arctic survey education

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**Statistics Toolkit**

# READING THE ICE: MAKING SENSE OF SEA ICE DATA

photograph © Martin Hartley www.martinhartley.com

**A science and mathematics enrichment toolkit for ages 14-19 (Key Stages 4 and 5)**

**Produced by the Millennium Mathematics Project, University of Cambridge, for Arctic Survey Education**

## Statistics Toolkit – Contents

**This enrichment toolkit explores some of the science that underlies the Catlin Arctic Survey and gives learners the chance to see curriculum science and maths applied to real-life problems. The overview article can be read on its own, or used as motivational material for the two worksheets. The worksheets are designed to promote group discussion of the topics, as well as provide hands-on activities. Because of the exploratory nature of the worksheets, less experienced students may require more guidance.**



Arctic Survey Education – new facts and knowledge to promote understanding

## Catlin Arctic Survey

The Catlin Arctic Survey is an international collaboration between polar explorers, some of the world's foremost scientific bodies and WWF. The intention is to better predict how much time there is before the North Pole sea ice cover melts by collecting and analysing new accurate data on snow and sea ice thickness gathered by the expedition team as they journey across the Arctic.

The scientific endeavour began on 1st March 2009. The expedition was led by highly experienced polar explorer and Expedition Leader, Pen Hadow. He was accompanied by Ann Daniels, one of the world's foremost female polar explorers and Martin Hartley, the leading expedition photographer. The team travelled on foot, having hauled sledges from 81°N 130°W across drifting sea ice, for 73 days, in temperatures from 0°C to -50°C towards the North Geographic Pole.

Current estimates for the total disappearance of the Arctic Ocean's sea ice vary from 50 years down to just four. Whatever happens, the consequences of its melt-down will be of global significance in terms of sea level rise, the geo-politics of energy resources, rainfall patterns and the availability of water supplies and, of course, the impact on biodiversity, including the polar bear.

## Millennium Mathematics Project – bringing mathematics to life

The Millennium Mathematics Project (MMP) is a maths education initiative for ages 5 to 19 and the general public, based at the University of Cambridge but active nationally and internationally. We aim to support maths education and promote the development of mathematical skills and understanding, particularly through enrichment activities. More broadly, we want to help everyone share in the excitement and understand the importance of mathematics. The MMP consists of a family of complementary programmes, each with a different focus, including Plus Magazine (Plus).

This enrichment toolkit was produced by Plus, a free online magazine (http://plus.maths.org) for GCSE, A level and undergraduate students, and the general public. Plus opens a door to the world of maths, with all its beauty and applications, by providing articles from the top mathematicians and science writers on topics as diverse as art, medicine, cosmology and sport. Plus provides weekly news updates, a fortnightly email newsletter, an extensive 'Careers with Maths' library and monthly podcasts.

# MAKING SENSE OF SEA ICE DATA

**The Arctic Survey's measurements will allow us to better characterise the current state of the Arctic sea ice cover and predict its declining trend.**

**The Arctic ice cap is in trouble. Due to global warming, summer sea ice cover has been shrinking by an area the size of Scotland every year. But scientists believe that the thinning of the ice is even more important when it comes to the future of the ice caps – they believe that the Arctic ice cover will break up and disappear through thinning, rather than shrinkage. While it's easy to measure the sea ice extent from satellites, it's much more difficult to assess the thickness of the ice. This is the aim of the Catlin Arctic Survey: along their route through the Arctic, they will gather much-needed information on the ice thickness, as well as the type of ice to be found in the Arctic. All the data they gather will need to be organised and analysed, and the results will need to be presented accurately and in a way that's accessible to everyone – this means that statistics lie at the heart of the scientific part of the Arctic Survey.**



*The ice team drill into the ice to measure its thickness.*

Statistics are something we all come across every day when we read the papers or watch TV. It might be the risk of cancer, the changing crime rate, the rise and fall of house prices or the melting of the Arctic ice cap – all of these are described by numbers which summarise large sets of data.

