Drin/Drim – Buna/Bojana Basin

Flow and Flood Forecasting System

1. Introduction

The Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH, on behalf of the German Federal Ministry for Economic Cooperation and Development (BMZ), has implemented the Drin–Bojana Basin Flow and Flood Forecasting System in two project phases since 2012, in the course of the project Climate Change Adaptation in Transboundary Flood Risk Management in the Western Balkans. The third project phase has just started.

The National Hydromet Services (NHMS) of Albania, Kosovo, Macedonia and Montenegro have been beneficiaries of the project from the very beginning. Based on a participatory approach, networks of hydrometeorological online measuring stations in the basin were agreed upon and set up, with financing from the project. The four NHMS actively provided historical hydrometeorological data to the modeling team of Leichtweiss Institute, at the Technical University of Braunschweig, Germany, for setting up and calibrating the hydrological model of the Drin-Bojana basin on the basis of PANTA RHEI.

In 2016 the NHMS of Albania, Kosovo, Macedonia and Montenegro, upon the initiative of GIZ, signed a Memorandum on the exchange of hydrometeorological data between them. This formal agreement, in particular with respect to online hydrometeorological data, forms the foundation for the basinwide operation of the Drin–Bojana Basin Flow and Flood Forecasting System.

The developed Drin–Bojana Basin Flow and Flood Forecasting System is based on an analysis of requirements of all four NHMS. The system is operated by all four NHMS for flow and flood forecasting. The staff of all four NHMS have been extensively trained in using the system. The trainings will be continued in the present third project phase, to assure reliable operation and flood forecasting.

Improvements are mostly needed on the data supply side: Density of the station network, quality and consistency of input data, and others (outlined below).

2. System Overview

Fig. 1 depicts the Drin-Bojana basin as well as main rivers, lakes and dam sites within the basin which are part of the Drin-Bojana Basin Flow and Flood Forecasting System. The figure also shows the selected discretization of the whole basin into subcatchments.

Fig. 2 depicts the general set-up of the Drin–Bojana Basin Flow and Flood Forecasting System as it is installed and operated at the NHMS in Albania, Kosovo, Macedonia and Montenegro. The system is comprised of three major components:

(i) Data Services

The left-hand side of Fig. 2 shows data services available online (e.g. downscaled meteorological forecasts to the Western Balkan region and online measurement time series from stations located in the region) accessible either via FTP or HTTP protocols by the Online Data Management Component.

(ii) Online Data Management Component

The online measurement data from hydrometeorological stations distributed in the Drin-Bojana basin are compiled into the MCH server (Meteorological, Climatological and Hydrological Data Base System, from the World Meteorological Organization WMO) which is located within the intranet of each NHMS. The MCH server functions as a data repository for MCH and simulation clients (PANTA RHEI, GECKO, HEC-RAS 2D). These clients feed on the data stored on this server for in-time flow and flood forecasts.

Meteorological forecasts for the Drin-Bojana basin e.g. from the Montenegro Institute of Hydrometeorology and Seismology (set up with support from GIZ in the previous phase of the project) are also referred to as data services and are assessed by means of FTP. These data are then stored within the Data Management Component.

A special software has been generated during the second phase of the project for automatically pulling these online data into the Data Management Component at user defined cycles in the background.

