COST Action TD1105 - *New Sensing Technologies for Air-Pollution Control and Environmental Sustainability*
Second Scientific Meeting, Queens' College, University of Cambridge, 18-20 December 2013

Simulation of severe pollution events by Bulgarian Emergency Response System

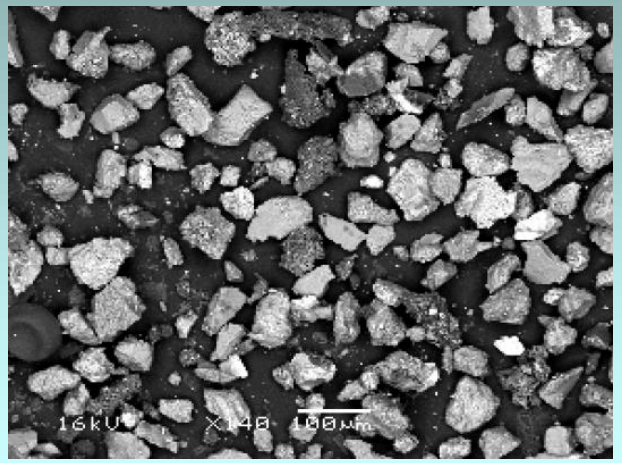
Kiril Slavov, Dimiter Syrakov, Maria Prodanova

- **AP (traffic & industry) – key element**
  Chemical Weather (Bulgarian CWFS)
  http://www.meteo.bg/en/cw/
- **Industrial Accidents (toxics, radioactivity)**
  Emergency Response Systems (ERS), BERS
  http://info.meteo.bg/ews/index-en.html
- **Natural disasters (volcanos, wild fires etc.)**
  Sometimes extremely damaging

National Institute of Meteorology and Hydrology, Bulgarian Academy of Sciences

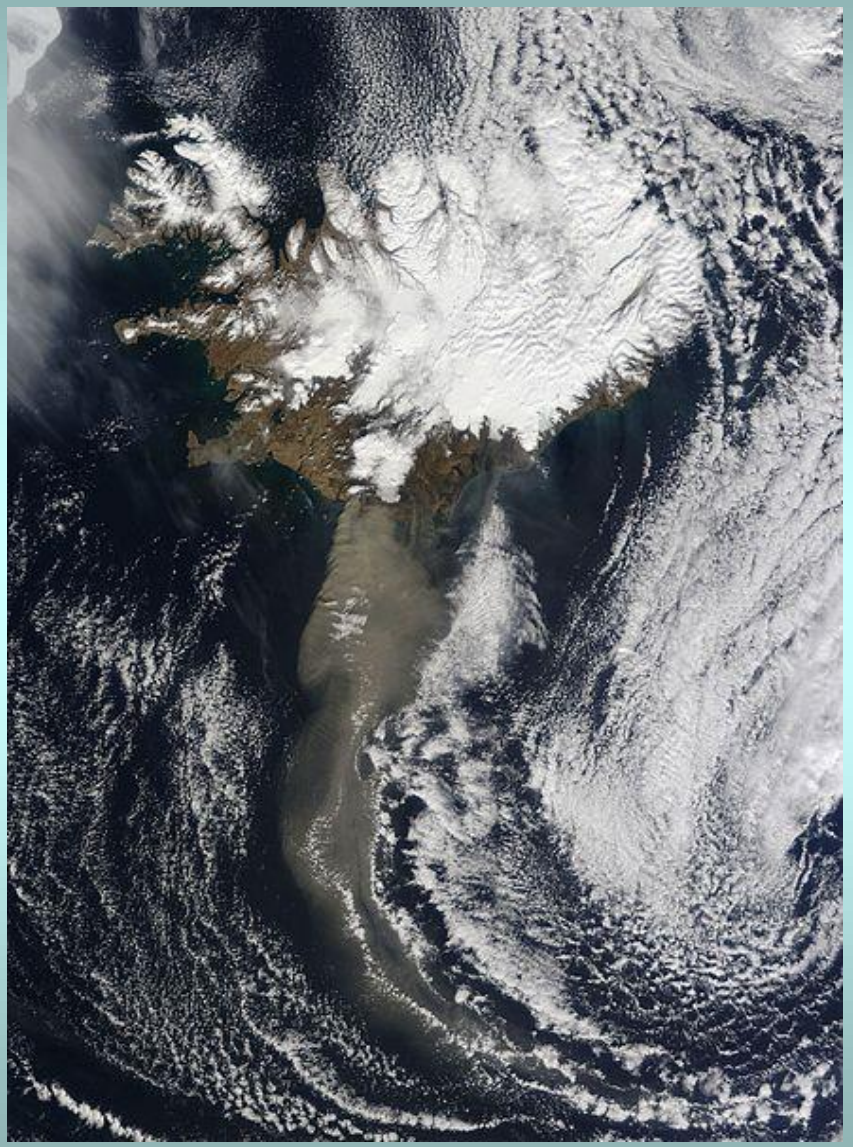
Iceland Volcano

- Start of event: 14 April 2010
- Duration: more of 1 month (two periods)
- Volcanic ash clouds over Europe
- Damages jet engines
- 100,000 flights canceled
- Millions of passengers stranded
- 1.5 – 2 billons euros losses



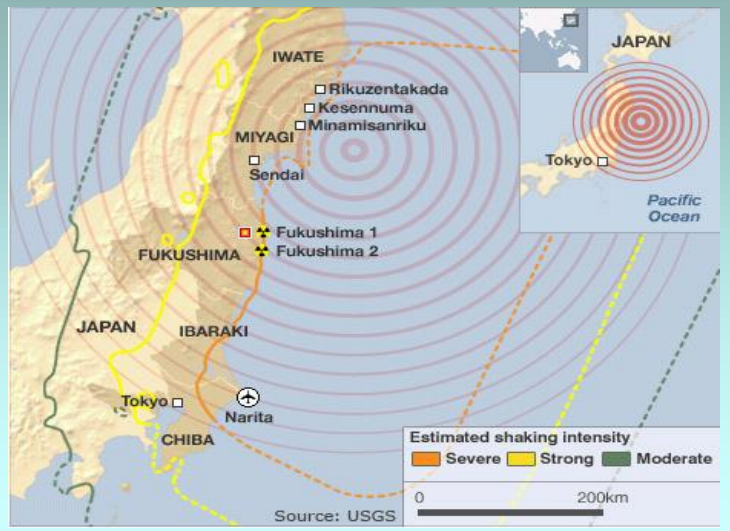
COST Action TD1105 - ***New Sensing Technologies for Air-Pollution Control and Environmental Sustainability***

Second Scientific Meeting, Queens' College, University of Cambridge, 18-20 December 2013



National Institute of Meteorology and Hydrology, Bulgarian Academy of Sciences

Fukusima Nuclear Accident



The Fukushima Eerthquake:

Records from 1600 years
The greatest Japan event
5th in the world
Date: 11 March 2011 at 2.46
Magnitude: 9.0 – the most powerful
Duration: 2 shocks in 3 minutes
Japan moved 2.4 metres East
The local coastline subsided 0.5 m
The released energy: 480 Mt TNT
(The Nagasaki A-bombe – 20-22 kt)
Hundreds of foreshocks
About 2000 aftershocks with M>4

The tsunami

The earthquake caused a rising by 5 to 8 m of a 180-km wide seabed at 60 km offshore.

