Global Climate Change and Flooding

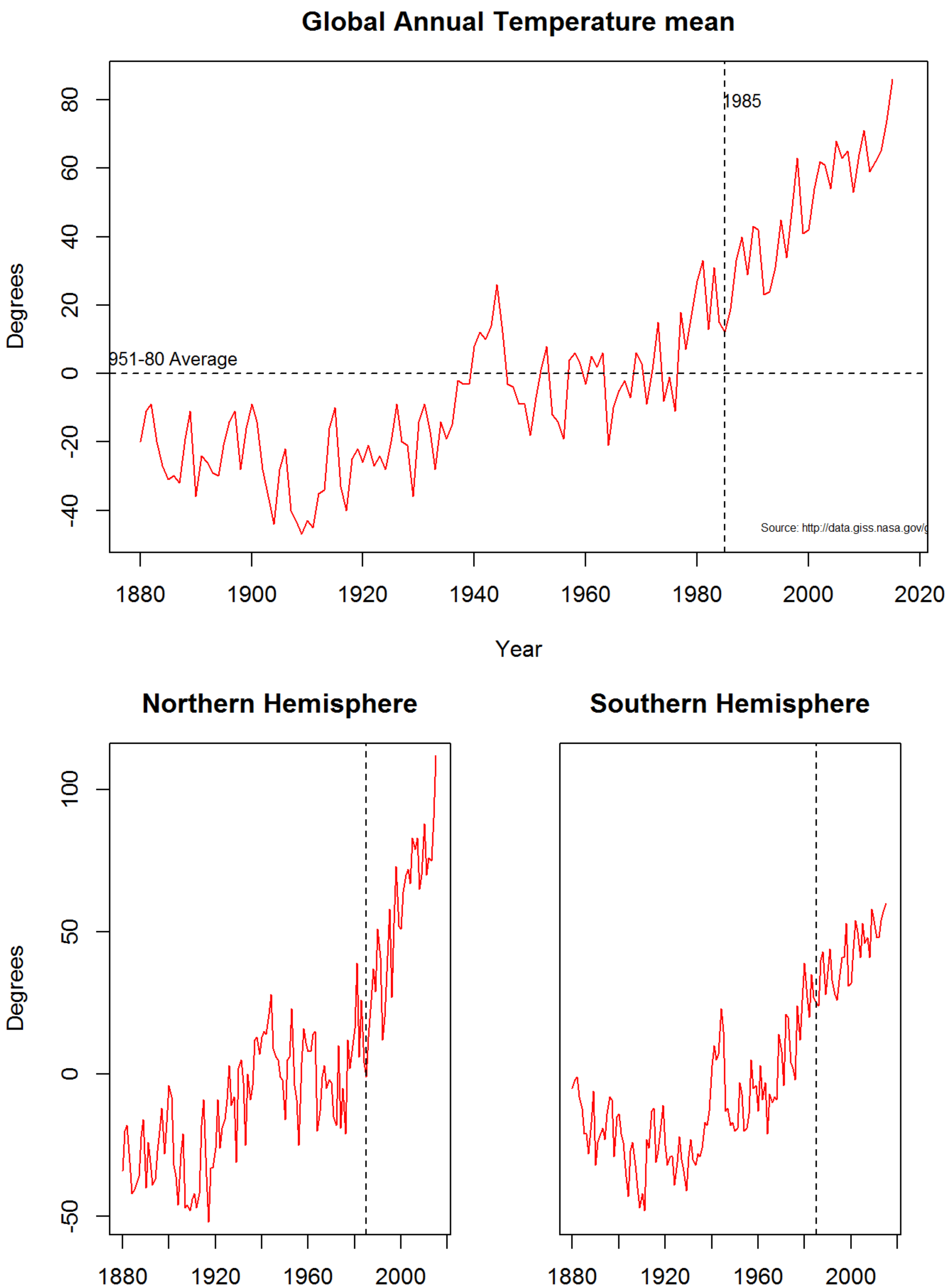
Team - Room Next Door

March 8, 2016

The Context of Rising Global Temperatures

Using global temperature data from NASA's Goddard Institute for Space Studies (http://data.giss.nasa.gov/gistemp (http://data.giss.nasa.gov/gistemp)), we wanted to investigate whether and how changes in global temperature over many decades affected changes in flood incidence. In the first plot, an average temperature baseline was drawn based on the years 1951 to 1980; clearly, the trend has been an inexorable march up, but it is telling that since shortly before 1980, the global annual temperature mean has never returned to that average.

In the second set of plots, we compare annual mean temperature flucutations over the last 130 years in the northern and southern hemispheres. Rather intuitively, heavier energy use, greater overall population, and greater number of cities and other dense population clusters in the northern hemisphere have accelerated the annual mean temperature increase far more significantly than in the southern hemisphere. In particular, these factors' effects did not come lead to the temperature explosion in the northern hemisphere until the mid-20th century, when energy consumption really boomed.

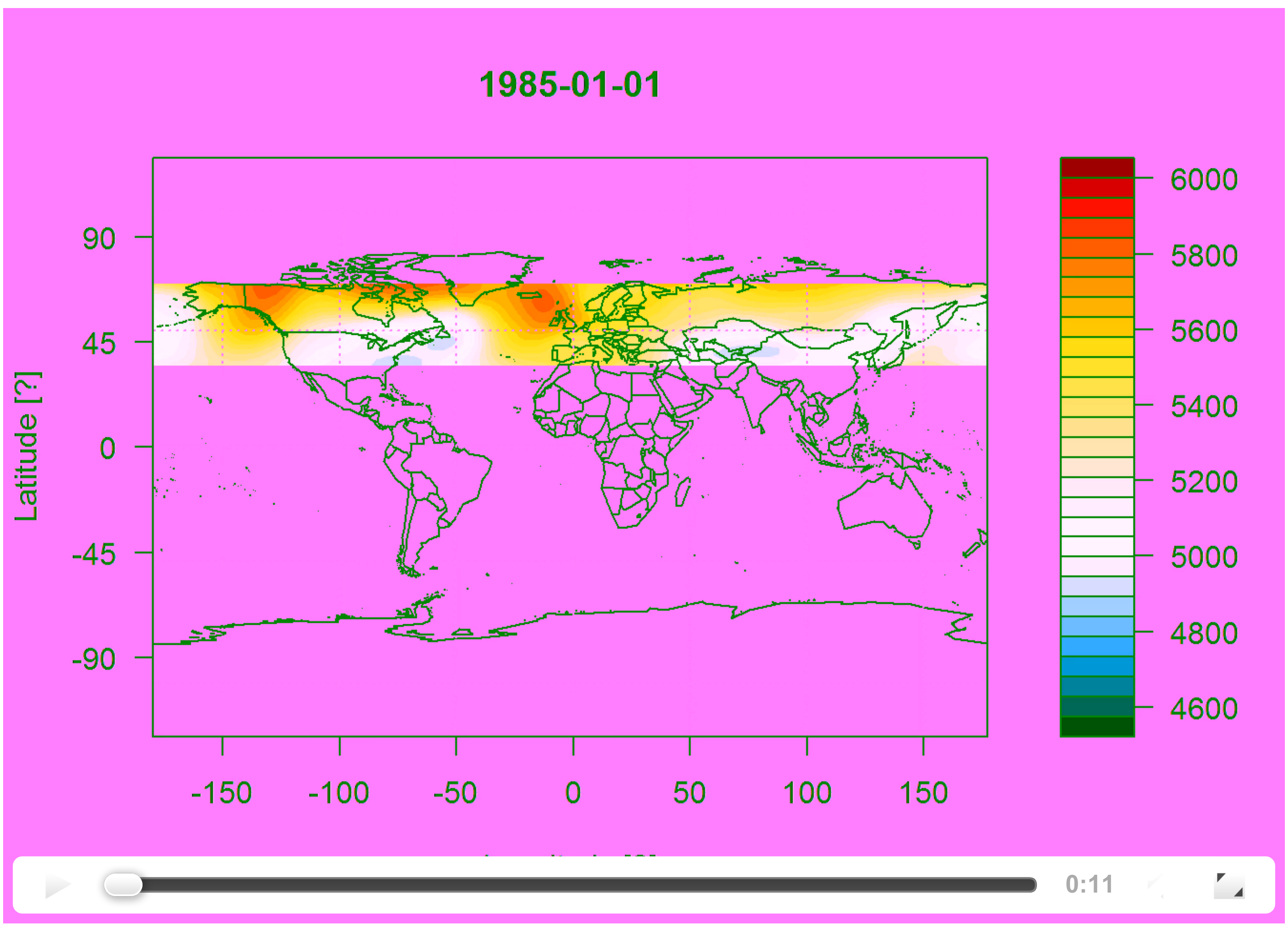

Global Annual Temperature mean
Degrees
80
60
40
20
0
-20
-40
1985
951-80 Average
Source: http://data.giss.nasa.gov/
1880
1900
1920
1940
1960
1980
2000
2020
Year
Northern Hemisphere
Southern Hemisphere
Degrees
100
50
0
-50
1880
1920
1960
2000

Year Year

There is plenty of discussion about what causes these temperature changes and the main implications we can derive from it. One of the biggest concerns about climate change is the rising levels of water, as well as the change in precipitation patterns worldwide. For instance, and as we will see further ahead, the number of severe floods has been steadily increasing since 1985, which is consistent with the period of time in which the global temperature has changed the most. While we can not prove that one variable is causing the other, we certainly can point out that there is a positive correlation between temperature and number of severe floods.

