Christian-Albrechts-Universität zu Kiel

Faculty of Mathematics
and Natural Sciences

Module Catalogue

for

Master of Science Climate Physics: Meteorology and Physical Oceanography
Degree: M.Sc.

Effective 01.10.2023

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Key: Workload calculation is based on 13 sessions / semester (excl. exams)

Exam prerequisites: Work on written exercises, demonstration of exercise solution in tutorial according to §5 examination regulations

Pflichtmodule (Compulsory (C) Modules)

climAGFD Advanced Geophysical Fluid Dynamics

Module Name	**Module Code**
Advanced Geophysical Fluid Dynamics	climAGFD
Module Coordinator	
Prof. Dr. Claus Böning	
Organizer	
GEOMAR Helmholtz Centre for Ocean Research Kiel	
Faculty	
Faculty of Mathematics and Natural Sciences	
Examination Office	
Examination Office Geosciences	

Status[1] *(C / CE / O)*	C
ECTS Credits	5
Evaluation	Graded
Duration	1 semester
Frequency	Winter semester, every two years
Workload per ECTS Credit	30 hours
Total Workload	150 hours
Contact Time	39 hours
Independent Study	111 hours

Teaching Language	English
Entry Requirements as Stated in the Examination Regulations	None
Recommended Requirements*	

Module Course(s)			
Course Type	**Course Name**	**Compulsory/Compul-sory elective/optional**	**Credit hours**
Lecture	Advanced Geophysical Fluid Dynamics	Compulsory	2
Practical Exercise	Advanced Geophysical Fluid Dynamics	Compulsory	1
Further Information on the Course(s)*			
Prerequisites for Admission to the Examination(s)*	Work on written exercises, demonstration of exercise solution in tutorial. Compulsory attendance of practical exercise.		

[1] Status of whole module

Examination(s)				
Examination Name	**Type of Examination**	**Evaluation**	**Compulsory/Compulsory elective/ optional**	**Weighting**[1]
Advanced Geophysical Fluid Dynamics	Oral Examination	Graded	Compulsory	100 %
Further Information on the Examination(s)*				

Short Summary*

An introduction to Advanced Geophysical Fluid Dynamics, including rotating flow and basic approximations.

Course Content

The basic principles of fluid mechanics, in particular the Navier-Stokes equations, are discussed and derived from first principles using tensor and vector calculus. The students are introduced to basic kinematics, including the Eulerian and Lagrangian descriptions of the flow, streamlines, particle paths, streamfunctions, and the formulation of the acceleration and tracer advection in both the Eulerian and Lagrangian frameworks. The fundamental concept of vorticity dynamics is introduced, including vortex stretching and the derivation of Ertel's potential vorticity for a rotating fluid. The concept of form drag, ubiquitous to rotating fluid dynamics, is illustrated by asking how aircraft fly and pointing out the role played by viscosity and frictional processes. Viscous diffusion, another important concept, is illustrated using the Rayleigh problem. The energetics of fluid flow is introduced noting the importance of mechanical energy dissipation by viscosity. A comprehensive derivation is then given of the governing equations for atmosphere/ocean dynamics, in particular the treatment of the Coriolis term and the Boussinesq and hydrostatic approximations. Finally, the course gives an introduction to basic thermodynamics, including a discussion of neutral surfaces in the ocean.

Learning Outcomes

Students can describe the fundamental concepts of fluid flow and apply these concepts to tackle more advanced topics and research questions.

Reading List

1. Gill, A.E., 1982: Atmosphere – Ocean Dynamics. Academic Press, London, UK, 662 pp.
2. Holton, J.R.,, 1992: An Introduction to Dynamic Meteorology. Academic Press, 511pp
3. Kundu, P., and I. Cohen, 2002, Fluid Mechanics (3rd Edition), Academic Press, 730pp.
4. Pedlosky, J., 1992, Geophysical Fluid Dynamics, Springer, 710pp.
5. Vallis, G. K., 2006. Atmospheric and Oceanic Fluid Dynamics. Cambridge University Press, 745 pp.
6. Batchelor, G.K., 1970, An Introduction to Fluid Dynamics, Cambridge University press, 615pp.

Additional Information

Application of module

Master, 1-subject, Climate Physics: Meteorology and Physical Oceanography

[1] Weighting within the module

climGD Geostrophic Dynamics

Module Name	**Module Code**
Geostrophic Dynamics	climGD
Module Coordinator	
Prof. Dr. Claus Böning	
Organizer	
GEOMAR Helmholtz Centre for Ocean Research Kiel	
Faculty	
Faculty of Mathematics and Natural Sciences	
Examination Office	
Examination Office Geosciences	

Status[1] *(C / CE / O)*	C
ECTS Credits	5
Evaluation	Graded
Duration	1 semester
Frequency	Winter semester, every two years
Workload per ECTS Credit	30 hours
Total Workload	150 hours
Contact Time	39 hours
Independent Study	111 hours

Teaching Language	English
Entry Requirements as Stated in the Examination Regulations	None
Recommended Requirements*	

Module Course(s)			
Course Type	**Course Name**	**Compulsory/Compul-sory elective/Optional**	**Credit hours**
Lecture	Geostrophic Dynamics	Compulsory	2
Practical Exercise	Geostrophic Dynamics	Compulsory	1
Further Information on the Course(s)*			
Prerequisites for Admission to the Examination(s)*	Work on written exercises, demonstration of exercise solution in tutorial. Compulsory attendance of practical exercise.		

Examination(s)				
Examination Name	**Type of Examination**	**Evaluation**	**Compulsory/Compulsory elective/ Optional**	**Weighting**[2]
Geostrophic Dynamics	Oral Examination	Graded	Compulsory	100 %

[1] Status of whole module
[2] Weighting within the module

Further Information on the Examination(s)*	

Short Summary*

An introduction to Geostrophic Dynamics.

Course Content

The governing equations for atmosphere/ocean dynamics are first presented, followed by a discussion of waves in a rotating shallow water model covering, in particular, Poincare waves, Kelvin waves and the geostrophic adjustment process. Small Rossby number approximations are then introduced covering geostrophic flow regimes, in particular the quasi-geostrophic and planetary geostrophic approximations with the quasi-geostrophic approximation dealt with in detail. This then leads to a discussion of planetary and topographic waves and finally, barotropic and baroclinic instability in the atmosphere and ocean.

Learning Outcomes

The students have a core understanding of rotating fluid dynamics and can apply it to problems ranging from synoptic dynamics to climate time scales.

Reading List

1. Gill, A.E., 1982: Atmosphere – Ocean Dynamics. Academic Press, London, UK, 662 pp.
2. Holton, J.R., 1992: An Introduction to Dynamic Meteorology. Academic Press, 511pp
3. Kundu, P., and I. Cohen, 2002, Fluid Mechanics (3rd Edition), Academic Press, 730pp.
4. Pedlosky, J., 1992, Geophysical Fluid Dynamics, Springer, 710pp.
5. Vallis, G. K., 2006. Atmospheric and Oceanic Fluid Dynamics, Cambridge University Press, 745 pp.

Additional Information

Application of module

Master, 1-subject, Climate Physics: Meteorology and Physical Oceanography

climDAT Data Analysis and Statistics

Module Name	**Module Code**
Data Analysis and Statistics	climDAT
Module Coordinator	
Prof. Dr. Claus Böning	
Organizer	
GEOMAR Helmholtz Centre for Ocean Research Kiel	
Faculty	
Faculty of Mathematics and Natural Sciences	
Examination Office	
Examination Office Geosciences	

Status[1] *(C / CE / O)*	C
ECTS Credits	5
Evaluation	Graded
Duration	1 semester
Frequency	Every summer semester
Workload per ECTS Credit	30 hours
Total Workload	150 hours
Contact Time	39 hours
Independent Study	111 hours

Teaching Language	English
Entry Requirements as Stated in the Examination Regulations	None
Recommended Requirements*	

Module Course(s)			
Course Type	**Course Name**	**Compulsory/ Compulsory elective/Optional**	**Credit hours**
Lecture	Data Analysis and Statistics	Compulsory	2
Practical Exercise	Data Analysis and Statistics	Compulsory	1
Further Information on the Course(s)*			
Prerequisites for Admission to the Examination(s)*	Work on written exercises, demonstration of exercise solution in tutorial. Compulsory attendance of practical exercise.		

Examination(s)				
Examination Name	**Type of Examination**	**Evaluation**	**Compulsory/Compulsory elective/Optional**	**Weighting**[2]
Data Analysis and Statistics	Oral Examination	Graded	Compulsory	100%
Further Information on the Examination(s)*				

[1] Status of whole module
[2] Weighting within the module

Short Summary*
Basic concepts and techniques of data analysis and statistical methods for climate research.
Course Content
The course is composed of topical lectures as well as exercises (theoretical and computational) applying concepts and methods discussed during the lectures. The topics covered by the lectures include: fundamentals of the probability theory, probability distributions and moments central for the description of climate variables; statistical inference methods (estimators and confidence intervals); significance tests, normality tests and bootstrapping methods; multivariate analysis (correlation, regression analysis, Principal Component Analysis); time series analysis and spectral analysis; strategies and pitfalls of statistical analysis.
Learning Outcomes
Students will obtain understanding of fundamental concepts and basic methods for statistical analysis of spatially and temporally varying climate variables. They learn and practice how to estimate statistical quantities describing climate data (both, model outputs and observations) in terms of probability distributions and statistical moments and how to quantify significance of the estimators and test statistical hypotheses. They learn how to quantify time series of climate variables by spectral analysis and autoregressive processes. Students learn and practice how to analyze multi-variate data and characterize relations between the different variables in terms of correlation and linear regression and are made aware of limitations and pitfalls of these methods. They learn about techniques of dimensionality reduction for highly dimensional spatio-temporal data (Principal Component Analysis) and their application to study modes of climate variability. Students practice examples demonstrating strategies and pitfalls of statistical analysis for applications akin to these they may encounter in their future research.
Reading List
1. D. Wilks, 2011, "Statistical Methods in the Atmospheric Sciences", Academic Press, 704pp. 2. G. E. P. Box, G. M. Jenkins & C. Reinsel, 1994, Time Series Analysis: Forecasting and Control, Prentice Hall, 598pp. 3. W.J. Emery & R.E. Thomson, 2001, Data Analysis Methods in Physical Oceanography, Second edition, Elsevier Science, 654pp. 4. H. von Storch & F. W. Zwiers, 2002, Statistical Analysis in Climate Research, Cambridge University Press, 496pp.
Additional Information
Application of module
Master, 1-subject, Climate Physics: Meteorology and Physical Oceanography

climNUM Numerical Methods and Models

Module Name	**Module Code**
Numerical Methods and Models	climNUM
Module Coordinator	
Prof. Dr. Claus Böning	
Organizer	
GEOMAR Helmholtz Centre for Ocean Research Kiel	
Faculty	
Faculty of Mathematics and Natural Sciences	
Examination Office	
Examination Office Geosciences	

Status[1] *(C / CE / O)*	C
ECTS Credits	5
Evaluation	Graded
Duration	1 semester
Frequency	Winter semester, every two years
Workload per ECTS Credit	30 hours
Total Workload	150 hours
Contact Time	39 hours
Independent Study	111 hours

Teaching Language	English
Entry Requirements as Stated in the Examination Regulations	None
Recommended Requirements*	

Module Course(s)			
Course Type	**Course Name**	**Compulsory/Compulsory elective/ Optional**	**Credit hours**
Lecture	Numerical Methods and Models	Compulsory	2
Practical Exercise	Numerical Methods and Models	Compulsory	1
Further Information on the Course(s)*			
Prerequisites for Admission to the Examination(s)*	Work on written exercises, demonstration of exercise solution in tutorial. Compulsory attendance of practical exercise.		

Examination(s)				
Examination Name	**Type of Examination**	**Evaluation**	**Compulsory/Compulsory elective/ Optional**	**Weighting**[2]
Numerical Methods and Models	Oral Examination	Graded	Compulsory	100%

[1] Status of whole module
[2] Weighting within the module

Further Information on the Examination(s)*	

Short Summary*

An introduction to basic numerical methods.

Course Content

The course begins with some historical background, going back to L.F. Richardson's 1923 proposal for numerical weather prediction and covers the early ocean modelling work by Sarkisyan, Kirk Bryan and Mike Cox. The basic properties of finite difference schemes are then discussed, in particular time stepping schemes, stability analysis, advection schemes, computational dispersion and time splitting. The importance of choosing the correct grid arrangement is then introduced, focusing on the Arakawa A, B, C, D and E grids and the representation of inertia-gravity waves on these grids. The importance of using numerical schemes that preserve basic conservation laws, e.g. for tracer, energy and enstrophy leads to a discussion of conservative grid schemes including the Arakawa Jacobian and extensions thereof by Sadourny, Arakawa and Lamb, etc. Relaxation techniques for solving elliptic equations are introduced. Finally, spectral models and the Galerkin method are discussed with examples from the atmosphere and the ocean.

Learning Outcomes

Students are in a position to write their own numerical code to integrate the equations of motion, in particular to build their own shallow water model and also to understand the basic numerical schemes underlying more complex models used for ocean, atmosphere and climate modelling.

Reading List

1. F. Mesinger and A. Arakawa, 1976: "Numerical methods used in atmospheric models", GARP Publication Series No 17, World Meteorological Organisation.
2. J.J. O'Brien, Editor, 1986: "Advanced Physical Oceanographic Numerical Modelling", Nato ASI series, Series C: Mathematical and Physical Sciences Vol 186.
3. W.H. Press, S.A. Teukolsky, W.T. Vetterling and B.P. Flannery, 1992: "Numerical Recipes: The Art of Scientific Computing", Cambridge University Press, 1992.
4. Griffies, S.M., et al., 2000: "Developments in ocean climate modeling", Ocean Modelling, 2, 123-192.
5. G.J. Haltiner and R.T. Williams, 1980: "Numerical Prediction and Dynamic Meteorology", Wiley and Sons, 447 pp.
6. S.M. Griffies, 2004, "Fundamentals of ocean climate models", Princeton University Press, 528pp.

Additional Information

Application of module

Master, 1-subject, Climate Physics: Meteorology and Physical Oceanography

climOMSEM Oceanography-Meteorology Seminar

Module Name	**Module Code**
Oceanography-Meteorology Seminar	climOMSEM
Module Coordinator	
Prof. Dr. Martin Visbeck	
Organizer	
GEOMAR Helmholtz Centre for Ocean Research Kiel	
Faculty	
Faculty of Mathematics and Natural Sciences	
Examination Office	
Examination Office Geosciences	

Status[1] *(C / CE / O)*	C
ECTS Credits	5
Evaluation	Graded
Duration	1 semester
Frequency	Every winter semester
Workload per ECTS Credit	30 hours
Total Workload	150 hours
Contact Time	26 hours
Independent Study	124 hours

Teaching Language	English
Entry Requirements as Stated in the Examination Regulations	None
Recommended Requirements*	

Module Course(s)			
Course Type	**Course Name**	**Compulsory/Compulsory elective/ Optional**	**Credit hours**
Seminar	Oceanography-Meteorology Seminar	Compulsory	2
Further Information on the Course(s)*			
Prerequisites for Admission to the Examination(s)*	Compulsory attendance.		

