Measurement uncertainties and their impact on decision support

Johan Camps
Belgian Nuclear Research Centre (SCK•CEN)

johan.camps@sckcen.be

STUDIECENTRUM VOOR KERNENERGIE
CENTRE D'ETUDE DE L'ENERGIE NUCLEAIRE

Why looking into measurement uncertainties?

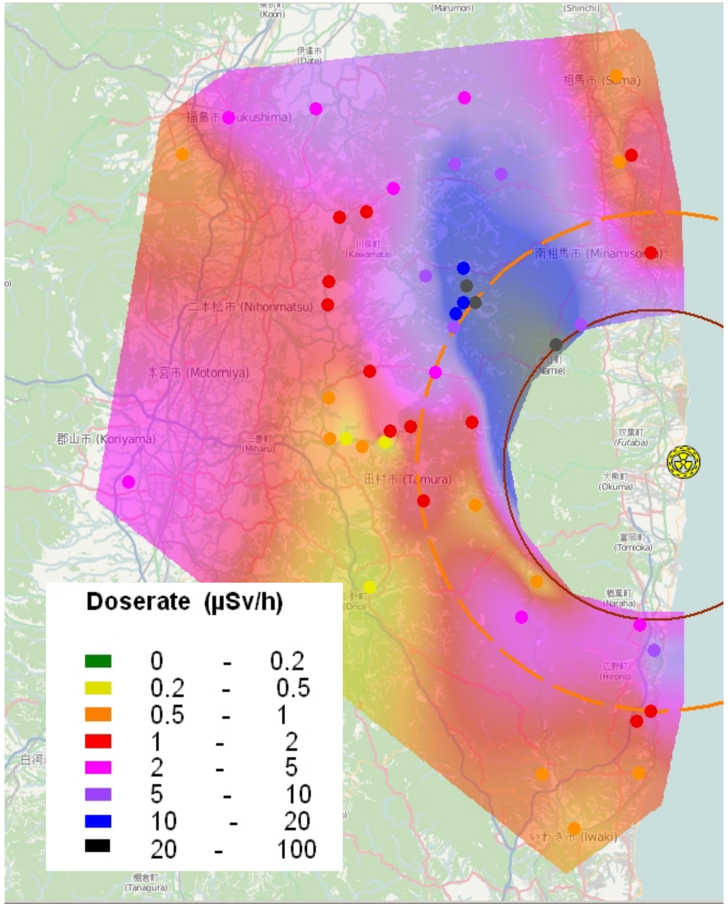
- Impact assessments of nuclear and radiological events are always characterized by large uncertainties:
  - Monitoring uncertainties;
  - Model uncertainties (models itself but also input , e.g.; exact location of the people: inside, outside , …)
  - The radiation induced effects: e.g. the effect of low-level radiation exposure

    See for example: **Fukushima's uncertainty problem**, Nature, 18 June 2012: **"It's remarkable how little we know about Fukushima's impact"**

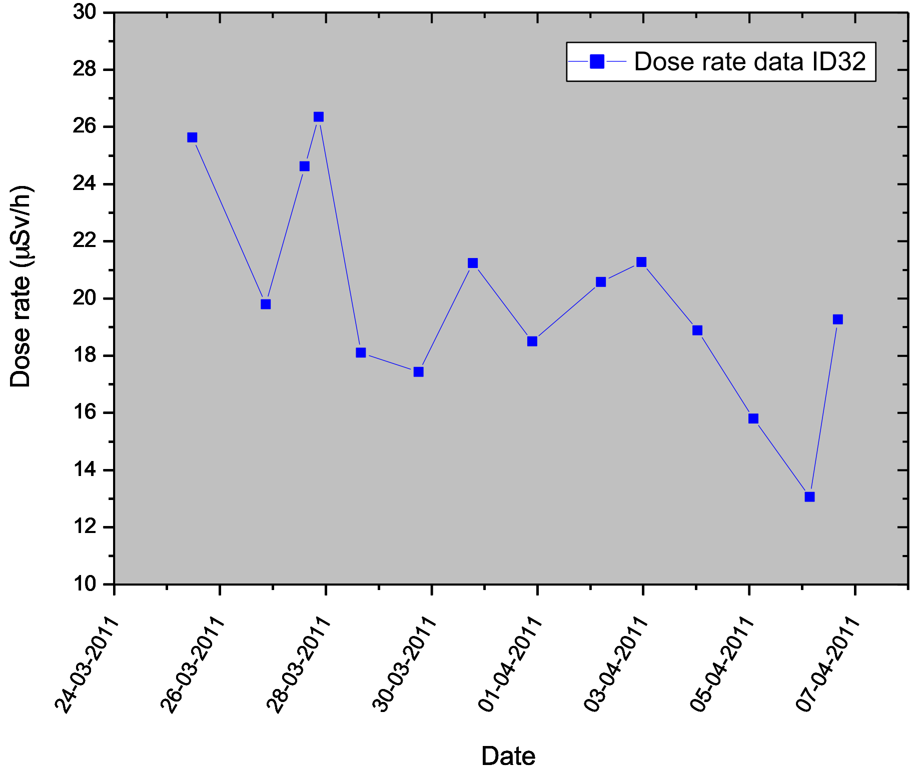
Monitoring (=measurement+interpretation) is often seen as least uncertain.

BUT: measurement/monitoring results are often directly used for protective actions: e.g. zoning (re-allocation), lifting of protective actions, decontamination actions, …

Example



Based on MEXT data
(30/03/2011)



General decreasing trend → decay short-lived radionuclides
But: what about the scatter?

- Real effects
- or uncertainties in measurements?

Uncertainty and good practice?

Measurement uncertainties are often not reported in emergency related measurements* (cf. early warning network results, contamination maps, …)

Code of ethics (IRPA/ Belgian Radiation Protection Society)

- Professional reports, statements, publications or advice produced by members should be based on sound radiation protection principles and science, be accurate to the best of their knowledge, **specifying uncertainty**, and be appropriately attributed.

*Note: this is in general the case for in-situ measurements, laboratories do report uncertainties on samples, but these include only the laboratory uncertainties and in general not uncertainties due to sampling. We focus here on in-situ measurements.

Why are uncertainties so hard

- Uncertainty is complex, often underestimated and, what is exactly meant by uncertainty:
  - Accuracy/error;
  - Precision;
  - Consistency;
  - Credibility;
  - Interrelatedness;
  - Representativeness, …;
- Uncertainty propagates: often measurements are used to calculate other quantities (e.g. 1st year dose);
- Uncertainty adds a dimension to the visualization: especially in geo-visualization (e.g. dose & contamination maps) this can be difficult;
- Uncertainty adds another discipline.

Do we have good knowledge of measurement uncertainties?

