CITIES AND CLIMATE CHANGE – A LOOK TO THE FUTURE

Group 11

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About this Project

This section is about the information of Group 11, the project file locations and project outline. The reader can find all elements (website code, data, photo and logo) by clicking on the Project output online link to Github below in Table 1.

Group-11 Members

Daniel Rennie, Xudong Zhang, Melissa Cotrina, Meng Chen

Outputs and Contributions

Table.1. Project Output Description Table

Project Output	Output Description
Project Output Files	Zip File on Moodle Online link: https://github.com/Climate-Change-and-City-Transformation
Project Website	https://climate-change-and-city-transformation.github.io/

Table.2. Individual Contributions Outline Table

Task Name	Major Contributors	Additional Contributors	Relevant Chapters in Report
Concept Development	All team members		Introduction
Data preparation and integration	All team members		Introduction
Visualisation 1: Global Trends	Daniel Rennie		Visualisation 1
Visualisation 2: China	Xudong Zhang		Visualisation 2
Visualisation 3: India	Melissa Cotrina		Visualisation 3
Visualisation 4: Future Impacts	Meng Chen		Visualisation 4
Presentation video	Melissa Cotrina	All team members	-

Website Development	Xudong Zhang	All team members	Website Development
Paper Format	Xudong Zhang	All team members	-
Paper Editing and Combining	Daniel Rennie	All team members	-

Introduction

Climate change impacts the entire world and is one of the biggest existential threats to the future. The shift to urbanisation through the 19th and 20th centuries has seen cities playing an ever-bigger role in how humans interact and influence climate change; as people have concentrated in urban areas, environmental requirements and pressures have shifted.

The earlier mentioned 19th and 20th centuries were dominated primarily by the United States and Europe. However, through the first two decades of the 21st century, much of the world's economy and power has shifted eastward to China and India. These two countries together hold 30% of the world's population and four of the top ten largest cities in the world by population (World City Populations 2021, no date). China and India will play critical roles in defining how and how effectively climate change is combatted in the coming years.

This report and accompanying site aim to explore the global trends that have gotten us to where we are today. It looks at China and India, respectively, focusing on their cities and then looks to understand what potential futures may be based on how successfully the world deals with the climate change problem.

Concept Development

This concept was developed and worked through as a group. While the visualisations were created on our own, the report was brought together to have a unified vision and narrative.

Data Preparation and Integration

All data was sourced independently and integrated into the site and visualisations by each group member individually.

Visualisation 1: Global Trends

Introduction and Motivation

The key to beginning the story about climate change is understanding where the Earth is today and the steps that have taken us to this spot. Fundamentally, the Earth's atmosphere, sea levels, glacier levels and temperatures are constantly changing and are inextricably linked to one another. Ice ages occur, temperatures go up and down, and atmospheric particles rise and fall due to events like volcanos. However, what is now becoming undeniable according to the Intergovernmental Panel on Climate Change's (IPCC) 5th Assessment Report is that humanity is extremely likely, between 95% and 100% likely, to be responsible for the surge in observed global average surface temperature seen in the last 50 years (‘AR5 Synthesis Report: Climate Change 2014 — IPCC’, no date).

It is widely accepted that this steep increase in global temperatures that has started to occur since the mid 20th century is due to much of the world increasing its reliance on the combustion of fossil fuels. Fossil fuels power the vast majority of our vehicles and cities. They are ever-present in so many items that are used daily, including almost all of those that contain plastic.

When fossil fuels are burnt to power our vehicles or create the energy needed to run our cities and industries, they release greenhouse gases. The most commonly discussed greenhouse gas is carbon dioxide. While naturally occurring in the Earth’s atmosphere, current carbon dioxide levels are unseen in the last 800,000 years of tracked history (Ritchie and Roser, 2020). The IPCC has stated clearly that the marked increase since the mid 20th century is “extremely likely” to be attributed to human activities (‘AR5 Synthesis Report: Climate Change 2014 — IPCC’, no date).

As the presence of greenhouse gases in the atmosphere increases, this has many effects, including increasing temperatures. As temperatures increase, glaciers melt, and their mass and size decrease, leading to an increase in sea levels, which could cause millions of people who live in coastal cities to lose their homes and ways of life.

The purpose of this section of the report and site is to set the broader scene of climate change so that the subsequent sections and visualisations can delve deeper into more detailed examples across China, India and some hypothetical scenarios for the future.

Methods and Processes

This section was split into two visualisations with text descriptions accompanying both. Both visualisations show five key climate change indicators, which are:

1. Sea Level Rise
2. Global Land-Ocean Temperature Index
3. Atmospheric Carbon Dioxide Concentration
4. Average Arctic Ice Area in September
5. Antarctica Glacier Mass Variation

Indicators 1, 2, 4 and 5 were visualised using data from NASA (Climate Change: Vital Signs of the Planet, no date). Whereas indicator three was visualised using data from Our World in Data (Atmospheric CO_2 concentration, no date).

