Study Guide Land Surface Process Modelling (GEO4 - 4406)

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CHAPTER

ONE

CONTENTS

1.1 Course information

1.1.1 General information

Name of course: Land Surface Process Modelling

Course Code: GEO4-4406

ECTS: 7.5

Category / Level: M (Master)

Teaching period: 3

Contact hours: appr. 6 h / week

Language of instruction: English

1.1.2 Lecturers

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1.1.3 Place in curriculum and entry requirements

The course provides a theoretical and practical basis of spatio-temporal (process-based) modelling of land surface processes, and is relevant for all disciplines related to land surface processes (hydrology, land degradation, geomorphology, natural hazards, ecology). In addition is provides a background in geoinformatics which is relevant for appropriate use of modelling tools and GIS.

Entry requirements: you must have study entrance permit.

1.1.4 Aims and content

Numerical simulation models of processes on the earth surface are essential tools in fundamental and applied research in the geosciences. They are used in almost all disciplines in the geosciences, for instance hydrology, geomorphology, land degradation, sedimentology, and most fields in ecology. They are important instruments in research for a number of reasons. First, they provide understanding of how systems work, in particular how system components interact, how systems react to changes in drivers, and how non-linear responses emerge. Also, simulation models can be used to forecast systems, which is essential in planning and decision making. Finally, land surface process models provide a means to evaluate theory of simulated processes against observational data.

In this course we will focus on generic principles of land surface modelling. You will study a number of different approaches to represent land surface processes in a simulation model, including differential equations, rule based modelling, cellular automata, individual (agent) based approaches, and probabilistic models. We will discuss how local interactions in large systems can lead to complexity and the impliction of this for forecasting. Also, you will learn how to combine information from observational data and simulation models using error propagation, calibration, and data assimilation techniques.

During the course you will learn how these principles can be applied in a number of different disciplines, in particular in the field of hydrology, geomorphology, sedimentology, and ecology. You will also learn how very similar approaches are used in other fields, for instance in urban geography and social sciences.

In addition to principles of land surface modelling, you will learn how to use software tools for land surface modelling. You will study theoretical concepts of software environments for land surface modelling, and you will learn how to program land surface models. In this part of the course we will use the Python programming language and PCRaster. These tools provide standard frameworks for model construction and techniques to combine a model with observational data. Other tools for model construction use similar concepts, so you will be able to apply your knowledge from this course to other software environments.

The course aims are:

- To retrieve a theoretical basis of land surface modelling, including approaches to represent processes and approaches to combine data and models.
- To retrieve an understanding of how various systems in the geosciences are represented with land surface models.
- To learn principles of software environments for modelling and how to use these software environments.

1.1.5 Course outline (time table)

Course outline and schedule are provided in this document. You can also use https://mytimetable.uu.nl to get access to the schedule (like with all Utrecht University courses).

As shown in the outline of the course in the table below, the course consists of two blocks, Model Theory and Geoinformatics. These are run parallel in time. Model theory contains (web)lectures, a working group meeting, and paper assignments. Geoinformatics is taught mainly using computer practicals. At the end of the course you will do a personal project, consisting of a case study model and a written report. The detailed course schedule below gives the date and location of lectures, working groups, and computer practicals. It also provides due dates for the computer practicals and other assignments.

Important: this course is taught following the blended learning model, which implies we combine e-learning and classical learning methods. Note that a large part of the lectures is provided as e-lectures instead of lectures in a classroom. It is strongly recommended to follow the general course outline below strictly, also during self study (e.g. watch e-lectures and read the text in the reader related to a topic in the week the topic is scheduled in the general course outline below). Of course you can allow yourself some flexibility regarding the e-lectures, it is not forbidden to work ahead of time, of course.

