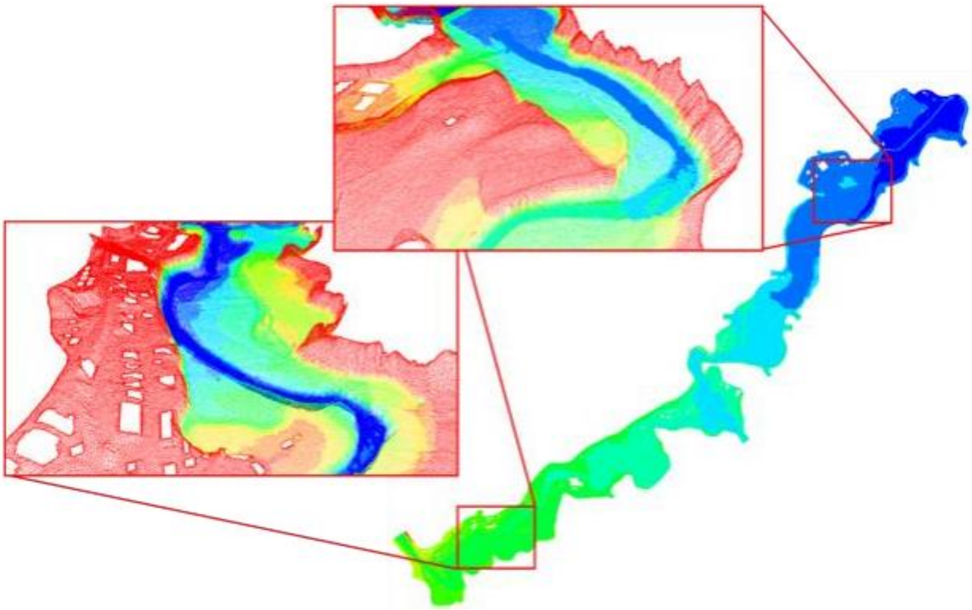

Figure 4. example of 3D mesh generated by python language method and associated to DEM and modified according to field survey - CH2 (Caccamo-Grazie) domain (blue colour is for lower elevation points, red is for more elevated points)

Model was implemented over Foglia and Chienti watersheds.

