Project RIOT – "Ring of Threats" as an example of a Decision Support System (DSS). Concept and realization

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Abstract: The current state of knowledge and the latest trends and examples of decision support systems (DSSs) are presented in this paper. Special emphasis was placed on a DSS proposal based on post-processed numerical weather forecasts operating in a real time. There is an essential need for decision support systems that can react to any incidents – including those that pose a risk to the natural environment or human activity in general. For this purpose an exemplary system has been prepared, which was – from its conception to implementation – the original idea of the author. The system enables communication with the user via a graphical user interface that controls the operation of the program, the course of the algorithm and the data flow. The system is modular, allowing the connection of other applications to carry out the work of a DSS. A basic view of the operating window and working panels have been designed for proper demonstration of various types of information and visualizations – the substantial products and results of the system. Further research in the field of DSS of this kind should be the implementation within the RIOT system of mechanisms of notification and response to crisis events related to extreme weather phenomena (whirlwinds, intensive rains, strong frosts or heats).

Keywords: Decision Support System, hazards, incidents, warning, weather forecasts

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1. Introduction

An essential tool for supporting the efficient use of information is an information system (Harsh 1998) which allows the collection of data and it's processing into an easily readable form and shape. Specialized information systems, which generate information useful for decision-making in specific cases, together with presentation in a form that facilitates their use (for example, by providing a range of solutions with an indication of the best solutions in terms of specific criteria), are called decision support systems (DSSs). A decision support system is a system for providing information and knowledge, used for decision making, mostly by executives at the medium or high level and corporate analysts. As a result, the use of DSSs can result in reports and listings that are provided within the framework of management information systems executives (Executive Information Systems – EIS). Therefore, DSSs are often referred to as a specialized – dedicated to specific applications – form of EIS. The same concept of "Decision Support Systems" was described by Morton (1971) for the first time in his dissertation. The term "Decision Support Systems" also appeared in the early 1980s in the United States and Europe, including in Poland. With the start of the construction of microcomputers, DSSs could be made easily available. Over the past years the name of programs for supporting decisions changed from EIS through DSS to BI (Business Intelligence). The three basic components of DSS architecture are (Holsapple, Whinston 1996): a database (or knowledge base or metadata-base, that is, a database of data), a model (for example, a model of the decision-making criteria, user-defined) and a user interface (where the user himself is an essential part of the architecture).

DSS technology levels (in terms of software and hardware) can include (Laudon, Laudon 2000):

- specific applications that will be used by the user. These are parts of an application that allow for a decision on a given problem to be made.
- a generator with a software/hardware environment that enables the smooth development of the DSS application's specifications and
- tools, including software and/or lower-level equipment, generators, DSS-containing languages, library functions and linking modules.

Good examples of DSSs – in terms of response to crisis events of radiation safety – are ARGOS (see e.g. Hoe et al. 2009) and RODOS (Ehrhardt et al. 1993) systems (delivered to the NAEA as part of a bilateral agreement by the Danish government and by the European Commission, respectively). Since the end of the 1990s, these systems have operated at the Centre for Radiological Events (CEZAR)

– a department of NAEA. The systems perform predictions of possible dispersion of radioactive contamination in the air and food chains, as well as risk assessment of a radiological emergency resulting from radiation events related to nuclear accidents. These and similar systems were prepared as a result of experiences following the accident at Chernobyl; this however, reduces their applicability to nuclear and radioactive contamination incidents.

2. The concept, goals and products of the project

The RIOT project is designed to assist in determining the response to the occurrence of potential danger to Poland associated with at least two types of risks:

1. Anthropogenic threats, which are primarily results of an incident at a nuclear power plant (or power plants) in neighboring countries, and ways to respond to this threat (see fig. 1, locations of nuclear power stations in Europe, and fig. 2, nuclear power plants at a distance of up to 300 km from the Polish border) as well as other disasters or failures of emission incidents that cause environmental pollution with toxic substances (more generally, dangerous substances);
2. Natural threats and events, such as volcanic eruptions and their impact on general transport safety, in particular air transport (see fig. 3, location of volcanoes in Europe).

The main objective of the project is to raise the security of Poland in the context of the nuclear installations in neighboring countries and to enhance the safety and "smoothness" of air traffic over Poland in the case of volcanic eruptions, which may result in the introduction of an interim ban on flights over part of or over the entire area of Poland, together with the ability to respond to other releases of hazardous or toxic substances. The specific objective of the project was to develop a decision support system in the event of failure at a nuclear installation or of a volcanic eruption, combined with emissions to the atmosphere of volcanic dust (in future – substances like sulfur dioxide, hydrogen chloride, sulfide or fluoride or ammonia), dangerous to environment and people.

