Contract No:

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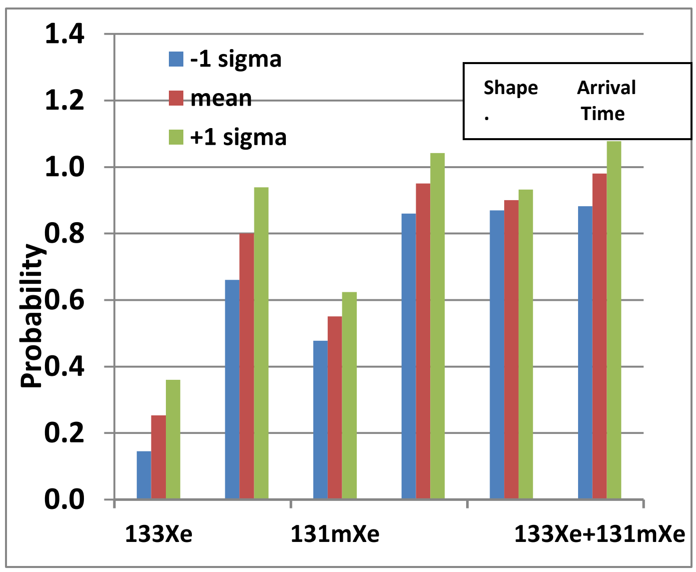
Evaluation and Uncertainty of a New Method to Detect Suspected Nuclear and WMD Activity: Project Report

The Atmospheric Technology Group at SRNL developed a new method to detect signals from Weapons of Mass Destruction (WMD) activities in a time series of chemical measurements at a downwind location. This method was tested with radioxenon measured in Russia and Japan after the 2013 underground test in North Korea. This LDRD calculated the uncertainty in the method with the measured data and also for a case with the signal reduced to 1/10 its measured value. The research showed that the uncertainty in the calculated probability of origin from the NK test site was small enough to confirm the test. The method was also well-behaved for small signal strengths.

The figure shows the probability that the radioxenon plume detected at Ussuriysk, Russia on Apr 12/13 of 2013 originated from the underground nuclear test at Punggye, North Korea. Two probabilities are shown for each isotope and for both isotopes considered together - one based on the signal shape and the second on its arrival time at the receptor. For example, the probability of origin increases from 0.27 (133Xe, shape only, leftmost red bar) to over 0.9 when both isotopes are considered, (two rightmost red bars).



Awards and Recognition

A paper on the method has been submitted to *Atmospheric Environment.*

A paper on uncertainty in the predicted concentration at receptors downwind of the test site in North Korea is in draft stage and will be submitted to *J. Appl. Met. and Clim.*

Results were presented at George Mason University, 21'st Conf. on Atmospheric Transport and Dispersion Modeling, 2017.

Intellectual Property Review

This report has been reviewed by SRNL Legal Counsel for intellectual property considerations and is approved to be publically published in its current form.

SRNL Legal Signature

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Signature **Date**

LDRD-2017-00030
LDRD Report

Title

Project Team: R. Kurzeja, D. Werth, R. Buckley

Thrust Area: NS

Project Start Date: October 1, 2016
Project End Date: September 30, 2017

Abstract: The detection of surreptitious production and testing of Weapons of Mass Destruction (WMD) is hampered by low-signal-to-noise measurements which frustrates focused analyses. The uncertainty associated with a new method to detect the development and testing of WMD from downwind chemical measurements has been calculated. The probability of origin of radioxenon from the Feb 2013 underground nuclear test in North Korea was calculated from an ensemble of atmospheric model simulations that captures the range of variability, i.e., uncertainty. It was found that the uncertainties in the method are low enough to yield reasonable conclusions about chemical origin, even at low signal-to-noise. Furthermore, the behavior of the method was predictable for a range of signal strengths.

FY2017 Objectives

- Evaluate the predicted probabilities of origin and uncertainties with an ensemble of model simulations.
- Evaluate behavior for very low signal strength.
- Present the method to potential users in the Intel community.
- Extend the presentation to a wider audience in the atmospheric science community.

Introduction

The search for indications of WMD activity is difficult because small amounts of chemical are involved and the operation is concealed. This results in weak signals within a complicated background of information from upwind and global sources. The net effect is to discourage systematic analysis except for cases with a clearly detected signal. Furthermore, efforts for new measurement campaigns are poorly received because of low confidence in significant improvement.

Approach

SRNL's new approach is based on the assumption that atmospheric transport of a chemical from a source to a receptor produces a unique signature, which can be used as a template to analyze a data series for evidence of the source. The method can be applied to arbitrary sampling and multiple signals. The method also yields the probability of origin which is essential for weak signals. SRNL's new method was used to

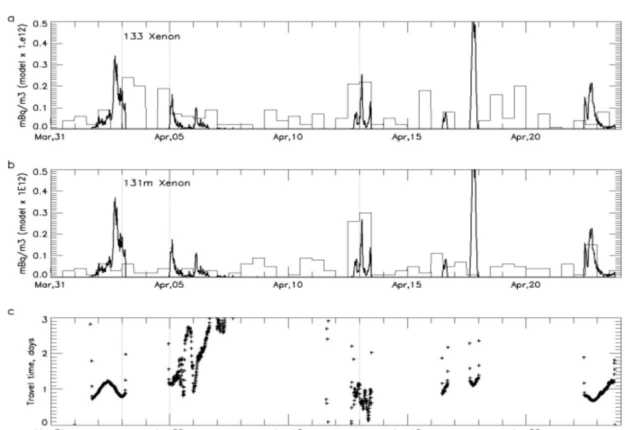

Figure 1: Top: measured 133 Xenon activity (thin lines) plus model predictions (heavy lines). Middle: as above but for 131m Xenon. Bottom: travel time in days from source to receptor.

determine the probability that radioxenon detected in Russia originated from the February 2013 underground test in North Korea. The derived probabilities are based on the signal shape and arrival time at the receptor. The LDRD calculates the uncertainties in these predictions from an ensemble of model simulations.