Land surface process modelling: course outline									
week in year									
6	7	8	9	10	11	12	13	14	15
week in course									
1	2	3	4	5	6	7	8	9	10
Model Theory									
Intr. to land surface process model.	Local (point) models		Spatial Models	Stochastic Models	Agent-based models	Calibration			
							Personal Project	Personal Project	Personal Project
Geoinformatics (mainly lab work)									
Python Program.	Python Program.	Python Program.	Dynamic Modelling	Dynamic Modelling	Stochastic modelling	Stochastic modelling			
Short paper assignments									
	Intro. case		Spatial models						
Exams									
							Exam (all material)		
Final report on personal project									
									Final report

1.1.6 Calculation of final mark

For passing the course you need to:

- Submit answers to the questions of all computer labs (before the deadline),
- Active participation in working groups,
- Hand-in short paper assignment and report on the personal project in time,
- Get a final mark of 5.5 or higher.

The final mark M is calculated as:

M = 0.15A + 0.65B + 0.2C

with A, the average of the marks for the short paper assignments, B, the mark for the closed book exam, and C, the mark for the written report on the personal project. A, B, and C are not rounded.

Absence (for instance as a result of illness or family circumstances) during the exam must be agreed with the coordinator of the course in advance by phone or email. You need to hand over a sick note (medical certificate from your doctor) afterwards to get access to a resit.

The course has been passed if the final grade is >=5.5 and all obligations have been fulfilled. If not, and only in case the final grade is 4.00 or higher a repair exam (supplementary test) could be attended. If the repair exam has been successfully passed and all other obligations have been fulfilled, the final grade of the course will be 6.

For details on the above and further information, see the OER (Education and Examination Regulations).

1.1.7 Study material

All study material needs to be studied for the written exam, except material explicitly indicated as reading material in this document. This information (reading material) is provided in the sections Model Theory content and Geoinformatics content of this document.

Study material: syllabus, book, practicals

Land Surface Process Modelling, syllabus. Available from blackboard.

Articles to be downloaded by yourself (as indicated in this document).

Think Python, An introduction to software design, A. Downey, 2008, Green Tea Press, Needham, 234 pp. Chapters 1, 2, 3, 5, 6, 7, 8, 10, and 14. Online at http://www.greenteapress.com/thinkpython/thinkpython.html or order a print from blackboard.

Computer practicals Map Algebra, available in Blackboard.

Computer practicals Python, available in Blackboard.

Computer practicals modelling with PCRaster Python.

Lectures, powerpoints, and e-Lectures.

1.1.8 OSIRIS information on the course

Additional information is available at https://www.osiris.universiteitutrecht.nl/osistu_ospr/StartPagina.do

1.1.9 Tutor support

Tutor support: ask fellow students or email a lecturer.

1.2 Model Theory content

1.2.1 Introduction to land surface process modelling

Key topics

- General introduction to land surface process modelling.
- Forward modelling
- Aims of modelling
- Model development cycle

Literature for exam

Wainwright, J. and Mulligan, M., 2004, Modelling and model building, in: Environmental Modelling: finding simplicity in complexity, Second Edition. J. Wainwright, M. Mulligan (eds), p. 7-26, Wiley, Chichester.

Karssenberg, D., 2010, Introduction to dynamic spatial environmental modelling.

Burrough, P.A., McDonnel, R. & Lloyd, C.D., 2015, Principles of Geographical Information Systems, Oxford University press, Chapter 12, Space-time modelling and error propagation, p. 251-260.

Reading material

Karssenberg, D., Bridge, J.S., 2008, A three-dimensional numerical model of sediment transport, erosion and deposition within a network of channel belts, flodplain and hill slope: extrinsic and intrinsic controls on floodplain dynamics and alluvial architecture, Sedimentology, 55, 1717-1745. Link.

Lectures, e-Lectures

Lecture slides Introduction to land surface process modelling

Short paper assignment 1

Please read the excerpt from Wainwright & Mulligan (first edition) The excerpt distinguishes three type of models: empirical models, conceptual models, and physically based models. Read the paper by Karssenberg & Bridge (2008, reading material for this topic). Consider the following questions:

- What type of model is the model described in the paper (empirical, conceptual or physically based)?
- Would it be possible to model the same system using another approach (empirical, conceptual, or physically based)?

Write a 1.5-2.0 page (not longer, 12 points font size, single line spacing) short paper that gives a short summary of the paper, poses the above questions and provides an answer (and discussion) to these questions. Hand in by uploading to Blackboard (assignments section in Blackboard).

