Name: Armant Touche

Class: UNST-286D

Streamflow Variability

Introduction

Streamflow refers to the amount of water flowing in a river at any given time in a hydrological system ("Streamflow and the Water Cycle," n.d.). The variance in streamflow differ from each region of the United States. Changes in hydrological systems, especially streamflow, in the Continental United States (CONUS) have caused some negative outcomes such as an increase in floods in some regions (Rice et al., 2016). A regional example of a negative outcome from increased streamflow variability is the increasing number of floods in California (Tucker, 2020). The human "disturbance index" is measurement tool used by the United States Environmental Protection Agency (USEPA) to measure the amount of human disturbance present in watershed regions across the nation (Falcone et al., 2010). The reason for needing the index is to use this measurement to track the past, present, and future behavior of these hydrological systems and how humans affect streamflow variation. The scale of variability is still being studied since previous methods used datasets that contained redundancies, which decreased accuracy but Falcone et al. (2010) described the best approach to accurately classifying watershed disturbance by humans.

There is a relationship between streamflow variability and both water resource availability and management (Rice et al., 2016). For present and future studies of hydrological systems, understanding the effects of humans' activity on streamflow variability is crucial to positively manage water resources in the CONUS and elsewhere in the world.

Data Analysis

First, some regional examples in the CONUS of streamflow variability effects. To better understand the negative outcomes from increased streamflow variability and increasingly changing climate, the Mallakpour et al. (2018) study reported streamflow minimum and maximum annual streamflows mean ($m^3\,s^{-1}$) trends in various watersheds in Northern California.

In *Figure 1*, notice the minimum streamflow values (red-down arrows) in panels (D-F). In D-panel, there are more reports on negative trends occurring in streamflow values from 1950-2005 which means that inland streams are displaying a decreasing mean during the dry seasons and in G-panel, during the wet season, there is an increase in the mean streamflow value. The increase in streamflow mean during the wet-season promotes more floods and a decrease in mean during dry-season promotes more droughts (Mallakpour et al., 2018). Although the trends are minor from 1950-2005, the cumulative distribution for future trends highlight a negative trend. Cumulative distribution is likelihood or probability for a non-discrete value to occur at any given point ranging from one to zero, usually referred to as a random variable. In the current context, the random variable is streamflow discharge ($m^3\,s^{-1}$) ("Related Distribution," n.d.).

