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**Proxy Climatology**

Student Page

## Question: What is proxy data and how can it be used to look at historical trends in temperature & CO2 and changes in ice across the planet.

## Materials: Part I - Analyzing tree rings as an example of proxy data

* Tree cuts (1 for two people)
* Rainfall data from area the tree was cut
* Dissecting scopes and/or magnifying lenses

## Background information:

## Each year, the tree forms new cells, arranged in concentric circles called annual rings or annual growth rings. These annual rings show the amount of wood produced during one growing season. In the areas of the United States with four seasons, the growing season begins in the spring. At first, the cambrium produces large cells with thin walls (this is the light-colored ring.) Then at the end of the summer, growth slows down and the cells added are small with thick walls (the darker ring). During the winter months the tree doesn’t add any cells to the cambrium, therefore one year of growth is represented by a ring consisting of a light part and a dark part. The following year, a new two-part ring is added to the outer edge and this is why the oldest rings are in the center and the youngest ring is on the outer edge.

## Investigate: Part I – Analyzing tree rings as an example of proxy data

1. With your partner, select one of the tree ring cuts and observe it under the magnifying lens or if you have a [picture of a tree](https://drive.google.com/drive/folders/1EdShLLbvVOd5VxKT8_16ieZg5_Phcs9o?usp=sharing) cut observe it and magnify it using the computer.
2. Count the number of rings found in your tree cut and record this in the table.
3. Assign each ring a number with the center ring = #1.
4. Find the widest ring & and ring that is the narrowest and identify each in the table below.
5. Get the date the tree was cut down from your instructor and fill out the dates for the age of the tree, the widest & narrowest ring number.
6. Get the data on [rainfall](https://www.usclimatedata.com/climate/waterloo/iowa/united-states/usia0894) and find the total rainfall for the years of the widest ring number and the narrowest ring number.
7. Then match another ring (3rd ring to match) with the rainfall from that year and repeat with another ring.

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| **Part I Tree Ring Data vs. Rainfall** |
| Description of the data set | Number of ring(s) | Date (year) | Rainfall (inches) |
| Total number of rings in tree cut (Age of the tree) |  |  |  |
| Widest ring number |  |  |  |
| Narrowest ring number |  |  |  |
| 3rd ring |  |  |  |
| 4th ring |  |  |  |

Summing Up – Part 1:

1. Describe the patterns you see between tree ring data and rainfall data.
2. It can be said that tree ring data is proxy data for rainfall amounts. Explain what proxy means in this venue.

## Materials: Part II - Data sets from

1. Video/Images of [Artic Change](https://drive.google.com/file/d/1KKUFh6lAjSrEd8hfIaWzTkJqpZ_3OSI6/view?usp=sharing) and [Sea Ice](https://drive.google.com/file/d/1WSNULwOYpaw5fVDy3NnislmNvV3W4Ut7/view?usp=sharing) and [Snow Cover](https://drive.google.com/file/d/15k_Fh_N5AQ5xGIG8zgAaqoNyYmQ9Z7RB/view?usp=sharing) (All are Google access)
2. [Yukon River Ice Breakup – 1896-2017 (Alaska)](http://www.yukonriverbreakup.com/statistics) – [Google sheet](https://docs.google.com/spreadsheets/d/143RQJTCGVu4_g4n-HnvN6WRgZCKG2G59MiMeK-GtzfQ/edit?usp=sharing)
3. [Mauna Loa CO2 concentrations – 1952-2004 (Hawaii)](https://www.esrl.noaa.gov/gmd/ccgg/trends/data.html) – [Google sheet](https://docs.google.com/spreadsheets/d/1kKzx3CekqF6tNpcFo1s8AvtqfKHvw5IkdDYQUeSIQ7c/edit?usp=sharing)
4. [Northern Tanana River Ice Break Dates (Alaska)](http://nsidc.org/data/nsidc-0064.html) - [Google sheet](https://docs.google.com/spreadsheets/d/1TQqK4ypnLJvLkSc7-_KO3pv1uWthoAsEJEYASUjzyY0/edit?usp=sharing)
5. Artic ice Thickness – 1936-2000 (East Siberian Sea) – [Google Sheet](https://docs.google.com/spreadsheets/d/1cCcP9Q5DHbBpf11UdMhO-2k9e0MB9BF_igcU1LC-Nsg/edit?usp=sharing)
6. Monthly Mean Temperature Tornedalen – 1802-2002 (Sweden)
7. Temperatures for River Tornio – 1692-2011 (Finland)
8. Vostok Ice Core Data 414,00 years BP (before present)
	* CO2 concentration (Antarctica)
	* Vostok Ice Core Data on Temperature (Antarctica)
9. Multi-proxy Temperature data using Tree-ring, Ice Cores, Corals & Sediments – 1000-1991

