Predicting peak lake levels in Eastern North Carolina post Hurricane Florence

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UNC WinS

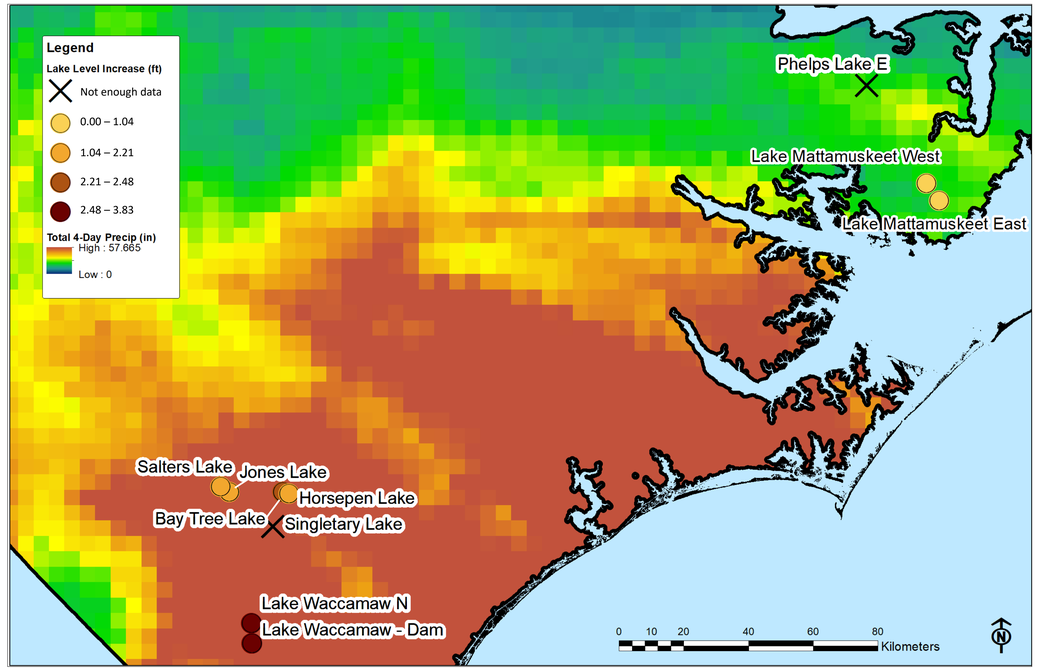
1. Abstract

Hurricane Florence made landfall in North Carolina on September 14th, 2018, and traveled across North Carolina and South Carolina over the course of four days. It brought intense flooding to lakes in North Carolina, particularly in the southeast, which left lasting impacts on surrounding communities. Using preexisting lake level data gathered by citizen scientists, I analyzed the similarity in the recession of lake levels after Hurricane Florence in nine lakes across North Carolina. I also looked at the impact of total precipitation during the hurricane on the magnitude of increase in lake level. I used data from eleven different gauges across the nine lakes to track lake level increase during the hurricane. However, over 1 million people were told to evacuate as Florence approached. Because of this, only one lake, Bay Tree Lake, has readings throughout the course of the hurricane. Bay Tree Lake is a 5.84 km^2 lake in southeast North Carolina disconnected from any riverine inputs or outputs and has readings for seventeen of the twenty days following the landfall of Hurricane Florence, including daily readings from September 14th to September 22nd. Because Bay Tree Lake has consistent hurricane readings, I used it to predict the peak lake levels for the lakes without consistent hurricane readings. Based upon the hypothesis that water levels in geographically and hydrologically similar lakes respond similarly to extreme precipitation events, I applied a power law recession curve to Bay Tree Lake and modified the coefficient to fit other lakes in the dataset. I was able to successfully apply a modified power law to other disconnected lakes in the dataset, but I could not fit it precisely to Lake Waccamaw, the only connected lake in the dataset, as well as Lake Mattamuskeet, which experienced relatively low precipitation during Hurricane Florence, resulting in a much smaller height increase in comparison to the other lakes in the dataset. While there was a moderate positive correlation between rainfall during the hurricane and increase in lake level (r = 0.69), it was not a perfect predictor of the increase that each lake would experience. This is due to other geomorphic factors such as connectivity and surface area. The accuracy of these results is limited by the low number of observations for most lakes during the hurricane, and the results may not be applicable outside of the limited spatial scope of the nine lakes in the dataset.