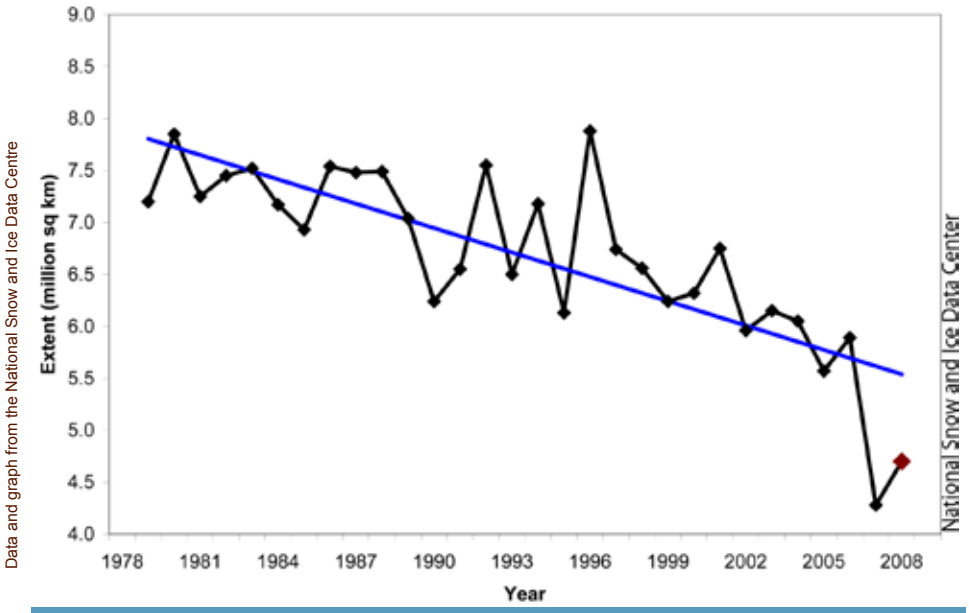
We couldn't imagine making important decisions without a solid base of evidence. You wouldn't want your doctor to guess what dose of medicine to prescribe – decisions on dosages and medical treatment are based on large sets of data from clinical trials to reduce the risks to patients. Scientists, like those working with the Catlin Arctic Survey, often base their theories on a large number of data from observations of the world around us. Governments collect large amounts of data which they will use to formulate policy that impacts on all of our lives. Even commercial companies design and launch new products after carefully collecting and interpreting consumer data.

Some people don't like the use of statistics. The saying "There are three kinds of lies: lies, damn lies and statistics" [1] illustrates that for centuries people have felt that statistics have been used to mislead rather than to reveal the truth. Even correct figures can be framed in such a way as to put a positive or negative spin on the data. But an understanding of statistics, and an awareness on how they should be presented, can help all of us identify when the numbers are being used to mislead, and when they accurately portray the data they summarise.

## Trendsetters

One way of interpreting data is to look for trends – if we can mathematically describe the relationship between the variables in the data (the amount of sea ice over time, or the global mean temperature over time), we can understand the past and even make predictions about the future.

The simplest way to do this is to plot the data collected and try to fit a line to the points on the graph, a technique called *linear modelling*. Statisticians want the line that most closely matches the data, and have standard methods to calculate the line of best fit. One method, called the *least squares method*, involves examining the distances between each of the data points and the line, and choosing a line that minimises the sum of the squares of these distances.




*This graph shows the sea ice extent measured in September each year from 1979 to 2008, together with a line of best fit.*

The graph above shows the extent of Arctic sea ice as measured in September of each year since 1979, together with a line of best fit. The slope of the line of best fit can be interpreted as the annual decrease in sea ice extent each September. The year-by-year figures vary, but data covering a longer period gives us a bigger picture of what is happening. Not all data sets can be approximated by straight lines of course, and statisticians can also fit more complicated curves to real data.

1 Benjamin Disraeli, 19th century British Prime Minister'

But what happens if observations differ drastically from the curve of best fit, as is the case with the 2007 and 2008 figures in the graph above? When this happens statisticians use mathematical methods to establish whether the discrepancy is likely to be a statistical blip that occurred by chance, or whether it indicates a genuine change of trend. If the latter is the case, scientists go off to investigate the reasons for the drastic change, and statisticians fit new curves to the data to predict the future.

## Reading between the headlines

Summarising a data set in a single number can give us a snapshot of the situation and can be a powerful way to communicate information. Single statistics are often used in the media, but also in other places such as briefing documents for politicians or decisions makers. But although the numbers used may well be correct, the person using that number (the reporter or the politician) has great power over the impression such a statement will create.

