A radon mapping exercise within the European MetroRadon project

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& data providers & participants of the exercise

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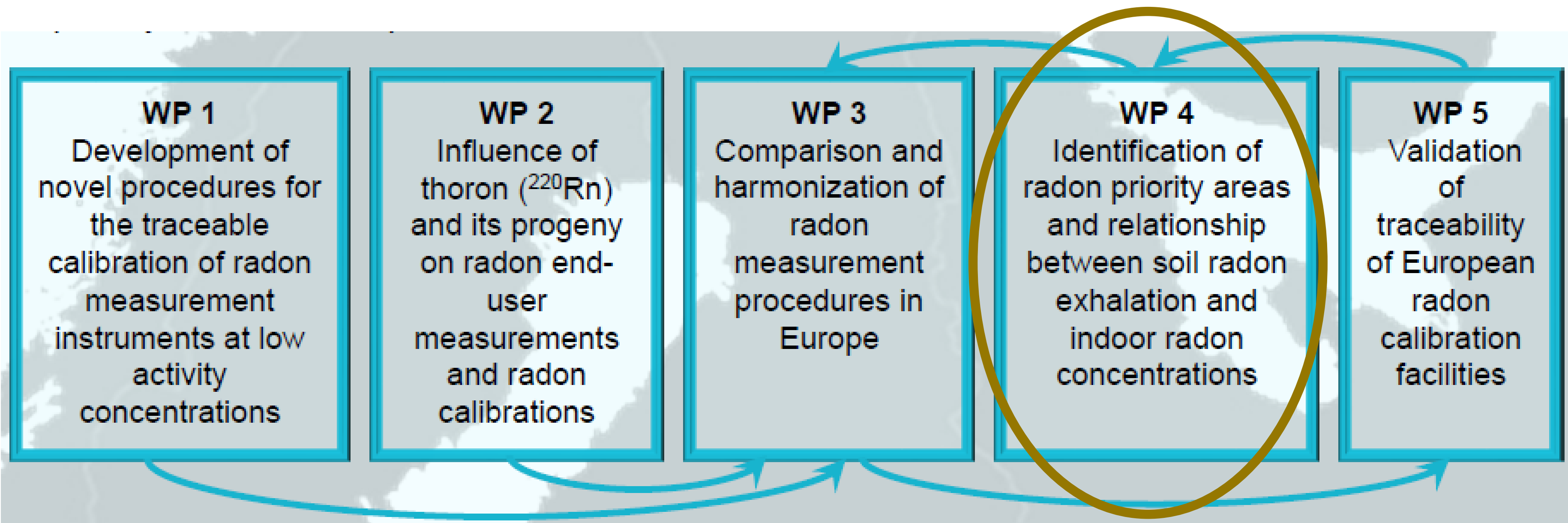
MetroRADON

Metrology for Radon Monitoring

- European Metrology Programme for Innovation and Research (EMPIR)
- June 2017 – May 2020
- 17 European partners, collaborators
- http://metroradon.eu/ - News, Reports, Presentations, Newsletter etc.
- QA "chain" from primary standards to radon maps

