CES Nordic Project on Climate and Energy Systems

The impact of climate change on glaciers and glacial runoff in the Nordic countries

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IMO, IES/UI, NVE, GEUS, DMI, DES/UU, GI/UA

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Impacts, Risks and Adaptation
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CHIN Chiefs of the Hydrological Institutes in the Nordic Countries

Nordic Council of Ministers

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Overview

- Background
- International context
- Climate change scenarios
- Mass balance and dynamic modelling
- Ice-volume and runoff changes
- Conclusions

Background

- The Arctic and in particular the Nordic countries are home to many of the most accessible glaciers on Earth
- The small glaciers and ice caps are a part of the global reservoir of ice stored in glaciers and small ice caps which is likely to contribute substantially to the expected future rise in global sea level
- The glaciers are also important locally for various economic and societal reasons
- Melting and discharge of ice from the Greenland Ice Sheet is one of the most important causes of global sea level rise
- Research of the response of Greenland Ice Sheet and Arctic glaciers to future climate change is potentially one of the most important contribution of Nordic and Arctic scientists to global change research in the future

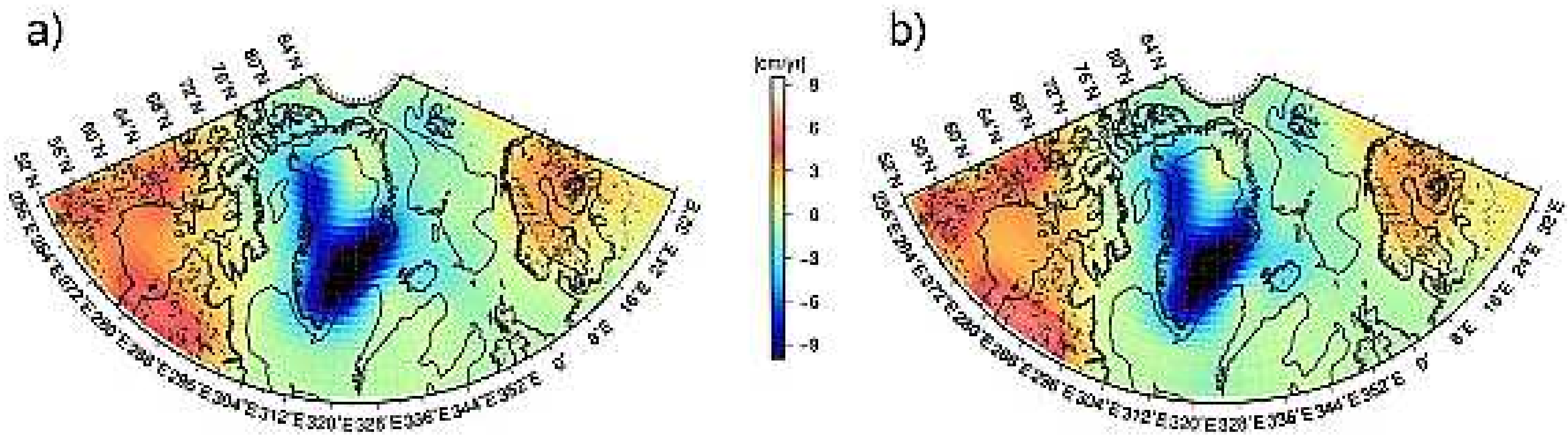
Importance of glacier changes

- Runoff changes
- Changes in subglacial water divides
- Changes in river courses at the glacier margins and, as a consequence, changes in river flow away from the ice margin, problems for communication lines
- Changes of terminal lakes with effect on jökulhlaups (glacial outburs floods)
- Sedimentation in marginal lakes, changes in sediment transport to the ocean, long-term changes in coastlines
- Isostatic land rise, coastal changes, problems in harbour management

Water on Earth as an average ocean depth or sea-level rise equivalent

	Amount (m)
The world oceans	3500–4000
Antarctica	56.6
Greenland Ice Sheet	7.3
Small ice caps and glaciers	0.2–0.4
Permafrost	0.03–0.1
Glaciers in Iceland	0.01

Glaciers and sea-level rise/GRACE



- Antarctica 0.4/0.7 ± 0.2 mm/yr
- Greenland 0.5/0.8 ± 0.1 mm/yr
- Iceland 0.032 ± 0.01 mm/yr
- Svalbard 0.026 ± 0.01 mm/yr
- Small glaciers and ice caps in total ~1.0 mm/yr
- Global sea-level ~3 mm/yr

Velicogna, I., and J. Wahr. 2006. Measurements of Time-Variable Gravity Show Mass Loss in Antarctica. *Science*, 311, 5768, 1754 – 1756. DOI: 10.1126/science.1123785.

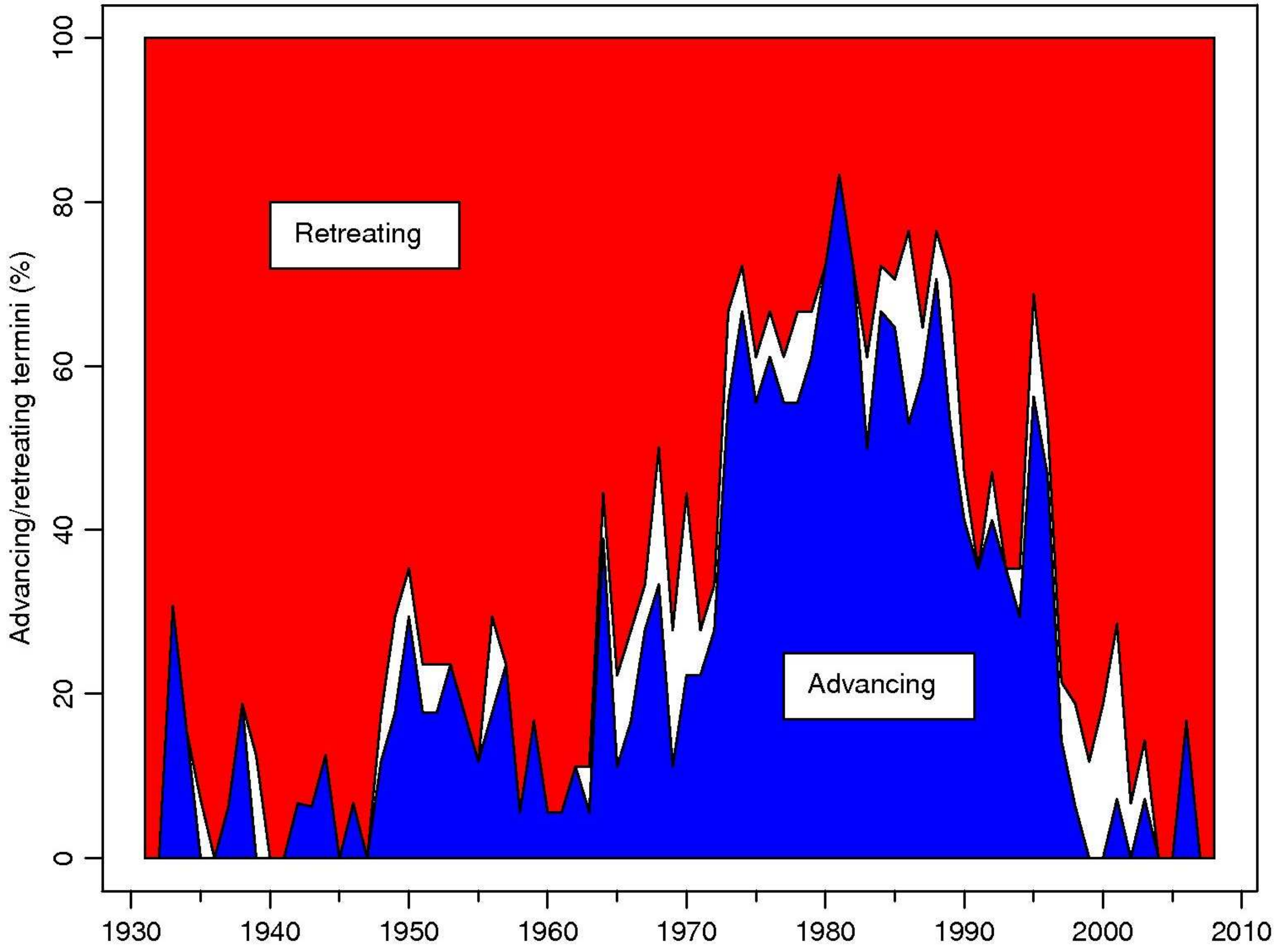
Wouters, B., D., Chambers and E. J. O. Schrama. 2008. GRACE observes small-scale mass loss in Greenland. *Geophys. Res. Lett*., 35, L20501, doi:10.1029/2008GL034816.

Meier, F. M., and others. 2007. Glaciers Dominate Eustatic Sea-Level Rise in the 21st Century. Science, 317, 1064–1067, doi: 10.1126/science.1143906.

van den Broeke and others. 2009. Partitioning Recent Greenland Mass Loss. *Science*, 326(5955), 984-986, doi: 10.1126/science.1178176