**Investigate: Part II - Analyzing temperature, CO2, and global ice data**

 You will be working with one other person and will be given a data set by your instructor. This data set has been collected by scientists. Your data is provided in *Google sheets* format, which can be exported as a *Microsoft Excel*. Your job is to analyze your data to look for patterns and make conclusions based on that analysis. Look over your data and look for obvious patterns. One good way to find patterns is through graphing. Once you have made your initial graph of your data you will need to meet with the other person(s) who are also looking at the same data set. During this meeting you need to share how you have analyzed and graphed your data and your preliminary conclusions with the other person(s) and they will share their information with you. Each individual needs to provide supportive criticisms and analysis of the other. Once you have met you must mutually agree on an analysis graphic of the data as a group decide on your analysis and conclusions that your will present to the class. Your group (all those individuals working on the same data set) will be making a presentation to the entire class where you will present your data so conclusions you explain are supported by your data. The following summary question, may help you will your presentation. Follow the rubric for your group presentation.

Summing Up – Part II:

1. Provide a graph of your data set. Make sure your graph is complete.

2. Analyze your data set from a different perspective and graph it from this new perspective.

3. Write a written analysis that provides specific interpretation of the data and references specific data points. Explain what might be happening in the environment to “cause” these changes in your data.

4. Predict what you think will happen to your data if it were collected for another 100 years.

5. After the class discussion of all the data sets write a short synopsis of the summary of each data set.

6. If your data continues to change as it has in the past, propose three logical environmental consequences of this change.

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| **Group Presentation Rubric: Scientific Data Evidence & Claim** |
| Question # | Score = 1 | Score = 2 | Score = 3 | Score = 4 |
| Introduction | • The introduction is incomplete in that two or more of the following are missing:•what data was analyzed•members of group introduced•short oral preview of content of presentation | • The introduction mentions •what data was analyzed•the members of the group•a short preview of the content of the presentation but introduction-lack detail -lack participation by all members of the group | • The introduction mentions •what data was analyzed•the members of the group•a short preview of the content of the presentation provides detail and incorporates all members of the group in the introduction | • The introduction is dynamic and draws the audience into the presentation topic by presenting what data was analyzed where it came from and how it was collected and introducing all the members of the group, incorporating many in this introduction. |
| Visuals  | Data analyzed is presented visually but the visual presentation may not:•provide clarity •be big enough to see clearly•include proper titles, labels and units or these may not be bold enough to be seen.•be used in the presentation  |  Data analyzed is presented visually and used in the presentation but the visual presentation may not do one of the following:•provide clarity •be big enough to see clearly•include proper titles, labels and units or these may not be bold enough to be seen. | Data visuals are provided and used in the presentation. They are used to support the claim made by the group, but integration of the visual is not as rich or detailed.  | Data is shown in a dynamic, visually appealing manner. The visuals are used to focus the audience on the important points the group makes on what they learned and support the group’s claim.  |
| ContentOrganization | The group as a whole does not •have a grasp of the information and cannot answer questions about the data or their conclusions. •clearly define their claims & evidence•provides weak or little support of the claim | The group as a whole • is uncomfortable with the data/conclusions and cannot answer questions concerning these•attempts to explain the data and the claim but do not provide adequate explanation of how the data supports the claim.  | Every member of the group • has a grasp of the data evidence and the claim.•is involved in the presentation • is able to answer questions concerning the data and the claim•the data clearly supports the claim.  | •Every member of the group •demonstrates a full grasp of the data by answering all class questions on the group’s claim with explanations and elaboration. • participates fully in each aspect of the presentation• uses the data evidence to richly support the claim. |
| Delivery | Two or more members of the group does **not**• have enough grasp of the content to maintain eye contact with the class•show little to no interest in the presentation•speak loudly & clearly or speaks in monotones causing the audience to disengage. | One of more members of the group • reads directly from notes and had trouble maintaining eye contact •shows minimal or mixed interest in the presentation•speak softly so sh/e can’t be heard or speaks in monotones causing the audience to disengage. | All members of the group use•consistent eye contact with the class when speaking•a variety of volume and inflection• demonstrates enthusiasm about the topic•show enthusiasm about the topic and raises audience awareness of most points | All members of the group are involved and hold the attention of the class by•direct eye contact and seldom looking at notes•speaking with fluctuation is volume and inflection, emphasizing key points•demonstrating strong enthusiasm during the entire presentation•significantly increasing the audience knowledge of the topic & convincing them of the validity of claim. |
| Comments |  |