*Does bacon cause cancer?*

A recent media storm erupted over the dangers of the humble bacon sandwich. Many papers reported on figures released by the World Cancer Research Fund that eating 50g of processed meat a day (equivalent to a bacon sandwich) increased your chance of cancer by 20%. This sounded like a huge increase, but really it only represents an increase in your risk of cancer from 5% to 6%. That's just 1%, which no longer sounds quite so huge. The numbers in the sensational press coverage ("Careless pork costs lives" cried The Sun) were technically correct (1% is a fifth of 5%, so the 20% figure is fine), but they were presented in a way that gave a false impression of the data involved .

The important thing when faced with a single statistic is to ask yourself if it gives you the full picture. If it describes how your behaviour changes your exposure to risk, for example bacon sandwich eating causing a 20% increase in your risk of cancer, ask yourself what the risk was before, and what it would be after. If you're told you have a 10% chance of winning a lottery, remember you have a 90% chance of losing. The statistics might be correct, but they might be intentionally framed in a way to make you feel more positive or negative about the situation they describe.

To find out more about linear modelling and presenting statistical evidence, have a look at our worksheets *Making sense of ice data – predicting the trend* and *Arctic sea ice data – presenting the evidence.*

**Further reading:**

- From restaurants to climate change – linear modelling and trend analysis http://plus.maths.org/issue49/features/cook/index.html
- The tiger that isn't: numbers in the media – how to unravel misleading statistics in the media http://plus.maths.org/issue45/features/tiger/index.html
- 2845 ways of spinning risk – you can experiment online with different ways of framing evidence to give it a positive or negative spin http://plus.maths.org/issue50/risk/index.html
- Career interview, government statistician – discover how statistics can be used to provide aid to the developing world http://plus.maths.org/issue42/interview/index.html

# MAKING SENSE OF SEA ICE DATA – PREDICTING THE TREND

**The Arctic Survey's measurements will allow us to better characterise the current state of the Arctic sea ice cover and predict its declining trend.**

**The Arctic sea ice extent is the area of the Arctic that is covered by at least 15% of sea ice, including areas of the Arctic ocean completely covered by ice, and those that are only partially covered. Scientists have used satellites to measure sea ice extent every September in the years from 1979 through to 1996.**

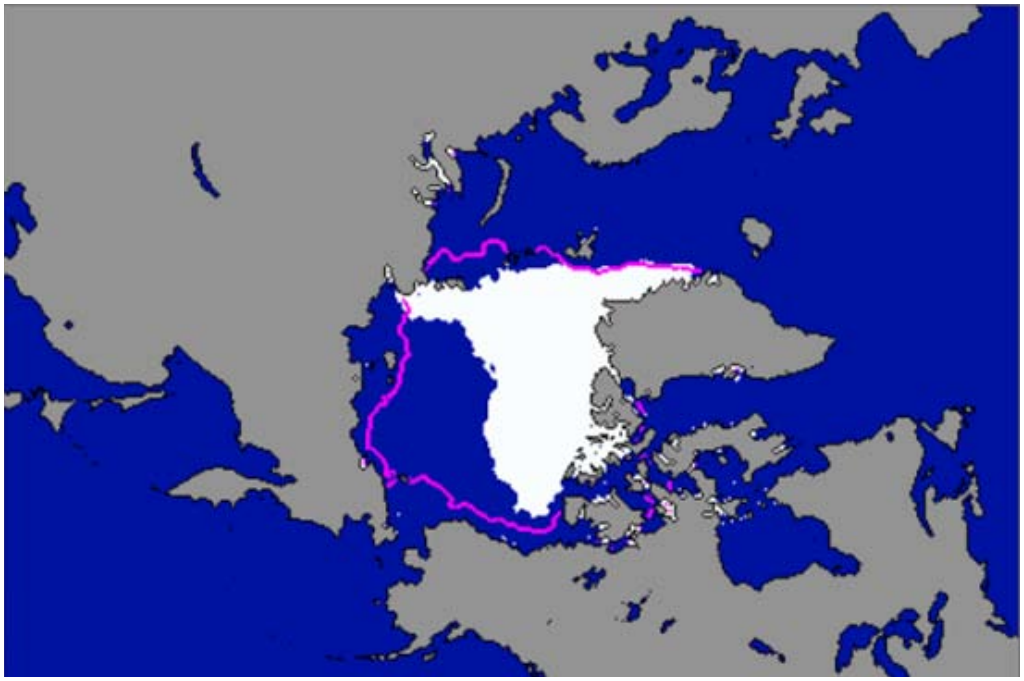


Image courtesy National Snow and Ice Data Center

*Sea ice extent in September 2007. The pink line indicates the average extent over the years 1979 to 2000.*

