CS171 Design Sprint Process Book

OTC

Outdoor Thermal Comfort in a Changing Climate

Basic Info

Group Leader: Sarah Mokhtar (51481216, smokhtar@fas.harvard.edu)
Group Member 1: Caroline Effinger (81426317, cstedman@g.harvard.edu)
Group Member 2: Steven Walz (91245833, stevenwalz@college.harvard.edu)

TIMELINE - OVERVIEW

Week	**Main Tasks**	**Submissions (Sundays)**
Week 8 (Oct 19 - Oct 25)	Find a team and a topic	Process Book & Project Proposal
Week 9 (Oct 26 - Nov 1)	Team Agreement and Map	Team Agreement & Detailed Project Plan
Week 10 (Nov 2 - Nov 8)	Data, Sketch, Storyboard, Decide	Data, Sketches & Storyboard
Week 11 (Nov 9 - Nov 15)	Prototype	Prototype V1
Week 12 (Nov 16 – Nov 22)	Prototype	Prototype V2
Week 13 (Nov 23 – Nov 29)	Prototype and Test	Think Aloud Study Results
Week 14 (Nov 30 – Dec 6)	Prototype & Wrap Up	Final Submission
Week 15 (Dec 7 – Dec 13)	Project Video Watch Party & Best Project Awards!	Self and Group Peer Assessment

Week 8: Project Proposal

Project Title

Outdoor Thermal Comfort in a Changing Climate

Project Abstract

We propose using climate/weather data and spatial mapping to outline the variations in thermal comfort across the globe and the implications of climate change upon them, as well as analyzing the role human design can have in addressing the issue.

Project Proposal

The global trend towards urbanization, with an expectation of 70% of the world's population living in cities by 2050, places increased strain on cities which face densification and higher vulnerability to climate change and extreme weather conditions. Urban public spaces form an increasingly significant contributor to the quality of life of people living within cities. These in turn are largely affected by the outdoor thermal comfort environment which, with a warming climate, have the potential to deteriorate. Global mean air temperatures are projected to increase by 0.3 to 4.8oC according to the Intergovernmental Panel on Climate Change (IPCC) by the end of the 21st century, coupled with variations in solar radiation and wind speeds. This places uncertainties on the usability and comfort conditions of urban outdoor spaces in the coming decades.

In this context, the proposed project is to investigate through data visualizations and storytelling the impact of climate change scenarios on the outdoor thermal comfort in eight cities representative of different climates. This topic will be primarily investigated through data extracted from weather data files (epw format) which are publicly accessible as well as versions morphed to model climate change scenarios using the free CCWorldWeatherGenerator tool. The meteorological parameters extracted from those sources will be integrated into the outdoor thermal comfort metric Universal Thermal Climate Index (UTCI). The latter is a thermal comfort model which estimates the ‘felt temperature’ based on a human heat balance model combining air temperature, mean radiant temperature, humidity, and wind speed. The goal of this project is to increase awareness of the impacts of climate change on life in cities and highlight the role of the urban design choices on mitigating some of those issues.

Week 9: Team Agreement and Detailed Project Plan

Team Agreement

In order to facilitate the project work, the team has agreed on the following terms:

- Workload on the design and technical aspects of the projects will be shared equally among all team members, and assigned on a weekly basis.
- Design decisions will be based on discussions among all members, and compromises will be made as necessary.
- A fair distribution of work will be assigned and will be based on the time needed to complete the task relative to the individual's experience and ability. This is to ensure equal learning opportunities within the team and hold members accountable for the work.
- The main communication channel will be through a Whatsapp group and response to any messages from another team member is expected to be within the same day.
- A Google Collaboratory Notebook workflow will be used to help keep track of the members' progress and work distribution as needed.
- Work will primarily be done remotely as long as collaboration and communication is effective between team members.
- We will all meet weekly to review progress and outline and assign next tasks.
- Team members must notify the group, via WhatsApp or during reoccurring team meetings, if they are unable to meet deadlines or perform their assigned tasks. Persistent failure to communicate issues and complete assignments will result first in mediation with CS 171 Teaching Staff and ultimately in a lack of credit for the team's work.

Signatures: Steven Walz, Caroline Effinger, Sarah Mokhtar
Date: 01 November 2020

Detailed Project Plan

- **Basic Info**

Project Title: Outdoor Thermal Comfort in a Changing Climate
Team Members and Email Addresses: Sarah Mokhtar (smokhtar@fas.harvard.edu), Caroline Effinger (cstedman@g.harvard.edu) and Steven Walz (stevenwalz@college.harvard.edu)
Team Name: OTC

- **Background and Motivation**

The global trend towards urbanization, with an expectation of 70% of the world's population living in cities by 2050, places increased strain on cities which face densification and higher vulnerability to climate change and extreme weather conditions. Urban public spaces form an increasingly significant contributor to the quality of life of people living within cities. These in turn are largely affected by the outdoor thermal comfort environment which, with a warming climate, have the potential to deteriorate. Global mean air temperatures are projected to increase by 0.3 to 4.8oC according to the Intergovernmental Panel on Climate Change (IPCC) by the end of the 21st century, coupled with variations in solar radiation and wind speeds. This places uncertainties on the usability and comfort conditions of urban outdoor spaces in the coming decades.

In this context, the proposed project is to investigate through data visualizations and storytelling the impact of climate change scenarios on the outdoor thermal comfort in eight cities representative of different climates. The main motivation behind the selection of this project is our strong belief in the importance of climate change and the need for increased awareness among the global community on how it will shape cities and our lives if we choose not to take action. It is also our goal to highlight the role of the urban design choices on mitigating some of those issues.

- **Related Work**

There are a number of visualizations that inspired us that relate to this topic. Among them, the NY times article 'How Decades of Racist Housing Policy Left Neighborhoods Sweltering' that was presented in class and which is very powerful in showing the relevance of urban design on outdoor thermal comfort conditions in neighborhoods.
(https://www.nytimes.com/interactive/2020/08/24/climate/racism-redlining-cities-global-warming.html?searchResultPosition=1)
Other visual inspirations include:
- https://coolinfographics.com/blog/2016/3/3/weather-portraits-2014-us-cities.html
- https://www.pinterest.co.uk/pin/316659417536169899/
- https://www.behance.net/gallery/31279439/Carbon-Dioxide-Emissions
- https://crowtherlab.pageflow.io/cities-of-the-future-visualizing-climate-change-to-inspire-action#213121

- **Audience and Questions**:

For this visualization project, we are targeting an international audience of the general public which is a quite large audience across the world given climate change's international reach. More specifically, the audience does not have any expertise in the field of climate change, and comprises a diverse range of awareness about the issue and different levels of data literacy.

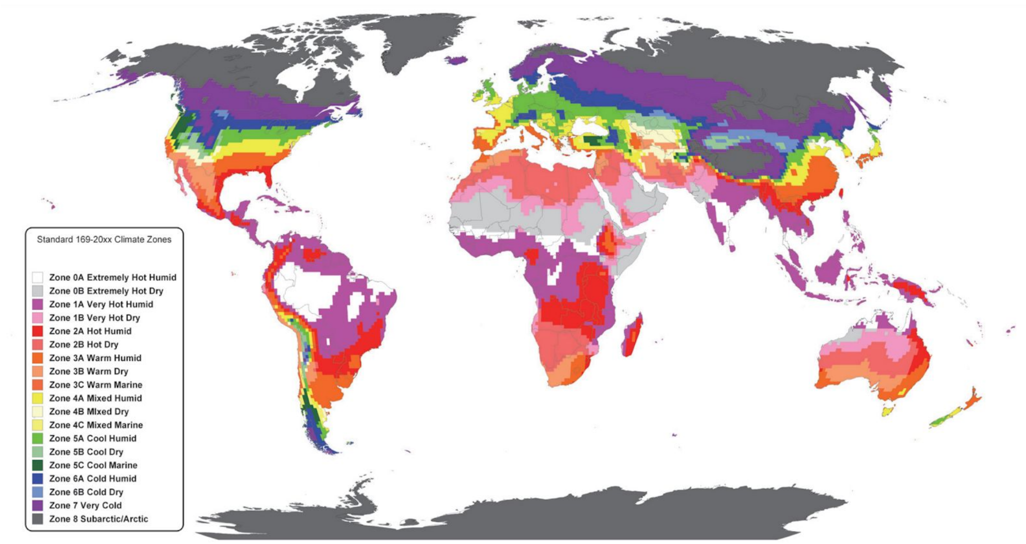
Through this data story, we aim to explore the following questions:

- What is the variation in outdoor thermal comfort across the globe?
- Which cities have the highest potential of adverse impacts on outdoor thermal comfort?
- Which cities will be least impacted from an outdoor thermal comfort perspective by climate change?
- What are the most relevant factors affecting outdoor thermal comfort?
- What design decisions can have the largest impact in mitigating thermal stresses in cities?
- How large are the variations between outdoor thermal comfort today and in 30 and 50 years from now?
- How large are the thermal stresses across climates?
- Are the popular and comfortable public spaces today in key cities going to stay comfortable in the future?
- Are our expectations about the urban microclimate the same as the reality?
- What can each person contribute to improve the outdoor thermal conditions in a city?
- Which actions can we take to make cities "bearable" in the face of increasing climate adversity?

- **Data**

This topic will be primarily investigated through data extracted from weather data files (epw format) which are publicly accessible (http://climate.onebuilding.org/) as well as versions morphed to model climate change scenarios using the free CCWorldWeatherGenerator tool (https://energy.soton.ac.uk/climate-change-world-weather-file-generator-for-world-wide-weather-data-ccworldweathergen/). The data included in those resources include meteorological data such as the air-bulb temperature, relative humidity, wind speeds and directions, horizontal solar radiation values, etc.. The meteorological parameters extracted from those sources will be integrated into the outdoor thermal comfort metric Universal Thermal Climate Index (UTCI). The latter is a thermal comfort model which estimates the 'felt temperature' based on a human heat balance model combining air temperature, mean radiant temperature, humidity, and wind speed.

In order to capture the global diversity of climates, we will use eight cities representative of eight of the climate zones as classified by the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) in the map below.



ASHRAE 90.1 Climate Classification

The selected cities and their respective climates for the data story are:
- Dubai, United Arab Emirates - 0B - Extremely Hot Dry
- Singapore, Singapore - 1A - Very Hot Humid
- Cairo, Egypt - 2B - Hot Dry
- San Diego, USA - 3C - Warm Marine
- New York, USA - 4A - Mixed Humid
- Berlin, Germany - 5A - Cool Humid
- Oslo, Norway - 6A - Cold Humid
- Reykjavik, Iceland - 7 - Very Cool

For each city, three climate data files will be used: the most recent epw file representative of current conditions, as well as the morph files with projections for 2050 and 2080.

- **Data Cleanup**

Minor data preparation will be required for the main dataset to be ready for visualization. While all weather data files are structured in an efficient manner, three main components will need preparation:
- Morph the selected weather file for the 2050 and 2080 projections using the CCWorldWeatherGenerator tool
- Convert the .epw files to a .csv equivalent consisting only of meteorological parameters explored.
- Calculate the UTCI equivalent for each climate based on the files for the following conditions: sun-exposed wind-exposed, sun-shaded and wind-exposed, sun-exposed and wind-shielded and sun-shaded and wind-shielded. This will be done using the Climate Studio plugin to Rhino3D.

The three steps outlined here should not require a substantial amount of time, and are expected to be prepared and ready for use by all team members within a couple days.

Week 10: Data, Sketch, Decide and Storyboard

Data

The dataset was prepared for the project and includes weather data for the eight cities selected as well as short-term, medium-term and long-term projections. The data fields included in the dataset are listed in the following table, along with a description and the data type categorized as: categorical (C), ordinal (O), or quantitative (Q).

