Unless someone like you cares a whole awful lot, nothing is going to get better. It's Not.
- Dr. Seuss, The Lorax

UNIT 1
THE BIG CLIMATE CHANGE EXPERIMENT
Lesson 3: Climate Change Lines of Evidence

Unit 1 Guiding Question

Does the world's rising temperature affect me?

A NOTE FROM THE HOT AUTHORS

The Hot: One World, One Climate curriculum and simulation is a collaborative effort among secondary teachers, educational experts and journalists with faculty and staff from the NASA Goddard Institute for Space Studies (GISS) and the Columbia University Earth Institute. This interdisciplinary team – known as The GISS Climate Education Advisory Group – has been able to draw on many perspectives and areas of expertise to advance a real world, problem-based approach for student learning around many climate change topics.

The curriculum is designed to reinforce academic knowledge and skills outlined in national education standards with an eye toward student inquiry and research-like experiences. While exploring the science and stories of climate change, our goal is for students to use scientific research to build science and climate literacy, evaluate climate change solutions and develop 21st Century skills for informed civic engagement.

Our development process has been an iterative. The Climate Change in the Classroom (CCIC) Teacher Workshop at NASA GISS/Columbia University is a continuation of this process as we broaden the Hot collaboration to include the review, critique and recommendations more scientists and educators from 5 U.S. states.

It is important to note that we are in the active stage of review and development of the Hot curriculum and simulation. Hence, the materials being field-tested in the CCIC are not in their final form and require additional educational and scientific review. This is one of the major goals of the CCIC Teacher Workshop.

We hope that the Hot curriculum and simulation will prove to be a meaningful way for you and your students to engage in learning about Earth, and the intersections of science and society in the context of an important global issue – climate change. We also hope Hot is personally relevant students, and motivates a lifetime of interest and critical thinking about our planet and the special role humans have in the Earth system.

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Special thanks to Eric Roston, the author of "The Carbon Age," and to Gavin Schmidt and Josh Wolfe, the author-editors of "Climate Change: Picturing the Science," for the inspiration, knowledge and content their books provided to writing the Hot materials.

UNIT 1 AT-A-GLANCE

Students engage in lessons where they develop some basic background knowledge about climate change drawing on research from scientists around the world. They will begin to develop key ideas that climate change is happening, we can observe it and it is a global problem. Students also begin to understand some of the lines of climate change evidence. More fundamentally, Unit 1 explores the relationship between climate and life, and helps students explain the difference between weather and climate.

Summative Assessment

Write a short news story using initial understandings developed in Unit 1 to describe the roles of humans and carbon in Earth's climate change story. The essay should accurately relate and explain at least one key climate science concept (e.g., difference between weather and climate) as well as 3 or more lines of climate change evidence. It should also express the influence of these roles in terms of time and spatial scale relevant to the climate change story.

National Education Standards Addressed

Learning objectives for each lesson relate to national education standards found in the Common Core State Standards (CCSS) and Next Generation Science Standards (NGSS). Each lesson identifies the specific standards addressed.

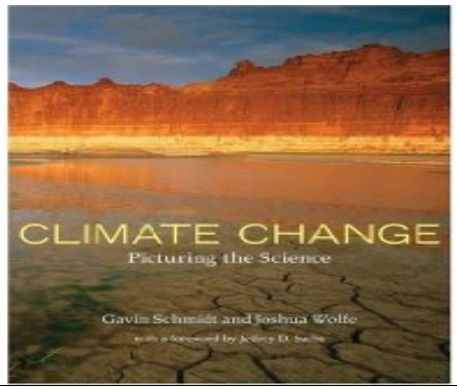
Unit 1 Learning Progression

Following input received from the 2013 Climate Change in the Classroom Teacher workshop, we will prepare a learning progression for the Unit. In its final form it will provide a short introduction and a lesson grid with brief summaries of student activities, learning objectives, standards addressed and performance assessments.

