The geogenic radon hazard index

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v.21.2.2020

Vienna Radon Week, 26 Feb 2020

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- Different approaches
- Estimation methods
- Trial results

Motivation of motivation

- **We want a European map of geogenic radon**

  = a map of the geogenic contribution to indoor radon;

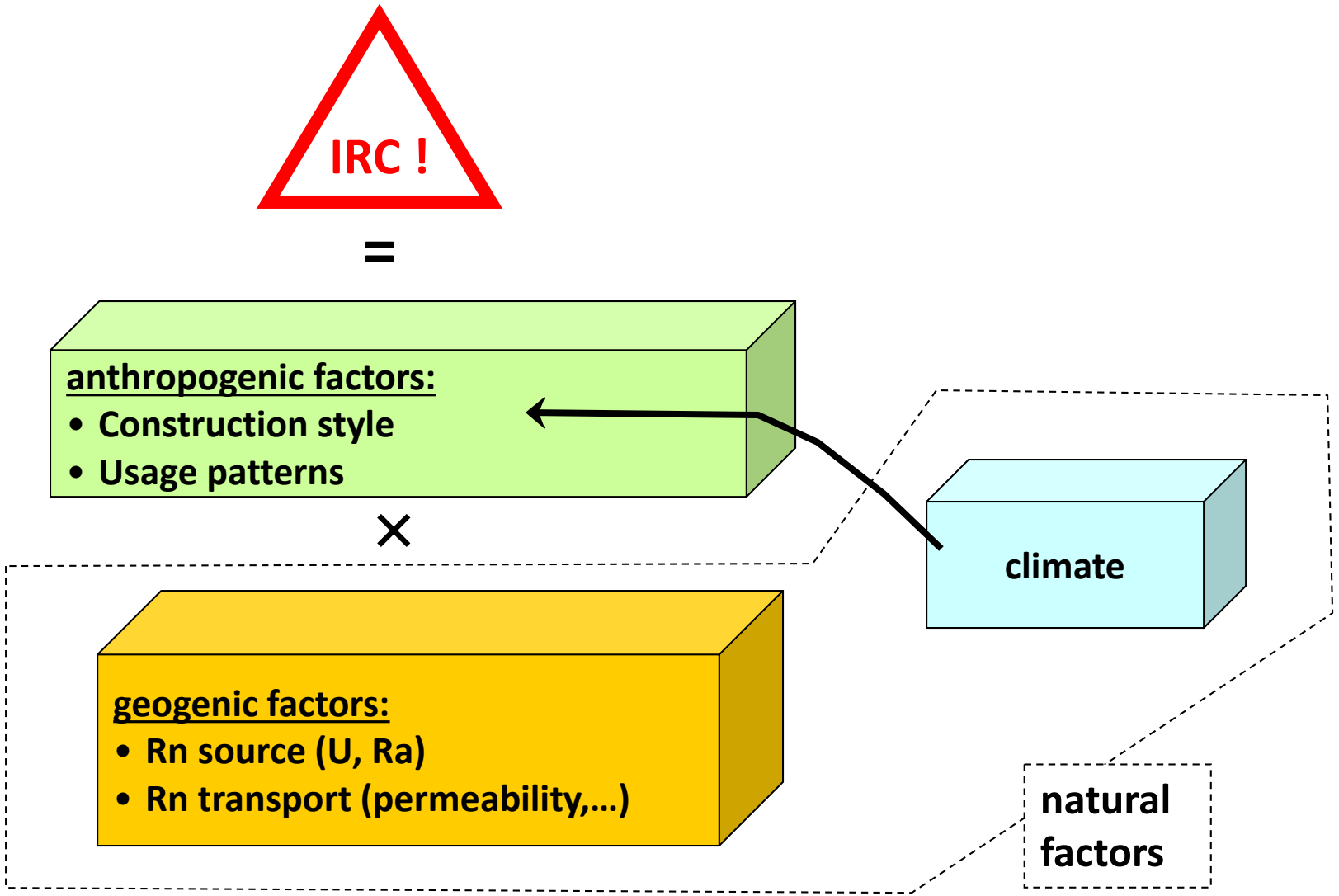
  therefore the mapped quantity is called
  “Geogenic Radon Hazard Index” – GRHI

