Climate Literacy Guidebook (CLG)

Reading materials for students participating in the CLUVEX Virtual Exchange Week

Version 3.0

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This document is the 3rd version of the "Climate Literacy Guidebook (CLG) - Reading materials for students participating in the CLUVEX Virtual Exchange Week", which serves as a primer on climate literacy—a critical 21st-century skill set for future employment. It is intended as a resource for students participating in the Climate-University-for-Virtual Exchange (CLUVEX) Virtual Exchange (VE) Weeks. This guide introduces foundational concepts of the climate system and its components, as well as essential knowledge in climate research, communication, and the competencies and skills requisite for future careers.

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FOREWORD

The Climate University for Virtual Exchanges (CLUVEX; https://www.atm.helsinki.fi/cluvex; 2023-2026) orchestrates a three-year project delivering a series of Virtual Exchange (VE) Weeks for students. These interactive online workshops, hosted on Zoom, delve into various aspects of climate change. Each VE Week (comprising 3 hours online work per day) features a blend of brief lectures in joint sessions and moderated discussions in small groups. These are structured around a CLUVEX Group Exercise (GE), henceforth referred to as "GE Climate Horizon" (see Part 1), tailored for academic students from diverse scientific disciplines and geographical origins.

Learning Outcomes During the VE Week:

- Students will gain an understanding of both foundational and cutting-edge knowledge regarding climate change, its impacts in historical and contemporary contexts, and strategies for envisaging environmentally sustainable futures.
- Students will acquire tools for visualizing and analysing climate-related data.
- Students will experience working online within an international team comprising 10 students and 1 moderator, focusing on the "GE Climate Horizon", engaging in discussions to brainstorm climate solutions and actions toward a sustainable future, incorporating a wide range of perspectives.

Students who actively participate in the VE Week, including attending lectures and completing the "GE Climate Horizon" and associated tasks, will earn 1 credit point (ECTS) granted by the University of Helsinki. The course code at the University of Helsinki is ATM398 (details available in APPENDIX 3).

Upon successful completion of the VE Week, students will also receive a certificate designating them as "Climate Messengers." This certification acknowledges their competence in fostering climate awareness and developing sustainability strategies within their home organizations and throughout their professional lives. They will be well-versed in the basics of climate change, science communication, problem-solving skills, and cross-cultural dialogue.

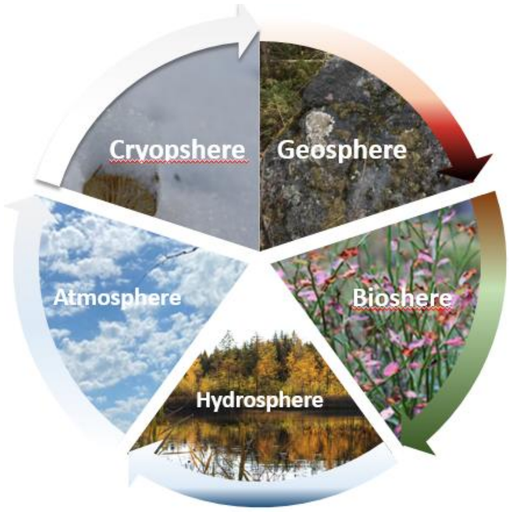
Furthermore, post the VE Week, students will have the opportunity to partake in online courses offered by the Climate University (CU; https://climateuniversity.fi) free of charge (see APPENDIX 4). These courses are designed to deepen understanding of climate sciences and facilitate tangible sustainability transitions in society (https://climateuniversity.fi/info). The CU courses are a product of a multidisciplinary collaboration among several Finnish universities, funded by the Finnish Ministry of Education and Culture, the Finnish Innovation Fund Sitra, and the involved universities. Students are encouraged to use the CU Blog (http://blogs.helsinki.fi/climateuniversity) to access information about ongoing online courses, study instructions, and updates. Additionally, students will be introduced to the SmartSMEAR ("Stations Measuring Ecosystem and Atmospheric Relations", operated by the CLC) and the "Electronic Research Data Archive" (ERDA), operated by the University of Copenhagen, Denmark (see APPENDIX 2).

The GE "Climate Horizon" revolves around an introductory exploration into climate change, leveraging recent science-based insights and fostering discussions through critical thinking. To construct their "Climate Horizon", students will assess the topic of climate change and its associated actions from various perspectives: historical (causes), present (current situation), and future (viable transformative actions). At the VE Week conclusion, teams will collectively formulate their visions of a sustainable future. Throughout such Week, all participants will share and reflect on their learning and experiences.

The original workshop, now termed "Climate Horizon", was devised by the education team at the Institute for Atmospheric and Earth System Research (INAR), University of Helsinki. This workshop has been successfully implemented in secondary schools across Finland, receiving widespread acclaim from students, and is continuously evolving.

This document, the Climate Literacy Guidebook (CLG), provides essential pre-material for students engaging in the VE Week.

Welcome to the "Climate University for Virtual Exchanges" CLUVEX Virtual Exchange Week



HOW TO USE THIS GUIDEBOOK

During CLUVEX, you will learn basic concepts about climate change and climate expertise competencies, how climate scientists work and communicate, and the importance of joint and inclusive dialogue in reducing climate change and building resilient futures for all. This document serves as a guidebook to better understand the CLUVEX Climate Horizon Group Exercise (GE) planned for the VE Week, and to introduce you to the climate change topics and competencies covered in the CLUVEX project. This document consists of the following main parts:

- **Part 1** provides a general description of the VE Week program (including a list of short lectures, and tools for climate-related data visualization and analysis useful for discussing the present, past, and future), the "GE Climate Horizon" topics, and VE Week questionnaires (Pre-task: Connections with climate change; Pre-questions before the VE Week; Questionnaire on Feedback for the VE Week).
- **Part 2** introduces lectures to be delivered during the VE Week.
- **Part 3** introduces to tools for climate-related data visualization, analysis and interpretation) to be used during the VE Week.

- **Part 4** provides concept definitions, and basic information and definitions on general terminology, and terminology used in lectures for climate and climate change, sustainable development, and other topics (note, most, but not all, of these terms will be used in Part 1).
- **APPENDIX 1** provides a list of recommended reading, references, and examples (not included in the VE Week) of tools related to environmental and climate sciences.
- **APPENDIX 2** provides an introduction to the SmartSMEAR and ERDA data tools.
- **APPENDIX 3** describes the VE Week learning outcomes for 1 credit point.
- **APPENDIX 4** introduces the Climate University and its online MOOC courses, where you can learn (free of charge!) more about climate change topics after the VE Week.

Before the VE Week starts, please, read this guidebook, familiarize yourself with the lectures and terminology, and complete the pre-task exercise at DigiCampus (refer to Chapter 1.5 for guidance) to share during the first day of the VE Week.

Part 1: VE WEEK & GROUP EXERCISE "CLIMATE HORIZON", LECTURES AND TOOLS

In the Virtual Exchange (VE) Week (scheduled in Table 1) we introduce you the climate change topics based on the latest scientific findings and give you some tools to visualise and analyse climate relevant data, debate your own case of current situation, potential causes and probable actions for better future. The main goal of VE Week is you to share different experiences related to climate change cases, and to discuss and brainstorm together best actions applicable for your own and common environmentally friendly futures or Horizons.

Before the VE week you should read this material, especially lectures included in Appendix 1, and report the tasks included in the lectures and pre-tasks listed below and at the DigiCampus educational platform. The access to the DigiCampus will be granted to you 2 weeks before the VE Week.

1.1. Virtual Exchange Week program

The VE Week will last five days and include three hours of online work each day. This includes joint sessions for up to 500 students with 50 moderators and extended time for teamwork in small groups of 10 students with 1 CLUVEX educated moderator. During joint sessions, introductory lectures on climate change and critical thinking topics will be shown (see following chapters), as well as demonstrations of some tools used by climate researchers in analysing climate change data and designing mitigation and adaptation strategies. In Table 1, we introduce the VE Week program.

Table 1. Program of the VE Week. In each day we 3 hours on-line in Zoom. During joint sessions we altogether up to 500 students on-line and in small groups 10 students (in the Zoom break-out rooms) and one moderator. Day 1 = Monday, 2=Tuesday, 3=Wednesday, 4 = Thursday and 5 = Friday.

DAY no	DAILY TOPICS OF THE VIRTUAL EXCHANGE WEEK	GROUP size
1	Welcoming words Lectures (see Appendix 1) **Lecture 1**: Navigating Planetary Boundaries: Our Blueprint for a Sustainable Future **Lecture 2**: Climate Change, Disasters, Carbon-neutrality and UN Sustainable Development Goals **Lecture 3:** Climate Change Impact on Water Resources **Lecture 4**: Nature Hazards: Floods **Lecture 5**: Impacts of Climate Change and Future Outlook **Lecture 6**: Climate Change, Mitigation and Adaptation Strategies **Lecture 7:** Artistic Research and Critical Thinking at the Intersection of Art, Science and Society **Lecture 8:** Towards Sustainable Future Utopia Breaking in small groups Introduction round. Pre-task sharing	*up to* 500 10 + 1
2	**Tool 1**: Environment and Data Visualization. **PAST & PRESENT** Breaking in small groups Work on GE Climate Horizon - Mapping Past & Present	*up to* 500 10 + 1
3	**Tool 2**: Socio-Economic Drivers of Climate Change. **PAST & FUTURE** Breaking in small groups Work on GE Climate Horizon - Mapping Past & Drafting Future	*up to* 500 10
4	**Tool 3**: Climate Scenarios. **FUTURE** Breaking in small groups Work on GE Climate Horizon - Mapping Future	*up to* 500 10+1
5	Discussion on a Common Climate Horizon Questionnaire Break Joint ending	10+1 *up to* 500

With the support of the lectures, tools, and your moderator, the primary focus of your teamwork will be to design both your individual and collective Climate Horizon. This involves mapping and discussing the Present (current climate change), the Past (causes of climate change), and the Future (climate scenarios) from your unique perspective, considering your own environment and situation. This process will be facilitated using an online whiteboard platform, such as Miro, as illustrated in Figure 1.

Throughout the week, you will document each step in a workbook, which will serve as your work diary to be submitted to your moderator at the end of the week. You have the flexibility to choose the format for your workbook. It can be a written report in Word, a PowerPoint presentation, a recorded video, or an interactive online whiteboard like Miro.

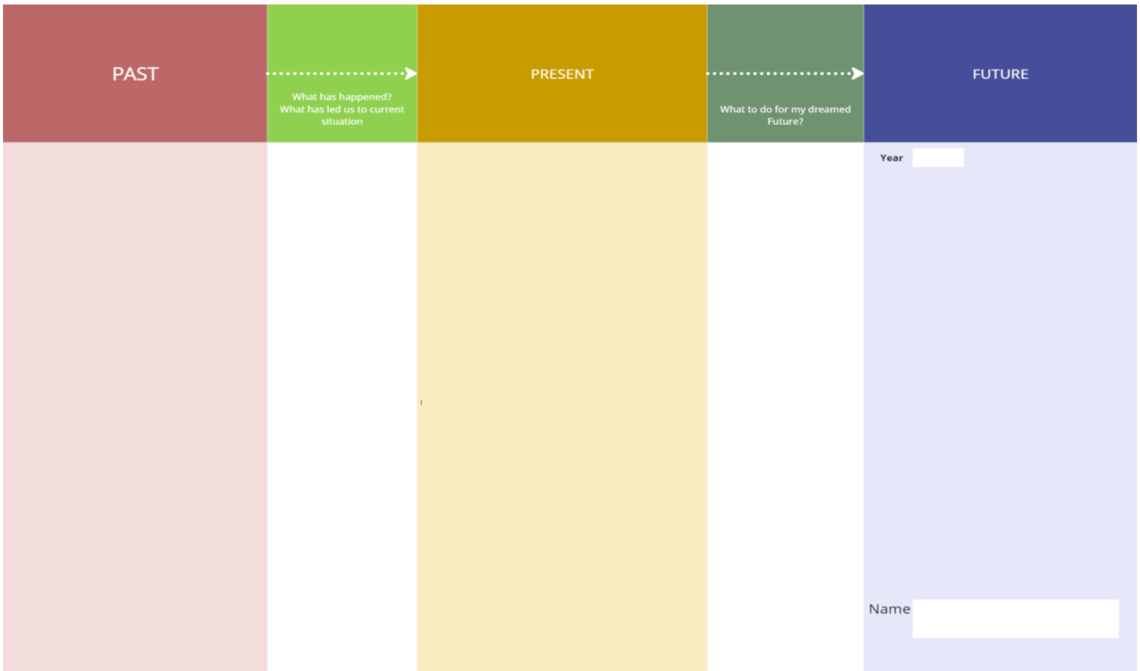


Figure 1. Climate Horizon-whiteboard, online Miro platform for mapping the Climate Horizon.

On the last day of the VE Week, your group will work together to design your Team's Climate Horizon and contribute it to the Common Horizon during the joint session with 500 students. An example of a Miro e-whiteboard is shown in Figure 2. The format for your Team's Climate Horizon should be discussed and agreed upon within your group. It could take the form of a recorded Zoom video where each team member expresses a key idea, a written format such as a PowerPoint slide, or utilizing the Miro e-whiteboard in collaboration with your moderator.

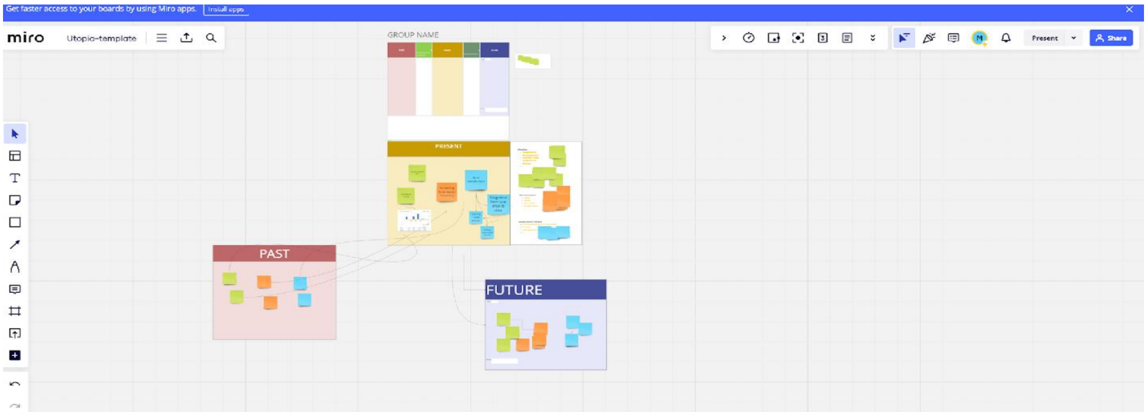


Figure 2. Example of Miro e-whiteboard.

