Operational forecasts for air dispersion of hazardous pollutants based on results of the COSMO model

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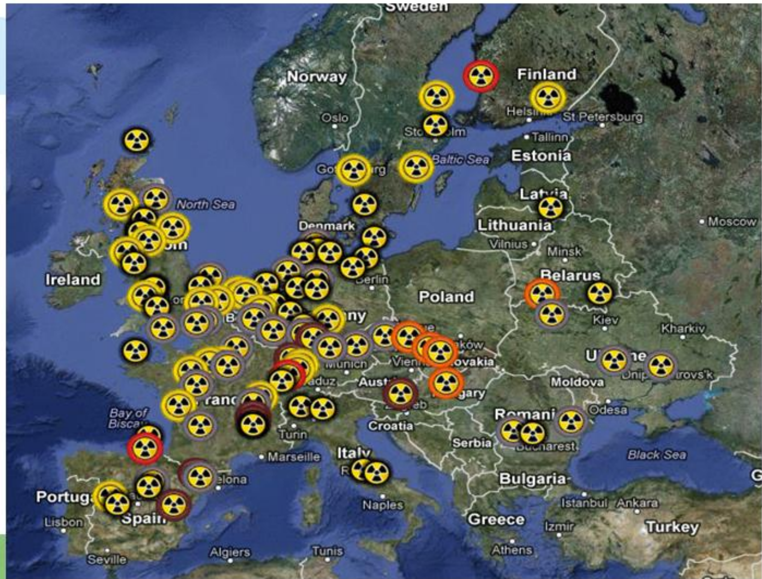
INTRODUCTION

The project developed at the IMWM-NRI is intended to help in determining the response to the occurrence of a potential danger to Poland, related to at least two types of threats:

1. anthropogenic threats, resulting mainly from incidents in nuclear power plants (NPPs) in neighboring countries, as well as other disasters or accidents of the nature of emission incidents, causing contamination of the environment with toxic (more generally: dangerous) substances ;
2. natural threats, such as volcanic eruptions and eruptions, and their impact on broadly understood safety, including e.g. the safety of air transport.

Red – the type used in Fukushima;
Orange – inadequate security;
Yellow – older than 30 years;
Brown – seismically active region.
Other:
Gray – under construction;
Black – turned off.
(Status – end of 2015 yr.)



High-risk reactors in Europe

NPP within 300 km from Poland

In terms of safety, the key issue is information – including forecasts – if/how the territory of Poland may be endangered as a result of a hypothetical accident in selected NPP(s) or of a release of another contamination.

At IMWM-NRI a system for forecasting – in operational mode – the dispersion of pollutants from locations in the COSMO model domain has been prepared.

Two models (Lagrangian – trajectory and Eulerian – field) are complementary in terms of information on dispersion of pollutants.

1.The Lagrangian model: three-dimensional trajectory calculated – a solution for the following set of equations:

$$\frac{d\boldsymbol{x}}{dt} = \boldsymbol{u}(\boldsymbol{x}; t)$$

where $\boldsymbol{x}=\boldsymbol{x}(t)$ – 3D coordinates of the trajectory point; $\boldsymbol{u}$ – 3D windspeed field.

Solution (change of point's location): $$\Delta \boldsymbol{x_0} = \boldsymbol{u}(\boldsymbol{x_0}; t_0) \cdot \Delta t$$

Iterative correction (i=1,3): $$\Delta \boldsymbol{x_i} = \frac{\Delta \boldsymbol{x_0} + \boldsymbol{u}(\boldsymbol{x_0} + \Delta \boldsymbol{x_{i-1}}; t + \Delta t) \cdot \Delta t}{2}$$

Finally (for N=3): $$\boldsymbol{x}(t + \Delta t) = \boldsymbol{x}(t) + \Delta \boldsymbol{x_N}$$

2.Eulerian model

General equation of dispersion (advection-diffusion) of contamination concentration *c*:

$$\frac{\partial c}{\partial t}+\frac{\partial uc}{\partial x}+\frac{\partial vc}{\partial y}=\frac{\partial}{\partial z}\left(Kv\frac{\partial c}{\partial z}\right)+G$$

where *u, v* – 2-D windspeed field; K_v – tensor of turbulent diffusion (vertical component), *G* – contamination's emission and removal (wet- and dry deposition).

Solution: horizontal advection – *Flux Correction (AFP – Area Flux Preserving)*, vertical diffusion – semi-explicit Crank-Nicholson's method

Both types of models are used in the system, giving complementary information.

