Module Handbook

Master Program

Environmental Modelling

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10.01.2014

Degree Course	**MSc Environmental Modelling**
Module Description	**Introduction to Environmental Modelling**
Module Code	EUM
Semester / Module Length	1st semester / 1 semester
Association with Other Degree Courses / Curricula	
Courses	Lecture series ‘Introduction to Environmental Modelling’ (3 CP) Practical to ‘Introduction to Environmental Modelling’ (3CP)
Teaching Language	German or English
Module Coordinator	Prof. Dr. Ulrike Feudel
Lecturers	Lecturers of the degree course ‘Environmental Modelling’
Workload	Contact time: 56 hrs, self-study: 124 hrs
Learning / Teaching Method	Lecture; practical
Available Credit Points / ECTS	6 CP
Module Content	***Lecture series ‘Introduction to Environmental Modelling’*** In this lecture series, lecturers of the participating working groups, and if applicable visiting lecturers, give a lecture based on their field of research. Students choose from one of the working groups, in which they will get deeper insight into the research topics of the selected group. Under the guidance of lecturers from the working group, a scientific topic will be worked on independently to produce an assignment.
Module Aims	The students have basic knowledge of environmental modelling. They have a first glimpse of the involved working groups and their current research topics. They know key fields of environmental modelling from the perspective of various experts and methods they use. They have learned to deal with scientific issues independently and critically.
Media Format	Lecture with discussion; guided or partly independent work with a computer and common software tools; independent approach to literature and computer-based presentation techniques
Literature	Will be introduced in the lectures,

	recent journal publications
Prerequisite for Participation	None
Useful Previous Knowledge	
Associated with the Modules	
Minimum / Maximum Number of Participants	Corresponding to the number admitted to the course
Study / Examinations to be Completed	Examination: Assignment Examination prerequisite: Active participation in the lecture
Criteria for receiving Grades	An examination result assessed as adequate, in accordance with general standards

Degree Course	**MSc Environmental Modelling**
Module Description	**Basic Skills**
Module Code	BK
Semester / Module Length	1st semester / 1 semester
Association with Other Degree Courses / Curricula	Bachelor Computer Science; Bachelor Environmental Sciences; Bachelor Biology
Courses	The selection of courses is largely set by the admissions committee, in order to compensate for deficits from the previous Bachelor degree course: (VL = lecture, Ü = tutorial, S = seminar) VL Java Programming Course (3 CP) Ü Java Programming Course (3 CP) VL Introduction to Computer Science for Scientists (4,5 CP) Ü Introduction to Computer Science for Scientists (1,5 CP) VL Applied Statistics in Biology and Environmental Sciences (3 CP) Ü Applied Statistics in Biology and Environmental Sciences (3 CP) VL Exploratory Data Analysis (3 CP) Ü Exploratory Data Analysis (3CP) VL Biological Oceanography (3 CP) VL Microbial Ecology (3 CP) VL Introduction to Organic Geochemistry (2 CP) VL Introduction to Inorganic Geochemistry (2 CP) VL Introduction to Marine Chemistry (2 CP) Ü Geochemistry Tutorial (2 CP) VL Environmental Statistics (3 CP) VL Physical Oceanography (3 CP) Ü Physical Oceanography (3 CP) VL General Ecology (3 CP) VL Hydrology (3 CP) VL Introduction to Soil Science (3 CP) VL Introduction to the Resources of Central Europe’s Plant Population (3 CP) VL Hydrodynamics (3 CP) Ü Hydrodynamics (3 CP) VL Basics of Mathematical Modelling (3 CP) Ü Basics of Mathematical Modelling (3 CP) VL Measuring Techniques in Oceanography (3 CP)

Teaching Language	German or English
Module Coordinator	Prof. Dr. Bernd Blasius
Lecturers	Lecturers of the courses Marine Science, Biology / Landscape Ecology, Computer Science
Workload	Contact time: 168 hrs, self-study: 372 hrs
Learning / Teaching Methods	Lecture; tutorial
Available Credit Points / ECTS	18 CP
Module Content	This module contains courses, which are necessary to close the knowledge gaps from the previous bachelor degree. The committee for ??? gives individual recommendations, which of the courses should be taken to make sure, that the student can follow the remaining courses of the study course Environmental Modeling. The courses in this module cover several topics in mathematics, modelling, computer science, geochemistry, marine chemistry, biology, landscape ecology, hydrology, ecology, physics, and oceanography. ***Java Programming Course (VL+Ü)*** The first part introduces general basics of programming (algorithm, computer, compiler, syntax diagrammes, logic, …). The hamster model, a simple but powerful model which teaches basic concepts of programming in a playful manner, is also introduced. The second part deals with the imperative programming concepts of Java for “Programming in the Small”, such as types, variables, instructions and functions. The third part introduces further object-oriented concepts of Java, such as class definition, interfaces and inheritance mechanisms, which make it possible to develop large, structured, reusable and expandable programming systems. ***Introduction to Computer Science for Scientists (VL+Ü)*** This module introduces basic concepts and the corresponding skills from computer science on the following topics: • Algorithms and data structures • Databases • Computer networks • Operating systems • Computer architecture

	Applied Statistics in Biology and Environmental Sciences (VL+Ü) The development of skills in the field of applied statistics includes the following emphases: Investigation of a research hypothesis and its transfer to statistical operationalization Planning experiments and assistance in the preparation of sampling procedures Selection of appropriate statistical analysis method Preparation of the sample values for a statistical data analysis Use of statistical programmes and programming systems and assistance in their application Professional scientific interpretation of statistical analysis results ***Exploratory Data Analysis (VL+Ü)*** The contents of the module are aimed at teaching specific knowledge in the following areas: Univariate data: Characterisation through tables, graphics and parameters, invariant and equivariant properties of parameters, outlier-robustness. Bivariate data: Pearson's contingency coefficient, rank correlation coefficient, Bravais-Pearson correlation coefficient, linear regression, non-parametric regression, multiple regression, general regression, total least squares estimate, outlier-robust alternatives. Multivariate data: Generalizations of the median, principal component analysis, canonical correlation, multivariate regression, discriminant analysis, classification, cluster analysis. ***Biological Oceanography (VL)*** Abiotic environmental conditions of the seas: Light atmosphere, thermal balance, physic-chemical properties of seawater. Wave formation, tides, global distribution of water masses and currents. Pelagic communities, plankton (phytoplankton, zooplankton, bacterioplankton, virioplankton, mycoplankton) microbial loop, sediment transport, C-cycle and N-cycle, nekton (fish, marine mammals, cephalopods, birds), fishing, El Nino. Benthic communities (rock, sand, silt, salt marshes, mangroves), estuaries. ***Microbial Ecology (VL):*** Determination of microbial biomass, documentation of species composition: Molecular ecology, in situ determination of microbial activity, isolation, "cultivability", persistence, famine

	conditions, aerobic degradation of organic matter, anaerobic microbial food chain, interactions with bacteria, animals and plants. Importance of microbes for the biogeochemical cycles. Locations to be discussed: The sea, lakes, sediments, soil, microbial mats, and intestine, "extreme" locations: Submarine hydrothermal vents, salt pans, alkaline lakes. The principles of environmental microbiology for wastewater treatment, remediation of water and soil will be explained. This will include the explanation of different methods (use of micro-electrodes, interpretation of gradients, isotopic techniques, techniques of molecular biology, etc.). ***Introduction to Organic Geochemistry (VL):*** Basic knowledge about the sedimentation of organic and inorganic material and the whereabouts of the material in the geosphere over geological time or about the processes in the water column in different sedimentation environments. The parameters derived from this knowledge are required to assess the environmental situation. ***Introduction to Inorganic Geochemistry (VL):*** It covers processes that are largely responsible for the specific conditions on our planet from a geological and geochemical point of view. These include the early universe (Big Bang, origin of the elements, galaxies and planets), the internal elemental and biogeochemical cycles, the livelihood of our planet as well as the natural and man-made global environmental changes. ***Introduction to Marine Chemistry (VL):*** Hydrological cycle, sources and sinks of salts, salinity, gases, biogeochemical cycles (carbon, nitrogen, phosphorus, sulphur, silicon), the formation and decomposition of organic matter, atmosphere-ocean interactions, sediment-water ***Geochemistry Tutorial (Ü):*** Practical tasks from the three lectures on marine geochemistry, inorganic and organic geochemistry. ***Environmental Statistics (VL):*** Introduction to statistical methods for the analysis of spatial and/or time-dependent variables based on case studies with a specialised scientific context, significance testing, spatial and temporal autocorrelation, principal component analysis and

	non-metric multidimensional scaling, classification procedures, procedures for the analysis of transient event sequences and flat dot patterns. ***Physical Oceanography (VL+Ü):*** Development, aims and objectives of geophysics and oceanography; formation and dynamics of the Earth's crust; physical properties of sea water; basic equations of hydrodynamics; currents on the rotating earth, waves, tides, regional oceanography (North Sea, Baltic Sea, Atlantic) ***General Ecology (VL)*** Organism and environment, population ecology, interrelationships among species, design and structure of ecosystems, biotic/abiotic factors, species and habitat protection. ***Hydrology (VL)*** Introduction to the water cycle, basics of hydrology, introduction to hydrological processes and storage in the terrestrial part of the hydrological cycle, overview of hydrological measuring and calculation methods. ***Introduction to Soil Science (VL)*** Properties of soil, transformation and translocation processes, nutrients and pollutants, soil formation and classification. ***Introduction to the Mineral Balance of Central Europe's Plant Population (VL)*** Water, carbon and nutrient balance of Central Europe's plant populations (including forest community, grassland, arable landscapes). ***Hydrodynamics (VL+Ü)*** Scalars and vectors, gradient, divergence, curl, Gauss's theorem , Stokes' theorem, continuum hypothesis, continuity equation, Navier-Stokes equations, diffusion equation, streamlines and path lines, Euler and Bernoulli equations, hydrostatics, buoyancy, kinematics, dynamics , turbulent flows, applications in marine research. ***Fundamentals of Mathematical Modelling (VL+Ü)*** Principles of analysis, basics of programming in MATLAB Empirical models, difference and differential equation

	models, Lotka-Volterra models, epidemic models Methods for the construction of mathematical models by example of natural systems Numerical and analytical solutions Spatially extended systems, cellular automata ***Measuring Techniques in Oceanography (VL)*** An overview of the measuring devices and systems, in oceanography, as well as the individual sensor components, system concepts, recording methods and evaluation procedures and device holders.
Module Aims	The students have closed their knowledge gaps from their different bachelor degrees and are well-prepared for the remaining courses of the study course Environmental Modeling. They have the required basic knowledge in mathematical modelling and are able to use the computer including programming. ***Java Programming Course (VL+Ü)*** With completion of this module students have acquired basic skills in Java programming and have learned about the basic concepts of imperative and object oriented programming using Java. Students can independently develop Java programmes to solve small and medium-sized problems. ***Introduction to Computer Science for Scientists (VL+Ü)*** Students attain the necessary basic concepts and skills of computer science in order to successfully participate in further modules. They know the structure of databases and operating systems, and have knowledge about the development of algorithms and data structures. ***Applied Statistics in Biology and Environmental sciences (VL+Ü)*** In accordance with application-and problem-oriented explanations of selected sub-areas of applied statistics, and using statistical programming systems implementation methods, students are able to competently assess the applicability and meaningfulness of selected methods of applied statistics in the context of case studies. ***Exploratory Data Analysis (VL+Ü)*** The students are able to present and interpret high-dimensional data through tables, graphs and