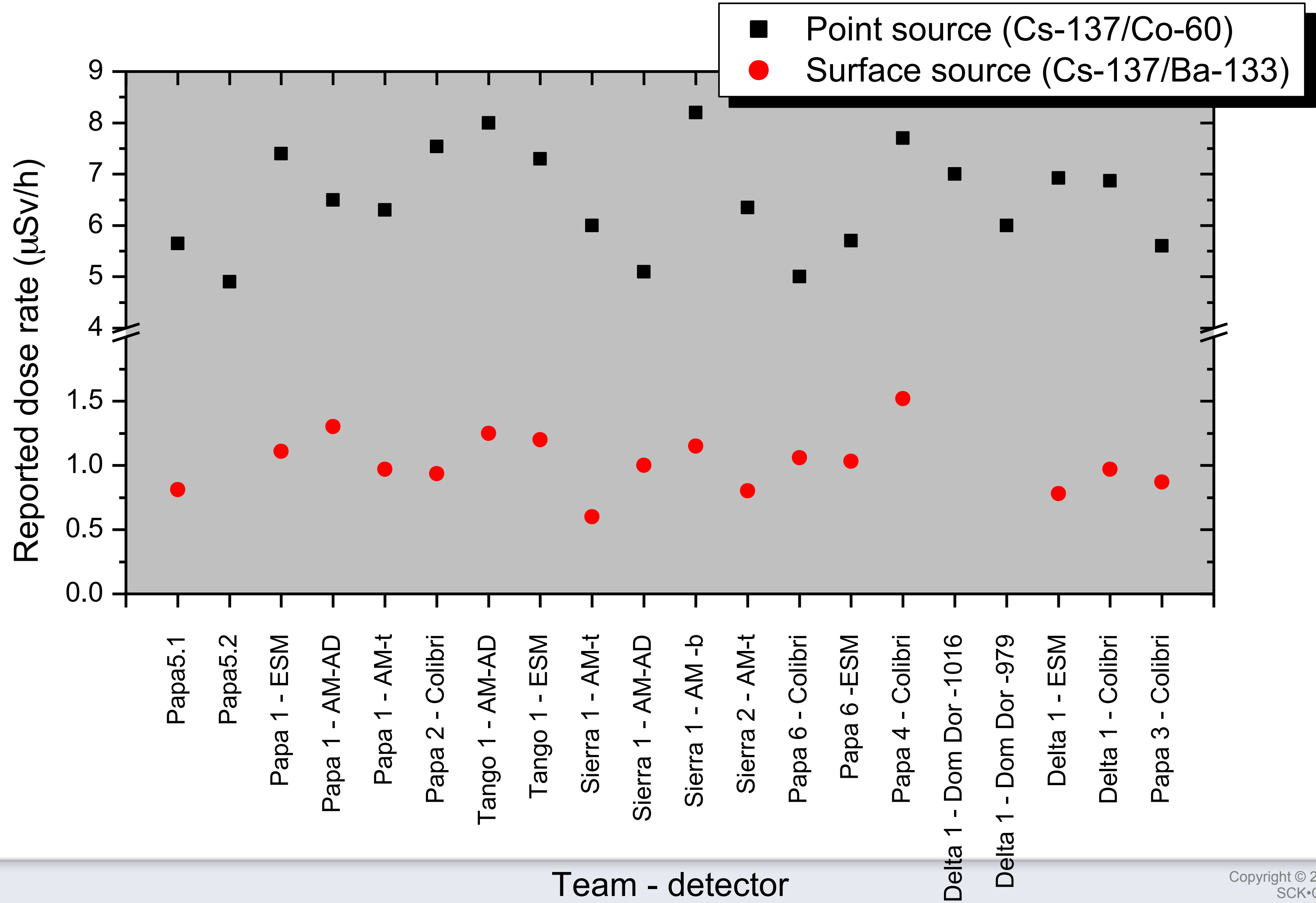
- Intercomparisons
  - Long tradition in intercomparisons for early warning networks in Europe (EURADOS)
  - European and national intercomparison (field) exercises
- Experience from accidents: e.g. Fukushima
- What about new technologies: e.g. radiation detection with smartphones

European intercomparisons early warning stations

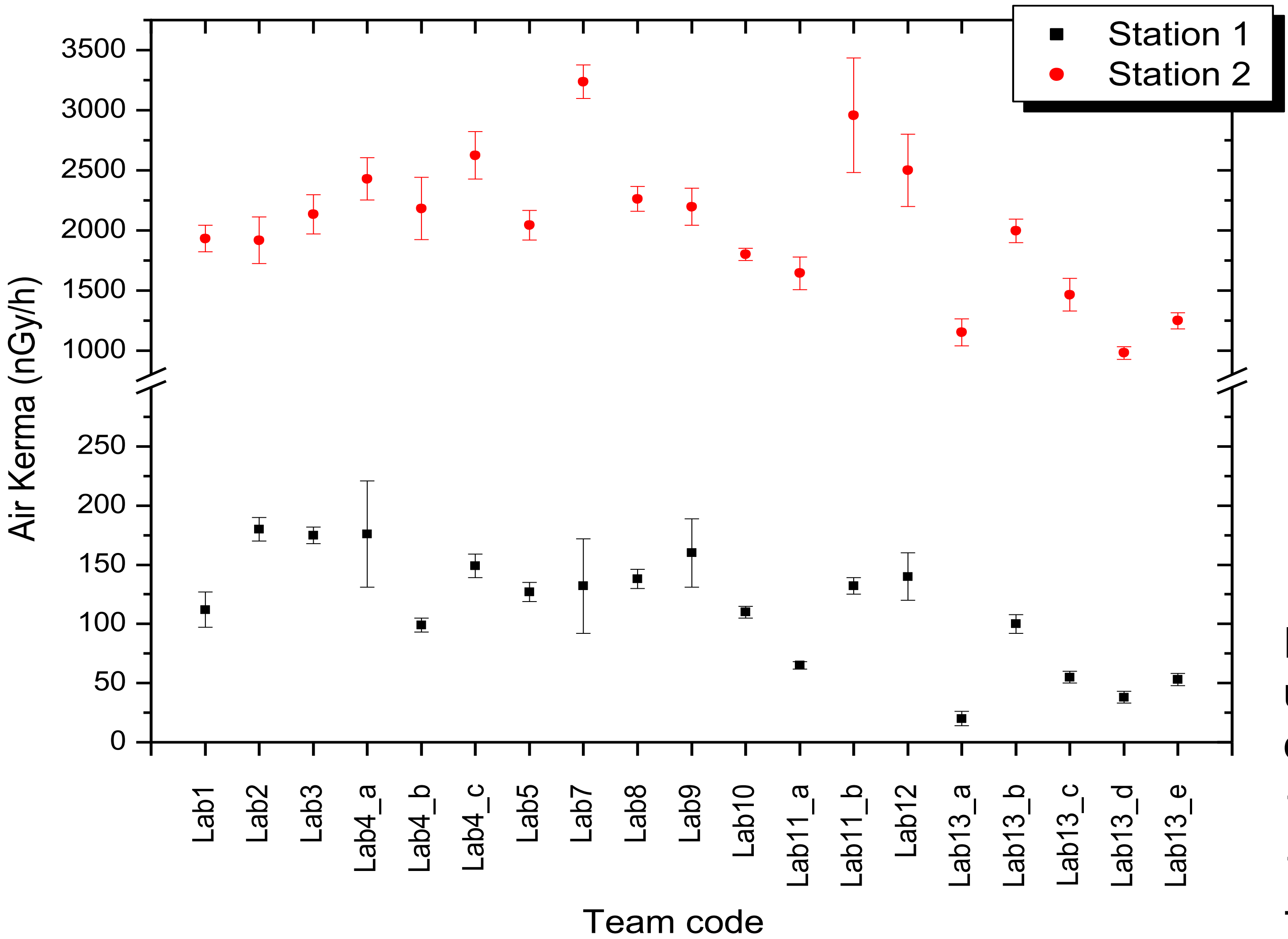
- Often focused on:
  - background levels;
  - minimal detectable levels of artificial radioactivity;
- Some conclusions from different exercises extrapolated to a real nuclear emergency:
  - problems can arise from harmonizing all the reported measurements because of different quantities used (air kerma rate K_a , ambient dose equivalent rate $H^*(10)$, photon dose equivalent rate H_x);
  - Some detectors have inaccurate calibrations (exceeding the IEC standards) or inappropriate automatic background subtractions, detectors with very specific response as a function of energy;
  - Huge differences (**up to a factor of 2**) in the absolute dose equivalent rate values.

