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The Select Committee on the Arctic

Inquiry on

THE ARCTIC

Evidence Session No. 2    Heard in Public    Questions 16 - 28

TUESDAY 15 JULY 2014

10.50 am

Witnesses: Professor Chris Rapley, Dr Ed Hawkins and Dr Sheldon Bacon
Members present

Lord Teverson (Chairman)
Lord Addington
Baroness Browning
Lord Hannay of Chiswick
Viscount Hanworth
Lord Hunt of Chesterton
Lord Moynihan
Lord Soley
Baroness Symons of Vernham Dean
Lord Tugendhat

Examination of Witnesses

Professor Chris Rapley, University College London, Dr Ed Hawkins, University of Reading, and Dr Sheldon Bacon, National Oceanography Centre

Q16 The Chairman: Good morning, and welcome to the second evidence session of the Arctic Select Committee. Today we are dealing with climate change in the first session, and in the second session with sea ice. Perhaps I may ask you briefly to introduce yourselves. I think you have a good idea of the type of questions that we will be asking you. I should say that we are not expecting everyone to answer all the questions, but please speak if you have something to contribute. I should remind everyone that the session is being broadcast.

Professor Chris Rapley: I am Professor Chris Rapley. I am the professor of climate science at University College London. Previously I was the director of the Science Museum and prior to that the director of the British Antarctic Survey, which obviously has a role for UK science in the Arctic. I am also currently the chair of the London Climate Change Partnership, which seeks to climate-proof London.
Dr Ed Hawkins: I am Dr Ed Hawkins. I am the principal research fellow in the National Centre for Atmospheric Science at the University of Reading. My research interests lie in climate variability and predictability.

Dr Sheldon Bacon: I am Dr Sheldon Bacon. I am the associate head of the Marine Physics and Ocean Climate Group at the National Oceanography Centre in Southampton. My main interest is in the high latitude oceans.

Q17 Viscount Hanworth: When we compare the temperature series from the northern hemisphere with the southern hemisphere, we can see that whereas there has been a monotonic increase over the past century in the temperature of the southern hemisphere, there has been a hiatus in the increase of the northern hemisphere temperature, with even a decline towards the middle of the 20th century. However, it seems that the current rates of increase are very high. Can we explain the reasons for this hiatus, which I think is even more pronounced in the Arctic temperature series? Also, can we identify the factors that have led to the underprediction of the northern hemisphere temperature increases, and certainly the Arctic ones, by the models? Finally, can we trust the models to make reasonable predictions of the future, or do they need to be substantially revised?

Professor Chris Rapley: The first observation I would make is that the increase in greenhouse gases in the atmosphere has caused an energy imbalance so that at present the planet is collecting more energy than it is radiating into space. More than 90% of that energy goes into the ocean because it is dark and covers such a substantial part of the planet. The evidence that we have indicates that the energy imbalance is alive and well, if you like, and that a substantial amount of energy is going into the deep ocean. The fact that we see temperature fluctuations in particular regions or in a hemisphere means, particularly in the atmosphere, that we are talking about a few per cent of that energy imbalance. We can
expect to see fluctuations and variations. I am not a climate modeller, but models are not simulations; they are the best that science can do to illustrate what we know and use what we know about the physics, chemistry, dynamics and so on of this complex system. It seems to me that models do a reasonable job of simulating what we have seen so far, but where they differ is where we learn about new science. The fact that there are discrepancies between what the models may have predicted and what is observed shows us that we can learn more about how the planet works. Any predictions of the future have to be taken with caution because there will always be irreducible uncertainties. It is the job of any decision-maker in any walk of life to recognise those irreducible uncertainties and take them into account in their decision-making.

Viscount Hanworth: Perhaps I may make a supplementary comment. We do see a systematic difference between the northern hemisphere and the southern hemisphere. Have the models been able to explain that, because if it could be explained that would surely be a validation of the models to pitch against the declared deficiencies in forecasting temperatures, as has been shown over the past 30 years?

Professor Chris Rapley: I think it would be safer if a modeller commented on what that means for the models. It does not surprise me that the Antarctic, being a huge mass of very cold ice, is responding differently from the Arctic, which is an ocean surrounded by land.

Viscount Hanworth: It has much more inertia.

Professor Chris Rapley: Yes. There is a huge inertia in the Arctic and there are processes which I think are becoming understood that describe or account for why the Antarctic sea ice has extended its areal coverage by a few per cent, whereas of course the Arctic ice, particularly in the summer, has melted back very dramatically. I believe that it is of the order
of minus 7% per year. So there are big differences between the two hemispheres, but how the models interpret those differences should be answered by a modeller.

