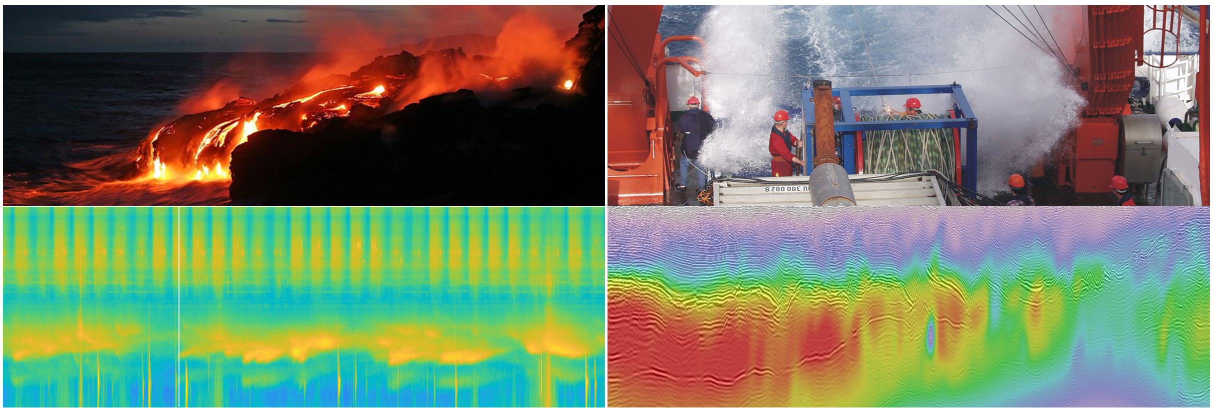
Module Handbook

Master of Science Geophysics

University of Hamburg

April 2025



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

<table>
<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>
<tr><td>Semester 2</td></tr>
<tr><td rowspan="2">Research Phase</td><td>Semester 3</td><td>Orientation Project
15 ECTS</td><td colspan="3">Preparatory Project
15 ECTS</td></tr>
<tr><td>Semester 4</td><td colspan="4">Master's Thesis
30 ECTS</td></tr>
</table>

The curriculum of the Institute of Geophysics represents the focus of the working groups in research and teaching:

- 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

- **Dr. Stefanie Donner**

Fields of work:

– Observational seismologist with focus on the earthquake source and rotational seismology

Modules:

– Earthquakes
– Fracture processes and Earthquake sources

Contact: stefanie.donner@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
– Fracture processes and Earthquake sources
– 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:

- Body and surface wave seismology
- Ambient seismic noise
- 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:

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

Modules:

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

Contact: claudia.vanelle@uni-hamburg.de

Examination board

The current (April 2025) 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	Annalena Friedrich, Daniel Peppel	

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	Individual contents can be chosen from the following list of compulsory elective courses: • Ambient seismic noise • Applied volcanology • Body and surface wave seismology • Borehole geophysics 1: Tools and applications • Borehole geophysics 2: Special applications and evaluation methods • Digital signal processing • Earthquakes • Fracture processes and Earthquake sources • Inversion problems • Machine learning in geophysics • Migration of seismic reflection data • Potential theory • Seismic anisotropy • Volcanology
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. completion of exercises, homework assignment.
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.

<table>
<tr><td>Module code</td><td colspan="4">GP-M-SEM</td></tr>
<tr><td>Module name</td><td colspan="4">Seminar</td></tr>
<tr><td>Lecturer(s)</td><td colspan="4">The teaching staff of the Institute of Geophysics</td></tr>
<tr><td>Module type</td><td colspan="4">Compulsory</td></tr>
<tr><td>Objectives / learning outcomes</td><td colspan="4">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.</td></tr>
<tr><td>Contents</td><td colspan="4">• ASEM: Seminar on Applied Geophysics
• MSEM: Seminar on Machine Learning
• SSEM: Seminar on Seismology
• VSEM: Seminar on Volcanology</td></tr>
<tr><td>Language</td><td colspan="4">English</td></tr>
<tr><td>Teaching methods</td><td colspan="4">Seminar</td></tr>
<tr><td>Prerequisites for participation</td><td colspan="4">None</td></tr>
<tr><td>Target audience</td><td colspan="4">For students in the M.Sc. Geophysics: compulsory module.
For students in M.Sc. programmes in physical and earth sciences: elective module.</td></tr>
<tr><td>Recommended semester</td><td colspan="4">1 or 2</td></tr>
<tr><td>Requirements for exam registration</td><td colspan="4">Regular attendance. Details will be announced at the beginning of the respective course.</td></tr>
<tr><td>Type of exam</td><td colspan="4">Presentation and report.</td></tr>
<tr><td>Grading scale</td><td colspan="4">Pass/fail.</td></tr>
<tr><td rowspan="2">Workload</td><td>Seminar per course</td><td>Directed study time per course</td><td>Self study per course</td><td>Exam preparation per course</td></tr>
<tr><td>Credit points: 3 ECTS</td><td>30 hrs.</td><td>30 hrs.</td><td>30 hrs.</td></tr>
<tr><td>Frequency</td><td colspan="4">Every term</td></tr>
<tr><td>Duration</td><td colspan="4">2 semesters</td></tr>
<tr><td>Literature</td><td colspan="4">Will be announced at the beginning of the course.</td></tr>
</table>