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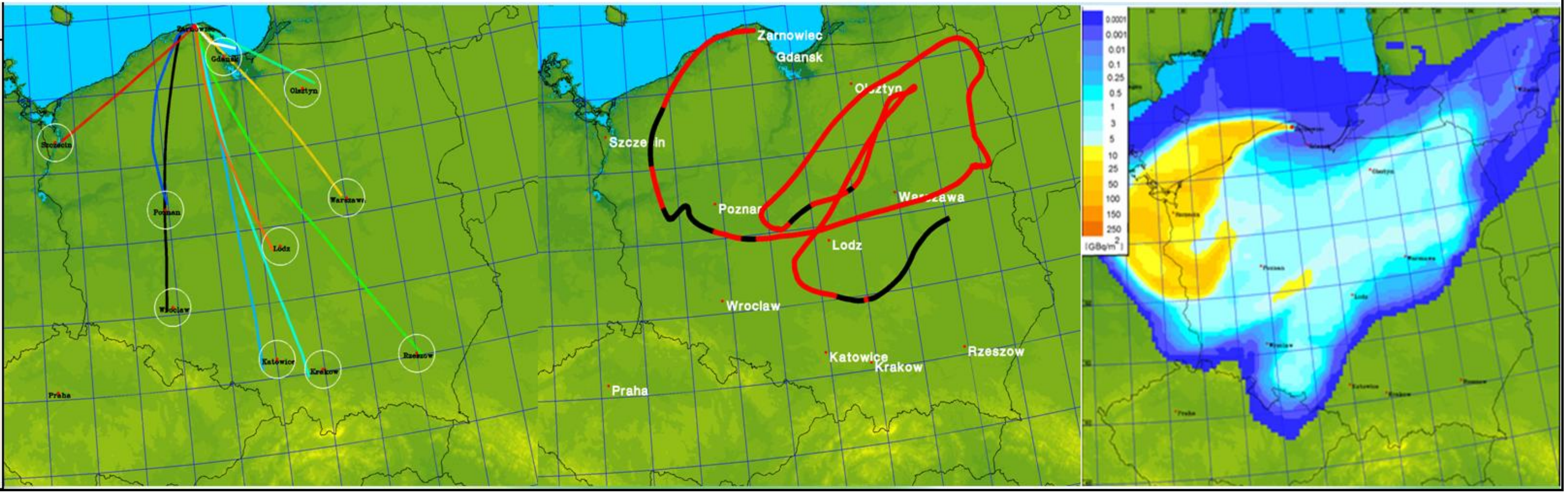
CONCEPT, GOALS AND RESULTS

- Main goal – to increase an overall level of Poland's safety in the context of nuclear installations located in neighboring countries, safety and fluency of air traffic over Poland in the event of volcanic eruptions (introduction of a periodic ban on flights over Poland), the possibility of reacting to the occurrence of other releases of hazardous, toxic substances, etc.
- Effect of implementation – a system for forecasting and informing about the possible effects of incidents related to nuclear accidents of a wide scale of intensity or volcanic eruptions located throughout Europe, which may result e.g. in the introduction of a flight ban over selected areas of the continent, including Poland.
- The results may be used to determine actions and responses for the event of an incident at a NPP, volcanic eruptions or the release of other toxic substances to the atmosphere.

Example: assessment of the impact of the future Polish NPP; climatological data 2001-2010

City	ETA
Gdańsk	0.1
Olsztyn	1.1
Szczecin	2
Poznań	2.3
Warsaw	2.5
Łódź	2.5
Wrocław	3.9
Katowice	4
Kraków	4.3
Rzeszów	4.9



