Arctic Sea Ice Extent

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Abstract

Arctic Sea Ice Extent: A Qualitative Literacy Project and an Entry Point for Environmental Mathematics

We present a group project based on Arctic Sea Ice Extent data for 1979 to the present obtained from the National Snow and Ice Data Center. This project offers an easy entry for integrating environmental mathematical modeling into lower division courses in a significant way. The topical nature of Arctic Sea Ice Extent, especially given the current historically low September minimum value, ties current events, the environment, and mathematical modeling together in powerful ways. Student teams can use their simple models to predict the first ice-free summer for the Arctic Ocean. Students' project reports were also used as a quantitative literacy assessment for precalculus students and for the course; results of the projects use in class will be discussed.

Outline

1. Background
   Melting arctic sea ice and the Greenland ice cap have been in the news. The data gives strong evidence of the impacts of climate change.

2. Student Project
   Easily available data allows us to bring environmental mathematics into the classroom at multiple levels.

3. First Results
   An environmental data project was used in precalculus to introduce and reinforce:
   - Discovering trends in data sets
   - Mathematical modeling
   - Environmental mathematics

Background

National Snow and Ice Data Center (NSIDC)

NSIDC: The NSIDC is housed at the U of Colorado, Boulder. The Center conducts programs in the Arctic and Antarctic, has partnerships with NASA, NOAA, and maintains archives of data, historical notes, "journals, books, maps, photographs, prints, and expedition notebooks."

History: Established at U of CO in 1982 and merged with the World Data Center for Glaciology.

Today: The Center produces Daily Image Updates for Arctic Sea Ice Extent.

Sources: NSIDC *and* Mathematics of Planet Earth 2013

Student Project

The Arctic Sea Ice Extent Project

QL PROJECT **Arctic Sea Ice Extent** [GenEd: 1B, 1D, 2F, 2G, 4C]

NAME:_____ NAME:_____ NAME:_____

Background

European explorer's, beginning with Cabot's 1497 attempt to sail to the Orient from England, searched for the *Northwest Passage*, a route through the Arctic Ocean along the coast of Canada. See Figure 1. The Norwegian explorer Amundsen was the first to complete the journey, though it took from 1903 to 1906. In 1957, the U.S. Coast Guard Cutter *Storis* became the first U.S. vessel to circumnavigate the continent, a 22,000 mile trek.

The problem is the Arctic Ocean is covered by a sea ice pack nearly all the time—the passage is closed. Since the beginning of the Industrial Revolution, global temperature averages have risen overall causing more of the ice pack to melt in the summer, which leaves more ocean open. Ice is very reflective giving the arctic region a high *albedo*; ice reflects up to 70% of the sun's energy. The ocean is darker, reflecting only 6% of the sun's energy, so as the ice pack retreats, the area's albedo gets lower. More energy is absorbed by ocean water than by sea ice increasing the temperature, causing more ice to melt leading to more open water, creating a positive feedback loop.

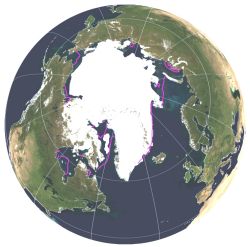


Figure 1: Arctic Sea Ice[1]

NASA's *National Snow and Ice Data Center* at the U. of Colorado, Boulder, has collected data provided by satellites, over-flights, submarines, and other observations measuring the amount of sea ice in the Arctic Ocean for several decades. Figure 2 shows the average July total arctic sea ice area in millions of square kilometers versus the year from 1979 to 2011. The line ("line of best fit") in Figure 2 shows an annual decrease of 6.8% in the amount of sea ice cover for the Arctic Ocean. If positive feedback causes the rate of change to be increasing, a linear trend will underestimate sea ice loss.

