Workshop on "Radiological characterisation for decommissioning"
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Data Analysis for Radiological Characterisation: Geostatistical and Statistical Complementarity

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More information:
http://www.geovariances.com/

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The characterisation triptych

- A three legged stool: stability and simplicity
- If one leg is missing, the stool falls
- A stable position but uncomfortable

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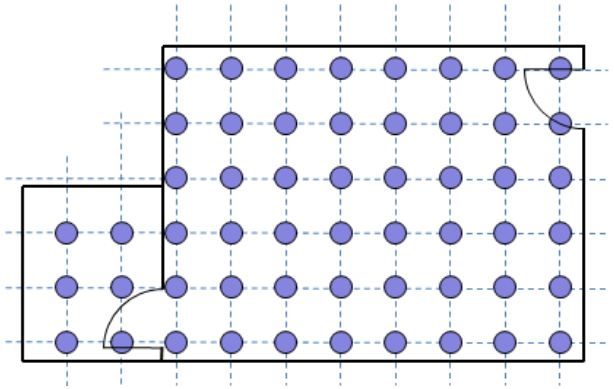
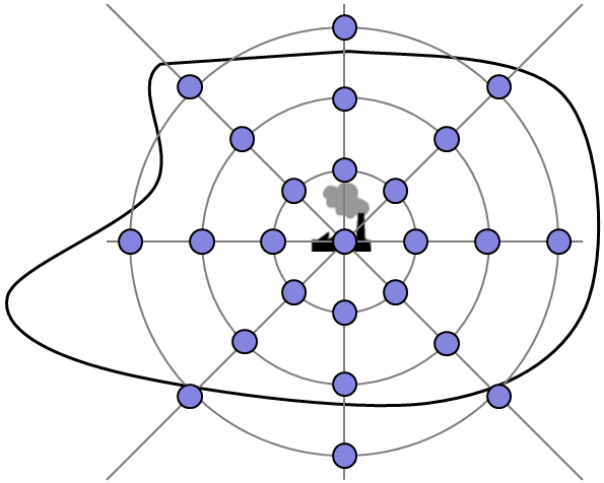
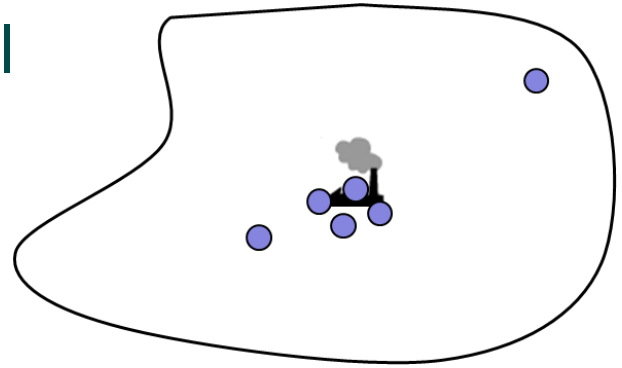
Reminder about sampling designs

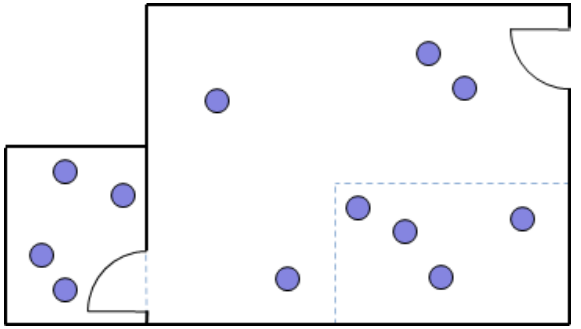
- Two main categories
  - Probability-based
    - Systematic
    - Random
  - Judgmental





- Mix possible to fulfil the evaluation objectives
- Iterative approach recommended





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Context

- Interrelated issues of D&D projects:
  - Regulatory deadlines, costs (maintenance, contractor, waste…)
  - Characterisation: Radiation protection of workers, waste categorisation and optimisation, monitoring, clearance criteria…