OBSERVE AND ANALYZE

1.3 CLIMATE CHANGE: LINES OF EVIDENCE

TIME: 90 minutes or 2 class periods + homework



"A doctor can examine our symptoms, try to diagnose our condition, and suggest treatments if the prognosis is not favorable. The success of modern science shows clearly that, even when medical knowledge is not perfect, it is useful. This is also true for climate scientists studying the Earth – the science is imperfect – but still useful. "

- Climate Change: Picturing the Science

overview

Students observe and analyze images and graphs scientists use to explain climate change. They also make initial inferences about relationships between energy use, CO_2 emissions and global temperature.

objectives

The student will be able to…

- identify 3-5 lines of climate change evidence related to land, ocean and/or the atmosphere
- interpret graphical data to describe climate change lines of evidence qualitatively and quantitatively
- make inferences from the results of climate change research to construct an evidence-based narrative about the underlying science for a general audience

Prerequisite

None

key vocabulary

Anomaly: Something that deviates from the normal, standard or expected.
Diagnosis: Identifying the nature or cause of a condition or problem.
Inference: To shift from analyzing data to making a generalization or formulating an opinion based on facts or evidence.
Infrastructure: Basic structures and facilities (roads, buildings, etc.) in an area.
Prognosis: The prospect, chance or outlook for recovery from the condition/problem.
Policy-maker: Someone who sets plans for government and/or business.
Qualitative Data: describe the quality of something like size, appearance, change, etc., using adjectives as opposed to numbers.
Quantitative Data: describe something as a measured quantity.
Symptom: Evidence that indicates the existence of condition or problem.
Unabated: Without any reduction in strength, force, or intensity.

subjects

English Language Arts, Earth and Environmental Science, Social Studies and Mathematics

standards

NGES ESS3.D Global Climate Change
Human activities affect climate

CCSS Math Literacy
Describe relationships between quantities in a graph (F.B.5)

CCSS ELA-Literacy:
Analyze author ideas and claims from text (RI.5)

Engage in collaborative discussions and claims and findings (SL.1-3, 4)

resources / materials

Chasing Ice film clip (4:41 minutes) at http://youtu.be/hC3VTglPoGU

Synopsis of *Chasing Ice* film at http://goo.gl/TOizX

Cut up copies of CLIMATE CHANGE IN THE NEWS DATA SHEETS 1-11

Copies of Climate Math, answers are on the following teacher page

differentiation guide

This lesson differentiates content, process, product based on student readiness, interests and learning profile. To be completed….

background

Climate change is becoming a ubiquitous topic in today's news headlines. Extreme weather events related like Hurricane Katrina's devastation of New Orleans in 2005 or the 2012 wildfire season that destroyed millions of acres of land and infrastructure across the American west are increasingly connected to climate change and our national narrative.

Scientists are often asked to comment on these and other climate change related stories to provide expert opinion. When scientists comment on these events, they utilize various lines of evidence to help explain the extreme weather we are increasingly experiencing. For this reason some graphical representations of this evidence are used so frequently they are becoming recognizable, even "popular" to the general public.

The purpose of these lines of visual evidence is to help the public and policymakers understand research-based evidence about how climate is changing, why it is changing, and what climate change and impacts we might expect in the future (predictions). For that reason, to gain a deeper understanding of climate change story, one must have science, math and media literacy skills.

In this lesson students begin thinking about the numerous lines of evidence scientists have found as a result of decades of climate measurements and research that indicate human emissions of greenhouse gases like CO_2 are the major cause of increasing global temperature. By observing and analyzing various climate data presented in graphs and images, students practice interpreting science data that comes to us in various forms. Exploring this data allows students to begin to develop understandings of the climate change story.

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suggested procedure

K-W-L Chart

1. Read the quote at the beginning of the lesson out loud to the class. Ask students to elaborate on how the medical analogy relates to climate change.

2. Have students complete the first two columns of the K-W-L Table on the student pages to organize their current thinking about - "What do they know" and "What they want to know about climate change." Teachers can choose whether they want to have students share some of their responses and organize them around broad topics and questions.

3. Tell students they are going to "think and act like climate scientists" preparing to present their research to the public. Before they do this, teachers may want to have a short discussion with students about methods scientists use to analyze data. The discussion should highlight that scientists make observations (measurements of the real world) to answer scientific questions. These measurements are transformed in various ways for analysis – graphs, images, formulas, statistics, data tables, etc. Also, scientific analysis involves looking at one or more variables over some time and spatial scale. Teachers might also want to ask students what skills are needed for scientific analysis – possible responses might include: patience, creativity, technical, open-mindedness, objectivity, perseverance, etc. Teachers can also get more specific by asking students – what quantitative skills do scientists need to analyze data and what qualitative skills do scientists need?

observe

4. To give students guided practice in making observations and analyzing climate data (qualitatively), show the class film clips from the movie *Chasing Ice*. Stop the film at 3:30 minutes. The film can be introduced by telling students that environmental photographer, James Balog, traveled to the Arctic on assignment for National Geographic. The assignment turned into a multi-year project – "An Extreme Ice Survey" – to record what is happening to Earth's glaciers. Before you play the clip a second time distribute the student page *CHASING ICE* OBSERVATION GUIDE. As students watch the film they record their observations on the sheet.