It triggered powerful tsunami - about 67 cub.km ocean water moved towards 860 km Japanese shore line in a wave reaching heights of up to 40.5 m and which traveled up to 10 km inland.

The tsunami inundated about 560 sq km and resulted in over 19,000 human deaths toll of and much damage to coastal ports and towns with over a million buildings destroyed or partly collapsed.

The Nuclear Accident

In the area operate 4 NPPs with 11 reactors, 3 of which stopped for inspection. During the EQ the other were automatically stopped and do not produced electricity.

The electric power for cooling process was provided by emergency diesel generators.

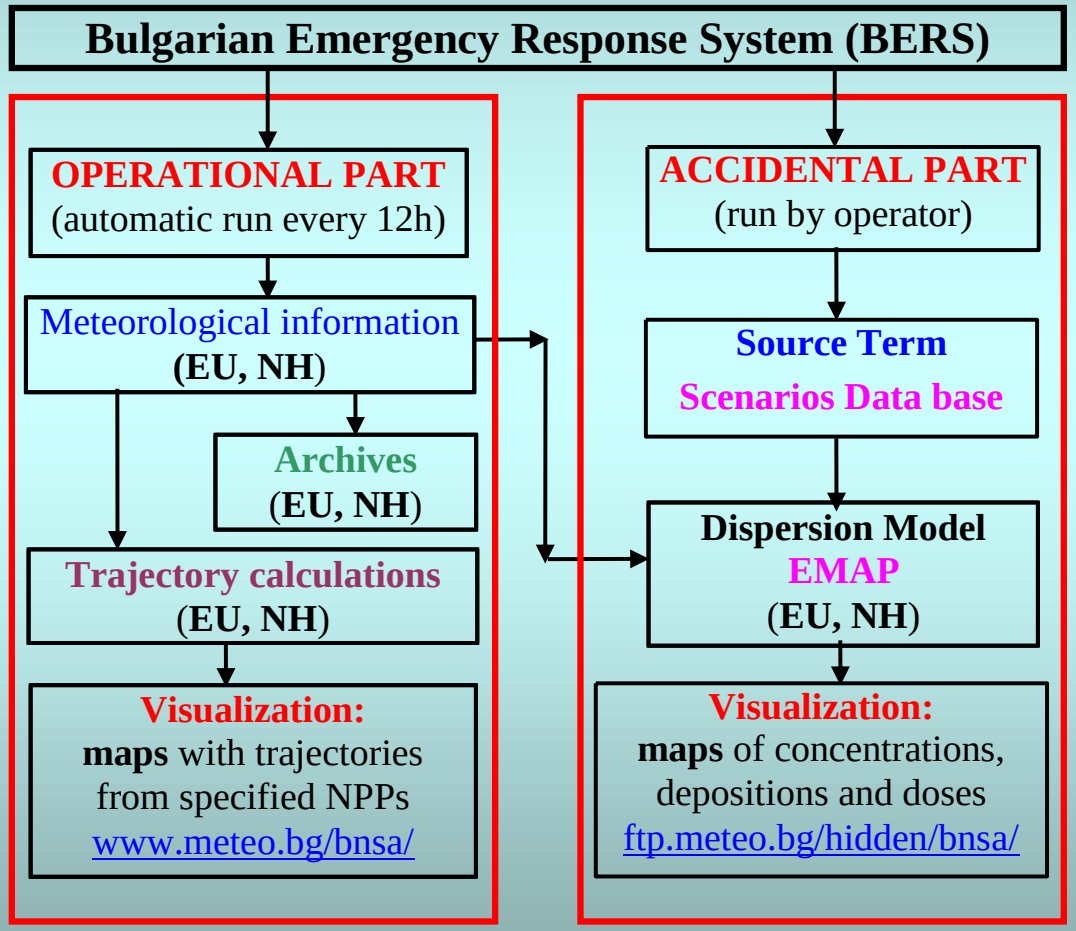
The tsunami with height of 14 m crashed the 2.5 km breakwater and the 5.6 m protective wall and flooding the area broke down the electricity lines.

This caused overheating of the reactor 1, 2 and 3 of Fukushima Daichi NPP and initiated a chain of process that leaded to release of radioactive materials into the atmosphere and the ocean lasting more than a month.

IAEA rated the Fukushima NPP release to level 7 of the international scale INES.

Description of BERS and its Upgrades

http://info.meteo.bg/ews/index-en.html

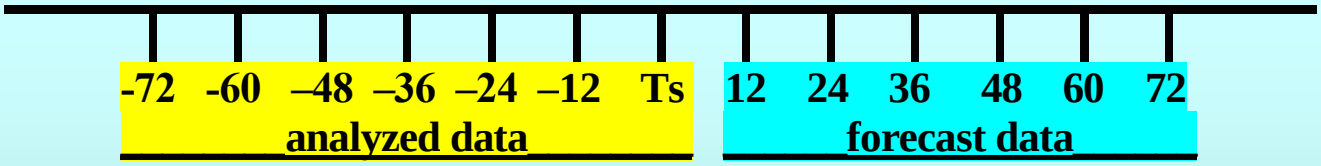


Meteorological pre-processing (input to the built in PBL model)

Two sources of met-data: **from UK Met.Office, Bracknell (2.5°, GRID)**
from DWD, Offenbach (1.5°, GRIB)

Type of meteo-data: U_{850}, V_{850}, T_{850}, T_{gl}, Prec (Δt=12 h)

