ITC
STUDY GUIDE

2008/2009

Water Resources and Environmental Management

Water Resources and Environmental Management

ITC Study Guide
2008 / 2009

Contents

Foreword

Dear course participants,

Welcome to ITC.

Having left your family and country, you have come to ITC to further your education. We hope that the course you have selected will fulfil your expectations.

Education at ITC is characterised by:

- a modular set-up,
- a mixture of theory and practice, often including participants' own experiences
- a core curriculum for Remote Sensing (RS) and Geo-information Systems (GIS), common to all programmes, and
- choice options according to individual (research) interest and/or the needs of your own organisation.

We are pleased to present you this study guide for the 2008/2009 courses offered full-time at ITC Enschede. This study guide gives you information on the courses, an overview of the modules and the detailed content of the course modules. ITC is continuously modifying its courses to the needs of its students and their organisations. The structure of the MSc courses was adjusted last year in order to strengthen the links between the courses and the research projects, implemented by ITC.

Description of all elements of education at ITC and the descriptions of the modules of other courses are available on the ITC website (http://www.itc.nl/education/courses/modules.aspx).

But there is more to life at ITC than only education. You have arrived at an institute with more than 400 students from over 70 countries. Furthermore, also the ITC staff is originating from more than 30 countries: a truly international environment where you will be able to meet colleagues from all over the world. ITC is organising all sorts of social, cultural and sports activities. Well-known are the International Sports Tournament, the International Food Festival and the International Cultural Event. We would like to encourage you to participate in many if not all of these events and to make new friends in the process.

We will do our best to provide you with the quality of education that you expect from our institute.
We wish you the best of success during your studies and a pleasant stay at ITC and in The Netherlands.

Prof. Dr. Ir. M. Molenaar, Rector ITC

Introduction to ITC

One of humanity's greatest challenges is to achieve an appropriate balance between the development of natural resources and the maintenance of an optimal natural environment. To meet this challenge we need information on the earth's surface and sub-surface: spatially referenced information or *geo-information*.

Many different types of *earth observation* provide efficient ways of gathering geo-information. These types include conventional photographic and non-photographic imaging techniques, electro-optical sensing of the wider spectrum by multi-spectral, thermal infrared and radar scanning as well as geophysical and geochemical data-acquisition techniques. All these methods are used in mapping the earth's topography, monitoring the natural environment and exploring for natural resources and all are applied by specialist groups within the Institute.

ITC specializes in the collection, management and visualisation of geo-information and its integrated interpretation in support of resource management and policy development. In this way, scientific earth observation supports decision-making for sustainable development and the alleviation of poverty in the developing world.

The International Institute for Geo-Information Science and Earth Observation was established in 1950, and is usually referred to as ITC because of its original name: International Training Centre for Aerial Survey. It is the largest institute for international higher education in the Netherlands.

ITC is an autonomous organisation operating under the aegis of the University of Twente, and is funded by the Ministry of Education, Cultural Affairs and Science of the Netherlands. ITC is subject to the national quality assurance procedure for universities in the Netherlands. It is based in Enschede. ITC’s main activities are education, research and advisory services. These activities are carried out by six scientific Departments:

- Department of Earth Observation Science (EOS)
- Department of Earth Systems Analysis (ESA)
- Department of Geo-information Processing (GIP)
- Department of Urban and Regional Planning and Geo-information Management (PGM)
- Department of Natural Resources (NRS)
- Department of Water Resources (WRS)

They are supported by the education, research, consultancy and general support departments.

Education

ITC has a scientific staff of some 150 professionals of 31 nationalities. More than 19,000 students from over 150 countries have graduated from courses at the institute since 1952. ITC offers courses at different levels: PhD degree (conducted in collaboration with Netherlands universities), Master of Science degree, Master degree, postgraduate and undergraduate Diploma and Certificate courses.

The ITC degree programmes are nationally accredited and registered in the Central Register of Higher Education (CROHO) of The Netherlands.

Recently ITC embarked on a programme of decentralizing its education, through joint education programmes with partners in various countries throughout the world. ITC also offers a growing number of distance education courses.

Updating the knowledge and skills of ITC alumni is an important task, in addition to the institute's regular courses. Therefore, ITC organises refresher courses at ITC and abroad.

The language of instruction is English.

Research

ITC carries out multidisciplinary and problem-oriented research that focuses on strengthening organisations involved in survey, management and planning for sustainable development. To this end, a strategic multidisciplinary research programme with the following themes is established:

- Biodiversity in fragmenting landscape
- Carbon-cycle and climate change
- Stochastic methods for image mining and data quality
- Disaster management
- Earth systems science
- Food security and environmental sustainability
- Governance and Integrated Spatial Assessment
- Spatial data infrastructure technology
- Spatio-temporal data integration and visualization
- Informed multilevel governance of urban regions
- Land administration for informed governance
- Managing water scarcity
- Sustainable urban-regional dynamics
- Utilisation of sensor developments for efficient topographic mapping
- Water cycle climate

Advisory services

ITC's transfer of knowledge also encompasses advisory services, mainly in developing countries. Advisory services of ITC often act as a follow-up service to alumni and their organisations and institutes.
Approximately 1000 projects have now been completed and ITC is presently committed to a wide variety of assignments around the world. The majority of these are based in developing countries and are education-oriented.

Introduction to ITC's educational programmes

At degree level ITC offers PhD, MSc and Master degree courses. Also Diploma courses, and short courses (some through distance education) are offered as part of the regular education.

The MSc degree programme in Geo-Information Science and Earth Observation (lasting 18 months) consists of seven courses, each with a specific orientation:

- **Applied Earth Sciences**
- **Geoinformatics**
- **Land Administration**
- **Natural Resources Management**
- **Urban Planning and Management**
- **Water Resources and Environmental Management**
- **Governance and Spatial Information Management**

The Master degree programme (lasting 12 months) consists of two courses:

- **Geoinformatics**
- **Natural Resources Management**

Postgraduate Diploma courses (lasting 9 months) are offered in:

- **Applied Earth Sciences**
- **Geoinformatics**
- **Land Administration**
- **Natural Resources Management**
- **Urban Planning and Management**
- **Water Resources and Environmental Management**

Programmes in cooperation with other institutes
ITC cooperates with Universities in The Netherlands, Europe and throughout the world in full-time and part-time joint education programmes, leading to MSc and Master degrees and to Diplomas:

- In The Netherlands ITC cooperates with the universities of Utrecht, Delft and Wageningen in an MSc course, focusing on Geographic Information Management and Applications (GIMA). The course is offered through distance learning, with four periods of classroom learning.
- In Europe, ITC cooperates with the universities of Southampton, Lund and Warsaw in an MSc course on Geo-information Science and Earth Observation for Environmental Modelling (GEM). The course is taught in four countries: UK, Sweden, Poland and The Netherlands.
- ITC has entered into partnership with reputable education institutes for the purpose of providing joint courses in several countries throughout the world. At present, MSc and Master courses are or will be conducted in Bolivia, China, Ghana, India, Indonesia, Iran, Kenya, Mexico, Nigeria and Tanzania.

For more information on our joint courses, please consult the ITC website (http://www.itc.nl/education/jointcourses.aspx).

Master of Science degree, Master degree and Postgraduate Diploma

Master of Science degree

The 18 month Master of Science degree programme is intended for participants with a future task in research and development. In addition to 12 months regular coursework, the Master of Science participants learn by doing research and/or by developing new methods or techniques in a 6 months thesis period.

Successful completion of the MSc degree programme provides graduates with a qualification that enables them to continue to PhD level, either in the Netherlands or abroad.

All Master of Science courses lead to a degree with the title:
"Master of Science in Geo-Information Science and Earth Observation".

Master degree

The 12 month Master degree programme is more profession oriented and teaches more practical skills. It could be compared to taught masters in other countries.

All Master courses lead to a degree with the title:
"Master in Geo-Information Science and Earth Observation".

Postgraduate diploma

The 9 month Postgraduate diploma programme caters for young and mid-career professionals who need to be proficient in applying geo-information science and earth observation in their field of interest, analysing problems and applying new methods and techniques, and managing (multi)disciplinary scientific teams.
The Postgraduate diploma course is equal to the taught part of the MSc course.

The Postgraduate Diploma course leads to a Diploma with the title:
"Postgraduate Diploma in Geo-Information Science and Earth Observation''

Course structure

The duration of the Master of Science courses is 18 months, of the Master courses 12 months and of the Postgraduate Diploma course 9 months.
All ITC courses are divided into 3 week periods (modules) or multiples of 3 weeks (blocks) in which one subject or related subjects are taught. All Master, Master of Science and Postgraduate Diploma courses start on the same date in September each year. The Postgraduate Degree programme is taught together with the MSc programme during the first nine months. The Master programme is taught separately.

ITC's core business is the collection and handling of geo-information and its application in various fields involved in sustainable resource development. ITC has given its core business a prominent place in the courses. Block 1 (modules 1-4) in all degree courses contains ITC's core curriculum: (at least) three weeks of these core modules are spent on Geographic Information Systems (GIS) and (at least) three weeks are spent on Remote Sensing. In addition to these core modules all programmes offer more advanced modules in geo-information and earth observation techniques that vary per course.

Master of Science and Postgraduate Diploma programme

The Master of Science programme is split up in 4 *blocks*. The PGD programme is equal to the MSc programme during Block 1 and 2. MSc and PGD students follow these blocks together in class.

Figure 1

Structure of MSc and PGD courses

Block 1	Block 2	Block 3	Block 4
Principles of RS and GIS (4 modules)	Scientific domain (6 modules)	Research profile (5 modules)	Individual MSc research (8 modules)
MSc programme →			
PGD programme →			

Figure 2

MSc and PGD course structure in detail

			MSc	**PGD**
Block 1	1	Introduction, Principles of RS and GIS, Application in domain		
	2			
	3			
	4			
Block 2	5	Domain modules, different per course (AES, GFM, GSIM, LA, NRM, UPM, WREM)		
	6			
	7			
	8			
	9			
	10			
Block 3	11	Research skills		Final assignment
	12	Advanced subjects		
	13			
	14	Research themes, MSc proposal		
	15			
Block 4	16	Individual MSc research	MSc thesis	
	17			
	18			
	19			
	20			
	21			
	22			
	23			

Block 1: Principles of GIS/RS

Block 1 is the common core of all ITC educational programmes. It teaches the basic principles of Remote Sensing and GIS, and how these can be applied in various domains. This common core ensures a basic level of GIS and RS for all students, regardless of their background and experience. Block 1 also contains an introduction to the course as a whole and the teaching approach, and a student advisor is assigned to each student.

Block 2: Domain
Block 2 is specific for the different courses within ITC MSc programme (AES, GFM, GSIM, LA, NRM, UPM, WREM). In this block the basic principles of the domain and application of GIS and RS in it are taught and deepened. Please look at the course specific parts of this study guide to find out more about the content of Block 2 in your course. Students need to select an MSc thesis topic in this block and work this out in an MSc pre-proposal. An MSc day and MSc fair are organised to support this.

