Master of Science in Environmental Physics

Module Guide

University of Bremen
Faculty 1 Physics and Electrical Engineering

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This module guide describes the syllabus of the M.Sc. degree course in Environmental Physics for informational purposes. The legally binding rules are found in the specific examination regulations for the M.Sc. in Environmental Physics.

We attempt to keep this module guide up to date, however, modifications with respect to the personnel and content may occur between editions of this document.

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Module Plan / MSc Environmental Physics

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CP = Credit Points / Sem. = Semester

Abbreviations used in the following module descriptions

CP	Credit points	EC	Example classes
h	Hours	L	Lecture
SWH	Semester weekly hours	Lab	Laboratory
		PS	Proseminar

Remarks:

Module exam: Exam with only one component.
Credit points are granted upon a successful completion of the respective examination(s) of the module.

Combination exam: Exam with several components.
Credit points are granted upon a successful examination performance and a successful course performance.

Partial exam: Exam with several components.
Credit points are granted upon successful examination performance(s) and a successful course performance.

Examination performances are graded.
Course performances are not graded.

Compulsory Modules

Module code	01-01-03-AMMDA
Module title	Applied Mathematical Methods and Data Analysis
Responsible for the module, lecturers	Prof. Dr. Mihalis Vrekoussis
Type of module	Compulsory for MSc Environmental Physics
Programs using the module	Compulsory for MSc Space Sciences and Technologies Compulsory for MSc Space Engineering II Compulsory elective for MSc Physik Elective for MSc Marine Geosciences + MSc Applied Geosciences
Content-related prior knowledge or skills	No formal requirement
Learning contents	The course lectures cover the theoretical and practical basis of the following subject areas: PART A: • Calculus I (Functions, theorems) • Calculus II (Differentiations, applications of derivatives, approximations, errors) • Calculus III (Integrations, applications of integrals) • Calculus IV (Series, convergence, divergence) • Differential equations I (ordinary first, second and higher-order differential equations - ODE) • Differential equations II (partial differential equations - PDE) • Exercises on all the above PART B • Introduction to Python (Installation, build-in functions, arrays, data loading, handling, visualizing) • Hands – on examples (numerical approximations, differential equations)
Learning outcomes/ competencies/ targeted competencies	Introduction to essential and advanced mathematical methods (Part A) and applying these using the Python programming language. In the example classes (part B), students will learn how to apply the taught knowledge, both analytically and numerically. In order to facilitate the latter, students will learn the basics of the Python programming language and how to use Python to solve real-world problems from the course's topic areas.
Semester weekly hours (SWH)	4 SWH / 2x lecture (L) + 2x example classes (EC)
Workload / credit points	6 CP, 180 h • presence (L + EC): 56 h (4 SWH x 14 weeks) • preparation, learning + examples: 56 h (4 SWH x 14 weeks) • preparation for exam: 68 h
Language of instruction	English
Frequency	Winter semester, yearly
Duration	1 semester / winter semester (1st academic year)
Literature	Thomas Calculus 13th or 14th edition (Hass, Heil, Weir) Pearson Mathematical Methods in the Physical sciences (Boas) Wiley
Type of examination / exam components	Module exam Examination performance: Written exam (or as announced by the respective lecturer)

Module code	01-01-03-AtC
Module title	Atmospheric Chemistry
Responsible for the module, lecturers	Prof. Dr. John P. Burrows / Prof. Dr. Annette Ladstätter-Weißenmayer / Prof. Dr. Mihalis Vrekoussis
Type of module	Compulsory for MSc Environmental Physics
Programs using the module	Compulsory elective for MSc Physik
Content-related prior knowledge or skills	No formal requirements
Learning contents	The history and evolution of the composition of the earth's atmosphere; thermodynamics, thermochemistry and chemical equilibria; photochemistry; kinetic theory of reactions and reaction rate coefficients; chain reactions; key atmospheric photochemical and chemical reactions, catalytic cycles and transformations in the thermosphere, mesosphere, stratosphere and the troposphere.
Learning outcomes/ competencies/ targeted competencies	The learning outcomes are that students obtain an adequate knowledge of the following: a) the evolution of the chemical composition of the atmosphere and its origins; b) chemical equilibrium, chemical kinetics, photochemistry, and chain reactions; c) the key photochemical, chemical reactions and mechanisms, which determine chemical composition in the different regions of the atmosphere.
Semester weekly hours (SWH)	4 SWH / 2x lecture (L) + 2x example classes (EC)
Workload / credit points	6 CP, 180 h • presence (L + EC): 56 h (4 SWH x 14 weeks) • preparation, learning + examples: 56 h (4 SWH x 14 weeks) • preparation for exam: 68 h
Language of instruction	English
Frequency	Winter semester, yearly
Duration	1 semester / winter semester (1st academic year)
Literature	• John H. Seinfeld, Spyros N. Pandis Atmospheric Chemistry and Physics: From Air Pollution to Climate Change, 3rd Edition • Finlayson-Pitts B. J. and J. N. Pitts, Atmospheric Chemistry • Ann M. Holloway and Richard P. Wayne, Atmospheric Chemistry, RSC Publishing, 2010 • John M. Wallace and Peter V. Hobbs Atmospheric Science (Second Edition): An Introductory Survey • R.P. Wayne, Chemistry of Atmospheres, third edition, Oxford University Press
Type of examination / exam components	Module exam Examination performance: Written exam (or as announced by the respective lecturer)

Module code	01-01-03-AtPhy
Module title	Atmospheric Physics
Responsible for the module, lecturers	Prof. Dr. John P. Burrows
Type of module	Compulsory for MSc Environmental Physics
Programs using the module	Compulsory for MSc Space Sciences and Technologies Compulsory for MSc Space Engineering II Compulsory elective for MSc Physik Compulsory elective for MSc Physical Geography: Environmental History
Content-related prior knowledge or skills	No formal requirements
Learning contents	The origin of the solar system and the earth's atmosphere; the physical parameters, which determine the conditions in the atmosphere (e.g. temperature, pressure, and vorticity); the physical laws, which describe electromagnetic radiation; the interaction between electromagnetic radiation and matter (absorption, emission and scattering); atmospheric radiative transport; radiation balance, climate change; atmospheric thermodynamics and the hydrological cycle; aerosols and cloud physics; an introduction into atmospheric dynamics (kinematics, circulation etc.)
Learning outcomes/ competencies/ targeted competencies	An adequate understanding of the fundamentals of atmospheric physics. This addresses a) gaining an understanding of the laws of physics, which determine the behaviour of the earth system, which comprises the sun, the atmosphere and earth surface, b) learning the ability to apply the laws of physics to calculate parameters and forecast conditions in the atmosphere. This knowledge is required for subsequent advanced courses in the M.Sc. programme. These learning outcomes provide essential knowledge required for success in the following areas: a) research in the atmospheric, environmental and climate sciences meteorology, earth observation and remote sensing from ground based ship, aircraft and space based instrumentation, b) employment in earth observation, meteorology, and education by industry, governmental and space agencies.
Semester weekly hours (SWH)	4 SWH / 2x lecture (L) + 2x example classes (EC)
Workload / credit points	6 CP, 180 h • presence (L + EC): 56 h (4 SWH x 14 weeks) • preparation, learning + examples: 56 h (4 SWH x 14 weeks) • preparation for exam: 68 h
Language of instruction	English
Frequency	Winter semester, yearly
Duration	1 semester / winter semester (1st academic year)

Literature	• Houghton, J.T., The physics of atmospheres, Cambridge University Press, 1977, ISBN 0 521 29656 0 • Wallace, John M. and Peter V. Hobbs, Atmospheric Science, An Introductory Survey, Academic Press, 2nd Edition 2005, ISBN 0-12-732951-x
Type of examination / exam components	Module exam Examination performance: Written exam (or as announced by the respective lecturer)