Geopotential Height and Flooding

To continue our analysis, we included a worldmap animation that shows the relationship between geopotential height and floods. To visualize the relationship between global Geopotential 5000 meter height and flooding we animate the Geopotential height over 10 days, plotting any floods that occur during those days. We see that floods occur on low pressure boundaries (5000 meters is the center of the GeoPotential weather height). [Animation is in WebM format, supported browsers include: Mozilla Firefox 4 and later, Opera 10.60 and later, Google Chrome 6 and later, Microsoft Internet Explorer 9 and later (requires WebM MF components)]

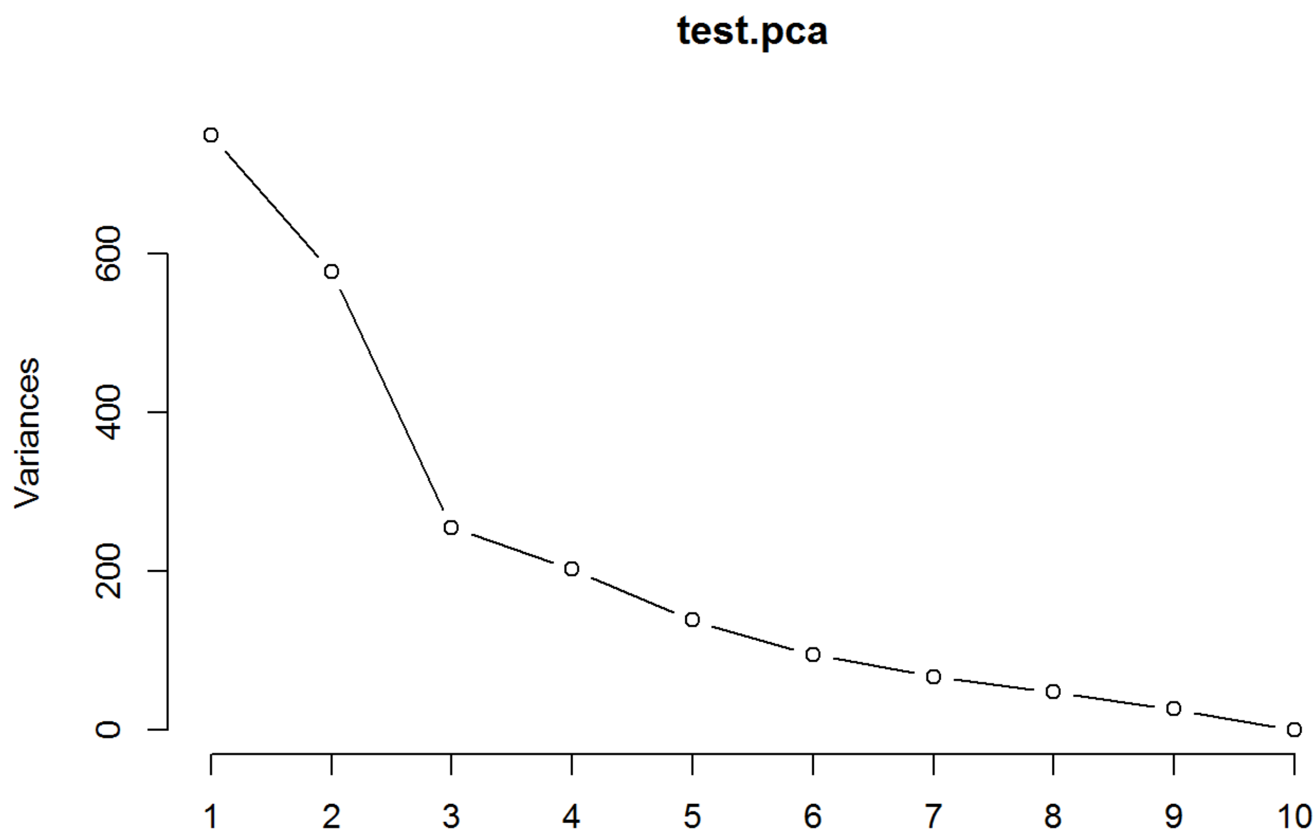


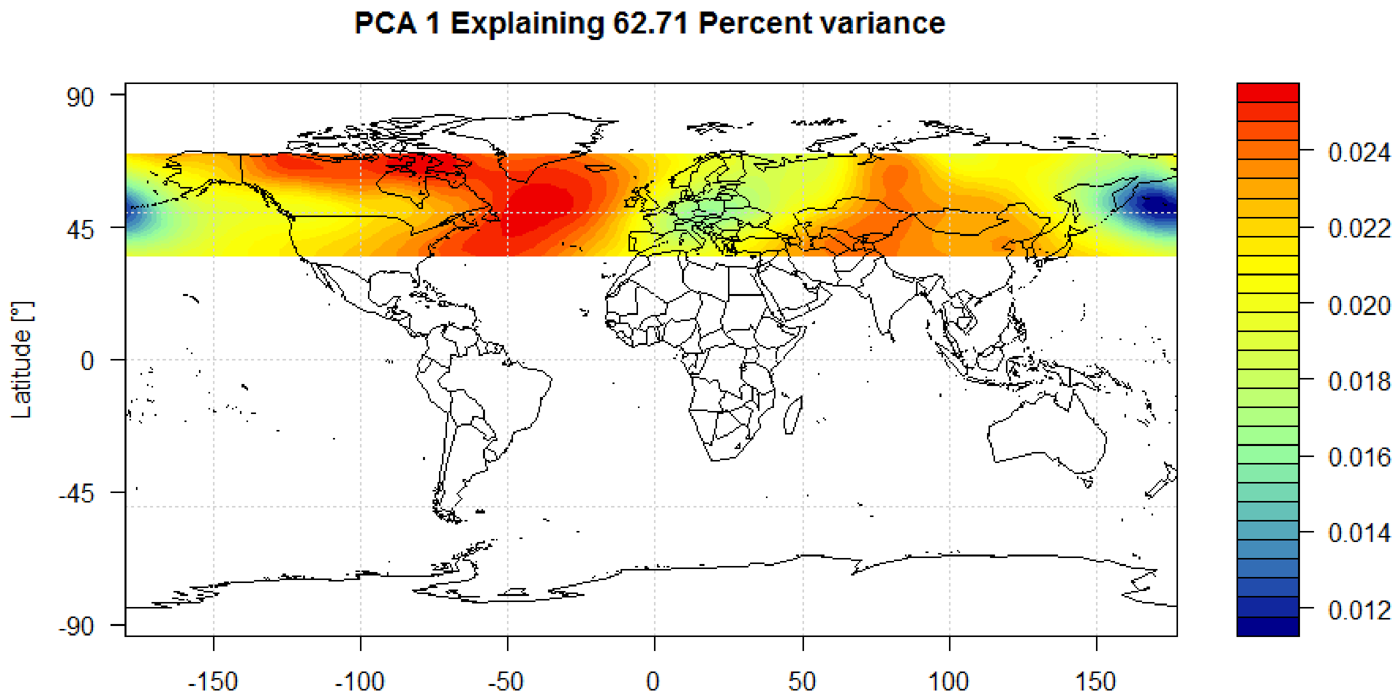
PCA

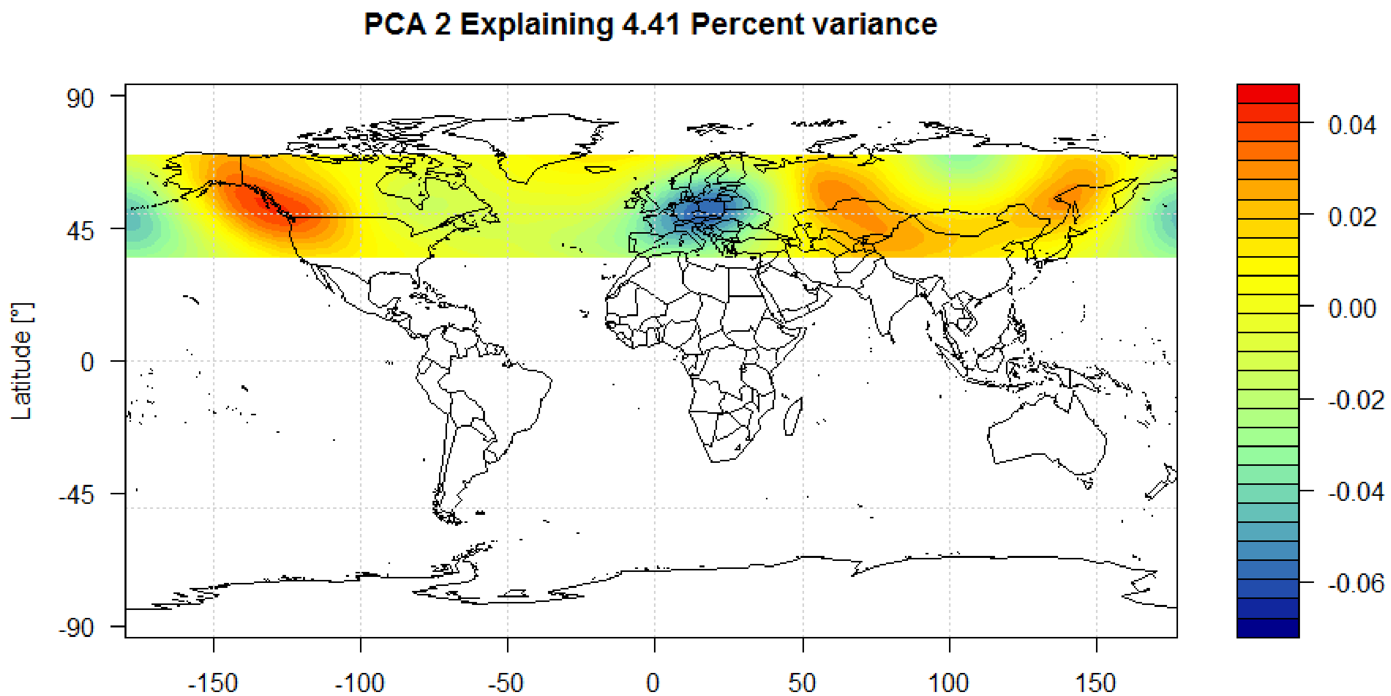
Following the same line of analysis, we conducted a PCA analysis to understand which are the regional areas that "explain" the largest amount of GeoPotential height over time.

