The European Atlas of Natural Radiation: Indoor Radon Concentration and Geogenic Radon

Peter Bossew[1], Giorgia Cinelli[2], Valeria Gruber[3],
Tore Tollefsen[2], Marc De Cort[2]

1 German Federal Office for Radiation Protection (BfS), Berlin
2 European Commission, Joint Research Centre (JRC), Ispra, Italy
3 Austrian Agency for Health and Food Safety (AGES), Linz

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Life – RESPIRE midterm meeting, Rome, 11 Dec 2018

RESPIRE
Radon real time monitoring system

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Motivation

A tool for the public to:

- ✓ familiarize itself with natural environmental radioactivity;
- ✓ be informed about the levels of natural radioactivity caused by different sources;
- ✓ have a more balanced view of the annual dose received by the world population, to which natural radioactivity is the largest contributor;
- ✓ make direct comparisons between doses from natural sources of ionizing radiation and those from man-made (artificial), and hence to better understand the latter.

For the scientific community:

- ✓ An extensive database (property and access problems still to be clarified);
- ✓ Models have been developed in course of the work on the Atlas, involving many colleagues across Europe;
- ✓ Work on the Atlas has given rise to a number of publications, and many ideas about further work are around.

Legal background

- **Euratom Treaty**

Art.35: Each Member State shall establish the facilities necessary to carry out continuous monitoring of the level of radioactivity in the air, water and soil and to ensure compliance with the basic standards…

Art.36: The appropriate authorities shall periodically communicate information on the checks referred to in Article 35 to the Commission so that it is kept informed of the level of radioactivity to which the public is exposed.

Art. 39: The Commission shall set up within the framework of the Joint Nuclear Research Centre, as soon as the latter has been established, a health and safety documentation and study section. This section shall in particular have the task of collecting the documentation and information referred to in Articles 33, 36 and 37 and of assisting the Commission in carrying out the tasks assigned to it by this Chapter.

- **Basic Safety Standards**

Council Directive 2013/59/Euratom laying down basic safety standards for protection against the dangers arising from exposure to ionizing radiation (BSS) http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=OJ:L:2014:013:TOC (OJ L, 17.01.2014)

Potential support to EU Member States for the radon action plan Art. 103: "*Member States shall identify areas where the radon concentration (as annual average) in a significant number of buildings is expected to exceed the relevant national reference level*" (a.k.a. "radon-priority areas" unofficially, formerly "radon-prone areas")

