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A Data Visualisation Tool for Radionuclide Detection Events

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P3.5-245 – Data Analysis and Algorithms

POSTER

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Abstract

The United Kingdom Radionuclide National Data Centre (UK RN NDC) operates and maintains a series of custom pipelines for the analysis of data relevant to the verification of the Comprehensive Nuclear-Test Ban Treaty (CTBT). Algorithms periodically identify so called 'detection events' at International Monitoring System (IMS) stations; either 'plumes' of Xe-133 or high-category radionuclide (RN) detections. A new tool developed within the UK NDC, which involves the fusing of RN data with Atmospheric Transport Modelling (ATM) simulations, aims to combine the outputs of several data streams for the analysis of these detection events and the assignment of a Possible Source Region (PSR). The tool, named CARVE, puts interactive virtual maps at an analysts disposal for rapid data interrogation.

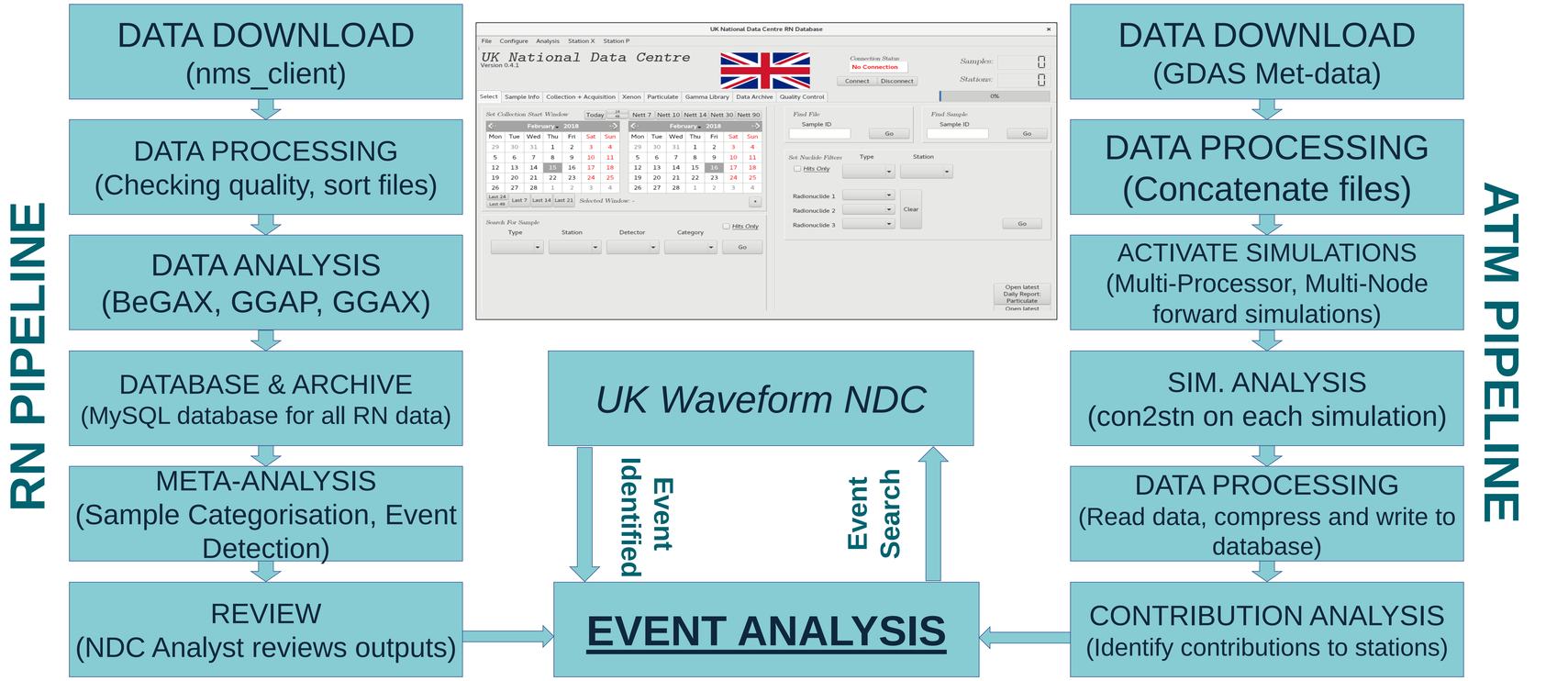

Fig 1. NDC analysis pipelines

UK RN NDC Pipelines

Detection event analysis within the UK NDC is underpinned by two main data streams, each a custom made, automated pipeline. First is a radionuclide pipeline, which downloads, processes, analyses and archives raw data from the International Monitoring System. The analysis of gamma spectra and 2D beta-gamma coincidence matrices is handled entirely by software developed in-house. Second is an atmospheric transport modelling pipeline, which involves continuously running forward simulations in HYSPLIT from various locations of interest known or suspected to release radionuclides into the atmosphere. The contributions of each of these simulated emissions to the IMS network is assessed, and the results archived. All data is stored within an SQL database management system.