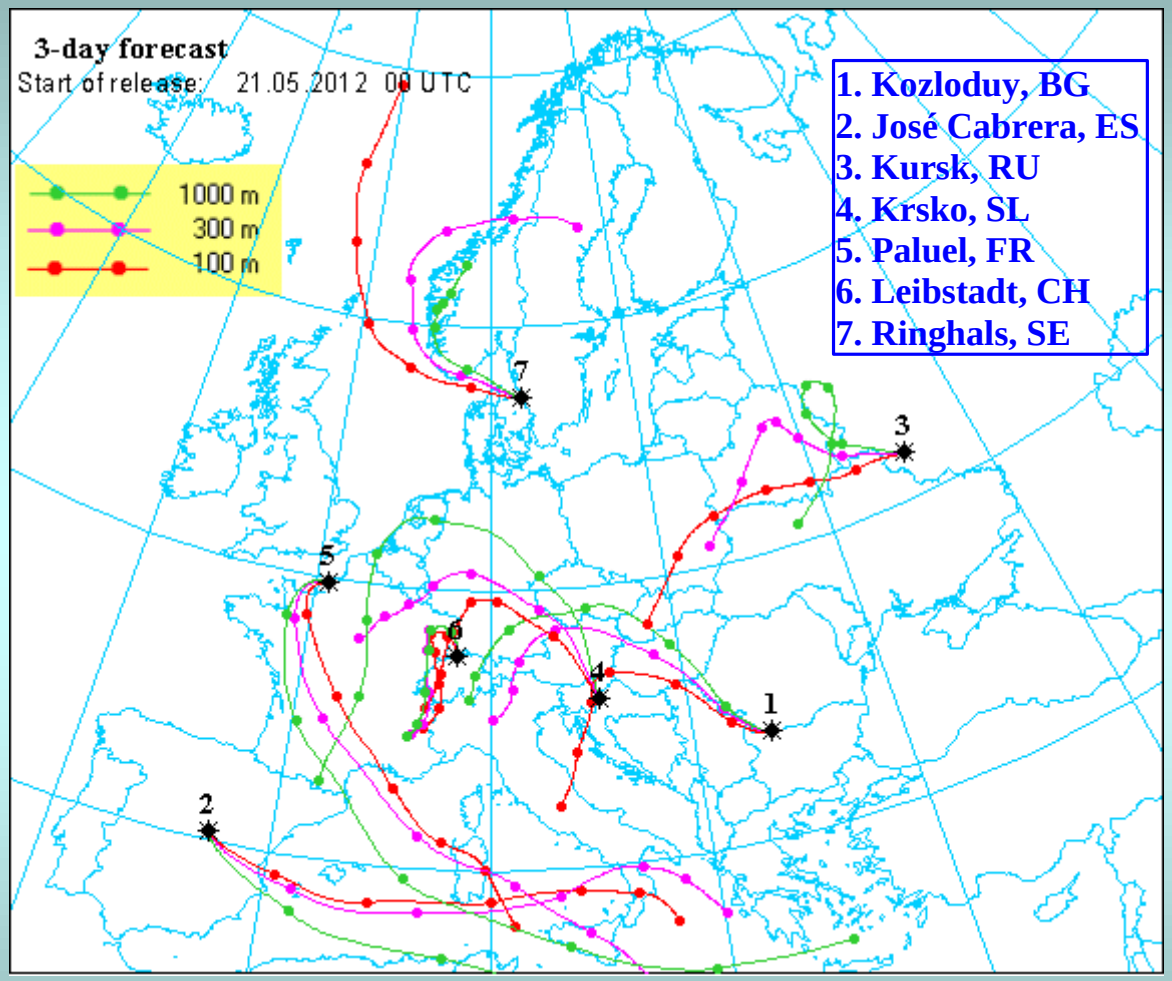
Operational data base (Ts - current synoptic term)



Archive data base

Trajectory calculations

$$\boldsymbol{X}(t+\Delta t) = \boldsymbol{X}(t) + \boldsymbol{V}(t).\Delta t$$


3-day forecast
Start of release: 21.05.2012 00 UTC
1000 m
300 m
100 m
1. Kozloduy, BG
2. José Cabrera, ES
3. Kursk, RU
4. Krsko, SL
5. Paluel, FR
6. Leibstadt, CH
7. Ringhals, SE

Dispersion model EMAP (Eulerian Model for Air Pollution)

Time splitting approach.
Cartesian coordinate system in horizontal (Arakawa's C type).
Log-linear terrain-following staggered Z-coordinate system.
Processes involved:

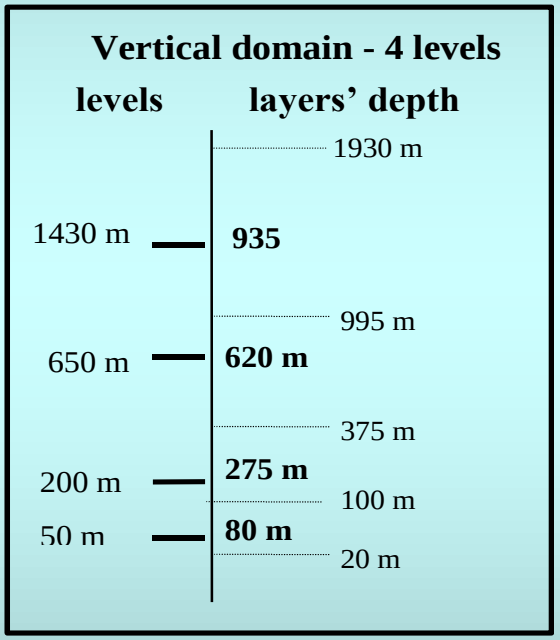
Advection
- TRAP scheme
  - Bott's type
  - explicit
  - positively definite
  - conservative
  - limited numerical viscosity
  - very fast

Horizontal diffusion:
- the simplest **explicit** scheme

Vertical difusion
- the simplest **implicit** scheme
- variable steps
- variable diffusion coefficient

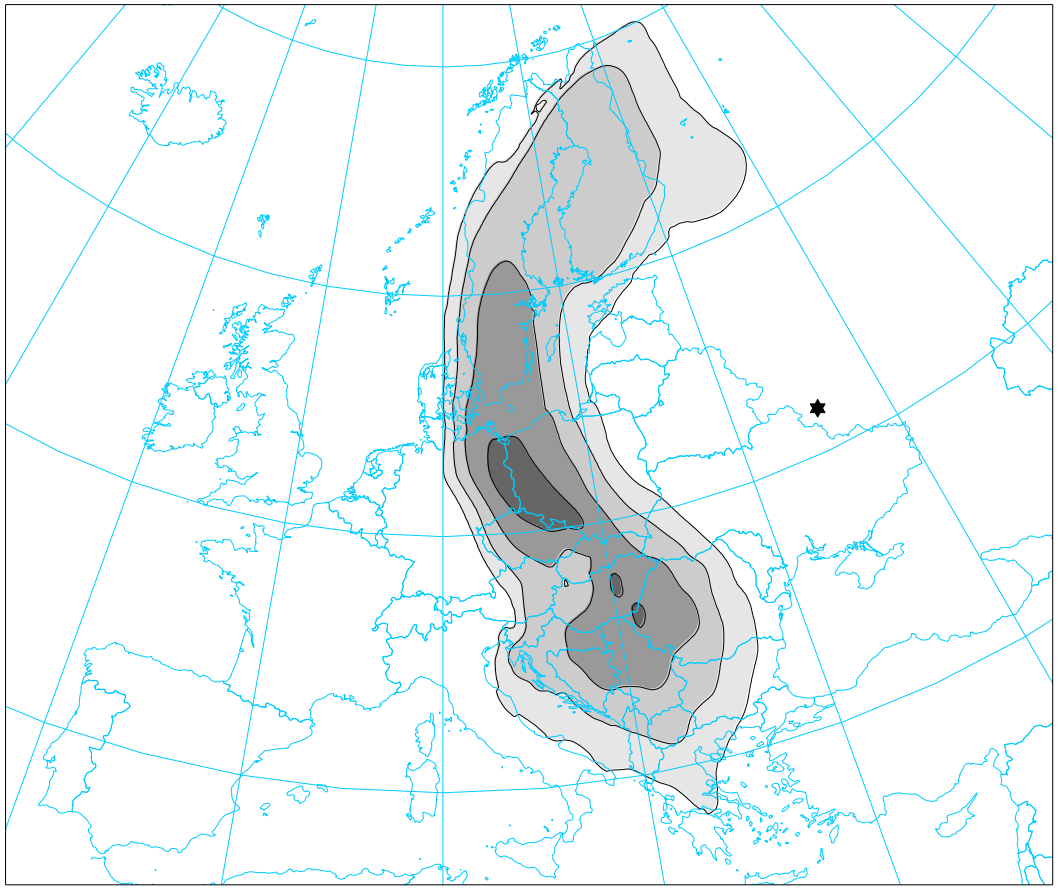
Dry deposition: bottom boundary condition to vertical diffusion equation

