Case study: Why is the arctic warming so fast?

Introduction

This activity is designed to help students prepare for the Unit 4 assessment as well as to learn more about topic 3.4. It provides articles and a scientific paper on the way both measurement and modelling are used to develop explanations for the rapid warming in the Arctic. In this case study the magazine article is related to the abstract of one scientific paper and the full account of another, published in the open access journal 'The Cryosphere'.

Students should review all the sources before they start to answer any of the questions. They are not expected to read and understand source D in detail.

Note that because this is a learning task and not an assessment task it should not be regarded as being typical, in all respects, of Unit 4 exam questions.

Science explanations

Nd All objects emit radiation; the hotter they are the more radiation they emit and the shorter the wavelength at which they emit most radiation.

Ne When radiation strikes another object it can be reflected, transmitted or absorbed (or a combination of these). Reflected or transmitted radiation is similar to the original radiation. When radiation is absorbed, however, it ceases to exist as radiation, instead causing heating and perhaps also changes to molecules or other effects.

Ob The temperature of an object changes if the energy it absorbs and the energy it radiates from its surface are not in balance.

How Science Works

Aa We can never be sure that an observation is accurate or that a measurement tells us the 'true' value of the quantity we are measuring. We may be influenced by what we expect. Random and/or systematic errors can arise from limitations of the measuring equipment used, or our skill in using it. A single measurement of anything is therefore inherently risky.

Af In many situations, scientists have to observe or measure a sample of the objects or cases they are studying (for example, observations in the field, cases of an illness, etc.). Data are more reliable if systematic sampling and observing/measuring methods are used.

Cd Scientists test an explanation by seeing if specific predictions based upon it are in agreement with data from observation or from an experiment (a deliberate intervention to generate data). If data agree with predictions that are very novel or unexpected, this is particularly influential. The aim is to rule out alternative explanations, and so reach a single explanation that most scientists can agree about.

Ce Scientists are more confident about theories that include a plausible mechanism for causing the events observed. It is also important that a new theory is consistent with existing theories that are well-established and generally accepted.

Da A dynamic model is a set of proposed inter-relationships between key variables in a situation. Dynamic models can be constructed and implemented on a computer. They are widely used in science to make predictions and to test explanations in complex situations.

Db A dynamic model incorporates hypotheses about the important variables in a situation, and the way they inter-relate. The outputs from the model will depend on the assumptions built into it and the data used to set the initial conditions. Data derived from a computer model are therefore less trustworthy than data that have been measured directly.

Dc A dynamic model shows negative feedback if a change in the input tends to be cancelled out by changes in other variables, so that the output remains relatively constant. A model may behave in this way for small changes in input, but not if the change in input is large.

DdA dynamic model shows positive feedback if a small change in the input tends to be magnified by changes in other variables, leading to a large change in the output.

De Dynamic models also differ in their sensitivity to small changes in the nature of the inter-relationships proposed. So we cannot ever be entirely certain of the initial conditions, predictions from a sensitive model should be treated with more caution than those from a more stable model.

Df One way to test a dynamic model that predicts the future behaviour of a system is to see how accurately it would have predicted the current state of the system, if provided with past data on it. A dynamic model shows negative feedback if a change in the input tends to be cancelled out by changes in other variables, so that the output remains relatively constant. A model may behave in this way for small changes in input, but not if the change in input is large.

Eb Findings reported by an individual scientist or research group, and their interpretations of these, are carefully checked by the scientific community before they are accepted as reliable scientific knowledge. This process of 'peer review' is essential both for detecting invalid claims and adding weight to valid ones.

Ec Scientists publish their work in technical journals, in conference papers and on the internet. This enables other scientists to see and comment on the data collected, the methods used, and the interpretations made.

Ed Scientists value observations and measurements that are replicable (on different occasions and/or by different people), and are generally sceptical of findings that cannot be repeated.

Ef In situations where scientific explanations are contested and different conclusions can legitimately be drawn from the available data, the personal background and interests of scientists (e.g. their education, past experience, previous areas of work, political and/or religious views, the interests of organisations they work for) may influence their judgments.

Resources

Source A: Arctic's personal greenhouse turns up the heat
http://www.newscientist.com/article/dn16623-arctics-personal-greenhouse-turns-up-the-heat.html

Source B: Polar amplification in a coupled climate model with locked albedo by Rune Grand Graversen1, and Minghuai Wang in *Climate Dynamics* (2009).
http://www.springerlink.com/content/j2832332508u0156/

Source C: The home page of The Cryosphere which is An Interactive Open Access Journal of the European Geosciences Union
http://www.the-cryosphere.net/index.html

Source D: The emergence of surface-based Arctic amplification by M. C. Serreze, A. P. Barrett, J. C. Stroeve, D. N. Kindig, and M. M. Holland - the final paper published in February 2009 in *The Cryosphere*.
http://www.the-cryosphere.net/3/11/2009/tc-3-11-2009.html