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Detection Event Analysis

Radionuclide detection events are assigned by the RN pipeline into two distinct categories. For noble gas data, an algorithm periodically identifies ‘plumes’ of Xe-133 passing over IMS stations by looking for at least two consecutive measurements above the minimum detectable concentration (MDC). Along side this, the pipeline identifies high-category detection events based on isotopes relevant to the Treaty verification regime. Upon the assignment of a detection event, subsequent atmospheric transport modelling simulations are performed; these include computationally light-weight trajectory models and full backwards dispersion simulations. From the backwards simulations, Source Receptor Sensitivity (SRS) fields are produced, which can be used as inputs for the Bayesian source location tool, FREAR.

1.Xenon Plume Analysis

2.RN Detection Event Analysis

3.HYSPLIT Trajectory Model Simulations

4.HYSPLIT Backward ATM Simulations

5.SRS Fields

6.Bayesian Source Determination (FREAR)

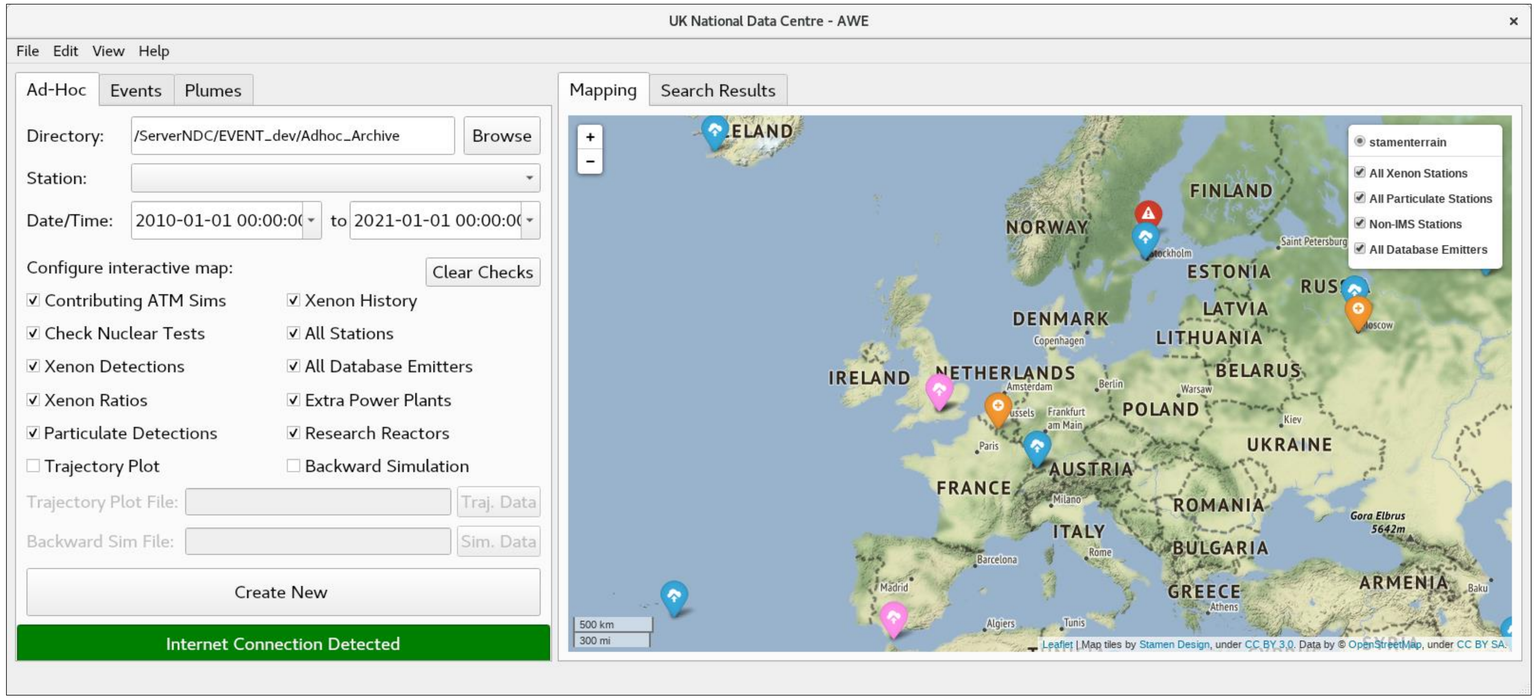

Fig 2. The CARVE graphical user interface

CARVE

Contributions Analysis of Radioisotopes from Virtual Emitters (CARVE) is the main tool used by the UK NDC for assessing radionuclide detection events on the IMS. The algorithm fuses the output of each data stream described previously. In doing so, an assessment of which emitters of interest an IMS was sensitive to emissions from at the time of a detection event can be produced. This data is then all