CLIMATE CHANGE *IN THE* *ARCTIC* – *A HOT TOPIC!*

SWIPA 2011:
Snow, Water, Ice and Permafrost in the Arctic

AMAP

GLOSSARY

AMAP
Arctic Monitoring and Assessment Programme

Arctic
Often defined as the Earth's surface north of 66° N

Arctic Council
A high-level body addressing issues faced by the eight Arctic nations and the indigenous peoples of the Arctic

Carbon dioxide
The main greenhouse gas released from human activities

Climate
The average weather over long periods – from months to thousands or millions of years

Climate change
Any significant change in climate

Climate model
A mathematical model used to calculate elements of past, present and/or future climate

Cryosphere
The parts of the Earth's surface that are frozen for at least some part of the year

Feedback
An interaction between processes

Gigatonne
1000 000 000 metric tonnes

Glacier
Land ice that flows downhill under gravity

Greenhouse gas
Any gas that absorbs infrared radiation in the atmosphere

Ice cap
A dome-shaped mass of glacier ice that spreads out in all directions

Ice sheet
A layer of thick glacier ice covering a vast area of the Earth's surface

IPCC
United Nations Intergovernmental Panel on Climate Change

Methane
A very potent greenhouse gas produced naturally in the environment

Permafrost
Ground that is frozen for two or more consecutive years

Prediction
An event that is more or less certain to happen

Projection
An event that could possibly happen, given certain conditions

Sea ice
Ice produced by the freezing of seawater

Weather
Short-term changes in the state of the atmosphere as they affect people

INTRODUCTION

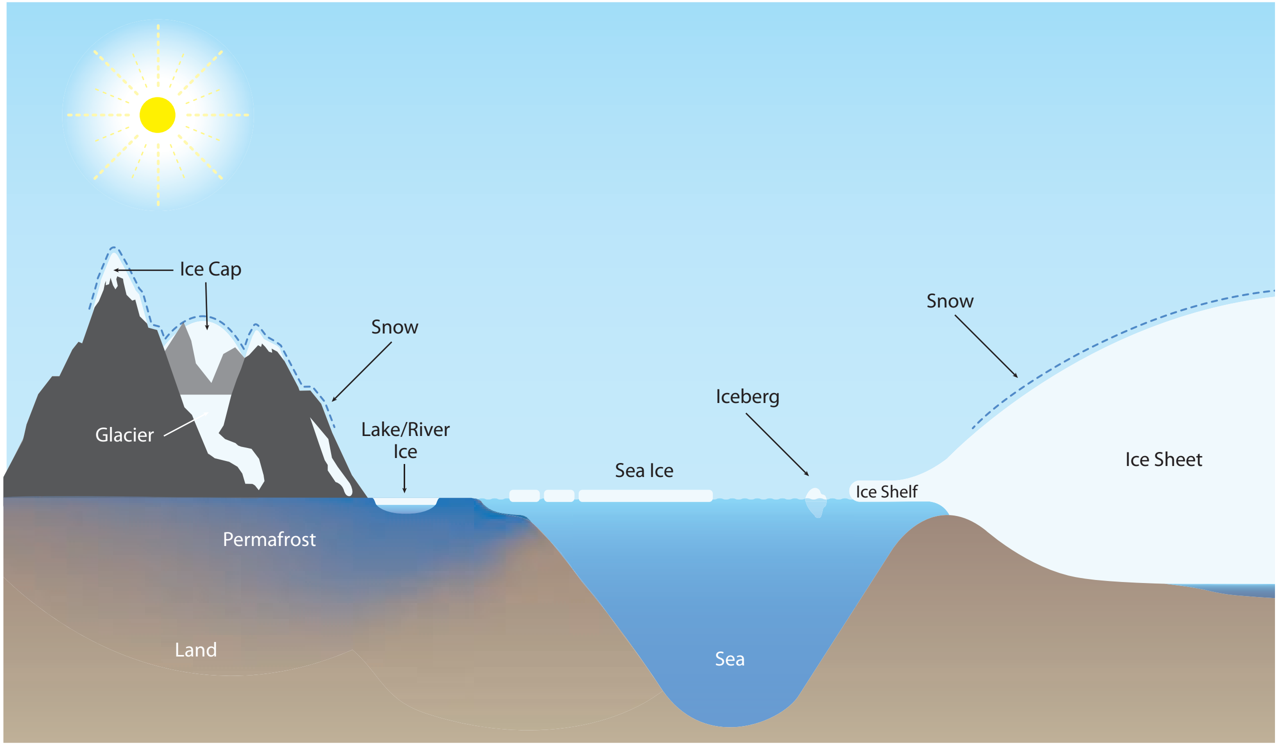
The world is warming and the Arctic is thawing. Scientists in many countries are trying to decide what a warming Arctic will mean for the plants, animals and people that live there, as well as for the world as a whole. The scientists are particularly interested in studying changes in the Arctic cryosphere. The cryosphere is the part of the Earth's surface that is frozen for at least some part of the year. It includes snow, permafrost (permanently frozen ground), ice on rivers and lakes, glaciers, ice caps, and sea ice.

The SWIPA project – **S**now, **W**ater, **I**ce and **P**ermafrost in the **A**rctic – was set up by the Arctic Council so that scientists could work together to examine the available information and to try and agree on answers to six important questions:

- Why is the Arctic changing?
- How is the Arctic cryosphere changing?
- Will these changes continue into the future?
- How do changes in the Arctic cryosphere affect nature and people?
- Why do changes in the Arctic matter for the Earth as a whole?
- What can we do about the warming in the Arctic?