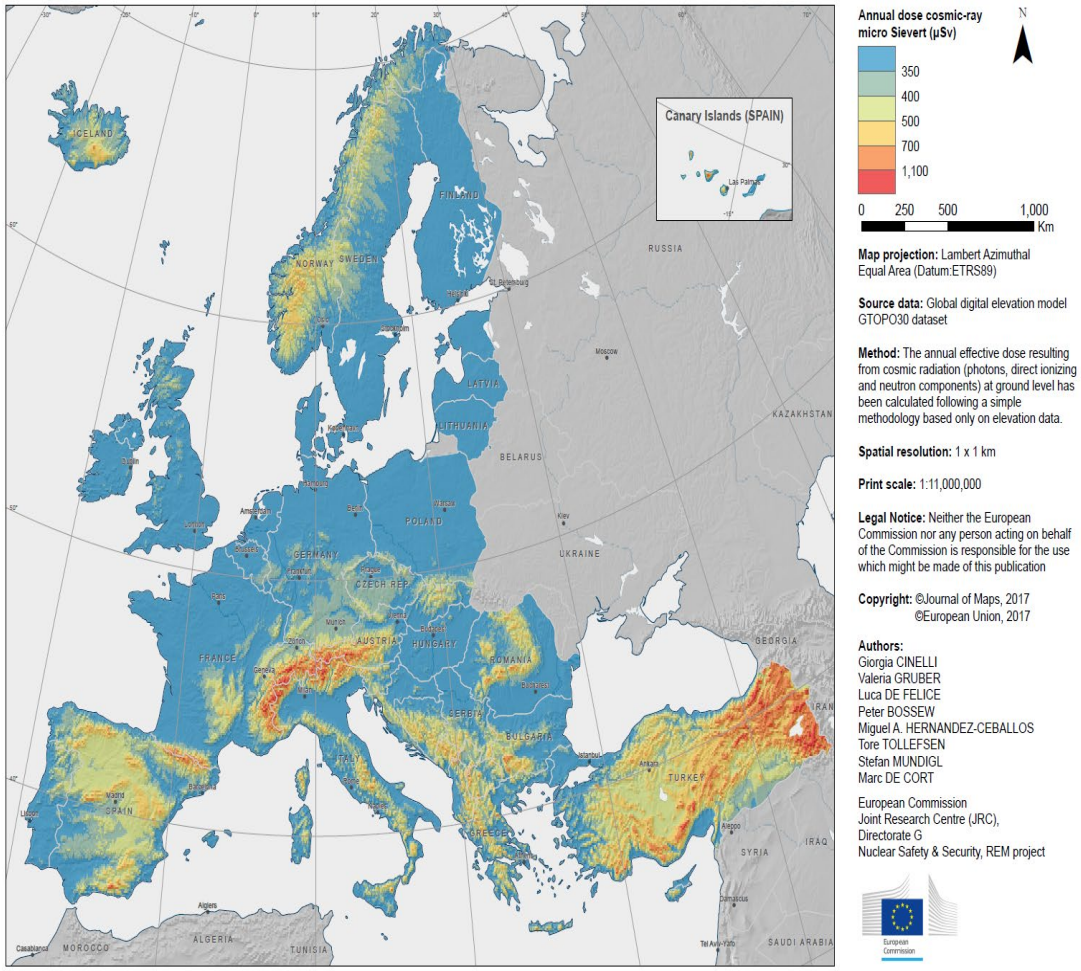
Atlas, current state - overview

Exposure components already covered:

- **Cosmic** exposure and dose: **finished**;
- **Terrestrial radionuclides:**
  - geochemical concentrations: **finished**
- **Terrestrial gamma radiation:**
  - Ambient dose rate (ADER) calculated from geochemistry: **complete**
  - ADER from surveys and EURDEP: some countries **complete**, many only **partly**; **to be continued** (difficult; data missing)
- **Indoor Rn:**
  - Source: indoor concentrations: only ground floor; **34 countries (regionally incomplete)**
  - Effect (exposure, dose, risk): **on going (methodology defined within the working group)**

Missing components → later slide

Cosmic radiation



Cinelli G. *et al*., 2017. *European annual cosmic-ray dose: estimation of population exposure.* Journal of Maps, 13:2, 812-821; https://doi.org/10.1080/17445647.2017.1384934

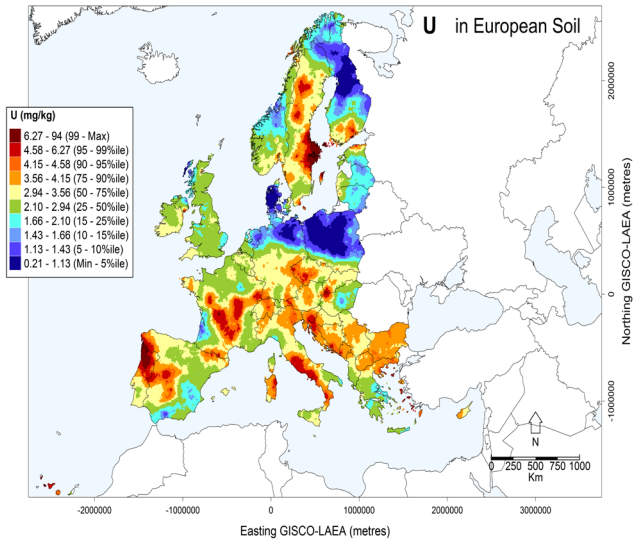
The map displays the annual effective dose that a person may receive from photons, direct ionizing and neutron components of cosmic radiation at ground level.

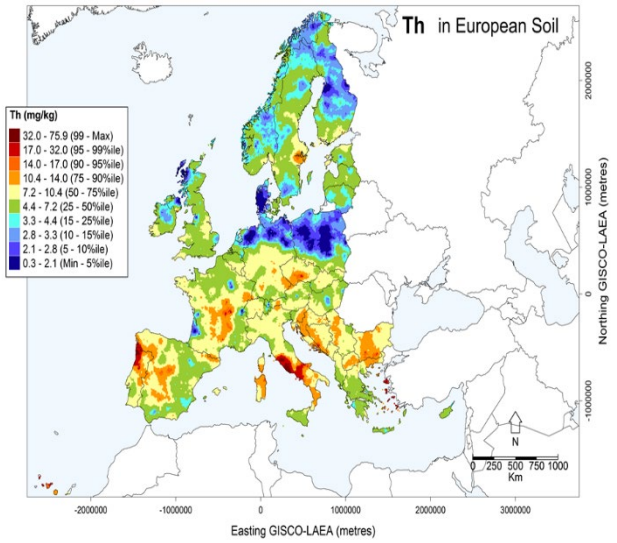
The dose has been assessed according to methods described in UNSCEAR (2008) and a global digital elevation model (DEM), called the GTOPO30 dataset.

