PREDEC 2016

International Symposium on PREparation for DECommissioning

Geostatistics for radiological characterization: overview and application cases

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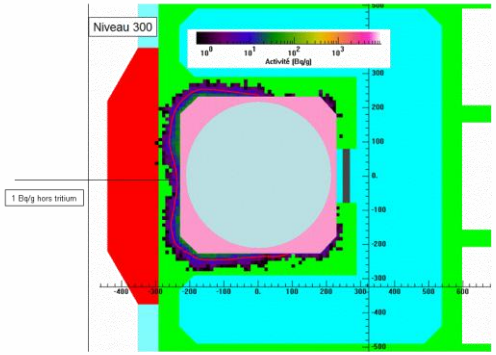
Geovariances

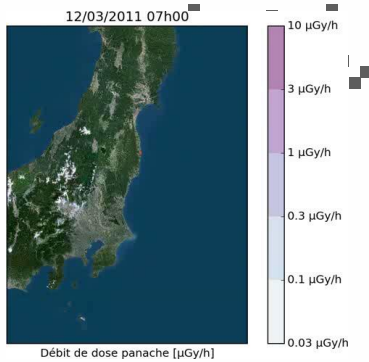
17th February 2016

Data processing: where is the model?

- Deterministic models
  - Based on physical behavior / mathematical formulae
  - Calibration on data
  - Examples: migration, activation, flow transport…



SILOE Reactor: Activation model of the concrete pool block
Source: DAPNIA



Atmospheric spreading Fukushima
Source: IRSN

- Added values of geostatistics
  - The model is within the data!
  - Implemented in the methodology for the radiological waste characterization in former nuclear facilities (site, building and equipment) thanks to uncertainty quantification
  - Sampling optimization according to spatial structure inventory

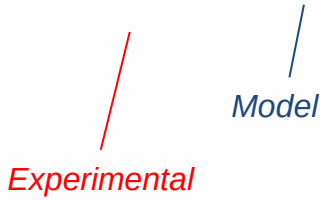
Spatial structure: central point of geostatistics

- 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

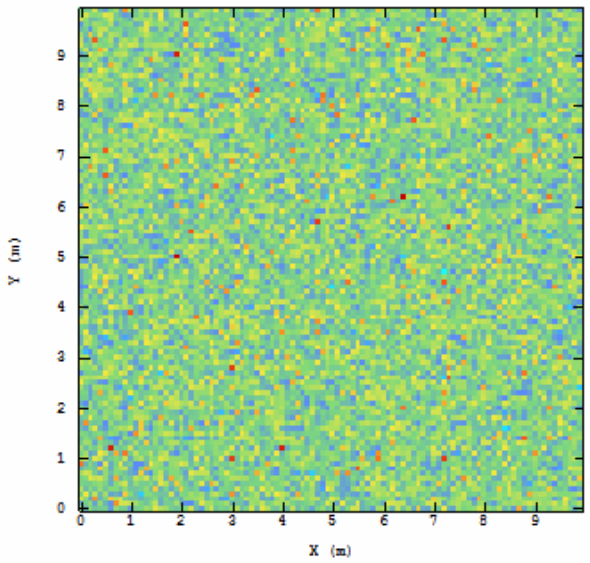
$$\gamma(h) = \frac{1}{2} E\left[Z(x) - Z(x+h)\right]^2$$

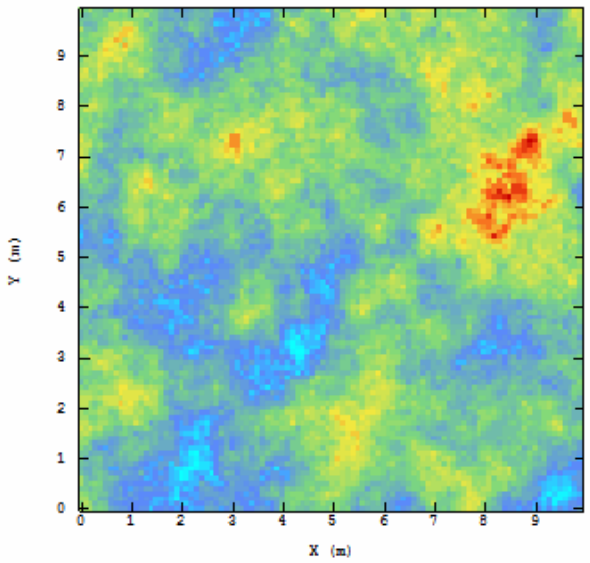
- The way the variogram increases with distance is linked to the phenomenon spatial variability