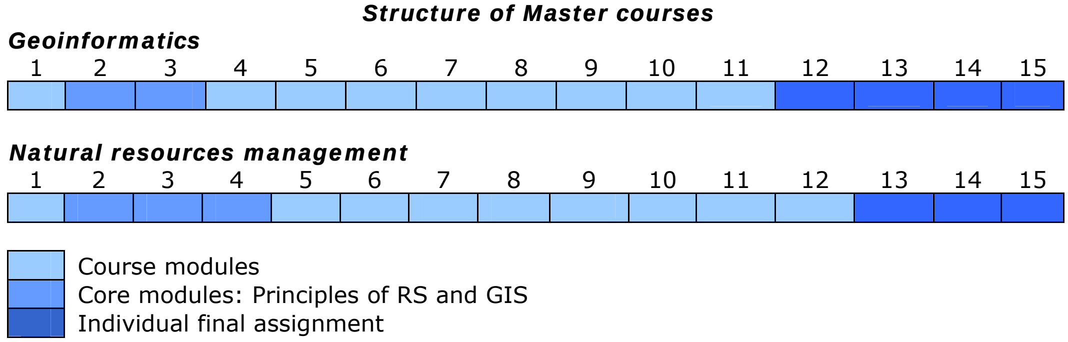
Block 3: Research profile
Block 3 prepares the student for his/her MSc research by offering learning opportunities on research skills, advanced research tools and methods, and deepening of research topics.
It starts with a module on research skills. The module is similar for all courses. The objectives are common, but examples and cases are used from the scientific domain of each course. Two MSc supervisors are assigned to each student.
The second part contains "advanced topics". These topics go in-depth in a certain research method or tool. These have a more generic nature and are supposed to attract students from different domains. Students have to make a choice from these advanced topics, which match to their envisaged MSc thesis topic. Because of the advanced level, entry requirements may be defined for the advanced topics.
The third part of this block is assigned to the ITC research themes. Students have to formulate their MSc thesis topic within one of ITC research themes. In the last two modules students will study state-of-the-art knowledge and research in these themes in a group research assignment. Parallel to this, the student will work on his/her final MSc thesis proposal. The student has to make a choice for a certain research theme, based on his envisaged MSc thesis topic.

Block 4: Individual MSc research
In Block 4 the student works individually on his/her MSc thesis. It is required to have an approved MSc research proposal before entering this block. During this block there is interaction with the staff, PhD and MSc students of the research theme, for example in *capita selecta*. Each student will be assigned 2 MSc supervisors. Formal assessment will be given at the mid-term presentation and of course the final MSc exam (see MSc regulations).

Master programme
The Master programme is made up of 15 modules, consisting of core modules about GIS and Remote Sensing, course modules, and an individual final assignment.

Figure 3

Structure of Master courses



Course modules
In the first module, the course domain and principles of databases are introduced. In module 5 and further the core modules are applied within this course domain.

Core modules
Modules 2 and 3 teach the basic principles of Remote Sensing and GIS, and how these can be applied in various domains. This common core ensures a basic level of GIS and RS for all students, regardless of their background and experience. The core modules are taught together in class with the MSc and PGD students.

Individual final assignment
The Master programme concludes with an individual final assignment in which the participant can work on a case and topic which is tailored to his or her particular situation and interest. Participants are encouraged to bring data and other material from their home country for this purpose, subject to approval.

Academic Profile MSc

The academic profile of the MSc programme puts strong emphasis on the scientific discipline, a scientific approach, basic intellectual skills, co-operation and communication and the temporal and social context of research. The emphasis on doing research and/or designing or developing new methods or techniques depends on the application domain.

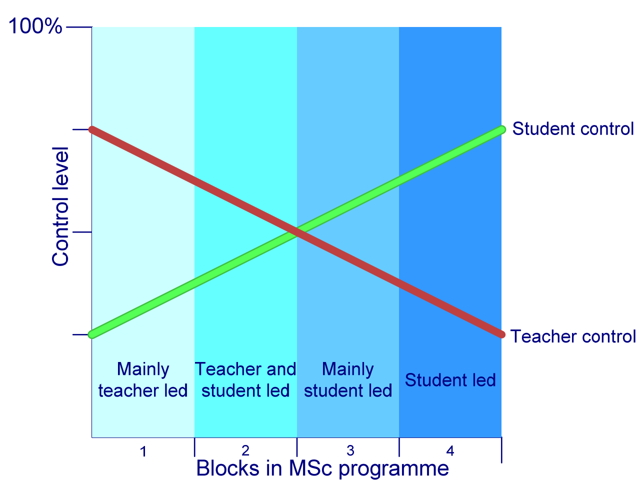
Multi-disciplinary research is an important focus for the MSc programme because (applied) research in practice seldom concerns one discipline but is more likely to be multidisciplinary. Students have to be prepared for that. Starting with a sound basis in their own domain they will be brought into learning situations in which students from different domains work together. It should be noted that most if not al research at ITC is already multidisciplinary in nature. This is evident in the wide scope of expertise within departments, and the common denominator to carry out applied research contributing towards development related issues as specified in ITC's mission.

Teaching Approach MSc

In their profession, the graduates have to apply knowledge and skills independently. The MSc programme is therefore focused at handing over the control of the learning process to the student. At the beginning of the programme, the teacher will have the main control and the programme will contain some choices, especially concerning preparation for the MSc research. The choices should be motivated, fit to the envisaged research trajectory, and be accepted by the course director. During the programme the teacher role will develop towards the role of advisor. The student takes the lead in his/her own learning process by developing his/her own learning plan within the MSc framework and guidelines. The teacher supports this as a coach (while still passing on his/her experience).

Figure 4

Handing over control from the teacher to the student



Block 1: Mainly teacher led
In Block 1 the teacher takes the lead. He/she defines the content to be studied and learning tasks and exercises which have to be executed. Students can make limited choices between learning strategies and learning tasks. The number of contact hours between teacher and students is relatively large in this stage, mainly consisting of lectures and supervised practical exercises. Each student will be assigned a student advisor in Module 1 for advice on

study related matters, especially the choice trajectory towards the MSc topic selection, but also for day-to-day problems, remedial self-study, etc. The student advisor is assigned for the whole MSc course.

Block 2: Teacher and student led
In Block 2 both the teacher and the student take the lead. The teacher defines the framework in which the student can make his/her own choices about study tasks. The amount of choice options varies across the different courses (or streams). The student has to start thinking about his/her MSc research topic and consult staff about its feasibility. The number of contact hours between teacher and students is reduced in favour of group work and independent study and assignments.

Block 3: Mainly student led
In Block 3 the student takes control by choosing advanced subjects and a research theme which fit within his/her MSc thesis topic. The student works on the final version of MSc research proposal and consults his student advisor and other specialised staff about its feasibility and quality. The final version of the MSc research proposal has to be presented and defended by the student for the Thesis Admission Committee. The number of contact hours between teacher and student is further reduced to make room for independent study by the student. Two MSc supervisors (first and second) are assigned for MSc supervision at the beginning of Block 3.

Block 4: Student led
In Block 4 the student works individually and independently on his/her MSc research project. This will be supported by meetings with the MSc supervisors and *capita selecta* meetings, organised by the research themes. The student is responsible for progress and quality of his/her own research project and its defence at the end. The number of contact hours between teacher and students is reduced to a minimum in this period. It is therefore wise to look for peer support and peer review opportunities in this phase, which is offered in the research theme where staff, PhD and MSc students are together.

Study load of the ITC degree programmes

The European Union has developed a European Credit Transfer System (ECTS) to allow easy comparison of study load of courses within Europe. ITC has adopted this system as a means of improving academic recognition for study abroad.
In ECTS, 60 credits represent the workload of an academic year (9-10 months) of study. These include lectures, practical work, seminars, tutorials, fieldwork, and self study. At ITC, each module of three-week duration has a study load of 5 ECTS.
The MSc course consists of 23 modules and three additional weeks of remedial teaching, catch-up activities and graduation ceremonies, totalling 118 ECTS. The Master course consists of 15 modules and two weeks of remedial teaching, catch-up activities and graduation ceremonies, totalling 77 ECTS. The Postgraduate Diploma course consists of 12 modules and 1 week of remedial teaching, and catch-up activities, totalling 61 ECTS.

Opening hours of various ITC facilities

ITC building	
Monday-Thursday	07:30 - 22:30
Friday	07:30 - 21:00
Saturday	09:00 - 17:00

Bookshop (room 0-006)	
Monday-Friday	08:30 – 12:15 12:45 – 16:00

Library (room 3-038)	
Monday, Thursday, Friday	08:30 - 17:00
Tuesday, Wednesday	08:30 – 21:00

Audio-Visual centre (room 3-039)	
Monday, Thursday, Friday	08:30 - 17:00
Tuesday, Wednesday	08:30 – 21:00

Students' financial administration desk (room 1-130)	
Monday-Friday	10.30 – 13.30

Computer helpdesk (room 1-004)	
Monday-Friday	08:30 - 12:45 13:30 – 17:00

Restaurant (ground floor)	
	Monday-Friday
Coffee break *free coffee/tea*	10:15 – 10:45
Lunch	12:00 - 13:30
Tea break *free coffee/tea*	15:15 – 15:45

Starting dates modules and holidays

Module number	**2008 / 2009 / 2010**
Registration *Opening Academic year*	*Monday, September 15, 2008* *Thursday, September 25, 2008*
Module 1	September 29 through October 17
Module 2	October 20 through November 7 *RS core exam: November 7*
Module 3	November 10 through November 28 *GIS core exam: November 28*
Module 4	December 1 through December 19 *RS core re-sit exam: December 10*
DIES celebration	*GIS core re-sit exam: December 17: morning* *Wednesday, December 17: afternoon no classes*
X-mas	*December 25 through December 26*
New Year	*January 1, 2009*
X-mas break	*December 22, 2008 through January 2, 2009*
Module 5	January 5 through January 23, 2009
Module 6 *MSc day*	January 26 through February 13 *Wednesday, January 28, 2009*
Module 7	February 16 through March 6
Module 8 *MSc fair*	March 9 trough March 27 *Wednesday, March 11, 2009*
Module 9	March 30 through April 17
Good Friday	*April 10*
Easter Monday	*April 13*
Module 10	April 20 through May 8
Queen's day	*Thursday, April 30*
Catch-up week	*May 11 through May 15*
Module 11	May 18 through June 5
Ascension Day + compulsory ADV	*May 21 through May 22*
Whitsun Monday	*June 1*
Closing week PGD	*June 8 through June 12*
Closing PGD	*Friday, June 12*
Module 12	June 8 through June 26
Module 13	June 29 through July 17
Module 14	July 20 through August 7
Module 15	August 10 through August 28
Closing week Master - Catch-up week MSc	*August 31 through September 4*
Graduation Master	*Friday, September 4*
Module 16	September 7 through September 25
Module 17	September 28 through October 16
Module 18	October 19 through November 6
Module 19	November 9 through November 27
Module 20	November 30 through December 18
X-Mas, New year break	*December 24, 2009 through January 1, 2010*
Module 21	December 21, 2009 through January 15, 2010
Module 22	January 18 through February 5
Module 23	February 8 through February 26
Closing week MSc	*March 1 through March 5, 2010*
Graduation MSc	*Friday, March 5, 2010*

WATER RESOURCES AND ENVIRONMENTAL MANAGEMENT COURSES

1. Introduction

Security and sustainable development of our water resources is one of the key problems of the 21st century. Improved Water Management can make a significant contribution to achieve important Millennium Development Goals established by the UN General Assembly in 2000, in particular poverty, hunger, child and maternal mortality, and major diseases. During the World Summit on Sustainable Development in 2002, Water and Sanitation received great attention. It is identified that massive efforts in developing and application of science and technology are needed. In Water Resources Management and Hydrology important issues are sustainability of water resources, floods, droughts, water scarcity, water usage, water quality, water-ecosystem interactions and soil-water-climate interactions.

Current international initiatives, such as:

- the Integrated Global Observing Strategy– Partnership, the integrated Global Water Cycle Observations (IGOS-P IGWCO) theme;
- the Water Cycle Research Agenda undertaken by World Climate Research Programme, Global Energy and Water Cycle Experiment (WCRP GEWEX) and;
- the Water Targets in Global Earth Observation System of Systems 10-Year Implementation Plan (GEOSS);

have placed Earth Observation for Water Cycle Research as the key in helping to solve the world’s water problems.

The availability of spatial information on water quantity and quality will enable closure of the water budget at river basin and continental scales to the point where effective water management is possible. The closure of the water budget is an important element in the EU Water Framework Directive (WFD) as well as national policies. Geo-information Science and Earth Observation will be vital in achieving a better understanding of the water cycle and better monitoring, assessment, prediction and management of the world’s water resources.

