UK National Data Centre: Radionuclide Event Analysis

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POSTER

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ABSTRACT

The UK National Data Centre (NDC) operates a series of custom-developed software tools for the automatic processing, analysis, archiving and interpretation of radionuclide (RN) data from the International Monitoring System (IMS). The tools include an RN Pipeline for the analysis of radionuclide data (noble gas and particulate), and a series of simulation pipelines to provide accompanying atmospheric transport modelling (ATM) data. The ATM products are triggered on the identification of an 'RN detection event', which can include radioxenon plumes or 'high-priority' detections.

An overview of the toolset is presented, along with case-studies using interesting RN detections from recent years, such as the Scandinavian fission products (2020) and Dubna iodine detections (2020).

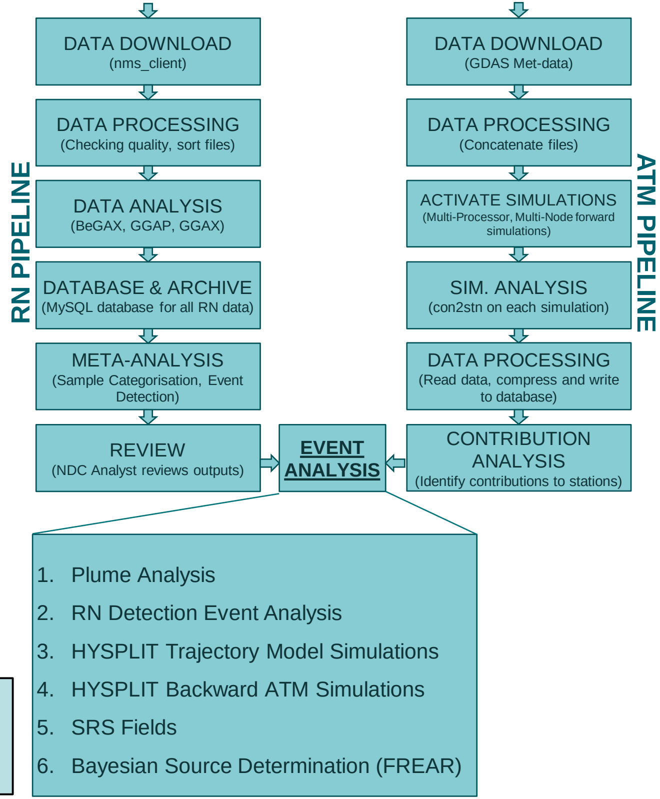

Fig. 1. Radionuclide and atmospheric transport modelling pipeline diagrams, detailing the current 'detection event' analysis processes

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RN DETECTIONS

^{131}I is frequently detected at RUP61. Detections at RUP54 have been correlated with these using backwards ATM simulations

These detections were flagged by the UK NDC RN Pipeline as high-category samples, since multiple fission products were detected

^{134}Cs, ^{137}Cs & ^{103}Ru were detected at SEP63 (collection start 22-06-2020).

Other fission products were detected at national monitoring stations.

"The Scandinavian Fission Products"

RN Detection Event **Analysis**

Identify radionuclide events based on the time series and composition analysis, and use a combination of sample categorisation and 'plume' detection

- ^{133}Xe plumes are often detected – back-to-back detections of ^{133}Xe showing a plume passing through a station location, over multiple collection periods
- RN Categorisation logic based on detections most likely from a nuclear explosion (particulate & noble gas)
- Radionuclide bulletins are produced using UK NDC analysis results

For detected events:

- Activate TRAJ_Pipeline (HYSPLIT trajectory runs) to highlight wind vector fields for the 48 hours preceding the detection(s)
- Activate Backward ATM Simulation (HYSPLIT) to identify a Possible Source Region (PSR)
- Compile an Event file – HTML data file to visualise all event-related data (CARVE)

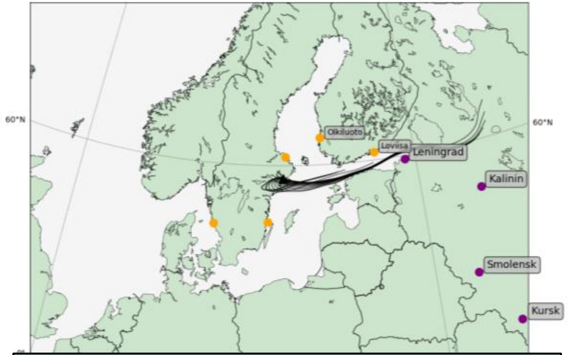

Fig. 2. TRAJ model from the SEP63 detections

Are the Iodine RN detections correlated?
RN detection → RN detection event ?
What is the source of the SEP63 detections?

