Master of Science in Environmental Physics

Module Guide

University of Bremen
Faculty 1 Physics and Electrical Engineering

March 2020

This module guide merely serves for the orientation of the students. Legally binding is the German version of the valid Examination Regulations for the M.Sc. in Environmental Physics.

We try to keep this module guide up-to-date, however, modifications with respect to personnel and content may occur.

History of changes to the module guide:

Date	Version	Changes
March 2020	Summer Semester 2020	• optional courses: Mathematical Modelling renamed to Mathematical Modelling of Complex Systems
Oct. 2019	Winter Semester 2019/2020	• new module plan • cancelled compulsory courses: Soil Physics
April 2019	Summer Semester 2019	• new optional courses: Fortran for Environmental Sciences Isotopes in Environmental Physics Practical Physical Oceanography • several assignments for MSc Technomathematik + MSc Marine Geosciences deleted
Nov. 2018	Winter Semester 2018/2019	• update course numbers • cancelled optional courses: Cloud Physics Environmental Radioactivity • several courses assigned to MSc Prozessorientierte Materialforschung (ProMat)
March 2018	Summer Semester 2018	• new optional course: Atmospheric Chemistry Modelling: Part 2 (Laboratory)
Jan. 2018	Winter Semester 2017/2018	• new course numbers • new order sorted by module sections and in alphabetical order within the module sections • changes of course titles: old: Aerosol and Radiative Aspects in Clouds / new: Atmospheric Aerosols old: Atmospheric Chemistry II / new: Biogeochemistry old: Molecular Physics / new: Atmospheric Spectroscopy • new optional courses: Atmospheric Chemistry Modeling: Part 1 Climate Modelling: Part 1 Climate Modelling: Part 2 Ice Mass Balance and Remote Sensing
March 2017	Summer Semester 2017	• 2 lecturers changed
Dec. 2016	Winter Semester 2016/2017	• module guide in English only

		• cancelled optional courses: Physics of Polar Ice Core Records The Upper Atmosphere • new optional courses: Practical Data Analysis with Python
Nov. 2015	Winter Semester 2014/2015	• module guide in German + English • description per individual course • Atmospheric Chemistry II: Change from compulsory module to optional module
Nov. 2013	Winter Semester 2013/2014	• module guide in German only • description per general modules 1 – 7 • each including a list of the appendant courses

Contents

Overview + Module Plan M.Sc. Environmental Physics

Semester	Compulsory Modules + Module Master Thesis (99 CP)			Elective Modules (21 CP)	CP/Sem.
1	Atmospheric Physics (6 CP)	Physical Oceanography (6 CP)	Atmospheric Chemistry I (6 CP)		30
	Inverse Methods and Data Analysis (6 CP)	Dynamics I (6 CP)			
2	Climate System I (4 CP)	Dynamics II (4 CP)	Remote Sensing I (4 CP)	Special Topics (12 CP)	30
	Measurements Techniques (6 CP)				
3	Proseminar on Presentation Techniques in Environmental Physics(3 CP)	Preparatory Project (18 CP)		Special Topics (9 CP)	30
4	Master's Thesis (30 CP)				30

Abbreviations:

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

Remarks:
Partial examination: Credit points for a module are granted upon successful examination performance and successful course performance.
Module examination: Credit points are granted upon a) successful assessment of the thesis paper as the final product of the preparatory project and
b) successful assessment of the master's thesis incl. colloquium.
Examination performances are graded.
Course performances are not graded.

Module Section 1: Basics

Code no.	01-01-03-AtC1
Module title	Atmospheric Chemistry I
Responsible for the module, lecturers / module assignment	PD Dr. Annette Ladstätter-Weißenmayer / Prof. Dr. Mihalis Vrekoussis Module section 1 / Basics
Assignment to study programmes	Compulsory for MSc Environmental Physics Optional compulsory for MSc Physik
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
Offered frequency	Annually / winter semester
Duration / semester	1 semester / winter semester (1st academic year)
Course language	English
Compulsory / optional	Compulsory
Requirements for participation	No formal requirements
Content	History of the atmospheres of the earth; atmospheric composition; thermodynamics, thermochemistry and chemical equilibria; photochemistry; kinetic theory of reactions and reaction rate coefficients; chain reactions; atmospheric chemical mechanisms and transformations in the thermosphere, mesosphere, stratosphere and the troposphere.
Learning outcome	Basics chemistry of the atmosphere
Course and examination performance, type of exam	Partial exam Examination performance: Written exam/oral exam (will be announced by the respective lecturer) Course performance: Successful assessment of example classes or as announced by the respective lecturer
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

Code no.	01-01-03-AtPhy
Module title	Atmospheric Physics
Responsible for the module, lecturers / module assignment	Prof. Dr. John P. Burrows Module section 1 / Basics
Assignment to study programmes	Compulsory for MSc Environmental Physics Compulsory for MSc Space Sciences and Technologies Compulsory for MSc Space Engineering II Optional compulsory for MSc Physik Optional compulsory for MSc Physical Geography: Environmental History
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
Offered frequency	Annually / winter semester
Duration / semester	1 semester / winter semester (1st academic year)
Course language	English
Compulsory / optional	Compulsory
Requirements for participation	No formal requirements
Content	The origin of the solar system and the earth's atmosphere; the evolving atmospheric composition; the physical parameters determining conditions in the atmosphere (e.g. temperature, pressure, and vorticity); the laws describing electromagnetic radiation; the interaction between electromagnetic radiation and matter (absorption emission and scattering); atmospheric radiative transport; radiation balance, climate change; atmospheric thermodynamics and hydrological cycle; aerosols and cloud physics; an introduction into atmospheric dynamics (kinematics, circulation etc.)
Learning outcome	An adequate understanding of the fundamentals of atmospheric physics. This addresses a) gaining an understanding the laws of physics, which determine the behaviour of the earth system comprising 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. programmes. In later life, these learning outcomes are essential for undertaking a) research in atmospheric, environmental and climate science Earth observation and remote sensing form ground based ship, aircraft and space based instrumentation, b) being employment in earth observation, earth science, meteorology, industry, or governmental and space agencies.