**Viscount Hanworth**: That is judicious scientific caution. Thank you.

**Dr Ed Hawkins**: Global temperatures have increased by around 0.8 degrees over the past 150 years, but that increase has not been uniform, which you alluded to. Particularly in the Arctic we have seen a warming period from about 1900 to 1940, followed by a period of cooling and then by a period of warming since around 1970. That is particularly pronounced in the Arctic. The features of the warming are pretty well understood. The recent warming has been ascribed mainly to greenhouse gas increases, while the cooling from 1940 to 1970 is generally attributed to volcanic eruptions and an increase in particulate emissions from coal-fired power stations—the so-called aerosols. The warming from 1900 to 1940 was probably due to a mixture of causes: in part to an increase in solar activity, in part to an increase in greenhouse gases, and in part due to random variability in the climate system, as well as to a recovery from previous volcanic eruptions in the late 19th century. There are many things that affect how global temperatures and Arctic temperatures behave, and we have had to piece them together to understand the whole, which is a slowly varying temperature that is generally increasing but has variability on top of the long-term increase. As for the models, they reproduce the spatial pattern of that warming particularly well. We can see higher rates of warming in the Arctic, at about two times the global average, and models have reproduced that. The observations show that the land is warming up more than the ocean, and again the models reproduce that. We see more warming in the northern hemisphere and so on. The models reproduce the spatial pattern of warming very well, so when you include all the different factors that change global and Arctic temperatures, they can reproduce them relatively well. However, on top of those is a natural variability—
random fluctuations in how the climate behaves on top of any changes that are due to human activities and other forcing agents.

**Q18 Lord Soley:** My question in a sense follows on from that. I am interested in the question of uncertainty in the predictions about the Arctic. What techniques do you use to monitor the changes in the Arctic, and how reliable are they in predicting future trends?

**Dr Ed Hawkins:** Is this a question about current monitoring?

**Lord Soley:** Yes, it is.

**Dr Ed Hawkins:** We have pretty good records of land temperature in the Arctic and from long-term meteorological stations situated on the northern land areas. We have less information about temperatures over the ocean in the Arctic, which are particularly difficult to observe for obvious reasons. We are fairly confident about the temporal change in the warming, although there are uncertainties because we have not observed everything at all times. Unfortunately, we do not have a time machine and so we cannot go back and make observations for where we do not have any. We are reconstructing from the information that we do have, and that has improved over time. We are taking more observations now than we were and our ability to monitor what is going on has improved, but it could be improved further.

**Lord Soley:** So you are saying that you can monitor land temperatures fairly well but it is more difficult to monitor at sea.

**Dr Ed Hawkins:** We do have some monitoring.

**Lord Soley:** Of course, I understand that. I want to ask a follow-up to that. Given the differences and the difficulties in getting the models right for the whole thing, how confident are you about future predictions?
Dr Ed Hawkins: The future predictions are based on sound physical principles. We understand the basic physics of the greenhouse effect, so if we add more greenhouse gases to the atmosphere, temperatures will rise. We have understood that since the 1860s.

Lord Soley: But the Arctic is different from the rest of the planet.

Dr Ed Hawkins: Yes, so the Arctic is projected and has been observed to warm at around twice the average global rate. That is roughly speaking. We do not know whether the rate is 1.9 times as fast or 2.3 times, but it is warming at roughly double the rate. Again, that is based on sound physical principles, because there is a feedback. As you warm the planet you melt the ice, as we have been seeing. That reduces the reflectivity of the planet so that more energy is absorbed into the oceans rather than reflected out into space, which amplifies the warming that we are seeing. Again, this is based on physical principles and without necessarily any reference to models.

Lord Soley: You are therefore assuming that the variability, and therefore the difference in the Arctic as opposed to other areas, will continue. Will you be able to measure that?

Dr Ed Hawkins: We expect to see amplified warming in the Arctic in the future, and on top of that we will see random fluctuations that are to a degree essentially unpredictable. They will mask or enhance temperature trends at different times in the future. However, we will see an overall warming with an Arctic amplification.

Professor Chris Rapley: It is probably worth making the point that you can imagine the human signal, the secular increase of temperature, emerging out of fluctuations. Scientifically that is called the signal-to-noise ratio. When the signal emerges from the noise, you have made a detection. It is not at all clear that the signal-to-noise ratio in the Arctic is better than down in the tropics, because although the fluctuations in the weather in the tropics are much smaller, the secular signal from human drivers of change might be more
easily detectable there. The point is that the amplifying process that we have just heard about, the so-called ice-albedo or snow-albedo feedback, amplifies the variability just as much as it amplifies the signal. It is a very complex area.

In terms of monitoring, I would add that for 40 years now we have had satellite observations of physical features such as sea ice coverage, which have been enormously helpful in revealing what is going on in the Arctic. Not all the satellites go right up to the North Pole, although more recently some satellites have been launched that have what is called a higher-inclination orbit, so they can get closer to it. However, the coverage has been sufficient to show that there have been very dramatic changes. Interestingly, the fact that the models may not be perfect should not be a source of complacency, because those models have underestimated the rate at which the sea ice has been observed to decline, so the models can err either way.

You have heard that we do not have a time machine, but actually we do have one in the sense that we have evidence of how the Arctic has behaved in the past. That evidence has come from ice cores, lake sediments and tree rings. Although, as you well know, there is huge controversy around the so-called hockey stick and whether tree ring data are reliable about the past, at least one recent paper seems to be fairly convincing. It suggests that what we are observing despite the natural variability in the Arctic is rather unusual now compared with what has happened over the past 1,000 years or so.