Finally, before the last joint-ending session, you will complete the feedback on the VE Week questionnaires (refer to Chapter "1.5. VE Week Questionnaires" below) and write a letter to one of your team members, encouraging them to achieve their own "Climate Horizon."

1.2. VE Lectures on climate-relevant topics

The VE Lectures (see Part 2) to be delivered during the VE Week include the following:

- ❖ **Lecture 1**: Navigating Planetary Boundaries: Our Blueprint for a Sustainable Future
- ❖ **Lecture 2**: Climate Change and Air Quality
- ❖ **Lecture 3**: Climate Change Impact on Water Resources
- ❖ **Lecture 4**: Nature Hazards: Floods
- ❖ **Lecture 5**: Impacts of Climate Change and Future Outlook
- ❖ **Lecture 6**: Climate Change, Mitigation and Adaptation Strategies
- ❖ **Lecture 7**: Artistic Research & Critical Thinking at Intersection of Art, Science, & Society
- ❖ **Lecture 8:** Towards Sustainable Future Utopia

Each lecture is accompanied by a short description with illustrations, as well as a take-home assignment that includes short educational videos from DigiCampus, a list of reflective questions, and suggested readings ("Read more").

1.3. VE Tools for climate related data visualisation and analysis

The VE Tools (see Part 3) for visualization and analysis of climate-relevant data, which can be demonstrated and used in the "GE Climate Horizon" during the VE Week, include the following:

- ❖ **Tool 1**: Environment and Data Visualization. PAST & PRESENT (to be used in work on GE - Mapping Past & Present). This tool is introduced on Tuesday.
- ❖ **Tool 2**: Socio-Economic Drivers of Climate Change. PAST & FUTURE (to be used in work on GE - Mapping Past & Drafting Future). This tool is introduced on Wednesday.
- ❖ **Tool 3**: Climate Scenarios. FUTURE (to be used in work on GE - Mapping Future). This tool is introduced on Thursday.

Each tool includes a short description with illustrations, as well as a case example, suggested simple tasks, other useful tools, and readings.

1.4. VE Group Exercise – Joint Climate Horizons

During the Virtual Exchange (VE) week, you will imagine and construct a **Climate Horizon** that describes a hopeful state of future from a climate change perspective.
For this task, you will need to utilize and apply what you will learn from the lectures, tool tutorials and your small group discussions. It is important to stay active and take notes throughout the week.
During the VE Week, you will begin by sharing and discussing each other's **Present–Past–Future** mappings and collaboratively building a **joint Climate Horizon** for your group.
You will use platforms like **Miro (an online whiteboard)** to share your work during the joint session with all students (see example in Figure 3).

Detailed instructions for the **Climate Horizon** group exercise will be provided separately, and your group moderator will assist you throughout the three days of the joint exercise.

Personal Climate Horizon (Monday-Thursday)

During VE Week, you will examine your own living environment and map its past, present, and possible future. Over the week, you will gradually develop your **Personal Climate Horizon**, using lectures, exercises, and group discussions for reference and inspiration.

- On **Friday**, you will present your Climate Horizon to your group members (max. 5-minute presentation).
- After VE Week, you will submit a short report (max. 2 pages, MS Word or PDF format) to the Digicampus course folder within one week after the end of VE Week.

Purpose of the exercise:

- To explore climate change from multiple perspectives.
- To exchange thoughts and viewpoints with students from different backgrounds.
- To collectively envision a better future.
- The **Personal Climate Horizon** is developed step by step throughout the exchange

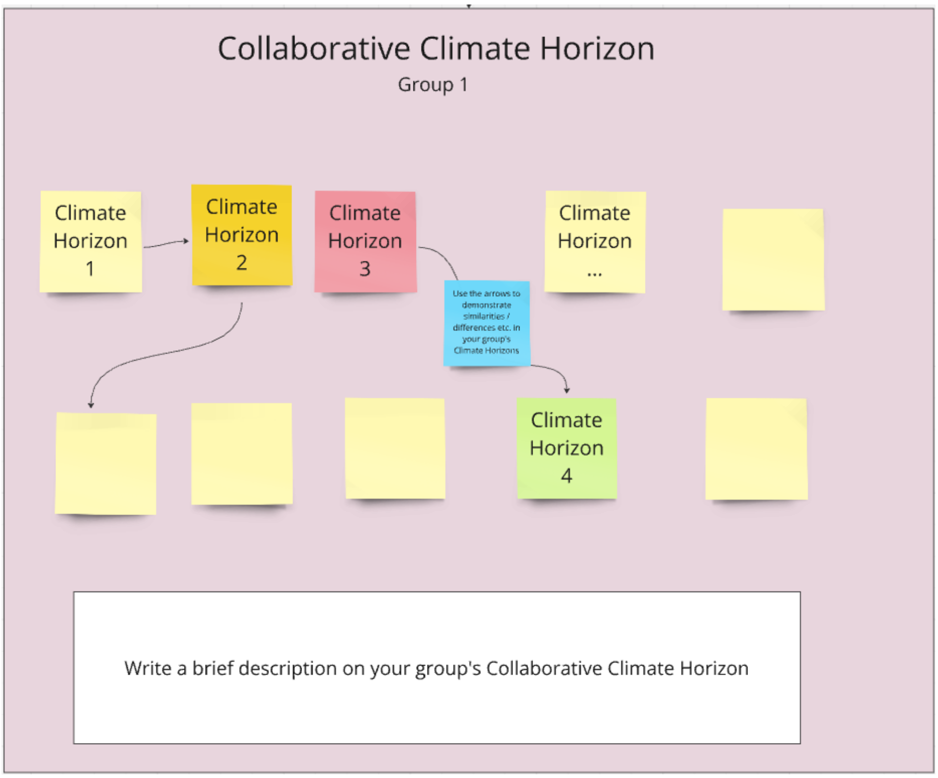


Figure 3. Example of joint Horizons in online whiteboard.

Collaborative Climate Horizon (Friday)

On **Friday**, share your **Personal Climate Horizons** with your group and reflect on commonalities and differences. Consider these key discussion questions:

- What **visions of a good life** are embedded in your Climate Horizons?
- What changes in **institutions, policies, and societal structures** are needed to achieve these visions?

Summarize your **Collaborative Climate Horizon** on your **Miro board** – the **group moderator** will lead the finalization of this group assignment.

Key points:

- The goal is **not to reach a single unified vision** but to demonstrate the **variety of ideas and perspectives** that Climate Horizons can encompass.
- Different or even conflicting views should be seen as opportunities for **deeper discussions** on topics such as:
  - Different understandings of a **good life**.
  - Social and economic arrangements that support sustainability.
  - The feasibility and political viability of various **Green Transition** approaches.

Group activities throughout the week will support the development of your **Collaborative Climate Horizon**.

Final Steps

After working with your group on the **Collaborative Climate Horizon**, you will:

1. Complete the **feedback questionnaire** (see Chapter 1.5, "VE Week Questionnaires").
2. Write a **one-to-one letter** to a group member. This letter should include **positive encouragement** and **supportive reflections** on their Climate Horizon ideas.

1.5. VE Week questionaries

All the questionaries will be made available at the DigiCampus.

Pre-tasks to develop before the VE Week

1. Choose a reference of any kind (book, essay, poem, video, podcast, image, tool or memory) which speaks to your interest or experience in learning about Climate Change and be prepared to introduce yourself and the example you bring to your working group (10 people, plus moderator). Sharing and exchanging these will help create a common resource list for you and your group to continue learning-with after the VE Week.
2. What do you think about climate change?
3. What is your motivation/thoughts about climate activism ?

Feedback of the VE Week

1. What is your overall rating for VE Week?
2. How relevant and helpful do you think it was for your study or life experience?
3. Was anything missing in this training that you had expected to learn?
4. How satisfied were you with the logistics [Giving clear instructions to learners; Course layout in Moodle; Communication; Learning activities]?
5. Would you recommend CLUVEX to your friends?
6. General feedback of the week ?

Part 2: LECTURES

2.1. Lecture 1: Navigating Planetary Boundaries: Blueprint for Sustainable Future

Lecturer: Inna Khomenko, Odessa State Environmental University (now Mecnikov's Odessa National University), Ukraine

In the vast cosmos we call home, our planet Earth is a precious oasis teeming with life. But as inhabitants of this blue orb, we face a critical challenge: how do we maintain the delicate balance that sustains life as we know it? Enter the concept of Planetary Boundaries – a scientific framework that delineates the safe operating space for humanity within the bounds of our planet's capacity to support life.

Imagine Earth as a spaceship hurtling through the cosmos, carrying all the resources and conditions necessary for life. Planetary Boundaries are like the controls in our spaceship, helping us navigate and ensure the health and stability of our onboard systems.

At the heart of this framework lie nine interlinked planetary boundaries, ranging from climate change and biodiversity loss to freshwater use and ocean acidification. These boundaries represent the critical thresholds beyond which human activities risk destabilizing Earth's systems, triggering irreversible and catastrophic changes.

Consider climate change, one of the most pressing boundaries we face today. As greenhouse gas emissions soar, Earth's climate system is pushed perilously close to tipping points, leading to extreme weather events, rising sea levels, and disruptions to ecosystems and societies worldwide.

Biodiversity loss presents another stark challenge. Every species, from the tiniest microbe to the mightiest predator, plays a vital role in maintaining the intricate web of life. Yet, human activities such as habitat destruction, pollution, and overexploitation are driving species to extinction at an alarming rate, threatening the stability of entire ecosystems.

Freshwater, essential for human survival and myriad other life forms, is also under pressure. Unsustainable water consumption, pollution, and the diversion of rivers for agriculture and industry are depleting freshwater reserves, exacerbating water scarcity and exacerbating conflicts over this precious resource.

Ocean acidification, fueled by the absorption of excess carbon dioxide, poses a grave threat to marine life and the millions who depend on oceans for food and livelihoods. As acidity levels rise, coral reefs bleach, shellfish struggle to form shells, and entire marine food chains are disrupted.

To ensure a sustainable future for generations to come, we must heed the warning signs provided by Planetary Boundaries. This means adopting bold measures to mitigate climate change, protect biodiversity, conserve freshwater resources, and safeguard our oceans.

Fortunately, solutions abound. Embracing renewable energy sources, transitioning to regenerative agricultural practices, and establishing marine protected areas are just a few examples of actions we can take to stay within the safe operating space of our planet.

In essence, Planetary Boundaries offer us a roadmap for navigating the complexities of our interconnected world. By respecting these boundaries and embracing a harmonious relationship with our planet, we can chart a course towards a thriving and sustainable future for all life on Earth.

Six of the nine boundaries are transgressed (Figure L1). In addition, ocean acidification is approaching its planetary boundary. The green zone is the safe operating space (below the boundary). Yellow to red represents the zone of increasing risk. Purple indicates the high-risk zone where interglacial Earth system conditions are transgressed with high confidence. Values for control variables are normalized so that the origin represents mean Holocene conditions, and the planetary boundary (lower end of zone of increasing risk, dotted circle) lies at the same radius for all boundaries (except for the wedges representing green and blue water, see main text).

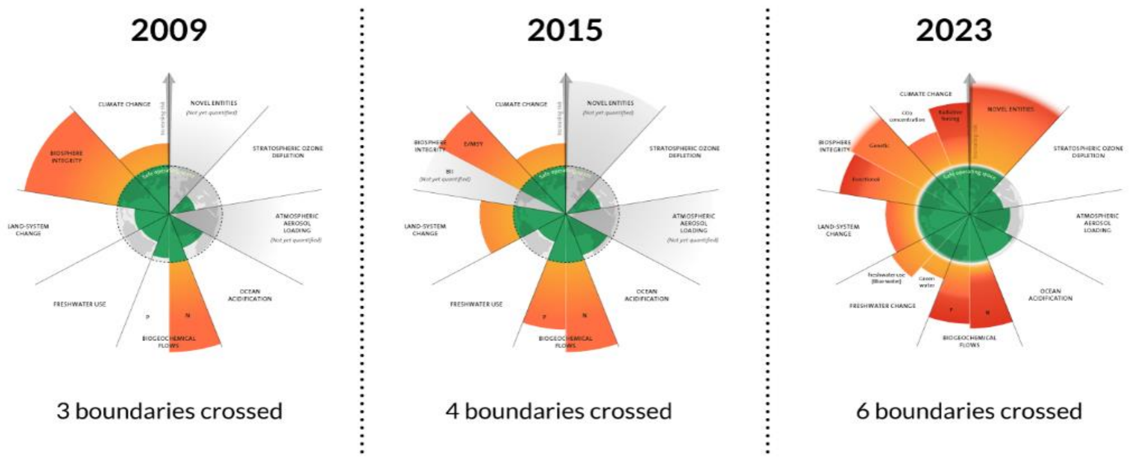


Figure L1. Planetary boundaries. Credit: Azote for Stockholm Resilience Centre, based on analysis in Richardson et al 2023. Attribution: CC BY-NC-ND 3.0

Wedge lengths are scaled logarithmically. The upper edges of the wedges for the novel entities and the genetic diversity component of the biosphere integrity boundaries are blurred either because the upper end of the zone of increasing risk has not yet been quantitatively defined (novel entities) or because the current value is known only with great uncertainty (loss of genetic diversity). Both, however, are well outside of the safe operating space. Transgression of these boundaries reflects unprecedented human disruption of Earth system but is associated with large scientific uncertainties.

Take a look: Planetary boundaries, the safe operating limits of humanity

https://www.youtube.com/embed/PQ2pHDokns4?feature=oembed

Reflexive Questions:

1. What are Planetary Boundaries and how do they serve as a framework for understanding humanity's impact on Earth's systems?

2. How are human activities, such as greenhouse gas emissions and habitat destruction, pushing Earth's climate & ecosystems beyond safe thresholds?

3. What are some concrete actions individuals and societies can take to mitigate the risks posed by exceeding Planetary Boundaries and promote a sustainable future?

Read more:

(*) What Are Planetary Boundaries, And Why Are They Significant?

(*) Humans Have Crossed 6 of 9 ‘Planetary Boundaries’

(*) Earth ‘well outside safe operating space for humanity’, scientists find

2.2. Lecture 2: Climate Change, Disasters, Carbon-neutrality and UN SDGs

Lecturer: Alexander Baklanov, Niels Bohr Institute, Copenhagen University, Denmark

Climate change is a real and undeniable threat to our entire civilization. The effects are already visible and will be catastrophic unless we act now.