Course and examination performance, type of exam	Partial exam Examination performance: Written exam/oral exam (will be announced by the respective lecturer) Course performance: Successful assessment of example classes or as announced by the respective lecturer
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

Code no.	01-01-03-CliS1
Module title	Climate System I
Responsible for the module, lecturers / module assignment	Prof. Dr. Torsten Kanzow Module section 1 / Basics
Assignment to study programmes	Compulsory for MSc Environmental Physics Optional compulsory for MSc Physik Optional compulsory for MSc Marine Geosciences
Semester weekly hours (SWH)	3 SWH / 2x lecture (L) + 1x example classes (EC)
Workload / credit points	4 CP, 120 h • presence (L + EC): 42 h (3 SWH x 14 weeks) • preparation, learning + examples: 42 h (3 SWH x 14 weeks) • preparation for exam: 36 h
Offered frequency	Annually / summer semester
Duration / semester	1 semester / summer semester (1st academic year)
Course language	English
Compulsory / optional	Compulsory
Requirements for participation	No formal requirements
Content	Climate on earth / climate variations / the climate system / energy balance models / radiation & convection / role of the ocean in climate
Learning outcome	Climate physics
Course and examination performance, type of exam	Partial exam Examination performance: Written exam/oral exam (will be announced by the respective lecturer) Course performance: Successful particiation in the tutorials (this requires reaching at least 50% (of maximum number of points) in the assignments) or as announced by the respective lecturer
Literature	Will be announced in the respective course.

Code no.	01-01-03-PhyO
Module title	Physical Oceanography
Responsible for the module, lecturers / module assignment	Prof. Dr. Monika Rhein / Dr. Reiner Steinfeldt / Dr. Oliver Huhn Module section 1 / Basics
Assignment to study programmes	Compulsory for MSc Environmental Physics Optional compulsory for MSc Physik Optional compulsory for MSc Marine Geosciences
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
Offered frequency	Annually / winter semester
Duration / semester	1 semester / winter semester (1st academic year)
Course language	English
Compulsory / optional	Compulsory
Requirements for participation	No formal requirements
Content	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 outcome	Understand fundamentals of physical oceanography
Course and examination performance, type of exam	Partial exam Examination performance: Written exam/oral exam (will be announced by the respective lecturer) Course performance: Successful assessment of example classes or as announced by the respective lecturer
Literature	Will be announced in the respective course.

Module Section 2: Theoretical Basics

Code no.	01-01-03-Dyn1
Module title	Dynamics I
Responsible for the module, lecturers / module assignment	Prof. Dr. Thomas Jung Module section 2 / Theoretical Basics
Assignment to study programmes	Compulsory for MSc Environmental Physics Optional compulsory for MSc Physik Optional for MSc Space Sciences and Technologies
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
Offered frequency	Annually / winter semester
Duration / semester	1 semester / winter semester (1st academic year)
Course language	English
Compulsory / optional	Compulsory
Requirements for participation	No formal requirements
Content	Governing equations, basic conservation laws, balances, elementary applications of the basic equations, circulation and vorticity, planetary boundary layer, Rossby waves
Learning outcome	Understanding of the basic dynamical processes in atmosphere and ocean; learning how to interpret physical equations physically
Course and examination performance, type of exam	Partial exam Examination performance: Written exam/oral exam (will be announced by the respective lecturer) Course performance: Successful assessment of example classes (active engagement in the example classes including (two times) the successful presentation of solutions at the blackboard) or as announced by the respective lecturer
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

Code no.	01-01-03-Dyn2
Module title	Dynamics II
Responsible for the module, lecturers / module assignment	Prof. Dr. Gerrit Lohmann Module section 2 / Theoretical Basics
Assignment to study programmes	Compulsory for MSc Environmental Physics Optional compulsory for MSc Physik
Semester weekly hours (SWH)	3 SWH / 2x lecture (L) + 1x example classes (EC)
Workload / credit points	4 CP, 120 h • presence (L + EC): 42 h (3 SWH x 14 weeks) • preparation, learning + examples: 42 h (3 SWH x 14 weeks) • preparation for exam: 36 h
Offered frequency	Annually / summer semester
Duration / semester	1 semester / summer semester (1st academic year)
Course language	English
Compulsory / optional	Compulsory
Requirements for participation	No formal requirements
Content	Fluid dynamics, ocean circulation, wind-driven and thermohaline circulation; atmosphere dynamics and teleconnections, dynamical system theory, non-dimensional parameters, bifurcations and instabilities; gravity, Rossby, Kelvin waves; Simple models, Stochastic climate model; Analytical and Programming techniques; Fourier and Laplace transformation; Time series analysis
Learning outcome	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
Course and examination performance, type of exam	Partial exam Examination performance: Written exam/oral exam (will be announced by the respective lecturer) Course performance: Successful assessment of example classes or as announced by the respective lecturer
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 • Marchal, J., and R. A. Plumb, 2008. Atmosphere, Ocean and Climate Dynamics: An Introductory Text. Academic Press, 344 pp; videos • Stewart, R. H., 2008: Introduction To Physical Oceanography • Lohmann, G., 2014: Ocean Fluid Dynamics: Concepts, Scaling and Multiple Equilibria.

