Earth Systems Investigations and EarthLabs: Inquiry Investigations of Earth System Science and Climate Change

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Julie Libarkin, Michigan State University

Kathy Ellins, University of Texas Austin

With funding from

Educational Resources Addressing Climate Science and Earth System Science

Earth Exploration Toolbook
- http://serc.carleton.edu/eet

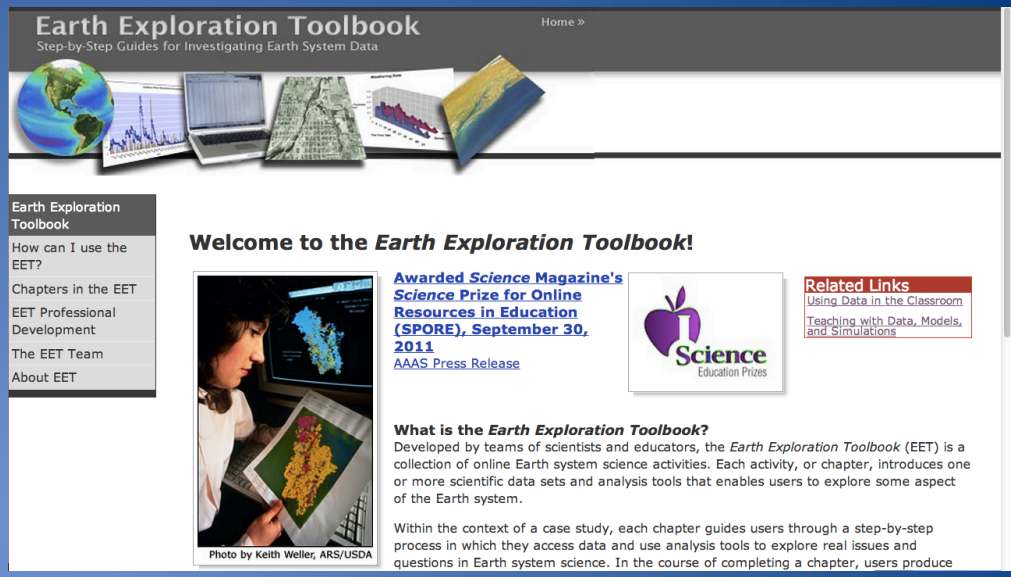
Climate Literacy and Energy Awareness Network (CLEAN)
- http://cleanet.org

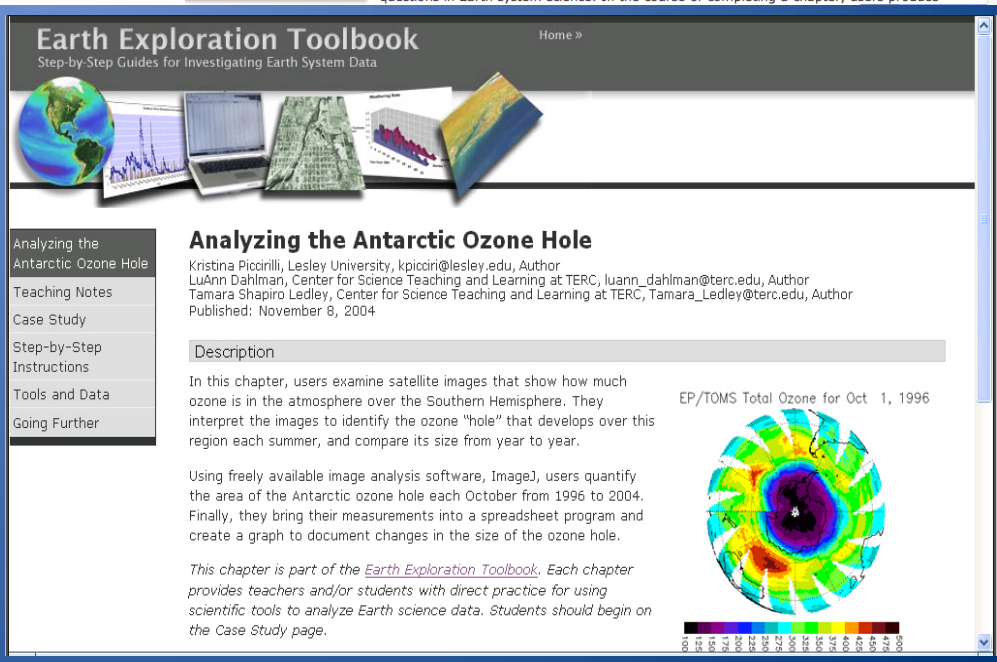
EarthLabs
- Teachers Guide http://serc.carleton.edu/earthlabs
- Student Guide
- http://serc.carleton.edu/eslabs

The Earth Exploration Toolbook (EET)

http://serc.carleton.edu/eet

- The **EET** is a collection of computer based activities that feature Earth science datasets and data analysis tools.
- EET chapters provide step-by-step instructions for accessing and analyzing data to explore issues or concepts in Earth system science.
- 44 EET chapters





Ledley et al, Science, vol 333, no 6051, pp1838-1839, 2011

CLEAN

CLIMATE LITERACY & ENERGY AWARENESS NETWORK

http://cleanet.org

Collection of Climate and Energy Educational Resources

A collection of 600+ free, ready-to-use resources rigorously reviewed by educators and scientists.

Suitable for secondary through higher education classrooms.

Explore the Collection »

Featured Resources from our Collection

Ice Core Secrets Could Reveal Answers to Global Warming

This video features research conducted at University of Colorado's Institute of Arctic and Alpine Research, which studies isotopes of hydrogen trapped in ice cores to understand climate changes in the past.

- CLEAN
- Collection of Educational Resources
- Guidance in Teaching Climate and Energy
- CLEAN Network
- About CLEAN

News

The CLEAN Collection is now aligned with NGSS!

Guidance in Teaching Climate and Energy Science

Background information, pedagogic approaches, links to relevant educational resources in the CLEAN collection.

CLEAN Network

A community of professionals committed to improving climate and energy literacy.

About the CLEAN Project

CLEAN Review Process

Climate Literacy and Energy Awareness Network (CLEAN)

http://cleanet.org

- >645 climate an
- Activities, video
- Grades 6-16
- Reviewed for sc effectiveness, a and educators
- Collection of ed Climate section www.climate.go
  - Won 2014 We Category

Gold et.al, Journal of Geos

CLEAN Resources: Tagged with the NGSS

CLEAN
CLIMATE LITERACY & ENERGY AWARENESS NETWORK

CLEAN
- Climate and Energy Educational Resources
- Teaching Climate and Energy Science
- CLEAN Network
- About CLEAN

Mauna Loa CO2 Collection Data

Jump to this Activity »

http://www.ctenergyeducation.com//lesson.htm?id=7gb7b019

Connecticut Energy Education

Students examine data from Mauna Loa to learn about CO2 in the atmosphere. The students also examine how atmospheric CO2 changes through the seasonal cycle, by location on Earth, and over about 40 years and more specifically over 15 years. Students graph data in both the Northern and Southern Hemisphere and draw conclusions about hemispherical differences in CO2 release and uptake.

Activity takes about one to two class periods.

Learn more about Teaching Climate Literacy and Energy Awareness»

NEXT GENERATION SCIENCE STANDARDS

See how this Activity supports the Next Generation Science Standards»

Middle School: 1 Performance Expectation, 1 Disciplinary Core Idea, 5 Cross Cutting Concepts, 7 Science and Engineering Practices

High School: 1 Performance Expectation, 1 Disciplinary Core Idea, 5 Cross Cutting Concepts, 9 Science and Engineering Practices

Notes From Our Reviewers

The CLEAN collection is hand-picked and rigorously reviewed for scientific accuracy and classroom effectiveness. Read what our review team had to say about this resource below or learn more about how CLEAN reviews teaching materials

Teaching Tips | Science | Pedagogy | Technical Details

Teaching Tips

- Read the student worksheet first, which has a more constrained dataset for graphing. Educators' guide contains a more extensive dataset that the educator can give to more advanced students.
- Younger students may require additional scaffolding for graphing and analyzing the graphs.
- We suggest that educator look for the most up-to-date Keeling Curve. Suggested link: http://www.esrl.noaa.gov/gmd/ccgg/trends/#mlo_full.
- Educator should be prepared to explain to students that the volcanic gases are not affecting the measurements, which is an often-cited argument that climate change deniers use to discredit these CO_2 measurements.

Topics

Greenhouse Effect
See more on this topic.

Atmospheric Circulation
See more on this topic.

Carbon Cycle
See more on this topic.

Greenhouse Gases
See more on this topic.

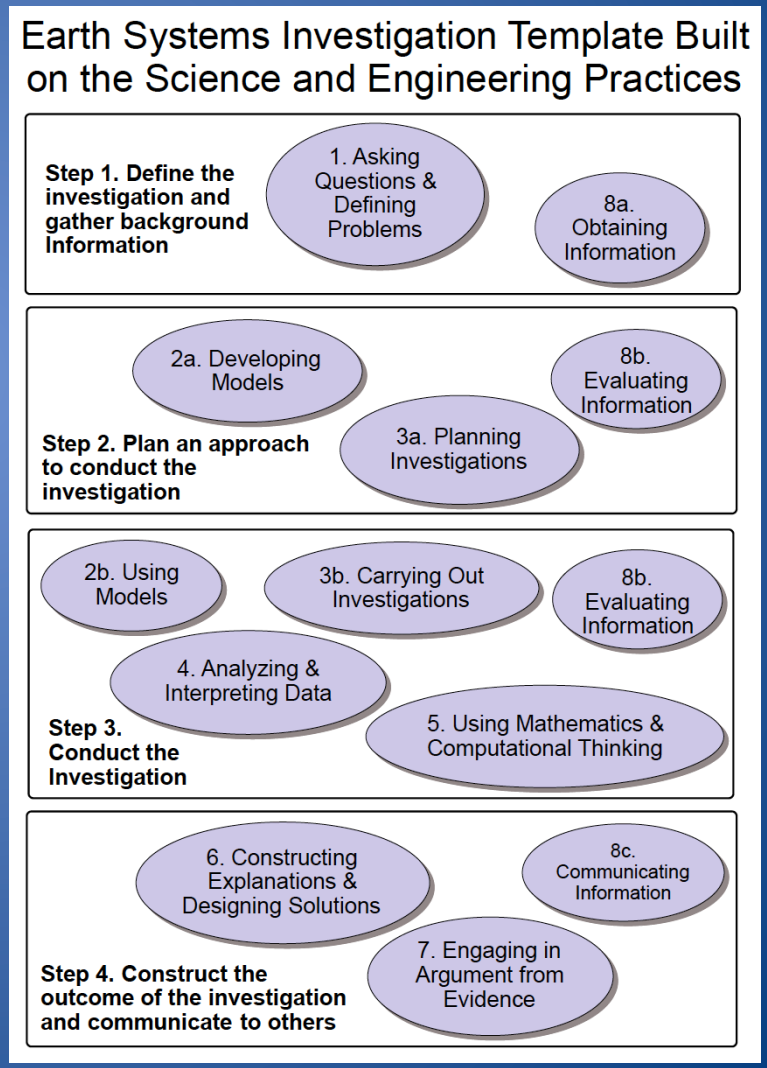
Seasonal Variability
See more on this topic.