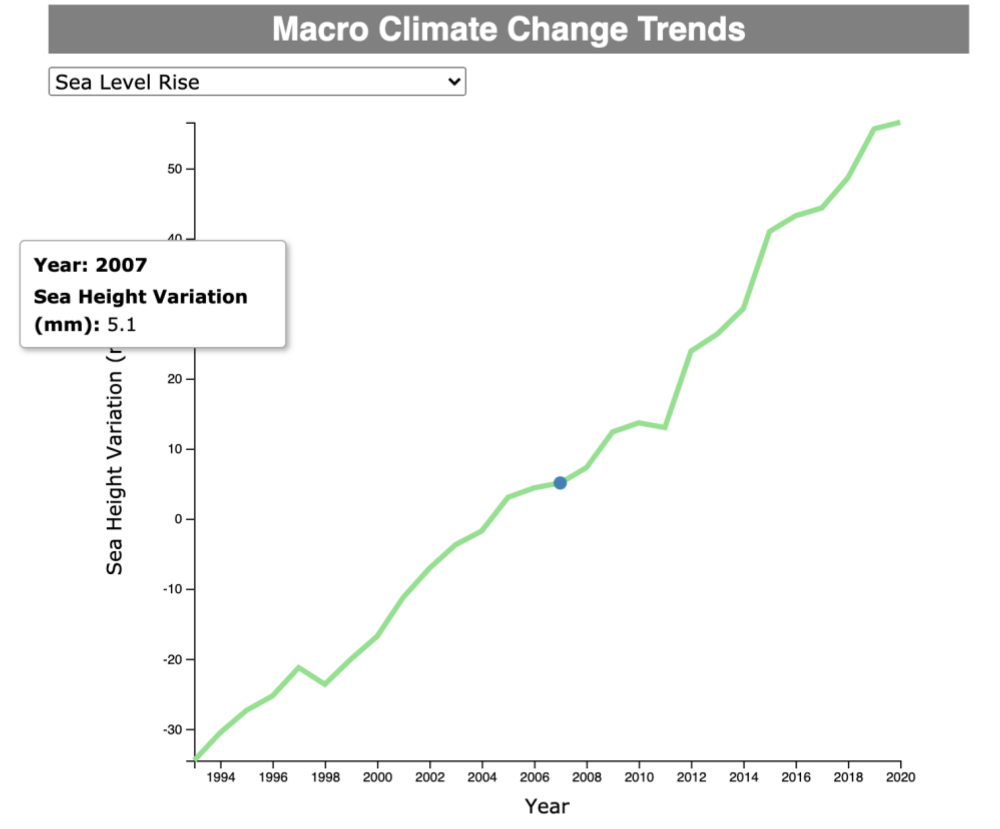

Fig.1. First Visualisation: Macro Climate Change Trends – Sea Level Rise

The first visualisation on the site, shown above in Figure 1, allows the reader to select the climate change indicator that they are interested in using a drop-down box. As a user runs their mouse over the line graph, a tooltip allows them to see the indicator's value for that year.

This line graph was created using D3. The first step was combining all the data into one CSV file with the following columns:

- Year
- ClimateEvent
- Label
- Value

The data was then read into the site using D3 to create the line graph. A drop-down box was created for interactivity, and the different indicators were read into the box so that the user could select the variable of interest. Finally, as mentioned above, a tooltip was created to see the appropriate information for each variable.

A line graph was chosen because it most clearly can show the trend of each indicator over time. The drop-down box was used because each variable has a slightly different timeframe along the x-axis. For example, the Atmospheric Carbon Dioxide indicator goes back to 1860, whereas the Antarctica Glacier Mass Variation indicator only goes back to 2002. As the user chooses a new option in the drop-down box, the axes change to reflect the unique parameters of the chosen indicator.

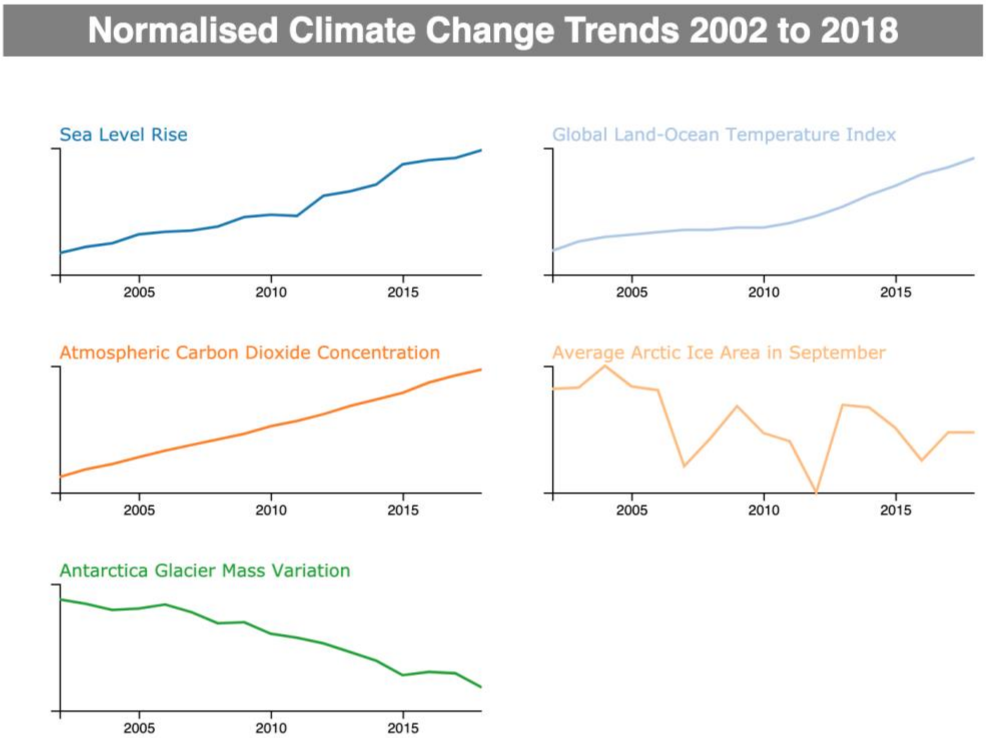

Fig.2. Second Visualisation: Small Multiples Normalised Climate Change Trends Plot

The plot show in figure 2 is the second and final visualisation in the Global Trends section. Like the first visualisation this plot reads in data from a CSV and then is visualised using D3. However, this plot shows the indicators in the form of a small multiples plot. The plot shows the same data as the first visualisation but uses normalised data for the y-axis indicator values but uses one timeline along the x-axis, not differing the differing timelines of the first visualisation. As it is a small multiples plot it allows the reader to see all the indicators in one image allowing them to more easily understand how they are affected in the same timeframe.

The single timeline allows the user to quickly compare the different indicators in a meaningful and relevant context helping to understand climate change in the more contemporary context of 2002 to 2018. The same colours were used for each variable as in the first visualisation so that the different indicators could be easily recognised. Lastly, a tooltip was not used in this visualisation because the values are normalised and do not provide accurate information to the reader. This visualisation is used to understand the current trend of each indicator, and for the actual values, the first visualisation should be used.

Challenges

Compared to some of the other sections that will be explored in later parts of this paper and throughout the website, the visualisations in the Global Trends section are more straightforward. While the challenges in this section may not be as significant as the later ones, there were some unique challenges presented for these visualisations, especially for the first visualisation.

The main challenge of the first visualisation was the changing axes, line and tooltip. Two sets of functions had to be created in order for the visualisation to be initially loaded correctly and then subsequently update correctly upon a new user selection in the dropdown box. When the visualisation iterations were started, this was not apparent. The visualisation either only loaded correctly initially and then lost items like the tooltip when a new value was selected, or it only worked once a new value was selected it loaded without the tooltip.

Stylistically, two different visualisations were chosen because, as mentioned before, it allowed the user to understand each indicator on its own in the appropriate context in the first visualisation while understanding the indicators as a group in the second visualisation. Initial attempts tried to include both views in one visualisation, but this created messy, confusing visualisations that were not easy to interpret.

Lastly, D3 and JavaScript struggled with dates in the extreme past. The Atmospheric Carbon Dioxide Concentration indicator had values going back 800,000 years, but when loaded as a date in D3, all years earlier than 1860 went unrecognised and led to the graph displaying odd dates. In order to go back further in the past, it appeared that the years in the x-axis would have to be read in as values and not years and would subsequently display incorrectly as values. Therefore, a decision was made to only go far as back as 1860 as this was more closely aligned to the other dates and allowed the x-axis to display the year value consistently in the correct format.

