OPERATİONAL FORECASTING SYSTEM FOR FLOOD EARLY WARNİNG İN EVROS/MARİTSA TRANSBOUNDARY BASİN (GREECE)

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ABSTRACT

We develop an operational, flood early warning system for the Evros River. The system comprises a web-based platform that generates short-term forecasts by combining meteorological, hydrological and hydraulic models, to support proactive decision making in the wider Evors area. The meteorological and hydrological models spatially cover and provide forecasts for the whole Evros/Maritsa basin. The hydraulic model simulates fluvial flooding for the downstream part of the Evros River, covering the area from the Greek-Bulgarian borders, downstream to the rivers outlet to the Aegean see. The web-based interactive platform, deployed using cloud computing services, allows user to visualize the forecasted information from the three coupled models in a user-friendly environment. Warning thresholds have been set based on information from local authorities and Civil Protection, experienced in the study area. The early warning system is based on a modular architecture, easily extendable and updatable to incorporate future needs and corrective actions. The developed system supports, and is part of, a modular platform that sets the standards for a National Flood Early Warning hub.

Keywords: *flood, early warning, operational, modeling, forecasting*

1. INTRODUCTION

Floods are identified globally as a major climatic threat, augmented by climate change. Flood Early Warning Systems (FEWS), as a risk management tool, are recognized as of significant importance with the UN Office for Disaster Risk Reduction advocating for an increase in their use, in accordance with the targets of the Sendai Framework for Disaster Risk Reduction and Sustainable Development Goals (SDGs) [1] while recent discussions focus also on the social aspects of such systems [2, 3], indicating their widespread application. Addressing challenges of flood risk management was taken under an institutional framework on a pan-European level more than fifteen years ago, when Directive 2007/60/EC on the assessment and management of flood risks was issued [4]. Under this frame, the Flood Risk Management Plans (FRMP) of Greece [5] were undertaken and foresee the development of FEWS for all the Water Districts in Greece. A FEWS for the Evros River, in the 12th Water District of Greece, has been developed by EMVIS Consultants SA on behalf of General Secretariat for Natural Environment and Water, Directorate General for Water, under the frame of the EU Cooperation

Programme INTERREG V-A GREECE – BULGARIA 2014-2020, Project "Integrated actions for joint coordination and responsiveness to flood risks in the Cross Border area – FLOODGUARD", which focuses on the challenges of flood risk management via integrated actions for joint coordination and responsiveness to flood risks in the Cross-Border (CB) area of Greece and Bulgaria.

2. SYSTEM DEVELOPMENT

The FEWS comprise three numerical models and four sub-systems, seamlessly connected on a data exchange chain, as shown graphically below (Figure 1). The meteorological model produces forecasts of meteorological parameters which are then used as input data for the hydrologic model. The latter then produces outflow forecasts on specific points of the Evros/Maritsa hydrologic system which are fed into the hydraulic model, to produce forecasts of river flows (speed, depth) and flood inundation. All the data which are produced and used by the models are stored on a sub-system for data management and model coupling and are finally transferred to the front-end system of the FEWS, coupled with warning and alarm thresholds, to be communicated to the end-users.

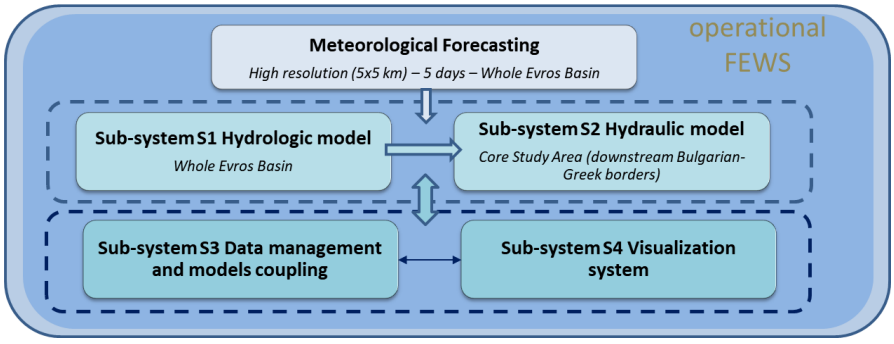

Figure 1. Flood Early Warning System (FEWS) in the river basin of Evros /Maritsa: sub-systems and data flow.

