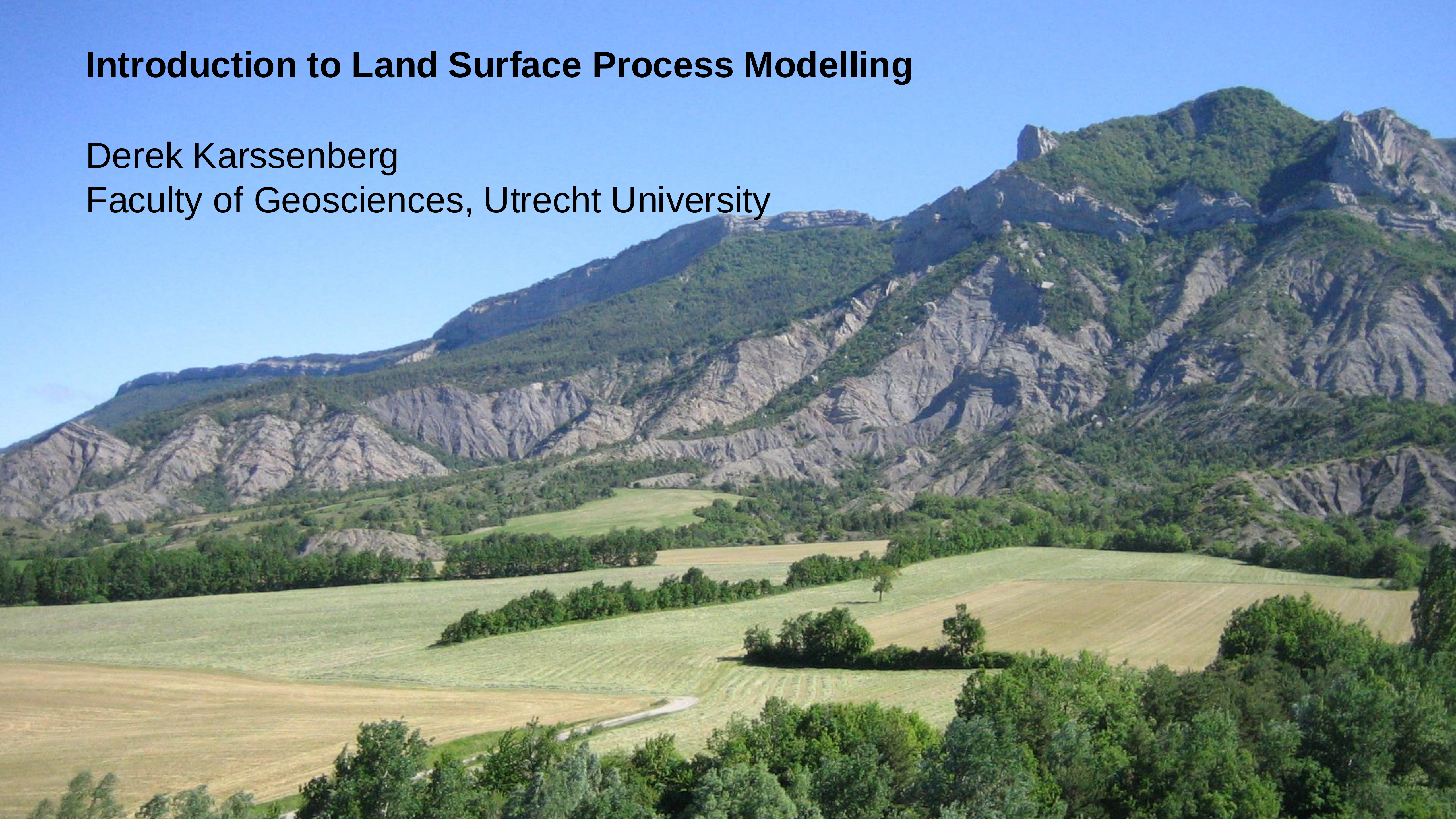
Introduction to Land Surface Process Modelling

