Geostatistics

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Mines ParisTech

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MINES PARIS | PSL

Geostatistics team – Centre de Géosciences

- 5 scholars, 3 Ph.D. students, 2 post-docs
- Main research themes : geostatistics (models, methods, applications), data assimilation, deep generative models
- Research axis :
  - models development
  - research with partners (public institutes, private companies)
  - Software development gstlearn

`https://www.geosciences.minesparis.psl.eu/en/presentation/geostatistique/`

Athens week: Geostatistics

- Objectives
  master the theoretical and practical basis of the mathematical modeling of regionalized phenomena by probabilistic methods
- Prerequisites
  basic probability and statistics courses
- Teachers
  Nicolas Desassis, Mike Pereira, Thomas Romary

History

- Origin 1950's : Mining applications (D. Krige, South Africa)
- Geostatistics (french school) : G. Matheron, from the 1960's
- Based on the random functions formalism (Lévy, Kolmogorov)

What goals ?

- Describe, model the behaviour of a variable in space (and/or in time)
  Ex: depth variation of a geological horizon
  $\Rightarrow$ spatial variability, spatial structure, stationarity or not
- Understand and predict the support effects
  Ex: log porosity vs block porosity
  $\Rightarrow$ dispersion variances, support effect, information effect
- Estimate, map the variable
  Ex: estimate the atmospheric pollution at different scales
  $\Rightarrow$ stationary/nonstationary kriging, estimation variance

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What goals ?

- Study jointly several variables
  Ex: topography and pluviometry
  $\Rightarrow$ multivariate geostatistics
- Estimate, map the variable and transformed versions of that variable
  Ex: estimate the probability of an atmospheric pollution to exceed a given threshold at different scales
  $\Rightarrow$ non-linear Geostatistics
- Simulate the variable to estimate complex quantities
  Ex: confidenc intervals on a reservoir volume
  $\Rightarrow$ geostatistical simulations

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Some examples

Mine : gisements de diamants

Modélisation de dépôts de diamants alluvionnaires

- Estimation du nombre de pierres à partir de données de supports différents (2 à 10000 m^2)
- Echantillonnage
- Distribution de la taille des pierres (des microdiamants aux macrodiamants)

Exemple d'irrégularités dans la roche mère

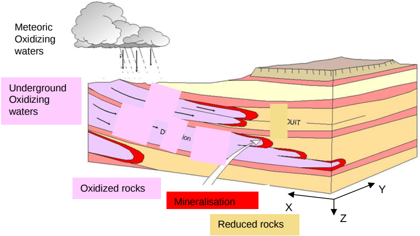
Christian Lantuéjoul,
Collaboration avec De Beers

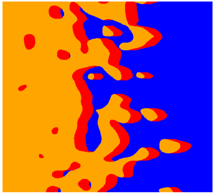
Some examples

Mine : gisements d'Uranium

Modélisation de gisements de type roll front

- ❑ Simulation d'exploitation par lixiviation
- ❑ Géologie– Chimie – hydrogéologie
- ❑ Modèles géostatistiques ad hoc



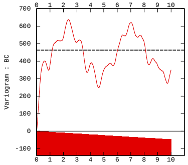


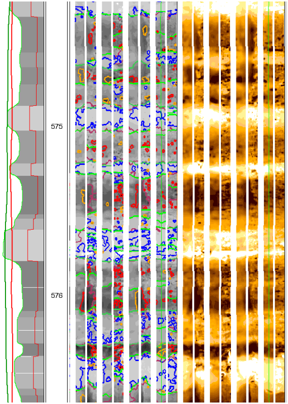
Some examples

Stockage de déchets radioactifs

Variabilité des caractéristiques des argilites

- ❑ analyse de diagraphies haute résolution
  et passage en repère chronostratigraphique