1.2.2 Local (point) models

Key topics

- Dynamic point models
- Numerical solution of differential equations

Literature for exam

Kreyszig, E., 1999, Numerical Methods for Differential Equations, in Advanced Engineering Mathematics, New York, N.Y., Wiley: p. 942-952.

Lectures, e-Lectures

Lecture slides Local point models

1.2.3 Spatio-temporal models: neighbourhood interaction

Key topics

- Neighbourhood interaction
- Neighbourhoods by a defined topology
- Dynamic neighbourhood models: cellular automata

Literature for exam

Burrough, P.A., McDonnel, R. & Lloyd, C.D., 2015, Principles of Geographical Information Systems, Oxford University press, Chapter 7, Analysis of discrete entities in space, p. 127-145, and Chapter 10, Analysis of continuous fields, p. 201-229.

Favis-Mortlock, D., 2004, Non-linear dynamics, self-organization and cellular automata models, in: Environmental Modelling: finding simplicity in complexity, J. Wainwright, M. Mulligan (eds), p. 45-67, Wiley, Chichester.

Reading material

Saco, P.M., Willgoose, G.R., Hancock, G.R., 2007, Eco-geomorphology of banded vegetation patterns in arid and semi-arid regions, Hydrology and Earth System Sciences, 11: 1717-1730. Link.

Lectures, e-Lectures

e-Lecture Neighbourhood interaction

e-Lecture slides Spatio-temporal models: neighbourhood interaction, pdf

Working group session

We will have a working group session on this topic.

To prepare for the session:

- Listen to the e-Lecture (see above for the link)
- Study the literature for the exam (related to this topic, see above)
- Create a group (consisting of two students)
- Prepare a 10 minute presentation (one per group), for topics see below

During the working group session:

- Bring your presentation (powerpoint or pdf) on a usb stick (computer is available).
- Each group gives a 10 minute presentation.
- After each presentation: 5 minutes discussion with questions

The presentation should describe an example of either 1) the use of cellular automata or 2) self organisation in the earth sciences (or related fields). Search the literature (use a bibliographic database, e.g. http://www.scopus.com) to find at least one paper on one these topics. Prepare a presentation which explains how cellular automata are used in the article or what kind of self organisation is described. If you want you can add items for discussion at the end.

Short paper assignment 2

Favis-Mortlock (2004, in the reader) discusses self-organizing systems and why feedback mechanisms may lead to self-organization. Read the paper by Saco et al. (reading material). In a short paper (1.5-2.0 pages, not longer, 12 points font, single line spacing), explain the concept of self-organization and discuss why the system studied by Saco et al. is a self-organizing system. In addition, provide the main feedback mechanisms that lead to the observed self-organization. Hand in by uploading in Blackboard.

1.2.4 Stochastic models (and error propagation)

Key topics

- Stochastic variables
- Probability distributions, categorial and continuous variables
- Properties of probability distributions: percentiles, confidence intervals
- Stochastic variables to represent uncertain model inputs and parameters
- Solving stochastic models: Monte Carlo simulation

Literature for exam

Karssenberg, D. de Jong, K., 2005, Dynamic environmental modelling in GIS: 2. Modelling error propagation. International Journal of Geographical Information Science, 19, p. 623-637.

Karssenberg, D., Schmitz, O., Salamon, P., De Jong, K. and Bierkens, M.F.P., 2010, A software framework for construction of process-based stochastic spatio-temporal models and data assimilation. Environmental Modelling & Software, 25, pp. 489-493.

Kreyszig, E., 1999, Data Analysis. Probability Theory, in Advanced Engineering Mathematics, New York, N.Y., Wiley, Chapter 22, the following pages:

- Pages 1050-1064, except 22.4 (Permutations and Combinations), Problem Sets and Examples

Reading material

No reading material.

e-Lectures

e-Lecture Introduction to Stochastic Modelling

e-Lecture Monte Carlo simulation

e-Lecture slides Stochastic models, Monte Carlo simulation, pdf

Lecture, Q&A session

During a Q&A session (it appears as 'lecture' in the course schedule) your tutor will answer questions related to this topic. You can also ask questions related to other topics that were treated during the course.

