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USING HYDROLOGICAL CATCHMENT MODEL IN FLOOD FORECAST SYSTEM

by

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ABSTRACT

The extreme precipitations and the floods originating from them in the recent years highlighted that the adequate flood forecast on the upper catchment of the rivers can be implemented successfully only with connection of the hydrodynamic and the hydrological models. This kind of forecasting system were made for catchment of two Hungarian rivers (the Raba and the Mura) in 2011 developed by DHI a.s.; where the most of the frame conditions of hydrodynamic models are provided by an algorithm, called NAM; that is using a complex parameter kit. The NAM is an algorithm developed by DHI; which is based on water change processes between aquifers connected in series (e.g.: snow, surface, root zone, groundwater). Charging and overflow of the different aquifers were counted on the base of the parameters featuring the competent aquifer. The input data of the NAM model is the meteorological forecast and the output is the appearing discharge in the watercourse. The model runs hourly, therefore it uses the results of previous running so it continues counting with the stored water quantity of the aquifers. The forecast system recently is operating in test mode. On the base of our experiences the meteorological forecasts influence operation and punctuality of the forecast system significantly. Furthermore in case of not adequate calibration the stored water quantity can reach unreal quantity in the aquifers due to lack of feedback (mainly in case of snow).

Keywords: catchment model, flood forecast, NAM

1 INTRODUCTION

Developments of flood forecast for the Raba and the Mura river network have been made between 2008 and 2011 in the West-transdanubian and North-transdanubian Water Directorate within the frame of projects which supported by sources of EU. The results of projects, which in the frame of transboundary programs with the neighbouring countries (AT-HU Transboundary cooperation program 2007-2013, Sl-HU Transboundary cooperation program 2007-2013), online alarming and forecasting systems were prepared or were developed.

In the case of Mura it means to join an existing model, which operating in the Slovenian and Austrian catchment, while in the case of Raba it happened a development a new model which is same as before. The complex model system, which contains hydrological and hydrodynamical modules also, expand the whole catchments of the rivers, provide six days forecast of waterlevel and discharge, based on the available meteorological and hydrological data and forecasts (FICSOR & JUHÁSZ, 2012).

2 FLOOD FORECAST SYSTEM

The essence of the forecasting system, which working online, that collect and process the meteorological forecast for the hole catchment and hydrographical data after it run the model from time to time (hourly) and it publishes the ready forecast for the stakeholders in the same frequency. The center of the forecast systems is in Graz, the automatic forecasts are made in here. Local models could be operating in the competent Water Directorates also, besides the center model in Graz. The local model could be run directly by using databases of the central model, which operating automatically.

In keeping with the Austrian existing developments, the Hungarian Mura section and the forecast system of Raba are based the software family developed by Danish Hydrological Institute (DHI). The basis of the forecast system is given by 1 dimension hydro-dynamical model (MIKE11) with boundary conditions are given by the rainfall-runoff models of single catchments and the detected and forecasted discharge data.

The responsible for the continuous online operation of modeling task is the Flood Watch frame system. Through this frame system could be controlled the running of the model, the data flowing for the model and the publishing of results (FICSOR & JUHÁSZ, 2012).

2.1 Flood forecast model

The flood forecast model is created by a hydro-dynamical model covered the whole river system of the catchment and rainfall-runoff models which determines the gathering water amount in the sub-basins. The responsible for the adjusting the prepared forecast for the real data is the data assimilation module (DHI, 2011a,b,c & d).

Hydro-dynamic model

The hydro-dynamic model involves the whole river network in both of cases. In case of Raba means more than 1623 km river system, with 151 isolated branches of river (river channel section); in the case of Mura 1020 km river, with 28 main and collateral branches of river (FICSOR & JUHÁSZ, 2012).

The 1dimensonal model takes notice of every state variable (water level, discharge, velocity, concentration, flow area, width of water surface) with the section mean value. The system is using for the describe of processes the numerical solution of the partial differential equations based on physically (Saint Venant equations).