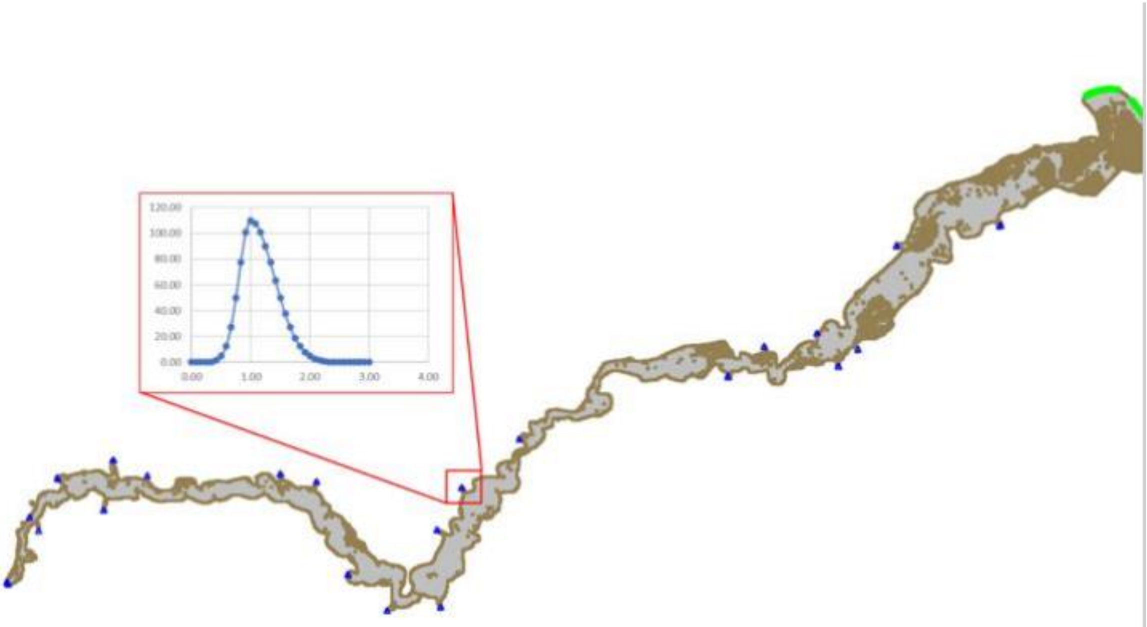

Figure 5. example of boundary condition for Foglia river simulation

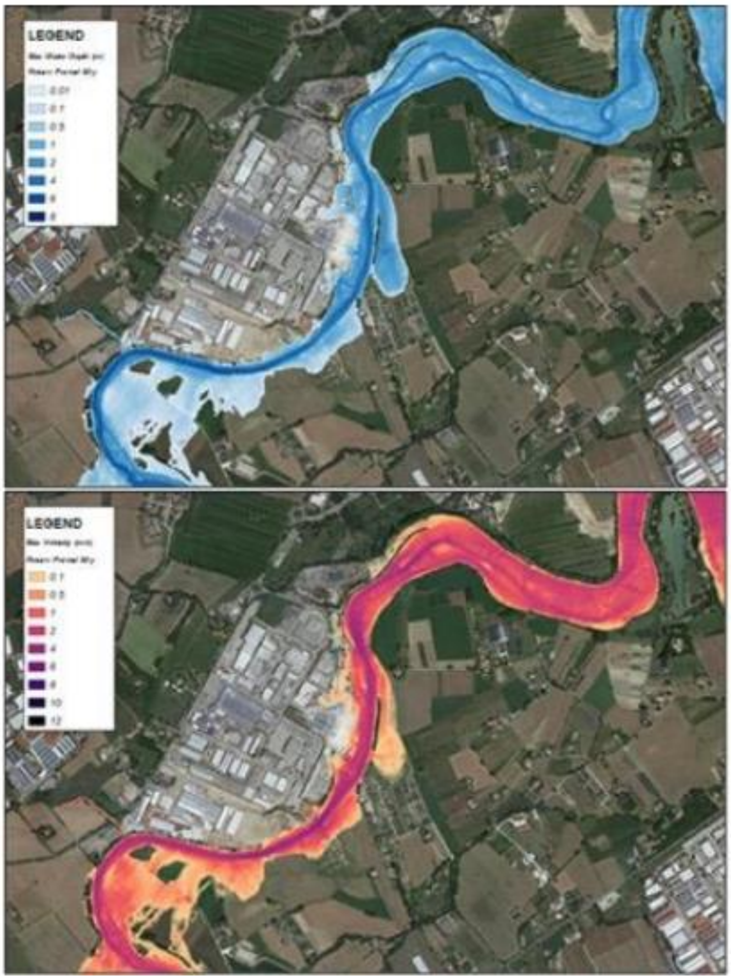

Figure 6. Details for Foglia, return period 50 years – maximum water depth and maximum water velocity

