Danmarks
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# Source Localization by Inverse Methods (SLIM)

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# Background

In early October 2017, low concentrations of Ru-106 were measured in many high-volume air samples in Europe from filter-station monitoring networks. However, no information was given that an accidental release of Ru-106 had taken place.

The event shared the no-information with the Chernobyl accident where it took two days before the Soviet authorities declared that they had an accident.

Such events, indicating a release of anthropogenic radionuclides to the environment, signify that there is a need for prompt and accurate responses from national radiation protection authorities.

This requires that robust and accurate methodologies, suited for operational use, are developed and implemented for spatial and temporal localization of the source of contamination based on available monitoring data.

In the NKS-B project SLIM, five different methods have been applied to the Ru-106 case of autumn 2017 and to the European Tracer Experiment (ETEX). Partners: FMI, MET no, SMHI, DMI, DEMA, DSA, SSM, STUK, DTU, and PDC-ARGOS.

# Autumn 2017 Case of Ru-106

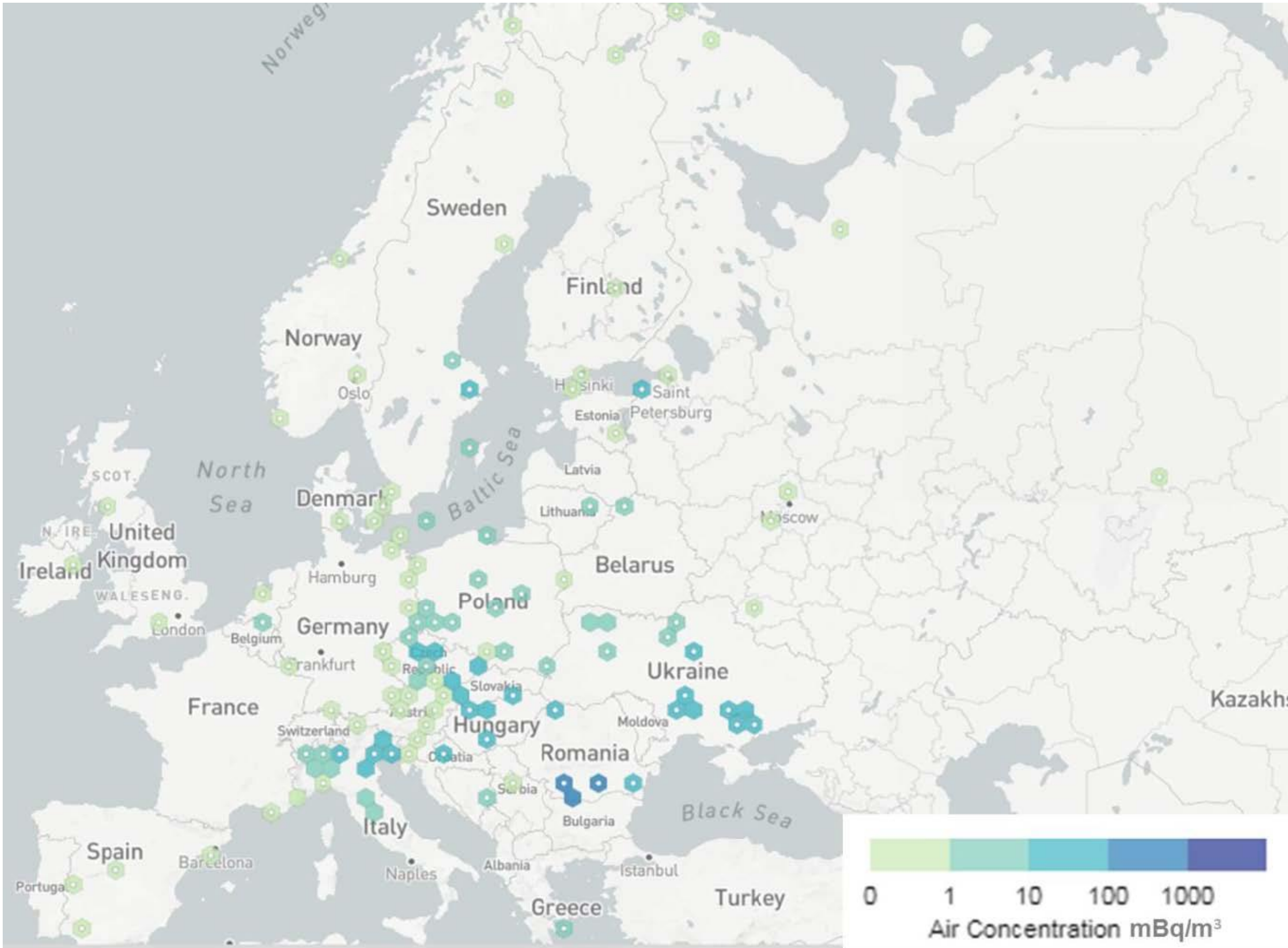
## Sampling stations

In 3–6 October 2017, low concentrations of Ru-106 were measured in filter stations in Europe. No other fission products such as Cs-137 were recorded, and therefore it could be concluded that the Ru did not come from an NPP accident.

The Ru-106 levels were far below those requiring public protective actions. However, one would expect higher levels closer to the release point, and thus one wishes to have a better understanding of what has taken place.

The data comprise around 400 measurements, some of which correspond to levels below minimum detectable activities, so-called zero-measurements.

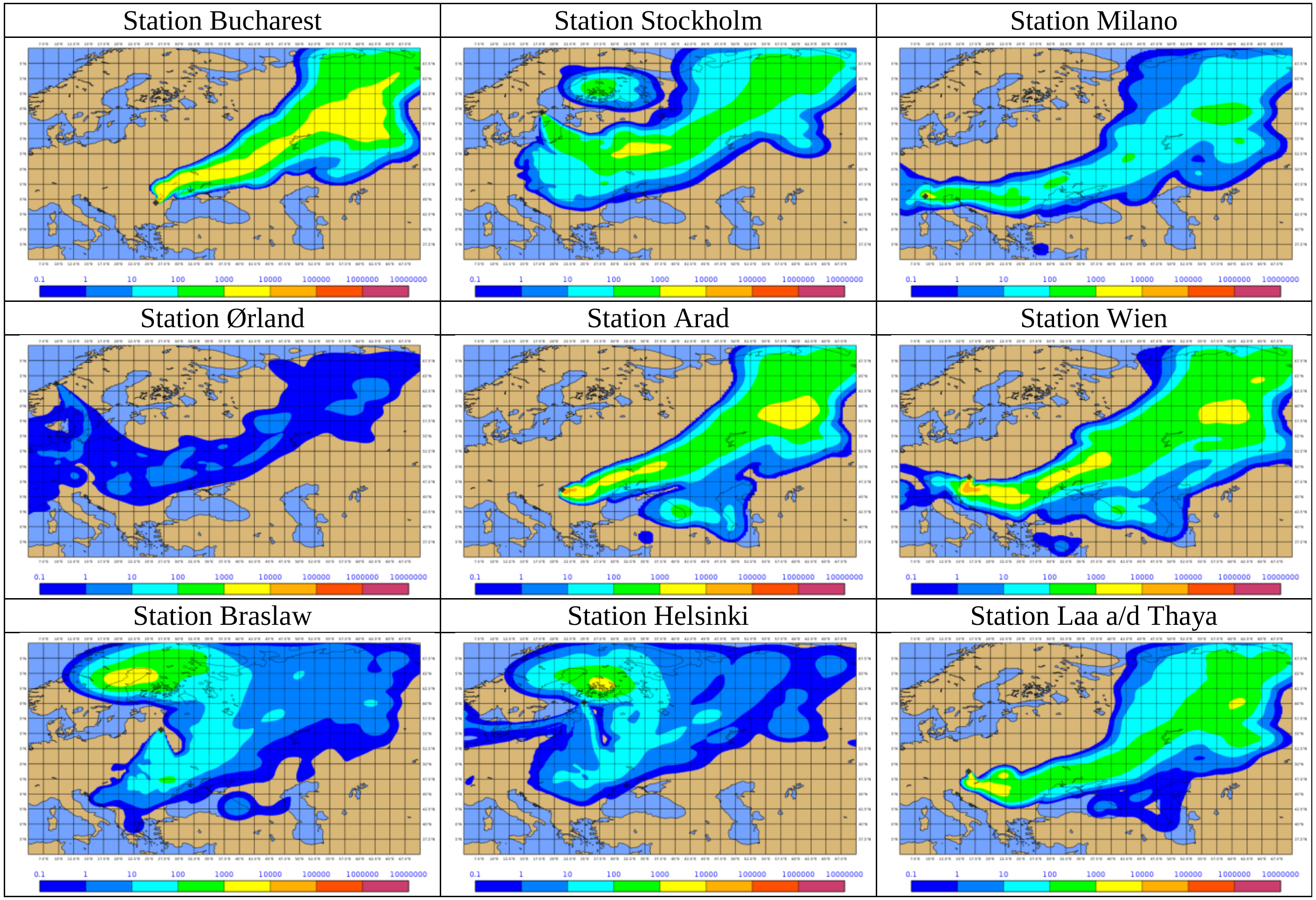
The data are time-average concentrations corresponding to time periods from 12 hours and up to seven days. From a meteorological point of view, and thereby also from an atmospheric dispersion point of view, a week is a long period.




