Project: Climate Change Impacts

1. Introduction

A changing climate and possible impacts on hydrological processes are currently intensely discussed issues. As the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC, 2014) states, temperature, water vapor and precipitation patterns will significantly change by the end of the 21st century. With these variables being the main factors influencing the hydrologic cycle, climate change is expected to have a major impact on watersheds at both global and local scales. Since water is an essential resource, variations in the hydrologic cycle can have serious consequences. It is, thus, necessary to adjust future flood control concepts, hydropower production, agricultural irrigation, ecosystem preservation strategies and many more. To provide responsible decision makers with the best possible information, it is the scientists' and consultants' responsibility to apply reliable and accurate methods, especially in such a relatively uncertain domain as climate modeling.

In this project you will work in groups of 3 students and combine a literature review, an analysis of real-world data and statistical methods to learn more about climate change and to explore the effect of a changing climate on different hydrological processes.

Your task is to first familiarize yourself with the topic of hydrological climate-change impacts and thereafter to analyze current streamflow regimes in different Swedish regions and to assess the impact of a changing climate. Based on the skills you previously gained in your Master's program, you now get a chance to identify and apply statistical tools (descriptive and inferential) suitable for exploring, describing, comparing and visualizing hydrological data. You are expected to justify your choices of methods, interpret and discuss the results as well as draw appropriate conclusions based on your results.

Each group works on the same set of three different Swedish study sites to be investigated (Figure 1). You will be randomly assigned to a student group (see section *4.1 Groups*) and it is your responsibility to follow the instructions further below for your group and to download the correct data files from STUDIUM (see module *Course Project*). There are roughly 50 hours scheduled over the next 4 weeks to work on the project.

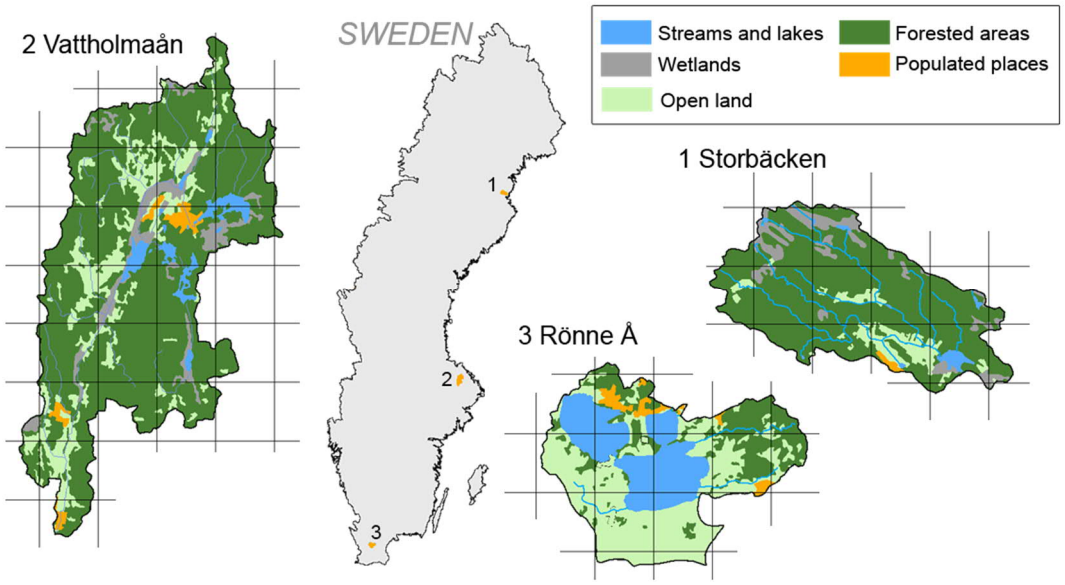

Figure 1: Swedish catchments: (1) Storbäcken, (2) Vattholmaån and (3) Rönne Å

2. Input Data

Download the available Excel files from STUDIUM. In *data_1961_1990.xlsx*, you are provided with 30 years (1961-1990) of daily ***observed*** air temperature, precipitation and streamflow for three catchments. In addition, this data file contains daily values of streamflow for the same period that was ***simulated*** with a hydrological model (the HBV-light model, Seibert, 1997) using observed daily air temperature and precipitation as input. In *data_2021_2050_RCA.xlsx* and *data_2021_2050_HadRM3Q0.xlsx* you will see daily simulated precipitation, temperature and streamflow data for the future period 2021-2050, which were obtained by using temperature and precipitation simulations for the period 2021-2050 provided by 2 different regional climate models (RCMs): the Hadley Center model HadRM3Q0 and the SMHI model RCA (both run under greenhouse gas emission scenario A1B). These simulations were used as input to the HBV-light model to get future streamflow simulations.

