Review of flood and ice forecasting systems and methodologies in the Danube River countries

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INTRODUCTION

The Danube River basin is the most international river basin in the world including the territories of 19 countries. Since frequency of floods in the Danube River basin increased in the last decades, the need for a more effective and harmonized regional and cross-border cooperation in the field of flood and ice forecasting arises. The need for enhanced cooperation in flood protection was officially recognized in various international and interregional policy documents, therefore DAREFFORT project was initiated under the Interreg Danube Transnational Programme to identify the state of the art of flood and ice forecasting techniques and raise awareness among the countries about the basic problems of flood and ice forecasting (e.g. the lack of a unified data exchange at the catchment level) and to help implement the Danube Flood Risk Management Plan in line with the Flood Risk Directive.

Figure 1. The Danubian countries participating in the DAREFFORT project.

MAIN AIMS

The main aim of the DAREFFORT project is to give a comprehensive overview about the complex national flood and ice forecasting systems and to eliminate the shortcomings of the existing forecasting practices as well as to improve the exchange and availability of hydrological and meteorological data between the participating countries with establishment of the Danube Hydrological Information System (Danube HIS). In order to achieve this goal, national reports on the status quo of the Danube regional flood and ice forecasting system and methodologies as well as a detailed questionnaire were prepared by all project partner countries. Information about the countries' hydrological and meteorological data availability, recording methods and coverage with the monitoring networks, codings and national database system, data flow, forecasting time intervals and accuracy, response times, cross-border issues and data dissemination etc. was covered in the questionnaire. The evaluation of 12 national reports and results of questionnaires showed a comprehensive overview of flood and ice forecasting systems and methodologies in the Danube River basin.

The gathered information about national flood and ice forecasting practices and the acquired knowledge through the project implementation process will result into an international policy proposal for a harmonized data exchange protocol, including the sufficient quantity, quality, and format of the data exchange.

MONITORING AND DATA INVENTORY

Meteorological and hydrological measurements and data collection have a long history in all countries (more than hundred years). Generally, regular network of meteorological and hydrological gauging stations started to develop in the 19th century. Nowadays almost all countries provide a modern network of hydrological and meteorological stations to ensure real-time data used in forecasting and warning procedures and flood forecasting models.

All countries have extensive exchange of meteorological and hydrological data and information with domestic and foreign institutions. Hydrological services exchange data and information with neighbouring countries for border and cross-border watercourses (Table 1). The harmonization of flows for border profiles is performed in accordance with pre-defined hydrological criteria and agreements.

Table 1. Data exchange and harmonization with neighbouring countries.

	Data exchange and harmonization mainly based on bilateral agreements
Austria	Data harmonization is done for the Mura River with the Slovenian hydrological service, with Hungarian service for the cross-border streams between Austria and Hungary, and with the Hydrometerological Institut of the Czech Republic.
Bulgaria	Exist various international agreements regarding hydrological and meteorological data exchange. Data on water levels and discharges at the outlet stations of the six main Danube tributaries is sent daily to the telecommunication hubs in Bucharest, Romania, Belgrade, Serbia and Bratislava, Slovakia.
Croatia	Strong cooperation on transboundary data harmonization with the Slovenian hydrological service, strong cooperation and data harmonization with Hungary, cooperation and data exchange with relevant hydrometeorological and water management institutions from Bosnia and Hercegovina.
The Czech Republic	Within the Morava river basin, the Brno regional branch of CHMI cooperates with Austrian hydrological service (Dyje river) and Slovak Hydrometeorological Institute (Morava river).
Germany	Data is exchanged with the Austrian federal states Tyrol, Salzburg, Upper Austria and Lower Austria.
Hungary	The data harmonization is done for border and cross-border rivers with all neighbouring countries (Austria, Slovakia, Ukraine, Romania, Serbia, Croatia and Slovenia). Joint measurements of discharge on border sections are carried out with neighbouring countries, regularly or if necessary.
Moldova	The hydrological data exchange with the neighbouring countries for hydrological forecasting and in general for water management activity, in the transboundary River Basins, is done according to bilateral agreements.
Romania	The hydrological data exchange with the neighbouring countries for hydrological forecasting and in general for water management activity, in the transboundary River Basins, is done according to bilateral agreements.
Serbia	Exchange of data and information with neighbouring countries for border and cross-border watercourses and harmonization of flows for border profiles according to predefined hydrological criteria. Joint measurements of discharge are carried out on the border sections with neighbouring countries – Croatia, Montenegro and Bosnia and Hercegovina, regularly or if necessary.
Slovakia	The cooperation on bordering surface streams is regulated by intergovernmental contracts and agreements with neighbouring countries.
Slovenia	Exchange of data and information with neighbouring countries for border and cross-border watercourses and harmonization of flows for border profiles according to predefined hydrological criteria.
Ukraine	Data harmonization and data transfer are carried out with Hungary, Slovakia, Romania, Moldova according to previously agreed and defined hydrological criteria. Joint measurements of water discharge with neighbouring countries are carried out, regularly or as necessary.

REVIEW OF FLOOD AND ICE FORECASTING SYSTEMS

There is a large diversity among Danube River countries in terms of hydrological and hydraulic models used, the number of models applied, the complexity of these models, etc. Some countries such as Slovenia or Croatia use the same hydrological model type for the entire country, while the others such as Austria use different models in different parts of the country (i.e. regional-province based approach). Moreover, some countries such as Bulgaria or Serbia also use catchment-based approach, where they use different models for different rivers. In terms of model types one can notice large diversity, which means that conceptual (e.g., DHI NAM, HBV), physically based (e.g., TOPMODEL), empirical models are used for forecasting process.

Table 2. An overview of hydrological models used in different Danube River countries and organizations.

Hydrological model	**Country / Organization**	**Model Type**
DHI NAM	Austria, Bulgaria, Croatia, Slovenia, ISRBC	Lumped/semi-distributed (deterministic, conceptual)
HBV/HBV-light	Austria, Serbia, Slovakia, ISRBC	Lumped/semi-distributed (deterministic, conceptual)
HEC-HMS	Bulgaria, Czech, Slovakia, ISRBC	Lumped/semi-distributed or distributed (deterministic, conceptual)
LISFLOOD	EFAS	Distributed (deterministic, semi-physical, semi-conceptual)
WFLOW	ISRBC	Distributed (deterministic, conceptual)
TOPKAPI	Bulgaria	Distributed (deterministic, physically based)
ANN	Bulgaria	Lumped (deterministic, empirical)
SWAT	Bulgaria	Semi-distributed (deterministic, physically based)
ISBA-TOPMODEL	Bulgaria	Distributed (deterministic, physically based)
HYDROG	Czech Republic	Lumped/semi-distributed (deterministic, conceptual)
LARSIM	Germany	Lumped/semi-distributed or distributed (deterministic, conceptual)
TAPI	Hungary	Lumped/semi-distributed (deterministic, conceptual)
SAC-SMA	Romania	Lumped/semi-distributed (deterministic, conceptual)
NOAH-R	Romania	Distributed (deterministic, physically based)
MANS	Serbia	Lumped (deterministic, conceptual)
Regression models	Serbia	Lumped (deterministic, empirical)

CONCLUSIONS

In-situ monitoring of meteorological and hydrological variables is crucial for reliable hydrological forecast. Based on the evaluation of the national reports and the completed questionnaires, policy proposal for a harmonized data exchange as well as the recommendations for development of hydrological forecasting methods will be prepared in the frame of the Dareffort project. The improvement of forecasting capabilities on basin-wide scale is the most cost-effective non-structural tangible solution.