To prepare for the session:

- Listen to the e-Lectures on Stochastic Modelling and Monte Carlo simulation (see above for the links)
- Study the literature for the exam (related to this topic, see above)
- E-mail Derek Karssenberg (d.karssenberg@uu.nl) questions at least 1 day in advance of the Q&A session, we will discuss these topics during the Q&A.

1.2.5 Calibration of Environmental Models

Key topics

- Objective function
- Minimizing the objective function: hillclimbing, brute force and other techniques

Literature for exam

Beven, K.J., 2002, Parameter estimation and predictive uncertainty, in Rainfall-runoff modelling, the primer, Wiley, Chichester, p. 217-233.

Janssen, P.H.M, Heuberger, P.S.C., 1995, Calibration of process-oriented models, Ecological Modelling 83, 55-66.

Reading material

No reading material.

e-Lectures

e-Lecture Calibration - 01 Introduction

e-Lecture Calibration - 02 Objective Functions & Response Surfaces

e-Lecture Calibration - 02 Calibration Algorithms

Lecture slides Combining observations and models: calibration, pdf

1.2.6 Agent-based modelling

Key topics

- Agents vs Fields
- Agent representations
- Examples

Literature for exam

Macal, C.M., North, M.J., 2010, Tutorial on agent-based modelling and simulation. Journal of Simulation, 4, pp. 151-162.

Reading material

Bennett, D.A., Tang, W., 2006, Modelling adaptive, spatially aware, and mobile agents: Elk migration in Yellowstone. International Journal of Geographical Information Science, 20, pp. 1039-1066. Link.

Railsback, S.F., 2001, Concepts from complex adaptive systems as a framework for individual-based modelling. Ecological modelling, 139, pp. 47-62. Link.

e-Lectures

No e-Lectures.

1.3 Geoinformatics content (mainly computer labs)

1.3.1 Python programming

Key topics

- Principles of computer programming
- Python programming
- Introduction to object orientation

Literature for exam

Think Python, An introduction to software design, A. Downey, 2008, Green Tea Press, Needham, 234 pp. Chapters 1, 2, 3, 5, 6, 7, 8, 10, and 14., online at http://www.greenteapress.com/thinkpython/thinkpython.html

e-Lectures

e-Lecture Programming Python - 01 Introduction

e-Lecture Programming Python - 02 Variables, expressions, statements

e-Lecture Programming Python - 03 Functions

e-Lecture Programming Python - 04 Conditionals and user intervention

e-Lecture Programming Python - 05 Fruitful functions and program development

e-Lecture Programming Python - 06 Strings

e-Lecture Programming Python - 07 Lists

e-Lecture Programming Python - 08 Files

e-Lecture slides Python programming, pdf

Computer lab

Available at the PCRaster site, please ask your tutor for the password.

1.3.2 Map Algebra

Key topics

- Static modelling with PCRaster
- Point operations and neighbourhood operations

e-Lectures

e-Lecture Introduction to Map Algebra

e-Lecture Map Algebra Operations

e-Lecture slides Map Algebra, pdf

Computer lab

Map algebra course, available in Blackboard. In Blackboard, go to 'Communities', select the community 'PCRaster Python - Map Algebra' and go to 'My Tasks', 'Assignment'.

Literature for exam

Burrough, P.A. & McDonnel, R., Principles of Geographical Information Systems, Oxford University press, Chapter 7, The analysis of discrete entities in space, p. 162-170, and Chapter 8, Spatial analysis using continuous fields, p. 183-209. (Note: this is the same literature that also need to be studied for Model Theory, Spatial Models)

1.3.3 Dynamic modelling with PCRaster Python

Key topics

- Forward modelling
- Importing / reporting to the database
- Point models

Spatial models with neighbourhood interaction

Computer lab

Available in Blackboard.

Reading material (not for exam)

Karssenberg, D., De Jong, K. and Van der Kwast, J., 2007, Modelling landscape dynamics with Python. International Journal of Geographical Information Science, 21, pp. 483-495. Link. This article explains how you can construct dynamic models using the PCRaster Python framework.

