Hydrology MSc

Vrije Universiteit Amsterdam - Fac. der Aard- en Levenswetenschappen - M Hydrology - 2017-2018

The Hydrology master's programme provides the student with sound scientific knowledge of how water cycles through the Earth’s atmosphere, surface and groundwater systems and how water quantity and quality are modified due to natural processes, or in response to human interference with the water cycle (e.g. pollution, land use change, etc.). This knowledge is a prerequisite for the sustainable use of our water resources that are being threatened by the continuous increase in the world’s population and the associated increase in water use and agricultural and industrial pollution. As water issues are often not restricted to a single country, the Master’s programme is strongly oriented to provide an international perspective.

The programme is strong in both hydrogeology and ecohydrology. Hydrogeology deals with (un)saturated groundwater and surface water flows on a local to regional scale (0-500 km), groundwater exploration and water quality issues in relation to the geology and land-use. Groundwater and surface water flow patterns and associated variations in the chemical composition of water due to interaction with the environment are assessed using a combination of lectures, field studies and hydrological and hydrochemical modelling workshops. Exploration and water resources assessments are made through application of water balance techniques, geophysical techniques and chemical and isotope tracer methods. Ecohydrology focuses on processes regulating the hydrological cycle and how these are affected by changes occurring at the land surface in response to human activities (e.g. deforestation, climate change). It combines micro-meteorology, (forest) hydrology, Quaternary geology, and environmental sciences to study processes that regulate how water, nutrients, sediment and gases are exchanged between the soil, water, vegetation and the atmosphere. These transfers are studied mostly on small catchment scales. A range of field measurement and sampling techniques are used including micro-meteorology, hydrology, plant physiology, soil physics, chemical isotope tracer methods, in combination with detailed, process-based models.

More information

- All compulsory courses and electives you find in the year schedule;
- A complete description of the programme you find in the Teaching and Examination Regulations;
- For more information about the programma you can contact the academic advisor (VU students only);
- As a VU student you need to register for all courses via VUnet. Only after you completed your enrollment for the study programme you can register for courses;
- More information on all the courses you find through the links below.

Inhoudsopgave

M Hydrology year 1

The MSc Hydrology is a two year program. The first year of the program consists completely of compulsory courses that are distributed over the two teaching lines (1) Process Hydrology (2) Water Risk. Here the students get acquainted with several key components of the hydrological system (e.g. catchment hydrology, ecohydrology, groundwater etc.), as well as their links to society (explicit in e.g. Water Economics and Integrated Modelling in Hydrology courses). At the end of the year the students learn how to perform measurements, and then apply these themselves in a field study (including 3-4 week field trip) which is aimed at teaching the students to collect data themselves, formulate and find answers to hypothesis, and link the various subsystems in hydrology and their ties to societal issues.

Vakken:

Naam	Periode	Credits	Code
Catchment Response Analysis	Periode 1	6.0	AM_450003
Climate Hydrological Processes	Periode 2	6.0	AM_1196
Ecohydrology	Periode 1	6.0	AM_450014
Field Course Hydrology	Periode 5+6	12.0	AM_1169
Groundwater Processes	Periode 4	6.0	AM_1164
Integrated Modeling in Hydrology	Periode 3	6.0	AM_1165
Measuring Techniques in Hydrology	Periode 5	6.0	AM_1168
Water Economics	Periode 4	6.0	AM_1167
Water Quality	Periode 2	6.0	AM_1166

M Hydrology year 2

The second year of the MSc Hydrology programme is more open for the student, where he/she can follow courses according to their own interest. The only compulsary part is the thesis (36 ects), leaving 24 ects (4 full time courses) open on elective courses. These elective options can be filled with advanced courses building on some courses from the first year (Advance Groundwater Processes and Water Risks), courses shared with other programs (such as Earth Sciences, ERM), or even courses offered by partner universities (such as UvA). The planning is flexible; the student works on a thesis research, and follows elective courses whenever they are given. This means that the student can already start with his/her thesis research directly at the start of the academic year.

Opleidingsdelen:

- MSc Hydrology year 2 elective options
- MSc Hydrology year 2 compulsory modules

MSc Hydrology year 2 elective options

In the 2nd year of the MSc Hydrology, 24 ects should be spend on elective courses. These can include advanced courses in Hydrology, courses from related MSc programs (such as Earth Sciences and ERM), of even courses offered at partner universities (such as UvA). In case you are interested in following a course which is not listed here, you can contact the coordinator after whose approval a request can be send to the exam committee for the student to include that course in his/her programme.

Vakken:

Naam	Periode	Credits	Code
Advanced Groundwater Processes	Periode 1	6.0	AM_1171
Advanced Spatial Analyses	Periode 2	6.0	AM_1197
Applied Water Science	Periode 2	6.0	AM_1054
Biological Oceanography	Periode 2	6.0	AMU_0021
Climate Modelling	Periode 3	6.0	AM_450004
Environmental Remote Sensing	Periode 3	6.0	AM_450145
Geothermal Energy		6.0	AM_450409
Global Biogeochemical Cycles	Periode 4	6.0	AM_450332
Groundwater Microbiology and Geochemistry (Geomicrobiology)	Ac. Jaar (september)	6.0	AM_450132
Modern Climate and Geo-ecosystems	Periode 1	6.0	AM_1124
Project Environmental Impact Assessment	Periode 3	6.0	AM_450406
Reflection Seismic for Geologists	Periode 4	6.0	AM_450170
Scientific Writing in English	Periode 2, Periode 5	3.0	AM_471023
Tectonic Geomorphology	Periode 2	6.0	AM_450146
Water Governance	Periode 3	6.0	AM_1192
Water Risks	Periode 1	6.0	AM_1210

MSc Hydrology year 2 compulsory modules

The only compulsary course in the 2nd year of the Hydrology MSc programme is the Thesis Research (36 ects). The remaining 24 ects should be filled with elective courses.

Vakken:

Naam	Periode	Credits	Code

Master Thesis Hydrology	Ac. Jaar (september)	36.0	AM_1170

Advanced Groundwater Processes

Vakcode	AM_1171 ()
Periode	Periode 1
Credits	6.0
Voertaal	Engels
Faculteit	Fac. der Aard- en Levenswetenschappen
Coördinator	dr. ir. Y. van der Velde
Examinator	dr. ir. Y. van der Velde
Docent(en)	dr. ir. Y. van der Velde
Lesmethode(n)	Werkcollege
Niveau	400

Doel vak
The goal of this course is to deepen the understanding of groundwater processes for which the Groundwater Processes course laid the fundamentals. The objective is to make the student thoroughly familiar with the modelling of groundwater flow processes and the transport of solutes through groundwater systems.

Inhoud vak
Hydrogeology is to a large extent concerned with the flow of water in the subsurface. Groundwater flow models are powerful tools to study this movement of water in the subsurface. Hence, they are widely used in research and consultancy, and thus a key skill for hydrologists. This course you will deepen your understanding of groundwater flow modelling and develop basic programming skills to investigate these processes. Moreover, fundamental transport processes taking place in groundwater bodies will be included in this (advection, diffusion, dispersion, first-order reactions) using numerical methods.

Onderwijsvorm
The course consists of a set of lectures supplemented with practicals.

Toetsvorm
Written examination, presentations and practicals

Vereiste voorkennis
Groundwater processes

Doelgroep
Hydrology MSc students and other earth sciences related MSc programs

Advanced Spatial Analyses

Vakcode	AM_1197 ()
Periode	Periode 2
Credits	6.0
Voertaal	Engels
Faculteit	Fac. der Aard- en Levenswetenschappen

Coördinator	dr. ir. J. van Vliet
Examinator	dr. ir. J. van Vliet
Docent(en)	dr. ir. J. van Vliet
Lesmethode(n)	Hoorcollege, Computerpracticum, Werkgroep
Niveau	500

Doel vak
The main objective of this course is to become familiar with more advanced approaches for the analysis of spatial problems, and to apply these approaches in a research context. Students will be trained in designing appproaches to solve spatial analysis question and in the techniques needed to do so (specifically including the Arc GIS model builder and Python Scripting). As methods evolve quickly, and sa a very large number of tools is available for spatial analysis, this course strives to teach how to learn new tools, rather than teaching how to use a predefined set of tools.

Inhoud vak
In the first part of the course we will learn how to approach spatial propblems using ArcGIS, and especially the Model builder. In this part we will analyse recently published research papers, conduct analyses of increasing complexity, and revisit some important issues related to GIS and spatial data, such as data quality, uncertainty, and meta-data, but also more technical aspects such as file types and data types.

In the second part of the course we will learn how to make a script (in Python) in order to conduct a spatial analysis. In this section we will first practice with very simple exercises, in order to learn basic principles of scripting / programming (operators, variables, functions, loops, conditional statements). Subsequently, we will learn to apply these to spatial analyses specifically, using the ArcPy module (a module to conduct GIS analyses).

At the start, each student will select a (different) case study region in Europe, to which s/he will apply a number of (environmental) spatial analyses using the methods and techniques listed above: a state-of-the-environment analysis. These analyses could include, but are not restricted to:
- Analsyis of observed land cover changes between two time periods
- Anlaysis of the thematic accuracy of a land cover map using Google Earth imagery
- Calculation of soild erosion in the case study area
- Calculation of changes in aboveground biomass and land related carbon emissions
- Consequences of land cover changes for biodiversity

These assignments are selected because they require the application of a number of different tools, and thus allow for one overarching theme while doing seperate exercises. It should be noted that the focus of the course is on the approaches and methods used to conduct a spatial analysis. Hence land use and land cover change are only used as a topic to practice these methods, while they are not the topic of this course in itself. Towards the end of the course students will write a paper in which they report on their state-of-the-environment analysis in a scientifically sound way.

Onderwijsvorm
The course will take 8 weeks of part-time (50%) study. In the first six weeks, each week will be used to conduct one spatial analysis for your case study area. Each week will start with a lecture about theory and application of spatial analyses, including some example of ongoing research in the department, and an explanation of the exercise and tools of that week. Throughout the week students will work on this exercise independently, with the possibility of support and feedback during the computer lab hours. On friday we will have feedback and discussion lectures, where students present their intermedoiate results and provide and receive feedback.

