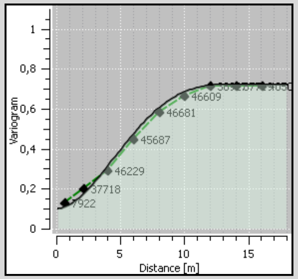
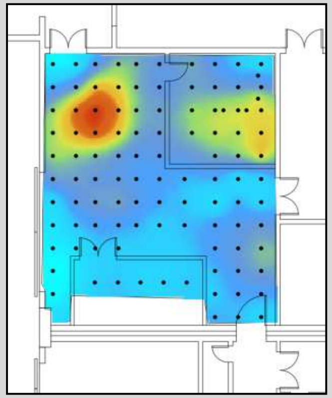
DE LA RECHERCHE À L'INDUSTRIE

International Experts' Meeting on
Decommissioning and Remediation
after a Nuclear Accident

RADIOLOGICAL CHARACTERIZATION OF ACCIDENT-DAMAGED FACILITIES AND SITES





Yvon DESNOYERS – desnoyers@geovariances.com

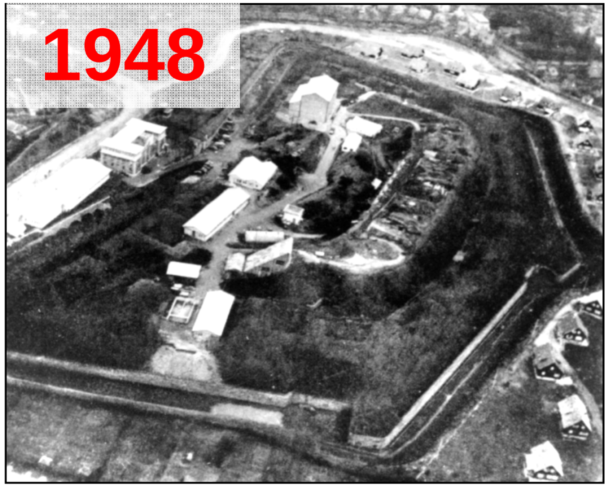
Didier DUBOT – didier.dubot@cea.fr

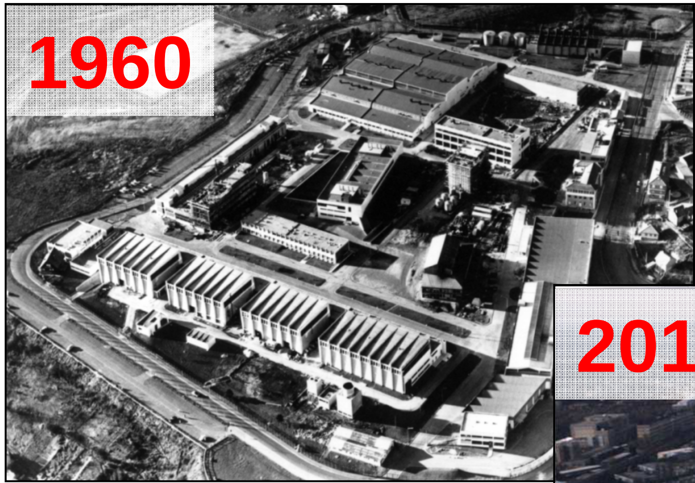
www.cea.fr

Challenges in Planning and Implementation of Decommissioning

January 30th, 2013

CONTEXT AND METHODOLOGY





CEA-FAR:
1st CEA Centre,
created in 1945

1999: Decision to clean up the site
→ Remediation Service: SAS

- Clean up of hazardous places done by 2012-2013
- Tools development dedicated to sites and soils remediation
- Expertise in French and foreign sites

Exploitation of the 1st generation facilities

Exploitation of the 2nd generation facilities

Progressive stop of nuclear activities and 2nd generation facilities decommissioning

Facilities decommissioning New facilities for medical research

1945 1965 1985 2010 2012

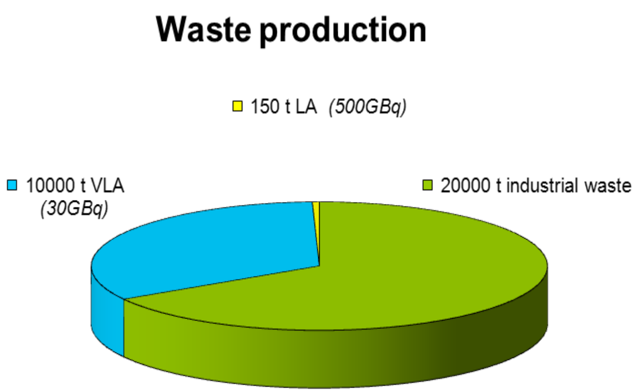
CONTEXT AND METHODOLOGY

French context:

- No remediation level in France for polluted site and soils
- No regulation for soil under and around nuclear facilities

- Optimizing the sanitary impact: between 0.01 and 0.3 mSv/yr

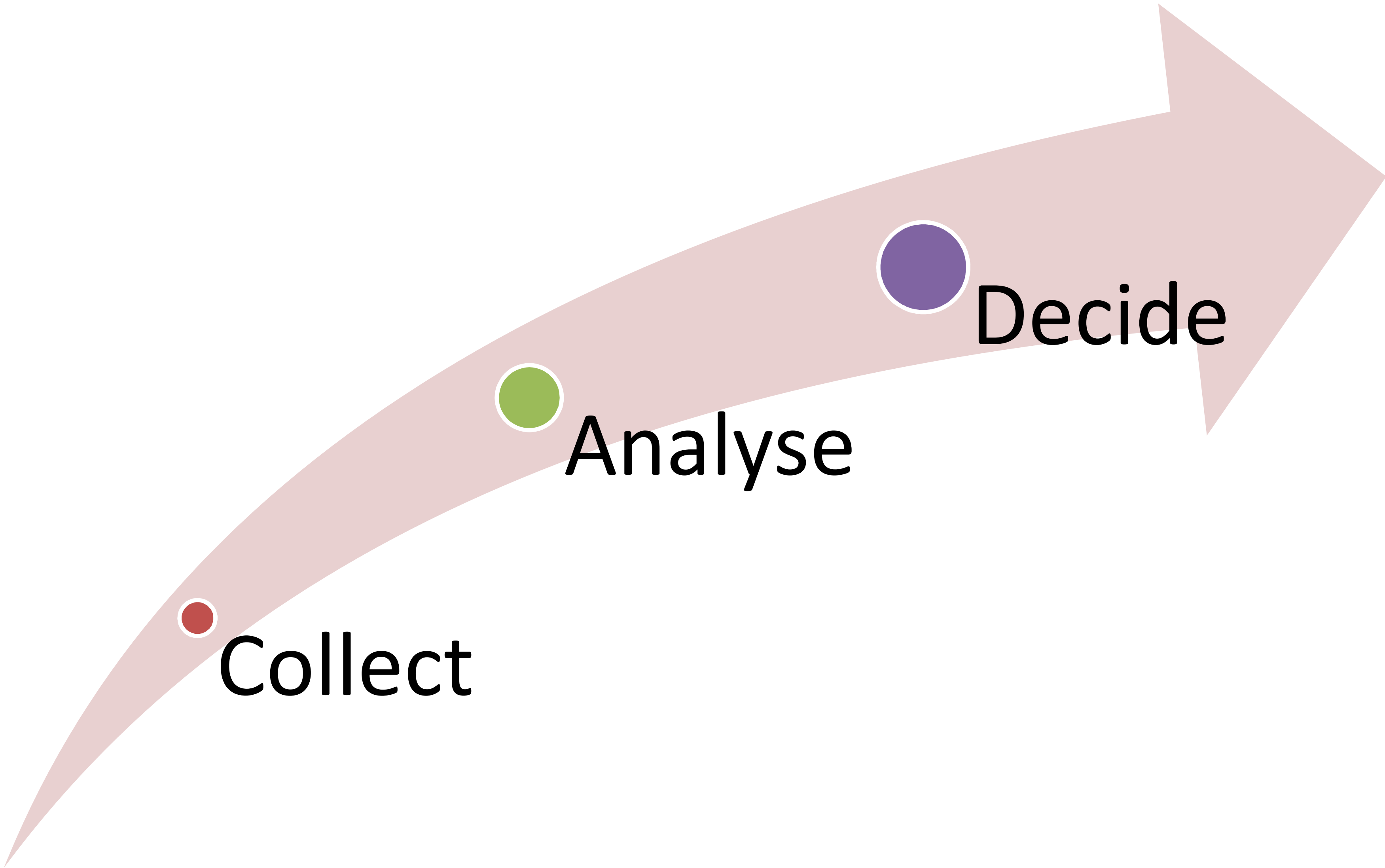
- Necessity to have methods, procedures and reliable tools dedicated to sampling



Clean-up Process of CEA/FAR Site → 45 M€

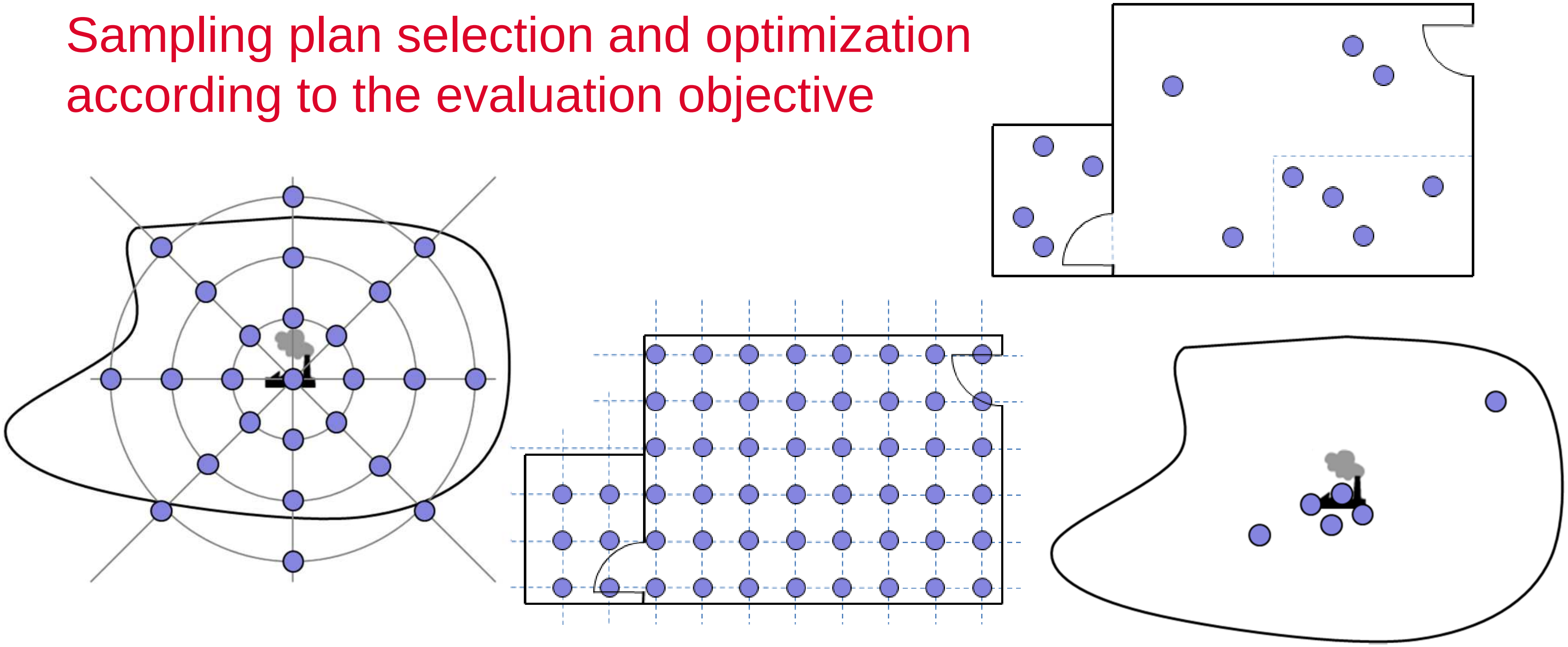
Historical investigations
↓
Functional analysis
↓
Radiological surface evaluation
↓
Radiological in-depth evaluation
↓
Cost/advantage study
↓
Optimized remediation works
↓
Final survey

TABLE OF CONTENTS



SAMPLING STRATEGY

Sampling plan selection and optimization according to the evaluation objective



- **Circular grid**: Extension of contamination diffusion (plume models)
- **Regular mesh**: Mapping the contamination / Hot spot identification
- **Random design**: Statistical tests and results (Marssim, Wilks…)
- **Exhaustive survey**, **Judgmental approach**…

TWO EXPERTISE VEHICLES

LAMAS

- Acquisition cell: gamma spectrometry, GPS, atmospheric, weather
- Sample treatment cell (radiochemistry)

