The ISVOLC project - addressing the effects of climate change induced Ice-retreat on Seismic and VOLCanic activity

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Michelle M Parks, Freysteinn Sigmundsson, Peter Schmidt, Rémi Vachon, Elisa Trasatti, Fabien Albino, Halldór Geirsson, Vincent Drouin, Benedíkt G Ófeigsson, Finnur Pálsson, Guðfinna Aðalgeirsdóttir, Eyjólfur Magnússon, Joaquin Belart, Andrew Hooper, Erik Sturkell, John Maclennan, Kristín Vogfjörd, Sigrún Hreinsdóttir, Sara Barsotti, Björn Oddsson, Josefa Araya, Chiara Lanzi, Yilin Yang, Catherine O´Hara, Siqi Li.

Thank you to ISVOLC partners!!!

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Effects of climate change induced Ice-retreat on Seismic and VOLCanic activity (ISVOLC)

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Project details

- Start date 1 April 2023
- Project duration is 3 years
- Total budget of ~ 153 million ISK
- 55.7 million ISK has been granted in YR 1
- 2 PhD students
- 1 PostDoc
- Contractor services
- Field work
- COMSOL license

Subglacial volcanic eruption. Eruption in Grímsvötn in 1998. ISVOLC will study the influence of ongoing glacial retreat on magmatic activity at four volcanic systems in Iceland: Grímsvötn, Bárðarbunga, Katla and Askja. Photo: The Icelandic Met Office / Oddur Sigurðsson.

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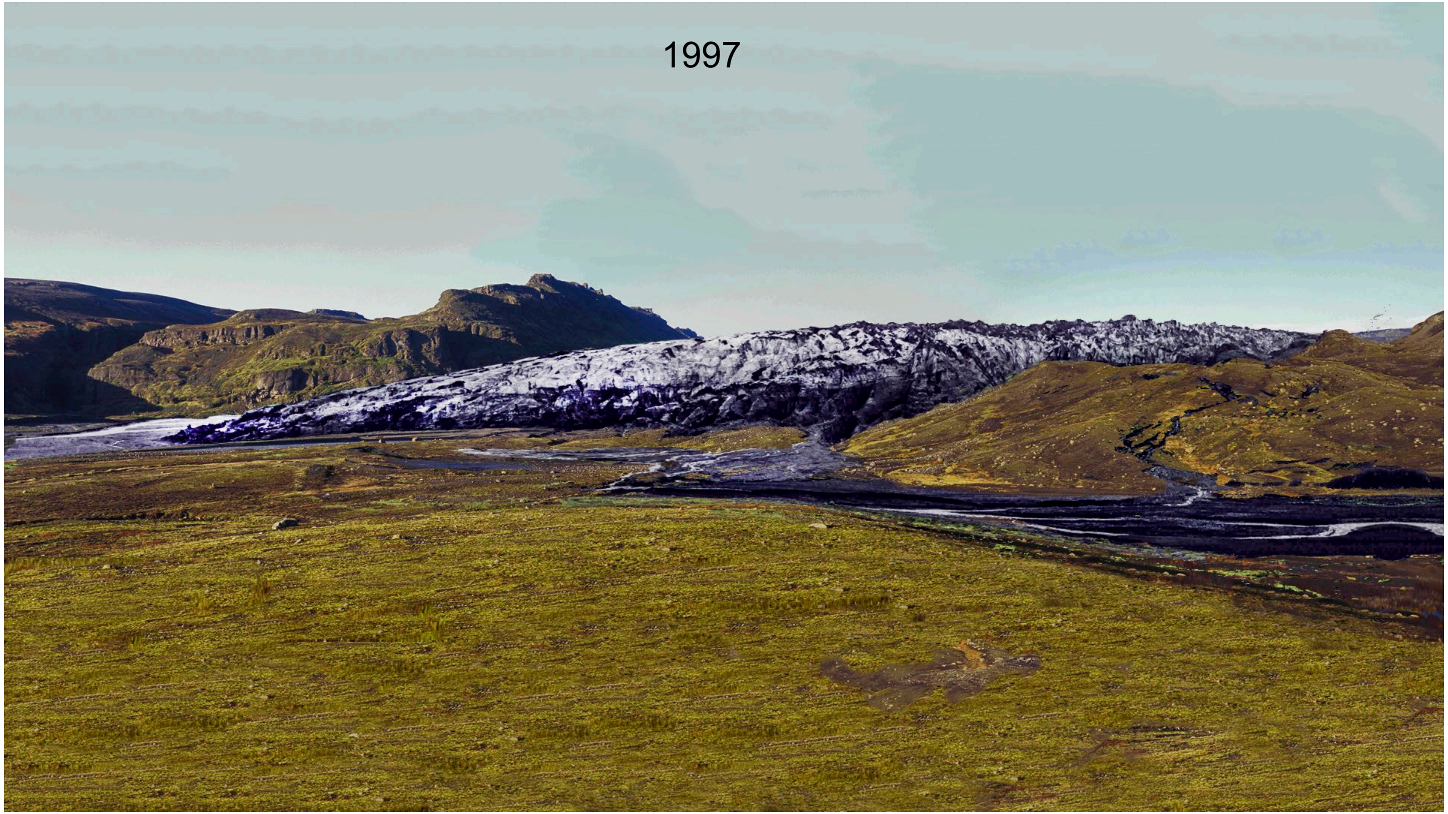
Why are we doing this?