	parameters. They know basic statistical methods for data analysis such as regression, correlation and discriminant analysis and can apply these to sample data sets. ***Biological Oceanography (VL) / Microbial Ecology (VL)*** The students have a basic understanding of biological oceanography. They know the most important abiotic parameters as well as the pelagic and benthic communities. They understand the role of micro-organisms for the biogeochemical cycles and at different locations. They know how to investigate these. ***Introduction to Organic Geochemistry (VL) / Introduction to Inorganic Geochemistry (VL) / Introduction to Marine Chemistry (VL) / Geochemistry (Ü)*** After successful completion of this module the students possess: (i) In-depth knowledge of organic-geochemical aspects of environmental science (ii) In-depth knowledge of inorganic-geochemical aspects of environmental science (iii) Basic knowledge of geochemically important processes of the carbon cycle on Earth (iv) Basic knowledge of the geochemically important elemental cycles (v) The skills to independently research literature and information on geochemistry ***Environmental Statistics (VL)*** The students have a basic understanding of statistical methods and can apply them to environmental issues. ***Physical Oceanography (VL+Ü)*** Students have basic knowledge in the fields of geophysics and physical oceanography. They have an understanding of the movement of the atmosphere and ocean on the rotating earth and the respective boundary layers. The results of the hydrodynamic equations of motion enable the students to understand the physical processes in oceans and coastal seas. This particularly includes thermohaline convection, geostrophy, wind-driven circulation, waves and tides. The importance of physical processes in the biology and chemistry of the oceans is recognised.

	General Ecology (VL) Students have knowledge of the theoretical principles of the various disciplines of ecology and can apply them in practice. They can evaluate, display and critically interpret the results from literature on ecology and their own research. ***Hydrology (VL) /*** ***Introduction to Soil Science (VL) /*** ***Introduction to the Mineral Balance of Central Europe's Plant Population (VL)*** After successful completion of this module the students possess: (i) Comprehensive basic knowledge of soil science and hydrology (ii) Basic knowledge of the relationship of ecosystems in vegetation ecology (iii) Methodology skills in soil science, hydrology and vegetation as well as knowledge about the correlation between processes, measurement methods and analysis techniques (iv) Advanced skills in evaluation and presentation of soil science, hydrology and phytosociology research (v) The skills to independently research literature and information on soil science, hydrology and phytosociology ***Hydrodynamics (VL+Ü)*** Students will acquire basic knowledge of fluid mechanics / hydrodynamics. They know the basic equations of hydrostatics, kinematics, and hydrodynamics, and they can understand and process applications and special cases in the area of atmospheric and marine physics with the help of vector analysis. ***Basics of Mathematical Modelling (VL+Ü)*** To earn the mathematical skills for describing and analysing models, setting up models independently and learning the basic techniques for analytical and numerical solutions of differential equations. ***Measuring Techniques in Oceanography (VL*)** The students get a comprehensive overview of measurement procedures and instruments currently used in oceanography and are familiar with their use.
Types of Media	Projector, computer, board, slides
Literature	*Java Programming Course (VL+Ü)*

	Essential: Script of the slides Recommended: D. Boles: "Programmieren spielend gelernt mit dem Java-Hamster-Modell", Teubner-Verlag D. Boles: "Objektorientierte Programmierung spielend gelernt mit dem Java-Hamster-Modell", Teubner-Verlag Good secondary literature: J. Goll, C. Weiß, F. Müller: "Java als erste Programmiersprache", Teubner-Verlag D. Ratz, J. Scheffler, D. Seese: "Grundkurs Programmieren in Java, Band 1", Hanser-Verlag *Introduction to Computer Science for Scientists (VL+Ü)* U. Rembold : Einführung in die Informatik für Ingenieure und Naturwissenschaftler *Applied Statistics in Biology and Environmental Sciences (VL+Ü)* Stoyan, D., Stoyan, H. und Jansen, U. (1997). Umweltstatistik. Teubner, Stuttgart. Khazanie, R. Basic probability theory and applications (1976) Pacific Palisades. Internet: Module script with context related literature references and relevant URLs. *Exploratory Data Analysis (VL+Ü)* Anderson, T.W. (1984). Introduction to Multivariate Statistical Analysis. Wiley, New York. Bortz, J. (1999). Statistik für Sozialwissenschaftler. Springer, Berlin. Burkschat, M., Cramer, E., und Kamps, U. (2004). Beschreibende Statistik. Grundlegende Methoden. Springer, Berlin. Everitt, B.S. and Dunn, G. (1991). Applied Multivariate Data Analysis. Edward Arnold, London. Fahrmeier, L., Künstler, R., Pigeot, I., und Tutz, G. (1997). Statistik. Springer, Berlin. Härdle, W., und Simar, L. (2003). Applied Multivariate Statistical Analysis. Springer, Berlin. Hartung, J., Elpelt, B., und Klösener, H.P. (1998). Statistik. Oldenbourg, München. Lehn, J., Müller-Gronbach, T., und Rettig, S. (2000). Einführung in die Deskriptive Statistik. Teubner, Stuttgart. Rencher, A.C. (1995). Methods of Multivariate Analysis. Wiley, New York. Rencher, A.C. (1998). Multivariate Statistical

	Inference and Applications. Wiley, New York. Stoyan, D., Stoyan, H. und Jansen, U. (1997). Umweltstatistik. Teubner, Stuttgart. *Biological Oceanography (VL), Microbial Ecology (VL)* S. Gerlach, Marine Systeme, Springer Verlag, Heidelberg 1994. T. Garrison, Oceanography – an invitation to marine science, Brooks/Cole, Wadsworth, New York 1999. C.M. Lalli, T.R. Parsons, Biological Oceanography: An Introduction, Elsevier, Oxford 1995. U. Sommer, Biologische Meereskunde, Springer Verlag, Heidelberg 2005. U. Sommer, Planktologie, Springer Verlag, Heidelberg 1994. H. Cypionka, Grundlagen der Mikrobiologie, Springer Verlag, Heidelberg 2003 *Introduction to Organic Geochemistry (VL) / Introduction to Inorganic Geochemistry (VL) / Introduction to Marine Chemistry (VL) / Geochemistry (Ü)* S Killops, V. Killops, Introduction to Organic Geochemistry, 2^{nd} edition, 2004, Blackwell. B.P. Tissot, D.H. Welte, Petroleum Formation and Occurrence, 1984, 2. Aufl, Springer. W.Broecker, Labor Erde, Bausteine für einen lebensfreundlichen Planeten, 1994, Springer. Press und Siever, Allgemeine Geologie, 5. Auflage, 2008, Springer Spektrum F.J. Millero, Chemical Oceanography, 2nd edition, 1996, CRC Press. S.M. Libes, An Introduction to Marine Biogeochemistry, 1992, Wiley Open University Series, 1989, Ocean Chemistry and Deep-Sea Sediments; Seawater: Its Composition, Properties and Behaviour, Pergamon Press. W.S. Broecker, T.-H. Peng, Tracers in the Sea, 1982, Eldigio Press. *Physical Oceanography (VL+Ü)* Dietrich, Kalle, Krauss, Siedler: Allgemeine Meereskunde. Thurman, Burton, Introductory Oceanography, Prentice Hall Open University, Ocean Circulation, Pergamon Press

	<u>*General Ecology (VL)*</u> Wittig u. Streit: Ökologie, Townsend, Harper, Begon: Ökologie, Wilson, Bossert: Populationsökologie, Mühlenberg: Freilandökologie, Krebs: Ecological Methodology Larcher: Ökophysiologie der Pflanzen; Steubing & Schwantes: Ökologische Botanik; Ellenberg: Vegetation Mitteleuropas mit den Alpen. Kratochwil u. Schwabe: Ökologie der Lebensgemeinschaften; Schaefer: Wörterbuch der Ökologie; <u>*Hydrology (VL) / Introduction to Soil Science (VL)/ Introduction to the Mineral Balance of Central Europe's Plant Population (VL)*</u> Scheffer & Schachtschabel: Bodenkunde. Springer Mückenhausen: Bodenkundliche Kartieranleitung Hölting: Hydrogeologie Mattheß & Ubell: Allgemeine Hydrogeologie Schulze, Beck, Müller-Hohenstein: Pflanzenökologie. <u>*Hydrodynamics (VL+Ü)*</u> Schade & Kunz, Strömungslehre, de Gruyter <u>*Fundamentals of Mathematical Modelling (VL+Ü)*</u> Script will be available via StudIP Imboden, D.M. & Koch, S.: Systemanalyse - Einführung in die mathematische Modellierung natürlicher Systeme, Springer-Verlag <u>*Measuring Techniques in Oceanography (VL)*</u> Stewart: Introduction to Physical Oceanography (2008) Dietrich, Kalle, Krauss, Siedler: Allgemeine Meereskunde.
Prerequisite for Participation	None
Useful Previous Knowledge	Familiarity with the use of computers and Matlab
Study / Examinations to be Completed	<u>1 graded examination:</u> Oral examination of about 30 minutes with contents from two parts of the areas (A, B, C, D).

	The examiners must each represent one of at least two subject areas; among the examiners one at least must be an academic member of staff. Ungraded examinations: Written examination, oral examination, presentation of a paper, assignment, practical exercise, term paper, internship report, presentations as stipulated by the lecturer; these must at least be graded as passed.
Criteria for receiving Grades	An examination result assessed as adequate, according to general standards

Degree Course	**MSc Environmental Modelling**
Module Description	**Environmental systems and Biodiversity**
Module Code	USB
Semester / Module Length	1st and 2nd semester / 2 semesters
Association with Other Degree Courses / Curricula	Master in Landscape Ecology, Biology and Marine Environmental Sciences as well as Master in Ecology Uni Bremen
Courses	(VL = lecture, Ü = tutorial, S = seminar) VL Ecology of Plants in Landscapes (2 CP) VL Material Balance of Plants in Landscapes (2 CP) VL Ecology of Animals in Landscapes (2 CP) VL Specific Hydrogeology (3 CP) VL Specific Soil Science (1,5 CP) VL Environmental Chemistry (3CP) VL Environmental Physics (3CP) VL Fundamentals of Water Conservation (3CP) VL Basic Ecological Processes (3CP) Ü Interdisciplinary Analysis of Ecosystem Processes and Water and Nutrient Transport in Landscapes (3CP) VL „Scaling“: Physiological Ecology from Individual Organ to Ecosystem (3CP) VL Biodiversity of Plants (3CP) S Functional Consequences of Marine Biodiversity Change (3CP)
Teaching Language	German or English
Module Coordinator	Prof. Dr. Michael Kleyer
Lecturers	Prof. Dr. Michael Kleyer, Prof. Dr. Gerhard Zotz, Dr. Luise Giani, Prof. Dr. Gudrun Massmann, Prof. Dr. Bernd Blasius, Prof. Dr. Jörg Wolff, Prof. Dr. Ulrike Feudel, Dr. Karsten Lettmann, Dr. Julia Stahl, PD Dr. Thorsten Henning Brinkhoff, Prof. Dr. Gerd Liebezeit, Prof. Dr. Helmut Hillebrand, Dr. Jannek Greskowiak, Prof. Dr. Dirk Albach
Workload	Contact time: 112 hrs, self-study: 248 hrs
Learning / Teaching Methods	Lecture; tutorial; seminar
Available Credit Points / ECTS	12 CP
Module Content	This module provides a specialization on applications in environmental systems and biodiversity. For their specialization the students can choose any courses from the list according to their own interests in terrestrial and/or marine environmental systems.

