EGU General Assembly 2020

Using Safecast data for estimating ambient dose rate in cities around the world

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Introduction

Citizen Science

- participation of the public in research or monitoring
- public may share control over objective, methodology, progress, interpretation
- https://en.wikipedia.org/wiki/Citizen_science

SAFECAST

- Safecast was founded after the Fukushima Daiichi NPP accident in 2011 as reaction to the perceived poor communication on radiation situation from the authorities and the TEPCO company operating the NPP
- all measurements published as open data
- later extended to the whole world
- provides online platform for submitting data, interactive map etc.
- standard GPS equipped radiation detector, bGeigie Nano
- openly accessible documentation, code, methodology

Introduction

advantages of citizen radiation monitoring

- able to create large amounts of data, which is almost impossible for institutions due to necessarily limited resources
- discovering and mapping natural or anthropogenic anomalies, not yet covered by professional measurement
- educative: getting familiar with scientific methods
- helping to reduce mistrust of the public towards official institutions (people can “verify” the official measurements)
- participation increases motivation

bGeigie adopted by professionals

- SÚRO (Czech Republic), IAEA, IRSN (France) and others
- RAMESIS (Czech Rep.) - project for institutions and schools to assure early awareness and enhancing safety of citizens, also includes providing common citizens, schools, voluntarily firemen etc. with bGeigie detectors and easy to use mapping software (QGIS)

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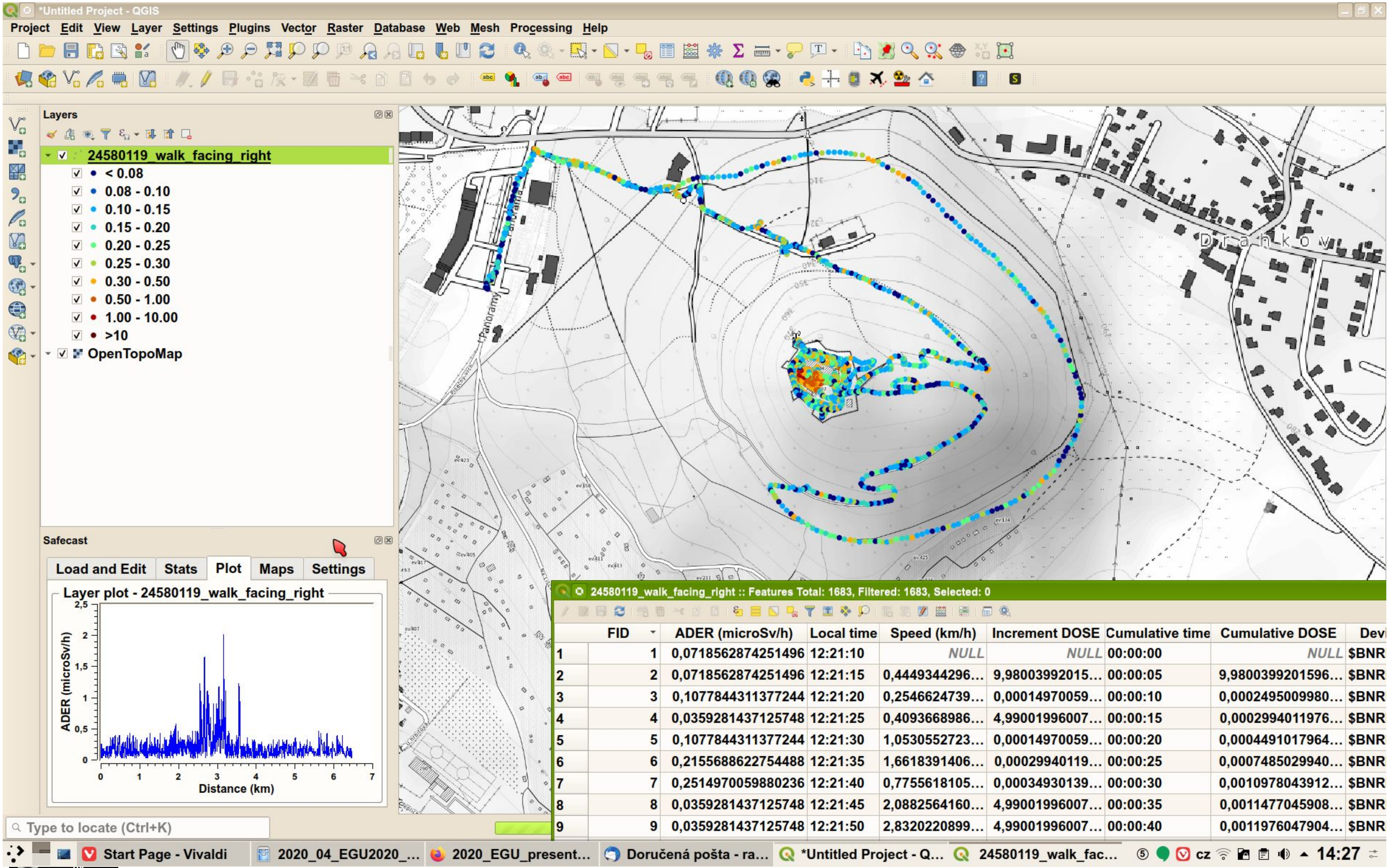
QGIS 3.12 with Safecast plugin