The Weather Research and Forecasting (WRF) Model is used in this project, a state-of-the-art mesoscale numerical weather prediction system designed for both atmospheric research and operational forecasting applications. The model serves a wide range of meteorological applications and is currently in operational use at U.S. NCEP and other national meteorological centers. The Advanced Research WRF (ARW) version of the model is used (Version 4). It produces 5days forecasts, on a horizontal resolution of two downscaling domains, a 1st with a horizontal resolution of 15km and a second, which operates as a nested domain within the first one, with a resolution of 5km. The initial conditions received from GFS have a resolution of 25km. Deterministic forecasting is used as input further down the modeling chain. The meteorological model features also ensemble forecasting, from NCEP Global Ensemble Forecast System (GEFS), that generates 21 separate forecasts (ensemble members) to address underlying uncertainties in the input data and the limitations of the model itself.

The semi-distributed hydrological model HYPE (Hydrological Predictions for the Environment) [6] is used, a conceptual rainfall-runoff model designed specifically for hydrological model applications from river catchments up to continental scales. The model is developed and maintained by the Swedish Meteorological and Hydrological Institute (SMHI) under an open – source license. The model has been set-up and calibrated using discharge data from Bulgaria, Greece and Turkey for the period 2020–2022 at a total of 31 gauging locations (Figure 2a). Explicit representation of reservoir regulation has been included. The model shows good performance across the model domain with best performance in the lower reaches, downstream of Harmanli (Bulgaria). Best performance is obtained at Kipoi – Ipsala area

(Greek-Turkish borders, KGE = 0.89). Peak timing and magnitude are generally captured well. The model has been operationalized using SMHI's SMHF system. It is run twice daily, using the 00:00 and 12:00 WRFM forecasts, and produces forecast discharge for the full WRFM forecast horizon (5 days). Real-time updating of discharge stations is currently implemented at 3 locations, and can be expanded to include additional real-time stations in the future.

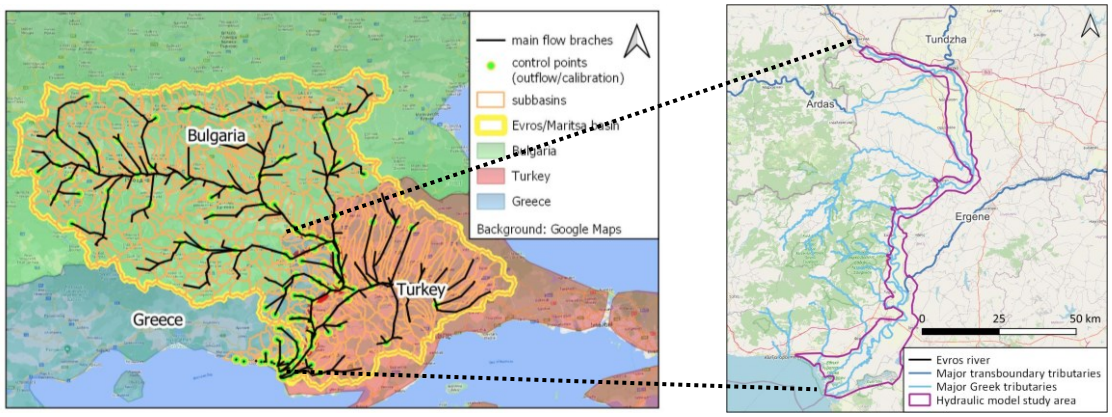

Figure 2. (a) Hydrologic model implementation area, **(b)** Hydraulic model study area.

