Module Handbook

Bachelor of Science
Earth System Physics

Faculty of Mathematics, Informatics
and Natural Sciences
University of Hamburg

preliminary version under construction (August 2025)

Universität Hamburg
DER FORSCHUNG | DER LEHRE | DER BILDUNG

University of Hamburg (UHH)
Faculty of Mathematics, Informatics and Natural Sciences
Department of Earth System Sciences

Institute of Geophysics
Bundesstr. 55, 20146 Hamburg
https://www.geo.uni-hamburg.de/en/geophysik.html

Institute of Oceanography
Bundesstr. 53, 20146 Hamburg
https://www.ifm.uni-hamburg.de/en.html

Meteorological Institute
Bundesstr. 55, 20146 Hamburg
https://www.mi.uni-hamburg.de/en.html

More information on the B.Sc. Earth System Physics can be found on our website: https://www.ifm.uni-hamburg.de/en/education/bsc-earthsystemphysics.html (under construction).

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Abbreviations

UHH	University of Hamburg
MIN	Faculty of Mathematics, Informatics and Natural Sciences
ESW	Department of Earth System Sciences
IfG	Institute of Geophysics
IfM	Institute of Oceanography
MI	Meteorological Institute
Phys	Department of Physics
Math	Department of Mathematics

V	Vorlesung / lecture
Ü	Übung / exercises
VÜ	integrierte Vorlesung mit Übung / integrated lecture with exercises
P	Praktikum / Practical training
S	Seminar

CP	ECTS credit points
SWS	Semesterwochenstunden / weakly work hours on-campus

Introduction

Overview

The B.Sc. Earth System Physics is a joint study programme by the disciplines of Geophysics, Oceanography and Meteorology within the department of Earth System Sciences of the MIN-Faculty at the University of Hamburg.
It is an English-language Bachelor's programme designed for 6 semesters full-time study, with an annual start in the winter term. It provides profound knowledge on the physics of the earth system with its components solid earth, ocean and atmosphere. The coursework takes place on-campus and has a workload of 30 ECTS credit points per semester, structured in modules.
This interdisciplinary programme is directed at students who are driven by the curiosity to gain a holistic understanding of the physics of the earth system and to understand how its key components function physically. Students will acquire the scientific foundations to investigate and describe the dynamics of the solid earth, the oceans, and the atmosphere using physical and mathematical methods. Through this programme, they will learn about important topics such as earthquakes, climate change, and hurricanes— areas of great public interest. The course work conveys skills in observation methods, interpretation procedures, and modelling techniques. The study programme is closely linked to current research in the respective disciplines, offering opportunities to engage in research projects early on, to participate in measurement campaigns, and to work with data evaluation and modelling. The degree qualifies for a profession as well as subsequent deepening master studies.
The Bachelor's degree Earth System Physics replaces the former German-language B.Sc. Geophysik/Ozeanographie since the winter term 2025/2026.

Context

We are living in a time in which humanity is reaching the limits of planet Earth in many respects. Climate change and the increasing environmental risks associated with it are harsh boundary conditions to which we must adapt. The physical earth system sciences provide the hard facts that politics and society need to make decisions. Above all, however, they are driven by the curiosity to understand how the earth system and its most important components function physically. The interdisciplinary B.Sc. Earth System Physics programme combines the teaching of the fundamentals of various specialist disciplines with the idea that many topics today require a more holistic view of the earth system in order to answer pressing questions. It is aimed at anyone who shares this curiosity and enjoys physics and mathematics.

Hamburg is a leading hub for teaching and research in earth system sciences. At the heart of this academic environment is the Bachelor's programme Earth System Physics (BSc), which plays a central role in the University of Hamburg's research focus on "Climate, Earth, Environment." The programme is taught primarily by faculty from the Department of Earth System Sciences, which offers a broad and interdisciplinary education spanning physical Earth sciences—such as geophysics, meteorology, and oceanography—as well as geology, soil science, and geography. Thanks to a strong student-to-faculty ratio, students benefit from close personal mentorship, ensuring high-quality education and consistently excellent satisfaction ratings in teaching evaluations and alumni surveys.

What sets this program apart is its strong integration with world-class research. Students have the opportunity to engage with the Cluster of Excellence “Climate, Climatic Change, and Society” (CLICCS), a collaborative network of 12 premier climate research institutions in Hamburg. Teaching and research are conducted in close cooperation with key partners such as the Max Planck Institute for Meteorology (MPI-M), Hereon, and the German Climate Computing Center (DKRZ). This partnership provides access to top-tier expertise, fosters interdisciplinary learning, and opens doors to international academic and research networks—making Hamburg an outstanding place to begin your journey in earth system sciences.

Programme goals

Learning goals

General academic learning goals of a Bachelor of Science programme

The primary academic objectives of a Bachelor of Science programme are to equip students with a solid foundation of knowledge in their chosen field, develop critical thinking and analytical skills, and foster an understanding of scientific methods and research techniques. Students are encouraged to independently analyse complex problems, formulate evidence-based solutions, and communicate their findings effectively, both orally and in writing, in a scientifically appropriate manner. The programme also emphasizes the ability to apply scientific knowledge, methods, and skills autonomously, as well as to continue their education independently. Additionally, students are trained to act responsibly and in accordance with the principles of good scientific practice within their discipline. Overall, the programme aims to promote teamwork, ethical awareness, and lifelong learning, preparing graduates for professional careers and further academic pursuits.

Subject-specific learning goals of the B.Sc. Earth System Physics

Graduates have the ability to apply basic physical and mathematical knowledge, apply general physical evaluation techniques and use the results to infer and interpret geophysical processes on the solid earth, in the oceans and in the atmosphere. Graduates have acquired the competence to diagnose and assess the dynamics of the solid earth, the oceans and the atmosphere on the basis of geophysical, oceanographic and meteorological data and models. Furthermore, they have acquired the ability to mathematically and scientifically observe, analyse and predict variations and variability in the solid earth, the oceans and the atmosphere, as well as an awareness of the socio-economic relevance of the statements.

Legal documents

Details on the formal qualification and learning goals can be found in the following legal documents:

- The General Examination Regulations for Academic Examinations (Rahmenprüfungsordnung**)** at Universität Hamburg defines the goals of university teaching.
- The Examination Regulations (Prüfungsordnung) of the Faculty of Mathematics, Informatics and Natural Sciences for Bachelor of Science Degree Programs specify the goals.
- The Subject-Specific Provisions (Fachspezifische Bestimmungen) for the Bachelor's program *Earth System Physics* defines concrete learning goals.

Career prospects

The program structure offers a great deal of freedom and flexibility in the selection of courses, enabling either a disciplinary focus on one subject area or a broad interdisciplinary education. Students can tailor their studies to their individual interests and career aspirations. The holistic view of the Earth system opens up excellent career prospects both in the field of academic research and in industry.
Most alumni continue their career in subsequent Master's programs at the University of Hamburg:

- M.Sc. Geophysics
- M.Sc. Atmospheric Science
- M.Sc. Ocean Climate Physics
- M.Sc. Integrated Climate Systems Sciences.

or at other national and international universities, often continuing in a research or academic career afterwards. Alternatively, a Bachelor's and particularly a Master's degree in the field of Earth system physics equally qualifies for a career in the private sector. Experts in Earth system physics are for example needed in geo-resources, renewable energies, data science, system administration, large data processing, consulting, and in public agencies or science communication.

Programme structure

The programme B.Sc. Earth System Physics has a total workload of 180 ECTS credit points. For a standard period of study of six semesters this amounts to 30 credit points per semester (formally about 20 contact hours of on-campus courses).

As the subjects of geophysics, meteorology and oceanography all require a sound basic education in mathematics and physics, we combine this with an introduction to earth system sciences in the first three to four semesters of the course. We also provide training in numerical and statistical methods during this period. Beginning in the third semester, there is a steadily growing proportion of electives, which allow students to specialise in the various disciplines, but also offer the possibility of a free combination of modules with a view to specialising in earth system sciences.

The coursework is modularised into categories, which are colour-coded in the following figure Fig. 1.

- Required Modules (90 CP, light grey and pink): These 11 modules are compulsory for every student.
    - Physical foundations (24 CP, light grey): They provide a basic understanding of the physical fundamentals required for the following coursework.
    - Mathematical foundations (16 CP, light grey): They provide a basic understanding of the mathematical theory and methods required for the following coursework.
    - Subject-specific foundations (50 CP, pink): They provide an introduction to the physics of the earth system, fluid dynamics and first practical experiences.
- Required Elective Modules (60 CP, dark grey): The students can choose from a pool of specialised courses. They may focus on a preferred discipline or widen their knowledge in the field of earth system physics.
- Free Elective Modules (18 CP, light blue): The students can elect further specialised courses offered by the three disciplines or by the faculty. Cross-disciplinary diversification from the university-wide offer is encouraged.
- Bachelor's Thesis Module (12 CP, pink): Under supervision and embedded in a research group, students investigate and document a current research question in the field of earth system physics.

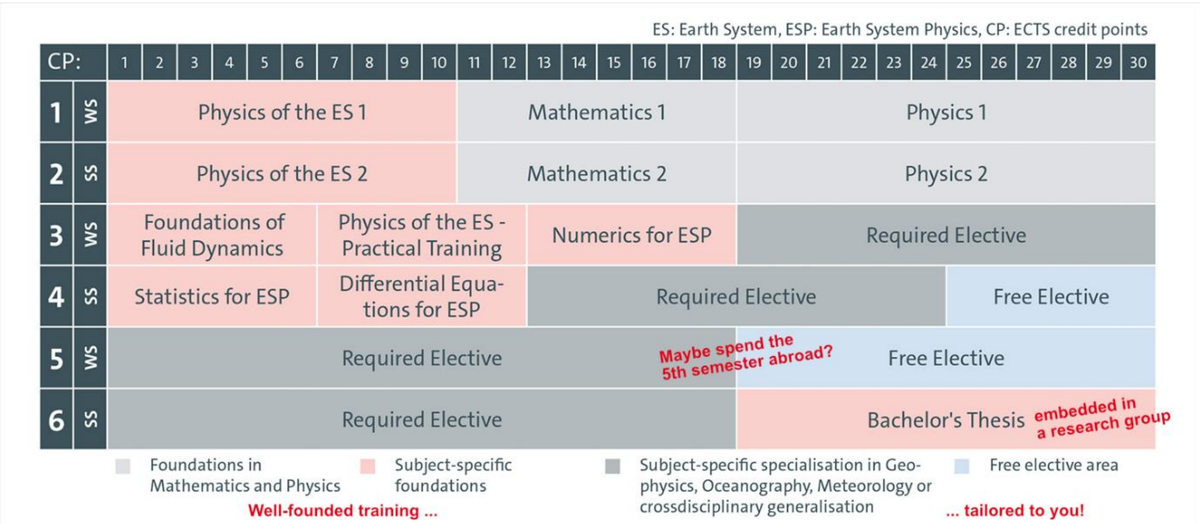

Fig. 1: Recommended programme schedule for the Earth System Physics Bachelor's programme.

All modules in the **first year of study** are compulsory for all students. They take the lectures *Mathematics 1* and *2* and the modules *Physics 1* and *2* to acquire the mathematical and physical foundations. Parallel to this, there is an introduction to the physics of the earth system, which provides an initial overview of the earth system and its subsystems. Students learn about the subject areas of geophysics, oceanography, meteorology and climate as well as the interlinking of the topics in earth system research. In the first semester, there is an introduction to Python to acquire initial programming skills, which are required as a basis for various subsequent modules. In the second semester, there is also an introduction to scientific work, in which students learn basic scientific practices such as literature research, writing scientific texts and preparing presentations. These skills are required in the subsequent modules, especially in the final Bachelor's thesis.

The **second year of study** includes the three compulsory modules *Numerics*, *Differential equations* and *Statistics for Earth System Physics*. In addition, *Fundamentals of Fluid Dynamics* and the *Practical Training* are compulsory courses for all students. Together with the modules from the first year of study, these modules form the solid basic training for earth system sciences, but also for further disciplinary training.
In the second academic year, students start choosing courses based on their interests to deepen or widen their knowledge. There is a large Required Elective block, in which students can choose from the lectures and modules offered by the department. Here, students do not have to focus on a single disciplinary specialisation but can also combine specialisations. This elective area is supplemented by a Free Elective block, where students can choose from the university-wide offer to acquire cross-disciplinary skills.

In the **third year of study** no compulsory modules are scheduled. The students continue choosing courses from the Required Elective Area and the Free Elective Area. Therefore, the 5th semester facilitates the recognition of externally collected credit points and provides the ideal **mobility window**. Interested students can spend a semester abroad at one of the partner universities or as a self-organised research stay. For their 6-week **Bachelor's thesis** in the 6th semester the students can choose from a broad range of research topics provided by the professors of the different disciplines in the Department of Earth System Sciences. Collaboration with neighbouring institutions or foreign universities is possible. Embedded in a research group and under supervision the students investigate and document a current research question.