- **What is a map?**

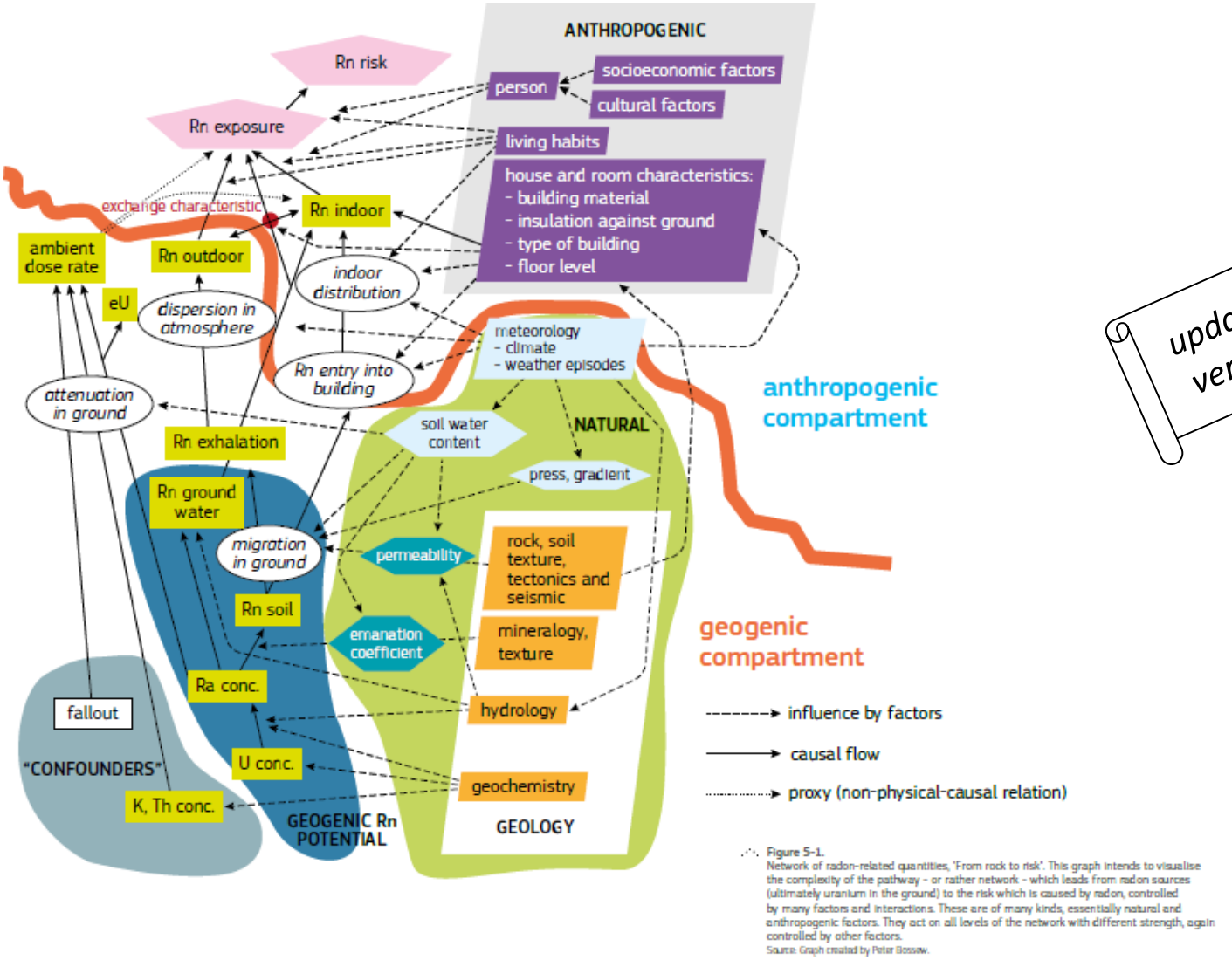
  = the display of geographical variability of a quantity