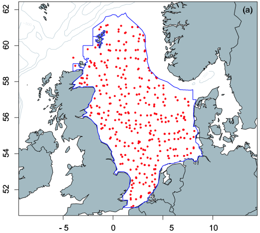


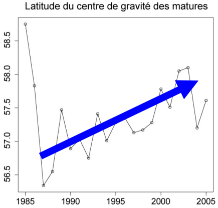
Thèse Marie Lefranc 2007

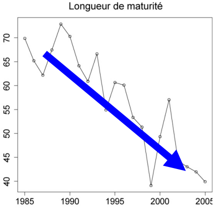
Some examples

Halieutique

Mise au point de méthodes d'évaluation des stocks à partir de campagnes scientifiques (acoustique / coups de chalut) et/ou des captures commerciales







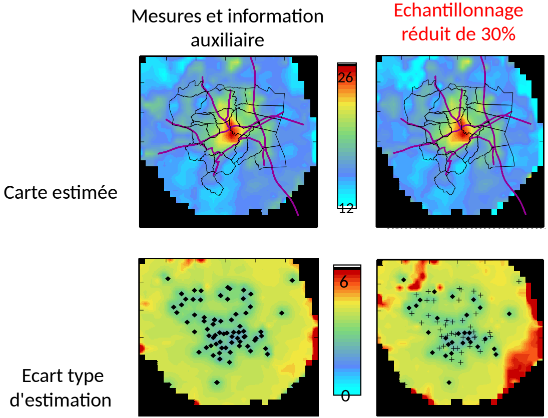
Thèses M. Faraj et E. Walker *Coll. Ifremer, IRD, instituts européens d'halieutique*

Some examples

o**Qualité de l'air**

o**Etude du $NO_{2\ \text{annuel}}$**

Mulhouse

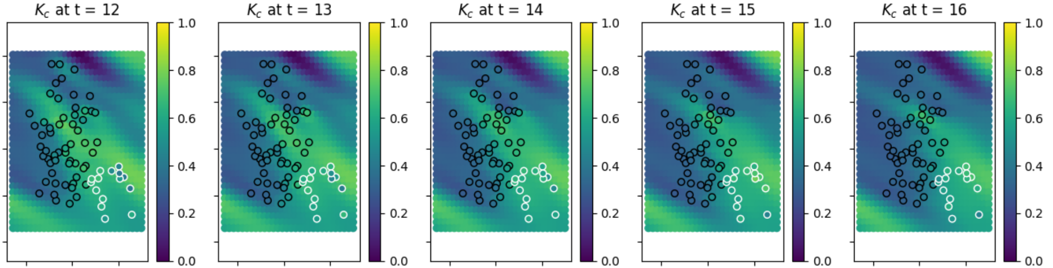


D. Gallois, Ch. de Fouquet *Partenaires* INERIS, ASQUA

Some examples

Spatio-temporal SPDE

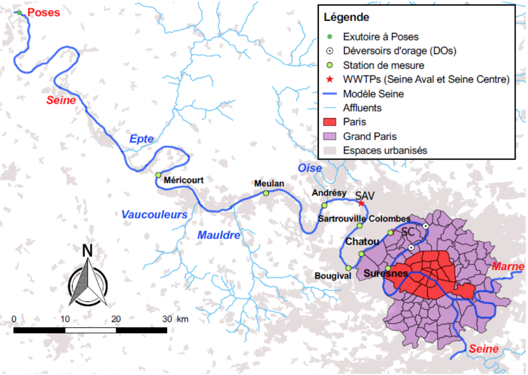
$$\left[\frac{\partial}{\partial t} + \frac{1}{c}(\kappa^2 - \nabla \cdot \mathbf{H}\,\nabla)^{\alpha} + \frac{1}{c}\boldsymbol{\gamma} \cdot \nabla\right] X(\mathbf{s}, t) = \frac{\tau}{\sqrt{c}} Z(\mathbf{s}, t)$$