Module code	01-01-03-CliS1
Module title	Climate System I
Responsible for the module, lecturers	Prof. Dr. Torsten Kanzow
Type of module	Compulsory for MSc Environmental Physics
Programs using the module	Compulsory elective for MSc Space Sciences and Technologies Compulsory elective for MSc Physik Elective for MSc Marine Geosciences + MSc Applied Geosciences
Content-related prior knowledge or skills	No formal requirements
Learning contents	Climate on earth / climate variations / the climate system / energy balance models / radiation & convection / role of the ocean in climate
Learning outcomes/ competencies/ targeted competencies	Climate physics
Semester weekly hours (SWH)	2 SWH / 1,5x lecture (L) + 0,5x example classes (EC)
Workload / credit points	3 CP, 90 h • presence (L + EC): 28 h (2 SWH x 14 weeks) • preparation, learning + examples: 28 h (2 SWH x 14 weeks) • preparation for exam: 34 h
Language of instruction	English
Frequency	Summer semester, yearly
Duration	1 semester / summer semester (1st academic year)
Literature	Will be announced in the respective course.
Type of examination / exam components	Combination exam Examination performance: Written exam (or as announced by the respective lecturer) Course performance: Portfolio (series of exercise sheets or as announced by the respective lecturer)

Module code	01-01-03-Dyn1
Module title	Dynamics I
Responsible for the module, lecturers	Prof. Dr. Thomas Jung
Type of module	Compulsory for MSc Environmental Physics
Programs using the module	Compulsory elective for MSc Physik Elective for MSc Space Sciences and Technologies
Content-related prior knowledge or skills	No formal requirements
Learning contents	Governing equations, basic conservation laws, balances, elementary applications of the basic equations, circulation and vorticity, planetary boundary layer, Rossby waves
Learning outcomes/ competencies/ targeted competencies	Understanding of the basic dynamical processes in atmosphere and ocean; learning how to interpret physical equations physically
Semester weekly hours (SWH)	4 SWH / 2x lecture (L) + 2x example classes (EC)
Workload / credit points	6 CP, 180 h • presence (L + EC): 56 h (4 SWH x 14 weeks) • preparation, learning + examples: 56 h (4 SWH x 14 weeks) • preparation for exam: 68 h
Language of instruction	English
Frequency	Winter semester; yearly
Duration	1 semester / winter semester (1st academic year)
Literature	• Holton, *An Introduction to Dynamic Meteorology*, Elsevier Academic Press • Marshall and Plumb: *Atmosphere, Ocean, and Climate Dynamics*, *An Introductory Text*, Academic Press, 2008 • Wallace and Hobbs, *Atmospheric Science: An Introductory Survey*, Academic Press
Type of examination / exam components	Module exam Examination performance: Written exam (or as announced by the respective lecturer)

Module code	01-01-03-Dyn2
Module title	Dynamics II
Responsible for the module, lecturers	Prof. Dr. Gerrit Lohmann / Dr. Monica Ionita-Scholz
Type of module	Compulsory for MSc Environmental Physics
Programs using the module	Compulsory elective for MSc Physik
Content-related prior knowledge or skills	No formal requirements
Learning contents	Fluid dynamics, ocean circulation, wind-driven and thermohaline circulation; atmosphere dynamics, dynamical system theory, non-dimensional parameters, bifurcations and instabilities; Gravity, Rossby and Kelvin waves; Conceptual models, Analytical and Programming techniques; Time series analysis
Learning outcomes/ competencies/ targeted competencies	Advanced dynamics of the ocean and atmosphere, applications in the fields of climate dynamics and fluid mechanics. Programming skills (R studio) and usage of the climate data operators. Theoretical concepts in physics of climate, temporal and spatial scales of climate dynamics
Semester weekly hours (SWH)	3 SWH / 2x lecture (L) + 1x example classes (EC)
Workload / credit points	3 CP, 90 h • presence (L + EC): 36 h (3 SWH x 12 weeks) • example classes homework: 32 h (4 SWH x 8 weeks) • repeating the lectures/learning: 12 h (1 SWH x 12 weeks) • additional preparation for exam: 10 h
Language of instruction	English
Frequency	Summer semester, yearly
Duration	1 semester / summer semester (1st academic year)
Literature	• Holton, J.R., Introduction to Dynamical Meteorology, Academic Press • Gill, A., Atmosphere-Ocean Dynamics, Academic Press • Dutton, J.A., The Ceaseless Wind, Dover • Olbers, D.J., et al., Ocean Dynamics, Springer • Cushman-Roisin, B. & Beckers, J.-M., Introduction to Geophysical Fluid Dynamics: Physical and Numerical Aspects
Type of examination / exam components	Combination exam Examination performance: Written exam (or as announced by the respective lecturer) Course performance: Portfolio (series of exercise sheets, calculation on blackboard)

Module code	01-01-03-MeTe
Module title	Measurement Techniques
Responsible for the module, lecturers	PD Dr. Andreas Richter / Dr. Christian Mertens
Type of module	Compulsory for MSc Environmental Physics
Programs using the module	
Content-related prior knowledge or skills	Participation in the university's safety instructions and the fire drill is mandatory before getting access to the laboratories.
Learning contents	A set of practical measurements and computational experiments of meteorological quantities, atmospheric trace gases, ocean currents, ice thickness, and absorption cross-sections using different techniques is performed by the students under supervision of tutors. The measurements and data sets obtained in the lab will then be analysed and the experiment, its background and the results as well as their interpretation be documented in a written report.
Learning outcomes/ competencies/ targeted competencies	Participants will perform measurements in Environmental Physics using scientific techniques and methods. They learn to analyse the measurements and to document the results in a written report.
Semester weekly hours (SWH)	4 laboratory (Lab) + 1 lecture (L)
Workload / credit points	6 CP, 180 h • presence (L): 18 h (6 SWH x 3 weeks) • presence (Lab): 24 h (6 SWH x 4 weeks) • preparation, report: 84 h (12 SWH x 7 weeks) • preparation for exam: 54 h
Language of instruction	English
Frequency	Summer semester, yearly
Duration	1 semester / summer semester (1st academic year)
Literature	Will be announced in the respective course.
Type of examination / exam components	Combination exam Examination performance: Oral exam Course performance: Portfolio (series of successful experiments with accepted reports)

Module code	01-01-03-MES
Module title	Modelling of the Earth System
Responsible for the module, lecturers	Prof. Dr. Gerrit Lohmann / Dr. Silke Thoms / Prof. Dr. Thomas Jung / Prof. Dr. Mihalis Vrekoussis
Type of module	Compulsory for MSc Environmental Physics
Programs using the module	Elective for MSc Marine Geosciences + MSc Applied Geosciences
Content-related prior knowledge or skills	No formal requirements
Learning contents	1) Types of models, linear vs. non-linear, box & complex models 2) Finite differences and spectral methods 3) Examples: waves, diffusion, boundaries 4) Finite Elements and spectral methods (atmosphere and ocean) 5) Model coupling (atmosphere and ocean) 6) Data assimilation (Kalman filters etc) 7) High-performance computing in modelling (scalability) 8) Random Systems (Stochastic equations, Lattice Gases) 9) Cryosphere (Sea ice, ice sheets, and permafrost) 10) Earth system models including tracers and dynamical vegetation 11) Chemistry Transport Models 12) Inverse methods in chemistry
Learning outcomes/ competencies/ targeted competencies	Theoretical concepts of Earth models; Applications
Semester weekly hours (SWH)	2 SWH / 1,5x lecture (L) + 0,5x example classes (EC)
Workload / credit points	3 CP, 90 h • presence (L + EC): 28 h (2 SWH x 14 weeks) • preparation, learning + examples: 28 h • preparation for exam: 34 h
Language of instruction	English
Frequency	Summer semester, yearly
Duration	1 semester / summer semester (1st academic year)
Literature	Will be announced in the respective course.
Type of examination / exam components	Module exam Examination performance: Written exam (or as announced by the respective lecturer)

Module code	01-01-03-PhyO1
Module title	Physical Oceanography I
Responsible for the module, lecturers	Prof. Dr. Monika Rhein / Dr. Reiner Steinfeldt / Dr. Oliver Huhn
Type of module	Compulsory for MSc Environmental Physics
Programs using the module	Compulsory elective for MSc Physik Elective for MSc Marine Geosciences + MSc Applied Geosciences
Content-related prior knowledge or skills	No formal requirements
Learning contents	External forcing (radiation, winds, tides), global distribution of important dynamic and physical parameters, water mass formation, wind-driven 3D circulation, geostrophy, meridional overturning, role of ocean in climate change
Learning outcomes/ competencies/ targeted competencies	Understand fundamentals of physical oceanography
Semester weekly hours (SWH)	4 SWH / 2x lecture (L) + 2x example classes (EC)
Workload / credit points	6 CP, 180 h • presence (L + EC): 56 h (4 SWH x 14 weeks) • preparation, learning + examples: 56 h (4 SWH x 14 weeks) • preparation for exam: 68 h
Language of instruction	English
Frequency	Winter semester, yearly
Duration	1 semester / winter semester (1st academic year)
Literature	Will be announced in the respective course.
Type of examination / exam components	Module exam Examination performance: Written exam (or as announced by the respective lecturer)

