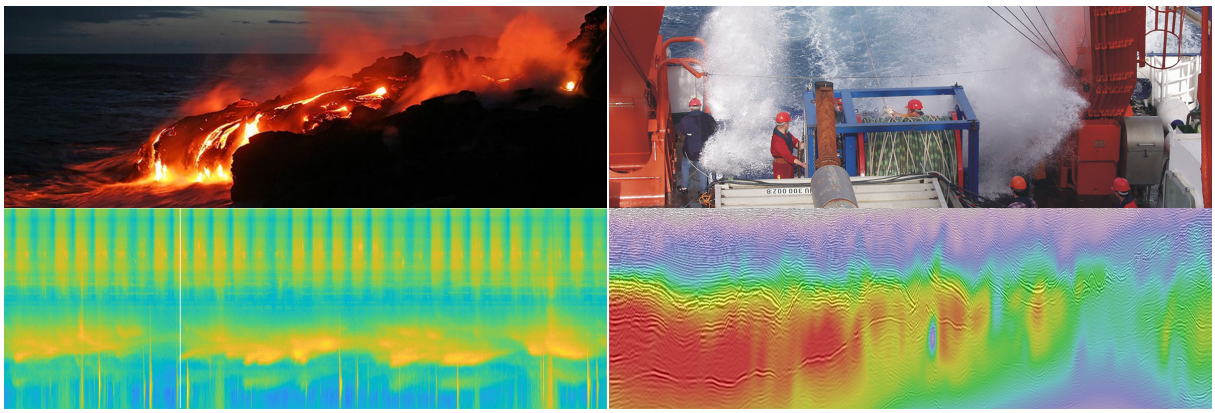
Module Handbook

Master of Science Geophysics

University of Hamburg

March 2023



Contents

Introduction

The M.Sc. Geophysics is a research-oriented programme that offers individual specialisation. Students can choose those lectures from the curriculum of the Institute of Geophysics that best suit their scientific interests. The programme is divided into two phases, beginning with the Advanced Studies Phase, where students develop advanced knowledge and understanding in geophysics and related interdisciplinary subjects. This phase is followed by the Research Phase, where students specialise in a geophysical research field that eventually becomes the topic of their Master's thesis.

Overview

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<tr><td rowspan="2">Advanced Studies Phase</td><td>Semester 1</td><td rowspan="2">Advanced Studies and Specialisation in Geophysics
min. 30 ECTS</td><td rowspan="2">Seminar
min.
6 ECTS</td><td rowspan="2">Interdisciplinary Studies
max.
15 ECTS</td><td rowspan="2">Elective Studies
max.
6 ECTS</td></tr>
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The curriculum of the Institute of Geophysics represents the focus of the working groups in research and teaching:

- Applied Seismics
- Marine Geophysics
- Seismology
- Physical Volcanology
- Machine Learning
- Interdisciplinary expertise
- Learning by active participation in research

Lecturers

- **Dr. Christian Bücker**

Fields of work:

- Borehole measurements and a statistically validated objectified assessment of the underlying rock and fluid physical parameters

Modules:

- Borehole geophysics 1: Tools and applications
- Borehole geophysics 2: Special applications and evaluation methods

Contact: christian.buecker@uni-hamburg.de

- **Prof. Dr. Céline Hadziioannou (staff lecturer)**

Fields of work:

- Seismology
- Studying seismic background noise
- Rotational seismology
- Scattered wavefileds

Modules:

- Body and surface wave seismology
- Ambient seismic noise
- Earthquakes
- Seminar on seismology
- Orientation project
- Preparatory project
- Master's thesis

Contact: celine.hadziioannou@uni-hamburg.de

- **Prof. Dr. Conny Hammer (staff lecturer)**

Fields of work:

- Machine learning in geophysics
- Seismic event detection
- Natural hazards

Modules:

- Machine learning in geophysics
- Machine learning: generative models in geophysics
- Orientation project
- Preparatory project
- Master's thesis

Contact: conny.hammer@uni-hamburg.de

- **Prof. Dr. Matthias Hort (staff lecturer)**

Fields of work:

- Geophysical volcanology
- Dynamics of the interior of the earth
- Volcanoes and climate

Modules:

- Potential theory
- Volcanology
- Seminar on volcanology
- Orientation project
- Preparatory project
- Master's thesis

Contact: matthias.hort@uni-hamburg.de

- **Prof. Dr. Christian Hübscher (staff lecturer)**

Fields of work: seismic interpretation with focus on

- Salt tectonics
- Slope slumping
- Sequence stratigraphy
- Fluid and gas escape
- Mud volcanoes
- Paleooceanography

Modules:

- Seismic data processing
- Seminar on applied geophysics
- Orientation project
- Preparatory project
- Master's thesis

Contact: christian.huebscher@uni-hamburg.de

- **Dr. Lea Scharff (staff lecturer)**

Fields of work:

- Geophysical volcanology

Modules:

- Applied volcanology
- Inversion problems
- Seminar on volcanology
- Orientation project
- Preparatory project
- Master's thesis

Contact: lea.scharff@uni-hamburg.de

- **Dr. Sven Schippkus (staff lecturer)**

Fields of work:

- The ambient seismic field and its applications

Modules:

- Ambient seismic noise
- Earthquakes
- Seminar on seismology
- Orientation project
- Preparatory project
- Master's thesis

Contact: sven.schippkus@uni-hamburg.de

- **PD Dr. Claudia Vanelle (staff lecturer)**

Fields of work:

- Subsurface imaging with seismic data
- Elastic wave propagation
- Multiparameter methods
- Seismic anisotropy

Modules:

- Seismic anisotropy
- Migration of seismic reflection data
- Digital signal processing
- Seminar on applied geophysics
- Orientation project
- Preparatory project
- Master's thesis

Contact: claudia.vanelle@uni-hamburg.de

Examination board

The current (March 2023) members of the examination board for the M.Sc. Geophysics are:

	Primary representative	Deputy representative
Professor	Prof. Dr. Matthias Hort (head)	
Professor	Prof. Dr. Céline Hadziioannou	
Professor	Prof. Dr. Conny Hammer	
Research assistant	PD Dr. Claudia Vanelle	Dr. Lea Scharff
Student representative	Maryse Schmidt	Laurin Müller

Study advice

The study advisor for the M.Sc. Geophysics is PD Dr. Claudia Vanelle.

Contact: claudia.vanelle@uni-hamburg.de

Academic Services Office

The Academic Services Office is the central contact point for questions and queries of students and lecturers at the Department of Earth System Sciences. Their tasks include the coordination of degree programs, subject counselling, and exam management.

Contact: studienbuero.geo@uni-hamburg.de

Module code	GP-M-AS
Module name	Advanced studies and specialisation in geophysics
Lecturer(s)	The teaching staff of the Institute of Geophysics
Module type	Compulsory
Objectives / learning outcomes	After successful completion of the module, students are familiar with the state of the art in research as well as an advanced understanding of selected problems, methods, and results in fields of geophysical research. They are competent in applying advanced scientific methods and techniques in these fields. They are capable of performing self-directed scientific work in the fields and have gained knowledge and experience with scientific literature.
Contents	See the respective courses.
Language	English
Teaching methods	Lectures, exercises, and any other method according to §5 MIN PO.
Prerequisites for participation	See the respective courses.
Target audience	For students in the M.Sc. Geophysics: compulsory module. For students in M.Sc. programmes in physical and earth sciences: elective module.
Recommended semester	1 and 2
Requirements for exam registration	Details will be announced at the beginning of the respective course.
Type of exam	Written exam or homework assignment. Details will be announced at the beginning of the respective course.
Grading scale	Five point (1-5) or pass/fail. Details are given in the description of the respective course.
Workload	A minimum of 30 ECTS with five point (1-5) grading system must be achieved, while a maximum of 54 ECTS is possible. • Lectures: 1 ECTS for 1 hr./week of directed study time • Exercises: 2 ECTS for 1 hr./week of directed study time
Frequency	Every term
Duration	2 semesters
Literature	See the respective courses.

Note: For technical resasons, the individual courses that are listed in the section below are implemented in the STiNE system as modules. Their description in this handbook is, therefore, also provided in terms of modules.

Module code	GP-M-SEM			
Module name	Seminar			
Lecturer(s)	The teaching staff of the Institute of Geophysics			
Module type	Compulsory			
Objectives / learning outcomes	After successful completion of the module, students can familiarise themselves with an advanced geophysical topic. They can present their results in an oral lecture and lead a scientific discussion.			
Contents	• ASEM: Seminar on Applied Geophysics • SSEM: Seminar on Seismology • VSEM: Seminar on Volcanology			
Language	English			
Teaching methods	Seminar			
Prerequisites for participation	None			
Target audience	For students in the M.Sc. Geophysics: compulsory module. For students in M.Sc. programmes in physical and earth sciences: elective module.			
Recommended semester	1 or 2			
Requirements for exam registration	Regular attendance. Details will be announced at the beginning of the respective course.			
Type of exam	Presentation and report. Details will be announced at the beginning of the respective course.			
Grading scale	Pass/fail.			
Workload	Seminar per course	Directed study time per course	Self study per course	Exam preparation per course
	Credit points: 3 ECTS	30 hrs.	30 hrs.	30 hrs.
Frequency	Every term			
Duration	2 semesters			
Literature	Will be announced at the beginning of the course.			