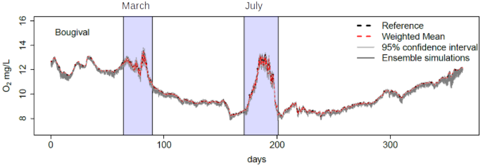


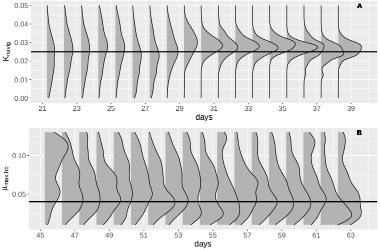
Kriging of clear sky index over 5 time steps

Some examples

Data assimilation in water quality

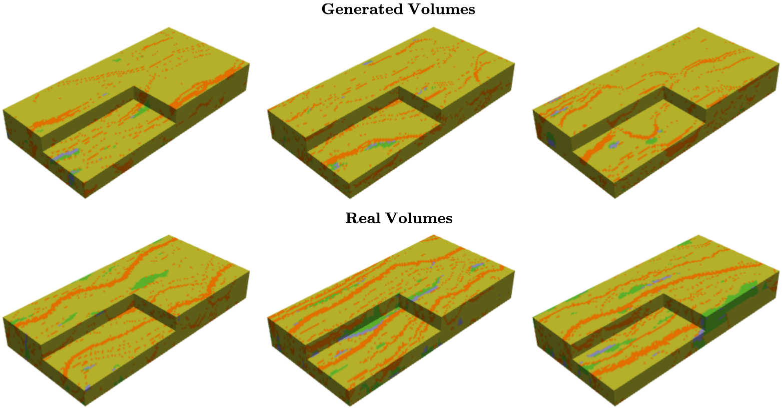






Some examples

Deep generative models



Visual comparison of 3D volumes generated with the Multi-Scale Wasserstein GAN (top) and the Flumy 3D volume (bottom)

Chaire geolearning

`chaire-geolearning.org/en`

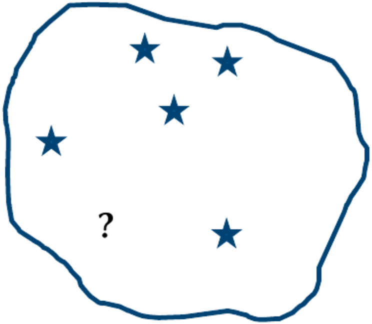
Geostatistics, extreme events and Machine Learning for the climate transition

- 3 main research axis
  - Geostatistical methods for spatio-temporal data
  - Hybridize Machine Learning with geostatistics
  - Methods for extreme events
- 4 partners
  - Andra
  - BNP Paribas
  - CCR
  - Fondation SCOR

Why a probabilistic approach?

- It is generally impossible to
  - build a quantitative description based solely on physical laws
  - build a deterministic mathematicall model due to the complexity of the problem
- The probabilistic approach allows to
  - integrate data from different sources to reduce the uncertainties
  - generate multiple realizations of the natural variable for the quantification of the uncertainties incertitudes

En résumé



★ **On observe**

- Valeurs ponctuelles
- Valeurs moyennes sur un support donné
- Valeurs transformées
- Informations qualitatives
- Modèles physiques
- ...

? **On cherche**

- Valeurs possibles?
- Valeur moyenne?
- Probabilité que la valeur soit supérieure à un seuil?

Program

Room L218

	Mon	Tue	Wed	Thu	Fri
Morning 9h - 12h15	General introduction Probability	Random Functions	Kriging	Maximum Likelihood Approach	Summary Project
After-noon 13h45-17h	Regression & Spatial Interpolation	Variography & parametric models	Multi-variate modelling	Simulations	Project

Evaluation

- Report on mini-project to be delivered on november 24th at 23:59
- Kaggle competition :
  `https://www.kaggle.com/c/geostatistics-athens-week-2024`

References

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- Diggle P.J. and Ribeiro P.J. (2007) Model-based Geostatistics. Springer, New-York.
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- Lantuéjoul C. (2002) Geostatistical simulation ; models and algorithms. Springer, Berlin.
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- Stein M. L. (2005) Interpolation of Spatial Data: Some Theory for Kriging. Springer, New York.
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