SWIPA Summary Excerpts

This report presents AMAP's new assessment of the impacts of climate change on Snow, Water, Ice and Permafrost in the Arctic (SWIPA). It brings together the latest scientific knowledge about the changing state of each component of the Arctic "cryosphere. It examines how these changes will impact both the Arctic as a whole and people living within the Arctic and elsewhere in the world. "Cryosphere is the scientific term for the part of Earth's surface that is seasonally or perennially frozen. It includes snow, frozen ground, ice on rivers and lakes, glaciers, ice caps, ice sheets and sea ice. The cryosphere structures the physical environment of the Arctic. It provides services to humans such as freshwater supplies and transport routes. The Arctic cryosphere is an integral part of the climate system, and affects climate regionally and globally. The SWIPA report follows on from the Arctic Climate Impact Assessment (ACIA), published in 2005. It aims to update the findings from ACIA and to provide more in-depth coverage of issues related to the Arctic cryosphere.

The observed changes in sea ice on the Arctic Ocean and in the mass of the Greenland Ice Sheet and Arctic ice caps and glaciers over the last ten years are dramatic and represent an obvious departure from the long-term patterns.

Some Key Findings

- The last six years (2005-2010) have been the warmest period ever recorded in the Arctic. Higher surface air temperatures are driving changes in the cryosphere.
- There is evidence that two components of the Arctic cryosphere – snow and sea ice - are interacting with the climate system to accelerate warming.
- The extent and duration of snow cover and sea-ice have decreased across the Arctic. The temperatures in the permafrost have risen by up to 2 C. The southern limit of permafrost has moved northwards in Russia and Canada.
- The largest and most permanent bodies of ice in the Arctic – multi-year sea ice, mountain glaciers, ice caps and the Greenland Ice Sheet - have all been declining faster since 2000 than they did in the previous decade.
- Model projections reported by the Intergovernmental Panel on Climate Change (IPCC) in 2007 underestimated the rates of change now observed in sea ice.
- Maximum snow depth is expected to increase over many areas by 2050, with largest increases over Siberia. Despite this, average snow cover duration is projected to decline by up to 20% by 2050.
- The Arctic Ocean is projected to become nearly ice-free in summer within this century, likely within the next thirty to forty years.
- Loss of ice and snow in the Arctic enhances climate warming by increasing absorption of the sun s energy at the surface of the planet. It could also dramatically increase emissions of carbon dioxide and methane and change large-scale ocean currents. The combined outcome of these effects is not yet known.
- Arctic glaciers, ice caps and the Greenland Ice Sheet contributed over 40% of the global sea level rise of around 3 mm/year observed between 2003 and 2008. In the future, global sea level is projected to rise by 0.9 – 1.6 m by 2100 and Arctic ice loss will make a substantial contribution to this.

Why the Arctic cryosphere is changing

The Arctic is warming. Surface air temperatures in the Arctic since 2005 have been higher than for any five-year period since measurements began around 1880. The increase in annual average temperature since 1980 has been twice as high over the Arctic as it has been over the rest of the world. Evidence from lake sediments, tree rings and ice cores indicates that Arctic summer temperatures have been higher in the past few decades than at any time in the past 2000 years. Previously unseen weather patterns and ocean currents have been observed, including higher inflows of warm water entering the Arctic Ocean from the Pacific. These changes are the main drivers of change in the Arctic cryosphere. In attributing the cause of warming in the Arctic, SWIPA refers to the findings of the Fourth Assessment Report from the Intergovernmental Panel on Climate Change (IPCC).