The SWIPA assessment brings together the latest scientific knowledge about the changing state of each component of the Arctic cryosphere and examines how these changes will affect both the Arctic as a whole and people living within the Arctic and elsewhere in the world. Detailed information on the SWIPA project can be found on the SWIPA website: www.amap.no/swipa

The Arctic Cryosphere



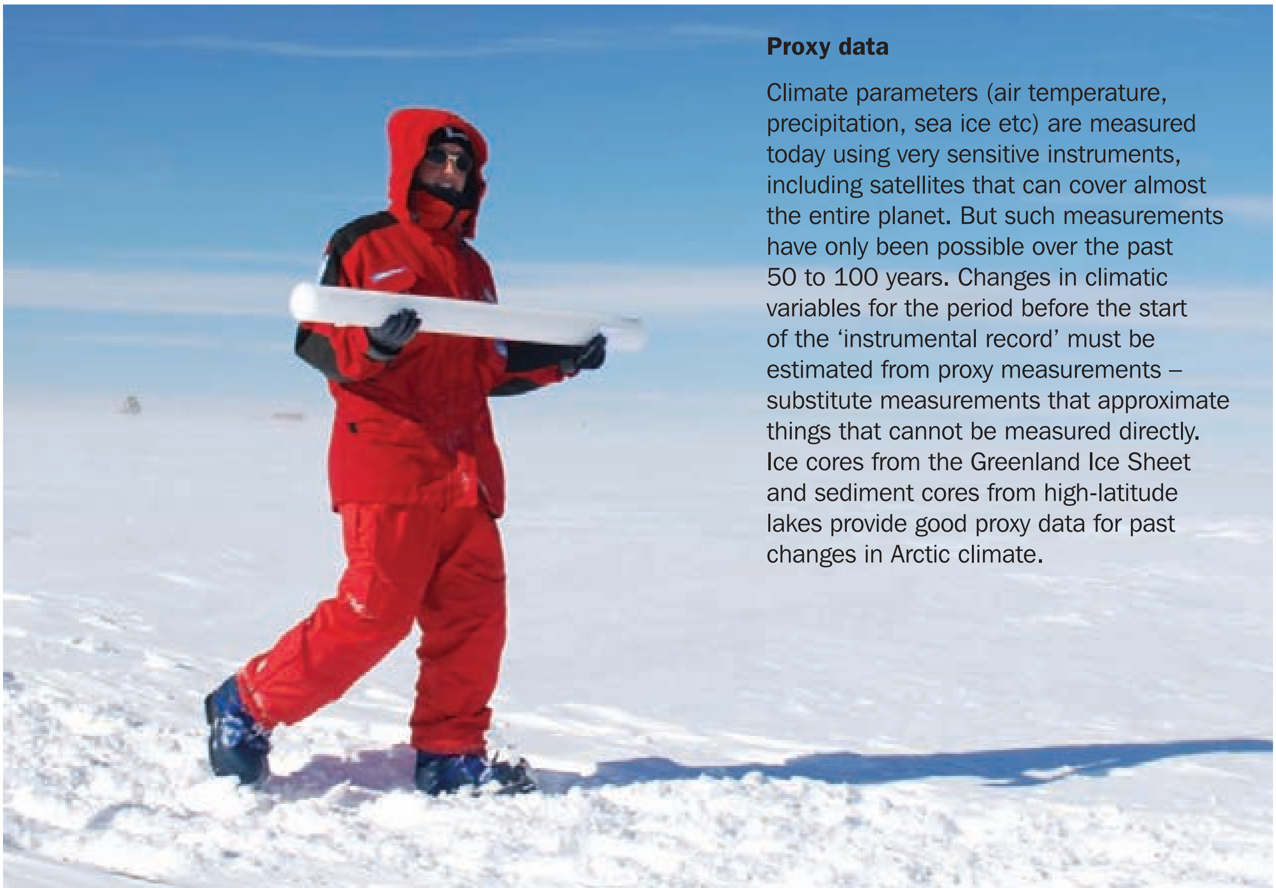
WHY IS THE ARCTIC CHANGING?

Natural variations in global climate have always been a feature of the Earth's history. There have been periods of extreme cold during which large parts of the Earth's surface were covered with ice ('Ice Ages') and warmer periods with little or no ice. However, the rate of current warming goes way beyond natural variability.

The Arctic is warming and is warming faster than almost anywhere else on Earth. Since 1980, the rise in annual average temperature has been twice as high over the Arctic as it has over the rest of the world. In fact, measurements show that the past seven years (2005 to 2011) have been the warmest ever recorded in the Arctic.

Going further back in time, evidence from lake sediments, tree rings and ice cores ('proxy data') suggests that Arctic summer temperatures have been higher in the past few decades than at any time in the last 2000 years.

Most of the observed increase in global temperature is very likely to be due to 'greenhouse gases' released from human activities, such as the burning of fossil fuels (coal, oil, natural gas). The main greenhouse gas responsible for the rise in air temperature is carbon dioxide. Natural gas (methane) is also a very powerful greenhouse gas.

