POLAR PARTNERSHIP

Exploring The Polar Connection to Sea Level Rise

NGSS

Disciplinary Core Ideas	Science & Engineering Practices	Crosscutting Concepts
MS - ESS: Earth & Space Science • **ESS2: Earth Systems** - ESS2. C The role of water in Earth's Surface Processes – - ESS2.D Weather and Climate • **ESS3: Global Climate Change** - ESS3.D Global Climate Change	1. Ask questions 2. Developing and using models 4. Analyzing and interpreting data 5. Using mathematics and computational thinking 6. Constructing Explanations 7. Engaging in argument from evidence 8. Obtaining, evaluating and communicating information	• Patterns • Cause & Effect • Scale, proportion and quantity • Systems and systems models • Energy and matter • Stability and change
HS – ESS: Earth & Space Science • **ESS1: Earth's Place in the Universe** - ESS1.B Earth and the Solar System - • **ESS2: Earth Systems** - ESS2. C The role of water in Earth's Surface Processes - ESS2.D Weather and Climate • **ESS3: Earth and Human Activity** - ESS3.D Global Climate Change	1. Ask questions 2. Developing and using models 4. Analyzing and interpreting data 5. Using mathematics and computational thinking 6. Constructing Explanations 7. Engaging in argument from evidence 8. Obtaining, evaluating and communicating information	• Patterns • Cause & Effect • Scale, proportion and quantity • Systems and systems models • Energy and matter • Stability and change

Grade Level: 8^{th}-12^{th} grade, undergraduate (different age groups will vary in the time spent analyzing and discussing)

Class Time & Activity Overview: The activity is split into 3 separate parts. Each activity has a graph reading and recording piece and a small group discussion piece.

- Part 1: What Makes Sea Level Change – examines the multiple inputs in sea level change
- Part 2: How Fast Can Sea Level Change – looks back through time through glacial and interglacial cycles
- Part 3: How Much Ice Is There At the Poles – looks at the potential of the polar ice sheets to contribute to sea level rise.

Part 1 and Part 2 will each take a class period. Part 3 is short but combining it with hands on activities puts things into context and provides for a final wrap up.

Subject: Science, Math

Skills: Graph Reading, Data Analysis, Map Visualization Skills, Critical Thinking, Group Discussion. The use of maps to show a spatial array of data combined with graphs to show temporal array introduces students to the strengths of each type of data.

This activity combines maps (a spatial array of climate data) with graphs of averages of how climate has changed through time (temporal data), and is a good introduction for students of the strengths of various ways of displaying science data. The activity is based on the 'Polar Explorer' app on Sea Level Rise to be released Dec. 2013 from Columbia University.

Supplies Needed:
Computer & projector or Smartboard to display ppt of the activity.
Worksheets for each student
Supplies for each hands-on-activity are on the sheets for each activity

Concepts:

- Sea Level is the result of many factors all working together in the climate system
- Sea Level has changed through time as our planet has warmed and cooled through glacial and interglacial cycles.
- Currently global sea level is rising at a rate of ~3mm/yr as our planet warms.
- Change does not occur quickly as Hollywood would have us believe! Change occurs over decades to centuries to millennia. However even this is fast for geologists!
- There is a lot of ice currently stored at the polar regions. The potential of these polar regions to have an impact on future sea level is significant.

Learning Objectives:
Students will be able to:

- Identify that tide gauge readings confirm that local coastal sea level is rising and has been for the last 100 years.
- Identify that measurements in multiple parts of the climate system tell us that the climate is warming
- Understand that sea level has varied throughout the Earth's history
- Calculate 'Rate of Change'
- Connect the Polar Regions to the rest of the climate system

Background Reading:

1. There is a good background reading on the Polar Connection to Sea Level Rise at this link that has been developed by the University of Delaware. Full text ay the link by an excerpt is below:
http://co2.cms.udel.edu/SeaLevel_DE.htm

"As the global average air temperature warms due to climate change, it increases the net melting of large ice masses on the planet. The effects are complex, vary regionally, cycle seasonally, have feedback effects, and shift the balance between accumulation and ablation (melting and evaporation), but the basic principle is the same as what we see of ice and snow in our neighborhoods as the weather warms. When ice floating on water melts, such as the Arctic sea ice and parts of the Antarctic ice shelves, the height of the water does not change (you can verify this with a glass water, ice cubes, and a crayon). When we melt ice that is sitting on land, such as glaciers, Greenland's ice cap, and most of the Antarctic, the meltwater runs into the ocean and raises sea level.