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Teaching Tips & Notes

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## Materials: Part II - Data sets from

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2. [Yukon River Ice Breakup – 1896-2017 (Alaska)](http://www.yukonriverbreakup.com/statistics) - [Google sheet](https://docs.google.com/spreadsheets/d/1cewjv0UHiR1r1m3LCzNimwnbXzaXfm1v00wSIPYx0wg/edit?usp=sharing)
3. [Mauna Loa CO](https://www.esrl.noaa.gov/gmd/ccgg/trends/data.html)[2](https://www.esrl.noaa.gov/gmd/ccgg/trends/data.html) [concentrations – 1952-2004 (Hawaii)](https://www.esrl.noaa.gov/gmd/ccgg/trends/data.html) - [Google sheet](https://docs.google.com/spreadsheets/d/1kKzx3CekqF6tNpcFo1s8AvtqfKHvw5IkdDYQUeSIQ7c/edit?usp=sharing)
4. [Northern Tanana River Ice Break Dates (Alaska)](http://nsidc.org/data/nsidc-0064.html) – [Google sheet](https://docs.google.com/spreadsheets/d/1TQqK4ypnLJvLkSc7-_KO3pv1uWthoAsEJEYASUjzyY0/edit?usp=sharing)
5. Artic ice Thickness – 1936-2000 (East Siberian Sea) – [Google Sheet](https://docs.google.com/spreadsheets/d/1cCcP9Q5DHbBpf11UdMhO-2k9e0MB9BF_igcU1LC-Nsg/edit?usp=sharing)
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7. Temperatures for River Tornio – 1692-2011 (Finland) – [Google Sheet](https://docs.google.com/spreadsheets/d/14cPhts97kEicRWHyj16iFNKopIH4a-1ZEE4YKujYboc/edit?usp=sharing)
8. Vostok Ice Core Data 414,00 years BP (before present)
	1. CO2 concentration (Antarctica) – [Google Sheet](https://docs.google.com/spreadsheets/d/1WJIm_nG00nczZCovm58AA141jAYZVFlc27h31Ejsukk/edit?usp=sharing)
	2. Vostok Ice Core Data on Temperature (Antarctica) – [Google Sheet](https://docs.google.com/spreadsheets/d/1oACLKuCm_NBBMl7-N1FMvjPdPOYVgTSD0AcVlgey70I/edit?usp=sharing)
9. Multi-proxy Temperature data using Tree-ring, Ice Cores, Corals & Sediments – 1000-1991 – [Google sheet](https://docs.google.com/spreadsheets/d/1URQtMjdX9JWkGteDoAcWO5sKGMnFgSqREv9ZAqOtAxw/edit?usp=sharing)

## Background information

Scientists study how the Earth's climate is changing via satellites, instrumental records, historical records and proxy data. The first three sources of contain real-time data collected for the most part over the last 150 years, back to the 1800s. Some historical records from grape growers in Europe can extend the temperature record back to the late 18th century. These records show how the Earth's global average temperature has [increased by approximately 0.5 degrees centigrade](http://www.ncdc.noaa.gov/paleo/globalwarming/howdo.html) or 0.9 degrees Fahrenheit, but they don’t provide a long-term picture of the temperature trends. If students are to understand global warming, they need to understand that looking at temperature records only during recorded temperature history is not enough to see the global trends. It is important to also look at temperature records over a longer period of historical time, to determine how much of this warming is a natural and how much is due to human activities. This can be done using **proxy data**. The term “proxy” means the authority to represent something else.