Toetsvorm
Students will be evaluated based on their contributions to a series of Python exercises (10%) the Friday discussions/presentations (10%), the spatial analysis tools they develop (30%), and the paper (50%).

Literatuur
Selected literature will be provided on Canvas.

Vereiste voorkennis
This course assumes a basic knowledge of GIS and GIS-based spatial analysis (such as GIS and Digital Spatial Data (AB_1076), or equivalent). This requirement is met by all students that completed their BSc in Earth Sciences or Earth and Economics at VU University. No prior knowledge of programming or scripting is expected.

Aanbevolen voorkennis
Any additional experience with GIS and spatial analysis is recommended, but not necessary.

Doelgroep
Master students in Earth Sciences (ESPCaR track), other Master students in Earth Sciences, and related relevant disciplines (such as ecology or hydrology).

Overige informatie
Lecturers:
Dr. Jasper van Vliet, invited guest lecturers

Applied Water Science

Vakcode	AM_1054 ()
Periode	Periode 2
Credits	6.0
Voertaal	Engels
Faculteit	Fac. der Aard- en Levenswetenschappen
Coördinator	dr. ir. T.H.M. Hamers
Examinator	dr. ir. T.H.M. Hamers
Docent(en)	dr. ir. T.H.M. Hamers
Lesmethode(n)	Hoorcollege, Practicum
Niveau	400

Doel vak
After the course, the student is able to:
• analyze scientific and societal issues related to human impacts on aquatic ecosystems
• combine scientific knowledge on aquatic systems with socio-economic arguments to develop a scientifically supported opinion on environmental management issues
• engage in the social debate on environmental management issues
• communicate in writing to a wide audience

Inhoud vak
Water is the prime necessity of life and the quality of drinking water directly influences public health and plays a major economic role. Yet, deterioration of water quality, overexploitation of aquatic resources, climate change and ecosystem all pose risks to human health, and potentially impact ecosystem values and services. This course builds on three pillars:
1) Human impacts. Which chemical contaminants are present and how can they be detected? What organisms are sensitive to poor water quality? What are the ecological risks and the treats to drinking water? How to improve water quality?
2) Conservation and restoration. How to protect aquatic ecosystems on an overpopulated and industrialized continent? How to spend millions of euros wisely to ensure that restoration measures will lead to ecological recovery of deteriorated aquatic ecosystems?
3) Social aspects and legislation. How are ecological risks assessed and how are they perceived and managed? Which legislative tools are at hand to halt environmental contamination and ecosystem degradation?

Onderwijsvorm
Lectures and guest lectures are given by internationally recognized experts. Excursions take place to Waternet, a joint water board and drinking water company, to a large scale low land stream restoration project and to the newly constructed ecosystems “Markerwadden”. FMB Cinema combined with a keynote lecture will address fish stock depletions. Students will work in small groups on case studies including oil drilling in polar regions; endocrine disrupting compounds, marine protected areas, restoration projects, water balance and eutrophication. All case studies jointly will be published as a prestigious e-book.
• Lecture (52)
• Fieldwork/excursion (24)
• Presentation/symposium (12)
• Self-study (28)
• Working independently on e.g. a project or thesis (24)
• Supervision/feedback meeting (12)

Toetsvorm
• Case study - practical assignment (50%)
• Exam (50%)

The student has passed if each of the components has received a minimum score equal to or higher than 5.50, in a range from 1-10.

Literatuur
Scientific articles will be provided during the course

Aanbevolen voorkennis
Introduction to Freshwater & Marine Biology; Aquatic Ecology, Marine Biology and Ecotoxicology on BSc level

Doelgroep
Open to all MSc students in Biology, Ecology, Hydrology, Biomedical Sciences, Health Sciences, Earth Sciences, Chemistry or related fields. Optional course for UvA MSc Biology, L&O track.

Intekenprocedure
This course is offered at the UvA. For more information contact:
FNWI
Education Service Centre, Science Park 904,
servicedesk-esc-science@uva.nl, +31 (0)20 525 7100.
Enrolment via https://m.sis.uva.nl/vakaanmelden is required.
For courses taught in period 1 and period 2, enrolment via https://datanose.nl/#specialenrol is required.

Overige informatie
This course is offered at the UvA

Lecturers:
Dr. Harmen van der Geest (UvA)
Dr. Michiel Kraak (UvA)
Dr. Jessica Legradi
Dr. Timo Hamers (contact person VU)

Biological Oceanography

Vakcode	AMU_0021 ()
Periode	Periode 2
Credits	6.0
Voertaal	Engels
Faculteit	Fac. der Aard- en Levenswetenschappen
Coördinator	dr. G.M. Ganssen
Examinator	dr. G.M. Ganssen
Niveau	500

Doel vak
At the end of the course, the students are able to:
1. Identify main biological oceanographic processes (4) and describe their interdependence
2. specify and differentiate between biological processes involved in the biological pump
3. survey relevant literature about a given research topic within biological oceanography and summarize in an abstract
4. develop and formulate a follow-up research question / objective on a given topic within biological oceanography and describe how the research should be conducted
5. present a lecture aimed at explaining a research topic to a scientific audience and proposing a continuation research project
6. explain the importance of the biology of the ocean for global change developments
7. critically discuss, oppose and defend scientific issues within the field of biological oceanography

Inhoud vak

http://studiegids.uva.nl/xmlpages/page/2016-2017-en/search-course/course/1545258
Biological Oceanography: a systems approach
Oceans cover 70% of the surface of the Earth and their vast total volume makes it the largest continuous habitat. Half of the oxygen production on Earth occurs in the oceans. The oceans have a critical function for the supply of food and raw materials, and marine ecosystems are crucial in the regulation of Earth's climate and biogeochemical cycles. Our understanding of the ocean and the life it supports is, however, far from complete. Biological oceanography improves our understanding of the principles underlying marine ecosystem organization, and the processes that govern spatial and temporal distribution, dynamics, biodiversity and evolution of auto-, hetero- and mixo-trophic organisms as well as trophic interactions. Only an interdisciplinary and (eco)system-wide approach will enable us to unravel the mysteries and the unknowns of the ocean. Physical, chemical and geological processes in the oceans are fundamental to biological oceanography and vice versa, therefore a few of the initial lectures in this course will be dedicated to the different disciplines. This course will give an in-depth insight in the current knowledge of life in the ocean from viruses to metazoans and from production to burial. The knowledge will be largely framed within the complex suite of processes that are involved in the transformation and transfer of fixed organic carbon (particulate and dissolved) from the surface to the deep ocean (collectively referred to as the 'biological pump'). The factors involved in the functioning of the biological pump are linked and diverse for different systems but influence virtually the entire ocean ecosystem.
The course consists of lectures, discussion forums, (computer) practicals, a one-day excursion, and a symposium. For the latter, students can choose a topic from a list provided (including papers as a starting point) which they will investigate and summarize (extended abstract) including a follow-up research objective for a new research project within the field. Students will be coached by teachers in this course to come up with new research ideas and communicate these effectively. Students are expected to actively participate in discussions and provide constructive comments.

Onderwijsvorm
FORMAT
- Lectures
- Discussion forums, flipped classrooms
- Homework assignment (literature survey, abstract writing, oral presentation)
- Computer and lab practicals
- Excursion
- Student symposium

Toetsvorm
ASSESSMENT (%)
Exam: 60%
Abstract and formulation research objective: 20%
Oral presentation: 20%

Literatuur
STUDY MATERIALS
Lectures (power point files)
Selection of scientific papers (will be provided)
(not obligatory) the book: Oceanography and Marine Biology. An Introduction to Marine Science. (D.W. Townsend. Sinauer Associates, ISBN

9780878936021) may serve as introduction to the course.

Vereiste voorkennis
basics in (biological) Oceanography

Doelgroep
master students in the field of climatology, oceanography, ecology, hydrology

Intekenprocedure
This course is offered at the UvA. For more information contact: FNWI Education Service Centre, Science Park 904, servicedesk-esc-science@uva.nl, +31 (0)20 525 7100.
Enrolment via https://m.sis.uva.nl/vakaanmelden is required.

Overige informatie
Biological Oceanography: a systems approach

Catchment Response Analysis

Vakcode	AM_450003 ()
Periode	Periode 1
Credits	6.0
Voertaal	Engels
Faculteit	Fac. der Aard- en Levenswetenschappen
Coördinator	dr. ir. M.C. Westhoff
Examinator	dr. ir. M.C. Westhoff
Docent(en)	dr. ir. M.C. Westhoff
Lesmethode(n)	Werkcollege, Computerpracticum
Niveau	400

Doel vak
The objectives of the course are to provide the student with scientific theory, tools and methods for understanding and evaluating the response of a catchment to precipitation in terms of surface water flows. This requires knowledge about processes regulating the flow of water on the land surface and in river channels, the techniques for quantification of surface water flows and statistical methods for predicting extreme runoff events. In addition, experience with surface water flow modelling for predicting the behaviour of rivers under different land use or climate conditions should be acquired.

The course contributes to the Knowledge and Understanding and Application of Knowledge and Understanding final attainment levels of the Msc Hydrology Programme. Knowledge and understanding is obtained through the studying of theory as provided in the textbook, during the oral lectures and through self-study of scientific papers on rainfall-runoff response topics. Knowledge and understanding is applied in the setting up and execution of a rainfall-runoff model and the critical evaluation of the model simulation with measured data.

Inhoud vak
The course consists of three main topics. We start with runoff processes leading to stormflow. This is followed by lectures on different hydrological modelling practices, and goodness-of-fit criteria. Finally,

an overview of hydrodynamic and hydraulic theory that governs flow in open channels is given as well as an overview of discharge measuring techniques.
Topics are hill slope hydrology, hydrograph analysis, statistical methods to describe and quantify spatial and temporal variation in catchment runoff and reservoir and flow routing and scaling in hydrology The spectrum of available models for runoff modelling, from classical lumped models to data-demanding distributed, physically-based hydrological models, will also be discussed. Finally, theory and understanding will be applied in a series of modelling exercises applying the HBV-light rainfall – runoff model to simulate runoff of the Dinkel River in East Netherlands.