- **⇒ Keyword: Geographical variability**

Motivation


IRC !
=
anthropogenic factors:
• Construction style
• Usage patterns
×
climate
geogenic factors:
• Rn source (U, Ra)
• Rn transport (permeability,…)
natural factors

Reminder --- From rock to risk

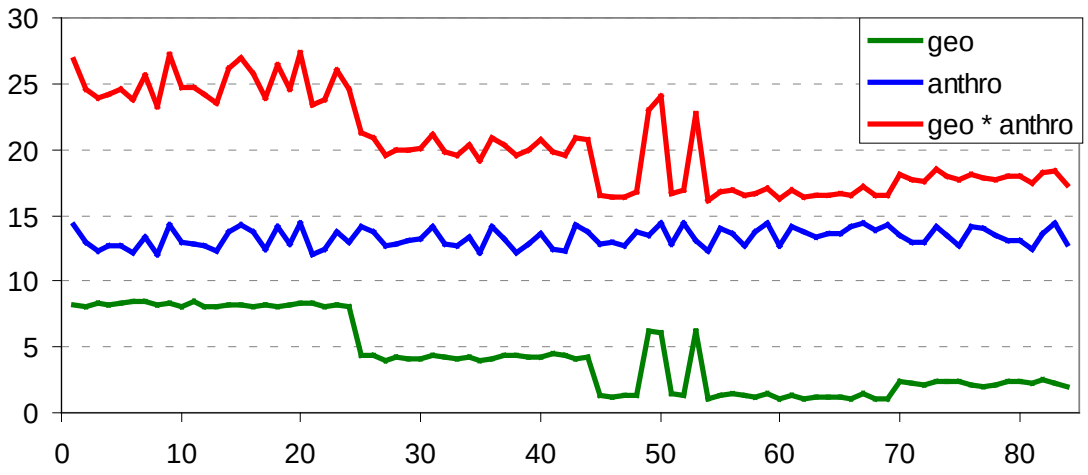


updated version!

Figure 5-1.
Network of radon-related quantities, 'From rock to risk'. This graph intends to visualise the complexity of the pathway - or rather network - which leads from radon sources (ultimately uranium in the ground) to the risk which is caused by radon, controlled by many factors and interactions. These are of many kinds, essentially natural and anthropogenic factors. They act on all levels of the network with different strength, again controlled by other factors.
Source: Graph created by Peter Bossew.

European Commission, Joint Research Centre – Cinelli, G., De Cort, M. & Tollefsen, T. (Eds.): European Atlas of Natural Radiation, Publication Office of the European Union, Luxembourg, 2019. ISBN 978-92-76-08259-0, doi:10.2760/520053, Catalogue number KJ-02-19-425-EN-C, EUR 19425 EN. Printed by Bietlot in Belgium 2019 – 190 pp. – 30.1 × 42.4 cm