The topography of the river system is defined by observed cross-sections with adequate chainage and the junctions of branches. The spatial points of calculation for the system are the cross-sections, and if necessary (for example: before and after the junctions) it adds interpolated cross-sections of calculation between the known cross-sections. The hydro-dynamically important structures (bridges, weirs, reservoirs) were built up also to the river network.

The results of calculation can be displayed like the time series of state variables of cross-sections or the longitudinal-sections of extreme values of state variables and the longitudinal-sections of values for certain times. In practice, this means time series and longitudinal-sections of the water level, the discharge, the velocity, the flow area, the width of water surface. Beside the graphical and tabular view the databases can be process and move to other programs for example Excel etc. (DHI, 2011a,b,c & d).

Rainfall-runoff model

Maybe the most important boundary condition is the expected discharge effect of the meteorological forecast from the single catchment. In determining this is happened by special algorithm, this algorithm could be possible to join the meteorological forecast and the hydro-dynamical model. The developers used the NAM rainfall-runoff model for this task, with detailed parameter set, in case of Raba and in case of Mura too.

The NAM approach determine the inflow discharge to the channel in the last point in catchment, it is based on the storage capacity of daily or hourly precipitation time series, parameter of evaporation, surface and groundwater inflow and different layers of storage (snow storage, vegetation, surface, root zone, groundwater, formation water). (*Figure 1.*) The model is based on describe of water change processes between aquifers (storages) connected in series. Charging and overflow of the different aquifers were counted on the base of the parameters featuring the competent aquifer. The input parameter is the probable amount of precipitation and the output is the appearing discharge in the watercourse.

One of the advantages of the used model, and it is disadvantage too in case of inadequate calibration about our experiences, that in case of model run it uses the results of former running like initial condition, so it "remembers" the former period too. In case of adequate operation this is a very important property of the model, because the evolution of neither flood is not independent from the hydrological events in previous period. However in case of inadequate parameterization it can generate and keep long time significant error in the forecast. We find problem like this during the test period on last months, in case of calculation of water amount stored in snow in the NAM model. In this case the "power of memory" of model does not allow the automatic correction of the initial parameter based on the observed data, it needs manual correction. But it can not build up to the automatic hourly repeating operation. The correction of such errors is had to happen during the updating and actualization of model too, which are previously mentioned (DHI, 2011a,b,c & d).