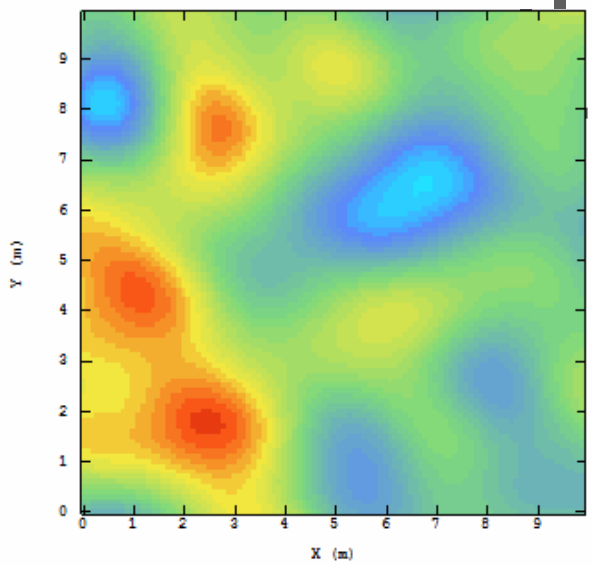


Spatial structure analysis: experimental variogram and its modelling

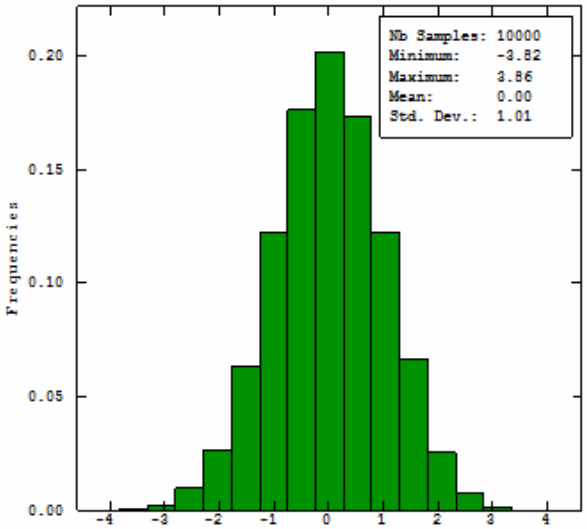
Variograms of three examples



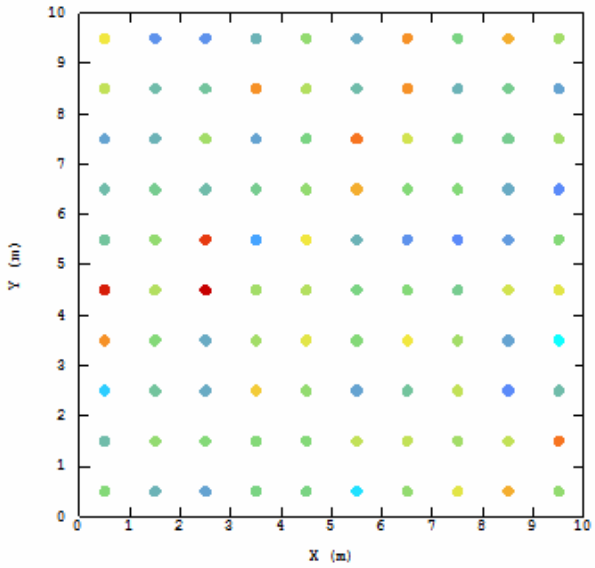


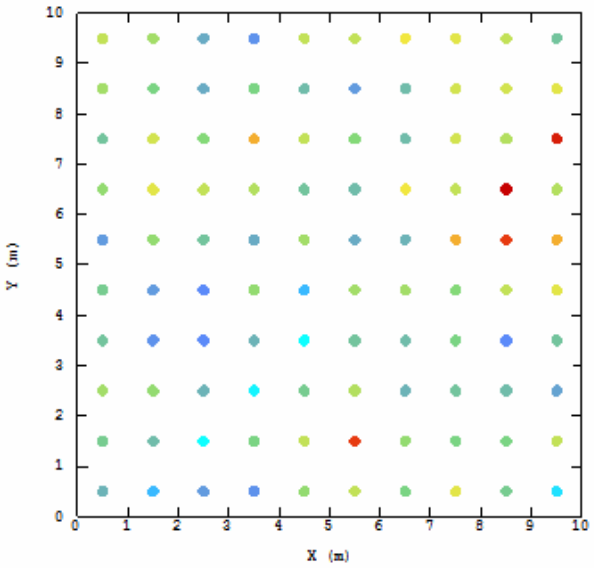


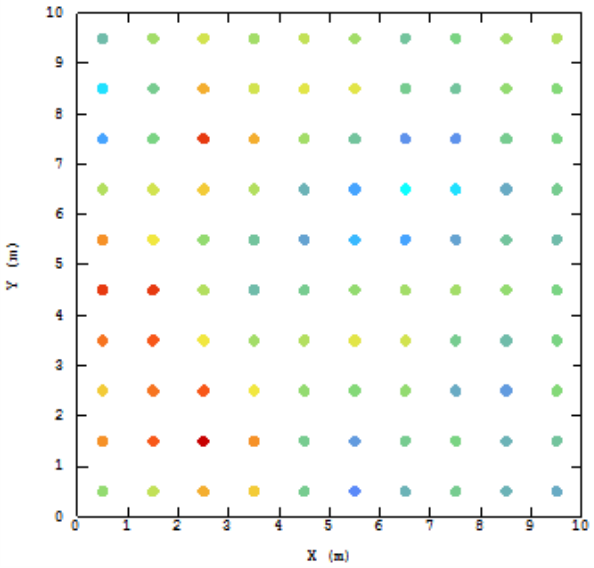
- Three spatial phenomena with the same statistical distribution
- Characterisation of the spatial structure thanks to a regular sampling grid