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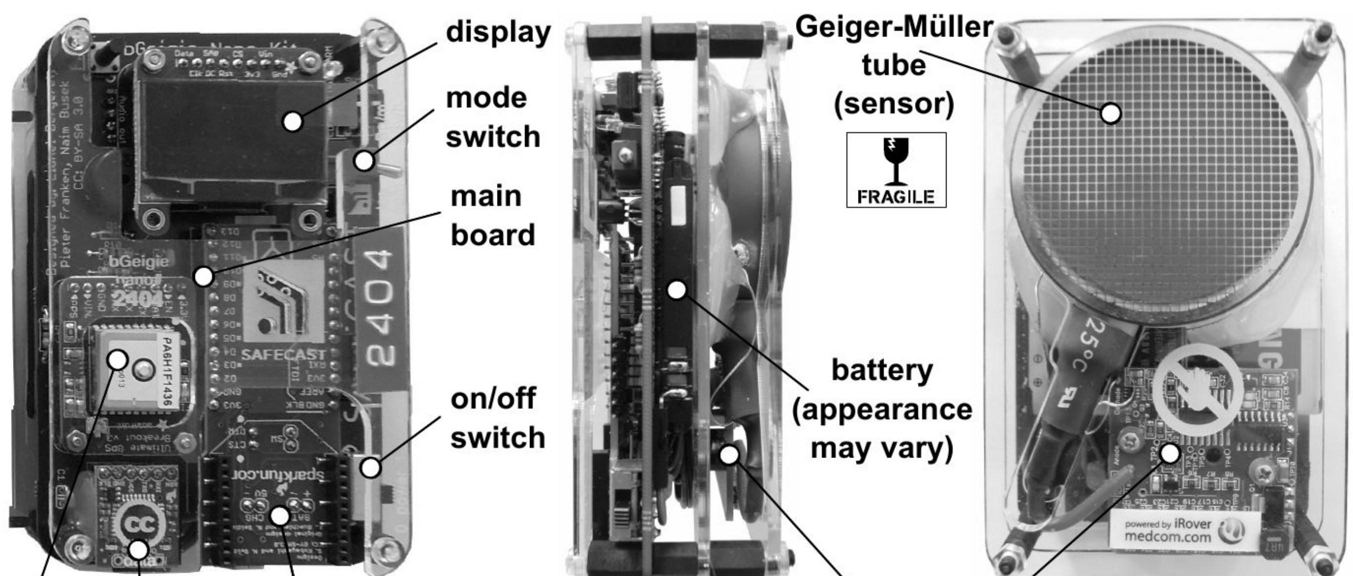
Safecast bGeigie Nano detector

- rugged weather-proof case, simple use - just switch on and go
- Geiger pancake tube sensor, Li-Ion battery (up to 40 hours)
- automatic data logging (radiation data, GPS, time/date) to microSD card



iRover module by International Medcom Inc. California, USA
- GM tube power supply (about 500 V, a few μA)
- do not touch when switched on

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Possible disadvantages of Citizen Science

- citizen monitoring is mostly performed by people without metrological experience - resulting into not negligible higher uncertainty of results

Possible errors:

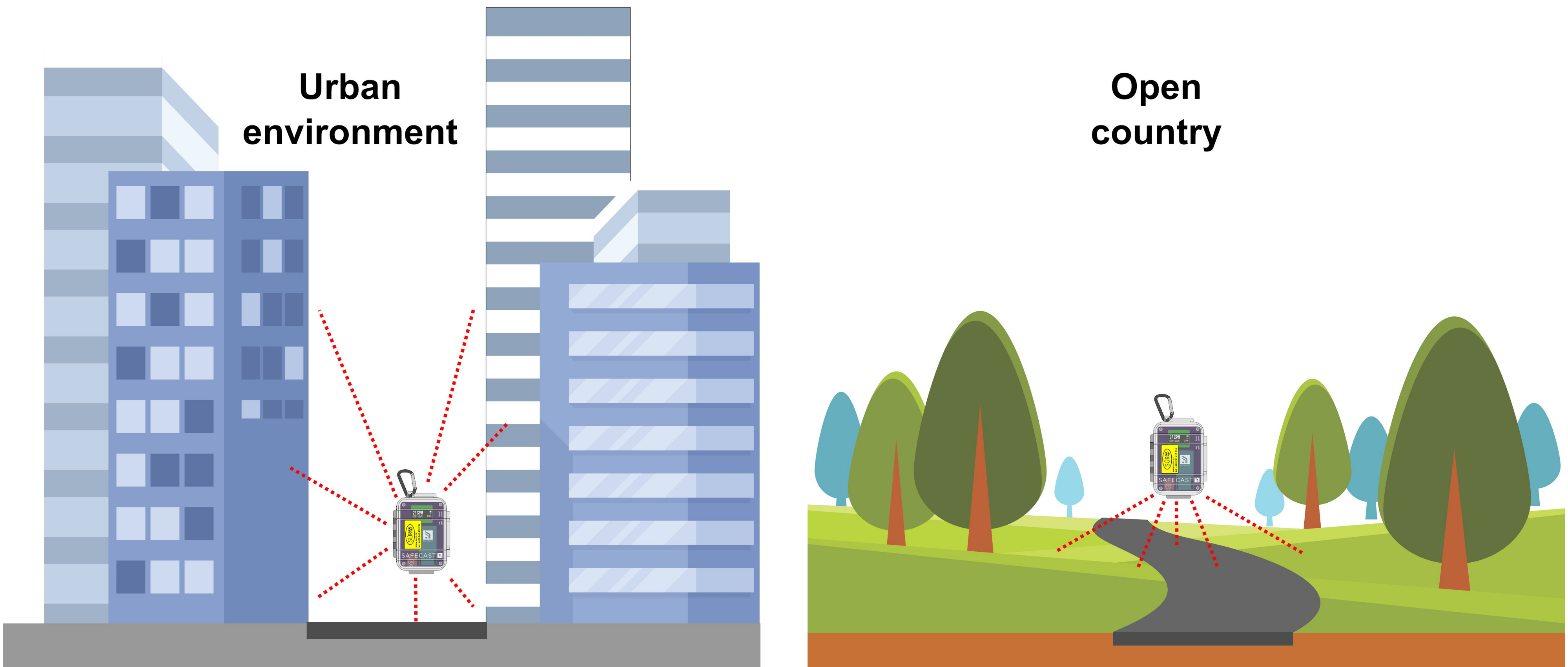
- wrong device settings - not a problem with bGeigie (no user settings :-)
- different device position or measurement height above ground than declared or changed during measurements
- influence of detector facing and inclination (the pancake GM is directionally dependent)

… adds to uncertainty budget!
… needs to be discussed and evaluated. Specific experiments are necessary to improve QA.

