To discover how Earth's living skin is structured, evolves, and provides critical functions that sustain life.

INTRODUCTION TO THE CRITICAL ZONE

Overview

The *Critical Zone* supports terrestrial life on Earth. It is the region above and below the Earth surface, extending from the tops of the trees down through the subsurface to the bottom of the groundwater.

The US Critical Zone Observatory network consists of nine field stations, each located in a different climatic and geologic setting. CZO scientists observe and measure many of the same parameters at each site. Building a common set of measurements across a diverse range of environmental conditions allows scientists to examine the underlying factors responsible for ecosystem growth and resilience.

Water is one of the most important factors in any natural system. In this investigation we will look at three sites – each with a different amount of annual rainfall – and explore the behavior of water once it enters the Critical Zone.

Video Link …



Figure 1: Location of the three Critical Zone Observatories featured in this activity.

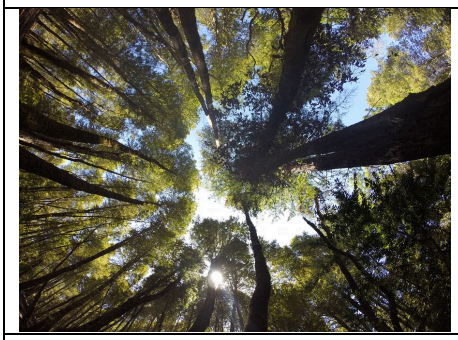
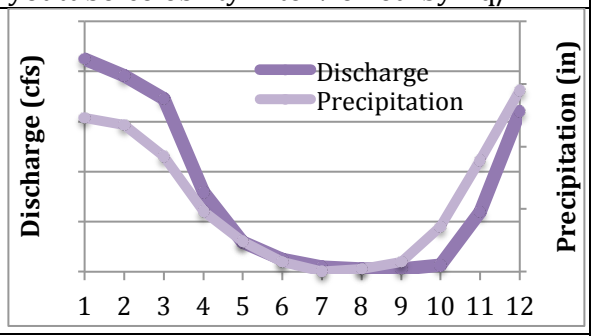
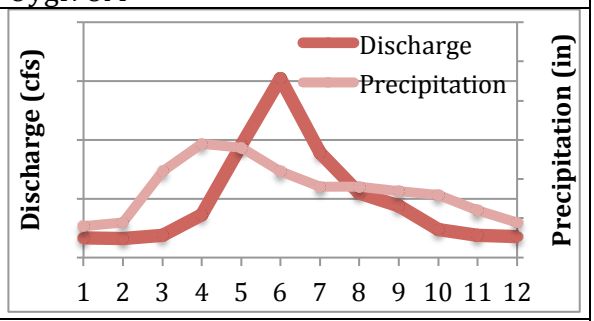
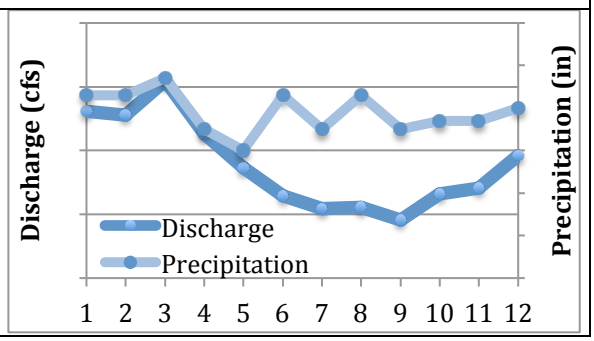
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Focus Question
What natural processes impact water as it enters and moves through the Critical Zone? Are these processes the same everywhere?

Objectives
Students will use data to examine and draw conclusions about hydrologic pathways in the Critical Zone.

Materials
Data and maps are provided within this document. Students should have internet access to watch short videos and complete a simple data search.