Module code	01-01-03-RemS
Module title	Remote Sensing
Responsible for the module, lecturers	Prof. Dr. Astrid Bracher
Type of module	Compulsory for MSc Environmental Physics
Programs using the module	Compulsory elective for MSc Physik Compulsory elective for MSc Physical Geography: Environmental History
Content-related prior knowledge or skills	No formal requirements
Learning contents	The course introduces the theoretical background of remote sensing methods (interaction of electromagnetic radiation with matter (spectroscopy), radiative transfer, principles of satellite remote sensing). Mostly passive (thermal emission, backscattered light) but also Active (radar used in sea ice) remote sensing techniques and their data analysis (retrievals) are explained. This is illustrated by a large number of examples available and in use in the different research groups in the Institute of Environmental Physics (IUP).
Learning outcomes/ competencies/ targeted competencies	Basics of radiative transfer, spectroscopy, retrieval techniques. Overview of remote sensing from satellite, ground and airborne platforms in MW, IR and UV-VIS spectral range. Techniques in atmospheric remote sensing, sea ice remote sensing, ocean color remote sensing
Semester weekly hours (SWH)	2 SWH / 1,5x lecture (L) + 0,5x example classes (EC)
Workload / credit points	3 CP, 90 h • presence (L + EC): 28 h (2 SWH x 14 weeks) • preparation and re-analysing examples: 32 h (3,2 SWH x 10 weeks) • preparation for exam: 30 h
Language of instruction	English
Frequency	Summer semester, yearly
Duration	1 semester / summer semester (1st academic year)
Literature	Will be announced in the respective course.
Type of examination / exam components	Combination exam Examination performance: Written exam (or as announced by the respective lecturer) Course performance: Portfolio (series of exercise sheets or as announced by the respective lecturer)

Module code	01-01-03-PresT
Module title	Presentation Techniques in Environmental Physics
Responsible for the module, lecturers	PD Dr. Andreas Richter
Type of module	Compulsory for MSc Environmental Physics
Programs using the module	
Content-related prior knowledge or skills	No formal requirements
Learning contents	Structure and content of oral presentations, layout and organization of slides, how to give good oral presentations (content, presentation style, body language, …), how to deal with questions and answers, how to prepare a poster for a conference, how to write an extended abstract, how to do a literature research, how to cite and how to use bibliographic software.
Learning outcomes/ competencies/ targeted competencies	How to prepare and give oral presentations, posters, and extended abstracts on topics of Environmental Physics.
Semester weekly hours (SWH)	2 SWH (2 PS)
Workload / credit points	3 CP, 90 h • presence (L): 28 h (2 SWH x 14 weeks) • preparation of two talks: 40 h (20 h/week x 2 weeks) • preparation of one poster / extended abstracts: 22 h
Language of instruction	English
Frequency	Winter semester, yearly
Duration	1 semester / winter semester (2nd academic year)
Literature	Will be announced in the respective course.
Type of examination / exam components	Combination exam Examination performance: 1 poster or 1 extended abstract (4 pages) Course performance: 2 oral presentations (participation in discussion of all presentations)

Module code	01-01-03-PrEPhy
Module title	Preparatory Project
Responsible for the module, lecturers	Prof. Dr. John P. Burrows, Prof. Dr. Justus Notholt, Prof. Dr. Monika Rhein, Prof. Dr. Annette Ladstätter-Weißenmayer, Prof. Dr. Mihalis Vrekoussis, Prof. Dr. Veronika Eyring, Prof. Dr. Christian Haas, Prof. Dr. Thomas Jung, Prof. Dr. Torsten Kanzow, Prof. Dr. Gerrit Lohmann as well as further university lecturers of the IUP (Institute of Environmental Physics) / AWI (Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research) depending on the area of research
Type of module	Compulsory for MSc Environmental Physics
Programs using the module	
Content-related prior knowledge or skills	No formal requirements
Learning contents	The content is related to the respective area of research of the preparatory project.
Learning outcomes/ competencies/ targeted competencies	• Transfer of a scientific problem/question into an experimental and/or theoretical study • Successful strategies for the planning and conducting of scientific studies • Summarize and present preliminary scientific results in a thesis paper
Semester weekly hours (SWH)	Working in the laboratories of the IUP / AWI Individual instruction (practical training) Preparation of a thesis paper on a possible research project which - as a rule - should be closely related to the subsequent Master's Thesis.
Workload / credit points	18 CP, 540 h
Language of instruction	English
Frequency	Winter semester, yearly
Duration	Winter semester (2nd academic year)
Literature	Will be announced by the respective examiners.
Type of examination / exam components	Module exam (graded) • Successful assessment of the preparatory project • Preparation of a thesis paper on a research project which can be conducted within the context of the Master's Thesis • Students have 12 weeks to work on their preparatory project and to prepare the final thesis paper • The thesis paper has to be written in English and by one person alone (not a group). • The thesis paper will be evaluated by two examiners.

Module Master Thesis (incl. Colloquium)

Module code	01-01-03-MTEPhy
Module title	Master Thesis
Responsible for the module, lecturers	Prof. Dr. John P. Burrows, Prof. Dr. Justus Notholt, Prof. Dr. Monika Rhein, Prof. Dr. Annette Ladstätter-Weißenmayer, Prof. Dr. Mihalis Vrekoussis, Prof. Dr. Veronika Eyring, Prof. Dr. Christian Haas, Prof. Dr. Thomas Jung, Prof. Dr. Torsten Kanzow, Prof. Dr. Gerrit Lohmann as well as further university lecturers of the IUP (Institute of Environmental Physics) / AWI (Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research) depending on the area of research
Type of module	Compulsory for MSc Environmental Physics
Programs using the module	
Content-related prior knowledge or skills	As per §6 (2) of the subject-specific examination regulations, 66 CPs and thus passing all the compulsory modules except the module Presentation Techniques in Environmental Physics are required for the registration of the master thesis.
Learning contents	The content is related to the respective area of research of the Master's Thesis.
Learning outcomes/ competencies/ targeted competencies	• Transfer of a scientific problem/question into an experimental and/or theoretical study • Successful strategies for the planning and conducting of scientific studies • Ability for a critical evaluation, assessment and discussion of own scientific results • Summarize and present scientific results in a Master's Thesis
Semester weekly hours (SWH)	Master's Thesis Colloquium to the Master's Thesis
Workload / credit points	30 CP, 900 h
Language of instruction	English
Frequency	Summer semester, yearly
Duration	Summer semester (2nd academic year)
Literature	Will be announced by the respective examiners.
Type of examination / exam components	Module exam (graded) • Successful assessment of the Master's Thesis (graded) • Successful colloquium to the Master's Thesis (graded) • Master's Thesis and colloquium are marked in a common grade; grade master's thesis will be considered with 2/3 and grade for colloquium with 1/3

Elective Modules

Module code	01-01-03-AtCM1
Module title	Atmospheric Chemistry Modelling: Part 1 (Theory)
Responsible for the module, lecturers	Prof. Dr. Mihalis Vrekoussis / Dr. Nikos Daskalakis / Dr. Alexandros Poulidis
Type of module	Elective for MSc Environmental Physics
Programs using the module	Compulsory elective for MSc Space Sciences and Technologies
Content-related prior knowledge or skills	No formal requirements
Learning contents	• Concept of chemistry transport models • Atmospheric Chemical Composition/Processes • Model equations and numerical approaches focusing on the: a) formulation of atmospheric rates b) numerical methods for chemical systems • Surface fluxes/emissions • Observations and model evaluations • Inverse modeling for atmospheric chemistry
Learning outcomes/ competencies/ targeted competencies	Participants will have the chance to: Get a theoretical overview of the concepts of numerical atmospheric chemistry modelling, to review fundamentals of atmospheric chemistry and physics, to formulate model equations and numerical (differential) approaches for various systems focusing on atmospheric chemistry mechanisms and to assess the role of chemistry transport models as components of the atmospheric observing system. Concepts of inverse modelling will be also presented.
Semester weekly hours (SWH)	2 SWH / 1,5x lecture (L) + 0,5x example classes (EC)
Workload / credit points	3 CP, 90 h • presence (L + EC): 28 h (2 SWH x 14 weeks) • preparation, learning + examples: 42 h (3 SWH x 14 weeks) • preparation for exam: 20 h
Language of instruction	English
Frequency	Winter semester, yearly
Duration	1 semester / winter semester
Literature	Will be announced in the respective course.
Type of examination / exam components	Module exam Examination performance: Oral exam (or as announced by the respective lecturer)