Influence of the environment on the measured values: Urban vs. open country

- in cities the detector is surrounded by potential sources of radiation
  + pavement and building cladding from granite (higher K, U, Th)

→ often higher ADER values in urbanized environments



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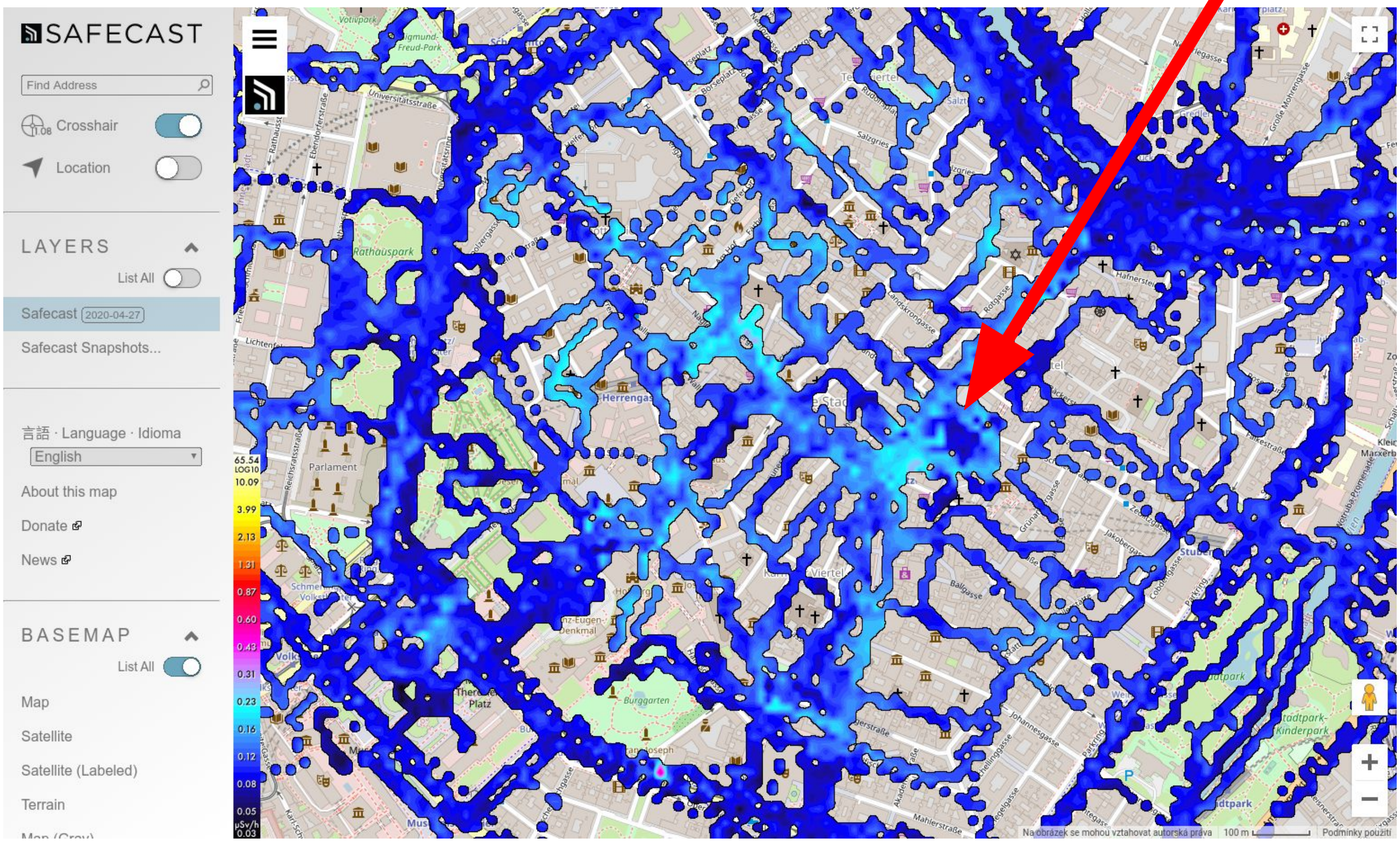
Higher ADER values in historic city centers

- often stone buildings or pavement
- example: Wien, Austria, screenshot from [Safecast Tile Map]

granite
pavement



What are the differences of mean ADER between cities?

- is it possible to identify meaningful, characteristic mean ambient dose equivalent rate (ADER) for a city?
- here this is attempted using Safecast data, for cities and towns world-wide, where sufficient data is available

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Input data

- complete Safecast dataset - approx. 4.5 GB tar.gz download (downloaded on 25 Jan 2020), about 16.1 GB unpacked CSV file

```
Captured Time,Latitude,Longitude,Value,Unit,Location Name,Device ID,MD5Sum,Height,Surface,Radiation,Uploaded Time,Loader ID
2020-02-03 17:00:00,37.507551666667,139.94117,72,cpm,,,6449bbf7ce3b30a8e05bc23a0bc40644,,,,2020-02-03 17:00:00,633
2020-02-03 11:00:00,37.50725,139.94,55,cpm,,,2fa8bccef282796bcdc297679c4db5b3,,,,2020-02-03 11:00:00,614
2020-02-03 11:00:00,37.505445,0.016666666666667,68,cpm,,,a166df14f60b61095693684fc0f89c54,,,,2020-02-03 11:00:00,614
2020-02-01 03:00:00,34.066486666667,-118.89521666667,50,cpm,,,da79c21520d3ff3f5ed010a70f4a6d29,,,,2020-02-01 03:00:00,507
```

