# Interactive visualisation

## Climate Change Data

Thomas Mandelz
June 15, 2022

GitHub Repository for my own work (Prototyping)
GitHub Repository Climate Challenge

# Contents

# 1 Introduction

In the spring semester of 2022 whilst doing the IVI report, I did the climate data challenge simultaneously with a group of four other students. While doing the challenge, the group and I created a dashboard to show heatwaves in Europe from 1979 until 2020. In the following chapters, I will reference examples from third parties (Visual effect scenes, video games, etc.) as well as from the above-mentioned climate data dashboard. Third party references are either in the text or the captions of figures.

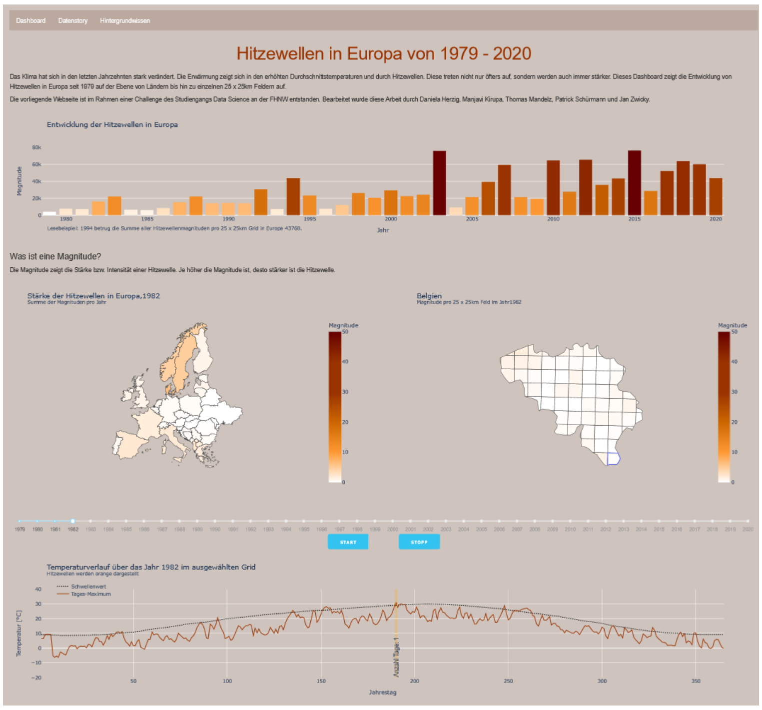


Figure 1: Climate change dashboard of spring semester 2022

Even though the dashboard was part of a group work, all individuals contributed to the visualisations. I focused mainly on the country figure with tiles as well as performance increasing measures, by creating materialized views in SQL. The plots, I am referencing in the figures, are always the final plots of our dashboard. In my own GitHub repository I provide my own visualisation work which does not match with the final layout of the dashboard. Be aware of this distinction while reading the subsequent chapters.

## 2 Performance

The 2.5 quintillion data bytes (Bulao, 2022) which are currently generated daily are evermore going to be featured in visualisations. The main challenge while visualising this vast amount of data is performance.

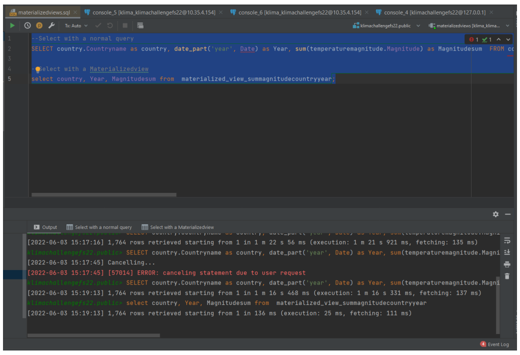


Figure 2: Performance differences between query and a materialized view with the same resultset [1]

Performance is a crucial factor in a visualisation, because for the audience it is frustrating to have an intriguing visual which is not performing in a timely manner. To mitigate this, a performance evaluation of the used visualisation is of great help.

There may be several reasons for a slow performance of a visualisation. The three main categories are hardware, bandwidth, and software.

Hardware is the powerhouse of any visualisation because it is responsible for any processing and rendering of the requested visualisation. Having enough bandwidth is important to be able to stream data fast enough to present the visualisation in its fullest form to a client. A well written software component may be able to decrease the usage of the hardware and make the processing more streamlined.

### 2.1 CPU and GPU rendering

The tasks of a CPU (Central Processing Unit) and a GPU (Graphics Processing Unit) are inherently different on the hardware level. The CPU has a broader area of responsibility.

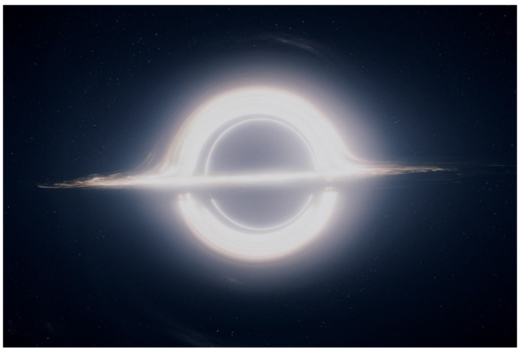

Figure 3: Visual effects scene of a black hole from the movie "Interstellar" (Pictures, 2014)

Most of the times, a CPU has four to eight physical cores and a multitude of logical cores for each physical core. Normally the CPU does tasks serially, meaning one at a time. There is the possibility for multi core threading in which all cores can process tasks parallelly.

On the other hand, GPUs are tasked with more specific functions like rendering graphics or 3D visualisations. They have thousands of efficient processor cores, which all work in parallel. There are also render farms which put together many GPU's to be used for a single task (for example rendering a vfx scene in a movie) (Glawion, 2020). The VFX scenes in the movie *Interstellar* are visually fantastic and unique: "Some individual frames took up to 100 hours to render, the computation overtaxed by the bendy bits of distortion caused by an Einsteinian effect called gravitational lensing." a CG supervisor said (Rogers, 2014). Without a multitude of high tech GPU's (render farms), they could not have processed the 800 terabytes of data which in the end was generated for the final movie.

[1] Materialized views were implemented by me in PostgreSQL. The difference from normal query to materialized view is immense. In this example the materialized view was 558 times faster in execution.

## 2.2 Level of detail management

The management of level of detail refers to the process of simplifying how much detail is needed in a visualisation to be accurate enough for its purpose. With this information we can gain performance by removing data which is so far away from the user that it would not be visible to him anyway (Eugene, 2022). Video games use this concept by implementing for example a "render distance". Other level of detail concepts are "culling", distance, size and others (Cöltekin, 2006).

Figure 4: Level of detail in the game "Skyrim" with different render distances (DanBrown, 2016).

In a perimeter around the player, in his virtual world, a fully detailed world is rendered. The level of detail is then gradually declining the more distant an object. This render distance is normally changed by a setting in the video games options. Players with a better hardware setup (CPU & GPU) may also enjoy more detail.

In Figure 4 a level of detail comparison of the game "Skyrim" is shown. On the left side you can see the blurry ground textures in the distance, while on the right side there are still rocks and tree details visible far in the distance.

## 2.3 Tiling

If we want to visualise a big entity, for example a map of multiple countries, we sometimes need to break the entity into smaller tiles. By breaking it down into smaller tiles we can save memory, computing power and even bandwidth.

In the climate data challenge of this semester, we wanted to show all the European countries and their heatwaves over the years. For this we gathered data for 25 x 25km grids.

While starting, we tried to visualise all the grids in a single map for Europe. Soon the map became very processing and memory intensive. As a solution we created another visualisation for a single map[2] which uses the data for each single grid (see Figure 5), while the European map (see Figure 6) only shows the data for all grids combined. By clicking on a country in the European map, the second visualisation is updated with the respective country. The interaction between the visualisations rounds up the initial purpose of the visualisations and makes all data accessible to the user.

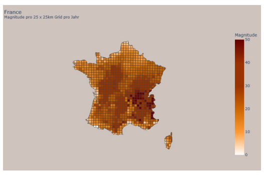

Figure 5: Climate dashboard country map to show the temperature data in grids

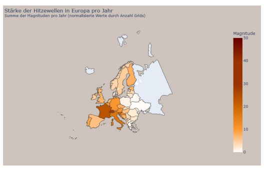

Figure 6: Climate dashboard European map to show aggregated data

[2]I made a prototype of this map with the intersection of the grids and the outline of the country. In Figure 5 a polished version is viewable. This end product was done by several people of our group and multiple design iterations.

# 3 Dashboard design principles

## 3.1 Dashboard Concept

A dashboard, in the context of visualisation, is a type of graphical user interface used as a tool which provides an overview of the domain it was developed to portray. It has controls and multiple linked visuals. On a closer look, insight in the details of the topic are available, normally by the multiple visuals. Key areas of information are aggregated and displayed in an intuitive and visually pleasing way (Calzon, 2021). The handling of the dashboard should be as clear and intuitive as possible.

In Figure 7 a dashboard from Justin Fung[3] is shown. It has a data story which shows pre-set control configurations and tells a story of the Manhattan population density over a week. There is also the possibility for the user to freely adjust the controls and explore the data themselves.

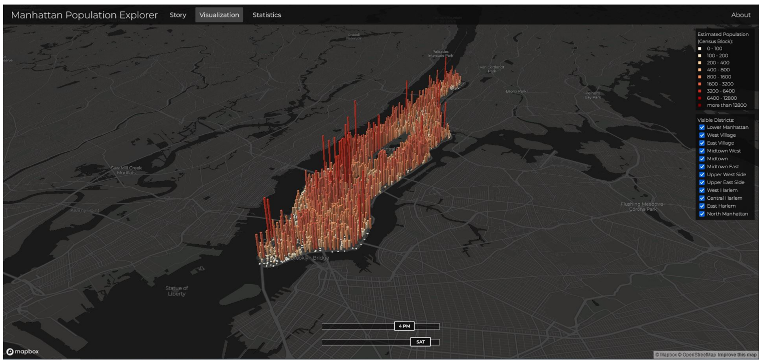


Figure 7: Manhattan Population Explorer dashboard (Fung, 2018)

## 3.2 Controls

A dashboard often consists of multiple layers of data. To explore these layers the user needs tools to interact with them. These tools are controls by which the user can manipulate the shown data by filtering (e.g., a slider for a time range) or selecting a specific set of data (e.g., choosing a country shape on a map).