Module code	01-01-03-AtCM2
Module title	Atmospheric Chemistry Modelling: Part 2 (Laboratory)
Responsible for the module, lecturers	Prof. Dr. Mihalis Vrekoussis / Dr. Nikos Daskalakis / Dr. Alexandros Poulidis
Type of module	Elective for MSc Environmental Physics
Programs using the module	
Content-related prior knowledge or skills	No formal requirements
Learning contents	• introduction to the moguntia model • explanation input files manipulation and analysis of results • study of interhemispheric transports • study the budget of simulated CO • simulate the growth of CO_2 mixing ratios • simulate the concentrations of methyl chloroform • simulate the methyl-chloroform/OH constrains
Learning outcomes/ competencies/ targeted competencies	Participants will have the chance to: Have a hands-on experience on how atmospheric chemistry models work, prepare the input needed by a model, run the model and process the output of the model in order to come to scientific conclusions
Semester weekly hours (SWH)	2 SWH / 1x lecture (L) + 1x example classes (EC)
Workload / credit points	3 CP, 90 h • presence (L + EC): 28 h (2 SWH x 14 weeks) • preparation, learning + examples: 42 h (3 SWH x 14 weeks) • preparation for exam: 20 h
Language of instruction	English
Frequency	Summer semester, yearly
Duration	1 semester / summer semester
Literature	Will be announced in the respective course.
Type of examination / exam components	Module exam Examination performance: Written exam (or as announced by the respective lecturer)

Module code	01-01-03-AtSp
Module title	Atmospheric Spectroscopy
Responsible for the module, lecturers	Prof. Dr. Justus Notholt
Type of module	Elective for MSc Environmental Physics
Programs using the module	Compulsory for MSc Space Sciences and Technologies
Content-related prior knowledge or skills	No formal requirements
Learning contents	Huygens-principle, interference, prism and grating spectrometers, Fourier-Transform-Spectroscopy, transitions, rotational spectra, vibrational spectra, rotational-vibrational spectra, remote sensing methods
Learning outcomes/ competencies/ targeted competencies	Basics of spectroscopy, basics of molecular spectroscopy. Understanding and interpretation of measured spectra with regard to the structure of the molecules. Basics of prism, grating and FTIR-spectroscopy, understanding of remote sensing methods.
Semester weekly hours (SWH)	2 SWH / 2x lecture (L)
Workload / credit points	3 CP, 90 h • presence (L): 28 h (2 SWH x 14 weeks) • preparation + learning: 28 h (2 SWH x 14 weeks) • preparation for exam: 34 h
Language of instruction	English
Frequency	Summer semester, yearly
Duration	1 semester / summer semester
Literature	Will be announced in the respective course.
Type of examination / exam components	Module exam Examination performance: Written or oral exam (as announced by the respective lecturer)

Module code	01-01-03-BGC
Module title	Biogeochemistry
Responsible for the module, lecturers	Prof. Dr. Annette Ladstätter-Weißenmayer
Type of module	Elective for MSc Environmental Physics
Programs using the module	Compulsory elective for MSc Physik Elective for MSc Space Sciences and Technologies
Content-related prior knowledge or skills	No formal requirements
Learning contents	Global biochemical cycles of elements, important biophysical processes in atmosphere and ocean, carbon-, methane-, nitrogen and water cycle, greenhouse gases
Learning outcomes/ competencies/ targeted competencies	Advanced biogeochemistry
Semester weekly hours (SWH)	2 SWH / 1x lecture (L) + 1x example classes (EC)
Workload / credit points	3 CP, 90 h • presence (L + EC): 28 h (2 SWH x 14 weeks) • preparation, learning + examples: 28 h (2 SWH x 14 weeks) • preparation for exam: 34 h
Language of instruction	English
Frequency	Summer semester, yearly
Duration	1 semester / summer semester
Literature	Will be announced in the respective course.
Type of examination / exam components	Module exam Examination performance: Oral exam (or as announced by the respective lecturer)

Module code	01-01-03-CliM1
Module title	Climate Modelling: Part 1
Responsible for the module, lecturers	Prof. Dr. Veronika Eyring
Type of module	Elective for MSc Environmental Physics
Programs using the module	Compulsory elective for MSc Physik Elective for MSc Space Sciences and Technologies
Content-related prior knowledge or skills	No formal requirements
Learning contents	Introduction to Climate Modelling Types of Climate Models Components of Atmosphere Ocean General Circulation Models (AO-GCMs) Fundamentals and representation in GCMs: Radiation Fundamentals and representation in GCMs: Dynamics of the Atmosphere Fundamentals and representation in GCMs: Ocean and sea ice component Fundamentals and representation in GCMs: Land component Parametrizations in climate models Steps in climate model formulation Frequently Asked Questions IPCC Assessment Reports Introduction to the ICON climate model Computational exercises with the ICON model: running a climate model Computation exercises in Python: plotting ICON model output
Learning outcomes/ competencies/ targeted competencies	Overview how a climate model works and how to set up a climate model simulation (without covering all details); getting some first experience with running a climate model and plotting its output using python
Semester weekly hours (SWH)	Block course(corresponding to 2 SWH / 1,5x lecture (L) + 0,5x example classes (EC)
Workload / credit points	3 CP, 90 h • presence (L + EC): 28 h (block course 5 days) • preparation, learning + examples: 42 h • preparation for exam: 20 h
Language of instruction	English
Frequency	Summer semester, yearly
Duration	1 semester / summer semester
Literature	Will be announced in the respective course.
Type of examination / exam components	Module exam Examination performance: Written exam or oral exam (as announced by the respective lecturer)

Module code	01-01-03-CliM2
Module title	Climate Modelling: Part 2
Responsible for the module, lecturers	Prof. Dr. Veronika Eyring
Type of module	Elective for MSc Environmental Physics
Programs using the module	Compulsory elective for MSc Physik
Content-related prior knowledge or skills	Climate Modelling: Part 1
Learning contents	Components of Earth System Models (ESMs) Fundamentals and representation in ESMs: carbon cycle Fundamentals and representation in ESMs: atmospheric chemistry Fundamentals and representation in ESMs: aerosols Earth system model evaluation with observations Earth system feedbacks and projections Understanding and modelling the Earth System with Machine Learning Computational exercises with the Earth System Model Evaluation Tool (ESMValTool, http://www.esmvaltool.org/) and interpretation of ESM results Computational exercises hands-on Machine Learning
Learning outcomes/ competencies/ targeted competencies	Overview how an Earth system model works and learn about results of current models regarding climate change; first experience how to analyse Earth system model output with the ESMValTool and how to use machine learning techniques to better understand and model the Earth system
Semester weekly hours (SWH)	Block course (corresponding to 2 SWH / 1,5x lecture (L) + 0,5x example classes (EC)
Workload / credit points	3 CP, 90 h • presence (L + EC): 28 h (block course 5 days) • preparation, learning + examples: 42 h • preparation for exam: 20 h
Language of instruction	English
Frequency	Winter semester, yearly
Duration	1 semester / winter semester
Literature	Will be announced in the respective course.
Type of examination / exam components	Module exam Examination performance: Written exam or oral exam (as announced by the respective lecturer)