**The sea ice extent in the years from 1979 until 1996 data is given in the table below. The second column shows you how many years have passed since measurements began in 1979.**

| Year | Years from start of measurements | Sea ice extent in million km$^2$ |
|---|---|---|
| 1979 | 0 | 7.20 |
| 1980 | 1 | 7.85 |
| 1981 | 2 | 7.25 |
| 1982 | 3 | 7.45 |
| 1983 | 4 | 7.52 |
| 1984 | 5 | 7.17 |
| 1985 | 6 | 6.93 |
| 1986 | 7 | 7.54 |
| 1987 | 8 | 7.48 |
| 1988 | 9 | 7.49 |
| 1989 | 10 | 7.04 |
| 1990 | 11 | 6.24 |
| 1991 | 12 | 6.55 |
| 1992 | 13 | 7.55 |
| 1993 | 14 | 6.50 |
| 1994 | 15 | 7.18 |
| 1995 | 16 | 6.13 |
| 1996 | 17 | 7.88 |

**Question 1:** **Plot the data points in a coordinate system, with the x-axis labelled by column 2 (0 year, 1 year, 2 years, etc) and the y-axis by column 3. Can you discern a trend?**

**Question 2:** **In your coordinate system, draw a straight line which you think best approximates the data. Using two points on your line, work out its equation. What does this line predict for the sea ice extent in the years 2000, 2005 and 2010?**

**Question 3:** **The table below gives additional data from 1997 through to 2006. Add the new points to the existing data on your coordinate system. How does the new data compare to your predictions? Can you discern a new trend in the data from 1979 to 2006?**

| Year | Years from start of measurements | Sea ice extent in million km$^2$ |
|---|---|---|
| 1997 | 18 | 6.74 |
| 1998 | 19 | 6.56 |
| 1999 | 20 | 6.24 |
| 2000 | 21 | 6.32 |
| 2001 | 22 | 6.75 |
| 2002 | 23 | 5.96 |
| 2003 | 24 | 6.15 |
| 2004 | 25 | 6.05 |
| 2005 | 26 | 5.57 |
| 2006 | 27 | 5.92 |

**Question 4:** **Draw a new line to approximate the data and work out its equation. How does this compare to the line you found in question 2? What does this predict for 2007, 2008 and 2010?**

**Question 5:** **The measurements of September sea ice extent for 2007 and 2008 are 4.30 and 4.67 million square kilometers respectively. How does this tally with your observations so far? Should we be worried?**

**Question 6:** **Based on what you have learned so far, what predictions would you make for the future of the Arctic ice cap?**

The process of fitting a straight line to a set of data points is called *linear modelling*. In reality, statisticians do not simply guess the straight line as we have just done, but use mathematical techniques to minimise the discrepancy between the data point and the line. The straight line they choose then indicates future trends. When data points are way out of line with predictions, as happened here with the years 2007 and 2008, statisticians use mathematical techniques to determine whether the unusual result is just a blip, or gives true cause for concern.

