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Developments toward a Radionuclide Event Computational Pipeline

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INTRODUCTION

A goal for radionuclide monitoring is to automatically create a radionuclide event bulletin from multiple sample measurements across the network, inspired by what is done with waveform processing.

METHODS/DATA

Many radionuclide samples in the IMS contain isotopes released by industrial nuclear facilities. A RN pipeline provides automated information to analysts to help them determine if the nuclides were released by activities not relevant to the Treaty.

START

RESULTS

New automated sample association rules feed source-location algorithms that incorporate multiple isotopes and background information. Seismic or other information can be included when developing the source-location attribution.

CONCLUSION

Many of the algorithms and computational tools needed to implement a radionuclide analysis pipeline have been developed. The next step is to combine them in a prototype automated pipeline.

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Goal: Implement a Radionuclide Data Pipeline that Focuses on Release Events rather than Samples using Data Fusion

IMS System

Spectrum and Analysis

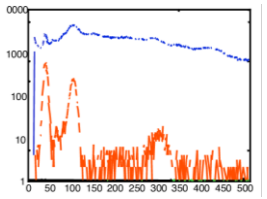
Sample Flagged as L5/LC

Sample Automated RN Report

Sample Reviewed RN Report

Analyst Review

Sensitivity & Selectivity



IDC Algorithm and Lists

Transport Parameter Calculations

Fused Event Bulletin

Waveform Fusion

Bayesian Analyses

Detect Anomaly

Find Associated Samples

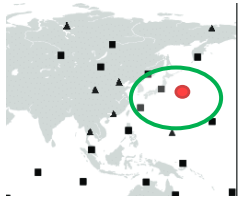
Estimate T_0, Release Strength, Location

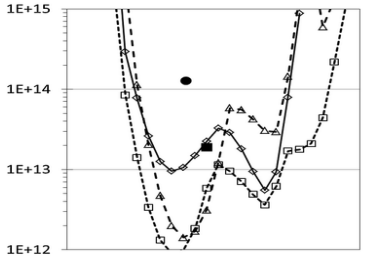
Analyst Review

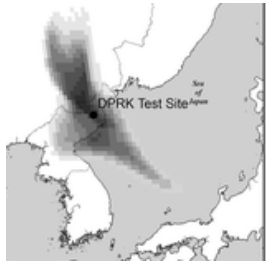
EVENT Bulletin 1

EVENT Bulletin 2

Includes local BKG







Events developed with new automated tools can bring 'network power' to RN

- Merge ATM with RN measurements
- Improve Sensitivity, Location, Screening

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Radionuclide Pipeline Algorithm Objectives

Many of the radionuclide samples collected every day in the IMS contain measurable levels of isotopes released to the atmosphere by industrial nuclear applications or residue from past weapons testing. **The top-level objective of a RN pipeline is to provide automated information to analysts to help them quickly determine if measured nuclides were released by activities not relevant to the Treaty.** Steps include:

- **Anomaly Detection** – Do the measured samples exhibit unusual characteristics?
  - Consistent with historical magnitudes? Unusual isotopic mixtures? Unusual groupings of detections?
- **Sample Association** – Do multiple samples have information about a common release event?
  - Would they be at the same sampling location? At other sampling locations?
  - Would an as-yet undetermined release event result in more measurable samples?
- **Source-Location Determination** – What release event (location, magnitude, time) could have caused the sample measurement (or associated sample measurements)?
  - Source-location algorithms depend on computationally demanding atmospheric transport models.
  - Can fuse data from seismic, infrasound, or hydroacoustic measurements.
- **Event Bulletin** – Preliminary evaluation of multiple hypotheses.
  - Are measurements consistent with releases from industrial facilities?
  - Are measurements consistent with historical background?
  - Should this suite of measurements be elevated for more detailed study?

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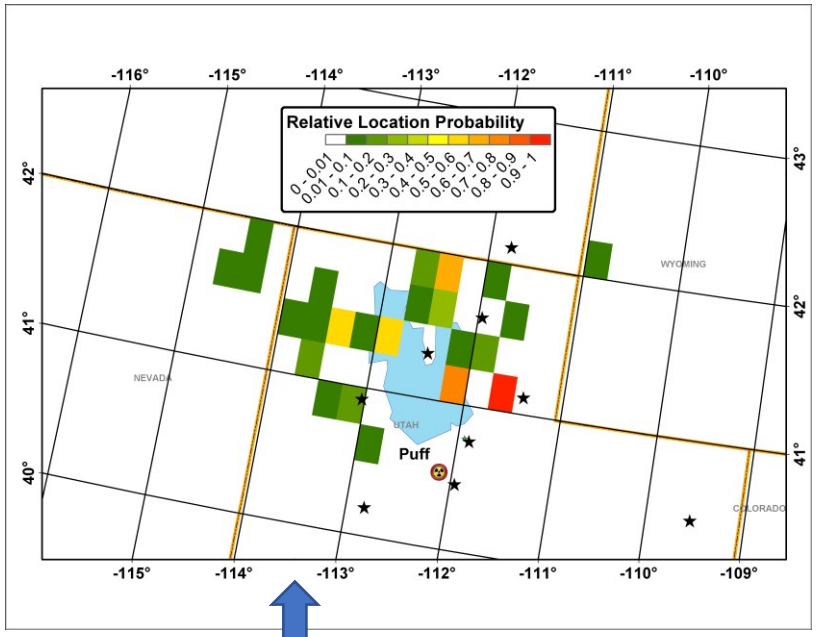
Methods and Data

Algorithm research and expanded data sets are required to finish an automated RN pipeline. Key areas of current investigation are:

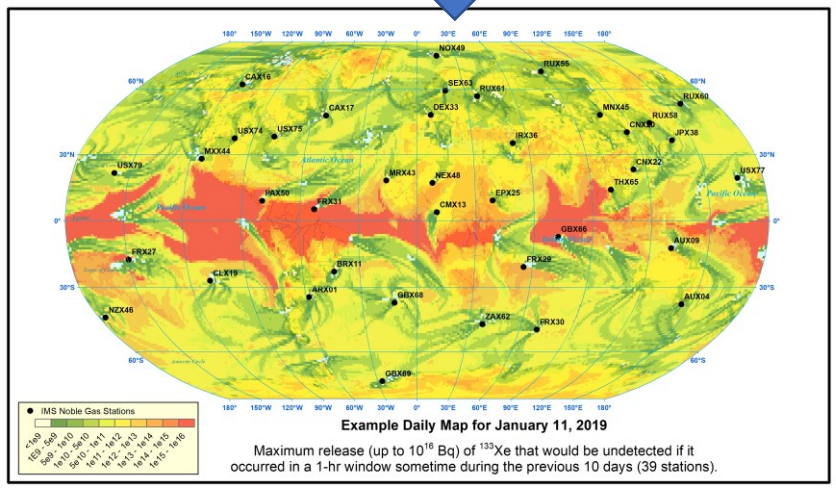
- **Anomaly Detection**
  - Developing rules for automatically identifying anomalies
  - Status of industrial nuclear facilities and their release history (with isotopic composition)
- **Sample Association**
  - Computing and storing historical station affinities for quick access
  - Fast atmospheric transport models to replace precomputed affinities on demand
- **Source-Location Determination**
  - Quick development of source-receptor matrices for every RN sample
  - Global network coverage for emissions in the last few days
  - Single-isotope and multiple-isotope source-location models that can explicitly incorporate background measurements
- **Event Bulletin**
  - Initial determination of the plausibility of a comprehensive suite of hypotheses

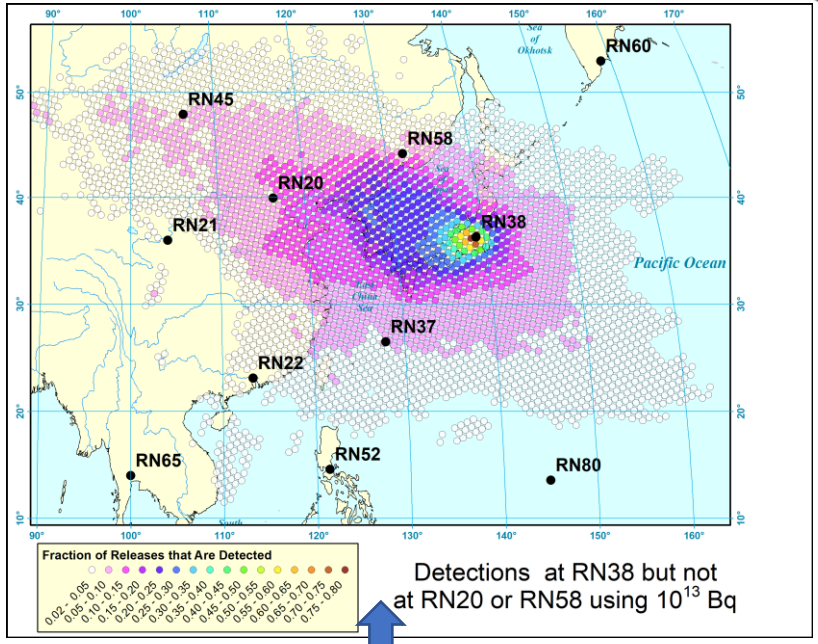
Results Using the Algorithms that would be Included in a Radionuclide Event Pipeline



The magnitude of detections of interest may be smaller than typical measurements caused by industrial emissions. This synthetic data set shows a new algorithm that explicitly uses industrial emissions when locating a puff release.

An example plot showing what magnitude of short-duration releases of ^{133}Xe should have been detected if they had been released in the last ten days. This plot is indicative of the network coverage at the time that a sample with a detection is collected. This type of plot could be updated every day.





An example sample association result using synthetic releases showing the most plausible release locations based on historical weather patterns when stations close to JPX38 didn't have detectable quantities of ^{133}Xe but JPX38 had a detection. These results can be precomputed and archived for different station combinations.

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Conclusions

As the volume of data grows and backgrounds increase, the pressure to leverage automatic data techniques across the network will also increase. An important step is to combine aerosol and xenon measurements and enable data fusion with other technologies such as seismic. Many of the analysis tools needed for a RN analysis pipeline have been developed, but have not yet implemented in an automated prototype:

- **Anomaly Detection**: Have a draft journal article on different anomaly detection algorithms. Magnitude-only anomaly rules are insufficient.
- **Sample Association**: Developed on an approach for automated sample association and published a journal article (doi:10.1016/j.jenvrad.2021.106777).
- **Continued study of industrial emissions** to understand their influence on samples. (doi:10.1016/j.jenvrad.2022.107081, 10.1016/j.jenvrad.2022.107037, 10.1016/j.jenvrad.2022.106916)
- **Bayesian source-location algorithms**. Have developed new multiple-isotope and background cognizant algorithms (doi:10.1016/j.jenvrad.2019.04.004, 10.1016/j.jenvrad.2019.03.022). Have a draft journal article comparing single-isotope algorithms with maximum correlation approaches and FREAR.
- **Analysis of network performance** for new generation samplers. Have studied network performance for new generation noble gas and aerosol samplers (doi:10.1016/j.jenvrad.2022.106963, 10.1016/j.jenvrad.2022.107088).

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