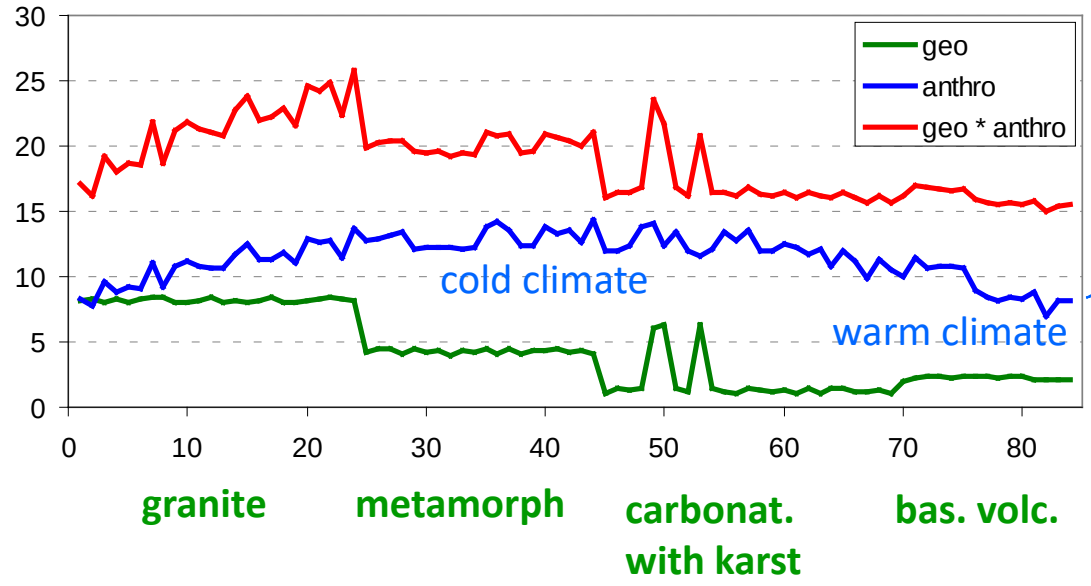
Spatial variability of IRC



indoor Rn = (geogenic factor) × (anthropogenic factor)

anthropogenic factors random

variability of indoor Rn essentially determined by the one of geogenic factor + some random noise



anthropogenic factors random with trend

variability of indoor Rn determined by the one of geogenic factor + some noisy trend → statistically more difficult!

Spatial variability of IRC (2)

1. Under the assumption that anthropogenic spatial variability is only random noise:
   $\Rightarrow$ Spatial variability of IRC controlled by the one of geogenic factors. Anthropogenic factor contributes to nugget (in geostat. language), i.e. local uncertainty.
   This is the justification that geogenic factors can be used for spatial modelling (=mapping) of IRC.
2. If the anthropogenic factor has itself a spatial structure (trend) beyond white noise:
   $\Rightarrow$ neglecting this can lead to regional mis-estimation of IRC based on geogenic factors only.

Consequences of 2.

- The assumption
  "anthropogenic factor = white noise"
  is certainly a gross simplification.
  - Climate →
  - Urban / sub-urban / rural environments →

construction style, life habits, usage patterns

- Therefore, we try to include "climate" as additional geogenic (in broader sense; natural) factor.
  Urbanisation is an anthropogenic factor.
  Whether to include: to be discussed!
  (My opinion: should be included for IRC prediction, but not for definition of GRHI)

Idea of Geogenic radon hazard index

The GRHI can be conceptualized in different terms:

- A quantity which measures the contribution of geogenic factors to the potential risk that exposure to indoor Rn causes.
- A quantity which measures the availability of geogenic Rn at surface level.
- Measure of susceptibility of a location or of an area to increased indoor radon concentration for geogenic reasons.
- Measure of "Rn proneness" or “Rn priorityness” (in the logic of the BSS) of an area due to geogenic factors

→ GRHI – generalization of GRP
→ “Index” – normalized, e.g. [0,1]

Idea, 2

- One quantity whose regional variability represents as much as possible the variability of the geogenic controls of Rn hazard. In other words, these factors shall be squeezed appropriately into one quantity “GRHI”;
- A measure of geogenic Rn hazard which is defined homogeneously across Europe. This means, determine a value of GRHI everywhere in Europe, irrespective of regionally available geogenic databases, but still comparable between any locations. Such GRHI would be the base of a European map of geogenic Rn and a European wide determination of Rn priority areas.

Role of MetroRadon

- Development of the GRHI is one of the objectives of MetroRn! (WP 4.3.4)
- Harmonization of geogenic Rn quantification across Europe (~ WP 3.2)
- Possibly harmonized Rn priority areas (delicate subject!) (WP 4.4)

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

Desired properties

I. Consistency: across borders between regions in which different databases are used for estimation; this implies independence of actual database used.

