课程详述

COURSE SPECIFICATION

以下课程信息可能根据实际授课需要或在课程检讨之后产生变动。如对课程有任何疑问，请联系授课教师。

The course information as follows may be subject to change, either during the session because of unforeseen circumstances, or following review of the course at the end of the session. Queries about the course should be directed to the course instructor.

1.	**课程名称 Course Title**	灾害风险分析导论 Introduction to Catastrophe Risk Modelling
2.	**授课院系 Originating Department**	地球与空间科学系 Department of Earth and Space Sciences
3.	**课程编号 Course Code**	ESS322
4.	**课程学分 Credit Value**	2
5.	**课程类别 Course Type**	专业选修课 Major Elective Courses
6.	**授课学期 Semester**	春季 Spring
7.	**授课语言 Teaching Language**	英文 English
8.	**授课教师、所属学系、联系方式（如属团队授课，请列明其他授课教师） Instructor(s), Affiliation& Contact （For team teaching, please list all instructors）**	Arnaud MIGNAN，风险研究院&地球与空间科学系 邮箱：mignana@sustech.edu.cn 办公室：创园 6 栋 511-3 Prof. Arnaud MIGNAN, Institute of Risk Analysis, Prediction and Management, Academy for Advanced interdisciplinary Studies; Department of Earth and Space Sciences Email: mignana@sustech.edu.cn Office: 511-3, 5th floor, building 6, Innovation Park
9.	**实验员/助教、所属学系、联系方式 Tutor/TA(s), Contact**	待公布 To be announced
10.	**选课人数限额(可不填) Maximum Enrolment（Optional）**	

		讲授 Lectures	习题/辅导/讨论 Tutorials	实验/实习 Lab/Practical	其它(请具体注明) Other（Please specify）	总学时 Total
11.	授课方式 Delivery Method 学时数 Credit Hours	26		6		32

12.	先修课程、其它学习要求 Pre-requisites or Other Academic Requirements	MA212 概率论与数理统计、CS102B 计算机程序设计基础 B MA212 Probability and Statistics, CS102B Introduction to Computer Programming B
13.	后续课程、其它学习规划 Courses for which this course is a pre-requisite	
14.	其它要求修读本课程的学系 Cross-listing Dept.	

教学大纲及教学日历 SYLLABUS

15. 教学目标 Course Objectives

本课程将介绍采用模型对巨灾风险进行预测和评估的基本原理和方法。内容涵盖各种类型的灾害，即讨论自然灾害（例如地震、暴风、传染病），也包括人为灾害（例如工业事故、异常断电），学习如何从定性和定量的角度研究这些灾害的特征，学习对灾害进行评估的技术。经过本课程的学习，学生将掌握风险建模的理论和实践，并熟悉统计分析和计算常用的 R 编程语言。

This course will introduce the principles of catastrophe risk modelling. We will explore the rich universe of perils, both natural (e.g. earthquakes, storms, epidemics) and man-made (e.g. industrial accidents, blackouts), study their characteristics both qualitatively and quantitatively, and develop techniques for their assessment. We will get familiar with the theoretical and practical aspects of risk modelling, as well as with R programming for statistical analysis and computing.

16. 预达学习成果 Learning Outcomes

完成课程后，学生将掌握以下内容：

1.了解灾害的不同类型和规模及其对我们社会的潜在影响；

2.巨灾风险建模的基本知识，包括理论和实践方面；

3. R 统计编程的基础知识（概率分布，参数估计，模拟，绘图）；

4.基本物理概念的基本知识（能量，幂律，网络，公用事业等）；

5.贝叶斯推理方法的基础知识；

6.实践动手能力：批判性思维、实用主义、以目的为主的原则、第一性原理、团队合作精神。

Upon completing the course, students will master the following items:

1. Understanding of the different types & scales of hazards and their potential impact on our society;
2. Fundamental knowledge of catastrophe risk modelling including both theoretical and practical aspects;
3. Basic knowledge of R statistical programming (probability distributions, parameter estimation, simulations, plotting);
4. Basic knowledge of fundamental physical concepts (energy, power-law, network, utility, *etc.*);
5. Basic knowledge of Bayesian inference methods for forecasting;

6. Hands-on knowledge: Critical thinking, pragmatism, top-down view, first physical principles, teamwork.

17. 课程内容及教学日历（如授课语言以英文为主，则课程内容介绍可以用英文；如团队教学或模块教学，教学日历须注明主讲人）
Course Contents (in Parts/Chapters/Sections/Weeks. Please notify name of instructor for course section(s), if this is a team teaching or module course.)