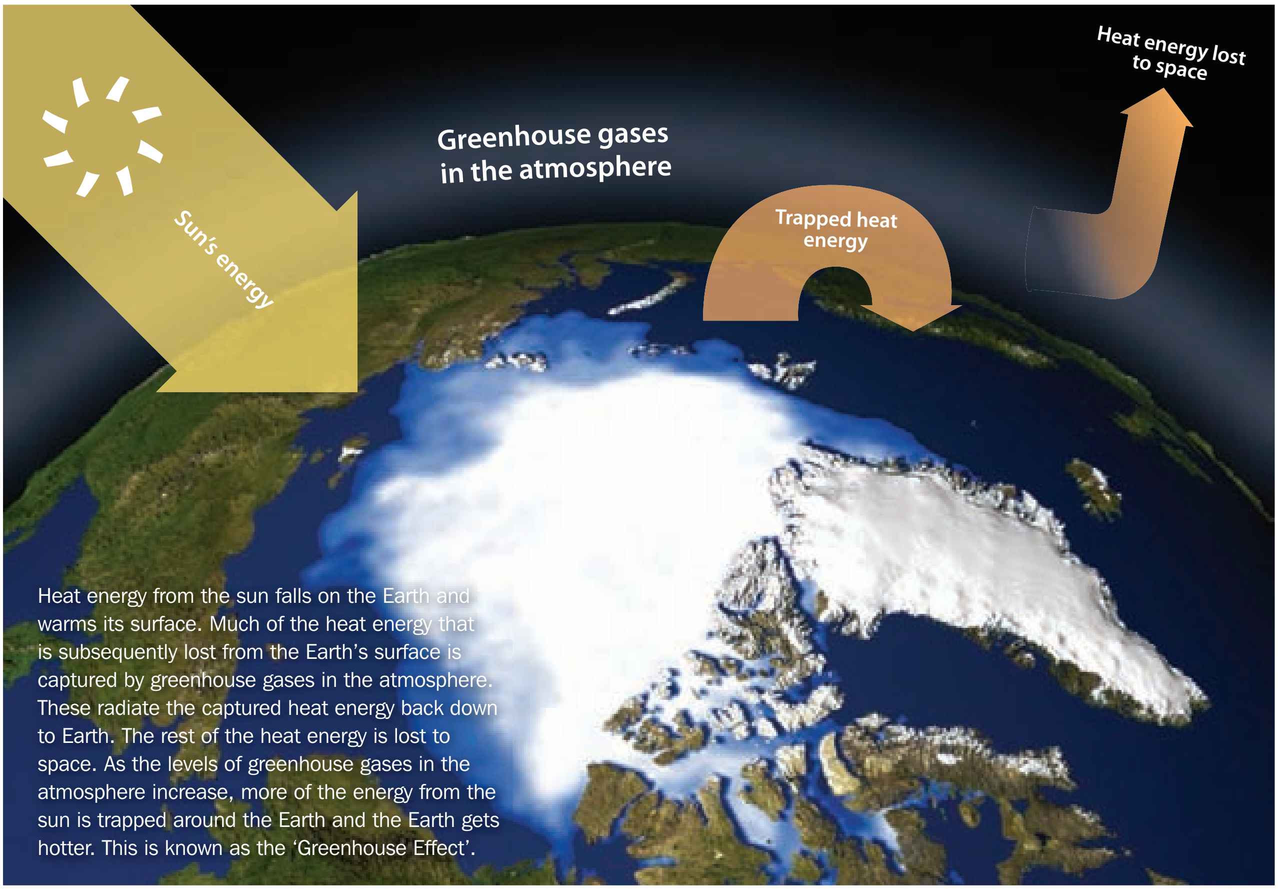


Proxy data

Climate parameters (air temperature, precipitation, sea ice etc) are measured today using very sensitive instruments, including satellites that can cover almost the entire planet. But such measurements have only been possible over the past 50 to 100 years. Changes in climatic variables for the period before the start of the 'instrumental record' must be estimated from proxy measurements – substitute measurements that approximate things that cannot be measured directly. Ice cores from the Greenland Ice Sheet and sediment cores from high-latitude lakes provide good proxy data for past changes in Arctic climate.

Air trapped in ice cores has been analyzed to provide information about past temperatures and levels of greenhouse gases in the atmosphere.

The Greenhouse Effect



Heat energy from the sun falls on the Earth and warms its surface. Much of the heat energy that is subsequently lost from the Earth's surface is captured by greenhouse gases in the atmosphere. These radiate the captured heat energy back down to Earth. The rest of the heat energy is lost to space. As the levels of greenhouse gases in the atmosphere increase, more of the energy from the sun is trapped around the Earth and the Earth gets hotter. This is known as the 'Greenhouse Effect'.

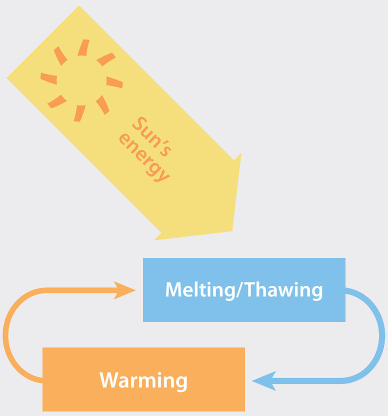
It is no surprise that higher temperatures are causing melting and thawing of the Arctic cryosphere. But scientists are now seeing evidence that parts of the cryosphere – snow and ice – are interacting with the climate system itself, speeding up the warming. Scientists refer to these special connections as 'feedbacks'. Snow feedbacks have been known about for a while, but evidence for sea ice feedbacks has only been seen in the Arctic in the past five years.

As well as connections between the cryosphere and the climate system, there are also connections between different parts of the cryosphere. This means that changes in one part of the cryosphere (such as snow) may cause changes in another (such as permafrost).

How feedbacks work

Light surfaces such as snow and ice reflect more of the sun's energy than darker surfaces such as water, soils and vegetation. In places where the land or sea is no longer covered by snow or ice, more of the sun's energy gets absorbed (because less is being reflected). This means that the land or sea becomes warmer than it would if the snow or ice were still there. Some of this extra heat is stored and then released to the atmosphere later in the year, delaying the formation of new snow and ice.

This is how most (but not all) snow and ice feedbacks in the Arctic work: warming causes melting/thawing, which causes even more warming, which causes even more melting/ thawing.



HOW IS THE ARCTIC CRYOSPHERE CHANGING?

Changes are being seen and measured across the Arctic in snow, permafrost, ice on rivers and lakes, glaciers and ice caps, and sea ice. Some of the changes are taking place quite fast (over seasons, or just a few years) while others are taking place very slowly (over centuries). Also, some of these changes affect very large areas of the Arctic (such as changes in sea ice) while others affect only very small areas.

Changes that are happening now

Snow is a major feature of the Arctic and covers the ground for about three-quarters of the year. The size of the area covered by snow is decreasing and the length of time that snow lies on the ground is falling. Over the past 50 years the area covered by snow has dropped by almost a fifth and snowmelt in spring is happening increasingly earlier, especially near the sea.

The permanently frozen ground – **permafrost** – that is present under much of the Arctic land and under the seabed in some parts of the Arctic is beginning to thaw. Permafrost temperatures are now 2 °C higher than 20 to 30 years ago. The total size of the area with permafrost is also shrinking. As the land is getting warmer the upper parts of the permafrost are thawing. Over the past 20 years, the unfrozen soil layers overlying the permafrost in summer have become up to 20 cm thicker in parts of Russia and Scandinavia.

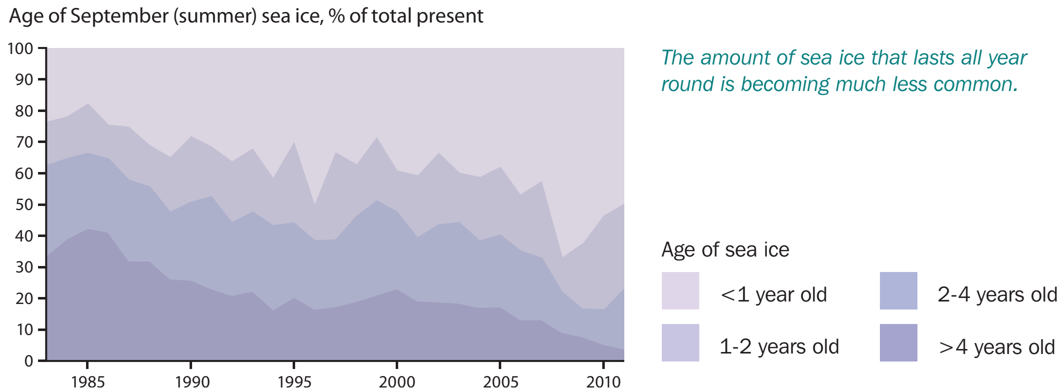
Scientists make accurate measurements in order to document changes in the cryosphere. Satellites have improved the capacity to observe changes but surface based measurements are also needed.

