Estimation of Source Parameters of Radionuclides applied to the ^{106}Ru case

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Introduction

During the Autumn of 2017, the radioisotope ^{106}Ru was measured in air filters at several locations in Europe, and concentrations where found to exceed the background level. ^{106}Ru is not naturally occurring in the environment and must be created, however no facilities had reported any accidents.

To locate the source of such releases, inverse methods using air dispersion models must be employed. This project aims to investigate a set of models to estimate source parameters such as location, time of release, release duration, and total released activity.

Previous work [2] was further examined and continued, and new methods were tested and evaluated. For decision makers, the methods are required to be

- Accurate
- Fast enough for use in time sensitive decision making
- Resilient to measurement errors

Figure 1: Station for radiation measurements (`radnett.dsa.no`)

Method

The dispersion problem was solved using the open source SNAP model [1], running the model backwards in time. The collection of model runs was combined using overlaps of the concentration fields, assigning each area affected by the concentration a probability. Using Bayes' rule, one finds an estimator for probability density:

$$\Pr\left(rel_{x,y,\bar{t}} \mid \text{measurements}\right) \propto \prod_i \Pr_i(T_i > T \mid rel_{x,y,\bar{t}}) \prod_j \Pr\left(T_j \not> T \mid rel_{x,y,\bar{t}}\right) \quad (1)$$

The probability fields for all the single adjoint runs are calculated using the infrastructure at `met.no`, running the backwards models in parallel for each measurement. These are combined to simulate the release duration, and plotted to provide figures of the highest probability likelihoods.

Validation

The ETEX-1 case was used for validating the method. A known amount of tracer gas was released for twelve hours from Monterfil, France (marked with black diamond). The resulting gas cloud was transported by winds across Europe, shown in Figure 2.

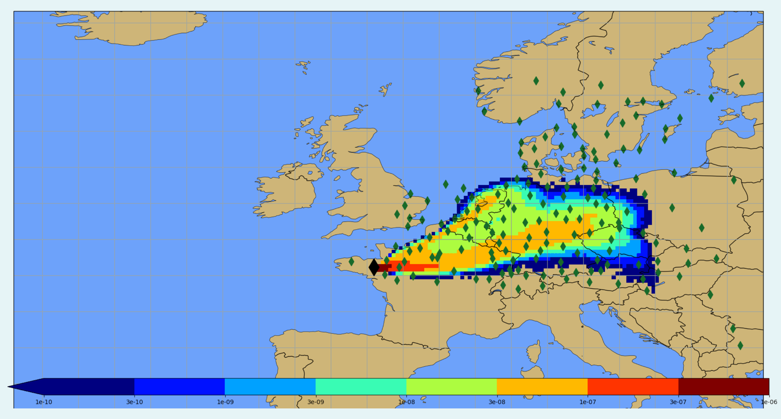
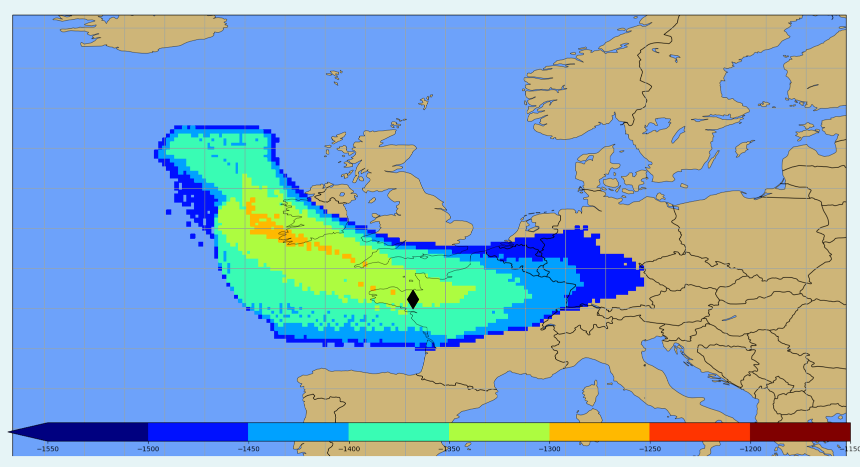
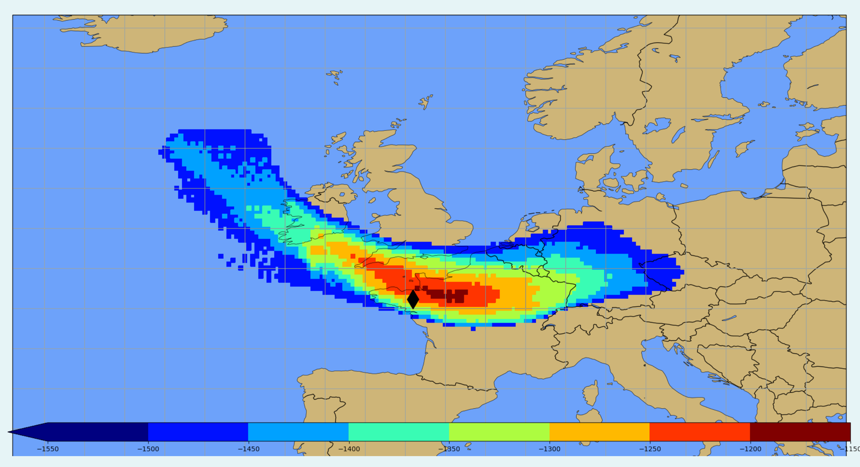