Module code	01-01-03-CliS2
Module title	Climate System II
Responsible for the module, lecturers	Prof. Dr. Gerrit Lohmann / Dr. Martin Werner
Type of module	Elective for MSc Environmental Physics
Programs using the module	
Content-related prior knowledge or skills	No formal requirements
Learning contents	Climate models, possibilities and limitations to observe climate change, ice ages and orbital variations, Holocene, glacial-interglacial variability; Cenozoic climate, abrupt climate change; climate scenarios, sea level, environmental archives, paleoclimate data, biogeochemical cycles, feedbacks; Spectra and time series analysis; Modes of variability
Learning outcomes/ competencies/ targeted competencies	Advanced climate course: Theories, models, observations. Past-present-future climate changes
Semester weekly hours (SWH)	2 SWH / 2x lecture (L)
Workload / credit points	3 CP, 90 h • presence (L): 28 h (2 SWH x 14 weeks) • preparation + learning: 42 h (3 SWH x 14 weeks) • preparation for exam: 20 h
Language of instruction	English
Frequency	Winter semester, yearly
Duration	1 semester / winter semester
Literature	• Bradley, Paleoclimatology-Reconstructing climates of the Quaternary, 1999 • Saltzman, Dynamical Paleoclimatology - A generalized theory of global climate change, Academic Press, San Diego, 2002 • Ruddiman, Earth's Climate Past and Future • Paleoclimate, Global Change and the Future, 2003 by Keith D. Alverson, Raymond S. Bradley, Thomas F. Pedersen (Editors) • Archer & Pierrehumbert, The Warming Papers, The Scientific Foundation for the Climate Change Forecast https://www.ipcc.ch/documentation/ https://paleodyn.uni-bremen.de/gl/climate.html
Type of examination / exam components	Module exam Examination performance: Oral exam

Module code	01-01-03-DIP
Module title	Digital Image Processing
Responsible for the module, lecturers	Dr. Gunnar Spreen / Dr. Christian Melsheimer
Type of module	Elective for MSc Environmental Physics
Programs using the module	Compulsory for MSc Space Sciences and Technologies
Content-related prior knowledge or skills	No formal requirements
Learning contents	• Digital images, sampling • Grey level transformations, color images • Image enhancement using filters • Image analysis methods using segmentation, feature extraction and classification • Fourier transformation of digital images, linear filters in spatial and frequency domains • Data compression, image coding, image formats
Learning outcomes/ competencies/ targeted competencies	Fundamentals, basic concept and methods of digital image processing, enabling the students to identify and understand image processing problems (encountered in Environmental Physics, Space Science etc.) and to find appropriate solutions
Semester weekly hours (SWH)	2 SWH / 1,5x lecture (L) + 0,5x example classes (EC)
Workload / credit points	3 CP, 90 h • presence (L + EC): 28 h (2 SWH x 14 weeks) • preparation, learning + examples: 28 h (2 SWH x 14 weeks) • preparation for exam: 34 h
Language of instruction	English
Frequency	Summer semester, yearly
Duration	1 semester / summer semester
Literature	• K. R. Castleman: Digital Image Processing. Prentice Hall, Englewood Cliffs, 1996. • R. C. Gonzalez, R. E. Woods: Digital Image Processing. Addison-Wesley, Second Edition, 2002. • B. Jähne: Digital Image Processing. Springer, 2002. • J.C. Russ: The Image Processing Handbook, 5th Edision. CRC Press, 2006 (ISBN 0-8493-7254-2). • R. A. Schowengerdt: Remote Sensing, Models and Methods for Image Processing. Academic Press, 1997.
Type of examination / exam components	Combination exam Examination performance: Written exam (or as announced by the respective lecturer) Course performance: Portfolio (series of exercise sheets or as announced by the respective lecturer)

Module code	01-01-03-FES
Module title	Fortran for Environmental Sciences
Responsible for the module, lecturers	Dr. Nikos Daskalakis
Type of module	Elective for MSc Environmental Physics
Programs using the module	
Content-related prior knowledge or skills	No formal requirements
Learning contents	• Introduction to programming languages and differences between compiled/interpreted languages • Flow charts and their use in coding • Structure of a serial FORTRAN code • Implicitly, variables, intrinsic functions • Input/output of a program • Loops in coding and their use • Logical statements • Subroutines • READ-WRITE-PRINT-FORMAT
Learning outcomes/ competencies/ targeted competencies	Participants will have the chance to: Learn the basic structure and rules of FORTRAN and apply this knowledge in computing complex environmentally relevant systems.
Semester weekly hours (SWH)	2 SWH / 1x lecture (L) + 1x example classes (EC)
Workload / credit points	3 CP, 90 h • presence (L + EC): 28 h (2 SWH x 14 weeks) • preparation, learning + examples: 42 h (3 SWH x 14 weeks) • preparation for exam: 20 h
Language of instruction	English
Frequency	Summer semester, yearly
Duration	1 semester / summer semester
Literature	Will be announced in the respective course.
Type of examination / exam components	Module exam Examination performance: Oral exam (successful assessment of an environmental problem using programming or as announced by the respective lecturer)

Module code	01-01-03-FVTT
Module title	Fundamentals of Volcanology and Tephra Transport
Responsible for the module, lecturers	Dr. Alexandros Poulidis
Type of module	Elective for MSc Environmental Physics
Programs using the module	
Content-related prior knowledge or skills	No formal requirements
Learning contents	Introduction to volcanology The volcanic system Magma composition and types of eruptive activity Volcanic plumes and volcanic hazards Volcanic emissions transport and deposition Introduction to tephra observation and modelling Tephra ground deposits Tephra morphology and aggregation Airborne tephra observations Volcanic ash and the climate Volcanic gas emissions Operational aspects of volcanology Operational tephra monitoring and forecasting Volcanic hazard and risk assessment Lab - Numerical modelling techniques Modelling volcanic plumes Modelling tephra transport Source parameter estimation techniques
Learning outcomes/ competencies/ targeted competencies	Students will develop an understanding of fundamental concepts in volcanology and get hands-on experience with applied modelling. The module will give students relevant skills that will allow them to look for employment opportunities in volcano observatories, airports, and volcanic ash advisory centres around the world.
Semester weekly hours (SWH)	2 SWH / 1x lecture (L) + 1x example classes (EC)
Workload / credit points	3 CP, 90 h • presence (L + EC): 28 h (2 SWH x 14 weeks) • preparation, learning + examples: 28 h (2 SWH x 14 weeks) • preparation for exam: 34 h
Language of instruction	English
Frequency	Winter semester, yearly
Duration	1 semester / winter semester
Literature	[Introductory Reading] Fundamentals of Physical Volcanology, Parfitt and Wilson, 2008 [Main] Volcanic Ash Hazard Observations, Mackie et al, 2016 [Extra Reading] The Encyclopedia of Volcanoes, Houghton et al, 1999
Type of examination / exam components	Combination exam Examination performance: 1 essay Course performance: 1 oral presentation

Module code	01-01-03-GCC
Module title	Global Carbon Cycle
Responsible for the module, lecturers	Dr. Christoph Völker
Type of module	Elective for MSc Environmental Physics
Programs using the module	Compulsory elective for MSc Physik Compulsory elective for MSc Physical Geography: Environmental History
Content-related prior knowledge or skills	No formal requirements
Learning contents	• Working of the natural and anthropogenic greenhouse effect • Existence and magnitude of the different reservoirs of carbon in the earth system, and their role on different climatic time-scales • role of carbon in the chemistry of the ocean and in setting its pH • changes in the carbon cycle over glacial-interglacial cycles • carbon isotopes as tool to understand the cycling of carbon • influence of weathering and volcanism on the carbon cycle over geological time-scales
Learning outcomes/ competencies/ targeted competencies	Knowledge of the different carbon reservoirs on earth, and their role on different timescales, from current to geological. Understanding that the cycling of carbon between those reservoirs is related to global climate by a number of feedbacks.
Semester weekly hours (SWH)	2 SWH / 2x lecture (L)
Workload / credit points	3 CP, 90 h • presence (L): 28 h (2 SWH x 14 weeks) • preparation + learning: 28 h (2 SWH x 14 weeks) • preparation for exam: 34 h
Language of instruction	English
Frequency	Winter semester, yearly
Duration	1 semester / winter semester
Literature	• Principles of Planetary Climate: Raymond Pierrehumbert • Ocean Biogeochemical Dynamics: Jorge L. Sarmiento & Nicolas Gruber • Earth's Climate: Past and Future: William F. Ruddiman
Type of examination / exam components	Module exam Examination performance: Oral exam (or as announced by the respective lecturer)