Table 1: Information about selected Critical Zone Observatories

Eel River CZO, California	**Video link ->**	http://criticalzone.org/eel/news/story/chris-wong-eel-river-czo-technician-and-youtube-celebrity-interviewed-by-kq/
	Elevation: 690 feet Watershed area: 248 mi^2 Forest: mixed conifer-deciduous Annual rainfall: 69 inches Max Temperature: 87F Min Temperature: 37F	
Boulder Creek CZO, Colorado	**Video link ->**	https://www.youtube.com/watch?v=0UpyOygI78M
	Elevation: 5106 feet Watershed area: 307 mi^2 Forest: mixed conifer-deciduous Annual Rainfall: 21 inches Max Temperature: 88F Min Temperature: 21F	
Calhoun Forest CZO, S. Carolina		
	Elevation: 300 feet Watershed area: 759 mi^2 Forest: mixed conifer-deciduous Annual Rainfall: 47 inches Max Temperature: 92F Min Temperature: 28F	

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Procedure

Answer the boxed questions on the accompanying answer sheet.
Compare three Critical Zone Observatories:

- Eel River, California
- Boulder Creek, Colorado
- Calhoun Forest, South Carolina

Maps at the back of this handout show the location of the observatories, and the summary chart on the previous page gives information for each, including elevation, annual *precipitation*, average temperature, and forest type. There are video links to two of the sites, Boulder and Eel, so that you can get a better view of the locations and learn a little more about each one. Additionally, the chart includes a graph of the seasonal distribution of rainfall, as well as the seasonal flow in a river that runs through each observatory.

The Critical Zone is where we live. It is where we grow our food, and where we get our water and most of the other resources that we use every day. We will consider the motion of water in time – in each month of the year – and in space, at three sites in the eastern, central, and western US.

- Begin by looking up data for your home town. On the chart below, fill in the upper row with the name and data for your own site.
- Next, add the data from Table 1 for Eel, Boulder and Calhoun CZOs.

◈ Which CZO is most like your home town? Explain why.