To date, another cause of sea level rise has been the thermal expansion of the oceans—warm water expands. In Delaware, there is also an effect from "subsidence", that is, the land is still dropping slightly due to after-effects of the last Ice Age. Thermal expansion and local subsidence are both significant effects to date. However, as the earth warms, the melting of ice will become the dominant effect in sea level rise, much larger than thermal expansion and subsidence combined"

2. In addition here is a link to a piece that was published by the National Science Teacher's Association as part of another activity:

Part of A Publication by NSTA: Turrin, M, and R. Bell, 2013, Antarctica's Pine Island Glacier: A 'Climate Canary'?, Using atmospheric and oceanic processes and the poles to teach the climate system, The Science Teacher, *Vol. 80, No 7: 57-62.*

The piece called ***"Why Teach About the Poles"*** is relevant to this activity as well.
http://www.ldeo.columbia.edu/edu/polareducation/Activities/Sea%20Level%20Rise/WhyFocusOnThePoles.pdf

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POLAR EXPLORER SEA LEVEL RISE

Teacher Version

The Polar Regions, the Arctic and Antarctica, are far away from us geographically, but you have heard that they are connected to us through the Earth's climate system. As a Polar Explorer you are interested in collecting evidence from Earth's climate system that is connected to changing sea level. Your goal is to determine connections to the Polar Regions. Use the 3 grids below to collect your data, and the questions to analyze it.

WHAT MAKES SEA LEVEL (SL) CHANGE?

ITEM MEASURED	TIME PERIOD	TOTAL TIME	BEGINNING MEASURE	ENDING MEASURE	TOTAL CHANGE	INCREASE/ DECREASE
Average Sea Surface Temp.	1880-2011	31 yrs.	-0.5 Degrees F	0.3 Degrees F	0.8 Degrees F	Increase
Atmosphere Temperature	1901-2011	110 yrs.	-0.3 Degrees F	0.9 Degrees F	1.2 Degrees F	Increase
Ocean heat content	1960-2007	47 yrs.	1 (10^{22} Joule)	17 (10^{22} Joule)	16 (10^{22} Joule)	Increase
Ocean Expansion	1960-2007	47 yrs.	0 mm	22 mm	22 mm	Increase
Polar Meltwater Contributions	1989-2009	20 yrs.	AIS 0 GrIS 0 Sum 0	AIS ~4 mm GrIS ~6 mm Sum 10 mm	~10mm	Increase

*Answers from graph may vary due to resolution of graph data – focus should be on trends.

1. The items listed in Column #1 are observations of what is happening on our Earth. What types of measurements are included?

Ocean surface water temperature, air temperature, ocean heat to 700 meters depth, water expansion from warming and glacier meltwater.

2. Identify if the measurements were *Increasing* or *Decreasing* and explain what this means for future SL.

All are increasing meaning climate is warming both water and air temperature. This is causing sea level to rise due to expanding water and melting glaciers.

3. Which measurements from Column #1 are **factors that cause** SL to change?

Sea Surface Temp., Atmosphere Temperature, Ocean heat content

4. Which items from Column #1 are **measurements of the resulting** SL change?

Ocean Expansion and Polar Meltwater Contribution

5. Review the time range covered in each of the measurements. Explain if you feel this is sufficient or insufficient to understand the trends being observed?

Measurements collected from 20 to 110 years. An argument can be made either way here. This is long enough to see that we currently are warming, but longer data streams are always better.

6. Use the evidence you collected in your table to develop a hypothesis about what makes SL change.

Will vary but something like "If the ocean and atmosphere warm then sea level will rise because the ocean water will expand as it warms, and glaciers will melt at they warm."

