Subject identification

Subject	11275 - Predictability
Credits	0.72 de presencials (18 hours) 2.28 de no presencials (57 hours) 3 de totals (75 hours).
Group	Group 1, 1S (Campus Extens)
Teaching period	1st semester
Teaching language	English

Professors

Lecturers	Horari d'atenció alumnes					
	Starting time	**Finishing time**	**Day**	**Start date**	**Finish date**	**Office**
Víctor Homar Santaner victor.homar@uib.cat	16:00h	20:00h	Friday	01/09/2014	31/07/2015	MO-F110. Mateu Orfila 1r pis.
	16:00h	18:00h	Monday	01/09/2014	31/07/2015	MO-F110. Mateu Orfila 1r pis.

Contextualisation

Why the calendars and almanacs we buy every year contain an infallible prediction of the phases of the moon and, instead, do not venture to forecast the weather throughout the year? In this course we try to answer this question with physical and mathematical arguments. The Numerical Weather Prediction problem comprise scientific fields beyond the integration of the Navier-Stokes equations scaled to the Earth's atmosphere and the corresponding parameterizations of the sub-gridphysical processes. In particular, current weather prediction systems integrate not only knowledge from Atmospheric Physics, Numerical Methods and Supercomputing, but also aspects of Nonlinear Dynamical Systems, Statistical Physics and the Inverse Problem (adjoint models).

This course in the Master of Advanced Physics and Applied Mathematics is part of the block of courses leading tothe Master's Degree with the specialty in Geophysical Fluids. The contents of this course describenumerical weather prediction systems, and therefore the subject Numerical Simulation of Geophysical Fluid is closely related with it. In addition, the data assimilation process is discussed as a component of the prediction chain, linking concepts described in the course *Space and Data Assimilation Analysis* of the same block.

By following this course, students will learn the theoretical and strategic foundations of the weather prediction challenge, its practical implementation and its implications in decision-makingthat depends on atmospheric phenomena. Thus, the approach to the problem of atmospheric prediction (weather and climate) will naturally lead the discussion towards the identification of the problem in a general theoretical framework, and the multiple approaches used today for its practical solution. Thus, the presentation of the problem itself will bring us to the identification of error sources (1st and 2nd class), and its appropriate structural inclusion in the forecastingsystem and the prediction products themselves. Students not only learn to interpret current probabilistic predictions but also to analyze and study the main sources of uncertainty in a given prediction problem, and to propose methods to cope with themand generate accurate and reliable predictions.

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As for career opportunities, skills learned in this courseenable students to integrate into any professional field that requires rigorous and structured use of weather and/or climate predictions for their operations. In addition, the skills acquired will allow the student to generate ensemble-based operationalforecasting systems. Finally, we must emphasize the value of this course in the training record of a holder of the Master's Degree in Advanced Physics and Applied Mathematics when undertaking a research career in the physics of the atmosphere and/or weather forecasting disciplines.

Professor Dr. Víctor Homar has recognized expertise in the study of atmospheric predictability. This experience is accredited by leading several national projects and directing PhD. thesis, having participated in international projects and publications in the field of both the study of atmospheric sensitivities and resolution of Inverse Problem by adjoint models and statistical methods, as well as the study ofensemble prediction systems.

Requirements

Although it has no formal requirement for enrollment, the practical activities of this course make use of weather models and data stored in standard formats in meteorology and climatology. Therefore, on the one hand it is desirable to have a background in atmospheric physics and numerical weather simulation(geophysical fluid). On the other hand, the general use of computers (any operating system in common use: Windows, MacOS, or Linux) will greatly facilitate the realization of the assigned practical work.

Recommendable

It is desirable to have studied the subject of *Atmospheric Physics*, an undergraduate optional course of thePhysics Grade at UIB to possess the physical basis for understanding the case studies to be discussed in this course. Furthermore, given the numerical component of the proposed activities to achieve the skills of this course, it is advisable to have passed the course in *Numerical Simulation of Geophysical Fluids*. The subject of *Spatial Analysis and Data Assimilation* also has connections with this and it is therefore advisable to be followed.

Skills

The skills of this course dealwith the physical understanding and modeling of the atmosphericsystem, both from a standpoint of a rigorous approach to the problem of predicting the weather, and its resolution, all this from an open perspective to introduce students to current research on the subject.

Specific

* Acquire advanced knowledge in the frontiers of knowledge and demonstrate, in the context of internationally recognized scientific research, a full understanding of the theoretical and practical aspects and scientific methodology.
* Students must possess the ability to use and adapt mathematical models to describe physical phenomena of different nature.
* Interpret and use efficiently probabilistic information contained in or derived from geophysical prediction systems, as well as to possess the ability to critically analyze proposed systems and procedures for geophysical prediction.

