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Inter-calibration of gamma dose rate detectors on the European scale

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Abstract. A project to compare the response of different detector types was started in 1996 at the Schauinsland mountain (1200 m above sea level) close to Freiburg, Germany, where the German office for radiation protection (BfS) runs a trace analysis laboratory since about 50 years. The aim of this inter-calibration experiment is to compare different gamma dose rate detector types over long periods and under rather unfavorable climatic conditions. This allows to characterise different probe types under environmental conditions and it complements the EURADOS inter-comparison exercises, which a carried out every 2 to 3 years. Both projects dealing with the harmonization of gamma dose rate data in the EU are used to derive terrestrial dose rate from the raw data. Using interpolation techniques provided by INTAMAP seasonal maps of the terrestrial dose rate could be generated. It is shown, that this information can be used for the calibration of satellite based soil moisture methods as well for the calculation of radon emission maps on the European scale, which are of interest for the research community, since Radon is used as a passive tracer in atmospheric research to examine transport processes on synoptic time scales.

1. INTRODUCTION

Following the reactor accident in Chernobyl in 1986, most countries in the European Union (EU) have installed networks for the monitoring radioactivity in the environment. Since more than one decade, a common European data exchange platform (EURDEP) [1] has been established, to which all EU member states are reporting their measurement results on a daily basis under routine conditions. In case of emergency the agreed reporting interval is one hour.

Today, different types of detectors (Geiger-Mueller counters, proportional counters, scintillation detectors and semi-conductor based detectors with semi-spectroscopic or even spectroscopic capabilities) are used in European countries. The characteristics of these different detector types show large variations even with respect to the most important criteria like for example sensitivity, linearity, energy dependence, self-effect and response to secondary cosmic radiation (Figure 1). The sensitivity to cosmic radiation varies with altitude and type of gamma probes (the over- or underestimation ranges from −40% to +60%). Also the self effect varies from 2 to 50 nSv/h depending on detector type.

A project to compare the response of different detector types was started in 1996 at the Schauinsland mountain (1200 m above sea level) close to Freiburg, Germany, where the German office for radiation protection (BfS) runs a trace analysis laboratory since about 50 years. In contrast to the inter-comparison experiments performed by the European Dosimetry group (EURADOS) [2] the aim of this inter-calibration experiment is to compare different gamma dose rate detector types over long periods and under rather unfavorable climatic conditions. Thus, the facility is intended to characterise the behaviour of different probe types under environmental conditions and it complements the EURADOS inter-comparison exercises, which a carried out every 2 to 3 years and focus on the self-effect and response to secondary cosmic component. In addition, some of the GDR detectors installed at the Schauinsland site have been characterized in co-operation with the German metrological institute PTB [2]. In Summer 2007, the Schauinsland facility was re-designed for the simultaneous inter-comparison of 20 different devices measuring ambient gamma dose rate (GDR) under the same environmental conditions.

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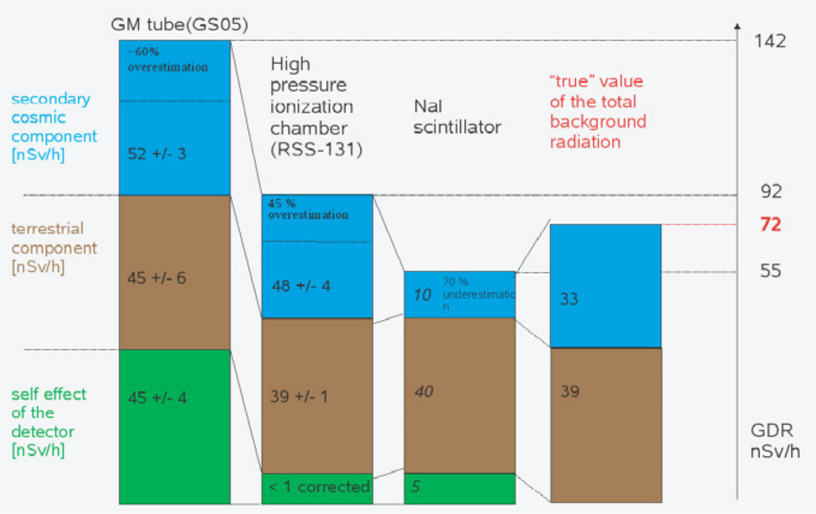

Figure 1. Response of different detector types to the background radiation at typical site.

