MSc thesis topics Derek Karssenberg
Version May 2020

Earth Surface and Water	Hydrology
Earth Surface and Water	Geohazards and Earth observation

Environmental Justice

Supervision:	**Prof Dr Derek Karssenberg (Utrecht University)**
In cooperation with:	**Julius Centre, UMCU and with team members of the Global Geo Health Data Center (http://www.gghdc.nl).**

Description:
Human exposure to our environment has considerable effects on human health. The spatial distribution of human exposures to environmental variables such as air pollution, urban green, noise and fast-food restaurants, is believed to reflect differences in income, ethnicity, unemployment and education-levels. This study aims to explore the patterns of the environmental exposures across the Netherlands and identify relations with the neighbourhood deprivation (income, ethnicity, unemployment and education-levels). The results of this study would have implications in restoring environmental justice and consequently reduce health inequalities amongst different socio-economic groups. The thesis will include implementation of human exposure assessment techniques to be applied across the Dutch population and methods to compare spatial patterns in human exposure and neighbourhood deprivation.

Location:	**Utrecht University**
Period:	**To be determined**
Number of students:	**1-2**
Programme / track:	**Preferably Natural Hazards and Earth Observation but other tracks may fit as well.**
Prerequisites:	**Courses in geographical information science and statistics is a requirement. Preferably basic knowledge in scripting (programming), remote sensing and/or simulation modelling (content of project can be adjusted to your background).**
Contact / info:	**Derek Karssenberg (d.karssenberg@uu.nl), Anna-Maria Ntarladima (a.m.ntarladima@umcutrecht.nl)**

Earth Surface and Water	Hydrology
Earth Surface and Water	Coastal dynamics and fluvial systems
Earth Surface and Water	Geohazards and Earth observation

Parallel algorithms for environmental modeling¶

Supervision:	**Prof. Dr. Derek Karssenberg (d.karssenberg@uu.nl), Dr Oliver Schmitz (o.schmitz@uu.nl), Drs Kor de Jong (k.dejong1@uu.nl)**
In cooperation with:	-

Description:

Algorithms for environmental modeling are at the heart of any raster-based environment model. The environmental modeller combines these core model building blocks to build a unique model. There are many different environmental modelling algorithms, some of which are also found in geographic information systems (GIS).
Until around 2005, CPU cores found in computers doubled in clock speed about every two years. Environmental modellers who wanted to use more complex modelling rules and/or larger data sets, just had to buy a new computer to decrease the increased model run times. That is not the case anymore and so model run times keep increasing with added model complexity and data.
Because CPU cores are not getting much faster anymore, hardware vendors have been adding additional CPU cores to their CPU's. One obvious way to solve the issue of increasing model run times is to make models use the multiple CPU cores. This requires a reimplementation of the above-mentioned environmental modelling algorithms.
This project is about parallizing one or more environmental modelling algorithms. Some of these algorithms are very easy to parallize, and some are not. In this project you will look into parallizing one or more algorithms from the latter category. You will design one or more approaches to parallize the algorithm and, depending on your interest and background, test these approaches by implementing them.
This work is highly relevant, because the results may be used in a new implementation of our own library of modelling algorithms. Faster algorithms will have obvious benefits for the modellers and you can make a very concrete contribution to this.
Supervision: You will be supervised by a team of experienced modellers and software engineers. They will provide you with a description of the sequential version of each algorithm and help you getting up to speed quickly. This team will at least consist of Dr. Derek Karssenberg and Drs. Kor de Jong.

Location:	**Utrecht University**
Period:	**To be determined**
Number of students:	**1-3**
Programme / track:	**Earth Surface and Water: Hydrology or Coastal dynamics and fluvial systems, or Geohazards and Earth observation**
Prerequisites:	**preferably courses in spatio-temporal modelling, geoinformatics, computer science**
Contact / info:	**Derek Karssenberg (d.karssenberg@uu.nl), Kor de Jong (k.dejong1@uu.nl)**

Earth Surface and Water	Hydrology
Earth Surface and Water	Coastal dynamics and fluvial systems
Earth Surface and Water	Geohazards and Earth observation

Formalising interactions between environmental models

Supervision:	**Prof. Dr. Derek Karssenberg (d.karssenberg@uu.nl), Dr Oliver Schmitz (o.schmitz@uu.nl), Drs Kor de Jong (k.dejong1@uu.nl)**
In cooperation with:	-

Description:

Environmental modelling tools are today an important tool to construct spatio-temporal models. They outperform system programming languages as a model development environment regarding programming errors and implementation time and are therefore suitable for domain specialists like hydrologists, climatologists or ecologists.
Nevertheless, these tools have mostly focused on the syntax of modelling languages ignoring the semantic aspect of models, i.e. the meaning of the inputs, functions and outputs of a component model. Without a formal definition of the semantics of model components it is almost impossible to provide generic principles for coupling component models.
The coupling of specialized component models is certainly a requirement for the construction of integrated models, as these represent a more holistic view on environmental processes. Therefore, the development of a formal definition of model components is required. A formal approach is provided by ontologies, which describe a conceptual domain, usually consisting of a set of statements that define concepts and relationships between concepts. While first steps towards ontologies for environmental models exist (e.g. Williams, M et al 2009, Lake, R.et al 2004) most of these approaches do not provide a complete description of all aspects of inputs and outputs. Research on the development of an ontology describing the whole domain of spatio-temporal models, including various modelling paradigms, spatial domains, and application domains is still required.
The research will be incorporated in an ongoing research project of integrated model development. Several research questions that are appropriate for a MSc thesis are available:

