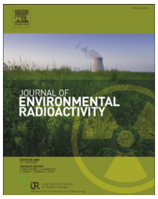
Journal of Environmental Radioactivity 169-170 (2017) 214–220

Contents lists available at ScienceDirect

Journal of Environmental Radioactivity

journal homepage: www.elsevier.com/locate/jenvrad



Characterizing the detectability of emission signals from a North Korean nuclear detonation

David Werth*, Robert Buckley

Savannah River National Laboratory, Building 773-A, Aiken, SC 29808, United States

ARTICLE INFO

Article history:
Received 9 September 2016
Received in revised form
10 December 2016
Accepted 11 December 2016
Available online 1 February 2017

Keywords:
Transport
Modeling
Detectability
Emissions

ABSTRACT

The detectability of emission sources, defined by a low-level of mixing with other sources, was estimated for various locations surrounding the Sea of Japan, including a site within North Korea. A high-resolution meteorological model coupled to a dispersion model was used to simulate plume dynamics for four periods, and two metrics of airborne plume mixing were calculated for each source. While emissions from several known sources in this area tended to blend with others while dispersing downwind, the North Korean plume often remained relatively distinct, thereby making it potentially easier to unambiguously ‘backtrack’ it to its source.

© 2017 Elsevier Ltd. All rights reserved.

1. Introduction

The Comprehensive Test Ban Treaty Organization (CTBTO) is charged with the detection of clandestine nuclear detonations worldwide (Auer and Prior, 2014). The International Monitoring System (IMS) is to accomplish this through 1) the detection of sonic and seismic waves emitted from an explosion and 2) the monitoring of radionuclides expected to be released (Wotawa et al., 2003; Auer and Prior, 2014), xenon in particular (Medalia, 2010; Kokaji and Shinohara, 2014). This noble gas (created in nuclear explosions and as a decay product of iodine, another fission product (Medalia, 2010)) is very difficult to contain (Hafemeister, 2007; Wotawa et al., 2010) and is detectable at low levels (Medalia, 2010). The monitored xenon isotopes of interest are ^{135}Xe (half-life = 9.14 h), ^{133m}Xe (half-life = 2.19 days), ^{133}Xe (half-life = 5.24 days), and ^{131m}Xe (half-life = 11.93 days) (Wotawa et al., 2010), and can be measured at long distances for up to two weeks after a release (Medalia, 2010). As an example, early suggestions that the Democratic People's Republic of Korea (DPRK) had completely contained radioxenon from its test of February 2013 (Dahl, 2013) were refuted with the April identification of a corresponding xenon signal by the IMS stations at Ussuriysk, Russia and Takasaki, Japan (Ringbom et al., 2014). Similarly, the 2006 DPRK test emitted radionuclides that were observed as far away as Canada (Saey et al., 2007; Kokaji and Shinohara, 2014).

It is desired that any signal detected at a sensor be ascribed to a known source, or else flagged as being from an unknown source. To accomplish this, the Provisional Technical Secretariat (PTS) of the CTBTO currently runs the FLEXPART diffusion model (Stohl et al., 2005), forced with ECMWF 1° × 1° meteorological data (Wotawa et al., 2010) as part of its Atmospheric Transport Modeling system. This is used to calculate the ‘source receptor sensitivity’ (SRS) – a matrix that relates the ‘signal’ at any sensor location to all potential source points (Wotawa et al., 2003). Given a signal at a sensor, the SRS can be used to produce a ‘Field of Regard’ (FOR) – the area that influences that sensor and could be the source region (Wotawa et al., 2003). Detections of a single source at several sensors will yield multiple FORs, and the area over which they intersect will represent a suspected source region, as was done for the 2013 test (Ringbom et al., 2014). These results demonstrate that atmospheric transport models coupled with meteorological models are powerful tools for recreating the motion of a plume from its point of emission (Kim et al., 2008; Eslinger et al., 2014; Arnold et al., 2015; Saito et al., 2015).