Examination(s)				
Examination Name	**Type of Examination**	**Evaluation**	**Compulsory/ Compulsory elective / Optional**	**Weighting**[2]
Oceanography-Meteorology	Presentation	Graded	Compulsory	100 %

[1] Status of whole module
[2] Weighting within the module

Further Information on the Examination(s)*	

Short Summary*
Prepare a concise 20 min long seminar using the material and graphics from originally published scientific work.
Course Content
Seminar series of student presentations.
Learning Outcomes
Students are able to read, understand and contextualize the ocean and atmospheric science literature. They are able to prepare a seminar presentation based on recent scientific literature and present the scientific knowledge in a confident way. They are also able to present and critically discuss actual physical oceanography and meteorology topics in the seminar with the other participants and the lecturers.
Reading List
The literature for the seminar will be provided at the beginning of the semester.
Additional Information
A scientist will support the student to review the paper and provide guidance for the presentation.
Application of module
Master, 1-subject, Climate Physics: Meteorology and Physical Oceanography

climCSEM Climate Seminar

Module Name	Module Code
Climate Seminar	climCSEM
Module Coordinator	
Prof. Dr. Martin Visbeck	
Organizer	
GEOMAR Helmholtz Centre for Ocean Research Kiel	
Faculty	
Faculty of Mathematics and Natural Sciences	
Examination Office	
Examination Office Geosciences	

Status[1] *(C / CE / O)*	C
ECTS Credits	5
Evaluation	Graded
Duration	1 semester
Frequency	Every summer semester
Workload per ECTS Credit	30 hours
Total Workload	150 hours
Contact Time	26 hours
Independent Study	124 hours

Teaching Language	English
Entry Requirements as Stated in the Examination Regulations	None
Recommended Requirements*	

Module Course(s)			
Course Type	**Course Name**	**Compulsory/Compulsory elective/ Optional**	**Credit hours**
Seminar	Climate Seminar	Compulsory	2
Further Information on the Course(s)*			
Prerequisites for Admission to the Examination(s)*	Compulsory attendance.		

Examination(s)				
Examination Name	**Type of Examination**	**Evaluation**	**Compulsory/ Compulsory elective / Optional**	**Weighting**[2]
Climate Seminar	Presentation	Graded	Compulsory	100 %
Further Information on the Examination(s)*				

[1] Status of whole module
[2] Weighting within the module

Short Summary*
Read and understand the literature on climate processes, phenomena or diagnostics. Prepare a concise 20 min long seminar using the material and graphics from originally published scientific work.
Course Content
Seminar series of student presentations.
Learning Outcomes
Students are able to read, understand and contextualize the climate science literature. They are able to prepare a seminar presentation based on recent scientific literature and present the scientific knowledge in a confident way. They are also able to present and critically discuss actual climate topics in the seminar with the other participants and the lecturers.
Reading List
The literature for the seminar will be provided at the beginning of the semester.
Additional Information
A scientist will support the student to review the paper and provide guidance for the presentation.
Application of module
Master, 1-subject, Climate Physics: Meteorology and Physical Oceanography

climTHES Master Thesis

Module Name	Module Code
Master Thesis	climTHES
Module Coordinator	
Prof. Dr. Mojib Latif	
Organizer	
GEOMAR Helmholtz Centre for Ocean Research Kiel	
Faculty	
Faculty of Mathematics and Natural Sciences	
Examination Office	
Examination Office Geosciences	

Status[1] *(C / CE / O)*	C
ECTS Credits	25
Evaluation	Graded
Duration	1 semester
Frequency	Every summer semester
Workload per ECTS Credit	30 hours
Total Workload	750 hours
Contact Time	26 hours
Independent Study	724 hours

Teaching Language	English
Entry Requirements as Stated in the Examination Regulations	At least 60 credit points.
Recommended Requirements*	

Module Course(s)			
Course Type	**Course Name**	**Compulsory/ Compulsory elective/ Optional**	**Credit hours**
Project work + presentation	Master of Science thesis	Compulsory	
Further Information on the Course(s)*			
Prerequisites for Admission to the Examination(s)*			

Examination(s)				
Examination Name	**Type of Examination**	**Evaluation**	**Compulsory/ Compulsory elective / Optional**	**Weighting**[2]
Master's Thesis +	Written Examination	Graded	Compulsory	100 %

[1] Status of whole module
[2] Weighting within the module

Further Information on the Examination(s)*	

Short Summary*
Course Content
Independent completion of a scientific manuscript on a specified subject guided by a tutor.
Learning Outcomes
Students apply their theoretical knowledge, experience and methods learned in the frame of the Master's Course to a specific topic under scientific guidance of mentors. They present, and critically discuss their findings in their written thesis and an oral presentation in front of a scientific audience in order to prepare them for the international arena.
Reading List
Additional Information
Application of module
Master, 1-subject, Climate Physics: Meteorology and Physical Oceanography

Wahlpflichtmodule (Compulsory Elective (CE) Modules)

climAME Advanced Meteorology

Module Name	Module Code
Advanced Meteorology	climAME
Module Coordinator	
Prof. Dr. Katja Matthes	
Organizer	
GEOMAR Helmholtz Centre for Ocean Research Kiel	
Faculty	
Faculty of Mathematics and Natural Sciences	
Examination Office	
Examination Office Geosciences	

Status[1] *(C / CE / O)*	CE
ECTS Credits	10
Evaluation	Graded
Duration	2 semesters
Frequency	Every two years: Part 1, Stratospheric Physics & Dynamics in winter semester, Part II, Tropospheric Physics & Dynamics in summer semester
Workload per ECTS Credit	30 hours
Total Workload	300 hours
Contact Time	78 hours
Independent Study	222 hours

Teaching Language	English
Entry Requirements as Stated in the Examination Regulations	None
Recommended Requirements*	

Module Course(s)			
Course Type	**Course Name**	**Compulsory/Compul-sory elective/ Optional**	**Credit hours**
Lecture	Stratospheric Physics and Dynamics	Compulsory	2
Practical Exercise	Stratospheric Physics and Dynamics	Compulsory	1
Lecture	Tropospheric Physics and Dynamics	Compulsory	2
Practical Exercise	Tropospheric Physics and Dynamics	Compulsory	1
Further Information on the Course(s)*			
Prerequisites for Admission to the Examination(s)*	Work on written exercises, demonstration of exercise solution in tutorials. Compulsory attendance of practical exercise.		

[1] Status of whole module

Examination(s)				
Examination Name	**Type of Examination**	**Evaluation**	**Compulsory/Compulsory elective/ Optional**	**Weighting[1]**
Advanced Meteorology: Stratospheric Physics and Dynamics and Tropospheric and Dynamics	Oral Examination	Graded	Compulsory	100 %
Further Information on the Examination(s)*				

Short Summary*
Course Content
Stratospheric Physics and Dynamics: Introduction to radiative, dynamical and chemical aspects of the stratosphere (e.g., stratospheric warmings, wave-mean flow interactions, planetary waves, tropical waves, ozone hole, QBO, SAO) insight into current research (e.g., stratosphere-troposphere coupling, future ozone and atmospheric circulation changes, external natural and anthropogenic forcing of the stratosphere) Tropospheric Physics and Dynamics: Diabatic heating (e.g. latent heat release and cloud formation, radiative forcing), zonally averaged circulation, Lorenz energy cycle, longitudinally dependent time-averaged flow (stationary Rossby waves, jetstreams and storm tracks), low-frequency variability (Climate Regimes, Annular Modes, SST Anomalies), anthropogenic climate change
Learning Outcomes
Students obtain advanced knowledge in stratospheric and tropospheric physics and dynamics and the effects of climate change. They are able to apply mathematical methods to solve physical problems in atmospheric physics and dynamics in practical exercises. Furthermore they present and critically discuss recent scientific literature to deepen the understanding of climate variability and climate change.
Reading List
Brasseur, G. und S. Solomon, 1986. Aeronomy of the Middle Atmosphere. D. Reidel Publishing Company, Dodrecht, Holland. Labitzke, K. and H. van Loon, 1999: The Stratosphere: Phenomena, History, Relevance, Springer-Verlag, Berlin. Andrews, D., J. Holton, and C. Leovy, 1987: Middle Atmosphere Dynamics, Academic Press, New York. Holton, J.R. (1992, 2004): An Introduction to Dynamic Meteorology, International Geophysics Series, Vol. 48, Academic Press. P.K. Wang (2013): Physics and Dynamics of Clouds and Precipitation, Cambridge University Press, New York. J.M. Wallace and P.H. Hobbs: Atmospheric Sciences: An Introductory Survey, 2006, 2nd edition, Academic Press
Additional Information
Application of module
Master, 1-subject, Climate Physics: Meteorology and Physical Oceanography

[1] Weighting within the module

climAPC Advanced Physical Climate

Module Name	**Module Code**
Advanced Physical Climate	climAPC
Module Coordinator	
Prof. Dr. Martin Visbeck	
Organizer	
GEOMAR Helmholtz Centre for Ocean Research Kiel	
Faculty	
Faculty of Mathematics and Natural Sciences	
Examination Office	
Examination Office Geosciences	

Status[1] *(C / CE / O)*	CE
ECTS Credits	10
Evaluation	Graded
Duration	2 semesters
Frequency	Every two years: Part 1, Climate Feedbacks in winter Semester, Part 2: Regional Climate Variability in summer semester
Workload per ECTS Credit	30 hours
Total Workload	300 hours
Contact Time	78
Independent Study	222 hours

Teaching Language	English
Entry Requirements as Stated in the Examination Regulations	None
Recommended Requirements*	

Module Course(s)			
Course Type	**Course Name**	**Compulsory/Compul-sory elective/ Optional**	**Credit hours**
Lecture	Climate Feedbacks	Compulsory	2
Practical Exercise	Climate Feedbacks	Compulsory	1
Lecture	Regional Climate Variability	Compulsory	2
Practical Exercise	Regional Climate Variability	Compulsory	1
Further Information on the Course(s)*			
Prerequisites for Admission to the Examination(s)*	Work on written exercises, demonstration of exercise solution in tutorials. Compulsory attendance of practical exercise.		

[1] Status of whole module

Examination(s)				
Examination Name	**Type of Examination**	**Evaluation**	**Compulsory/ Compulsory elective / Optional**	**Weighting[1]**
Advanced Physical Climate: Regional Climate Variability and Feedbacks in the Climate System	Oral Examination	Graded	Compulsory	100%
Further Information on the Examination(s)*				

Short Summary*
Advanced Physical Climate focusses on regional modes of climate variability, their diagnostics, impacts and predictability, on climate feedback mechanisms and the IPCC process.
Course Content
Advanced aspects of the Physical Climate System will be addressed by lectures and practical application. The following topics will be covered: North Atlantic Oscillation, Pacific Decadal Oscillation, Tropical Atlantic Variability, Southern Annular Mode, Monsoon Dynamics (MJO), Regional Impacts of Climate Change, Ice-Albedo Feedback, Cloud/Water Vapor - Radiation Feedback, Wind – SST (Bjerkness) Feedback, MOC – Sea-Ice Feedback, Vegetation – Radiation Feedback, Ocean ventilation – CO2, Biogeochemical Feedbacks. In addition the IPCC process and content of the report will be studied.
Learning Outcomes
Students will become familiar with the basic regional modes of physical climate variability with a focus on the ocean and atmosphere and their interaction with an emphasis on interannual to centennial time scales. They will learn about climatic impacts on human activity and obtain a basic understanding of the IPCC process. Moreover, they will understand the underlying positive and negative feedbacks of the climate system and how they can be simulated in models. They will be able to make use of mathematical methods needed to solve physical problems in climate dynamics with a particular focus on advanced statistical data analysis and simple models.
Reading List
Kump, L.R., J.F. Kastings, and R.G. Crane: The Earth System. Prentice Hall, 1999, 351pp. Hartmann, D.L. Global Physical Climatology. Academic Press, 1994, 408pp. IPPC Volume I „The Scientific Basis“, 2013, pp
Additional Information
Application of module
Master, 1-subject, Climate Physics: Meteorology and Physical Oceanography

[1] Weighting within the module

climAPO Advanced Physical Oceanography

Module Name	**Module Code**
Advanced Physical Oceanography	climAPO
Module Coordinator	
Prof. Dr. Peter Brandt	
Organizer	
GEOMAR Helmholtz Centre for Ocean Research Kiel	
Faculty	
Faculty of Mathematics and Natural Sciences	
Examination Office	
Examination Office Geosciences	

Status[1] *(C / CE / O)*	CE
ECTS Credits	10
Evaluation	Graded
Duration	2 semesters
Frequency	Part 1: Thermohaline Circulation every two years in winter semester, Part 2: Wind-driven Circulation in every summer semester.
Workload per ECTS Credit	30 hours
Total Workload	300 hours
Contact Time	78 hours
Independent Study	222 hours

Teaching Language	English
Entry Requirements as Stated in the Examination Regulations	None
Recommended Requirements*	

Module Course(s)			
Course Type	**Course Name**	**Compulsory/Compulsory elective/ Optional**	**Credit hours**
Lecture	Thermohaline Circulation	Compulsory	2
Practical Exercises	Thermohaline Circulation	Compulsory	1
Lecture	Wind-driven Circulation	Compulsory	2
Practical Exercises	Wind-driven Circulation	Compulsory	1
Further Information on the Course(s)*			
Prerequisits for Admission to the Examination(s)*	Work on written exercises, demonstration of exercise solution in tutorials. Compulsory attendance of practical exercise.		

[1] Status of whole module

Examination(s)				
Examination Name	**Type of Examination**	**Evaluation**	**Compulsory/Compulsory elective / Optional**	**Weighting**[1]
Advanced Physical: Oceanography: Thermohaline Circulation + Wind-driven Circulation	Oral Examination	Graded	Compulsory	100 %
Further Information on the Examination(s)*				

[1] Weighting within the module

Short Summary

This course covers fundamental aspects of the ocean circulation using theory and observations.

Course Content

Wind-driven Circulation:
The course begins with a brief review of the governing equations and basic approximations followed by a discussion of shallow water models, in particular the 1 and 1 1/2 layer models, vertical normal modes, and the projection of wind forcing onto these modes, including the representation of vertical mixing following McCreary. There then follows a discussion of Ekman dynamics, the Sverdrup balance and western intensification, introducing the models of Sverdrup (1947), Stommel (1948) and Munk (1950). This leads naturally into linear vorticity dynamics, the role of density stratification, bottom pressure torque, JEBAR and the closing of the circulation at the western boundary by bottom pressure torque rather than friction. The spin-up of an ocean to a suddenly applied wind forcing is then considered, introducing adjustment by Rossby waves in both a stratified and unstratified ocean, including variable bottom topography and leading to a discussion of time-dependent wind forcing and the annual cycle. The recirculation gyres in the Gulf Stream and Kuroshio Extension regions is then noted including the role of upgradient momentum transfer by eddies in their dynamics. The dynamics of the Southern Ocean in then discussed, including the role of eddies and topographic and interfacial form drag, the Gent and McWilliams/Greatbatch and Lamb eddy parameterisations for use in models, and the connection between these parameterisations and baroclinic instability, in particular the release of available potential energy.

Thermohaline Circulation:
The course begins with the heat and freshwater budgets, the surface buoyancy fluxes and the transport of heat and freshwater by the ocean. The distribution of water masses is then discussed, in particular the central, intermediate, deep and bottom waters. The concepts of the “warm water sphere”, the ventilated thermocline, subduction and the subtropical cells are then introduced. Attention then turns to higher latitudes, the process of deep water formation and the role of convection and mesoscale eddies. This leads naturally to a discussion on the circulation in the Nordic Seas, the overflows
deep western boundary currents and simple models for the deep circulation. The formation of Antarctic bottom water and the role of shelf convection is addressed, followed by the global thermohaline circulation and its variability and observations of the meridional overturning circulation.

Learning Outcomes

Students will have a comprehensive knowledge of the ocean circulation enabling them to tackle research problems in the field, including the analysis and interpretation of both observations and models.