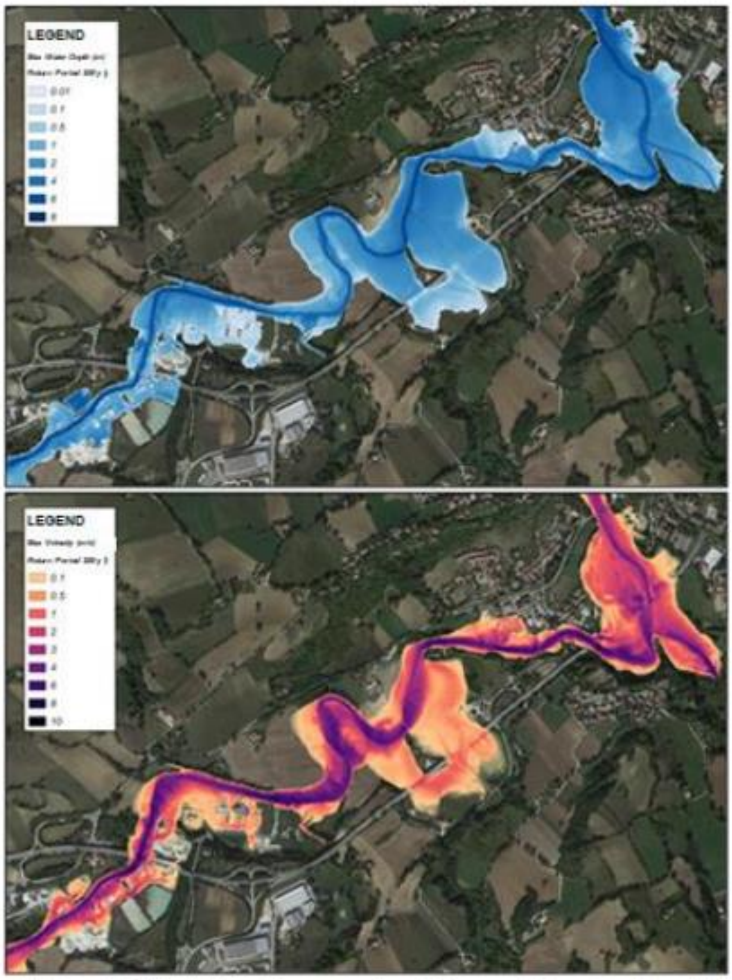

Figure 7. Detail of the Chienti results (domain CH2), return time 200 years - Water Depth and Velocity

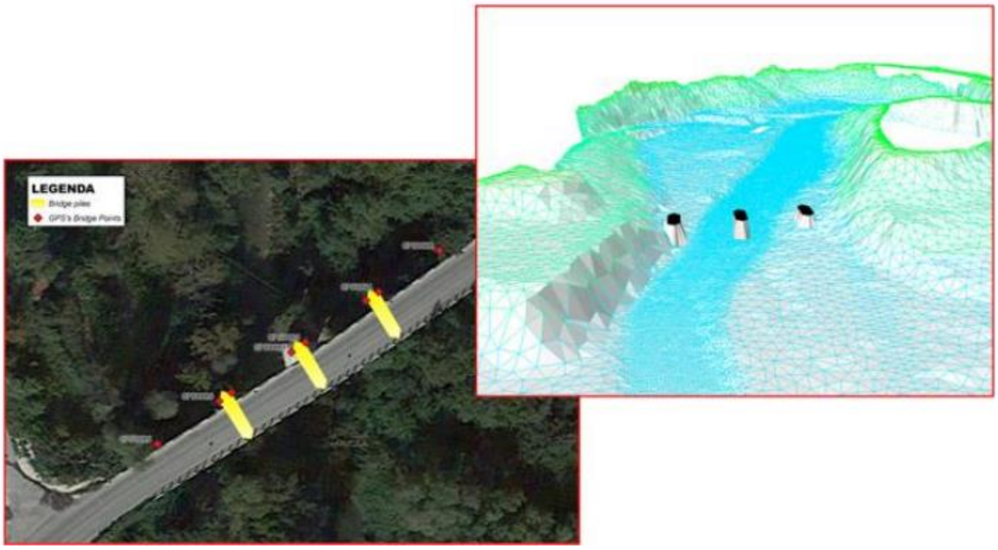

Figure 8. example of bridge pile survey/measure and elaboration on the Telemac2D mesh

3.1. Creation of an abacus of hazard maps

A map interpolation procedure has been used to obtain hazard maps for return period not modelled using the hydraulics model. The goal of the procedure is to create an abacus of hazard maps that can be used combined with FloodPROOFS in real time. FloodPROOFS can provide a forecast of discharge in a specific river section, to that value of discharge is associated a return period and the corresponding hazard maps is extracted from the abacus.

The interpolation procedure allows to create maps for whatever return period starting from two hazard maps of assigned return period obtained from hydraulic modelling.

Software FLOMART (FLOod MAp in Real Time) provides flood hazard map in real time. Its main objective is to integrate the operational hydro-meteorological forecasting and monitoring chain (e.g. FloodPROOFS) with flood hazard maps for the generation of forecasting or near-real-time flood maps. To reduce computational time of hydraulic model and support Civil Protection activities the actual hazard maps are created through an abacus of hazard maps.