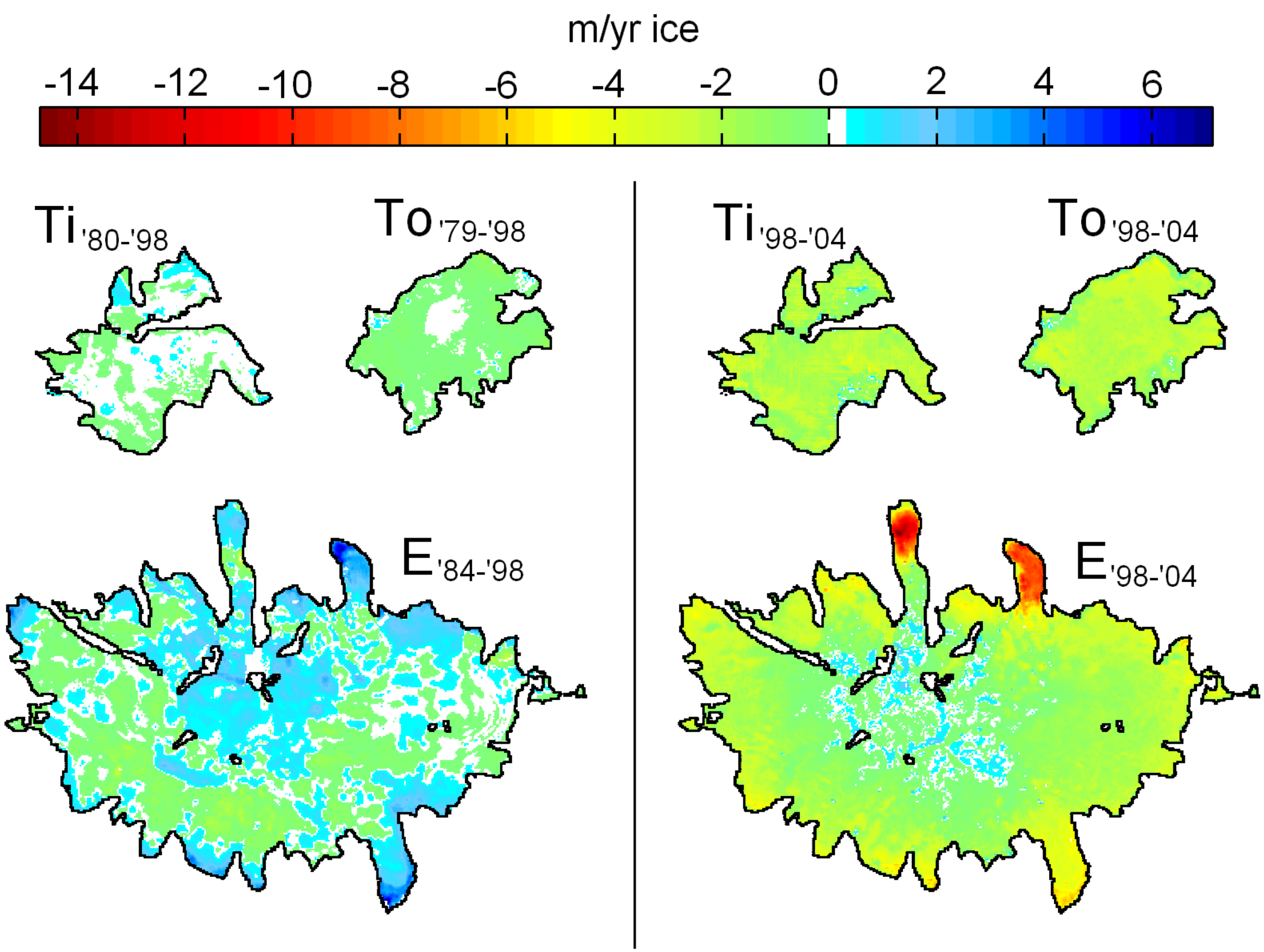
Velicogna, I. 2009. Increasing rates of ice mass loss from the Greenland and Antarctic ice sheets revealed by GRACE. *Geophys. Res. Lett*., 36, L19503, doi:10.1029/2009GL040222

Advancing/retreating non-surging termini

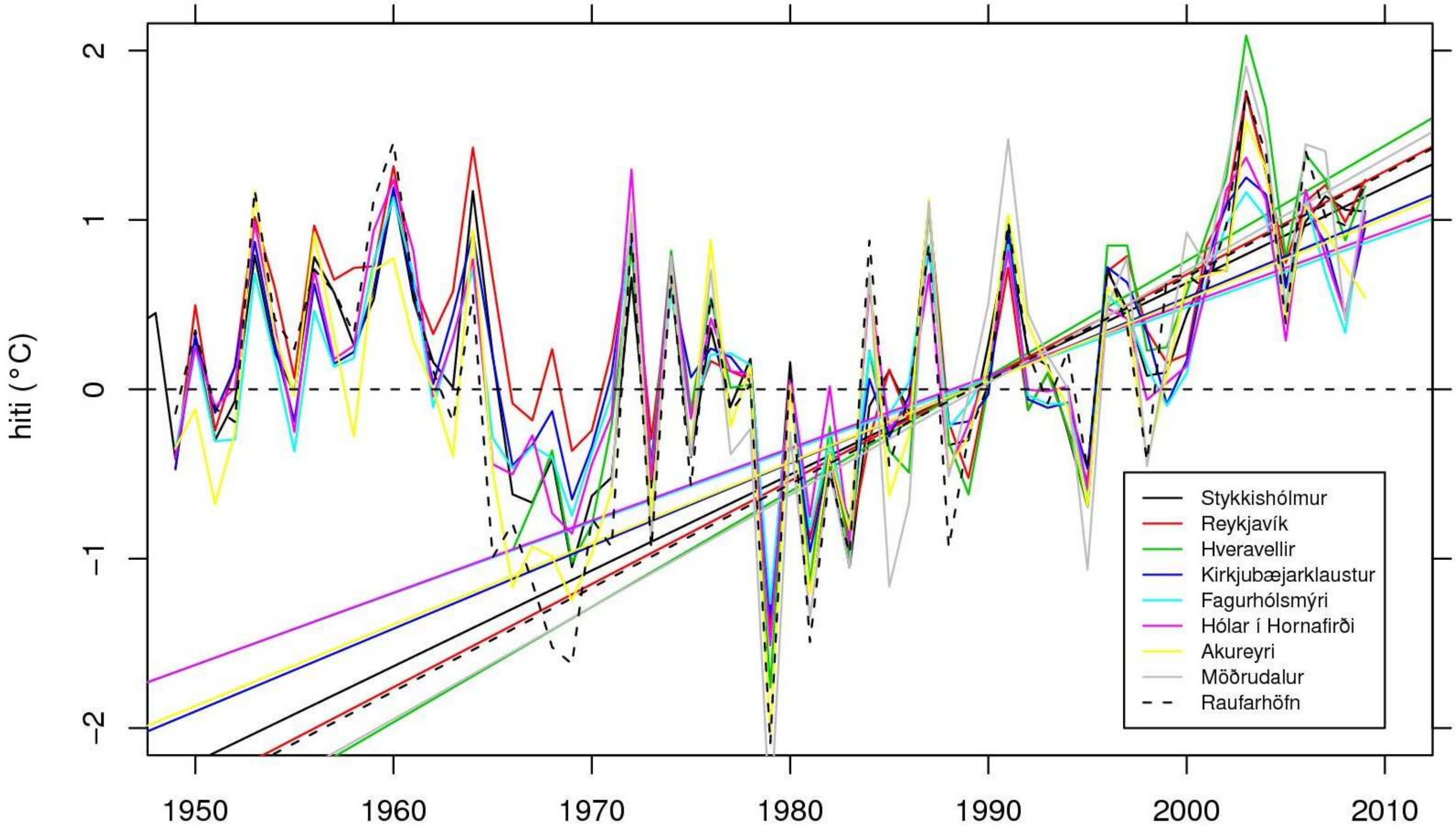


Maps of annual average elevation changes

- E: Eyjafjallajökull, Ti: Tindfjallajökull and To: Torfajökull ice caps
- periods displayed as subscripts of E, To and Ti



Temperature at 8 weather stations in Iceland



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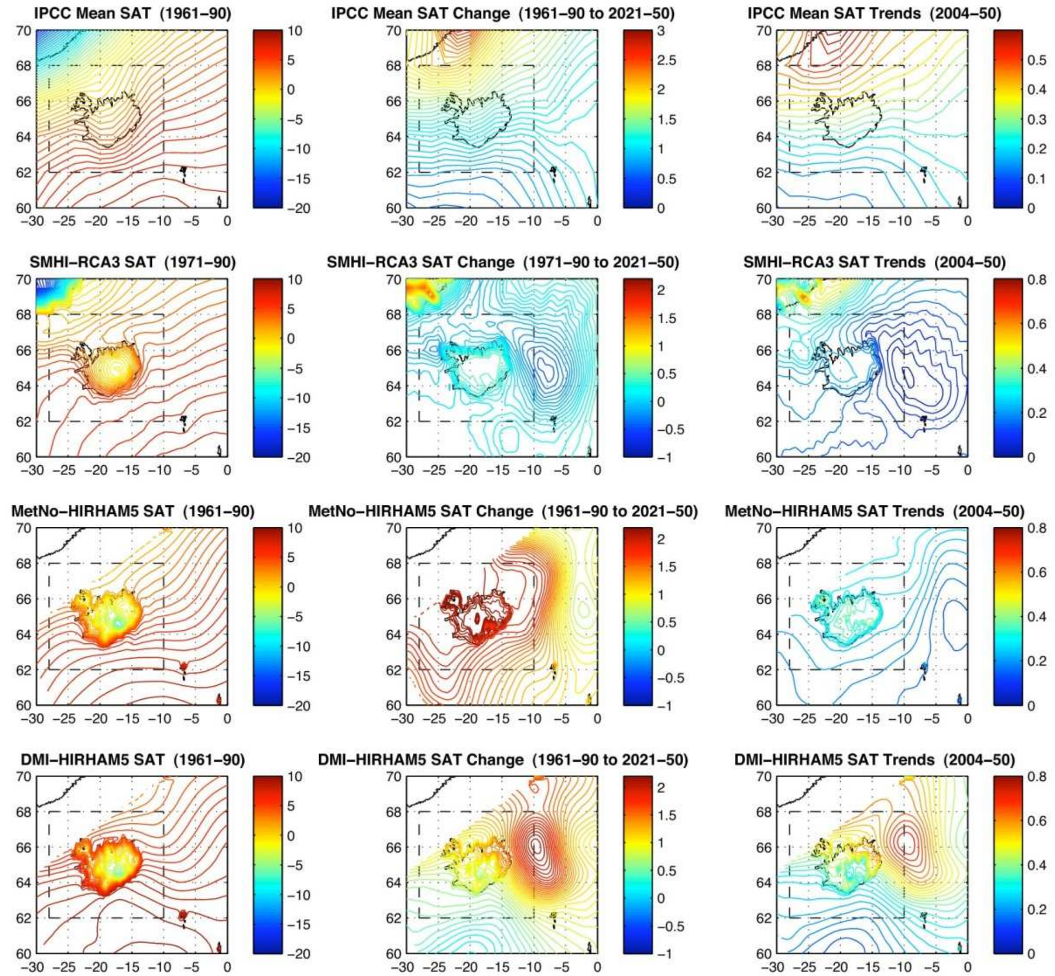
GCM/RCM temperature