The flood dynamics and the flow in the main river bed as well as the overtopping of the riverbanks and flow in the floodplains is simulated with the use of the HEC – RAS software, a model designed to perform one and two-dimensional hydraulic calculations for a full network of natural and constructed channels (https://www.hec.usace.army.mil/software/hec-ras/features.aspx, accessed: 01/07/2023). The model extent covers the area that is affected from flood events directly caused or amplified by the flow of Evros River (Figure 2b), using a full 2D approach. The model was calibrated against the flood events of 2010, 2018 and 2021 and is under a validation period.

The services of the FEWS are provided through an operational web-based, interactive platform, deployed using cloud computing services. The overall architecture of the system is based on various, open-source systems and technologies, carefully selected to ensure the robustness, flexibility, and expandability (e.g. DJANGO web framework, PostgreSQL database with PostGIS extension, GeoServer, React JavaScript e.tc). The platform facilitates data exchange and communication of the different technological components and workflows that need to be coupled for operationalizing the complete service line of FEWS. A rich set of API services have been created to allow the individual workflows to communicate with each other as well as to push the generated data into the Graphical User Interface.

3. THE FLOOD EARLY WARNING SYSTEM

The FEWS for Evros/Maritsa basin provides 5days forecast, updated twice per day, for three different sets of parameters, i.e. meteorological, hydrological and hydraulic, organized under three distinct modules of the front-end graphical user interface of the system (Figure 3). It provides a series of customization options for map layouts and variable graphical representations of the results. Warning thresholds are integrated in the system and have been set based on data and experience in the study area provided by the local authorities and Civil Protection. FEWS is currently under a pilot application period during which the performance of the models and the overall system is evaluated and refined.

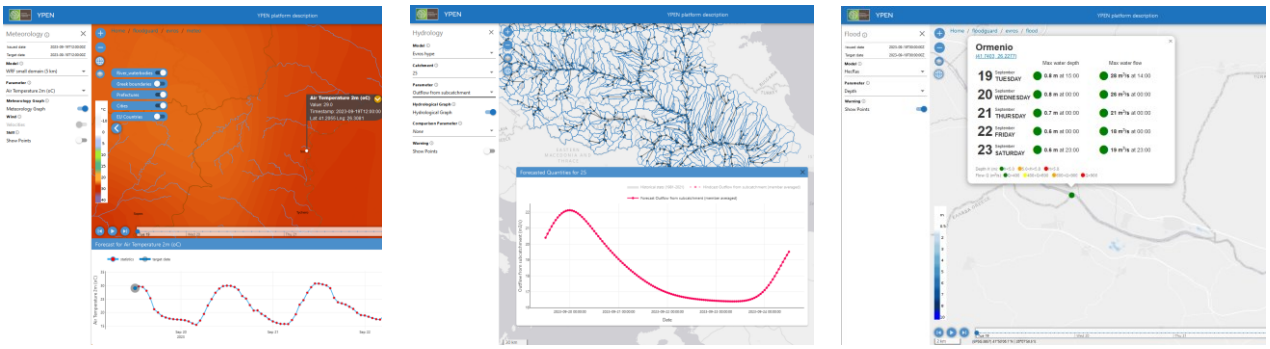

Figure 3. Flood Early Warning System (FEWS) in the river basin of Evros /Maritsa: **(a)** Meteorologic module, **(b)** Hydrologic module and **(c)** Hydraulic module.

4. DISCUSSION

The development of the FEWS for the Evros River corresponds to the needs and program of measures defined in the relevant Greek FRMP of WD 12, as well as to the recognized need for operational and flexible measures for the support of flood management in the transboundary area of Evros/Maritsa River. Given the constraints of the models, the complexity of the natural system, the limitations of the available data and flood mechanisms which are not considered (e.g., non – fluvial surface water or groundwater flooding contributions), the system provides a state-of-the-art, flexible tool which may support flood management decisions, locally or transboundary. Future modifications based on the planed validation period are expected to further improve the overall system performance. Based on a modular and expandable architecture, the system is easy to maintain, update and transfer to other river basins, setting the standards and the basis for a National Flood Early Warning hub.

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