The front of the Muir glacier in Alaska retreated by over 12 km between 1941 (left) and 2004 (right).

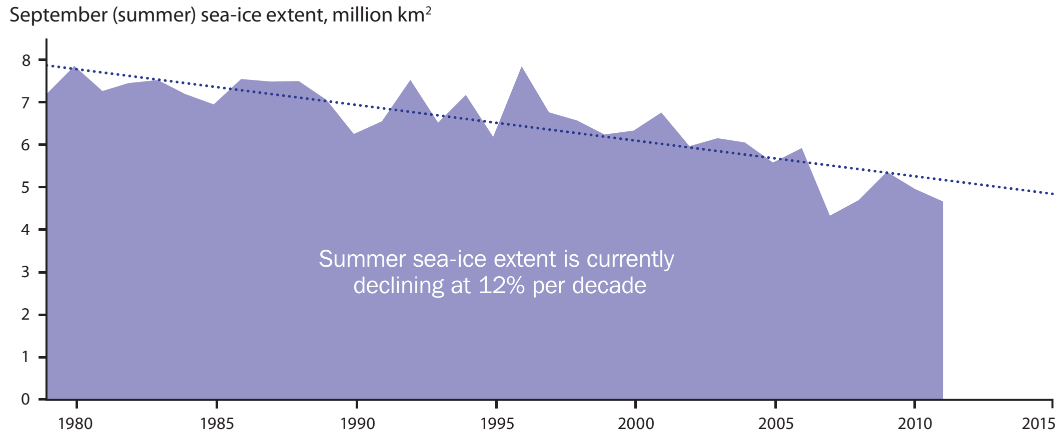
There are thousands of **lakes, streams and rivers** in the Arctic. Most of these are covered by ice for six months or more of the year. Although there are differences across the Arctic, the length of time these waters are covered by ice is now shorter than it was 100 years ago. This is because the ice is forming later in the autumn and melting earlier in spring.

Parts of the Arctic Ocean have **sea ice** all year round, while others have sea ice in winter and open water (once the ice has melted) in summer. There can be as much as three times more sea ice in winter than summer. The extent of the sea ice in summer has shrunk dramatically over the past 30 years, especially in the past ten years. In fact, this disappearance of Arctic sea ice is now happening much faster than predicted by computer models just a few years ago. The sea ice is also getting thinner because the thick sea ice that stays through winter and builds up over time is becoming less common.

Nearly all the **glaciers and ice caps** in the Arctic have shrunk over the past 100 years. In many places the shrinking has got faster over the past ten years. The Greenland Ice Sheet – the single largest body of land ice in the Northern Hemisphere – has shown particularly fast changes. Around four times more ice is currently being lost in meltwater from its surface and in icebergs from glaciers that end in the sea than was the case ten years ago.



The amount of sea ice that lasts all year round is becoming much less common.



WILL THESE CHANGES CONTINUE INTO THE FUTURE?

A **prediction** concerns an event that is more or less certain to occur in the future. In contrast, **projections** represent possible futures, with some of these futures more likely to happen than others. For example, scientists predict that global sea levels will rise as a result of global warming and use models to generate projections of sea level rise under different scenarios of future greenhouse gas emissions.

Scientists are using computer models to anticipate possible changes in the Arctic. In general, the models suggest that the changes happening now in the Arctic are likely to carry on happening, and may even speed up. However, it is important to remember that the statements made by the scientists from their model results are not firm **predictions**, but 'best estimates' based on current understanding of complex processes and interactions. These best estimates are referred to as **projections**. They tell us how the Arctic cryosphere *may* change, and when and where these changes *may* occur.

There are several reasons for the uncertainty in model projections. For example, scientists are still learning about the ways in which snow, ice and the atmosphere are connected (especially concerning feedbacks – see page 3), and as knowledge improves so do the models. Also, predicting the future amounts of greenhouse gases in the atmosphere (which the climate models need to work) is extremely difficult and depends on many factors that are themselves difficult to predict. Such factors include how fast emerging economies like India and China are developing and the types and amounts of fuel used for energy production in the future.

To help keep the uncertainty in their model projections as low as possible, scientists use models that are good at reproducing past changes in climate and the responses in different parts of the cryosphere.

Anticipating climate change

The main scientific body responsible for assessing climate change and for informing governments about the likely consequences of climate change is the United Nations' Intergovernmental Panel on Climate Change (IPCC). Thousands of scientists from all over the world take part in its work. The IPCC scientists have developed 'scenarios' that describe how greenhouse gas emissions may change in the future. These are used in computer models to make projections about how the world climate is likely to change in the future, especially how quickly the changes are likely to occur and what effects will be seen and where. This information is important for governments, to allow them to plan for, prepare for and take decisions in relation to the anticipated changes. The IPCC Fifth Assessment Report is due in 2013/2014.

Current scientific projections

- Air temperatures will continue to rise faster in the Arctic than elsewhere in the world. Models suggest that before the end of the century temperatures could be 3 to 6 °C higher than they are now. The biggest increase will be in autumn and winter in areas where summer sea ice is disappearing.
- Snowfall and rain are likely to increase in many Arctic areas, especially in winter. Snow will get deeper in many places, but the snow season will be up to 20% shorter over most of the Arctic. Rain falling on snow-covered ground will become more common.
- Permafrost will continue to thaw across vast areas of the Arctic. A type of wetland unique to permafrost areas known as 'palsa mire' (see page 8) is shrinking fast and could be completely gone within the next 30 to 40 years.
- The enormous Greenland Ice Sheet will continue to melt, but exactly how fast is uncertain. Up to a third of the ice in glaciers and ice caps elsewhere in the Arctic may be lost by the end of the century.
- Sea-ice thickness and extent will continue to decline and the Arctic Ocean will be largely ice free in summer by the middle of the century. In the 30 to 40 years it is expected to take for this to happen, the amount of ice present each summer will vary widely (some years will have more than expected and some will have less). Open water (i.e. no ice) in summer will mean that ice that lasted from year to year will have been replaced by ice that forms new each winter. This young ice melts more easily than the older thicker ice.