Code no.	01-01-03-IMDA
Module title	Inverse Methods and Data Analysis
Responsible for the module, lecturers / module assignment	Prof. Dr. Reiner Schlitzer Module section 2 / Theoretical Basics
Assignment to study programmes	Compulsory for MSc Environmental Physics Compulsory for MSc Space Sciences and Technologies Compulsory for MSc Space Engineering II Optional compulsory for MSc Physik Optional compulsory for MSc Marine Geosciences
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
Offered frequency	Annually / winter semester
Duration / semester	1 semester / winter semester (1st academic year)
Course language	English
Compulsory / optional	Compulsory
Requirements for participation	No formal requirements
Content	Error analysis and statistics, techniques for the optimal solution of under and over determined systems of linear equations including methods for calculating variances and covariances of the solutions, concepts of resolution and methods to calculate them, practical examples and applications to test data sets from oceanography, image processing and remote sensing of the atmosphere, earth, outer space, and celestial bodies.
Learning outcome	Introduction to linear inverse methods
Course and examination performance, type of exam	Partial exam Examination performance: Written exam/oral exam (will be announced by the respective lecturer) Course performance: Successful assessment of example classes or as announced by the respective lecturer
Literature	Will be announced in the respective course.

Module Section 3: Experimental Techniques

Code no.	01-01-03-MeTe
Module title	Measurement Techniques
Responsible for the module, lecturers / module assignment	Dr. Andreas Richter / Dr. Christian Mertens Module section 3 / Experimental Techniques
Assignment to study programmes	Compulsory for MSc Environmental Physics
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
Offered frequency	Annually / summer semester
Duration / semester	1 semester / summer semester (1st academic year)
Course language	English
Compulsory / optional	Compulsory
Requirements for participation	No formal requirements
Content	A set of practical measurements of meteorological quantities, atmospheric trace gases, ocean currents, environmental radioactivity, and absorption cross-sections using different techniques is performed by the students under supervision of tutors. The measurements 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 outcome	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.
Course and examination performance, type of exam	Partial exam Examination performance: Oral exam Course performance: Successful experiments with accepted reports
Literature	Will be announced in the respective course.

Code no.	01-01-03-RemS1
Module title	Remote Sensing I
Responsible for the module, lecturers / module assignment	Prof. Dr. Astrid Bracher / Dr. Mathias Palm Module section 3 / Experimental Techniques
Assignment to study programmes	Compulsory for MSc Environmental Physics Optional compulsory for MSc Physik Optional compulsory for MSc Prozessorientierte Materialforschung Optional compulsory for MSc Marine Geosciences Optional compulsory for MSc Physical Geography: Environmental History
Semester weekly hours (SWH)	3 SWH / 2x lecture (L) + 1x example classes (EC)
Workload / credit points	4 CP, 120 h • presence (L + EC): 31,5 h (2,25 SWH x 14 weeks) • preparation for rapport: 13,5 h • preparation and re-analysing examples: 45 h (4,5 SWH x 10 weeks) • preparation for exam: 30 h
Offered frequency	Annually / summer semester
Duration / semester	1 semester / summer semester (1st academic year)
Course language	English
Compulsory / optional	Compulsory
Requirements for participation	No formal requirements
Content	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 outcome	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
Course and examination performance, type of exam	Partial exam Examination performance: Written exam/oral exam (will be announced by the respective lecturer) Course performance: Successful assessment of example classes (oral rapport of 5-10 min. summarizing one of the lectures, exercises and a total of 70 points need to be reached in 10 exercises with 10 points each) or as announced by the respective lecturer
Literature	Will be announced in the respective course.

Module Section 4: Advanced Environmental Physics

Code no.	01-01-03-AtA
Module title	Atmospheric Aerosols
Responsible for the module, lecturers / module assignment	Dr. Marco Vountas / Dr. Linlu Mei / Dr. Nikos Daskalakis Module section 4 / Advanced Environmental Physics
Assignment to study programmes	Optional for MSc Environmental Physics Optional compulsory for MSc Space Sciences and Technologies Optional compulsory for MSc Physik
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
Offered frequency	Annually / winter semester
Duration / semester	1 semester / winter semester
Course language	English
Compulsory / optional	Optional
Requirements for participation	No formal requirements
Content	Description of atmospheric aerosols, their composition and measuring methods. Introduction to radiative transfer in the troposphere with emphasis on aerosols and clouds
Learning outcome	Advanced knowledge of the atmosphere and light scattering
Course and examination performance, type of exam	Partial exam Examination performance: Written exam/oral exam (will be announced by the respective lecturer) Course performance: Successful assessment of example classes or as announced by the respective lecturer
Literature	Will be announced in the respective course.

