Íslenskir jöklar á tímamótum. Áhrif loftslagsbreytinga á jökla og afrennsli frá þeim á næstu öld

Icelandic glaciers `at a watershed'. The impact of climate change on glaciers and glacier runoff during the next century

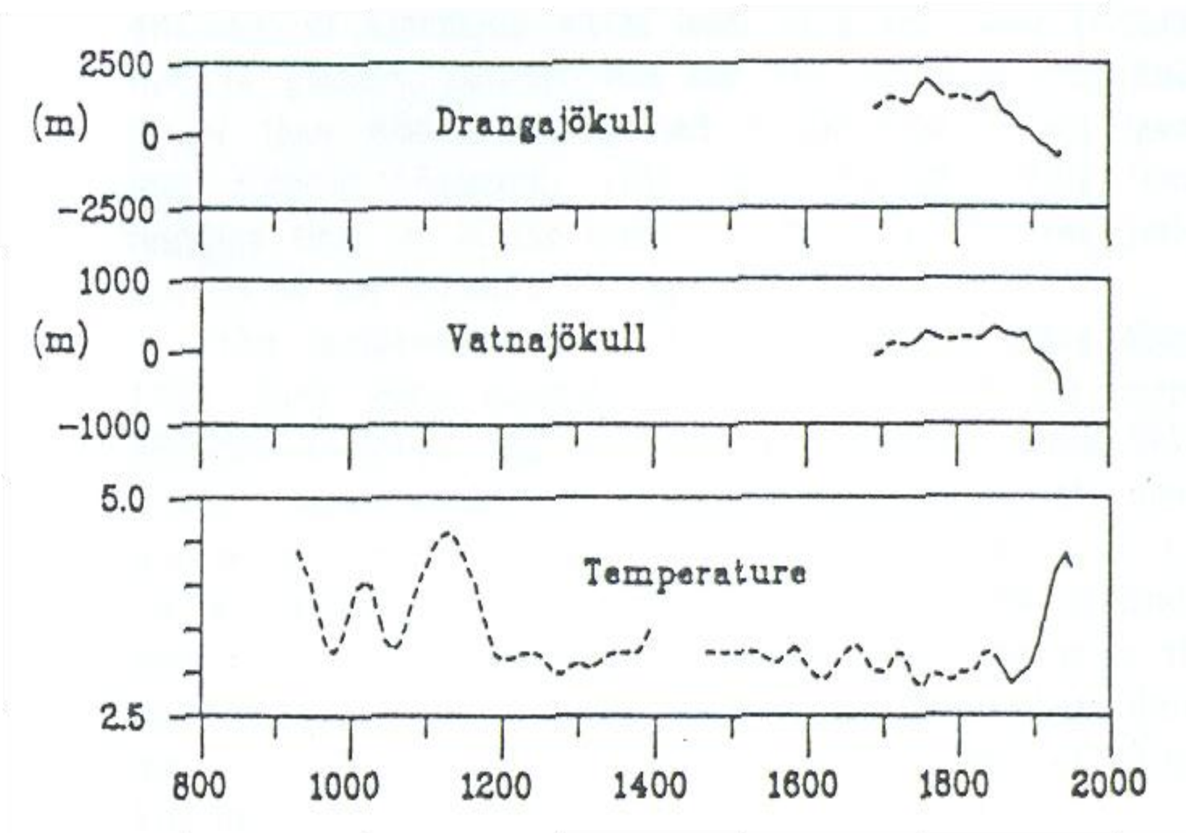
Tómas Jóhannesson, Þorsteinn Þorsteinsson, Oddur Sigurðsson, Philippe Crochet, Helgi Björnsson, Sverrir Guðmundsson, Finnur Pálsson og Eyjólfur Magnússon

Overview

Icelandic Met Office

- Glacier variations in Iceland in historical time
- The international context, where do we stand?
- Recent changes of the Icelandic glaciers
- Climate scenarios for glacier modelling
- The future of the Icelandic glaciers. Do they have a future?
- Nordic and international collaboration in glaciological research
- Lidar mapping of Icelandic glaciers

Glacier variations in Iceland since the settlement



Sigurður Þórarinsson (1943, 1974)

S-Langjökull, western Iceland, photo: Oddur Sigurðsson, 2003

Icelandic Met Office

Blágnípujökull, central Iceland, photo: Oddur Sigurðsson, 2001

Icelandic Met Office

The international context

Icelandic Met Office

- Glaciers are retreating rapidly in all corners of the world
- 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, currently ~1 mm per year
- 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, currently ~0.5–0.8 mm per year
- 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
- Contribution to global sea-level rise
- Iceland is a natural laboratory for studying glacier changes

Donald Rumsfeld's classification of “problems”

Icelandic Met Office

Known knowns

- Mass balance changes
- Glacier retreat, and many changes in glacial hydrology
- Sea-level rise corresponding to well know processes
- Effect of reduction in lithospheric load on isostatic uplift

Known unknowns

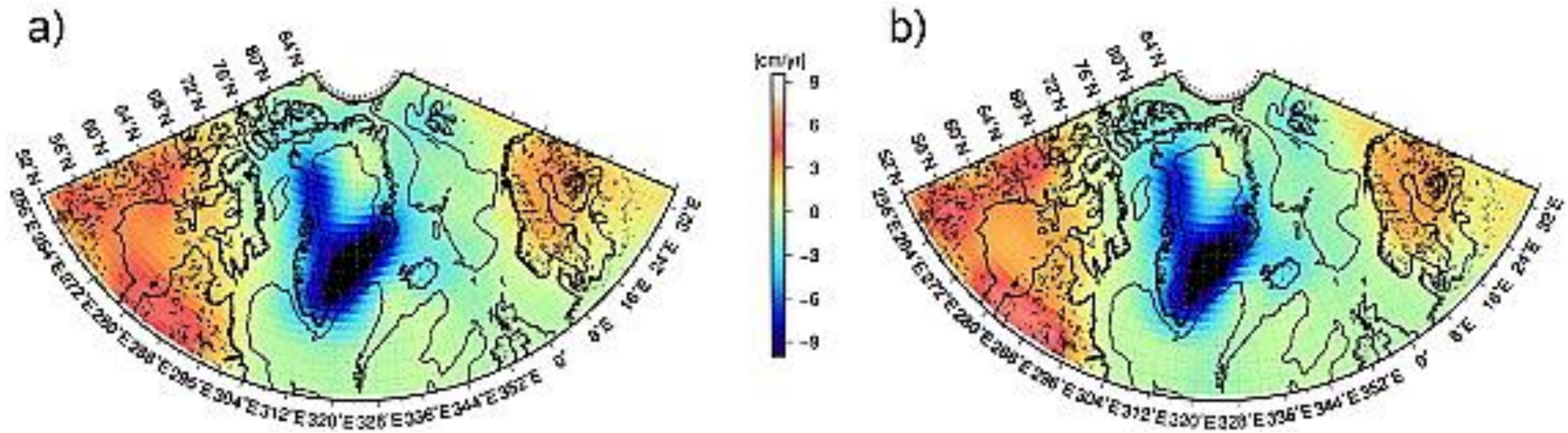
- Changes of subglacial watersheds
- Speed-up of outlet glaciers due to more surface melt water
- Response of calving glaciers and tidewater glaciers to warmer ocean temperatures
- Response of the large ice sheets to break-up of ice shelves
- Effect of reduction in lithospheric load on volcanism
- ...

Unknown unknowns

- ??? (two/three recent examples from climate change research have recently become “known unknowns”)

The most important task of the glaciological community is to identify “unknown

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.

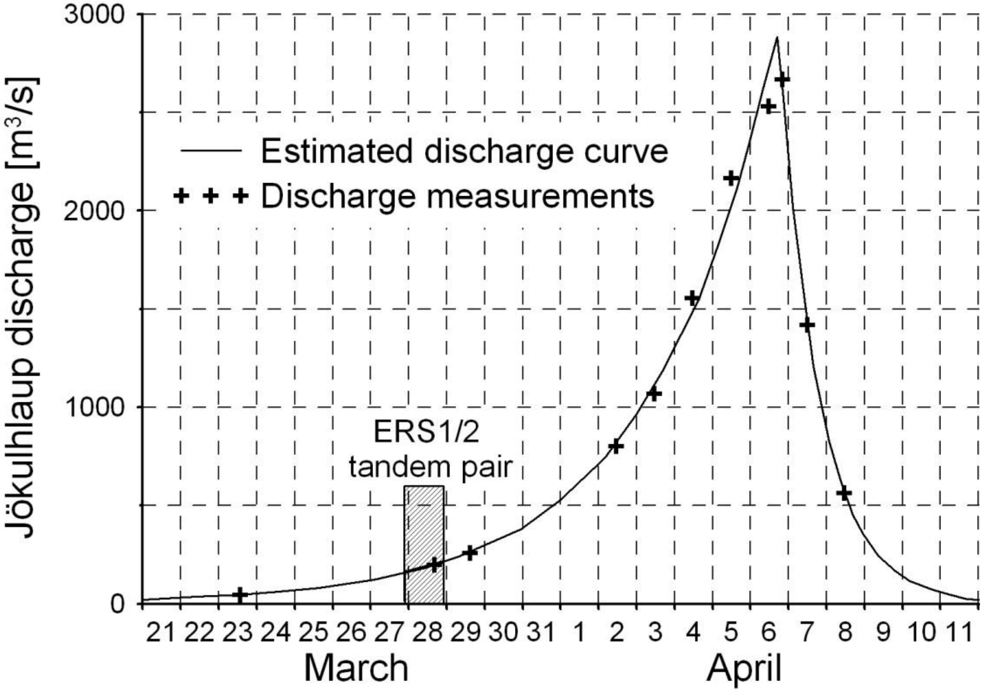
Wouters, B., D., Chambers and E. J. O. Schrama. 2008. GRACE observes small-scale mass loss in Greenland. *Geophys. Res. Lett*., 35, L20501, doi:10.1029/2008GL034816.

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.

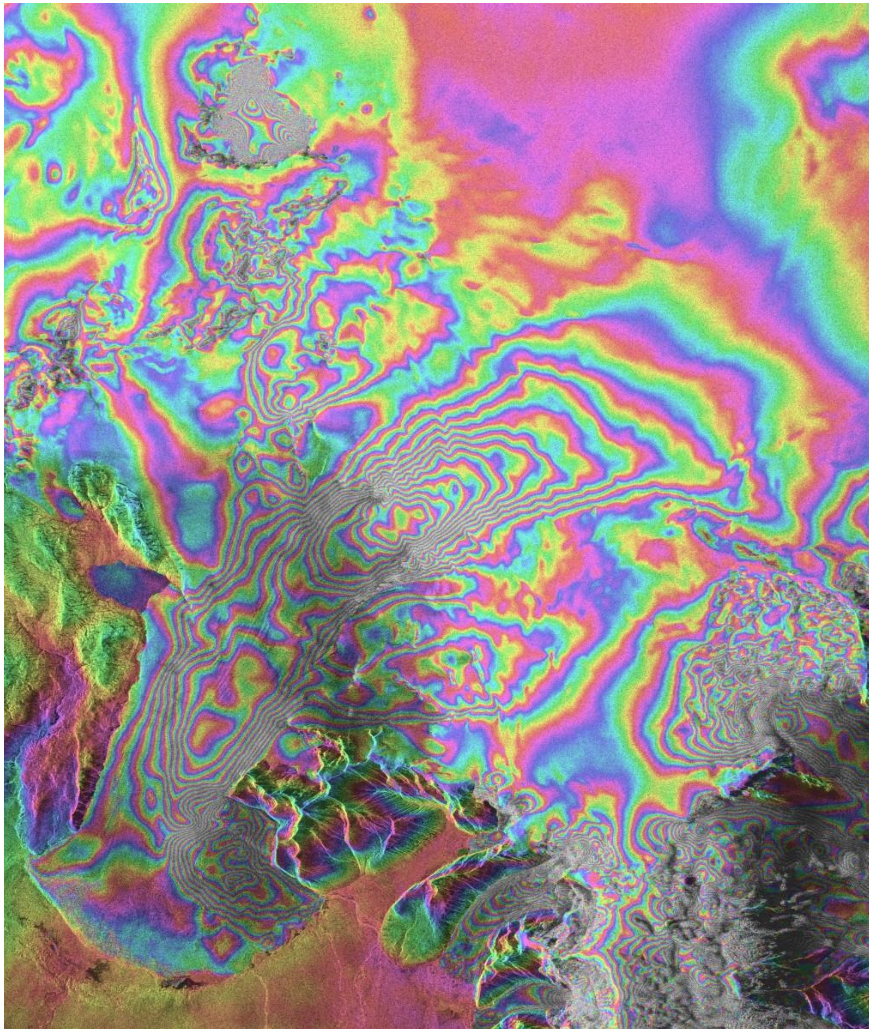
van den Broeke and others. 2009. Partitioning Recent Greenland Mass Loss. *Science*, 326(5955), 984-986, doi: 10.1126/science.1178176

