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The EMPIR initiative is co-funded by the European Union's Horizon 2020 research and innovation programme and the EMPIR Participating States

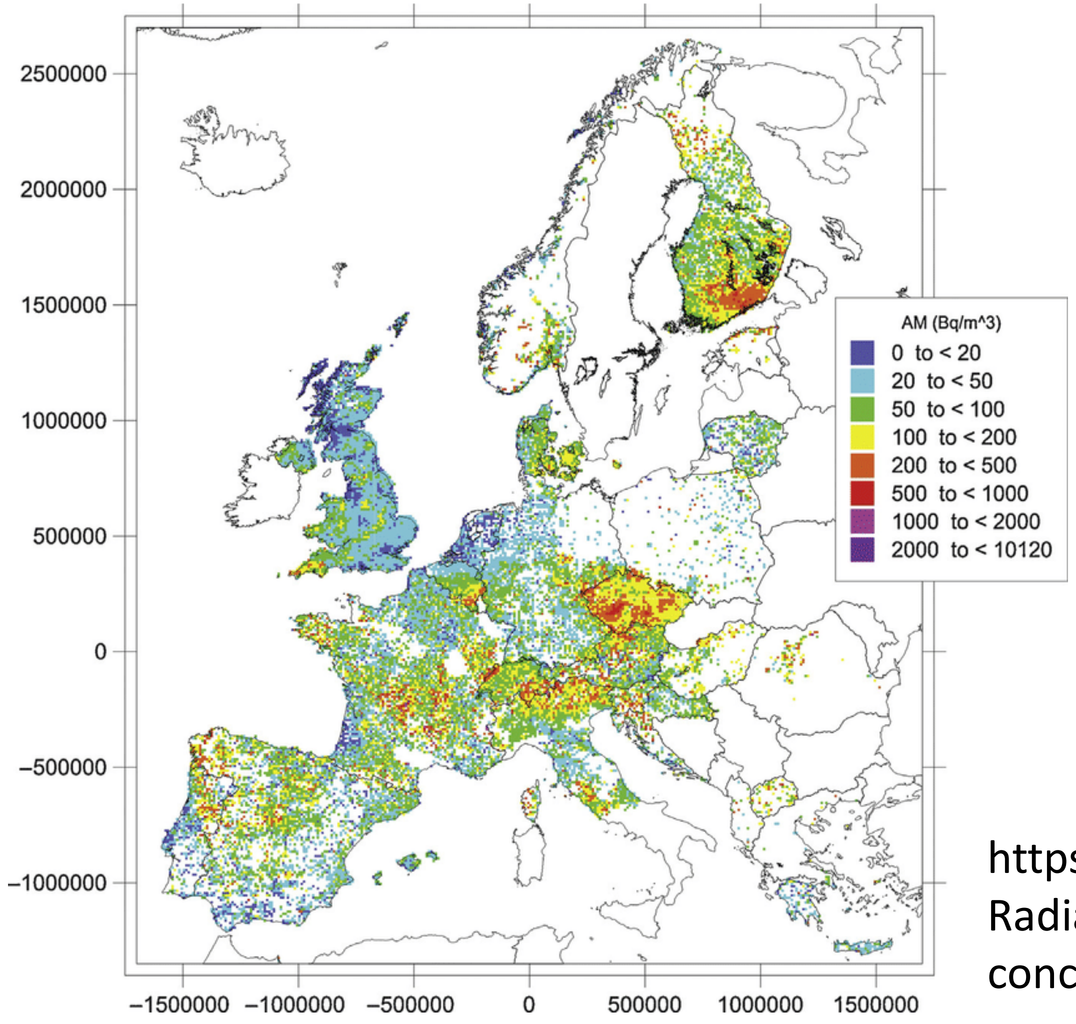
EMPIR 19ENV01 traceRadon project
Radon flux campaigns

EURADOS WG3 Annual Meeting 2022

C. Grossi on behalf of WP2 participants

Contents of this talk:

The need: Identification of Radon Prone Areas (RPAs)