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



MetroRADON

WP4 - „Radon priority areas“ - Tasks

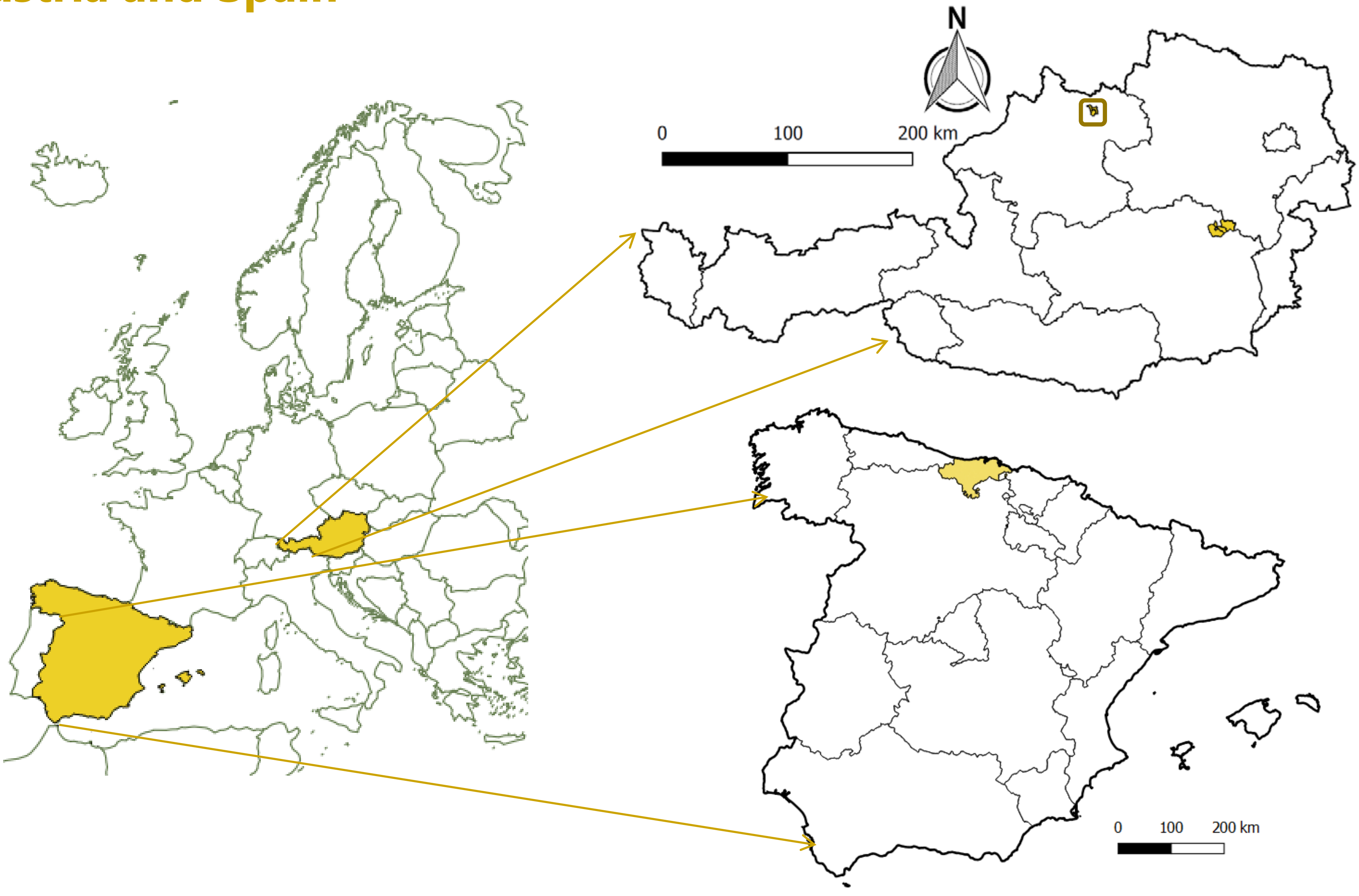
- Evaluation of the concepts for the definitions of radon priority areas
- Relationship between indoor radon concentration and geogenic radon
- New developments in estimation of radon priority areas
- Harmonisation of radon priority areas across borders

The exercise: *“Test existing mapping methods used in various countries with different datasets and evaluate their usability for other countries”*