	Data Variable	**Type**	**Description**
1	City	C	City name from the following eight cities: Dubai, Singapore, Cairo, San Diego, New York, Berlin, Oslo, Reykjavik
2	Type	C	A category identifying whether the data is for the 'Current' condition, or a projection: 'Short-Term Projection', 'Medium-Term Projection', or 'Long-Term Projection'
3	Month	Q	Month as a number (1 - January, 12 - December)
4	Day	Q	Day (ranging from 1 to 31)
5	Hour	Q	Hour of the day (ranging from 1 to 24)
6	Annual Hour	Q	Hour of the year (ranging from 1 to 8760)
7	Dry-bulb Temperature	Q	Dry-bulb temperature (air temperature) in Celsius
8	Relative Humidity	Q	Relative humidity (%)
9	Wind Speed	Q	Wind speed at a reference height of 10m from the ground in m/s
10	Direct Radiation	Q	Direct radiation in Wh/m2
11	Diffuse Radiation	Q	Diffuse radiation in Wh/m2
12	Sun Elevation	Q	Sun altitude as an angle (in degrees)
13	UTCI - Sun Exposed, Wind Exposed	Q	'Felt temperature' in Celsius in a condition with exposure to sun and wind
14	UTCI - Sun Exposed, Wind Protected	Q	'Felt temperature' in Celsius in a condition with exposure to sun but shielded from wind

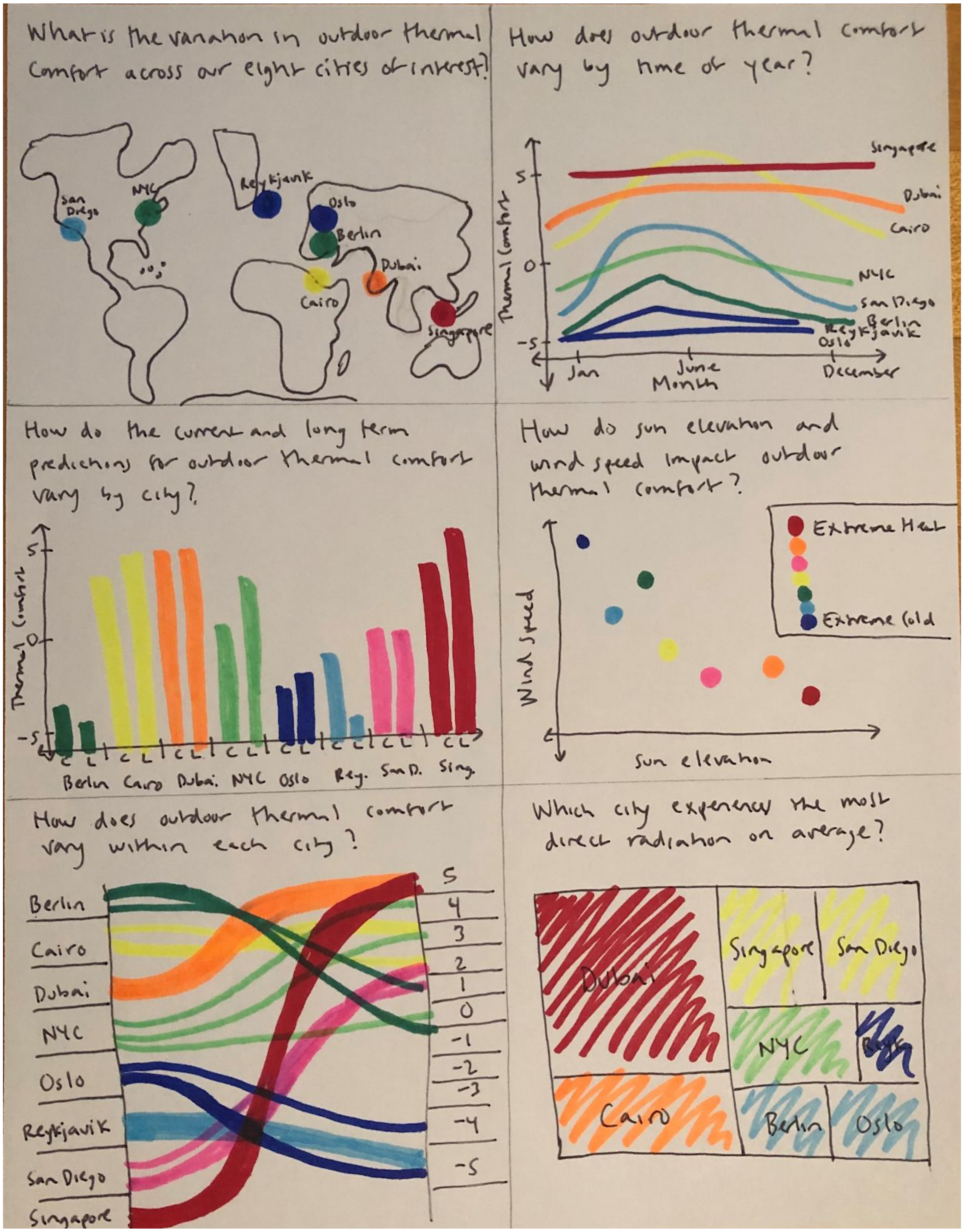
15	UTCI - Sun Shaded, Wind Exposed	Q	‘Felt temperature’ in Celsius in a condition with sun shading but with wind exposure
16	UTCI - Sun Shaded, Wind Protected	Q	‘Felt temperature’ in Celsius in a condition with sun shading and protected from wind
17	Comfort Conditions - Sun Exposed, Wind Exposed	O	Comfort condition* at exposure to sun and wind, ranging from -5 to 5.
18	Comfort Conditions - Sun Exposed, Wind Protected	O	Comfort condition* at exposure to sun but shielded from wind, ranging from -5 to 5
19	Comfort Conditions - Sun Shaded, Wind Exposed	O	Comfort condition* at sun shading but with wind exposure, ranging from -5 to 5
20	Comfort Conditions - Sun Shaded, Wind Protected	O	Comfort condition* at sun shading and protected from wind, ranging from -5 to 5

*Comfort conditions are defined as (-5) Extreme Cold Stress – *UTCI < -40,* (-4) Very Strong Cold Stress - -40 < *UTCI < -27,* (-3) Strong Cold Stress - -27 < *UTCI < -13,* (-2) Moderate Cold Stress - -13 < *UTCI < 0,* (-1) Slight Cold Stress - 0 < *UTCI < 9,* (0) Comfort - 9 < *UTCI < 26,* (1) Slight Heat Stress - 26 < *UTCI < 28,* (2) Moderate Heat Stress - 28 < *UTCI < 32,* (3) Strong Heat Stress - 32 < *UTCI < 38,* (4) Very Strong Heat Stress - 38 < *UTCI < 46,* (5) Extreme Heat Stress - *UTCI > 46.*

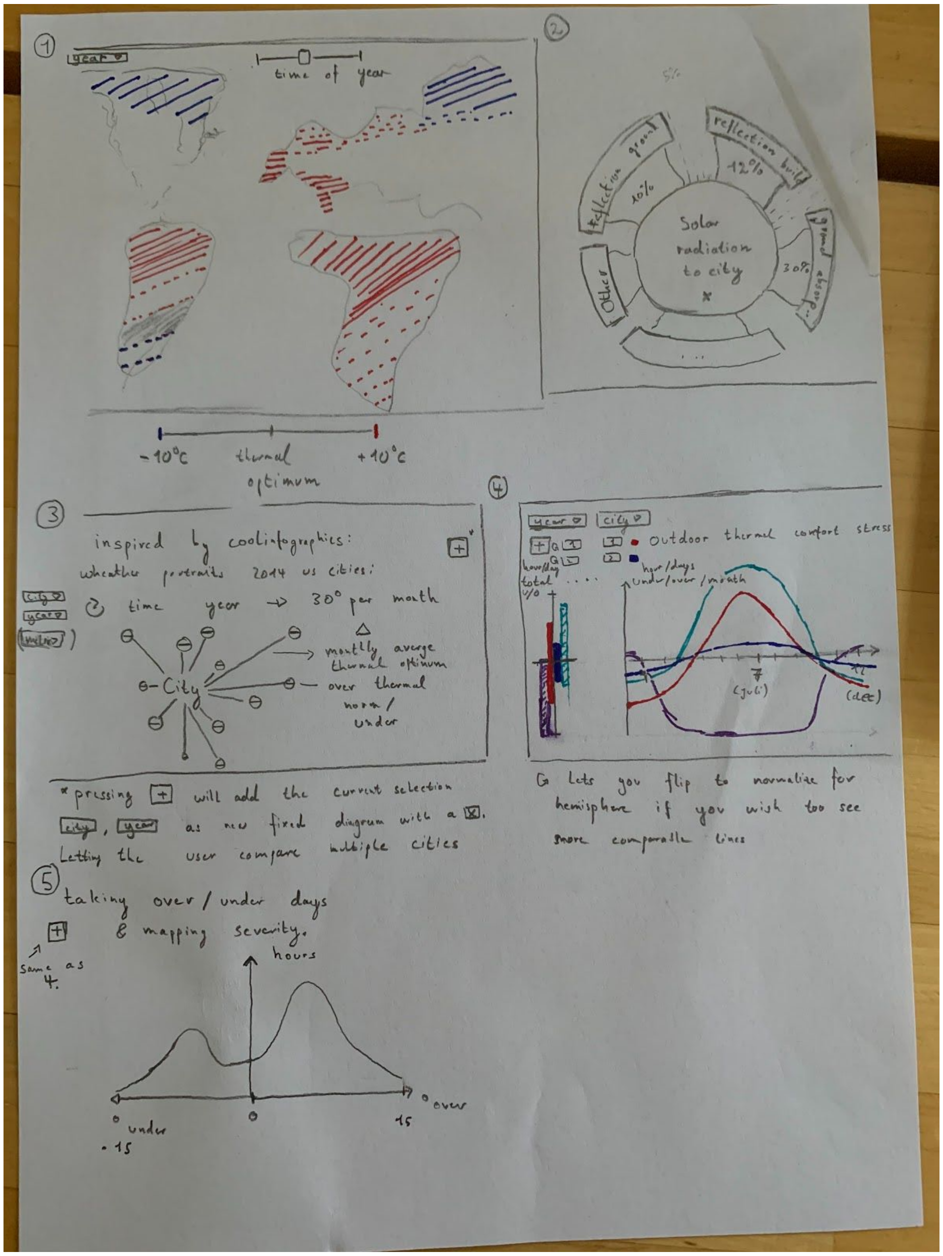
Sketch

Through sketching, we started to explore different design approaches to answer some of our questions through visualizations.

Sketches - Caroline Effinger



Sketches - Steven Walz



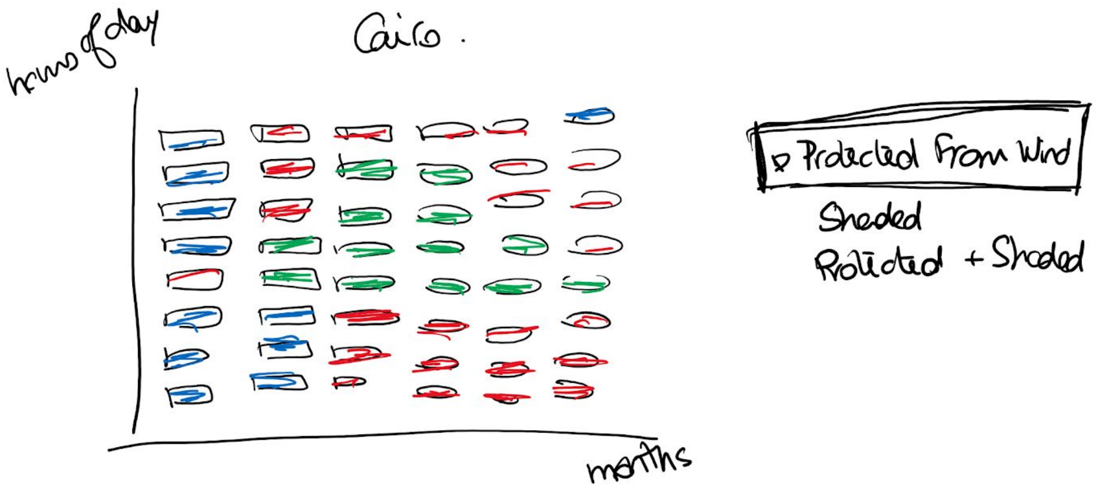
The questions explored through those sketches are:

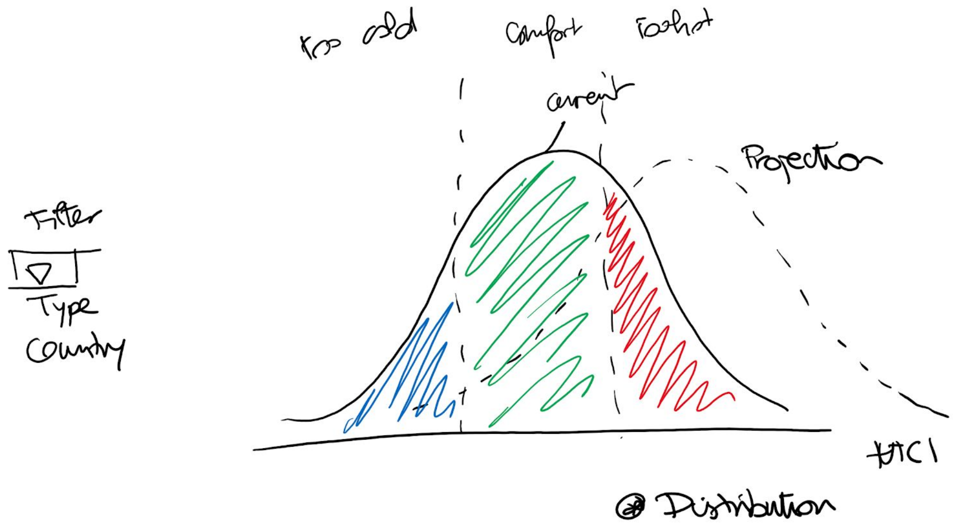
1. What is the global effect and change in thermal comfort? And how will this develop in the next half-century?
2. How is solar radiation received in city x. What variables lead to more reflection / absorption and how are they associated with heat (could add one more layer of connection)?
3. Thermal comfort analysis by city: How does the thermal comfort through the year look like in city x for year x? Seasonal trends?
4. How do normalized thermal comforts compare with other cities? Can we see at which point human action seems ineffective based on a per country case basis? What is the duration of deviation from thermal comfort optimum?
5. What is the severity of deviation from the thermal comfort level?