- data for analysis:

"*Latitude*","*Longitude*", coordinates in decimal degrees (WGS 84 EPSG:4326)

"Value" - quantity of interest; cpm of ADER readings, status, temperature

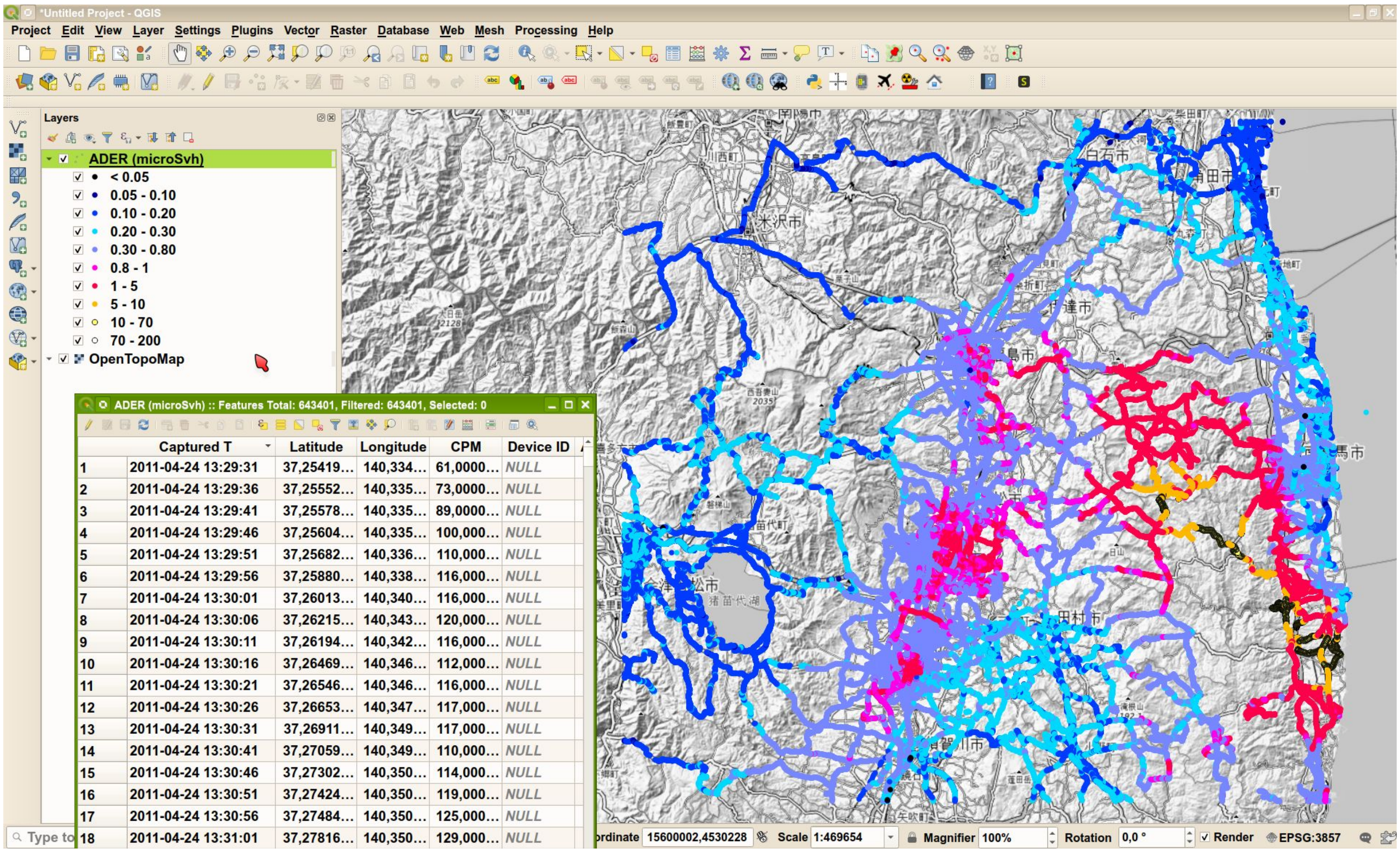
- only "cpm" values used

"Unit" - cpm and others

- too big for common spreadsheet program or even text editor
- requires some preliminary filtering to keep only data rows with "CPM" values
- there might be some outliers so "valid dose rate" range must be determined

Input data

- even this small portion of data for Fukushima prefecture (and year 2011) consists of more than 640 000 data points