→ Post-accidental intervention and remediation work monitoring

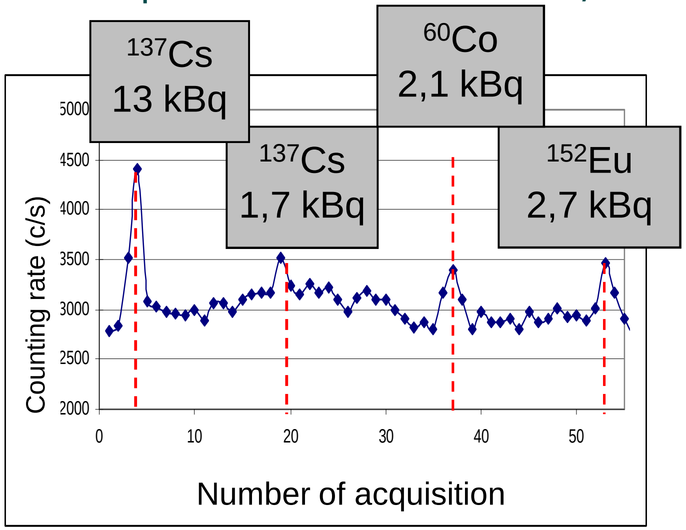
VEGAS

- 4 WD vehicle with speed control system and differential GPS for real-time positioning, submetric accuracy
- Radiation measurement devices

→ Initial mapping of contaminated sites, localization of « hot spots »

VEGAS: DETECTION PERFORMANCES

For a punctual source at 5km/h



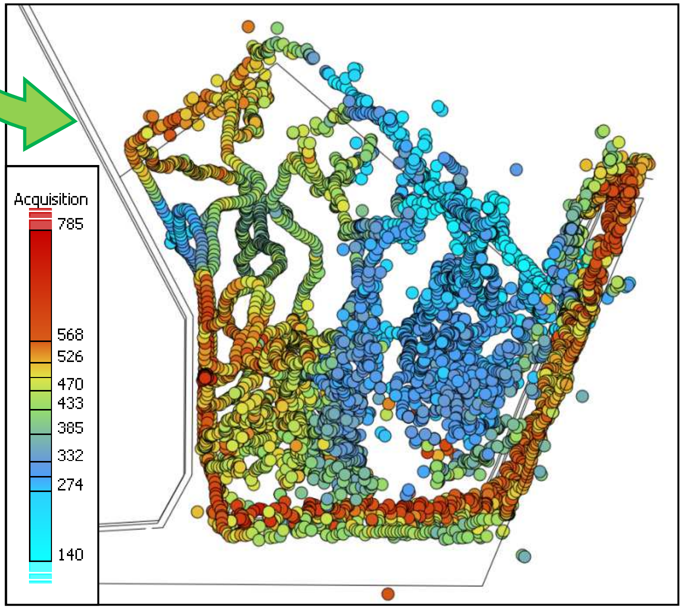
Geometry and extent of surface contamination can be defined with good accuracy

Relevance for quick identification and characterization of areas with high counting rates (1 ha/hour)

Radionuclides	Punctual source (kBq)		Tar roads (kBq/m²)		Grounds (kBq/kg)	
	2.6 km/h	5 km/h	2.6 km/h	5 km/h	2.6 km/h	5 km/h
^{137}Cs	3.8	5.9	3.7	5.1	68	95
^{60}Co	2.0	3.1	1.9	2.7	36	50

LIGHT REAL TIME ACQUISITION DEVICE

Complementary way to the use of Vegas in order to characterize difficult areas : forests, narrow places, rugged places…



<u>Simple equipment:</u>
GPS + NaI 3" connected to a laptop

<u>Detection limit when walking:</u>
1Bq/g eq. ^{137}Cs

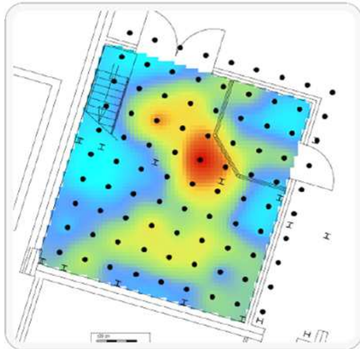
ONE METHODOLOGY, MANY WAYS TO APPLY

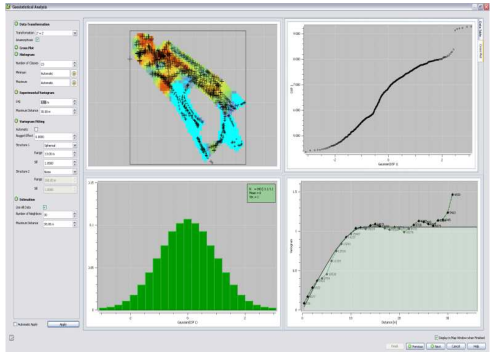
Mandatory equipment:
- Computer
- GPS device
- Measuring device(s)
- Centralization software
- Training & experience

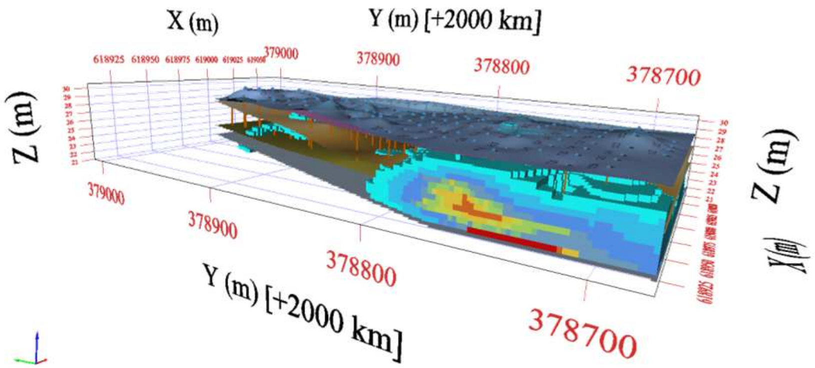
SOFTWARE SOLUTION kartotrak

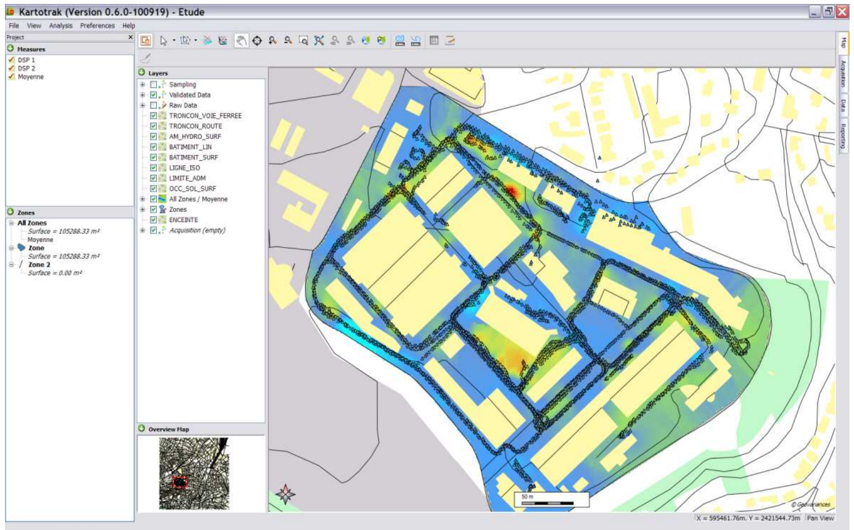
All-in-one software solution for contaminated site characterization
Born-out from a partnership between CEA and Geovariances

- Integrated workflow based on GIS component and 3D viewer
- Real-time data positioning and acquisition (GPS and measuring devices)
- Data analysis, quality control, contamination mapping and risk assessment based on geostatistics methods

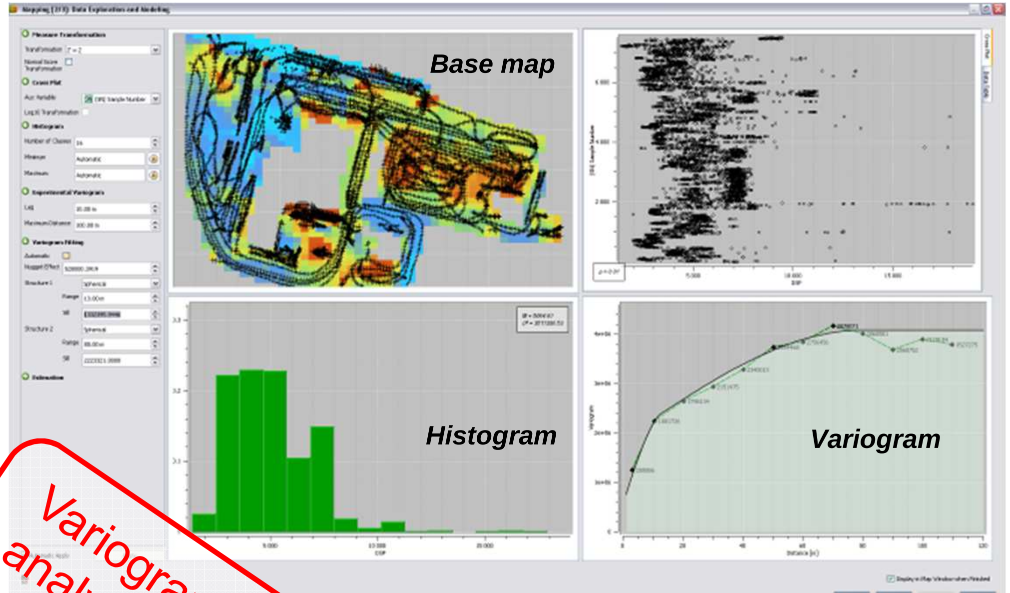




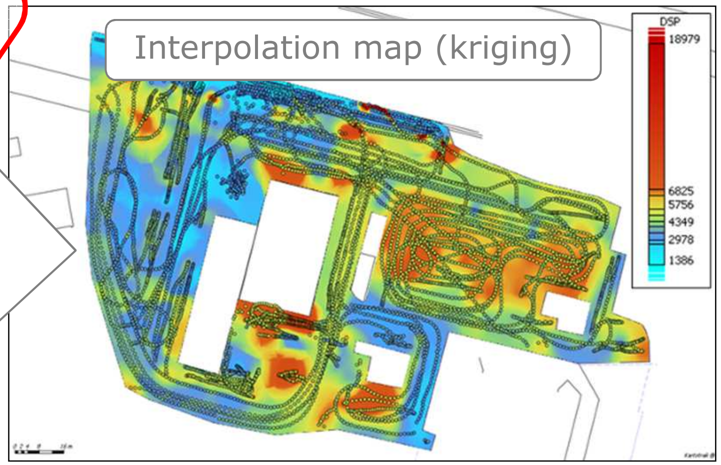




DATA PROCESSING: GEOSTATISTICS



Variographic analysis and modeling



Integration of
the spatial structure
of the contamination

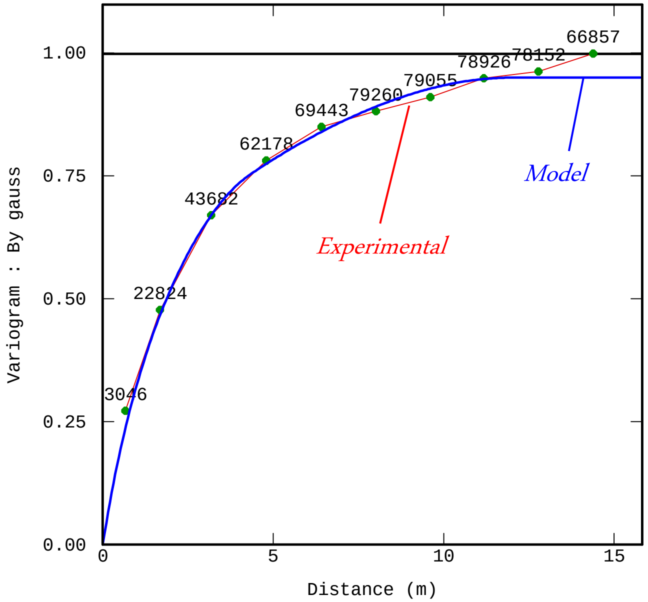
INNOVATIVE RADIOLOGICAL MAPPING SOLUTION

Geo + Statistics: integration of the phenomenon spatial continuity

Main tool of geostatistics: the variogram
(describes the variability between 2 points)

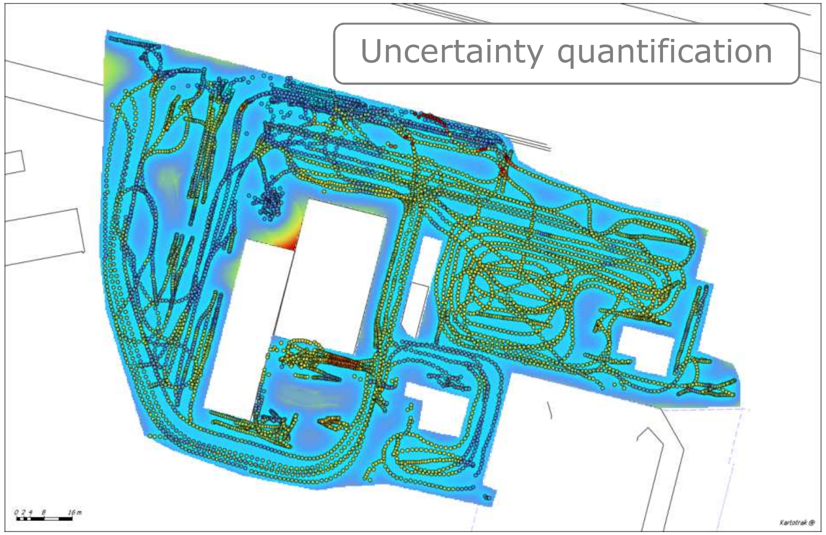
- On average, the difference between two CLOSE measures is LOW
- On average, the difference between two DISTANT measures is HIGH

