Water Cycle: Lessons using data skills

Royal Geographical Society with IBG

Advancing geography and geographical learning

Lesson 4: Flood Frequency

Lesson Objective

- To understand the concept of flood recurrence interval and how it is calculated
- To describe the changing frequency and magnitude of river flooding in the USA

Setting the Scene

Rivers and streams experience flooding as a natural result of large rain storms or spring snowmelt that quickly drains into streams and rivers. Although the risk for flooding varies most areas are susceptible to floods, even in dry and mountainous regions. The size, or magnitude, of flood events is influenced by how much water enters the catchment upstream and how quickly. Flood frequency largely depends on the frequency of weather events.

Large flood events can damage homes, roads, bridges, and other infrastructure; wipe out farmers' crops; and harm or displace people. Although regular flooding helps to maintain the nutrient balance of soils in the flood plain, larger or more frequent floods could disrupt ecosystems by displacing aquatic life, impairing water quality, and increasing soil erosion. Climate change may cause river floods to become larger or more frequent than they used to be in some places, yet become smaller and less frequent in other places. As warmer temperatures cause more water to evaporate from the land and oceans, changes in the size and frequency of heavy precipitation events may in turn affect the size and frequency of river flooding. Changes in streamflow, the timing of snowmelt, and the amount of snowpack that accumulates in the winter can also affect flood patterns.

This lesson is focused on beginning to explore how we can calculate flood recurrence intervals and how we can use that data to understand the likelihood of a future flooding. This is framed in the context of describing the patterns of change in the frequency and magnitude of floods in the USA.

1) Estimating Flood Frequency – Exactly what does this mean?

Whenever a large flood event happens and the media report on it they often use the term flood frequency or recurrence interval. However, this term is very poorly understood by many people so in this section we will explore how to calculate recurrence intervals to see what they actually mean. The recurrence interval is a statistical measure of the amount of time it takes for a discharge event of given size to reoccur. For example, a flood whose recurrence interval is 100 years means that 100 years should pass, on average, before the same discharge level occurs again. However, because the recurrence interval is based on the use of statistics, it could take more than 100 years for such a flood to repeat, but could just as easily take less than 100 years.

To calculate recurrence intervals for a given stream, hydrologists make use of historical discharge records. Here scientists normally tabulate the highest (maximum) discharge values that occurred during each year in the record. Because the focus is on the recurrence interval of very large discharge events (i.e., floods), it is best to have discharge records cover the longest span of time as possible.

Task

This task uses data from the St Louis gauging station on the Mississippi River between 1844 and 2014.

- Open the Microsoft Excel Flood Frequency data file. There are two columns: 1) year 2) Max Annual Discharge (cubic feet per second). You need to fill in column 3) Rank and 4) Recurrence Interval
- To do this, firstly rank the floods in terms of discharge where the flood with the largest discharge is ranked 1. Your first 10 columns should look like this:

Year	Max Annual Discharge	Rank
1993	1080000	1
1903	1020000	2
1844	1000000	3
1892	926000	4
1927	889300	5
1883	893000	6
1909	861000	7
1973	852000	8
1908	850000	9
1944	844000	10

  - *tip* - do to this use the data sort function where you sort based on max annual discharge

- To fill on column 4 (Recurrence Interval you need to use the following equation

$$T = \frac{n+1}{m}$$

Where T is the Recurrence Interval, n is the number of years on record and m is the rank order of the flood. Your first ten columns should look like this:

Year	Max Annual Discharge	Rank	Recurrence Interval
1993	1080000	1	155
1903	1020000	2	77.5
1844	1000000	3	51.7
1892	926000	4	38.8
1927	889300	5	31
1883	893000	6	25.8
1909	861000	7	22.1
1973	852000	8	19.4
1908	850000	9	17.2
1944	844000	10	15.5

- Plot your Recurrence Interval data (x axis) and Discharge (y axis) data as an x,y scatter plot. Your plot should look like figure 1.