Onderwijsvorm
The tuition consists of eleven classroom lectures and four computer modelling workshop sessions. The number of contact hours is in the order of 42.

Toetsvorm
The assessment is through a written exam (80%) and assessment of a selection of excercises and the
modelling workshop report (20%). Grades of both assessments should be at least a 5.5

Literatuur
Main Textbook:
S.L. Dingman, 2015. Physical hydrology, 3rd edition. ISBN: 978-1-4786-1118-9

Articles (provided on Canvas)

McGlynn, B. L.; McDonnel, J. J. & Brammer, D. D., A review of the evolving perceptual model of hillslope flowpaths at the Maimai catchments, New Zealand. Journal of Hydrology , 2002, 257, 1 - 26

Blöschl, G. Wilderer, P. (Ed.). Scaling and Regionalization in Hydrology. Treatise on Water Science , Elsevier, 2011, 519 - 535

Seibert, J. & Vis, M. J. P. Teaching hydrological modeling with a user-friendly catchment-runoff-model software package. Hydrology and Earth System Sciences, 2012, 16, 3315-3325

Selection of Reader "Hydrology of catchments, rivers and deltas", TUDelft, 2016

Chapter 5 of Hydrodynamics, surface water hydraulics and catchment rainfall– runoff response analysis, by A.A.van der Griend and M.J.Waterloo, 2014

Extra optional articles:

Kirchner, J. W. Catchments as simple dynamical systems: Catchment characterization, rainfall-runoff modeling, and doing hydrology backward. Water Resources Research, 2009, 45, W02429

Vereiste voorkennis
The student should be familiar with the subjects of the BSc course Introduction to Hydrology and Climatology (AB_1074) as detailed in the Introduction to Hydrology and Climatology (2013) course reader by M.J.

Waterloo, V.E.A. Post and K. Horner.

Aanbevolen voorkennis
The student should have a good background knowledge of mathematics and physics at BSc level and have basic computer skills. In addition, the student should have basic knowledge of Earth Science, as provided by the System Earth course (AB_450067).

Doelgroep
First-year M.Sc. Hydrology students, students from Earth Sciences, Earth and Economy or Natural Sciences M.Sc. programmes.

Overige informatie
The course is open for participation to students from alternative M.Sc. programmes at the VU University Amsterdam, or from other universities. If you are a professional and wish to attend this course you can also participate on a contract basis. In both cases please do contact the course coordinator to find out if you fulfill the background knowledge requirements and for enrollment procedures.

Climate Hydrological Processes

Vakcode	AM_1196 ()
Periode	Periode 2
Credits	6.0
Voertaal	Engels
Faculteit	Fac. der Aard- en Levenswetenschappen
Coördinator	dr. D. Coumou
Examinator	dr. D. Coumou
Docent(en)	dr. D. Coumou
Lesmethode(n)	Werkcollege, Computerpracticum
Niveau	400

Doel vak
Present-day climate change is already increasing the intensity and/or frequency of some types of extreme weather events. A key challenge for environmental scientists today is to assess the likely societal impacts from future changes in hydro-meteorological extremes, with heavy rainfall leading to flooding and persistent dry conditions leading to drought-related impacts. To do such impact assessments, scientists have to rely on global climate models in combination with local hydro-meteorological impact models. This process is associated with substantial uncertainty for example because those models operate at different spatial resolution. To be able to properly interpret future impact studies, one needs to understand the most relevant physical processes within the climate system and the hydrological cycle and how those processes are represented in models. This will be the focus of this course.

This course aims to provide students a solid understanding of the climate system including the most important underlying physical processes, its overall characteristics and its variability. The focus will be towards the intimate links between the climate system, the hydrological cycle and the large-scale atmospheric circulation. We will analyse which type of weather extremes have increased in intensity

already and what kind of changes are to be expected for the near future.

Key goals for students to reach at the end of the course are:
• To understand basic radiative transfer, the greenhouse effect and the role of water and clouds on global climate and climate change
• To understand the fundamental drivers of tropical circulation and its implications for rainfall in the tropical belt (inter-tropical convergence zone, Hadley circulation, desert regions, monsoons, ENSO, etc)
• To understand the fundamental drivers of extra-tropical circulation and its implications for rainfall outside the tropics (Coriolis effect, storm tracks, jet streams, NAO).
• To understand local rain and cloud formation processes.
• To learn how some type of extreme weather events are changing due to global warming and why.
• To learn how climate models work, their usefulness and their limitations.
• To understand what challenges need to be overcome to do future impact assessments of hydro-meteorological extremes and what type of uncertainties are involved.
• To develop basic data processing skills and analyse rainfall extremes in observational data.
• To develop basic scientific presentation and discussion skills

Inhoud vak
This course consists of several sessions going into different subjects related to Climate Hydrology. These sessions will consist of lectures by the professors with interactive discussion; some practical assignments, and student presentations & discussions. You will team up in pairs of two (maybe three) students to present a recent scientific paper which discusses the state-of-the-art of a particular lecture-topic. The day before presenting this, you are expected to hand in a short resume of paper and presentation. During these presentation sessions, all students are expected to participate in discussions.

Toetsvorm
The course will be assessed through a written closed book examination based on the compulsory readings and the lectures. Also questions related to insights learned during the computer exercises can be asked. There may be some quantitative question where a small calculation has to be made, so please bring a calculator. This closed book examination counts for 70% of the final grade. Furthermore, students will be paired up to present a scientific paper and discuss this in class. The day before presenting this, students are expected to hand in a short resume of paper and presentation. The short resume and presentation/discussion in class will together constitute 30% of the final grade.
The computer exercises will not be graded. They are, however, a compulsory part of the course and need to be handed in via Canvas. Students will not receive a final grade if not all computer exercises have been handed in.

Literatuur
Apart from attending the sessions, you are expected to study the readings associated with the lectures (‘compulsory reading’) before attending them. This helps you both to actively engage in discussions during our meetings, and also makes it easier to prepare for the final exam at the end of the course.
The readings are provided as chapters and papers and aim to give you a broad understanding of Climate Hydrology as befits a master’s program.

However, you will be examined only on some elements of the course; in other words you do not have to memorize entire pieces of text. The structure of the lectures in class will help you identify the key questions on which you will be examined.

Climate Modelling

Vakcode	AM_450004 ()
Periode	Periode 3
Credits	6.0
Voertaal	Engels
Faculteit	Fac. der Aard- en Levenswetenschappen
Coördinator	dr. D.M.V.A.P. Roche
Examinator	dr. D.M.V.A.P. Roche
Docent(en)	prof. dr. A.J. Dolman, dr. D.M.V.A.P. Roche
Lesmethode(n)	Werkcollege, Computerpracticum
Niveau	400

Doel vak
The objective of this course is to provide an overview of numerical climate models and their applications, with a focus on Earth Science studies.

Inhoud vak
Geological archives show convincingly that the climate system experiences variability on a wide range of time-scales. For Quaternary studies, climate variations at the following time-scales are most important: glacials-interglacials, millennia and centuries-decades. This course focuses at the mechanisms behind these variations, thereby using climate models as a tool, i.e. numerical computer models in which the dynamics of the climate system are calculated. The combination of these models and geological data will be treated extensively. The course consists of lectures giving an overview of climate models and their application (different types for different time-scales), computer practicals and discussion meetings, in which students discuss the recent literature in detail. In this way the course considers case studies for the different time-scales and deals with recent developments in climate modelling. The following two questions are central to the course: 1) What is the driving mechanism behind climate change at a particular time-scale? 2)
How can we optimise the combination of climate models and geological data in order to increase our understanding of climate evolution?

Onderwijsvorm
Lectures, discussion meetings and computer exercises.

Toetsvorm
Compulsory participation in discussion meetings, computer exercises, oral presentation and written exam.

Literatuur
Text book:
Goosse, H. (2015) Climate System Dynamics and Modelling. Cambridge University Press, 358 p., ISBN 978-1-107-44583-3

Additional:
Lecture notes and selected papers (made available through Canvas).

Overige informatie
The course is open for participation to students from alternative M.Sc. programmes at the VU University Amsterdam, or from other universities. If you are a professional and wish to attend this course you can also participate on a contract basis. In both cases please do contact the course coordinator to find out if you fulfill the background knowledge requirements and for enrollment procedures.

Ecohydrology

Vakcode	AM_450014 ()
Periode	Periode 1
Credits	6.0
Voertaal	Engels
Faculteit	Fac. der Aard- en Levenswetenschappen
Coördinator	prof. dr. A.J. Dolman
Examinator	prof. dr. A.J. Dolman
Lesmethode(n)	Werkcollege, Computerpracticum
Niveau	400

Doel vak
Ecohydrology is a combination of ecology (study of how organisms interact with each other and with the natural environment) and hydrology (study of how water cycles in terrestrial environments). It focuses on the role of ecosystems in the water cycle of terrestrial landscapes. The objectives of the course is to provide understanding of the functioning of ecosystems in relation to water availability and the movement of water in terrestrial ecosystems under different climates. This ecohydrological knowledge forms the basis for supporting decisions on sustainable land use from a water resources point of view. It requires fundamental theoretical knowledge on plant physiology and on the exchange of water between the soil, vegetation and the atmosphere. As such, limitations to ecosystem functioning posed by water availability in relation to evaporation and transpiration by different plant communities is a central theme in this course. In addition, the student needs to learn basic computer programming for meteorological data processing and analysis.

Inhoud vak
This course describes and discusses basic interactions between the vegetated land surface, the atmosphere and the hydrosphere. Basic questions dealt with include: what determines the broad vegetation patterns of the world, and how do these in turn determine the ecohydrological behaviour of different vegetation types? This requires understanding of primary ecohydrological processes (rainfall and cloud water interception, transpiration, soil moisture dynamics) and feedback mechanisms between the vegetation and the atmosphere as well as insight into the measurement, data analysis and modelling of these processes. The ecohydrological aspects of Dynamic Vegetation Models (DGVMs) will be discussed. Tropical and temperate deforestation impacts on catchment hydrological functioning and climate as well as desertification processes are considered. Ecohydrological processes in boreal and tundra

regions, as well as in montane cloud forests will be discussed in some detail. Emphasis throughout the course is on a combination of process understanding, interpretation of experimental results, and modelling. Finally, a computer programming workshop is included to become familiar with the basics of computer programming, meteorological data processing, analysis and rainfall interception modelling.