Based on different published articles by Dombrowski et al. and Thompson et al; Radiation Protection Dosimetry

Results field intercomparisons - Belgian field drill (2014)



Results field intercomparisons – field exercise Spain 2011



Intercomparsion under field conditions:

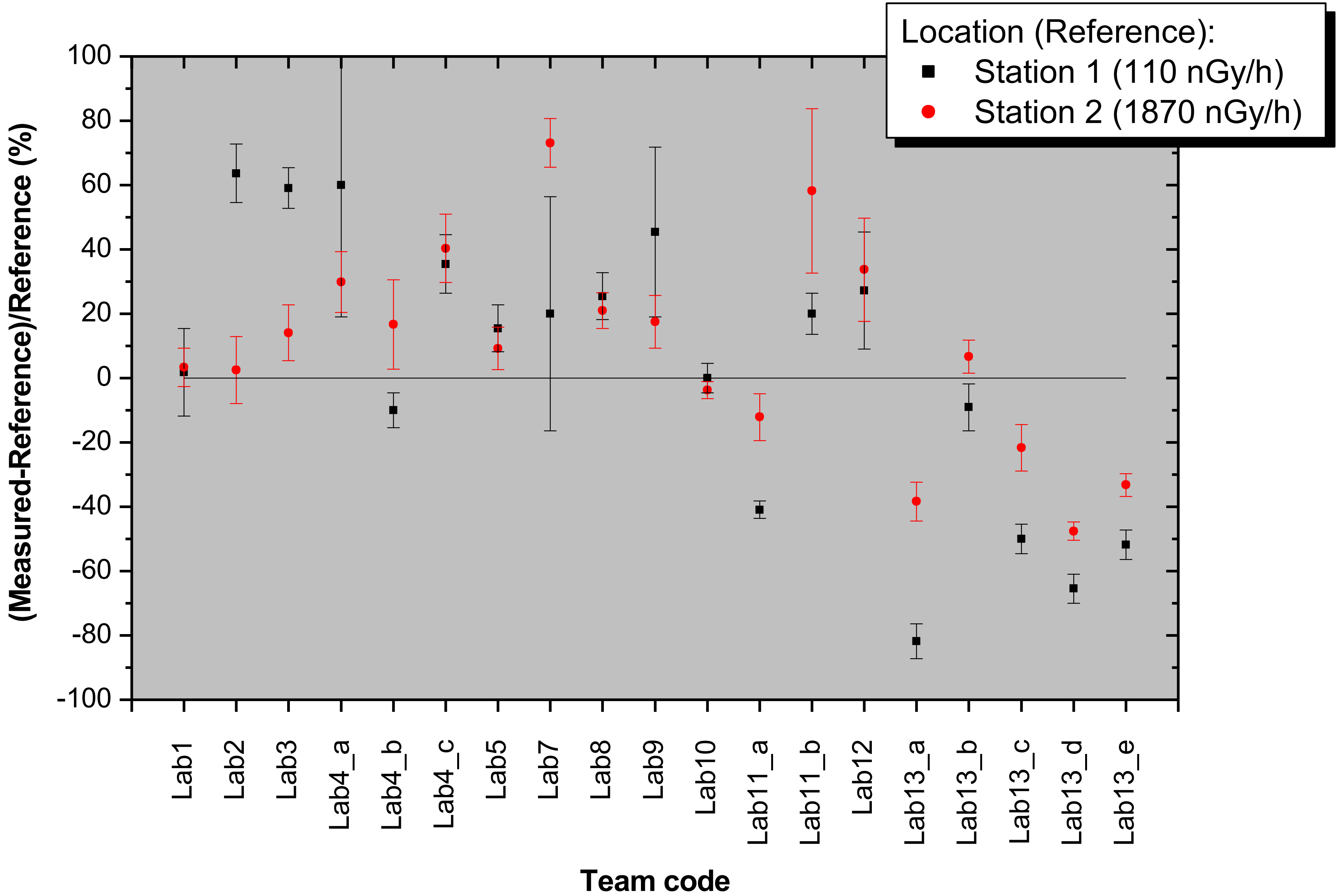
19 instruments

12 institutes

7 countries

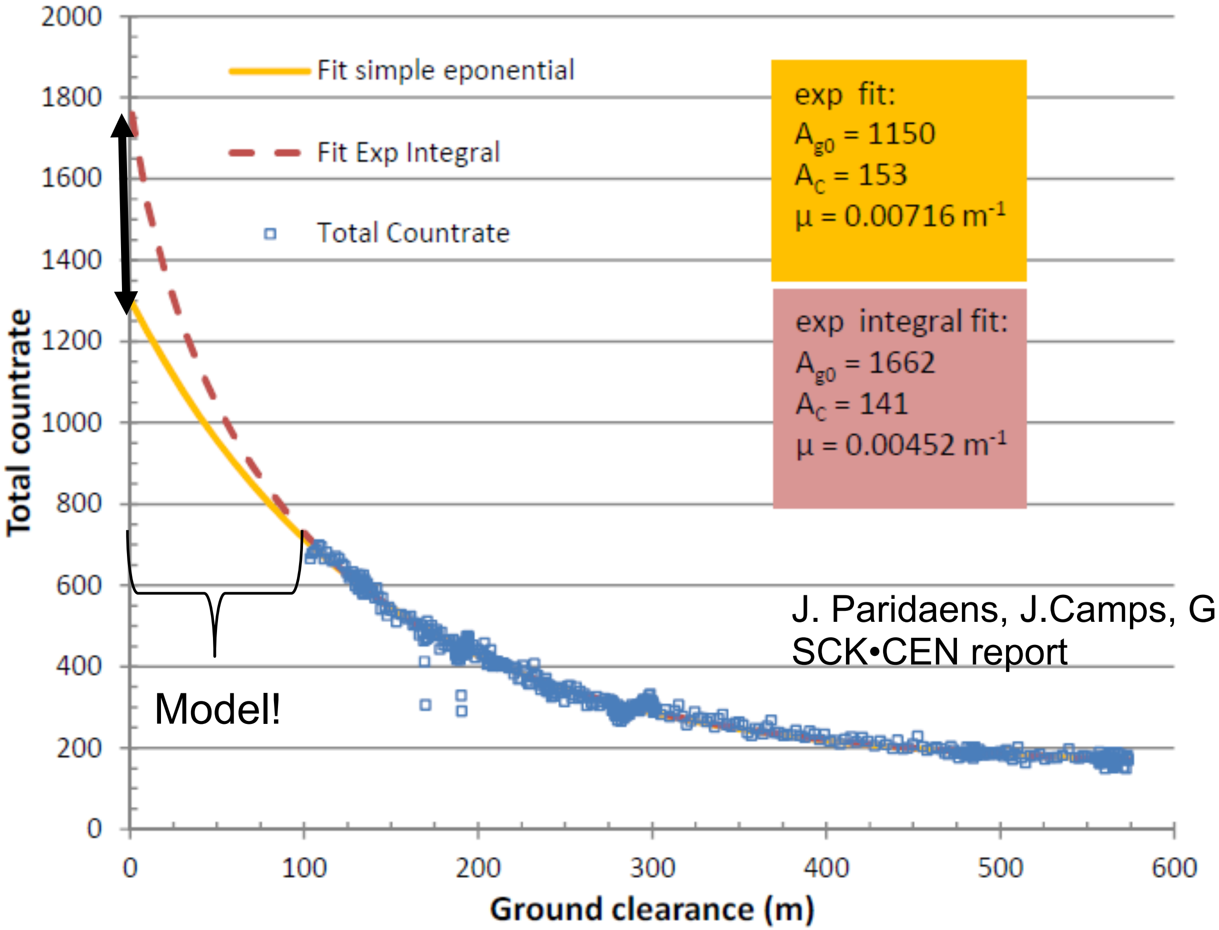
Based on data from: J.L. Gutierrez-Villanueva et al., Radiation Protection Dosimetry (2013), pp.1-8

