Panel Session #87

Characterization & Survey for
Decommissioning and Waste Management
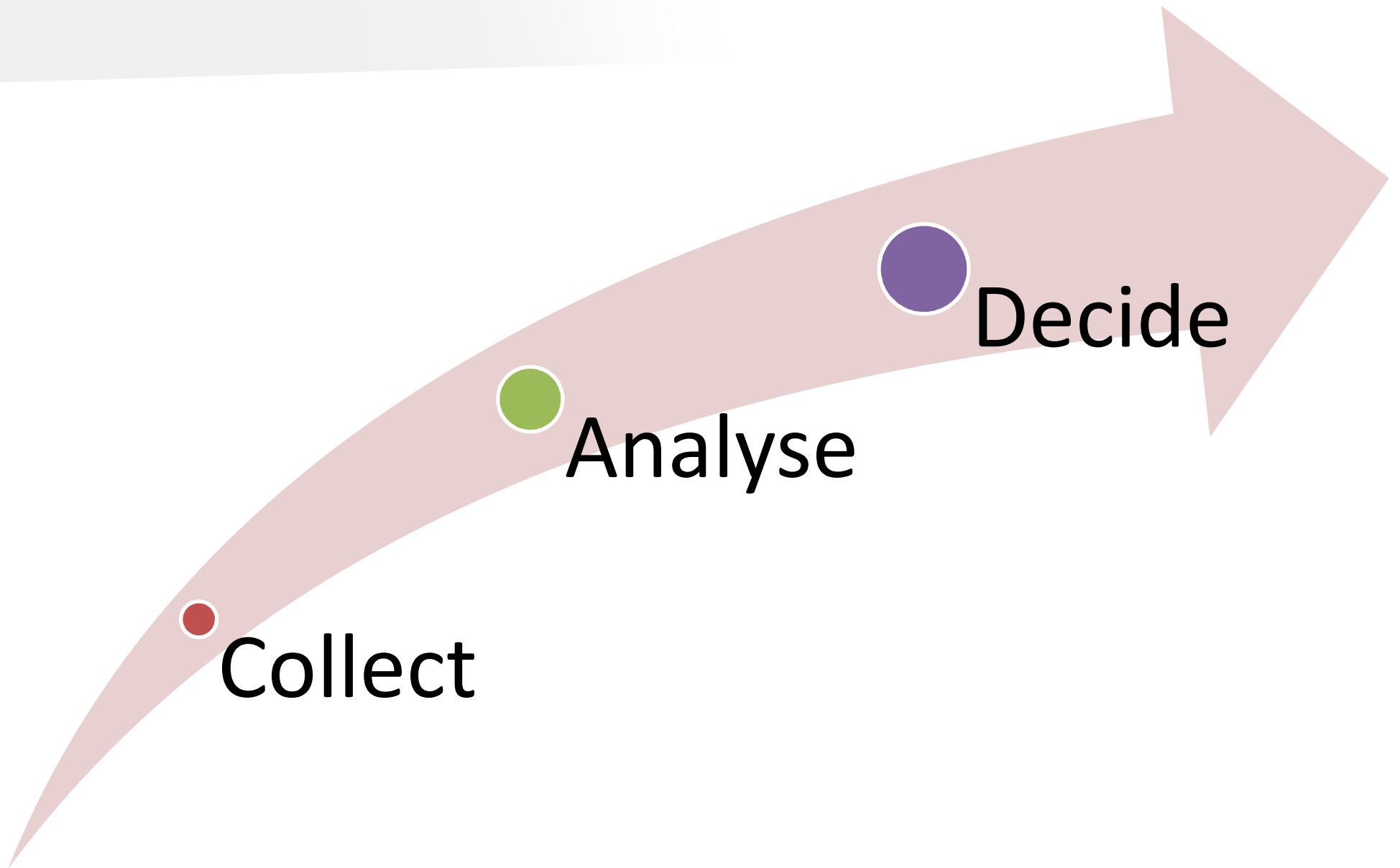
# Geostatistics
# for Radiological Characterization
# and Sampling Optimization

Yvon DESNOYERS

*More information:*
*www.geovariances.com*

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Collect

Analyse

Decide

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# Radiological Characterization Context

- Interrelated issues of D&D projects:

  - Regulatory deadlines, costs (maintenance, contractor, waste…)

  - Characterization: Radiation protection of workers, waste categorization and optimization, monitoring, clearance criteria…

| Characterization | Decontamination | Decommissioning |
|---|---|---|
| • Geostatistics<br>• Modeling… | • Monitoring<br>• Waste control | • Statistical tests<br>• Sanitary impact |

- Initial characterization: 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)

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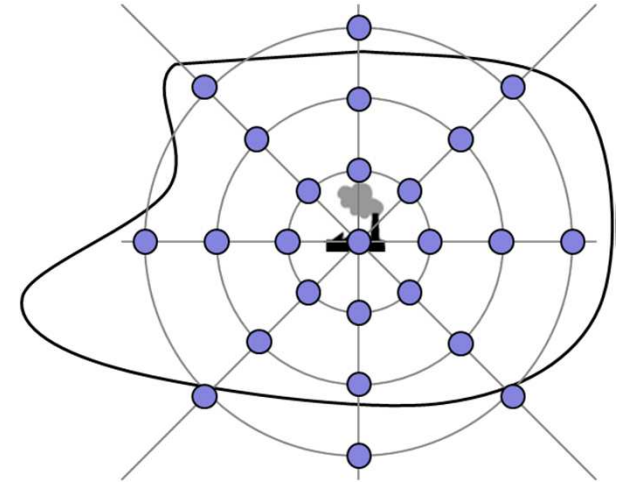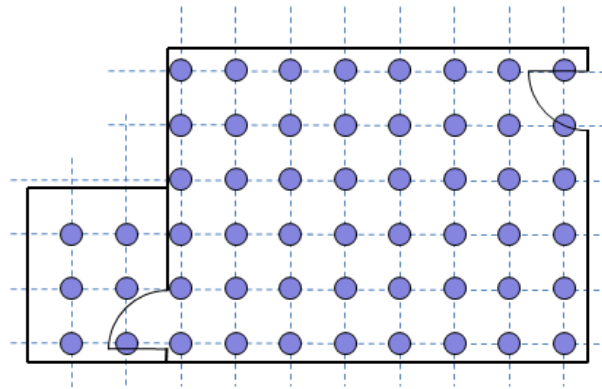# The Characterization Triptych
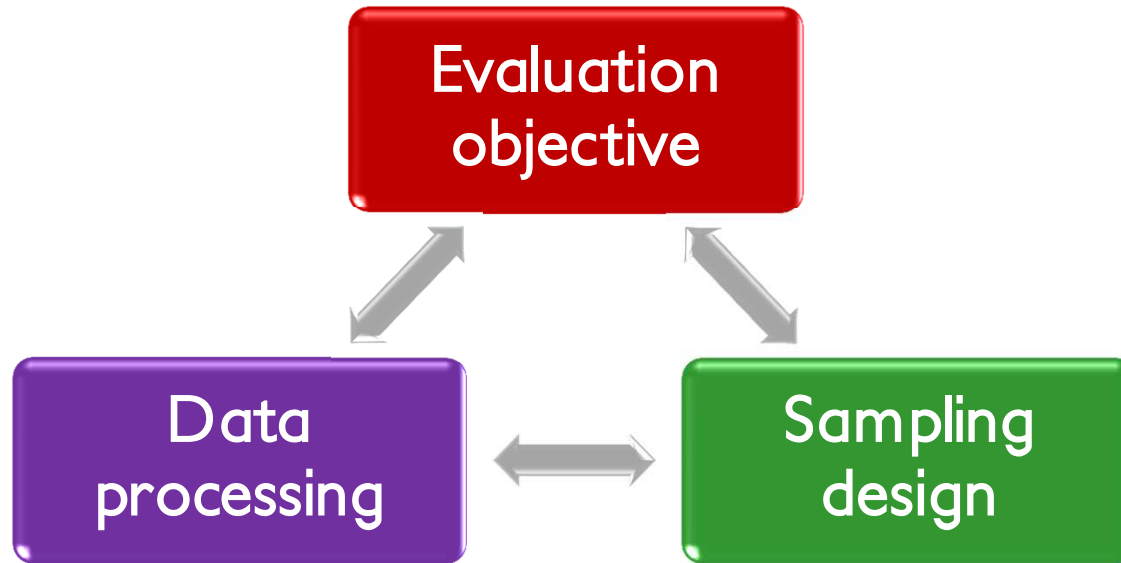


