

Analysis of Worldwide Large Flood Events

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Introduction

At the end of August this year, a historic flooding has devastated the southern part of Louisiana killed 13 and displaced thousands. Earlier in June, another tragic flooding accident happened at Fort Hood, Texas and brought 9 soldiers to death. Deaths due to flooding are all around us and leave properties of people living in river regions unprotected. In fact, according to the recent research released by NSSL (The National Severe Storms Laboratory), flash flooding, as a worldwide hazard, has become the number one hazardous weather related killer in the United States. The risk of flooding and its hazardous effects inspired us to do our final project on world flood events and to explore recognizable patterns of evolution of these floods. We acquired our dataset from the Dartmouth flood Observatory at the University of Colorado. It is a data set actively recording large flood events around the world in the past 30 years, and details of the floods are derived from a wide variety of news and governmental sources. The time range we are interested in for our project is from Jan 1, 1985 to Oct 9, 2016, which contains 4411 records for 31 variables.

In our final project, we focused on seasonality, severity, causation and consequences of floods to find interesting trends in the patterns of floods around the world.

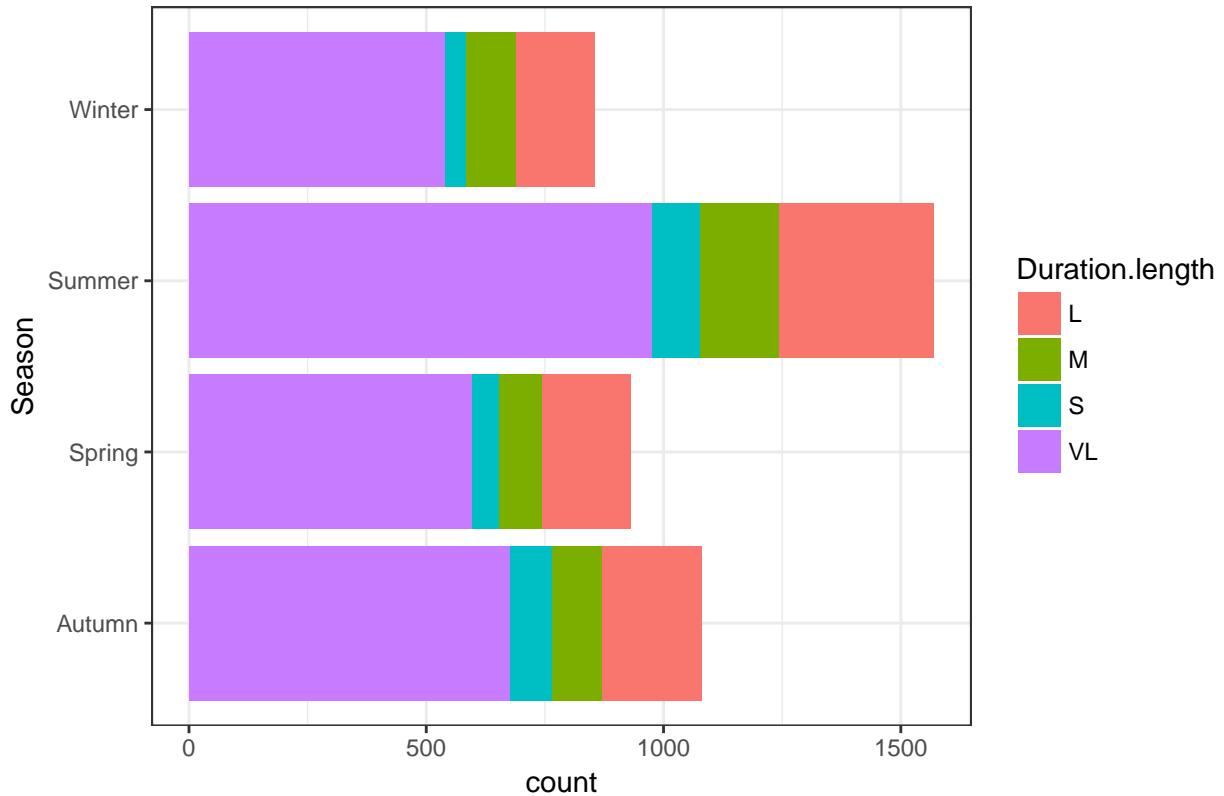
Part 1: Evolution of flood Since 1985

1. Seasonality

For the 21 years of flood data, we divided twelve months into four seasons: December to February as the winter, March to May as Spring, June to August as summer and September to November as autumn. For a better visualization, we also divided the flood duration days (with minimum 1 day to maximum 111 days' flood) into 4 different categorical levels. Duration days less than a week are assigned to group "S", which stands for "short" duration; flood with duration days from 1 weeks to 3 weeks are assigned to group "M", which stands for "medium length flood"; flood with duration from 3 weeks to 5 weeks as group "L", which stands for "long duration flood" and flood longer than 5 weeks are group "VL", which is "very long duration flood".

We plot a summary graph as below:

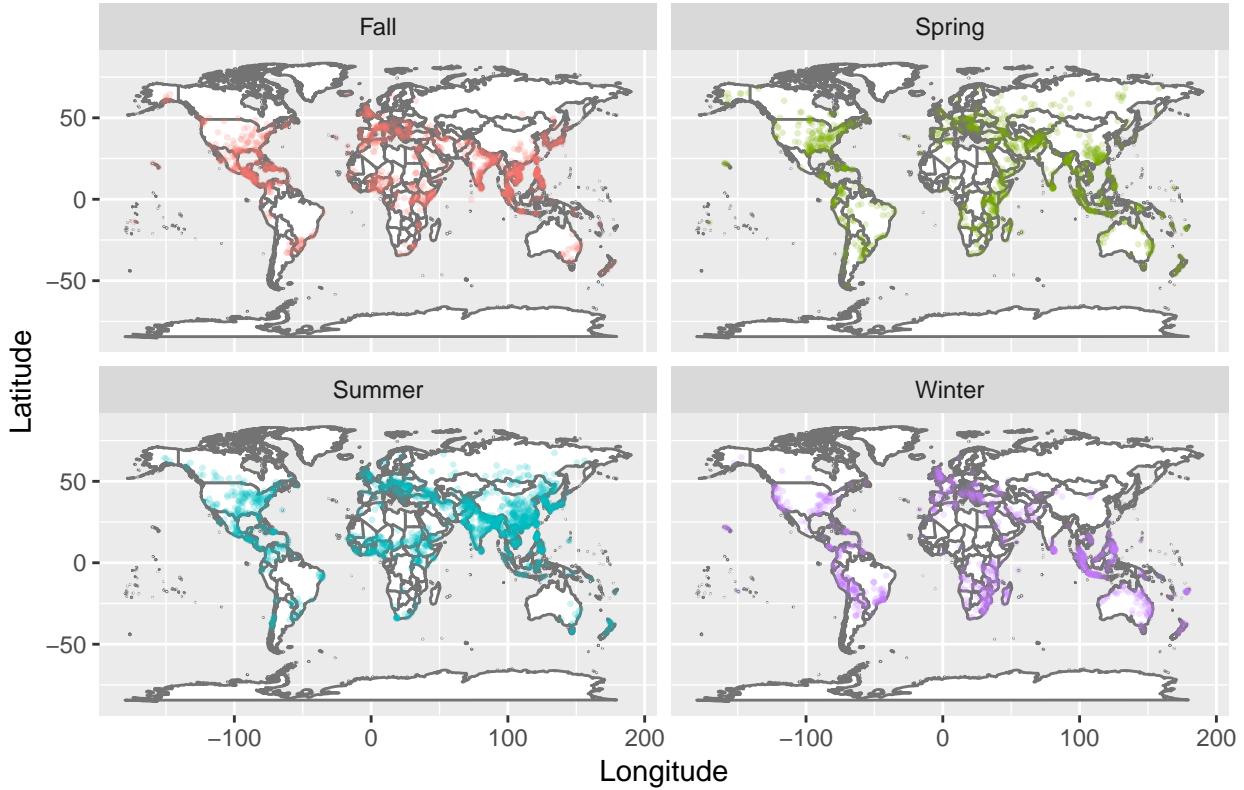
flood seasonality and duration



Based on the graph, we could see the summer is the time when most of the flood are happening, the total counts of flood happened during the summer is around 1500 in the past 21 years. Winter and spring time faced relatively less flood hazard when compared to summer. Based on our graph, the summer is more vulnerable to flood and within the large number of flood happening in the summer, there are larger portion of them are long and very long flood in duration.

On a graphical map, we will analyze the variation in floods around the world by the season in which they occur:

Floods Around the World by Season



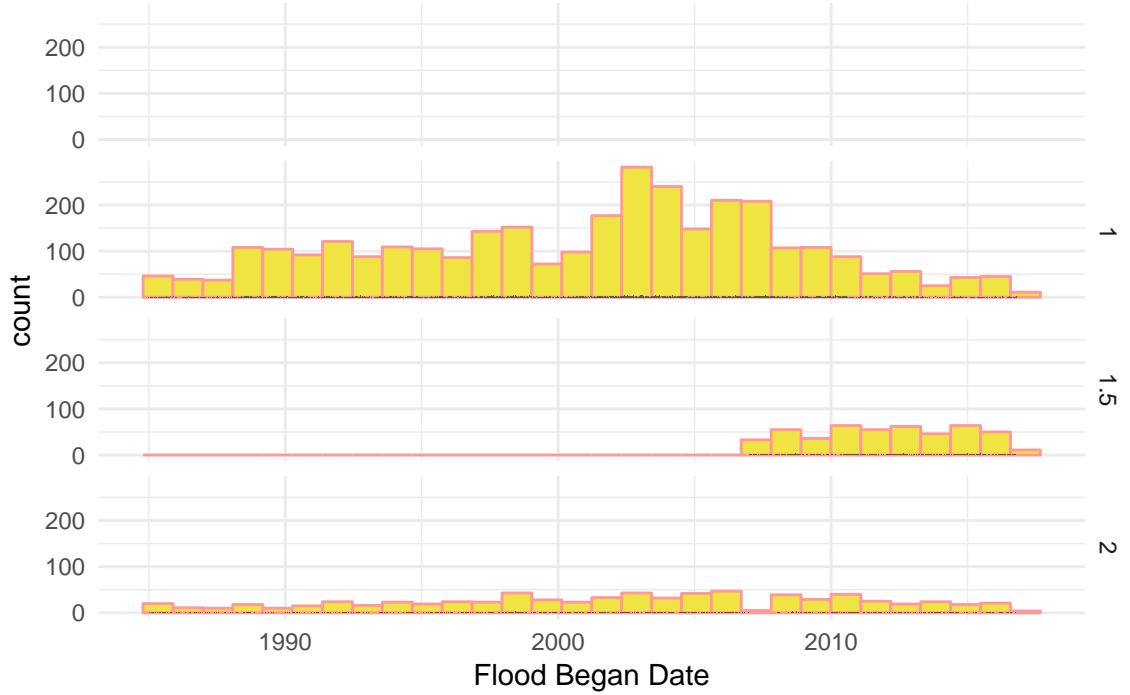
The above map reflects how floods vary by the season in which they occur around the world. There are several interesting trends in the way location corresponds to different seasons of flooding. Summer floods (during the months of June, July, and August) are concentrated near the equator, and there are high amounts in Asia. Winter floods (during the months of December, January, and February) are concentrated in the Southern hemisphere. This makes sense given that Summer and the rainy season occurs during these months in the Southern hemisphere. There are noticeably more floods during Fall months (September, October, and November) in Central America and Europe. Hurricane season for the North Atlantic takes place during these months, which explains the concentration of floods near the Caribbean during this season.