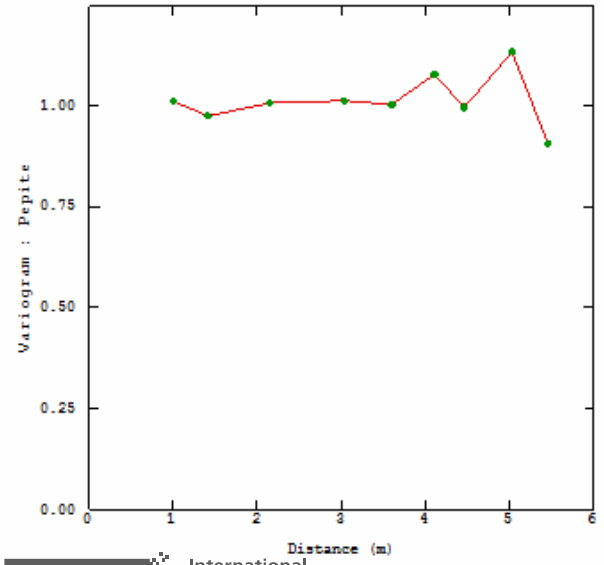


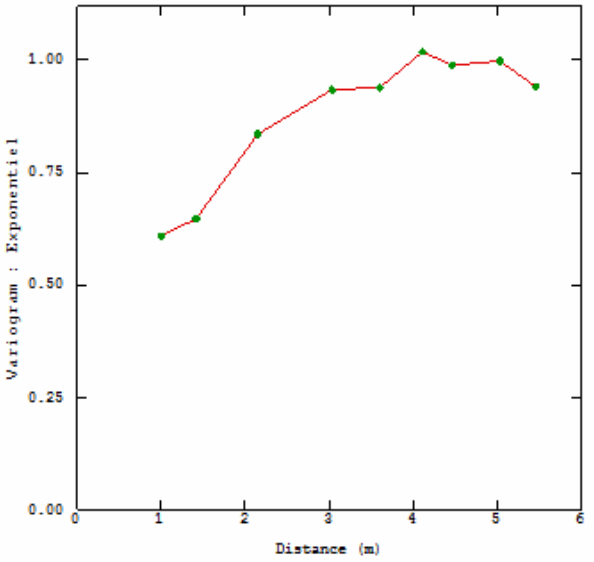
Variograms of three examples

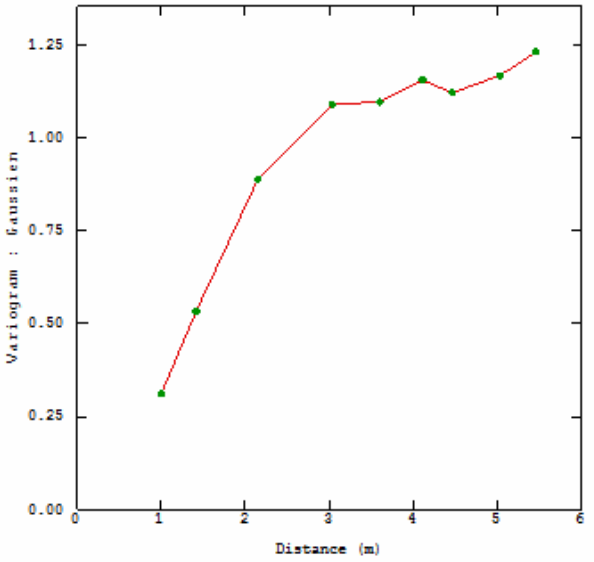




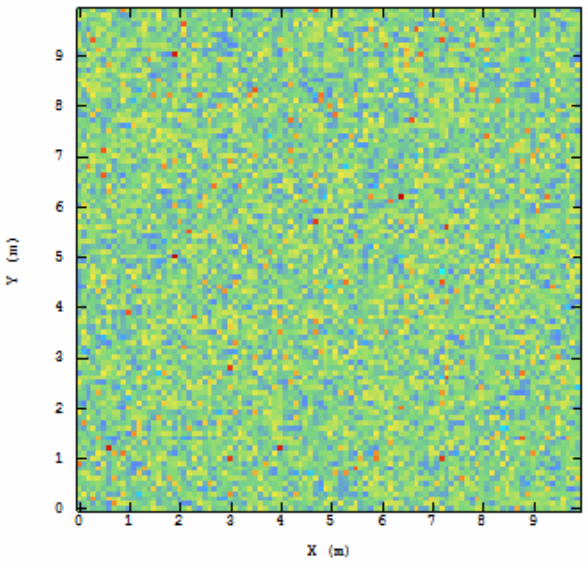


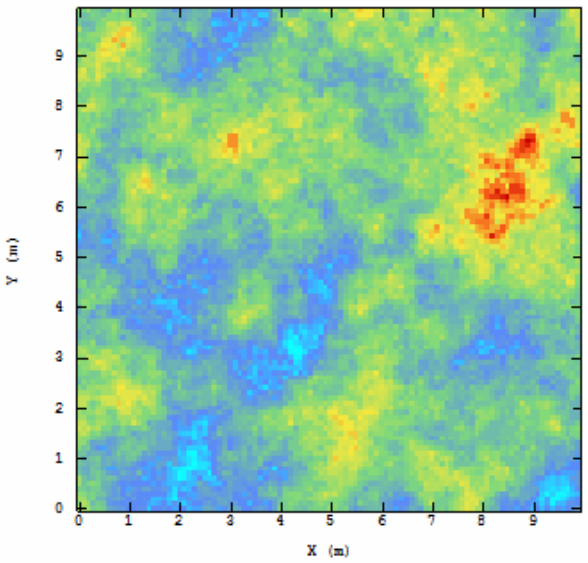


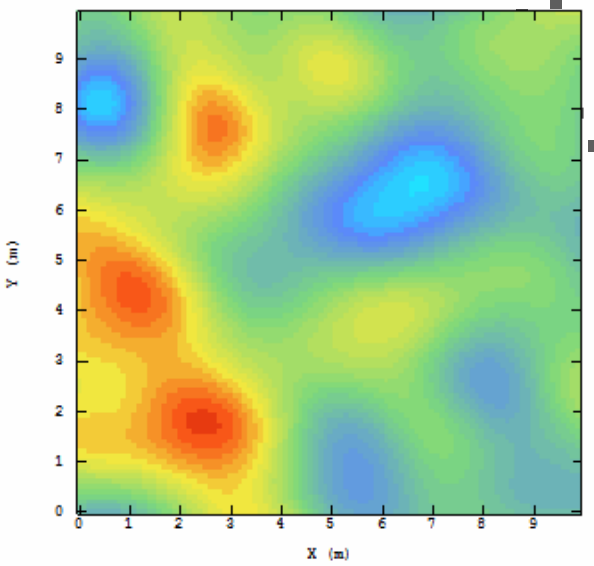


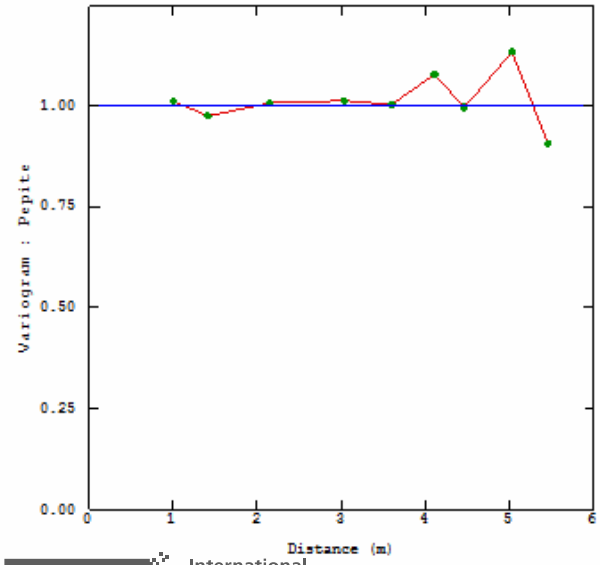


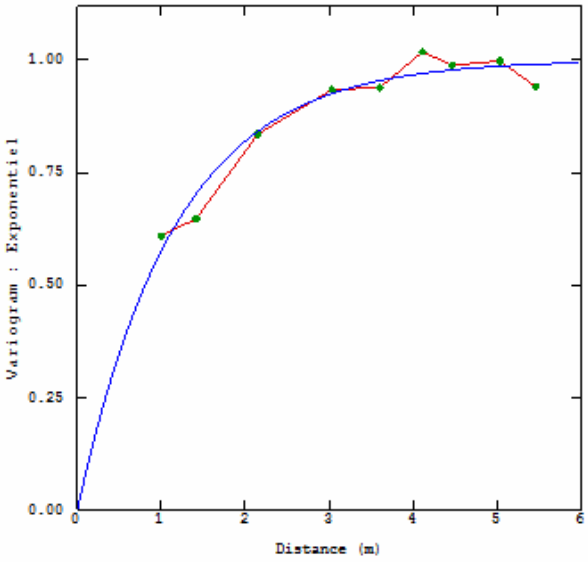
Variograms of three examples