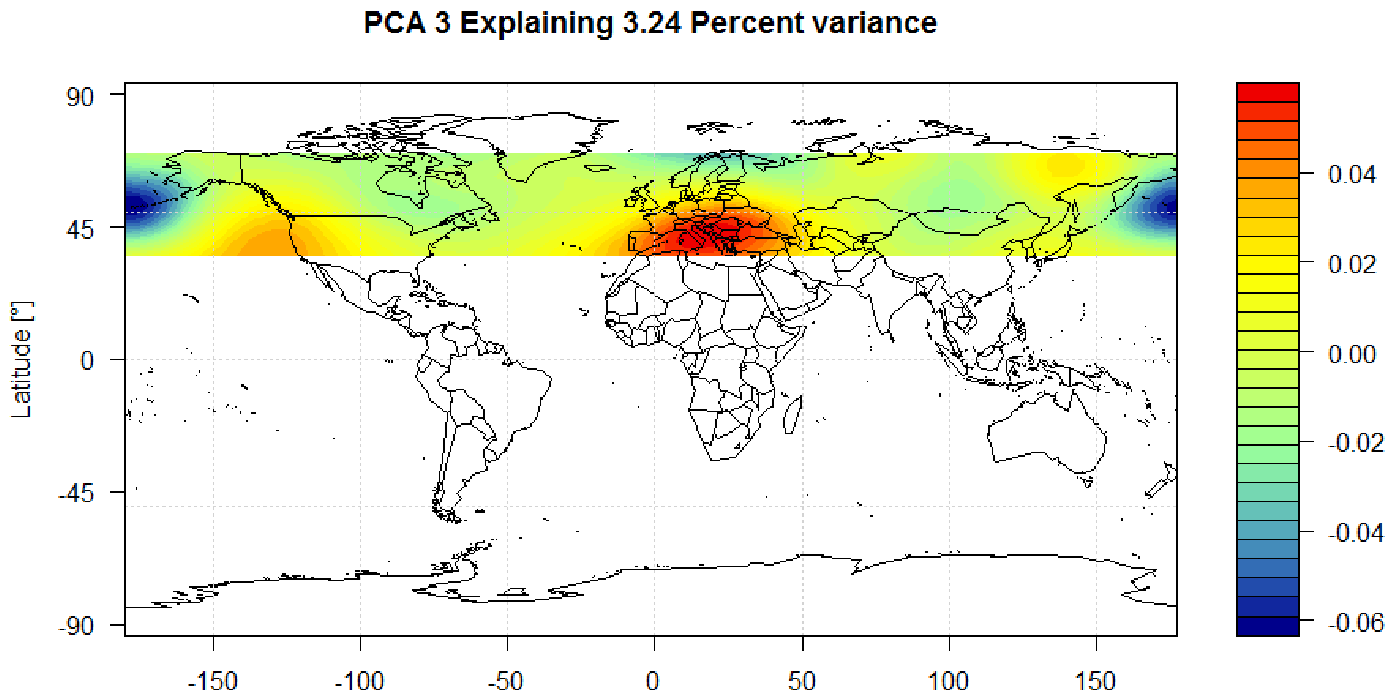
As we can see, the first principal component explains slightly over 60% of the variation observed. It is interesting to see how a large region in the Atlantic Ocean between North America and Europe (in red), is negatively correlated with a large region (in blue) between Alaska and Eastern Russia along the first component. What this means is that these two regions have experienced the most different changes throughout the analyzed period.

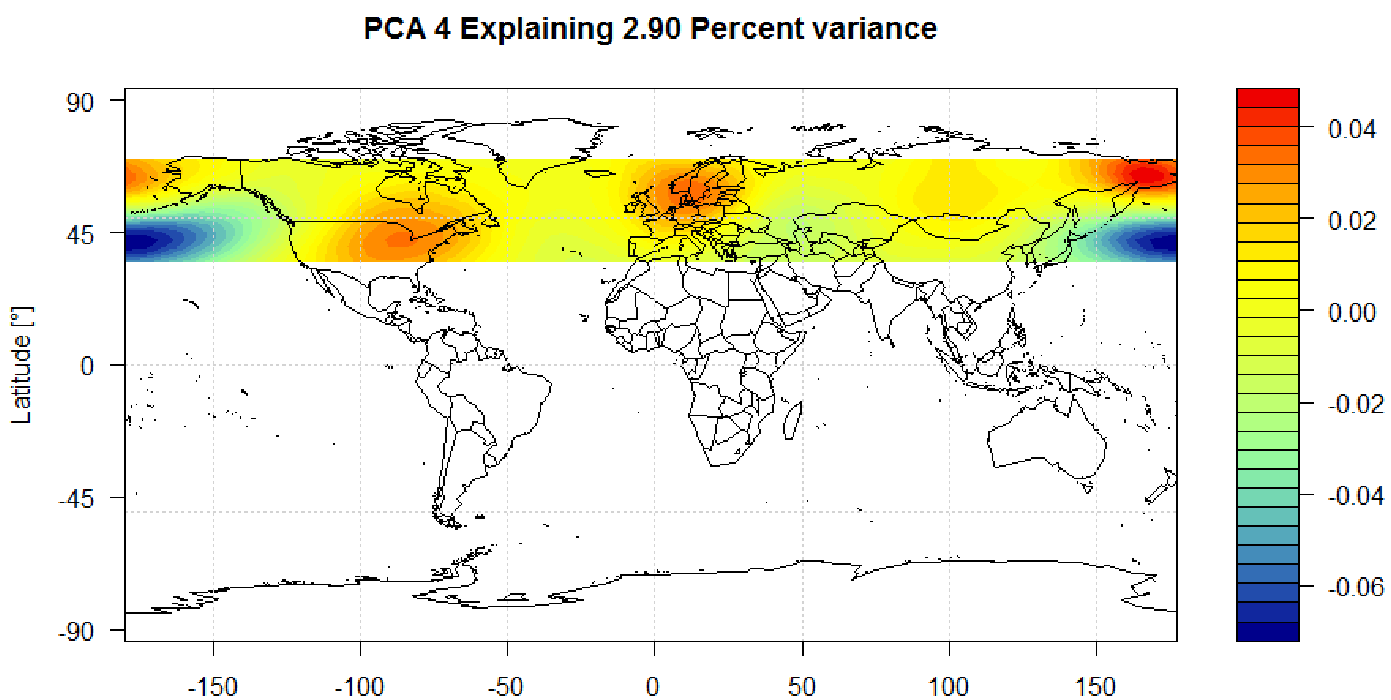
We also included plots for the second, third, and fourth principal components for informative purposes, even when they do not explain much of the observed variance.




PCA 1 Explaining 62.71 Percent variance
90
45
0
-45
-90
Latitude [°]
-150
-100
-50
0
50
100
150
0.024
0.022
0.020
0.018
0.016
0.014
0.012


PCA 2 Explaining 4.41 Percent variance
90
45
0
-45
-90
Latitude [°]
-150
-100
-50
0
50
100
150
0.04
0.02
0.00
-0.02
-0.04
-0.06





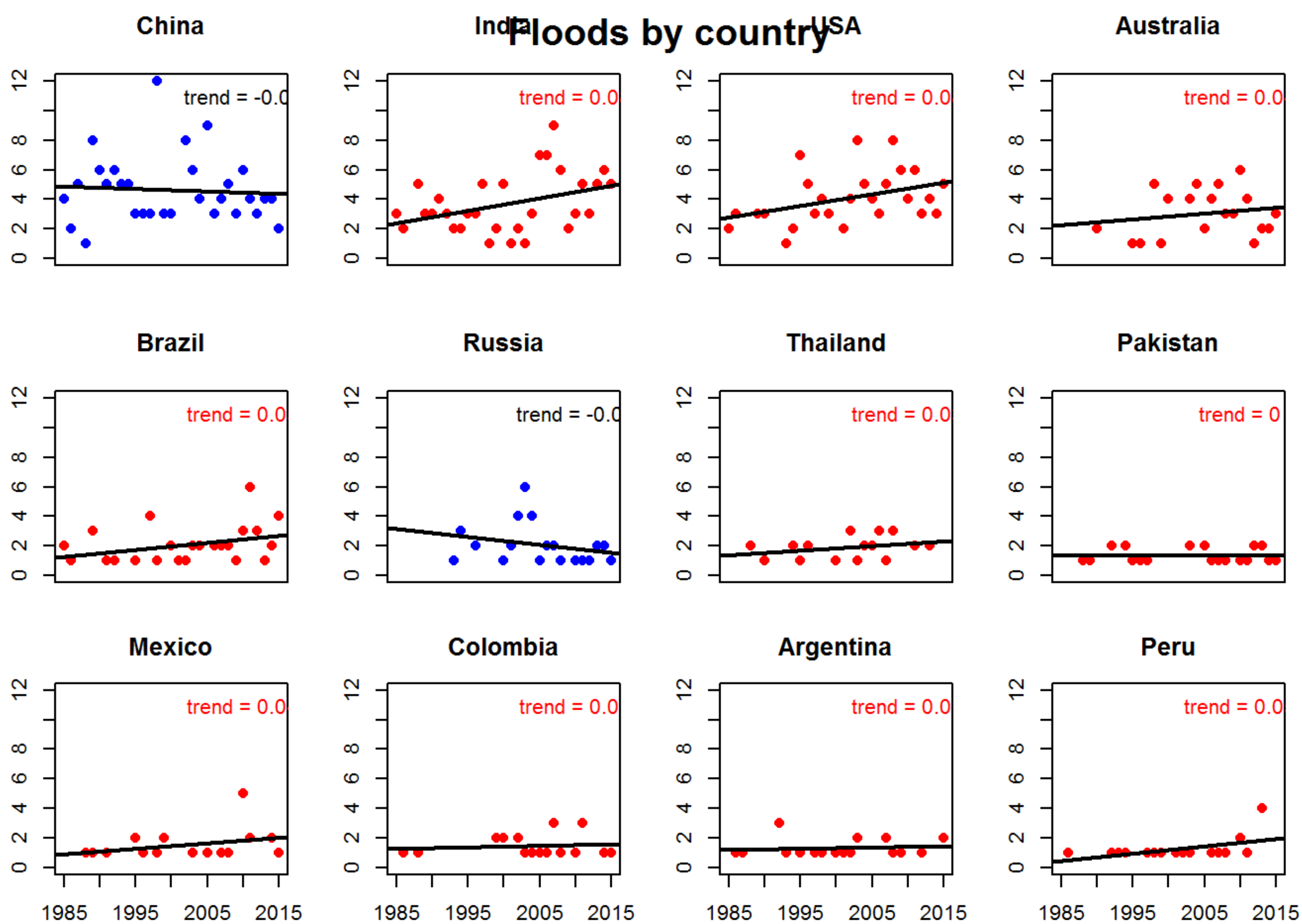
Frequency and Magnitude of Floods Worldwide

After having studied the changes in GeoPotential height across the northern hemisphere, we continue our exploratory analysis by looking at how floods have been changing over time, both in terms of quantity, as well as characteristics.

Here we take an initially broad view of the incidence of severe global floods since 1985 and then narrow our scope to focus on individual countries. In the first plot, over thirty years, we observe that the number of floods worldwide has been increasing overall and at roughly the same rate between those under and over magnitude of six. It can also be seen that the number of floods changes sinusoidally, following the roughly decade-long global weather phenomena El Nino and La Nina.