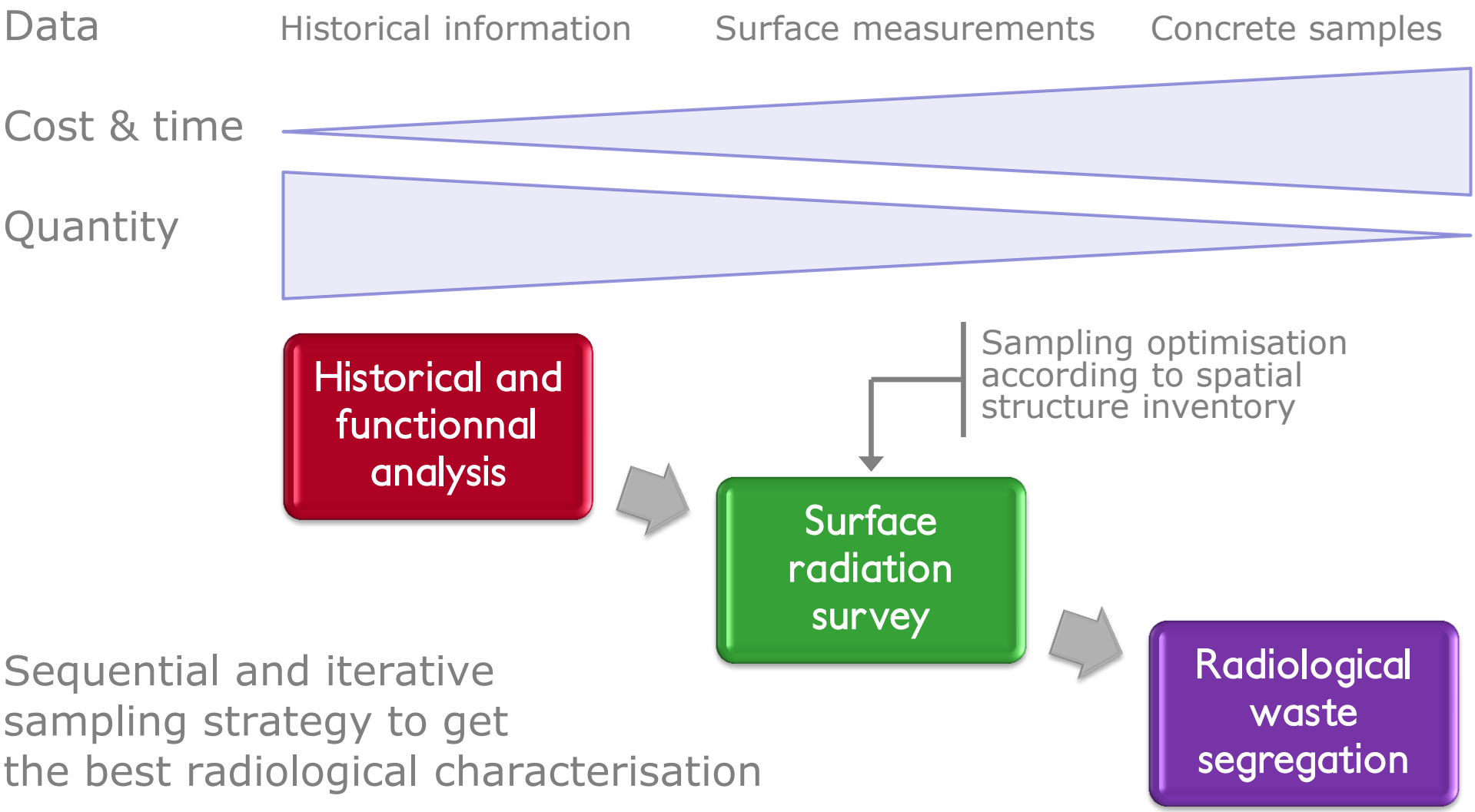
- Initial characterisation: a key stage for D&D success
  - "Segregation and characterization of contaminated materials are the key elements of waste minimization"
    (*Methods for the Minimization of Radioactive Waste from Decontamination and Decommissioning of Nuclear Facilities*, IAEA)

Geostatistics for initial characterisation

- Added values of geostatistics:
  - Successfully used for site characterisation (chemical & nuclear)
  - Implemented in the methodology for the radiological waste characterisation in former nuclear facilities
  - Sampling optimisation according to spatial structure inventory

- Key issues:
  - How to optimise the investigation costs?
  - How to take auxiliary information such as historical inventory and radiation maps consistently into account?
  - How to quantify uncertainties in the remediation costs while computing contaminated surfaces or volumes?

Characterisation Methodology



Sequential and iterative
sampling strategy to get
the best radiological characterisation

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Historical & Functional Analysis

- "Atelier D" of the ATUE facility, Cadarache CEA Centre
  - Exploitation for 30 years, several contamination incidents…
  - Radiological characterisation of a 800m² area (floors only)

