REGIONAL FLOOD EARLY WARNING SYSTEM

REGIONÁLNÍ SYSTÉM VAROVÁNÍ PŘED POVODNĚMI

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Abstract

Natural disasters have occurred for a very long time, virtually on all continents, and it is obvious that in the areas where human's social, economic and cultural activities are concentrated, their impacts are more severe. The Laboratory for Modelling and Simulations of Hazardous Situations, operating at the VSB-Technical University of Ostrava, works on a long-term basis on a project called FLOods REcognition On the Net (FLOREON) aimed at development (to meet the needs of the Moravian-Silesian Region) a system for modelling, simulating, monitoring and if appropriate even predicting crisis situations caused by both adverse natural, and possibly human effect. The paper describes principles which the FLOREON system is built on, a conception of the entire system and the first results achieved. In conclusion its further development is outlined, and focused on an extension of the system by next hazardous phenomena such as the modelling of dangerous substance leakage, monitoring of traffic situations and others. So a system occurs denoted as FLOREON+. The plus sign in the name means the system will deal not only with floods, but also with other phenomena in the territory.

Abstrakt

Přírodní extrémy se objevují od nepaměti, prakticky na všech kontinentech, a pokud zasáhnou oblasti, kde se koncentrují ekonomické, sociální nebo kulturní aktivity lidí, mohou být jejich dopady velice vážné. Laboratoř pro modelování a simulaci krizových situací na Vysoké škole báňské – Technické univerzitě Ostrava pracuje na dlouhodobém projektu nazvaném FLOREON (FLOods REcognition On the Net) a zaměřeném na vývoj systému pro monitorování, modelování, simulaci a pokud to bude možné, tak i predikci krizových situací, způsobených jak nepříznivými přírodními, případně i lidskými vlivy. Článek popisuje principy, na nichž je systém FLOREON budován, koncepci celého systému a první dosažené výsledky. V závěru je nastíněn jeho další rozvoj, zaměřený na rozšíření o další krizové jevy, jako je modelování úniků nebezpečných látek, monitorování dopravní situace a další. Rozšířený systém je označován jako FLOREON+. Znaménko plus v názvu vyjadřuje, že systém již nebude pracovat jen s povodněmi, ale i s dalšími jevy v území.

Key words: hydrology; rainfall-runoff modelling; geoinformation technology; GIS; flood prediction

1 INTRODUCTION

Disastrous flash floods occurred in the Czech Republic in the years 1997 and 2002 (Bedient et al. 2007), (Brázdil et al. 2005), (Wohl 2008), (Pascal et al. 2006). The first flood affected the Moravian-Silesian Region, among others. Besides these extremely large flash floods bringing extensive material damage and death toll, repetitive flood-related incidents arise on a yearly basis that are not as significant in extent, but they also endanger property and lives of citizens and so there is a need to react adequately. A disadvantage of these minor floods is a relatively high rapidity of occurrence, relatively fast course as well as higher frequency of occurrence, and frequent repetitiveness in the same areas. To protect the property and inhabitants effectively it would be useful to have a system available that would continuously track the development of meteorological conditions, state of water in stream channels and be capable, pursuant to the information and also based on the existing

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experience, of assessing on a nearly real-time basis the potential threat of floods. Such a system would, in the case of an adverse development, warn various units of the Integrated Rescue System and staff of the River Basin Board and upon their authorization also the population of potentially threatened areas.

2 RELATED WORKS

Within the EU Framework Programs several projects have been completed with a similar goal – to create systems to support decision-making during floods. For instance the project FLOODRELIEF (Havnoe et al. 2006) focused on the development and demonstration of a new generation of flood forecasting methods that develop and improve the existing methods and furthermore on making the forecast outcomes available to both the experts responsible for floods management and the people threatened by a given flood. The system has been based on the integration of geodata from different resources and integration of hydrological models into the system to support decision-making. Another project is FloodMAN. The main objective of the project FloodMAN is to develop, demonstrate and validate a prototype information system for cost effective near real-time flood forecasting, warning and management using Earth observation data, in particular space-borne Synthetic Aperture Radar data, hydrological and hydraulic models and in-situ data (Malnes et al. 2006). Even in this project one worked only with hydrological and hydraulic models. Both projects have been focused on the utilization of Internet Technologies (Web) to make final predictions available. In Turkey the project TEFER (Turkey Emergency Flood and Earthquake Recovery Project) (Dokuyucu 2008), (Hakyemez 2007) has been realized focusing on flood predictions. The developed system gathers real-time data on meteorological situations and the state of river basins and generates predictions of flood situations. The results are again presented over the Internet in text, table and graphic forms. In a work (Al-Sabhan et al. 2003) the development of a system for predicting floods is described, and is being designed on the basis of GIS and distributed over the Internet. It is assumed that the results are published on a website as well. In another work (Rubuffetti, Barbero 2005) a system for predicting floods that is operated in the upper reaches of the Po River basin in Italy is described. It again concerns a system receiving data from weather forecasts and from monitoring the network of the river basin that, through the use of a hydrological and dynamic model, assesses the development of flood situation and issues warnings to responsible bodies.

All these projects have certain common positive features:

- Gathering near real-time hydrological and meteorological geodata,
- Integration of various models,
- Utilization of advanced information and geoinformation technologies,
- Output published on websites,
- Practical deployment.

Their fundamental disadvantages involve predominantly:

- Integration of specific models (or modelling tools) only,
- Focus only on a certain locality,
- In most cases constrained solely to floods.

As our system FLOREON is being developed we have decided to proceed from the positive features of the above mentioned systems and to eliminate their drawbacks.

3 WATER COMPONENT IN A LANDSCAPE

Water in the landscape represents one of the most important components of the natural environment. Without its presence life cannot exist. It then concerns a very important natural resource with a significant property: Contrary to other natural resources it continually regenerates by natural circulation. Under standard circumstances the water cycle takes place more or less fluently, however circumstances may occur under which a dramatic oscillation takes place in this process. Extreme phenomena may mean either a lack of water or on the contrary a temporary distinct surplus. In both cases the water function in the landscape is disturbed. In an extreme case the arisen situation may endanger the life, tangible and other property. In the first case (extreme drought) the extreme situation affects as a rule indirectly and its effect will develop only after a certain period of its duration. The other case (floods) is featured usually by a direct and as a rule immediate (sometimes extremely fast) impact that can affect a considerable area of territory.

People would like to protect themselves from the extreme effects of the natural water cycle, or at least to minimize effects on human health, tangible and other property created by people. The important thing is especially the protection from dynamically running processes. One of (preventive) actions going in this direction is also the building up of emergency management service and convenient information systems that provide them with adequate information security.

In terms of emergency management two situations are important:

1. Extremely fast influence (flash floods) that typically (but not always) affects a small area, but on the other hand it does not give inhabitants too much chance for preparation; usually it concerns short-term events that arise suddenly, without warning, to which as a rule the emergency bodies have today no chance to react beforehand and usually render assistance only to reduce their impact. These flood events are caused in temperate zones, usually in summer, by strengthened convection, formation of thunderclouds and local initiation of precipitation falling for a relatively short time and with higher intensity. For this reason the term convective precipitation has become accepted for that situation. A major problem of the precipitation consists especially in that it is hardly spatio-temporally predictable in a satisfactory way using numerical meteorological models (NWFS) due to a scale and physical character of these phenomena.
2. A slower influence that usually, contrarily, affects large areas, but its course tends to be less dynamic. The population has a chance to prepare for a flood at least to a certain extent, or the emergency bodies are in a position to intervene meaningfully from the very beginning of the flood, or perhaps before. A reason of these floods is so-called regional or stratiform precipitation. Under such situations the precipitation lasts longer (in a horizon of days), is of a minor intensity, and covers larger regions.