	VL Ecology of Plants in Landscapes: Niche theory, habitat models, relationships between biological characteristics and environmental conditions, population biology, successions, propagation. ***VL Material Balance of Plants in Landscapes:*** Plant ecophysiology in relation to environmental stress ***VL Ecology of Animals in Landscapes:*** Biological mechanisms that lead to the survival of species in landscapes, habitat models, fragmentation, isolation ***VL Specific Hydrogeology:*** Advanced theoretical principles of hydrogeology: hydrochemistry, water / rock interactions, biogeochemical cycles, material transport, isotope hydrogeology, age determination of groundwater, groundwater contamination, water and groundwater protection ***VL Specific Soil Science:*** Pedogenesis; soil systematic, soil classification; soil minerals; geological output ratios: Pleistocene era, Holocene period; pedogenesis from quartz-rich parent material; Gleye and alluvial soils; pedogenesis of boulder clay - clay, from carbonate rocks, from organogenic sediments; properties of peat soils; pedogenesis from marine formed sediments; properties of marsh soils , pedogenesis of anthropogenic terrestrial soils; properties of anthrosols. ***VL Environmental Chemistry:*** The lecture will impart in-depth knowledge of organic and inorganic chemical aspects of environmental science in the terrestrial and marine sector, with particular focus on environmental science significant processes in atmosphere, soil and water. The extent of anthropogenic overprinting of natural ecosystems is dealt with by way of examples. ***VL Environmental Physics:*** Introduction to the physics of the ocean and atmosphere, coupling between ocean and atmosphere, compartments of the climate system, climate phenomena, e.g. El Nino, thermohaline ocean circulation, ocean deep convection

	VL Fundamentals of Water Conservation: General limnological principles, interference in natural waters, eutrophication, phosphorus and nitrogen pollution in natural waters, saprobic systems, water acidification, hygiene pollution, drinking water supply and treatment, wastewater treatment, hormonally active substances; implications for the requirements of the EU Water Framework Directive. ***VL Basic Ecological Processes***: The principles of ecology are discussed in this course. The principles of population ecology and the interaction between species (competition, predator-prey process, and mutualism) will be explained, based on the adaptation of individuals to their environment. Finally, the structure and function of ecosystems and the ecology of ecosystems are discussed. Numerous examples from the empirical and theoretical ecology are used to describe the basic principles of ecology. Another focus is on the representation of the human reshaping of ecosystems and their processes. ***Ü Interdisciplinary Analysis of Ecosystem Processes and Water and Nutrient Transport in Landscapes*** This module will convey, practical and procedural knowledge for data collection, sample analysis and data interpretation in the soil-water-plant system. The fieldwork is done in the context of current research issues. This work aids the forecasting at various levels of the environmental change impact on water and material flow in the countryside as well as the introduction to broader research activity. The field data collected also form the basis for the laboratory work in this module and in further modules, e.g. in the context of modelling. ***VL „Scaling": Physiological Ecology from Individual Organ to Ecosystem*** *In-depth understanding of the scale-dependency of ecological processes in time and space (basic concepts of allometry, scaling, non-linearity, intraspecific variability, emergent properties)* ***VL Biodiversity of Plants*** Quantification of the numbers of species, spread, gradients, biogeography, biomes, functional diversity, pollination systems, life history, rarity, coexistence, invasive plants, global change, wildlife conservation ***S Functional Consequences of Marine Biodiversity***

	Change ***In tutorials*** The seminar consists of an initial workshop in Wilhelmshaven, project work and a closing symposium in Groningen
Module Aims	The students have the required advanced knowledge about environmental systems and biodiversity to model various problems on their own. ***Ecology of Plants in Landscapes (VL) /*** ***Material Balance of Plants in Landscapes (VL) /*** ***Ecology of Animals in Landscapes(VL):*** • advanced knowledge of environmental conditions and the biological mechanisms which lead to survival of plants species in landscapes • advanced knowledge of the regional differentiation of hydrological processes in various landscapes • advanced knowledge of mass balance of plants in landscapes • advanced knowledge of environmental conditions and the biological mechanisms which lead to the survival of animal species in landscapes Successful students of this module have sufficient knowledge of theory and models of survival conditions of plants and animals in heterogeneous landscapes at the beginning stage of their Master study. ***Specific Hydrogeology (VL) /*** ***Specific Soil Science(VL):*** • advanced knowledge of modelling methods of hydrological processes in landscapes • advanced knowledge of regional differentiation of hydrological processes in various landscapes • advanced knowledge of causes of soil hazards, chemical-physical processes of soil alteration and prophylactic and therapeutic measures of soil protection • advanced knowledge of physical/chemical processes in soil and their characteristic attributes Successful students of this module have advanced knowledge of theory and models of hydrological processes, physical-chemical processes in soil as well as hazard and protection in various landscapes in the beginning stage of their Master study. ***Environmental Chemistry (VL),*** ***Environmental Physics (VL):*** Students have an advanced knowledge of the organic and inorganic chemical and physical-analytical as well

	as physical-systematic aspects of environmental science in terrestrial and marine areas. They can understand and evaluate models of processes concerning the environment. They are aware of and can discuss modern research approaches. They have become acquainted with environmental systems and approaches to their investigations by way of examples taken from environmental chemistry and physics. ***Fundamentals of Water Conservation (VL):*** Students have an advanced knowledge of biological aspects of environmental science in terrestrial and marine areas. They understand important environmental biological and biogeochemical processes in the atmosphere, soil and water, and can evaluate the anthropogenic overprint of natural ecosystems. They are aware of the fundamentals of limnolgy and the demands on water conservation. They are acquainted with modern research approaches to environmental science and can discuss these. They have learned about environmental systems and approaches to their investigation exemplarily in the field. ***Basic Ecological Processes (VL)*** In this course the fundamentals of ecology are presented. Based on the adaptation of individuals to their environment, the principles of population ecology and interaction between species (competition, predator-prey processes, and mutualism) will be explained. Finally, the structure and function of living communities as well as the ecology of ecosystems are illustrated. Numerous examples from empirical and theoretical ecology will be applied, in order to describe elementary ecological principles. An additional focus is the presentation of the human transformation of ecosystems and their processes. ***Interdisciplinary Analysis of Ecosystem Processes and Water and Nutrient Transport in Landscapes (Ü)*** After successfully attending this module, students possess: • practical knowledge of field recording on a soil-scientific, hydrologic, and vegetation ecological basis • advanced knowledge of laboratory analysis of soil, plant and water samples • advanced knowledge of ecosystematic process operations • advanced knowledge of current research topics ***Scaling (VL):***

	The successful student will understand that ecological processes have to be studied at the appropriate scale. Top-down and bottom-up are not only important concept in ecological theory but should also be considered to find the appropriate ecological methodology. Larger entities are not simply the sum of their components, but are likely to show emergent properties. ***Biodiversity of Plants (VL)*** Students have an in-depth knowledge of the distribution of biodiversity and the causes and consequences of its changes. Beside ecological parameters, phylogenetic histories of plants are emphasised. ***Functional Consequences of Marine Biodiversity Change (S)*** Current issues of biodiversity research are taught in a workshop, and then it follows the elaboration of a project topic, for which the students carry out an independent literary research. The results will be presented in a final colloquium. The course takes place in cooperation with the University of Groningen.
Types of Media	Projector, computer, board, slides
Literature	*Ecology of Plants in Landscapes / Material Balance of Plants in Landscapes / Ecology of Animals in Landscapes:* Tilman, D., Kareiva, P. (eds.) (1997): Spatial ecology. Princeton University Press, Princeton, NJ Tilman, D. (1988): Plant strategies and the dynamics and structure of plant communities. Princeton University Press, Princeton, NJ. Bazzaz, F.A. (1996): Plants in changing environments. Cambridge University Press, Cambridge Hubbell, S.P. (2001): The unified neutral theory of biodiversity and biogeography. Princeton University Press, Princeton, NJ. Grime, J.P. (2001): Plant strategies, vegetation processes and ecosystem properties. Wiley, Chichester. *Specific Hydrogeology / Specific Soil Science:* Adler, G.H., Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit, Bundesanstalt für Gewässerkunde, Institut für Hydrologie (2000): Hydrologischer Atlas von Deutschland. Deutschland. Baumgartner, A. & Liebscher, H.-J. (1996): Allgemeine Hydrologie – Quantitative Hydrologie. Lehrbuch der

	Hydrologie, Band 1. Bornträger, Berlin. Beven, K.-J. (2001): Rainfall-Runoff Modelling: The Primer. John Wiley & Sons. Blume, H.-P. (2007): Handbuch des Bodenschutzes. Ecomed. 3. Auflage. Blume, H.-P., Felix-Henningsen, P. & Fischer W. R. (1998): Handbuch der Bodenkunde. Verlag Hüthig Jehle Rehm. 7. Auflage. Dyck & Peschke (1995): Grundlagen der Hydrologie; Verl. f. Bauwesen, 3. Auflage. Knapp, B. (1989): Elements of geographical hydrology, Unwin Hyman, London. Scheffer, F., Schachtschabel, P. (2002): Lehrbuch der Bodenkunde. Spektrum Akademischer Verlag. 15. Auflage. Schultz, J. (2002): Die Ökozonen der Erde, UTB, 3. Auflage. *Environmental Chemistry:* C. Bliefert, 2002. Umweltchemie, 3. Aufl. Wiley-VCH, Weinheim, F. Press, R. Siever, 1995. Allgemeine Geologie, Spektrum, Heidelberg J. Matschullat, H.J. Topschall, H.-J. Voigt, 1997. Geochemie und Umwelt, Springer, Heidelberg *Environmental Physics:* J. P. Peixoto, A.H. Oort: Physics of Climate AIP 1993. G. Guyot: Physics of the environment and climate. Wiley 1997 *Fundamentals of Water Conservation:* C. Bliefert, 2002. Umweltchemie, 3. Aufl. Wiley-VCH, Weinheim, F. Press, R. Siever, 1995. Allgemeine Geologie, Spektrum, Heidelberg J. Matschullat, H.J. Topschall, H.-J. Voigt, 1997. Geochemie und Umwelt, Springer, Heidelberg *Basic Ecological Processes* To be announced in the lecture. *Interdisciplinary Analysis of Ecosystem Processes and Water and Nutrient Transport in Landscapes* Will be introduced at the beginning of the lectures.