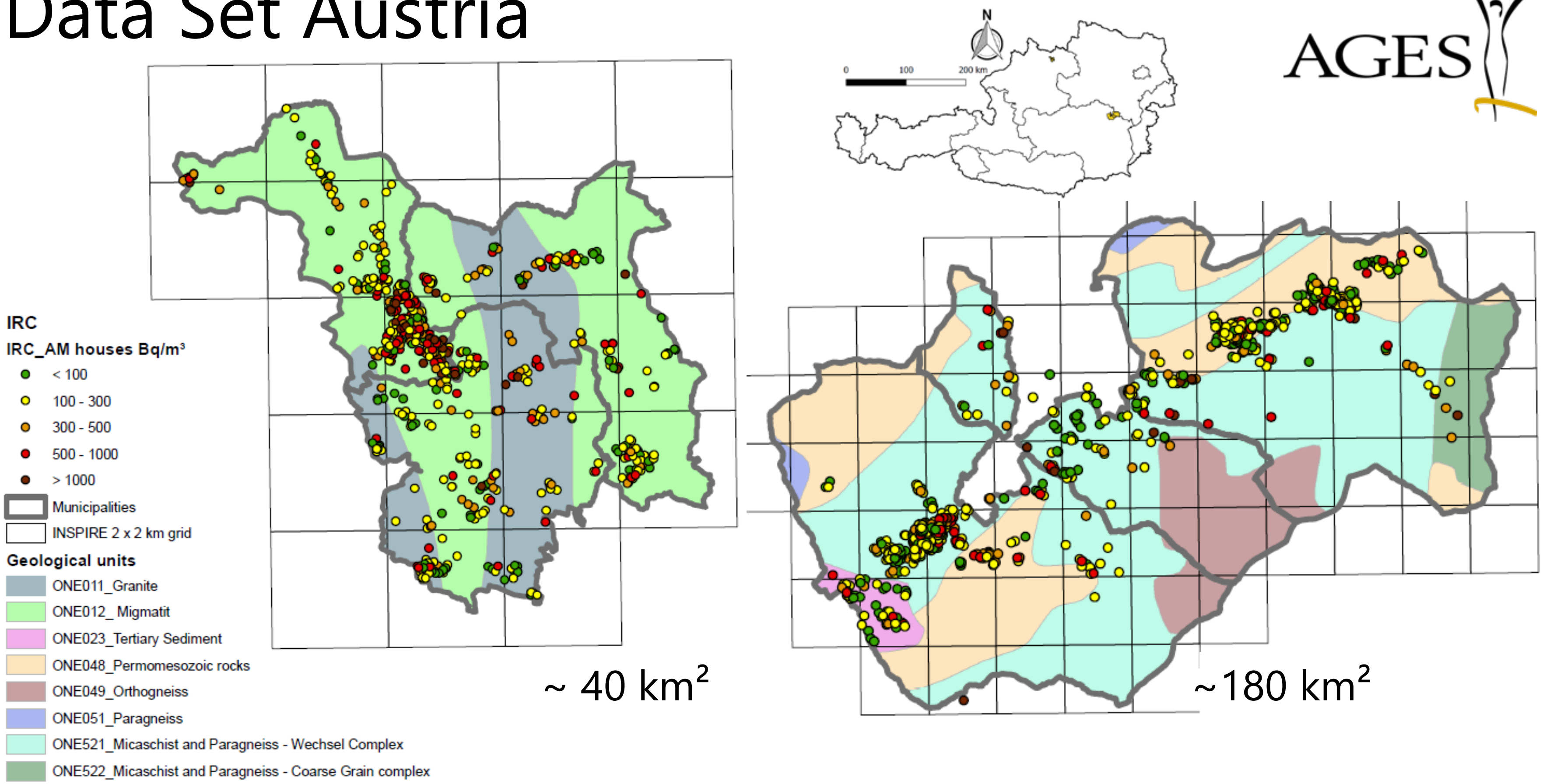
- Find usable datasets and prepare them for the exercise ✓
- Find participants/volunteers ✓
- Participants apply their mapping method and definition of radon priority areas ✓
- Analyse, compare, evaluate results