Well known controls are:

- Textboxes to search for keywords
- Dropdown lists with preselected keywords
- Checkboxes to select/deselect multiple options
- Sliders for selecting a range or a specific point in a time series (see Figure 8)

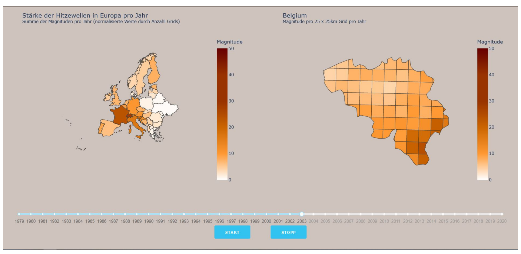

Figure 8: Slider of the climate data dashboard

## 3.3 Multiple linked visuals

Visuals which are related can be linked, enhancing both visuals in the process. By linking visuals, they are dependent on each other. This means if a user

[3]Justin Fung is a data scientist and software engineer who works for Hyperloop. He created the Manhattan Population Explorer dashboard.

interacts with one of the visuals, the others are updated according to the changes made. Using this concept, hierarchical data is easily separated into multiple visualisations. Each individual view is also easier to comprehend because the data complexity is divided amidst several views.

### 3.4 Brushing

Brushing is the process of selecting a subset of data items by an input device (mouse, touchscreen, etc.). This technique is used to highlight the selected subset or remove it from the view (Becker & Cleveland, 1987).

For instance, in Figure 9 a subset is chosen by brushing over the data. In Figure 10 you can see the result of the brushing.

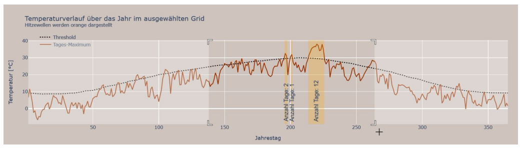


Figure 9: Selection of a subset of data with a brushing function

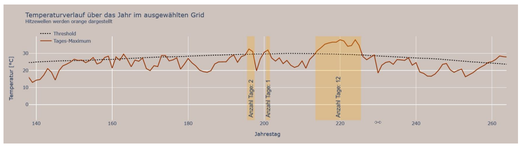


Figure 10: Result of the brushing selection, x axis was changed to only show the selected period

### 3.5 Shneiderman's mantra

A useful starting point for designing advanced graphical user interfaces is the Visual Information-Seeking Mantra: overview first, zoom and filter, then details on demand. While Shneiderman's mantra focuses on the three mentioned parts of the mantra there are seven parts to it (Shneiderman, 1996). Shneiderman's mantra is a summary of best practises for Visualising.

#### 3.5.1 Overview first

An overview of the entire data collection should be gained by this first mantra. In a first step context as well as content should be given to the user. For example, a zoomed-out view of a whole map could be an appropriate choice for a first overview. In our dashboard we used a bar chart for all years.

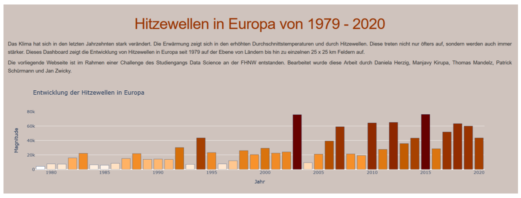


Figure 11: Entry to the climate data dashboard[4]

#### 3.5.2 Then zoom and filter

Zooming into the whole set of data is allowing you to show more detail in the chosen subset. Also, data points can be hidden to remove clutter. You can also use controls (as described in the controls chapter) to filter the whole dataset. In our dashboard we used filtering and brushing techniques (European map, country map and detail view).

#### 3.5.3 Details on demand

Offering more details gives the users more control over their experience. The most used technique for this third mantra is a tooltip which is displayed when you hover over an item. The tooltip offers more information, affiliated to the item.

[4]The first figure in the dashboard shows the full time range of the data. The context of increasing heatwaves is showed by the increasing bars over the last forty years.

# 4 Human-computer Interaction Basics

Human computer interaction is a multidisciplinary field of study that focuses on designing technology, regarding interaction with humans. It surfaced parallelly to the broad distribution of the first personal computers in the 1980s. For the first time many people interacted with computers.

This generated the need for an easy and efficient interaction between humans and computers (Foundation, n.d.-b). Today, HCI combines the study fields of computer science, cognitive science, and human factors engineering.

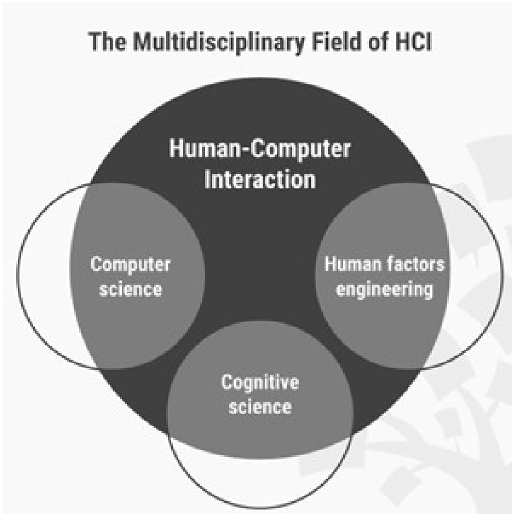


Figure 12: The field of human–computer interaction and its subfields (Foundation, n.d.-a)

## 4.1 Interaction design

When we create a product that users will interact with, we need to keep the principles of interaction design in mind, throughout all interactions a user will have. Interaction design is constructing a conversation a product or system has with its users (Jamal Nichols, 2017).

Some of the key principles while creating visualisations, software or other interaction-based products are:

- Designed interactions should feel like natural, human conversations
- Digital products should behave more like people than systems
- Design a product with how you think something will work, based on your experience

Interaction design uses five dimensions (words, visual representation, physical objects, time and behaviour) to describe a meaningful interaction (Devazya, 2019). The thoughtful implementation of the dimensions will increase the changes for a successful interaction between a product and a user.

The theory of the dimensions is important to know but it's even more important to gather hands-on experience in HCI.

## 4.2 Practical Execution of the dimensions

Our target audience are European citizens who have an interest in climate change topics, especially heatwaves. The scope of viewership is limited to browser-based devices such as personal computers or smartphones. Interactions with the dashboard or datastory were created with this in mind.

### 4.2.1 Words

Our audience is not well versed in scientific formulas or heatwaves. To guarantee a pleasing interaction in our dashboard, sentences are scarce and written concisely. With a minimal number of words, technical terms are explained.

To make it as simple as possible for the user, a written interpretation for the magnitude is available.


Figure 13: explanatory text for the word "Magnitude" in the climate change dashboard

### 4.2.2 Visual representations

The dashboard has several visual elements to aid the user in their interaction with the site. In the following sub-chapters two elements are explained in detail: our navigation bar and our slider.

#### 4.2.2.1 Navigation Bar

I added a navigation bar to each subsite. This navigation bar is added horizontally at the top of each subsite. The users know its purpose by past experience with navigation bars who are looking similar to ours. The names of the subsites (e.g, about-us section) are also an indication to its purpose.


Figure 14: Example of a navigation bar used in the climate change dashboard [5]

#### 4.2.2.2 Slider

For our presentation of the timeseries data, we added a slider to the dashboard. This slider uses the years as steps. It is automatically started when the site is first called. The step marks are an indicator for the user what year of data is shown. This is supported by showing it in the figure title of the European map.

Buttons to start and stop the slider are added beneath. By using the words Start and Stop and making the buttons visually different (blue color, in the foreground) to the rest of the dashboard, users are able to easily distinguish them and their function.

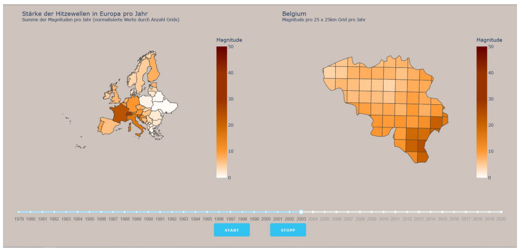


Figure 15: Example of a slider and start and stop buttons in the climate change dashboard [6]

### 4.2.3 Physical objects

All countries on the map can be clicked either by a mouse or also with a touch screen. For mouse users there is also a hover action added to indicate the clicking possibility. Touch screen users unfortunately do not have this action.

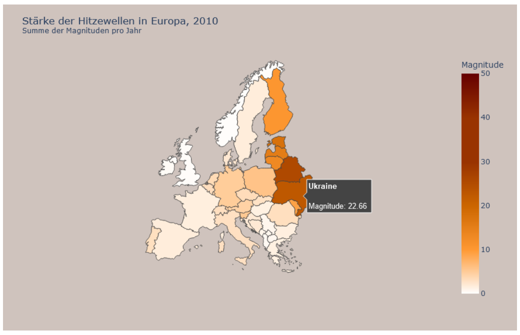


Figure 16: Example of a hover action for users with a mouse in the climate change dashboard

### 4.2.4 Time

In the dashboard the time dimension is used by the slider. When the users select a certain year the the interactive maps are live updated to present the data of the chosen year.

### 4.2.5 Behaviour

When accessing the site it automatically walks through the years. We have made this behaviour because we want to show the change of heatwaves over time. The users should not be discouraged by a need to click through all years themselves.

[5]implemented by me, layout by Daniela Herzig
[6]implemented by Jan Zwicky

# 5 Evaluation

For the last learning objective I wanted to evaluate the climate data dashboard. For this I read into the theory of an evaluation. Informing myself about the methodology of a user study was the first step to take.

According to Moran, 2019 usual goals of usability tests are:

- Identifying problems in the design of the product or service
- Uncovering opportunities to improve
- Learning about the target user's behavior and preferences

The evaluator in a user study should gain insights into changes needed in the visualisation for a better understanding or any inconveniences for the user.

