

# **CLIMATE CHANGE**

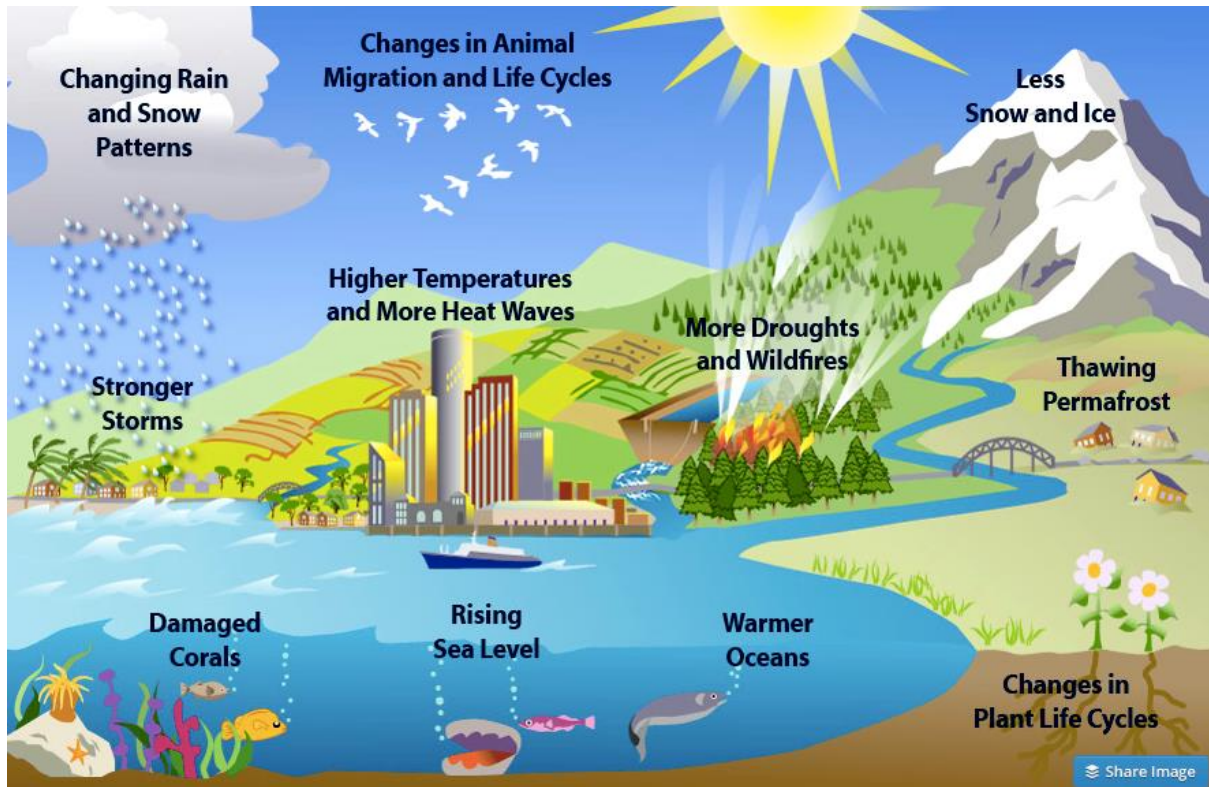
## **Causes of Global Warming and Impact of Global Warming**

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**Lab Number:** 18

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## Introduction

We are debating on Global Warming since beginning of last century without knowing what global warming is. This topic came into light after the Paris Agreement in 2016. Since amount of loss due to global warming is increasing every day, now people are getting more concerned about it. Global Warming is basically rise in earth mean temperature and Global Warming is closely related to Climate Change.

Using narrative visualisation, I want to convey how deadly is Climate Change and what factors are responsible for the climate change. So that people can get more concerned about it and take action to stop Climate Change.

Messages conveyed by my narrative visualisation can be divided in four parts:

- **Causes of Global Warming:** To control Global Warming we need to understand what are the major causes of Global Warming.
- **Global warming is changing nature unnaturally:** What unnatural changes occur in nature due to Global Warming.
- **Reason for increasing natural disaster:** How the above unnatural changes are responsible of increasing natural disaster.
- **Climate Change is a global phenomenon:** We should see Climate Change as global phenomenon because controlling greenhouse gases by a particular locality will not help it to get immune from increasing natural disasters.

My audience are of two type:

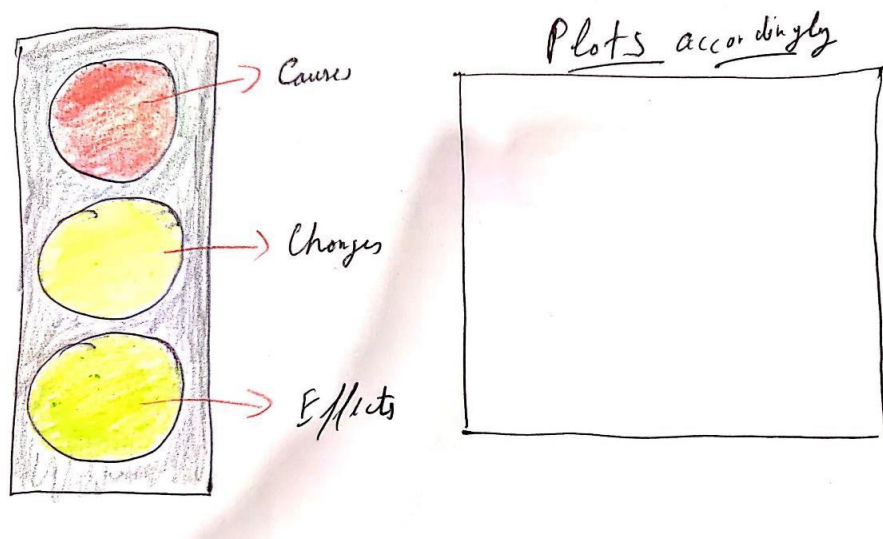
- **Big global organisations:** Organisations such as United Nations, World Meteorological Organization etc. are my 1<sup>st</sup> audience. Since Climate Change is Global Phenomenon it needs to be addressed by global organisations.
- **General Public:** Since we need to spread awareness about global warming and climate change therefore general public is also my important audience.

## Design

In Five Design Sheet, in 3<sup>rd</sup> design I have considered a traffic light type design which have three lights, by clicking on each light it will produces or shows plots related to that light. Each light defines a unique sub question of the bigger question.

- **Red light:** It shows the plots related to the causes of the Global Warming.
- **Orange light:** It shows the plots related to the unnatural changes happening in the nature due to global warming.
- **Green light:** It shows the plots related to show the effects of those unnatural changes.

3<sup>rd</sup> design of my Five Design Sheet was similar like this:



At the time of implementation I came up with one more sub question which cannot be fixed in the above traffic light design therefore I considered Tabs like structure so that it can incorporate the 4<sup>th</sup> sub question and also I choose tabs instead of Red Light design if I came up with more sub question while implementation, Tabs are more flexible and I can easily fix that new sub question inside the tabs structure.

My tabs structure looks like this:

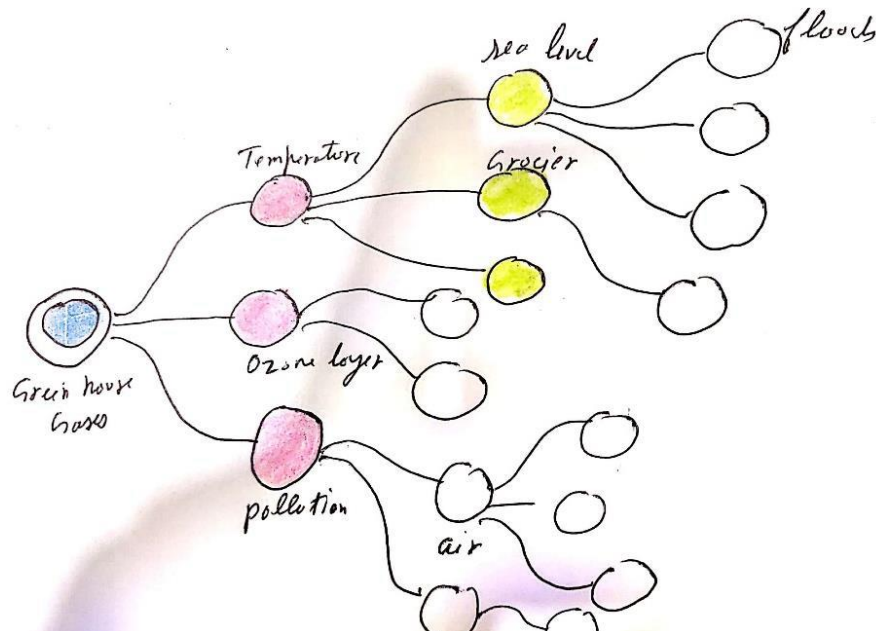


Here 'Causes tab' has been selected and its related plots and information are shown on the right side. Similarly, other tabs are also present here, we can select them too.

