DEVELOPMENT OF WEB-BASED ENVIRONMENT FOR ATMOSPHERIC DISPERSION MODELING

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ABSTRACT

The paper presents a new web interface to the atmospheric dispersion model HARP (HAzardous Radioactivity Propagation) which is a segmented Gaussian plume model certified for the emergency management use in the Czech Republic. Up to now, the model was available only as a desktop application. The new web-based user interface should bring the basic functionality of the model to the web environment and allow its usage on portable devices connected to the internet, e.g. tablets. The system was designed with focus on ease of use and enables to perform simulation runs of the dispersion model with different source terms and meteorological conditions. Its main application domains are education and training in the fields of atmospheric dispersion of radioactive pollutants and consecutive decision making. The system is equipped with tools for visualization of results as transparent overlays on Google Maps. With prospects of multiple concurrent users of the system, a scalable distributed framework was developed in order to ensure sufficient computational resources. Technical concepts of the system, its basic functionality and the embedded atmospheric dispersion model are described.

Key Words: Atmospheric dispersion modeling, segmented Gaussian plume model, web interface, distributed computing, education and training

1   INTRODUCTION

Nowadays, web environment is a very popular platform for sharing knowledge and providing software tools as on-line applications. It has following advantages: (i) user does not need to carry out often cumbersome installation, (ii) user always works with the latest version of the application, and (iii) user's data are securely stored on a remote server and available on every device connected to the internet. Many applications traditionally developed for the desktop environment migrate to web [1].

The trend of providing different services as web-based services is also evident in the field of emergency decision support systems focused on atmospheric events, e.g. [2], [3], [4]. The most notable example is the IXP (International Exchange Program) system hosted by the National Atmospheric Release Advisory Center (NARAC) [4]. The system provides a web interface to complex atmospheric flow and dispersion models capable of simulation of a wide range of hazards and on local-, regional-, continental- and global-scales. However, the system is not open to public and a potential user must fulfill many criteria to obtain access right, e.g. be an emergency manager in an IAEA Member State.

Our goal is to develop an easy-to-use interface to the atmospheric dispersion model HARP (HAzardous Radioactivity Propagation) [5] enabling to: (i) perform simulation runs of the model

with different source terms and meteorological conditions, and (ii) view results as transparent overlays on Google Maps. Its main application domains are education and training in the field of atmospheric dispersion of radioactive pollutants and consecutive decision making.

Architecture of the system is described in Section 2. Section 3 presents embedded atmospheric dispersion model. Demonstration of the system is given in Section 4 and we conclude up-to-now results and outline plans to the future in Section 5.

2   ARCHITECTURE OF THE SYSTEM

Web development has many different aspects contrary to the development of desktop applications. The most important is the fact that the web application must be able to serve many concurrent user at a time. To ensure sufficient computational resources without extensive investments into the hardware we developed a framework for construction of distributed computational environments using a large number of common personal computers connected to the internet (workers).
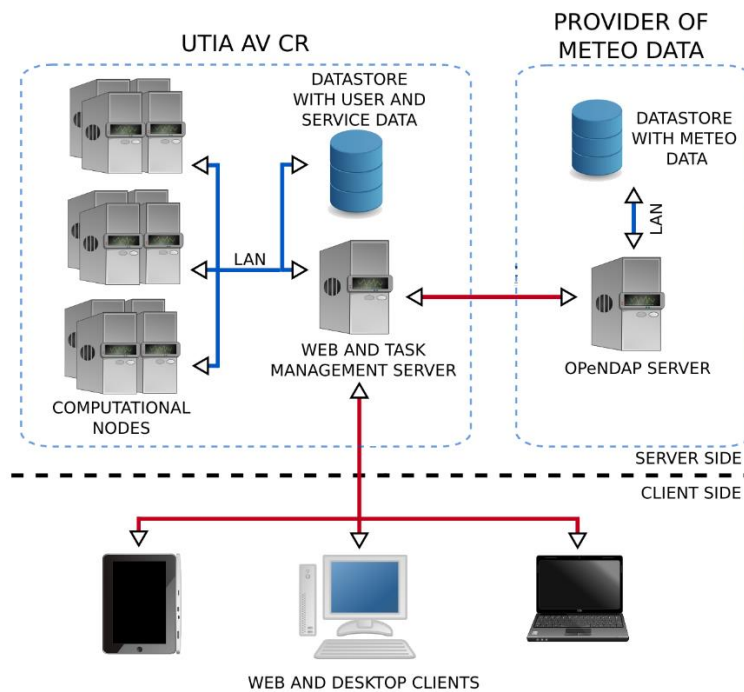