In both cases the emergency management service needs sufficient information such as warning, current information on the situation, and prediction of further development. However, especially in the first case the early warning systems are faced with the formidable task to ascertain the risk in time and predict the situation development so an effective intervention can be performed within the emergency management groups. It is complicated furthermore by the fact that it often concerns an area outside the network of warning and forecasting profiles, such as minor streams and less urbanized areas.

The FLOREON system intends to provide significant help for the emergency management service in both situations.

4 WATER CYCLE IN NATURE

The water cycle in nature represents a very complex process consisting of so-called small and great cycles. Regarding its extreme behaviour, the great cycle is of a dominant significance for us. The one starts with water evaporation from the oceans, continues with transport of water vapour through the atmosphere over land, water condensation and falling from the atmosphere as precipitation, water running to river networks and its transport through channels back to the seas and oceans.

As for the water cycle we are interested particularly in water that falls over land in the form of precipitation and water runoff from the precipitation area - so-called rainfall-runoff process. For a detailed study of the water cycle we refer to e.g. (Maidment ed. 1993) or (Bedient, Huber et Vieux 2007).

5 RAINFALL-RUNOFF PROCESS

Over land quite a number of partial processes which are closely interconnected take place in relation to the water cycle. The essential partial processes involve:

- Precipitation,
- Interception,
- Evapotranspiration,
- Snow accumulation or melt,
- Infiltration,
- Surface runoff (overland flow),
- Subsurface runoff (runoff in an unsaturated zone),
- Groundwater runoff (base flow),
- Water accumulation in surface water bodies.

Input precipitation passes through the rainfall-runoff process within a territorially limited hydrological unit (river basin). It propagates resulting in either runoff in channels, or runoff loss.

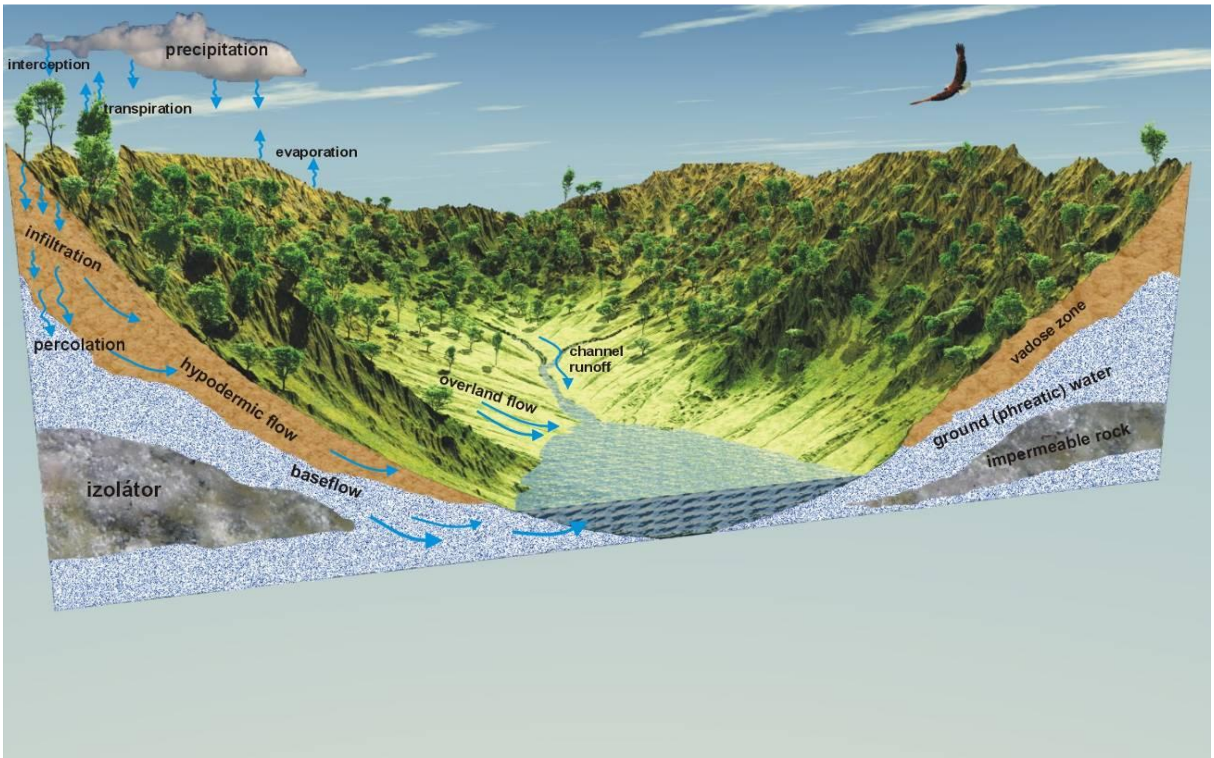

Fig. 1. Rainfall-runoff scheme (Klimant et Unucka in (Rapant 2007)).

Interrelations of these partial processes are schematically captured in Figure 1 (Klimant et Unucka in (Rapant 2007)). In short, it could be said it concerns sub-processes of the rainfall-runoff process some from which bring water to the landscape, other ones accumulate it and further ones drain it on the contrary.

6 FACTORS AFFECTING WATER BEHAVIOUR IN A LANDSCAPE

The behaviour of water in the landscape is affected by a whole series of factors. In terms of our project we are mainly interested in those that immediately affect precipitation flowing down and runoff. We may divide them into several groups (adapted according to (Boucníková 2005)):

- Land cover,
- Land use,
- Water management (e.g. water reservoirs operations),
- Properties of urban drainage networks,
- State of river basin saturation,
- Previous and current meteorological conditions (hydro synoptic situation).

The first two groups of factors are relatively stable over time, it is sufficient only to update them periodically. The third group of factors lies on the border – water structures and channel regulation are relatively stable, hence it is again sufficient to update them periodically, but modes of water structures are relatively variable and furthermore they can be purposefully and actively manipulated during events to regulate the course of water flow. Urban drainage networks have similar impact on the actual runoff conditions mainly in large cities. Therefore we have to obtain the information on a real-time basis.

The next group represents time-varying dynamic factors which carry the necessity of updating within a relatively short periods of time (days). Finally, the last group are the most dynamic factors, changing in relatively short periods of time, hence it is necessary to gain the information on them if possible on a real-time, or at least near real-time basis (in practice a one-hour period to gather the geodata that was proven adequate).

7 MODELLING OF THE SUB-PROCESSES OF RAINFALL-RUNOFF PROCESS

To identify and describe processes of water motion in nature, models are applied that are capable in a relevant way to approximate, schematize and simulate individual parts of the natural environment and individual processes running there based on their mathematic description (Horák et al. 2007).

A traditional approach to modelling the behaviour of water in the landscape represents the utilization of separated mathematic models: hydrological (for example rainfall-runoff or hydraulic ones that model the water behaviour on the land surface – they model a hydrologic system such as watershed or river channel) and hydro geological (predominantly models of the water flow in non-saturated and saturated zones). The approach was suitable when solving partial issues in a river basin such as calculations of resources, propagation of contamination, prediction of flooded areas for n-year waters and others.