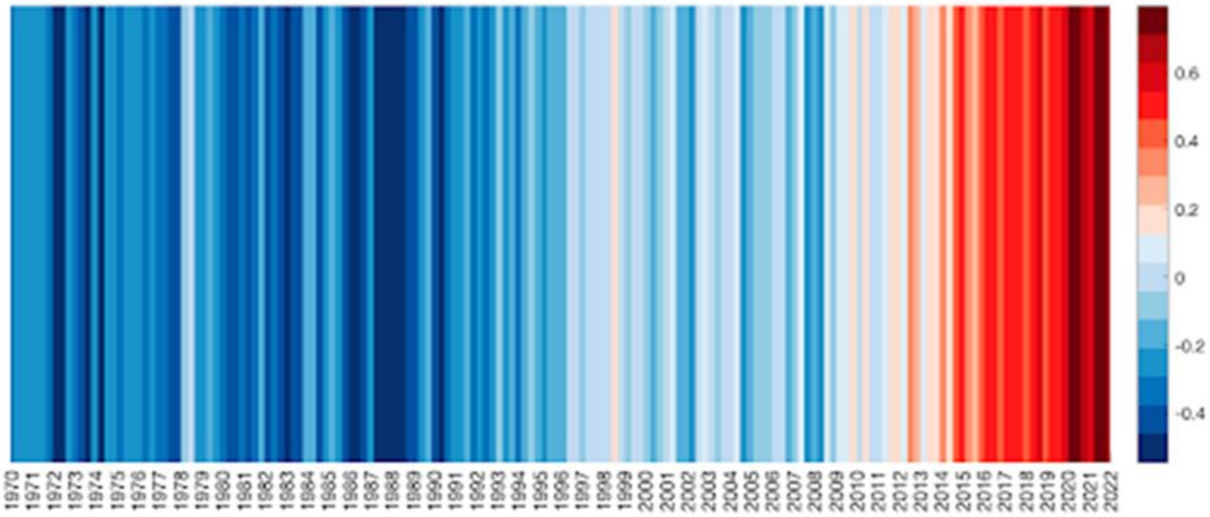


Figure L2. Ed Hawkins' Global Warming Stripes 1970-2022.

Sustainable Development Goal 13 commits us to "take urgent action to combat climate change and its impacts." Progress in this goal underpins progress in all Sustainable Development Goals.

The work of the international community is indispensable to climate action and to the Sustainable Development Goals across the board. The work is of huge societal importance: reducing hunger and poverty; improving health and well-being; ensuring clean water and affordable and clean energy; protecting life below the water and life on land; and making our cities and communities more resilient to climate change.

Weather and climate predictions help boost food production and move closer to zero hunger. Integrating epidemiology and climate information helps understand and manage diseases sensitive to climate. And early-warning systems help to reduce poverty by giving people the chance to prepare and limit the impact of extreme weather.

The scientific community together with UN Agencies and National Hydrometeorological Services drive the full value cycle, from science to services to action for the good of society. It advances knowledge of our Earth system, monitors the state of the climate and water resources, provides scientific information to inform greenhouse gas emissions reductions and delivers climate services and early warnings to support climate adaptation. Science is central to solutions and can supercharge progress on the Sustainable Development Goals (SDGs) across the board.

The lecture considers key issues of Climate Change, Disasters, Carbon-neutrality and UN Sustainable Development Goals, including the following points:

- ❖ Climate trend and future projections

- Large weather disasters: economic losses and mortality
- Climate change and sustainable development
- Main drivers of climate change
- Greenhouse gases: new records and trends
- Wildfires contribute to CO_2 emissions
- Heat health risks, pollution and vector-borne/water-borne diseases increasing
- Climate change and food security
- Water availability and population growth 2050
- UNFCCC process and GHG monitoring: evolve from “Top Down” to “Bottom Up”
- Emission control: co-benefits for environment and climate
- Global warming and cities: towards climate-smart and sustainable urban developments

2.3. Lecture 3: Climate Change Impact on Water Resources

Lecturers: Sergiy Snizhko and Olga Shevchenko, Taras Shevchenko National University of Kyiv, Ukraine

Water resources are important to both society and ecosystems. We depend on a reliable, clean supply of drinking water to sustain our health. We also need water for agriculture, energy production, navigation, recreation, and manufacturing. Many of these uses put pressure on water resources, stresses that are likely to be exacerbated by climate change.

In most parts of the world, water is a scarce resource. That might seem strange, because there is so much water on Earth. Almost all the water on the Earth, more than 97% of it, is seawater in the oceans according with the U.S. Geological Survey Department of the Interior (Gleick, 1996). The rest is called fresh water, because it does not have a high salt content. Most of the world’s fresh water is frozen solid in large glaciers in Antarctica and Greenland. Almost all of the fresh water that is available for human use is either contained in soil and rock below the surface, called groundwater, or in rivers and lakes (see Gleick, 1996).

Climate change impacts the world’s water in complex ways. The water cycle diagram (as seen in Figure L3) is altering nearly every stage due to global warming. The IPCC reported that human-induced warming reached in 2017 approximately 1°C above pre-industrial levels, increasing at a rate of 0.2°C per decade (IPCC, 2018). Increased heating of the sea and land surface leads to greater evaporation, increasing the amount of water vapor in the atmosphere. According to the Clausius-Clapeyron equation, the water-holding capacity of air increases by 7% for every 1 degree Celsius (Karl and Trenberth, 2003).

The last IPCC report predicts that climate-related extreme events will become more frequent around the world (IPCC, 2021). Rising global temperatures increase the moisture the atmosphere can hold, resulting in more storms and heavy rains, but paradoxically also more intense dry spells as more water evaporates from the land and global weather patterns change. (World Bank). Drought and flood risks, and associated societal damages, are projected to further increase with every degree of global warming (IPCC).

The frequency of heavy precipitation events will very likely increase over most areas during the 21st century, with more rain-generated floods. By 2050, the number of people at risk of floods will increase from its current level of 1.2 billion to 1.6 billion.

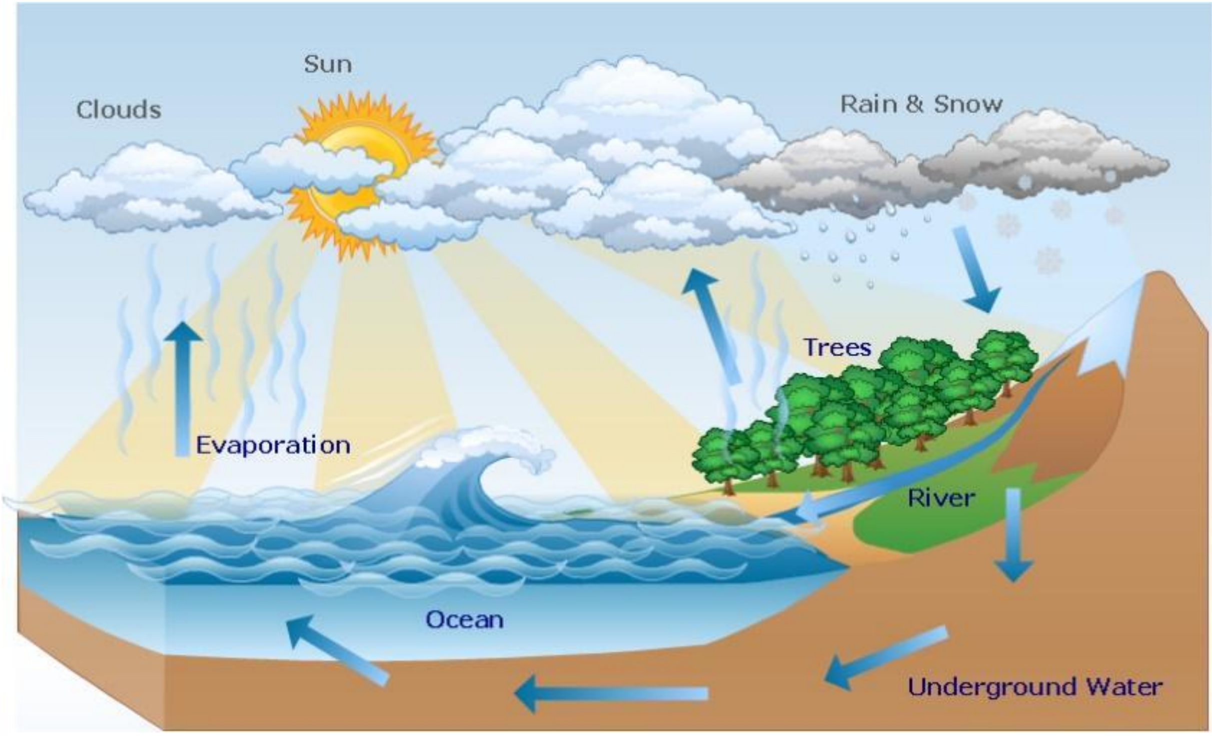


Figure L3. Global water cycle diagramme. Credits K. Tapdigova, Atribution CC BY-SA 4.0 DEED.

At the same time, the proportion of land in extreme drought at any one time is also projected to increase (IPCC). In the early to mid-2010s, 1.9 billion people, or 27% of the global population, lived in potential severely water-scarce areas. In 2050, this number will increase to 2.7 to 3.2 billion people (United Nations, 2020).

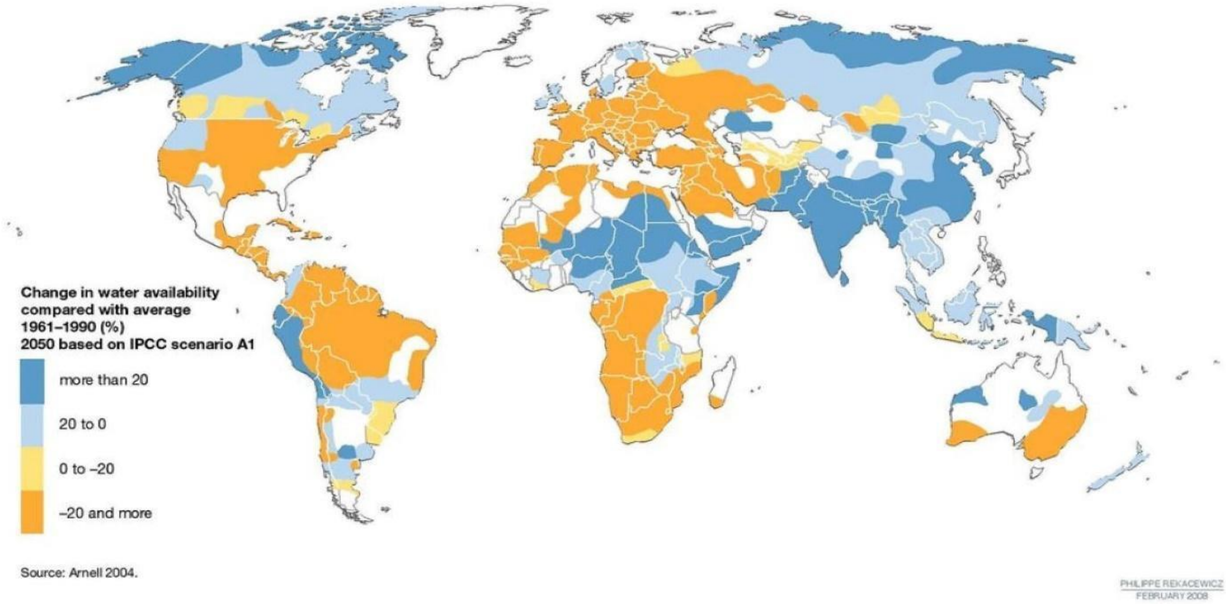


Figure L3.2: The contribution of climate change to declining water availability; source: *www.grida.no*

The real concern for the future, in the context of changing patterns of rainfall, is the decrease of run-off water which may put at risk large areas of arable land. Figure L3.2 shows how seriously this issue must be taken, while the forecast indicates that some of the richest arable regions (Europe, United States, parts of Brazil, southern Africa) are threatened with a significant reduction of run-off water, resulting in a lack of water for rain-fed agriculture and thus putting millions at risks.

The gradual onset or abrupt escalation of environmental changes, ranging from rising sea levels to prolonged droughts, catastrophic floods, and encroaching desertification, compels communities to abandon their homes in search of safer and more sustainable living conditions. Conversely, regions grappling with recurrent droughts face dwindling water resources and dwindling agricultural productivity, compelling residents to migrate in search of alternative means of subsistence.

According to the forecast of Institute for Economics & Peace, as early as 2040, 5.4 billion people (more than half of the projected world population) will live in the 59 countries experiencing high or extreme water stress, including India and China. If the availability of water resources in these countries continues to decline at the same rate as today, the number of climate refugees will increase to 1.2 billion by 2025.

Take a look: How does the climate crisis impact our water cycle?

https://www.youtube.com/watch?v=BgnB7KJqUbg

Reflexive Questions:

1. 75% of the surface of our planet is covered with water. Why is water a scarce resource in most parts of the world?

2. How does human-induced warming affect the global water cycle?

3. How does climate change affect the planet's water resources

Read more:

(*) U.S. Geological Survey Department of the Interior/USGS, Gleick, P. H., 1996: Water resources. In Encyclopedia of Climate and Weather, ed. by S. H. Schneider, Oxford University Press, New York, vol. 2, pp.817-823

(*) Over one billion people at threat of being displaced by 2050 due to environmental change, conflict and civil unrest. Source: www.economicsandpeace.org

(*) The World Bank Group, 2020. World Bank Open Data. https://data.worldbank.org.

(*) IPCC Sixth Assessment Report. Chapter 4: Water | Climate Change 2022: Impacts, Adaptation and Vulnerability (ipcc.ch). DOI: 10.1126/science.aan2506.2017

2.4. Lecture 4: Nature hazards - Floods

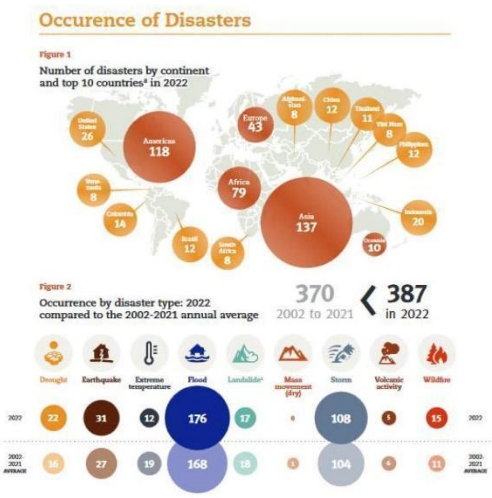
Lecturer: Valeriya Ovcharuk, Odesa State Environmental University (now Mechnikov's Odessa National University), Ukraine

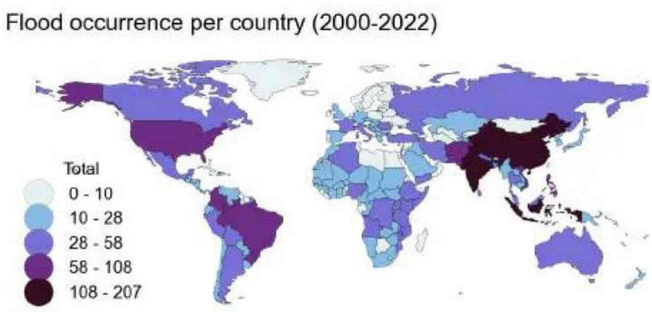
According to the data of the European Environmental Agency between 1980 and 2020, weather and climate-related extremes accounted for around 80% of the total economic losses caused by natural hazards in the EEA Member States, amounting to EUR 487 billion. This is equivalent to EUR 11.9 billion per year. In the period of global and regional climate changes in almost all the regions of our planet, there is an increase in extreme natural phenomena, which include floods of different origins. In the last decades, according to the data of the Centre for Research on the Epidemiology of Disasters (CRED), in many countries of the world there has been a record-high number of natural disasters that affected about 2.7 billion people, that is a third of the world's population.