Chapter 1: Overview of Catastrophe Risk (2 hours)

Week 1 (lecture 1): Concepts & terminology, such as 'disaster', 'hazard', 'risk', 'probability', 'uncertainty' and 'model'; History of catastrophe risk (myths, infamous disasters, scientific & engineering milestones); Types of perils, defined by category, such as natural (extra-terrestrial, meteorological, geological, hydrological, biological) or anthropogenic (accidental, malicious), defined by scale & frequency (low to high impact, common to very rare); Syllabus overview & what the student is expected to learn throughout the course [*assignment #1: Describe 5 perils not discussed in class & classify them*].

Chapter 2: Basics of Catastrophe Modelling (4 hours)

General framework describing hazard assessment (source definition, event frequency and severity) & risk assessment (exposure, vulnerability, risk metrics); Application to various natural & anthropogenic hazards discussed in Chapter 1, conceptualised and compared using first physical principles. Fundamental concepts to be addressed include energy release, power-laws, and probability distributions, illustrated with basic R codes for an initiation to this programming language.

Week 2 (lecture 2): Hazard part [*assignment #2: Download R & run provided hazard code*]; *Week 3 (lecture 3):* Risk part [*assignment #3: run provided full risk code, the template for the main student project*].

Chapter 3: Probabilistic Seismic Risk Assessment (4 hours)

Detailed framework based on the concepts learned in Chapter 2 but with application to seismic risk assessment; Concepts of probability distributions for hazard curve, vulnerability/fragility curves and loss curve definition. Calibration methods to estimate hazard, vulnerability and risk from historical data; Engineering approach to seismic risk quantification. A full R program will be studied in detail and proposed as template for the student-group project (transfer to other risks, of their choice).

Week 4 (lecture 4): Hazard part [*assignment #4: Modify input parameter values & compare resulting hazard curves*]; *Week 5 (lecture 5):* Risk part [*assignment #5: Compute damage ratio expected for different earthquake magnitudes*].

Student project session A: Brainstorming & early-stage programming (2 hours)

Week 6 (interactive session): Interactive session during which the students formally decide which risk they want to quantify (by groups); Feasibility analysis, data accessibility, transfer of knowledge from chapters 1-3. Start to draft their model in a report and R code. Any peril may be considered for this project except earthquakes (i.e. provided template).

Chapter 4: Hazard Footprint Modelling for different Classes of Perils (4 hours)

Presentation of different approaches for the modelling of hazard footprints of different classes of perils, moving from the diffusion processes mentioned in previous chapters to: Brownian motion (e.g. storm tracks), cellular automata to model interface events (landslides, wildfires, tsunamis) and site-specific conditions (e.g. seismic wave), and networks to model network-based events (epidemics, lifeline failures, such as blackouts).

Week 7 (lecture 6): Concepts of Brownian motion and cellular automata [*assignment #6: Run the provided cellular automaton code & plot the resulting footprint*]; *Week 8 (lecture 7):* Concepts of network theory [*assignment #7: Run the provided network propagation code & plot the resulting footprint*].

Student project session B: Consolidation of program & first results (2 hours)

Week 9 (interactive session): Follow-up on session A and further work done outside the classroom; Investigation of possible gaps, errors, and other problems; verify that each group is able to produce a loss curve for their selected peril.