# MAKING SENSE OF SEA ICE DATA – PREDICTING THE TREND

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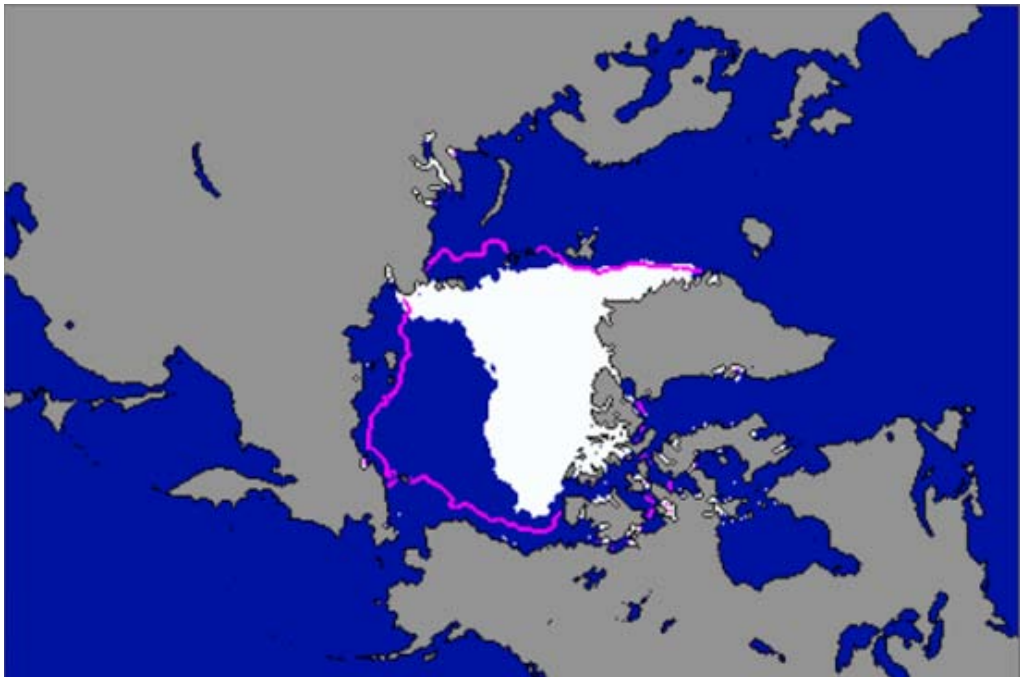

Image courtesy National Snow and Ice Data Center

*Sea ice extent in September 2007. The pink line indicates the average extent over the years 1979 to 2000.*

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| 1984 | 5 | 7.17 |
| 1985 | 6 | 6.93 |
| 1986 | 7 | 7.54 |
| 1987 | 8 | 7.48 |
| 1988 | 9 | 7.49 |
| 1989 | 10 | 7.04 |
| 1990 | 11 | 6.24 |
| 1991 | 12 | 6.55 |
| 1992 | 13 | 7.55 |
| 1993 | 14 | 6.50 |
| 1994 | 15 | 7.18 |
| 1995 | 16 | 6.13 |
| 1996 | 17 | 7.88 |

**Question 1: Plot the data points in a coordinate system, with the x-axis labelled by column 2 (0 year, 1 year, 2 years, etc) and the y-axis by column 3. Can you discern a trend?**

**Answer:** *This is an open-ended question designed to stimulate discussion around year-to-year variations and long-term trends. A slight downward trend can be discerned in the data.*

**Question 2: In your coordinate system, draw a straight line which you think best approximates the data. Using two points on your line, work out its equation. What does this line predict for the sea ice extent in the years 2000, 2005 and 2010?**

**Answer:** *Answers will depend on students' interpretation of data and choice of line. For guidance, the least squares method of fitting a line (one of the mathematical techniques for finding a line of best fit) gives*

$$y = -0.04x + 7.47$$

*predicting that the sea ice extent will be 6.66 million square kilometers for 2000 (year 21), 6.46 million square kilometers for 2005 (year 26) and 6.26 million square kilometers for 2010 (year 31).*

**Question 3: The table below gives additional data from 1997 through to 2006. Add the new points to the existing data on your coordinate system. How does the new data compare to your predictions? Can you discern a new trend in the data from 1979 to 2006?**

| Year | Years from start of measurements | Sea ice extent in million km$^2$ |
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| 1997 | 18 | 6.74 |
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| 2003 | 24 | 6.15 |
| 2004 | 25 | 6.05 |
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**Answer:** *The downward trend has become a lot more marked.*

**Question 4: Draw a new line to approximate the data and work out its equation. How does this compare to the line you found in question 2? What does this predict for 2007, 2008 and 2010?**

**Answer:** *Answers vary according to the line chosen by students. For guidance, the least squares method of fitting a line gives*

$$y = -0.06x+7.64,$$

*predicting a sea ice extent of 5.96 square kilometers for the year 2007, 5.9 square kilometers for the year 2008, and 5.78 square kilometers for the year 2010. The new line has a steeper slope, reflecting the change in the trend.*

**Question 5: The measurements of September sea ice extent for 2007 and 2008 are 4.30 and 4.67 million square kilometers respectively. How does this tally with your observations so far? Should we be worried?**

**Answer:** *This is an open-ended question designed to stimulate discussion. There was a dramatic drop in sea ice extent in 2007, followed by a slight recovery in 2008. Discuss that a single unusual result may not indicate a change in the overall trend (compare to the unusually large sea ice extent in 1994), but that two results that are out of line with predictions may indeed indicate a change in the trend. Point out that more information is needed to predict the future.*