Data Sets

Austria and Spain

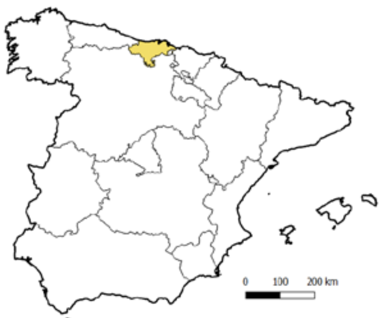


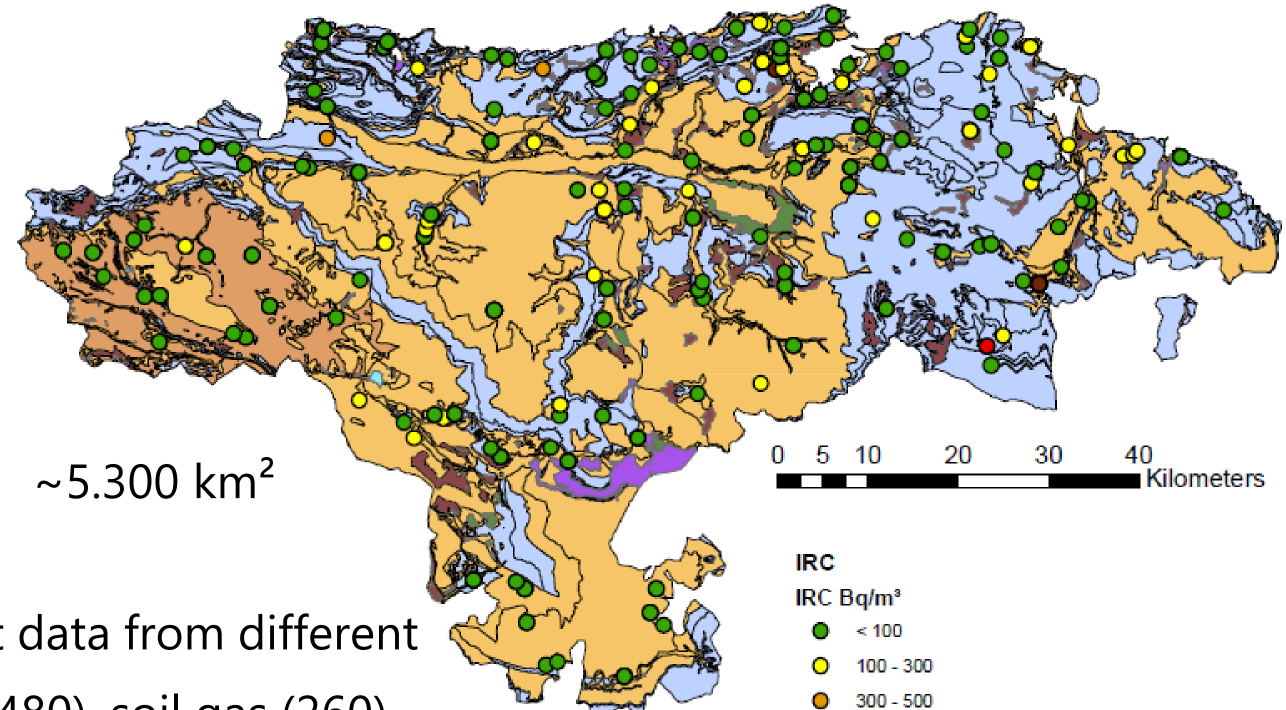
Data Set Austria



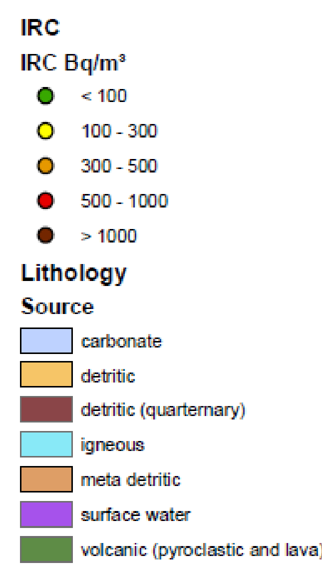
- Extensive survey in 6 municipalities – IRC (1638 households), soil gas & permeability (~ 150 locations), soil samples, ADR (~ 100 locations)
- Additional data from literature (geology, soil map etc.)
- All data available in shp-files and tables; georeferenced

Data Set Cantabria





~5.300 km²



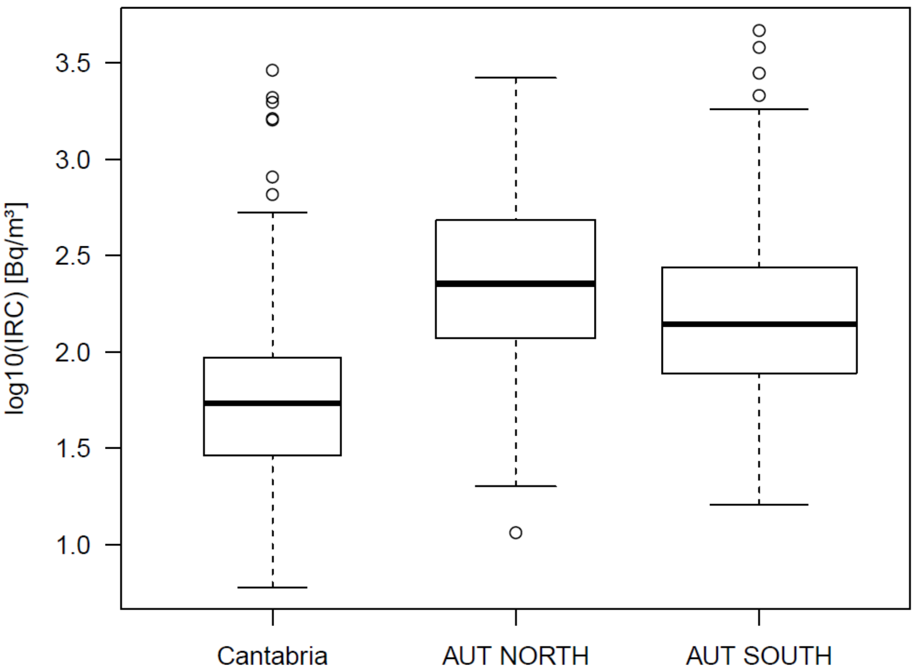
- Measurement data from different surveys (IRC (480), soil gas (260), ADR (80))
- Additional data from literature (geology, karst etc.)
- All data available in shp-files and/or tables; georeferenced