Onderwijsvorm
The tuition consists of nine classroom lectures, a half-day student presentation session and a computer work.

Toetsvorm
Written test on lecture notes and selected literature (65%), computer assignments (15%), and a presentation to be given on a pre-determined topic (20%).

Literatuur
Scientific papers and handouts are provided during the course via Canvas

Vereiste voorkennis
The student should be familiar with the subjects of the BSc course Introduction to Hydrology (450024) as detailed in the Introduction to Hydrology (2012) .

Aanbevolen voorkennis
The student should have a good background knowledge of mathematics and physics at BSc level and basic computer skills

Doelgroep
First-year MSc Hydrology students, students from alternative Earth Sciences, Earth and Economy or Natural Sciences MSc programmes

Overige informatie
The course is open for participation to students from alternative M.Sc. programmes at the VU University Amsterdam, or from other universities. If you are a professional and wish to attend this course you can also participate on a contract basis. In both cases please do contact the course coordinator to find out if you fulfill the background knowledge requirements and for enrollment procedures.

Environmental Remote Sensing

Vakcode	AM_450145 ()
Periode	Periode 3
Credits	6.0
Voertaal	Engels
Faculteit	Fac. der Aard- en Levenswetenschappen
Coördinator	dr. S.S.N. Veraverbeke
Examinator	dr. S.S.N. Veraverbeke
Docent(en)	dr. S.S.N. Veraverbeke
Lesmethode(n)	Werkcollege, Computerpracticum
Niveau	400

Doel vak
The course objectives are:
- Understanding of fundamental principles of electromagnetic radiation and remote sensing in applications focused on land, ocean and atmosphere
- Air- and spaceborne image interpretation
- Knowledge of various satellite sensor systems and data availability
- Performing image analyses using both GIS and object-oriented coding

Inhoud vak
Topics include:
- Definition of remote sensing and the electromagnetic spectrum
- Short history of remote sensing
- Fundamental radiation laws
- Variety of remote sensing technologies (RADAR, LIDAR, optical, thermal), sensor systems (polar-orbiting and geostationary), and important satellite missions
- Photogrammetry
- Geometric, atmospheric and topographic image corrections
- Principal component analysis
- Land cover mapping
- Spectral indices
- Spectral mixture analysis
- Change detection and multitemporal analysis
- Soil moisture retrievals
- Applications focused on ocean and atmosphere
- Visual image interpretation and color composites
- Digital image analysis using GIS and object-oriented coding

Onderwijsvorm
Lectures, including guest lectures, supplemented with reading materials.
Computer lab sessions.

Toetsvorm
Written exam and lab assignments.

Literatuur
Selection of scientific papers and book sections.
Chuvieco, Emilio. Fundamentals of Satellite Remote Sensing: An Environmental Approach. CRC press, 2016.
Lillesand, Thomas, Ralph W. Kiefer, and Jonathan Chipman. Remote sensing and image interpretation. John Wiley & Sons, 2015.

Aanbevolen voorkennis
Good background knowledge of mathematics and physics, and basic knowledge of GIS and object-oriented coding is recommended.

Doelgroep
First-year MSc Hydrology students and students from alternative Earth Sciences, Earth and Economy or Natural Sciences MSc programs.

Field Course Hydrology

Vakcode	AM_1169 ()
Periode	Periode 5+6
Credits	12.0
Voertaal	Engels

Faculteit	Fac. der Aard- en Levenswetenschappen
Coördinator	dr. ir. M.C. Westhoff
Examinator	dr. ir. M.C. Westhoff
Docent(en)	dr. H. de Moel, dr. ir. M.C. Westhoff
Lesmethode(n)	Werkcollege, Computerpracticum, Veldwerk
Niveau	500

Doel vak
This course main objective is to instill “hydrological system thinking” in the student's mind. This is done through a combination of practical application of the earth scientific and hydrologic theory given in the period before the field course to solve hydrological questions in the field. The objectives include planning and making decisions about research strategies (this includes defining testable hypotheses), learning to make relevant measurements of all the components of the hydrological cycle (surface water, ground water storage, soil moisture, vegetation, and the atmosphere) and use these measurements to make realistic qualitative and quantitative interpretations regarding the hydrological processes and conditions in the field and their relation to local and regional issues related to water resources.

Inhoud vak
This course covers the practical side of hydrological research through application of geological and hydrological knowledge to solve the water balance of target areas and to study water quality issues.

In this course, the students will carry out a research project that includes field work in Luxembourg. Focus will be on developing research skills,
including making research questions and work plans, carrying out field measurements, processing data and critically discussing the whole process.
The fieldwork course will consist of an introductory part at VU, then fieldwork in Luxemburg, followed by a two-week period to finalize the data processing and reporting part after arrival back in Amsterdam.

During the first two weeks of the course, lectures and practicals are given at the VU. During these lecture, you will get an introduction about the fieldwork area and you will be divided into small groups that will be assigned a study catchment.
The other lectures and practicals focus on research skills that are needed for the fieldwork and for developing the work plan. In between lectures, you will be working with your group on your work plan.

After these first two weeks, we will go to Luxembourg for almost 4 weeks, where the fieldwork will be carried out. During these 4 weeks, the students are responsible for their own measurements. Besides doing measurements, data have to be analyzed and interpreted. Once a week, each group will give a short presentation about their findings and discuss new ideas. The four weeks of fieldwork will end with presentations at specific locations within the different catchments.
During our stay in Luxembourg a couple of mandatory excursions will be organized in which we visit different hydrologically interesting locations in Luxembourg.

Back at VU, you will have another two weeks to finalize your reports.

Onderwijsvorm
The course is subdivided in two parts. Before the fieldwork preparatory lectures will be organised. In the fieldwork region, each group will be assigned a study catchment in which a hydrological observation network (surface water, ground water, meteorology, etc.) will be installed. Students are expected to work independently and make their own decisions regarding planning and research strategy. Data processing, analysis and modelling are an integral part of the field course to scale up the measurements and link their findings to water resources issues in the region. An individual report will be finalized in Amsterdam during the final two weeks of the course.
Staff members will be present during the whole course period for supervision and for consultation by students.

Toetsvorm
- Execution of field campaign
- Final presentation in the field
- Publication of report on results

Literatuur
Handbook for Hydrological Field Measurements. Adapted from: Boris M. van Breukelen, Michel M.A. Groen, Koos Groen, Ko van Huissteden, Richard A.M. de Jeu, Vincent E.A. Post, Jaap Schellekens and Maarten J. Waterloo (2018). VU University Amsterdam.

Vereiste voorkennis
Admission to this field course is granted to students who have been admitted to the Hydrology MSc Programme. Furthermore, students must have completed the course Measuring Techniques in Hydrology and, before mid-April, must have passed at least two of the courses Catchment Response Analysis, Groundwater Processes, Water Quality and Unsaturated Zone and Near Surface Hydrological Processes.

Aanbevolen voorkennis
The student should have a good general knowledge of the subjects discussed in the basic theoretical courses M.Sc. Hydrology master, i.e. Catchment Response Analysis, Ecohydrology, Groundwater Processes, Water Quality, Unsaturated Zone and Near Surface Hydrological Processes. Participants will need to work with GIS for analysing and displaying spatial spatial data and will need to be familiar with field methods.

Doelgroep
First year MSc Hydrology Programme students

Overige informatie
The course coordinator will send you an e-mail asking for information about your participation in this course in January. Besides registering for this course via the VUnet portal please respond to the e-mail request of the coordinator before 31 of January. The course is
partly subsidized by the faculty and the students are obliged to pay for the other part of the course (travel, residence costs, etc.).

Geothermal Energy

Vakcode	AM_450409 ()

Credits	6.0
Voertaal	Engels
Faculteit	Fac. der Aard- en Levenswetenschappen
Coördinator	dr. M.P. Bokhorst
Examinator	dr. M.P. Bokhorst
Lesmethode(n)	Hoorcollege, Computerpracticum
Niveau	500

Doel vak

• To provide students with an overview of the current status and future outlook of geothermal exploration and production (heat/cold and electricity)
• To assess its impact in the energy-transition challenge, being a major alternative source for renewable energy.
• To provide insight into the energetical and economical aspects of different ways to supply thermal energy to buildings and processes.
• To review main categories of operational geothermal systems, the governing processes and relevant boundary conditions, linking hydrogeology to subsurface understanding
• To assess exploration concepts of geothermal prospecting and see how they can be applied to future subsurface analysis and energy supply prediction
An additional practical aim is to improve your communication and writing skills.

Inhoud vak

This course provides a comprehensive overview of existing systems that are used to supply thermal energy to buildings and/or industrial processes. The course starts with a general introduction to the history of geothermal exploration and production, what kind of geothermal systems exist, and how these are linked to particular subsurface and economical conditions. In addition it is explained what benefits of geothermal energy exist compared to other energy resources. Subsequently different aspects are explained in more detail. We will first
concentrate on the demand side, by showing how the heat and cold demand of a building can be provided by different types of energy systems and how the economical aspects of the different options relate. Later on we will focus on the hydrogeological parameters that contribute to successful geothermal systems. This is achieved through a review of several such systems, including borehole heat exchangers (closed loop systems), aquifer thermal energy storage (ATES or open loop systems) and systems for the production of deep geothermal heat for heating and/or electricity production (enhanced geothermal systems). Special emphasis is placed on the relation of subsurface conditions and operational excellence.
During the course the students are put in the role of consultants that have to choose an optimal solution for the customer. A business case is build in which different geothermal options have to be considered and compared to a conventional solution for climate control in the buildings concerned.

Onderwijsvorm

The course uses two different methods:
Oral lessons in the form of lectures and tutorials/seminars (distributed equally) where various topics are presented by the

lecturer and discussed in common with the students. Students must be aware that the content of this course is difficult to find in one-two textbooks. Therefore, understanding the handouts is essential. Our advice is to attend the oral lessons during class hours. Further students are expected to read and present material from selected papers in a short presentation and abstract.
Practical lessons: this course includes a number of practical exercises and a few case studies. Exercises and case studies will be worked out individually and in small groups and discussed in class. The rule of thumb: this is individual work, unless otherwise specifically noted.

