Annexe A: New/Revised Course Content in OBTL+ Format

Course Overview

The sections shown on this interface are based on the templates UG OBTL+ or PG OBTL+
If you are revising/duplicating an existing course and do not see the pre-filled contents you expect in the subsequent sections e.g. Course Aims, Intended Learning Outcomes etc. please refer to Data Transformation Status for more information.

Expected Implementation in Academic Year	AY2025/26
Semester/Trimester/Others (specify approx. Start/End date)	Semester 2
Course Author * Faculty proposing/revising the course	David Lallemant
Course Author Email	dlallemant@ntu.edu.sg
Course Title	Fundamentals of Data Science for Earth and Environmental Systems Science
Course Code	ES0002
Academic Units	3
Contact Hours	39
Research Experience Components	Research Defined Course (at least 50% of deliverables involve practical research activities: problem identification, hypothesis forming, data collection/analysis/interpretation, result communication)

Course Requisites (if applicable)

Pre-requisites	MH1800 Calculus for the Sciences I, ES2001 Computational Earth Systems Science
Co-requisites	N/A
Pre-requisite to	N/A
Mutually exclusive to	N/A
Replacement course to	N/A
Remarks (if any)	N/A

Course Aims

The goal of this class is to develop a working knowledge of data science and its use in earth systems research and practice. The course is split evenly between key concepts / theory and practical experience writing code and analyzing outputs. Some introductory knowledge of statistics is assumed, and some familiarity with programming is helpful but not required.

Course's Intended Learning Outcomes (ILOs)

Upon the successful completion of this course, you (student) would be able to:

ILO 1	Develop rationally designed statistical learning and machine learning models to extract meaningful insight from data.
ILO 2	Write logical expressions in R.
ILO 3	Generate meaningful visualizations of data and data analysis results.
ILO 4	Design appropriate experiments for data collection and apply statistical tests to answer research questions.
ILO 5	Illustrate theoretical knowledge of key concepts in statistical learning and data science.
ILO 6	Develop communication, creative and critical thinking skills.
ILO 7	Discuss the role of big data, statistical learning, machine learning and AI in earth and environmental systems sciences.
ILO 8	Discuss the social-ethical implications of data science technologies

Course Content

The course will focus on fundamental processes for scientific modelling, inference and data-science and their application in earth and environmental system science. The class will cover (1) basic concepts and tools in data science, (2) brief review of statics, (3) goals and principles of scientific modeling, (4) model development, (5) model calibration and selection, (6) sensitivity analysis, (7) model evaluation, (8) model predictions, (9) results visualization and communication.

Reading and References (if applicable)

This is course aims to encourage you to think critically, and solve practical problems with a series of tools. The following books will be used as the main references/textbooks:

1. Hastie, Trevor J, Robert J Tibshirani, and J Jerome H Friedman. The Elements of Statistical Learning: Data Mining, Inference and Prediction, Springer, 2017. [https://web.stanford.edu/~hastie/ElemStatLearn/]

2. Kabacoff, Robert. R in Action, Second Edition: Data analysis and graphics with R. Manning, 2015

3. Pebesma E., Nüst D., Bivand R. (2012) The R software environment in reproducible geoscientific research. EOS, Transactions American Geophysical Union 93:163-163.

4. Chamberlin, T.C., 1890. The method of multiple working hypotheses: Science, v. 15. doi, 10: 92–96.

5. Jackson, L.J., Trebitz, A.S., Cottingham, K.L., 2000. An introduction to the practice of ecological modeling. Bioscience. 50, 694-706.

6. Strayer, D.L., Ewing, H.A., Bigelow, S., 2003. What kind of spatial and temporal details are required in models of heterogeneous systems? Oikos. 102, 654-662.

7. Schewe J., Levermann A. (2012) A statistically predictive model for future monsoon failure in India. Environmental Research Letters 7:044023.

8. Saltelli, A., K. Chan, and E.M. Scott, (eds.) 2000. Sensitivity Analysis. John Wiley and Sons, New York. First chapter

Planned Schedule

Week or Session	Topics or Themes	ILO	Readings	Delivery Mode	Activities
1	Introduction to course, algorithms, programing, statistical learning	1, 2, 4, 5, 6, 7, 8		In-person	Lecture and tutorial
2	Review of statistics, introduction to R	1, 2, 4, 5, 6, 7	Kabacoff, 2015	In-person	Lecture and tutorial
3	Goal and principles of scientific modeling; modeling examples.	1, 2, 3, 4, 5, 6, 7, 8	Pebesma, 2012	In-person	Lecture and tutorial
4	Designing and programing models (statistical and machine learning) – Part 1	1, 2, 4, 5, 6, 7		In-person	Lecture and tutorial
5	Designing and programing models (statistical and machine learning) – Part 2	1, 2, 4, 5, 6, 7	Schewe and Leverman, 2012	In-person	Lecture and tutorial
6	Model Calibration and Selection	1, 2, 4, 5, 6, 7, 8		In-person	Lecture and tutorial
7	Model Calibration and Selection	1, 2, 4, 5, 6, 7, 8	Saltelli, 2000	In-person	Lecture and tutorial