The hydrological dangerous events most of all represent a flood that has different origins, and they caused 43% of economic losses in the last 30 years.

Climate change affects the water cycle in complex ways. There are concerns that a warmer climate may shift the flood regimes and thus increase potential flood damage and/or reduce the economic efficiency of flood management measures. To assess the changes in flood risk it is essential to understand the process causes of any changes, both in the past and in the future.

Regarding floods, in most parts of the globe, they are caused by prolonged cloudbursts and storms as a result of passing cyclones. On the rivers of the Northern Hemisphere, floods are caused by the rapid snowmelt, snow dams, and ice jams. In areas with snow cover, which is about 1/3 of the land surface, snowmelt and rain floods are the most common. They are especially widespread in Eurasia and North America.





(a) (b)

Figure L4.1: (a) Disasters occurrence; source https://www.cred.be/sites/default/files/CredCrunch70.pdf, (b) Flood occurrence per country: 2000-2022; source EM-DAT https://www.emdat.be, international disaster database.

Flood is formed due to the main source of feeding (on plain rivers due to snowmelt, in high mountains due to melting of snow and glaciers, in monsoon and tropical zones as a result of spring and summer precipitation, etc. For rivers in one climatic zone, it annually repeats in the same season with different intensity and duration. Snow melting at plain river catchments causes the emergence of spring floods, the melting of high mountain snow and glaciers, and also rainfalls cause spring-summer and summer floods. Sharp and continuous increases in temperature in spring with significant stocks of water in the snow greatly influences the nature of the formation and flow of the flood.

Floods become catastrophic if the infiltration properties of soils have decreased significantly due to their moisture saturation as a result of abundant autumn rains and deep freezing in severe winters. Spring rains can cause a significant increase in floods when the snowmelt flood peak coincides with the peak of the rain flood. According to the size and scale of damage the classification of floods and divided into low (small), high, significant, and catastrophic.

The catastrophic floods cause enormous material loss and lead to people's deaths, covering enormous areas within one or more river systems; more than 70% of agricultural land, large number of settlements, industrial plants, and utilities are flooded; economic and production activities are completely paralyzing, the way of life of the population is temporally changed. The periodicity or return period of this phenomenon is once in 100-200 years.

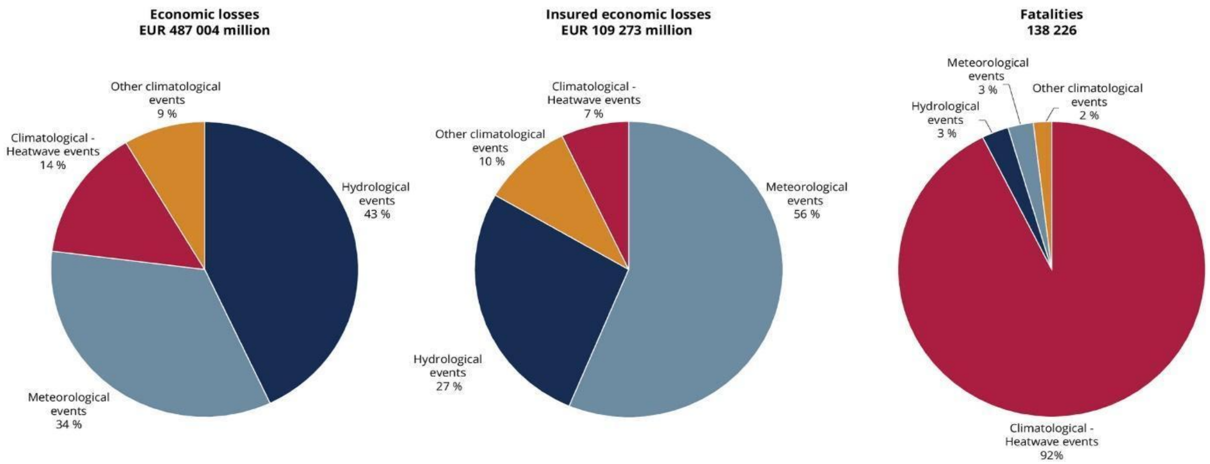


Figure L4.2: Economic damage caused by weather - and climate-related extreme events in EU Member States (1980-2020) - per hazard type based on CATDAT; source: ***https://www.eea.europa.eu/publications/economic-losses-and-fatalities-from***

Take a look: Floods: The new abnormal:

https://www.youtube.com/watch?v=JWQi1F_AFKk&list=PPSV

Repeated events are still possible:

https://youtube.com/shorts/gFGB6JZ4AU0?si=LtLOVrb-cmjZPOtu

Reflexive Questions:

1. What types of natural hazards/disasters do you know?

2. What are floods and why do they occur?

3. Is climate change affecting the water cycle and increasing the number of catastrophic floods??

Read more:

(*) https://www.cred.be/sites/default/files/2021_EMDAT_report.pdf

(*) https://www.preventionweb.net/understanding-disaster-risk/key-concepts/deterministic-probabilistic-risk

(*) https://www.eea.europa.eu/ims/economic-losses-from-climate-related#footnote-NEDVA9FL

(*) Blöschl G. et al. (): Changing climate both increases and decreases European river floods. Nature, 2019, 573(7772), 108-111 https://doi.org/10.1038/s41586-019-1495-6

(*) Blöschl G. et al. (2017): Changing climate shifts timing of European floods. Science. 357(6351),588-590. DOI: 10.1126/science.aan2506.2017

2.5. Lecture 5: Impacts of Climate Change and Future Outlook

Lecturer: Hamsik Movseyan, Yerevan State University, Armenia

The biosphere has been greatly altered by the demands of human societies. Greenhouse gases like carbon dioxide, methane, nitrous oxide, and water vapour were thought to come solely from natural sources preceding the industrial revolution. However, anthropogenic activities are currently regarded as most accountable for climate change. Changes observed in Earth's climate since the mid-20th century are driven by human activities, particularly fossil fuel burning, which increases greenhouse gas levels in Earth's atmosphere, raising Earth's average surface temperature. The interconnected nature of climate change's effects across ecological, environmental, sociopolitical, and socioeconomic domains makes it a formidable intergovernmental problem.

Some of the key impacts (see Figure L5) of climate change include:

- **Rise in global temperatures**: global temperatures are increasing due to the accumulation of greenhouse gases in the atmosphere, leading to heatwaves, melting glaciers and ice caps, and shifts in weather patterns.
- **Extreme weather events**: climate change intensifies extreme weather events such as hurricanes, cyclones, droughts, wildfires, and floods (especial case explained below in this guidebook). Thus, extreme weather events cause widespread damage to infrastructure, agriculture, and human settlements.
- **Sea-level rise**: melting ice sheets and glaciers contribute to rising sea levels, which pose threats to coastal communities, infrastructure, and ecosystems, leading to increased flooding, erosion, and saltwater intrusion.
- **Ocean acidification**: increased levels of carbon dioxide in the atmosphere lead to ocean acidification, affecting marine life such as coral reefs, shellfish, and fish populations, with cascading effects on marine ecosystems and fisheries.
- **Loss of biodiversity**: climate change threatens biodiversity by altering habitats, disrupting ecosystems, and increasing the risk of species extinction, which can have profound consequences for ecosystem services, food security, and human well-being.

- **Impact on agriculture**: changes in temperature, precipitation patterns, and extreme weather events affect agricultural productivity, crop yields, and food security, leading to reduced crop yields, changes in crop distribution, and increased vulnerability of smallholder farmers.
- **Health impacts**: climate change exacerbates health risks by increasing the incidence of heat-related illnesses, vector-borne diseases, waterborne diseases, and mental health issues, disproportionately affecting vulnerable populations and regions.
- **Social and economic impacts**: climate change exacerbates existing social inequalities and economic disparities, leading to displacement of populations, loss of livelihoods, increased migration, conflicts over resources, and challenges to sustainable development efforts.

Figure L5: Anthropogenic activities contributing to climate change and climate change impacts (prepared by YSU team).

Research on future scenarios predict climate change will have a dramatic effect on natural environments, plants, and animals, leading to acceleration in biodiversity loss in some areas. The impacts will have knock-on effects for many communities and sectors that depend on natural resources, including agriculture, fisheries, energy, tourism, and water. It may aggravate erosion, decline in organic matter, salinization, soil biodiversity loss, landslides, desertification and flooding.

Global climate is anticipated to keep on changing over this century and afterwards. Decisions made now and in the following couple of decades will decide the measure of extra future warming. Past mid-century, bringing down levels of warmth catching gases in situations with decreased discharges will prompt detectably less future warming. Higher emanations levels will bring about all the more warming, and consequently more serious effects on human culture and the common world. It is essential to take necessary action at the earliest else it would lead to irreversible changes to the environment we live in.

Take a look: Climate Change 2022: Impacts, Adaptation & Vulnerability:

https://www.youtube.com/watch?v=SDRxfuEvqGg

Causes and Effects of Climate Change:

https://www.youtube.com/watch?v=G4H1N_yXBiA

When The World Gets 1℃ Hotter:

https://www.youtube.com/watch?v=dIsjcG7hTmo

Reflexive Questions:

1. What are the key impacts of climate change?

2. Why is climate change and its effects are of great concern in future?

3. Which steps can be taken to decrease the effects of climate change?

Read more:

(*) Raihan, A. (2023). A review of the global climate change impacts, adaptation strategies, and mitigation options in the socio-economic and environmental sectors. *Journal of Environmental Science and Economics*, 2(3), 36-58. https://doi.org/10.56556/jescae.v2i3.587

(*) IPCC, 2022: Climate Change 2022: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [H.-O. Pörtner, D.C. Roberts, M. Tignor, E.S. Poloczanska, K. Mintenbeck, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem, B. Rama (eds.)]. Cambridge University Press. Cambridge University Press, Cambridge, UK and New York, NY, USA, 3056 pp., doi:10.1017/9781009325844.

2.6. Lecture 6: Climate Change, Mitigation, and Adaptation Strategies

Lecturer: Hasmik Movsesyan, Yerevan State University, Armenia

Mitigation and adaptation are two interconnected approaches people can take in addressing climate change, which is considered one of the most intricate challenges of our time. Mitigation involves efforts to decrease greenhouse gas emissions and control the extent of global warming. On the other hand, adaptation focuses on initiatives to assist people in coping with both present and future impacts of climate change. These dual strategies collaborate to safeguard communities from the adverse effects of climate change: one aims to minimize and manage future climate change, while the other aims to address the consequences of climate change that cannot be prevented.

The primary objective of mitigation is to address the fundamental cause of climate change, which is the accumulation of heat-trapping greenhouse gases in the atmosphere at a rate faster than the Earth can absorb them. This can be achieved by either reducing the sources of greenhouse gas emissions or enhancing the mechanisms that remove these gases from the atmosphere.

Figure L6: Climate change mitigation and adaptation require a combination of strategies that foster resilience in local communities and ecosystems (prepared by YSU team).

To reduce sources of greenhouse gas emissions, a significant focus is placed on decreasing the burning of fossil fuels such as coal, oil, and natural gas, which account for nearly three-quarters of human-generated emissions. Mitigation efforts often involve replacing these fuels with alternative energy sources like renewables (e.g., solar and wind power) and nuclear energy. Additionally, mitigating greenhouse gas emissions can involve addressing other sources such as preventing deforestation or capturing methane emissions from landfills.

On the other hand, enhancing sinks refers to mitigation strategies that involve removing greenhouse gases from the atmosphere. This can be achieved through initiatives like reforestation, where new forests are grown to absorb carbon dioxide. Another approach is the development of "direct air capture" systems, which directly extract greenhouse gases from the air.

Agriculture has a positive and important role to play in climate change mitigation. The crops, hedgerows, and trees found on farmland sequester carbon from the atmosphere through photosynthesis, while properly managed soils provide carbon storage.

Carbon pricing is an effective strategy to drive climate action by altering consumption and investment behaviours, while also promoting economic development that aligns with climate change mitigation efforts. The fundamental concept behind carbon pricing involves imposing charges on emitters or providing incentives for reducing emissions. This approach ensures that the external costs associated with carbon emissions are accounted for, thereby transferring the responsibility of addressing climate change damages from the public to the greenhouse gas emitters.

Even with significant cuts in greenhouse gas emissions, many of the impacts of climate change will be felt for many years to come, and many are effectively irreversible. This means hotter temperatures, sea level rise, longer drought periods, and extreme, unpredictable weather events will gradually become the new norm.

Hence adaptation to climate change should be considered an essential element in the global effort to safeguard people, livelihoods, and ecosystems in the long run. It involves making adjustments to ecological, social, or economic systems in response to actual or anticipated climate-related stimuli and their impacts. The nature of adaptation measures can vary greatly, depending on the specific circumstances of a community, business, organisation, country, or region. It can also take a variety of approaches depending on its context in vulnerability reduction, disaster risk management or proactive adaptation planning. There is no universal solution that fits all situations. Adaptation can encompass a wide range of actions, such as constructing flood defences, seawalls, levees, and dikes, establishing early warning systems for cyclones, switching to drought-resistant crops, implementing conservation agriculture and drip irrigation techniques, or even reconfiguring communication networks, business practices, and government policies.

Another important element of adaptation is ecological restoration. Restoring ecosystems such as mangroves, tidal marshes, kelp forests, seagrass meadows, coastlines, coral reefs, and shellfish reefs can provide protection to communities and inland habitats against storm surges and rising sea levels. The restoration of floodplains, wetlands, rivers, and streams helps in minimizing the risk of flooding. Moreover, reintroducing natural disturbance patterns and eliminating invasive species can help mitigate the effects of wildfires. Furthermore, the expansion of green spaces and appropriate vegetation cover can help lower temperatures and encourage non-motorized transportation in urban areas.