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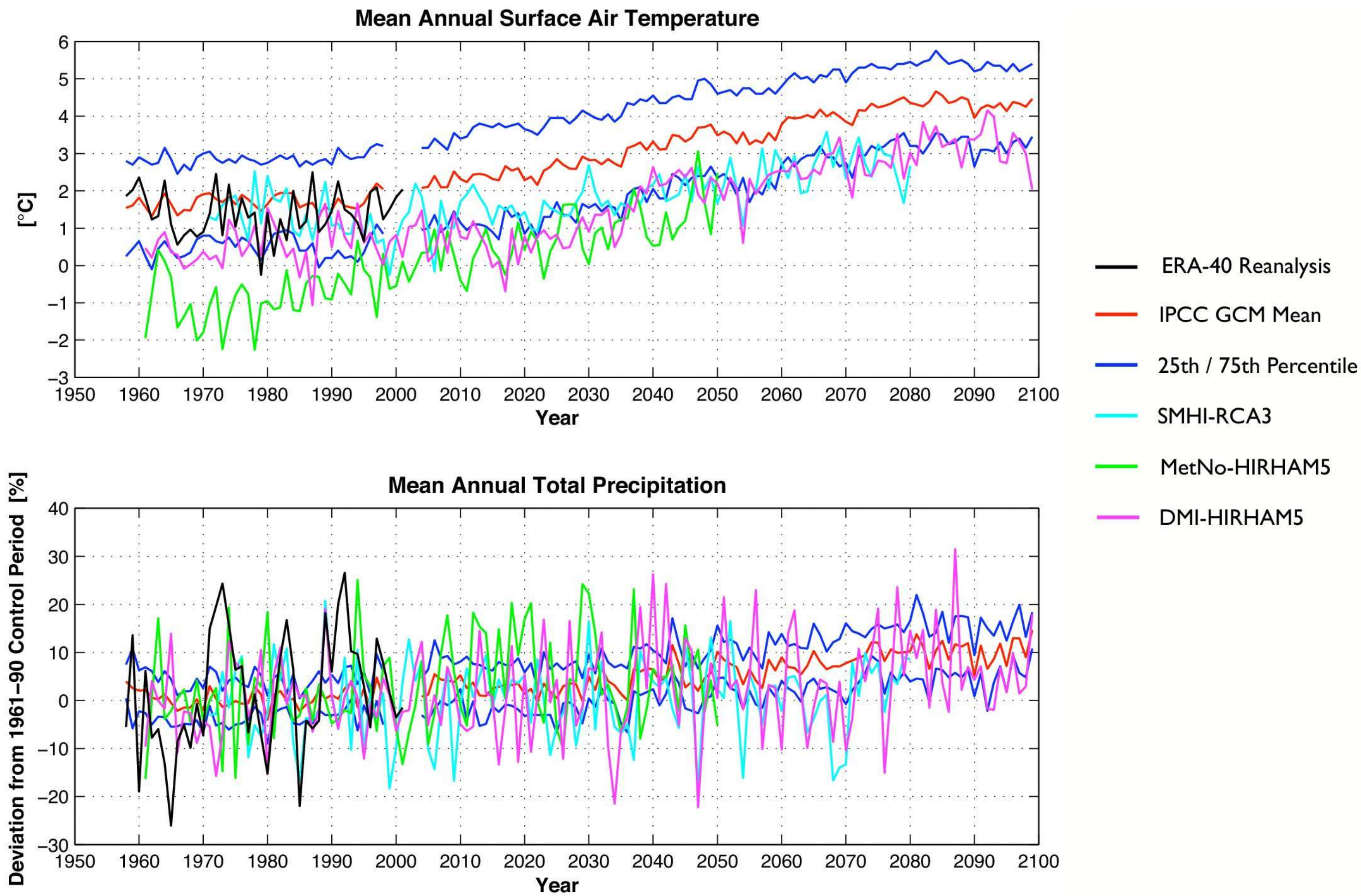
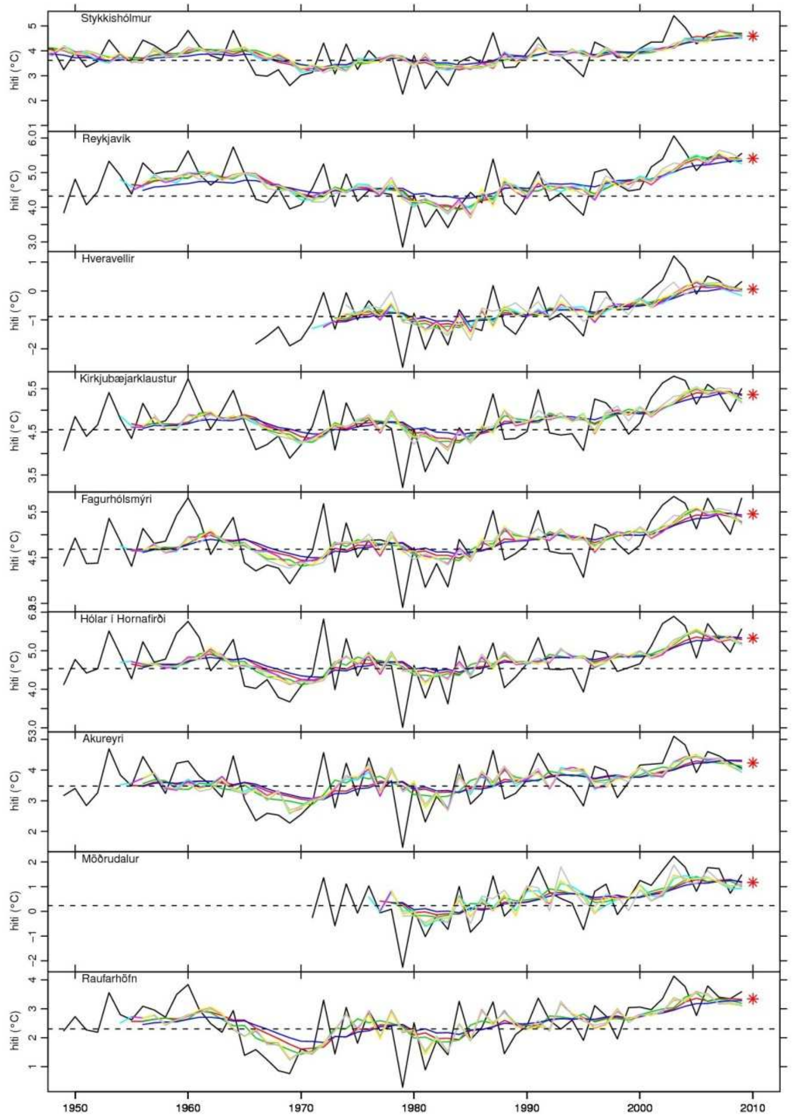
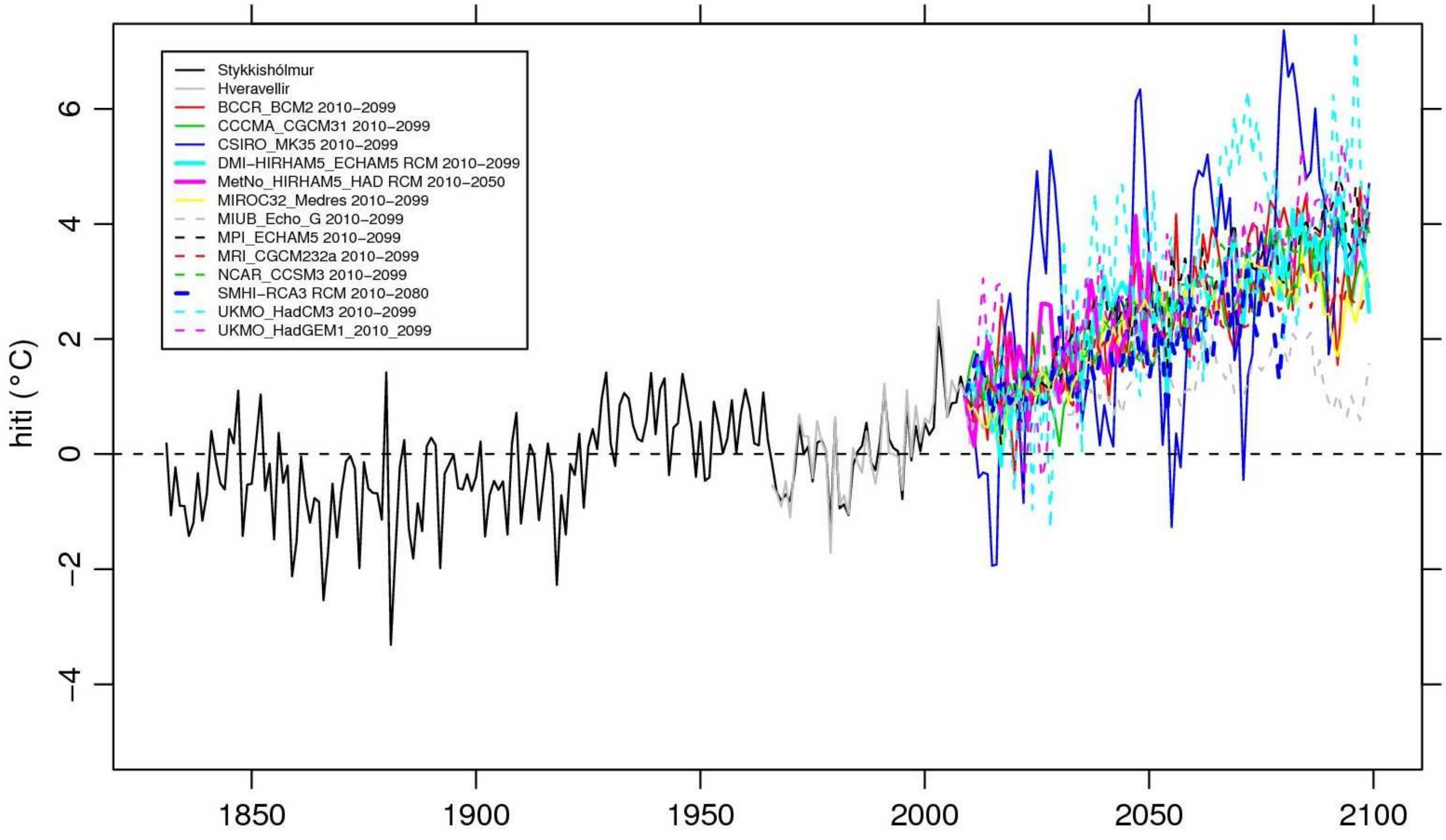
GCM/RCM temperature simulations



