

# Icelandic perspectives on adaptation to climate change and variability

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**I**n good weather, the picturesque Snæfellsjökull ice cap can be seen across the bay from Reykjavík. In the 1864 novel *Journey to the Centre of the Earth*, by Jules Verne, the ice cap serves as the entrance to a passage that led to the middle of our planet. It is the only ice cap that can be seen from Reykjavík, and has existed for many centuries, at least since Iceland was settled in the ninth century. Recent measurements show that this ice cap is shrinking rapidly in size.

The climate of Iceland exhibits considerable variability on annual and decadal timescales. However, long-term temperature records from the weather station at Stykkishólmur, about 60 kilometres from the Snæfellsjökull ice cap, show that during the last two centuries the climate of Iceland has warmed by about 0.7°C per century. In recent decades the warming has been very rapid with significant impacts on many natural systems in Iceland.

Recent measurements show that the Snæfellsjökull ice cap, which has an average thickness of less than 50 metres, thinned by approximately 13 metres in the last decade. At the current rate of thinning it will disappear within the century.

Snæfellsjökull ice cap is not an isolated case in this regard, most monitored glaciers are retreating. The thinning of large glaciers, such as the Vatnajökull ice cap, one of Europe's largest ice masses, reduces the load on the Earth's crust, and the crust rebounds. Consequently large parts of Iceland are now experiencing uplift. However, the uplift does not reach to the urban south west part of Iceland, where subsidence is occurring.

Changes are also evident in glacial river runoff, with earlier onset of the melting season and enhanced late summer melting. Recent warming has also impacted the fauna and flora of Iceland. Tree limits are now found at higher altitudes than before and the productivity of many plants has increased. In the ocean, there have been significant changes associated with warmer sea surface temperatures. Several new species of fish have expanded their range into Icelandic waters, and Icelandic stocks that traditionally were mostly found along the south coast have expanded their range to the north coast.

During the 21st century the climate of Iceland is likely to warm even further. Natural variability, while considerable, will not overwhelm the projected long-term warming of more than 2°C during the century. Because of natural variability the warming is, however, likely to be uneven with the climate exhibiting rapid warming during some decades, but little or none in others.

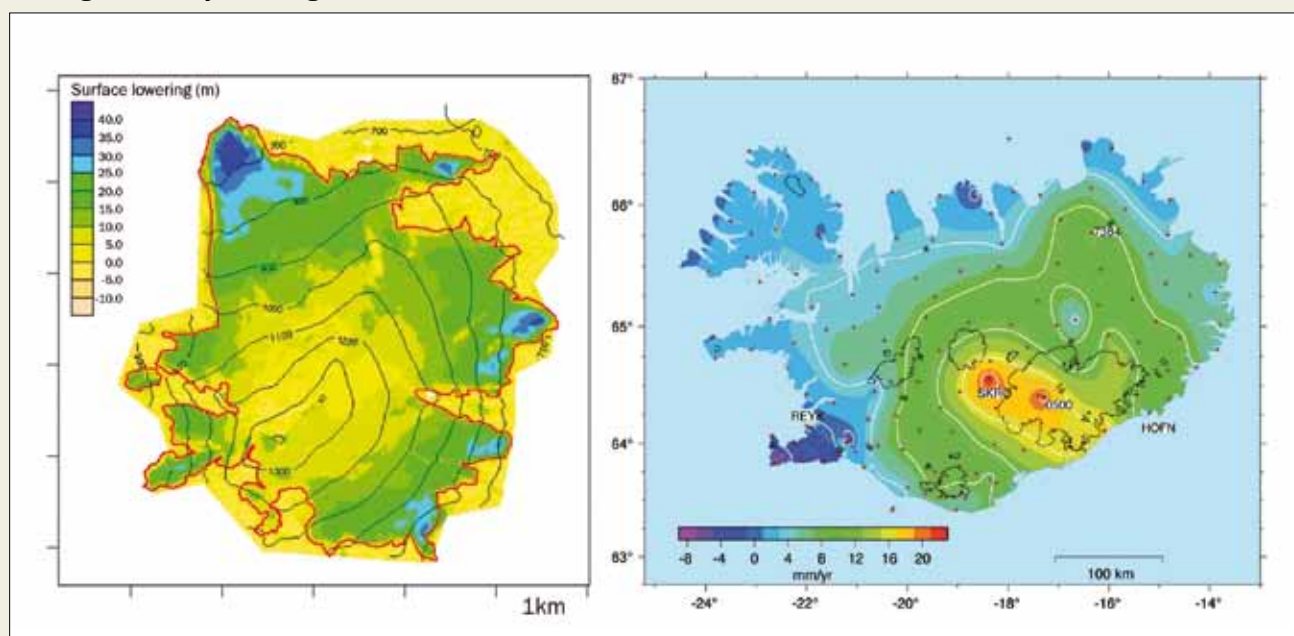
The projected warming is likely to cause a pronounced retreat of glaciers in Iceland. By the end of the century Langjökull, the second largest ice cap in Iceland is projected to have shrunk to 15 per cent of the size it was in 1990. The projected retreat is not as large for glaciers that are at a higher altitude, but by the end of the century they are still likely to lose at least half the volume they had in 1990.