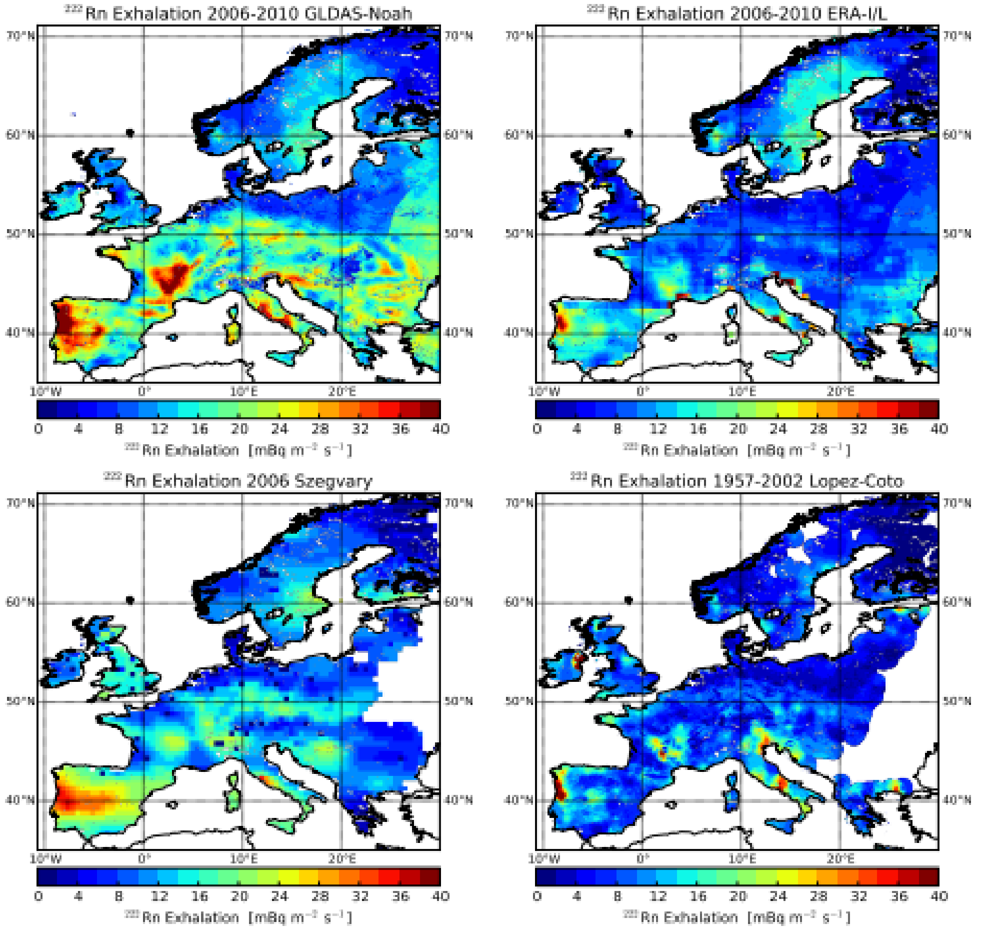


2013/59/EURATOM – Article 103(3)

'Member States shall identify areas where the radon concentration (as an annual average) in a significant number of buildings is expected to exceed the relevant national reference level.'

https://remon.jrc.ec.europa.eu/About/Atlas-of-Natural-Radiation/Digital-Atlas/Indoor-radon-AM/Indoor-radon-concentration

The need: Identification of Radon Prone Areas (RPAs)



Karstens et al., 2015

Available ^{222}Rn flux models and inventories could be used to identify RPAs but they need to be validated

The Problem

High quality long term radon flux measurements should be carried out

The problem: Reliable high quality radon flux measurements are still difficult to obtain

Radon flux/exhalation from the soil = Activity concentration of radon exchanged between the soil surface and the lower atmosphere per unit area and time (S.I. unit: mBq m^{-2} s^{-1})

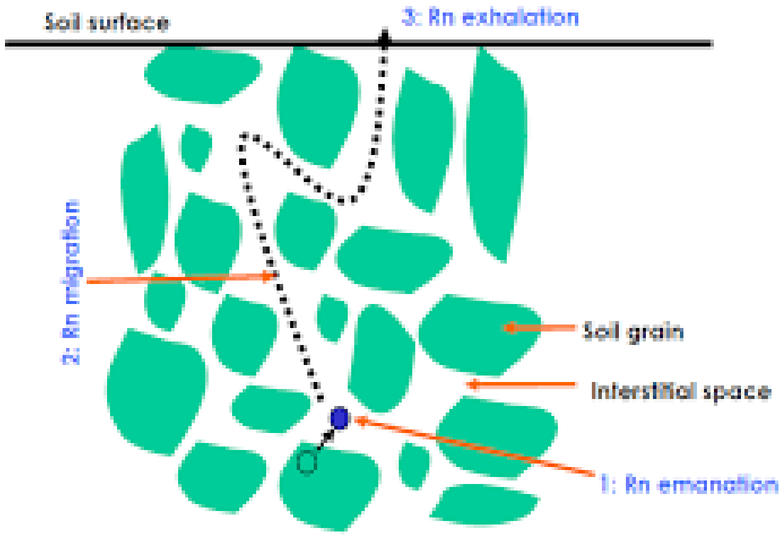


Figure 2.6: Radon emanation, migration and exhalation

Source: https://inis.iaea.org/collection/NCLCollectionStore/_Public/43/106/43106942.pdf

Fick's Law (Molecular Diffusion)

$$\vec{J}_d = -D \cdot \nabla C$$

Darcy's Law (Forced Convection)

$$J_a = vC$$

Other physical conditions that may lead to a diffusive flux , in particular temperature gradients, pressure gradients and external forces are neglected in this expression. They are usually unimportant relative to the concentration gradient into the soil

It is usually neglected…but…

$$v = \frac{-K \cdot \nabla p}{\eta}.$$

$$\vec{J} = -D\vec{\nabla}C + \vec{v}C$$

Nazaroff and Nero, 1988

$$\vec{J} = -D\vec{\nabla}C$$

$$j(z=0) = -D_e \left.\frac{\partial c(z)}{\partial z}\right|_{z=0} = -D_e \frac{c_\infty}{\bar{z}} = -\bar{z}\, c_\infty \lambda = -Q\sqrt{\frac{D_e}{\lambda}} = -\rho_b c_{Ra} \varepsilon \sqrt{D_e \lambda}.$$

From soil surface

Karstens et al., 2015

Soil humidity and Temperature influence

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The problem: Reliable high quality radon flux measurements are still difficult to obtain

$$C(t) = \frac{E_{Rn}}{\lambda^0 V_u}(1 - e^{-\lambda^0 t})$$

Many Laboratory and in field studies of radon fluxes have been carried out indicating **an influence of environmental parameters within the accumulation chamber and the exterior, setting conditions (insertion depth) on the accumulation method results both for total curve or linear approximations**.