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	English or German. 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.
Grading scale	Five point (1-5)
Workload	Lectures and exercises: Credit points: 5 · Directed study time: 45 hrs. · Self study: 45 hrs. · Exam preparation: 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.			
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, S. Schippkus			
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.			
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.			

<table>
<tr><td>Module code</td><td colspan="4">BLG-1</td></tr>
<tr><td>Module name</td><td colspan="4">Borehole geophysics 1: Tools and applications</td></tr>
<tr><td>Lecturer(s)</td><td colspan="4">C. Bücker</td></tr>
<tr><td>Module type</td><td colspan="4">Compulsory elective</td></tr>
<tr><td>Objectives / learning outcomes</td><td colspan="4">After successful completion of the module, the students are able to recognise simple lithologies and hydrocarbon contents on the basis of borehole measurements.</td></tr>
<tr><td>Contents</td><td colspan="4">• Drilling and coring
• Depth and depth measurement
• Caliper and quality control
• Gamma ray
• Electrical resistivity
• Rock density
• Seismic velocities
• Case studies
• Logs and hydrocarbons</td></tr>
<tr><td>Language</td><td colspan="4">German or English. The actual language will be announced at the beginning of the course.</td></tr>
<tr><td>Teaching methods</td><td colspan="4">Lectures (2 hrs.)</td></tr>
<tr><td>Prerequisites for participation</td><td colspan="4">Recommended: basic knowledge in geology and physics</td></tr>
<tr><td>Target audience</td><td colspan="4">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.</td></tr>
<tr><td>Recommended semester</td><td colspan="4">1 or 2</td></tr>
<tr><td>Requirements for exam registration</td><td colspan="4">Regular attendance. Details will be announced at the beginning of the course.</td></tr>
<tr><td>Type of exam</td><td colspan="4">Written exam.</td></tr>
<tr><td>Grading scale</td><td colspan="4">pass/fail</td></tr>
<tr><td rowspan="2">Workload</td><td>Lectures and exercises</td><td>Directed study time</td><td>Self study</td><td>Exam preparation</td></tr>
<tr><td>Credit points: 3</td><td>30 hrs.</td><td>30 hrs.</td><td>30 hrs.</td></tr>
<tr><td>Frequency</td><td colspan="4">Every summer term, depending on the availability of the lecturer.</td></tr>
<tr><td>Duration</td><td colspan="4">1 semester</td></tr>
<tr><td>Literature</td><td colspan="4">Will be announced at the beginning of the lecture.</td></tr>
</table>