Derek Karssenberg
Faculty of Geosciences, Utrecht University



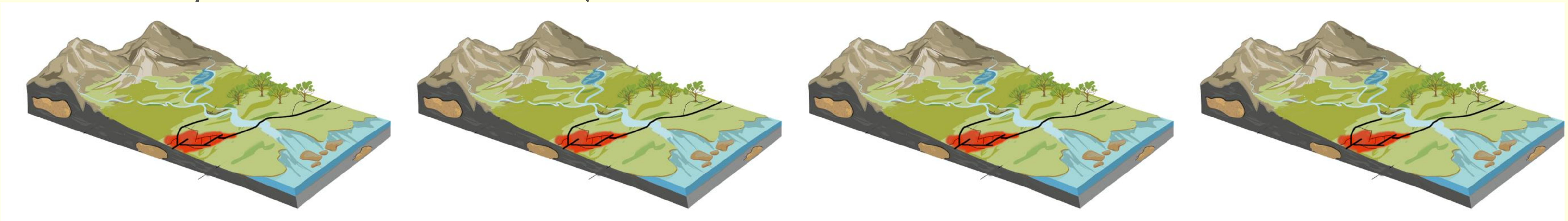
What are the two major groups of modelling approaches employed in Earth Sciences?

How are these models created (what do they rely on)?

	Process-based models	**Statistical models**
Also	Physically-based, numerical models, simulation models, mechanistic models	Machine Learning models
Rely on	Theory (and observations)	Observations (and theory)
Good for	Understanding (and predictions)	Predictions (and understanding)

Spatio-temporal simulation model

calculation calculation calculation calc

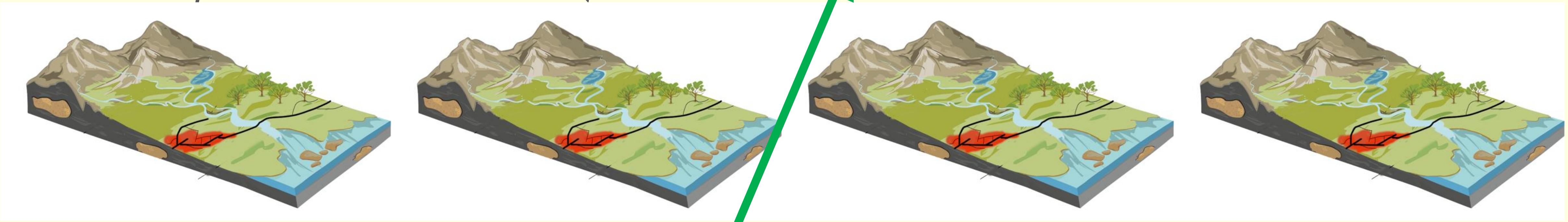


Timestep 1 2 3 4

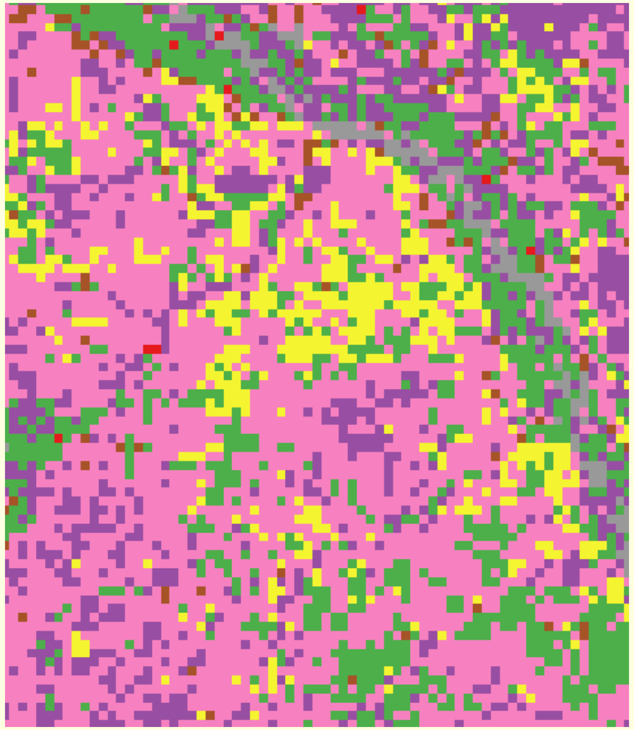
- Mimics processes that occur in a spatio-temporal system
- Runs forward in time