Under ideal 'hermetic' conditions $\lambda^0 = \lambda$

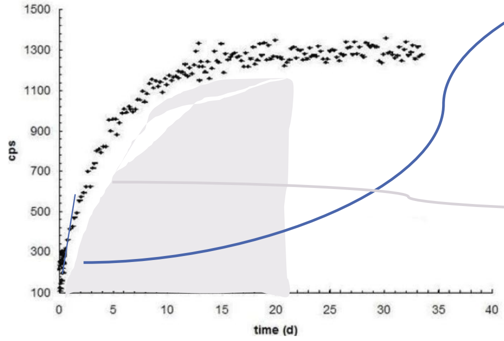
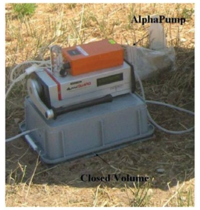


Figure 2.1: ^{222}Rn accumulation evolution in time inside a closed volume.

Grossi, 2012

Linear Approximation

$$C(t) = \frac{E_{Rn}}{V_u}t = \frac{FA}{V_u}t$$

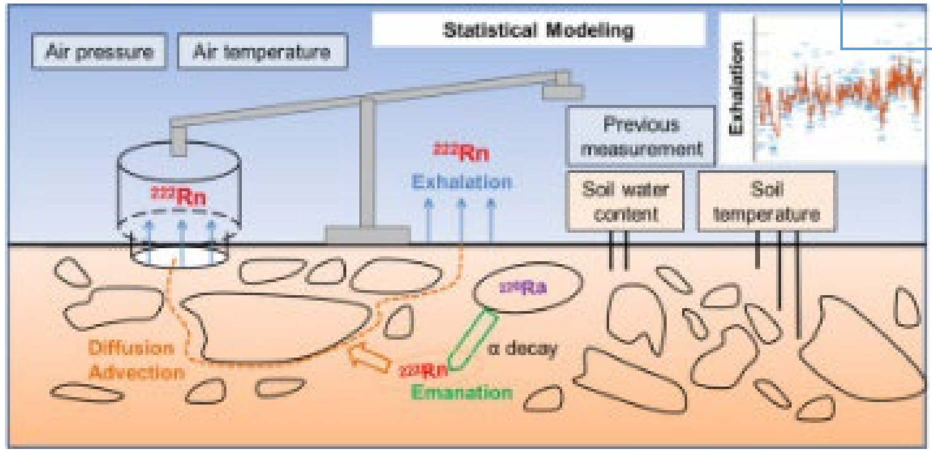


Integrated measurement

$$C(Rn)Av = \frac{1}{T}\int_0^T C(t)dt = \frac{FxA}{\lambda^0 V_u}\left(1 - \left(\frac{1 - e^{-\lambda^0 t}}{\lambda^0 T}\right)\right)$$

A is the Surface area of the accumulation chamber

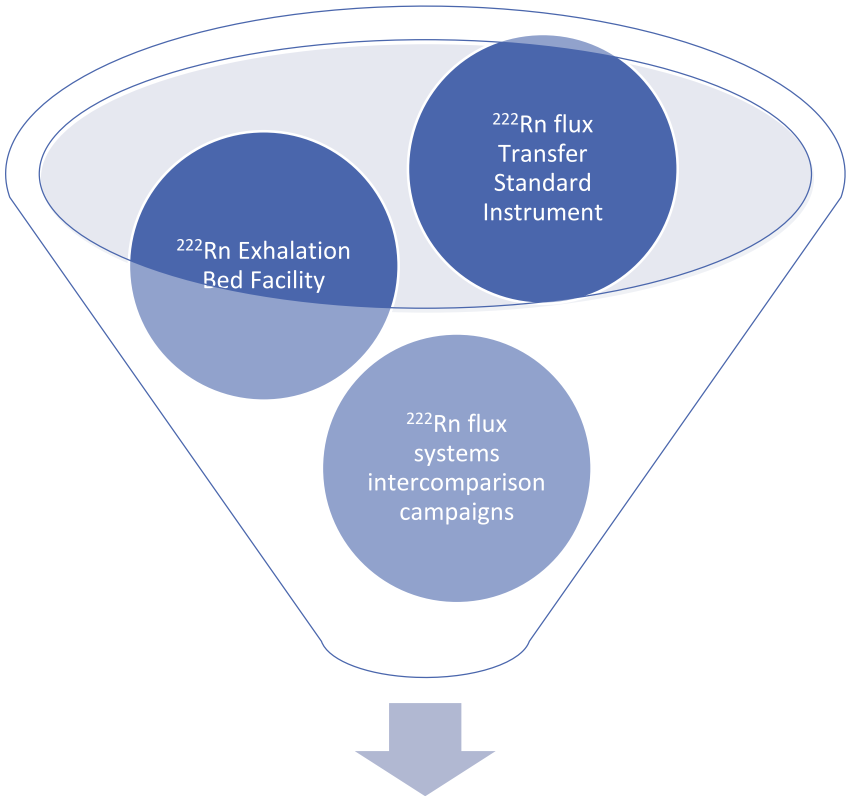
Grossi, 2011



Yang et al., 2019

There is a strong need of correctly quantifying all these influences to perform a protocol and guide to continuous radon flux measurements

The solution: The design and construction of a complete metrology infrastructure for conducting long-term radon flux measurements at different European sites



Traceable ^{222}Rn flux measurements

Grossi et al., in preparation

The different elements required to build a robust metrology chain for reliable radon flux measurements:

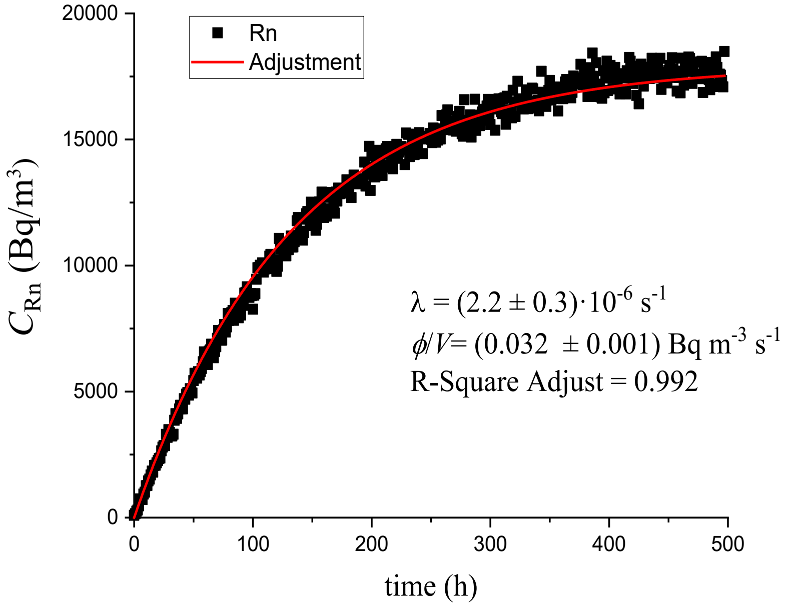
i) a **^{222}Rn Exhalation Bed (EB) facility** to ensure reference radon fluxes under controlled laboratory conditions;

ii) a **Transfer Standard (TS) instrument** to be calibrated using the EB and useful as reference monitor for in situ measurements;

iii) **inter-comparison campaigns** of radon flux systems under in situ environmental conditions.

iv) **Long term radon flux and environmental measurements** at different European sites

i) a ^{222}Rn Exhalation Bed (EB) facility was designed and built at Cantabria University following a literature review of requirements



The EB was characterized using both theoretical and experimental approaches. A difference of 9% was founded between the two methods

Grossi et al., in preparation

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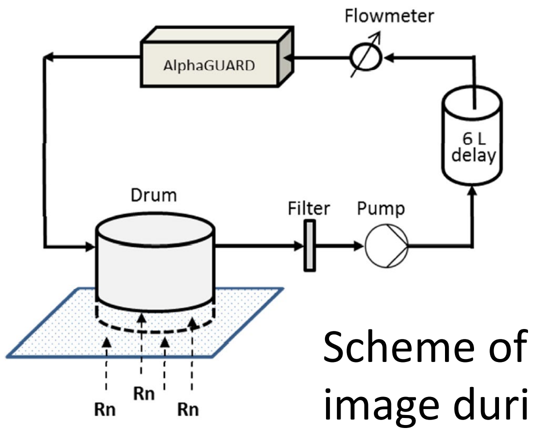
ii) a **Transfer Standard (TS) instrument** to be calibrated using the EB and useful as reference monitor for in situ measurements;

ANSTO

Automatic Radon Flux measurement system AutoFlux

Description and specification of ANSTO AutoFlux system



Scheme of the Autoflux system and its image during a field measurement

Autoflux system on the UC Exhalation Bed

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iii) **inter-comparison campaigns** of radon flux systems under in situ environmental conditions.

HIGH

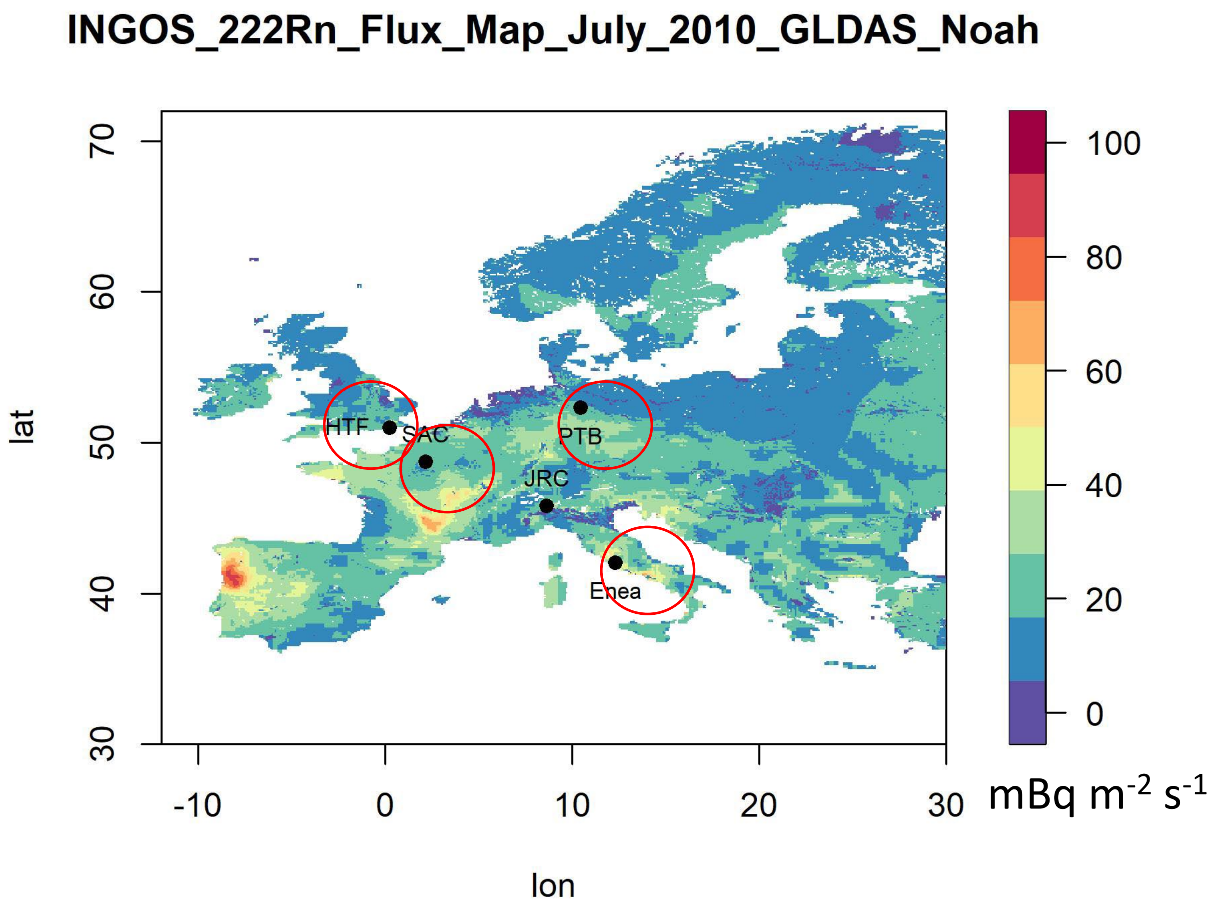
Saelices el Chico (Salamanca, Spain) (latitude: 40.65, longitude: −6.63, with an average radium concentration of (814 ± 65) Bq/kg (k = 2).

