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Pacific Northwest
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Source Term Estimation in the Presence of Nuisance Signals

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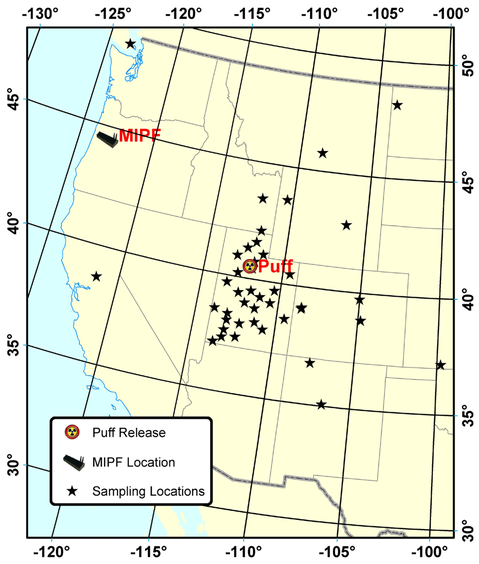
T3.5-P62

Simulated Releases and Atmospheric Transport



Synthetic Puff Release

- 10 min (puff) release starting at 1/10/2011 23:30 UTC at a mining location in Utah
- Atmospheric transport using the LODI code in the National Atmospheric Release Advisory Center modeling system (Sugiyama et al., 2015)
- Fine-scale 1-h meteorological data generated using the Weather Research and Forecasting (WRF) model
- Initialization data and boundary conditions for WRF from Global Forecast System (GFS) data archive (NOMADS)
- Concentrations output on a 9 km computational grid

Synthetic Medical Isotope Production Facility (MIPF) Release

- Continuous time-varying release from Jan 6 to Jan 18, 2011 at a hypothetical medical isotope facility in Oregon
- Atmospheric transport using HYSPLIT (Stein et. al., 2015)
- Archived meteorological data (12-km and 3-hr) from National Oceanic and Atmospheric Administration (nam12)

Synthetic Samples

- Six isotopes tracked, only ^{133}Xe used in this analysis
- Puff: 14 samples, 12 h collection, at 50 locations
- MIPF: 14 samples, 12 h collection, at 50 locations
- Combined: 14 samples, 12 h collection, at 50 locations

Bayesian Source-Term Model

$$\overbrace{P(\vec{M}|D,I)}^{\text{posterior}} = \frac{\overbrace{P\left(D|\vec{M},I\right)}^{\text{likelihood}}\overbrace{P\left(\vec{M},I\right)}^{\text{prior}}}{\underbrace{P\left(D\right)}_{\text{normalizing constant}}}$$

Model ($\vec{M}$) uses the following release characteristics:

- Location (latitude and longitude)
- Elevation (set to ground level in this analysis)
- Time-varying release rate
- **Two (or more) release locations are allowed**

The likelihood function uses data (D), subject matter expert information (I), and predicted concentrations (C) of ^{133}Xe in each of the samples as follows:

$$\mathrm{P}\left(\mathrm{D}|\vec{M},I\right) \propto \exp\left[-\frac{1}{2}\sum_{\mathrm{i}}\frac{\left(\mathrm{D_i}-\mathrm{C_i}(\vec{M})\right)^2}{\sigma_{\mathrm{D,i}}^2+\sigma_{\mathrm{C,i}}^2}\right]$$

The unnormalized likelihood function has a value of 1 if the model fits the sampled data perfectly, and is less than 1 otherwise.

Solution Technique

For 1 location:

- Estimate the release rate that maximizes the likelihood function for a grid of candidate locations

For 2 locations:

- Jointly estimate the release rates from two locations that maximizes the likelihood function
  - ➢ For a large number of pairs of locations
  - ➢ For one fixed location and one varying location

Use the suite of maximized likelihood values to estimate the posterior distribution on location.

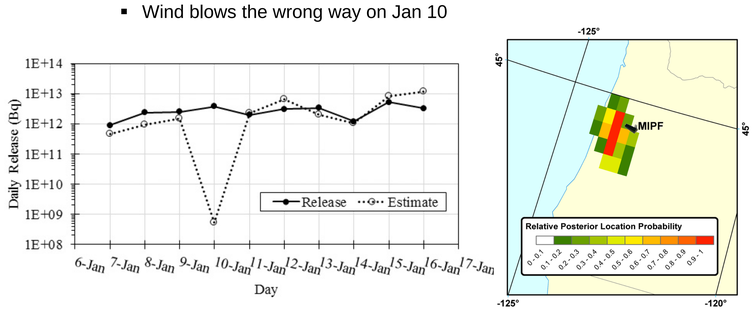
Solution Approach

- Use sampler data from the MIPF releases to determine the location of the MIPF
- Use sampler data with combined MIPF and Puff releases to estimate the Puff release location, time, and magnitude

Results

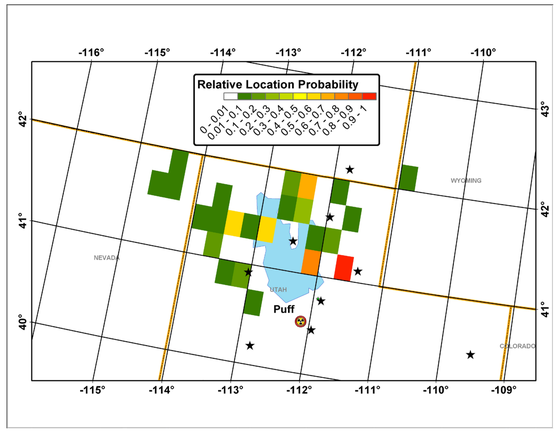
Medical Isotope Facility

- Most likely release locations are 30 to 70 km from facility
- Estimated releases (summed to daily) are slightly (17%) high
- Wind blows the wrong way on Jan 10



Puff (MIPF Operating at Known Location)

- Most likely release location is 60 km from actual release
- Puff occurs in the correct 6-h time interval
- Puff is short duration (one time interval)
- Estimated release is low by a factor of 3.6



References

Stein, A.F., Draxler, R.R., Rolph, G.D., Stunder, B.J.B., Cohen, M.D., Ngan, F., 2015. NOAA's HYSPLIT atmospheric transport and dispersion modeling system. Bulletin of the American Meteorological Society 96(12), 2059-2077. doi:10.1175/BAMS-D-14-00110.1

Sugiyama, G., Nasstrom, J., Pobanz, B., Larsen, S., Eme, B., 2015. National Atmospheric Release Advisory Center (NARAC) Overview, LLNL-PRES-609358-Rev1, Lawrence Livermore National Laboratory, Livermore, California

Abstract

Many source-term estimation algorithms for atmospheric releases assume the measured concentration data are influenced only by the releases of interest. However, there are situations where identifying a short-term release from an unknown location in the presence of long-term releases from a different location is of interest. One such example is determining if part or all of a typical magnitude concentration of a radioactive isotope in a sampler came from a nuclear explosion, such as the explosion announced by DPRK in 2013, while medical isotope facilities and nuclear power plants were also operating in the region.

An estimation algorithm has been developed for the case where a short-duration release is confounded by a long-term nuisance signal associated with an additional release location. The technique is demonstrated using synthetic release data for a hypothetical medical isotope production facility and a hypothetical puff release from a different location. The algorithm successfully determines the location (within 30 km) and time-varying release rate (within a factor of 2) for the medical isotope production facility and the location (within 60 km), time (within 6 h), and release magnitude (within a factor of 4) of the puff release.

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ABOUT

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