Reading List

1. Gill, A.E., 1982: “Atmosphere – Ocean Dynamics”. Academic Press, London, UK, 662 pp.
2. Holton, J.R., 1992: “An Introduction to Dynamic Meteorology”, Academic Press, 511 pp.
3. Kundu, P., and I. Cohen, 2002: “Fluid Mechanics” (3rd Edition), Academic Press, 730pp.
4. Pedlosky, J., 1992: “Geophysical Fluid Dynamics”, Springer, 710pp.
5. Vallis, G. K., 2006: “Atmospheric and Oceanic Fluid Dynamics”, Cambridge University Press, 745 pp.
6. Olbers, D., J. Willebrand, and C. Eden, 2012: “Ocean Dynamics”, Springer, 704pp
7. Apel, J.R., 1988: Principle of Ocean Physics. International Geophysics Series, Vol. 38, Academic Press, Fifth printing 1999, 634 pp.
8. Siedler, G., J. Church, J. Gould (eds), 2001: Ocean Circulation & Climate, International Geophysics Series, Vol. 77, Academic Press, 715 pp.

Talley, L.D., G.L. Pickard, W. J. Emery, J. H. Swift, 2011: “Descriptive Physical Oceanography: An Introduction”, Academic Press, 555 pp.

Additional Information
Application of module
Master, 1-subject, Climate Physics: Meteorology and Physical Oceanography

Wahlpflichtmodule Vertiefung/Übergreifende Inhalte (Specialization (SP) Modules)

climCOL Ocean Circulation and Climate Dynamics Colloquium

Module Name	**Module Code**
Ocean Circulation and Climate Dynamics Colloquium	climCOL
Module Coordinator	
Prof. Dr. Martin Visbeck	
Organizer	
GEOMAR Helmholtz Centre for Ocean Research Kiel	
Faculty	
Faculty of Mathematics and Natural Sciences	
Examination Office	
Examination Office Geosciences	

Status[1] *(C / CE / O)*	CE
ECTS Credits	2
Evaluation	Not graded
Duration	1 semester
Frequency	Every semester
Workload per ECTS Credit	15 hours
Total Workload	30 hours
Contact Time	13
Independent Study	0

Teaching Language	English
Entry Requirements as Stated in the Examination Regulations	None
Recommended Requirements*	

Module Course(s)			
Course Type	**Course Name**	**Compulsory/Compul-sory elective/ Optional**	**Credit hours**
Seminar	FB1 Seminar	Compulsory	1
Further Information on the Course(s)*			
Prerequisites for Admission to the Examination(s)*	Compulsory attendance.		

Examination(s)				
Examination Name	**Type of Examination**	**Evaluation**	**Compulsory/Compulsory elective / Optional**	**Weighting**[2]
Ocean Circulation and Climate Dynamics Colloquium	Testate	Not graded	Compulsory	

[1] Status of whole module
[2] Weighting within the module

Further Information on the	Mandatory attendance of 10 FB1 Seminars

Short Summary*
The FB1 Seminar exposes students to research topics in ocean and climate sciences. The seminars are held by experts from GEOMAR and national and international visitors.
Course Content
Students are exposed to current research topics. They experience professional oral lectures and are expected to actively contribute to the post-seminar discussion.
Learning Outcomes
Students will have advanced their skills in scientific presentations by being exposed to the state of the art in the field. They have an overview of current research topics in ocean, atmosphere and climate science and learn to participate in scientific debates.
Reading List
Additional Information
Application of module
Master, 1-subject, Climate Physics: Meteorology and Physical Oceanography

climSCHOOL Environmental Science Summer School

Module Name	**Module Code**
Environmental Science Summer School	climSCHOOL
Module Coordinator	
Prof. Dr. Martin Visbeck	
Organizer	
GEOMAR Helmholtz Centre for Ocean Research Kiel	
Faculty	
Faculty of Mathematics and Natural Sciences	
Examination Office	
Examination Office Geosciences	

Status[1] *(C / CE / O)*	CE
ECTS Credits	5
Evaluation	Not graded
Duration	Min. of 5 days
Frequency	variable
Workload per ECTS Credit	24 hours
Total Workload	120 hours
Contact Time	>30 hours
Independent Study	>80 hours

Teaching Language	English
Entry Requirements as Stated in the Examination Regulations	None
Recommended Requirements*	

Module Course(s)			
Course Type	**Course Name**	**Compulsory/Compul-sory elective/ Optional**	**Credit hours**
Lecture	Environmental Sciences Summer School	Compulsory	-----
Further Information on the Course(s)*			
Prerequisites for Admission to the Examination(s)*			

Examination(s)				
Examination Name	**Type of Examination**	**Evaluation**	**Compulsory/Compulsory elective / Optional**	**Weighting**[2]
Environmental Science Summer School	Assignment	Not graded	Compulsory	

[1] Status of whole module
[2] Weighting within the module

Further Information on the Examination(s)*	Provide written report of summer school activity including lecture program.

Short Summary*
Summer Schools can provide a fantastic opportunity to expand the scientific knowledge beyond the curricular activities in Kiel. The School needs to be properly documented and at least 5 days of duration.
Course Content
Enhance knowledge base in ocean, atmospheric, climate and environmental sciences. Prepare for lectures. Practical experience with debates, home works and/or lab work. Learn to work in new teams of non Kiel based students. Exposure to non Kiel based lecturers.
Learning Outcomes
Students have broadened their knowledge base of ocean, atmosphere, climate or earth science in the context of the broader environmental science agenda. They have improved their communication and networking skills. They become part of an international learning activity and environment.
Reading List
Additional Information
Application of module
Master, 1-subject, Climate Physics: Meteorology and Physical Oceanography

climINTERN Ocean and Climate Physics Research Internship

Module Name	**Module Code**
Ocean and Climate Physics Research Internship	climINTERN
Module Coordinator	
Prof. Dr. Martin Visbeck	
Organizer	
GEOMAR Helmholtz Centre for Ocean Research Kiel	
Faculty	
Faculty of Mathematics and Natural Sciences	
Examination Office	
Examination Office Geosciences	

Status[1] *(C / CE / O)*	CE
ECTS Credits	5
Evaluation	Not graded
Duration	1 semester
Frequency	variable
Workload per ECTS Credit	30 hours
Total Workload	120 hours
Contact Time	60
Independent Study	60 hours

Teaching Language	English / German / other
Entry Requirements as Stated in the Examination Regulations	None
Recommended Requirements*	

Module Course(s)			
Course Type	**Course Name**	**Compulsory/Compul-sory elective/ Optional**	**Credit hours**
Research Internship	Ocean and Climate Physics Research Internship	Compulsory	-----
Further Information on the Course(s)*			
Prerequisites for Admission to the Examination(s)*			

Examination(s)				
Examination Name	**Type of Examination**	**Evaluation**	**Compulsory/Compulsory elective / Optional**	**Weighting**[2]
Ocean and Climate	Assignment	Not graded	Compulsory	
Physics Research Internship				

[1] Status of whole module
[2] Weighting within the module

Further Information on the Examination(s)*	Written report is required.

Short Summary*
Research Internships of at least two weeks duration provide a fantastic opportunity to learn how science is done professionally.
Course Content
Learn skills in the areas of field and/or laboratory based observations, data analysis, model development, model analysis.
Learning Outcomes
Students have obtained experience in doing science in the context of an ongoing research project and within a professional scientific environment. They have learned new tools, methods and the practicalities of doing science. They are able to gain from interaction with more experienced researchers. They learn how to work in a professional team of scientist.
Reading List
Additional Information
Application of module
Master, 1-subject, Climate Physics: Meteorology and Physical Oceanography

climSUSTAIN Ocean Sustainability

Module Name	**Module Code**
Ocean Sustainability	climSUSTAIN
Module Coordinator	
Prof. Dr. Martin Visbeck	
Organizer	
GEOMAR Helmholtz Centre for Ocean Research Kiel	
Faculty	
Faculty of Mathematics and Natural Sciences	
Examination Office	
Examination Office Geosciences	

Status[1] *(C / CE / O)*	CE
ECTS Credits	6
Evaluation	Graded
Duration	1 semester
Frequency	Summer semester, every two years
Workload per ECTS Credit	30 hours
Total Workload	180 hours
Contact Time	39 hours
Independent Study	141 hours

Teaching Language	English
Entry Requirements as Stated in the Examination Regulations	
Recommended Requirements*	

Module Course(s)			
Course Type	**Course Name**	**Compulsory/Compul-sory elective/ Optional**	**Credit hours**
E-Learning-lecture	Ocean Sustainability	Compulsory	2
Colloquium	Ocean Sustainability	Compulsory	1
Further Information on the Course(s)*			
Prerequisites for Admission to the Examination(s)*			

Examination(s)				
Examination Name	**Type of Examination**	**Evaluation**	**Compulsory/Compulsory elective / Optional**	**Weighting**[2]
Ocean Sustainability	Portfolio	Graded	Compulsory	100 %

[1] Status of whole module
[2] Weighting within the module

Further Information on the Examination(s)*	The portfolio consists out of three elements. 1: A poster produced by a group of students. 2: A discussion and explanation of the work at the poster where all participants contribute. 3: An individually written, 2-4 pages long report describing the group project and the students' contribution to the work.

Short Summary*
Ocean Sustainability covers a broad range of topics in marine science and their connection to society. The learner is given the opportunity to brush up their understanding of key ocean aspects using on-line lectures and apply this knowledge in a small practical project and poster presentation.
Course Content
Explain the fundamentals of Ocean Sustainable Development and review the most salient aspects of marine science including: Ocean Change: Ocean Circulation and Sea Level, Ocean Chemistry, Marine Biodiversity, Ocean Acidification Ocean Climate Engineering: Living Resources Sustainable Fisheries, Aquaculture, Invasive Species Marine Substances Non-living resources: Mineral exploitation, Gas Hydrates Ocean Governance: Common Heritage of Mankind / International Public Law, Legal aspect of Marine Spatial Planning & Global, Regional and Local Marine Protected Areas
Learning Outcomes
The student have gained knowledge ocean sustainable development and obtained a broad overview of relevant topics on key themes of ocean science related to ocean sustainability. They will have studied based on on-line lectures as part of a Massive Open Online Course. They are able to work in teams to bring complementary skills to a small project dealing with ocean sustainability. They have learned how to showcase their results on form of a poster presentation.
Reading List
Literature/topics for the seminar will be provided at the beginning of each semester.
Additional Information
Application of module
Master, 1-subject, Climate Physics: Meteorology and Physical Oceanography
Master, 1-subject, Praktische Philosophie der Wirtschaft und Umwelt

climMESEM Meteorological Lunch Seminar

Module Name	**Module Code**
Meteorological Lunch Seminar	climMESEM
Module Coordinator	
Prof. Dr. Katja Matthes	
Organizer	
GEOMAR Helmholtz Centre for Ocean Research Kiel	
Faculty	
Faculty of Mathematics and Natural Sciences	
Examination Office	
Examination Office Geosciences	

Status[1] *(C / CE / O)*	CE
ECTS Credits	5
Evaluation	Graded
Duration	1 semester
Frequency	Every semester
Workload per ECTS Credit	30 hours
Total Workload	150 hours
Contact Time	26 hours
Independent Study	124 hours

Teaching Language	English
Entry Requirements as Stated in the Examination Regulations	None
Recommended Requirements*	

Module Course(s)			
Course Type	**Course Name**	**Compulsory/Compul-sory elective/ Optional**	**Credit hours**
Seminar	Meteorological Lunch Seminar	Compulsory	2
Further Information on the Course(s)*			
Prerequisites for Admission to the Examination(s)*	**Compulsory attendance**		

Examination(s)				
Examination Name	**Type of Examination**	**Evaluation**	**Compulsory/Compulsory elective / Optional**	**Weighting**[2]
Meteorological Lunch Seminar	Presentation	Graded	Compulsory	100 %
Further Information on the Examination(s)*				

[1] Status of whole module
[2] Weighting within the module

Short Summary*
Course Content
Presentation of literature and own research by Master students, PhDs, and PostDocs. Read and understand the meteorological literature. Prepare a concise 20 min long seminar using the material and graphics from originally published scientific work or own (Bachelor or Master thesis) work. Talks will be followed by extensive discussions.
Learning Outcomes
Students obtain an overview on recent developments in the field of meteorology. They practice to prepare a seminar talk either by presenting results of recent scientific articles or their own research and discuss their topic critically within the seminar group consisting of master and PhD students as well as more advanced scientists. Students learn to present scientific results for the international arena.
Reading List
Literature/topics for the seminar will be provided at the beginning of each semester.
Additional Information
Application of module
Master, 1-subject, Climate Physics: Meteorology and Physical Oceanography

climMEMODEL Modern Aspects in Meteorology I: Climate Modeling

Module Name	**Module Code**
Modern Aspects in Meteorology I: Climate Modeling	climMEMODEL
Module Coordinator	
Prof. Dr. Katja Matthes	
Organizer	
GEOMAR Helmholtz Centre for Ocean Research Kiel	
Faculty	
Faculty of Mathematics and Natural Sciences	
Examination Office	
Examination Office Geosciences	

Status[1] *(C / CE / O)*	CE
ECTS Credits	5
Evaluation	Graded
Duration	1 semester
Frequency	Winter semester, every two years
Workload per ECTS Credit	30 hours
Total Workload	150 hours
Contact Time	39 hours
Independent Study	111 hours

Teaching Language	English
Entry Requirements as Stated in the Examination Regulations	None
Recommended Requirements*	Advanced knowledge in Physics and Meteorology

Module Course(s)			
Course Type	**Course Name**	**Compulsory/Compul-sory elective/ Optional**	**Credit hours**
Lecture	Climate Modeling and IPCC	Compulsory	2
Seminar	Climate Modeling and IPCC	Compulsory	1
Further Information on the Course(s)*			
Prerequisites for Admission to the Examination(s)*	Compulsory attendance of seminar.		

Examination(s)				
Examination Name	**Type of Examination**	**Evaluation**	**Compulsory/Compulsory elective / Optional**	**Weighting**[2]
Modern Aspects in Meteorology I: Climate Modeling and IPCC	Presentation	Graded	Compulsory	100%

[1] Status of whole module
[2] Weighting within the module

Further Information on the Examination(s)*	

Short Summary*
Course Content
This course will give an introduction to climate modeling: history, structure and physical parameterization of global climate models of different complexity and their applications such as in the fifth Assessment Report (AR5) report. The lecture will be accompanied by a seminar where the students have to present selected parts of the IPCC report 2013 and critically discuss possibilities and limits of climate models.
Learning Outcomes
Students obtain a theoretical understanding of the structure of climate models, their application as well as their limits. They practice to prepare a seminar talk based on selected parts of the most recent IPCC report and guided by the lecturers. They are able to present and critically discuss their topics in the block course with the other students and the lecturers.
Reading List
T. Stocker (2011), Introduction to Climate Modeling, Springer Verlag Berlin Heidelberg. IPCC WG I (The Physical Science Basis) Report 2013, see https://www.ipcc.ch/report/ar5/wg1/
Additional Information
Application of module
Master, 1-subject, Climate Physics: Meteorology and Physical Oceanography

climMEASSIM Modern Aspects in Meteorology II: Data Assimilation

Module Name	**Module Code**
Modern Aspects in Meteorology II: Data Assimilation	climMEASSIM
Module Coordinator	
Prof. Dr. Katja Matthes	
Organizer	
GEOMAR Helmholtz Centre for Ocean Research Kiel	
Faculty	
Faculty of Mathematics and Natural Sciences	
Examination Office	
Examination Office Geosciences	

Status[1] *(C / CE / O)*	CE
ECTS Credits	5
Evaluation	Graded
Duration	1 semester
Frequency	Summer semester, every two years
Workload per ECTS Credit	30 hours
Total Workload	150 hours
Contact Time	39 hours
Independent Study	111 hours

Teaching Language	English
Entry Requirements as Stated in the Examination Regulations	None
Recommended Requirements*	Advanced knowledge in Physics and Meteorology

Module Course(s)			
Course Type	**Course Name**	**Compulsory/Compul-sory elective/ Optional**	**Credit hours**
Lecture	Data Assimilation	Compulsory	1
Practical Exercise	Data Assimilation	Compulsory	1
Seminar	Data Assimilation	Compulsory	1
Further Information on the Course(s)*			
Prerequisites for Admission to the Examination(s)*	Work on written exercises, demonstration of exercise solution in tutorial. Compulsory attendance of practical and seminar.		