compiled onto interactive virtual maps where it can be interrogated by analysts. CARVE is complete with a graphical user interface within which the user can view information regarding detection events and ATM simulations, as well as query relevant database fields and customise the algorithm input parameters.

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Plume Identification

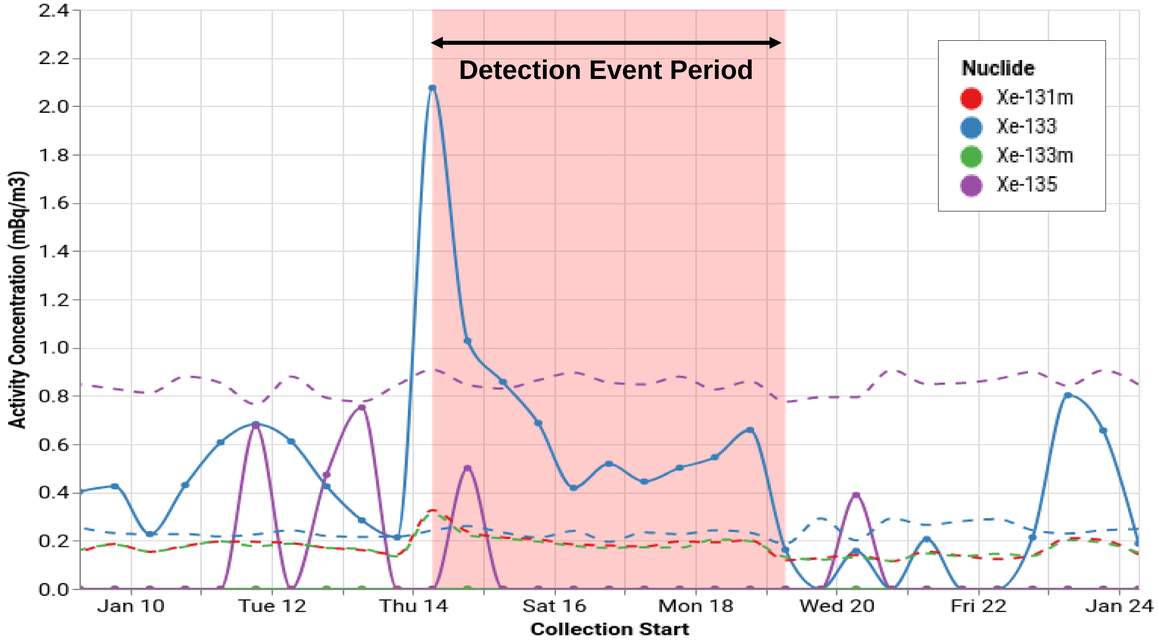

Fig 3. A plume detection at Takasaki, Japan

'Plume' detection events are assigned when the Xe-133 activity concentration has been measured above the stations MDC during at least two consecutive collection periods. This observation is common at noble gas stations due to a dynamic global radioxenon background, which can be attributed to releases from nuclear power plants (NPPs) and medical isotope production facilities (MIPFs). The plume is represented in the four isotope plot by the solid blue line, and measurements of other radioxenons of interest to Treaty verification are also displayed.

Particulate Filter Detections

The measurements of radioisotopes in particulate filter samples during the detection event period are also assessed. These include commonly observed detections of cosmically induced, naturally occurring and terrestrial isotopes such as Be-7, Pb-212 and U-235. Measurements of radioisotopes at particulate IMS stations may inform experienced analysts as to the processes that underpinned the detection event. Furthermore, isotopic ratio analysis may be able to distinguish between civil and military nuclear activities.