**Question 6: Based on what you have learned so far, what predictions would you make for the future of the Arctic ice cap?**

**Answer:** *This is an open-ended question designed to stimulate discussion. The data very strongly indicates a decrease in sea ice extent, so it seems reasonable to assume that this decrease will continue. The new data from 2007 and 2008 may indicate an alarming acceleration in the rate at which the extent is shrinking.*

The process of fitting a straight line to a set of data points is called *linear modelling*. In reality, statisticians do not simply guess the straight line as we have just done, but use mathematical techniques to minimise the discrepancy between the data point and the line. The straight line they choose then indicates future trends. When data points are way out of line with predictions, as happened here with the years 2007 and 2008, statisticians use mathematical techniques to determine whether the unusual result is just a blip, or gives true cause for concern.

# ARCTIC SEA ICE DATA – PRESENTING THE EVIDENCE

**The Arctic Survey's measurements will allow us to better characterise the current state of the Arctic sea ice cover and predict its declining trend.**

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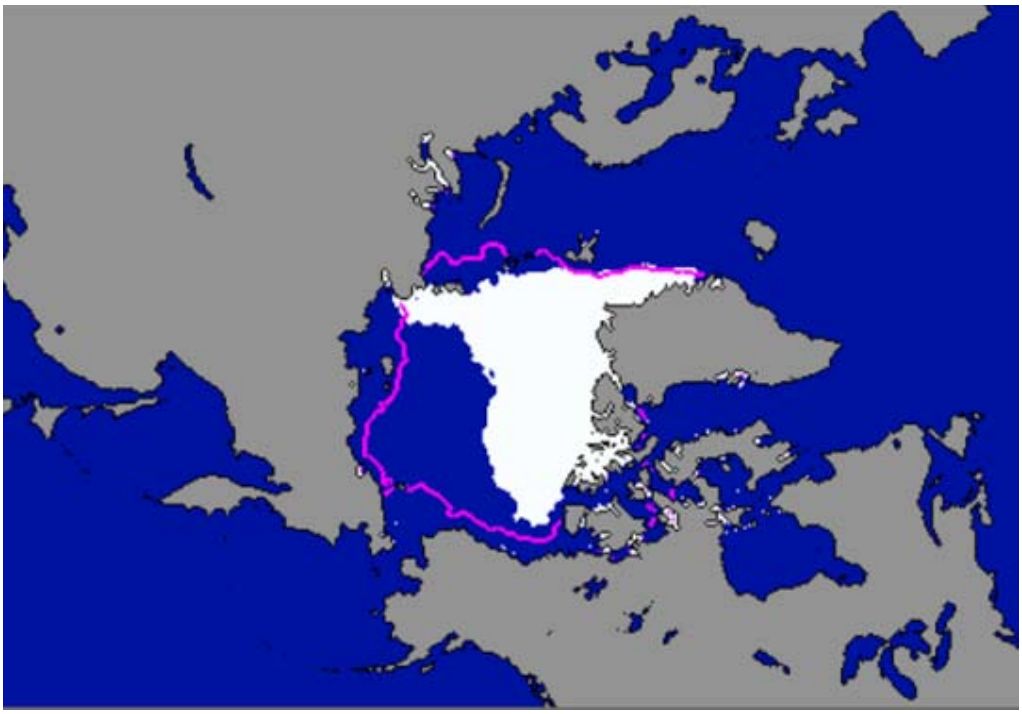

Image courtesy National Snow and Ice Data Center

*Sea ice extent in September 2007. The pink line indicates the average extent over the years 1979 to 2000.*

**Question 1:** **While you are having breakfast one morning you notice that both your newspapers are running leading articles on the decrease in Artic sea ice extent. *The Daily Panic* headline screams:**

***"Arctic sea ice extent decreases by over 20%".***

**The *Laid-back Weekly* says:**

***"Artic sea ice extent decreases by only 5% a year".***

**Which of the two headlines do you think indicates a faster decrease of sea ice extent? Do they give you enough information to assess the rate at which the ice cap is disappearing?**

Intrigued, you look up figures on the Arctic sea ice extent on the Internet. You find the following data for the years 2004 to 2008:

| Year | Sea ice extent in million km$^2$ |
|---|---|
| 2004 | 6.05 |
| 2005 | 5.57 |
| 2006 | 5.92 |
| 2007 | 4.30 |
| 2008 | 4.67 |

**Question 2:** Work out the percentage decrease from 2004 to 2008.

**Question 3:** Work out the year-on-year percentage changes from 2004 to 2008, and work out the average percentage change over this period.