LOW

Esles de Cayón (Cantabria, Spain) (latitude: 43.28, longitude: –3.80), with an average radium concentration average of (29 ± 3) Bq/kg (k = 2).

Rabago et al., 2022

iv) **Long term radon flux and environmental measurements** at different European sites



Measurements during the intense radon flux campaigns:

- Volumetric water content and Temperature sensors (NPL)
- Radon flux systems (UPC, ENEA, ARPA)
- Dose rate monitors (Router Stikes) (PTB, ENEA)
- Spectro-dosemeters (DorayMon) (PTB, UPC)
- Physical soil properties (soil density, radium content, porosity) (ENEA, LSCE, NPL, PTB)

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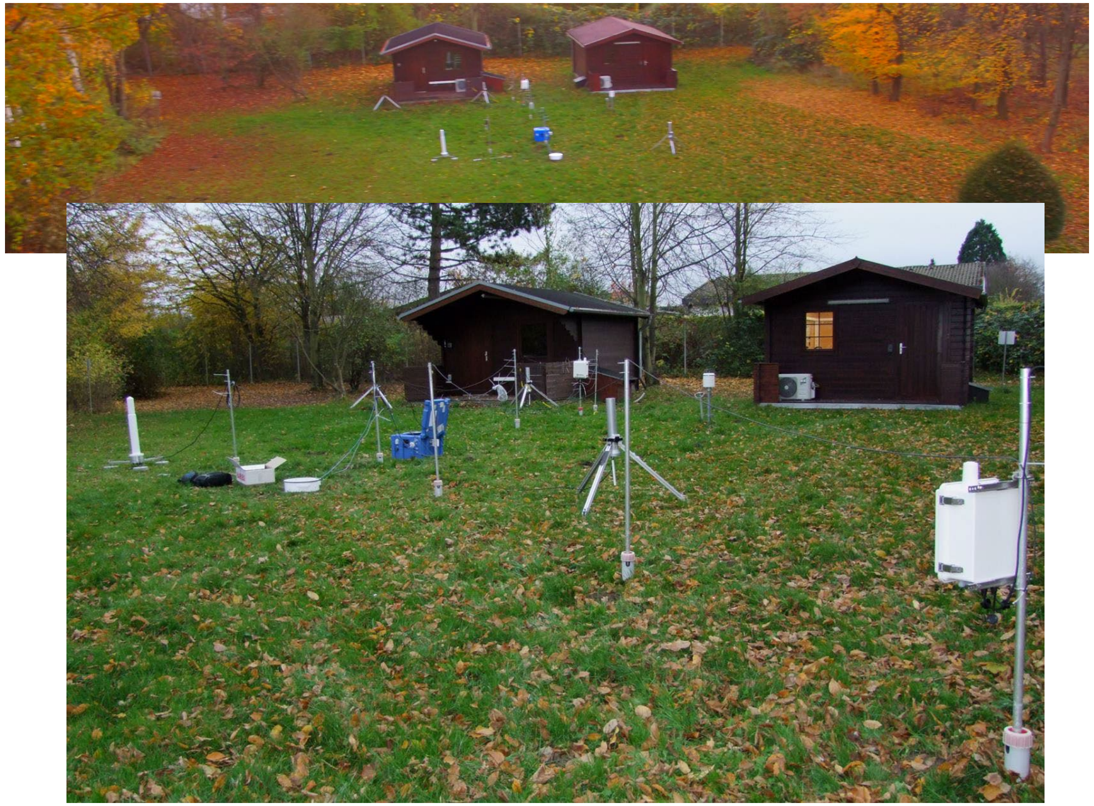
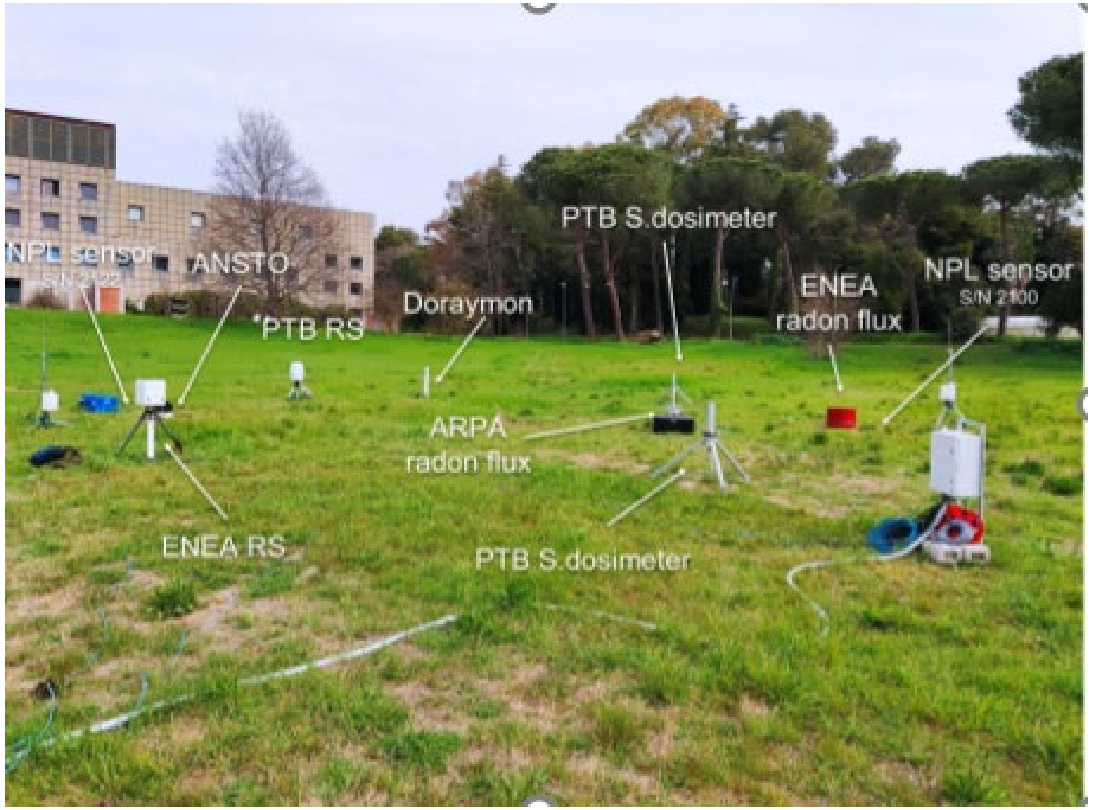
iv) **Long term radon flux and environmental measurements** at different European sites