In the plot of floods by country, we display only those floods with magnitude greater than six, which correspond to the red dots in the plot above. Furthermore, blue dots in the "Floods by Country" panel of plots correspond to a decreasing trend in flood frequency from 1985 to 2015, while red dots correspond to an increasing trend.

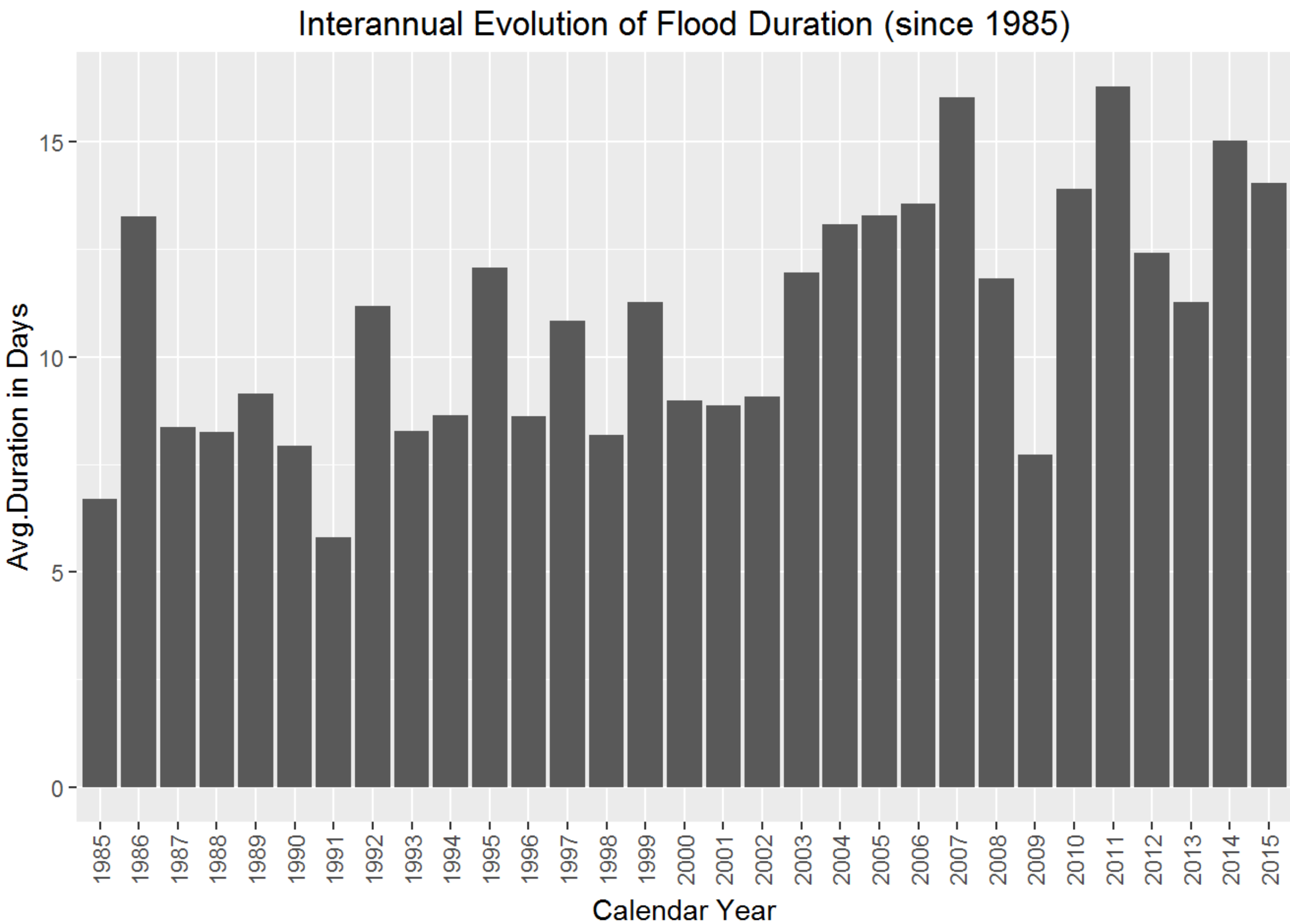
As expected, if we then break down flood incidence by country, we see that of the twelve countries with the most floods, the number of floods has risen in more cases than not. We could not find any geographical correlation with flood incidence decrease or increase.



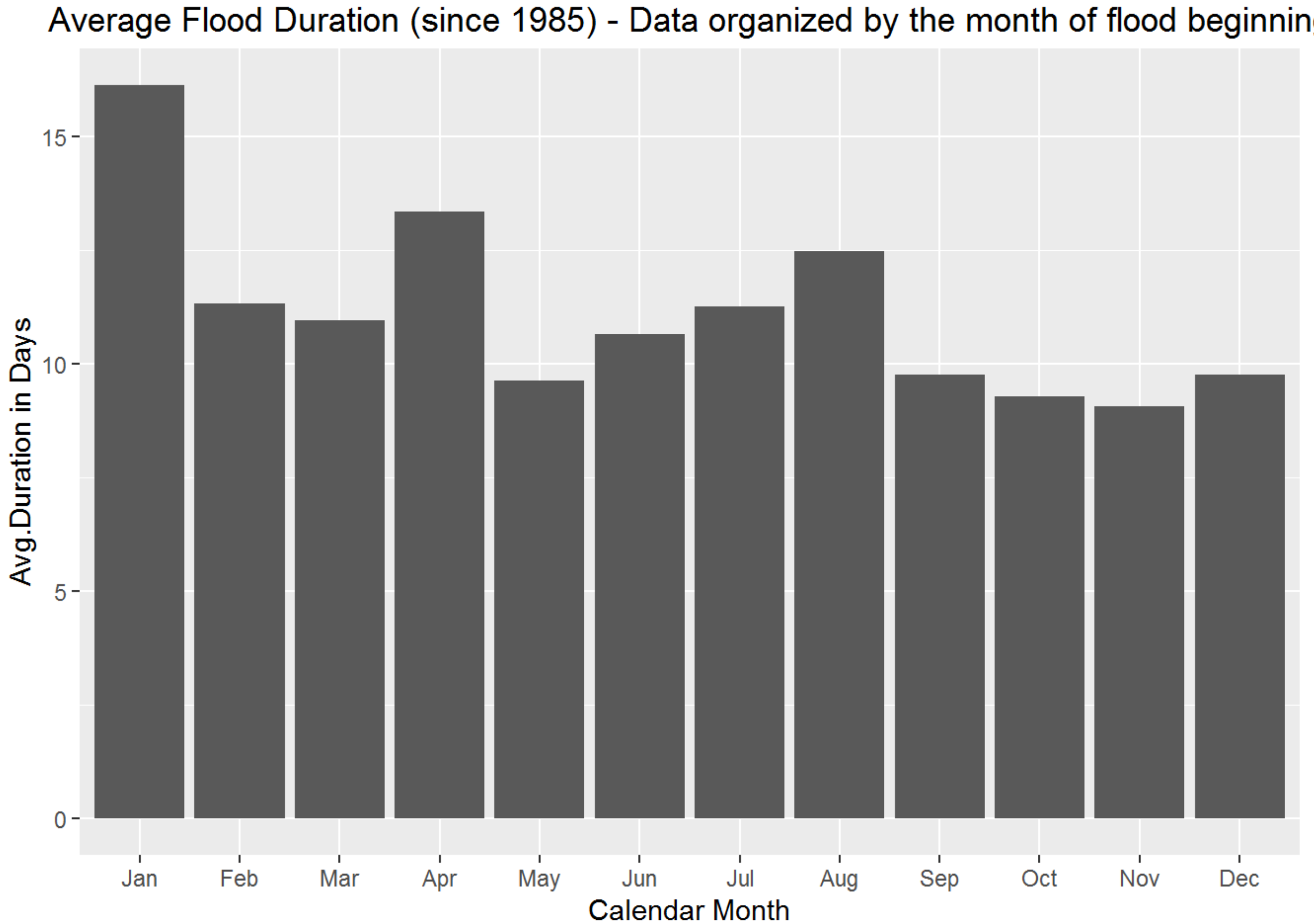
Flooding Seasonality and Historical Analysis

In addition to looking at how the number of floods has increased, we explored some of the relevant characteristics of these floods across time, to better understand the implications of these phenomena.