**Lord Soley:** Do you mean by that that the speed of change has become even greater?

**Professor Chris Rapley:** I mean the speed and the size of the change.

**Q19 Baroness Symons of Vernham Dean:** I want to pick up on the time machine point touched on by Dr Hawkins and the random nature of these temperature fluctuations. I was very interested in what he said about the 20th century in that there was Arctic warming at
the beginning of the 20th century because of solar activity and the effect of greenhouse gases. Then we had a cooling period and now we are in a warming period. We do not have a time machine, so how do we know that these periods of 30 or 40 years do not happen as a matter of natural course in every century? Why was this not happening in the 1800s and the 1700s? Perhaps you have a bit of a time machine, but I was very struck by the random nature of how this is going. Has it always happened in every century?

**Dr Ed Hawkins:** Undoubtedly yes. We do not have long records going back to those times.

As an aside, we have additional observations that we have not included in our estimates, because they are handwritten and we have not digitised them all. A very good task would be to rescue some of the older data that we have not yet used in order to reconstruct some of the variability further back in time. Particularly during the period from 1900 to around 1940, there are several factors to take into account: solar activity, recovery from volcanoes, and a small greenhouse gases increase, along with a suggested contribution by soot emissions. Soot lands on the snow, making it darker and less reflective. That was happening particularly during that period. Also, we think that there was a positive warming from variability, which we would expect to see in the future as well as back in the past.

Several factors will come into play to cause the time structure of the warming that we are seeing. There are several factors, and variability has happened in the past and will continue in the future. It is entirely plausible that we will see a decade or more of cooling during certain periods in the future on top of a long-term warming trend. Although temperatures will generally go up, that will not happen smoothly; rather, it will happen in fits and starts as variability enhances or counteracts the trend.

**Viscount Hanworth:** I have one more question on the model described by Dr Hawkins. In modelling the temperature series, do you regard the random fluctuations as statistically
independent of the underlying trend, or would you imagine that a positive deviation from the trend would actually feed back into the trend in order to amplify it further?

**Dr Ed Hawkins:** I think it is fair to say that they are not independent.

**Lord Hunt of Chesterton:** It is about the distance.

**Viscount Hanworth:** I am sure that they are not independent, so I wonder whether the modelling takes that into account.

**Dr Ed Hawkins:** They are not independent, which is a bit of a challenge because the particular realisation of variability that we have seen in the real world is not seen exactly in the modelling. We do not see the fluctuations occurring at random times.

**Viscount Hanworth:** The positive deviation ought to be taken into account in modelling the trend, and you are saying that it is taken into account.

**Dr Ed Hawkins:** The models reproduce similar features. We do not expect them to reproduce the exact timing, but they have reproduced similar features in the simulations.

**The Chairman:** Can I follow up on the first question and ask you once more what the projections are for the future? What can we expect to see happen over the next one or two decades? What is the best estimate?

**Dr Ed Hawkins:** Do you mean for temperature in particular?

**The Chairman:** The temperature and other major effects. Perhaps you can respond briefly.

**Dr Ed Hawkins:** We expect to see continued temperature rises in the Arctic at around twice the global average rate. There is also the contribution of variability, which could go against that long-term trend in the near term. We might see a period of cooling; that is entirely plausible. However, we might see variability enhancing warming as well. The next 10 to 20 years are particularly difficult because of the interaction between the long-term trends and the variability on top of those trends.
Q20 Lord Hunt of Chesterton: First, I must declare my interests. I am the president of ACOPS, an NGO. I am a former professor at University College London and I am a director of a small consulting company. Dr Bacon has not spoken so far. Perhaps I may ask him about the data on the Arctic and how the Arctic may be connected to what is happening in the north Atlantic. As you know, there were some discussions earlier on that the so-called thermohaline circulation would dominate changes in a very dramatic way, but equally the Met Office itself, which always believes in the Gulf Stream being driven by the westerly winds, means that there are two big effects. Do we have enough data on these things? Is the modelling adequate, and is the public explanation of these relatively big effects becoming better understood?

Dr Sheldon Bacon: It is probably worth commenting, in the context of an inquiry such as this about the Arctic, that the Arctic is a great deal closer than we generally recognise. If you start in the Shetland Islands and go five miles west, you only have to go down 500 metres into the ocean to find a freezing cold body of Arctic water, so the Arctic is part of our territorial waters; it is just not at the surface. Those waters happen to comprise roughly half of the headwaters of the feature that Julian referred to: the thermohaline circulation, which is also called the meridional overturning circulation. It is mostly commonly perceived by the press and the public as the surface expression, which is the Gulf Stream. It draws warm Atlantic waters northwards past our latitudes and has been called a fan-assisted storage heater because the westerly winds extract heat from the ocean. The ocean cools, the atmosphere warms, and thus delivers us our benign climate. Regions at the same latitudes experience much colder and harsher continental climates that do not have that oceanic heat supply to ameliorate the conditions.
Can the Arctic play a role in modulating the circulation feature, which takes warm water northwards at the surface and cold dense water back down south? Yes, it can. There is a well hypothesised mechanism whereby the Arctic is the source of huge volumes of fresh water. Some 10% of the entire world’s river flows enter the Arctic Ocean, although the Arctic Ocean itself comprises only 3% of the world’s ocean surface area. That huge volume of fresh water, if released in a burp, can interrupt the overturning circulation. There are stories about it stopping. I think that is highly unlikely, but it certainly stands to slow it down, and various model projections into the future do indicate that that might happen—possibly to the order of 20%. It might have that level of impact on our climate by delivering less heat.