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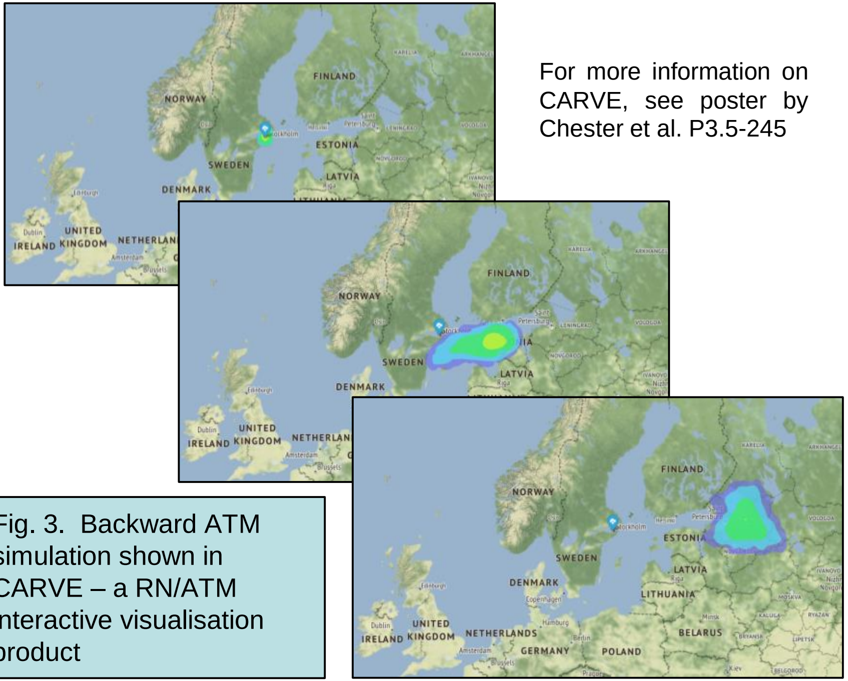
ATM PRODUCTS

Backwards Simulations



For more information on CARVE, see poster by Chester et al. P3.5-245

Fig. 3. Backward ATM simulation shown in CARVE – a RN/ATM interactive visualisation product

SRS Fields

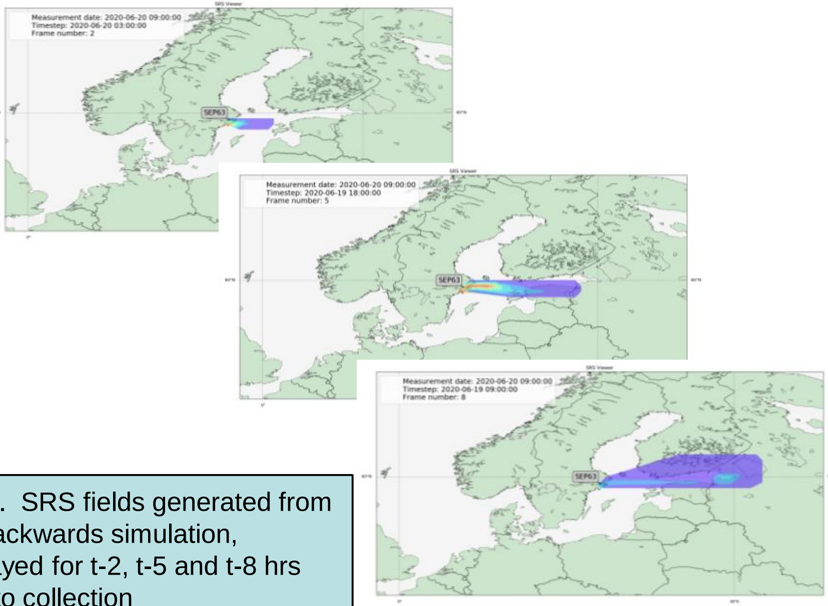


Fig. 4. SRS fields generated from the backwards simulation, displayed for t-2, t-5 and t-8 hrs prior to collection

The Source-Receptor-Sensitivity (SRS) fields generated can be used to determine a possible source location, together with the results of possibly correlated RN detections.