Toetsvorm
The final mark is made up of assignments (10%), a presentation (pre), an excursion(10) (exc) and a 1-page abstract of relevant paper(s) (10%) (O) and case
studies (70%).
The practicals and case studies will cover the topics presented during the course.

Literatuur
All materials will be digitally provided through Canvas

Vereiste voorkennis
To facilitate a rapid in- depth study at MSc level, students are required to know in advance basic notions of hydrogeology (groundwater flow, impact of wells on hydraulic head) which were already studied during their BSc curriculum. Furthermore sufficient knowledge of mathematics and MS Office (Excel) is required.

Global Biogeochemical Cycles

Vakcode	AM_450332 ()
Periode	Periode 4
Credits	6.0
Voertaal	Engels
Faculteit	Fac. der Aard- en Levenswetenschappen
Coördinator	prof. dr. G.R. van der Werf
Examinator	prof. dr. G.R. van der Werf
Docent(en)	dr. J. van Huissteden, dr. G.M. Ganssen, prof. dr. G.R. van der Werf, prof. dr. ir. J.W. Erisman, prof. dr. G.J.A. Brummer
Lesmethode(n)	Computerpracticum, Hoorcollege
Niveau	400

Doel vak
To understand and quantify the role of biogeochemical cycles (Carbon, Nitrogen, Phosphorus, Water) in the Earth system.

Inhoud vak
The course starts with an overview of the major global biogeochemical cycles, their role in the Earth system, and how they are modified by humans. The main subject is exchange of C, N, P, and S between the soil, water, atmosphere, and biota on global and local scales in different climatic zones (tropics, temperate, boreal and arctic zone) and environments. We address the relation of biogeochemical cycles with the

climate system. Each week consists of two lectures where the first one serves as an introductory lecture and the second a more in-depth view of a theme in global biogeochemical cycles. The themes include: 1) the global terrestrial carbon cycle, 2) forests, 3) the nitrogen cycle, 4) the oceanic carbon cycle, 5) oceanic cycles of N, P, and S, 6) wetlands, and 7) disturbances including deforestation and forest fires.

Onderwijsvorm
12 Lectures, assistance with essay writing

Toetsvorm
Written exam

Literatuur
W.H. Schlesinger: Biogeochemistry: An analysis of Global Change, 3th edition (Academic Press).
Lecture notes and additional literature will be made available during the course.

Doelgroep
MSc students Earth Sciences, Hydrology, Environment and Resource management

Groundwater Microbiology and Geochemistry (Geomicrobiology)

Vakcode	AM_450132 ()
Periode	Ac. Jaar (september)
Credits	6.0
Voertaal	Engels
Faculteit	Fac. der Aard- en Levenswetenschappen
Coördinator	U. Nunes da Rocha
Examinator	U. Nunes da Rocha
Niveau	400

Doel vak
At the end of this interdisciplinary course, students will be able to describe and explain:
- Aspects of the growth and cellular functioning of microorganisms
- The role of microorganisms in nutrient cycli
- Important microbial processes in polluted and pristine groundwater ecosystems
- The dependency of microbial presence and activity on environmental conditions
- Modern methods in microbial ecology
Students can relate the obtained knowledge to hydrology.

Inhoud vak
Theory will consist of:

Introduction to environmental microbiology:
- Microbial growth, metabolism and kinetics in relation to environmental conditions.
- Types and diversity of micro-organisms in groundwater ecosystems.
- Interactions between micro-organisms.

- Basics of molecular microbiology; overview of modern techniques in microbial ecology and biogeochemistry.

Impact of microbiological processes on hydrochemistry:
- Microbial contribution to important biogeochemical processes and nutrient cycles.
- Microbial mediated mineral dissolution and precipitation.

Degradation of organic contaminants in groundwater:
- Biodegradation, bioremediation and "natural attenuation" of pollution.

Onderwijsvorm
~90 hours of guided self-study (the student will study the book Brock Biology of Microbiology, on basis of 5 modules containing instructions and about 20 questions per module), 70 hours for essay writing. After each of
the five modules, the student and lecturer discuss the answers (~1 h per module).

Toetsvorm
Written essay (70% of final mark) on a geo-microbiological subject, linked to the interests of the student and general course content. Oral discussion on the essay and studied text (30%).

Literatuur
Michael T. Madigan, John M. Martinko, Kelly S. Bender, Daniel H. Buckley, David A. Stahl (2014), Brock biology of microorganisms, 14th edition. Pearson Higher Education. ISBN-3: 9781292018317 (about 85 euro) [you may also use the 13th edition]

Weber K.A. et al.(2006), Microorganisms pumping iron: anaerobic microbial iron oxidation and reduction. Nature Reviews in Microbiology, 4, p. 752-764.

Handout for guided self-study (via lecturer).

Intekenprocedure
The course can be started at any time during the academic year, in consultation with the coordinator

Overige informatie
This course is an elective option for master students in Hydrology. The course is also open to students in the masters Biology and Earth Sciences. Part of the content can be adapted to fit the interest and educational background of the student. Students are advised to contact the coordinator before starting.

Groundwater Processes

Vakcode	AM_1164 ()
Periode	Periode 4
Credits	6.0
Voertaal	Engels
Faculteit	Fac. der Aard- en Levenswetenschappen
Coördinator	dr. ir. Y. van der Velde
Examinator	dr. ir. Y. van der Velde

Lesmethode(n)	Werkcollege
Niveau	400

Doel vak
The objective of the course on Groundwater Processes is to gain knowledge and insight in the terminology and theory of groundwater hydraulics, including its mathematical notation and physical meaning.

Inhoud vak
The movement of groundwater through the subsurface is a fundamental part of the hydrological cycle. In this course, you will get acquainted with the fundamental hydraulics of groundwater flow. You will get profound insight into fundamental hydrological concepts related to groundwater flow and its mathematical notation and solutions. The application of this knowledge will be illustrated using some basic groundwater flow modelling exercises.

Onderwijsvorm
The course consists of a set of lectures supplemented with practicals.

Toetsvorm
Written examination

Doelgroep
Hydrology MSc students and other earth sciences related MSc programs

Integrated Modeling in Hydrology

Vakcode	AM_1165 ()
Periode	Periode 3
Credits	6.0
Voertaal	Engels
Faculteit	Fac. der Aard- en Levenswetenschappen
Coördinator	dr. H. de Moel
Examinator	dr. H. de Moel
Docent(en)	dr. P.J. Ward, dr. H. de Moel
Lesmethode(n)	Werkcollege, Computerpracticum
Niveau	400

Doel vak
The objectives of this course are for the students to:
- get acquainted with the wide range of modeling tools used in integrated hydrological studies
- understand the type of questions that can be answered using such tools
- acquire hands-on modelling skills and gain experience with some commonly used analytical programs (Matlab, GIS, Excel)

Inhoud vak
The course is set up with a limited amount of lectures and two large exercises. In these exercises the students will set up and apply their own models from start to finish. The first exercise concerns a spatial rainfall-runoff model using publicly available data sources. This model will be used to simulate river discharge under current and future climatic conditions, and results will be related to water resources

availability and associated measures. The second exercise is a flood risk assessment where hazard, exposure and vulnerability will be combined to estimate flood risks. Using the model, measures will be evaluated on their risk reducing effect.

Onderwijsvorm
There will be a limited amount of lectures (in mornings) as the focus is on the development of the two exercises. Practical sessions are scheduled throughout the period where staff will be available to help with technical questions and to help start up the model development. The rest of the time students will work on their models, analyses and reporting themselves.

Toetsvorm
Assessment will be done in the form of a report (50%) and a presentation (50%) related to the assignments.

Literatuur
Relevant course reading material (papers, reports) will be provided via canvas

Doelgroep
Hydrology MSc students and other earth sciences related MSc programs

Master Thesis Hydrology

Vakcode	AM_1170 ()
Periode	Ac. Jaar (september)
Credits	36.0
Voertaal	Engels
Faculteit	Fac. der Aard- en Levenswetenschappen
Coördinator	dr. H. de Moel
Examinator	dr. H. de Moel
Lesmethode(n)	Werkcollege
Niveau	600

Doel vak
To conduct a research project in the scope of the MSc program Hydrology. The student will learn to develop his/her own research question, plan this research, collect data, perform analyses, draw proper findings and report on this.

Inhoud vak
The student will set up, execute and report on a research project on a hydrological topic. This research and report serves as the final activity of the student within the MSc program where knowledge and skills obtained during the program are integrated and demonstrated by the student.

Onderwijsvorm
This is course consist of self-study by the student, under guidance of a supervisor from the staff related to the MSc hydrology.

Toetsvorm

Written report/paper (60%), execution (30%) and oral presentation (10%).

Vereiste voorkennis
A minimum of 36 ects is required before starting with this thesis project.

Doelgroep
MSc Hydrology students

Measuring Techniques in Hydrology

Vakcode	AM_1168 ()
Periode	Periode 5
Credits	6.0
Voertaal	Engels
Faculteit	Fac. der Aard- en Levenswetenschappen
Coördinator	dr. R. Lasage
Examinator	dr. R. Lasage
Docent(en)	dr. J.E. Blasch, dr. ir. M.C. Westhoff
Lesmethode(n)	Werkcollege, Computerpracticum, Practicum
Niveau	400

Doel vak
The objective of this course is to familiarize students with measurement methods and techniques from different disciplines, that are commonly used in hydrology and related environmental sciences. The course is divided into 3 modules, in four weeks. The three parts are focused on measuring hydrological processes: a module focuses on measuring techniques to understand and quantify the basic processes in the water balance and hydro chemistry, such as measuring discharge and rainfall. A module focuses on using remote sensing to measure variables such as soil moisture and vegetation characteristics. And a module 3 focuses on measuring the effects from hydrological processes (water availability and quality, and extremes such as floods) on people and the economy. For this, students will learn how to design, conduct, and statistically analyse a household survey to quantify economic impacts.
At the end of the course the student should be able:
1. to select the appropriate field measurement methods and techniques to measure hydrological processes and impacts on society;
2. to implement the methods and techniques, including equipment operation;
3. to analyse, evaluate and interpret the results, using computer models and statistical methods;
4. to carry out the final integrating fieldwork, which directly follows this course, and other research projects independently.