Paleoclimatologists gather proxy data from natural recorders of climate such as tree rings, ice cores, fossil pollen, ocean sediments, and corals. To analyze this data, scientists must accept one assumption: the processes we observe now are the same processes that functioned throughout the earth’s history. For example: tree rings today are influenced by climatic conditions. The width, density, and chemical composition reflect the length of the growing season, the amount of water available and the temperature conditions present. Scientists must make the assumption these same conditions can be determined by analyzing historical tree rings. Since trees growing in a temperate region have one growing season, they tend to produce one ring a year and thus can provide information about climate. Trees can grow to be hundreds or thousands of years old and therefore contain annual proxy records of climate for centuries to millennia. One doesn’t need to cut a tree down to investigate its rings. Instead, paleoclimatologists use a hollow drill to remove a cylindrical sample of the tree, called a tree core. Cores are taken of other sources to obtain additional proxy data.

There are several places on earth where ice has been undisturbed and has accumulated over millennia: high mountain glaciers and polar ice caps. Ice cores can be taken from these areas and scientists can look at the dust, air bubbles and isotopes of oxygen to [interpret the past climate](http://www.ncdc.noaa.gov/paleo/vostok-dd.html) of that area. Cores from the sediment of long standing bodies of water such as large lakes or oceans can be taken. These cores provide a record of fossil pollen. All flowering plants produce pollen. This pollen is unique to the plant that produced it. If we know the plants that were present and we know the climates that these plants are found in today, we can use this pollen to estimate the historical climates at the time in which the sediment was deposited. Since billions of tons of sediments are deposited each year, cores taken from the ocean floor can be analyzed for other fossils and chemicals adding to the interpretation of the past climates.

The last major piece of proxy data comes from coral. Corals are sessile ocean animals that build hard skeletons from calcium carbonate, a mineral extracted from seawater. These carbonate skeletons contains [isotopes](http://nndc.noaa.gov/cgi-bin/wt/nndcp/ShowDatasets?fn_0=PCLSLIDE.GLOSSARY.TERM&type_0=Exact&query_0=isotope&query=&dataset=400116&search_look=2&group_id=NONE&display_look=2&source_id=11) of oxygen, as well as trace metals, that can be used to determine the temperature of the water in which the coral grew. These temperature recordings can then be used to reconstruct the climate when the coral lived.

The second part of this activity gives students the opportunity to analyze scientifically collected data on climate parameters and to then make their own decisions about the realities of climate change. In this second part, each pair of students is assigned one data set from the nine different observational data sets. Links to each of these scientific data sets are provided on the articles weblink page. Some of these data sets can be downloaded as excel files, whereas others are long text files or webpages themselves. To facilitate students being able to easily access and analyze the data sets, these data sets have been translated into Google Sheets formats. All that is needed are computers for each student group. Some data sets are much larger than others while several of the data sets The difficulty is gauged by the number of data points, span of data set, clarity of data units, and ease of data manipulation. Figure 1 lists the data sets from least difficult to most difficult. This will help the teacher differentiate by assigning data sets to appropriate groups:

***Figure 1: Data Sets for Student Analysis (See Google links above in data sets)***

1) video & images of Artic Ice Change, Sea Ice and Snow Cover (This can be used for students who struggle with excel data, charting, and mathematical calculations. This comes from videos , change maps, graphing of artic ice);

2) Yukon River Breakup, Alaska 1896-2017;

3) CO2 concentration from the volcano Mauna Loa 1952-2004 on Hawaii;

4) Northern Tanana ice breaking dates in Alaska;

5) the depth of the Arctic ice in the East Siberian Sea from 1936-2000;

6) Monthly Mean Temperature Tornedalen, Sweden from 1802-2002;

7) temperature data for the river Tornio1693-2011;

8) Vostok – Antarctic ice core measurements of temperature & CO2 for 414, 000 years BP (before present)

Many of these data sets show the rising of global temperatures and CO2 levels. The thinning of the Arctic sea-ice cover demonstrates one consequence to this increase in temperature along with the ice break-up dates for rivers.

## Introducing the Activity

This activity supports the five phases of the learning cycle advocated by *Every Learner Inquires (ELI).*

 Engage/Explore: Engage students in exploring historical and proxy data by asking them to look at cross-sectional tree cuts. Have them observe the cut and generate observations about the number of rings, the width of the rings and/or the color of the rings. Once these observations are made have students predict what environmental conditions caused these differences. Give the students the year the tree was cut down and have them predict when it was planted. Have them track from this point and predict what the environmental conditions were for each year. You can learn more about tree rings at the NASA web page for the Earth Observatory at the website: ttp://earthobservatory.nasa.gov/Study/Paleoclimatology\_CloseUp/ This website not only provides background information about how tree rings can serve as proxy data for climate, but provides lessons and accompanying data students can graph and analyze so they can construct their own understanding of this concept.