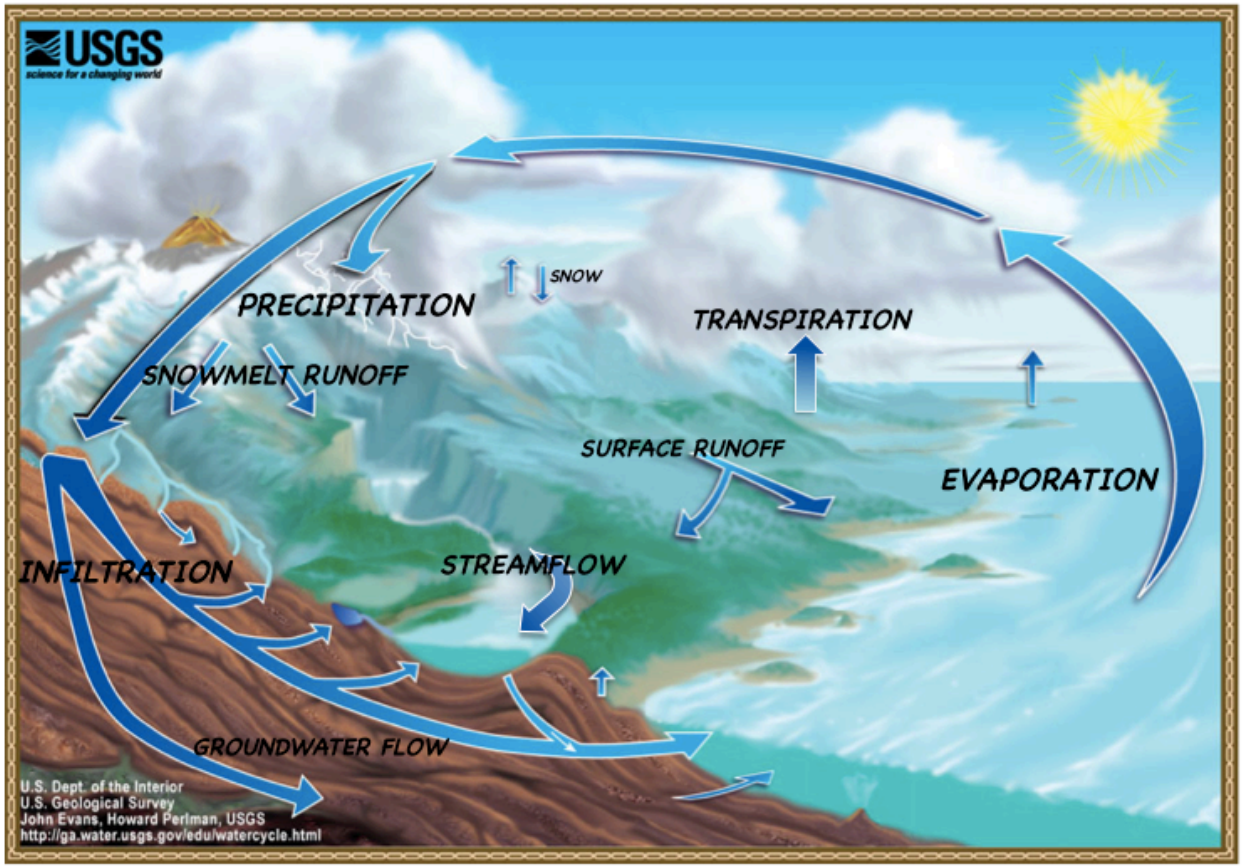
Table 2

Site	Elevation	Annual Precip	Max Temp	Min Temp	Forest Type
Eel River CZO					Mixed conifer/ deciduous
Boulder CZO					Mixed conifer/ deciduous
Calhoun CZO					Mixed conifer/ deciduous

Examine Figure 2, the *Hydrologic Cycle*. The Sun heats Earth's surface and causes water to *evaporate*. Liquid water becomes water vapor in the atmosphere. Water vapor eventually *condenses* to liquid rain or solid ice/snow, and returns to the surface as precipitation. Water runs off/under the surface and returns to the ocean. This simple cycle operates with many different variations depending on the ecology and physical conditions within the Critical Zone.

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Figure 2: The Hydrologic Cycle



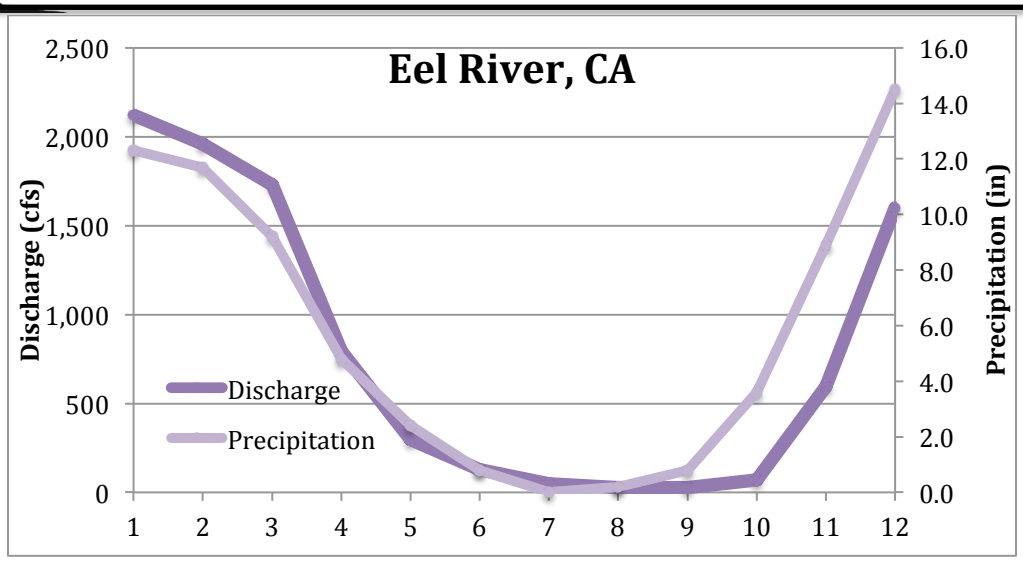
We will begin our exploration of the Critical Zone at the Eel River CZO in California, and then move east to Boulder and Calhoun.

