The Winter-Spring Shoulder Season Timeline Activity

Purpose:

- To recognize the processes that define an important ecological event, the winter-spring shoulder season. This is the season spanning snowmelt in late winter to forest canopy closure in late spring, also known as the vernal window.
- To practice developing and evaluating hypotheses about energy, water and carbon in local ecosystems
- To discuss how warmer winters, snowless winters, and earlier springs, due to climate change, may impact northern temperate forest ecosystems during the winter-spring shoulder season

Overview:

This activity introduces students to the winter-spring shoulder season and eight important ecosystem processes relating to energy, water, and carbon that occur during this transitional season in northern temperate forest ecosystems. They will use knowledge gained through fieldwork and additional research to develop and test hypotheses about the timeline of events that take place during the winter-spring shoulder season. Students are then prompted to consider how the timeline of events would change in a world warmed by greenhouse gases.

Student Outcomes

Students will be able to:

- Define the winter-spring shoulder season (aka: vernal window)

- List major energy, water, and carbon related events that occur during the winter-spring shoulder season
- Hypothesize a sequence of ecosystem processes during the winter-spring shoulder season
- Compare and contrast the winter-spring shoulder season following a warm, low snow winter and a cold, snowy winter
- Write a claim, evidence, reasoning statement that predicts the order of ecological processes in future years

Questions

Content

- What ecosystem processes define the beginning and end of the winter-spring shoulder season?
- Which ecosystem processes relate to energy, water, and carbon?
- How would the timing and duration of events in the winter-spring shoulder season differ following a warm, low snow winter versus a cold, snowy winter?

Science Concepts

See Winter-Spring Shoulder Season Timeline NGSS Matrix at bottom of this document.

Time/Frequency:

60-75 minutes (1 session)

10 minutes (weekly during winter-spring shoulder season to reflect on hypothesis)

Level

Secondary (*primarily high school*)

Materials and Tools

- Resources about the winter-spring shoulder season (*What is the Winter-Spring Shoulder Season?*)
- Orange, blue, and green card stock
- Photos of winter-spring shoulder season events (*Winter-Spring Shoulder Season Photos*)
- 8.5 x 11 blank paper (1 per student) OR individual science notebook

Prerequisites

None

Preparation

- Print photos of winter-spring shoulder season events and glue to orange (energy), blue (water), and green (carbon) cardstock. Write names of events on back of card stock. One packet of cards per group of 4-6 students.
- Display content questions for all students to see
- *Read up on the concept of claim, evidence and reasoning in science classrooms: *Supporting Grade 5-8 Students in Constructing Explanations in Science: The Claim, Evidence, and Reasoning Framework for Talk and Writing (McNeill and Krajcik, 2011)*

Background

The winter-spring shoulder season is the shoulder season that occurs as winter transitions into spring. It is defined as the period from the start of snowmelt to the closure of forest canopies (full leaf out). In between these two events, six other key transitions occur that play an essential role in the forest ecosystem's energy, carbon, and water cycles. They include in no particular order: snow-free date (energy), timing of peak streamflow (water), river/lake/stream ice-out (water), stream temperature warm-up (energy), soil thaw (carbon), budburst (carbon). These events are all interconnected and affect ecosystem functioning as a whole. For example, as the snow melts it delivers a pulse of water to rivers, lakes, and streams. This meltwater helps move key nutrients from forest ecosystems to water bodies, which supports aquatic food webs.

Light availability in ecosystems is primarily driven by latitude and the Earth's rotation around the sun. It is relatively constant that drives the growing degree days before trees enter budburst. Temperature and precipitation patterns are more variable from year to year, however, drastically changing the amount of snowpack that can accumulate. Historically, in cold, snowy regions, including both higher latitudes and higher altitudes, the winter-spring shoulder season is typically shorter than in warmer regions that receive less snow. Areas with deeper snowpack require warmer temperatures (greater energy input) to melt the snow completely, causing the time between snow melt and full leaf out to be shorter.