<table>
<tr><td>Module code</td><td colspan="4">BLG-2</td></tr>
<tr><td>Module name</td><td colspan="4">Borehole geophysics 2: Special applications and evaluation methods</td></tr>
<tr><td>Lecturer(s)</td><td colspan="4">C. Bücker</td></tr>
<tr><td>Module type</td><td colspan="4">Compulsory elective</td></tr>
<tr><td>Objectives / learning outcomes</td><td colspan="4">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.</td></tr>
<tr><td>Contents</td><td colspan="4">• 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</td></tr>
<tr><td>Language</td><td colspan="4">English or German. The actual language will be announced at the beginning of the course.</td></tr>
<tr><td>Teaching methods</td><td colspan="4">Lectures (2 hrs.)</td></tr>
<tr><td>Prerequisites for participation</td><td colspan="4">Recommended: basic knowledge in geology, physics, and mathematics</td></tr>
<tr><td>Target audience</td><td colspan="4">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.</td></tr>
<tr><td>Recommended semester</td><td colspan="4">1 or 2</td></tr>
<tr><td>Requirements for exam registration</td><td colspan="4">Regular attendance. Details will be announced at the beginning of the course.</td></tr>
<tr><td>Type of exam</td><td colspan="4">Written exam.</td></tr>
<tr><td>Grading scale</td><td colspan="4">pass/fail</td></tr>
<tr><td rowspan="2">Workload</td><td>Lectures and exercises</td><td>Directed study time</td><td>Self study</td><td>Exam preparation</td></tr>
<tr><td>Credit points: 3</td><td>30 hrs.</td><td>30 hrs.</td><td>30 hrs.</td></tr>
<tr><td>Frequency</td><td colspan="4">Every winter term, depending on the availability of the lecturer.</td></tr>
<tr><td>Duration</td><td colspan="4">1 semester</td></tr>
<tr><td>Literature</td><td colspan="4">Will be announced at the beginning of the lecture.</td></tr>
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<table>
<tr><td>Module code</td><td colspan="4">DIG</td></tr>
<tr><td>Module name</td><td colspan="4">Digital signal processing</td></tr>
<tr><td>Lecturer(s)</td><td colspan="4">C. Vanelle</td></tr>
<tr><td>Module type</td><td colspan="4">Compulsory elective</td></tr>
<tr><td>Objectives / learning outcomes</td><td colspan="4">After completing the module, students have gained a solid background in the fundamental methods of signal processing and the analysis of data in different domains.</td></tr>
<tr><td>Contents</td><td colspan="4">• Geophysical time series
• Analog-to-digital conversion
• Representation of numbers
• Fourier series and Fourier transform
• Laplace Transform
• Sampling theoreme
• Uncertainty relations
• Convolution
• Causality
• Linear filters
• Window functions and tapering
• Z-transform
• Hilbert transform
• τ-p transform
• Phase properties of wavelets</td></tr>
<tr><td>Language</td><td colspan="4">English</td></tr>
<tr><td>Teaching methods</td><td colspan="4">Lectures (2 hrs.) and exercises (2 hrs.)</td></tr>
<tr><td>Prerequisites for participation</td><td colspan="4">Required: programming
Recommended: elastic wave propagation (VGSW or equivalent) and applied seismics (VGAN-S or equivalent)</td></tr>
<tr><td>Target audience</td><td colspan="4">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.</td></tr>
<tr><td>Recommended semester</td><td colspan="4">1 or 2</td></tr>
<tr><td>Requirements for exam registration</td><td colspan="4">Completion of exercises. Details will be announced at the beginning of the course.</td></tr>
<tr><td>Type of exam</td><td colspan="4">Completion of exercises.</td></tr>
<tr><td>Grading scale</td><td colspan="4">Five point (1-5)</td></tr>
<tr><td rowspan="2">Workload</td><td>Lectures and exercises</td><td>Directed study time</td><td>Self study</td><td>Exam preparation</td></tr>
<tr><td>Credit points: 6</td><td>60 hrs.</td><td>60 hrs.</td><td>60 hrs.</td></tr>
<tr><td>Frequency</td><td colspan="4">Every second summer term</td></tr>
<tr><td>Duration</td><td colspan="4">1 semester</td></tr>
<tr><td>Literature</td><td colspan="4">• Buttkus, B., 2000, Spectral Analysis and Filter Theory in Applied Geophysics: Springer.</td></tr>
</table>

Module code	EARTHQUAKES			
Module name	Earthquakes			
Lecturer(s)	C. Hadziioannou, S. Donner			
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.			
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	FRACTURES
Module name	Fracture processes and Earthquake sources
Module coordinator	S. Donner, C. Hadziioannou
Module type	Compulsory elective
Objectives / learning outcomes	After successfully completing the module, students are able to locate an Earthquake, determine its focal mechanism, and relate this to the moment tensor. They have an understanding of the physical processes occurring during earthquake rupture. This includes a base understanding of processes that happen on the micro scale when materials break, and how this relates to phenomena at larger scales. Students are able to place the understanding gained in this course within the framework of open questions and challenges in seismology. They are able to answer the question ”why can earthquakes not be predicted?”
Contents	• Earthquake sources: localization, focal solution, moment tensor • Earthquake rupture processes: how does a rupture start (and stop)? • Micro-scale fracture processes and non-linear elasticity
Language	English.
Teaching methods	Lectures (2 hrs./week) and computer exercises and presentations by the students (2 hrs./week)
Prerequisites for participation	Recommended: Knowledge in seismology at the level of the modules VGSEI and/or VGSW. Required: Programming in Python (and ideally Obspy). Students who do not have this skill have to complete a Python & Obspy introductory exercise before the start of the semester.
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 mathematical, 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	Presentation
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 summer term
Duration	1 semester
Literature	Will be announced at the start 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 • Damping • Generalized inverse • (In-)equality 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.
Grading scale	Five point (1-5)
Workload	Lectures and exercises: Credit points: 6 · Directed study time: 60 hrs. · Self study: 75 hrs. · Exam preparation: 45 hrs.
Frequency	Every winter term
Duration	1 semester
Literature	• Menke (2012): Geophysical Data Analysis: Discrete Inverse Theory