HOW DO CHANGES IN THE ARCTIC CRYOSPHERE AFFECT NATURE…

Changes happening in the Arctic cryosphere are having big impacts on the plants and animals adapted to life in these icy conditions. Species that migrate into the Arctic in summer are also being affected. The changes include loss of entire habitats. This section gives examples of how Arctic ecosystems are being affected.

Snow

The amount of land covered by snow and the length of the snow season are very important for the Arctic's plants and land animals. A shorter snow season means a longer 'growing season' (when it is warm enough for plants to grow) and as the growing season gets longer the mix of plants changes. For example, more bushy plants appear and there are fewer lichens. This means more food for some animals and less for others.

Higher air temperatures mean more occasions when precipitation falls as rain rather than snow. Rain falling onto snow creates an ice crust on the surface that makes it harder for grazing animals to get at the plants underneath. In 2003, around 20 000 muskox died during winter on Banks Island in the Canadian Arctic because they could not break through the ice crust to graze.

Soils in areas where snow is getting deeper are better protected from the cold air above. Deeper snow is also better at protecting the small animals that live and breed beneath the snow, such as lemmings. Sometimes there is a sudden thaw during winter and the snow disappears. When the freezing conditions return, frost can kill bushes and trees that are no longer protected by a covering of snow.

Permafrost

Thawing permafrost mostly affects Arctic ecosystems through changes in the water cycle. Many ponds and small lakes, which are an important source of insects for birds and other animals, are drying out as the permafrost below them thaws and the water drains away. Palsa mires – a special sort of wetland – are important breeding habitat for some of the several hundred million birds that migrate into the Arctic each summer. If, as expected, the palsa mires largely disappear within the next 30 to 40 years there could be a big impact on the worldwide numbers of birds like waders that only visit areas with palsa mires.

In other areas, new wetlands are forming as soils become waterlogged when water from the thawing permafrost cannot drain away.

Forest trees can start leaning and fall when thawing permafrost makes the ground less stable.

Polar bears and the disappearing sea ice

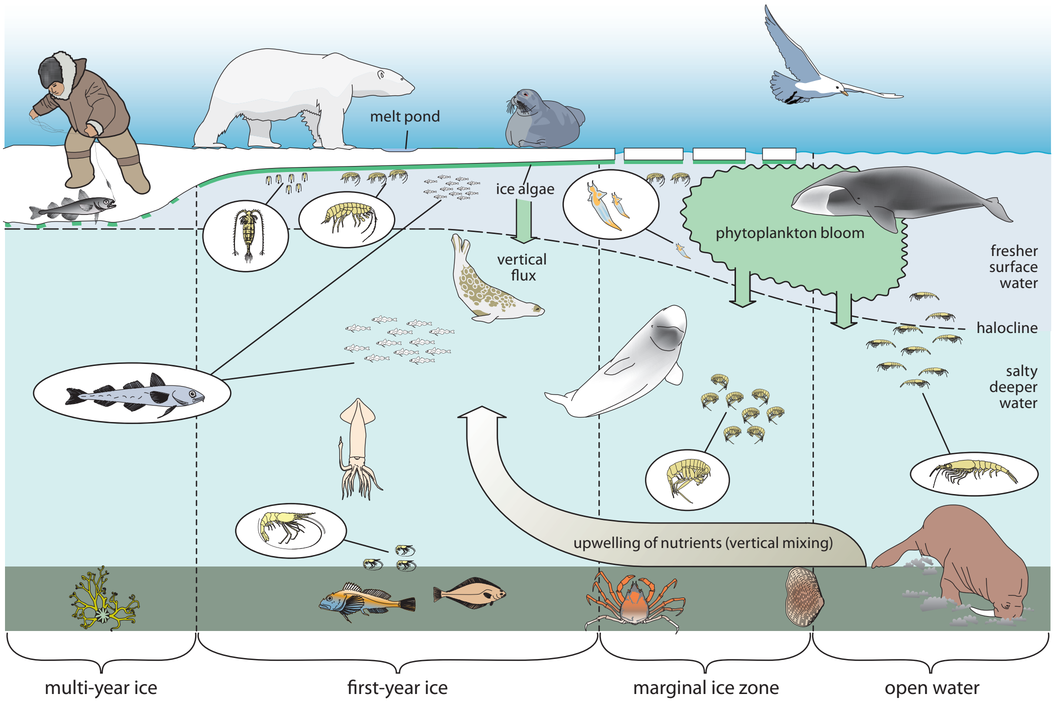
Polar bears are extremely dependent on sea ice. They hunt their favorite prey – ringed seals – from the ice. The number of polar bears in the Arctic is expected to fall dramatically as the sea ice declines. A total loss of summer sea ice would be devastating for polar bears and some scientists say they could be lost forever from areas where they are currently common.

Hungry polar bears that are unable to hunt seals from the ice are forced to turn to other food.

Sea ice

Tiny species of plankton live in the water near the edge of the ice and are important elements of the ice-edge food web. Less sea ice will mean less food for the birds, seals, whales and fish that feed in or near ice-covered waters. However, some animals, particularly some types of fish will see their habitats expand as the sea ice recedes. Some fish stocks may increase.

Sea ice is a unique habitat and one that is important for the survival of many species such as polar bears and several species of seal. Hooded seals, harp seals, ribbon seals and spotted seals all give birth on the ice. Other animals use the ice to rest on. For example, walruses feed on clams on the seabed and rest on the sea ice between dives. Disappearing sea ice is likely to mean a big fall in the numbers of animals adapted to living on or close to the ice.



Changes in the Arctic cryosphere could cause major changes in the marine food web.

...AND PEOPLE?

Changes in the Arctic cryosphere are also affecting people living and working in the Arctic. The changes will be good for some, while others will lose out. This section gives examples of how people in the Arctic are being affected.

The traditional way of life

People have lived in the Arctic for thousands of years. Scattered across the Arctic from the coasts to the vast inland regions, they survived by hunting, herding, fishing and gathering. Many of these traditional activities are still taking place. But everyday life in local communities is changing.

Hunters are finding journeys over land and sea ice more difficult and more dangerous as conditions become increasingly unpredictable. As the snow/ice season gets shorter, snowmobiles become less useful, ice roads exist for shorter periods, and travel to and from some remote villages may be impossible for parts of the year. Temporary shelters constructed during hunting trips are more difficult to build and the numbers of species that are hunted for food (such as polar bears and ringed seals) are falling as their habitat disappears. Less sea ice in spring and autumn also means fewer trips to hunt seals and walruses. Reindeer are moving to different pastures and herders often have to travel further to find them.