   Alternate idea: prior to watching the film, teachers can divide students into four groups, each responsible for reviewing the climate information presented in the film with a certain temporal or spatial scale perspective – global, regional, short-term or long-term.

5. Give students a few moments to complete recording their observations and identify 3-5 questions they have about what they observe and would want to know to quantify these observations.

6. Play the remainder of the film clip. Discuss student observations and questions. Ask students whether the film's documentation of retreating glaciers should be considered a line of evidence for climate change and why or why not.

analyze lines of evidence

7. Cut up the attached student pages DATA SHEETS so that each student can have two pieces of data to explore individually. Give them the student page REFLECTING ON LINES OF EVIDENCE. Individually students should imagine they are a group of climate scientists preparing to present research to a journalist developing a story about climate change. The images and graphs are provided on the student page CLIMATE RESEARCH IN THE NEWS and the questions to answer are the student page CLIMATE CHANGE EVIDENCE REFECTION. Students answer such questions such as: What is being measured? What is the time or spatial scale? What does the graph or image show?

8. Divide the students into small groups – first in groups that have the same graphs and then groups with a wide variety of graphs. Have students share their findings from their individual images and graphs used by scientists to explain evidence of climate change to the public and the media.

9. Tell the students that they are going to be responsible for analyzing the data to answer various questions. It will be important to look for what is being measured, the scale (time and space) covered by the data and what the data tell us.

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wrap-up and discussion .

10. As a group students should reflect on the question at the bottom of the CLIMATE CHANGE EVIDENCE REFLECTOIN SHEET.

EXTENSIONS: Students can draw on the lines of climate change evidence they studied as well as Internet research about the climate change debate to consider possible reasons why some Americans do not recognize the scientific agreement that humans are the main drivers of present-day climate change and potential consequences of unabated climate change.

Climate Math: Students solve math problems on the Climate Math student pages. Answers are on Teacher Page that follows.

assessment

Making Inferences about Climate Change (responses to reflection and graphic organizer)

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feedback

The authors of Hot value your thoughts and feedback on this curriculum. Please feel free to send us any suggestions or share anything your students found particularly interesting or engaging.

Comments can be sent to cah40@columbia.edu

STUDENT PAGES: LESSON 1.3 LINES OF EVIDENCE **K-W-L CHART**	Name: _____ Date: _____

What do I know ... About evidence supporting climate change	**What do I want to know ...** About evidence supporting climate change	**What have I learned ...** About evidence supporting climate change

STUDENT PAGES: LESSON 1.3 LINES OF EVIDENCE ***CHASING ICE* OBSERVATION GUIDE**	Name: _____ Date: _____

DIRECTIONS

After viewing the *Chasing Ice* clip, use the spaces below to think about what you observed and how scientists might develop this as a line of evidence.

My observations Qualitative e.g. things I observed but did not measure.	**My inferences about causes and effects** What might have caused the things they are observing?
My questions to quantify observations How might we find ways to quantify (aka measure) my observations?	**What this will tell us?** How might the quantitative data work with the qualitative data?

Suggestion: you might consider the scale of the effects (global, regional, short term, long-term)

Film Review Questions

Consider the following quote below from James Balog and write a short reflection about how it relates to the observations you made watching the excerpt from his film *Chasing Ice*.

"I had this idea, the most powerful issue of our time was the interactions of humans and nature."

