

### History and Motivation

Since Charnobyl accident there is a need for Early Warning Systems (EWAS) being able to respond to release of toxic and/or harmful substances into the atmosphere.

“Early Warning” – the ability to quickly provide information about the occurrence of an event and its possible consequences.

Operational EWAS use meteorological data (from operational forecast models).

Released contaminations are dangerous due to its nature (i.e. radioactive, toxic...) and/or emission intensity (i.e., the amount released).

The RIOT (Ring Of Threats) system working operationally at IMWM enables dispersion modeling at three spatio-temporal scales (Polish, European and Atlantic domains).

### Description of The System

Two basic approaches to the dispersion problem may be used.

The Eulerian method – the dispersion of a chemically inert tracer is generally described by a (tracer) mass conservation equation which in basic form can be written as

$$\frac{\partial c}{\partial t} + \vec{\nabla}(\vec{u}c) = \vec{\nabla}(\vec{K} \cdot \vec{\nabla}c) + Q$$

For the numerical solution a directional splitting method is used, which allows the solution of 3D dispersion equation as a system of one-dimensional processes. Each of these processes can be treated with a different numerical method, appropriate for a given problem. Subsequently, emission, advection, diffusion and deposition are separated. The advection part of the equation is solved using one of the class of conservative methods of Flux Correction – time-implicit, positive defined and mass-conservative. In turn, diffusion (right) term can be solved with, for instance, semi-implicit Crank-Nicolson method. An alternative – so-called Lagrangian description, where the position of individual fluid particles is evaluated from

$$X(t) - X(t_0) = \int_{t_0}^t U(t') dt'$$

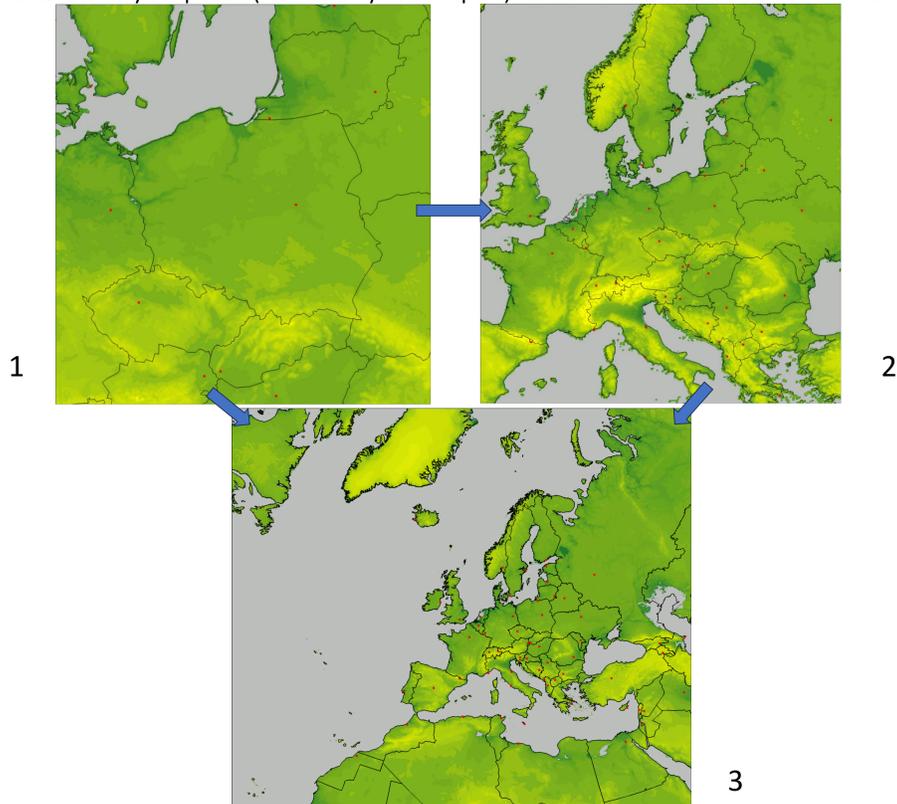
$X$  – particle’s position;  $U$  – its velocity (mean and fluctuating component). Any initial concentration field at time  $t_0$  can now be mapped onto a new field at arbitrary time  $t$ , through integration of the above equation which displaces particles with conserved mixing ratios. Both these descriptions are mathematically equivalent (the absence of numerical diffusion in the latter method offers some advantages, though, certainly in the case of a single point source).