Some modules are taken together with students of the other study degrees at the Department for Earth System Sciences or the Physics Department. The structure similarity between the degree programmes in the first semesters enables mutual recognition of the modules and thus facilitates a potential change of degree programme.

Programme language

The B.Sc. Earth System Physics is an English-language programme. Courses are generally taught and examined in English. For individual modules, German may be specified as the teaching and examination language in the module descriptions. By agreement between the examiner and the examinee, an examination held in English according to the module description can also be held in German and vice versa.
In the Free Elective area, where students can attend modules from other degree programs, students may also select courses held in German, provided they are in sufficient command of the German language. Attendance of German language lessons is possible and encouraged.

Programme evaluation

All modules are subject to examination. The type of examination varies between courses (written exam, oral exam, report, home exercises, or other). For the most part exams are graded but can also be pass/fail. Details on module examinations and their assessment can be found in the Subject-Specific Provisions (Fachspezifische Bestimmungen).

The overall grade of the Bachelor's examination is calculated as an average of the module grades weighted by credit points, with a few exceptions, see Table 1.

Category	**Evaluation**
Physical Foundations	graded, best out of 2
Mathematical modules	graded, 3 best out of 5
Program-specific Foundations	graded
Required Elective Modules	usually graded
Free Elective Modules	pass/fail
Bachelor's Thesis	graded, counts double

Table 1: Programme evaluation.

Required Modules

The area of required modules serves to acquire the general mathematical-physical and subject-specific fundamentals. Understanding the dynamic processes of the earth system requires a sound education in mathematics and physics. Students learn about the earth system and its subsystems, geohazards and climate, as well as fluid dynamics. They gain their first practical experience by completing 4-6 subject-specific experiments in order to familiarise themselves with the measuring instruments. Subsequently, they evaluate the data and write an internship report. As part of the Required Modules students will also learn the basics of scientific work, to derive and process a scientific question and present the results. They also learn the basics of programming.

Reference semester: 1st and 2nd semester

Winter term	Summer term
• Mathematics 1 • Numerics for Earth System Physics • Physics of the Earth System 1 • Physics of the Earth System – Practical Training • Foundations of Fluid Dynamics	• Mathematics 2 • Differential Equations for Earth System Physics • Statistics for Earth System Physics • Physics of the Earth System 2
Both terms	
• Physics 1 (Mechanics and Heat Theory) • Physics 2 (Electrodynamics and Optics)	

Table 2: List of Required Modules.

Exams: The type of exam is specified in the respective detailed module description below. All courses are graded. Of the modules *Physics 1 (Mechanics and Heat Theory)* and *Physics 2 (Electrodynamics and Optics)*, only the module with the better grade is included in the calculation of the overall grade for the Bachelor's examination. Of the modules *Mathematics 1*, *Mathematics 2*, *Numerics for Earth System Physics*, *Differential Equations for Earth System Physics* and *Statistics for Earth System Physics*, only the three with the best grades are included in the calculation of the overall grade for the Bachelor's examination.

Required Elective Modules

In the Required Elective Area, students gain a deeper scientific or methodological expertise in the areas of the physical earth system sciences. Based on their interests, they choose subject-specific specialisations to become experts in the physics of a certain system (e.g. geophysics, oceanography, meteorology, climate, ...), or to generalise their expertise in the broad field of earth system physics.

Reference semester: 3rd to 6th semester

Courses: Students can select from a list of courses announced at the beginning of the respective teaching term; the courses listed below (Table 3) are examples and subject to change. Courses are usually offered annually by the three organising disciplines. Therefore, thematically, the course contents are orientated towards their research focus.
Upon request, modules not covered by this list can be accepted. Students might also choose suitable courses from other curricula at the Universität Hamburg, such as other Earth System Science tracks or study paths of the MIN faculty.
In addition to the courses offered at Universität Hamburg, there is the possibility to take courses at other universities or research institutions.

Exams: Normally the required elective modules are subject to examination. The type of examination and evaluation can be found in the detailed module descriptions below.

Winter term	Summer term
• Fundamentals of Physical Oceanography • Coastal and Shelf Sea Oceanography • Oceanographic Field Work (Part 2) • Fundamentals of Dynamical Oceanography • The Cryosphere • Atmospheric Thermodynamics • Atmosphären-Messungen [in German] • Synoptik (Part 1) [in German] • Air Chemistry • Cloud Physics • Environmental Meteorology • Data Analysis and Software Development • Programming in Fortran • Applied Geophysics (Part 1) • Machine Learning in Physical Earth System Sciences • Data Processing and Geophysical Model Building • Seismology and Earthquakes	• Ocean and Ice in the Climate System • Oceanographic Field Work (Part 1) • Ocean Modelling • Synoptik (Part 2) [in German] • Dynamics of Weather and Climate • Weather Forecasting and Modeling • Climate Physics • Radiation and Remote Sensing • Climate Variability and Diagnostics • Applied Geophysics (Part 2) • Geophysics Practical Training • Geodynamics and Vulcanology • Geophysical Geohazard Research
Both terms	
• Thesis Seminar	

Table 3: List of Required Elective Modules.

Free Elective Modules

The Free Elective area serves the acquisition of interdisciplinary competences and the broadening of knowledge in one's own discipline and beyond. Students are encouraged to select subjects that both suit their interests and open up their view.

Reference semester: 5th and 6th semester

Courses: Free Elective Modules can be chosen from the university-wide course catalogue. As part of the free choice, further in-depth content of Earth System Physics is offered that is not currently part of the current compulsory or required elective programme, see Table 4.
Students are recommended to choose content from neighbouring disciplines at the Department of Earth System Sciences and the MIN faculty, e.g. courses offered in Physics, Mathematics, Computational Science or Biological Oceanography. The MIN faculty also offers a voluntary programme to gain a Sustainability Certificate.
Students can also choose freely from the courses offered by the entire University of Hamburg. It is also possible to apply for credit for courses from an external institution. Upon request, there is also the opportunity to take external courses (such as courses offered by other

universities or research institutions, as well as summer schools and workshops), as long as the courses require active participation. The acquisition of German language skills can be recognised.

Exams: In case modules attended in the Free Elective area are graded, the grades for these courses do not count towards the final Bachelor's grade. Students can select courses that are offered as 'pass/fail'.

Winter term	Summer term
•	•

Table 4: List of courses suitable for the Free Elective Area offered by the Department of Earth System Sciences.

Thesis Module

The programme concludes in the sixth semester with the completion of the Bachelor's thesis, in which students investigate and document a current issue in the field of Earth system physics under supervision and embedded in a research group.

Reference semester: 6th semester

Choice of topic: Students decide on a working group and a supervisor with whom they would like to write their thesis. An overview of research at the institutes can be found on the respective websites.

Current list of possible research groups and supervisors (not exclusive):

- Any group at the Institute of Geophysics
- Any group at the Institute of Oceanography
- Any group at the Meteorological Institute
- Suitable groups within the Department of Earth System Sciences
- Suitable groups within the MIN-faculty, e.g.
  - Numerical Methods in Geoscience (Prof. Dr. Jörn Behrens)
  - Climate Extremes and Climate Risks (Prof. Dr. Jana Sillmann)
  -
- Suitable groups at other faculties of the University of Hamburg
- Upon prior approval: Suitable groups at an external university or research institution

Module descriptions: Required Modules

Physical Foundations

PHY-E1 Physics 1 (Mechanics and Heat Theory)

Module type	Required Module
Title	Physics 1 (Mechanics and Heat Theory)
Course number	PHY-E1-EN
Learning outcomes	Students understand the basic phenomena of mechanics and heat theory and are able to explain them. They are familiar with the fundamentals of theoretical conceptualization and master the associated mathematical methods. They understand the connection between experimental observation and theoretical description within the framework of Newtonian mechanics.
Contents	Experimental physics: 1. measurement process and measurands: physical quantities, SI base units, measurement accuracy and measurement error 2. kinematics of the mass point: trajectory, velocity, acceleration 3. dynamics of the point of mass: Newton's laws, decomposition of forces, circular motion 4. moving reference systems: Galilei transformation, accelerated reference systems, apparent forces 5. gravitation: Kepler's laws, Newton's law of gravitation, gravitational and inertial masses 6. work and energy: work, conservative forces, kinetic and potential energy, conservation of energy 7. dynamics of mass point systems: elastic and inelastic collisions, momentum and conservation of momentum, dynamics of rigid bodies, angular momentum and torque 8. oscillations: Harmonic oscillator, forced oscillations, resonance, coupled oscillators 9. waves: Wave equation, reflection and transmission, standing waves, sound waves, acoustics, Doppler effect, Mach waves 10. liquids and gases: Hydro- and aerostatics, hydro- and aerodynamics 11. thermodynamics: temperature and thermal expansion, kinetic theory of gases, heat and work, entropy, real gases, phase transitions Introduction to theoretical physics: 1. kinematics: trajectory of a point particle, basis and coordinates, curvilinear coordinates 2. dynamics of a point of mass: Inertial systems and Galilean invariance, Newton's equation of motion, harmonic oscillator, differential equations 3. force fields: Conservative and central forces, work and existence of a potential, Kepler's problem, scalar fields and vector fields, path integral, differentiation of fields 4. dynamics of multi-particle systems: Equations of motion and

	conservation laws, complex numbers, Fourier series 5. special relativity: relativistic kinematics, Lorentz transformations
Course type and weakly work hours	Lecture *Physics 1*: 4 SWS Lecture *Introduction to Theoretical Physics 1*: 3 SWS Exercises for *Physics 1* and *Introduction to Theoretical Physics 1*: 3 SWS
Language	English
Prerequisites	Required: None. Recommended: None.
Verwendbarkeit des Moduls	Das Modul ist Bestandteil der Studiengänge/Profile: 1. B.Sc. Earth System Physics;
Exam type and requirements for registration	Module examination: Joint written exam (90 min.) at the end of the semester Exam language: English Requirements: None
Work load / credit points	Lecture *Physics 1*: 5 CP Lecture *Introduction to Theoretical Physics 1*: 4 CP Exercises for *Physics 1* and *Introduction to Theoretical Physics 1*: 3 CP On-campus-study: 140 h Self-study: 134 h Exam preparation: 86 h
Total credit points	12 CP
Duration	1 semester
Frequency of offer	Every semester
Reference semester	1st semester
Contact	

PHY-E2 Physics 2 (Electrodynamics and Optics)

Module type	Required Module
Title	Physics 2 (Electrodynamics and Optics)
Course number	PHY-E1-EN
Learning outcomes	Students know the basic phenomena of electricity, magnetism and optics and can explain them. They are familiar with the basics of theoretical conceptualization of classical fields and how to use the calculation methods of vector analysis. They understand the connection between experimental observation and theoretical description within the framework of Maxwell's theory.
Contents	Introduction to theoretical physics: 1. Charge and current density: conservation of charge, continuity equation, delta distribution, curved surfaces and curvilinear coordinates, surface and volume integrals, sources of a vector field, divergence and Gauss' theorem

	2. Electrostatics: Field concept, differential and integral form of the field equation, symmetrical charge distributions, potential of point charges/charge distributions, electrostatic energy of point charges/charge distributions, electrostatic potential and Poisson's equation, vortices of a vector field, rotation, Stoke's theorem 3. Magnetostatics: Differential and integral form of the field equations, solution of the field equations for symmetrical current distributions, vector potential and calibration freedom, vector potential for an arbitrary current distribution, magnetic field of an arbitrary current distribution, Biot-Savart law 4. Electrodynamics: Maxwell's equations, conservation laws, electromagnetic waves, electromagnetic potentials, Lorenz calibration Experimental physics: 1. electrostatics: Coulomb force and electric charge, electric field, potential and voltage, superposition principle, electric dipole, capacitor and field energy, dielectrics 2. electric currents: continuity equation, resistance, Ohm's law, Kirchhoff's rules 3. magnetostatics: magnetism and currents, Lorentz force, Biot-Savart law, Ampère's law, magnetic dipole, dia-para- and ferromagnetism 4. electrodynamics: induction, Lenz's rule, self-inductance and mutual inductance, switch-on and switch-off processes, displacement current 5. alternating current circuits: RMS values, pointer representation, complex impedances, RLC circuits, three-phase current 6. electromagnetic waves: Wave equation, transmission of waves, Hertzian dipole 7. optics: geometrical optical instruments, Huygen's principle and wave propagation in matter, interference and diffraction, coherence
Course type and weakly work hours	Lecture *Physics 2*: 5 SWS Lecture *Introduction to Theoretical Physics 2*: 3 SWS Exercises for *Physics 2* and *Introduction to Theoretical Physics 2*: 3 SWS
Language	English
Prerequisites	Required: None. Recommended: Successful completion of module *Physics 1 (Mechanics and Heat Theory)*.
Verwendbarkeit des Moduls	Das Modul ist Bestandteil der Studiengänge/Profile: 1. B.Sc. Earth System Physics;
Exam type and requirements for registration	Module examination: Joint written exam (90 min.) Exam language: English Requirements: None
Work load / credit points	Lecture *Physics 2*: 5 CP Lecture *Introduction to Theoretical Physics 2*: 4 CP Exercises for *Physics 2* and *Introduction to Theoretical Physics 2*: 3 CP On-campus-study: 140 h Self-study: 134 h Exam preparation: 86 h