While snowpacks are melting significantly earlier as Earth's climate warms, northern forest canopy leaf out is responding more slowly because light availability remains constant, resulting in a longer winter-spring shoulder season. In regions that have lost seasonal snowpack entirely, the winter-spring shoulder season ceases to exist, being replaced by a prolonged dormant period similar to more southerly regions (e.g. low elevation forests in North Carolina, or the forests of coastal New Jersey). Loss of snowpack and the winter-spring shoulder season may lead to changes in the tree species present, as the current species would be ill adapted to new conditions, making them vulnerable to stressors such as drought, fungal infection and insect infestation. In places with a lengthening winter-spring shoulder season, the timing of key winter-spring shoulder season events also shifts and can lead to mismatches between ecosystem processes such as leaf out, insect emergence, and the return of migratory birds that use insects as a major food resource. Yet the full picture of long-term impacts on forests remains unclear, which is what drives the need for additional investigation.

Students can track changes in the winter-spring shoulder season at their schools using bundled Global Learning and Observations to Benefit the Environment (GLOBE, www.globe.gov) protocols.

What to do and How to do it

Engage

Grouping: Class

Time: 15 minutes

- Begin the study by reminding students what they already know about seasons in their area and then connect it to this other very specific period between winter and spring that happens each year in northern temperate forest ecosystems.
- Example starter question: You might use something like: “If you live in a place with 4 seasons you undoubtedly learned their names when you were just 3 or 4 years old and learned in elementary school that the transition between them happens as a result of the Earth’s rotation around the sun, but have you ever heard of our 5th season, mud season?”
    - What is mud season? What happens in mud season?
    - Has anyone experienced mud season?
    - What causes mud season anyway?
    - When does mud season begin?
    - When does mud season end?
    - What causes mud season to end?
    - Why might we study mud season, what could be important about it?

Explore

Grouping: small groups (4-6 students)

Time: 15 minutes

- Groups of students will organize 8 winter-spring shoulder season cards into a hypothesized sequence of events along a timeline. They will also record a specific date for each event. Remind them about the best practices of group work before handing out cards.

- Each group should draw a horizontal line on a working space (board, table, floor), approximately 5ft in length, and label one end 'January 1st' and the other end 'June 1st'. (Or other appropriate dates if you live in the southern hemisphere and still have distinct seasons based on temperature.)

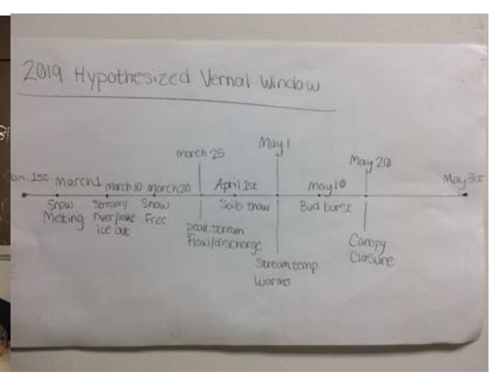
- Prompt students to discuss how each event is related to energy, water, and/or carbon as they organize the processes.
    - This is the most important part of the activity. Students should be encouraged to discuss the real phenomena that are occurring and trying to explain why they are happening in that way. They should use their prior experience and expertise to engage in productive argumentation about their competing models of how the world works.

- Depending on the age and independence of your students, you will need to decide how much information/support to provide before students begin and while they work.

- You may want to guide them on which events start their timeline (snowmelt initiation) and/or end it (full canopy closure).
- If they are struggling you may let them know that some events can occur simultaneously.
- Highlight that each group may come up with different event sequencing and provide different reasoning and this is no different than a diverse group of scientists (biologist, forest ecologist, hydrologist) having the same conversation. (This is where the fun starts!)

- Once the group has agreed on a timeline, take a picture of the timeline to be saved and/or have them draw their final timeline on an 8.5x11 piece of paper or in their science notebooks to be referred to throughout the unit. (For older students you may want them to include their reasoning for the order of events.)