- A three legged stool: stability and simplicity
- If one leg is missing, the stool falls
- A stable position but uncomfortable
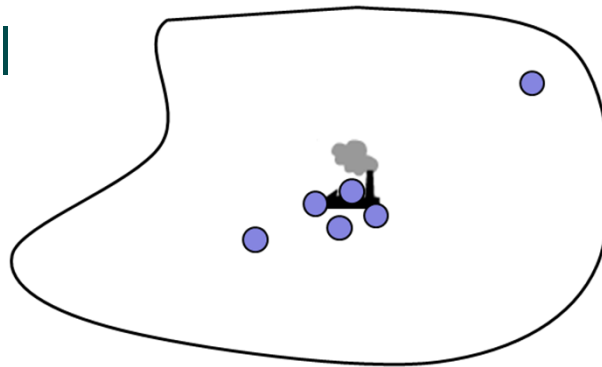
# Reminder about Sampling Designs

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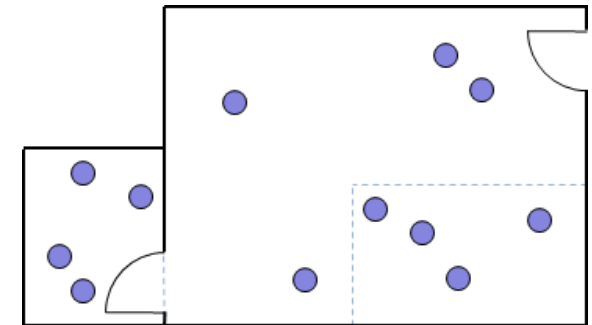    - Probability-based
        - Systematic
        - Random
    - Judgmental

- Mix possible to fulfil the evaluation objectives

- Iterative approach recommended

# Geostatistics for Initial Characterization

- Added values of geostatistics:

  – Successfully used for site characterization (chemical & nuclear)

  – Implemented in the methodology for the radiological waste characterization in former nuclear facilities

  – Sampling optimization according to spatial structure inventory

- Key issues:

  – How to optimize 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?

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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

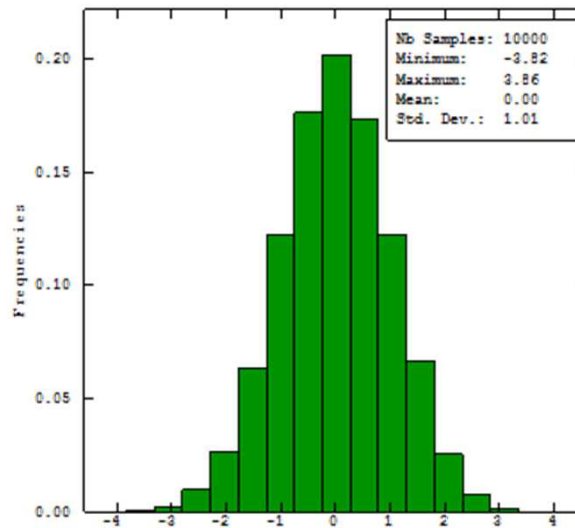$$\gamma(h) = \frac{1}{2} E\left[Z(x) - Z(x+h)\right]^2$$

