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# Mapping terrestrial γ-dose rate in Europe based on routine monitoring data

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**Abstract**

After the nuclear reactor accident in Chernobyl in 1986, most countries of the European Union (EU) established monitoring networks measuring outdoor γ-dose rates for early warning. The data are composite values γ-dose rate due to terrestrial, cosmic and artificial radiation sources, and in most cases also include some instrument background. While EURDEP is mainly designed for exchanging and stocking data during radiological emergencies, the data it is storing in its database may potentially contain valuable information about spatio-temporal variations of the $^{222}$Rn source term which can be used for the validation of atmospheric transport models and other atmospheric tracer applications. The use of γ-dose rates as a proxy for outdoor radon concentrations is indeed possible if one can extract the terrestrial γ-dose rate contribution from the values reported in EURDEP.

It is the purpose of this paper to discuss the preparation of the terrestrial γ-dose rates using EURDEP data and to present seasonal maps of terrestrial γ-dose rates in Europe. Such maps could be used for the preparation of $^{222}$Rn source term which can be used for the validation of atmospheric transport models as well as for exploring variations in soil moisture content, an important parameter in flood prediction. These applications are the focus of the ongoing studies, but beyond the scope of this paper. In this paper, we show how the terrestrial γ-dose rate can be derived from the emergency monitoring data and two seasonal maps of γ-dose rates at the European scale are produced using geostatistics.


*Keywords:* γ-Dose rate; Radon; Monitoring networks; EURDEP; European map

## 1. Introduction

A lot of effort and financial input are usually required to gather the necessary data for modelling any parameter of scientific interest on a large scale such as Europe. Using existing networks providing data about a variable that is a proxy of a desired parameter can therefore be an interesting solution. For investigating spatio-temporal variations of the $^{222}$Rn source term for the validation of atmospheric transport models and other atmospheric tracer applications—a variable that is measured only at few locations—other sources of data were explored, among which total γ-dose rates that are monitored intensively in most European countries.

In 1986, after the Chernobyl accident, most European countries extended their γ-dose rate monitoring networks or established new ones. The data they collect are transmitted regularly in the situation of routine to the EUropean Radiological Data Exchange Platform (EURDEP, http://eurdep.jrc.it). This activity initiated by the European Commission is designed to store and exchange data from the national networks in situations of routine monitoring and in emergencies (with higher temporal resolution). Because of the continuous monitoring, temporal variability in terrestrial γ-dose rates can be observed and potentially used for scientific purposes. Terrestrial γ-dose rates are indeed closely related to factors affecting $^{222}$Rn fluxes (Schery et al., 1989) and could enable the large-scale modelling of the $^{222}$Rn source term (Szegvary et al., 2007). This term, in combination with observations of atmospheric $^{222}$Rn concentrations, should allow the evaluation and calibration of climate models simulating transport, transformation and removal processes of gases and aerosols. Used in inverse mode, these models can further provide information on location, extent and strength of sources and sinks of greenhouse gases based on the

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measurement of changes in their atmospheric concentrations. Currently, the effective use of $^{222}$Rn in this context is limited by the accuracy of the $^{222}$Rn source term (WMO, 2004). Changes in the terrestrial $\gamma$-dose rates also indicate changes in soil moisture (Jones and Carroll, 1983), a central parameter in streamflow forecasting. Aubert et al. (2003) showed the potential of sequential assimilation of soil moisture and streamflow data in forecasting of flood events. The currently central limitation to the operational implementation is the availability of soil moisture data. This information might be derived at a sufficiently high temporal resolution and with little effort from the existing radiological emergency monitoring network. To gain more information about the terrestrial $\gamma$-dose rate to be used as a proxy for such applications, the objectives of this study were twofold:

(I) to extract the natural terrestrial component from reported data on total $\gamma$-dose rate, considering all factors of different networks and
(II) to interpolate the data for generating seasonal maps of the natural terrestrial dose rates at the European level.

## 2. The European radiological data exchange platform (EURDEP)

The EURDEP network is currently used by 30 European countries for the continuous exchange of data from their national radiological monitoring networks while several other European countries applied for participation and are in the process of interfacing to the network. During routine operation, monitoring data is made available by the participating organizations at least once a day. During an emergency, data have to be made available at least once every 2 h. In practice, more and more organizations make data available on an hourly basis as a routine. The status of June 2007 is that 13 countries make their data available during routine once per hour, four countries each 2 h and the remaining countries between 3 and 24 h. As a result of this network of networks, measurements of more than 4000 monitoring stations (Table 1) are made accessible to the competent authorities in almost real-time and—with some restrictions and delays—to the public.

The total number of measurements listed in Table 1 is not always closely matching the theoretical number of measurements

Table 1
Overview of the $\gamma$-dose stations that contributed to EURDEP in 2006

| Country | No. of stations | No. of stations/2500 km$^2$ | Total no. of measurements | Measuring period | Transmission interval during routine (h) |
|---|---|---|---|---|---|
| Austria | 334 | 9.96 | 166 414 | 24 h | 24 |
| Belgium | 130 | 10.65 | 1 086 046 | 1 h | 1 |
| Bulgaria | 27 | 0.61 | 9 228 | 10 min | 24 |
| Croatia | 12 | 0.53 | 166 925 | 30 min | 6 |
| Czech Republic | 54 | 1.71 | 427 079 | 1 h | 1 |
| Denmark | 10 | 0.58 | 79 643 | 1 h | 2 |
| Estonia | 10 | 0.55 | 83 106 | 1 h | 3 |
| Finland | 256 | 1.90 | 1 414 803 | 1 h | 1 |
| France | 168 | 0.77 | 9 821 873 | 10 min | 12 |
| Germany | 2068 | 14.48 | 780 992 | 24 h | 24 |
| Great Britain | 91 | 0.93 | 751 413 | 1 h | 1 |
| Greece | 24 | 0.45 | 183 171 | 1 h | 24 |
| Hungary | 86 | 2.31 | 283 024 | 1 h | 1 |
| Iceland | 1 | 0.02 | 33 713 | 15 min | 2 |
| Ireland | 14 | 0.50 | 112 943 | 1 h | 1 |
| Italy | 38 | 0.32 | 206 043 | 1 h | 24 |
| Latvia | 15 | 0.58 | 110 901 | 1 h | 2 |
| Lithuania | 11 | 0.42 | 45 104 | 1 h | 1 |
| Luxembourg | 17 | 16.43 | 131 420 | 1 h | 1 |
| Netherlands | 165 | 9.93 | 7 073 751 | 10 min | 1 |
| Norway | 43 | 0.33 | 111 743 | 10 min | 1 |
| Poland | 13 | 0.10 | 106 830 | 1 h | 2 |
| Portugal | 13 | 0.35 | 80 055 | 20 min | 24 |
| Romania | 37 | 0.39 | 13 120 | 24 h | 24 |
| Russia | 294 | 0.04 | 41 788 | 10 min | 24 |
| Slovakia | 23 | 1.18 | 33 997 | 1 h | 1 |
| Slovenia | 37 | 4.56 | 199 335 | 30 min | 1 |
| Spain | 32 | 0.16 | 1 285 935 | 10 min | 24 |
| Sweden | 35 | 0.19 | 862 605 | 15 min | 24 |
| Switzerland | 55 | 3.33 | 153 266 | 1 h | 1 |
| Average | 137 | 2.82 | 861 876 | 3 h | 9 |
| Total | 4151 | | 25 856 266 | | |