Source E: Two referees' comments (RC) and authors' responses in the interactive discussion of Source D. This can also be found from the link to 'discussion paper' on Source D.
http://www.the-cryosphere-discuss.net/2/601/2008/tcd-2-601-2008-discussion.html

Part A

1 Refer to **sources A** and **B**
In the context of these sources, outline your understanding of these terms:
(a) Arctic (or polar) amplification
The greenhouse effect/air temperature in the Arctic (1)
is having twice the effect/warming at double the rate compared to the rest of the northern hemisphere. (1)

(b) albedo
Albedo is a measure of the extent to which the Earth's surface (1) reflects radiation from the Sun (1)

(c) greenhouse gas
A gas that contributes to the greenhouse effect (1)
by absorbing infrared radiation. (1)

(6 marks) (SE Nc, Nd, Ne)

2 In **source A** three factors are mentioned as possible explanations for the fact that the Arctic air temperature is warming at a faster rate than the global average. All involve positive feedback. Outline the science of each of the three explanations.

(a) Albedo feedback: *If warming leads to sea ice melting this exposes the sea surface with a much lower albedo (1) so more radiation from the Sun is absorbed (1) leading to more warming (1)*

(b) Increased greenhouse effect: *Melting ice and warming sea water mean that more water vapour enters the atmosphere (1). Water vapour is a greenhouse gas (1) and so the greenhouse effect is enhanced. (1)*

(c) Direct heating effect: *Melting ice and warming sea water mean that more warmer sea water is exposed to the atmosphere (1). Energy transfer from the warmer sea surface to the air (1) heats up the air in the lower atmosphere. (1)*

(any two in each for 6 marks total) (SE Nc, Nd, Ne)

3 Refer to **sources A** and **B**

(a) Why did the research team that wrote the abstract in source B carry out a computer model experiment to compare the outcomes of their model when the surface albedo was 'locked' with when it was 'unlocked'?
The scientists wanted to discover the extent to which albedo-feedback could account for the observed warming in the arctic. (1) By keeping the albedo fixed in the model they could examine the extent to which other factors were involved. (1)

(b) What did the results of this experiment tell them?
The scientists found that the differences when running the model with albedo 'locked' and 'unlocked' showed that albedo-feedback could not account for all the extra warming in the Arctic. (1), other variables were having a significant effect: water vapour in the air and clouds (1)

(4 marks) (HSW Bd, Cd, Da)

4 Refer to **source C**.
(a) Explain the importance of 'peer review' in scientific publishing.
Peer review checks the quality of the scientific work. (1) The aim is to ensure that the research itself has been properly conducted and the paper reporting the work is clear enough and well argued (1).
(2 marks) (HSW Eb)

(b) Identify **two** differences between the electronic journal, *The Cryosphere* and a journal published in print.
Differences include:
- *articles are published very soon after they are received by the journal*
- *peer review is not restricted to experts chosen by the editors*
- *any scientist can access the article and discuss its findings earlier*
- *the judgements made during the review stage are public*
- *the on-line journal is free*

(any two for 2 marks) (HSW Eb, Ec)

5 Refer to **source E**. Suggest:
(a) **one** reason why the referee, RC S260, might wish to remain anonymous?
A researcher, especially one at the start of a careers, might fear that a critical reviews of work by senior scientists, could have an affect on future career prospects.
(1 mark) (HSW Ef)

(b) **one** reason why the referee, RC S290, is an appropriate person to be invited to review the paper?
Rune Grand Graversen is an expert in the field – he is one of the authors of source B.
(1 mark) (HSW Eb, Ec)

(c) See 'Response to reviewer's comments' in source E
(i) What was the major change to the paper suggested by the referee, R.Graversen?
Observational data from two sources rather than just NCEP should be used. (1)

(ii) How did the authors change the paper in response to this suggestion?
They undertook detailed comparisons between JRA-25 and NCEP results. (1)

(2 marks) (HSW Eb, Ec)

(d) Refer to **source D** figure 2
Figure 2(b) and 2(c) shows one of the comparisons between results from NCEP and JRA-25. What conclusions do you draw from this comparison?
Very similar anomalies overall
Both show increased warming in recent years
JRA-25 shows slightly warmer summers as well as autumns

(any two for 2 marks)

6 Refer to **source D**
(a) Figure 3 presents the results as 'Anomalies in NCEP surface air temperature for 2003-2007'. A student seeing this figure says "it is strange that the temperature is higher in autumn than in summer".
This student has wrongly interpreted figure 3. Explain why. To do this you will need to explain what *anomaly* means, as used in source D.
Figure 3 does not show the temperature for 2003-2007 it shows a difference in temperature (1)
The outcomes of the model show the temperature for 2003-2007 relative to the mean value over period 1979-2007(1)
These differences from the mean are described as anomalies. (1)
An anomaly is a deviation from normal conditions. (1)