Solving complex issues of the river basin administration, including performing real-time predictions of flood states, necessitates integrated simulations of all sub-processes of the rainfall-runoff process under natural marginal conditions. A comprehensively conceived hydrologic modelling system should be able to parameterize and appropriately simulate all sub-processes of rainfall-runoff process in a river basin.

This approach leads to a holistic conception of modelling the water system in the landscape in its complexity and in natural boundaries. It is based on the integration of models of individual sub-processes of the rainfall-runoff process. One of the possibilities is an interconnection of individual hydrologic and hydro geological models that would enable significant improvement of some components of hydrologic balance and rainfall-runoff process relationships in a river basin at least within short-time incidents. The integrated modelling of the components of water balance would enable the reduction of uncertainties in the calibration of marginal model conditions that are, within a separate modelling of individual sub-processes, physically unnatural and often represent a key issue of simulations (Horák et al. 2007).

For each of the modelled sub-processes, as a rule, a mathematic description exists coming out of a physical process standing in the background, however there may exist even more mathematic models. Each of them may be in addition realized by even more modelling tools - so-called models in a strict sense. The models can differ in application conditions, demands for input parameters and data, attainable degree of conformity with the reality, complexity of data preparation and calculation etc.

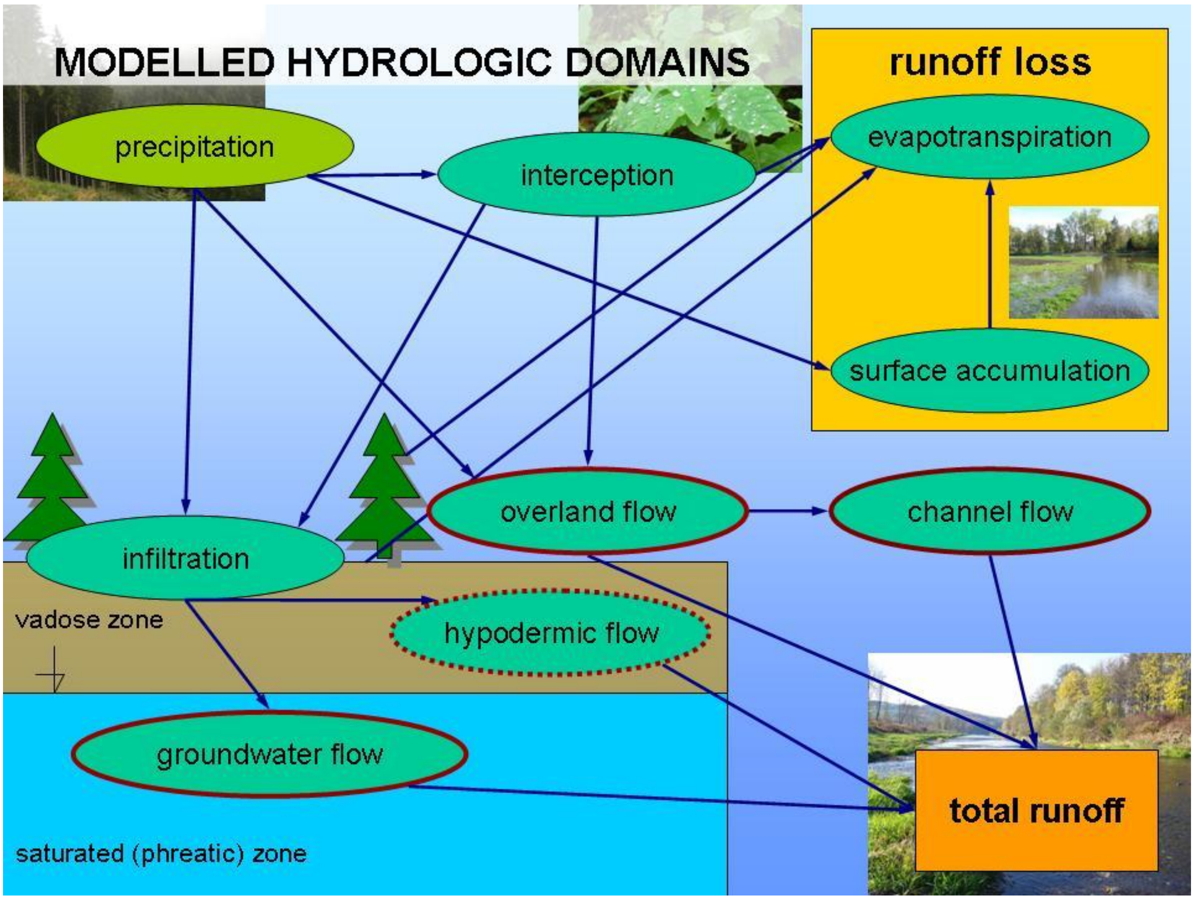

Fig. 2. Interrelations of individual sub-processes of rainfall-runoff process.

As mentioned above the individual sub-processes of the rainfall-runoff process do not exist independently of each other, but are closely related, and relations exist between them that are expressed, as a rule, by mass flows. At the level of mathematical models the mass flows are substituted by information flows. Therefore among the individual models information transmission should occur. However, the fact is that at present the models of individual sub-processes are solved completely separately, direct communication among the models is not currently supported. The models are not well adapted for direct communication with other models, in particular from several reasons:

- They use different conceptions of hydrologic system schematization,
- They use different methods of solving rainfall-runoff process,
- They use different geodata,
- They use various geodata formats.

In Figure 2 the individual sub-processes of rainfall-runoff process and their mutual relationships are schematically illustrated. When connecting individual sub-processes that model these domains it is necessary to respect these interrelations.

For each of these sub-processes mathematical models already exist, however they show the above mentioned practical issues. Any system that intends to model comprehensively and nearly in real-time the water behaviour in the landscape has to solve these issues, i.e. it has both to ensure a continuous flow of the conveniently structured input geodata for the individual models and to be able to take over their results, transform them to the form required for tie-in models and also present the final results in a relevant way to individual target groups. One of the way how to solve these issues is to create a complex system that implements, among others, some standardization of the structures and formats of the transferred geodata and where required it provides appropriate transformation modules that are able to convert the geodata between the individual structures and formats.

8 OUR APPROACH

As presented above the Czech Republic was affected in the years 1997 and 2002 by disastrous flash floods. Pursuant to the obtained experience the public administration and emergency management service are seeking new ways to better cope with such situations. The building of applicable information systems is one of them. For this reason, with cooperation of the Moravian-Silesian Region and VSB-Technical University of Ostrava, the FLOREON project started (http://www.floreon.eu) and focused on building an information system allowing to comprehensively model, simulate, monitor and in the future also predict crisis situations caused by adverse natural, and perhaps even by human effects. In the first stage the efforts of the problem solvers are focused on emergency phenomena connected with the behaviour of water in the landscape.

The goal of the FLOREON project is to fully integrate individual partial models of the rainfall-runoff process, as described above, into a complex system capable of working on-line and nearly in real-time so that it would be possible to timely predict an imminent flood situation and generate the appropriate warning information. The system will provide the data on a real-time basis to the rescue units that will assess their relevancy and if appropriate publish it (or authorize publication) again through the FLOREON system for needs of the public administration and possibly even for the needs of population.

