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Non-eruptive Uplift and Subsidence episodes beneath the Hengill Triple Junction, SW Iceland

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Picture credits: O. Lamb. View from Þingvellir (NW of Hengill) towards the SE.

Geological and Geophysical Background

The Hengill area:

→ Triple junction between the North American plate, Eurasian plate and Hreppar Microplate. (Plate boundaries (Fig.1) from Árnadóttir et al. 2009)

→ Host 2 active volcanic systems: Hengill and Hrómundartindur. The last eruption dates from 2000 years ago.

→ 2 geothermal plants (Hellisheiði and Nesjavellir) currently produce a total of ~ 400 Mth and ~ 400 Mwe.

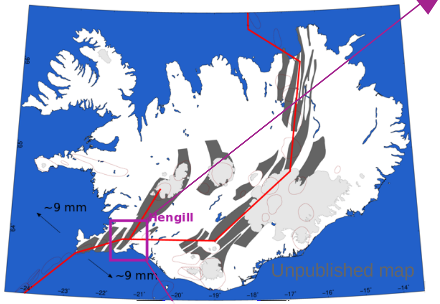

Figure 1 : Location of the Hengill triple junction (purple box). The dark grey areas represent the main fissure swarms of Iceland, the red lines the plate boundaries, the light grey areas represent the current ice caps and glaciers. The red dashed lines shows the location of the main Icelandic volcanic systems

Geophysical state of knowledge:

→ Uplift episode between 1993-1999 associated with large seismicity (Sigmundsson et al. 1997, Feigl et al. 2000).

→ Subsidence sources: 2 shallow (< 3km) sources of subsidence linked to the areas of extraction in the 2 geothermal plants (Juncu et al. 2017) seen in Fig. 2.

→ Large earthquakes (~ Mw 6) recurrent in the area. The last ones occurred in 2008 in the East of the Hengill volcanic complex (Fig.2).

→ Deep-seated subsidence (~6km depth) in the area (Juncu et al. 2017) since 2006.

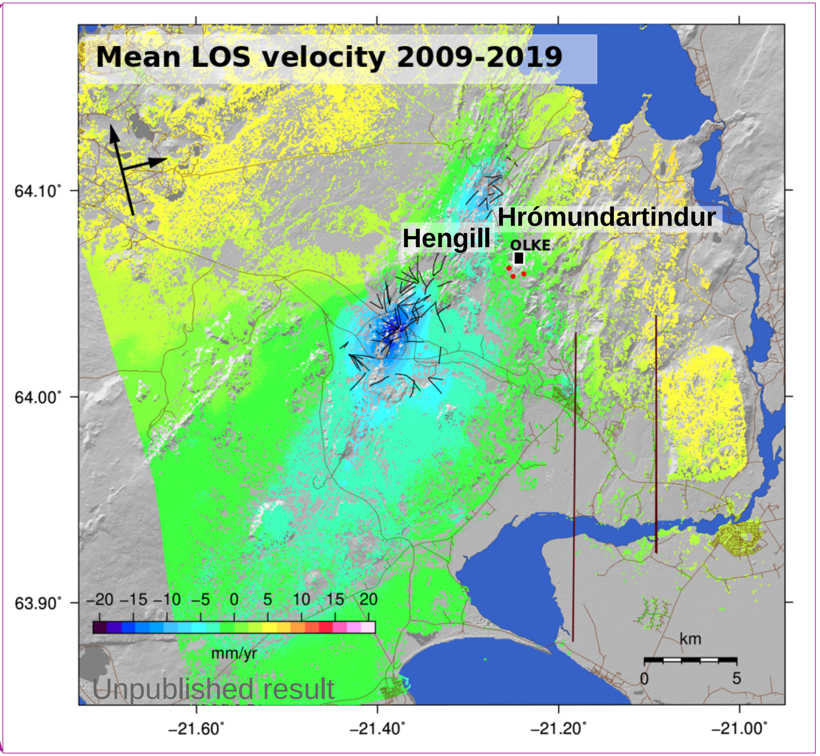

Figure 2 : 2009-2019 Mean LOS velocity from TerraSAR-X SAR data using the PS processing from StaMPS (Hooper et al. 2008). The borehole tracks in black) and well-heads (red dots) from the Hellisheiði and Nesjavellir geothermal power plants (Courtesy of Reykjavík Energy). The brown lines highlights the faults rupturing in the 2008 doublet of earthquakes (Decriem et al., 2010). The location of main continuous GNSS station OLKE of the Eastern part of the Hengill area in noted by a black box.