- What is the current state of formal descriptions of model inputs and outputs, what are limitations and potentials of those approaches
- Development (design and implementation) of or extension of an exisiting ontology suitable for coupling spatio-temporal model components
- Development (design and implementation) of a user interface for creating and modifying ontology descriptions by model developer
- Evaluating the possibilities of auto-generating ontology descriptions for existing models by software applications
- Assessing conversion problems of environmental variables occurring in the coupling of model components including different temporal and spatial resolutions, units, coverage, ...

Own proposals are welcome.

Location:	**Utrecht University**
Period:	**To be determined**
Number of students:	**1-2**
Programme / track:	**Earth Surface and Water: Hydrology or Coastal dynamics and fluvial systems, or Geohazards and Earth observation**
Prerequisites:	**courses in spatio-temporal modelling, geostatistics, remote sensing, hydrology, geomorphology, and/or natural hazards (content of project can be adjusted to**

	your background)
Contact / info:	**Derek Karssenberg (d.karssenberg@uu.nl)**

Earth Surface and Water Earth Surface and Water Earth Surface and Water	Hydrology Coastal dynamics and fluvial systems Geohazards and Earth observation

Coupled field-agent modelling: an algebra for fields and objects

Supervision:	**Prof. Dr. Derek Karssenberg (d.karssenberg@uu.nl), Dr Oliver Schmitz (o.schmitz@uu.nl), Drs Kor de Jong (k.dejong1@uu.nl)**
In cooperation with:	-

Description:

In our view, a modelling language is a language for expressing environmental models, by modellers. Modellers are domain experts who are not necessarily knowledgeable or interested in software development. They need an environment with a high level of abstraction. A modelling language, like a script language or a graphical language for example, provides the means for the domain expert to express his ideas about the phenomena being modelled. Most domain experts are not able to express such ideas in lower level languages like C++, C#, Java or even Python. The use of these languages require the domain expert to know things that are not directly related to expressing a model, like managing computer memory, managing files, handling errors. Another reason to provide a modelling environment directly to the domain expert, instead of asking a software developer to develop models for the domain expert, is that important decisions that have to be made during the development of the model get taken by the domain expert, instead of the developer. Like software development, model development is a highly iterative process, and decisions about the implementation need to be made continuously during the development of a model. Only for the most trivial models can the domain expert provide the software developer with the full specification of the model beforehand. In most cases the requirements of the model get adjusted continuously, based on the model's performance.
Modellers mostly construct models along one of two modelling paradigms: field based or agent based. In the field based approach, phenomena are considered as spatially continuous, and spatial variation is represented by changes in the attribute value. Examples of fields are air temperature or elevation. In the agent based approach (also individual based, feature based, or object based approach), phenomena are represented as bounded objects that can be mobile. Spatial variation is represented by the distribution of objects in space. Although many landscape systems require to combine the field and agent based approaches, it is notably hard to do so in a model. This is mainly due to modelling languages being monolithic: they are either build around the field based or agent based paradigm. Integrating the two approaches requires coupling different modelling frameworks, which can be error prone, difficult, and time consuming. To overcome this problem, this study aims at developing a modelling language that integrates the two approaches. The envisioned language should provide functions that operate on fields and/or agents, in a similar fashion. This will allow modellers to construct heterogeneous models consisting of agents and fields, in one single modelling language. Depending on your background, you can focus on designing concepts of such a language (e.g. the syntax), implementing a prototype (in your preferred programming language), or implementing a case study model that can be used to benchmark such a language.
This is an interesting study if you like to combine your knowledge in spatio-temporal modelling and computer science or GIS. It gives you the opportunity to work in a multi disciplinary team consisting of environmental scientists and (PCRaster) software engineers.

Location:	**Utrecht University**
Period:	**To be determined**
Number of students:	**1-2**

Programme / track:	**Earth Surface and Water: Hydrology or Coastal dynamics and fluvial systems, or Geohazards and Earth observation**
Prerequisites:	**courses in spatio-temporal modelling, geostatistics, remote sensing, hydrology, geomorphology, and/or natural hazards (content of project can be adjusted to your background)**
Contact / info:	**Derek Karssenberg (d.karssenberg@uu.nl)**

Earth Surface and Water	Hydrology
Earth Surface and Water	Geohazards and Earth observation

Early-warning signals of desertification (or recovery)

Supervision:	**Prof. Dr. Derek Karssenberg (Utrecht University)**
In cooperation with:	**Researchers in Spain**

Description:

Landscape systems may undergo abrupt transitions as a result of a gradual change in system drivers. Such regime shifts, or critical transitions, are often considered undesirable because they cause large changes in the landscape that are often irreversible. A well-known regime shift in land surface systems is desertification, i.e. the shift from a vegetated landscape to a largely unvegetated landscape, often with degraded soils and increased erosion. The process of desertification is often abrupt, while it may be driven by a rather gradual increase in grazing intensity. At a certain threshold grazing intensity, biomass starts to decrease, which results in increased throughfall and runoff, causing increased runoff erosion, reducing soil thickness, which again has a negative effect on biomass growth. This positive feedback loop results in a relatively abrupt degradation at the grazing intensity threshold.
It is notably hard to detect this upcoming regime shift, because mean values of the system state variables (e.g. soil thickness, discharge, vegetation biomass) show little change before a transition occurs. This problem has sparked research focused on finding alternative properties of the system that show a more marked change before a transition is coming. It has been shown that such so-called early-warning signals exist, more specifically higher-order statistics of state variables (e.g. instead of the mean value of discharge, the variance; instead of the mean vegetation biomass the spatial variation in biomass). Thus far, however, the existence of such early warning signals is mainly shown for virtual realities, i.e. modelled hillslopes. The aim of this study is to investigate the existence of early-warning signals in the real-world. You will address the questions of 1) What are the statistical properties of vegetation cover, soil moisture and/or discharge of various catchments at different stages of soil degradation or soil recovery? 2) Can differences in statistical properties be explained by the occurrence of (or upcoming) system shifts?
You will answer these questions by a statistical analysis of time series of high-resolution remote sensing data, including soil moisture, leaf area index and vegetation cover and possibly hydrographs for the same area. We have access to a data set in an area close to Zaragoza, Spain, and cooperation with the research group in Zaragoza is an option if you choose for this topic. Results of this analysis will be combined with information on the occurence of soil degradation or recovery in the same area, possibly by making a field visit. If time allows (or if the study is done by two students), the study can be extended by a modelling study investigating the occurence of early-warning signals in similar, modelled, systems. Most of the data is already available.

Location:	**Utrecht University, possibility to visit Spain to collect additional data**
Period:	**To be determined**
Number of students:	**1-2**
Programme / track:	**Earth Surface Hydrology or Natural Hazards and Earth Observation**
Prerequisites:	**courses in spatio-temporal modelling, geostatistics, remote sensing, hydrology, geomorphology, and/or natural hazards (content of project can be adjusted to your background)**
Contact / info:	**Derek Karssenberg (d.karssenberg@uu.nl)**

Earth Surface and Water	Hydrology
Earth Surface and Water	Coastal dynamics and fluvial systems
Earth Surface and Water	Geohazards and Earth observation

Evaluating hydrograph and sedigraph characteristics as early-warning signals of soil degradation

Supervision:	**Prof Dr Derek Karssenberg (Utrecht University)**
In cooperation with:	-

Description:
Landscape systems my undergo abrupt transitions as a result of a gradual change in system drivers. Such regime shifts, or critical transitions, are often considered undesirable because they cause large changes in the landscape that are often irreversible. A well known regime shift in land surface systems is the shift from thick hillslope soils with high biomass to soils with almost no soil cover and low biomass. This process of land degradation is often abrupt, while it may be driven by a rather gradual increase in grazing intensity. At a certain threshold grazing intensity, biomass starts to decrease, which results in increased throughfall and runoff, causing increased runoff erosion, reducing soil thickness, which again has a negative effect on biomass growth. This positive feedback loop results in a relatively abrupt degradation at the grazing intensity threshold. It is notably hard to detect this upcoming regime shift, because mean values of the system state variables (e.g. soil thickness, discharge, vegetation biomass) show little change before a transition occurs. This problem has sparked research focused on finding alternative properties of the system that show a more marked change before a transition is coming. It has been shown that such so-called early-warning signals exist, more specifically higher-order statistics of state variables (e.g. instead of the mean value of discharge, the variance; instead of the mean vegetation biomass the spatial variation in biomass). In this study you will evaluate whether statistical properties of hydrographs and/or sedigraphs can be used as early-warning signals for soil degradation. This is done in a modelling study. An existing hillslope evolution model that runs over time periods of hundreds to thousands of years is used to simulate the shift from a vegetated hillslope with thick soils to a degraded hillslope. Its main output is a timeseries of hillslope geometries (topographical surface, development of gullies, regolith thickness) and vegetation coverage. This output is used as input to an event-based hydrological model that is capable of modelling the complete hydrograph for individual events. It is expected that the hydrograph properties will change in advance of the upcoming shift towards a degraded system. To analyse, this, statistical properties (e.g. peakflow, time to peak, total discharge) will be calculated of hydrographs. This is an interesting topic if you like a fundamental approach to hydrology, with a focus on modelling. The study is quite innovative, and you will be able to position your work in a (recently emerged) large body of literature on critical shifts and early-warning signals.