Locations where concentrations of Ru-106 in the air have been reported to the IAEA. The measurements were taken during different sampling periods ranging from 12 hourly to weekly.

# Inverse Modelling

In SLIM, five different methods were applied.




Time-integrated adjoint concentration of Ru-106 at 2-m height valid at 2017-09-26, 00 UTC.
The filter stations are indicated by black diamonds.

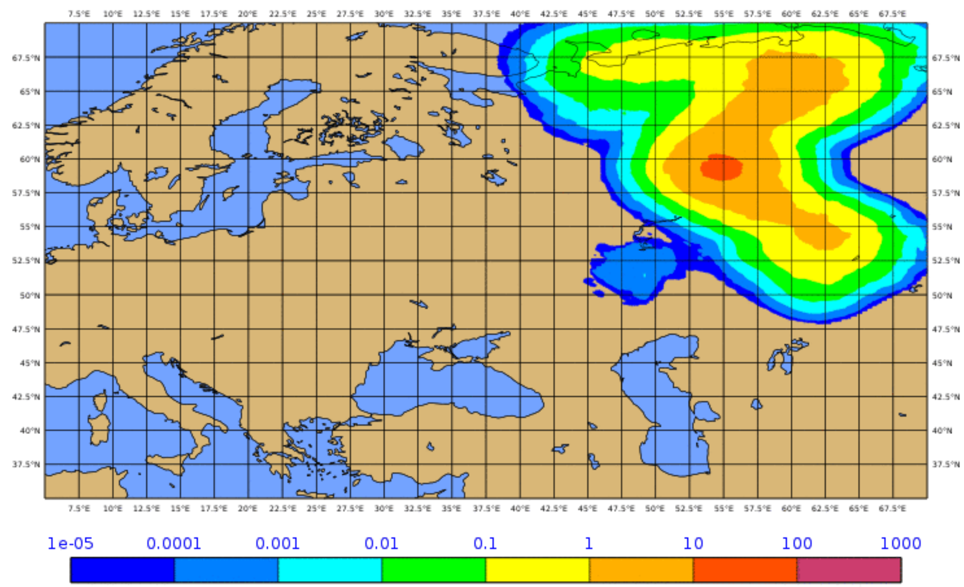
# Overlap method

We assumed a ground-level release from a fixed geographical location.

The release should come from a point within the overlap between the adjoint instantaneous concentration plumes.

