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Recommendations for improvement of the flood and ice forecasting systems

WP3 Deliverable 3.2.3

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1 Introduction

Frequency of floods in the Danube River Basin increased in the last decades (e.g. major floods in 2002, 2005, 2006, 2009, 2010, 2013, and 2014), urging the need for a more effective and harmonized regional and cross-border cooperation in the field of flood and ice forecasting. Flood forecasting is one of the most effective flood risk mitigation measures serving to protect human lives and social estate, however, the quality of hydrological forecast depends on several factors like the accuracy of meteorological forecast, the quantity and quality of meteorological and hydrological data, data exchange, organizational structure of national hydrological and meteorological services, etc. The world is rapidly changing and the meteorological and hydrological services need to follow the developments in science and technology, in particular regarding digitalization and IT-infrastructure, and to response to new challenges. Of course, an optimal solution should be find considering limited sources of meteorological and hydrological services, especially in some countries.

In order to eliminate the shortcomings of the existing forecasting practices as well as to improve the exchange and availability of hydrological and meteorological data among the countries in the Danube River Basin recommendations for improvement of the flood and ice forecasting systems based on Activity 3.1 (Output 3.1 and corresponding Deliverables), identified gaps and bottlenecks (Deliverable 3.2.4) as well as the Report on elaboration of the forecasting conditions (Deliverable 3.2.1) were prepared.

2 Recommendations related to meteorological and hydrological monitoring and data

Reliable hydrological forecast depends in a great extent on the quantity and quality of the measured meteorological and hydrological variables, which are part of the national monitoring systems of individual countries. It should be mentioned that DAREFFORT project partners are from 12 out of 19 countries covering almost the whole Danube region. However, also data from non-participating countries are needed (e.g. data from Bosnia and Herzegovina are very important for the Sava River Basin). Therefore, we also try to include non-participating countries in some of the DAREFFORT project activities, e.g. Bosnia and Herzegovina supported the project by completing the questionnaire, which was part of the Output 3.1.

Furthermore, reliable data control and data processing as well as an effective data flow are extremely important for efficient data management and therewith also for hydrological forecast.

Despite the fact that most countries in the Danube River Basin have made a significant progress in the modernization of the meteorological and hydrological measuring networks and that the modernized networks provide high quality data for forecasting models and warning procedures, there is still room for improvements.

2.1 Meteorological data

Meteorological observations are an essential part of flood and ice warnings and forecasting systems. The most important variables are precipitation, air temperature, air humidity, wind speed, air pressure, solar radiation, sunshine duration, evaporation, soil moisture, snow depth and snow water equivalent. Based on the results of the Activity 3.1 (Output 3.1 and all corresponding deliverables) as well as the Report on elaboration of the forecasting conditions (Deliverable 3.2.1) prepared in the frame of DAREFFORT project, the recommendations to meteorological services are as follows:

- The Danube River Basin countries should consider the need to improve the measuring network in terms of the stations density and the inclusion of measurements of additional variables such as evapotranspiration, soil moisture, snow water equivalent, etc. At the moment measurements of actual evaporation and transpiration are performed only in some countries at few meteorological stations. Furthermore, potential evaporation is measured only at some locations (see Output 3.1). In addition, soil moisture measurements are hardly taken. In most countries, there are no systematic measurements of snow water equivalent or its spatial distribution, despite the fact that floods in the Danube River Basin are mainly generated in mountainous areas as a combination of rainfall and snowmelt.
- The Danube River Basin countries should consider the need for development of meteorological products also at regional level, e.g. development of composite weather radar outputs at regional level.
- Countries should consider providing free access to some of the meteorological data related to the national hydrological forecasting services in the Danube River Basin for their official needs.
- Collection of historical data records, digitization and storage in a database would also be beneficial, since this data is very important for water resources management and modelling, climate change assessment, flood modelling and other meteorological and hydrological analyses.
- In relation to all above recommendations, the meteorological services should consider providing strong arguments for obtaining sufficient financial, technical and human resources to operate the services.

2.2 Hydrological and ice data

In the frame of hydrological monitoring all countries collect data on hydrological parameters, i.e. water level, discharge and water temperature. Some of them collect also information about sediments and ice and there are practically no systematic measurements of water flow velocity. Bed load transport is hardly ever measured. There are also no systematic measurements of channel morphology, with the exception of navigable waterways along the Danube and its tributaries (see Output 3.1).