Inhoud vak
Module Hydrological field tools
This part of the course deals with a broad range of field measurement aspects of hydrological studies. Practical research experience is gained through a study of the water balance and hydrochemistry of the field area. This includes instructions in geohydrological, meteorological, and hydrochemical measurement techniques that are commonly used in surface and groundwater movement studies and in water quality investigations. Spatial data collection and processing methods are practiced through the

use of portable geographic information systems. Key course subjects are installation of hydro-meteorological equipment for measuring rainfall, temperature, water level and discharge, soil and aquifer permeability measurements, soil moisture and tension measurements, water sampling and chemical analysis, datalogger programming, data processing and analyses.

Module Remote sensing
This module will make the student more familiar with remote sensing and the main objectives of this module are: (i) to understand the fundamental characteristics of electromagnetic radiation and how this interacts with vegetation, soil, rock and water; (ii) to understand and master the methodology behind a large variety of remote sensing applications related to land surface observations, including a clear understanding of the limitations of these observations; (iii) to develop practical computer skills to use remote sensing products in environmental studies. During the lectures the physical basics and mathematical principles of remote sensing will be discussed. During the practical exercises we will use a suite of remote sensing-derived environmental data from satellites to derive information on geology, soil, water, and vegetation. The focus is on the integration of several remote sensing techniques in hydrological analysis and modeling

Module Measurement of economic values of water
The discipline of environmental economics has developed stated preference techniques whereby non-market values of water can be estimated, such as those related to water quality, amenities of water and the control of water risks. This module will make students familiar with these techniques, such as contingent valuation and choice experiment methods that elicit water related values using surveys of households. During the lectures these techniques as well as the design of surveys will be discussed. Moreover, students will get hands on experience with data collection by conducting a stated preference survey in the field. In a practicum class students will learn to analyse the data they collected using statistical methods.

Onderwijsvorm
Lectures, practicals, field practicals.

Toetsvorm
Written exam, assignment report, participation during field practical.

Literatuur
Will be provided by the teachers

Modern Climate and Geo-ecosystems

Vakcode	AM_1124 ()
Periode	Periode 1
Credits	6.0
Voertaal	Engels
Faculteit	Fac. der Aard- en Levenswetenschappen
Coördinator	dr. G.M. Ganssen
Examinator	dr. G.M. Ganssen
Docent(en)	dr. G.M. Ganssen
Lesmethode(n)	Werkcollege, Hoorcollege

Niveau	400

Doel vak
In the first part the course gives an introduction of modern atmospheric and oceanic processes which form an important basics for the reconstruction of the climate of the past. Next to important basic parameters which trigger the modern circulation of both spheres, atmosphere and oceans, the main circulation paterns will be discussed together with the implications for the global climate.
In the second part the modern ocean changes and their implications for the geoecosystems will be discussed. Together, this will form the basic understanding of processes which govern changes in the geological past.

Inhoud vak
-the basic parameters and properties for atmospheric and ocean processes leading to the formation and circulation of air and water masses
- characterization of climatic regions of the world from the poles to the tropics
- special features of the climate systems like the monsoon, ENSO and NAO systems
- the effect of ocean changes on geoecosystems now and in the recent past

Onderwijsvorm
Lectures and workshops, literature reading, oral and written presentations by the students and discussing the results and quality of the presentation

Toetsvorm
Written exam after week 2 about the basics (50% of the grade)
oral and written presentation of a topic (second part of the course, 50% of the grade)

Literatuur
Lecture notes (powerpoints of the presentations by the teacher), selected papers and Ruddiman, W.F., 2013. Earth's Climate: past and future.W.H. Freeman and Company New York.

Vereiste voorkennis
Some basic knowledge of the climate system, interest in climate change

Doelgroep
Students from the geo and environmental study areas

Intekenprocedure
Subscription via BB

Project Environmental Impact Assessment

Vakcode	AM_450406 ()
Periode	Periode 3
Credits	6.0
Voertaal	Engels
Faculteit	Fac. der Aard- en Levenswetenschappen
Coördinator	dr. M.P. Bokhorst

Examinator	dr. M.P. Bokhorst
Lesmethode(n)	Werkcollege, Computerpracticum, Excursie
Niveau	400

Doel vak
After successfully completing this course the student:
• Is able to apply geographical information systems and multicriteria analysis to a real-life case study;
• Obtained project management skills;
• Has a good overview of the tasks, roles and activities of specialists working at consultancy firms and commercial research organizations;
• Knows the important do’s and don’ts for making tenders;
• Can write a research report that is client-oriented and scientifically sound.

Inhoud vak
In this course students will experience how commercial consultancy firms operate. They organize their work in projects. During the course the students have to deal with all relevant aspects of working in projects: writing a tender (including cost estimation, time schedules), managing a project (task divisions, communication, time writing, sending bills), data management, analysis, reporting, presenting. There will be introducing lectures, workshops, an excursion to the Vondelpark and opportunities to get advice.

Onderwijsvorm
Students carry out an Environmental impact assessment in a group of about six. By definition, Environmental Impact Assessments (EIAs) have an important spatial component. Most relevant steps of the EIA must be taken, including the problem definition, choosing the relevant alternatives (including the zero alternative and the most environmentally friendly alternative), gathering data for an effects table, setting up maps, ranking alternatives and writing a report. The case study will deal with the Vondelpark's drainage system.

Toetsvorm
Students will be assessed on specific assignments: writing a tender (in couples), process management (in groups of 5-7 students), the environmental impact assessment report and presentation .
Details about the assignment are in the study manual.The students will be assessd.

Literatuur
Vondelpark. (2011, March 6). In Wikipedia, The Free Encyclopedia. Retrieved 11:02, March 11, 2011, from http://en.wikipedia.org/w/index.php?title=Vondelpark&oldid=417414362
An introductory text about the study area.
Van Herwijnen, and Janssen, R. (2004) Software support for multi-criteria decision making. In Sustainable Management of Water Resources: an integrated approach. Giupponi C., Jakeman T., & Kasserberg D., (eds.), Edward Elgar, Cheltenham. Available from Google Books.
An introductory text about DEFINITE.
Janssen, R. (2001). On the use of multi-criteria analysis in environmental impact assessment in the Netherlands. Journal of multi-criteria decision analysis, vol. 10, no. 2, pp. 101-109.
Use of multi-criteria analysis in practice. Selection of alternatives

and evaluation criteria. Application issues and pitfalls.
Van Drunen, M., R. Janssen and N Groenendijk (2001). Interactive tutorial evaluation methods. IVM/Vrije Universiteit, Amsterdam, Universiteit Twente, Enschede.
This is a tutorial that can be run from any computer using Windows Explorer. Go to: http://www.ivm.vu.nl/en/projects/Projects/spatial-analysis/DEFINITE/index.asp scroll down to Tutorial. Read the instructions. Click on: DEFINITE tutorials, Download and unzip the files. Run: Evaluationmethods 1 UK.exe. This tutorial teaches you the basics of multicriteria analysis (and cost-benefit analysis). If you are short on time you could do lessons 1-5 and 11 only.

Vereiste voorkennis
Students must have followed Empirical Methods for Spatial Policy (AM_450401) and Assessing the Landscape (AM_450404).

Overige informatie
lecturer:
Wouter Wuite MSc

Reflection Seismic for Geologists

Vakcode	AM_450170 ()
Periode	Periode 4
Credits	6.0
Voertaal	Engels
Faculteit	Fac. der Aard- en Levenswetenschappen
Coördinator	dr. P.J.F. Verbeek
Examinator	dr. P.J.F. Verbeek
Lesmethode(n)	Werkcollege, Computerpracticum
Niveau	400

Doel vak
Understanding the fundamentals and limitations of the application of reflection seismic to describe geology in the subsurface at depths of 200 m - 6 km.
This includes,
- Seismic Sequence Stratigraphic interpretation
- Seismic Stuctural interpretation
- Seismic Acquisition and processing principles and potential problem areas
- Calibration with petrophysical information/synthetic seismogrammes and potential problems
- Time Depth Conversion methods
- Modern Techniques, Volume interpretation, Use of Special Attributes
- Examples/Special Case studies (4D time lapse, use of Seismic inversion)
In an extensive workstation Exercise (A/B), the theory will be applied to a real 3D dataset, using an industry interpretation software package.
The Exercise part of the course is done by Teams. Teamwork is essential in this type of work and will also be gauged during the assessment.

Inhoud vak
Assuming a basic knowledge of the principles of reflection seismology, this course provides a modular programme with hands-on experience on

interpreting seismic 3D data and integrating data from well logs, principles and interpretation of reflection seismic data and geology. Special attention will be paid to pitfalls in data acquisition, processing and interpretation. During the course standard methodologies will be applied used in hydrocarbon exploration and development in the industry.
The course consists of,
- Introduction to seismics. The introduction will cover the technical and methodological principles of reflection seismology. Note that this section will built on already existing Applied Geophysics course knowledge; special emphasis will be on the recognition of processing errors and distinguishing them from geological information contained in the seismic images.
- Structural interpretation. Students will learn how to interpret basic geological features, such as strata relationships, faults and folds as well as the reliability of seismic interpretation at various scales;
- Seismic Sequence Stratigraphy entails the extraction of stratigraphic, sedimentological and basin evolution information from seismic data. This information can be used in exploration and basin analysis to derive regional
analysis of sedimentary basin-fills in order to construct models for gross lithology prediction (Students should review the principles of sequence stratigraphy, acquired during their BSc courses);
- Interpretation on workstation. Students work on a case study using standard workstation methodologies and learn how to handle, visualize and interpret 2D and 3D seismic data using a standard industrial software package;
- Advanced seismic interpretation This section will show examples of recently developed techniques in 3D seismic information analysis

Onderwijsvorm
The course uses two different methods:
- Oral lessons, where the lecturer presents various topics. Students must be aware that the content of this course is difficult to find in textbooks. Therefore, understanding the handouts is essential. Our advice is to attend all oral lessons. The exam will test the theoretical knowledge and contributes 50% to the final score.
- Practical Exercise A/B. The practicals are done in Teams. Attendance of the practicals is compulsory. By the end of the course, students present the team results in an oral presentation as well as in a report. The results from the presentation and report contribute the remaining 50% to the final score.