Time series of 60th percentile adjoint instantaneous concentration values.

20170925 00:00 UTC Instantaneous concentration at 2 m, Ru-106

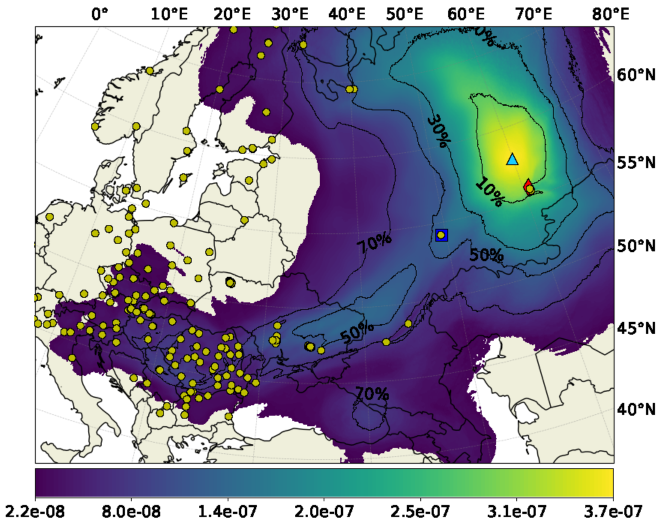


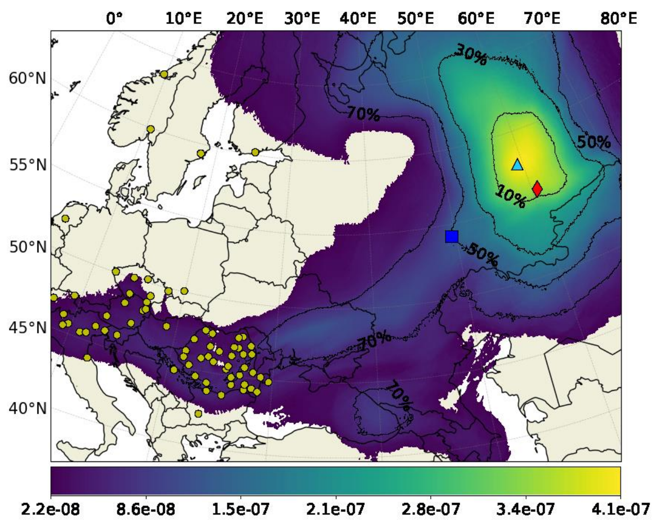
# Location of release site

Applying Bayesian inference:

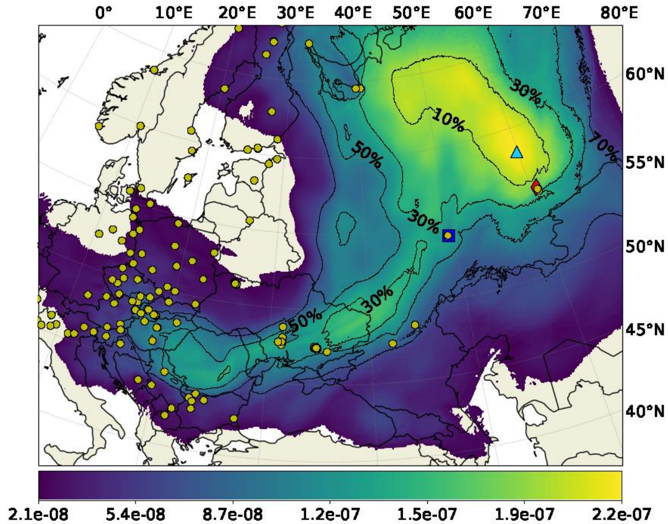
The figure shows probability density for the release location (km$^{-2}$). The blue triangle indicates the highest probability, the red diamond Mayak, the blue square NIIAR, and the yellow circles the sampling stations used.

This result is based on *all* non-zero measurements as well as non-detections (below threshold mesurements) which reduce probabilities in corresponding areas.