STUDENT PAGE: LESSON 1.3 LINES OF EVIDENCE

CLIMATE RESEARCH IN THE NEWS

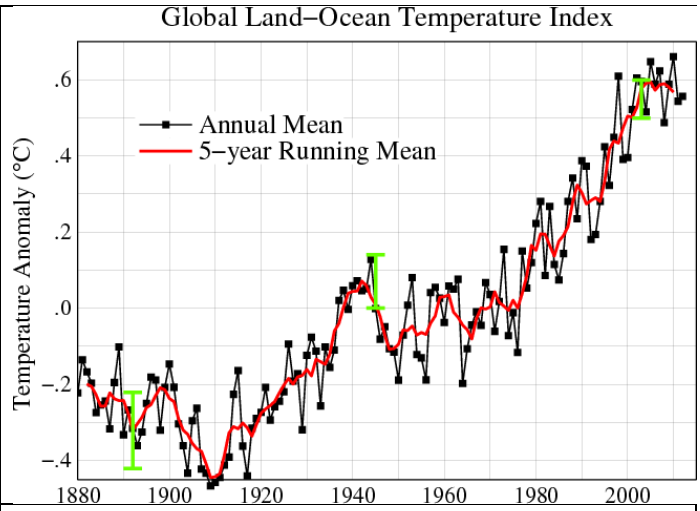
Name: _____

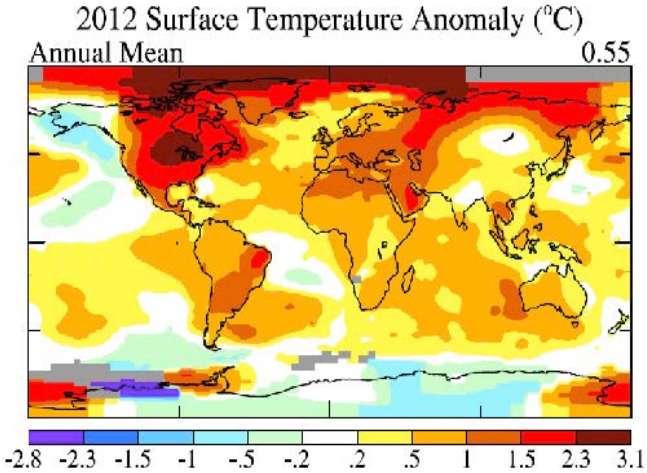
Date: _____

Data Sheet One
Global Surface Temperature Analysis

Line plot of global mean land-ocean temperature index, 1880 to present, with the base period 1951-1980. The dotted black line is the annual mean and the solid red line is the five-year mean. The green bars show uncertainty estimates.

Source: NASA Goddard Institute for Space Studies, http://goo.gl/rKtsq





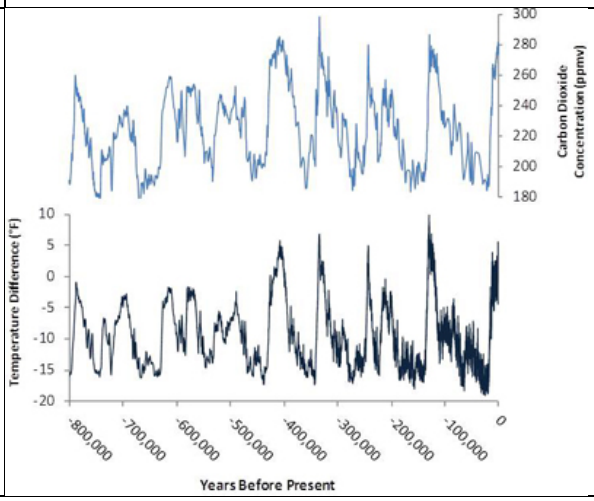
Data Sheet Two
Global Surface Temperature Map

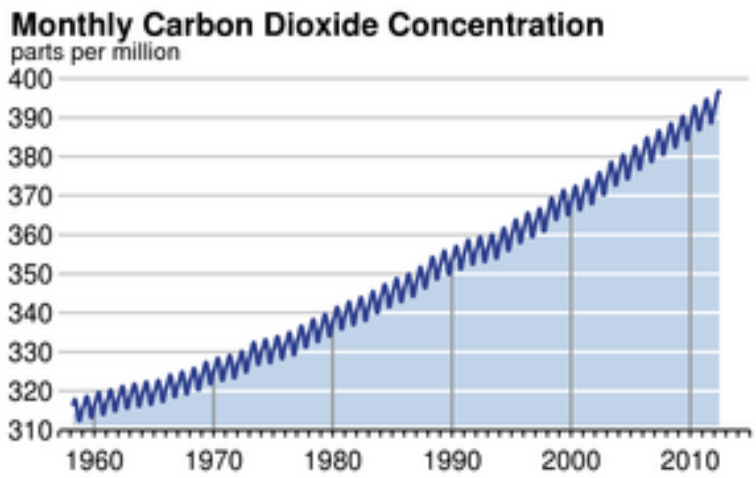
The average temperature in 2012 was about 58.3 degrees Fahrenheit (14.6 Celsius), which is 1.0 F (0.6 C) warmer than the mid-20th century baseline (1950). The average global temperature has risen about 1.4 degrees F (0.8 C) since 1880, according to the new analysis.