3. Task

Elaborate on how Sweden's climate may develop and analyze the consequences for hydrological processes in general and streamflow in particular!

Use the data provided, the statistical tools and methods learned in this and previous classes. Make also use of the provided literature and do further research in the internet (e.g. google scholar) to get further inspiration on how to tackle this problem!

The project is deliberately defined rather broad to resemble a realistic situation in your future professional career, in which you may be asked to deliver a report on the hydrological challenges that Sweden is facing under changing climate conditions. The aim is to give you more freedom in terms of your methodological choices, to allow you to independently search for relevant scientific literature, and to place your results in relevant context. But please make sure to adhere to the instructions below.

3.1. Literature Review

Each student in the group must provide a short literature review of one of the following three topics:

1 General climate change impacts on hydrology, considering the different components and processes in the water cycle globally and in different climate zones *(suggested publications no. 01a-c)*

2 Hydrological climate change impacts in Sweden, including the current state of knowledge as well as general trends and tendencies *(suggested publications no. 02a-c)*

3 Challenges of hydrological climate-change impact modelling, including the main sources of uncertainty *(suggested publications no. 03a-c)*

You should decide fairly within the group who will work on which of these topics. All three topics must be covered in the final written report.

3.2. Hydrological Analysis

Each student in the group must perform one hydrological analysis to evaluate climate change impacts for all 3 study sites. This should be done by using hydrological signatures to analyze the given data records in terms of seasonal patterns, correlations, frequency/timing/duration of extreme flows or seasonal and annual flow variability. Such signatures act as a mirror of a catchment's dynamic response behavior and patterns and they are typically indicative for a specific catchment and how it differs from others. Table 1 below provides a potential list of such signatures. Each student in the group should be working on 1 hydrological signature so that the entire group evaluates 3 different signatures. As a group, you must collectively decide who will be working on which signature. Each student is then responsible for describing the selected signature in the methods section as well as estimating and statistically analyzing the signature for each of the 3 study sites, both for observed data and future projections.

Note that you are not solely limited to the signatures in Table 1. Additional relevant signatures (sometimes called indicators) can be found in the scientific literature and portals of certain national weather services and hydrological institutes. Such signatures can for instance also relate to the return periods of certain events (e.g., a 100-yr flood) or the correlation between hydrological variables (e.g. between precipitation and streamflow). When submitting your time plan and task distribution, we will inform you whether your chosen signatures are suitable or not.

Table 1: Overview of streamflow signatures, which are largely based on signature listings by Clausen and Biggs (2000), Shamir et al. (2005), Yadav et al. (2007), Yilmaz et al. (2008) and Ley et al. (2011). The signatures are grouped based on what they describe: group 1 = hydrograph (i.e., seasonal and annual flow variability), group 2 = flow durations (i.e., frequency and timing of high, mid-segment and low flows), group 3 = water balance.

Abbr.	Signature	Calculation
1(a) Hydrograph (streamflow)		
FMean	Mean streamflow (annual or seasonal)	$FMean_{ANN/DJF/MAM/JJA/SON} = mean(Q) = \frac{\sum_{i=1}^{N} Q_i}{N}$, where Q_i is daily streamflow for days i= 1, 2, …N within a specific year (ANN) or a specific season (DJF = winter, MAM = spring, JJA = summer, SON = autumn).
1 (b) Hydrograph (baseflow)		
BMean	Mean baseflow (annual or seasonal)	$BMean_{ANN/DJF/MAM/JJA/SON} = mean(Q_b) = \frac{\sum_{i=1}^{N} Q_{b,i}}{N}$, where $Q_{b,i}$ is daily baseflow for days i= 1, 2, …N within a specific year (ANN) or a specific season (see definition above).
BFI	Baseflow index (annual or seasonal)	$BFI = 100 \cdot \frac{BMean_{ANN/DJF/MAM/JJA/SON}}{FMean_{ANN/DJF/MAM/JJA/SON}}$
1 (c) Hydrograph (spring flood)		
SFD	Spring flood duration	$SFD = no.of\ days$ (between starting (*SFstart*) and ending (*SFend*) point of the spring flood)
SFP_{mag}	Magnitude of flood peak	SFP_{mag} = max(Q) within the first 6 months of the year
SFP_{time}	Timing of flood peak	$SFP_{time} = day\ i$ on which SFP_{mag} occurs; with $1 \leq i \leq 182$
SFV	Total spring flood volume	$SFV = \sum_{i=SFstart}^{SFend} Q_i$
2 (a) Flow duration curve (high flow)		
FHS	High-segment flow	$FHS = \frac{\sum_{h=1}^{H} Q_h}{H}$, where h = 1, 2, … H are the flow indices for flows with exceedance probabilities lower than 0.02, H being the maximum flow.
2 (b) Flow duration curve (median flow)		
CV	Streamflow variability	$CV = std(Q)/mean(Q)$ where *std* is the standard deviation.
FMed	Median streamflow	$FMed = median(Q)$
FMS	Mid-segment slope	FMS = log(Q_{m1}) – log(Q_{m2}), where m_1 and m_2 are the lowest and highest flow exceedance probabilities (0.33 and 0.66 respectively) within the midsegment.
FSkew	Streamflow skewness	$FSkew = FMean/FMed$
2 (c) Flow duration curve (low flow)		
FLS	Low-segment flow	$FLS = \frac{\sum_{l=1}^{L} Q_l}{L}$, where l = 1, 2, … L are the flow indices for flows with exceedance probabilities between 0.7 and 0.9, L being the minimum flow in the interval.
3 (a) Water Balance		
RR	Runoff coefficient	$RR = 100 \cdot \frac{\sum_{i=1}^{N} Q_i}{\sum_{i=1}^{N} P_i}$, with daily streamflow Q_i and daily precipitation P_i for days i= 1, 2, …N.