Among lay users and experts usually a considerable knowledge gap exists. The FLOREON system should therefore be able to provide the information in a simple form that is both understandable and unambiguously interpretable by lay public and also in a much more comprehensive form convenient for different groups of experts, and perhaps even allowing their active query processing or request-sending for changes in future situation simulation parameters, et al.

9 CONCEPTUAL SYSTEM DESIGN

The conceptual design of the FLOREON system results from the analyses of external and internal demands.

The fundamental external (or let us say functional) requirements for the FLOREON system may be summarized as follows:

- Near real-time work,
- Continuous prediction of the closest development of flood situation (ca 72 hours ahead)
- Continuous acquiring of the input geodata from external subjects (in real time, rather near real time),

- Cooperation with emergency management service:
  - Preparation of details for their activity,
  - Receiving authorization to disclose the geoinformation,
- Disclosure of the authorized information to various target groups (public administration, general population and others).

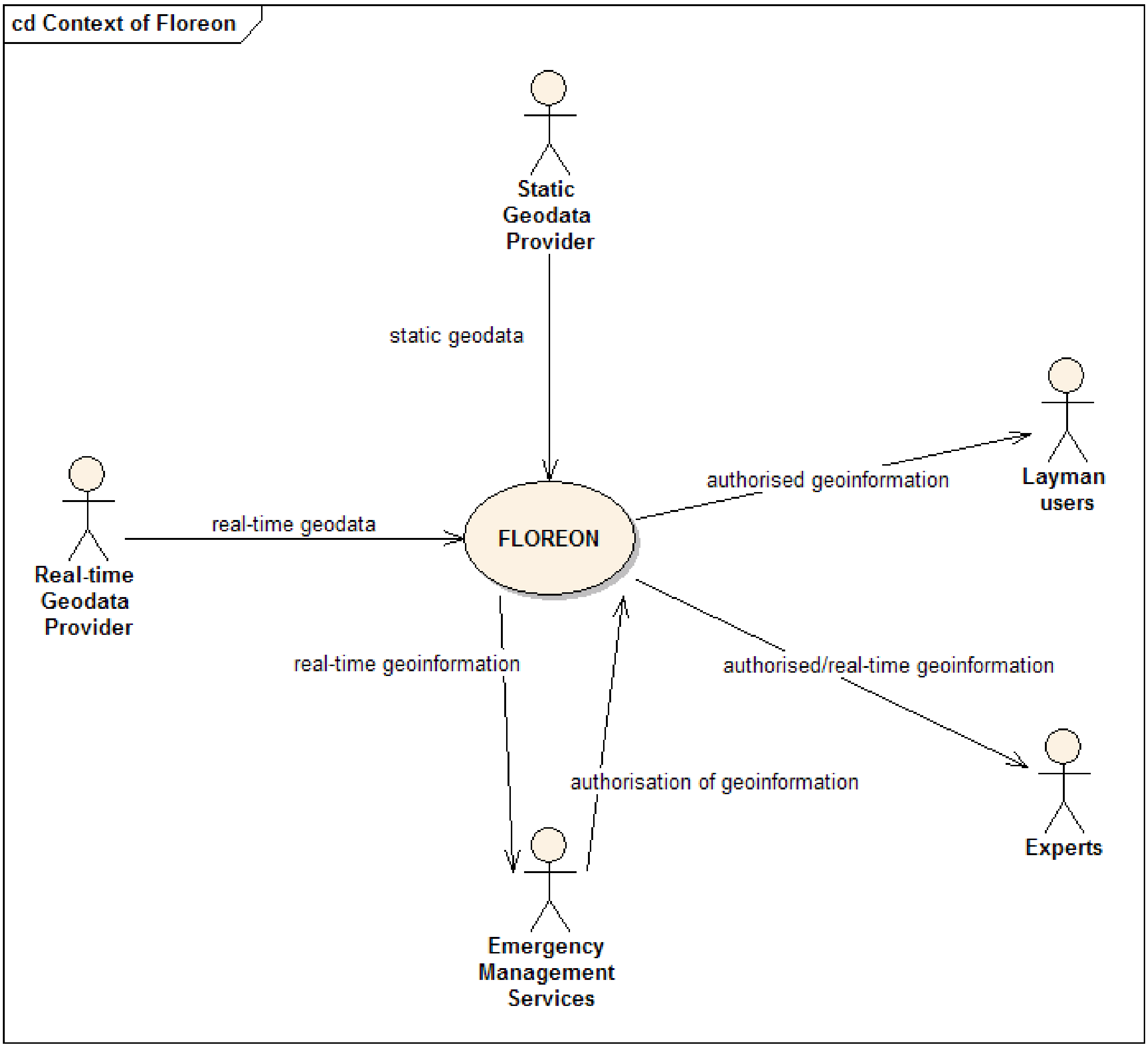

Fig. 3. Context of FLOREON.

From these requirements the contextual scheme results as shown in Figure 3.

The fundamental internal (or rather non-functional) requirements for the FLOREON system may be summarized as follows:

- Open modular architecture,
- Utilization of Internet technologies,
- Use of the Web services concept,
- Possibility of integration of various models,
- Models 'packed' as Web services,
- Automated models, without interventions of operators,

- All geodata, either gathered from the outside or generated inside the system is stored using a database system capable of saving the geodata with its spatial and temporal aspects,
- Individual modules have a clearly defined interface,
- Continuous monitoring of change history in the real world and its saving in a spatial database,
- …

These principles, or rather, requirements, which the below presented system architecture design proceeds from.

An important feature of the system being designed has to be a modular architecture allowing use of different components carrying out a wide scale of functions and pertinently allowing in future an extension of the system functionality also to the areas of other crisis situations such as forest fires, release of hazardous substances into the atmosphere and water and others. The existence of the wide scale of modules involving various models for various cases, various environments etc., modules allowing receipt of input data from a wide scale of resources and modules allowing the visualisation of the results in various ways, will enable to reconfigure the system dynamically so the maximum of computing capacities in situations where there is a need to redirect to solve a given current crisis situation.

It is necessary to lay the FLOREON system on a reliable architecture and graphic user interface (2D and 3D) that will satisfy needs of all types of users communicating with the system. The system modules have to be developed so their addition or subtraction will function on the plug-and-play principle (Vondrák et al. 2008).

All these FLOREON system features create fundamentals of a complex and unique system allowing users to observe and cope with different disaster types.

Since models are integrated into the system as separate modules, it is possible for multiple modules to exist for the same issue, and for the most relevant one to be integrated into the calculations at a given moment; or perhaps multiple models, and if need be model variants, will be used simultaneously (so-called ensembles) and results will be compared and provided to experts for assessment.

A model exchange can be induced also by some circumstances: If for instance some of data sources are subtracted, it will be necessary to use a simpler model that provides indeed less precise results, but is less demanding as for input and thanks to it is therefore able (though with limited accuracy) to function even under an crisis situation.

10 SYSTEM ARCHITECTURE

For the FLOREON system a modular architecture has been chosen. Individual module groups herewith have to support the following functionality:

- Input and pre-processing of static geodata,
- Input and pre-processing of real-time geodata,
- Saving geodata,
- Input preparation for models and their transfer,
- Gathering and saving output data from models,
- Analyses of modelling results,
- Visualization of results for different target user groups.

The individual modules have clearly defined interfaces for both input and output geodata.