2. Severity

According to the definition from our data source, the severity class 1 floods include large flood events that cause significant human and economic damage with an estimated recurrence period of 10-20 years. Severity class 1.5 floods contain very large flooding events whose return period is greater than 20 years but less than 100 years. Finally, the severity class 2 includes truly extreme events, with an estimated recurrence interval equal to or greater than 100 years.

To analyze the severity patterns of the historical flood events, we first plotted out the severity levels on the hori-

Severities by Years

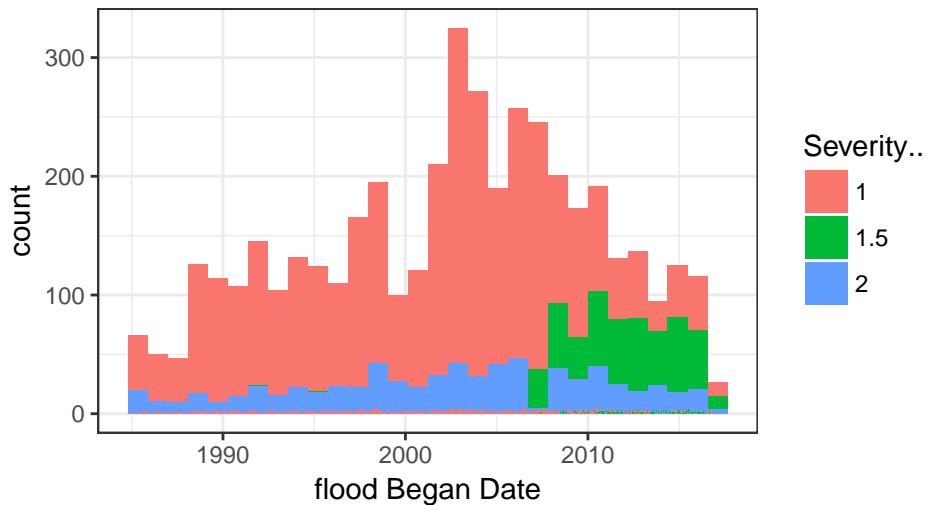


zontal timeline:

From the graph above, we see that for different years, the number of floods with different severities seems to move in the same direction: when severity 1 floods are at their peak, the number of severity 2 floods is also climbing. But there is one exception that for the year of 2007, the occurrence of severity 2 flood reached its minimum, but the occurrence of severity 1 floods are not surprisingly rare. Our guess is that this may caused by the first occurrence of severity 1.5 floods. Maybe there are some severity 2 floods relabeled as severity 1.5 started from 2007, hence the count decreased for the year of 2007.

For a better visualization of flood evolution pattern in the past 30 years, we plotted another histogram where we compiled all the severity classes together:

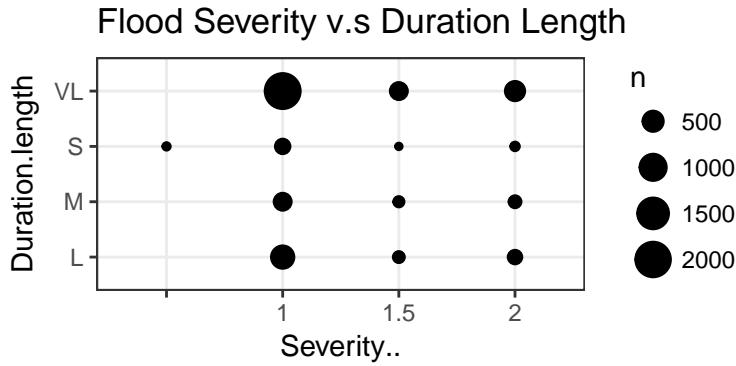
Severity Across Years



From the plot above, we could clearly see that floods with severity 1 are the most common flood type across

years. The histogram also indicates that the total number of floods was climbing to its peak at around 2003 and started going downhill after 2003. The number of floods in the first 10 months of 2016 came to be a historical minimum.

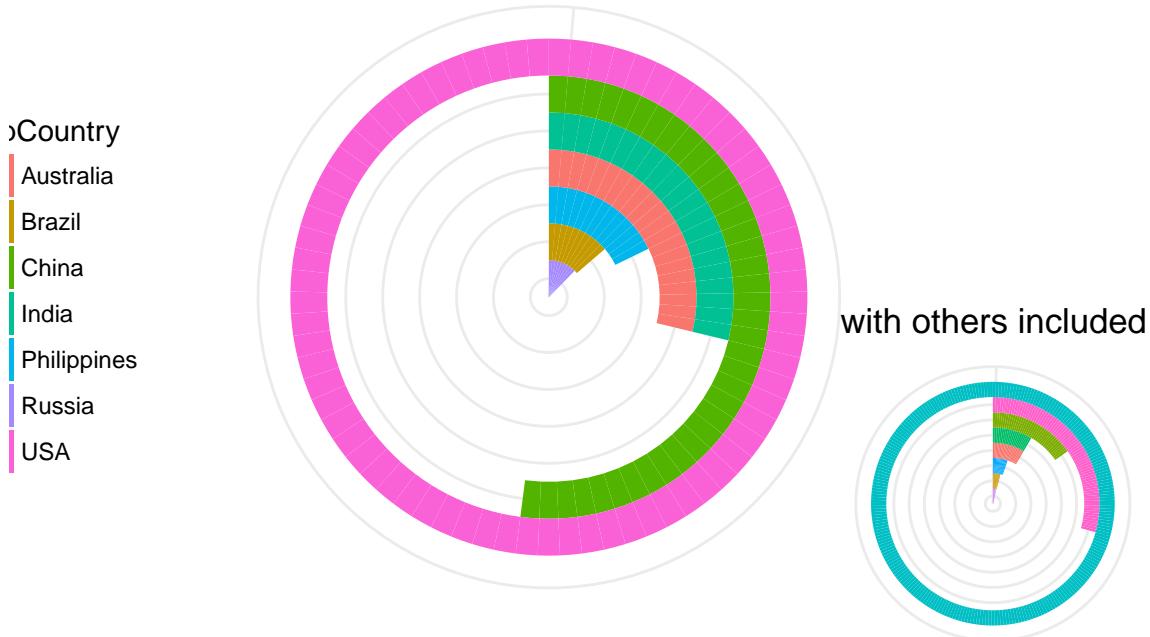
In order to provide a more sensible measurement on flood magnitude, we look at another dimension of flooding, which is flood duration and plot the graph as below:



Extreme floods with very long duration length will bring more tragic damage to the local economy and people's safety. Luckily enough, according to our summary graph above, the most common flood type in the past 30 years is the very long lasting floods which are not disastrous in terms of severity. At the same time, the least common type of flooding has medium severity and short duration.

The graph below shows the top countries vulnerable to the most common very long but not very severe floods:

Long & Severe floods Among Countries

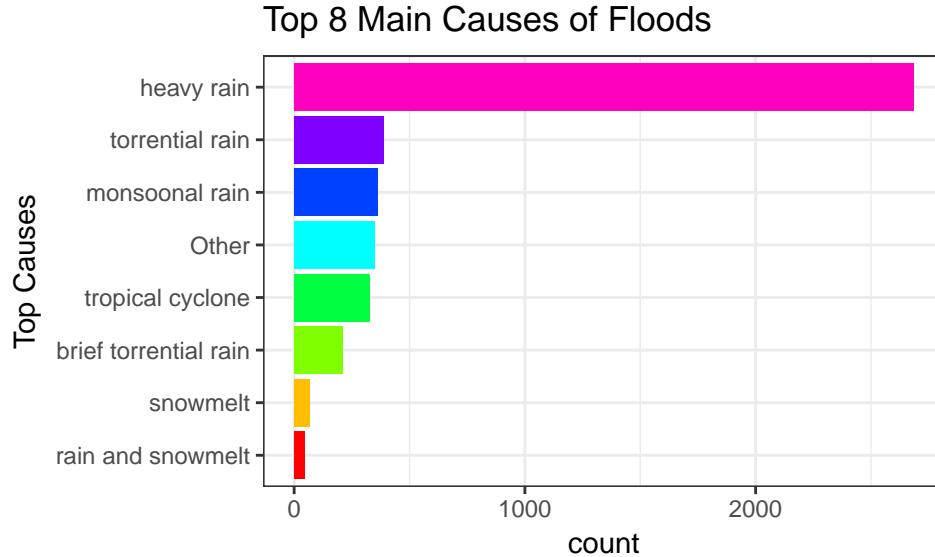


The bottom right plot displays the top 8 countries where long and severe floods are frequently occurring. It is not very surprising that there are still a lot more countries other than the top 8 have suffered from long and severe floods in the past. Hence after recategorizing the countries, the group "Others" is ranked as No.1 for the having the highest frequency of long & severe floods.

After taking out countries labeled as “Others” and only looking at the top 2-8 countries with most frequent long and severe flooding events, we could see USA ranked as the top. The No. 3 country China only equals about half of the number of the USA’s very long & not very severe floods. Philippines has only half of the number of China and one quarter of the USA.