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

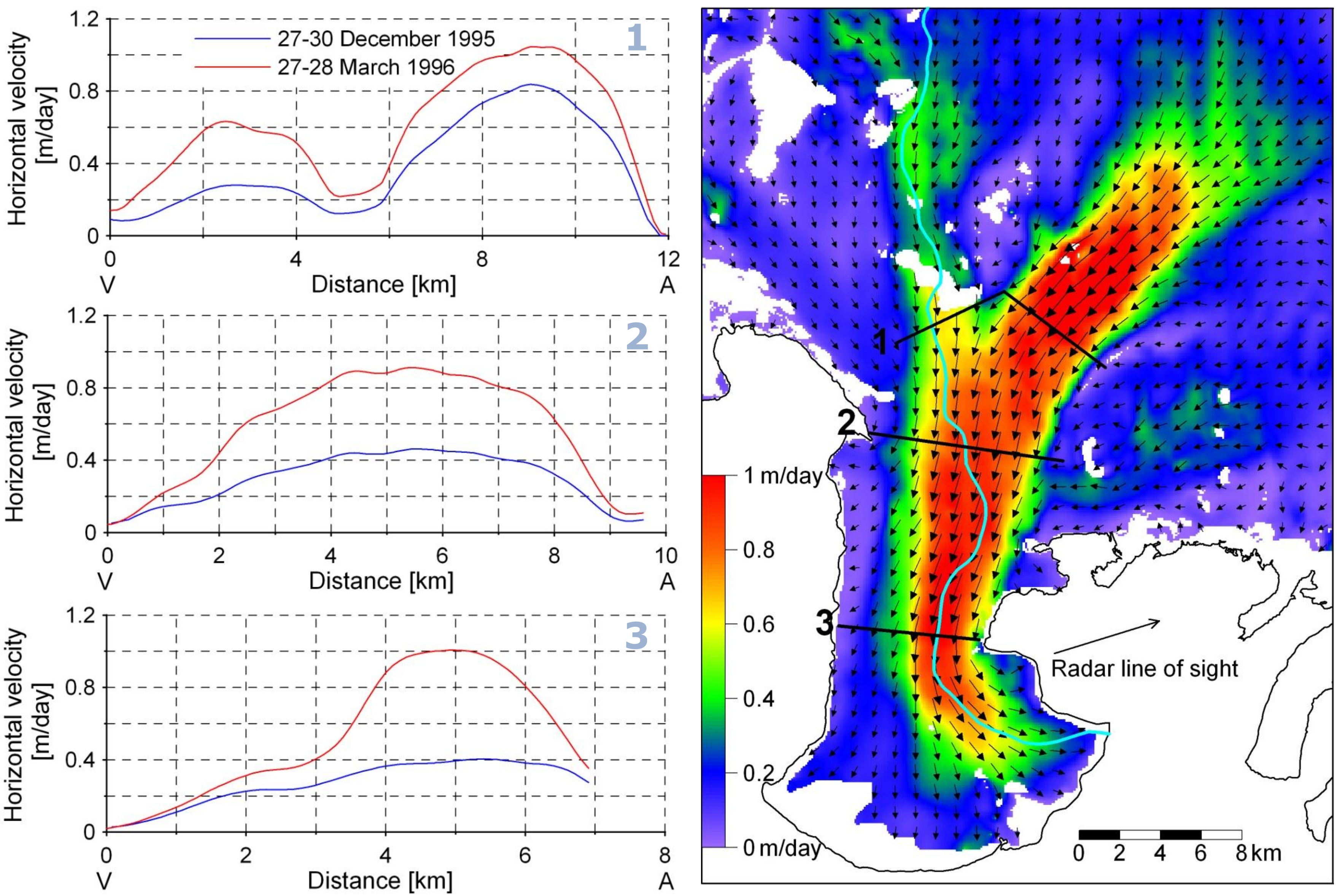
March-April 1996: Jökulhlaup draining from Grímsvötn into Skeiðará



InSAR image 27-28 March 1996



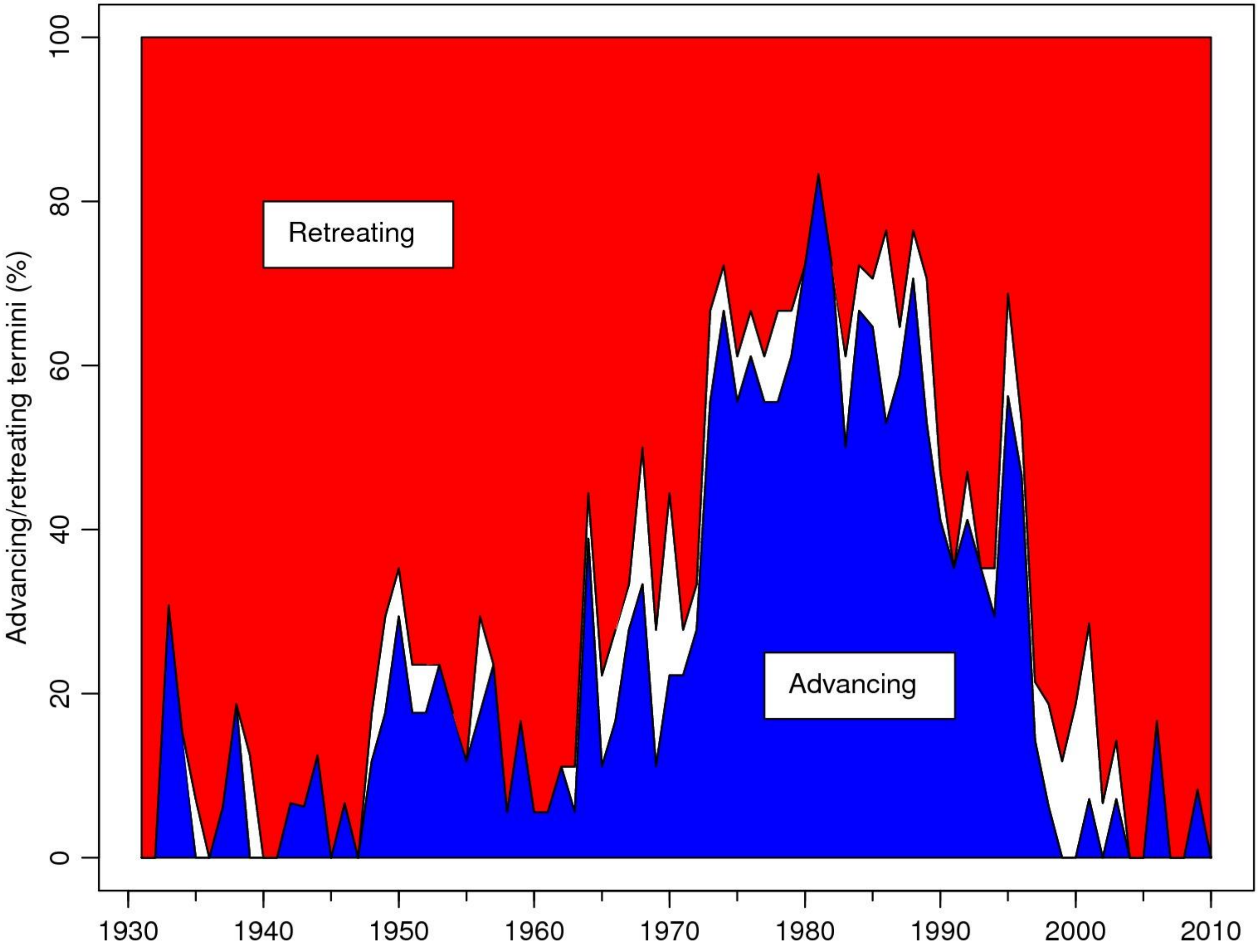
27-30 December 1995   27-28 March 1996



Magnússon, E., H. Rott, H. Björnsson and F. Pálsson, 2007. The impact of jökulhlaups on basal sliding observed by SAR interferometry on Vatnajökull, Iceland. Journal of Glaciology, 53(181), 232-240.

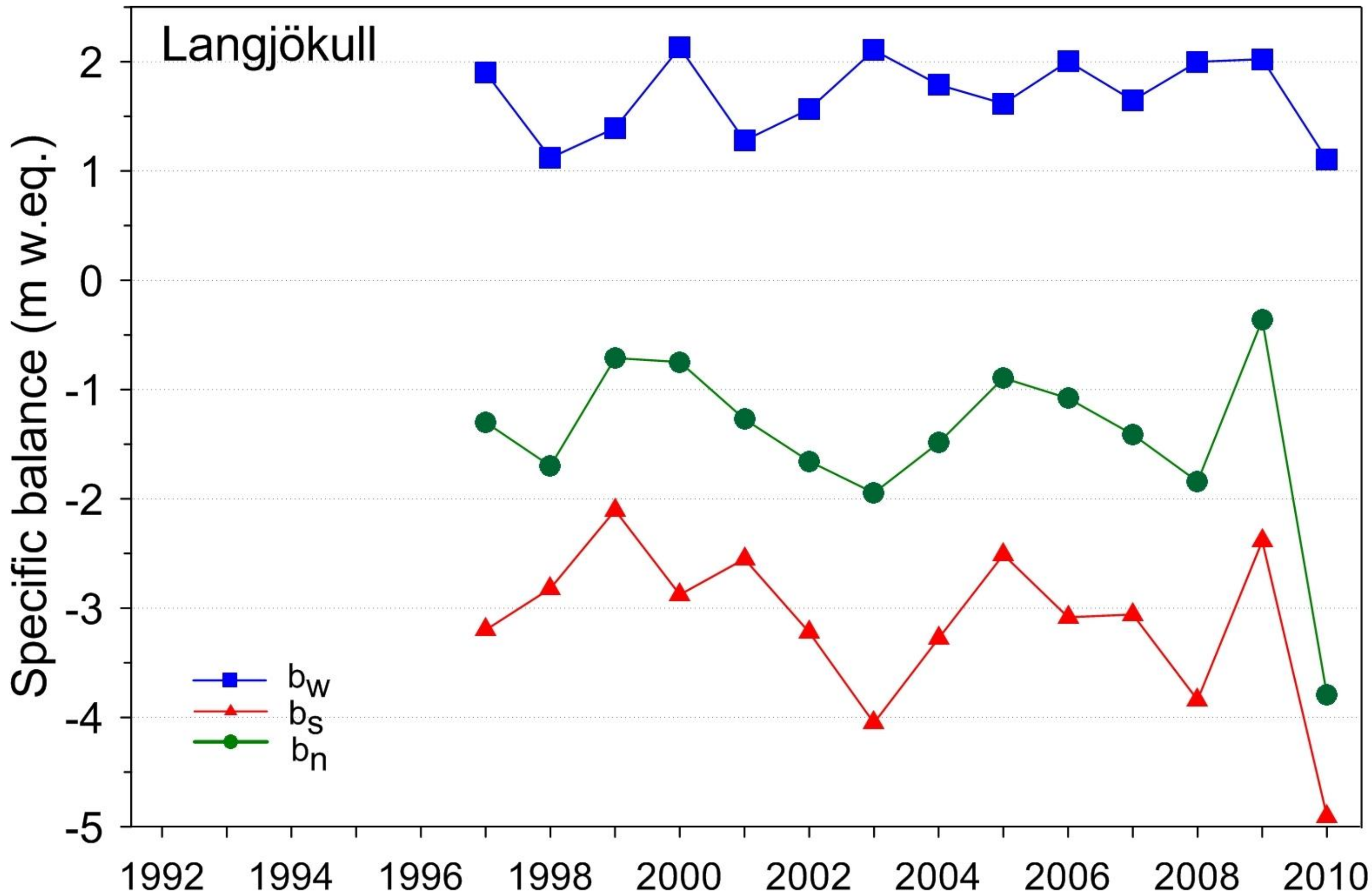
Variations of the termini of non-surging glaciers in Iceland 1930-2010