The ability to detect any signal of interest and ‘backtrack’ it to a unique source depends on the proximity of that source to other sources, as transport modeling will associate the composite signal from a set of mixed plumes from different sources with a large FOR that encompasses the overall source area of all the plumes, not just that of the clandestine signal. This could result in the emissions

---

* Corresponding author.
E-mail address: David.Werth@srnl.doe.gov (D. Werth).

http://dx.doi.org/10.1016/j.jenvrad.2016.12.002
0265-931X/© 2017 Elsevier Ltd. All rights reserved.

from a nuclear test remaining indistinguishable from known sources. Radioxenon is released from nuclear power plants and medical isotope facilities (Kalinowski and Tuma, 2009; Matthews and co-authors, 2010) as well as from a nuclear detonation, so the task of uncovering a DPRK radioactive source is complicated by the existence of nuclear facilities in South Korea, China, and Japan (Wotawa et al., 2010). In particular, ^{133}Xe is emitted from weapons tests, reactor operations, and medical isotope facilities (Kokaji and Shinohara, 2014). While isotope ratios for nuclear detonations are different from other sources (Matthews and co-authors, 2010), the reliable detection of multiple isotopes from an underground nuclear test is not always possible (Bowyer et al., 2013; Eslinger et al., 2014).

Mesoscale modeling has been applied to identify the source regions of observed signals for specific releases (e.g., the 2006 and 2013 DPRK tests) (Kim et al., 2008; Ringbom et al., 2014), and the simulation of a series of hypothetical releases has been used by Eslinger et al. (2015) to derive general properties of radioactive plume dispersion. Our goal here is to quantify our ability to discriminate a clandestine DPRK signal from known signals (the 'detectability'), and we do so by simulating a series of hypothetical releases (similar to the methodology of Eslinger et al. (2015)). Plume simulations were done with a mesoscale meteorological model coupled to a transport model. By simulating emissions from locations surrounding the Sea of Japan for several periods, the degree to which the DPRK signal stands out from the known signals emitted in the same region was quantified with two defined metrics: the signal strength and the area overlap ratio of the plumes, and compared to that of the other sources in the region. A partially distinct plume is required if we hope to narrow the potential source region based on an FOR analysis alone, and we demonstrate that the DPRK source will often extend over a large area without being strongly mixed with plumes from other sources in the region.

2. Material and methods

2.1. Modeling

The meteorological conditions were generated using the Regional Atmospheric Modeling System (RAMS) (Pielke et al., 1992). RAMS has been applied extensively to produce meteorological simulations on a range of scales (e.g., Cotton et al., 2003), and is ideal for this research. A domain over the Sea of Japan was selected, encompassing Japan and the Korean peninsula (Fig. 1). The model used two grids − a larger, outer grid at 30 km grid spacing, and an inner grid at 10 km spacing (Fig. 1a). The inner grid (depicted in Fig. 1b) comprises 251 × 251 grid points and was centered at 39°N, 133.5°E. The vertical spacing started at 30 m for the lowest level, and increased 15% for each successive level. The model was run with the Harrington radiation scheme (Harrington, 1997), and the LEAF-2 land surface scheme (Walko et al., 2000). The Mellor-Yamada planetary boundary layer scheme (Mellor and Yamada, 1982) was used to calculate vertical turbulent (sub-grid scale) diffusion, with a Smagorinsky (1963) horizontal deformation scheme used for the horizontal diffusion. The model also used a 30 s (roughly 800 m) topographic field (Fig. 1b), which can resolve many of the interactions between orography and airflow. Boundary conditions were supplied using the Global Forecast System (GFS, Environmental Modeling Center, 2003) output, with 0.5° horizontal resolution and at 3-hr intervals.