Location:	**Utrecht University**
Period:	**To be determined**
Number of students:	**1**
Programme / track:	**Earth Surface Hydrology or Natural Hazards and Earth Observation**
Prerequisites:	**courses in spatio-temporal modelling, hydrology, geomorphology, and/or natural hazards (content of project can be adjusted to your background)**
Contact / info:	**Derek Karssenberg (d.karssenberg@uu.nl)**

Earth Surface and Water	Hydrology
Earth Surface and Water	Coastal dynamics and fluvial systems
Earth Surface and Water	Geohazards and Earth observation

Identifying systemic change in catchment hydrology

Supervision:	**Prof Dr Derek Karssenberg (Utrecht University)**
In cooperation with:	-

Description:
Temporal change in landscape systems is mostly studied with a focus on temporal variation in system states (e.g. groundwater level, discharge, denudation rate). These changes are driven by the landscape system, which includes all driving forces active in the landscape. In most cases, this system is considered constant, which implies that it is assumed that the processes and their interconnections remain the same. For instance, model calibration against observational data (aiming at parameter identification) mostly assumes that the set of modelled processes and their associated parameters remain the same: a single set of equations and parameters is assumed to represent the past and future behavior of the system. In many cases, however, the system itself may change over time, due to external forces or due to internal mechanisms in the landscape that completely alter the system processes and system behavior. An example is the land use system. Land use change is driven by many factors, including land prices, transport costs, housing costs, environmental properties. In many cases, these factors are considered constant and land use change is modelled with the same set of rules for all time steps. In reality however, many of these factors may change due to implementation of new technology or environmental laws, which implies systemic change of the land use system. In this study you will address systemic change in the hydrological system. Hydrological models are nowadays-important tools for forecasting drought and flooding. To reduce uncertainty in forecasts, these models are calibrated against observational data, in most cases river discharge time series. As noted above, it is mostly assumed that one unique set of model parameters can be used to represent hydrologic behavior for all time periods (both past and future simulations, for all years). In reality, however, systemic change will occur, which will be associated with changes in parameter values. Systemic change in catchment hydrology may be due to changes in land use (causing changes in interception, infiltration), changes in geomorphology (causing changes in soil depth and subsurface hydrology), or other changes such as implementation of new reservoirs. In this study you will identify these changes by an inverse method, by calibrating a catchment model separately for each time period (typically one year) in a series of time periods. This will result in a time series of parameter values (i.e., a value for each year), that represent the temporal change in the hydrologic system. Following this approach you can address the questions of 1) What is the temporal change in parameter values of a catchment model? 2) Is it possible to relate these temporal changes to changes in the modelled catchment (e.g. landuse, geomorphology, reservoirs) that caused this systemic change in the hydrology? 3) What are the possible implications of this systemic change for forecasts of catchment discharge? For this study you will use existing calibration techniques on an existing data set (large time series data are available for multiple decennia) and model (one of the data sets available, most likely the Danube catchment). This is an interesting topic if you would like to apply your knowledge in hydrology in a challenging rather innovative study. You will get technical support from staff and PhD students at our institute to get the calibrations running. The content of the study can be adjusted to your interests (e.g. you could also study systemic change in other landscape systems).

Location:	**Utrecht University, possibility to cooperate with Münster University**
Period:	**To be determined**
Number of students:	**1-2**
Programme / track:	**Earth Surface Hydrology or Natural Hazards and Earth Observation**
Prerequisites:	**courses in (stochastic) hydrology, spatio-temporal modelling (content of project can be adjusted to your**

	background)
Contact / info:	**Derek Karssenberg (d.karssenberg@uu.nl)**

Earth Surface and Water	Hydrology
Earth Surface and Water	
Earth Surface and Water	Geohazards and Earth observation

Re-vegetation and water availability in Mediterranean areas: a study case in northeastern Spain

Supervision:	**Prof Dr Derek Karssenberg (d.karssenberg@uu.nl)**
In cooperation with:	**Dr Noemí Lana-Renault (noemi-solange.lana-renault@unirioja.es)**

Description:

In Mediterranean regions, water availability is low and depends on runoff generated in mountain areas. However, a marked decline in river discharges has been observed in the last century, related to i) decreasing precipitation and increasing temperature and ii) increasing expansion of vegetation in the headwaters due to land abandonment. On the other hand, increasing water consumption for domestic, industrial and agricultural uses is occurring in the lowlands. Future water management will need to cope with these changing scenarios in order to ensure water supply.
In this study we will focus on the impact of re-vegetation in the headwaters on future trends of water availability. Questions addressed include: how will re-vegetation affect water availability? What is the seasonality of river flows? What is the water demand in the lowlands? What is the spatio-temporal pattern of the resulting water stress?
The research will be carried out in the Ebro basin, an example representative for large Mediterranean rivers. An existing process-based distributed hydrological model developed within the PCRaster Python framework and calibrated in a small catchment in the Pyrenees will be used. The model will be run under future land cover and climate change scenarios for a larger area in the Pyrenees. The discharge simulated in the upstream area will be compared to future downstream demand to calculate water stress.

Location:	**Utrecht University, possibility to visit the research area (Ebro basin) to collect additional data**
Period:	**To be determined**
Number of students:	**1-3**
Programme / track:	**Earth Surface Hydrology or Natural Hazards and Earth Observation**
Prerequisites:	**courses in spatio-temporal modelling, hydrology, geomorphology, and/or natural hazards**
Contact / info:	**Noemí Lana-Renault (noemi-solange.lana-renault@unirioja.es) or Derek Karssenberg (d.karssenberg@uu.nl)**

Earth Surface and Water	Hydrology
Earth Surface and Water	Coastal dynamics and fluvial systems
Earth Surface and Water	Geohazards and Earth observation

Streamflow prediction under different re-vegetation scenarios

Supervision:	**Prof Dr Derek Karssenberg (d.karssenberg@uu.nl)**
In cooperation with:	**Dr Noemí Lana-Renault (noemi-solange.lana-renault@unirioja.es)**