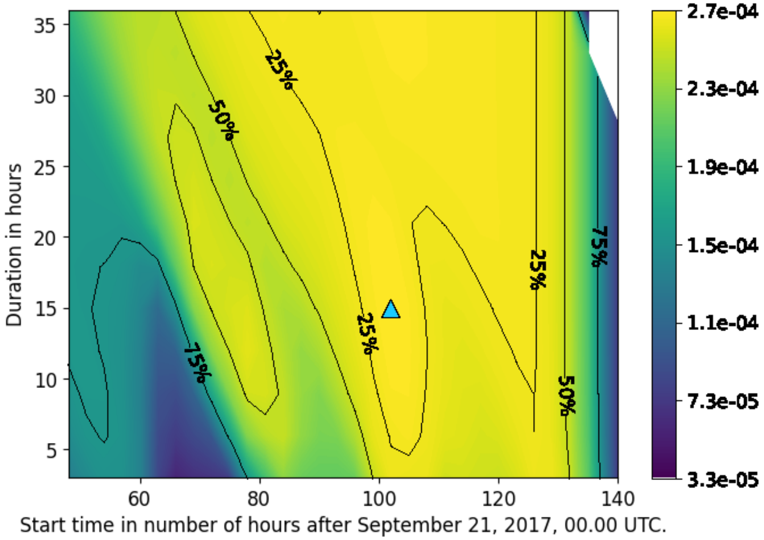

Based on non-zero measurements and non-detections, both up to and including 36 hours.

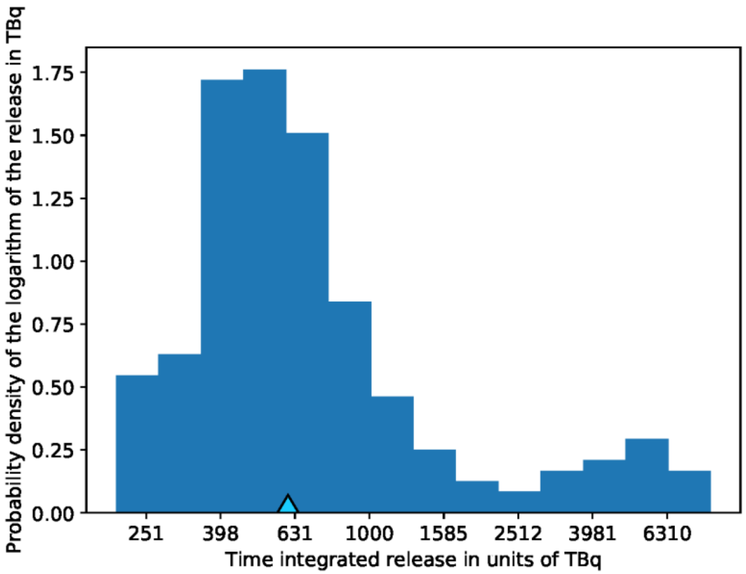



Based on non-zero measurements and non-detections, both more than 36 hours.

If diurnal measurements are available, then weekly measurements do not deteriorate the localization.
If not, weekly measurements tend to blur the localizing the release... A week is quite long in meteorology.