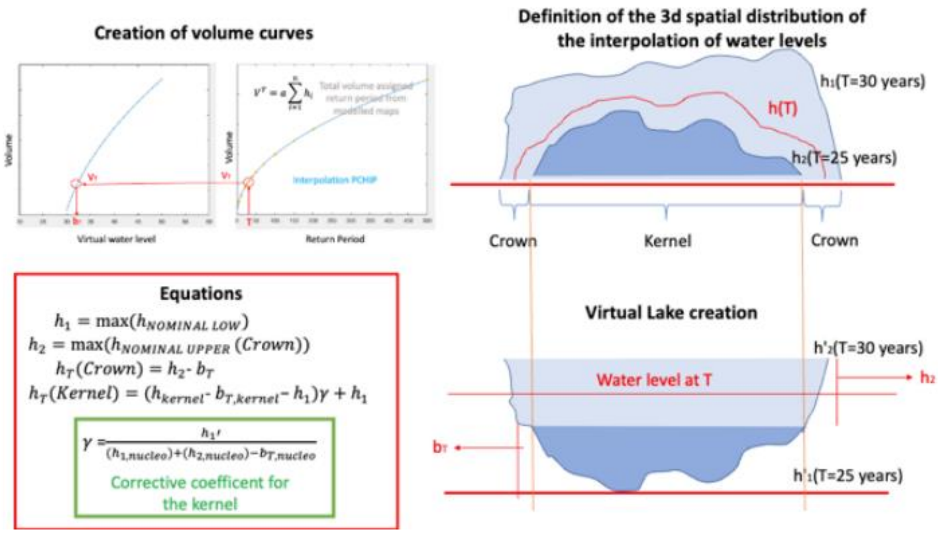

Figure 9. Sketch of the interpolation procedure that allows to obtain hazard maps for “intermediate” return period starting from two known hazard maps obtained by modelling.

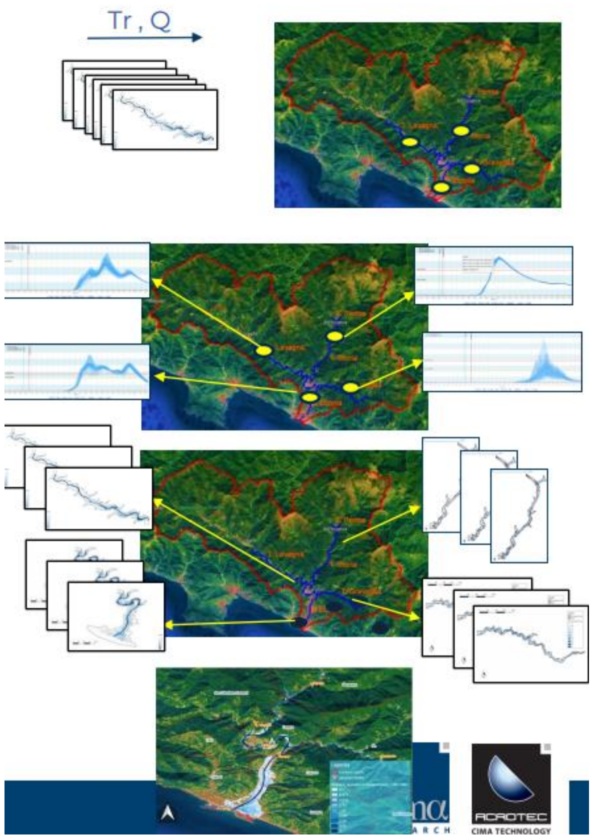

Figure 10. Sketch of FLOMART operative chain

4. Operative tool for lamination

The general objective of this task is the quantitative prediction of the flood control capacity of an examined reservoir in response to a specific hydrological forecast. This prediction must account for the current initial conditions, for the hydraulic/geometric characteristics of the reservoir and for any management constraints or any tributary downstream rivers.
The flood control tool provides the planning (timings and magnitudes) of the water flow to be released during the simulation window so that the flow peak Qmax is minimized and the desired flow to be derived (e.g., for hydropower production) is ensured.

The fundamental characteristic of the tool is the reservoir-specificity, not only in terms of characterization of the reservoir and of the outlet gates, but mostly for the design of the objective function to be minimized. This optimization must account for:
- the catchment hydrography of the interested river stretches for flood attenuation (e.g., presence or absence of one or more significant confluences in the section immediately downstream of the reservoir to avoid an amplification effect);
- the constraints connected to the reservoir structure (e.g., limitations on the level drawdown rate in the reservoir to avoid possible banks instability, on the increase or decrease in the flow rate between two releases, and on the duration of each planned released).