Description:

Mediterranean mountains have been largely affected by agricultural abandonment and subsequent vegetation recovery. The resulting expansion of forest and shrubs has modified the hydrological behavior of these areas, with significant impact on runoff production. Forecasting the effect on stream flow response of such vegetation recovery is particularly relevant in the Mediterranean region, where water resources are scarce and uneven, and they rely on runoff generated in mountain areas.
With this purpose, a process-based distributed hydrological model was developed within the PCRaster Python framework. The model has been calibrated in a past agricultural catchment (2.8 km2) in the Spanish Pyrenees, monitored by the Instituto Pirenacio de Ecologia (CSIC). In order to reproduce realistic vegetation recovery scenarios, we need to determine the soil and vegetation parameters for several stages of land abandonment. The aim of this research is to characterize several stages of land abandonment in terms of vegetation and soil properties, and to identify their effect on the stream flow response. The research will include:

- Fieldwork in the study area (Spanish Pyrenees): at each site (representing a stage of land abandonment) we will collect data related to vegetation and soil characteristics
- Statistical analysis of the field data
- Simulation of the hydrological response of the catchment under different re-vegetation scenarios, based on the data collected in the field

Detailed content of the research can be discussed and tailored to your background. The fieldwork will take place preferably in September.

Location:	**Utrecht University, possibility to visit the research area (Ebro basin) to collect additional data**
Period:	**To be determined**
Number of students:	**1-3**
Programme / track:	**Earth Surface Hydrology or Natural Hazards and Earth Observation**
Prerequisites:	**courses in spatio-temporal modelling, hydrology, geomorphology, and/or natural hazards**
Contact / info:	**Noemí Lana-Renault (noemi-solange.lana-renault@unirioja.es) or Derek Karssenberg (d.karssenberg@uu.nl)**

Earth Surface and Water	Hydrology
Earth Surface and Water	Coastal dynamics and fluvial systems
Earth Surface and Water	Geohazards and Earth observation
Earth, Life and Climate	Integrated stratigraphy and sedimentary systems

Earth Surface and Water	Hydrology
Earth Surface and Water	Coastal dynamics and fluvial systems
Earth Surface and Water	**Geohazards and Earth observation**
Earth, Life and Climate	Integrated stratigraphy and sedimentary systems
Earth, Life and Climate	Climate reconstruction

Title: Personal exposure to air pollution in megacities of the world

Supervision:	**Prof Dr Derek Karssenberg, Dr Oliver Schmitz**
In cooperation with:	Institute for Risk Assessment Sciences (Utrecht University)

Description:

Air pollution is one of the major concerns for human health. The effect of air pollution on health is often estimated using personal exposure to air pollution. This is the exposure to air pollution aggregated along the space-time path visited by an individual. An important question is how megacities in the world differ regarding personal exposure of their population. In this topic you will try to answer this question by calculating personal exposure of the entire population of a number of megacities in the world, using publicly available information. Air pollution will be mapped by downscaling (increasing the level of detail) remotely sensed air pollution products to a spatial resolution of approximately 10 m using existing land use regression models, using open streetmap data as input. Space-time paths visited by individuals are estimated using location of houses, possibly enriched with census data or other high-resolution information on location of dwellings. Then, air pollution is aggregated for these locations, for each individual in the population. This results in distributions of personal exposure for the population of the city. The objective is to do this for a number of major cities in the world. This requires good skills in programming GIS operations, e.g. using Python and/or PCRaster, ArcGIS.

Location:	**Utrecht University, cooperation possible with Instititute for Risk Assessment Sciences, University Medical Centre Utrecht**
Period:	**Any period is possible.**
Number of students:	**1-2 students**
Programme / track:	**Earth Surface Hydrology or Natural Hazards and Earth Observation**
Prerequisites:	**Experience with programming (scripting, e.g. Python), background in GIS, spatio-temporal modelling, (geo-statistics).**
Contact / info:	**Dr Derek Karssenberg, d.karssenberg@uu.nl**

Earth Surface and Water	Geohazards and Earth observation

Title: Improving air pollution modelling using Earth observation satellite imagery

Supervision:	Dr. Meng Lu (m.lu@uu.nl), Prof. Dr. Derek Karssenberg (d.karssenberg@uu.nl), Dr. Oliver Schmitz
In cooperation with:	Risk Assessment Institute Utrecht University, KNMI

Description:	Air pollution is a major environmental risk to health, causing 2-3 million premature deaths per year worldwide (WHO). Air pollution mapping provides important information for health researchers and policy makers. Ground sensor networks are usually sparse and incidental, especially in developing countries, and can have low resolution in space and/or time. Land use variables (e.g. road infrastructure, traffic, population) that are related to air pollution have been used to interpolate air pollution to a finer spatiotemporal scale; however, the variable set is commonly incomplete to fully explain the spatiotemporal distribution of air pollution. Moreover, their joint effects maybe complex, which makes is difficult to build a model that features both high prediction power and generality. A promising improvement of the challenge of air pollution mapping could be to integrate information from satellite management. Satellite observations of air pollutants offer a wide spatial coverage and high continuity. Space borne platforms provide measurements for a wide range of air pollutants. Satellite observations alone are shorter than most ground data time series, and the temporal and spatial resolution are coarse for personal exposure assessment. The newly launched TROPOMI (available since 2018) measures gas pollutant (e.g. NO2, O3) at a significantly improved spatiotemporal resolution comparing to it precursors and will be a focus of this study. Questions that can be defined related to this topic are: How do we improve air pollution mapping with Earth observations and/or variables such as are used in land use regression models? What are the benefits and drawbacks of different classical statistical and machine learning methods, and how could they be used jointly to integrate information with a balance of model generality and prediction accuracy? How does the technical implementation work (e.g. big data storage and computation)? What is the improvement of the combination of (suggested) data sources, and how can we quantify that? For example, will the combination of satellite data with ground data be more beneficial globally or regionally (e.g. the Netherlands)? Can we expect an improvement of air pollution mapping at all in the Netherlands?