Sketches - Sarah Mokhtar

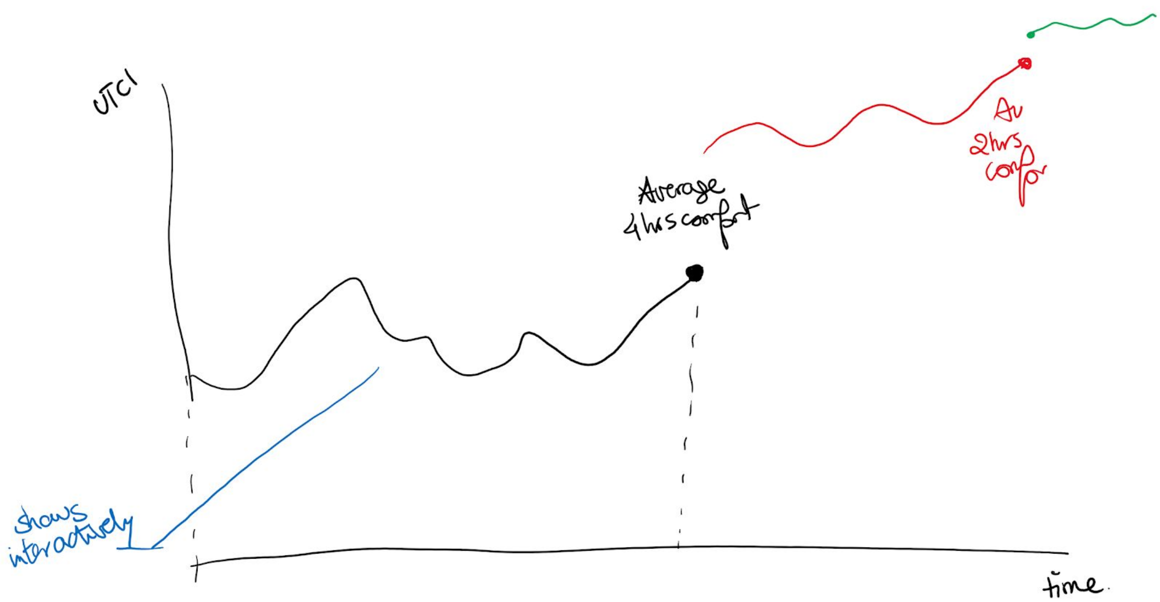
- Which actions can we take to make cities “bearable” in the face of increasing climate adversity?

- How large are the variations between outdoor thermal comfort today and in 30 and 50 years from now?

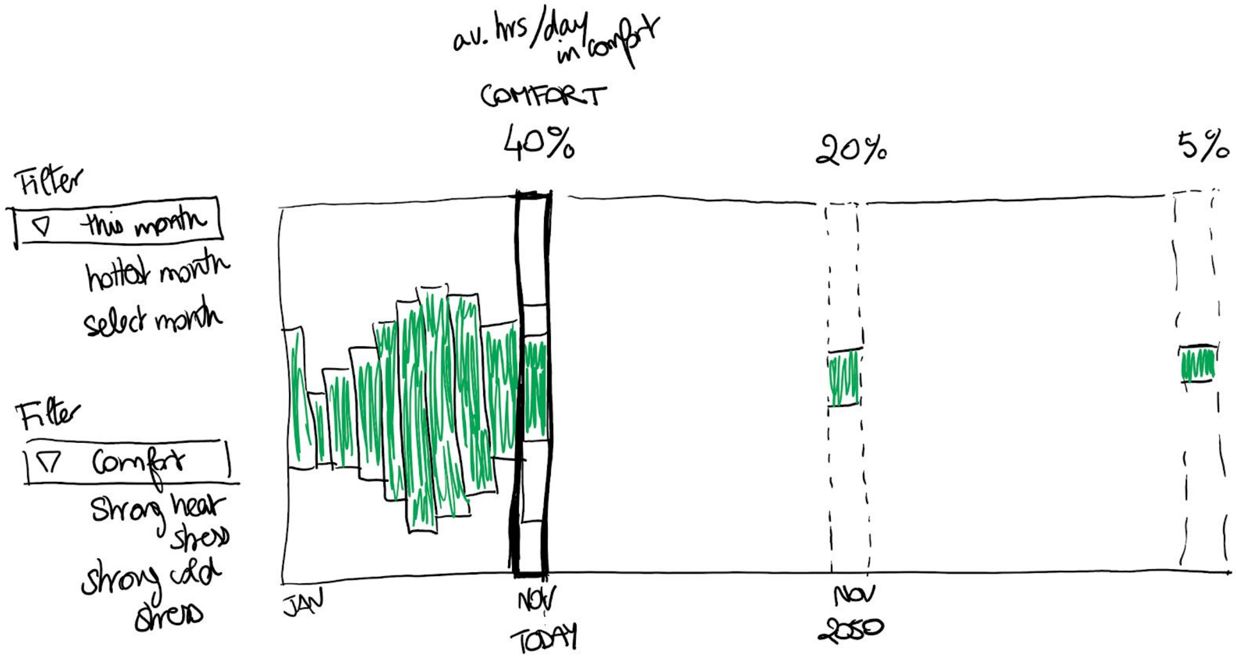




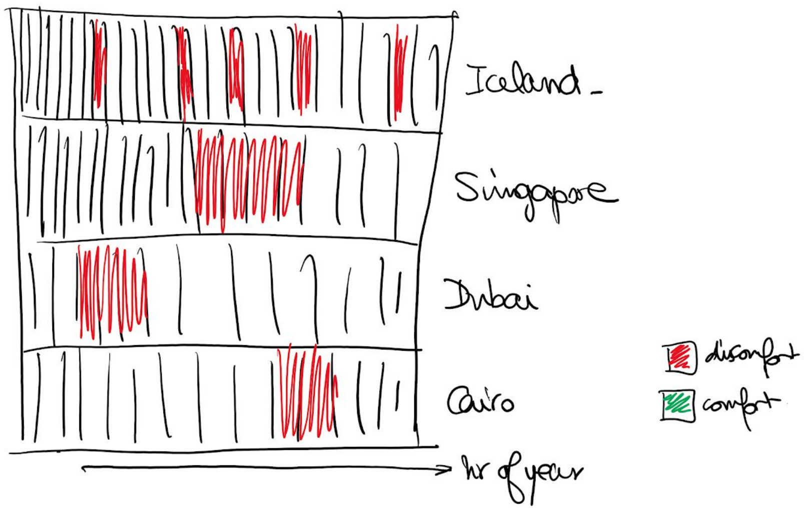
- How large are the variations between outdoor thermal comfort today and in 30 and 50 years from now?



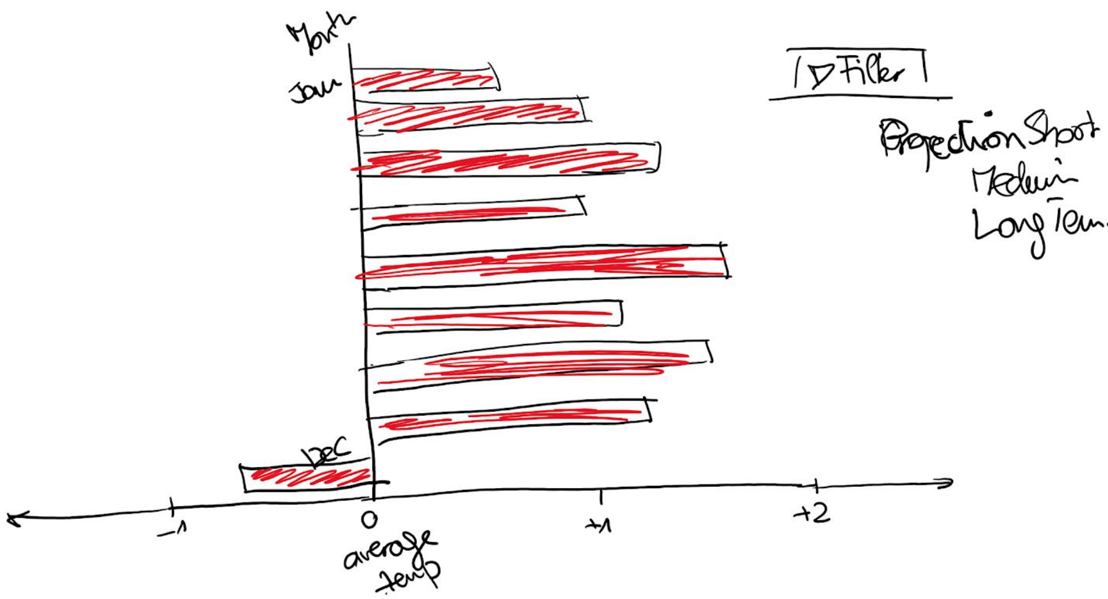
- What design decisions can have the largest impact in mitigating thermal stresses in cities?



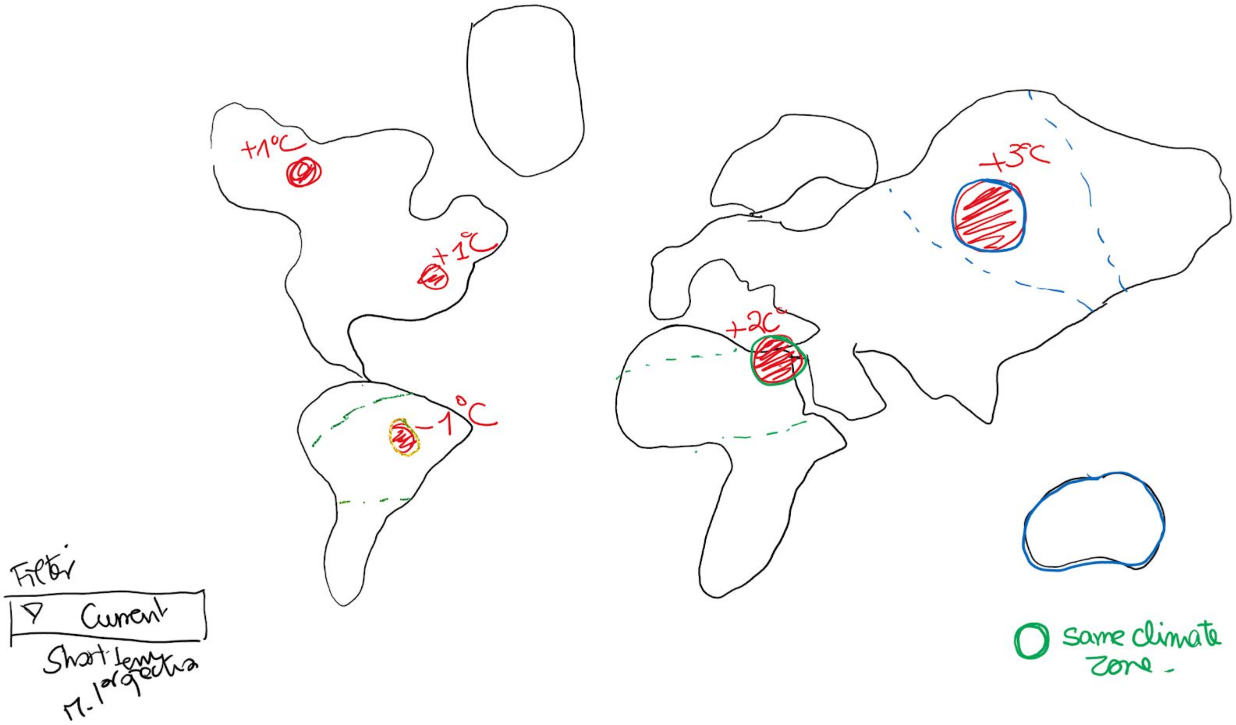
- How large are the thermal stresses across climates?



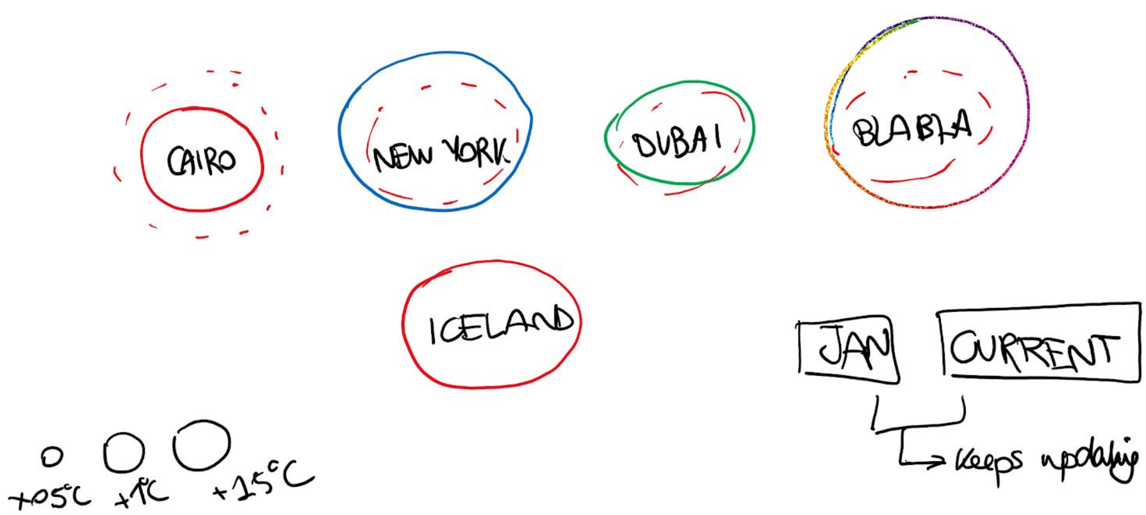
- How large are the variations between outdoor thermal comfort today and in 30 and 50 years from now?