Module code	GP-M-IS
Module name	Interdisciplinary studies
Lecturer(s)	According to the specified course(s)
Module type	Elective
Objectives / learning outcomes	After successful completion of the module, students have complemented their expertise in geophysics with knowledge of their chosen interdisciplinary subject.
Contents	Course(s) from M.Sc. modules offered by the departments of Geosciences (including ICSS), Mathematics, Physics, Informatics of the University of Hamburg Exceptions are possible, but must be cleared beforehand with the study coordinator. Please contact the study advisor for details.
Language	According to the specified course(s)
Teaching methods	According to the specified course(s)
Prerequisites for participation	According to the specified course(s)
Target audience	For students in the M.Sc. Geophysics: elective module.
Recommended semester	1 or 2
Requirements for exam registration	According to the specified course(s)
Type of exam	According to the specified course(s)
Grading scale	According to the specified course(s). The grade does not contribute to the final grade of the M.sc. Geophysics.
Workload	While there is no minimum requirement, a maximum of 15 ECTS will be accepted. The workload follows according to the specified course(s).
Frequency	Every term
Duration	According to the specified course(s)
Literature	According to the specified course(s)

Module code	GP-M-ES
Module name	Elective studies
Lecturer(s)	According to the specified course(s)
Module type	Elective
Objectives / learning outcomes	After successful completion of the module, students have gained fundamental knowledge of their chosen subject.
Contents	Course(s) from M.Sc. modules offered by the University of Hamburg with the exception of language courses in English, French, Spanish, German if the CEFR level is below C1. Exceptions are possible, but must be cleared beforehand with the study coordinator. Please contact a study advisor for details.
Language	According to the specified course(s)
Teaching methods	According to the specified course(s)
Prerequisites for participation	According to the specified course(s)
Target audience	For students in the M.Sc. Geophysics: elective module.
Recommended semester	1 or 2
Requirements for exam registration	According to the specified course(s)
Type of exam	According to the specified course(s)
Grading scale	According to the specified course(s) The grade does not contribute to the final grade of the M.Sc. Geophysics.
Workload	While there is no minimum requirement, a maximum of 6 ECTS will be accepted. The workload follows according to the specified course(s).
Frequency	Every term
Duration	According to the specified course(s)
Literature	According to the specified course(s)

Module code	GP-M-OP
Module name	Orientation project
Lecturer(s)	The teaching staff of the Institute of Geophysics
Module type	Compulsory
Objectives / learning outcomes	After successful completion of the module, students are familiar with the current state of the art in a modern research topic, from which the master's thesis should originate. They have learned to independently acquire requisite information and background knowledge and to familiarise themselves with a special subject.
Contents	Will be announced at the beginning of the course.
Language	German or English. The actual language will be announced at the beginning of the course.
Teaching methods	Any method according to §5 MIN PO.
Prerequisites for participation	None.
Target audience	For students in the M.Sc. Geophysics: compulsory module.
Recommended semester	3
Requirements for exam registration	Details will be announced at the beginning of the course.
Type of exam	Oral presentation or written project report. Details will be announced at the beginning of the respective course.
Grading scale	Pass/fail.
Workload	15 ECTS
Frequency	Every term
Duration	1 semester
Literature	Will be announced at the beginning of the course.

Module code	GP-M-PP
Module name	Preparatory project
Lecturer(s)	The teaching staff of the Institute of Geophysics
Module type	Compulsory
Objectives / learning outcomes	After successful completion of the module, students have gained knowledge and developed special methods of the chosen research field to the extent that they can successfully apply them to work on the topic, from which the master's thesis should originate. They can plan and structure the planned research project.
Contents	Will be announced at the beginning of the course.
Language	German or English. The actual language will be announced at the beginning of the course.
Teaching methods	Any method according to §5 MIN PO.
Prerequisites for participation	Successful completion of Orientation project (OP).
Target audience	For students in the M.Sc. Geophysics: compulsory module.
Recommended semester	3
Requirements for exam registration	Details will be announced at the beginning of the course.
Type of exam	Oral presentation or written project report. Details will be announced at the beginning of the respective course.
Grading scale	Pass/fail.
Workload	15 ECTS
Frequency	Every term
Duration	1 semester
Literature	Will be announced at the beginning of the course.

Module code	GP-M-MT
Module name	Master's thesis
Lecturer(s)	The teaching staff of the Institute of Geophysics
Module type	Compulsory
Objectives / learning outcomes	After successful completion of the module, students are able to familiarise themselves with a topic of current geophysical research within a given time frame. They have gained the ability to apply suitable scientific methods independently and to present the results in a scientifically appropriate form.
Contents	Will be announced at the beginning of the course.
Language	German or English. The actual language will be announced at the beginning of the course.
Teaching methods	Final module.
Prerequisites for participation	Successful completion of Advanced studies and specialisation in geophysics (AS).
Target audience	For students in the M.Sc. Geophysics: compulsory module.
Recommended semester	4
Requirements for exam registration	Details will be announced at the beginning of the respective course.
Type of exam	Written thesis and oral lecture with the content of the written thesis to be presented in a scientific seminar. The lecture should be given shortly after the submission of the written work.
Grading scale	Five point (1-5). The grade of the written thesis contributes 80 % to the final grade and the grade of the oral presentation contributes 20 % to the final grade.
Workload	30 ECTS
Frequency	Every term
Duration	Six months
Literature	Will be announced at the beginning of the course.