Icelandic Met Office



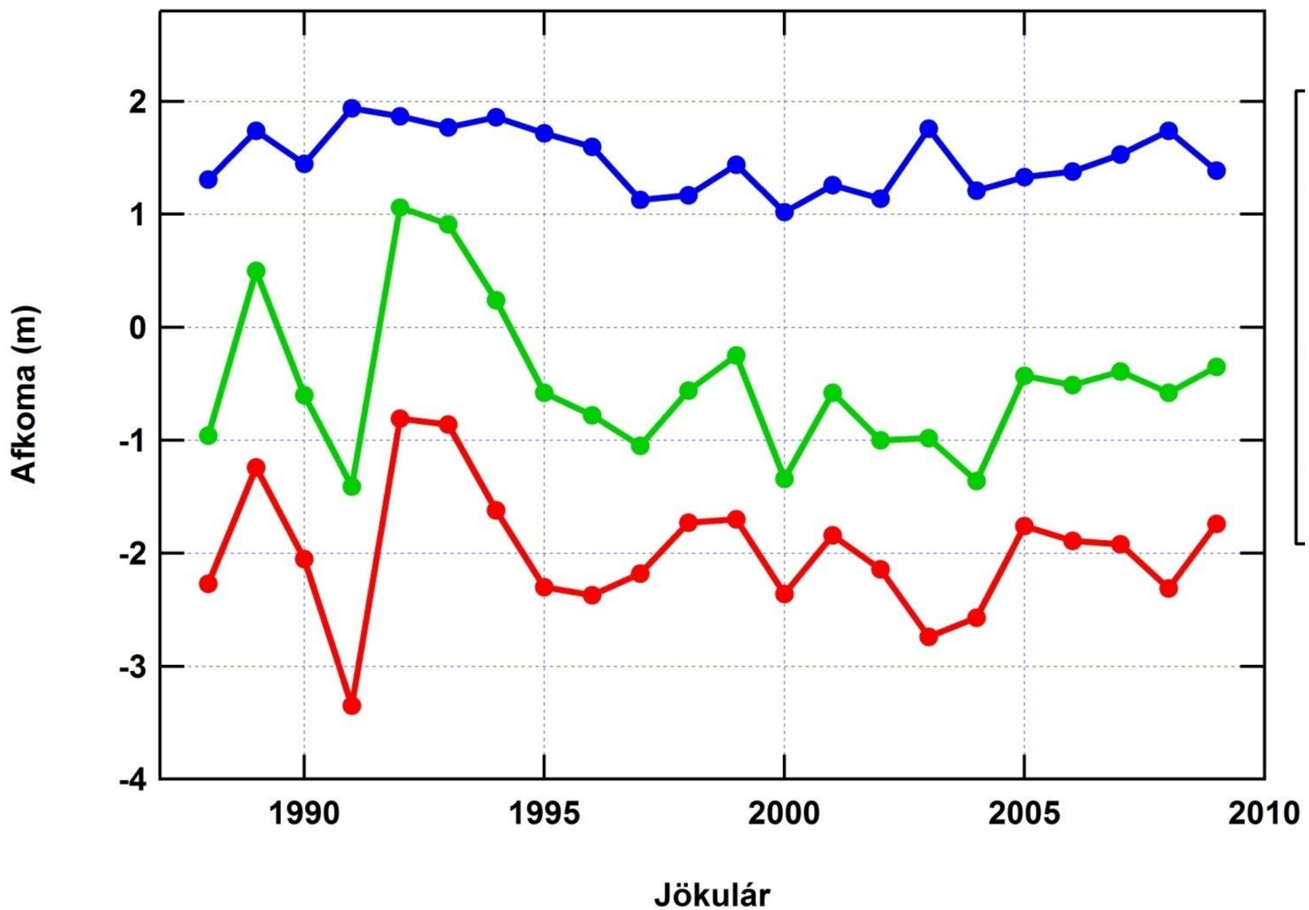
Mass balance measurements on Langjökull for 14 years

Icelandic Met Office



Institute of Earth Sciences, 2010

Mass balance measurements on Sátujökull/Hofsjökull for 22 years



Winter balance

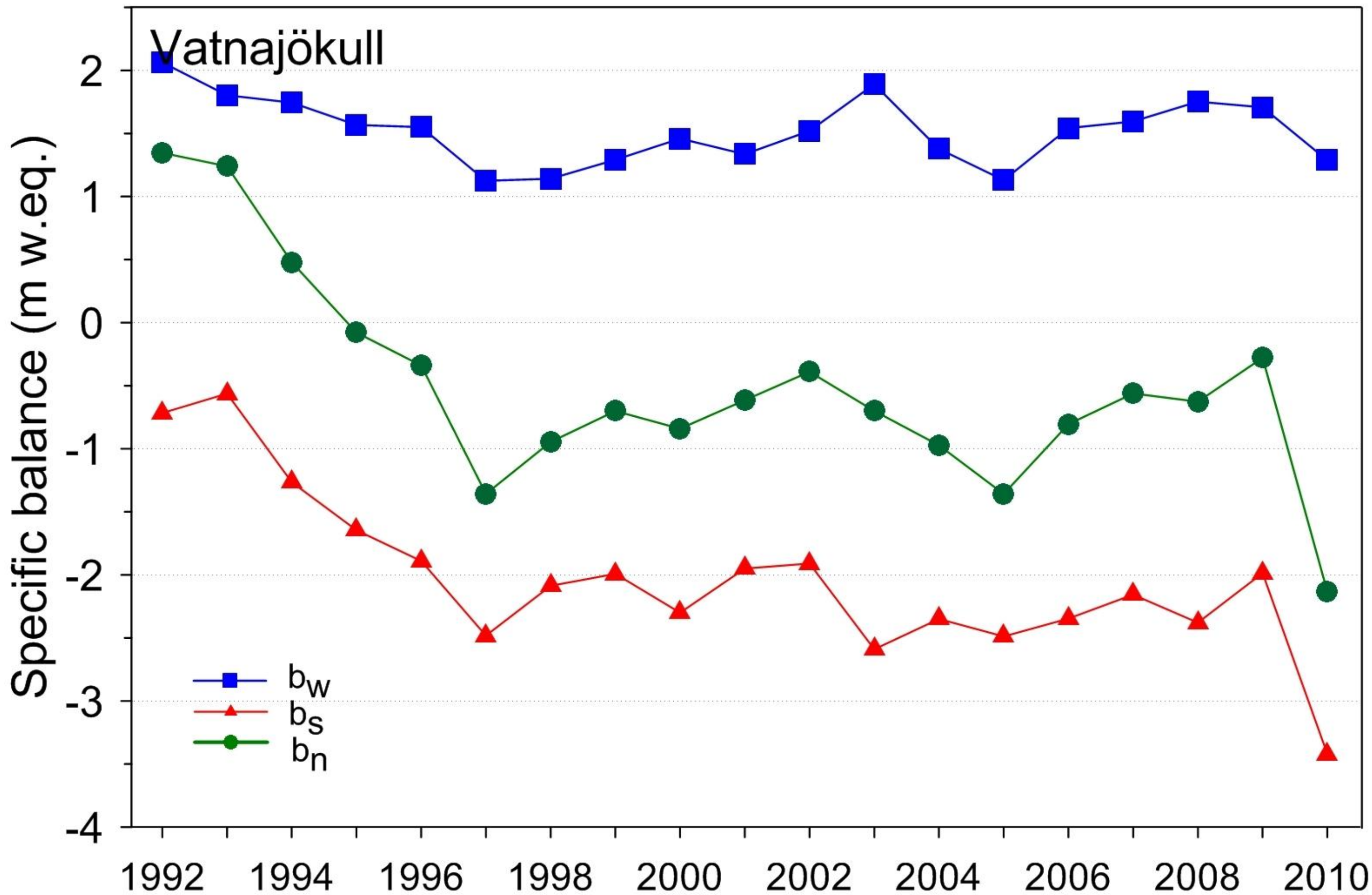
Annual balance

Summer balance

IMO, 2010

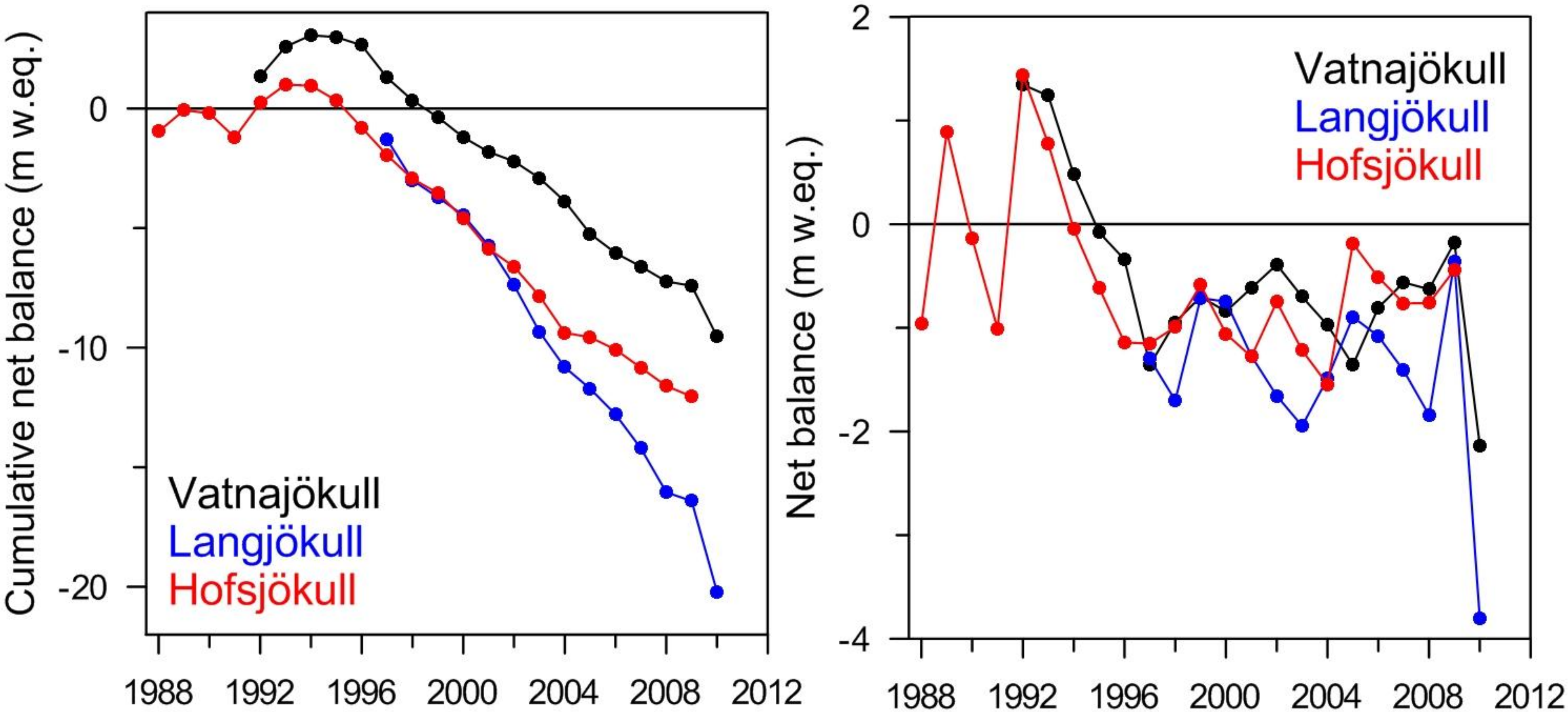
Mass balance measurements on Vatnajökull for 19 years