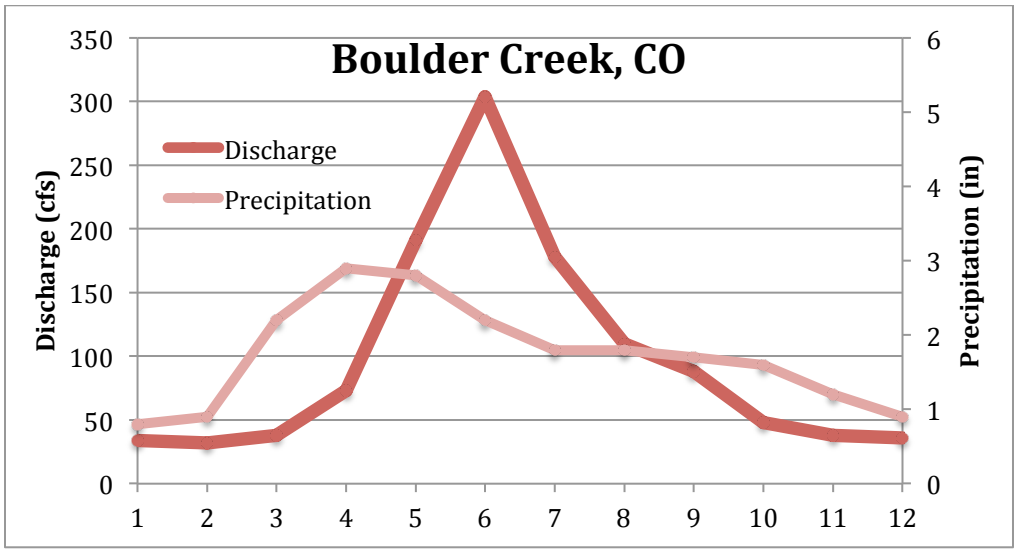
- Examine the Eel River graph in Figure 3. Note which month has the highest rainfall and which month has the highest river discharge, and also the lowest rainfall and discharge.

◈ Do rainfall and river flow make a consistent pattern? Do they rise and fall at the same time or does one process lead the other? Explain, with reference to the Hydrologic Cycle, what you think happens to rainfall in the Eel River watershed.

- Examine the Boulder Creek graph in Figure 3. Do these data make a consistent pattern? Make note of when the highest/lowest rainfall and discharge occurs, and compare these data to the data from Eel River.

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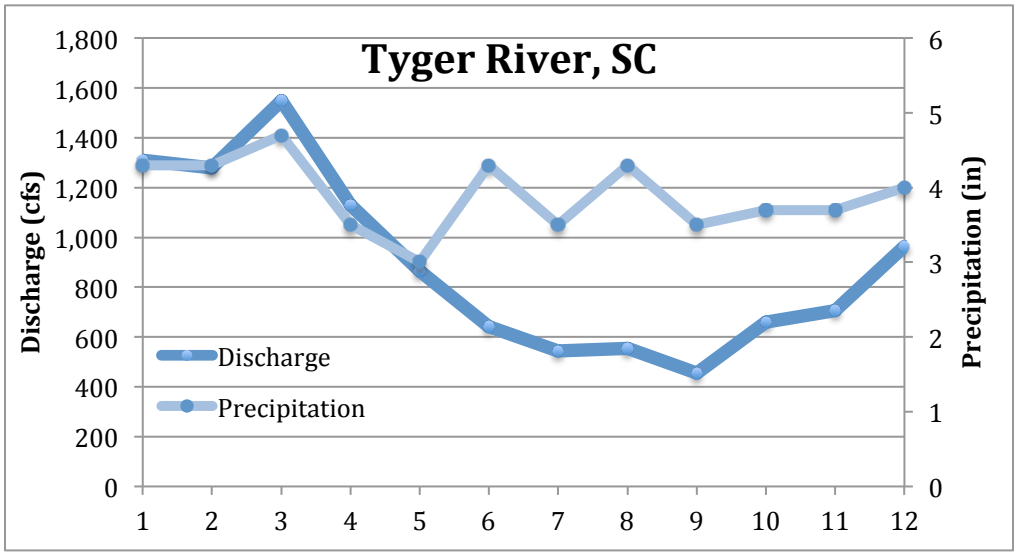


Figure 3: Monthly rainfall and river discharge at three CZOs. River discharge is the dark line in each graph. Discharge is measured in cubic feet per second (cfs) and is plotted on the lefthand axis. Rainfall is the lighter line, measured in inches, and plotted on the righthand axis.

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- Describe how seasonal river discharge is different at Eel River and Boulder Creek. Consider amount and timing of precipitation, river response, as well as the monthly maximum and minimum temperatures. Explain, with reference to the Hydrologic Cycle, what you think happens to precipitation in the Boulder Creek watershed.

- Now look at data for the Tyger River that flows through Calhoun Forest. Do these data make a consistent pattern? Make note of when the highest/lowest rainfall and discharge occurs, and compare these data to the data from Eel River and Boulder Creek.