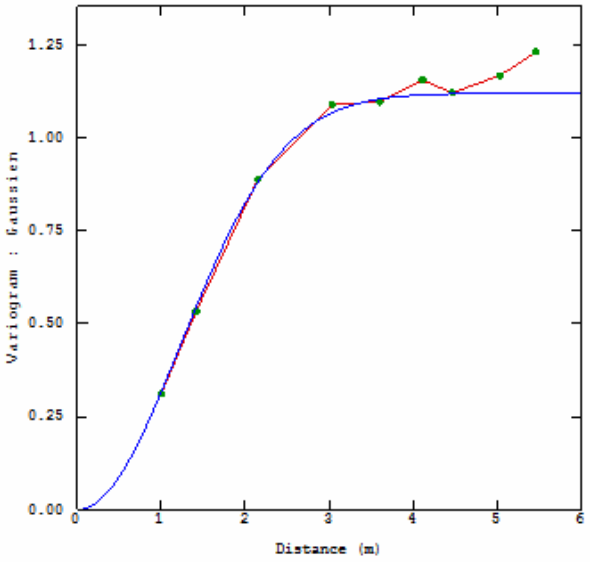




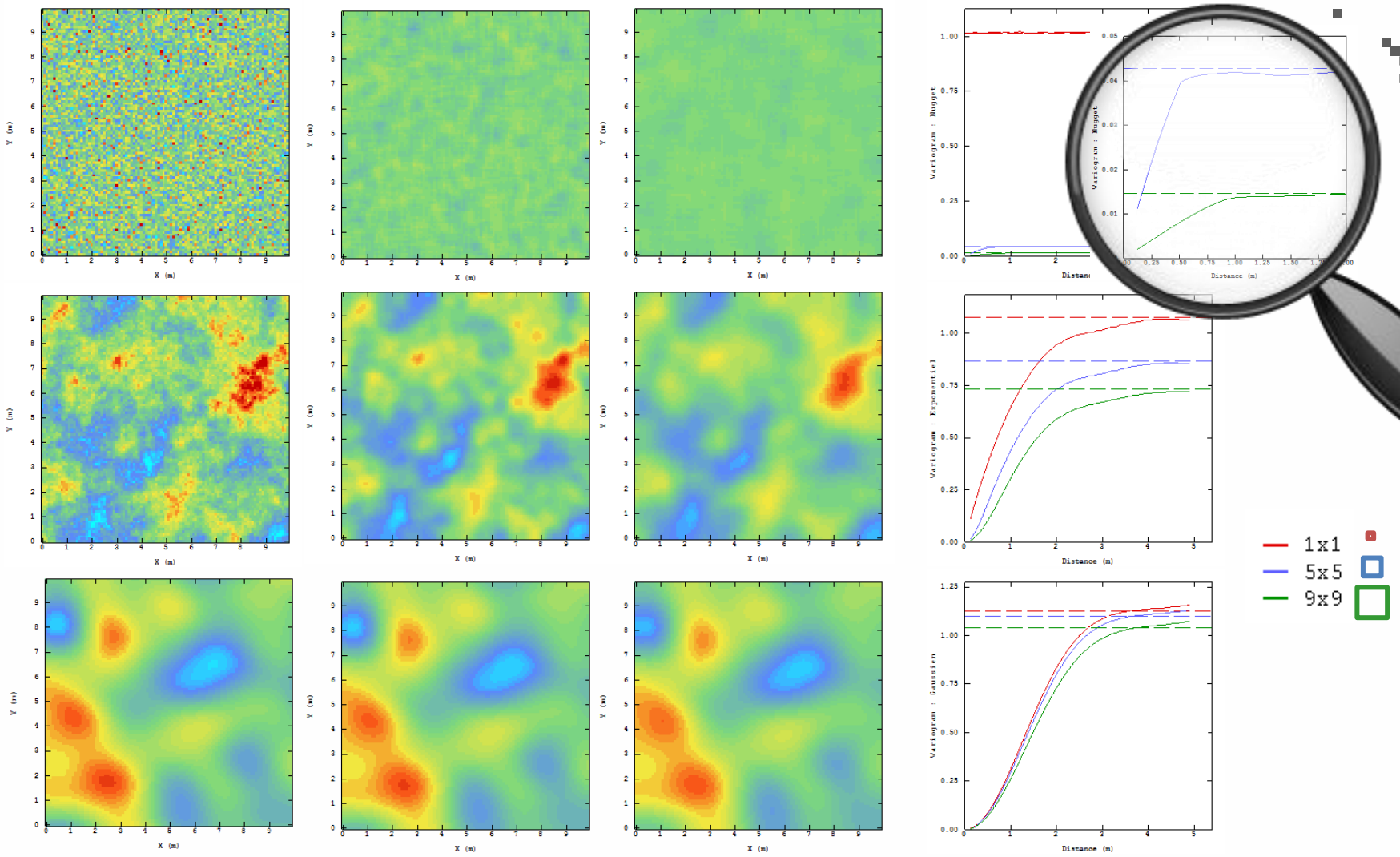








Support effect and spatial structure



Multivariate approach for characterization methodology

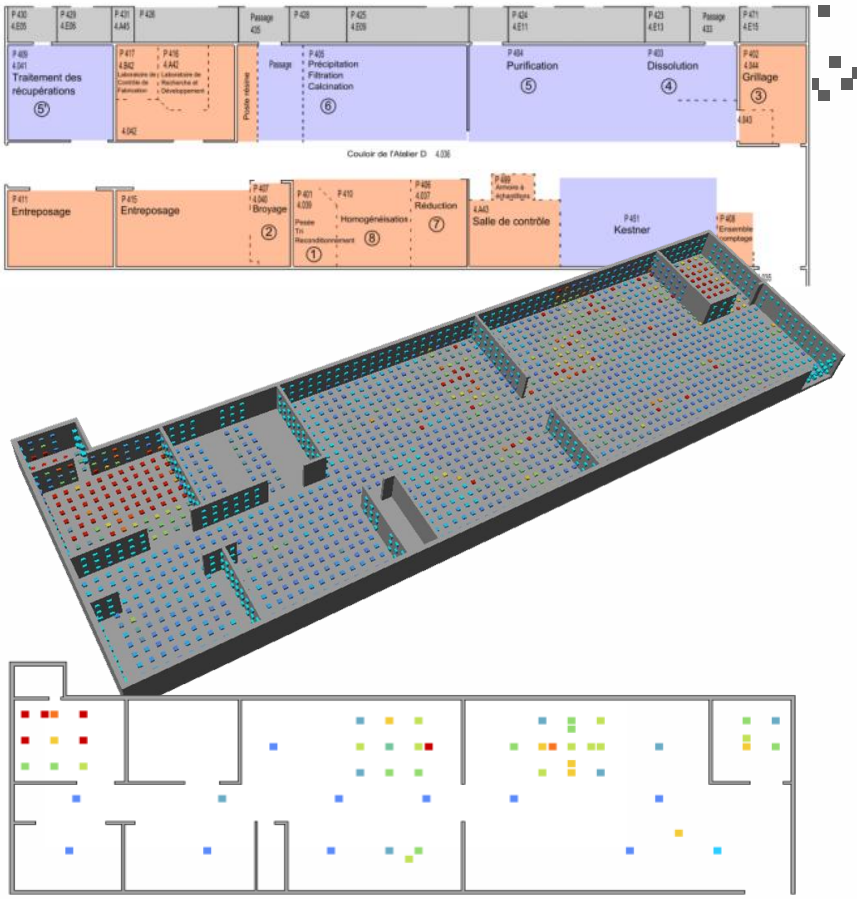
Quantity

Historical and functional analysis

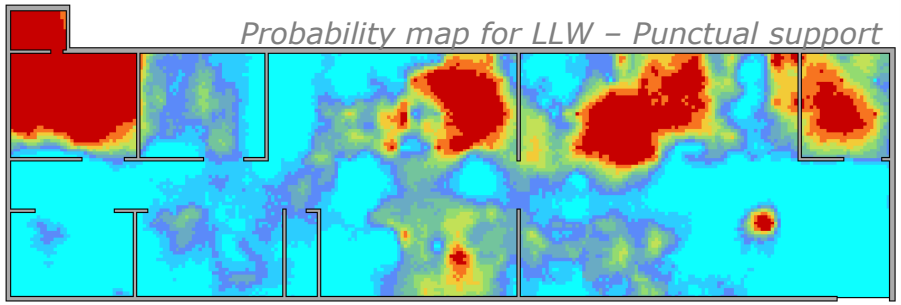
Surface radiation survey

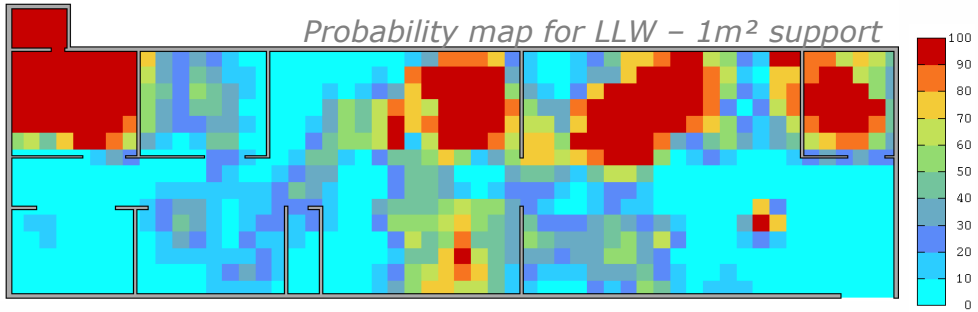