## 5.1 Personas

I created personas for the climate data dashboard. They are representing the audience for the climate data dashboard. In Figure 17 an example of those personas is included in the report. Unfortunately they are in German, but I included the full document in the appendix.

For the user study people with a background close to these personas should be used to execute the user study. As I am limited by budget and time, I could not find enough people with this background. This is why I chose people close to me.

**Persona 3**

**Name**: Georgi Petrenko
**Alter**: 34
**Bildung**: Landwirtschaftliche Grundlagen erlernt von seinem Vater
**Zivilstatus**: ledig
**Profession**: Landwirt
**Einkommen**: 40'000
**Umgebung**: Westukraine, Grossbetrieb auf dem Land

Abbildung 3 - Shutterstock Images Bauer

**Psychologischer Hintergrund**: Ist interessiert an der langfristigen Fortführung des Betriebs seiner Familie und will diesen robust für die Zukunft machen. Er möchte sich mit anderen Bauern in Europa über die Hitzewellen austauschen und wie deren Folgen bestenfalls negiert werden können.

**Ziele mit Dashboard**: Neugier an der Vergangenheit der Ukraine und deren Hitzewellen sowie Informationsbeschaffung. Sucht nach Ländern in Europa welche ebenfalls Hitzewellen erlebten, um dabei Betroffene zum Austausch zu finden.

Figure 17: Persona for an European peasant

## 5.2 User study object

In my usability test I want to assess the main climate data dashboard. Its main goal is to visualise heatwaves from 1979 until 2020 in European countries.

The dashboard has the following components:

- Bar chart from 1979 - 2020
- European map for the summarised heatwaves
- Selected country map for the heatwaves
- Detail view of a grid inside a country
- Text elements to describe heatwaves

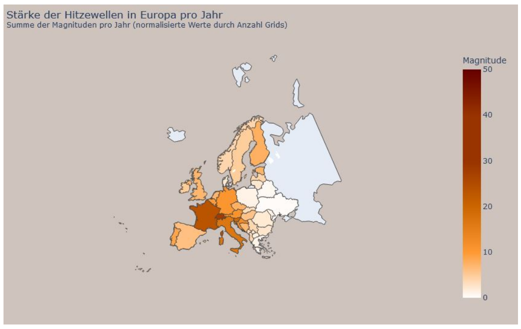


Figure 18: European map in the climate change dashboard

In my user study, I want to focus on the European map.
The other components should also be tested but due to constraints in budget and time I could not do this in the learning objective.

### 5.3 Usability test

For the usability test I chose to guide the participants through the test by explaining to them the different components and their purpose. I then told them that they should only use the European map for this test. I used a test group of five people which are between 24 and 28 years old. The European map should be tested with the system usability scale (SUS)[7]. The SUS is an industry standard and is technology independent, it also uses the Likert scale which my subjects and I are already familiar with. The details of the scoring system for the SUS are described in Sauro, 2011.

A second more specific test should determine to either leave the zoom function in the European map or remove it completely. I want to evaluate if the users gain usability by using the zooming feature (Figure 20) or if the map should be on a fixed position like in Figure 19.

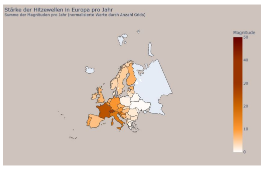

Figure 19: Fixed position of zoom for the European map

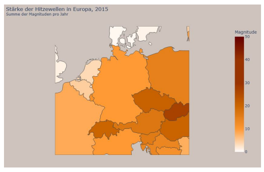

Figure 20: Zoomed in (dynamic) zoom for the European map

#### 5.3.1 Results

For the first user test (European map with SUS scoring), the mean of all user scores was 78. Overall, no user was beneath the critical score of 68.

| User | SUS scoring |
|---|---|
| User A | 77.5 |
| User B | 72.5 |
| User C | 72.5 |
| User D | 82.5 |
| User E | 85 |

Table 1: system usability scores of the usability test

The users D and E both have a technical background which is definitely showing in their scores. All the scores and results are added to the appendix.

The users unanimously told me to fix the zoom in a position rather than leaving it to the user. This is because, while scrolling through the dashboard page they sometimes accidentally zoomed inside the map. It also does not help them while using the map and it even might be a distraction. We have taken this feedback seriously and removed the zoom feature from the map.

#### 5.3.2 Conclusion

Our visualisation was overall awarded with good scores and the feedbacks were positive. Suggestions like removing the zoom function were already anticipated by me. Nonetheless the confirmation by the users strengthens the decision to remove it.

[7]The SUS scale evaluates mainly satisfaction. Other metrics like effectiveness and efficiency (for Standardisation, 2018) should also be tested. Because of time constraints and as I am not benchmarking this visualisation to another I will only test the for the user satisfaction metric.

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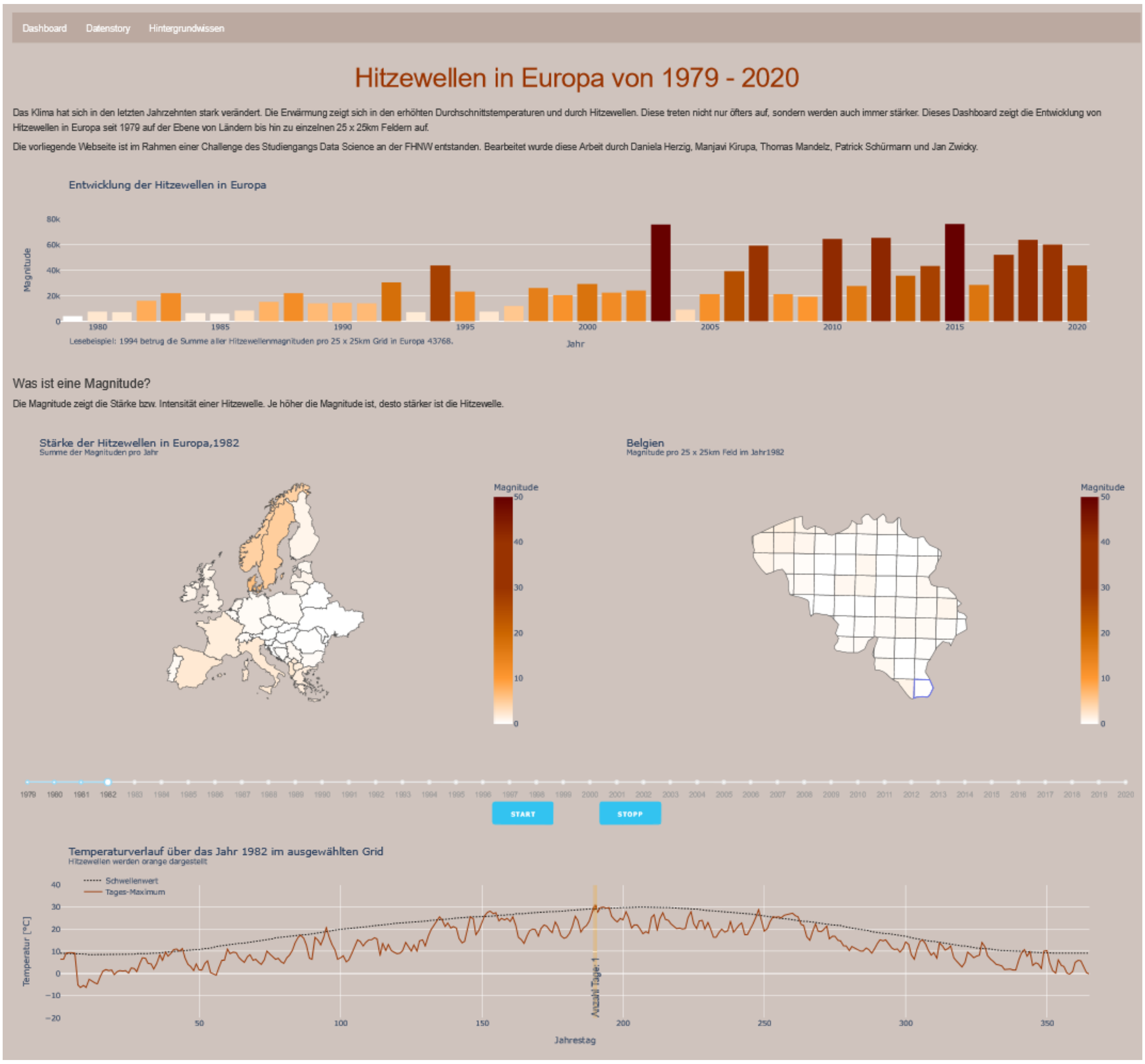
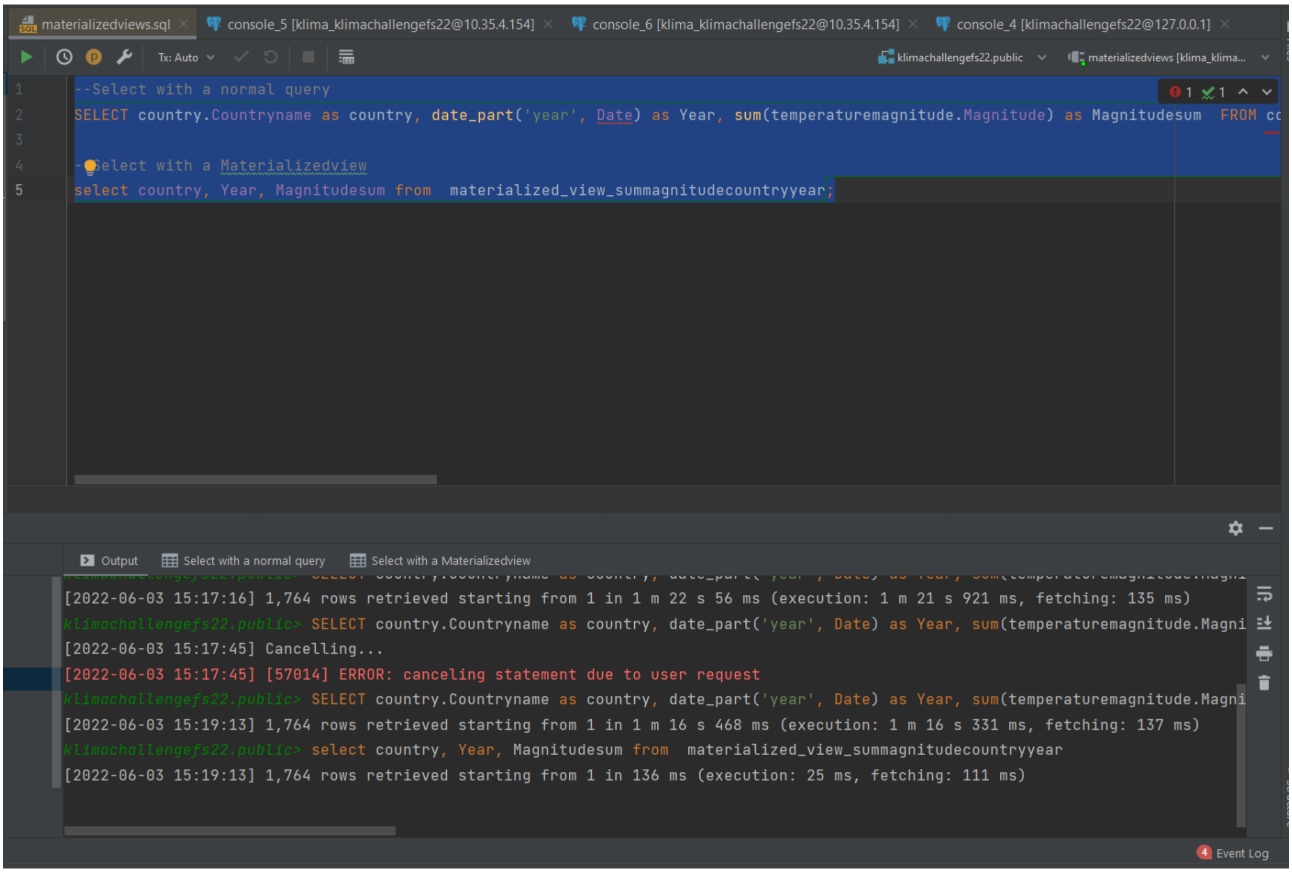
## List of Figures