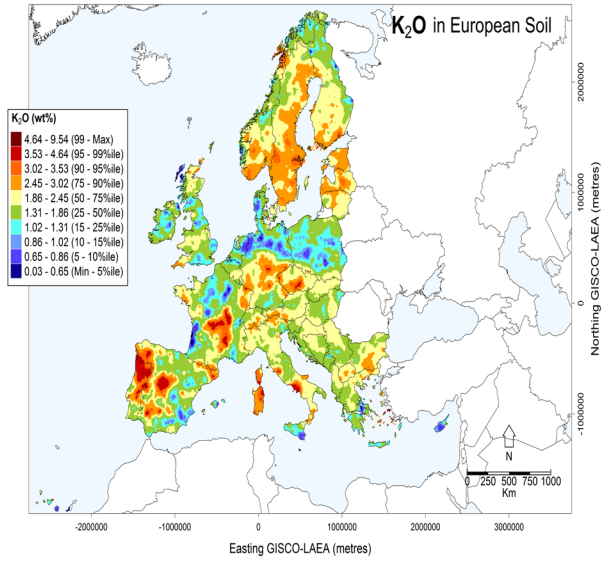
The values displayed are only linked to elevation. Latitude effect and influence of solar activity not considered.

The discrepancy between our results and the ones obtained with the two models (long-lat) is below 15%, values on the same order of magnitude of the uncertainties variation due to other parameters such as solar modulation, building shielding effects, ground condition and indoor occupancy.

U, Th and K concentration in soil







Maps of estimated U, Th and K total concentrations in topsoil over Europe, based on data collated from FOREGS (ICP-MS) and GEMAS (XRF) European datasets. The colours are attributed according to the percentiles estimated map points.

Acknowledgment: Antonio Ferreira, Bob Lister, Andrew Tye (British Geological Survey)

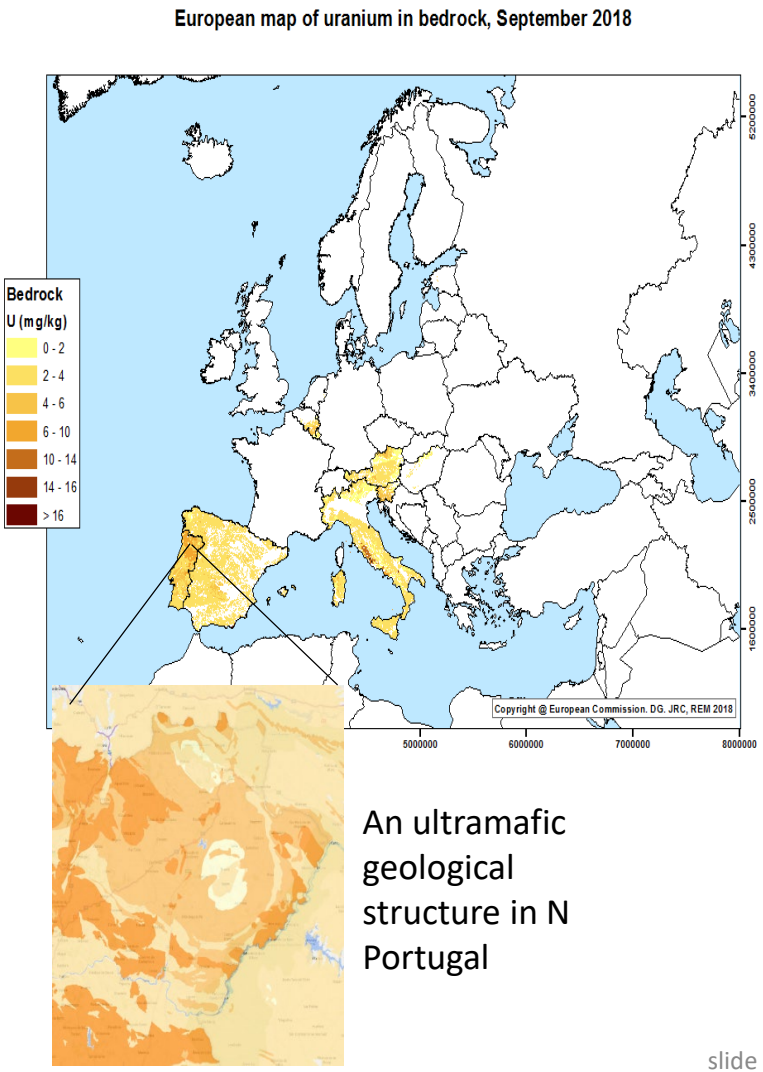
U, Th and K concentration in bedrock

Bedrock geochemistry

The map displays the arithmetic mean of the concentrations of U, Th and K in bedrock over geological units

Methodology:

1. Identifying geological units homogenous in U, Th and K content using OneGeology-Europe data (http://www.onegeology-europe.org/).
2. Collecting data of K_2O, U and Th concentration in bedrock using scientific literature sources;
3. Checking the quality of the data
4. Assigning K_2O, U and Th concentration values in bedrock to each geological unit using the collected data
5. Mapping K_2O, U and Th concentration in bedrock