PTB from November 2021 to January 2022



^{226}Ra activity= 25 Bq/kg

ENEA: from February 2022 to June 2022



^{226}Ra activity= 100 Bq/kg

iv) **Long term radon flux and environmental measurements** at different European site: **PTB**

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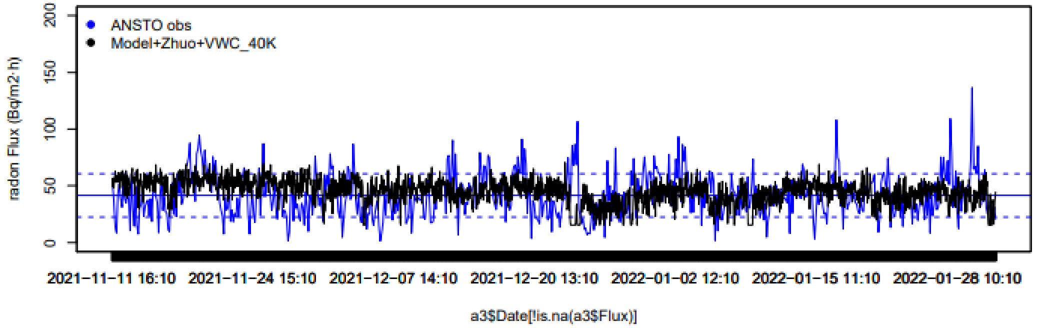
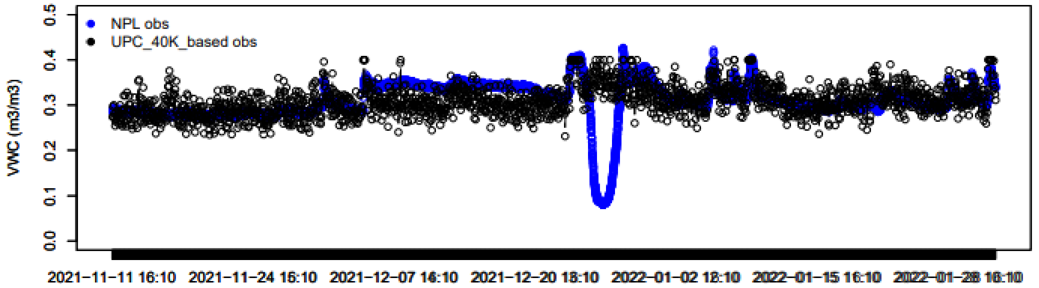
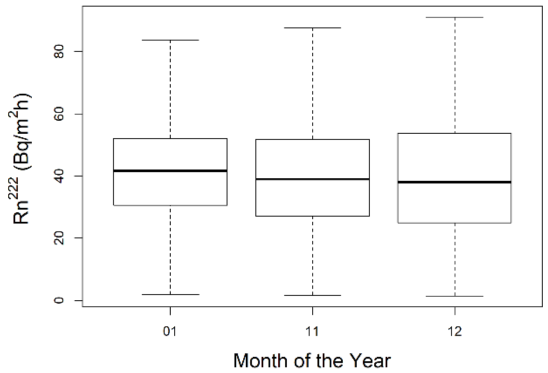