Code no.	01-01-03-AtCM1
Module title	Atmospheric Chemistry Modelling: Part 1 (Theory)
Responsible for the module, lecturers / module assignment	Prof. Dr. Mihalis Vrekoussis / Dr. Nikos Daskalakis Module section 4 / Advanced Environmental Physics
Assignment to study programmes	Optional for MSc Environmental Physics Optional compulsory for MSc Space Sciences and Technologies
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
Offered frequency	Annually / winter semester
Duration / semester	1 semester / winter semester
Course language	English
Compulsory / optional	Optional
Requirements for participation	No formal requirements
Content	• 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 outcome	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.
Course and examination performance, type of exam	Partial exam Examination performance: Written exam/oral exam (will be announced by the respective lecturer) Course performance: Successful assessment of example classes and/or successful writing of an essay and/or successful presentation of a given topic or as announced by the respective lecturer
Literature	Will be announced in the respective course.

Code no.	01-01-03-AtCM2
Module title	Atmospheric Chemistry Modelling: Part 2 (Laboratory)
Responsible for the module, lecturers / module assignment	Dr. Nikos Daskalakis Module section 4 / Advanced Environmental Physics
Assignment to study programmes	Optional for MSc Environmental Physics
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
Offered frequency	Annually / summer semester
Duration / semester	1 semester / summer semester
Course language	English
Compulsory / optional	Optional
Requirements for participation	No formal requirements
Content	• 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 outcome	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
Course and examination performance, type of exam	Partial exam Examination performance: Written exam/oral exam (will be announced by the respective lecturer) Course performance: Successful assessment of example classes and/or successful writing of an essay or as announced by the respective lecturer
Literature	Will be announced in the respective course.

Code no.	01-01-03-AtSp
Module title	Atmospheric Spectroscopy
Responsible for the module, lecturers / module assignment	Prof. Dr. Justus Notholt Module section 4 / Advanced Environmental Physics
Assignment to study programmes	Optional for MSc Environmental Physics Compulsory for MSc Space Sciences and Technologies
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
Offered frequency	Annually / summer semester
Duration / semester	1 semester / summer semester
Course language	English
Compulsory / optional	Optional
Requirements for participation	No formal requirements
Content	Prism and grating spectrometers, Fourier-Transform-Spectroscopy, transitions, rotational spectra, vibrational spectra, rotational-vibrational spectra, remote sensing methods
Learning outcome	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.
Course and examination performance, type of exam	Partial exam Examination performance: Written exam/oral exam (will be announced by the respective lecturer) Course performance: Successful assessment of example classes or as announced by the respective lecturer
Literature	Will be announced in the respective course.

Code no.	01-01-03-BGC
Module title	Biogeochemistry
Responsible for the module, lecturers / module assignment	PD Dr. Annette Ladstätter-Weißenmayer Module section 4 / Advanced Environmental Physics
Assignment to study programmes	Optional for MSc Environmental Physics Optional compulsory for MSc Physik Optional for MSc Space Sciences and Technologies
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
Offered frequency	Annually / summer semester
Duration / semester	1 semester / summer semester
Course language	English
Compulsory / optional	Optional
Requirements for participation	No formal requirements
Content	Global biochemical cycles of elements, important biophysical processes in atmosphere and ocean, carbon-, methane-, nitrogen and water cycle, greenhouse gases
Learning outcome	Advanced biogeochemistry
Course and examination performance, type of exam	Partial exam Examination performance: Written exam/oral exam (will be announced by the respective lecturer) Course performance: Successful assessment of example classes and/or successful writing of an essay and/or successful presentation of a defined topic or as announced by the respective lecturer
Literature	Will be announced in the respective course.

Code no.	01-01-03-CDOL
Module title	Chemistry and Dynamics of the Ozone Layer
Responsible for the module, lecturers / module assignment	PD Dr. Björn-Martin Sinnhuber Module section 4 / Advanced Environmental Physics
Assignment to study programmes	Optional for MSc Environmental Physics
Semester weekly hours (SWH)	Block course (corresponding to 2 SWH)
Workload / credit points	3 CP, 90 h • presence (L + EC): 40 h (block course 5 days) • preparation, learning + examples: 25 h • preparation for exam: 25 h
Offered frequency	Annually / winter semester
Duration / semester	1 semester / winter semester
Course language	English
Compulsory / optional	Optional
Requirements for participation	No formal requirements
Content	Dynamics and chemistry of the ozone layer, implementation of a numerical model of the ozone layer and model based analyses • The ozone layer and its role in the climate system • Introduction to scientific programming (with practical exercises) • Atmospheric chemistry modeling (with practical exerises)
Learning outcome	Further understanding of chemistry-climate-interactions, skills in scientific computer programming
Course and examination performance, type of exam	Partial exam Examination performance: Written exam/oral exam (will be announced by the respective lecturer) Course performance: Successful assessment of example classes or as announced by the respective lecturer
Literature	No particular literature needed, recommended reading will be announced in the course.