Figure 1: Architecture of the distributed computational framework.

The framework is based on the client-server architecture, Fig. 1. It core components are:

- Webserver providing web pages with user interface for configuration of tasks - simulation runs of the model.

- Document-oriented (NoSQL) database suitable for storage of various data in different formats (user data, model data, model inputs and outputs etc.).
- Task scheduler for assigning tasks to workers (computational codes).

2.1 Typical task lifecycle

Tasks (simulation runs of the model) are configures by users via web pages. Tasks are stored in a queue implemented using database. Workers-computer codes run on remote machines-repeatedly query the queue for free tasks. If a new task is inserted into the queue, an idle worker is assigned to it. Configuration of the task is sent to the worker over the internet and a simulation run is performed. When the computation is done the worker sends outputs back to the webserver where the owner of the task (user) can view results. If all the workers are busy, an inserted task is queuing until the previously entered tasks are done. Number of available workers, some of their basic properties and particularly their states (IDLE, BUSY, DOWN) can be found in Workers' list, see Fig. 2.

Worker list List of all workers registered to the system

No.	Username	Machine	IP address	System	Worker's state	Ping latency
1	worker_3	thinker.utia.cas.cz	147.231.12.248	Linux	IDLE	6 ms
2	worker_2	thinker.utia.cas.cz	147.231.12.248	Linux	IDLE	40 ms
3	worker_4	thinker.utia.cas.cz	147.231.12.248	Linux	IDLE	10 ms
4	worker_1	thinker.utia.cas.cz	147.231.12.248	Linux	IDLE	39 ms

Figure 2: List of workers registered to the system. One physical computer can host multiple workers.

Since workers communicate over http protocol, they can run without any special need of configuring firewalls etc. This design offers a good scalability and almost seamless extension of computational resources. In the case of a large number of concurrent users, e.g. a group of students in a class, the number of workers can be easily increased just by launching the worker code on computers with Linux, OS X or Windows operating systems connected to the internet. As a side effect we obtain a robust solution where the functionality of the system is not influenced by unavailability or a failure of a subset of workers.

3   ATMOSPHERIC DISPERSION MODEL HARP

HARP is a short-range atmospheric dispersion model certified for the emergency management use in the Czech Republic. It has been developed for more than 10 years and among its users is the Czech National Radiation Protection Institute. HARP was successfully validated against COSYMA, MACCS and RODOS codes.

It is a segmented Gaussian plume model focused on modelling of aerial propagation of radioactive pollutants. The model takes into account many physical processes, like radioactive decay, reflections from the ground and top of mixing layer, dry and wet deposition, buildup of daughter products, orography and land-use (for selected sites). Desktop version of HARP also contains food chain model for simulation radionuclides' propagation through the environment up to human body.

3.1   Evaluated radiological quantities

Web version of HARP evaluates the following radiological quantities with respect to the reference time T_{ref} entered by user:

- Time integrals of near-ground activity concentration in air [Bq.s/m^3].

- Deposition of radionuclides in time T_{ref} [Bq/m^2].

- Time integrals 0-T_{ref} of radionuclides' deposition [Bq.s/m^2].