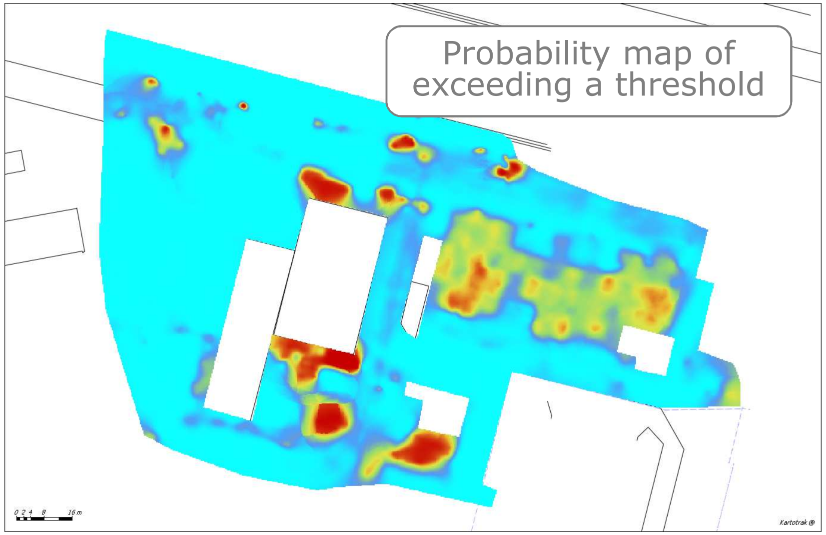
$$\gamma(h) = \frac{1}{2} E\left[Z(x) - Z(x+h)\right]^2$$



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

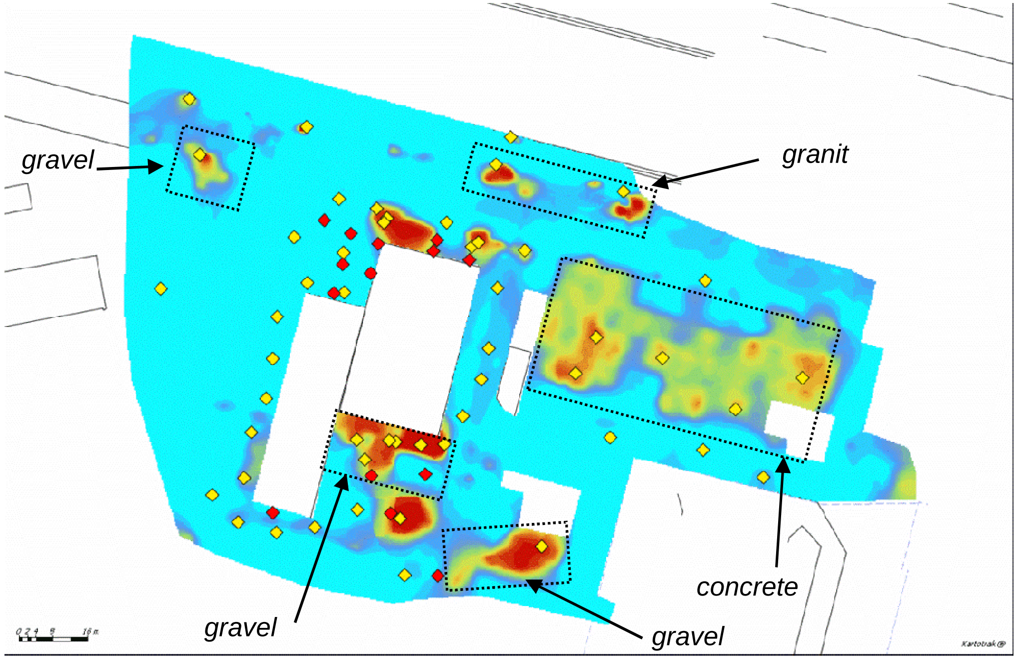
GEOSTATISTICS: MAPPING RESULTS



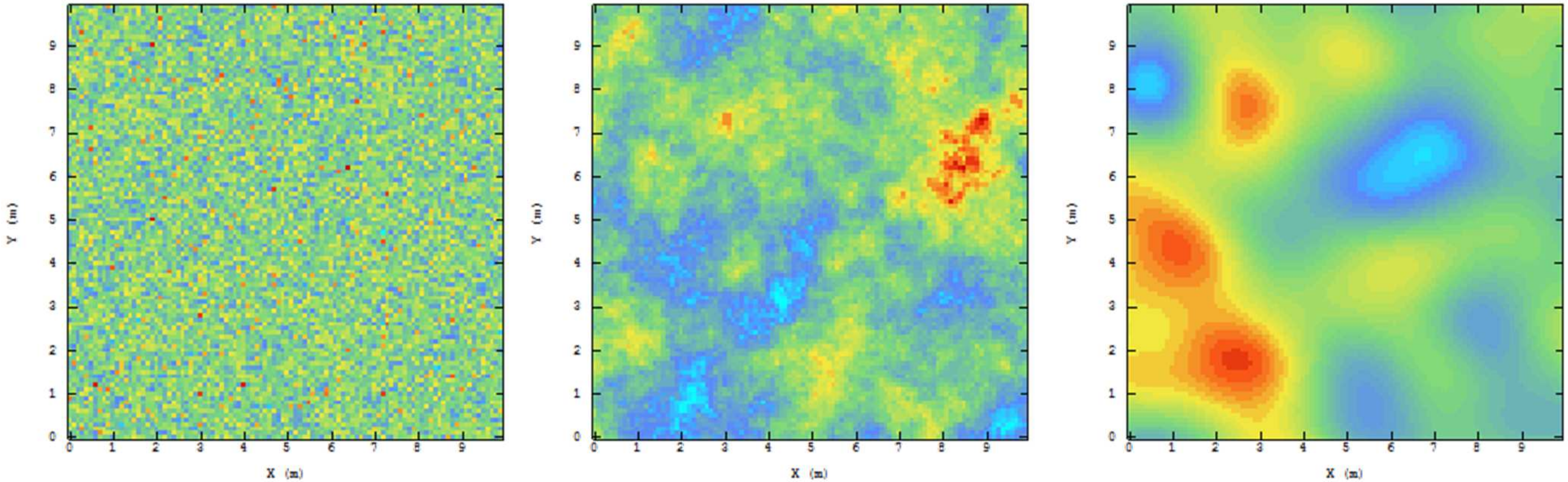


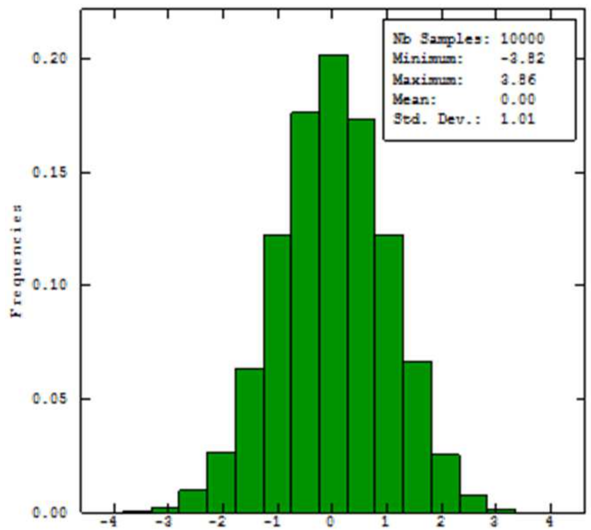
Combined with uncertainty and probability maps, the kriging result helps decide further actions to reduce uncertainty:

- Gamma spectrometry ◇ for nuclide identification (fingerprint)
- Soil samples ◆ for activity quantification
- Drillings…