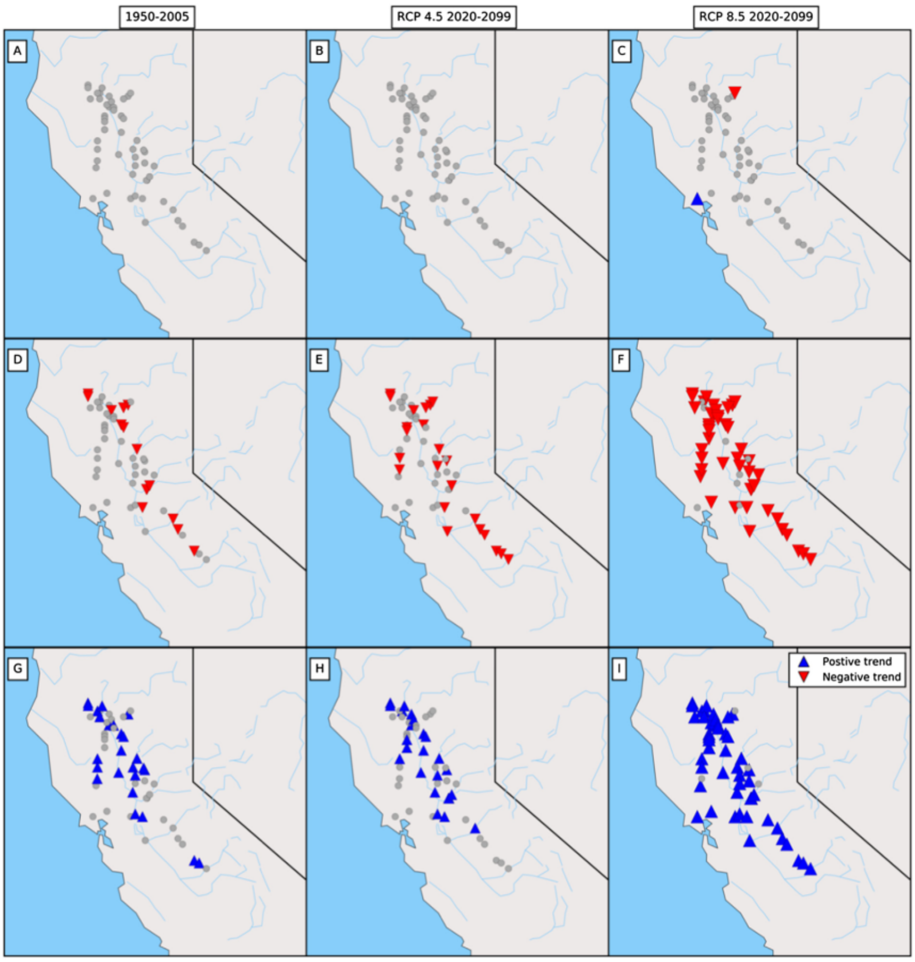

Figure 1

(Mallakpour et al., 2018)

Figure 2 highlights cumulative trend which displays the cumulative distribution of three datasets – (1) 1950-2005 (2) Representative Concentration Pathway (RCP) 4.5 2020-2099 (3) RCP 8.5 2020-2099. The left panel is Oroville Lake in California and the right panel is Shasta Lake. Notice the blue line's distribution is greater than the two project trends from RCP 4.5 and RCP 8.5. RCP 4.5 is a model of future streamflow trends which uses a bias-corrected projection on data derived from global climate model (GCM) and RCP 8.5 also uses data derived from GCM to simulate future streamflows trends. GCM data is known to have systematic error (biases) due to limited GIS spatial resolution which is why one (RCP 4.5) of the two future projections uses a bias correction projection to account for theses errors (biases).

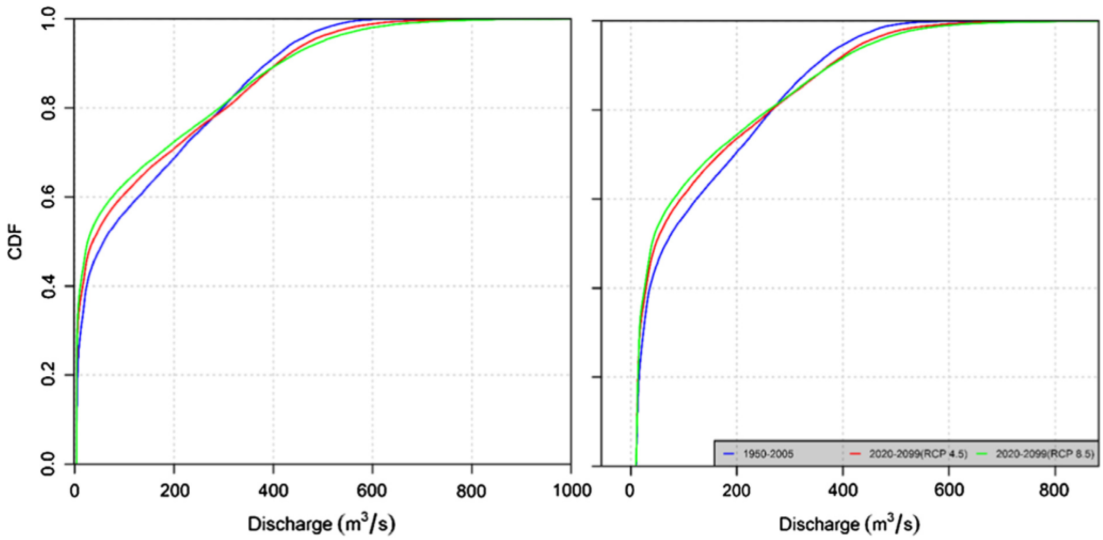

Figure 2

Empirical Cumulative Distribution Functions (ECDFs) (Mallakpour et al., 2018)

But how does climate change affect streamflow variability? From Rice et al. (2016) study, atmospheric variables may be potential drivers in streamflow variability. Rice et al. (2016) results suggest that human activities may magnify or amplify the expression of changes. P_{mean} (mm) and DI_{mean} (Soil Dryness index) which were the important atmospheric variables that acted as drivers. There were more variables being used by United State Geological Survey (USGS) but watershed climatology, for instance was too varied amongst CONUS watersheds. *Figure 3* models streamflow trends across the CONUS (Rice et al., 2016). The red markers depict a decreasing trend in streamflow mean values and blue depicts an increase in streamflow mean values. Again, drawing our notice to the Southwest region, the increased number cases of floods in California highlights the relationship with the blue markers which model increased streamflow variability.