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RN DETECTION EVENTS

In order to determine whether multiple RN detections (possibly at different locations) are correlated, we consider the temporal and spatial overlap of the backwards atmospheric transport and dispersion plumes. The overlap region is quantified using Equations 1 - 2. If the RN detection events score high, they are considered to be ***Correlated RN Detection Events***

Multiple RN detection events correlated

$$M_{spatial} = \frac{2 \cdot A_{1+2}}{(A_1 + A_2)} \qquad \textit{Eq. 1}$$

$$M_{time} = 1 - \frac{\left(\frac{\Delta t_1}{t_1} + \frac{\Delta t_2}{t_2}\right)}{2} \qquad \textit{Eq. 2}$$

The $M_{spatial}$ and M_{time} metrics score the degree of spatial and time overlap using the plume area A_n at time t_n, for simulation n.

The overlap region is plotted for each correlated RN detection event (see Fig. 5)

Table 1. A selection of correlated RN detection events recorded in the NDC events database

Period	Station 1	Station 2	$M_{time} \cdot M_{spatial}$	Common Isotopes
April-21	RUP54	RUP61	0.3916	^{131}I
Feb-21	RUP54	RUP61	0.26	^{131}I
Sept-20	RUP54	RUP61	0.1779	^{131}I
Feb-21	RUP54	RUP61	0.154	^{131}I
Feb-21	RUP54	RUP61	0.1427	^{131}I
Dec-20	CNP20	MNP45	0.1379	^{131}I

Can we determine a source location based on the detections (and nearby non-detections)…?

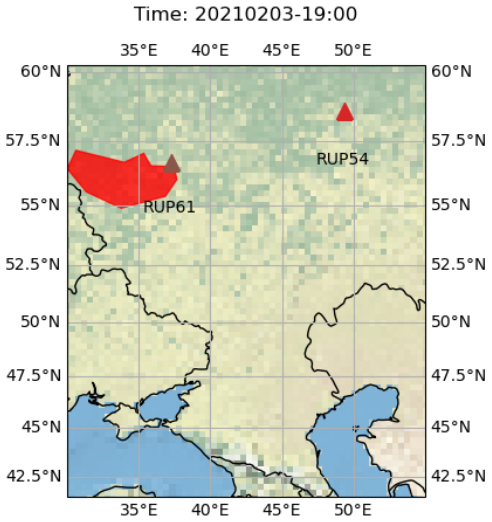

Fig. 5. The backwards overlap region of the ^{131}I detections at RUP61 and RUP54

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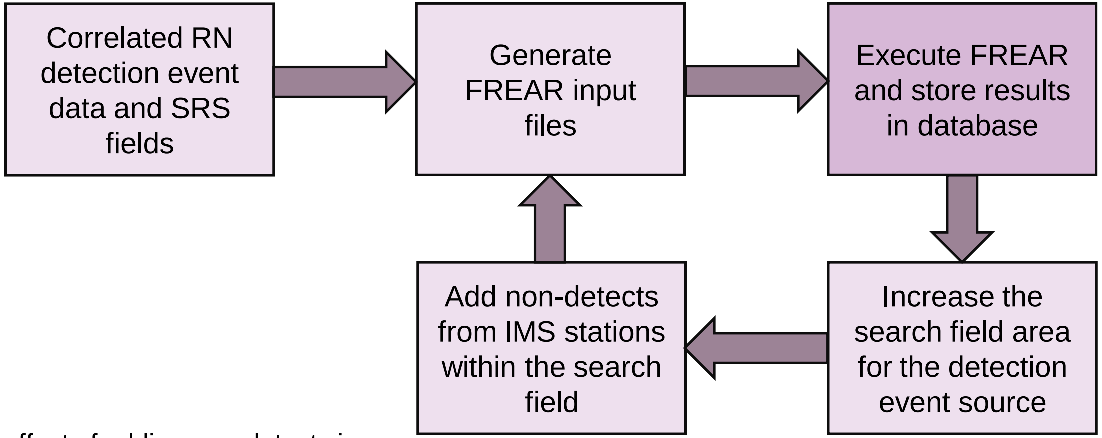
Forensic Radionuclide Event Analysis and Reconstruction (FREAR) is a programme developed by a Belgian/Canadian collaboration and can be used to reconstruct a source (release location, release amount, and release start and release stop times) using observations from monitoring networks such as the IMS. UK NDC use FREAR to determine the possible source parameters for each *correlated RN detection event*.