Now, my 2<sup>nd</sup> design in Five design sheet was about showing what is the flow of things in the process of climate change. I was showing the flow and connection with the help of

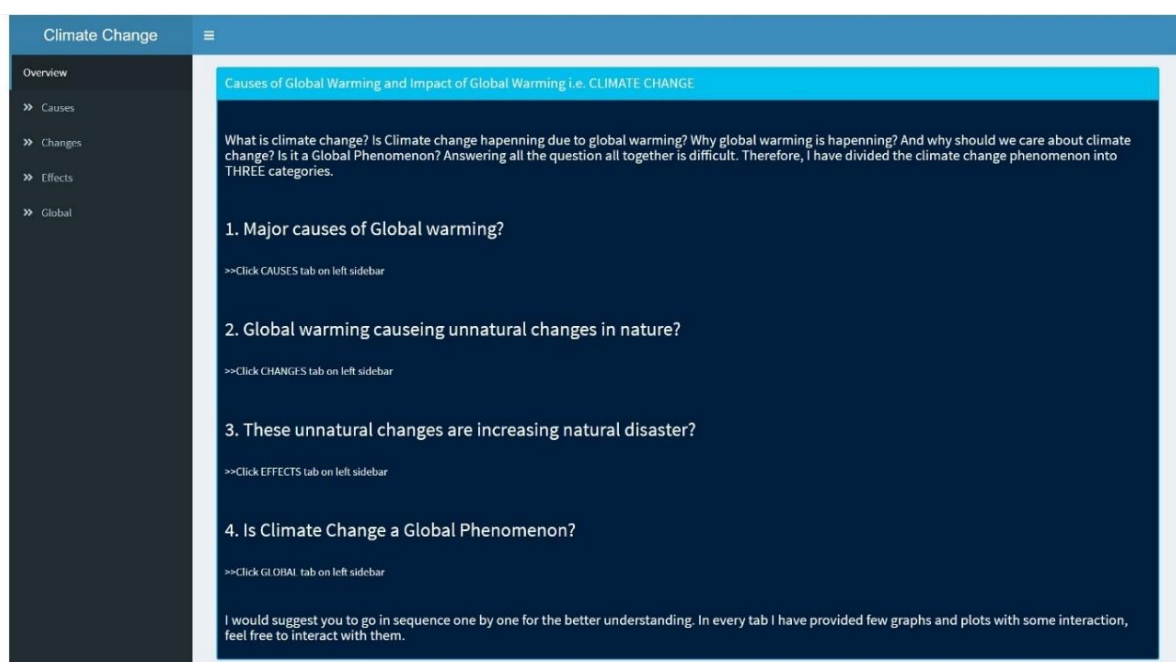
dendrogram but I found a problem implementing using dendrogram, that is it was hard to give explanations of the things and how they are related and why they are related. Also, in a good looking dendrogram number of nodes should be more than 10 nodes but in my case study I was not considering so much connections and variables. Therefore, I have to changes this design.

My 2<sup>nd</sup> design that is dendrogram looks like this:



Because of the above two problems I decided to use textual way to guide the user about the connections and the flow of things. For this I have used overview page where it discusses about the flow of things and how they are connected. Also, in every tab I have provided textual data which also help in showing the connection between the things.

My overview page looks like this:

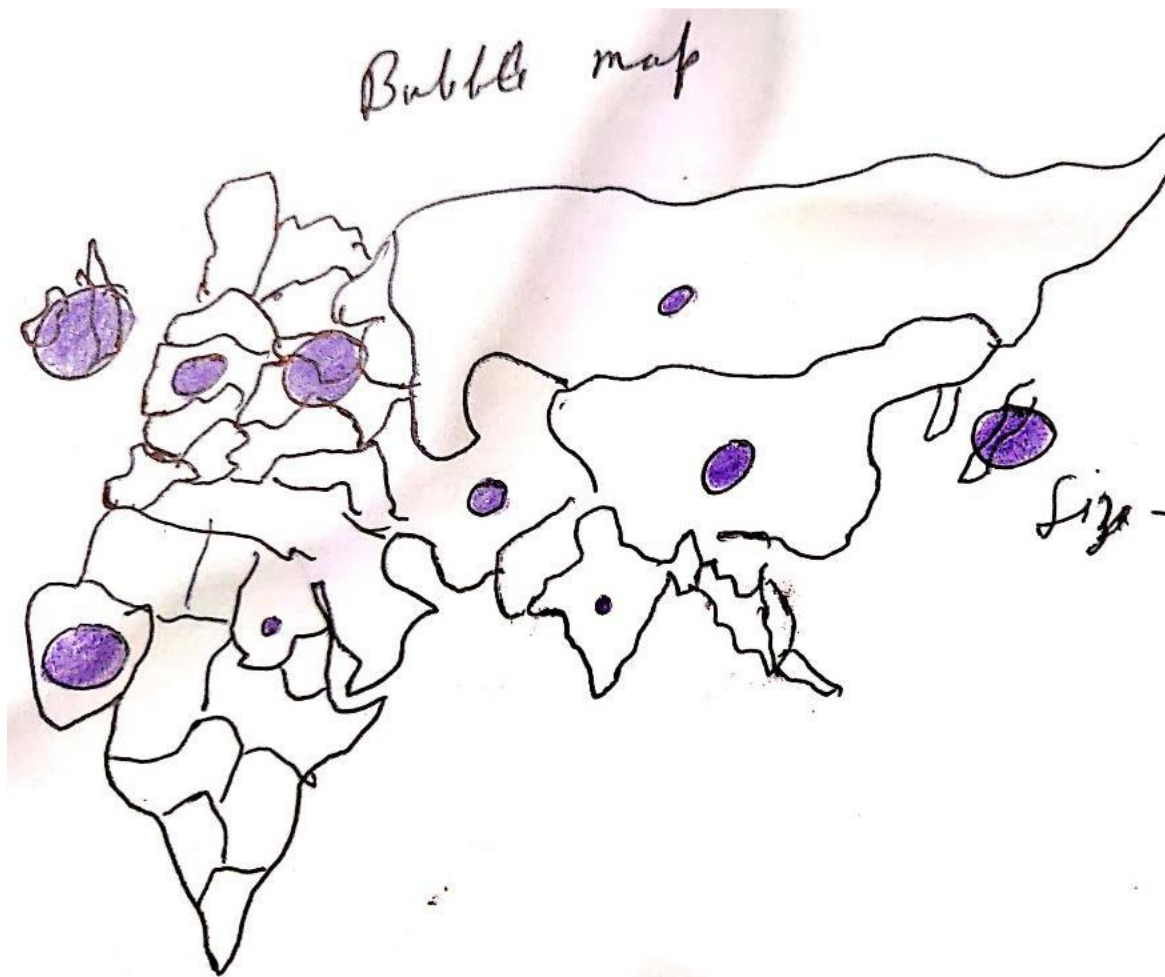


Now, my 1<sup>st</sup> design in five design sheets was a proportional symbol map to show that Climate Change is a global phenomenon. It was basically to see that which countries are emitting most CO<sub>2</sub> and which countries are suffering due to increase in natural disasters so that we can compare and prove that these two statements are wrong:

- If a country is emitting high CO<sub>2</sub> then it will suffer more natural disasters.
- If a country or locality stops emitting CO<sub>2</sub> then it will become immune to increasing natural disasters.

We can prove above two statements wrong using proportional symbol map.