(any two for 2 marks)

(b) Summarise two main conclusions to be drawn from Figure 3.
Very little anomaly in summer (1)
Anomaly of between 1 and 5 ^{o}C in autumn (1)
Autumn warming greater over sea than over land (1)

(any two for 2 marks)

(c) Why does the paper end with an extensive list of references?
Scientists generally build on the previous work by other scientists (1)
in doing so they give credit to the work of others (1)
also they value work that is replicable and consistent with well established explanations. (1)
(Any two for 2 marks) (HSW Ea, Ed, Ee)

Part A total 32 marks

Part B

7 Computer models are an essential tool for climate scientists. However, the general public and even some journalists do not always understand their role, either treating their predictions as fact or dismissing them as merely guesswork.

Explain why scientists studying the climate in the Arctic use computer models. Explain how they develop a model and test its validity. Include examples to show why the current models have limitations.

Write for a public audience interested in climate change

Use the level descriptors as in the table that follows, but expect to see points such as:

- *the models are based on well-understood physical laws describing transfers of mass and energy*
- *the complexity and scale of the climate system means only computers have the capacity to carry out the calculations*
- *a model is only as good as the assumptions built into it and the completeness of the data fed into it*
- *the feedbacks (such as the ice-albedo feedback or feedback from clouds or water vapour in the air) add to the complexity and the nature of the processes involved is not always well understood*
- *gathering systematic and complete data under extreme conditions, such as in the Arctic, is very difficult.*
- *scientists test their models by seeing how well they can account for the present and recent state of the climate based on past data.*

(12 marks) (Da, Db, Dc, De, Df)

8 The authors of **source D** conclude the paper with the statement
"With models consistently simulating reductions of ice cover into the future, we view the emerging Arctic amplification documented in this paper as but a harbinger of a more pronounced signal to appear in the near future with impacts that may extend well beyond the Arctic Ocean".

They are saying that they expect the effects of climate change to get much worse. Action to minimise climate change is however, primarily a political not a scientific responsibility.

Do you think climate scientists have a particular responsibility to engage in the political process and attempt to influence decision-making on climate change, or should their role be confined to providing information and predictions? Justify your opinion using any ideas and examples you have studied.

Use the level descriptors as in the table that follows, but expect to see points such as:
Yes

- *Their views based on real understanding*
- *they can best explain issues, public engagement*
- *they are respected and trusted by the public*
- *they communicate with other scientists so their views represent more than their own opinion*

No

- *personal involvement or their source of funding can influence their judgements on the science*
- *they have no more political authority than any other citizen and should be involved as citizens, not as scientists*
- *scientists may have irrational or highly partisan views on issues outside their speciality (such as James on Watson on race, see Topic 3.2)*
- *they may not understand the economics and cost-benefit implications of different choices*

A2 Science in Society - Level descriptors for 12 mark questions

The marking scheme for this section includes an overall assessment for the quality of written communication. There are no discrete marks for the assessment of written communication but quality of written communication will be one of the criteria used to assign the answer to one of four levels.

Marks are assigned according to level descriptors.

Candidates would be expected to achieve at least 3 of the 6 descriptors to be awarded marks at that level. Not all descriptors are relevant to each answer.

The marks awarded within the range depend on the extent to which candidates have met the criteria for that range and also on guidance relevant to the specific question

level of response	**descriptors:**	**mark range**
good level 4	• clear exposition of science explanations relevant to the issue; • appropriate and effective use of the relevant ideas about how science works; • good overall grasp of the range and nature of the issue(s); • interprets arguments presented, recognising evidence, claim and counterclaim; • writes well structured argument using a range of evidence to reach a reliable conclusion, includes counter-argument; • fluency and accuracy of expression, with only minor errors of grammar, punctuation or spelling.	**10-12**
competent level 3	• good attempt at exposition of science explanations; • use of some relevant ideas about how science works; • general grasp of the range and nature of issue(s); • interprets arguments presented, recognising some of the main components • writes structured argument using some evidence to reach a conclusion; • accuracy of expression, with some errors of grammar punctuation or spelling	**7-9**
limited level 2	• exposition of science explanation minimal or inaccurate • minimal use of ideas about how science works; • grasp of some features of the issue(s); • interprets only part of arguments presented • arguments presented but with weak structure and/or minimal evidence • accuracy of expression, but with serious errors of grammar punctuation or spelling	**4-6**
inadequate level 1	• exposition of science explanation confused • use of ideas about how science works absent or wrong • appears not to understand the issue; • cannot interpret the argument presented • argument presented as just a claim with no structure or evidence expression unclear with serious errors of grammar punctuation or spelling	**1-3**
0	**incorrect or no response**	**0**
	Total	**12**

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Introduction

In this case study you are going to study articles, abstracts and papers related to the effect of climate change on Arctic sea ice. You should review all the sources carefully before you start to answer the questions. You are not expected to read and understand source D in detail. You will be referred to particular diagrams in the questions.

