Course offered for the STAT PhD program starting from a.y. 2026/2027

TITLE	Geostatistics and Stochastic Methods to empower your Spatial Data on 3D models
Main Lecturer	Simone Pittaluga, Daniela Cabiddu, Marianna Miola (CNR-IMATI, Genova, Italia)
Duration and Credits	4 CFU - 16 hours
Course description	The aim of this course is to provide participants with the theoretical and practical tools required to develop **spatial models of environmental variables on complex computational domains**. The course covers the complete modeling workflow, from the analysis of spatial data and the characterization of spatial variability to the definition of computational geometry, spatial prediction, uncertainty quantification, and stochastic simulation. A central theme of the course is the interaction between **geostatistics and computational geometry**. Attention will be given to the role of spatial support and domain representation, showing how complex geometries and unstructured meshes can be incorporated into geostatistical workflows and how they influence prediction and simulation. The theoretical concepts will be complemented by their practical implementation using **MUSE (Modeling Uncertainty as a Support for Environments)** (Miola et al., STAG2022; Miola et al., preprint, 2026), an open-source software framework designed to integrate geostatistical modeling, computational geometry, and stochastic simulation. Participants will be introduced to the MUSE workflow, software structure, input data, and executable commands, and will use the software to construct uncertainty-aware spatial models from environmental datasets, spanning from elemental concentration to the discrete presence of specific elements like rock facies or biological species, with applications to environmental characterization and monitoring. By combining theoretical lectures with practical exercises, the course will enable participants to understand both the principles underlying geostatistical spatial modeling and their implementation within MUSE, providing the tools required to construct robust, flexible, and uncertainty-aware models of environmental variables.
Course organization	The course is organized into two complementary parts. **Part I – Theoretical Foundations** The first part introduces the theoretical and methodological concepts required to describe, model, and predict spatially heterogeneous phenomena: • **Random Function Theory:** regionalized variables, random functions, and probabilistic representations of natural phenomena; • **Spatial Variability and Dependence:** experimental and theoretical variograms, covariance, spatial correlation, and isotropic and anisotropic structures;

	• **Geometry and Spatial Support:** representation of complex computational domains, unstructured meshes, and the role of geometry and spatial support in spatial analysis; • **Spatial Prediction and Uncertainty:** geostatistical prediction, kriging, and uncertainty quantification; • **Stochastic Simulation:** generation of alternative realizations and reproduction of spatial variability. Particular emphasis will be placed on connecting these concepts into a coherent modeling workflow and on understanding how the choice of spatial model and computational domain affects the resulting predictions and simulations. **Part II – Practical Application with MUSE** The second part translates the theoretical concepts into a complete computational workflow using MUSE. Participants will work with environmental datasets and progressively construct a spatial model through: • data preparation and exploratory spatial analysis; • variogram analysis and spatial-dependence modeling; • identification and modeling of isotropic and anisotropic spatial structures; • construction of computational geometries and unstructured meshes; • spatial prediction and uncertainty quantification; • stochastic simulation and generation of alternative realizations; • mapping simulated variables onto the computational mesh; • analysis and visualization of realizations, summary statistics, and uncertainty. Hands-on examples will guide participants through the complete workflow, showing how spatial observations can be transformed into geostatistical models and subsequently predicted and simulated over flexible computational domains. Case studies from different environmental applications, ranging from geology to geochemistry, will illustrate how the same methodology can accommodate different datasets, spatial structures, and domain geometries.
Teaching period	Winter / Spring / Summer