TEACHER PAGE – *Trial Version*

** After completion of the lesson, please take a moment to fill out the feedback form on our web site (https://www.cresis.ku.edu/education/k-12/online-data-portal)**

Lesson Title: Investigation – Climate Change Projection, A Look at the Water Budget
Grade: 9-12

Questions:

- How much temperature change is needed to have an environmental impact?
- Are some biomes affected differently by temperature change than others?
- What are some positive and negative aspects of the climate change on your biome?

Time:
Two 45 minute class periods. Lesson can be structured to 20-30 minute segments or as stand-alone activities.

Scope of the Lesson:
One of the challenges facing educators of climate change is the spatial and temporal separation of the effects of climate change that is perceived by students. In order to help with these separation issues, students need to understand that climate change does not only impact the poles but can have significant local impacts as well. Accessed through the internet, WebWIMP is a Web-based, Water budget, Interactive Modeling Program that in essence is a simple climate model that can be used to predict some basic impacts of climate change at a given location.

Temperature and precipitation changes predicted from the 2007 IPCC report will be used to simulate possible climate changes. The IPCC is an international organization that has compiled a series of reports that summarize the potential climate changes that might occur because of human impacts on the atmosphere. By comparing water balance diagrams of present-day and IPCC based future climate scenarios, students can evaluate the type of climate changes Kansas could experience due to the projected global warming.

Objectives:
The students will:

- Use WebWIMP to create a water budget diagram for two major geological regions.
- Use WebWIMP to create a water budget table and diagram for the same two regions to model the conditions if the changes in temperature and precipitation occur as predicted in the 2007 IPCC (Intergovernmental Panel on Climate Change) report.
- Locate analog cities in United States resembling the IPCC predicted water budget diagrams.

Standards:

- National 9-12: A1, 2, 3; B1; E1; F1; G3, 4, 5, 6; H1, 2, 3

Vocabulary:

- actual evapotranspiration: the actual amount of water becoming water vapor due to evaporation and transpiration from plants. It can be thought of the water the plants actually extract from the soil for transpiration in addition to evaporation.
- potential evapotranspiration: the potential amount of water plants need for transpiration plus evaporation.

- analog city - an equivalent city with a comparable water budget diagram representing a city's projected climate change due to global warming.

Background:

A water budget is a simple accounting scheme used to compare water supply and demands in a specific area. The budget considers the water supply, represented by precipitation, the ability of a soil to retain water, and the loss of water to the atmosphere through the processes of transpiration from vegetation and evaporation of water (together these are called evapotranspiration). Water demand is represented by potential evapotranspiration, which depends on the amount of energy available to a location. The actual amount of evapotranspiration is the amount of water that is actually lost to the atmosphere which depends in part on the water demand and the water supply. This is an important tool for calculating water surplus and deficit in an area (Figure 1). The water for evapotranspiration can come from both precipitation and soil moisture. When the water needs of the vegetation (potential evapotranspiration) and water actually used (actual evapotranspiration) are compared, an estimate of the water shortage can be made for an environment (moisture deficit). The moisture deficit can be directly related to plant health and productivity.