Lectures, e-Lectures

e-Lecture Dynamic Modelling with PCRaster Python, part 1

e-Lecture Dynamic Modelling with PCRaster Python, part 2

e-Lecture Dynamic Modelling with PCRaster Python, part 3

e-Lecture slides PCRaster Python, pdf

1.3.4 Stochastic modelling with PCRaster Python

Key topics

- Defining probability distributions as inputs to models
- Monte Carlo simulation

Computer lab

Available in Blackboard.

1.4 Personal Project

1.4.1 Introduction

Choose one of the topics below and email me your choice of the topic. It is obligatory to work in a couple; this means you do all the work together, including writing the report. You will both get the same mark.

Most topics include literature study and modelling. The last topic however includes literature study only.

Before starting, it is important to define research questions. This will determine what modelling work you will do and how you will report on the modelling results. For some topics I give hints for research questions (see below).

Keep your model simple. Note that you have little time to develop your model.

The report should be written as a scientific article with the following structure:

- Abstract
- Introduction (problem definition, research questions or objectives, outline of the rest of the paper)
- Methods (here: description of the model and/or scenarios done)
- Results (provide results of model simulations, without extensive discussion)
- Discussion and conclusions (discuss results, compare with other studies, provide main findings)
- References

For the last topic (without modelling) you are allowed to use a different structure for the paper.

The report should not be longer than 4 pages (12p font, single line spacing). If needed you can provide tabulated data, additional figures, or details on implementation of the model as an appendix.

Tutor support is provided during the scheduled lab hours (see the course schedule) or on request by e-mail or by passing by at your tutors' office, in case it is urgent.

1.4.2 Topics

Land degradation modelling

Indication for the content of the topic: literature study 20%, modelling 40 %, writing report 40%.

The output from rainfall-runoff models can be used to calculate water erosion. Extend the snowmelt model (the one you used in the dynamic modelling exercises) with a component that calculates a map with the total amount of water erosion over the winter season (180 days simulated by the model).

Use the Morgan, Morgan and Finney model described in Morgan, R.P.C., 2005, Soil Erosion and Conservation, Blackwell. You at least need to include detachment of soil by raindrop impact and runoff, ignoring the transport capacity (i.e. assuming everything can be transported).

Compare modelled soil loss with tabulated values from the literature (to see whether the order of magnitude of the modelled values is correct); this could be one of your research questions.

Download dataset and model.

Email me if you would like to borrow the Morgan (2005) book.

Early warning signals of critical transitions

Indication for the content of the topic: literature study 40%, modelling 20 %, writing report 40%.

In the dynamic modelling practicals you developed a vegetation model with a critical transition to lower biomass when a threshold of grazing pressure is exceeded. It is notably difficult to predict such critical transitions as the change in biomass is very low before the transition occurs. However early warning signals exist that show a change well ahead of a transition. These include spatial variance of biomass (you calculated this in the exercise), spatial skewness of biomass, and so-called 'flickering'.

Study the literature below. Extend the vegetation growth model (the one you constructed during the practicals) with calculation of spatial skewness of biomass (calculated over the map for each timestep, just like variance). Compare the two early warning signals (variance and skewness) regarding their capability to forecast the transition. If you want you can do this for different scenarios of model parameters (e.g., spatial diffusion parameter).

Download dataset and model.

Literature:

- Dakos V., van Nes E.H., Donangelo R., Fort H. & Scheffer M. (2009). Spatial correlation as leading indicator of catastrophic shifts. Theor. Ecol., 3, 163-175.
- Guttal V. & Jayaprakash C. (2009). Spatial variance and spatial skewness: Leading indicators of regime shifts in spatial ecological systems. Theor. Ecol., 2, 3-12.
- Scheffer M., Bascompte J., Brock W.A., Brovkin V., Carpenter S.R., Dakos V., Held H., Van Nes E.H., Rietkerk M. & Sugihara G. (2009). Early-warning signals for critical transitions. Nature, 461, 53-59.

Hydrological model: calibration

Indication for the content of the topic: literature study 5%, modelling 65%, writing report 30%.

In this assignment you will calibrate the snowmelt model developed in the practical exercises. You need to calibrate on the observed discharge at the outflow point. Have a look at the script included in the zip file for some helper functions and explanation of the data set. Choose the calibration method yourself. It is recommended to use a brute force technique. Decide yourself which parameters to calibrate, but be sure to include the snow melt parameter.

