UNSW Science

School of Mathematics & Statistics

Course Outline

MATH5231
Prediction and Inverse Modelling in the Ocean and Atmosphere

Term 1, 2023

Staff

Position	Name	Email	Consultation times and locations	Contact Details
Lecturer and Course Convenor	Dr Shane Keating	s.keating@unsw.edu.au	Available on Course Moodle site	Contact me via email, Moodle, or during consultation hours

Please refer to your Timetable on MyUNSW for your Lecture/Seminar Tut, Lab enrolment days and times. Timetable MATH5231 http://timetable.unsw.edu.au/2023/MATH5231.html

Course information

Units of credit: **6UOC**

Pre-requisite(s): 12 units of credit in Level 2 Maths courses including (MATH2011 or MATH2111) and (MATH2120 or MATH2130 or MATH2121 or MATH2221), or (both MATH2019 (DN) and MATH2089),or (both MATH2069 (DN) and MATH2099). Some computing experience (R, Fortran, Maple, Matlab, or Python) is strongly recommended.

Teaching times and locations:

This is a blended learning course, with course materials presented in pre-recorded lecture videos that you will watch in your own time. We will meet once per week for two hours at the times indicated below, alternating between online Python labs and tutorials/discussion sessions, plus group and individual consultations as needed.

Course summary

This course is a graduate level overview of the mathematical foundations of inverse modelling and prediction and their application to real-world systems, primarily the ocean and atmosphere. The scientific emphasis is on the formal testing of models, formulated as rigorous hypotheses about the errors in all the information: dynamics, initial conditions, boundary conditions and data. Applications in meteorology, oceanography, and climate are presented in detail.

Course aims

Real-world physical systems, like the ocean and atmosphere, are immensely complicated, and understanding and predicting the future behaviour of these systems is crucial for weather forecasting, marine operations, and climate science. However, our knowledge of the real world sits upon two shaky pillars: imperfect observations on the one hand, and incomplete models (both mathematical and computational) on the other. The mathematical discipline for merging observations and models, plus their relative uncertainties, to form a best-guess estimate for the true state of a system is called *inverse modelling*, also known as data assimilation (in the applied mathematics literature) or filtering (in engineering).
This course aims to provide a graduate-level overview of the mathematical foundations of inverse modelling and prediction and their application to real-world systems, primarily the ocean and the atmosphere. The course introduces the fundamental mathematical underpinnings of forward and inverse modelling in the ocean and the atmosphere. The process of assimilating data into models using the calculus of variations is discussed, and the concept of over-determined and ill-posed problems is introduced. A step-by-step development of maximally efficient inversion algorithms, using ideal models, is complemented by computer codes and comprehensive details for realistic models. Variational tools and statistical concepts are concisely introduced, and applications to contemporary research models, numerical weather prediction, climate forecasting, and observing systems, are examined in detail.

Relationship between course and program learning outcomes and assessments

Course Learning Outcome (CLO)	LO Statement	Related Tasks & Assessment
CLO 1	Demonstrate in-depth knowledge of the fundamental mathematical underpinnings of forward and inverse modelling in the ocean and the atmosphere	Assignment 1, participation in discussion sessions, final group presentation, final project report
CLO 2	Implement idealized and realistic computational models of atmosphere/ocean dynamics	Assignment 2, participation in discussion sessions, final group presentation, final project report

CLO 3	Apply variational and statistical techniques in inverse modelling and data assimilation to real- world systems including numerical weather prediction and ocean state estimation	Assignment 3, participation in discussion sessions, final group presentation, final project report
CLO 4	Communicate discipline specific information in a written form with appropriate referencing	Assignments 1-3, participation in discussion sessions, final group presentation, final project report

Strategies and approaches to learning

Learning and teaching activities

We believe that effective learning is best supported by a climate of inquiry in which students are actively engaged in the learning process. Hence this course is structured with a strong emphasis on critical analysis and problem solving in discussion sessions and assessments. Students are expected to devote the majority of their study time to such tasks.

There are no formal lectures: new ideas and methods are first encountered from reading the textbook, and then students develop these ideas through active participation in the discussion sessions, and completing the assignments. A short research project will test the ability of students to integrate and apply the facts, concepts, and theory introduced in the discussion sessions.