Examination(s)				
Examination Name	**Type of Examination**	**Evaluation**	**Compulsory/Compulsory elective / Optional**	**Weighting**[2]
Modern Aspects in Meteorology II: Data Assimilation	Presentation	Graded	Compulsory	100%

[1] Status of whole module
[2] Weighting within the module

Further Information on the Examination(s)*	

Short Summary*
Course Content
This course will give an overview of various applications of data assimilation in both weather and climate modeling after introducing the most important concepts (Bayes’ theorem, optimal interpolation, variational assimilation, ensemble assimilation). The lecture will be accompanied by student seminars and practical computer exercises. Successful completion of the course will require presenting a publication and completing a group practical exercise.
Learning Outcomes
Students obtain a theoretical understanding of data assimilation principles. They apply their theoretical knowledge in practical group exercises with a simple model to deepen their understanding. They also practice to prepare a seminar talk based on recent scientific literature and guided by the lecturer and mentors. They are able to present and critically discuss their topics in the block course with the other students, the lecturer and their mentors.
Reading List
Kalnay, E., Atmospheric Modeling, Data Assimilation and Predictability, Cambridge University Press, 2002. Lahoz, W., B. Khattatov, and R. Ménard, Data Assimilation – Making Sense of Observations, Springer-Verlag Berlin Heidelberg, 2010.
Additional Information
Example lecture in Modern Aspects in Meteorology. Topic may change depending on available lecturer.
Application of module
Master, 1-subject, Climate Physics: Meteorology and Physical Oceanography

climMECARBON Modern Aspects in Meteorology III: Carbon cycling in a changing climate

Module Name	**Module Code**
Modern Aspects in Meteorology III: Carbon cycling in a changing climate	climMECARBON
Module Coordinator	
Prof. Dr. Birgit Schneider	
Organizer	
GEOMAR Helmholtz Centre for Ocean Research Kiel	
Faculty	
Faculty of Mathematics and Natural Sciences	
Examination Office	
Examination Office Geosciences	

Status[1] *(C / CE / O)*	CE
ECTS Credits	5 ECTS
Evaluation	Graded
Duration	Compact course: 5 days, full time
Frequency	Every summer semester
Workload per ECTS Credit	30 hours
Total Workload	150 hours
Contact Time	39 hours
Independent Study	111 hours

Teaching Language	English
Entry Requirements as Stated in the Examination Regulations	None
Recommended Requirements*	None

Module Course(s)			
Course Type	**Course Name**	**Compulsory/Compulsory elective/ Optional**	**Credit hours**
Lecture	Carbon Cycling in a Changing Climate	Compulsory	1
Practical Exercise	Carbon Cycling in a Changing Climate	Compulsory	1
Seminar	Carbon Cycling in a Changing Climate	Compulsory	1

Further Information on the Course(s)*	
Prerequisites for Admission to the Examination(s)*	Compulsory attendance of practical exercise and seminar.

[1] Status of whole module

Examination(s)				
Examination Name	**Type of Examination**	**Evaluation**	**Compulsory/Compulsory elective / Optional**	**Weighting**[1]
Carbon Cycling in a Changing Climate	Oral examination	Graded	Compulsory	100 %
Further Information on the Examination(s)*	Work on written exercises, demonstration of exercise solution in tutorial.			

Short Summary*
The block course is on the various aspects of the carbon cycle in changing climates (past, present, future) and its role in the Earth system.
Course Content
The course is composed of topical lectures, related student seminar presentations, as well as modelling exercises. It will give an introduction into the role of carbon (including the greenhouse gases CO_2 and methane) in the climate-system, with a focus on the coupling of atmosphere, ocean, land surface and the terrestrial biosphere. The seminar will teach the basics of the earth's climate history, with an emphasis on the cycling of carbon through atmosphere, ocean, sediments and biosphere. Climate change issues will be discussed interactively with the students along the current IPCC assessment.
Learning Outcomes
Students practice to prepare a seminar talk during the semester based on recent scientific literature and guided by the lecturers. They are able to present and critically discuss their findings during the block course. Within teams and aided by the lecturers the students will learn to analyze and discuss scientific papers and IPCC chapters in detail. Furthermore, they are able to apply simple modeling tools, as provided by the science community. Finally, an overall synthesis will be developed as team-work by all participants together.
Reading List
IPCC AR5, Summary for Policymakers + individual chapters (www.ipcc.ch)
Additional Information
Application of module
Master, 1-subject, Climate Physics: Meteorology and Physical Oceanography

[1] Weighting within the module

climMECLOUD Modern Aspects in Meteorology IV: Cloud Physics

Module Name	**Module Code**
Modern Aspects in Meteorology IV: Cloud Physics	climMECLOUD
Module Coordinator	
Prof. Dr. Katja Matthes	
Organizer	
GEOMAR Helmholtz Centre for Ocean Research Kiel	
Faculty	
Faculty of Mathematics and Natural Sciences	
Examination Office	
Examination Office Geosciences	

Status[1] *(C / CE / O)*	CE
ECTS Credits	5
Evaluation	Graded
Duration	1 semester
Frequency	Winter semester, every two years
Workload per ECTS Credit	30 hours
Total Workload	150 hours
Contact Time	39 hours
Independent Study	111 hours

Teaching Language	English
Entry Requirements as Stated in the Examination Regulations	None
Recommended Requirements*	Advanced knowledge in Physics and Meteorology

Module Course(s)			
Course Type	**Course Name**	**Compulsory/Compulsory elective/ Optional**	**Credit hours**
Lecture	Cloud Physics and Precipitation	Compulsory	2
Seminar	Clouds and Circulation	Compulsory	1
Further Information on the Course(s)*			
Prerequisites for Admission to the Examination(s)*	Compulsory attendance of seminar.		

Examination(s)				
Examination Name	**Type of Examination**	**Evaluation**	**Compulsory/Compulsory elective / Optional**	**Weighting**[2]
Modern Aspects in Meteorology IV: Cloud Physics	Presentation	Graded	Compulsory	100%

[1] Status of whole module
[2] Weighting within the module

Further Information on the Examination(s)*	

Short Summary*
Course Content
Clouds in the climate system, cloud classification, general thermodynamics, atmospheric instability, curvature and solute effects, condensation growth, coagulation, precipitation (rain and snow), severe storms and hail, stochastic coalescence equation, parameterization of cloud processes in the climate system, interaction between clouds and circulation.
Learning Outcomes
Students obtain a theoretical understanding of cloud physics and precipitation as well as the role of clouds in the climate system. They apply their theoretical knowledge in practical group exercises to deepen their understanding. They also practice to prepare a seminar talk based on recent scientific literature and guided by the lecturer and mentors. They are able to present and critically discuss their topics in the block course with the other students, the lecturer and their mentors.
Reading List
U. Lohmann, F. Lüönd, F. Mahrt, 2016: An Introduction to Clouds from the Microscale to Climate, Cambridge University Press P.K. Wang, 2013: Physics and Dynamics of Clouds and Precipitation, Cambridge University Press J.M. Wallace and P.H. Hobbs: Atmospheric Sciences: An Introductory Survey, 2006, 2nd edition, Academic Press Papers for seminar presentations will be provided at the beginning of the course.
Additional Information
Example lecture in Modern Aspects in Meteorology. Topic may change depending on available lecturer.
Application of module
Master, 1-subject, Climate Physics: Meteorology and Physical Oceanography

climPOSEM Physical Oceanography Lunch Seminar

Module Name	**Module Code**
Physical Oceanography Lunch Seminar	climPOSEM
Module Coordinator	
Prof. Dr. Peter Brandt	
Organizer	
GEOMAR Helmholtz Centre for Ocean Research Kiel	
Faculty	
Faculty of Mathematics and Natural Sciences	
Examination Office	
Examination Office Geosciences	

Status[1] *(C / CE / O)*	CE
ECTS Credits	5
Evaluation	Graded
Duration	1 semester
Frequency	Every semester
Workload per ECTS Credit	30 hours
Total Workload	150 hours
Contact Time	26 hours
Independent Study	124 hours

Teaching Language	English
Entry Requirements as Stated in the Examination Regulations	None
Recommended Requirements*	

Module Course(s)			
Course Type	**Course Name**	**Compulsory/Compul-sory elective/ Optional**	**Credit hours**
Seminar	Physical Oceanography Lunch Seminar	Compulsory	2
Further Information on the Course(s)*			
Prerequisites for Admission to the Examination(s)*	Compulsory attendance.		

Examination(s)				
Examination Name	**Type of Examination**	**Evaluation**	**Compulsory/Compulsory elective / Optional**	**Weighting**[2]
Physical Oceanography Lunch Seminar	Presentation	Graded	Compulsory	100 %

[1] Status of whole module
[2] Weighting within the module

Further Information on the Examination(s)*	

Short Summary*
Course Content
Presentation of literature and own research by Master students, PhDs, and PostDocs. Read and understand the physical oceanography literature. Prepare a concise 20 min long seminar using the material and graphics from originally published scientific work or own (Bachelor or Master thesis) work. Talks will be followed by extensive discussions.
Learning Outcomes
Students obtain an overview on recent developments in the field of physical oceanography. They practice to prepare a seminar talk either by presenting results of recent scientific articles or their own research and discuss their topic critically within the seminar group consisting of master and PhD students as well as more advanced scientists. Students learn to present scientific results for the international arena.
Reading List
Literature/topics for the seminar will be provided at the beginning of each semester.
Additional Information
Application of module
Master, 1-subject, Climate Physics: Meteorology and Physical Oceanography

climPOTROPIC Modern Aspects in Physical Oceanography I: Tropical Ocean Dynamics

Module Name	**Module Code**
Modern Aspects in Physical Oceanography I: Tropical Ocean Dynamics	climPOTROPIC
Module Coordinator	
Prof. Dr. Peter Brandt	
Organizer	
GEOMAR Helmholtz Centre for Ocean Research Kiel	
Faculty	
Faculty of Mathematics and Natural Sciences	
Examination Office	
Examination Office Geosciences	

Status[1] *(C / CE / O)*	CE
ECTS Credits	5
Evaluation	Graded
Duration	1 semester
Frequency	Winter semester, every two years
Workload per ECTS Credit	30 hours
Total Workload	150 hours
Contact Time	39 hours
Independent Study	111 hours

Teaching Language	English
Entry Requirements as Stated in the Examination Regulations	None
Recommended Requirements*	Advanced knowledge in Physics and Oceanography

Module Course(s)			
Course Type	**Course Name**	**Compulsory/Compul-sory elective/ Optional**	**Credit hours**
Lecture	Tropical Ocean Dynamics	Compulsory	2
Seminar	Tropical Ocean Dynamics	Compulsory	1
Further Information on the Course(s)*			
Prerequisites for Admission to the Examination(s)*	Compulsory attendance of seminar.		

Examination(s)				
Examination Name	**Type of Examination**	**Evaluation**	**Compulsory/Compulsory elective / Optional**	**Weighting**[2]
Modern Aspects in Physical Oceanography I: Tropical Ocean Dynamics	Oral Examination	Graded	Compulsory	100%

[1] Status of whole module
[2] Weighting within the module

Further Information on the Examination(s)*	

Short Summary*
Course Content
The course is composed of topical lectures as well as discussions led by students. It includes the preparation of a short report. The course will cover the following topics: tropical mean state, western boundary currents, water masses, seasonal cycle, equatorial waves, baroclinic modes, equatorial deep jets, intraseasonal waves, tropical instability waves, tropical mixed layer heat and freshwater budgets, shallow overturning circulation in the tropical-subtropical oceans, oxygen minimum zones, equatorial and coastal upwelling, coupled ocean-atmosphere processes, tropical climate variability, predictability of tropical climate.
Learning Outcomes
On completion of this module, the students will obtain an understanding of oceanic processes impacting tropical climate variability and its predictability. Within teams and aided by the lectures the students will present and critically discuss scientific papers in the context of current research. They will be able to stimulate discussions by short presentations and raising open questions. Students practice to prepare a report during the semester regarding an open science question based on own literature search and guided by the lecturers. The students will be able to identify and evaluate existing research and information about a specific topic.
Reading List
Gill, A. E., 1982: Atmosphere-Ocean Dynamics, Academic Press, London, 662pp. Marshall, J. and R. A. Plumb, 2008:Atmosphere, Ocean, and Climate Dynamics: An Introductory Text, Academic Press, London, 319pp. Philander, S. G., 1990: El Niño. La Niña, and the Southern Oscillation, Academic Press, 293 pp.
Additional Information
Application of module
Master, 1-subject, Climate Physics: Meteorology and Physical Oceanography

climPOLAGRANGE Modern Aspects in Physical Oceanography II: Lagrangian analysis and dispersion in the ocean

Module Name	Module Code
Modern Aspects in Physical Oceanography II: Lagrangian analysis and dispersion in the ocean	climPOLAGRANGE

Module Coordinator
Prof. Dr. Peter Brandt
Organizer
GEOMAR Helmholtz Centre for Ocean Research Kiel
Faculty
Faculty of Mathematics and Natural Sciences
Examination Office
Examination Office Geosciences

Status[1] *(C / CE / O)*	CE
ECTS Credits	5 ECTS
Evaluation	Graded
Duration	1 semester (1 week, 5 days)
Frequency	Summer semester, every two years
Workload per ECTS Credit	30 hours
Total Workload	150 hours
Contact Time	39 hours
Independent Study	111 hours

Teaching Language	English
Entry Requirements as Stated in the Examination Regulations	None
Recommended Requirements*	None

Module Course(s)			
Course Type	**Course Name**	**Compulsory/Compulsory elective/ Optional**	**Credit hours**
Lecture	Lagrangian analysis and dispersion in the ocean	Compulsory	2 SWS
Seminar	Lagrangian analysis and dispersion in the ocean	Compulsory	1 SWS

Further Information on the Course(s)*	
Prerequisites for Admission to the Examination(s)*	Compulsory attendance of seminar.

[1] Status of whole module

Examination(s)				
Examination Name	**Type of Examination**	**Evaluation**	**Compulsory/Compulsory elective / Optional**	**Weighting[1]**
Modern Aspects in Physical Oceanography II: Lagrangian analysis and dispersion in the ocean	Seminar Paper with Written Report	Graded	Compulsory	100 %
Further Information on the	Based on homework reports delivery			

Short Summary*

Basic techniques of Lagrangian analysis and modeling, concepts of dispersion and diffusion, and their applications to studies of ocean circulation.

Course Content

The course is composed of topical lectures as well as exercises practicing techniques and concepts discussed during the lectures. The topics covered by the lectures include: Lagrangian framework, water particles, parcels, trajectories and pathways; Lagrangian observations in the ocean; theory of random walk and diffusion, single and relative particle dispersion and diffusivity, quantifying transport by mesoscale ocean turbulence using dispersion and diffusivity diagnostics; pseudo-Eulerian diagnostics and diffusivity maps; basic techniques for Lagrangian modeling and stochastic Lagrangian modeling (Markov models). Several applications of the Lagrangian analysis to studies ocean circulation are discussed by the lecturer(s) in detail based on their own research. The practical computational exercises cover Lagrangian diagnostics (pathways, single and relative diffusivity derived from surface drifter trajectories), diffusivity mapping and Lagrangian modeling including stochastic modeling (first-order Markov model).