Greenhouse Gas Emissions
See more on this topic.

Measurements and Observations

Earth Systems Investigations New in July 2016

- Suggested learning paths that integrate reviewed CLEAN resources into a 3-dimensional learning sequence.
- Three Dimensions
  - Science and Engineering Practices
  - Disciplinary Core Ideas
  - Crosscutting Concepts



NGSS Science & Engineering Practices

- 1. Asking questions and defining problems
- 2. Developing and using models
- 3. Planning and carrying out investigations
- 4. Analyzing and interpreting data
- 5. Using mathematics and computational thinking
- 6. Constructing explanations and designing solutions
- 7. Engaging in argument from evidence
- 8. Obtaining, evaluating, & communicating information

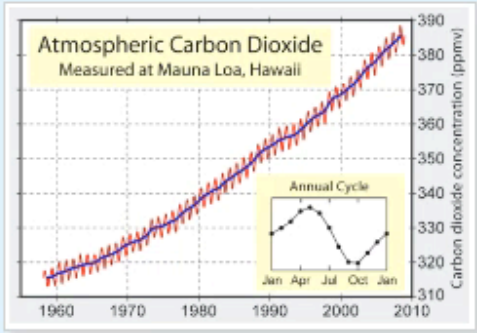
http://cleanet.org/clean/literacy/tlp/ecocarbon/

CLEAN

CLIMATE LITERACY & ENERGY AWARENESS NETWORK

Ecosystem's Role in the Carbon Cycle

Users of this Earth Science Investigation Plan engage with twelve resources in a four-step learning sequence to investigate the role of the ecosystem in cycling of carbon dioxide among the hydrosphere, atmosphere, geosphere, and biosphere. Through the course of the guided investigation users view short video clips, download, graph and analyze CO_2 data, and work with interactive modeling online resources.



Mauna Loa Graph

Next Page »

http://cleanet.org/clean/literacy/tlp/ecocarbon/Investigation.html

CLEAN

CLIMATE LITERACY & ENERGY AWARENESS NETWORK

CLEAN > Teaching Climate and Energy Science > Earth Systems Investigations > Ecosystems and Carbon Cycle

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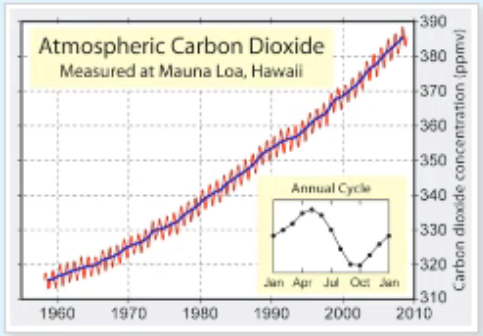

Mauna Loa Graph

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NSF NOAA U.S. DEPARTMENT OF ENERGY TERC CIRES Science Education Resource Center @ Carleton College

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CLIMATE LITERACY & ENERGY AWARENESS NETWORK

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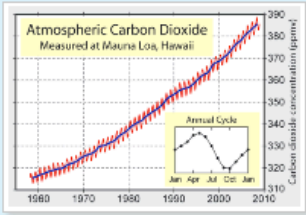
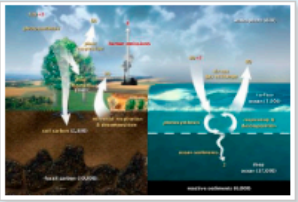


CLEAN

CLIMATE LITERACY & ENERGY AWARENESS NETWORK

Carbon Cycle

Users of this Earth Science Investigation engage with eight CLEAN, NASA, and NOAA resources in a four-step learning sequence to investigate cycling of carbon dioxide among the hydrosphere, atmosphere, geosphere, and biosphere. Through the course of the guided investigation users view short video clips, analyze CO_2 data, do hands-on experiments, and work with several interactive models. In the final step, students do a summative performance assessment to communicate their results and conclusions using interactive and physical models to illustrate the cycling of carbon in Earth systems. They use an interactive online resource to produce a single carbon pathway and then combine their results on a large poster in their classroom to construct a visual model of the carbon cycle.



carbon cycle diagram

Next Page »

EarthLabs Climate Modules

http://serc.carleton.edu/earthlabs/index.html

Project Components

Curriculum Development Professional Development

Educational Research on Student Learning

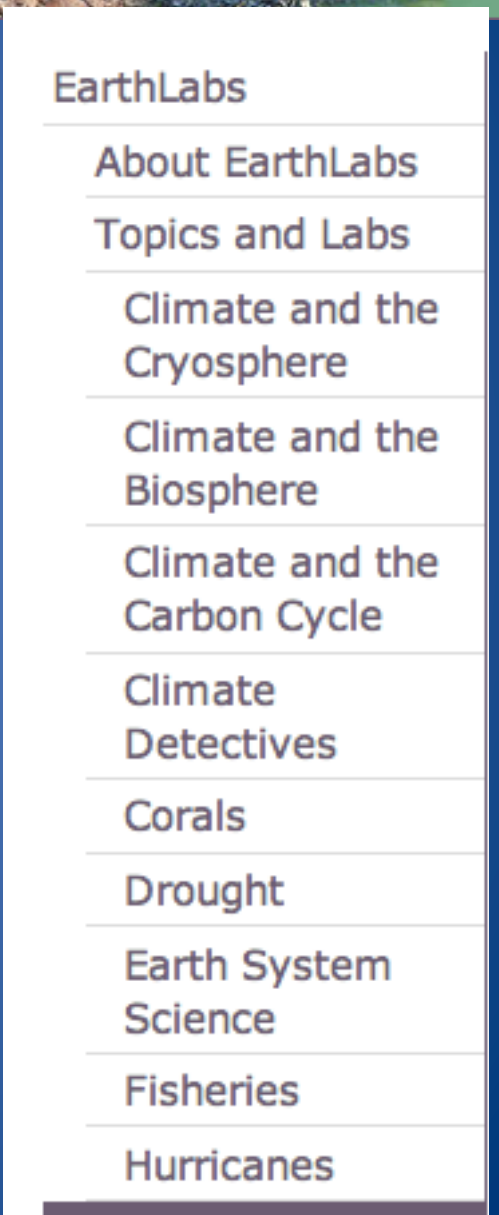
Ellins et al, Journal of Geoscience Education, vol 62, No. 3, pp307-318, Sept 2014

McNeal et al, Journal of Geoscience Education, vol 62, No. 4, pp560-577, Nov 2014

- 9 Modules comprised of 5-9 labs each in Earth and climate science
- Modules illustrate sequences for learning science concepts through data analysis and hands-on experiments.
- Use satellite imagery, numerical data, and computer visualization software to explore Earth system processes
- Include the use and development of quantitative skills that enable students to evaluate scientific results for themselves.

- Time requirement: 12 – 14 hours
- Each module uses a variety of instructional strategies
  - readings
  - videos, animations
  - interactive visualizations
  - hands-on lab investigations
  - data analysis
  - classroom discussions

http://serc.carleton.edu/earthlabs/index.html



EarthLabs website has 2 Parts

EarthLabs for Educators

Educator's Information Page

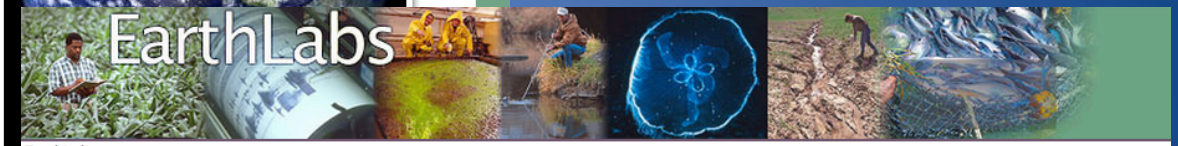
- EarthLabs for Educators
- About This Project
- The EarthLabs Team
- The Labs
- Climate Series Intro
- Climate and the Cryosphere
- Climate and the Biosphere
- Climate and the Carbon Cycle
- Climate Detectives
- Corals
- Drought
- Earth System Science
- Fisheries
- Hurricanes

EarthLabs

Earth science is emerging as a demanding high-school science course that prepares learners for college admissions and informed citizenship. Long perceived as a low-level science subject without a lab component, it now challenges and inspires students by leveraging visualization technologies and orbital and aerial perspectives to present Earth's components, including human activities, as a single interacting system. Earth science classes integrate physics, chemistry, and biology to introduce students to a rich body of concepts and knowledge with which to understand the world around them and pressing environmental, social, and economic issues.

EarthLabs supports this transformation by providing a m
environmental science labs. EarthLabs offer the laborato
science to a capstone high-school science course that c
students for college placement.

EarthLabs units offer sequences for learning science con
data analysis. Using satellite imagery, numerical data, c
explore Earth system processes and build quantitative s
scientific findings for themselves.



EarthLabs

- EarthLabs
- About EarthLabs
- Topics and Labs
- Climate and the Cryosphere
- Climate and the Biosphere
- Climate and the Carbon Cycle
- Climate Detectives
- Corals
- Drought
- Earth System Science
- Fisheries
- Hurricanes

EarthLabs

Earth and environmental science classes are changing. Long perceived as low-level courses with little to engage or challenge students, they are becoming vital, rich, invigorating courses. As more humans recognize that our planet's resources are being stressed, these classes are receiving more interest and they are being taught as true laboratory science courses.