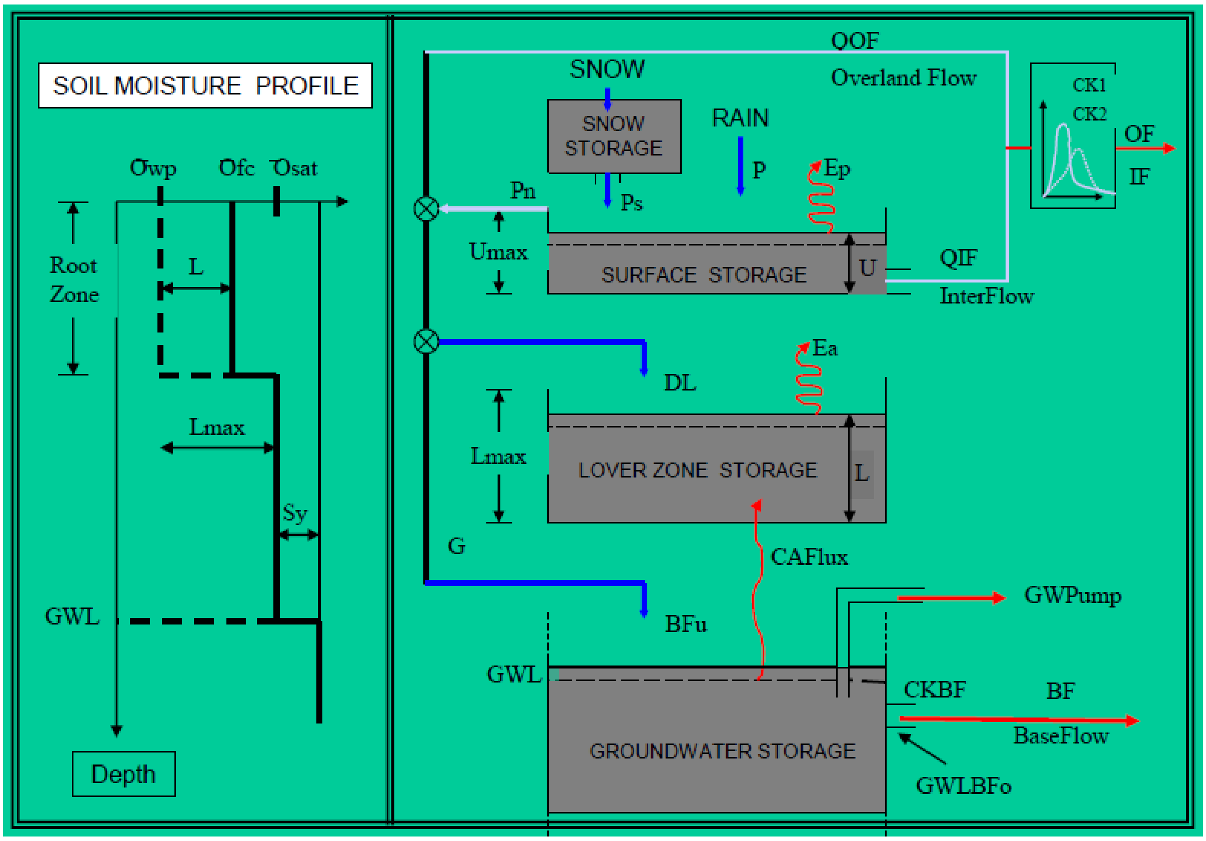

Figure 1 - The strukture of the NAM model

Where:

- P: is precipitation
- P_S: is the excess melt water from the snow storage
- E_p: potential evapotranspiration
- U_{max}: denotes the upper limit of the amount of water in the surface storage (mm)
- U: the amount of water, in the surface storage
- L_{max}: denotes the upper limit of the amount of water in the lower zone or root zone storage (mm)
- L: the amount of water, in the lower zone or root zone storage
- P_N: enter the streams as overland flow
- QOF: denotes the part of P_N that contributes to overland flow
- QIF: the interflow contribution
- OF: is the overland flow (mm/hour)
- IF: is the interflow (mm/hour)
- $CK_{1,2}$: are the time constants for routing interflow and overland flow (hours)
- Ea: if the moisture content U in the surface storage is less than these requirements ($U < E_p$), the remaining fraction is assumed to be withdrawn by root activity from the lower zone storage at an actual rate E_a.

G: is portion of the infiltration is assumed to percolate deeper and recharge the groundwater storage
BF: is the baseflow from the groundwater storage
CK_{BF}: is the time constant for baseflow (hours)
CAFlux: capillary flux
GWL: is the groundwater table depth
GWPump: groundwater abstraction
GWL_{BF0}: maximum groundwater table depth causing baseflow (m)
S_Y: values of the specific yield for the groundwater storage

Data assimilation

Accepted the outlined possibilities and barriers against the online hourly prepared forecasts in the previous chapters, still the most important expectation, that the results of model have to adjust to the latest available observed data from run to run. Because in quick situation between two runnings it is not possibilities to reset or recalibrate the parameters of model, so it needs an automatically operating possibility to correction, which makes the got results to usable against the barriers of model. The assimilation is solution for this, which correct automatically the results of model based on the latest available observations in the changed discrete points (the single influential stations).

This correction is happened during the data assimilation in every running based on the errors of the differences between the results of the model and observed data. The model technically draws the results on the observed data for the two days of time series of the modeled parameter, while the correction of time series is happened based on the equation of assimilation regarding the forecasted six days.

The correcting of the results of model is happened by the equation which defined by the user in the program. Based on the previous experiences the developer determined unique error function for every station, which depends on modeled parameter (often discharge, sometimes water level) and it is changing in the time. With this solution (using the error function changing in the time) the value of error, which is valid in the time of forecast, gradually decreases in the time of six days forecast, so the further forecast in time contains less correction, and the got results is rather determined by the parameters of model and regularities of hydro-dynamically.