Module code	SEISNOISE			
Module name	Ambient seismic noise			
Lecturer(s)	C. Hadziioannou, S. Schippkus			
Module type	Compulsory elective			
Objectives / learning outcomes	After completing the module, students will be able to locate sources of ambient seismic noise and compute Green's functions between station pairs. Students will be very familiar with the most important sources of ambient seismic noise and their mechanisms. Students will have broad knowledge about common applications of ambient noise in modern seismology (tomography, structural monitoring), and will have basic knowledge of more exotic applications (amplitudes, other celestial bodies).			
Contents	• Sources of ambient seismic noise: global, regional, local; Source mechanisms • Methods for source identification and localization: Beamforming and Matched Field Processing • Interferometry of seismic noise for retrieval of estimated Green's functions • Applications of estimated Green's functions: Tomography, amplitudes • Monitoring approaches, coda sensitivity, environmental monitoring • Seismic noise on Moon and Mars			
Language	English.			
Teaching methods	Lectures (15 hrs.) and computer exercises (30 hrs.), taught as block course.			
Prerequisites for participation	Programming skills (Python, Obspy) and knowledge in Seismology at the level of the B.Sc. module VGSEIS			
Target audience	For students in the M.Sc. Geophysics: core module in Advanced Studies and Specialisation in Geophysics (AS). For students in M.Sc. programmes in physical and earth sciences: elective module.			
Recommended semester	1 or 2			
Requirements for exam registration	Regular attendance and completion of exercises. Details will be announced at the beginning of the course.			
Type of exam	Homework assignment. Deviations will be announced at the beginning of the course.			
Grading scale	Five point (1-5)			
Workload	Lectures and exercises	Directed study time	Self study	Exam preparation
	Credit points: 5	45 hrs.	45 hrs.	60 hrs.
Frequency	Every other summer term.			
Duration	1 semester			
Literature	Will be announced at the beginning of the course.			

Module code	APPVOLC			
Module name	Applied volcanology			
Lecturer(s)	L. Scharff			
Module type	Compulsory elective			
Objectives / learning outcomes	Upon successful completion, the students are familiar with the most abundant measurement devices used at volcanoes worldwide. They have identified the physical parameters, relevant to volcanological research and know how to retrieve them. They gained overview on the measurement principles and function of devices and their installation in the field. In addition, an introduction to general periphery (electronic and IT), power supply, data storage and transmission, as well as accurate timing of instruments will enable students to plan their own campaigns.			
Contents	• Volcano seismology • Infrasound • Deformation • Radar • Gas and temperature measurement • Remote sensing • Data storage and transmission • Isolated power supply			
Language	English			
Teaching methods	Lectures (2 hrs./week) and exercises (1 hr./week)			
Prerequisites for participation	Required: physics basics (radiation and absorption, electronics) Recommended: basic programming skills, lecture inverse problems			
Target audience	For students in the M.Sc. Geophysics: core module in Advanced Studies and Specialisation in Geophysics (AS). For students in M.Sc. programmes in physical and earth sciences: elective module.			
Recommended semester	1 or 2			
Requirements for exam registration	Regular attendance. Details will be announced at the beginning of the course.			
Type of exam	Homework assignment. Deviations will be announced at the beginning of the course.			
Grading scale	Five point (1-5)			
Workload	Lectures and exercises	Directed study time	Self study	Exam preparation
	Credit points: 4	45 hrs.	45 hrs.	30 hrs.
Frequency	Every summer term, depending on the availability of the lecturer.			
Duration	1 semester			
Literature	Will be announced at the beginning of the course.			

Module code	SEI			
Module name	Body and surface wave seismology			
Lecturer(s)	C. Hadziioannou			
Module type	Compulsory elective			
Objectives / learning outcomes	After completing the module, the students should understand the fundamental concepts of seismic wave propagation and put these concepts into practice. They will be familiar with the theory, analysis and application of surface waves. Through computer exercises, they will have some practical experience in the application of several seismological methods.			
Contents	• Basic theorems in dynamic elasticity • Wave potentials • Wave excitation from a point source • Representation of the seismic source • Surface waves; surface wave modes • Dispersion • Surface wave tomography • Earth's normal modes			
Language	English.			
Teaching methods	Lectures (2 hrs.) and exercises (2 hrs.)			
Prerequisites for participation	Recommended: basic programming skills; VGSEI or equivalent introductory seismology course			
Target audience	For students in the M.Sc. Geophysics: core module in Advanced Studies and Specialisation in Geophysics (AS). For students in M.Sc. programmes in physical and earth sciences: elective module.			
Recommended semester	1 or 2			
Requirements for exam registration	Completion of exercises. Details will be announced at the beginning of the course.			
Type of exam	Written exam. Deviations will be announced at the beginning of the course.			
Grading scale	Five point (1-5)			
Workload	Lectures and exercises	Directed study time	Self study	Exam preparation
	Credit points: 6	60 hrs.	90 hrs.	30 hrs.
Frequency	Every winter term			
Duration	1 semester			
Literature	Most material will be provided, but the following references contain helpful background information: • Aki, K., & Richards, P. G. (2002). Quantitative seismology. • Shearer, P. M. (2019). Introduction to seismology. Cambridge university press.			