Wet removal: simple decay rate



NATIONAL INSTITUTE OF METEOROLOGY AND HYDROLOGY

Numerical Simulation of Radioactive Pollution Distribution



Ground-Level Concentration in Air (Bq/cub.m)

SIMULATION DESCRIPTION:

Source Location (*):
51.75N 35.62E

Release Rate:
0.10E+11 Bq/s

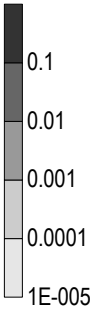
Release Height:
650

Release Duration:
12.00 hrs

Start of Release:
30/11/01 09:00 UTC

Forecast for:
03/12/01 09:00 UTC

Maximum Value:
0.266E-01



Verification of EMAP: comparison with ETEX-I data, FMS

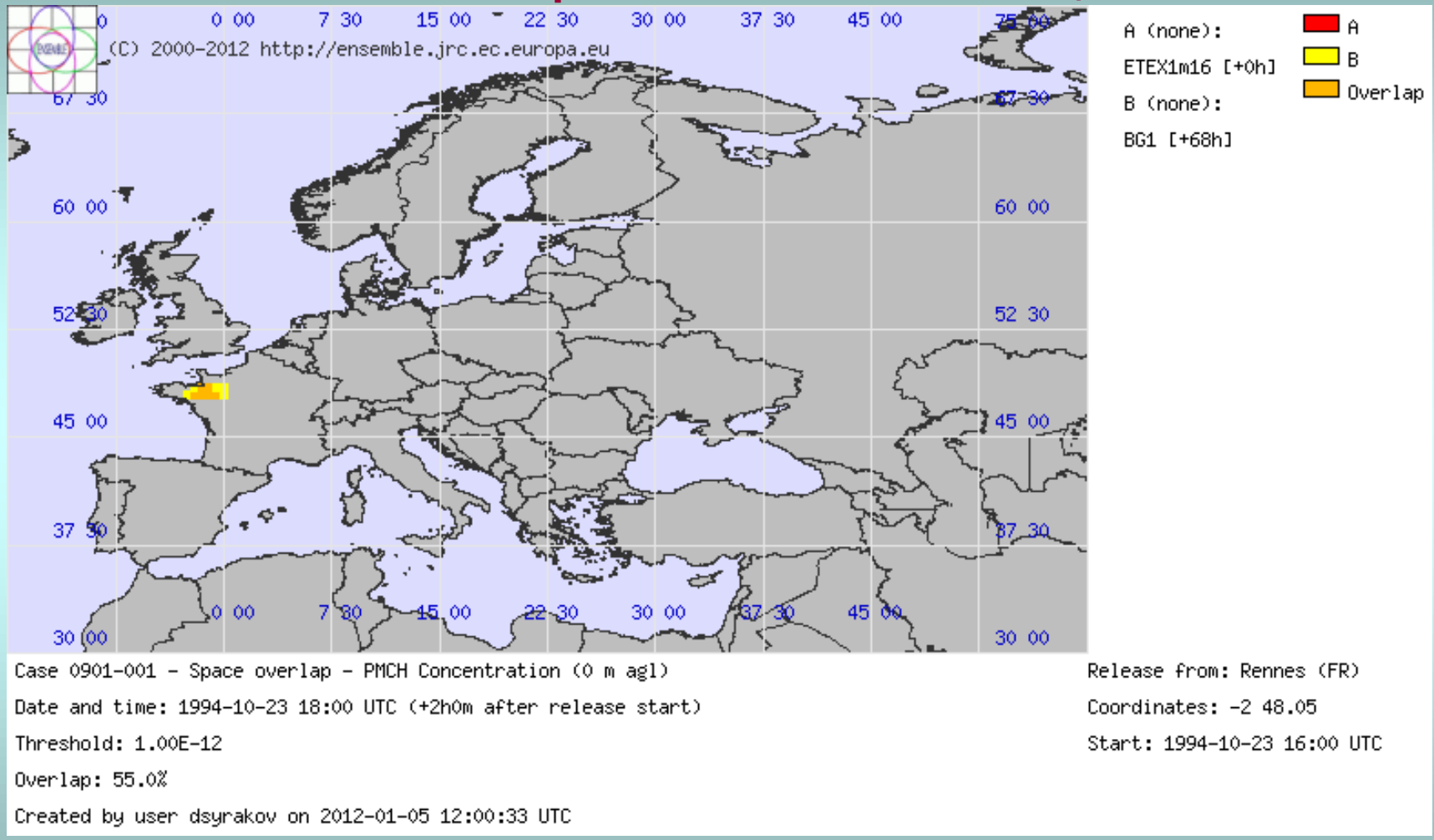
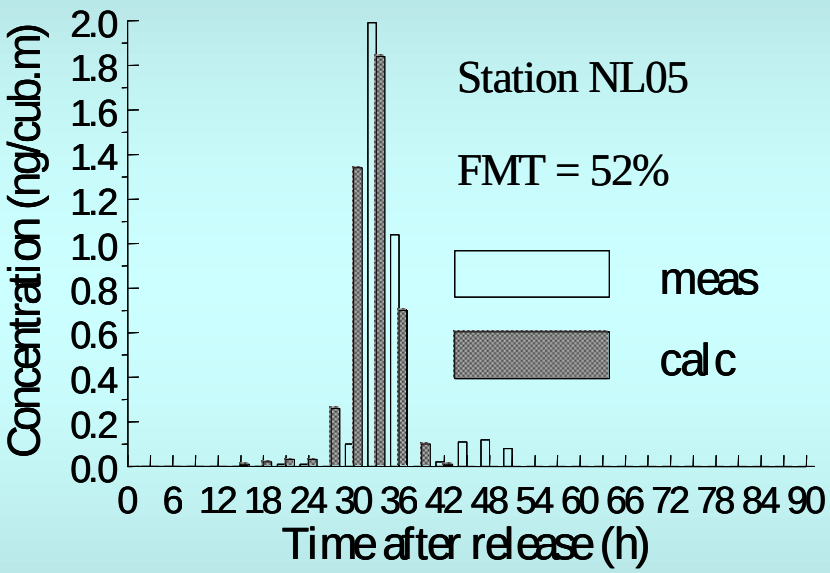