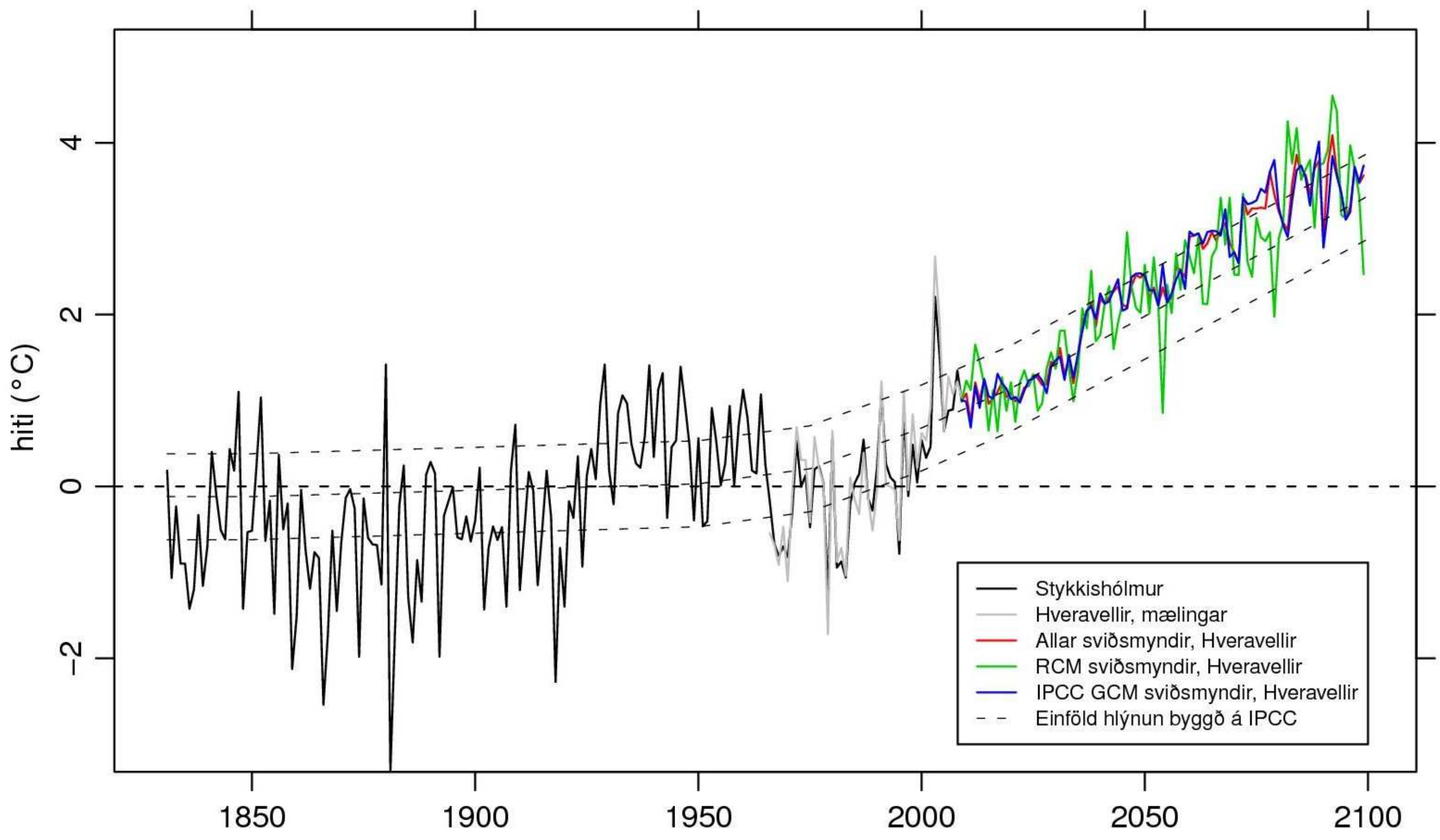
“Expected value” for 2010 temperature



Past temperatures + 13 scenarios



Past temperatures + medians of scenarios



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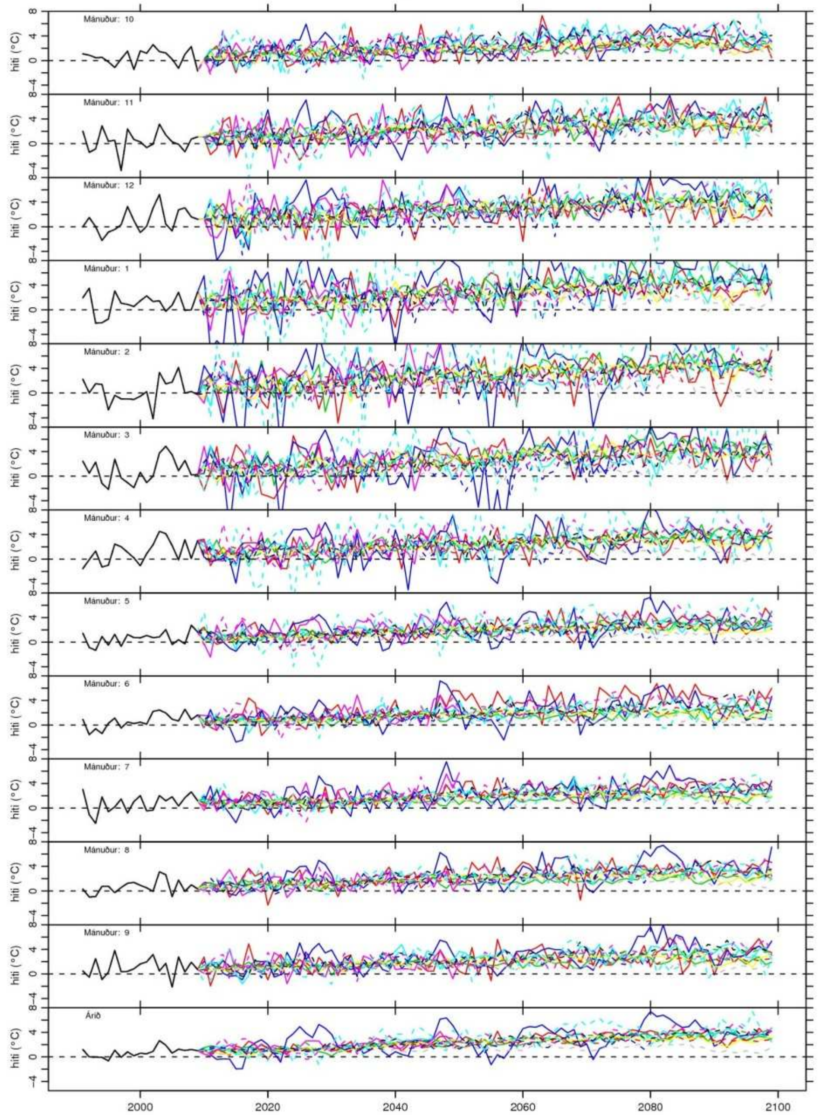
Monthly delta change temperature scenarios



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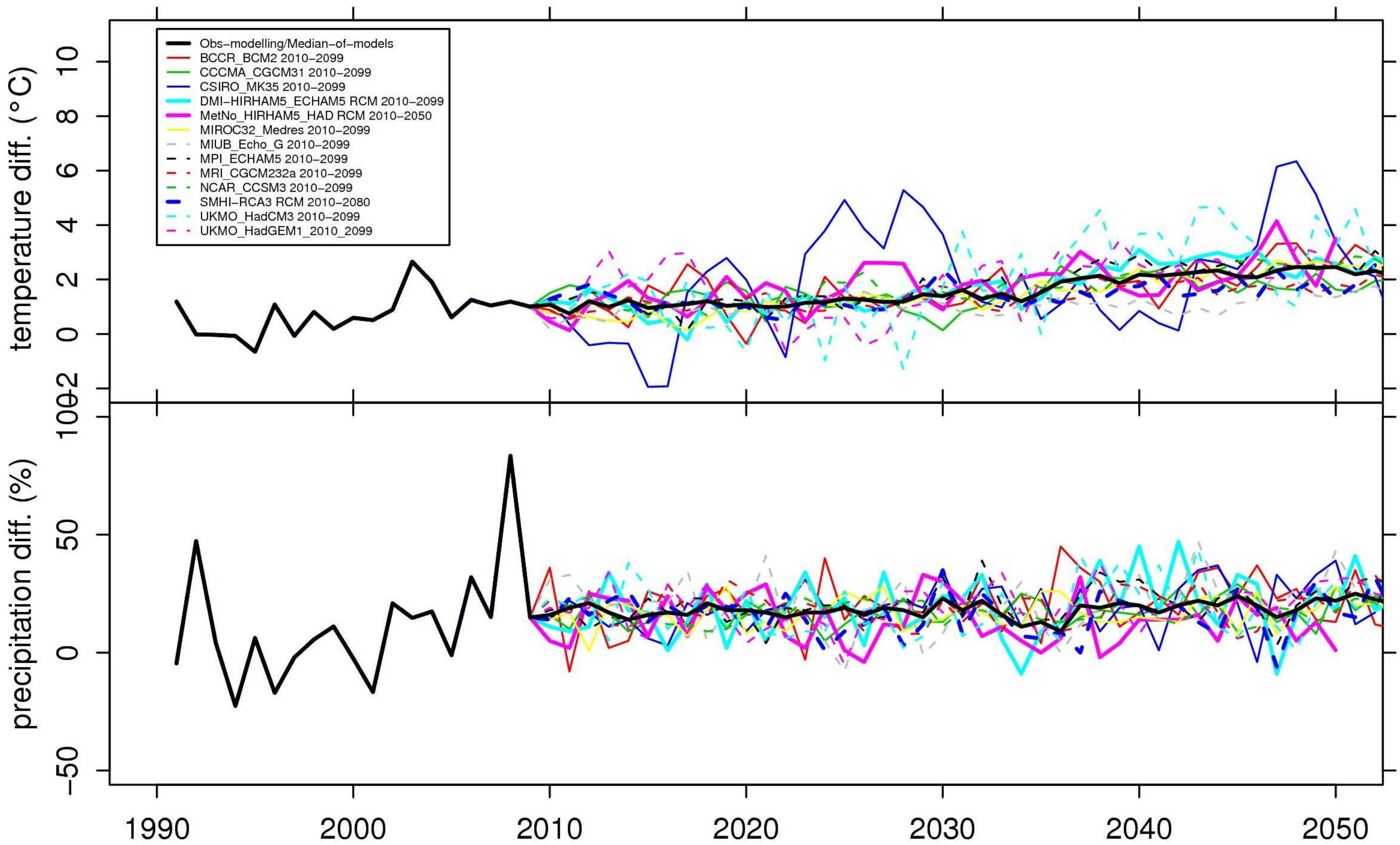
Hveravellir, temperature and precipitation scenarios