- Glaciers have been retreating since 1890

Skálafellsjökull 1989-2019. Myndvinnsla: Kieran Baxter

Glacial variations at Solheimajökull – Oddur Sigurðsson



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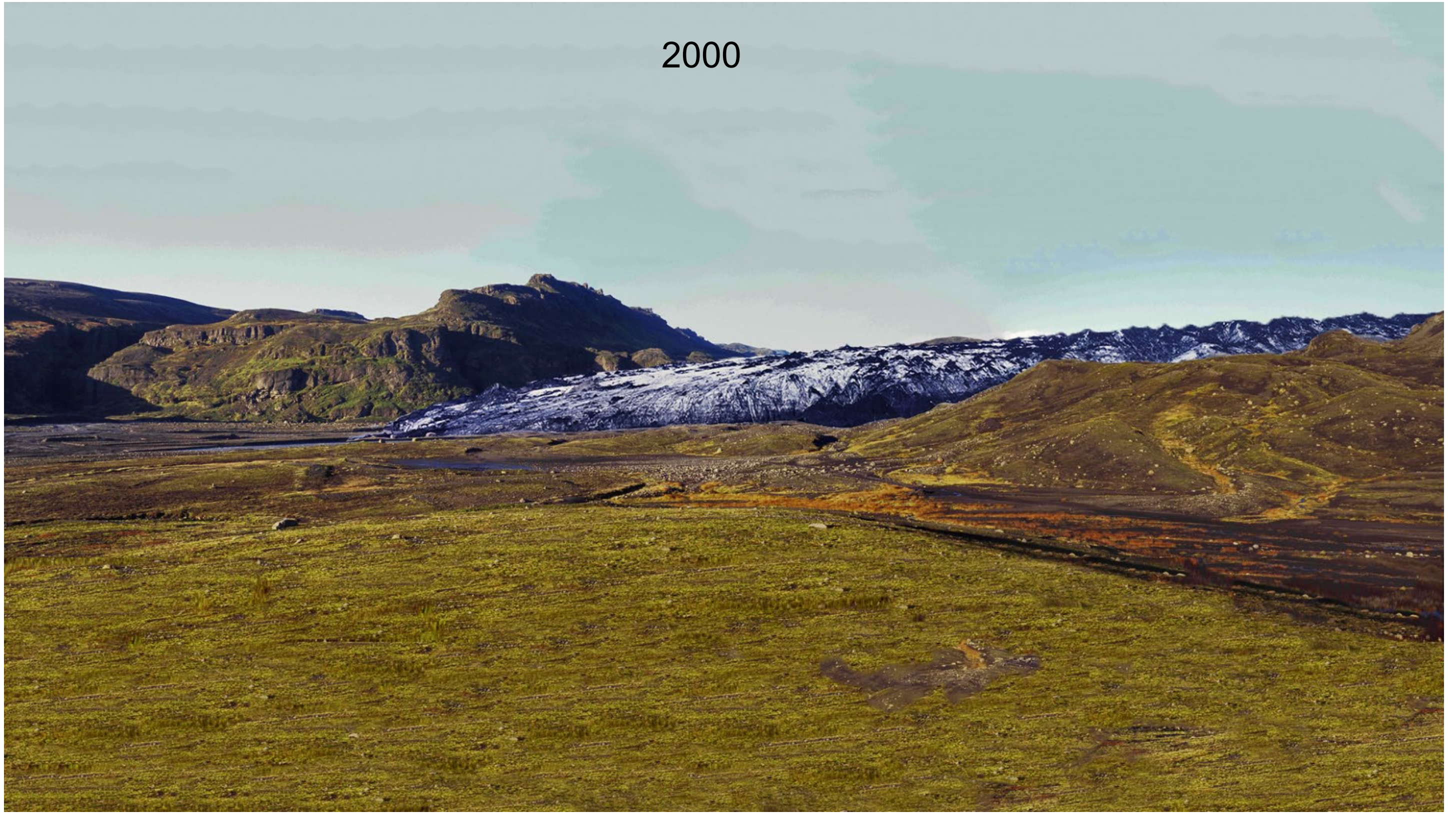