Results and Importance

Overall, the global trends are an alarming indicator of the danger of unchecked climate change. When the graphs are analysed and compared, it highlights that all indicators are travelling in the wrong direction.

Atmospheric carbon dioxide levels are going up. This increase in carbon dioxide subsequently increases the average global temperature, evidenced by nineteen of the hottest years since 1880 occurring since the year 2000. This increase in temperature then melts glaciers, decreasing their size, evidenced by Antarctica losing 2,500 gigatons of its mass since 2001. Finally, the melted glaciers then raise the sea levels across the globe which can be seen in figure 1 above.

No indicator shows that a decrease in the rate at which it is progressing is likely. However, a decrease in these rates is required for the health of the Earth to improve. Subsequent sections will explore how China and India are influencing climate change and are also being influenced by climate change themselves. Finally, the last section will highlight some potential futures for the planet if things remain unchecked.

Visualisation 2: China

Introduction and Motivation

In this section, we focus on China. As we all know, our climate has been deeply affected by carbon dioxide emissions, especially since the mid-19th century. Carbon dioxide emissions have traditionally been led by countries in North America and across Europe, but more recently, China has become one of the largest carbon dioxide emitters. In 2017, China released 9.8 billion tons of carbon dioxide (Chen et al., 2020). Most of these emissions come from fossil fuel combustion, especially coal, which generates 70% of China's total energy production.

To look deep into the relationships among carbon dioxide emissions, economic structures, geographical elements and population in China, we focus on the current emission pattern at the province and city level and look deep into how this pattern transformed from 2000 to 2016 (Wang et al., 2021). Finally, we use population, GDP, region information and carbon dioxide emission data to visualise how Northern and Southern cities divided as time went by.

Methods and Processes

For the first map, we visualised the carbon dioxide emission patterns across China's provinces and cities. This visualisation also uses a map of China's provinces and cities as a base map. The main packages and code used here are from this website: https://github.com/the-pudding/eu-regions/blob/master/src/js/graphic.js.

The code structure for this project contains three parts:

1. Setting the initial attributes for the SVG, chart area, and other required inputs
2. Drawing the province map, city map, scatter graph and legends
3. Creating the scroll function to link the map with the scatter graph together to make use of the animation feature

All the code is controlled by the async function main() section. The core part of this code is to regulate the path to animate the transformation of each province or city shape into the circle in the scatter graph by using D3 and flubber (flubber.toCircle()). We also use the scrollFunc() function and scrollDirection variable to control the scrolling of the text boxes on the right and the changes of the map on the left and the transition from the province map to city map and finally to the scatter graph. Using .on("mouseover", this.tool_tip.show) for the province and city path shows the relevant information when the mouse moves over.

For the second map, we visualised the annual volume of carbon dioxide emissions for 50 cities. The emission information is shown by using the flourish platform. The base map is a raster layer and is from the National Geophysical Data Center. The size of the white circle represents the annual volume. The timeline shown below controls the changing of circles' radius.

For the third and last graphs, we use charts to visualise the structure and distribution of cities in the context of carbon dioxide emission. Both of them were finished on the flourish platform.

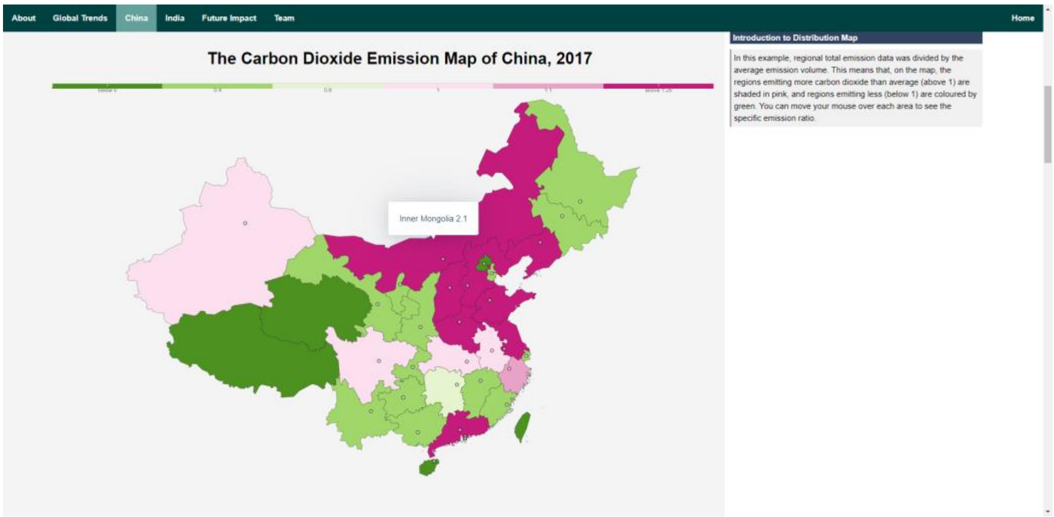

Fig.3. First Visualisation: Carbon dioxide Emission Pattern of China, 2017

Fig.4. Second Visualisation: Carbon dioxide Emission Volume of 50 Cities, from 2000 to 2016

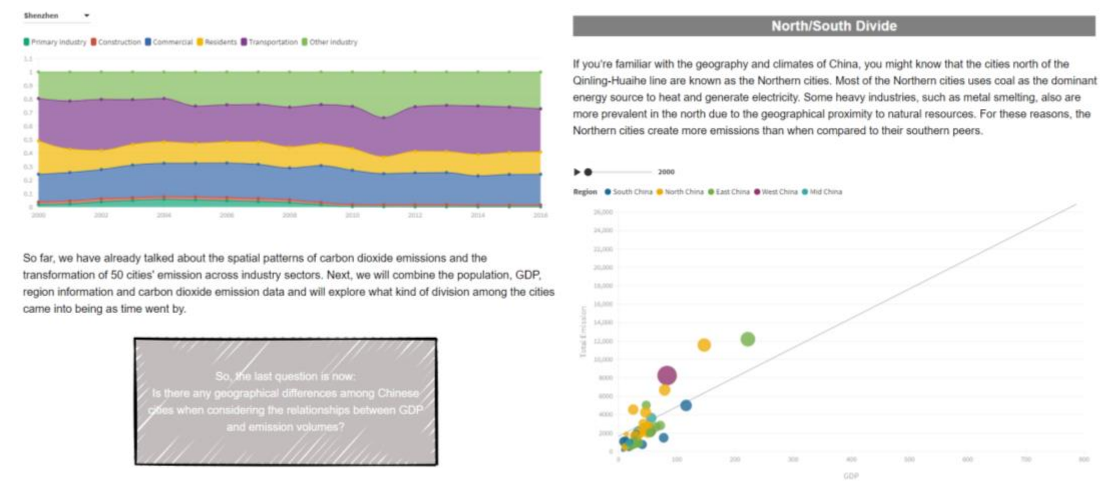

Fig.5&6. Third and Forth Visualisation: Chart Graphs to Reveal the Structure of City Emission and Evolution of Northern and Southern Cities

Challenges

The most challenging part of this section is the first visualisation. It is not easy to think about how to organise the whole structure of code, control the core animation from geographical item shapes to circles, and use scroll event to control the transforming of the province, city map, and scatter graph. Also, because JavaScript is an asynchronous language (which is more efficient), it is crucial to organise the logic and sequence of animation in mind, such as using main() to organise the whole visualisation process.