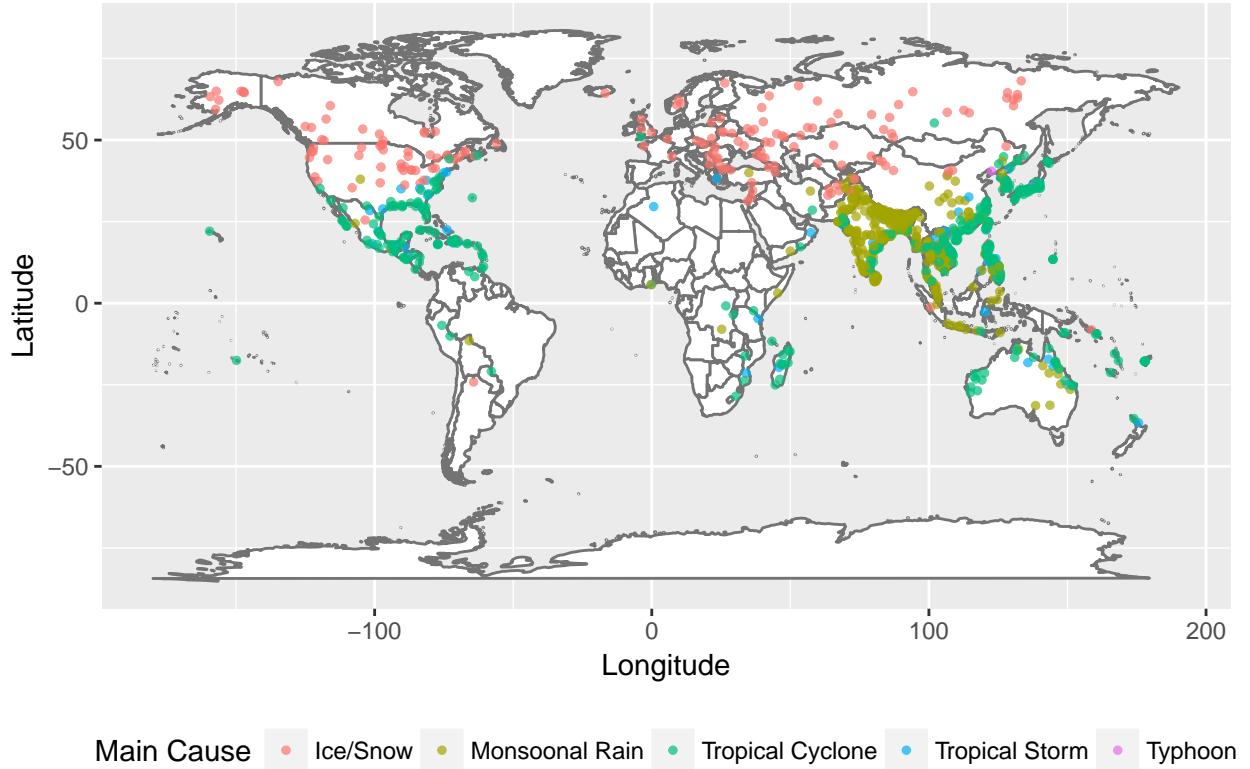
3.Causation of Floods

Next, we focus on analyzing different causes of floods to see if there are any pattern exists in the historical flood evolution events.



As showed by the histogram, heavy rain is the dominant cause for the flood evolution in the past 30 years, followed by torrential rain, then monsoonal rain. Geographically, we can see the distribution of floods by cause in the following map.

Floods Around the World by Cause



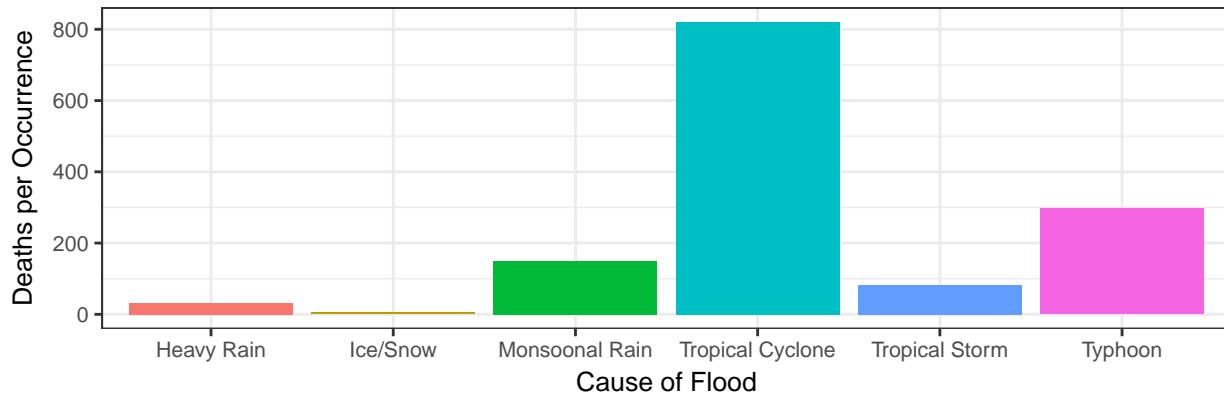
This map plots latitude and longitude of each flood on the world map with color varying by cause of the flood. The floods caused by heavy rain were removed because they were evenly distributed across the world and so great in quantity that they obscured the other types of flooding. There are more floods caused by ice or snow in Northern North America and Russia, which makes sense given the cooler climates in these regions. Floods caused by tropical storms occur near the equator around the Caribbean, in Southeast Asia and Australia. Floods caused by monsoons dominate in India, but are relatively uncommon in the rest of the world.

Part2: Consequences of Floods

In this section, we aim to analyze the impact of different types of flooding on people around the world. We look at the number of people displaced and killed per flood in order to get information about which floods are most damaging, and which countries deal with floods most efficiently.

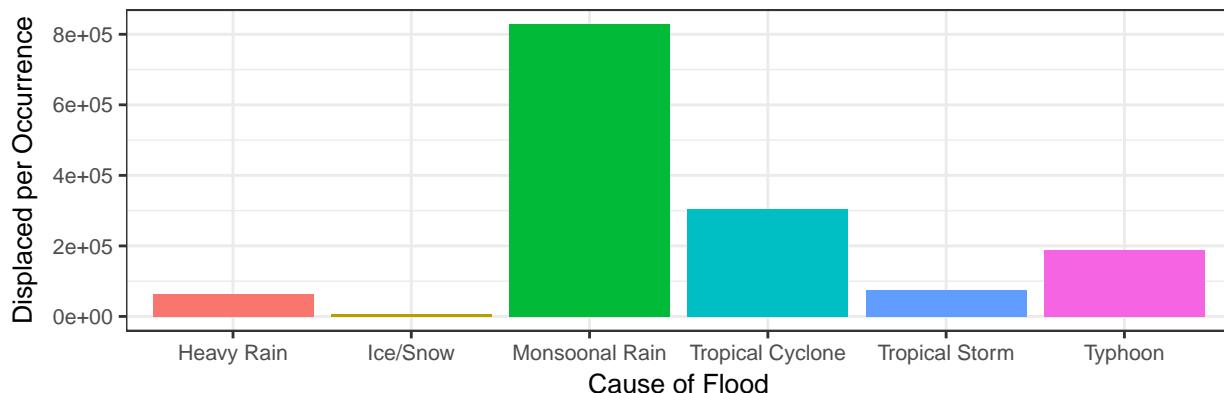
1. How do the number of people displaced and dead per flood vary by cause of flooding?

People Killed per Flood by Cause of Flood



The above bar plot shows the average number of people killed per flood for various types of flooding. Tropical cyclones were responsible for the most deaths per flood, followed by typhoons and monsoonal rain.