Reflexive Questions:

1. What is the difference between climate change mitigation and adaptation?

2. What is the significance of mitigation and adaptation in addressing climate change?

3. In what ways can vulnerability be reduced through adaptation measures?

Read more:

(*) Wang F., Harindintwali J.-D., Wei K., et al., (2023). Climate change: Strategies for mitigation and adaptation. The Innovation Geoscience 1(1), 100015. https://doi.org/10.59717/j.xinn-geo.2023.100015

(*) IPCC (2022): Climate Change 2022: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [H.-O. Pörtner, D.C. Roberts, M. Tignor, E.S. Poloczanska, K. Mintenbeck, A.

Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem, B. Rama (eds.)]. Cambridge University Press. Cambridge University Press, Cambridge, UK and New York, NY, USA, 3056 p. https://doi.org/10.1017/9781009325844

(*) Chunli Zhao, Yan Yan, Chenxing Wang, Mingfang Tang, Gang Wu, Ding Ding & Yang Song (2018): Adaptation and mitigation for combating climate change – from single to joint, Ecosystem Health and Sustainability, 4:4, 85-94. https://doi.org/10.1080/20964129.2018.1466632

2.7. Lecture 7: Artistic Research and Critical Thinking at the Intersection of Art, Science and Society

Lecturer: Yvonne Billimore, Bioart Society, Finland

This lecture will give an introduction to the field of art and science, sharing concepts and processes which encourage you to adopt your own methods of artistic and critical engagement within the CLUVEX exercises.

Artists working in the field of art and science have long been engaging with our troubled realities, and continue to play a pivotal role in problematising, raising questions and creating awareness on the political and ethical dimensions of life/living. In their encounters—engaging in the complexities of multiple entangled crises and their material consequences—artists and scientists do the critical work of imagining and making more liveable futures.

While often presented as worlds apart or at other ends of the spectrum—one is relational, the other rational—art and science are “in fact” not so different. They share a history, in early modern Europe they were very much interconnected and considered to be of the same root. It was not until the 19th century when art and science split, in part due to the recategorization of knowledge production by western European academic institutions. Even since this supposed divide, they have been embroiled in the same western-capitalist-colonial systems that have determined their trajectories, technologies, and epistemologies that uphold the idea there is one way to know. In this lecture I ask you to question dominant and singular approaches to knowing and instead to embrace an “ecologies of knowledges” which positions artistic and critical knowledges (amongst others) as valid and valuable as science fact.

Artistic research, in the field of art and science, might take place as hands-on research the lab, growing artworks that work with microorganisms, e.g., bacteria, archaea, fungi, protozoa, algae, and viruses. Or it can equally take place in the field through situated, embodied and relational research practices as well as observation, documenting and collecting. These are of course very similar processes to scientific research, but often the reason or thinking behind these processes differ. As do the questions asked. In the arts we are encouraged to challenge normative thinking and ways of knowing, and to explore the world from different viewpoints.

Artists spend much of their formal and informal education training in diverse research methods and developing practices which employ critical thinking. Critical thinking is a process of personal investigation and investment: it is self-led, self-reflective and self-critical. It is something that is developed over time, and obviously cannot be taught in a week (in fact by its own definition it cannot be taught). Therefore, this lecture points to critical thinking as an approach and encourages you to adopt this frame of thinking—which involves combination of "conceptualising, applying, analysing, synthesising, and/or evaluating information gathered from, or generated by, observation, experience, reflection, reasoning, or communication" (see definition note below).

(a) (b)

Figure L7: Field_Notes: (a) The Heavens, HAB-Group (photo by Till. Bovermann, tai-studio.org, 2018) and (b) The North Escaping (photo by Teemu Lehmusruusu, 2023).

Artistic methods and critical thinking involve thinking-with complexity, which is core to addressing the climate crisis. Climate change is a global crisis – which intersects with a complexity of social, ecological, political and cultural crises. However, it also needs to be investigated and made tangible on a local scale. Researching, collecting data and observing the tangible effects and effects of climate change requires paying attention to and attending to your immediate context as much as it does connect it to the macro scale. Cross pollinating "data" from your specific locales with those in their groups across eco-socio-political contexts illustrates the criticality of approaching climate change from situated yet interconnected perspectives and the value in sharing knowledge and experience.

In the virtual exchange weeks encourage you to engage in processes of which combine scientific and artistic methods with embodied and situated knowledge. This lecture will offer some tools and exercises for fieldwork research that supports embodied, relational and critical thinking such as: (i) observational documentation, note taking and drawing; (ii) sensing and listening practices; (iii) prompts for asking the "other question" (leaning intersectional feminism) and considering other perspectives and less dominant narratives.

Reflexive Questions:

If the memory of climate catastrophe is lodged "not only in something we might call mind or psyche, but in the wet fabric of our flesh" how might we access our internal registers, our sensory, lived and embodied knowledge, as a way to read and know the changes of the world through our bodies, towards imagining a "different kind of ethics and politics". (A question posed in reference to Astrida Neimanis text "The body is the site of climate catastrophe", in Yvonne Billimore and Jussi Koitela (eds.), Rehearsing Hospitalities Companion 2, 2020.)

Read more:

(*) Bioart Society website: https://bioartsociety.fi

(*) The North Escaping project: https://bioartsociety.fi/projects/the-north-escaping/pages/about-the-the-north-escaping

(*) Astrida Neimanis, “The body is the site of climate catastrophe”, in Yvonne Billimore and Jussi Koitela (eds.), Rehearsing Hospitalities Companion 2 (Berlin and Helsinki: Archive Books & Frame Contemporary Art Finland, 2020), 179. Available as an open access PDF.

(*) Erich Berger, Mari Keski-Korsu, Marietta Radomska and Line Thastum (eds). *State Of The Art - Elements for Critical Thinking and Doing*. Bioart Society. 2023. Available as open access PDF.

(*) Erich Berger, Kasperi Mäki-Reinikka, Kira O'Reilly and Helena Sederholm (eds). *Art as We Don’t Know It.* Aalto Arts Books. 2020. Available as open access PDF.

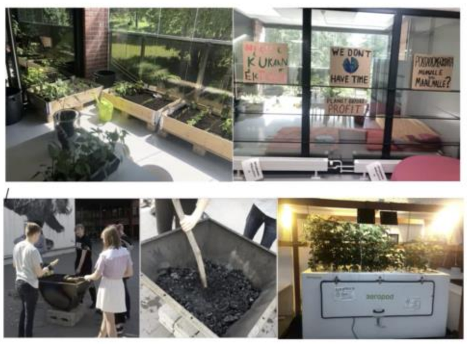
(*) Laura Beloff, E. Berger, T. Haapoja (eds). *Field_Notes – From Landscape to Laboratory.* Bioart. 2023. Available as open access PDF.

(*)https://www.criticalthinking.org/pages/defining-critical-thinking/766

2.8. Lecture 8: Towards Sustainable Future Utopia

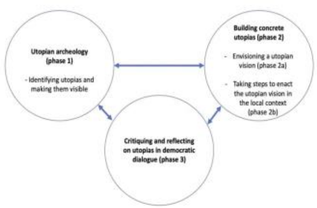
Lecturer: Antti Rajala, University of Helsinki (UH), Finland

This lecture introduces the concept of utopia as a method based on Ruth Levitas’ theory. Utopia is understood not as a final destination but as a process—a continuous, critical, and imaginative activity directed towards envisioning alternative and more sustainable futures. The pedagogy of utopias fosters reflexivity, dialogue, and "blueprint thinking" aimed at creating realistic pathways toward social transformation.



Alternative forms of food production

Bicycles on the move!



Climate warriors

Figure L8: Model of pedagogy of concrete utopias; source: https://www.utopiaproject.fi/en

A key concept discussed is that of Concrete (Real) Utopias, which are grounded in actual social innovations that reflect possibilities for broader systemic change. Examples include initiatives such as participatory city planning, Wikipedia, and universal basic income schemes. These examples demonstrate that utopian imagination can be practical and actionable.

The lecture highlights that hope is not a passive feeling but an active engagement with the present aimed at constructing better futures. Participants are encouraged to view utopia not as fantasy but as a critical method to explore possibilities for socio-environmental justice.

The lecture also includes real-life examples of concrete utopias, such as alternative food production systems, bicycle city infrastructure, and community climate actions, linking them to broader sustainability transformations.

Reflexive Questions:

- How can the concept of "utopia as a method" help in designing actionable pathways for social and environmental sustainability?

- What are some examples of "concrete utopias" you see around you or could imagine creating in your own community?

- How does hope function as a practical tool for envisioning and realizing sustainable futures?

Read more:

(*) Ruth Levitas, Utopia as Method: The Imaginary Reconstitution of Society, Palgrave Macmillan, 2013.

(*) Ernst Bloch, The Principle of Hope, MIT Press, 1986.

(*) Erik Olin Wright, Envisioning Real Utopias, Verso Books, 2010.

(*) Antti Rajala (2021), "Book Review of Utopia as Method" (Mind, Culture, and Activity, 28(1), 82–88).

(*) Utopia Project website: https://www.utopiaproject.fi/en

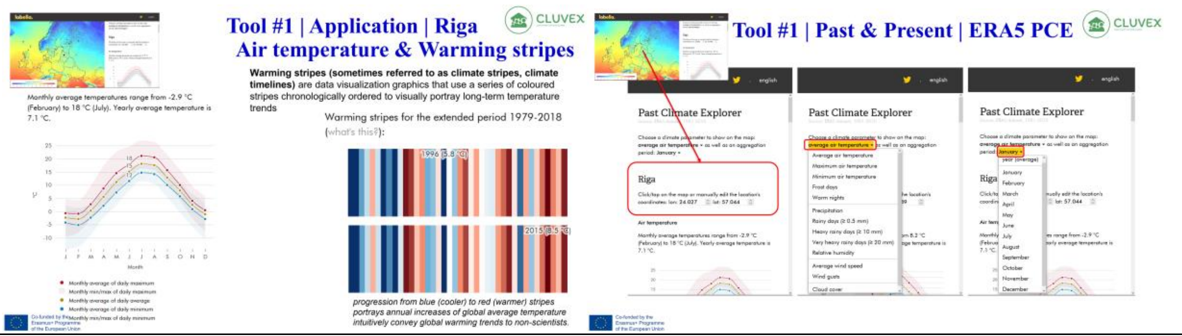
Part 3: DATA VISUALIZATION TOOLS

3.1 Tool 1: Past & Present. Environment and Data Visualization

Tool	ERA-5 Past Climate Explorer Tool https://era5.lobelia.earth/en **Lecturer: Alexander Mahura, University of Helsinki, Finland**
Tool is used to visualize historical climate statistics for any geographical location around the world. Click anywhere on the interactive map or search for a city to explore the typical	

monthly climate and discover how the climate has changed over the past years. Driven by ERA5 (ECMWF Reanalysis v5) - the 5th generation ECMWF (European Centre for Medium-Range Weather Forecasts) atmospheric reanalysis of the global climate. ERA5 describes the global history of the atmosphere, using a combination of forecast models and data assimilation systems to "reanalyse" past observations.

Case-example
User-selectable parameters:
(1) Geographical location: Click by mouse on the interactive map at any geographical location over the globe OR manually edit the location's coordinates (longitude and latitude) to generate location-specific climate statistics.
(2) Parameter: Global average fields (for 1981-2010 period) to visualize in the interactive map. The available options are average, maximum, and minimum air temperatures; frost days and warm nights; precipitation; rainy, heavy rainy, and very heavy rainy days; relative humidity; average wind speed and wind gusts; cloud cover.
(3) Statistics: Aggregation period: average "year" and average "month" (January – December) for parameters listed above



Click on:

https://era5.lobelia.earth/en

1) Look for the climate conditions of your location/ city and copy the report.
2) Check 2-3 other locations/ cities away from your location and compare differences.
3) Did you find the "City of your dream summer vacation"?

Other tools	Climate Explorer https://climexp.knmi.nl/start.cgi
Readings	

3.2 Tool 2: Past & Future. Socio-Economic Drivers of Climate Change

Tool	**Historic time-series of socio-economic indicators, World Bank Open data:** https://data.worldbank.org/indicator SSP Database (Shared Socioeconomic Pathways)-Version 2.0 https://tntcat.iiasa.ac.at/SspDb/dsd?Action=htmlpage&page

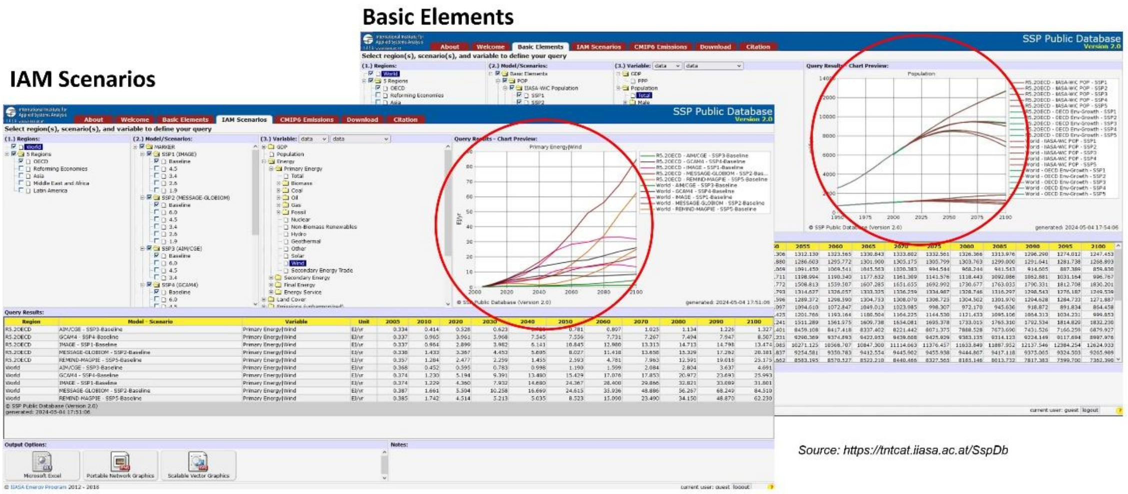
Lecturer: Stefan Fronzek, Finnish Environment Institute, Finland

Socioeconomic development and climate change are strongly intertwined by determining resource use and GHG emissions driving climate change on the one hand and impacts of climate change affecting socioeconomic conditions on the other hand.

This exercise aims to explore several open online databases and visualization tools to characterize some socio-economic drivers of climate change and the context they are setting for determining vulnerability and exposure to climate change. Key indicators such as population and gross domestic product (GDP) will be summarized for their historic development as well as for a set of future projections under the so-called Shared Socioeconomic Pathways (SSPs) that describe alternative developments up until 2100 (O'Neill et al. 2017).