The WREM-course (both MSc and PGD) exposes participants to the latest development in Geo-information Sciences and Earth Observation for assessment, monitoring and predictions in Water Resources, Hydrology and Environmental Management. Participants will obtain in-depth knowledge in Geo-information Science, Earth Observation and automated field data acquisition methods, as well as in public domain data and advanced hydrological models, all for the purpose of sustainable water resources and environmental management.

The WREM course is developed for those with a Bachelor of Science degree in fields such as (environmental) hydrology, geo-hydrology, civil engineering, agricultural engineering, agronomy, environment and geology. Most participants are having a profession in which ‘water’ plays an important role such as: lecturer-researcher at college and university level - executive officers, project planners, project designers at Water Board, Ministry of Water Resources, Provinces and NGO’s dealing with water resources - researcher at international organizations (like IWMI, FAO) and agricultural engineers, agronomists working for irrigation boards. Mast of our clients (applicants) have a background in Civil engineers or (Hydro-)geology.

3 WREM streams are offered at both Postgraduate Diploma level and Master of Science level:

- Groundwater Assessment and Modelling (GAM)
- Surface Hydrology (SH)
- Environmental Hydrology (EH)

The 9 months Postgraduate Diploma course (PGD) is for the first 10 modules similar to the MSc course. The last 2 modules (11 and 12) of the PGD course will be spent on some fieldwork near Enschede and with dedicated case-studies.

For the 18 months MSc course in module 11 Research Skills are developed needed to write a research proposal and execute MSc research. In module 12-13 the MSc course will focus on advanced topics. In module 14-15 participants will work on a project related to a specific research theme and parallel to that work on their research proposal. At the end of module 15 the research proposal should be defended. The teaching modules are followed by the execution of the MSc research: data collection, analyses, reporting and finally the thesis defence.

1.1 WREM course domain

Recent developments in the field of Earth Observation, GIS and data collection have led to different approaches to water resources and environmental research. Data acquired from Earth Observation and data analyses within a GIS environment can substantially contribute to obtain insight in the water resources processes on various scales (from sub-catchments to entire river basins). The WREM-course exposes participants to the latest development in Geo-information Sciences and Earth Observation for assessment, monitoring and predictions for Water Resources and Environmental Management.

The course addresses the use of quantitative earth observation techniques in combination with in-situ observations for gathering, analysing, modelling and interpreting geo-data within the context of water resources and environmental management. Management is defined as the management of hydrological processes. Starting point of this is the hydrological cycle, which integrates water processes and takes into account groundwater, surface water and water quality. Based on the assessment of the available resources and understanding of the processes management options can be analysed and reviewed.
Where applicable, quantitative earth observation techniques will be integrated in the curriculum. The curriculum focuses on earth observation and geo-information techniques applied for water resources management. The course covers techniques and methods to observe aspects of the hydrological cycle and move from there to processing, data assimilation, modelling, dissemination and information to contribute to solve water and environmental issues. The issues can be categories as too much, too little and/or too dirty water.

1.2 Streams

Water Resources and Environmental Management is a very wide knowledge field, in order to cater for specific sub-fields within the WREM domain 3 streams are developed within the WREM course:

- Groundwater Assessment and Modelling (GAM)
- Environmental Hydrology (EH)
- Surface Hydrology (SH)

Groundwater Assessment and Modelling (GAM)
The groundwater stream covers the use of earth observation for groundwater exploration, recharge assessment and the mapping of aquifer vulnerability. Attention will be paid to environmental monitoring, including automated data

acquisition systems and data integration and modelling for purposes of assessing and managing groundwater, artificial recharge and irrigation.

Surface Hydrology (SH)
This stream focuses on how earth observation and GIS can be used to obtain relevant information for water resources assessment and rainfall-runoff modelling.

Environmental Hydrology (EH)
This stream deals with the environmental aspects of hydrology and water resources, including water quality assessment and management and the environmental impacts of water resource projects on water quality and environmental aspects related to water resources.

1.3 Research themes

The MSc course is strongly linked to ITC's research activities. Two research themes are defined within the WREM domain:

Water Cycle and Climate
Research leader(s): Prof. Z. (Bob) Su, Prof. W. Verhoef
Keywords: Water cycle, quantitative earth observation, field experiment, modelling and data assimilation, water management, ecosystem, climate

This research theme broadly addresses the following sub-themes or science and application profiles with the central aim of advancement of our understanding of the water and energy cycle and their interactions with climate, ecosystem and human activities:

- Water and climate: Land - atmosphere exchanges of water and energy (precipitation, evaporation/transpiration, discharge, soil moisture, as well as agricultural water uses, with
- application areas in droughts, food security and water use
- Water and ecosystems: Water quality (lakes, wetlands, rivers, coastal areas) and integrated
- water and environment management
- Water resources and security: Integrated watershed and aquifer management, rainfall-runoffs, floods, surface-groundwater interactions, Integrated Water Resources Management

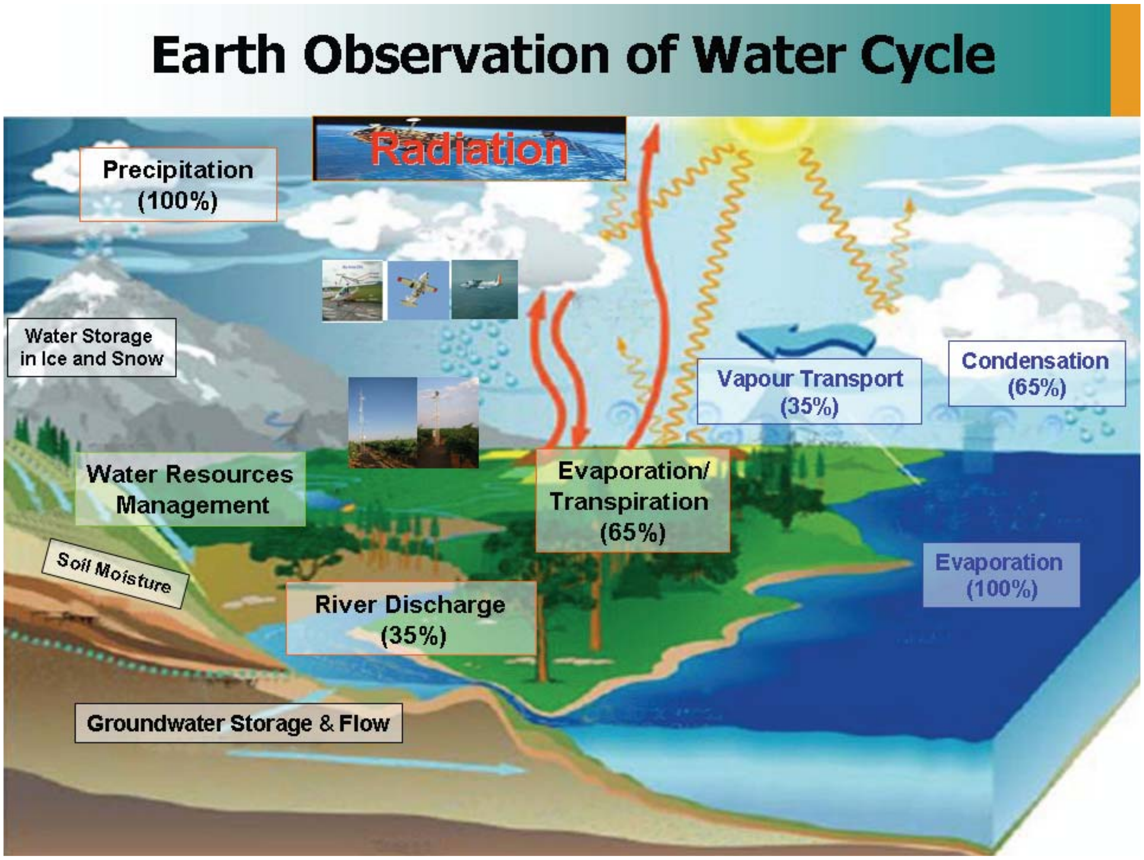


Figure 1: Schematic representation of the Water Cycle. (taken from presentation Prof. Su)

Managing Water Scarcity

Research leader(s)

Keywords: Water allocation, river basin, irrigation, water use, groundwater, surface water, management, crop production, transpiration, hydro-geophysics

In water scarce basins, surface water resources are unreliable and highly dependent upon quantity and temporal distribution of rainfall. During the dry season, river flow reduces to base flow while small streams run dry. During this dry season, groundwater is a major source of water for ecosystems, irrigated agriculture and urban/industrial users. Groundwater, however, cannot be analyzed in separation from surface water. Hence, a reliable parameterization of the entire basin and good understanding and definition of all hydrological fluxes involved in the water balance of the basin is needed to improve water management.

Water flows from one user to the next downstream user. Thus, the non-consumed part of the used water will be reused again. In the case of extreme water scarcity, this continues until drainage into the sea is zero. Under these conditions, all water that leaves one user system (e.g. leakage, spills, etc.) is reused by the next. Hence, increasing the efficiency of water use within one user system does not create “new” water for the next downstream user system.

Therefore the most important water management questions are the following:
To which user subsystem should water be allocated?
And which allocation criteria are to be used?

Using decision support systems (PC software) as a management tool is made to derive generic guidelines facilitating answers to those questions. To assess the allocation of water to (land) uses, these DSS should provide sufficiently accurate answers at a cost that meets the budget of managing organizations.

2 Competencies of ITC MSc graduates[1]

In this paragraph the objectives of the WREM course are described. The objectives are given related to the overall MSc programme of ITC, objectives specific for Earth Observation - GIS and WREM in general followed by stream-specific objectives.

2.1 Tasks of the WREM graduates

WREM-course graduates have a wide variety of tasks. MSc graduates work in a research and or water resource management setting where analytical and research skills are needed. Generally the tasks of a WREM graduate can be summarized as follows:

- studies and analyses physical aspects of the earth, focusing on the hydrosphere using Earth Observation information where applicable;
- studies, measures, and interprets hydrological and geographical data in relation to water resources assessment, modelling and management;
- compiles, analyses and evaluates data to prepare hydro(geo)logical maps and prepare environmental reports;
- Evaluates data in reference to project planning and project execution and management for projects such as flood and drought control, water supply, drainage, irrigation, environmental monitoring etc.
- Work in a multi-disciplinary environment and thus is able to communicate in an effective way outcome of research findings in scientific and non-scientific forums.
- Integrates the social context (water is not an isolated commodity) of water resource management with the scientific work.

Based on these tasks, competences which have to be acquired during the MSc study can be formulated (see paragraph 2.3.2 XXX check).

2.2 Course Objectives

The ITC MSc degree programme occupies a specific niche in the educational 'playing field'. ITC's MSc graduates get a degree in Geo-information Science and Earth Observation. Those who take the WREM course combine and apply knowledge in the above mentioned fields with WREM-specific course content.

At the end of the study the participants will be able to integrate data acquired from earth observation and in-situ observations in order manage, simulate, evaluate and validate water management problems.

It is possible to distinguish seven areas of competence that characterise a university graduate.
He or she:
1. is competent in one or more scientific disciplines
2. is competent in doing research
3. is competent in designing
4. has a scientific approach
5. possesses basic intellectual skills

[1] Taken from Criteria for Academic Bachelor's and Master's Curricula .TU, 2005

6. is competent in co-operating and communicating
7. takes account of the temporal and the social context

The Master of Science programme at ITC aims at educating professionals who have predominantly tasks in the field of (applied) research. The exposure to new methods and concepts (area 1) development of critical understanding (area 4 and 5), and the development of research skills (area 2) are important.

The general MSc degree programme and specific WREM course objectives are given below:

Table 1: MSc program and specific WREM course objectives.