Telling the story of China’s carbon dioxide emissions is also a challenge. China is a big country, the difference among regions is vast, and their unique transformations are also highly varied. For readers, it might be appropriate to show them the current pattern first to gain an initial feeling. And then, the visualisation could add more elements, such as timeline and relevant data, which could help them get more information about the truth of China's carbon dioxide emission in a more logical and orderly manner

Last but not least, organising the individual works, such as the China section with other team members, is vital for the success of this project in order to tell a reasoned narrative with a logical story. Climate change is relevant to all of us, and China and India are two countries, which will have a significant impact on this issue in the 21st century and beyond. It is vital to show and make some comparisons between these two countries and tell the truth to the audience.

Results and Importance

For the province and city map, the most developed provinces, like Guangdong and Shanghai, produce relatively more carbon dioxide annually, as seen in this province boundary map. However, some provinces like Inner Mongolia, Shanxi, and Heibei, located in the North of China, still contain much higher emission levels than the average. At the city level, the cities that emit more carbon dioxide than average are clustered in China's North and Eastern coastal regions. Some core cities, which contain the circles on the map, usually have higher access to natural resources in their provinces.

For the scatter graph, most of the core cities are distributed to the right side of the graph, meaning that these cities have emitted more carbon dioxide. Nine provinces, the bigger circles, are above the average level. The Northern provinces, Shandong, Hebei, Inner Mongolia, Henan, Liaoning and Shanxi, cover 66.7% of the total emissions.

The second visualisation shows that as time passed, the most noticeable regions of China became the Eastern portion, around the Yangtze Delta, the Southern part, around the Pearl River Delta, and the Northern part, centred around Beijing-Tianjin-Hebei.

The third graph shows us the structure of emissions in each city. Changes to the ratio of the emission volumes in the different sectors in each city are relatively small; most cities followed their distinctive paths to development. However, we still can find some differences if we make comparisons between the cities. Taking Shenzhen and Guangzhou as an example, they are two of the largest cities in China, but their emission structures are very different. The commercial sector in Guangzhou covered a large percentage of emission annually, whereas Shenzhen is relatively balanced across all sectors.

Furthermore, the last graph shows that division between the cities begins to appear as time goes by; in 2016, there were 10 Northern cities above the trend line, covering more than 70% of entire cities above this line. All Southern Chinese cities were below the trend line, while most cities from East and West were below the trend line. This distribution means that Southern cities could maintain a higher economic output than Northern cities but produce less or similar carbon dioxide emission levels. This graph clearly shows where and when this division between South and North begins to happen and how a pattern emerges.

This section focuses on China's carbon dioxide emissions and where the emissions have already become most significant. Carbon dioxide emissions have affected almost all aspects of our life and environment, like increasing temperatures, sea levels, and an increase in the number of endangered species. We must continue to analyse the current emissions spatial pattern, future trends and how they may impact our lives and the environment.

Visualisation 3: India

Introduction and Motivation

India is the second most populated country globally and is characterised by high poverty levels across its population. For this reason, it is also one of the most affected countries by Climate Change.

Even though India's CO2 emissions per capita are low compared to other countries, exposure to climate change is very high that it is manifested in different ways. This can be seen in the natural disasters which have killed thousands of people over the last twenty years. However, the Indian government is making many efforts to mitigate the adverse effects of this global issue. One of these is to put India on track to meet its targets for the Paris Agreement in Climate Change.

According to the 2019 Intergovernmental Panel on Climate Change (IPCC) report, an increase of 1.5ºC in the following years could have even more hazardous consequences (‘Global Warming of 1.5 ºC —’, no date). This is especially true in the most vulnerable areas of India. For this reason, it is expected that India could make an investment of USD 1,558.8 billion for clean energy by 2030, which is more complicated due to the limited resources (Opportunity 2030 - SDG investment map | Standard Chartered, no date).

The set of visualisations presented in this section will further explore the contribution of India to global electricity consumption, how India has been affected by climate change to date and will consider some of the major natural disasters that hit the country every year. Moreover, it will look at the variation of the temperatures in the country's main cities over the last ten years and what it could mean for the country in the future.

Methods and Processes

The methods and datasets for each section and vary and are referenced accordingly. Once all the information was prepared, it was subsequently stored in GitHub.

In the case of the top ten countries that contribute the most to electricity consumption, the dataset used was from Enerdata Research Consulting (World Energy Statistics | Enerdata, no date). The data used contains the absolute values per year. When analysing this data just the top ten countries in 2019 were used so that the graph was not overloaded; moreover, it was necessary to reshape the data by obtaining one column per country. Once the data was prepared, it was displayed in a line chart with a filter to select the countries and a range time slider to select a specific period of time.

The second visualisation looks at natural disasters in India from 2000 to 2020. The data sources used come from EM-DATA public and the Census 2011 (Census of India Website : Office of the Registrar General & Census Commissioner, India, no date; EM-DAT | The international disasters database, no date). The first contains most of the natural disasters registered since 1900 in the different locations of all Asian countries, where India and the same range time were then selected to be displayed in the chart. In order to show the most common natural disasters, it excluded those with fewer than five records. Once the data was filtered, it was aggregated to get one value for each year and natural disaster, showing it through a bubble chart using a filter per natural disaster.

The last two visualisations used information from Berkeley Earth (Regional Climate Change: India, no date). The data available contains the monthly estimated variations per city since 1796 and the average monthly temperatures per city. For this reason, it was necessary to create a new variable adding the average temperature plus the variations, using the same period and just the month of May across the years so that the differences between years was shown and not simply seasonality. The data was then merged with the population information to display in the map plot. A button was then added to evaluate the variation in the temperatures in order to animate the graph. This visualisation and its animation was inspired by Github user akanksha0514's *chanellingHansRosling* work (akanksha0514, 2019).