Figure of Merit in Space

Verification of EMAP: comparison with ETEX-I data



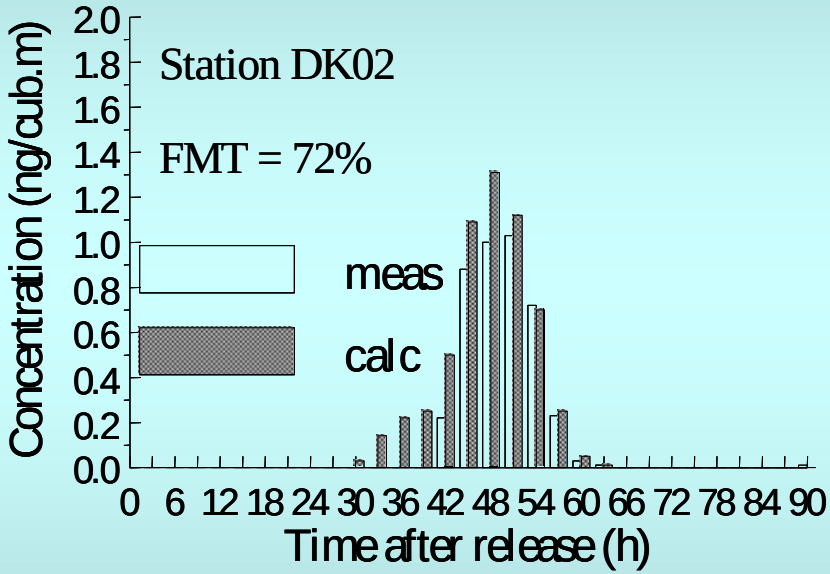


Figure of Merit in Time

UPGRADES of BERS

2001 – putting of BERS into operation

2007 – multi-nuclide treatment, exposure doses calculations

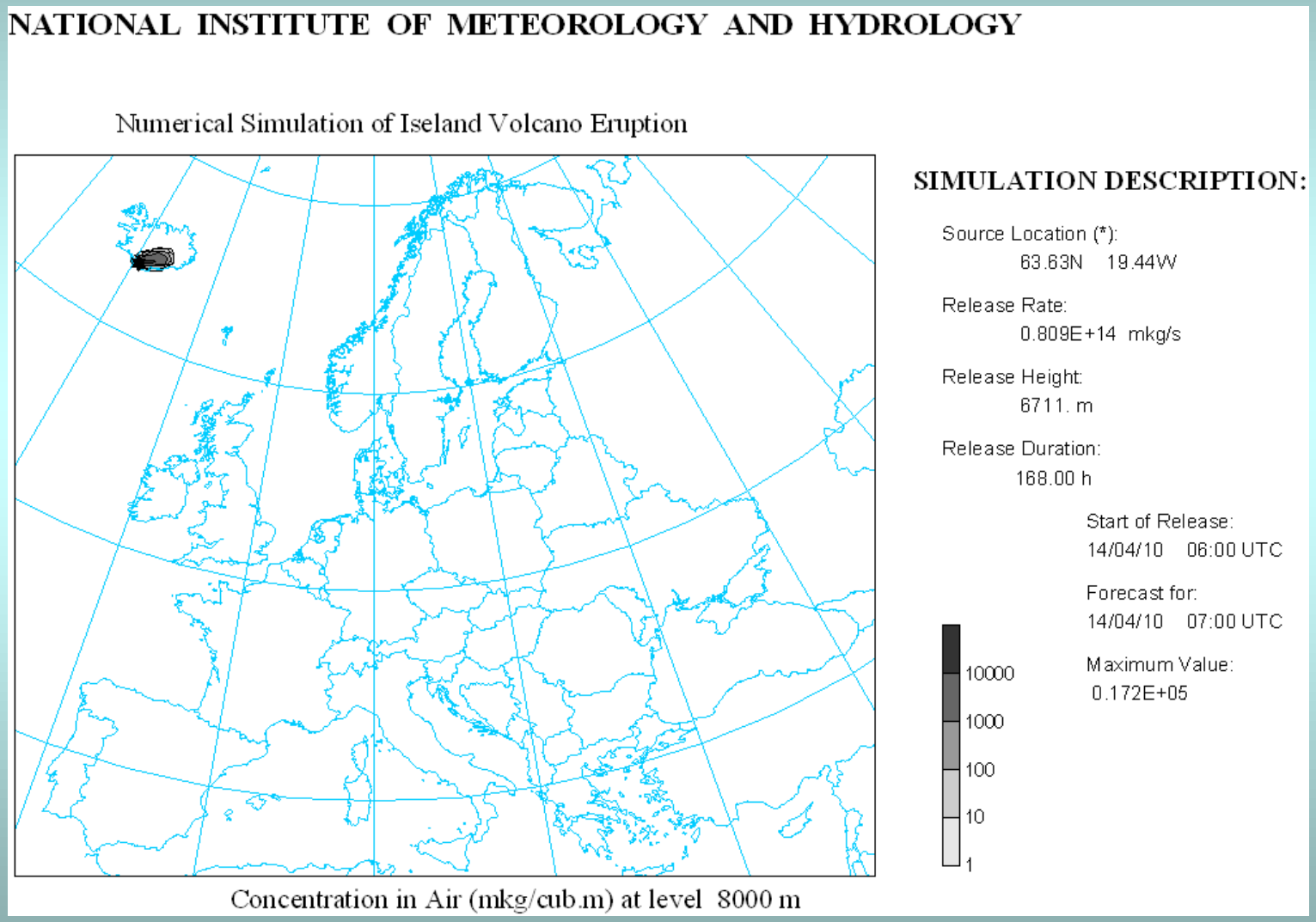
2010 – for ENSEMBLE Volcano exercise:

- **new vertical structure – up to 12 km, exercise specific levels**
- **vertical diffusion coefficients aloft – 10% of PBL ones**
- **NCEP meteorology added over 2 km (to the DWD data)**
- **continuous source long term calculations**

2011 – for ENSEMBLE Fukushima exercise:

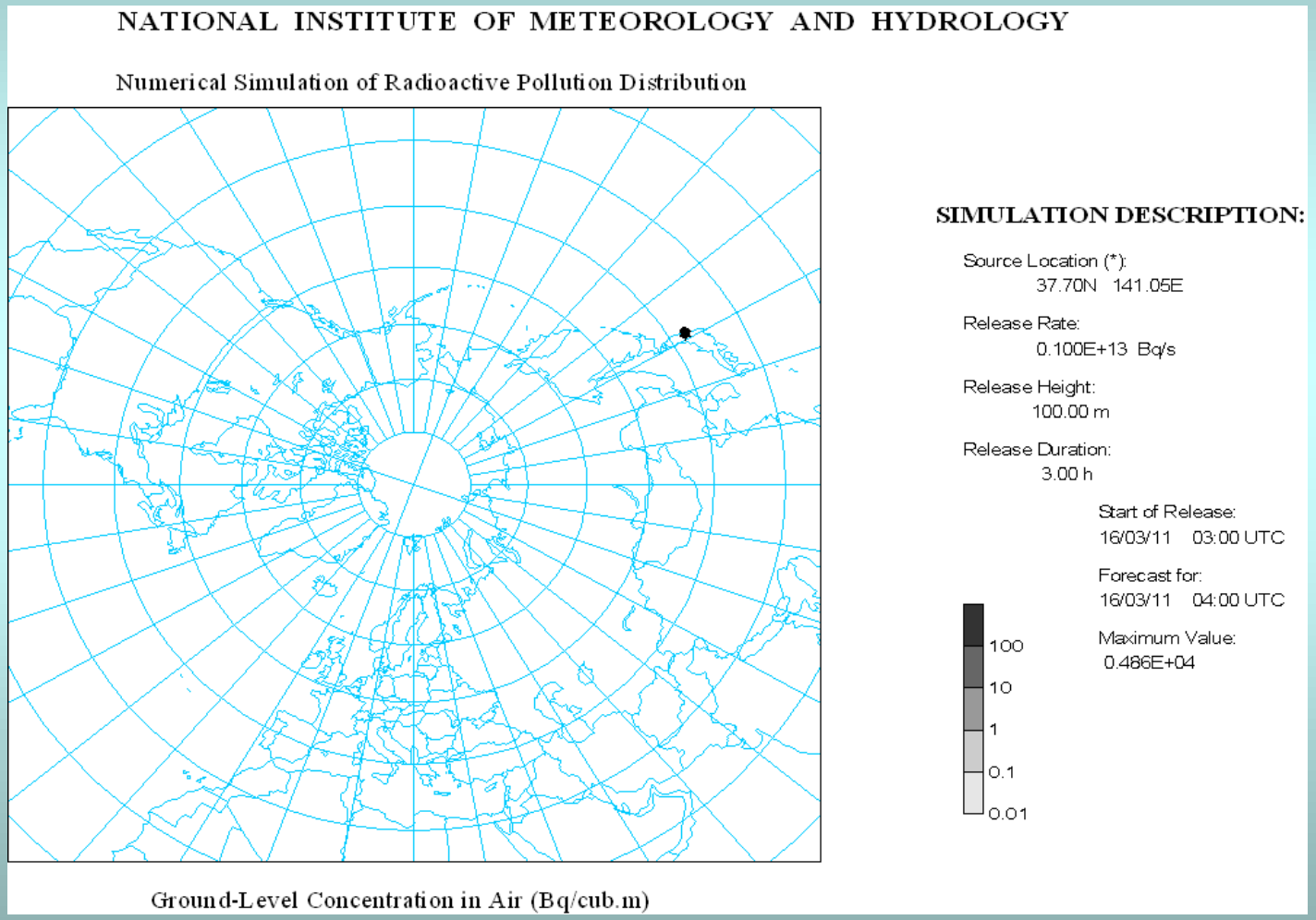
- **increase the space resolution of NH from 300 to 25 km**
- **respective upgrade of meteorological pre-processing**
- **respective upgrade of EMAP and visualizing software**
- **new Figures 7, 8 added to BERS web-site containing the results from every day hypothetical release simulations (animated).**