This conception and architecture (see Figure 4) of the FLOREON system has shown itself to be very powerful and favourable for the further system development. The FLOREON system today represents a general framework for integration of various phenomena in the territory into the models, i.e. not only the behaviour of water component in the landscape, but also the propagation of contamination in waters and in the air, spread of forest fires, explosions of hazardous substances, collapse of transport system and others. It is possible to insert a new phenomenon into the FLOREON system by merely adding new modules with relevant mathematical models and by their integration into the environment of the system, and pertinently by extending the spatial database by the geodata newly required for modelling the newly integrated phenomenon.

11 TECHNOLOGIES USED

The FLOREON system is based on the Internet technologies allowing the realization of the open system architecture and supporting its dynamic reconfigurability. It proceeds from both general standards for information and communication technologies (W3C ...) and standards for work with geodata, particularly the Open Geospatial Consortium (OGC) standards. For pre-processing of static data ArcGIS is used. Dynamic geodata is gathered on-line through the technologies of Web services. To work with vector data we use the PostgreSQL database with the PostGIS extension, to store relational data Microsoft SQL Server is used, and further we have implemented own database storage for raster data based on the Raster Provider technology. To visualize outputs we use our own application, however in future it is assumed to move ahead towards the ESRI/ArcGIS technologies. The FLOREON+ system will be in addition in future directed to the area of high performance computing.

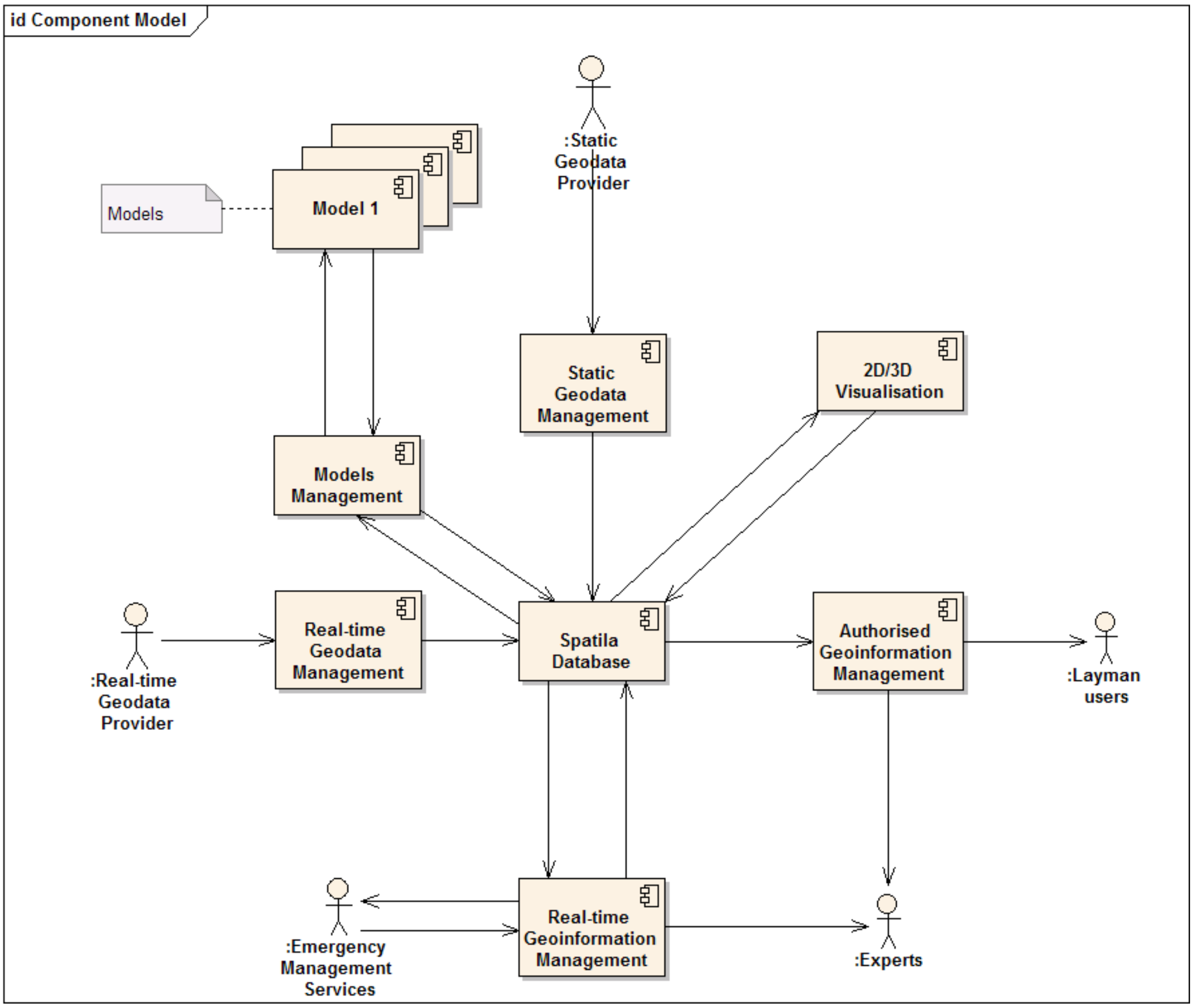

Fig. 4. Architecture of FLOREON.

12 INTEGRATION OF MODELS INTO THE SYSTEM

The first two groups of models that have been integrated into the FLOREON system were rainfall-runoff and hydrodynamic (hydraulic) models.

To choose hydrological models three fundamental criteria have been defined:

1. The model is implemented, validated and well documented,
2. The model is able to be operated in the FLOREON system,
3. The model is capable to communicate with GIS.

Within the first criterion requirements of the project partners have also been taken into account, especially the institutions acting in the Warning and Forecast Flood Service (Czech Hydrometeorological Institute, River Basin Boards), which has also affected the selection of the software solutions.

The second criterion then imposes requirements for automatic start of the model, data formats and model parameterization. If the model does not directly support the automatic start and is preferred within the first criterion it was necessary to attend the automatic start in the programme.

It is necessary to satisfy the third criterion to facilitate the pre-processing of the input geodata and post-processing of the models outputs.

For the first stage of the FLOREON project the following programmes have been chosen:

Rainfall-runoff models:

- HEC-HMS,
- HYDROG,
- MIKE SHE,
- SIMWE.

Hydrodynamic models:

- MIKE 11,
- HEC-RAS,
- Own 1D and 2D models.

13 GATHERING AND PRE-PROCESSING INPUT GEODATA

As mentioned above the factors affecting runoff from precipitation were listed and these factors were, in term of their changes, dynamic divided into three groups:

1. Factors relatively unchangeable, changes occur rather by jump,
2. Factors changing relatively slowly, in a horizon of at least days and with a variable speed of change,
3. Factors changing relatively fast, in a horizon of tens of minutes.

Each of these factor groups requires a different approach to gathering and updating the relevant geodata. These factors groups all have only two things in common:

- Necessity to record continuously all changes, in order to be able to determine retroactively the state valid in a given period of time,
- Common spatial and temporal frameworks, which must be preserved to sustain the consistency of the entire system.

Ad 1) Treatment of the first group of factors is relatively the least demanding. Here a single acquisition of geodata is assumed, along with subsequent updates. Depending on the geodata type it can be performed either periodically in time intervals specified here (e.g. as for the data of the real estate cadastre it is a period of 3 months, as for the topographic geodata once a year) or ad-hoc according to changes found in-situ. The FLOREON system in this area does not usually offer automated modules to support any of the activities. For updating the geodata current functions of the ArcGIS programme package are used, and for storing the newly generated geodata a specialized module is used, which ensures the preservation of the history of saved changes.

