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Forward and backward analysis of the 2017 release of Ru-106 over Europe using a Lagrangian dispersion model and monitoring station data

EUROSAFE 2019

Outline

Motivation

Atmospheric dispersion tools

Backward simulations

Forward simulations

Conclusions and future developments

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Motivation

- at the end of September 2017 many monitoring stations have detected unexplained levels of Ru-106 in the atmosphere over Europe
- the concentration of the radioactive cloud was not dangerous for the health, but it could not be connected to any known episode of release in any nuclear power plant or factory that deals with radioactive material over the area that registered the abnormal concentrations
- inverse Lagrangian dispersion atmospheric modeling to determine the origin and timing of a release starting from the measured concentrations at different sites

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Atmospheric dispersion using Lagrangian models

- FLEXPART – *FLEXible PARTicle dispersion model*
- Lagrangian transport and dispersion model
- suitable for large-scale atmospheric transport simulations
- turbulent diffusion using the Langevin equations
- takes into account dry and wet deposition, decay, etc.
- forward and backward mode, with defined sources or in a domain-filling setting. It can be used from local to global scale
- open source: check `flexpart.eu`

Meteorological data

- FLEXPART requires an extensive set of meteorological data
  - surface quantities (2m temp., 10m wind, solar radiation, humidity, etc.)
  - vertical quantities (temperature, wind velocity, vertical velocity)
- all simulations performed use ECMWF ERA-Interim reanalysis data
- horizontal resolution is 75 Km, all (91) vertical levels used
- dataset covers all the period from 2017-09-25 up to 2017-10-05 with time frequency of 6 hours

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Measured data

Stockholm

START DATE	END DATE	VALUE [mBq / m3]	UNCERT. [mBq / m3]
2017-09-30 08:43	2017-10-01 08:43	0.032	—
2017-10-01 08:43	2017-10-02 08:43	17	—
2017-10-02 08:43	2017-10-03 08:43	9.8	—

Udine

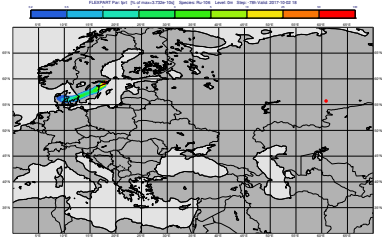
START DATE	END DATE	VALUE [mBq / m3]	UNCERT. [mBq / m3]
2017-09-29 00:00	2017-10-02 00:00	12.3	3
2017-10-02 00:00	2017-10-03 00:00	49.1	12
2017-10-03 00:00	2017-10-04 00:00	30	9
2017-10-04 00:00	2017-10-05 00:00	5.2	1.5
2017-10-05 00:00	2017-10-06 00:00	3.3	1.5

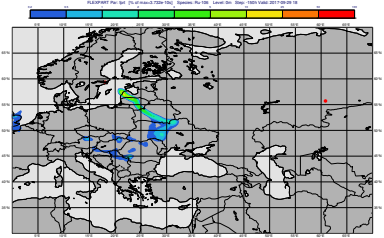
Backward simulation setup

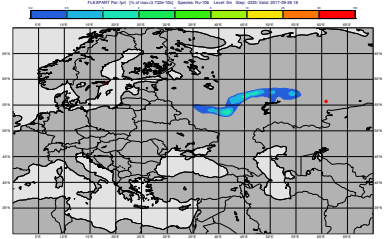
- multiple *releases* for each day from a single location
- each release is proportional to the measured amount
- release height up to 150 m
- backward tracking up to 2017-09-25 00:00
- 10M total particles for each location
- release amount c_k can be estimated using Source-Receptor-Sensitivity (SRS) M_{kijt} and the measured value S_{ijt} as