Spatio-temporal simulation model

calculation calculation calculation calc



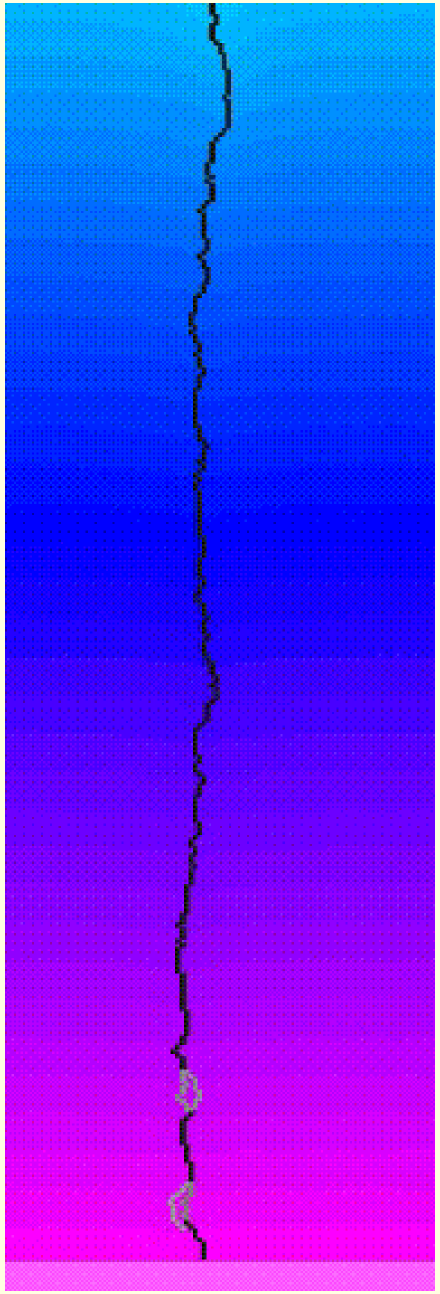
Does this change over time?