Total credit points	12 CP
Duration	1 semester
Frequency of offer	every semester
Reference semester	2nd semester
Contact	

Mathematical Foundations

MATH1 Mathematics 1

Module type	Required Module
Title	Mathematics 1
Course number	MATH1-EN
Learning outcomes	Confident mastery of mathematical methods based on a good understanding of mathematical theories.
Contents	1. The number spaces N, Q, R and C 2. Vectors and vector spaces 3. Convergent sequences and series 4. Linear systems of equations 5. Continuity and differentiability (of real functions of one variable) 6. Integration (of real functions of one variable)
Course type and weakly work hours	Lecture *Mathematics 1 for Earth System Physics Students*: 4 SWS Exercises for *Mathematics 1 for Earth System Physics Students*: 2 SWS
Language	English
Prerequisites	Required: None. Recommended: None.
Verwendbarkeit des Moduls	Das Modul ist Bestandteil der Studiengänge/Profile: 1. B.Sc. Earth System Physics;
Exam type and requirements for registration	Module examination: Joint written exam (90 min.) Exam language: English Requirements: None
Work load / credit points	Lecture *Mathematics 1 for Earth System Physics Students*: 6 CP Exercises for *Mathematics 1 for Earth System Physics Students*: 2 CP On-campus-study: 84 h Self-study: 94 h Exam preparation: 62 h
Total credit points	8 CP
Duration	1 semester
Frequency of offer	Annually during winter term
Reference semester	1st semester
Contact	

MATH2 Mathematics 2

Module type	Required Module
Title	Mathematics 2
Course number	MATH2-EN

Learning outcomes	Confident mastery of mathematical methods based on a good understanding of mathematical theories.
Contents	1. Function series 2. Hilbert spaces 3. Fourier series 4. Ordinary differential equations 5. Differential calculus in Rn
Course type and weakly work hours	Lecture *Mathematics 2 for Earth System Physics Students*: 4 SWS Exercises for *Mathematics 2 for Earth System Physics Students*: 2 SWS
Language	English
Prerequisites	Required: None. Recommended: Successful completion of module *Mathematics 1.*
Verwendbarkeit des Moduls	Das Modul ist Bestandteil der Studiengänge/Profile: 1. B.Sc. Earth System Physics;
Exam type and requirements for registration	Module examination: Joint written exam (90 min.) Exam language: English Requirements: None
Work load / credit points	Lecture *Mathematics 2 for Earth System Physics Students*: 6 CP Exercises for *Mathematics 2 for Earth System Physics Students*: 2 CP On-campus-study: 84 h Self-study: 94 h Exam preparation: 62 h
Total credit points	8 CP
Duration	1 semester
Frequency of offer	Annually during summer term
Reference semester	2nd semester
Contact	

ESW-B-Num Numerics for Earth System Physics

Module type	Required Module
Title	Numerics for Earth System Physics
Course number	ESW-B-Num
Learning outcomes	Students have developed an understanding of basic numerical methods. They have gained an insight into the existence, convergence and stability of solutions of linear and non-linear systems of equations and can apply initial algorithms to solve simple systems.
Contents	The guiding questions (“mantra”) of the course for all individual parts will be: 1. Is there a solution to the problem? 2. Is the solution unique? 3. Is there an algorithm to compute the solution?

	4. Is the algorithm efficient? 5. Is the computed solution accurate? While the first two questions are usually answered by purely mathematical results (and mostly covered in the modules *Mathematics 1* and *2*) it is important to recall their validity. The last question is the one about convergence and therefore stability, consistency and condition of the problem need to be discussed. The course covers basic numerical methods for diverse applications, like solving linear and non-linear systems of equations, root finding, interpolation and approximation, fast Fourier transform, quadrature and numerical differentiation. All the sessions are in a sense self-contained, covering one topic from problem formulation to some analysis of error. Additionally, all sessions can be accompanied by exercises with small programming examples in Python. 1. Introduction to the problem of numerical analysis (floating point number arithmetic, some examples of failure) 2. Linear Systems of Equations (Problem set up, unique solvability, Kramer's rule as an example of an inefficient algorithm, the Gauß Algorithm or LU-Factorization, flop count as efficiency indicator, condition of the problem and spectral condition number, stability of the algorithm, algorithmic improvements – pivoting and iterative refinement, special algorithms for special matrices – Cholesky factorization) 3. Polynomial Interpolation (Problem formulation, idea of polynomial interpolation, Vandermonde matrix, unique solvability, efficiency, condition, Lagrange polynomial, Lebesgue constant, variants: Chebychev nodes, piecewise linear and spline interpolation) 4. Least Squares Approximation (Problem formulation, comparison with interpolation problem, basic similarity with assimilation problem, least squares and weighted least squares, normal equation and condition, setting up least squares problems, solution by QR-factorization, application example GPS location) 5. Trigonometric Interpolation (problem formulation and idea, example application: mp3 compression, fast Fourier transform algorithm, efficiency, data analysis by discrete Fourier transform) 6. Numerical Integration (problem formulation, semi-numerical approach, structure of the problem, linear form, interpolatory quadrature rules, uniqueness, consistency, Newton-Cotes formulae, Clenshaw-Curtis formula, er-ror analysis, composite rules, precision-cost diagram) 7. Eigenvalue Problems (problem formulation, recapitulation of singular values – multiplicity of eigenvalues – characteristic polynomial, eigen value decomposition, similarity transform, sensitivity of characteristic polynomial, condition, Jordan canonical form, Schur form, QR Algorithm)

	8. Classical Iteration for Linear Systems (motivation from numerical solution to PDEs, idea of classical iteration, fixed point iteration and its convergence, Jacobi and Gauss-Seidel iteration, convergence, Krylov space methods – specifically conjugate gradients, efficiency of CG algorithm, idea of pre-conditioning) 9. Multigrid Methods for solving Linear Systems (revisiting classical iteration properties, detailed convergence observations, idea of 2-level algorithm, v-cycle geometrical multigrid, generic algorithm formulation, convergence results, efficiency, variant: cascadic multigrid) 10. Non-linear Systems (motivation, solvability considerations, local uniqueness, condition considerations, iteration – fixed point iteration, convergence, example: bisection iteration, stopping criteria, Newton iteration, non-linear approximation) 11. Numerical Differentiation (problem example, finite differences, Taylor series error estimate, grid function and equidistant grids, interpolatory/collocation methods)
Course type and weakly work hours	Lecture *Numerics for Earth System Physics*: 2 SWS Exercises for *Numerics for Earth System Physics*: 2 SWS (attendance requirement)
Language	English
Prerequisites	Required: None. Recommended: Successful completion of the modules *Mathematics 1*, *Mathematics 2* and *Physics of the Earth System 1.*
Verwendbarkeit des Moduls	Das Modul ist Bestandteil der Studiengänge/Profile: 1. B.Sc. Earth System Physics;
Exam type and requirements for registration	Module examination: graded coursework Exam language: English Requirements: None
Work load / credit points	Lecture *Numerics for Earth System Physics*: 3 CP Exercises for *Numerics for Earth System Physics*: 3 CP On-campus-study: 60 h Self-study: 90 h Exam preparation: 30 h
Total credit points	6 CP
Duration	1 semester
Frequency of offer	Annually during winter term
Reference semester	3rd semester
Contact	Jörn Behrens

ESW-B-DiffEqs Differential Equations for Earth System Physics

Module type	Required Module
Title	Differential Equations for Earth System Physics

Course number	ESW-B-DiffEqs
Learning outcomes	Students know and understand the basic theory of ordinary and partial differential equations. They have become familiar with initial methods for the numerical solution of differential equations and can apply them.
Contents	The guiding questions ("mantra") of the course for all individual parts will be: 1. Is there a solution to the problem? 2. Is the solution unique? 3. Is there an algorithm to compute the solution? 4. Is the algorithm efficient? 5. Is the computed solution accurate? While the first two questions are usually answered by purely mathematical results (and mostly covered in the modules *Mathematics 1* and *2*) it is important to recall their validity. The last question is the one about convergence and therefore stability, consistency and condition of the problem need to be discussed. The course is dedicated to some theory and numerics of differential equations. In the first part ordinary differential equations – and thus time integration methods – are covered, while in the second part a number of methods for solving partial differential equations are presented. All the sessions are in a sense self-contained, covering one topic from problem formulation to some analysis of error. Additionally, all sessions can be accompanied by exercises with small programming examples in Python (or MATLAB). 1. Introduction to ODEs (problem formulation for linear ODEs and systems of first order linear ODEs, initial and boundary value problems, basic solution methods such as separation of variables and variational methods, reduction of high-order ODEs to systems of first order) 2. Numerical methods for ODEs (Euler's method, Heun's method, Runge-Kutta methods, adaptive time stepping, error analysis, condition and stability, implicit methods) 3. Introduction to PDEs (problem formulation of generic PDE, types of PDEs, well-posedness, prototypical elliptic, parabolic and hyperbolic equation, elementary properties) 4. Numerical methods for PDEs (Semi-discrete problem formulation, finite-differences, finite element and finite volume methods, Lagrangian methods, conservation properties, von-Neumann stability analysis)
Course type and weakly work hours	Lecture *Differential Equations for Earth System Physics*: 2 SWS Exercises for *Differential Equations for Earth System Physics*: 2 SWS (attendance requirement)
Language	English
Prerequisites	Required: None. Recommended: Successful completion of the modules *Mathematics 1*,

	Mathematics 2, Physics of the Earth System 2, Numerics for Earth System Physics.
Verwendbarkeit des Moduls	Das Modul ist Bestandteil der Studiengänge/Profile: 1. B.Sc. Earth System Physics;
Exam type and requirements for registration	Module examination: graded coursework Exam language: English Requirements: consistent active participation in the tutorial
Work load / credit points	Lecture *Differential Equations for Earth System Physics*: 3 CP Exercises for *Differential Equations for Earth System Physics*: 3 CP On-campus-study: 60 h Self-study: 90 h Exam preparation: 30 h
Total credit points	6 CP
Duration	1 semester
Frequency of offer	Annually during summer term
Reference semester	4^{th} semester
Contact	Jörn Behrens

ESW-B-Stat Statistics for Earth System Physics

Module type	Required Module
Title	Statistics for Earth System Physics
Course number	ESW-B-Stat
Learning outcomes	Students know and understand the basics of statistical analysis in geophysics, oceanography and meteorology. They have an initial understanding of statistical methods and can apply them to simple examples. They have developed a statistical and dynamic understanding of time series analysis.
Contents	1. Statistics and Stochastics 2. Aleatoric vs epistemic uncertainty 3. Descriptive Statistics (histograms, cumulative distributions, moments, quantiles) 4. Probability (incl. distributions and limit theorems; from that motivating the frequent utilization of Gaussian distributions) 5. The rationale of inductive statistics 6. Estimators 7. Intervals of confidence (focus on estimating the expected value of a Gaussian; student's distribution; Gaussian as a limit of that; Pearson Clopper values; bootstrapping) 8. Correlation 9. Linear regression (univariate; multivariate – incl. nonlinear fit functions – elimination of periodical backgrounds; intervals of confidence for slopes

	and extrapolations; ellipsoids of confidence; qualitative discussion: when does linear regression make sense?) 10. Outlook on Optimal Fingerprinting / Detection/Attribution as an extension of linear regression to correlated data 11. Hypothesis tests (only now, as linear regression should be treated as early as possible to foster intuition; errors of 1st and 2nd kind, significance and power, KS-test, chi-square test; Durbin Watson test; link between hypothesis test and confidence interval) 12. The concept of time series 13. Autocorrelation (incl. white noise) 14. AR1-process 15. Equivalence of higher dimensional AR1-processes and univariate higher order AR-processes (incl. background discussion Taken's Theorems) 16. AR1-processes near bifurcations (power and limitations of early warning methods) 17. Estimation of spectra and filters 18. EOF analysis 19. Outlook on Bayesian statistics as against above frequentist statistics (which school of thought does answer which questions?) 20. Outlook on decision theory The sessions may be accompanied by examples from geophysics, oceanography and meteorology.
Course type and weakly work hours	Lecture *Statistics for Earth System Physics*: 3 SWS Exercises for *Statistics for Earth System Physics*: 2 SWS (attendance requirement)
Language	English
Prerequisites	Required: None. Recommended: Successful completion of the modules *Mathematics 1*, *Mathematics 2* and *Physics of the Earth System 1*
Verwendbarkeit des Moduls	Das Modul ist Bestandteil der Studiengänge/Profile: 1. B.Sc. Earth System Physics;
Exam type and requirements for registration	Module exam: written exam, coursework or completion of exercises Exam language: English Requirements: consistent active participation in the tutorial
Work load / credit points	Lecture *Statistics for Earth System Physics*: 3 CP Exercises for *Statistics for Earth System Physics*: 3 CP On-campus-study: 60 h Self-study: 90 h Exam preparation: 30 h
Total credit points	6 CP
Duration	1 semester
Frequency of offer	Annually during summer term
Reference semester	4th semester