- What Critical Zone process is responsible for the behavior of the Eel River? What CZ process is responsible for the behavior of Boulder Creek? Is the Tyger River responding in the same way as either Eel or Boulder? Explain, with reference to the Hydrologic Cycle, what you think happens to precipitation in the Tyger River watershed.

- You have looked at precipitation and river response in three different places. Which was the most surprising to you? Explain why.

Vocabulary

Condensation: The change of the physical state of matter from a gas phase into a liquid phase. It is the reverse of evaporation.

Conifer: Evergreen trees and shrubs with long, thin needle-like leaves. They are the dominant plants over huge areas of land, most notably high latitude forests but also in similar cool climates in mountains further south. Boreal conifers have many wintertime adaptations such as downward-drooping limbs that help them shed snow. Many of them seasonally alter their biochemistry to make them more resistant to freezing.

Critical Zone: The region above and below the Earth surface, extending from the tops of the trees down through the subsurface to the bottom of the groundwater; the zone that supports terrestrial life on Earth.

Deciduous vegetation: Deciduous means "to fall off," and is typically used to refer to trees or shrubs that lose their leaves seasonally (most commonly during autumn); also to the shedding of other plant structures such as petals after flowering or fruit when ripe. In tropical regions deciduous plants often lose their leaves during the dry season.

Discharge: The volume of water that passes a given location within a given period of time. Usually expressed in cubic feet per second.

Evaporation: The process of liquid water becoming water vapor, including vaporization from water surfaces, land surfaces, and snow fields.

Hydrologic cycle: The cyclic transfer of water vapor from the Earth's surface via evapotranspiration into the atmosphere, from the atmosphere via precipitation back to earth, and through runoff into streams, rivers, and lakes, and ultimately into the oceans.

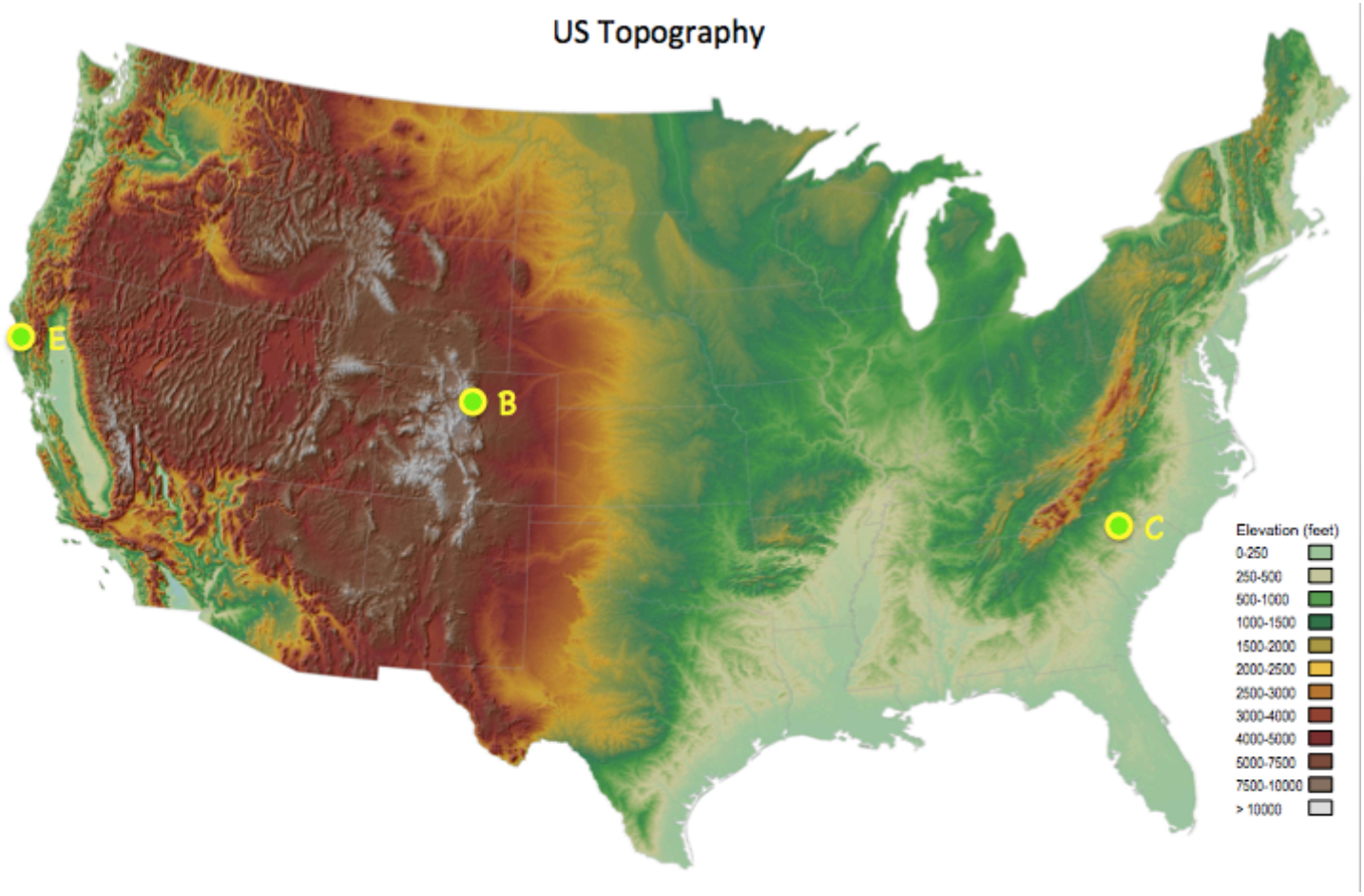
Infiltration: The flow of water from the land surface into the subsurface.