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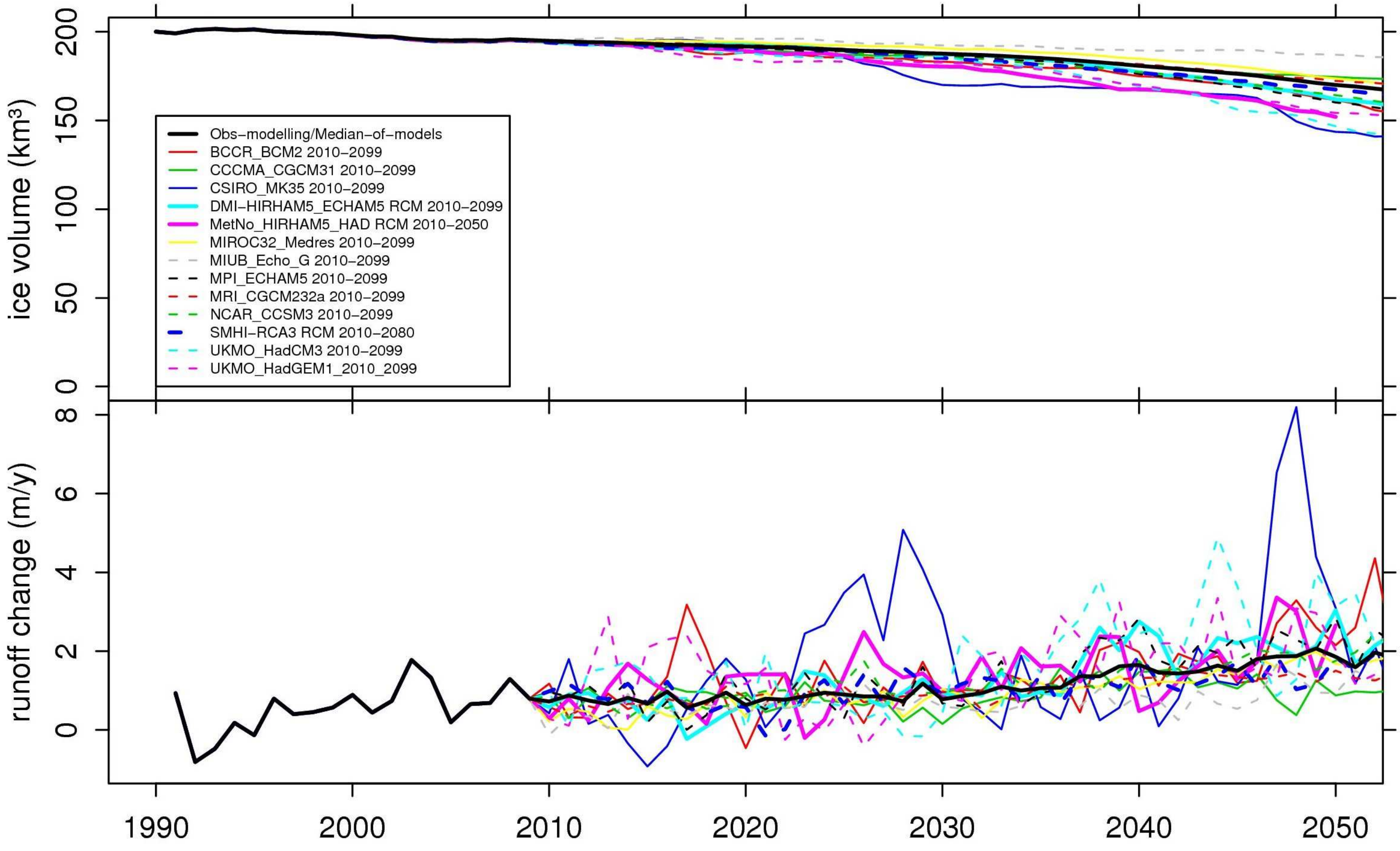
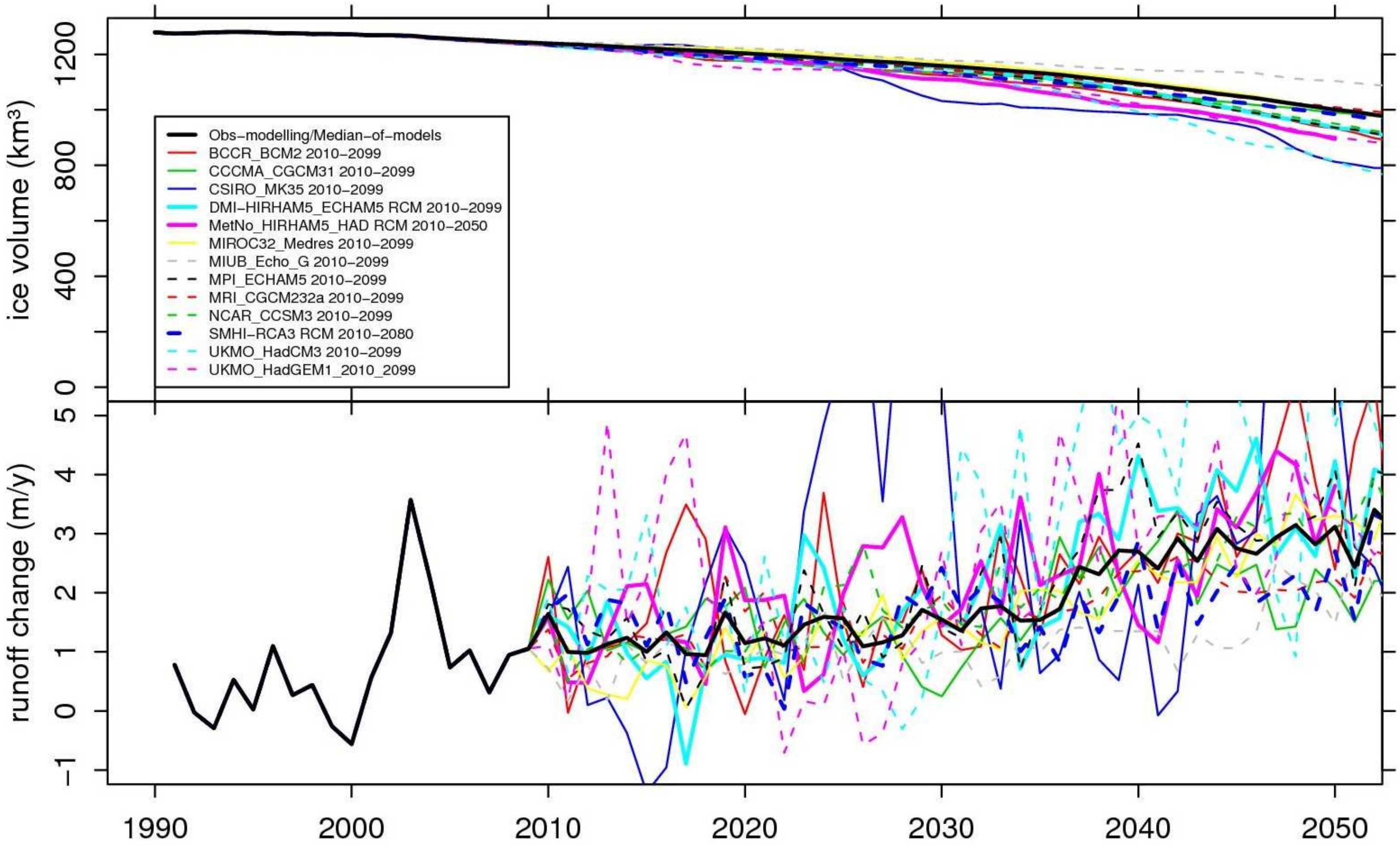
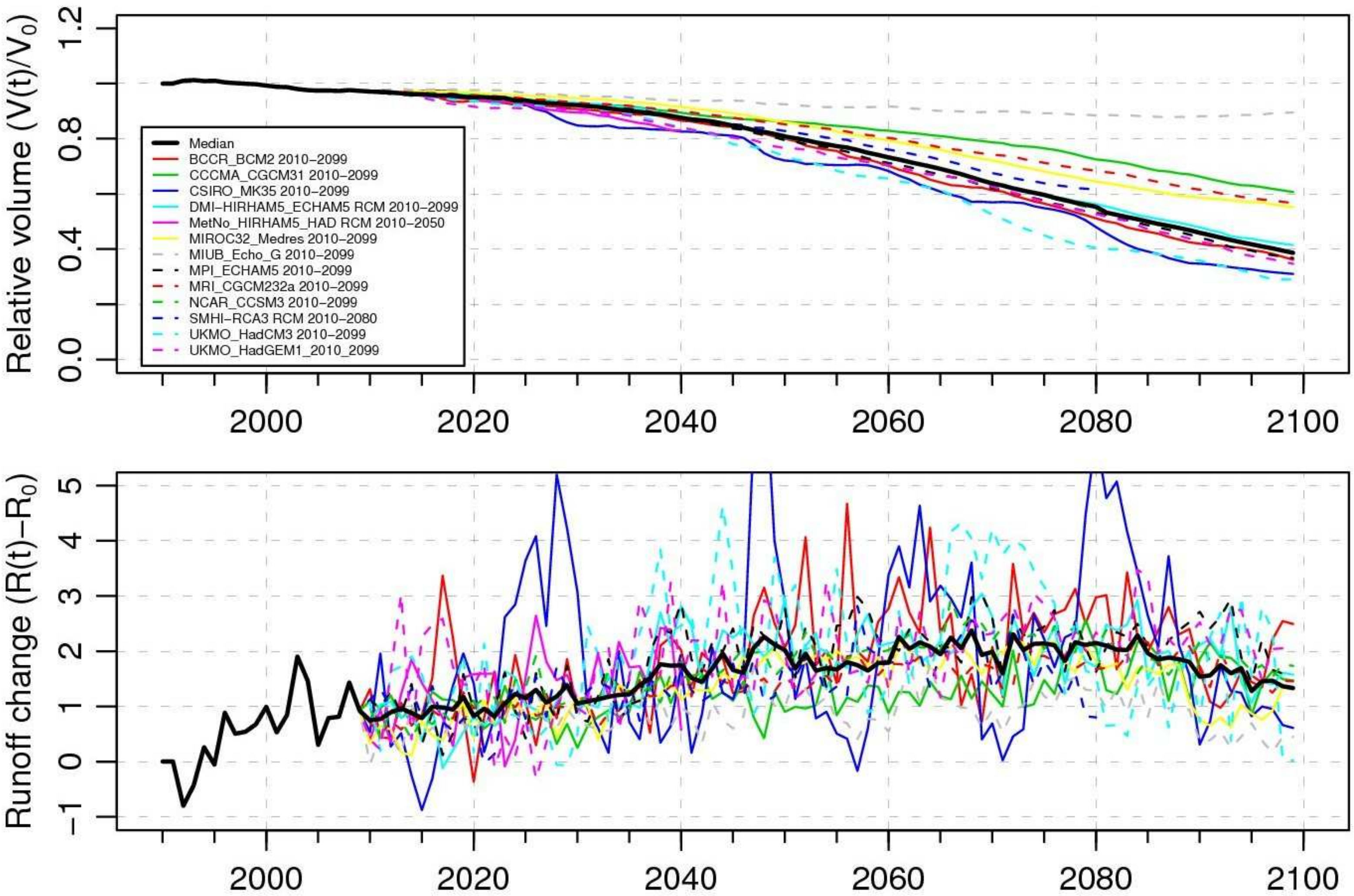
Hofsjökull, mass balance modelling