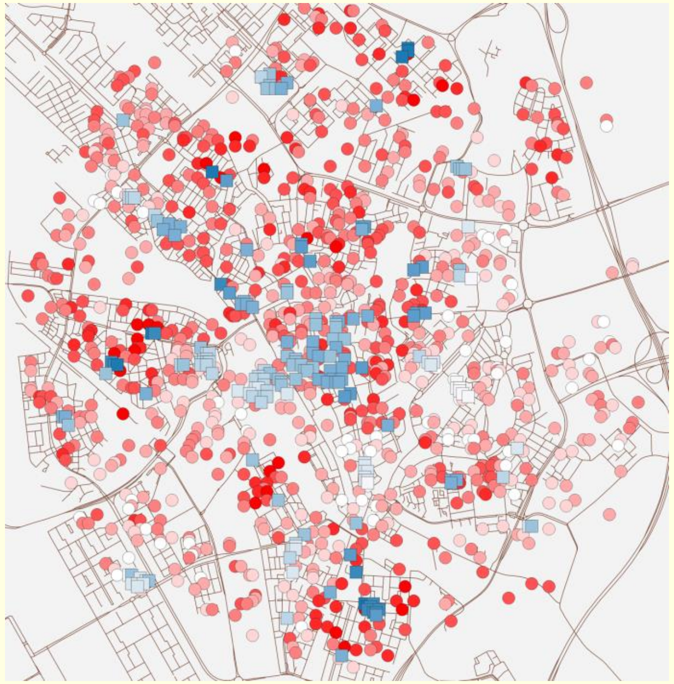
Verstegen et al., 2012

Changes in land use, Mozambique

Fluvial sedimentology



Karssenberg et al., 2008



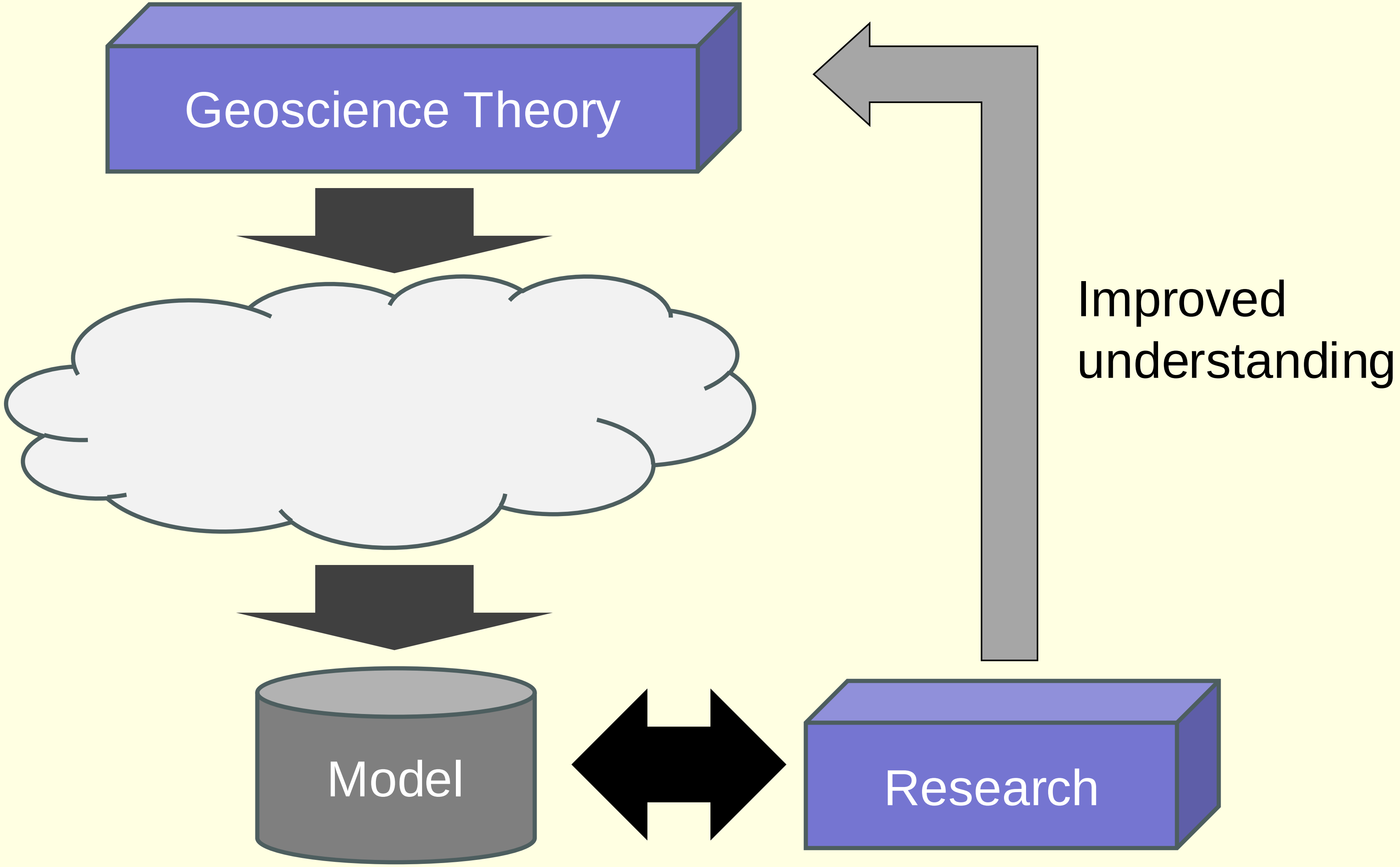