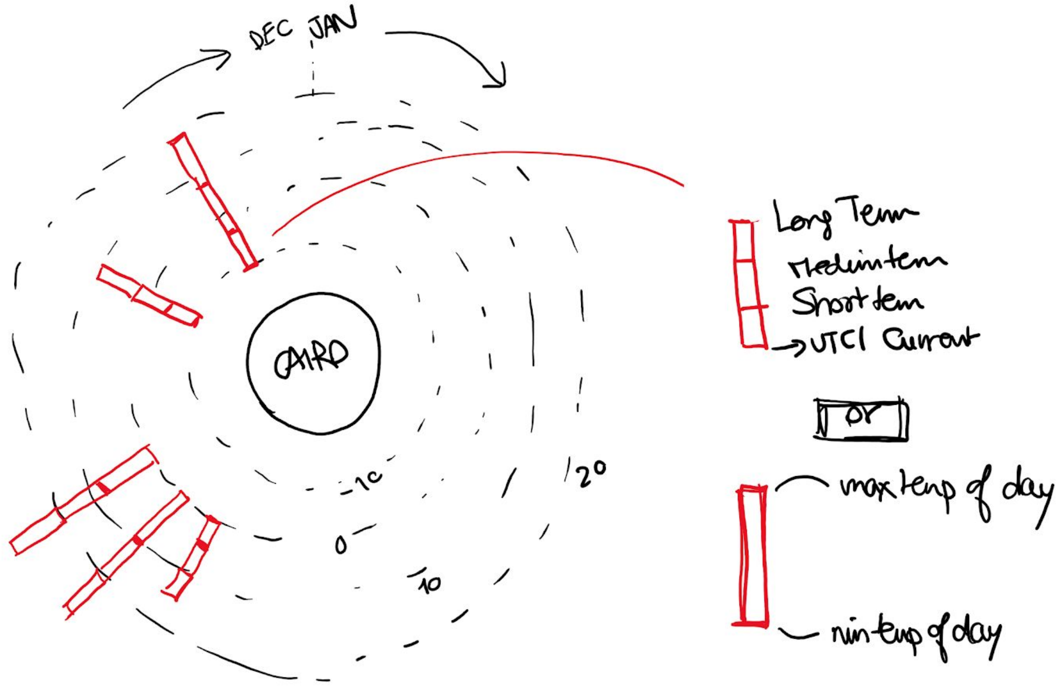
- What is the variation in outdoor thermal comfort across the globe? Which cities have the highest potential of adverse impacts on outdoor thermal comfort?



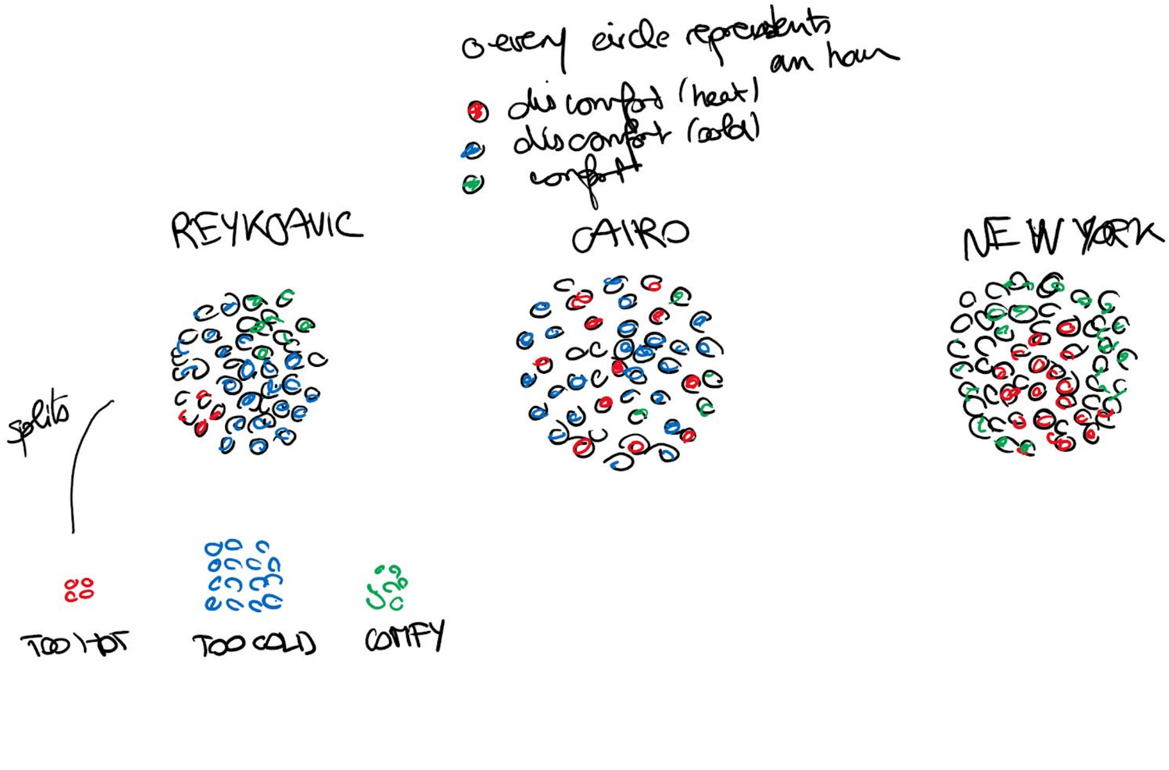
- What is the variation in outdoor thermal comfort across the globe?



- What is the variation in outdoor thermal comfort across the globe?



- What is the variation in outdoor thermal comfort across the globe?



Decide

Through affinity diagramming, we are exploring the sketches that we produced and the questions they answer. This intends to identify similarities in sketches and identify the most visually impactful sketches.

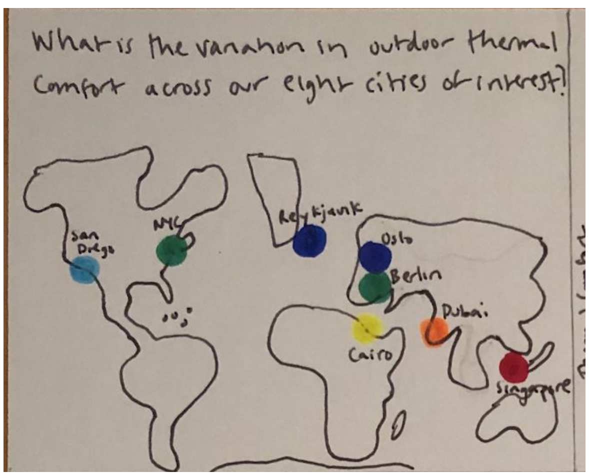
Sketch ID	Question(s)	Author(s)
1, 7, 18, 19	What is the variation in outdoor thermal comfort across the globe?	CE, SW, SM
2	How does outdoor thermal comfort vary by time of year?	CE
3	How do the current and short term predictions of outdoor thermal comfort vary by city?	CE
4	How do sun elevation and wind speed impact outdoor thermal comfort?	CE
5	How does outdoor thermal comfort vary within each city?	CE
6	Which city experiences the most direct radiation on average?	CE
8	How is solar radiation received in city x. What variables lead to more reflection / absorption and how are they associated with heat (could add one more layer of connection)?	SW
9	How does the thermal comfort through the year look like in city x for year x? Seasonal trends?	SW
10	How do normalized thermal comforts compare with other cities? Can we see at which point human action seems ineffective based on a per country case basis? What is the duration of deviation from thermal comfort optimum?	SW
11, 13	How large are the variations between outdoor thermal comfort distributions today and in 30 and 50 years from now?	SW, SM
12	Which actions can we take to make cities “bearable” in the face of increasing climate adversity?	SM
14	How large are the variations between outdoor thermal comfort today and in 30 and 50 years from now?	SM

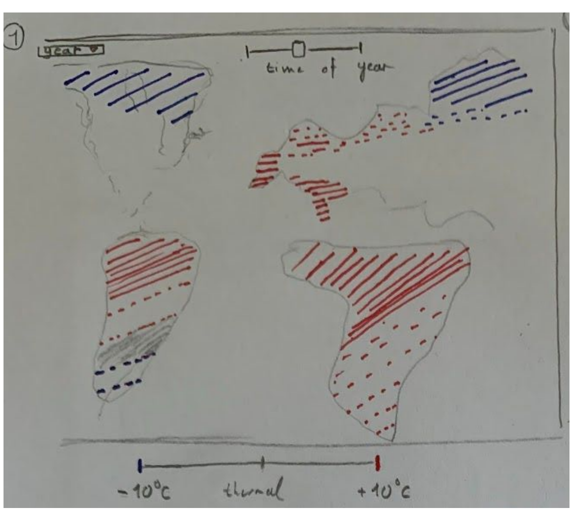
15	What design decisions can have the largest impact in mitigating thermal stresses in cities?	SM
16	How large are the thermal stresses across climates?	SM
17	How large are the variations between outdoor thermal comfort today and in 30 and 50 years from now?	SM
20, 21, 22	What is the variation in outdoor thermal comfort across the globe?	SM

Based on group discussions, the selected sketches and their corresponding questions are as follows.

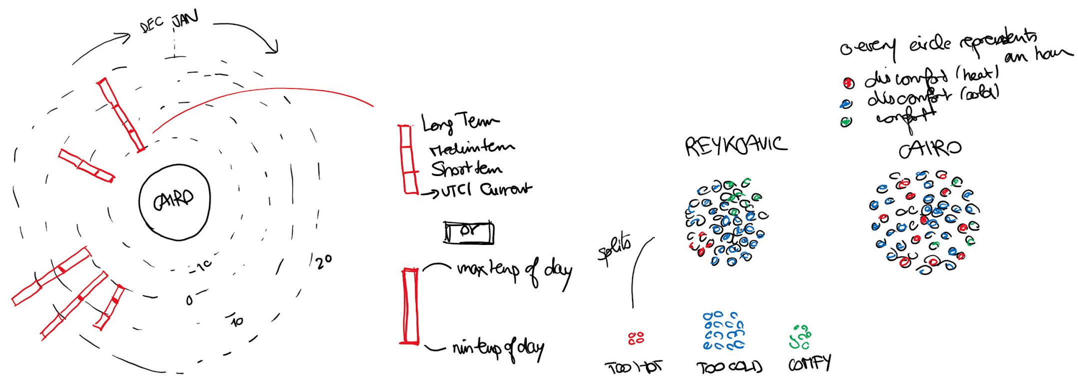
1. **What is the variation in outdoor thermal comfort across the globe?**

Global map representation **(ID: Vis A1)**

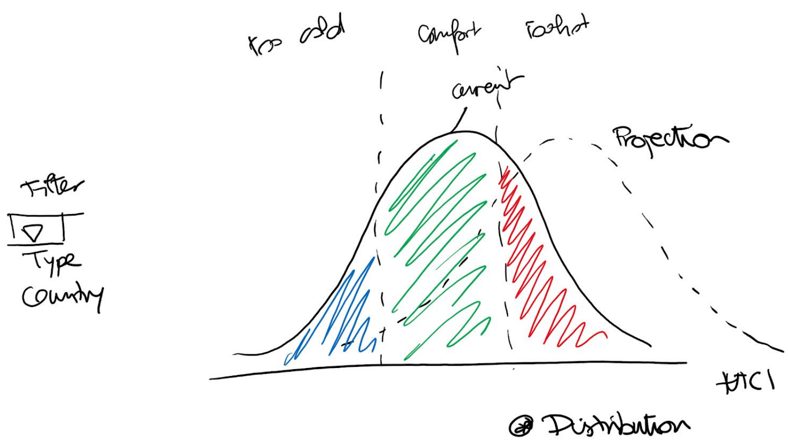




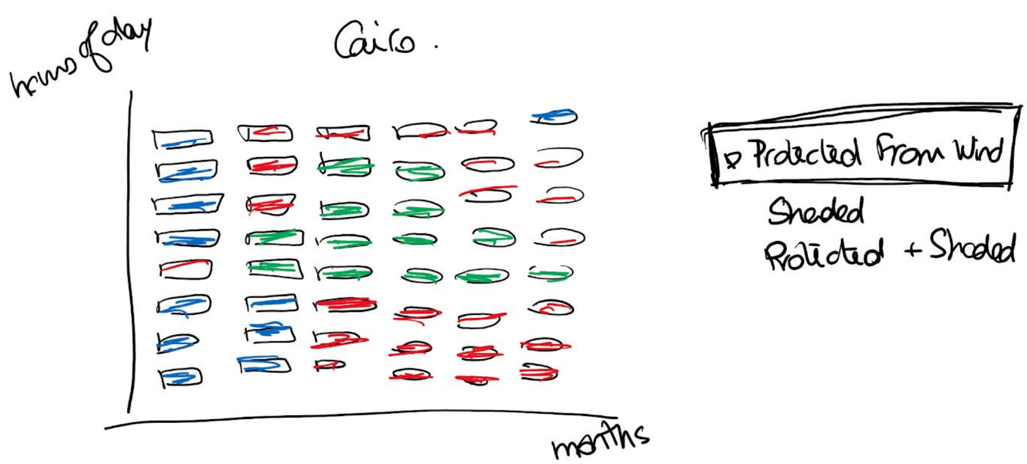
Cities comfort profile **(ID: Vis A2)**



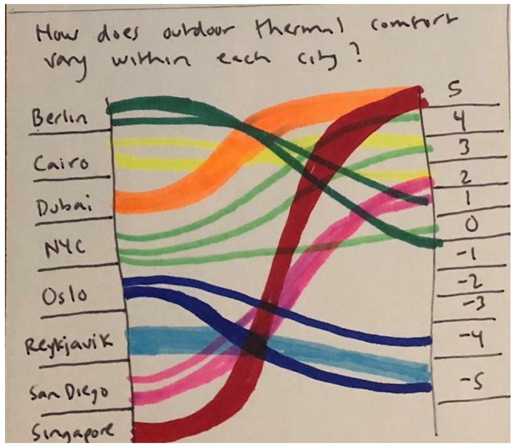
2. **How large are the variations between outdoor thermal comfort distributions today and in 30 and 50 years from now? (ID: Vis B)**



3. **What design decisions can have the largest impact in mitigating thermal stresses in cities? (ID: Vis C)**



4. **How does outdoor thermal comfort vary within each city? (ID: Vis D)**



We based our final selection of the visualizations on a number of factors: the clarity of answering the corresponding question, the effective use of visual cues (color, shape, ..) and principles (contrast, similarity, alignment, …) and the creativity of implementation. We also considered the coverage of most interesting questions that the dataset presents, and the complementary nature of sketches together.