	Scaling Niklas, K.J., 1994. Plant allometry: the scaling of form and process. Chicago University Press, Chicago. Schulze, E. D., E. Beck and K. Müller-Hohenstein. 2002. Pflanzenökologie. Berlin, Springer *Biodiversity of Plants* Kevin Gaston & John Spicer – 1998 - Biodiversity – An Introduction, Blackwell Publ. *Functional Consequences of Marine Biodiversity Change* To be announced in the lectures.
Prerequisite for Participation	None
Useful Previous Knowledge	Knowledge of vegetation, animal ecology and ecology; comparable with similar modules from the Bachelor in Environmental Sciences
Study / Examinations to be Completed	1 graded examination: Oral examination of about 30 minutes with two module lecturers, whereby at least one examiner must be an academic member of staff. Ungraded examinations: Written examination, presentation of a paper, assignment, practical exercise, term paper, internship report, portfolio or presentation as stipulated by the lecturer; and these must at least be graded as passed.
Criteria for receiving Grades	An examination result assessed as adequate, according to general standards

Degree Course	**MSc Environmental Modelling**
Module Description	**Energy Systems**
Module Code	ES
Semester / Module Length	1st and 2nd semester / 2 semesters
Association with Other Degree Courses / Curricula	MSc Physics, MSc Computer Science
Courses	(VL = lecture, S = seminar) VL/S Computational Fluid Dynamics I + II (6CP) VL Energy Meteorology I (Solar) (3CP) VL Energy Meteorology II (Wind) (3CP) VL Wind Energy (3 CP) VL Wind Energy II (3 CP) VL Solar Energy (3CP) S Current Research Topics in Wind Energy Meteorology (3CP)
Teaching Language	German or English
Module Coordinator	Dr. Detlev Heinemann
Lecturers	Dr. Detlev Heinemann, Prof. Dr. Joachim Peinke, Prof. Dr. Jürgen Parisi, Dr. Gerald Steinfeld, Dr. Bernhard Stoevesandt
Workload	Contact time: 112 hrs, self-study: 248 hrs
Learning / Teaching Methods	Lecture, seminar
Available Credit Points / ECTS	12 CP
Module Content	This module provides a specialization on applications in energy systems. For their specialization the students can choose any courses from the list according to their own interests in wind and/or solar energy systems. ***Computational Fluid Dynamics I+ II (VL, S)*** • Navier-Stokes-Equations • Filtering/averaging of Navier- Stokes-Equations • Introduction to numerical methods • Finite-differences, finite-volumes methods • Linear equation systems, NS-solvers, RANS, URANS, LES, DNS • Turbulent flow, incompressible & compressible flow • Efficiency and accuracy • Application of OpenFOAM and PALM models

	Energy Meteorology I (Solar) • Physics of radiative processes in the atmosphere • Physical modelling of atmospheric radiative transfer (incl. computing tools) • Solar irradiance modelling for solar energy applications • Solar spectral irradiance: Theory & relevance for solar energy systems • Satellite-based estimation of solar irradiance • Solar irradiance (& solar power) forecasting • Solar radiation measurements: Basics & setup of high-quality measurement system ***Energy Meteorology II (Wind)*** Dynamics of Horizontal Flow (forces, equation of motion, geostrophic wind, frictional effects, primitive equations, general circulation) Atmospheric Boundary Layer (turbulence, vertical structure, specific BL effects) Atmospheric Flow Modelling: Linear models, RANS & LES models Wind farm modelling Offshore-Specific Conditions Resource Assessment & Wind Power Forecasting Wind Measurements & Statistics ***Wind Energy I*** • Physical properties of fluids • Wind characterization and anemometers, • Aerodynamic aspects of wind energy conversion, • Dimensional analysis, (pi-theorem) • Wind turbine performance • Design of wind turbines • Electrical systems ***Wind Energy II*** • Assessment/estimation of wind energy resources (Weibull distribution, basics of WAsP methods, long-term correction of wind measurement data, influence of layer stability, wind energy output estimation, establishing yearly wind energy output potential) • Wake effects and wind farms (restoration of the original wind field in the wakes of wind turbines, basics of the Risø model, efficiency of wind turbines in wind farms, effect of wind farms) • Wind farm operation (influences of the energy output of

	wind farms) ***Solar Energy*** Components: • Descriptions of components in stationary as well as dynamic installations: Mode of Operation, technology, characteristics • Photovoltaics (PV): Solar cells, PV generator, system components • Solar thermal collector (Flat Plate, Vacuum, Concentrating), thermal storage System: • Descriptions of systems in stationary and dynamic installations: Construction, interaction of components, losses • Photovoltaics: PV Island Systems, PV Grid- coupled systems, PV pumping systems, hybrid systems • Solar Thermal: Hot water production, heat- supporting solar thermal systems, solar cooling, solar thermal power stations ***Current Research Topics of Wind Energy Meteorology*** Per semester, this seminar deals with blocks of topics on the meteorological constraints of wind energy. Examples are: offshore-specific wind conditions and their influence on wind farms; current models for wind fields within and trailing wind farms; large-scale meteorological influences on the feeding into the web of wind energy; numerical methods of wind energy specific current modelling.
Module Aims	The students have the required advanced knowledge about energy systems to model various problems on their own. ***Computational Fluid Dynamics I+ II (VL, S)*** • Provide basic knowledge in physical flow modelling and turbulence • Mathematical realizations, i.e., numerical methods • Overview of numerical techniques of practical relevance, capability of selecting a model for specific applications (strengths and weaknesses of various model classes) • Practice with state-of-the-art models ***Energy Meteorology I (Solar)*** • Providing a solid understanding of physical processes governing the surface solar irradiance available for solar energy applications • Developing skills in solar radiation modelling, i.e., expertise in application, adaptation and development of

	models • Solid knowledge in state-of-the-art-methods in satellite-based irradiance estimation and solar power forecasting • Detailed understanding of the influence of meteorological/climatological aspects on the performance of solar energy systems ***Energy Meteorology II (Wind)*** • Detailed understanding of the influence of meteorological/climatological aspects on the performance of wind power systems • Solid knowledge of physical processes governing atmospheric wind flows • Understanding atmospheric boundary layer flow relevant for wind power conversion • Knowledge in methods for wind resource assessment and forecasting ***Wind Energy I / Wind Energy II*** Students acquire advanced knowledge in the field of wind energy applications. Special emphasis is on connecting physical and technical skills with know-how in the fields of logistics, management, environment, finances, and economy. Practice-oriented examples enable students to assess and classify real wind energy projects. Special situations such as offshore wind farms and wind farms in non-European foreign countries are included to give students insight into the crucial aspects of wind energy relating to non-trivial realizations as well as to operating wind farm projects. ***Solar Energy*** "Solar Energy" conveys knowledge about photovoltaic and solar thermal systems and components. Students learn to dimension and economically evaluate installations, on both a general and detailed level with the help of software. Furthermore, students will gain insight into physical and engineering processes for solar energy utilization.
Literature	<u>*Computational Fluid Dynamics I+ II:*</u> J.H. Ferziger, M. Peric, Computational Methods for Fluid Dynamics, Springer, 2002 C. Hirsch, Numerical Computation of Internal and External Flows: Introduction to the Fundamentals of CFD: Vol 1: The Fundamentals of Computational Fluid Dynamics, 2nd edition, Butterworth-Heinemann, 2007 P. Sagaut, Large Eddy Simulation for Incompressible Flows, Springer, 1998 J. Fröhlich, Large Eddy Simulationen turbulenter Strömungen, Teubner, 2006 (in German)

	Energy Meteorology I (Solar): M. Iqbal: An Introduction to Solar Radiation (Academic Press, Toronto, 1983) K.-N. Liou: An Introduction to Atmospheric Radiation, 2nd Ed. (Academic Press, Orlando, 2002) Thomas, G. E. and K. Stamnes: Radiative Transfer in the Atmosphere and Ocean, Cambridge University Press, 1996. A. Marshak, A. Davis (Eds.): 3D Radiative Transfer in Cloudy Atmospheres (Springer Berlin Heidelberg New York, 2005) J.A. Duffie, W.A.Beckman: Solar Engineering of Thermal Processes, 2nd Ed. (Wiley& Sons, 1991) *Energy Meteorology II (Wind):* J. R. Holton: An Introduction to Dynamic Meteorology (3rd Edition, Academic Press, New York, 1992) Stull, R.B., 1988: An Introduction to Boundary Layer Meteorology. Kluwer Academic Pub. *Wind Energy I / Wind Energy II:* T. Burton et. al.: Wind Energy Handbook. John Wiley, New York, 2nd ed., 2011 R. Gasch, J. Twele: Wind Power Plants. Springer, 2nd ed., 2011. *Solar Energy:* Duffie, John A. & Beckman, William A. , 2006: Solar Engineering of Thermal Processes, Wiley. Green, Martin A. , 1981: Solar cells : operating principles, technology and system applications, Prentice Hall. Green, M.A., 2007: Third Generation Photovoltaics, Advanced Solar Energy Conversion, Springer Series in Photonics Twidell, John & Weir, Toni, 2005: Renewable Energy Resources Taylor & Francis. *Current Research Topics of Wind Energy Meteorology:* Issue-specific, will be introduced in the lectures.
Prerequisite for Participation	None
Useful Previous Knowledge	Basic knowledge in mathematics, physics
Study / Examinations to be Completed	1 graded examination: Oral examination of about 30 minutes with two module lecturers, whereby at least one examiner must be an academic member of staff.

	Ungraded examinations: Written examination, presentation of a paper, assignment, practical exercise, term paper, internship report, portfolio or presentation as stipulated by the lecturer; and this must at least be graded as passed.
Criteria for receiving Grades	An examination result assessed as adequate, according to general standards

Degree Course	**MSc Environmental Modelling**
Module Description	**Environmental and Resource Economics**
Module Code	URÖ
Semester / Module Length	1st and 2nd semester / 2 semesters
Association with Other Degree Courses / Curricula	Master Sustainability Economics and Management
Courses	(VL = lecture) VL Environmental Economics (3 CP) VL Resource Economics (3CP) VL Energy Economics (3CP) VL Economics of Climate Change (3CP) VL Environmental Policy (3CP)
Teaching Language	German or English
Module Coordinator	Prof. Dr. Heinz Welsch
Lecturers	Prof. Dr. Heinz Welsch, Prof. Dr. Christoph Böhringer, Prof. Dr. Carsten Helm, Prof. Dr. Klaus Eisenack
Workload	Contact time: 112 hrs; self-study 248 hrs
Learning / Teaching Methods	Lecture
Available Credit Points / ECTS	12 CP
Module Content	This module provides a specialization on applications in environmental and resource economics. For their specialization the students can choose any courses from the list according to their own interests. ***Environmental Economics:*** The lecture deals with the economic theories of the environment. It examines environmental problems and policy using microeconomics and welfare economics. The following contents will be dealt with: • Elements of sustainability problems • Normative and ethical basics • Terms of sustainability • Welfare economics and environment • Aims of environmental policy • Instruments of environmental policy • Environmental policy in fragile states • Environmental valuation and decision making Teaching language: German