Schmitz & Karssenberg, 2023

Dietary habits and food environment

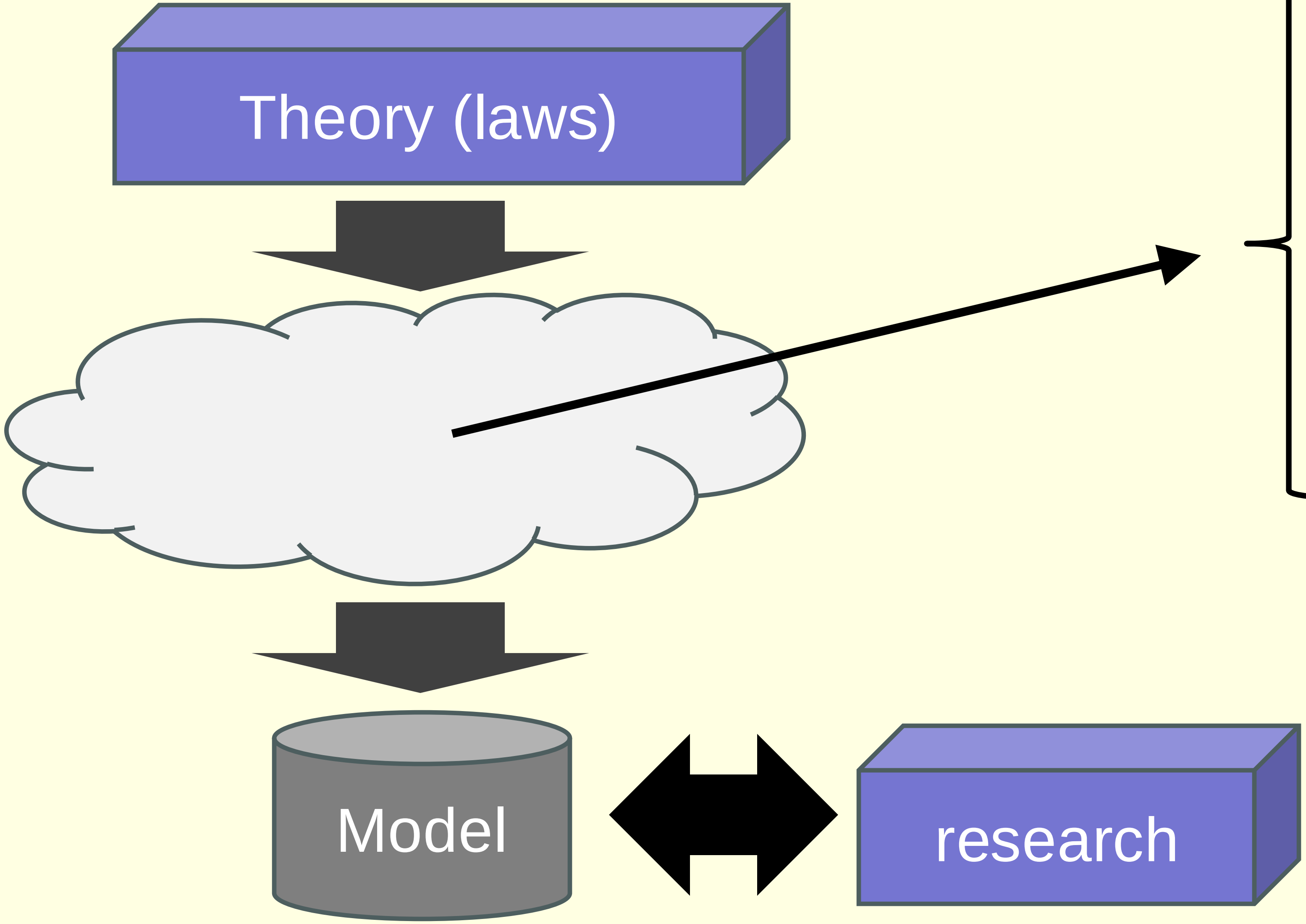
Spatio-temporal simulation models: examples