Storyboard

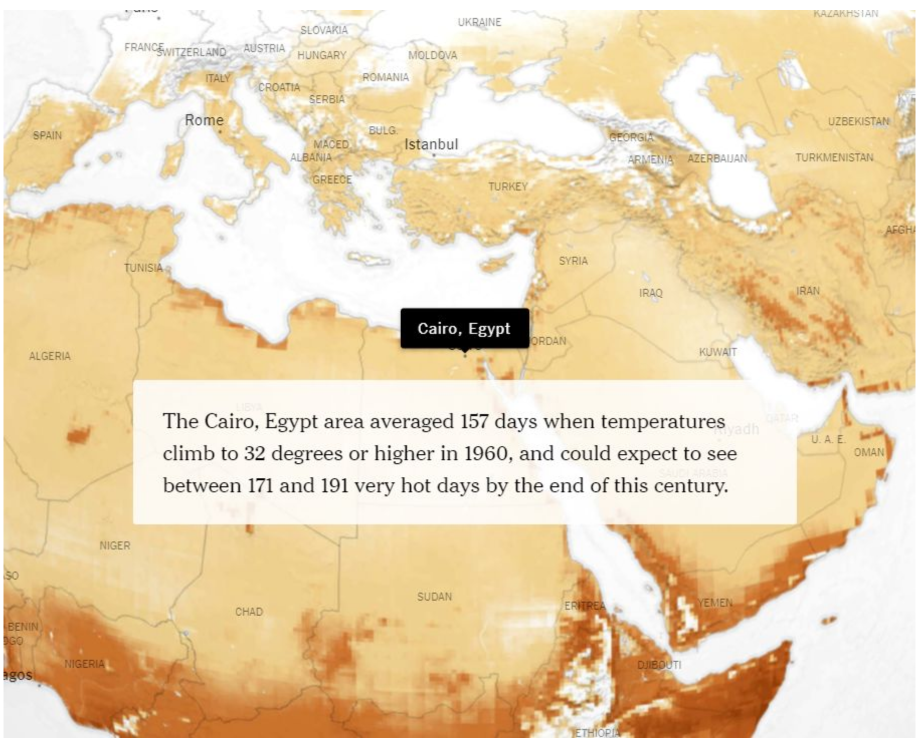
Through discussions, we developed our data story into a narrative that explores all the dimensions of the data: the variation of outdoor comfort conditions across the world, how those weather profiles are projected to change and the impact on time in comfort and heat stress, and finally how design can help mitigate the conditions and its limitations.

<u>Narrative Progression</u>:

<u>Hook</u>

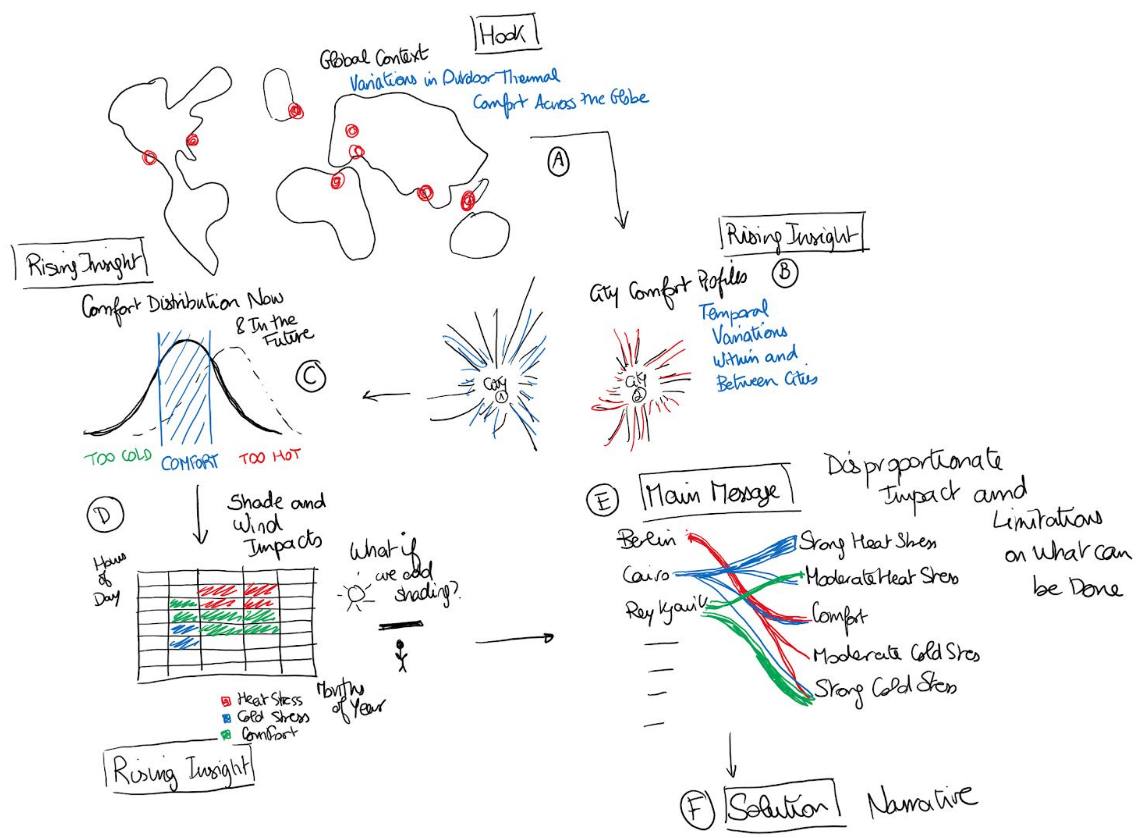
We initiate and captivate the audience with a global perspective of outdoor thermal comfort to establish our topic through a progressive fly-through the eight cities we are studying. We are using this view to spatially place the data in context and engage the audience. We highlight the number of hours in a year that would lend discomfort conditions or conditions with serious heat or cold risks. We here present **Vis A1**.

We are inspired in this section also by the NY Times data story ‘How much hotter is your hometown?’ which presents the issue in a very engaging visual narrative. (https://www.nytimes.com/interactive/2018/08/30/climate/how-much-hotter-is-your-hometown.html)



Rising Insights:

We follow with a series of visualizations which bring insights into the selected questions of interest.



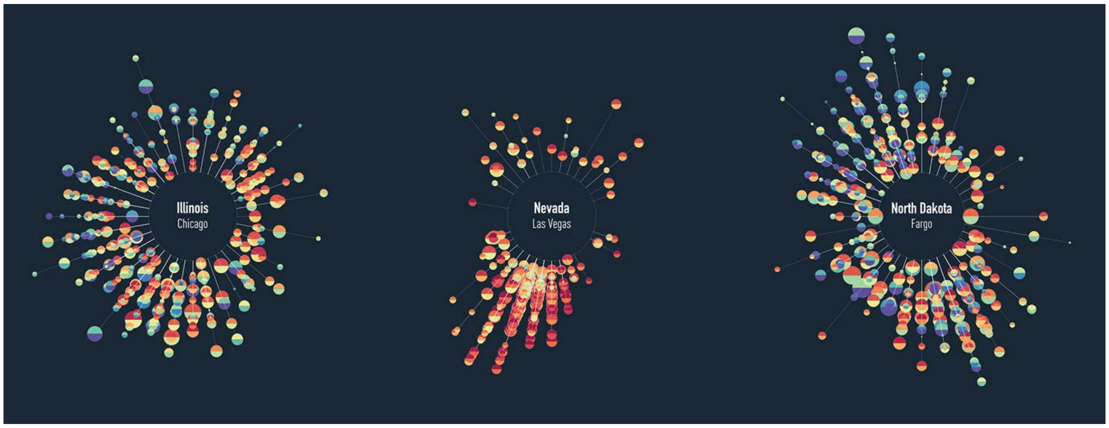
Visualization 1:

The first visualization capitalizes on these rising insights by making a concrete comparison, between the 8 climate zones. It highlights the distinct ‘city comfort profiles’ of the eight cities in one comprehensive visualization. The latter allows for exploration from the user and most importantly brings this thermal comfort variation into clear perspective. We present here **Vis A2**.

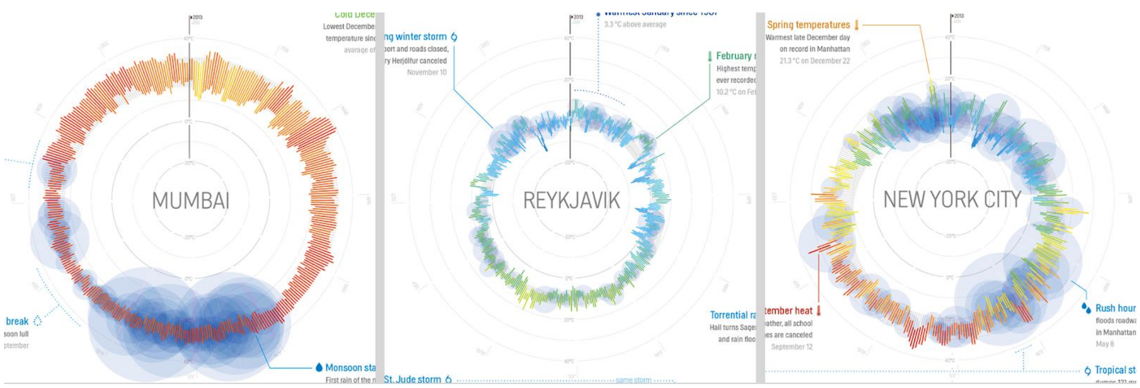
The rising insights through this visualization are:

- How diverse is the outdoor thermal comfort annual profile globally?
- What trends do the specific climate zones show?
- What areas are most affected by thermal discomfort?
- How large are the variations in key cities around the world?

This visualization is inspired by Nicholas Rougeux's 'Weather Portraits of US Cities' (https://www.c82.net/work/?id=345).



The interest in this approach to visualizing city weather is augmented by the following design by Raureif 'Weather Radials' (http://www.weather-radials.com/).



Visualization 2:

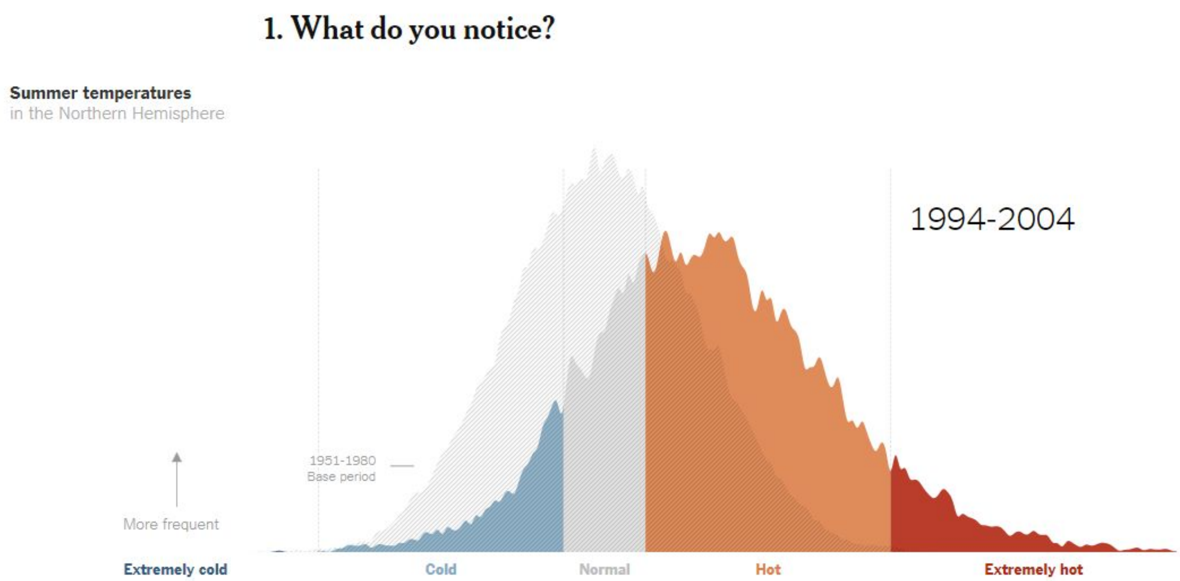
We then project the user into the future by visualizing the distribution of 'felt temperatures' in the short-term, medium-term and long-term. We also highlight which parts of that distribution fall into the comfort range, heat stress and cold stress ranges. We present here **Vis B**.