Data Sets – Data extent / quality

Variable	Cantabria	Austria
IRC	location approx., low sample density	exact location, high sample density
Soil air Rn	*measured.*, similar	*measured*; similar
Act. conc. in soil	European K, Th, U in soil maps (JRC) 10x10 km grid AM/GM (FOREGS, GEMAS)	^{40}K, ^{210}Pb, ^{226}Ra, ^{228}Ra, ^{228}Th, ^{238}U measurements
ADR	*measured*; similar	*measured*; similar
Faults	map; similar	map; similar
Geology	map; similar	map; similar
Permeability	estimates derived from lithological units	Soil permeability *measurements* + estimates derived from soil units
Karst	Binary, derived from lithological units	-
Building characteristics	-	Questionnaire; at location of IRC
Soil map	-	Soil unit, water conditions, soil depth, …
Airborne radiometry	-	eU; measured only North region

Mapping Methods

Basic statistics (IRC)



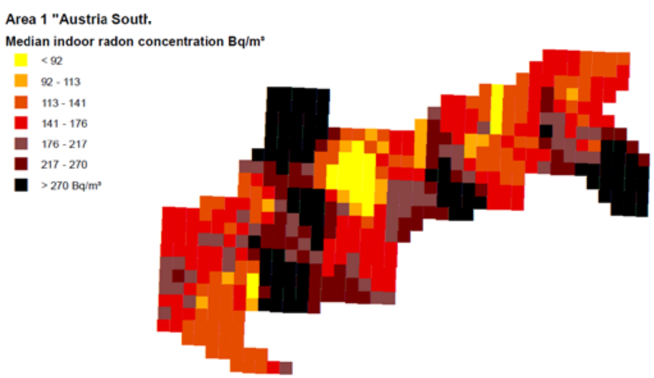
Area	AM	GM	Med	% > 300
Cantabria	97	54	54	3
N Mun. 1	289	196	197	31
N Mun. 2	313	207	213	36
N Mun. 3	429	273	266	45
S Mun. 4	289	165	168	28
S Mun. 5	251	157	144	22
S Mun. 6	234	146	130	21

Mapping Methods

Belgian Radon Mapping software (F. Tondeur)

- Map variation of radon risk within geological units
- Moving average method
- Geological units with significantly different levels of risk – separately
- 500 m x 500 m grid

Geological unit	Number of data	Geometrical mean indoor Rn
AREA 1 (Austria South)		
Coarse Gneiss Complex	460	186
Permomesozoic rocks	266	161
Tertiary sediments	47	174
Other	9	233
AREA 2 (Austria North)		
Granite	123	254
Migmatite	455	248



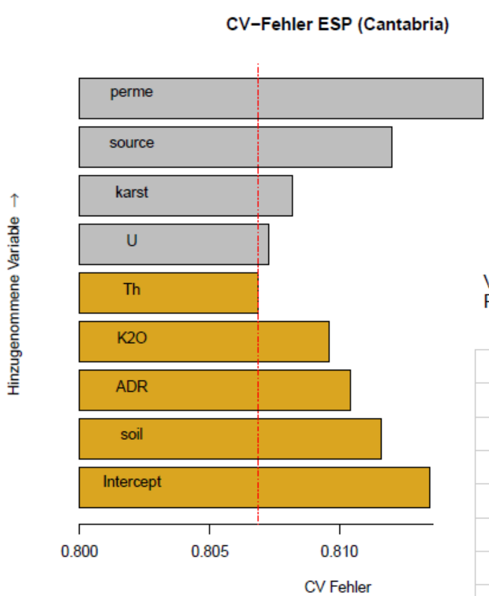
Cinelli, G., Tondeur, F., Dehandschutter, B (2011): Development of an indoor radon risk map of the Walloon region of Belgium, integrating geological information, Environmental Earth Sciences 62(4):809-819