THREE SPATIAL STRUCTURES

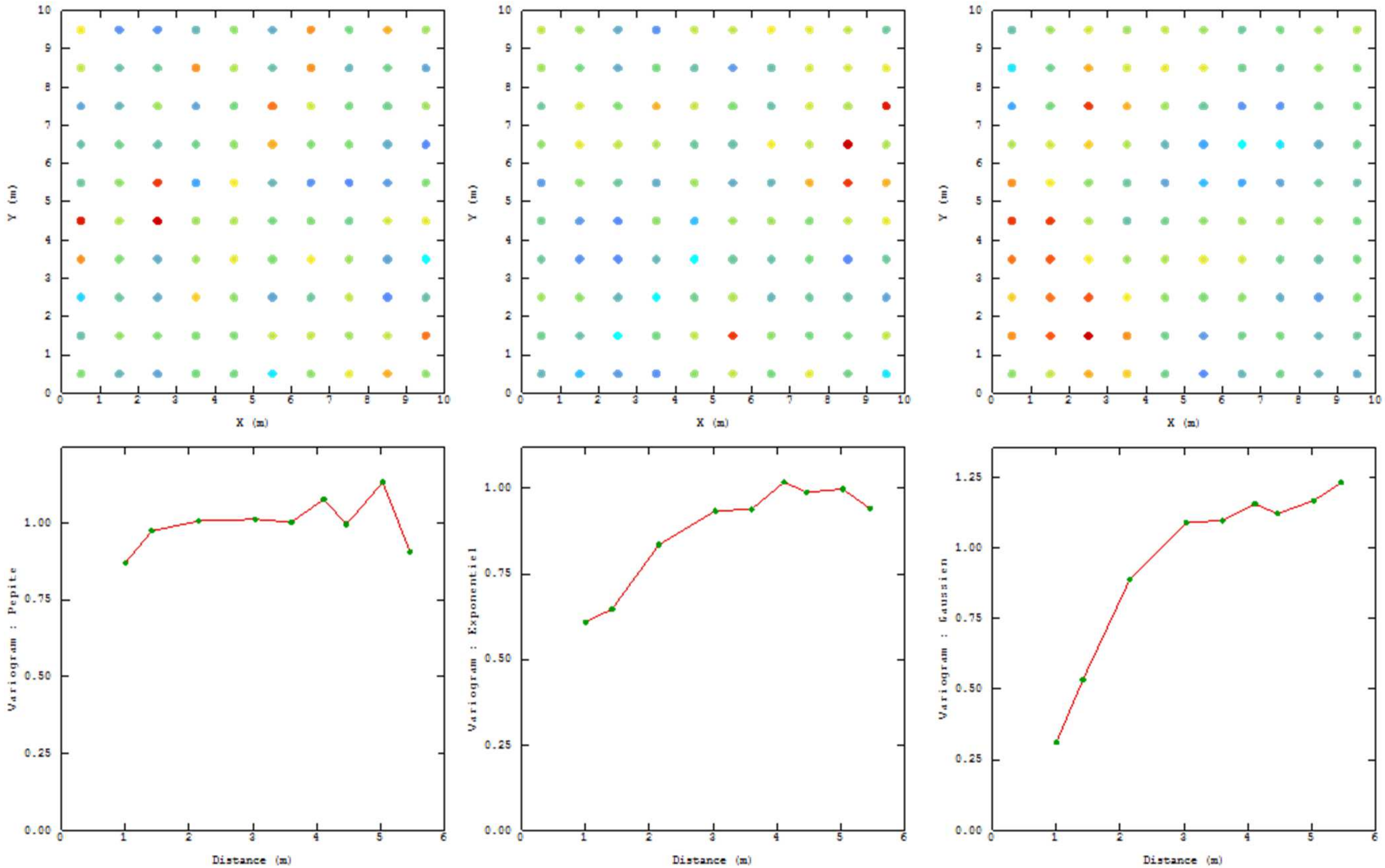




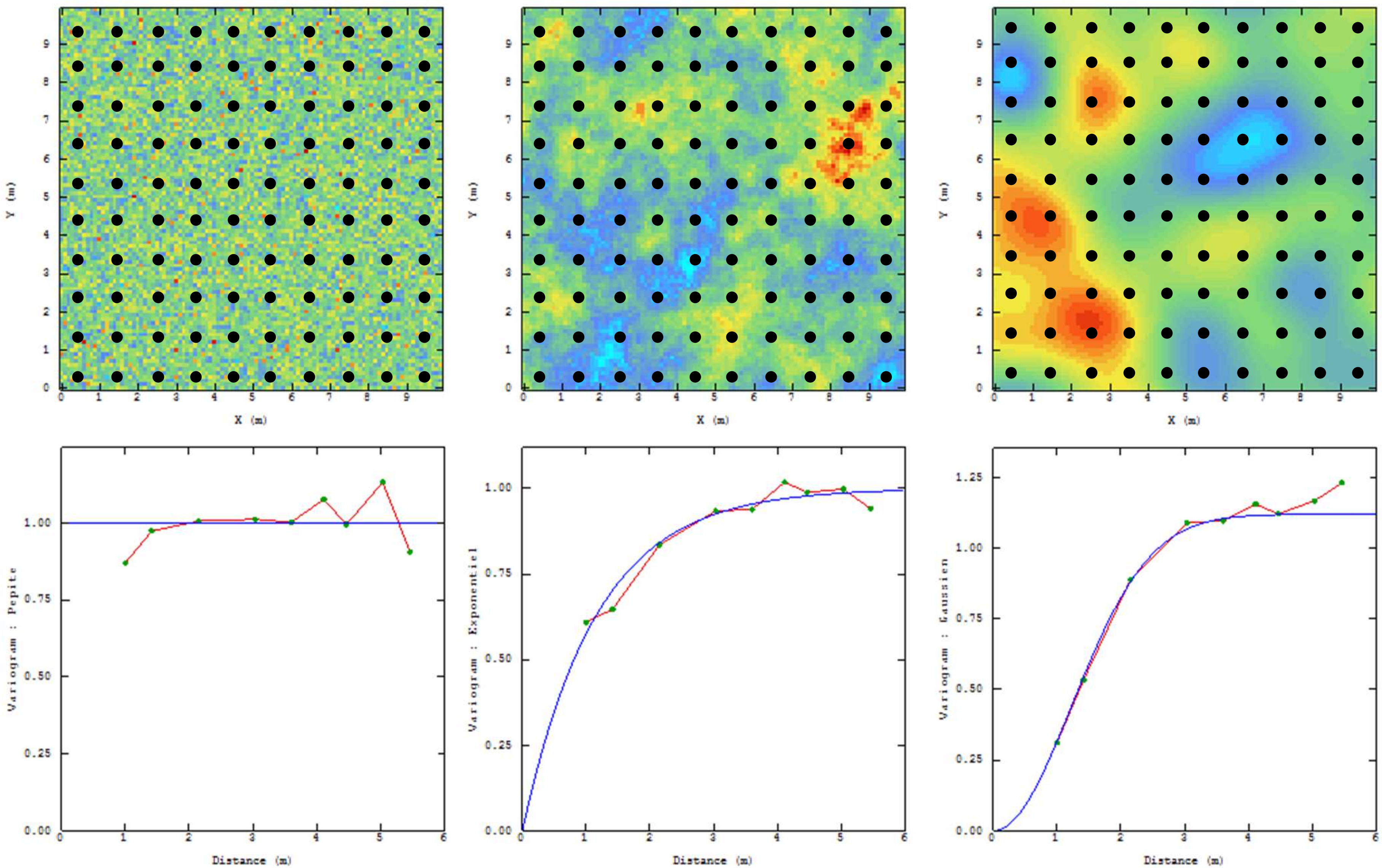
Three spatial representations of the same statistical distribution

Caracterisation of the spatial structures thanks to a regular sampling grid

THREE SPATIAL STRUCTURES



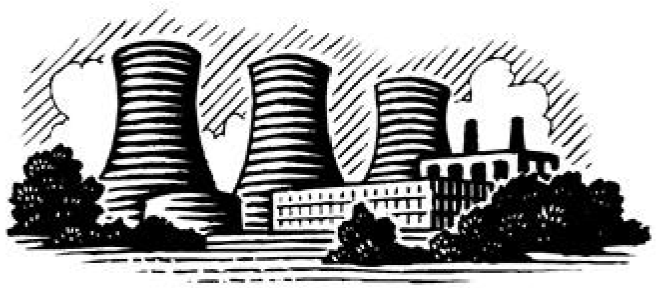
THREE SPATIAL STRUCTURES

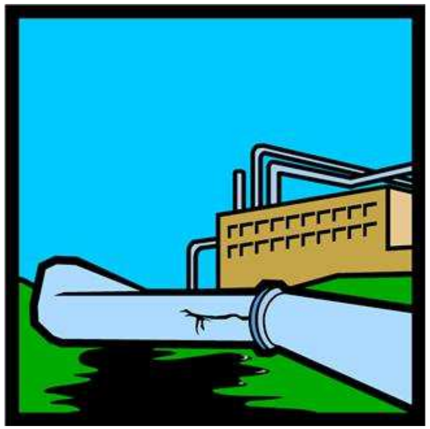


APPLICATION CASES

Geostatistics use at different scales

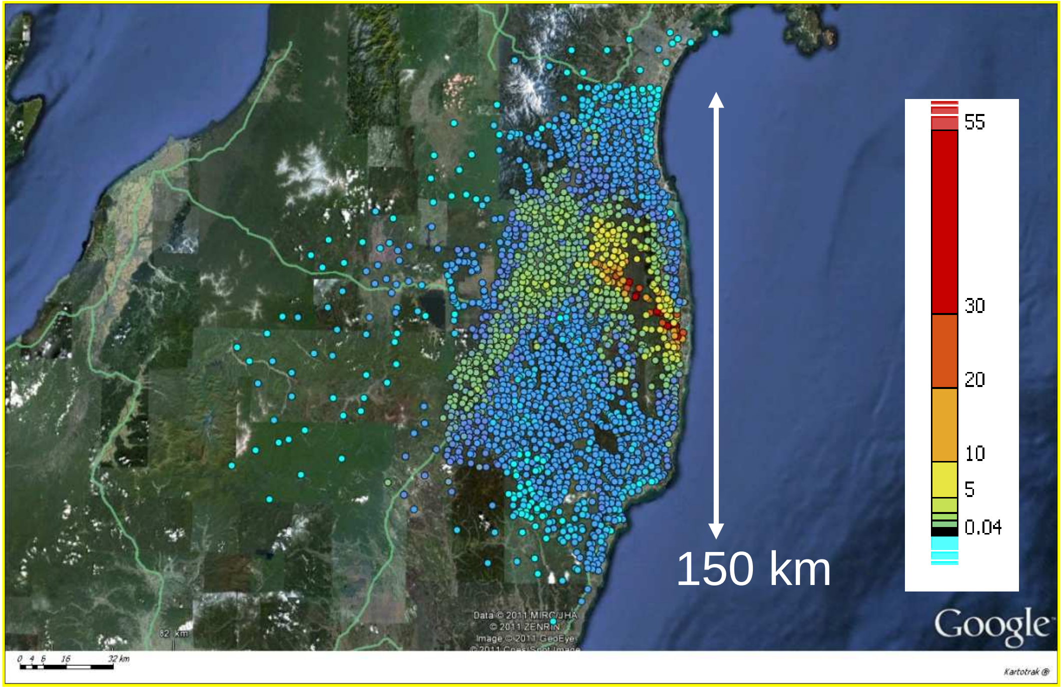
- Regional scale
- Nuclear site scale
- Buildings structures
- In-depth soil contamination
- Other application fields



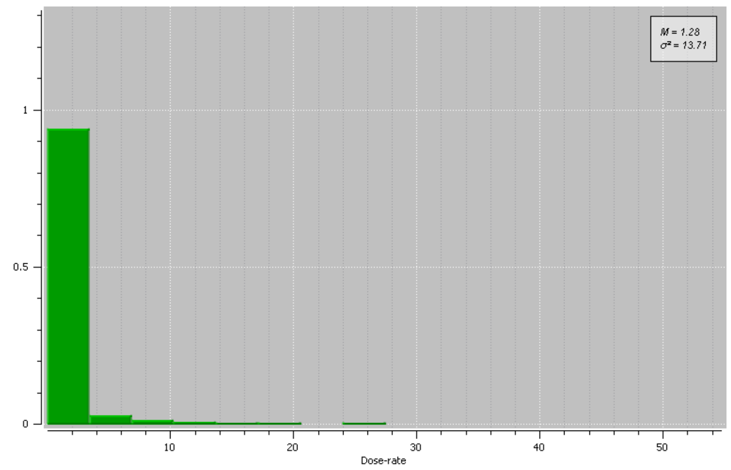


JAPAN, FUKUSHIMA (REGIONAL SCALE)

Display of the Dose rate data (µSv/h)



Histogram



All presented maps were obtained with the software Kartotrak, with a Google Earth capture.
The computations have been performed based on 2182 measures of dose rate.

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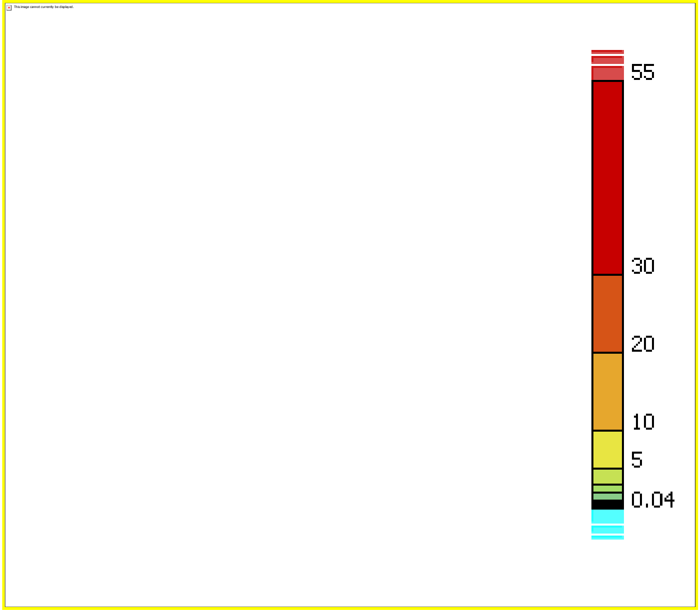
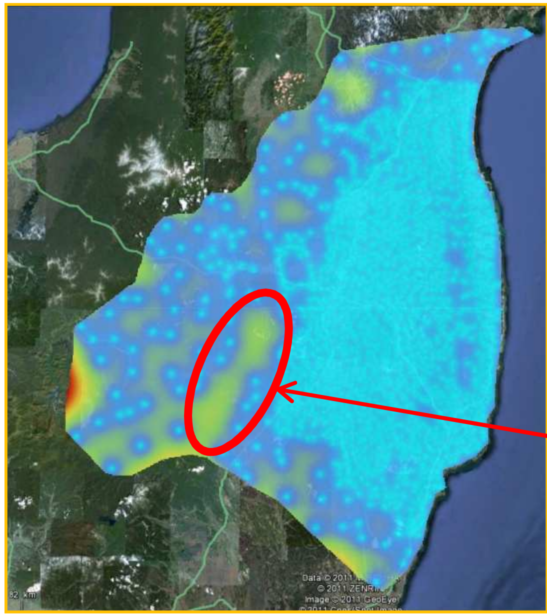
JAPAN, FUKUSHIMA (REGIONAL SCALE)

Data interpolation

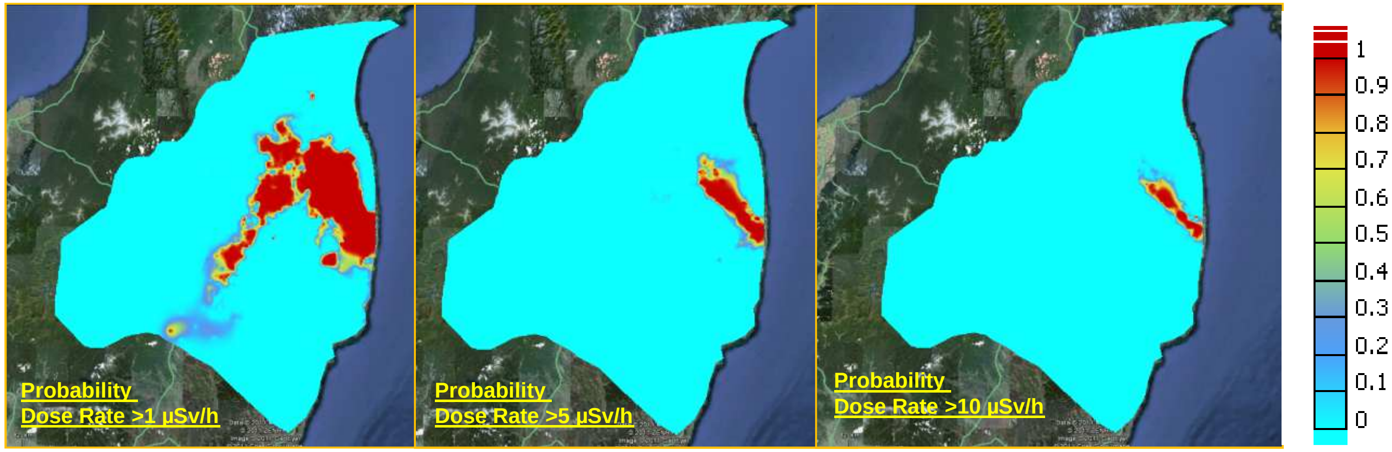


Uncertainty map



Having more data would be very interesting in this area

Probabilty maps

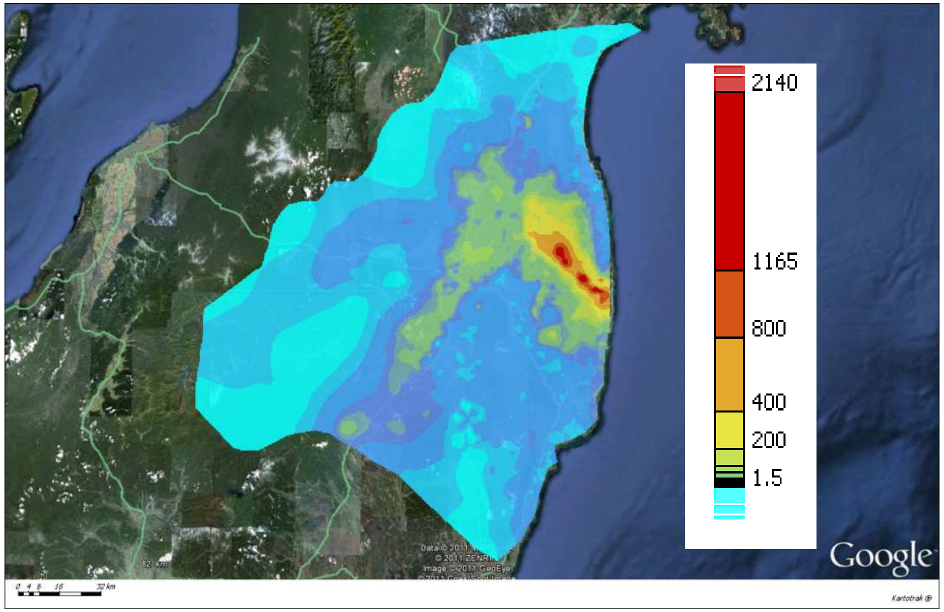


JAPAN, FUKUSHIMA (REGIONAL SCALE)