The results, which consist of a decision support system, can be used to identify the reactions in many dimensions (social, economic, environmental, etc.) to a possible incident at a power plant (or power plants) or nuclear particulate emissions of volcanic gases into the atmosphere. The lack of such a system, generally speaking, may cause delays in the response to crisis situations and, critically

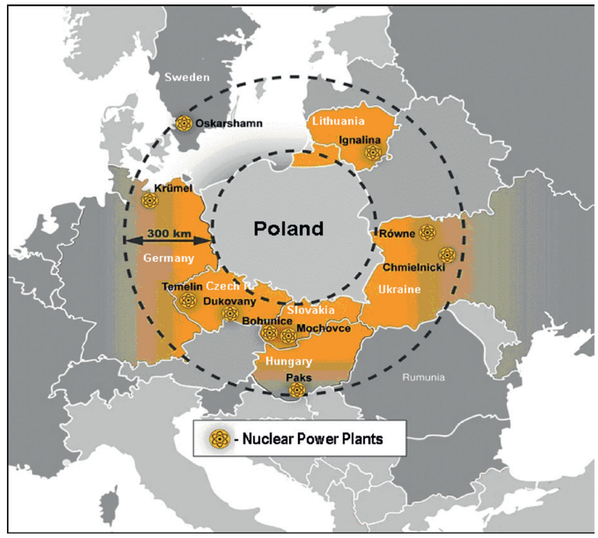

Fig. 2. Nuclear power plants up to 300 km from the Polish border (http://elektrownia-jadrowa.pl/Elektrownie-jadrowe-na-swiecie-i-wokol-Polski-1.html)

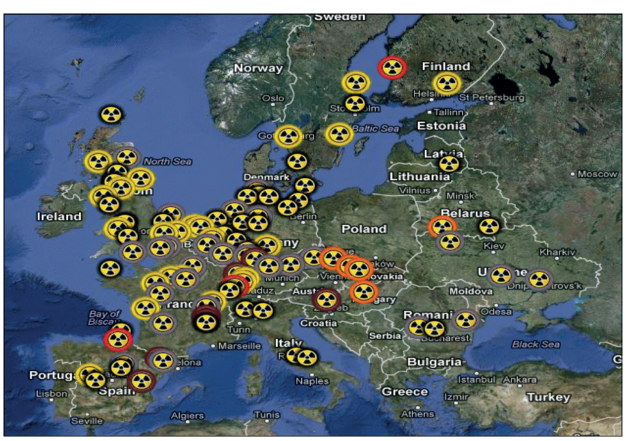

Fig. 1. Locations of nuclear power stations in Europe (except in the European part of Russia – no data available). Legend: high risk reactors: Red – the type used in the Fukushima Daiichi NPP; Orange – inadequate security; Yellow – older than 30 years; Brown – located in a seismically active region. Other: Gray – under construction; Black – turned off (https://www.global2000.at/en)

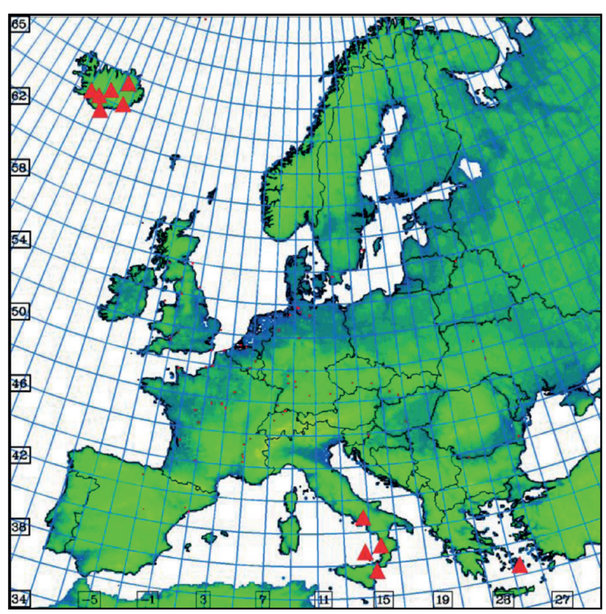

Fig. 3. Location of volcanoes (red triangles) in Europe

this may result in wrong decisions, which can be disastrous. The details of the concept and implementation of the system are described in the following chapters.