Learning Outcomes

Students obtain understanding of fundamental concepts and basic methods for Lagrangian analysis and their applications to studies of ocean circulation. They become familiar with representation of the oceanic flow in terms of particles, parcels, trajectories and water mass pathways, and the techniques to observe and model these quantities. Students learn the background theory of random walk, diffusion and diffusivity and their application to study the turbulent transport in the ocean. The students practice how to estimate pathways, dispersion and diffusivity from Lagrangian observations and how to construct and apply a simple Lagrangian model and analyze the simulated particle trajectories.

Reading List

1. LaCasce, J., 2008. Statistics from Lagrangian observations. Prog. Oceanogr. 77 (1), 1–29.
2. Koszalka, I. et. al., 2009. Relative dispersion in the Nordic Seas. J. Mar. Res. 67, 411–433.
3. Koszalka, I. et. al., 2011. Surface circulation in the Nordic Seas from clustered drifters. Deep-Sea Res. I 58 (4), 468–485.
4. Van Sebille E. et. al., (2018): Lagrangian analysis of ocean velocity data: Fundamentals and practices. A review, Oc. Modelling, 121, p. 49-71.
5. Recent publications will be distributed during the course.

Additional Information

Application of module

Master, 1-subject, Climate Physics: Meteorology and Physical Oceanography

[1] Weighting within the module

climPOENSO Modern Aspects in Physical Oceanography III: The El Niño-Southern Oscillation

Module Name	**Module Code**
Modern Aspects in Physical Oceanography III: The El Niño-Southern Oscillation	climPOENSO
Module Coordinator	
Prof. Dr. Peter Brandt	
Organizer	
GEOMAR Helmholtz Centre for Ocean Research Kiel	
Faculty	
Faculty of Mathematics and Natural Sciences	
Examination Office	
Examination Office Geosciences	

Status[1] *(C / CE / O)*	CE
ECTS Credits	5
Evaluation	Graded
Duration	1 semester
Frequency	Winter semester, every two years
Workload per ECTS Credit	30 hours
Total Workload	150 hours
Contact Time	39 hours
Independent Study	111 hours

Teaching Language	English
Entry Requirements as Stated in the Examination Regulations	None
Recommended Requirements*	Advanced knowledge in Physics and Oceanography

Module Course(s)			
Course Type	**Course Name**	**Compulsory/Compulsory elective/Optional**	**Credit hours**
Lecture	The El Niño-Southern Oscillation	Compulsory	2
Seminar	The El Niño-Southern Oscillation Seminar	Compulsory	1
Further Information on the Course(s)*			
Prerequisites for Admission to the Examination(s)*	Compulsory attendance of seminar.		

Examination(s)				
Examination Name	**Type of Examination**	**Evaluation**	**Compulsory/ Compulsory elective / Optional**	**Weighting**[2]
Modern Aspects in Physical Oceanography III:	Presentation	Graded	Compulsory	100 %

[1] Status of whole module
[2] Weighting within the module

The El Niño – Southern Oscillation				
Further Information on the				

Short Summary*
Course Content
The course is guided by the overarching question of what one would need to know to successfully predict an El Niño event. The students identify topics and collaboratively construct a concept map which then serves as a structure for the course. During each session, students are actively involved in the learning process. They work individually or in small groups, for example testing different El Niño index definitions, analyzing data sets, setting up simple numerical models and planning and constructing hands-on experiments to demonstrate physical processes involved in the formation of El Niño events. Starting from the mean state of the tropical Pacific, over processes and feedbacks involved in ENSO dynamics, the course addresses recent ENSO research question as decadal variability and changes to ENSO under global warming.
Learning Outcomes
Based on the concept map that is constructed in the beginning of the course, each learning outcome is directly motivated by a need to know expressed by the students themselves. Students will get to know different data sets and analysis tools that they use themselves in class. This work is done in small groups, aided by the lecturer. On completion of this course, they will understand the underlying dynamics of ENSO and know about the current state of ENSO research. They will be able to work on ENSO-related research questions using the tools they encountered. Students will practice to present results from recent scientific literature on a poster, and the presentation of the final poster will serve as the examination.
Reading List
Sarachik, E. S. and M. A. Cane, 2010: “The El Niño-Southern Oscillation Phenomenon“. Cambridge University Press, Cambridge, UK
Additional Information
Application of module
Master, 1-subject, Climate Physics: Meteorology and Physical Oceanography

climPOSHALLOW Modern Aspects in Physical Oceanography IV: Shallow water analogues of ocean/atmosphere processes

Module Name	Module Code
Modern Aspects in Physical Oceanography IV: Shallow water analogues of ocean/atmosphere processes	climPOSHALLOW
Module Coordinator	
Prof. Dr. Richard Greatbatch	
Organizer	
GEOMAR Helmholtz Centre for Ocean Research Kiel	
Faculty	
Faculty of Mathematics and Natural Sciences	
Examination Office	
Examination Office Geosciences	

Status[1] *(C / CE / O)*	CE
ECTS Credits	5
Evaluation	Graded
Duration	1 semester
Frequency	Summer semester, every two years
Workload per ECTS Credit	30 hours
Total Workload	150 hours
Contact Time	39 hours
Independent Study	111 hours

Teaching Language	English
Entry Requirements as Stated in the Examination Regulations	None
Recommended Requirements*	Advanced knowledge in Physics and Oceanography

Module Course(s)			
Course Type	**Course Name**	**Compulsory/Compulsory elective/ Optional**	**Credit hours**
Lecture	Shallow water analogues of ocean/atmosphere processes	Compulsory	2
Seminar	Shallow water analogues of ocean/atmosphere processes	Compulsory	1
Further Information on the Course(s)*			
Prerequisites for Admission to the Examination(s)*	Compulsory attendance of seminar.		

[1] Status of whole module

Examination(s)				
Examination Name	**Type of Examination**	**Evaluation**	**Compulsory/Compulsory elective / Optional**	**Weighting[1]**
Shallow water analogues of ocean/atmosphere processes	Assignment	Graded	Compulsory	100%
Further Information on the Examination(s)*				

Short Summary*
Students get to run a shallow water model in different physically relevant configurations, analyse the output, and write a report on each experiment.
Course Content
The shallow water equations are used to illustrate fundamental processes in the ocean and the atmosphere. The students receive basic training in running a shallow water model. They then code the model themselves to tackle each problem in turn and write a report that describes and interprets the model results. The theoretical underpinning for each topic is discussed in detail in the lectures. The first topic covered is the adjustment of a stratified lake to an applied wind forcing, first dealing with a narrow lake so that the effect of the Earth's rotation can be neglected, and then dealing with a rectangular lake to illustrate Kelvin waves and inertial waves arising from the Earth's rotation. The spin-up of a stratified, mid-latitude ocean basin to an applied wind stress is then addressed, demonstrating the role played by Rossby waves that propagate into the ocean basin from the eastern boundary and the establishment of both the interior Sverdrup balance and of a western boundary current. The next topic is the spin-up of the equatorial ocean to an applied wind stress, illustrating the role played by equatorial Kelvin and Rossby waves, as well as Mixed Rossby Gravity (Yanai) waves. This is followed by the response of a two-hemisphere abyssal ocean to a deep water source, illustrating the approach to the Stommel-Arons solution in the limit of weak diapycnal mixing. This is then extended to include a re-entrant channel in the southern hemisphere, southern hemisphere wind forcing and a deep water source in the northern hemisphere, providing a shallow water analogue for the Atlantic Meridional Overturning Circulation. Other problems are addressed as appropriate and time permitting.
Learning Outcomes
On completion of this module, the students have an understanding of the dynamic adjustment of the ocean and atmosphere by wave processes. They are able to run a shallow water model and apply the shallow water model to different problems and analyze the output.
Reading List
1. Gill, A.E., 1982: "Atmosphere – Ocean Dynamics". Academic Press, London, UK, 662 pp. 2. Anderson, D.L.T., and A. E. Gill, 1985: Spin-up of a stratified ocean, with applications to upwelling. *Deep Sea Res*., 22, 583-596. 3. Kawase, M., 1987: Establishment of deep ocean circulation driven by deep-water production, J. Phys. Oceanogr., 17, 2294-2317. 4. Greatbatch, R.J. and J. Lu, 2003: Reconciling the Stommel box model with the Stommel–Arons model: A possible role for Southern Hemisphere wind forcing?, J. Phys. Oceanogr., 33, 1618-1632.
Additional Information
Application of module

[1] Weighting within the module

Master, 1-subject, Climate Physics: Meteorology and Physical Oceanography

climPOOGCM Modern Aspects in Physical Oceanography V: Ocean General Circulation Modelling

Module Name	**Module Code**
Modern Aspects in Physical Oceanography V: Ocean General Circulation Modelling	climPOOGCM
Module Coordinator	
Prof. Dr. Arne Biastoch	
Organizer	
GEOMAR Helmholtz Centre for Ocean Research Kiel	
Faculty	
Faculty of Mathematics and Natural Sciences	
Examination Office	
Examination Office Geosciences	

Status[1] *(C / CE / O)*	CE
ECTS Credits	5
Evaluation	Graded
Duration	1 semester
Frequency	Winter semester, every two years
Workload per ECTS Credit	30 hours
Total Workload	150 hours
Contact Time	39 hours
Independent Study	111 hours

Teaching Language	English
Entry Requirements as Stated in the Examination Regulations	None
Recommended Requirements*	

Module Course(s)			
Course Type	**Course Name**	**Compulsory/Compulsory elective/ Optional**	**Credit hours**
Lecture	Ocean General Circulation Modelling	Compulsory	2
Seminar	Ocean General Circulation Modelling	Compulsory	1

Further Information on the Course(s)*	
Prerequisites for Admission to the Examination(s)*	

[1] Status of whole module

Examination(s)				
Examination Name	**Type of Examination**	**Evaluation**	**Compulsory/ Compulsory elective / Optional**	**Weighting[1]**
Modern Aspects in Physical Oceanography V: Ocean General Circulation Modelling	Seminar Coursework	Graded	Compulsory	100 %
Further Information on the				

Short Summary*
Ocean models are essential tools in ocean research. Output from ocean models is now routinely and publically available, also for non-specialists. The goal of the course is to provide insight into the field of modern ocean modelling and get aware of the possibilities but also limitations of ocean models used in ocean and climate research.
Course Content
The course will be structured from the hydrodynamic equations to the ocean model output. It includes aspects on approximations, discretization and numerical schemes, resolution, parameterizations, community codes, input fields, and the verification of ocean models.
Learning Outcomes
Students practice to prepare a seminar talk during the semester based on recent scientific literature guided by the lecturer. Together with the taught content, they will be able to critically evaluate and present the findings of scientific papers describing and using ocean models. They will be able to make own decisions and choices in respect to the use and the analysis of ocean models.
Reading List
Papers for seminar presentations will be provided at the beginning of the course.
Additional Information
Application of module
Master, 1-subject, Climate Physics: Meteorology and Physical Oceanography

[1] Weighting within the module

climPOMODCIRC Modern Aspects in Physical Oceanography VI: The modelled wind-driven and thermohaline circulation

Module Name	**Module Code**
Modern Aspects in Physical Oceanography VI: The modelled wind-driven and thermohaline circulation	climPOMODCIRC
Module Coordinator	
Prof. Dr. Arne Biastoch	
Organizer	
GEOMAR Helmholtz Centre for Ocean Research Kiel	
Faculty	
Faculty of Mathematics and Natural Sciences	
Examination Office	
Examination Office Geosciences	

Status[1] *(C / CE / O)*	CE
ECTS Credits	5
Evaluation	Graded
Duration	1 semester
Frequency	Summer semester, every two years
Workload per ECTS Credit	30 hours
Total Workload	150 hours
Contact Time	39 hours
Independent Study	111 hours

Teaching Language	English
Entry Requirements as Stated in the Examination Regulations	None
Recommended Requirements*	climPOOGCM

Module Course(s)			
Course Type	**Course Name**	**Compulsory/Compulsory elective/Optional**	**Credit hours**
Lecture	The modelled wind-driven and thermohaline circulation	Compulsory	2
Seminar	The modelled wind-driven and thermohaline circulation	Compulsory	1
Further Information on the Course(s)*			
Prerequisites for Admission to the Examination(s)*			

[1] Status of whole module

Examination(s)				
Examination Name	**Type of Examination**	**Evaluation**	**Compulsory/ Compulsory elective/ Optional**	**Weighting[1]**
Modern Aspects in Physical Oceanography VI: The Modelled Wind-driven and Thermohaline Circulation	Seminar Coursework	Graded	Compulsory	100 %
Further Information on the Examination(s)*				

Short Summary*
Ocean models are heavily used to explore the wind-driven and thermohaline circulation. Output from ocean models is now routinely and publically available, also for non-specialists. The main topic is not the formulation of numerical models itself, but rather its application and analysis to understand mechanisms and dynamics. The goal of the course is to get aware of the possibilities but also limitations of research performed with ocean models.
Course Content
The course covers a series of aspects of the wind-driven circulation (western boundary currents, mesoscale eddy dynamics, Southern Ocean), aspects of the thermohaline circulation (meridional overturning circulation, convection, mixing), experiment design and interdisciplinary analyses.
Learning Outcomes
Students practice seminar talks. On completion of this module, they will be able to critically evaluate scientific literature that is based on ocean general circulation models. They will be able to make own choices in respect to the use of ocean model data.
Reading List
Literature/topics for the seminar will be provided at the beginning of each semester.
Additional Information
This course is a follow-on from Modern Aspects in Physical Oceanography V: Ocean General Circulation Modelling but can also be taken independently.
Application of module
Master, 1-subject, Climate Physics: Meteorology and Physical Oceanography

[1] Weighting within the module

climPOCOAST Modern Aspects in Physical Oceanography VII: Coastal Oceanography

Module Name	**Module Code**
Modern Aspects in Physical Oceanography VII: Coastal Oceanography	climPOCOAST
Module Coordinator	
Prof. Dr. Peter Brandt	
Organizer	
GEOMAR Helmholtz Centre for Ocean Research Kiel	
Faculty	
Faculty of Mathematics and Natural Sciences	
Examination Office	
Examination Office Geosciences	

Status[1] *(C / CE / O)*	CE
ECTS Credits	5
Evaluation	Graded
Duration	1 semester
Frequency	Winter semester, every two years
Workload per ECTS Credit	30 hours
Total Workload	150 hours
Contact Time	39 hours
Independent Study	111 hours

Teaching Language	English
Entry Requirements as Stated in the Examination Regulations	None
Recommended Requirements*	Advanced knowledge in Physics and Oceanography

Module Course(s)			
Course Type	**Course Name**	**Compulsory/Compul-sory elective/Optional**	**Credit hours**
Lecture	Coastal Oceanography	Compulsory	2
Seminar	Coastal Oceanography	Compulsory	1
Further Information on the Course(s)*			
Prerequisites for Admission to the Examination(s)*			

Examination(s)				
Examination Name	**Type of Examination**	**Evaluation**	**Compulsory/Compulsory elective/ Optional**	**Weighting**[2]
Modern Aspects in Physical Oceanography VII: Coastal	Oral Presentation	Graded	Compulsory	100 %