The interaction of a DPRK plume with plumes from other sources can be sensitive to seasonal shifts in wind patterns (Achim et al., 2013). Therefore, RAMS was run for four periods: Autumn (October 21st through October 31st, 2012), Summer (July 22nd through July 28th, 2012), Winter (Feb 10th through Feb 19th, 2013) and Spring (April 4th through April 15th, 2013). Data were saved every 10 min, allowing the dispersion simulations to resolve features with short time scales. The RAMS meteorological output was used as input to the Hybrid Single-Particle Lagrangian Integrated Trajectory dispersion model (HYSPLIT, Draxler and Hess, 1998). HYSPLIT has been used in numerous applications (e.g., Becker et al., 2007; Butler et al., 2005; Yerramilli and co-authors, 2012; Stunder et al., 2007) related to simulating the large-scale dispersion of effluent. This Lagrangian model simulates the release of a large number of 'particles', recalculating the position of each one at each time step according to both an advective wind field (resolved in the RAMS model) and a dispersive term derived from the RAMS-simulated turbulent kinetic energy (which RAMS does not explicitly resolve). The particles begin at the release point as a concentrated cloud, which then spread out and are transported downwind as the simulation progresses. Data from the first two days of each coupled simulation (e.g., April 4th and 5th) were eliminated as spin-up.

The RAMS/HYSPLIT coupled models were run for the four periods with releases at eight known source locations: nuclear power plants at Ohi (release rate 9.13 × 10^3 GBq/yr), Wolsong (9.13 × 10^3 GBq/yr), Hanbit (1.37 × 10^4 GBq/yr), Hanul (1.37 × 10^4 GBq/yr), Kori (9.13 × 10^3 GBq/yr), Tianwan (4.56 × 10^3 GBq/yr), Qinshan (1.14 × 10^4 GBq/yr) (all from Kalinowski and Tuma, 2009), and a medical isotope production (MIP) facility (7.3 × 10^2 GB/yr)

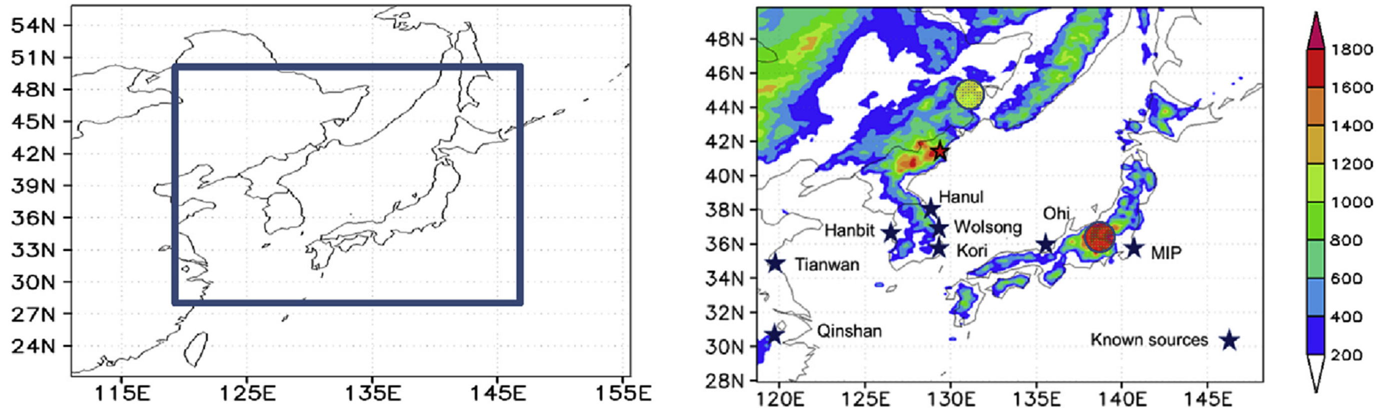


Fig. 1. a) Domains for RAMS grids 1 and 2. b) Grid 2, with topographic heights (in meters) shaded and sources (including the hypothetical source in DPRK) indicated by stars. The circles indicate the CTBTO monitoring stations at Takasaki, Japan (red) and Ussuriysk, Russia (yellow). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Download English Version:

https://daneshyari.com/en/article/5477733

Download Persian Version:

https://daneshyari.com/article/5477733

Daneshyari.com