Week or Session	Topics or Themes	ILO	Readings	Delivery Mode	Activities
8	Sensitivity Analysis	1, 2, 4, 5, 6, 7, 8		In-person	Lecture and tutorial
9	Model Evaluation	1, 2, 4, 5, 6, 7, 8		In-person	Lecture and tutorial
10	Model Predictions	1, 2, 4, 5, 6, 7, 8		In-person	Lecture and tutorial
11	Model Predictions and uncertainties	1, 2, 3, 4, 5, 6, 7, 8		In-person	Lecture and tutorial
12	Visualization	1, 2, 3, 4, 5, 6, 7, 8		In-person	Lecture and tutorial
13	Ethical data science and AI applications	1, 2, 3, 4, 5, 6, 7, 8		In-person	Lecture and tutorial

Learning and Teaching Approach

Approach	How does this approach support you in achieving the learning outcomes?
Lectures	Lectures will pass on the theoretical knowledge required to understand the different components of data analysis and statistical learning process.
Tutorial	Tutorial sessions will: • Demonstrate practical applications of statistical learning and data science in the field of earth and environmental system science. • Enable students to code using R and address any coding issues.

Assessment Structure

Assessment Components (includes both continuous and summative assessment)

No.	Component	ILO	Related PLO or Accreditation	Weightage	Team/Individual	Rubrics	Level of Understanding
1	Continuous Assessment (CA): Class Participation(Contributions during class time & online Q&A forum)	5,6,7,8	2,3,8,9,10	20	Individual	Holistic	Extended Abstract
2	Continuous Assessment (CA): Assignment(Assignments 1-2 – Coding)	1,2,4,5	1,2,3,4,5,8,9	10	Individual	Analytic	Multistructural
3	Continuous Assessment (CA): Assignment(Assignments 3-6 – (Coding + reports))	1,2,3,4,5,6,7,8	1,2,3,4,5,8,9	70	Individual	Holistic	Extended Abstract

Description of Assessment Components (if applicable)

Refer to Rubrics attached.

Formative Feedback

You will receive written feedback for Component 2 & 3.

NTU Graduate Attributes/Competency Mapping

This course intends to develop the following graduate attributes and competencies (maximum 5 most relevant)

Attributes/Competency	Level
Ethical Reasoning	Intermediate
Problem Solving	Advanced
Self-Management	Advanced
Systems Thinking	Intermediate
Embrace Challenge	Intermediate

Course Policy

Policy (Academic Integrity)

Good academic work depends on honesty and ethical behaviour. The quality of your work as a student relies on adhering to the principles of academic integrity and to the NTU Honour Code, a set of values shared by the whole university community. Truth, Trust and Justice are at the core of NTU's shared values. As a student, it is important that you recognize your responsibilities in understanding and applying the principles of academic integrity in all the work you do at NTU. Not knowing what is involved in maintaining academic integrity does not excuse academic dishonesty. You need to actively equip yourself with strategies to avoid all forms of academic dishonesty, including plagiarism, academic fraud, collusion and cheating. If you are uncertain of the definitions of any of these terms, you should go to the academic integrity website for more information. On the use of technological tools (such as Generative AI tools), different courses / assignments have different intended learning outcomes. Students should refer to the specific assignment instructions on their use and requirements and/or consult your instructors on how you can use these tools to help your learning. Consult your instructor(s) if you need any clarification about the requirements of academic integrity in the course.

Policy (General)

Students are expected to complete all assigned pre-class readings and activities on time, attend all lectures, tutorial and class discussions, and submit all scheduled assignments by due dates. Students are expected to take responsibility to follow up with course notes, assignments and course related announcements for sessions they have missed.
We encourage you to ask questions and provide advice to your fellow students as part of your learning process, but require that you do this through the class online forum (in the appropriate public channel, not as a direct message). This will guarantee that (1) all other students benefit equally, since they might have the same question, and (2) the teaching team is aware of what information has been shared, so we can chime in with additional comments and resources if needed. We know that the best way to learn is often by asking questions and teaching each other, and so are providing you an appropriate platform to do so.

Policy (Absenteeism)

Absence from scheduled lectures and discussion without a valid reason will affect your overall course grade. Valid reasons include falling sick supported by a medical certificate.
If you miss a lecture or tutorial exercise you must inform me via email (dlallemant@ntu.edu.sg) prior to the start of the class.

Policy (Others, if applicable)

ASE Diversity and Inclusion policy
Integrating a diverse set of experiences is important for a more comprehensive understanding of science. It is our goal to create an inclusive and collaborative learning environment that supports a diversity of thoughts, perspectives, and experiences, and that honours your identities (including ethnicity race, gender, socioeconomic status class, sexual orientation, religion or, ability., etc.).
To help accomplish this:

- If you feel like your performance in the class is being impacted by your experiences outside of class, please don't hesitate to come and talk with one of the instructors or an ASE faculty member. We want to be a resource for you.
- Your classmates and instructors (like many people) are still in the process of learning about diverse perspectives and identities. If something was said in class (by anyone) that made you feel uncomfortable, please talk to the instructors or an ASE faculty member about it.
- As a participant in course discussions, you should also strive to honour the diversity of your classmates. You can do this by: (e.g., using preferred pronouns and names; being respectful of others opinions and actively, making sure all

voices are being heard; and refraining from the use of derogatory or demeaning speech or actions., etc.).
We expect all members of the class to adhere to the NTU Anti-harassment policy (https://ts.ntu.edu.sg/sites/policyportal/new/Documents/msrf%20included%20NIE%20staff/Anti-Harassment%20Policy.pdf), if you witness something that goes against this or have any other concerns, please speak to your instructors or an ASE faculty member.

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Last Updated By: Natasha Bhatia (Dr)