2003


2005

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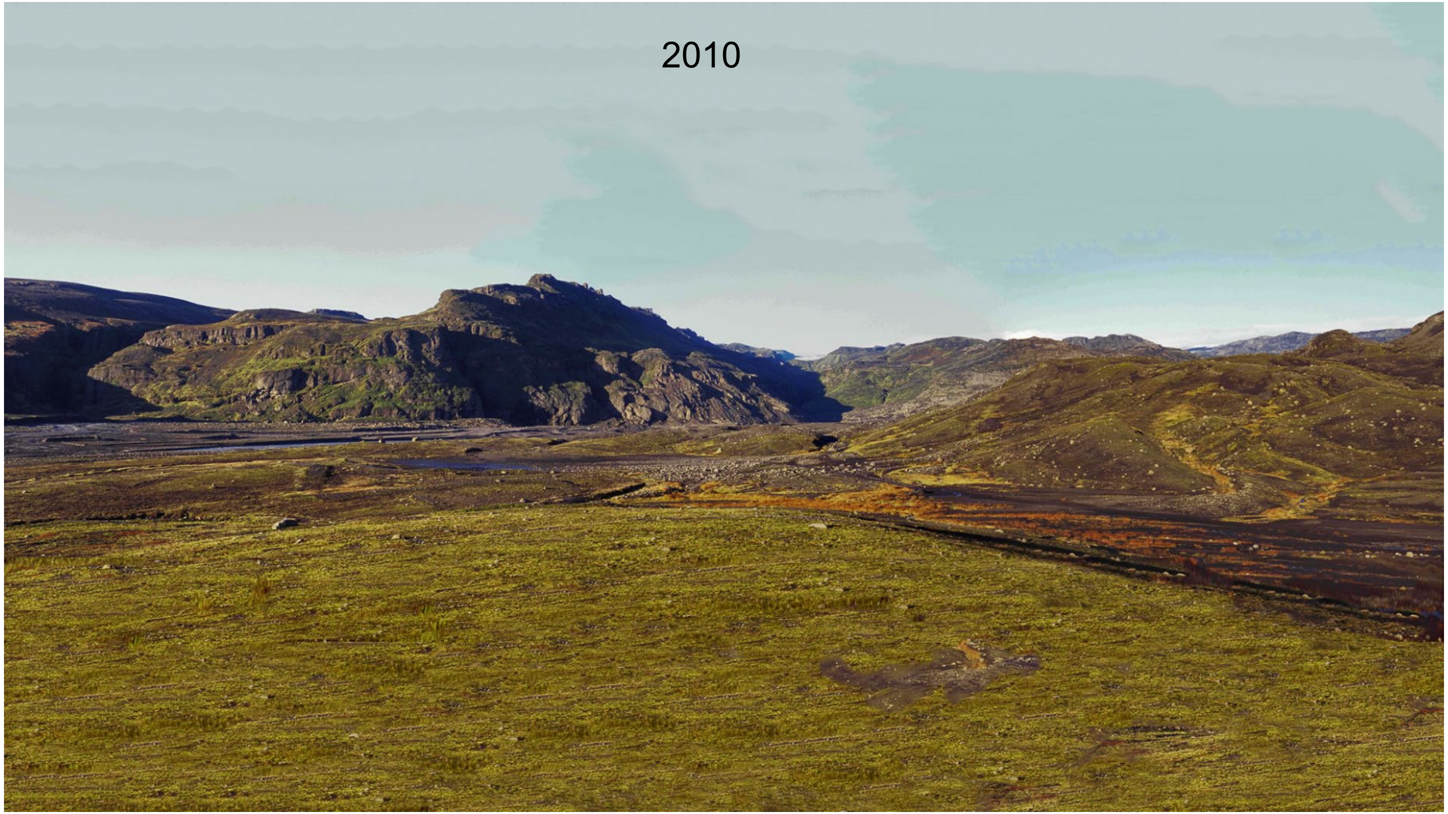
2010