Course schedule and structure

Week	Topic [Module]	Activity [Learning opportunity]	Related CLO
Week 1-2	Fundamentals of forward and inverse modelling	Lab 1, Tutorial 1, Assignment 1	1,4
Week 2-3	Generalized inverse; Optimal interpolation	Lab 2, Tutorial 2, Assignment 2	2,4
Week 4-5	The Kalman filter	Lab 3, Tutorial 3, Assignment 3	3,4
Week 6	Flexibility week – No lectures	Project group discussions	1,2,3,4

Week 7-8	Applications to ocean-atmosphere-climate science	Lab 4, Tutorial 4, Project group discussions	1,2,3,4
Week 9-10	Final projects	Project group discussions, Final group presentations, Final project report	1,2,3,4

Assessment

Assessment tasks

Throughout the course you will complete three assignments worth 60% of the final mark. The assessment of the assignments is based on the written worked solutions that you submit according to the timetable below.

A final research project will test the ability of students to integrate and apply the facts, concepts, and theory introduced in the discussion sessions. Students will work in small groups and will meet regularly with the course convenor in weeks 7-10 to discuss their project. In Week 10, students will make a group presentation to the rest of the class and will submit an individual project report in Week 11.

Assessment task	Release date	Due date	Weight	CLO
Assignment 1	Monday week 1	Monday week 4	20%	CLO1 and CLO4
Assignment 2	Monday week 4	Monday week 6	20%	CLO2 and CLO4
Assignment 3	Monday week 7	Monday week 9	20%	CLO3 and CLO4
Final Project Presentation and Report	n/a	Thursday week 11	40%	

Marks will be awarded for approach, clarity of explanation, and, as required, appropriate referencing, not just the final result. Students will be provided feedback in written form as well as in person during face-to-face consultations.

All assessments must be submitted online via the course Moodle page by 12 noon on the due date. Assessments handed late incur a 10% reduction in the mark per late day. Assessments handed in more than 5 days late will not be marked.

Final exam

There is no final exam for this course.

Further information

UNSW grading system: https://student.unsw.edu.au/grades

UNSW assessment policy: https://student.unsw.edu.au/assessment

Academic integrity, referencing and plagiarism

Referencing is a way of acknowledging the sources of information that you use to research your assignments. You need to provide a reference whenever you draw on someone else's words, ideas or research. Not referencing other people's work can constitute plagiarism.
Further information about referencing styles can be located at
https://student.unsw.edu.au/referencing

Academic integrity is fundamental to success at university. Academic integrity can be defined as a commitment to six fundamental values in academic pursuits**:** honesty, trust, fairness, respect, responsibility and courage.[1] At UNSW, this means that your work must be your own, and others' ideas should be appropriately acknowledged. If you don't follow these rules, plagiarism may be detected in your work.

The *Conduct and Integrity Unit* provides further resources to assist you to understand your conduct obligations as a student: https://student.unsw.edu.au/conduct.
For information about Additional Assessments and other Administrative matters relating to your course please consult the School of Mathematics and Statistics web page at
http://www.maths.unsw.edu.au/currentstudents/assessment-policies

[1] International Center for Academic Integrity, 'The Fundamental Values of Academic Integrity', T. Fishman (ed), Clemson University, 2013.

Resources

Recommended textbooks

No textbook is required for this course. If a textbook is desired, students are referred to:

- Inverse Modeling of the Ocean and Atmosphere, Andrew Bennett, CUP (2002)
- Discrete Inverse and State Estimation Problems, Carl Wunsch, CUP (2006)

Coding resources

Although not a prerequisite for this course, students are encouraged to familiarize themselves with Python before term begins.

Code Academy (https://www.codecademy.com) provides free online tutorials in Python and other programming languages and is an excellent resource for beginners. The labs will run in the Google Colab environment, a free web-based Python notebook server. As such, students do not need to install Python or any other specialist software on their own computers.

School and UNSW Policies

The School of Mathematics and Statistics has adopted a number of policies relating to enrolment, attendance, assessment, plagiarism, cheating, special consideration etc. These are in addition to the Policies of The University of New South Wales. Individual courses may also adopt other policies in addition to or replacing some of the School ones. These will be clearly notified in the Course Initial Handout and on the Course Home Pages on the Maths Stats web site.

Students in courses run by the School of Mathematics and Statistics should be aware of the School and Course policies by reading the appropriate pages on the Maths Stats web site starting at: https://www.maths.unsw.edu.au/currentstudents/assessment-policies

The School of Mathematics and Statistics will assume that all its students have read and understood the School policies on the above pages and any individual course policies on the Course Initial Handout and Course Home Page. Lack of knowledge about a policy will not be an excuse for failing to follow the procedure in it.