<table>
<tr><td>Module code</td><td colspan="4">MLG</td></tr>
<tr><td>Module name</td><td colspan="4">Machine learning in geophysics</td></tr>
<tr><td>Lecturer(s)</td><td colspan="4">C. Hammer</td></tr>
<tr><td>Module type</td><td colspan="4">Compulsory elective</td></tr>
<tr><td>Objectives / learning outcomes</td><td colspan="4">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.</td></tr>
<tr><td>Contents</td><td colspan="4">• Machine learning
• Objects and features
• Supervised and unsupervised methods
• Deep learning
• Applications in geophysics</td></tr>
<tr><td>Language</td><td colspan="4">English</td></tr>
<tr><td>Teaching methods</td><td colspan="4">Lectures (2 hrs./week) and exercises (2 hrs./week).</td></tr>
<tr><td>Prerequisites for participation</td><td colspan="4">Recommended: basic programming skills</td></tr>
<tr><td>Target audience</td><td colspan="4">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.</td></tr>
<tr><td>Recommended semester</td><td colspan="4">1 or 2</td></tr>
<tr><td>Requirements for exam registration</td><td colspan="4">Completion of exercises. Details will be announced at the beginning of the course.</td></tr>
<tr><td>Type of exam</td><td colspan="4">Homework assignment.</td></tr>
<tr><td>Grading scale</td><td colspan="4">Five point (1-5)</td></tr>
<tr><td rowspan="2">Workload</td><td>Lectures and exercises</td><td>Directed study time</td><td>Self study</td><td>Exam preparation</td></tr>
<tr><td>Credit points: 6</td><td>60 hrs.</td><td>30 hrs.</td><td>90 hrs.</td></tr>
<tr><td>Frequency</td><td colspan="4">Every winter term.</td></tr>
<tr><td>Duration</td><td colspan="4">1 semester</td></tr>
<tr><td>Literature</td><td colspan="4">Will be announced at the beginning of the course</td></tr>
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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: programming, elastic wave propagation (VGSW or equivalent) and applied seismics (VGAN-S or equivalent)			
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.			
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.			

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.
Grading scale	Five point (1-5)
Workload	Lectures and exercises: Credit points: 4; Directed study time: 45 hrs.; Self study: 45 hrs.; Exam preparation: 30 hrs.
Frequency	Every summer term, depending on the availability of the lecturer
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: programming, elastic wave propagation (VGSW or equivalent) and applied seismics (VGAN-S or equivalent)
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.
Grading scale	Five point (1-5)
Workload	Lectures and exercises: Credit points: 4 Directed study time: 45 hrs. Self study: 45 hrs. Exam preparation: 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.

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<tr><td>Module code</td><td colspan="4">VOLC</td></tr>
<tr><td>Module name</td><td colspan="4">Volcanology</td></tr>
<tr><td>Lecturer(s)</td><td colspan="4">M. Hort</td></tr>
<tr><td>Module type</td><td colspan="4">Compulsory elective</td></tr>
<tr><td>Objectives / learning outcomes</td><td colspan="4">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.</td></tr>
<tr><td>Contents</td><td colspan="4">• Overview plate tectonics
• Volcano types
• Phase diagrams
• Crystallisation processes
• Lava lakes
• Rheology of magma
• Conduit flow
• Eruption dynamics</td></tr>
<tr><td>Language</td><td colspan="4">English</td></tr>
<tr><td>Teaching methods</td><td colspan="4">Lectures (2 hrs./week) and exercises (1 hr./week)</td></tr>
<tr><td>Prerequisites for participation</td><td colspan="4">Recommended: Matlab, Python or Fortran</td></tr>
<tr><td>Target audience</td><td colspan="4">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.</td></tr>
<tr><td>Recommended semester</td><td colspan="4">1 or 2</td></tr>
<tr><td>Requirements for exam registration</td><td colspan="4">Completion of exercises. Details will be announced at the beginning of the course.</td></tr>
<tr><td>Type of exam</td><td colspan="4">Written exam.</td></tr>
<tr><td>Grading scale</td><td colspan="4">Five point (1-5)</td></tr>
<tr><td rowspan="2">Workload</td><td>Lectures and exercises</td><td>Directed study time</td><td>Self study</td><td>Exam preparation</td></tr>
<tr><td>Credit points: 4</td><td>45 hrs.</td><td>45 hrs.</td><td>30 hrs.</td></tr>
<tr><td>Frequency</td><td colspan="4">Every winter term</td></tr>
<tr><td>Duration</td><td colspan="4">1 semester</td></tr>
<tr><td>Literature</td><td colspan="4">• Schmincke, Volcanism, Springer, 2004.
• Philpotts, Principles of igneous and metamorphic petrology, Prentice Hall, 1990.
• Okrusch, Matthes, Mineralogie, Springer, 2005.</td></tr>
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