Ad 2) These group factors are partially supported again by an external system, e.g. remote sensing is used for processing the geodata and only then the processing results are stored through a specialized module into the database. In the future it is assumed the prediction of the parameters values will be computerized through different models in shorter time horizons that will periodically verify their results with the data acquired by an external processing (an example can be soil moisture being determined within a several-day period and in meantime derived from mathematical models).

Ad 3) The third group of factors is vital for the FLOREON system function. The group involves the input values of all mathematical models of individual sub-processes of rainfall-runoff process. The data must continuously enter into the system automatically without the necessity to intervene on the part of operators and the need to cooperate with any external system (e.g. GIS). The FLOREON system offers all modules needed for continuous input of geodata delivered by external subjects (Czech Hydrometeorological Institute, Odra River Basin) and storing it into the central database along with recording the history of changes.

14 PREPARATION FOR MODELLING

The data preparation for modelling hydrological processes can be in principle divided in two areas:

1. Territory schematization for needs of individual models (rainfall-runoff, hydrodynamic),

2. Pre-processing and import of dynamic geodata (time series of hydro meteorological geodata).

Such division has a versatile validity; however, the real extent of the geodata being processed is a product of the modelling purpose, the model used and the methods selected. Here software tools have a considerable advantage as they offer several methods of hydrological and hydraulic transformations as well as advanced tools for processing the input geodata. It is true as well that today especially in the first area GIS analytical tools are often used, so the stage of the geodata processing may be called the GIS pre-processing. The leading manufacturers of hydrological models such as DHI/MIKE, USACE/HEC or AQUAVEO support this approach.

If we describe the first area as a process within the preparation of the rainfall-runoff model, it predominantly concerns a transfer of real conditions of river basin into a schematic expression of key hydrological parameters which the model is further able to work with - to perform a simulation of the hydrological system behaviour. The key geodata for the process are especially as follows:

1. Digital Terrain Model (DTM),
2. Hydrographical data (drainage network, water areas),
3. Data on soil conditions,
4. Land use and land cover (LULC).

While using the GIS pre-processing tools or our own hydrological models we are able to perform within this data file a complete schematization of river basin herewith that also the pre-processing tool of type HEC-GeoHMS or TOPAZ, or perhaps the adequate tools in ArcGIS or GRASS are able to derive the hydrographical network.

At the level of the hydrodynamic model schematization the situation is rather more complex, as the preparation of a correct hydrodynamic model requires also manual actions especially in the area of finalization of stream cross sections. Advanced tools such as HEC-GeoRAS or MIKE 11 GIS are able indeed to generate the cross sections directly from DTM, but owing to the small spatial resolution of currently available DTMs some errors occur in such generated cross sections that must be eliminated. Fortunately the models of types HEC-RAS and MIKE 11 offer an advanced user interface that considerably facilitates the work.

The processing is performed whenever substantial changes occur in the territory, which cause the model behaviour to differ from the hydrological system behaviour.

In the area of time series processing it concerns mostly interpolations and extrapolations of missing values within a measuring device (e.g. precipitation gauge station, water level or discharge gauge station) and check of homogeneity of time series (e.g. the monitoring of rate-of-rise of water flow values or hour rate of precipitation). Further, also spatial interpolations of geodata may be made, especially of precipitation or thermal data. Standard methods such as kriging and co-kriging, IDW or spline are combined here with more advanced methods that reflect e.g. the terrain morphography and troposphere stratification.

If we intend also to forecast the hydrological system behaviour in future time segments, the input time series must be as well completed with a prediction of major meteorological elements (especially precipitation and air temperatures). For this prediction most often products of the Numerical Weather Forecast System (NWFS) of types GFS, MM5/WRF, ALADIN are used. Recently still more often also so-called ensemble forecasts are used (the result is a variance of the predicted values depending on the model setting, input conditions or through the use of more kinds of NWFS) and nowcasting (very short-term forecasts using e.g. a radar).

15 MODELLING

After completing the stage of the geodata pre-processing the own simulation of the hydrological system behaviour can be carried out. Again it is here necessary to know the purpose and scenario, which the simulation is performed for. Other requirements are for the simulation in case of a standard hydrological forecast, or for example, for the scenario of the determination of forest influence on the long-term drainage from a river basin. If we confine ourselves to the needs of a hydrological forecast, which is the scenario being used most often even at the level of the FLOREON system, it involves setting a range of simulation and prediction and time step of results output. Most often the range of short-term forecast is used, i.e. 48 or 54 hours, and a one-hour step of the results output. In case of non-standard hydrological situations of flash floods or spring thaw the forecast period is being adjusted just like the time step of generation of outputs.

The manual start of a simulation requires setting these parameters along with the marginal and initial conditions of solution. However, at the level of the FLOREON system we have implemented the automatic start of the models. Therefore these settings are performed automatically using algorithms for their derivations from current hydrological conditions at the river basin.

After performing a simulation the results are checked by way of running a comparison of the simulated hydrograph (graph of flow rates) and the hydrograph measured. Based on this comparison a skilled worker is able to adjust the key model parameters so the conformity is as good as possible. The process is called model calibration, where advanced modelling tools simplify the activity to a great extent by means of e.g. statistic functions and automated derivation of optimum values of calibration coefficients. In a system such as FLOREON these operations have to automatically run again to ensure continuous routine operation.

After performing the calculations of the rainfall-runoff process, when hydrographs for required cross sections at the river basin are produced, a calculation of a hydrodynamic model can be done, where the output of the rainfall-runoff model enters into this type of model as marginal conditions. The hydrodynamic model solves numerically in detail the transport and transformation of the water continuum in stream segments and water management premises and if a local river overspill occurs, the range of flood is solved within GIS post-processing.

Even this activity runs in the FLOREON system automatically and through the use of more types of models.

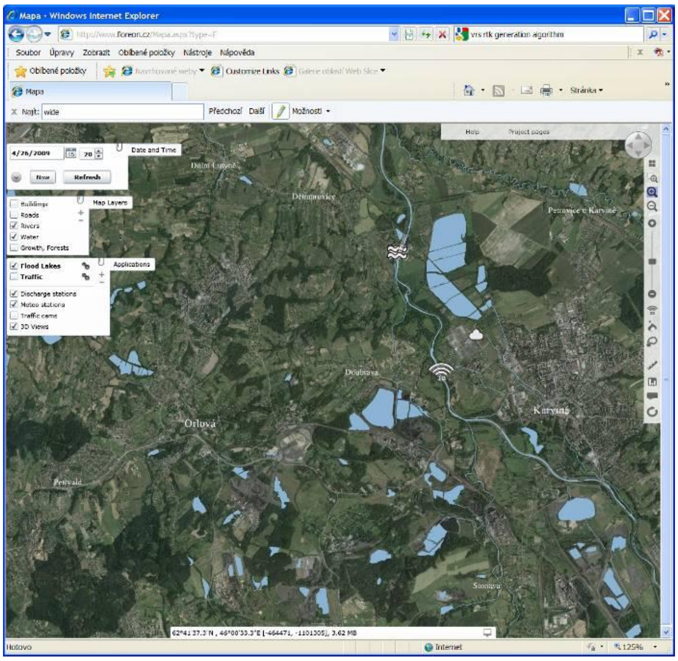

Fig. 5. Introductory map of FLOREON+ for visualization of information from the area of flood monitoring and forecasting.