General MSc Degree in Geo-information Sciences and EO objectives	Specific WREM-related MSc objectives
Analyse a problem encountered in professional practice and develop an appropriate method to study and/or solve the problem.	Be able to analyse a problem related to too much, too little and/or too dirty water and develop an appropriate method to study the problem.
Apply appropriate methods for spatial data collection, verification and acquisition.	Be able to collect and verify relevant data on various hydrological cycle components from in-situ and EO techniques..
Use geo-information and earth observation to generate, integrate, analyse and display spatial data.	Be able to use geo-statistical, spatial and visualisation techniques to generate, structure and analyse hydrological data.
Evaluate and apply relevant and appropriate methods and models for data analysis and problem solving.	Evaluate and apply relevant and appropriate methods and models for data analysis and problem solving for specific WREM related problems.
Apply research skills to formulate and carry out an independent research project.	Apply research skills to formulate and carry out an independent research project.
Communicate and defend findings of research work.	Communicate and defend findings of research work.

The objectives can be translated in more specific competences. This is done in the following paragraph.

2.3 Competencies at Course Level

Generally speaking the participant who followed the WREM course will:
'have acquired up-to-date knowledge on appraisal, computational and management techniques used in WREM. Participant will be in the position to take-up research assignments, take initiatives and/or participate in establishing and managing Earth Observation and GIS activities for water resources related services'
The general objectives given in 2.3.2 can be made specific for WREM graduates as is done below.

1. Is competent in the scientific disciplines of GIS-EO in relation to WREM

- Be able to analyse a problem related to too much, too little or too dirty water and develop an appropriate method to study the problem.
- Be able to collect and interpreted relevant data on water cycle components from various in-situ observation methods and EO.

- Be able to quantify the components and processes of the water cycle at various scales with Earth Observation as data source.
- Master the concepts of hydrological modelling, its application and limitations.
- Know the concepts of Integrated Water Resources Management.
- Operate a GIS for spatial analysis and visualization tasks related to water resources and environmental issues.
- Apply appropriate EO data pre-processing techniques (geometric, atmospheric and radiometric corrections)
- Be able to select appropriate images and image processing operations in order to extract information from EO data required for the quantification of water cycle processes.
- Understand the details of the energy balance equation in its application to hydrology-related applications from remote sensing;
- Post-process the images to create hydrological relevant output

2. Is competent in doing research in the field of Water Resources and Environmental Management

- The WREM course participant should be aware of the main research questions which currently exist in the water sector and the role EO and Geo-information science can play to answer these questions.
- With this knowledge he/she should be able with supervision to produce and execute a research plan, defend the plan and its results.
- Where necessary knowledge and skills from related disciplines such as agricultural sciences, physics and geology should be draw upon.

3. Is competent in designing

The WREM graduate might develop a specific software or model-setup which should meet the requirements in terms of stability and transparency.

4. Has a scientific approach

The WREM course graduate:

- should be able to systematically work on a WREM-related problem and thus be able to justify the use of a certain (Earth) observation and/or hydrological process model if required for the analysis.
- has skills in, and affinity with the use, development and validation of hydrological process models; is able consciously to choose between modelling techniques.
- has insight in the purpose, methods, differences and similarities between scientific fields, nature of laws, theories, explanations, role of the experiment, objectivity
- has insight into the scientific practice such as publication system and the importance of integrity
- is able to document (proper referencing) and publish adequately (proper use of scientific English) the results of research.

5. Possesses basic intellectual skills

The WREM graduate should be competent in reasoning, reflecting, and forming a judgment specifically related to the water sector. He/ she should have:

- a critical yet constructive attitude towards analysing and solving simple problems in the field of EO-Geo-information science and hydrology
- basic numerical skills, and has an understanding of orders of magnitude and knows how to deal with incomplete or poor data sets
- logical reasoning and reflection skills.

6. Is competent in co-operating and communicating

The WREM graduate should be able to work with and for others. This requires not only adequate interaction, a sense of responsibility, and leadership, but also good communication with colleagues and non-colleagues. He or she is also able to participate in a scientific or public debate. In order to do so the graduate should:

- be able to communicate verbally and in writing about research and solutions to problems with colleagues, non-colleagues and other involved parties.
- be able to work within an interdisciplinary team involving civil engineers, agricultural-irrigation engineers and others and thus should be able to deal with team roles and dynamics.
- be able to perform project-based work: should be pragmatic and has a sense of responsibility; should be able to deal with limited sources; is able to deal with risks; is able to compromise.

7. Takes account of the temporal and the social context
WREM graduates do not work in isolation. Their work always has a temporal and social context. Beliefs and methods have their origins; decisions have social consequences in time. The WREM graduate is aware of this, and has the competence to integrate these insights into his or her scientific work. He/she is able to:

- analyse the consequences of scientific thinking and acting on the environment and sustainable development
- analyse and to discuss the social consequences (economical, social, cultural) of new developments in with colleagues and non-colleagues

2.4 Stream Specific Knowledge

In order to do research in one of the streams, specific knowledge is required. For each of the streams, additional specific objectives related are formulated below. Most of the objectives relate to the scientific discipline of the graduate.

Competencies related to the Groundwater Assessment and Modelling stream

- Master the collection of relevant data during a fieldwork campaigns using discharge measurements, hydrochemistry, hydrograph, pumping tests, and image interpretations
- Be able to make a hydro-geological interpretation of satellite images including well siting.
- Be able to interpret geophysical data, question its validity and applicability
- Be able to set up groundwater monitoring schema
- Estimate recharge using field and remote sensing data
- Execute and analyse pumping tests result
- Set-up, calibrate and run a regional groundwater model
- Develop groundwater management guidelines for sustainable groundwater exploration

Competencies related to the Environmental Hydrology stream

- Has a thorough mastery of parts of the methodology on pollutant inventories and water quality sampling
- Be able to quantify water quality parameters from appropriate EO data
- Be able to critically analyze and interpret hydro chemical and water quality data
- Be able to design water quality monitoring and assessment schemes
- Carry out environmental impact assessments related to water resources using earth observation and ground-based data
- Be able to develop, test and apply environmental systems approaches to water management
- Develop and apply water quality and environmental modelling tools in GIS environment

Competencies related to the Surface Hydrology stream

- Master the collection of relevant data during a fieldwork campaign in combination with EO techniques
- Analyse surface hydrological data of various timeframes (hours-years) and for various catchment sizes (50-several hundred-thousand km^2)
- Develop and critically use techniques based on GIS and Earth Observation data for catchment parameterization
- Set-up, calibrate and validate rainfall-runoff models ranging from simple black box models to advanced physical based models with a strong GIS-component and EO-based input

Be able to quantify surface hydrology relevant parameters (e.g. evapotranspiration) from appropriate EO data.

3 COURSE Set-up

3.1 Set-up of PGD and MSc course

Both the PGD and MSc course consist of a series of several building blocks and comprises of theoretical lectures, workshops and practical assignments. A fieldwork assignment + cases studies including reporting completes the PGD course. Those in the MSc course get some additional training in research skills, proposal writing and advanced topics. The MSc course is concluded with a research project, which results in a thesis. An outline of the module names and sequence is given below.

	Stream	Modules	Title
Block 1 Core	All	1-2-3-4	Principles and Application of Geographic Information Systems and Remote Sensing in Water Resources and Environmental Management.
Block 2 Domain	All	5-6-7-8	EO and Quantification of Water Cycle Components
	GAM	9-10	Integrated EO and Modelling for WRM with Emphasis on Groundwater
	Surface Hydrology	9-10	Integrated EO and Modelling for WRM with Emphasis on Surface Hydrology
	Environmental Hydrology	9-10	Integrated EO and Modelling for WRM with Emphasis on Environmental Hydrology
GROUPWORK MODULE 11-13 FOR POST GRADUATE DIPLOMA STUDENTS			
Block 3 Research Profile	All	11	Research Skills
		12-13	Various Advance Topics
		14-15	Research Themes and Proposal Writing
Block 4 MSc Research	All	16-23	Individual MSc research

3.1 Block-1 (modules 1-4)

Block-1 (modules 1-4) deals with principles and applications of geographic information systems and EO to water resources and environmental management. Relevant applications to water resources and environmental management are added.

3.2 Block-2 (modules 5-10)

Block-2 (modules 5-10) is subdivided in two sub-blocks. The first, block-2a contains module 5 to 8 and forms a short course on EO and Quantification of Water Cycle Components. The second, block-2b contains modules 9 to 10 and forms an advance level on Integrated EO and Modeling for WRM.
On the one hand, block-2a focuses on quantitative remote sensing of the water cycle components coupled with basic understanding of the theory, processes and measurements of the hydrological cycle. On the other hand, block-2b focuses on the integrated application of earth observation and numerical process models for a better management of water resources.
A schematic illustration of the proposed block-2 is shown in figure 2.

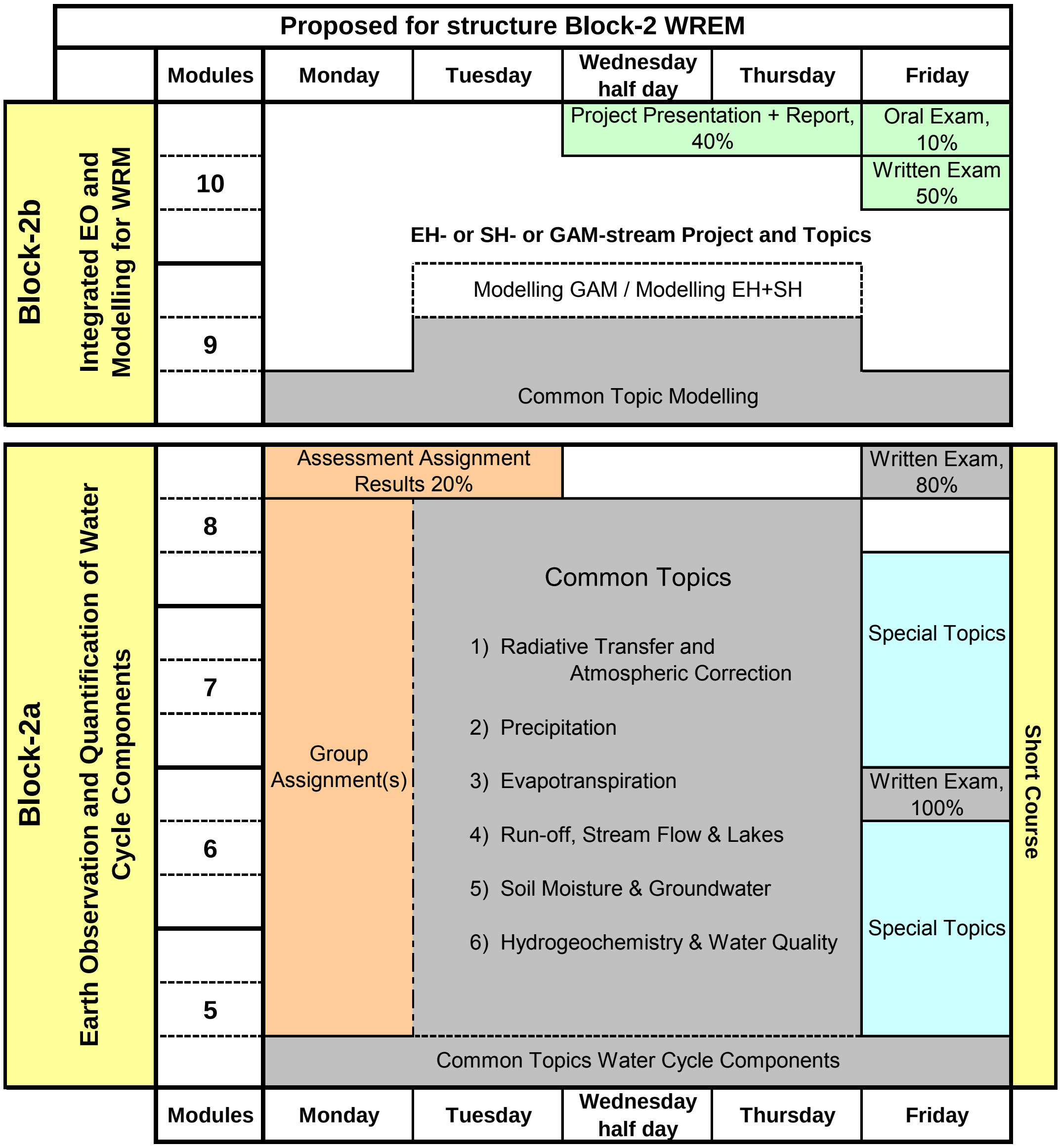
3.2.1 Block-2a: EO and Quantification of Water Cycle Components

