ENVIROMIS INTERNATIONAL CONFERENCE on environmental observations, modeling and information systems TOMSK, RUSSIA, JULY, 5–11, 2010

Identification of Radioactive Noble Gases Sources in the North-West Russia

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Abstract

In our study, a time-series of long-term measurements of radioactive noble gases (^{85}Kr and ^{133}Xe) carried out by Radium Institute of V.G. Khlopin (St. Petersburg, Russia) at the measurement site near the city of Cherepovets (Vologda Region, Russia) was analyzed. In total, 45 episodes for ^{85}Kr and 62 for ^{133}Xe were identified from the time-series covered a two-year period (Sep 2006 – Jul 2008).

In order to estimate atmospheric transport of the radioactive gases as well as identify potential sources of their emissions the NOAA model called HYSPLIT 4.5 (HYbrid Single-Particle Lagrangian Integrated Trajectory model) was employed to simulate multiple backward trajectories arriving at the measurement site at times corresponding to measurements. In total, 622 and 473 seven-day trajectories for ^{85}Kr and ^{133}Xe, respectively, were calculated and analyzed in more details. The heights of trajectories arrival were chosen as 100 m (attributed to the surface layer) and 500 m (as for a lower part of the boundary layer).

In order to obtain and visualize dominating atmospheric transport pathways (or mean backward trajectories) a cluster analysis technique was employed. The Euclidian distances method was used for estimation; and pairs of latitude and longitude values at each time-step were applied as criteria. In addition, percentage probability of arrival from different directions was estimated as well as geographical regions that are responsible for noble gases emissions were identified. Finally, nuclear power plants, that were presumed to be the potential sources of these gases emissions, were named.

Topicality

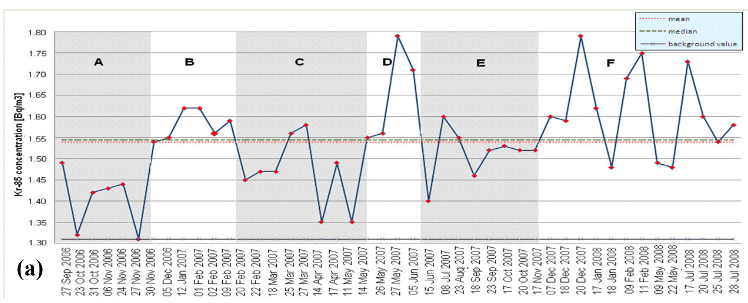
Radioactive noble gases (^{85}Kr and ^{133}Xe) are emitted into the environment mainly during operation of nuclear power plants (NPP) and nuclear fuel reprocessing.

Continuous accumulation of ^{85}Kr in the atmosphere as well as identification of accidental nuclear releases and monitoring of safe operation of nuclear power plants by evaluating ^{133}Xe atmospheric transport are challenging problems that are needed serious attention of the scientific community.

Time-series of Kr and Xe Measurements

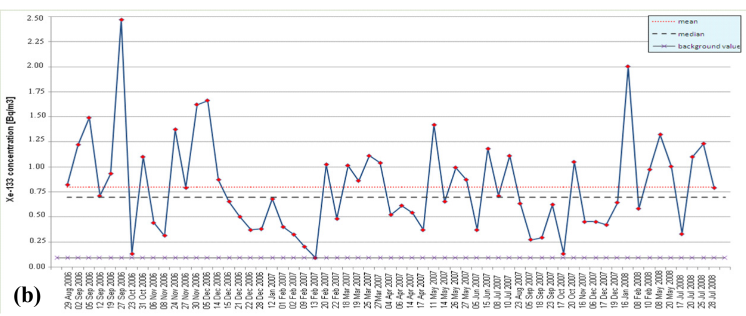
The radioactive noble gases monitoring was realized by the V. G. Khlopin Radium Institute's specialists during the period of two years (Sep 2006 – Jul 2008) in the Cherepovets city (Vologda region) within the framework of the international project «*Development of methodical bases and mobile equipment for monitoring of Xe and Kr radionuclides in the Northwest region of Russia*» (2005-2009) (*Dubasov et al., 2007*).

The time-series of these measurements obtained for ^{85}Kr and ^{133}Xe volumetric activity values at the Cherepovets site are shown in Fig. 1ab.



(a)

Figure 1. Time series of ^{85}Kr (a) and ^{133}Xe (b) concentration measured at the Cherepovets measurement site during Sep 2006 – Jul 2008.



(b)

- *Kr:* The specific cases in total have accounted 28 episodes for elevated and 17 episodes for lowered concentrations.

Maximum: 1.79±0.27 Bq/m^3 (25 - 27 May 2007)
Minimum: 1,31±0,20 Bq/m^3 (25 - 27 Nov 2006)

- *Xe:* In total 26 elevated and 36 lowered cases were selected and analyzed.

Maxima: 2,47 Bq/m^3 (25 - 27 Sep 2006)
2,00 Bq/m^3 (14 - 16 Jan 2008)
Minimum: 0,09 Bq/m^3 (11 - 13 Feb 2007)

Atmospheric Trajectory Modeling

For selected episodes, the HYbrid Single-Particle Lagrangian Integrated Trajectory (HYSPLIT, *see at: http://www.arl.noaa.gov/ready/open/hysplit4.html; Draxler R.R., Rolph G.D., 2003; Rolph G.D.,2003)* NOAA model was run to calculate multiple individual backward trajectories.