3. Realization

This application has been designed to ensure comprehensive support for users in terms of information about the potential consequences of nuclear accidents, as well as of the volcanoes in Europe. In general, the system can be used to prepare estimates of the effects of many incidents and accidents *in statu nascendi*, such as intense forest fires or road traffic accidents linked to the issue of toxic substances (Mazur et al. 2014b). The system was prepared in such a way as to assist the user in the process of making (suggesting) decisions related to such events. The system allows for the interactive definition of the parameters of an event (the location, the duration of the event or time horizon predictions). It also generates reports with the results of the work, in the form of text and graphics with the use of the DISLIN library of procedures (http://www.dislin.de). Hence the system should perform the following actions:

- download meteorological input data, prepared for the current day,
- parse them into a form and format required by the calculation module,
- read-in all user-input parameters, specifying the details of the event (accident, incident) to be assessed,
- simulate the dispersion of contamination,
- process results as required by the user,
- present processed results.

The main requirement of the system is an access to the Internet[1], preferably through the technology of symmetrical DSL (Digital Subscriber Line), support for http(s) and ftp, and sufficient space on the user's server to store the input data together with the results of the calculations (estimates of pollution dispersion) afterwards. Meteorological data should be downloaded as soon as they are available (i.e. as soon as a new meteorological forecast is prepared). The choice of data source depends on the application. In this particular case the meteorological data are the result of the GFS (Global Forecasting System) model of NOAA.

The system is supposed to work in an interactive mode in the graphical user interface (GUI). The interface is as far as possible based on the intuitive use of standard computer accessories (keyboard, mouse/other pointing device). It also allows to control the operation of the system, starting with the simplest tasks (selecting data and input parameters), to obtain the output result (hazard forecast in graphical form), along with the functionality of the system cleanly (log entry, a printout of the results). Window layout was created to be ergonomic and easy to use even for novice users, and – especially for beginners – to minimize the possibility of an error preventing further work on the system.

The interface has been implemented in the HTA (HTML Application, or a combination of HTML, CSS and Javascript in dynamic HTML), with attached executable application (.exe files and dynamically linked libraries of functions and procedures .dll[2]). GUI system is designed ergonomically and, at the same time, simple, functional and intuitive. In general, the GUI is divided into several areas with different purposes (workspace, display of the data area, action buttons, etc.), according to the standards of ergonomics (see e.g. Pearrow 2000; Sikorski 2009). In figure 4 an overall view of the user interface is shown.

The functionality of the entire interface can be divided into three basic areas:

1. The introduction of input data (panel on the left side of the screen), with elements of a drop-down type list, combo fields to enter the required values, and action buttons. All these elements are programmed in Javascript or CSS, in order to handle user interaction with the system in an appropriate way.
2. Central area (map of Europe in the middle of the screen) with two basic functionalities – selection of emission point and presentation of results in the continental scale.
3. The results of work for Poland – panels on the right side of the screen – presentations of forecasts of dispersion trajectories and a hazard level – a percentage of the maximum value of the dangerous substance concentration in the air.

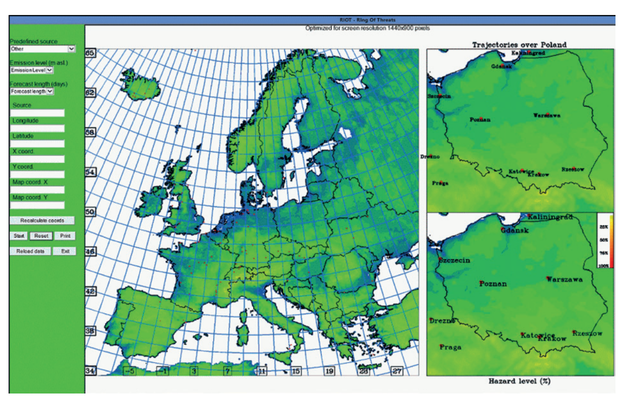

Fig. 4. An overall view of the user interface

[1] A constant internet access would the ideal solution. However, in crisis situations it is hard to achieve. Anyhow, it should be fast enough and uninterrupted enough to load input data and to send results afterwards.