Figure 2 shows the facility with 20 probe holders installed in a circular arrangement with a radius of 5 m. This design allows the simultaneous calibration of all detectors at the same time using radioactive calibration sources placed into the centre of the circle.

Figure 2. The Schauinsland inter-calibration facility in Summer 2007.

After completion of the modernisation, the different components of the natural radiation fields at Schauinsland inter-calibration facility were characterized. The contribution of charged particles and photons of the secondary cosmic radiation is about 50 nSv/h. The terrestrial dose rate contribution is not constant over the whole area but varies between the different detector positions. This was investigated using a handheld device and a range from 72 to 82 nSv/h between the different positions was found.

During rain events the background value can be increased by a factor 3. The background value can be reduced to 10% of its usual value by snow cover in winter.

2. INTER-COMPARISON METHOD

The facility provides rich additional instrumentation: several monitors are operated at the Schauinsland site, allowing to extend the investigation of the GDR detectors by taking into account for example air-borne activity concentrations of aerosols, nuclide specific activity on ground, intensity of the cosmic radiation, neutron flux, soil moisture, amount of precipitation, air pressure, temperature or ^{222}Rn-exhalation. Today, 18 different detector types are under operation representing about 20 member states of the EU. The observed data are transferred to a common data base, thus allowing systematic evaluations of the data.

With the data available since the start of the operation of the modernized inter-calibration facility, direct comparison and correlation methods have been developed. For example, direct comparison methods are used to detect technical problems with a given device and to compare the time evolution as recorded by different probes during the same rain events. The impact environmental parameters on observed dose rate – e.g. snow cover, soil moisture or temperature – can be investigated with the help of direct comparison methods (Figure 3).

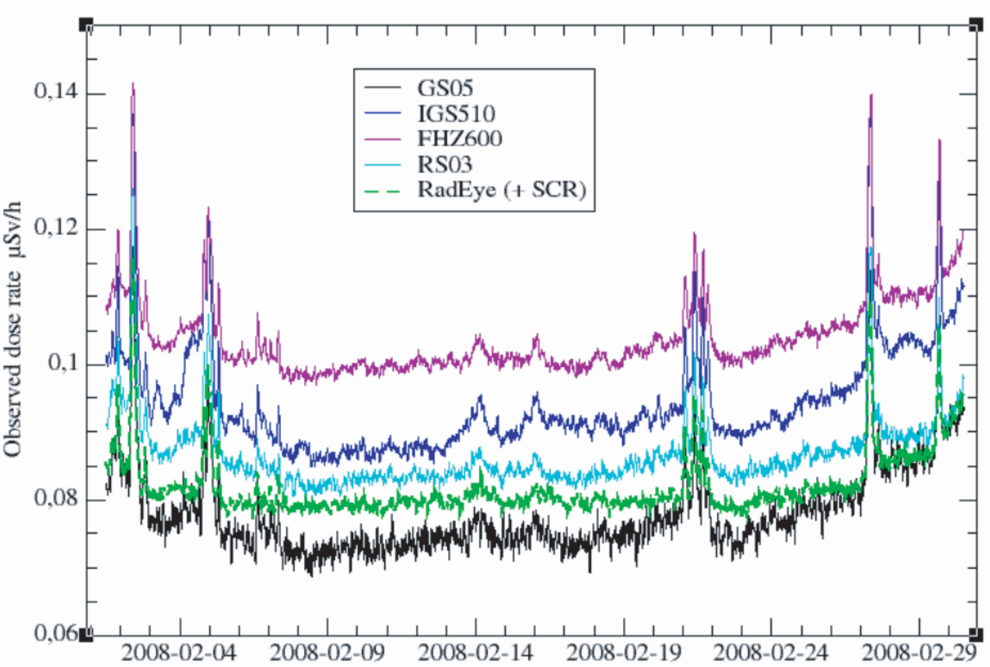

Figure 3. Time evolution of observed 1h mean values of GDR – measured by different devices on Schauinsland inter-calibration platform during February 2008. The platform was covered with snow and the contribution of terrestrial radiation was reduced to about 50% of its snow-free value.