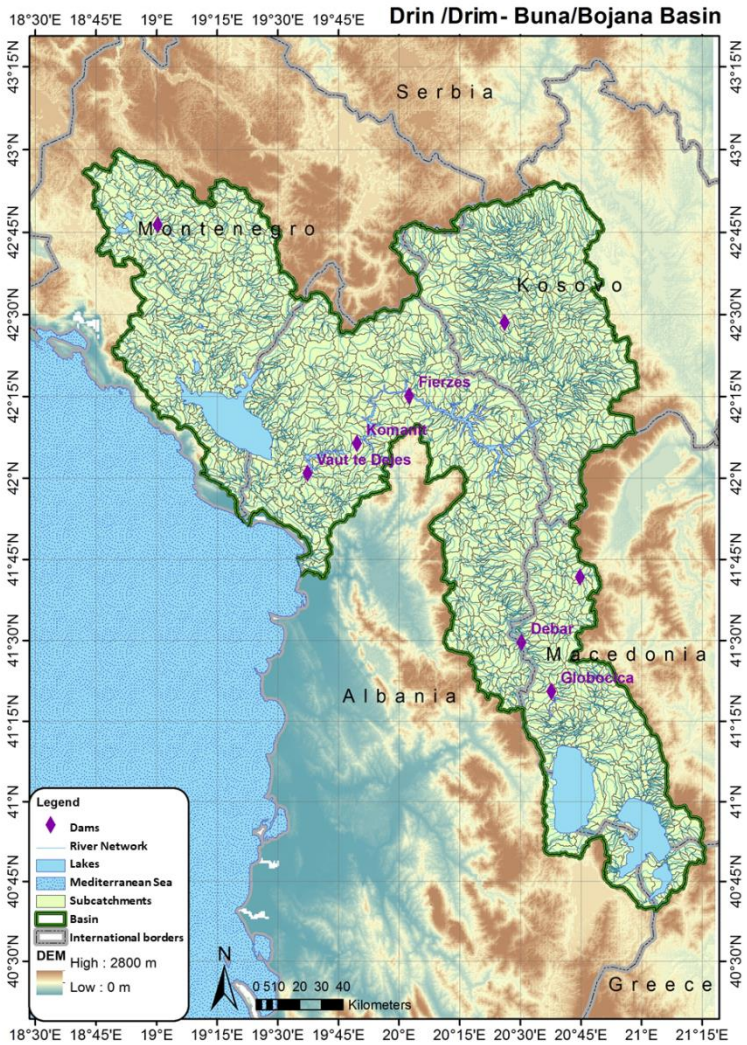

Fig. 1: Drin-Bojana basin overview.

(iii) Simulation and Analysis Component

The Simulation and Analysis Component consists of three interconnected components.

(a) A hydrologic catchment model which has been set up for the Drin-Bojana river basin on the basis of the distributed physically based hydrologic modeling system PANTA RHEI.

(b) The dam cascade in Albania is modeled with the GECKO system.

(c) In particular, the flood prone areas on the lower Drin-Bojana in Albania as well as Montenegro are modeled with HEC-RAS 2D in order to determine inundation areas, flow depths as well as flow velocities for flood events.

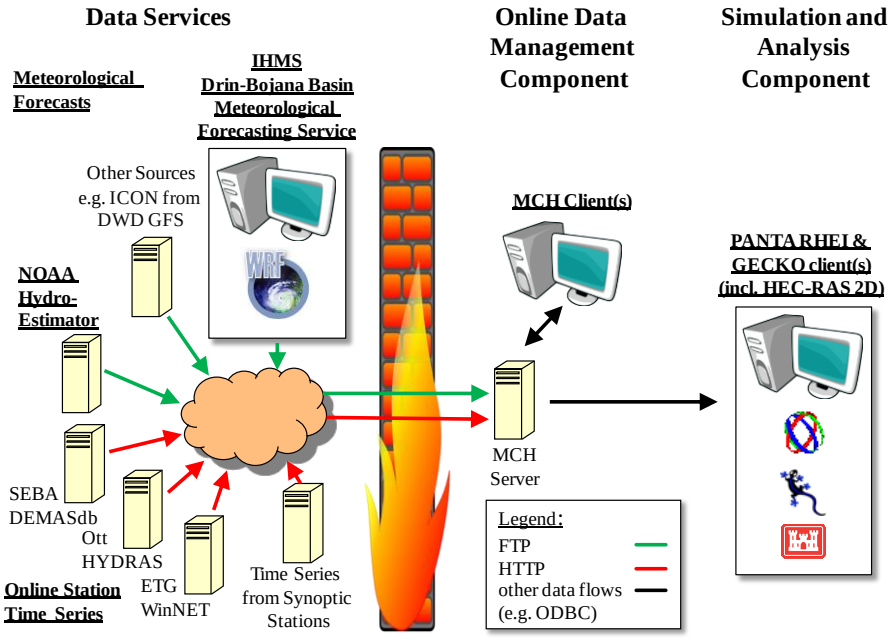

Fig. 2: System overview of the Drin-Bojana Flow and Flood Forecasting System.

A meteorological forecasting service has been specially set up for the Drin-Bojana basin by the Montenegro Institute of Hydrometeorology and Seismology (IHMS) with support from GIZ in the previous project phase. These forecasts play a key role in the forecasting process because the main hydrological driving variables such as precipitation, temperature and wind speed are imported into the hydrological model from them.