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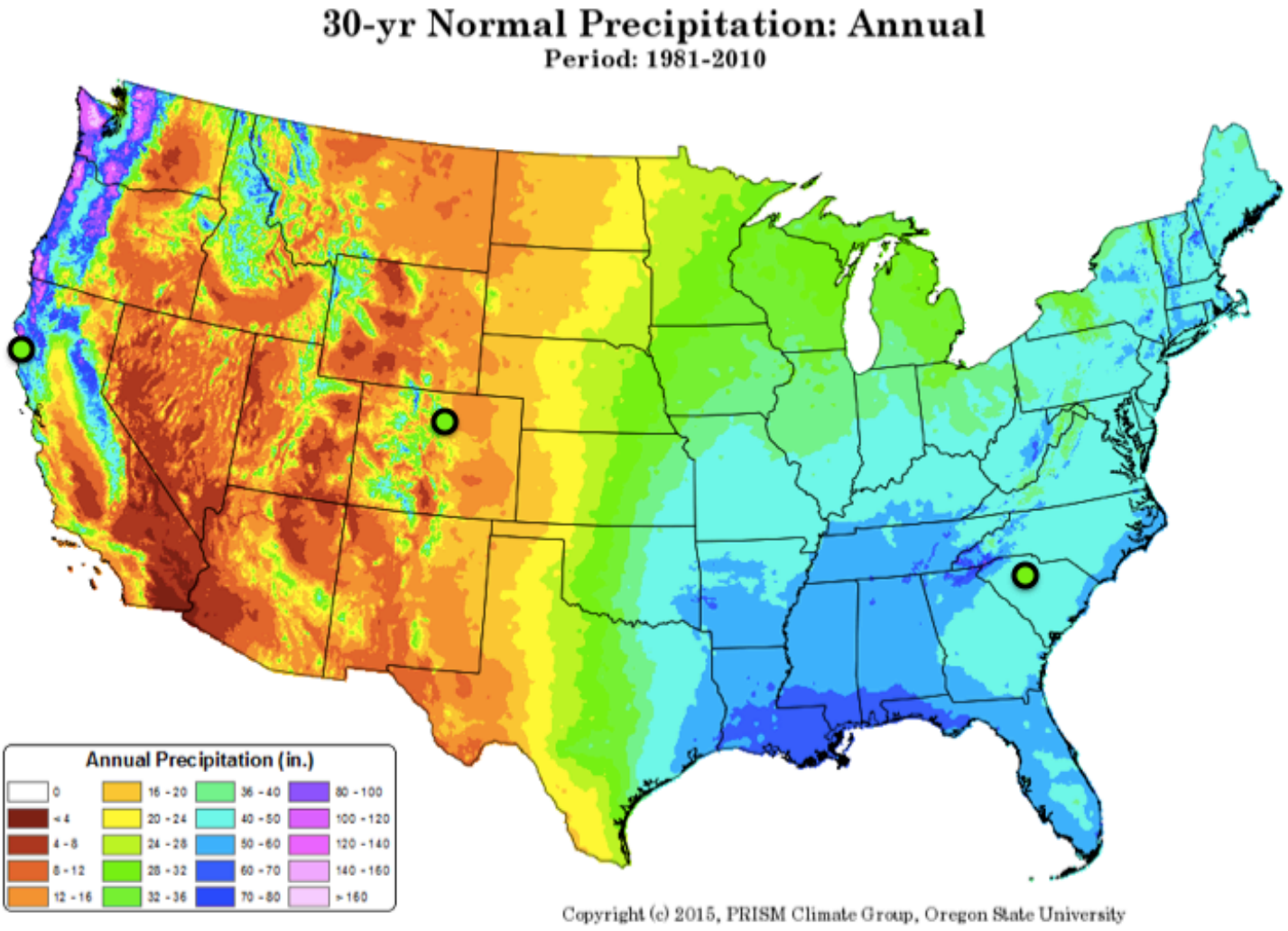
Precipitation: Any product of the condensation of atmospheric water vapor that falls under gravity; rain, snow, hail, sleet, dew, and frost.