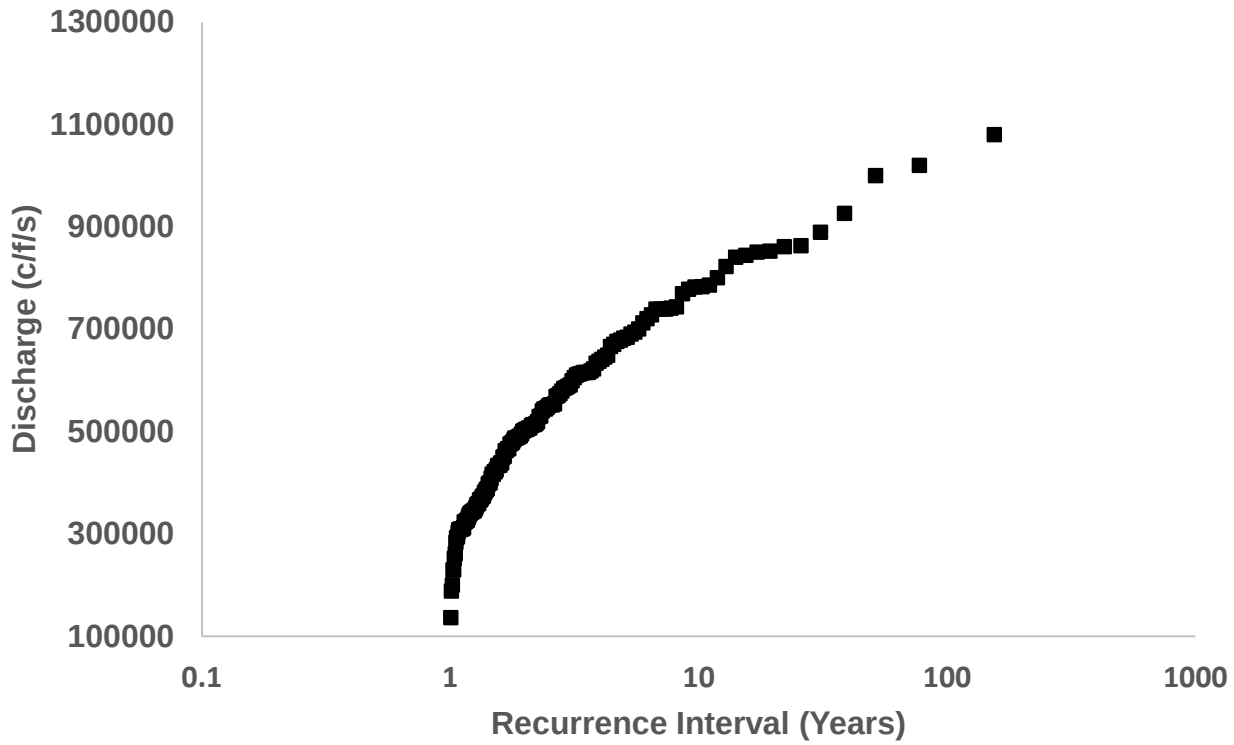


Figure 1: Recurrence Interval of flood flows on the Mississippi River at St Louis between 1844 and 2014.

Look at your table and Figure 1 and discuss the findings. You might want to think about:

- How many floods with are there with a recurrence interval of between 5-10 years as compared to 10-50 years? What are the implications of this?
- Is there a change in recurrence interval through time i.e. are bigger floods happening more frequently in the past 20 years as compared to the first 20 years of the data record
- How would you describe the pattern in recurrence interval to the media to help members of the public to better understand the likelihood of flooding?

Take it Further

Recurrence interval data was calculated for a 200 year long data set. The flood which happened in 1947 had a 10 year recurrence interval so theoretically a flood of that magnitude or equal should not have happened in the ten years prior to following on from that date. The flood which happened in 1973 had a 20 year recurrence interval so theoretically a flood of that magnitude or equal should not have happened in the twenty years prior to following on from that date.