4. Group Work

4.1. Groups

You will be working in groups of 3 students as follows:

Group			
1	Abu Mohammad Kawsar Arafat	Rasmus Lundstedt	Franziska Pezzei
2	Aaron Boateng-Duah	Shivam Gusain	Prajwol Prajapati
3	Laura Nina Bettoni	Frederico Vega Ezpeleta	Maryam Shakibi
4	Ahmed Ashraf Ahmed Elhabashy	Israfil Hossain Akanda	Ruixiao Jin
5	Fatin R Jabbar Al-Zuhairi	André Hofstedt	Amrith Kumar
6	Nathalie Jonasson Collett	Thomas Gentsch	Klara Lundqvist
7	Ali Reza Sadeghi	Reza Ghadam	Irina Elina

4.2. Group Management

As a group, you work collectively towards tackling the given task and towards producing a final written project report. Within the group, you will fairly distribute the different tasks among all group members.

As a group member, each student is expected to agree to the ground rules, cooperate with the other members of the group in good faith and with a view to realize the project's goals. Each student should contribute to the development of the common group project with the purpose of accomplishing the goals in a timely fashion to the best of their respective abilities. You should treat the beliefs, contributions and opinions of the other group members with all due respect. Make sure to keep all scheduled appointments, prepare for group meetings and provide constructive feedback.

Please contact the responsible teacher in case of any violation of the above!

4.3. Group Deadlines

Each group is expected to

- Submit by Thursday, **February 11, 17:00** a **time plan** for the project work and an overview of the **distribution of tasks/roles** (specified under section *3. Task*) among the group members
- Give an **oral mid-term presentation** on Tuesday, **February 23** (for times, see schedule) to demonstrate their progress in the group project
- Submit by Wednesday, **March 10, 17:00** a **written group report**.

Each student is expected to individually

- Submit by Friday, **March 12, 17:00** a short personal reflection of the **relative contribution of each group member** to the project

4.4. Written Report

Thoroughly read and follow the Writing Guide provided. Make sure your report adheres to the following requirements:

- Report style: at least 3000 words in length (without references and appendix), Times New Roman, Font size 11, Spacing: 1.5
- Include relevant tables and/or figures with proper captions and references.
- Support your arguments and basic facts with references, formatted according to the Harvard Referencing System (https://libguides-en.ub.uu.se/citationguide/harvard)
- Make sure to refer and cite properly to sources using in-text references or citations
- Separately upload any relevant programming code (Matlab, Python etc) and Excel files as they are. They are not part of your grade, but might be used when there is a suspicion of plagiarism.
- The report should include at least the sections outlined below:

1. **Title page, with title and contributing authors**
2. **Introduction**

   The project must include an introduction that places the study into a relevant broader context. As this is a group work, there are three literature reviews (one for each student) to be included here, and you should decide fairly within the group who will work on which:

   a. Overview of **general climate change impacts** on hydrology, considering the different components and processes in the water cycle globally and in different climate zones
   b. Summary of hydrological **climate change impacts in Sweden**, including the current state of knowledge as well as general trends and tendencies
   c. Introductions to the **challenges of hydrological climate-change impact modelling**, including the main sources of uncertainty
3. **Material & Methods**

   Here a thorough and complete description of the case study sites (e.g. location, climate zone, catchment properties) and the study approach (e.g., tools, equations) must be given. Each student is responsible for describing, estimating and statistically analyzing one selected signature each of the 3 study sites both for observed and future data.
4. **Results (Case Study Analysis)**