Module code	BLG-1			
Module name	Borehole geophysics 1: Tools and applications			
Lecturer(s)	C. Bücker			
Module type	Compulsory elective			
Objectives / learning outcomes	After successful completion of the module, the students are able to recognise simple lithologies and hydrocarbon contents on the basis of borehole measurements.			
Contents	• Drilling and coring • Depth and depth measurement • Caliper and quality control • Gamma ray • Electrical resistivity • Rock density • Seismic velocities • Case studies • Logs and hydrocarbons			
Language	German or English. The actual language will be announced at the beginning of the course.			
Teaching methods	Lectures (2 hrs.)			
Prerequisites for participation	Recommended: basic knowledge in geology and physics			
Target audience	For students in the M.Sc. Geophysics: core module in Advanced Studies and Specialisation in Geophysics (AS). For students in M.Sc. programmes in physical and earth sciences: elective module.			
Recommended semester	1 or 2			
Requirements for exam registration	Regular attendance. Details will be announced at the beginning of the course.			
Type of exam	Written exam. Deviations will be announced at the beginning of the course.			
Grading scale	pass/fail			
Workload	Lectures and exercises	Directed study time	Self study	Exam preparation
	Credit points: 3	30 hrs.	30 hrs.	30 hrs.
Frequency	Every summer term, depending on the availability of the lecturer.			
Duration	1 semester			
Literature	Will be announced at the beginning of the lecture.			

Module code	BLG-2			
Module name	Borehole geophysics 2: Special applications and evaluation methods			
Lecturer(s)	C. Bücker			
Module type	Compulsory elective			
Objectives / learning outcomes	After completing the module, the students have gained an overview of 'advanced' borehole sensors. They have learned to evaluate borehole field measurements regarding fluid detection as applied by the carbohydrate industry as well as geothermic applications. They are able to recognise simple lithologies and calculate fluid contents.			
Contents	• Borehole Imaging (SHDT, FMS, FMI, ...) • Vertical Seismic Profiling (VSP) • Nuclear Magnetic Resonance (NMR) • Temperature Measurements (DTS) • Borehole Gravity, Magnetic Susceptibility • Formation Testing and Sampling (RFT, MDT) • Evaluation Methods, Software			
Language	English			
Teaching methods	Lectures (2 hrs.)			
Prerequisites for participation	Recommended: basic knowledge in geology, physics, and mathematics			
Target audience	For students in the M.Sc. Geophysics: core module in Advanced Studies and Specialisation in Geophysics (AS). For students in M.Sc. programmes in physical and earth sciences: elective module.			
Recommended semester	1 or 2			
Requirements for exam registration	Regular attendance. Details will be announced at the beginning of the course.			
Type of exam	Written exam. Deviations will be announced at the beginning of the course.			
Grading scale	pass/fail			
Workload	Lectures and exercises	Directed study time	Self study	Exam preparation
	Credit points: 3	30 hrs.	30 hrs.	30 hrs.
Frequency	Every winter term, depending on the availability of the lecturer.			
Duration	1 semester			
Literature	Will be announced at the beginning of the lecture.			

Module code	DIG			
Module name	Digital signal processing			
Lecturer(s)	C. Vanelle			
Module type	Compulsory elective			
Objectives / learning outcomes	After completing the module, students are familiar with the methods and techniques of digital signal processing of time series.			
Contents	• Geophysical time series • Discrete Fourier transform and FFT • Correlation and convolution • Sampling theorem • Linear filters (causal and acausal) • Window functions in geophysics • Hilbert transform • Uncertainty relation • Vibroseis • Z transformation • Recursive filters • Phase properties of wavelets in seismics • Optimum filtering • Deconvolution in seismics			
Language	English			
Teaching methods	Lectures (2 hrs.) and exercises (2 hrs., partially as block course)			
Prerequisites for participation	Recommended: basic programming skills			
Target audience	For students in the M.Sc. Geophysics: core module in Advanced Studies and Specialisation in Geophysics (AS). For students in M.Sc. programmes in physical and earth sciences: elective module.			
Recommended semester	1 or 2			
Requirements for exam registration	Completion of exercises. Details will be announced at the beginning of the course.			
Type of exam	Homework assignment. Deviations will be announced at the beginning of the course.			
Grading scale	Five point (1-5)			
Workload	Lectures and exercises	Directed study time	Self study	Exam preparation
	Credit points: 6	60 hrs.	60 hrs.	60 hrs.
Frequency	Every second summer term			
Duration	1 semester			
Literature	• Buttkus, B., 1991, Spektralanalyse und Filtertheorie: Springer. • Müller, G., 2007, Signalbearbeitung: Vorlesungsskript. • Robinson, E.A., Treitel, S, 2000, Geophysical Signal Analysis: SEG, Tulsa.			