Conditions are changing so quickly and in such unexpected ways that traditional knowledge about hunting and travelling, passed through the generations, is becoming less reliable.

Resources in the Arctic

Renewable resources (resources that are replenished) such as fish, timber, and hydroelectric power are directly affected by the changing conditions. Catches of some commercially important fish species are going up, while catches of others are going down. The places where the fish are caught are also changing. Forestry is important in the southern Arctic and although some forests are producing less timber as trees grow more slowly (mainly due to changes in the water cycle), thawing permafrost is allowing the forests to spread further north as growing conditions improve. The potential for hydroelectric power is also improving as glaciers and ice sheets continue to melt and rain and snowfall increase.

Access to non-renewable resources, like oil, gas and minerals is becoming easier in some areas, but harder in others. For example, the decline in sea ice is opening up the Arctic Ocean to ships, making it easier to access offshore oil and gas reserves and to transport oil, gas and other goods to, from and across the Arctic. But more icebergs and stormier weather could increase the risk of accidents, such as oil spills from tankers and oil rigs. On land, most oil and gas extraction is based on facilities and pipelines built on permafrost. As the permafrost thaws, buildings, pipelines, roads and other infrastructure are likely to suffer damage.

Pollutants carried into the Arctic by winds and ocean currents from industrial areas further south have been stored in the Arctic ice and permafrost for decades. As the ice melts and the permafrost thaws, these pollutants are being released. Some are getting into the foods eaten by Arctic animals, and even the people that hunt and eat these animals.

Other challenges and opportunities

Two-thirds of the Arctic coastline is held together by permafrost and protected by sea ice. This also includes areas where glaciers reach the sea. If coastal sea ice disappears or is present for shorter periods, the coasts become more exposed to storms. In parts of the Arctic, coastlines are being eroded as storms batter the land and the permafrost crumbles. In Alaska alone, about 30 villages are currently threatened by coastal flooding and erosion.

Many people live in permafrost regions. Their houses and other key infrastructure like roads, bridges and dams are built on frozen ground. As the permafrost thaws, the ground becomes weaker, less stable and less able to support these structures. This can cause buildings to collapse and roads and pipelines to fail. Sorting out these problems is usually possible – but very expensive. Buildings can also collapse under the weight of too much snow.

As travel over permafrost and ice roads becomes more difficult (with all-weather roads cracking and ice roads melting) more people are travelling along rivers by boat.

Tourism is increasing as it becomes easier for people to get to the Arctic, especially by cruise ship. This may bring opportunities for Arctic people to become guides on hunting and fishing trips, to provide accommodation for tourists, and to sell handicrafts. But there is concern about the potential for accidents; if a large ship gets into trouble in a remote area the possibilities for rescue are limited.

The Northern Sea Route and the Northwest Passage, which provide commercial ships with a short-cut across the Arctic in summer, are opening up more often. The Northern Sea Route is 40% shorter than the normal trade route between Europe and the Pacific and transpolar shipping is expected to increase as sea ice declines. However, the transpolar routes are more hazardous than the normal trade routes as the ships will face icebergs, drifting sea ice and stormier weather.

Tuvalu is a Polynesian island nation in the Pacific Ocean halfway between Hawaii and Australia. At only 26 km^2 it is the smallest country in the world. Funafuti Atoll (photo) is just 5 m above sea level at its highest point. Rising sea level is putting Tuvalu's population of 10 000 at risk. This small island nation will probably be the first country to disappear as a result of climate change.

WHY DO CHANGES IN THE ARCTIC MATTER FOR THE EARTH AS A WHOLE?

Although the effects of changes in the Arctic cryosphere are most noticeable in the Arctic region itself, they are also felt worldwide, mainly through their effects on global climate and sea level rise.

Global climate

Snow and ice cover reflect the sun's energy back into space, helping to keep the Arctic cold. As the area covered by snow/ice is becoming smaller and the snow/ice season is getting shorter, the 'whiteness' of the Arctic is declining, reducing its ability to reflect sunlight. As a result the cooling effect of the Arctic on the rest of the planet is weakening.

At more southerly latitudes the sun warms the Earth's land surface, air and oceans to a much greater extent. This difference in heat input across the planet is partly balanced by the transfer of heat energy from the warmer regions to the poles (by ocean currents in particular). The Arctic is an important part of this large-scale movement of heat energy around the planet – acting as a 'pump' that drives cold seawater south in deep ocean currents and draws warm seawater north at the surface. As the Arctic Ocean freshens, this pump could weaken. The amount of extra freshwater added to the Arctic Ocean over the past few years from rivers, meltwater, and precipitation is enormous – roughly equivalent to a lake 1 m deep the size of Australia. Any change in the strength and pattern of the large-scale ocean currents would affect how heat energy is transferred around the world. This could have a big impact on global weather and climate.

As Arctic soils, rivers and lakes get warmer and permafrost beneath the seabed begins to thaw, carbon that is currently locked in the frozen soils could be released to the atmosphere. This carbon is released to the air in the form of carbon dioxide and methane – both important greenhouse gases. It is still unclear what this will mean for global climate, but both processes could certainly cause warming to accelerate.

Large amounts of methane are stored in submarine permafrost. Methane is a particular concern because it is over 20 times more powerful than carbon dioxide as a greenhouse gas.