[2] Because the technology HTA is used, the DSS operates under Windows (starting from XP with Service Pack 3 and Internet Explorer 8)

Summing up, (i) a visual interface to control the operation of the program, the course of the algorithm and data flow, which in a simple and intuitive way allows for the entering of specific values was created as a result of the project, (ii) main window and the window's panel schemes were worked out to display various types of information, (iii) visualization of system products was prepared and implemented.

4. The results of implementation of the project

Over time, the catastrophe at the Chernobyl nuclear power station has become – in some way – a kind of test-bed, where a variety of concepts, models and simulations, and environmental and hazardous contamination analyses were tested (Strupczewski 1987; Nodop 1997; Trojanowski et al. 2006; http://www.oecd-nea.org/rp/chernobyl/c02.html). Hence, the first example of the application of a decision support system, described in this study, also applies to this event. In figure 5 there are examples of prints from the RIOT system, prepared using historical meteorological data (forecasts on 27.04.1986, 00:00 UTC, with time horizon of 120 hours).

On 16 July 2007, near the village of Ożydiw in the Lviv' oblast in Ukraine, a freight train carrying highly toxic yellow phosphorus from Kazakhstan to Poland was derailed. Fifteen tanks of the train off the track, six of them were in flames, and, as a result of the accident, a cloud of dangerous fumes was released into the atmosphere. According to the reports from the Ukrainian side, a toxic cloud covered an area of about 90 km^2 around the scene of the accident. From the imminent danger zone about 900 people were evacuated. There were about 11,000 people in the area adjacent to the accident site. The first reports suggested the impact of the accident to be as severe as in the Chernobyl case, but thankfully it turned out not to be such a nightmare scenario.

In agreement with the National Headquarters of The State Fire Service (responsible for the security of the country in terms of protection against chemical contamination), IMWM-NRI has conducted simulations of dispersion of pollutants from the accident. Both of the studies carried out on an ad hoc basis, as well as systematic calculation after the incident, showed that until the fire was extinguished (18 July) the pollution released into the atmosphere could reach Poland during the entire period of emission. In figure 6 results of the simulation are shown – a dispersion of a chemical contamination cloud, from July 16th to 20th, 2007 (for comparison see e.g. Mazur et al. 2014a).

Another example of the application of the system was to present the results of the simulations of the dispersion of volcanic dust during the second eruption of Eyjafjallajökull (the volcano in Iceland), which began on April 15th, 2010. In figure 7 there are examples of prints from the RIOT system, prepared using historical meteorological data (forecasts on April 15th, 2010, at 00:00 UTC, the time horizon of the 120 hours) is shown.

All necessary meteorological data (in standard WMO format GRIB – Gridded Binary) for the above historical cases have been obtained from the ECMWF.

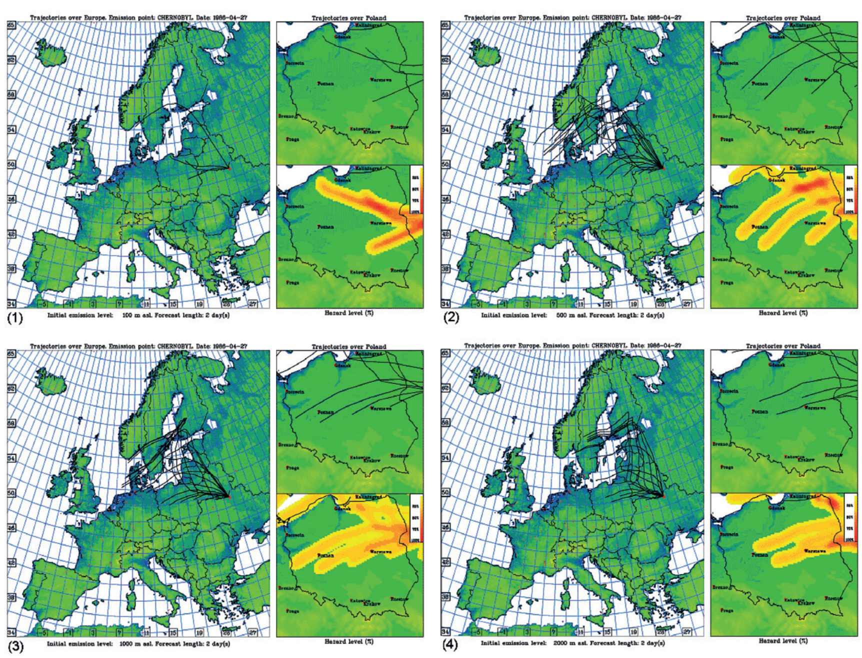

Fig. 5. Interface of RIOT decision support system – simulation of the dispersion of radioactive contamination as a result of the disaster at the Chernobyl nuclear power-station (April 27th to May 1st, 1986). The length of the forecast – 5 days. Charts show the look of the interface as a result of calculations of various effective emission heights: (1) 100 m, (2) 500 m, (3) 1000 m and (4) 2000 m above sea level