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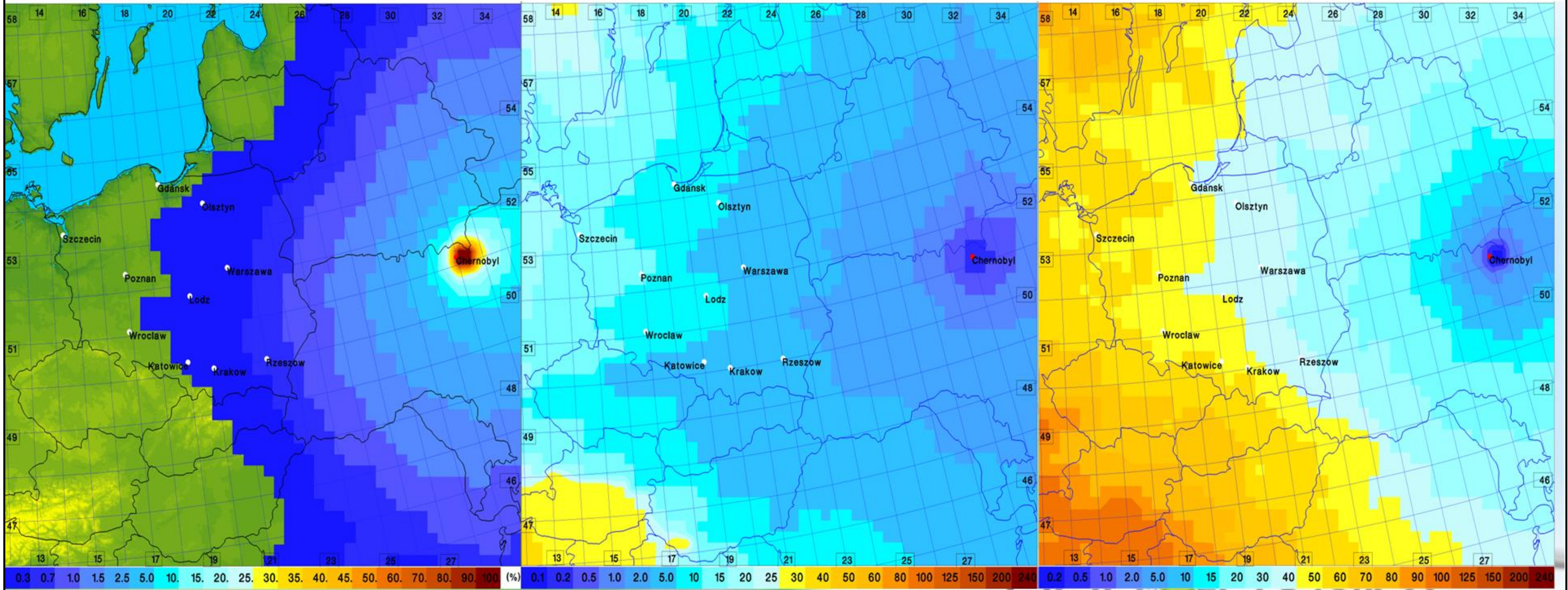
CONCEPT, GOALS AND RESULTS

Example: assessment of the impact from Chernobyl NPP; climatological data 2001-2010

Chernobyl

probability of impact | shortest ETA | mean ETA



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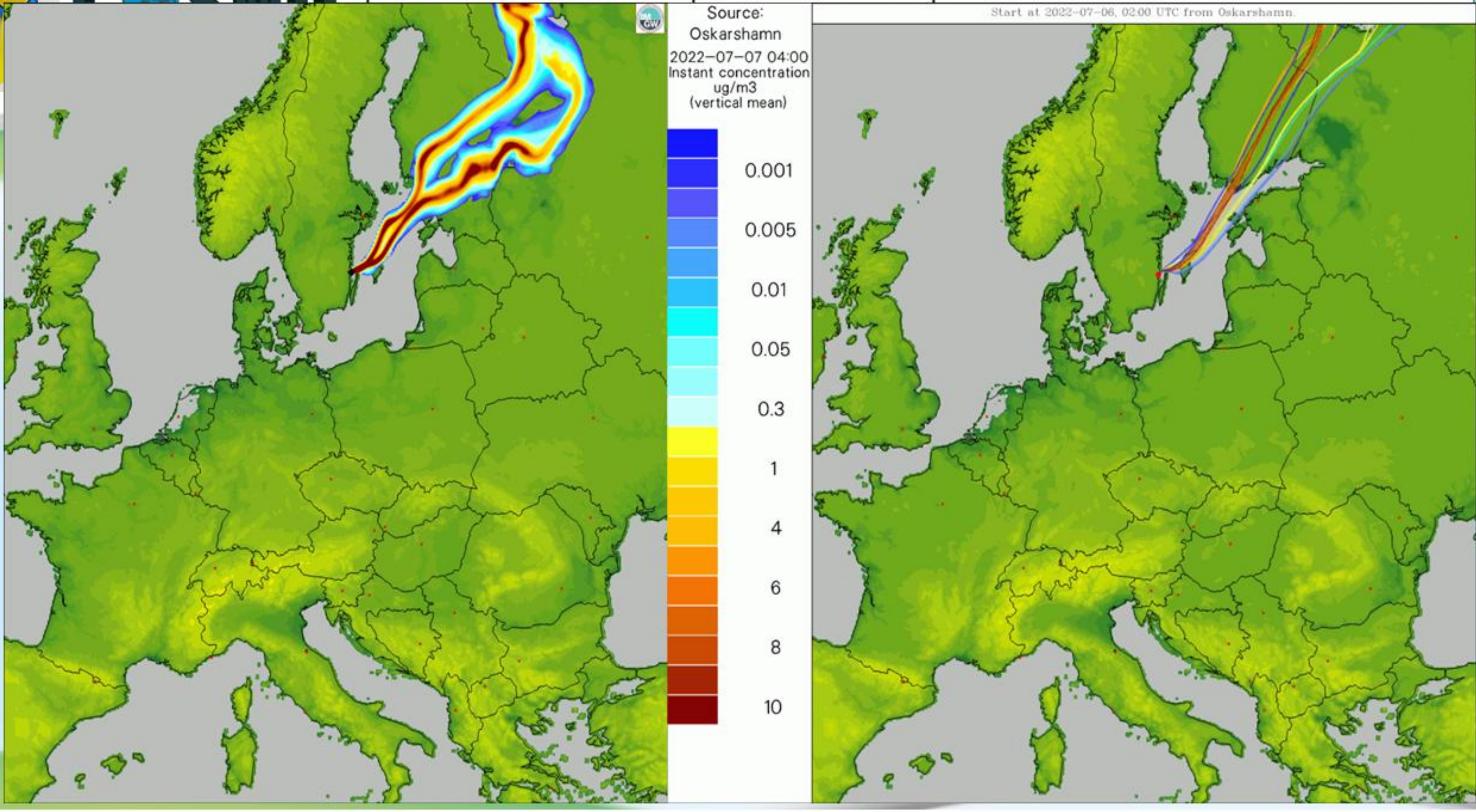