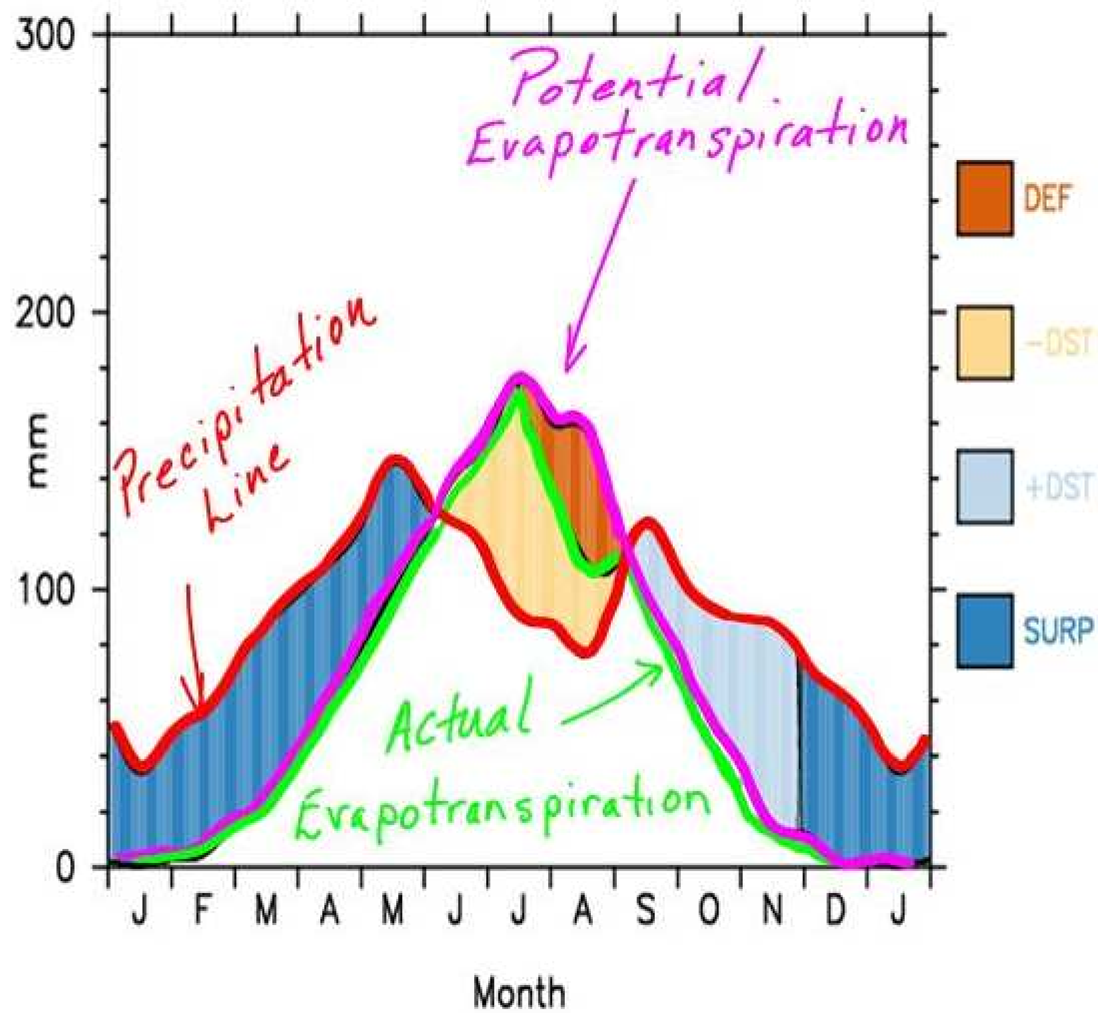


Figure 1 – Water budget diagram key. Diagram courtesy: WebWIMP.

From Figure 1 above, **DST** is the estimated change in soil moisture from the end of the previous month to the end of the current month (mm/month). (-) is water taken from the soil to meet needs of evapotranspiration. (+) is water put back into the soil by precipitation. **DEF** is the estimated deficit or unmet atmospheric demand for moisture (mm/month). **SURP** is the estimated surplus (surface runoff plus percolation below the plant root zone) (mm/month).

The water for evapotranspiration can come from both precipitation and soil moisture. When the water needs of the vegetation (potential evapotranspiration) and water actually used (actual evapotranspiration) are compared, an estimate of the water shortage can be made for an environment (moisture deficit). The moisture deficit can be directly related to plant health and productivity.

Since water is one of the main limiting factors in the growth of vegetation, the amount of water available to plants will determine biodiversity of vegetation in a given area. By using water budget models, a projection of the water deficit and surplus for an area can be formulated. Therefore, water budget assays are indicative of biome types and vegetation growth and health.

The land surface temperature affects potential evapotranspiration. According to the IPCC, due to an increase of greenhouse gases, an increase in land surface temperature will occur during the 21st century. Water budget models are useful for determining changes in water need due to increase in annual surface temperature.

The greenhouse gases are chemical compounds that are also found in the atmosphere. The essential gases are carbon dioxide, methane, nitrous oxide, and fluorocarbon; these greenhouse gases absorb the infrared radiation and trap the heat in the atmosphere. They can raise the temperature of the earth and cause unprecedented climate change if the gases do not reflect back into the space. This warming of the earth could cause a change of weather patterns affecting the water budget or availability of water for plants and agriculture.

Materials:

- Computer
- Internet access
    - o WebWIMP - http://climate.geog.udel.edu/~wimp/
- Student Worksheet

Engage (for group discussion):

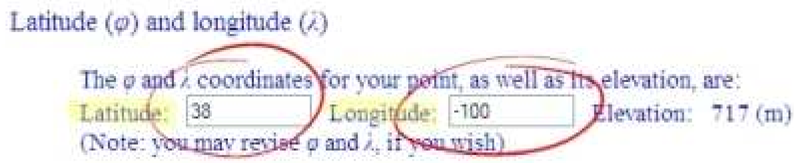
- Play the video clip "U.S. Dust Bowl of the 1930s," a segment from the Discovery Channel's 'Making of a Continent (http://youtu.be/x2CiDaUYr90)

Q1) What are two key human-induced factors that lead to the Dust Bowl of the 1930s?