Figure 2: Accumulated concentration after 36 hours for forwards run

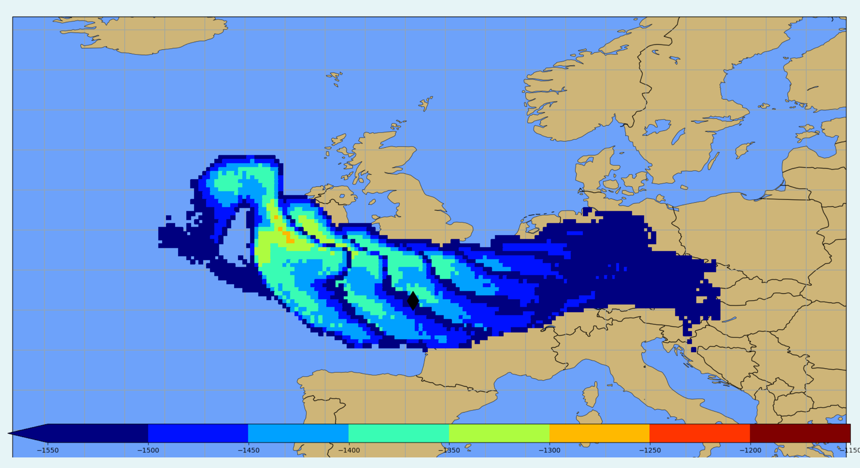
The estimates of spatial and temporal location matches within ~3 h, equal to the sampling time for the stations.



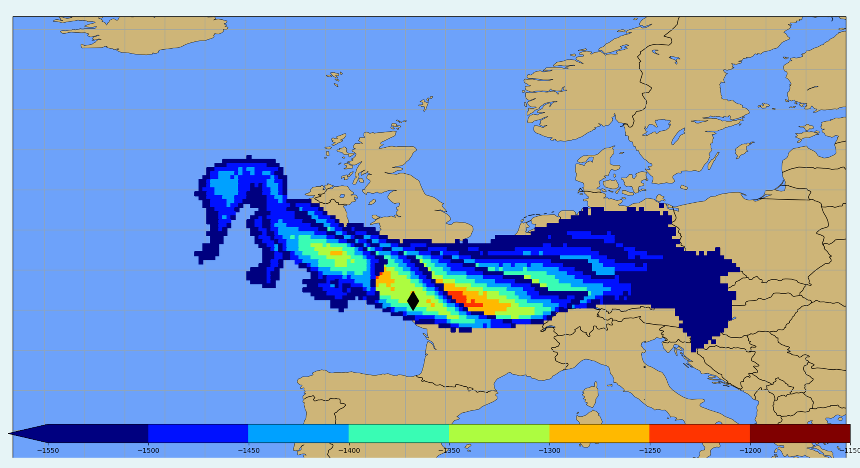
(a) Release duration of one hour



(b) Release duration of twelve hours



(c) Release duration of one hour



(d) Release duration of twelve hours

Figure 3: Probability densities for ETEX-1 in space (3a, 3b) and in time (3c, 3d). Colours to the right on the colour bar marks higher probability densities.