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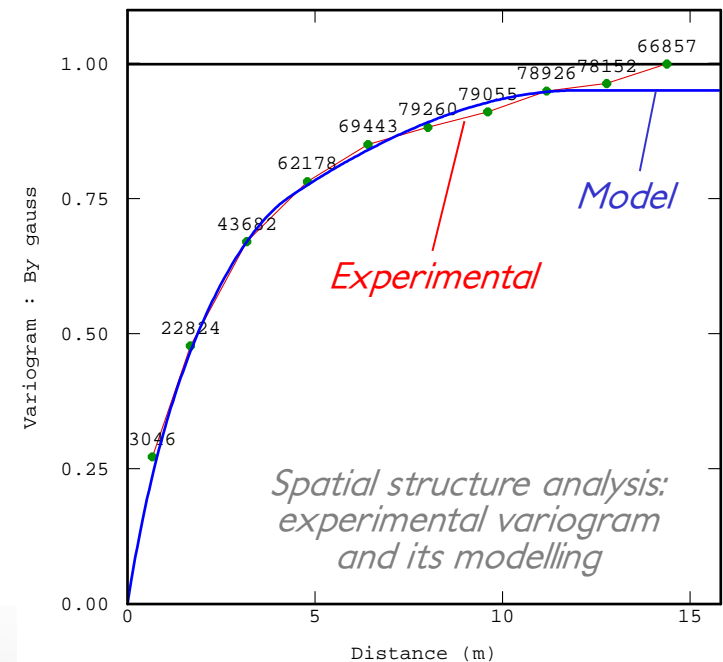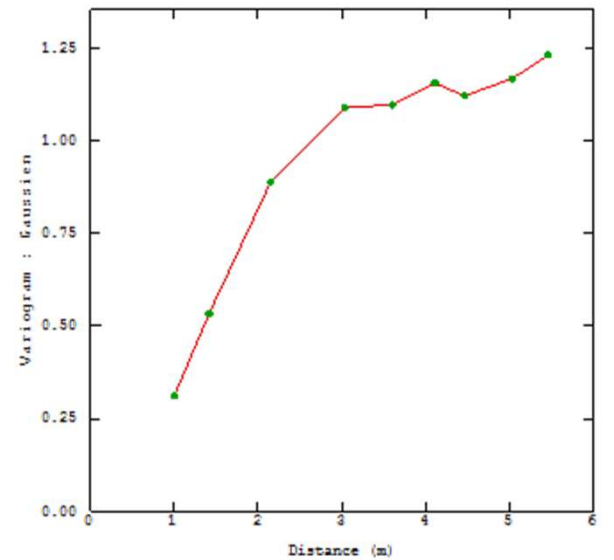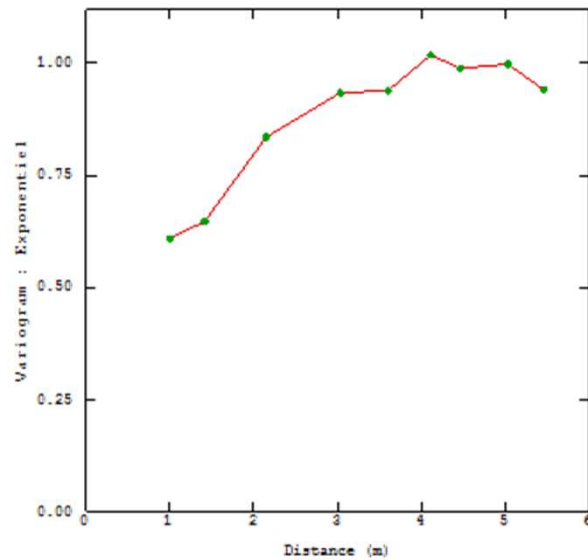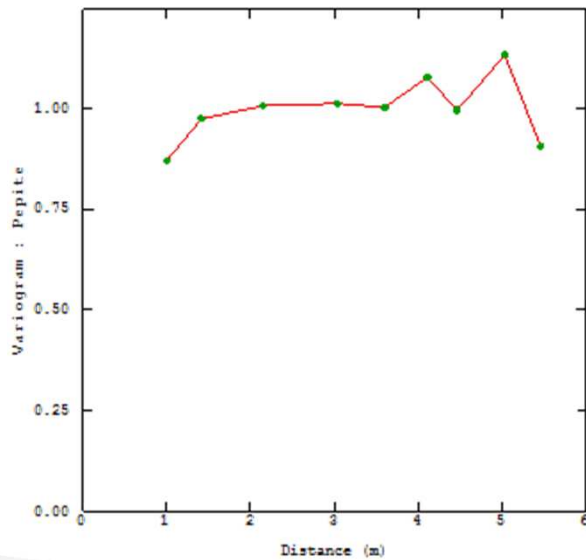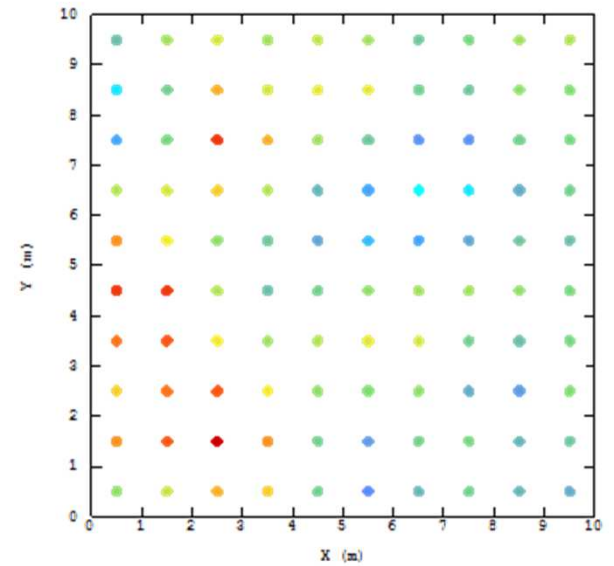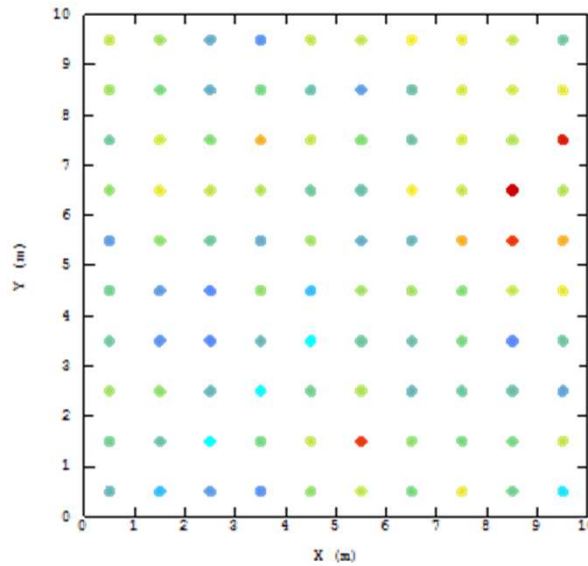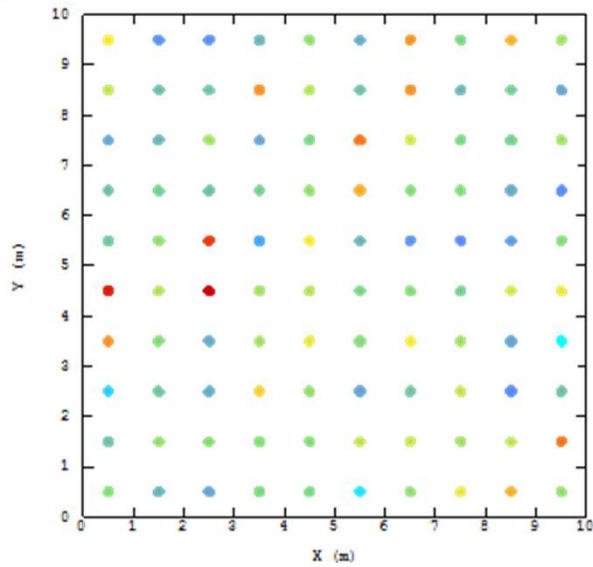
# Three spatial structures
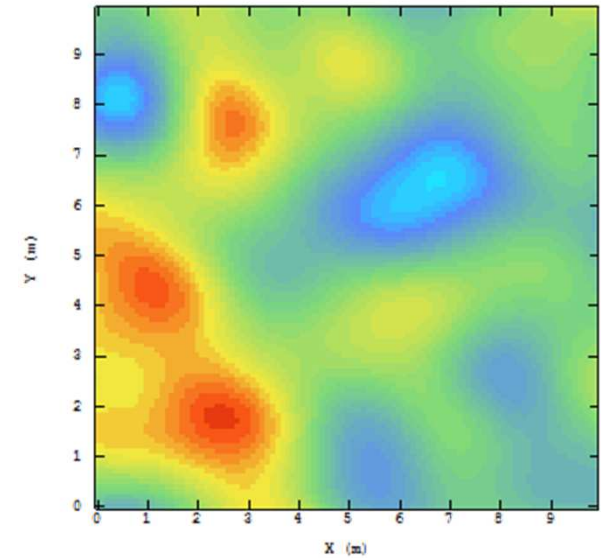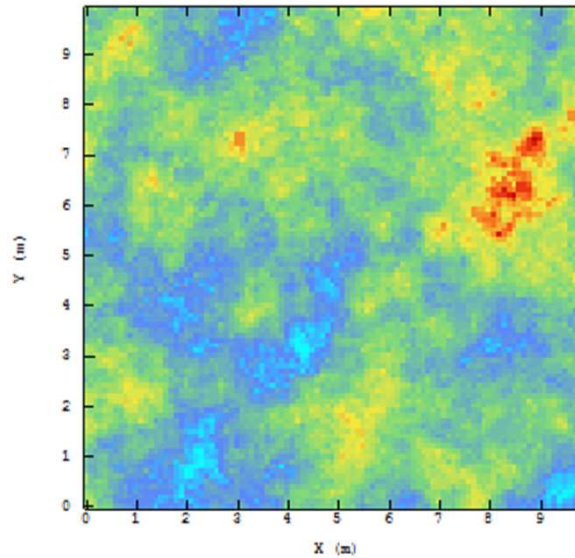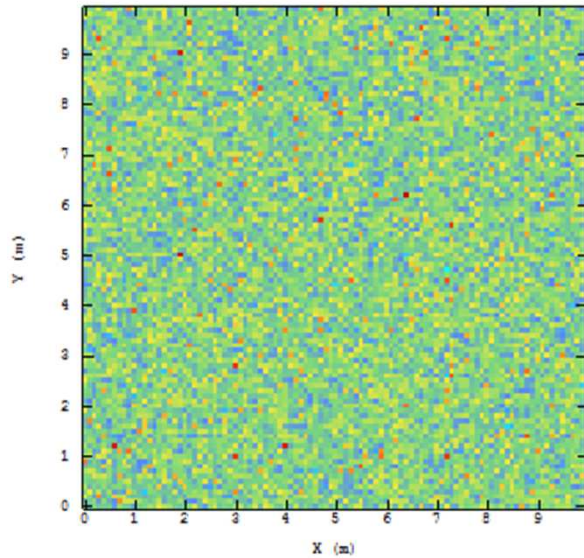