All backward trajectories were simulated in accordance with a sample time of measurements performed for two levels in height: 100 and 500 meters above ground level (agl).

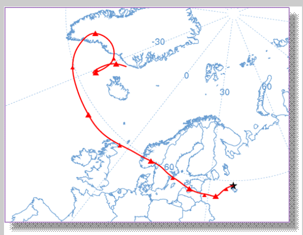


Figure 2. Kr: backward trajectory on 25 May 2007, 19 UTC at 100 m agl (elevated episode)

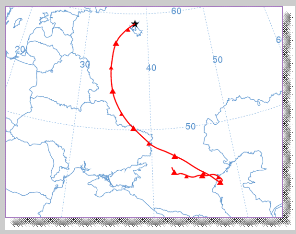


Figure 3. Kr: backward trajectory on 25 Nov 2006, 19 UTC at 100 m agl (lowered episode)

Figure 4. Xe: backward trajectory on 25 Sep 2006, 07 UTC at 500m agl (elevated episode)

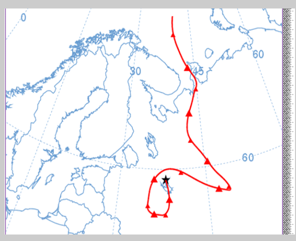


Figure 5. Xe: backward trajectory on 13 Feb 2007, 07 UTC at 500 m agl (lowered episode)

Along with individual (Fig. 2,3,4,5) backward trajectories obtained the **ensembles** (Fig. 6ab) of trajectories were also simulated for both noble gases, and air parcels paths were compared with NPP locations (Fig.7).

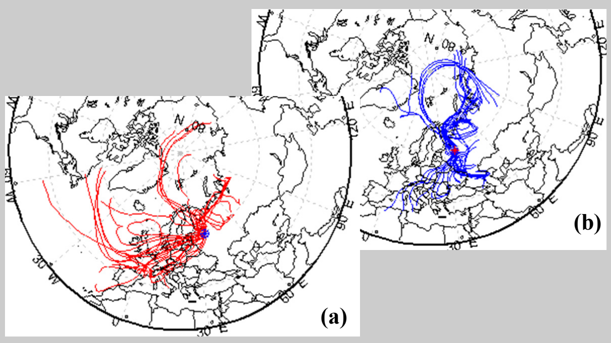


Figure 6. Kr case: All backward trajectories arrived at the site at the height of 100 m agl during the sampling period of (a) 30 Nov 2006 – 9 Feb 2007 with elevated and (b) 27 Sep 2006 – 27 Nov 2006 with lowered concentration.

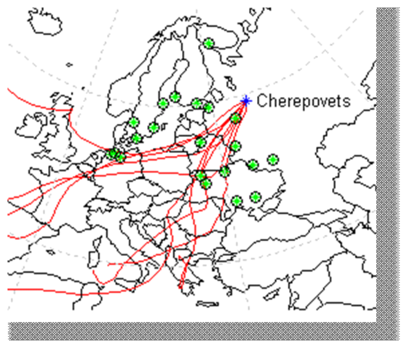


Figure 7. Backward trajectories for 100 and 500 m agl corresponded to the two maxima of ^{133}Xe concentration recorded on 14-16 Jan 2008

Trajectories travelled near Russian (*Kalinin and Smolensk*), Lithuanian (*Ignalina*), Ukrainian (*Rovno, Chernobyl and Khmelnitskiy*) and German (*Brokdorf and Brunsbuettel*) NPPs.

Cluster Analysis

In order to get additional probability information on general arrival directions as well as to visualize mean atmospheric flows (*Mahura & Baklanov, 2003*) the cluster analysis technique for trajectories was applied by making use of software of MATLAB.

At first, the number of latitude/ longitude pairs per cluster obtained were plotted in a form of histograms. (Fig. 8). Then the pairs of averaged latitude and longitude values for each cluster at each time step were derived, classified and plotted (Fig. 9).

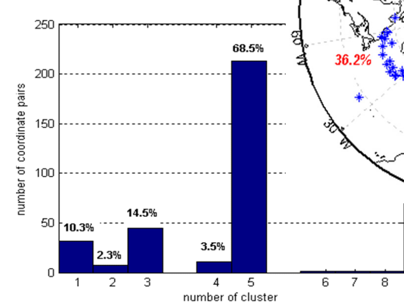


Figure 8. Kr case: Number of latitude/ longitude pairs per cluster obtained for the first time interval of 6 h corresponding to the height of 100 m agl

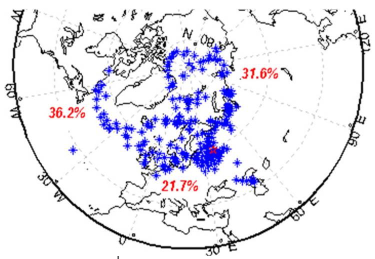


Figure 9. General atmospheric transport patterns represented by averaged coordinate pairs at all time intervals for ^{133}Xe for the level of 100 m agl

References

- Draxler R.R., Rolph G.D., (**2003**): HYSPLIT (HYbrid Single-Particle Lagrangian Integrated Trajectory) Model access via NOAA ARL READY Website (*http://www.arl.noaa.gov/ready/hysplit4.html*). NOAA Air Resources Lab., Silver Spring, MD.
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