Course guide
250COD007 - 250COD007 - Applied Statistics and Uncertainty Quantification

Last modified: 16/06/2026

Unit in charge: Barcelona School of Civil Engineering
Teaching unit: 751 - DECA - Department of Civil and Environmental Engineering.

Degree: MASTER'S DEGREE IN COMPUTATIONAL AND DATA-ASSISTED ENGINEERING (Syllabus 2026). (Compulsory subject).

Academic year: 2026 **ECTS Credits:** 5.0 **Languages:** English

LECTURER

Coordinating lecturer: Giacomini, Matteo

Others: Giacomini, Matteo

PRIOR SKILLS

Basic knowledge of probability, statistics, linear algebra, and programming.

TEACHING METHODOLOGY

The course consists of 4 hours of in-person classes per week, divided between theoretical sessions introducing the fundamental concepts of the subject and sessions devoted to worked examples, applied exercises, and laboratory activities.

Support material in the form of a detailed teaching plan is provided using the virtual campus ATENeA: content, learning plan, assessment activities, and literature.

LEARNING OBJECTIVES OF THE SUBJECT

The course on Applied Statistics & Uncertainty Quantification (StatUQ) provides an introduction to the methodological and computational statistical tools used to analyse and manage uncertainty in complex systems. The module is specifically designed to target these challenges in the framework of simulation-based and data-driven computational engineering, with real-world applications stemming from automotive engineering and geophysics. After reviewing the foundational concepts in probability and statistics, the module addresses three main challenges:
1. How to approximate data and provide estimates of accuracy and uncertainty?
2. How to design experiments, propagate uncertainty, and identify the most influential parameters in a model?
3. How to perform credible predictions and update uncertain model parameters?
Subjects covered in the module include: error decomposition, response surfaces, Gaussian process regression, sampling methods, sensitivity analysis, uncertainty propagation, model calibration and validation, Bayesian inference, Markov Chain Monte Carlo, and a selection of advanced topics such as multi-fidelity modelling and time series analysis.

The main objective of the course is to enable students to:
Understand and distinguish the different types of uncertainty (aleatoric vs epistemic) and their role in simulation-based and data-driven models.
Approximate data using response surfaces (polynomial and Gaussian process regression) and estimate model accuracy and uncertainty (bias-variance tradeoff and error decomposition).
Design experiments for computational models and understand the impact of dimensionality and sampling strategies.
Propagate uncertainty through models using Monte Carlo methods.
Perform sensitivity analysis and identify the most influential parameters in a model.
Formulate Bayesian inference and understand the concepts of model calibration, model validation, and model update.
Understand the limitations of the presented approaches and possible solutions (multi-fidelity, ARMA models, …).
Understand the difference between statistical methods and computational tools, and integrate them to solve problems in engineering and applied sciences.

STUDY LOAD

Type	Hours	Percentage
Hours large group	45,0	36.00
Self study	80,0	64.00

Total learning time: 125 h

CONTENTS

Review the foundational concepts of probability and statistics

Description:
Examples of uncertainty in computational models; examples of empirical uncertainty propagation; descriptive statistics; conditional probability; Bayes' theorem; univariate and multivariate random variables; joint, marginal and conditional distributions; covariance matrices and correlation; dependence vs independence; input-output uncertainty maps.

Full-or-part-time: 7h
Theory classes: 7h

Challenge 1: How to approximate data and provide estimates of accuracy and uncertainty?

Description:
Functional approximation of data-based models; polynomial response surfaces; bias-variance tradeoff; verification & validation; error decomposition in UQ; nonlinear least squares; regularisation; variograms and spatial correlation; Gaussian processes as stochastic response surfaces; prediction uncertainty.

Full-or-part-time: 10h
Theory classes: 10h

Challenge 2: How to design experiments, propagate uncertainty, and identify the most influential parameters in a model?â□¨

Description:
Random and stratified sampling; Latin Hypercube Sampling; variance reduction concepts; Monte Carlo integration; convergence; Monte Carlo uncertainty propagation; exploration VS exploitation; importance sampling; rare events; sensitivity analysis; Sobol' indices; parameter ranking; model simplification.

Full-or-part-time: 10h
Theory classes: 10h

Challenge 3: How to perform credible predictions and update uncertain model parameters?â□¨

Description:
Bayesian paradigm; prior, likelihood, posterior; Bayesian updating with data; model calibration vs model validation; Markov Chain Monte Carlo; Metropolis-Hastings algorithm; convergence diagnostics.

Full-or-part-time: 12h
Theory classes: 12h

Advanced Topics in Computational Statistical Modelling

Description:
Advanced topics beyond the foundational methodologies presented in the course.

Full-or-part-time: 6h
Theory classes: 6h

GRADING SYSTEM

The course grade is based on continuous assessment throughout the term through progressive, individual and group, activities carried out both inside and outside the classroom.

Assessment activities will evaluate the assimilation of the fundamental concepts related to the course learning objectives and will include theoretical questions, exercises, practical problems, and result interpretation tasks.

The final course grade is computed as follows:
-50% exam
-50% coursework (periodic assignments, practical and programming exercises, and presentations).

EXAMINATION RULES.

The exam must be performed individually. Books and lecture notes are not allowed. Plagiarism will be punished with a 0.

Assignments must be submitted via ATENeA by the announced deadline. Late submissions or assignments submitted using other means will not be accepted and will be graded 0.

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BIBLIOGRAPHY

Basic:

- McClarren, R.G. Uncertainty Quantification and Predictive Computational Science [on line]. Cham: Springer, 2018 [Consultation: 28/07/2026]. Available on: https://link-springer-com.recursos.biblioteca.upc.edu/book/10.1007/978-3-319-99525-0. ISBN 9783319995250.
- Wang, Y.; Tran, A.V.; Mcdowell, D.L. Fundamentals of Uncertainty Quantification for Engineers [on line]. Amsterdam: Elsevier, 2025 [Consultation: 29/06/2026]. Available on: https://www-sciencedirect-com.recursos.biblioteca.upc.edu/book/monograph/9780443136610/fundamentals-of-uncertainty-quantification-for-engineers. ISBN 0443136629.

Complementary:

- Shumway, R.H.; Stoffer, D.S. Time Series Analysis and Its Applications: With R Examples [on line]. 5th ed. Cham: Springer, 2025 [Consultation: 28/07/2026]. Available on: https://link-springer-com.recursos.biblioteca.upc.edu/book/10.1007/978-3-031-70584-7. ISBN 9783031705847.

RESOURCES

Other resources:

Teaching material, including slides, exercises, and computer programmes, is available on ATENEA.