Code no.	01-01-03-Cli2
Module title	Climate II
Responsible for the module, lecturers / module assignment	Prof. Dr. Gerrit Lohmann / Dr. Martin Werner Module section 4 / Advanced Environmental Physics
Assignment to study programmes	Optional for MSc Environmental 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: 42 h (3 SWH x 14 weeks) • preparation for exam: 20 h
Offered frequency	Annually / winter semester
Duration / semester	1 semester / winter semester
Course language	English
Compulsory / optional	Optional
Requirements for participation	No formal requirements
Content	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, palaeoclimate data, biogeochemical cycles, feedbacks; Spectra and time series analysis; Modes of variability
Learning outcome	Advanced climate course: Theories, models, observations. Past-present-future climate changes
Course and examination performance, type of exam	Partial exam Examination performance: Written exam/oral exam (will be announced by the respective lecturer) Course performance: Successful assessment of example classes and/or successful writing of an essay or as announced by the respective lecturer
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) • Broecker, THE GLACIAL WORLD ACCORDING TO WALLY

Code no.	01-01-03-CliM1
Module title	Climate Modelling: Part 1
Responsible for the module, lecturers / module assignment	Prof. Dr. Veronika Eyring Module section 4 / Advanced Environmental Physics
Assignment to study programmes	Optional for MSc Environmental Physics Optional compulsory for MSc Physik Optional for MSc Space Sciences and Technologies
Semester weekly hours (SWH)	Block course (corresponding to 2 SWH)
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
Offered frequency	Annually / summer semester
Duration / semester	1 semester / summer semester
Course language	English
Compulsory / optional	Optional
Requirements for participation	No formal requirements
Content	Types of Climate Models Energy Balance Models Radiative-Convective Models Components of Atmosphere Ocean General Circulation Models (GCMs) Fundamentals and representation in GCMs: atmospheric component Fundamentals and representation in GCMs: ocean and sea ice component Fundamentals and representation in GCMs: terrestrial component Steps in Model Formulation Introduction to the Coupled Model Intercomparison Project (CMIP) Results from GCMs: Climate change and climate warming Climate model evaluation with observations Frequently Asked Questions IPCC Assessment Reports Computational exercises with simple climate models Computation exercises in Python
Learning outcome	Understanding simple climate models and General Circulation Models (GCMs), their results and limitations; basics in Python.
Course and examination performance, type of exam	Partial exam Examination performance: Written exam/oral exam (will be announced by the respective lecturer) Course performance: Successful assessment of example classes and/or successful writing of an essay or as announced by the respective lecturer
Literature	Will be announced in the respective course.

Code no.	01-01-03-CliM2
Module title	Climate Modelling: Part 2
Responsible for the module, lecturers / module assignment	Prof. Dr. Veronika Eyring Module section 4 / Advanced Environmental Physics
Assignment to study programmes	Optional for MSc Environmental Physics Optional compulsory for MSc Physik
Semester weekly hours (SWH)	Block Course (corresponding to 2 SWH)
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
Offered frequency	Annually / winter semester
Duration / semester	1 semester / winter semester
Course language	English
Compulsory / optional	Optional
Requirements for participation	Climate Modelling: Part 1
Content	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 feedbacks and projections Decadal climate predictions Detection and attribution of climate change Earth system model evaluation with observations Climate informatics Results from ESMs Computational exercises with the Earth System Model Evaluation Tool (ESMValTool, http://www.esmvaltool.org/) and interpretation of ESM results
Learning outcome	Understanding Earth System Models (ESMs), their results and limitations, computational skills in the analysis of ESM output.
Course and examination performance, type of exam	Partial exam Examination performance: Written exam/oral exam (will be announced by the respective lecturer) Course performance: Successful assessment of example classes and/or successful writing of an essay or as announced by the respective lecturer
Literature	Will be announced in the respective course.

Code no.	01-01-03-DIP
Module title	Digital Image Processing
Responsible for the module, lecturers / module assignment	Dr. Christian Melsheimer / Dr. Gunnar Spreen Module section 4 / Advanced Environmental Physics
Assignment to study programmes	Optional for MSc Environmental Physics Compulsory for MSc Space Sciences and Technologies Optional compulsory for MSc Prozessorientierte Materialforschung
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
Offered frequency	Annually / summer semester
Duration / semester	1 semester / summer semester
Course language	English
Compulsory / optional	Optional
Requirements for participation	No formal requirements
Content	• 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 outcome	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
Course and examination performance, type of exam	Partial exam Examination performance: Written exam/oral exam (will be announced by the respective lecturer) Course performance: Successful assessment of example classes or as announced by the respective lecturer
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.

Code no.	01-01-03-FES
Module title	Fortran for Environmental Sciences
Responsible for the module, lecturers / module assignment	Dr. Nikos Daskalakis Module section 4 / Advanced Environmental Physics
Assignment to study programmes	Optional for MSc Environmental Physics
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
Offered frequency	Annually / summer semester
Duration / semester	1 semester / summer semester
Course language	English
Compulsory / optional	Optional
Requirements for participation	No formal requirements
Content	• 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 outcome	Participants will have the chance to: Learn the basic structure and rules of FORTRAN and apply this knowledge in computing complex environmentally relevant systems.
Course and examination performance, type of exam	Partial exam Examination performance: Written exam/oral exam (will be announced by the respective lecturer) / Successful assessment of an environmental problem using programming Course performance: Successful assessment of example classes and/or successful writing of an essay or as announced by the respective lecturer
Literature	Will be announced in the respective course.

Code no.	01-01-03-GenM
Module title	General Meteorology
Responsible for the module, lecturers / module assignment	Dr. Anne-Marlene Blechschmidt Module section 4 / Advanced Environmental Physics
Assignment to study programmes	Optional for MSc Environmental Physics Optional compulsory for MSc Physik
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
Offered frequency	Annually / summer semester
Duration / semester	1 semester / summer semester
Course language	English
Compulsory / optional	Optional
Requirements for participation	No formal requirements
Content	Typical flow patterns of the atmosphere, static (in-)stability, circulation systems, mid-latitude cyclones.
Learning outcome	Fundamentals of general meteorology.
Course and examination performance, type of exam	Partial exam Examination performance: Written exam/oral exam (will be announced by the respective lecturer) Course performance: Successful assessment of example classes and/or successful writing of an essay or as announced by the respective lecturer
Literature	Will be announced in the respective course.