At IMWM a post-processing system for dispersion simulation and analysis called RIOT (Ring Of Threats) based on meteorological fields (forecasts) from the COSMO model for almost the entire Europe runs operationally.

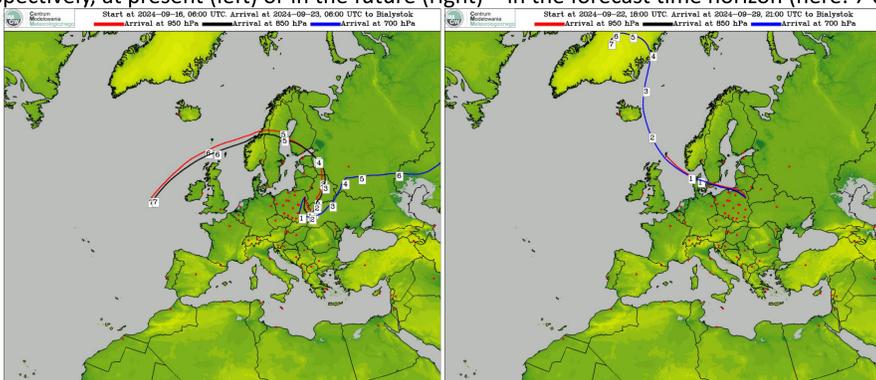
The RIOT system enables dispersion modeling at three spatiotemporal scales (Polish – 1 – European – 2 – and Atlantic – 3 – domains).

For areas outside the basic COSMO domain (1/2 below) – the system switches to ICON-EU data from the DWD open data server and/or from the Global Forecasting System (GFS, available at NOAA; 3 below), converted from a rectangular to rotated lon-lat grid.

In both cases, the Eulerian and Lagrangian models are used simultaneously to simulate the spread of pollutants. An Eulerian model is based on an original version of the H-MET model, without taking into account chemical changes during pollutant dispersion. In turn Lagrangian model is a very simplified (limited only to transport) version of the A. Stohl’s FLEXTRA model.