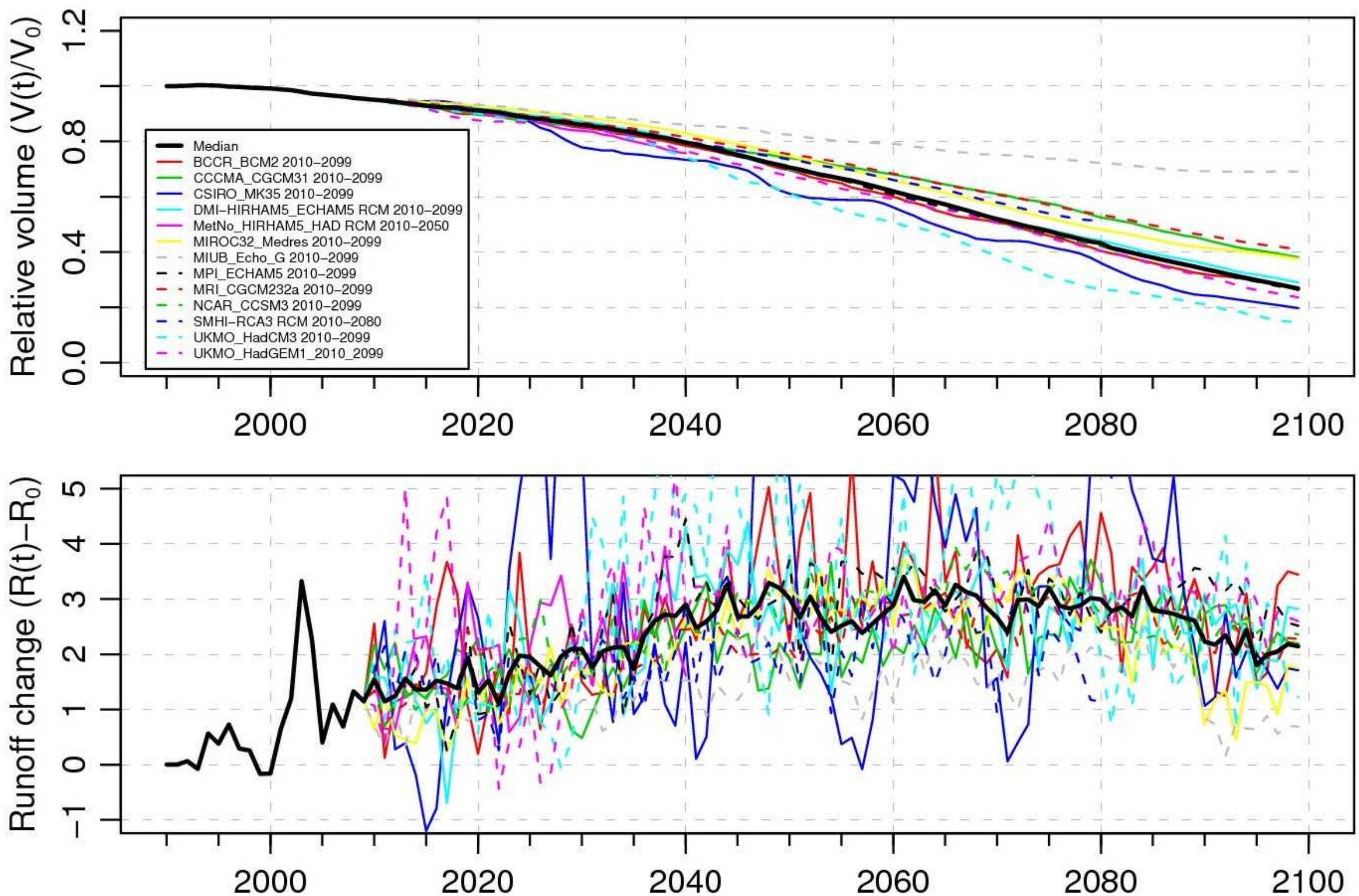
S-Vatnajökull, mass balance modelling



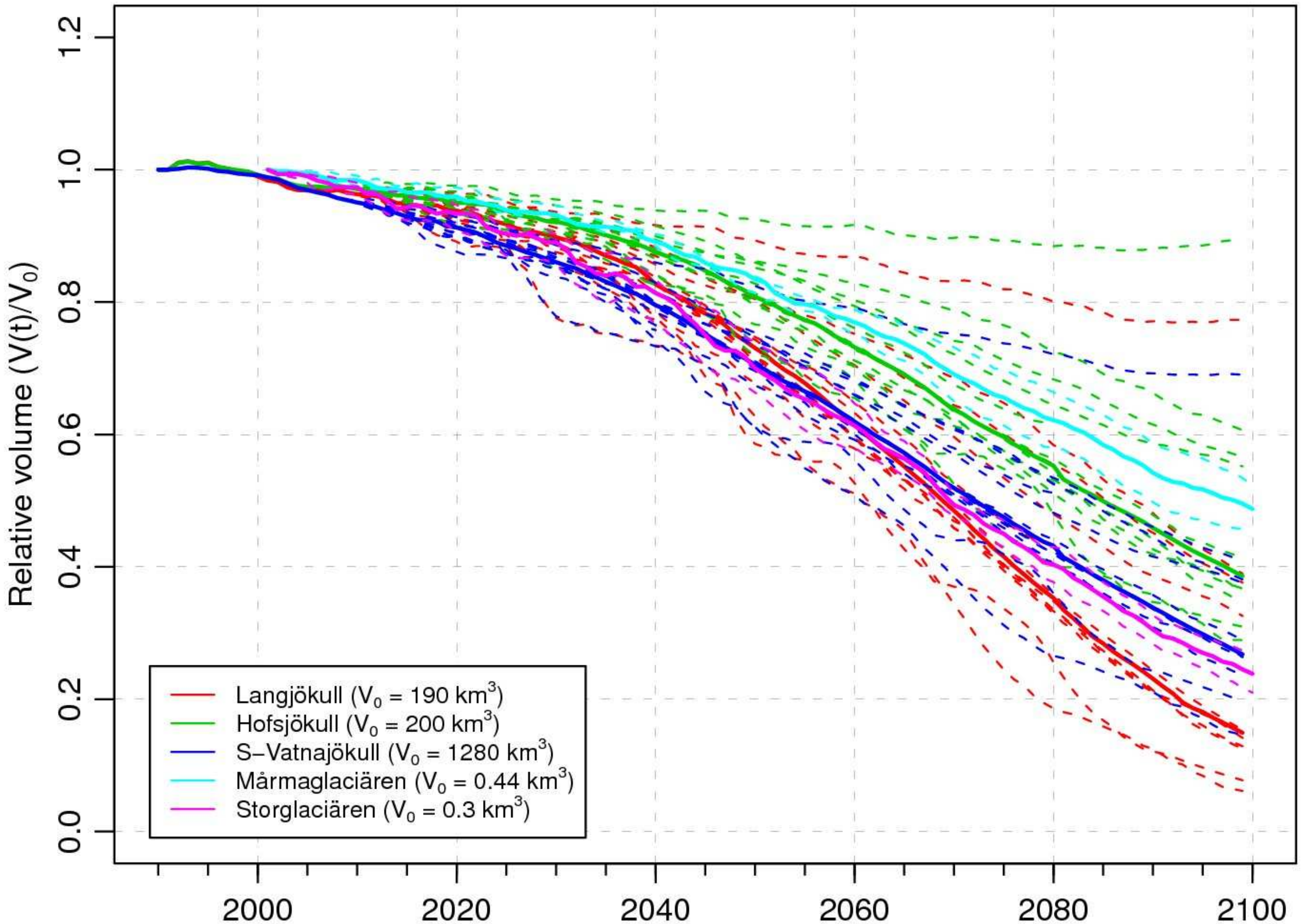
Hofsjökull, coupled model



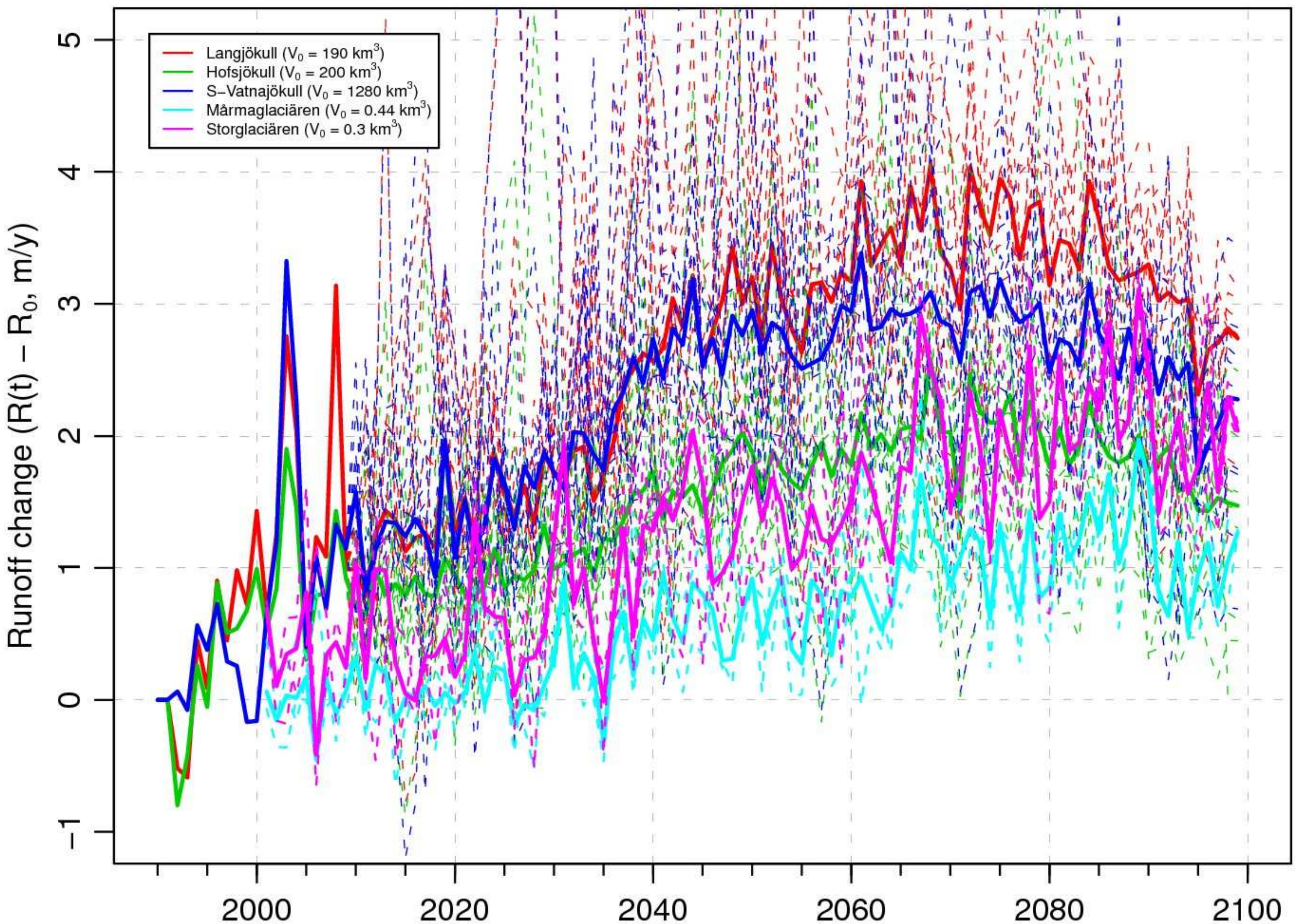
S-Vatnajökull, coupled model



Ice volume, Icelandic and Swedish glaciers

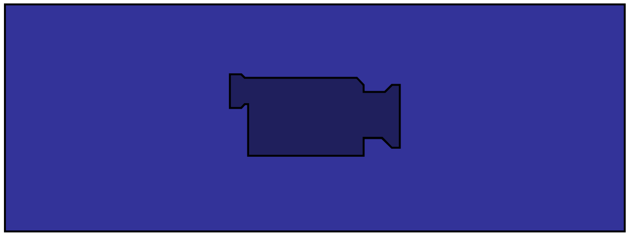