The tool outputs are essentially:
- the planned releases (discharge magnitudes and timings),
- the temporal evolution of the water level in the reservoir,
- the estimated hydrograph with the planned releases downstream of the dam.

Tool was implemented to Mercatale dam in Foglia catchment, in collaboration with National Civil Protection, and to Polverina, Caccamo and Fiastrone dams system in Chienti catchment.

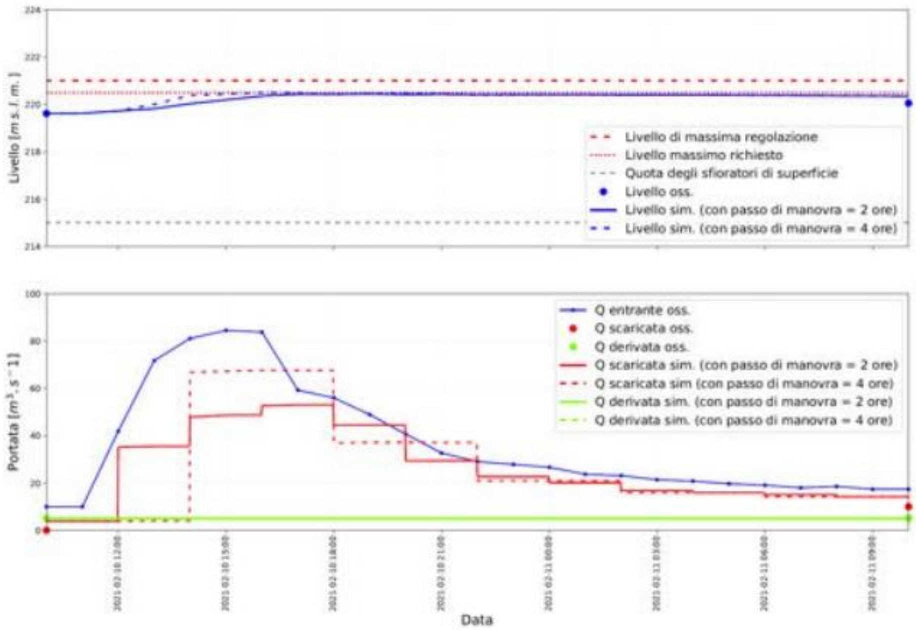

Figure 11. results of simulation for event from 2021-02-10 10:00 to 2021-02-11 10:00 by using the optimization mode with an initial level in the reservoir of 219.62 m a.s.l. (observed value) and with duration of each release (2 hours, 4 hours) for Mercatale Dam.

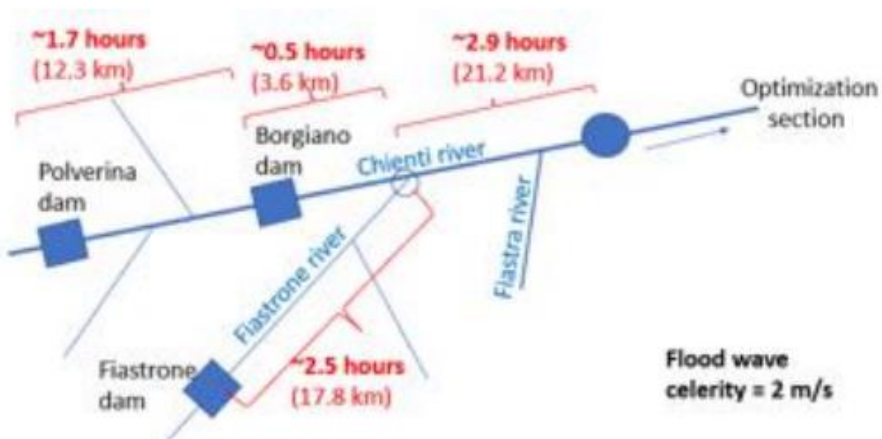

Figure 12. General scheme for flood lamination of the multi-reservoir system along the Chienti river