- Understanding how vegetation influences water erosion
- Forecasting streamflow of large rivers under climate change
- Evaluating scenarios of human activity for disease spreading
- Forecasting land use change in Netherlands 2020 – 2050
- Understanding the formation of fluvial deposits
- …

Learning outcomes & course components



Learning outcomes & course components



- Model Theory ~ 40%
  - Model concepts: field-based, agent-based, stochastic, …
  - Use of observations: model calibration
- Model Tools ~ 40%
  - Coding the model
- Case study ~ 20%

Lecturers (1)

Derek Karssenberg - Coordinator

- Computational Geography, http://www.computationalgeography.org
- Hydrology, geomorphology, energy science, geography & health
- https://www.uu.nl/staff/djkarssenberg

Oliver Schmitz – Simulation modelling labs

- Computer science & simulation modelling
- Hydrology, Human Environmental Exposures, agent-based modelling
- https://www.uu.nl/staff/oschmitz

Kor de Jong – Simulation modelling labs

- Computer science
- Cluster computing (for large models / data sets)
- https://www.uu.nl/staff/KdeJong1

Lecturers (2)

Edwin Sutanudjaja – Simulation modelling labs

- Simulation modelling
- Hydrology
- https://www.uu.nl/staff/EHSutanudjaja/

Saeb Faraji Gargari – Simulation modelling labs

- Simulation modelling
- Computational Fluid Dynamics
- https://www.uu.nl/staff/SFarajiGargari

Oriol Pomarol Moya – Simulation modelling labs

- PhD student
- AI & Simulation modelling
- https://www.uu.nl/staff/opomarolmoya

What is your background?

www.wooclap.com

Code FZAENM

Course Outline

Course outline									
week in year									
6	7	8	9	10	11	12	13	14	15
Start day									
03/02/2025	10/02/2025	17/02/2025	24/02/2025	03/03/2025	10/03/2025	17/03/2025	24/03/2025	31/03/2025	07/04/2025
week in course									
1	2	3	4	5	6	7	8	9	10
Model Theory									
Introduction	Local Models	Spatial Models	Stochastic Models	Agent-based models	Calibration			**Personal project**	
Model Tools									Presentation on Project
Python Programing	Python Programming, Map Algebra	Dynamic Modelling	Stochstic Modelling	Agent-based modelling	Calibration	Calibration	Project proposal		Report on Project
Short paper assignment									
			first version		second version				
Exam									
						Exam			

Model Theory

Course outline									
week in year									
6	7	8	9	10	11	12	13	14	15
Start day									
03/02/2025	10/02/2025	17/02/2025	24/02/2025	03/03/2025	10/03/2025	17/03/2025	24/03/2025	31/03/2025	07/04/2025
week in course									
1	2	3	4	5	6	7	8	9	10
Model Theory									
Introduction	Local Models	Spatial Models	Stochastic Models	Agent-based models	Calibration			**Personal project**	
Model Tools									Presentation on Project
Python Programing	Python Programming, Map Algebra	Dynamic Modelling	Stochastic Modelling	Agent-based modelling	Calibration	Calibration	Project proposal		Report on Project
Short paper assignment									
			first version		second version				
Exam									
						Exam			

Contents of the course: 1. Model Theory

- Modelling approaches
  - Differential equations (local models)
  - Spatial models and cellular automata
  - Stochastic models (or probabilistic models)
  - Agent-based models (or individual based models)

- Combining observations and data
  - Error propagation modelling
  - Model calibration (historical data)

Contents of the course: 1. Model Theory

Study material:

- Reader
  - Study material for exam
- Powerpoint sheets
- eLectures

The reader is available for download from Blackboard or can be ordered from there as a hardcopy!