# Appendices




Appendix for Figure 1

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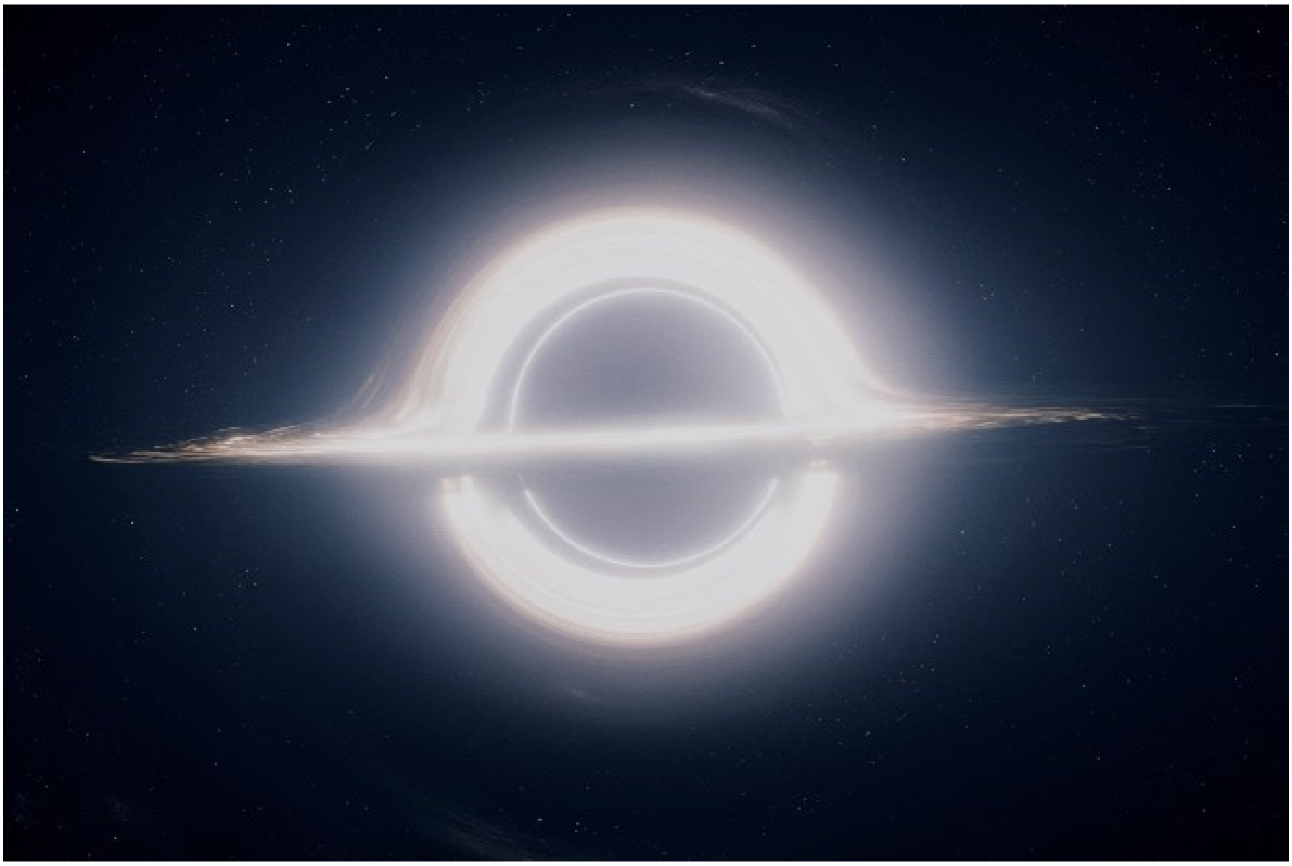

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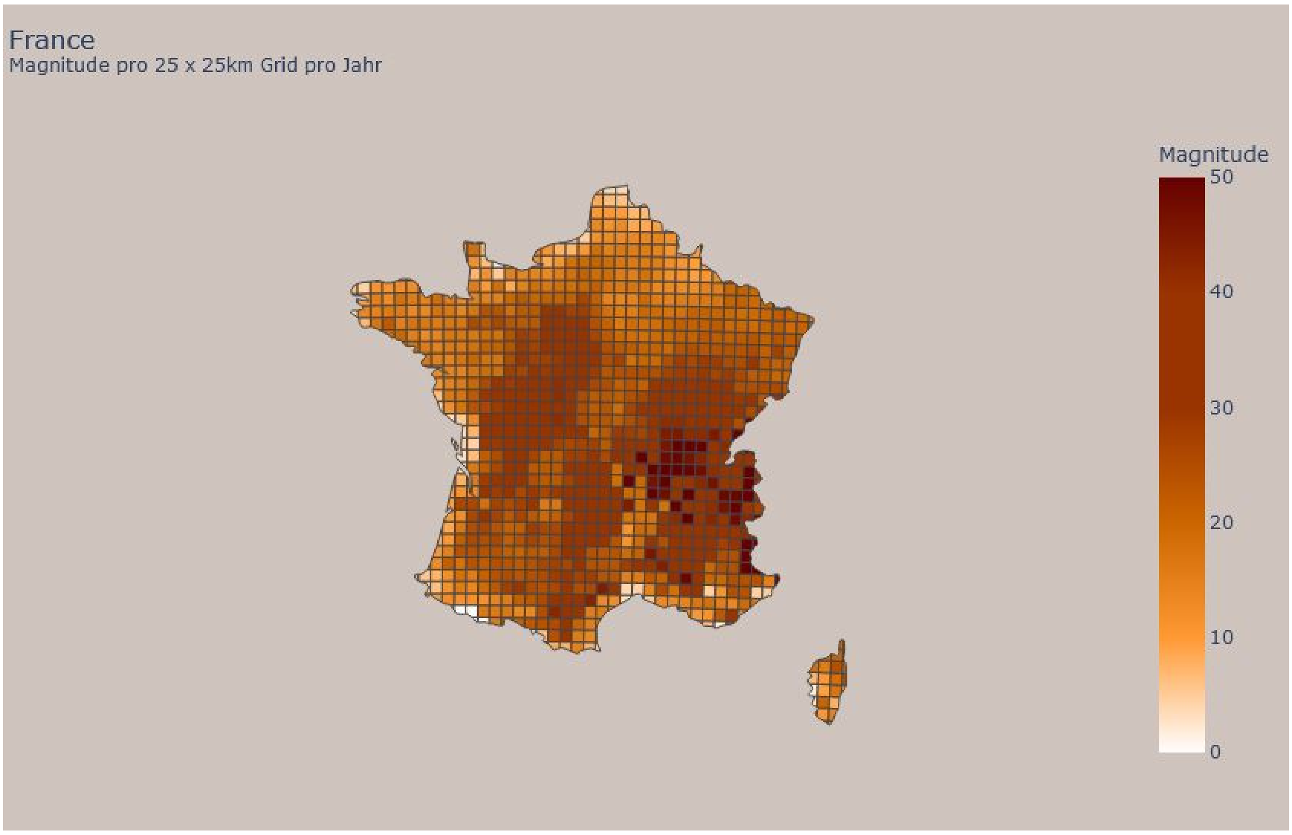
Appendix for Figure 4