Forecasts of dispersion for hypothetical accidents in selected NPPs

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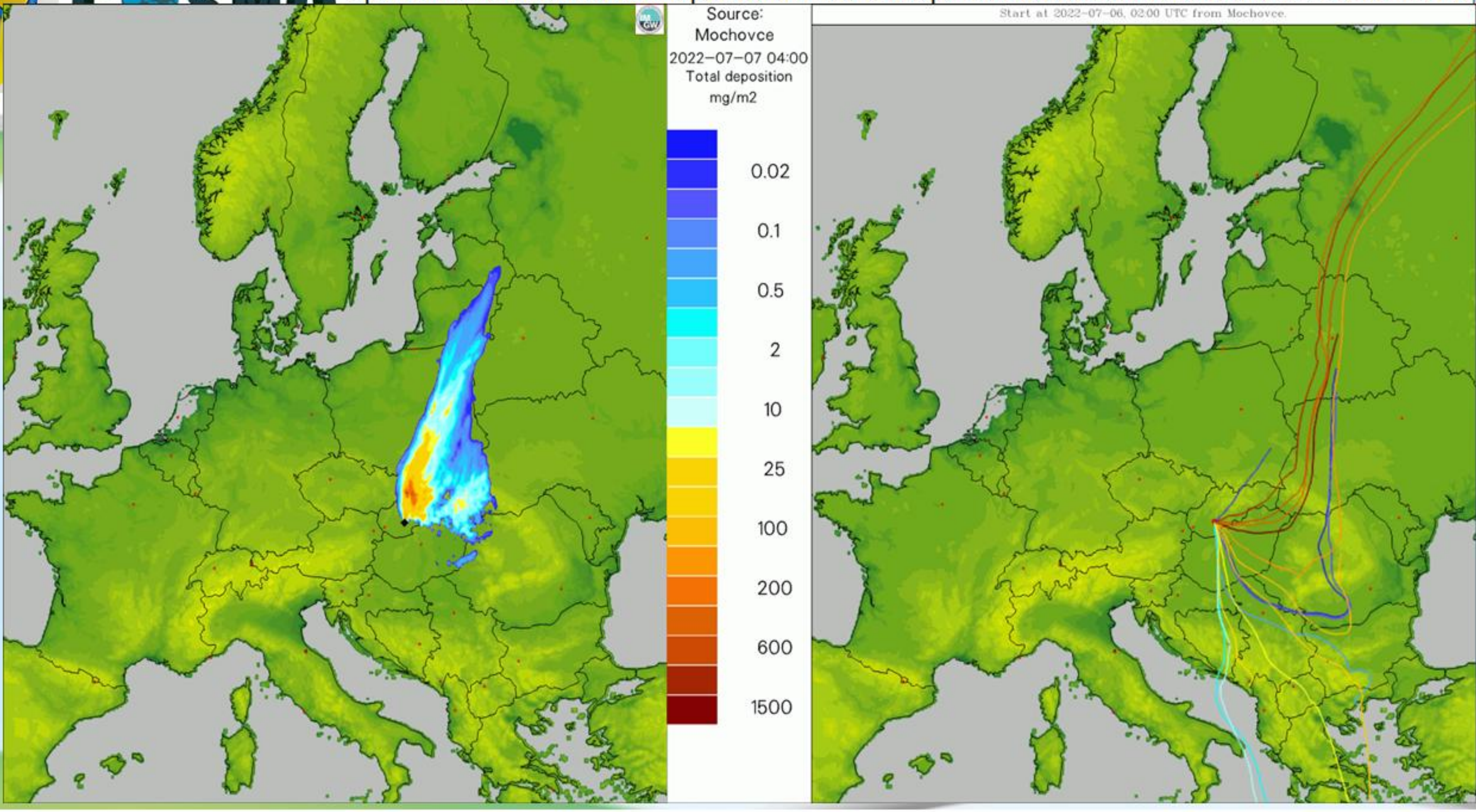
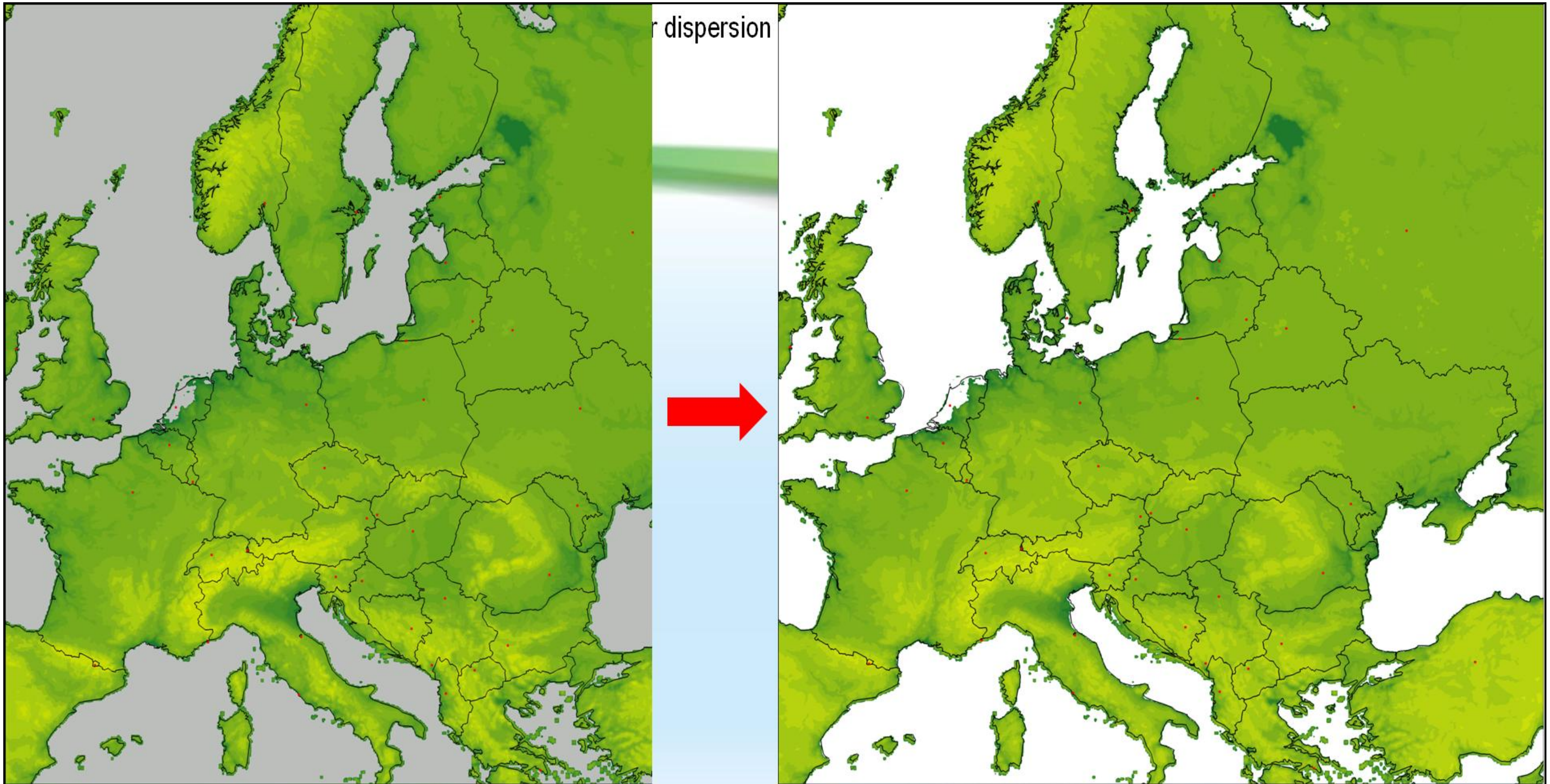