Download dataset and model.

Land use change modelling using cellular automata

Indication for the content of the topic: literature study 10%, modelling 60%, writing report 30%.

Cellular automata is a type of model that uses local neighbourhood interactions to simulate the larger scale behaviour of a spatio-temporal system. These local neighbourhood interactions are given by transition rules valid for each cell on a grid of cells, where the state of a cell changes over a timestep as a function of the state of cells of directly neighouring cells. Cellular automata are widely used in the spatial sciences, e.g. for modelling plant growth and spread, modelling forest fire spreading, modelling growth of bacteria on leaves of vegetation, modelling socio-economic systems. The aim of this topic is to learn more about cellular automata modelling in general, by studying literature. In addition you will construct a simple cellular automata model of expansion of cities (Randstad, the Netherlands). Start with the landuse situation in 2000 (as represented by the data set) and try to simulate the change in landuse over the coming decennia. Use simplified landuse change transition rules - the approach is more important than the outcome! Alternatively, there is a possibility of using an existing (large) land use change model that you can use for a case study area in Mozambique (e.g. for a scenario analysis).

Literature:

Torrens, P.M., 2000, How cellular models of urban systems work (1. theory). Centre for advanced spatial analysis, working paper series. Paper 28. Available at http://www.bartlett.ucl.ac.uk/casa/publications/working-paper-28

Batty M., Xie Y., Sun Z., 1999. Modeling urban dynamics through GIS-based cellular automata. Computers, Environment and Urban Systems 23:205-233. To retrieve this paper, email me and I will email you the pdf.

White, R. 1998. Cities and Cellular Automata. Discrete dynamics in Nature and Society 2:111-125. To retrieve this paper, email me and I will email you the pdf.

Download dataset and model.

Download information regarding the data set.

Validation of models in the earth sciences

Indication for the content of the topic: literature study 50%, writing report 50%.

In 1994 Oreskes et al published a paper discussing validation of numerical models in the earth sciences. Their main message was that validation of models is not possible. This raised a lot of dicussion in the earth science community. You can find hundreds of papers citing the Oreskes paper. Read the paper by Oreskes and collect a number of other papers on the same topic (e.g. those that cite Oreskes). In your report either provide a review of these papers or provide a discussion on validation of models in the earth sciences. This topic is a good choice if you are interested in philosophy of science.

Literature:

- Oreskes N., Shrader-Frechette K. & Belitz K. (1994). Verification, validation, and confirmation of numerical models in the earth sciences. Verification, validation, and confirmation of numerical models in the earth sciences, Science, 263, 641-646.

1.4.3 Writing a short paper: checklist, misc. recommendations

- Do not hand in a report that is longer than the maximum number of pages allowed (see above).
- Hand-in your report in time. See the course schedule for the deadline.
- Use Italics (‘cursief’) for all symbols in equations or in the text. However a vector (‘list of values’) is mostly given in bold. The style in the equations and in the main text should correspond.
- Avoid multi symbol variables or parameters in equations. E.g. Evap = Soilwater / SoilP . Better: E = s/a. Use subscribts when you have many parameters and variables. Note however that in programming, the use of long variable names (that describe the content of the variable) names is recommended.
- Do not write like in a diary (‘First we did this,. . . . Then we started to realize.. and we did this and that. . . ’).
- Put larger blocks of computer code (say, more than 2 lines) in a table instead of inserting it in the main text. Whole programs should be given in an appendix.
- Use a main (cover) title that makes sense.
- Provide quantitative data in figures (bar graphs, line graphs, scatter plots, use e.g. Excel, Splus), not tables. It is allowed using a table but it is almost always better using figures.
- If you write the report with Microsoft Word, use Microsoft Equation editor (available in Word) for equations. Do not copy paste bitmaps (gif or tifs) of equations from other docs into your paper.
- Number equations - always (provide the number after the equation, e.g, (3)).
- Check out an article from a scientific journal (e.g. from your reader) and use that as an example for formatting, layout, use of figure captions, literature references, etc.
- Do not use language as if you are talking (spreektaal)
- When you submit your report by email, put everything in one file (word or pdf). Do not send a whole bunch of files (it is too much work printing everything).
- Describe content in a logical order, instead of describing content in the order you dealt with it while modelling. So, do not use sentences like ‘eerst deden we dit, toen zijn we dat gaan doen, etc..).
- Use a spellchecker (always)
- A caption of a figure or table should at least explain all symbols used in the figure or table. The same holds for an appendix. In principle, the table/figure should be understandable without reading the main text (although there are exceptions to this rule)