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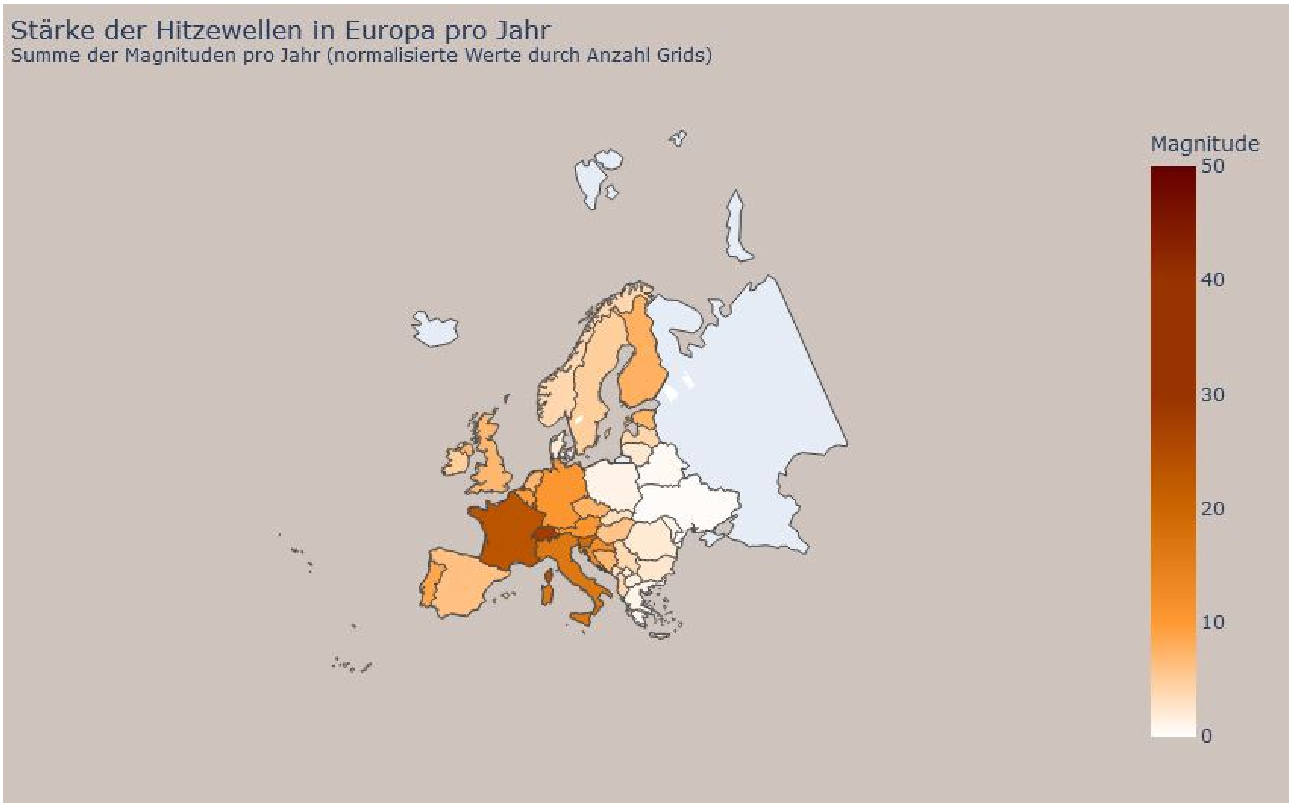


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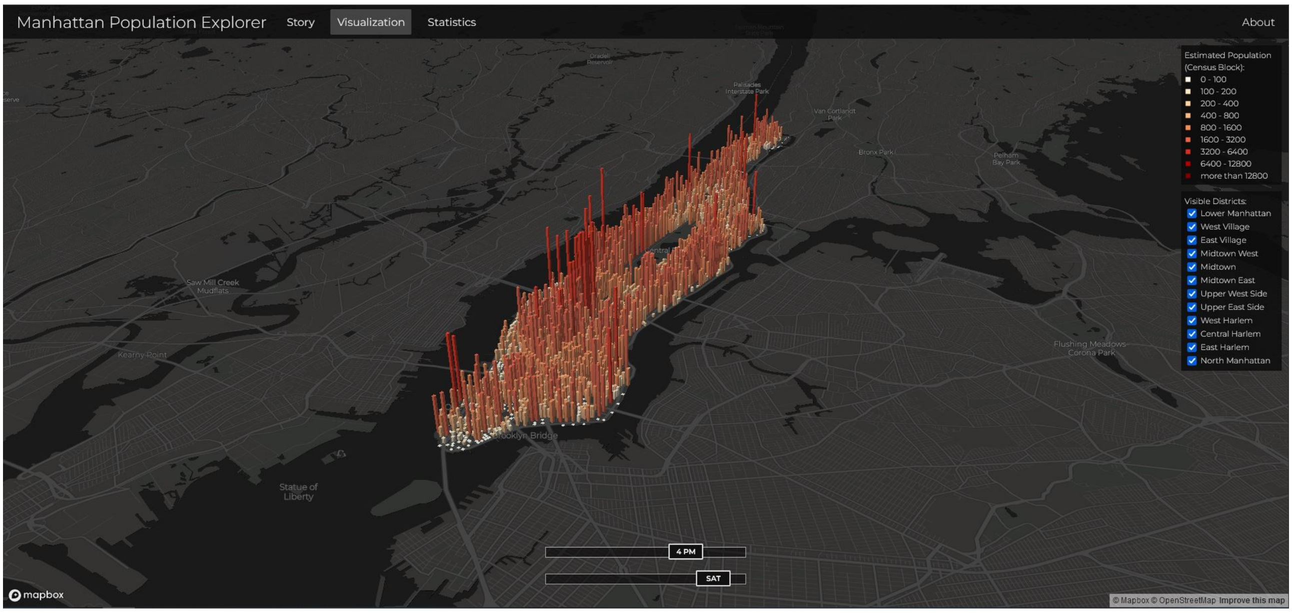


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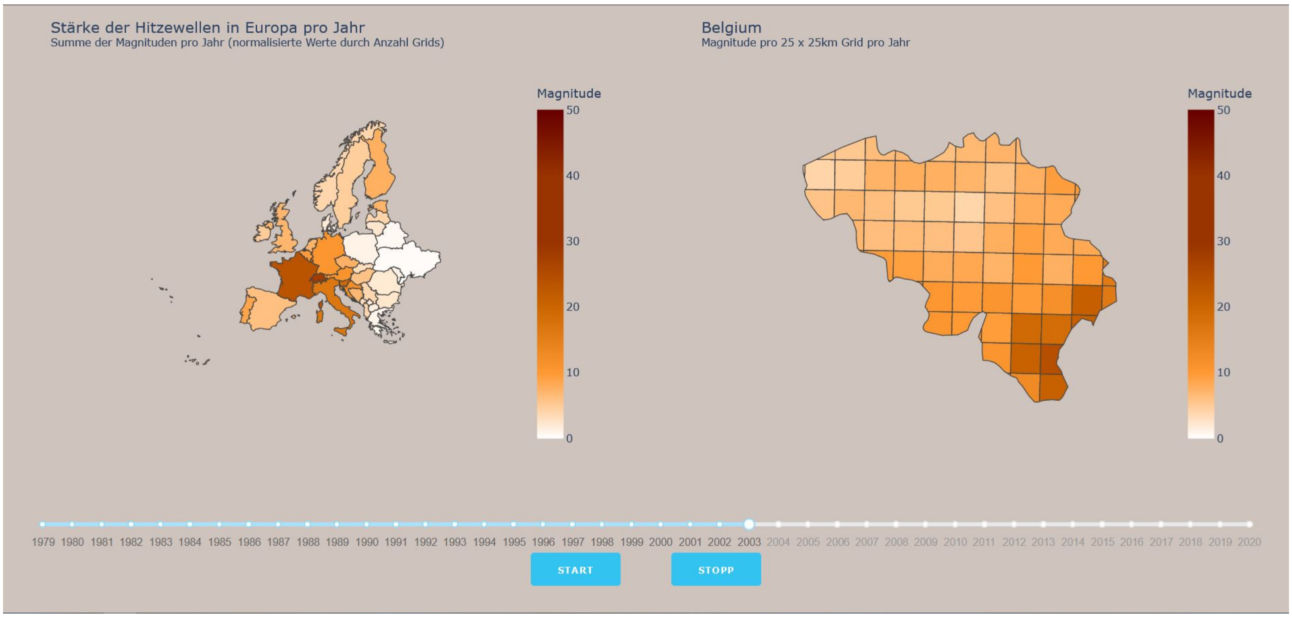
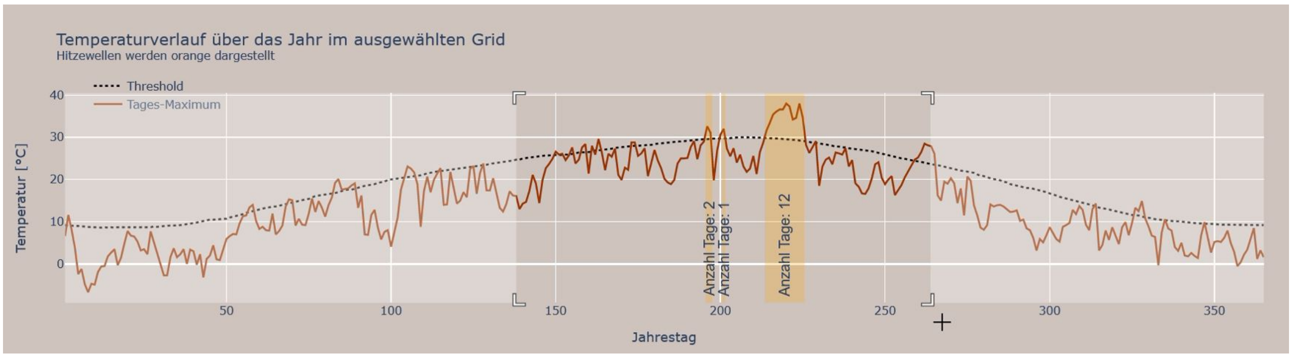
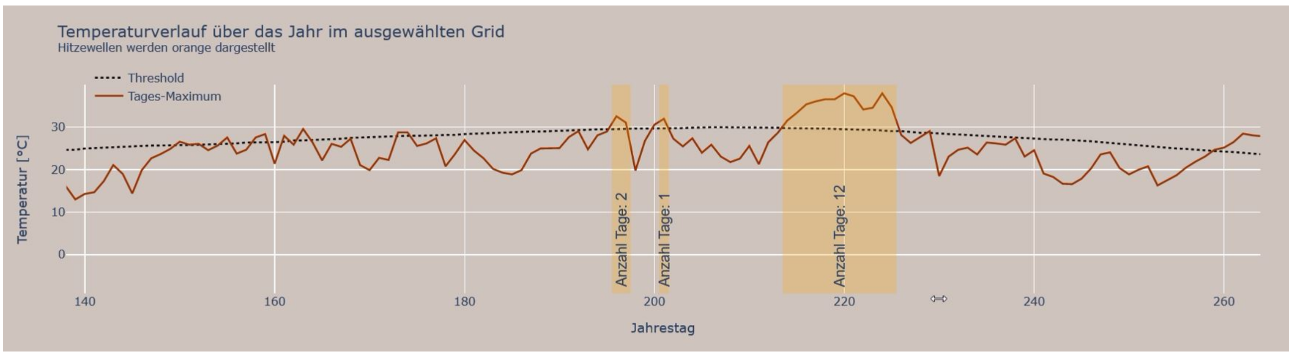