Module code	EARTHQUAKES			
Module name	Earthquakes			
Lecturer(s)	C. Hadziioannou, S. Schippkus			
Module type	Compulsory elective			
Objectives / learning outcomes	After completing the module, students will be able to describe the earthquake source mechanism. Students will be familiar with the processes driving earthquakes. Students will have explored different aspects of current research on earthquake source processes.			
Contents	• Focal parameters and source mechanism of earthquakes • Models of fracture, nucleation, propagation and arrest of a rupture • Methods of determination of source mechanisms • Different types of earthquakes: tectonic, volcanic, induced • Seismicity, seismotectonics and seismic risk • Current research in earthquake characterization and simulation The exact contents of the course will be adapted to the interest of the participating students.			
Language	English.			
Teaching methods	Lectures and discussion (30 hrs), taught as a seminar with strong student participation.			
Prerequisites for participation	Knowledge of seismic wave propagation at the level of the B.Sc. module VGSW. Knowledge in Seismology at the level of the B.Sc. module VGSEIS is not required, but it is an advantage.			
Target audience	For students in the M.Sc. Geophysics: core module in Advanced Studies and Specialisation in Geophysics (AS). For students in M.Sc. programmes in physical and earth sciences: elective module.			
Recommended semester	1 or 2			
Requirements for exam registration	Regular attendance and participation in the discussion. Details will be announced at the beginning of the course.			
Type of exam	Presentation. Details will be announced at the beginning of the respective course.			
Grading scale	Pass/Fail			
Workload	Lectures and exercises	Directed study time	Self study	Exam preparation
	Credit points: 3	30 hrs.	30 hrs.	30 hrs.
Frequency	Every second winter term			
Duration	1 semester			
Literature	Will be announced at the beginning of the course.			

Module code	INV			
Module name	Inversion problems			
Lecturer(s)	L. Scharff			
Module type	Compulsory elective			
Objectives / learning outcomes	After completing the module, students are familiar with concepts, theory and limitations of linear and non-linear inversion methods and algorithms. They have inverted diverse data sets using self-written programs and gained experience in the application of established inversion methods. They are capable of solving inverse problems efficiently on their own. They are familiar with confidence intervals and the concept of errors and recognize instabilities and non-unique solutions.			
Contents	Linear inverse problems: • Least squares method, incl. weighting • Errors and norms • Under- and overdetermined problems • Regularization • Damping • Generalized inverse • Constraints • Interpolation and model fitting • Hypothesis testing Non-linear inverse problems: • Gradient methods, incl. conjugate gradients • Grid search • Monte Carlo methods • Simulated Annealing • Evolutionary Algorithms			
Language	English			
Teaching methods	Lectures (2 hrs.) and exercises (2 hrs.)			
Prerequisites for participation	Recommended: basic programming skills			
Target audience	For students in the M.Sc. Geophysics: core module in Advanced Studies and Specialisation in Geophysics (AS). For students in M.Sc. programmes in physical and earth sciences: elective module.			
Recommended semester	1 or 2			
Requirements for exam registration	Completion of exercises. Details will be announced at the beginning of the course.			
Type of exam	Completion of exercises. Deviations will be announced at the beginning of the course.			
Grading scale	Five point (1-5)			
Workload	Lectures and exercises	Directed study time	Self study	Exam preparation
	Credit points: 6	60 hrs.	75 hrs.	45 hrs.
Frequency	Every winter term			
Duration	1 semester			
Literature	• Menke (2012): Geophysical Data Analysis: Discrete Inverse Theory			

Module code	MLG			
Module name	Machine learning in geophysics			
Lecturer(s)	C. Hammer			
Module type	Compulsory elective			
Objectives / learning outcomes	After successful completion of the module, students will have an overview of machine learning, including theory and specific applications in Geophysics. They have applied various machine learning techniques to geophysical problems using self-written programs but also get to know several open source machine learning frameworks. They learned how to evaluate the performance of their implemented algorithms.			
Contents	• Machine learning • Objects and features • Supervised and unsupervised methods • Deep learning • Applications in geophysics			
Language	English			
Teaching methods	Lectures (2 hrs./week) and exercises (2 hrs./week).			
Prerequisites for participation	Recommended: basic programming skills			
Target audience	For students in the M.Sc. Geophysics: core module in Advanced Studies and Specialisation in Geophysics (AS). For students in M.Sc. programmes in physical and earth sciences: elective module.			
Recommended semester	1 or 2			
Requirements for exam registration	Completion of exercises. Details will be announced at the beginning of the course.			
Type of exam	Homework assignment. Deviations will be announced at the beginning of the course.			
Grading scale	Five point (1-5)			
Workload	Lectures and exercises	Directed study time	Self study	Exam preparation
	Credit points: 6	60 hrs.	30 hrs.	90 hrs.
Frequency	Every winter term.			
Duration	1 semester			
Literature	Will be announced at the beginning of the course			