UNSW has an ongoing commitment to fostering a culture of learning informed by academic integrity. All UNSW staff and students have a responsibility to adhere to this principle of academic integrity. Plagiarism undermines academic integrity and is not tolerated at UNSW. *Plagiarism at UNSW is defined as using the words or ideas of others and passing them off as your own.*

The **UNSW Student Code** provides a framework for the standard of conduct expected of UNSW students with respect to their academic integrity and behaviour. It outlines the primary obligations of students and directs staff and students to the Code and related procedures.

In addition, it is important that students understand that it is not permissible to buy essay/writing services from third parties as the use of such services constitutes plagiarism because it involves using the words or ideas of others and passing them off as your own. Nor is it permissible to sell copies of lecture or tutorial notes as students do not own the rights to this intellectual property.

If a student breaches the Student Code with respect to academic integrity, the University may take disciplinary action under the **Student Misconduct Procedure**.

The UNSW Student Code and the Student Misconduct Procedure can be found at: https://student.unsw.edu.au/plagiarism

An online Module "Working with Academic Integrity" (https://student.unsw.edu.au/aim) is a six-lesson interactive self-paced Moodle module exploring and explaining all of these terms and placing them into your learning context. It will be the best one-hour investment you've ever made.

Additional Support

ELISE (Enabling Library and Information Skills for Everyone)

ELISE is designed to introduce new students to studying at UNSW. Completing the ELISE tutorial and quiz will enable you to:

- analyse topics, plan responses and organise research for academic writing and other assessment tasks
- effectively and efficiently find appropriate information sources and evaluate relevance to your needs
- use and manage information effectively to accomplish a specific purpose
- better manage your time
- understand your rights and responsibilities as a student at UNSW
- be aware of plagiarism, copyright, UNSW Student Code of Conduct and Acceptable Use of UNSW ICT Resources Policy

- be aware of the standards of behaviour expected of everyone in the UNSW community
- locate services and information about UNSW and UNSW Library

Some of these areas will be familiar to you, others will be new. Gaining a solid understanding of all the related aspects of ELISE will help you make the most of your studies at UNSW.

The *ELISE* training webpages: https://subjectguides.library.unsw.edu.au/elise/aboutelise

Equitable Learning Services (ELS)

If you suffer from a chronic or ongoing illness that has, or is likely to, put you at a serious disadvantage, then you should contact the Equitable Learning Services (previously known as SEADU) who provide confidential support and advice.

They assist students:

- living with disabilities
- with long- or short-term health concerns and/or mental health issues
- who are primary carers
- from low SES backgrounds
- of diverse genders, sexes and sexualities
- from refugee and refugee-like backgrounds
- from rural and remote backgrounds
- who are the first in their family to undertake a bachelor-level degree.

Their web site is: https://student.unsw.edu.au/els/services

Equitable Learning Services (ELS) may determine that your condition requires special arrangements for assessment tasks. Once the School has been notified of these, we will make every effort to meet the arrangements specified by ELS.

Additionally, if you have suffered significant misadventure that affects your ability to complete the course, please contact your Lecturer-in-charge in the first instance.

Academic Skills Support and the Learning Centre

The Learning Centre offers academic support programs to all students at UNSW Australia. We assist students to develop approaches to learning that will enable them to succeed in their academic study. For further information on these programs please go to: http://www.lc.unsw.edu.au/services-programs

Applications for Special Consideration for Missed Assessment

Please adhere to the Special Consideration Policy and Procedures provided on the web page below when applying for special consideration.
https://student.unsw.edu.au/special-consideration

Please note that the application is not considered by the Course Authority, it is considered by a centralised team of staff at the Nucleus Student Hub.

The School will contact you (via student email account) after special consideration has been granted to reschedule your missed assessment, for a *lab test or paper-based test* only.

For applications for special consideration for *assignment extensions*, please note that the new submission date and/or outcome will be communicated through the special consideration web site only, no communication will be received from the School.

For Dates on Final Term Exams and Supplementary Exams please check the "Key Dates for Exams" ahead of time to avoid booking holidays or work obligations.
https://student.unsw.edu.au/exam-dates

If you believe your application for Special Consideration has not been processed, you should email specialconsideration@unsw.edu.au immediately for advice

Course Evaluation and Development (MyExperience)

Student feedback is very important to continual course improvement. This is demonstrated within the School of Mathematics and Statistics by the implementation of the UNSW online student survey *myExperience*, which allows students to evaluate their learning experiences in an anonymous way. *myExperience* survey reports are produced for each survey. They are released to staff after all student assessment results are finalised and released to students. Course convenor will use the feedback to make ongoing improvements to the course.