FutureWater Exercise Option 1: Climate Change and Seasonal Changes in Rainfall and Streamflow

This lesson centers around the use of https://futurewater.indiana.edu/, a science gateway that presents a model of the hydrologic changes happening in the Wabash River basin over the next 80 years. Our goal with this module is to show, in concrete terms, what changes in climate will mean for the behavior of the water cycle where the students live.

First, we will ask students to find a local body of water (a lake, stream, etc.) to serve as a reference point for discussion. Then, the students will find that water body's watershed on the FutureWater website and extract the pertinent data of predicted changes. Students will be asked to make predictions about seasonal variability and streamflow changes compared to the historical mean.

After determining the reference water body, students will be asked to identify changes in precipitation and streamflow for the area. After finding the annual data, the focus should shift to seasonal variability. To illustrate the importance of seasons, students will look at data from March and September, representing fall and spring. These two seasons are chosen because they represent the most dramatic swing in conditions in the Wabash basin. The students will record rainfall and streamflow values for these two months and compare them to annual averages, then discuss the importance of looking at seasonal variability. Based on their findings, students will predict any changes to crop yields and other economic and environmental impacts.

Student Worksheet

This lesson is designed to give you a tangible insight into seasonal changes in precipitation and streamflow due to climate change. Discuss the following questions:

1. What is precipitation? What sorts of things count?

   Precipitation is water falling out of the atmosphere in different forms; for example, rain, snow, sleet, hail.

2. What is streamflow? How is it measured?

   Streamflow is a measure of the water moving through a stream or channel. Streamflow can be measured by stream gauges or it can be estimated by Manning's equation. It is measured as a volume per time, for example, cubic meter per second or gallons per second.

Next we'll look at precipitation and streamflow data from your local area.

Head over to futurewater.indiana.edu. Futurewater hosts a model which simulates how water patterns will change over your lifetime. You are going to find the watershed with your stream and look at a few important numbers around precipitation and streamflow.

1. Go to futurewater.indiana.edu
2. Click 'explore modeling forecasts'
3. Choose your watershed at the HUC-12 scale (the pre-selected **Subwatershed Size**)
4. Locate your watershed by typing the zip code in the box "Zip Code" at the upper right corner on your screen. For example, you type 47401, the watershed containing downtown Bloomington and the southeast of Monroe County will be zoomed in on the map at left. Note the faint label "Bloomington" in the background.
5. Select "Precipitation" as the **Variable** and **Summary Period** as "Annual".
6. Go to the **Emissions Scenario** drop-down and select "High (RCP 8.5)"

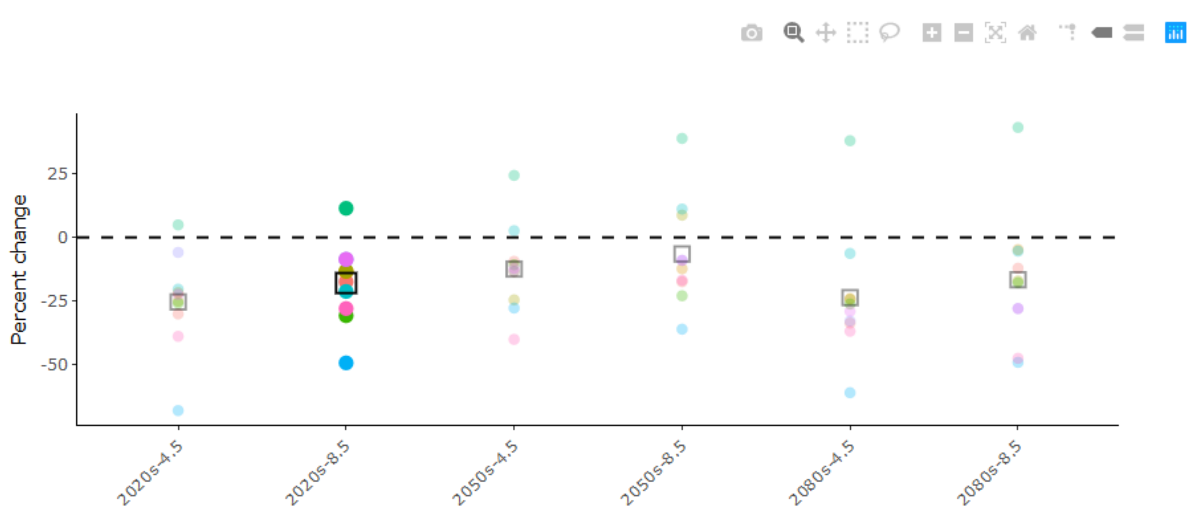
Let's make some guesses. What do you think will happen to precipitation in the next 80 years? What about streamflow? Why?