The fourth bar chart used the same data, but this time it was aggregated, obtaining one value per year. After that, a new variable was then created b calculating the variation for each year, using 2000 as a baseline.

Challenges

Some of the challenges presented in general were to understand the structure of the data used for each chart and how to read the variables using the different libraries.

Even though the two first figures have almost the same structure, both were built in different ways. In the line chart, every category was considered an independent variable, while in the second one, all the categories were part of one variable.

Concerning the map chart, it was not easy to connect the CSV file with the JSON file and then include both files using the D3 library to show the data across the years.

Results and Importance

As it was mentioned before, the figures considered in this section will help us to have a clear view of the current situation that India is facing.

The figure below shows the top 10 countries which consumed the most electricity domestically between 1990 and 2019. As we can see, India was the third country on the list, just below China and United States in 2019. Concerning China, it shows a significant increase in the last 20 years while the United States remains almost the same in the same period. On the other side, India has shown a steady rise in the previous ten years, becoming one of the highest contributors but not when it is compared with the two first countries.

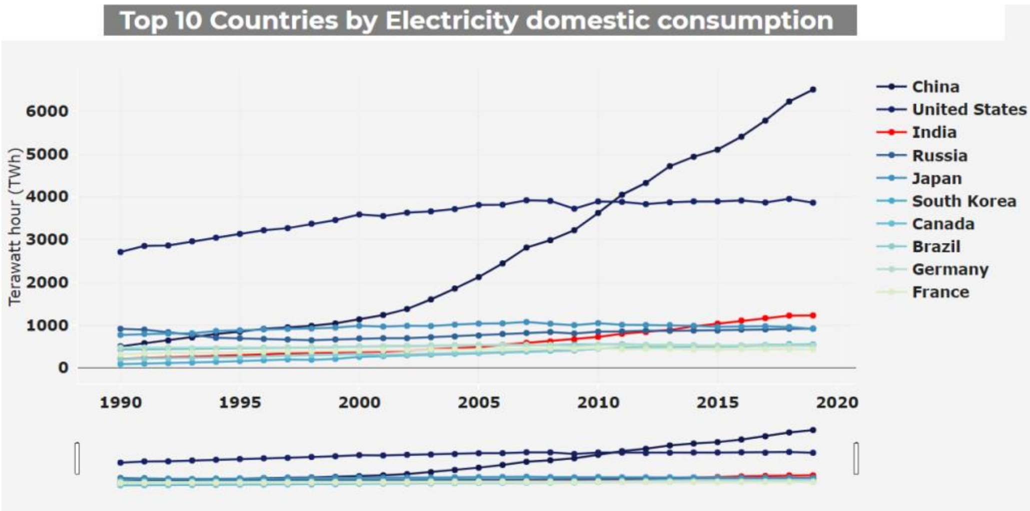

Fig.7. Top 10 Countries by Electricity Domestic Consumption

As India's geography is extensively diverse, it is also affected by many different types of natural disasters. Some of those related to climate change are displayed in the following figure. Earthquakes registered in 2001 and 2004 killed more than 16,000 people. Another natural disaster that has been even more affected by climate change is floods.

Floods have consistently killed thousands of people every year, being the most fatal in 2013 when more than 6,000 people died. Moreover, India is acutely affected by deadly heatwaves where thousands of people have died. The city most affected by these heatwaves is Kolkata.

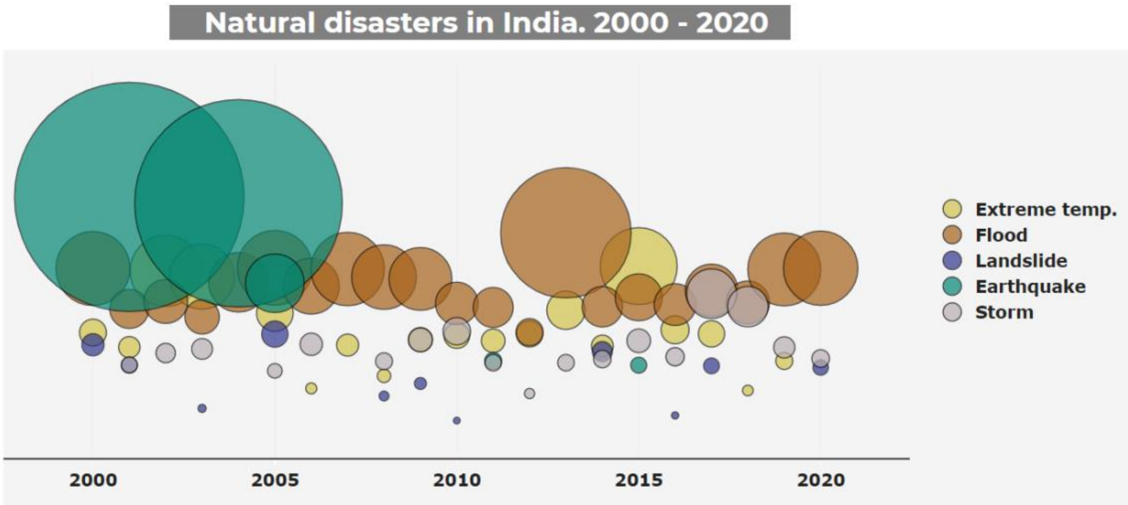

Fig.8. Natural disasters in India. 2000 - 2020

Regarding India's temperatures, it becomes evident that India has a wide range of climates. It becomes apparent that the hottest weather occurs in May, where tropical monsoons characterise the south of the country whereas the north has comparably temperate weather. The northwest part of the country is mainly composed of deserts, and it is also the most affected region by climate change. Analysing the average temperatures in the main cities of India, we can visualise that these temperatures have increased through the years, especially in central India.

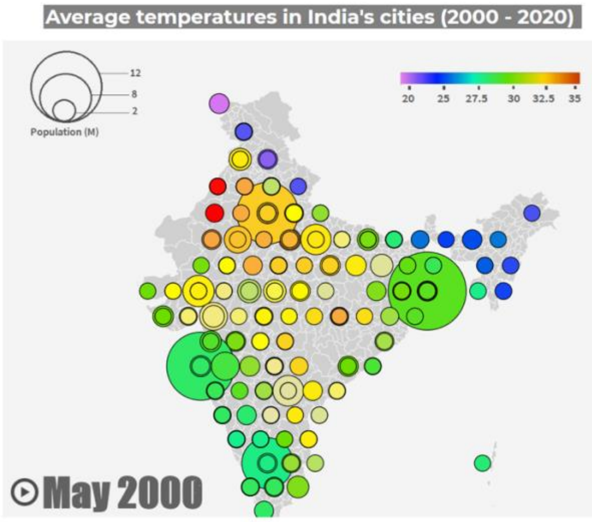

Fig.9. Average temperatures in India's cities (2000-2020)

When looking at the average temperature in the whole country, the following figure shows the annual temperature variations compared to the year 2000, where most of the years, the country has experienced high temperatures. However, in 2020, the increase was not significant if it is compared to the other years.