Forecasts of dispersion for hypothetical accidents in selected NPPs



Extension of domain due to war in Ukraine and situation in Enerhodar NPP

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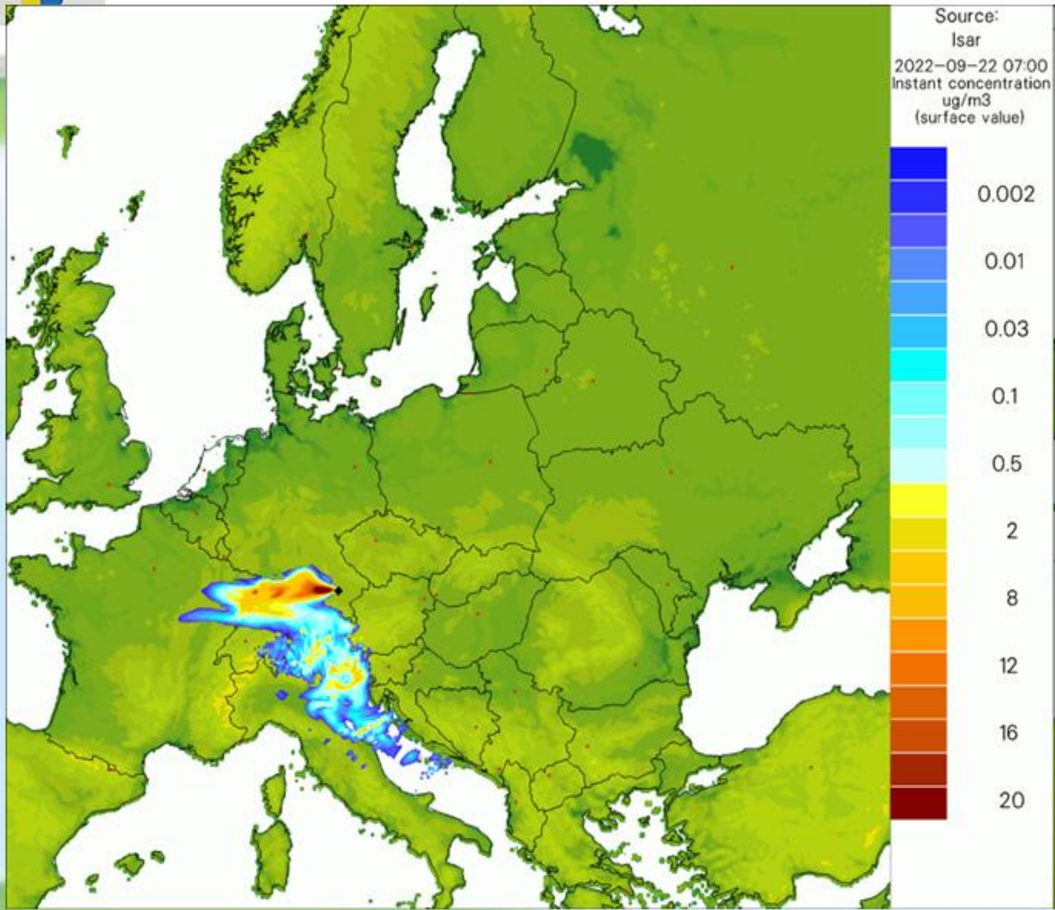