In keeping with this transformation, the EarthLabs project provides a national model for rigorous, engaging Earth and environmental lab science courses. Four units illustrate a sequence for learning science concepts through data analysis activities, satellite imagery and computer visualizations, and hands-on experiments that illustrate processes of our Earth system.

Teacher Guide: http://serc.carleton.edu/earthlabs

Student Portal: http://serc.carleton.edu/eslabs

EarthLabs Topics
Brief Overview of Each Module

EarthLabs for Educators

- About This Project
- The Labs
  - Climate Series Intro
  - Climate and the Cryosphere
  - Climate and the Biosphere
  - Climate and the Carbon Cycle
  - Climate Detectives
  - Corals
  - Drought
  - Earth System Science
  - Fisheries
  - Hurricanes
- Partners
- EarthLabs for Students

EarthLabs Topics

EarthLabs presently includes eight modules. The sequence of labs in each module represent active learning experiences that are meant to be a part of integrated instructional units.

Climate and the Cryosphere
The cryosphere, which includes all of Earth's snow and ice, is highly variable on time scales ranging from days to hundreds of thousands of years. Changes in the cryosphere influence environmental conditions like air temperature, sea level, ocean currents, storm patterns, and ultimately Earth's climate. What can the cryosphere teach us about past, present, and future changes in Earth's climate?.

Climate and the Biosphere
Climate results from a complex set of interactions between the Sun and multiple components of the Earth system, interactions that we can't always see and that many poorly understand. What is the relationship between climate and the biosphere, and how does a change in one influence the other?

Climate and the Carbon Cycle
Carbon is essential to life as we know it. It is a component of our DNA and of the foods we eat, and its presence in the atmosphere (in the form of carbon dioxide) helps shape our planet's climate. As we alter the amount of carbon dioxide in the atmosphere through the burning of fossil fuels, how do we change the planet's carbon cycle and everything that is linked to that cycle, including climate?

Corals: Rainforests of the sea
Coral reefs are often compared to rainforests for the vast biodiversity they support, and to old growth forests for the longevity of their ecological communities. Now, forty percent of Earth's coral reefs are in critical condition or already degraded beyond recovery. Learn more about why these amazing marine animals are so important to our planet.

Drought: Dealing with a dry spell

Educator's Information Page

EarthLabs Climate Introduction

Preparing to Teach a Climate EarthLabs Module

Introduction

Studies about weather and climate and the ways in which they shape life on Earth have long had a place in the school curriculum. Today, as we struggle to understand the surprisingly new ways in which weather and climate are influencing our lives, the need for an informed citizenry is greater than ever. The most recent set of three EarthLabs climate modules will play a key role in helping students deepen their understanding of how our climate system works. Like their EarthLabs Climate Series predecessors (Drought; Hurricanes), the new modules address weather and climate not simply as atmospheric processes, but in the context of the interconnected Earth system, which includes the planet's oceans, landmasses, biosphere, and cryosphere (Earth's frozen places), as well as the atmosphere.

Although the main focus of the three new climate modules is climate literacy, it is impossible to ignore climate change when one looks seriously at climate data, something that students will do in all three of the new modules.

A brief introduction to each of the new modules (below) is followed by some classroom implementation suggestions and short science background notes that apply to all three modules.

▸ Show *Climate and the Cryosphere*

▸ Show *Climate and the Biosphere*

▸ Show *Climate and the Carbon Cycle*

In the Classroom

Student Prerequisite Knowledge: The Earth System

All students should read Earth System: The Basics (Microsoft Word 2007 (.docx) 151kB Jun6 12) before starting one of the Climate modules. It is short

http://serc.carleton.edu/earthlabs/climate_intro/index.html

Lab Overviews

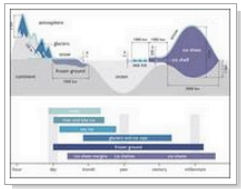
http://serc.carleton.edu/earthlabs/cryosphere/lab_overviews.html

EarthLabs for Educators and Policy Makers — a National Model for Earth Science Lab Courses

EarthLabs for Educators > Climate and the Cryosphere > Lab Overviews

EarthLabs for Educators
- Climate Series Intro
- Climate and the Cryosphere
  - Lab Overviews
  - Lab 1: Getting to Know the Cryosphere
  - Lab 2: Earth's Frozen Oceans
  - Lab 3: Land Ice
  - Lab 4: Climate History & the Cryosphere
  - Lab 5: Evidence of Recent Change
  - Lab 6: Future of the Cryosphere
- Climate and the Biosphere
- Climate and the Carbon Cycle

Climate and the Cryosphere: Lab Overviews



1. Getting to Know the Cryosphere
In Part A of this lab, students will learn about the different components that make up the cryosphere and where they can be found on Earth. In Part B, they will be introduced to some of the ways climate and the cryosphere influence one another, as well as how and why scientists study changes in our planet's snow and ice. In Part C, students will learn about some of the ways that humans, plants, and anima
cryosphere.
Tools Needed: Internet brows

▸ Show me materials needed for this lab

2. Earth's Frozen Oceans
In Part A of this activity, studer
influences ocean currents arour
ice thickness changes over time
ice index data to explore how s
year.
Tools Needed: Internet brows
program, RealPlayer media play

▸ Show me materials needed for this lab

3. Land Ice
In the first part of this lab, stud

Educator's Information

EarthLabs for Educators and Policy Makers — a National Model for Earth Science Lab Courses

EarthLabs for Educators > Climate and the Cryosphere > Lab Overviews

EarthLabs for Educators
- Climate Series Intro
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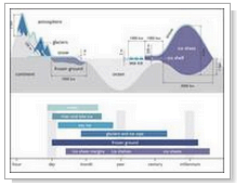
Climate and the Cryosphere: Lab Overviews



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In Part A of this lab, students will learn about the different components that make up the cryosphere and where they can be found on Earth. In Part B, they will be introduced to some of the ways climate and the cryosphere influence one another, as well as how and why scientists study changes in our planet's snow and ice. In Part C, students will learn about some of the ways that humans, plants, and animals are connected to and affected by the cryosphere.
Tools Needed: Internet browser, Media player plugin such as QuickTime

▾ Hide

- light source
- 4 plastic containers (plastic shoe boxes work well)
- snow or shaved ice
- dirt or soil
- gravel
- sand
- light meter or probe
- printed image of Antarctic sea ice
- two thermometers

Educator's Information Page

EarthLabs
for Educators and Policy Makers
a National Model for Earth Science Lab Courses

rthLabs for Educators > Climate and the Cryosphere > Lab 1: Getting to Know the Cryosphere

Educator's Information Page

- arthLabs for ducators
- Climate Series Intro
- Climate and the Cryosphere
  - Lab Overviews
  - Lab 1: Getting to Know the Cryosphere
  - Lab 2: Earth's Frozen Oceans
  - Lab 3: Land Ice
  - Lab 4: Climate History & the Cryosphere
  - Lab 5: Evidence of Recent Change
  - Lab 6: Future of the Cryosphere
- Climate and the Biosphere
- Climate and the Carbon Cycle
- Climate Detectives
- Corals
- Drought
- Earth System Science
- Fisheries

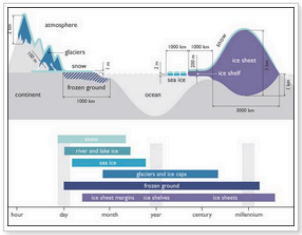
Lab 1: Getting to Know the Cryosphere

The lab activity described here was developed by Erin Bardar of TERC for the EarthLabs project.

Summary and Learning Objectives

In Part A of this lab, students will learn about the different components that make up the cryosphere and where they can be found on Earth. In Part B, they will be introduced to some of the ways climate and the cryosphere influence one another, as well as how and why scientists study changes in our planet's snow and ice. In Part C, students will learn about some of the ways that humans, plants, and animals are connected to and affected by the cryosphere.

Open the Student Lab »



After completing this investigation, students will be able to:

- list the major components of the cryosphere
- identify where snow and ice are found on Earth
- explain the role of albedo in balancing Earth's r
- give at least 3 examples of how the cryopshere
  Earth
- explain why scientists use the cryosphere to st

Overview and Teaching Materials

Detailed overview of what students will do in each lab activity, h

▸Read more

Printable Materials

Download and print files needed for each lab activity, including

EarthLabs

EarthLabs > Climate and the Cryosphere > Lab 1: Getting to Know the Cryosphere

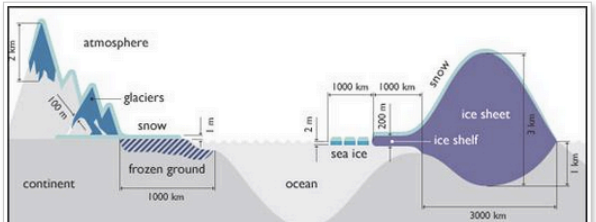
- EarthLabs
- Climate and the Biosphere
- Climate and the Carbon Cycle
- Climate and the Cryosphere
  - Lab Overviews
  - Lab 1: Getting to Know the Cryosphere
    - 1A: Introduction to the Cryosphere
    - 1B: Why We Study the Cryosphere
    - 1C: The Changing Cryosphere
  - Lab 2: Earth's Frozen Oceans
  - Lab 3: Land Ice
  - Lab 4: Climate

Getting to Know the Cryosphere

Introduction

The Earth's surface contains many forms of snow and ice, including sea ice, lake and river ice, snow cover, glaciers, ice caps and sheets, and frozen ground. Together, these features are known as the **cryosphere**. Snow and ice are a vital part of the global climate system because they influence air temperatures, sea levels, ocean currents, and storm patterns all over the world. Life on Earth depends on the cryosphere for many different things. In Arctic regions, sea ice provides a home for animals like seals and polar bears, feeding and breeding areas for a variety of migrating species, and hunting grounds for local communities. Much of the world depends on the cryosphere for fresh drinking water, while others use it for recreation—without the cryosphere, there would be no skiing, sledding, or snowball fights!