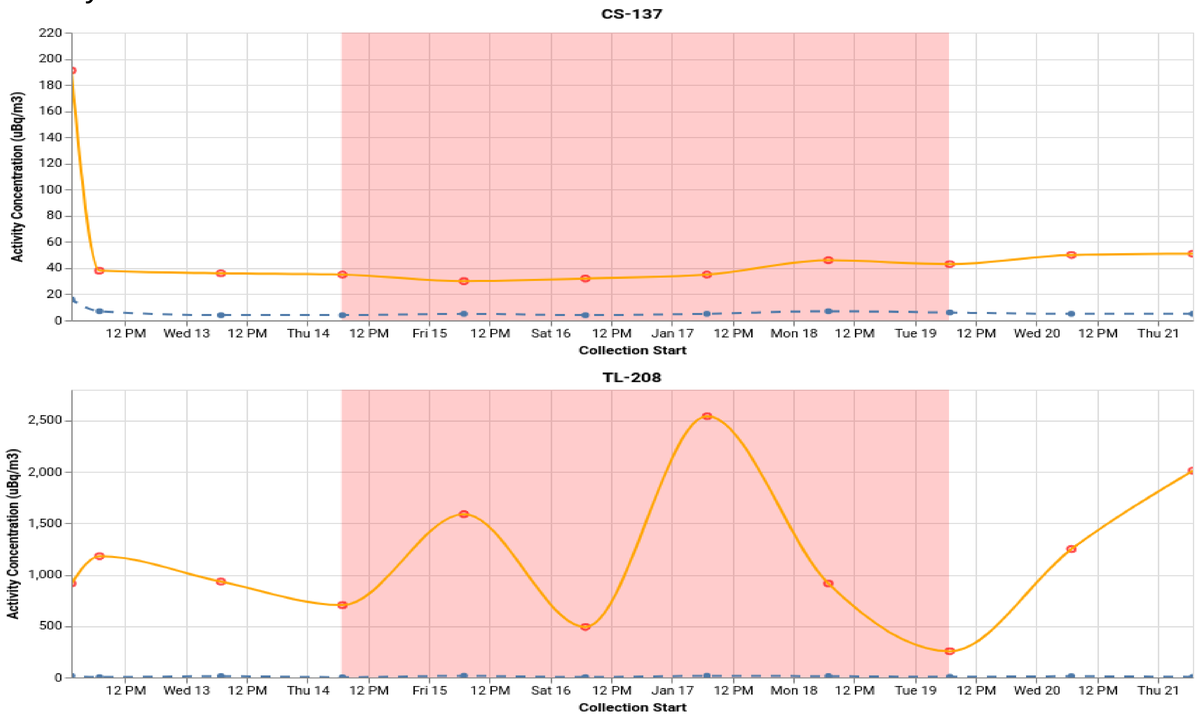

Fig 4. Particulate filter measurements of Cs-137 and Tl-208

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Contributions Analysis

The time period bounding the detection event can be crossed checked against the output of the ATM pipeline. Simulated emissions which contributed to the IMS station during this period are flagged, allowing for an assessment of the sensitivity of the station to radionuclide emissions from various locations of interest. The noble gas station at Takasaki, Japan (blue icon) is deemed sensitive to several local nuclear power plants (trefoil icons) as well as nuclear materials production facility at Yongbyon, North Korea (red icon) during this detection event.