Example of BERS simulation of Volcano ash distribution



Example of BERS simulation of Fukushima accident

BERS web-site: http://info.meteo.bg/ews/index-en.html **(Figure 7)**



ENSEMBLE Project

Ensemble modeling: originally developed for weather prediction, lately extended to atmospheric dispersion applications (Galmarini et al., 2001, 2004a) is in fact statistical analysis of several dispersion simulations of a common case study, giving the uncertainties in addition to main fields.

Five classes of ensemble, many different statistics

ENSEMBLE project – successor of ATMES, ETEX, RTMOD projects.
ENSEMBLE is an EU FP5 project, recognized as quite important by EC.
ENSEMBLE consortium has been kept active by JRC in Ispra, Italy.
Many runs performed since that time (see http://ensemble2.jrc.ec.europa.eu/).

Main achievement of ENSEMBLE:

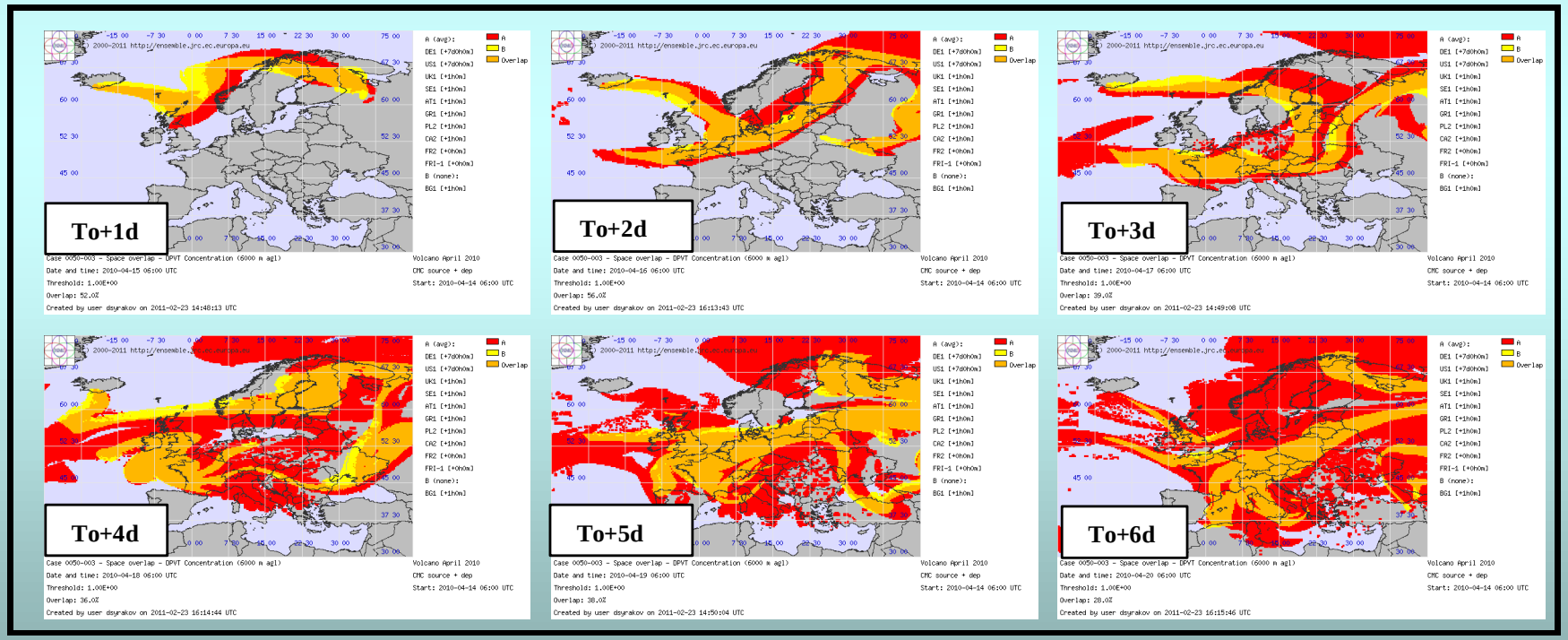
Web-based decision support system to collect atmospheric dispersion forecasts produced by various participants. It enables qualitative and quantitative comparisons of the different forecasts so as to determine their degree of consensus, essential for the decision making process. The ENSEMBLE system allows users to perform on line ensemble analysis.

ENSEMBLE consortium decided to run *Volcano&Fukushima exercises*.
Bulgarian ERS, as a member of ENSEMBLE consortium, took place in it.