Although concentrated in the polar regions, parts of the cryosphere can be found at nearly all latitudes, which make them useful indicators of global climate and climate change. Different parts of the cryosphere change on different timescales ranging from less than a day to more than a millennium, as shown in the figure below. Scientists keep a close watch on the cryosphere and patterns in how the cryosphere changes over time to find important clues about the health of our planet.



Keeping track of What You Learn

In these pages, you'll find two kinds of questions.

- **Checking In** questions are intended to keep you focused on key concepts. They allow you to check if the material is making sense. These questions are often accompanied by hints or answers to let you know if you are on the right track.
- **Stop and Think** questions are intended to help your teacher assess your understanding of the key concepts and skills. These questions require you to pull some concepts together or apply your knowledge in a new situation.

Your teacher will let you know which questions you should answer and turn in.

Checking In

- During which months does soil moisture at 10 cm remain basically steady?
- During which months does soil moisture at 10 cm change quite frequently?
- What change do you notice as you compare soil moisture for 1998 with 1999?

Stop and Think

1: Do air temperature and soil moisture at 10 cm follow the same pattern? Why or why not?

2: What does this graph show about the interconnection between air temperature and soil moisture at 10 cm?

Explore the Climate and the Cryosphere Module

Key Questions

- What is the cryosphere?
- How and why does the cryosphere change over time?
- What are the timescales associated with changes in the cryosphere?
- How do climate and the cryosphere influence each other?

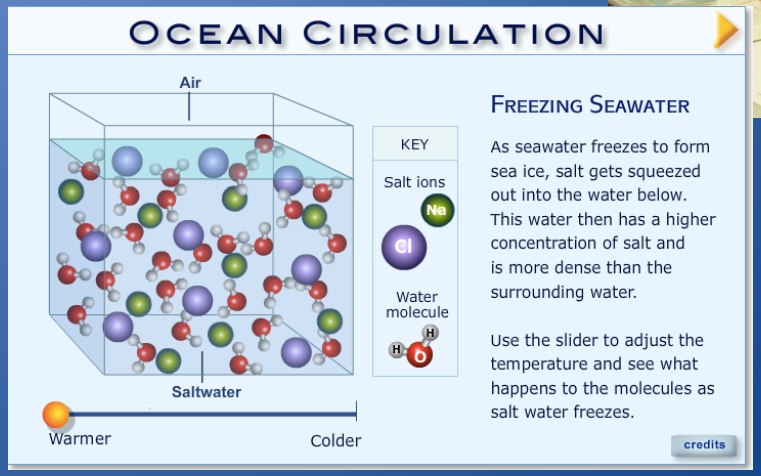
http://serc.carleton.edu/earthlabs/cryosphere/index.html

Explore the Climate and the Cryosphere Module

- Teachers Guide
  - http://serc.carleton.edu/earthlabs/cryosphere/1.html
- Student Portal
  - http://serc.carleton.edu/eslabs/cryosphere/index.html
- Lab Overviews
- The Cryosphere Labs
  1. Getting to Know the Cryosphere
  2. Earth's Frozen Oceans
  3. Land Ice
  4. Climate History and the Cryosphere
  5. Evidence of Recent Change
  6. Future of the Cryosphere
- Cryosphere Glossary

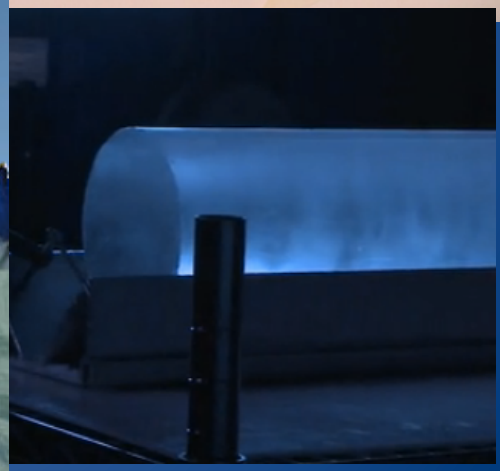
EarthLabs - Cryosphere

- Getting to Know the Cryosphere
  - What are the components of the cryosphere
  - How climate and the cryosphere influence each other
- Earth's Frozen Oceans
  - How does sea ice form and how it influences ocean currents
  - How does sea ice thickness and extent change over time
- Land Ice
  - How does glacier mass balance reflect climate change
  - How do glaciers move



EarthLabs - Cryosphere

- Climate History and the Cryosphere
  - Timescales associated with glacial and interglacial periods
  - How do ice cores record atmospheric and climate data
  - Impacts of climate change on land ice and oceans
- Evidence of Recent Change
  - Examine how land glaciers and sea ice have changed over the recent past
  - What is the ice-albedo feedback loop
- Future of the Cryosphere
  - Explain how climate will change in the future based on model results
  - What are the potential impacts on life of predicted changes in the cryosphere



Cognitive Challenges to Understanding Climate Change – Education Research

- Earth System Science
  - Understanding the interconnectedness of all of the components of the system
  - Changes in one component can have large and unanticipated impacts on other components
- Change Over Time on Multiple and Embedded Time Scales
  - Daily, seasonal, annual, interannual, decadal, century, glacial, geologic…
  - Long-term change manifested as impact on shorter cycles

EarthLabs Educational Research Questions

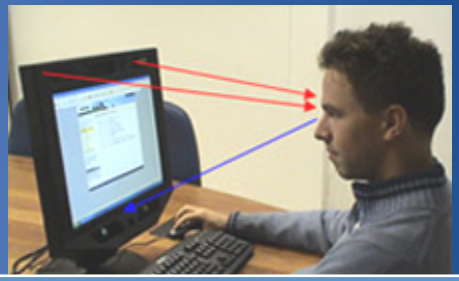
- How does the on-line EarthLabs curriculum assist students in developing understanding of temporal and spatial dynamics, system interactions, and conceptual knowledge of climate?

- How do users engage with and navigate the on-line EarthLabs curriculum?

Preliminary Research Outcomes Climate & Biosphere, Climate & Cryosphere, and Climate & Carbon Modules

- 500 Students in 20 classrooms in Texas and Mississippi
- Pre- and Post- Test contained
  - Content multiple choice questions
  - Affective-based multiple choice questions
  - Confidence question
  - Open ended questions
- Positive gains on 90% of content questions (2%-42%)
- Significant increase in student confidence in answers
- Affective questions – significant gains in knowledge, awareness, and information about the Earth's climate system

Populations & Methods
Cryosphere & Earth System Science Modules



Teachers (n=8)	Students (n=205)	External Users (n=49)
Post-implementation Interviews	Pre-post open-ended response surveys	Eye-tracking
Post-workshop surveys	Classroom observations	Interviews

http://gettingsmart.com/cms/edreformer/new-report-highlights-real-teacher-retention-crisis-america/

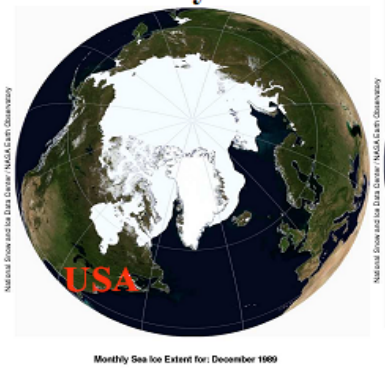
http://www.mnsu.edu/newstudent/seminar/

http://www.uxmatters.com/mt/archives/2005/12/introduction-to-eyetracking-seeing-through-your-users-eyes.php

Example open-ended *Cryosphere EarthLabs* pre-post assessment

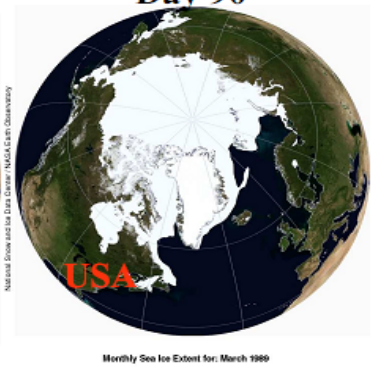
The images below show ice extent (in white) in the Northern Hemisphere over a 270 day period. Notice that the approximate location of the Unites States (USA) is labeled in each of the figures. Answer the following questions to the best of your ability.

Day 1



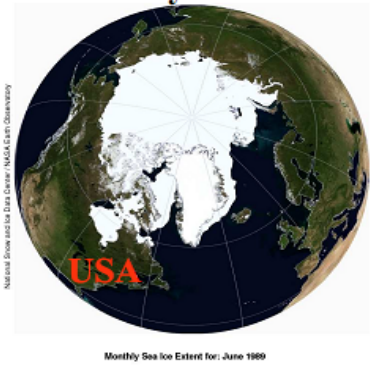
Monthly Sea Ice Extent for: December 1989

Day 90



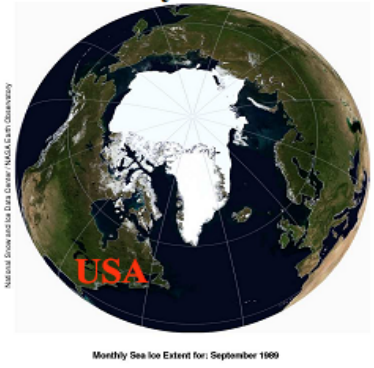
Monthly Sea Ice Extent for: March 1989

Day 180



Monthly Sea Ice Extent for: June 1989

Day 270



Monthly Sea Ice Extent for: September 1989

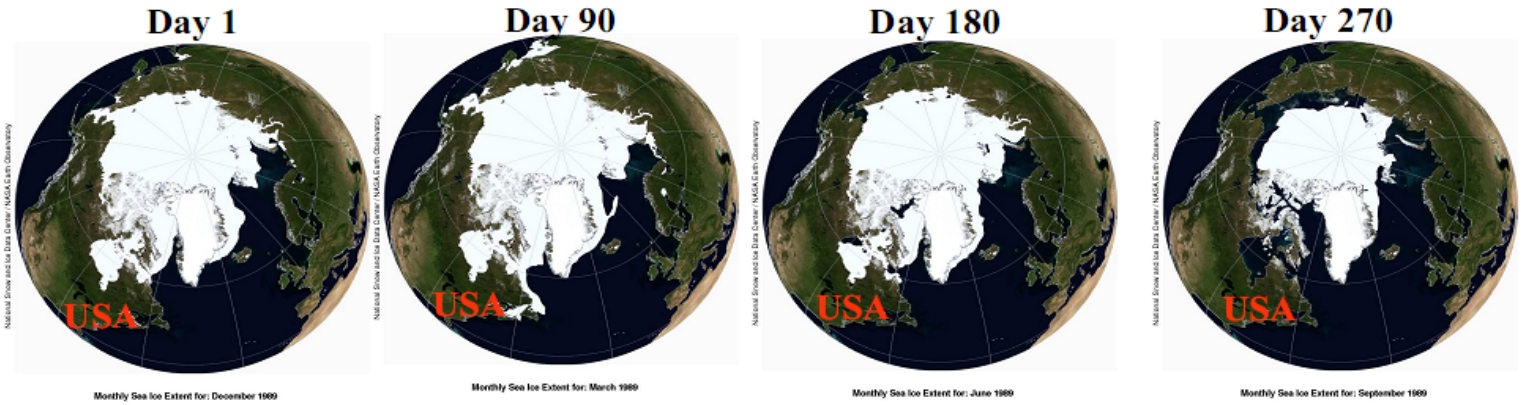
2. Explain in your own words why the ice extent in each of these images is different.