"Atelier D" before process equipment dismantling

Before concrete decontamination

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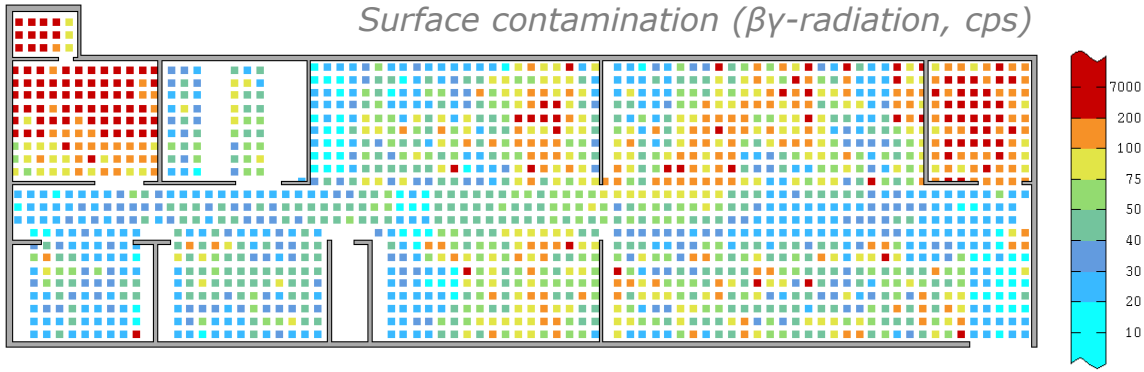
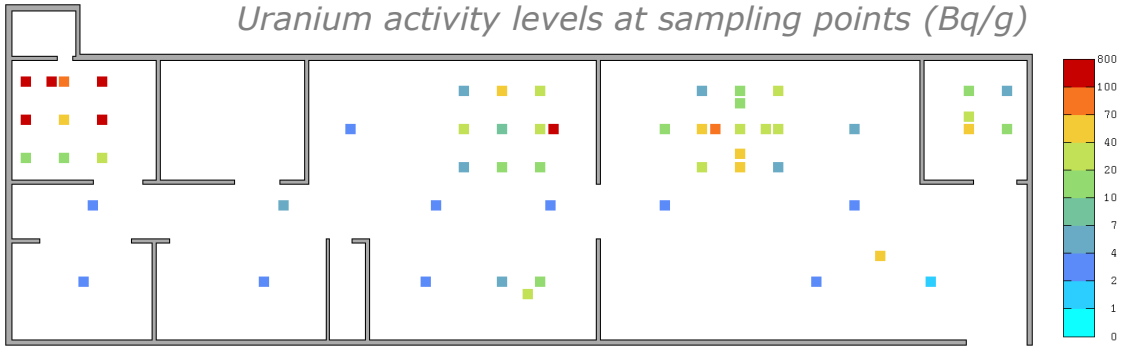
Data Collection

- Surface measurements
  - More than 1,600 based on a regular grid (66cm mesh)
  - Based on experience feedback on spatial structure
  - Additional measurements on walls, singularities…



- 56 sample points (scabbling):
  - Judgment localisation
  - Concrete samples, 1cm depth
  - ^{235}U activity levels



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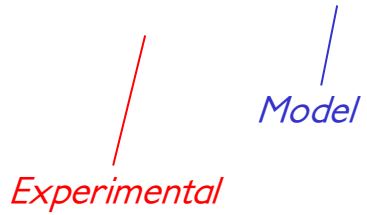
Methodology: Geostatistics

- Geo + Statistics: integration of the phenomenon spatial continuity
- Main tool of geostatistics: the variogram (describes the variability between 2 points)
  - on average, the difference between two CLOSE measures is LOW
  - on average, the difference between two DISTANT measures is HIGH

$$\gamma(h) = \frac{1}{2} E\left[Z(x) - Z(x+h)\right]^2$$

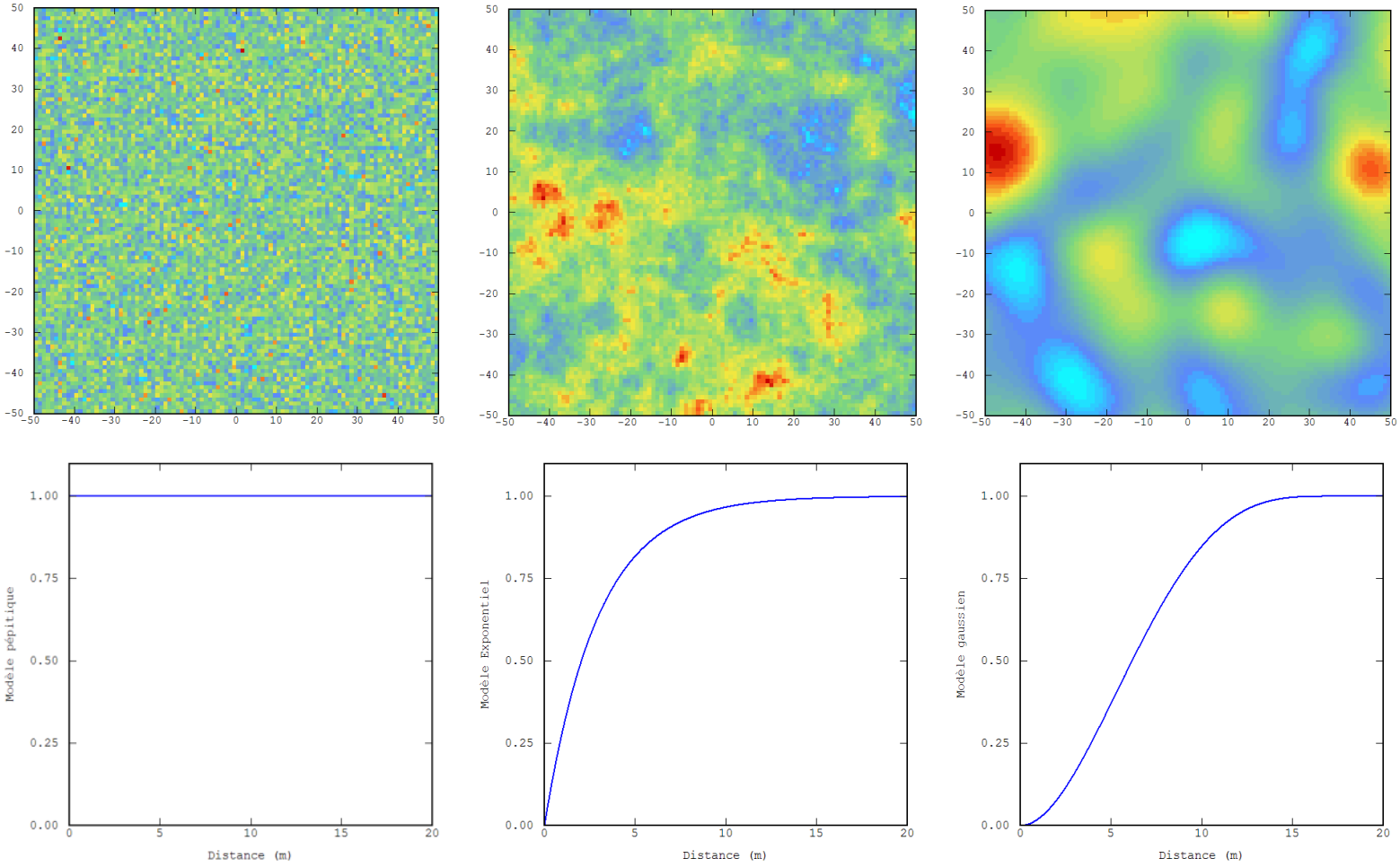
- The way the variogram increases with distance is linked to the phenomenon spatial variability