An ultramafic geological structure in N Portugal

Terrestrial Gamma Dose Rate 1/2

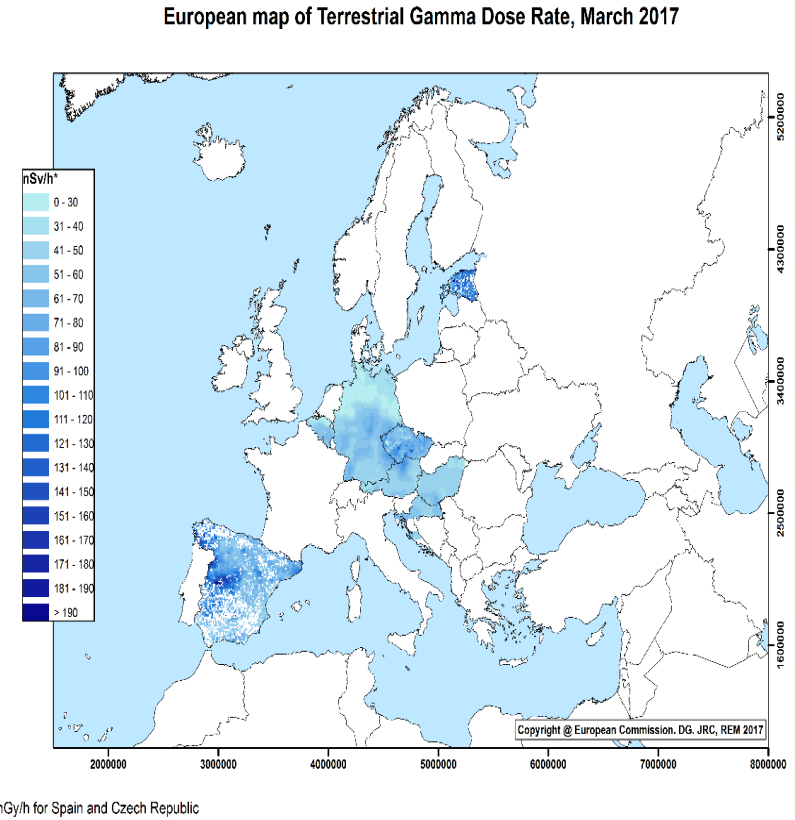
Mapping options: 1. **Measurement:** national surveys, EURDEP system
2. **Calculate** ambient dose rate from terrestrial radionuclide concentrations

Option 1:

AT,DE,HR,HU: Terrestrial gamma radiation has been estimated from the total ambient dose rate data transmitted to the EURDEP system (https://eurdep.jrc.ec.europa.eu) after subtracting:

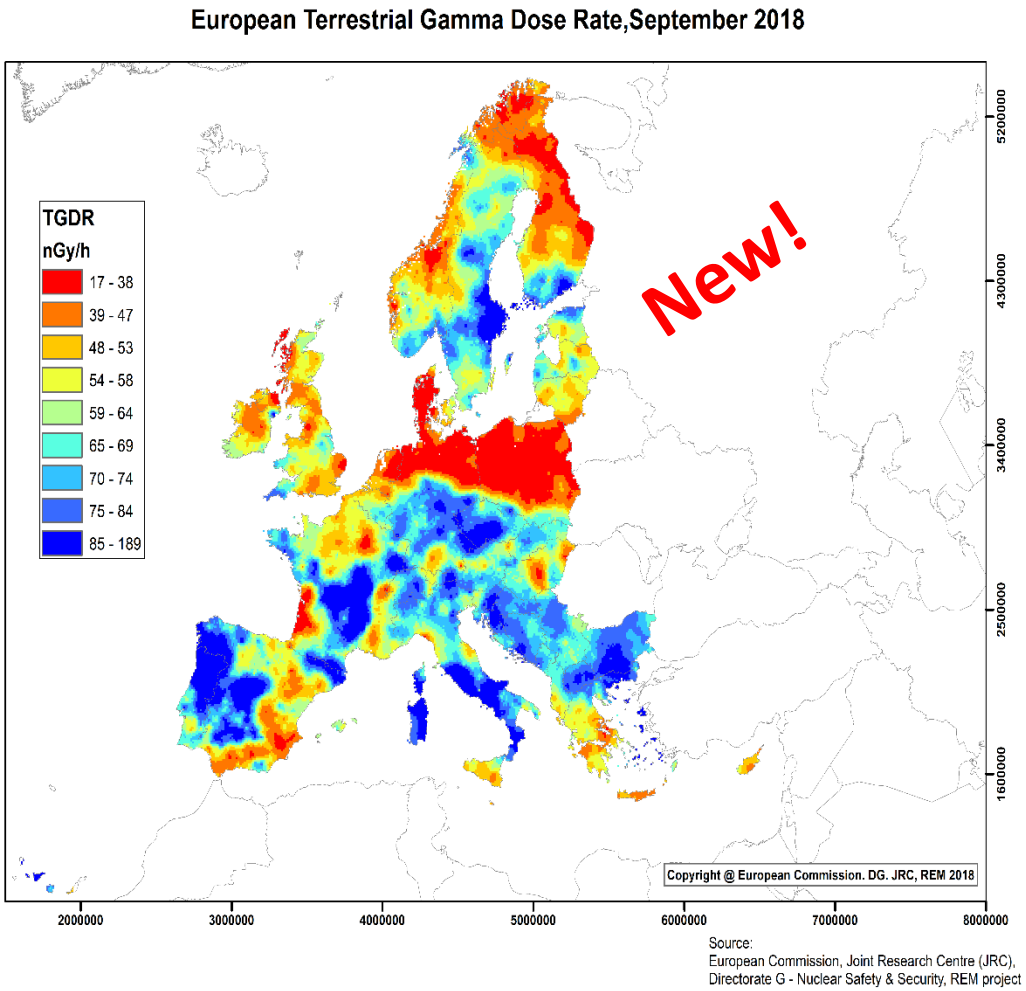
1) cosmic,
2) Radon-washout and
3) internal background effects.

