An extensive indoor radon measurement campaign to define radon priority areas in Austria

V. Gruber, S. Baumann, W. Ringer

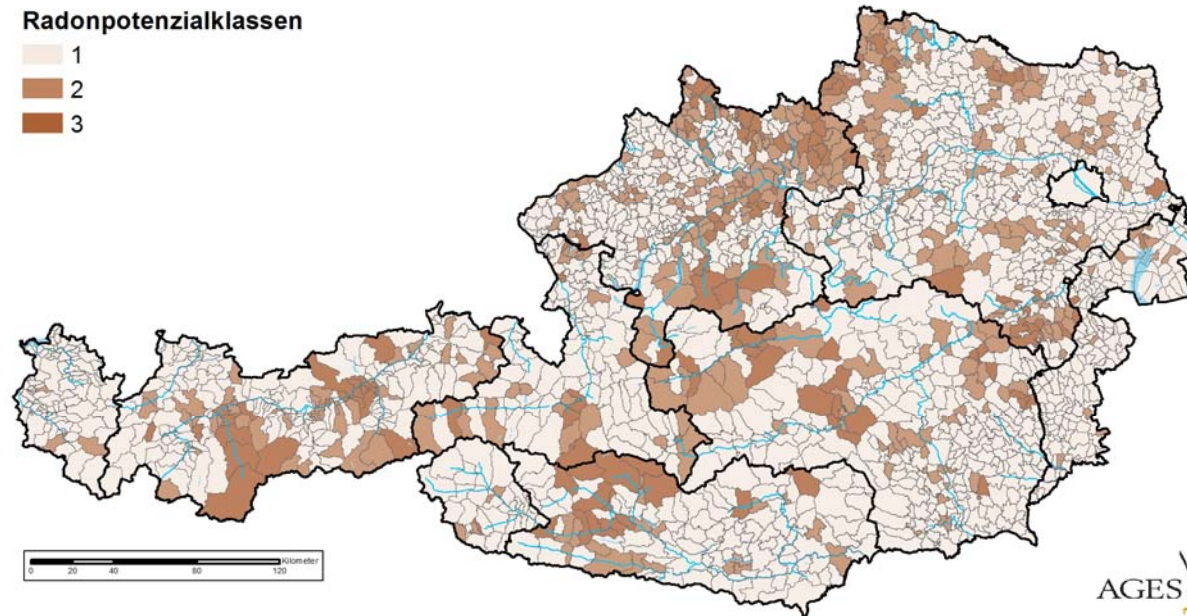Radon & Radioecology, National Radon Centre of Austria

O. Alber, S. Kuchling, C. Laubichler, C. Schleicher

Service, Data and Statistics

Austrian Agency for Health and Food Safety

Austrian Radon Potential Map (2017)

Austrian National Radon Project (1992-2004)

AGES

Sources of uncertainty:
- small number of dwellings per municipality (3 – 5)
- different measurement systems used, short-term measurements included
- calculation of the annual mean (extrapolation)
- geology (variation within municipality) was not taken into account

On the way to the new map

Basic Workflow
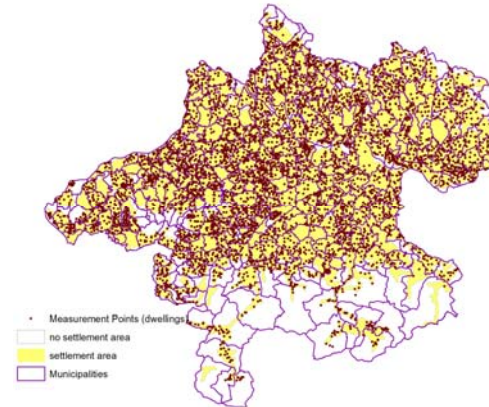
administrative — technical — political

Sampling

Modeling

$$\log(IRC_{ij}) = \beta_0 + \beta_1 z_{ij} + \ldots + \beta_m z_{ij} + s(x_j, y_j) + u_j + \varepsilon_{ij}$$

¤	Datensatz¤					¤	¤	¤
1.·Faltung¤	Training¤	Training¤	Training¤	Training¤	Test¤	→¤	Fehler·1¤	¤
2.·Faltung¤	Training¤	Training¤	Training¤	Test¤	Training¤	→¤	Fehler·2¤	¤
3.·Faltung¤	Training¤	Training¤	Test¤	Training¤	Training¤	→¤	Fehler·3¤	¤
4.·Faltung¤	Training¤	Test¤	Training¤	Training¤	Training¤	→¤	Fehler·4¤	¤
5.·Faltung¤	Test¤	Training¤	Training¤	Training¤	Training¤	→¤	Fehler·5¤	¤
¤	¤	¤	¤	¤			⇒: Kreuzvalidierungsfehler¤	¤

Municipality Bq/m³
- < 150
- 150 - 300
- > 300

Classification
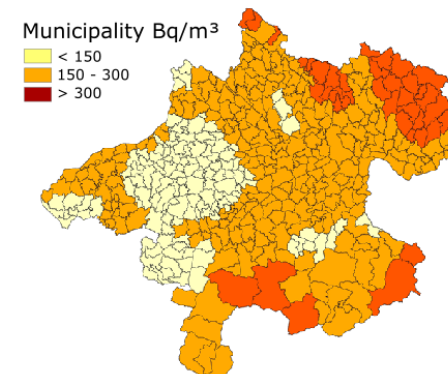
Sampling Strategy

Extension of Radon measurements in dwellings (2013 ff)

**Goal**: ca. 70,000 measurements (35,000 dwellings) in Austria

Strategy:

- selection according to **grid**, **municipalities**, **geology**
- measurements in houses of **members of the voluntary fire brigades**
- **6 months** (half winter, half summer) radon measurements (track etch)
- 2 (most used) rooms, preferable ground floor
- questionnaire

grid (2 x 2 km)