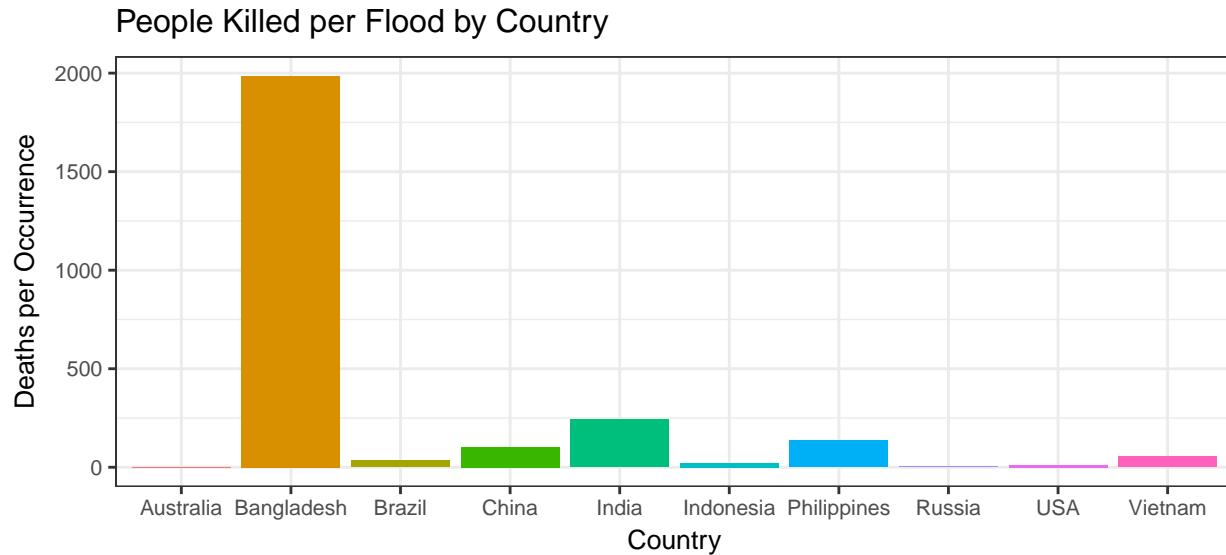
People Displaced per Flood by Cause of Flood



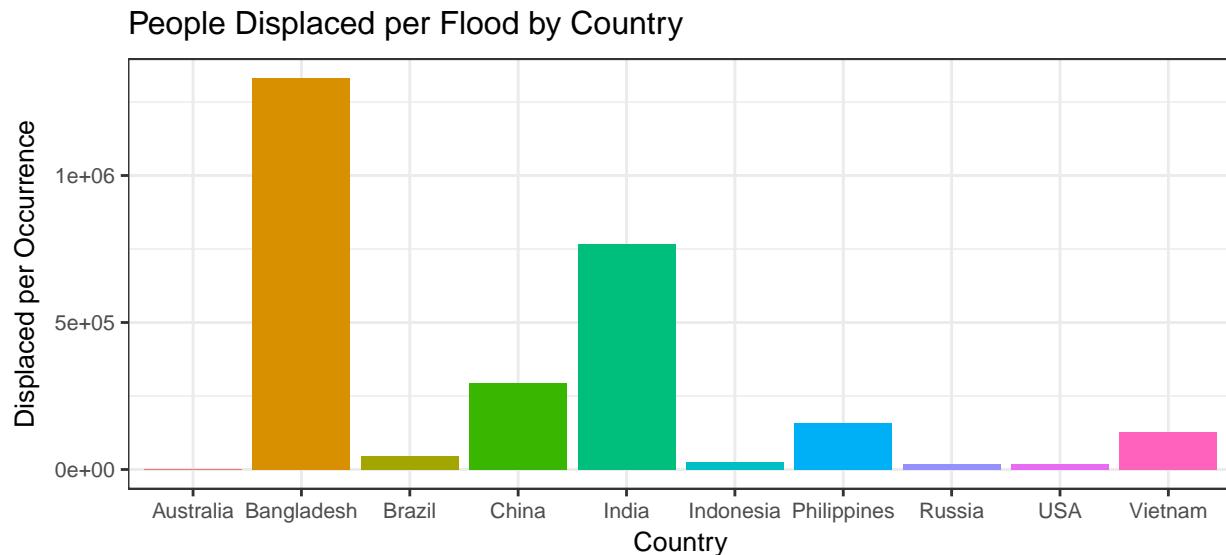
The above bar plot shows the average number of people displaced per flood for various types of flooding. Monsoonal rain had the most people displaced per flood occurrence, followed by tropical cyclones and then typhoons.

The differences between the above plots are interesting, because there is a discrepancy in the type of flood responsible for displacing the most people and the type responsible for killing most people. Both monsoonal rain and tropical cyclones are concentrated in areas of the world with very high and dense populations (India, Southeast Asia, and Central America). Monsoonal rain causes more displacements, while tropical cyclones cause more deaths. This suggests that monsoonal rains may affect a greater area, while tropical cyclones are more intense. The discrepancy could also come from the countries affected by each type of flooding, since they are distributed quite differently. Different infrastructure or safety systems in India, where monsoonal rain is concentrated, and Southeast Asia and Central America, where tropical cyclones are concentrated could lead to these differences as well.

2. How do the number of people displaced and dead per flood vary by country?



The above bar plot shows the average number of people killed per flood for the top ten countries with the most flood occurrences. We see that Bangladesh by far has the most deaths per flood at around 2000. India, the Phillipines and China follow with between 100 and 250 deaths per flood. Australia, Russia and the USA have very low deaths per flood.



The above bar plot shows the average number of people displaced per flood for the top ten countries with most flood occurences. There are many similarities to the plot of people killed per flood above. Bangladesh, once again has the most people displaced per flood, followed by India and China. Australia, Russia and the USA have the lowest numbers of people displaced per flood.