My 1<sup>st</sup> design in Five Design Sheet which shows proportional symbol map was like this:



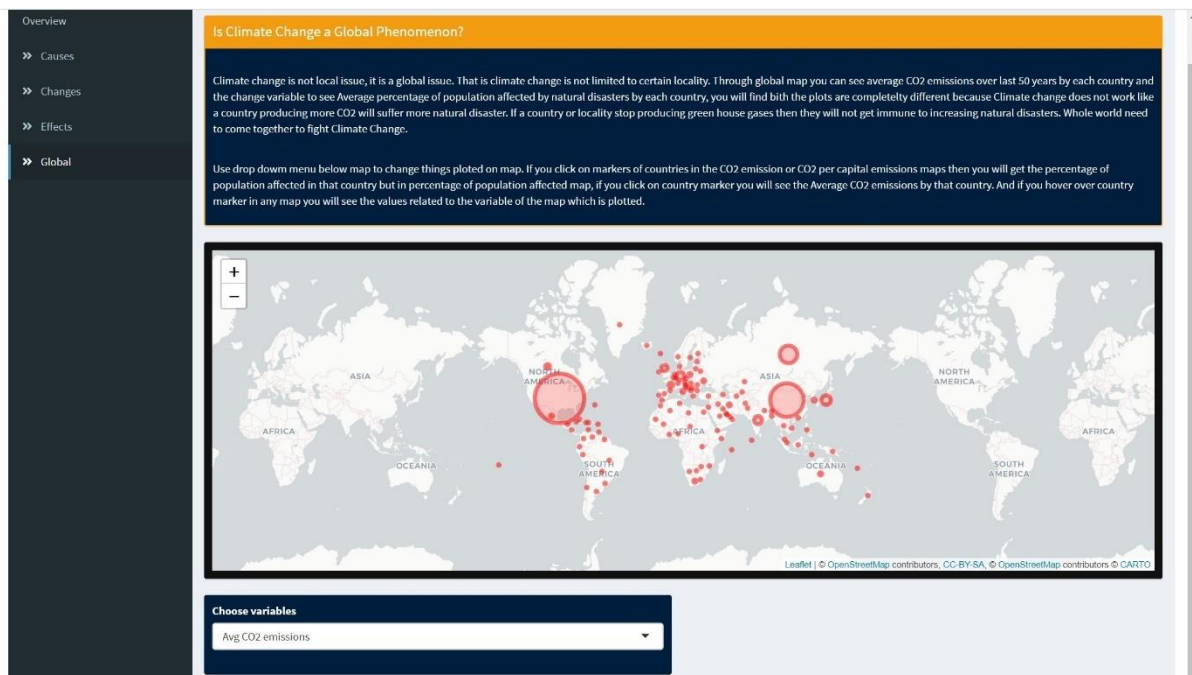
In the above design if we click on the circular marker then will produce the plots showing the CO<sub>2</sub> emission or CO<sub>2</sub> emission per capita and percentage of population affected by that selected country. In the above design if we click on the circular marker then it will produce the plots showing the CO<sub>2</sub> emission, CO<sub>2</sub> emission per capita and percentage of population affected by that selected country. But instead of this I decided give the functionality that user can select what to plot on the map, one thing at a time, such as Average CO<sub>2</sub> emission annually by country or percentage of population affected annually by natural disaster in the



country. The size of the circle will show the magnitude of that plotted variable therefore by changing variable on plot user can easily identify the difference in the size of the bubbles for different variables and hence easily make comparison. Therefore, to make it easily understandable by the user I made some changes mentioned above in the proposed 1<sup>st</sup> design i.e. proportional symbol map in the Five Design Sheet.

My changed design looks like this:

My updated proportional symbol map design looks like this:



## Implementation

I have used **R** and **Shiny** to produce the narrative visualisations. I have used them because I was more familiar with R and shiny as compared to java script and D3.

To show how I implemented by Narrative Visualisation I will go step by step.

1. As discussed above I designed the similar dashboard structure using the “**shinydashboard**” library and the “**shiny**” library. Using “**dashboardPage**”, “**dashboardHeader**”, “**dashboardSidebar**”, “**sidebarMenu**”, “**menuItem**”, “**menuSubItem**”, “**dashboardBody**” etc. I designed the structure of the dashboard in the shiny app.
2. Since, the dashboard is empty I need to put content in it. I started with Overview page in dashboard. It was simple I have added textual content in it by ‘**h1()**’, ‘**h2()**’, ‘**p()**’, ‘**box()**’ etc html type tags. Overview page is to explain the project and how to use the narrative visualisations and dashboard.

3. Since overview page is completed, I have to put content inside each tab. Let's, start with causes tab. Here I have to show the reason for global warming and most correlated greenhouse gas with the temperature anomaly. First, I need to find out which plots are most suitable to show the correlation between temperature anomaly and each greenhouse gas. I decide to go with scatter plots since they are best to show the correlation between two variables. I plotted scatter plot using 'ggplot2' library. Now to find out correlation I used 'cor()' function given in R and find out correlation of every type of greenhouse gas with the temperature anomaly. Then I incorporated the correlation value to the title of the scatter plot dynamically that is every time plot is created, the correlation value is calculated and put in the title of the scatter plots. To make it easy to understand the correlation, I have also added linear regression line with confidence band with each scatter plot using 'geom\_smooth(method="lm")'. Hence, I plotted 4 scatter plots with calculated correlations and linear regression line. Now to make the plots interactive I used 'plotly' library and the function 'ggplotly()'.  
4. Since, all the plots for the 'Cause Tab' has been created now I have to incorporate them with Shiny App and the Shiny-Dashboard. For this is used 'plotlyOutput()' and 'renderPlotly()' functions in the R Shiny App. Here to increase the interactivity I have used the drop down slider bar input so that user can see scatter plots of each greenhouse gas using drop down slider input, for this I have used 'selectInput()' function. Then I added the some text in the 'cause tab' using 'h1()', 'h2()', 'p()' etc. html tags to make the design more narrative.  
After doing all the above things "Cause Tab" looks like this:



5. We will go to next tab and put content in it. Next tab is "Changes Tab". This tab is to show how global warming is changing nature unnaturally and how each unnatural

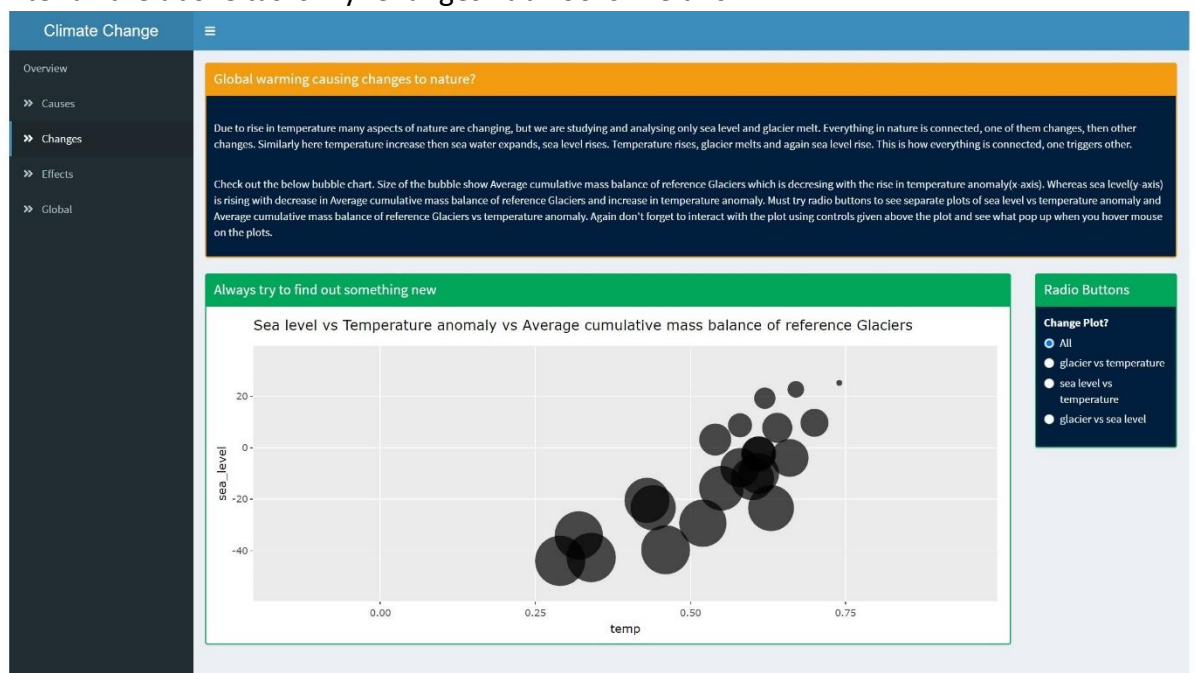
change is related to other unnatural change. I have used sea level rise, average cumulative mass balance of reference Glaciers and temperature anomaly to show this study.

Since 3 variables correlation with each other need to be shown I came up with two possible ideas 1<sup>st</sup> 3D-Cube and 2<sup>nd</sup> Bubble Scatter plot. I choose Bubble scatter plot because it is easy to understand since my one of the audience is general public and also size of bubble can be easily related to the Average cumulative mass balance of reference Glaciers and the way size to bubble decreases according to decrease in Average cumulative mass balance of reference Glaciers is more relatable as compared to 3D-Cubes.

Now to plot the bubble scatter plot I used `'ggplot()'`, `'geom_point()'`, `'scale_size()'`, `'mutate()'` etc. functions. Where `'scale_size()'` was used to scale the size of bubble according to the average cumulative mass balance of reference Glaciers. Now to make it interactive I used `'plotly()'` library and `'ggplotly()'` function along with `'mutate()'` function to show values when user hover above the bubble .