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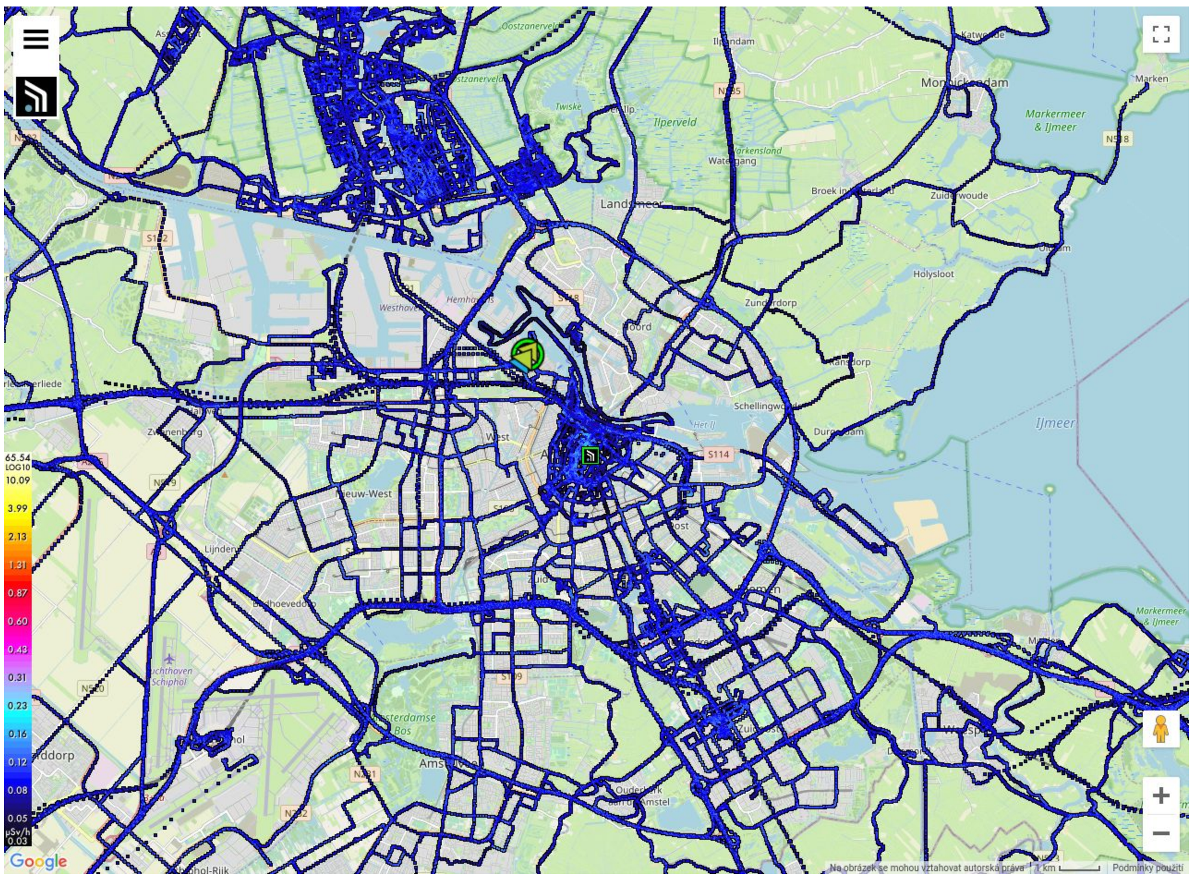
Issues with filtering data for particular cities

- how to define the territory of a particular city?
- so far: rectangle visually circumscribed a city, using Google Earth
- should we use some advanced approach?



- what is the minimal amount of data points per city for valid results?
- how to deal with not uniform distribution of measurement points?

figure - Amsterdam

from [Safecast Tile Map]

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Exploratory statistics

- simple statistics per city (or any spatial unit) including: number of valid data points in a spatial unit, arithmetical mean, standard deviation, coefficient of variation, standard error, geometric mean, geometric standard deviation, maximum etc.

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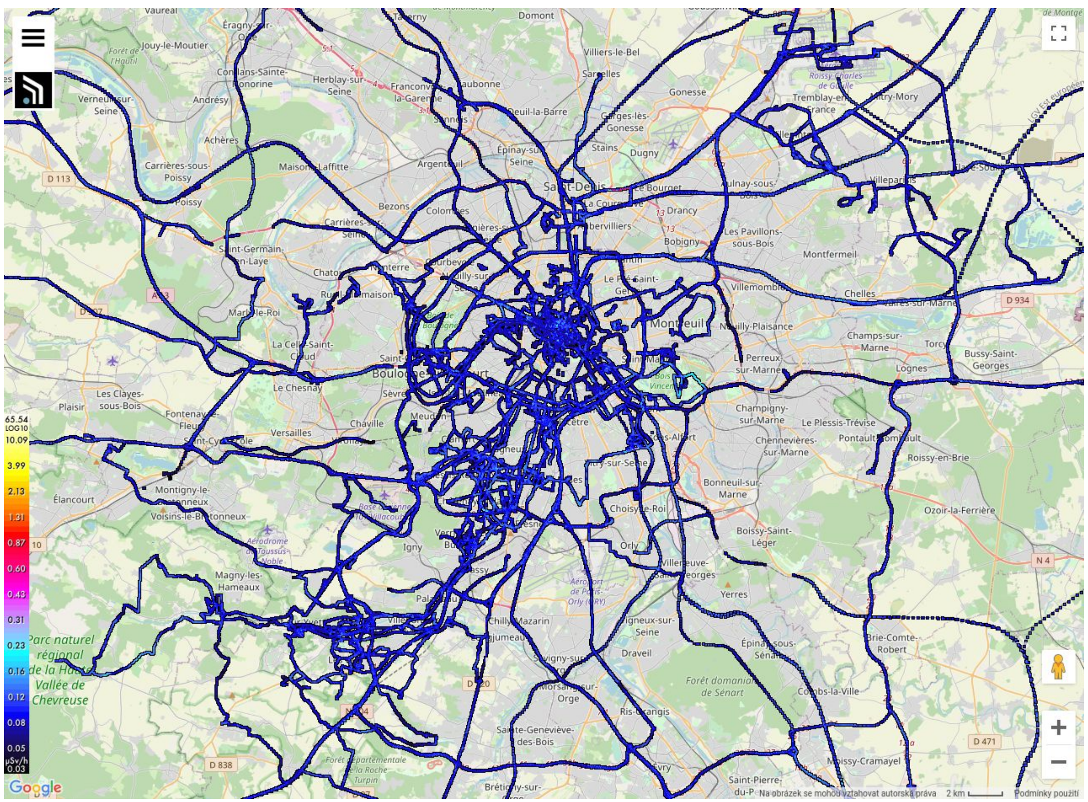
Spatial mean and data clustering

- the measurement points are not uniformly distributed
- usually higher sampling density in city centres, much more points following streets than in open country
- in general, ADER is truly variable within a city;



- statistics from raw, clustered data will therefore in general be biased towards region with higher data density
- data processing requires de-clustering

figure - Paris

from [Safecast Tile Map]

Spatial mean and data clustering

The spatial mean of a quantity Z over area B is defined,

$$SpM_B(Z) = \frac{1}{|B|} \int_{x \in B} Z(x)\,dx$$

This can be approximated:

$$SpM_B(Z) \approx AM_i\left[AM\left(z : z \in B_i\right)\right]$$

Therefore, practically, divide B into several sub-areas (we chose 5 x 5 equally shaped sub-rectangles) and calculate the mean (AM) in each of them; the de-clustered mean is the mean of the sub-areas.