Contact	Hermann Held

Programme-specific Foundations

ESW-B-PES1 Physics of the Earth System 1

Module type	Required Module
Title	Physics of the Earth System 1
Course number	ESW-B-PES1
Learning outcomes	After successfully completing the module, students will have an understanding of the structure and dynamics of the Earth system from a physical perspective. They are familiar with the structure of the solid Earth, the ocean and the atmosphere and the most important processes that make up their respective dynamics. They know the basic variables, forces and measured quantities. They have also acquired basic programming skills with Python under the Linux operating system. They can read in and process scientific data and output and visualize results.
Contents	Introduction to the physics of the earth system: 1. introduction to geophysical basics: structure and dynamics of the solid earth, plate tectonics, volcanism, environmental geophysics 2. introduction to meteorological basics: structure and dynamics of the atmosphere – structure, concepts, equations of motion 3. introduction to oceanographic basics: structure and dynamics of the oceans - water masses, circulation, volume and heat transport Introduction to programming with Python: 1. computer infrastructure: operating system Linux, directories, files, commands 2. programming concepts with Python: variables, data types, operations, arrays, branching and looping, control structures, formatted input and output, data visualization The programming tasks use variables and examples from the Physics of the Earth System lecture.
Course type and weakly work hours	Lecture *Physics of the Earth System 1*: 4 SWS Exercises *Introduction to Python Programming*: 2 SWS (attendance requirement)
Language	English
Prerequisites	Required: None. Recommended: None.
Verwendbarkeit des Moduls	Das Modul ist Bestandteil der Studiengänge/Profile: 1. B.Sc. Earth System Physics;
Exam type and requirements for registration	Module examination: graded coursework or take-home exam Exam language: English Requirements: consistent active participation in the tutorial
Work load / credit points	Lecture *Physics of the Earth System 1*: 6 CP Exercises *Introduction to Python Programming*: 4 CP

	On-campus-study: 120 h Self-study: 120 h Exam preparation: 30 h
Total credit points	10 CP
Duration	1 semester
Frequency of offer	Annually during winter term
Reference semester	1st semester
Contact	1st year coordinator

ESW-B-PES2 Physics of the Earth System 2

Module type	Required Module
Title	Physics of the Earth System 2
Course number	ESW-B-PES2
Learning outcomes	After successfully completing the module, students will have an understanding of the relationships between geophysical, oceanographic and meteorological processes in the Earth system, including possible geohazards, and their interactions with the climate system. In addition, students have gained an overview of the common forms of scientific work. They will be able to derive and process a scientific question and present the results.
Contents	Introduction to the physical interactions in the Earth system using the examples of geohazards and climate: 1. geohazards, geosystem monitoring, climate-relevant applications 2. earth system cycles and their couplings: Energy, atmosphere, water, carbon 3. climate, sensitivity, feedbacks 4. modelling Introduction to scientific work: 1. scientific discovery process 2. scientific writing and other forms of presentation 3. project and time management 4. review process The processing of a scientific question is demonstrated using an example from the field of georisks or the climate system.
Course type and weakly work hours	Lecture *Physics of the Earth System 2*: 4 SWS Lecture + Exercises *Basics of Academic Research*: 2 SWS (attendance requirement)
Language	English
Prerequisites	Required: None. Recommended: Successful completion of the module *Physics of the Earth System 1.*

Verwendbarkeit des Moduls	Das Modul ist Bestandteil der Studiengänge/Profile: 1. B.Sc. Earth System Physics;
Exam type and requirements for registration	Modul examination: graded course work or take-home exam Exam language: English Additional coursework: Additionally, a presentation/report may be required; this will be announced at the beginning of the course. Requirements: consistent active participation in the tutorial
Work load / credit points	Lecture *Physics of the Earth System 2*: 6 CP Lecture + Exercises *Basics of Academic Research*: 4 CP On-campus-study: 120 h Self-study: 120 h Exam preparation: 30 h
Total credit points	10 CP
Duration	1 semester
Frequency of offer	Annually during summer term
Reference semester	2nd semester
Contact	1st year coordinator

ESW-B-PESPract Physics of the Earth System – Practical Training

Module type	Required Module
Title	Physics of the Earth System – Practical Training
Course number	ESW-B-PESPract
Learning outcomes	After successfully completing the module, students will be able to plan experiments in the field of Earth system physics, guided by questions and hypotheses, carry them out and analyse and interpret the data obtained. They are familiar with basic concepts of experimental work, such as measurement uncertainty, error propagation and reproducibility. They will be able to document their experimental work, including the evaluation, in a scientific test protocol.
Contents	1. Planning and execution of laboratory experiments in a team 2. Automatic and manual recording of measurement data 3. Creation of analysis scripts in Python 4. Use of dedicated measurement software 5. Evaluation of the measurements and answering the experimental question(s) 6. Preparation of a practical report
Course type and weakly work hours	Accompanying Lecture for *Physics of the Earth System Practical Training*: 1 SWS Practical *Physics of the Earth System Practical Training*: 3 SWS
Language	English

Prerequisites	Required: None. Recommended: Successful completion of the modules *Physics of the Earth System 1, Physics of the Earth System 2.*
Verwendbarkeit des Moduls	Das Modul ist Bestandteil der Studiengänge/Profile: 1. B.Sc. Earth System Physics;
Exam type and requirements for registration	Module examination: completion of practical (pass/fail) Exam language: English Requirements: consistent active participation in the practical
Work load / credit points	Accompanying Lecture for *Physics of the Earth System Practical Training*: 1,5 LP Praktikum *Physics of the Earth System Practical Training*: 4,5 LP On-campus-study: XX h Self-study: XX h Exam preparation: XX h
Total credit points	6 CP
Duration	1 semester
Frequency of offer	Annually during winter tern
Reference semester	3rd semester
Contact	

ESW-B-FluidDyn Foundations of Fluid Dynamics

Module type	Required Module
Title	Foundations of Fluid Dynamics
Course number	ESW-B-FluidDyn
Learning outcomes	After successfully completing the module, students are familiar with the basics of working on fluid mechanics problems and are able to compile the relevant equations for simple fluid mechanics problems and to classify and describe the forces and parameters involved.
Contents	1. State variables and properties of fluids 2. Fluid statics 3. Methods of flow description 4. Conservation equations for fluids 5. Approximations of the equation of motion 6. Dimensional analysis 7. Similarity of flows
Course type and weakly work hours	Lecture *Foundations of Fluid Dynamics*: 3 SWS Exercises for *Foundations of Fluid Dynamics*: 1 SWS (attendance requirement)
Language	Englisch
Prerequisites	Required: Attendance of modules *Mathematics 1*, *Mathematics 2*, *Physics 1 (Mechanics and Heat Theory)* and *Physics 2 (Electrodynamics and Optics).* Recommended: Successful completion of modules *Mathematics 1,*

	Mathematics 2, *Physics 1 (Mechanics and Heat Theory)* and *Physics 2 (Electrodynamics and Optics)*.
Verwendbarkeit des Moduls	Das Modul ist Bestandteil der Studiengänge/Profile: 1. B.Sc. Earth System Physics;
Exam type and requirements for registration	Module partial examination: 1. Lecture *Foundations of Fluid Dynamics*: written exam (90 min.) 2. Exercises for *Foundations of Fluid Dynamics*: completion of exercises Exam language: English Requirements: consistent active participation in the tutorial
Work load / credit points	Lecture *Foundations of Fluid Dynamics*: 4,5 LP Exercises for *Foundations of Fluid Dynamics*: 1,5 LP On-campus-study: 60 h Self-study: 90 h Exam preparation: 30 h
Total credit points	6 LP
Duration	1 semester
Frequency of offer	Annually during winter term
Reference semester	3rd semester
Contact	Matthias Hort

Module descriptions: Required Elective Modules

Geophysics

ESW-B-AppGP Applied Geophysics

Module type	Required Elective Module
Title	Applied Geophysics
Course number	ESW-B-AppGP
Learning outcomes	After successfully completing the module, students will know and understand the physical principles of applied geophysics with regard to the properties of the earth to be measured and the respective measurement technology. They will be able to plan and carry out simple measurements using the methods presented and to evaluate and interpret the measured data.
Contents	1. Seismic methods: Refraction seismics, reflection seismics, sediment echo sounder, multibeam 2. Non-seismic methods: Potential methods, gravimetry, direct current geoelectrics, electromagnetic induction methods, magnetics, ground penetrating radar, borehole geophysics
Course type and weakly work hours	Lecture *Seismic Methods*: 2 SWS Exercises for *Seismic Methods*: 1 SWS (attendance requirement) Lecture *Non-Seismic Methods*: 2 SWS Exercises for *Non-Seismic Methods*: 1 SWS (attendance requirement)
Language	English
Prerequisites	Required: Attendance of the modules *Mathematics 1*, *Mathematics 2*, *Physics 1 (Mechanics and Heat Theory)*, *Physics 2 (Electrodynamics and Optics)* and *Physics of the Earth System 1.* Recommended: Successful completion of the modules *Mathematics 1*, *Mathematics 2*, *Physics 1 (Mechanics and Heat Theory)*, *Physics 2 (Electrodynamics and Optics)* and *Physics of the Earth System 1.*
Verwendbarkeit des Moduls	Das Modul ist Bestandteil der Studiengänge/Profile: 1. B.Sc. Earth System Physics;
Exam type and requirements for registration	Module examination: Joint written exam (90 min.) at the end of the second course semester Exam language: English Requirements: consistent active participation in the tutorial and completion of the exercises
Work load / credit points	Lecture *Seismic Methods*: 3 CP Exercises for *Seismic Methods*: 1,5 CP Lecture *Non-Seismic Methods*: 3 CP Exercises for *Non-Seismic Methods*: 1,5 CP On-campus-study: 90 h Self-study: 60 h Exam preparation: 30 h

	<table><tr><td></td><td>On-campus-study</td><td>Self-study</td><td>Exam preparation</td></tr><tr><td>Seismic Methods</td><td>45 h</td><td>30 h</td><td>15 h</td></tr><tr><td>Non-Seismic Methods</td><td>45 h</td><td>30 h</td><td>15 h</td></tr></table>
Total credit points	9 CP
Duration	2 semesters
Frequency of offer	Every semester Lecture *Seismic Methods*: annually in winter term Exercises for *Seismic Methods*: annually in winter term Lecture *Non-Seismic Methods*: annually in summer term Exercises for *Non-Seismic Methods*: annually in summer term
Reference semester	3rd and 4th semester
Contact	C. Hübscher, L. Scharff, C. Vanelle

ESW-B-GPPract Geophysics Practical Training

Module type	Required Elective Module
Title	Geophysics Practical Training
Course number	ESW-B-GPPract
Learning outcomes	After successfully completing the module, students will be able to operate geophysical measuring equipment independently and apply geophysical measuring methods independently. They can collect and evaluate their own measurement data. They are able to plan field experiments for given questions, carry out the measurements and record them in an appropriate manner. They can interpret their own measurement data and are able to plan, carry out and evaluate geophysical measurements for engineering offices in practice.
Contents	Geodesy (surveying), gravimetry, magnetics, direct current geoelectrics, georadar, model seismics, field seismics.
Course type and weakly work hours	*Accompanying Seminar for Geophysics Practical Training*: 1 SWS *Geophysics Practical Training*: 3 SWS
Language	English
Prerequisites	Required: Attendance of module *Applied Geophysics.* Recommended: Successful completion of the module *Applied Geophysics.*
Verwendbarkeit des Moduls	Das Modul ist Bestandteil der Studiengänge/Profile: 1. B.Sc. Earth System Physics
Exam type and requirements for registration	Module examination: completion of practical (pass/fail) Exam language: usually English Requirements: consistent active participation in the practical

Work load / credit points	*Accompanying Seminar for Geophysics Practical Training*: 1,5 CP *Geophysics Practical Training*: 4,5 CP On-campus-study: 75 h Self-study: 75 h Exam preparation: 30 h
Total credit points	6 CP
Duration	1 semester
Frequency of offer	Annually during summer term
Reference semester	4th or 6th semester
Contact	M. Hort, C. Hübscher, L. Scharff, C. Vanelle