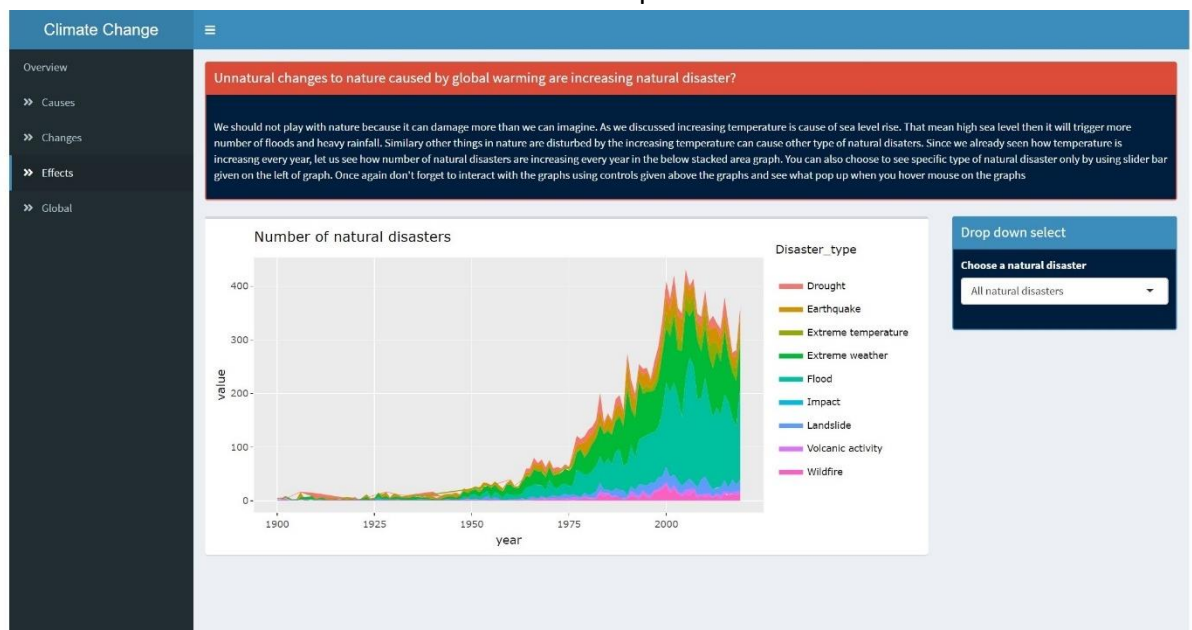
While implementing I came up with thought, might be user want to see individual scatter plots of sea level vs temperature anomaly, Average cumulative mass balance of reference Glaciers vs temperature anomaly or sea level vs Average cumulative mass balance of reference Glaciers. Therefore, for this I made three more scatter plots. I gave the functionality of radio buttons with the help of `'radioButtons()'`, I gave radio buttons so that user can select what they want to see bubble plot which includes all the three variables together or the user want to see individual scatter plot for each two variables to make things clearer. I have also added some text for the narrative visualisations.

After all the above tasks my 'Changes Tab' looks like this:





6. After implementing Causes and Changes TABS next tab is Effects tab, here I want to show plots which will be capable to show the increase in number of natural disasters every year. First, I thought of line graph but I want to show every type of natural disaster in a single line graph therefore I come up with the stacked area graph with different colours showing different type of natural disasters. Implemented it using 'ggplot()'. I am using 'geom\_area()' and also legends to show which colour is for which natural disaster. Since, some users may want to see single natural disaster at one time, for this I have provided drop down slider bar so that user can also select his or her preference of natural disaster to compare. Implementation in the shiny app and shiny dashboard was same as I did in above tabs, similar I have added some text for the narration. I made the plot interactive using 'plotly' library. This is how 'Effects tab' looks like after the full implementation.

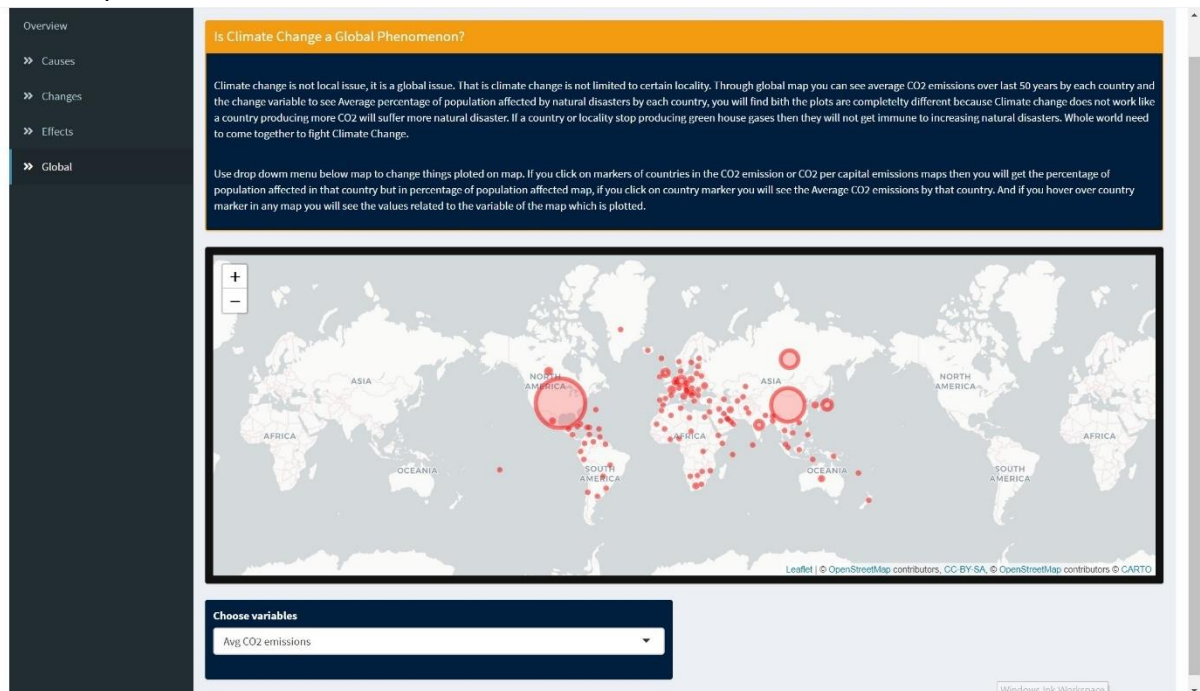


7. Last Tab is remaining and that is Global Tab. This tab is used to show how we can say that Climate Change is Global Phenomena. To show this I have considered Average CO2 emission in every country and Average percentage of population affected by natural disaster in that country. So that user or audience can compare and find out that if a country or any locality even stops producing CO2, still it is going to face increase in natural disasters because of other countries or locality are still producing CO2. To explain this, proportional symbol map is best suited. Here audience can select which thing they want to plot on map such as Average CO2 emission by each country or average percentage of population affect by natural disaster. Since few people can think about, countries with big population are going to produce more CO2 therefore it is hard to compare with the percentage of population affected by increasing natural disaster with Average CO2 emissions by country. To solve this problem, I have also added CO2 emission per capita by each country. Now, we have three global maps with circle marker and radius of each circle marker shows the magnitude of variable plotted on that map. Instead of plotting these maps adjacent

to each other I have provided a drop-down slider to select which variable audience want to plot on same map and compare them.

This is implemented using 'leaflet()' library. Also, I need to install Maps for this. In shiny app, implementation was done with 'leafletOutput()' and 'renderLeaflet()' functions.

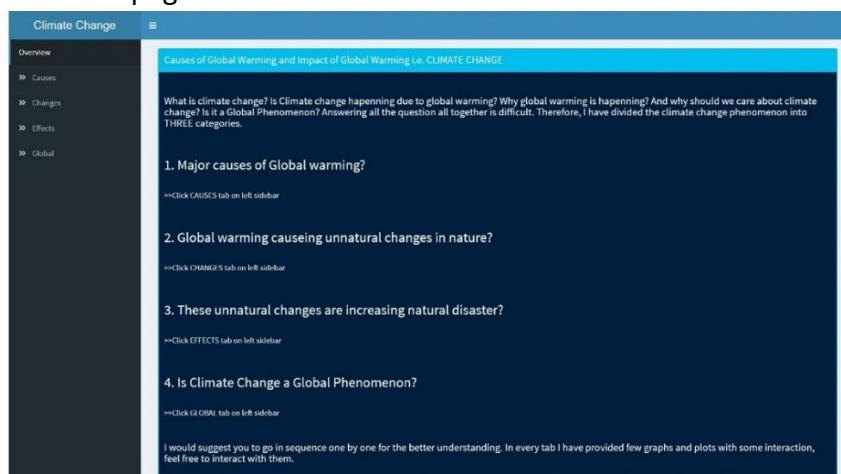
After implementation, Global Tab looks like this:



## User Guide

Instructions for viewing and exploring my narrative visualisation are:

1. Open the Shiny Application.
2. Overview Page will come 1<sup>st</sup>, now user need to read all the information provided on the Overview page, it explains the project and tell user where user need to go next. Overview page looks like this:



3. As suggested by the Overview page, user need go to the 'causes tab', which is on top left corner. User can also click and go to other tabs but it is not recommended, user should visit tabs one by one in a sequence for the better understanding of the questions and their answers.
- Select 'Causes tab' by clicking on it.