The meteorological forecasts provided by IHMS are based on the Weather Research and Forecasting (WRF) model which is jointly developed by the US National Oceanic and Atmospheric Administration (NOAA) and the US National Centers for Environmental Prediction (NCEP). The WRF model is a non-hydrostatic model for meso-scale meteorological modeling. The meteorological forecasting model built on this basis covers the entire region of the Drin-Buna river basin riparian countries and provides weather forecasts up to 120 hours ahead with a one hour temporal resolution at about 3x3 km and 9x9 km horizontal spatial grid resolutions. Boundary conditions are retrieved from the Global Forecast System (GFS) at NCEP in Washington, USA and the European Center for Medium-range Weather Forecasts (ECMWF) in Reading, United Kindom. The forecasts are available twice a day with boundary conditions retrieved for 00 and 12 hours UTC (Universal Time Coordinated) from these two centers.

3. Simulation and Analysis Component

Fig. 3 depicts how the different models within the Simulation and Analysis Component of the Drin-Bojana Flow and Flood Forecasting System interrelate. This component consists of three different modeling systems, namely PANTA RHEI, GECKO and HEC-RAS 2D.

(i) PANTA RHEI

The hydrological model PANTA RHEI is a distributed physically based meso-scale model which comprises all relevant hydrological processes on subcatchment scale. It was developed by the Leichtweiss Institute at Technical University of Braunschweig, Germany, and corresponds to the present international state-of-the-art in hydrological modeling. PANTA RHEI comprises submodules for modeling all relevant hydrological processes within the Drin-Bojana basin as there are e.g.: snow accumulation and snow melt, interception and depression storage, evapotranspiration, surface runoff (sealed and unsealed areas), soil infiltration, soil water accumulation, percolation into groundwater, interflow, base flow from groundwater, open channel flow, lake/ reservoir routing. The detailed process modeling in PANTA RHEI allows to use the model for continuous hydrological modeling as is required in the context of flow forecasting. The general set-up of PANTA RHEI is very similar to the well known SWAT model from Texas A&M University.

Distributed catchment models are defined by subdividing the river basin into subcatchments based on the river network and the overall topography (delineation). Further subdivision into hydrological response units or hydrotopes (unique combinations of land use and soil types) may take place to account for specific hydrologic properties within a subcatchment. The Drin-Bojana basin has been subdivided into about 2,600 subcatchments including about 17,400 hydrotopes. The model was set up on a fixed one-hour time step which is well suited for a flow forecast system taking the overall size of the Drin-Bojana basin into account. The model parameters were calibrated for the period from 1979 until 1989 and were validated for the period from 2001 until 2010. With the available data for these periods, simulated and gauged runoffs show a high and satisfactory degree of congruence. The model calibration and validation could only be effectively carried out as all NHMS actively supplied long range hydrometeorological time series for the Drin-Bojana basin.

A model run with a forecast horizon of 72 hours for the entire basin only takes a few minutes and is therefore very well suited for conducting online flow forecasts. Fig. 4 shows an example of the operator's view for a flow forecast starting on 03/16/2018 for Kpuze station, Kosovo, for a five day period based on global weather forecasts downscaled to the Western Balkans by the Montenegro Institute of Hydrometeorology and Seismology.

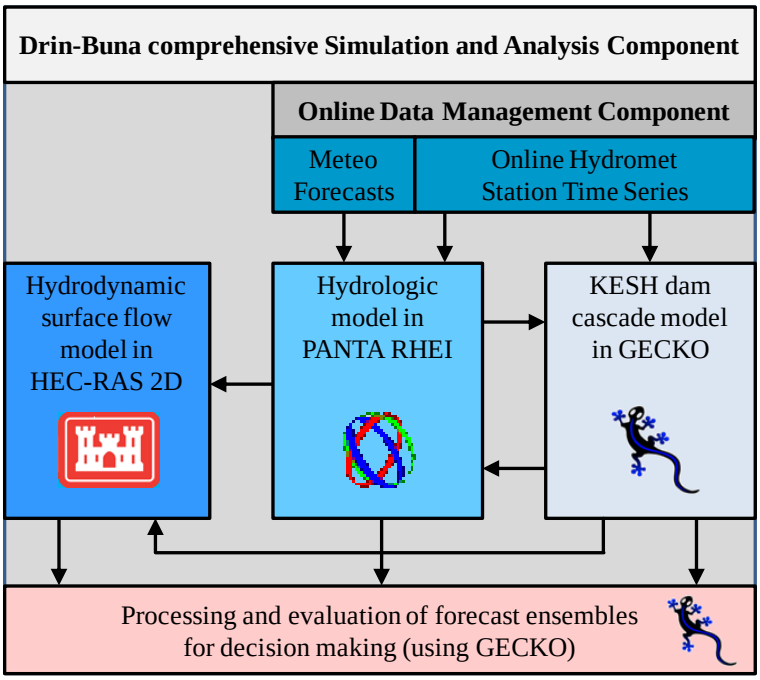

Fig. 3: Interrelation of models within the Simulation and Analysis Component.