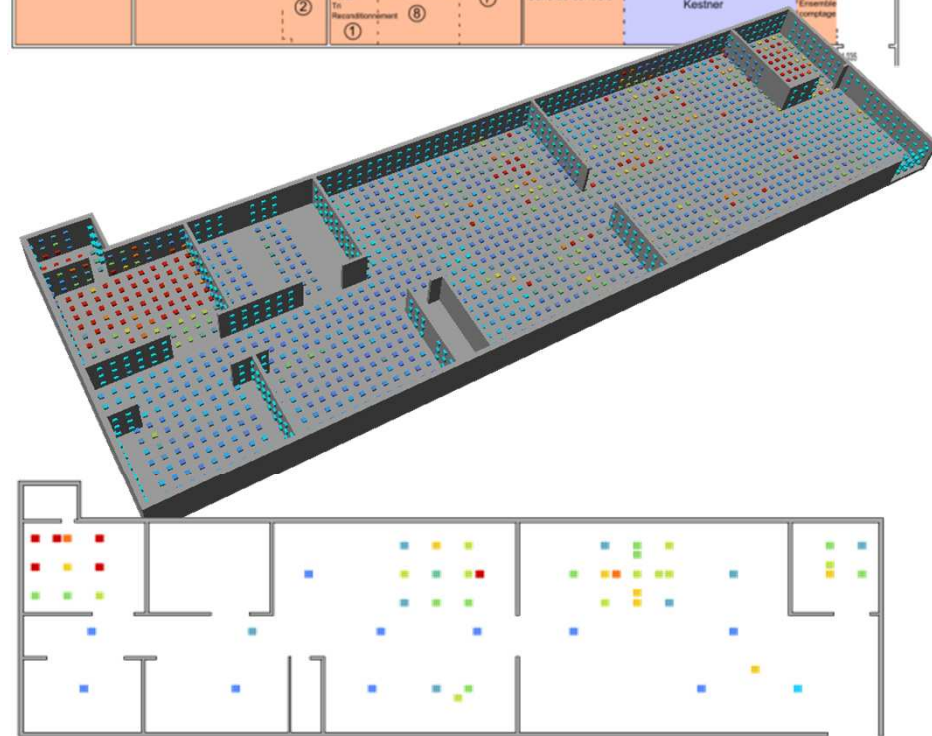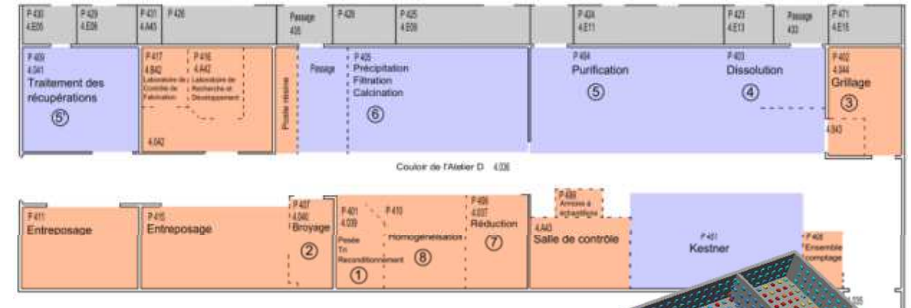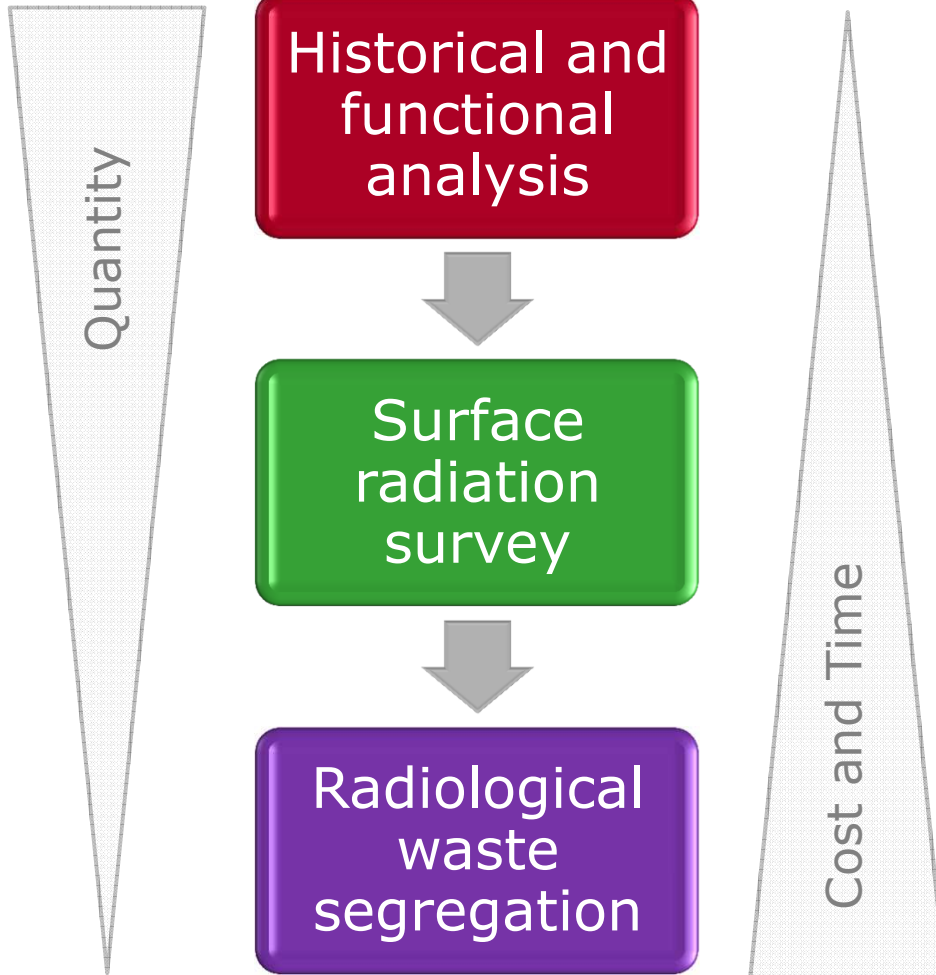
– Three spatial representations of the same statistical distribution



Nb Samples: 10000
Minimum:     -3.82
Maximum:      3.86
Mean:         0.00
Std. Dev.:    1.01

– Characterization of the spatial structures thanks to a regular sampling grid

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# Three spatial structures

# Characterization Methodology



Quantity

Historical and functional analysis

Surface radiation survey

Radiological waste segregation

Cost and Time

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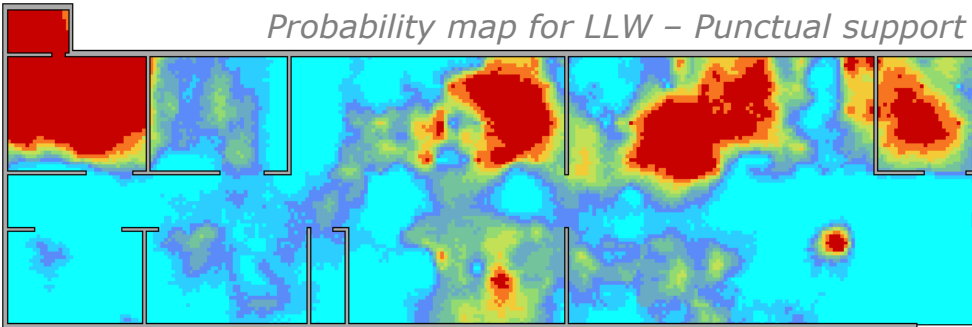
# Data Analysis & Modeling

- Use of the geostatistical multivariate approach

  - Integration of all relevant information and data

  - Description of the spatial correlation between two variables:
    → Cross-variogram

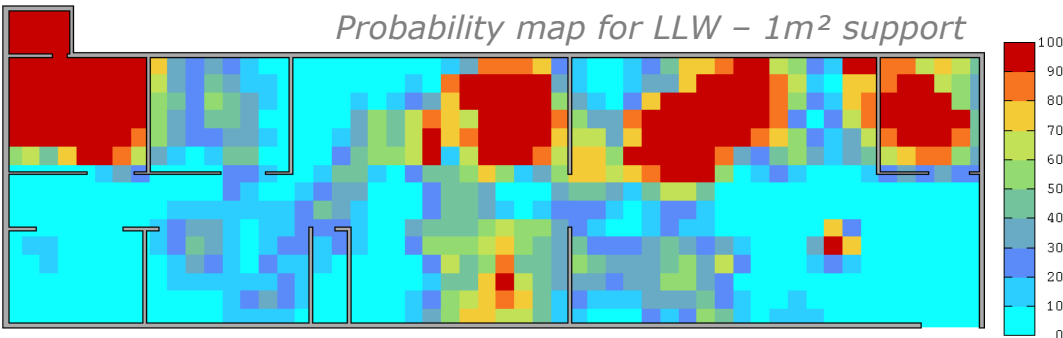  - Use of surface radiation data so as to improve the estimation of activity levels (uncertainty reduction)