Module code	MLGM			
Module name	Machine learning: generative models in geophysics			
Lecturer(s)	C. Hammer			
Module type	Compulsory elective			
Objectives / learning outcomes	After successful completion of the module, students have an overview of a specific topic in machine learning, i.e., generative models, including theory and specific applications in Geophysics. They learned the benefits of generative modelling and how to use it for geophysical problems. They are capable of applying generative models on their own using self written programs but also some standard open source tools.			
Contents	• Machine learning in general • What is generative modelling and what is the benefit? • Different types of generative models • Inference • Applications in Geophysics			
Language	English			
Teaching methods	Lectures (2 hrs./week) and exercises (2 hrs./week).			
Prerequisites for participation	Recommended: basic programming skills			
Target audience	For students in the M.Sc. Geophysics: core module in Advanced Studies and Specialisation in Geophysics (AS). For students in M.Sc. programmes in physical and earth sciences: elective module.			
Recommended semester	1 or 2			
Requirements for exam registration	Completion of exercises. Details will be announced at the beginning of the course.			
Type of exam	Homework assignment. Deviations will be announced at the beginning of the course.			
Grading scale	Five point (1-5)			
Workload	Lectures and exercises	Directed study time	Self study	Exam preparation
	Credit points: 6	60 hrs.	60 hrs.	60 hrs.
Frequency	Every summer term.			
Duration	1 semester			
Literature	Will be announced at the beginning of the course			

Module code	MIG			
Module name	Migration of seismic reflection data			
Lecturer(s)	C. Vanelle			
Module type	Compulsory elective			
Objectives / learning outcomes	After successful completion of the module, students are familiar with the foundations of subsurface imaging by depth conversion of poststack and prestack reflection seismic data.			
Contents	• Wavefields • Modelling • Time migration • Geometric migration • Summation migration • Imaging condition • Kirchhoff migration • Frequency-wavenumber migration • Migration with finite differences • Full-waveform migration • Migration velocity analysis			
Language	English			
Teaching methods	Lectures (2 hrs./week) and exercises (2 hrs./week, partially as block course)			
Prerequisites for participation	Required: basic programming skills Recommended: basic understanding of wave propagation			
Target audience	For students in the M.Sc. Geophysics: core module in Advanced Studies and Specialisation in Geophysics (AS). For students in M.Sc. programmes in physical and earth sciences: elective module.			
Recommended semester	1 or 2			
Requirements for exam registration	Completion of exercises. Details will be announced at the beginning of the course.			
Type of exam	Written exam. Deviations will be announced at the beginning of the course.			
Grading scale	Five point (1-5)			
Workload	Lectures and exercises	Directed study time	Self study	Exam preparation
	Credit points: 6	60 hrs.	90 hrs.	30 hrs.
Frequency	Every winter term			
Duration	1 semester			
Literature	• Bancroft, J., 1997/98, A Practical Understanding of Pre- and Poststack Migration, Vol. I and II: SEG, Tulsa. • Claerbout, J.F., 1985, Imaging the Earth's Interior: Blackwell. • Scales, J.A., 1995, Theory of Seismic Imaging: Springer. • Vanelle, C., current, Migration of Seismic Reflection Data: Lecture notes, University of Hamburg.			

Module code	POTTHEO			
Module name	Potential theory			
Lecturer(s)	M. Hort			
Module type	Compulsory elective			
Objectives / learning outcomes	After completing the module, students have a firm understanding of the basics of potential theory. They are able to answer fundamental questions in potential theory. They will have written a code by themselves to numerically calculate gravity anomalies of arbitrarily shaped bodies.			
Contents	• Potentials • Greens functions • Newtonian potential • Magnetic potential • Spherical harmonics • Laplace equation • Gravity of the Earth			
Language	English			
Teaching methods	Lectures (2 hrs./week) and exercises (1 hr./week)			
Prerequisites for participation	Recommended: Matlab, Python or Fortran			
Target audience	For students in the M.Sc. Geophysics: core module in Advanced Studies and Specialisation in Geophysics (AS). For students in M.Sc. programmes in physical and earth sciences: elective module.			
Recommended semester	1 or 2			
Requirements for exam registration	Completion of exercises. Details will be announced at the beginning of the course.			
Type of exam	Homework assignment. Deviations will be announced at the beginning of the course.			
Grading scale	Five point (1-5)			
Workload	Lectures and exercises	Directed study time	Self study	Exam preparation
	Credit points: 4	45 hrs.	45 hrs.	30 hrs.
Frequency	Every summer term			
Duration	1 semester			
Literature	• Blakely, Potential Theory in gravity & magnetic applications, Cambridge Univ. Press, 1995. • John Wahr, Geodesy and Gravity, Samizdat Press, 1996.			