(ii) GECKO

GECKO serves two functions in the Simulation and Analysis Component.

(a) It serves as an instrument to model the KESH dam cascade in Albania. All relevant operating rules of the KESH dam cascade are implemented into this model as well as flow routing between dams. The KESH dam cascade model is nested into the PANTA RHEI model and is automatically executed during PANTA RHEI model runs.

Representatives from KESH (Korporata Elektroenergjitike Shqiptare) as well as from the NHMS Albania were involved in reviewing and analyzing the operating rules of the KESH dam cascade.

(b) GECKO also serves as a modeling result repository (database). It thereby, in particular, allows for spatial analysis of results in a GIS like (Geographical Information System) environment. For example, inundation areas can be easily derived on-the-fly from precalculated hydrodynamic model scenarios (see HEC-RAS 2D).

(iii) HEC-RAS 2D

HEC-RAS 2D is a well known hydrodynamic modeling software supplied by the US Army Corps of Engineers as freeware. The modeling software is based on the finite volume approach which represents the current state-of-the-art in hydrodynamic modeling of complex flow regimes.

The complex flow regime of the Drin-Bojana river system downstream of Vau-i-Dejës dam and its floodplains up to the Adriatic Sea, the confluence of the Bojana emerging from Lake Skadar/Shkodra and Drin rivers as well as Lake Skadar/Shkodra and its vicinity have been implemented into a hydrodynamic model with HEC-RAS 2D. This model allows to simulate the complex hydraulic interaction between the Drin/Bojana and Lake Skadar/Shkodra as well as its outlet during floods (with possible flow reversions). The model has been calibrated with all data available for the floods of 2010 and 2018 – the

calibration results coincide fairly reasonably with gauging and satellite data compiled. Analysis in the aftermath of flood events of 2010 and also 2018 showed that water levels in Lake Skadar/Shkodra may have severe effects on flooding in the downstream Bojana river.

The NMHS of Albania and Montenegro were actively involed in setting up this model and contributed important data sets for setting up and calibrating the model. Representatives of these two NHMS were also trained in using the Lower Drin-Bojana Hydrodynamic Model.

As this Lower Drin-Bojana Hydrodynamic Model is quite big in its spatial extent, model execution may take up to several hours. This, of course, cannot be tolerated for a flood forecasting system which should generate results in time. Therefore, a different approach was chosen: The Lower Drin-Bojana Hydrodynamic Model is simulated (pre-calculated) for a set of likely flood inflow conditions derived and extrapolated from historical data as well well as flow forecasts generated by PANTA RHEI. In addition, the Lower Drin-Bojana Hydrodynamic Model can also be directly run for forecasted inflows in real-time. However, as stated above, the duration of the execution time of the model might not be tolerable for real-time forecasting purposes during flood events. The precalculated results are stored in the GECKO repository. In case of a flood event GECKO selects the respective precalculated scenarios and spatially interpolates between them to generate inundation areas on-the-fly based on real-time forecasted inflows to the Lower Drin-Bojana Hydrodynamic Model by PANTA RHEI.

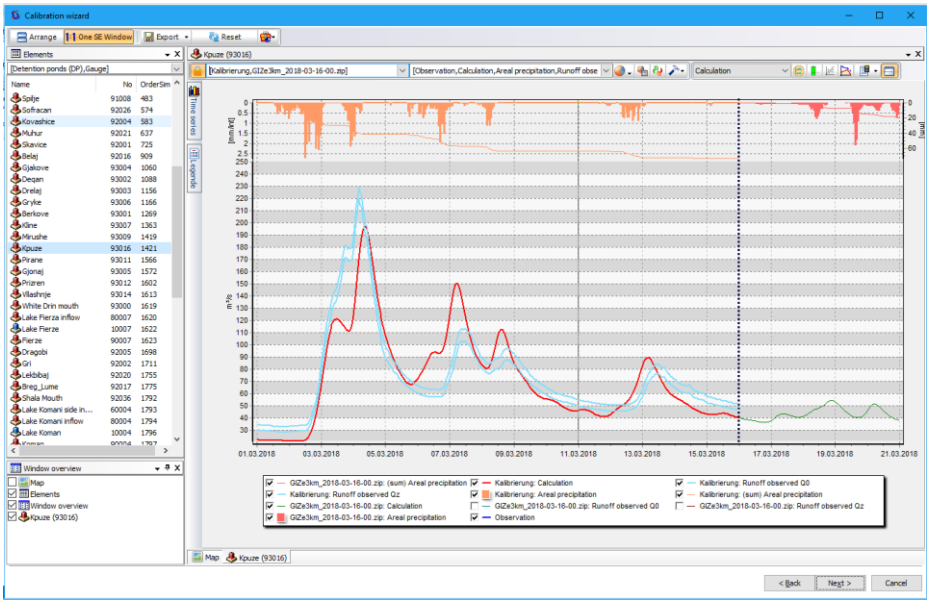

Fig. 4: PANTA RHEI operator's view for an example flow forecast starting on 03/16/2018 for Kpuze station, Kosovo.