Relative differences:



What about using only 1 detector: the example of airborne monitoring

- Good agreement within International Intercomparison Exercises (Germany, France & Switzerland)
  - Uncertainties reported of 40% in dose rate



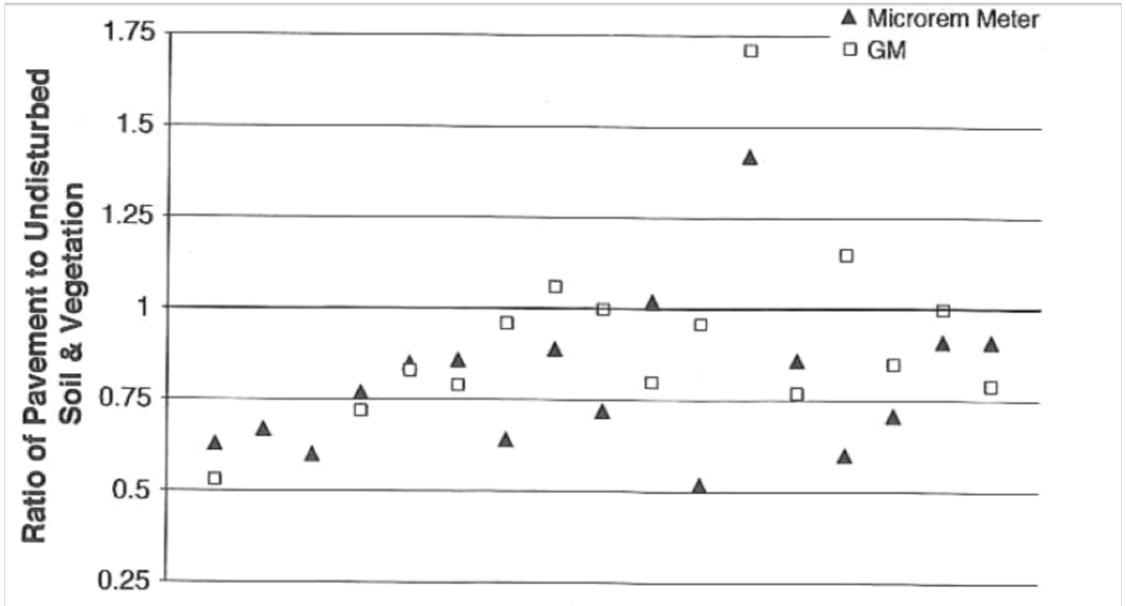
J. Paridaens, J.Camps, G.Olyslaegers & T. Vidmar, SCK•CEN report

Fukushima experience

Initial results US-DoE showed up to a factor of 2 between airborne measurements and measurements at ground level

In addition to uncertainty:

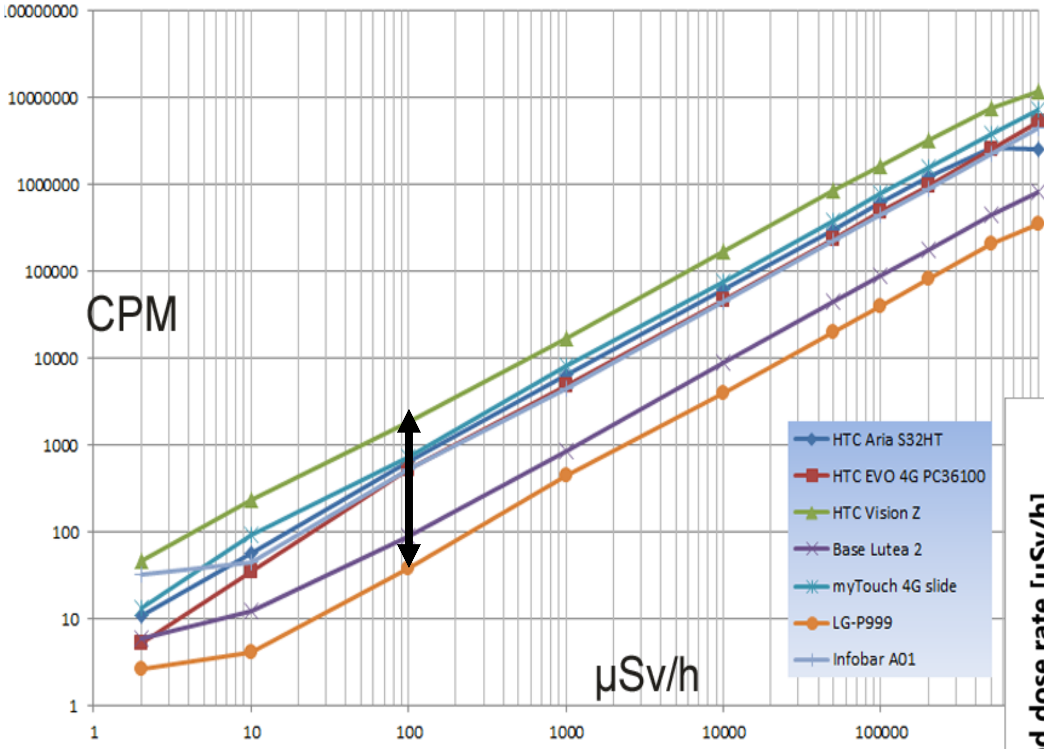
Representativeness: e.g. paved/undisturbed soil & vegetation



"Environmental measurements in an emergency: This is not a drill", Musolini et al., Health Physics, May 2012 – Volume 102 – Issue 5 – p 516-526

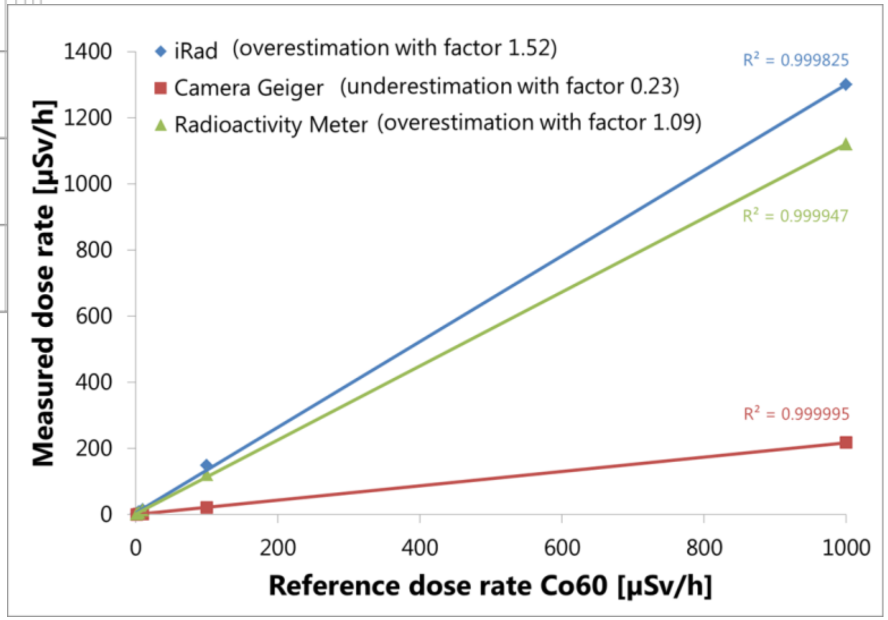
Combine many measurements?
Smartphone apps: typical response curves

Laboratory calibrations!



Android app Radioactivity Counter, R.D. Klein, www.hotray-data.de

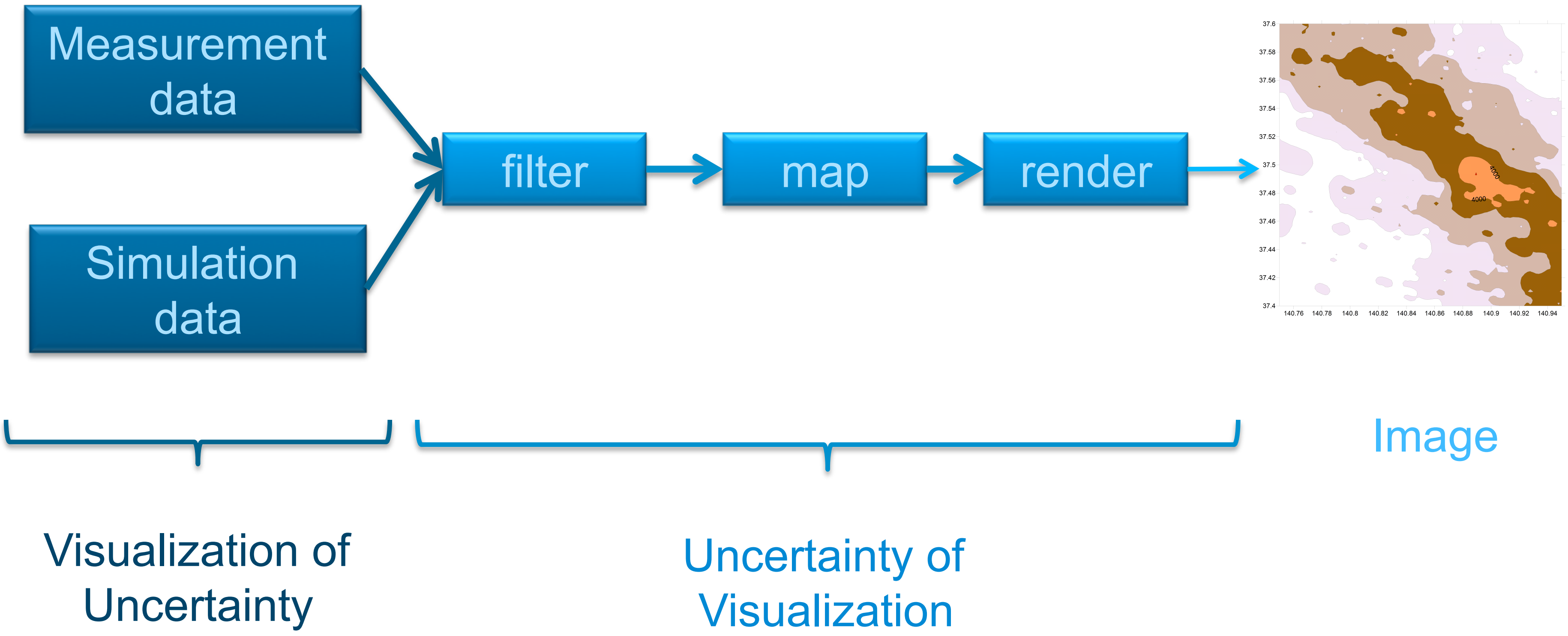
Different iPhone apps
V. Cauwels et al., SCK•CEN



Very large differences observed between phones and apps!