Radiological waste segregation

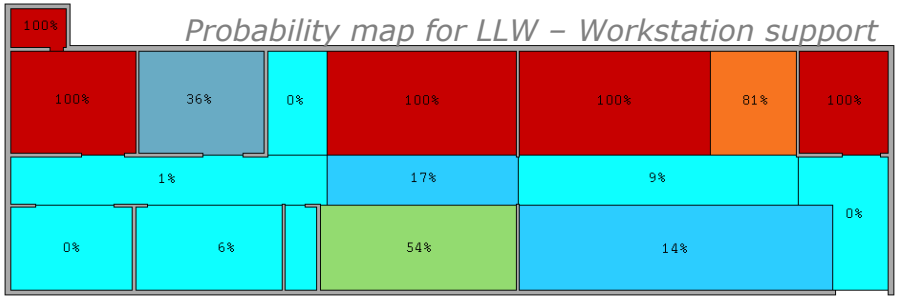
Cost and Time



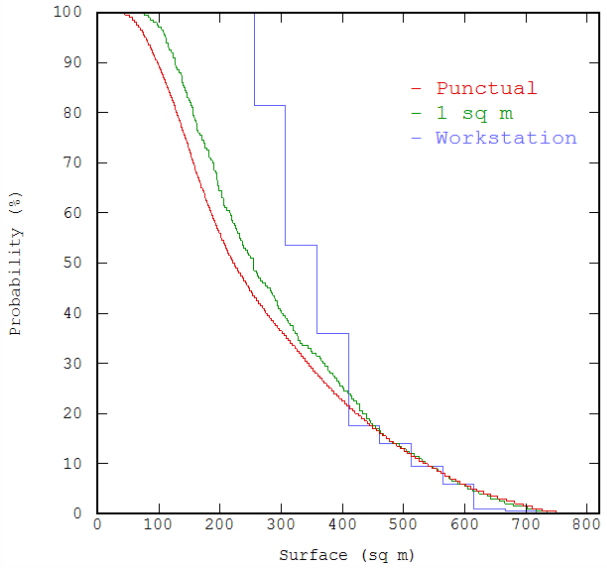
Risk analysis & estimation support





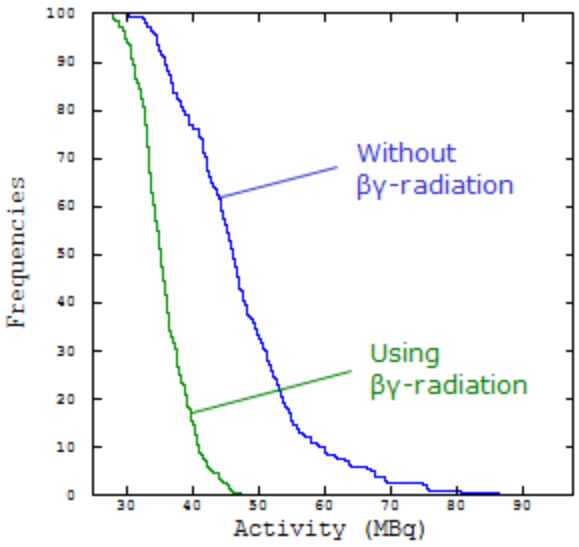


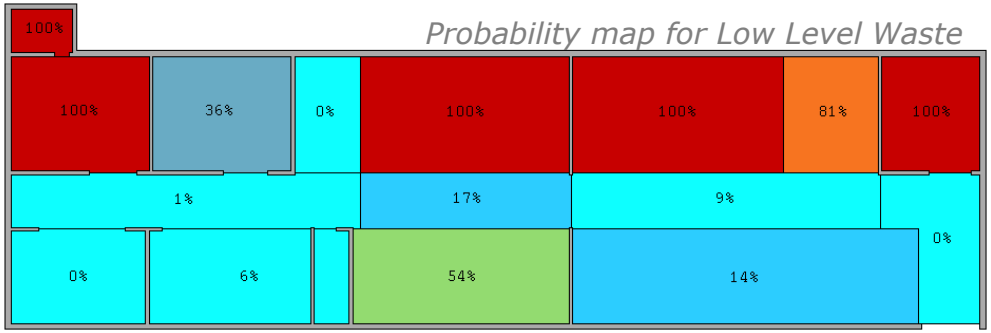
- Taking the decision support into account:
  - Punctual → Hot spots
  - Block → Waste category
- Impact on categorisation surfaces (averaging)