Lord Hunt of Chesterton: My question turned more on the data and the analysis. Are we measuring the ocean and the surface waters of the ocean in sufficient detail to detect this? Let us suppose that there was going to be a significant oscillation. Oscillations do not happen in a day. As we know from El Niño, they develop over time. By studying the oscillations of the Pacific, people can now forecast what is going to happen to their crops in terms of floods and so on. Could we and should we be doing something like that in the Arctic?

Dr Sheldon Bacon: The state of knowledge is problematic but improving. If we go back into the past, we find that there is a scarcity of data through difficulty of access. The Arctic is covered in ice and the climate is harsh. Analyses that attempt to identify changes in temperature and in the freshwater content of the Arctic Ocean, and thus the dilution of salinity, must perforce aggregate over long periods of time. It is therefore very difficult to identify changes on timescales shorter than a decade. Typical analyses involve comparing the 1990s with the 2000s, for example. That has started to change through the development of new technologies. Ice-tethered profilers are gadgets that sit on an ice floe and have a kilometre of wire underneath to provide ocean data in the upper waters, where it is needed.
Remote-sensed measurements, which my colleagues in the next session may tell the Committee about in the context of sea ice, are also effectively able to detect sea surface variability through the ice. They can tell you about circulation changes, which in turn can tell you about the storage and release of volumes of fresh water.

The question therefore has two answers. This is rather hard to do for the past other than on rather coarse timescales, but our ability is improving. Boundary measurements in the ocean are quite good sources of data.

The Chairman: Let me say that this session is not just about sea-based elements but about the land-based areas of the Arctic as regards climate change.

Dr Sheldon Bacon: I think the land is not too bad.

Lord Hunt of Chesterton: Do we have data on Russia?

Dr Sheldon Bacon: I am sure that the Russians have data on Russia, but it is rather hard to extract them. It is possible, but that usually involves some scheme involving lobbing balls over walls, as it were. You can give a friend in Russia a programme and he will send you back a derived product.

Lord Hunt of Chesterton: It seems to me that one of the things that this Committee might discuss is whether more could be done on collaborating with Russian colleagues.

Dr Sheldon Bacon: Yes.

Lord Hunt of Chesterton: You said that it is important, so if it is important, people can make the effort.

Dr Sheldon Bacon: It is indeed important. Thus far, when I have required certain amounts of Russian data, I have used the method that I described, which relies very much on personal contacts. You have to know someone who can access, in a perfectly proper way, foreign archives and deliver, again in a proper way, a derived product.
Q21 The Chairman: If we had a wish list of what data we would like to collect but are not collecting for the region generally, what would they be?

Professor Chris Rapley: For me, it would be a greater density and range of ocean measurements because, as I said earlier, that is where the energy tends to go. In the end that is what will be a driving force in the climate change that follows. In particular, for example, the absorption, or not, by the Arctic Ocean of carbon dioxide is virtually unmeasured. Is that fair to say?

Dr Sheldon Bacon: It is, yes. Carbon dioxide is important, but while physical oceanographic measurements are growing and we can start to look at circulations and transports of heat and fresh water, it is very difficult to say much about biogeochemical properties or likely changes in the ecosystem.

The Chairman: Do you have a wish list, Dr Hawkins?

Dr Ed Hawkins: As Chris has said, ocean observations in the centre of the Arctic would be very useful not only for monitoring but to help to validate and test our models and our ability to simulate the climate in the region. That would be particularly useful.

Dr Sheldon Bacon: Key to this would be atmospheric observations over the ocean. That is one thing that is almost totally absent.

Dr Ed Hawkins: One other point I mentioned is data rescue, where we recover data from handwritten records dating all the way back to 1800 or so that have not been digitised until now. They can tell us a lot about variability, which we think is going to be very important.

Professor Chris Rapley: Perhaps I could add a word on the Russian data that were mentioned by Lord Hunt. It is certainly clear that the Russian meteorological network was much reduced following the fall of the Soviet Union, simply because there was not the finance or the infrastructure to keep it going. We should mention that the World
Meteorological Organization and the World Climate Research Programme have recognised this and have attempted to assist Russian scientists to carry on making useful observations. I cannot remember the name of the particular site, but one investment was celebrated: it was an Arctic Rim station where the finance was projected into Russia in order to provide support. This problem has been recognised and people are trying to work through it.

Q22 Lord Addington: We have heard through other work in the Committee that Canada is the other big player in the area. I was wondering whether you need support. What have we done to encourage the Canadians, as members of the Commonwealth, NATO and all the world organisations to actually undertake an interface with Russia? Are we supporting them or helping them to do this?

Professor Chris Rapley: You may recall the famous International Geophysical Year 1957-58, which was the third major international effort that included a massive programme to look at the polar regions. Then in 2007-08 we had the International Polar Year, which had 60 nations represented by 15,000 scientists. Interestingly, I was the chair of the planning group for it. The International Council for Science and the World Meteorological Organization sponsored it. The Canadians played a tremendously strong role in the International Polar Year, and in doing so established very close collaborations with the other Arctic Rim science nations, including the Russians to the best of their ability. The Canadians essentially saw that climate change in the Arctic was of huge national interest to them and they have therefore felt very motivated to be central players, and indeed have continued to be so.