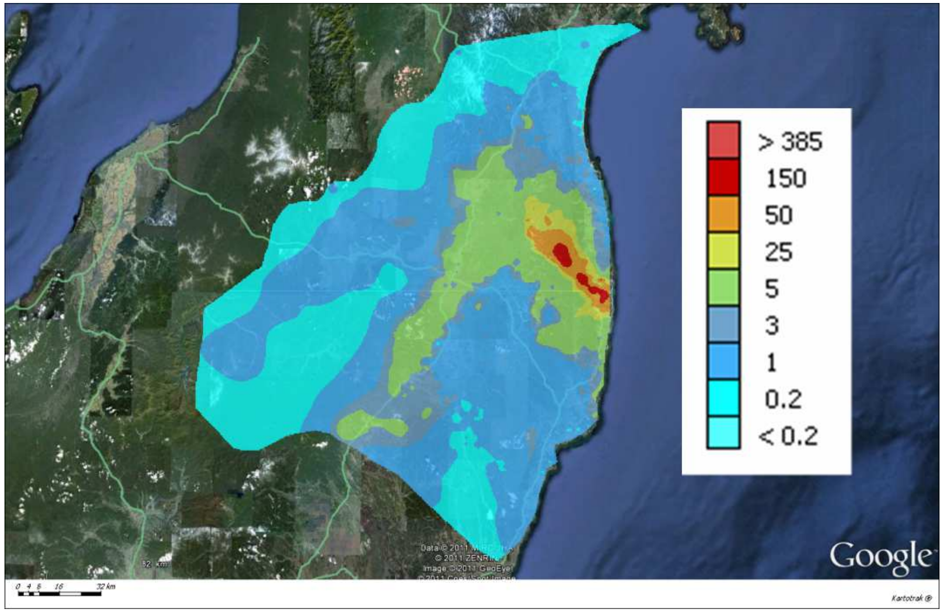
Based on the dose rate values, a modeling was performed in order to estimate the ^{137}**Cs mass activity**, following these hypotheses :

- The dose rate was measured 1m above the ground surface.
- The contamination is spread on 1500m² and is 1cm thick.
- The density of the ground is 1.6.
- The nuclide considered is ^{137}Cs.

An **impact study** was carried out to assess the global dose for the population. Considering the following scenario :
A family spends a lot of time in a single house with a garden and vegetable garden located on the contaminated site.
The people impacted, from a radiological exposition point of view, are a parent at home and mostly their 5-year old child.
Over one year, the child is supposed to stay 1000 hours in the garden, 7760 hours inside the house, including 3300 hours of sleep. We assume as well that half the vegetable they eat come from their vegetable garden. We consider that this house does not have a well or pond.
This scenario takes into account the ingestion, inhalation and extern exposition.



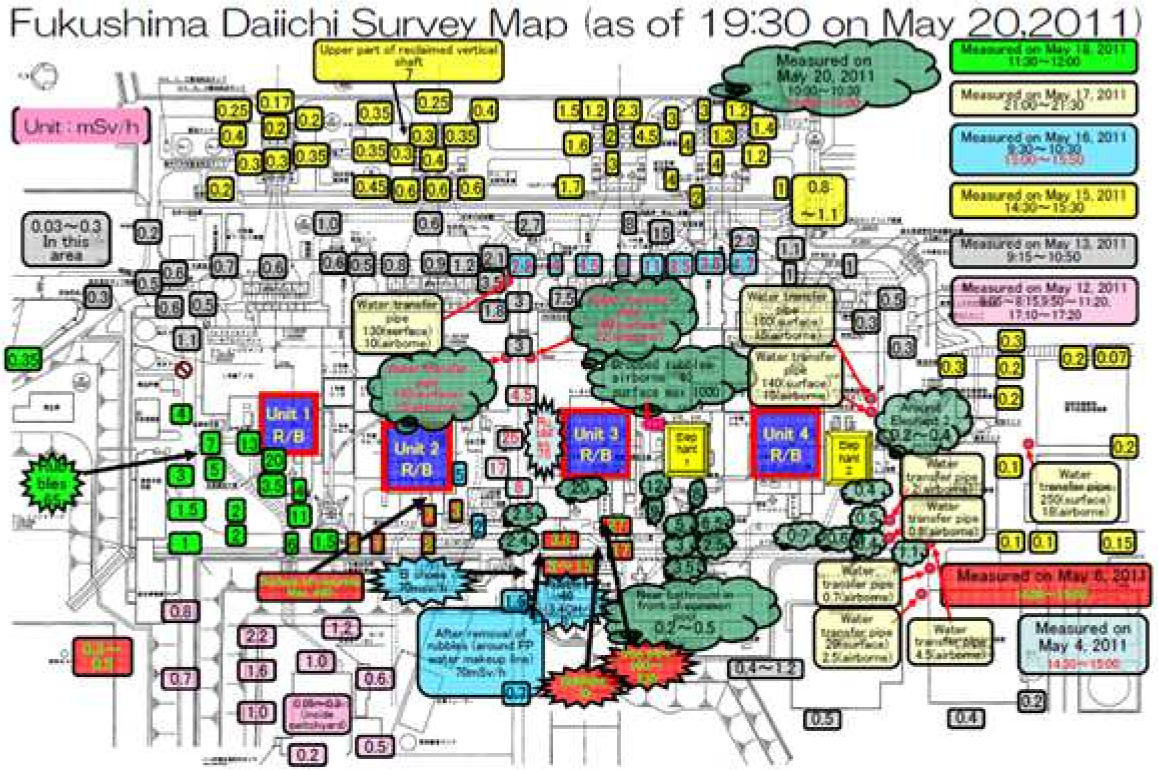
^{137}Cs mass activity (Bq/g)



Yearly impact (mSv/yr)

JAPAN, FUKUSHIMA (NUCLEAR SITE SCALE)

- Data collected by Tepco around Fukushima Daiichi Nuclear Power Plant during the first month after the accident

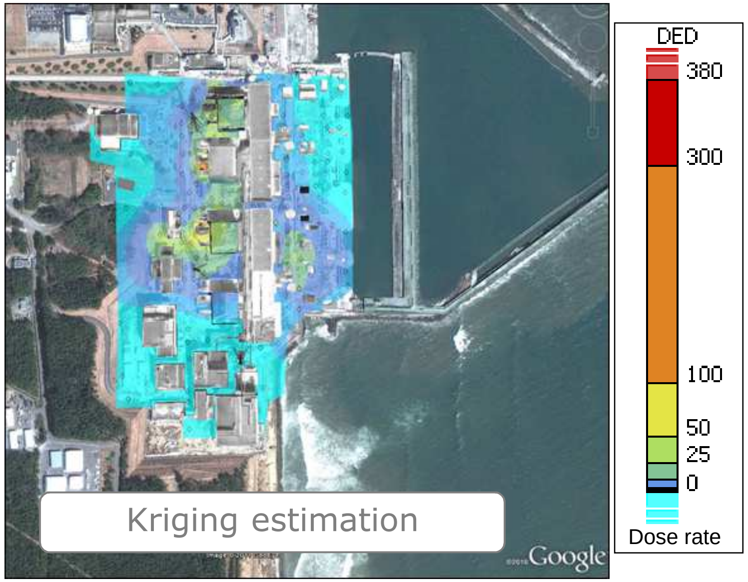


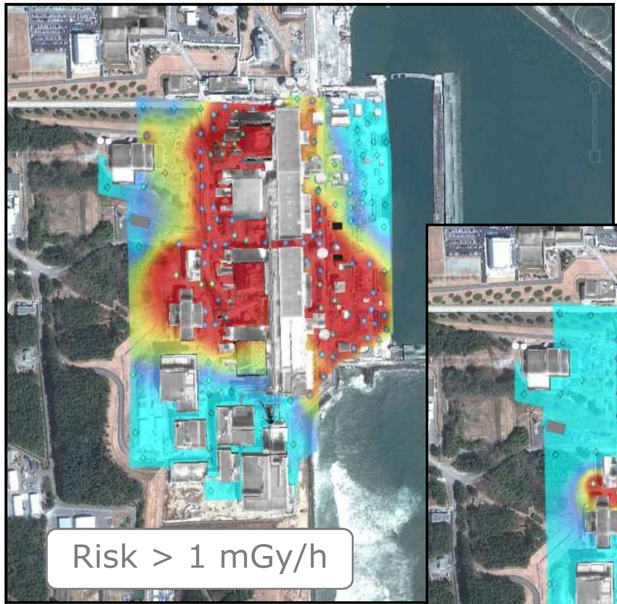
- Digitalization of survey maps (local coordiantes)
- Difficulties for data consolidation temporal variation, measurement protocol…

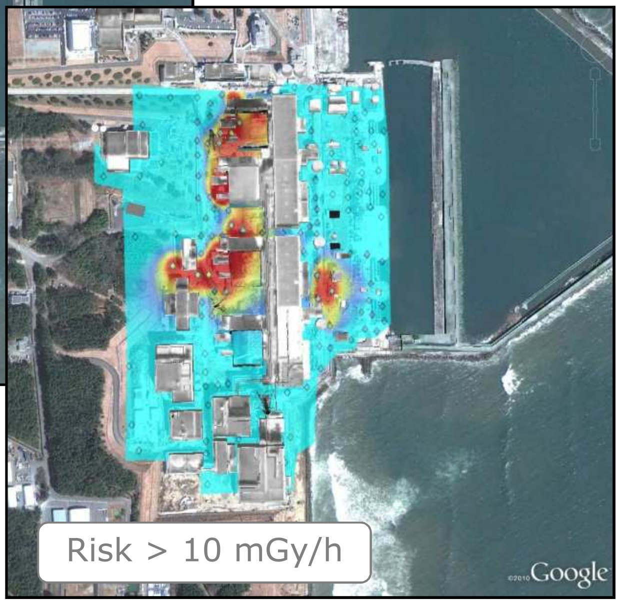
JAPAN, FUKUSHIMA (NUCLEAR SITE SCALE)

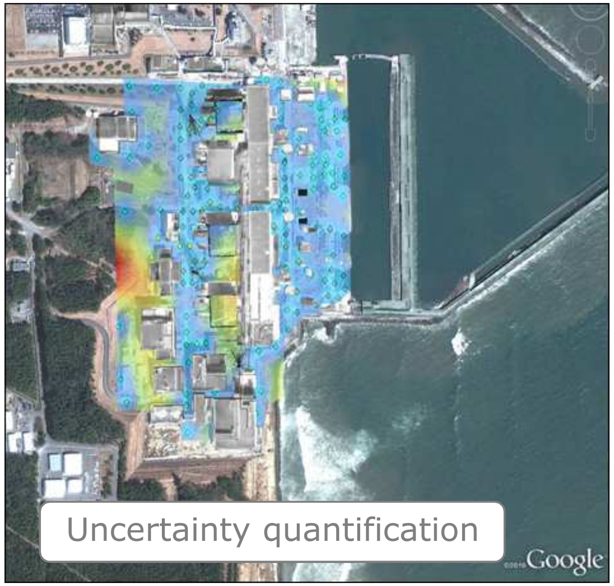
- Quick dose rate mapping
- Easy update (with additional data)

- Dose rate estimation for workers
  (risk maps and cumulative paths)