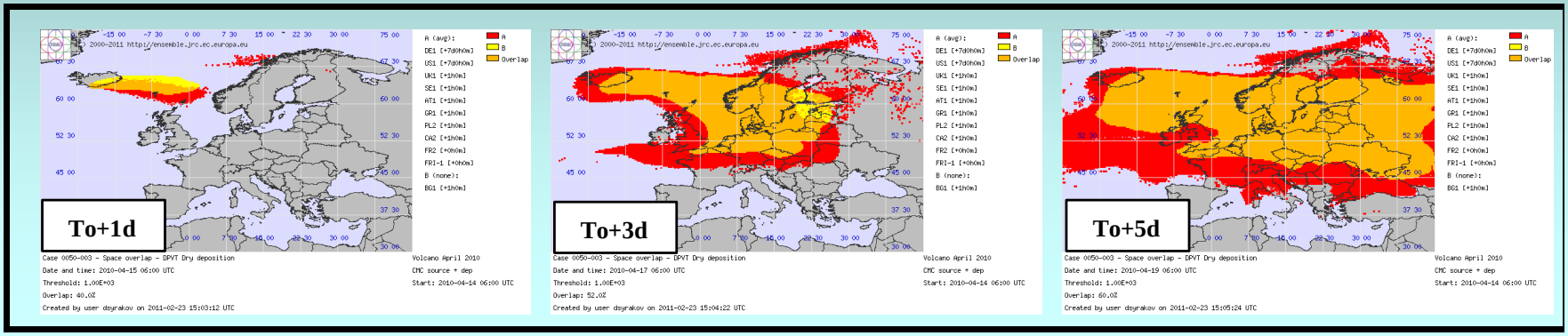
ENSEMBLE Volcano Exercise

BERS simulations *vrs.* ensemble ones

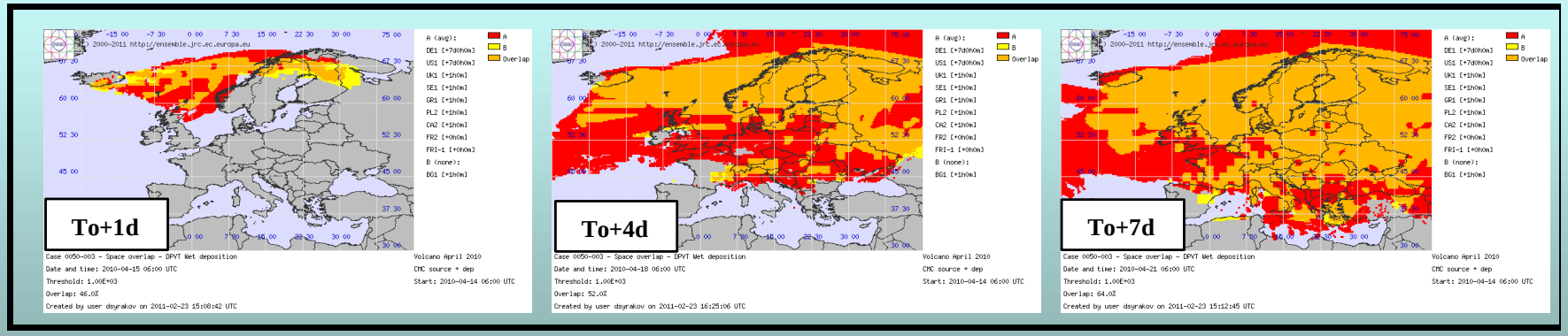
A. Concentration fields at height 6 km



B. Accumulated Dry Deposition fields (earth surface)



C. Accumulated Wet Deposition fields (earth surface)



Volcano Results Model Ranging

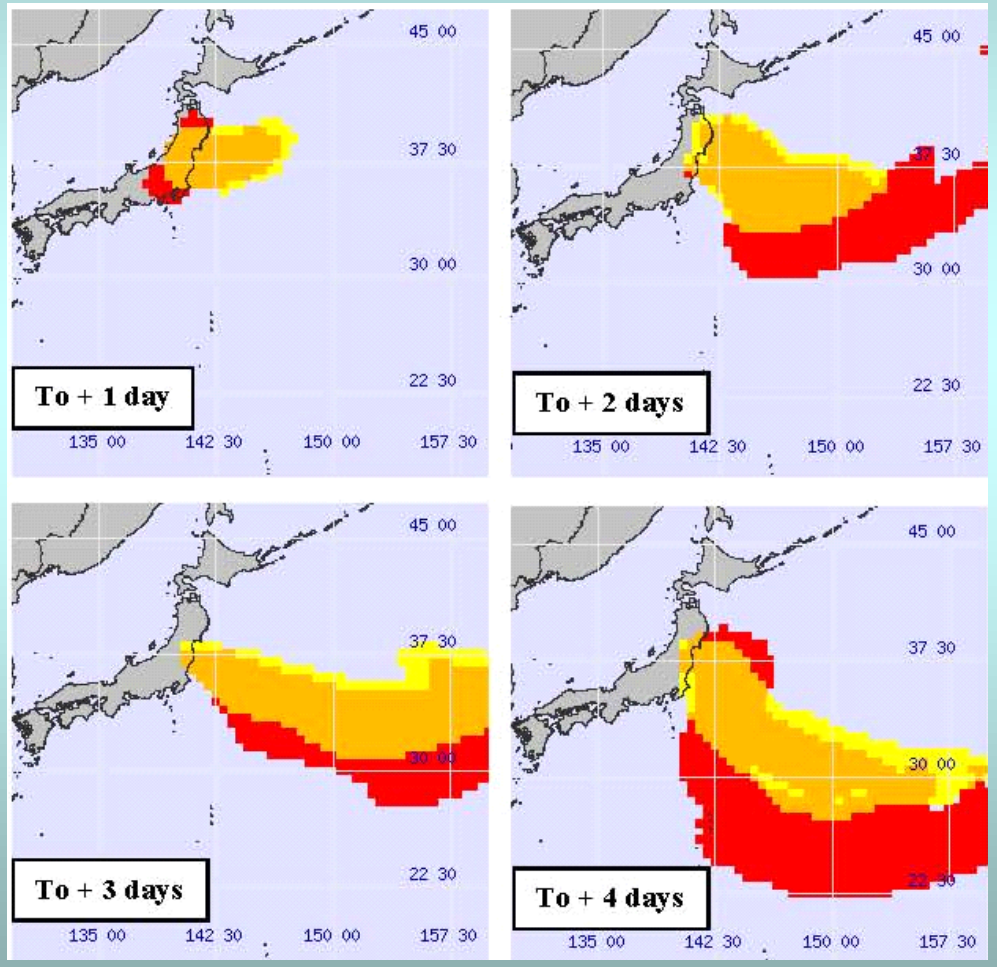
In order to investigate the simulation ability of the EMAP model following table is created. It presents the percentage of overlapping of each model in the Volcano Exercise versus the ensemble of the remaining 10 models.

	Simulation period							mean	rank
Model	**24 h**	**48 h**	**72 h**	**96 h**	**120 h**	**144 h**	**168 h**		
UK1	61	62	59	51	43	38	32	49	4
SE1	69	81	69	74	75	74	79	74	1
DE1	8	5	8	7	10	9	6	8	11
AT1	20	23	27	22	15	22	27	22	8
GR1	4	15	24	28	29	34	41	25	7
PL2	10	9	12	15	14	13	11	12	10
US1	21	20	17	17	16	16	15	17	9
BG1	**52**	**56**	**39**	**36**	**38**	**28**	**19**	**38**	**5**
CA2	36	34	35	42	43	37	34	37	6
FRI-1	76	77	68	69	65	67	65	70	2
FR2	56	70	65	72	73	70	74	69	3

ENSEMBLE Fukushima Exercise

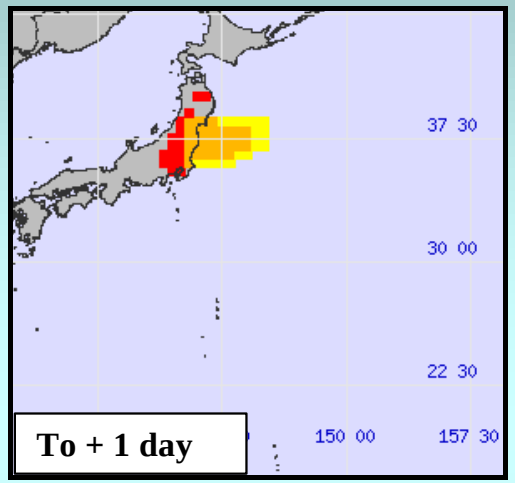
BERS simulations *vrs.* ensemble ones: Concentration fields