Doses from the following irradiation pathways for time 0-T_{ref} are evaluated for 6 age groups:

- External irradiation from the cloud (cloudshine) [Sv].

- External irradiation from deposition (groundshine) [Sv].

- Internal irradiation from inhalation [Sv].

- Total committed doses = cloudshine + inhalation + groundshine [Sv].

- Internal irradiation from inhalation due to long term resuspension [Sv].

The model respects geometry of the plume when computing cloudshine dose. This is important for correct evaluation of cloudshine dose close to the source, e.g. in an emergency planning zone, where commonly used semi-infinite approximation is not valid [5]. The quantities are computed on a polar grid up to 100km from the source. Single model evaluation lasts from seconds to minutes, depending of the release duration and number of propagated radionuclides. This is particularly important in cases when many model runs with different setting are needed, e.g. in the case of PSA Level 3 [6].

3.2   Model inputs

User can choose and arbitrary source location over the globe. Currently, the system is localized for both Czech nuclear power plants Temelín a Dukovany. When a release is simulated from one of these two sources, the real orographic and land use data are used. For other sites the simulations are carried out with flat terrain and homogeneous land cover.

3.2.1 Source term

The model can simulate dispersion of 120 different radionuclides, see Table I. However, in order to maintain the computation time and amount of transferred data reasonable the maximum number of nuclides in a single run of the web version of the model is currently limited to 25.

The release of maximal length of 3 days can be split up to 12 segments. For each nuclide, activities released in respective segments are entered in terms of total released activity and subsequently homogenized over segments' duration into release rates.

Table I. Radionuclides supported by HARP system.

^{3}H	^{7}Be	^{14}C	^{18}F	^{22}Na	^{24}Na	^{38}Cl	^{41}Ar
^{42}K	^{51}Cr	^{54}Mn	^{56}Mn	^{55}Fe	^{59}Fe	^{58}Co	^{60}Co
^{63}Ni	^{64}Cu	^{65}Zn	^{76}As	^{85m}Kr	^{85}Kr	^{87}Kr	^{88}Kr
^{89}Kr	^{90}Kr	^{86}Rb	^{88}Rb	^{89}Rb	^{89}Sr	^{90}Sr	^{91}Sr
^{92}Sr	^{88}Y	^{90}Y	^{91m}Y	^{91}Y	^{95}Zr	^{97}Zr	^{95}Nb
^{97}Nb	^{99}Mo	^{99m}Tc	^{99}Tc	^{103}Ru	^{105}Ru	^{106}Ru	^{105}Rh
^{106m}Rh	^{110m}Ag	^{122}Sb	^{124}Sb	^{125}Sb	^{127}Sb	^{129}Sb	^{125m}Te
^{127m}Te	^{127}Te	^{129m}Te	^{129}Te	^{131m}Te	^{131}Te	^{132}Te	^{133m}Te
^{133}Te	^{134}Te	^{129o}I	^{129}I	^{129a}I	^{130o}I	^{131}I	^{131a}I
^{132o}I	^{132}I	^{132a}I	^{133o}I	^{133}I	^{133a}I	^{134o}I	^{134}I
^{134a}I	^{135o}I	^{135}I	^{135a}I	^{131m}Xe	^{133m}Xe	^{133}Xe	^{135m}Xe
^{135}Xe	^{137}Xe	^{138}Xe	^{134}Cs	^{136}Cs	^{137}Cs	^{138}Cs	^{139}Ba
^{140}Ba	^{140}La	^{139}Ce	^{141}Ce	^{143}Ce	^{144}Ce	^{143}Pr	^{144}Pr
^{147}Nd	^{147}Pm	^{153}Sm	^{154}Eu	^{187}W	^{235}U	^{238}U	^{239}Np
^{238}Pu	^{239}Pu	^{240}Pu	^{241}Pu	^{241}Am	^{242}Cm	^{244}Cm	

3.2.2 Meteorological inputs

Although the desktop version of HARP uses gridded meteorological forecasts, the web version currently uses the following hourly-variable but spatially homogeneous meteorological data entered by users:

- Wind speed at 10m [m/s] (wind speed at effective height is evaluated using power law formula)
- Wind direction at 10m [deg]
- Pasquill's stability category [A-F]
- Precipitation intensity [mm/hour]
- Inversion layer height [m]

We plan to connect the system to a database of spatially variable meteorological data with grid step 3km and 9km in the future.