 Explore: Once students have a solid understanding of proxy data they are ready to start analyzing data sets. Distribute one data set to a pair of individuals. Some data sets are much larger than others. If one group gets done analyzing their data set while other groups are still working, assign this group another data set to analyze. It would be good to have more than one group analyze each data set.

 Explain: When the groups doing the same data set are both finished analyzing the data, they should meet and confer, comparing their data. Explain to students that this meeting’s purpose is to allow them to present their findings to the other group and receive critical feedback from the other group. After this meeting each group is encouraged to return to their data and make changes based upon this feedback. You might have your students practice providing feedback in a supportive but critical fashion. This is an essential life skill for your students.

 Encourage students to analyze the data to identify trends. Expect students to perform a line graph of the data over time, but push students to take the data, manipulate it (i.e. combining, averaging, finding % change) and graph the result. Students should use their trends to define the claim(s) supported by their data/evidence. Working with the mathematics teacher who also works with your students, enhances this unit as the math teacher can be addressing content in manipulation of data. When everyone is finished with their data analysis meet as a class and allow each group to present its findings/claims. Make sure that students support these claims with evidence from their data analysis.

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| **Engage/Explore** |
| Circulate around the room providing students with the year their tree slice was cut and asking them to explain some of their observations about the tree cut. | * Students observe tree cuts to collect and analyze tree ring data to understand proxy data.
 |
| **Explain** |
| Facilitate the class discussion. As students share ask them questions about their data to bring out additional information about what tree rings can tell about the environmental conditions. Help students crystallize their understanding of proxy data. | * Students share their observations in a class discussion.
 |
| Circulate around the room helping students with initial computer issues. | * Students will work in groups of two and will graph & analyze at least one data set two different ways.
 |
| Ask questions focusing students on what they think are the best ways to analyze the data for trends. Remind students of the need to manipulate the data and graph the results in addition to graphing the simple change over time.  | Each group analyzing the same data set will meet and confer prior to finishing their data analysis. The point of this meeting is to provide supportive but critical feedback to each group. |
| **Elaborate** |
| If any groups are done early and have met with the other group assigned to the same data set then assign the finished group another data set to analyze. |  |
| Monitor the groups and ensure that each is on task. |  |
| Ensure the groups analyzing the same data have a chance to meet and confer. If a group needs to reconsider their analysis after this meeting, allow this to happen. At this meeting both groups should provide critical feedback to the other. | Students support each other by offering suggestions for additional analysis and critically reflecting on each other’s work. |
| Monitor the feedback at the group meeting and facilitate the supportive but critical analysis of each group’s work. |  |
| **Evaluate** |
| Assist students as they interpret their data and answer the Summing Up questions. | Each group will complete the Summing Up questions in preparation for their presentation. |

## Assessing the Activity

*Formative Assessment (See table below)*

*Summative Assessments:*

Performance Assessment

* For the primary assessment each student group will be presenting their data to the class and answering questions posed by the class. Assess students on their presentation of data, answering of questions and involvement of all group members.
* Student responses to the *Summing Up* questions guide the development of the presentation as a performance assessment for this activity. It is best to allow students the opportunity to make corrections to any incorrect or weakly formulated *Summing Up* answers where necessary. They will receive teacher guidance on this, but may also prefer to work with a partner in trying to make their corrections.
* Sample Answers to Summing Up:

1. Graphs of some of the data sets can be found at:

 Mauna Loa CO2 concentrations < <https://www.esrl.noaa.gov/gmd/ccgg/trends/full.html>>

 Tornedalen Temperature – shows a gradual increase

 Thinning of Arctic sea-ice < https://www.climate.gov/news-features/features/arctic-sea-ice-getting-thinner-younger>

 Vostok Ice Core CO2 and temperature data < http://cdiac.ess-dive.lbl.gov/trends/co2/vostok.html> Multiproxy data

 Ice Break-Up Data for River Tornio < <http://www.grida.no/climate/vital/31.htm>>

2. Accept any manipulated data graphs that are logical and show a clear or different pattern to the data. Students may wish to combine the data into “data clumps” (i.e. on the temperature data they may generate means for similar time frames; every decade or in the case of the proxy data every 500 years.) or look at percentile increases.