Block-2a consists of four modules 5 to 8. These modules are developed around one broad theme which can form a short course. The theme deals with all water cycle components that can be quantified using earth observation approach. For those components where EO can not contribute (or contribute to a limited extend), in-situ observations or traditional methods should be introduced as well.
Since it treats the water cycle as such, a basic understanding of the hydrological cycle is, first, initiated. Three types of educational methods are recommended: common topics, group assignment and special topics.

a) Levelling Week: basics of the hydrological cycle
This is an introductory and refreshing week that provides the students with a basic knowledge on the physical processes of the hydrological cycle and related measurements. The objective is to bring the students, with diverse backgrounds, to the same level of understanding to water resources and their physical processes.
Time schedule: 5 study days.
Method: frontal teaching including self study.

b) Common topics
These topics introduce the participant to theory and process understanding, in-situ and satellite measurements, EO based retrieval models, data access and applications and principles of radiative transfer of the hydrological cycle components.
Time schedule: 22.5 study days.
Method: frontal teaching.

c) Group assignments
Group assignments are sort of exercises to be solved by pre-defined teams of students. The objective is to master their acquired knowledge and build up a practical experience as individuals and part of a team. Group assignments include but not limited to; data integration; water balance and energy balance, water resources assessment on different spatial/temporal levels including the impact of climate change.
Time schedule: 10 study days.
Method: student centred learning.



Block 2a:	grey	Common Topics	29.5 days
		The order of Common Topics is only a suggestion	
	blue	Special Topics, compulsory but not part of exam	8 days
	orange	Group Assignment w.a.o. Data Integration	10 days
		Exams & Presentations	4

Block 2b:	grey	Common Topics	9.5 days
	white	Stream related topics	6.5 days
	white	Stream Projects	6.5 days
	green	Exams CT and ST topics & Presentations	4.5 days

4.5 days per eek of which at least 25% (1 period/day) is reserved for selfstudy
Week days are not fixed

Figure 2: structure Block-2

d) Special topics

The participants are then exposed to more complex WREM problems where multidisciplinary or/and more specialized approaches can be employed as specific topic. The objective here is to deepen the knowledge of students about the complexity of real-world problems and their long term impacts and possible solutions and adaptation strategies. Special topics can be offered to the whole group or for specific streams Specific topics include but not limited to; Ph.D. research topics; EO (GRACE) for groundwater; drought monitoring and time series analysis and Capita Selecta topics in Hydro-geophysics, IWRM methods and techniques and hydrologic-optic.
Time schedule: 8 study days.
Method: student centred learning

e) Evaluation of the students

The exams of block-2a consist of three separated tests; two written exams (3 hours each) and one assignment assessment (2 days are reserved for presentations). The first written exam takes place at the end of module 6. The objective is to examine the understanding of students to the common topics. Weight 100% for the first 2 blocks.
Block-2a is terminated with a final written exam. The grad of module 7-8 is composed of a written exam (80%) and group assignment (20%)
Time schedule: 4 study days.

3.2.2 Block-2b Integrated EO and Modelling for WRM

Block-2b focuses on modeling in three specific streams: surface hydrology (SH), ground water assessment and modeling (GAM) and Environmental Hydrology (EH). Block-2b has common topics that focus on the principle of modeling in general; stream related topics that focus on modeling in specialized area and stream projects related to the specific streams.

a) Common topics

This is a general introduction n on the principles of modeling.
Time schedule: 9.5 study days.
Method: frontal teaching + self-study

b) Stream topics

Specific models of each application will separately be treated in each stream. Based of the student’s interest she/he may choose a specific stream to expand her/his knowledge in these specific numerical and physical models.
Time schedule: 6.5 study days.
Method: frontal and student-centred learning.

c) Stream projects

The students are confronted with real-world WREM projects where multidisciplinary or/and more specialized approaches should be employed. The objective here is to strengthen the skills of the students about the integrated solution of complex problems and their long term impacts and possible scenarios for adaptation.
Time schedule: 6.5 study days.
Method: student-centred learning.

d) Evaluation of the students

The exams of block-2b consist of three separated tests; one written exams (3 hour), project reporting + presentations and oral exam (one day). The first written exam takes place at the end of second week of module 10. The objective is to examine the understanding of students to modelling principles in common and stream specific topics.
The final exams are placed in the last week of module 10. First, projects reports and presentations are assessed for their scientific quality. Block-2b is terminated

with a short (10 min.) final oral exam. The total grad is a weighted sum of written exams 50%, project presentation (group work) 40% and oral exam 10%.
Time schedule: 4 study days

3.3 Final project Post Graduate Diploma

The PGD course is finalised with a fieldwork project + case-study (module 11-12). They will write a small report, give a presentation on the work they have done. The course is finalized by an interview with 2-3 staff.

3.4 Block 3: MSc research profile

All MSc students receive a 3 weeks course in research skills in which research methodology, information skills and writing and communication skills are developed. These 3 weeks are followed by 6 weeks (2 modules) of advanced subjects which are directly relevant for MSc research in one of the MSc research themes and generic. In module 14-15 research theme leaders (per ITC Research Programme) devises / offers one project. Each project makes use of tools learned in modules 12-13. Each student carries out independent work/research in a project team environment. In this period the MSc research proposal is prepared and presented.

3.5 Block 4: Research

Depending on the proposal the research activities (data collection, methodology development, fieldwork etc) are executed. Finally the thesis is defended in front of a Thesis Assessment Board.

4 Teaching Method

Students arriving at ITC have a diverse cultural background with educational experiences and habits which might differ from our views on good teaching methods. According to our view on good teaching methods, students should work and learn independently from their teacher. ITC uses the term "student-centred learning" to describe this method of teaching.
The following starting points for teaching methods are defined for the WREM curriculum:

- The students have to gradually adjust to become more independent in their learning so they will be able to conduct an MSc thesis research independently. This calls for more frontal teaching at the beginning of the course and more independent (group) work at the end.
- The group assignments in block-2a and the group project in block-2b prepare students for more independent learning and their MSc thesis research in block-4.

It is acknowledged that the amount of lectures should not be too big. However, each topic needs a certain amount of lectures for introduction of the topic and feedback to the students.

For teaching of the common topics in block -2a and -2b the following division is set: maximum of 50% for lecturing, 25% to work on assignments and exercises and 25% for self-study.

The overall programme offers an attractive and intensive educational package, including lectures and practicals, self-study, multi-disciplinary project work and hands-on case studies. Practicals may be in the form of discussion groups and assignments, image interpretation, computer assisted analysis and multi-media exercises. The programme is intended to deepen knowledge and skills in a practical problem-solving approach. Case studies and projects are designed to simulate realistic situations in your own organisation or country.

5 Assessment and certification

Degrees are awarded to participants who have fulfilled the conditions and passed the examination required in accordance with the official assessment rules of the Institute. Course records, that list the results for the specific modules and subjects, accompany the degree obtained

6 Lecture Timing

Lectures and practicals are given in four periods every day except Wednesday when only two periods are scheduled in the morning:
1st period 08.40 till approx. 10.20
2nd period 10.40 till approx. 12.20
3rd period 13.40 till approx. 15.20
4th period 15.40 till approx. 17.20

Table of contents[2]

Water Resources and Environmental Management 2008 – 2009

[2] Content is under review, some modifications might be incorporated during the academic year.

Principles and Applications of GIS and Remote Sensing for Water Resources and Environmental Management

Module: 1-4		Co-ordinating staff: Ing. R.J.J. Dost, MSc	
Start:	29-9-2008		
End:	19-12-2008		
Level: MSc, PG			U08-WREM-122

Introduction

This block forms the start of the Water Resources and Environmental Management (WREM) course. First the students are introduced to the WREM course curriculum. Then the principal concepts and techniques of Geographic Information Systems (GIS) and Remote Sensing (RS) in Water Resources and Environmental Management (WREM) are addressed. As such, the block consists of four interrelated parts:

- Introduction to the WREM program;
- A theoretical part which focuses on the main principles of GIS and (Quantitative) RS;
- A practical part that illustrates this theory using WREM specific exercises and industry standard software and tools;
- An application oriented part in which participants learn how to individually design and carry out sequential data processing steps typical for the creation and use of GIS and RS applications in WREM.
- The concepts and techniques introduced in this block will be further enhanced during subsequent modules within the programme.

Contents

The block covers the following topics:

- Integrated Water Resource Management;
- Water Resources Conflicts;
- Geographic information and spatial data types;
- Spatial data entry and preparation;
- Spatial data analysis;
- The electromagnetic spectrum as required for RS analysis;
- Sensors and platforms;
- Geometric aspects of remotely sensed data;
- Image enhancement and visualisation;
- Image classification and interpretation;
- Spatial data visualisation;
- Quality assessment of spatial data;
- Field observations for satellite image interpretation.

Objectives

Main objective: to learn how to generate, store, analyze and present information about the Earth required for Water Resources and Environmental Management (WREM).
At the end of the block participants must be able to:

1. Explain the principles and use the vocabulary of GIS and RS:

- Describe the nature of geographic phenomena and their representation in the context of geo-informatics;
- Outline the principal data models for spatial and non-spatial data used in GIS databases;
- Outline the main components of a GIS and their functions;
- Explain the relationship between spatial data and coordinate systems;
- Outline the main spatial data analysis functions;
- Explain the role of RS in GIS;
- Describe the physical background of remote sensing and compare the main platforms and sensor systems;
- Explain the main digital image processing procedures;
- Describe the common methods of image analysis;
- Outline the principal rules for cartographic visualisation;
- Describe aspects of data quality and how various stages of spatial data handling affect it.

2. Carry out GIS and RS operations:

- Independently search Internet Archives and download images and other resources from the Archive Internet Sites or Clearinghouses;
- Carry out data preparation, geo-referencing and data entry into a GIS;
- Perform manipulation, analysis and visualisation operations using a GIS;
- Perform image processing techniques;
- Carry out a visual interpretation of a satellite image;
- Apply data quality assessment procedures.

3. Apply appropriate GIS and RS methods in applications:

- Understand the capabilities, uses and limitations of GIS and RS in their field of application;
- Design and carry out sequential data processing steps typical for the creation and use of GIS and RS applications in WREM;
- Evaluate the results of data processing;
- Understand organisational issues of GIS development and implementation.

Prerequisites

Admission to WREM programme or short course.

Recommended Knowledge

Computer skills (Windows OS, Office), physics/mathematics skills.

Staff involved

Prof.Dr. Z. (Bob) Su
Ing. R.J.J. (Remco) Dost, MSc
Dr. B.H.P. (Ben) Maathuis
Ir. G.N. (Gabriel) Parodi, MSc
Dr. A.S.M. (Ambro) Gieske
Ir. A.M. (Arno) van Lieshout, MSc
Drs. R. (Robert) Becht, MSc
Dr. C.M.M. (Chris) Mannaerts
J.H.M. (Jan) Hendrikse, MSc

Hardware and Software Requirements

(Handheld)PC with GIS and Image Processing Software (ILWIS, ERDAS, ARCGIS and ArcPad), GPS.

Teaching Materials

- R.A. de By, 2004: Principles of Geographic Information Systems – An introductory textbook, 3rd edition, ITC, Enschede, The Netherlands, 226 p. ISBN 90-6164-226-4;
- N. Kerle, L. L.F. Janssen, G.C. Huurneman, 2004. Principles of Remote Sensing – An introductory textbook, 3rd edition, ITC, Enschede, The Netherlands, 250 p. ISBN 90-6164-227-2;
- World Water Report Executive Summary;
- No Water, No Future: A Water Focus for Johannesburg;
- WREM specific case studies;
- Relevant data (such as satellite imagery) of selected areas.