Case-example

User-interface and population projections of the SSP database (Version 2.0)



Click in:

https://data.worldbank.org/indicator & https://tntcat.iiasa.ac.at/SspDb

(1) Describe the historic development of GDP and total population for your home country and compare these to 2 other countries of your choice. Select up five other indicators from the WorldBank Open data that (i) indicate drivers of climate change by affecting GHG emissions and carbon storage or (ii) that determine the exposure or the vulnerability of society to climate change impacts.

(2) Describe future projections of GDP and population for five SSPs for your home country and to other countries of your choice.

(3) Optional task: Expand your results by additional socio-economic indicators from the SSP Extensions Explorer (https://ssp-extensions.apps.ece.iiasa.ac.at). Compare your results for population and GDP projections in the previous task to the SSP 3.0 release (https://data.ece.iiasa.ac.at/ssp).

Other tools	https://ssp-extensions.apps.ece.iiasa.ac.at – additional socio-economic indicators that extend the basic SSPs

	https://data.ece.iiasa.ac.at/ssp/ – new version of the SSP drivers with revised GDP and population projections for the same SSP storylines
Readings	O'Neill et al. 2017. The roads ahead: Narratives for shared socioeconomic pathways describing world futures in the 21st century. Global environmental change, 42:169-180, https://doi.org/10.1016/j.gloenvcha.2015.01.004

3.3 Tool 3: Future. Climate Scenarios

Tool	IPCC Interactive Atlas https://interactive-atlas.ipcc.ch **Lecturer: Risto Makkonen, Finnish Meteorological Institute, Finland**

Earth System Models (ESM) are numerical tools consisting of three main components: atmosphere, ocean, and land models. Such models can be used for studying climate-relevant processes, future trajectories of global climate system or for example events in historical record or even deeper in geological past. While weather models operate in kilometre-scale horizontal resolution (e.g., 2 km or 10 km), Earth System Model resolution is typically over 50 km and can even exceed 200 km in horizontal. This is necessary due to the complexity (more components than in weather models) of the model but also since Earth System Models are simulated over decades, centuries and even millennia. The coarse resolution should be considered when analysing model output, as the data cannot represent small-scale geological (e.g., hills, lakes) or anthropogenic (cities) features. Many models are already open access, or at least the code can be obtained easily. Some models can even be run on standard PC environments with open-access tools.

ESM data that formed the basis of IPCC AR6 WG1 has been published openly, and there are several ways to browse and visualize the data. The official repository of the data is Earth System Grid Federation (ESGF) network, which provides a distributed infrastructure for storing climate data. There are multiple ways of downloading, processing and visualizing data from ESGF. Typically, this is done via a programming interface e.g. in Python by accessing the data directly or by downloading the data to local computer. You can find examples of such codes here.

A direct way to look at IPCC AR6 WG1 data is via IPCC Interactive Atlas. The browser-based tool can directly visualize distinct future scenarios, subset of variables and focus on specific geographical regions.

Case-example

First, use web browser to open https://interactive-atlas.ipcc.ch

From "Regional information", select "Advanced". You will already see climate information projected to a global map. You can browse available datasets, variables and scenarios.

Compare alternative future scenarios for the "Northern Europe" region. After selecting the region, you can utilize the "Table summary", which can be exported as CSV (and analyzed in e.g. Excel). How much is the region warming until end-of-century ("Long Term 2081-

2100”)? How large are the differences in future scenarios (SSP1-2.6, SSP2-4.5, SSP3-7.0, SSP5-8.5)? What happens to snowfall in the different scenarios compared to present-day (1995-2014)?

Plot the scatter plot between total precipitation and mean temperature (“Scatter plot” under regional view): select Mean temperature as variable (from top menu), and select “Y Axis variable” to be Total precipitation. Does the plot indicate a relation between the two variables in climate models? Is there a similar relation with mean temperature and snowfall?

Can you pin-point major climate model differences in the region (e.g., a single model indicating either significantly lower or higher changes compared to other models)?

If you want, you can also have a closer look at the underlying data. There is a button “Download” on the main screen of the Interactive Atlas. This downloads the map-view as NetCDF. You can load several of these maps in and plot e.g., differences between the projections.

Click in:

https://interactive-atlas.ipcc.ch/regional-information

Part 4: CLIMATE CHANGE RELATED CONCEPTS AND TERMINOLOGY

4.1. General terminology, mainly used in lectures

This part describes general concepts for a basic understanding of the VE week topics and included in the three principals CLUVEX thematic areas: 1. Environmental and climate change, 2. Climate action, environment, and nature protection, and 3. Green skills.

- **Anthropogenic activities**: activities caused or influenced by people.
- **Bioart:** Wikipedia definition states: BioArt is an art practice where artists work with biology, live tissues, bacteria, living organisms, and life processes. However, during the course of the 21st century so far bioart has grown to intervene with and hack interactions with other species and living matter outside of traditional biolab scenarios and areas of expertise. Bio-artistic practice ranges from critical interventions into contemporary biotech practices to proposals for techno-horizon solutions.
- **Biodiversity:** variety of living organisms, from single-celled to complex life forms, in the ecosystems where they naturally occur.
- **Biodiversity loss:** Imagine Earth like a big puzzle, and each animal and plant is a piece of that puzzle. When animals and plants disappear because of things like cutting down forests or polluting rivers, it's like losing pieces of the puzzle. The fewer pieces we have, the harder it is to see the whole picture and for life to work the way it should.
- **Biosphere:** part of the Earth where living things thrive and live. Biosphere encompasses all areas of the Earth — land, air and water — that support life.
- **Biosphere:** part of the Earth where living things thrive and live. Biosphere encompasses all areas of the Earth — land, air and water — that support life.

- **Climate change**: This is like Earth's fever. It's when the planet gets too hot or too wild because people are burning too many things like gas and coal, which makes the air dirty and heats up the Earth.
- **Conservation:** This is all about protecting nature. It's like being a superhero for the environment—making sure we don't chop down too many trees, pollute the air and water, or harm animals. Conservation is our way of keeping Earth's beautiful landscapes and creatures safe.
- **Conservation agriculture:** a farming system that promotes maintenance of a permanent soil cover, minimum soil disturbance, and diversification of plant species.
- **Contemporary investigative art***:* An artistic practice that develops/enables artworks according to new, available investigative technologies.
- **Critical thinking:** Critical thinking is the intellectually disciplined process of actively and skilfully conceptualizing, applying, analysing, synthesizing, and/or evaluating information gathered from, or generated by, observation, experience, reflection, reasoning, or communication, as a guide to belief and action. In its exemplary form, it is based on universal intellectual values that transcend subject matter divisions: clarity, accuracy, precision, consistency, relevance, sound evidence, good reasons, depth, breadth, and fairness.
- **International/ Intercultural Interactions:** Which action/solution is better (connected with critical thinking). Conflicts between judging/understanding actions from others, or other cultures.
- **Drip irrigation:** an efficient and precise method of watering plants by delivering water directly to the root zone.
- **Ecological restoration:** process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed.
- **Ecology:** Has become a widespread term within the 21st century. It is used in reference of almost anything that can be seen in connection to another thing, action, process or entity. Originally the term ecology was used in reference to science that investigated living beings and their environment. The term was coined by Ernst Haeckel in 1866.*
- **Ecology of knowledges:** Sociologist Bonaventura de Souza santos's concept of "ecology of knowledges" articulates that all knowledges have internal and external limits. Linda Tu-hi-wai Smith, writes that: *"*Santos calls for ecology of knowledge/s that enables alternative ways of knowing and scientific knowledge to coexist, and argues that there can be no global social justice without global cognitive justice". For further thought on "ecologies of knowledges", see Boaventura de Sousa Santos, Epistemologies of the South: Justice Against Epistemicide (Boulder CO: Paradigm Publishers, 2014).
- **Ecosystem:** community of organisms and their physical environment. Ecosystems may be as small as organisms living under a rock or involve large geographic areas.
- **Erosion:** loss of soil and wearing away of rock, often by wind and water. A natural process, erosion can be exacerbated by agricultural practices; residential and commercial land clearing and road construction.
- **Fieldwork:** More than just being outside, fieldwork is seen as a method of enquiry and in-situ prototyping, that starts from radical non-isolation of the participants, their thoughts, and their acts, aiming for full exposure to the complexities and subtleties of a given area which is being navigated in collaboration with local experts.*
- **Flood, flooding, high water: r**ise, usually brief, in the water level of a stream or water body to a peak.

- **Flood frequency or flood probability, return period** - Number of times a flood above a given discharge or stage is likely to occur over a given number of years.
- **Floodplain:** flat land area adjacent to a stream, composed of unconsolidated sedimentary deposits (alluvium) and subject to periodic inundation by the stream.
- **Freshwater:** Water that is not salty, for instance water found in lakes, streams, and rivers, but not the ocean. All freshwater ultimately comes from precipitation of atmospheric water vapor, reaching inland lakes, rivers, and groundwater bodies directly, or after melting of snow or ice.
- **Freshwater use:** Picture a giant water tank that everyone needs to share. But if some people use too much water or pollute it, there won't be enough clean water left for everyone. That's what happens with freshwater use—it's about how we take care of and share Earth's water.
- **Groundwater**, generally of high quality, is being withdrawn mostly to supply drinking water and support farming in dry climates. The resource is considered renewable as long as groundwater is not withdrawn faster than nature can replenish it, but in many dry regions the groundwater does not renew itself or only very slowly. Few countries measure the quality of groundwater.
- **Glaciers:** store water as snow and ice, releasing varying amounts of water into local streams depending on the season. But many are shrinking as a result of climate change.
- **Heatwave:** period of time during which the weather is much hotter than usual, a prolonged period of abnormally hot weather.
- **Invasive species:** an introduced, nonnative organism (disease, parasite, plant, or animal) that begins to spread or expand its range from the site of its original introduction and that has the potential to cause harm to the environment, the economy, or to human health.
- **Kelp forests:** underwater ecosystems formed in shallow water by the dense growth of several different species of large brown algae known as kelp.
- **Mangroves**: a type of coastal or estuarine wetland, characterized by the presence of salt adapted trees and shrubs, that grows along the coast in tropical or subtropical latitudes throughout the world.
- **Marine protected areas:** These are like nature reserves but underwater. Just like how we have parks on land to keep animals safe, marine protected areas do the same for creatures in the ocean. They're special places where fish and other sea creatures can live and grow without being disturbed by people. …from which the water level recedes at a slower rate.
- **Mitigation:** This is like putting out a fire before it gets too big. When we do things to stop or slow down climate change, like using clean energy instead of dirty fuels or planting trees, we're mitigating its effects.
- **Ocean acidification:** Imagine pouring something acidic, like lemon juice, into a fish tank. That's what's happening to the oceans because we're putting too much carbon dioxide into the air. The oceans absorb it, and it makes the water more acidic, which is bad news for all the creatures living there.
- **Planetary boundaries:** Think of these as the safety limits for Earth's health. Just like you have limits for your health, like how much junk food you can eat before feeling sick, Earth has limits too, but for things like climate change, biodiversity loss, and water use.
- **Precipitation (rain, snow):** Liquid or solid products of the condensation or sublimation of water vapor falling from clouds or deposited from air onto the ground. Precipitation plays the key role in renewing water resources and in defining local climatic conditions and

biodiversity. Depending on the local conditions, precipitation may feed rivers and lakes, replenish groundwater, or return to the air by evaporation.

- **Regenerative agriculture:** Picture a farm that's like a big, happy ecosystem. Instead of just taking from the land, regenerative agriculture gives back. It's about farming in a way that makes the soil healthier, helps plants grow better, and even sucks carbon out of the air.
- **River basins:** are a useful "natural unit" for the management of water resources and many of them are shared by more than one country. The largest river basins include the Amazon and Congo Zaire basins. River flows can vary greatly from one season to the next and from one climatic region to another. Because lakes store large amounts of water, they can reduce seasonal differences in how much water flows in rivers and streams.
- **Snowmelt flood:** Significant flood rise in a river caused by the melting of snowpack accumulated during the winter.
- **Vector-borne disease:** disease that results from an infection transmitted to humans and other animals by blood-feeding arthropods, such as mosquitoes, ticks, and fleas.
- **Wetlands:** including swamps, bogs, marshes, and lagoons – cover 6% of the worlds land surface and play a key role in local ecosystems and water resources. Many of them have been destroyed, but the remaining wetlands can still play an important role in preventing floods and promoting river flows. Of the freshwater which is not frozen, almost all is found below the surface as groundwater.

*) *Terminology from Erich Berger, Kasperi Mäki-Reinikka, Kira O'Reilly and Helena Sederholm (eds). Art as We Don't Know It. 2020.*

4.2. Climate sciences related concepts´ definitions

Earth´s systems and interactions

The Earth can be defined as a complex and adaptative system, composed of several subsystems interconnected to each other with circulating flow of elements, and energy. While the Earth's system is a closed system for material elements (i.e., carbon - C, nitrogen - N, oxygen - O, phosphorus - P, etc.) it is open for energy (main source coming from the Sun).

In general—beside other distinctions— we can distinguish the following Earth´s systems (also known as geospheres): the Atmosphere (gases in the air surrounding the Earth), the Hydrosphere (water bodies), the Geosphere (the "solid" Earth, including the core, mantle, curst

and soil layers, some references distinguish in geosphere the lithosphere or solid rocks, and pedosphere the soil), the Biosphere (all living organisms and matter that has not yet decomposed), and the Cryosphere (frozen water).

Figure 4. Definition of Earth Systems. Some references include Cryosphere as part of Hydrosphere and Lithosphere (not included in this diagram) as the solid rocks part of the Geosphere. Adapted from My NAS in https://mynasadata.larc.nasa.gov/basic-page/about-earth-system-background-information

Geochemical cycles

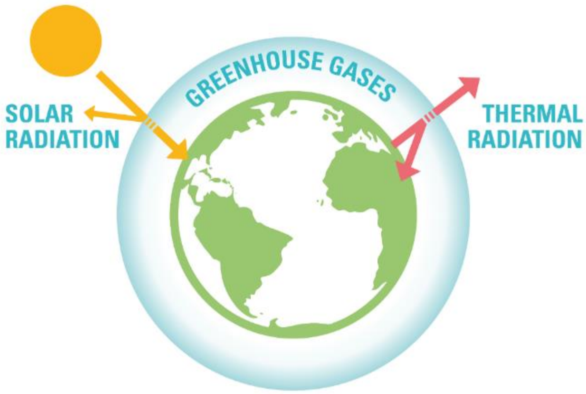
Elements are physically and chemically transformed in each Earth´s sphere to flow from one to another systems, in the so-called circulated cycle or geochemical. For example, C flows from Atmosphere to Biosphere when, among others, plants absorbed it in gas form (CO_2) and transform it into organic form (sugars and others) to be used for energy use and to grow, process known as photosynthesis. Part of absorbed carbon return back into the atmosphere (respiration), part is accumulated in plant tissues and part is transferred into soil (Geosphere), and water (Hydrosphere), and after a very long (geological time units) is sedimented into rocks (Lithosphere).