Climate-cryosphere interactions may now be accelerating warming. The greatest increase in surface air temperature has happened in autumn, in regions where sea ice has disappeared at the end of summer. This suggests that the sea is absorbing more of the sun's energy during the summer because of the loss of ice cover. The extra energy is being released as heat in autumn, further warming the Arctic lower atmosphere. Over land, the number of days with snow cover has changed mostly in spring. Early snow melt is accelerated by earlier and stronger warming of land surfaces that are no longer snow-covered. Snow feedbacks are well known. The sea ice feedback has been anticipated by climate scientists, but clear evidence for it has only been observed in the Arctic in the last five years. Of other feedbacks expected to have strong effects, eight lead to further and/or accelerated warming, and just one leads to cooling. The intensity of feedbacks between the cryosphere and climate are not yet well quantified, either within the Arctic or globally. This lends considerable uncertainty to predictions of how much and how fast the cryosphere and the Arctic environment will change.

How the Arctic cryosphere is changing

The extent and duration of snow cover have decreased throughout the Arctic. The Arctic land area covered by snow in early summer has fallen by 18% since 1966. Coastal areas of Alaska and northern Fennoscandia have seen the strongest decreases in the number of days with snow cover. The change is largely caused by snow melting earlier in the spring. Snow depth has decreased in some areas such as the North American Arctic, but has increased in others such as northern Russia.

Permafrost – permanently frozen ground – underlies most of the Arctic land area and extends under parts of the Arctic Ocean. Temperatures in the permafrost have risen by up to 2C over the past two to three decades, particularly in colder sites. The soil above the permafrost that seasonally thaws each year has increased in Scandinavia, Arctic Russia west of the Urals and inland Alaska. The southern limit of permafrost moved northwards by 30-80 km in Russia between 1970 and 2005, and by 130 km during the last 50 years in Quebec. Ice cover on lakes and rivers in the Northern hemisphere is breaking up earlier than previously observed. Studies of sediments in High Arctic lakes indicate that the duration of ice cover on some lakes has declined significantly in the last 100 years.

Large bodies of ice are melting faster. Net loss of mass from the Greenland Ice Sheet has increased from an estimated 50 Gt/year (50,000,000,000 metric tonnes per year) from 1995-2000 to ~200 Gt/year from 2004-2008. The current loss (~200 Gt/yr) represents enough water to supply more than one billion city dwellers. Nearly all glaciers and ice caps in the Arctic have shrunk over the past 100 years. Their rate of ice loss has increased during the last decade in most regions, but especially in Arctic Canada and southern Alaska. Total loss of ice from glaciers and smaller ice caps in the Arctic probably exceeded 150 Gt/yr in the last decade, similar to the estimated amount being lost from the Greenland Ice Sheet.

Arctic sea ice decline has been faster during the past ten years than in the previous twenty years. The area of sea ice persisting in summer has been at or near record low levels every year since 2001. It has retreated faster than projected by the models reported in the IPCC's Fourth Assessment Report in 2007. It is now about one third smaller than the average summer sea ice cover from 1979 to 2000. New observations reveal that average sea ice thickness is decreasing and the sea ice cover is now dominated by younger, thinner ice.

More change is expected

Average Arctic autumn-winter temperatures are projected to increase by between 3 C and 6C by 2080, even using scenarios in which emissions are predicted to be lower than they have been for the past 10 years. The climate models used for SWIPA do not include possible feedback effects within the cryosphere system that may release additional stores of greenhouse gases from Arctic environments. Arctic rain and snowfall are projected to increase in all seasons, but mostly in the winter. Despite this, Arctic landscapes are generally expected to dry out more during summer. This is because higher air temperatures mean that more water evaporates, melt finishes earlier and water flow regimes are altered.

Models project continued thawing of permafrost. Projections show that sea ice thickness and summer sea ice extent will continue to decline in the coming decades, although considerable variation from year to year will remain. A nearly ice-free summer is now considered likely for the Arctic Ocean by mid-century. This means there will no longer be any thick multi-year ice consistently present. Climate model projections show a 10-30% reduction in the mass of mountain glaciers and ice caps by the end of the century. The Greenland Ice Sheet is expected to melt faster than it is melting now, but no current models tell us exactly how this and other land-based ice masses in the Arctic will respond projected changes in the climate. This is because ice dynamics and complex interactions between ocean, snow, ice and the atmosphere are not fully understood.

