GREENPEACE Briefing

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The State of the Cryosphere - what the ice is telling us

Introduction

The cryosphere comprises all the frozen water and soil on the surface of the Earth. The book from Cambridge University Press, “Mass Balance of the Cryosphere”, to be published in January 2004, focuses on two key components of this sensitive environment: land ice, in the form of ice sheets, caps and glaciers; and sea ice. These are important indicators of both short and long- term climate change. Written by a team of 23 expert scientists and edited by Dr Jonathan Bamber and Dr Anthony Payne of Bristol University, the book warns that the cryosphere is extremely sensitive to climate change and we ignore at our peril the dramatic and disturbing trends that have already been observed globally.

Summary Findings

- The cryosphere is generally in a poor state and the scientific consensus that average global temperatures will continue to increase over the next century means that the risk to these already climatically sensitive areas is increasing.

- The Greenland ice sheet - the biggest ice mass in the Northern Hemisphere - is losing mass from around its margins. Some climate models predict it could lose half its mass in the next 500-1000 years, contributing 3 m to global sea level rise.

- The amount of Arctic summer sea ice is has reduced dramatically in the past 20 years and could disappear completely within an estimated 100 years.

- Globally mountain and alpine glaciers everywhere are losing mass, except for a few glaciers in Europe that are not retreating. The rate of retreat is expected to accelerate over the next Century.

- Antarctica - the largest ice mass in the world - presents a more complex picture, although parts of the West Antarctic Ice Sheet and Peninsula ice shelves are in decline.

- Evidence indicates that the some of the changes being seen in the cryosphere are related to the underlying anthropogenic (man-made) component of global warming.

Key findings

The implications of the decline of the cryosphere are far reaching and go beyond merely losing snow and ice. These include risks of:

- Increased fresh water influxes from the Arctic which could trigger a slow down or diversion of the thermohaline circulation of the North Atlantic (Gulf Stream) that helps give most of Europe its relatively mild climate. In turn this could impact other sea currents and temperatures around the globe.

- Global sea level rise measurable in metres, depending on how much of the cryosphere is lost. A sea level rise of only 1.5m would displace up to 17million people in Bangladesh alone.

- Increased moisture fluxes in the Arctic and Northern European atmosphere, resulting in increased rainfall and serious changes to the climate

- Accelerated warming in the Arctic due to the strong feedback between snow cover and absorption of solar radiation.

- Loss of habitat for Arctic animals such as polar bears, seals and other large predators.

- Reduction of glacier meltwater, which in many parts of the world provides water for human consumption, agriculture and hydro-electricity.

If a dramatic change to the cryosphere takes place, it could trigger rapid and catastrophic changes to the global climate - enough to alter the current climate as we know it.

Sea Ice

A variety of indicators suggest that during the latter half of the 20th Century the Arctic has undergone substantial climate change. One of the key indicators is sea ice extent and thickness, both of which have shown a measurable and disturbing decrease during the last half of the century.

The rate of decrease appears to be at maximum during summer. Extrapolation forward in time suggests that there could, potentially, be no summer sea ice in the Arctic within 100 years or less. This will have major impacts on energy and moisture exchange and consequently on the climate of the Northern Hemisphere, including the risk of altering or slowing down the Gulf Stream. The consequences of such dramatic changes in sea ice cover are the subject of a number of climate modeling studies and it is, currently, too early to say precisely what the implications of these changes might be. However such changes are likely to include impacts on wildlife and indigenous populations, as well as increasing the positive feedback of higher temperatures as the ice disappears.

There is general agreement that acceleration in mass loss globally will take place over the next century if greenhouse gas emissions continue to accelerate at the rate they have done for the past 50 to 100 years. Extrapolation of the present trend suggests a reduction in area of the Arctic sea ice of 4.7 M square kilometers by 2100, i.e. virtually complete elimination of the Arctic ice pack in summer. If the predictions of warming in the Arctic over the same time period are taken into account, the rate of attrition could be considerably faster as the Arctic is particularly sensitive to temperature increase. In contrast to the Arctic, there is no measurable trend in sea ice mass balance in the Southern Ocean, although some substantial regional variations have been seen over the last twenty years, which appear to be strongly coupled to regional changes in air temperature.