2. Questions and Importance

Question 1: Can we apply a recession curve from one lake to other similar lakes where post-hurricane data is minimal?
Question 2: What factors control the applicability of the recession curve to nearby lakes?
Question 3: To what extent does precipitation influence the change in lake levels during an extreme weather event?

Importance:
- Quantifying the magnitude of damage that lakes experienced after Hurricane Florence
- Identifying similarities and differences between lakes with varying attributes
- Understanding the effect of precipitation on lake level

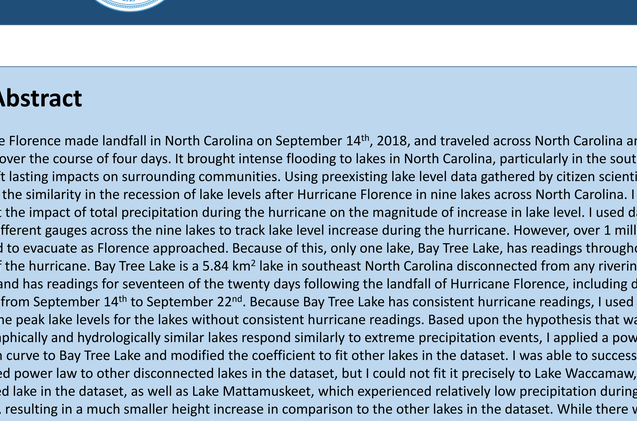


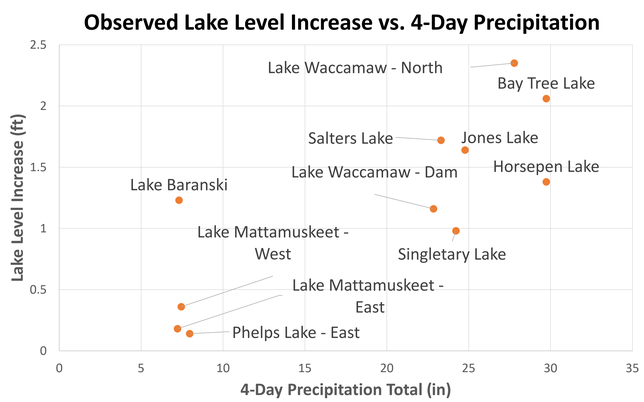
5. Conclusions

- The power law is applicable to disconnected lakes with similar magnitude of water level increase, but is not applicable to connected lakes (such as Lake Waccamaw) or lakes with a smaller increase in water level (such as Lake Mattamuskeet).
- The Pearson's Correlation Coefficient between the observed increase in water level and four-day total precipitation is higher than that of the predicted increase and four-day total precipitation.
- Observed peaks are biased low because measurements were taken several days after the hurricane.
- Overall correlation between lake level and four-day total precipitation is moderate (r = 0. 69).

Figure (right): LOCSS gauge location at Lake Mattamuskeet - East

Figure (left): LOCSS gauge location at Jones Lake





Overall Pearson's Correlation Coefficient: 0.69
Pearson's Correlation Coefficient for Predicted Peaks: 0.70
Pearson's Correlation Coefficient for Observed Peaks: 0.81

3. Data

- **Lake Level Data[1]:**
  - Lake Observations by Citizen Scientists and Satellites (LOCSS)
  - 9 Lakes / 11 Gauges
  - September 16th to October 16th, 2018
- **Gridded Precipitation Data[2]:**
  - National Oceanic and Atmospheric Administration (NOAA)
  - Summed total precipitation from September 15th to September 18th, 2018
  - Spatial Resolution: 16 km^2

4. Methods

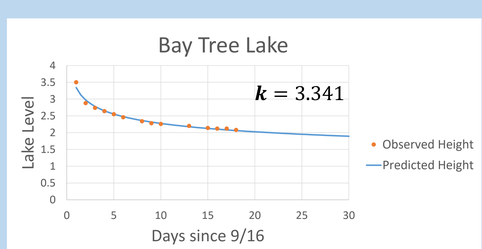
Bay Tree Lake is the only lake in the dataset with consistent observations during Hurricane Florence.