Climate Change

Overview

- » Causes
- » Changes
- » Effects
- » Global

### Causes of Global Warming and Impact of Global Warming i.e. CLIMATE CHANGE

What is climate change? Is Climate change hapenning due to global warming? Why global warming is hapenning? And why should we care about climate change? Is it a Global Phenomenon? Answering all the question all together is difficult. Therefore, I have divided the climate change phenomenon into THREE categories.

1. Major causes of Global warming?  
»Click CAUSES tab on left sidebar
2. Global warming causeing unnatural changes in nature?  
»Click CHANGES tab on left sidebar
3. These unnatural changes are increasing natural disaster?  
»Click EFFECTS tab on left sidebar
4. Is Climate Change a Global Phenomenon?  
»Click GL O B A L tab on left sidebar

I would suggest you to go in sequence one by one for the better understanding. In every tab I have provided few graphs and plots with some interaction, feel free to interact with them.

4. Now, the causes tab is open, here user will see some information about the plots in the tab and reason for this tab. User should read them and then look at the scatter plot below it. User can change the scatter plot by using the drop-down slider on the right side of the plot.

Climate Change

Overview

- » Causes
- » Changes
- » Effects
- » Global

### Major causes of Global warming?

According to science major cause of global warming are greenhouse gases. Now questions is which greenhouse gas is more correlated with increase in global temperature. Since global temperature is rising every year, this question becomes more important

To find out the correlation between Green house gas and global temprature anomaly I have plotted a scatter plot with data of annual temp anomaly and green house gas emission every year of last 50 years and also calculated the correlation between them. Don't forget to interact with the plot using controls given above the plot and see what pop up when you hover mouse on the plots.

#### Scatter plot with linear regression line, Green house gas type vs temp

Correlation = 89.31 %

temp

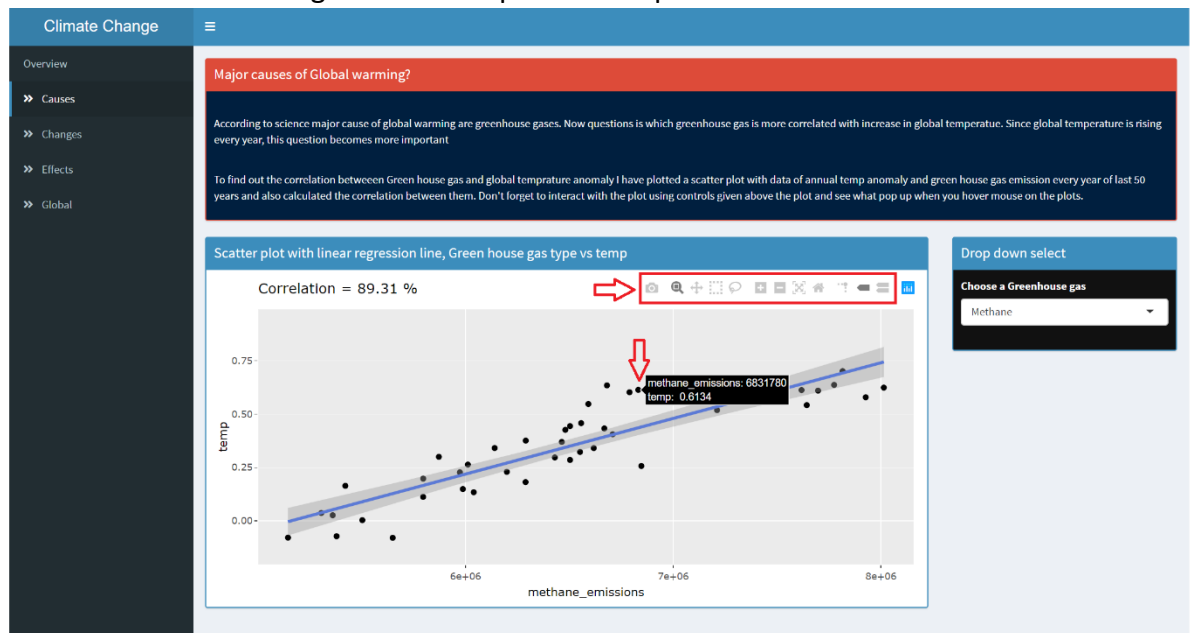
methane\_emissions

Drop down select

Choose a Greenhouse gas

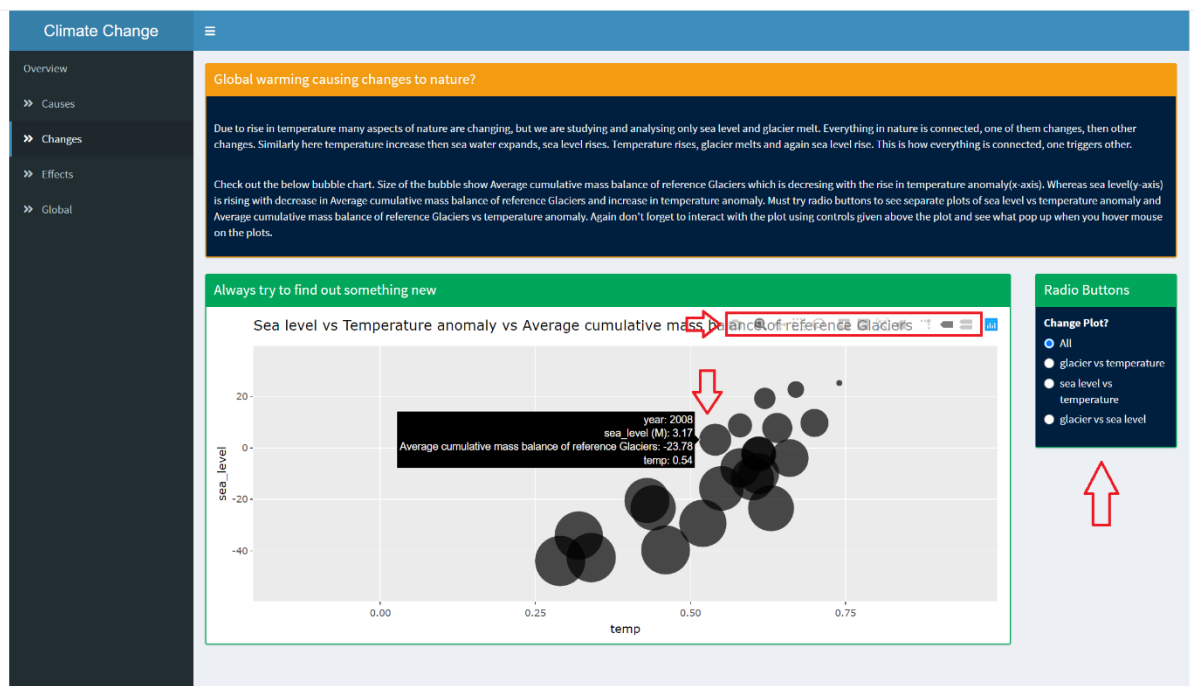
- Methane
- CO2
- Methane
- Nitrous Oxide
- HFC, PFC and SF6

- User can also interact with the scatter plots by hovering over the points and also by the interaction controls given at the top of scatter plots.