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Why are we doing this?

- Glaciers have been retreating since 1890
- Climate change predictions indicate this will continue
- Volcanic activity increased during the Pleistocene deglaciation
- This will happen again - it is now a question of when and by how much …

Skálafellsjökull 1989-2019. Myndvinnsla: Kieran Baxter

The ISVOLC hypothesis:

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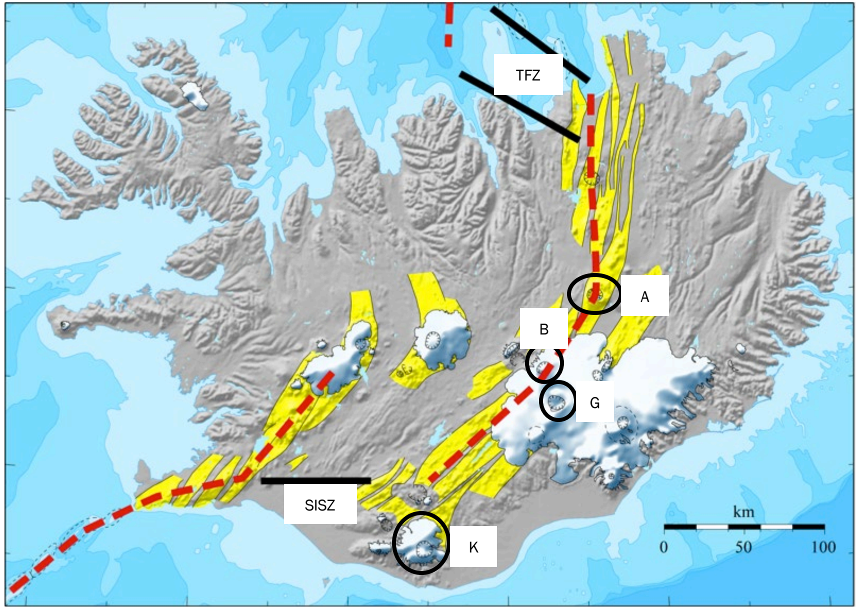
- That glacier mass loss is already producing excessive melt, affecting magma migration beneath Iceland, and stress changes are affecting the stability of existing magma bodies, as well as influencing earthquake activity.
- We will focus on 4 volcanoes and 2 seismic zones that serve as a natural laboratory for studying the effects of deglaciation on volcanism and seismicity.



ISVOLC study areas: Map of Iceland with glaciers (white) and fissure swarms (yellow), showing target areas: Katla (K), Askja (A), Grímsvötn (G), Bárðarbunga (B), South Iceland Seismic Zone (SISZ) and Tjörnes Fracture Zone (TFZ).

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What we plan to do

- Generate a unified database of volume changes of the Icelandic glaciers since the end of Little Ice Age.
- Create a new set of three-dimensional (3D) GIA models considering a realistic lithospheric/mantle structure.
- Develop advanced 3D models of magma plumbing beneath key volcanoes.
- Combine the GIA model predictions and the magma plumbing models to produce 3D models that describe effects from both deglaciation and magma influx.
- Generate future scenarios of glacial mass loss for Vatnajökull based on ice dynamic modelling and detailed retreat history for the last 4 decades.
- Determine the effect of both recent and future scenarios of glacier changes on magma generation and supply to, and stability of magma bodies beneath volcanoes and effect on seismic triggering of faults in major fault zones.