ESW-B-ML Machine Learning in Physical Earth System Sciences

Module type	Required Elective Module
Title	Machine Learning in Physical Earth System Sciences
Course number	ESW-B-ML
Learning outcomes	Upon successful completion of the module, students will have acquired an overview of machine learning methods, including theory and specific applications in physical earth system sciences. They will be able to apply various machine learning techniques to geoscience problems using self-written programs and will be familiar with various open-source machine learning frameworks. They are able to qualitatively and quantitatively evaluate the performance of their implemented algorithms.
Contents	Objects and their properties, unsupervised learning strategies, supervised learning strategies, metrics for evaluating the performance of the various algorithms.
Course type and weakly work hours	Lecture *Machine Learning in Physical Earth System Sciences*: 2 SWS Exercises for *Machine Learning in Physical Earth System Sciences*: 2 SWS (attendance requirement)
Language	English
Prerequisites	Required: Successful completion of the module *Physics of the Earth System 1;* attendance of the module *Statistics for Earth System Physics*. Recommended: Successful completion of the module *Statistics for Earth System Physics*.
Verwendbarkeit des Moduls	Das Modul ist Bestandteil der Studiengänge/Profile: 1. B.Sc. Earth System Physics
Exam type and requirements for registration	Module examination: Hausarbeit Exam language: usually English Requirements: consistent active participation in the tutorial and completion of the exercises
Work load / credit points	Lecture *Machine Learning in Physical Earth System Sciences*: 3 CP Exercises for *Machine Learning in Physical Earth System Sciences*: 3 CP

	On-campus-study: 60 h Self-study: 90 h Exam preparation: 30 h
Total credit points	6 CP
Duration	1 semester
Frequency of offer	Annually during winter term
Reference semester	5th semester
Contact	C. Hammer

ESW-B-GaV Geodynamics and Vulcanology

Module type	Required Elective Module
Title	Geodynamics and Vulcanology
Course number	ESW-B-GV
Learning outcomes	After successfully completing the module, students will have basic knowledge of large-scale dynamic processes in the solid Earth system. They will have developed an understanding of the Earth as a heat engine and gained knowledge of the general structure of the solid Earth and the basic principles of volcanic activity.
Contents	In this module, students are introduced to dynamic processes in the solid Earth. First, relevant processes in the solid earth system are presented qualitatively. Based on this, heat transport in the Earth system is discussed, large-scale tectonic processes are underpinned with mathematical models and a connection to geothermal energy is established. Finally, volcanic activity is illuminated from the dynamic processes in the earth and simple physical models for volcanic activity are derived.
Course type and weakly work hours	Lecture *Geodynamics and Vulcanology*: 3 SWS Exercises for *Geodynamics and Vulcanology*: 1 SWS (attendance requirement)
Language	English
Prerequisites	Required: Attendance of the modules *Mathematics 1*, *Mathematics 2*, *Physics 1 (Mechanics and Heat Theory)*, *Physics 2 (Electrodynamics and Optics)* and *Physics of the Earth System 1*. Recommended: Successful completion of the modules *Mathematics 1*, *Mathematics 2*, *Physics 1 (Mechanics and Heat Theory)*, *Physics 2 (Electrodynamics and Optics)* and *Physics of the Earth System 1*.
Verwendbarkeit des Moduls	Das Modul ist Bestandteil der Studiengänge/Profile: 1. B.Sc. Earth System Physics.
Exam type and requirements for registration	Module examination: Joint written exam (90 min.) Exam language: English Requirements: consistent active participation in the tutorial and completion of the exercises

Work load / credit points	Lecture *Geodynamics and Vulcanology*: 4,5 CP Exercises for *Geodynamics and Vulcanology*: 1,5 CP On-campus-study: 60 h Self-study: 90 h Exam preparation: 30 h
Total credit points	6 CP
Duration	1 semester
Frequency of offer	Annually during summer term
Reference semester	3rd semester
Contact	M. Hort, L. Scharff

ESW-B-DPGM Data Processing and Geophysical Model Building

Module type	Required Elective Module
Title	Data Processing and Geophysical Model Building
Course number	ESW-B-DPGM
Learning outcomes	After successfully completing the module, students will be able to develop initial evaluations of data and, based on the data evaluation, simple geophysical models that identify the essential physical processes to explain the data.
Contents	Data processing and geophysical modelling using three different data examples from geophysics, one from the field of potential methods, one from the field of seismology/seismics, and one from the field of geodynamics.
Course type and weakly work hours	Lecture *Data Processing and Geophysical Model Building*: 1 SWS Exercises for *Data Processing and Geophysical Model Building*: 3 SWS (attendance requirement)
Language	English
Prerequisites	Required: Attendance of the modules *Mathematics 1*, *Mathematics 2*, *Numerics for Earth System Physics*, *Physics 1 (Mechanics and Heat Theory)*, *Physics 2 (Electrodynamics and Optics)* and *Physics of the Earth System 1*. Recommended: Successful completion of the modules *Mathematics 1*, *Mathematics 2*, *Numerics for Earth System Physics*, *Physics 1 (Mechanics and Heat Theory)*, *Physics 2 (Electrodynamics and Optics)*, *Physics of the Earth System 1*, *Applied Geophysics*, *Geodynamics and Volcanology*.
Verwendbarkeit des Moduls	Das Modul ist Bestandteil der Studiengänge/Profile: 1. B.Sc. Earth System Physics
Exam type and requirements for registration	Module examination: completion of exercises or Hausarbeit Exam language: usually English Requirements: consistent active participation in the tutorial and completion of the exercises
Work load / credit points	Lecture *Data Processing and Geophysical Model Building*: 1,5 CP Exercises for *Data Processing and Geophysical Model Building*: 4,5 CP

	On-campus-study: 60 h Self-study: 90 h Exam preparation: 30 h
Total credit points	6 CP
Duration	1 semester
Frequency of offer	Annually during winter term
Reference semester	5th semester
Contact	M. Hort

ESW-B-GeoHaz Geophysical Geohazard Research

Module type	Required Elective Module
Title	Geophysical Geohazard Research
Course number	ESW-B-Geohaz
Learning outcomes	After successfully completing the module, students will know and understand the basics of geophysical geohazard research in theory and practice. They have the basic knowledge to process selected geophysical data and interpret it with regard to the relevant earth processes.
Contents	Geological background of geohazards due to volcanism, landslides, tsunamis or earthquakes. Processing of selected geophysical data with a focus on seismics, seismology or ground penetrating radar.
Course type and weakly work hours	Lecture *Geophysical Geohazard Research*: 2 SWS Exercises for *Geophysical Geohazard Research*: 2 SWS (attendance requirement)
Language	English
Prerequisites	Required: Attendance of the module *Applied Geophysics*. Recommended: Successful completion of the module *Applied Geophysics*.
Verwendbarkeit des Moduls	Das Modul ist Bestandteil der Studiengänge/Profile: 1. B.Sc. Earth System Physics
Exam type and requirements for registration	Module examination: Joint written exam (90 min.) Exam language: English Requirements: consistent active participation in the tutorial and completion of the exercises
Work load / credit points	Lecture *Geophysical Geohazard Research*: 3 CP Exercises for *Geophysical Geohazard Research*: 3 CP On-campus-study: 90 h Self-study: 60 h Exam preparation: 30 h
Total credit points	6 CP
Duration	1 semester

Frequency of offer	Annually during summer term
Reference semester	4^{th} or 6^{th} semester
Contact	C. Hübscher

ESW-B-SEQ Seismology and Earthquakes

Module type	Required Elective Module
Title	Seismology and Earthquakes
Course number	ESW-B-SEQ
Learning outcomes	After successfully completing the module, students will have learned the basics of time-of-flight seismology, will be familiar with analysis and evaluation methods for investigating structures and foci and will be able to apply them. They are familiar with the handling of seismological travel time data as well as the creation of velocity models from travel time data. They can classify seismic 3D tomography. They are familiar with array methods and can use them to localize earthquakes and other seismic sources.
Contents	Propagation of elastic waves, seismic rays through the earth, ray parameters, global travel time curves and phases, determination of structures in the subsurface and tomography, sources and localization of earthquakes.
Course type and weakly work hours	Lecture *Seismology and Earthquakes*: 3 SWS Exercises for *Seismology and Earthquakes*: 1 SWS (attendance requirement)
Language	English
Prerequisites	Required: Attendance of the modules *Mathematics 1*, *Mathematics 2*, *Physics 1 (Mechanics and Heat Theory)*, *Physics 2 (Electrodynamics and Optics)* and *Physics of the Earth System 1*. Recommended: Successful completion of the modules *Mathematics 1*, *Mathematics 2*, *Physics 1 (Mechanics and Heat Theory)*, *Physics 2 (Electrodynamics and Optics)* and *Physics of the Earth System 1*.
Verwendbarkeit des Moduls	Das Modul ist Bestandteil der Studiengänge/Profile: 1. B.Sc. Earth System Physics
Exam type and requirements for registration	Module examination: Joint written exam (90 min.) Exam language: English Requirements: consistent active participation in the tutorial and completion of the exercises
Work load / credit points	Lecture *Seismology and Earthquakes*: 4,5 CP Exercises for *Seismology and Earthquakes*: 1,5 CP On-campus-study: 60 h Self-study: 90 h Exam preparation: 30 h
Total credit points	6 CP

Duration	1 semester
Frequency of offer	Annually during winter term
Reference semester	3rd semester
Contact	C. Hadziioannou, S. Schippkus

Oceanography

ESW-B-PhysOcean Fundamentals of Physical Oceanography

Module type	Required Elective Module
Title	Fundamentals of Physical Oceanography
Course number	ESW-B-PhysOcean
Learning outcomes	Upon completion of the module, students will have an understanding of the fundamental structure of the oceans, including their stratification and circulation, as well as the underlying dynamic processes. Additionally, they will be familiar with oceanographic investigation methods, measurement parameters, the principles of oceanographic instruments, and basic data analysis techniques, and will have an up-to-date overview of the field.
Contents	Influence of tectonics and continental drift on the oceans, effect of topography and basin shape on ocean circulation, thermohaline and wind-driven circulation, convection, influence of Earth's rotation on dynamic processes (e.g., Ekman dynamics, geostrophy), atmospheric impact on the ocean, Earth's heat and radiation balance, characteristics of warm and cold water spheres, regional oceanography and its comparative analysis, water mass analysis, oceanic fronts and exchange through passages, physical and chemical properties of water, phase transitions, and the biosphere in the sea.
Course type and weakly work hours	Lecture *Fundamentals of Physical Oceanography*: 2 SWS Exercises for *Fundamentals of Physical Oceanography*: 2 SWS (attendance requirement)
Language	English
Prerequisites	Required: Attendance of the modules *Physics 1 (Mechanics and Heat Theory)*, *Physics 2 (Electrodynamics and Optics)*, *Physics of the Earth System 1* and *Physics of the Earth System 2.* Recommended: None.
Verwendbarkeit des Moduls	Das Modul ist Bestandteil der Studiengänge/Profile: B.Sc. Earth System Physics.
Exam type and requirements for registration	Module examination: Joint written exam (90 min.) Exam language: English Requirements: consistent active participation in the tutorial and completion of the exercises
Work load / credit points	Lecture *Fundamentals of Physical Oceanography*: 3 CP Exercises for *Fundamentals of Physical Oceanography*: 3 CP

	On-campus-study: 90 h Self-study: 135 h Exam preparation: 45 h
Total credit points	6 CP
Duration	1 semester
Frequency of offer	Annually during winter term
Reference semester	3rd semester
Contact	Stefanie Arndt

ESW-B-CoastShelf Coastal and Shelf Sea Oceanography

Module type	Required Elective Module
Title	Coastal and Shelf Sea Oceanography
Course number	ESW-B-CoastShelf
Learning outcomes	After successfully completing the module, students will know the basic structure of shelf and marginal seas in terms of stratification and circulation and understand the essential dynamics underlying this structure.
Contents	Comparative analysis of the coastal shelf regions and marginal seas. Hydrography of arid and humid marginal seas; interactions with land and atmosphere; tides; mixing in boundary layers; wind- and thermohaline-driven circulation; exchange processes of surface and bottom water through passages; hydraulic control; front formation; upwelling areas; water mass analysis; typification of estuaries, sediment and suspended sediment transport, wave dynamics at coasts, erosion, sedimentation.
Course type and weakly work hours	Lecture *Coastal and Shelf Sea Oceanography*: 2 SWS
Language	English
Prerequisites	Required: Attendance of the modules *Physics of the Earth System 1* and *Physics of the Earth System 2*. Recommended: Parallel attendance of the module *Fundamentals of Physical Oceanography*.
Verwendbarkeit des Moduls	Das Modul ist Bestandteil der Studiengänge/Profile: 1. B.Sc. Earth System Physics
Exam type and requirements for registration	Module examination: presentation or written exam Exam language: English
Work load / credit points	Lecture *Coastal and Shelf Sea Oceanography*: 3 CP On-campus-study: 30 h Self-study: 30 h Exam preparation: 30 h

Total credit points	3 CP
Duration	1 semester
Frequency of offer	Annually during winter term
Reference semester	3rd semester
Contact	Corinna Schrum