**Question 4:** Were the two newspaper headlines wrong?

**Question 5:** Can you come up with a headline that describes the decrease of sea ice extent from 2004 to 2008 more accurately?

**Question 6:** What is the most dramatic change in the years from 2004 to 2008? How does this compare to the average annual decrease?

**Question 7: Now suppose that you are a newspaper editor. Based on the data from 2004 to 2008, what headline would you run if you wanted to make the decrease of sea ice extent appear as dramatic as possible? What headline would you run if you wanted to play down the decrease?**

**Question 8: Based on your data, write a paragraph which gives an accurate representation of the decrease in sea ice extent since 2004.**

Presenting statistical evidence in a way that puts a negative or positive spin on it is called *framing the evidence*. This doesn't mean that the numbers presented are actually wrong, but it does mean that the picture created can be misleading. Evidence framing is not just something that is practiced by tabloid newspapers – politicians are sometimes guilty of it, and it can be found in serious newspapers and sometimes even scientific publications and press releases. So whenever you read about a statistical result, make sure that the article gives you all the information you need to understand it, and look at the figures carefully.

The data used in this worksheet was collated by the Snow and Ice Data Centre http://nsidc.org/index.html.

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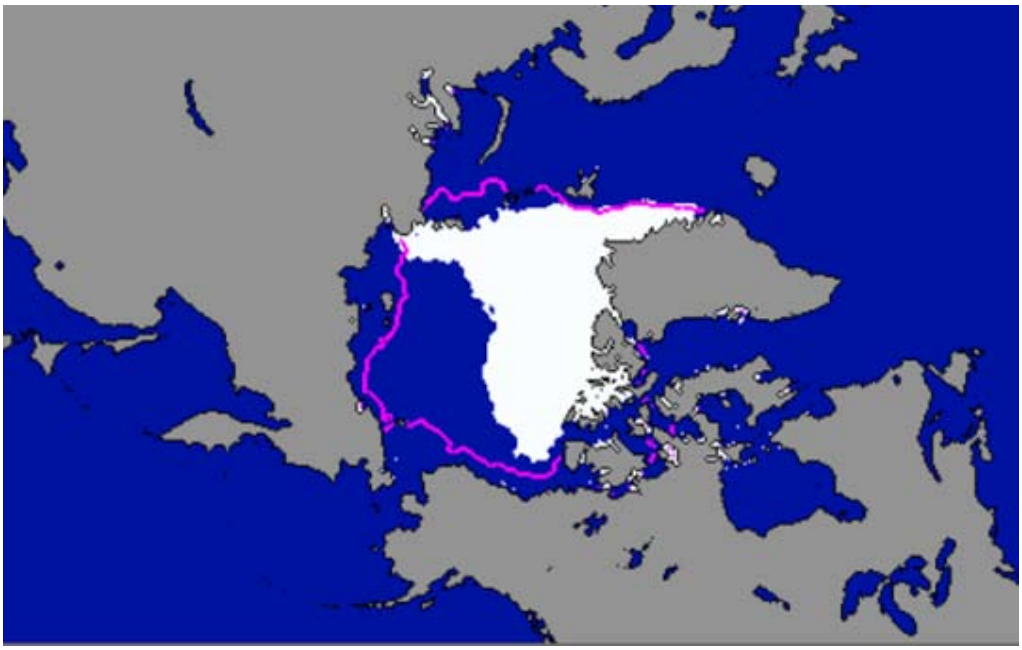

Image courtesy National Snow and Ice Data Center

*Sea ice extent in September 2007. The pink line indicates the average extent over the years 1979 to 2000.*

**Question 1: While you are having breakfast one morning you notice that both your newspapers are running leading articles on the decrease in Artic sea ice extent. *The Daily Panic* headline screams:**

***"Arctic sea ice extent decreases by over 20%".***

**The *Laid-back Weekly* says:**

***"Artic sea ice extent decreases by only 5% a year".***

**Which of the two headlines do you think indicates a faster decrease of sea ice extent? Do they give you enough information to assess the rate at which the ice cap is disappearing?**