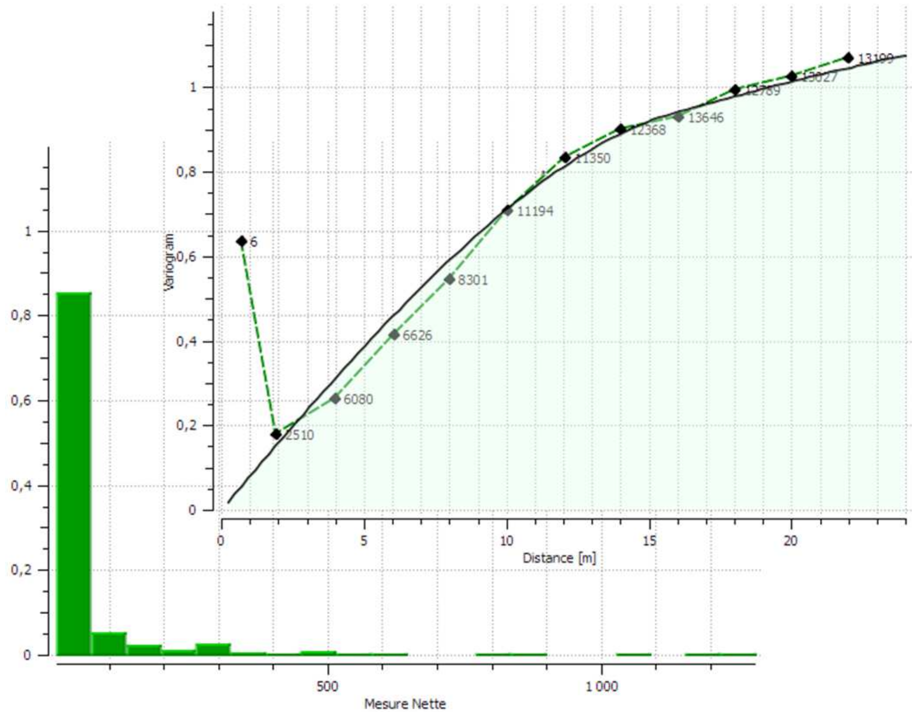




BUILDING CHARACTERIZATION (RM2)

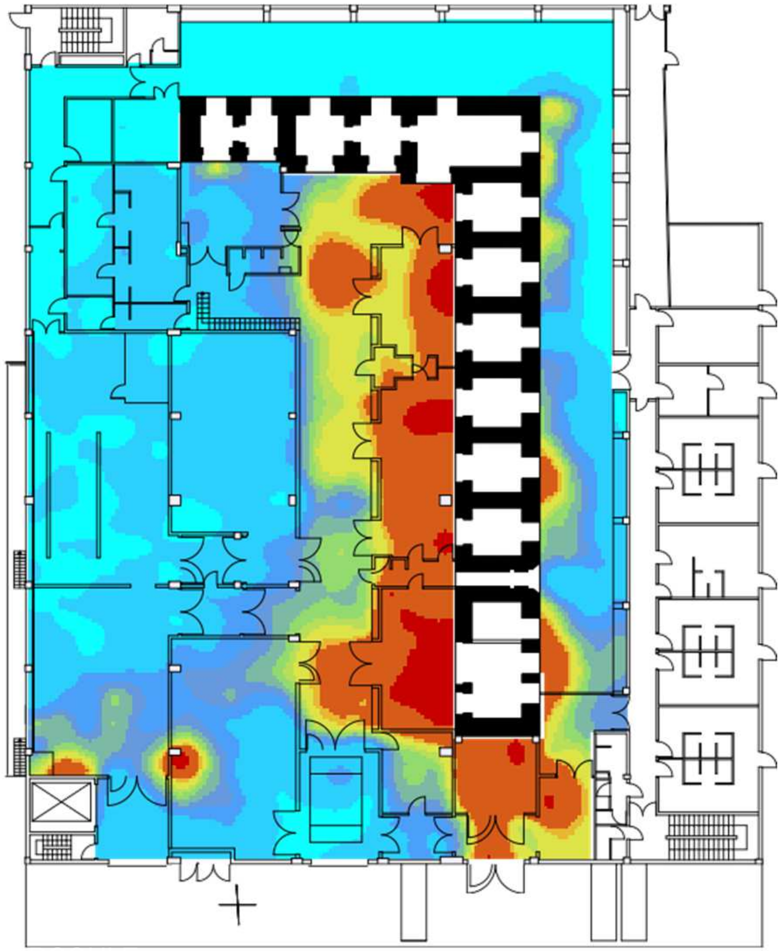
Radio-metallurgy building at CEA-FAR

- Irradiated fuel between 1968 and 1982
- 1,500 m² per level
- Regular mesh: 1.5 m → 650 points

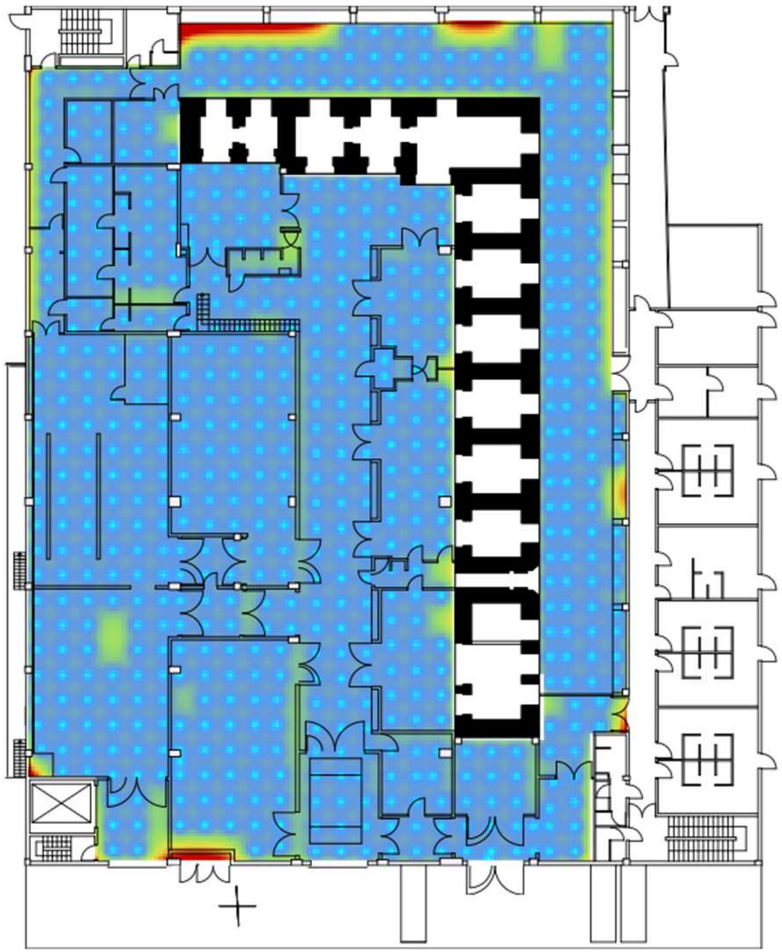


BUILDING CHARACTERIZATION (RM2)

Kriging estimation



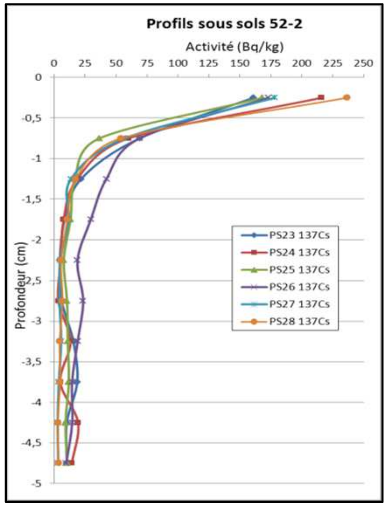
Kriging uncertainty



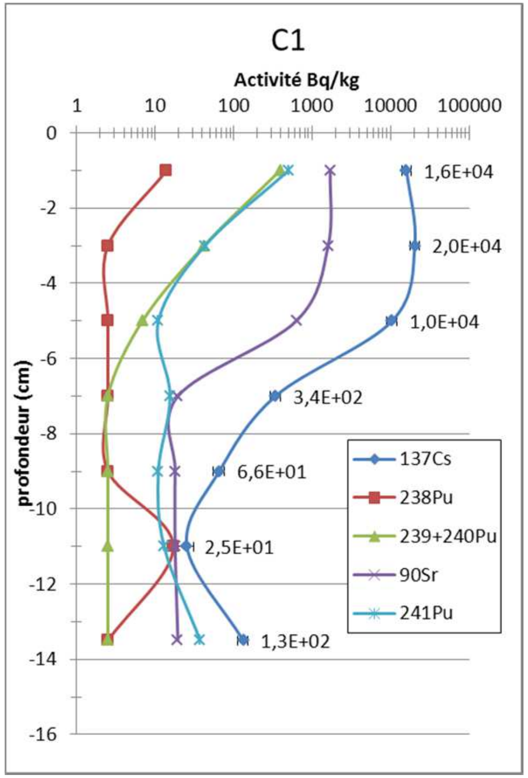
BUILDING CHARACTERIZATION (RM2)

1st campaign: NaI, samples, profiles and spectrums examples

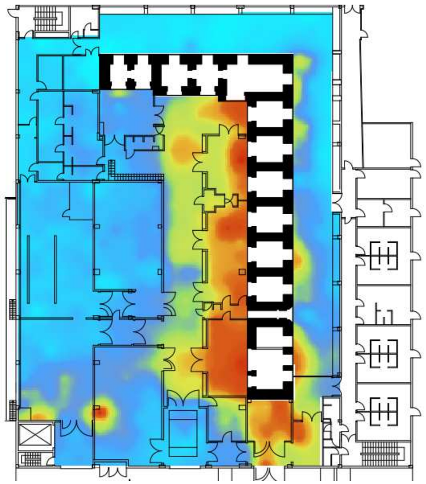
- Basement

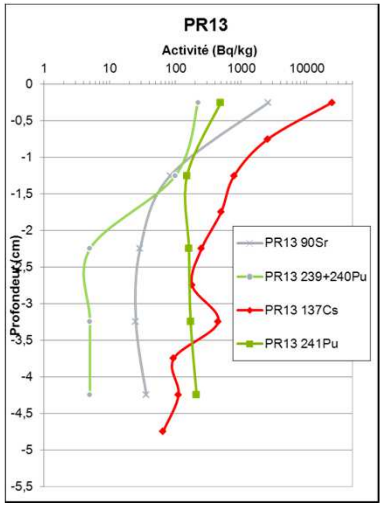


Other singularities: activity <1Bq/g



- Ground floor

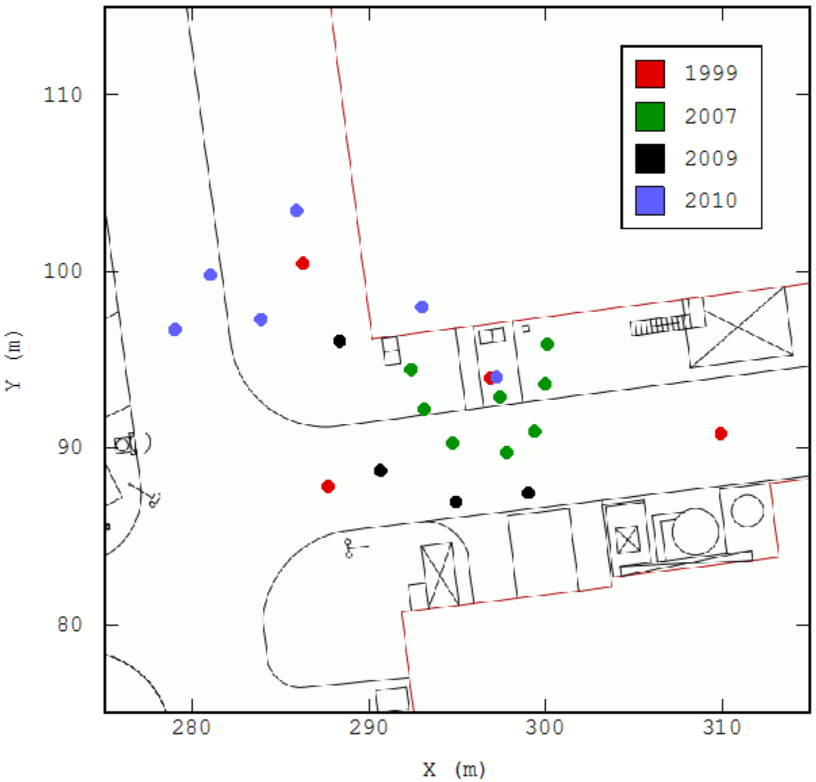


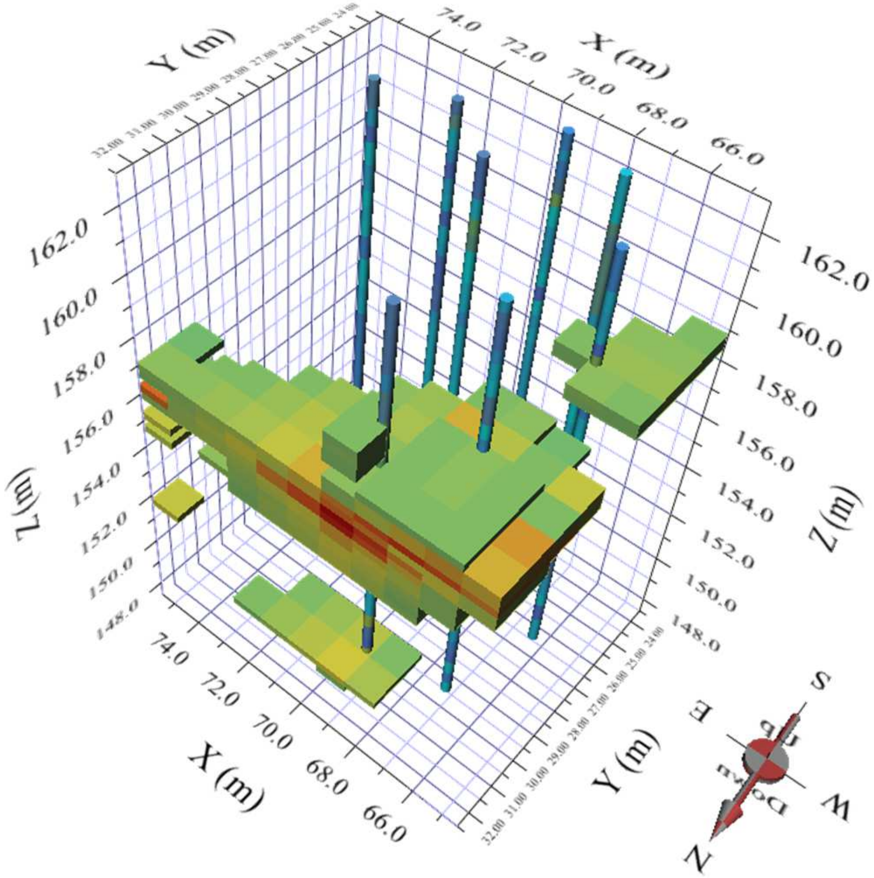


A DEEP CONTAMINATION EXAMPLE (3D)