Icelandic Met Office



Institute of Earth Sciences, 2010

Specific and cumulative mass balance of all three ice caps

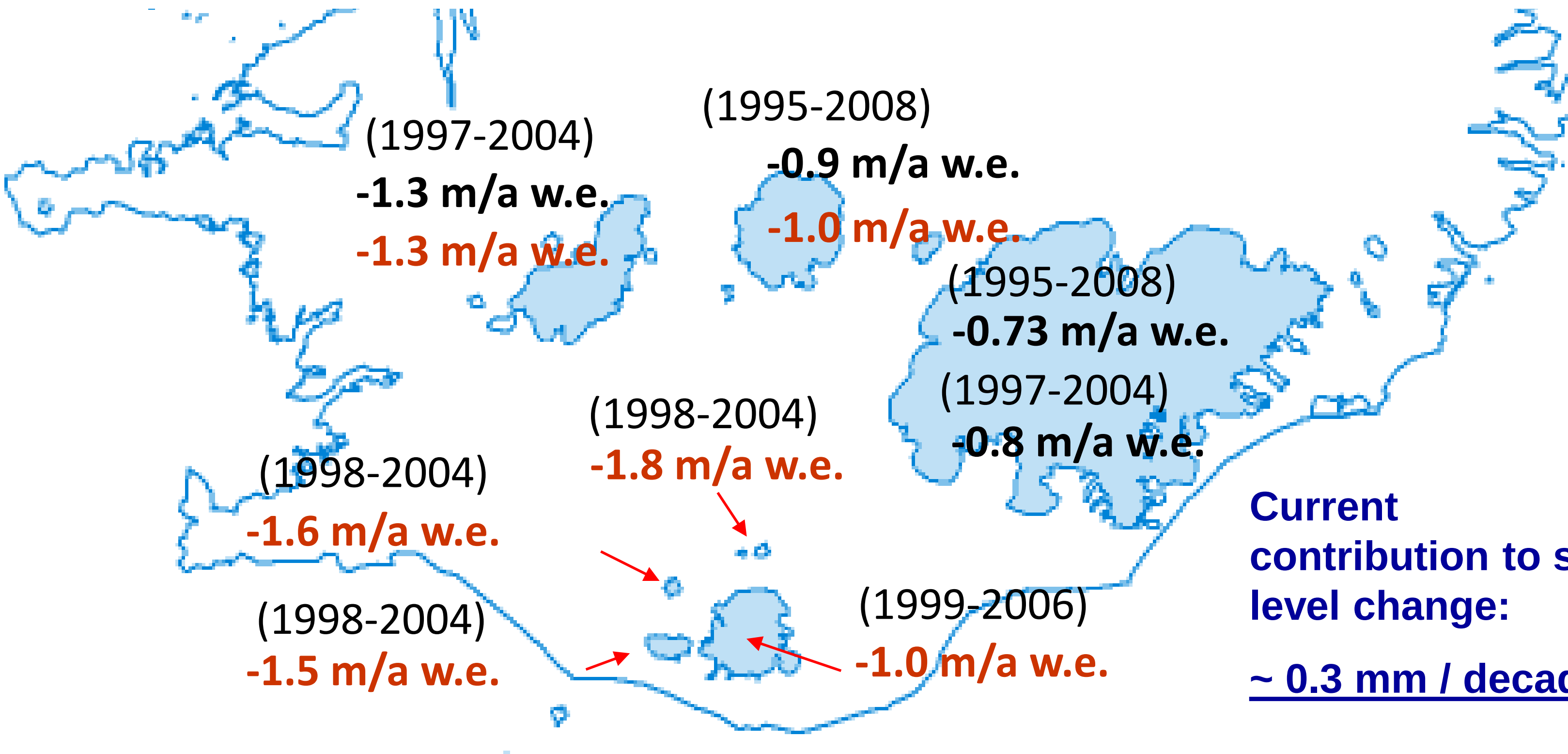


Institute of Earth Sciences/IMO, 2010

Specific mass balance during the past 10 to 15 years

- **Black**: from the in-situ observations:
-1.3 to -0.9 m/a w.eq.

- **Red**: from differential DEMs:
-1.8 to -1.0 m/a w.eq.

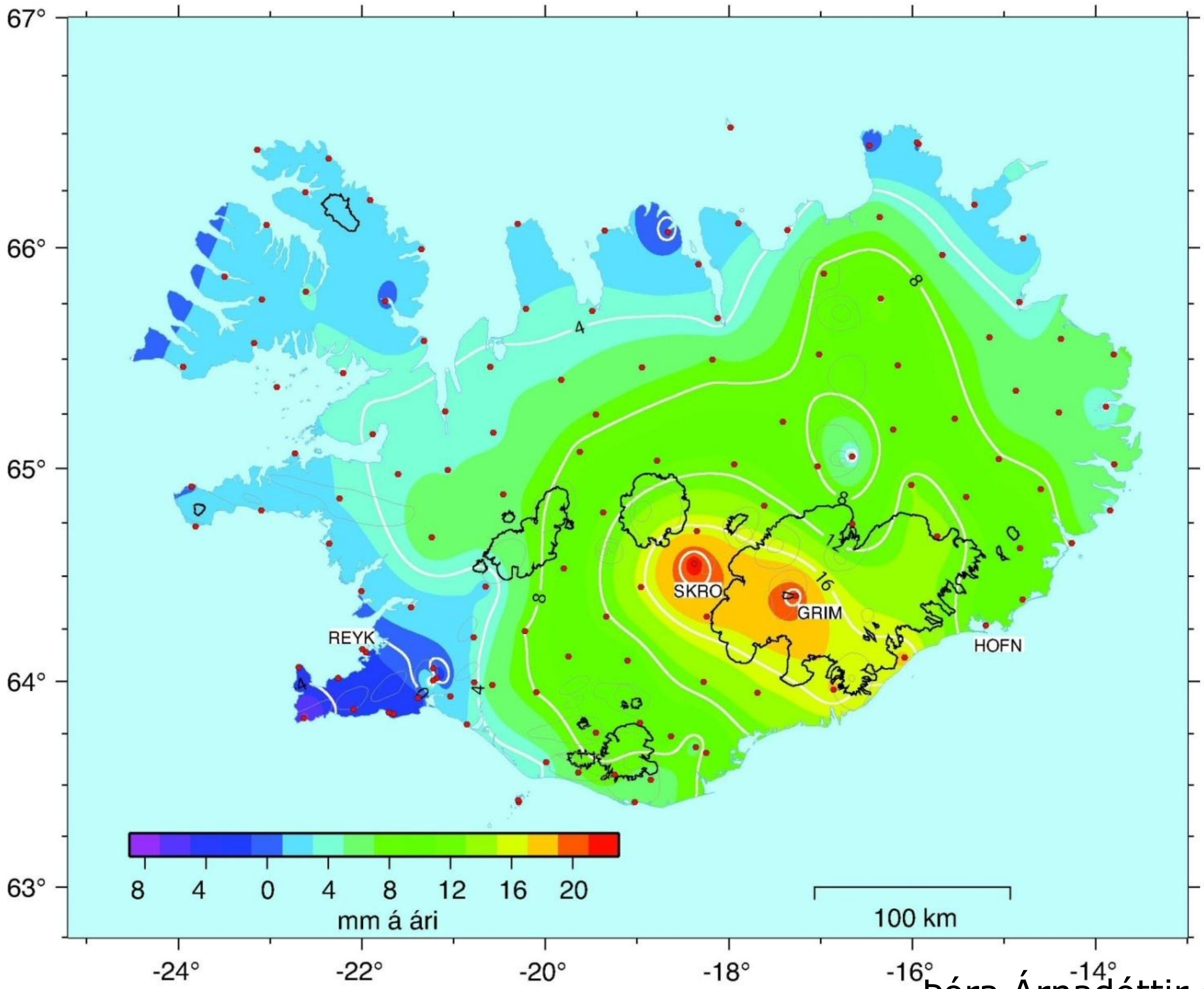


Current contribution to sea level change:

~ 0.3 mm / decade

Sverrir Guðmundsson, in press

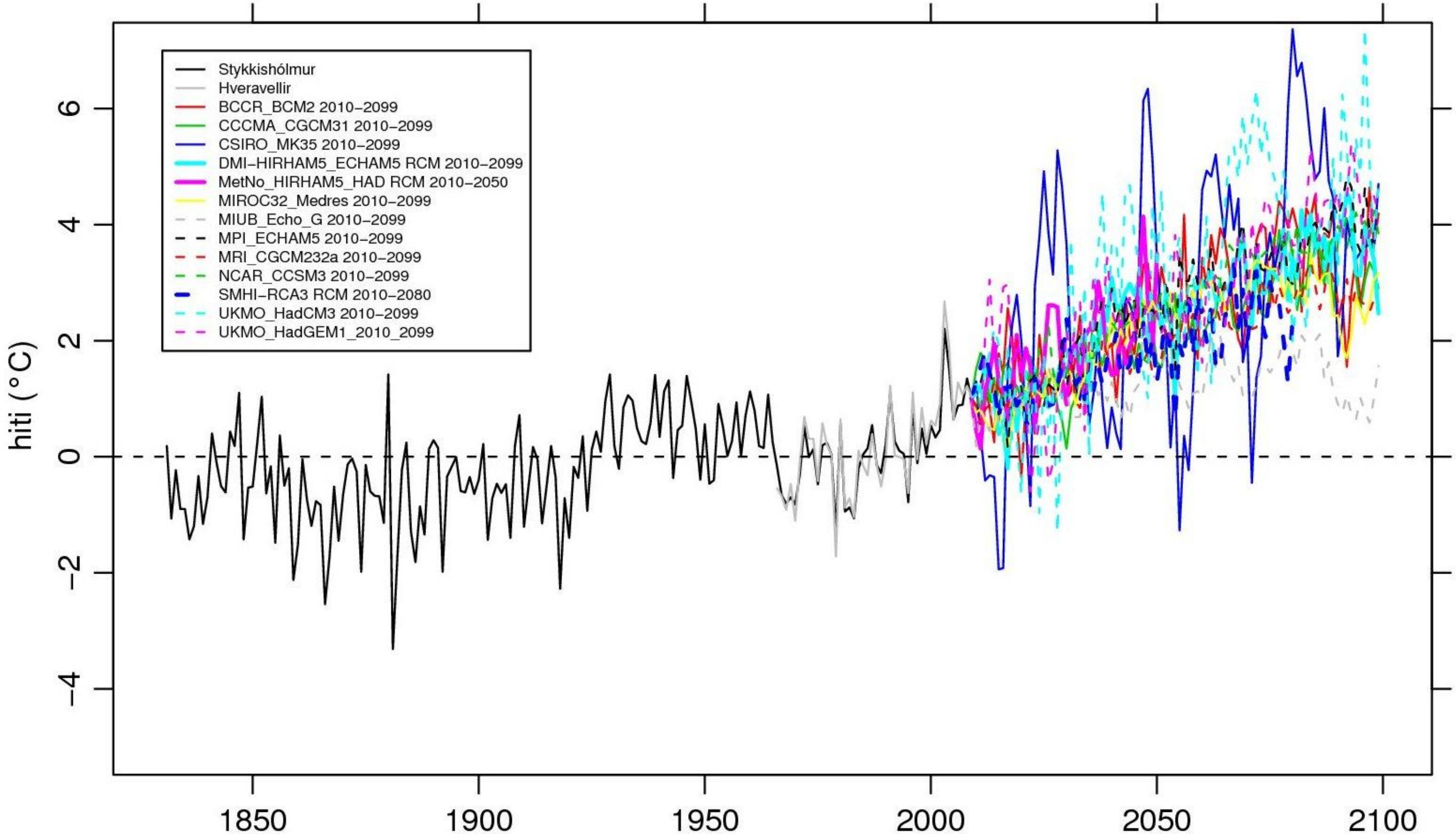
Isostatic rebound measured by GPS



Þóra Árnadóttir et al., 2009, GJI

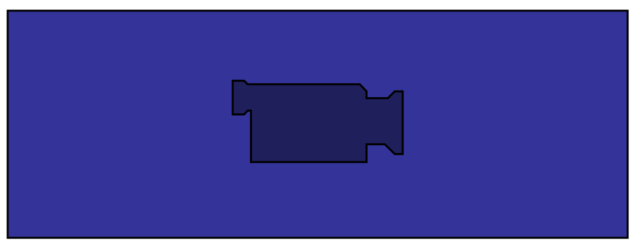
Past temperatures + 13 scenarios

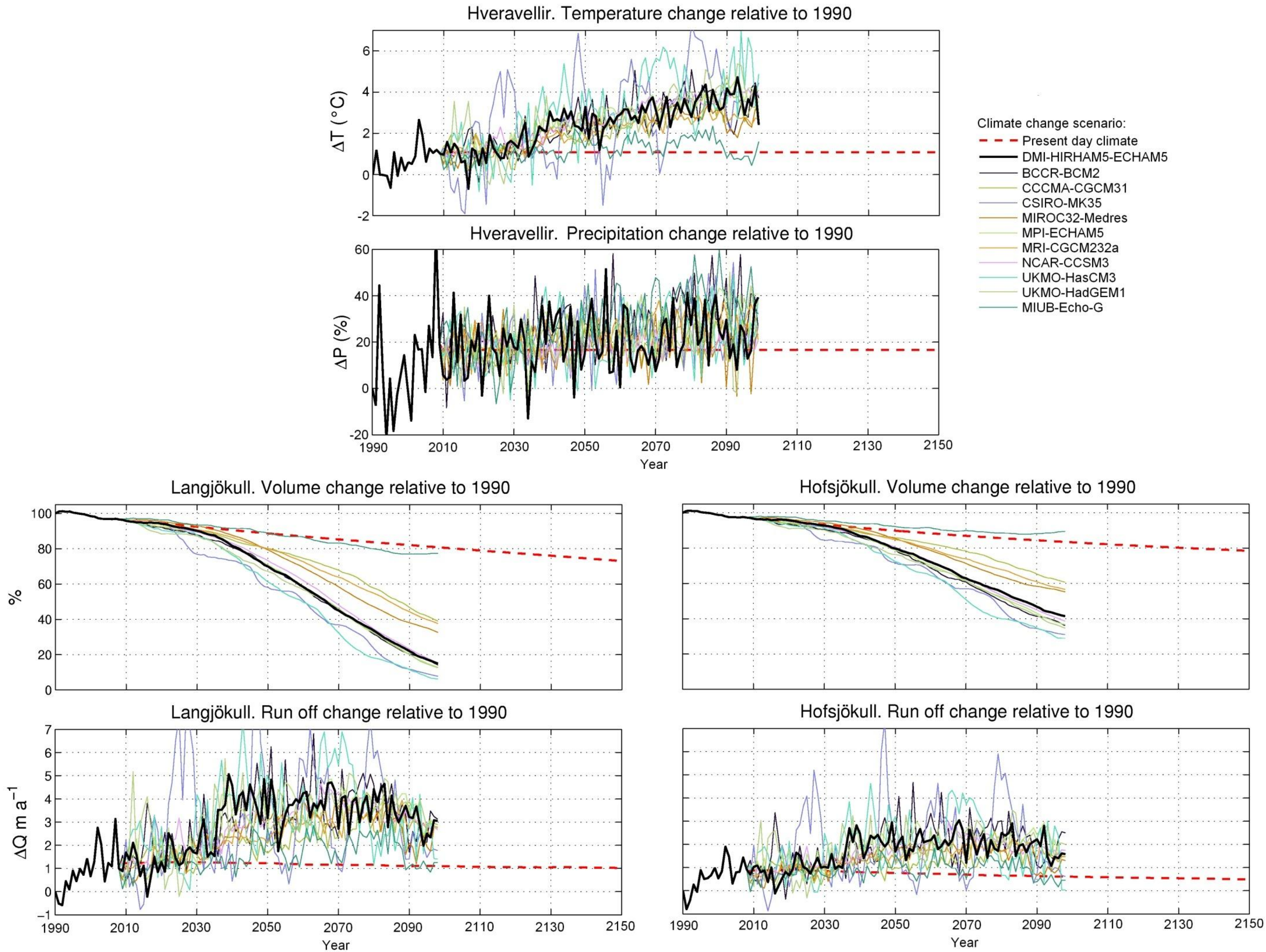
Icelandic Met Office



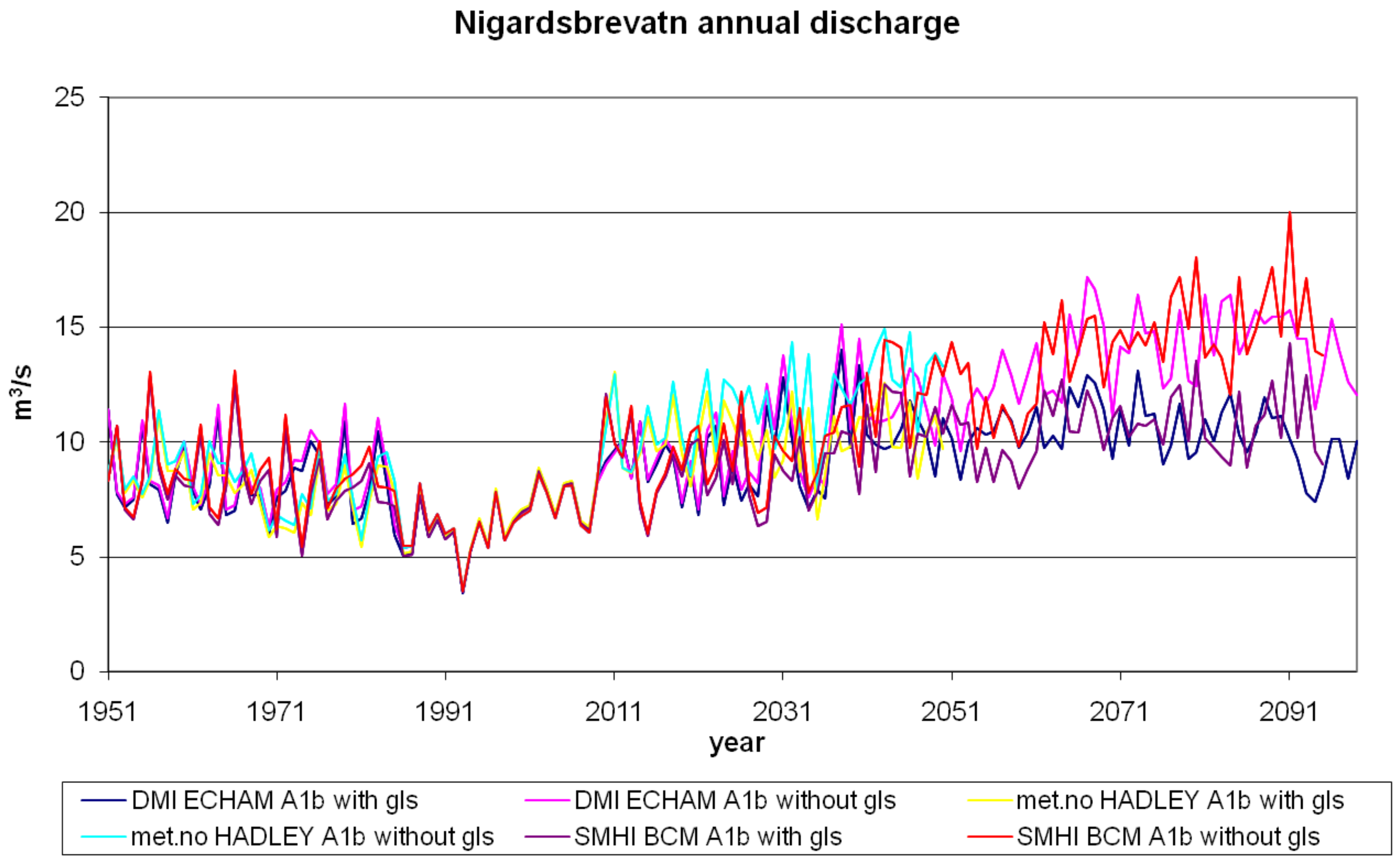
Retreat of Langjökull and Hofsjökull, 1990-2100

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




Hveravellir. Temperature change relative to 1990
ΔT (°C)
Hveravellir. Precipitation change relative to 1990
ΔP (%)
Year
Climate change scenario:
Present day climate
DMI-HIRHAM5-ECHAM5
BCCR-BCM2
CCCMA-CGCM31
CSIRO-MK35
MIROC32-Medres
MPI-ECHAM5
MRI-CGCM232a
NCAR-CCSM3
UKMO-HasCM3
UKMO-HadGEM1
MIUB-Echo-G
Langjökull. Volume change relative to 1990
%
Hofsjökull. Volume change relative to 1990
Langjökull. Run off change relative to 1990
ΔQ m a^{-1}
Hofsjökull. Run off change relative to 1990
Year
Year

Annual discharge, HBV/GLS models



Results of the CES project

Icelandic Met Office

- 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 runoff change may be important for the design and operation of hydroelectric power plants and other utilisation of water
- There is a large uncertainty associated with differences between the modelled climate development by different GCMs and RCMs


SVALI
SVALI
Stability and Variations of Arctic Land Ice

Key questions

Icelandic Met Office

- How fast is land ice volume in the Arctic/N-Atlantic area changing?
- Why is the ice-volume reduction more rapid than previously expected?
- Will the mass loss continue to accelerate?
- What are the consequences of ice-volume changes for sea-level and ocean circulation?
- What are the societal implications of changes in glacial hydrology?

SVALI strategy

Icelandic Met Office

- Study basic processes using remote sensing, airborne and in-situ measurements
- Carry out advanced Earth Systems Modelling
- Create a platform for
  - ✓ joint process studies, analyses and sharing of methods
  - ✓ researcher training
  - ✓ outreach activities
  - ✓ for reporting of scientific results regarding the impact of climate change on terrestrial ice

LIDAR glacier mapping

Icelandic Met Office

2008:
Mapping of Snæfellsjökull, Eiríksjökull and most of Hofsjökull (total mapped area ~800 km²)

2009:
No mapping due to adverse weather conditions

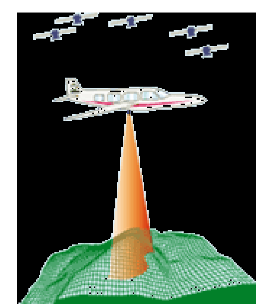
2010:
Completion of Hofsjökull, Mýrdalsjökull, Eyjafjallajökull, S- and SE-Vatnajökull

Total mapped area now is >4500 km² + ~900 km² on Langjökull (by SPRI) = ~5500 km²

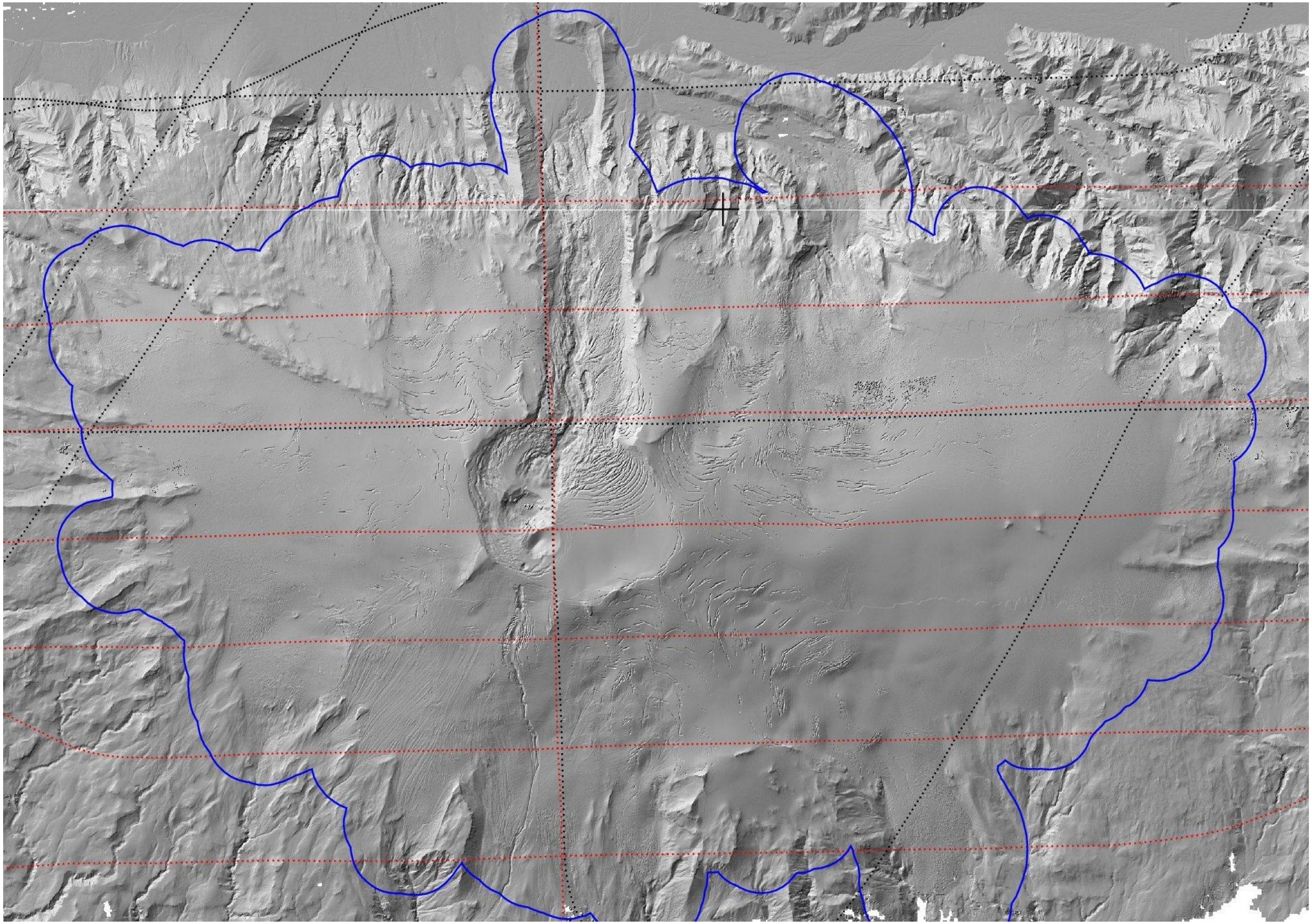
5x5 or 10x10 m digital elevation models of the ice caps are produced