7. Identify any polar connections you found between sea level rise and the Polar Regions?

The polar regions are adding glacial meltwater to the oceans causing sea level to rise.

NOW TRAVEL BACK THROUGH TIME TO SEE HOW FAST SEA LEVEL (SL) CAN CHANGE

ITEM MEASURED	TIME PERIOD	TOTAL TIME	BEGINNING MEASURE	ENDING MEASURE	TOTAL CHANGE	INCREASE/ DECREASE
SL Trend own Location	1900-2013	113 yrs.	-0.3 m (MD)	0.07 m	.37 m	Increase @ *0.003 m/yr*
SL Last 8000 yrs (Humans)	8000 BP - present	8000 yrs	-16 m	0	16 m	Increase @ *0.002 m/yr*
SL 21,000 yrs.to present (LGM)	21,000-present	21,000 yrs	-120 m	0 m	120 m	Increase @ *0.006 m/yr*
SL 125,000 yrs to present (Eemian)	125,000-present	125,000 yrs	8-10m	0 m	-8 m	Decrease @ *0.00006 m/yr*
*Predicting the future	1950-2100	150 yrs	-10 cm	165 cm	175 cm or 1.75 m	Increase @ *0.01 cm/yr*

* This calculation is listed in ***cm*** and will need to be converted for comparison

1. This chart is a table of changes in sea level over a range of times. Identify the shortest and longest periods of time reviewed.

113 years and 125,000

2. List the measure(s) that were *Increasing* and explain why.

Sea Level local, sea level last 8000 years, sea level since the LGM and predictions for the future are all increasing since the climate has overall been warmer for those periods.

3. List the measure(s) that were *Decreasing* and explain why.

Sea Level since the Eemian has decreased since the temperature was warmer at that. The ice sheets were smaller and more water was in the global oceans so sea level was higher.

4. Think about the **shapes** of the sea level graphs you reviewed. Explain why using only a beginning and ending measurement may not be the best way to see how fast SL can change.

If you just look at the beginning and ending point you assume linear steady-state changes and ignore places where steep lines show quicker changes that later level out (like since the LGM), or times when sea level has gone both up and down (like since the Eemian). This creates a false sense of time, making the end result look more gradual than it really was.

5. How does the last column showing SL 'predictions' for the next 100 years compare to your first column showing changes from 1900 to 2013?

Sea level predictions suggest that sea level will rise much more quickly than from 1900-2013.

6. Identify any connection you found between these measurements and the Polar Regions?

During cold periods global ocean water is frozen into polar ice sheets and in warm periods the ice sheets melt back adding the water back into the ocean.

7. **BONUS QUESTION:** One way to look at how quickly SL has changed involves calculating the ***rate of change*** per year for each column. You will record this in the last column of the table along with your 'Increase' or 'Decrease'.
   Rate of change = Total Change/Total Time
   To compare your answers you will need to convert all into meters

Answers entered above in the graph

Analyze your ***Rate of Change.*** Does the evidence suggest SL has changed quickly in the past? Most would say this does not show change was quick, although as we noted earlier the '**rate of change'** assumes a linear steady-state increase which is not what occurred.

HOW MUCH ICE IS THERE AT THE POLES?

ITEM MEASURED	AMOUNT SEA LEVEL RISE
GREENLAND ICE SHEET	7 M
WEST ANTARCTIC ICE SHEET	6 M
EAST ANTARCTIC ICE SHEET	52 M
TOTAL SEA LEVEL RISE AVAILABLE FROM THE POLES	65 M

The final set of questions focuses on the **potential** of the Polar Ice Sheets.

1. You have recorded the amount of Sea Level (SL) rise available from each of the polar ice sheets. Complete your chart by adding them together. Consider future **potential**. How significant a role do you see polar ice sheets playing in future SL rise? Explain your answer.

There is considerable potential for the polar ice sheets to play a much larger role in SL rise. There is a lot of ice stored at the poles and if the climate continues to warm they will continue to melt adding water into the global oceans.