Contents of the course: 1. Model Theory

Form (1):

- e-Lectures (pre-recorded)

- Question-based lecture, weekly

  Preparation for question-based lecture:
    - Listen to the eLectures (online)
    - Study related literature (reader, additional material if needed)

  During question-based lecture:
    - Answer and discuss questions

Contents of the course: 1. Model Theory

Form (2):

- Working group on neighborhood interaction (groups of 3 students)

  Preparation for working group meeting:

  - Listen to the eLecture
  - Study related literature (reader, additional material if needed)
  - Prepare a short presentation related to the material (topics will be provided), one presentation per group

  During working group meeting:

  - Presentations by students
  - Discussion related to presentation

Contents of the course: 1. Model Theory

Form (3):

- Short paper assignment
  - Topic / questions provided
  - Related to one or more articles in reader
  - Work in a group of 2 students
  - 2 versions with feedback on version 1
  - Max. 1000 words

Model Tools

Course outline									
week in year									
6	7	8	9	10	11	12	13	14	15
Start day									
03/02/2025	10/02/2025	17/02/2025	24/02/2025	03/03/2025	10/03/2025	17/03/2025	24/03/2025	31/03/2025	07/04/2025
week in course									
1	2	3	4	5	6	7	8	9	10
Model Theory								**Personal project**	
Introduction	[illegible]	Spatial Models	Stochastic Models	Agent-based models	Calibration				
Model Tools									Presentation on Project
Python Programing	Python Programming, Map Algebra	Dynamic Modelling	Stochstic Modelling	Agent-based modelling	Calibration	Calibration	Project proposal		Report on Project
Short paper assignment									
			first version		second version				
Exam									
						Exam			

Contents of the course: 2. Model Tools

Topics:

- Python programming
- Static modelling: Map Algebra with PCRaster Python
- Temporal (dynamic) modelling with PCRaster Python
- Stochastic modelling with PCRaster Python
- Agent-based modelling with Campo (Python module)
- Calibration with PCRaster Python

Contents of the course: 2. Model Tools

Study material:

- Think Python book, 2nd edition
- Powerpoint slides
- Computer practicals
- eLectures

The reader is available for download from Blackboard or can be ordered from there as a hardcopy!

Contents of the course: 2. Model Tools

Form:

- eLectures

- Computer practicals (groups of 2 students)
    - Available in Blackboard (click on ‘Communities’)
    - Fill in questions in Blackboard (most labs) or upload answers to questions as text document (agent-based modelling labs only)
    - During lab hours
    - Self study (outside lab hours)

Written Exam

- On Campus, written on paper
- Open Book exam (bring your laptop if you like)
- Questions on all study materials
- Some questions in context of research paper that you receive ~2 days in advance
- Details: refer to online study guide

Case Study Project

Course outline									
week in year									
6	7	8	9	10	11	12	13	14	15
Start day									
03/02/2025	10/02/2025	17/02/2025	24/02/2025	03/03/2025	10/03/2025	17/03/2025	24/03/2025	31/03/2025	07/04/2025
week in course									
1	2	3	4	5	6	7	8	9	10
Model Theory									
Introduction	Local Models	Spatial Models	Stochastic Models	Agent-based models	Calibration			**Personal project**	
Model Tools									Presentation on Project
Python Programing	Python Programming, Map Algebra	Dynamic Modelling	Stochstic Modelling	Agent-based modelling	Calibration	Calibration	Project proposal		Report on Project
Short paper assignment									
			first version		second version				
Exam									
						Exam			

Contents of the course: 3. Case Study Project

Work in groups of 3 students

Modelling work or literature study

Topics: see website http://karssenberg.geo.uu.nl/lspm

Form:

- Research proposal (with feedback)
- Report
- Presentation on project (last week of course)
- Self study
- Scheduled hours in computer lab (see course schedule), tutor support