Moreover, ice measurements are conducted only along the Danube River’s main flow and its navigable tributaries, based on the recommendation adopted by the Danube Commission. In the other rivers there are only some ice measurements or observations (see Output 3.1), despite the fact that ice events are dangerous because in combination with increase of river flow due snowmelt or rainfall can cause catastrophic floods.

Based on the results of the Activity 3.1 (Output 3.1 and all corresponding deliverables) as well as the Report on elaboration of the forecasting conditions (Deliverable 3.2.1) prepared in the frame of DAREFFORT project, the recommendations to hydrological services are as follows:

- The Danube River Basin countries should consider the need to improve the measuring network in terms of the stations density and the inclusion of measurements of additional variables such as bed load, periodical cross-section morphology, water velocity measurements, etc. In the last decades, the number of observation stations has unfortunately decreased and therewith the valuable information regarding the heterogeneity and dynamics of the phenomena measured is lost.
- The Danube River Basin countries should consider the need to improve the measuring network in terms of the inclusion of ice and snow measurements, since the combinations of extremely rare events the so-called compound events, such as ice and rainfall, snow cover and rainfall, are not covered adequately enough by hydrological models or forecasting protocols.
- Countries should consider providing free access to some of the hydrological data related to the national hydrological forecasting services in the Danube River Basin for their official needs.
- Development of hydrological products at regional level, e.g. hydrological bulletins of transboundary rivers, etc. Such efforts could be also supported by making use of the Danube River Basin wide outputs from EFAS.
- Collection of historical data records, digitization and storage in a database would also be beneficial, since this data is very important for water resources management and modelling, climate change assessment, flood modelling and other meteorological and hydrological analyses.
- In relation to the project scope, countries should consider standardized data exchange for sharing hydrological data. The Environet Data Exchange Platform developed in DAREFFORT project supports this standardized data exchange. It is highly recommended to use this platform and to establish it as a standard for hydrological data exchange within the Danube basin, e.g. in future Danube HIS.
- In relation to all above recommendations, the hydrological services should consider providing strong arguments for obtaining sufficient financial, technical and human resources to operate the services.

3 Recommendations related to hydrological forecasting methods and models

Since frequency of floods in 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 forecasting is needed. The overview of the national hydrological forecasting services organizational structure prepared in the frame of DAREFFORT project (Output 3.1) demonstrates that most of the services operate in several regional offices accompanied by a central office. They are usually organized within the national hydrometeorological or water management organization as bodies of ministries from various fields (environment, agriculture, defence, inner affairs).

Based on the results of the Activity 3.1 (Output 3.1 and all corresponding deliverables) as well as the Report on elaboration of the forecasting conditions (Deliverable 3.2.1) prepared in the frame of DAREFFORT project, the recommendations for development of hydrological forecasting methods and models are as follows:

- Hydrological forecasting systems for various catchments within the Danube River Basin (micro, meso and macro scale) should be developed taking into account already existing systems at the different scales particularly the only Danube wide forecasting system EFAS and the Sava forecasting system from the ISRBC. Early establishment and capacity development of appropriate teams for development and management of the future forecasting system is strongly recommended.
- The catchment characteristics (size, topography, land cover, river network, slope, etc.), the river flow characteristics (floodplains, reservoirs, diversions, backwater effects, etc.), the hydro-climatic conditions, the forecasting purpose and the administrative conditions and constraints (organisational capability, computational resources, data and weather forecast availability) should be taken into account while making the choice on the appropriate hydrological/hydraulic model to be used. It is strongly suggested to follow the WMO Manual on flood forecasting and warning (WMO, 2011), the guidelines of the WMO Flood forecasting initiative (Decision-Support for the Selection of Flood Forecasting Models, 2013) as well as the latest literature on flood forecasting techniques and their applications (examples: Jain et al., 2018; Kauffeldt et al., 2016; Adams and Pagano, 2016).
- Enhancement of the hydrological service relationship with the responsible meteorological service related to data exchange, consultations, joint warnings etc. It is true that the national hydrological and the meteorological forecasting services of the Danube River countries mostly operate within the same institution, on a door-to-door principle (see Output 3.1), which enables the hydrological services access to the meteorological data and predictions free of charge, daily consultations with meteorologists and preparation of joint warning product as well. However, there are some countries, where the hydrological services operate separately from the meteorological services and have fee-based access to the meteorological data and predictions, limited consultation options and independent warning products.