For Belgium, the Czech Republic and Spain, data from their national databases have been used.



Bossew P. *et al*., 2017. *Estimating the terrestrial gamma dose rate by decomposition of the ambient dose equivalent rate.* Journal of Environmental Radioactivity 166, 296 – 308; doi: 10.1016/j.jenvrad.2016.02.013

Terrestrial Gamma Dose Rate 2/2



Input data: U, Th and K concentration maps (above):

- 0.83 K%/K2O%
- 309.7 Bq/kg K / K%
- 12.35 Bq/kg U / ppm
- 4.072 Bq/kg Th / ppm

TGDR(nGy/h) =

$0.0417 * C_K + 0.462 * C_U + 0.604 * C_{Th}$

[UNSCEAR, 2008]

Resolution:10 km x 10 km

Acknowledgment: Paolo Falletti, Enrico Chiaberto, Anselmo Cucchi, Mauro Magnoni (Arpa Piemonte)

Indoor Radon - essentials

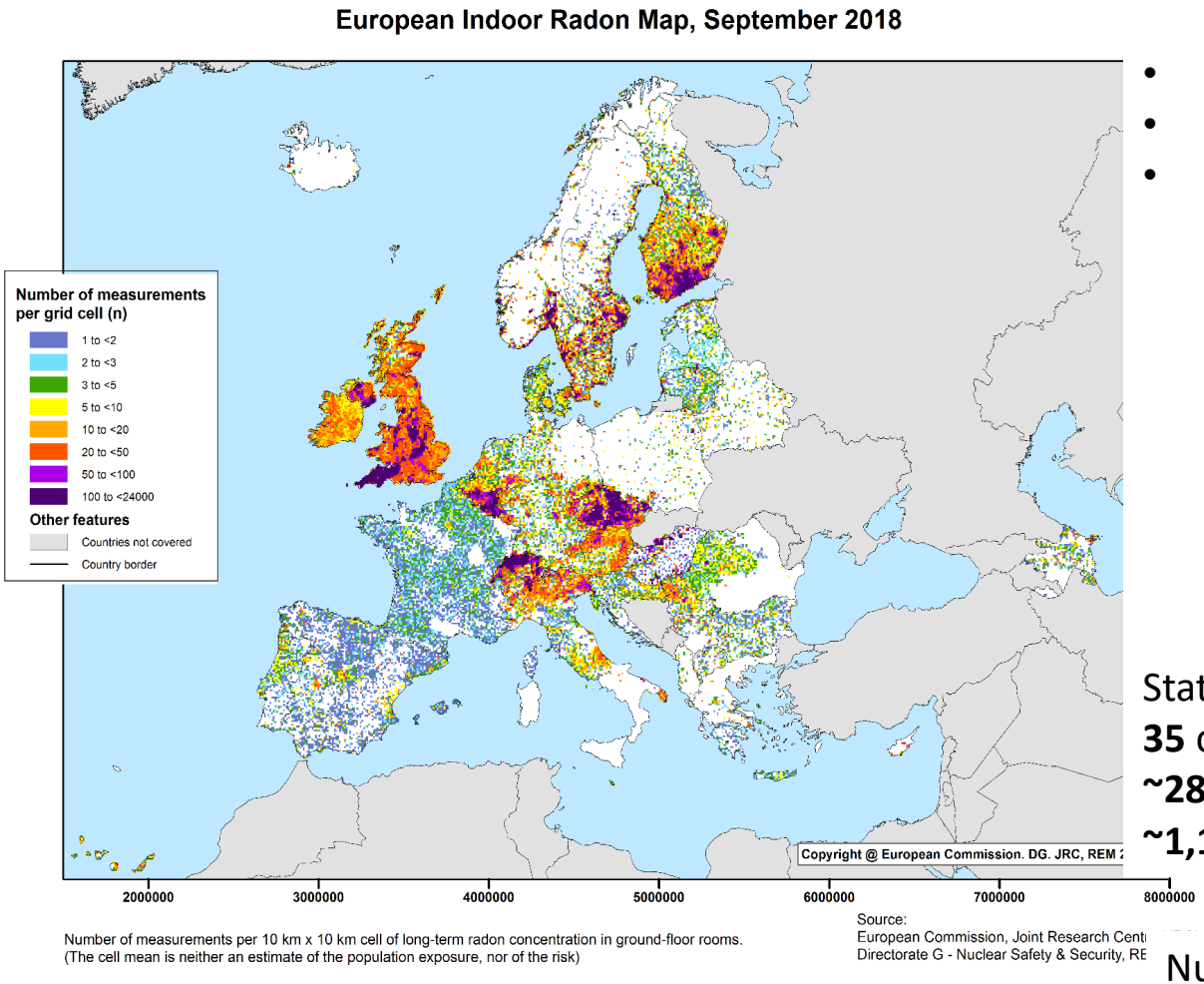
Indoor radon – most important contribution to dose!
Second most important cause of lung cancer after smoking!
In Europe estimated about 62,000 lung cancer fatalities per year attributed to Rn.
(Gaskin et al., Envir. Health Perspectives 125, 5 (2018); incl. RU, TR; missing: BiH, LV, MD, MK, MT, RS, UA)