Q2) Describe the relationship between soil moisture, precipitation, and temperature.

Explore:

- Go to WebWIMP (http://climate.geog.udel.edu/~wimp/)
- Click on the PROCEED TO THE WORLD MAP button.
- Locate North America on the World map and click on the general region of Kansas.
- Now create a water budget diagram for Dodge City by entering Latitude of 38 and enter a Longitude of -100. Leave all other parameters as they are.



- Scroll to bottom of page and click on the WATER BALANCE button.
- A Data Table will open in a new window. Scroll to the bottom and click on Monthly and annual climatic water balance graph.
- Print this graph and label it: Dodge City/Current Conditions
- Exit out of graph page. Exit out of table page. The input page should be open. (if not go back and redo step 2 and 3 to open it)
- Now create a water budget diagram for Pleasanton by entering Latitude of 38 and enter a Longitude of -95. Leave all other parameters as they are.
- Again, click WATER BALANCE button.
- Scroll to the bottom and click to make graph.
- Print this graph and label it: Pleasanton/Current Conditions.

Groups may be assigned different hypothetical climate changes to try (annual temperature change; annual precipitation change, or change either by month to represent seasonal climate change).

Q3) Based on comparison of the diagrams, which city shows a larger annual water deficit?

Q4) Comparatively, which city has a longer growing season?

Q5) Without irrigation, which city supports greater evapotranspiration?

Q6) What might be some possible variables for the differences?

Elaborate:

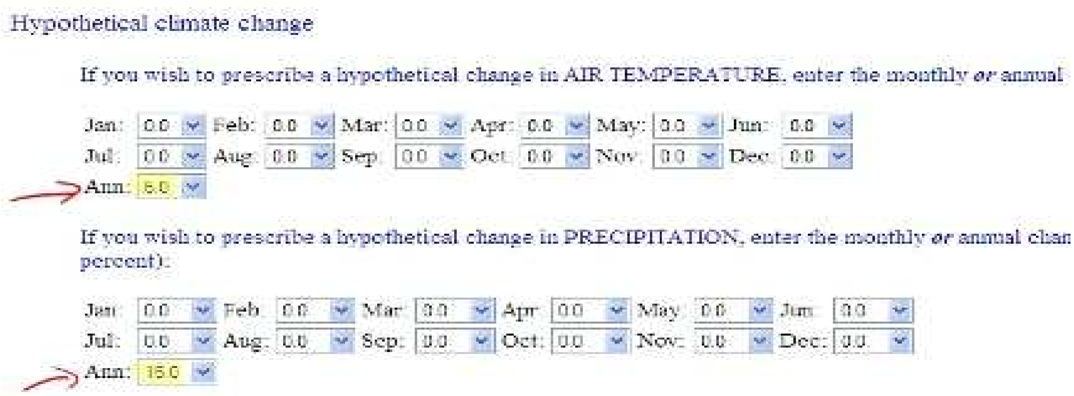
What do water budgets look like for other climates? What if the climate changed?

- Go to the map page and try some different regions or enter a latitude and longitude on the input page to compare water budgets.
- View the water budgets for at least three different regions.
- Also try changing AIR TEMPERATURE or PRECIPITATION to see a change in the water budget for a particular area.
- You may choose to assign change values for the students to see water budgets under different circumstances. If you do not assign a change values, view the water budget diagrams for at least 3 different hypothetical climate changes.

Explore:

Two water budget diagrams will be made using the IPCC projected amounts of temperature and precipitation.

- Return to the input page on WebWIMP and enter the latitude and longitude for Dodge City.
- Scroll down to the Hypothetical climate change part of the page.
- Enter an annual change for temperature to 5.0 degrees by clicking on the down arrow by the Ann: and selecting 5.0. (this number most closely matches the max temperature change on the IPCC)
- Enter an annual change for precipitation to 15.0 by clicking on the down arrow by the Ann: and selecting 15.0. (this number most closely matches the max precipitation change on the IPCC)



- Make water budget graph as you did above and print and label it: Dodge City/Projected Conditions.
- Return to input page and enter latitude and longitude for Pleasanton, enter the same temperature and precipitation changes and make graph.
- Print and label it: Pleasanton/Projected Conditions

Q7) What type of changes would be expected for both cities?