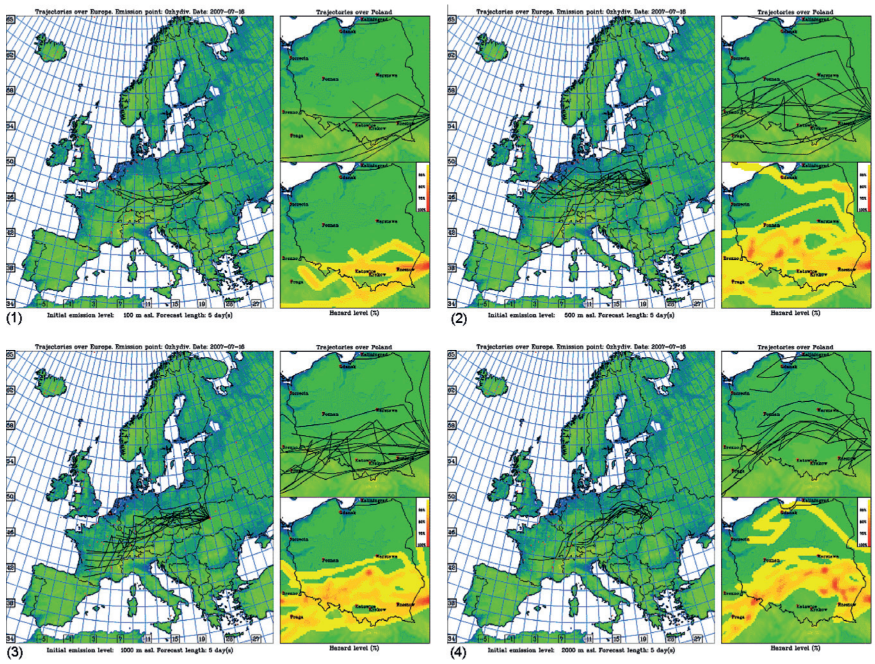

Fig. 6. Interface of RIOT decision support system – simulation of the dispersion of toxic substances as a result of the accident near Ożydiw (16-20.07.2007). The length of the forecast – 5 days. Charts show the look of the interface as a result of calculations of various effective emission heights: (1) 100 m, (2) 500 m, (3) 1000 m, and (4) 2000 m above sea level