Estimation maps and decision making tools

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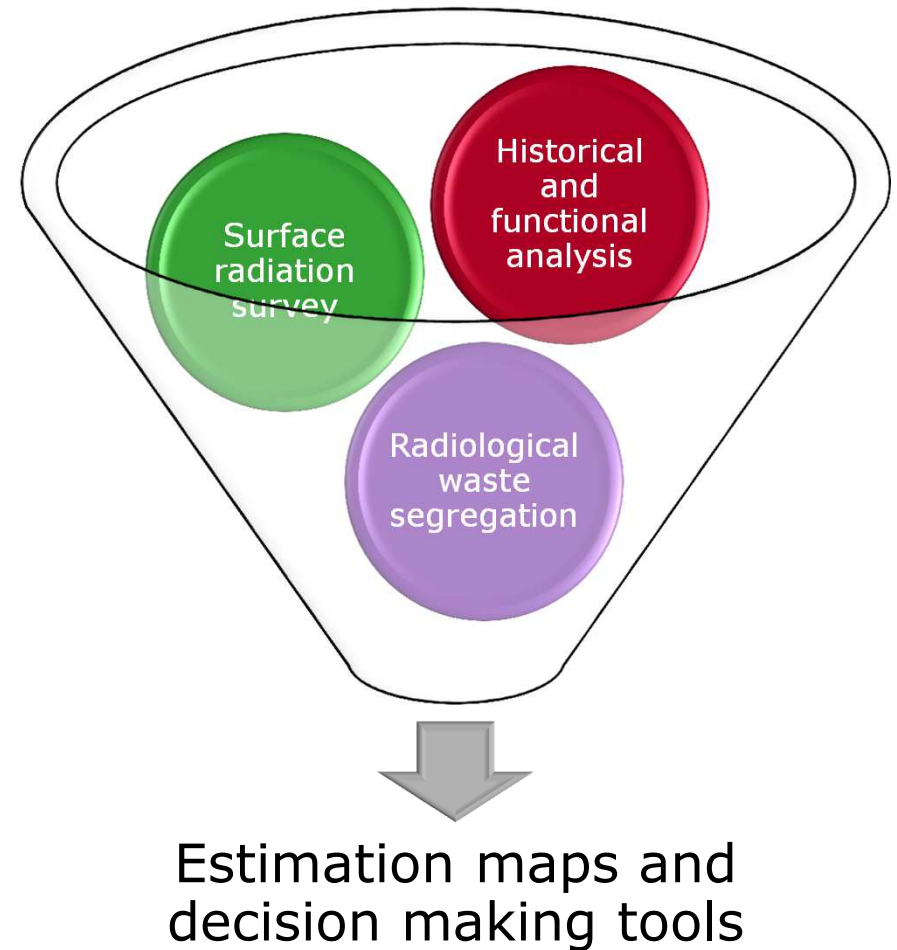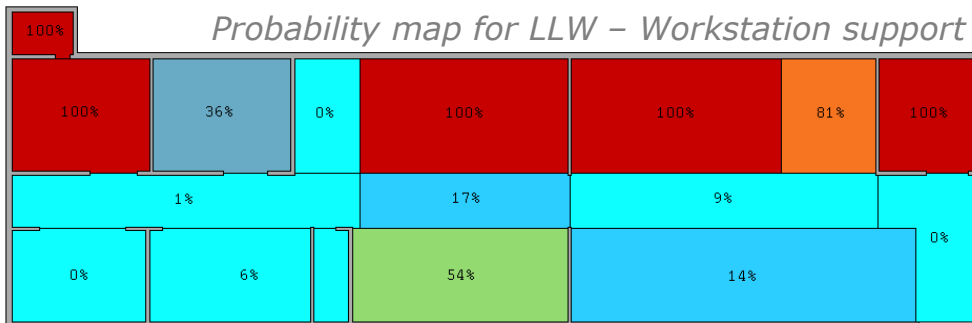
# Risk Analysis & Estimation Support



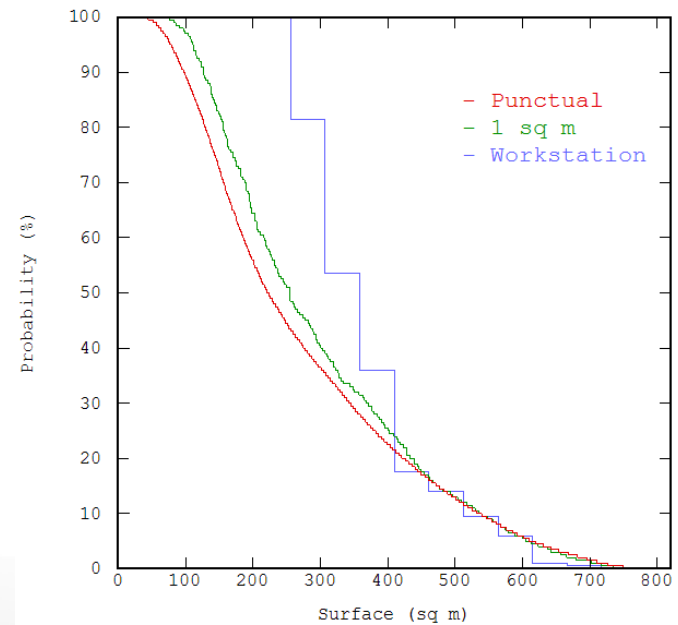*Probability map for LLW – Punctual support*



*Probability map for LLW – 1m² support*



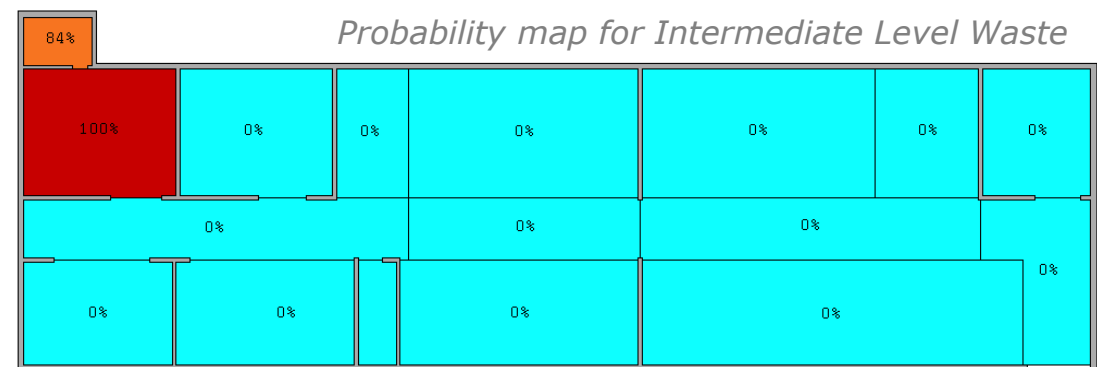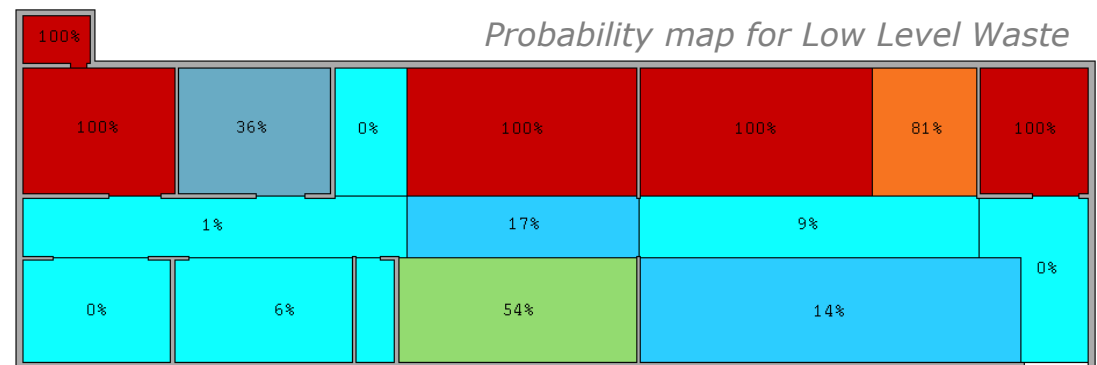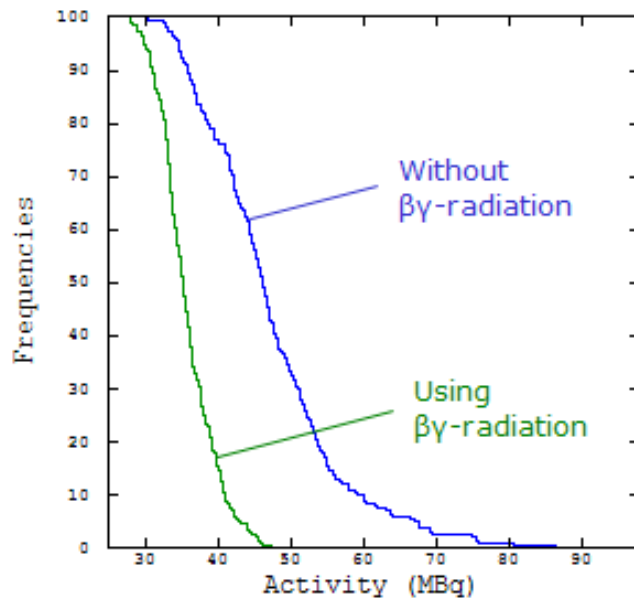*Probability map for LLW – Workstation support*