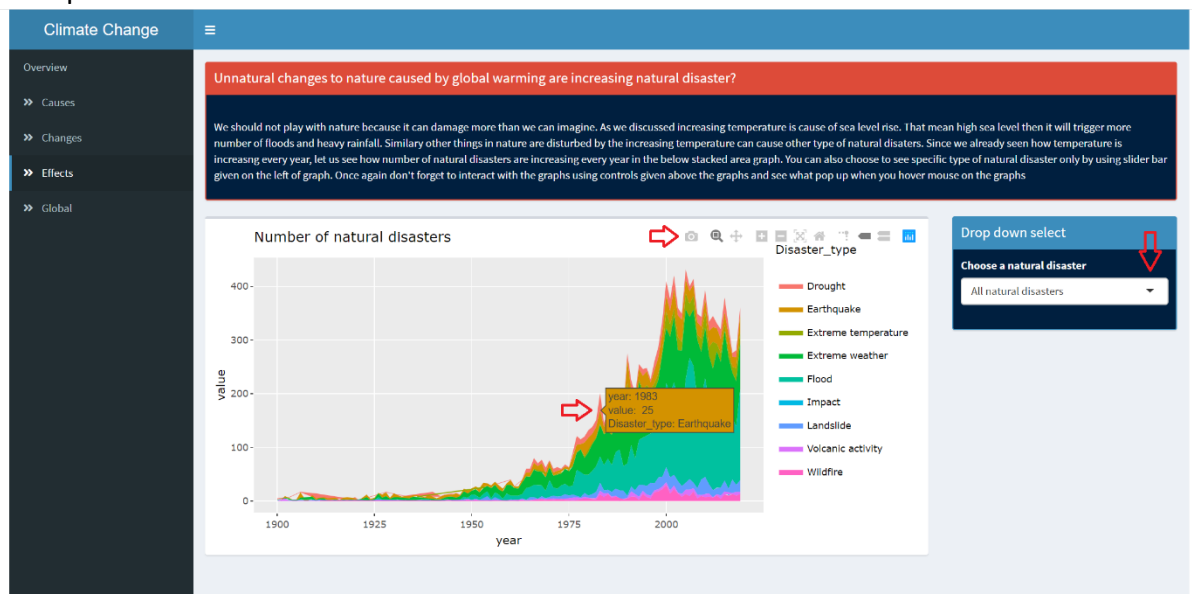


- Now user should go to the next tab which is 'Changes'. User can select the tab the same way he/she did while selecting 'Causes Tab'.

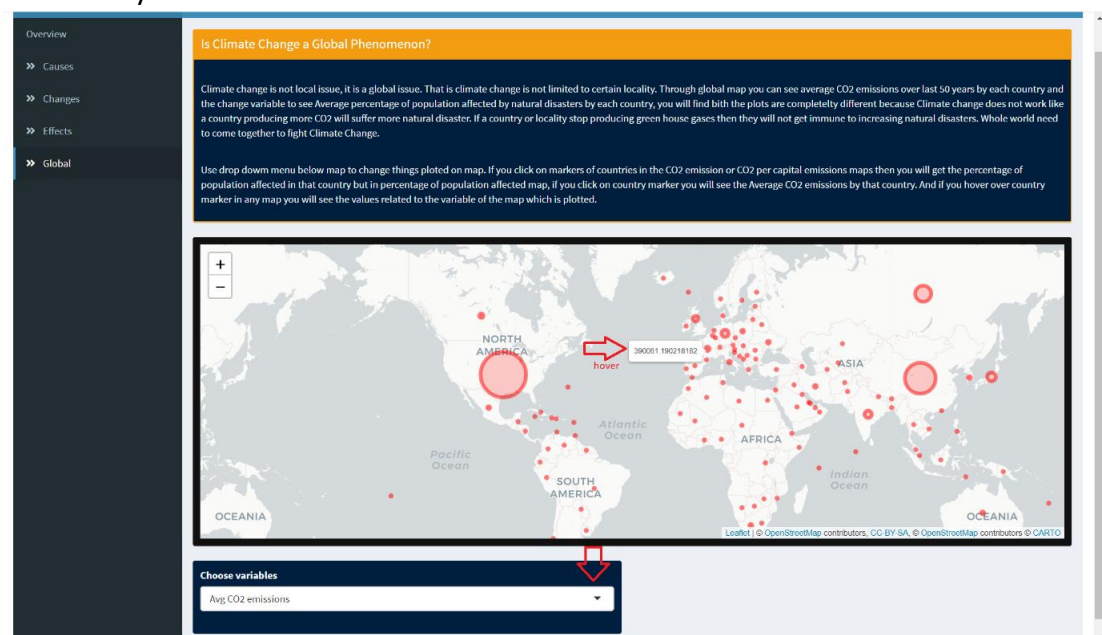
Here, similar design is given, just some changes instead of drop-down slider bar, I have given radio buttons. User can change plots using the radio buttons. User can interact with the plot by hovering over it and also using the interaction controls given above it. Here bubble scatter plot is provided so that user can see three variable and their correlation. Size of the bubble represents Average cumulative mass balance of reference Glaciers, x-axis and y-axis variables are clearly mentioned. Hover over the bubble and user will see the details related to that bubble.



7. Now, user should visit “Effects Tab”. Here everything is same as “Causes Tab” except instead of scatter plot stacked area graph are given. 1<sup>st</sup> stacked area graph show all the natural disasters, user can differentiate them by colours. Drop down slider bar is for change the plots to see individual natural disasters increase. User can hover over the stacked area graph to see three parameter 1<sup>st</sup> one is showing the year, 2<sup>nd</sup> is showing the number of natural disaster and the 3<sup>rd</sup> one showing the type of natural disaster. Again, user can use and explore the interactive control give on the top of each plot.

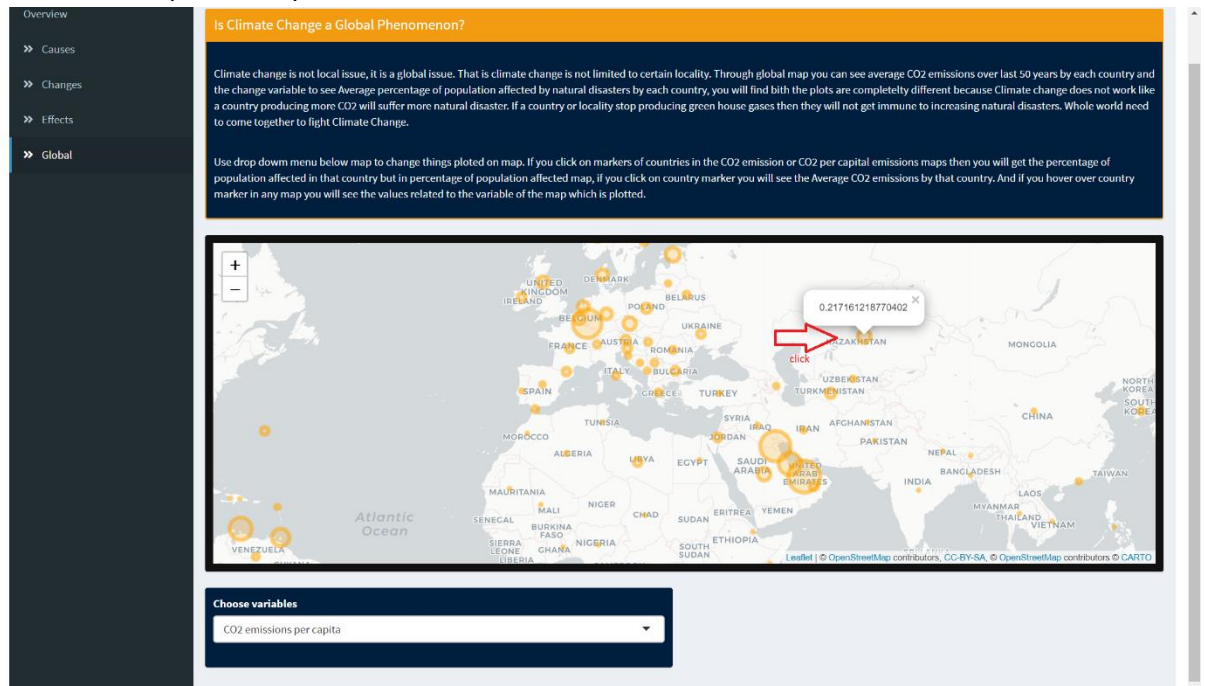


8. Last but not least, ‘Global Tab’. Here user will find a world map with all the countries. User will see the circular markers on each country. The radius of these circular markers is showing the magnitude of the value plotted on this map. Value plotted on the map is controlled by the drop-down slider bar given below the map. Here user can compare the average CO2 emissions by country and percentage of population affected by natural disaster in the countries.





When user hover over the circular marker, it will show the magnitude of the plotted variable but if user click the circular marker it will show percentage of population affected by the natural disaster if the plotted values are either Average CO2 emissions or Average per capita CO2 emissions, but if plotted value is percentage of population affected by natural disaster in the country then clicking on marker will show the Average CO2 emission by the country. User can also zoom in, zoom out and move the maps and explore it.