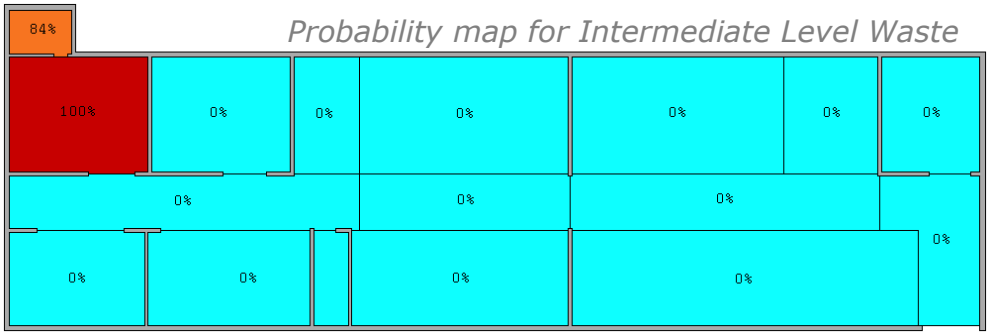


Radiological categorization

- 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)

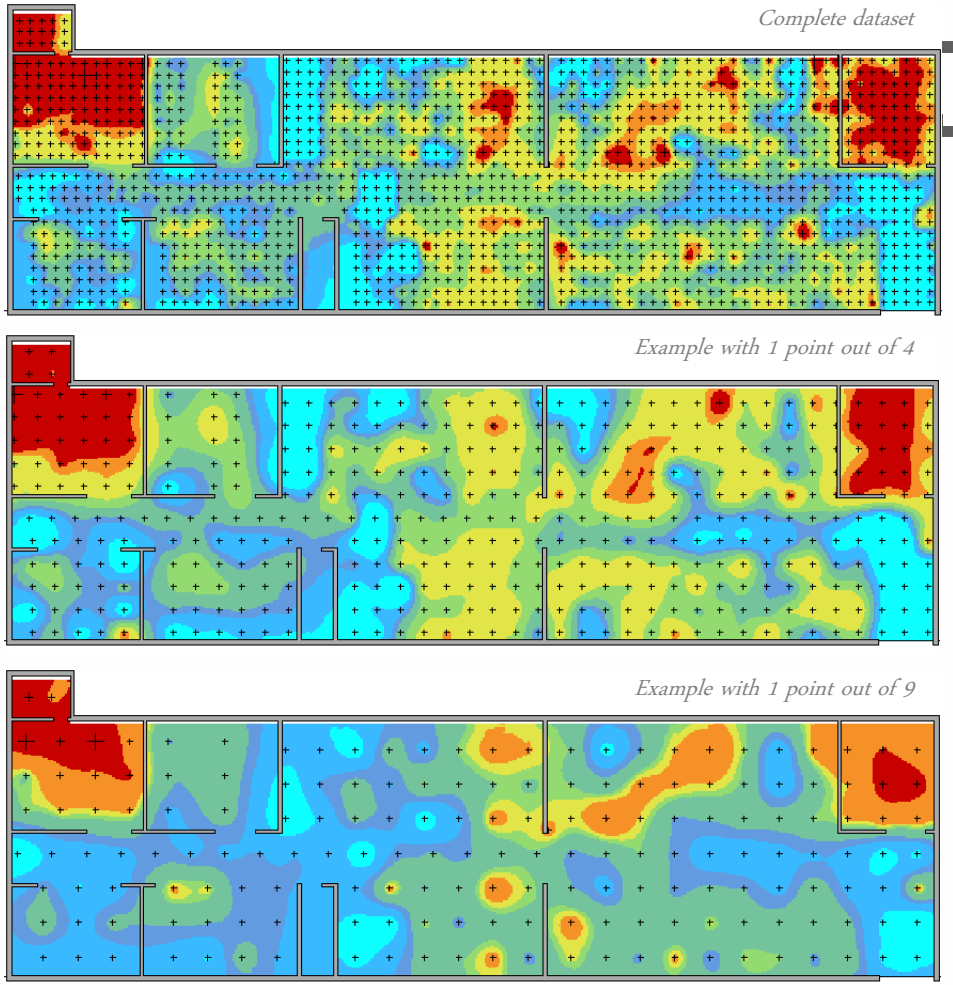






Sampling optimization

- 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
  - …



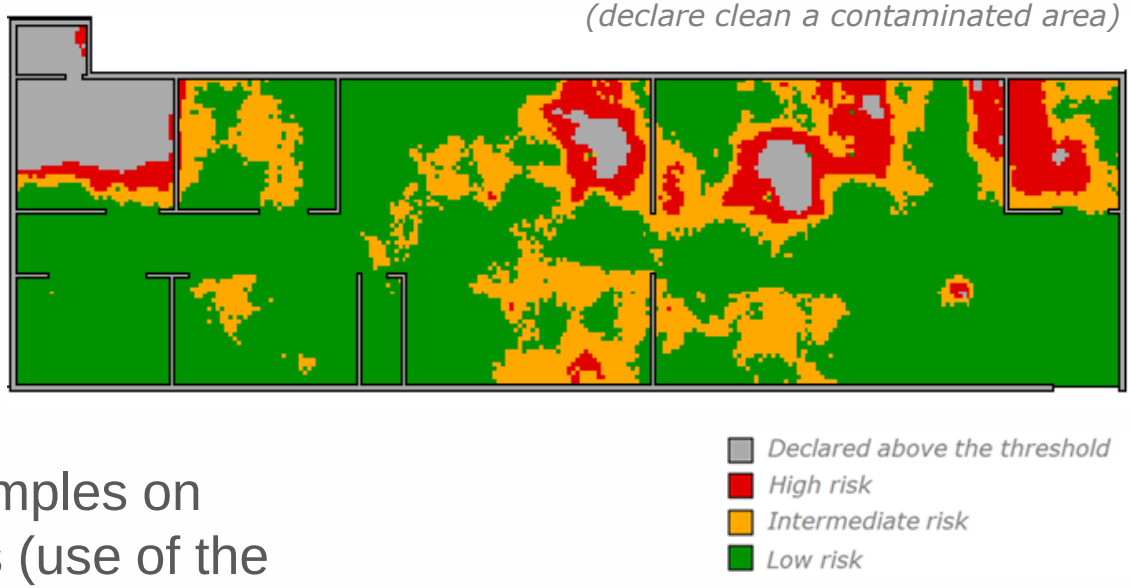
Sampling optimization

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

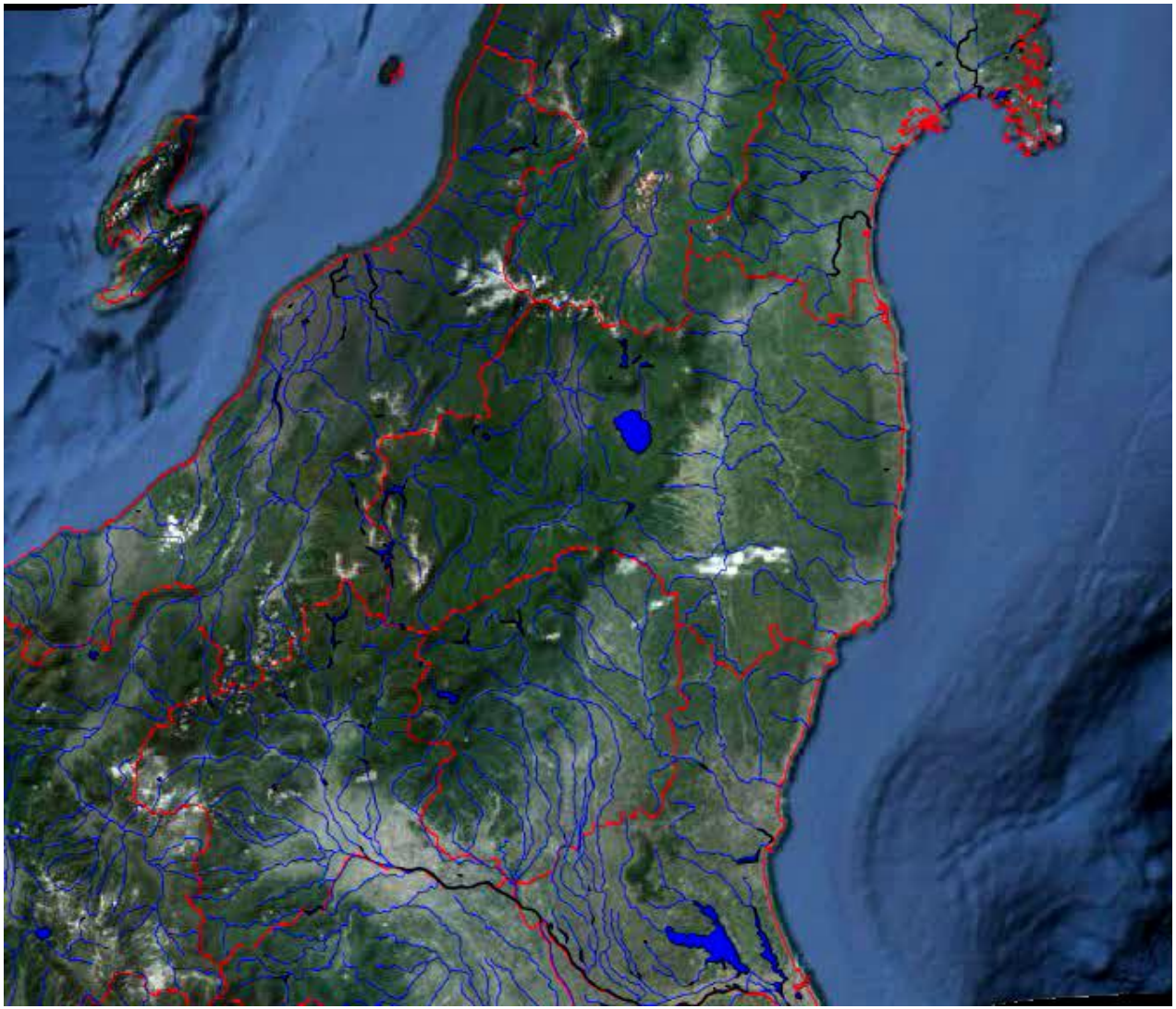
  - Initial mesh determination (feedback on spatial structures)
  - Defining additional points (on risk maps)
  - Positioning samples on radiation maps (use of the correlation between values)

Map of the false negative risk

(declare clean a contaminated area)