	Resource Economics: This course deals with the economic theory of natural resource utilization from a normative and a positive perspective. The following issues are covered: • Basic Concepts and Methods of Resource Economics • The Basic Model of Natural Resource Utilization • Non-Renewable Resources • Renewable Resources/Fishery • Forest Resources • “Green” Accounting Teaching language: English ***Energy Economics:*** This course deals with the economic analysis of energy markets and their regulation. The following issues are covered: • Fundamentals of Energy Analysis • Energy Resources • The Coal Market – Perfect Competition • The Oil Market – OPEC Cartel • The Gas Market – Oligopoly • Introduction to Electricity Markets • Market Power in Electricity Markets • Investment in Reliability • Regulation of Electricity Markets Teaching language: English ***Economics of Climate Change:*** This course deals with economic causes of climate change and approaches, problems and impacts of climate change policy. The following issues are covered: • The Science of Climate Change • Why Climate Policy – Market Failure • Cost-Benefit and Inter-temporal Problems • International Cooperation • Instruments of Climate Policy • Climate Policy in Practice Teaching language: English ***Environmental Policy:*** This course deals with problems of environmental policy

	predominantly in the context of sustainable development. It covers: • Sustainable development • Population growth • Poverty and international distribution • Economic growth • International Development and Climate Policy Teaching language: German
Module Aims	The students have the required advanced knowledge about environmental and resource economics to model various problems on their own. ***Environmental Economics; Environmental Policy:*** Students can use the economic structures, which lie behind many problems in the environmental field, and work out and develop possible solutions. They are able to consider and disclose incentives, as offered by the various stakeholders. Based on the current problematic situations the students have • Understanding of the basic problems and contexts, • Understanding of relevant concepts, • Understanding of the behaviour of typical actors, • Mastery of the usual modelling, • Ability to evaluate environmental economic problems. ***Resource Economics; Energy Economics:*** Students acquire an understanding for the normative problems of using natural resources, their efficient and optimal use as well as the functioning of real resource markets (in particular, energy markets) and their regulation. Based on current problems, students can: • Understand basic problems • Understand relevant concepts • Command methods of analysis • Understand the basics of the respective markets, in particular energy markets • Understand reasons and instruments for the regulation of energy markets. ***Economics of Climate Change:*** Students acquire the ability to analyse the economic forces behind climate change in the light of scientific principles, and understand and evaluate regulatory-policy approaches to solutions. They can: • Understand basic problems

	• Understand relevant concepts • Master the methods of analysis • Understand intertemporal and international incentive problems • Understand the instruments of climate policy for the regulation of energy markets.
Types of Media	Projector, computer, board, slides
Literature	*Environmental Economics / Environmental Policy* Feess, E. (2007): Umweltökonomie und Umweltpolitik. München: Vahlen. Michaelis, P. (1996): Marktwirtschaftliche Instrumente der Umweltpolitik, Heidelberg: Physica. *Resource Economics / Energy Economics* Roger Perman et al.: Resource and Environmental Economics, Pearson 2003. John Hartwick, Nancy Olewiler: The Economics of Natural Resource Use, 2nd edition, Addison Wesley 1997; Carol Dahl: International Energy Markets, PennWell 2004; Steven Stoft, Power System Economics : Designing Markets for Electricity, New York 2002; IEA: World energy outlook, annual. Knut Sydsaeter, Peter Hammond: Essential Mathematics for Economic Analysis, Pearson. *Economics of Climate Change* Will be introduced in the lectures.
Prerequisite for Participation	None
Useful Previous Knowledge	Microeconomics
Study / Examinations to be Completed	1 graded examination: Oral examination of about 30 minutes with two module lecturers, whereby at least one examiner must be an academic member of staff. Ungraded examinations: Written examination, presentation of a paper, assignment, practical exercise, term paper, internship report, portfolio or presentation as stipulated by the lecturer; and this must at least be graded as passed.
Criteria for receiving Grades	An examination result assessed as adequate, according to general standards

Degree Course	**MSc Environmental Modelling**
Module Description	**Process- and System-Oriented Modelling**
Module Code	PSM
Main Focus	Specialisation process-and system-oriented modeling
Semester / Module Length	2nd and 3rd semester / 2 semesters
Association with Other Degree Courses / Curricula	MSc Marine Environmental Sciences, MSc Physics
Courses	If PSM is the main focus, a course selection of 18 CP is required; any PSM courses can be selected as supplementary subjects (maximum of 12 CP). (VL = lecture, S = seminar, Ü = tutorial) VL Models in Populations Dynamics (3 CP) Ü Models in Populations Dynamics (3 CP) S Models of Ecosystems (3 CP) VL Theory of Dynamic Systems (3 CP) Ü Theory of Dynamic Systems (3 CP) S Critical Conditions of System Earth (3 CP) S Theoretical Oceanography (3CP) S Climate Dynamics (3CP) VL Shelf Sea and Coastal Oceanography (3CP) VL Climate Models: Theory and Practice (3CP) Ü Climate Models: Theory and Practice (3CP) VL, Ü, S Specific Methods in Process and System-oriented Modelling (3CP) VL Theory of Ecological Communities (3 CP) Ü Theory of Ecological Communities (3 CP) VL Fluid Dynamics I (3CP) VL Fluid Dynamics II (3CP) S Complex Systems and Modelling Seminar (3 CP)
Teaching Language	German or English
Module Coordinator	Prof. Dr. Ulrike Feudel
Lecturers	Prof. Dr. Ulrike Feudel, PD Dr. Jan Freund, Prof. Dr. Bernd Blasius, Prof. Dr. Jörg Wolff, Prof. Dr. Emil Stanev, Prof. Dr. Joachim Peinke
Workload	Contact time: 168 hrs, self-study: 372 hrs
Learning / Teaching Methods	Lecture, seminar, tutorial
Available Credit Points / ECTS	18 CP

Module Content	This module provides courses, which teach a large spectrum of methods in process- and system-oriented modelling including their application in ecology, climate dynamics and oceanography. ***Models of Populations Dynamics (VL+Ü):*** Time continuous and time discreet models (prey-predator interactions, competition, food webs), age-structured models, adaptive models, stochastic population models, individual-based modelling. ***Models of Ecosystems (S):*** Discussion of current work of modelling in processes in the environment. Modelling of food chains, special aquatic and terrestrial ecosystems, spread of pests, modelling of biogeochemical and ecological networks, coupling of biological and physical processes, models of evolution and assimilation (evolutionary game theory, molecular evolution, modelling qualitative parameters e.g. edibility), self organised criticality. ***Theory of Dynamic Systems (VL+Ü):*** Introduction to birfucation theory: creation of temporary structures, instabilities; introduction to chaos theory: attraktors, saddle, their characteristics and bifurcations; characteristic examples from physics, chemistry and biology; specific problems of nonlinear dynamics: multistability, synchronisation, control, influence of noise ***Critical Conditions of System Earth (S):*** Discussion of current original works from environmental research, which are primarily based on conceptual process-models (e.g. El Nino, thermohaline circulation, algae blooms, changes in weather conditions, Dansgaard-Oeschger events). ***Theoretical Oceanography (S):*** Immersion in teh theoretical fundamentals of hydro dynamic base equations in oceanography, continuum hypothesis, laws of conservation, master equations for impulse, temperature, salinity, pressure and density. Methods of perturbation calculation in waves. Sound, capillary and surface gravity waves, as well as waves influenced by the rotation of the earth (Rossby and Kelvin waves). Geostrophic currents and satellite measurements. Friction and blending processes. Interaction between atmosphere and ocean (impulse, warmth, fresh water). Selected topics of theoretical oceanography.

	Climate Dynamics (S): Conveyance of the theoretical basis of climate dynamics, the fundamental equations of climate systems, including atmosphere and ocean. Radiation balance and interation between atmosphere and ocean. Average conditions of atmosphere, ocean and cryosphere. Energy in climatical system and water cycles. Climate modes and time restricted climate fluctuations of the scale of months to thousands of years (NAO and ENSO). Predictability of the climate system. ***Shelf-sea and Coastal Oceanography (VL)*** Circulation in shelf sea and coastal area; hydrodynamics of tidal currents, coastal waves, wind-powered transport and thermohaline circulation (incl. suspension currents); basics of coastal and benthic boundary layers, oceanic fronts and water exchange, circulation in Zirkulation estuaries, mud flats, waterways, nearly closed seas and shelf seas, theoretical application for the exchange of material between land and ocean. ***Climate Models: Theory and Practice (VL+Ü):*** Introduction to the operation of complex climate models. Conveyance of mathematical and physical basics for comprehension of modelled processes and their implementation in the models. Creation of simple test cases in the partial systems of ocean and atmosphere, as well as test cases of the coupled system of ocean-atmosphere. Evaluation and preparation of model results. ***Theory of Ecological Communities (VL+Ü):*** Conveyance of basic theoretical models of biodiversity: population ecology vs. community ecology, statistical measures of biodiversity, rank abundance curve, competition models: Lotka-Volterra model vs. resource-based competition, competition for two resources, ecological niches, mechanisms of coexistance, limiting similarity, competition for niche gradient, MacArthur-Levin-May model, Levin's model and competition-colonisation trade off, diversity-stability debate, island biogeography and neutral theory of biodiversity. ***Specific Methods in Process and System-Oriented Modelling (VL, Ü, S):*** Special lecture (partly with tutorial) or seminar with varying content, to present current areas of research in process and system-oriented modelling. Possible content: numerical methods in oceanography, coupled systems, synchronization, structure formation in specific systems, particles in currents, biogeochemical material cycles.

	Fluid Dynamics I (VL): Base equations: Navier-Stokes equation, continuity equation, Bernoulli-equation; vortex and energy equations, laminar flows and stability analysis, exact solutions, applications. ***Fluid Dynamics II (VL):*** Reynolds equation, closure problems and approaches, turbulance models: cascade models – stochastic models. ***Seminar Complex Systems and Modelling (S):*** Introduction to current topics in environmental modeling.
Module Aims	The students posses a comprehensive overview over modern methods of process- and system-oriented modelling. They are able to develop models of different complexity for various environmental problems and to implement them on the computer on their own. Besides simulation methods, they are capable of using sophisticated tools to analyse the models. They are able to get quickly into new scientific questions in environmental science and to proposae solutions upon the basis of models. They have learned to think in an interdisciplinary way and to put environmental systems into the context of earth system science as a whole. Students can comprehend contemporary methods of analysis and simulation methods of modern environmental research, and can understand and classify even the newest approaches through self-study of current literature. Students can critically acknowledge publications in journals, conceptualise process- and systemoriented environmental models to various problems, and interpret the results of model studies within the context of a particular problem. The expertises gained in each course are listed separately. ***Models in Population Dynamics (VL+Ü) / Models of Ecosystems (S) / Theory of Ecological Communities (VL+Ü)*** Students possess the ability to create and analyse simple models of ecosystems, and to simulate them on the computer. They have a command of the basic principles of setting up models of ecosystems and can create these themselves for simple problems. ***Theory of Dynamic Systems (VL+Ü) / Critical Conditions of System Earth (S) / Specific Methods in***