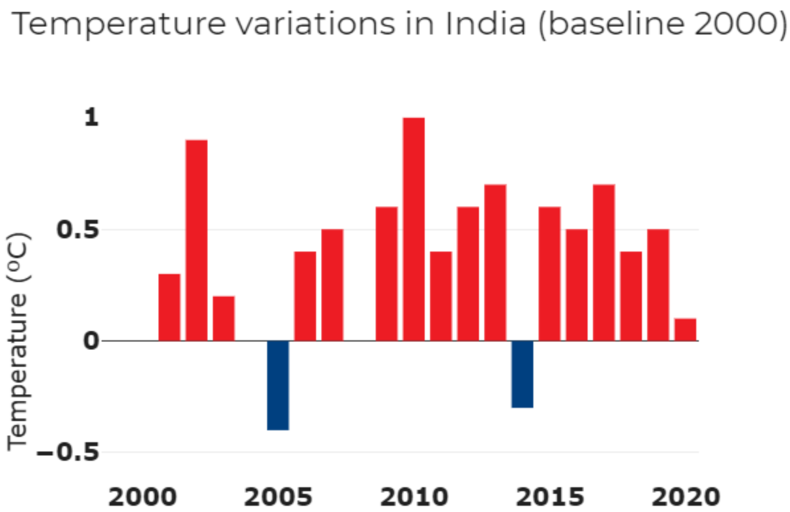

Fig.10. Temperature variations in India (baseline 2000)

Visualisation 4: Future Impacts

Introduction and Motivation

The previous sections showed the carbon emissions and climate change of China and India. However, what specific impact will the climate change caused by carbon emissions have on the global environment? In this part, we will make assumptions about the future situation.

One of the most famous risk factors of climate change is sea-level rise. When humans pollute the atmosphere with greenhouse gases, the Earth heats up. As a result, ice sheets and glaciers melt, and seawater warms, which expands the area of the world's oceans. Consequences include the recent increase in coastal flooding (which can damage infrastructure and crops), resulting in the permanent displacement of coastal communities. In the 21st century, global sea levels are expected to rise by 2 to 7 feet, possibly even higher (New elevation data triple estimates of global vulnerability to sea-level rise and coastal flooding | Nature Communications, no date). The key variables will be the number of pollutants that are heating the environment, the number of pollutants released into the atmosphere by humans, and the rate at which the Greenland ice sheet, especially Antarctica, has destabilised.

So, in this section, we will show a hypothesis. We will use a map to show how coastal cities will be affected if the temperature rises using the slider to change the temperature. As the temperature rises and the sea level changes, the submerged area will be marked in blue. This map centres on China's Jiangsu Province, one of the regions significantly affected by sea-level rise. However, by clicking the buttons of different countries or by dragging and zooming freely the user can see the conditions in different parts of the world. Furthermore, we also simulate some reference periods from the global level.

Methods and Processes

The first step is to obtain the data of sea level rising with the temperature. According to the past temperature change trend shown in the Global Trends section, we used the regression method to simulate the subsequent temperature change. It is estimated that the temperature will rise by half-degree centigrade in 2050 and 1-degree centigrade in 2080. Then we get the change of sea level when the global temperature rises to 4℃ from central climate website https://www.climatecentral.org/ (Climate Central: A Science & News Organization, no date). Based on this data, we simulate the sea level after the temperature rises to 4℃. At the same time, three cases with reference value are simulated. The three timeframes are shown below:

1. The first is the last interglacial period when the highest temperature period of the Earth in 150 thousand years occurred.
2. The second is the last glacial minimum period which is the initial stage of the last glacial period meaning that more parts of the Earth were covered by ice than they are now.
3. The final simulation shows the Earth if all the ice caps melt, meaning that the sea level will rise by 70 meters.

The terrain data is from https://registry.opendata.aws/terrain-tiles/, and the map uses the tilemap of Google maps.

The core idea of sea level simulation is that when the slider slides to a certain height, the part below the height is covered with blue (otherwise, it is filled with green). The web page's design is divided into three parts: slider drawing, slider event drawing, and map visualisation. In the drawing of the slider, firstly determine the drawing area of the slider, then draw the coordinate axis and slider, and add text and marks.

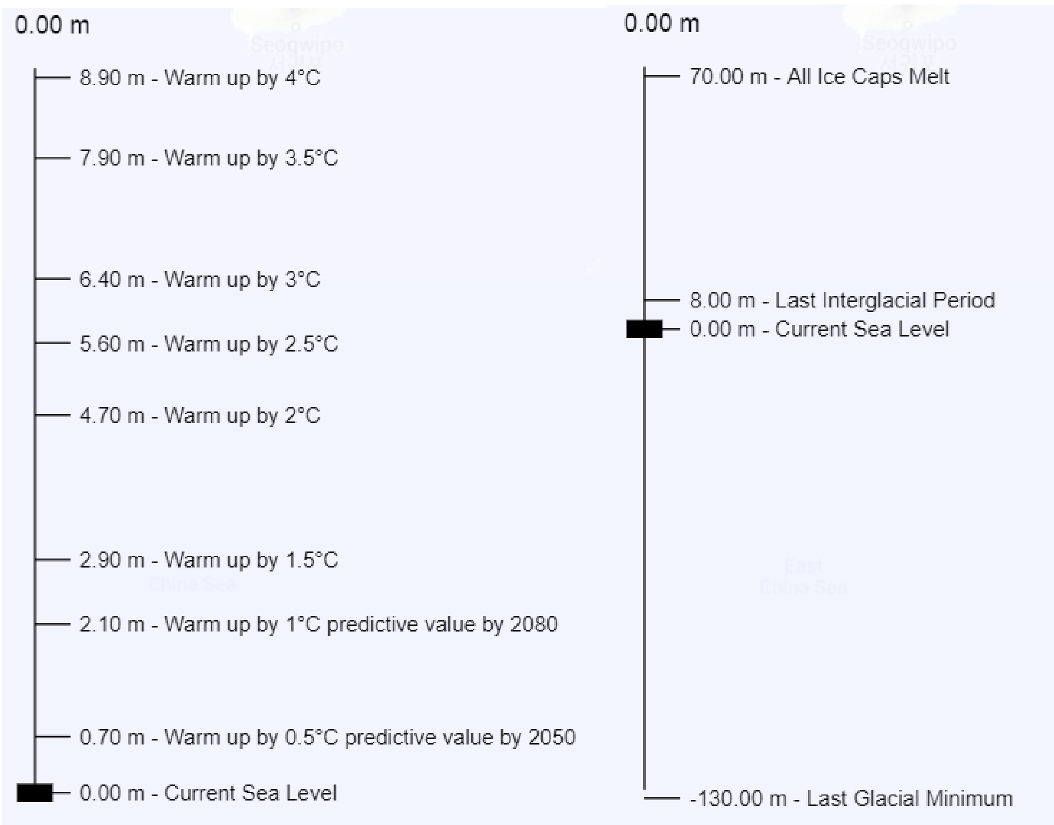

Fig.11. Screenshot of Future Impact Sliders

You then add events for the slider, including mouse press and move, get the height value of the slider, and pass the value to the map to update the map. After introducing terrain data and

Google tilemap in the visualisation, the function is used to judge. If the sea level is higher than the terrain level, it is covered with blue. If the sea level is lower than the terrain level or the terrain level is less than zero, it is green.