Code no.	01-01-03-GCC
Module title	Global Carbon Cycle
Responsible for the module, lecturers / module assignment	Dr. Christoph Völker Module section 4 / Advanced Environmental Physics
Assignment to study programmes	Optional for MSc Environmental Physics Optional compulsory for MSc Physik Optional compulsory for MSc Prozessorientierte Materialforschung Optional compulsory for MSc Marine Geosciences Optional compulsory for MSc Physical Geography: Environmental History
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
Offered frequency	Annually / winter semester
Duration / semester	1 semester / winter semester
Course language	English
Compulsory / optional	Optional
Requirements for participation	No formal requirements
Content	• 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 outcome	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.
Course and examination performance, type of exam	Partial exam Examination performance: Written exam/oral exam (will be announced by the respective lecturer) Course performance: Successful assessment of example classes and/or successful writing of an essay or as announced by the respective lecturer
Literature	• Principles of Planetary Climate: Raymond Pierrehumbert • Ocean Biogeochemical Dynamics: Jorge L. Sarmiento & Nicolas Gruber • Earth's Climate: Past and Future: William F. Ruddiman

Code no.	01-01-03-IMBRS
Module title	Ice Mass Balance and Remote Sensing
Responsible for the module, lecturers / module assignment	Prof. Dr. Christian Haas Module section 4 / Advanced Environmental Physics
Assignment to study programmes	Optional for MSc Environmental Physics
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
Offered frequency	Annually / summer semester
Duration / semester	1 semester / summer semester
Course language	English
Compulsory / optional	Optional
Requirements for participation	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
Content	• Glacier mass balance • Measurements of radiation balance • Snow pit studies of snow properties • Oxygen isotope analysis of snow • Optical and radar remote sensing of glaciers
Learning outcome	Surface mass balance and remote sensing of ice and snow
Course and examination performance, type of exam	Partial exam Examination performance: Preparation of final report Course performance: Data processing and analysis
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.

Code no.	01-01-03-ITE
Module title	Instrumental Techniques for Environmental Measurements
Responsible for the module, lecturers / module assignment	Prof. Dr. Mihalis Vrekoussis Module section 4 / Advanced Environmental Physics
Assignment to study programmes	Optional for MSc Environmental Physics Optional compulsory for MSc Physik Optional compulsory for MSc Prozessorientierte Materialforschung
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
Offered frequency	Annually / summer semester
Duration / semester	1 semester / summer semester
Course language	English
Compulsory / optional	Optional
Requirements for participation	No formal requirements
Content	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 outcome	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.
Course and examination performance, type of exam	Partial exam Examination performance: Written exam/oral exam (will be announced by the respective lecturer) Course performance: Successful assessment of example classes and/or successful writing of an essay or as announced by the respective lecturer
Literature	Quantitative chemical analysis, 9th edition, (Daniel. C. Harris)

Code no.	01-01-03-IEPhy
Module title	Isotopes in Environmental Physics
Responsible for the module, lecturers / module assignment	PD Dr. Thorsten Warneke Module section 4 / Advanced Environmental Physics
Assignment to study programmes	Optional for MSc Environmental Physics Optional compulsory for MSc Physical Geography: Environmental History
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
Offered frequency	Annually / summer semester
Duration / semester	1 semester / summer semester
Course language	English
Compulsory / optional	Optional
Requirements for participation	No formal requirements
Content	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 outcome	Understanding isotopic fractionation, radiactive decay and the use of isotopes in paleoclimatology and for source characterization
Course and examination performance, type of exam	Partial exam Examination performance: Written exam/oral exam (will be announced by the respective lecturer) Course performance: Successful assessment of example classes and/or successful giving a presentation or as announced by the respective lecturer
Literature	Will be announced in the respective course.

Code no.	01-01-03-MaMCS
Module title	Mathematical Modelling of Complex Systems
Responsible for the module, lecturers / module assignment	Dr. Silke Thoms Module section 4 / Advanced Environmental Physics
Assignment to study programmes	Optional for MSc Environmental Physics Optional compulsory for MSc Prozessorientierte Materialforschung Optional compulsory for MSc Marine Geosciences
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
Offered frequency	Annually / summer semester
Duration / semester	1 semester / summer semester
Course language	English
Compulsory / optional	Optional
Requirements for participation	No formal requirements
Content	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 outcome	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).
Course and examination performance, type of exam	Partial exam Examination performance: Oral exam Course performance: Successful assessment of example classes (practical exercises where students write/change models that are given as small computer programs in MATLAB/OCTAVE or PYTHON)
Literature	• Numerical Recipes: William H. Press, Saul Teukolsky, William T. Vetterling and Brian P. Flannery

Code no.	01-01-03-MRS
Module title	Microwave Remote Sensing
Responsible for the module, lecturers / module assignment	Dr. Christian Melsheimer / Dr. Gunnar Spreen Module section 4 / Advanced Environmental Physics
Assignment to study programmes	Optional for MSc Environmental Physics Optional compulsory for MSc Marine Geosciences
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
Offered frequency	Annually / winter semester
Duration / semester	1 semester / winter semester
Course language	English
Compulsory / optional	Optional
Requirements for participation	No formal requirements
Content	• 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 outcome	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
Course and examination performance, type of exam	Partial exam Examination performance: Written exam/oral exam (will be announced by the respective lecturer) Course performance: Successful assessment of example classes or as announced by the respective lecturer