2. Your Polar Exploration is drawing to an end. What will you say to convince your colleagues that it is important to FOCUS ON THE POLES when studying climate!

The climate system is tightly linked to the polar regions. When the climate cools polar ice sheets grow from the freezing of ocean water and when the climate warms the polar ice sheets begin to melt adding meltwater into the oceans. By focusing on the poles we can see the evidence of change early.

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Vocabulary

Anomaly –A method of measurement that scientists often use to show change, it measures differences compared to the average for a period of time.

Geologic Time – A way of organizing the timing and relationship of events that have occurred throughout Earth's ~4.5 billion year history. Note that Sea Level does NOT remain constant throughout geologic time.

Elevation – The height of a geographic location above a fixed reference point.

Sea Level – The height of the sea surface which varies by time and place. Sea level is affected by waves, wind and currents, atmospheric pressure, tides, topography, and even gravitational attraction due to the presence of mountains & large amounts of ice!

Observation: When discussing Earth data this refers to data collected from measurements. For sea level these include observations from tide gauges (from the1850s) and more recently from satellites (starting in the late 1960s).

Proxy: A preserved chemical or physical characteristic from the past that can be used to understand past conditions when direct measurements are not available.

Prediction: Estimates based on prior data and understanding?

Temperature Anomaly: A change from the long-term average temperature and generally shown as the ***difference*** between the two temperatures. Anomalies are a method of normalizing data collected across various areas and conditions.

Last Glacial Maximum (LGM): Refers to the peak of the last glacial period or ice age when ice sheets were at their maximum size ~25,000 years ago. Much of the northern hemisphere was covered with ice sheets causing sea levels to be ~120 m lower.

Eemian: The most recent interglacial, or warm period ~125,000 years ago, when temperatures were 3-5° warmer and melting polar ice added close to 8 meters of water into the global oceans.

Glacial/Interglacial: In Earth's history we experienced periods of extreme cold, often referred to as ice ages or glacial periods, and warmer periods occurring between times of glacial action referred to as interglacial periods.

Frequently Asked Questions?

1. Q. Does melting sea ice have anything to do with sea level rise?
    a. Sea Ice is already resting in the water and so when it melts it does not directly affect sea level.

2. Q. Do calving or melting Ice Shelves in Antarctica affect sea level rise?
    a. Ice Shelves, like sea ice are already floating so when they calve or melt they do not directly affect sea level, however, when they are in place they stabilize and hold the ice sheet on the land behind them. Melting ice shelves are weakened and the land ice will often speed up and push forward once the ice shelf is gone. The additional land ice added to the global ocean does affect sea level.

3. Q. Does the Ozone hole affect glacial melting?
    a. Ozone is a layer in the Earth's upper atmosphere that blocks out the Sun's ultraviolet rays. These rays do not contribute directly to melting glaciers or warming. However recent studies have suggested that the hole in the ozone has increased Antarctic winds causing that continent to remain much colder than it might be otherwise. As the ozone hole closes over the next few decades these studies suggest Antarctica will begin to warm.

4. Q. How does storm surge relate to sea level rise?
    a. Storm surge is the high-energy wave action that comes with large storms. These waves are often larger and more powerful than normal waves would be. As sea level rises the waves will also rise becoming more of a problem for coastal regions.

5. Q. How are the maps in this activity made?
    a. These maps are data that has been put into a spatial format. Each map is really data that has been linked to a geographic location. Since much of the data varies by specific region or location viewing it as a map is useful.

6. Q. How do we gather the evidence for the changes?
    a. We use several methods of collecting data about our changing Earth: **Direct measurements** include individual instruments such as tide gauges that are carefully referenced in location and depth so they can record small changes, argo floats that are placed in the ocean to collect data through sensors, and satellites that circle in space collecting measurements from the Earth below. **Indirect measurements** are used to gather data about the past. These are called ***proxy measures*** and include, but are not limited to, examining ice cores, tree rings, plankton (forams and diatoms), pollen, corals, sediments.