Module code	01-01-03-IMBRS
Module title	Ice Mass Balance and Remote Sensing
Responsible for the module, lecturers	Prof. Dr. Christian Haas
Type of module	Elective for MSc Environmental Physics
Programs using the module	
Content-related prior knowledge or skills	No formal requirements • Fitness for mountain hikes of 4-5 hours and 1000 m elevation gain, with heavy backpack. • Some experience with outdoor activities in exposed rock and ice alpine environment
Learning contents	• Glacier mass balance • Measurements of radiation balance • Snow pit studies of snow properties • Surface elevation measurements with laser scanner and drone • Optical and radar remote sensing of glaciers
Learning outcomes/ competencies/ targeted competencies	• Understanding of energy and surface mass balance of ice and snow • Understanding of optical and radar remote sensing of ice and snow • Acquisition and analysis of geocoded data
Semester weekly hours (SWH)	Block/Field course (corresponding to 2 SWH)
Workload / credit points	3 CP, 90 h • presence (L + EC): 80 h (field course 48 h + data processing/analysis 32 h) • final report: 10 h
Language of instruction	English
Frequency	Summer semester, yearly
Duration	1 semester / summer semester
Literature	• Cuffey&Patterson, Physics of Glaciers, 2010 • Bamber&Payne, Mass Balance of the Cryosphere, 2004 • Lubin&Massom, Polar Remote Sensing, 2006 • http://glaziologie.de/vernagt/vernagt.html More will be announced in the respective course
Type of examination / exam components	Combination exam Examination performance: Preparation of final report (participation in the field course is mandatory for taking the exam). Course performance: Data processing and analysis

Module code	01-01-03-ITE
Module title	Instrumental Techniques for Environmental Measurements
Responsible for the module, lecturers	Prof. Dr. Mihalis Vrekoussis
Type of module	Elective for MSc Environmental Physics
Programs using the module	Compulsory elective for MSc Physik
Content-related prior knowledge or skills	No formal requirements
Learning contents	Theoretical aspects on analytical methods including spectroscopic and chromatographic techniques. Introduction to the principle of operation and design of instruments used in environmental analysis.
Learning outcomes/ competencies/ targeted competencies	Students are expected to enhance their knowledge on the theoretical aspects, design and operation of a number of instruments used in environmental analysis. Ultimately, students will improve their analytical thinking by recognizing and understanding the advantages and disadvantages of the environmental instrumental methods to be used depending on the material under investigation.
Semester weekly hours (SWH)	2 SWH / 1x lecture (L) + 1x example classes (EC)
Workload / credit points	3 CP, 90 h • presence (L + EC): 28 h (2 SWH x 14 weeks) • preparation, learning + examples: 28 h (2 SWH x 14 weeks) • preparation for exam: 34 h
Language of instruction	English
Frequency	Summer semester, yearly
Duration	1 semester / summer semester
Literature	Quantitative chemical analysis, 9th edition, (Daniel. C. Harris)
Type of examination / exam components	Module exam Examination performance: Written exam (or as announced by the respective lecturer)

Module code	01-01-03-IEPhy
Module title	Isotopes in Environmental Physics
Responsible for the module, lecturers	PD Dr. Thorsten Warneke / Dr. Alexandra Klemme
Type of module	Elective for MSc Environmental Physics
Programs using the module	Compulsory elective for MSc Physical Geography: Environmental History
Content-related prior knowledge or skills	No formal requirements
Learning contents	Stable and radioactive isotopes, Isotopic fractionation: Processes and examples for their occurence in the environment, Radioactive decay and emitted radiation, Measurements of isotopic composition, Examples for the use of isotopes (Source characterization, Paleoclimatology)
Learning outcomes/ competencies/ targeted competencies	Understanding isotopic fractionation, radiactive decay and the use of isotopes in paleoclimatology and for source characterization
Semester weekly hours (SWH)	2 SWH / 1x lecture (L) + 1x example classes (EC)
Workload / credit points	3 CP, 90 h • presence (L + EC): 28 h (2 SWH x 14 weeks) • preparation, learning + examples: 28 h (2 SWH x 14 weeks) • preparation for exam: 34 h
Language of instruction	English
Frequency	Summer semester, yearly
Duration	1 semester / summer semester
Literature	Will be announced in the respective course.
Type of examination / exam components	Combination exam Examination performance: Oral exam (or as announced by the respective lecturer) Course performance: 1 presentation (or as announced by the respective lecturer)

Module code	01-01-03-MaMCS
Module title	Mathematical Modelling of Complex Systems
Responsible for the module, lecturers	Dr. Silke Thoms
Type of module	Elective for MSc Environmental Physics
Programs using the module	
Content-related prior knowledge or skills	No formal requirements
Learning contents	Steps in the development of mathematical/computational techniques originated from the emerging interdisciplinary field of complex systems science to get insight into the function of the complex environmental systems. Basic computational techniques: • solution of static and discrete/continuous-time models • methods to solve continuous-field models • mean-field approximation and cellular automata • networks and agent-based models
Learning outcomes/ competencies/ targeted competencies	Ability to understand and analyse mathematical models for complex systems from selected fields in the natural and earth sciences (e.g. phase transitions and pattern formation, systems biology and ecology, biogeochemistry and oceanography).
Semester weekly hours (SWH)	2 SWH / 1x lecture (L) + 1x example classes (EC)
Workload / credit points	3 CP, 90 h • presence (L + EC): 28 h (2 SWH x 14 weeks) • preparation, learning + examples: 28 h (2 SWH x 14 weeks) • preparation for exam: 34 h
Language of instruction	English
Frequency	Summer semester, yearly
Duration	1 semester / summer semester
Literature	• Numerical Recipes: William H. Press, Saul Teukolsky, William T. Vetterling and Brian P. Flannery
Type of examination / exam components	Module exam Examination performance: Oral exam (or as announced by the respective lecturer)

Module code	01-01-03-MRS
Module title	Microwave Remote Sensing
Responsible for the module, lecturers	Dr. Gunnar Spreen / Dr. Christian Melsheimer
Type of module	Elective for MSc Environmental Physics
Programs using the module	
Content-related prior knowledge or skills	No formal requirements
Learning contents	• Microwaves: Definition, physical quantities to describe them • Microwave antennas, working principle of radiometers and radars • Interaction of microwaves with the atmosphere and the earth surface, radiative transfer • Retrieval of geophysical parameters from microwave measurements • Current microwave instruments and satellites
Learning outcomes/ competencies/ targeted competencies	Knowledge of basic concepts and methods of microwave remote sensing, enabling the students to appropriately deal with microwave remote sensing data, understand and interpret them
Semester weekly hours (SWH)	2 SWH / 1,5x lecture (L) + 0,5x example classes (EC)
Workload / credit points	3 CP, 90 h • presence (L + EC): 28 h (2 SWH x 14 weeks) • preparation, learning + examples: 28 h (2 SWH x 14 weeks) • preparation for exam: 34 h
Language of instruction	English
Frequency	Winter semester, yearly
Duration	1 semester / winter semester
Literature	• Elachi, C., and J. van Zyl: Introduction to the physics and techniques of remote sensing. Wiley – Interscience, second edition, ISBN 978-0-471-47569-9, 552 pages, 2006. • C. Mätzler, editor. Thermal Microwave Radiation: Applications for Remote Sensing, volume 52 of IET Electromagnetic Wave Series. Institution of Engineering and Technology, Stevenage, Hertfordshire, UK, ISBN 0-86341-573-3 / 978-086341-573-9, 2006. • Woodhouse, I.H.: Introduction to Microwave Remote Sensing. CRC Press, Taylor & Francis Group, 2006. • Janssen, M.A. (ed.): Atmospheric Remote Sensing by Microwave Radiometry, Wiley & Sons, 1993. • Ulaby, F. T, R.K. Moore, A.K. Fung: Microwave Remote Sensing, Active and Passive. Vol. 1: Microwave Remote Sensing Fundamentals and Radiometry; Vol. 2: Radar Remote Sensing and Surface Scattering and Emission Theory; Vol. 3: From Theory to Applications. *Artech House,* 1981 (Vol. 1), 1982 (Vol. 2), 1986 (Vol. 3).
Type of examination / exam components	Combination exam Examination performance: Oral exam (or as announced by the respective lecturer) Course performance: Portfolio (series of exercise sheets or as announced by the respective lecturer)