Q8) Based on the water budget diagrams, how do the projected increases affect the water deficits?

Q9) How do models support the concern of increasing greenhouse gases?

Q10) Does the current model or the projected model have the greatest water deficit, for each city?

Q11) What trend is observed between the potential evapotranspiration line and the actual evapotranspiration line on the projected diagrams when compared to the current diagrams?

Elaborate:

Is there a region of the United States that currently has a climate like the projected climate?

- Choose one of the two Water Budget Diagrams from Activity II (Dodge City or Pleasanton)
- Use the interactive longitude and latitude map (http://itouchmap.com/latlong.html) to locate a city in the United States which will most closely match the water budget diagram which you chose from Activity II.
- Enter the latitude and longitude on WebWIMP (make sure hypothetical climate change precipitation and temperature are back to zero) to see if diagrams match. When you find a match, print it and label it with the city name/current conditions.

Q12) What is the difference in latitude and longitude for your chosen city and the analog city?

Q13) Would you expect similar latitude changes for the analog city of Wichita, KS?

Evaluate:

Q14) Using the rubric provided in Table 1, evaluate the overall output for this lesson.

Acknowledgments:

This lesson was created as part of the 2008 ‘The Heat is On: Confronting Climate Change’ workshop. Contributions for this lesson were made by Susan Jayne Jones, Nancy Frazier, Cynita (Woods) Jones, and Lynda Burghart.

References:

- *WebWIMP version 1.02 is an upgraded version of WebWIMP 1.01, which was implemented by K. Matsuura, C. Willmott and D. Legates at the University of Delaware in 2003. The upgrades were made by K. Matsuura in late 2009. Earlier PC-based versions of WIMP were developed by C. Willmott, D. Legates, and C. Rowe.*
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STUDENT PAGE

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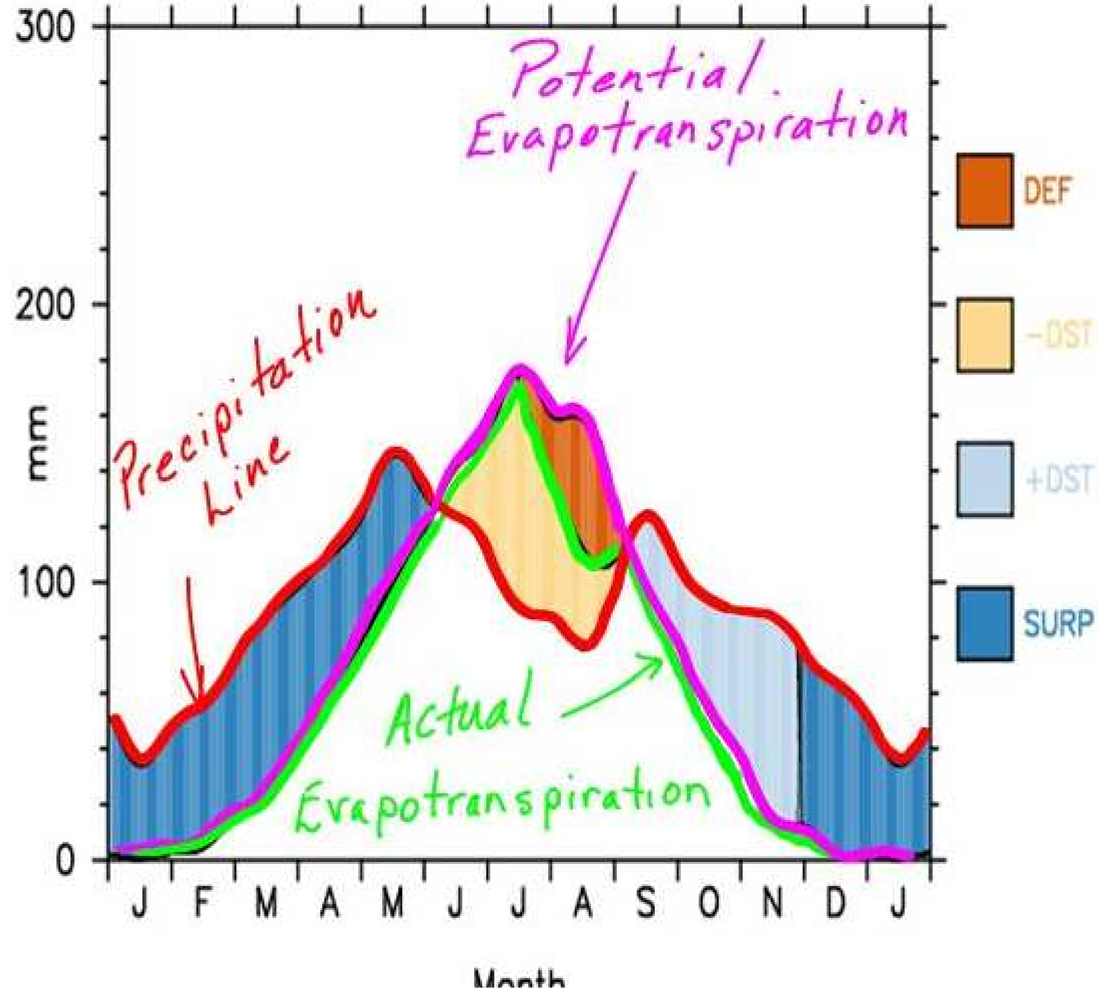