Sources of indoor Rn:
1. Geogenic Rn (most important in most cases)
2. Building materials
3. Tap water, natural gas

Concentrations of indoor Rn controlled by
Geogenic factors:
Geology, soil type, U concentration in topsoil, permeability, granulometry,…
Anthropogenic factors:
Construction type (tightness of structures in contact with the ground),
life or usage patterns (ventilation)

Very high local and temporal variability → makes prediction very difficult.

European Indoor Radon Map: data



Number of measurements per 10 km x 10 km cell of long-term radon concentration in ground-floor rooms.
(The cell mean is neither an estimate of the population exposure, nor of the risk)

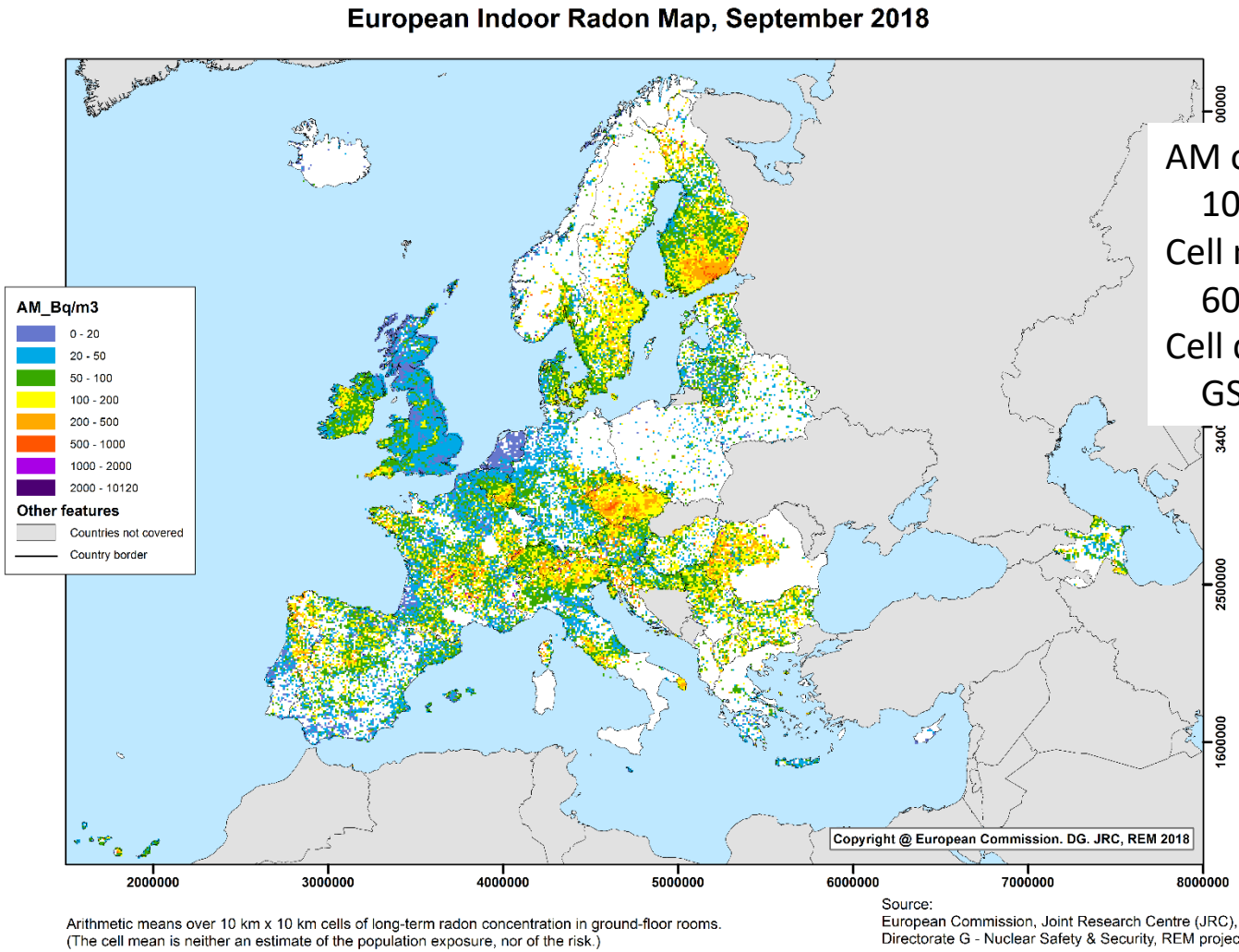
- 10 km x 10 km grid cells
- Living rooms, ground floor
- Participants send statistics:
  - number of measurements
  - arithmetic mean (AM)
  - standard deviation (SD)
  - AM(ln data)
  - SD(ln data)
  - Median
  - minimum
  - maximum