Allocated Time per Teaching Learning Method

L	SP	GA	IA	S	O
108	140	58	46	52	60

Time (in # of hours) allocated per major method:
L lecture,
SP supervised practical,
GA group assignment (e.g. workshop, project),
IA individual assignment (including Thesis, IFA),
S self study,
O overhead (e.g. QH, exam, opening)

Assessment

- Written closed book examinations on the theoretical part;
- Assessment of the case studies.

Note(s)

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Earth Observation and Quantification of Water Cycle Components

Module: 5-8		Co-ordinating staff: Ir. G.N. Parodi	
Start:	05-01-2009		
End:	27-03-2009		
Level: MSc, PG			U09-WREM-114

Introduction

In this block the theoretical background of the different water budget and water quality components are discussed including the methodology to use EO to quantify each of the components. To assess the water balance component you need data. Data can be obtained from the ground or from satellite observations. Also applications of process modelling require reliable data related to water quantity & quality, climate, soils and vegetation. Today, using the newest sensor and environmental technologies, a large number of these data can be acquired relatively easy from space and can be integrated with in-situ and laboratory measurements.

Besides water quantity assessment also hydrochemical data analysis and interpretation techniques are taught, along with an overview on biogeochemical cycles.

Knowledge of the principles and processes underlying the interaction of electromagnetic radiation with materials at the Earth's surface is crucial to many environmental issues. Turning raw satellite data into useful information requires Radiative Transfer (RT) models that relate measurements of reflectances to specific properties of the land surface and water bodies. RT models can help establish the relationships between these properties and remotely sensed top-of-atmosphere signals.

In the 12 week block time is reserved for group assignments on data integration and capita selecta in which PhD students can present their work and specific stream-oriented.

Contents

This block consists of three components:

- the theory on and computational methods for water cycle quantification, water quality and ecosystems analysis. The following components will be discussed:
    1. Precipitation
    2. Rainfall/runoff processes
    3. Evaporation /Transpiration
    4. Soil water and groundwater
    5. Hydrochemistry and Water quality
- The theory and methods for the use of Earth Observation for the quantification of Water Cycle components. Aspects of atmospheric correction, radiative transfer, accuracy and resolutions will be discussed.

Methodology of data integration methods of water cycle components to assess closure of the balance.

Keywords

Hydrologic and Environmental Monitoring, hydrological cycle, hydrological components, precipitation, groundwater, rainfall-runoff, water quality, hydrochemistry. In-situ measurements and Earth observation.

Objectives

Regarding processes, upon completion of this module students should have acquired knowledge of:

- Methods to quantify different components of the hydrological budget.
- the exiting controls on the budget fluxes and storages
- The role EO can play in the quantification of the Water cycle

Through exercises students develop skills in:

- The quantification of components of the hydrological cycle
- The determination and monitoring of environmental indicators like water quality parameters, soil and climate data (meteorological and energy budget);
- The use of Earth Observation for the acquisition of hydrological, meteorological, soil and groundwater data;

To obtain experience in working in groups, writing reports and present results.

Prerequisites

Core module EO and GIS.

Recommended Knowledge

- Basic knowledge in hydrological sciences, soil science, chemistry; Computer handling skills.
- Basic knowledge in Excel and computer data processing.

Staff involved

Various staff from WRS department.

Hardware and Software Requirements

PCs with EXCEL, ILWIS, AQUACHEM, AWSET and Word for reporting

Teaching Materials

- Hydrology: An Introduction - by Wilfried Brutsaert
- Various articles and handouts.
- Laboratory equipment - GWS lab, ITC.
- Field measurement instrumentation, sensors, ADAS station.
- Lecture materials; various handouts, background literature and operation procedures / manuals for measurements equipment, etc.

Allocated Time per Teaching Learning Method

L	SP	GA	IA	S	O
154	100	80	0	30	32

Time (in # of hours) allocated per major method:
L lecture,
SP supervised practical,
GA group assignment (e.g. workshop, project),
IA individual assignment (including Thesis, IFA),
S self study,
O overhead (e.g. QH, exam, opening)

Assessment

Two exams, one after 6 weeks resulting in one mark. Another exam at the end of the 12 weeks (weight 80 % and assigments 20 %.)

Note(s)

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Integrated EO and Modelling for WRM with emphasis on Groundwater			
Module: 9-10		Co-ordinating staff: Dr. M.W. Lubczynski	
Start:	30-03-2009		
End:	08-05-2009		
Level: MSc, PG			U09-WREM-115

Introduction

To exploit, protect and manage groundwater resources in a sound manner requires a thorough understanding of groundwater flow and transport processes and quantification of these processes in time and space that is typically done by groundwater modelling. Groundwater modelling is nowadys indispensable also for modern planning and management of groundwater resources in sustainable manner.

For the reliable setup of groundwater model, good understanding of the hydrogeological system and data describing its spatio-temporal characteristic are needed. This can be best achieved by data acquisition based on the combination of EO (Earth Observation), geophysical remote sensing techniques for spatial assessment as well as hydrological montoring for temporal assessment. Various techniques of such data acquisition and data integration in groundwater models will be discussed. The calibrated models will be finally used to show their applicability in groundwater management such as for example determination of borehole safe yield, remedial of contamination etc.

Contents

The course consists of a total of 6 weeks in which groundwater assessment, modelling, specific applications and the role of EO in groundwater modelling will be discussed. The 6 weeks will start with methods of groundwater resources assessment, then is followed by principles of groundwater modelling, spatio-temporal data integration, transport modelling and finally groundwater management.

In the first 3 weeks of the course, lectures will be interacted with exercises to demonstrate various aspects of the groundwater system analysis and groundwater modelling such as: hydrology of unsaturated zone, recharge and discharge, theory of groundwater flow, aquifer parameterization, theory and practice of groundwater modelling with MODFLOW, theory and practice of advective transport modeling with PMPATH and theory and practice of advective-dispersive transport modeling with MT3DMS.

In the second half of the course i.e. in the last 3 weeks of the course, the individual groundwater modelling study cases will be carried out by students. They will involve: data processing, numerical model setup, spatio-temporal data integration, model calibration, model sensitivity and uncertainty analysis, prediction scenarios related to safe yield and contaminant transport modeling and finally project reporting. The overall program will be interacted by special lectures on: the role of groundwater studies in IWRM, the coupling of models etc.

Objectives

- Understand different hydrogeological modeling concepts and their limitations;
- Develop practical skills in setting-up, running and applying groundwater models in practice.

Specific objectives:

- Learn principles of hydrology of unsaturated zone and recharge modeling
- Understand principles of flow system analysis contaminant transport processes
- Learn to analyse hydro geological data for groundwater resource evaluation
- Learn principles of groundwater flow and transport modeling with MODFLOW and MT3DMS
- Apply groundwater model in groundwater management type of case study
- Compile groundwater modeling report

Prerequisites
Module 1-8 of WREM course.

Recommended Knowledge
Module 1-8 of WREM course

Staff involved
Various staff from WRS department.

Hardware and Software Requirements

Computer cluster with installed ILWIS, ARCVIEW, EARTH, FLONET, MODFLOW, MT3DMS.

Teaching Materials
- Fetter C.W. Applied Hydrogeology
- Various handouts and lecture notes

Allocated Time per Teaching Learning Method*

L	SP	GA	IA	S	O

Time (in # of hours) allocated per major method:
L lecture,
SP supervised practical,
GA group assignment (e.g. workshop, project),
IA individual assignment (including Thesis, IFA),
S self study,
O overhead (e.g. QH, exam, opening)

Assessment
This block will be assessed as follows:
- Written exam - 50%
- Modelling assignments - 50 %

* # of hrs. per Teaching Learning Method will be announced later

Integrated EO and Modelling for WRM with emphasis on Surface Water

Module: 9-10		Co-ordinating staff: Ir. G.N. Parodi	
Start:	30-03-2009		
End:	08-05-2009		
Level: MSc, PG			U09-WREM-116

Introduction
The course consists of a total of 6 weeks in which integrated monitoring, assessment and modelling of water resources as well as applications in floods and droughts are introduced.

The 6 weeks start with a short introduction on modelling concepts. Different componets of a modeling system will be addressed. Uncertainties in model processes, parameters and variables as well as model calibration and validation at different spatial and temporal scales will be addressed. Applications of the modeling approach to data poor area will be treated. Finally applications of the modeling approach in flood monitoring, drought assessment and land use and climate change impacts will be worked out as case studies.

Special attentions are given to the integration of Earth Observation data of water cycle variables conventional hydrometric data, vegetation properties and catchment characteristics in a GIS based modelling framework.

Contents
Lectures and exercises demonstrate the various aspects of the modelling process.

Keywords

Hydraulic and Hydrologic modelling; Model structures, Model design, Data requirements; Integration of EO data in modelling.

Objectives
General objectives:
- Understand different hydrologic modelling concepts and their application potential and limitations;
- Develop practical skills in setting-up, running and evaluating specific hydrological models;
- Develop capability to use earth observation data in modelling context

Specific objectives:
- Set-up, run and evaluate various hydrological models;
- Adapt model structure for use of earth observation data in modelling;
- Develop applications with a generic modelling system on the basis of physical process description and earth observation derived data base.

Prerequisites
Module 1-8 WREM.

Recommended Knowledge
- Basic mathematics and understanding of the concepts of numerical modelling
- Methods for field data collection and generalization
- GIS and EO techniques for hydrologic modelling
- Knowledge in water cycle variables

Staff involved
Various staff from WRS department.

Hardware and Software Requirements

Computer cluster with ILWIS, GWFL, SAC-SMA, HBV. STELLA 7.0.

Teaching Materials

- Various reference books and handouts
- Sections from Encyclopedia of Hydrological Sciences. Edited by M.G. Anderson, 2005 John Wiley & Sons.

Allocated Time per Teaching Learning Method*

L	SP	UP	GA	IA	S	O

Time (in # of hours) allocated per major method:

L lecture,
SP supervised practical,
UP unsupervised practical,
GA group assignment (e.g. workshop, project),
IA individual assignment (including Thesis, IFA),
S self study,
O overhead (e.g. QH, exam, opening)

Assessment

This block will be assessed as follows:

- Written exam 50%
- Modelling assignments 40 %
- Short oral exam 10 %

Note(s)

-

* # of hrs. per Teaching Learning Method will be announced later

Integrated EO and Modelling for WREM on Environmental Hydrology

Module: 9-10		Co-ordinating staff: Dr. Ir. C.M.M. Mannaerts	
Start:	30-03-2009		
End:	08-05-2009		
Level: MSc, PG			U09-WREM-117

Introduction

The course consists of a total of 6 weeks in which water quality assessment, water quality modelling and the use of EO and *in situ* data for water quality monitoring, are being exposed. Assessment of human and climate impacts on water quality is a central theme.

The course starts with a short primer (1-wk) on basic modelling concepts, incl. application of generic systems approaches for analyzing hydrologic and environmental phenomena incl. human and climate impacts.

This 1st week is followed by sections on watershed erosion - sediment transport and diffuse source pollution models (1-wk), and numerical water quality process modelling (1-wk).

The second part of the module is used for EO for water quality of lakes and coastal waters (2-wk). Retrieval of water quality parameters from space a/o airborne sensors, using atmospheric corrections and WQ algorithms is taught. Included is a primer on coupling of EO data with process models.

The last week is devoted to integration of EO and models in IWRM. Assigments are concluded by written exercises, workshops and presentations by students on how to apply EO data and modelling results in IWRM, with focus on environmental and water quality issues.