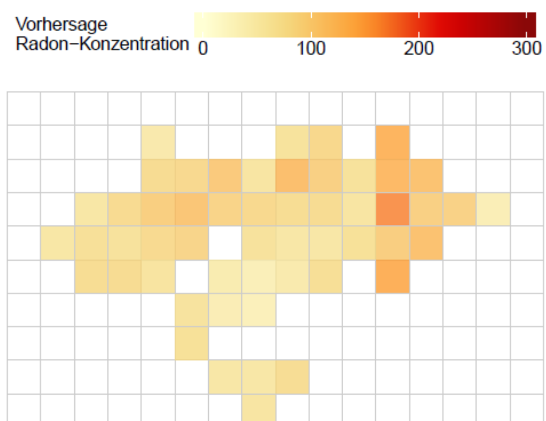
Tondeur , F. and Cinelli, G. (2014): A software for indoor radon risk mapping based on geology, Nuclear Technology and Radiation Protection XXIX:S59-S63

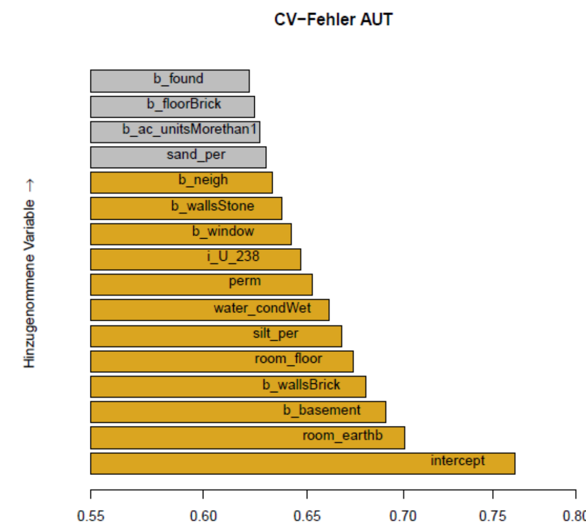
Mapping Methods

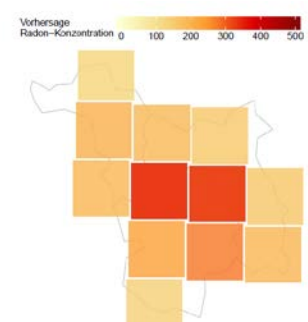
GAMM (AGES, AT)

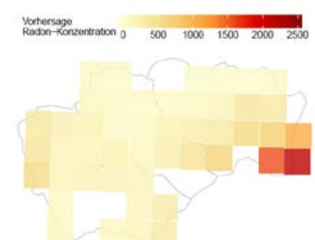
- Generalised Additive Mixed Model for log(IRC) (Gaussian)
- 5-fold cross validation; stepwise forward selection
- Define relevant variables for model
- Prediction of IRC for location/grid cell/municipality