The Snæfellsjökull ice cap

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### Thinning of Snæfellsjökull and glacial rebound in Iceland



Left: the changes in surface topography of the Snæfellsjökull glacier 1999-2008. The figure shows a widespread loss of ice, on average about 1.5 metres per year. The red line indicates the outline of the glacier in 2000<sup>1</sup> Right: vertical motion of the land surface in Iceland based on measurements 1993-2004. Positive numbers (green to red colours) indicate uplift, negative numbers (blue to violet colours) indicate subsidence<sup>2</sup>. Dots show the station network.

As a consequence, glacial river runoff will increase during the first half of the 21st century and peak before its end. Hydropower potential can therefore be expected to increase in the first half of the century. Based on past experience, changes in glacial riverbeds are likely, which can impact both energy production and road services. Furthermore, it is likely that production of magma will increase under the thinning Vatnajökull ice cap, which may result in more frequent or larger volcanic eruptions in the area.

Concomitant with the projected warming, further changes in biota are likely. The enhancement of plant productivity and upward displacement of tree limits is likely to continue. The impact on marine life is more uncertain, not the least due to insufficient knowledge of the long-term consequences of recently discovered acidification of the oceans.

Impacts of projected climate change are likely to touch all sectors of Icelandic society. Projected increases in hydropower potential, along with enhanced plant productivity will affect the resource base of the country, while increased risk of flooding both from rivers and rising sea levels will influence planning and civil response. Because it is likely that there will also be impacts that are not presently anticipated, decision makers must be equipped to deal with uncertainties in impact projections.

The Fourth Assessment of the IPCC discusses the need for adopting risk management practices in dealing with projected impacts. In Iceland, there is a need to better quantify the magnitude of impacts and assess the probability of significantly adverse outcomes. To this end, further monitoring, systematic attribution and enhanced modelling, both of regional climate change and also of likely impacts, will be required.

Iceland already has substantial experience in dealing with risk management of natural hazards, and existing frameworks can be adopted to deal with some climate risks, such as possible increases in extreme weather, flooding and volcanic eruptions. To deal with impacts that are not related to singular events but rather affect the background conditions of natural and societal systems, policy makers will need different methodologies

and frameworks. Examples of these kinds of impact include changes in river runoff that may necessitate changes in the management of energy and water resources.

Capacity building to meet these challenges is ongoing. Institutional realignment, starting with the merger of the Icelandic Meteorological Office (IMO) and the Hydrological Service will enable better support for policy makers. Climate information services must be strengthened to ensure that stakeholders have access to relevant information in a timely manner. It is also important to participate at the regional and international level. IMO has been active in several International Polar Year projects, leading one on hydrology, called Arctic-Hydra. Furthermore, IMO has headed a series of Nordic-Baltic climate impact projects focusing on three main renewable energy resources; hydropower, bio-fuels and wind power, and how future climate change within the next 20–30 years can impact these resources. All the National Hydro-Meteorological Services in the region are partners in this cooperation, which in many respects constitutes a regional Climate Services Application Program for the Nordic-Baltic region, including Greenland. A future ambition is to develop the network into a formal Regional Climate Service Application Program.

The project also intends to contribute to the Nordic Council of Ministers Top-level Research Initiative Programmes 2009–2013, which will focus on impact studies, adaptation to climate change and the interaction of climate change with the cryosphere, among other themes. Recognizing and responding to the risks and opportunities posed by climate change is a challenging task for both scientist and policy makers alike.