On the other hand, mean values of measured data observed by different probes in a given time period can be compared and correlation methods based on a linear regression allow to assess the relative response of different probes to variations of the natural radiation field. With this method, data from all detectors have been compared with data observed by FHZ600 proportional counter (see Table 2 and Figure 4).

Table 1. Terrestrial component measured at the individual detector positions.

Pos	Owner	device	type	GDR (nSv/h)	Pos	Owner	Device	Type	GDR (nSv/h)
1	Baden-Württemberg	XL	GM	77	11	Germany	AMES	GM	81
2	Germany	GS05	GM	76	12	Austria	RS03/A232	PC	80
3	Germany	GS05	GM	80	13	Germany	XL2	GM	83
4	Germany	RadEye	NaI	79	14	Germany	XL2-LND	GM	80
5	Netherlands	RS03/232	PC	77	15	–			76
6	Finland	XL2-3	GM	79	16	Germany	FHT 681	PSC	77
7	Finland	IGS421	GM	82	17	Germany	NanoSpec	NaI	75
8	Switzerland		GM	83	18	Germany	FHZ 600 A	PC	77
9	France	Alnor	GM	83	19	Germany	FHZ 601	PC	72
10	Germany	RSS	IC	82	20	Germany	IGS510	PC	75

Table 2. Parameters of linear regression method: Slope B and its standard deviation (Stdev) characterise the response relative to reference device (FHZ600); additionally Pearsons correlation coefficient R and number of compared data (1 hour mean values) are given.

Device	Slope B	Stdev.	R	Number
A_RS03	1,188	0,004	0,959	6327
NL_RS03	0,999	0,002	0,991	4855
IGS510	1,209	0,003	0,976	6245
GS05	1,092	0,002	0,987	6625
XL2	1,114	0,005	0,950	5776
FI_XL2	1,362	0,008	0,947	3974
FI_IGS421	1,364	0,008	0,934	3974
RSS	0,871	0,004	0,992	724
NBR	0,896	0,003	0,969	6187

The results shown above are results of a preliminarily investigation. The properties of the selected reference device are not known with the needed accuracy. However, the observed relative response of the devices are in the range between 0.85 and 1.35. In two cases, probes of the same type show deviations in observed response which exceed the range of uncertainty. The differences could be explained by different calibration strategies used in different countries.

On the other hand, the method could be used to assess the uncertainty of measured dose rate for different devices. In principle, the uncertainty of measured data depend on the uncertainty of calibration factor and the influences of deviations from calibration conditions on observed dose rate due to environmental conditions. Thus, long-term inter-calibration experiments can improve the knowledge about the impact of environmental conditions. For example, the uncertainty of measured dose rate could be derived from relative deviation of observed dose rate from one device compared to dose rate measured by reference device (see Figure 5).

Obviously, the results of the regression method depend on the observation period and the selected reference device. In future, it is planned to use the Reuter Stokes high pressure ionisation chamber (RSS) as reference device. The method depend on the assumption of homogeneous radiation field on the platform. However, the terrestrial component shows a spatial variability in the order of 7% (see Table 1). Further investigation have to check, if this variability is increased by rain events or due to snow cover