II. It should reflect as much geogenic information as available;

III. It should be simple to calculate.

IV. Valid predictor of the geogenic contribution of indoor Rn concentration. This is motivated by its very concept.

Approaches A and B

A
"pure geogenic"

B
"optimal for IRC"

Given:	Action:
Approach A	
Set of geogenic quantities (assumed predictors and proxies of the IRC, possibly incl. IRC itself)	⇒ Combine quantities into a new quantity, which reflects as much as possible of the spatial variability of the given quantities
Approach B	
• Independent: predictor quantities and proxies (treated as predictors) • Dependent: target quantity = IRC	⇒ Combine predictors such as to optimally predict the IRC

bottom up / top down

a) **Bottom-up** or global approach:
For the domain to be covered (e.g. Europe), only predictors are used which are available in the entire domain (e.g., European geological map)

b) **Top-down** or local:
In each region, available predictors are used; afterwards, the regional maps are “sewn” together.

	Advantage	**Disadvantage**
Bottom-up (global)	No consistency problem across borders	Regionally existing predictors cannot be used
Top-down (local)	Maximum information used	Consistency difficult!

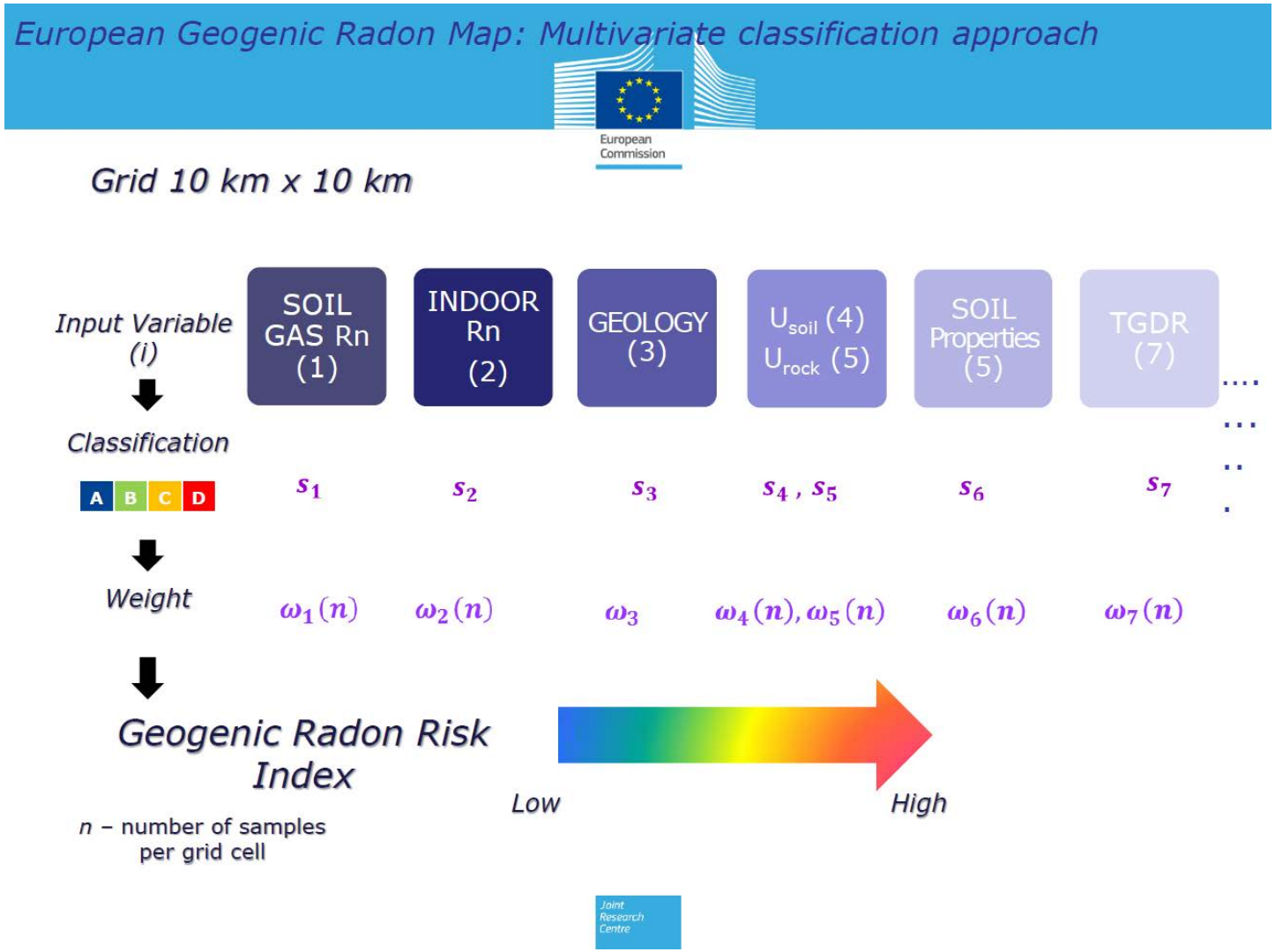
Methods

- Different attempts for about 30 years
- Intensified since about 10 years – development of European Atlas of Natural Radiation
- Turned out more difficult than thought; mainly because of data heterogeneity across Europe
- Not yet included in the first edition of European Atlas of Natural Radiation

Tentative taxonomy of GRHI definitions and estimation methods