Spatial structure analysis: experimental variogram and its modelling

Spatial phenomena

- Same statistical distribution but…



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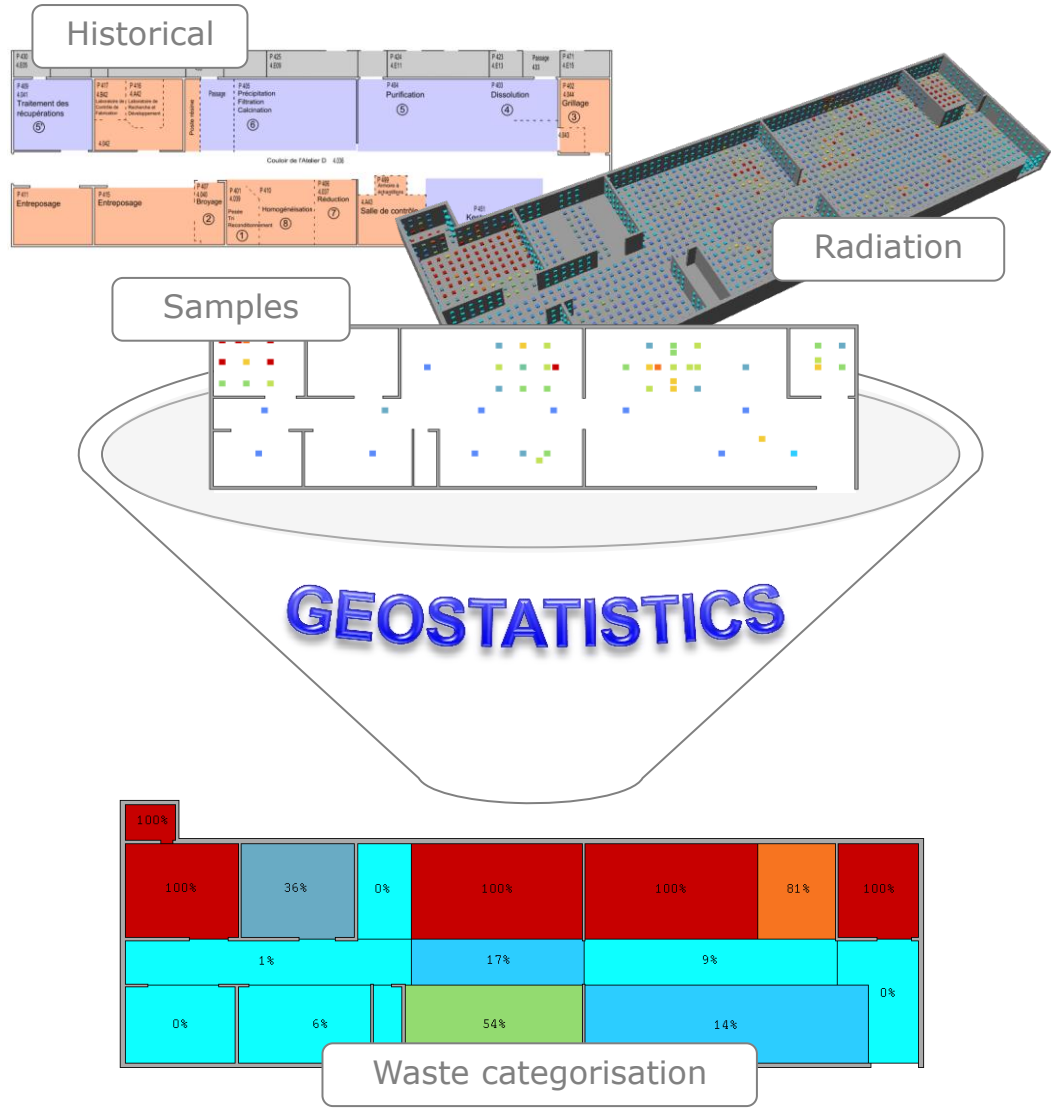
Data Analysis & Modelling