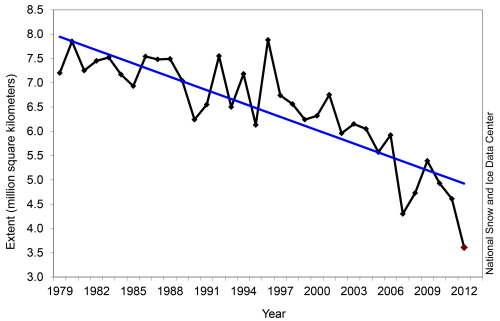


Figure 2: Average September Arctic Sea Ice Extent, 1979 to 2012

[1] All images courtesy of NASA and the National Snow and Ice Data Center, U. C., Boulder. (http://nsidc.org)

Project

Determine the overall trend in the average monthly sea ice extent using the data given in Table 1.

1. List the month _____ your group is assigned.
2. Use NSIDC's *Arctic Sea Ice Extent Averages* data given in Table 1 for your assigned month to derive a linear function giving the overall trend of the average sea ice extent.
3. Plot the linear function and your data on the same graph.
4. Predict your month's 2013 and 2014 values.
5. Explain why the slope of the linear function describes the trend of your data. What is the trend as a percentage?
6. Is the trend you found reasonable? Why or why not?

Extra for Experts: Explore quadratic models of the data.

Table 1: **MONTHLY ARCTIC SEA ICE EXTENT AVERAGES** (million square km.)

Year	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
May	14.06	14.04	13.9	14.17	13.54	13.68	14.23	13.52	13.81	13.69	12.98	13.3
June	12.59	12.31	12.57	12.69	12.35	12.20	12.40	12.10	12.57	12.02	12.31	11.68
July	10.47	10.39	10.62	10.75	10.91	10.15	10.09	10.47	9.98	10.04	10.38	9.62
Aug	8.15	8.04	7.86	8.26	8.36	7.87	7.46	8.01	7.69	7.90	7.92	6.82
Sept	7.20	7.85	7.25	7.45	7.52	7.17	6.93	7.54	7.48	7.49	7.04	6.24
Oct	9.39	9.46	9.19	9.98	9.64	8.84	8.88	9.89	9.29	9.47	9.52	9.35

Year	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
May	13.51	13.25	13.54	13.73	13.04	13.06	13.32	13.80	13.86	13.18	13.72	13.12
June	12.23	12.13	11.99	12.10	11.55	12.10	11.91	11.85	12.10	11.71	11.69	11.69
July	9.68	10.61	9.66	10.22	9.15	10.36	9.59	9.62	9.59	9.75	9.22	9.49
Aug	7.40	7.86	7.29	7.61	6.68	8.17	7.30	7.49	7.38	7.21	7.47	6.53
Sept	6.55	7.55	6.50	7.18	6.13	7.88	6.74	6.56	6.24	6.32	6.75	5.96
Oct	9.16	9.6	9.18	9.48	8.94	9.39	8.76	8.85	9.1	8.92	8.59	8.81

Year	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
May	13.00	12.58	12.99	12.62	12.89	13.16	13.39	13.10	12.79	13.13		
June	11.77	11.51	11.29	11.06	11.49	11.46	11.49	10.87	11.01	10.97		
July	9.46	9.60	8.93	8.67	8.13	9.06	8.82	8.39	7.92	7.94		
Aug	6.85	6.83	6.30	6.52	5.36	6.06	6.26	5.98	5.52	4.72		
Sept	6.15	6.05	5.57	5.92	4.30	4.68	5.36	4.90	4.61	3.61		
Oct	8.65	8.48	8.45	8.33	6.77	8.42	7.52	7.71	7.10	7.00		

Source: NASA's National Snow and Ice Data Center, Univ. of Colorado, Boulder; http://nsidc.org/arcticseaicenews/

Report Requirements

Your report must include:

1. Your project team members' names.
2. Your linear model and predictions for 2013 and '14 with a justification of its appropriateness.
3. A graph showing your model with the data points.
4. A discussion of the trend you calculated and whether or not it reasonably describes the data.

You may produce your final report as your choice of

- a standard paper (in **pdf** format; **not** doc, docx, &c.)
- a slide-show (Impress, Keynote, Powerpoint, or pdf)
- a video of your team presenting to a group of classmates (in Quicktime or Windows Media format; mp4, mpeg, mov, wmv, or avi; **not** flv or swf)

Upload your report file to our AsULearn class web site.