- Taking the decision support into account:
  - Punctual → Hot spots
  - Block → Waste category

- Impact on categorisation surfaces (averaging)
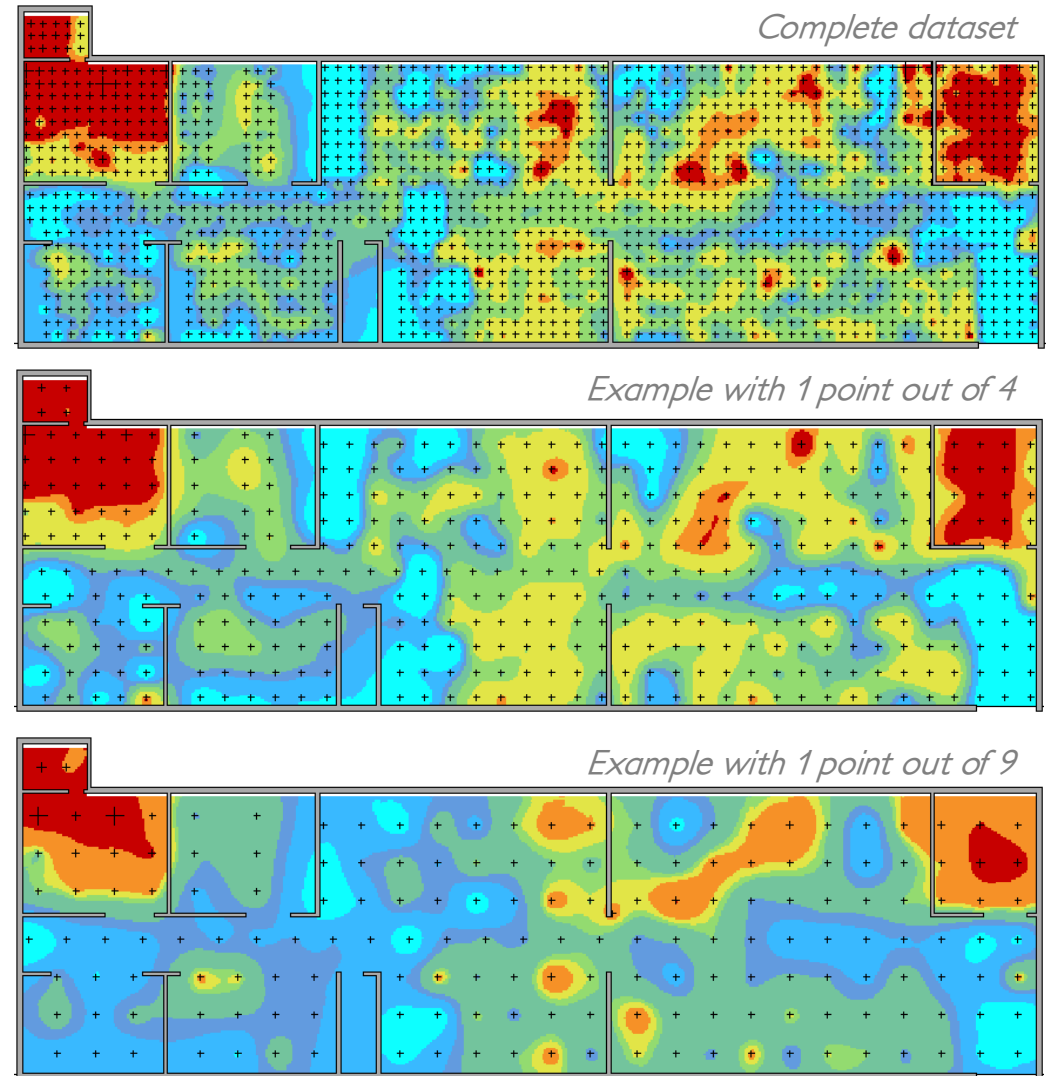
# Radiological Categorization

- Decision-making tools for decontamination process:

  - Waste segregation according to activity levels and risk levels

  - Average activity per "decontamination unit"

  - Accumulation (total amount of activity)



*Probability map for Low Level Waste*

*Probability map for Intermediate Level Waste*

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# Sampling Optimization

- 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
  - ...