1-3 dwellings/cell depending on versatility of geology in the cell

○ dwellings of fire brigade members

☆ selected dwellings
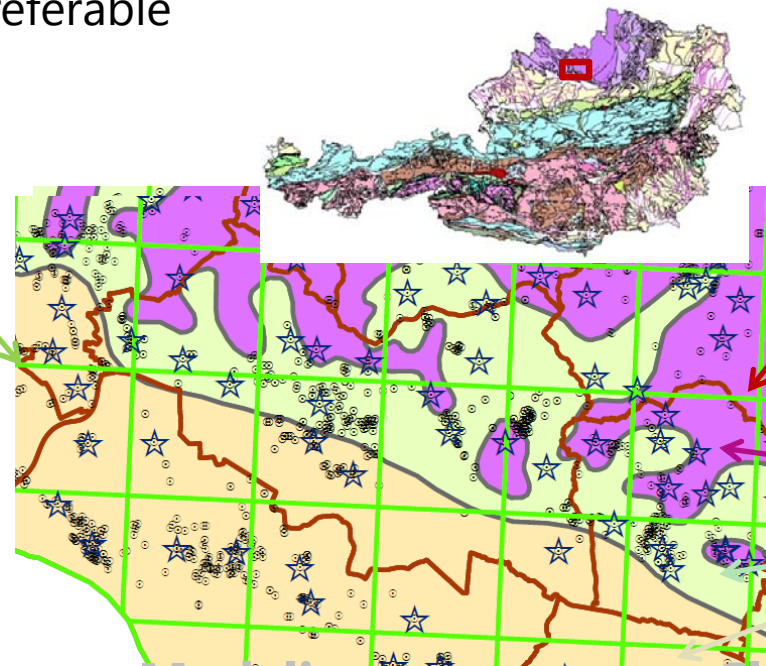
municipalities
(at least 12 dwellings)
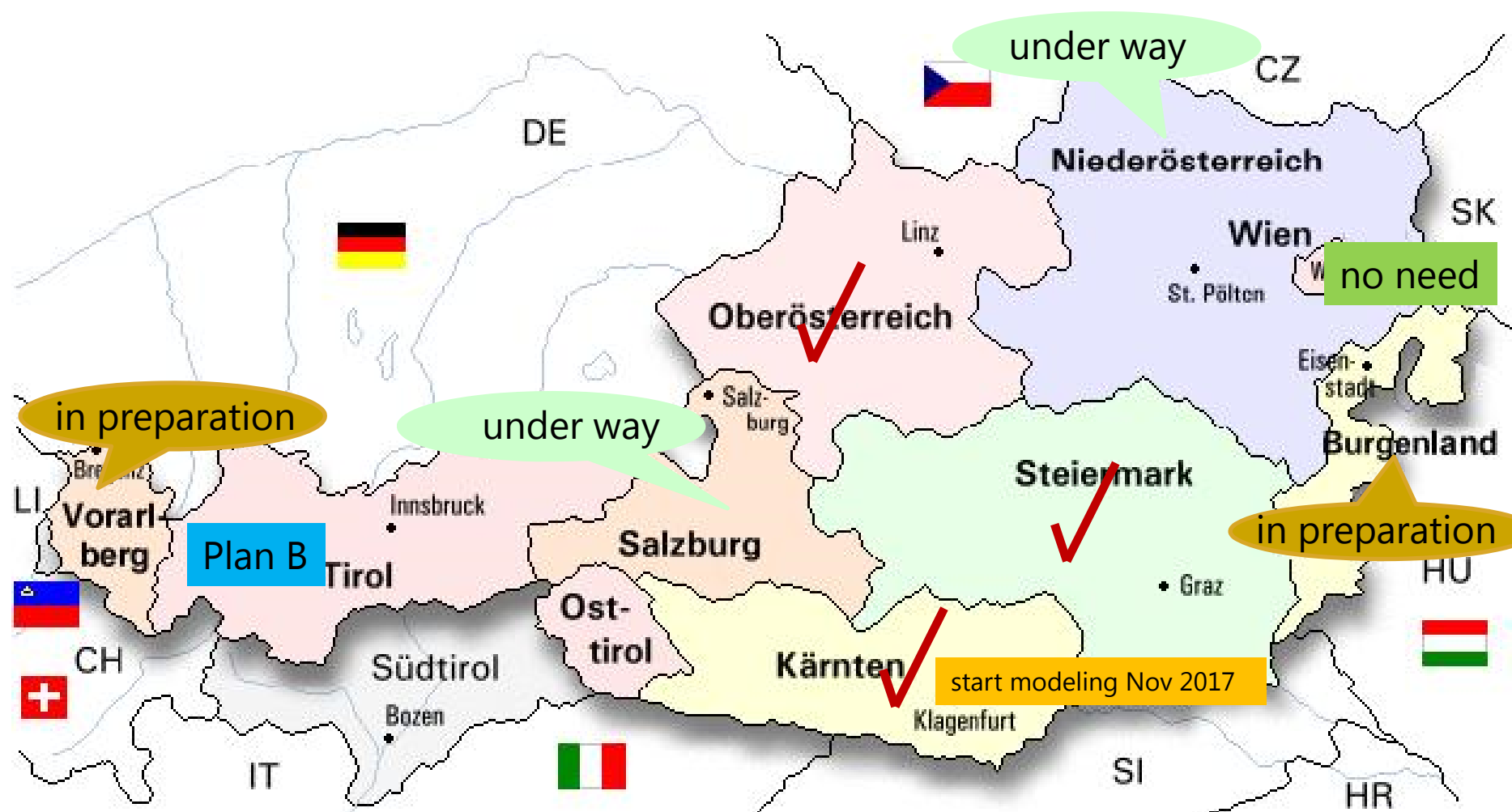
geological units
(1:500.000)

Sampling – **Modeling** – **Classification**

Measurement campaign

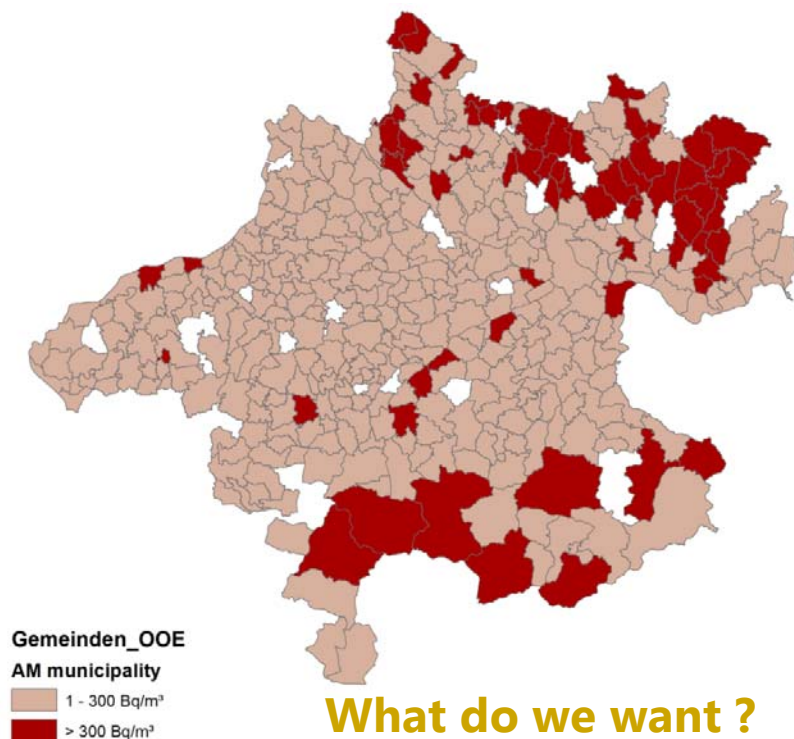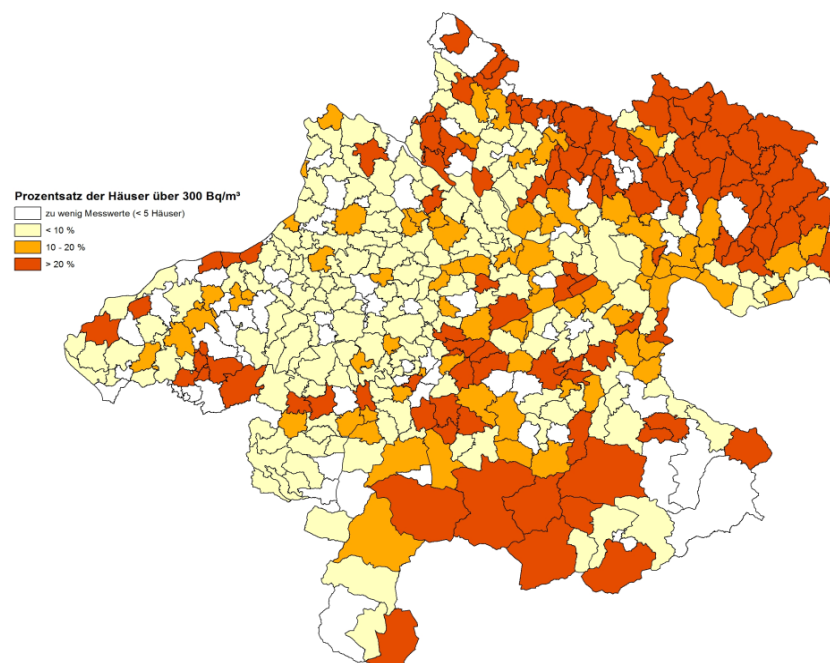## Status October 2017