Q23 Lord Hannay of Chiswick: Perhaps Dr Bacon can start this response. Can you say a bit about the changes that we are seeing within the Arctic Ocean and within neighbouring waterways as a result of rising temperatures and declining sea ice? Is it possible to predict what any future impacts might be?
Dr Sheldon Bacon: That is rather tricky to answer because of the paucity of observations. The things that we observe are the rising temperatures and the declining sea ice. Beyond that, my personal view is that possibly the most important clear change that we have seen—let me take a step back—is that if you take the ice away from the top of the ocean, the ocean is exposed to direct forcing by the winds, which means that the ocean will move in response to the winds blowing. This is called spin-up. You are removing a lid, so the winds can in effect transmit momentum directly to the ocean circulation. At the present time, the Arctic is a very sluggish ocean. It has average circulation speeds of perhaps a couple of centimetres a second. That is slower by an order of magnitude or more than typical open ocean circulation speeds. If the ice is removed and the ocean can then spin-up, the Arctic Ocean might become more like an ordinary mid-latitude ocean like the Atlantic.

If that happens, one remarkable and potentially worrying possibility is that the ocean turbulence could increase. At the moment the Arctic is very quiescent. Turbulence generates mixing in the ocean. If you were to take a slice down the middle of the Arctic, it would look like a Victoria sandwich. There is cold water at the top, cold water at the bottom, and in the middle is the jam of warm water that originated in the Atlantic. It cannot reach the surface because it is at least 200 metres down. If you allow for an increase of an order of magnitude or greater in turbulent mixing, that heat could be mixed up to the surface through the insulating overlying layer of cold water. That is a potential direct consequence of sea ice decline. We have observed the first evidence of spin-up through colleagues at the Centre for Polar Observation and Modelling at UCL. The recent retreat of Arctic sea ice permitted the atmosphere to grab the ocean north of Alaska and Canada and caused a spin-up of a feature called the Beaufort Gyre. This is detectable from space because basically it causes a bulge in the ocean surface. What is the possibility of that happening? Spin-up can also store fresh
water by effectively corralling the water into a particular place. If you allow the bulge to collapse back to a level surface, that can export or flush out a large volume of fresh water that originated from the rivers. That can impact on the overturning circulation outside the Arctic.

Perhaps of more concern for the interior Arctic is that if you enable a mechanism to mix heat up from below towards the surface, the confidently predicted seasonal decline of sea ice could very rapidly transition into a continuous absence through accessing the large subsurface reservoir of heat.

Those are the sorts of potential impacts that are in the front of my mind.

**Lord Hannay of Chiswick**: Would that mean that we would see a rate of melt of Arctic sea ice at twice the rate of sea ice melt at, say, the Antarctic in those circumstances?

**Dr Sheldon Bacon**: Yes.

**Q24 Lord Hannay of Chiswick**: Could we go on to a slightly different aspect? Is there any clear scientific correlation between the effects of warming in the Arctic on both land ice and sea ice and the rise in sea levels outside the Arctic? Is there a clear correlation so that we know that if the land ice and the sea ice melt, as the model predicts in the Arctic, there will be a rise of X elsewhere?

**Dr Sheldon Bacon**: Sea ice melt obviously will not do anything to sea level rise, but the major ice cap is Greenland, and its melt rate has accelerated. Perhaps I may refer the question to a colleague, Professor Andy Shepherd, who knows about terrestrial glaciology, is witnessing the session and will come before the Committee in the second evidence session. But, yes, Greenland ice will melt and sea levels will rise accordingly.
**Lord Hannay of Chiswick:** My question is whether there a clear correlation: that is, can you scientifically state that if the Greenland ice cap melts in a particular volume over a particular period, that will produce a particular amount of sea level rise?

**Dr Sheldon Bacon:** Oh yes, absolutely.

**Lord Hannay of Chiswick:** Is that public knowledge?

**Dr Sheldon Bacon:** Yes, it is. If you add mass to the ocean it will rise by a certain amount. That has presently been identified with some confidence as being part of the last century’s contribution to sea level rise. The other part is thermal expansion.

**Lord Hannay of Chiswick:** And the evidence we have from the facts in recent years shows that that correlation is robust.

**Dr Sheldon Bacon:** Yes.

**Lord Moynihan:** Perhaps I may preface my supplementary question with a declaration of interests by declaring my shareholdings in Rowan Companies plc and in Canadian Natural Resources Ltd. I am also a director of a number of renewables and clean tech companies in the UK and the USA, none of which is active in the Arctic.

Dr Bacon, I was really interested in your comments about the impact of turbulence. Given Lord Hannay’s question about future impacts, can you make comment on the impact that turbulence could have on a shift in marine distribution, particularly in the context of fishing grounds, plankton and the general depletion of fishing stocks, as well as the timescale of these effects? Some observations on these would be very helpful.

**The Chairman:** Would you please also address the issue of ocean acidification and whether that would be relevant?
Dr Sheldon Bacon: That, too, is immensely difficult, because we lack carbon measurements in the ocean, so it is very hard to make any clear statements about which way the Arctic is going. It is likely to be acidifying, but we do not know.