Visualization: the Uncertainty Reference Model

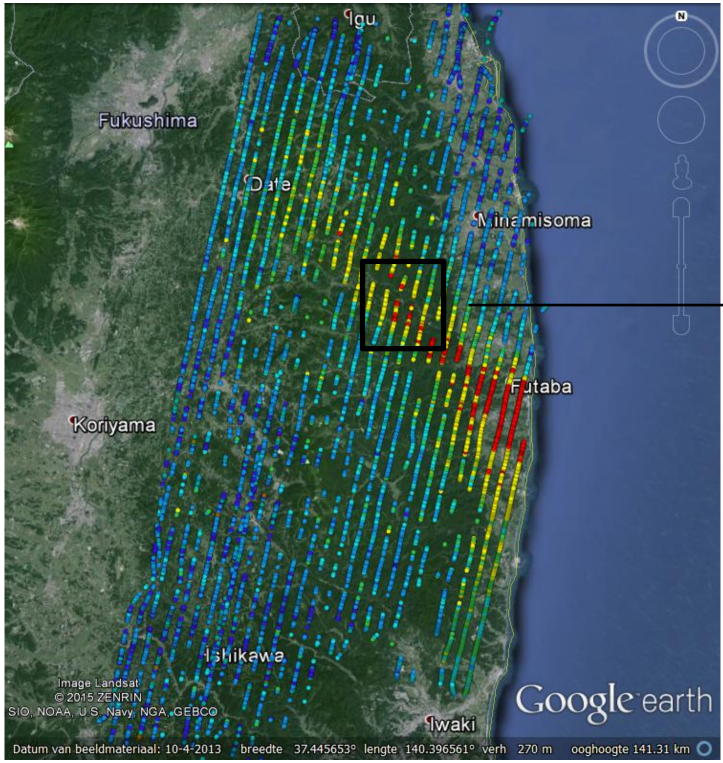
- Model of Haber & McNabb



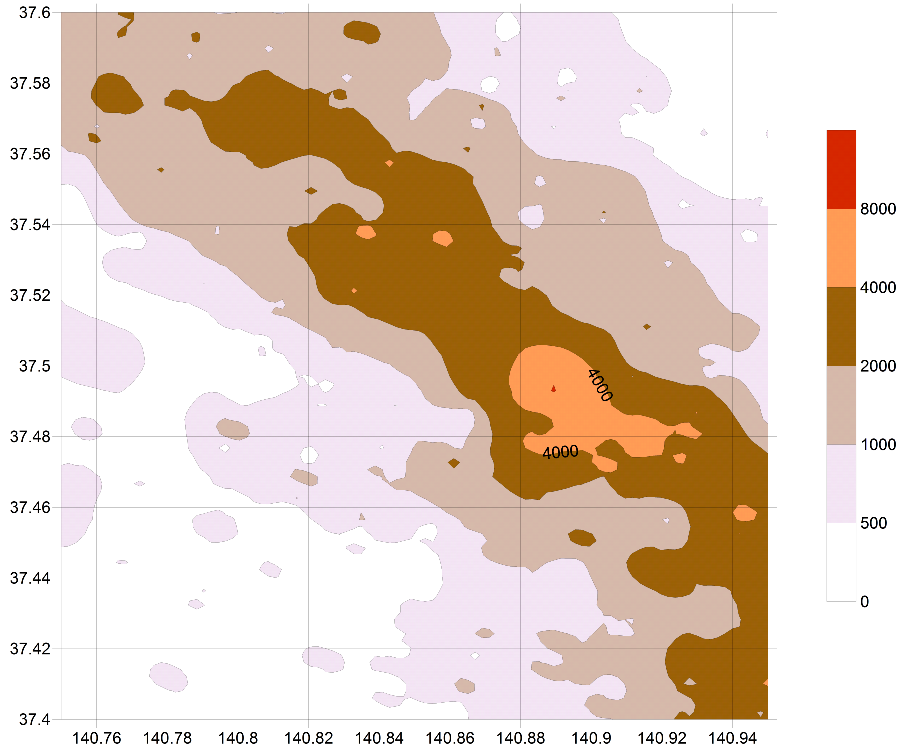
Based on: K. Brodlie et al., A Review of Uncertainty in Data Visualization

- What's the effect of the uncertainties encountered in the field intercomparsions on

→ Hypothetical case studied based on US-DoE data Fukushima (available via data.gov)

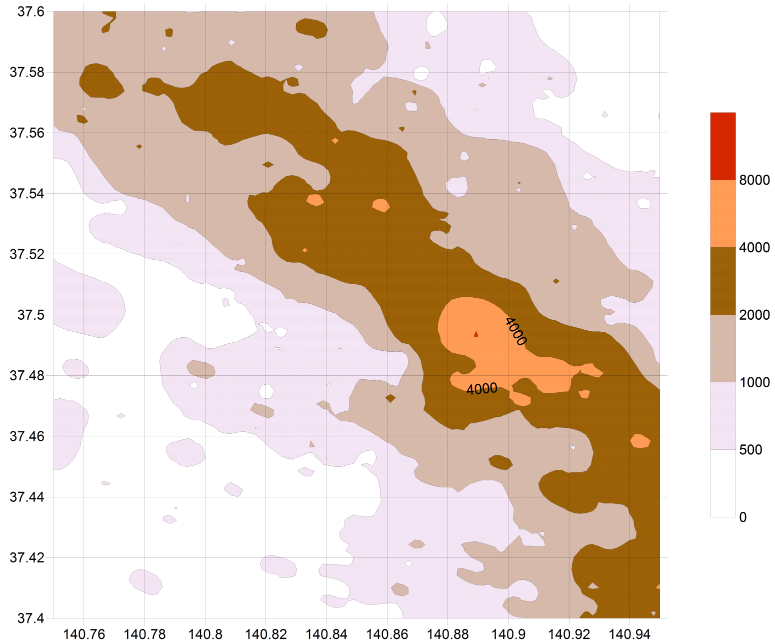


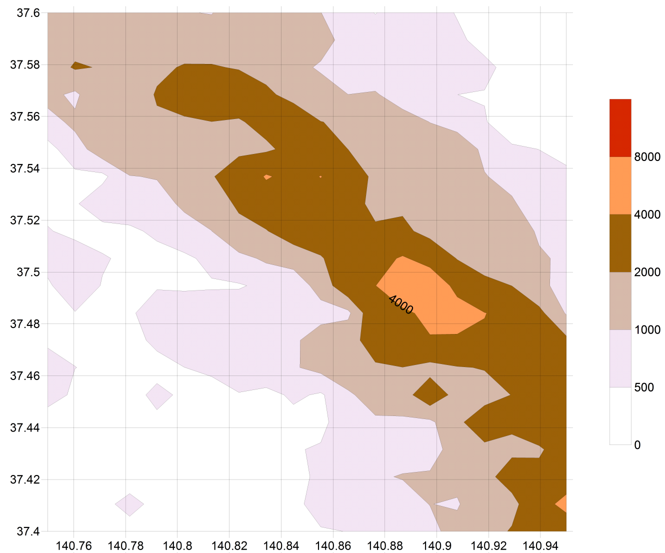
US- DoE Iodine Deposition data from Early Aerial Surveys (kBq/m^2)