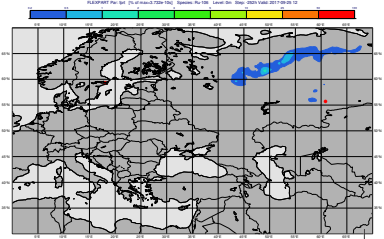
$$c_k = M_{kijt} \cdot S_{ijt}$$

Stockholm



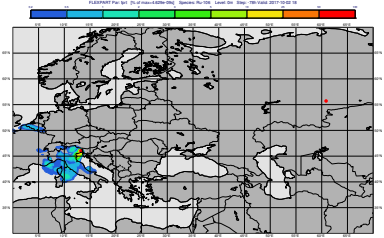


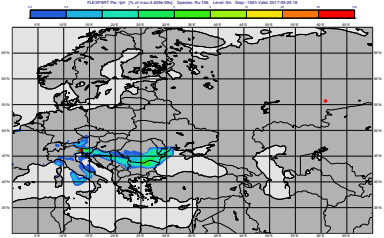


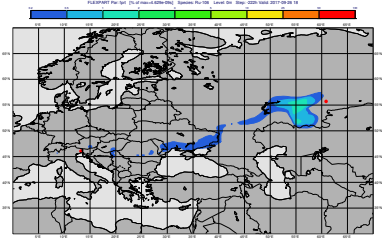


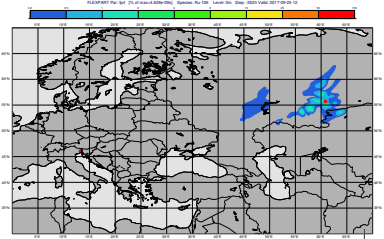
movie

Udine



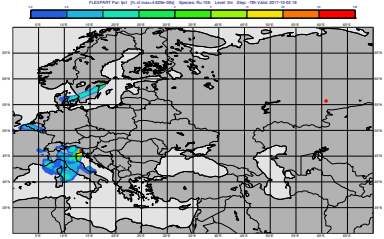


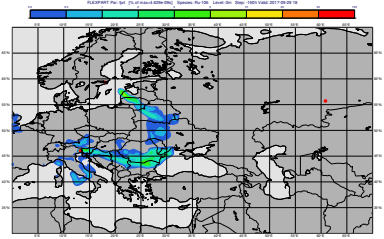


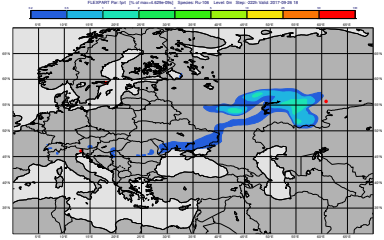


movie

Combination by sum







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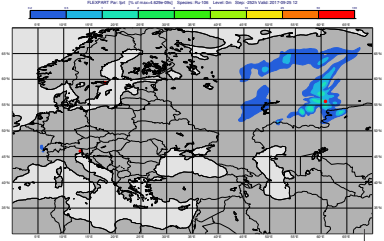
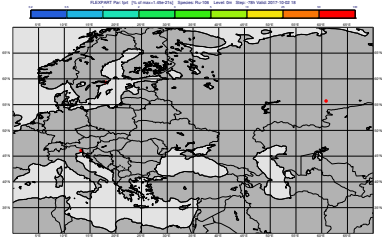
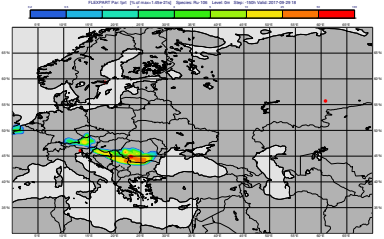
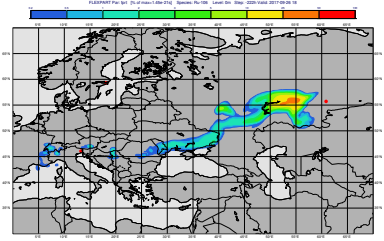
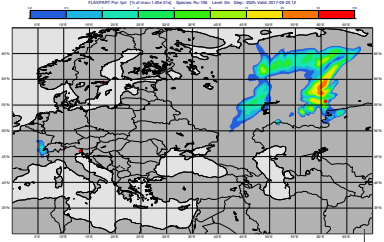


Combination by intersection









movie

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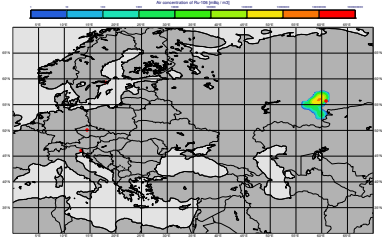
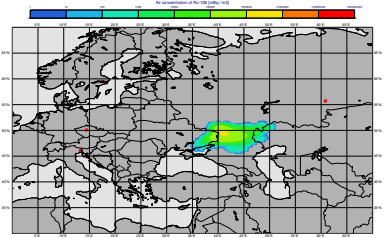
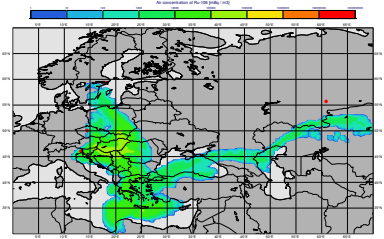
Forward simulation setup

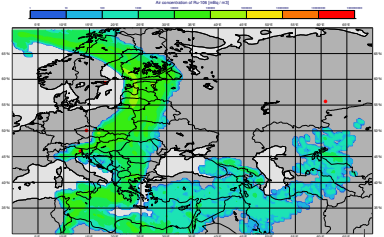
- release point: Mayak
- release amount: 150 MBq
- release height: up to 150 m
- release period:
  A) from 2017-09-25 12:00 to 2017-09-26 00:00 (12h)
  B) from 2017-09-25 18:00 to 2017-09-26 00:00 (6h)
  C) from 2017-09-26 00:00 to 2017-09-26 12:00 (12h)
- simulation up to 2017-10-06 00:00
- 10M particles

Mayak release case A





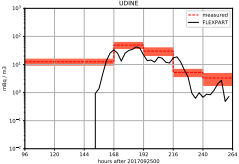


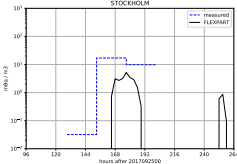


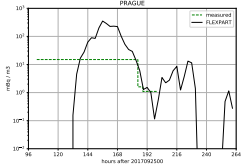
movie

Comparison with measured data

A)







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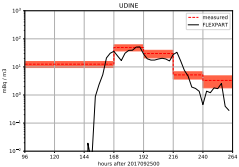
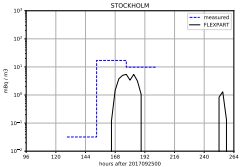
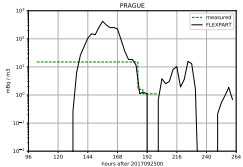
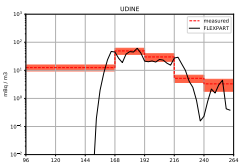
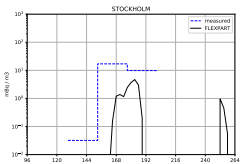


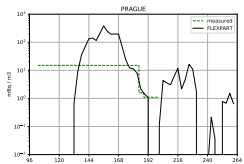




C)







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Conclusions

- determination of radioactive release starting from measured data
- identification of possible source location, timing and amount
- comparison with measured data using forward simulation

Future developments

- improve meteo data using latest ERA5 dataset from ECMWF with higher resolution (28 Km horizontal, 137 vertical levels)
- extend to more measurement stations
- sensitivity to more simulation parameters (release height, simulation setup, particle number, etc.)

Thanks for the attention!

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