Sampling – **Modeling** – **Classification**

How to display results in a map?

Examples Upper Austria

AM in municipalities

% of dwellings above 300 Bq/m³
in municipalities

Gemeinden_OOE
AM municipality
- 1 - 300 Bq/m³
- > 300 Bq/m³

Prozentsatz der Häuser über 300 Bq/m³
- zu wenig Messwerte (< 5 Häuser)
- < 10 %
- 10 - 20 %
- > 20 %

What do we want ?
- Take into account building characteristics
- Take into account geology
- Characterisation of areas with no or few measurements
- Homogenous classification (e.g. neighbouring, geological comparable municipalities)

Sampling – **Modeling** – **Classification**

Modeling

- Modeling of the measurement results in dependency of relevant, explaining factors
- Generalised Additive Mixed Model (GAMM)
- based on Borgoni et al., 2014
- Log-norm-distribution assumed

Fixed effects according to the relevant parameters (building characteristics)

Random effect (dwelling)

$$\log(IRC_{ij}) = \beta_0 + \beta_1 z_{ij} + \ldots + \beta_m z_{ij} + s(x_j, y_j) + u_j + \varepsilon_{ij}$$

Intercept (Rn background level)

Smoothing function *(thin plate regression splines)*, spatial intercept

rest variation

To evaluate influence of variables (building characteristics) →
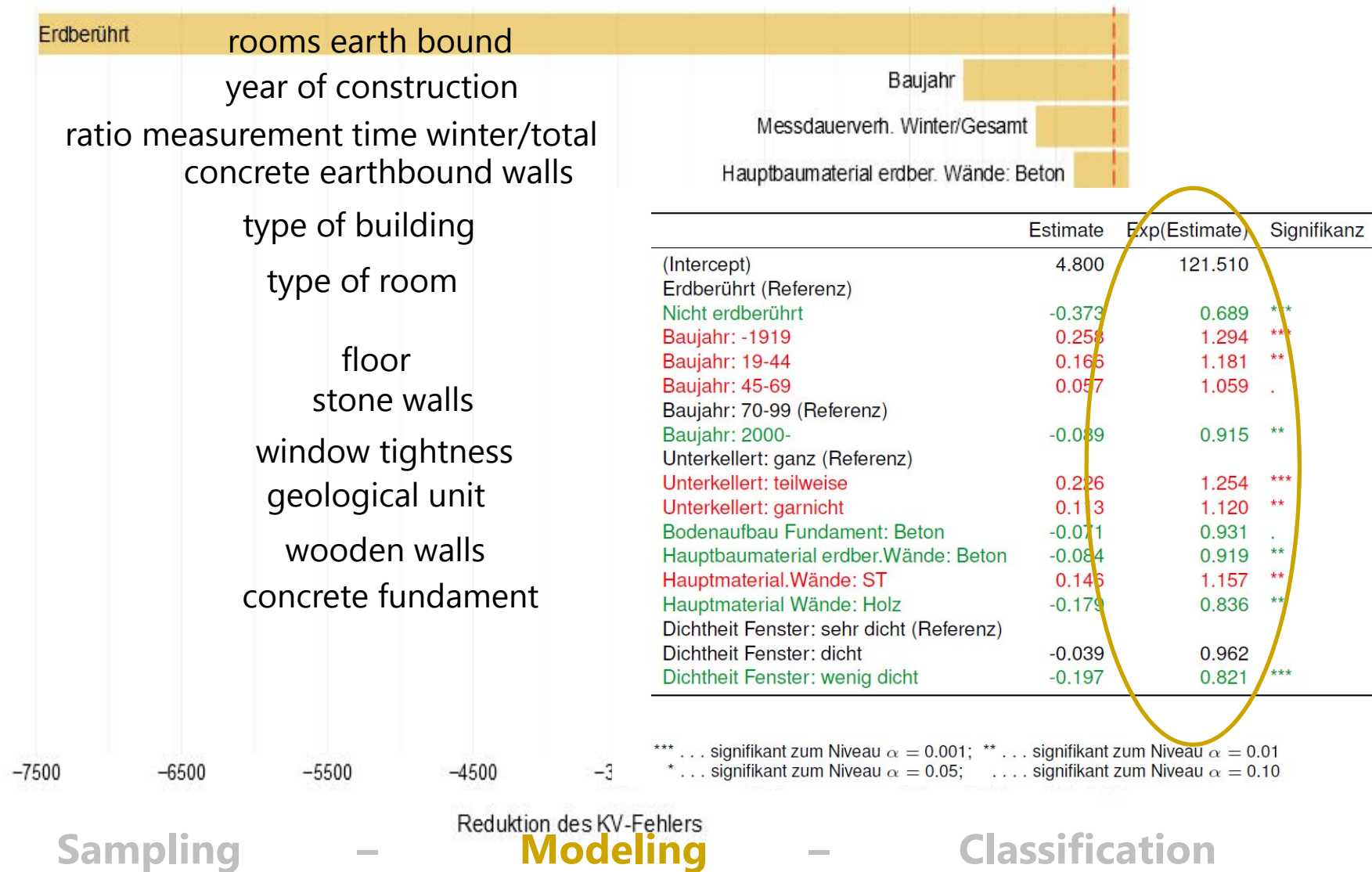Stepwise forward selection with *5-fold cross validation*

Sampling – **Modeling** – **Classification**

Modeling

Relevant Parameters

rooms earth bound
year of construction
ratio measurement time winter/total
concrete earthbound walls
type of building
type of room

floor
stone walls
window tightness
geological unit
wooden walls
concrete fundament