Greenland

Below 2000m elevation, there is extensive thinning leading to a net loss from the ice sheet as a whole, which is conservatively estimated to be 50 cubic kilometers/year, which is equivalent to 0.13 mm/year of sea level rise. As most ice sheet data has been collected only over the past few decades or less, it is difficult to know how long this negative imbalance has existed but it has certainly been enhanced by the warming during the 1990s, and the record melt extent observed in 2002.

The thinning rates cannot be explained by increased ablation (surface melting) alone, so the implication is that something else is causing this. Extensive thinning in several separate areas suggests that this may be climatically induced, for example, by increased surface meltwater reaching the bedrock on which the ice sits, causing the ice to slide on its bed. If true, this is of profound significance as it suggests that the dynamic response time of the ice sheet is, potentially, much shorter than previously believed. Such a rapid dynamic response to changing climate has not, to date, been satisfactorily incorporated in modeling studies as the mechanisms are poorly understood and constrained which means that ice loss could in fact be much faster and greater than currently predicted.

Flow effects are of great importance and future efforts in improving predictions of Greenland’s response to climate change should not concentrate solely on processes directly affecting the surface mass balance, but must also include flow effects below the surface. Under some UNFCCC mid range climate model predictions, the ice-sheet volume and area could reduce by about 3% by 2130, and by 40% by the year 3000. This implies that the ice sheet margin would retreat significantly by 200km to 300 km from its present coastal location, and that the ice sheet would separate into northern and southern domes. Higher greenhouse emissions could result in the complete loss of the southern dome.

Assumptions that appear to work for the present-day may be wrong when applied to future configurations of the ice sheet. For example, calving could become less important as less of the shrinking ice margin is in direct contact with the sea, or more important as outlet glaciers retreat into over-deepened troughs.

Most predictions of the future response of Greenland to anthropogenic climate change ignore the links between the ice sheet and the atmosphere/ocean system. While several of the feedbacks may not be triggered by partial deglaciation over hundreds of years, others may well be crucial i.e., the release of meltwater into the North Atlantic and its impact on deep-water formation. It is clear that future models must take into account the complex interaction between the oceans, the atmosphere and the ice.

However this increased melting of ice could lead to substantial cooling in the North Atlantic and parts of northwestern Europe. The melting ice could interact with the denser waters of the Gulf Stream, weakening its strength or possibly shutting it down altogether. The presence of the Gulf Stream currently keeps a large part of Europe much milder than it should be given its latitude. Without this warmer water, temperatures there would be several degrees cooler.

Antarctic Ice Sheet

While the East Antarctic Ice Sheet appears to be close to balance, it is a different story on the West Antarctic Ice Sheet. While there is glacial retreat and lowering of the ice surface in the Thwaites and Pine Island basin it is thought unlikely to be a reaction to recent climate change because of the long response times associated with the Antarctic ice sheet. There has been a significant warming on the peninsula of about 4 degrees Celsius in the last 50 years, associated with a regional decline in sea ice. While this is a strong signal, it's quite localised. Ice shelves along the Peninsula are only a few hundred meters thick and float on the surface of the ocean and are quite sensitive to changes in the ocean temperature and ocean circulation. Two major ice shelf collapses have been observed over the last decade along the Peninsula.

Arctic Ice Masses

The ice caps and glaciers of the Arctic islands make up around 45% of the total volume of ice outside Antarctica and Greenland and therefore may be a significant contributor to glacial sea level rise as climate change impacts are felt, with a total volume equivalent to 0.5 m sea level. Although data on these ice masses is limited, the literature suggests that they have a slight negative balance, contributing 0.05 mm a year to global sea level rise.

Glaciers and ice caps

Water stored in glaciers and icecaps around the world would contribute 0.5m sea level rise if they all melted. This is small compared to the 68.3m sea level rise that total melting of the Greenland and Antarctica ice sheets would cause (6m and 62m, respectively). However, glaciers respond much more rapidly than ice sheets. Glacier and ice cap response times are typically below 100 years, which means that the bulk of the cryosphere's contribution to anthropogenic sea-level rise over the coming century is likely to come from these types of ice mass. There are more than 160,000 glaciers worldwide, making measurement of glacier mass balance very difficult, but existing research indicates that glacial loss is responsible for between 0.22mm to 0.25mm a year sea level rise.