[1] Status of whole module
[2] Weighting within the module

Further Information on the Examination(s)*	

Short Summary*
Course Content
Students are introduced into the study of physical coastal oceanography. Lectures on fundamental principles such as estuarine circulation and processes are given. In addition, students work in groups to learn about hydraulically controlled flow, tidal fronts, submesoscale processes, shallow water waves as well as energy dissipation, storm surges, extreme events and mixing. The human impact on coasts and estuaries will also be discussed. Further topics cover coastal engineering, observing techniques and coastal modelling. Students read key papers and work on applied problems that they will present in a seminar. To reach their goals, the students have to learn to use back-on-the-envelope calculations and rough numbers for first order estimates. The course aims at providing a feeling for the energetic processes in the coastal ocean and to learn how to come up with a first educated guess for ambitious problems. Projects are e.g. “How many years will it take until the Isle of Sylt is completely eroded?”, “Do the windfarms in the North Sea change currents due to mixing?”
Learning Outcomes
On completion of this module, the students will obtain an understanding of the dynamics of the coastal ocean with its many different relevant time scales and processes, focus is on physical processes and their interaction with biology and biogeochemistry,most topics have a strong applied component (e.g. windfarms, wave energy, erosion).
Reading List
Baschek, B., et al. 2017. The Coastal Observing System for Northern and Arctic Seas (COSYNA). Ocean Sci., 13, 379-410, 2017 https://doi.org/10.5194/os-13-379-2017 Armi, L. 1986 The hydraulics of two flowing layers of different densities. J. Fluid Mech. 163, 27.
Additional Information
Application of module
Master, 1-subject, Climate Physics: Meteorology and Physical Oceanography

climPALEO-01a Modern Aspects in Physical Oceanography VIII: Introduction to Paleoceanography/Paleoclimatology

Module Name	**Module Code**
Modern Aspects in Physical Oceanography VIII: Introduction to Paleoceanography /Paleoclimatology	climPALEO-01a
Module Coordinator	
Prof. Dr. Martin Frank	
Organizer	
GEOMAR Helmholtz Centre for Ocean Research Kiel	
Faculty	
Faculty of Mathematics and Natural Sciences	
Examination Office	
Examination Office Geosciences	

Status[1] *(C / CE / O)*	CE
ECTS Credits	5
Evaluation	Graded
Duration	1 semester
Frequency	variable
Workload per ECTS Credit	30 hours
Total Workload	150 hours
Contact Time	39 hours
Independent Study	111 hours

Teaching Language	English
Entry Requirements as Stated in the Examination Regulations	None
Recommended Requirements*	Advanced knowledge in Physics and Oceanography

Module Course(s)			
Course Type	**Course Name**	**Compulsory/Compulsory elective/Optional**	**Credit hours**
Lecture	Paleoceanography / Paleoclimatology	Compulsory	2
Seminar	Literature Seminar: Case studies in Paleoceanography / Paleoclimatology	Compulsory	1
Further Information on the Course(s)*			
Prerequisites for Admission to the Examination(s)*			

Examination(s)

[1] Status of whole module

Examination Name	Type of Examination	Evaluation	Compulsory/Compulsory elective/ Optional	Weighting [1]
Modern Aspects in Physical Oceanography VIII: Introduction to Paleoceanography/ Paleoclimatology	Oral Presentation	Graded	Compulsory	100 %

Further Information on the Examination(s)*	

Short Summary*

The variability of ocean circulation and climate are closely linked and have undergone major changes in the past such as during the major transition from the Cretaceous greenhouse conditions to the Ice-house of the past 30 million years but have also been subject to large variations on shorter millennial and centennial time scales such as during the glacial/interglacial cycles of the past 3 million years. These changes have been caused by a combination of global and regional changes but also due to tectonic changes such as mountain uplift and the opening and closing of major oceanic seaways. The module will give an overview of these changes and their causes on different time scales based on the application of a range of different proxies for past environmental conditions.

Course Content

Students are introduced into the basic principles of paleo-oceanography. Lectures on fundamental principles are given such as a basic introduction into marine sedimentology, stratigraphy and sediment geochemistry. Based on this knowledge major variations in the ocean/atmosphere/climate system on a range of time scales including perturbations of the ocean circulation, the carbon cycle, and weathering inputs will be discussed. An introduction into examining and processing marine sediments for the purpose of the extraction of tracer information will also be included.

Learning Outcomes

On completion of this module, the students will have obtained an understanding of the amplitudes and causes of major changes of physical and chemical oceanography in the past and their linkages to the climate of the past, which will allow them to put the currently ongoing changes of the ocean-atmosphere-climate system into perspective of the range of natural variations in the recent and more distant past.

Reading List

Additional Information

Application of module

Master, 1-subject, Climate Physics: Meteorology and Physical Oceanography

[1] Weighting within the module

climAMESTRAT-01a Advanced Meteorology: Stratospheric Physics and Dynamics

Module Name	**Module Code**
Advanced Meteorology: Stratospheric Physics and Dynamics	climAMESTRAT-01a
Module Coordinator	
Prof. Dr. Katja Matthes	
Organizer	
GEOMAR Helmholtz Centre for Ocean Research Kiel	
Faculty	
Faculty of Mathematics and Natural Sciences	
Examination Office	
Examination Office Geosciences	

Status[1] *(C / CE / O)*	CE
ECTS Credits	5
Evaluation	Graded
Duration	1 semester
Frequency	Every two years in winter semester
Workload per ECTS Credit	30 hours
Total Workload	150 hours
Contact Time	39 hours
Independent Study	111 hours

Teaching Language	English
Entry Requirements as Stated in the Examination Regulations	None
Recommended Requirements*	

Module Course(s)			
Course Type	**Course Name**	**Compulsory/Compul-sory elective/ Optional**	**Credit hours**
Lecture	Stratospheric Physics and Dynamics	Compulsory	2
Practical Exercise	Stratospheric Physics and Dynamics	Compulsory	1
Further Information on the Course(s)*			
Prerequisites for Admission to the Examination(s)*	Work on written exercises, demonstration of exercise solution in tutorials. Compulsory attendance of practical exercise.		

Examination(s)				
Examination Name	**Type of Examination**	**Evaluation**	**Compulsory/Compulsory elective/ Optional**	**Weighting**[2]

[1] Status of whole module
[2] Weighting within the module

Advanced Meteorology: Stratospheric Physics and Dynamics	Oral Examination	Graded	Compulsory	100 %
Further Information on the Examination(s)*				

Short Summary*
Course Content
Stratospheric Physics and Dynamics: Introduction to radiative, dynamical and chemical aspects of the stratosphere (e.g., stratospheric warmings, wave-mean flow interactions, planetary waves, tropical waves, ozone hole, QBO, SAO) insight into current research (e.g., stratosphere-troposphere coupling, future ozone and atmospheric circulation changes, external natural and anthropogenic forcing of the stratosphere).
Learning Outcomes
Students obtain advanced knowledge in stratospheric physics and dynamics and the effects of climate change. They are able to apply mathematical methods to solve physical problems in atmospheric physics and dynamics in practical exercises. Furthermore they present and critically discuss recent scientific literature to deepen the understanding of climate variability and climate change.
Reading List
Brasseur, G. und S. Solomon, 1986. Aeronomy of the Middle Atmosphere. D. Reidel Publishing Company, Dodrecht, Holland. Labitzke, K. and H. van Loon, 1999: The Stratosphere: Phenomena, History, Relevance, Springer-Verlag, Berlin. Andrews, D., J. Holton, and C. Leovy, 1987: Middle Atmosphere Dynamics, Academic Press, New York. Holton, J.R. (1992, 2004): An Introduction to Dynamic Meteorology, International Geophysics Series, Vol. 48, Academic Press. P.K. Wang (2013): Physics and Dynamics of Clouds and Precipitation, Cambridge University Press, New York. J.M. Wallace and P.H. Hobbs: Atmospheric Sciences: An Introductory Survey, 2006, 2nd edition, Academic Press
Additional Information
Application of module
Master, 1-subject, Climate Physics: Meteorology and Physical Oceanography

climAMETROP-01a Advanced Meteorology: Tropospheric Physics and Dynamics

Module Name	Module Code
Advanced Meteorology: Tropospheric Physics and Dynamics	climAMETROP-01a
Module Coordinator	
Prof. Dr. Katja Matthes	
Organizer	
GEOMAR Helmholtz Centre for Ocean Research Kiel	
Faculty	
Faculty of Mathematics and Natural Sciences	
Examination Office	
Examination Office Geosciences	

Status[1] *(C / CE / O)*	CE
ECTS Credits	5
Evaluation	Graded
Duration	1 semester
Frequency	Every two years in summer semester
Workload per ECTS Credit	30 hours
Total Workload	150 hours
Contact Time	39 hours
Independent Study	111 hours

Teaching Language	English
Entry Requirements as Stated in the Examination Regulations	None
Recommended Requirements*	

Module Course(s)			
Course Type	**Course Name**	**Compulsory/Compulsory elective/ Optional**	**Credit hours**
Lecture	Tropospheric Physics and Dynamics	Compulsory	2
Practical Exercise	Tropospheric Physics and Dynamics	Compulsory	1
Further Information on the Course(s)*			
Prerequisites for Admission to the Examination(s)*	Work on written exercises, demonstration of exercise solution in tutorials. Compulsory attendance of practical exercise.		

Examination(s)				
Examination Name	**Type of Examination**	**Evaluation**	**Compulsory/ Compulsory elective/ Optional**	**Weighting**[2]

[1] Status of whole module
[2] Weighting within the module

Advanced Meteorology: Tropospheric and Dynamics	Oral Examination	Graded	Compulsory	100 %

Further Information on the Examination(s)*	

Short Summary*
Course Content
Tropospheric Physics and Dynamics: Diabatic heating (e.g. latent heat release and cloud formation, radiative forcing), zonally averaged circulation, Lorenz energy cycle, longitudinally dependent time-averaged flow (stationary Rossby waves, jetstreams and storm tracks), low-frequency variability (Climate Regimes, Annular Modes, SST Anomalies), anthropogenic climate change
Learning Outcomes
Students obtain advanced knowledge in tropospheric physics and dynamics and the effects of climate change. They are able to apply mathematical methods to solve physical problems in atmospheric physics and dynamics in practical exercises. Furthermore they present and critically discuss recent scientific literature to deepen the understanding of climate variability and climate change.
Reading List
Brasseur, G. und S. Solomon, 1986. Aeronomy of the Middle Atmosphere. D. Reidel Publishing Company, Dodrecht, Holland. Labitzke, K. and H. van Loon, 1999: The Stratosphere: Phenomena, History, Relevance, Springer-Verlag, Berlin. Andrews, D., J. Holton, and C. Leovy, 1987: Middle Atmosphere Dynamics, Academic Press, New York. Holton, J.R. (1992, 2004): An Introduction to Dynamic Meteorology, International Geophysics Series, Vol. 48, Academic Press. P.K. Wang (2013): Physics and Dynamics of Clouds and Precipitation, Cambridge University Press, New York. J.M. Wallace and P.H. Hobbs: Atmospheric Sciences: An Introductory Survey, 2006, 2nd edition, Academic Press
Additional Information
Application of module
Master, 1-subject, Climate Physics: Meteorology and Physical Oceanography

climAPCFEED-01a Advanced Physical Climate: Feedbacks in the Climate System

Module Name	**Module Code**
Advanced Physical Climate: Feedbacks in the Climate System	climAPCFEED-01a
Module Coordinator	
Prof. Dr. Martin Visbeck	
Organizer	
GEOMAR Helmholtz Centre for Ocean Research Kiel	
Faculty	
Faculty of Mathematics and Natural Sciences	
Examination Office	
Examination Office Geosciences	

Status[1] *(C / CE / O)*	CE
ECTS Credits	5
Evaluation	Graded
Duration	1 semester
Frequency	Every two years in winter semester
Workload per ECTS Credit	30 hours
Total Workload	150 hours
Contact Time	39
Independent Study	111 hours

Teaching Language	English
Entry Requirements as Stated in the Examination Regulations	None
Recommended Requirements*	

Module Course(s)			
Course Type	**Course Name**	**Compulsory/Compul-sory elective/ Optional**	**Credit hours**
Lecture	Climate Feedbacks	Compulsory	2
Practical Exercise	Climate Feedbacks	Compulsory	1
Further Information on the Course(s)*			
Prerequisites for Admission to the Examination(s)*	Work on written exercises, demonstration of exercise solution in tutorials. Compulsory attendance of practical exercise.		

Examination(s)				
Examination Name	**Type of Examination**	**Evaluation**	**Compulsory/ Compulsory elective / Optional**	**Weighting**[2]

[1] Status of whole module
[2] Weighting within the module

Advanced Physical Climate: Feedbacks in the Climate System	Oral Examination	Graded	Compulsory	100%
Further Information on the Examination(s)*				

Short Summary*
Advanced Physical Climate: Feedbacks in the Climate System focusses on climate feedback mechanisms and the IPCC process.
Course Content
Advanced aspects of the Physical Climate System will be addressed by lectures and practical application. Ice-Albedo Feedback, Cloud/Water Vapor - Radiation Feedback, Wind – SST (Bjerkness) Feedback, MOC – Sea-Ice Feedback, Vegetation – Radiation Feedback, Ocean ventilation – CO2, Biogeochemical Feedbacks. In addition the IPCC process and content of the report will be studied.
Learning Outcomes
Students will become familiar with the positive and negative feedbacks of the climate system and how they can be simulated in models. They will be able to make use of mathematical methods needed to solve physical problems in climate dynamics with a particular focus on advanced statistical data analysis and simple models.
Reading List
Kump, L.R., J.F. Kastings, and R.G. Crane: The Earth System. Prentice Hall, 1999, 351pp. Hartmann, D.L. Global Physical Climatology. Academic Press, 1994, 408pp. IPPC Volume I „The Scientific Basis“, 2013, pp
Additional Information
Application of module
Master, 1-subject, Climate Physics: Meteorology and Physical Oceanography

climAPCREGION-01a Advanced Physical Climate: Regional Climate Variability

Module Name	Module Code
Advanced Physical Climate: Regional Climate Variability	climAPCREGION-01a
Module Coordinator	
Prof. Dr. Martin Visbeck	
Organizer	
GEOMAR Helmholtz Centre for Ocean Research Kiel	
Faculty	
Faculty of Mathematics and Natural Sciences	
Examination Office	
Examination Office Geosciences	

Status[1] *(C / CE / O)*	CE
ECTS Credits	5
Evaluation	Graded
Duration	1 semester
Frequency	Every two years in summer semester
Workload per ECTS Credit	30 hours
Total Workload	150 hours
Contact Time	39
Independent Study	111 hours

Teaching Language	English
Entry Requirements as Stated in the Examination Regulations	None
Recommended Requirements*	

Module Course(s)			
Course Type	**Course Name**	**Compulsory/ Compulsory elective/ Optional**	**Credit hours**
Lecture	Regional Climate Variability	Compulsory	2
Practical Exercise	Regional Climate Variability	Compulsory	1
Further Information on the Course(s)*			
Prerequisites for Admission to the Examination(s)*	Work on written exercises, demonstration of exercise solution in tutorials. Compulsory attendance of practical exercise.		