The new ice surface maps will make it possible to assess past ice volume changes since 1990-2000 using available maps together With InSAR and SPOT satellite data and future changes from remote sensing data that will become available after 2008-2011

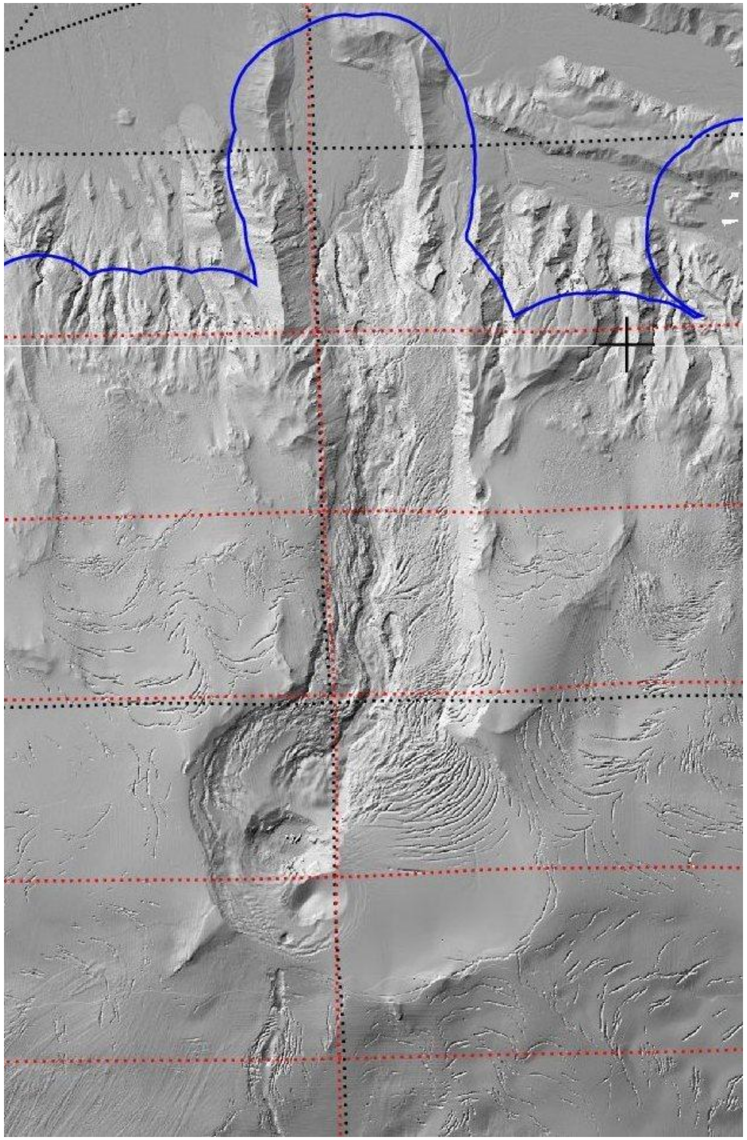
Glacier surfaces are mapped with *airborne laser scanning*.
It relies on the combination of high-precision DGPS positioning in kinematic mode, inertial systems, and lase distance measurements.
Accuracy in elevation measurement better than 0.5 m.