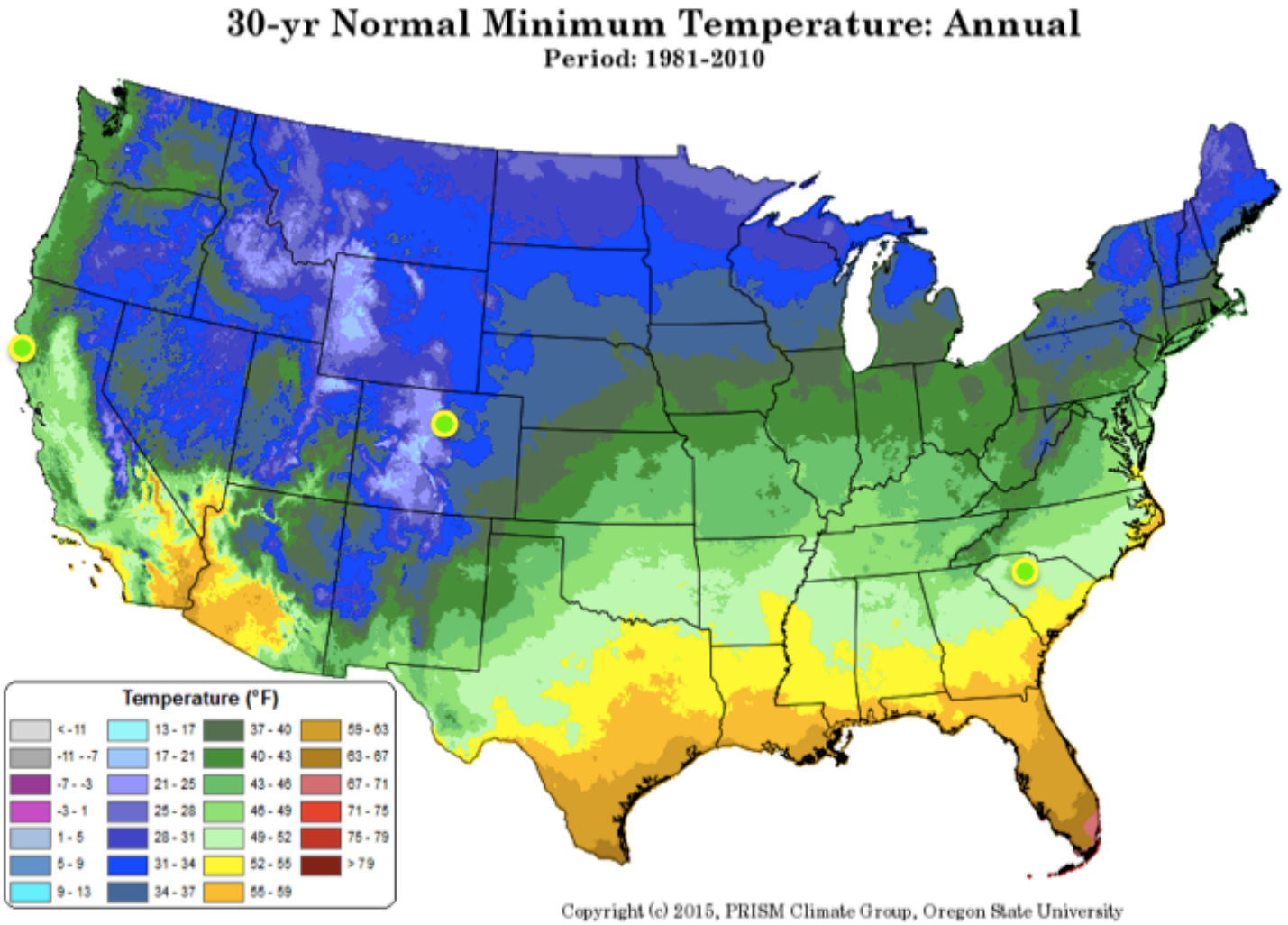
Transpiration: The process by which water that is absorbed by plants, usually through the roots, is evaporated into the atmosphere from the plant surface, such as leaf pores.