Fig 5. Radionuclide emitters potentially contributing to JPX38

Source Term Estimation

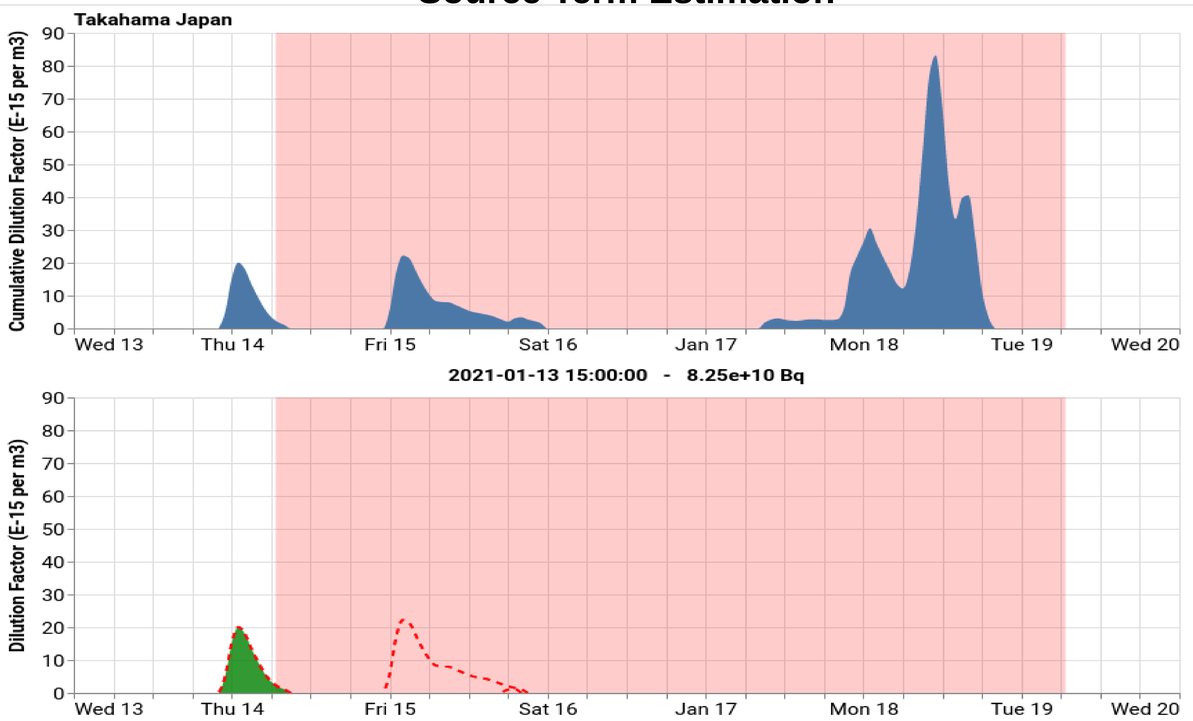

Fig 6. 2D plots of contributions from a local nuclear power plant

The contribution profiles of the emissions relevant to the detection event can be represented in 2-dimensions. CARVE allows for the viewing of both the cumulative and individual profiles. An estimation of the magnitude of the emission can be made using both the detection information and the simulated dilution factors. This can then be cross checked against literature estimations of release magnitudes from NPPs and MIPFs to rule out improbable emissions.

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Backwards ATM Simulations

The output of the backwards atmospheric transport modelling simulation pipeline can be overlaid onto the interactive virtual maps to further inform the analyst as to a possible source region. These backwards simulations are triggered automatically upon the identification of radionuclide detection events, and are run for 7 days backwards in time. The plume of 200,000 particles accounts for the radioactive decay of radioxenon and can be tracked over time to assess how it may coincide with the flagged forward simulations. Contours pertaining to the estimated dilution factors are also shown. The plume in the example here is shown to initially track over the south of Japan, before becoming more disperse and tracking over South Korea, North Korea and the eastern region of China. Backwards simulations are used to produce source receptor sensitivity fields, which are subsequently used as inputs for the Bayesian source location tool, FREAR, along with the concentrations, uncertainties, and MDCs of high-category radionuclides measured during detection events. In the case of JPX38, the vast majority of detection events can be linked to emissions from local nuclear facilities.