Student Methods: Systems Understanding Rubric

Symbol	Description	Points
Arrow 	Actions/Processes (Usually a verb)	1 point
Boxes 	Inputs/Outputs (Usually a noun)	2 points
Connections 	Between Actions/Processes or Inputs/Outputs (Usually a conjunction)	3 points

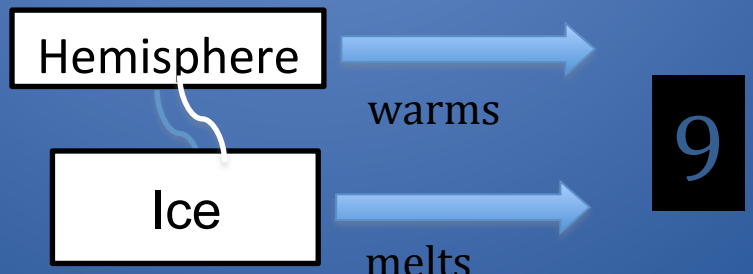
Example open-ended *Cryosphere EarthLabs* pre-post assessment

The images below show ice extent (in white) in the Northern Hemisphere over a 270 day period. Notice that the approximate location of the Unites States (USA) is labeled in each of the figures. Answer the following questions to the best of your ability.



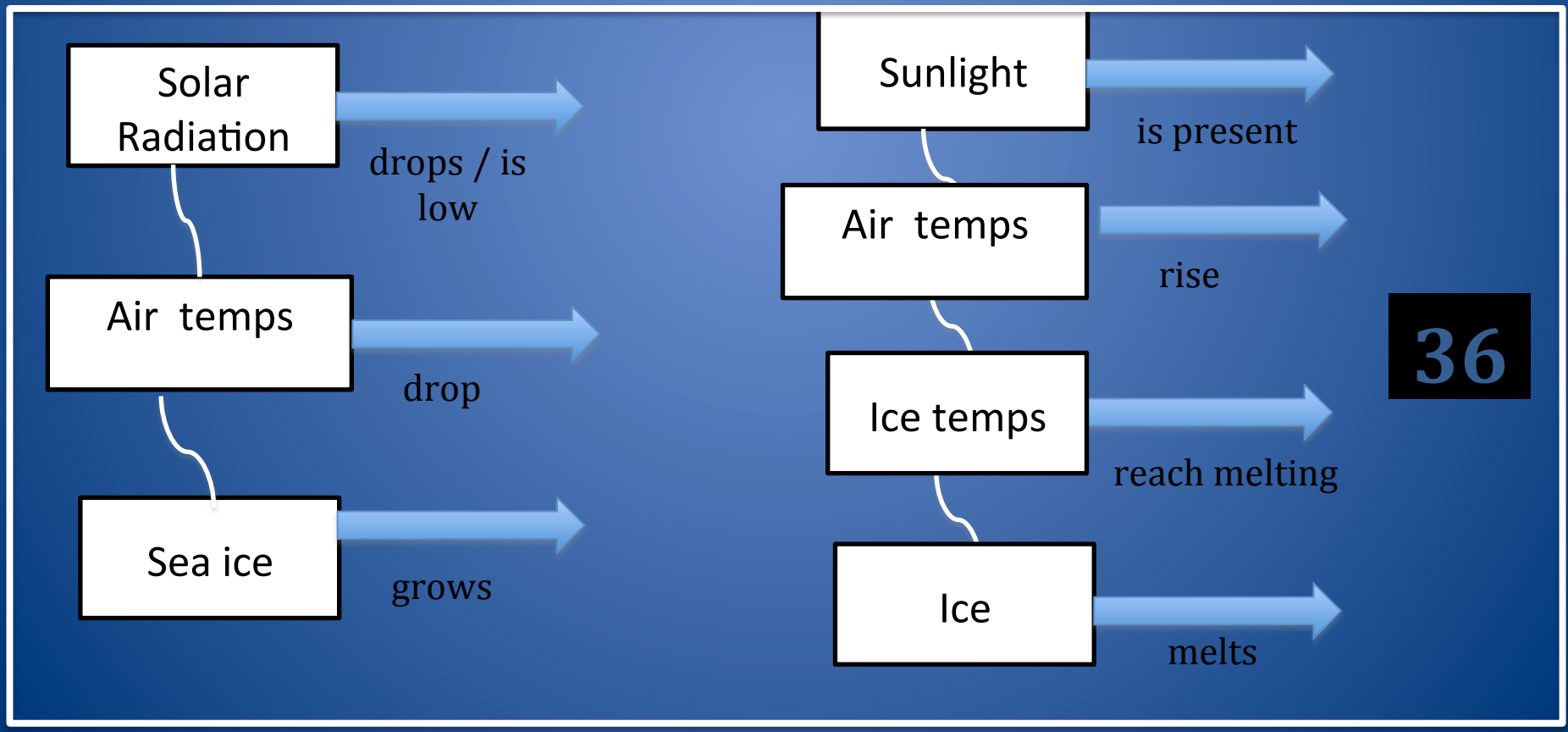
2. Explain in your own words why the ice extent in each of these images is different.

Student response:
"The hemisphere is warming, causing ice to melt."



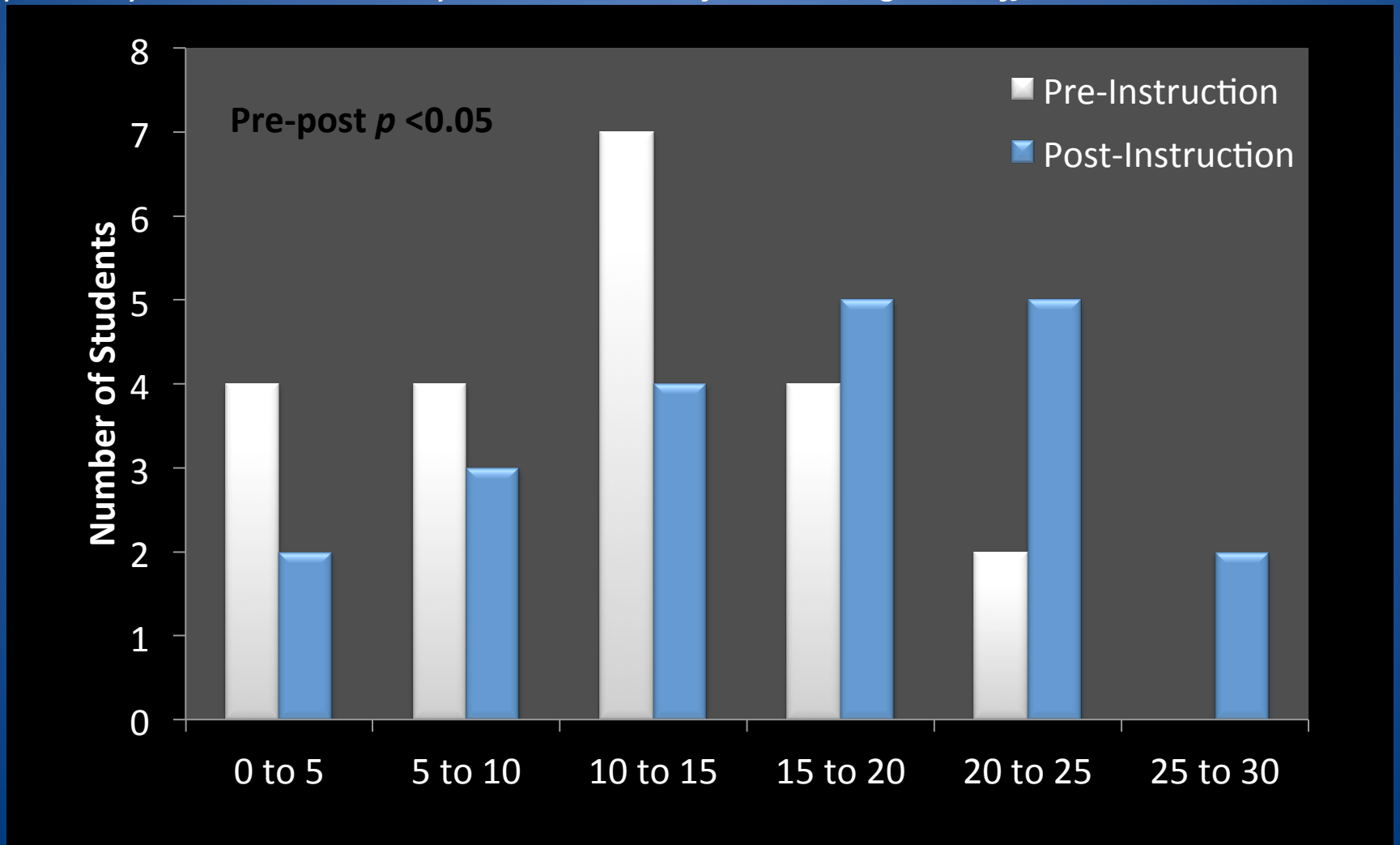
9

Expert response: "The images show the sea ice extent through the seasonal cycle. In the winter the sea ice extent would be the greatest. This is because there is no or little solar radiation over the region at that time of the year, causing air temperatures to be very low, resulting in a growth and expansion of sea ice at the surface of the ocean… The image for day 180 shows the sea ice extent reduced from the image for day 90 so that image shows the sea ice extent in the spring."