- Use your data to see if this is true?
- If it isn't true what implications does this have?

2) Changes to the magnitude and frequency of flooding across the USA

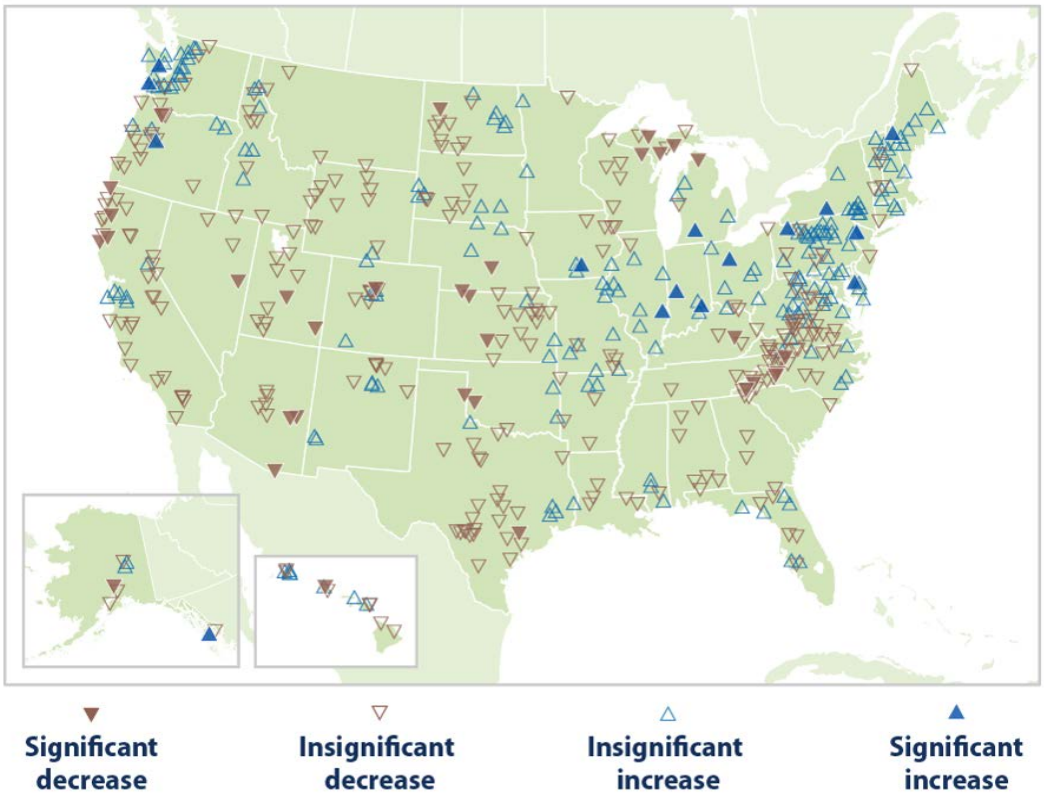
The U.S. Geological Survey maintains thousands of stream gauges across the United States. Each gauge measures water level and discharge—the amount of water flowing past the gauge. Figure 2 below uses total daily discharge data from about 500 long-term stream gauge stations where trends are not substantially influenced by dams, reservoir management, wastewater treatment facilities, or land-use change.

As used above to calculate flood recurrence interval, one way to determine whether the magnitude of flooding has changed is by studying the largest flood event from each year. Figure 2 examines the maximum discharge from every year at every station to identify whether peak flows have generally increased or decreased. Figure 3 also analyses whether large flood events have become more or less frequent over time, based on daily discharge records.

Task

Look at Figure 3 and discuss the findings. You might want to think about:

- Is there a spatial trend in the magnitude of change data?
- Is there is a spatial trend in the magnitude of the frequency data?
- Is there a difference between the two spatial trends? If so why might this be?
- What do you think the implications for these data patterns are? What might happen under a changing climate?