Literature	• Elachi, C.: *Introduction to the physics and techniques of remote sensing*, Wiley, 1987, 2006 • Mätzler, C. (ed.): *Thermal Microwave Radiation: Applications for Remote Sensing*, ed.: Christian Mätzler, no.: 52, series: IEE Electromagnetic Wave series, The Institution of Engineering and Technology (IET), ISBN 0-86341-573-3 / 978-086341-573-9, IEE Press, Stevenage, Hertfordshire, UK, 2006 • Janssen, M.A. (ed.): *Atmospheric Remote Sensing by Microwave Radiometry*, Wiley & Sons, 1993. • Stephens, G.L.: *Remote Sensing of the Lower Atmosphere: An Introduction*,Oxford University Press, 1994. • 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).

Code no.	01-01-03-OOOC
Module title	Ocean Optics and Ocean Color Remote Sensing
Responsible for the module, lecturers / module assignment	Prof. Dr. Astrid Bracher Module section 4 / Advanced Environmental Physics
Assignment to study programmes	Optional for MSc Environmental Physics Optional compulsory for MSc Marine Geosciences
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
Offered frequency	Annually / winter semester
Duration / semester	1 semester / winter semester
Course language	English
Compulsory / optional	Optional
Requirements for participation	No formal requirements
Content	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 biogeochemical models are presented.
Learning outcome	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, neuronal 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.

Course and examination performance, type of exam	Partial exam Examination performance: Written exam/oral exam (will be announced by the respective lecturer) Course performance: Successful assessment of example classes, participation in lab tour and successful writing of an essay (one oral rapport on one lecture) or as announced by the respective lecturer
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

Code no.	01-01-03-PhyO2
Module title	Physical Oceanography II
Responsible for the module, lecturers / module assignment	Prof. Dr. Monika Rhein Module section 4 / Advanced Environmental Physics
Assignment to study programmes	Optional for MSc Environmental Physics Optional compulsory for MSc Physik Optional compulsory for MSc Marine Geosciences
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
Offered frequency	Annually / summer semester
Duration / semester	1 semester / summer semester
Course language	English
Compulsory / optional	Optional
Requirements for participation	No formal requirements
Content	The topics of the lecture varies 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 outcome	Insightful knowledge of processes important for climate role of ocean
Course and examination performance, type of exam	Partial exam Examination performance: Written exam/oral exam (will be announced by the respective lecturer) Course performance: Successful assessment of example classes and/or successful writing of an essay or as announced by the respective lecturer
Literature	Will be announced in the respective course.

Code no.	01-01-03-PoOc
Module title	Polar Oceanography
Responsible for the module, lecturers / module assignment	Prof. Dr. Torsten Kanzow Module section 4 / Advanced Environmental Physics
Assignment to study programmes	Optional for MSc Environmental Physics Optional compulsory for MSc Marine Geosciences
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
Offered frequency	Annually / summer semester
Duration / semester	1 semester / summer semester
Course language	English
Compulsory / optional	Optional
Requirements for participation	No formal requirements
Content	Properties of cold sea water, sea ice formation, ocean – sea ice interaction, arctic circulation and water mass formation, antarctic circulation and water mass formation, ocean – ice shelf interaction
Learning outcome	Introduction to polar oceanography
Course and examination performance, type of exam	Partial exam Examination performance: Written exam/oral exam (will be announced by the respective lecturer) Course performance: Successful particiation in the tutorials (this requires reaching at least 50% (of maximum number of points) in the assignments) or as announced by the respective lecturer
Literature	Will be announced in the respective course.

Code no.	01-01-03-PDAP
Module title	Practical Data Analysis with Python
Responsible for the module, lecturers / module assignment	Dr. Andreas Hilboll Module section 4 / Advanced Environmental Physics
Assignment to study programmes	Optional for MSc Environmental Physics Optional compulsory for MSc Physik Optional compulsory for MSc Marine Geosciences Optional for MSc Space Sciences and Technologies
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: 26 h (2 SWH x 13 weeks) • homework project (examination): 36 h
Offered frequency	Annually / winter semester
Duration / semester	1 semester / winter semester
Course language	English
Compulsory / optional	Optional
Requirements for participation	No formal requirements
Content	The course will touch on the following subjects: • "But this worked yesterday, before I made some changes ..." or: An introduction to version control • Getting started: How to setup your own computer for data analysis in Python. • Hands-on introduction to the Python scientific ecosystem: Arrays and mathematical operations, using NumPy. • Labeled arrays or how to intuitively work with data, using Pandas and xarray. • Reading and writing data in common file formats. • Making both meaningful and beautiful plots, using matplotlib. • Statistical analysis in Python using the SciPy and Statsmodels packages. • Parameter estimation / regression using SciPy • An overview of the most common special-topic libraries for the research areas covered by the students’ study programmes. • Working with geoscientific data and plotting maps, using Cartopy and Shapely. • Other data analysis tasks needed by the students for their study program, upon demand.