16 PRESENTATION OF FLOREON+ RESULTS

The FLOREON+ system exists in a derivative version that however already shows a full functionality for hydrological modelling for flood prediction and a partial functionality for transport monitoring. The web interface of the system exists both in Czech and English versions. After entering the system and moving to the page devoted to floods we can see a map of a part of the Moravian-Silesian Region focused on the testing area of the junction of the Stonávka brook and the Olše river (Figure 5). Through the map we may obtain actual information on the water discharge in the points of gauging stations or values of basic meteorological elements in the points of meteorological stations (Figure 6). One needs only to place the mouse cursor over the appropriate symbol representing the given station. In case of need it is possible to obtain also the information related to the development history for the elapsed week (Figure 7). In this case it is necessary to click on the symbol by the mouse. In this way the system input geodata are visualized virtually.

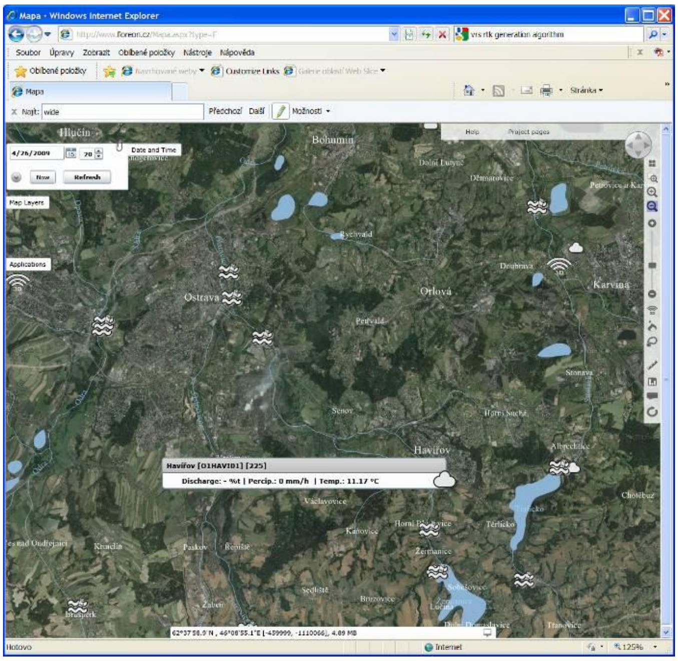

Fig. 6. Visualization of actual data from a meteorological station.

One of possible modelling outputs is shown in Figure 8. To visualize the development for the last week also the prediction of the situation development for 36 hours ahead is connected, acquired based on the models integrated into the FLOREON system. The prediction calculations run automatically every hour so it is possible to compare relatively quickly the models behaviour with the real situation development in situ.

Figure 9 provides an illustration of another visualization – predicted inundation that occurred on September 7, 2007. The real range of the inundated area was smaller in this case. The thing is the used terrain relief data did not involve the existing flood-control dam that reduced the overflowing.

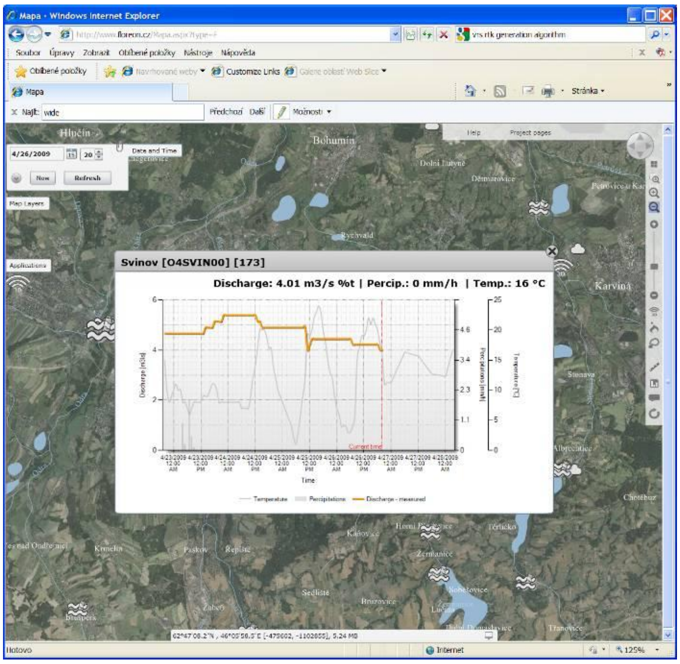

Fig. 7. Visualization of data history from a gauging station for the last week.

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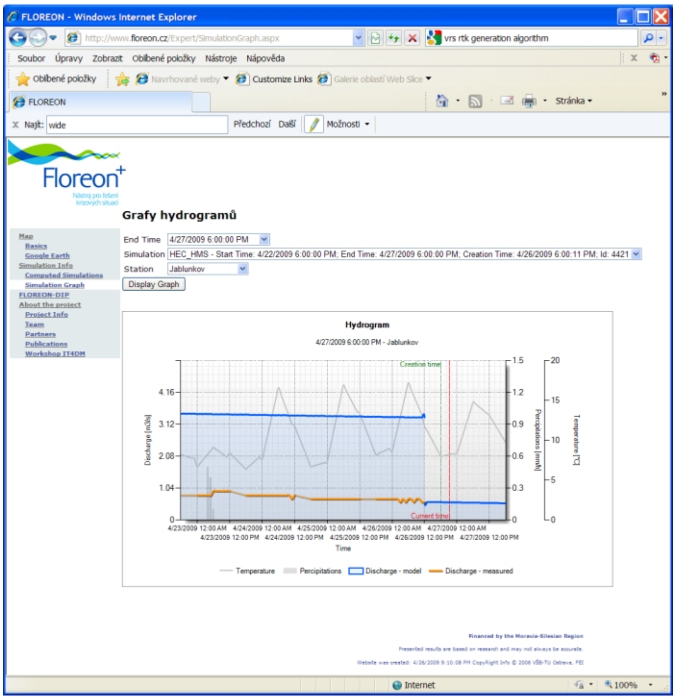

Fig. 8. Visualization of data history from a gauging station for the last week together with a development prediction for 36 hours ahead.

And finally, in Figure 10 there is an illustration of an output from the new part of the system devoted to the monitoring of road traffic. The individual road elements are coloured according to average speeds of vehicles. The data are gathered in real-time through cars fitted with GPS receivers and on-line communications with the central server from which the data travels into the FLOREON+ system. The map further contains also symbols representing cameras located at intersections and monitoring the actual traffic situation. When placing the mouse cursor over the appropriate symbol a window opens with on-line visualization of the situation at the intersection.