Figure 1 shows measured radioxenon data and also the model prediction from which the search template is generated. The figure illustrates various signals present in the data, some of which resemble model predictions.

Results/Discussion

The results (Fig. 2) showed that the uncertainties of origin are small enough to yield confidence in the calculated probabilities. Furthermore, we showed that the method remains reliable as the signal strength is reduced to background values. This implies that results for a range of signal strengths will be interpreted with the appropriate level of confidence.

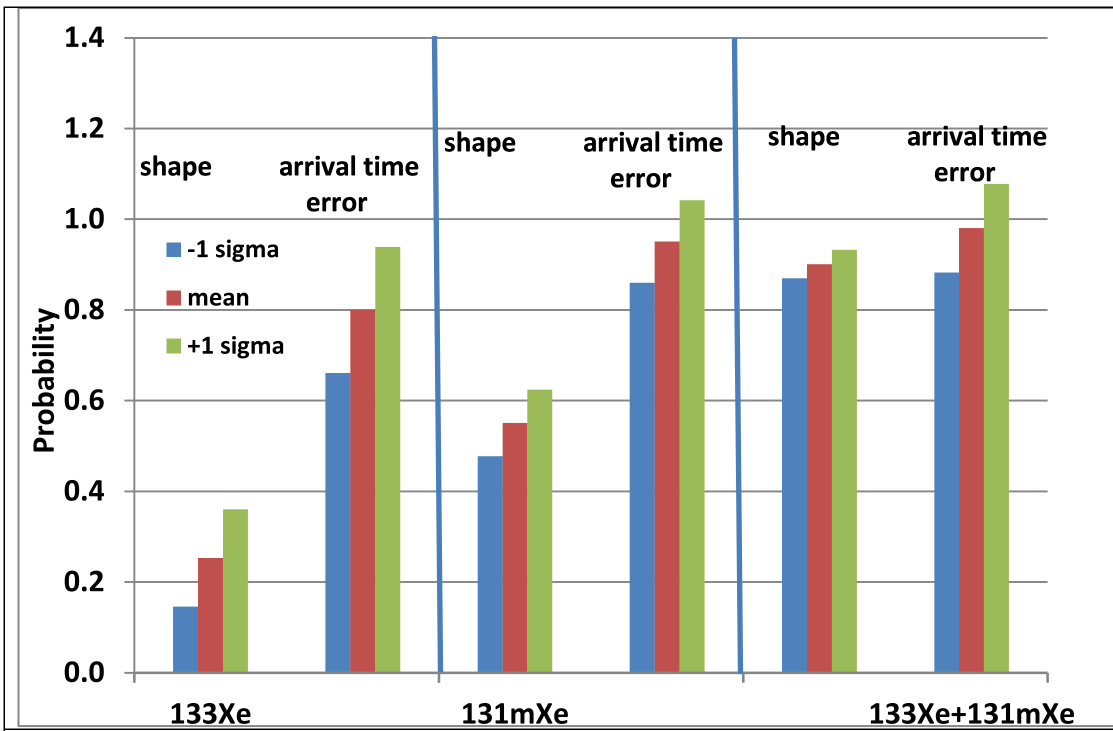

Figure 2: Probabilities plus and minus one-sigma uncertainty is shown for each isotope and both isotopes. The first probability is based on the similarity between the predicted and measured plume shapes. The second is based on the error in the predicted center of mass arrival time. The average of these two probabilities gives the net probability of origin. The two probabilities for 133Xenon alone (left red bars) are 0.27 and 0.8, respectively. The net probability (right red bars) =(0.27+0.8)/2. = 0.53.

FY2017 Accomplishments

- A paper describing the method has been submitted to *Atmospheric Environment.*
- The scope of work for the project was extended to satisfy interest of the atmospheric transport community. A manuscript is in draft status and will be submitted to the *Journal of Applied Meteorology and Climatology*.
- The method is the basis for funding requests directed to DOE's National Nuclear Security Administration and other intelligence organizations.

Future Directions

- The method should be applied to other signals of interest, e.g., optical, electromagnetic, acoustic.
- Another useful test of the method would be the detection of a weak signal added to a measured complex background, which is particularly relevant to the WMD problem.

FY 2017 Publications/Presentations

1. Uncertainty in mesoscale modeling of radioxenon transport and dispersion after the Feb 2012 underground test in North Korea. To be submitted to the *Journal of Applied Meteorology and Climatology*.

2. Detection of nuclear testing from surface concentration measurements: Analysis of radioxenon from the February 2013 underground test in North Korea. Submitted to *Atmospheric Environment.*

3. A new method to detect nuclear testing with atmospheric measurements: The Feb 2013 underground test in North Korea. Presented at George Mason University, 21'st Conf. on Atmospheric Transport and Dispersion Modeling, 2017.

References

Acronyms

WMD: Weapons of Mass Destruction

Intellectual Property

Total Number of Post-Doctoral Researchers