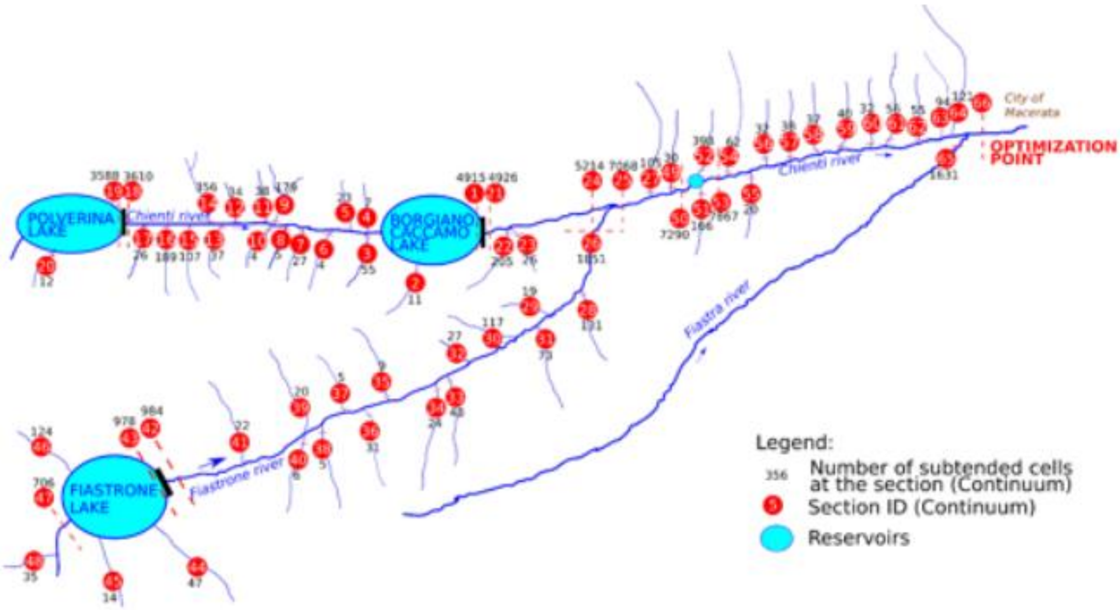

Figure 13. schematic illustration of the selected sections for the hydrological modelling of Chienti multi-reservoir system.The scheme reports the sections ID (circles) and the number of cells (with a size of around 245x245 m) hydrographically subtending the sections.

5. Customization of the national MyDewetra platform with new products: operative chain set up

National Platform Dewetra (www.mydewetra.org), a based GIS application dedicated to support civil protection forecasters (available by user name and password), was updated with the new forecast and monitoring products produced by STREAM and its operative set up was finalized. Models run on a regional server and outputs are published on Dewetra throught a WebServer.