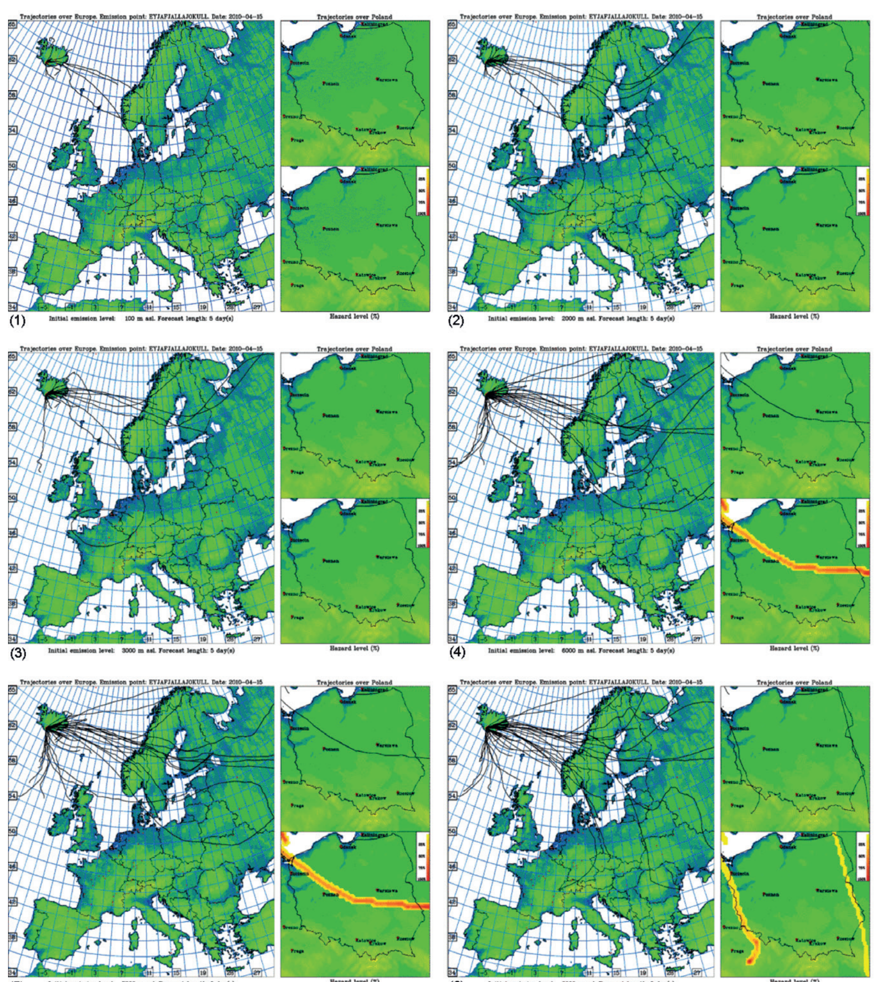

Fig. 7. Interface of RIOT decision support system – simulation of the dispersion of volcanic dust due to the eruption of Eyjafjallajökull (15-19.04.2010). The length of the forecast – 5 days. Charts show the look of the interface as a result of calculations of various effective emission heights: (1) 100 m, (2) 2000 m, and (3) 3000 m, (4) 6000 m, (5) 7000 m and (6) 8000 m above sea level

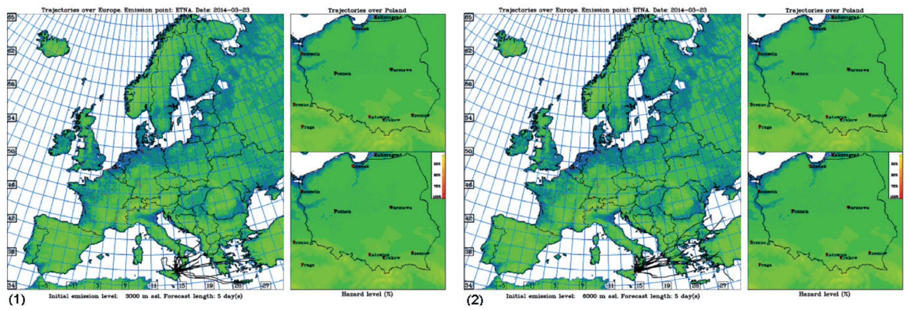

Fig. 8. Interface of RIOT decision support system – simulation of the dispersion of volcanic dust due to the eruption of Mount Etna volcano on March 23rd, 2014. The length of the forecast – 5 days. Charts show the look of the interface as a result of calculations of various effective emission heights: (1) 3000 m and (2) 6000 m above sea level