Location:	Utrecht University
Period:	any period

Number of students:	1-3
Programme / track:	Geohazards and Earth observation
Prerequisites:	Remote sensing (content of project can be adjusted to your background)
Contact / info:	Meng Lu (m.lu@uu.nl)

Earth Surface and Water	Hydrology
Earth Surface and Water	Geohazards and Earth observation

Title: **The multi-scale impact of land use and land cover on land surface temperature dynamics**

Supervision:	**Prof. Dr. Derek Karssenberg (d.karssenberg@uu.nl)**
In cooperation with:	**Dr Jon Wang, Twente University**

Description:	The global temperature continues rising, which is partially due to land surface cover change. In order to understand the relationship between temperature and the land surface characteristics, the land surface temperature (LST) became one of the primary concerns as it reflects the sensitivity of land surface to solar radiation in the most precise manner. The importance of investigating the LST dynamics is straightforward in at least two aspects: (1) it governs the energy balance above and below the earth surface, and (2) it modifies the air temperature at the lowest layer of atmosphere, which in turn determines the thermal environment for human beings. Although studies has been concentrated on the patterns and mechanisms determining the LST, the dynamics of the relationship between the LST and the characteristics of the land surface is mostly ignored. When different spatial and temporal scales are applied, the relationship between the LST and land surface can be distinctively different leading to difficulties in understanding and interpreting the underlying process. In this study, multi-source remotely sensed time series imagery will be employed to investigate the LST-land surface relationship at multiple spatial and temporal resolutions. The study starts with generating multi-resolution times series imagery for both the LST and temperature sensitive land surface factors, including but not limited to NDVI, impervious surface fraction, NDWI, surface albedo and building density. The maps will be aggregated in terms of different spatial and temporal resolutions. Then the LST-land surface relationship will be investigated through the application of spatial autocorrelation regression in various forms, where uncertainties in spatial dependence and model form will be characterized. In the process, the study will bring insights to the variation of LST-land surface relationship across continents at multiple spatial and temporal scales.

Location:	Utrecht University
Period:	any period
Number of students:	1-2
Programme / track:	Geohazards and Earth observation
Prerequisites:	Remote sensing

	(content of project can be adjusted to your background)
Contact / info:	d.karssenberg@uu.nl

Earth Surface and Water	**Geohazards and Earth observation**

Title: **Earth observation based monitoring of heat exposure**

Supervision:	**Prof. Dr. Derek Karssenberg (d.karssenberg@uu.nl)**
In cooperation with:	**Dr Jon Wang, Twente University**

Description:	The increasing frequency and intensity of excessive heat events (EHE) due to climate change propel the demand of sophisticated data and methods to assess human heat exposures. To assess heat exposure across a population and its relation to health outcomes, it is preferable to estimate personal exposures for each individual in the target population. Assessment of personal exposures to heat requires space-time mapping of near surface air temperature at a high resolution. Earth observation (EO) based measurement of land surface temperature (LST) potentially provides high resolution and continuous coverage (gap free) information for estimating personal human heat exposures. However, the relation between LST and near surface air temperature remains uncertain. Thus, its potential in support of assessing personal exposures to heat has not been sufficiently explored. This study follows a 3-step workflow to identify the scope and limitations of applying LST to heat exposure analysis. First, a multi-resolution diurnal LST dataset is derived over a period of 3 months (containing an EHE) of the province of Utrecht (~1000 km2), the Netherlands. The multi-resolution dataset contains original and downscaled LST data at high temporal resolution. Then, relations between LST and observed near surface air temperature were drawn for multiple resolutions of LST, in order to identify the optimal LST resolution for estimating near surface air temperature. Finally, the transferability of LST-based heat exposure to the air temperature-based one is examined given the distribution pattern of home locations in Utrecht. This study pioneers research in the applicability of earth observation based techniques to personal heat exposure assessment.

Location:	Utrecht University
Period:	any period
Number of students:	1-2
Programme / track:	Geohazards and Earth observation
Prerequisites:	Remote sensing (content of project can be adjusted to your background)
Contact / info:	j.wang2@uu.nl

Title: Global data driven methods for Malaria epidemics risk assessment

Supervision:	Dr. Meng Lu (m.lu@uu.nl), Prof. Dr. Derek Karssenberg (d.karssenberg@uu.nl)
In cooperation with:	Partners in https://globalgeohealthdatacenter.com

Description:

Malaria poses serious social and health burdens in many tropical and subtropical countries. It is widely acknowledged that the malaria transmission dynamics are closely related to climatic and environmental factors. With the burgeoning availability of global Earth observation data, the opportunity arises to examine how a data-driven approach could contribute to global malaria epidemic risk assessing and warning. The objective of this study is to examine whether Earth observations and a data driven approach can improve understanding of the linkage between weather, surface water, vegetation, and Malaria occurrence.