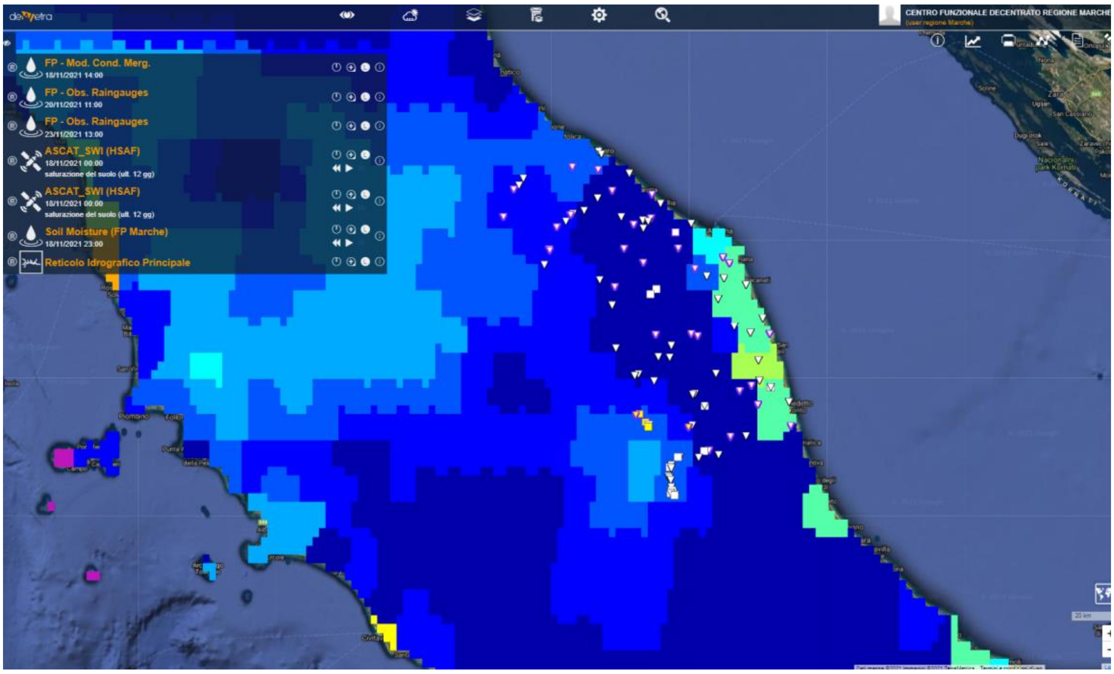

Figure 14. Flood Proofs regional sections – hydrological model on MyDewetra platform

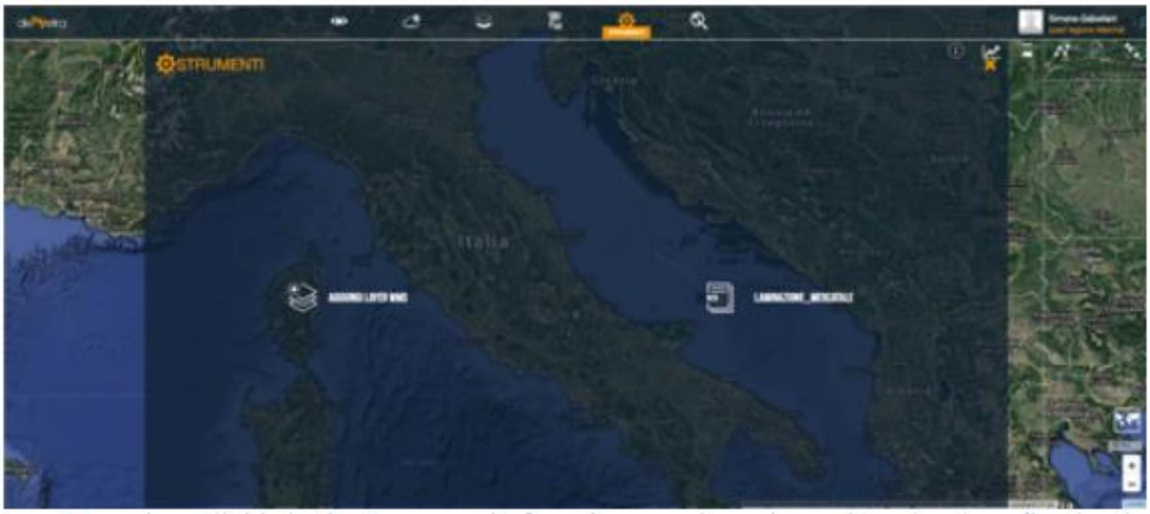

Figure 15. tool for Mercatale reservoir available in the Dewetra platform (among them the tool Laminazione (lamination)