The rising insights through this visualization are:

- How large are the variations between outdoor thermal comfort distributions today and in 30 and 50 years from now?

We are inspired in this section also by some great visualizations by the NY Times about climate change 'Teach about Climate Change with these 24 New York Times Graphs'. In particular, we find the graph below highly effective in bringing the insights to light about how the comfort levels are changing.

(https://www.nytimes.com/2019/02/28/learning/teach-about-climate-change-with-these-24-new-york-times-graphs.html)



Visualization 3:

We then present an exploratory visualization by city that shows the impact of human design on outdoor thermal comfort patterns. This is showcased by a tabular classification (expressed in strips of colors) of comfort conditions based on average hourly conditions for the different months of the year. We allow the user to flip between four different conditions that may be possible with good urban design. These conditions are: No shade, no wind; 2. No wind, shade; 3. Wind, no shade; 4. Wind, Shade.

We present here **Vis C**.
The rising insights through this visualization are:

- What design decisions can have the largest impact in mitigating thermal stresses in cities?
- What areas could benefit from mitigating strategies through urban design?
- How large is the role of shade and wind in thermal comfort?

<u>Main Message</u>:

Taking these rising insights to an hourly and city scale back to a more holistic perspective, we convey our main message through visualization 4.

Visualization 4:

We use the visualization to bring back into a holistic perspective of the outdoor thermal comfort in cities in terms of annual proportion of hrs of comfort and heat stress. We allow the user to explore each city separately as well as toggle between projection scenarios. We present here **Vis D**.

Our main message is that we are globally affected by climate change and that its impact will be felt disproportionately across the world. Our cities in the coming years will no longer be experienced the same way: we might feel discomfort more extensively, be exposed to heat stress, skip seasons.. and we might no longer be able to use outdoor spaces the same way. There are urban design interventions that we can implement to mitigate some of that, but we will still be limited by our capacity.

Through our story board, we highlight the projections into how thermally comfortable our cities will become. We then visualize what our potential is in mitigating those impacts locally in cities across the world through careful design.

We bring home the main message for not only the relevance of the climate change around us that is well established (and will inevitably bring incredible adversity to humanity given our inability to change behavioural patterns). But the human impact we can have to sustainably mitigate its effects on fundamental living conditions and the possibility to prolong larger surface habitability.

Solution:

We then end with a short ending paragraph after the visualizations outlining:

- The importance of climate change and its impact on cities
- Measures that can be taken globally, locally or personally to act responsibly
- Effective urban design approaches to different climates and regions

We will not be able to reverse climate change, and we should take action today.

Week 11: Prototype V1

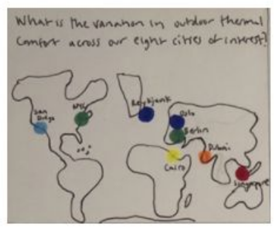
The focus of the first prototype was to develop a rough webpage design with the sequence of visualizations implemented, as well as start developing three visualizations including our ‘innovative vis’. While the design thinking was done in group, Caroline developed the Sankey diagram, Sarah developed the climate roses, and Steven developed the UTCI/comfort distribution graph. Below is a snippet of the V1 prototype, with comments on future work.

Outdoor Thermal Comfort in a Changing Climate

Climate Zone Overview

Through discussions, we developed our data story into a narrative that explores all the dimensions of the data: the variation of outdoor comfort conditions across the world, how those weather profiles are projected to change and the impact on time in comfort and heat stress, and finally how design can help mitigate the conditions and its limitations.

We initiate and captivate the audience with a global perspective of outdoor thermal comfort to establish our topic through a progressive fly-through the eight cities we are studying. We are using this view to spatially place the data in context and engage the audience. We highlight the number of hours in a year that would lend discomfort conditions or conditions with serious heat or cold risks.

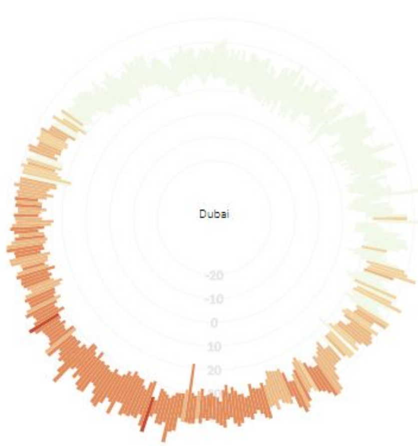


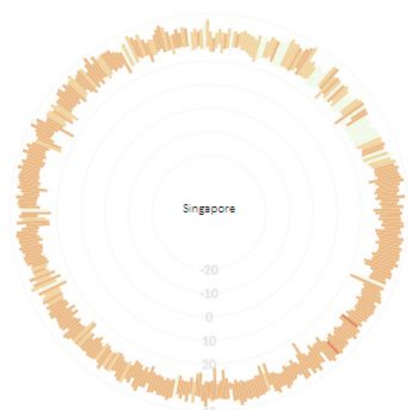
The first visualization capitalizes on these rising insights by making a concrete comparison, between the 8 climate zones. It highlights the distinct ‘city comfort profiles’ of the eight cities in one comprehensive visualization. The latter allows for exploration from the user and most importantly brings this thermal comfort variation into clear perspective.

For future work, we plan to implement the following:

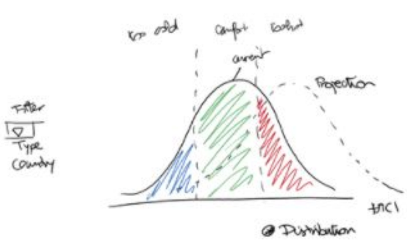
- A label per country profile highlighting the number of hours a year in comfort.
- A tooltip to display information for each day on hover, such as comfort distribution of hours within each day.
- Transitions in order to better highlight the change in the distribution of comfort levels over time (each projection).
- The color scheme will also be revisited to better represent the categories.

Current ⬍   Sun Exposed and Wind Exposed ⬍

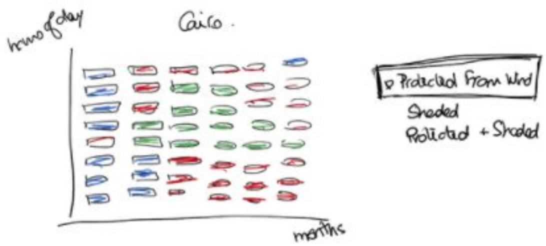




We then project the user into the future by visualizing the distribution of 'felt temperatures' in the short-term, medium-term and long-term. We also highlight which parts of that distribution fall into the comfort range, heat stress and cold stress ranges.

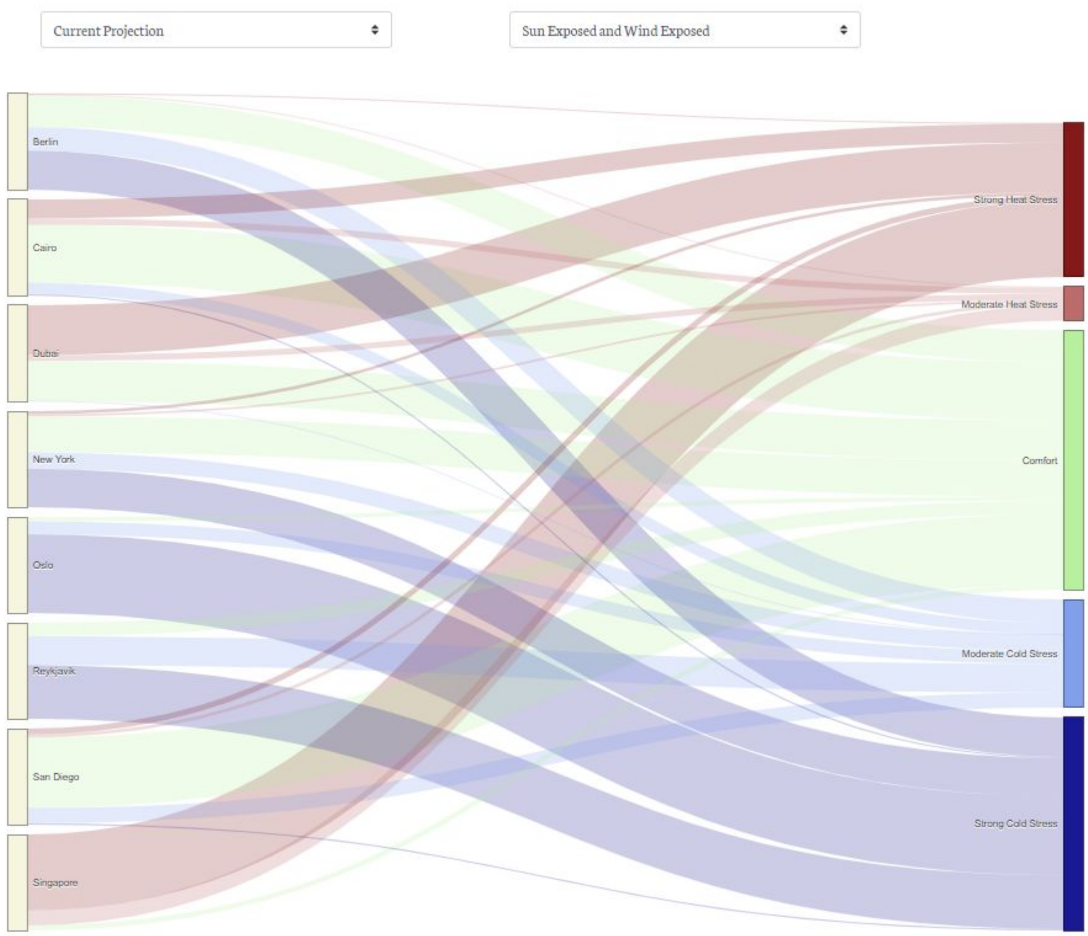


We then present an exploratory visualization by city that shows the impact of human design on outdoor thermal comfort patterns. This is showcased by a tabular classification (expressed in strips of colors) of comfort conditions based on average hourly conditions for the different months of the year. We allow the user to flip between four different conditions that may be possible with good urban design. These conditions are: No shade, no wind; 2. No wind, shade; 3. Wind, no shade; 4. Wind, Shade.



We use the visualization to bring back into a holistic perspective of the outdoor thermal comfort in cities in terms of annual proportion of hrs of comfort and heat stress. In our current implementation, we allow the user to toggle between projection and condition scenarios. For future work, we plan to implement the following:

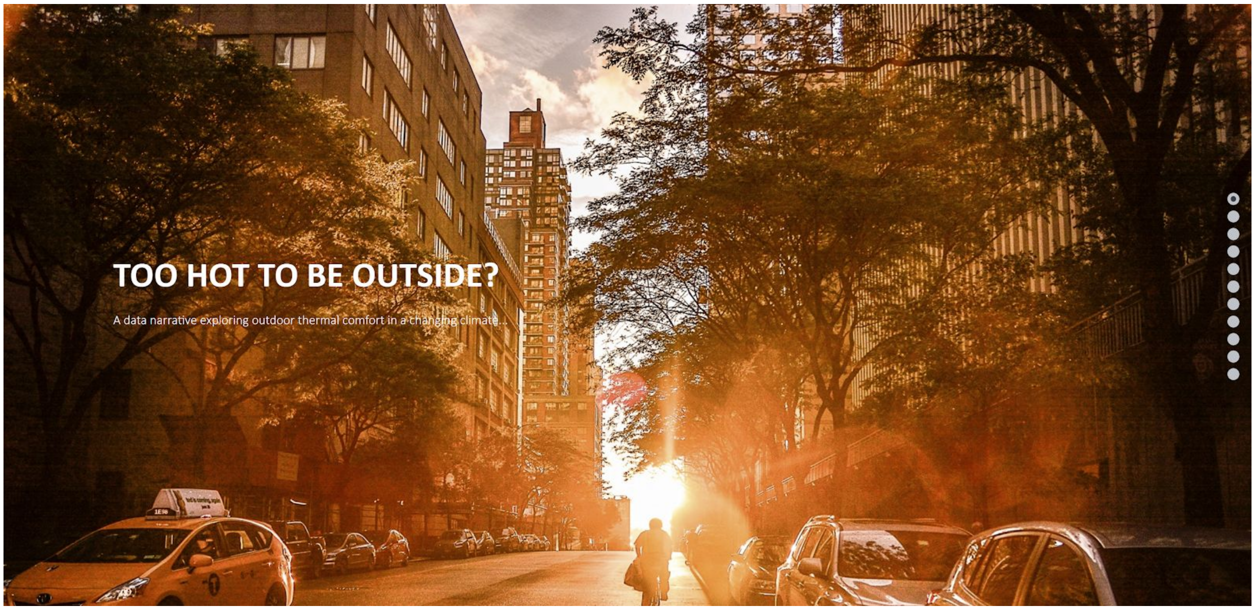
- Additional filtering capabilities so that the user can also visualize just one city at a time.
- A tooltip to display information for each link. Right now we have title text that appears on hover, but we would like to make use of a tooltip to allow for advanced styling options.
- Transitions in order to better highlight the change in the distribution of comfort levels over time (each projection).
- We also plan to adjust our color scheme used in this sankey diagram. We will explore the best colors to represent cities and comfort levels, and we will explore whether the sankey link colors should represent the source or target nodes.