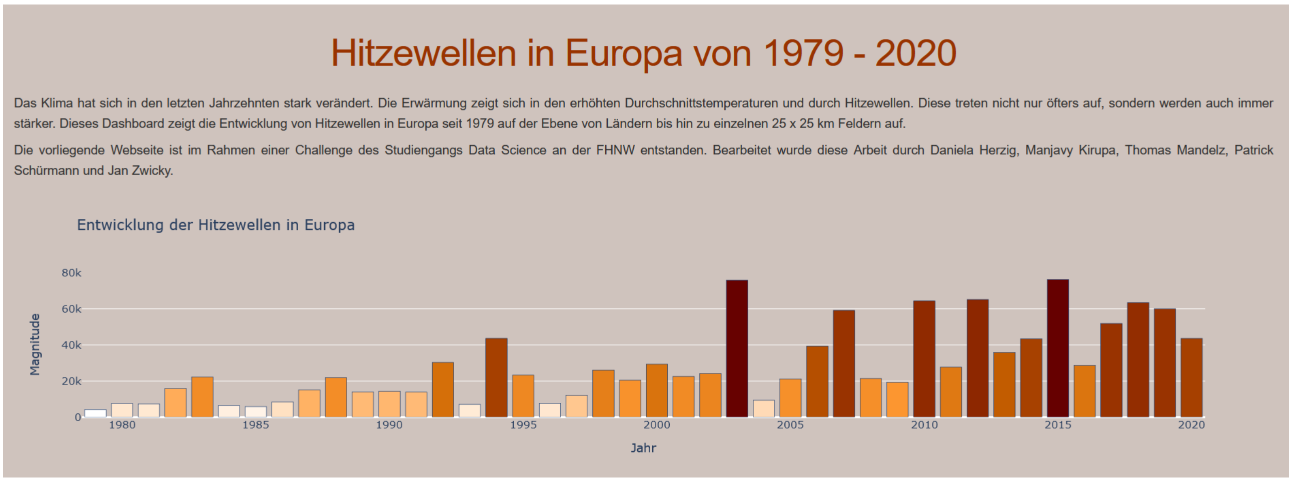

Appendix for Figure 8



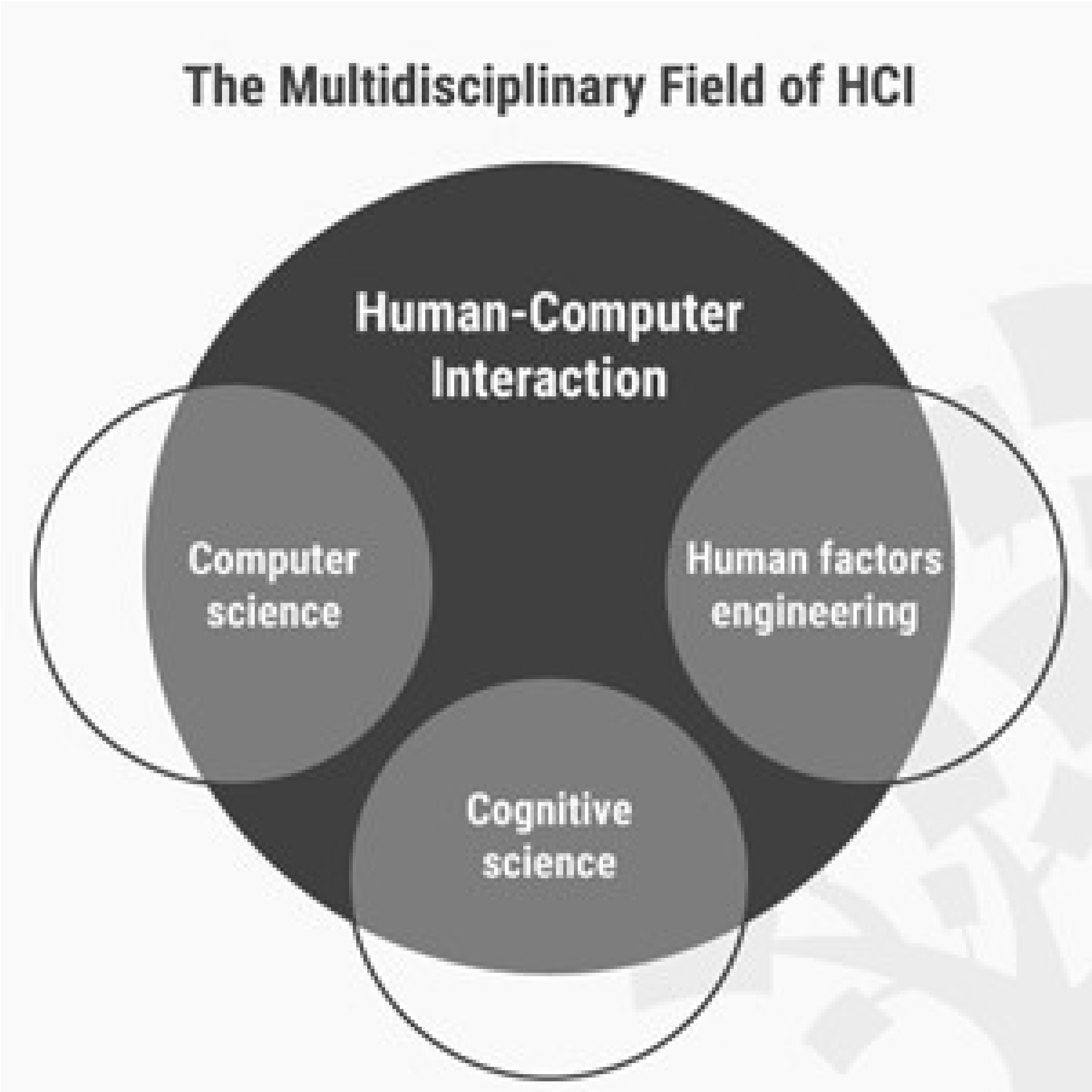

Appendix for Figure 9




Appendix for Figure 10




Appendix for Figure 11

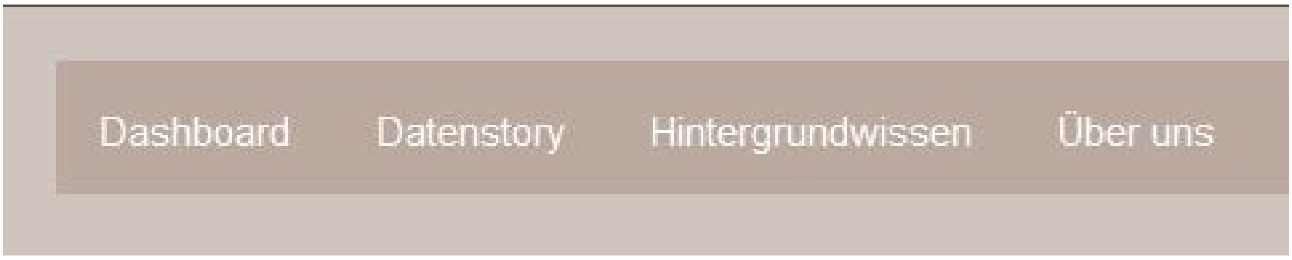



Appendix for Figure 12

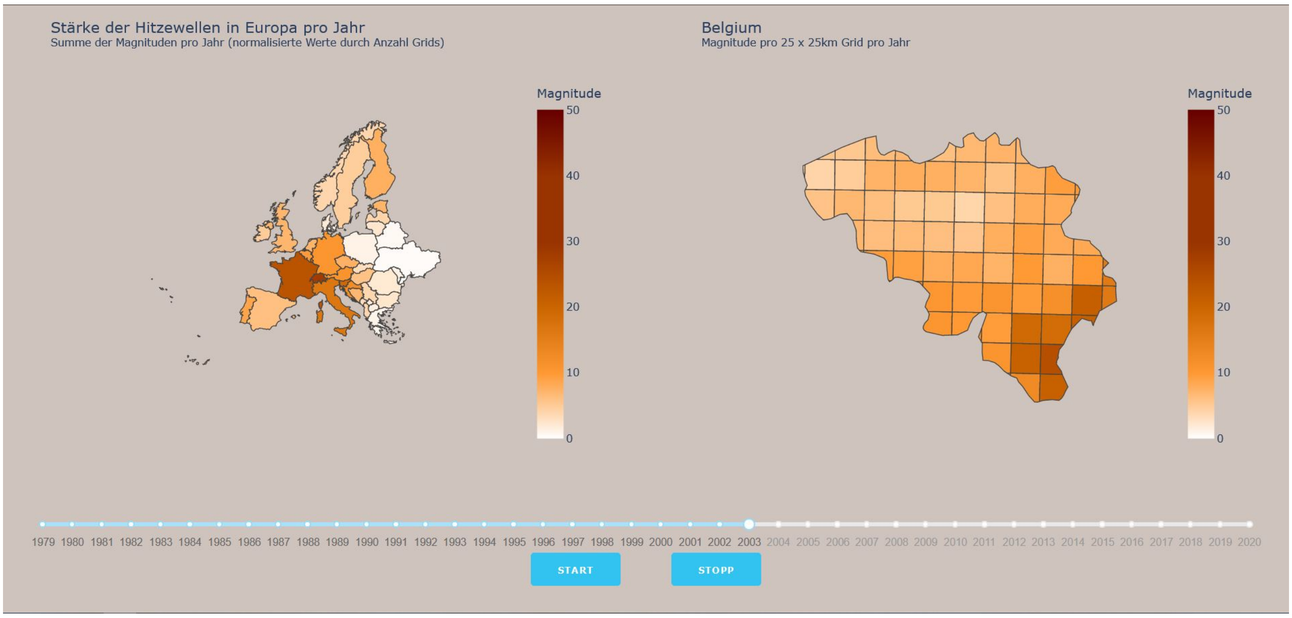
**Was ist eine Magnitude?**

Die Magnitude zeigt die Stärke bzw. Intensität einer Hitzewelle. Je höher die Magnitude ist, desto stärker ist die Hitzewelle.