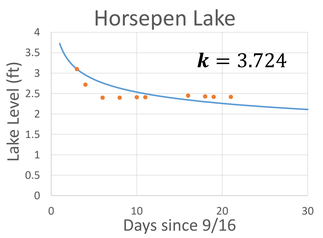
1. Calculate the power law for lake level recession of Bay Tree Lake

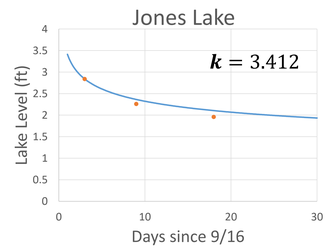
$$h = k(x^{-0.167})$$

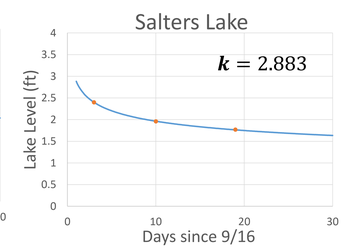
h = predicted height
k = lake-specific calibration coefficient
x = days since 9/16/2018

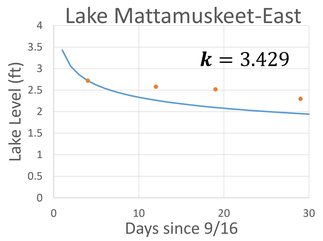
2. Calibrate k for other lakes based on first recorded lake level after 9/16/2018
3. Apply modified equation to all dates between 9/16/2018 and 10/16/2018 to calculate predicted water levels
4. Compare predicted water levels to observed water levels
5. Calculate the difference between water levels before the hurricane and predicted peak water level (when available) or observed peak water level to find the increase in water level caused by the hurricane
6. Identify correlation between precipitation and peak water level

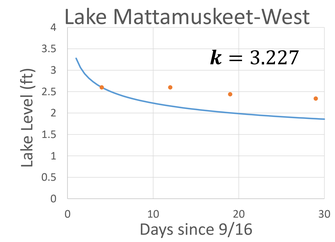


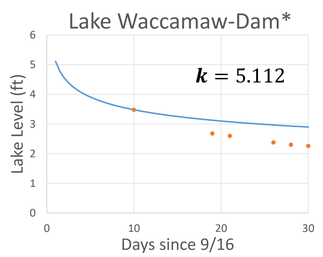


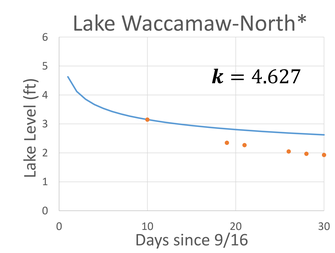












	Mean Absolute Error (ft)	Root Mean Square Error (ft)
Horsepen Lake	0.160	0.185
Jones Lake	0.083	0.103
Salters Lake	0.003	0.004
Lake Mattamuskeet - East	0.365	0.411
Lake Mattamuskeet - West	0.396	0.440
Lake Waccamaw – Dam	0.516	0.570
Lake Waccamaw - North	0.559	0.617

*Only lake that is connected to a river

Legend
Observed water level
Predicted water level

6. References

1. Lake Observations by Citizen Scientists and Satellites (2017). North Carolina Gauges List, September 2018 to October 2018, https://liquidearthlake.website/index.php/gauge, LiquidEarth Lake: Citizen Science Data Portal, Cookeville, TN. (Updated daily.)
2. National Oceanic and Atmospheric Administration (2019). North Carolina Observed Quantitative Precipitation Estimation, September 2018, https://water.weather.gov/precip/download.php, National Weather Service Advanced Hydrologic Prediction Service, Silver Spring, MD. (Updated daily.)

7. Acknowledgements

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