Toetsvorm
The final mark is made up by 50% from the results of the exam which will cover the topics presented during course.
The Report on the practical exercises (A/B) should be handed in at the end of the course. Together with the oral presentation, it contributes another 50 % to the final result. Reports must be handed in immediately before or after the oral presentation.

Literatuur
All materials will be digitally provided through Canvas.

Overige informatie
Teaching staff: John Verbeek plus guest lecturers

Scientific Writing in English

Vakcode	AM_471023 ()
Periode	Periode 2, Periode 5
Credits	3.0
Voertaal	Engels
Faculteit	Fac. der Aard- en Levenswetenschappen
Coördinator	M. van den Hoorn
Examinator	M. van den Hoorn
Lesmethode(n)	Werkgroep
Niveau	400

Doel vak
The aim of this course is to provide Master's students with the essential linguistic know-how for writing a scientific article in English that is well organized, idiomatically and stylistically appropriate and grammatically correct.
At the end of the course students
know how to structure a scientific article;
know what the information elements are in parts of their scientific article;
know how to produce clear and well-structured texts on complex subjects;
know how to cite sources effectively;
know how to write well-structured and coherent paragraphs;
know how to construct effective sentences;
know what collocations are and how to use them appropriately;
know how to adopt the right style (formal style, cohesive style, conciseness, hedging)
know how to avoid the pitfalls of English grammar;
know how to use punctuation marks correctly;
know what their own strengths and weaknesses are in writing;
know how to give effective peer feedback.

Final texts may contain occasional spelling, grammatical or word choice errors, but these will not distract from the general effectiveness of the text.

Inhoud vak
The course will start with a general introduction to scientific writing in English. Taking a top-down approach, we will then analyse the structure of a scientific article in more detail. As we examine each section of an article, we will peel back the layers and discover how paragraphs are structured, what tools are available to ensure coherence within and among paragraphs, how to write effective and grammatically correct sentences and how to choose words carefully and use them effectively.

Topics addressed during the course include the following:
Structuring a scientific article
Considering reading strategies: who is your readership? How do they read your text? What do they expect? How does that affect your writing?
Writing well-structured and coherent paragraphs
Composing effective sentences (sophisticated word order, information distribution).
Arguing convincingly – avoiding logical fallacies
Academic tone and style: hedging – why, how, where?
Using the passive effectively

Understanding grammar (tenses, word order, etc.)
Understanding punctuation
Referring to sources: summarising, paraphrasing, quoting (how and when?)
Avoiding plagiarism
Vocabulary development: using appropriate vocabulary and collocations

Onderwijsvorm
Scientific Writing in English is an eight-week course and consists of 2 contact hours a week. Students are required to spend at least 6 to 8 hours of homework per week. They will work through a phased series of exercises that conclude with the requirement to write several text parts (Introduction, Methods or Results section, Discussion and Abstract). Feedback on the writing assignments is given by the course teacher and by peers.

Toetsvorm
Students will receive the three course credits when they meet the following requirements:
Students hand in three writing assignments (Introduction, Methods, Discussion)
Students get a pass mark for all writing assignments;
Students provide elaborate peer feedback (Introduction, Methods, Discussion, Abstract);
Students attend at least 7 out of 8 sessions;
Students are well prepared for each session (i.e. do all homework assignments);
Students participate actively in class;
Students do not plagiarise or self-plagiarise.

Writing assignments:
1. If students have a BSc thesis in a traditional thesis form (e.g., 20+ pages) and written in English, they may use this for the writing assignments.
2. If students have a BSc thesis in a traditional form (e.g., 20+ pages) written in another language than English, they may use this for the writing assignments.
3. If students have written a paper or report in English that's not already in article form, they may use this for the writing assignment.
4. If students are working on their MSc thesis or internship report when taking Scientific Writing in English, they may use this for the writing assignments. They will have to notify their supervisor to make sure that they won't be accused of self-plagiarism.
5. If students cannot or do not wish to use any of the above-mentioned texts for the writing assignments (1-4), they are expected to do a limited Literature Review on a topic in their field of research, using at least 5 articles.

Students are not allowed to use the following texts for the writing assignments:
1. A BSc thesis written in English that's already in article form.
2. A MSc thesis written in English that's already in article form (and that has already been marked).
3. An internship report written in English that's already in article form (and that has already been marked).
4. A paper or report written in English that's already in article form.

Literatuur
Effective Scientific Writing: An Advanced Learner's guide to Better English, 4th edition (February 2016) (A. Bolt & W. Bruins, ISBN 978 90 8659 617 1). VU bookstore: €27.95.

Doelgroep
This course is only open to students of the two-year Master's programmes of the Faculty of Earth and Life Sciences. These students are only eligible to the course if they have already conducted scientific research (e.g. for their Bachelor's thesis) or if they will be working on a research project when taking Scientific Writing in English.

Overige informatie
- To do well, students are expected to attend all lessons. Group schedules are to be found at rooster.vu.nl and on Canvas.
- A VUnet registration for this course automatically gives access to the corresponding Canvas site. Group registration only takes place via Canvas (general groups: registration by students following FALW programmes offering this course; groups assigned to specific studies: registration through programme and course coordinator).
- Make sure Scientific Writing in English does not overlap with another course.
- If you have registered for a group in Canvas, you are expected to attend all sessions (eight). If you decide to withdraw from the course, do so in time in VUnet. This will avoid a 'fail' on your grade list for not taking part in this course and allows other students to fill in a possible very wanted group spot.
- For specific Canvas matters concerning this course, please contact canvas.beta@vu.nl.
- Full time students with their main registration at VU will be given preferential treatment for placement in this course. For secondary students proof of enrollment is not a guarantee of placement.

Tectonic Geomorphology

Vakcode	AM_450146 ()
Periode	Periode 2
Credits	6.0
Voertaal	Engels
Faculteit	Fac. der Aard- en Levenswetenschappen
Coördinator	dr. M. ter Voorde
Examinator	dr. M. ter Voorde
Docent(en)	dr. M. ter Voorde
Lesmethode(n)	Werkcollege, Computerpracticum
Niveau	400

Doel vak
After having attended this course, the student should have gained knowledge and understanding about
- The interplay of (physical) mechanisms responsible for landscape evolution
- The relative importance and the mutual interaction between these processes
- The methods to put constraints on these processes from geological data, and the strength and limitations of these methods

as well as the skills to
- Read and critically assess significant literature about these subjects
- Actively participate in (oral) discussions about these subjects
- Judge research methods applied on this subject critically on their merits and weak points
- Compare and/or combine the results of different studies.

This implies that the course is not mainly focused on acquiring new knowledge, but especially on using, integrating and reflecting on the things you may have learned before.

Inhoud vak
This course deals with the parameters regulating the production, transfer and storage of sediments and solutes from their sources to their sinks, addressing short-term and long-term landscape evolution and sustainability. It covers the linked processes of tectonics, weathering, erosional systems (fluvial, glacial, marine) and climate changes, including ‘real-world’ examples on the SE Netherlands, the Ardennes, the Pyrenees and western Scandinavia, as well as the methods to constrain these processes (e.g. provenance studies and thermochronology). Lecturers from a variety of disciplines will teach the student how to view these topics from various backgrounds.

Onderwijsvorm
Lectures, exercises, literature study. A selected set of papers will be used for a 'PhD- defense'-role play. In addition, numerical modelling of topography development will be carried out by the students.
Aantal contact-uren: 45 (inclusief tentamen)

Toetsvorm
Exam (45%), essay (20%), computer-practicum report (10%) PhD-defense-"game"(25%).

Literatuur
• Book:
Tectonic Geomorphology, D.W. Burbank and R.S. Anderson, 2nd edition, 2011. John Wiley & Sons, 320 pp.

Additional papers, which will be made available via Canvas

Doelgroep
Masterstudents GBL, Earth Sciences Solid Earth, Earth Sciences AEG, Earth Sciences Paleoclimate and Geo-ecosystems

Water Economics

Vakcode	AM_1167 ()
Periode	Periode 4
Credits	6.0
Voertaal	Engels
Faculteit	Fac. der Aard- en Levenswetenschappen
Coördinator	dr. J.E. Blasch
Examinator	dr. J.E. Blasch
Docent(en)	dr. P.J.H. van Beukering, prof. dr. W.J.W. Botzen, dr. J.E. Blasch
Lesmethode(n)	Werkcollege, Hoorcollege, Practicum, Computerpracticum

Niveau	400

Doel vak
The objective of this course is to familiarize students with the economic analysis of water-related problems and solutions. After following this course, students should be able to judge how well certain policy instruments and institutional arrangements perform in terms of effectiveness, efficiency and sustainability of water management. More specifically, after having participated in this module, students should be able to answer the following questions:
1. What is the fundamental nature of water and water-related problems from an economic perspective and what does this imply for water management and the feasibility of solutions to water-related problems?
2. How are water resources and the economy and society interlinked, and what are the implications of such linkages for sustainable and economically efficient water use?
3. How to conduct cost-benefit analysis (CBA) to guide the design of water management strategies and what are the critical assumptions that underlie a CBA?
4. What are the guiding principles of economic analyses of solutions for water-related problems, such as the principles underlying hydro-economic modelling?
5. How to characterize and measure the economic value of water and hydrological processes?
6. Which economic policy instruments are available for water management, and what are their (dis-)advantages?

Inhoud vak
The course Water Economics aims at introducing students to the analysis of the drivers behind and effects of water-related problems and solutions around the world, in order to move towards a sustainable and economically efficient use and management of water resources. Topics include an introduction into water economics and water management, water markets and water pricing, valuation of water resources as well as the costs and benefits of alternative water policies to deal with water pollution, river and groundwater ecosystem restoration, water quantity and water-related hazards, such as floods. Also integrated river-basin management and hydro-economic modelling will be addressed.