Status (September 2018):
35 countries participate
~28,000 non-empty cells
~1,150,000 original measurements

No individual data transmitted! Only grid aggregates!

Number of measurements per cell,
MED ± MAD: 4 ± 4
Min/Max number of
measurements per cell: 1/23,993

European Indoor Radon Map: cell means

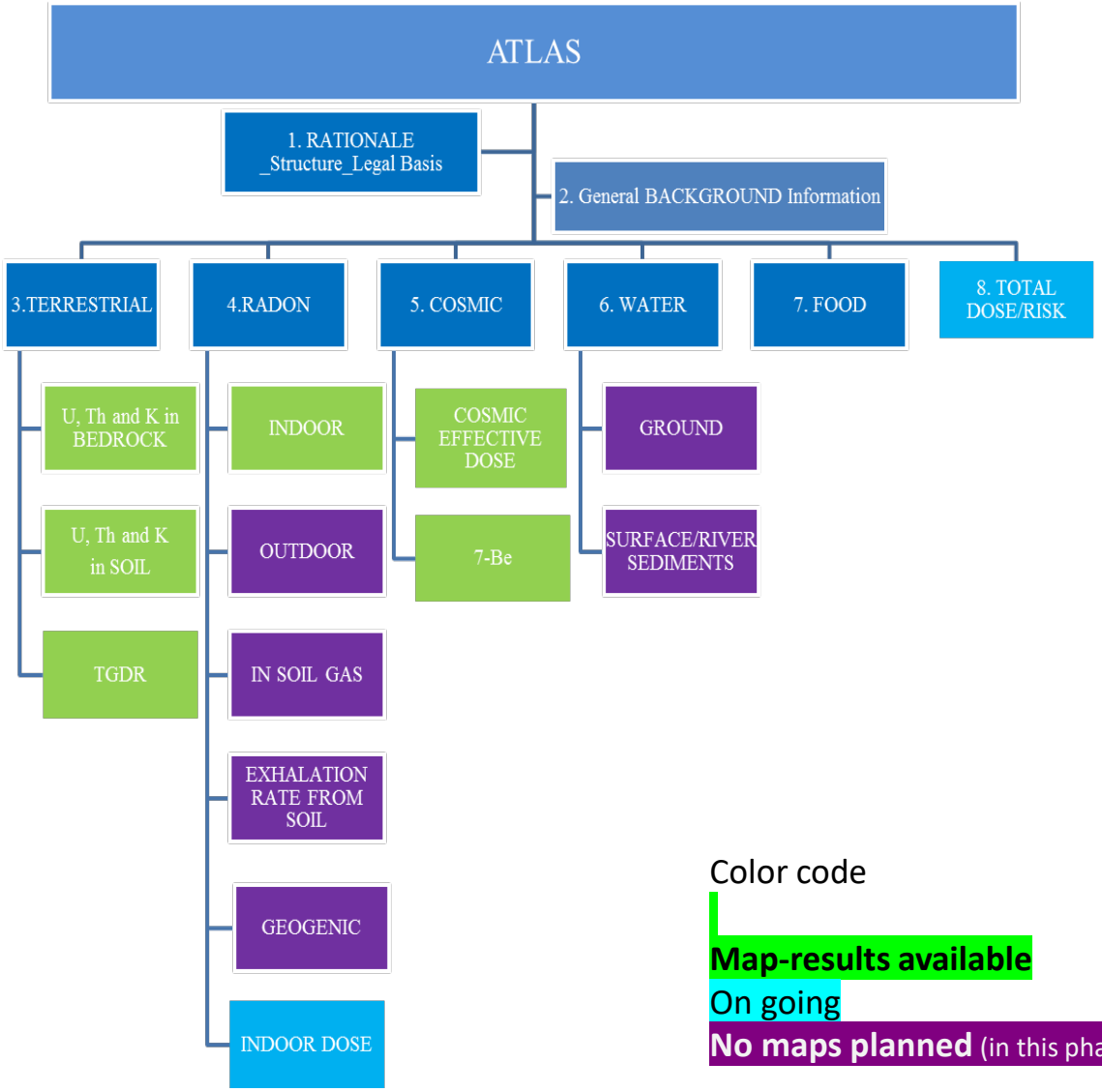


AM over cell means:
103 Bq/m^3
Cell median, MED $\pm$ MAD:
60 $\pm$ 46 Bq/m^3
Cell dispersion:
GSD about 1.9

Digital version of the Atlas

Cinelli G. *et al.* 2018. *Digital version of the European Atlas of Natural Radiation*, Journal of Environmental Radioactivity. Article just published. https://doi.org/10.1016/j.jenvrad.2018.02.008

Structure of the print version



First draft:
December 2018

Publication:
Summer 2019

Color code

Map-results available

On going

No maps planned (in this phase)

Shortcomings of the current indoor radon map

- The European Indoor Rn Map (EIRM) currently shown in the European Atlas of Natural Radiation (EANR) is **regionally incomplete**.
  - Reasons: data generation is slow; political problems.
- **Only ground floor** concentrations, although many people live in higher floors.
  - Reason: When started in 2006, it was concluded (Prague conference) that if at all, only for ground floor rooms ± representative data would be available. It seems that this argument is still valid.
  - However, first studies showed that averaged over Europe, most people indeed live on ground floor – even in some cities… investigation to be continued.
- Exposure requires input of **demographic and sociological** knowledge:
  - time spent indoors
  - home // workplace ?
    - -- how much time spent at either?
    - -- they are usually located in some distance
- Physics input:
  - **equilibrium factors, unattached fraction**? Reasonable to use default values?
  - Rn characteristic of **workplaces**!
    Data only for homes; workplaces probably different.

Proposed procedure

existing indoor Rn database

coregionalization model

existing U in ground database; geology

completed (by model) indoor Rn database (ground floor)

model of floor distribution by geography

sociological databases

representative Rn surveys

model of Rn(floor)

completed (by model) indoor Rn database (all floors)

literature

models of usage patterns

Rn surveys

exposure

F, f-values

dose

DCF

risk

risk factors

Expert group under JRC umbrella working on it !