- Provide figure legends (always)
- If a figure contains a map, provide a scale (scale bar)
- Do not hand in black and white prints of color figures (never.., even not when emailing originals..)
- Use the same format for each reference in your literature list and refer to the references in the text.
- Number the sections in your report, provide these numbers also in the contents Preferably use some kind of hierarchical numbering, for instance 1 1.1 1.1.1 1.1.2 2 2.1 2.2 etc
- Number figures and tables. In the main text, refer to figures or tables by using these numbers.
- All literature refered to in the main text should appear in the literature/references section at the end of the report. Check this in detail before handing in!
- Do not mix past and present tense. Sometimes it is possible, but in many cases it is better to stick to past or present tense.
- Avoid the use of 'I' or 'we' (1e persoon). However you can use it sometimes (if you really want and think it is apprpriate).
- If you use a figure from a book or another report, always provide the reference.
- Do not use English terminology in a report written in Dutch when correct Dutch terms are available (e.g. 'catchment' = 'stroomgebied')
- Have a look at comments on earlier papers you wrote. Take them into account when writing your next paper.
- Provide units (all variables in equations)!
- Avoid the use of abbreviations.
- Do not use 'etc.'
- Provide page numbers.
- Write concise. Also, do not add figures that could be left out. And, if possible combine to figures in one figure (e.g. two lines (of the same attribute) in a graph is better than two graphs each with one line). You can also use panels, Fig 1A, Fig 1B, etc.
- Use every page from top to bottom (apart from last pages of very long sections), do not include too much whitespace!
- Do not just copy-paste figures (maps) from screen. Adjust colors, add a legend, remove MS Windows bars, buttons, check size of text or modify text, etc. Use a graphics package (e.g. Freehand, Paintshop or whatever).
- Try to come up with interesting results (do not just list all results from your model, but try to emphasize the most interesting results). But note that this should always fit with the goals of your research (if needed adjust these goals).
- Use courier font for computer code, PCRaster scripts, or filenames. Also in the main text (not just in tables).
- In a paper reporting research in the geosciences, you should avoid the use of computer code to explain calculations. Many people will not know the programming language you used, and they won't understand the code. Instead, explain calculations using mathematical equations. If you write a report on a geoinformatics related topic (e.g. how you construct a piece of software) you *can* however include code as code is the topic of your research.
- Use a good dictionary. If you do not have one, buy one. I could recommend Longman Dictionary of Contemporary English (http://www.longman.com/ldoce). Or use the online version at http://www.ldoceonline.com. Google translate is also useful.
- Read through the text and correct all small (or large..) errors (typos for instance) before handing in!
- Do not use a title that ends with a ':'. For instance, do not use the title 'Discussie:'

- Do not come up with things in the Conclusions section that have not been described earlier in the paper.
- 'Introduce' an equation. Do not just put your equations somewhere between the text. You need to introduce it by stating e.g. 'Evapotranspiration is calculated as: '. Below the equation be sure to explain ALL symbols (except if they were explained earlier, however it does not hurt explaining a symbol again if it was explained 10 pages back..).
- Do not write 'wouldn't', 'doesn't', etc.