# Start time, duration, and total release



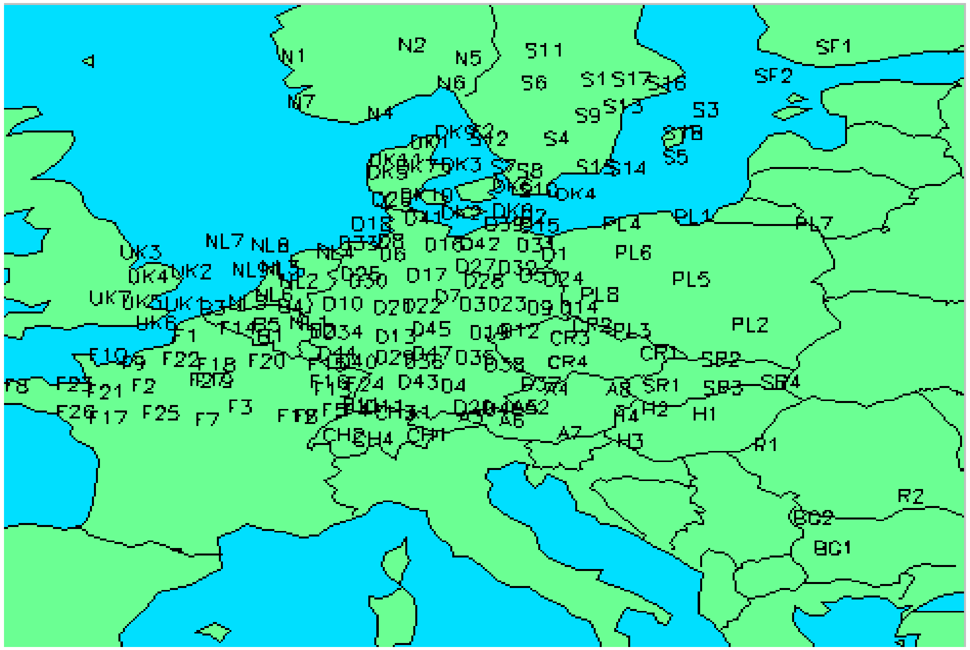

Probability density (hours$^{-2}$) for start time and duration.

Probability density for total release (TBq).

The blue triangle indicates the most likely release point.

# European Tracer Experiment (ETEX-1)

## Sampling network stations



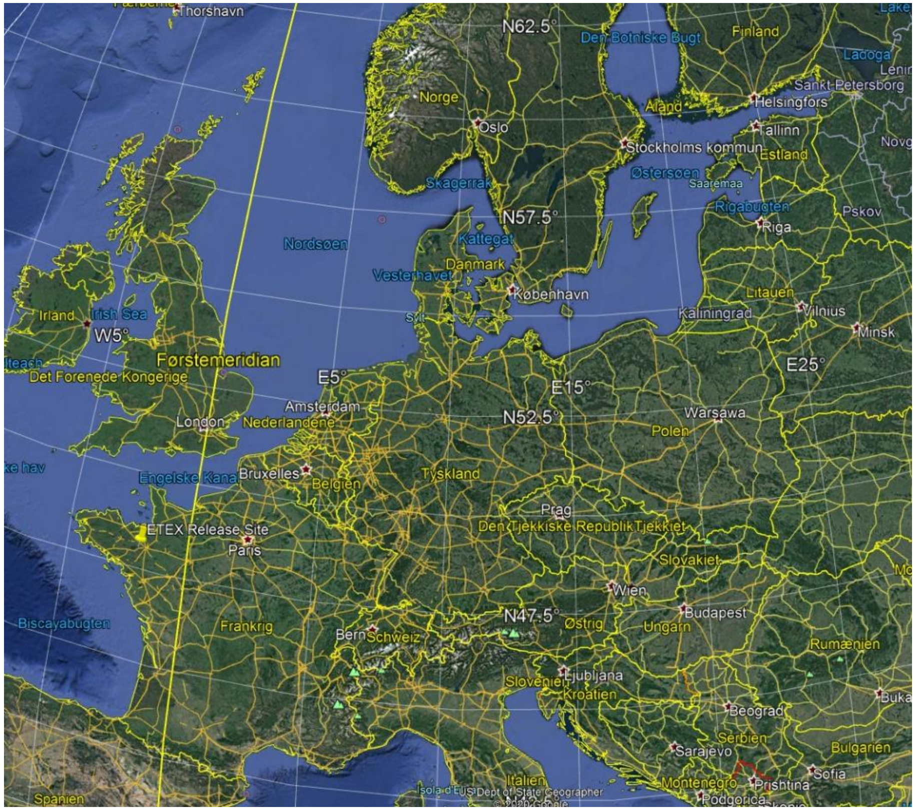

168 filter stations sampling at three-hour intervals over a period of 72 hours.
The stations closest to the source started sampling 3 hours before the release start; the most distant stations ended sampling 90 hours after the release start.
In total, 5040 measurement data; 939 non-zero data.