Chapter 5: Extreme Event Modelling (4 hours)

Week 10 (lecture 8): Definition of tail-events & maximum-size events (more on power-laws and physical thresholds); Application of the Negative binomial distribution to intra-hazard interactions (earthquake & tropical cyclone clustering); Illustration of how complex inter-hazard interactions can be simply encoded in a relation matrix (natural, technical and socio-economic interactions) [*assignment #8: fill the relation matrix using reasoned imagination*];

Week 11 (lecture 9): Inter-hazard interactions described quantitatively with basic concepts of catastrophe dynamics; General notes on global changes including climate change and other catastrophe trends (presentation of famous system dynamics models, such as World 3).

Chapter 6: Forecasting (4 hours)

Week 12 (lecture 10): Forecasting versus prediction (history of earthquake prediction); Parallel between machine learning & hazard forecasting (features, models, binary classes); Statistics of forecasting (accuracy, precision/recall, receiver operating characteristic curve, skill score, *etc.* with examples from tornadoes and aftershocks); Bayesian formalism (prior, likelihood, posterior) described for the toss of a coin;

Week 13 (lecture 11, interactive session): Applications of Bayesian inference in anthropogenic seismicity forecasting and in typhoon forecasting (including stochastic process simulation and model validation); Testing in classroom with provided R codes (students to compare different stochastic iterations, observe how probability distributions evolve and parameters are updated with more data, forecasting skills versus time horizon).

Chapter 7: Risk Governance & Decision under Uncertainty (2 hours)

Week 14 (lecture 12): Description of the different types of risk stakeholders, decision frameworks for risk reduction and risk transfer (early warning, regulations and stress tests, insurance and bonds), and risk communication; Concept of risk perception (subjectivity and biases, risk and loss aversion) and decision theories (based on utility, subjective probability or ambiguity).

Student project session C: Final presentation (2 hours)

Week 15 (graded interactive session): Presentation by each group of their probabilistic risk analysis (slides + report).

Chapter 8: The Future of Catastrophe Risk Analysis: Big Data & Artificial Intelligence (2 hours)

Week 16 (lecture 13): Basic definition of deep learning, reinforcement learning, and big data; Examples of recent applications (e.g. recognition of wildfires from space imagery, constrained reinforcement learning for safe exploration); Current limitations (e.g. AI pitfalls in earthquake prediction); Discussion on the next horizons (e.g. blockchain-based catastrophe risk insurance; catastrophe big-data in the Data-Information-Knowledge-Wisdom pyramid context).

18. 教材及其它参考资料 Textbook and Supplementary Readings

教材 Textbook：

自编英文讲义 Coursepacks in English

参考资料 Supplementary Readings：

1. Grossi P., Kunreuther H. (2005), Catastrophe Modeling: A New Approach to Managing Risk. Springer Science +

Business Media, Inc., Boston, 241 pp.

2. Woo G. (1999), The Mathematics of Natural Catastrophes. Imperial College Press, London, 292 pp.

3. Woo G. (2011), Calculating Catastrophe. Imperial College Press, London, 355 pp.

4. Smil V. (2008), Global Catastrophes and Trends, The Next Fifty Years. The MIT Press, Cambridge, 307 pp. - see chapter 2. Fatal Discontinuities.

课程评估 ASSESSMENT

19.

评估形式 Type of Assessment	评估时间 Time	占考试总成绩百分比 % of final score	违纪处罚 Penalty	备注 Notes
出勤 Attendance				
课堂表现 Class Performance				
小测验 Quiz				
课程项目 Projects		50		
平时作业 Assignments		10		
期中考试 Mid-Term Test				
期末考试 Final Exam		40		
期末报告 Final Presentation				
其它（可根据需要改写以上评估方式） Others (The above may be modified as necessary)				

20. 记分方式 GRADING SYSTEM

☑ A. 十三级等级制 Letter Grading
☐ B. 二级记分制（通过/不通过） Pass/Fail Grading

课程审批 REVIEW AND APPROVAL

21. 本课程设置已经过以下责任人/委员会审议通过
This Course has been approved by the following person or committee of authority

地球与空间科学系本科教学指导委员会
Undergraduate Teaching Steering Committee of the Department of Earth and Space Sciences