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Generic

* Possess the knowledge and its understanding to provide the basis or opportunity to be original in developing and/or applying ideas, often within a research context.
* Students should be able to integrate knowledge and handle complexity, and formulate judgments based on information that, being incomplete or limited, include thoughts on social and ethical responsibilities linked to the application of their knowledge and judgments.
* Systematic understanding of a field of study and mastery of the research skills and methods associated with that field.

Basic

* You may consult the basic competencies students will have to achieve by the end of the Master's degree at the following address: http://estudis.uib.cat/master/comp_basiques/

Content

The course begins with a first introductory issue for harmonizing concepts and definitions necessary for the course. It is organized in 3 major issues that form the core content. First the fundamental role of errors in a forecasting system and how to cope with them both theoretically and practically. Later the ensemble prediction systems, as discrete approximations to the fundamental problem of strict weather forecasting approaches, are studied. Finally the problem of identifying cause-effect relationships in a complex system such as the atmosphere is studied. Thetangent linear and adjoint modelsformalism is discussed, linking them with practical applications in meteorology and climatology.

Theme content

Lesson 1. Introduction to forecasting systems

Components of a forecasting system. Characteristics ofcurrent systems. Data assimilation. Families of models,scales andsettings. Verification: objects. Cost/loss ratio. Value of a forecast.

Lesson 2. Characterization of forecasting system errors. Statistical principles

Brief introduction to chaos concepts. Identificationand quantification of errorsources. Predictability of 1st and 2nd kind. Coping with error: probabilistic framework.Fokker-Planckand Langevin type equations from statistical mechanics applied to the atmosphere.

Lesson 3. Ensemble prediction systems

Sampling uncertainties in initial and boundary conditions: Singular vectors, Bred vectors, monte-carlo based climatology of PV and Kalman filters. Sampling model uncertainties: multimodel, multiphysics and stochastic settings. Ensemble prediction systems products interpretation. Systematic errors correction. Verification.

Lesson 4. Numerical analysis of forecast sensitivities

Sensitivity analysis: classical vs. inverse problem method. Brute force methods: limitations. Tangent linear model and adjoint model: calculation of gradients. Application of adjoint model sensitivities:examples in the Western Mediterranean and North America. Alternative methods: statistical sensitivities. Examples applied to climate and weather forecasting.

Teaching methodology

We detail here the activities planned during the course to facilitate the learning of the assigned skills and assess the their level of achievement. We describe both presentialactivities led by the professor and the autonomous work that the student must perform on its own, relying on the literature of the subject, and the materials available in the Virtual Classroom (Campus Extens). In this sense, the Virtual Classroom, contain autonomous activities that will allow you to acquire more specific and extended knowledge of atmospheric predictability.

Workload

By its nature, with clear links to practical applications, this is a subject with a certain practice component. This is reflected in the volume of work and the evaluation methodology. The course is designed for students to perform 57 hours of autonomous work, of which about two thirds are expected to engage in autonomous work.

In-class work activities

Modality	Name	Typ. Grp.	Description	Hours
Theory classes	Lectures	Large group (G)	The theoretical foundations and illustrative examples of the contents of this field will be presented. These lectures take 11 hours.	11
Seminars and workshops	Practical training	Medium group (M)	These are guided by the teacher in which the tools shown in the theoretical sessions are further shown, and which are necessary to carry out the autonomous assignement. In these sessions, we will see how to generatea simple prediction system, use an adjoint model and compute statistical sensitivities, as well as classicalsensitivities.	2
ECTS tutorials	Tutoring of individual progress	Small group (P)	In smaller sessions, organized by subject taken by students in their autonomous assignements, we will work on the projects that students develop.	3
Assessment	Practical exam	Large group (G)	Practical examination of the concepts worked on during the course. Also,the discussion of some concept worked for the course, theand ability to use probabilistic predictions on the Internet will be requested. The test can be made without limit of material used or accessed.Only communication with other individualsis forbidden.	1
Assessment	Short presentation of the individual project	Large group (G)	The student will present to the rest of the group the autonomous project conducted, using an electronic format (slides presentation) and accurately using the concepts and language of the subject.	1

At the beginning of the semester a schedule of the subject will be made available to students through the UIBdigital platform. The schedule shall at least include the dates when the continuing assessment tests will be conducted and the hand-in dates for the assignments. In addition, the lecturer shall inform students as to whether the subject work plan will be carried out through the schedule or through another way included in the Campus Extens platform.