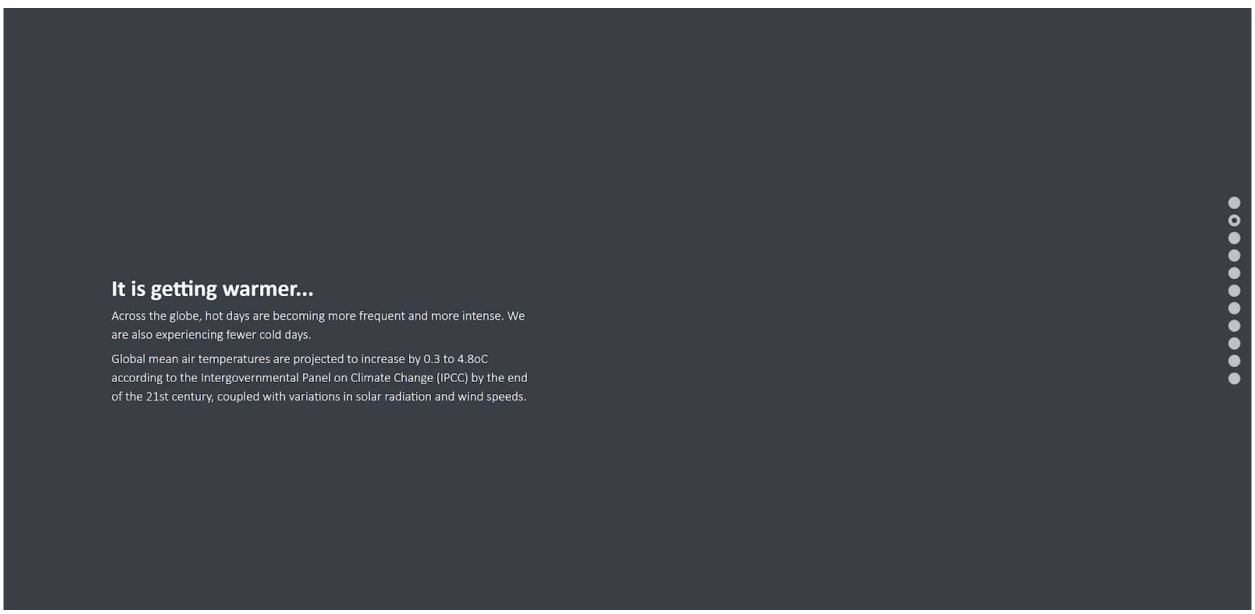


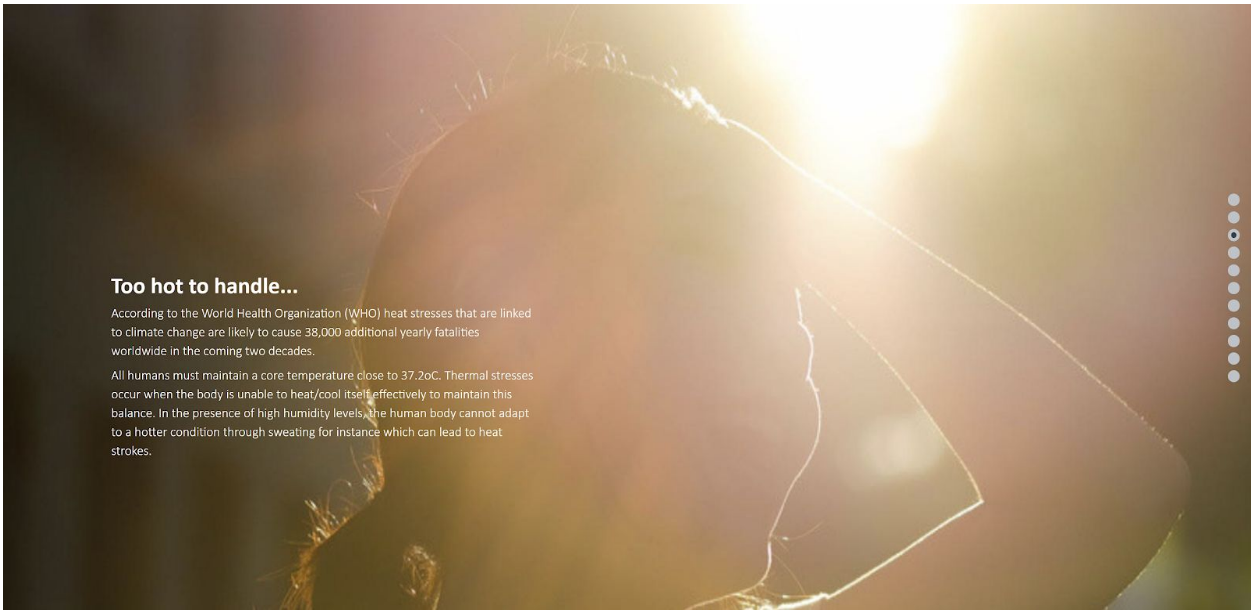
Helpful sources regarding climate change and actions you can take toward a better future:
https://www.greenpeace.org/international/explore/
News:
https://onlinepublichealth.gwu.edu/resources/sources-for-climate-news/
US-based:
https://climate.nasa.gov/
https://www.nrdc.org/stories/global-climate-change-what-you-need-know
https://www.nature.com/subjects/climate-change
Intergovernmental:
https://www.ipcc.ch/
https://www.who.int/health-topics/climate-change#tab=tab_1
Individual action:
https://davidsuzuki.org/what-you-can-do/top-10-ways-can-stop-climate-change/
https://www.bbc.com/future/article/20181102-what-can-i-do-about-climate-change
United Nations:
https://unfccc.int/
https://www.un.org/en/climatechange
https://www.unep.org/
UN Climate Change twitter:
https://twitter.com/UNFCCC?ref_src=twsrc%5Egoogle%7Ctwcamp%5Eserp%7Ctwgr%5Eauthor

Week 12: Prototype V2

The second prototype of the data story is shown below:







Cities are most vulnerable...

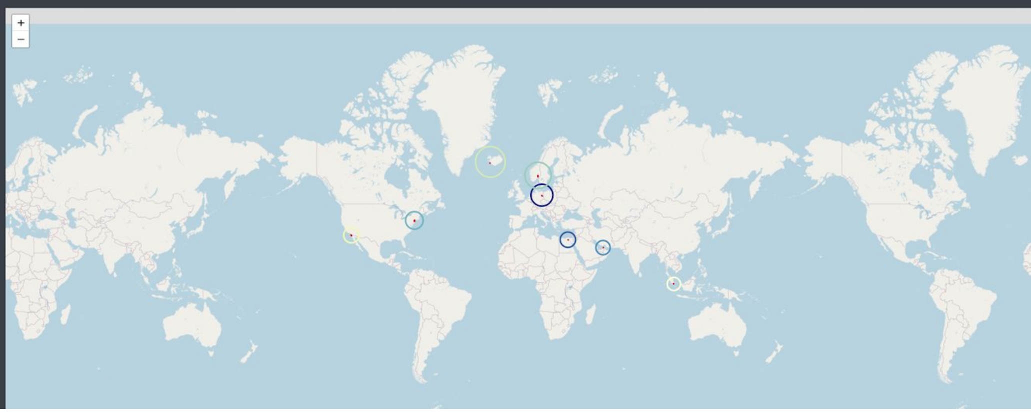
The global trend towards urbanization, with an expectation of 70% of the world's population living in cities by 2050, places increased strain on cities which face densification and higher vulnerability to climate change and extreme weather conditions.

Urban areas experience warmer conditions than surrounding rural areas, a phenomenon named the urban heat island (UHI) effect. This is primarily caused by the natural land cover replaced by a concentration of heat-absorbing and retaining surfaces for pavement and buildings as well as from waste heat generated from buildings, cars, etc...

How does it feel outdoors in different cities, regions and climates around the globe?

On the map below, you see a global picture of how eight cities in different climate zones experience the warmer temperatures today.

Entire World View | Berlin | Cairo | Dubai | New York | Oslo | Reykjavik | San Diego | Singapore



How hot is too hot?

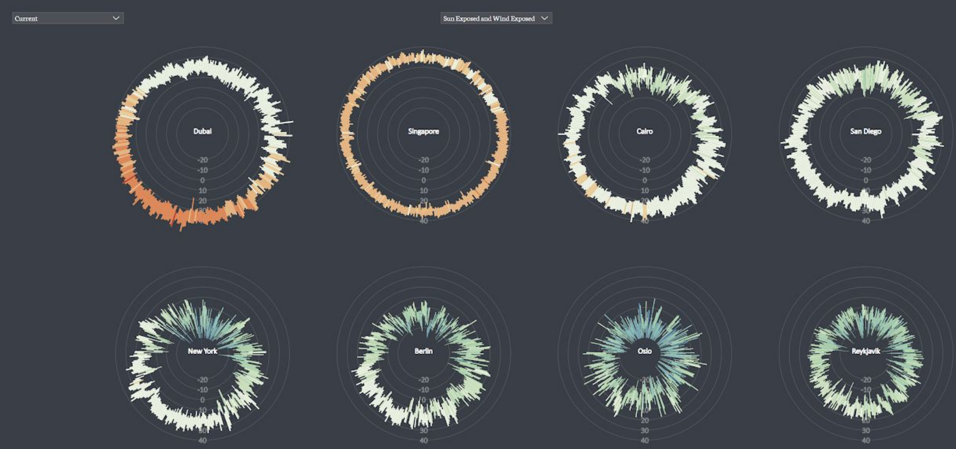
Among the most comprehensive indices for estimating thermal comfort and stresses in outdoor environments is the Universal Thermal Climate Index (UTCI). It is a thermal comfort model which estimates the 'felt temperature' (in degrees Celsius) based on a human heat balance model that combines the air temperature, mean radiant temperature, humidity, and wind speed.

We use this scale to model the conditions outdoors, where a 'felt' temperature of 9 to 26oC is within a comfortable range.

UTCI (°C) range	Stress Category
above +46	extreme heat stress
+38 to +46	very strong heat stress
+32 to +38	strong heat stress
+26 to +32	moderate heat stress
+9 to +26	no thermal stress
+9 to 0	slight cold stress
0 to -13	moderate cold stress
-13 to -27	strong cold stress
-27 to -40	very strong cold stress
below -40	extreme cold stress

When are we comfortable?

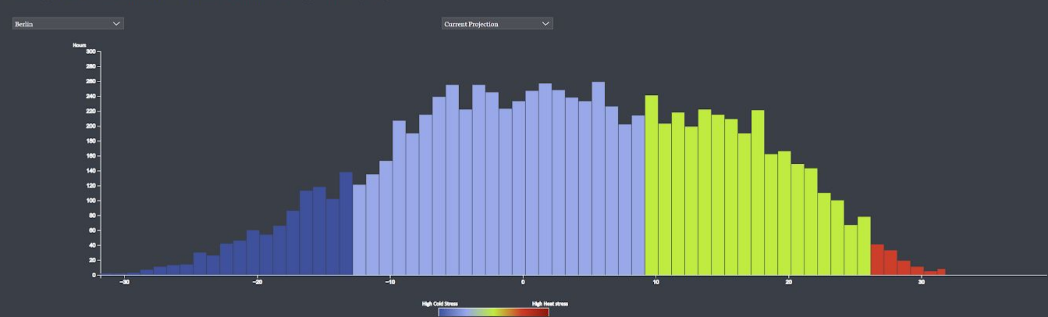
The visualization maps the outdoor thermal comfort profile of the cities based on minimum and maximum felt temperatures throughout the year.