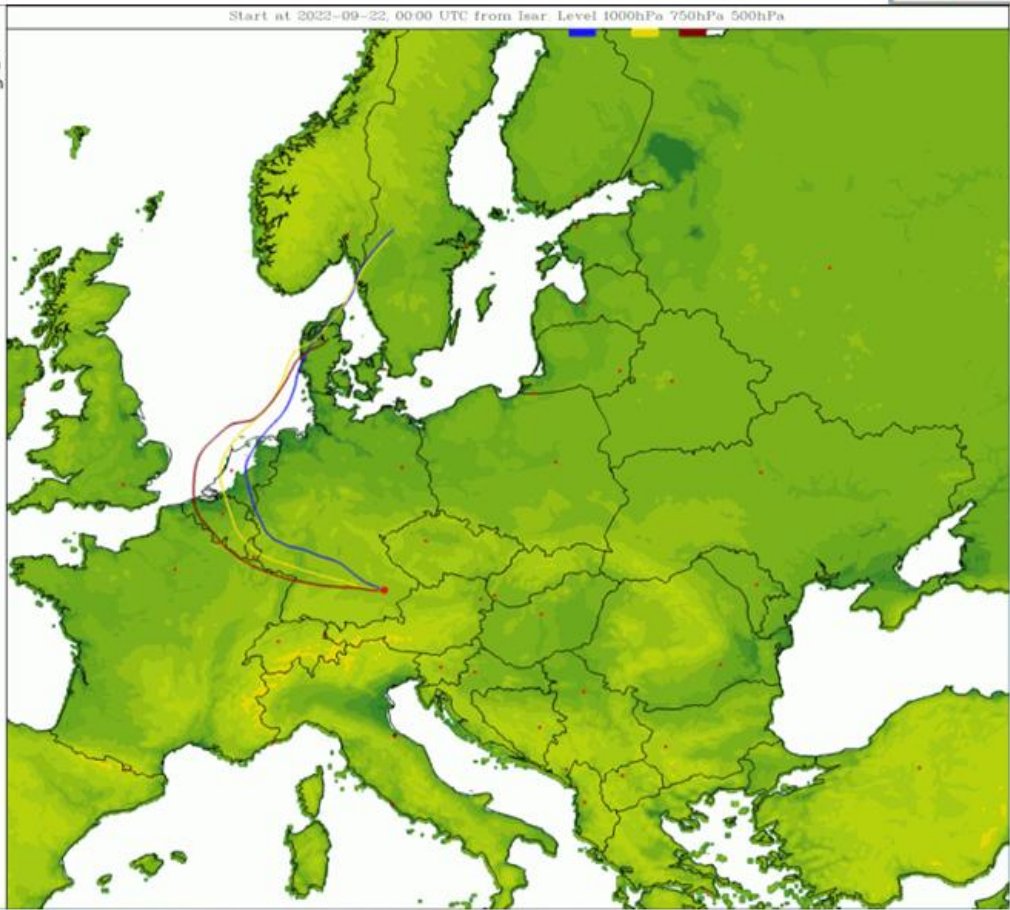

Forecasts of dispersion for hypothetical accidents in selected NPPs

CONSORTIUM FOR SMALL SCALE MODELING
COSMO

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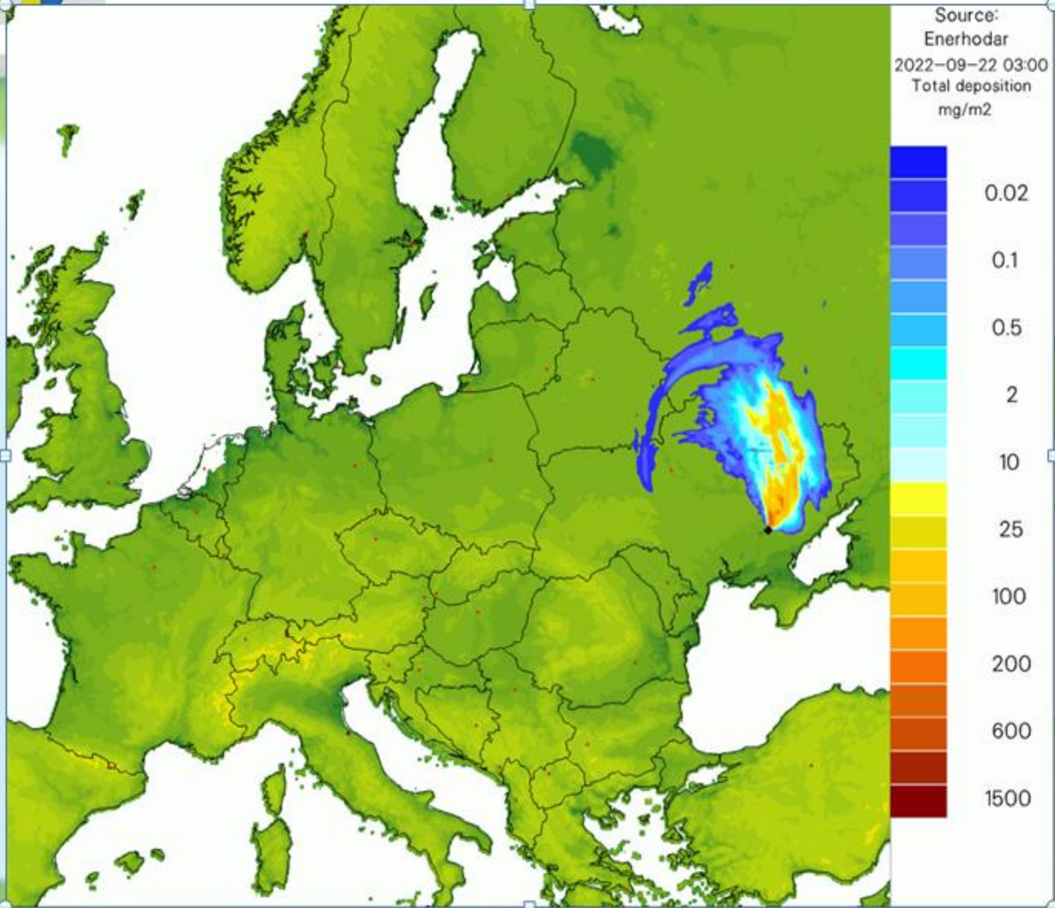

