Climate EarthLabs Overview

The Climate EarthLabs project is developing a set of three separate high school level modules designed to help students understand the ways in which the natural cycles of the Earth system, cycles with periods that range from daily, seasonally, and annually to tens of thousands of years, influence Earth's climate and ultimately life on Earth. Each module will require approximately 12 to 15 classroom sessions to implement.

Each module can be used as a stand-alone curriculum unit with individual learning goals. The three also work together to support a deeper understanding of the major learning goals as students encounter key concepts multiple times in various contexts and degrees of complexity. Each module engages students in a variety of learning modes, including: individual readings; hands-on labs; class discussions; the use of images, graphics, and animations; video; and the use of data analysis tools. Each module also provides students with frequent opportunities to check their own understanding, and teachers with materials that allow for formative and summative assessment of student learning.

The key concepts that these three modules support are:

- Earth is a complex system of interacting rock, water, air, and life.
- Earth scientists use repeatable observations and testable ideas to understand and explain our planet.
- Climate varies over space and time through both natural and man-made processes.
- Life on Earth depends on, is shaped by, and affects climate.
- Earth's climate depends on the balance between how much solar energy the Earth absorbs and how much it radiates back into space.

Cryosphere Module Overview

The Cryosphere Module will focus on the cryosphere as an indicator of climate change. The cryosphere is highly variable on time scales ranging from days to hundreds of thousands of years. Changes in snow and ice cover affect things like air temperature, sea level, ocean currents, water supply, and storm patterns. By studying the cryosphere, we can learn about past, present, and future changes in climate and how those changes will impact life on Earth.

This unit will introduce students to many of the complex issues surrounding the cryosphere. Using data from a variety of sources, students will learn about thermodynamic, dynamic, and feedback processes in the cryosphere. As the first module in the Climate Literacy grouping, the Cryosphere module will also introduce concepts that are relevant to all three modules, including things like Earth's systems, energy balance, and predicted climate scenarios.

Key content addressed by this unit includes:

- **The cryosphere as part of the Earth system.** *Where are snow and ice found on Earth? What role does the cryosphere play in maintaining Earth's energy balance? How do changes in snow and ice cover affect things like air temperature, sea level, ocean currents, water supply, and storm patterns?*

- **The cryosphere as an indicator of climate change.** *What clues does the cryosphere give us about past, present, and potential future climate?*

- **The changing cryosphere.** *What are some of the natural & anthropogenic causes for variations in cryosphere? How does the cryosphere change over multiple timescales (seasonal through ice age)? What thermodynamic and dynamic processes drive change in the cryosphere?*

- **Human connections to the cryosphere.** *How do changes in the cryosphere impact hunting, animal populations, recreation, agriculture, trade, travel, etc.?*

- **How we know what we know about the cryosphere.** *How do remote sensing, buoys, ice cores, and personal accounts help scientists monitor the conditions of the cryosphere and track change over time?*

Climate Patterns Module Overview

The climate patterns module will include basic weather and climate information as well as examples of climate's effects on plants, especially trees. The impacts of changes in regional climate on well-known agricultural products, such as maple syrup production in New England, will serve as an engaging case study to hook students. The overall theme of the module will focus on energy transfer and climate patterns in the Earth system. Earth's energy budget will be introduced and explored. Global, regional, and local climate and weather systems will be examined for both temporal and spatial patterns. Plant adaptations to climate will be incorporated as an illustration of the interdependence of life and climate.

Key content addressed by this unit includes:

- **The atmosphere as part of the Earth system.** *What are the key elements of weather and climate? What are the forces that drive weather and, ultimately, climate? What are the time and space scales of weather and climate patterns?*

- **Earth's energy balance.** *What is the structure and composition of the atmosphere and how does it affect the energy balance of Earth? How the atmosphere and ocean redistribute thermal energy around the Earth's surface?*

- **Climate patterns and life.** *What determines the climate of a region? How does climate influence the distribution of plant species? How do changes in the climate impact natural ecosystems and agricultural species, (e.g. Maple trees)?*

- **Altered weather patterns as indicators of climate change.** *What clues do weather patterns give us about past, present, and potential future climate? What extreme weather events are taking place as a result of an altered climate system?*

- **The changing climate.** *How has climate changed in the past and how may it change in the future? What are some of the natural and anthropogenic causes for variations in climate patterns? How does weather and climate change over multiple timescales (seconds through ice age)? What are the processes that are forcing climate change?*

- **How we know what we know about climate patterns.** *How do remote sensing, pollen records, tree rings, ice cores, weather instruments, and personal accounts help scientists monitor the climate and track change over time? What are the patterns and cycles that can be seen in the long-term climate record?*

Carbon Module Overview

The ***Carbon*** module will examine carbon as a greenhouse gas and as a driver of climate change. In investigating how carbon cycles through the Earth's system, students will understand that perturbations to any of the biogeochemical components of carbon cycle will/may result in changes in global carbon balance. There will be a strong emphasis on the biosphere and how the biosphere responds to changes to the carbon cycle, and conversely, how the carbon cycle responds to changes in the biosphere. Students will look at examples of biosphere interactions with the carbon cycle by examining current and/or predicted natural and anthropogenic changes in three carbon sinks – forests, permafrost and oceans. Students will have opportunities to evaluate strategies to reduce carbon emissions and/or sequester carbon as feasible solutions to mitigate climate change.

Key content addressed by this unit includes:

- **The Carbon Cycle and the Earth System.**
  What are the biological and geological components of the carbon cycle? What pathways and processes does carbon take as it cycles through these components and at what time frames? *Where are the Earth's carbon reservoirs and sinks and how much carbon is there? How much carbon can carbon sinks absorb before they become carbon sources?*

- **Carbon and Other Greenhouse Gasses (GHG).**
  What are the GHGs and what is their role in the natural greenhouse effect? How has the amount of global carbon dioxide changed over time and how do these changes inform predictions about climate change? What is carbon's role in making the Earth habitable for life? What happens to components of the biosphere as the atmospheric level of carbon dioxide increases? How do ecosystems and individual species respond?

- **Carbon Cycling and Biomes.**
  How is carbon exchanged across vegetation, soil, and the atmosphere? How does carbon storage in various biomes compare? Which biomes are significant carbon sinks and why? What is the relationship between carbon storage (i.e. terrestrial primary production) and global carbon balance? What are the impacts of both natural and anthropogenic events on terrestrial net primary production (NPP) and global carbon balance?

- **Carbon Cycling and Permafrost:**
  What is the structure of permafrost? How is carbon exchanged between the permafrost and the atmosphere? What makes permafrost a carbon sink? Why is the permafrost melting? How do NPP and the global carbon balance respond to this melting?

- **Carbon Cycling and Blue Carbon: Open oceans and coastal ecosystems:**
  Why are sea grass, mangrove, and salt marsh coastal ecosystems, and open oceans carbon sinks? How is carbon exchanged between the atmosphere and the open ocean? What can

change the balance of this exchange? How will NPP and the global climate balance change in response?

- **Ocean Acidification: The Other Carbon problem:**
  What is the downside of the oceans acting as a strong carbon sink? What is causing the oceans to become more acidic? How is ocean acidification impacting coastal and ocean ecosystems?

- **How do we know what we know about past and current changes in carbon and the relationship of these changes to the global climate cycle and to the biosphere?**
  How does analysis of proxy data from marine sediments and ice cores help scientists determine past changes in carbon dioxide levels over thousands of years in Earth's history? How do scientists use remote sensing, CO2 tracking instruments, radiocarbon dating, and ocean chemistry analysis to monitor changes in CO2, primary productivity and ocean acidification?