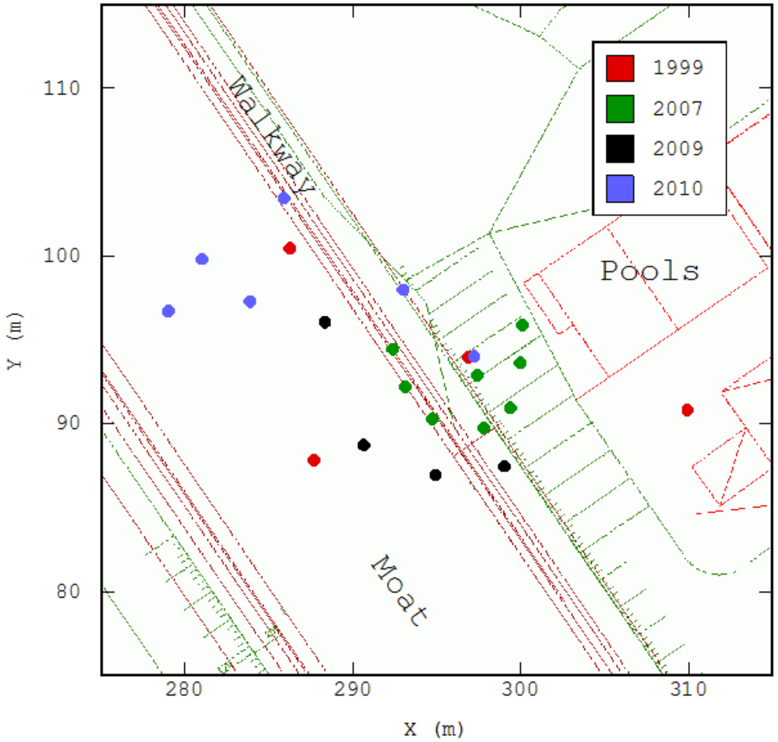
First data analysis (in 2007)

4 drilling campaigns

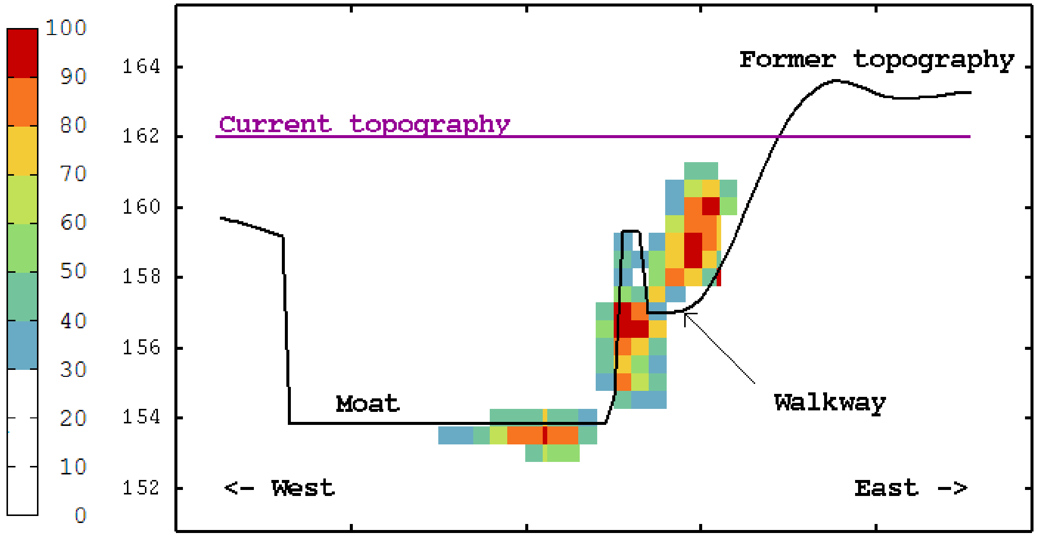




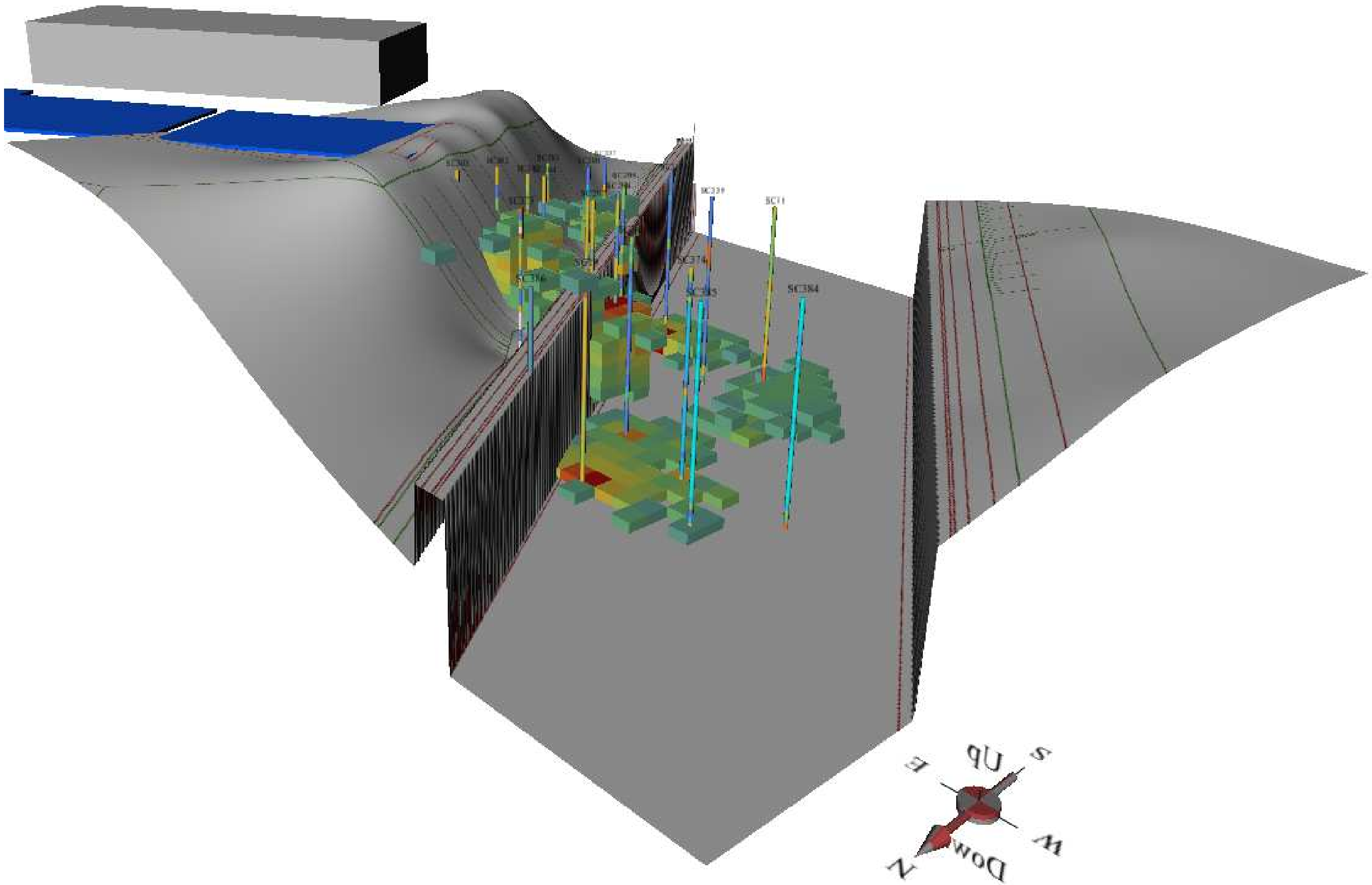
INTEGRATION OF HISTORICAL INFORMATION



- Topography of the former military fortification (first generation of installations)
- Correct delineation and interpretation of contaminated areas



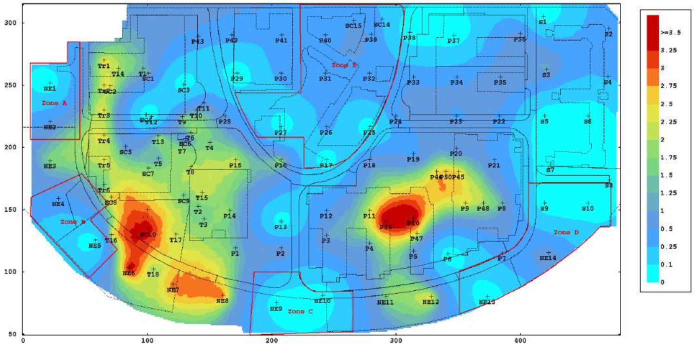
3D REPRESENTATION

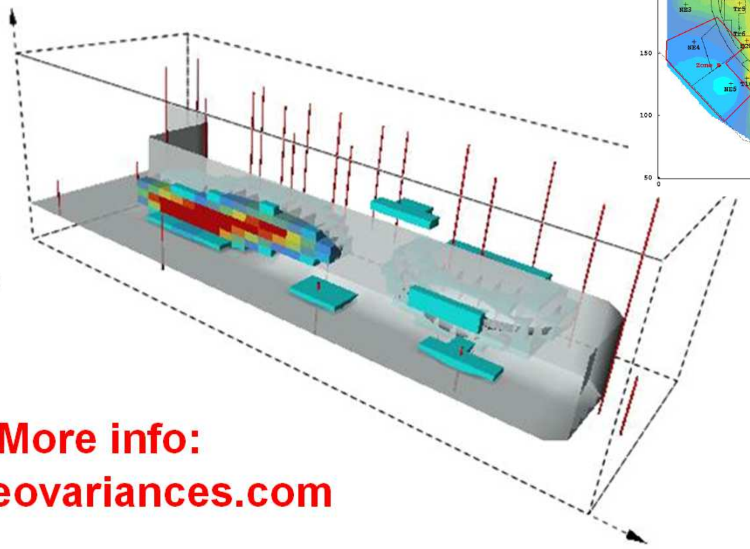


OTHER APPLICATION FIELDS

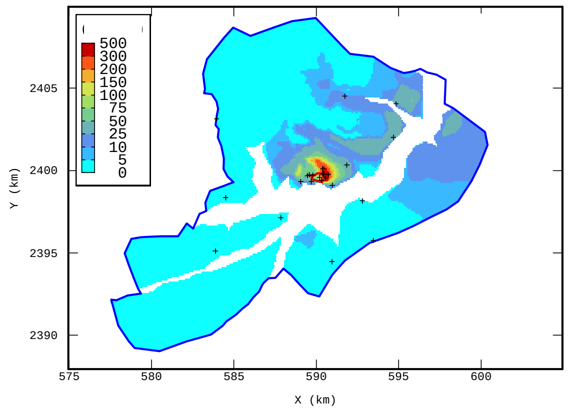
- Soil pollution
- Hydrogeology
- Air quality
- Bathymetry
- Civil engineering
- Fisheries…