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Terrestrial dose rate

Measured ADER =

Terrestrial component (natural and anthropogenic gamma radiaton)
+
Cosmic component (from secondary cosmic rays, mostly muons)
+
Airborne radiation (normally very small component, can be neglected)
+
Internal background of the instrument (electronic noise etc.)

Natural and anthropogenic terrestrial gamma radiation cannot be distinguished with bGeigie nano. However, anthropogenic radiation from nuclear fallout is almost negligible except in strongly affected areas, e.g. Chernobyl and Fukushima zones.

Here:
Terrestrial ADER = raw ADER - internal BG - estimated cosmic DR.

ca. 10 nSv/h

from formula

more experiments necessary!

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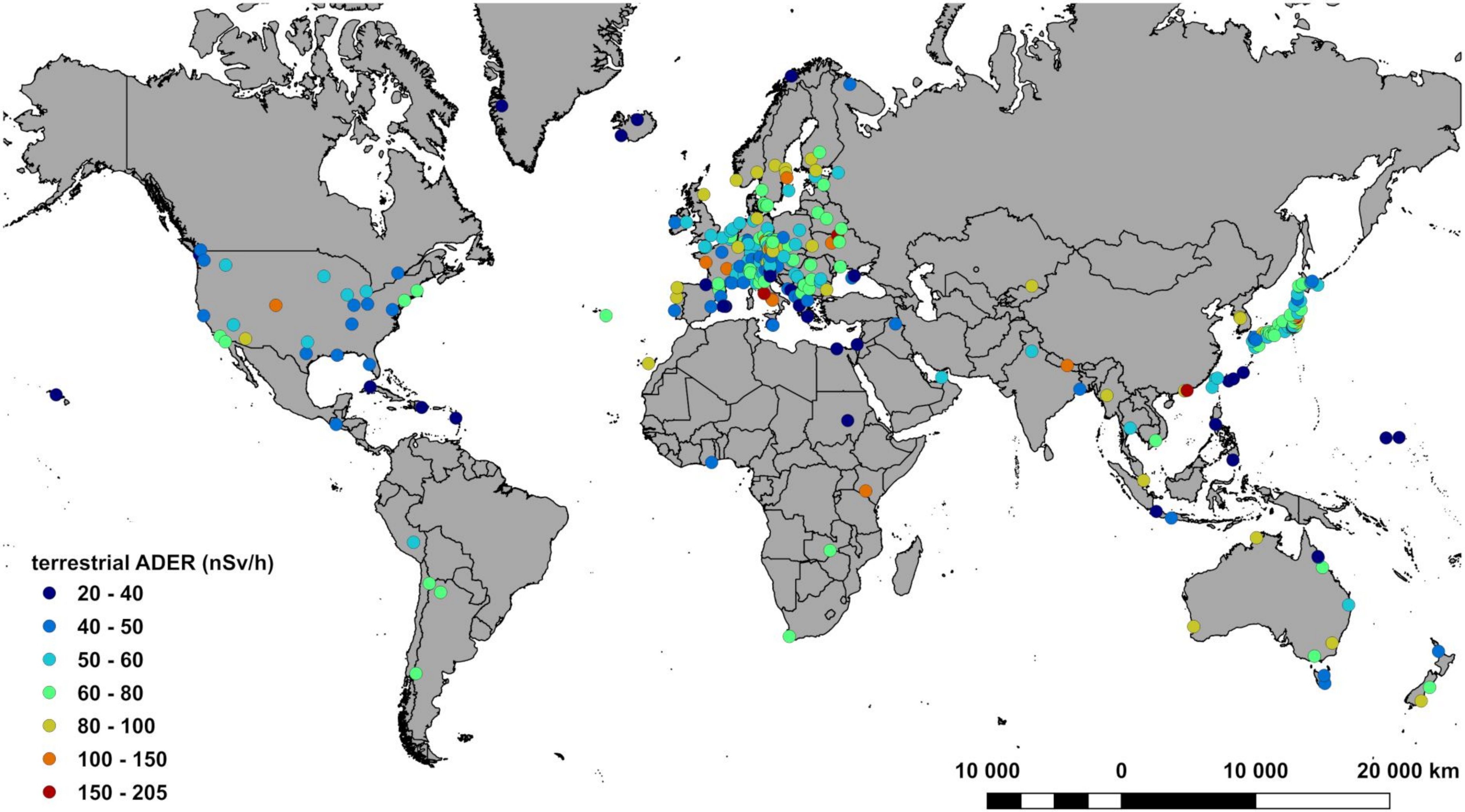
Mean estimated terrestrial ADER - world