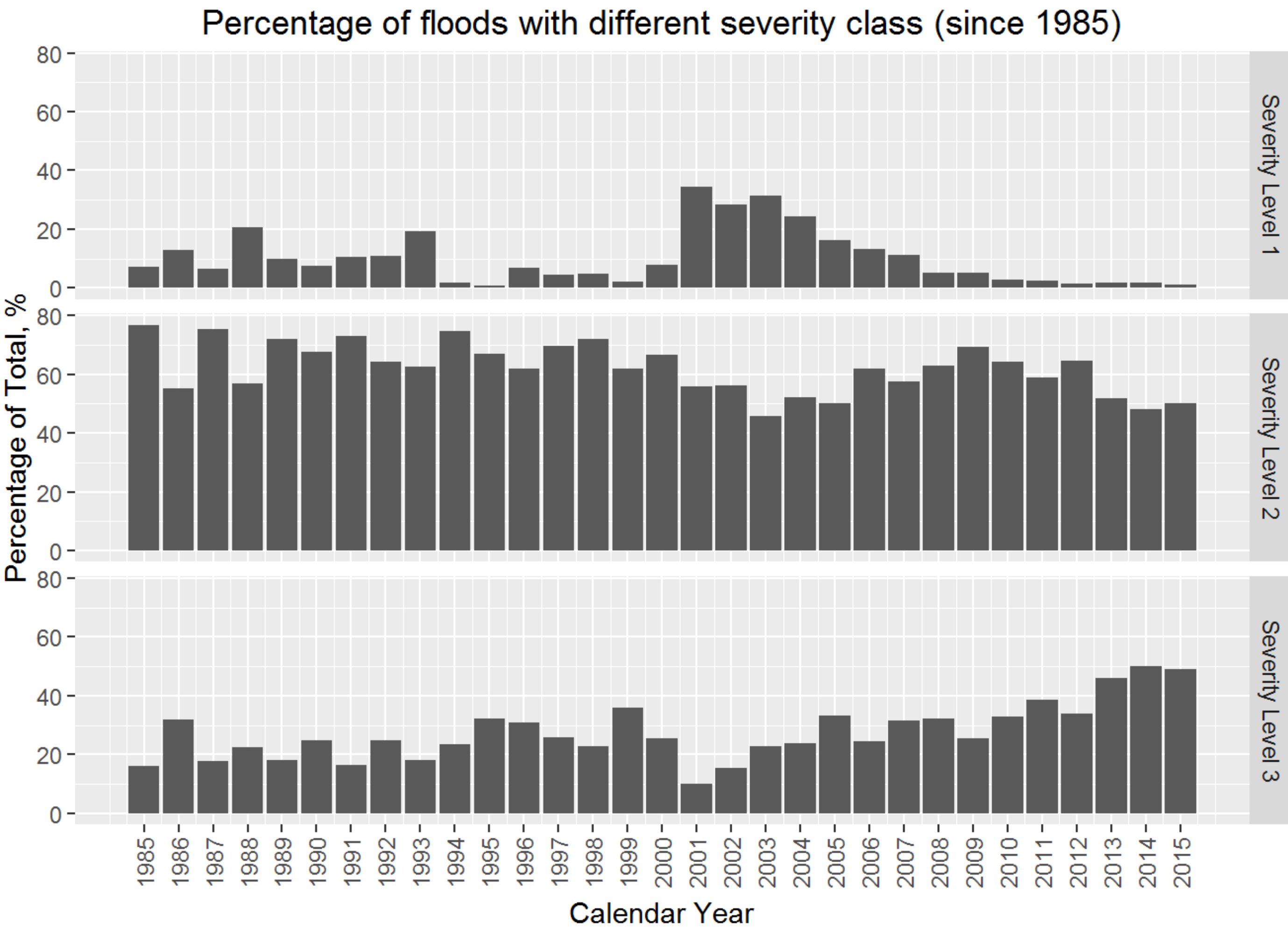
By plotting the data we have, we see a clear general trend that flooding is getting more severe year after year - the duration and severity level are both increasing. The months with the most severe floods are December-January, April, and August. We also notice that there are at least one extremely severe flood that killed hundreds people in year 1991, 2004, and 2008. There are most people displaced on average in 1999 and 2000, which are the years with low level of fatality. It may imply that we can reduce the level of fatality by making accurate prediction of floods and displacing residents in flooded area on time. Now let's take a look at each graph individually:



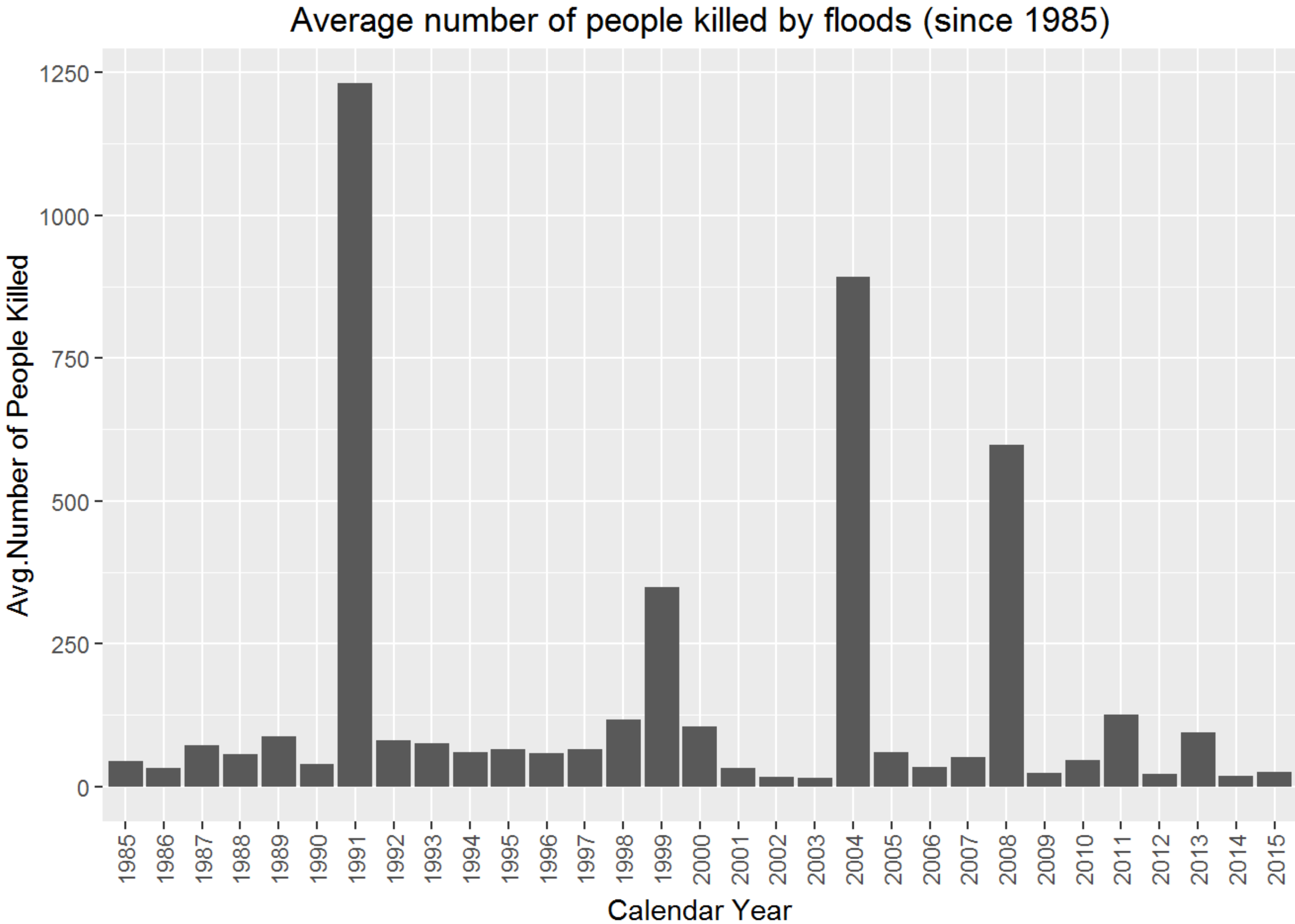
The graph on Interannual Evolution of Flood Duration shows us a clear trend that the average duration of flood is increasing. Particularly, the average duration of flood exceeds 15 days in 2007, 2011, 2014, which are the recent 10 years. This implies that the severity of floods is increasing since 1985.



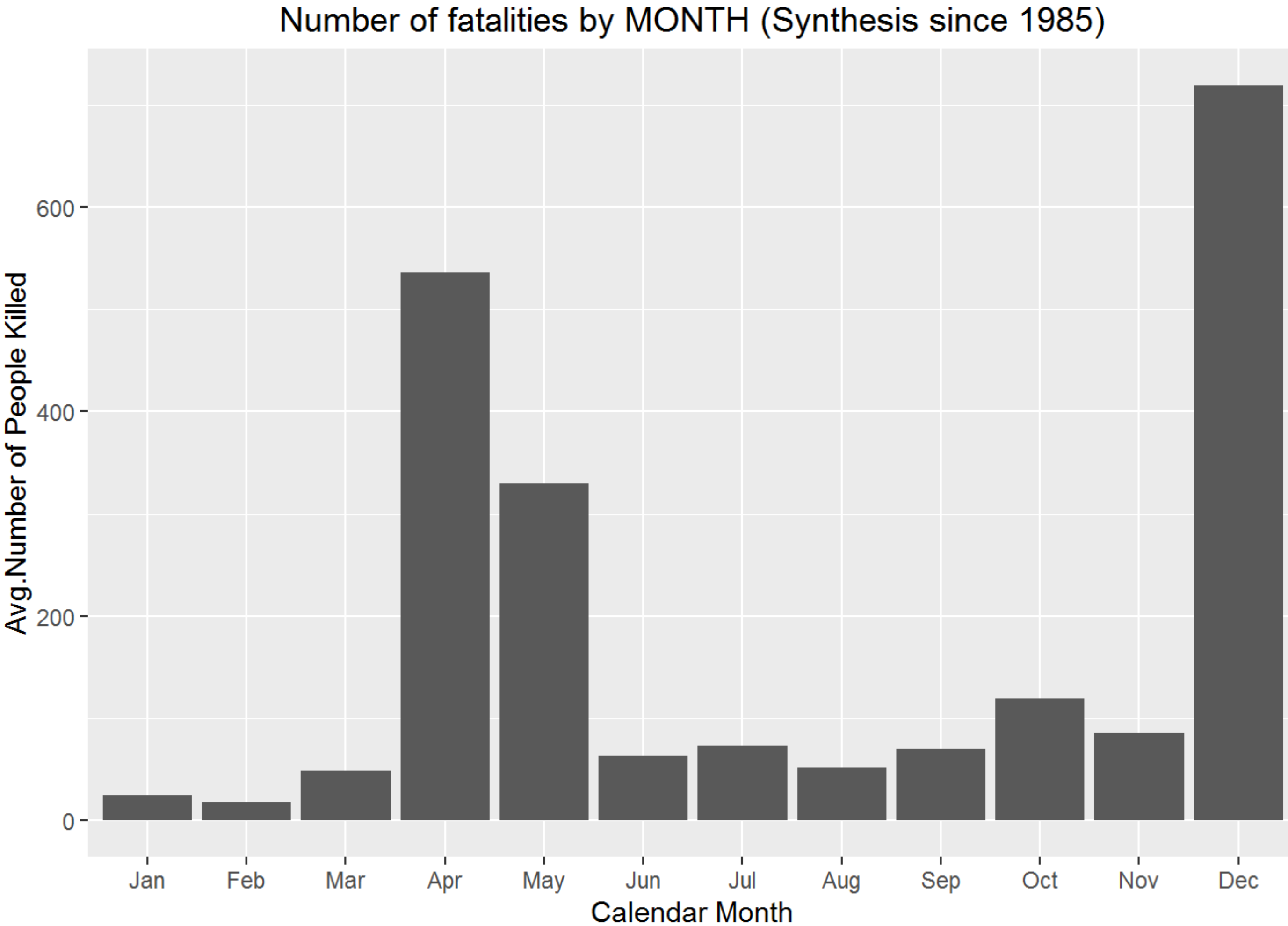
In this graph, we summarize the average flood duration in days in terms of month. It is interesting to see that January has the longest flood duration - it is the only month that has average flood duration of more than 15 days. Notice that the flood duration in April and August are between 12 and 14 days. The rest of the months all have the average flood duration of around 10 days.