The course has been designed to balance learning and training skills related to both theory and applied (quantitative) methodologies. Moreover, the students will apply their newly developed skills to relevant case studies. Each week will center around a main specific economic topic and/or method, allowing students to learn specific skills while practicing them on specific water topics.

Onderwijsvorm
Lectures, Practicum, Computer lab.

Toetsvorm
Written exam and assignment.

Literatuur
Readings will be announced on Canvas.

Doelgroep
Hydrologist, Water Science.

Water Governance

Vakcode	AM_1192 ()
Periode	Periode 3
Credits	6.0
Voertaal	Engels
Faculteit	Fac. der Aard- en Levenswetenschappen
Coördinator	dr. J. Dell'Angelo
Examinator	dr. J. Dell'Angelo
Docent(en)	prof. dr. D. Huitema
Lesmethode(n)	Hoorcollege
Niveau	400

Doel vak
Water is central for ecosystems, human wellbeing and development. The relationship between society and water resources is critical and complex. Water issues have been historically treated as a technical problem, something to be resolved through hydraulic and engineering solutions. However the increasing and exacerbating competition over water resources due to expanding global population, climate change and conflicting production activities raises new political and democratic challenges. Understanding water governance implies developing multidisciplinary knowledge about the different problems, approaches, perspectives and controversies related to how societies cooperate and compete over water resources. This course aims at building students' knowledge, critical thinking and analytical skills on the governance of freshwater resources with particular emphasis on the institutional, political and organizational dimensions.

Course objectives:
The main objective of this course is for you to develop an expert understanding of the multidimensional challenges of governance of water resources. Collectively as a class, and individually, you will develop expertise in the water governance world by engaging with the core scientific literature, discussing and tackling real world problems and independent research activities. By the end of the course, you will have gained an understanding of the complexity of water governance: the various models of governance, its structures and institutions at multiple scales, the different values and uses of water, and the main frames and debates from multiple perspectives.

By the end of this course you will be able to:
• Describe various principles and theories for water governance and management
• Apply these to analyze different water policy and governance interventions, by analyzing them from diverse and diverging perspectives
• Formulate your own analysis and suggestions regarding water-governance interventions on multiple scales: local, national and international
• Synthesize and communicate your ideas and expertise orally and in written form

Inhoud vak
Week 1: Global dimensions of water and the role of water governance
1. Introduction to water governance, global dimensions of water

governance
2. NEXUS
a. Virtual water, agriculture and food security
b. Water and Energy
3. Water wars, conflicts and competition

Week 2: Water Governance: foundations and trends
4. Adaptive Governance and Management
5. Integration, participation and democracy
6. International Cooperation

Week 3: Water Governance: policy and management
7. Preparation session for the final exam
8. Water Rights
9. Urban and rural water worlds
10. Water politics, privatization and controversies

Week 4: Exam week
11. Q&A class session before exam

Onderwijsvorm
Format of the Course:
This course will be intensive, because during three weeks you will be "immersed" in water governance studies [pun intended]. We will spend an important amount of the course in the classroom but you will also be required to study the readings to prepare for lectures and discussions. We will have three weekly meetings and each day we will mix: frontal lectures, discussions and group activities and we will have guest speakers delivering lectures on specific topics.

The structure of each session consists of lectures at the start, where I will first highlight concepts and key questions related to the topics we are working on. We will then engage in-group discussions associated with the key issues addressed in each session. The group activities will include simulations and team assignments and presentations. Readings will be assigned for each session and it will be essential to be well prepared in order to successfully participate and address key questions that we will tackle. Finally, writing assignments, problem solving and pop-up quizzes will be an integral part of the course too.

Participation: Due to the complexity of the issues addressed and the concentrated length of the course I highly recommend attending every session. Of course, if you will have serious family or health reasons you can count on my help for making up for your absence and catching up, but otherwise it will really not be in your interest to miss classes.
The amount of the material that we will go through and the very short time to prepare between the end of classes and the final exam will not allow you to be successful in this course if you procrastinate.

I will lead group discussions on key questions related to the readings. To make the most of our time together, I will call on students directly to address specific question during the group discussion. I will apply the "Socratic method" and challenge you to defend your opinions. (This is a method that might seem a little intimidating, but is particularly useful to develop the capacity to debate publicly and defend your opinions – in line with the learning goals of the course.)

Preparation advice: As MSc students you are very qualified, motivated and brilliant therefore some of this advice might be unnecessary.

However.. I can’t stress enough the importance to hit the ground and start running from day one, actively participate and not fall behind…keep in mind it’s only 3 weeks of classwork. A critical aspect is that you make an effort to study the assigned readings before class. If you don’t you will see pages adding up quickly and you not be as able to engage productively in discussions and have less information and tools to understand the lectures. I will be available almost every afternoon during the weeks of classwork, my objective is that you learn and succeed and I look forward to work with you, so please take advantage of office hours.

Toetsvorm
Assessment: assignments, exams and grading system:

Pop quizzes: without prior notice I will give you short quizzes on the readings. Being prepared for the quizzes is a great way to prepare in advance for the final exam. (Some of the questions in the quizzes will be on your final exam). Feedback but no formal grading

Public presentations: You will be paired in teams and will give a power point presentation on a key issue from the course. In another document I will give advice and instructions. 15%

Research short paper (1500 words excluding references): the paper will be on the same topic that you will choose for your presentation. In another document I will give advice and instructions. 25%

In class final exam: there will be a closed-book (nothing allowed on your desk except your pen) 2.5h exam. In another document I will give advice and instructions on preparation. 60%

Literatuur
Online reader, organized around the above topics

Aanbevolen voorkennis
Environmental policy, decision-making

Doelgroep
Master level students with an interest in understanding the role of governance in the emergence of water issues, and their potential resolution

Intekenprocedure
Through the regular VU channels

Water Quality

Vakcode	AM_1166 ()
Periode	Periode 2
Credits	6.0
Voertaal	Engels
Faculteit	Fac. der Aard- en Levenswetenschappen
Coördinator	dr. J.E. Vonk
Examinator	dr. J.E. Vonk
Docent(en)	dr. M.H. Lamoree, dr. J.E. Vonk
Lesmethode(n)	Werkcollege, Hoorcollege

Niveau	400

Doel vak
The objective of the water quality course is to provide students with a basic understanding of the landscape controls on water chemistry and quality. More specifically, the student will at the end of the course:
• have acquired a qualitative and quantitative understanding of biogeochemical processes in the soil that influence the chemical composition of water;
• understand how the chemical composition of water changes within the hydrological cycle: from precipitation, to groundwater to surface water;
• understand, describe and utilize techniques for assessing water quality, and be able to interpret hydro(geo)chemical data;
• be familiar with different types of pollutants affecting water quality, and understand how pollutants enter, move through, and interact with the hydrological system.
• be able to independently interpret, visualize, and discuss existing water quality data by means of development and presentation of a conference poster
• be able to comprehend and present scientific articles on water quality, and be able to criticise and discuss its content

Inhoud vak
The quality and chemistry of water on Earth is a function of processes that occur in the human and natural environment. Water of sufficient quality is required for, for example, agricultural and domestic usage, as well as for healthy ecosystems. Knowledge on water chemistry is needed to study and interpret the quality of ground and surface water. The following course topics are included: water sampling, analysis of water and its constituents, parameters for assessing water quality and chemistry (alkalinity, redox, nutrients), thermodynamics and kinetics of hydrogeochemical processes, isotopic composition of water and its constituents, how water properties change (reactive properties, dissolution, weathering, evaporation, mixing), carbonate chemistry, dynamics and transport of pollutants.

Onderwijsvorm
The course consists of lectures, supplemented with practicals (assignment on case-study), and presentations.

Toetsvorm
Written examination (50%), assignment (40%), presentations (10%). One has to pass all components (no compensation possible).

Doelgroep
Hydrology MSc students and other earth sciences related MSc programs

Water Risks

Vakcode	AM_1210 ()
Periode	Periode 1
Credits	6.0
Voertaal	Engels
Faculteit	Fac. der Aard- en Levenswetenschappen
Coördinator	dr. P.J. Ward

Examinator	dr. P.J. Ward
Docent(en)	dr. H. de Moel, T.I.E. Veldkamp MSc
Lesmethode(n)	Hoorcollege, Werkcollege
Niveau	500

Doel vak
The objective of this course is to provide the students with a thorough understanding of concepts, datasets, methods, and applications in the field of water and climate risk, with a focus on flood and drought risk.

Inhoud vak
Risk is defined as the probability of a natural hazard multiplied by its consequences, and can be calculated as the product of the hazard, exposure, and vulnerability. Students will learn the main concepts of natural disaster risk, and how these fit into international agreements on disaster risk reduction and recovery. They will also learn about different indicators that can be used to express flood and drought risk, and how flood and drought risk have changed over the past half century and are projected to change in the 21st century. Students will learn about the main datasets and methods that can be used to assess hazard, exposure, and vulnerability, and apply several of these to assess flood and drought risk at different spatial scales. Finally, students will learn about different measures that can be taken to reduce flood and drought risk, and the pros and cons of these measures.

Onderwijsvorm
The course will be taught as a mixture of lectures, computer practicals, group discussions, and serious games. Weeks 1-3 will focus on general risk concepts and flood risk assessment. Weeks 4-5 will focus on drought risk assessment. In weeks 6-7, students will work individually on an essay. The course ends with a written examination in week 8.
In order to participate in the course, students need to bring their own laptop computers, and will need to be able to install and run several programmes including Matlab and ArcGIS (licences available from VU), Python, HEC-RAS, and QGIS (open-source or licences freely available).

Toetsvorm
The course will be assessed through 3 components: a written examination (50%), an essay (35%), and answering written exercise questions during computer practicals (15%). The final grade is a weighted mean of the grades for the 3 components, whereby students must achieve a grade of at least 4.5 for each component. Resit opportunities will be provided in the form of: a resit of the written examination; a new essay based on a different topic for the essay; and improving the answers to the questions for the written exercise questions during computer practicals.

Literatuur
See Study Manual