	Estimate	Exp(Estimate)	Signifikanz
(Intercept)	4.800	121.510	
Erdberührt (Referenz)			
Nicht erdberührt	-0.373	0.689	***
Baujahr: -1919	0.258	1.294	***
Baujahr: 19-44	0.166	1.181	**
Baujahr: 45-69	0.057	1.059	.
Baujahr: 70-99 (Referenz)			
Baujahr: 2000-	-0.089	0.915	**
Unterkellert: ganz (Referenz)			
Unterkellert: teilweise	0.226	1.254	***
Unterkellert: garnicht	0.113	1.120	**
Bodenaufbau Fundament: Beton	-0.071	0.931	.
Hauptbaumaterial erdber.Wände: Beton	-0.084	0.919	**
Hauptmaterial.Wände: ST	0.146	1.157	**
Hauptmaterial Wände: Holz	-0.179	0.836	**
Dichtheit Fenster: sehr dicht (Referenz)			
Dichtheit Fenster: dicht	-0.039	0.962	
Dichtheit Fenster: wenig dicht	-0.197	0.821	***

*** . . . signifikant zum Niveau $\alpha = 0.001$;   ** . . . signifikant zum Niveau $\alpha = 0.01$
* . . . signifikant zum Niveau $\alpha = 0.05$;   . . . . signifikant zum Niveau $\alpha = 0.10$

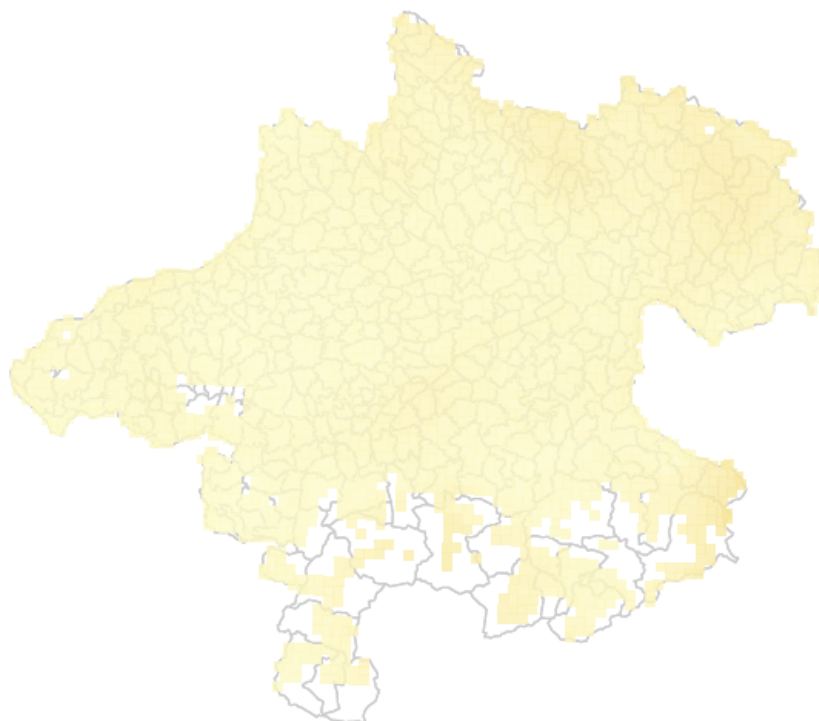**Sampling   –   Modeling   –   Classification**

Modeling, Reference House

Definition of Reference House has strong impact!

Prediction of Radon concentration for a Reference house per 2x2 km grid cell

Parameters for RH set for **„best" case**
for radon concentration
(basement, not earth bound, after 2000 etc).
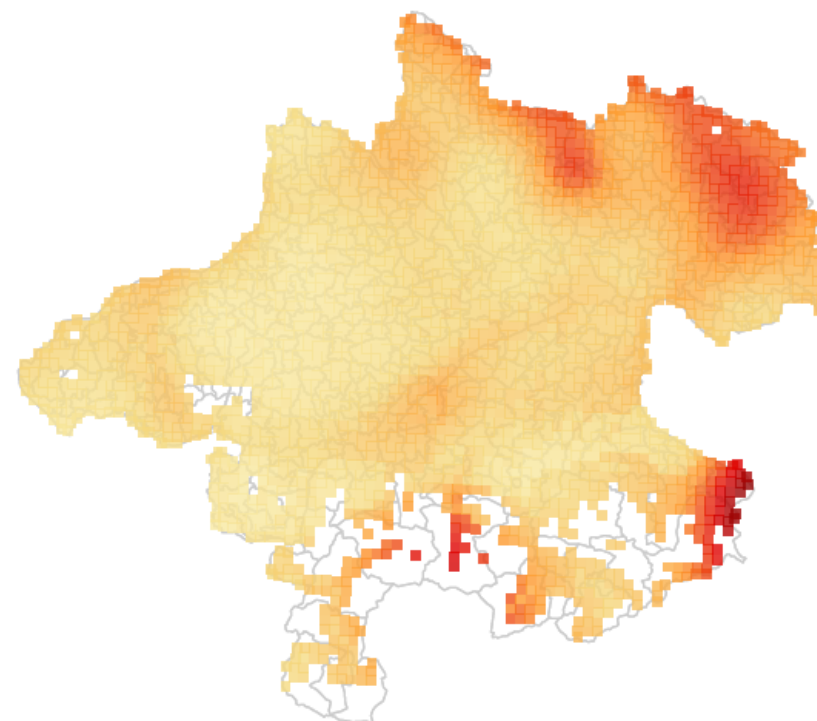
Parameters for RH set for **„worst" case**
for radon concentration
(no basement, earth bound, < 1919 etc.)

Sampling – **Modeling** – Classification

From prediction to classification

Predicted Rn concentration for a Reference house per 2x2 km grid cell
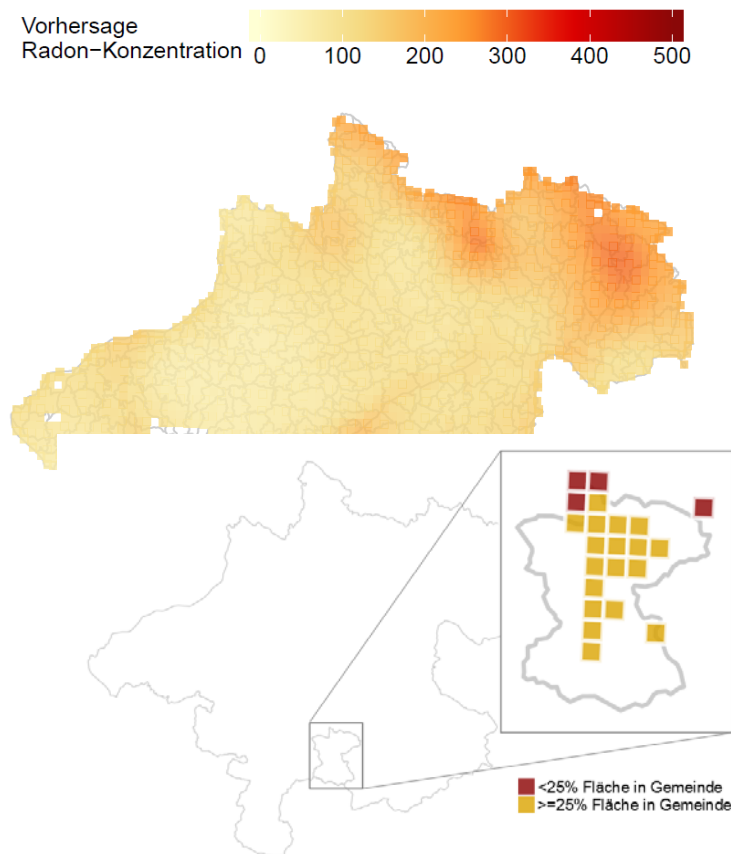
AM of predicted Rn concentration per cell in municipality