*Complete dataset*

*Example with 1 point out of 4*

*Example with 1 point out of 9*

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# Sampling Optimization

- Integration of the geostatistical analysis of values to optimize 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*
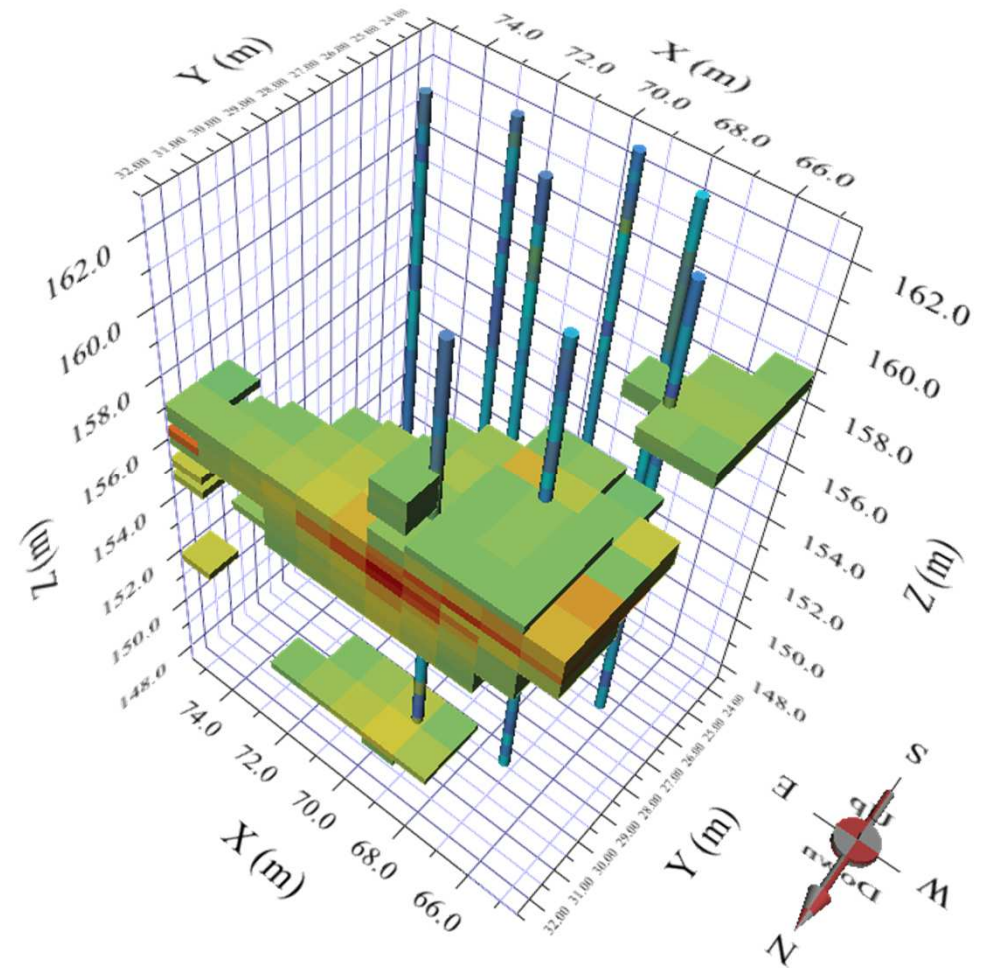
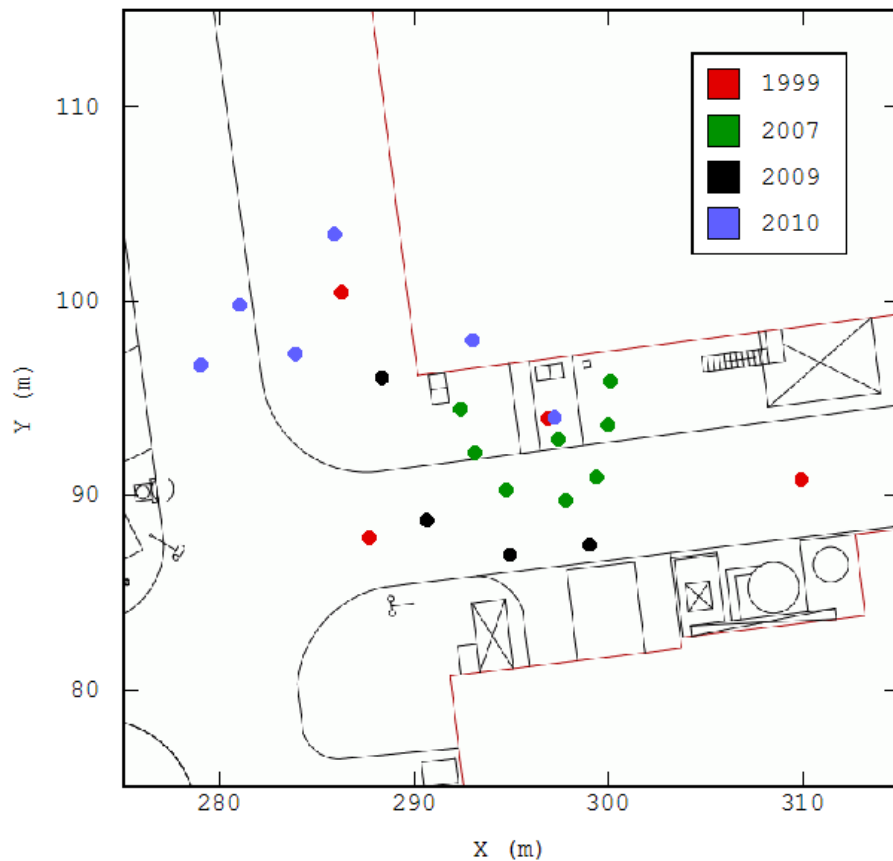*(declare clean a contaminated area)*
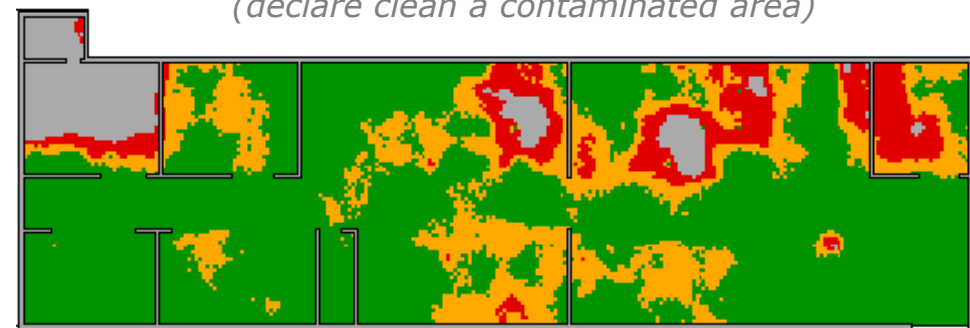


- Low risk
- Intermediate risk
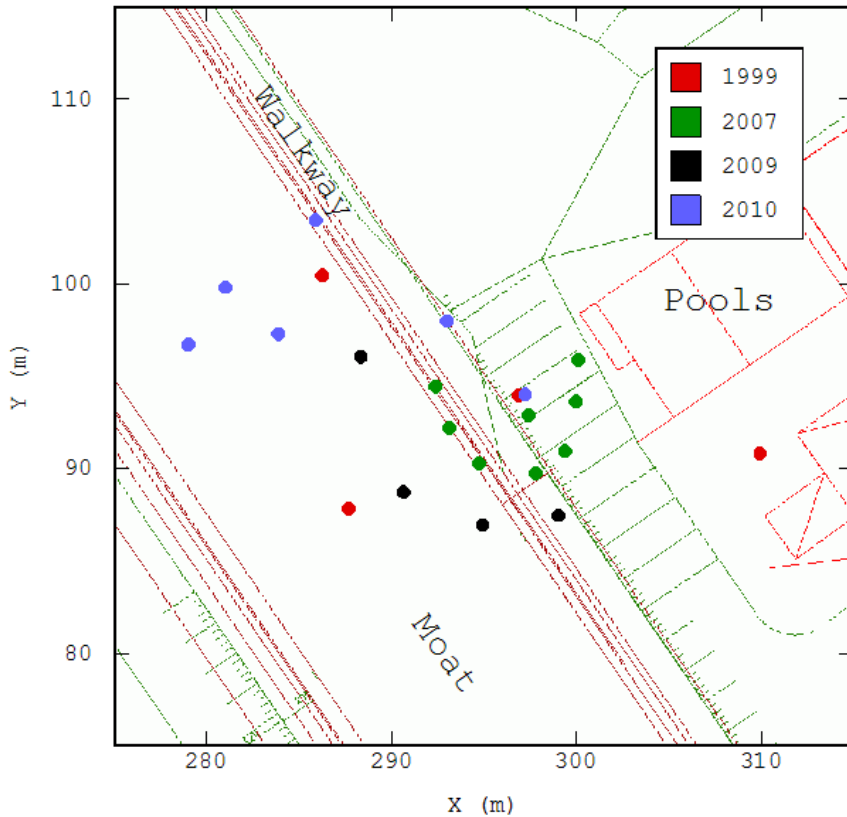- High risk
- Declared above the threshold

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# A Deep Contamination Example

- First data analysis (in 2007)