Figure 2 – Water budget diagram key. Diagram courtesy: WebWIMP.

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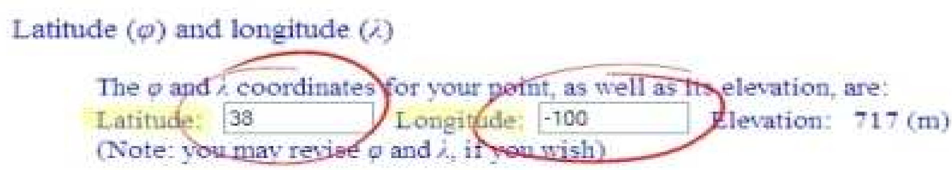

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NOTES:

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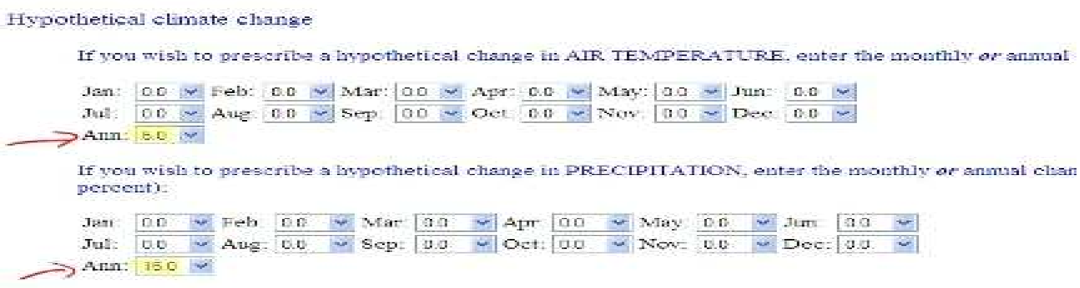

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Q13) Would you expect similar latitude changes for the analog city of Wichita, KS? Explain.

Evaluate:

Q14) Double check your work and output diagrams. You will be evaluated on your overall output of water budget diagrams.

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ANSWER KEY

Q1) For discussion

Q2) For discussion

Q3) Dodge City

Q4) Pleasanton

Q5) Pleasanton

Q6) Amount of precipitation, type of soil

Q7) Larger deficit

Q8) Larger deficit, deficit occurring earlier in the year

Q9) Larger water deficit will have an impact on what type of plants can be supported and duration of the growing season. Change in evapotranspiration will impact local weather.

Q10) Projected model

Q11) Potential evapotranspiration and actual evapotranspiration lines become further apart.

Q12) Longitude should be similar, while the latitude should be a bit south of the current city.

Q13) Yes, typically the climate warms as you move south, while longitude would impact storm systems moving west to east across the United States.

Q14)

Category	3	2	1
Generating Water Budget Diagram	Data (latitude, longitude) entered correctly to generate accurate water budget diagram. Diagram printed and labeled correctly.	Diagrams appear correct, not labeled *OR* diagrams not correct but are labeled.	Diagram not labeled and not correct.
Analysis of Water Diagrams	Accurately analyzes diagrams using terms: deficit, storage, surplus, and evapotranspiration.	Accurately analyzes diagrams using at least two terms: deficit, storage, surplus, and evapotranspiration.	Does not show understanding of terms: deficit, storage, surplus, and evapotranspiration.
Locating Analog City	Analog cities' water budget diagrams are analogous to the projected diagrams.	Analog cities' water budget diagrams are similar but not analogous to the projected diagrams.	Analog cities' water budget diagrams are not similar to the projected diagrams.