Potentially, we will use open surface water products derived from high resolution (30m) satellite imagery [1] with long time series. The corresponding paper has been published in Nature in 2016 [2]. This dataset will provide us information about spatiotemporal dynamics of global surface water to link it with Malaria incidence. The time series of precipitation volumes may be from TRMM (Tropical Rainfall Measuring Missing, flew from 1997-2015) products and GPMM (Global precipitation measurement Mission, launched on Feb.27, 2014)[3]. The Land surface temperature will be derived from the Landsat satellite product or using existing products. Besides, the project will also include local scale identification of malaria-weather relationships using precipitation and temperature data from local rainfall gauge network and meteorological stations.

The research questions are, but not confined to: what are the independent and joint effects of the above-mentioned variables on Malaria incidence? Can the Malaria epidemics be predicted? What is the potential of Earth observations in global Malaria mapping and warning? Can the locally identified relationship be extended to global mapping? How does climate change (e.g. in extreme weather events, temperature, precipitation) affect Malaria epidemics?

This interdisciplinary study will expose you to a wide range of global Earth observation products and novel data analytics methods. You will learn and develop novel spatiotemporal statistical algorithms to analyse dynamics of global climatic and environmental factors such as precipitation, land surface temperature, water surface, and identify their joined effects and spatiotemporal predicting power on Malaria epidemics.

[1] Global surface water. https://global-surface-water.appspot.com/
[2] Pekel, J. F., Cottam, A., Gorelick, N., & Belward, A. S. (2016). High-resolution mapping of global surface water and its long-term changes. Nature, 540(7633), 418-422.
[3] Global precipitation measurement: https://www.nasa.gov/mission_pages/GPM/overview/index.html

Location:	Utrecht University
Period:	Any period
Number of students:	1-3
Programme / track:	Geohazards and Earth Observation

Prerequisites:	Earth observation, basic spatiotemporal data analysis (content of project can be adjusted to your background)
Contact / info:	Derek Karssenberg (d.karssenberg@uu.nl)

Earth Surface and Water	Geohazards and Earth observation

Title: Near real-time deforestation monitoring from satellite time series imagery

Supervision:	Dr. Meng Lu (m.lu@uu.nl), Prof. Dr. Derek Karssenberg (d.karssenberg@uu.nl)
In cooperation with:	-

Description:	Forests around the world are under threat of deforestation, which impacts our livelihoods and threatens a wide range of plant and animal species. Human behavior induced deforestation includes clear-cutting for agriculture, ranching, and unsustainable logging for timber. A deforestation monitoring system can significantly facilitate forest conservation from relevant environmental and political agencies. Earth observation satellite imagery with ever-growing spatiotemporal resolution and spectral information provide us opportunities to automatically monitor deforestation. A global forest cover change study was published in Science [1] in 2013, and has demonstrated and generated tremendous interest in using Earth observations for global forest cover change. This study [1] used however relatively simple algorithms and has a high misclassification rate, and does not address monitoring forest dynamics in near real-time. In this study you will apply novel time series structural change methods to automatically detect forest change from optical satellite image time series. An open archive of satellite imagery products will be used, such as Landsat TM 5&7. Interesting challenges to be solved in this study include how to separate man-made deforestation events from natural disturbance such as fire and drought. How can we retrieve useful information from seasonality effects of a time series, (which commonly confuses the change signal)? Can the gradual change information be integrated into abrupt change detection? And, how could multidimensional information from space, spectral bands, other sensor data and environmental variables be integrated into a 1D time series analysis? This is a highly relevant research with the launching of Sentinel 2 satellite in 2015. A near real-time deforestation, or more broadly, vegetation monitoring system will greatly contribute to environmental conservation. [1] High-Resolution Global Maps of 21st-Century Forest Cover Change. M.C. Hansen, P.V. Potapov, R. Moore, M. Hancher, S.A. Turubanova, A. Tyukavina, D. Thau, S.V. Stehman, S.J. Goetz, T.R. Loveland, A. Kommareddy, A. Egorov, L. Chini, C.O. Justice, and J. R. G. Townshend

Location:	Utrecht University
Period:	Any period
Number of students:	1-2
Programme / track:	Geohazards and earth observation
Prerequisites:	Earth observation, basic spatiotemporal data analysis (content of project can be adjusted to your background)
Contact / info:	Meng Lu (m.lu@uu.nl)

Earth Surface and Water	Geohazards and Earth observation

Title: Novel air pollution exposure modeling - Evaluating spatial-temporal aggregation as substitute for uncertain activity patterns

Supervision:	Dr. Meng Lu (m.lu@uu.nl), Prof. Dr. Derek Karssenberg (d.karssenberg@uu.nl), Dr. Oliver Schmitz
In cooperation with:	Partners in https://globalgeohealthdatacenter.com