Sampling – **Modeling** – **Classification**
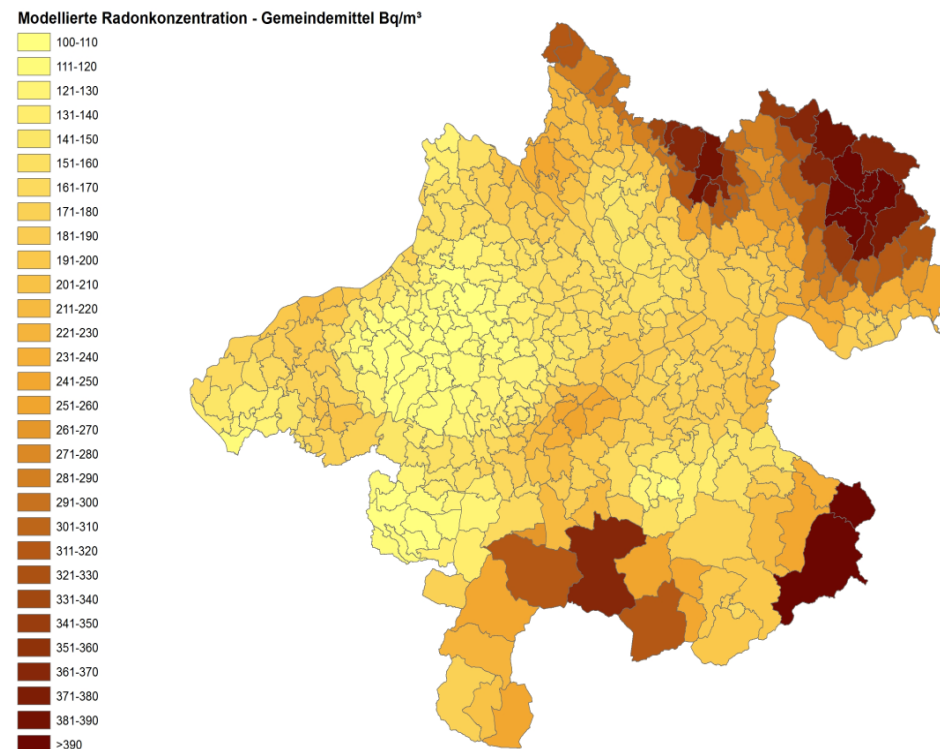
Classification, Reference Houses

Example, 3 classes, different reference houses

Variable	Most frequent building characteristics	Building characteristics used for "RH Upper Austria (UA)"
Rooms earth bound	**No**	**Yes**
Year of construction	**1970 - 2000**	**After 2000**
Concrete earthbound walls	Yes	Yes
Type of building	Single family house	Single family house
With basement	**Full basement**	**No basement**
Floor	Ground floor	Ground floor
Window tightness	tight	tight
Concrete fundament	Yes	Yes

Municipality Bq/m³
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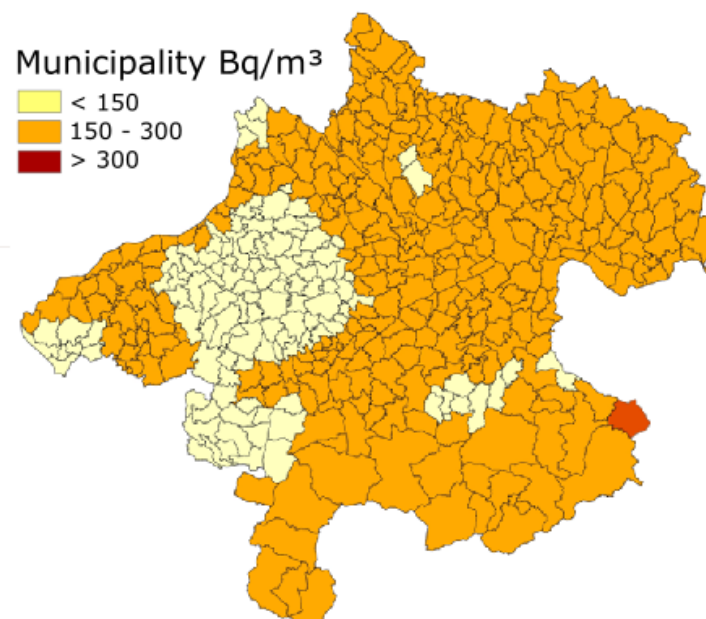
Sampling   –   **Modeling**   –   **Classification**
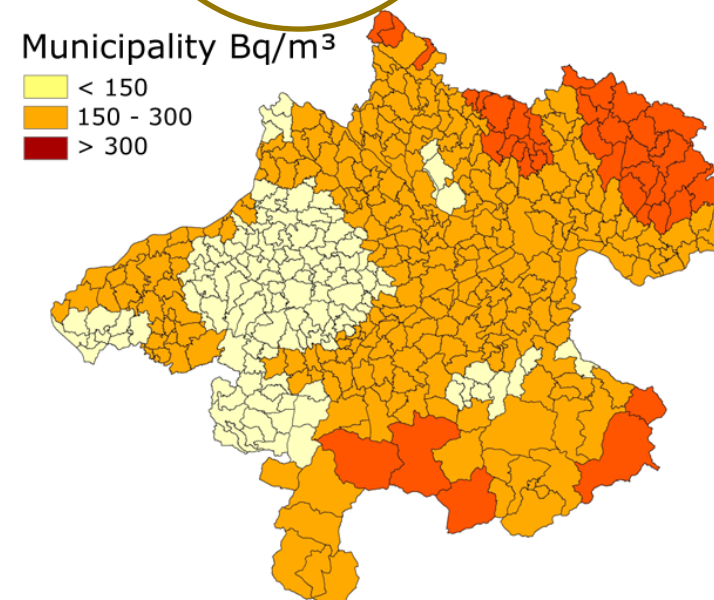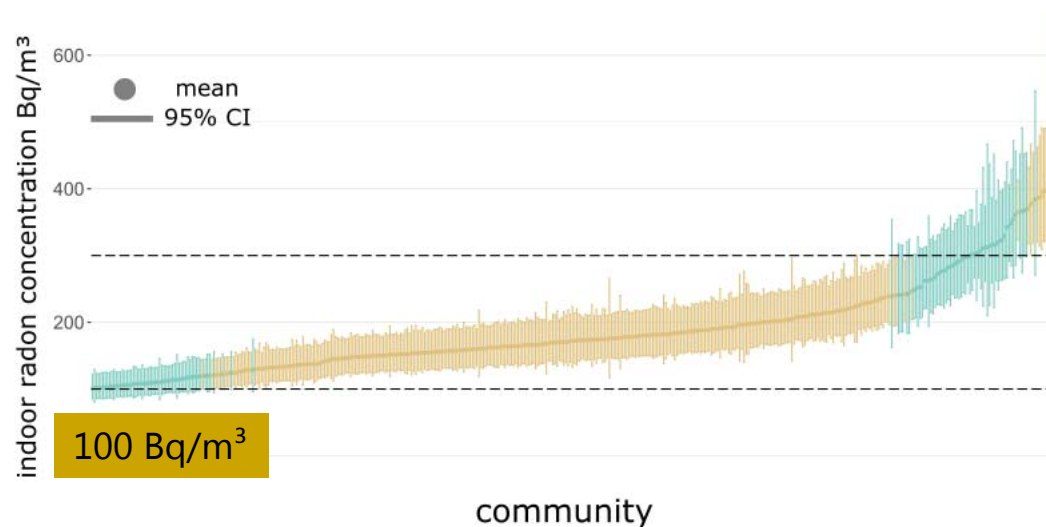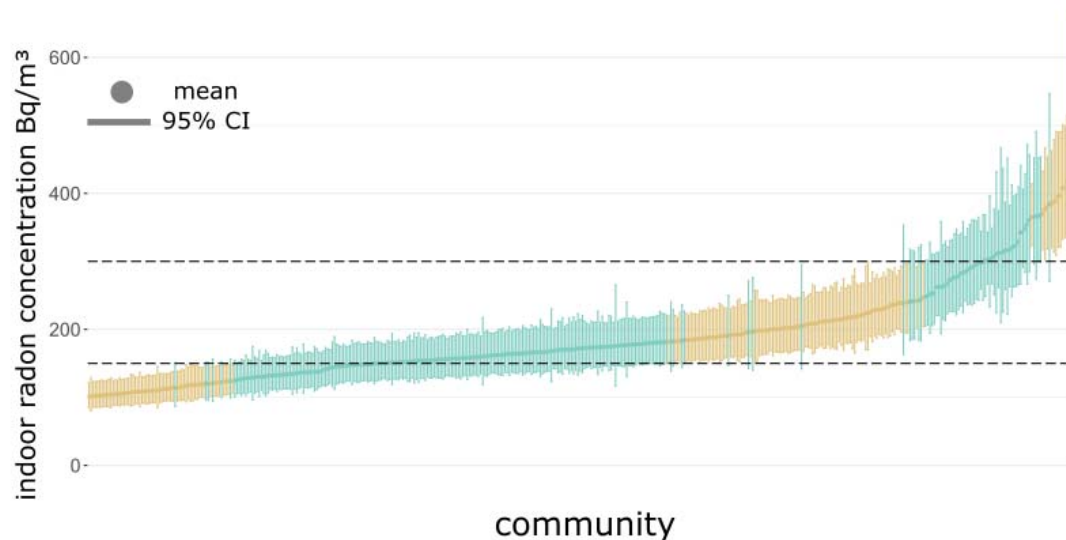
Validation of Classification