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2017-2018 Uplift episode from GNSS

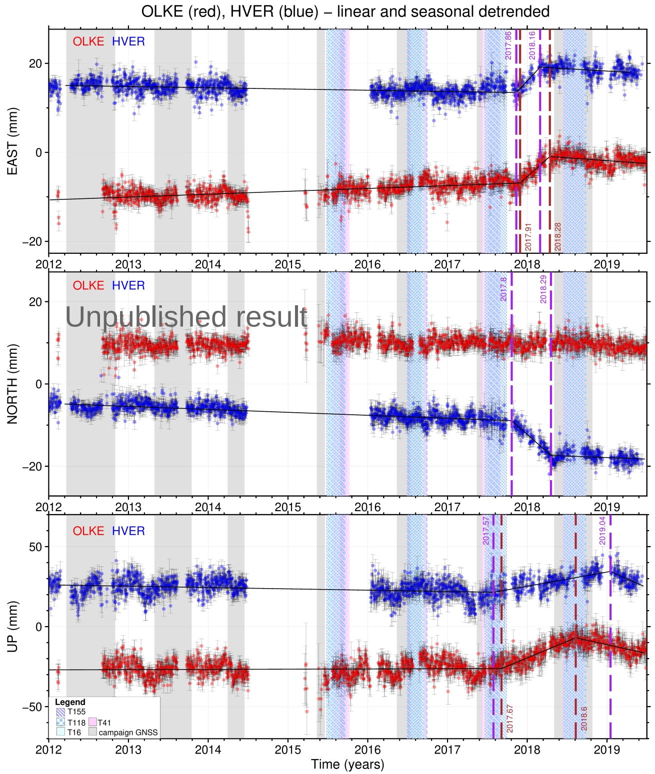


Figure 4 (on the left): Determination of the Uplift amplitude and time span from the North, East and Vertical component of the continuous stations OLKE and HVER (see Fig. 3 for locations).

The time series were generated using the GAMIT/GLOBK package (Herring et al. 2015) in the ITRF14 reference frame.

For each component of each station, the linear and seasonal signal were estimated and removed. This was done in order to remove the effect of the plate motions, and subsidence from geothermal production in the Hengill area (see in Fig. 2).

This figure shows the different data spans (InSAR and campaign GNSS (Fig. 3) used in the study of the 2017-2018 uplift episode.

Figure 3 (on the right): Near-Up component InSAR time series from Sentinel-1 data, between 2017-2018 relative to 2015-2017, using the methodology from Drouin et al. 2019. Overlayed are the 2017-2018 horizontal displacements, relative to 2012-2017, inferred from our campaign data sets.

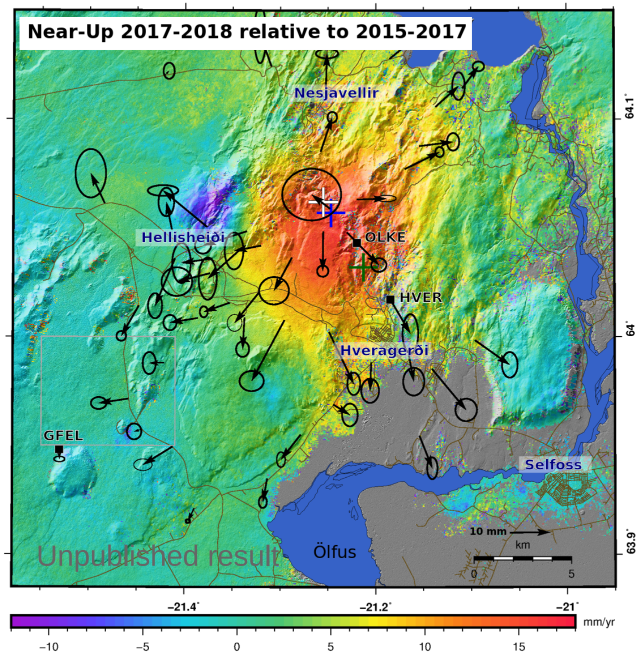
We observe some shallow subsidence W of Hengill (source < 3km) likely to be linked to the geothermal production in the Hellisheiði power plant.

Legend:

Best fit source of the 2017-2018 uplift episode from GPS data (Spherical source).
Depth: ~7 km
Volume change: ~4.6 Mm^3

Estimated source location of 2006-2017 subsidence episodes (Juncu et al. 2017)
Depth: 6-7km
Contraction rate: ~2.4 * 10^6 m^3/yr

Estimated source location of the 1993-1999 uplift episode (Feigl et al. 2000)
Depth: ~ 7km
Inflation rate: ~ 3.9 * 10^6 m^3/yr



Key Questions:

What drives these uplift and subsidence episodes?

Are the sources of these episodes related?

Are their origin magmatic or hydrothermal in nature?