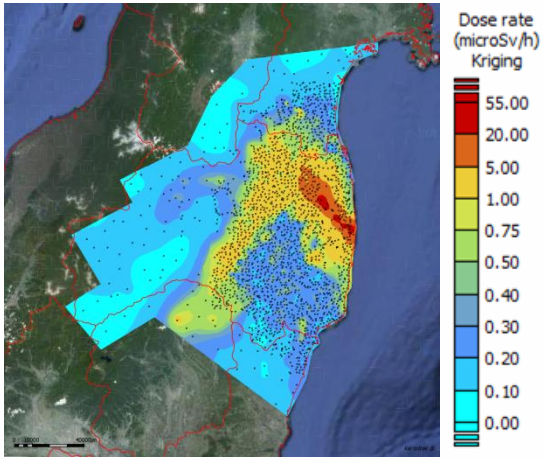


Post-accidental mapping: Fukushima

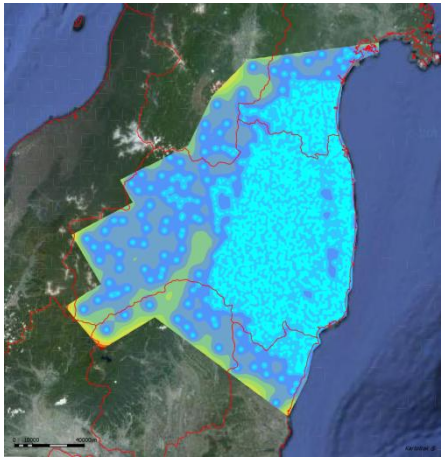


Post-accidental mapping: Fukushima

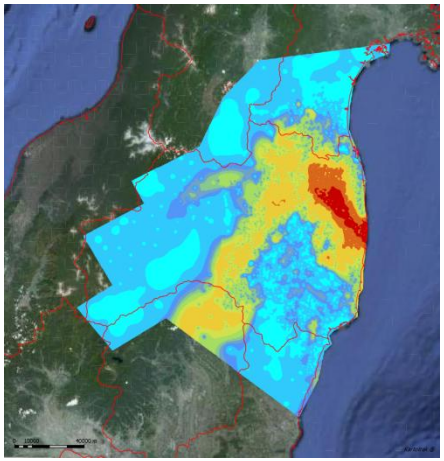
Kriging



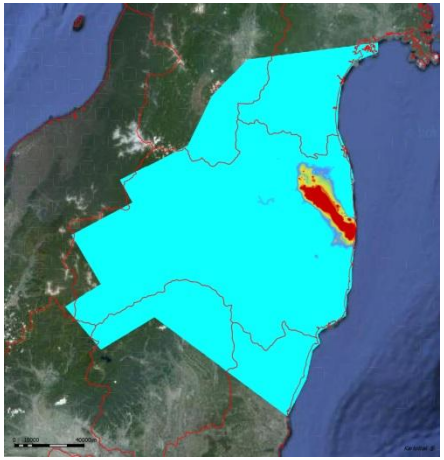
Error variance



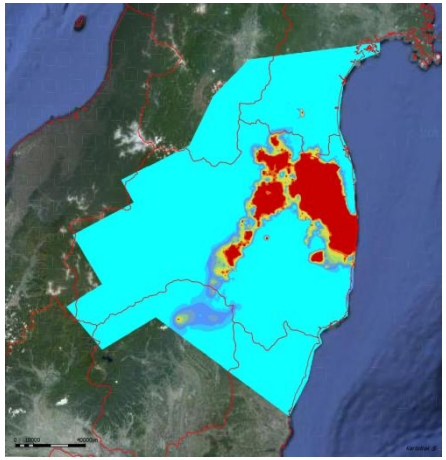
Confidence interval



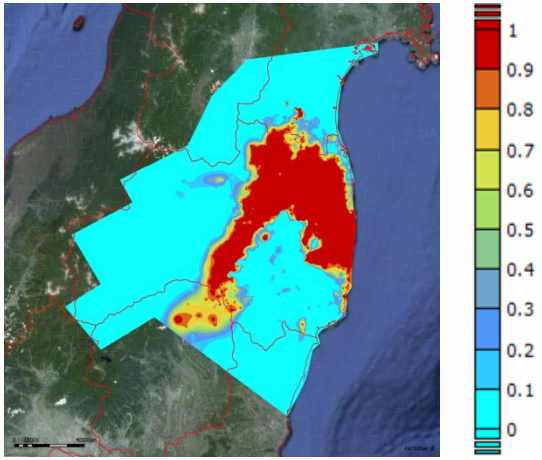
Probability > 5 µSv/h



> 1 µSv/h

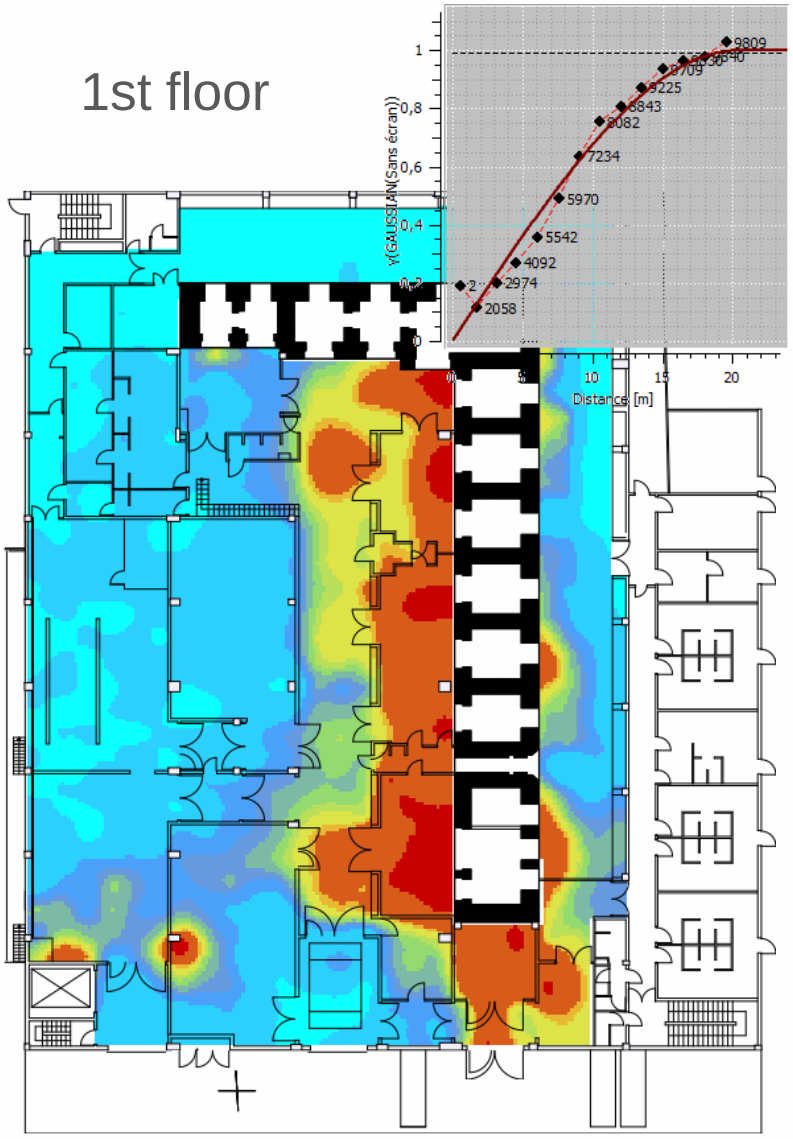


> 0.5 µSv/h

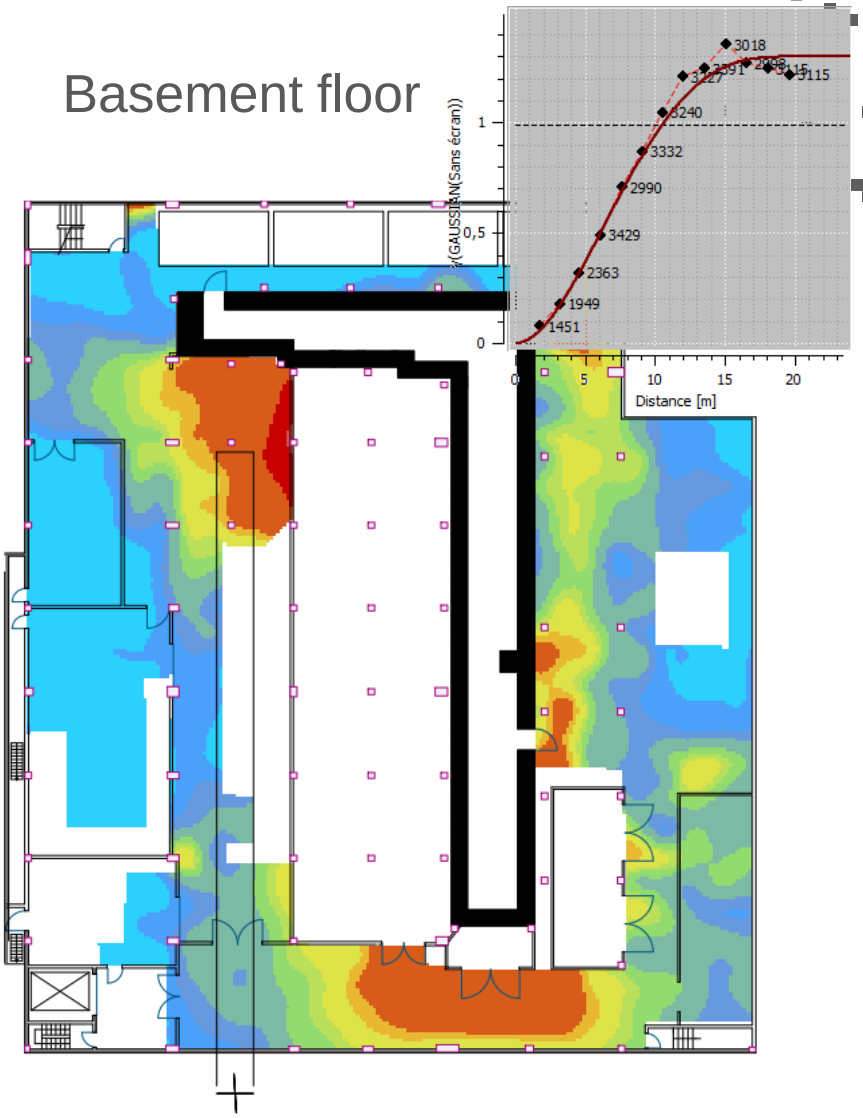


Concrete slab characterisation: RM2 building

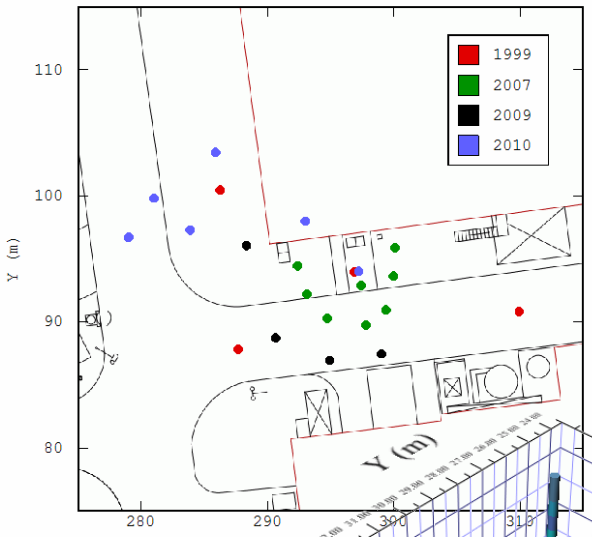
1st floor



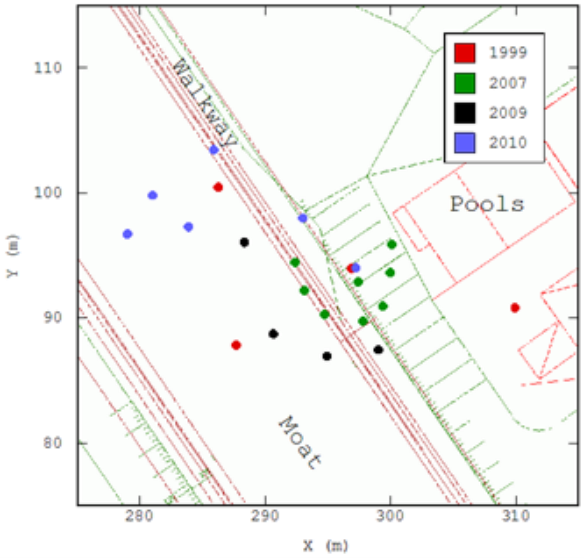
Basement floor



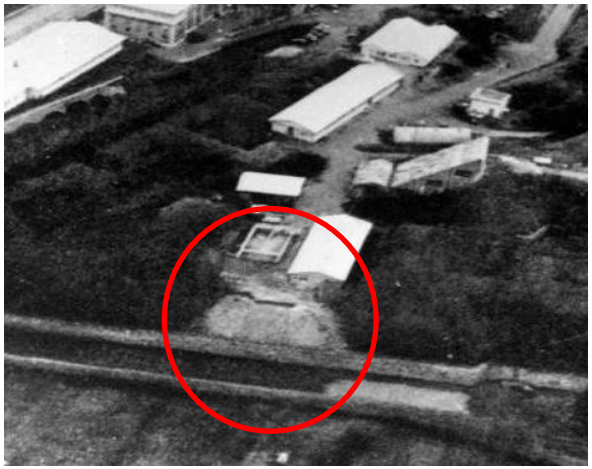
Contaminated soils: a 50 years old case



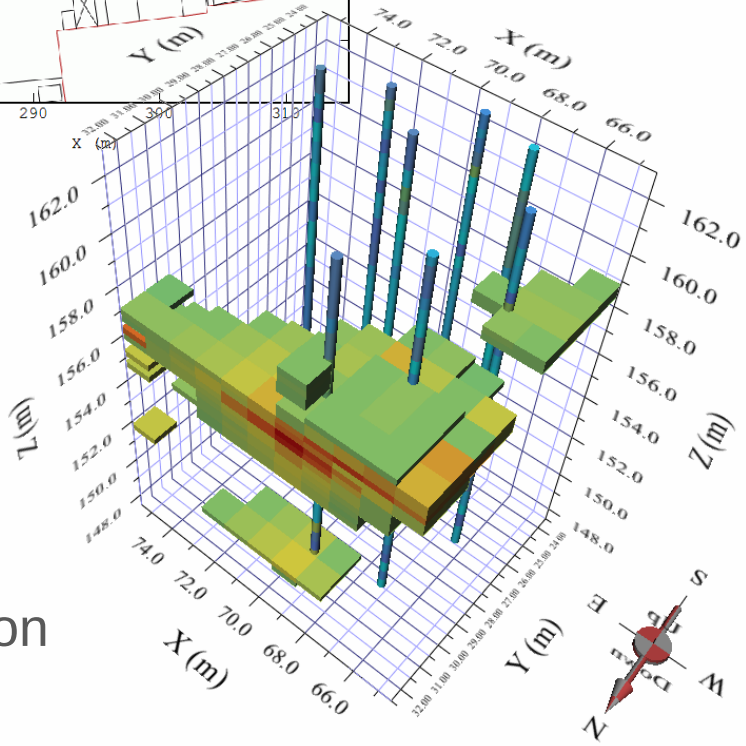
Base map of borehole tops



Historical context

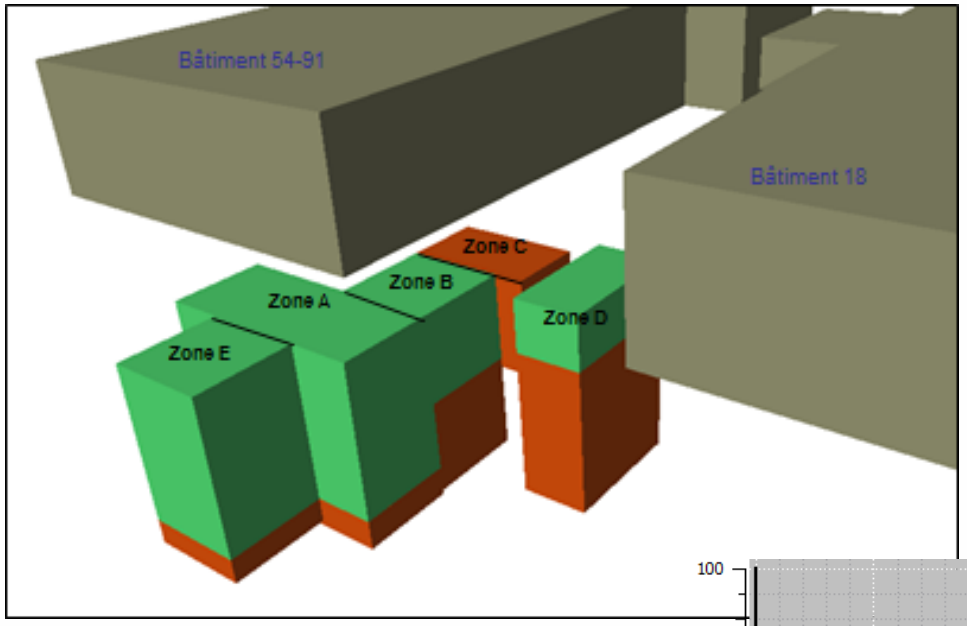


2007 volume estimation

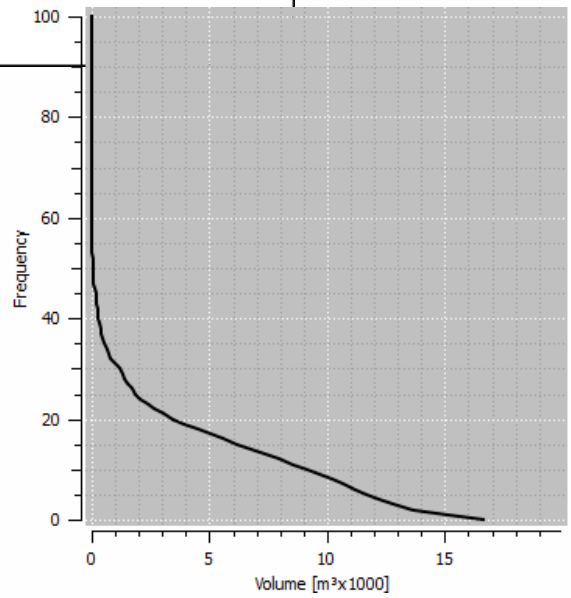


Contaminated soils: a 50 years old case

Contaminated soils: a 50 years old case



- 2000 m³ of conventional waste
- 2000 m³ of VLL waste