Source: NASA Goddard Institute for Space Studies, from NASA/NOAA press materials, http://goo.gl/ytq4W

Data Sheet Three
Global Atmospheric CO_2

The graphs show estimates of Earth's carbon dioxide (CO_2) concentrations (top) and Antarctic temperature (bottom), based on analysis of ice core data dating back 800,000 years.
Source: U.S. Environmental Protection Agency, http://goo.gl/ZMpqb.





Data Sheet Four

Monthly Carbon Dioxide Concentration

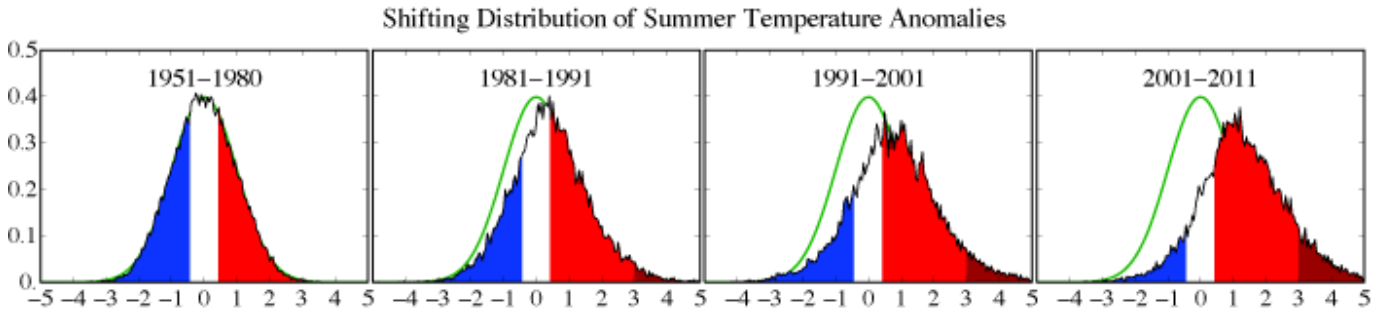
Average atmospheric carbon dioxide concentration versus time at Mauna Loa Observatory, Hawaii (20°N, 156°W) where CO_2 concentration is in parts per million in the mole fraction (p.p.m.).

Source: Scripps Institution of Oceanography, http://scrippsco2.ucsd.edu

Data Sheet Five

Likelihood of Warmer Summers

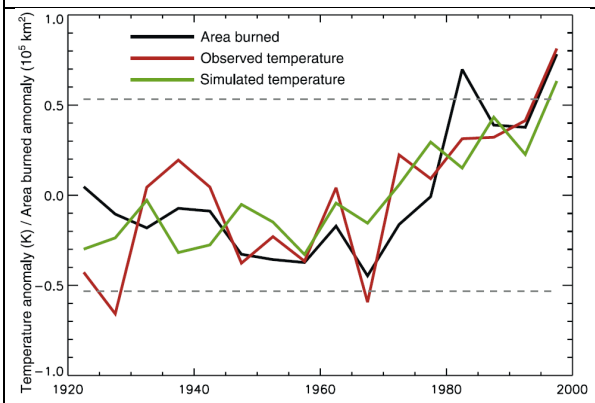
These graphs show changes in the mass of glaciers and ice caps in various world regions and the consequences of sea level rise. Graph (a) shows the changes of glacier mass per square meter for major mountain ranges in the listed regions. Graph (b) shows the total contribution of these changes in glacier mass to global average sea level rise. Source: NASA Goddard Institute for Space Studies, http://goo.gl/k2rI9.

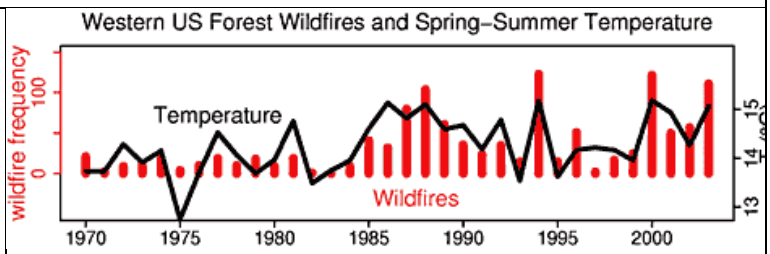


Data Sheet Six

Wildfire Trends

Multi-decadal trends in North American wildfires. **Top left**: Area burned annually in Canadian forest fires, 1920-1999 (black line; Gillett et al., *GRL*, 2004). **Top right**: Wildfire frequency (# fires) in the western US vs. spring/summer temperatures (Westerling et al., *Science,* 2006). Both graphs show strong correlations with temperature and changes in area and frequency.