Module code	01-01-03-OOOC
Module title	Ocean Optics and Ocean Color Remote Sensing
Responsible for the module, lecturers	Prof. Dr. Astrid Bracher
Type of module	Elective for MSc Environmental Physics
Programs using the module	
Content-related prior knowledge or skills	No formal requirements
Learning contents	First, the course covers the principles of ocean optics. Topics included are basic physics of light and interaction of light with matter in water. This includes the theory behind inherent and apparent optical properties and the, radiative transfer equation, e.g., the light field within the ocean is explained and the water-leaving radiance and remote-sensing reflectance terms are introduced. The effect of the various seawater constituents' (absorption, scattering, fluorescence) on ocean reflectance is presented. Optical instrumentation and measurement techniques to measure the relevant parameters are introduced. Secondly, the lecture focuses on ocean color remote sensing. This includes the principles of ocean color remote sensing, an overview of the technology of the instruments commonly used as ocean color satellite sensors and their satellite platforms. But also the streams of the data processing from raw data to the final geophysical product. Especially explained are various atmospheric correction methods and retrieval techniques of ocean color data products, such as phytoplankton biomass, phytoplankton photosynthetic activity, major phytoplankton groups, other particulates, coloured disolved organic matter and light penetration depth. Finally, also validation techniques of ocean color data products and the application of these data in global ecosystem and climate studies and marine and coastal management are presented.
Learning outcomes/ competencies/ targeted competencies	Basics of radiative transfer in water (inherent and apparent optical properties) and ocean color remote sensing, ocean optics measurement techniques, atmospheric correction, empirical, semi-analytical, neural network retrieval techniques to determine water constituents and radiation in the water, validation of algorithms and sensors and potential of such data for application in ecosystem and climate studies and marine and coastal management.
Semester weekly hours (SWH)	2 SWH / 1,5x lecture (L) + 0,5x example classes (EC)
Workload / credit points	3 CP, 90 h • presence (L + EC): 28 h (2 SWH x 14 weeks) • preparation for rapport: 29 h • preparation for exam: 33 h
Language of instruction	English
Frequency	Winter semester, yearly

Duration	1 semester / winter semester
Literature	• C. D. Mobley „Light and Water“, 1994 • J. T. O. Kirk „Light and Photosynthesis in Aquatic Ecosystems“, 1994 • S. Martin “An Introduction to Ocean Remote Sensing“, 2008 • Ocean Optics Webbook: http://www.oceanopticsbook.info/ • 2016 IOCCG Summer Lecture Series - lectures: http://www.ioccg.org/training/lectures.html
Type of examination / exam components	Combination exam Examination performance: Written or oral exam (as announced by the respective lecturer) Course performance: 1 rapport on one lecture and lab tour (or as announced by the respective lecturer)

Module code	01-01-03-PhyO2
Module title	Physical Oceanography II
Responsible for the module, lecturers	Prof. Dr. Monika Rhein
Type of module	Elective for MSc Environmental Physics
Programs using the module	Compulsory elective for MSc Physik Elective for MSc Marine Geosciences + MSc Applied Geosciences
Content-related prior knowledge or skills	No formal requirements
Learning contents	The topics of the lecture vary and will be announced at the start of the lecture. Topics include ocean change and impact on climate, more insight in climate relevant processes (large and small scale), method development, air - sea interactions.
Learning outcomes/ competencies/ targeted competencies	Insightful knowledge of processes important for climate role of ocean
Semester weekly hours (SWH)	2 SWH / 1x lecture (L) + 1x example classes (EC)
Workload / credit points	3 CP, 90 h • presence (L + EC): 28 h (2 SWH x 14 weeks) • preparation, learning + examples: 28 h (2 SWH x 14 weeks) • preparation for exam: 34 h
Language of instruction	English
Frequency	Summer semester, yearly
Duration	1 semester / summer semester
Literature	Will be announced in the respective course.
Type of examination / exam components	Module exam Examination performance: Written or oral exam (as announced by the respective lecturer)

Module code	01-01-03-PoOc
Module title	Polar Oceanography
Responsible for the module, lecturers	Prof. Dr. Torsten Kanzow
Type of module	Elective for MSc Environmental Physics
Programs using the module	
Content-related prior knowledge or skills	No formal requirements
Learning contents	Discussion of scientific papers regarding aspects of polar oceanography. Topics may include • Properties of cold sea water, sea ice formation, ocean – sea ice interaction, • Arctic Ocean circulation and water mass formation, • Southern Ocean circulation and water mass formation, • Ocean – ice shelf interaction
Learning outcomes/ competencies/ targeted competencies	• Introduction to polar oceanography • Paper reading skills • Development and judgement of scientific arguments
Semester weekly hours (SWH)	2 SWH / 1,5x lecture (L) + 0,5x example classes (EC)
Workload / credit points	3 CP, 90 h • presence (L + EC): 28 h (2 SWH x 14 weeks) • preparation, learning + examples: 28 h (2 SWH x 14 weeks) • preparation for exam: 34 h
Language of instruction	English
Frequency	Summer semester, yearly
Duration	1 semester / summer semester
Literature	Will be announced in the respective course.
Type of examination / exam components	Combination exam Examination performance: Oral exam (or as announced by the respective lecturer) Course performance: Portfolio (discussion of research papers or series of exercise sheets)

Module code	01-01-03-PPO
Module title	Practical Physical Oceanography
Responsible for the module, lecturers	Prof. Dr. Torsten Kanzow / Dr. Wilken-Jon von Appen
Type of module	Elective for MSc Environmental Physics
Programs using the module	Compulsory elective for MSc Physik
Content-related prior knowledge or skills	No formal requirements
Learning contents	The students will join the research vessel Heincke in Helgoland. During day trips in the North Sea around Helgoland the instructors will first demonstrate the usage of oceanographic measurement equipment. The students will subsequently handle the equipment themselves under supervision. Technically, this includes: software preparation, equipment preparation, decision regarding sampling strategy, hardware demobilization, data recovery, data conversion, data analysis. The investigated topics include: • Ocean stratification and water masses based in hydrographic measurements; • Ocean circulation based on ocean current measurements (underway + mooring); • Ocean forcing: Meteorological measurements; • Ocean surface processes: Underway surface measurements; • Biological sampling
Learning outcomes/ competencies/ targeted competencies	• Familiarity with modern way of performing observations from a research vessel. • Organization of field work including interdependence of different physical oceanographic and interdisciplinary measurement techniques. • Skills regarding data acquisition, analysis, and interpretation. • Skills with reporting on field work.
Semester weekly hours (SWH)	Block/Field course (corresponding to 2 SWH)
Workload / credit points	3 CP, 90 h • presence (L + EC): 45 h (field course 40 h + 5 h preparatory seminar) • postprocessing / protocol writing: 20 h • preparation for exam: 25 h
Language of instruction	English
Frequency	Summer semester, yearly
Duration	1 semester / summer semester
Literature	Will be announced in the respective course.
Type of examination / exam components	Combination exam Examination performance: Preparation of final report/essay (participation in the field course is mandatory for taking the exam). Course performance: Processing of a task incl. presentation of results

Elective Modules / Course Offers from other M.Sc. Programmes

Module code	01-29-03-RSOC
Module title	Remote Sensing of Ocean and Cryosphere
Responsible for the module, lecturers	Dr. Gunnar Spreen, Prof. Dr. Astrid Bracher, Prof. Dr. Christian Haas, Dr. Ilaria Stendardo
Type of module	Elective for MSc Environmental Physics
Programs using the module	MSc Space Sciences and Technologies
Content-related prior knowledge or skills	No formal requirements
Learning contents	• Concepts for satellite remote sensing of the ocean and cryosphere • Microwave radar and radiometer observations of sea and land ice and of sea surface temperature and salinity • Altimetry for sea surface height, circulation, sea level and ice thickness change • Optical satellite data for ocean color and sea ice • Error analysis and statistics • Practical examples and applications to use satellite data sets from oceanography and cryosphere • Satellite data processing A list of references will be provided at the start of the semester.
Learning outcomes/ competencies/ targeted competencies	Students gain knowledge in basics and application of remote sensing of sea ice extent, type, drift and thickness, ice shelves and glaciers, sea surface height, winds over the ocean, waves, ocean color, surface temperature and salinity, sea level rise, ocean color and other remote sensing applications for ocean and cryosphere.
Semester weekly hours (SWH)	4 SWH / 2x lecture (L) + 2x example classes (EC)
Workload / credit points	6 CP, 180 h • presence (L + EC): 56 h (4 SWH x 14 weeks) • preparation, learning + examples: 56 h (4 SWH x 14 weeks) • preparation of reports: 68 h (17h x 4 reports)
Language of instruction	English
Frequency	Summer semester, yearly
Duration	1 semester / summer semester
Literature	Will be announced in the respective course.
Type of examination / exam components	Partial exam Examination performance: Written examination by submitting reports Course performance: Successful assessment of exercise reports