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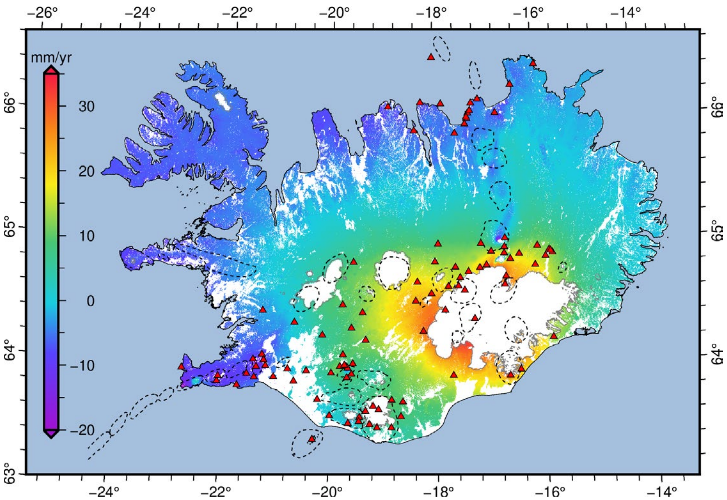
WP1: Geodetic and glacier mass balance observations (WP leaders GA & FP).

- Generate extended three-component GNSS time-series from ~1993 to present, using data from ~100 continuous GNSS stations + campaign observations.
- Countrywide InSAR mapped deformation fields using Sentinel-1 observations from ascending and descending tracks will be combined to form an estimate of near-vertical and near-east displacements.
- New time-variant ice-history models generated, describing the evolution of Icelandic glaciers during the past 130 years. Their mass balance history and uncertainties, as well as mass loss distribution, will be updated, using new observational constraints.
- Datasets will feed into WPs 2 and 3 – to produce a new generation of GIA and volcano models.



Estimated average vertical velocities induced by GIA between summer 2015 and summer 2020 in Iceland, derived from Sentinel-1 interferometry, using the procedure described by Drouin and Sigmundsson (2019).

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WP2: Country-wide GIA modeling (WP leaders FS & PS).

- Create a new generation of 4D (space and time) FE GIA models.
- WP1 mass balance models will be converted into surface pressure change and applied as a surface load in the GIA models.
- The Earth models will be constrained by comparing predicted ground deformation due to surface ice load changes with geodetic observations.
- Modeling will place constraints on plausible Earth model parameter ranges (e.g. viscosity structure beneath Iceland and elastic parameter ranges of the Icelandic crust).
- Modeling will aim to incorporate realistic 3D rheological structure for the Lithosphere and Mantle (i.e. a lithosphere thickness and mantle viscosity that varies laterally).
- Computed pressure changes in the mantle will be used to estimate the associated changes in the mantle magma production rate.

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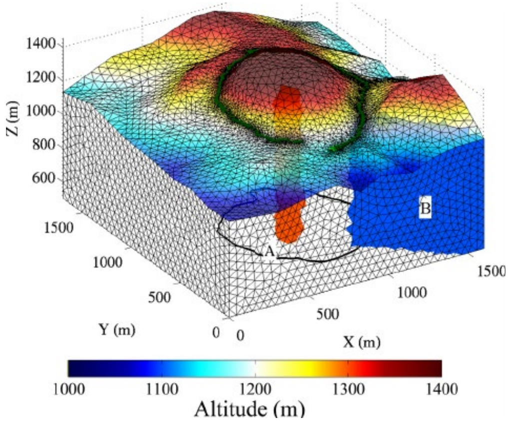
WP3: Advanced models of target volcano magmatic systems (WP leaders MMP & FA).

- Develop 3D FEM models of the magma plumbing systems beneath target volcanoes.
- Surface deformation measurements will be corrected for GIA deformation.
- Initially, a Bayesian inversion procedure using analytical models, will be used to infer the optimal parameters of the magma bodies responsible for the observed deformation.
- FE models will be generated and used to determine melt supply rates to shallow crustal magma bodies. These models will account for natural characteristics such as topography, crustal heterogeneities and poroelastic/viscoelastic effects.
- Coulomb Failure Stress (CFS) change within target seismic zones due to magma movements will be evaluated as will its role in influencing and modifying local seismicity at volcanoes.



Example of Finite Element model from Lesparre et al., 2014.

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WP4: Coupling of GIA and volcano deformation models (WP leaders FS & Postdoc).