- Select a spokesperson(s) for the group to present the timeline to the class. They should be prepared to highlight the group's reasoning for the order of events, "It happens this way because…" This process invites participation because every student feels like they have enough expertise or experience to defend their position. (approx 3 min of speaking)



Explain

Grouping: Class

Time: 25 minutes (depends on size of class)

- The spokesperson(s) from each student group should share their large timeline and reasoning for the order of events as part of a gallery walk through the classroom.
- After visiting all the timelines, as a class, compare and contrast the timelines presented by the different groups. What critiques and or questions do students have for each other? Where was there a lot of agreement? Where were there big differences?

**Note: You may need to remind students that it is normal and okay to disagree with one another about the order. When we ran this activity with professional snow, soil, water, and tree scientists, there was a lot of disagreement on the initial hypothesized order. Discussion followed, and the scientists came to a consensus that was a *testable hypothesis*. The hypothesis can then be tested with observations collected by the class or by other scientists.

Elaborate *(Can be completed immediately, while measurements are being made through the spring, or at the end of the measurement period as you wrap up the unit.)*

Grouping: Class

Time: 15 minutes

- Have the students consider how the sequence and/or timing of events would change in a warmer, less snowy winter compared to a cold, snowy winter.
    - Would certain events occur earlier or later?

    - Would there be larger gaps between certain events (i.e., snowmelt to budburst)?
    - How might a larger gap between events impact an ecosystem, if at all?

**Note: Point out that you could look at historic data for some information to confirm your ideas and that scientists have to consider these kinds of questions as the climate continues to change at a rapid rate. (see *Extensions*)

Evaluate

Grouping: individuals/small groups

Time: 5-10 minutes periodically throughout the winter and spring (during the winter-spring shoulder season)

- Optional: Display the group timeline of events throughout the classroom.
- Use GLOBE protocols to track the winter-spring shoulder season at school. Choose protocols that make the most sense for your students, location, time availability, and goals. The protocols can be supplemented with additional collected data such as stream flow as well as data from other sources.
    - Solid Precipitation: snowpack depth
    - Soil frost depth
    - Green-up
    - Air temperature
    - Soil temperature
    - Stream temperature

- If making your own GLOBE measurements, log the data on a calendar and display in a prominent location.
- Students should take time regularly to record data next to their original timeline in their science notebook and reflect on how well their group's hypothesis compares to measurements and observations from the field. Did events happen in the hypothesized order? If not, what event came earlier or later than expected?
- At the end of the winter-spring shoulder season, have groups discuss how close their original predictions were to what they actually observed and what may have caused the differences. (This may help resolve some of the tension among competing models from earlier in the unit.)
- Individuals or groups should then write a claim, evidence, reasoning statement to share with the teacher about what they expect the order of events will be next year or in 5 years.

Extensions

- Other data sources to track winter-spring shoulder season events:
  - United States Geological Survey Stream Gaging Network, https://waterdata.usgs.gov for peak streamflow and river ice out
  - Phenocam Ecosystem Phenology Camera Network, https://phenocam.sr.unh.edu for canopy green-up
  - Snow Data Assimilation System, https://www.nohrsc.noaa.gov/nsa/ for snow data
  - Snow Telemetry Network, https://www.wcc.nrcs.usda.gov/snow/ for western US snow data in mountains

  - USA National Phenology Network, https://www.usanpn.org/usa-national-phenology-network, for canopy green-up
- Use existing GLOBE archival data sets to explore how winter-spring shoulder season events have changed over time
- Compare student collected GLOBE data from the current year to previously collected student data for your location.
- Explore peer research articles on the topics of *phenology shift* and *phenological mismatch* to learn more about the possible impacts that a change in winter-spring shoulder season timeline events could have on individual species or the ecosystem as a whole.
- Investigate how Indigenous people, naturalists and writers have explored seasonal changes and their importance to our understanding of time, place, and the self (some suggestions are included here to get started, but there many additional options)
  - Naturalist Henry David Thoreau's writing in his famous book *Walden* has made it one of the best places to study climate change: find data and related articles using the phrase "studying climate change at Walden Pond".
  - In his four book series, *The American Seasons*, naturalist, photographer and writer, Edwin Way Teale documented the change of seasons as he travelled across America
  - Melissa Harrison brings together stories and poetry from across time to highlight an unfolding of spring in the UK through her compilation - *Spring: An Anthology for the Changing Seasons*
  - *Byron through the Seasons* is a Dené-English story book produced by the students and teachers of Ducharme Elementary School in La Loche, Saskatchewan, with