First Results

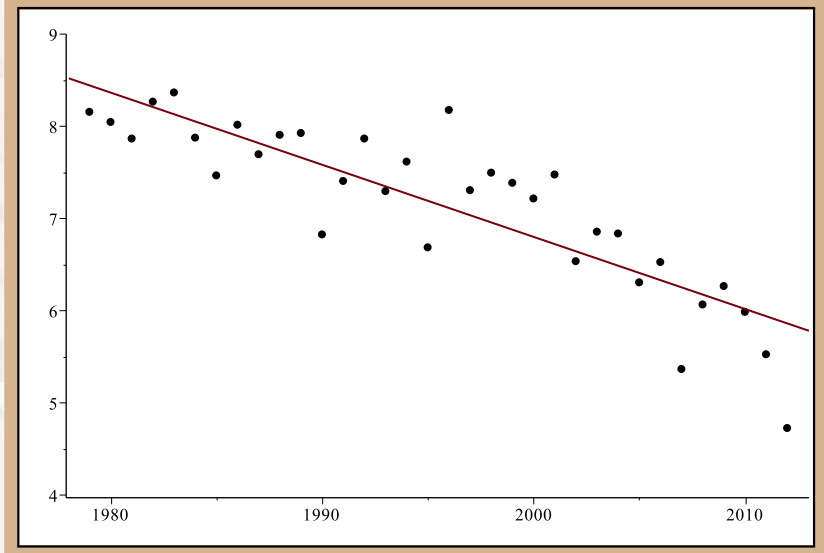
Student Reports

Initial Results Summary:

- Student teams easily discovered the linear fit's slope as a trend indicator.
- Students had difficulty writing their analysis. Most assimilated the obvious trend, but had trouble relating the trend to reality. Some resisted making the connection.
- Unsurprisingly, most students' effort was directly related to their perception of the project as a graded assignment versus a course assessment.

For the Curious...

Linear Fit

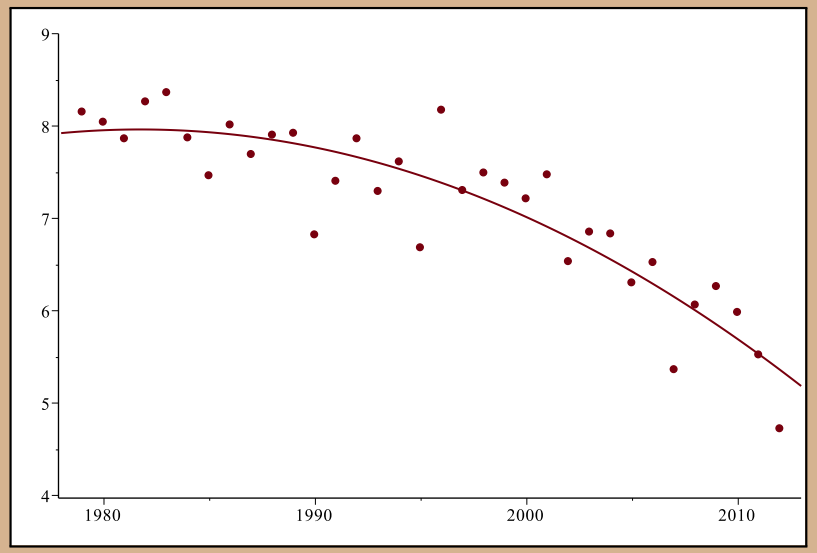


$$S_L = 163.28 - 0.0782x$$

$$S_L(2013) = 5.78$$

$$S_L(2014) = 5.70$$

Quadratic Fit



$$S_Q = -11152. + 11.263x - 0.00284x^2$$

$$S_Q(2013) = 5.18$$

$$S_Q(2014) = 5.00$$

Links to the Project and Data

Links

QR code links to the student project handout (.pdf), the sea ice extent data spreadsheet (.xlsx), and to me (.vcf):

Project Handout URL

Data Spreadsheet URL

My Contact Info