4   DEMONSTRATION OF THE SYSTEM

In this section we will go through the whole process of a single model run from its initialization up to visualization of results. The run will simulate a hypothetical release from the Czech nuclear power plant Temelín.
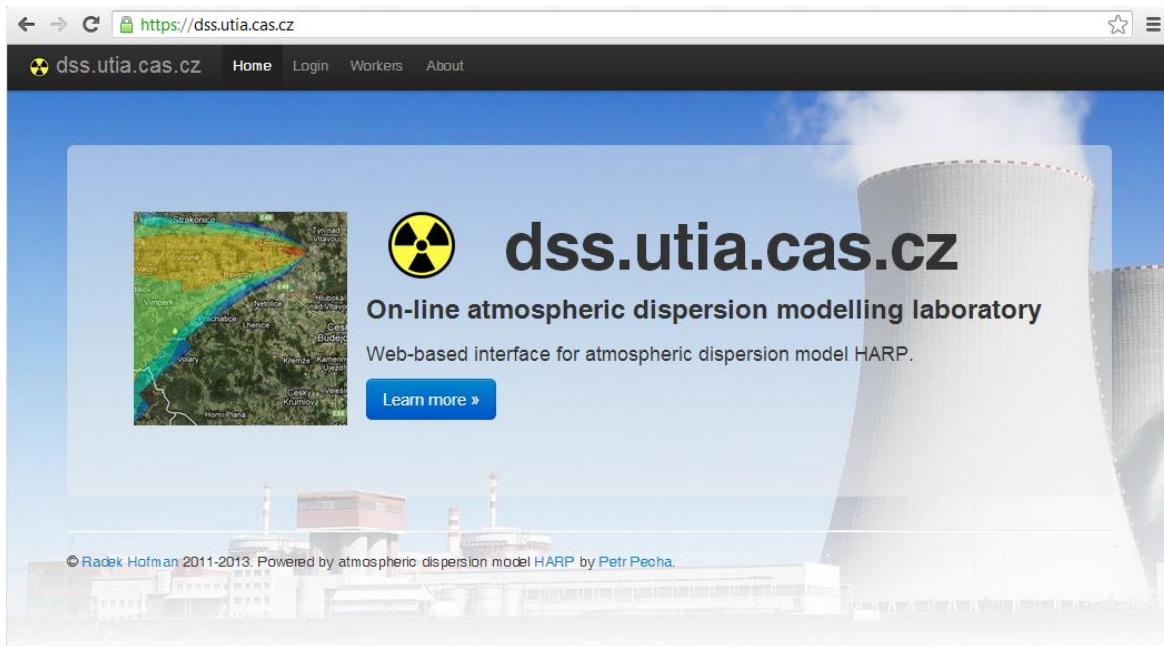

Figure 3. Browser window with the home page of the application.

The home page of the system is displayed in Fig. 3. The beta version of the system is hosted at url http://dss.utia.cas.cz. Connection is encrypted using SSL. At the top of the page, there is a navigation bar. Users can log in by pressing *Login* navigation bar entry. The way how to become a registered user of the system is described on the *About page* accessible through *About* navigation bar entry or *Learn more* button.

4.1 Initialization of a new task

After successful login, user can initialize a new dispersion modeling task. It comprises of the following steps:

1. Configuration of basic parameter of the release

2. Configuration of the source term

3. Configuration of the meteorological inputs

Each step has its own form. In the following sub-sections, each of the forms will be briefly described. After successful configuration of all inputs the task can be submitted to the task queue. As a prevention of typos and other errors, all the forms are validated and user is alerted in the case of a problem with parsing of entered values.