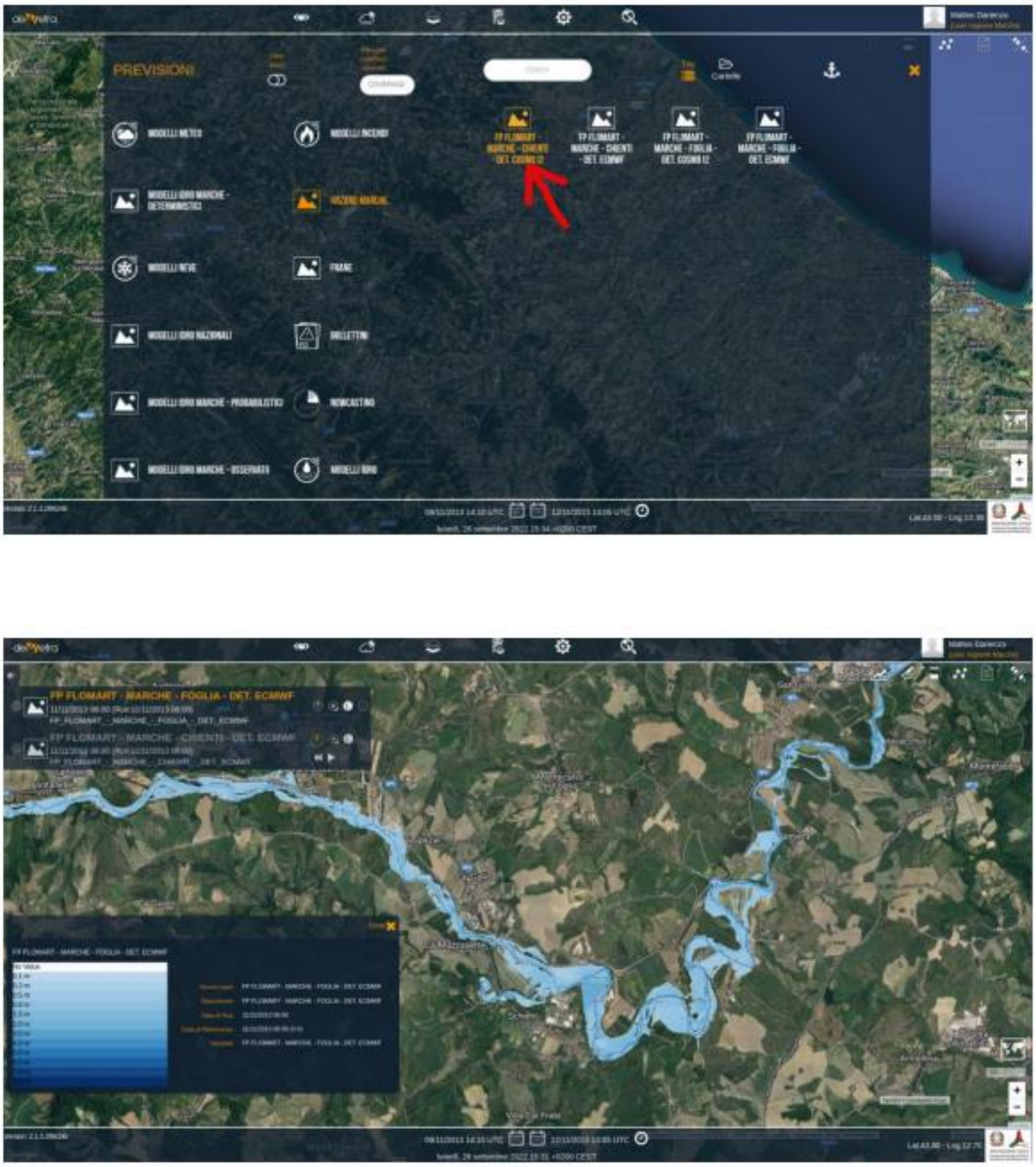

Figure 16. Implementation of FLOMART to MyDewetra online platform: example of the application to the Foglia river (Marche Region) for the event of November 2013 (maximum discharge input from FloodPROOFS, deterministic run ECMWF).

6. Conclusion

Hydrological model chain over the entire region was re-calibrated with longer flow data series and the code upgraded.
On Chienti and Foglia watershed a new tool for analyzing dam's manoeuvres was set up. Moreover fluvial flood hazard maps were created and hydraulic forecast scenarios in real time set up over these two watersheds. Modelling is daily runnning on regional server and output available to support forecasters and decision makers. Outputs are visualized through MyDewetra national platform.
Ownership of the implemented modelling over regional basins is by Marche Region (PP9).
Regional forecasters daily analyse Stream products in order to better evaluate soil effects in case of a precipitation severe event and broadcast hydrogeological and hydraulic bullettin.

Detailed technical reports produced by CIMA Foundation are available as annexes.

A dedicated training tools on new products and updating of the forecasting and visualization system, on the interpretation of results and management of the hydro-meteorological chain took place for the civil protection officers the 21th and 22nd of November 2022.

The results obtained in the Marche pilot project have been presented at the International Conference European Geosciences Union (EGU) – General Assembly in Vienna in April 2022.

7. Bibliography

Silvestro, F., Gabellani, S., Delogu, F., Rudari, R., & Boni, G. (2013). Exploiting remote sensing land surface temperature in distributed hydrological modelling: The example of the Continuum model. Hydrology and Earth System Sciences, 17(1), 39–62. https://doi.org/10.5194/hess-17- 39-2013

8. Annexes

Technical reports:

- D.5.1.1_Annex1.pdf
- D.5.1.1_Annex2_D.5.1.2_Annex3.pdf
- D.5.1.1_Annex3.pdf