Ruthenium case

The Ruthenium case involved a smaller number of measurements (383 vs 5040), with longer sampling times and different detection limits.

Applying the methodology to this dataset yields the following estimates of location and release time

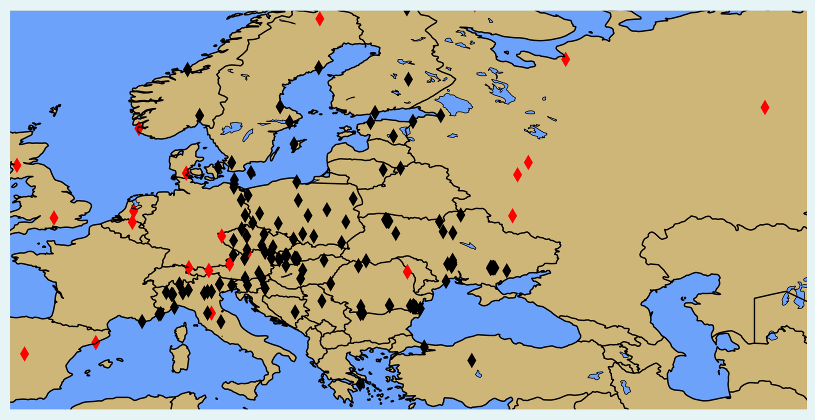
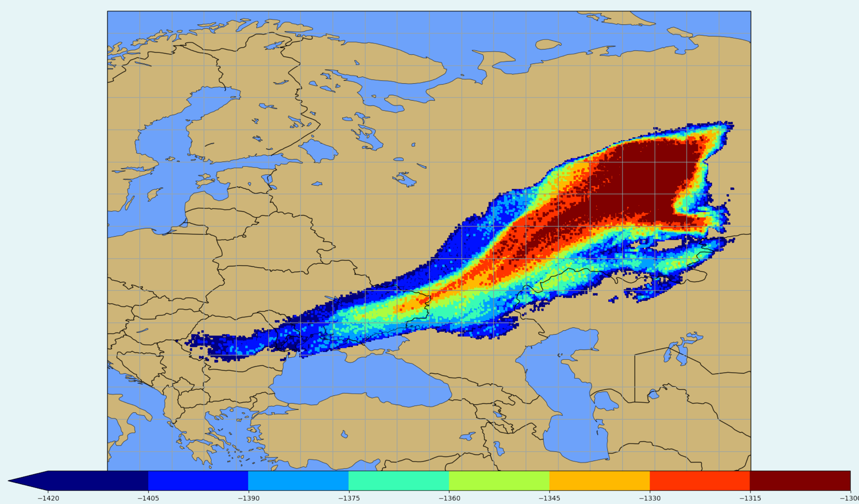
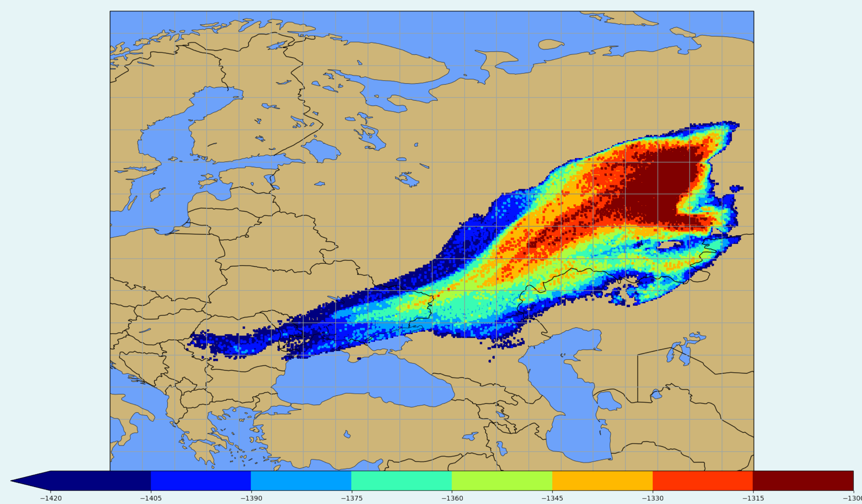