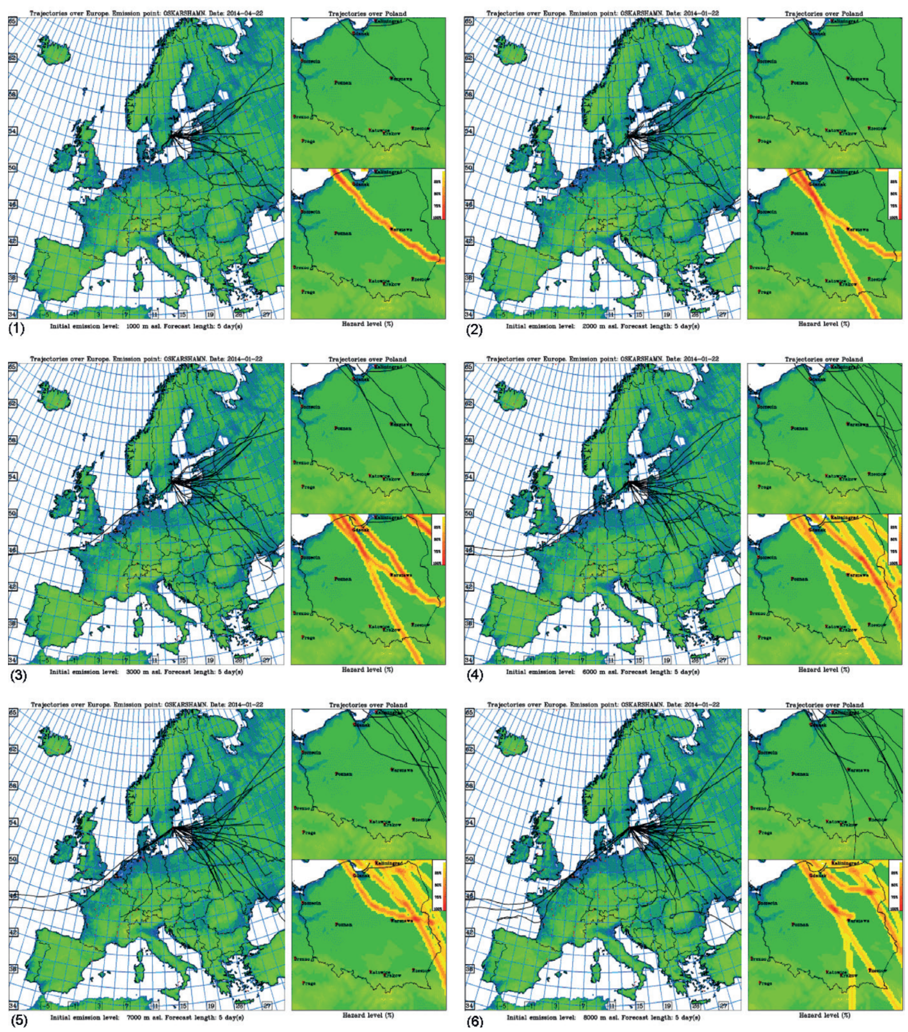

Fig. 9. Interface of RIOT decision support system – simulation of the dispersion of nuclear contamination as a result of a hypothetical accident at the nuclear power plant at Oskarshamn, January 22nd, 2014. The length of the forecast – 5 days. Charts show the look of the interface as a result of calculations of various effective emission heights: (1) 1000 m, (2) 2000 m, (3) 3000 m., (4) 6000 m, (5) 7000 m and (6) 8000 m above sea level

In turn, in fig. 8-10 the results of exercises with RIOT system are presented. These exercises covered practically all possible types of incidents, like an volcano eruption (fig. 8, volcanic eruption of Mount Etna), through a failure at a nuclear power station (fig. 9, hypothetical failure at nuclear power plant in Oskarshamn, Sweden), to a "classic" incident from the scope of the environment protection – as a result of the problems in conventional (coal heated) power plants (fig. 10, dispersion of toxic substances as a result of a failure in the Bogatynia power plant).

All of the above cases (exercises performed with the use of RIOT) serve to assess the readiness of the system to work, as well as to evaluate its results. These exercises also have to estimate the speed of system response to any

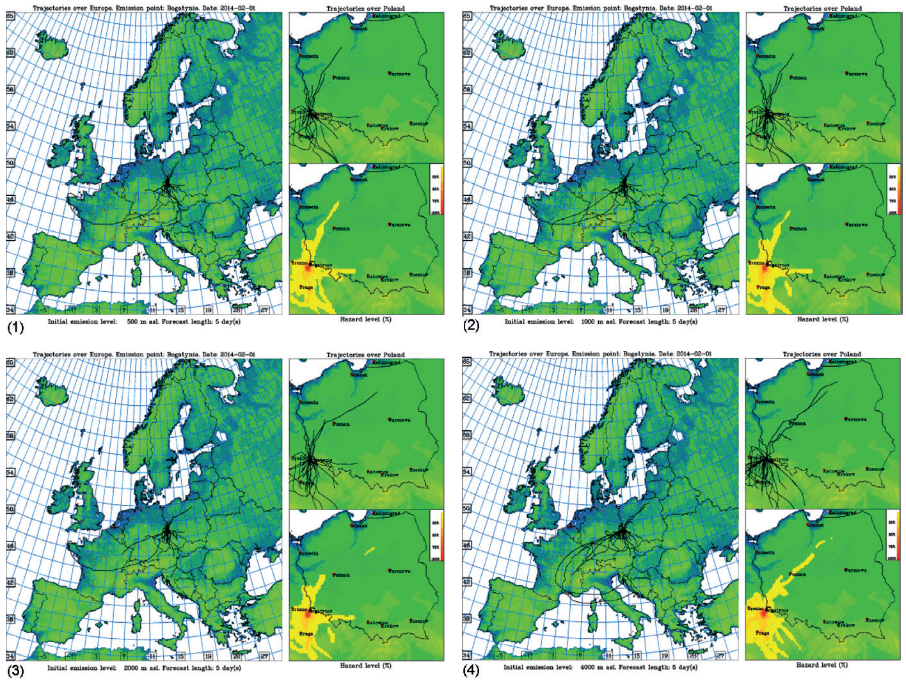

Fig. 10. Interface of RIOT decision support system – simulation of the dispersion of toxic substances as a result of a hypothetical failure at the Bogatynia power plant, February 1st, 2014. The length of the forecast – 5 days. Charts show the look of the interface as a result of calculations of various effective emission heights: (1) 500 m, (2) 1000 m, (3) 2000 m and (4) 4000 m above sea level