Conclusions

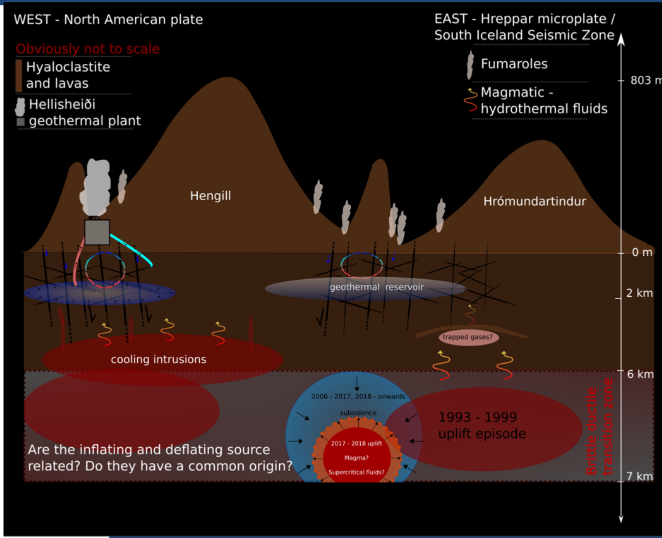
GNSS and InSAR studies:

→ 2017-2018 Uplift lasted close to 6 months – as seen from the OLKE and HVER Global Navigation Satellite systems time series – with a maximum estimated amplitude of ~ 1.7 cm.

→ Joint GPS and InSAR inversion shows a deep source (~7 km) between the Hrómundartindur and Hengill active volcanic systems. These sources are located within the brittle-ductile boundary of the area.

→ Close location of the deep-seated sources suggests a relation between these uplift and subsidence episodes.

Figure 9 (on the right) Conceptual model of the different processes in the Hengill area and summarises the plausible explanations for the uplift and subsidence episodes.

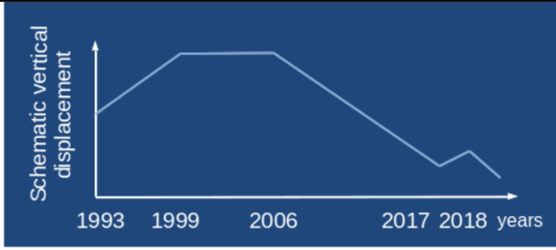


Other Geophysical/Geological data sets:

→ No significant increase in seismicity rate.

→ Borehole (Fig. 2) temperature measurements (max 1500 m b.g.l.) between 2015 – 2018 do not show consistent and significant temperature changes.

Figure 10 (on the right) Schematic temporal variations of the ground deformation in the hengill area, from deep-seated sources



These uplift and subsidence episodes can be explained by:

→ Inflation/Contraction of a magmatic source at depth?

→ Hydrothermal fluids migration? Heat mining?

→ Degassing (subsidence) and trapped fluids (uplift)?

→ The interaction of all or some of the above processes?

Currently in the field. If you are interested in the subject or have any questions, please send me an email at cad7@hi.is. Your input would be very appreciated.

References mentioned:

Árnadóttir, T., Lund, B., Jiang, W., Geirsson, H., Björnsson, H., Einarsson, P., and Sigurdsson, T. (2009). “Glacial rebound and plate spreading: Results from the first countrywide GPS observations in Iceland.”Geophysical Journal International, 177(2), 691–716.

Decriem, J., Árnadóttir, T., Hooper, A., Geirsson, H., Sigmundsson, F., Keiding, M., Ófeigsson, B. G., Hreinsdóttir, S., Einarsson, P., LaFemina, P., and Bennett, R. A. (2010). “The 2008 May 29 earthquake doublet in SW Iceland.”Geophysical Journal International, 181(2), 1128–1146.

Drouin, V. and Sigmundsson, F. (2019). “Countrywide Observations of Plate Spreading and Glacial Isostatic Adjustment in Iceland Inferred by Sentinel-1 Radar Interferometry, 2015–2018.”Geophysical Research Letters, 46(14), 8046–8055.

Feigl, K. L., J. Gasperi, F. Sigmundsson, and A. Rigo (2000), Crustal deformation near Hengill volcano, Iceland 1993–1998: Coupling between magmatic activity and faulting inferred from elastic modeling of satellite radar interferograms, J. Geophys. Res., 105(25), 655–25.

Herring, T. A., K. R. W. F. M. A. . M. S. C. (2015). “Introduction to GAMIT/GLOBK, Release 10.6. MA, USA: Mass. Inst. Technol.

Juncu, D., Árnadóttir, T., Hooper, A., and Gunnarsson, G. (2017). “Anthropogenic and natural ground deformation in the Hengill geothermal area, Iceland.”Journal of Geophysical Research: Solid Earth, 122(1), 692–709.

Sigmundsson, F., P. Einarsson, S. Røgnvaldsson, G. Foulger, K. Hodgkinson, and G. Thorbergsson (1997), The 1994–1995 seismicity and deformation at the Hengill triple junction, Iceland: Triggering of earthquakes by minor magma injection in a zone of horizontal shear stress, J. Geophys. Res., 102, 15,151–15,161.

Hooper, A. (2008), A multi-temporal insar method incorporating both persistent scatterer and small baseline approaches, Geophys. Res. Lett., 35, L16302, doi:10.1029/2008GL034654.

Wessel, P. and W. H. F. Smith, Free software helps map and display data, EOS Trans. AGU, 72, 441, 1991.

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