   Describe and present the main results and observations. Make sure to link the presented tables and figures to the text. Each student should in this section be responsible for describing the results related to his/her selected signature.
5. **Discussion**

   Each student is responsible for discussing and interpreting the main results of her/his own signature. Explain and highlight the main implications and conclusions drawn from the results. Link your findings to the main factors governing the hydrological processes in the three catchments. For example, think about different climate zones, topography, storage characteristics of the catchment (i.e., reservoirs/lakes, snow, etc.).
6. **Conclusions**

   This section should be a group effort to collectively summarize the main results and highlight implications that make your findings relevant in a broader context.
7. **References**

   The report should include in-text citations with the citations collated at the end of the report. In a well-documented report, the majority of the references should come from the primary hydrological literature, with any citation of Internet sources kept to a bare minimum.
8. **Appendix**

   If necessary, add any related data that is not required to the immediate understanding of the discussion in the report in this section. This may contain materials such as: tables, graphs, illustrations, description of equipment, samples of forms, data sheets, questionnaires, equations, and any material that must be included for record purposes.

4.5. Oral Mid-Term Presentation

On February 23, we have **mandatory MID-TERM presentations** scheduled, which implies that you are not expected to have all your final results ready. But in your presentation, you should be able to show substantial progress, give evidence that the main functionality of your project is working and show some initial results. See this presentation as a way to check your progress (also in relation to your fellow students), to catch-up and to exchange ideas for analytical tools and methods that might be useful within the project.

a. Thoroughly read and follow the Oral Presentation Guide provided
b. Presentation style: max 15 minutes per group, each member needs to present some progress
c. Presentations followed by a short group discussion (ca. 5min) to share thoughts and ideas

5. Grading Criteria

Each group member will get an individual grade based on the grading criteria below. Please make sure to check these criteria before submitting your report.

	Points	3	2	1	0	
Title	The report includes an ...	Interesting and stimulating	adequate	some	poor or no	... title *(group)*
Introduction (Literature Review)	The report contains an ...	advanced description	adequate description	some description	no or insufficient description	... of the chosen topic for the introduction *(individual)*
	The report includes a...	thorough review (>3 references)	adequate review (3 references)	partial review (2 references)	inadequate (0-1 references)	... of relevant literature to back up your descriptions of the chosen topic *(individual)*
Material & Methods	The report covers an ...	advanced description	adequate description	some description	no or insufficient description	... of the study sites *(group)*
	The report provides an...	advanced description	adequate description	some description	no or insufficient description	... of the chosen methods used for the analysis *(individual)*
Results (Analytical understanding)	The report demonstrates ...	advanced understanding	adequate understanding	some understanding	no or insufficient understanding	... of the analytical, statistical and hydrological tools typically applied in climate change impact studies *(individual)*
	The report provides...	insightful	adequate	some	no or insufficient	... results of the analysis *(individual)*
	The report contains a...	well considered	adequate	some	no or insufficient	... number of informative figures/tables as evidence to support the results *(individual)*
Discussion (Reflections)	Existing literature is used ...	extensively (>3 references)	adequately (3 references)	to some extent (2 references)	inadequately (0-1 references)	... to place individual analysis results in a wider context *(individual)*
	The report provides ...	insightful interpretation	adequate interpretation	some interpretation	no or insufficient interpretation	... of the results of the analysis *(individual)*
Conclusions	The report provides ...	insightful	adequate	some	no or insufficient	... implications that make the findings relevant in a broader context *(group)*
Form and language	Figures and tables are presented...	thoroughly and neatly	adequately	to some extent	poorly or not at all	... with respect to resolution, layout, readability, text size and captions *(individual)*
	Report style instructions are ...	thoroughly	adequately	to some extent	poorly or not at all	... followed in the report *(group)*
	The text of the report is written ...	in an adequate scientific tone without errors	in an adequate scientific tone with minimal errors	in an adequate scientific tone with some errors	poorly with many errors	... in grammar or spelling *(individual)*

Note: a delayed submission will result in a deduction of 7 points (only for the project grade).

Total number of points: _____ (of 39) *Grade:* _____ (according to the scale below)

Grading scale: 5: 33-39 points 4: 26-32 points 3: 19-25 points FAIL: <19

The majority of items in this grading scheme relates to each student's individual contribution to the report (marked in red), but there are a few points (e.g. title, study site description, conclusions, report style) that require group efforts (marked in blue). Therefore, you are also required to submit a short personal reflection of the relative contribution of each group member to the project. Please check the assignments for more detailed instructions.