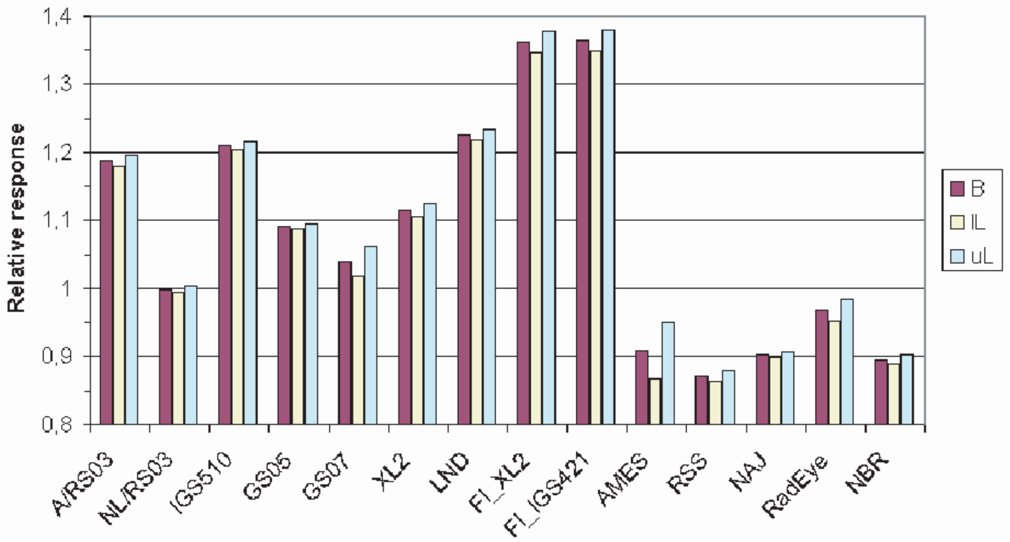

Figure 4. Relative response of different devices and the corresponding range of uncertainty assessed from observed data. The parameters are assessed by linear regression analysis of observed 1 hour dose rate values compared to reference device FHZ600. Observation period was 1st September in 2007 to 10th June in 2008.

effects. Additionally, further analysis will include other environmental parameters like temperature, air pressure and soil moisture.

3. ADJUSTING NETWORKS FOR THE VALIDATION OF CLIMATE MODELS

Monitoring of GDR in Europe has the purpose to inform about scale and intensity of radioactive contamination in case of a nuclear emergency. In the absence of such a situation, natural background radiation is monitored. This is the "normal" situation for most of the time. Small variations in background radiation contain information which can be very useful in a completely different context. Here, we provide an example. The terrestrial component of the GDR has been shown to be a good proxy for ^{222}Rn flux at the soil-atmosphere interface [3–5]. Information on ^{222}Rn flux and atmospheric concentrations has been widely used in the evaluation of atmospheric chemistry and transport models. Information on location, extent and strength of sources and sinks of greenhouse gases can be obtained when such models are linked to observed time series of atmospheric greenhouse gas concentrations, and are run in an inverse mode (e.g. [6]). Such an approach has, for example provided well constrained estimates of national CH_4 emissions in Europe (e.g. [7]). Also, the accumulation of ^{222}Rn and other gases in the nocturnal boundary layer has been extensively used to estimate the emissions of CO_2, CH_4, N_2O, Hg^o and other species by mass balance approach [8–10]. Currently, the effective use of ^{222}Rn as a tracer in these contexts is limited by the poor accuracy of the ^{222}Rn source inventory [11]. Knowledge of the terrestrial component of GDR and its correlation with ^{222}Rn flux are currently improving the situation in Europe.

It is well known that due to the diversity of European monitoring networks data from different countries show significant differences and the effects should be corrected in order to harmonize the data on the European scale. In 2004 the European Commission initiated the so called AIRDOS project ("Evaluation of existing standards of measurement of ambient dose rate; and of sampling, sample preparation and measurement for estimating radioactivity levels in air" [12]. This project covered detailed assessment and evaluation of systems for continuous measurement of external GDR in the EU.