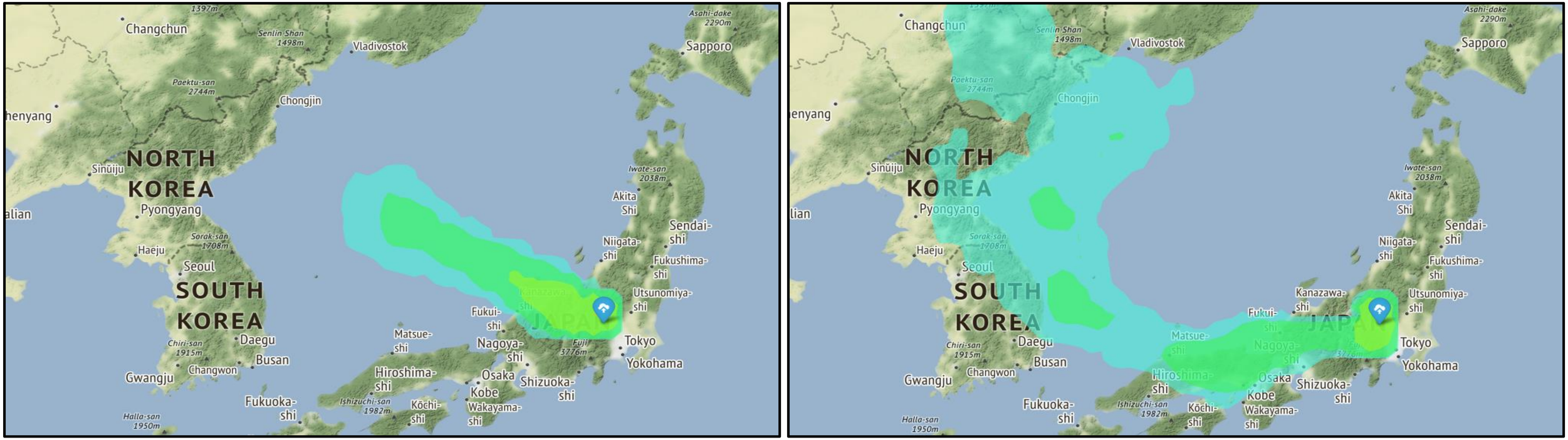

Fig 7. A backwards dispersion simulation plume at 12 hours (left) and 24 hours (right) prior to a radioxenon plume detection event at JPX38

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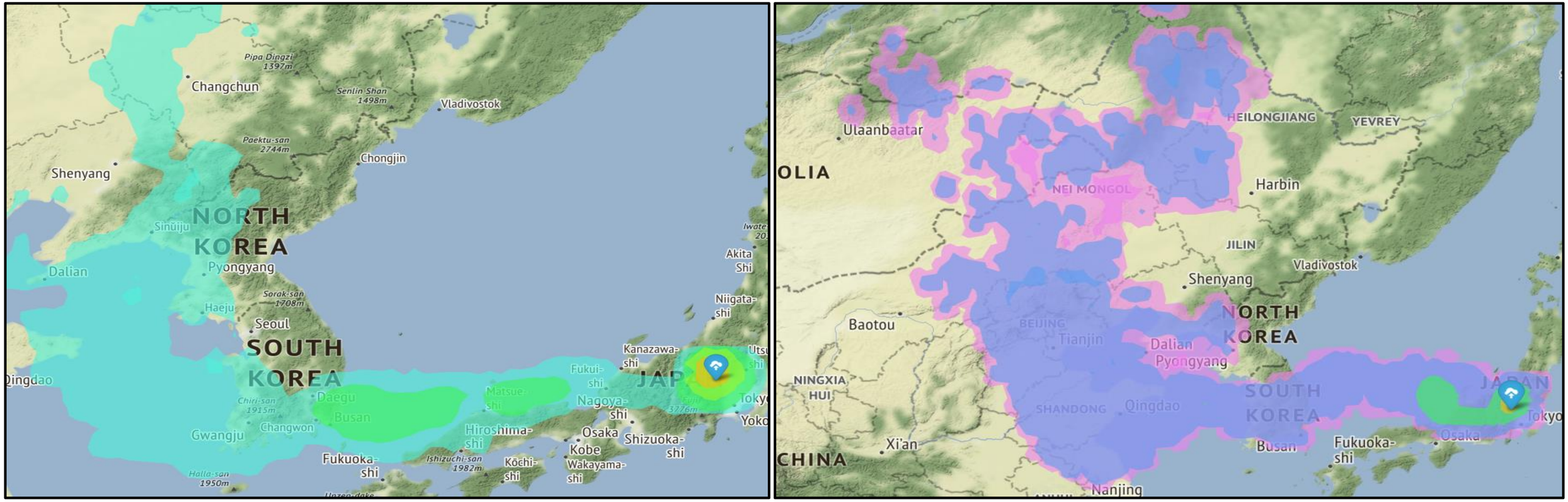
Fig 8. A backwards dispersion simulation plume at 36 hours (left) and 48 hours (right) prior to a radioxenon plume detection event at JPX38



CARVE Output Files

The custom RN/ATM pipelines and detection event analysis tools used within the UK NDC aim to condense down terabytes of meteorological data, gigabytes of RN data and megabytes of HYSPLIT output data into a single, easily manageable file. These HTML files contain all the relevant information pertaining to the radionuclide analysis and atmospheric transport dispersion simulations an analyst may need to rapidly interrogate a detection event and make judgements on possible source regions. The condensed files can be viewed from within either the CARVE graphical user interface or an internet browser, making them exceedingly easy to share to other interested parties.

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