Planning your work: stick to the activities scheduled for each week

Course outline									
week in year									
6	7	8	9	10	11	12	13	14	15
Start day									
03/02/2025	10/02/2025	17/02/2025	24/02/2025	03/03/2025	10/03/2025	17/03/2025	24/03/2025	31/03/2025	07/04/2025
week in course									
1	2	3	4	5	6	7	8	9	10
Model Theory									
Introduction	Local Models	Spatial Models	Stochastic Models	Agent-based models	Calibration			**Personal project**	
Model Tools									Presentation on Project
Python Programing	Python Programming, Map Algebra	Dynamic Modelling	Stochstic Modelling	Agent-based modelling	Calibration	Calibration	Project proposal		Report on Project
Short paper assignment									
			first version		second version				
Exam									
						Exam			

Planning your work: suggested weekly schedule

	Monday	Tuesday	Wednesday	Thursday	Friday
Morning	**computer labs**	eLectures, reading, labs	**computer labs + QB lecture**	labs	labs
Afternoon	eLectures, reading, labs	prepare questions for question-based lecture	eLectures, reading, labs	labs	finish labs / short paper, prepare for next week
5:15-7:00 pm		**Computer labs (self study, lab room booked)**			

focus on topic scheduled for the week

This week: introduction

karssenberg.geo.uu.nl

2.1. Introduction to land surface process modelling, week 1

2.1.1. Key topics

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

2.1.2. 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.

2.1.3. 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.

2.1.4. Lectures, e-Lectures

e-Lecture Introduction to simulation modelling

Lecture slides Introduction to simulation modelling

Table of Contents

Group work

- Computer Labs: group of 1 or 2 students (what you prefer; recommended is 2 students)
- Short Paper Assignment: group of 2 students
- Working Group: group of exactly 3 students (exceptions may apply)
- Case Study: group of exactly 3 students (exceptions may apply)

Self-subscribing to groups:

Blackboard -> Course Content

Please do so also if you work alone (thanks).

Illness

- If you are ill for several days, please inform Derek Karssenberg by e-mail on this (only to stay informed and to arrange an alternative work schedule)
- Exam: if you are ill, please inform Derek Karssenberg by e-mail (-> exam on other date)
- If you are ill the normal OER regulations apply of course

Please note:

Active participation is required for working groups and personal project presentation

For all other activities it is recommended to come to the campus (not required)

Communication

During lab hours: in lab room

- Ask staff in lab room 1.14

Outside lab hours: e-mail (no instant response)

- Questions on labs: join the computer labs at the scheduled hours and ask
- Personal questions related to course: send e-mail to Derek, d.karssenberg@uu.nl

Announcements or updates

- I will use Announcements on Blackboard

Software installation (1): Miniforge (also referred to as Miniconda)

- Package management system and environment management system
- Environment: separate folder on your computer containing the software
- You can have multiple environments and activate one depending on what you need

Installation:

- Vening Meinesz: Miniforge is already installed
- Your own hardware: install Miniforge, https://docs.conda.io/en/latest/miniconda.html

Software installation (2): PCRaster and other tools in Conda environment

- Open a Miniforge/Miniconda command prompt
- Create the pcraster environment and install software in the environment:

```
conda create --name pcraster …
```

- Activate the environment

```
conda activate pcraster
```

Details: http://karssenberg.geo.uu.nl/lspm/contentGeoinformatics.html#software-installation

Working in the Lab rooms V Meinesz

1) Self-subscribe to a Lab group (Blackboard)
2) *Login to computer with special account, account name is lspmGN, where GN is your Lab group number, for instance `lspm04` or `lspm12`, use the password provided in the Announcements (Blackboard)*
3) Start-up conda prompt (no need to install conda)
4) Install software (see previous slide)

Next time use same computer (and it will still be installed) otherwise install on other computer

All info on the course is at

http://karssenberg.geo.uu.nl/lspm

Marks

Final mark is weighted average of:

- Short paper assignment
- Written exam
- Oral presentation on case study project
- Report on case study project

Thank you!
Questions?