**Answer:** *We cannot say which headline indicates a faster decrease, as they do not give enough information. The* Daily Panic *headline does not indicate the time period in which the sea ice extent decreased by over 20%. The* Laid-back Weekly *figure seems to be an average over several years, but does not indicate which years these are.*

Intrigued, you look up figures on the Arctic sea ice extent on the Internet. You find the following data for the years 2004 to 2008:

| Year | Sea ice extent in million km$^2$ |
|---|---|
| 2004 | 6.05 |
| 2005 | 5.57 |
| 2006 | 5.92 |
| 2007 | 4.30 |
| 2008 | 4.67 |

**Question 2: Work out the percentage decrease from 2004 to 2008.**

**Answer:** *The percentage decrease is 22.8% (all figures are rounded to one decimal place).*

**Question 3: Work out the year-on-year percentage changes from 2004 to 2008, and work out the average percentage change over this period.**

**Answer:**
*From 2004 to 2005 there was a 7.9% decrease .*
*From 2005 to 2006 there was a 6.3% increase.*
*From 2006 to 2007 there was a 27.4% decrease.*
*From 2007 to 2008 there was a 8.6% increase.*
*This gives an average yearly decrease of 5.1%.*

**Question 4: Were the two newspaper headlines wrong?**

**Answer:** *Both papers were correct, but the information given was incomplete.*

**Question 5: Can you come up with a headline that describes the decrease of sea ice extent from 2004 to 2008 more accurately?**

**Answer:** *There are several possibilities, including "Arctic sea ice extent has decreased by over 20% between 2004 and 2008", "Arctic sea ice extent has decreased by over a fifth between 2004 and 2008", or "Arctic sea ice extent has decreased by an average annual rate of 5% in the period from 2004 to 2008".*

**Question 6: What is the most dramatic change in the years from 2004 to 2008? How does this compare to the average annual decrease?**

**Answer:** *The sea ice extent has decreased by 27.4% from 2006 to 2007. This is more than 5 times the average annual decrease of 5.1%.*

**Question 7: Now suppose that you are a newspaper editor. Based on the data from 2004 to 2008, what headline would you run if you wanted to make the decrease of sea ice extent appear as dramatic as possible? What headline would you run if you wanted to play down the decrease?**

**Answer:** *There are several possibilities. A headline to draw attention to the decrease might quote the sharp drop in 2007: "Sea ice extent has shrunk by 27% in a single year", or "In 2007 sea ice extent disappeared at over 5 times the average annual rate". It might also quote the overall drop of over 20% since 2004, or express this in fractions as "over a fifth". To play down the decrease, you might quote the increase from 2007 to 2008: "Sea ice extent increases by 8% in the last year", or quote the average annual rate of decrease of 5.1%, as this is less dramatic than the total rate. Lead students into a discussion on how all these headlines are correct, but frame the evidence in a positive or negative light.*

**Question 8: Based on your data, write a paragraph which gives an accurate representation of the decrease in sea ice extent since 2004.**

**Answer:** *The paragraph should include the percentage or fractional changes from 2004 to 2008 and point out the sharp drop in 2007, comparing this to the average annual rate. It should also note that there has been a small increase from 2007 to 2008.*

Presenting statistical evidence in a way that puts a negative or positive spin on it is called *framing the evidence*. This doesn't mean that the numbers presented are actually wrong, but it does mean that the picture created can be misleading. Evidence framing is not just something that is practiced by tabloid newspapers – politicians are sometimes guilty of it, and it can be found in serious newspapers and sometimes even scientific publications and press releases. So whenever you read about a statistical result, make sure that the article gives you all the information you need to understand it, and look at the figures carefully.

The data used in this worksheet was collated by the Snow and Ice Data Centre http://nsidc.org/index.html

## Acknowledgments

**Arctic Survey Education would like to thank its Founder Members and the members of the Advisory Panel for supporting the development of this education resource.**

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Pete Davis
*Public Engagement Team – Education, Oxfam*

Katie Marchant
*Deputy Head Teacher, St Angela's Ursuline Secondary School, Newham*

Steve Brace
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*Schools and Community Relations Manager, WWF-UK*

Alexandra Hartridge
*Climate Change Communications Manager, WWF-UK*

*Arctic Survey Education concept and development by James Forte www.vision40.com*

*Arctic Survey Education is a trading name of, and Catlin Arctic Survey is an event of, Pen Hadow Consulting Ltd.*

*Designed by Lydia Thornley www.thornley.co.uk*