- Use of the geostatistical multivariate approach
  - Integration of all relevant information and data
  - Description of the spatial correlation between two variables:
    → Cross-variogram
  - Use of βγ-radiation so as to improve the estimation of uranium activity levels (uncertainty reduction)



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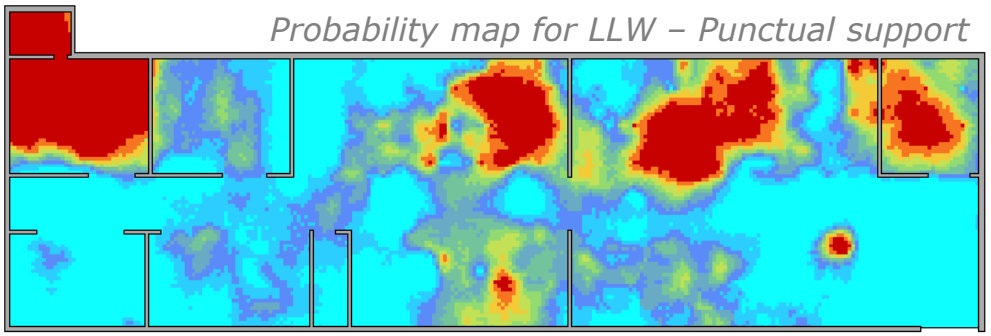
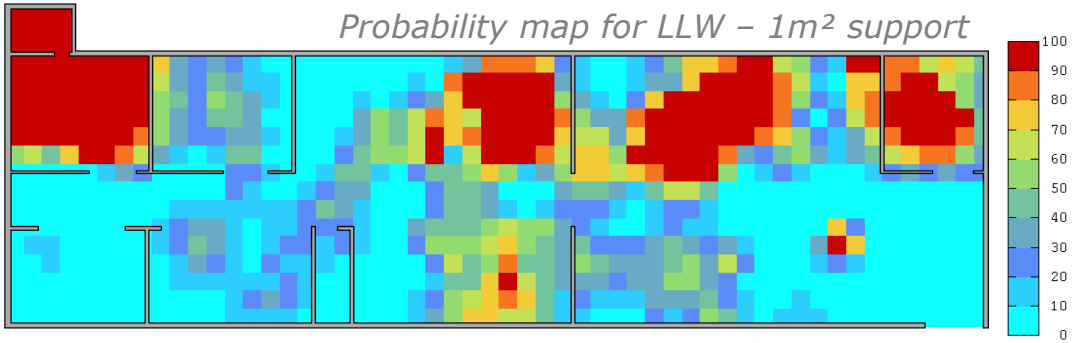
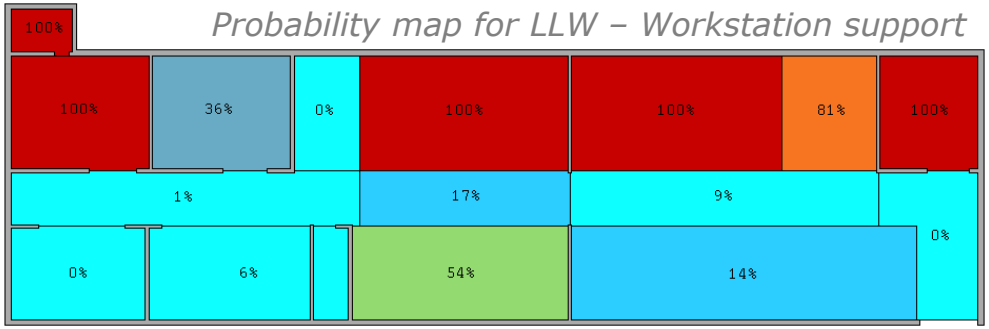
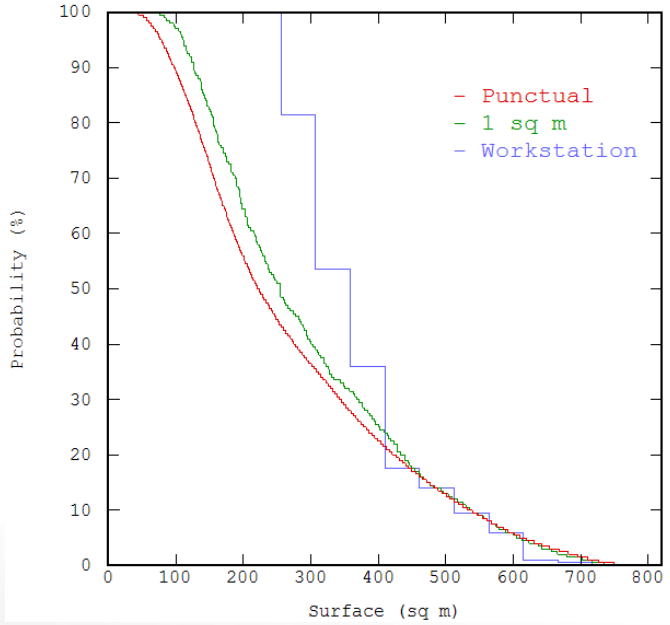
Risk Analysis & Estimation Support