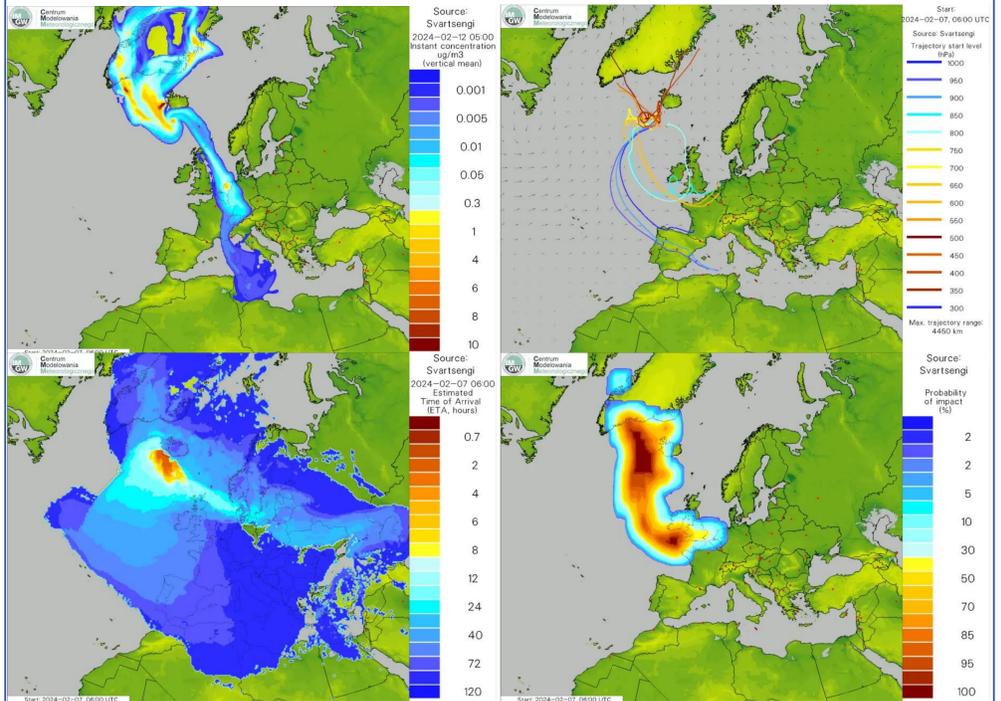


An additional function of the system is to detect, using a model of backward or forward trajectories, the location of source(s) of contamination that reaches the selected receptor, respectively, at present (left) or in the future (right) – in the forecast time horizon (here: 7 days)

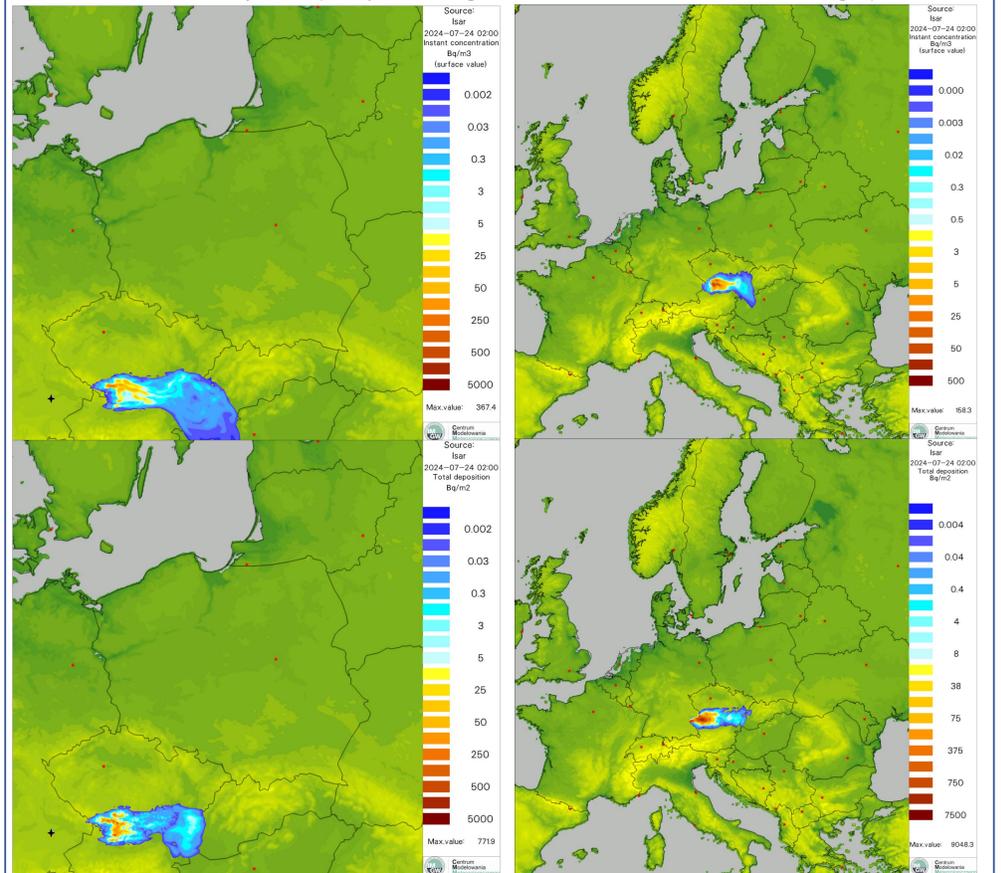


### Examples of results

Real case - emission from Svartsengi volcano (Iceland), February 2024:



Test case – Isar NPP, July 2024 (comparison high – left – vs. medium resolution – right):



Operational constant monitoring of Ukrainian NPPs – trajectories from Chmielnickij (upper left) and from SouthUkrainian NPP (upper right); dispersion from Rivne NPP (lower left) and from Enerhodar (lower right)