To sum up geostatistics

Understand

Exploratory data analysis

- Preliminary stage of geostatistics processing
- Data consolidation (cleaning errors and dealing with heterogeneities) and first spatial and statistical analyses (base map, histogram, correlation…)

Model

Spatial structure analysis (variography)

- Analysis and modelling of the phenomenon spatial continuity
- Integration of auxiliary variables to improve further estimates (multivariate, external drift…)

Interpolation (kriging estimates)

- Based on the variogram model, mapping of the phenomenon
- Kriging smoothing of the reality

Visualise

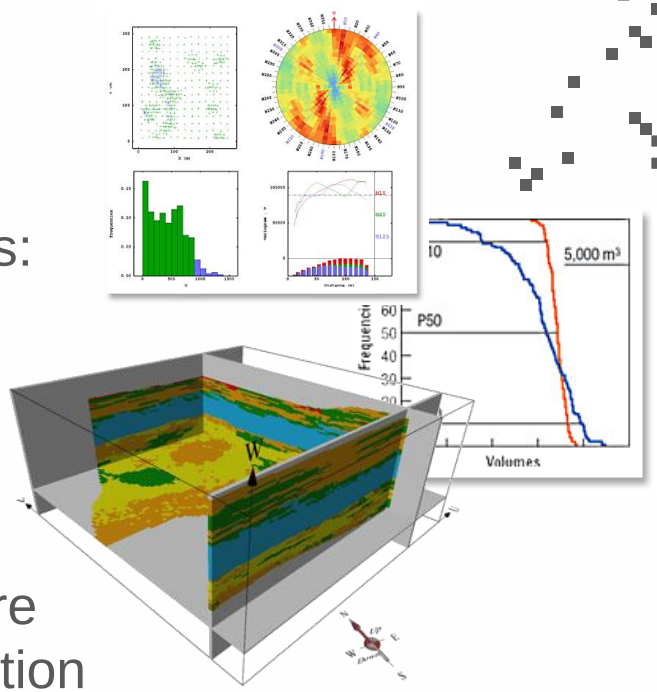
Risk analysis (uncertainty)

- Local mapping of the uncertainty
  - Geometric uncertainty
  - High variability areas
  - Probability of exceeding a threshold: waste classification
- Global estimates of total surfaces, volumes and accumulation (total activity)

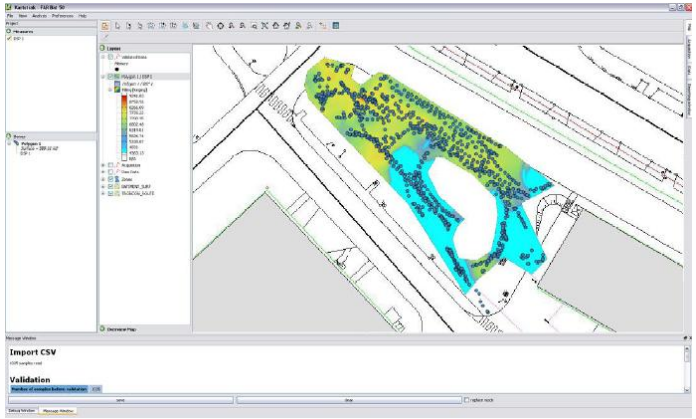
Decide

Geovariances

- 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)



Developed in partnership with cea