Fig.12. Screenshot of Change in Sliders in the Future Impact Section

Finally, you add the button of different regions, and click the button to move the map centre to display the sea level of different regions. The processing method here needs to be improved; just set up web pages, change the map centre and jump to the map.

Fig.13. Screenshot of Drop Box and Fly To Options

Challenges

The elevation of terrain data is represented by pixels, which need to be converted to elevation when they are used. Due to the limitation of the accuracy of terrain data, with the rise of sea level, the blue coverage of the map can only increase by one meter, and unfortunately this cannot be more accurate. At the same time, the problem of map centre transfer mentioned above is how to realise tilemap centre transfer at the same as the web page. This is the next problem that needs to be solved.

Results and Importance

Taking a closer look at the cases of mainland China; when the temperature rises by 4 degrees Celsius, the land now home to 93 million people could be lower than the height of the local average annual coastal flood. Shanghai, the country's most populous city, is projected to be particularly vulnerable to ocean flooding in the absence of coastal defences. Low-lying Jiangsu Province, which abuts Shanghai, is also vulnerable.

Next, we’ll consider India's situation; when the temperature rises by 4 degrees celsius, the projected sea-level rise could push average annual floods above land currently home to some 36 million people. West Bengal and coastal Odishaare are projected to be particularly vulnerable, as is the eastern city of Kolkata. Kolkata itself is home to 15 million people, and that number is growing. The city already faces flooding driven by heavy rain and other events and much of Kolkata lies in the annual coastal flood risk zone.

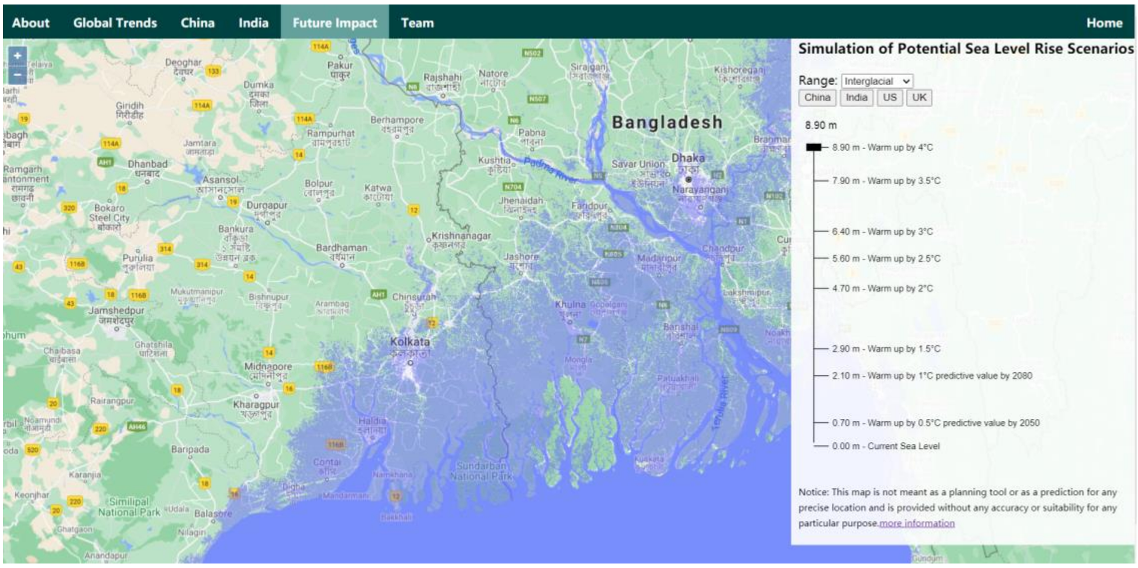

Fig.14. Screenshot of Indian Subcontinent impacted by Rising Sea Levels

As sea levels continue to rise throughout the century, chronic flooding will spread, and more land will be permanently lost to the ocean. The bad news is concentrated in Asia. China, Bangladesh, India, Vietnam, Indonesia, and Thailand are home to the most significant number of people who today live on land that could be threatened by permanent inundation by 2100. 151 million people in total and 43 million in China alone. However, the danger of permanent inundation is by no means be limited to Asia. In 19 countries, from Nigeria and Brazil to Egypt and the United Kingdom, the land now home to at least one million people could fall permanently below the high tide line at the end of the century and become permanently inundated in the absence of coastal defences.