Learning outcome	Upon successful completion of this course, the student will be able to work with scientific data using the Python scientific programming ecosystem, including the whole scientific data lifecycle (reading data, statistical analysis, plotting, storing results), following modern scientific programming best practices (e.g., version control, reproducibility, documentation, …).
Course and examination performance, type of exam	Partial exam Examination performance: One graded homework project Course performance: Successful assessment of example classes or as announced by the respective lecturer
Literature	• VanderPlas, Jake: Python Data Science Handbook, O'Reilly, 2016 (freely available online at https://jakevdp.github.io/PythonDataScienceHandbook/)

Code no.	01-01-03-PPO
Module title	Practical Physical Oceanography
Responsible for the module, lecturers / module assignment	Prof. Dr. Torsten Kanzow / Dr. Wilken-Jon von Appen Module section 4 / Advanced Environmental Physics
Assignment to study programmes	Optional for MSc Environmental Physics
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
Offered frequency	Annually / summer semester
Duration / semester	1 semester / summer semester
Course language	English
Compulsory / optional	Optional
Requirements for participation	No formal requirements
Content	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 outcome	• 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.
Course and examination performance, type of exam	Partial exam Examination performance: Successful writing of an essay/a report (participation in the field course is mandatory for taking the exam). Course performance: Successful writing of an essay / giving an oral presentation
Literature	Will be announced in the respective course.

Code no.	01-01-03-StEA
Module title	Statistics and Error Analysis
Responsible for the module, lecturers / module assignment	Prof. Dr. Reiner Schlitzer Module section 4 / Advanced Environmental Physics
Assignment to study programmes	Optional for MSc Environmental Physics Optional compulsory for MSc Physik Optional compulsory for MSc Prozessorientierte Materialforschung Optional compulsory for MSc Marine Geosciences Optional for MSc Space Sciences and Technologies
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
Offered frequency	Annually / summer semester
Duration / semester	1 semester / summer semester
Course language	English
Compulsory / optional	Optional
Requirements for participation	No formal requirements
Content	Random variables, probability, density and distribution functions, expectation values, covariance and correlation, error propagation, statistical tests
Learning outcome	Introduction to statistics, error calculation and data analysis
Course and examination performance, type of exam	Partial exam Examination performance: Written exam/oral exam (will be announced by the respective lecturer) Course performance: Successful assessment of example classes and/or successful writing of an essay or as announced by the respective lecturer
Literature	Will be announced in the respective course.

Module Section 5: Research in Environmental Physics

Code no.	01-01-03-PresT
Module title	Proseminar on Presentation Techniques in Environmental Physics
Responsible for the module, lecturers / module assignment	Dr. Andreas Richter Module section 5 / Research in Environmental Physics
Assignment to study programmes	Compulsory for MSc 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
Offered frequency	Annually / winter semester
Duration / semester	1 semester / winter semester (2nd academic year)
Course language	English
Compulsory / optional	Compulsory
Requirements for participation	No formal requirements
Content	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 outcome	How to prepare and give oral presentations, posters, and extended abstracts on topics of Environmental Physics.
Course and examination performance, type of exam	Partial exam Examination performance: 1 poster or extended abstract (4 pages) Course performance: Successful assessment of 2 oral presentations
Literature	Will be announced in the respective course.

Code no.	01-01-03-PrEPhy
Module title	Preparatory Project (Vorbereitungsprojekt)
Responsible for the module, lecturers / module assignment	Prof. Dr. John P. Burrows, Prof. Dr. Justus Notholt, Prof. Dr. Monika Rhein, PD Dr. Annette Ladstätter-Weißenmayer, Prof. Dr. Mihalis Vrekoussis, Prof. Dr. Veronika Eyring 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 Module section 5 / Research in Environmental Physics
Assignment to study programmes	Compulsory for MSc Environmental Physics
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
Offered frequency	Annually / winter semester
Duration / semester	Winter semester (2nd academic year)
Course language	English
Compulsory / optional	Compulsory
Requirements for participation	No formal requirements
Content	The content is related to the respective area of research of the preparatory project.
Learning outcome	• 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
Course and examination performance, type of exam	Module examination (graded) • Successful assessment of the preparatory project • Thesis paper on research project which can be conducted within the context of the Master's Thesis
Literature	Will be announced by the respective examiners.

Module 6: Module Master Thesis

Code no.	01-01-03-MTEPhy
Module title	Master Thesis
Responsible for the module, lecturers / module assignment	Prof. Dr. John P. Burrows, Prof. Dr. Justus Notholt, Prof. Dr. Monika Rhein, PD Dr. Annette Ladstätter-Weißenmayer, Prof. Dr. Mihalis Vrekoussis, Prof. Dr. Veronika Eyring 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 Module 6 / Final Module
Assignment to study programmes	Compulsory for MSc Environmental Physics
Semester weekly hours (SWH)	Master's Thesis Colloquium to the Master's Thesis
Workload / credit points	30 CP, 900 h
Offered frequency	Annually / summer semester
Duration / semester	Summer semester (2nd academic year)
Course language	English
Compulsory / optional	Compulsory
Requirements for participation	All the mandatory exams of the module sections 1 – 3 and the module "preparatory project" have to be passed.
Content	The content is related to the respective area of research of the Master's Thesis.
Learning outcome	• 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
Course and examination performance, type of exam	• Successful assessment of the Master's Thesis (graded) • Successful colloquium to the Master's Thesis (graded) • Credit points are granted on the basis of the marks for the Master's Thesis and the colloquium.
Literature	Will be announced by the respective examiners.