# Tracer release

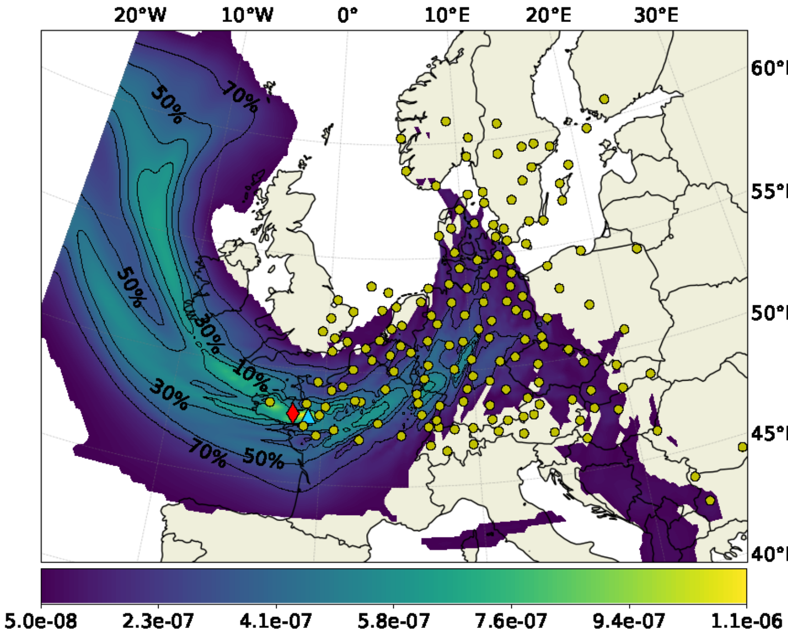
Atmospheric tracers were released in the form of a homogeneous air stream containing a few percent of perfluoromethylcyclohexane (PMCH) tracer.
The gas stream passed through a small chimney where the gas was released from the top.

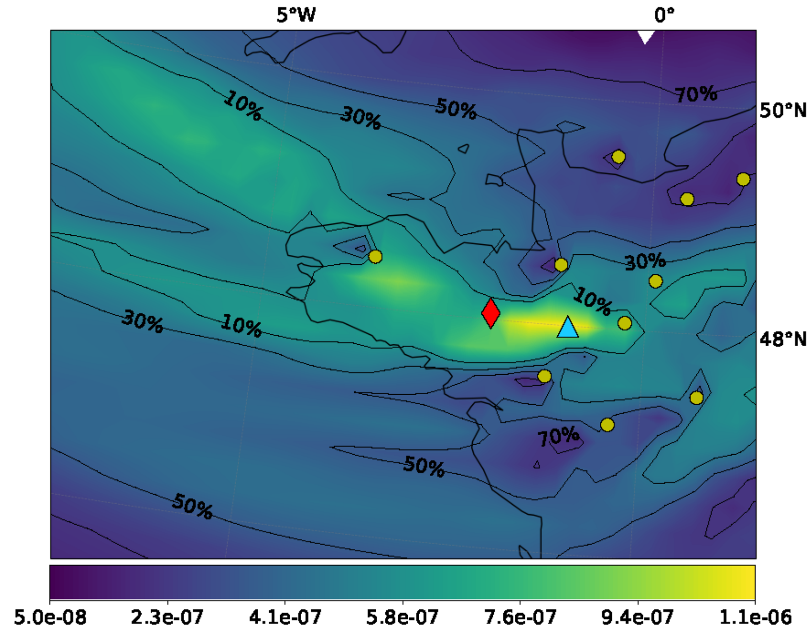
The first release started at 16:00 UTC on October 23, 1994, and lasted 11 hours and 50 minutes.