- Taking the decision support into account:
  - Punctual → Hot spots
  - Block → Waste category
- Impact on categorisation surfaces (averaging)



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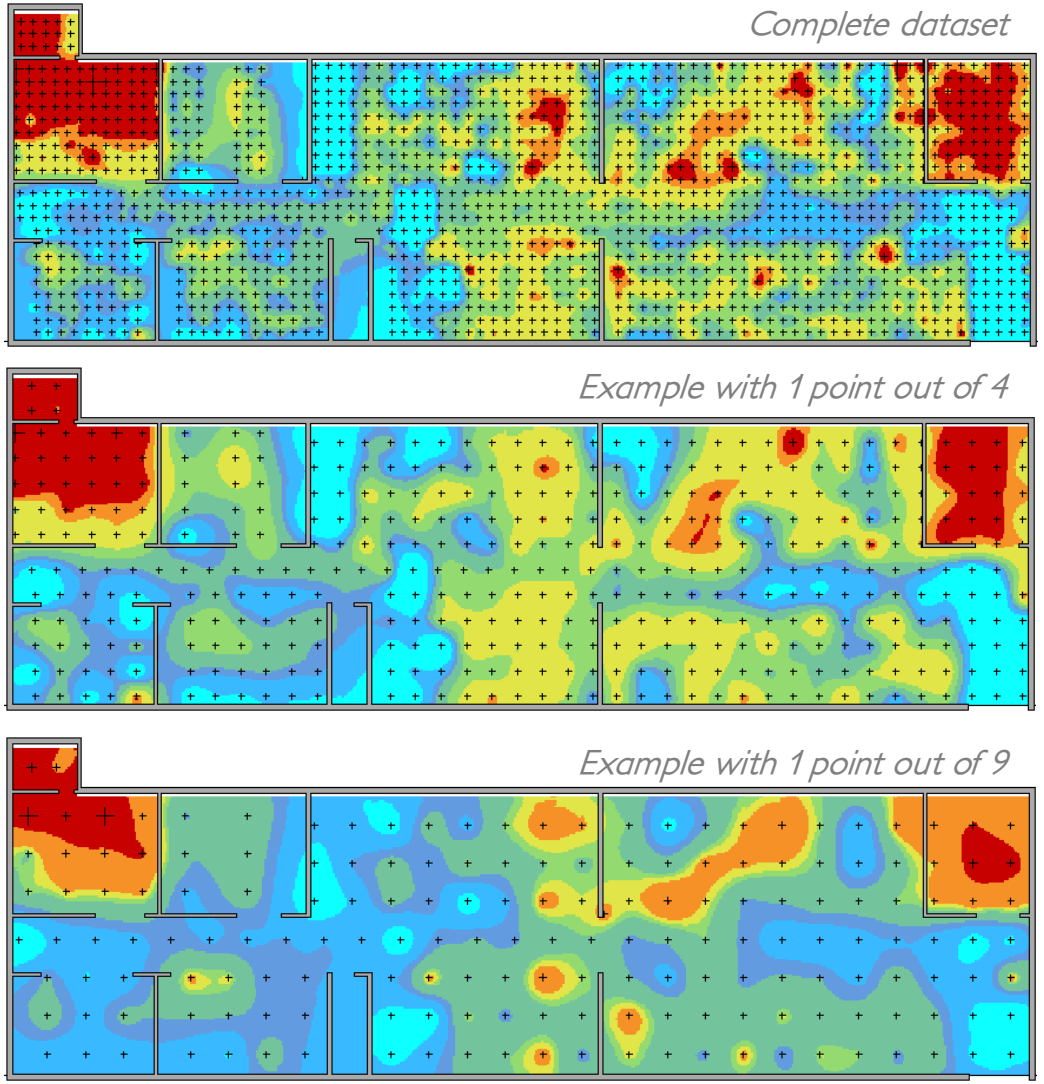
Sampling optimisation

- Impact of the initial mesh on the estimation maps:
  - 0.66m, 1.3m, 2.0m
- What is your objective?
  - Hot spots
  - Average dose rate
  - Waste zoning
  - …



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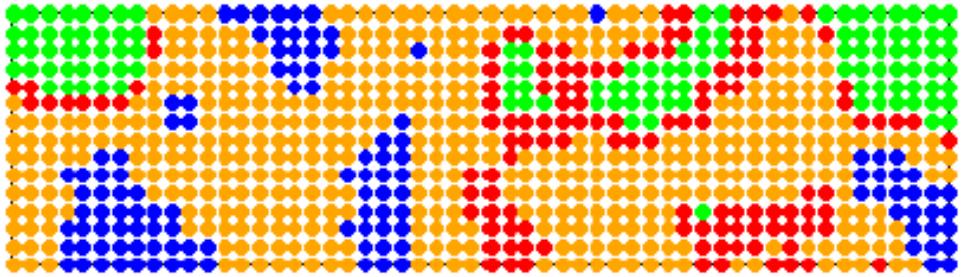
Sampling optimisation