It can reach with this method, that the occasional failure of observed data used for the assimilation is could abate the period of forecast, and it does not devolve on the forecast in further time such a big scale. In the case of the cause of difference between the observed time series and the modeled value is not in the failure of measuring, but contacts to parameter of model and quality or topicality of basic data of model, it can be that this smoothing decrease the goodness of the further forecast.

The data assimilation is using on discrete point (hydrographical stations), the effect of it does not extend to the whole results. The fitting for the modeled longitudinal section (how much distance become smooth to the original curve for the direction of up-water and down-water) is could define by parameters (DHI, 2011a,b,c & d).

2.2 FloodWatch frame system

The management of the model carries out the FloodWatch frame system, which automatically runs the model, makes the forecast and publishes the data in the central webpage finally makes it available to the forecasting sub-center. The local forecasting centers (Eisenstadt, Szombathely, Győr) estimate the results, make own forecast if it necessary and publish it their own webpages with this FloodWatch frame system also.

The local forecasting centers are not set for independent online automatically operation. The downloading from the center of Graz is working with FTP connection, the downloaded models could open. We can make new simulation in the opened model with some modification in the model parameters and the boundary conditions, it depends on the request. We can make and save five different versions (scenario) for each of the basic model (which are downloading from the center model). The application save the scenarios in full of value and complete sized zip files like the central system, so later we can use independently and publish.

The results of downloaded forecasts and made scenarios can inspect in graphically and tabular at the same time. It is possibility for graphically view the data stations which are indicated in the map layer, and it is possibility for view the precipitation amount, which fall to the sub-catchment, in every stored time step. We can view tabular the values of discharge, water level and precipitation, in case of own scenario it is together visible the observed data, the original results of run and the results of new scenario.

In the user interface of FloodWatch it can be directly available control files, which control the process of modeling and the publishing of the results, and the model itself and an application for inspect the results of model more detailed.

It is the most difficult to determine the amount of fell and the expectable precipitation, so the need of running of scenarios is particularly changed the expectable precipitation, therefore the application allows to make directly this modification without open the basic model. It is possible to change the precipitation in last one day and the next three day, on 24 hours steps in every sub-catchment.

After the necessary modifications the run of the scenario can start directly from the FloodWatch. The speed of simulation is depend on the speed of the computer, about our experiences it is between seven and twenty minutes (JØRGENSEN 2011).

2.3 Data flowing, network of flood forecast system

The automatic online forecast system naturally can not be operating without automatic and online data flowing. Essential, that the basic data for modeling, the meteorological and hydrological data and forecast are available on time in the adequate format for the central model. (*Figure 2.*).