- Ground deformation fields and stress changes from WP2 will be used to produce regional stress and strain rate fields to be applied within the domain of FE magma plumbing models.
- We will test the influence GIA has on the interpretation of volcanic processes and on the stability of magma bodies.
- We will investigate the impact of both long-term ice unloading and magma accumulation on fault stability at targeted volcanoes following the CFS change approach described in WP3, testing different fault orientations.
- For seismic zones, we will superimpose the GIA-induced stress field on the background tectonic stress in order to calculate CFS change on main faults.

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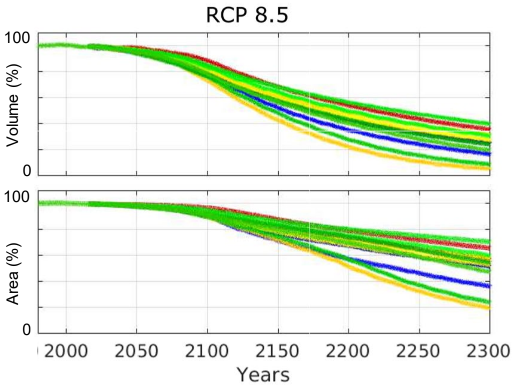
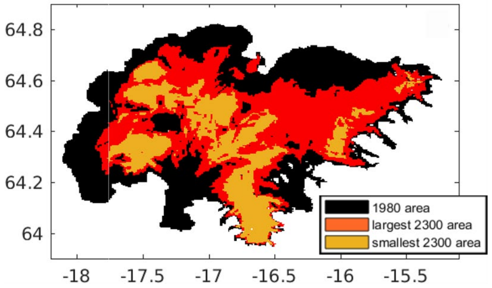
WP5: Hazard assessment, forecasting and public dissemination (WP leaders MMP & Postdoc).

- This WP will consider the wider implications of the modeling for natural hazards and forecast future effects of glacial retreat. We will consider (i) models of increased melt generation, (ii) models of magma transfer, and (iii) models of magma storage, and associated probability density functions for each of these processes.
- Future simulations of glacier mass loss rates based on model projections for Vatnajökull will be used to generate future GIA models and estimate future melt production rates.
- We will evaluate the present and future potential effects on both magmatic and seismic activity:
  - By determining how GIA and volcano deformation perturbs the tensile stresses along the volcanic rift zones, and by quantitative comparison to plate boundary deformation models we can assess by how much rifting events are advanced or delayed for each volcanic system.
  - The calculated CFS changes will be compared with (a) plate boundary stress build-up using existing models of the Iceland plate boundary and (b) co-seismic changes.





Simulations of future ice-retreat for Vatnajökull, from Schmidt et al., 2020.

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Dissemination plan

- The project will adhere to the Green Open Access policy, making all its publications available in an open access repository.
- Results will be presented to civil protection, the general public, power companies and at scientific conferences e.g. AGU, EGU, IAVCEI, IUGG.
- Any code developed during the project will be made freely available (in GitHub) along with the results of the data analysis (on OSF, https://osf.io/) to ensure this work is transferrable to other volcanoes under the influence of ice-retreat.
- A publicly available database where scientists can retrieve estimated GIA surface displacements/velocities (with uncertainty estimates) will also be generated.

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Field work

- Field work already undertaken this year at both Grímsvötn and Askja
- Grimsvötn – campaign GNSS and new site installations
- Askja – levelling, campaign GNSS, gravity and gas measurements

Campaign installation at HUSB (Grímsvötn)

Installation at Vestari Svíahnjúkur (SVV2) (Grímsvötn)

Campaign measurements at Askja

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Future ISVOLC meetings

- Planning to hold ISVOLC workshop in Iceland in the fall (Oct 2023)
- Presentation at AGU in December 2023
- Project meeting at EGU in April 2024

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PhD students, Postdoc and contract work

- 2 PhD students have already been hired! Plus an additional PhD through the University of Iceland Research Fund
- Also collaborating with James Hickey (Exeter) – an additional PhD student who is funded by the EPSRC will work on ISVOLC volcanoes
- Postdoc advertisement to be sent soon! If interested please email michelle@vedur.is
- Peter Schmidt (Uppsala) is currently updating GIA model in COMSOL, preliminary results expected in the fall (2023)

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Thank you!

Takk fyrir!