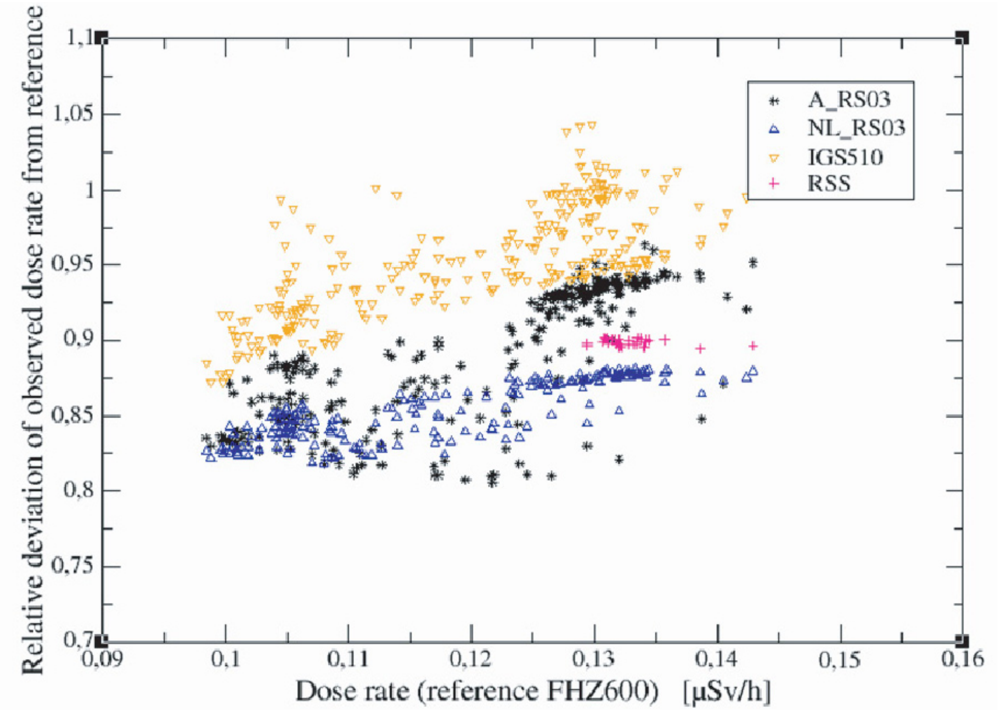

Figure 5. Relative deviation of observed dose rate compared to dose rate from reference device FHZ600. Each point represents observed mean dose rate for one day. Observation period was 1st September in 2007 to 10th June in 2008.

A questionnaire was developed, send to the EU member states and evaluated. Based on this work, a comprehensive data set was developed, describing and characterising all of the GDR networks in Europe in detail [12]. Probe related information provided by the network operators to AIRDOS is derived from the results of the EURADOS inter-comparison exercises and the Schauinsland inter-calibration site. Szegvary [13] applied corrections to the EURDEP data based on the AIRDOS: self-effect-corrections, correction of the cosmic radiation with empirical functions depending on the altitude asl; subtraction of the artificial radiation (mostly derived from the Chernobyl accident 1986); geometry of the measurement (e.g. height above ground). As a result of the harmonisation procedure Szegvary generated the first map of the terrestrial component of GDR in Europe were derived from EURDEP (Figure 1). AIRDOS provided information on whether corrections for, say self-effect or others, have already been carried out before data was submitted to EURDEP. Where necessary, the following adjustments were made to total GDR based on the information obtained through the AIRDOS project:

1. Subtraction of the cosmic component in total GDR, based on altitude above sea level and sensitivity of the reporting detector type.
2. Subtraction of detector type specific self-effect.
3. Normalisation of reported values to a measurement height 1 m above soil surface (correction functions for different detector types were obtained from measurements at different heights on a wooden look-out tower on Schauinsland).

Where applicable, an artificial component from ^{137}Cs was subtracted based on data in de Cort et al. [1]. Kriging methods developed within INTAMAP project are used for spatial interpolation between monitoring stations provided European maps of terrestrial GDR [13], which have then been transformed in ^{222}Rn flux maps for use in atmospheric transport applications using the empirical relation between terrestrial GDR and ^{222}Rn flux described in Szegvary et al. [5]. These maps are available at http://radon.unibas.ch/. They provide mean ^{222}Rn fluxes on a 0.5° × 0.5° grid for summer and winter 2006. Further refinement is possible and envisaged. It includes the generation of flux maps with the same spatial but higher temporal, if possible weekly, resolution. Use of automated mapping procedures [14] could reduce required efforts considerably. Generated spatially and temporaly resolved ^{222}Rn flux would constitute a useful contribution to the ongoing effort to establish an observing system for greenhouse gas emissions in Europe (http://www.geomon.eu/).

One future goal of the inter-comparison and inter-calibration facilities will be to keep the knowledge up-to-date about the physical properties of the GDR detectors. This is a fundamental pre-requisite for the preparation of the a common European map of the terrestrial gamma dose rates using EURDEP data, both under routine, alert and emergency conditions. Furthermore automatic procedures will be developed for the generation of actual and seasonal maps of terrestrial gamma dose rates at the European scale using geostatistics. These maps will made available to modellers to be used for the preparation of ^{222}Rn source term aiming to validate atmospheric transport models.

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