Evaluation of Atmospheric Transport for Elevated and Lowered ^{85}Kr Concentrations during Monitoring at Regional Background Measurement Station (Cherepovets, Vologda Region)

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Abstract

An identification of probable source regions and reasons for episodes characterized by elevated and lowered volumetric activity values of a noble gas krypton (^{85}Kr) was studied. The long-term measurements of this gas were carried out in the city of Cherepovets (Vologda region, Russia) for a two-year period (27 Sep 2006 – 28 Jul 2008). In total, 28 episodes for elevated and 17 episodes for lowered concentrations, with the highest (absolute maximum of 1.79±0.27 Bq/m^3) concentration during 25-27 May 2007 were identified.

For all these cases, the HYbrid Single-Particle Lagrangian Integrated Trajectory (HYSPLIT) NOAA model was run to calculate multiple individual backward trajectories (7 days in duration) arriving at the measurement site at times corresponding to sampling. In total 622 trajectories were calculated. In order to identify dominating atmospheric transport pathways to the site and associated with episodes, the cluster analysis technique with calculation of Euclidean distances was applied. In clustering, the pairs of latitude and longitude values of trajectories at each time step were used as criteria, as well as varying a number of clusters between 5-7. The probability of each transport pathway, its spatial extension characterizing an average speed of air parcels traveling and temporal variability were evaluated. The results obtained were analyzed as well as inconsistent cases were examined.

Introduction

Among all radionuclides released by nuclear power plants (NPP) only the krypton-85 (^{85}Kr) possesses to be accumulated in the atmosphere.

Nowadays typical content of ^{85}Kr in the atmosphere for the temperate latitudes' surface air of the Northern Hemisphere is equal to 0.9 Bq/m^3 that exceeds the initial value (before nuclear era) at almost million (!) times (*Pahkomov, 2009*).

Further growth of its content in the atmosphere will start to affect the atmospheric electroconductivity and may also cause a development of the global geophysical effects including hard predictable climate change. That is why the realization of permanent krypton monitoring as well as investigation of its peculiarities connected with transport and circulation in the Earth's atmosphere should be continuously performed.

Measurements

The radioactive noble gases monitoring was realized by the V. G. Khlopin Radium Institute's specialists during the period of two years (27 Sep 2006 – 28 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*» ISTC ? 2133.

The time series of these measurements obtained for ^{85}Kr volumetric activity values for Cherepovets are shown in Fig. 1.

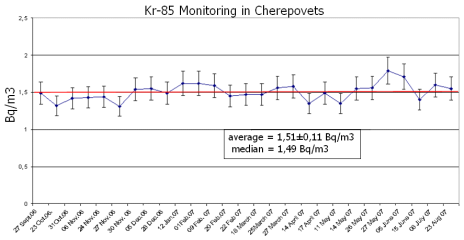

Figure 1. ^{85}Kr concentration variation in Cherepovets atmospheric air during the period of Sep 2006 – Aug 2007.

On the basis of implemented long-term measurements episodes with elevated (more than 1.51±0.11 Bq/m^3) and lowered (less than 1.51±0.11 Bq/m^3) concentrations above/ below background values were identified. These 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

The results of observations carried out in Cherepovets city showed that the volumetric activity of krypton in the North-western region of Russia for the last 15 years has grown upon 50% and amounted to 1.55 Bq/m3 (*Dubasov, 2007*).

Trajectory Modeling

For selected episodes, the HYbrid Single-Particle Lagrangian Integrated Trajectory (HYSPLIT, *see at: http://www.arl.noaa.gov/ready/open/hysplit4.html*) 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 m above ground level – as attributed to the surface level; 500 m - as a layer contained within the boundary layer of the atmosphere.

Examples of model simulations are shown in Fig. 2 (maximal concentration case) and Fig. 3 (minimal concentration case).

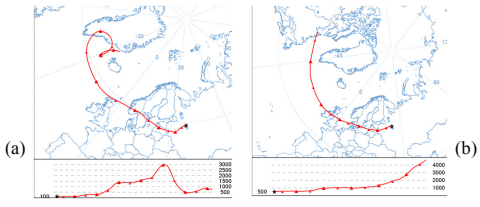

Figure 2. Backward trajectories arrived at Cherepovets on 25 May 2007, 19 UTC at (a) 100 and (b) at 500 meters height.

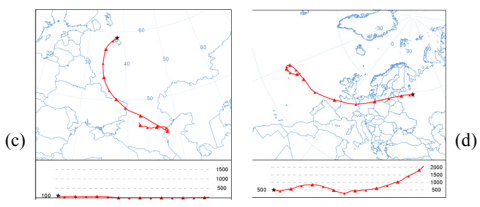

Figure 3. Backward trajectories arrived at Cherepovets on 25 Nov 2006, 19 UTC at (c) 100 and (d) at 500 meters height.

By analyzing backward trajectories obtained the preliminary estimation of geographical source regions with its approximate boundaries, identification of possible noble gas's sources of emissions which were assumed to be NPP, spatial extension characterizing an average speed of traveling air parcels and its temporal variability was carried out.

Cluster Analysis

In order to derive more representative single trajectories as well as trajectory ensembles and get additional probability information a cluster analysis technique was applied by making use of MATLAB.

Cluster histograms were plotted by using pairs of latitude and longitude values of trajectories at each time step as criteria (Fig. 4).

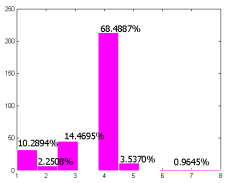

Figure 4. Clusters obtained for all coordinate points at distance corresponding to 6 h.

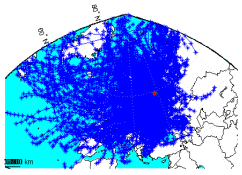

Figure 5. All backward trajectories arrived at Cherepovets (red dot) at the height of 100 meters.

All calculated percentage values in combination with cluster numbers were used for identification of general dependence of coordinate points at each time step on cluster number. The results obtained were also compared with multiple trajectories' plots (Fig.5).

References

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