ESW-B-OceanIce Ocean and Ice in the Climate System

Module type	Required Elective Module
Title	Ocean and Ice in the Climate System
Course number	ESW-B-OceanIce
Learning outcomes	Students have knowledge of climate-relevant oceanic processes and phenomena (ocean-atmosphere interactions at high latitudes, the role of the cold water sphere). They have gained an overview of the variability of the ocean on interannual and decadal time scales.
Contents	Earth's radiation balance; hydrological cycle, heat and material cycles; climate-relevant processes; role of ocean circulation in climate; ocean as a heat reservoir, sea level rise; role of sea ice; fluctuations in ocean circulation and the Earth's climate with time scales of several years to several thousand years; El Nino, North Atlantic Oscillation; Dansgaard-Oeschger cycles; simple climate models.
Course type and weakly work hours	Lecture *Role of the Ocean and Ice in the Climate System*: 2 SWS Exercises for *Ocean and Ice in the Climate System*: 2 SWS (attendance requirement)
Language	English
Prerequisites	Required: Attendance of the modules *Physics of the Earth System 1* and *Physics of the Earth System 2.* Recommended: None.
Verwendbarkeit des Moduls	Das Modul ist Bestandteil der Studiengänge/Profile: 1. B.Sc. Earth System Physics
Exam type and requirements for registration	Module examination: written course work Exam language: English Requirements: consistent active participation in the tutorial
Work load / credit points	Lecture *Role of the Ocean and Ice in the Climate System*: 3 CP Exercises for *Ocean and Ice in the Climate System*: 3 CP On-campus-study: 60 h Self-study: 105 h Exam preparation: 45 h
Total credit points	6 CP
Duration	1 semester
Frequency of offer	Annually during summer term

Reference semester	4th semester
Contact	Johanna Baehr, Dirk Notz

ESW-B-OceanField Oceanographic Field Work

Module type	Required Elective Module
Title	Oceanographic Field Work
Course number	ESW-B-OceanField
Learning outcomes	After successfully completing the module, students can operate oceanographic measuring instruments and apply methods independently. They have collected and evaluated their own measurement data. They are able to plan field experiments for given questions, carry out the measurements and log them in a suitable way (online Logbook). They will have gained experience analysing their own measurement data. The students can process and analyse standard oceanographic measurements, and communicate the results in a report synthesising the datasets.
Contents	Field course with seatime collecting samples and data to describe marine physics with some auxiliary measurements (chemistry, biology, meteorology). Students will work in teams taking a variety of roles, using a range of oceanographic equipment, planning and executing fieldwork in the marine environment. The preparatory seminar is used for planning and training with specialist equipment and software for data processing and analysis. Students will work with specialist software for oceanographic equipment, process data collected during their seatime, and generate a concise scientific report describing the data analysis and comparing it with published material.
Course type and weakly work hours	*Preparation Seminar for Oceanographic Field Work*: 1 SWS Practical *Oceanographic Field Work*: 3 SWS Seminar *Analysis of Oceanographic Field Work Data*: 4 SWS
Language	English
Prerequisites	Required: Attendance of the modules *Physics of the Earth System 1* and *Physics of the Earth System 2.* Recommended: Successful completion of the module *Fundamentals of Physical Oceanography.*
Verwendbarkeit des Moduls	Das Modul ist Bestandteil der Studiengänge/Profile: 1. B.Sc. Earth System Physics
Exam type and requirements for registration	Module partial examination (pass/fail): 1. Practical *Oceanographic Field Work* – completion of practical Requirements: consistent active participation in the practical 2. Seminar *Analysis of Oceanographic Field Work Data* – course work Requirements: consistent active participation in the seminar and presentation Exam language: English

Work load / credit points	*Preparation Seminar for Oceanographic Field Work*: 1,5 CP Practical *Oceanographic Field Work*: 4,5 CP Seminar *Analysis of Oceanographic Field Work Data*: 6 CP On-campus-study: 160 h Self-study: 270 h Exam preparation: 0 h
Total credit points	12 CP
Duration	2 semesters
Frequency of offer	Annual start in summer term *Preparation Seminar for Oceanographic Field Work*: annually during summer term Practical *Oceanographic Field Work*: annually during summer term (usually during the semester break) Seminar *Analysis of Oceanographic Field Work Data*: annually during winter term
Reference semester	4th and 5th semester
Contact	Eleanor Frajka-Williams, Martin Gade

ESW-B-DynOcean Fundamentals of Dynamical Oceanography

Module type	Required Elective Module
Title	Fundamentals of Dynamical Oceanography
Course number	ESW-B-DynOcean
Learning outcomes	After successfully completing this module, students will have acquired in-depth knowledge of fluid dynamics for unstratified and stratified fluids in a rotating system. They will have dealt in depth with the methods of theoretical oceanography (scaling, linearization, approximations).
Contents	Phenomenology of dynamic processes in the ocean and their mathematical description. Among others, the following topics (complexes) are covered: Large-scale circulation and mixing, dynamic instabilities (barotropic and baroclinic), waves, eddies, eddy shedding, internal waves, jets, topographic effects, boundary currents, intrusions, bottom-driven density currents, convection.
Course type and weakly work hours	Lecture *Fundamentals of Dynamical Oceanography*: 2 SWS Exercises for *Fundamentals of Dynamical Oceanography*: 2 SWS (attendance requirement)
Language	English
Prerequisites	Required: Attendance of the modules *Mathematics 1*, *Mathematics 2*, *Numerics for Earth System Physics*, *Differential Equations for Earth System Physics* and *Fundamentals of Fluid Dynamics*. Recommended: None.
Verwendbarkeit des Moduls	Das Modul ist Bestandteil der Studiengänge/Profile: 1. B.Sc. Earth System Physics

Exam type and requirements for registration	Module examination: Joint written exam (90 min.) Exam language: English Requirements: consistent active participation in the tutorial
Work load / credit points	Lecture *Fundamentals of Dynamical Oceanography*: 3 CP Exercises for *Fundamentals of Dynamical Oceanography*: 3 CP On-campus-study: 60 h Self-study: 90 h Exam preparation: 30 h
Total credit points	6 CP
Duration	1 semester
Frequency of offer	Annually during winter term
Reference semester	5th semester
Contact	Carsten Eden

ESW-B-OceanMod Ocean Modelling

Module type	Required Elective Module
Title	Ocean Modelling
Course number	ESW-B-OceanMod
Learning outcomes	After successfully completing the module, students will have mastered various methods and procedures of modelling in marine science and their application for selected case studies. Students are able to create their own 'model codes' and apply or modify existing modules.
Contents	Among other things, the following topics (complexes) are presented: Different types of prognostic and diagnostic partial differential equations and the treatment of initial and boundary value problems. Finite difference methods (explicit and implicit) and their stability analysis. Direct and iterative solution of linear systems of equations. Multigrid methods. Solution of non-linear systems of equations. Structured and unstructured grids, grid dispersion, as well as discretisations and numerical diffusion. Critical analysis of model results with knowledge of potential sources of error. Parallelization of programs. Where possible, model codes are compared with analytical solutions.
Course type and weakly work hours	Lecture *Ocean Modelling*: 2 SWS Exercises for *Ocean Modelling*: 2 SWS (attendance requirement)
Language	English
Prerequisites	Required: Successful completion of the modules *Mathematics 1, Mathematics 2, Numerics for Earth System Physics, Differential Equations for Earth System Physics* and *Physics of the Earth System 1.* Recommended: Successful completion of the modules *Fundamentals of Dynamical Oceanography,* as well as knowledge of a higher programming language like Python, Fortran or C and Matlab.

Verwendbarkeit des Moduls	Das Modul ist Bestandteil der Studiengänge/Profile: 1. B.Sc. Earth System Physics
Exam type and requirements for registration	Module examination: course work Exam language: English Requirements: consistent active participation in the tutorial
Work load / credit points	Lecture *Ocean Modelling*: 3 CP Exercises for *Ocean Modelling*: 3 CP On-campus-study: 60 h Self-study: 90 h Exam preparation: 30 h
Total credit points	6 CP
Duration	1 semester
Frequency of offer	Annually during summer term
Reference semester	6th semester
Contact	Carsten Eden

ESW-B-Cryo The Cryosphere

Module type	Required Elective Module
Title	The Cryosphere
Course number	ESW-B-Cryo
Learning outcomes	After successfully completing the module, students will be able to physically understand cryospheric processes in the Earth system, simulate them in the form of simple numerical models, classify the role of interactions, understand relevant specialist publications, and carry out basic laboratory experiments on freezing and melting.
Contents	Freezing and melting; cryosphere in the Earth system; snow; glaciers; ice sheets; sea ice; permafrost; ice clouds; cryosphere in climate change
Course type and weakly work hours	Lecture *The Cryosphere*: 2 SWS Exercises for *The Cryosphere*: 2 SWS (attendance requirement)
Language	English
Prerequisites	Required: None. Recommended: Attendance of the modules *Mathematics 1*, *Mathematics 2*, *Physics 1 (Mechanics and Heat Theory)*, *Physics 2 (Electrodynamics and Optics)*, *Physics of the Earth System 1.*
Verwendbarkeit des Moduls	Das Modul ist Bestandteil der Studiengänge/Profile: 1. B.Sc. Earth System Physics
Exam type and requirements for registration	Module examination: course work Exam language: English Requirements: consistent active participation in the tutorial
Work load / credit points	Lecture *The Cryosphere*: 3 CP Exercises for *The Cryosphere*: 3 CP

	On-campus-study: 60 h Self-study: 90 h Exam preparation: 30 h
Total credit points	6 CP
Duration	1 semester
Frequency of offer	Annually during winter term
Reference semester	5th semester
Contact	Dirk Notz

Meteorology

ESW-B-AtmoTherm Atmospheric Thermodynamics

Module type	Required Elective Module
Title	Atmospheric Thermodynamics
Course number	ESW-B-AtmoTherm
Learning outcomes	The first part of the course introduces classical thermodynamics. Starting from the concepts of mechanical equilibrium and work, the students learn the concepts of thermal equilibrium, internal energy, heat and entropy, as necessary to describe the observed natural processes. The second part of the course focuses on atmospheric thermodynamics. Equations of state for air, water and their mixture are derived and applied to describe relevant atmospheric variables, atmospheric processes and the static stability of the atmosphere. Non-equilibrium thermodynamics and transport phenomena are then introduced, where the students learn the balance equations that describe atmospheric dynamics.
Contents	1. Zeroth law: the concept of temperature 2. First law: the conservation of energy 3. Second law: the increase in entropy 4. Variable composition and phase equilibrium 5. Water in the atmosphere 6. Atmospheric processes 7. Static stability of the atmosphere 8. Non-equilibrium thermodynamics 9. Balance Equations 10. Transport phenomena
Course type and weakly work hours	Lecture *Atmospheric Thermodynamics*: 2 SWS Exercises for *Atmospheric Thermodynamics*: 2 SWS (attendance requirement)
Language	English
Prerequisites	Required: None. Recommended: None.

Verwendbarkeit des Moduls	Das Modul ist Bestandteil der Studiengänge/Profile: 1. B.Sc. Earth System Physics 2. B.Sc. Meteorologie
Exam type and requirements for registration	Module examination: graded oral exam (XX min) Exam language: English Requirements: consistent active participation in the tutorial
Work load / credit points	Lecture *Atmospheric Thermodynamics*: 3 CP Exercises for *Atmospheric Thermodynamics*: 3 CP On-campus-study: 60 h Self-study: 90 h Exam preparation: 30 h
Total credit points	6 CP
Duration	1 semester
Frequency of offer	Annually during winter term
Reference semester	3rd semester
Contact	Juan Pedro Mellado

ESW-B-AtmoMess Atmosphären-Messungen

Module type	Required Elective Module
Title	Atmosphären-Messungen
Course number	ESW-B-AtmoMess
Learning outcomes	Students have an overview of instruments and measurement methods used operationally for atmospheric measurements. They are familiar with their physical operating principles. From this, they can both evaluate the possible applications and interpret measurements scientifically, including their uncertainties and representativeness.
Contents	The course first introduces classical and modern measurement methods for basic meteorological variables such as temperature, humidity and wind. Building on this, the profiling of the atmosphere with in-situ measurements and remote sensing is presented. One focus is on ground-based active remote sensing using radar, lidar and sodar. Finally, airborne and satellite-based remote sensing, especially of clouds, is discussed.
Course type and weakly work hours	Lecture *Atmosphären-Messungen*: 2 SWS
Language	German
Prerequisites	Required: None. Recommended: None.
Verwendbarkeit des Moduls	Das Modul ist Bestandteil der Studiengänge/Profile: 1. B.Sc. Earth System Physics 2. B.Sc. Meteorologie

Exam type and requirements for registration	Module examination: completion of exercises (pass/fail) Exam language: German
Work load / credit points	Lecture *Atmosphären-Messungen*: 3 CP On-campus-study: 60 h Self-study: 90 h Exam preparation: 30 h
Total credit points	3 CP
Duration	1 semester
Frequency of offer	Annually during winter term
Reference semester	3rd semester
Contact	Felix Ament