3 classes (150/300 Bq/m³), Reference House UA

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- **Confidence intervals** of the expected IRC per municipality were calculated using the variances of raster cell estimates and the variability of different raster cells within a municipality.
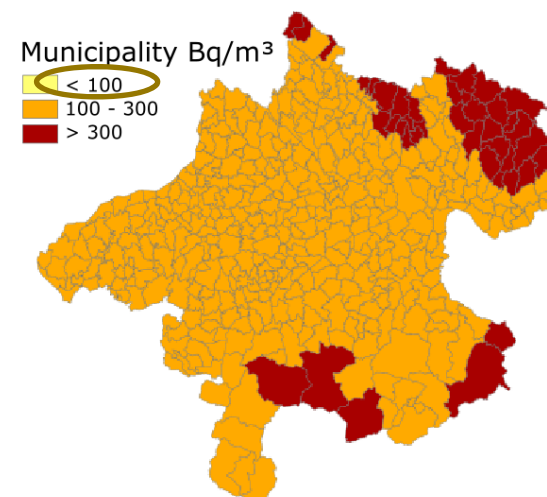

Sampling – **Modeling** – **Classification**
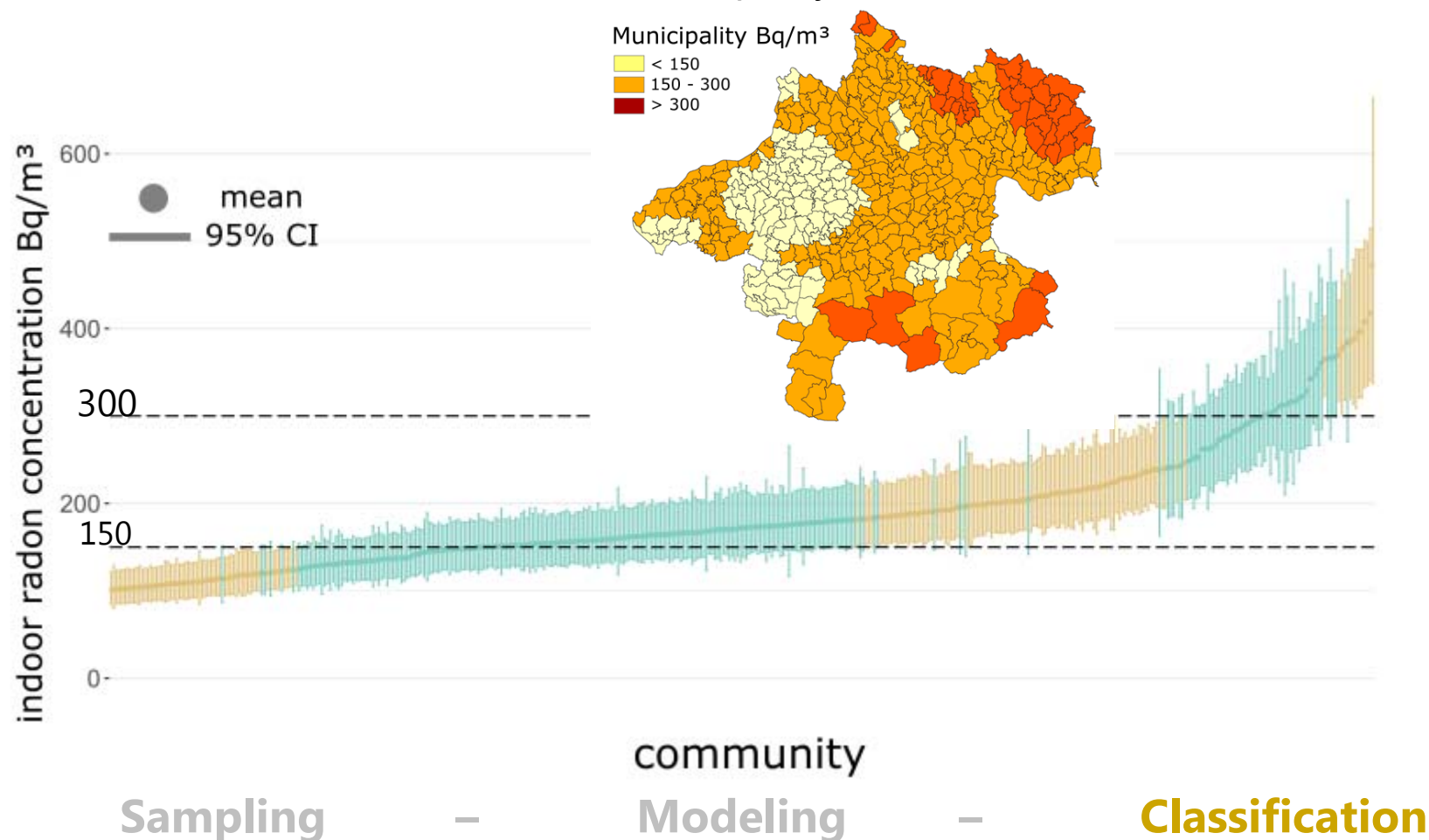
Validation of Classification