## **Conclusion**

In this project my findings are:

- What are the major causes of Global Warming, which greenhouse gas is more correlated with Global Warming?
- What unnatural changes occur to nature due to Global Warming?
- Consequences of above unnatural changes i.e. increase in number of natural disasters.
- Finally, I found out Climate Change is Global Phenomena. Whole world needs to come together and try to handle Climate Change.

In this project, I have learnt:

- Data cleaning using data frames in python.
- What are the good sources of data, if I have to find out data again for other projects.
- Plotting data in R using ggplot2 and plotly libraries.
- Creating interactive visualisations using R shiny.
- Creating well designed Shiny app using Shiny Dashboard library.
- How to improve visualisation so that it can become more appealing.
- Finding best visualisations to show clearly certain type of findings.
- How human visual system works.
- Report writing.

Hindsight I might have done differently to improve the result:

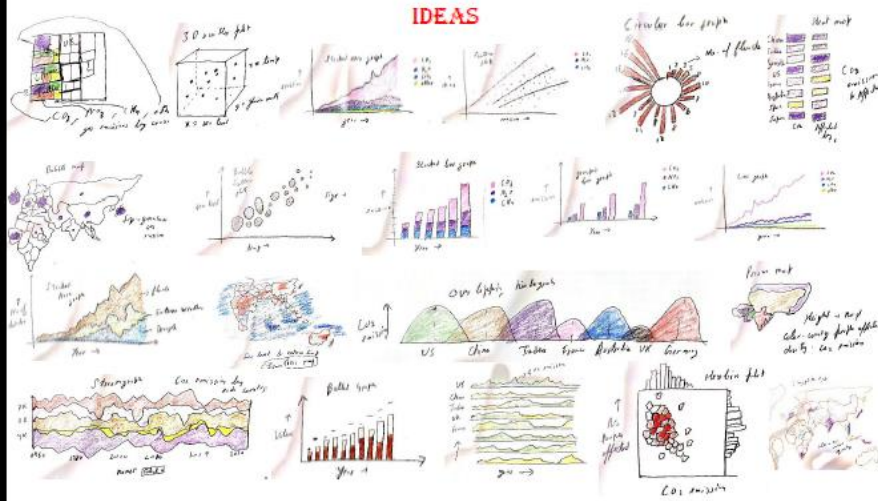
- I first started creating all the visualisations and after creating all of them I started implementing them in R shiny app. Unfortunately, every type of visualisations cannot be implemented using Shiny App or they are very difficult to implement. Huge amount of time could have been saved if I have implemented each visualisation directly in the Shiny App.

## **Bibliography**

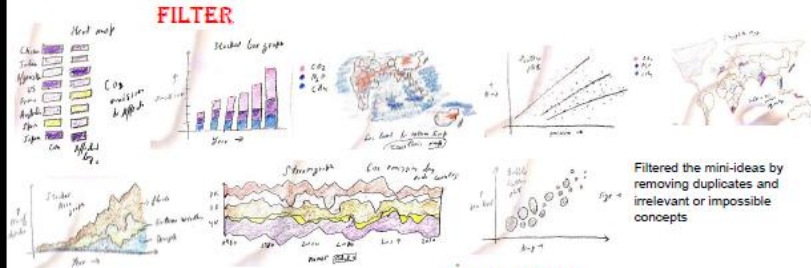
- Leaflet for R: <https://rstudio.github.io/leaflet/>
- Learn Shiny: <https://shiny.rstudio.com/tutorial/>
- Shiny Dashboard: <https://rstudio.github.io/shinydashboard/>
- ggplot2: <https://ggplot2.tidyverse.org/>
- Interactive web-based data visualization with R, plotly, and shiny: <https://plotly-r.com/>

## Appendix

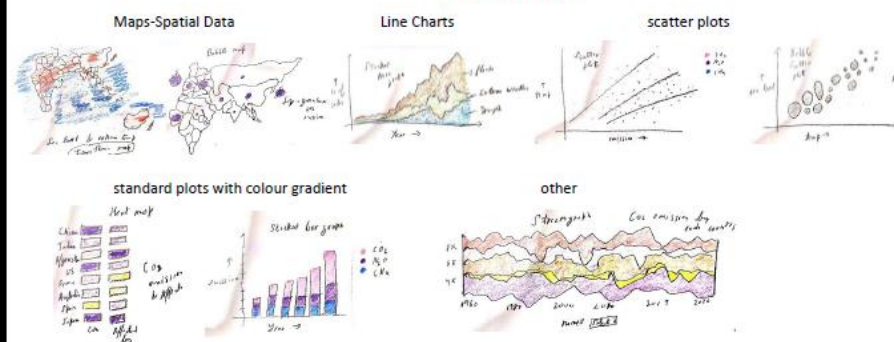
## IDEAS



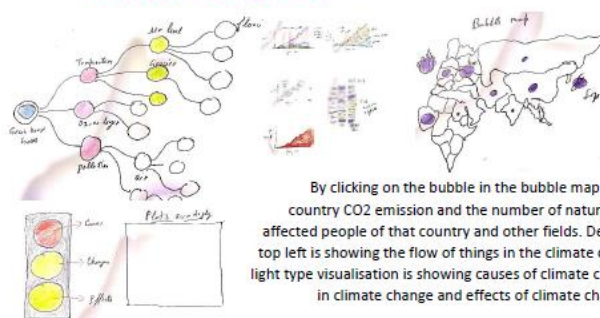
**FILTER**



## CATEGORISE



## COMBINE AND REFINE



By clicking on the bubble in the bubble map we see the country CO2 emission and the number of natural disaster and affected people of that country and other fields. Dendrogram on top left is showing the flow of things in the climate change. Traffic light type visualisation is showing causes of climate change, changes in climate change and effects of climate change.

## QUESTIONS

Q 1. Do the designs solve the original problem?

Ans: Each design partially solved some parts of the questions.

Q2. What are their advantages and disadvantages?

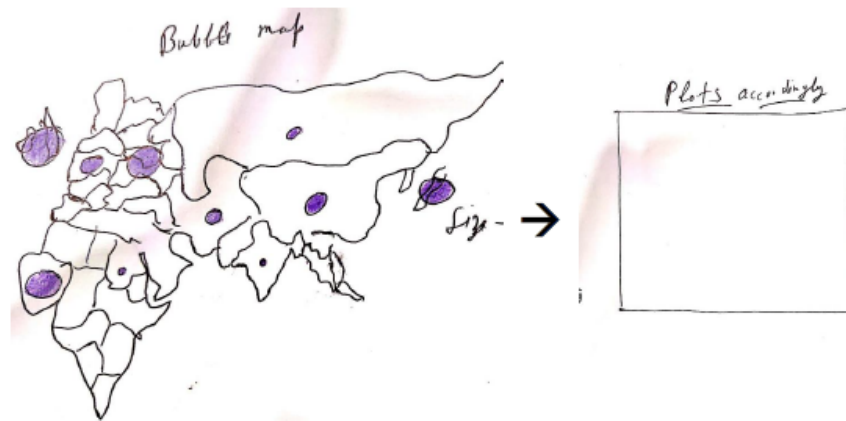
Ans: Each visualisation has its own advantages and disadvantages, will be discussed in details in the below sheets.

Q3. 3 ideas will be explored in more detail in Sheets 2,3 and 4.

Ans: Three designs Dendrogram, traffic light and bubble map will be explored I the sheet 2,3 and 4.

## Sheet 2: Alternative Design

### LAYOUT



### OPERATIONS

1. Select top 10: this will help the user highlight top 10 greenhouse gas emitting countries, affected by disaster countries etc.
2. Select Specific countries: This help in selecting desired countries only.
3. Year selector: This will help in selecting data for required number of years only.

### FOCUS AND ZOOM

1. Click on bubble will show the graphs and plot of that country which are related to greenhouse gases emission, Temperature rise, natural disasters and people affected etc.
2. Hover on bubble will show the total CO2 emission and the total number of natural disasters in that country.
3. Select Bubbles will show that stats comparing those selected countries in climate change.

### DISCUSSION:

#### Why bubble map?

Because in bubble map we can clearly see the data according to countries and also since it is a global map then we can see data globally as well. World map because climate change is a global phenomenon.

#### Plot on Right side?

Plots will come on right side of screen so that user can easily see stats and graphs according to the countries selected by him/her.