- Limited resources and lack of data reduce the development of hydrological models. Furthermore, it is questionable using complex models if there is no sufficient data available for their use. Additionally, individual modelling methods were developed in different climates and some processes are treated in the model in more detail than the others are. Therefore, it is recommended to further develop the existing modelling methods and to use various models in the development of hydrological forecasts (multi-model approach) as well as ensemble forecasting. Where possible, open-source models should be used and fostered to ensure transparency to the users and to make optimum use of the limited resources.
- Systematic forecasting accuracy assessment and critical evaluation of the forecast for the entire Danube River Basin should be developed. At the moment forecasting accuracy assessment is systematically undertaken only by some individual services, mostly on an occasional basis only. The Danube River Basin wide forecast accuracy assessment available in EFAS may serve as best-practice examples that can be transferred to national or regional systems.
- Continuous capacity building of the hydrological forecasting services is strongly recommended, since experienced hydrological forecasters hold a key role in the critical evaluation of the modelling system results as well as within the decision making processes of the hydrological forecasting service.
- Strengthening the IT support (skilled staff) and the IT capabilities (resources, tools, services) dedicated for flood forecasting in the individual forecasting services should be considered.
- Hydrological forecasting systems primarily use data from the observation network, which is maintained by the hydrological service. Data measured and collected by individual water users like hydroelectric power plants, water supply and irrigation systems and other users are not included in the forecast system. Therefore, it is recommended to collect all the water regime data in a single database, including data from private companies.
- Improvement of cooperation among the hydrological services within the Danube River Basin by organising regular expert meetings on flood forecasting.
- Establishment of regional or bilateral agreements is also strongly recommended. Platforms such as EFAS, where hydrological services from all Europe regularly exchange information and latest developments in flood forecasting represent already existing networks that can further foster the cooperation.

4 Recommendations related to data exchange and IT-infrastructures

The recommendations for hydrological and meteorological monitoring, and also the recommendations for improvements of hydrological forecasting described above imply that data and information exchange between countries a very important aspect to achieve the addressed improvements in flood and ice forecasting. With the HyMeDES Environet Platform a comprehensive software for exchanging measured data in a common format has been developed in the frame of DAREFFORT project, which will serve as basis for future Danube HIS. Based on the experiences in implementing the HyMeDES

Environet Platform common data exchange platform and the related flood forecasting and IT expert recommendations (Deliverable D4.1.1) following recommendations for further improvements of data exchange can be derived:

- Essential for data exchange between a multitude of different institutions is to agree on a standardized way of providing the data to the users (e.g. forecasting centres, ministries, civil protection, s, etc.). It is highly recommended to use well established standards for data provision. For HyMeDES Environet Platform the OGC standard WaterML 2.0 format has been chosen to provide the common data bases for the users.
- Today national data providers of measured data, but also national forecasting centres are using very different formats for providing their data / forecasting results. Whereas those formats have been developed and improved over time in established co-operations between data providers, forecasting centres, and stakeholders mainly on a national level, it would be helpful for further data exchange purposes, e.g. for developing a common forecasting result exchange platform to harmonize also the data formats in which data providers and or forecasting centres (which would serve as data providers for forecasted data) deliver data to the data exchange platform. This would shorten the development and implementation time for such platforms. Important topics which should be standardized are:

    - Regarding international data exchange naming of variables used in the data files should be defined in English language. Also a standardizes way for naming abbreviation of variables should be used (e.g. "h" for water level, "tw" for water temperature, "Q" for discharge, "ta" for air temperatue, "P_total_daily" for 24h amount of precipitation).
    - It is highly recommended to state the time zone of the data delivered in the data format using the UTC-standard (e.-g. UTC+1)

Regarding IT-standards following recommendations can be derived from the results of deliverable 4.1.1 (flood forecasting and IT expert recommendations) and the DAREFFORT project implementation:

- IT-standards in data delivery are mainly used by national data providers today:
    - **Data delivery:** FTP of Web-API are commonly used by data providers. Providing data on FTP servers is still the most common way used by national data providers to provide measured data. Nevertheless, from the perspective of modern IT-infrastructures it is recommended to use a Web-API for data provision in future implementations, because the access is more flexible, and the data itself can be served directly out of the data base using the Web-API, or even be stored in a state-of-the-art distributed storage infrastructure.
    - **File-Formats:** Most commonly used file formats today are CSV and XML (WaterML 2.0 is also based on XML). Whereas CSV-files are just tables which are easy to read by humans, XML format is more flexible for storing and particularly for describing the content of the file. Some countries which already implemented a Web-API like

Germany serve both formats according to parameters set when calling the API. This is a solution which can be recommended for other countries planning to move towards a Web-API.