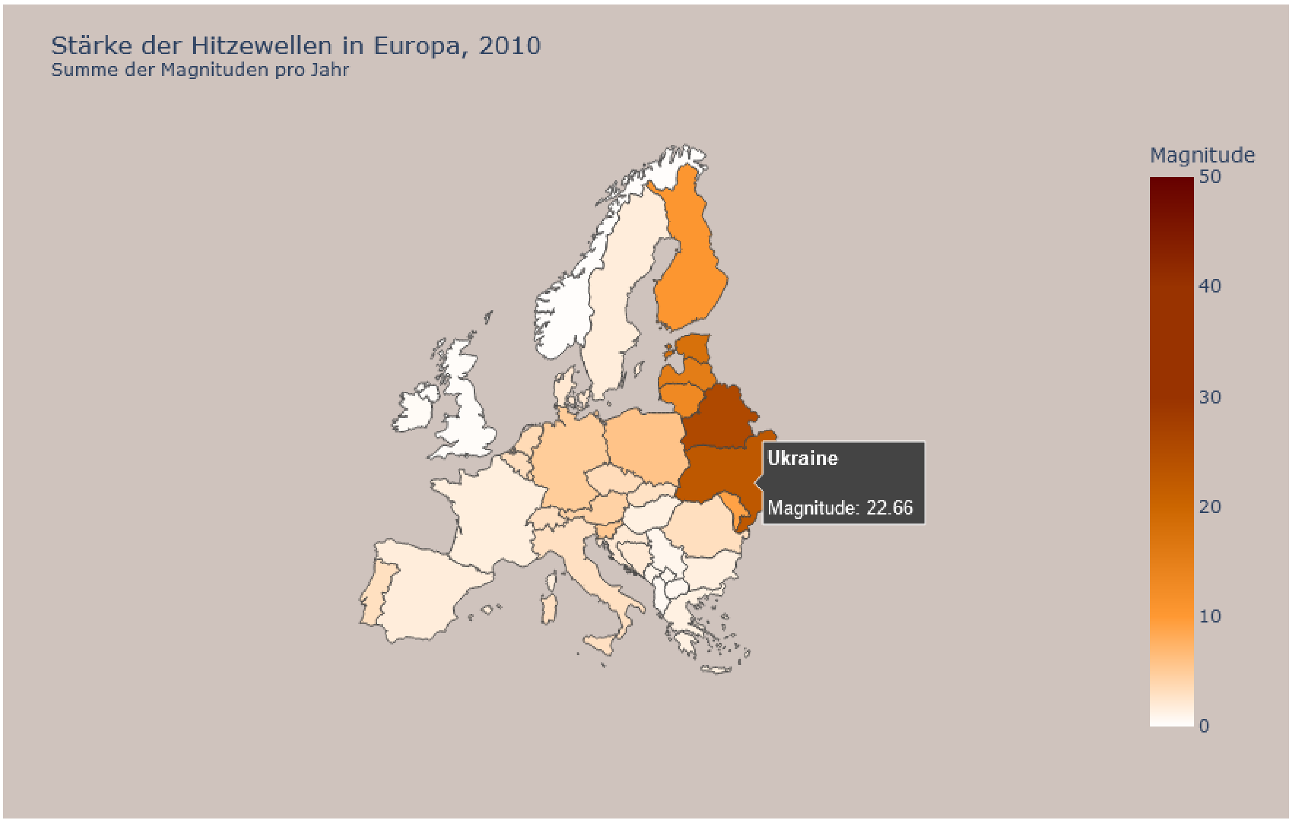
Appendix for Figure 13




Appendix for Figure 14




Appendix for Figure 15




Appendix for Figure 16

**Persona 3**

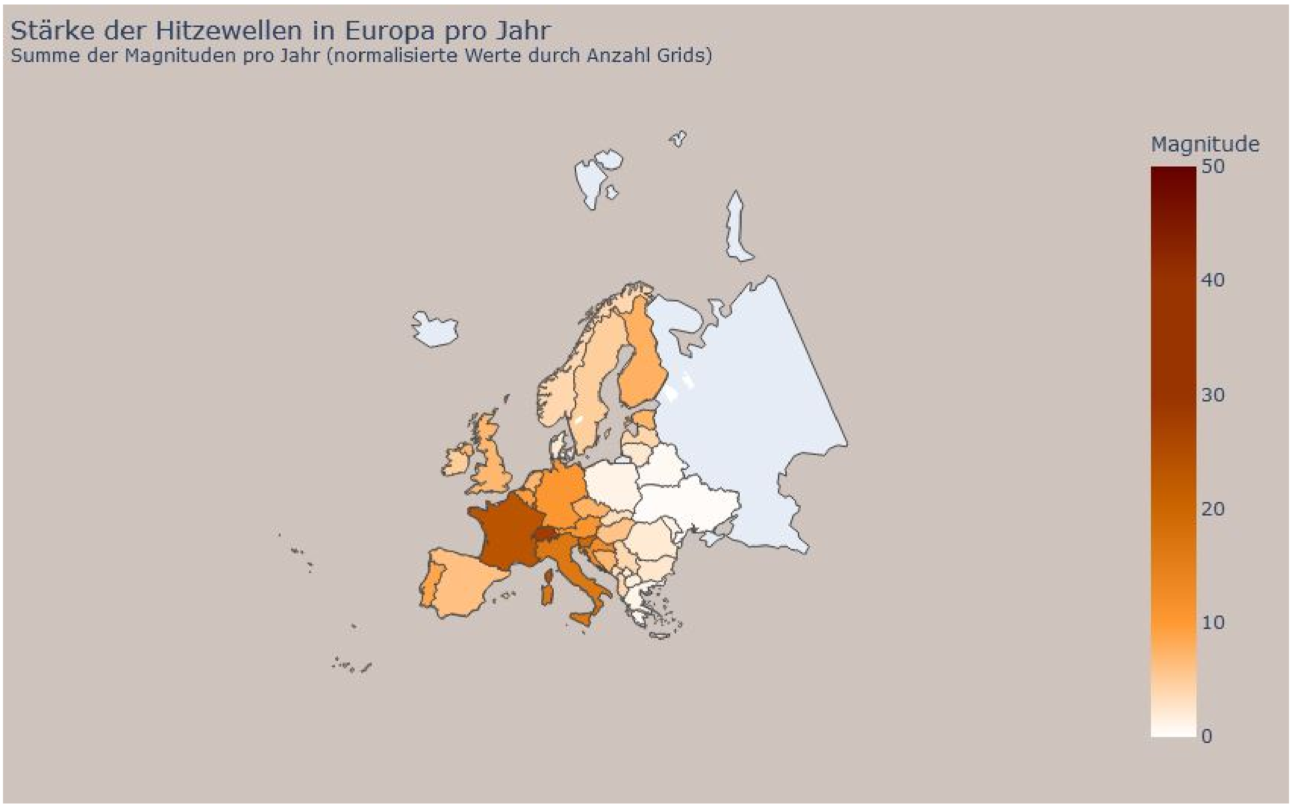
Abbildung 3 - Shutterstock Images Bauer

**Name**: Georgi Petrenko
**Alter**: 34
**Bildung**: Landwirtschaftliche Grundlagen erlernt von seinem Vater
**Zivilstatus**: ledig
**Profession**: Landwirt
**Einkommen**: 40’000
**Umgebung**: Westukraine, Grossbetrieb auf dem Land

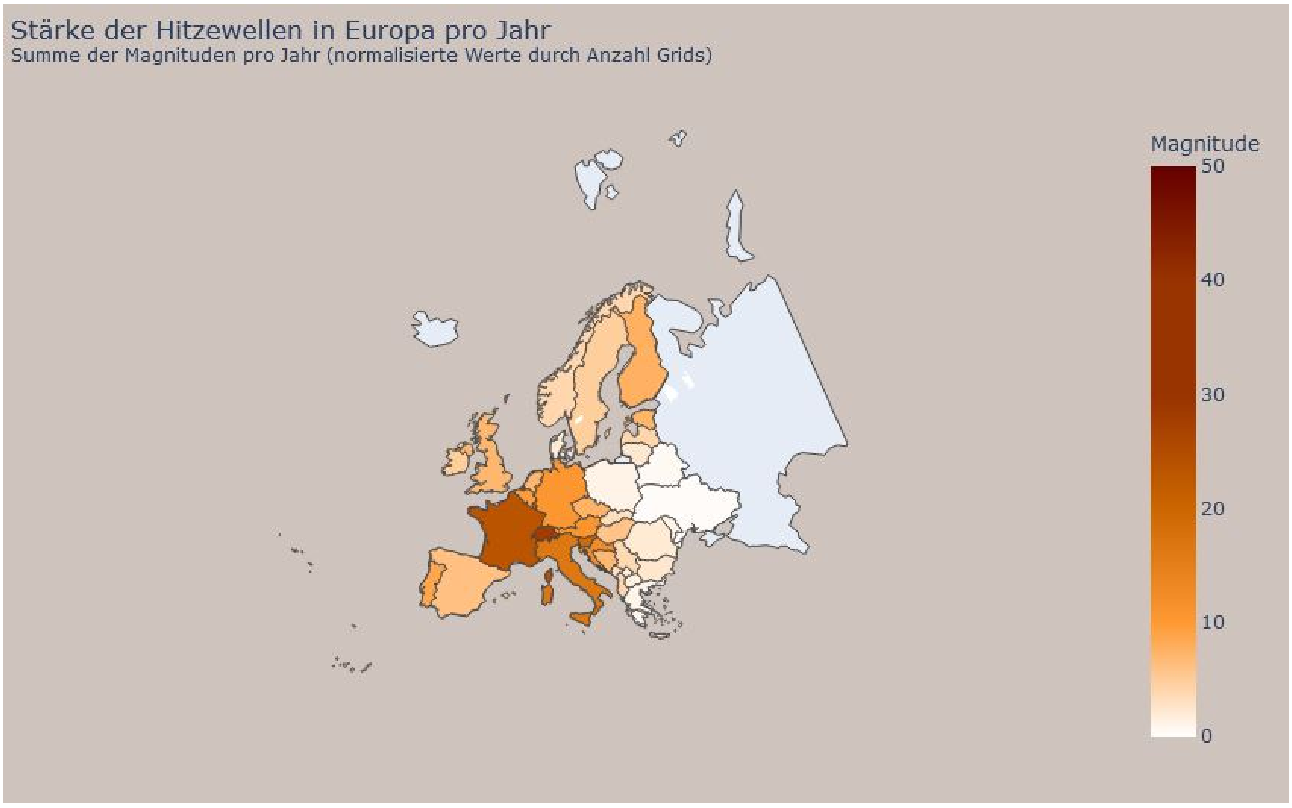
**Psychologischer Hintergrund**: Ist interessiert an der langfristigen Fortführung des Betriebs seiner Familie und will diesen robust für die Zukunft machen. Er möchte sich mit anderen Bauern in Europa über die Hitzewellen austauschen und wie deren Folgen bestenfalls negiert werden können.

