Long-term Flood Climatology in the Mid-Atlantic Region: An Analysis Using River Gauge Data (1920-2020)

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Abstract

In recent years, it has become crucial to understand historical flood patterns as it aids in planning activities and providing context for communicating flood risk. This study investigates flood climatology in the Mid-Atlantic region over two periods of time, all with the goal of better prediction and disaster preparedness for local communities. The first portion of this project analyzes data from river gauges from 1920-2020 in order to identify long-term trends and patterns for flooding in the region. These data have been collected at the Middle Atlantic River Forecast Center (MARFC) from the USGS and other sources. The second portion aims to examine the flood frequency patterns from a subset of gauges on smaller rivers where a weather forecast office (WFO) has flood stages defined but does not have official river forecast points. The findings provided valuable insight on flood patterns, both magnitude and frequency, that have increased over the last 100 years in the region. The work also augmented the MARFC flood climatology database, building a better foundation for analyzing climate change and flood risk in the Mid-Atlantic region.

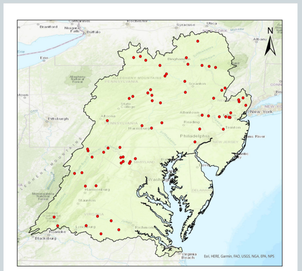
Background Information

Area of Interest

Gauges were selected based on the following criteria:

(1) Had flood records dating back to the 1920s
(2) Flood category had to be one of the following: minor, moderate, major

Narrowed down to 67 locations with 3500+ recorded floods



MARFC region, red dots indicate gages that were a part of the study

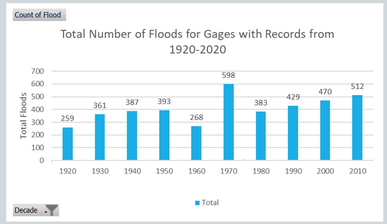
National Weather Service uses the following categories to rank the severity of floods:



Methodology

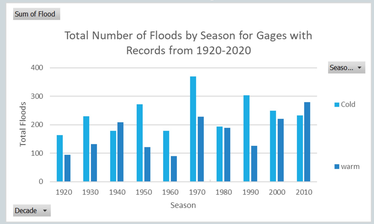
Part 1 - Looking at long-term flooding trends in the MARFC Area from 1920-2020.

Total number of Floods by Decade:



- Increasing flood frequency from 1920-1950
- Increasing flood frequency from 1980-present
- An overall increasing trend

Total number of Floods by Decade:

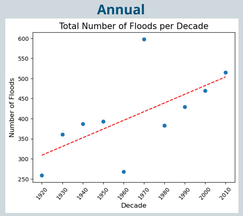


For each decade, there tends to be more floods in the cold season

Seasons defined as - Cold: Oct-Mar; Warm: Apr-Sept

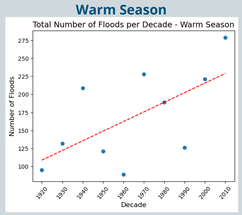
Mann-Kendall Trend Test

Annual



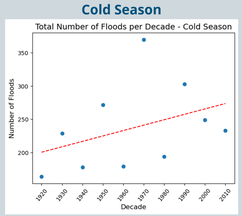
- **p:** 0.0200, 98% confidence that there is a non-zero trend
- **z:** 2.33

Warm Season



- p=0.107, only 89% confidence that there's an increasing trend
- z=1.61
- **slope=12.8**
- intercept=103

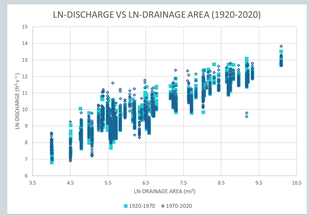
Cold Season



- p=0.152, only 85% confidence that there's an increasing trend
- z=1.43
- **slope=7.67**
- intercept=197

10 Highest Cubic Feet per Second/Area Floods:

cfs/ area	Period of Occurrence	Location	Event
397	1970-2020	Moorefield, WV	Election Day Floods, 1985
344	1970-2020	Monroeton, PA	Hurricane Agnes, 1972
316	1970-2020	Monroeton, PA	Flood of January 19-20, 1996
302	1970-2020	Cootes Store, VA	Hurricane Fran, 1996
299	1970-2020	Monroeton, PA	Tropical Storm Lee, 2011
259	1970-2020	Cooks Falls, NY	Flood of June 2006
238	1920-1970	Cootes Store, VA	Torrential Rains, 1942
234	1970-2020	Cootes Store, VA	Election Day Floods, 1985
233	1970-2020	Monroeton, PA	Hurricane Eloise, 1975
222	1970-2020	Harper Tavern, PA	Tropical Storm Lee, 2011



- **Discharge** - flow of water through a river (measured in cfs)
- **Drainage Area** - size of the watershed (measured in mi²)