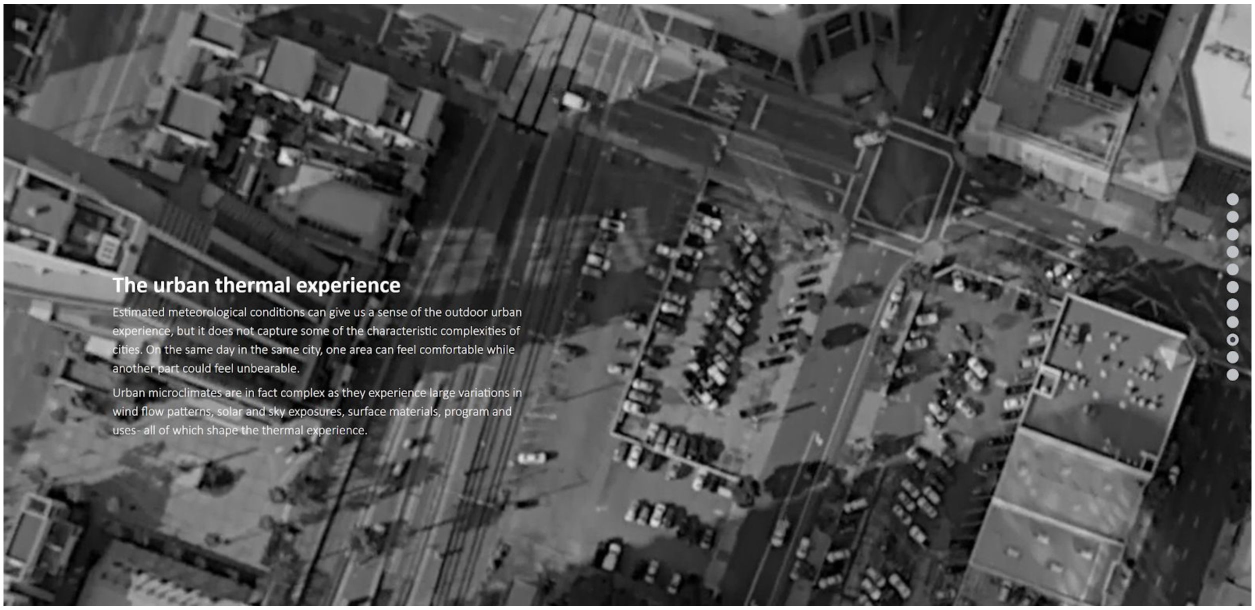


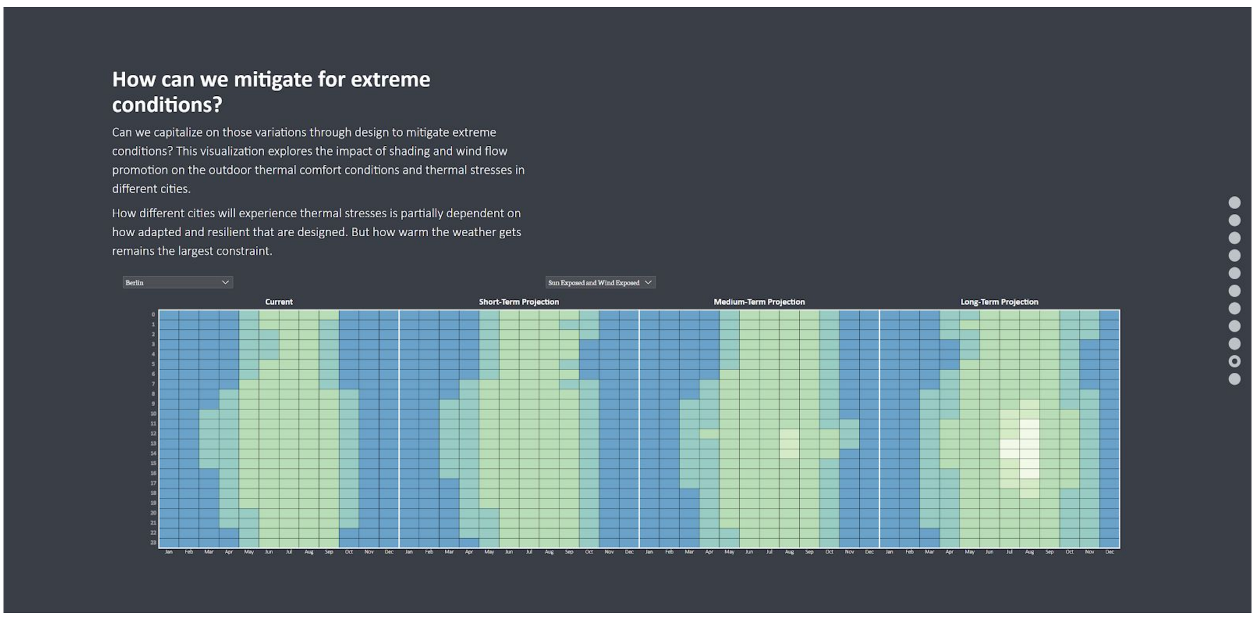
How hot is going to get?

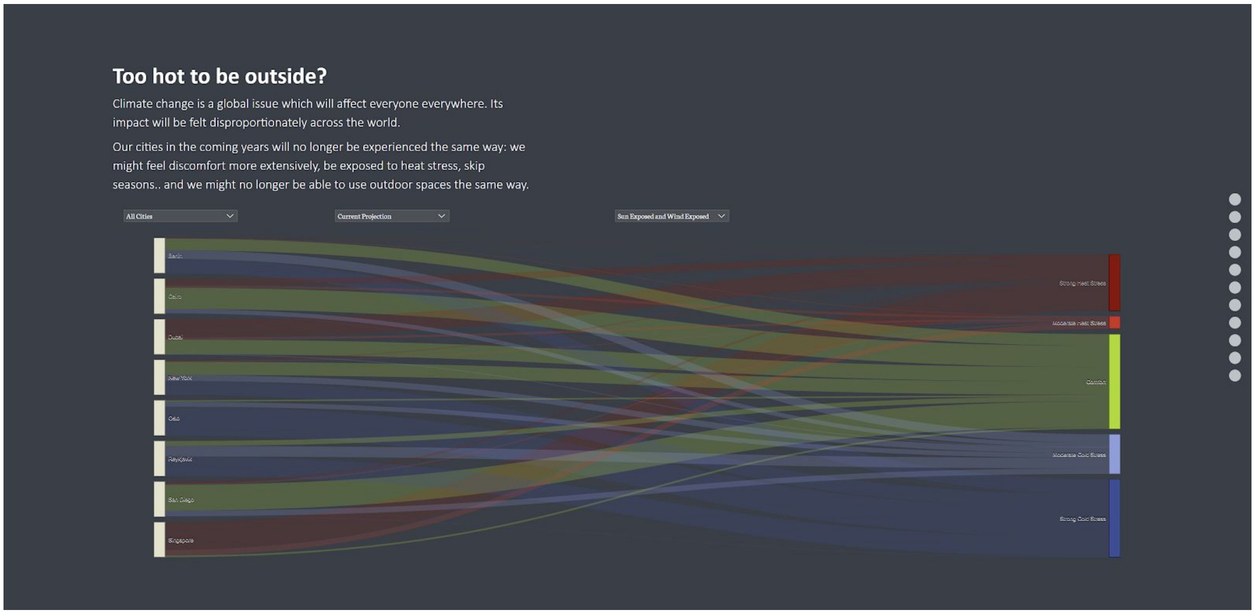
Based on future projections of climate change, the following visualization illustrates how the distribution of comfortable and thermal stress hours is projected to change in the short, medium, and long term for different cities around the world.

The future could even look hotter if no serious collective action is taken towards curbing emissions to match or be lower than the Paris Agreement pledges.




The urban thermal experience
Estimated meteorological conditions can give us a sense of the outdoor urban experience, but it does not capture some of the characteristic complexities of cities. On the same day in the same city, one area can feel comfortable while another part could feel unbearable.
Urban microclimates are in fact complex as they experience large variations in wind flow patterns, solar and sky exposures, surface materials, program and uses- all of which shape the thermal experience.


How can we mitigate for extreme conditions?
Can we capitalize on those variations through design to mitigate extreme conditions? This visualization explores the impact of shading and wind flow promotion on the outdoor thermal comfort conditions and thermal stresses in different cities.
How different cities will experience thermal stresses is partially dependent on how adapted and resilient that are designed. But how warm the weather gets remains the largest constraint.
Berlin
Sun Exposed and Wind Exposed
Current
Short-Term Projection
Medium-Term Projection
Long-Term Projection


Too hot to be outside?
Climate change is a global issue which will affect everyone everywhere. Its impact will be felt disproportionately across the world.
Our cities in the coming years will no longer be experienced the same way: we might feel discomfort more extensively, be exposed to heat stress, skip seasons.. and we might no longer be able to use outdoor spaces the same way.
All Cities
Current Projection
Sun Exposed and Wind Exposed
Berlin
Cairo
Dubai
New York
Oslo
Reykjavik
San Diego
Singapore
Strong Heat Stress
Moderate Heat Stress
Comfort
Moderate Cold Stress
Strong Cold Stress

Week 13: Test

Through a think-aloud study, we tested our data story prototype with two testers. The compiled notes from both studies are documented below.

Testers Names: Zhaodong Chen, Peitong Chen
Testers Emails: zchen01@college.harvard.edu, pchen@gsd.harvard.edu

General Observations from the think-aloud study:

- Nav Bar is bugged (does not jump to section headers (sometimes even to whitespace))
- Liked the Autumny color tone for title image
- General bugs with formatting/sections not lining up
- Add in some highlights/takeaways for each of the visualizations so help point out/provide explanations for the trends
- Found many of the visualizations to be novel and interesting

What do the testers like about your data story?

- Very fundamentally important and powerful narrative
- Like the use of colors and intuitive coding (red is hot / blue is cold) (Coloring should be consistent though)
- Not problematic like with genders and purely advantageous
- Liked the high contrast (white on dark grey) for titles and text (non image contrast)
- Liked the formatting of title in regards to contrast, font and size
- Consistent layout and therefore coherence (although bugged at times in formatting)
- Good use of images for background contrast and progression and pleasant alternation (that was slightly buggy at times)
- Thought Sankey, Dist and Radial as well as coordinated were all “cool” visualizations, that were visually appealing and striking (especially radial plot)
- Broad range of useful resources linked for a tangible solution, actionable steps

What improvements do the testers point out?

- Maybe change sun protected and sun exposed to just Sun and Shade for simplicity for all relevant filters
- Adjust the titles for the Navbar; they are not helpful for the user to navigate the web page since they are vague
- Spacing for some text content is slightly too large (a lot of grey space which looks clean but is overused slightly)
- Legends for coordinated plane view, sankey and radial chart
- Provide some explanations for what each of the projections means in terms of time
- Add hours (h or 0:00) for coordinated plane view
- Radial:
    - Add degrees for radial axis (maybe) in general found radial chart hard to read

    - What is the “thickness” of the lines on radial (max min of day needs to be clearer that it is a line for each day in year)
    - Increase size for clarity and more spacing on radial axis

- Sankey:
    - Change font color and size (cannot read labeling)
    - The sankey diagram should not be the last visualization as it does not provide any novel insights or calls to action

- Image for getting warmer is “cold” based on tones → Counter intuitive to content
- Image contrast for “too hot to handle” section could be higher (decrease img brightness)
- How hot is too hot?:
    - Put img with categories next to the paragraph on the right in one row
    - Increase font size to make legible → Probably make own version
- Map:
    - Pop up border problematic when over ocean
    - Nice to introduce cities → should be made clearer that dragging the map or clicking on the cities there is not the most effective way to navigate → Draw user more toward the top buttons
- Dist:
    - Contrast to background? (was in front of picture due to formatting issue)
    - On-hover tooltip for individual bars, as the user feels with histograms that we intuitively want to know what an individual bar is→ No additional data → Tooltip for aggregate hours in specific category: 100 very hot, 200 hot, 300 neutral, …
- Add in some calls to action
- Add in information about the team, the data and additional resources at the end of the page

Was the intended key message clear to the testers? Why or why not?
The message was clear, but could be driven home better:
Analogous to the coord plot text draw the connection between sankey being the global aggregate of the coordinated plot → We can generalize to an extent
In general clear, but individual issues like legends and axis labelling could improve clarity and comprehension ease and speed. Additionally, adding in text to explicitly highlight trends and calls to action would be helpful.

Did the testers get your next steps or call to action? Why or why not?
The Testers were very happy with our next steps and indirect call to action, as they understood the vastness of the issue, writing solutions to climate change on a page for climate comfort makes little sense given the existence of far superior resources to this extent. Therefore they were very happy with the provided links ranging from UN resources to greenpeace, nature and individual webpages that outline steps for individual action. Nonetheless, we should be more explicit at the end of the webpage about our conclusions and calls to action.

Overall insights from the think aloud study and action plan:

- The study was very insightful into what elements were successfully delivered and ones that need further improvements.
- The testers generally came out understanding the narrative and the key take-aways to a large extent, in particular relative to the projected rising temperatures and their negative impacts on heat stress in cities, as well as the global relevance of the issue. The message can though be delivered more effectively using additional legends, labelling and narrating text to augment the visualizations and improve comprehension.
- Based on the tester comments and our group discussions, we agreed that the following data story modifications will be updated:
    - Add appropriate legends, labelling and narrating text to all visualizations to help guide better through the narrative, and guide the exploration of the visualizations.
    - Use clearer navigation through the data story by adding more expressive text to what comes next, as well as more succinct text when possible such as Sun and Shade instead of Sun Protected and Sun Exposed.
    - Unify the colors for all visualizations and maintain a consistent visual encoding.
    - Improve the flexibility of the code to accommodate for different screen sizes without deterring the flow of the storyline or the visualizations.
    - Introduce the context of the data story: the data source, and what ‘projections’ mean as well as what assumptions were made in the data preparation.
    - Introduce the encodings of complex visualizations such as the radial one, highlighting what each bar represents.
    - Reinforce the key messages in the concluding parts of the data story, and more strongly explain the relevance of the sankey diagram in reflecting how those different comfort impacts within every city have global impacts and relevance.
    - Add an additional section that includes information about the team, context of the work, and provide additional resources to the data source.