Watershed: The land area that drains water to a particular stream, river, or lake. It is a land feature that can be identified by tracing a line along the highest elevations between two areas on a map, often a ridge. Large watersheds, like the Mississippi River basin contain thousands of smaller watersheds.

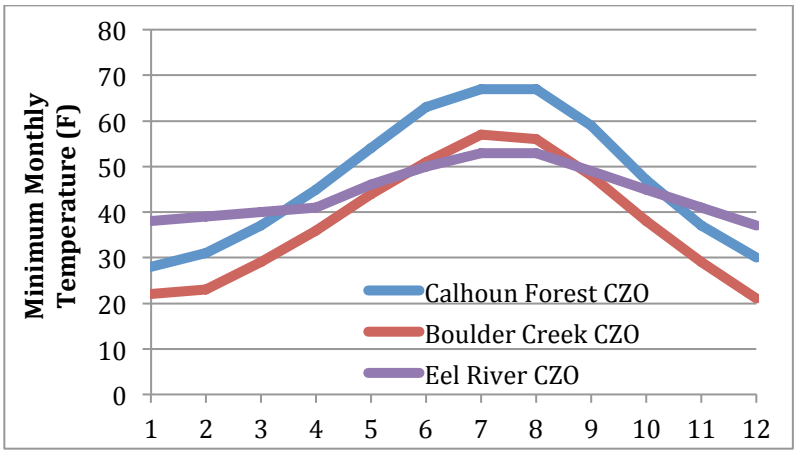


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30-yr Normal Precipitation: Annual
Period: 1981-2010
Annual Precipitation (in.)
0
< 4
4 - 8
8 - 12
12 - 16
16 - 20
20 - 24
24 - 28
28 - 32
32 - 36
36 - 40
40 - 50
50 - 60
60 - 70
70 - 80
80 - 100
100 - 120
120 - 140
140 - 160
> 160
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Questions

Fill in Table 2

Site	Elevation	Annual Precip	Max Temp	Min Temp	Forest Type
Eel River CZO					Mixed conifer/ deciduous
Boulder CZO					Mixed conifer/ deciduous
Calhoun CZO					Mixed conifer/ deciduous

Which CZO is most like your home town? Explain why.

Do rainfall and river flow at Eel River make a consistent pattern? Do they rise and fall at the same time or does one process lead the other? Explain, with reference to the Hydrologic Cycle, what you think happens to rainfall in the Eel River watershed.

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Describe how seasonal river discharge is different at Eel River and Boulder Creek. Consider amount and timing of precipitation, river response, as well as the monthly maximum and minimum temperatures. Explain, with reference to the Hydrologic Cycle, what you think happens to precipitation in the Boulder Creek watershed.

What Critical Zone process is responsible for the behavior of the Eel River? What CZ process is responsible for the behavior of Boulder Creek? Is the Tyger River responding in the same way as either Eel or Boulder? Explain, with reference to the Hydrologic Cycle, what you think happens to precipitation in the Tyger River watershed.

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You have looked at precipitation and river response in three different places. Which was the most surprising to you? Explain why.

Resources

Boulder Creek CZO You Tube Channel: https://www.youtube.com/watch?v=0UpyOygI78M
Critical Zone Observatory Network, http://criticalzone.org
Koeppen Climate Classes, http://koeppen-geiger.vu-wien.ac.at/pdf/KG_USA_UScounty.pdf
PRISM Climate Group, http://www.prism.oregonstate.edu/normals/
USGS Water Science School, https://water.usgs.gov/edu/

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