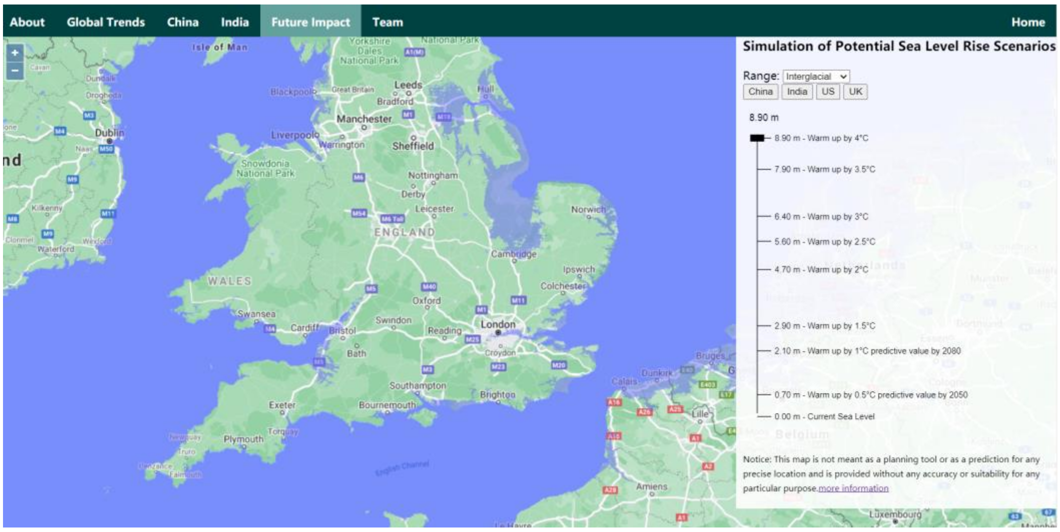

Fig.15. Impact of the United Kingdom and France Impacted by Rising Sea Levels

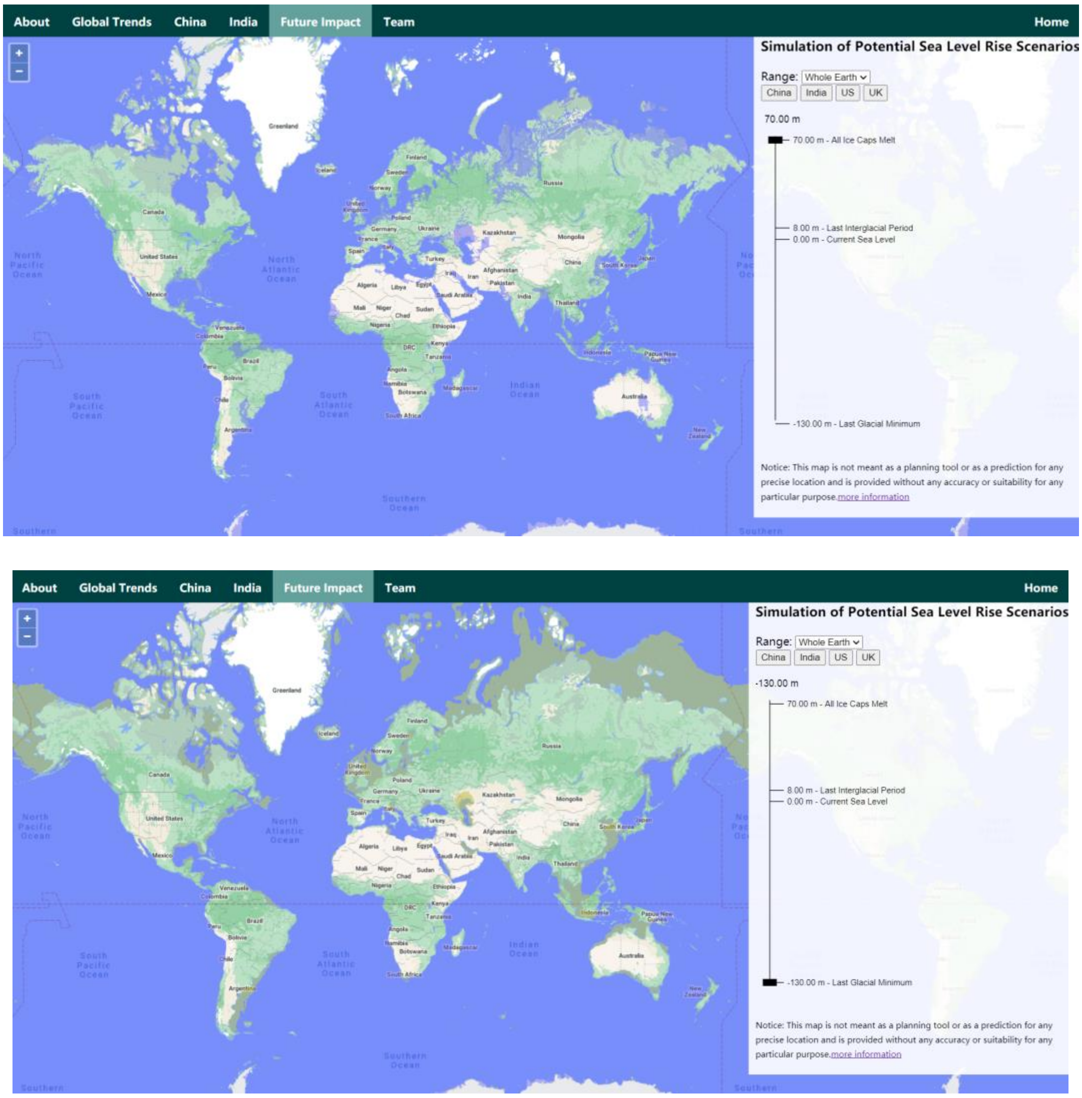

Fig.16&17. Global Screenshots of the Two Whole Earth Extremes from the Future Impact Page

Website Development

The website was built by following these principles: efficiency, conciseness, ease to control, ease to modify by group developers, and ability to deliver a strong narrative.

Narrative: Our Main Focus

We wanted to build a storytelling system to express our points to the audience in a quick and efficient manner. This storytelling system is expressed in a kind of website style, which centres our works and makes sure that our maps, graphs, and images have the appropriate amount of space to be explained by our developers when considering people's reading habits. This system helps us free from the "one-page" form. Moreover, group members could focus more on the story they wanted to tell.

Efficiency: Easy for Audience to Interact with our Website

In this principle, we aimed to show the maps and graphs with comments directly beside them to drive home the message and points of the visualisation to the audience and to limit their chance for confusion. Also, the navigation bars, set at the top or bottom in each part of our story, aim to be convenient for the user to choose what and where they want to go and learn more about.

Conciseness: Less is More

The website follows the structure of our story. We want to give the user a good experience by reducing irrelevant elements on the website. The contents in this website were kept based on the following rules:

1. Do the contents genuinely add value to user?
2. Does it contain valuable information that is relevant to our climate change and city transformation theme?
3. If we delete something, will adverse effects emerge in our storytelling?

These questions help us to focus on what we want to convey to the users.

Easy to Maintain

The biggest challenge for us as group developers was how to combine our individual pieces of work into one site as quickly and coherently as possible. When thinking about previous individual coursework, both in this course and others, it became apparent that it would be easiest for us to first focus on our own pages once we agreed on the structure and narrative of our storytelling system. Once this was decided we then chose Github pages as the platform for our website as it was easy for us to upload and share the latest versions of our sections and then see them reflected quickly in the live website.

Conclusion

As mentioned throughout this paper, global warming is a threat to every single person on this planet. Left unchecked, millions of people could lose their homes to rising sea levels within the next thirty years. This paper only lightly touches on the effect that climate change will have on topics like global crop levels, desertification of land and the subsequent political effect of mass migration due to climate change. If immediate action is not taken around the globe, by China, by India, by the United States, by the United Kingdom, by everyone, then the next century and beyond could prove disastrous and fatal to the entire globe. Unfortunately, those most vulnerable will feel the effects most sharply in the shortest amount of time.

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