On the subject of ecosystem variability, it is almost certain to change. However, you can find arguments on both sides for which way it will go. It is a very difficult topic. If you consider specifically turbulent mixing, at present in the Arctic there is a feature called subsurface chlorophyll maximum. Chlorophyll needs to exist within a range of light so that it can grow, but it also needs to swim in a bath of nutrients so that it can feed. At present, those two conditions are met at around a depth of 50 metres. If the turbulent environment were to strengthen, you could mix the nutrients up from below more powerfully and the chlorophyll could exist closer to the surface, where they would rather be. That has large ramifications for the biological carbon pump—the amount of carbon that is extracted from the atmosphere and deposited into the sea bed—and for the ecosystems that thrive on a likely greater bloom of plants in the ocean and the chlorophyll that would come to exist as a result of the greater uploading of nutrients.

Lord Moynihan: Have there been any studies that you can recommend or direct us towards on this specific issue? I acknowledge your opening comments about the proximity of the Arctic to the Shetland Islands, and therefore quite clearly we would be concerned, for example, about the impact on the Scottish fishing industry over time. If you could direct our attention towards some studies, possibly on both sides of the argument, that would be very helpful.

Dr Sheldon Bacon: Perhaps I may reply to the Committee in writing on this.

Lord Hunt of Chesterton: Researching something is always a good thing.
Q25 Baroness Browning: Can we turn to the land-based impacts of changing temperatures and how the permafrost thaw might impact on both species and the indigenous populations? Are we already seeing modification of species, and has that had an impact on working practices and so on among the indigenous populations?

Professor Chris Rapley: Everyone is looking in my direction. I am not sure about ecosystems and so on because I am not an ecologist, so perhaps I shall pass on that. I would say that there is plenty of evidence, particularly from the major operators like the oil companies that are working in these high latitudes, of a reduced period during the year when they can use ice roads. There are problems with permafrost heave that is damaging infrastructure. It is not scientific, but I was very taken two years ago while at a big conference in Montreal, the third conference of the International Polar Year looking at the results entitled Results to Action. The conference organisers went to great lengths to get representatives of the Circum-Antarctic peoples to take part in the conference. What I thought was fascinating—it can be discounted judiciously—was the consistent message from the elders of the Inuit and others who are long-standing survivors up there. They said, “We are survivors. We survive in a very harsh climate and we have done so for generations. Our traditional knowledge is based on a series of heuristics that tell us how to cope with various extreme weather events. When we see these changes, our traditional knowledge tells us that what we are experiencing now is outside the realms of our past experience”. The sealers are finding it very difficult, although interestingly they are now using modern technology to plan their sealing expeditions. The reindeer herders are also having difficulties. One interesting anecdote was that they had not previously experienced freezing rain early in the winter season. The rain lays down an impervious layer in the snow and the reindeer find it much more difficult to smell and find their fodder, thus making it much more difficult for them to
survive the winter. A number of pieces of anecdotal evidence of that sort show that these peoples are in trouble and are facing conditions that they have not encountered previously.

**Baroness Browning:** Who would actually take the lead on looking at possible changes in species modification and the impact on the indigenous populations?

**Professor Chris Rapley:** The Royal Swedish Academy of Sciences runs a research station at Abisko. Professor Terry Callaghan, a British expatriate, has been the director for years. I would recommend him as a good expert to talk to about these issues. I do not know the specific Canadian, American or Russian ones, but we could find them for you and write to the Committee.

**Lord Tugendhat:** Can I take up the anecdotal point that you made? You say that the Inuit are talking about things that are new to them in that they have not occurred in their life experience, and that you have scientific evidence and research that goes back for a period. However, if we were to delve deeper into history back to the period when the Vikings first settled in Greenland and the settlements then disappeared because of changes in the weather, do you think that what is happening now is very different in kind from what might have happened in the past? Alternatively, do you think that what happened in the past when settlements were formed and disappeared might have been more extreme or variable than the conditions at present?

**Professor Chris Rapley:** The paleoscience studies that look at the ice core, tree ring and lake sediment data do see those signals from the medieval warm period and the little ice age. There is a very interesting paper on this and I can give the Committee the reference. It attempts to look at the impact on sea ice covering the Arctic and air temperatures, and finds that sometimes when things have been warmer in the air the sea ice has reduced while at other times it has not. There are some quite complicated processes at play, and indeed the
warm water injection from the north Atlantic seems to be a much stronger indicator of ice retreat than air temperature necessarily might be. That at least is according to the paper, although it is always dangerous to base any conclusions on one study, but this one does seem to be fairly robust.

It is often suggested that the fact that there have been warm periods in the past indicates that what we are seeing at present is not something that we should particularly worry about, but what that actually shows is that the climate system is what I would call a frisky beast that is affected by quite small driving forces and cumulative forces. The fact that humans have changed the energy balance, which we know is true, leaves open the question that if one asserts that what we are seeing at present is just a natural fluctuation, how is it that the physics of the greenhouse effect have been neutralised? We need to see a mechanism to explain that, but as far as I am aware there is presently no such mechanism.

I can say one other thing on fluctuations in the Arctic. If we go back to the last ice age, again the ice core data from Greenland in particular and backed up by lake sediment data across Europe show that the climate was capable of flickering. It would suddenly change by five degrees or so beyond the resolution of the ice core, and possibly it happened in less than 10 years. It would jump up to a new state, sit there for 20, 50 or 100 years, and then jump back down again. The mechanisms that drove those flickers seem to be specific to the cold phase of the climate when it is in an ice age. The hypothesis is that it probably has something to do with fresh water injections into the meridional overturning circulation, so it is not clear that those mechanisms apply now that we are in a warm state; it simply illustrates that this is a very complex system that can change, through small driving forces, very dramatically.