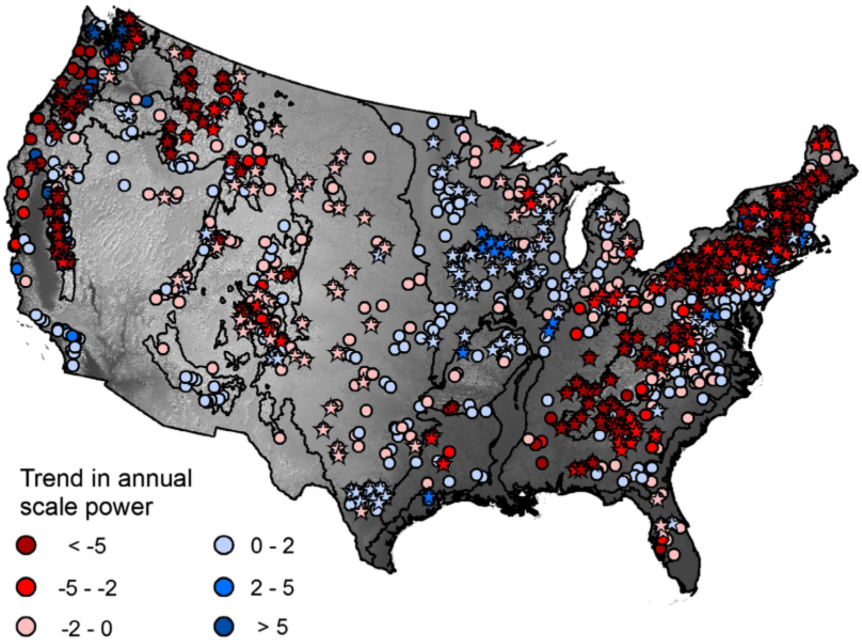

Figure 3

(Mallakpour et al., 2018)

Results

To understand how human activity contributes to streamflow variability within streams, let's discuss the human "disturbance index" mentioned in Falcone et al. (2010) study. Building roads, damming streams, and inputs from agricultural sources and urban sources serve as contributors to changes in stream ecosystems. Falcone et al. (2010) was not the only study to try to measure human activity. In Stein et al. (2002), they mentioned that previous studies used biological markers as a way of measuring human activity (i.e. soil sampling and other biological harvesting methods) which can be time consuming and are site-specific. The sample from one site does not necessarily mean that it represent the whole. Still, the duty of monitoring human effects of environment should be a priority when it comes to urban and landscape planning (Stein et al., 2002). With the advent of the Geographic Information System (GIS), better data can be derived which uses multiple variables versus the single variable approach described in Stein et al. (2002) and other studies (Falcone et al., 2010). The biggest take away from Falcone et al. (2010) is that a reduced variable set can reproduce inferences from different watershed sites and the main six variables that should be used to measure human's impact on streams are: (1) housing-unit density (housing unit km^{-2}), (2) Road density in watershed ($km\,km^{-2}$), (3) Sum of 43 major pesticide compounds ($kg\,km^{-2}$), (4) Urban-crops-pasture land cover in a 600 m mainstem buffer, (%), (5) Average linear distance of sampling site to all canals/ditches (m), (6) Dam storage in basin (liters $\times$ 1000 km^2).

Although the focus can be centered around these variables, there is still an issue with deriving GIS data on small-to-medium sized watersheds. The reason for difficultly is that the resolution is sometimes too low for accurate spatial analysis hence why the variables are not to reliant on variables involving spatial quantities. Examples of spatial quantities are most of the variables from the National Land Cover Data-set (Falcone et al., 2010). Even with resolution errors, the results from this study suggest that "disturbance index" is an objective, deductionist approach to measuring humans activities' effect on streamflow. The data analysis conducted by Mallakpour et al. (2018) suggests that anthropogenic effects are affecting streamflow and will continue effecting hydrologically systems like the watersheds in Northern California.