threat.[3] A possibility to generate reports about simulated incidents, based on the results of the work of the system, was also an important part of tests.

In that setup, in a sense, the diagnostic system generated results that, after clarification of our knowledge of an incident (for example, the amount of emissions), have served as an contribution to the larger report about causes, extents and consequences of a incident. However, the basics of the system consist primarily of forecasts that act as a basis for decision support in case of emergencies.

5. Discussion and summary of results

There is a need for a system to respond to an occurrence of an emergency situation in the sense of environmental hazards or, in general, of human activities. This system should be able to provide support for information about the further development of events, with the forecast of the status of the environment and the possibility of the negative impact of various factors on the population (human communities) within range of this impact. In view of the plans to build a nuclear power plant in Poland, it seems necessary to prepare tools that would allow errors to be avoided, or at least their negative effects to be minimized during the realization of these plans. A decision support system should be considered one of such tools, the use of which would be solely for the benefit of the many branches of the economy, from energy transport, but also for socially-oriented areas for departments, in terms of response to crisis events.

System RIOT has been prepared for the purposes of responding to these needs. It should be pointed out that it has been implemented in the Institute of Meteorology and Water Management – National Research Institute since the end of the project's research phase. It is installed in the Department of Numerical Weather Forecasts – COSMO, for exercises, tests, and screening. It should be noted that in the majority of applications, and for operational analysis and forecasting performed on an ad hoc basis, at a time when one receives information about the occurrence of an incident, the use of particle or trajectory (Lagrangian) models are more cost effective (Draxler, Hess 1997; Stohl 1996, 2000), than the more resource- and time-consuming field (Eulerian) ones (Mazur 2008). The profitability of this originates from three issues that play a key role:

1. Firstly, incidents usually are related to "point" emissions.
2. Secondly, in such cases, detailed information about the value, that is, the amount of issued contamination is usually not available.
3. Last but not least, in the case of incidents directly threatening human groups, it is not the precise concentration of contamination that is so significant, but

[3] The response time strongly depend on the speed of Internet connection and on processor speed, mainly due to loading and preprocessing of large volume of input meteorological data. Dispersion calculations themselves – in general – took no longer than several dozen of seconds.

more the mere fact that a cloud of contamination (for example, radioactive) would pass over an area of interest at all.

Applications using Lagrangian models yield a result faster and more cheaply (in terms of the required power, resources or the cost of computing). This problem is not the subject of this study and therefore was only briefly mentioned. Of course, in some cases of single emission sources the Eulerian approach to problem becomes more cost efficient. Hence, the best suitable method should be chosen and applied for the case(s).

A further direction of research in the field of DSS in the case of threats and emergencies should be an implementation to the RIOT system of a set of mechanisms of notification and response to crisis events, related to the extreme weather phenomena. The system, with access to current forecasts of the meteorological situation, and specific items (field values, indicators, etc.), could generate information, communication or warnings of the possible occurrence of extreme category phenomena, such as whirlwinds, intensive rains, strong frosts or – on the contrary – heats.

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Abbreviations: RIOT – Ring Of Threats, IMWM-NRI – Institute of Meteorology and Water Management – National Research Institute, DSS – Decision Support System, EIS – Executive Information Systems, ECMWF – European Centre for Medium-Range Weather Forecasts, BI – Business Intelligence, NAEA – National Atomic Energy Agency (Państwowa Agencja Atomistyki – PAA), DSL – Digital Subscriber Line, GUI – Graphical User Interface, html – HyperText Markup Language, http – hypertext transfer protocol, ftp – file transfer protocol, dll – dynamically linked library, hta – hypertext application, CSS – Cascading Style Sheets, NWS – National Weather Service, UTC – Universal Time Counter, GFS – Global Forecasting System, NOAA – National Oceanic and Atmospheric Administration.

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