340 kg of the non-depositing inert gas PMCH were released from Monterfil (48°03’30”N, 2°00’30”W) at a constant flow rate of 8.0 g/s.



# Location of release site



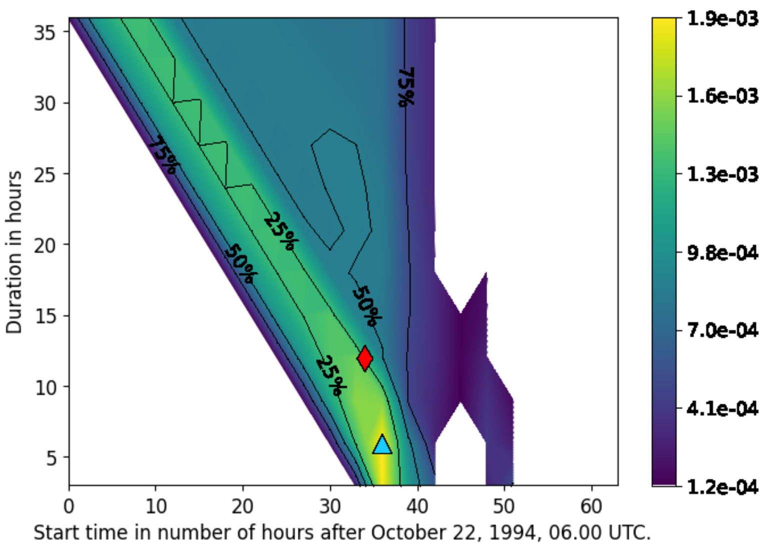



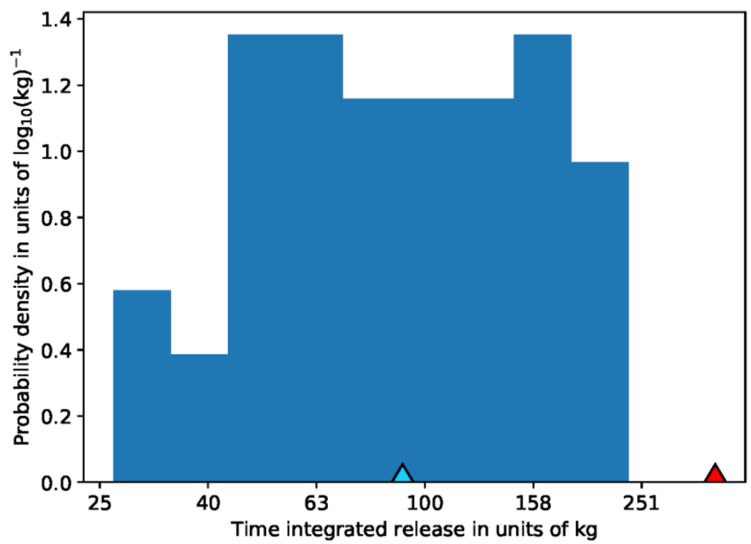

Probability density for the release location (km$^{-2}$). The blue triangle indicates the highest probability, the red diamond the actual release site, and the yellow circles the sampling stations.

This result is based on *all* non-zero measurements as well as non-detections (below threshold mesurements).

Zoom in.

# Start time, duration, and total release




Probability density (hours$^{-2}$) for start time and duration.

Probability density for total release (kg).

The blue triangle indicates the most likely release point, and the red diamond the actual release.

If you *know* the release location, the problem is reduced by two degrees of freedom. Can one then derive the release profile for the various radionuclides detected by filter stations and, if possible, also using recordings from nearby gamma stations?

This is studied in the ongoing NKS-B project: SOCHAOTIC
(SOurce CHAracterizatiOn accounting for meTeorologIcal unCertainties)

Partners: FMI, MET no, SMHI, DMI, DEMA, DSA, SSM, STUK, DTU, and PDC-ARGOS.

**Thank you!**