Class borders vs. accuracy

RH UA

100 Bq/m³
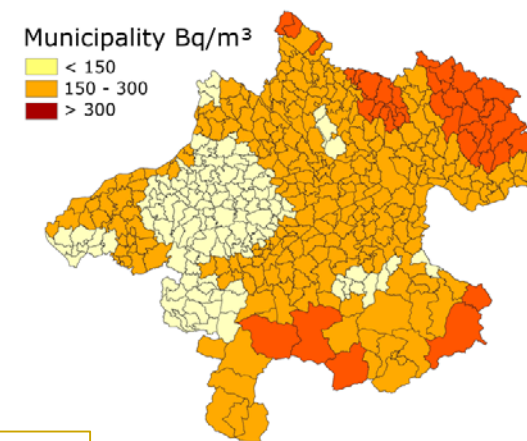
Sampling — Modeling — **Classification**

Validation of Classification

Impact on chosen reference house on classification accuracy

RH UA

most frequent house
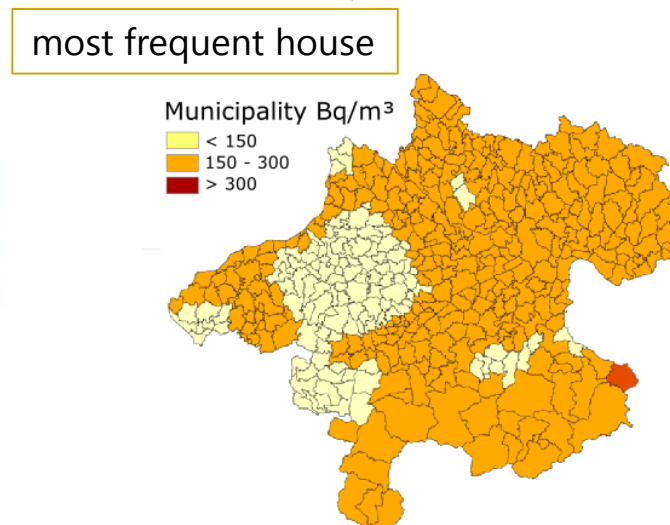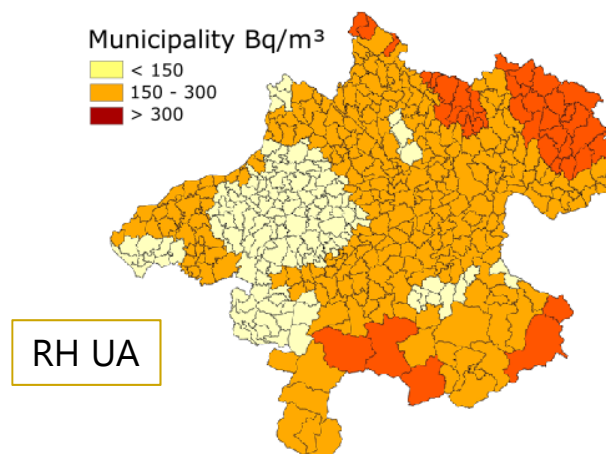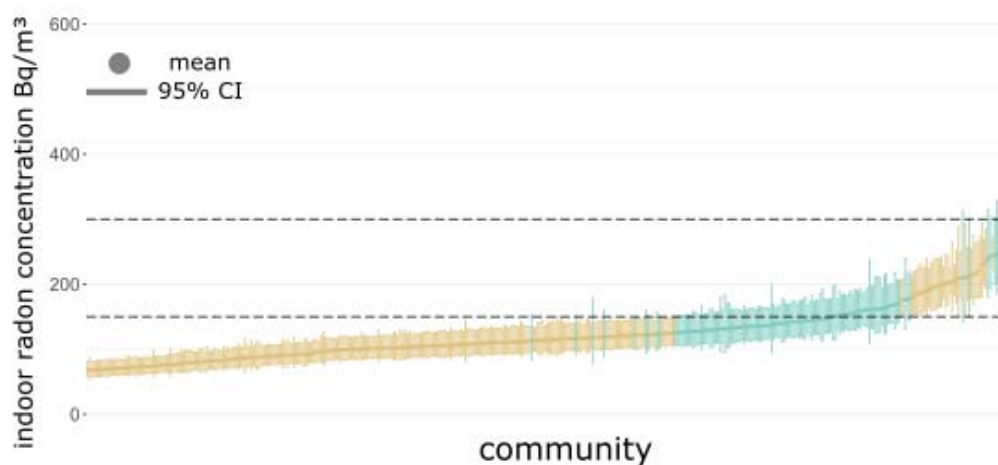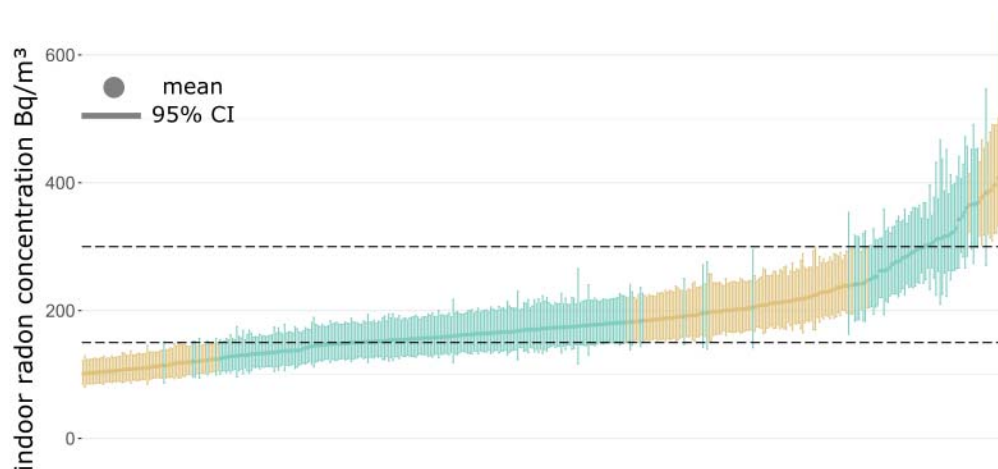
Delineation of Radon areas

Some considerations...

- Unit (administrative vs. grid, geology unit)

- Method (AM, % of dwelling above RL, etc.)

- Classes (y/n, more classes for graded approach, „introduce artifical RL")

- Class borders (accuracy?, be conservative? consequencies?)