Discussion

Water and climate change are quickly becoming global and political issues and many of these issues relate with national security and human health. Before the 70's, obtaining topological images without the aide of computers was a chore that many scientists did not like to do. Even after receiving images or maps, the accuracy may not or may have been the best because of the decentralized nature of information and standards back then. With better systems for acquiring maps, like the Internet, has boosted research interests into hydrological systems in order to understand water and climate change issues (Bras, 1999). In Bras (1999) article, he believes the studies of groundwater hydrology increased scientists' interest into studying the impact of certain variables that affect certain properties with hydrology, particularly flow and transport.

Conclusion

The results from Rice et al. (2016) conclude that climate change does and has affected streamflow in CONUS which serve as sources for freshwater. Using indexes like the "disturbance index" mentioned in Falcone et al. (2010) can objectively quantify the impact from human activity like urban developing and water flow controls. It's no wonder that the CONUS is experiencing more droughts in some areas like the Pacific Northwest and more floods in areas like Southern California. The usage of GIS-derived data can be prone to errors like low pixel resolution on small-to-medium watersheds but still, the "disturbance index" is a useful *a priori* method for measuring anthropogenic effects on streamflow.

Future streamflow models predict increasing variability in streamflow. Increased variability will further complicate water resource management in the CONUS and elsewhere in the world. Not only complicate water management but will also cause more floods and droughts as mentioned the data analysis performed by Mallakpour et al. (2018). In order to combat this difficult task, studies need to standardize what activites affect hydrological systems which are mainly the six variables mentioned in Rice et al. (2016). The variables that deserve to be highlighted are: (1) housing-unit density (housing unit km^{-2}), (2) Road density in watershed ($\mathrm{km\,km}^{-2}$), (3) Sum of 43 major pesticide compounds ($\mathrm{kg\,km}^{-2}$), (4) Urban-crops-pasture land cover in a 600 m main-stem buffer, (%), (5) Average linear distance of sampling site to all canals/ditches (m), (6) Dam storage in basin (liters $\times$ 1000 km^2). I feel confident that more studies are being had based on information stated in the data on sources section part of the appendix. The data from research on the sources suggests that there are more studies that are newer than 2017 taking place versus studies before 2017.

References

Bras, R. L. (1999). A brief history of hydrology*. *Bulletin of the American Meteorological Society*, *80*(6), https://doi.org/10.1175/1520-0477-80.6.1151, 1151–1164. https://doi.org/10.1175/1520-0477-80.6.1151

Falcone, J., Carlisle, D., & Weber, L. (2010). Quantifying human disturbance in watersheds: Variable selection and performance of a GIS-based disturbance index for predicting the biological condition of perennial streams. *Ecological Indicators*, *10*(2), 264–273.

Mallakpour, I., Sadegh, M., & AghaKouchak, A. (2018). A new normal for streamflow in california in a warming climate: Wetter wet seasons and drier dry seasons. *Journal of Hydrology*, *567*, 203–211.

Related distribution. (n.d.). National Institute of Standards and Technology. Retrieved May 8, 2020, from https://www.itl.nist.gov/div898/handbook/eda/section3/eda362.htm

Rice, J., Emanuel, R., & Vose, J. (2016). The influence of watershed characteristics on spatial patterns of trends in annual scale streamflow variability in the continental u.s. *Journal of Hydrology*, *540*, 250–860.

Stein, J., Stein, J., & Nix, H. (2002). Spatial analysis of anthropogenic river disturbance at regional andcontinental scales: Identifying the wild rivers of australia. *Landscape and Urban Planning*, *60*(1), 1–25.