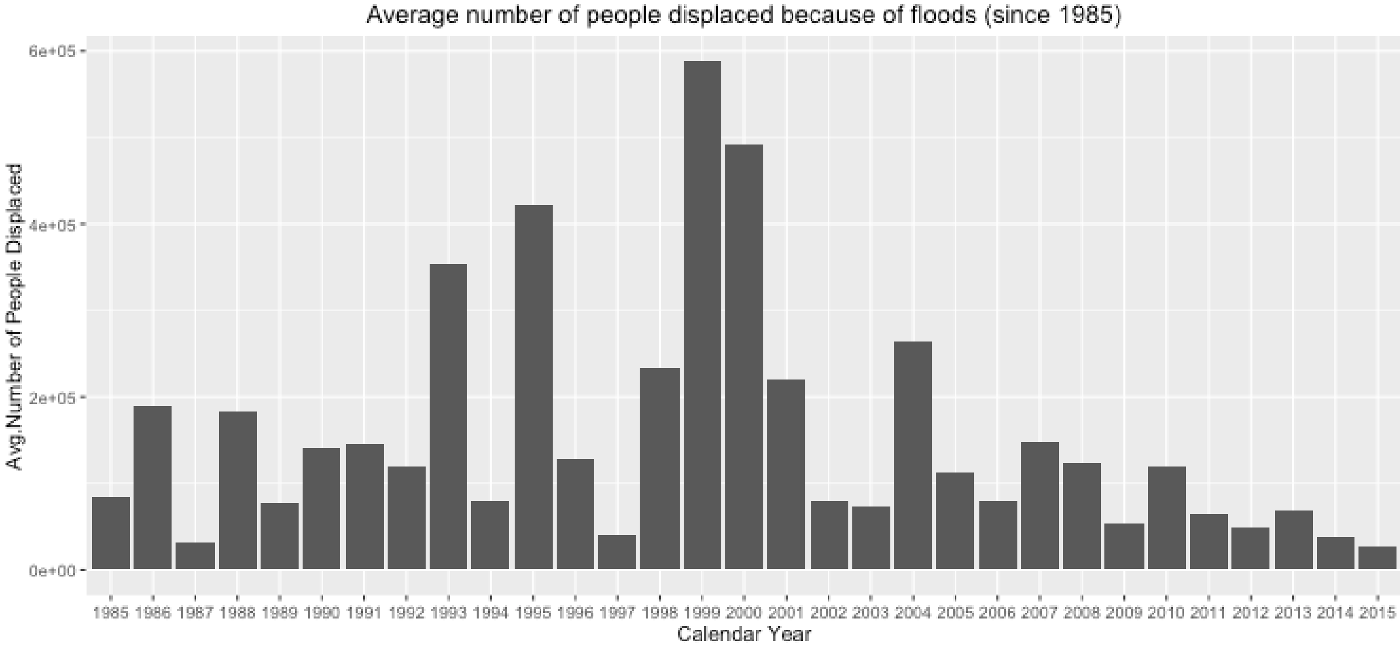
By visualizing the percentage of floods in different severity levels regarding different years, we see that severity level 2 floods take up the highest proportion in almost every year. Notice that severity level 2 floods and level 3 floods both take up almost 50% of the total floods in 2015. In 2013, the percentage of level 3 floods increased more than 10% from the level in 2012 and then stayed at around 50%. The graph shows us that flood severity is increasing in recent years. Now we barely have any severity level 1 flood.



We can see that the average amount of people killed in 1991, 2004, and 2008 is the highest. In 1991, the average number of people killed almost reached 1250. It means that there should be one or more extreme severe flood in 1991 which pull up the average of that year.



It is interesting to see that the average number of people skilled by flood is the highest in December. We suspect that one of the most severe flood that had enormous amount of people skilled happened in December, which then pull up the average in December. The month with the second largest amount of people skilled by flood is April, which makes sense because April is also one of the month we saw above that has the most sever floods in terms of duration.

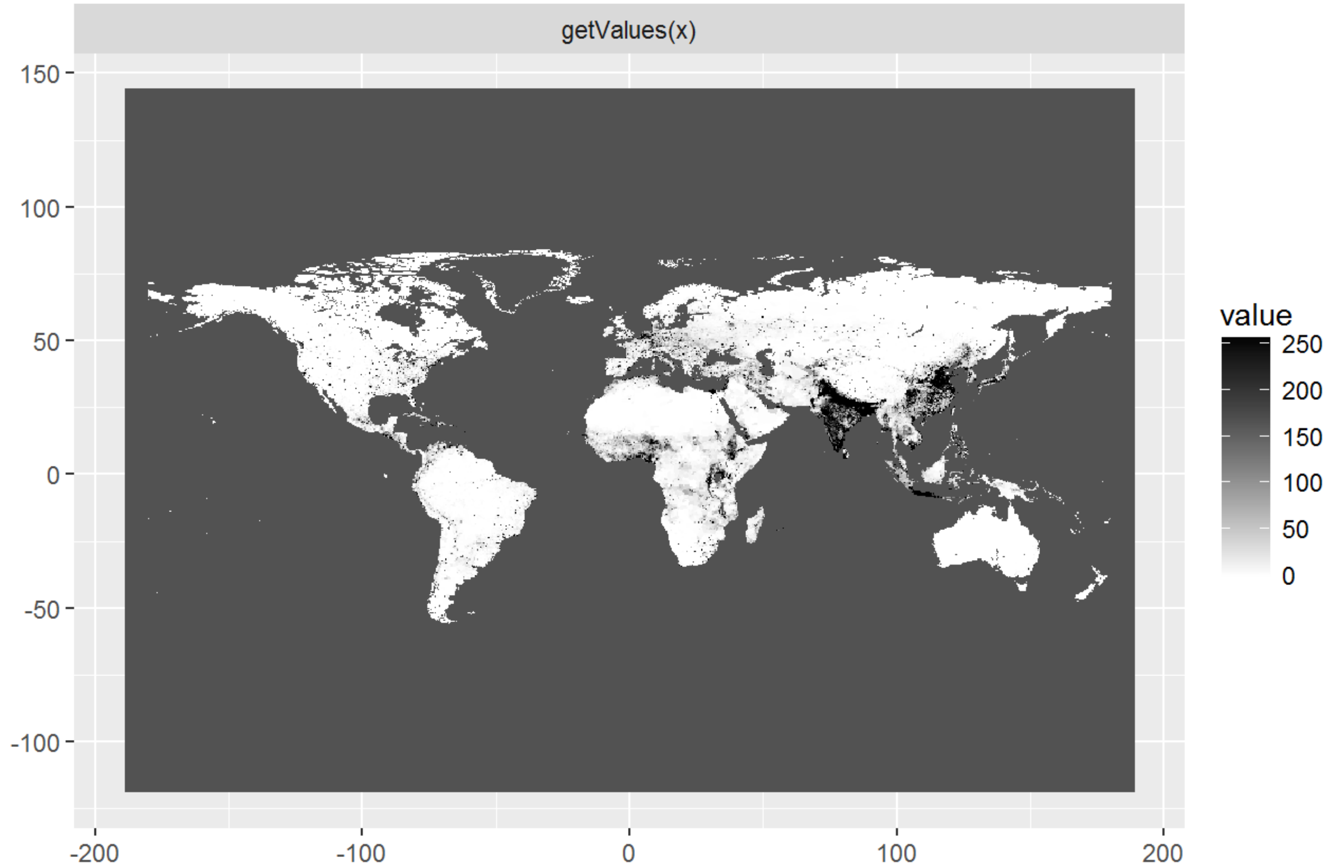


We can see that there are most people displaced on average in 1999 and 2000, which are the year with less people skilled. It implies that displacing residents in flooded area on time can significantly reduce the number of people killed by floods.