Runoff change, Icelandic and Swedish glaciers

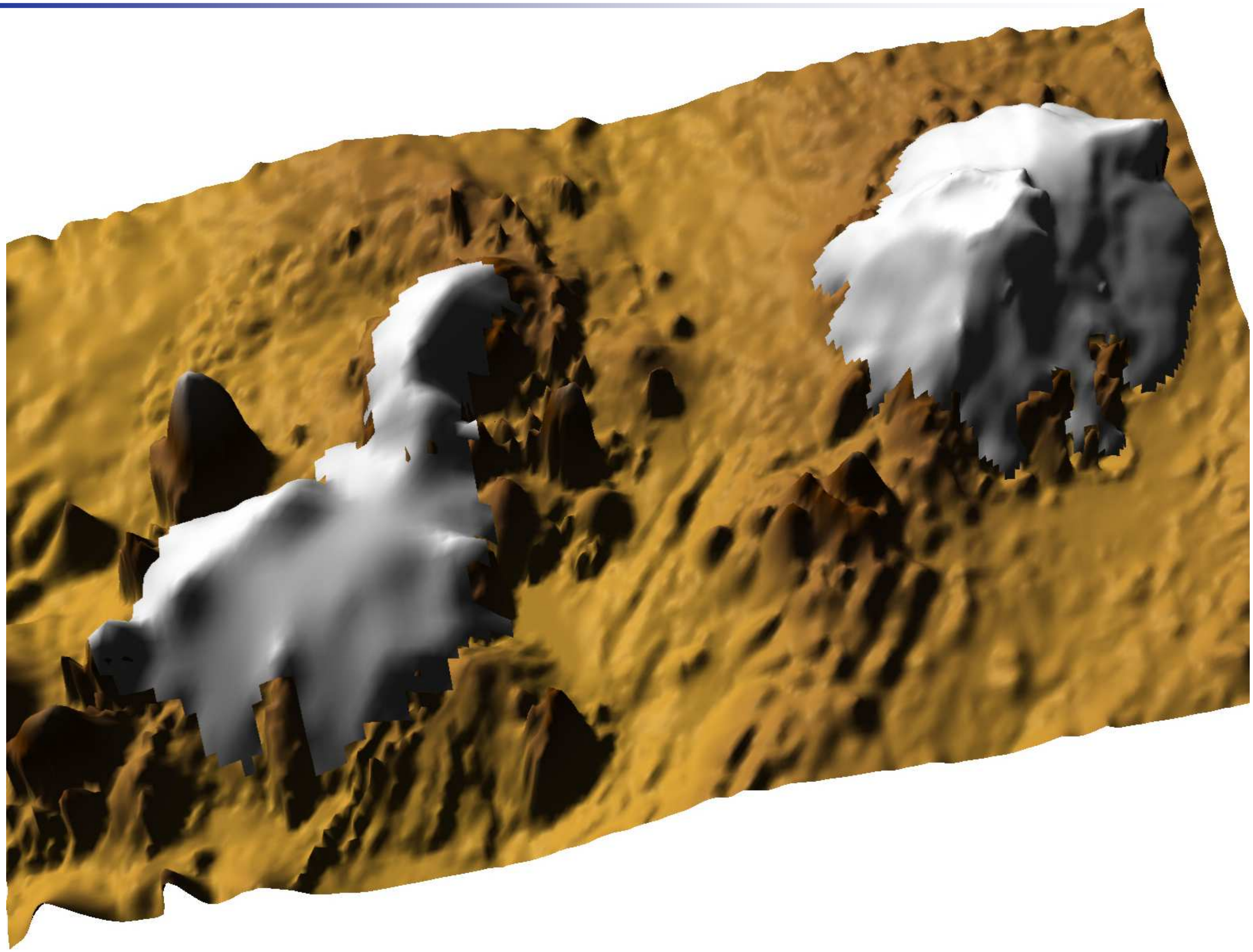


Retreat of Langjökull and Hofsjökull, 1990-2100

Sverrir Guðmundsson, Tómas Jóhannesson, Finnur Pálsson, Guðfinna Aðalgeirsdóttir, Helgi Björnsson, Oddur Sigurðsson, Þorsteinn Þorsteinsson