FREAR

The UK NDC have implemented the FREAR code into an automated event analysis pipeline. Upon the assignment of potentially correlated detection events, the relevant radionuclide measurement information and SRS fields are provided as inputs to FREAR.

The outputs can be visualised in the UK NDC CARVE software, and can be compared with the outputs of ATM Pipeline to assess emission contributions from forward simulations.



From the FREAR results collected in this process, the effect of adding non-detects is evaluated and the data is stored in the event analysis database.

The flow diagram above represents the UK NDC processing of *correlated RN detection events* using FREAR.

For more information on FREAR, see poster by Ian Hoffman P3.5-407, or:

De Meutter, P., Hoffman, I., Bayesian source reconstruction of an anomalous Selenium-75 release at a nuclear research institute, *Journal of Environmental Radioactivity*, 218, 2020 https://doi.org/10.1016/j.jenvrad.2020.106225.

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RESULTS

FREAR identifies a source and provides source magnitude, location and emission time/duration. This information is collected from FREAR and recorded. Visual maps are generated to display the results.

The UK NDC is currently participating in a blind test of FREAR, organised by Health Canada and AFTAC

FREAR testing underway to investigate correlated RN detection events. Current questions include:

- If we constrain the location can we better estimate the magnitude?
- What is the effect of adding extra non-detects?

ATM Pipeline shows that there are contributions from forward simulations of ‘Karpov Institute’, near Moscow, during the period 01-02-2021 to 03-02-2021.

Results based on IMS RN data and SRS fields

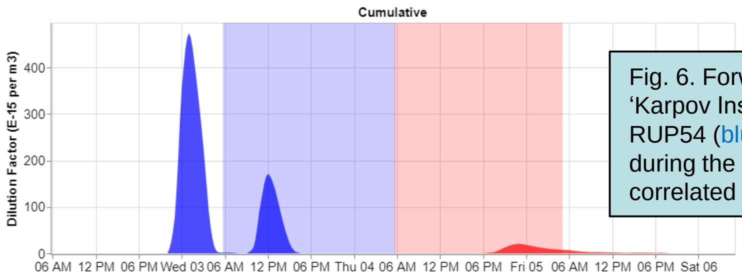

Fig. 6. Forward simulations from ‘Karpov Institute’ contribute to RUP54 (blue) and RUP61 (red) during the periods identified in this correlated RN detection event

FREAR estimates the location, magnitude and release times, based on the detections and SRS fields. The estimated magnitude is 10^{11} Bq.

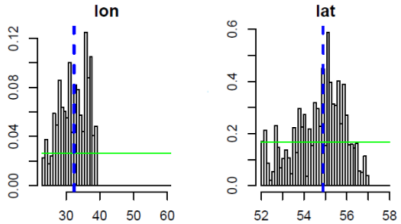

Fig. 7. (right) FREAR source location for the Iodine RN detection event. The red shading represents the probability distribution of the source location (shown as histograms – left).

Detections of ^{131}I on the IMS present an ideal opportunity to test new methods for source location analysis

Disclaimer: The views expressed on this poster are those of the author and do not necessarily reflect the view of the CTBTO