Pre-post student response rubric scores

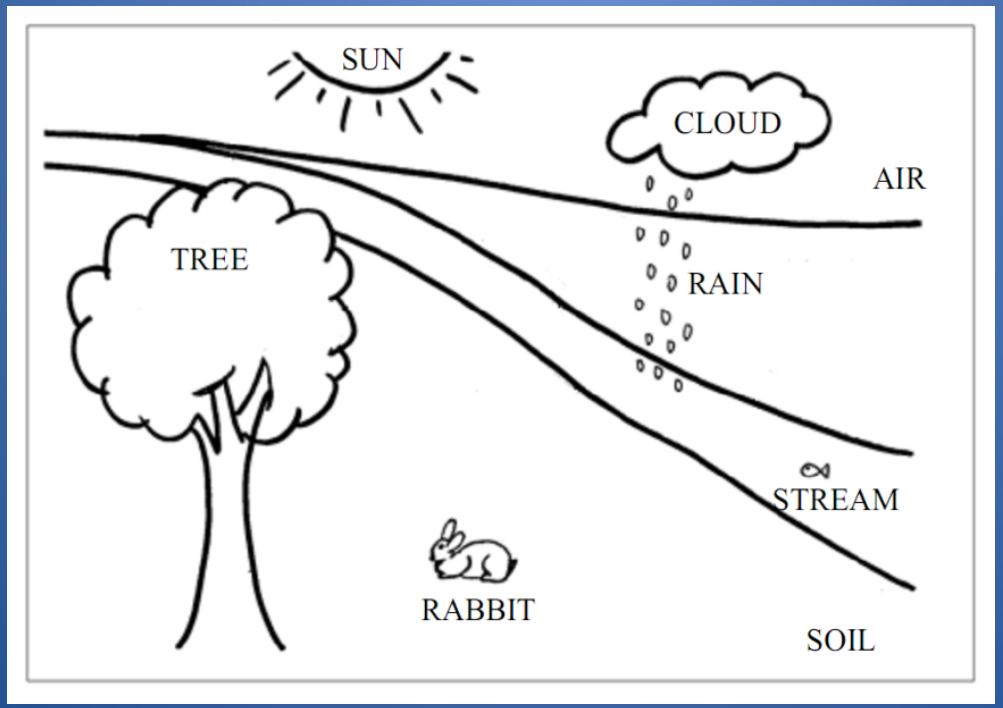
"Explain in your own words why the ice extent of these images is different"



Student Methods: Rubric #2 – Conceptual Understanding

Level 0. Simple restating of the question.
Level 1. Statement of a single correct fact.
Level 2. Statement of multiple correct facts.
Level 3. A. Statement of multiple correct facts, with a single connection between facts. OR B. Statement of multiple correct facts, with multiple connections between facts. Misconceptions equal to or dominate over scientific conceptions.
Level 4. Statement of multiple facts, with multiple connections between facts. Misconception(s) present, but scientific conceptions dominate.
Level 5. Statement of multiple facts, with multiple connections between facts. Misconceptions not present within a story that is cohesive; misconceptions about concepts outside of the core message may be present.

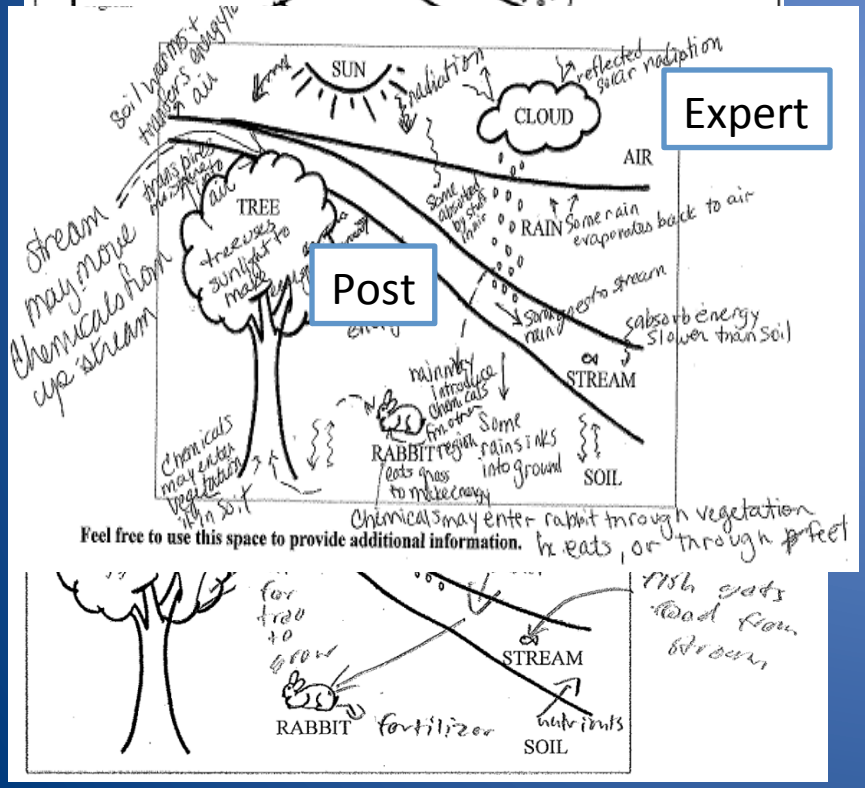
"The following diagram represents a region in the continental United States. Draw in and label arrows to represent ALL of the important processes that move or change energy, water, or chemicals in this region".