The sources

Source A: Arctic's personal greenhouse turns up the heat
http://www.newscientist.com/article/dn16623-arctics-personal-greenhouse-turns-up-the-heat.html

Source B: The abstract of the scientific paper: *Polar amplification in a coupled climate model with locked albedo* by Rune Grand Graversen1, and Minghuai Wang in *Climate Dynamics* (2009).
http://www.springerlink.com/content/j2832332508u0156/

Source C: The home page of *The Cryosphere* which is an Open Access Journal of the European Geosciences Union
http://www.the-cryosphere.net/index.html

Source D: The scientific paper called *The emergence of surface-based Arctic amplification* by M. C. Serreze, A. P. Barrett, J. C. Stroeve, D. N. Kindig, and M. M. Holland - the final paper published in February 2009 in *The Cryosphere*.
http://www.the-cryosphere.net/3/11/2009/tc-3-11-2009.html

Source E: Two referees' comments (RC) and authors' responses in the interactive discussion of Source E.
http://www.cosis.net/members/journals/df/article.php?paper=tcd-2-601

Part A
Questions

1 Refer to **sources A** and **B**
In the context of these sources, outline your understanding of these terms:

(a) Arctic (or polar) amplification

(b) albedo

(c) greenhouse gas

(6 marks)

2 In **sources A** and **B** three factors, listed below, are mentioned as possible explanations for the fact that the Arctic air temperature is warming at a faster rate than the global average. All involve positive feedback. Outline each of the three science explanations .

(a) Albedo feedback:

(b) Increased greenhouse effect:

(c) Direct heating effect:

(6 marks)

3 Refer to **sources A** and **B**

(a) Why did the research team that wrote the abstract in source B carry out a computer model experiment to compare the outcomes of their model when the surface albedo was 'locked' with when it was 'unlocked'?

(2 marks)

(b) What did the results of this experiment tell them?

(2 marks)

4 Refer to **source C**.
(a) Explain the importance of 'peer review' in scientific publishing.
(2 marks)

(b) Identify **two** differences between the electronic journal, *The Cryosphere* and a journal published in print.

(2 marks)

5 Referring to **source E** suggest:
(a) **one** reason why the referee, RC S260, might wish to remain anonymous?

(1 mark)

(b) **one** reason why the referee, RC S290, is an appropriate person to be invited to review the paper?

(1 mark)

(c) See 'Response to reviewer's comments' in **source E**
(i) What was the major change to the paper suggested by the referee, R.Graversen?

(ii) How did the authors change the paper in response to this suggestion?

(2 marks)

(d) Refer to **source D** figure 2
Figure 2(b) and 2(c) shows one of the comparisons between results from NCEP and JRA-25. What conclusions do you draw from this comparison?

(2 marks)

6 Refer to **source D**
(a) Figure 3 presents the results as 'Anomalies in NCEP surface air temperature for 2003-2007'. A student seeing this figure says "it is strange that the temperature is higher in autumn than in summer".
This student has **wrongly** interpreted figure 3. Explain why. To be clear you will need to explain what *anomaly*, as used in source D, means.

(2 marks)

(b) Summarise two main conclusions to be drawn from Figure 3.

(2 marks)

(c) Why does the paper end with an extensive list of references?

(2 marks)

(Total: 32 marks)

Part B

Use Sources A to E to provide examples and evidence for your argument.

Some of the marks will awarded for your ability to use an appropriate form and style of writing, to organise relevant information clearly and coherently, and to use specialist vocabulary, where appropriate

7 Computer models are an essential tool for climate scientists. However, the general public and even some journalists do not always understand their role, either treating their predictions as fact or dismissing them as merely guesswork.

Explain why scientists studying the climate in the Arctic use computer models. Explain how they develop a model and test its validity. Include examples to show why the current models have limitations.

Write for a public audience interested in climate change

(12 marks)

8 The authors of **source D** conclude the paper with the statement:

"With models consistently simulating reductions of ice cover into the future, we view the emerging Arctic amplification documented in this paper as but a harbinger of a more pronounced signal to appear in the near future with impacts that may extend well beyond the Artic Ocean".

They are saying that they expect the effects of climate change to get much worse. Action to minimise climate change is, however, primarily a political not a scientific responsibility.

Do you think climate scientists have a particular responsibility to engage in the political process and attempt to influence decision-making on climate change, or should their role be confined to providing information and predictions, such as those in source D? Justify your opinion using any ideas and examples you have studied.

(12 marks)

(Total: 24 marks)