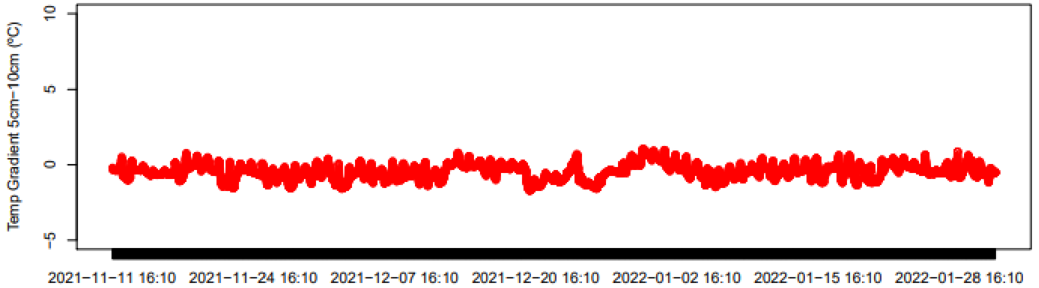
Mean = 41 Bq m^{-2} h^{-1} = 11.5 mBq m^{-2} s^{-1}

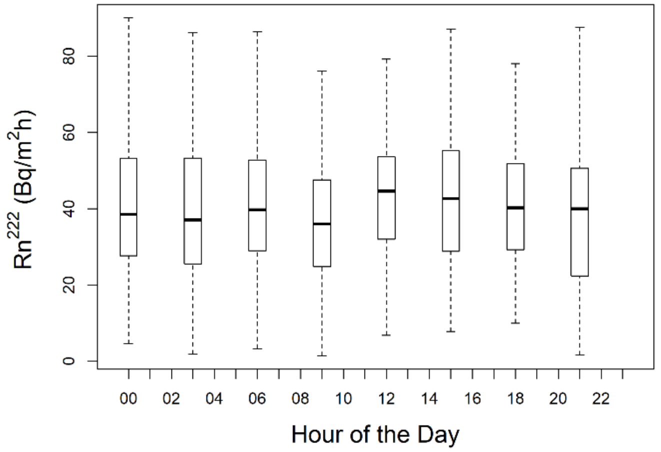
Standard Deviation = 19 Bq m^{-2} h^{-1} = 5.3 mBq m^{-2} s^{-1}

Uncertanty of the measurements: 40% (k=1)









iv) **Long term radon flux and environmental measurements** at different European site: **ENEA**

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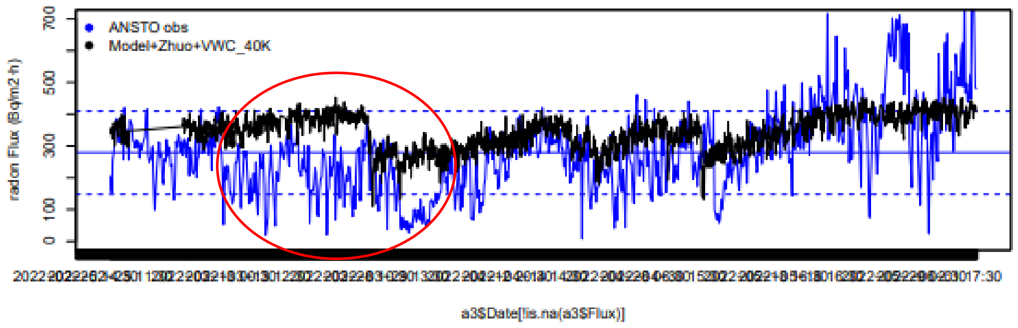
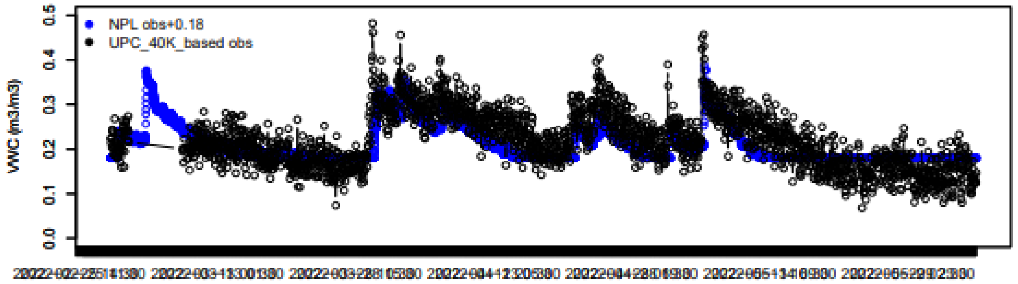
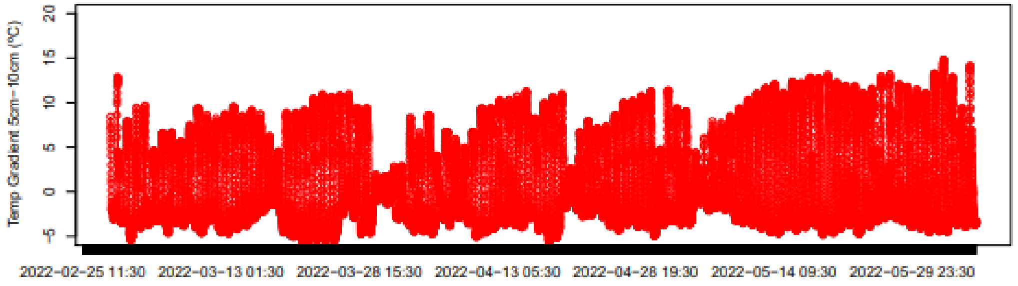