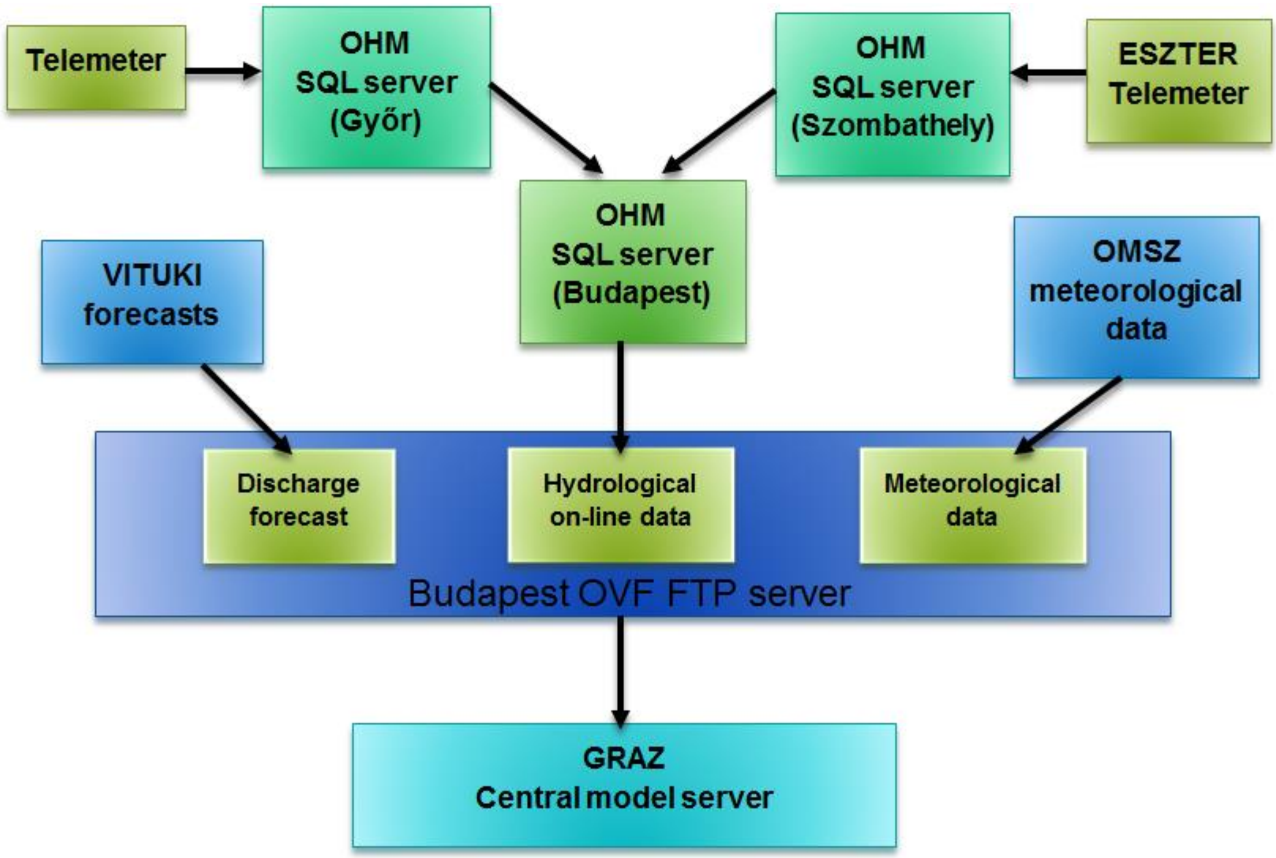

Figure 2 - The network of the data flowing

The boundary conditions, which defined during the development, and the reference values for the assimilation are had to refresh continuously in the model, because this is the basic condition for the online forecast. The boundary conditions for the model are: precipitation and air temperature data from the previous two days and forecast to the next six days for the defined catchment; the curve of discharge for the closing section of the model; and in case of Raba the discharge data for the recipient rivers from the previous two days and forecast to the next six days. The data assimilation needs to the telemetry time series data (water level and discharge) from the changed station too.

Every data is had to reproduce hourly except the curve of discharge for the closing section. This reproduction does not always mean to substantive changes of the data, because there are some parameters which are not refreshing in every hour, like the meteorological an hydrological forecast. However in case of water level and discharge data it strive for the hourly refreshing, because the topicality of this data, through the data assimilation, influences significantly the goodness of the forecast. The telemetry establishes the such a frequency refreshing of the hydrographical data. So it is essential condition for a good operating forecast model, that it has a hydrographical telemetry network with reliable operating and checking too.

The meteorological and the hydrographical raw data are had to get over a pre-processing, which means to conversation to usable form for the model and the detection and the correction for the occasional errors.

In order to the data will be available on time in adequate form, it needs to be cooperation for some independent organization. The concerned organizations in the data observation are the NYUDUVIZIG, the ÉDUVIZIG, the OVF and the OMSZ; while the concerned organizations in the forecast are the OMSZ, the VITUKI and the ÉDUVIZIG. The operator of sever farm responsible the adequate data processing and data flowing (FICSOR & JUHÁSZ, 2012).

3 EXPERIENCE TO DATE

In the last half year the testing time we can speak about that the running of the central model is stable and it is not sensitive to lack of data except of the meteorological forecast data.