Module code	05-MMG-CC2-1 (in MSc Marine Geosciences part of 05-MMG-CC2)
Module title	Abrupt, Past and Future Climate Changes (in MSc Marine Geosciences part of Climate Change II: Models and Data)
Responsible for the module, lecturers	Dr. André Paul, Dr. Stefan Mulitza, Prof. Dr. Michael Schulz
Type of module	Elective for MSc Environmental Physics
Programs using the module	MSc Marine Geosciences
Content-related prior knowledge or skills	No formal requirements for PEP students
Learning contents	This course introduces to the reconstruction and modeling of abrupt climate changes, provides an overview of paleo and historical climate changes (from the role of oceanic gateways in the Cenozoic through Pleistocene climate cycles to natural climate variability during the Holocene) and presents an outlook on future climate changes in response to projected anthropogenic climate forcings. Available evidence for past climate changes (from ice and marine sediment cores) as well as current climate change (from historical and instrumental data) is discussed. Computer lab exercises with conceptual climate models and results of comprehensive climate models are used throughout to investigate the processes that cause those climate changes.
Learning outcomes/ competencies/ targeted competencies	▪ to become familiar with the reconstructed climate variations for selected time intervals of the Cenozoic ▪ to gain an understanding of the dynamics of abrupt climate changes ▪ to become able to assess the respective roles of natural and anthropogenic climate variations in past and future climate changes
Semester weekly hours (SWH)	5 SWH / 2,5x lecture (L) + 2,5x example classes (EC)
Workload / credit points	6 CP, 180 h ▪ presence (L + EC): 70 h (5 SWH x 14 weeks) ▪ preparation, learning + examples: 56 h ▪ preparation for exam: 54 h
Language of instruction	English
Frequency	Summer semester, yearly
Duration	1 semester / summer semester
Literature	Alley et al.: Abrupt Climate Change: Inevitable Surprises. National Academy Press, Washington, DC, 238 pp., 2002 Ruddiman, W.F.: Earth's climate: past and future. W.H. Freeman, 3rd revised edition, 464 p., 2013
Type of examination / exam components	Module exam Examination performance: Oral exam

Module code	08-M27-1-EA1-1 (in MSc Physical Geography: Environmental History part of PG-EA)
Module title	Lakes and lacustrine sediments (in MSc Physical Geography: Environmental History part of Lacustrine Environmental Archives I)
Responsible for the module, lecturers	Dr. Christian Ohlendorf / Dr. Catalina Gebhardt
Type of module	Elective for MSc Environmental Physics
Programs using the module	MSc Physical Geography: Environmental History
Content-related prior knowledge or skills	No formal requirements
Learning contents	▪ Introduction into lake systems ▪ Basics of limnology ▪ Field and laboratory tools in limnogeology ▪ Particle dynamics and processes in lakes ▪ Imaging of the lake floor and the sediments ▪ Lake sediments as paleoclimate archives ▪ Different proxies in lake sediments and basic statistics ▪ Dating methods and age model generation ▪ Case studies of different lake systems
Learning outcomes/ competencies/ targeted competencies	The students will obtain knowledge about ▪ abiotic and biotic processes of sediment formation in lakes ▪ lake sediments as paleoclimate and paleoenvironmental archives
Semester weekly hours (SWH)	2 SWH / 2x lecture (L)
Workload / credit points	3 CP, 90 h ▪ 28 h lecture ▪ 37 h self-revision of lectures and additional complementary material ▪ 25 h study time for the final exam
Language of instruction	English
Frequency	Winter semester, yearly
Duration	1 semester / winter semester

Literature	▪ Bradley R.S. 2015. Paleoclimatology: reconstructing climates of the quaternary. Academic Press, Elsevier, Amsterdam [u. a.], 675 pp. ▪ Cohen, A.S., 2003: Paleolimnology: The History and Evolution of Lake Systems. Oxford University Press, USA, 485 pp ▪ Developments in Paleoenvironmental Research. Series Editor: Smol, J.P. (several specialised volumes) ▪ Håkanson L. and Jansson M. 1983. Principles of Lake Sedimentology. Springer, Berlin, Heidelberg, New York, Tokyo, 313 pp. ▪ Wetzel R.G. 2001. Limnology: lake and river ecosystems. 3rd ed., Acad. Press, San Diego, Calif, [u.a.] 1006 pp.
Type of examination / exam components	Module exam Examination performance: Written exam

Module code	08-M27-2-CL2-2 (in MSc Physical Geography: Environmental History part of PG-CL2)
Module title	Sea-level Change (in MSc Physical Geography: Environmental History part of Climatology II)
Responsible for the module, lecturers	Prof. Dr. Benjamin Marzeion
Type of module	Elective for MSc Environmental Physics
Programs using the module	MSc Physical Geography: Environmental History
Content-related prior knowledge or skills	No formal requirements for PEP students
Learning contents	Sea-level Change: ▪ steric and dynamic sea-level change ▪ exchange of mass with glaciers, ice sheets, and terrestrial water reservoirs; associated gravitational, rotational, tectonic effects ▪ tides and storm surges ▪ erosion, transportation, and sedimentation in coastal environments ▪ methods of sea-level reconstruction and projection
Learning outcomes/ competencies/ targeted competencies	▪ The students understand processes and mechanisms responsible for global mean and regional sea-level change on multimillennial to hourly time scales ▪ they understand the basic processes that dynamically shape the coastal landscape ▪ they know about methods of reconstructing and projecting global and regional sea-level changes
Semester weekly hours (SWH)	2 SWH / 2x lecture (L)
Workload / credit points	3 CP, 90 h ▪ 28 h lecture ▪ 47 h self-revision of lectures and additional complementary material ▪ 15 h study time for the final exam
Language of instruction	English
Frequency	Summer semester, yearly
Duration	1 semester / summer semester
Literature	Will be announced in the respective course.
Type of examination / exam components	Module exam Examination performance: Written exam

Special Module Sino-German Master Programme in Marine Sciences

Module code	01-01-03-APhOc
Module title	Advanced Physical Oceanography
Responsible for the module, lecturers	Prof. Dr. Monika Rhein
Type of module	Compulsory for Students of the Ocean University of China taking part in the Sino-German Master Programme in Marine Sciences while studying in their 3rd and 4th semester at the University of Bremen.
Programs using the module	
Courses	1) 01-01-03-PhOc1 / Seminar on Physical Oceanography I 2) 01-01-03-PhOc2 / Seminar on Physical Oceanography II
Content-related prior knowledge or skills	No formal requirements, but basic knowledge in Physical Oceanography is desireable
Learning contents	Specific topics from Physical Oceanography and the role of the ocean for climate change
Learning outcomes/ competencies/ targeted competencies	A detailed understanding of climate relevant processes in Physical Oceanography, the linkage between ocean and climate change / critical and analytical thinking and its application to problems in earth sciences
Semester weekly hours (SWH)	1) 2 SWH 2) 2 SWH
Workload / credit points	6 CP, 180 h 1) 3 CP, 90 h • presence: 28 h (2 SWH x 14 weeks) • preparation, learning: 22 • preparation for exam: 40 2) 3 CP, 90 h • presence: 28 h (2 SWH x 14 weeks) • preparation, learning: 22 • preparation for exam: 40
Language of instruction	English
Frequency	1) Winter semester 2) Summer semester
Duration	2 semesters 1) 1 semester 2) 1 semester
Literature	Will be announced in the respective seminars.
Type of examination / exam components	Combination Exam 1) Examination performance: Oral presentation (or as announced by the respective lecturer) 2) Examination performance: Oral presentation (or as announced by the respective lecturer)