- For measured data minimum common update interval for the parameters is daily. Hydrological parameters recommended to be exchanged by all countries are water level, discharge and water temperature. Meteorological parameters recommended to be exchanged by all countries are precipitation and air temperature, the latter one is not provided by all countries today.
- An alternative way to provide meteorological real time data could be to use the GTS network (Global Telecommunication System) of WMO. WMO collects meteorological real time data within the framework of its GTS network (Global Telecommunication System). The national weather service of each country which is member of WMO sends data to WMO in the complex binary format BUFR ("Binary Universal Form for the Representation of meteorological data").
- Currently regular practice is to publish processed data (historical) once a year. Therefore, the duration of storage of the real time data should be at least one year to avoid temporary data gaps in the database as far as possible. On the other hand, real time / unprocessed data should not be available indefinitely, because of possible data incorrectness.
- Rather general recommendations for IT-data exchange platforms are the same as derived for the HyMeDES Environet Platform:
    - development of software should to be based on established coding standards and to be well commented to be easy maintainable
    - modern data exchange software should be web driven applications, light-weight, and easy to implement and to maintain,
    - to make the system as open and platform independent as possible the core structure it is recommended to use simple and proven web technology (server side: HTTPS, PHP or node.js, Apache web server, Cron/Task scheduler, PostgreSQL with PostGIS extension client side: Html5, JavaScript),
    - data security: authentication should be verified using appropriate encryption methods,
    - the interaction with such platforms should be managed by Web APIs,
    - it is recommended to use a plug-in-based architecture (plug-in libraries) to be able to easily add additional features
    - no direct writing interaction with the underlying databases should be allowed (only access via API)

The ongoing demand for digitalization in all fields of society put an additional pressure on the development of smart information systems for citizens living or working close to rivers but also for professional stakeholders involved in flood management.

From the Evaluation of the possibilities of establishment of the international forecasting system's result exchange elaborated in the DAREFFORT project (deliverable D 3.2.2) platform it can be derived that bilateral exchange of forecasting results is already common practice in the Danube catchment and that there could be additional benefits of a Danube wide exchange platform for forecasting results. There is not a common view about the benefits of such a platform, mainly because all countries have different situations regarding their position as upstream- / downstream country and already established cross border co-operations. Nevertheless, it is recommended to work towards a Danube wide forecasting system's result exchange platform, because the harmonization of data exchange will be necessary with respect to the ongoing digitalization of society and of professional workflows in particular. Forecasted data of such a platform could also serve as a Danube wide flood forecasting information system. For such applications it is highly recommended to harmonize the flood warning systems between the countries in the Danube catchment.

With respect to smart information systems also warning apps for citizens about flood situations maybe integrated in other waring apps for catastrophes can be a helpful tool to reduce the harm of floods.

5 References

Adams, T.E., Pagano, T.C., 2016. Flood Forecasting: A Global Perspective, Flood Forecasting: A Global Perspective. https://doi.org/10.1016/C2014-0-01361-5

Jain, S.K., Mani, P., Jain, S.K., Prakash, P., Singh, V.P., Tullos, D., Kumar, S., Agarwal, S.P., Dimri, A.P., 2018. A Brief review of flood forecasting techniques and their applications. International Journal of River Basin Management 16, 329–344. https://doi.org/10.1080/15715124.2017.1411920

Kauffeldt, A., Wetterhall, F., Pappenberger, F., Salamon, P., Thielen, J., 2016. Technical review of large-scale hydrological models for implementation in operational flood forecasting schemes on continental level. Environ. Model. Softw. 75, 68–76. https://doi.org/10.1016/j.envsoft.2015.09.009

WMO, 2011. Manual of flood forecasting and warning. Geneva, Switzerland.

WMO, 2013. Intercomparison of flood forecasting models. Decision-Support for the Selection of Flood Forecasting Models.