- Integration of the geostatistical analysis of values to optimise the number and location of data points

  - Initial mesh determination (feedback on spatial structures)
  - Defining additional points (on risk maps)
  - Positioning samples on radiation maps (use of the correlation between values)

Map of the false negative risk

(declare as clean a contaminated area)



- *Low risk*
- *Intermediate risk*
- *High risk*
- *Declared above the threshold*

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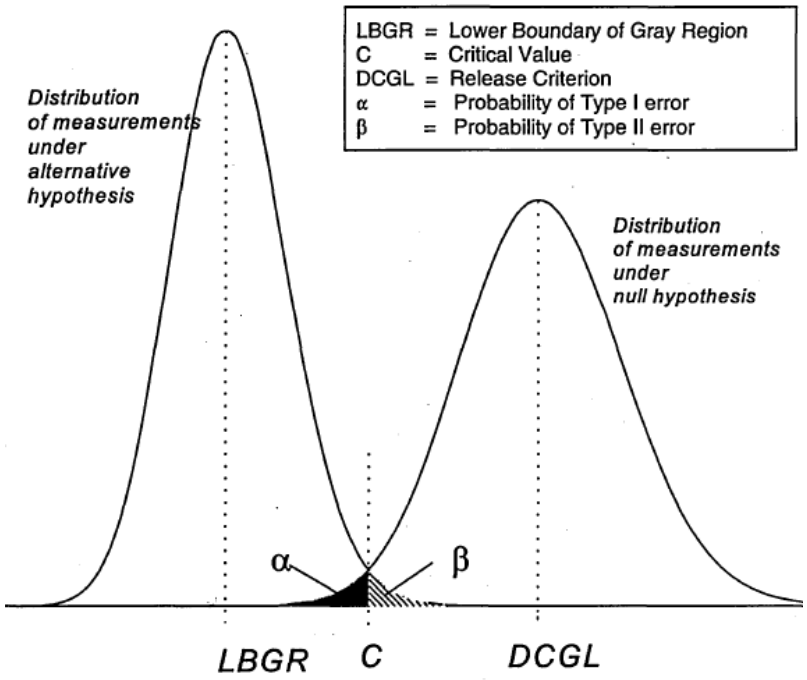
Final survey

- Natural use of classical statistics
  - Compare average to a fixed threshold, compare proportions, estimate the mean, construct a confidence interval on the mean, etc.
  - A lot of literature describing the statistical tests and the optimisation of the number of samples (MARSSIM…)
  - Attention should be paid to the underlying hypotheses:
    - spatial randomness of values,
    - shape of the distribution…



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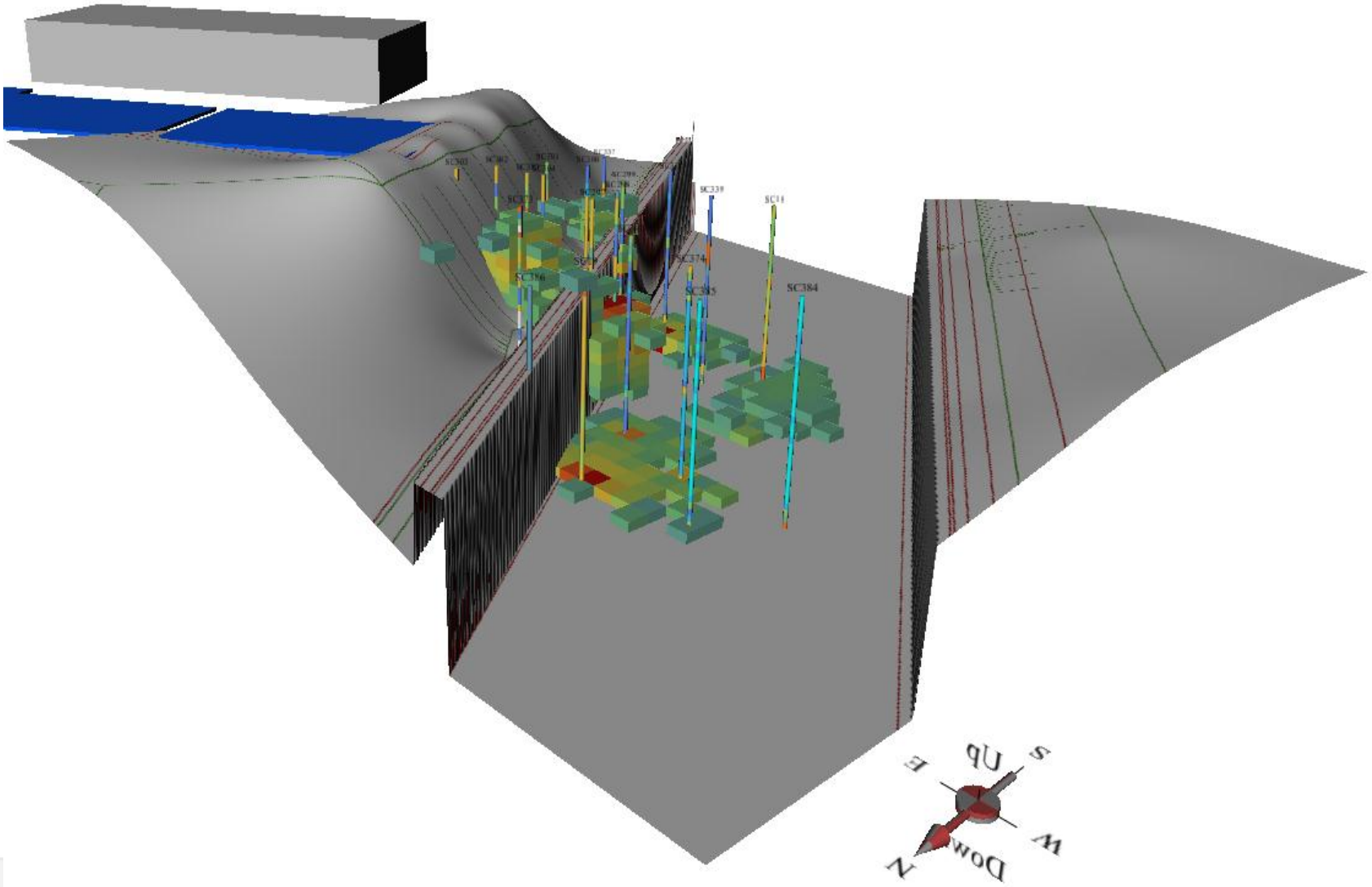
Conclusions