	A **"geogenic"**	**B** **"optimal ~ IRC"**
(a) **bottom-up,** **"global"**	Tanner (1988): *physica*l Wiegand (2001,2004), Tung (2013): *class*. Kemski (2001,2009): *class*. Guida (2010): *class*. Alonso (2010): *physical* Ielsch (2010): *Multivar. class*. Garcia-Talavera (2013), Sainz (2017): *Bivar. class.* Ciotoli (2017): *PCA* Bossew (2017): *regr.*	Neznal (2004): GRP *regr. class*. Kropat (2017): *logistic regr.* Petermann (2019): *ML* Bossew (2019): *regr.* Ciotoli (2020): *SMCDA* Multivariate classification through contingency tables.
(b) **Top-down,** **"local"**	Schumann (1993): *class.* Friedmann (2011): *transfer models* Cinelli (2015, 2017): *classes* Bossew (2016a): *correl.*	Bossew (2016a): *correl. with IRC*

Initial idea (Cinelli et al. 2015)



Methods

For approach A (geogenic)

- Multivariate classification
- Principal component analysis (PCA)
- Set of transfer models (for top-down)

For approach B (optimal for IRC)

- Multivariate regression
- Machine Learning
- Spatial multi-criteria decision analysis (SMDCA)

… Probably more !

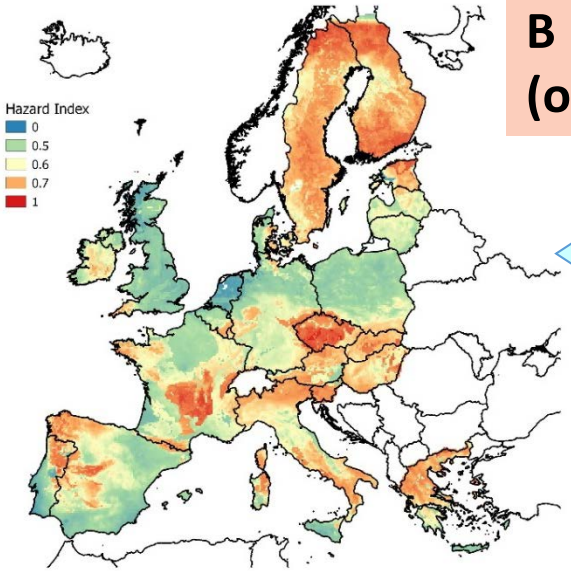
Predictors and proxies

Geogenic quantities of interest:

- Rn concentration in soil gas
- gas permeability
- U concentration,
- ambient dose rate ADR,
- geological units / lithology,
- fault density,
- groundwater recharge coefficient,
- soil properties (texture, humidity,…),
- karstification,
- standardized indoor Rn concentration,
- various geochemical concentrations,
- climate

} Geogenic Radon Potential GRP (e.g. Neznal definition); but: available only regionally - CZ, DE, BE, (IT), (ES), (AT), ?