4.1.1   Basic parameters

This form (Fig. 4) is for configuration of the basic properties of the release. Source location is given in terms of latitude-longitude in decimal format. Source location can by validated by *Show source on map* button displaying a modal window with the source marker on a map. Dispersion formula sets the parameterization of the horizontal and vertical dispersion of the Gaussian plume model. Reference time T_{ref} is also set here (see Section 3.1).

Figure 4. Form for initialization of basic parameters of the release.

4.1.2   Temporal profile and isotopic composition of the release

Released radionuclides and number of segments can be configured using a modal dialog, see Fig. 5. Required radionuclides are selected by checking respective checkboxes. In Fig. 6 we see a panel for configuration of the temporal profile of the release – total activities released in each segment. Besides activities, each segment is characterized by its duration, thermal power, vertical velocity and release height. We simulate a release comprised of three release episodes of durations 2, 5 and 2 hours (1st, 3rd and 5th segment), respectively. Between the episodes, there are intermissions of length 9 and 10 hours (2nd and 4th segment), where nothing is released. The whole source term can be loaded/saved from/to a database using buttons at the top of the form.

Figure 5. Modal form for configuration of isotopic composition of the source term.

Properties of segments	Segment 1	Segment 2	Segment 3	Segment 4	Segment 5
Segment duration [h]	2.00	9.00	5.00	10.00	2.00
Thermal power [kW]	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Vertical velocity [m/s]	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Release height [m]	50.0	50.0	50.0	50.0	50.0
Released activities [Bq]	Segment 1	Segment 2	Segment 3	Segment 4	Segment 5
1 ^{131}I	4.00E+14	0.00E+00	6.00E+17	0.00E+00	5.00E+16
2 ^{133}Xe	1.00E+18	0.00E+00	1.00E+18	0.00E+00	5.00E+17
3 ^{134}Cs	3.27E+13	0.00E+00	5.45E+16	0.00E+00	1.64E+16
4 ^{137}Cs	2.73E+13	0.00E+00	4.55E+16	0.00E+00	1.36E+16

Figure 6. Form for configuration of the time profile of the source term.

4.1.3 Meteorological inputs

Meteorological data are entered for each hour of the release (Fig. 7). User must enter data for at least 35 hours. If the number of hours entered by the user is smaller than the duration of the release, the last hour is used for the periodic extension.

Hour	Wind direction [deg]	Wind speed [m/s]	Stab. category	Precipitation [mm/h]
1	54.0	1.3	F	0.0
2	70.0	1.5	F	0.0
3	87.0	1.6	F	0.0

Figure 7. Form for configuration of hourly meteorological inputs to the model.

4.2 Viewing of results

Viewing of results is accomplished through the *View results* page accessible from the navigation bar. A list of all user's tasks is there, see Fig. 8. In the figure, there are only 3 task. In the case of more than 5 tasks browsing buttons appear. Details of tasks can be viewed using *Action* drop-down button.

Task list Your current and historic tasks

No.	Date	Description	Status	Actions
1	16-05-2013 19:23:39	Dukovany - source term 1	Done	Action ▾
2	16-05-2013 19:23:26	Temelin - source term 2	Computing	Action ▾
3	16-05-2013 19:23:10	Temelin - source term 1	Done	Action ▾

Task details of task no. 3 Comprehensive reyputs and results

Task information   Task initialization   Task results

Basic control radiological quantities

Time integrals of near-ground activity concentration in air

No.	Nuclide	Quantity	Unit	Actions
1	^{133}Xe	Time integrals of near-ground activity concentration in air	Bq.s/m^3	Action ▾
2	^{137}Cs	Time integrals of near-ground activity concentration in air	Bq.s/m^3	Action ▾

Figure 8. Panels with list of all user's tasks (top) and details of selected task (bottom).