Contents

- Lectures and exercises to demonstrate the various aspects of the modelling process and use of generic modelling tools (STELLA v.9.0.3, Excel, etc.).
- Watershed integrated modeling (erosion, sediment yield and water quality) using the SWAT2005 model - GIS link (ArcSWAT): watershed representation using GIS, weather generators, rainfall runoff, water and sediment yields, calibration and validation.
- Water Quality modelling using DMS 3.8.2 (DUFLOW): Advective, dispersive, reactive hydrologic transport phenomena; analytical solutions; numerical solutions of the 1-D transport equation; application to surface water and soils; exercise(s) advection-dispersion, oxygen-, contaminant transport in a river networks.
- Lectures on water quality remote sensing; spectral signatures of waters; inherent optical properties; radiative transfer concepts; atmospheric & water interface corrections; water quality algorithms; forward and inverse retrievals; EO sensors: MERIS, MODIS, SeaWIFS and others.
- Field excursions with practical in situ data collections for water quality modelling and remote sensing (in Regge & Dinkel area).

Keywords

Water Quality, modelling, remote sensing, freshwaters, coastal zones, human impact, climate change.

Objectives

General objectives:

- Understand different hydrologic modeling concepts and protocols, and develop practical skills in setting-up, running and evaluating watershed water quality hydrological models;
- Understand the physical and biogeochemical processes underlying water quality and water resources deterioration;
- Get familiar with concepts of IWRM including the role of Geo-information and Models;

Specific objectives:

- Understand the basic WQ and contaminant transport processes and apply watershed hydrologic and non-point source pollution model in GIS environment;
- Derive water quality information from EO sensor data using empirical and physical

retrieval methods.

Prerequisites
Module 1-8 WREM

Recommended Knowledge
Hydrochemistry, EO and GIS principles, Hydrological concepts.

Staff involved
S.Salama, R.Dost, T.Rientjes, Z.Vekerdy, invited guest lecturers.

Hardware and Software Requirements.

Computer cluster with installed ILWIS 3.4 Open, STELLA 9.0.3, SWAT 2005, ArcGIS 9.2, DMS 3.8.2 (DUFLOW), WASI, ENVI/IDL

Teaching Materials

- D.Chapman (2000): Water Quality Assessment and Monitoring
- C.Mannaerts (2004): Introduction to Hydrological amd Environmental Systems Analysis & modelling (using Stella).
- SWAT2005, DMS/Duflow, WASI model documentations.
- S.C.Chapra (1997): Surface Water Quality Modeling.
- C.Mobley (2004): Light & Water: radiative transfer in water.
- Handouts
- Encyclopedia of Hydrological Sciences

Allocated Time per Teaching Learning Method

L	SP	UP	GA	IA	S	O

Time (in # of hours) allocated per major method:
L lecture,
SP supervised practical,
UP unsupervised practical,
GA group assignment (e.g. workshop, project),
IA individual assignment (including Thesis, IFA),
S self study,
O overhead (e.g. QH, exam, opening)

Assessment
This block will be assessed as follows:

- Written exam 50%
- Modelling assignments 40 %
- Short oral exam 10 %

Note(s)
-

Final Project		
Module: 11-12	Co-ordinating staff: Drs. R. Becht	
Start: 18-05-2009		
End: 26-06-2009		
Level: PGD		U09-WREM-118

Introduction

Water Resources and Environmental Management can only be successful if management decisions are based on site specific field data investigations. The integration and verification of the remote sensing data with the field data in a GIS and models form the basis of the decision making process.

Contents

The objective of these 2 modules is to train the students in field data collection, its integration with the remote sensing data (satellite images and aerial photo) and the use of the above mentioned data in hydrological modelling. Fieldwork will be provided in the Regge and Dinkel watershed near Enschede. Students will be exposed to problems related to water resources evaluation, hydrologic data analysis, terrain mapping, water quality and parameterization. Students learn how to make a preliminary watershed assessment based mainly on remote sensing data, how to properly collect hydrologic data in the field and finally to report on their activities. Several data-sets and related issues will be offered to the student for analyses and reporting.

Keywords

Fieldwork, discharge measurements, infiltration measurements, ground truth collection, case studies

Objectives

Upon completion of these modules students should be able to:

- relate the hydrologic processes to the landscape;
- analyse time series of hydrologic data;
- do field measurements related to water resources evaluation;
- solve hydrological problems.

Prerequisites

All previous WREM programme and specialisation modules

Recommended Knowledge

Knowledge gained during all previous modules is expected.

Staff involved

Drs. R. (Robert) Becht
MSc G.N. (Gabriel) Parodi
MSc R.J.J. (Remco) Dost

Hardware and Software Requirements

ILWIS, Excel and other statistical software.

Teaching Materials

All materials, hand-outs related to previous models are used.

Allocated Time per Teaching Learning Method

L	SP	GA	IA	S	O
		120	120		

Time (in # of hours) allocated per major method:
L lecture,
SP supervised practical,
GA group assignment (e.g. workshop, project),
IA individual assignment (including Thesis, IFA),
S self study,
O overhead (e.g. QH, exam, opening)

Assessment

Group report and individual performance.

Note(s)

-

MSc Research Skills

Module: 11		Co-ordinating staff: Dr. D.G. (David) Rossiter	
Start:	18-05-2009		
End:	05-06-2009		
Level: MSc			P09-EDU-100

Introduction

The ITC MSc thesis research phase aims to strengthen your ability to execute scientific research. The success of your thesis research depends, apart from skills and conceptual background in your scientific discipline, also on the ability to adequately structure your thesis. This module provides a set of generic research skills applicable to all MSc students at ITC to improve performance in the subsequent thesis research. The module teaches you why research is structured as it is and challenges you to develop the ability to critically review scientific work of yourself and others. You will be trained to analyze the structure, logic and quality of research with examples from your own scientific field. Also you will develop skills to structure scientific research. The module finally aims to create common understanding of what is expected of a thesis and how it will be assessed, to allow you to comply with these expectations.

Contents

- Logic and structure of scientific research
- Inference in various scientific disciplines
- Literature search, citation and bibliography
- Abstracting and reviewing scientific research
- Scientific writing and argumentation
- Research quality and thesis assessment
- How to structure an MSc thesis
- Ethics and professionalism in research

Objectives

Upon completion of the module, participants will be able to:
- understand why scientific research is structured as it is,
- recognize and critically assess research quality,
- present scientific research at a standard acceptable to the scientific community,
- find, evaluate, and summarize the most relevant and up-to-date scientific literature to support research, and
- structure an MSc thesis research according to academic expectations.

Prerequisites

Before entering module 11 participants have to submit their intended line of research (MSc pre-proposal), based on the available MSc projects presented at the MSc fair (March 11). This includes: choice of topic and rationale, choice of module 12, 13 and 14-15, available datasets, (optional) fieldwork planning and envisaged MSc supervisors.

At the start of module 11 participants must be able to:
- Present and discuss research in public;
- Communicate about technical subjects in written English
- Understand the importance of innovation, quality and independent thinking in science;

Besides participants are expected to have:
- A background in at least one relevant scientific field
- A critical/creative attitude

Staff involved
Dr. P.M. van Dijk, Director Graduate Programme
Dr. D.G. Rossiter, overall coordinator module 11

Delegate coordinators per course:

Dr. N. Kerle (AES)
Dr. J.E. Stoter (GFM)
Ir. W.T. de Vries (LA)
Drs. J.C. de Meijere (GSIM)
Dr. J. de Leeuw (NRM)
Dr. R.V. Sliuzas (UPM)
Dr. A.S.M. Gieske (WREM)

Other departmental staff and supporting staff (Library, RC, IT)

Hardware and Software Requirements

Networked PCs, Word, End note and access to scientific bibliographic databases

Teaching Materials

Digital presentations, description of assignments, reader, scientific articles and MSc theses for review

Allocated Time per Teaching Learning Method

L	SP	GA	IA	S	O
31	4			98	11

Time (in # of hours) allocated per major method:
L lecture,
SP supervised practical,
GA group assignment (e.g. workshop, project),
IA individual assignment (including Thesis, IFA),
S self study,
O overhead (e.g. QH, exam, opening)

Assessment

(1) Full participation in (group)discussions is expected;

(2) Further, the mark is derived from four written assignments:

1. Literature skills: (i) Finding relevant literature from specified information resources, (ii) entering references to these in a bibliographic database, (iii) organizing the main points into a coherent paragraph, and (iv) formatting a reference list from the bibliographic database;
2. Summarizing and abstracting an important scientific paper in the research field of your course;
3. Assessing a published thesis from your course according to ITC criteria;
4. Arguing a scientific position in correct, compact and direct structured technical English.

Advanced topics 12 & 13			
Module: 12 & 13		Overall Co-ordinating staff: Dr. P.M. (Paul) van Dijk	
Start:	08-06-2009		
End:	17-07-2009		
Level: MSc			P09-EDU-101/102

Introduction

Modules 12 and 13 form the backbone of the third Block of the MSc programme. Following module 11 on research skills and before the engagement in research themes during modules 14-15, students are equipped with advanced subjects for their research. During modules 12 and 13 students will learn in depth about specific research tools, methodologies and applications that are important for their envisaged MSc research. Participants have to make a logical choice that fits with their envisaged MSc research during Block 4 (MSc research phase; modules 16-23). The choice is made and explained in the MSc pre-proposal that has to be submitted after the MSc fair (March 12th 2008) and before the start of module 11 (exact date and format to be specified).

The final list of choice for the 2008/09 courses will be available by January 2009, after evaluation of the 2007/08 courses and final approval by the Academic Board. The subjects may be updated/changed, new subjects may be added and some may be deleted.

In this generic study guide description the 24 advanced subjects of the 2007/08 course are mentioned to show the range of subjects. Their descriptions can be viewed in the "Search module descriptions" option on internet: http://www.itc.nl/education/courses/modules.aspx , select studyguide = 2007-2008, level = MSc and module = 12, respectively 13.

Contents

Module 12:	Title	Chair	Module Coordinator
M09-EOS-100	Advanced image analysis	Prof. A. Stein	Dr. V.A. Tolpekin
M09-GIP-100	Design and Implementation of Spatial Databases	Prof. M.J. Kraak	Dr. R.A. de By
M09-ESA-100	Essentials of physical process modelling	Prof. V.G. Jetten	Prof. V.G. Jetten
M09-EOS-101	Geostatistics	Prof. A. Stein	Dr. D.G. Rossiter
M09-ESA-101	Hyperspectral Remote Sensing	Prof. F.D. van der Meer	Dr. H.M.A. van der Werff
M09-EOS-102	Inferential statistics	Prof. A. Stein	Dr. J. de Leeuw
M09-EOS-103	Laser scanning and InSAR	Prof. M.G. Vosselman	Prof. M.G. Vosselman
M09-PGM-100	Managing geoinformation systems in the public sector	Dr. C.M.J. Paresi	Dr. D.D. Navarra
M09-NRS-100	SAR Remote Sensing	Prof. A.K. Skidmore	Dr. Y.A. Hussin
M09-PGM-101	Spatial growth and spatial interaction modelling	Dr. R.V. Sliuzas	Dr. M.H.P. Zuidgeest
M09-PGM-102	Spatial planning support systems and scenario development	Dr. C.M.J. Paresi	Dr. M.A. Sharifi
M09-PGM-103	Strategic Environmental Assessment (SEA) and Environmental Impact Assessment (EIA) applying Spatial Decision Support tools	Prof. A. van der Veen	Drs. J.M. Looijen
M09-GIP-101	Time series	Prof. M.J. Kraak	Prof. M.J. Kraak

Module 13:	Title	Chair	Module Coordinator
M09-EOS-104	3D Geoinformation	Prof. M.G. Vosselman	Dr. M. Gerke
M09-EOS-105	Advanced statistics	Prof. A. Stein	Prof. A. Stein
M09-PGM-104	Applying research methods for public sector geoinformation management	Dr. C.M.J. Paresi	Dr. D.D. Navarra
M09-GIP-102	Design and implementation of Geoinformation Services for SDI	Prof. M.J. Kraak	Ir. R.L.G. Lemmens
M09-ESA-102	Geophysics and 3D geo-visualization of the subsurface	Prof. F.D. van der Meer	Dr. M. van der Meijde
M09-ESA-103	Integrated Risk Assessment	Prof. V.G. Jetten	Dr. C.J. van Westen
M09-WRS-100	Large scale process modelling and data Assimilation	Prof. Z. Su	Prof. Z. Su
M09-PGM-105	Participatory GIS – principles and applications	Dr. R.V. Sliuzas	Dr. M.K. McCall
M09-WRS-101	Quantitative retrieval of geo(bio)physical parameters	Prof. W. Verhoef	Prof. W. Verhoef
M09-PGM-106	Scenario analysis and collaborative decision support	Dr. C.M.J. Paresi	Dr. M.A. Sharifi
M09-NRS-101	Spatial modelling of biological ecosystem Properties	Prof. A.K. Skidmore	Dr. P.E. van Laake

Objectives

Specified per advanced subject

Prerequisites

MSc modules 1-11 (and other specifications as given per subject)

Recommended Knowledge

Specified per advanced subject

Staff involved

Appointed per advanced subject

Hardware and Software Requirements

Specified per advanced subject

Teaching Materials

For each advanced subject a collection of resources will be available in the digital learning environment Blackboard, the library or in hard copy.