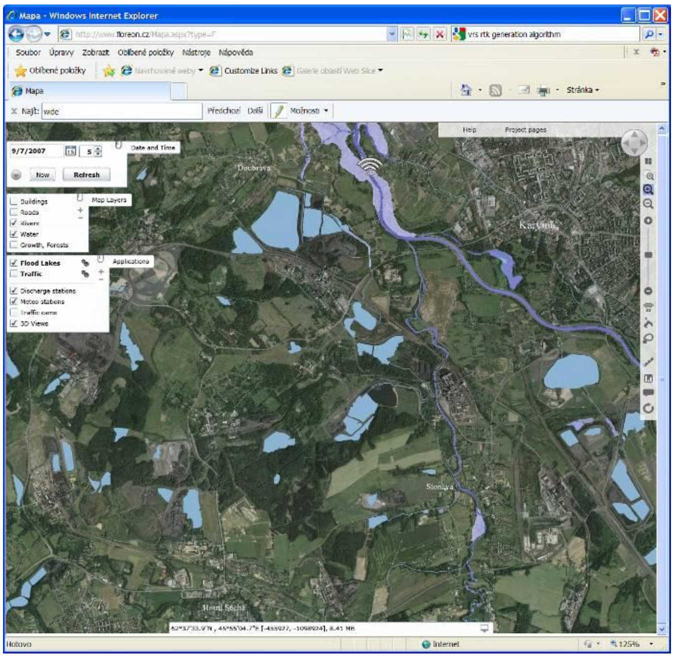

Fig. 9. Illustration of a prediction of an inundated area as of September 7, 2007.

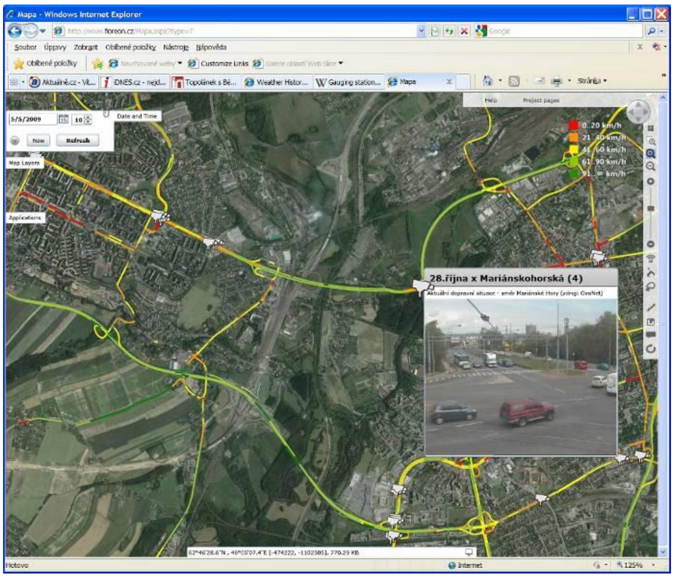

Fig. 10. Output of a part of the system devoted to road traffic monitoring. In the cut there is illustrated actual output from one of cameras (situation at ca 9:30 p.m.).

16 CONCLUSION

Although the FLOREON system has been primarily developed for predicting floods and support of coping with them, its open architecture allows a gradual extension of its functionality for other types of crises such as releases of hazardous substances into the air or water, forest fires, road transport collapses and others. Experience confirms the correctness of the selected conception and technologies used. The integrated application of information and geoinformation technologies and mathematical models offers an unprecedented functionality that enables an integrated processing of the geodata and geoinformation covering a wide scale of potential emergency phenomena in the territory.

At an early date we expect an extension of the functionality of the FLOREON+ system to cover the entire area of the Moravian-Silesian Region, and perhaps also other regions of the Czech Republic. Planning is underway for converting the system so that it can be routinely operated within the supercomputer centre (whose construction is planned for the coming years at the VSB-Technical University of Ostrava). This will allow running simultaneously variants (so-called ensembles) of the individual model so as to evaluate the variants of possible future situation developments. And lastly, our objective will be to integrate the FLOREON+ system into the Integrated Safety Centre of the Moravian-Silesian Region that is supposed to commence its full operation in the year 2011 (IBCMSK 2009).

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RESUMÉ

Českou republiku zasáhlo v posledních 15 letech několik vln rozsáhlých katastrofálních povodní. K tomu se přidává stále častěji další fenomén, náhlé povodně způsobené přívalovými srážkami, též často označované jako „bleskové povodně“, které sice zpravidla zasahují malé oblasti, ale za to s velkou rychlostí a vysokou intenzitou působení. Jejich výskyt a důsledky ukázaly potřebu vývoje propracovaného a specificky orientovaného systému informační podpory krizového řízení, zahrnujícího průběžné monitorování vodní složky v krajině, detekování limitních stavů, poskytování včasné výstrahy záchranným složkám a na podporu zvládání těchto situací.

Na Vysoké škole báňské – Technické univerzitě Ostrava je na základě požadavku Moravskoslezského kraje vyvíjen ve spolupráci řady pracovišť několika fakult speciální informační systém, který byl v prvopočátku zaměřen především na průběžné vyhodnocování povodňového rizika pro potřeby integrovaného záchranného systému. Systém dostal název FLOREON (z angl. FLOods REcognition On the Net).

Ve světě byla realizována celá řada projektů, zaměřených na vybudování systémů včasné výstrahy před povodněmi. Jejich společnými nevýhodami jsou integrace pouze specifických hydrologických modelů, zaměření se jen na konkrétní lokalitu a většinou orientace pouze na problematiku povodní. Systém FLOREON je koncipován tak, aby těžil z dobrých zkušeností těchto projektů a eliminoval jejich nedostatky.

Vodní složka krajiny je velice důležitou součástí přírodního prostředí. Je to navíc složka velice dynamická. Z koloběhu vody v krajině nás pro potřeby povodní zajímá především tzv. srážko-odtokový proces. Ten se skládá z celé řady podprocesů, které spolu interagují. Pro tyto podprocesy jsou sestavovány různé modely. Většinou však tyto modely pracují samostatně, nejsou navzájem provázané a neumožňují tak komplexní modelování vodní složky krajiny.

Pokud dojde ve srážko-odtokovém procesu k extrémnímu výkyvu, nastanou buďto extrémní sucha nebo povodně. Obě tyto situace jsou z hlediska krizového řízení významné, mohou vyžadovat zásahy složek integrovaného záchranného systému.

Chování vody v krajině je ovlivněno celou řadou faktorů (pokryv a využití území, nasycenost území, hospodaření s vodou v krajině apod.). Některé z těchto faktorů lze považovat za statické, jiné vykazují

dynamické chování. Statické faktory lze mapovat a získané mapy lze používat relativně dlouhou dobu s tím, že se jednou za poměrně dlouhou dobu provádí jejich aktualizace. Dynamické faktory však je nezbytné průběžně monitorovat. Jak mapy, tak i výsledky monitorování se používají jako vstupy pro modely.

Systém FLOREON je budován jako rozsáhlý modulární informační a monitorovací systém, umožňující průběžně sledovat zájmové území. Sdružuje databáze statických i dynamických geodat, je schopný generovat vstupy pro různé modely, přebírat jejich výstupy, ty dále analyzovat a výsledky vizualizovat pro potřeby koncových uživatelů (složky integrovaného záchranného systému, veřejná správa, v omezené míře občané).

Obecné modulární řešení, které vytváří určitý rámec pro integraci různých modelů, umožňuje systém dále rozšiřovat jak co do rozsahu zájmové oblasti, tak i codo monitorování a modelování dalších rizikových faktorů, jako je znečištění ovzduší, kolapsy dopravy, úniky nebezpečných látek apod. Toto rozšířené pojetí vedlo i k modifikaci názvu systému na FLOREON+.

V současné době FLOREON+ nabízí kromě problematiky povodní i informace o dopravě a pracuje se i na integraci problematiky modelování stavu ovzduší. Webové rozhraní systému je dispozici na adrese http://www.floreon.eu.