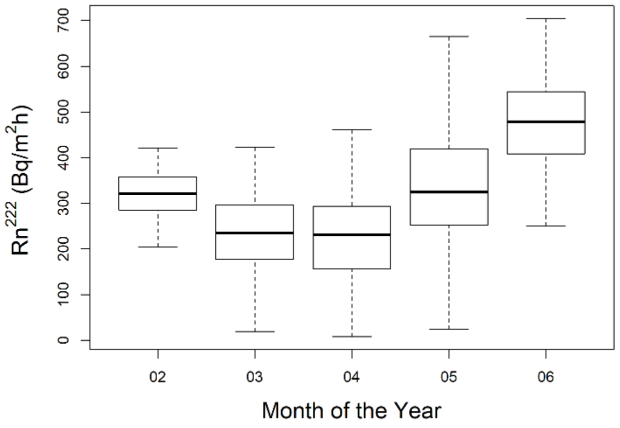


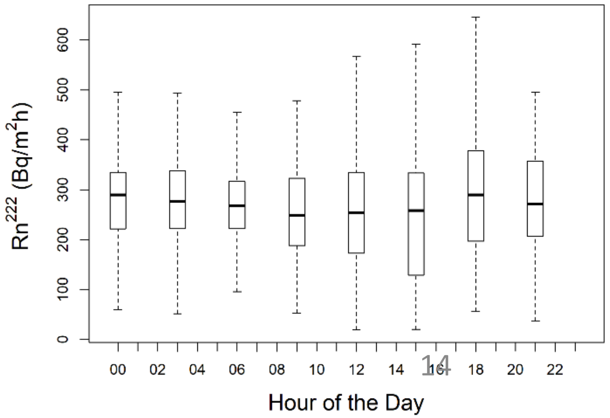


Mean = 279 Bq m^{-2} h^{-1} = 77.5 mBq m^{-2} s^{-1}

Standard Deviation = 131 Bq m^{-2} h^{-1} = 36.4 mBq m^{-2} s^{-1}

Uncertanty of the measurements: 20 % (k=1)





Conclusions and Next steps:

- Radon flux maps may help with the identification of RPAs;
- The project traceRadon offers for the first time the possibility to build a full metrology chain for long term radon flux measurement in field;
- Radon flux campaigns are being carried out at 4 sites in France, Germany, Italy and UK;
- Radon observations show large variability on daily scale which is not followed by models based only on diffusion;
- It is observed that soil moisture has a large influence on the radon fluxes but the temperature effect it is not yet clear (depth of the soil layer);
- Two additional radon flux campaigns are going to be carried out in France and UK during the next months of 2022 in the framework of the project traceRadon;
- Data analysis of time series of radon flux data and environmental data will be performed to investigate possible correlations;
- The influenced of the convection term within the radon transport model will be evaluated at the different sites benefiting of the physical parameters measured at the stations together with environmental data.

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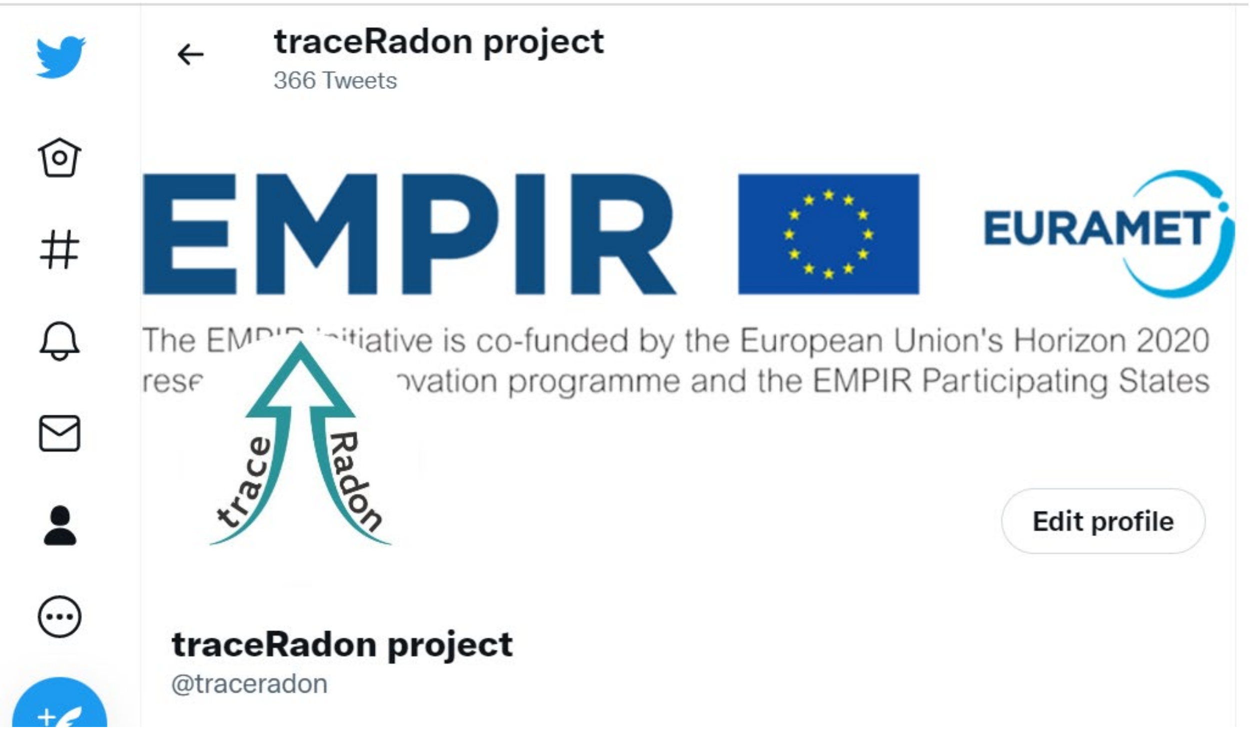

Thank You

ClaudiaGrossi4

EURADOS Annual Meeting WG3 -21st June, 2022 Belgrade