Allocated Time per Teaching Learning Method

L	SP	GA	IA	S	O
16	20	30	30	40	8

Time (in # of hours) allocated per major method:
L lecture,
SP supervised practical,
GA group assignment (e.g. workshop, project),
IA individual assignment (including Thesis, IFA),
S self study,
O overhead (e.g. QH, exam, opening)

Assessment

Specified per advanced module, the assessment must result in a mark.

Research Themes / MSc Qualifier			
Module: 14 & 15		Overall Co-ordinating staff: • Dr. P.M. (Paul) van Dijk/ • Research project coordinators appointed per research theme • 2 MSc supervisors appointed beforehand for each participant	
Start:	20-07-2009		
End:	28-08-2009		
Level: MSc			P09-EDU-103

Introduction

Modules 14 and 15 form the last part of Block 3 of the MSc programme. While Modules 11 to 13 have instrumented the students with research methods and tools, the last two modules focus on the research themes of ITC. These themes form the subject framework and organizational structure in which MSc students conduct their individual MSc research in Block 4 of the MSc programme (modules 16-23). At the end of Module 15, a Thesis Admission Committee decides whether a student is admitted to Block 4.

Each ITC research theme offers one or more projects for Module 14 and 15, where possible together with one or more other themes. The general structure is the same; the content will be theme specific, and where possible inter-disciplinary. Research themes are free to fill this in within the boundaries described in this module description.

The purpose of Modules 14 and 15 is to deepen the knowledge and skills of students within the research theme and to help students to define their own MSc research proposal.

The student has to make a choice for a certain research theme, based on his/her envisaged MSc thesis topic. The following 15 themes are available:

Education Unit 14/15:	Title Research theme	Research theme leader
U09-NRS-101	Biodiversity in fragmenting landscape	Prof. A.K. Skidmore
U09-NRS-102	Carbon-cycle and climate change	Prof. A. de Gier
U09-ESA-100	Disaster management	Prof. V.G. Jetten
U09-ESA-101	Earth systems science	Prof. F.D. van der Meer
U09-NRS-103	Food security and environmental sustainability	Prof. E.M.A. Smaling
U09-PGM-100	Governance and Integrated Spatial Assessment	Prof. A. van der Veen
U09-PGM-101	Informed multilevel governance of urban regions	Prof. Y. Georgiadou
U09-PGM-102	Land administration for informed governance	Prof. J. Zevenbergen, Prof. P. van der Molen
U09-WRS-100	Managing water scarcity	Dr. M. Lubczynski
U09-GIP-100	Spatial data infrastructure technology	Dr. R.A. de By
U09-GIP-101	Spatio-temporal data integration and visualization	Prof. M.J. Kraak
U09-PGM-103	Sustainable urban-regional dynamics	Prof. F.A.M. van Maarseveen
U09-EOS-100	Stochastic methods for image mining and data quality	Prof. A. Stein
U09-EOS-101	Utilisation of sensor developments for efficient topographic mapping	Prof. M.G. Vosselman
U09-WRS-101	Water cycle climate	Prof. Z. Su, Prof. W. Verhoef

For more information about the content and scope of the ITC research themes, please visit: http://www.itc.nl/research/themes.asp

Contents

Two main activities run parallel in Module 14 and 15:
1. Finalizing the research proposal for the individual MSc thesis.
2. A group research project.

1. Finalizing the research proposal

The MSc research proposal is finalized by the student in mutual agreement with his/her MSc supervisors, appointed in Module 11. The research proposal should be a logical and ordered exposition of the envisaged research (as introduced in Module 11), including data availability, (fieldwork) methodology, a flowchart, and time allocation. All data should be available at the time of the proposal presentation. The research proposal should be presented before a Thesis Admission Committee (see MSc assessment regulations paragraph 5.1.1). Acceptance of the proposal is a prerequisite for the start of module 16. The MSc student will draft a supervision plan with the two appointed MSc supervisors.

2. Group research project

The purpose of the group project is:
- To let students place their own MSc research project and research interests in a wider scientific context.
- To give students a possibility to practice conducting a research project before their individual MSc research project.
- To give students an opportunity to practice doing research in a team.
- To give students the opportunity to share their knowledge in a multi-disciplinary context.

These are considered important as a preparation for conducting the individual MSc research in Block 4, as well as the professional academic working practice afterwards in which projects are often conducted in multi-disciplinary groups.

Research projects can be defined by one or several research themes. In any case, the projects are defined with a wide angle in order to cater for a variety of research approaches and interests, as well as the relevance for society. Projects are described with a title, a problem definition, and available dataset. The student group, consisting of a maximum of 5 students, is responsible for working this out into various activities according to an agreed plan. The student group has the freedom to make their own choices, supported by a tutor. The available projects will be made known early in 2009 in order to give the participants the opportunity to select a project that matches with their research interest. The choice has to be submitted before the start of module 11 (exact date to be specified) and should be justified within the MSc pre-proposal.

In a plenary session at the start of module 14, the Principal Investigator of the research group will introduce the various MSc subjects and their interrelation in the framework of the research of his/her group, and introduce the research assignments. A tutor will be appointed during module 14-15 to guide the students groups. The tutors will convene plenary sessions (in principle per research group) to monitor the progress of all participating students and exchange experiences in a discussion forum.

Objectives

Upon completion of these modules students will be able to:
1. Write an MSc research proposal.
2. Define ways how to tackle a scientific problem and structure research.
3. Place research projects in a wider scientific and societal context.
4. Structure scientific research to specifications of the scientific discipline.
5. Meet quality standards and excellence in research.
6. Present scientific information in written English at a standard acceptable to the scientific community.

Prerequisites

Completion of Module 1 to 13 of the MSc curriculum
Because the research themes will be taught at advanced level, it is necessary to have a basic level of knowledge in the chosen research theme. Students who want to choose a research theme which differs from their choice in Block 1 and 2, have to provide evidence that they have the right background.

Recommended Knowledge

To be specified per research theme.

Staff involved

Overall coordination: Dr. P.M. van Dijk, Director Graduate programme

- Research project coordinators appointed per research theme
- 2 MSc supervisors appointed beforehand for each participant

Hardware and Software Requirements

Identified per research theme

Teaching Materials

For each research theme a collection of resources will be available in the digital learning environment Blackboard, the library or in hard copy.

Allocated Time per Teaching Learning Method

L	SP	GA	IA	S	O
10		70	(120)	16 (+32)	(40)

Time (in # of hours) allocated per major method:
L lectures, (max. 10 = 5 hr/week during 2 weeks of project)
SP supervised practical,
GA group assignment (= Group Research Project, incl. supervision),
IA individual assignment (= MSc proposal writing, incl. supervision),
S self study (8hr/week = 48 hr outside normal class/office hours),,
O overhead (last week reserved for MSc proposal presentations).

Important:

The numbers are calculated for **two** modules: 96 hr (= 2 weeks) are allocated for the group research project, and 192 hrs (= 4 weeks) are reserved for the MSc proposal (=numbers between brackets).

Assessment

1. Group report of the research project
2. Individual written reflection report on the group research project
3. Individual MSc research proposal (written and oral presentation)

MSc Research and Thesis Writing

<table>
<tr><td colspan="2">Module: 16-23</td><td colspan="2" rowspan="3">Co-ordinating staff:
Dr. P.M. van Dijk, Director Graduate Programme
Course directors of all MSc courses
2 MSc supervisors per student</td></tr>
<tr><td>Start:</td><td>07-09-2009</td></tr>
<tr><td>End:</td><td>26-02-2010</td></tr>
<tr><td colspan="2">Level: MSC</td><td>AES, GFM, GSIM, LA, NRM, UPM, WREM</td><td>U09-EDU-111</td></tr>
</table>

Introduction

The final stage of the MSc course is dedicated to the execution of an individual research project. Each student works independently on an approved research topic (see module 15) connected to one of the 15 research themes of ITC. In the project the students develop their research skills further, interact with their fellow students, PhD's and staff members, and have to demonstrate that they have achieved the course objectives for the Master of Science degree by research, on academic level.

Contents

Based on the pre-proposal handed in before module 11, and the final accepted research proposal prepared in module 15, the student will carry out the planned activities. The students will be provided with guidelines for the thesis early in the course (specifically in module 11). Regular individual progress meetings with the supervisors will be held to monitor the progress on the research and thesis writing, and records of the progress will be kept. The supervisors keep the course director informed about the progress.

The activities normally include:

- Describe and define a problem statement and research topic and its research margins.
- In-depth literature review, including assessment of the usability of literature and previous research.
- Collection of relevant on-line and archived data.
- Preparation and execution of a (data collection) fieldwork (optional).
- Data processing and analysis and, if deemed necessary, adjustment of the research plan in consultation with the supervisors (based on sound arguments).
- Active participation in Institute seminars and *capita selecta* of the research theme under which the MSc research resorts.
- Mid-term presentation (first week of November).
- Preparation of the final manuscript of the MSc thesis (=hardcopy thesis and CD-rom with thesis, appendices and full dataset including original data and results).
- A critical review of quality, use and usefulness of the data and results, as well as the learning process.
- Oral presentation and defence of the MSc thesis before the Thesis Assessment Board, all in accordance with the relevant paragraphs of the MSc regulations.

Objectives

The student must be able to:

- Define, plan and execute a research project dealing with a problem related to the application of geo-information and earth observation in a domain that suits his/her background and course followed.
- Write a concise, logical and well structured thesis describing the key elements of the research process, the findings and recommendations.
- Orally present and defend the work done before the Thesis Assessment Board.

Prerequisites

Successful completion of MSc modules 1-15, and the ability to do research independently (ref. to par. 5.3.1. of the MSc regulations).

Recommended Knowledge

During the research phase, the students can specialise further in their own field of expertise.

Hardware and Software Requirements

Any hardware and software with authorisation of the MSc supervisors.

Allocated Time per Teaching Learning Method

L	SP	UP	GA	IA	S	O
				1136		16

Time (in # of hours) allocated per major method:
L lecture,
SP supervised practical,
UP unsupervised practical,
GA group assignment (e.g. workshop, project),
IA individual assignment (including Thesis, IFA),
S self study,
O overhead (e.g. QH, exam, opening)

Assessment

A Thesis Assessment Board (TAB) will carry out the individual assessment based on the thesis and a presentation plus defence. The assessed aspects are:

- Research skills
- Contribution to the development of the scientific field
- Independent working
- Critical and professional thinking
- Scientific report writing
- Presentation and defence

For further details on the regulations and thesis assessment, see:

- ITC Regulations for courses leading to an ITC Master of Science (M.Sc.) Degree (September 2008)
- Instructions for Thesis Assessment Board

ASSESSMENT REGULATIONS