- Radon areas defined on basis of dwellings – used for decision about workplaces?

- How to deal with areas with insufficient data (conservative?)

→ Not only scientific decision! Also „political"!

→ Should be based on sound data and methodology, but has to be realizable (economical, administrative), ALARA!

→ start with smaller „radon areas" and extend (if applicable) – **priorisation!**
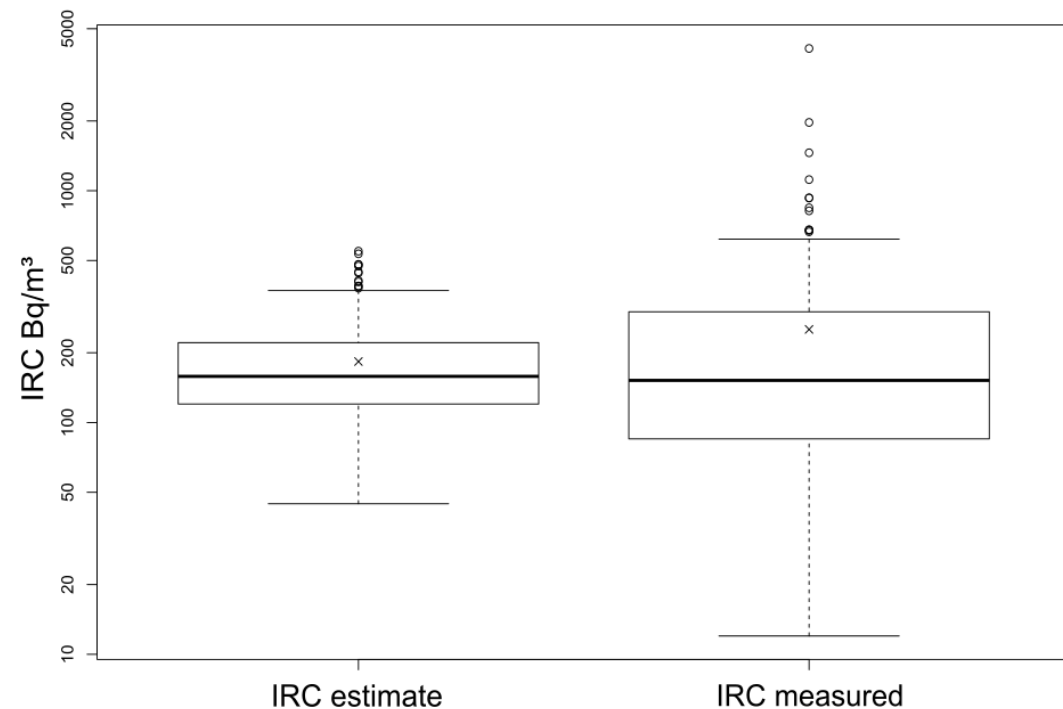
On the way to the new map...

 Validation of Model

Until now 192 additional measurements in UA (not used for modeling)
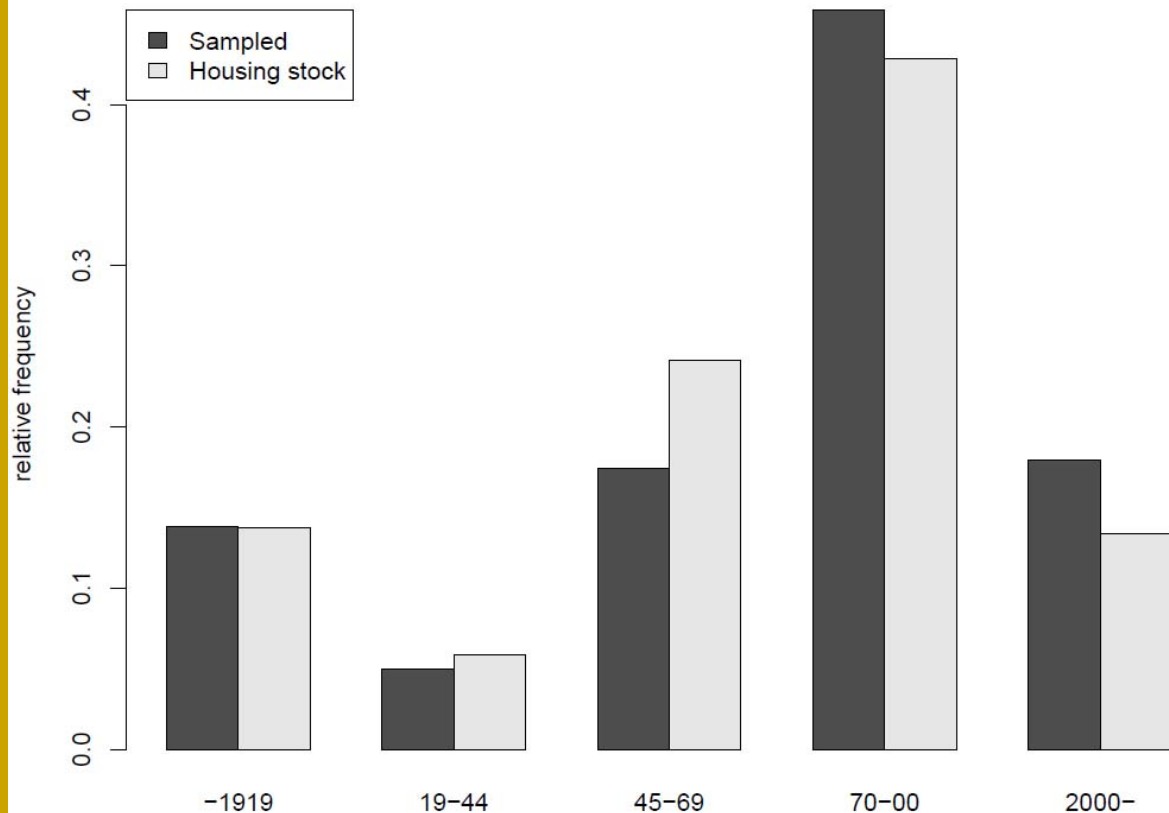
IRC were estimated with exact building characterisitcs

On the way to the new map...

Work in progress and next steps...

Test representativeness of sampled houses

- Comparison of sampled houses and housing stock shows differnce in building year

- Possible impact on the used reference house in the model

- Evaluation of the represantiveness of other building characteristics ongoing

On the way to the new map

Work in progress and next steps…

- Continue with the measurement campaign (mid 2018)
- Extend model with new data
- **Define method for delineation** (used reference house, classes)

- Finish map/delineation of „radon areas" – hopefully end of 2018

- Improvement of map with „geogenic factors" (if possible)

- Evaluation of delineation of „radon areas" with new data (dwellings, work places) after some years

Thank you for your attention!

Dr. Valeria Gruber

National Radon Centre
Austrian Agency for Health and Food Safety (AGES)
Radiation Protection
Department for Radon and Radioecology

Wieningerstrasse 8
A-4020 Linz, Austria
Tel. ++43-(0)50555-41906
Fax ++43-(0)50555-41915
valeria.gruber@ages.at
www.ages.at