

**Research and Innovation**

Code: 43475  
ECTS Credits: 6

Degree	Type	Year	Semester
4313136 Modelling for Science and Engineering	OB	0	1

### Contact

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### Use of languages

Principal working language: english (eng)

### Teachers

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### Prerequisites

There are no specific prerequisites. Students must have mathematical skills at a graduate level of a scientific or technological degree.

### Objectives and Contextualisation

The aim of this module is to show students the variety of fields in which they will be able to apply the tools acquired during the Master courses. Hopefully they will be able to use them as guidance when looking for Internships in Companies and Institutions and also when choosing a topic and an advisor for the Master's Thesis. We also expect that it will help them to find a career path.

### Skills

- Analyse complex systems in different fields and determine the basic structures and parameters of their workings.
- Analyse, synthesise, organise and plan projects in the field of study.
- Apply specific methodologies, techniques and resources to conduct research and produce innovative results in the area of specialisation.
- Apply techniques for solving mathematical models and their real implementation problems.
- Communicate and justify conclusions clearly and unambiguously to both specialised and non-specialised audiences.
- Formulate, analyse and validate mathematical models of practical problems in different fields.
- Integrate knowledge and use it to make judgements in complex situations, with incomplete information, while keeping in mind social and ethical responsibilities.
- Isolate the main difficulty in a complex problem from other, less important issues.
- Look for new areas to open up within the field.
- Recognise the human, economic, legal and ethical dimension in professional practice.
- Solve complex problems by applying the knowledge acquired to areas that are different to the original ones.

- Solve problems in new or little-known situations within broader (or multidisciplinary) contexts related to the field of study.

## Learning outcomes

1. Analyse, synthesise, organise and plan projects in the field of study.
2. Apply specific methodologies, techniques and resources to conduct research and produce innovative results in the area of specialisation.
3. Check the validity of the model with regard to the behaviour of the real system.
4. Communicate and justify conclusions clearly and unambiguously to both specialised and non-specialised audiences.
5. Describe the functional dependencies of the system with regard to the different parameters
6. Design mathematical models that represent the system and its behaviour.
7. Identify the parameters that determine how a system works.
8. Implement the proposed solutions reliably and efficiently.
9. Integrate knowledge and use it to make judgements in complex situations, with incomplete information, while keeping in mind social and ethical responsibilities.
10. Isolate the main difficulty in a complex problem from other, less important issues.
11. Look for new areas to open up within the field.
12. Recognise the human, economic, legal and ethical dimension in professional practice.
13. Solve complex problems by applying the knowledge acquired to areas that are different to the original ones.
14. Solve mathematical models efficiently.
15. Solve problems in new or little-known situations within broader (or multidisciplinary) contexts related to the field of study.

## Content

We have two types of activities during the semester: to attend a three innovative mini-courses and attend a series of lectures given by people who work for companies or researchers working in universities or research centres.

The courses are the following:

1. **Introduction to Machine Learning.** Linear Regression, Logistic Regression, SVM. Decision trees, Random Forests, Gradient Boosting. Neuronal Networks.
2. **Genetic algorithms.** An Overview of Combinatorial Optimization.- Theoretical Foundations of Genetic Algorithms.- Genetic Algorithms in Engineering and Optimization.- Genetic Algorithms in Natural Evolution.
3. **Numerical weather forecast models.** Numerical Weather Prediction (NWP): A general overview, Basic concepts of Atmospheric Modelization: Approximations and Parameterizations, NWP models and computational power, Applications of Numerical Weather Prediction at the Meteorological Service of Catalonia (SMC)

We will invite specialists in the fields of Modelling Complex Systems, Modelling of Engineering, Mathematical Modelling and Data Science. Among the others we will have talks from people coming from:

- SMC, Servei Meteorològic de Catalunya, <http://www.meteo.cat>
- CRM, Centre de Recerca Matemàtica, <http://www.crm.cat>
- BSC-CNS, Barcelona Supercomputing Center, <http://www.bsc.es>
- CVC, Computer Vision Center (UAB), <https://www.cvc.uab.es>
- IBM, International Business Machines, <https://www.ibm.com/es-es>
- IIIA-CSIC, Institut d'Investigació en Intel·ligència Artificial, <https://www.iiia.csic.es>

## Methodology

The methodology of the three courses is based on master classes which consist in the presentation of the theory, examples and some case studies.