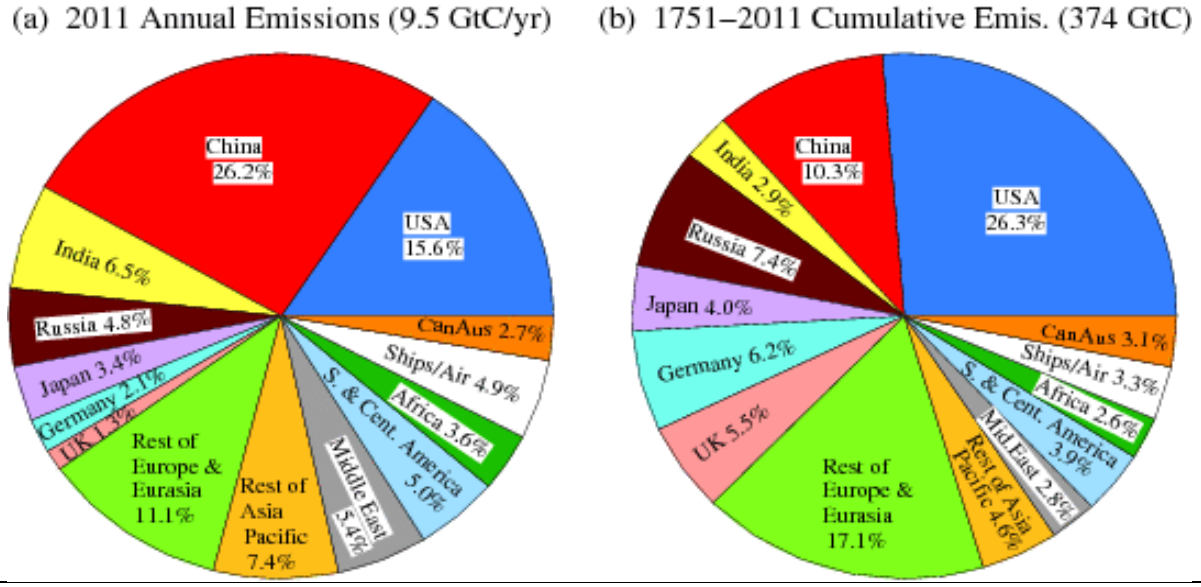




Data Sheet Seven

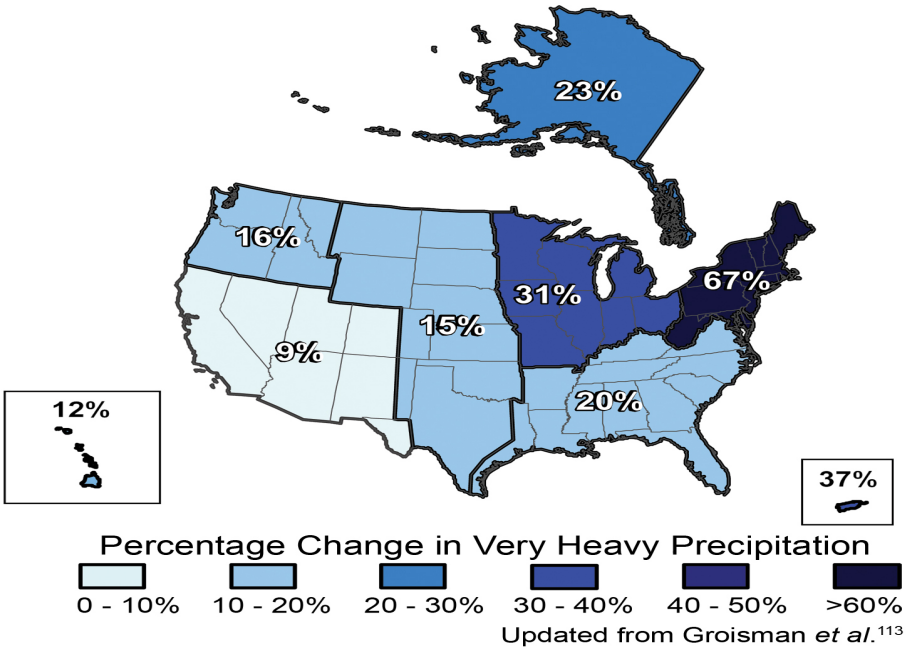
CO_2 Emissions from Fossil Fuels

(a) CO_2 emissions from global fossil fuel burning (and cement making and natural gas flaring) in 2011 shown by country/region. **(b)** Cumulative fossil fuel CO_2 emissions over the industrial era (1751-2011). The latter proportions are more important because CO_2 buildup in the atmosphere, and the resulting climate change, is a cumulative process. Source: Dr. Makiko Sato's web page and based on CDIAC data.