- Know your objective!
- Collect relevant data to be able to draw the conclusions needed
- Adapt the sampling design and the data processing

- Systematic presence of spatial continuity for initial characterisation of radiological contamination → Relevance of geostatistics
  - Risk analysis tools and sampling optimisation (iterative, multivariate)
- For final survey → Use of classical statistics

A deep contamination example



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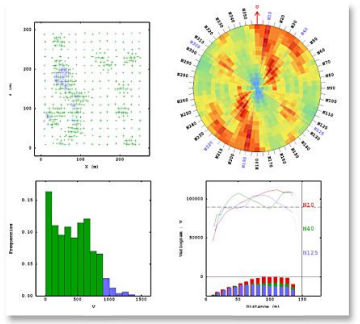
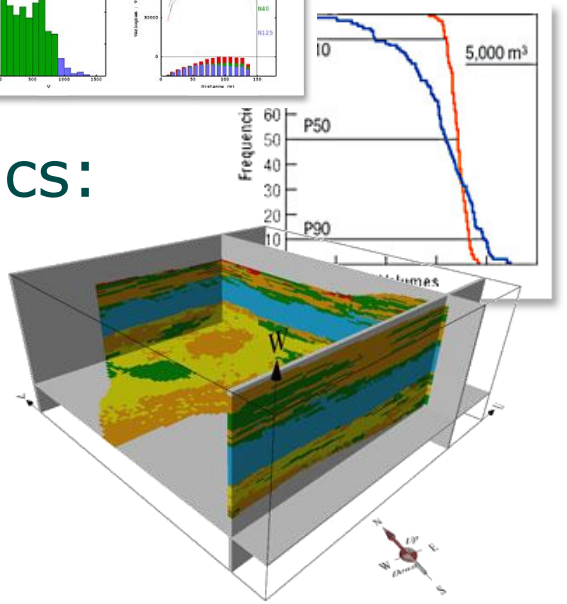
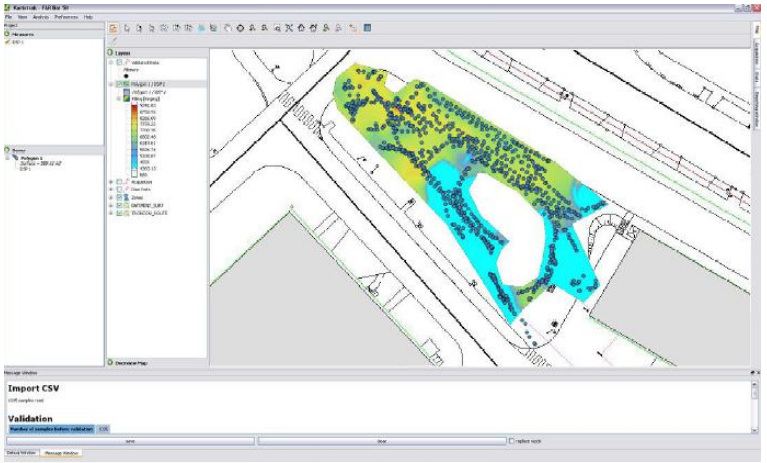
Geovariances in brief…





- World leader in advanced geostatistics
- The most complete solution in geostatistics:
  Innovative Methodologies,
  Experts & Software packages
- kartotrak all-in-one software solution for contaminated site characterization
  - GIS-based with sampling optimization
  - Real-time contamination mapping
  - Risk assessment for decision-making process



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Developed in partnership with cea