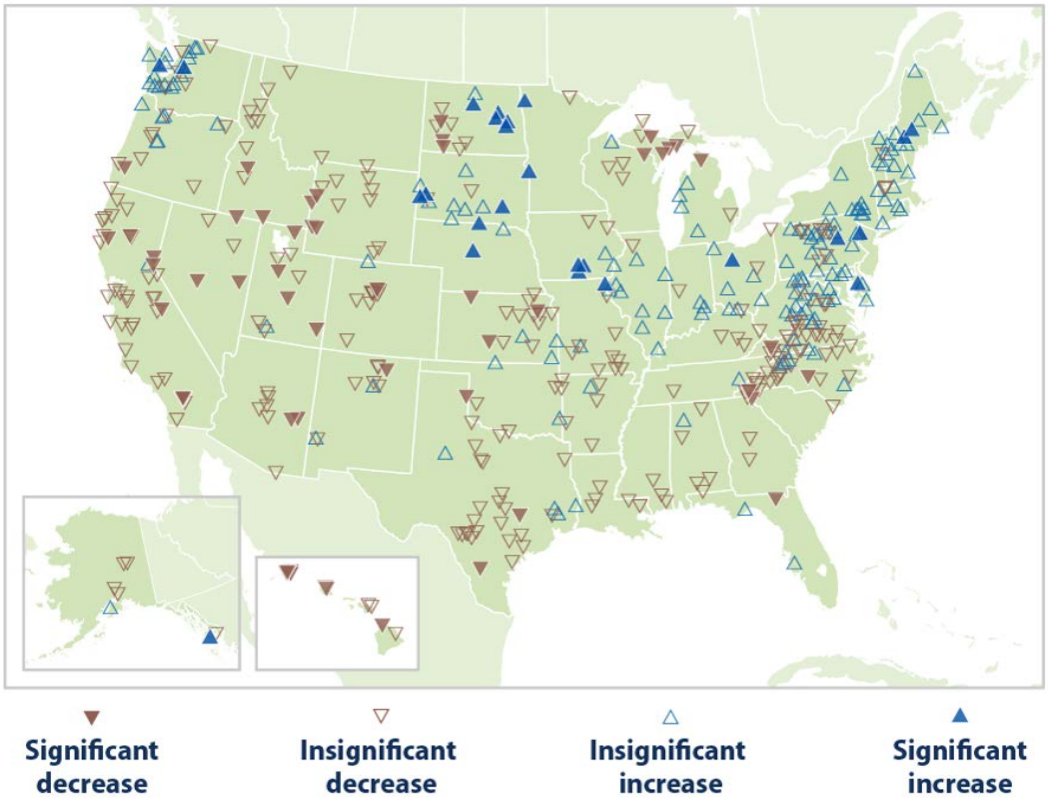


Figure 2: This figure shows changes in the magnitude (top) and frequency (bottom) of flooding events in rivers and streams in the United States between 1965 and 2015. Blue upward-pointing symbols show locations where floods have become larger; brown downward-pointing symbols show locations where floods have become smaller. Solid-colour symbols represent stations where the change was statistically significant. Data source - Slater, L., and G. Villarini. 2016 update and expansion to data originally published in: Mallakpour, I., G. Villarini. 2015. The changing nature of flooding across the central United States. Nature Climate Change 5:250–254.

Take it Further

- Open the Microsoft Excel Flood Frequency data file and the Flood frequency and magnitude sheets. In each there are three columns: 1) Longitude 2) latitude and 3) value.
- Create a frequency histogram of the changes to the flood magnitude and flood frequency.

Look at your histograms and discuss the findings. You might want to think about:

- Is there a difference between the shapes of the distribution for flood frequency as compared to flood magnitude?
- What are the implications of this?

Plenary

Return to the main lesson question. Ask the students to discuss to discuss:

- How useful flood recurrence interval is as an indicator of flooding likelihood
- How they might produce a better descriptor of flooding likelihood
- How they could explain flood recurrence to members of the public
- How future changes to the climate might affect flood frequency and magnitude