Examination(s)

[1] Status of whole module

Examination Name	Type of Examination	Evaluation	Compulsory/ Compulsory elective / Optional	Weighting[1]
Advanced Physical Climate: Regional Climate Variability	Oral Examination	Graded	Compulsory	100%
Further Information on the Examination(s)*				

Short Summary*
Regional Climate Variability focusses on regional modes of climate variability, their diagnostics, impacts and predictability
Course Content
Advanced aspects of the Physical Climate System will be addressed by lectures and practical application. The following topics will be covered: North Atlantic Oscillation, Pacific Decadal Oscillation, Tropical Atlantic Variability, Southern Annular Mode, Monsoon Dynamics (MJO), Regional Impacts of Climate Change.
Learning Outcomes
Students will become familiar with the basic regional modes of physical climate variability with a focus on the ocean and atmosphere and their interaction with an emphasis on interannual to centennial time scales. They will learn about climatic impacts on human activity and obtain a basic understanding of the IPCC process. They will be able to make use of mathematical methods needed to solve physical problems in climate dynamics with a particular focus on advanced statistical data analysis and simple models.
Reading List
Kump, L.R., J.F. Kastings, and R.G. Crane: The Earth System. Prentice Hall, 1999, 351pp. Hartmann, D.L. Global Physical Climatology. Academic Press, 1994, 408pp. IPPC Volume I „The Scientific Basis“, 2013, pp
Additional Information
Application of module
Master, 1-subject, Climate Physics: Meteorology and Physical Oceanography

[1] Weighting within the module

climAPOTHERM-01a Advanced Physical Oceanography: Thermohaline Circulation

Module Name	**Module Code**
Advanced Physical Oceanography: Thermohaline Circulation	climAPOTHERM-01a
Module Coordinator	
Prof. Dr. Peter Brandt	
Organizer	
GEOMAR Helmholtz Centre for Ocean Research Kiel	
Faculty	
Faculty of Mathematics and Natural Sciences	
Examination Office	
Examination Office Geosciences	

Status[1] *(C / CE / O)*	CE
ECTS Credits	5
Evaluation	Graded
Duration	1 semester
Frequency	Every two years in winter semester
Workload per ECTS Credit	30 hours
Total Workload	150 hours
Contact Time	39 hours
Independent Study	111 hours

Teaching Language	English
Entry Requirements as Stated in the Examination Regulations	None
Recommended Requirements*	

Module Course(s)			
Course Type	**Course Name**	**Compulsory/ Compulsory elective/ Optional**	**Credit hours**
Lecture	Thermohaline Circulation	Compulsory	2
Practical Exercises	Thermohaline Circulation	Compulsory	1
Further Information on the Course(s)*			
Prerequisites for Admission to the Examination(s)*	Work on written exercises, demonstration of exercise solution in tutorials. Compulsory attendance of practical exercise.		

[1] Status of whole module

Examination(s)				
Examination Name	**Type of Examination**	**Evaluation**	**Compulsory/ Compulsory elective / Optional**	**Weighting[1]**
Advanced Physical: Oceanography: Thermohaline Circulation	Oral Examination	Graded	Compulsory	100 %
Further Information on the Examination(s)*				

Short Summary

This course covers fundamental aspects of the ocean circulation using theory and observations.

Course Content

The course begins with the heat and freshwater budgets, the surface buoyancy fluxes and the transport of heat and freshwater by the ocean. The distribution of water masses is then discussed, in particular the central, intermediate, deep and bottom waters. The concepts of the "warm water sphere", the ventilated thermocline, subduction and the subtropical cells are then introduced. Attention then turns to higher latitudes, the process of deep water formation and the role of convection and mesoscale eddies. This leads naturally to a discussion on the circulation in the Nordic Seas, the overflows
deep western boundary currents and simple models for the deep circulation. The formation of Antarctic bottom water and the role of shelf convection is addressed, followed by the global thermohaline circulation and its variability and observations of the meridional overturning circulation.

Learning Outcomes

Students will have a comprehensive knowledge of the ocean circulation enabling them to tackle research problems in the field, including the analysis and interpretation of both observations and models.

Reading List

1. Gill, A.E., 1982: "Atmosphere – Ocean Dynamics". Academic Press, London, UK, 662 pp.
2. Holton, J.R., 1992: "An Introduction to Dynamic Meteorology", Academic Press, 511 pp.
3. Kundu, P., and I. Cohen, 2002: "Fluid Mechanics" (3rd Edition), Academic Press, 730pp.
4. Pedlosky, J., 1992: "Geophysical Fluid Dynamics", Springer, 710pp.
5. Vallis, G. K., 2006: "Atmospheric and Oceanic Fluid Dynamics", Cambridge University Press, 745 pp.
6. Olbers, D., J. Willebrand, and C. Eden, 2012: "Ocean Dynamics", Springer, 704pp
7. Apel, J.R., 1988: Principle of Ocean Physics. International Geophysics Series, Vol. 38, Academic Press, Fifth printing 1999, 634 pp.
8. Siedler, G., J. Church, J. Gould (eds), 2001: Ocean Circulation & Climate, International Geophysics Series, Vol. 77, Academic Press, 715 pp.

Talley, L.D., G.L. Pickard, W. J. Emery, J. H. Swift, 2011: "Descriptive Physical Oceanography: An Introduction", Academic Press, 555 pp.

Additional Information

Application of module

Master, 1-subject, Climate Physics: Meteorology and Physical Oceanography

[1] Weighting within the module

climAPOWIND-01a Advanced Physical Oceanography: Wind-driven Circulation

Module Name	**Module Code**
Advanced Physical Oceanography: Wind-driven Circulation	climAPOWIND-01a
Module Coordinator	
Prof. Dr. Peter Brandt	
Organizer	
GEOMAR Helmholtz Centre for Ocean Research Kiel	
Faculty	
Faculty of Mathematics and Natural Sciences	
Examination Office	
Examination Office Geosciences	

Status[1] *(C / CE / O)*	CE
ECTS Credits	5
Evaluation	Graded
Duration	1 semester
Frequency	Every summer semester
Workload per ECTS Credit	30 hours
Total Workload	150 hours
Contact Time	39 hours
Independent Study	111 hours

Teaching Language	English
Entry Requirements as Stated in the Examination Regulations	None
Recommended Requirements*	

Module Course(s)			
Course Type	**Course Name**	**Compulsory/ Compulsory elective/ Optional**	**Credit hours**
Lecture	Wind-driven Circulation	Compulsory	2
Practical Exercises	Wind-driven Circulation	Compulsory	1
Further Information on the Course(s)*			
Prerequisites for Admission to the Examination(s)*	Work on written exercises, demonstration of exercise solution in tutorials. Compulsory attendance of practical exercise.		

[1] Status of whole module

Examination(s)				
Examination Name	**Type of Examination**	**Evaluation**	**Compulsory/ Compulsory elective / Optional**	**Weighting[1]**
Advanced Physical: Oceanography: Wind-driven Circulation	Oral Examination	Graded	Compulsory	100 %
Further Information on the Examination(s)*				

Short Summary

This course covers fundamental aspects of the ocean circulation using theory and observations.

Course Content

The course begins with a brief review of the governing equations and basic approximations followed by a discussion of shallow water models, in particular the 1 and 1 1/2 layer models, vertical normal modes, and the projection of wind forcing onto these modes, including the representation of vertical mixing following McCreary. There then follows a discussion of Ekman dynamics, the Sverdrup balance and western intensification, introducing the models of Sverdrup (1947), Stommel (1948) and Munk (1950). This leads naturally into linear vorticity dynamics, the role of density stratification, bottom pressure torque, JEBAR and the closing of the circulation at the western boundary by bottom pressure torque rather than friction. The spin-up of an ocean to a suddenly applied wind forcing is then considered, introducing adjustment by Rossby waves in both a stratified and unstratified ocean, including variable bottom topography and leading to a discussion of time-dependent wind forcing and the annual cycle. The recirculation gyres in the Gulf Stream and Kuroshio Extension regions is then noted including the role of upgradient momentum transfer by eddies in their dynamics. The dynamics of the Southern Ocean in then discussed, including the role of eddies and topographic and interfacial form drag, the Gent and McWilliams/Greatbatch and Lamb eddy parameterisations for use in models, and the connection between these parameterisations and baroclinic instability, in particular the release of available potential energy.

Learning Outcomes

Students will have a comprehensive knowledge of the ocean circulation enabling them to tackle research problems in the field, including the analysis and interpretation of both observations and models.

Reading List

1. Gill, A.E., 1982: “Atmosphere – Ocean Dynamics”. Academic Press, London, UK, 662 pp.
2. Holton, J.R., 1992: “An Introduction to Dynamic Meteorology”, Academic Press, 511 pp.
3. Kundu, P., and I. Cohen, 2002: “Fluid Mechanics” (3rd Edition), Academic Press, 730pp.
4. Pedlosky, J., 1992: “Geophysical Fluid Dynamics”, Springer, 710pp.
5. Vallis, G. K., 2006: “Atmospheric and Oceanic Fluid Dynamics”, Cambridge University Press, 745 pp.
6. Olbers, D., J. Willebrand, and C. Eden, 2012: “Ocean Dynamics”, Springer, 704pp
7. Apel, J.R., 1988: Principle of Ocean Physics. International Geophysics Series, Vol. 38, Academic Press, Fifth printing 1999, 634 pp.
8. Siedler, G., J. Church, J. Gould (eds), 2001: Ocean Circulation & Climate, International Geophysics Series, Vol. 77, Academic Press, 715 pp.

Talley, L.D., G.L. Pickard, W. J. Emery, J. H. Swift, 2011: “Descriptive Physical Oceanography: An Introduction”, Academic Press, 555 pp.

Additional Information

Application of module

Master, 1-subject, Climate Physics: Meteorology and Physical Oceanography

[1] Weighting within the module

climSCIENCE-01a Introduction to scientific writing

Module Name	Module Code
Introduction to scientific writing	climSCIENCE-01a
Module Coordinator	
Prof. Dr. Katja Matthes	
Organizer	
GEOMAR Helmholtz Centre for Ocean Research Kiel	
Faculty	
Faculty of Mathematics and Natural Sciences	
Examination Office	
Examination Office Geosciences	

Status[1] *(C / CE / E)*	CE
ECTS Credits	3
Evaluation	Graded
Duration	1 semester
Frequency	Every semester
Workload per ECTS Credit	30 hours
Total Workload	90 hours
Contact Time	26 hours
Independent Study	64 hours

Teaching Language	English
Entry Requirements as Stated in the Examination Regulations	None
Recommended Requirements*	Basic knowledge in oceanography, meteorology and climate science

Module Course(s)			
Course Type	**Course Name**	**Compulsory/ Compulsory elective/Elective**	**Credit hours**
Seminar	Introduction to scientific writing	Elective	2
Further Information on the Course(s)*			
Prerequisites for Admission to the Examination(s)*			

Examination(s)				
Examination Name	**Type of Examination**	**Evaluation**	**Compulsory/ Compulsory elective / Elective**	**Weighting**[2]
Introduction to scientific writing	Seminar Paper with Written Report (RS)	Graded	Compulsory	100 %

[1] Status of whole module
[2] Weighting within the module

Further Information on the Examination(s)*	

Short Summary*
Prepare a written literature review in preparation for the Master thesis which will be discussed with and presented to the other participants in a 20 min long presentation under guidance of supervisors.
Course Content
Seminar series of student presentations including written reports.
Learning Outcomes
Students should be able to prepare a scientific review.
Reading List
The literature for the seminar will be provided at the beginning of the semester.
Additional Information
Application of module
Master, 1-subject, Climate Physics: Meteorology and Physical Oceanography

climCPPCLIM-01a Modern Aspects in Climate Physics I: Polar Climate

Module Name	**Module Code**
Modern Aspects in Climate Physics I: Polar Climate	climCPPCLIM-01a
Module Coordinator	
Prof. Dr. Martin Visbeck	
Organizer	
GEOMAR Helmholtz Centre for Ocean Research Kiel	
Faculty	
Faculty of Mathematics and Natural Sciences	
Examination Office	
Examination Office Geosciences	

Status[1] *(C / CE / O)*	CE
ECTS Credits	5
Evaluation	Graded
Duration	1 semester
Frequency	Winter semester, typically every two years
Workload per ECTS Credit	30 hours
Total Workload	150 hours
Contact Time	39 hours
Independent Study	111 hours

Teaching Language	English
Entry Requirements as Stated in the Examination Regulations	None
Recommended Requirements*	Advanced knowledge in Climate Science

Module Course(s)			
Course Type	**Course Name**	**Compulsory/ Compulsory elective/ Optional**	**Credit hours**
Lecture	Polar Climate	Compulsory	1
Seminar	Polar Climate	Compulsory	2
Further Information on the Course(s)*			
Prerequisites for Admission to the Examination(s)*	Compulsory attendance of seminar.		

Examination(s)				
Examination Name	**Type of Examination**	**Evaluation**	**Compulsory/ Compulsory elective / Optional**	**Weighting**[2]
Modern Aspects in Climate Physics I: Polar Climate	Seminar Coursework	Graded	Compulsory	100%

[1] Status of whole module
[2] Weighting within the module

Further Information on the Examination(s)*				

Short Summary*
Course Content
The course will be typically offered as a block and is composed of topical lectures given by a mix of Kiel based and external polar science experts followed by discussions led by students. It includes the preparation of the discussion session and short graded summary report. The course will cover modern research aspects of one or more of the following topics: Polar ocean dynamics, sea-ice physics, polar climate, high latitude climate feedbacks, ice shelves and ice sheet dynamics.
Learning Outcomes
On completion of this module, the students will obtain an overall understanding of the oceanic atmospheric processes impacting polar climate variability and its predictability. Within teams and aided by the Kiel based lectures the students will present and critically discuss scientific topics and papers in the context of current research. They will be able to organize scientific debate by short presentations and raising open questions. Students practice to prepare a report during the semester regarding an open science question based on own literature search and guided by the lecturers. The students will be able to identify and evaluate existing research and information about a specific topic.
Reading List
Books: Serreze and Barry, **The Arctic Climate System**, Cambridge University Press (2014) Barry and Hall-McKim, **Polar Environments**, Cambridge University Press (2018) Assessment: IPCC, **Special Report on the Ocean and Cryosphere in a Changing Climate** (2019) https://www.ipcc.ch/srocc/ Popular Science: **The Arctic and Antarctic –Extreme, Climatically Crucial and In Crisis**, World Ocean Review #6, (2019) https://worldoceanreview.com/en/wor-6/
Additional Information
Application of module
Master, 1-subject, Climate Physics: Meteorology and Physical Oceanography

climCPMCLIM-01a Modern Aspects in Climate Physics II: Mid-Latitude Climate

Module Name	**Module Code**
Modern Aspects in Climate Physics II: Mid Latitude Climate	climCPMCLIM-01a
Module Coordinator	
Prof. Dr. Martin Visbeck	
Organizer	
GEOMAR Helmholtz Centre for Ocean Research Kiel	
Faculty	
Faculty of Mathematics and Natural Sciences	
Examination Office	
Examination Office Geosciences	

Status[1] *(C / CE / O)*	CE
ECTS Credits	5
Evaluation	Graded
Duration	1 semester
Frequency	typically every two years
Workload per ECTS Credit	30 hours
Total Workload	150 hours
Contact Time	39 hours
Independent Study	111 hours

Teaching Language	English
Entry Requirements as Stated in the Examination Regulations	None
Recommended Requirements*	Advanced knowledge in Climate Science

Module Course(s)			
Course Type	**Course Name**	**Compulsory/ Compul-sory elective/ Optional**	**Credit hours**
Lecture	Mid-Latitude Climate	Compulsory	1
Seminar	Mid-Latitude Climate	Compulsory	2
Further Information on the Course(s)*			
Prerequisites for Admission to the Examination(s)*	Compulsory attendance of seminar.		