assistance from local advisors and elders. It is a story told by Grandfather Jonas that highlights stories of what Dené life is like during the four seasons of the year.

- A list of children's books that shares a variety of Native American stories about the seasons. https://www.colorincolorado.org/booklist/seasons-and-cycles-american-indian-heritage
- In *Pilgrim at Tinker Creek,* Annie Dillard explores on foot how the seasons cycle one into the next in Virginia's Roanoke Valley.

Images for Winter-Spring Shoulder Season Timeline Activity

1. Snowmelt (energy - ORANGE)

2. Snow-free (energy - ORANGE)

3. Peak streamflow (water - BLUE)

4. River/lake/stream ice-out (water - BLUE)

Photo by Terry Barber

5. Stream temperature warm-up (water - BLUE)

6. Soil thaw (carbon - GREEN)

7. Budburst (carbon - GREEN)

8. Canopy closure (carbon - GREEN)

The Vernal Window Timeline NGSS Matrix

Standards
HS-LS2 Interdependent Relationships

Performance Expectations
Statements in black text below are the direct connections to the core of the "Tracking the Vernal Window Bundled Global Observations to Benefit the Environment (GLOBE) protocols" unit, statements in black text indicate areas with direct connection to the Vernal Windows Timeline Activity, and statements in grey are directly addressed when completing the entire unit.

HS-LS2-6. Evaluate claims, evidence, and reasoning that the complex interactions in ecosystems maintain relatively consistent numbers and types of organisms in stable conditions, but changes conditions may result in a new ecosystem.

Dimension	**Name and NGSS Code/citation**	**Specific Connections to Classroom Activity**
Science and Engineering Practices	**Engaging in Argument from Evidence** ● Evaluate the claims, evidence, and reasoning behind currently accepted explanations or solutions to determine the merits of arguments (HS-LS2-6) ● Construct, use, and/or present an oral and written argument or counter-arguments based on data and evidence. ● Respectfully provide and/or receive critique on scientific arguments by probing reasoning and evidence and challenging ideas and conclusions, responding thoughtfully to diverse perspectives, and determining what additional information is required to resolve contradictions. ● Make and defend a claim based on evidence about the natural world or the effectiveness of a design solution that reflects scientific knowledge and	Students work as a small group to prepare an oral argument for the order of events on their vernal window timeline. Students listen to oral arguments presented by each small group about the order of vernal window events, ask questions to understand reasoning, and propose what additional evidence (data) they would need to come to a class-wide conclusion. Students use the data collected by themselves through GLOBE protocols and scientists to write a claim, evidence, reasoning statement that suggests the order of vernal window events in the

	student-generated evidence. **Planning and Carrying Out Investigations** ● Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitation on the precision of the data ● Select appropriate tools to collect, record, analyze, and evaluate data. **Analyzing and Interpreting Data** ● Analyze data using tools, technologies and/or models in order to make valid and reliable scientific claims or determine an optimal design solution ● Consider limitation of data analysis (e.g., measurement error, sample selection) when analyzing and interpreting data. ● Compare and contrast various types of data sets (e.g., self-generated, archival) to examine consistency of measurements and observations. ● Evaluate the impact of new data on a working explanation and/or model of a proposed process or system.	next 1-5 years. Students use discussions of the timeline to determine what data they will need to collect using GLOBE protocols or other available datasets to draw conclusions about the vernal window at their location. They may plan some or all of the investigation depending on age, experience, and time available. Students review GLOBE protocols, then gather measurement tools and data sheets. Students will use data tables and graphs to understand collected and researched data on snowpack, stream flow, canopy green-up, etc. in order to establish if their timeline hypothesis was correct or needs adjustment. Students will discuss if the data they collected is valid and reasonable to use when assessing their hypothesis (were they able to collect data regularly, were measurements taken precisely, etc.). Students use self-collected data to compare to data collected by previous classes and/or scientific datasets for how the current location's vernal window may be changing. Students will explore measurement results as they