1.5 Contact hours

Week	Start	Duration	Type	Location(s)	Description
6	Monday, 5 February 2018 09:00	01:45	GEO - Lecture	UNNIK - 209 (40)	Introduction
6	Monday, 5 February 2018 11:00	01:45	GEO - Computer practical	UNNIK - 108 (50)	Python
6	Wednesday, 7 February 2018 09:00	03:45	GEO - Computer practical	UNNIK - 101 (44)	Python
7	Monday, 12 February 2018 09:00	01:45	GEO - Lecture	UNNIK - 209 (40)	Local (point) models
7	Monday, 12 February 2018 11:00	01:45	GEO - Computer practical	UNNIK - 108 (50)	Python
7	Wednesday, 14 February 2018 09:00	03:45	GEO - Computer practical	UNNIK - 101 (44)	Python
7	Friday, 16 February 2018, 17:00		Assignment 1	Blackboard upload	Upload in Blackboard
8	Monday, 19 February 2018 09:00	03:45	GEO - Computer practical	UNNIK - 108 (50)	Python
8	Wednesday, 21 February 2018 09:00	03:45	GEO - Computer practical	UNNIK - 105 (44)	Python
8	Friday, 23 February 2018 17:00		Answers Python Practicals	Blackboard upload	Upload in Blackboard
9	Monday, 26 February 2018 09:00	01:45	GEO - Working group	UNNIK - 209 (40)	Neighbourhood interaction
9	Monday, 26 February 2018 11:00	01:45	GEO - Computer practical	UNNIK - 108 (50)	Map Algebra
9	Wednesday, 28 February 2018 09:00	03:45	GEO - Computer practical	UNNIK - 105 (44)	Dynamic Modelling
10	Monday, 5 March 2018 09:00	01:45	GEO - Lecture: questions based	UNNIK - 209 (40)	Stochastic models
10	Monday, 5 March 2018 11:00	01:45	GEO - Computer practical	UNNIK - 108 (50)	Dynamic Modelling
10	Wednesday, 7 March 2018 09:00	03:45	GEO - Computer practical	UNNIK - 105 (44)	Dynamic Modelling
10	Friday, 9 March 2018 17:00		Assignment 2	Blackboard upload	Upload in Blackboard
10	Friday, 9 March 2018 17:00		Answers Map Alg & Dyn Mod	Finish in Blackboard	Answer questions in Blackboard
11	Monday, 12 March 2018 09:00	03:45	GEO - Computer practical	UNNIK - 108 (50)	Stochastic Modelling
11	Wednesday, 14 March 2018 09:00	03:45	GEO - Computer practical	UNNIK - 105 (44)	Stochastic Modelling
12	Monday, 19 March 2018 09:00	01:45	GEO - Guest lecture	UNNIK - 209 (40)	Oliver Schmitz, Meng Lu
12	Monday, 19 March 2018 11:00	01:45	GEO - Computer practical	UNNIK - 108 (50)	Stochastic Modelling
12	Wednesday, 21 March 2018 09:00	03:45	GEO - Computer practical	UNNIK - 105 (44)	Stochastic Modelling
12	Friday, 23 March 2018 17:00		Answers Stoch Mod	Finish in Blackboard	Answer questions in Blackboard
13	Monday, 26 March 2018 09:00	03:45	GEO - Computer practical	UNNIK - 106 (44)	Personal Project
13	Wednesday, 28 March 2018 09:00	03:00	GEO - Exam	EDUC - ALFA (150)	
14	Wednesday, 4 April 2018 09:00	03:45	GEO - Computer practical	UNNIK - 105 (44)	Personal Project
15	Monday, 9 April 2018 09:00	03:45	GEO - Computer practical	UNNIK - 106 (44)	Personal Project
15	Wednesday, 11 April 2018 09:00	03:45	GEO - Computer practical	UNNIK - 105 (44)	Personal Project
15	Friday, 13 April 2018 17:00		Personal Project		E-mail to d.karssenberg@uu.nl

Contact hours with classroom reservations in Syllabus+	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Week 9	Week 10	Week 11	Total
Lecture	2	2		2	2		2					10
Tutorial/(computer) practical/workshop/semin- ar	6	6	8	6	6	8	6	4	4	8		62
exam, preliminary examination, computer test								3				3
Other, e.g. presentations												0
Programmed contact hours without classroom reservation												
Field work												0
Excursion												0
Atelier												0
Meeting between lecturer and student (real life or digital)												0
Supervision of paper/ assignment (real life or digital)		2		2				2				6
Open office hours lecturer (real life or digital)								4	4	4		12
Peer feedback (real life or digital)			2		2		2					6
Inter-student meetings (real life or digital)												0
Self-tuition hours												0
Total	8	10	10	10	10	8	10	13	8	12	0	99