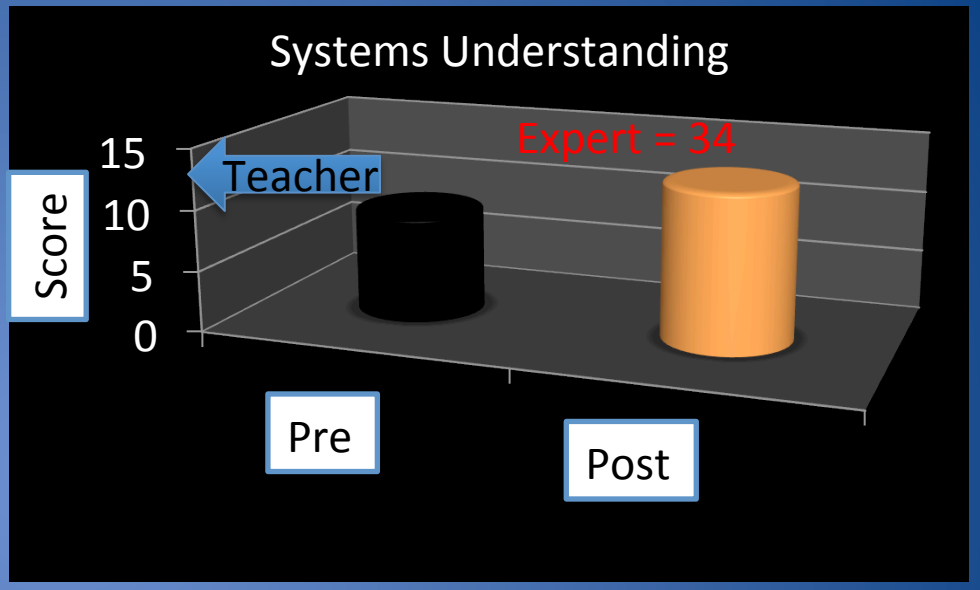


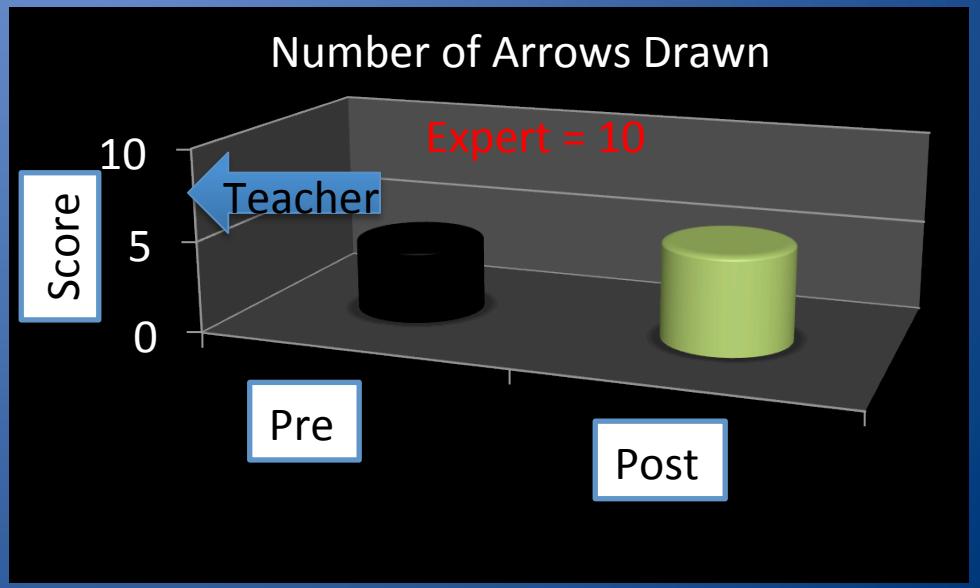
Pre

Expert

Post







Please describe and define The Cryosphere in your own words

Student Example

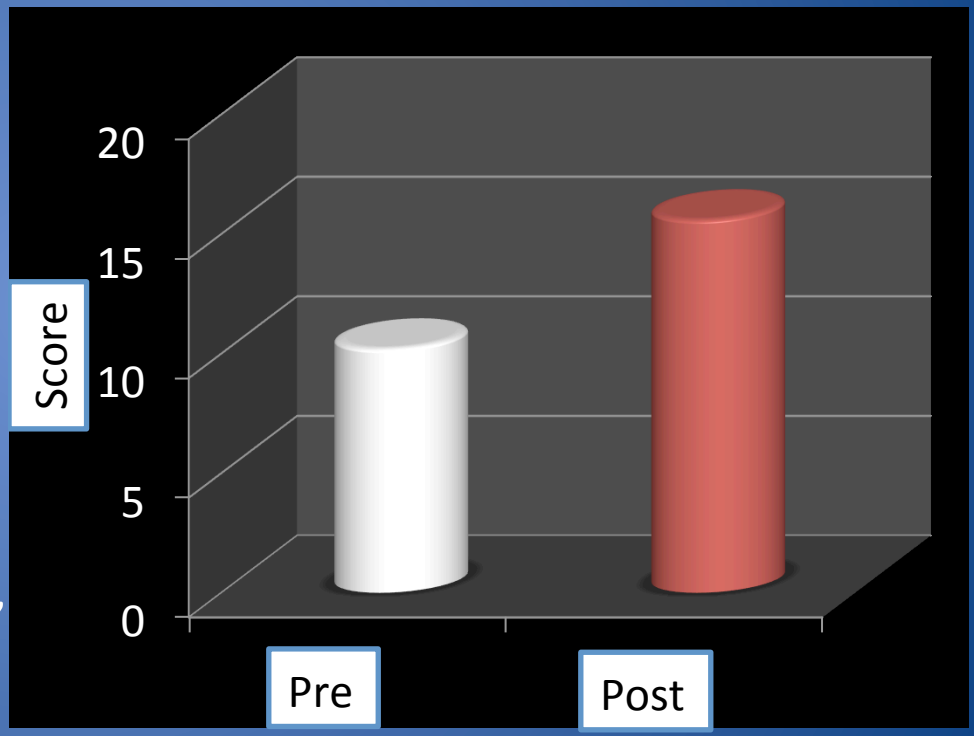
Pre: "*I don't know, sorry.*"

Post: "*The sphere with ice, snow, sleet, etc.*"

Pre-instruction = 42% "*I don't know*"
Post-instruction = 18% "*I don't know*"

Pre-instruction = 33% "*ice*"
Post-instruction = 57% "*ice*"

Systems Understanding



Paired Student's t-test $p < 0.05$
N = 163

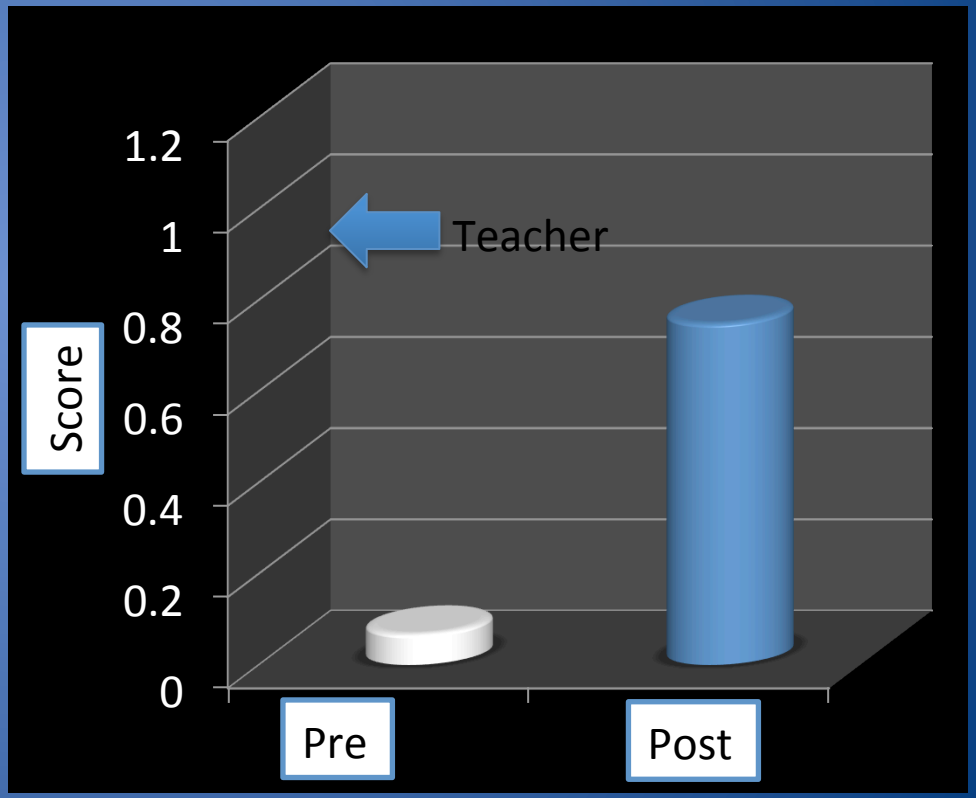
Please describe and define Earth system science in your own words

Student Example

Pre: "The research of the way that the Earth operates. This show us how the earth is changing as a whole."

Post: "The work of geography such as biosphere, pedosphere, atmosphere, and hydrosphere used to find information and solve facts for future use and help us find out more about the way our planet works"

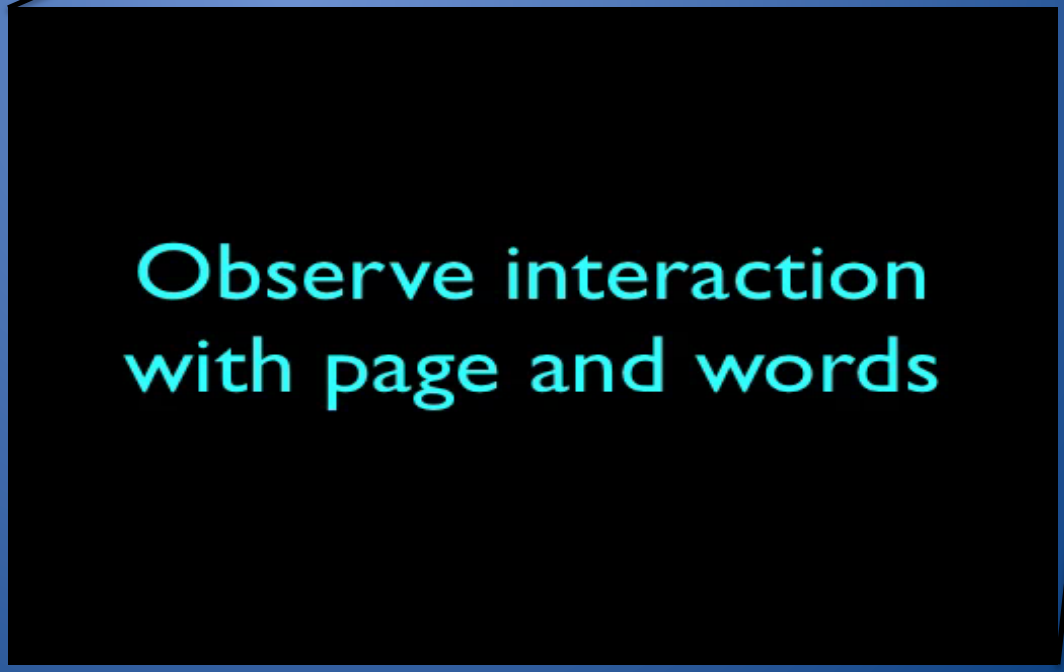
Conceptual Understanding



Paired Student's t-test $p < 0.05$
N = 163

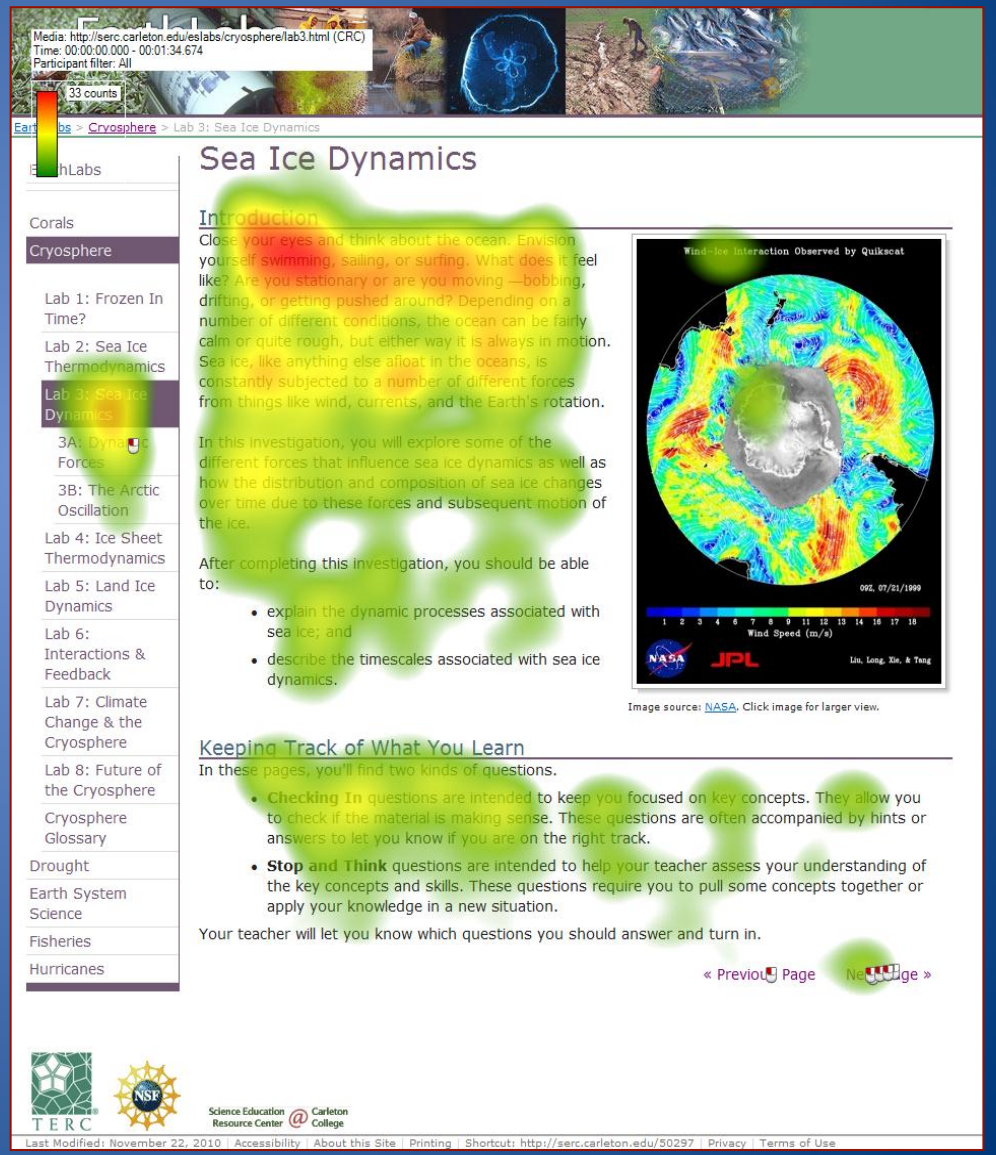
Methods: Eye-tracking studies

- Pre-Study Measures
  - Color-blindness
  - Climate change conceptions
  - Demographics