The time needed for each element to go in and out of each mentioned above sphere depends on the element and the time required for specific chemical/physical reaction/process to occur. For example, C circulates from land and biosphere during “short” time (from days to centuries) while to be sedimented as rocks it takes the longest (geological) time. Human activities have accelerated the flow of elements to certain spheres altering the natural equilibrium of the ecosystems. For example, burning fossil fuels increased the concentration of C and N in the atmosphere, or fertilization or industrialization increase the content of P and N in soils and water systems.

Climate system, energy flow and greenhouse gases

Although Earth is materially closed system, it is not a closed system to energy. The main source of energy in Earth is the solar radiation, a short-wave electromagnetic radiation, mostly in visible wavelength (light). From Earth surface radiation in long-wave electromagnetic radiation (thermal) is emitted back to the atmosphere. The atmosphere transparent to light but not to thermal radiation because it is absorbed by the so-called greenhouse gases. Hence, not all radiation coming from the sun return back, otherwise Earth’s surface temperature would be -18°C.

Greenhouse gases are atmospheric gases that absorb the Earth's thermal radiation efficiently. Greenhouse gases cause a greenhouse effect that warms the Earth. The most important greenhouse gases are water vapour, carbon dioxide, methane, nitrous oxide and ozone. Human activity has increased especially the atmospheric concentrations of carbon dioxide, methane, nitrous oxide and tropospheric ozone, which has strengthened the greenhouse effect and warmed the climate.



Carbon cycle in an illustrative video on the "**Climate.now**" course of the Climate University at the University of Helsinki, Finland

https://www.youtube.com/watch?v=9rcGAH2HZlUVideo

Figure 5. Energy flow and greenhouse effect. Source: Figure 1.1. from Climate.now course, Climate University, University of Helsinki.

See in

https://digicampus.fi/mod/book/view.php

The Intergovernmental Panel on Climate Change

https://www.ipcc.ch

The IPCC was created to provide policymakers with regular scientific assessments on climate change, its implications and potential future risks, as well as to put forward adaptation and mitigation options.

Through its assessments, the IPCC determines the state of knowledge on climate change. It identifies where there is agreement in the scientific community on topics related to climate change, and where further research is needed. The reports are drafted and reviewed in several stages, thus guaranteeing objectivity and transparency. The IPCC does not conduct its own research. IPCC reports are neutral, policy-relevant but not policy-prescriptive. The assessment reports are a key input into the international negotiations to tackle climate change. Created by the United Nations Environment Programme (UN Environment) and the World Meteorological Organization (WMO) in 1988, the IPCC has 195 Member countries. In the same year, the UN General Assembly endorsed the action by WMO and UNEP in jointly establishing the IPCC.

Sustainable Development Goals (SDGs)

In 2015, all United Nations (UN) Member States adopted the 2030 Agenda for Sustainable Development (https://sdgs.un.org/2030agenda). It provides a shared blueprint for peace and prosperity for people and the planet, now and into the future. There are 17 SDGs (https://sdgs.un.org/goals) which require urgent call for action by all countries. UN Member States recognize that "ending poverty and other deprivations must go hand-in-hand with strategies that improve health and education, reduce inequality, and spur economic growth – all while tackling climate change and working to preserve our oceans and forests". Some SDG important in this guidebook:

SDG11 – SUSTAINABLE CITIES AND COMMUNITIES

Make cities and human settlements inclusive, safe, resilient and sustainable

https://sdgs.un.org/goals/goal11

SDG12 – RESPONSIBLE CONSUMPTION AND PRODUCTION

Ensure sustainable consumption and production patterns

https://sdgs.un.org/goals/goal12

SDG13 – CLIMATE ACTION

Take urgent action to combat climate change and its impacts

https://sdgs.un.org/goals/goal13

Some nature protective global regulations

- The Rio Conventions | UNFCCC
- https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal_en
- Biodiversity strategy for 2030 - European Commission (europa.eu)

APPENDIX 1: RECOMMENED READING

Here you find references for scientific peer-reviewed papers which you may find useful as a Climate Messenger.

- Seinfeld, J.H. and Pandis, S.N. (2006) Atmospheric Chemistry and Physics: From Air Pollution to Climate Change. 2nd Edition, John Wiley & Sons, New York. (see Chapter 6).
- Baklanov, A., S. Korsholm, U., Nuterman, R., Mahura, A., Nielsen, K. P., Sass, B. H., Rasmussen, A., Zakey, A., Kaas, E., Kurganskiy, A., Sørensen, B., and González-Aparicio, I. (2017): Enviro-HIRLAM online integrated meteorology–chemistry modelling system: strategy, methodology, developments and applications (v7.2), Geosci. Model Dev., 10, 2971–2999, https://doi.org/10.5194/gmd-10-2971-2017
- Blöschl G, Hall J, Viglione A, Perdigão RAP, Parajka J, Merz B, Lun D, Arheimer B, Aronica GT, Bilibashi A, Boháč M, Bonacci O, Borga M, Čanjevac I, Castellarin A, Chirico GB, Claps P, Frolova N, Ganora D, Gorbachova L, Gül A, Hannaford J, Harrigan S, Kireeva M, Kiss A, Kjeldsen TR, Kohnová S, Koskela JJ, Ledvinka O, Macdonald N, Mavrova-Guirguinova M, Mediero L, Merz R, Molnar P, Montanari A, Murphy C, Osuch M, Ovcharuk V, Radevski I, Salinas JL, Sauquet E, Šraj M, Szolgay J, Volpi E, Wilson D, Zaimi K, Živković N. Changing climate both increases and decreases European river floods. Nature 573, 108–111 (2019). https://doi.org/10.1038/s41586-019-1495-6
- Blöschl G, Hall J, Parajka J, Perdigão RAP, Merz B, Arheimer B, Aronica GT, Bilibashi A, Bonacci O, Borga M, Čanjevac I, Castellarin A, Chirico GB, Claps P, Fiala K, Frolova N, Gorbachova L, Gül A, Hannaford J, Harrigan S, Kireeva M, Kiss A, Kjeldsen TR, Kohnová S, Koskela JJ, Ledvinka O, Macdonald N, Mavrova-Guirguinova M, Mediero L, Merz R, Molnar P, Montanari A, Murphy C, Osuch M, Ovcharuk V, Radevski I, Rogger M, Salinas JL, Sauquet E, Šraj M, Szolgay J, Viglione A, Volpi E, Wilson D, Zaimi K, Živković N. Changing climate shifts timing of European floods. Science. 2017 Aug 11;357(6351):588-590. doi: 10.1126/science.aan2506. PMID: 28798129.
- Scientific advice for the determination of an EU-wide 2040 climate target and a greenhouse gas budget for 2030–2050 (europa.eu)
- Astrida Neimanis, “The body is the site of climate catastrophe”, in Yvonne Billimore and Jussi Koitela (eds.), Rehearsing Hospitalities Companion 2 (Berlin and Helsinki: Archive Books & Frame Contemporary Art Finland, 2020), 179. Available as an open access PDF.
- Erich Berger, Mari Keski-Korsu, Marietta Radomska and Line Thastum (eds). State-Of-The-Art - Elements for Critical Thinking and Doing. Bioart Society. 2023. Available as open access PDF.
- Erich Berger, Kasperi Mäki-Reinikka, Kira O'Reilly and Helena Sederholm (eds). Art as We Don’t Know It . Aalto Arts Books. 2020. Available as open access PDF.
- Laura Beloff, Erich Berger, Terike Haapoja (eds). Field_Notes – From Landscape to Laboratory. Bioart Society. 2023. Available as open access PDF.
- Mahura, A., V. Ovcharuk, T. Kryvomaz, H. Lappalainen, K. Lauri, I. Khomenko, O. Shabliy, V. Kabin, M. Frankowicz, Yu. Rashkevych, L. Riuttanen, S. Tyuryakov, I. Bashmakova (2021): Online Approaches for Climate-Oriented Education. pp. 79-80, In Proceedings of the International Research-To-Practice Conference “Climate Services: Science and Education“, 144 p., ISBN 978-966-186-162-5
- Riuttanen, L., Ruuskanen, T., Äijälä, M., & Lauri, A. (2021). Society needs experts with climate change competencies–what is the role of higher education in atmospheric and Earth system sciences? Tellus B: Chemical and Physical Meteorology, 73(1), 1-14.
- Kulmala, et al. (2015): Introduction: The Pan-Eurasian Experiment (PEEX) – multidisciplinary, multi-scale and multi-component research and capacity building initiative, Atmos. Chem. Phys., 15, 13085-13096, 2015, doi:10.5194/acp-15-13085-2015.
- Lappalainen et al. (2016): Pan-Eurasian Experiment (PEEX): System understanding of the Arctic-boreal regions for constructing scenarios and assessments of the future development of the Northern Pan-Eurasian environments and societies, Atmos. Chem. Phys., 16, 14421-14461, 2016, doi:10.5194/acp-16-14421-2016.
- Gleick, P. H., 1996. Water resources. U.S. Geological Survey Department of the Interior/USGS. In Encyclopedia of Climate and Weather, ed. by S. H. Schneider, Oxford University Press, New York, vol. 2, pp.817-823.

APPENDIX 2: ENVIRONMENTAL DATA VISUALIZATION TOOLS AND DATABASES

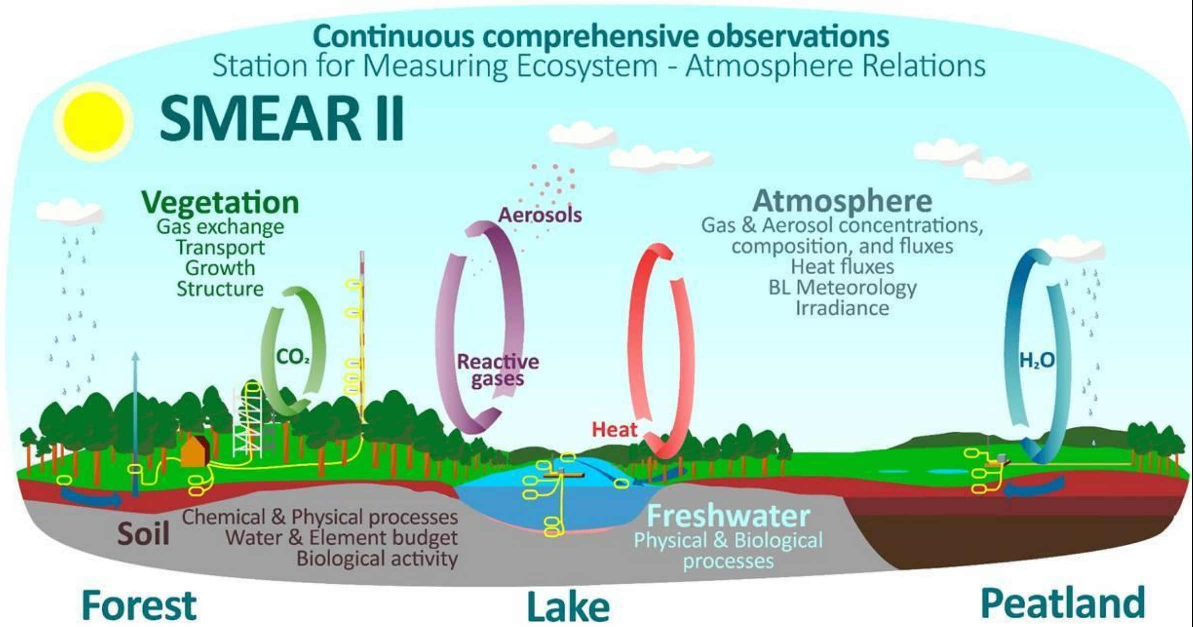
Here we introduce two data visualization tools. "Stations Measuring Atmosphere and Ecosystem Relations" based SmartSMEAR tool is an open access use interface, while the ERDA system hosted by the University of Copenhagen is based on granted accesses to the system.

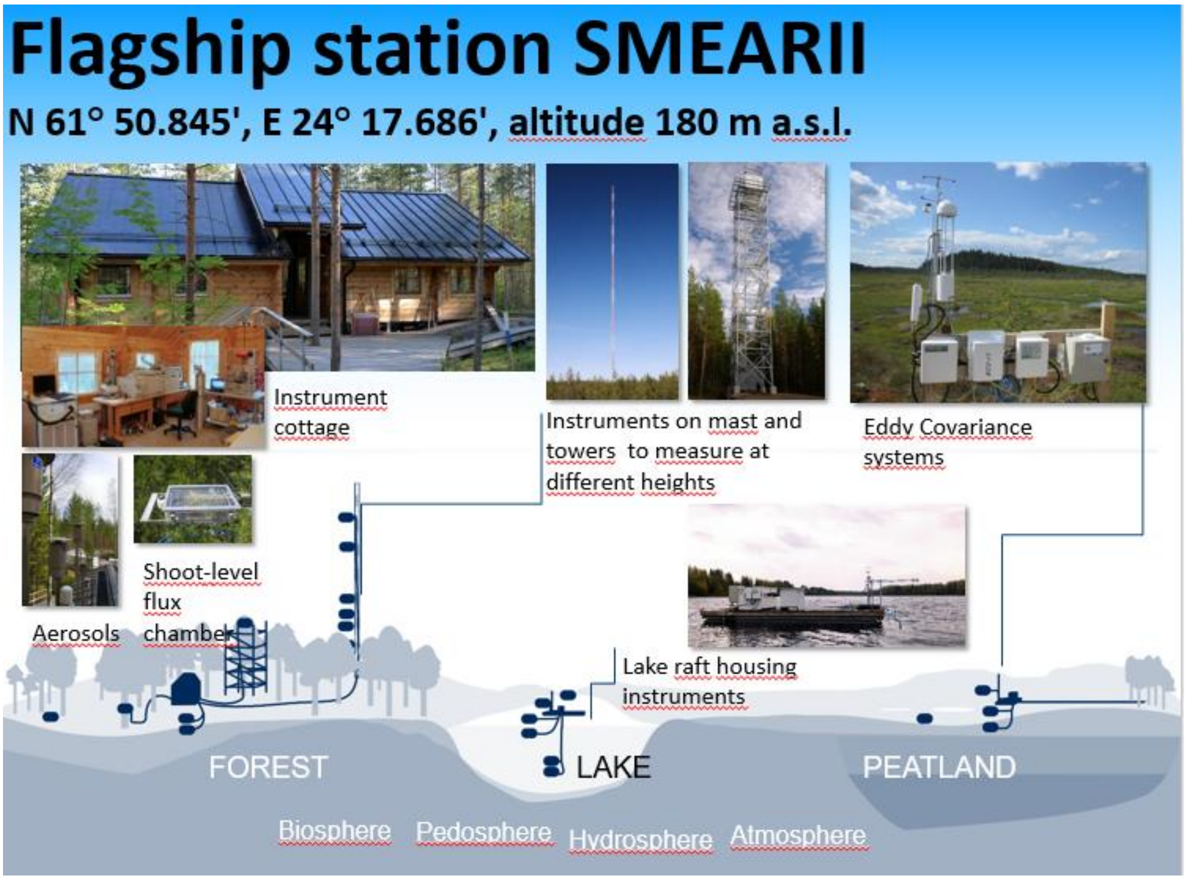
A2.1 Stations Measuring Atmosphere and Ecosystem Relations, SmartSMEAR

Topic	Stations Measuring Atmosphere and Ecosystem Relations, SmartSMEAR tool
by	INAR at University of Helsinki
Tool	https://smear.avaa.csc.fi/download

INAR at the University of Helsinki has been operating the " Stations Measuring Atmosphere and Ecosystem Relations" (SMEAR) station network in Finland for more than 20 years. Research based on the data originated from the SMEAR stations have produced over 2500 scientific, peer reviewed publications, 45 in Nature or Science, and obtained 15 European Research Council grants based on the comprehensive analysis of the atmosphere-biosphere interactions.