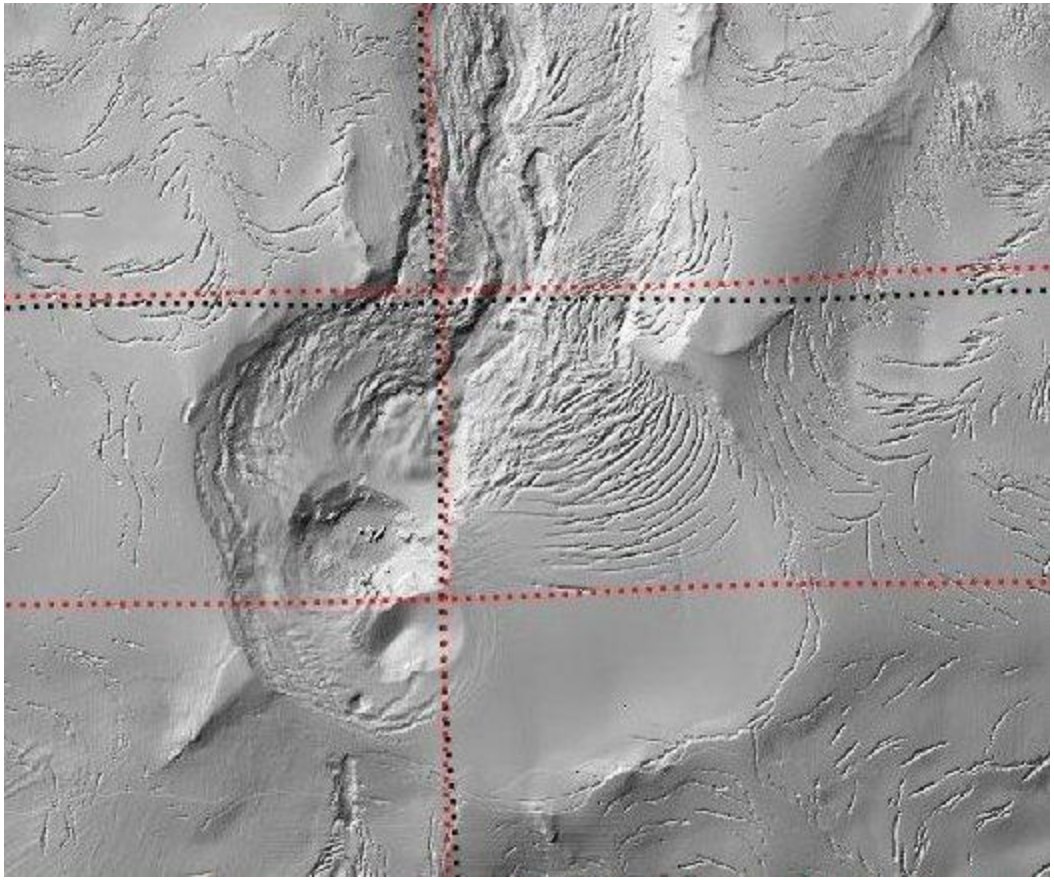


Eyjafjallajökull

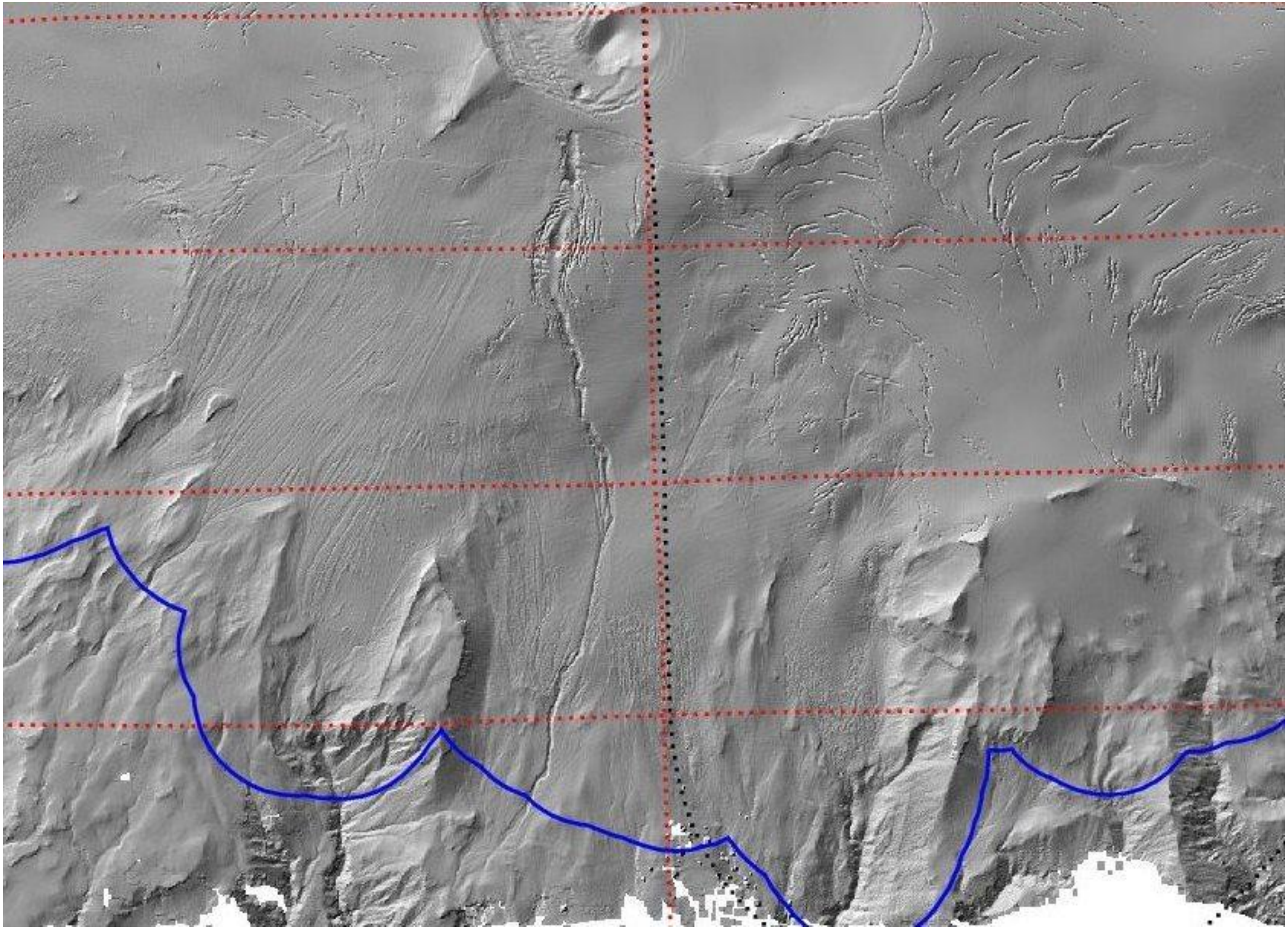


Eyjafjallajökull, lava path and top crater

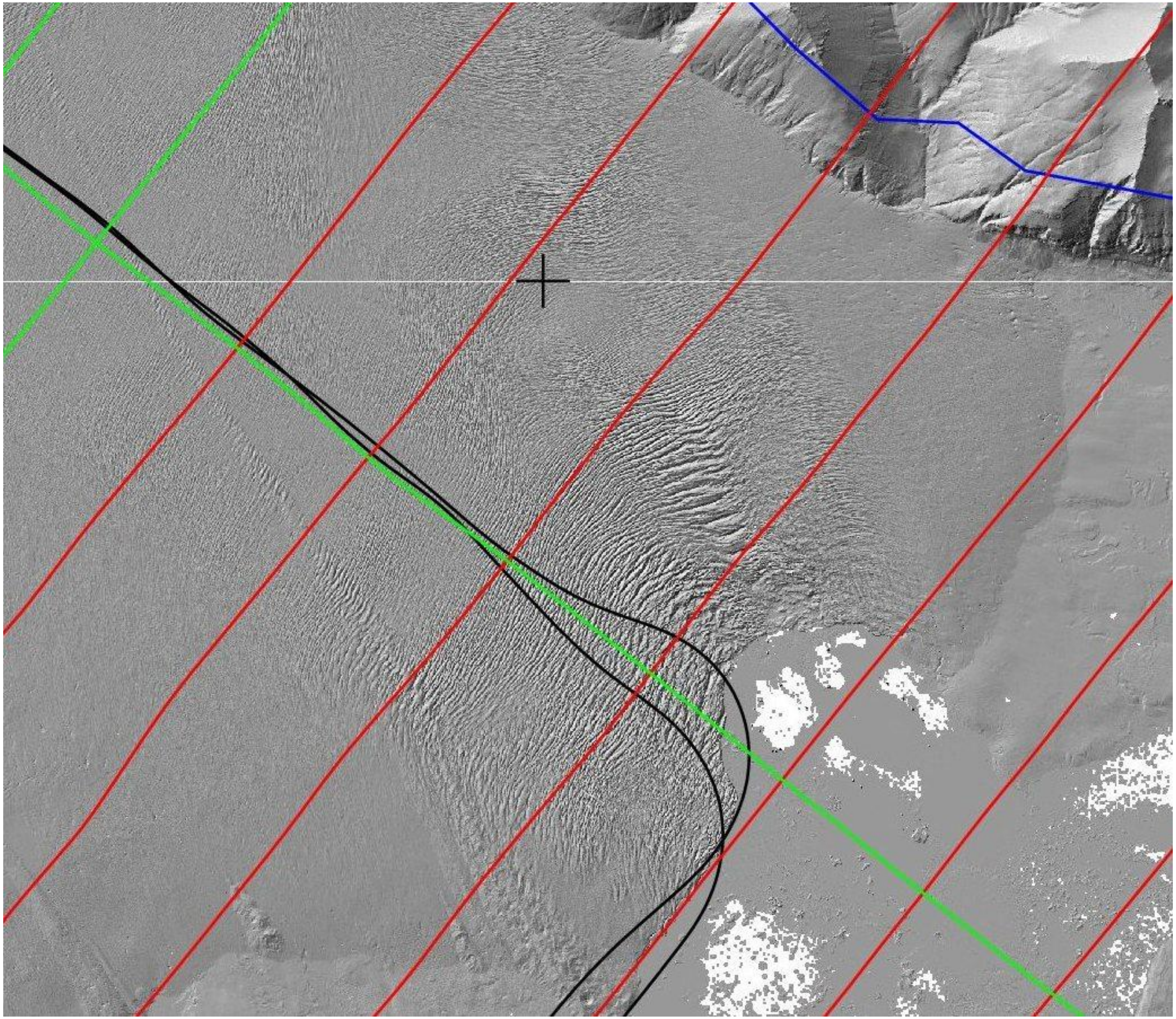




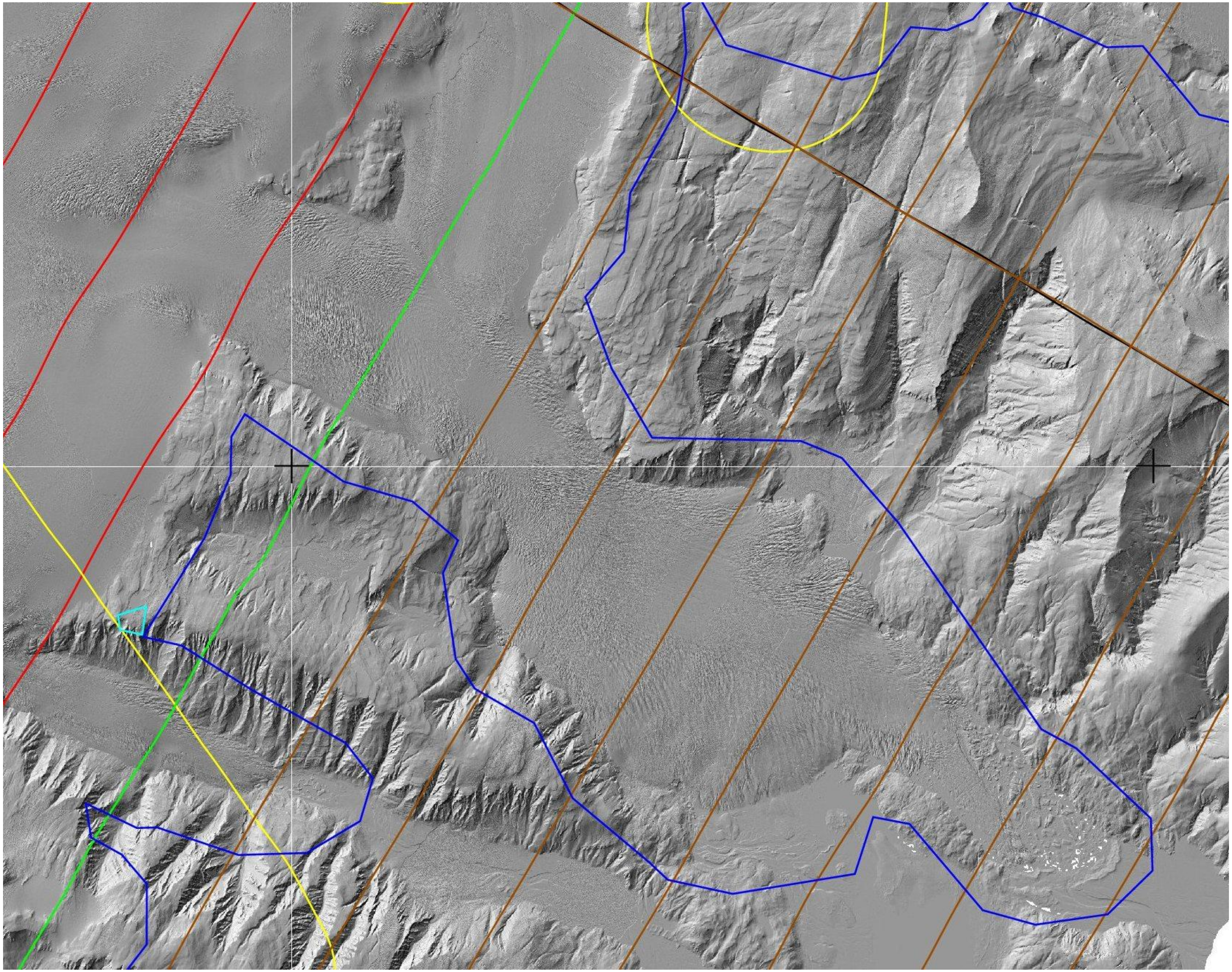
Eyjafjallajökull, jökulhlaup path, lahars