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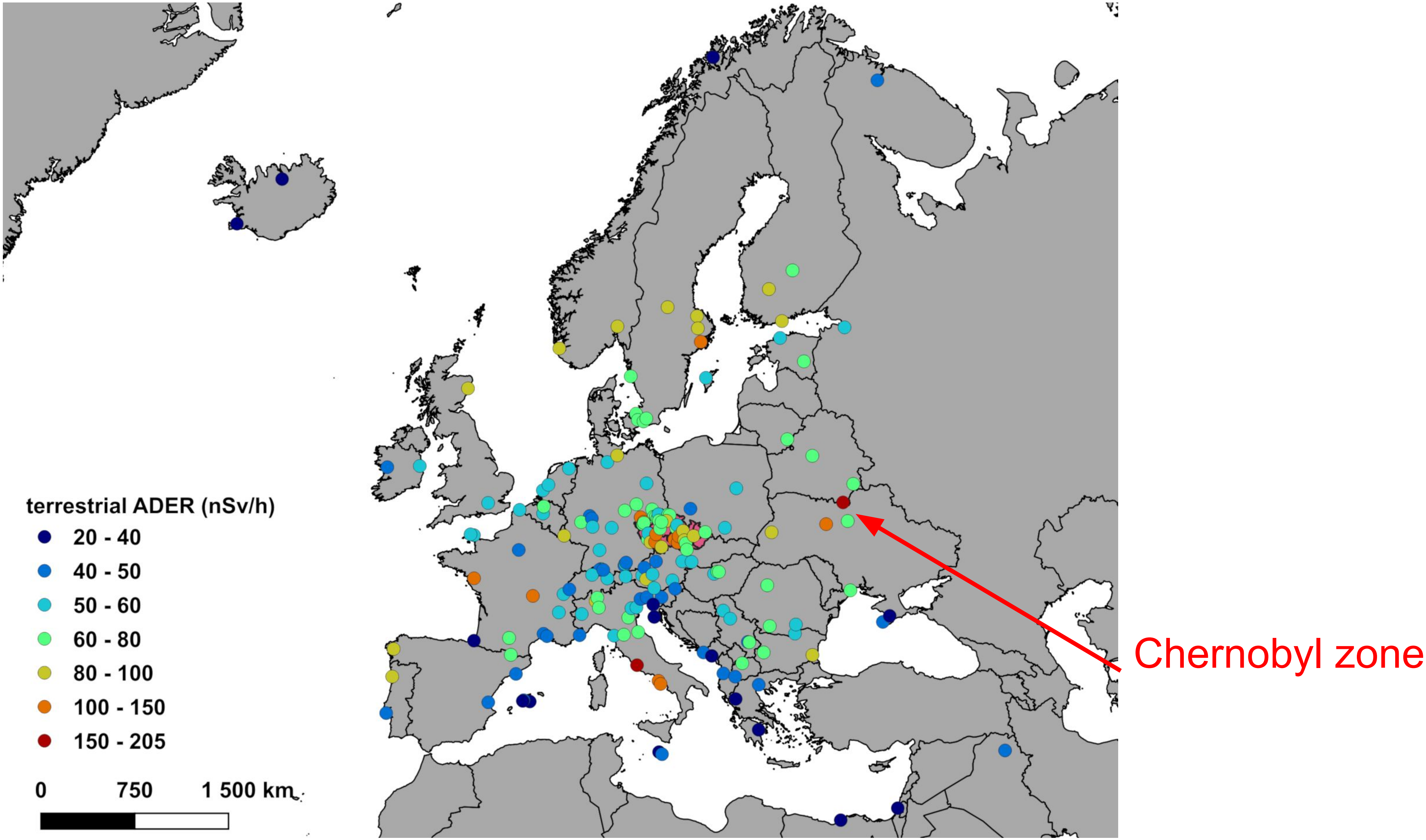
Mean estimated terrestrial ADER - Europe



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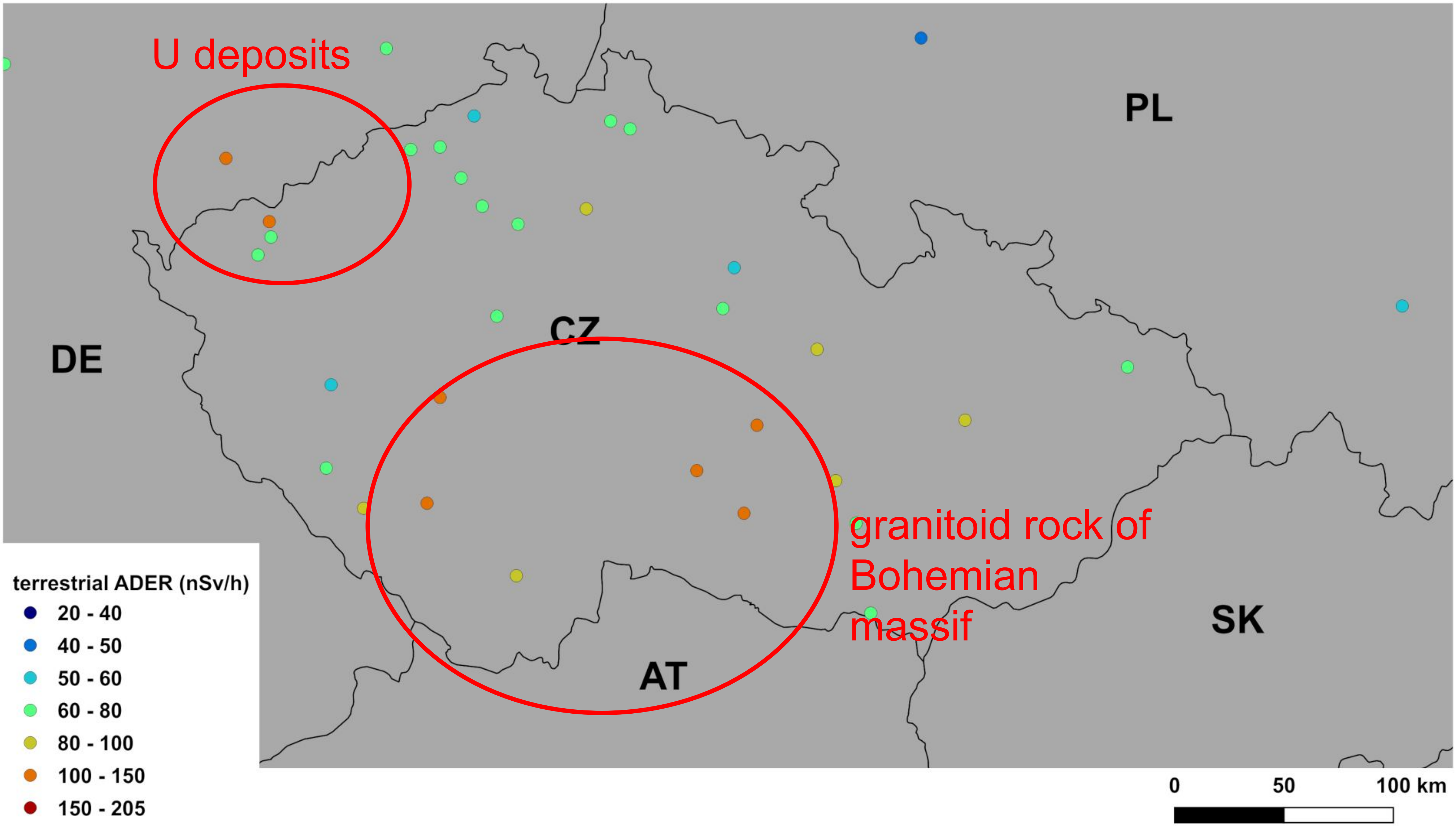
Mean estimated terrestrial ADER - Czech Republic