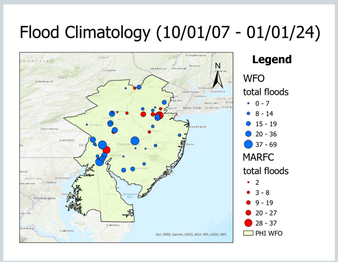
- Graph split into two time series
- Time period 2 (1970-2020) has more outliers indicating more floods with greater magnitudes than compared to time series 1

***Important note** – 9 of the 10 highest cfs floods have occurred in the last 50 years.

Part 2 - Examining the flood frequency from a smaller subset of gauges

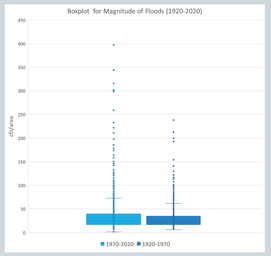
Subset of smaller gauges:

- Philadelphia (PHI) WFO
- WFO has flood stages defined but do not have river forecast points
- ~17 years of data (10/01/2007 - 01/01/2024)



- PHI WFO points cover smaller streams of the region that the MARFC does not
- More floods were reported by the WFO gauges in this region than by the MARFC gauges
- Avg. floods per point:
  - WFO - 18.3
  - MARFC - 17.4

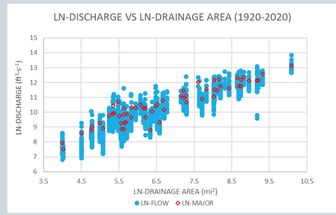
Flood Magnitude



- As previously mentioned, frequency of flooding has increased through time

Boxplot created for each time period -

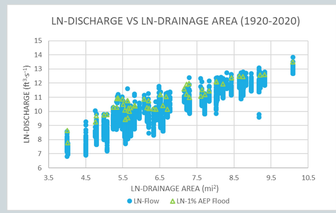
1. **(1920-1970)** - fewer outliers, average magnitude of floods is less than those in time series 2
2. **(1970-2020)** - More outliers, with greater floods
- Boxplot suggests that not only is the frequency of flooding is increasing but also the magnitude of the floods are increasing



Major Flooding:

- Many floods have reached a discharge amount that fall into or exceed the major flood category

(Based on flooding values the NWS considers as 'major')

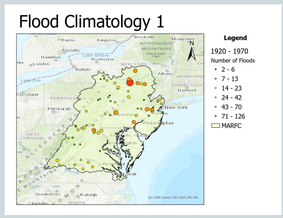


1% AEP Flood:

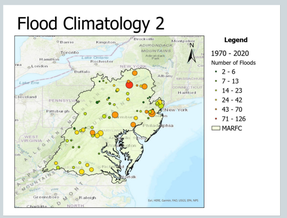
- For each drainage area, fewer floods have reached a discharge amount that exceeded the 1% AEP

(1% Annual Exceedance Probability (AEP) is considered a 'once every 100 years' flood by the USGS)

Flood Climatology of the Mid-Atlantic



1920-1970: Floods are less frequent compared to the second half of the data



1970-2020: For each gage location, there tends to be more floods in this time series

Part 2 (cont.) – Filling Gaps in Flood Database

After collecting all flood data, the final step was to cross-reference Philadelphia (PHI) WFO data on water.noaa.gov with our analysis.

NWSID	Number of Dates Missing
ALKP1	2
ALLP1	17
ALNP1	0
APAP1	0
CHBD1	32
COTP1	3
DPKD1	10
DWNP1	32
EGRP1	16
FARN4	0
FLAN4	11
GEHN4	6
HBRN4	4
HDDN4	0
HLGP1	3
HNBP1	21
MDBN4	3
MEDN4	1

NWSID	Number of Dates Missing
MITN4	21
MODP1	1
NEKD1	0
NLBN4	3
NORN4	13
PCTN4	6
PLLP1	49
RCCD1	11
SAMN4	9
SEEN4	10
SKVP1	3
STND1	3
SWBN4	1
SWVP1	19
TULP1	0
WETN4	10
WHIN4	8

Light blue column represents each gauge site (NWSID) in the PHI WFO that was utilized in this data set; Green column represents the number of flood dates missing on the water.noaa.gov site.

Water.noaa.gov has since been updated with missing flood date data.

Conclusion

In the past century, the MARFC region has experienced an increase in both the frequency and magnitude of floods. This conclusion is based on an analysis of NWS defined floods at RFC river forecast points. Further work was started to enhance our understanding of flooding trends on smaller streams. This involved analyzing USGS gage data at locations WFO PHI monitors for flash flooding. Notably, the WFO PHI flashy points recorded more floods per point on average than the MARFC river forecast points within the PHI region, highlighting the importance of incorporating local gauge data for a more comprehensive understanding of flood patterns.

Acknowledgements

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