**Ziele mit Dashboard**: Neugier an der Vergangenheit der Ukraine und deren Hitzewellen sowie Informationsbeschaffung. Sucht nach Ländern in Europa welche ebenfalls Hitzewellen erlebten, um dabei Betroffene zum Austausch zu finden.

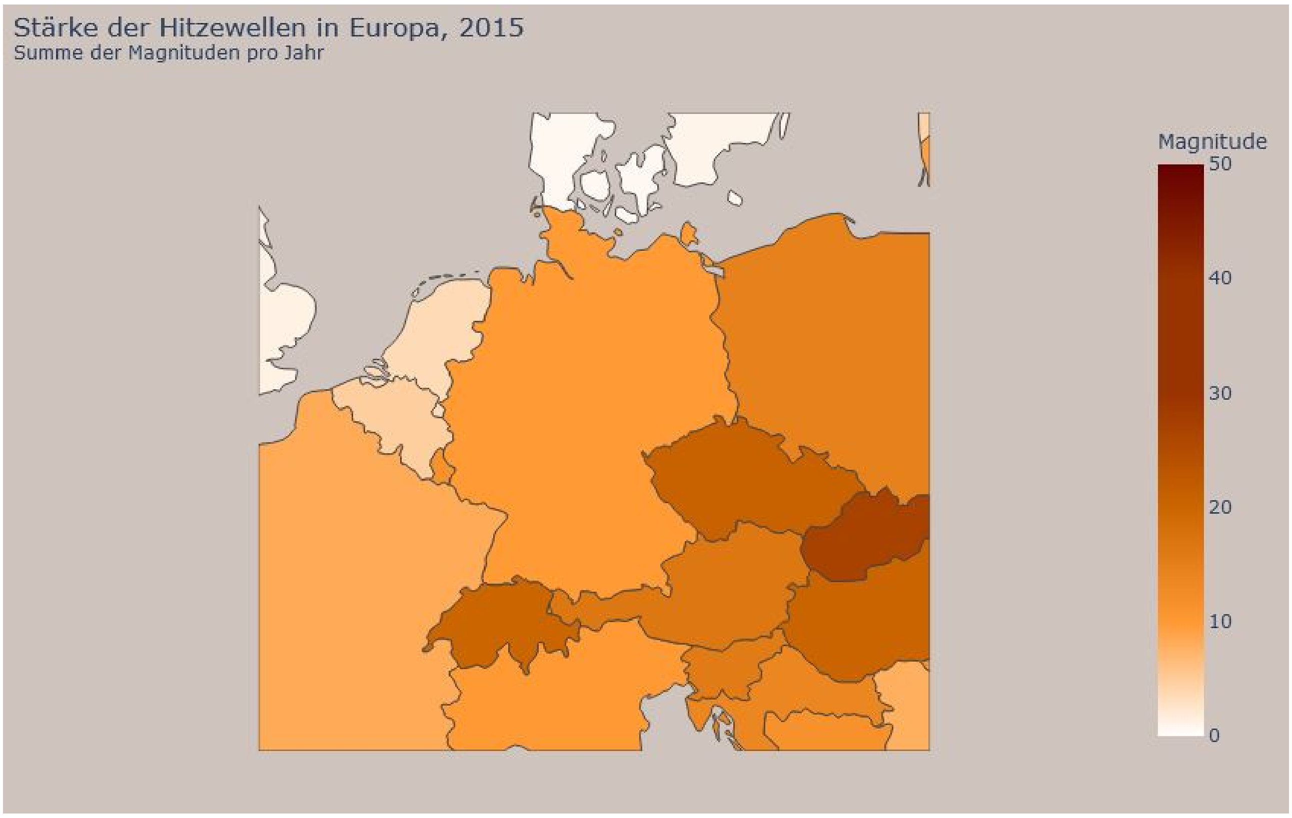
Appendix for Figure 17




Appendix for Figure 18




Appendix for Figure 19




Appendix for Figure 20

**Persona 1**

Abbildung 1 - Shutterstock Images Professor

**Name**: Peter Jörgenson
**Alter**: 52
**Bildung**: PHD in Social Science
**Zivilstatus**: verheiratet seit 25 Jahren, 2 Kinder
**Profession**: Doktor in Umeå University
**Einkommen**: 120’000
**Umgebung**: Nordschweden, eigenes Haus, Lehrstuhl an der Universität und eigenes Büro

**Psychologischer Hintergrund**: Peter Jörgenson ist interessiert an Klimaereignissen und allgemein an wissenschaftlichen Themen. Er vertraut der Wissenschaft da er diese selbst betreibt und er ist grundsätzlich zufrieden mit seinem Leben. Er bedauert sich nicht früher gegen den Klimawandel eingesetzt zu haben. Dies möchte er nun richtigstellen.

**Ziele mit Dashboard**: Will sich für die Zukunft seiner Kinder einsetzen und sammelt dafür Informationen, um sein Verhalten zu ändern. Als Zweitmotivation möchte er seinen Lernenden die Klimathematik näherbringen und sucht dafür geeignete Medien.

**Persona 2**

**Name**: Amelia Pereira
**Alter**: 18
**Bildung**: Sekundärabschluss
**Zivilstatus**: ledig
**Profession**: Teilzeitarbeit im Verkauf
**Einkommen**: 8’000
**Umgebung**: Küstenstadt Portugals, WG mit mehreren Mitbewohner:innen

Abbildung 2 - Shutterstock Images Surferin

**Psychologischer Hintergrund**: Ist noch nicht im Leben verankert und auf der Suche nach ihrer Passion. Möchte als Aktivistin gegen den Klimawandel versuchen diesen zu verhindern. Hat bereits Dürren in ihrem Land erlebt. Ihre Eltern mussten in die Stadt ziehen da ihr Landwirtschaftsbetrieb nicht mehr rentierte.

**Ziele mit Dashboard**: Sie möchte Informationen sammeln zur Verhinderung von Nahrungsmittelknappheiten und Dürren da sie diese in ihrem Umfeld bereits akut mitkriegt. Möchte diese Informationen mit ihren Freunden teilen, um diese zu motivieren ebenfalls gegen den Klimawandel vorzugehen.

**Persona 3**

Abbildung 3 - Shutterstock Images Bauer

**Name**: Georgi Petrenko
**Alter**: 34
**Bildung**: Landwirtschaftliche Grundlagen erlernt von seinem Vater
**Zivilstatus**: ledig
**Profession**: Landwirt
**Einkommen**: 40'000
**Umgebung**: Westukraine, Grossbetrieb auf dem Land

**Psychologischer Hintergrund**: Ist interessiert an der langfristigen Fortführung des Betriebs seiner Familie und will diesen robust für die Zukunft machen. Er möchte sich mit anderen Bauern in Europa über die Hitzewellen austauschen und wie deren Folgen bestenfalls negiert werden können.

**Ziele mit Dashboard**: Neugier an der Vergangenheit der Ukraine und deren Hitzewellen sowie Informationsbeschaffung. Sucht nach Ländern in Europa welche ebenfalls Hitzewellen erlebten, um dabei Betroffene zum Austausch zu finden.

## System usability scale test

| Participant | q1 | q2 | q3 | q4 | q5 | q6 | q7 | q8 | q9 | q10 | SUS Score |
|---|---|---|---|---|---|---|---|---|---|---|---|
| User A | 4 | 2 | 4 | 2 | 4 | 3 | 4 | 1 | 4 | 1 | **77.5** |
| User B | 3 | 2 | 3 | 3 | 4 | 2 | 4 | 1 | 4 | 2 | **72.5** |
| User C | 4 | 2 | 4 | 2 | 5 | 3 | 4 | 2 | 3 | 2 | **72.5** |
| User D | 4 | 1 | 4 | 1 | 5 | 2 | 5 | 1 | 3 | 1 | **82.5** |
| User E | 5 | 1 | 4 | 1 | 4 | 2 | 4 | 1 | 5 | 1 | **85** |

**Mean of SUS Scores:78**

### Questions

1. I think that I would like to use this system frequently.
2. I found the system unnecessarily complex.
3. I thought the system was easy to use.
4. I think that I would need the support of a technical person to be able to use this system.
5. I found the various functions in this system were well integrated.
6. I thought there was too much inconsistency in this system.
7. I would imagine that most people would learn to use this system very quickly.
8. I found the system very cumbersome to use.
9. I felt very confident using the system.
10. I needed to learn a lot of things before I could get going with this system.

**Likert Scale**

(1) Strongly disagree; (2) Disagree; (3) Neither agree nor disagree; (4) Agree; (5) Strongly agree

Appendix for SUS