SmartSMEAR is a data visualization and download tool for the database of continuous atmospheric, flux, soil, tree physiological and water quality measurements at SMEAR research stations of the University of Helsinki and the University of Eastern Finland. Data with basic metadata can be visualized and downloaded using Preview and Download pages. Application programming interface (API) provides access to additional variables and more complete metadata than the graphical user interface (UI). You van access to SMAR data from https://smear.avaa.csc.fi/download.



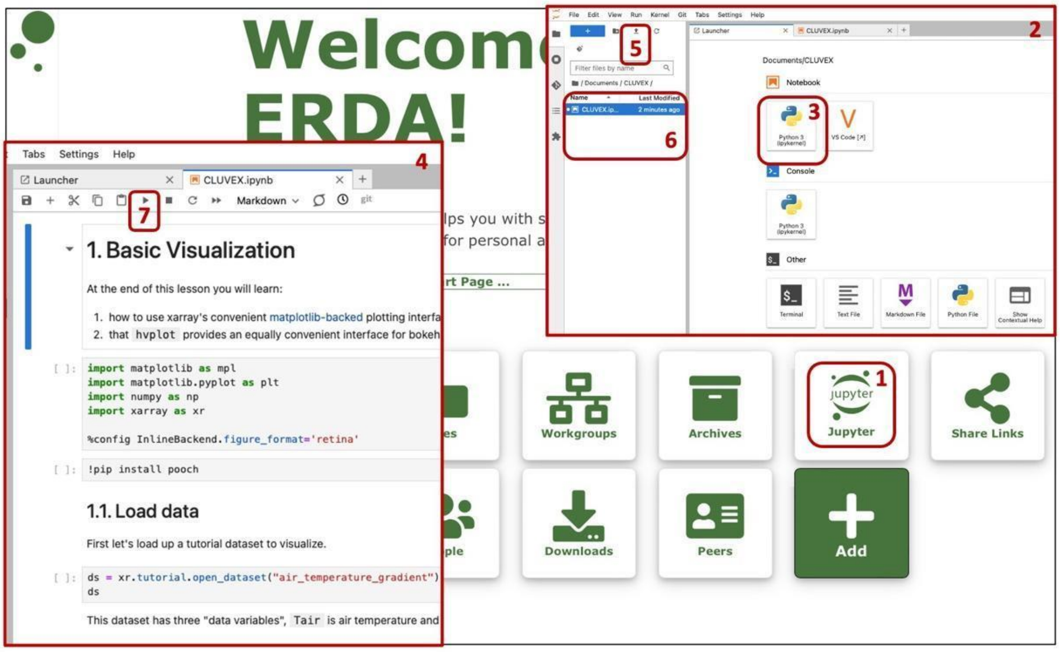
Here above an observation scheme of the SNEAR-II station in Hyytiälä, Finland. SMEAR-II station measures 24/7 different energy flows at the boreal forest site, over forest, lake and peatlands.  Here above a schematic figure of the measurement installations at the SEMAR-II station.
Lean more on the SMEAR-II research from: • https://webcast.helsinki.fi/unitube/embed.html?id=50addf4f-3a3c-4a8f-98a8-11f441d9898

A2.2 Electronic Research Data Archive (ERDA)

Topic	Electronic Research Data Archive (ERDA)
by	University of Copenhagen For contact: Roman Nuterman at the University of Copenhagen, Denmark
Tool	https://erda.ku.dk
ERDA or Electronic Research Data Archive at University of Copenhagen (UCPH) serves as a comprehensive platform for storing, sharing, analyzing, and archiving research data. Designed for use by employees, their collaborators, and students, ERDA offers secure central storage for individual and collaborative files, along with interactive analysis tools.	

Case-example

Log in ERDA and select the Jupyter option (1) from the main menu. This action takes you to the Data Analysis Gateway (DAG) interface, where you should initiate the process by clicking the "Start DAG" button. Following this, you'll be directed to the JupyterHUB page. Here, initiate your server by clicking on the "Start My Server" button, then choose the "Geo Notebook" image from the drop-down menu and click "Start". This procedure will activate an interactive platform (2), enabling you to subsequently create a new Jupyter Notebook (3). This environment is designed for conducting remote data analysis and visualization using Python programming language (4).



Click on: https://sid.erda.dk/cgi-sid/ls.py?share_id=hzQvWl20kg

(1) Locally download the notebook to your PC/Laptop (from link above) and upload it to ERDA using the upload feature (button 5) within the interactive environment (2).
(2) Find the notebook in your file browser (6) and initiate it with a double-click.
(3) Start the notebook analysis by pressing “Run this cell…” (button 7) to display the results cell-by-cell from top to the bottom of the notebook (4).

Other tools / resources	
	• ERDA short video introduction (*in Danish with English subtitles*): https://video.ku.dk/video/69574184/troels-haugbolle-erda-has-solved-a • ERDA documentation: https://erda.ku.dk/public/ucph-erda-user-guide.pdf • JupyterLab documentation: https://jupyterlab.readthedocs.io/en/latest/index.html# • YouTube JupyterLab channel: https://youtube.com/@ipython?si=xJ9knQtWvflHFkqn

APPENDIX 3: CLUVEX COURSE: 1 CREDIT POINT, LEARNING OUTCOMES

Course title: Climate University for Virtual Exchanges

Course code: ATM398 https://sisu.helsinki.fi/student/courseunit/otm-194d50be-b386-4a73-91d6-7fbe9b88ff44/brochure).

Course level: The course is interdisciplinary and suitable for students from different fields, from bachelor's studies to doctoral students.

Scope of the course in credits: 1 ECTS

Teacher coordinating the course: Laura Riuttanen, Maria del Rosario Dominguez Carrasco, Hanna K. Lappalainen

Course learning outcomes:

- Basics of the atmosphere, biosphere, hydrosphere and anthroposphere interaction and feedbacks
- Basics of Climate Change based on latest science:
  - Planetary boundaries concept.
  - Last methodological tools used in observing the Earth System.
- Understanding of the human role from different perspectives like ethical, social, different cultural backgrounds in climate change, adaptation, and mitigation advances.
- Critically reflect owns views on climate change, sustainability, and create new visions.
- Reflect different international and intercultural perspectives on climate change and sustainability.
- Reflect about global versus local challenges in finding adaptation and mitigation solutions.
- Work together in different online working environments.
- Work and be part of an international teams and manage small joint projects.
- Communicate and present their work in English.
- Learning basic study skills such as use of open data, literature search, critical reading and thinking.

Content

- The course consists of plenary talks, group exercise, joint discussions.
- Plenary talks on :
  - Introduction of Earth systems and interactions between different spheres.
  - Introduction of society related impacts of climate change.
- Examples of the latest tools to be used in the group exercise:
  - observing Earth systems, modelling, predictive models e.g., used for IPCC scenarios, models for mitigation and adaptation (including local socio-economic statistics).
- Introduction to different virtual-education tools.
- Information retrieval, literature search, guiding in reference, source criticism, use of open data.

Additional information

The course is part of the EU-funded ERASMUS project “Climate University for Virtual Exchanges” (CLUVEX), active in 2023-2026.

During the project we develop interactive online learning concept attached to MOOC education. This supports the students to participate the (Climate University) MOOCs, which often takes place as independent studies without connection to other students. This course will also provide basic knowledge and skills to participate in Climate University interactive online courses.

Completion methods

The interactive and intensive part of the course is offered during one calendar week and attendance to the plenaries and group exercise are obligatory. Before the intensive week students will be provided with pre-material to study independently. During the intensive week it is mandatory to be present in zoom 3h per day for 4-5 days. At the end of the week, it is also mandatory to present the group work and outcomes of the course in a joint session. Some tasks are to be completed after the intensive week.

Assessment practices and criteria

To pass the course, active participation and completion of online tasks are required.

Graded: pass / failed

Activities and teaching methods in support of learning

All groups will have the same exercise, independent reading material, and a guide for the web tools on the modelling and climate predicting scenarios and data sources.

Target groups: Bachelor, Master, PhD, post doc students, from all degree programs.

Teaching period when the course will be offered:

The course will be offered between 2024-2026 five times in total, the first course (Virtual Exchange Week) takes place one in Autumn 2024 following the courses taking place in Spring and Autumn 2025, and in Spring and Autumn 2026.

Recommended time or stage of studies for completion:

Study module

Prerequisites: Basic English language

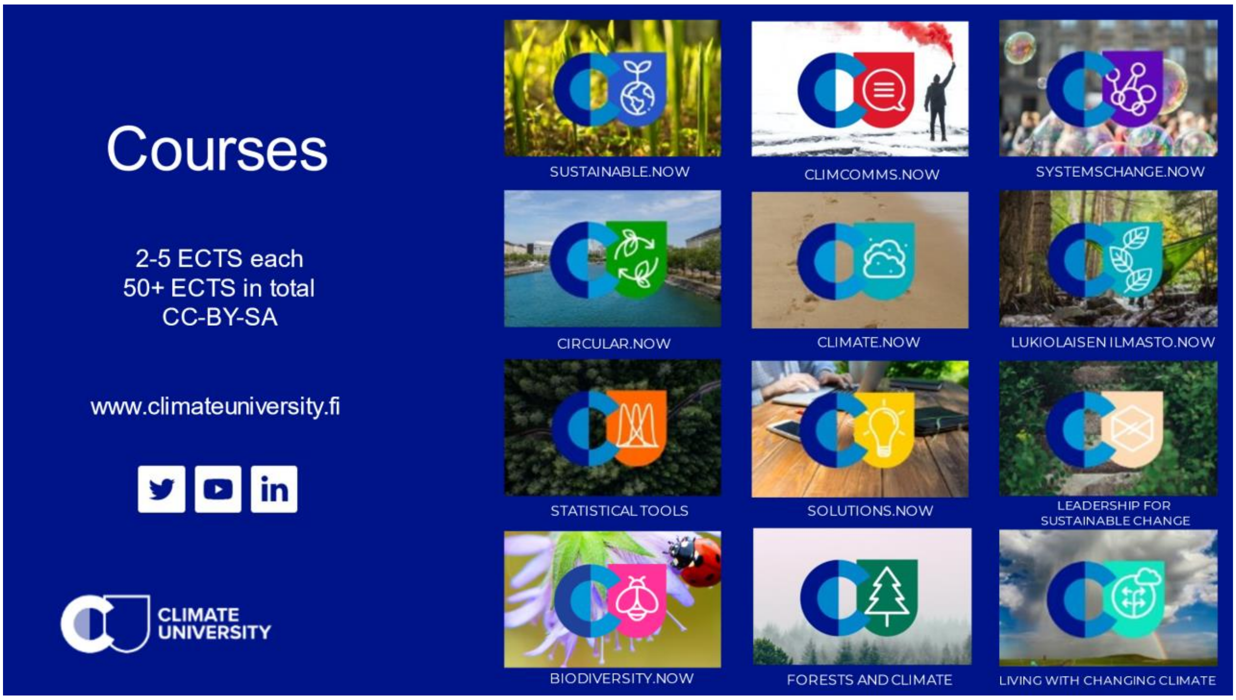
Description of prerequisites: Materials: consists of lecture videos, literature and tools related to climate data.

Field of study: Atmospheric sciences / multidisciplinary

APPENDIX 4: CLIMATE UNIVERSITY ONLINE COURSES

After you have completed the virtual exchange week, you will be able to continue online learning with Climate University's (CU) courses. Here we briefly introduce Climate University's current course offering. The Climate University contains climate change- and biodiversity-related online courses. Visit and explore (for example as guest) the Climate University in https://climateuniversity.fi

In CU there are courses for Sustainability, Biodiverity, climate change, Leadership, actions, solutions and much more! Climate University is in constantly growth. Here below there are only some examples of courses you will find:



As an example, the description of Biodiversity.now and Climate.now online courses:

❖ **Biodiversity.now (5 ECTS)**

The Biodiversity.now-course is multidisciplinary and suitable for everyone interested in biodiversity issues. It is a master's level course but does not require previous biological background knowledge. The course highlights the importance of one's own activity and participation in halting the biodiversity loss by encouraging one to think about biodiversity topics from the perspective of different fields and learn how to be part of the solution. In this course students will learn more about the reasons for the ongoing biodiversity crisis as well as its consequences to the nature, human society and personal life.

Learning outcomes of the course are:

- to recognize reasons for the ongoing biodiversity crisis and its consequences for human society and for one's personal life;
- to explore one's own connection to nature and the diverse values you assign to it;
- to recognize a variety of approaches and tools to protect biodiversity, increase biodiversity, and to promote the sustainable use of biodiversity;
- to apply the issues to one's own field of studies/work and learn how to be part of the solution.

❖ **Climate.now (2 or 5 ECTS)**

"What everyone needs to know about climate change? Climate.now is a course on the basics of climate system, its change and effects of the change, how to mitigate and adapt to changing climate.”

Course learning goals:

Having studied the course, the student can:

- look at climate change from many different perspectives and create connections between them as well as look for solutions to the climate challenge in a variety of ways;
- reflect on his or her own role in climate change and apply what has been learned on the course to his or her field of study;
- examine different perspectives, solutions, information sources and the current debate on climate change critically.