ESW-B-Syn Synoptik

Module type	Required Elective Module
Title	Synoptik
Course number	ESW-B-Syn
Learning outcomes	The course teaches the basic content of synoptic meteorology, which consists of the synopsis of meteorological phenomena in their spatial distribution and temporal changes with the aim of weather analysis and weather forecasting. Students gain an insight into the methods that lead from the analysis of the current state of the atmosphere to weather forecasting. Knowledge of the dynamics and interactions of weather-related processes is imparted. The course should enable students to interpret the various forms of representation of the forecast three-dimensional state of the atmosphere. Particular attention is paid to the question of which weather-determining and weather-changing processes come into effect in different synoptic constellations. How the concepts developed in theory come into effect in the real atmosphere is taught in the “weather discussion” exercise.
Contents	1. Analysis products: Ground weather maps, altitude weather maps 2. Uplift as a driver for weather changes 3. General circulation 4. Jet streams/Rossby waves 5. Fronts/frontogenesis 6. Mid-level pressure formations: high, ideal cyclone, Shapiro-Keyser cyclone, polar low 7. Cyclogenesis from the perspective of quasi-geostrophic theory: Omega equation and the processes involved 8. Cyclogenesis by conservation of isentropic potential vorticity (leeward cyclogenesis, dry intrusion), shear vorticity, vergences at jet streaks 9. Vorticity equation

	10. Boundary layer processes 11. TEMPs and their general role in short-term forecasting 12. Forecasting convection and thunderstorms by TEMP analysis
Course type and weakly work hours	Lecture *Synoptik*: 2 SWS Exercises *Übungen zur Synoptik I*: 1 SWS (attendance requirement) Exercises *Übungen zur Synoptik II*: 1 SWS (attendance requirement) Seminar zur *Synoptik*: 1 SWS (attendance requirement)
Language	German
Prerequisites	Required: None. Recommended: Attendance of the modules *Einführung in die Meteorologie I* and *Einführung in die Meteorologie II* or *Physics of the Earth System 1* and *Physics of the Earth System 2.*
Verwendbarkeit des Moduls	Das Modul ist Bestandteil der Studiengänge/Profile: 1. B.Sc. Meteorologie 2. B.Sc. Earth System Physics
Exam type and requirements for registration	Modulteilprüfungen: 1. Lecture *Synoptik*, Exercises *Übungen zur Synoptik I* and Exercises *Übungen zur Synoptik II*: joint written exam (graded) 2. Seminar zur *Synoptik*: Referat (pass/fail) Requirements: consistent active participation in the tutorials
Work load / credit points	Lecture *Synoptik*: 2 CP Exercises *Übungen zur Synoptik I*: 1 CP Exercises *Übungen zur Synoptik II*: 1 CP Seminar zur *Synoptik*: 2 CP On-campus-study: 60 h Self-study: 90 h Exam preparation: 30 h
Total credit points	6 CP
Duration	2 semesters
Frequency of offer	Annual start in winter term Lecture *Synoptik*: annually during winter term Exercises *Übungen zur Synoptik I*: annually during winter term Exercises *Übungen zur Synoptik II*: annually during summer term Seminar zur *Synoptik*: annually during summer term
Reference semester	3rd and 4th semester
Contact	Gerd Müller

ESW-B-DynWeather Dynamics of Weather and Climate

Module type	Required Elective Module
Title	Dynamics of Weather and Climate
Course number	ESW-B-DynWeather

Learning outcomes	Upon successful completion of this introductory module in atmospheric dynamics, students will have systematically acquired, in increasing complexity, knowledge of the equations and concepts and their use to understand synoptic weather and climate processes on time scales from a few days to decades. Students know the simplifications of primitive equations that describe large-scale circulation fluctuations with a focus on the extratropics and develop the ability to apply the theory to interpret observations and model simulations.
Contents	Primitive equations of atmospheric motions at a large scale in the pressure system. Vorticity equation and its simplification for synoptic scales. Barotropic Rossby waves and Rossby potential vorticity. Quasi-geostrophic approximations. Baroclinic instability and energy transformations Equations for the zonally averaged circulation. Concept of momentum fluxes. Large-scale circulation cells: stream function perspective.
Course type and weakly work hours	Lecture *Dynamics of Weather and Climate*: 2 SWS Exercises for *Dynamics of Weather and Climate*: 2 SWS (attendance requirement)
Language	English
Prerequisites	Required: None. Recommended: None.
Verwendbarkeit des Moduls	Das Modul ist Bestandteil der Studiengänge/Profile: 1. B.Sc. Earth System Physics 2. B.Sc. Meteorologie
Exam type and requirements for registration	Module examination: Joint written exam (90 min.) Exam language: English Requirements: consistent active participation in the tutorial
Work load / credit points	Lecture *Dynamics of Weather and Climate*: 3 CP Exercises for *Dynamics of Weather and Climate*: 3 CP On-campus-study: 60 h Self-study: 90 h Exam preparation: 30 h
Total credit points	6 CP
Duration	1 semester
Frequency of offer	Annually during summer term
Reference semester	4th semester
Contact	Nedjeljka Žagar

ESW-B-Forecast Weather Forecasting & Modelling

Module type	Required Elective Module
Title	Weather Forecasting and Modelling
Course number	ESW-B-Forecast

Learning outcomes	Upon completion of the module, students will have acquired basic knowledge of numerical weather prediction. The module focuses on the basic physical concepts and components of weather forecasting in operational weather services such as DWD and ECMWF, as well as the use of forecast products. The module provides a basic understanding of how prognostic equations learned in other courses become weather maps.
Contents	Components of the numerical weather prediction (NWP) process as an initial value problem. Concept and historical development of the “first guess”. Statistical foundations of data assimilation: least squares estimation and function fitting. The concept of covariances and correlations and application to surface observations and probe time series. Statistical interpolation. Examples with some observations and with Lorenz models. Continuous data assimilation in the satellite era: overview of modern NWP. Analysis and reanalysis datasets and their downscaling. Forecasting without physical equations: machine learning. The use of weather forecasts in the energy sector.
Course type and weakly work hours	Lecture *Weather Forecasting and Modelling*: 2 SWS
Language	English
Prerequisites	Required: None. Recommended: None.
Verwendbarkeit des Moduls	Das Modul ist Bestandteil der Studiengänge/Profile: 1. B.Sc. Meteorologie 2. B.Sc. Earth System Physics
Exam type and requirements for registration	Module examination: graded home assignments Exam language: English
Work load / credit points	Lecture *Weather Forecasting and Modelling*: 3 CP On-campus-study: 30 h Self-study: 60 h Exam preparation: XX h
Total credit points	3 CP
Duration	1 semester
Frequency of offer	Annually during summer term
Reference semester	4th semester
Contact	Nedjeljka Žagar

ESW-B-AirChem Air Chemistry

Module type	Required Elective Module
Title	Air Chemistry

Course number	ESW-B-AirChem
Learning outcomes	After completing the module, students will have detailed knowledge in the field of atmospheric chemistry. They know the trace substances and material cycles occurring in the atmosphere and have understood ozone chemistry.
Contents	The introduction to atmospheric chemistry includes an introduction to the basics of general chemistry and a study of chemical trace substances in the atmosphere. In particular, the atmospheric lifetime, toxicological environmental relevance and the radiative effect of trace substances are discussed. An introduction to the general kinetics of chemical reactions is followed by an explanation of ozone formation in the stratosphere and the troposphere. This includes a discussion of the annually recurring ozone depletion in the stratosphere at the beginning of the Antarctic spring ("ozone hole") and the formation of summer smog in the presence of nitrogen oxides, carbon monoxide and volatile organic compounds.
Course type and weakly work hours	Lecture with Exercises *Air Chemistry*: 2 SWS
Language	English
Prerequisites	Required: None. Recommended: None.
Verwendbarkeit des Moduls	Das Modul ist Bestandteil der Studiengänge/Profile: 1. B.Sc. Meteorologie 2. B.Sc. Earth System Physics
Exam type and requirements for registration	Module examination: Joint written exam (90 min.) Exam language: English Requirements: None.
Work load / credit points	Lecture with Exercises *Air Chemistry*: 3 CP On-campus-study: 60 h Self-study: 90 h Exam preparation: 30 h
Total credit points	3 CP
Duration	1 semester
Frequency of offer	Annually during winter term
Reference semester	5th semester
Contact	Volker Matthias

ESW-B-CloudPhys Cloud Physics

Module type	Required Elective Modules
Title	Cloud Physics
Course number	ESW-B-CloudPhys

Learning outcomes	Students have an overview of the sources and sinks of various atmospheric aerosol types. They understand the fundamental mechanisms of cloud and fog formation and, based on this knowledge, can identify, understand, and classify observed clouds. The students have learned methods to describe the equilibrium of aerosol and cloud droplets as a function of ambient humidity. They are familiar with approaches for describing the size and mass growth of hydrometeors in clouds at different levels of complexity, as well as the mechanisms of precipitation formation. They are able to apply the learned concepts to develop parametric approaches for describing clouds and precipitation in regional and global circulation models.
Contents	The course introduces the physics of aerosol particles and clouds, with a focus on microphysics. Specifically, how water vapor forms droplets and ice crystals, how these grow, and eventually fall to the ground as precipitation. The lecture structure follows the life cycle of the particles: from aerosols to the issue of nucleation, then to growth from the vapor phase, and finally to precipitation formation mechanisms. Separate chapters are dedicated to ice particles and clouds in circulation models.
Course type and weakly work hours	Lecture *Cloud Physics*: 2 SWS Exercises for *Cloud Physics*: 2 SWS (attendance requirement)
Language	English
Prerequisites	Required: None. Recommended: None.
Verwendbarkeit des Moduls	Das Modul ist Bestandteil der Studiengänge/Profile: 1. B.Sc. Earth System Physics 2. B.Sc. Meteorologie
Exam type and requirements for registration	Module examination: Joint oral exam (XX min.) Exam language: English Requirements: consistent active participation in the tutorial
Work load / credit points	Lecture *Cloud Physics*: 3 CP Exercises for *Cloud Physics*: 3 CP On-campus-study: 60 h Self-study: 90 h Exam preparation: 30 h
Total credit points	6 CP
Duration	1 semester
Frequency of offer	Annually during winter term
Reference semester	5th semester
Contact	Stefan Bühler

ESW-B-EnvMet Environmental Meteorology

Module type	Required Elective Module
Title	Environmental Meteorology
Course number	ESW-B-EnvMet
Learning outcomes	Students have essential basic knowledge in core areas of environmental meteorology, which enables them to take up expert work in the fields of pollutant dispersion, renewable energies or urban planning.
Contents	1. dispersion calculation 2. urban climatology 3. energy meteorology
Course type and weakly work hours	Lecture *Environmental Meteorology*: 2 SWS Exercises for *Environmental Meteorology*: 2 SWS (attendance requirement)
Language	English
Prerequisites	Required: None. Recommended: None.
Verwendbarkeit des Moduls	Das Modul ist Bestandteil der Studiengänge/Profile: 1. B.Sc. Earth System Physics 2. B.Sc. Meteorologie
Exam type and requirements for registration	Module examination: Projektabschluss Exam language: English Requirements: consistent active participation in the tutorial
Work load / credit points	Lecture *Environmental Meteorology*: 3 CP Exercises for *Environmental Meteorology*: 3 CP On-campus-study: 60 h Self-study: 90 h Exam preparation: 30 h
Total credit points	6 CP
Duration	1 semester
Frequency of offer	Annually during winter term
Reference semester	5th semester
Contact	Bernd Leitl

ESW-B-CliPhys Climate Physics

Module type	Required Elective Module
Title	Climate Physics
Course number	ESW-B-CliPhys
Learning outcomes	Students are familiar with the fundamental concepts and methods of climate physics. They understand the significance of the various climate system components and have comprehended the material cycles within the climate system (water and carbon cycles). They are able to

	qualitatively assess processes in the climate system (trends, fluctuations). Additionally, they are familiar with the basic methods of climate system analysis and know which types of models can be used to describe the dynamics of the climate system.
Contents	The lecture begins with the definition of the terms climate and climate system. Next, we clarify other important concepts such as climate forcing and climate feedbacks. We then examine Earth's radiation budget, which ultimately determines the climate. Chapter 3 focuses on the central topic of climate sensitivity: How much does the planet warm in response to a given radiative forcing? This leads to the crucial topic of climate feedbacks, which are explored in the following chapters: water vapor, temperature gradient, and ice-albedo in Chapter 4, followed by clouds and the biosphere in Chapter 5. Chapter 6 addresses biogeochemical cycles, with a particular focus on the water and carbon cycles. The study of the carbon cycle naturally provides a broader perspective on Earth's system history, which is the subject of Chapter 7, the final chapter of the lecture. In the accompanying exercises, the acquired knowledge is applied to solve basic problems.
Course type and weakly work hours	Lecture *Climate Physics*: 2 SWS Exercises for *Climate Physics*: 2 SWS (attendance requirement)
Language	English
Prerequisites	Required: None. Recommended: None.
Verwendbarkeit des Moduls	Das Modul ist Bestandteil der Studiengänge/Profile: 1. B.Sc. Earth System Physics 2. B.Sc. Meteorologie
Exam type and requirements for registration	Module examination: graded oral exam (XX min.) Exam language: English Requirements: consistent active participation in the tutorial
Work load / credit points	Lecture *Climate Physics*: 3 CP Exercises for *Climate Physics*: 3 CP On-campus-study: 60 h Self-study: 90 h Exam preparation: 30 h
Total credit points	6 CP
Duration	1 semester
Frequency of offer	Annually during summer term
Reference semester	6th semester
Contact	Stefan Bühler