These two plots show that Bangladesh has very poor flood safety systems because it has the highest numbers of people killed and displaced per flood. Australia, Russia and the USA most likely have good infrastructure for flooding because they have the fewest numbers of people killed and displaced per flood. The difference between the two plots is in the proportions of people killed and people displaced when you compare Bangladesh with India or China. The fact that India has around half Bangladesh's number of people displaced per flood

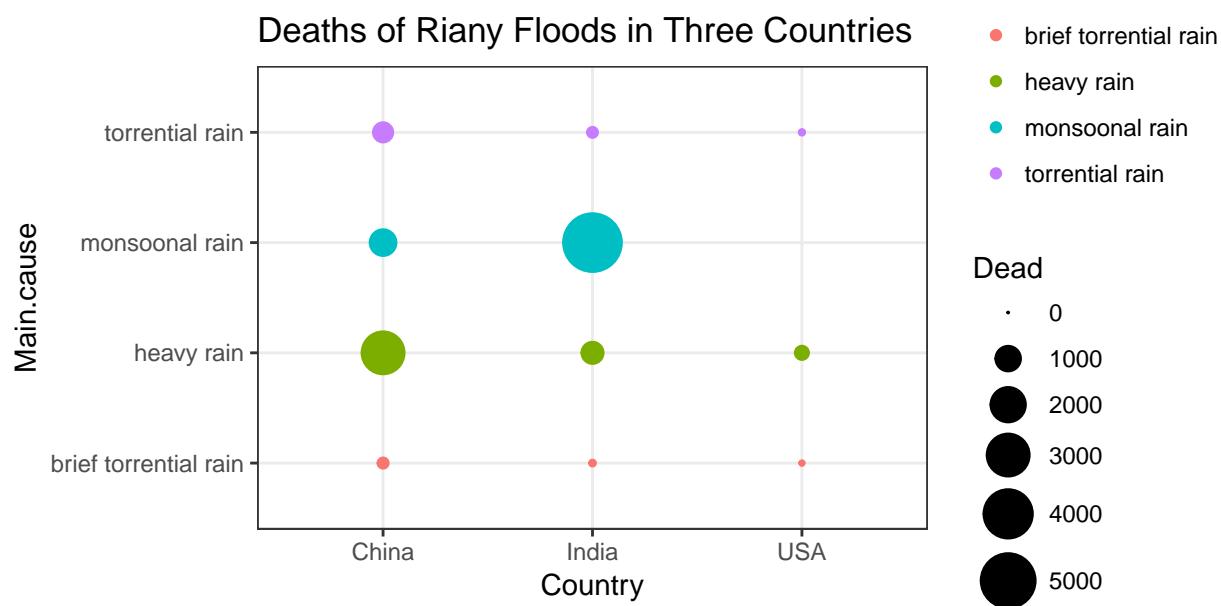
but a smaller proportion of people killed suggests that India may have better flood safety systems than Bangladesh in place that move people out of the flooding areas quickly so they avoid getting killed.

3. Consequences of Rainy Floods

Suggested by our previous summary on world's top causes for flooding, heavy rain, torrential rain and monsoonal rain has been causing the majority of flood events since 1985. Hence in this section, we focus on all the rainy causes for floods and explore whether different types of rain have brought different levels of consequences in the USA, China and India.

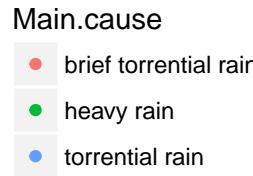
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## [1] "C"
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Main.cause	Dead_China	Dead_India	Dead_USA
brief torrential rain	495	45	85
heavy rain	21304	4120	1343
monsoonal rain	2666	25833	0
torrential rain	1082	380	213

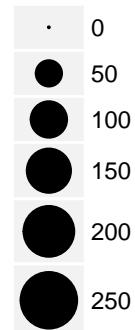


From the table and the plot above, we can see that the death numbers for all rainy causes in USA are much smaller than India and China. In China and USA, heavy rain causes the most fatalities, while in India, monsoonal rain is the top cause of flooding that causes fatalities. Our summary shows that there were no deaths caused by monsoonal rain in the USA even though the North American Monsoon is a significant meteorologic phenomenon in the southwestern United States and northwestern Mexico between July and mid September.

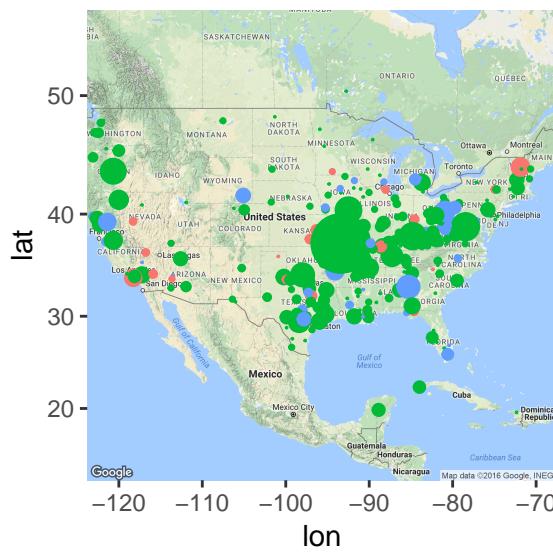
To analyze the fatalities caused by rainy floods in these countries, we plot the following maps to show the exact flood evolution in terms of location and number of deaths:



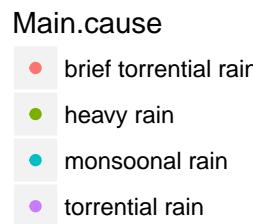
Dead



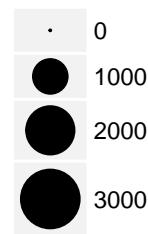
Death of Rainy Flood in USA



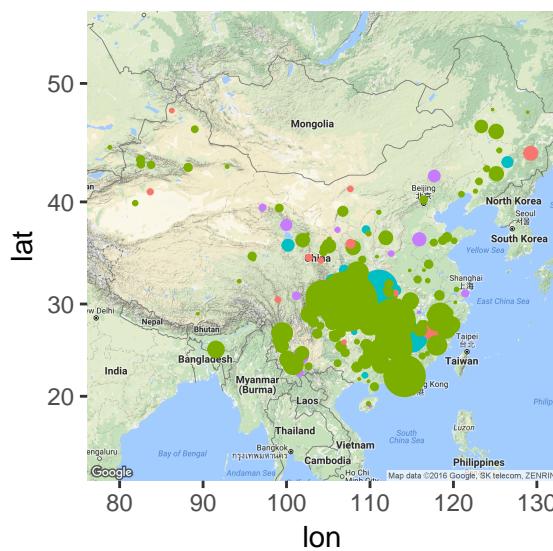
From the map of the USA, we see that eastern and southern parts of the country encounter the most floods caused by rain. These kinds of flood are rare in western (non-coastal) regions. Heavy rain is the most common cause for flooding in US and it also causes the most deaths. Missouri and Arizona are the two states with largest green dots, indicating most heavy rain caused deaths happened here.



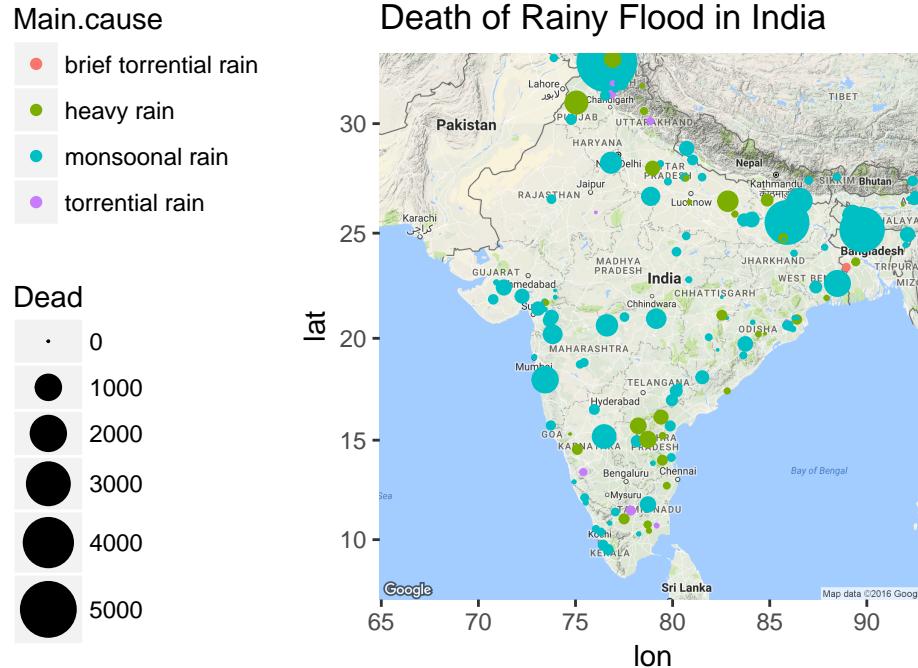
Dead



Death of Rainy Flood in China



From China's map, we can see that most floods caused by rains happened in the southern and central parts of China. Heavy rain is the most common cause of flooding and also causes the most fatalities, which is the same as the United States. Monsoonal rain takes the second place. We also recognize there are a lot of deaths caused by heavy rain happening in the downstream part of the Yangtze River. This also makes sense, because intense rain within short period of time will increase the risk of river overflow in this region. An notable disaster that happened in this region is the 1998 China Floods. It was a flood event caused by massive rains in the region of Yangtze River, Nen River and the Songhua River. 4150 people died because of this flood.



From India's map, we can see that monsoonal rain is the most common type of rain that causes floods, and is also the deadliest, especially in the northern regions. Heavy rain is also very common, but it causes fewer deaths than monsoonal rain.

Conclusion:

1.Seasonality

Based on our graphical analysis, most floods occur in the summer, and these floods have the highest proportion of long or very long floods. Geographically, summer floods are concentrated near the equator, while winter floods are concentrated in the Southern Hemisphere.

2.Severity

We found that very long but not very severe floods are the most common worldwide. Most of the very long and not severe floods happened in the USA, China, and India.

3.Causations and Consequence of Floods:

Heavy rain is the most common cause of flooding, while tropical cyclones are the deadliest type of flooding (most deaths per occurrence). Moreover, monsoonal Rain is the cause of flooding that causes the most displacement.

Geographically, tropical cyclones are common in Southeast Asia and Central America and monsoonal rain is prevalent in India. Our graphical representation also suggests that population dense areas leads to more people affected. Most floods caused by rain happen in eastern, southern and west coast regions of USA, in central and southern parts of China, and in northern and coastal regions of India.

4.Policy Implication:

As we finish up our project on analysis of worldwide large flood events, we come up with the following suggestions that may help researchers conducting futher research in this topic and protect people from flood hazards as much as possible.

- 1).** Improve flood forecasting ability and upgrade warning systems for tropical cyclones and typhoons, since they are the top 2 deadliest floods. With meteorological technology advancement, if extreme weather like cyclones and typhoons could be predicted and reported early enough, local goverments could displace people as needed before the storm comes. This may prevent more people from economic loss and life danger.
- 2).** Developing countries like India and China have many more fatalities than developed countries, which may be caused by the poor infrastructure and the lack of flood-related education in these countries. So we suggest developing countries invest more money on high-quality infrastructure buildings in flood hazard areas and provide proper education to their residents.
- 3).** Set up world standard for recording flood events so that scientists and the general public could have better access to actual flood magnitude. Because the flooding data set we are using is derived from a wide variety of news and governmental sources, the quality and quantity of information available about a particular flood is not always in proportion to its actual magnitude, and the intensity of news coverage varies from nation to nation. In general, news from floods in low-tech countries tends to arrive later and be less detailed than information from 'first world' countries. Hence, if a world standard of flood recording could be implemented, the data set would be more acurate and researchers could take better advantage of the available information.