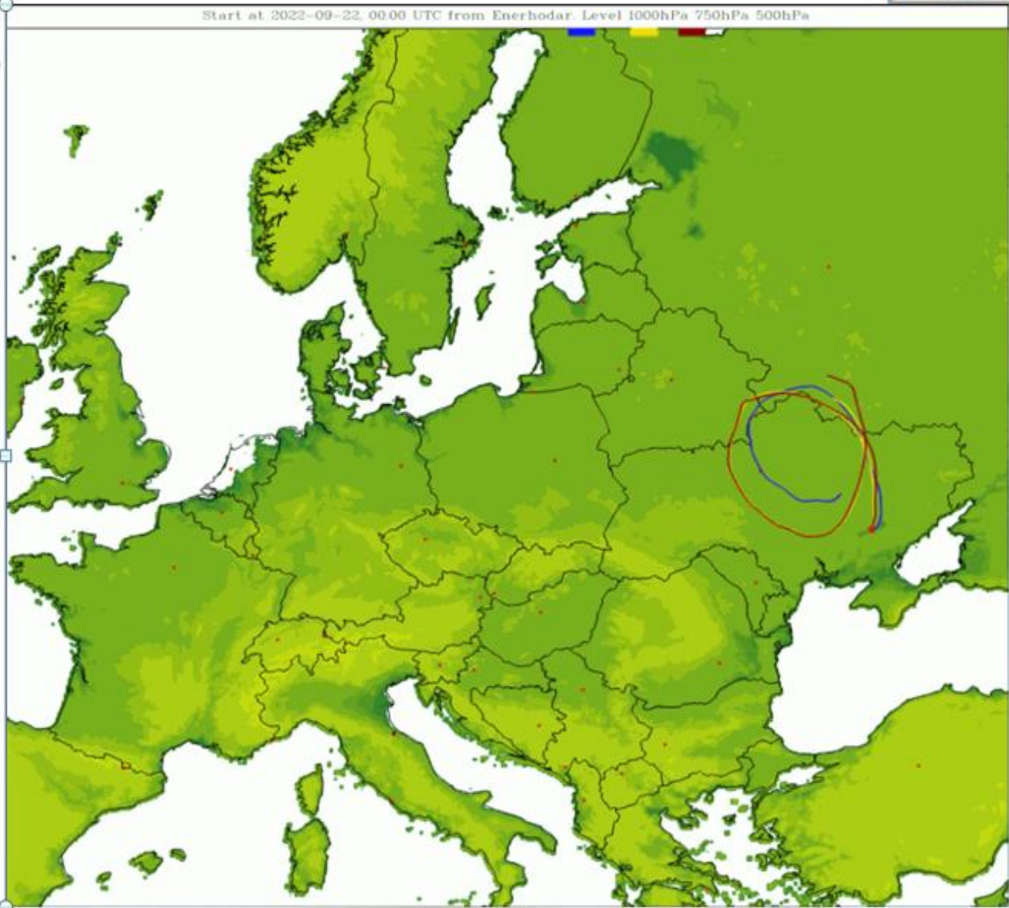

Forecasts of dispersion for hypothetical accidents in selected NPPs. Special case – Enerhodar

SUMMARY

- October 1957, accident in Windscale reactor (UK), contaminated 500 km^2 of the area around the NPP; similarly to the Chernobyl accident – a result of an unfortunate combination of many factors;
- April 1986, explosion and fire of Chernobyl reactor; commonly believed - a catastrophe on a global scale both in terms of the amount of the release and of it spatial extent;
- April 2010, eruption of Eyjafjallajökull volcano in Iceland, flight bans, threat to air traffic over Europe;
- March 2011, the disaster at the Fukushima NPP – the result of an earthquake, the impact of the tsunami wave and a confluence of unfortunate circumstances and human errors;
- September to December 2021, Cumbre Vieja volcano eruption – a hundred days of emission of volcanic ashes/sulfur compounds.

- There is a need for efficient systems that would respond to a crisis situation – a threat to the natural environment or human activity.
- It is important to prepare tools that allow to react and/or minimize the negative effects of possible accidents/releases.
- **Such systems are to provide support – an information on the further development of events, the forecasted state of the environment and the negative impact of various factors on human society within the range of such impact.**
- **"Si vis pacem, para bellum!"**

#StandWithUkraine