ESW-B-RRS Radiation and Remote Sensing

Module type	Required Elective Module
Title	Radiation and Remote Sensing
Course number	ESW-B-RRS
Learning outcomes	Students have a basic knowledge of the essential processes that govern radiative transfer, their significance for the energy budget, and typical optical phenomena that can be explained within the framework of geometric and wave optics. They are familiar with the fundamentals of radiative transfer calculations and have experience in radiative transfer modelling. They possess a basic understanding of common remote sensing techniques and their applications and can assess the potential and limitations of the methods discussed. Additionally, they are familiar with the most important meteorological satellites and their instruments.
Contents	Starting point of the course is the study of the propagation of electromagnetic waves in the clear, hazy, and cloudy atmosphere (refraction, reflection, diffraction, polarization; radiative transfer equation, scattering, absorption, emission), covering the frequency spectrum from the optical to the microwave frequency range. Fundamental relationships between radiative transfer and the atmospheric energy budget (e.g., energy fluxes, average temperature profile, greenhouse effect) as well as implications for optical phenomena (e.g., blue sky, scintillation, rainbow, halo, corona, aureole) are discussed. The most common active and passive remote sensing techniques are introduced, emphasizing that different remote sensing methods are based on specific cases of the radiative transfer equation. Additionally, each lecture includes a brief portrait of a meteorological satellite. The learning content is reinforced through accompanying exercises.
Course type and weakly work hours	Lecture *Radiation and Remote Sensing*: 2 SWS Exercises for *Radiation and Remote Sensing*: 2 SWS (attendance requirement)
Language	English
Prerequisites	Required: None. Recommended: None.
Verwendbarkeit des Moduls	Das Modul ist Bestandteil der Studiengänge/Profile: 1. B.Sc. Earth System Physics 2. B.Sc. Meteorologie
Exam type and requirements for registration	Module examination: Joint written exam (90 min.) Exam language: English Requirements: consistent active participation in the tutorial
Work load / credit points	Lecture *Radiation and Remote Sensing*: 3 CP Exercises for *Radiation and Remote Sensing*: 3 CP On-campus-study: 60 h Self-study: 90 h Exam preparation: 30 h

Total credit points	6 CP
Duration	1 semester
Frequency of offer	Annually during summer term
Reference semester	6^{th} semester
Contact	Stefan Bühler

Crosscutting

ESW-B-Data Data Analysis and Software Development

Module type	Required Elective Module
Title	Data Analysis and Software Development
Course number	ESW-B-Data
Learning outcomes	Students learn how to process scientific data using standard tools and procedures. After completing the course, students will be able to process scientific data in various formats. They will be able to use common software tools and automate tasks in a Linux environment. They will also have acquired basic knowledge of software development methods in earth system sciences. The course also makes it easier for students to join scientific working groups, for example as part of their final thesis.
Contents	The course introduces tools and working methods used in earth system sciences and thus also forms a basis for an introduction to the Fortran programming language. 1. Working on the command line and shell programming to automate tasks. To this end, use of Linux tools and regular expressions. Use of an editor. 2. Data processing based on different data formats. Dealing with the netCDF data format. Processing data with the tools nco and cdo. 3. Basics of software development in earth system sciences. Version control using git, tools for software development. 4. Word processing: introduction to Latex for editing large documents and maintaining a literature database.
Course type and weakly work hours	Lecture *Data Analysis and Software Development*: 2 SWS Exercises for *Data Analysis and Software Development*: 2 SWS (attendance requirement)
Language	English
Prerequisites	Required: Attendance of the module *Physics of the Earth System 1.* Recommended: Successful completion of the module *Physics of the Earth System 1.*
Verwendbarkeit des Moduls	Das Modul ist Bestandteil der Studiengänge/Profile: 1. B.Sc. Earth System Physics

Exam type and requirements for registration	Module examination: completion of exercises or Hausarbeit (pass/fail) Exam language: English Requirements: consistent active participation in the tutorial
Work load / credit points	Lecture *Data Analysis and Software Development*: 3 CP Exercises for *Data Analysis and Software Development*: 3 CP On-campus-study: 60 h Self-study: 90 h Exam preparation: 30 h
Total credit points	6 CP
Duration	1 semester
Frequency of offer	Annually during winter term
Reference semester	3rd semester
Contact	David Grawe, Nuno Serra, Silke Schubert

ESW-B-Fortran Programming in Fortran

Module type	Required Elective Module
Title	Programming in Fortran
Course number	ESW-B-Fortran
Learning outcomes	The course enables students to write their own powerful programs. They acquire basic knowledge of Fortran concepts, structure and syntax. This enables them to process data completely: Creating, modifying, reading in, outputting. Basic mathematical problems can be formulated and solved. In the same way, Fortran program code, which is very extensive (numerical models, global climate models, evaluation programs), can be read and expanded. The acquired knowledge is applied in the processing of scientific questions, for example in the Bachelor's thesis. Learning similar programming languages is also made easier.
Contents	1. Program structure, compiling 2. Data types, branches, loops, fields 3. Input/output, formats 4. Subroutines, modules, intrinsic functions 5. Name lists, structures
Course type and weakly work hours	Lecture *Programming in Fortran*: 2 SWS Exercises for *Programming in Fortran*: 2 SWS (attendance requirement)
Language	English
Prerequisites	Required: None. Recommended: Successful completion of the module *Physics of the Earth System 1;* attendance of the module *Data Analysis and Software Development.*
Verwendbarkeit des Moduls	Das Modul ist Bestandteil der Studiengänge/Profile: 1. B.Sc. Earth System Physics

Exam type and requirements for registration	Module examination: 1. Lecture *Programming in Fortran*: Joint written exam (90 min.) 2. Exercises for *Programming in Fortran*: completion of exercises Exam language: English Requirements: consistent active participation in the tutorial
Work load / credit points	Lecture *Programming in Fortran*: 3 CP Exercises for *Programming in Fortran*: 3 CP On-campus-study: 90 h Self-study: 90 h Exam preparation: 30 h
Total credit points	6 CP
Duration	1 semester
Frequency of offer	Annually during winter term
Reference semester	4th semester
Contact	David Grawe, Nuno Serra, Silke Schubert

ESW-B-CVD Climate Variability and Diagnostics

Module type	Required Elective Module
Title	Climate Variability and Diagnostics
Course number	ESW-B-CVD
Learning outcomes	After successfully completing this module, students have in-depth knowledge that enables them to check the validity of statements about past and future climate variability. They will have gained a thorough understanding of the components of the climate system as well as climate variables and indices. They are also familiar with methods for calculating, observing and simulating these variables. Students will be able to classify findings in the context of natural and anthropogenic climate variability.
Contents	Conceptual consideration of the climate system and its interaction with society, climate variability, climate indices, tools of climate diagnostics, such as fingerprint methods or multivariate regressions Using case studies, students will reflect on the knowledge gained and its uncertainties, especially with regard to past and future climate developments.
Course type and weakly work hours	Lecture *Climate Variability and Diagnostics*: 2 SWS Seminar on *Climate Variability and Diagnostics*: 2 SWS
Language	English
Prerequisites	Required: None.

	Recommended: Successful completion of the module *Ocean and Ice in the Climate System*.
Verwendbarkeit des Moduls	Das Modul ist Bestandteil der Studiengänge/Profile: 1. B.Sc. Earth System Physics
Exam type and requirements for registration	Module examination: Referat, oral exam or written exam (will be announced in the beginning of the corse) Exam language: English
Work load / credit points	Lecture *Climate Variability and Diagnostics*: 3 CP Seminar on *Climate Variability and Diagnostics*: 3 CP On-campus-study: XX h Self-study: XX h Exam preparation: XX h
Total credit points	6 CP
Duration	1 semester
Frequency of offer	Annually during summer term
Reference semester	5th semester
Contact	

ESW-B-XXX Ocean carbon dynamics in the Earth system

ESW-B-XXX Air-Ice-Sea Interaction

This course is offered in conjunction with University Centre in Svalbard.

Module type	Required Elective Module
Title	Air-Ice-Sea Interaction
Course number	ESW-B-XXX
Learning outcomes	Students obtain an understanding of the processes involved in the interaction between sea ice, the ocean and the atmosphere in regions totally or partly covered with sea ice.
Contents	Thermodynamic aspects of freezing and melting of sea ice; the fine-scale structure of sea ice; the formation and deformation of ice-cover caused by thermodynamic processes and influence of wind, currents and wave action; turbulent boundary layer, field work on Arctic sea ice.
Course type and weakly work hours	Lecture *Air-Ice-Sea Interaction*: XX Seminar/tutorial *Air-Ice-Sea Interaction:* XX *Field work Air-Ice-Sea Interaction:* XX
Language	English
Prerequisites	Required: XX. Recommended: XX.

	This module is part of course AGF-211 carried out by the University Centre in Svalbard. The students must apply for AGF-211 directly at the University Centre in Svalbard (http://www.unis.no).
Verwendbarkeit des Moduls	Das Modul ist Bestandteil der Studiengänge/Profile: 1. B.Sc. Earth System Physics 2. M.Sc. Ocean and Climate Physics
Exam type and requirements for registration	As announced by University Centre in Svalbard. Usually combination of report and oral exam. Exam language: English
Work load / credit points	Lecture *Air-Ice-Sea Interaction*: XX Seminar/tutorial *Air-Ice-Sea Interaction:* XX *Field work Air-Ice-Sea Interaction:* XX On-campus-study: XX h Self-study: XX h Exam preparation: XX h
Total credit points	15 CP
Duration	1 semester
Frequency of offer	Annually from January until June
Reference semester	6th semester
Contact	Dirk Notz

ESW-B-ThesisSem Thesis Seminar

Module type	Required Elective Module
Title	Thesis Seminar
Course number	ESW-B-ThesisSem
Learning outcomes	After completing the module, students will have developed a concept for their Bachelor's thesis in reflection on their own work process, agreed with their supervisor. Furthermore, they will be able to present such a concept and other scientific content to an audience in a confident and motivating manner and present it in writing in a concise form. Through intensive literature study and discussions in their working group, they have acquired in-depth knowledge of the oceanographic, meteorological and/or geophysical specialty in which the Bachelor's thesis is to be written.
Contents	Input on in-depth scientific work and the associated work process. Reflection on the work process in individual and group tasks.
Course type and weakly work hours	*Thesis Seminar*: 2 SWS
Language	English
Prerequisites	Required: None. Recommended: None.

Verwendbarkeit des Moduls	Das Modul ist Bestandteil der Studiengänge/Profile: 1. B.Sc. Earth System Physics
Exam type and requirements for registration	Module examination: Referat (pass/fail) Exam language: English Requirements: None.
Work load / credit points	*Thesis Seminar*: 3 CP On-campus-study: XX h Self-study: XX h Exam preparation: XX h
Total credit points	3 CP
Duration	1 semester
Frequency of offer	Every semester
Reference semester	6th semester
Contact	
Note	It is recommended to plan the registration for the final module in the same or the following semester.

Module descriptions: Final Module

ESW-B-ESP-BA Bachelor’s Thesis

Module type	Final Module
Title	Bachelor’s Thesis
Course number	ESW-B-ESP-Thesis
Learning outcomes	Students are able to work independently on a scientific problem in the field of oceanography, meteorology and/or geophysics under supervision and using scientific methods and document it in accordance with scientific standards. They can use literature research to work through the current state of science and, based on this, develop solutions for their research question and implement them under supervision. They are able to present and critically evaluate the results obtained in an appropriate manner.
Contents	Students work under supervision on a research topic of limited scope, which they subsequently work on. The results are documented in writing and with the help of figures and tables. In the process, students learn the techniques of scientific work and develop methodological skills in literature research, the development and documentation of scientific facts in addition to their professional competence.
Course type and weakly work hours	Individual learning
Language	English
Prerequisites	Required: Students who have earned at least 120 credit points and have successfully completed the modules *Mathematics 1*, *Mathematics 2*, *Numerics for Earth System Physics*, *Differential Equations for Earth System Physics*, *Statistics for Earth System Physics* as well as *Physics 1 (Mechanics and Heat Theory)* and *Physics 2 (Electrodynamics and Optics)* may be admitted to the final module *Bachelor's Thesis*. Recommended: None.
Verwendbarkeit des Moduls	Das Modul ist Bestandteil der Studiengänge/Profile: 1. B.Sc. Earth System Physics
Exam type and requirements for registration	Module examination: Bachelor’s thesis (usually 25 to 30 pages)
Work load / credit points	Bachelor’s thesis: 12 CP On-campus-study: 0 h Self-study: 360 h Exam preparation: 0 h
Total credit points	12 CP
Duration	1 semester

Frequency of offer	every semester
Reference semester	6th semester
Contact	