Dose maps

- Indoor Rn exposure and dose map: work already started, ± along proposal of previous slide;
- A simplified indoor Rn dose map is planned for the Atlas / print version;
- Other dose components: regionalized dose contributions partly achievable; for the Atlas / print version: maybe dose budgets per country;
- Later on, regionalized dose budget targeted.

Missing components

- Outdoor radon:
  - Typically 2 – 20 Bq/m³.
  - Surveys exist in DE, IE, SI, and scattered measurements in other countries.
  - Contribution to dose: small; mostly < 0.1 mSv/a (maybe more with new DCF)
- Cosmogenic radionuclides:
  - ^{14}C, ^{22}Na,… (^{7}Be already under development in context of REM Database)
  - pathways: external radiation (air + ground), inhalation, ingestion
  - very small contribution to dose
- Building materials:
  - "modified" natural materials.
  - Exhale Rn and Tn, produce gamma radiation.
- Water: Ground water, surface water, drinking water:
  - U, Ra, Rn contribute to dose
  - Strongly related to geology
  - Many local studies, but no European overview exists
- Foodstuff: Natural radionuclides in food.
  - Little known about regional variability.
  - Dose variability possibly mainly controlled by nutrition habits which vary regionally.
  - The Atlas will contain a chapter about foodstuff, but no map.
- *Anomalies: Not especial exposure components, but possibly relevant components of maps. Spatially "small" features, such as enhanced Rn along active tectonic faults, U mines etc., which contribute little to the regional mean, but are still relevant locally.*

Beyond the Atlas – possible future work

- **Map of geogenic radon**
  - Rn concentration in soil air
  - Ground permeability
  - Geogenic radon potential (GRP)

has turned out more complicated than anticipated; lot of literature exists

- **Tectonogenic radon**
  - Faults, volcanic areas
  - Regionalized tectonic enhancement potential

  Crowley et al.: Tectonically enhanced geogenic Rn (TEGR); EGU 2018
- **Local extremes, anomalies, hotspots**

  Bossew: Radon priority areas and radon extremes - an initial study; ICHLERA 2018
- **Geogenic radon hazard index (GRHI)**
- **Radon priority areas (RPA)**

under work, partly in the Metro Rn project

sensitive subject!

- **Thoron**

Any questions?

Please contact us at

JRC-EANR@ec.europa.eu

giorgia.cinelli@ec.europa.eu

Thank you!