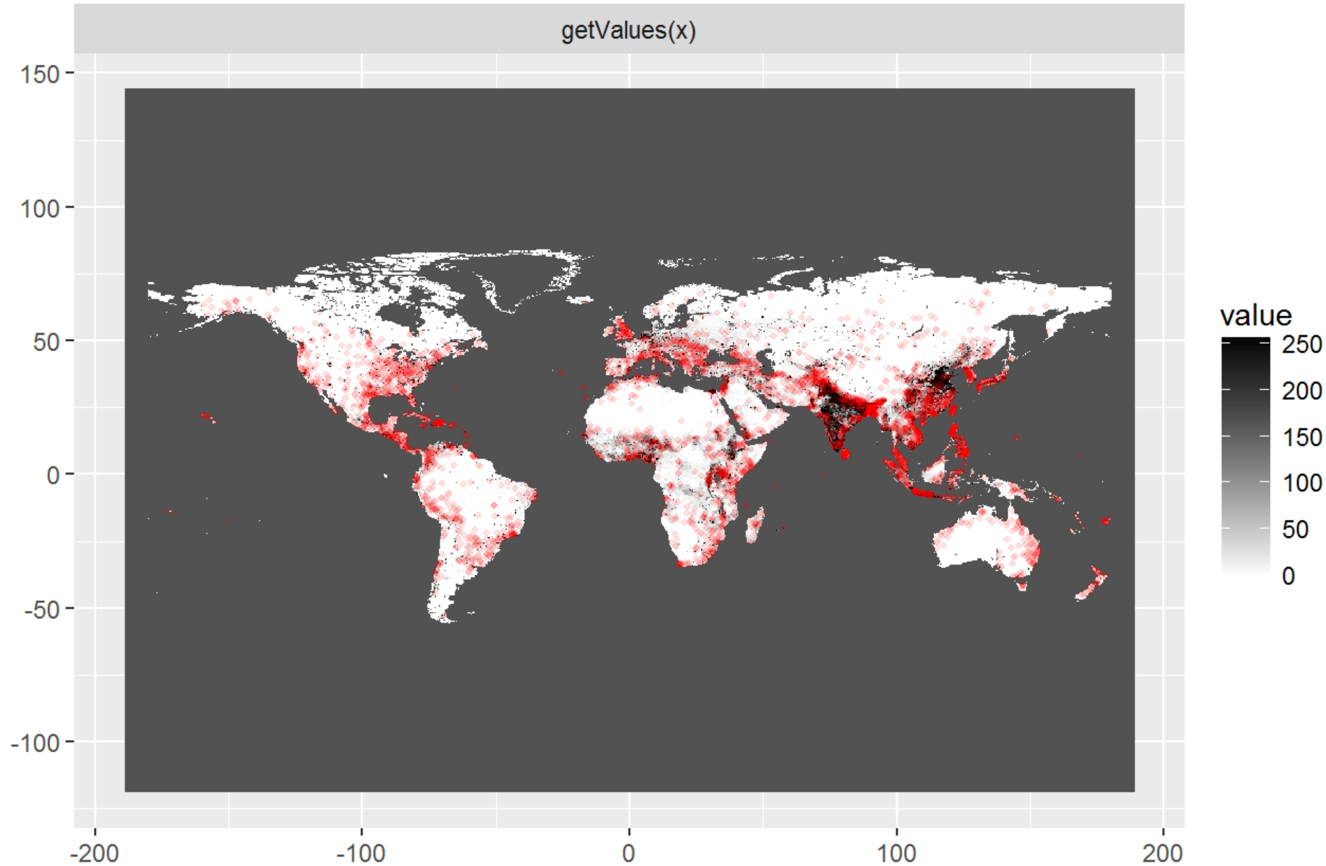
Flooding and Population

To visualize the relationship between floods and global population we superimpose transparent red dots for every flood on a global population map in GeoTiff format. (The map was retrieved from the NASA Socioeconomic Data and Applications Center (sedac) (http://beta.sedac.ciesin.columbia.edu/data/collection/gpw-v4 (http://beta.sedac.ciesin.columbia.edu/data/collection/gpw-v4)). The map was scaled to a manageable size using the QGIS desktop application). We see that global flooding tends to occur in heavily populated areas - which makes intuitive sense since human development has concentrated in coastal areas and fertile river valleys.