Module code	ANI			
Module name	Seismic anisotropy			
Lecturer(s)	C. Vanelle			
Module type	Compulsory elective			
Objectives / learning outcomes	After successful completion of the module, students are familiar with the causes and effects of elastic anisotropy in the context of seismic wave propagation and imaging of the subsurface.			
Contents	Physical principles of wave propagation in anisotropic media: • Causes of seismic anisotropy • Symmetries • Parameterisation • Weak anisotropy • Normal moveout • Nonhyperbolic moveout • Parameter estimation • Shear waves			
Language	English			
Teaching methods	Lectures (2 hrs./week) and exercises (1 hr./week)			
Prerequisites for participation	Required: basic programming skills Recommended: basic understandig of elastic wave propagation			
Target audience	For students in the M.Sc. Geophysics: core module in Advanced Studies and Specialisation in Geophysics (AS). For students in M.Sc. programmes in physical and earth sciences: elective module.			
Recommended semester	1 or 2			
Requirements for exam registration	Completion of exercises. Details will be announced at the beginning of the course.			
Type of exam	Written exam. Deviations will be announced at the beginning of the course.			
Grading scale	Five point (1-5)			
Workload	Lectures and exercises	Directed study time	Self study	Exam preparation
	Credit points: 4	45 hrs.	45 hrs.	30 hrs.
Frequency	Every summer term			
Duration	1 semester			
Literature	• Dellinger, J.A., 1991, Anisotropic Seismic Wave Propagation; Ph.D. thesis, Stanford University. • Fedorov, F.I., 1968, Theory of Elastic Waves in Crystals; Plenum Press. • Helbig, K., 1994, Foundations of Anisotropy for Exploration Seismics: Pergamon Press. • Musgrave, M.J.P, 1970, Crystal Acoustics; Holden-Day. • Thomsen, L., 2002, Understanding Seismic Anisotropy in Exploration and Exploitation: SEG-DISC. • Tsvankin, I., 2001, Seismic Signatures and Analysis of Reflection Data in Anisotropic Media: Pergamon Press. • Vanelle, C., current, Seismic anisotropy: Lecture notes, University of Hamburg.			

Module code	SEISPROC			
Module name	Seismic data processing			
Lecturer(s)	C. Hübscher			
Module type	Compulsory elective			
Objectives / learning outcomes	After successful completion of the module, the students are able to independently develop a processing flow to generate migrated time sections from raw field data.			
Contents	• Geometry (CMP-Binning) • Data editing • Frequency filtering • fk-filtering • tau-p transformation • Deconvolution • Multiple suppression • Velocity analysis • Stacking • Migration			
Language	English			
Teaching methods	Exercises (block course equivalent to 2 hrs./week)			
Prerequisites for participation	Recommended: basic programming skills			
Target audience	For students in the M.Sc. Geophysics: core module in Advanced Studies and Specialisation in Geophysics (AS). For students in M.Sc. programmes in physical and earth sciences: elective module.			
Recommended semester	1 or 2			
Requirements for exam registration	Completion of exercises. Details will be announced at the beginning of the course.			
Type of exam	Term paper			
Grading scale	Five point (1-5)			
Workload	Lectures and exercises	Directed study time	Self study	Exam preparation
	Credit points: 4	30 hrs.	60 hrs.	30 hrs.
Frequency	Every winter term			
Duration	5 days			
Literature	• Yilmaz, Ö., 2001. Seismic Data Analysis: Processing, Inversion and Interpretation of Seismic Data. Society of Exploration Geophysicists, Investigations in Geophysics Series, 2 Volumes, S. 2027.			

Module code	VOLC			
Module name	Volcanology			
Lecturer(s)	M. Hort			
Module type	Compulsory elective			
Objectives / learning outcomes	After completing this course students will have acquired a basic understanding of the physics of volcanological processes. They will be able to address interdisciplinary volcanological questions and to model volcanological processes.			
Contents	• Overview plate tectonics • Volcano types • Phase diagrams • Crystallisation processes • Lava lakes • Rheology of magma • Conduit flow • Eruption dynamics			
Language	English			
Teaching methods	Lectures (2 hrs./week) and exercises (1 hr./week)			
Prerequisites for participation	Recommended: Matlab, Python or Fortran			
Target audience	For students in the M.Sc. Geophysics: core module in Advanced Studies and Specialisation in Geophysics (AS). For students in M.Sc. programmes in physical and earth sciences: elective module.			
Recommended semester	1 or 2			
Requirements for exam registration	Completion of exercises. Details will be announced at the beginning of the course.			
Type of exam	Oral presentation and written report. Deviations will be announced at the beginning of the course.			
Grading scale	Five point (1-5)			
Workload	Lectures and exercises	Directed study time	Self study	Exam preparation
	Credit points: 4	45 hrs.	45 hrs.	30 hrs.
Frequency	Every winter term			
Duration	1 semester			
Literature	• Schmincke, Volcanism, Springer, 2004. • Philpotts, Principles of igneous and metamorphic petrology, Prentice Hall, 1990. • Okrusch, Matthes, Mineralogie, Springer, 2005.			