	Process and System-oriented Modelling (VL, Ü, S) Students possess basic knowledge of the analysis of nonlinear dynamic systems. They can recognise phenomena, resulting from nonlinear interations, in environmental systems, and know how to apply methods of nonlinear dynamics to environmental systems. ***Theoretical Oceanography (S) / Climate Dynamics (S) / Shelf-sea and Coastal Oceanography (VL) / Climate Models: Theory and Practice (VL+Ü) / Fluid Dynamics I and II (VL):*** Students are able to follow complex, theoretical procedures of modern oceanography and climate research, and understand and classify new and different approaches in theory out of current literature. Students are able to evaluate current publications in journals, analyse various issues about models of environmental systems and apply the results of research with environmental systems models to specific issues.
Literature	*Models in Population Dynamics:* F. Brauer/C. Castillo-Chavez: Mathematical Models in Population Biology and Epidemiology. Springer, 2001 A.D.Bazykin: Nonlinear dynamics of interacting populations. World Scientific, 2000. H. Caswell: Matrix Population Models. Sinauer 2001. L. Edelstein-Keshet: Mathematical Models in Biology. Birkhäuser, 1988. J.D. Murray: Mathematical Biology I und II. Springer, 2001. *Models of Ecosystems:* Recent publications from journals will be introduced in the lectures. *Theory of Dynamic Systems:* J. Guckenheimer und P. Holmes: Nonlinear Oscillations, Dynamical Systems, and Bifurcations of Vector Fields, Springer, 1983. J. Argyris, G. Faust, M. Haase: Die Erforschung des Chaos, Vieweg, 1994. E. Ott: Chaos in Dynamical Systems. Cambridge, 2002. P. Schuster: Deterministisches Chaos. Verlag Chemie Weinheim, 1994. *Critical Conditions of System Earth:* Recent publications from journals will be introduced in the lectures.

	Theoretical Oceanography: W. Krauss, 1973 Methoden und Ergebnisse der Theoretischen Ozeanographie, Gebr. Borntraeger J. Pedlosky, 2003, Waves in the Ocean and Atmosphere, Springer Climate Dynamics:: Recent publications from journals will be introduced in the lectures. *Climate Models: Theory and Practice:*Recent publications from journals will be introduced in the lectures. *Specific Methods of Process and System-oriented Modelling Spezielle:* Recent publications from journals will be introduced in the lectures. *Fluid Dynamics:* D. J. Tritton: Physical fluid dynamics. Clarendon Press, Oxford, 2003 G. K. Batchelor: An introduction to fluid dynamics. Cambridge University Press, Cambridge, 2002 U. Frisch: Turbulence: the legacy of A. N. Kolmogorov. Cambridge University Press, Cambridge, 2001 J. Mathieu, J. Scott: An introduction to turbulent flow. Cambridge University Press, Cambridge, 2000 P.A. Davidson: turbulence Oxford 2004
Prerequisite for Participation	None
Useful Previous Knowledge	Experience in using MATLAB and MAPLE
Study / Examinations to be Completed	2 graded examinations in main focus: 1) A graded examination (written examination, oral examination, presentation of a paper, assignment, practical exercise, term paper, internship report/report, presentations) in one of the lectures which is not part of the oral examination. Where necessary, further ungraded examinations as stipulated by the lecturer. 2.) Oral examination of about 30 minutes with content from the selected area. The examination is taken by two examiners, whereby at least one examiner must be an academic member of staff.
Criteria for receiving Grades	Both examinations described in 1) and 2) must at least be graded "adequate" and are each weighted with 50% of the overall module grade.

Degree Course	**MSc Environmental Modelling**
Module Description	Statistical and Stochastic Modelling
Module Code	SM
Main Focus	Specialisation Statistical and Stochastic Modelling
Semester / Module Length	2nd and 3rd semester / 2 semesters
Association with Other Degree Courses / Curricula	MSc Marine Environmental Sciences, MSc Physics
Courses	If SM is the main focus, a course selection of 18 CP is required; any SM courses can be selected as supplementary subjects (maximum of 12 CP). (VL = lecture, Ü = tutorial, S=seminar) VL Statistical Ecology (3 CP) Ü Statistical Ecology (3 CP) VL Time Series Analysis (3 CP) Ü Time Series Analysis (3 CP) VL Stochastic Processes (3 CP) VL Multivariate Statistics (3 CP) Ü Multivariate Statistics (3 CP) Ü Introduction to the Statistical Analysis of Environmental Data (3CP) Ü Modelling Spatial Data (3 CP) Ü Analysis of Vegetation Ecological Data (3 CP) VL,Ü, S Specific Methods of Statistical and Stochastic Modelling (3 CP) S Complex Systems and Modelling Seminar (3 CP)
Teaching Language	German or English
Module Coordinator	PD Dr. Jan Freund
Lecturers	Biedermann R., Freund J., Minden V., Peppler-Lisbach C., Stecking R.
Workload	Contact time: 168 hrs, self-study: 372 hrs
Learning / Teaching Methods	Lecture, seminar, tutorial
Available Credit Points / ECTS	18 CP
Module Content	This module provides courses, which teach a large spectrum of methods in statistical modelling including methods to trat stochastic processes and their in environmental science. ***Statistical Ecology (VL+Ü):*** Introduction to elementary probability theory, basic

	distributions, the estimation problem, estimation of population parameters, capture-recapture experiments, transect and distance sampling methods, recording of species, diversity indices. ***Time Series Analysis (VL+Ü):*** Time series as the result of stochastic processes, estimation of process descriptors, component models, trend elimination, spectral methods, filtering, linear processes, nonlinear processes, embedding methods, dimensions, Lyapunov exponent, symbolic dynamics, non-linear noise reduction. ***Stochastic Processes (VL):*** Basics of the theory of probability, characterisation of stochastic processes in time and frequency domains, Chapman-Kolmogorov, Master, Fokker-Planck equations, stochastic differential equations, stochastic simulation,(Ornstein-Uhlenbeck Process and numerical integration of SDEs, birth-death process and Gillespie Algorithm). ***Multivariate Statistics (VL+Ü):*** Linear and logistic regression analysis, discriminant analysis, principle component analysis, cluster methods, variable selection, model validation. ***Introduction to the Statistical Analysis of Environmental Data (Ü):*** Basic methods oft he exploratory statistics and statistical tests related to ecological data: study design, exploratory data analysis, distribution tests, data transformation, Chi² test, Anova, Kruskal-Wallis test, t-test and U-test, multiple comparisons, post hoc tests. ***Modelling Spatial Data (Ü):*** Methods of habitat modelling, basics of spatially explicit analysis of species-environment relationships and the spacial forecast of environmental requirements of species, spatially dependent measurement and observation data with methods of geostatics: linear (OLS) regression, GLM (logistic regression, Poisson regression), spatially explicit modelling, GIS incorporation, spatial statistics. ***Data analysis in vegetation ecology (Ü):*** Cluster analysis, statistical measures of fidelity, ordination methods: indirect methods (PCA, CA, DCA) as well as canonical (RDA, CCA).

	Specific Methods of Statistical and Stochastic Modelling (VL, Ü,SE): Special lecture (partly with tutorial) or lecture with varying content, to present current areas or research in statistical and stochastic modelling. Possible content: e.g. correlation, causality and its reconstruction from multivariate time series, generalised regression, mathematical basics of applied statistics, computer intensive methods. ***Complex Systems and Modelling Seminar (S):*** Introduction to current topics in environmental modelling.
Module Aims	Students are able to evaluate environmental data using descriptive processes and statistics. In addition to theoretical comprehension of methods of analysis, they have practical experience with algorithmic methods of analysising statistics and numeric simulation of stochastic environmental systems. Hereby they learn the use of the free statistic software R. Students are able to plan the collection of environmental, stastically evaluate it, and apply to stochastic models for the purpose of forecasting. Students can comprehend contemporary methods of analysis and simulation methods of modern environmental research, and can understand and classify even the newest approaches through self-study of current literature. Students can critically acknowledge publications in journals, conceptualise statistical environmental system models to various problems, and interpret the results of model studies within the context of a particular problem.
Literature	<u>Statistical Ecology:</u> D. Pfeifer, H.-P. Bäumer & U. Schleier: Grundzüge der statistischen Ökologie. CvO Univ., Inst. für Math. Stochastik; 1996. L.J. Young & J.H. Young: Statistical ecology: a population perspective. Kluwer Academic Publ.; 1998. M. Begon, J.L. Harper & C.R. Townsend: Ökologie: Individuen, Populationen und Lebensgemeinschaften. Birkhäuser, 1991. C.J. Krebs: Ecology: the experimental analysis of distribution and abundance. Benjamin Cummings u.a.; 2009. E.C. Pielou: Mathematical ecology. Wiley; 1977. O. Richter & D. Söndgerath: Parameter estimation in ecology: the link between data and models. VCH; 1990. <u>Time Series Analysis :</u>

	R. Schlittgen & B. Streitberg: Zeitreihenanalyse. Oldenbourg; 2001. R. Schlittgen: Angewandte Zeitreihenanalyse mit R. Oldenbourg; 2012. R.H. Shumway & D.S. Stoffer: Time series analysis and its applications: with R examples. Springer Science+Business Media, LLC; 2011. H. Kantz & T. Schreiber: Nonlinear time series analysis. Cambridge Univ. Press; 2005. H.D.I. Abarbanel: Analysis of observed chaotic data. Springer, 1996. M.B. Priestley: Spectral analysis and time series. Acad. Pr.; 1981. <u>Stochastic Processes:</u> C.W. Gardiner: Handbook of stochastic methods: for physics, chemistry and the natural sciences. Springer; 2002. N.G. van Kampen: Stochastic processes in physics and chemistry. Elsevier; 2007. J. Honerkamp & K. Lindenberg: Stochastic dynamical systems: concepts, numerical methods, data analysis. Wiley-VCH; 1994. H. Risken: The Fokker-Planck equation: methods of solution and applications. Springer, 1989. L. Schimansky-Geier: Stochastic dynamics. Springer; 1997. V.S. Anishchenko, V. Astakhov, A. Neiman, L. Schimansky-Geier & T. Vadivasova: Nonlinear dynamics of chaotic and stochastic systems: tutorial and modern developments. Springer; 2006. <u>Multivariate Statistics:</u> K. Backhaus et al.: Multivariate Analysemethoden (12. Aufl.). Springer; 2008. H.P. Litz: Multivariate Statistische Methoden. Oldenbourg; 2000. J. Hartung & B. Elpelt: Multivariate Statistik. Oldenbourg; 1995. M. Berthold & D.J. Hand: Intelligent Data Analysis (2. Aufl.). Springer;2003. I.H. Witten & E. Frank: Data Mining. Morgan Kaufmann; 2000. <u>Introduction to the Statistical Analysis of Environmental Data:</u> M.J. Crawley: The R Book. Wiley & Sons; 2007. M. Logan: Biostatistical Design and Analysis Using R. Wiley-Blackwell; 2010. C.F. Dormann & I. Kühn: Angewandte Statistik für die biologischen Wissenschaften http://cran.r-