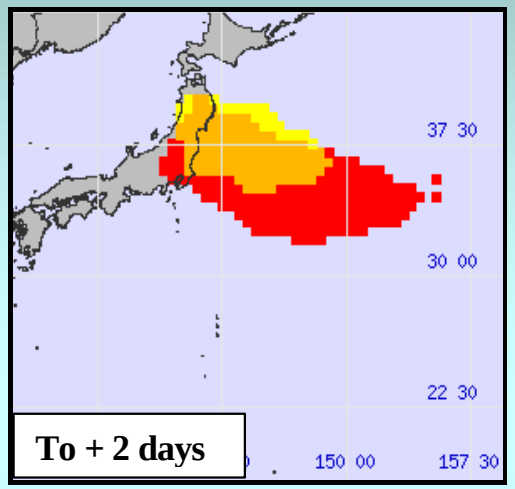
I-131

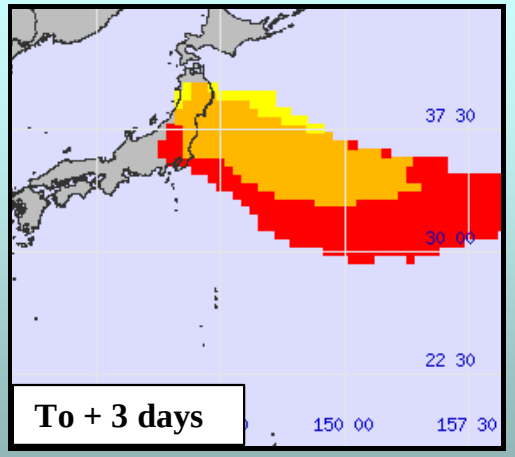


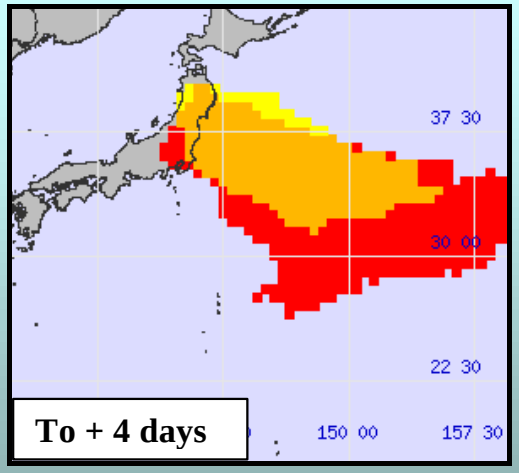
BERS simulations *vrs.* ensemble ones: Accumulated Dry Deposition

I-131



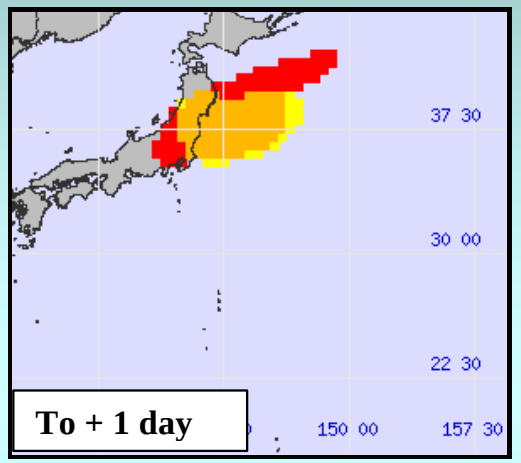


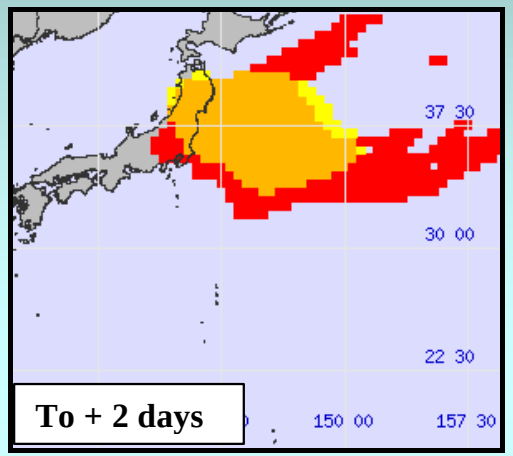


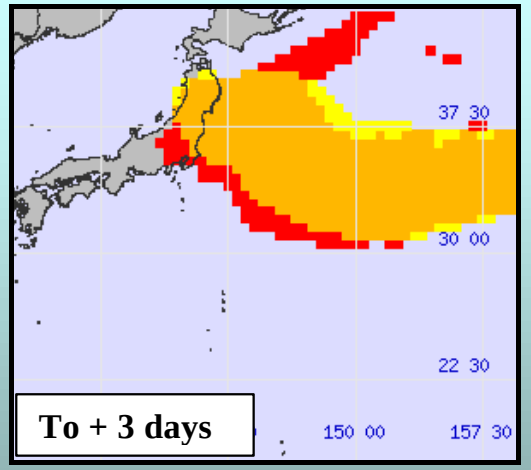


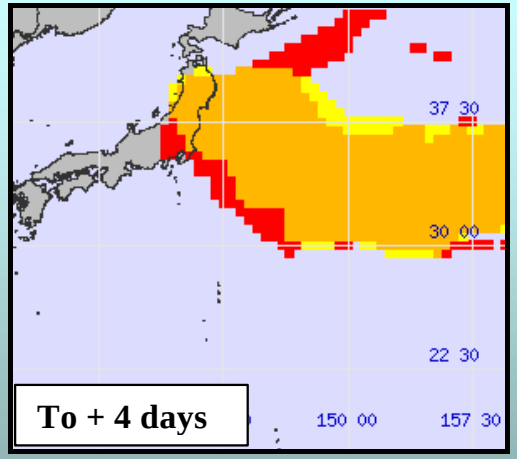
BERS simulations *vrs.* ensemble ones: Accumulated Wet Deposition

I-131









Conclusion

1. In this ENSEMBLE exercises, the BERS produced concentration and deposition fields are presented in evolution vs. the ensemble ones

2. Despite many unfavorable circumstances:

- **very poor met-data – only earth surface and 850 hPa level**
- **very low space resolution of the met-data – 1.5 deg**
- **very low time resolution of the met-data – 12 h**
- **the possibly most simple numerical schemes**

EMAP produces quite satisfactory results

3. All main features of the volcano ash and radioactivity distribution are captured by BERS and its dispersion model EMAP

All this means that BERS can be used with confidence in case of nuclear accidents and that NIMH with its BERS is a useful member of the ENSEMBLE Consortium.

ACKNOWLEDGEMENTS

This work is based on the results obtained within the ENSEMBLE Consortium (http://ensemble.jrc.ec.europa.eu) which is acknowledged. ENSEMBLE is a project supported by the European Commission.

Deep gratitude is due to EC Joint Research Centre in Ispra, Italy, for hosting ENSEMBLE system and supporting the ENSEMBLE activity.