Examination(s)				
Examination Name	**Type of Examination**	**Evaluation**	**Compulsory/Compulsory elective / Optional**	**Weighting**[2]

[1] Status of whole module
[2] Weighting within the module

Modern Aspects in Climate Physics II: Mid-Latitude Climate	Seminar Coursework	Graded	Compulsory	100%
Further Information on the Examination(s)*				

Short Summary*
Course Content
The course will be typically offered as a block and is composed of topical lectures given by a mix of Kiel based and external tropical climate science experts followed by discussions led by students. It includes the preparation of the discussion session and short graded summary report. The course will cover modern research aspects of one or more of the following topics: Mid-latitude storm track dynamics, North-Atlantic Oscillation, Southern Annular Mode, Ocean-Atmosphere coupling, re-emergence theory, upper ocean dynamics.
Learning Outcomes
On completion of this module, the students will obtain an overall understanding of the atmospheric and ocean processes impacting tropical climate variability and potential predictability. Within teams and aided by the Kiel based lectures the students will present and critically discuss scientific topics and papers in the context of current research. They will be able to organize scientific debate by short presentations and raising open questions. Students practice to prepare a report during the semester regarding an open science question based on own literature search and guided by the lecturers. The students will be able to identify and evaluate existing research and information about a specific topic.
Reading List
Books: Vikram M. Mehta, **Natural Decadal Climate Variability: Phenomena, Mechanisms, and Predictability** CRC Press (2020) John Marshall and R. Alan Plumb, **Atmosphere, Ocean and Climate Dynamics: An Introductory Text** Elsevier Academic Press (2008) James W. Hurrell, Yochanan Kushnir, Geir Ottersen, Martin Visbeck, **The North Atlantic Oscillation: Climatic Significance and Environmental Impact** American Geophysical Union Geophysical Monograph Series (2003) https://agupubs.onlinelibrary.wiley.com/doi/book/10.1029/GM134 Assessment: IPCC, **AR5/AR6 Climate Change 2013/2022: The Physical Science Basis** (2014/2022) https://www.ipcc.ch/report/ar5/wg1/ IPCC, **Special Report on the Ocean and Cryosphere in a Changing Climate** (2019) https://www.ipcc.ch/srocc/
Additional Information
Application of module
Master, 1-subject, Climate Physics: Meteorology and Physical Oceanography

climCPTCLIM-01a Modern Aspects in Climate Physics III: Tropical Climate

Module Name	Module Code
Modern Aspects in Climate Physics III: Tropical Climate	climCPTCLIM-01a
Module Coordinator	
Prof. Dr. Martin Visbeck	
Organizer	
GEOMAR Helmholtz Centre for Ocean Research Kiel	
Faculty	
Faculty of Mathematics and Natural Sciences	
Examination Office	
Examination Office Geosciences	

Status[1] *(C / CE / O)*	CE
ECTS Credits	5
Evaluation	Graded
Duration	1 semester
Frequency	typically every two years
Workload per ECTS Credit	30 hours
Total Workload	150 hours
Contact Time	39 hours
Independent Study	111 hours

Teaching Language	English
Entry Requirements as Stated in the Examination Regulations	None
Recommended Requirements*	Advanced knowledge in Climate Science

Module Course(s)			
Course Type	**Course Name**	**Compulsory/ Compulsory elective/ Optional**	**Credit hours**
Lecture	Tropical Climate	Compulsory	1
Seminar	Tropical Climate	Compulsory	2
Further Information on the Course(s)*			
Prerequisites for Admission to the Examination(s)*	Compulsory attendance of seminar.		

Examination(s)				
Examination Name	**Type of Examination**	**Evaluation**	**Compulsory/ Compulsory elective / Optional**	**Weighting**[2]
Modern Aspects in Climate Physics III: Tropical-Climate	Seminar Coursework	Graded	Compulsory	100%

[1] Status of whole module
[2] Weighting within the module

Further Information on the Examination(s)*	

Short Summary*
Course Content
The course will be typically offered as a block and is composed of topical lectures given by a mix of Kiel based and external mid-latitude climate science experts followed by discussions led by students. It includes the preparation of the discussion session and short graded summary report. The course will cover modern research aspects of one or more of the following topics: Coupled Modes of Tropical Climate, ENSO, TAV, IOD, Monsoons, Ocean-Atmosphere coupling, Teleconnections, Tropical Planetary Waves.
Learning Outcomes
On completion of this module, the students will obtain an overall understanding of the atmospheric and ocean processes impacting tropical climate variability and potential predictability. Within teams and aided by the Kiel based lectures the students will present and critically discuss scientific topics and papers in the context of current research. They will be able to organize scientific debate by short presentations and raising open questions. Students practice to prepare a report during the semester regarding an open science question based on own literature search and guided by the lecturers. The students will be able to identify and evaluate existing research and information about a specific topic.
Reading List
Books: Vikram M. Mehta, **Natural Decadal Climate Variability: Phenomena, Mechanisms, and Predictability** CRC Press (2020) Peter Webster, **Dynamics of the Tropical Atmosphere and Oceans** Wiley-Blackwell (2020) Assessment: IPCC, **AR5/AR6 Climate Change 2013/2022: The Physical Science Basis** (2014/2022) https://www.ipcc.ch/report/ar5/wg1/
Additional Information
Application of module
Master, 1-subject, Climate Physics: Meteorology and Physical Oceanography

climCPCARBON-01a Modern Aspects in Climate Physics IV: Carbon Budgets

Module Name	**Module Code**
Modern Aspects in Climate Physics IV: Carbon Budgets	climCPCARBON-01a
Module Coordinator	
Prof. Dr. Andreas Oschlies	
Organizer	
GEOMAR Helmholtz Centre for Ocean Research Kiel	
Faculty	
Faculty of Mathematics and Natural Sciences	
Examination Office	
Examination Office Geosciences	

Status[1] *(C / CE / O)*	CE
ECTS Credits	5
Evaluation	Graded
Duration	1 semester
Frequency	typically every two years
Workload per ECTS Credit	30 hours
Total Workload	150 hours
Contact Time	26 hours
Independent Study	124 hours

Teaching Language	English
Entry Requirements as Stated in the Examination Regulations	None
Recommended Requirements*	Advanced knowledge in Climate Science

Module Course(s)			
Course Type	**Course Name**	**Compulsory/ Compul-sory elective/ Optional**	**Credit hours**
Seminar	Modern Aspects in Climate Physics IV: Carbon Budgets	Compulsory	2
Further Information on the Course(s)*			
Prerequisites for Admission to the Examination(s)*			

Examination(s)				
Examination Name	**Type of Examination**	**Evaluation**	**Compulsory/ Compulsory elective / Optional**	**Weighting**[2]
Modern Aspects in Climate Physics IV: Carbon Budgets	Seminar Paper with Written Report	Graded	Compulsory	100%

[1] Status of whole module
[2] Weighting within the module

Further Information on the Examination(s)*	

Short Summary*

This course gives an overview of the most recent literature about the concept of carbon budgets and the key uncertainties surrounding it. In addition, we will discuss the impact of carbon budgets on the discussions around climate policy. Students will present and discuss papers from the recent literature with their peers and write a paper review.

Course Content

Net zero targets are all about how much more greenhouse gases we can globally or nationally emit before we reach the 1.5°C temperature goal. In this class, we look at the climate science behind carbon and GHG budgets. How are the budgets derived, what are the underlying model assumptions and the key uncertainties? As carbon budgets are constantly being used in the public discourse, we will also look at their policy relevance and how they are perceived in the public.
The course will be in the form of a weekly seminar, in which students present a current research paper (selected from the reading list) to their peers, and moderate the discussion on the methodology and the results among the students. Finally, each student will write a 2-page review on the presented paper.

Learning Outcomes

On completion of this module, the students will obtain an overall understanding of the carbon budget concept, as well as the uncertainties inherent in the metric. Uncertainties stemming from different components of the Earth system, biogeochemical and physical will be discussed, as well as socio-economic uncertainties associated with future mitigation activities and the prospect of carbon dioxide removal.

Reading List

Books:
Assessment:
IPCC, **AR5/AR6 Climate Change 2013/2022: The Physical Science Basis** (2014/2022)
https://www.ipcc.ch/report/ar5/wg1/
IPCC, **Special Report on the Ocean and Cryosphere in a Changing Climate** (2019)
https://www.ipcc.ch/srocc/
Papers :
Le Quéré, et al., (2009) Trends in the sources and sinks of carbon dioxide
Friedlingstein, et al.: Global Carbon Budget 2021, Earth Syst. Sci. Data Discuss. [preprint], https://doi.org/10.5194/essd-2021-386, in review, 2021.
Matthews, et al., (2009) The proportionality of global warming to cumulative carbon emissions
Matthews, D. H., Tokarska, K.B., Rogelj, J. et al. An integrated approach to quantifying uncertainties in the remaining carbon budget (2021).
MacDougall, A. H. (2017) The oceanic origin of path-independent carbon budgets
Mengis, N., Matthews, H.D. (2020) Non-CO2 forcing changes will likely decrease the remaining carbon budget for 1.5 °C.
Rogelj, J. et al. (2016). Differences between carbon budget estimates unravelled.
Tokarska, K. B., et al., (2019). Path independence of carbon budgets when meeting a stringent global mean temperature target after an overshoot.
Zickfeld, K., et al. (2021). Asymmetry in the climate–carbon cycle response to positive and negative CO2 emissions.
Keller, D.P. et al. (2018) The Effects of Carbon Dioxide Removal on the Carbon Cycle.
Matthews, H. D., et al. (2020). Opportunities and challenges in using remaining carbon budgets to guide climate policy.

Additional Information

Application of module

Master, 1-subject, Climate Physics: Meteorology and Physical Oceanography

climENERGY-01a Modern Aspects in Climate Physics V: Renewable Energy in Climate Change

Module Name	**Module Code**
Modern Aspects in Climate Physics V: Renewable Energy in Climate Change	climENERGY-01a
Module Coordinator	
Prof. Dr. Stephanie Fiedler	
Organizer	
GEOMAR Helmholtz Centre for Ocean Research Kiel	
Faculty	
Faculty of Mathematics and Natural Sciences	
Examination Office	
Examination Office Geosciences	

Status[1] *(C / CE / O)*	CE
ECTS Credits	5
Evaluation	Graded
Duration	1 semester or as block course
Frequency	typically every two years
Workload per ECTS Credit	30 hours
Total Workload	150 hours
Contact Time	39 hours
Independent Study	111 hours

Teaching Language	English
Entry Requirements as Stated in the Examination Regulations	None
Recommended Requirements*	Advanced knowledge in Physics and/or Climate Science

Module Course(s)			
Course Type	**Course Name**	**Compulsory/ Compulsory elective/ Optional**	**Credit hours**
Seminar	Renewable Energy in Climate Change	Compulsory	2
Lecture	Renewable Energy in Climate Change	Compulsory	1
Further Information on the Course(s)*			
Prerequisites for Admission to the Examination(s)*	Compulsory attendance of seminar.		

Examination(s)				
Examination Name	**Type of Examination**	**Evaluation**	**Compulsory/ Compulsory elective / Optional**	**Weighting**[2]

[1] Status of whole module
[2] Weighting within the module

Renewable Energy in Climate Change	Presentation	Graded	Compulsory	100%
Further Information on the Examination(s)*				

Short Summary*
The European Union committed itself to reduce greenhouse gas emissions and to increase the share of renewables in the total power production. Renewable power production, especially from wind and solar energy, strongly depends on the weather. Hence, adequate information from weather forecasting and future climate projections is urgently needed in decision making on different levels in the energy sector. This course offers an overview on the physical science basis for such energy meteorological needs.

Course Content

The course content allows students to develop an understanding of the requirements and meteorological conditions of power production from wind and solar energy. The course focus is on meteorological aspects for power production on different weather and climate scales, such as:

- Variability and changes in solar and wind power in a warming world
- Possible impacts of climate change on a future weather-dependent energy system
- Implication of renewables for climate neutrality
- Local weather influences, e.g., winds, clouds, aerosols, and temperature, on different components of the energy system

In addition to the fundamental knowledge of energy meteorology, the course may touch on:

- Economic and regulatory basics for operating an electricity grid
- The coupling of power production, demand, transfer, and supply
- Technical aspects of different power technologies, e.g., on- and off-shore wind parks, rooftop photovoltaic modules, and concentrating solar thermal power plants
- Operational wind and solar power forecasting

Learning Outcomes

Upon completion of the course, the students will have an understanding of the meteorological processes affecting a climate-neutral energy system. Specifically, they understand weather influences on the power production from wind and solar energy, and implications of renewable power in the context of climate change. Such knowledge is the basis for research in energy meteorology as well as site auditing and operational work in the energy sector. Through the course, the students will acquire transferable skills in multi-disciplinary thinking involving critical reflection and discussion of scientific results, working in diverse teams for solving problems, and giving effective oral presentations.

Reading List

Stefan Emeis (2018): Wind Energy Meteorology. Atmospheric Physics for Wind Power Generation. Berlin, Heidelberg, Springer
IPCC (2021): Climate Change 2021: The Physical Science Basis. Contributions of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. (IPCC AR6 WG I)
IPCC (2022): Climate Change 2022: Mitigation of Climate Change. Contributions of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. (IPCC AR6 WG III)
Paul S. Samuel (2016): Meteorology and Energy Security. Simulations, Projections, and Management. New York. Apple Academic Press
Roger Perman et al. (2003): Natural Resource and Environmental Economics. Harlow, Pearson Education
Volker Quaschning (2016): Understanding Renewable Energy Systems. London, Earthscan (translation of the German textbook Regenerative Energiesysteme)
Volker Quaschning (2019): Renewable Energy and Climate Change. Chichester, John Wiley & Sons, Ltd. (translation of the German textbook Erneuerbare Energien und Klimaschutz)

Additional Information

Application of module

Master, 1-subject, Climate Physics: Meteorology and Physical Oceanography

climPOSCAD-01a Modern Aspects in Physical Oceanography IX: Small-scale dynamics in Observations

Module Name	**Module Code**
Modern Aspects in Physical Oceanography IX: Small-scale dynamics in Observations	climPOSCAD-01a
Module Coordinator	
Prof. Dr. Peter Brandt	
Organizer	
GEOMAR Helmholtz Centre for Ocean Research Kiel	
Faculty	
Faculty of Mathematics and Natural Sciences	
Examination Office	
Examination Office Geosciences	

Teaching Language	English
Entry Requirements as Stated in the Examination Regulations	None
Recommended Requirements*	Advanced knowledge in Physics and Oceanography

Status[1] *(C / CE / O)*	CE
ECTS Credits	5
Evaluation	Graded
Duration	1 semester
Frequency	variable
Workload per ECTS Credit	30 hours
Total Workload	150 hours
Contact Time	39 hours
Independent Study	111 hours

Module Course(s)			
Course Type	**Course Name**	**Compulsory/Compul-sory elective/Optional**	**Credit hours**
Lecture	Small-scale dynamics in Observations	Compulsory	2
Seminar	Small-scale dynamics in Observations	Compulsory	1
Further Information on the Course(s)*			
Prerequisites for Admission to the Examination(s)*	**Compulsory attendance of seminar**		

Examination(s)

[1] Status of whole module

Examination Name	Type of Examination	Evaluation	Compulsory / Compulsory elective/	Weighting[1]
Modern Aspects in Physical Oceanography IX: Small scale dynamics in Observations	Oral Examination	Graded	Compulsory	100 %
Further Information on the Examination(s)*				

Short Summary*
The course covers small-scale dynamics in the ocean. It includes eddies and filaments on scales of <100 kilometers, which are fundamental to the entire oceanic system. In addition to their importance for the physics of the ocean, small-scale dynamics can have crucial ecological and climatic impacts.
Course Content
The course is based on observational data and the aim is to study small-scale dynamics in the ocean. During the course students are introduced to the fundamental physics of the small-scale, with lectures on the underlying fluid dynamics, turbulence, mixing, vorticity and waves. Additionally, the biogeochemical impacts of these small-scale dynamics such as their influence on nutrient distribution, carbon cycling or influence on ocean health are discussed. Furthermore, embedding the small-scale dynamics into the larger scale, such as the influence on regional and global climate patterns is taught. This course is composed of lectures as well as discussions / presentations by the students. It also includes the preparation of a short report.
Learning Outcomes
On completion of this module, the students will have obtained an understanding of the small-scale dynamics (filaments, eddies, waves) in the ocean with its many different relevant time-scales and processes, from an observational approach. They will also have a comprehensive knowledge about the importance of the small-scale dynamics for the physics and biogeochemical properties of the global ocean.
Reading List
McGillicuddy Jr, D.J., 2016. Mechanisms of physical-biological-biogeochemical interaction at the oceanic mesoscale. Annual Review of Marine Science, 8, pp.125-159.
Additional Information
Application of module
Master, 1-subject, Climate Physics: Meteorology and Physical Oceanography

[1] Weighting within the module