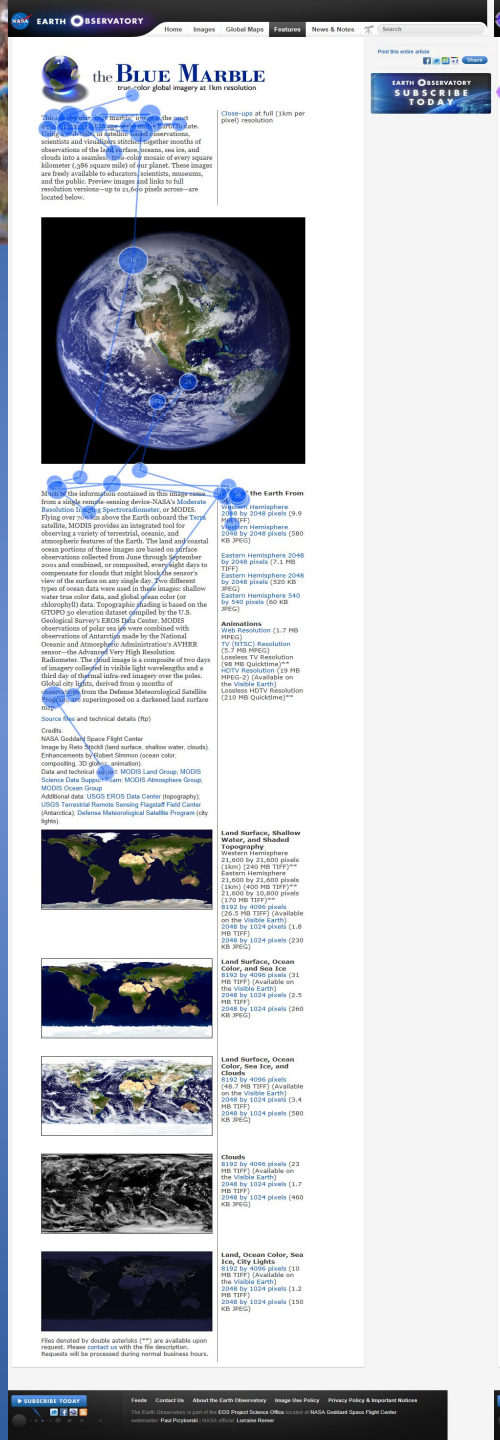
EarthLabs

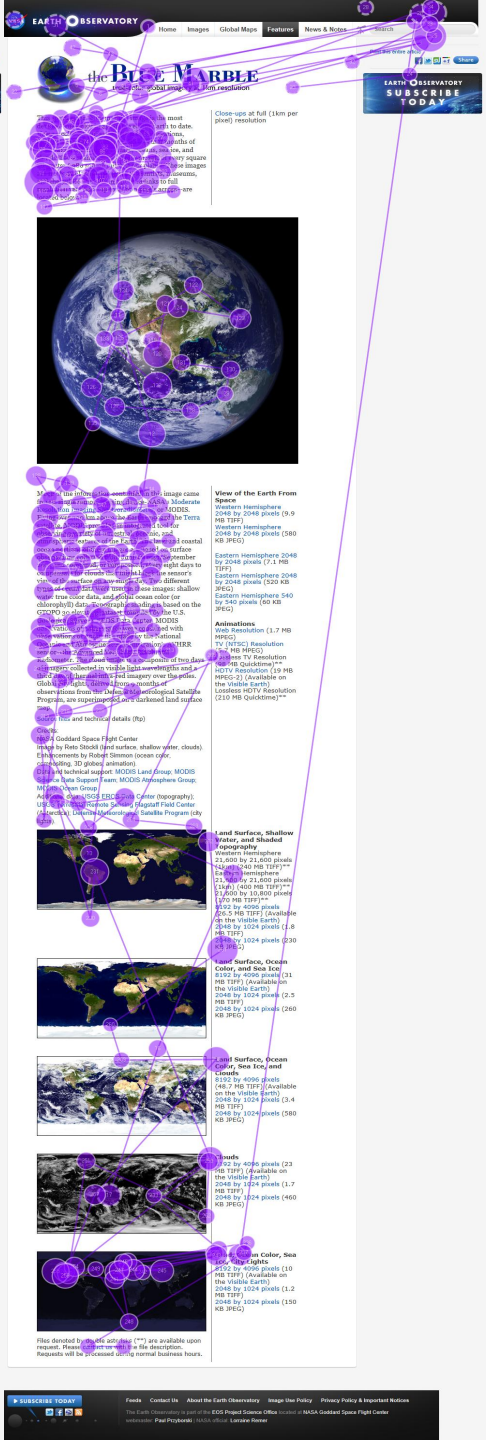
- Time to complete - 23 and 32 minutes
- Engaged less with images than with text
- Difficulty engaging with some materials posted on external sites



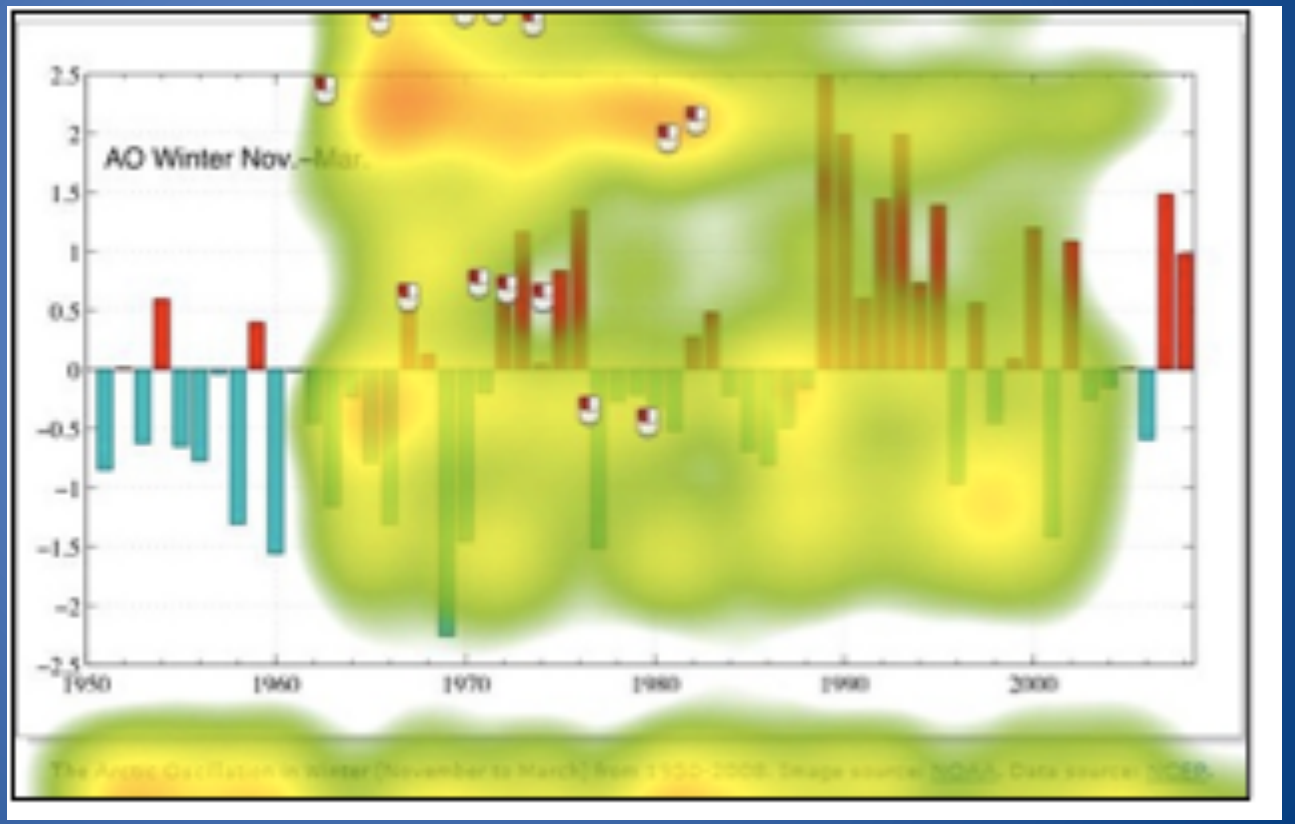
Purple path is a participant with significant attention.

Blue path is cursory and is typical of most participants.





Students had difficulty knowing where to look on complex scientific graphs/figures



Conclusions

- Students' **SYSTEMS UNDERSTANDING** and **CONCEPTUAL UNDERSTAND** significantly improved after exposure to *EarthLabs* modules, although students did not reach mastery levels on par with expert responses.

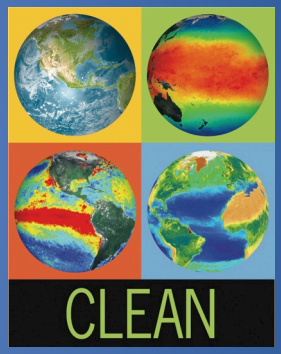
- Classroom observations combined with eye-tracking measures of external users indicate that the *EarthLabs* modules were **ENGAGING TO USERS**.

- The *EarthLabs* **CURRICULUM-RESEARCH** model is an example of how research can be used to inform curriculum development.

Educational Resources Addressing Climate Science and Earth System Science

- Earth Exploration Toolbook
  - http://serc.carleton.edu/eet

- Climate Literacy and Energy Awareness Network (CLEAN)
  - http://cleanet.org



- EarthLabs
  - Teachers Guide http://serc.carleton.edu/earthlabs
  - Student Guide
  - http://serc.carleton.edu/eslabs

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