- 4 drilling campaigns





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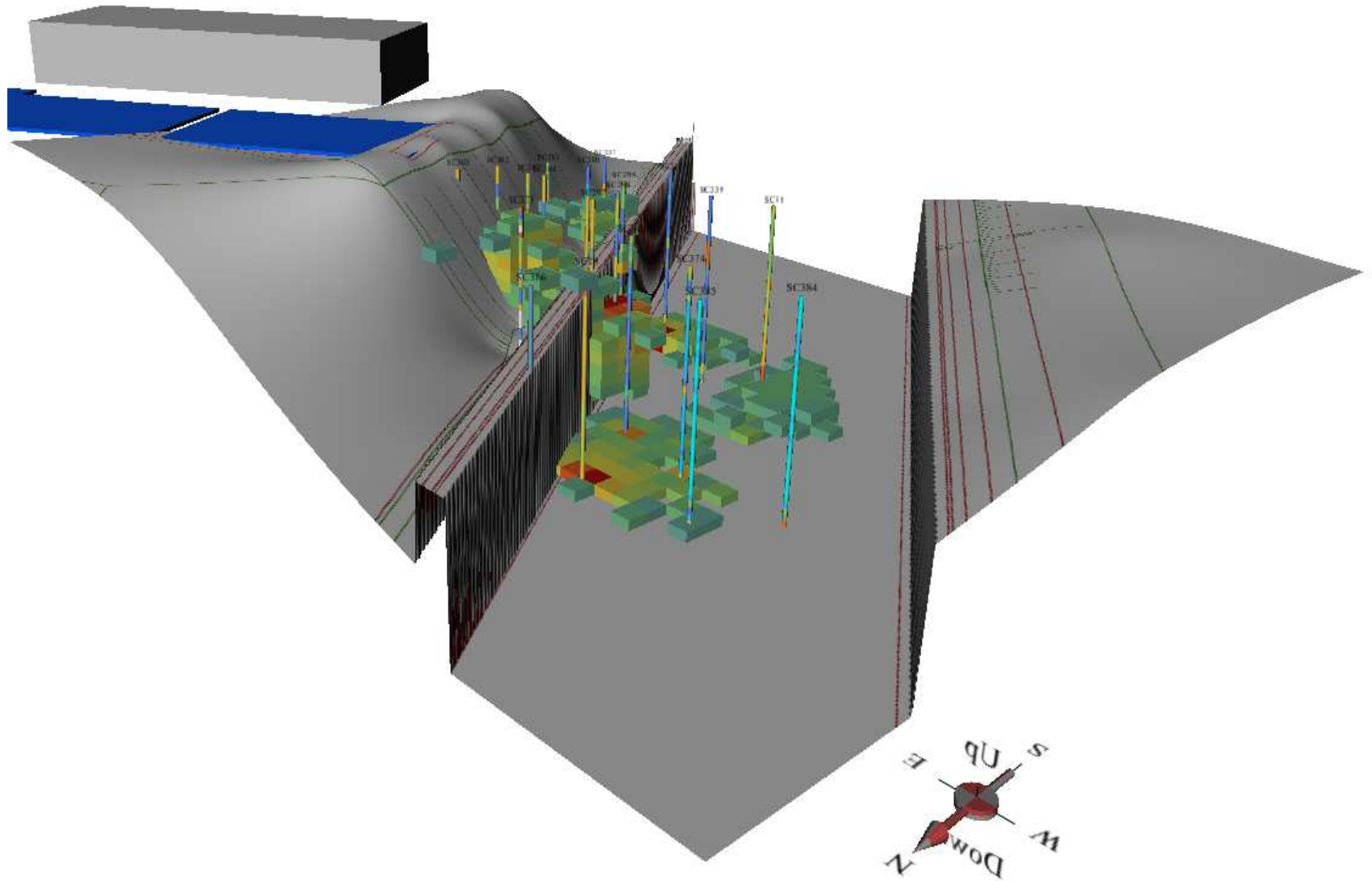Where no one has gone before

# Integration of Historical Information



- Topography of the former military fortification (first generation of installations)

- Correct interpretation of contaminated areas
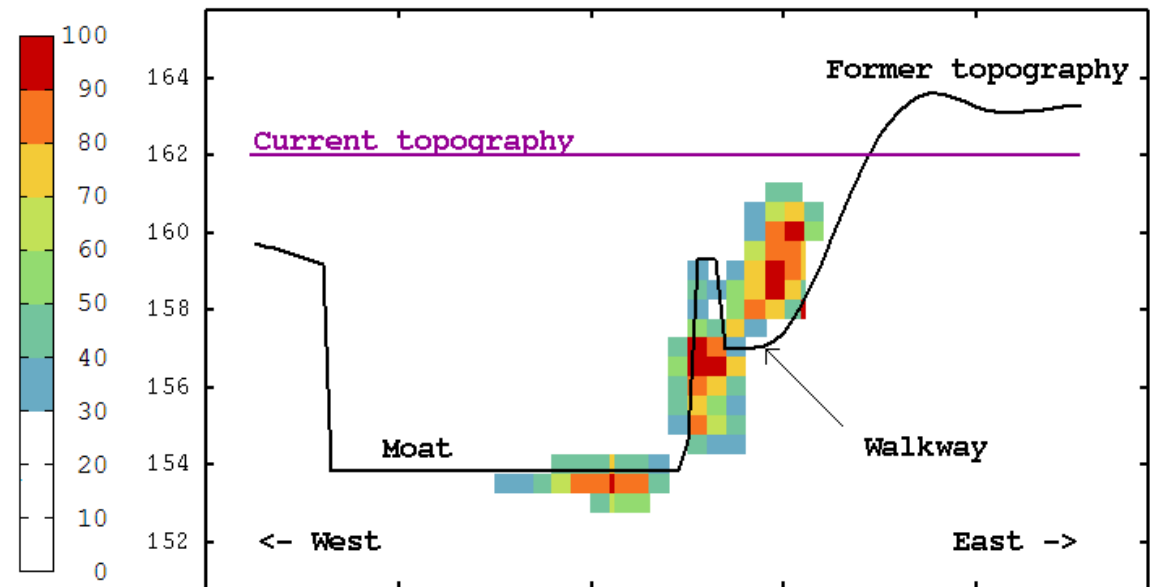
# 3D Representation

# Added Value of Geostatistics

- **Explore and valuate collected data**

  – Data cleaning and validation / Handling data anomalies and outliers...

- **Get a reliable mapping of the radiological contamination**

  – Take the spatial behavior (variographic analysis) into account

  – Assess the precision of the estimation map

  – Refine the estimation map using correlated data (destructive / in situ) and indirect information (historical knowledge)

- **Quantify uncertainties on contaminated volumes (or surfaces)**

  – Compute the probability of exceeding a radiological threshold

  – Assess the uncertainty on the volumes

- **Optimize the investigation effort / sampling strategy**

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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 (2D and 3D modeling)
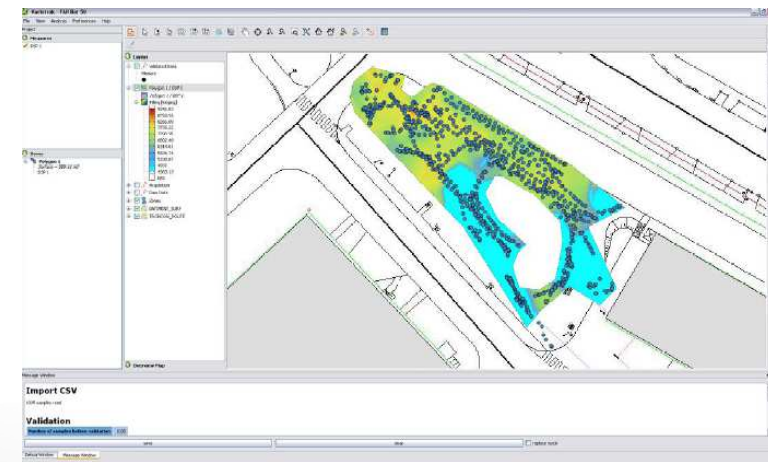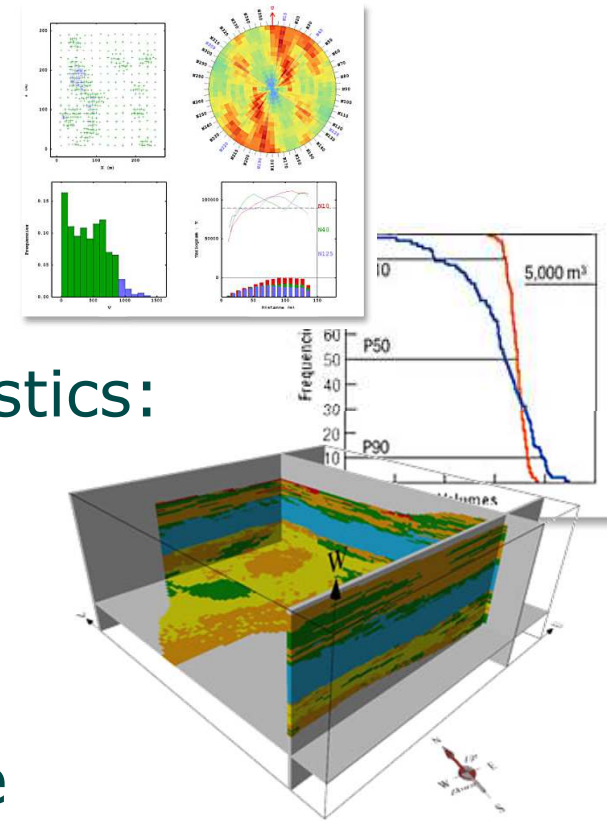
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Developed in partnership with cea