Data Sheet Eight

U.S. Extreme Precipitation Events

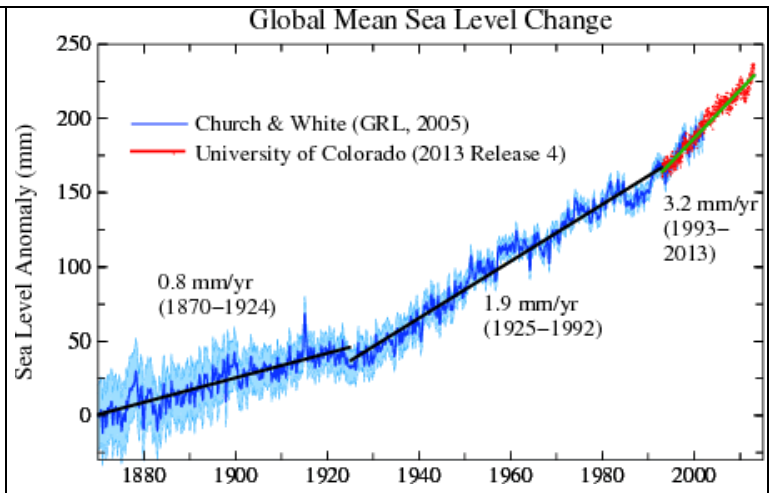


The map shows the percentage increases in very heavy precipitation (defined as the heaviest 1 percent of all events) from 1958 to 2007 for each region. There are clear trends toward more very heavy precipitation for the nation as a whole, and particularly in the Northeast and Midwest.

Data Sheet Nine

Global Sea Level Rise

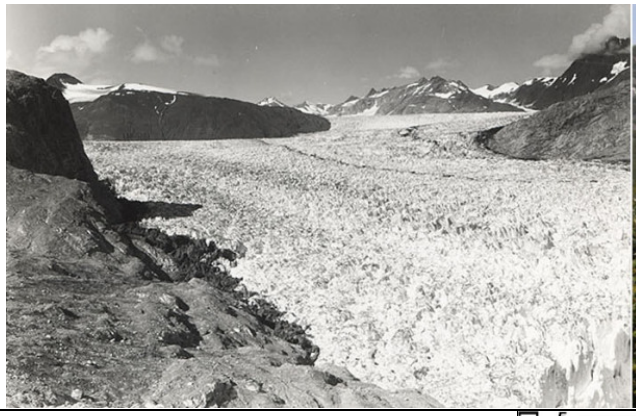
Global average sea level measured by tide gauges and satellites from 1870 to early 2013. **Source**: Dr. Makiko Sato's web site and satellite data from University of Colorado, http://goo.gl/1NPwW



Data Sheet 10

Muir Glacier and Inlet, Alaska

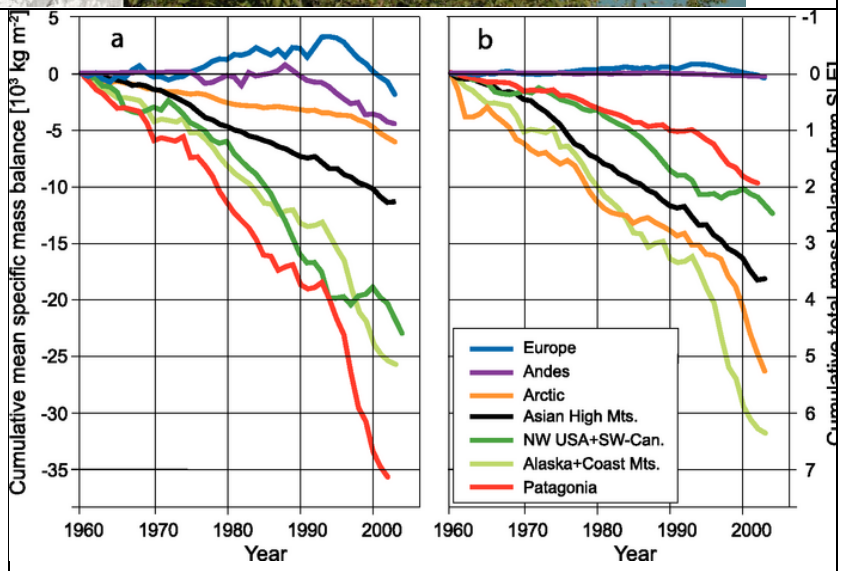
According to the U.S. Geological Survey (see: http://goo.gl/FN2ss), in 1850 there were an estimated 150 glaciers in Glacier National Park (left photo) and in 2010 only about 25 remain larger than 25 acres (right photo). **Source:** This is Climate Change, http://goo.gl/IKBZy.