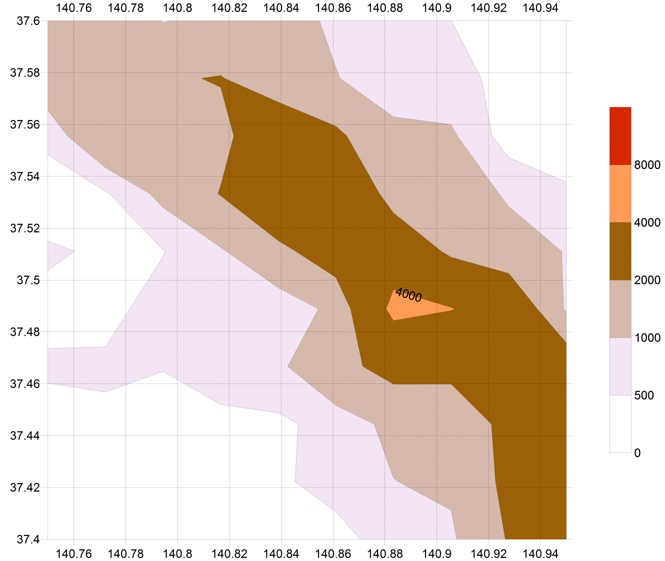


High resolution Kriging interpolated data used as reference

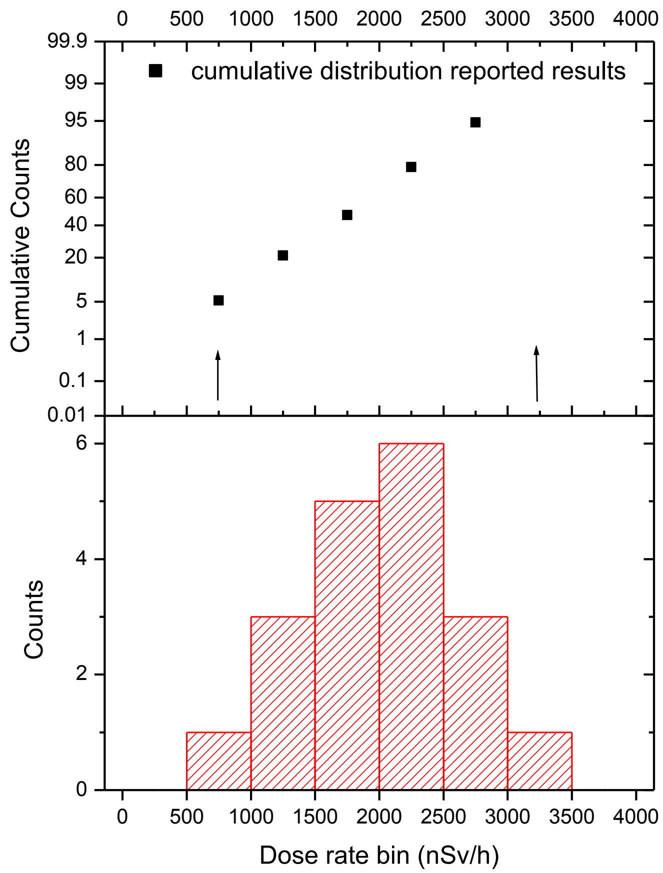
Uncertainty of visualization

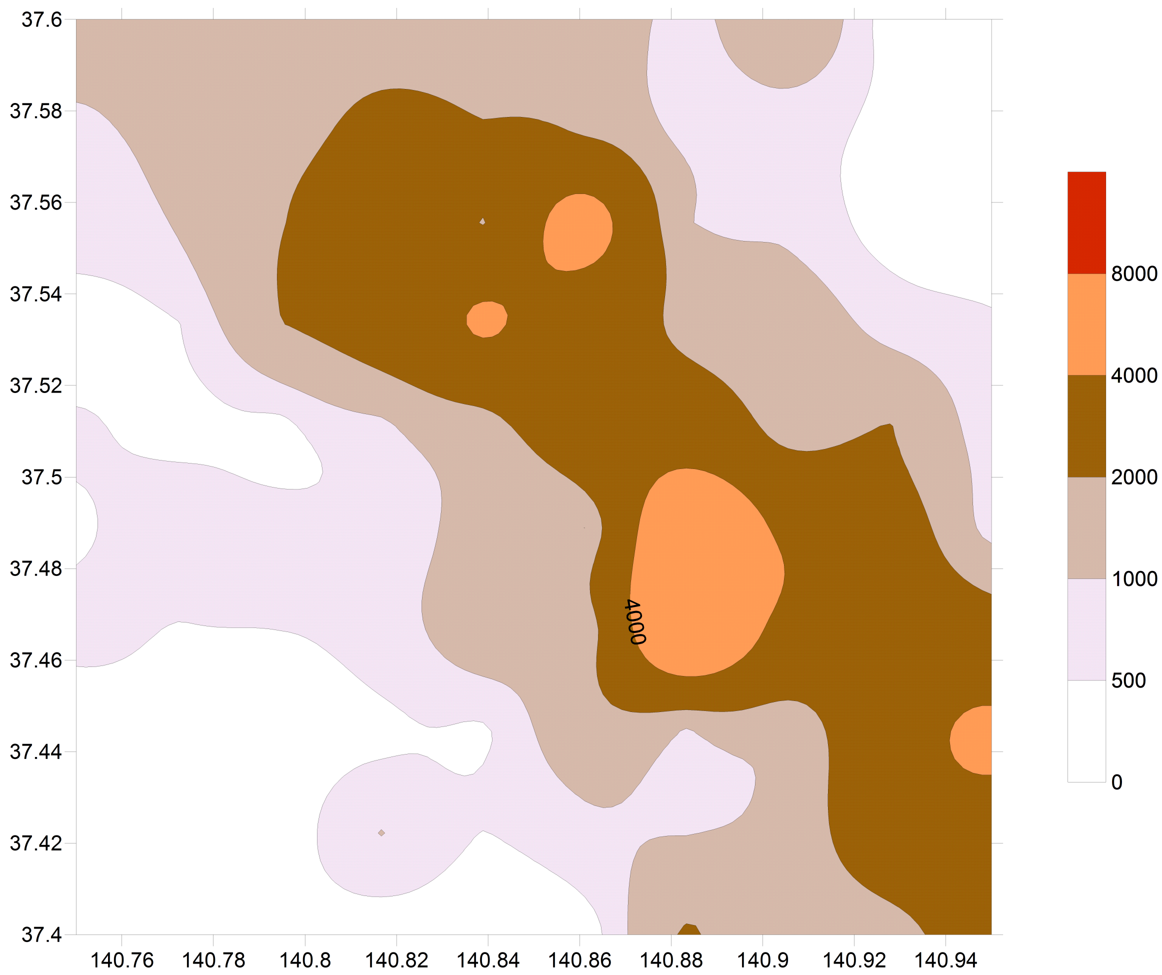






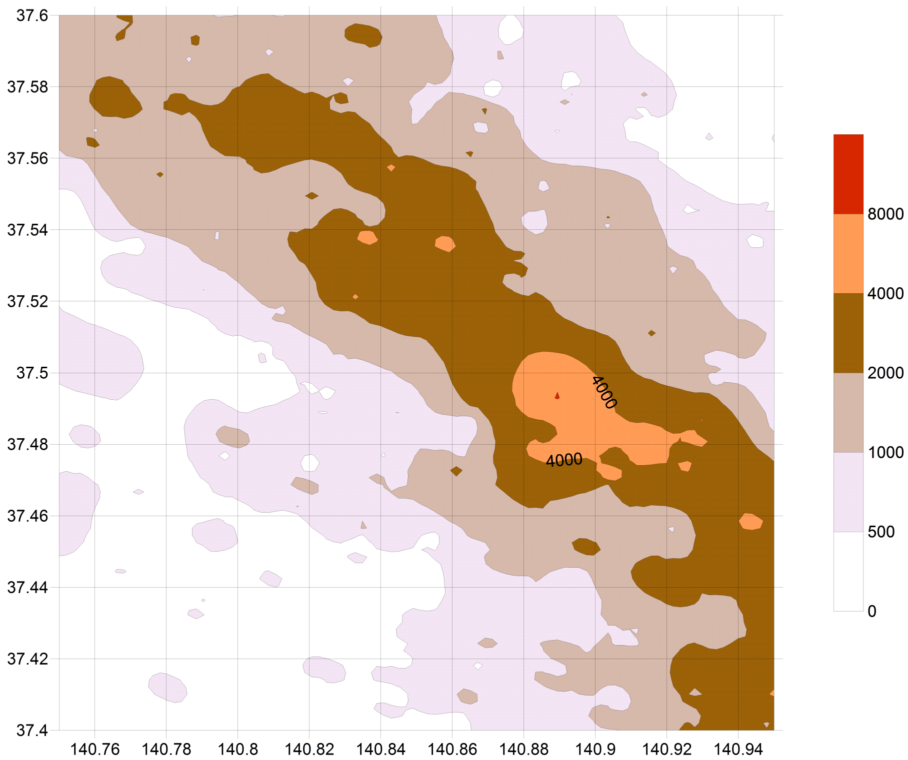
Visualization of uncertainty



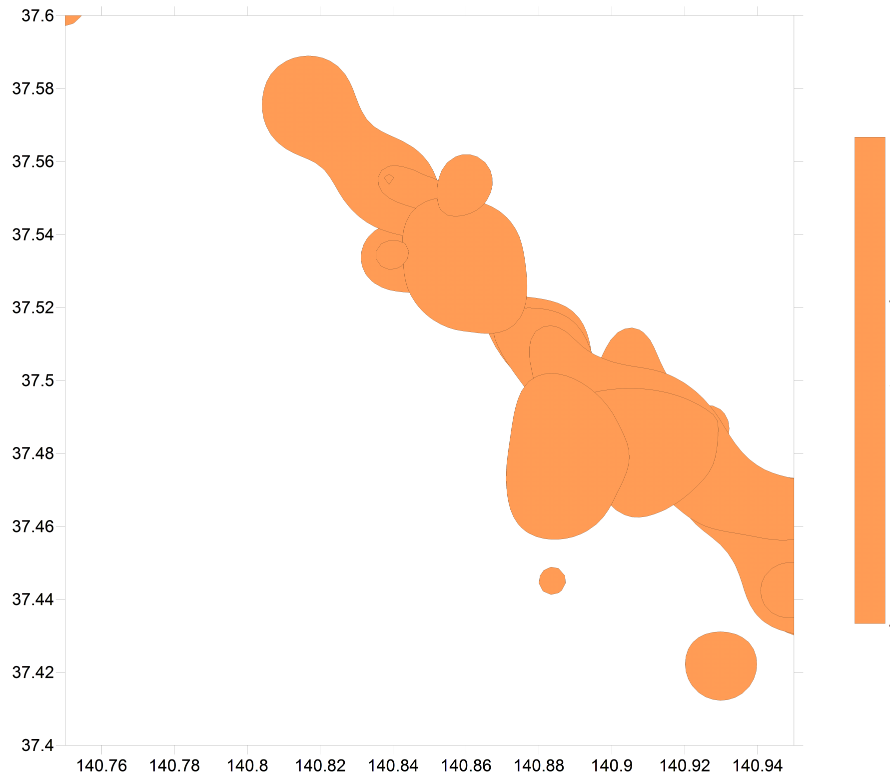


Data from field exercise used to create 10 maps, each map based on 100 measurements sampled according the distribution of field exercise results around values of reference map

A possible visualization:



Reference



Affected region (measurement uncertainty included)

Conclusions/Challenges

- Knowledge of measurement uncertainties: e.g. via intercomparison exercises in field conditions
  - It seems difficult to guarantee results within a factor of 2 without important effort
  - Much larger uncertainties are possible: e.g. for measurements with smartphones → clearly more research is needed
  - Intercomparisons are important to learn about uncertainties but do not directly lower them → how to lower them?
  - Use of reference areas (recommended within RANET)
- Incorporation of uncertainties in advise for decision makers
  - Uncertainty visualization: important R&D domain to be developed
  - Conservative approach: expand measured values by generic determined uncertainties
- Reverse the problem: what are the maximal uncertainties on measurement values to be useful for assessments and decisions?

SCK•CEN
Studiecentrum voor Kernenergie
Centre d'Etude de l'Energie Nucléaire
Belgian Nuclear Research Centre

Stichting van Openbaar Nut
Fondation d'Utilité Publique
Foundation of Public Utility

Registered Office: Avenue Herrmann-Debrouxlaan 40 – BE-1160 BRUSSELS
Operational Office: Boeretang 200 – BE-2400 MOL

SCK•CEN
STUDIECENTRUM VOOR KERNENERGIE
CENTRE D'ETUDE DE L'ENERGIE NUCLEAIRE