	project.org/doc/contrib/Dormann+Kuehn_AngewandteStatistik.pdf; 2008. <u>Modelling Spatial Data:</u> J. Franklin: Mapping Species Distributions: Spatial Inference and Prediction. Cambridge University Press; 2010. C.F. Dormann, T. Blaschke, A. Lausch, B. Schröder & D. Söndgerath: Habitatmodelle – Methodik, Anwendung, Nutzen. UFZ-Berichte 9/2004; 2004. J.M. Scott et al.: Predicting species occurrences: issues of accuracy and scale. Island Press; 2002. I. Hanski:Metapopulation ecology. Oxford University Press; 1999. <u>Data Analysis in Vegetation Ecology:</u> P. Legendre & L. Legendre: Numerical ecology 2nd ed. – Elsevier; 1998. I. Leyer & K. Wesche: Multivariate Statistik in der Ökologie. – Springer; 2007. B. McCune & J.B. Grace: Analysis of ecological communities. MJM Software Design. Glenedon Beach; 2002. <u>Specific Methods of Statistical and Stochastic Modelling:</u> Recent publications from journals will be introduced in the lectures.
Prerequisite for Participation	None
Useful Previous Knowledge	Experience with MATLAB and MAPLE, knowledge of a high-level programming language (C, C++, FORTRAN etc.)
Study / Examinations to be Completed	<u>2 graded examinations in the major field of study:</u> 1) A graded examination (written examination, oral examination, presentation of a paper, assignment, practical exercise, term paper, internship report/report, presentations) in one of the lectures which is not part of the oral examination. Where necessary, further ungraded examinations as stipulated by the lecturer. 2.) Oral examination of about 30 minutes with contents from the selected area. The examination is given by two examiners, whereby at least one examiner must be an academic member of staff.
Criteria for receiving Grades	Both examinations described in 1) and 2) must at least be graded “adequate” and are each weighted with 50% of the overall module.grade.

Degree Course	**MSc Environmental Modelling**
Module Description	**Modelling Large Systems**
Module Code	MGS
Faculty/Institute	Faculty II, Department of Computer Science
Degree Course	Master in Environmental Modelling
Main Focus	Modelling large systems
Type of Module	Elective, advanced module
Semester / Module Length	2nd and 3rd semester / 2 semesters
Association with Other Degree Courses / Curricula	MSc Computer Science, Bachelor Computer Science, MSc Physics, MSc Sustainability Economics and Management
Courses	If Modelling Large Systems is the main focus, a course selection of 18 CP is required; any courses from Modelling Large Systems may be selected as supplementary subjects (maximum 12 CP): (VL = lecture, Ü = tutorial, S = seminar) VL Software Engineering (4,5 CP) Ü Software Engineering (1,5 CP) VL Ecological System Modelling and Simulation (4.5 CP) Ü Ecological System Modelling and Simulation (1.5 CP) VL Environmental Information Systems (4.5 CP) Ü Environmental Information Systems (1.5 CP) VL Decisions Under Risk and Uncertainty (3CP) VL Environmental Management Information Systems (3CP) S Computational Economics (3CP) VL Computer-Oriented Physics (3CP) Ü Computer-Oriented Physics (3CP) VL Shortcut to the Physics of Complex Networks (3CP)
Teaching Language	German or English
Module Coordinator	Prof. Dr. Michael Sonnenschein
Lecturers	Prof. Dr. Michael Sonnenschein, Dr. Ute Vogel, Prof. Dr. Angelika May, Prof. Dr. Alexander Hartmann, Prof. Dr. Christoph Böhringer, Prof. Dr. Jorge Marx Gómez, Prof. Dr. Andreas Winter
Workload	Contact time: 168 hrs, Self-study: 372 hrs
Learning / Teaching Methods	Lecture, tutorial, seminar

Available Credit Points / ECTS	18 CP
Module Content	This module provides courses, which teach a large spectrum of methods in modelling of large systems, including information systems, netwok-methods, software engineering and their application in environmental science. ***Software Engineering (VL+Ü):*** Aim of the software engineering module is to convey the basic methods and techniques of software engineering along the software life cycle. These methods and techniques are practiced with hands-on exercises. After completion of the module, students know about the key activities of software development, basic modelling techniques of UML, basics of methods and techniques of requirements definition, to software design, quality assurance and software evolution. They can classify, evaluate and apply these methods and aids in various phases of projects. ***Ecological System Modelling and Simulation (VL+Ü):*** Methods of modelling and simulation initially serve to intensify the understanding of correlating effects of dynamic systems. For the area of application of ecology, there are numerous methodical approaches such as cause-effect graphs, differential equation systems, Markov models, L-systems, cellular automata or individual-oriented models, which are introduced and illustrated through examples during the course. Basic concepts of ecological systems are also conveyed. Modelling methods use simulation processes to create models, which are each treated in context. Software tools have and will be developed for the application of such methods, of which structure and function will be dealt with through examples. In particular, tools for simulation of mathematical models as well as for individual-oriented simulation will be introduced and applied in the form of exercises. The interpretation of simulation results eventually leads to the discussion of methods of model validation and the prognosis quality of models. The module "Modelling and simulation of ecological systems" is flanked by the module "Environmental information systems" in which concepts of persistent storage of specific information, as well as concepts of data analysis are covered. The modules are, however, contentually independent. ***Environmental Information Systems (VL+Ü):*** Environemental information systems supply information on environmental conditions to administrative and public institutions, businesses or concerned citizens. Capture, storing and evaluation of this information present

	interesting tasks for computer science. In this course we will investigate the steps in processing environmental information, meaning • Observing problems of data capture and processing, • Become acquainted with data structures and databank concepts for efficient access to (general) spacial data, • Introduction to methods of data analysis (in particular out of geostatic and data mining) • Introduction to multicriteria decision support, as well as • Dealing with the concept of meta data as support for the provision of data The module “Environmental information systems” is flanked by the module Das Module “Modelling and simulation of ecological systems”, in which dynamic aspects of environmental systems (maily ecological systems) are dealt with. The modules are, however, contentually independent. ***Decisions Under Risk and Uncertainty (VL)*** Main Topics are the following: maximize expected utility; binomial games and limits thereof; individual decision making under risk; ex-ante and ex-post consideration; certainty equivalent and insurance premium; option price and option value; risk and irreversibility; catastrophe risk; statistical models for natural catastrophes; environmental cost-benefit-analysis; decision making under uncertainty, payoff and regret matrix; Hurwicz criterion; Bernoulli model; risk hedging strategies, value of information. ***Environmental Management Information Systems (VL)*** In this session, business issues related to environment are discussed and methods, processes and techniques of information processing which facilitate problem solving are presented. Computer-assisted methods of production-integrated environmental protection, environmental controlling and the environmental reporting are presented and discussed. In order to integrate these methods intensively into the context of environmental protection, it is necessary also to convey problems of environmental management and environmental management systems as basis and contextual information. Because on one hand a synoptic view of production and on the other hand disassembly and recycling gives occasion to expect to a priori avoid environmental protection activities, this aspect will be given specific attention. Due to the fact that environmental information technology has established itself as its own discipline, it is also necessary to impart the knowledge of the fundamentals and basic concepts.

	Students should be familiar with and have a command over concepts and methods, for example mass flow analysis or mass flow management, ist connection to environmental management and especially standard software used in conducting mass flow analysis. Contents of the module are: • Environmental management as basis of sustainability • Sustainability and mass flow management • Strategic environmental management • Operational environmental management • Eco-controlling flow Kreislauf • Characterization of corporate environmental systems • EMIS architecture • Standard software systems • Ecobalance systems ***Computational Economics (SE)*** Energy markets are a primary target for policy regulation since they play a key role in the provision of basic services and account for major environmental hazards such as global warming or nuclear waste. The justification and design of regulatory policies require insights into the potential trade-offs between overall economic performance, distributional considerations, and environmental quality: Accomplishing one objective frequently means bacCPedaling on another. Against this background, numerical methods to quantify the implications of policy interference are essential for decision support. ***Computational Physics (VL+Ü)*** More than 20 percent of all scientific publications today are based on computer simulation. This course is an introduction to that area and deals with the most common methods. A central component is practical exercise on the computer, as practical skills are the most important factor of this area. Important chapters: (every semester a selection of): Data structures, algorithms, percolation, Monte-Carlo simulation, finite size scaling, neural networks, molecular dynamics simulation, quantum Monte Carlo, graph algorithms, genetic algorithms, optimization problems ***Shortcut to the Physics of Complex Networks (VL)*** Correlations between the components of physical, biological and social systems can often be characterised by the use of complex networks. Examples are citation networks, the internet and protein correlation networks. Their characteristics can be modelled through analytical

	approaches as well as computer simulation. One question is, for example, whether it is possible to make statements about their dynamic properties due to static network properties. In this lecture we offer an overview of current issues and developments in the area of the statistical physics of complex networks. Approximately 1/3 of the lecture time deals with analytical approaches, 2/3 deals with algorithms. Amongst the topics dealt with in the lectures: models for random graphs, growth models for the creation of special graphs, analytical/numerical characterisation of the structural characteristics of random graphs, assignment of statistical characteristics of networks through “generating functions”, dynamic processes in networks, community structures, optimal networks, phase boundaries in networks, analysis of measurement parameters via maximum likelihood methods.
Module Aims	The students possess the capabilities to work in a team on the development of large software systems, to develop algorithms and implement them using their knowledge of softwareengineering and finallz to use these software systems to analyse large network models fir energz networks and environmental studies. They know how to use environmental information systems as well as environmental management systems. Students can comprehend contemporary methods of analysis and simulation methods of modern environmental research, and can understand and classify even the newest approaches through self-study of current literature. Students can critically acknowledge publications in journals, conceptualise large simulation systems including network approaches to model various problems, and interpret the results of model studies within the context of a particular problem. The expertises gained in each course are listed separately. ***Software Engineering*** Basic terms and concepts of software engineering are imparted: • Activities in software development • Object-oriented modelling with UML (class and object diagrammes, use-case diagrammes, interaction diagrammes, activity diagrammes, state transition diagrammes) • Meta-modelling • Requirements analysis (vision, requirement, requirement definition) • Software system design (architecture, architecture and design patterns, interfaces, software specification) • Quality assurance (quality criteria, tests, reviews)

	• Software evolution (software maintenance, reverse engineering, reengingeering) • Procedure models and management of software projects (unified process, extreme programming) Tools (such as UML modelling tools including IDE, JUnit, SVN) will be introduced and practiced using tasks in lectures and exercises. ***Modelling and Simulation of Ecological Systems*** In this module, students acquire and intensify the following skills: • Aquainted with general methods of discrete and continual as well as spacially-based modelling • Understand basic concepts of ecological systems • Understand typical characteristics as well as advantages and disadvantages of various methods of modeling of ecological systems and can evaluate them critically • Can rationally apply learnt modelling concepts to ecological systems • Understand and practically apply basic simulation methods, especially for discrete models • Systematically and in a short period of time become acquainted with new simulation tools • Can implement simple ecological models • Enhanced team skills by solving small tasks in teams of 2-3 students and improving their presentation skills ***Environmental information systems*** Students in this module receive an overview of phases and important aspects of processing of environmental information. They learn to: • Apply basic processing algorithms in order to classify and format data, • Compare, evaluate and formulate data structures for saving spacial and temporal data, • Use basic functions of a geo-information system, • Understand, evaluate and apply basic methos of data mining • Understand, apply and evaluate basic methods of geostatistics • Understand and assess a method of multi criteria decision support They receive an overview of several areas of application for the provision and use of environmental information, especially provision in the internet. ***Decision under Risk and Uncertainty (VL)***

The aim of this course is to:

- Discriminate between risk and uncertainty,
- Model preferences under risk and uncertainty,
- Apply methods to deal with risk and uncertainty and imprecise information.