3. Each written analysis should provide specific conclusions about the data and should reference specific data points or trends shown on their table. Students should not speak in generalities only but need to back up their conclusions with specific data. Students should also provide some explanations as to what might be happening in the environment to “cause” these changes in the data.

4. Predictions/claims should be supported by an extrapolation of the data graphed (the evidence).

5. Students should be able to provide a summary of conclusions drawn by each data set.

1. Students should be able to provide three environmental consequences of the changes that have been described in the data sets.
2. This question requires students to make a definitive statement about what constitutes adequate proof for global warming. Students must provide data-based reasoning presented in a logical fashion. In cases where inadequate depth is provided, give students the opportunity to improve their response to this question.

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| **Learning Goals** | **Success Criteria** | **Formative Assessment Strategies** |
| **Activity 1:****Proxy Paleoclimatology** | Big Ideas: The analysis of historical data on air temperature and ice cover, in addition to Paleoclimatology data on tree rings, ice core and coral, allows students to draw their own conclusions about global warming. Through this analysis, students gain knowledge and skill in data analysis using spreadsheets and graphing software. |  |
|  |  | **Pre activity discussion questions:** What evidence do we have that there is or is not global warming? What constitutes evidence that global warming does or does not exist?  |
| How to analyze paleoclimatological evidence to reveal historical patterns of warming and cooling of the earth. | Explain the best ways to analyze large data sets for trends | **Questioning:** Show students models of analyses from other data sets. Ask if each is a good way to analyze the data for trends? If so, why? If not, why not? |
|  | Manipulate data and graph the results of the analysis | **Pre-assess** student understanding of the use of graphs and work with those students who have graphing difficulties so student skill level does not interfere with the opportunity to learn and demonstrate understanding of the concepts.**Observation:** Manipulation of data (combining, averaging, finding % change) while groups work on analysis.**Questioning:** Why have you chosen to manipulate the data in X way? What would happen if you ….?**Observation of discussion:** Groups present graphs of the analysis to peers and explain logic of analysis. Peers provide feedback. |

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|  | Identify patterns of warming and cooling trends | **Class presentations:**  Share the patterns you have observed in your data set. Get feedback from peers and teacher. |
| Understand the types of evidence from our past that can support or refute claims of global warming. | Draw conclusions from patterns. Justify conclusions by using relevant data. | **Individual written explanations**: Justify conclusions by articulating evidence for basis of conclusion. |

## Teaching for Learner Differences – Differentiation Tasks

**Less-Than-Proficient**

**Prioritized vocabulary, skills, concepts:** proxy data, climatology, ice cores, tree rings, atmospheric gases, and climate.

**Suggestions for supplemental instruction**

* Distribute data sets to ensure successful data analysis from each individual. Some data sets are a more simple to analyze than others. The difficulty is gauged by the number of data points, span of data set, clarity of data units, and ease of data manipulation. The following five data sets will be the simplest for students to analyze and are listed from least difficult to most difficult. This will assist you in assignment of data sets to appropriate groups.
* Video/Images of Artic Change and Sea Ice/Snow cover (requires no Excel experience)
* Arctic Ice Thickness
* Yukon River Ice Breakup
* Mauna Loa CO2 concentrations
* Temperatures for River Tornio
* Prepare an *Excel* TM help sheet that will assist those students in need of additional help in getting started using *ExcelTM*. (Internet resource for Excel http://www.usd.edu/trio/tut/excel/ )

**Highly Proficient**

**Suggestions for supplemental instruction**

* The following three data sets are more complex and are listed in order of increasing complexity. This will assist in assignment of data sets to appropriate groups.
* Vostok Ice Core Data on CO2 concentration
* Vostok Ice Core Data on Temperature
* Multi-Proxy Data on Temperature (most difficult)

Once students have completed the data set analysis, challenge them to conduct an internet search to see if their conclusions agree with scientists.

Data Set References

The Arctic’s oldest ice is vanishing. (13 December 2016). Climate.gov. Retrieved April 14, 2018 from <https://www.climate.gov/news-features/videos/old-ice-arctic-vanishingly-rare>

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Yukon River Breakup. (2 February 2018). Environment Yukon. Retrieved April 14, 2018 from <http://www.yukonriverbreakup.com/statistics>

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 *(PCA: Tree-rings, Ice Cores, Corals, Sediments, Historical), 1000 Years, Jones et al. 1998*