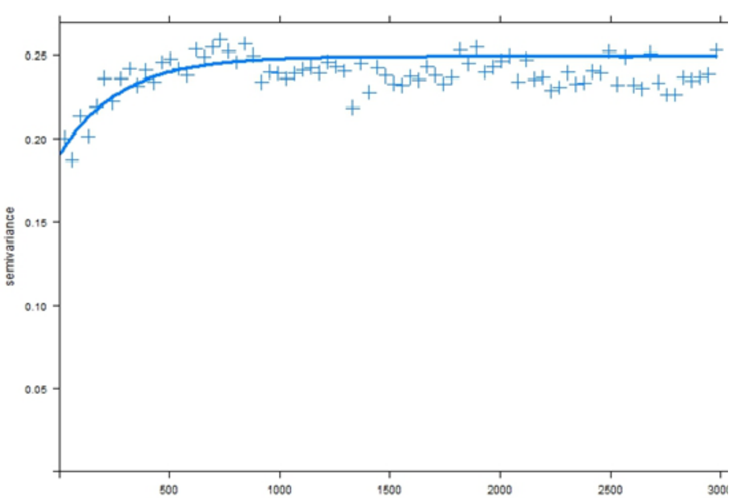




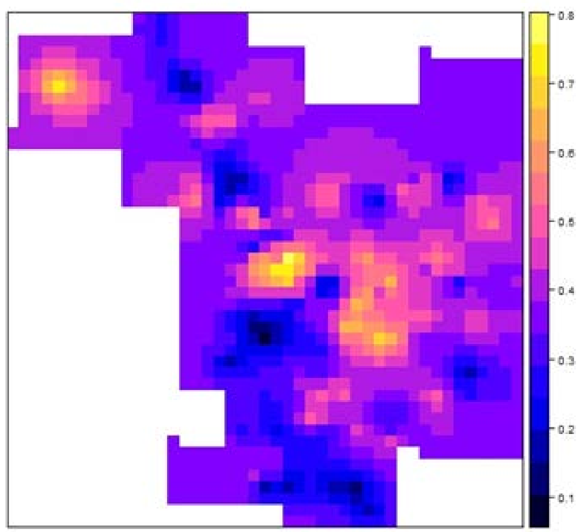
Mapping Methods

Ordinary kriging OK, Indicator kriging IK & more (E. Petermann; P. Bossew)

- ANOVA for target variables
- AT: High density of IRC; sufficient for radon risk estimation
- AT: Geogenic covariates as IRC predictor weak; best GRP (Soil radon & perm.)
- ES: No spatial autocorrelation of IRC → OK of soil gas radon; GRP calculated; Correlation between GRP and IRC weak



Variogram of binary coded IRC (AT north)
(0 < 300 Bq/m^3; 1 ≥ 300 Bq/m^3).
Empirical data (crosses), fitted model (solid line).



Exceedance probability

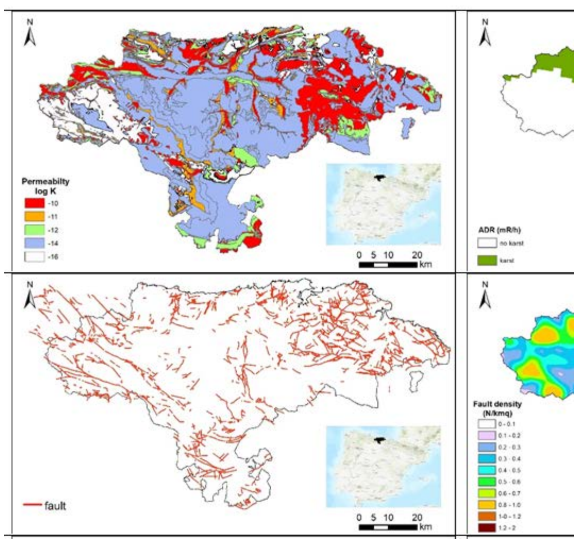
Z	Upper Austria	Styria
Rn(soil)	0.5	0.75
GRP	0.45	0.8
ADR	0.15	0.35
^{40}K	-	0.6
^{226}Ra	-	0.8
^{238}U	0.3	0.7
eU	0.3	n.a.
PC1	0.3	0.45