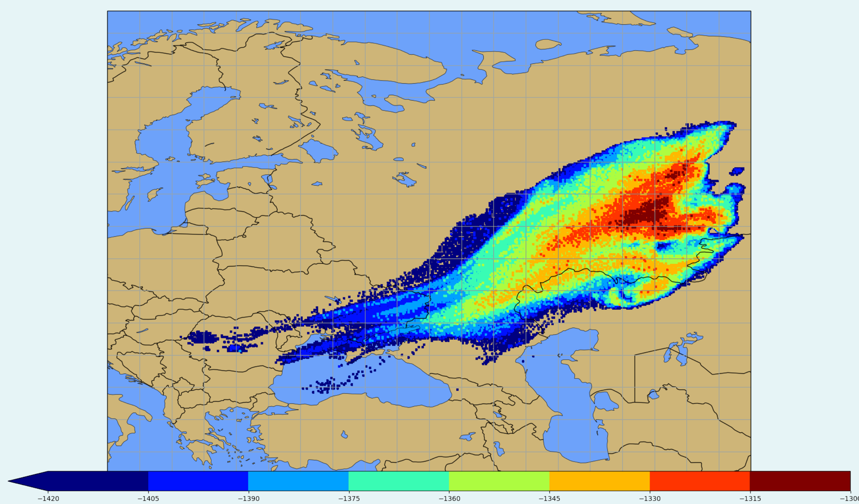
Figure 4: Stations measuring during the Ruthenium episode. Black diamonds mark measurements above limit of detection



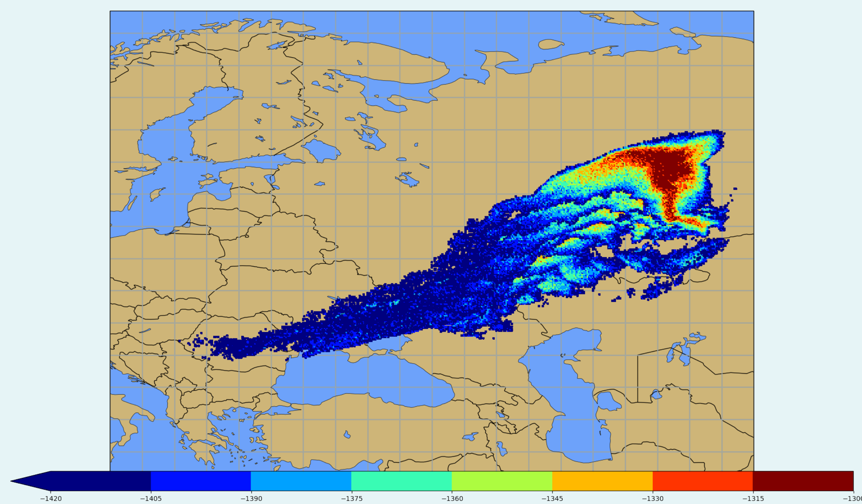
(a) Release duration of one hour



(b) Release duration of two hours



(c) Release duration of ten hours



(d) Time evolution assuming a release duration of one hour, slice for every 6 hours

Figure 5: Probability densities for the ^{106}Ru case in space (5a, 5b, 5c), and in time (5d). Colours rightwards in the colour bar mark higher probability densities

A clear location of the release can not be found, although we can make some observations based on the probability densities:

- A source outside of Russia or Kazakhstan is unlikely
- Source duration was short
- Release was likely in the interval 26th–28th September 2017

For operational usage where decision makers requests a localisation, this method is able to scale horizontally to provide results quickly. The creation of a dataset of adjoint runs allows modifications regarding concentration thresholds, measurement errors, or new measurements to be taken into account without rerunning the model.

Next steps

The use of a single weather forecast does not give any information regarding atmospheric uncertainty. During the next part of this project, several perturbed forecasts will be used to determine the effect on the localisation.

To determine released source activity, a forwards run must be conducted from a set of likely locations. Using the probability estimator, a Monte Carlo method could determine how much activity was released, verifying the consistency of the measurements and method.

References

[1] J Bartnicki, H Haakenstad, and Ø Hov. "Operational SNAP model for remote applications from NRPA". In: *Norwegian Meteorological Institute. Report* (2011), pp. 12–2011.

[2] Jens Havskov Sørensen. "Method for source localization proposed and applied to the October 2017 case of atmospheric dispersion of Ru-106". In: *Journal of environmental radioactivity* 189 (2018), pp. 221–226.

Acknowledgements

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