Environmental Management Information Systems (VL)

In this session, business issues related to environment are discussed, and methods, processes and techniques of information processing which facilitate problem solving are presented. Students

- Can integrate and clarify the sustainability paradigm
- Have current knowledge about sustainability reporting
- Can define and model mass flow
- Gain practical knowledge in corporate environmental information systems

The knowledge and skills of this module supplement, for example, the contents of environmental information technology and create a clear reference to current problems in the area of sustainability. These are also directly applicable and communicable at work.

Computational Economics (SE)

The course will provide an introduction into numerical partial and general equilibrium models for the state-of-the-art impact assessment of energy and climate policies. Drawing on basic microeconomic theory, the course will follow model-based peer-reviewed publications in international journals to cover contemporary issues in energy and climate policy such as the promotion of renewable energies, the phase-out of nuclear power, the implementation of environmental tax reforms, or the design of international emissions trading schemes.

Computer Oriented Physics (VL+Ü)

Knowledge in basic numeric methods of theoretical physics as well as algorithms and data structure in scientific calculation, debugging. Skills in secure use of modern methods of computer oriented physics, quantitative analysis of advanced problems of theoretical physics and further development of physical intuition.

Understanding of overall concepts and methods of theoretical physics and the natural sciences in general.

Shortcut to the Physics of Complex Networks (VL)

Students intensify their knowledge of theoretical physics and the area of statistical physics. In particular, they acquire fundamental knowledge in networks and their application in the investigation of physical, technical and

	social-economic problems. They further their knowledge through theoretical analysis and moldelling of transdisiplinary problems. Hereby they acquire further skills and expertise through independent practice in new areas, as well as the application of analytical methods and computer simulated algorithms
Literature	Software Engineering: Ian Sommerville: Software Engineering, Addison- Wesley Longman, Amsterdam, 9. Auflage, 2010. Jochen Ludewig, Horst Lichter: Software Engineering, Grundlagen, Menschen, Prozesse, Techniken, Dpunkt, 2. Auflage, 2010. Helmut Balzert: Lehrbuch der Softwaretechnik, Basiskonzepte und Requirements Engineering, Spektrum, Heidelberg, 3. Auflage, 2009. Helmut Balzert: Lehrbuch der Softwaretechnik: Software-Management, Spektrum, Heidelberg, 2. Auflage, 2008. Helmut Balzert: Lehrbuch der Softwaretechnik: Entwurf, Implementierung, Installation und Betrieb, Spektrum, Heidelberg; 3. Auflage, 2012. Modelling and Simulation of Ecological Systems: Script for the lecture Hartmut Bossel. Modellbildung und Simulation. Vieweg 1994 Paul A. Fishwick. Simulation model design and execution: building digital worlds. Prentice Hall, 1995 Environmental Information Systems: O. Günther: Environmental Information Systems I. H. Witten, E. Frank: Data Mining D. Stoyan, H. Stoyan: Umweltstatistik Decisions Under Risk and Uncertainty: T. Biswas: Decision-making under Uncertainty, Macmillan,1997 David Bjornstad, James R. Kahn: The Contingend Valuation of Environmental Resources, E. Elgar Publ., 2002 Louis Eeckhoudt et al: Economic and Financial Decisions under Risk, Princeton Univ. Press, 2005 Michel De Lara, L. Doyen: Sustainable Management of Natural Ressources, Spinger, 2008 Roger Perman et al.: Resource and Environmental Economics, 4th ed., Pearson 2011; Environmental Management Information Systems:

	Marx Gómez, J., Teuteberg, F. (Hrsg.) (2010): Corporate Environmental Management Information Systems – State of the Art and Future Trends. IGI Global, Hershey. Heck, P., Bemmann, U. (Hrsg.) (2002): Praxishandbuch Stoffstrommanagement. Deutscher Wirtschaftsdienst. Rüdiger, C. (2000): Betriebliches Stoffstrommanagement. Deutscher Universitätsverlag. Möller, A. (2000): Grundlagen stoffstrombasierter Betrieblicher Umweltinformationssysteme. Projekt Verlag. Rautenstrauch, C. (1999), Betriebliche Umweltinformationssysteme, Springer-Verlag, Berlin. Computer Oriented Physics:: T.H. Cormen, S. Clifford, C.E. Leiserson, und R.L. Rivest, Introduction to Algorithms, (MIT Press 2001) A.K. Hartmann, Practical guide to computer simulation, (World-Scientific 2009) J.M. Thijssen, Computational Physics, (Cambridge University Press, 2007) M. Newman, G. T. Barkema, Monte Carlo Methods in Statistical Physics, (Oxford University Press, 1999) Shortcut to the Phyics of Complex Networks: Alain Barrat et al., Dynamical Processes on Complex Networks, Cambridge University Press 2008 S.N. Dorogovtsev und J.F.F. Mendes, Evolution of Networks, Oxford University Press, 2002 M.E.J. Newman, The Structure and Function of Complex Networks, SIAM Review 45, 167 (2003) R. Sedgewick, Algorithms in C part 5: Graph Algorithms, Addison-Weseley, 2001
Prerequisite for Participation	Java programming course or similar knowledge
Useful Previous Knowledge	
Study / Examinations to be Completed	2 graded examinations in the major field of study: 1.) A graded examination (written examination, oral examination, presentation of a paper, assignment, practical exercise, term paper, internship report / report, presentations) in one of the lectures which is not part of the oral examination. Where necessary, further ungraded examinations as stipulated by the lecturer. 2.) Oral examination of about 30 minutes with contents from selected area. The examination is given by two examiners, whereby at least one examiner must be an academic member of staff.

Criteria for receiving Grades	Both examinations described in 1) and 2) must at least be graded "adequate" and are each weighted with 50% of the overall module.grade.

Degree Course	**MSc Environmental Modelling**
Module Description	**Practical Seminar on Modelling Studies**
Module Code	PS
Semester / Module Length	3rd semester
Association with Other Degree Courses / Curricula	
Courses	(PR = practical, S = seminar, Ex = excursion) PR/S (4 CP), Ex (2 CP) Interdisciplinary research project, generally conducted by a student, preferably guided by two lecturers from different areas of study at the location of practical training and also meet regularly, must be completed in the major area of study. Excursion
Teaching Language	German or English
Module Coordinator	Prof. Dr. Ulrike Feudel
Lecturers	Lecturers of the degree course
Workload	Contact time: 84 hrs, self-study: 96 hrs
Learning / Teaching Methods	Seminar, practical , excursion
Available Credit Points / ECTS	6 CP
Module Content	The research project must pertain to the major area of study. Contents vary and relate to current research questions which are carried out interdisciplinarily by work groups participating in this course of study. Students participate in workgroup seminars, where they present the results and conclusions of their project. This seminar serves the purpose of discussing all research projects from a cohort, so that students receive an interdisciplinary perspective in all of the different topics being worked on. ***Excursion (2 days):*** Should convey knowledge of envirnomental systems on site. This can be collecting samples in the field, excursion by ship, visit to a company which works in the environmental area, etc.
Module Aims	Students can independently conduct a comprehensive research project under guidance. They can understand current scientific literature and incorporate it into their work. They can prepare, carry out, present in written form and publicly defend a scientific project.
Literature	Determined individually depending on topic, generally current original work taken from scientific journals

Prerequisite for Participation	At least 6 CP in major or supplementary subjects have been earned
Useful Previous Knowledge	
Study / Examinations to be Completed	1 Examination: Presentation of a paper or assignment or practical exercise or term paper or internship report or portfolio and public presentation with discussion Proof of attendance of two excursion days
Criteria for receiving Grades	Quality of the scientific performance of the assignment (90%) and the presentation of a paper (10%)

Degree Course	**MSc Environmental Modelling**
Module Description	**Internship / Research Project**
Module Code	KPFP
Semester / Module Length	3rd semester
Association with Other Degree Courses / Curricula	
Courses	(PR = practical, S = seminar) PR (10 CP), S (2 CP), Interdisciplinary research project, usually done by one student, preferably supervised by two lecturers from different disciplinary areas with regular discussions at the internship location.
Teaching Language	German or English
Module Coordinator	Prof. Dr. Ulrike Feudel
Lecturers	Lecturers of the degree course
Workload	Contact time: 84 hrs, self-study: 276 hrs
Learning / Teaching Methods	Seminar, practical
Available Credit Points / ECTS	12 CP
Module Content	Contents vary and relate to current research questions which are carried out interdisciplinarily by work groups participating in this course of study, or developed in the context of application at another institution outside of the University of Oldenburg. One of the lecturers may also be located outside of the university. Students participate in the seminar on two occasions, firstly presenting the aims and secondly the results and conclusions of their project. This seminar serves the purpose of discussing all research projects from a cohort, so that students receive an interdisciplinary perspective in all of the different topics being worked on.
Module Aims	Students can independently conduct an interdisciplinary research project under guidance. They can understand current scientific literature and incorporate it into their work. They can prepare, carry out, present in written form and openly defend a scientific project.
Literature	Determined individually depending on topic, generally current original work taken from scientific journals
Prerequisite for Participation	At least 12 CP in the major or supplementary subjects must be proven
Useful Previous Knowledge	

Study / Examinations to be Completed	1 Examination: Presentation of a paper, assignment, practical exercise, term paper, internship report, portfolio or public presentation with discussion as stipulated by the lecturer
Criteria for receiving Grades	Quality of the scientific performance of the assignment (90%) and the presentation of a paper (10%)

Degree Course	**MSc Environmental Modelling**
Module Description	**Final Module: Master Dissertation**
Module Code	AMMA
Semester / Module Length	4th semester
Association with Other Degree Courses / Curricula	
Courses	
Teaching Language	German or English
Module Coordinator	Prof. Dr. Ulrike Feudel
Lecturers	Lecturers of the degree course
Workload	Contact time: 56 hrs, self-study: 844 hrs
Learning / Teaching Methods	Master dissertation Seminar about the Master dissertation
Available Credit Points / ECTS	30 CP (27 + 3 CP)
Module Content	Contents vary and relate to current research questions which are addressed at a high scientific level.
Module Aims	Students can independently conduct a comprehensive research project under guidance. They can understand current scientific literature and incorporate it into their work. They can prepare, carry out, present in written form and openly defend a scientific project.
Literature	Dependant upon the specific topic. Besides the literature, additional sources of information should be considered and evaluated.
Prerequisite for Participation	Regulated by the examination regulations
Useful Previous Knowledge	
Study / Examinations to be Completed	Written report, public presentation in a seminar with discussion, preferably in English, on aims and results.
Criteria for receiving Grades	Rules in accordance with the examination regulations. Quality of scientific performance and written work (90%), assessment of the dissertation defence (10%)