Why changes in the Arctic matter globally

Changes in the Arctic cryosphere have impacts on global climate and sea level. When highly reflective snow and ice surfaces melt away, they reveal darker land or ocean surfaces that absorb more of the sun's energy. The result is enhanced warming of the Earth's surface and the air above it. There is evidence that this is happening over the Arctic Ocean as the sea ice retreats, as well as on land as snow melts earlier.

Overall emissions of methane and carbon dioxide from the Arctic could increase due to warming of soils and freshwater systems, and thawing of ancient frozen soil beneath the seabed. For example, it has been calculated that a release of just 1% of the methane estimated to be present in permafrost below the seabed of the East Siberian shelf would have a warming effect equivalent to doubling the amount of carbon dioxide in the atmosphere. The combined outcome of these effects on global climate is not yet known.

All the main sources of freshwater entering the Arctic Ocean are increasing - river discharge, rain/snow and melting glaciers, ice caps, and the Greenland Ice Sheet. Recent calculations estimate that an extra 7,700 km3 of freshwater– equivalent to 1 metre of water over the entire land surface of Australia - has been added to the Arctic Ocean in recent years. There is a risk that this could alter large-scale ocean currents that affect climate on a continental scale. Melting glaciers and ice sheets worldwide have become the biggest contributor to global sea level rise. Arctic glaciers, ice caps and the Greenland Ice Sheet contributed 1.3 mm – over 40% – of the total 3.1 mm global sea level rise observed every year between 2003 and 2008. These contributions from the Arctic to sea level rise are much greater than previously 326 measured. High uncertainty surrounds estimates of future global sea level. Latest models predict a rise of 0.9 -1.6 m above 1990 level by 2100, with Arctic ice making a significant contribution.

Changes in the Arctic cryosphere affect global society. Sea level rise is one of the most serious societal impacts of cryospheric change. Higher average sea level and more damaging storm surges will directly affect millions of people in low-lying coastal flood plains. Sea level rise increases the risk of inundation in coastal cities such as Shanghai and New York. On the other hand, global economic activity may benefit from cryospheric changes in the Arctic. For example, opening transpolar sea routes across the Arctic Ocean will reduce the distance for ships travelling between Europe and the Pacific by 40% compared to current routes. This could reduce emissions and energy use. Some unique Arctic species, such as the narwhal, face particular threats as the cryosphere changes. The decline of cryospheric habitats such as sea ice and wetlands over permafrost will impact on migratory species of mammals and birds from elsewhere in the world.

Uncertainty can be reduced by further research. Current monitoring, research and model results provide high confidence that significant changes are occurring in the Arctic cryosphere, and these changes will continue in the future. Some of the observed changes align with expectations but one major component of the cryosphere (the sea ice) has reacted faster than anticipated just five years ago. Even so, substantial uncertainty remains, particularly concerning the future timing of changes, and the effects of interactions (feedbacks) between components of the cryosphere and climate system. To reduce the uncertainty in future assessments, more robust observational networks are needed. Satellites and airborne measurements have improved our ability to observe some elements of the Arctic cryosphere such as sea ice extent and snow cover. Monitoring of other key elements of the cryosphere, notably sea ice thickness, snow depth, permafrost and glaciers, requires surface-based observations. Many surface-based snow, freshwater ice, and precipitation gauge networks have diminished or have been completely lost, and sites for measuring sea ice, land ice, and physical properties of snow are sparse. Observational networks need to be expanded to provide a robust set of cryospheric data for monitoring, model improvement and satellite product validation. The biggest unanswered questions identified by this report are: What will happen to the Arctic Ocean and its ecosystems as freshwater is added by melting ice and increased river flow? How quickly could the Greenland Ice Sheet melt? How will changes in the Arctic cryosphere affect the global climate? How will the changes affect Arctic societies and economies? Answering some of these questions requires improved monitoring networks.

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