Data Sheet 11

Global Change in Glaciers and Ice

The graphs show changes in glaciers and ice caps around the world. Graph (a) shows the change in glacier mass in regions. Graph (b) shows the contribution of regional changes in glacier mass to sea level rise. Source: IPCC, http://goo.gl/qGt9S



STUDENT PAGE: LESSON 1.3 LINES OF EVIDENCE **CLIMATE CHANGE EVIDENCE REFLECTION**	Name: _____ Date: _____

DIRECTIONS

After looking at one or two lines of evidence, please respond to **four of the seven** prompts below.

1. What is being observed or measured and over what time period (timescale)?
2. What is the area covered by the observations (spatial scale)?
3. What does the graph show or what's happening? Is there a trend?
4. What are some interesting patterns in the graph? What might be causing these patterns?
5. What relationships (if any) do you find between the two variables being measured?
6. What questions would you ask climate scientists about the map in an interview?
7. What are the implications of this graph as it relates to people, communities, and the general environment?

DATA SHEET # THAT I EXPLORED: _____

?#

?#

?#

?#

DATA SHEET # THAT I EXPLORED: _____

?#

?#

?#

?#

Reflection

Please share your thoughts on how the passage below relates to your observations and inferences about climate change on the back of this paper.

> "A doctor can examine our symptoms, try to diagnose our condition, and suggest treatments if the prognosis is not favorable. The success of modern science shows clearly that, even when medical knowledge is not perfect, it is useful. This is also true for climate scientists studying the Earth – the science is imperfect – but still useful. "Climate Change: Picturing the Science", p. 3

STUDENT PAGE: LESSON 1.3 LINES OF EVIDENCE **CLIMATE MATH**	Name: _____ Date: _____

DIRECTIONS

Review Climate Change in the News Data Sheet 11

Level 1:

Given that the global ocean covers 360 million km^2 of the Earth's surface and the density of water is 1 g/cm^3, calculate the mass of water that's equivalent to 1 mm of global average sea level rise.

Explain how you solve the problem:

Level 2:

Given that the density of ice is 0.9 g/cm^3, show that 400 km^3 of ice volume loss is equivalent to 1 mm of sea level rise.

Explain how you solve the problem:

Level 3:

Current estimates show that worldwide, there is enough ice (that if it were to melt) to raise sea levels by 70 m. What volume of ice does this represent?

Explain how you solve the problem:

Lesson 1.3

Climate Math - TEACHER PAGE

Answers to Climate Math Problems

Level 1 Problem

Given that the global ocean covers 360 million km^2 of the Earth's surface and the density of water is 1 g/cm^3, calculate the mass of water that's equivalent to 1 mm of global average sea level rise.

1 mm of water over 360 million km^2 of Earth's surface means 360 km^3 of water (because 1 mm = 10^{-6} km). Note: there are 10^{15} cm^3 in 1 km^3. Then multiplying by the given density of water yields 360 x 10^{15} g = 360 Gt.

Level 2 Problem

Given that the density of ice is 0.9 g/cm^3, show that 400 km^3 of ice volume loss is equivalent to 1 mm of sea level rise.

ANSWER: To find the volume of ice is equivalent to this much mass of liquid water, we need to divide 360 Pg water by the given density of ice (0.9 g/cm^3) which yields 400 x 10^{15} cm^3 = 400 km^3 (after converting the units).

Level 3 Problem

Current estimates show that worldwide, there is enough ice (that if it were to melt) to raise sea levels by 70 m. What volume of ice does this represent?

From the above we know that 400 km^3 ice volume = 1 mm of sea level rise. Since there are 1000 mm in 1 m, multiplying both sides by 1000 yields 400,000 km^3 of ice volume = 1 m sea level. So 70 m sea level rise = 70 x 400,000 = 28 million km^3 of ice