It is also anticipated to employ the Lower Drin-Bojana Hydrodynamic Model in the context of deriving Flood Hazard and Risk Maps for the lower Drin-Bojana basin according to the EU Floods Directive.

4. Summary and Outlook

The Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH, on behalf of the German Federal Ministry for Economic Cooperation and Development (BMZ), has implemented the Drin–Bojana Basin Flow and Flood Forecasting System in two project phases since 2012 in the course of the project Climate Change Adaptation in Transboundary Flood Risk Management in the Western Balkans, and has just started into the third project phase. The NHMS of the Drin-Bojana basin riparian countries have been actively involved in designing and setting up the Drin–Bojana Basin Flow and Flood Forecasting System. The system as introduced above is installed at and operated by all four NMHS in their headquarters.

The Drin–Bojana Basin Flow and Flood Forecasting System

- allows to carry out flow forecasts for the entire Drin-Bojana basin including the KESH dam cascade in Albania,
- allows to derive inundation extensions for forecasted flood events downstream of Vau-i-Dejës dam and the floodplains of the Drin-Bojana up to the Adriatic Sea including Lake Shkodra,
- directly accesses and stores online meteorological forecasts downscaled to the Western Balkans region from global weather forecasts in the background,
- directly accesses and compiles online measurement data from hydrometeorological stations distributed in the Drin-Bojana basin in the background, and
- is being operated by the NHMS of all four riparian countries, and these NHMS have been extensively trained in using the system during flood seasons (the training activities will continue during the third project phase, with a focus on reliable model operation and maintenance).

The orography of the Drin-Bojana basin is quite diverse and ranges from low land plains to high and steep mountainous areas. On the western side of the Albanian Alps high rainfalls are recorded for precipitation fields moving in from the Adriatic Sea. At the moment the online hydrometeorological station density in the region is quite low. The reliability of the forecasting results could be easily improved by extending the online hydrometeorological station network in the region. An extension of this network should also take into account to set up new stations in higher altitudes to better monitor snow accumulation and melting processes, in particular in the Albanian Alps and on its western slopes. In general, the meteorological station density should be enhanced throughout the Drin-Bojana basin. Several new online hydro stations should be build or existing stations should be upgraded along the main river course and its main tributaries, in order to be accessible online. Existing stations which are at the moment out of order should first be restored and put back into service. The NHMS need to be equipped with the required budget and manpower by their governments to adequately operate, maintain and repair their online (and offline) hydromet station networks to ensure that the investments made are sustainable.

The system has been designed to easily incorporate new online hydrometeorological stations into the forecasting process. A detailed definition of subcatchments allows to carry out flow forecasts at virtually any point within the Drin-Bojana basin.

Some of the base data for the Lower Drin-Bojana 2D Hydrodynamic Model was incomplete, with had high levels of uncertainty. The quality of forecasts could be greatly improved, for

instance, by an updated high resolution bathymetry covering the entire Lake Skadar/Shkodra, a detailed terrain model in the vicinity of dikes including, dike crests, as well as up-to-date cross-sections along the main course of the Drin/Bojana rivers within the model area. An intact and properly working water level gauging network within the Lower Drin-Bojana Hydro-dynamic Model boundaries will also very much help to raise the quality of the model after recalibrating it with new data available from future flood events.

A detailed flood forecasting, including forecasts of inundation areas, is up to now only available for the areas with highest flood risk in the basin, i.e. the area around Lake Skadar/Shkodra and lower Drin/Bojana/Buna river in Albania and Montenegro. There are other flood risk areas within the basin, as recently identified in the Preliminary Flood Risk Assessment for the basin (with GIZ support). GIZ will support Flood Hazard and Risk Mapping (according to the EU Floods Directive) in many of those areas,and will support the development of hydrodynamic models for those areas, or employ existing ones (e.g. in the flood risk areas just north of Lake Ohrid in Macedonia). These models could then also be used for more detailed flood forecasts in those areas.

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