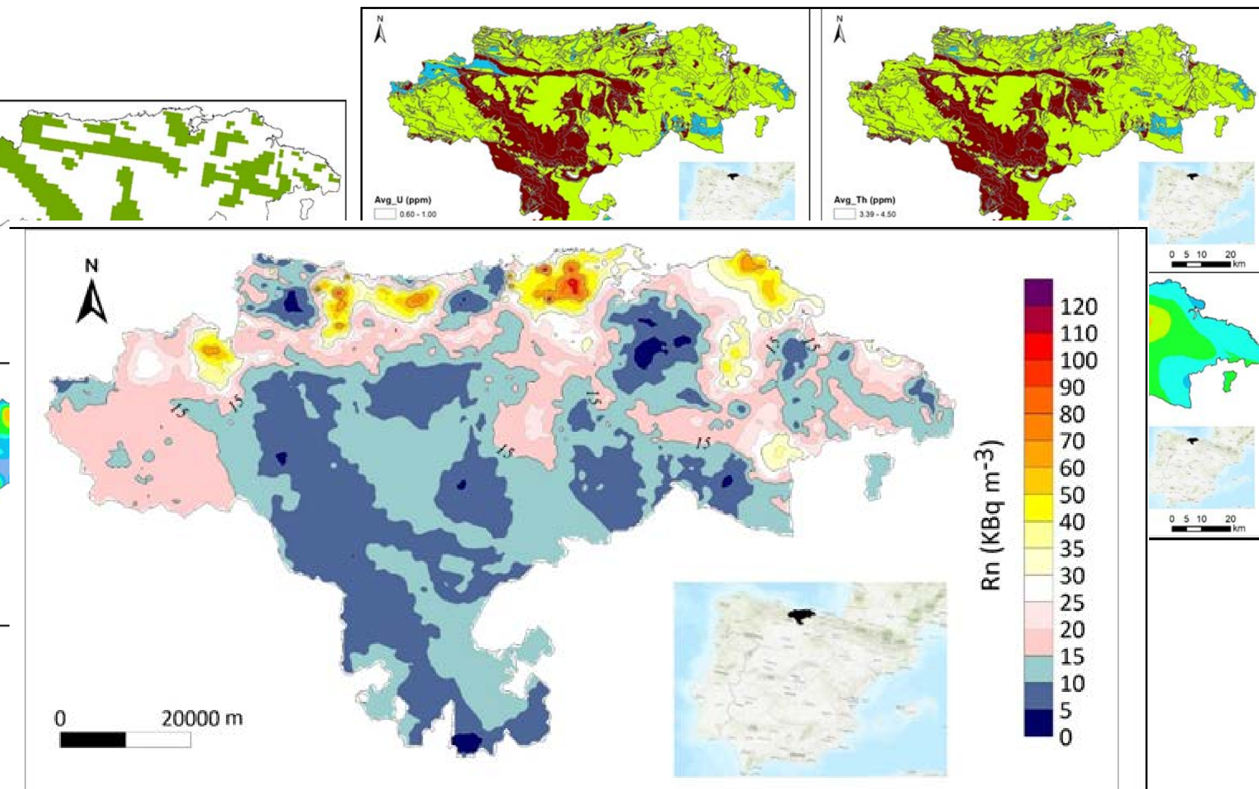
Correlation of variable Z with IRC; AT

Mapping Methods

Empirical Bayesian Kriging Regression EBKR (G. Ciotoli)

- Combines Kriging with regression analysis for more accurate predictions
- Uses response variable (soil gas Rn) and raster layers of the proxies
- GRP map – mainly faulted areas and high permeability areas affect radon in soil air





Mapping Methods

Geogenic Radon Potential Map – Testing of Correlation between variables and spatial variability

(A. Pereira, F. Domingos)

- Austria:
  - Lack of significance between ADR, eU and other parameters
  - No clear spatial correlation for soil gas radon, perm., ADR, soil conc.
  - No prediction of GRP possible
  - Only AT North: IRC of earthbound rooms show significant differences in soil characteristics, bedrock units, permeability

- Spain:
  - IRC, ADR, soil gas radon show significant differences in different bedrock units – but no correlation among them
  - No clear spatial correlation for IRC and soil gas radon (omnidirectional variogramms)
  - No prediction of GRP possible

Results – Overview

AGES

Based on IRC

	AM	GM	Med	% > 300	Med (BE)	% > 300 (BE)	GM GAMM (AT)	OK (DE)	IK % 300 (DE)
Cant.	97	54	54	3	-	-	54	-	-
Mun. 1	289	196	197	31	231	40	243	352	36
Mun. 2	313	207	213	36	240	41	201	360	39
Mun. 3	429	273	266	45	230	39	208	367	39
Mun. 4	289	165	168	28	209	38	153	305	26
Mun. 5	251	157	144	22	183	32	241	300	26
Mun. 6	234	146	130	21	173	31	310	304	26

RPA:
Prob (IRC>300) >10 %

RPA:
AM/GM/Med > 300

RPA:
AM/GM/Med > 100

Summary & first conclusions

MetroRn mapping exercise

- Different methods applied; exercise data are challenging
- Not all methods are suitable for all data/areas (depends on data quality, sam density, heterogeneity of the area, etc.)
- Different mapping methods, but definition of RPA in many countries similar
- Radon-characterisation of areas: different methods deliver similar results, depending on definition of RPA

Next steps:

- Collect more inputs/contributions
- Continue with analysis and evaluation
- MetroRADON report (available at metroradon.eu)
- Peer reviewed paper

Thank you for your attenti

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

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