Panel with details of selected task provides a comprehensive review of task inputs, outputs and other relevant information. It has three tabs:

- Task information – basic properties of the task and its worker.

- Task initialization – review of all task inputs.

- Task results – a list of all computed radiological quantities divided into groups.

User can click *Action* drop-down button corresponding to a certain quantity to:
- Visualize results on map background, see Fig. 9.
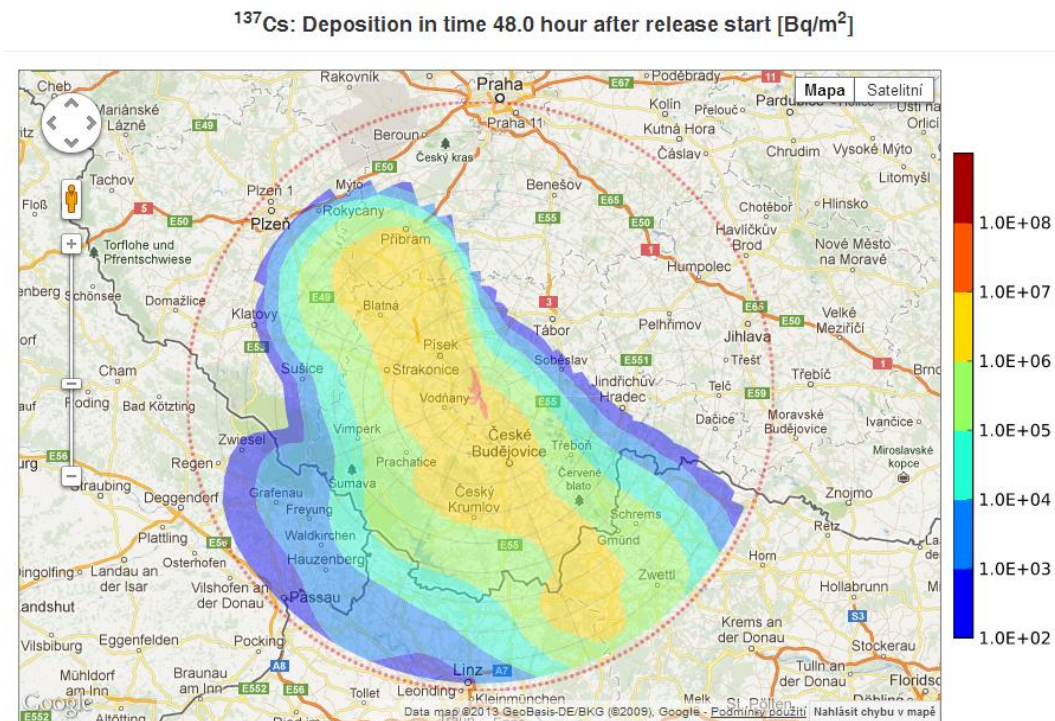- Export data in CSV format.

Figure 9. Visualization of a selected radiological quantity on map background.

5   CONCLUSIONS AND FUTURE WORK

A new web-based interface to the atmospheric dispersion model HARP was presented. Client-server architecture of the system, where all the computations are done on a remote server, together with a user-friendly interface provide a convenient way how to use the basic model functionality on an arbitrary device connected to the internet.

In the next development we want to bring other functionalities of the model to the web environment and improve overall user experience. The priority will be given to switching from point-wise to gridded meteorological inputs. It will require to provide an on-line access to a database of historic and possibly operational meteorological data (as indicated in Fig. 1).

The web version of the model is not intended to be a fully-fledged alternative to the desktop application. Contrary to the desktop version it has some limitations, e.g. the limit on the maximum number of nuclides. This is given by the chosen client-server architecture and the need to transfer

rather large amount of data over internet. However, we hope that the ease-of-use, automated processing of tasks, input validation, lucid presentation of results and other new features will be attractive for both present and new users of the model.

6   ACKNOWLEDGMENTS

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