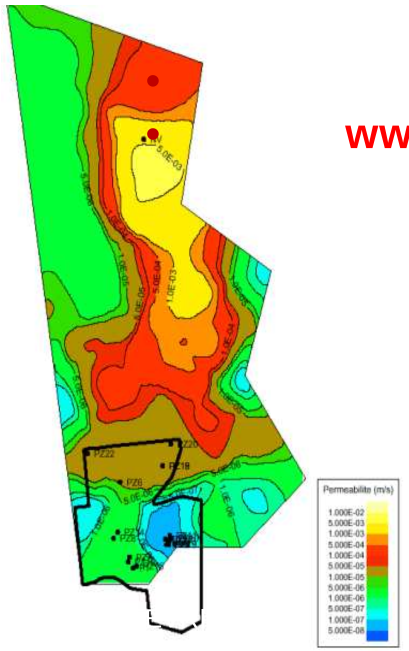
- Mining - Oil & Gas



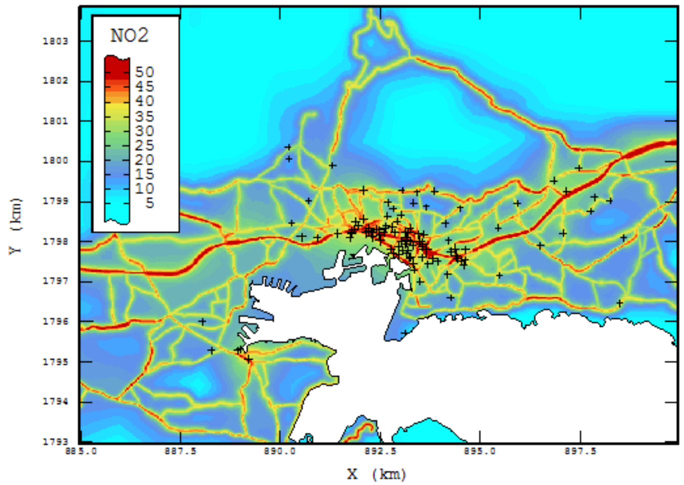


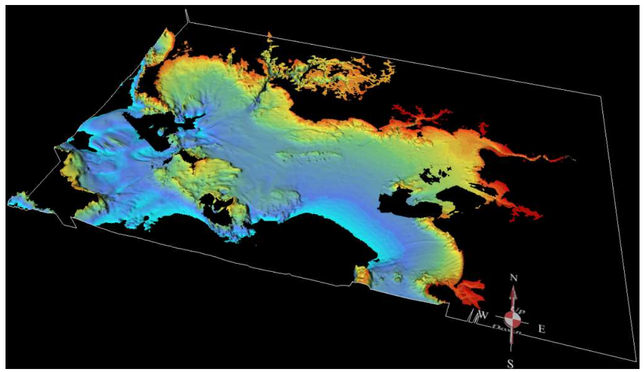
Isatis - 3D Viewer





More info:
www.geovariances.com





CONCLUSIONS: 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**
  - Characterize the spatial behavior (variographic analysis)
  - Compute accurate maps using appropriate kriging algorithms
  - Assess the precision of the estimation map with the kriging variance
  - 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 over a given remediation block
  - Get the probability distribution of contaminated materials and assess the uncertainty on the volumes

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

GIVING VALUE TO ALL KINDS OF INFORMATION

Context & Objectives:

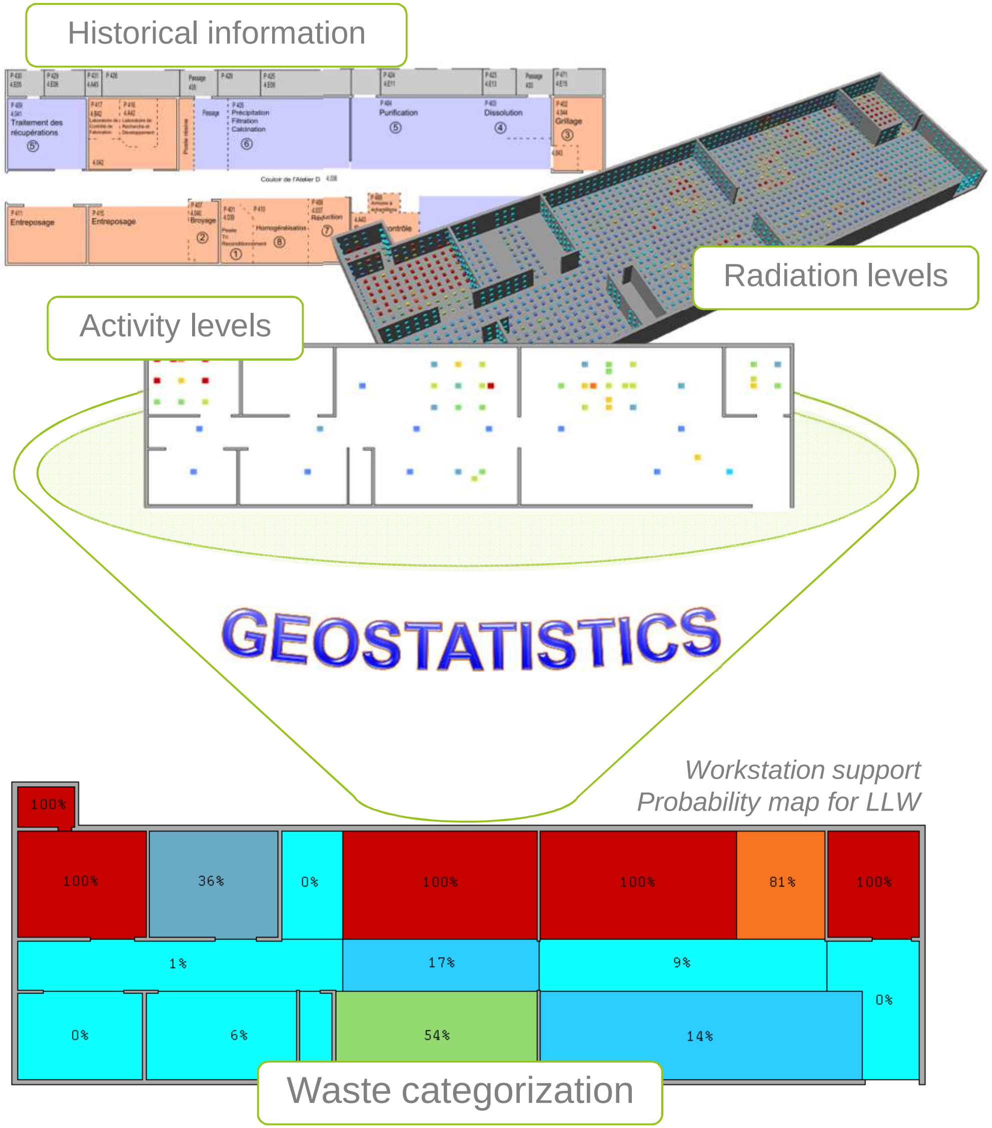
- Dismantling and decommissioning of ATUE facility (Uranium Workshops)
- Segregation and characterization of contaminated materials (mainly concrete structures)

Methods:

- Multivariate analysis
- Non-linear estimations

Outcomes:

- Optimization and rationalization of the evaluation methodology
- Providing essential decision-making tools for D&D projects saving time and money



ADAPTATION OF SAMPLING TO THE OBJECTIVE

Context & Objectives:

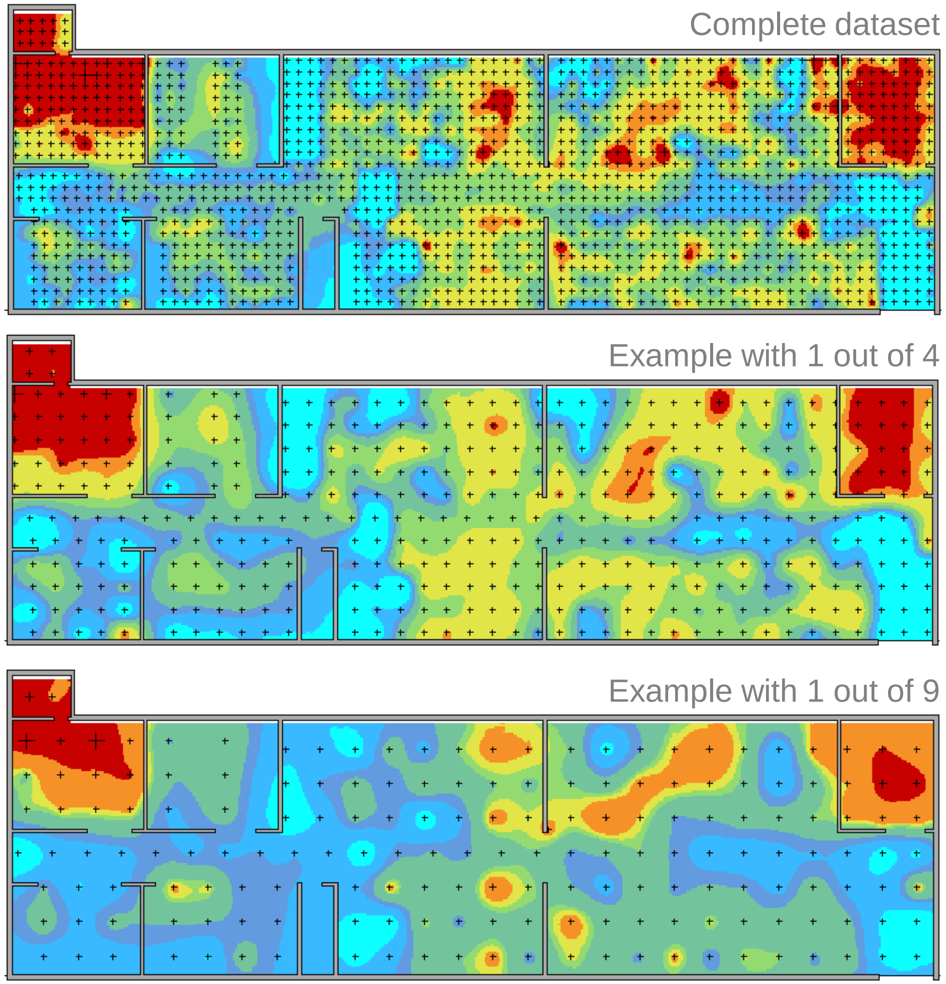
- Dismantling and decommissioning of ATUE facility (Uranium Workshops)
- Optimization and rationalization of the sampling strategy

Methods:

- Variographic analysis
- Non-linear and multivariate techniques

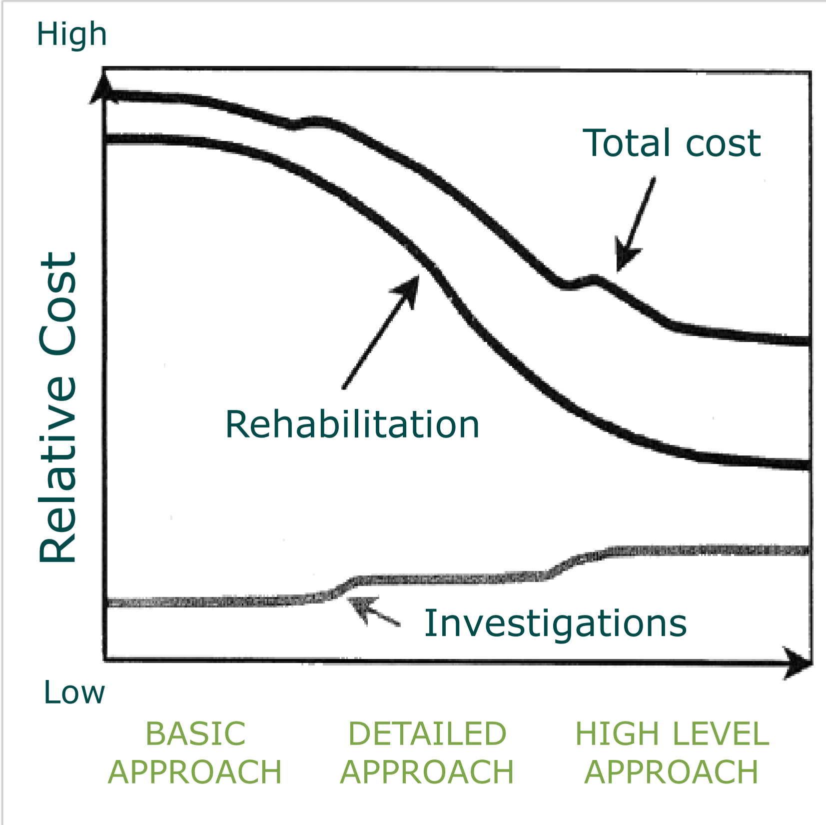
Outcomes:

- Systematic presence of spatial continuity for radiological contamination
- Optimize the different sampling phases
  - Determination of the initial mesh
  - Nearly real-time mapping to optimize
  - Iterative sampling strategies



CONCLUSIONS: RADIOLOGICAL CHARACTERIZATION

- Over 150 sites have been characterized with clean up methodology and tools
- Characterization of the waste before their removal
- Efficient tools and software making possible industrial optimized remediation projects
- Better controlled costs and deadlines
- Both for external areas and building structures



Better upstream characterization with surface and in-depth measures → Better management of the remediation operations, respecting the projected cost and deadlines.