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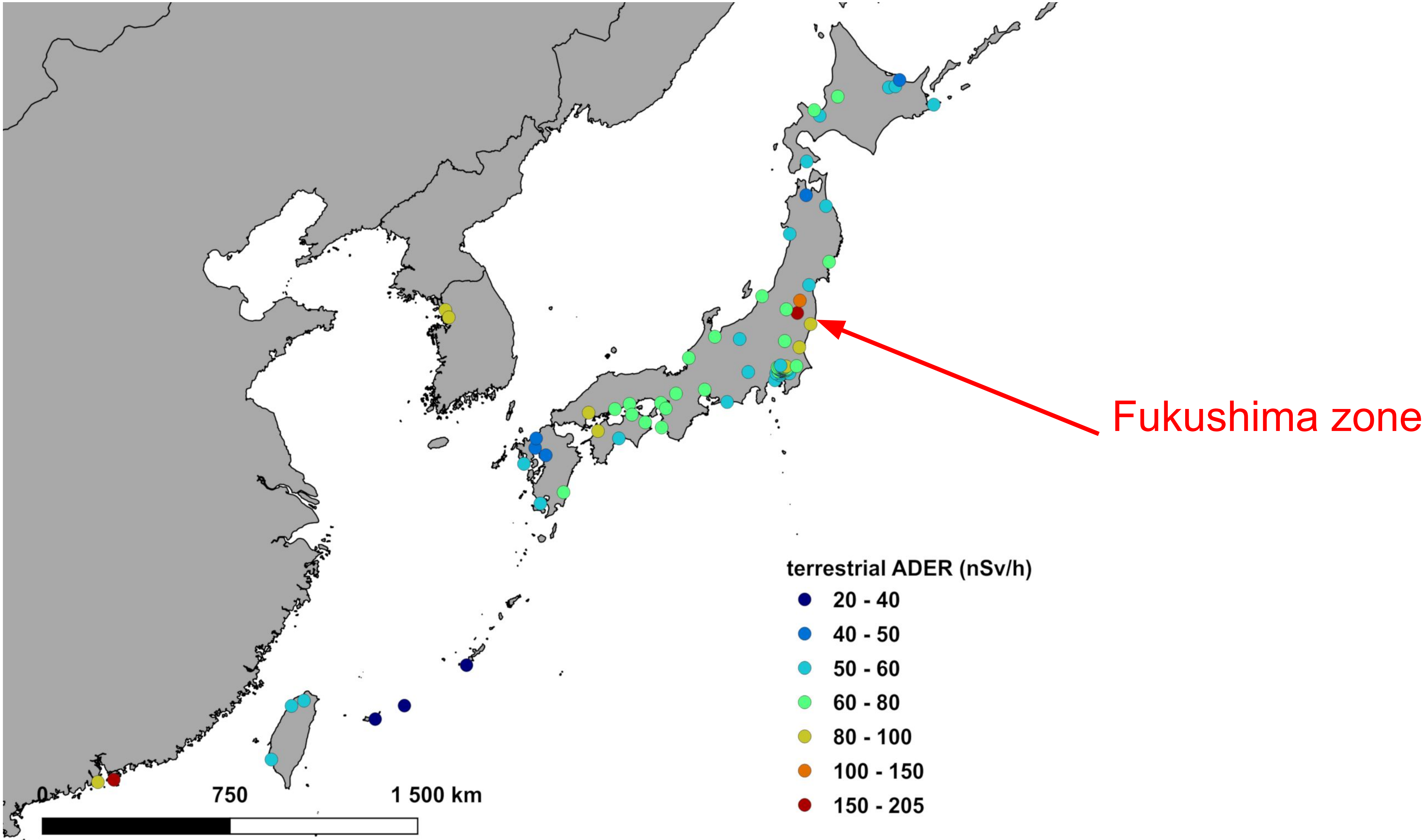
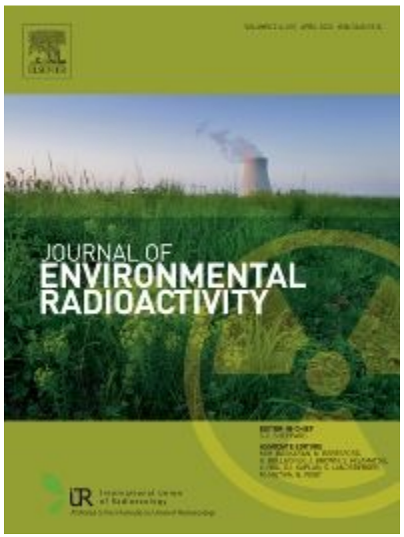
Mean estimated terrestrial ADER - Japan



Detailed results

- you will find all the results and more details about the processing in our article:



Peter Bossew, Petr Kuča, Jan Helebrant
Mean ambient dose rate in various cities, inferred from Safecast data
Journal of Environmental Radioactivity, in review

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Thank you for your attention