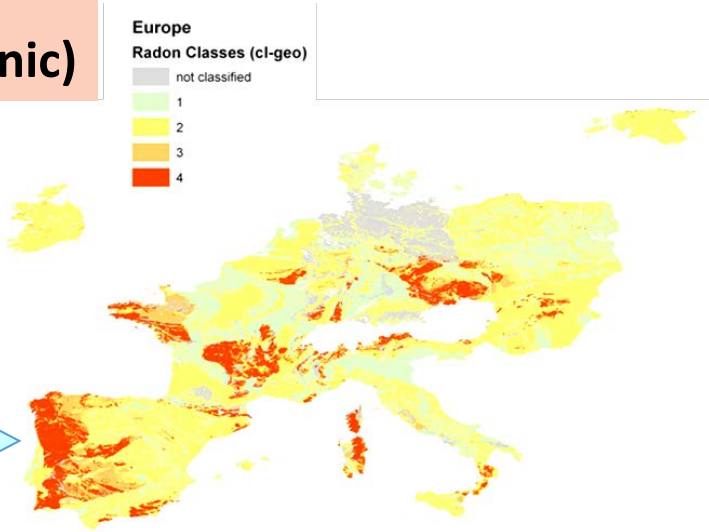
Some trial results



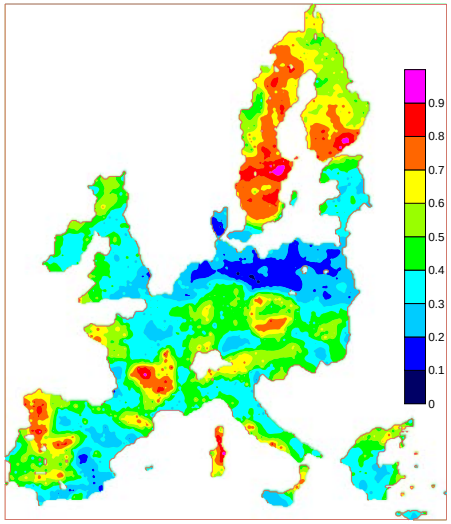
B (optimal- IRC)

machine learning Krakow (2019)

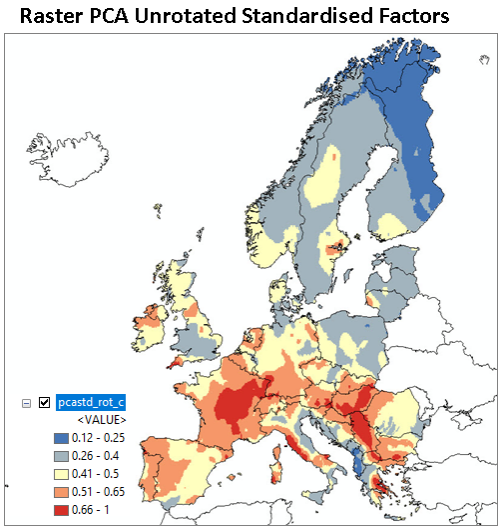
A (geogenic)



classification GARRM (2012)



multiple regression Krakow (2019)



PCA IWEANR (2017)

Conclusions

- Mapping of geogenic Rn on European level is not so easy!
  In 2010, a first report at JRC was called “The Long Way” – indeed it is.
- Concept / Definition / Estimation
- More datasets ?
- Metro Radon helped advance !
- Reliable European GRHI map should be available soon* !

(2010)

* sub specie aeternitatis…

Thank you!

This work is supported by the European Metrology Programme for Innovation and Research (EMPIR), JRP-Contract 16ENV10 MetroRADON (www.euramet.com). The EMPIR initiative is co-funded by the European Union's Horizon 2020 research and innovation programme and the EMPIR Participating States.