Relating the lectures, they will be announced previously on the virtual campus of the module Research and Innovation. There the students will find the title of the talk, the name of the speaker, a short summary and links of interest.

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## Activities

Title	Hours	ECTS	Learning outcomes
<b>Type: Directed</b>			
Attending Lectures	20	0.8	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15
Attending Mini-courses	18	0.72	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15
Making Reports	112	4.48	4, 5, 7, 9, 15

## Evaluation

The students have to present three projects on the three announced courses.

The course on Machine Learning will be held the days 25<sup>th</sup> and 28<sup>th</sup> of September and 2<sup>th</sup> of October. The corresponding report must be delivered before the 28<sup>th</sup> of October in the virtual campus. You can choose, either, to do a program from scratch in Python on one of the methods studied in class (technical) or to work with a dataset with several methods seen in class (applied). It must be done in teams of 2 people

The course on Genetic Algorithms will be taught the days 23<sup>th</sup> and 30<sup>th</sup> of October and 6<sup>th</sup> of November. The deadline to deliver the report is 30<sup>th</sup> of November. The assignment is to solve the 8 queens problem by means of a genetic algorithm which has to be developed "ad-hoc". It must be done in teams of 2 people.

Finally the course on Numerical Weather Forecast Models will be presented the days 27<sup>th</sup> of November and 4<sup>th</sup> and 11<sup>th</sup> of December. The report has to be delivered before 12<sup>th</sup> of January. It must be done in teams of 3 people. The assignment is to elaborate a report (length approximately 15 pages) explaining how to run the WRF model using the selected real data, display the obtained results and also do a description of the selected data. It must be done in teams of 3 people.

On the other hand attendance at talks contributes 10% of the final grade.

## Evaluation activities

Title	Weighting	Hours	ECTS	Learning outcomes
Attending Lectures	10%	0	0	3, 4, 5, 7, 9, 15
Making a report of Genetic Algorithms	30%	0	0	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15

Making a report of Machine Learning	30%	0	0	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15
Making a report of Numerical Weather Forecast Models	30%	0	0	3, 4, 5, 7, 9, 15

## Bibliography

- **Bibliography and links of interest**

- <http://shop.oreilly.com/product/0636920052289.do>
- <http://www.deeplearningbook.org/>
- [Melanie Mitchell, \*An Introduction to Genetic Algorithms\*, A Bradford Book, The MIT Press, Cambridge Massachusetts, 1999.](#)
- [David Beasley, David R. Bully and Ralph R. Martinz, \*An Overview of Genetic Algorithms \(Part 1: Fundamentals and Part 2: Research Topics\)\*](#)
- [Sean Luke, \*Essentials of Metaheuristics\*, 2009. <http://cs.gmu.edu/sean/book/metaheuristics>](#)
- [T. Starkweather, S McDaniel, K. Mathias, D. Whitley, C. Whitley. \*A Comparison of Genetic Sequencing Operatots\*.](#)
- Ahrens, C. *Meteorology Today: An Introduction to Weather, Climate, and the Environment*. International student edition. Brooks/Cole, CengageLearning. 2009
- Holton, J. R., & Hakim, G. J. (2012). *An introduction to dynamic meteorology* (Vol. 88). Academic press.
- Wilks, D. S. (2011). *Statistical methods in the atmospheric sciences* (Vol. 100). Academic press.
- [Gutiérrez, J. M. \(2004\). \*Redes probabilísticas y neuronales en las ciencias atmosféricas\*. Ministerio de Medio Ambiente, Secretaría General Técnica.](#)