		compare to their original timeline hypothesis and discuss why new evidence may be different than what they had predicted.
Disciplinary Core Ideas	**LS2.C. Ecosystem Dynamics, Functioning and Resilience** ● A complex set of interactions within an ecosystem can keep its numbers and types of organisms relatively constant over long periods of time under stable conditions. If a modest biological or physical disturbance to an ecosystem occurs, it may return to its more or less original status (i.e., the ecosystem is resilient), as opposed to becoming a very different ecosystem. Extreme fluctuations in condition or the size of any population, however can challenge the functioning of ecosystems in terms of resources and habitat availability. (HS-LS2-2), (HS-LS2-7) ● Moreover, anthropogenic changes (induced by human activity) in the environment--including habitat destruction, pollution, introduction of invasive species, overexploitation, and climate change--can disrupt an ecosystem and threaten survival of some species. (HS-LS2-7) **ESS2.E. Biogeology** ● The many dynamics and delicate feedbacks between the biosphere and other Earth systems cause a continual co-evolution of Earth's surface and the life that exists on it. (HS-ESS2-7)	Students learn about the importance of the vernal window to the stability of temperate forest ecosystems. They make measurements to confirm the current window's timeline of events. They explore questions about how ecosystem processes might change under different climate conditions. Students explore through scientific research or conversations with scientists how a change in the vernal window due to climate change would impact plant and/or animal species at their location. Students learn about the relationships between a change in snowpack, soil frost depth, green-up, and/or soil respiration at their site and the global carbon cycle through additional research.
Crosscutting Concepts	**Stability and Change** ● Much of science deals with constructing explanations	Students collect data about the current vernal window at their location and explore how the

	of how things change and how they remain stable. (HS-LS-6), (HS-LS2-7) **Energy and Matter** ● Changes of energy and matter in a system can be described in terms of energy and matter flows into, out of, and within that system. ● Energy cannot be created or destroyed--it only moves between one place and another place, between objects and/or fields, or between systems.	timeline of events might change in the future due to climate change. Students are introduced to the ecosystem processes that define the vernal window in temperate forest ecosystems including if they are part of the carbon cycle, water cycle, or energy flow. Students are exposed to the idea that if the timing of ecosystem processes changes, how their carbon, water, and energy move within and between systems will be impacted.

Connections to Nature of Science ● Scientific argumentation is a mode of logical discourse used to clarify the strength of relationships between ideas and evidence that may result in revision of an explanation. (HS-LS2-6), (HS-LS-8)	Students engage in discussion within small groups using logic and reason to develop a vernal window timeline of events. They continually refine their thinking as they receive critique from peers, collect their own data and/or analyze a scientific dataset.

Common Core State Standards Connections *ELA/Literacy* RST.11-12.7 Integrate and evaluate multiple sources of information presented in diverse formats and media in order to address a question or solve a problem WHST.9-12.2 Write informative/explanatory texts, including the	Students use self-collected data and scientific datasets (and conversations with scientists or peer research papers) to determine the timeline of ecosystem processes within the current vernal window and how they might change in the future. Students write a claim, evidence, reasoning statement about

narration of historical events, scientific procedures/experiments, or technical processes. *Mathematics* HSN-Q.A.3 Choose a level of accuracy appropriate to the limitations on measurements when reporting quantities.	the expected timeline of events in the vernal window over the next 1-5 years. Students review GLOBE protocols and decide what level of precision to use when making measurements and recording data.

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