Here students may say that greenhouse gas emissions will lead to a warming climate and that this might result in a) more precipitation and thus higher streamflow or b) more arid conditions (higher temperature, higher evaporation) and therefore lower streamflow.

These two competing factors play out in the future. Although we see more precipitation, we also see more evaporation (more precisely evapotranspiration). The net result is less water available in streams and aquifers (groundwater) (Dierauer & Zhu, 2020). This also results in a shift of seasonality – a warming climate moves the spring earlier in the year, which makes more water available for evaporation.

Now we'll go through and gather some data about annual precipitation values and annual streamflow values.

To the right of the map, you will see a chart similar to the one below. Take a look at the axes. The Y-axis represents percent change in the displayed variable from the average value taken from the years 1971-2000. The X-axis shows the different decade–emission scenario combinations. The data points for the selected decade–emission scenario



combination are shown in bold colors. The black box represents the Ensemble Mean (or average) of the 10 climate models represented by the different colored dots.

Fill out the following charts using the average value. Hint: you can view the value by hovering over the black boxes on the chart. ***(Answers provided for the Jackson Creek-Clear Creek watershed.)***

Annual Precipitation under RCP 8.5

	2020s	2050s	2080s
Change in precip (%)	**2.2**	**7.7**	**8.1**

Now change your variable to 'streamflow'.

Annual Streamflow under RCP 8.5

	2020s	2050s	2080s
Change in streamflow (%)	**-10.6**	**2.6**	**3.2**

What patterns do you see for the 2020s - 2080s in streamflow and in precipitation?

One would observe that from 2020s - 2080s precipitation increases compared to baseline data. Streamflow in the 2020s initially decreases relative to the baseline. Later in the century it also increases.

Next let's look at some seasonal data and see how they compare to the annual averages.

How do you think precipitation will increase or decrease in March and September compared to the historical mean? Why? How about streamflow?

One might speculate that seasonal changes in precipitation and streamflow will mimic annual changes. Alternatively, one might guess that some months will see

precipitation increase more than the annual change and other months less. Streamflow is somewhat more complicated as it depends on several variables. However, it should also display seasonal changes that average to the same order as annual changes.

Now, adjust the Summary Period and fill out the following charts for March and September as you did above for the annual projections.

Percent Change in Seasonal Precipitation

	2020s	2050s	2080s
March	10.1	16.5	15.5
September	-5.9	-5.4	-14

Percent Change in Seasonal Streamflow

	2020s	2050s	2080s
March	-8.9	13.2	3.2
September	-28.7	-25.7	-34.3

Look at the September data, are the changes in precipitation and streamflow at the same scale?

No. Precipitation decreases a moderate amount (5% to 14 %) while streamflow decreases rather drastically—up to 34%.

Does an increase of precipitation always result in an increase of streamflow? Why?

Not in this watershed. We see an increase of precipitation by 10.1% in March 2020s but streamflow decreases by 8.9%. This is because higher temperaturse increase evapotranspiration.

How do these seasonal changes compare to the annual summary?

Although we see small changes in the annual average values, the seasonal changes are large and alarming. It is important to analyze the seasonal data.

What does seasonal variation in water imply about how we should be managing water over the year?

In general, precipitation in winter is projected to increase while precipitation in late summer and fall is likely to decrease slightly (Dierauer & Zhu, 2020). The annual summaries provide information for the entire year and may not reflect seasonal trends. One strategy to deal with the variation is to store water during wet months for use in the drier months of summer and fall.

What impact does the increase in precipitation have on crop planting?

Crop growth depends on a good balance of precipitation. High precipitation can decrease the probability of drought and as a result strengthen the crop health. However, sudden and intense precipitation may damage crops and wash away nutrient-rich topsoil. Increased frequency and/or intensity precipitation events can delay planting and harvesting cycles, restrict root growth, and cause oxygen deficiencies and nutrient loss.

How might streamflow variation impact animal habitat? Do you think annual or seasonal variation would be more important?

The extremes of seasonal flows are especially important to aquatic habitat. Many aquatic species' reproductive cycles depend on minimum or maximum flows and may be disrupted by wide swings in streamflow. Annual variation (especially long droughts) affects both aquatic and terrestrial species at all levels of the food chain.