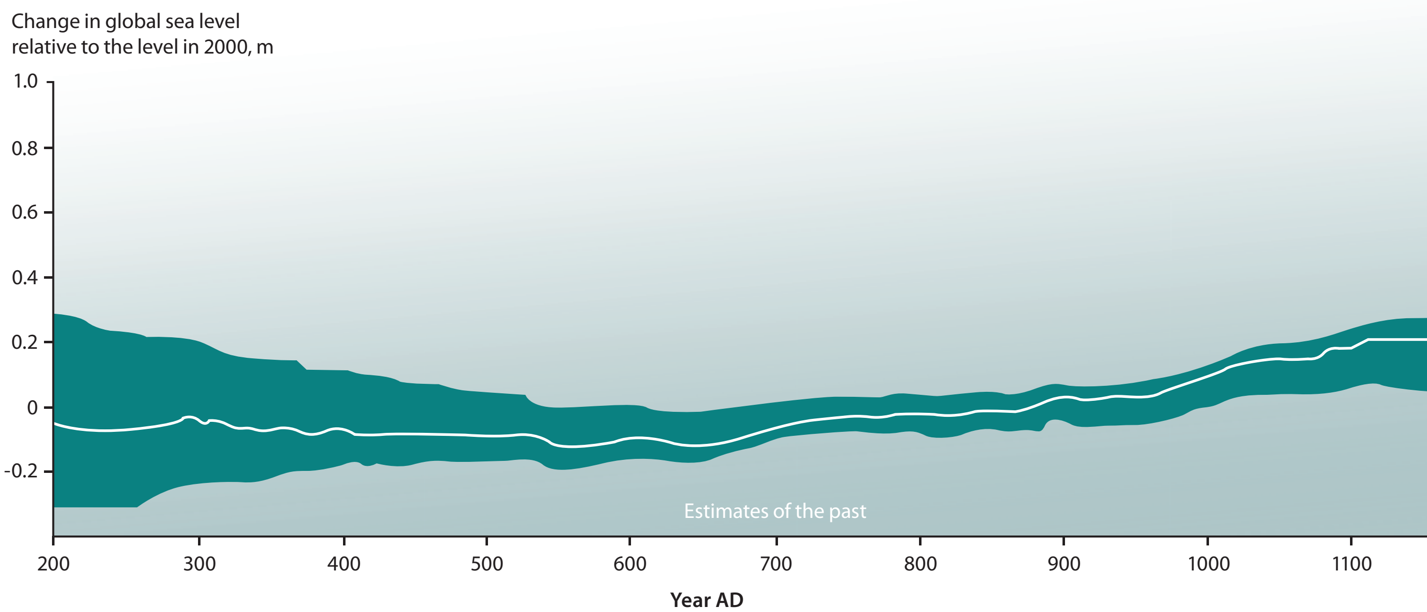
Arctic soils contain about twice as much carbon as the entire Earth's atmosphere. Widespread thawing of permafrost could release a significant amount of this carbon to the air.

Sea level rise and the Greenland Ice Sheet

The Greenland Ice Sheet has expanded and contracted many times in response to changes in the Earth's climate and this massive accumulation of land ice is highly vulnerable to the strong global warming that is predicted to occur over the coming decades and centuries. Containing around 3 million km^3 of ice, the Greenland Ice Sheet represents an enormous store of freshwater. If it were to melt completely (which is not expected to happen in the next few thousand years) global sea level would rise by roughly 7 m.

Before 1990, the amount of ice added to the ice sheet each year by snow was roughly the same as the amount lost through melting and the break-off of icebergs from glaciers around the edge of the ice sheet. Since then, and as a direct result of the recent warming over Greenland, the situation has changed dramatically and the amount of ice lost from the ice sheet is increasingly greater than the amount added. The extra quantities of meltwater entering the seas around Greenland are now so huge, they are affecting sea level at the global level. In the late 1990s, meltwater from the Greenland Ice Sheet was responsible for around 5% of the global rise in sea level – the latest estimates from around 2005 are that its contribution has now risen to around 20%.

As a rough calculation, about 360 gigatonnes of land-ice melt are required for a 1 mm rise in global sea level. In 2005/06, about 205 gigatonnes more ice was lost from the Greenland Ice Sheet than was added. This represents a rise of 0.57 mm in global sea level.



Sea level

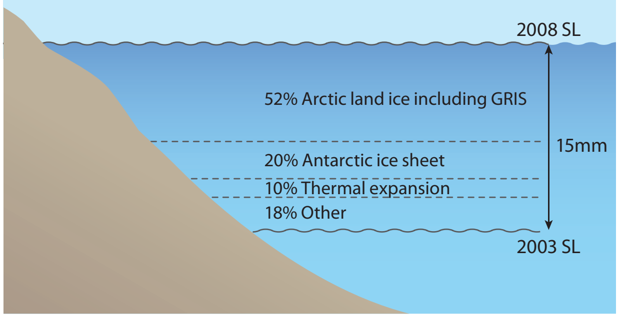
Natural variations in global climate have long been associated with the rise and fall of sea level. In cold periods (Ice Ages), water is locked-up in ice and sea level falls; in warm periods (Interglacials) sea level rises as the water is released and flows back to the sea.

There are two main causes of the recent rise in sea level: meltwater from glaciers and ice caps on land flowing into the sea and increasing its volume; and sea water expanding as it warms due to climate change ('thermal expansion'). Melting sea ice does not contribute to sea level rise because the ice is formed from the seawater itself.

Although sea level has been rising since the mid-1800s, the rate at which it is now rising is much faster than models suggested it would just a few years ago.

Current estimates are that global sea level may be up to ~1.5 m higher by the end of the century and that changes in the Arctic cryosphere will be responsible for a significant amount of this increase.