Before, 1981-2000 mean



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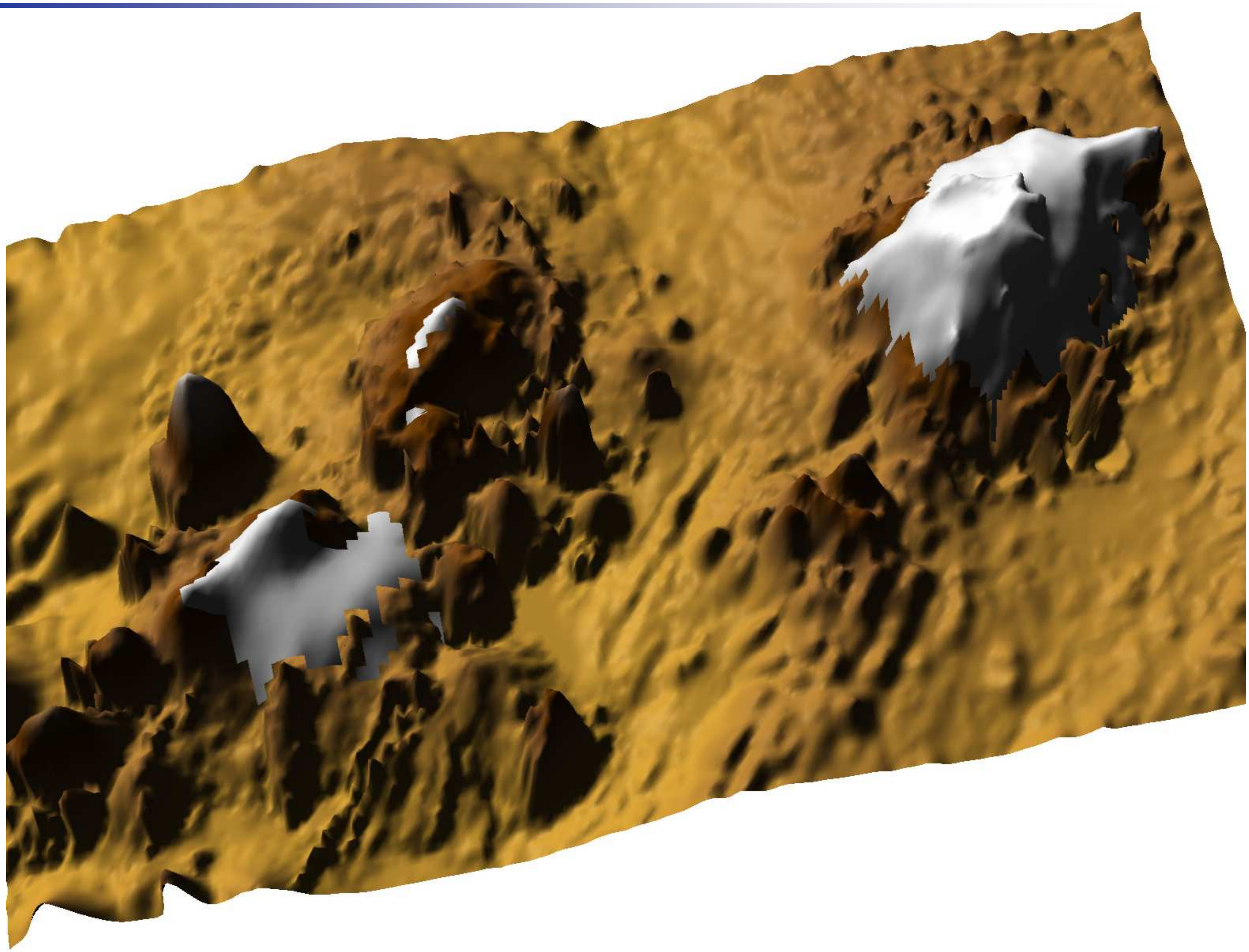
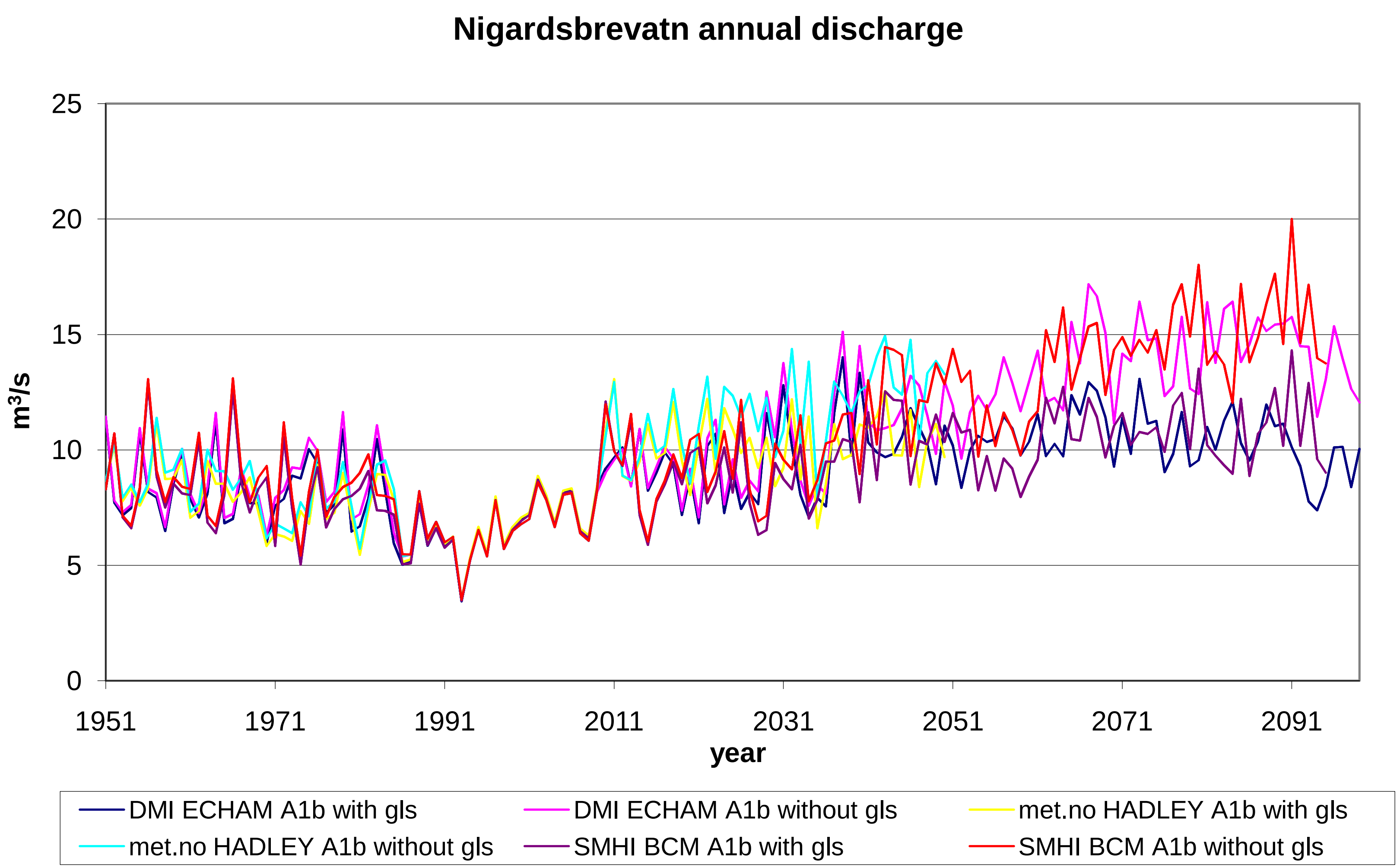
After, at ~2100, DMI scenario



Annual discharge, HBV/GLS models



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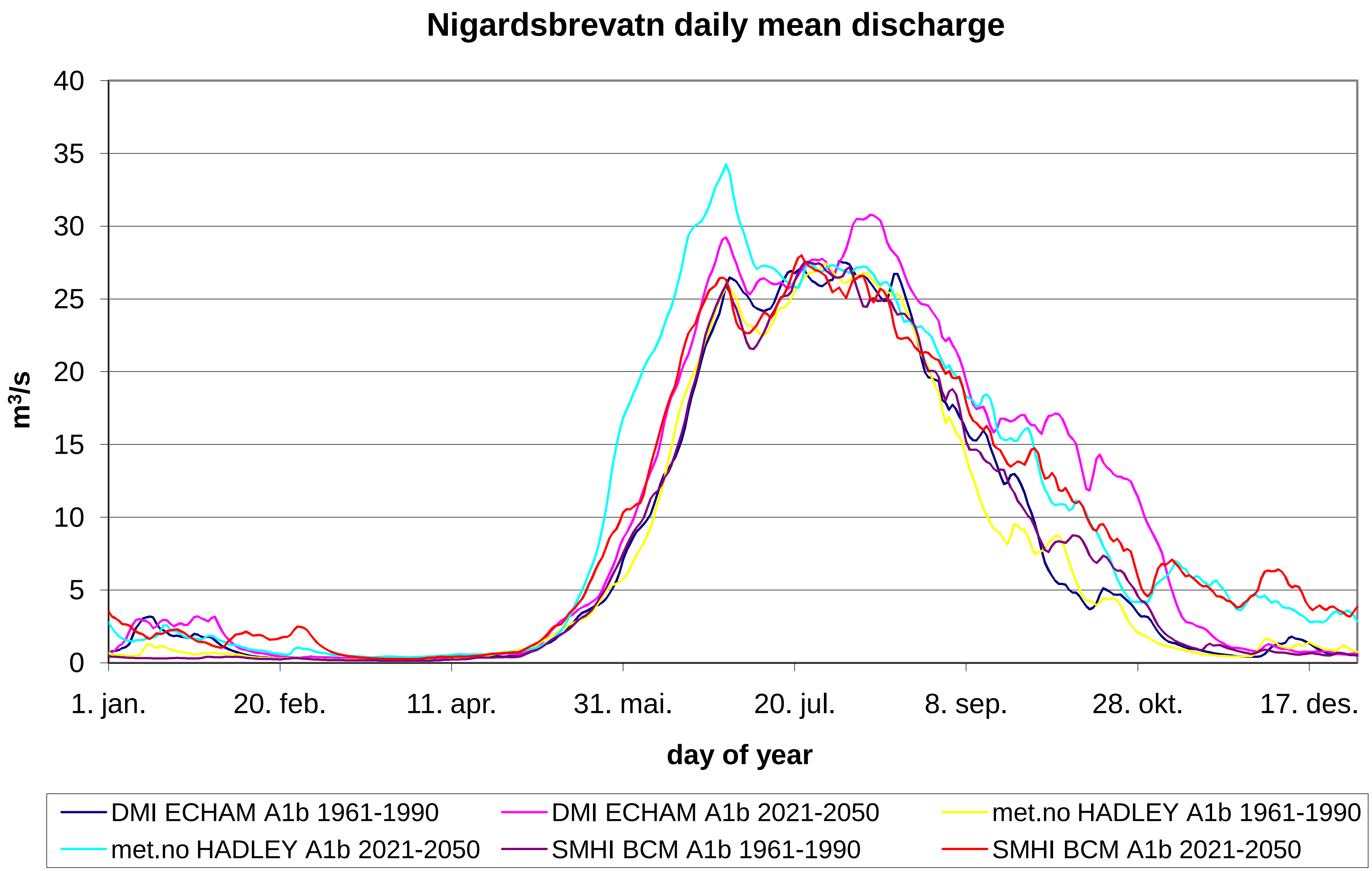
Discharge seasonality, HBV/GLS models



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Conclusions

- The results of the CES project largely confirm the main results obtained in the earlier CE and CWE projects.
- Many glaciers and ice caps, except the Greenland ice sheet, are projected to disappear in 100-200 years.
- Runoff from ice-covered areas in the period 2020-2051 may increase by on the order of 50% with respect to the 1961-1990 baseline, about half of which has already taken place in Iceland.
- There will be large changes in runoff seasonality and in the diurnal runoff cycle and, in some cases, changes related to migration of ice divides and subglacial watersheds.
- The dynamic response of the glaciers has little effect on these conclusions in the short term but becomes important in the second half of the 21st century.
- The runoff change may be important for the design and operation of hydroelectric power plants and other utilisation of water
- Detailed mass balance and dynamic modelling may be used to estimate runoff changes in individual watersheds
- There is a large uncertainty associated with differences between the modelled climate development by different GCMs and RCMs

Thank you for your attention!