More complex analysis is needed to understand how glaciers react once melting begins, and what a partial loss of glacier ice would mean for its water flow system. The assessment of historical and predicted future contributions to sea level from glaciers is still in its infancy. Mass balance changes have clearly been large and are likely to continue to be important over the coming century, however many challenges still remain in their accurate quantification.

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Sea ice loss - one example of how this might effect the environment

According to the Third Assessment Report of Intergovernmental Panel on Climate Change (IPCC), a reduction in sea ice will reduce ice edges, which are prime habitat for marine organisms. Habitat loss for some species of seal, walrus, and polar bear results from ice melt, and animals at the top of the food chain -with their low-reproductive rates- are vulnerable to changes in the polar marine food chains. Some animals may be threatened (e.g., walrus, polar bear, and some species of seal), whereas others may flourish (e.g., some species of fish and penguins).

According to Dr Andrew DeRocher of the University of Alberta, who is a world authority on polar bears, if the sea ice habitat continues to deteriorate at current rates, polar bears and their prey, such as ringed and bearded seals, would be unlikely to retain their current population sizes and distribution. At some point, if the loss of sea ice became so severe that all the Arctic sea ice was lost for a substantial part of the year, we may lose polar bears as a wild species.

The whole Arctic marine ecosystem is tied to the presence and dynamics of the sea ice. The main productivity bloom that occurs each spring is exploited by both resident species and migrants, which is tied to the melting of the annual sea ice. Some arctic species travel halfway around the world to exploit the bloom of primary productivity and invertebrates that flourish along the edge of the melting ice. Life along the edge of the melting sea ice is the driver for the Arctic marine ecosystems. Removing this dynamic would have profound consequences for all marine life. If the sea ice is drastically reduced or the timing changed, we can expect the loss of many species that are reliant upon this special habitat. It is likely that we will see species expand from southern latitudes to occupy some of these environments but it is impossible to say which ones. It is hard to understand the dynamics of Arctic ecosystems and even harder to predict with any certainty what may happen if the climate changes substantially.

What causes climate change

Climate change is directly linked to our fossil energy consumption. Global warming of the earth is the result of increasing greenhouse gas emissions. The principal cause is carbon dioxide (CO2), which is released when fossil fuels such as coal, oil and gas are burned.

In 2001 the IPCC issued its Third Assessment Report, which found new and stronger evidence that most of the observed warming of the past 50 years is attributable to human activities. It found that about three-quarters of the anthropogenic (human created) emissions of CO2 during the past 20 years are due to fossil fuel burning.

The IPCC also reported that the average global temperature was projected to rise between 1.4 and 5.8 degrees Celsius in the next 100 years. This is a large increase on the projections in the Second Assessment Report (1995), which estimated the increase in temperature to be between 1 and 3.5 degrees. In addition, predictions suggest that this warming will be amplified in the polar regions, exacerbating the worrying trends already observed. A 2-degree increase would produce substantial damage to or loss of many natural ecosystems, lead to spread of diseases such as malaria and cause substantial damage to agriculture in developing countries.

Conclusion

Scientific understanding of the Earth's climate and how humans are affecting it is constantly improving, but there is still much to learn about what climate change will mean to natural systems such as the cryosphere. For most people polar regions are remote places that are out of sight and perhaps out of mind. They are, however, highly sensitive to climate change with strong feedbacks at play. Dramatic and disturbing trends have already been observed in the Arctic, Greenland, the Antarctic Peninsula and in glaciers globally.

Risk of sea level rise that could displace millions of people; radical alterations of ocean currents that in turn effect regional climate; loss of glaciers that provide water people need to live; changes to the food chain and even possible dramatic and rapid irreversible changes to the global climate - these are some of the possible impacts of climate change.

The Kyoto Protocol is the one global mechanism to address climate change. As the latest round of Kyoto talks get underway in Milan in December 2003, evidence about the serious impact of climate change is mounting. Governments and industry must take action to protect the climate now and stop trying to weaken the Protocol. It is not only the cryosphere at risk, but also potentially the global climate system.

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