

Chapter 23

Backtracking Radioxenon in Europe Using Ensemble Transport and Dispersion Modelling

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Abstract The Comprehensive nuclear Test-Ban-Treaty bans nuclear explosions by everyone, everywhere. Radioxenon monitoring by the International Monitoring System is a key component of the verification of the Treaty. Atmospheric transport modelling can be used to determine the sources of radioxenon plumes. The Flexpart model is used to backtrack radioxenon observations in Europe to determine their source. An ensemble is used to quantify uncertainty.

23.1 Introduction

Certain radioactive xenon isotopes (^{131m}Xe , ^{133}Xe , ^{133m}Xe , ^{135}Xe ; further on called radioxenon) are monitored by the International Monitoring System (IMS), with the purpose of verifying compliance with the Comprehensive Nuclear-Test-Ban Treaty. If such radioxenon is measured at an IMS station, atmospheric transport models can be used to determine its source. These atmospheric transport models are, however, prone to errors. Therefore it is important to know the uncertainties on the analysis of nuclear explosion signals picked-up by the IMS.

Civil sources such as medical isotope production facilities and nuclear power plants also emit radioxenon. In this paper we backtrack episodes of high ^{133}Xe con-

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centration at the IMS station *RN33* in Schaunslund (Germany) to see whether we can link these to the medical isotope production facility *Institute for Radioelements (IRE)* at Fleurus (Belgium), which is the largest regional ^{133}Xe emitter. An ensemble of $50 + 1$ members is used to quantify uncertainty from the meteorological data.

23.2 Data and Methods

The atmospheric transport and dispersion simulations have been realized with the Lagrangian particle model Flexpart Stohl et al. (2005). Flexpart can be used to calculate the source-receptor-sensitivity in backward mode Seibert and Frank (2004).

The Ensemble Data Assimilation product of the European Centre for Medium-Range Weather Forecasts Buizza et al. (2008) has been used for the backtracking simulations. The spread between the individual realizations or members contains information about the uncertainty of the simulation.

The measured concentration at a receptor can be reconstructed by multiplying a source field $Q(x, y, z, t)$ with the source-receptor-sensitivity field $SRS(x, y, z, t)$, outputted by Flexpart, and by summing over all grid boxes and times (x, y, z, t) :

$$obs = \sum_{x,y,z,t} Q(x, y, z, t) SRS(x, y, z, t) \quad (23.1)$$

If we assume time independent point sources, we can readily calculate Q for every grid point.

23.3 Results

23.3.1 Case Study

We consider four consecutive days of elevated ^{133}Xe concentration at *RN33* in July 2014 (Table 23.1). For each measurement we calculate the SRS fields, from which we can calculate a corresponding source term. If the calculated source term is below 10^{13} Bq/day , which is the maximum expected ^{133}Xe release from civil sources Saey (2009), we consider that grid point as a possible source area. The possible sources for the four measurements are shown in Fig. 23.1 (left).

We assume that all four ^{133}Xe samples originates from the same source, and therefore plot the overlap of possible source areas in Fig. 23.1 (right). There are three areas where all four possible source regions overlap: the first area extends from the detector *RN33* to the northeast part of France, Belgium, Luxembourg and the Netherlands and a large part of the North Sea. The second area is located south-west of Denmark. The third area is located at the border of Poland and Ukraine.

Table 23.1 Elevated activity concentration measurements at RN33 in July 2014

Receptor	Collection start	Collection stop	Act. conc. (mBq/m^3)
RN33	10 Jul 2014 0600 UTC	11 Jul 2014 0600 UTC	4.5
RN33	11 Jul 2014 0600 UTC	12 Jul 2014 0600 UTC	5.3
RN33	12 Jul 2014 0600 UTC	13 Jul 2014 0600 UTC	6.1
RN33	13 Jul 2014 0600 UTC	14 Jul 2014 0600 UTC	1.4

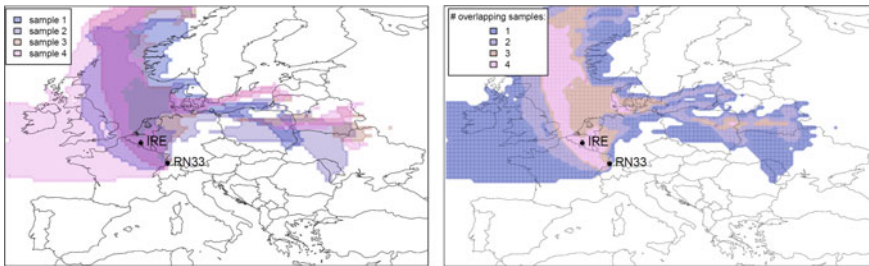


Fig. 23.1 Left for each sample, the area of possible sources is shown in transparent colors (assuming a source term below 10^{13} Bq/day). Right overlap of the areas of possible sources shown left

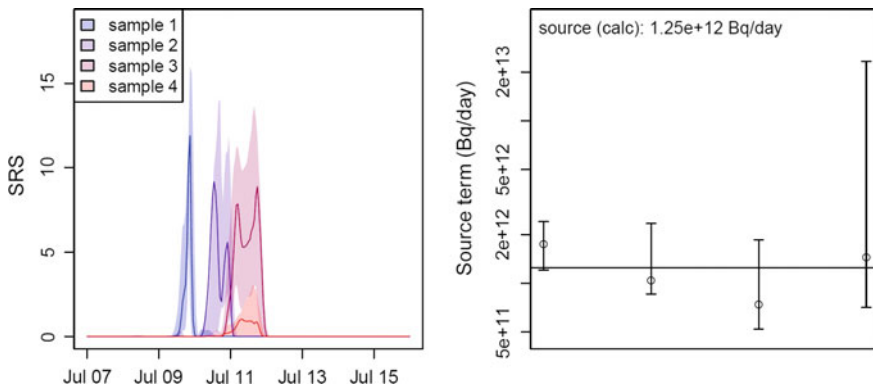


Fig. 23.2 Left SRS at IRE. Right source term for sample 1 (most left) to sample 4 (most right). Shaded areas (left) and error bars (right) represent 95% confidence interval

If we exclude grid points where the release exceeds 10^{11} Bq/day (which can be considered as the maximal release from nuclear power plants in that region), only a very small area around RN33 remains (not shown). We therefore consider IRE as the most likely source.

To determine the ^{133}Xe release, we have interpolated the SRS fields to the location of IRE. Figure 23.2 (left) shows the time series of the SRS of the four samples. The corresponding source term for each measurement is shown in Fig. 23.2 (right). We see that all four source terms are similar and the uncertainty depends on the flow.

23.3.2 Ten Highest ^{133}Xe episodes at RN33

We have selected the ten highest ^{133}Xe episodes at RN33 in 2014 and have calculated the corresponding source term (not shown), assuming IRE as dominant source. Nine out of ten gave a realistic source term. However, for one case we were not able to attribute the observed ^{133}Xe to IRE, suggesting that nearby nuclear power plants can also significantly contribute to the ^{133}Xe concentration at RN33.

23.4 Summary

ATM is a valuable tool for the Comprehensive nuclear Test-Ban-Treaty verification regime since it allows to calculate possible source regions and to estimate, for a specific location, when releases could have occurred, and what amount of radionuclides should have been released under different release duration assumptions.

We have selected elevated ^{133}Xe concentrations at RN33 and have calculated the corresponding source term assuming that IRE was the dominant source. Nine out of ten observations could be attributed to the IRE. The use of an ensemble allows to quantify uncertainty of the calculated source term.

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