Characterizing the Detectability of Atmospheric Emission Signals

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Project Objective

Overall Objectives:

- Quantify the ability to discriminate a clandestine signal from KNOWN signals
  (Distinguish between modeled proliferant plumes and background plumes of the same species)

- Use two metrics:
  - Signal Strength (*SS*)
  - Plume Overlap Ratio ($R_{m,n}$)

Background

Study region is eastern Asia centered on Japan and Korea

Noble gas detection systems in the region:
+Comprehensive Test Ban Treaty Organization (CTBT)
Takasaki, Japan
Ussuriysk, Russia

+System for Prediction of Environment Emergency Dose Information (SPEEDI) – almost 400 stations throughout the Japanese peninsula

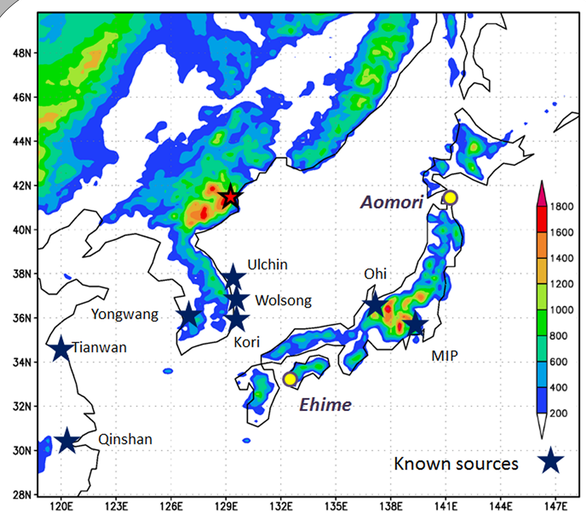
Significant sources of background radionuclides include:

- Reprocessing facilities
- Medical isotope production (MIP)
- Nuclear power plants (NPP)

Models Used

Meteorology: Regional Atmospheric Modeling System (RAMS). Use nested grid configuration (30 km and 10 km in the horizontal). Smallest vertical grid spacing 30 m. Boundary conditions supplied by Global Forecast System (GFS) at 0.5° and 3-hr intervals. Output results at 10-min intervals.

Transport: Hybrid Single-Particle Lagrangian Integrated Trajectory (HYSPLIT). Assume continuous unit release. *NOTE: Chinese sources shifted slightly eastward to be included in inner (10 km) RAMS nest.* Assume no radioactive decay or deposition onto surfaces.



Simulation domain with topography (color contours) and potential sources (including the hypothetical source in North Korea) indicated by stars. SPEEDI sites (prefecture) indicated by circles.

Approach

1. Define a Signal Strength, *SS*.

$$SS = \begin{cases} \dfrac{C_{UNK} - C_{KWN}}{C_{UNK}}, & C_{UNK} > C_{KWN} \\ 0, & C_{UNK} < C_{KWN} \end{cases}$$

where:

C_{KWN} = concentration of a KNOWN source
C_{UNK} = concentration of an UNKNOWN source

Implication:
SS = 1 ⇨ Unknown plume ONLY is over the detector (it stands out)
SS = 0 ⇨ Unknown plume does NOT stand out amidst known plumes

2. Define a plume overlap ratio, $R_{m,n}$.

$$R_{m,n} = \frac{A_{m,n}}{A_m}$$

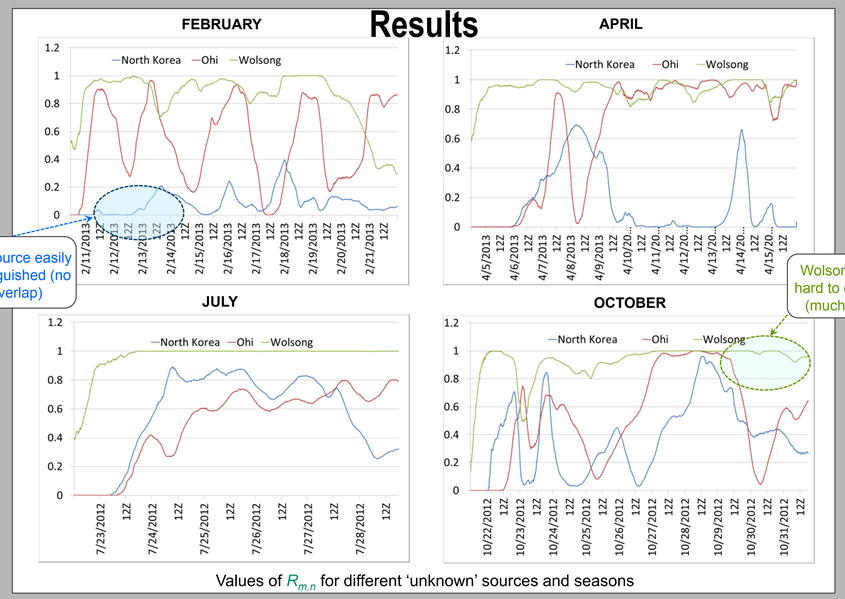
where:

A_m = area of plume *m*
A_n = area of plume *n*
$A_{m,n}$ = overlap area of plumes *m* and *n*

Implication:
$R_{m,n}$ = 1 ⇨ COMPLETE OVERLAP of signals
$R_{m,n}$ = 0 ⇨ NO OVERLAP (perfect detectability)

Assume minimum threshold consistent with typical xenon release from nearby NPPs. Examine 4 periods representing different seasons.

Results



Values of $R_{m,n}$ for different 'unknown' sources and seasons

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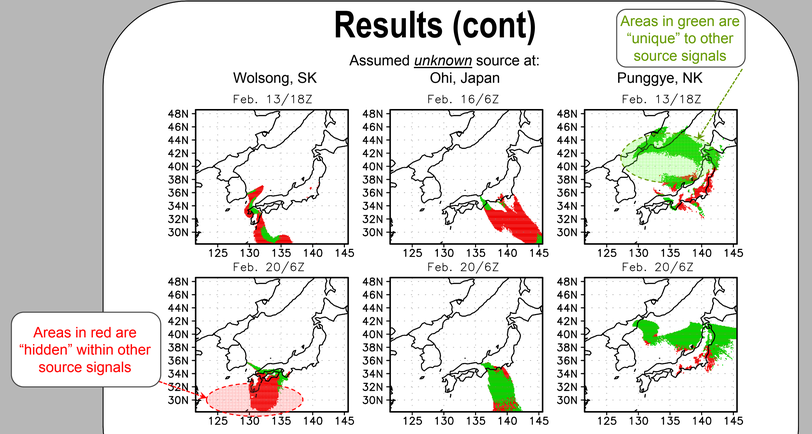
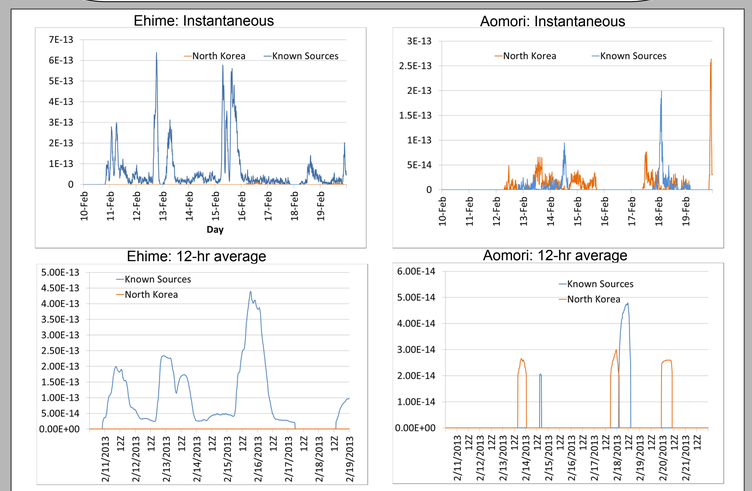
Results (cont)



Area over which the *SS* > .9 (green) and the area of the *unknown* plume in which the *SS* < .9 (red) for the *unknown* source as specified on the indicated dates in February.



Simulated concentration time series at 2 SPEEDI sites.
Blue lines assume KNOWN sources, Orange lines assume UNKNOWN sources

Project Summary

- High-resolution meteorology/transport modeling proven useful for this problem
- Source in NK is discernable for much of the time during 3 of 4 seasons examined
- Potential source area tends to encompass NK while excluding other potential source regions
- NK signal need not be significantly higher than nearby sources to be detected.
- Northern Japan would be ideal sampling location for permanent or mobile sampling unit for future tests from NK.

Proposed Future Work

- More thorough investigation of source *variability* & *strength* with time
- Continuous emission –vs– intermittent emission