Description:	Air pollution shows a high spatio-temporal variability and pollution can be influenced by land use, road traffic intensity, building height, meteorological conditions, and industrial use. To assess the severity of air pollution, human exposure to air pollution needs to be determined. Conventional air pollution exposure assessment methods often measure air pollution exposure at front door locations. This approach, however, does not take human activity patterns into account, which consequently may lead to over- or under-estimation of air pollution exposure. Assessing air pollution exposure considering activity patterns of individual persons remains to be a challenge as 1) the detailed working location information and detailed activity pattern of the residents are commonly unknown when large numbers of individuals need to be considered, 2) the modeling of air pollution exposure using a combination of process- and agent-based models across a large population (e.g. at country scale) may be computationally infeasible. This study aims at developing a novel method to assess air pollution exposure of different human activity patterns. The human activity patterns will be modelled by spatial (and temporal) aggregation using windows of various shapes and different buffer sizes. The window shapes are suitable to represent a series of activity patterns, and optimized for computation. The methodology will be tested and evaluated for a Dutch municipality. This study is highly related to our on-going project of improving air pollution exposure modeling using a combined field and agent based modeling.

Location:	Utrecht University
Period:	Any period
Number of students:	1-3
Programme / track:	Geohazards and Earth Observation

Prerequisites:	Earth observation, basic spatiotemporal data analysis (content of project can be adjusted to your background)
Contact / info:	

Earth Surface and Water	**Geohazards and Earth observation**

Title: Mapping road networks with hyper resolution earth observation to improve global assessment of personal exposures to air pollution

Supervision:	Dr. Meng Lu (m.lu@uu.nl), Prof. Dr. Derek Karssenberg (d.karssenberg@uu.nl)
In cooperation with:	Partners in https://www.globalgeohealthdatacenter.com

Description:	In many middle and low-income countries, air pollution monitoring networks are deficient or nonexisting, but in these countries people are the most vulnerable to air pollution, with young children suffering the most. The idea is to borrow information from countries where relatively dense ground monitors are available, and integrate information from satellite measurements and geospatial predictors, to give an estimation of global air quality, including low-income countries. Global air quality has a strong and complex relationship with transport networks. Cutting-age studies use this relationship to predict air pollution in space and time. It is a considerable challenge however to create consistent and complete data sets of global road networks. So far, the OpenStreetMap (OSM) provides the best open-source information on transport networks, including different types of tracks (e.g. roads, rails). A problem is that the transport network provided by OSM is incomplete in many countries, such as in China and African countries. Very High Resolution (VHR) satellite imagery (e.g. worldview2) and machine learning (particularly deep learning neural networks) are promising techniques to complement the OSM, and evaluate the consequences (errors) of directly using the OSM with missing roads to predict air pollution. On the other hand, OSM provides rich labels to perform supervised machine learning algorithms (e.g. to train a neural network). The expectation of this thesis is to develop an advanced deep learning algorithm to extract transport networks from VHR satellite imagery, using OSM as training and validation information. As the research matures, you will collaborate with environmental modellers to evaluate the consequences of using OSM for global air pollution mapping, and collaborate with software engineers to develop a tool to interactively, at near-real time, complete OSM using satellite imagery.

Location:	Utrecht University
Period:	Any period
Number of students:	1-3
Programme / track:	Geohazards and Earth Observation
Prerequisites:	Remote sensing course, spatial analysis/data science course, experience with scripting (e.g. R, Python, Java).
Contact / info:	Meng Lu (m.lu@uu.nl)

Earth Surface and Water	**Geohazards and Earth observation**

Title: Assessing spatiotemporal surface water patterns for improved vector-diseases mapping

Supervision:	Prof. Dr. Derek Karssenberg (d.karssenberg@uu.nl)
In cooperation with:	Partners in https://www.globalgeohealthdatacenter.com

Description:	Open surface water plays an important role in the epidemiology of vector-borne diseases such as Malaria and Dengue as the vectors of these diseases (Mosquitos) rely on open water for reproduction. In this project you will contribute to improved prediction in space and time of these diseases by mapping, at a high resolution, the occurrence and dynamics of open surface water. This can be done by using earth observation satellite imagery, which potentially enables quantifying the proportion of the land surface that is covered by open water, and how this changes over time. However, this does not enable forecasting of open surface water under climate change, which requires process-based modelling of the hydrological system, with an emphasis on the hydrological processes that steer the occurrence of land surface water. The idea is to use process-based modelling with high-resolution climate forcing combined with high-resolution land surface data such as surface topography and vegetation. This can be combined with observations of land surface water to validate outputs of the process-based modelling. Depending on your background and interests, and the size of your project, you can focus on process-based modelling or the use of earth-observation, or try to integrate both. There is also an option to associate land surface water occurrence to observed incidence of a disease. Data sets are available (and have been analyzed by our team) on Malaria incidence over Africa, for instance.

Location:	Utrecht University
Period:	Any period
Number of students:	1-3
Programme / track:	Geohazards and Earth Observation
Prerequisites:	Depending on the focus of the research a combination of earth observation, hydrology (e.g. land surface hydrology at MSc level), spatial simulation modelling (e.g. land surface process modelling MSc course), and/or data science methods, depending on basic spatiotemporal data analysis.
Contact / info:	Derek Karssenberg, d.karssenberg@uu.nl