Streamflow and the water cycle. (n.d.). United States Geological Survey. Retrieved May 8, 2020, from https://www.usgs.gov/special-topic/water-science-school/science/streamflow-and-water-cycle?qt-science_center_objects=0#qt-science_center_objects

Tucker, D. (2020, January 27). *More rain and less snow means increased flood risk, stanford study reveals*. Standford. Retrieved May 20, 2020, from https://news.stanford.edu/2020/01/27/rain-less-snow-increases-flooding/

Appendix

Data On Sources

1. Rice et al. (2016) - *Influence of watershed...*
   (a) Search engine used: https://search.library.pdx.edu/primo-explore/
   (b) Keywords: "streamflow variability"AND"human activity"
   (c) How many results: 8
   (d) How many were peer-reviewed: 8
   (e) How many are from 2017 or newer: 5
   (f) Calculate % new peer-reviewed 62.50 %
   (g) Link: https://www-sciencedirect-com.proxy.lib.pdx.edu/science/article/pii/S002216941630436X
   (h) Type: Peer-reviewed article
2. National Institute of Standards and Technology (NIST) - *Related Distribution*
   (a) Search engine used: Google
   (b) Keywords: Cumulative Distribution website:gov
   (c) How many results: 3.25×10^8
   (d) How many were peer-reviewed: N\A
   (e) How many are from 2017 or newer: N\A
   (f) Calculate % new peer-reviewed: N\A
   (g) Link: https://www.itl.nist.gov/div898/handbook/eda/section3/eda362.htm
   (h) Type: Reference
3. Stein et al. (2002) - *Spatial analysis of anthropogenic...*
   (a) Search engine used: Discovered source within Falcone et al. (2010)
   (b) Keywords: N\A

(c) How many results: N\A

(d) How many were peer-reviewed: N\A

(e) How many are from 2017 or newer: N\A

(f) Calculate % new peer-reviewed: N\A

(g) Link: https://www-sciencedirect-com.proxy.lib.pdx.edu/science/article/pii/S0169204602000488

(h) Type: article

4. United States Geological Survey (USGS) - *Streamflow and Water Cycle*

   (a) Search engine used: Google

   (b) Keywords: streamflow overview website:gov

   (c) How many results: 5.6×10^5

   (d) How many were peer-reviewed: N\A

   (e) How many are from 2017 or newer: N\A

   (f) Calculate % new peer-reviewed: N\A

   (g) Link: https://www.usgs.gov/special-topic/water-science-school/science/streamflow-and-water-cycle?qt-science_center_objects=0#qt-science_center_objects

   (h) Type: reference

5. Mallakpour et al. (2018) - *A new normal for ...*

   (a) Search Engine used: PSU library search engine

   (b) Keywords: southern california stream variability

   (c) How many results: 59,973

   (d) How many were peer-reviewed: 16,308

   (e) How many are from 2017 or newer: 8,038

   (f) Calculate % new peer-reviewed 49.29%

(g) Link: https://www-sciencedirect-com.proxy.lib.pdx.edu/science/article/pii/S0022169418307844

(h) Type: article

6. Falcone et al. (2010) - *Quantifying Human disturbance*

    (a) Search Engine used: PSU library search engine

    (b) Keywords: Discovered source within Rice et al. (2016) article

    (c) How many results: N\A

    (d) How many were peer-reviewed: N\A

    (e) How many are from 2017 or newer: N\A

    (f) Calculate % new peer-reviewed: N\A

    (g) Link: https://www-sciencedirect-com.proxy.lib.pdx.edu/science/article/pii/S1470160X09000983

    (h) Type: article

7. Bras (1999) - *A Brief History of Hydrology*

    (a) Search engine used: Google

    (b) Keywords: history of hydrology

    (c) How many results: 1.83×10^8

    (d) How many were peer-reviewed: N\A

    (e) How many are from 2017 or newer: N\A

    (f) Calculate % new peer-reviewed: N\A

    (g) Link: https://journals.ametsoc.org/doi/pdf/10.1175/1520-0477-80.6.1151

    (h) Type: article

8. Tucker (2020) - *More rain and less snow...*

    (a) Search engine used: Google

(b) Keywords: Southern California flooding

(c) How many results: 2.69×10^8

(d) How many were peer-reviewed: N\A

(e) How many are from 2017 or newer: N\A

(f) Calculate % new peer-reviewed: N\A

(g) Link: https://news.stanford.edu/2020/01/27/rain-less-snow-increases-flooding/

(h) Type: news article