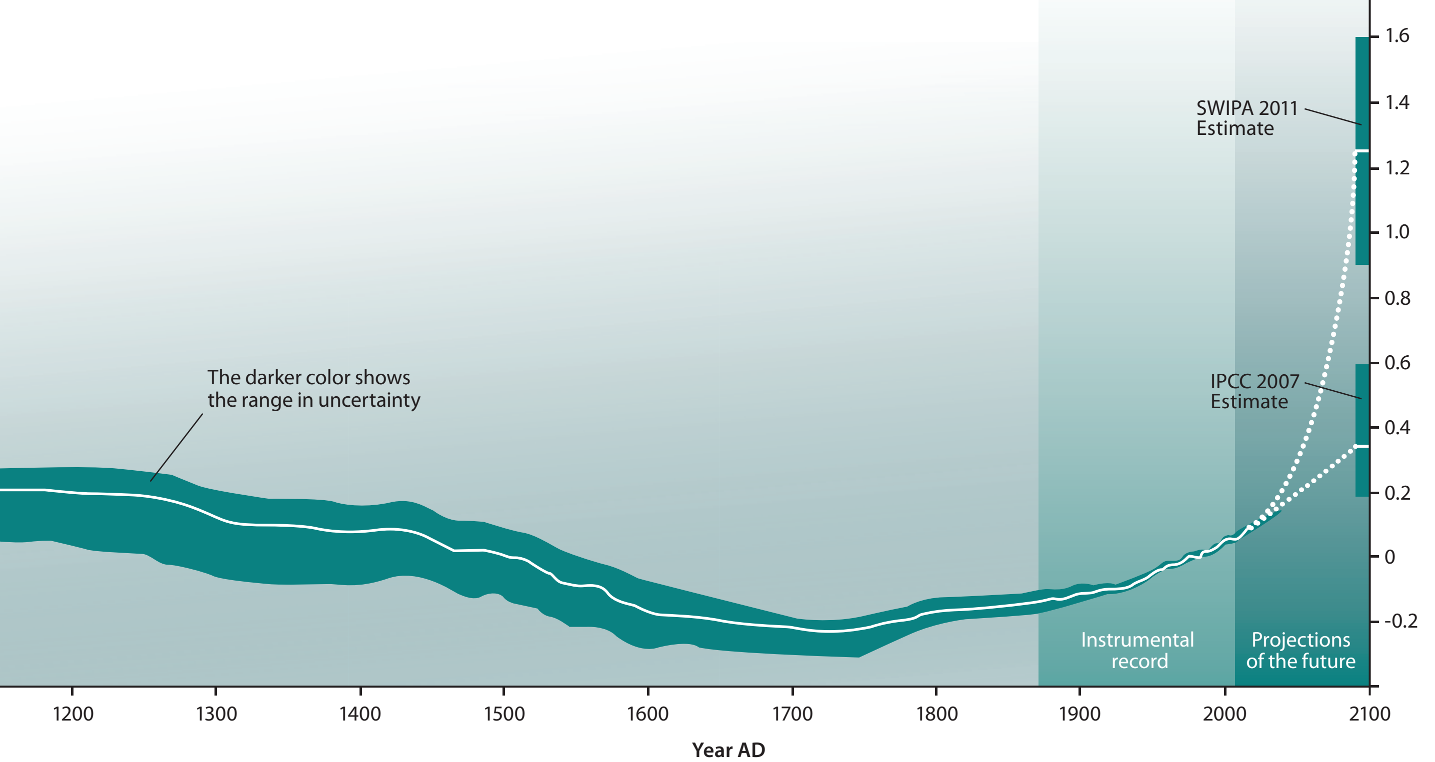
Meltwater from Arctic glaciers and ice sheets (especially the Greenland Ice Sheet – GRIS) was responsible for over half the rise in global sea level between 2003 and 2008.



Tidal surges flooded homes in Bangladesh city twice a day during August 2011.

Society

Rising sea levels could affect millions of people around the world. About 200 million people live less than one metre above current sea level. People living in low-lying coastal areas of Bangladesh and the Netherlands are vulnerable to more frequent storm surges and flooding, while some Pacific islands are in danger of being completely submerged.



WHAT CAN WE DO ABOUT THE WARMING IN THE ARCTIC?

Adaptation is urgent and needed at all levels

Changes in the Arctic cryosphere are felt first by people at the local level, and local communities across the Arctic are already responding by developing new ways of living within their changing environment. Sooner or later, however, everyone that lives or works in the Arctic will need to adapt to the changes taking place. But the changes being seen in the Arctic are just the beginning. More dramatic changes are expected, especially outside the Arctic (such as sea level rise). Beyond the Arctic, adaptation needs leadership from governments and international bodies.

Cutting greenhouse gas emissions globally is urgent

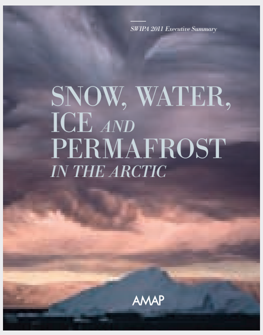
It is still not clear how fast the Arctic cryosphere will change in the future and what the final impacts of the changes will be. The interactions ('feedbacks') between parts of the Arctic cryosphere and the global climate system are particularly uncertain. More monitoring and further research will help to reduce this uncertainty. Nevertheless, the changes expected over the next hundred years or so, clearly represent an urgent and potentially irreversible worldwide threat to human societies. Climate model calculations show that deep and immediate cuts are needed in global greenhouse gas emissions.

Changes will continue

Even if significant measures are taken to reduce greenhouse gas emissions, the changes being seen in the Arctic cryosphere will continue for many years to come. If no action is taken to reduce greenhouse gas emissions, the changes are likely to take place even faster and some could become irreversible.

A committed coordinated response

Dealing with human-induced climate change is an urgent common challenge for the international community, one that requires immediate global action and international commitment. By responding now there is still time to alter the future trajectory of global climate change.



AMAP has used the outcome of the SWIPA assessment to make a number of recommendations for future action by Arctic countries and international organizations. These can be found in the SWIPA Summary Report for Policy Makers available through the SWIPA website: www.amap.no/swipa

Climate Change in the Arctic – A Hot Topic!

ISBN:
978-82-7971-072-1

Production

Author
Carolyn Symon *(carolyn.symon@btinternet.com)*

Production management
Carolyn Symon, Simon Wilson *(AMAP)*

Lay-out, graphics and technical production management
Burnthebook Design, Derby DE24 8HR, United Kingdom *(burnthebook.co.uk)*

Printing
Narayana Press, Gylling, DK-8300 Odder, Denmark (www.narayanapress.dk)

Photo credits

Cover: © Frans Lanting / Corbis. Tourists watching calving of Monaco Glacier on Spitsbergen
Page 2: © NEEM ice core drilling project, www.neem.ku.dk
Page 4: © B&C Alexander / ArcticPhoto (left), © ESA / AOES Medialab (right)
Page 5: © National Snow and Ice Data Center, W. O. Field, B. F. Molnia
Pages 6 and 7: © Lars Witting / ARC-PIC.COM
Page 8: © Natural Resources Canada / Geological Survey of Canada, Linda Dredge
Page 9: © Kerry Woo (upper), © Russ Hopcroft – University of Alaska Fairbanks & CoML (lower)
Page 10: © B&C Alexander / ArcticPhoto
Page 11: © Gazprom (upper), © Ryerson Clark (middle), © B&C Alexander / ArcticPhoto (lower)
Page 12: © Ashley Cooper / Corbis
Page 13: © George Burba
Page 14: © Paul Souders / Corbis
Page 15: © Jashim Salam / Demotix / Corbis
Page 16: © Paul Souders / Corbis

AMAP Secretariat

Gaustadalléen 21, N-0349 Oslo, Norway

T +47 22 95 83 40 F +47 22 60 44 27

www.amap.no

ARCTIC COUNCIL

AMAP
Arctic Monitoring and Assessment Programme

AMAP – IASC – IASSA – WCRP-CliC