**Viscount Hanworth:** I have a brief question regarding the balance between respiration and photosynthesis in the Arctic. I have just read that at present there is a consensus that the
Arctic is now in fact a sink rather than a source, which is quite a different appraisal from what seemed to be in people’s minds 20 years ago when there were horror stories about the effect of emissions of methane from the melting tundra. What is the current prognosis, and will that horror story play out at some point in the future?

*Dr Sheldon Bacon:* The Arctic Ocean is a sink for carbon at present. How that will change in the future is not clear.

*Lord Hunt of Chesterton:* As far as I understand it, the party line—

*The Chairman:* Perhaps we could hear from the witnesses just for the moment.

*Professor Chris Rapley:* Briefly, the alarming prospect of methane clathrates being released from the shallow oceans or methane being released from the permafrost is a scientific issue that needs to be studied very closely. For my own part, I look back at what the paleo-evidence is about the state of the planet in previous warm periods, the Illinoian and so on. What we do not see is a dramatic thermal runaway of the planet. The planet was a few degrees warmer and sea levels would have been higher, but we do not see massive and long-lasting methane injections. We were discussing this before we came in, and we suspect that methane is a relatively short-lived greenhouse gas, although a very powerful one, and so a sudden release of a certain amount of methane will have a transient effect, but it seems that it is then oxidised away and that is an end to it. I think that is where the story is now. It is not quite as frightening as it seemed to be a few years ago.

*The Chairman:* Thank you, that is very useful. I would like to get one thing clear on permafrost. On reading the background material, the boundary of the polar permafrost seems to have retreated, I believe, by around 100 kilometres in the past year alone. For the record, would you quantify the big picture on what is happening on permafrost? Is this really happening?
*Dr Sheldon Bacon:* I do not have the numbers to hand.

*Professor Chris Rapley:* It is regionally variable. It is happening more in some places than in others. Again, perhaps we may provide the Committee with further written material.

**Q26 The Chairman:** That would be very useful. We are looking at strategies that we might be able to apply locally in the Arctic. Could you comment on the mitigation and adaptation strategies in the Arctic itself? Are there particular things that we should be getting on with and doing that will help us to mitigate or to adapt?

*Dr Ed Hawkins:* One possible aspect is emissions of soot in the Arctic, an example of which would be black carbon, particularly from shipping. As I mentioned earlier, the soot can be deposited on the ice and thus reduce its reflectivity. It then absorbs more energy, which increases the rate of melt. We should ensure that we reduce as much as possible such emissions around the Arctic and bear it in mind when considering future growth in shipping. That is one avenue to think about.

The other impact that could be touched on a little is coastal erosion, particularly in Alaska. There is evidence that the removal of the coastal sea ice has allowed waves to erode the shorelines much more than in the past. Protecting shorelines potentially needs to be thought about as well.

**The Chairman:** Alaska has quite a long shoreline.

*Dr Ed Hawkins:* It does indeed, yes.

*Professor Chris Rapley:* That was in part the point I was going to make. The residents, the indigenous peoples, will almost certainly have to retreat from some areas because it will be hugely expensive and quite difficult to protect them. Given that these are small communities, it is probably not cost-effective to do so. Of course, they also see big opportunities with the likely increase in shipping traffic in the summer. There are plans for
large ports and installations that will require monitoring services, support services, rescue services and so on. The people who live in the area are very resourceful—they have had to be. They are looking for opportunities as well as considering the negative side.

Lord Hannay of Chiswick: I should like to ask a follow-up question to that. The Arctic Circle is a very thinly populated area. Does it therefore offer quite a bit of scope for the indigenous peoples to move if the climate compels them to do so in a way that might not be the case in parts of the world that are not so thinly populated?

Professor Chris Rapley: I am sure that the reindeer herders will be very flexible. Part of their annual cycle is to move considerable distances. The coastal communities are by and large not rich, so poor people are seeing what infrastructure and property they have threatened. I think they will probably have to move, and I suspect that individual Governments may well have to take a position in assisting them to do so.

Q27 Baroness Symons of Vernham Dean: Can we turn to the importance of the research going on in this country? I was staggered to learn that 77 institutions in the UK are engaged in research—46 universities and 20 research institutions, as well as others. I was also staggered to see that this is all being done on the princely sum of £50 million, which struck me as being on the low side. I imagine that you would agree and say, “Absolutely. We need to see lots more money going into this research”. The Government’s Arctic Policy Framework says that, “highly regarded UK science is present in most areas of Arctic research and also helps to underpin good policy.” I am sure you would all agree with that, being part of the research institutions. However, are we really able to do our bit on this? Are there areas of research that you think are being neglected for want of money? Can you make some sort of comment on the real value of what this country is able to do? Can you also say how much of the research that is undertaken in this country is actually used by the Arctic Council, and very
particularly within the six working groups? Are there formal links between the working groups and the institutions carrying out the research?