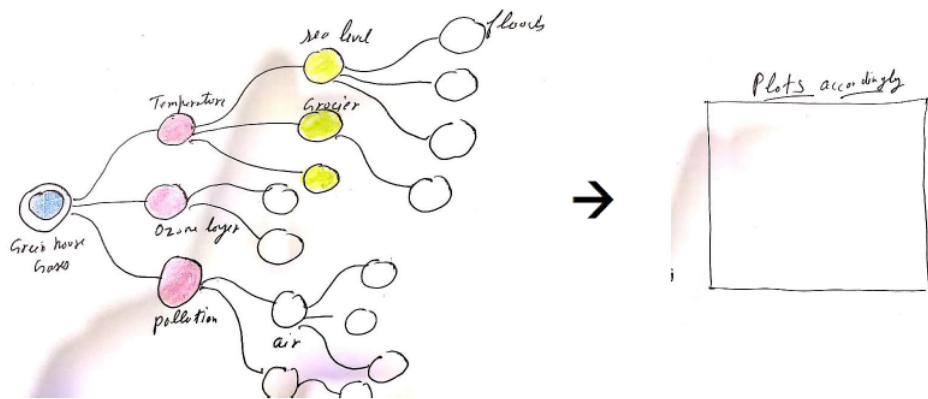
#### Advantages:

1. Data can be filtered by countries and the user can see which countries are connected to sea and other countries, location with respect to equator and many other things in the map to conclude about the natural disasters prone countries and connected countries to the high greenhouse emitting countries.
2. Plots will come on right side of screen so that user can easily see stats and graphs according to the countries selected by him/her.
3. Select Bubbles will show that stats comparing those selected countries in terms of climate change. And also multiple select compares the data in the countries.

#### Disadvantages:

1. Not able to show the bigger picture and the conclusion of the research question.
2. Quite challenging to make all this type of aggregation functions such as selecting countries, mouse hover changing years etc.

## LAYOUT



## OPERATIONS

1. **Filter years:** This will help in selecting data for required time period and then make the dendrogram according to the specific time period.
2. **Select countries:** dendrogram will be created according to the selected countries.
3. **Data filter for top 10:** this will help the user to see the data graphs and plot only of the top 10 countries causing and facing climate change.

## FOCUS AND ZOOM

1. **Click on Nodes:** click on each node will give birth to several nodes connected by edges or branches.
2. **Double click on Nodes:** double click on node will show the plots and graphs which will help the user to understand how the node gives birth to the other nodes.
3. **Select and highlight the connected nodes:** to see the flow of cause and effects, user can select the nodes and highlight them and the flow.

## DISCUSSION:

### Why dendrogram?

Because dendrogram help in seeing the flow of things happening in climate change.

### Plots area and the filters?

Plots will come on right side of screen so that user can easily see stats and graphs according to the nodes selected by him/her. Data filter for top 10 will help the user to see the data graphs and plot only of the top 10 countries causing and facing climate change.

### Advantages:

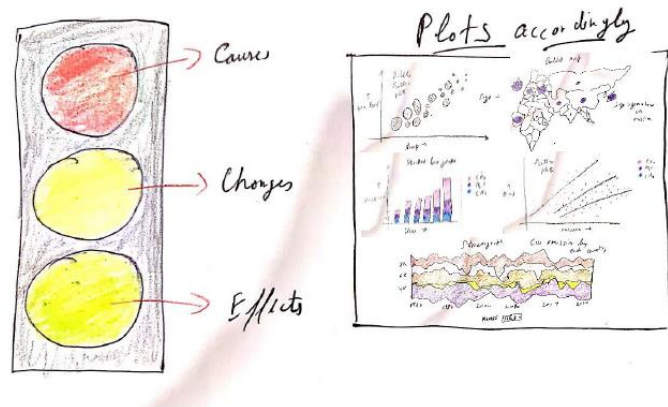
4. Better understanding of flow of things happening in climate change.
5. User can easily see stats and graphs according to the nodes selected by him/her. This will help him/her understand the reason for the nodes connect and its creation.
6. Able to show the bigger picture and the conclusion of the research question that is climate change.

### Disadvantages:

3. Hard to see the countries wise data. And also, user cannot select and aggregate data for the specific set of countries.
4. Challenging to make all this type of dendrograms according to the filters and sometimes wrong connection of node can be seen if user select unusual filters.



## LAYOUT



## OPERATIONS

1. **Selective plots:** select only plots of any pair from causes, changes and effects.
2. **Adjustable time period:** This will help in selecting time period and then show the causes, changes and effects of climate change in that particular time period.
3. **Select countries:** This will help in selecting countries and then show the cause, changes and effects of climate change according to the data from those particular countries.

## FOCUS AND ZOOM

1. **Click on lights:** click on each light will show graphs and charts based on that light. For example, if user select red light then only plots and graphs related to red light (i.e. causes).
2. **select the lights:** to see only the graphs and charts based on that lights.

## DISCUSSION:

### Why traffic lights?

Because traffic lights are easy to understand by general public. They are clearly specifying cause, changes and effects by the climate change.

### Plots changes according to the light selected and the filters?

Plots will change as the user select lights there a smaller number of plots will be visible to user so that user will not get confuse or intimidate after see so many plots and graphs all together.

### Advantages:

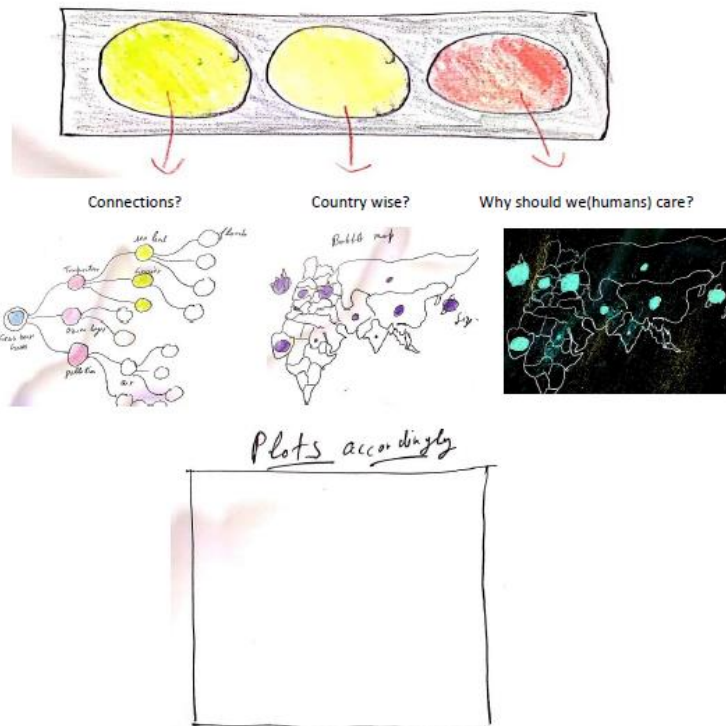
7. Easy to use and understand different areas in climate change.
8. User can easily see plots and graphs according to the lights selected by him/her. This will help him/her understand the causes, changes and effects of climate change.
9. Able to show different areas of the research question and hence user can make conclusion after combining all the areas of research question.

### Disadvantages:

5. Less number of filters available for example no filter is available to see countries wise data.
6. Hard to see the bigger picture and conclusion to the research question if the user is not smart.

## Sheet 5: Realisation

### LAYOUT



### DESCRIPTION

#### Operations

1. **Adjustable time period:** This will help in selecting time period and then show the three tabs of connections, country wise and why should we care of climate change in that particular time period.
2. **Select countries:** This will help in selecting countries and then show the three tabs of connections, country wise and why should we care of climate change according to the data from those particular countries.

Interaction will be divided into three parts:

- **Connections shown by dendrogram graph.**
  - **Click on Nodes:** click on each node will give birth to several nodes connected by edges or branches.
  - **Double click on Nodes:** double click on node will show the plots and graphs which will help the user to understand how the node gives birth to the other nodes.
  - **Select and highlight the connected nodes:** to see the flow of cause and effects, user can select the nodes and highlight them and the flow.
- **Country wise by bubble map.**
  - **Click on bubble** will show the graphs and plot of that country which are related to greenhouse gases emission, Temperature rise, natural disasters and people affected etc.
  - **Hover on bubble** will show the total CO2 emission and the total number if natural disasters in that country.
  - **Select Bubbles** will show that stats comparing those selected countries in climate change.
- **Why should we care by bubble map with isarithmic map of sea level change and extreme weather?**
  - **Play button for animation:** this animation shows animation of sea level rise and extreme weather over the years
  - **Hover on bubble** will show the total CO2 emission and the total number if natural disasters in that country.
  - **Select Bubbles** will show the plots and graphs of natural disasters and number of people affected of those selected countries due to climate change.

### SOFTWARE REQUIREMENTS:

R, RStudio, ggplot, shiny, leaflet and many plotting libraries in R.

### ESTIMATES OF COST, TIME ETC

Cost will be not high but it will take a lot of time because of creating customised interactive user interface is going to take a lot of research work and need to learn and combine many things. And the aggregation functions create sometime, need a lot of data wrangling also which can increase cost but cost will be less in front of time taken.