Hitherto the models were primarily operating in small water situation, just some small flood flown down in the rivers, therefore it is hard to adjudicate the goodness of models in present conditions. About our experiences till now we can ascertain that the actual meteorological forecast greatly influences the farthest period of forecast. The precision of model depends on greatly the precision of meteorological forecast, so the changes of the precipitation amount in the meteorological forecast greatly influences the precision of forecast primarily in the 4-6 days perspective. About our experiences in some cases the operation of NAM models and within them the snow accumulation and melting module is not adequate, the calibration of it be had to check.

In the case of hydro-dynamical models the quality of the upper part (foreign) of the model greatly influence the quality of the results of lower part (Hungarian) of the model. Because one uniform model was built therefore we can follow the errors in the running of the model though the borders and optionally we can attempt to moderate them in case of each running. We make diary about the errors and make propose to fix them during the annual review.

During the time of testing we have been fixing about the data assimilation, which increase the goodness of forecast just in short period and only in case of actual running. The correction of basic data (river network, cross-sections, parameters of NAM model) using for build of model and structure of model is not a task for operating but it is a task for the updating of model and actualization. We make diary about such errors, and in case of planned annual updating of model we try to correct them if it needs involving the developer.

In case of the data, which using for reference for data assimilation is not correct or deficient, it is possible to correct them. If the replacement is not possible or the reason of the faulty of the data assimilation is not the wrong data, we can modification the equation of assimilation too, or temporarily the assimilation is could turn off for the involved station. But the last two solutions do not mean final solution, in case of that the correction have to do during the regular maintenance (FICSOR & JUHÁSZ, 2012).

4 CONCLUSIONS

Nowadays the development of information technology allowed of application of decision support tools in the area of flood forecast too. This tools with adequate maintenance help for the flood forecast. The described forecasted system give six days forecast based on the available meteorological data and forecasts. The using of the meteorological forecasts allows the extension for the two days advantage to six days, but we need to know that the goodness of the six days forecast is reduced in going forward in the time, and the uncertainty in the sixth day is very high. About our experiences, that the automatically online forecast system can be rather called alarm system in Hungarian usage.

Unfortunately neither the time of development neither previous period of testing time it was not formed such hydrological situation in the catchment what could be possible to testing the operation of the model in flood, because the calibration and the validation was happened for some previous flood. Although under the previous operation just some small floods flown down, still some failure have been occurred there made it clear to the models need updates and actualization from time to time.

The basic conditions for the operating of the model is the undisturbed data flowing, the conditions for this is the good cooperation with concerned organizations. Unfortunately under the previous time of testing some problems were formed in the life of organizations which can be jeopardized the cooperation too. The continuous and undisturbed operations of the concerned organizations are necessary for the point of view of cooperation too.

About our experiences, that the previously developed model, which developed for mountain catchment, adaptation for lowland area is not easy task. The build of well-defined model system and the parameterization of model needs great caution too. Despite of all efforts in some cases there are big uncertainty in the results of models (seasonality of the run-off coefficient). Therefore it is essential to check the results in case of this model, which created with the greatest care but in some ways it is a static model. The many years of the professional experience will be the most important pillar in the forecast beside a such of advanced decision support system too (FICSOR & JUHÁSZ, 2012).

5 REFERENCES

DHI, 2011a. MIKE 11, A Modelling System for Rivers and Channels, Reference Manual, DHI, Hørsholm

DHI, 2011b. MIKE View, A Result Presentation Tool for MOUSE, MIKE URBAN, MIKE NET and MIKE, User Guide, DHI, Hørsholm

DHI, 2011c. MIKE ZERO, Preprocessing and Postprocessing, User Guide, Volume 1 and 2, DHI, Hørsholm

DHI, 2011d. MIKE ZERO, The Common DHI User Interface for Project Oriented Water Modeling, User Guide, DHI, Hørsholm

FICSOR, J. & JUHÁSZ, I., 2012. Árvízi előrejelzés korszerűsítése a Rábán és a Murán, Magyar Hidrológiai Társaság által rendezett XXX. országos vándorgyűlés. Kaposvár, 2012. július 4-6. CD melléklete, Magyar Hidrológiai Társaság. Budapest, ISBN 978-963-8172-29-7

JØRGENSEN, G., 2011. Flood Watch Online User Guide, DHI, Hørsholm