**Professor Chris Rapley**: From my experience, it is certainly true that UK scientists have had an interest in the polar regions, particularly the Arctic, for a long time and that there is plenty of evidence of both excellence and volume of research. I have a background in satellite observations of the earth and I think it is fair to say that the European Space Agency has an exemplary record of developing satellites that use novel instruments to monitor the Arctic, particularly the Arctic ice. It has been UK science that has very much influenced the development of the ERS-1 and ERS-2 satellites—Envisat and now CryoSat. In fact, for many years CryoSat was known as “Duncansat” in honour of Professor Duncan Wingham, who is now the chief executive of the Natural Environment Research Council. I shall leave others to comment on the land side and on the surface side both on the land and in the ocean. The British Antarctic Survey operates the Natural Environment Research Council’s research base, Ny-Ålesund, on Svalbard. Universities and others can use the base to carry out excellent research. BAS’s icebreaking vessel, the RRS “James Clark Ross”, operates in both the Arctic and the Antarctic and carries out ice and oceanographic research. We have good assets and we deploy them routinely to do excellent science.

The connection with the Arctic Council is, in my view, a little more problematic. Certainly when we were developing the International Polar Year, the Arctic Council invited a number of us to make presentations to the plenary sessions because its members were interested in understanding what was being planned, executed and delivered. But my understanding is that the presence of UK scientists on the advisory committees is at best patchy, because there does not seem to be a well established funding mechanism by which they can be delivered. Obviously the FCO has observer status on the Arctic Council and exercises its
position very effectively, but I understand that there is a bit of a gap as regards scientific expertise being delivered to those groups. That is quite different from the Antarctic, where the Scientific Committee on Antarctic Research makes the connection very effectively.

**Baroness Symons of Vernham Dean:** That includes British scientists, but not in the Arctic. Do they want us there or are they actually a bit wary and chary about it? Is it just the money or is it that they are not entirely happy with the idea?

**Professor Chris Rapley:** My experience in the International Polar Year was that they welcomed any insights that would help them with the issues that they were attempting to address. As far as I know, they would welcome UK scientists to the advisory committees, but the Foreign Office view might be different.

**Baroness Symons of Vernham Dean:** But there is no funding mechanism as it is.

**Professor Chris Rapley:** Not that I am aware of, no.

**Lord Hunt of Chesterton:** Voluntary bodies sometimes fund British scientists to go to those meetings.

**Dr Sheldon Bacon:** It is worth noting that there is a different body called the International Arctic Science Committee. UK scientists play a full and active part on that committee and in all its working groups, so that is one vehicle whereby research and advice can find their way to government. The Arctic Council is a rather different organisation in that it is more of an intergovernmental and political body than an intergovernmental research and advisory body. You have picked on an interesting point here. We do not really have much in the way of access to or impact on the Arctic Council.

**Dr Ed Hawkins:** Perhaps I could just add that UK research in my area is very highly regarded. We lead the way in some areas and are very highly regarded in others. There are lots of formal and informal collaborations with the international community. The UK is involved
with many international committees, as Dr Bacon has highlighted. In a couple of years’ time we will have the Year of Polar Prediction, and the UK is very heavily involved in it. There are many other committees that UK science is involved with.

Baroness Symons of Vernham Dean: Are there are some bits where we are regarded as the team leaders?

Dr Ed Hawkins: Yes. We are certainly leading the way in some aspects of Arctic research.

Q28 The Chairman: Thank you very much. I want to take us back to the really big picture. Before we finish, perhaps each of you could outline what you think is the most important priority in your own area when considering the recommendations that we might make in our report. I am putting you on the spot a little with that.

Dr Sheldon Bacon: The Arctic is very difficult to understand as a system because there is a dynamical feature called the deformation radius. That can be thought of as the natural turning circle of a fluid. In the Arctic Ocean it is very small, which means that ideally you need to take measurements at a spacing of 5 kilometres in the deep water and 1 kilometre or less in the shallow water. Super-high resolution measurements, indeed not even satellites, do not get down that far, which is a challenge for measurements and modelling alike.

Dr Ed Hawkins: I would say that it is about improved observations in the central Arctic to help validate the models and satellite observations in order to understand how the Arctic varies over all the timescales—from days to decades.

Professor Chris Rapley: For me, it would be to distinguish clearly between two strands. We have heard that the Arctic is a very complicated part of the earth’s system, which in itself is very complicated. Just as an aside, if you wanted to pick something that would be particularly mischievously difficult to model, it would be sea ice. That is because you need to
resolve such small spatial and temporal scales, and the connection between the ocean, the atmosphere and the ice is so complex. On the one hand there is still a huge amount of basic research to do in order to understand how the system works. As we have heard, there is a growing database to work with, but it was poor in the past. Maintaining that in the future will be important.

On the other hand is the issue that has just been raised, which is that of connecting what we already know with the decision-making process. I think that is very important. These two things get entangled and are often muddled together. Separating them and dealing particularly with the linkage between scientific knowledge and the political process—the local decision-making process—is an area that should be developed, because it would be helpful.

**The Chairman:** That is very useful and I am sure that it is something we will pursue. I am afraid that I must ask you rather unceremoniously to make your exit quite quickly so that we can bring in the second team. If there is anything that you feel we have not covered sufficiently and you want to submit further evidence, along with the areas that you have already mentioned, we will be very pleased to receive your material. Again, thank you very much indeed.