Global population GeoTiff



Global population with Floods

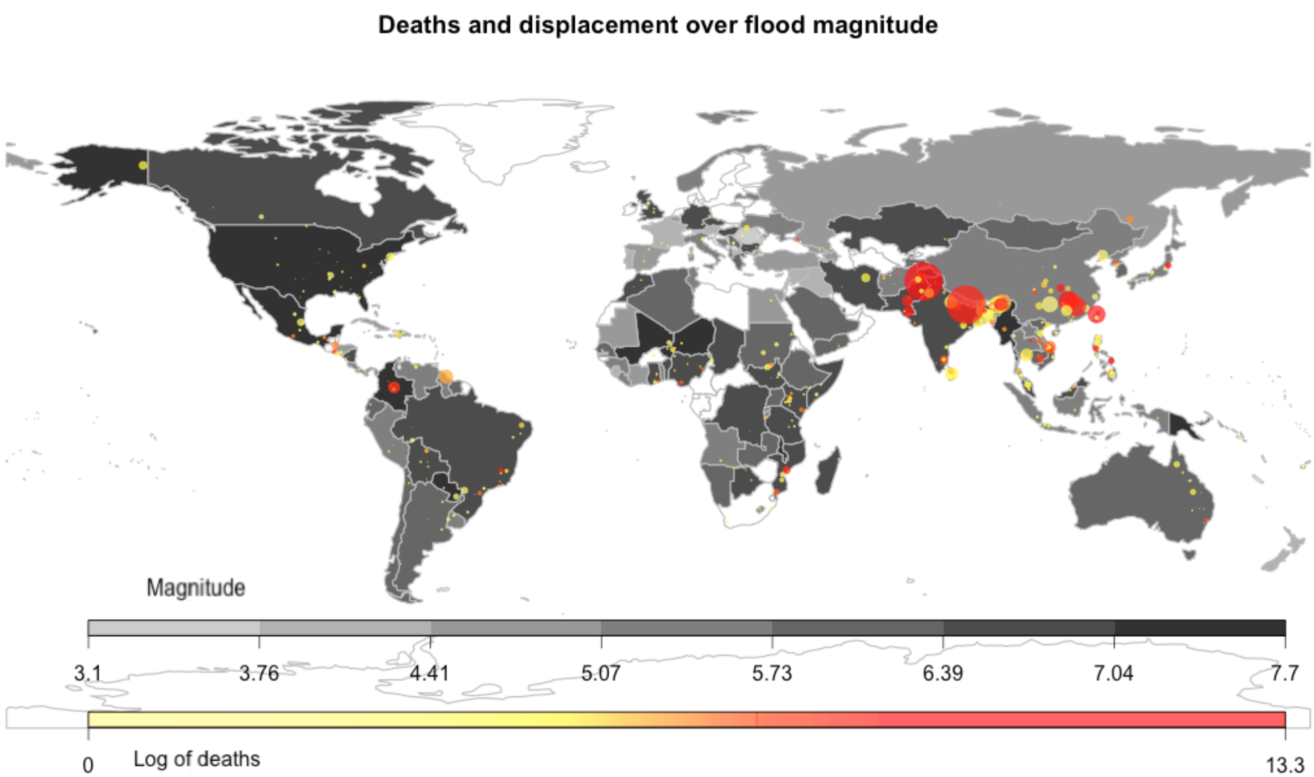


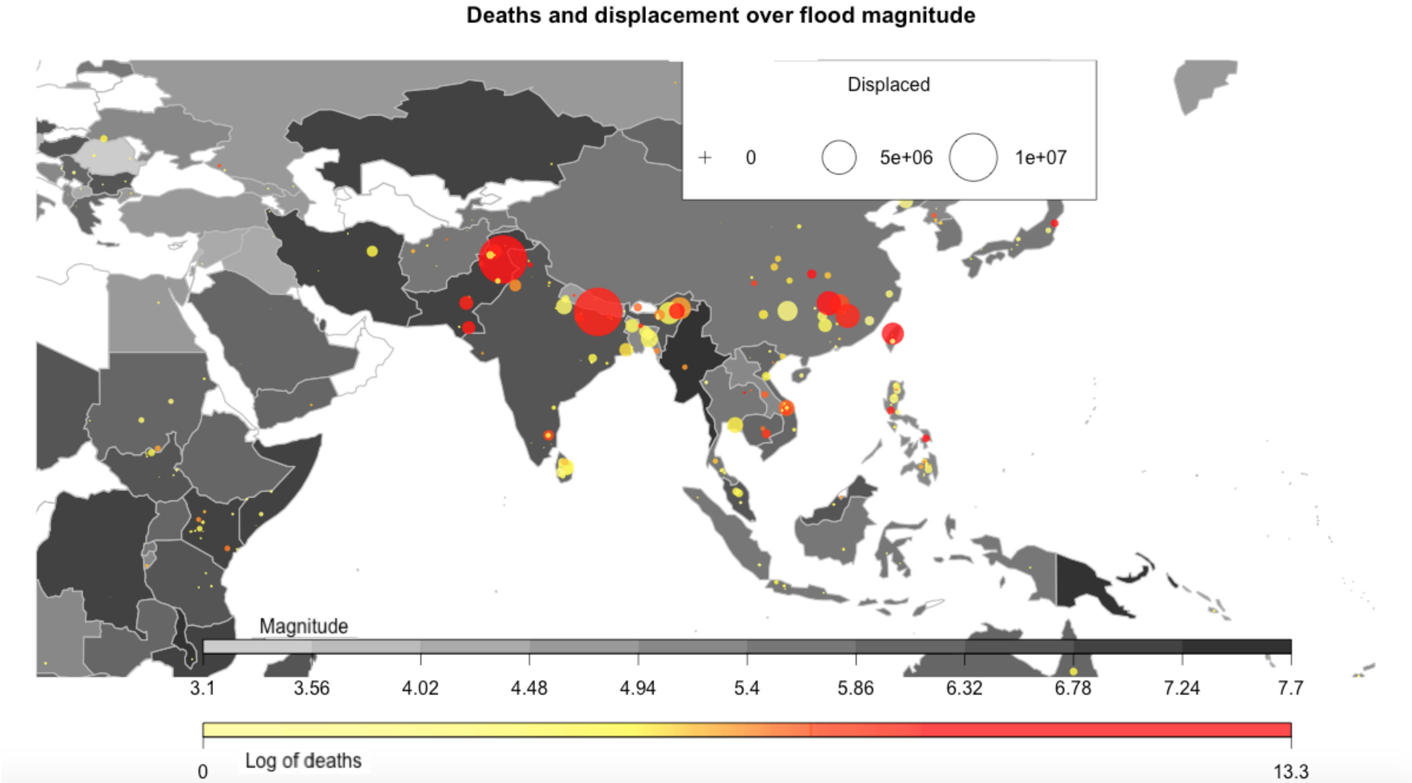
Flood Impact Around the World

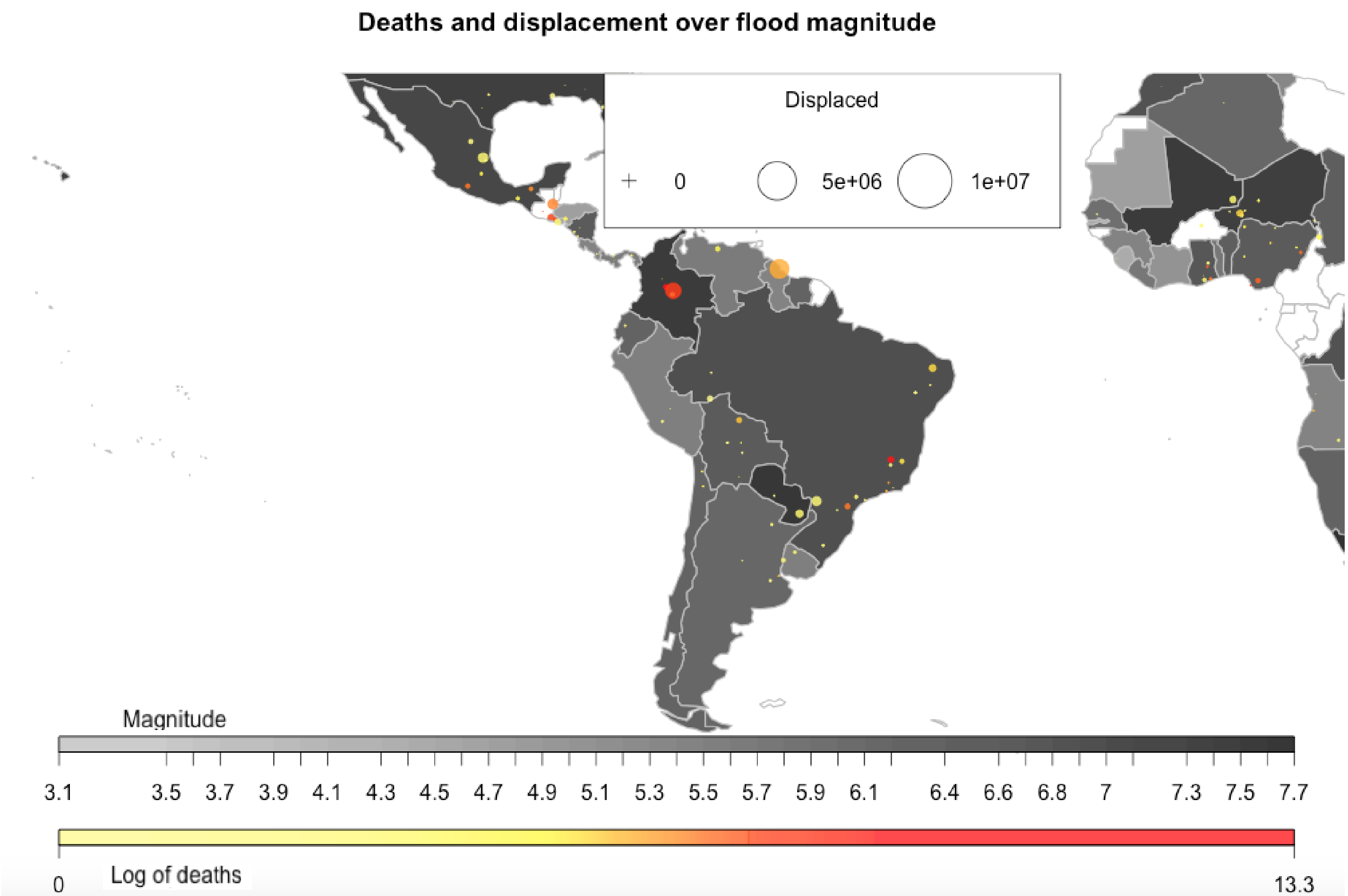
By superimposing the mapBubbles upon a map filled by flood magnitude, we sought to compare the floods of similar magnitude and how tramautically they impacted people around the world. The US, for example, has on average been home to some of the most severe, long duration, and widely affecting floods, but most of the actual flooding events caused relatively little loss of home and life. Of course, the majority of the floods occurred along the river basin in the sparsely-populated Midwest, and the higher quality infrastructure and emergency response in developed countries must come into play.

We first took a broader view of floods' impact on communities globally. Our plots in this section cross-examine three variables: number of deaths, number of displaced flood victims, and the average flood magnitude for each country, where magnitude is pre-calculated as the log of the product of the severity, duration, and area affected by the flood. Several outliers are immediately self-evident. South Asia has witnessed two of the largest population displacements by a flood in the last half century. Moreover, South and Souteast Asia, including Southeast China, regularly suffer floods that cause much population displacement and an inordinate number of deaths. We can also see how the floods in the Eastern Hemisphere tend to hug the coastlines or at least crowd around primary monsoon corridors. Similarly, in Africa, South America, and Australia, bubbles tend to populate the eastern shorelines of the continents. This likely suggests that settlements tend to be more populous and thus likely to experience displacement and death along the eastern coast of most continents. Moreover, perhaps global wind patterns also factor into the propensity for severe floods to cause death and displacement along eastern coasts, however large or small the toll may be.

With three variables at our disposal to display and interpret, the task at hand was deciding which ones to use. We decided it was important to focus a section on the direct human impact of the floods, so loss of life and home were chosen to be represented by color and size of bubble, respectively. By overlaying the mapBubbles plot over the mapCountryData fill map, we had our pick of the variable on which to compare the deaths and displacements. As flood magnitude enveloped three highly relevant variables - severity, duration, and area affected - we decided it was the most suitable third variable to serve as the "backdrop".




Deaths and displacement over flood magnitude
Displaced
0
5e+06
1e+07
Magnitude
3.1
3.56
4.02
4.48
4.94
5.4
5.86
6.32
6.78
7.24
7.7
Log of deaths
0
13.3


Deaths and displacement over flood magnitude
Displaced
0
5e+06
1e+07
Magnitude
3.1
3.5
3.7
3.9
4.1
4.3
4.5
4.7
4.9
5.1
5.3
5.5
5.7
5.9
6.1
6.4
6.6
6.8
7
7.3
7.5
7.7
Log of deaths
0
13.3

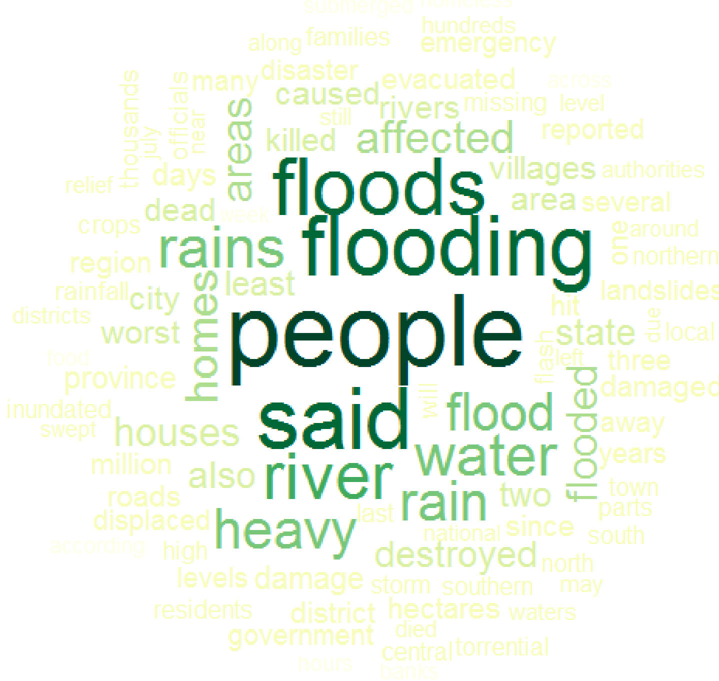
Text Analysis

We analyzed the news headlines accompanying the NOAA flood data and found that there were certain words and ideas that resonated across most countries and magnitude groupings, as well as differed. Predictably, words like “people”, “water”, and “river” recurred amongst word clouds for the US, China, and India, as well as for floods of magnitude greater than 6 and less than 4.6. Interestingly enough, for floods of magnitude less than 4.6, emphasis was rather evenly spread amongst “rain”, “river”, “heavy”, and “people”, while for floods greater than magnitude 6, emphasis shifted singularly to “people”.

Cultural differences may also come into play in the differences between the word clouds for China, India, and the US. China and India’s headlines more frequently mentioned “people” and, quite uniquely, “provinces” and “villages”, respectively. Meanwhile, headlines in the US mentioned more often the cause of the flood itself (ie. “river”, “water”, “rain”) rather than the people and communities affected. It is also singular that the most commonly used word for communities in the US was “county”, and not “city”, “town”, or “neighborhood”.

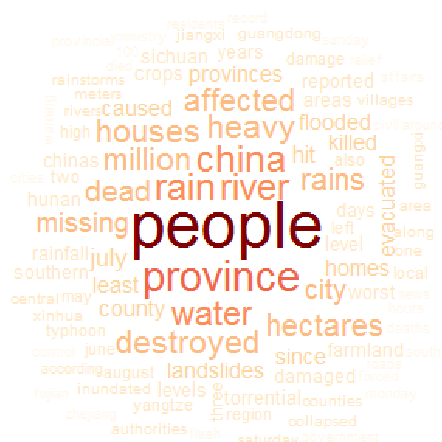
A brief look at the less frequent, background words provides even more context. Floods of magnitude greater than six, for example, generated headlines more often involving “hectares” (this from China, mostly), “state”, and “displaced” - all words that convey a sense of large scale. Floods of magnitude less than six generated headlines containing words such as “flash”, “landslides”, “houses”, “villages”, and “city”, which are smaller scaled words in terms of time and space. Relatively frequent mention of a specific, local cause like a landslide further suggests the locality of these lower magnitude flood events. Besides “hectares” in China, other frequent, specific headline words were: “relief”, “districts”, “moonsoon”, and “villages” in India; “province”, “missing”, “July”, “evacuated”, and “million” in China; as well as “record”, “inches”, “county”, “officials”, and “levels” in the United States. These sets of words suggest, perhaps, a tendency to emphasize measurements and quantifiables in the US and a particular primary cause for flood events in India (monsoons). Similarly, China headlines tend to point us to a particular month in the year when significant, headline-grabbing floods occur, as well as “scale” words such as “million” (explicit) and “missing” (implicit: if many headlines are mentioning missing people, there may be more missing people in China floods due to larger affected populations).

Overall Wordcloud based on All News



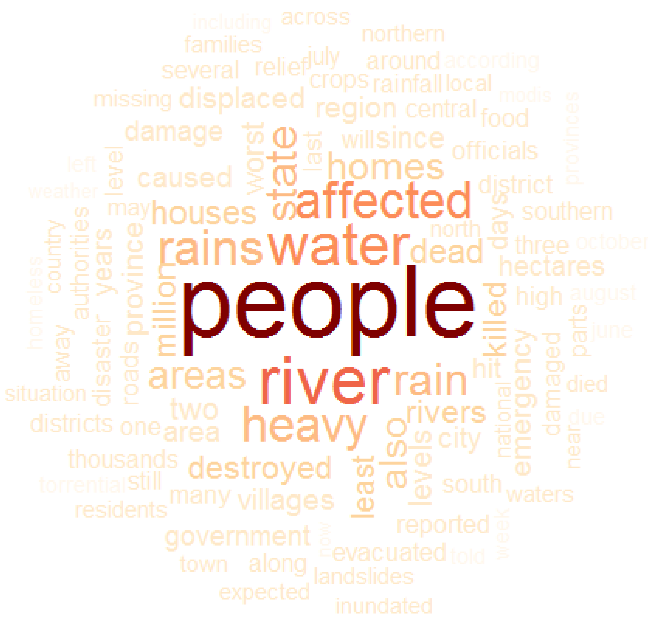
USA

China



India

Magnitude > 6



Magnitude < 4.6