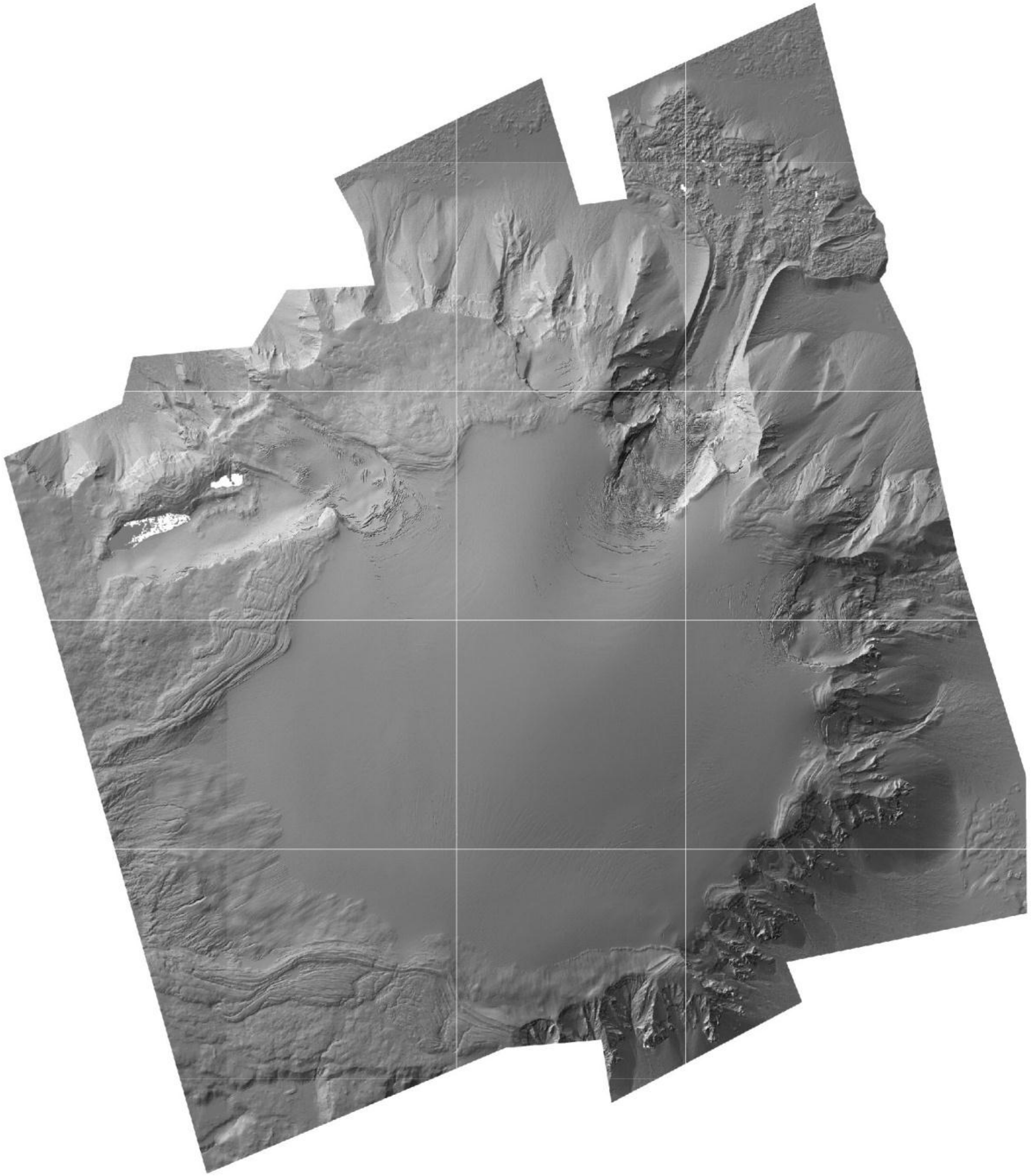
Breiðamerkurjökull



Hoffellsjökull, SE-Vatnajökull

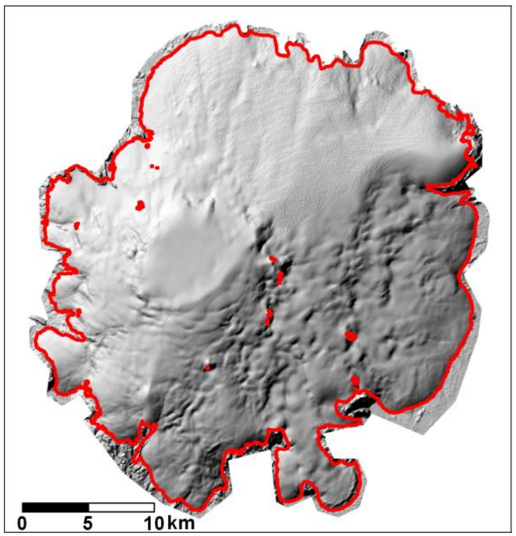


Eiríksjökull

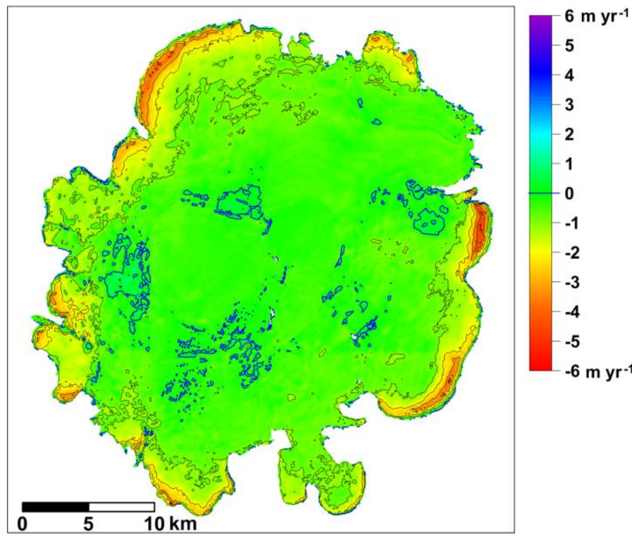


Hofsjökull, elevation change rates 1986 to 2004 to 2008

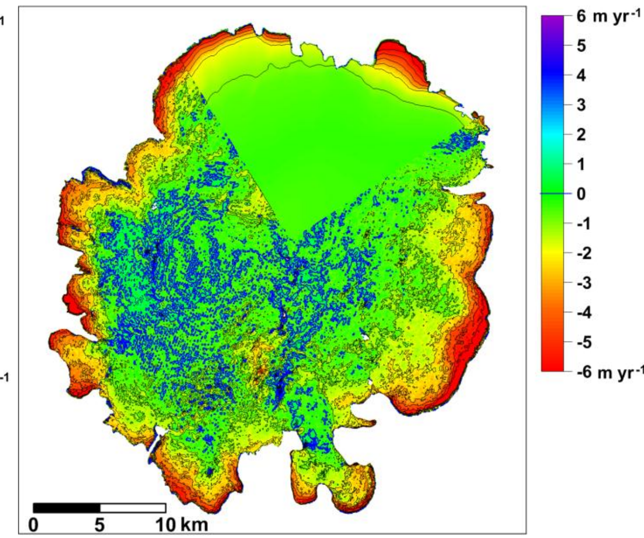
2008 DTM

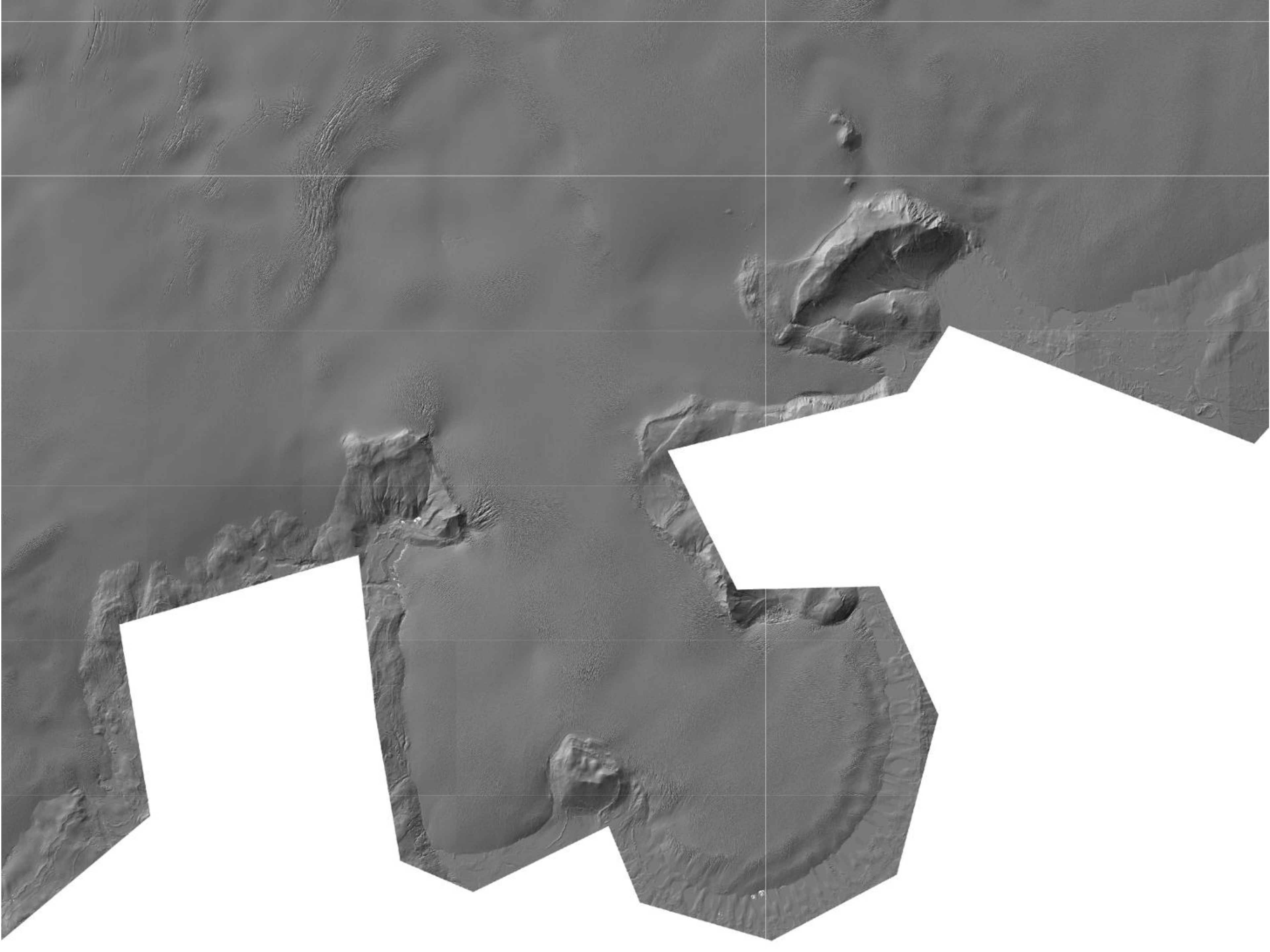


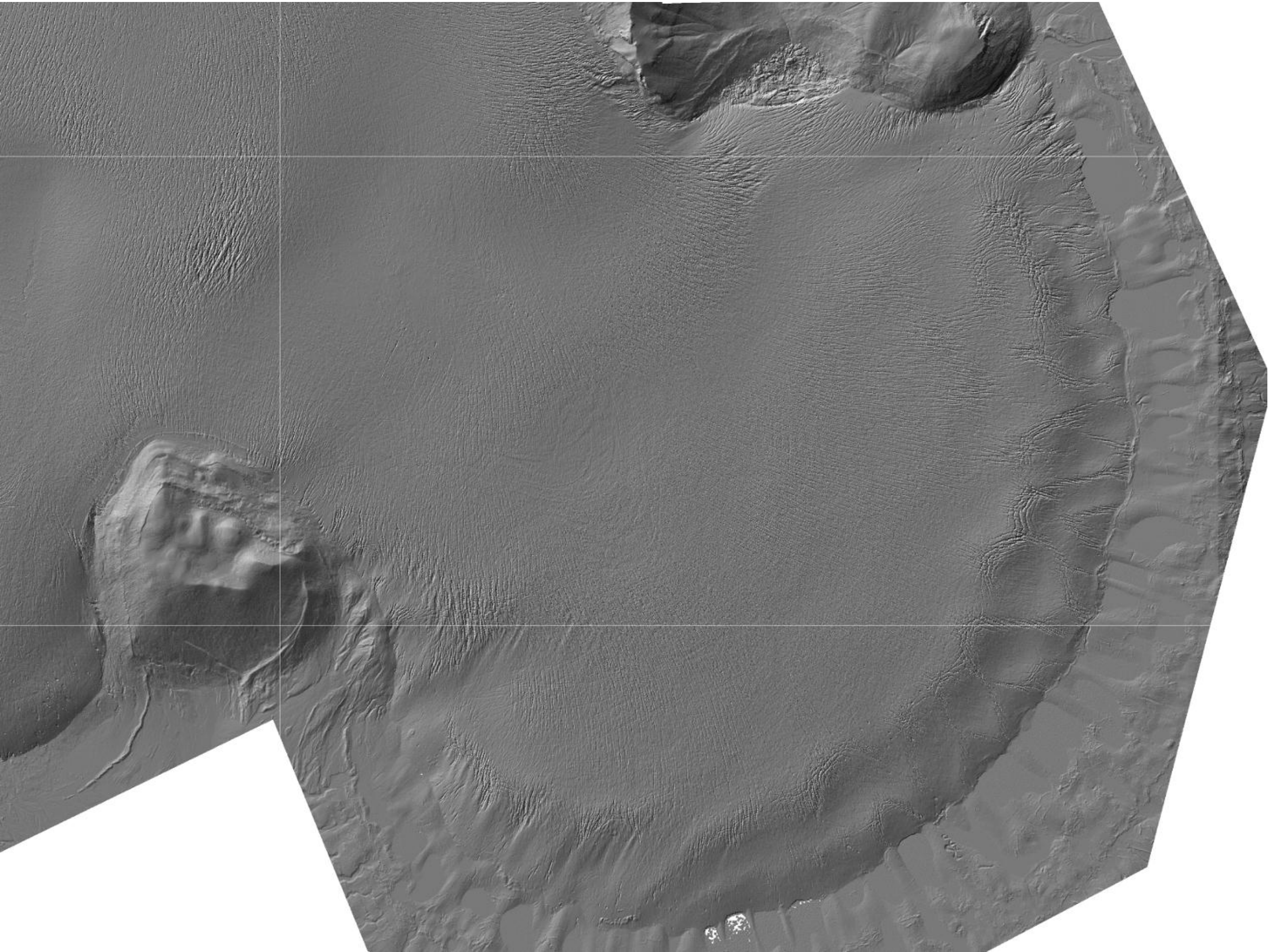
1986-2004 rate

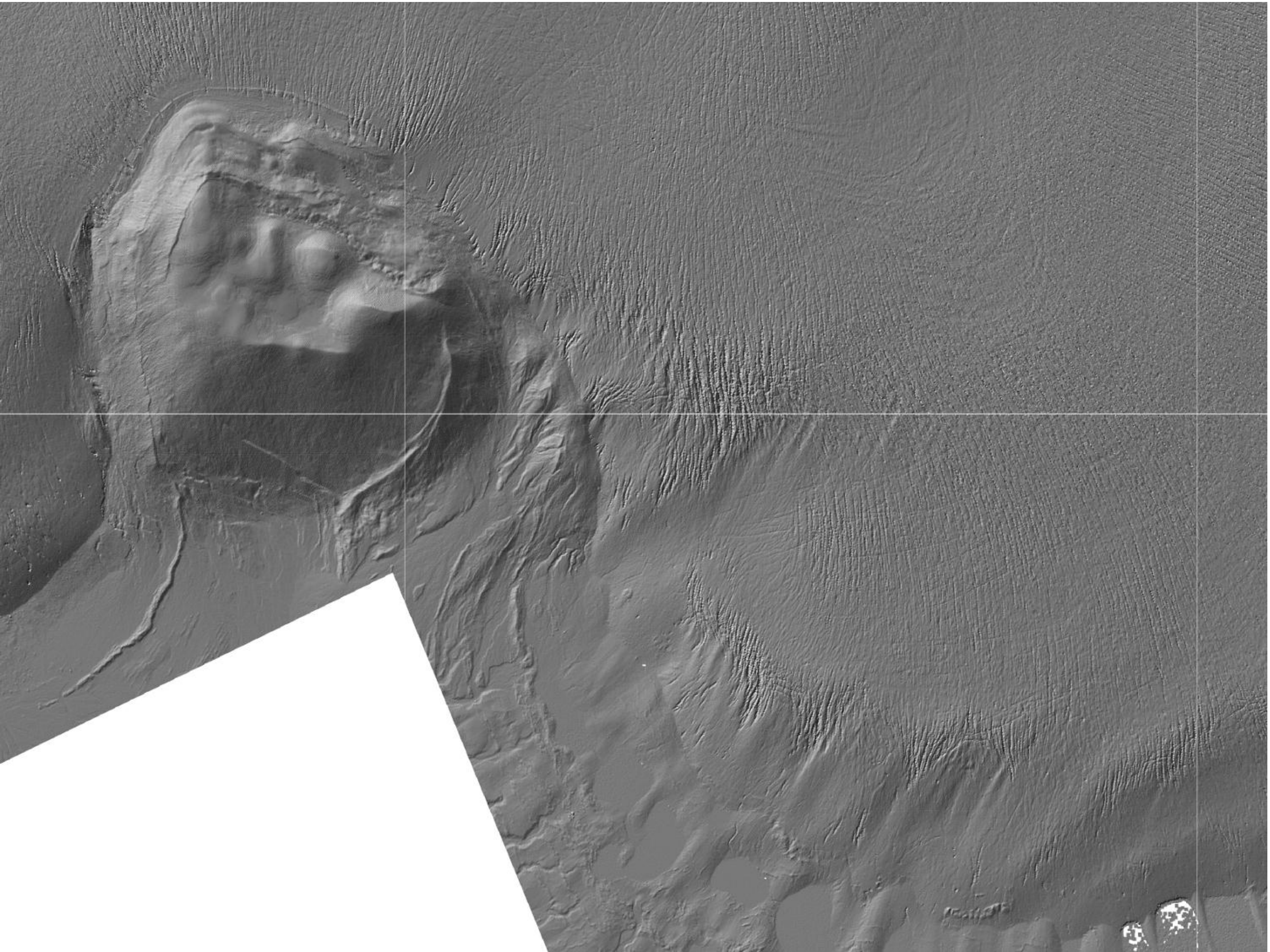


2004-2008 rate









Takk fyrir áheyrnina!