Distance education work activities

Modality	Name	Description	Hours
Individual self-study	Theoretical study	The student will have to delve into the matter by studying the literature of the subject and the small tasks assigned during the theory sessions, which will help to initiate the successive sessionsUsig. The student will have to find sources of probabilistic information on the Internet, in preparation for the practical test.	17
Group or individual self-study	Autonomous project	Using as starting pointa specific matterdiscussed in this sylabus, and treated specificlly by one or more bibliographic resources offered in a catalog prepared by the professor specificallyfor the subject (articles, technical reports, book chapters, ...) the student has to study the subject in more detail, design a numerical experiment about that matter(and in agreement with the teacher inthe ECTS tutoring sessions), perform the experiment and write a short report (2-3 pages extended abstract maximum) about the work, whichmust also present to the group.	40

Specific risks and protective measures

The learning activities of this course do not entail specific health or safety risks for the students and therefore no special protective measures are needed.

Student learning assessment

Practical exam

Modality	Assessment
Technique	Papers and projects **(retrievable)**
Description	Practical examination of the concepts worked on during the course. Also,the discussion of some concept worked for the course, theand ability to use probabilistic predictions on the Internet will be requested. The test can be made without limit of material used or accessed.Only communication with other individualsis forbidden.
Assessment criteria	The exam will consist in explaining some concept worked in lectures and the discussion of a probabilistic prediction problem. Theaccuracy and proper use of the concepts and reasoning studied in class will be assessed.

Final grade percentage: 35% with minimum grade 4

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Short presentation of the individual project

Modality	Assessment
Technique	Extended-response, discursive examinations **(retrievable)**
Description	The student will present to the rest of the group the autonomous project conducted, using an electronic format (slides presentation) and accurately using the concepts and language of the subject.
Assessment criteria	The student must presentthe autonomous project carried out to the rest of thecolleagues, in a slot of 10-20 minutes, depending on the number of students enrolled. Thecapacity to synthesizethe work, the precision in the use of concepts and language as well as the quality of work performed will contribute tothe qualification.

Final grade percentage: 25% with minimum grade 3

Autonomous project

Modality	Group or individual self-study
Technique	Papers and projects **(retrievable)**
Description	Using as starting pointa specific matterdiscussed in this sylabus, and treated specificlly by one or more bibliographic resources offered in a catalog prepared by the professor specificallyfor the subject (articles, technical reports, book chapters, ...) the student has to study the subject in more detail, design a numerical experiment about that matter(and in agreement with the teacher inthe ECTS tutoring sessions), perform the experiment and write a short report (2-3 pages extended abstract maximum) about the work, whichmust also present to the group.
Assessment criteria	The short report will be evaluated by analysing the precision of language used, the clarity in the presentation of the results, and the level of the physical interpretations of the results provided in the discussion. The capacity for synthesis and distillation of relevant information will also be valued.

Final grade percentage: 40% with minimum grade 4

Resources, bibliography and additional documentation

Although there are a huge variety of sources of weather and climate information online, discussing the rigorous and scientific manner the problem and challenges of prediction are rare. Here we detail an overview of the recommended sources.

Basic bibliography

* Kalnay, E.;Atmospheric modelling, data assimilation and predictability.Cambridge University Press. 2003. pp. xxii + 341
* Palmer, T. and Hagedorn, R.; Predictability of weather and climate. Cambridge University Press. 2006. pp. xv + 702
* Errico, Ronald M., 1997: What Is an Adjoint Model?. Bull. Amer. Meteor. Soc., 78, 2577–2591.

Complementary bibliography

* ECMWF Workshop on Predictability (1997 : Reading, England) & European Centre for Medium Range Weather Forecasts (1999).Proceedings of a workshop held at ECMWF on predictability, 20-22 October 1997. European Centre for Medium-Range Weather Forecasts, Shinfield Park, Reading
* ECMWF Workshop on Representing Model Uncertainty and Error in Numerical Weather and Climate Prediction Models (2011 : Reading, England) & European Centre for Medium Range Weather Forecasts (2011).Proceedings of a workshop held at ECMWF on Representing Model Uncertainty and Error in Numerical Weather and Climate Prediction Models, 20-24 June 2011. European Centre for Medium-Range Weather Forecasts, Shinfield Park, Reading

* Tomkins Warner, T.;Numerical Weather and Climate Prediction.Cambridge University Press. 2011. pp. 550
* Pasini, A.;From Observations to Simulations. A conceptual Introduction to Weather and Climate Modelling.World Scientific. 2005. pp. 201
* Stensrud, J; Parameterization Schemes: Keys to Understanding Numerical Weather Prediction Models.Cambridge University Press, 2009. pp. 480