DRF- practical implementation in Iceland

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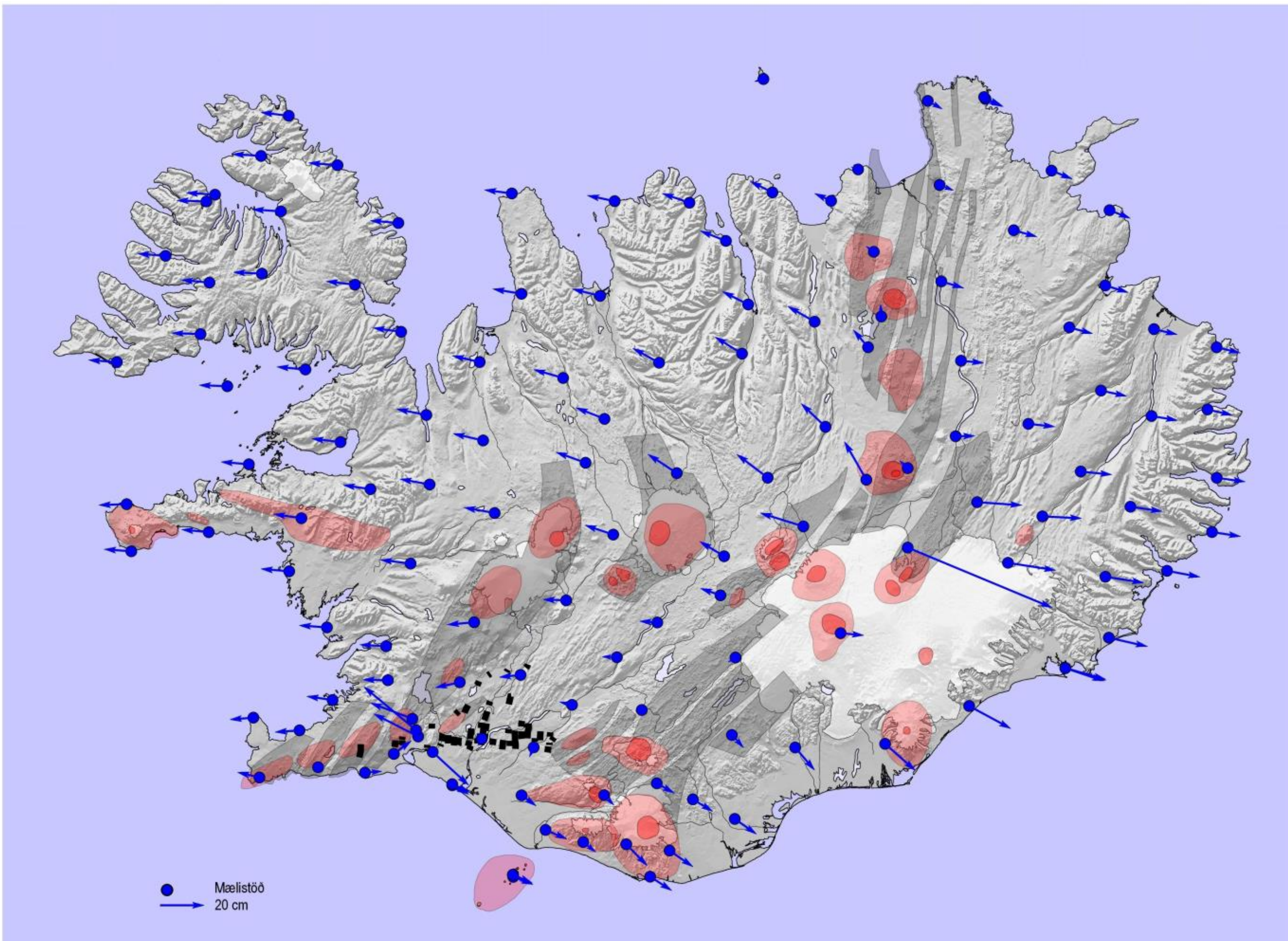
ISN2016 and ISN_DRF

- NLSI is introducing a new geodetic datum ISN2016
- ISN2016 is a semi-dynamic datum and it‘s dynamic part is called ISN_DRF
  - Two frame approach
- Replaces ISN93 and ISN2004
  - Static datums
- ISN2016
  - IGS14 epoch 2016.5
- ISN_DRF
  - Current IGS/ITRF

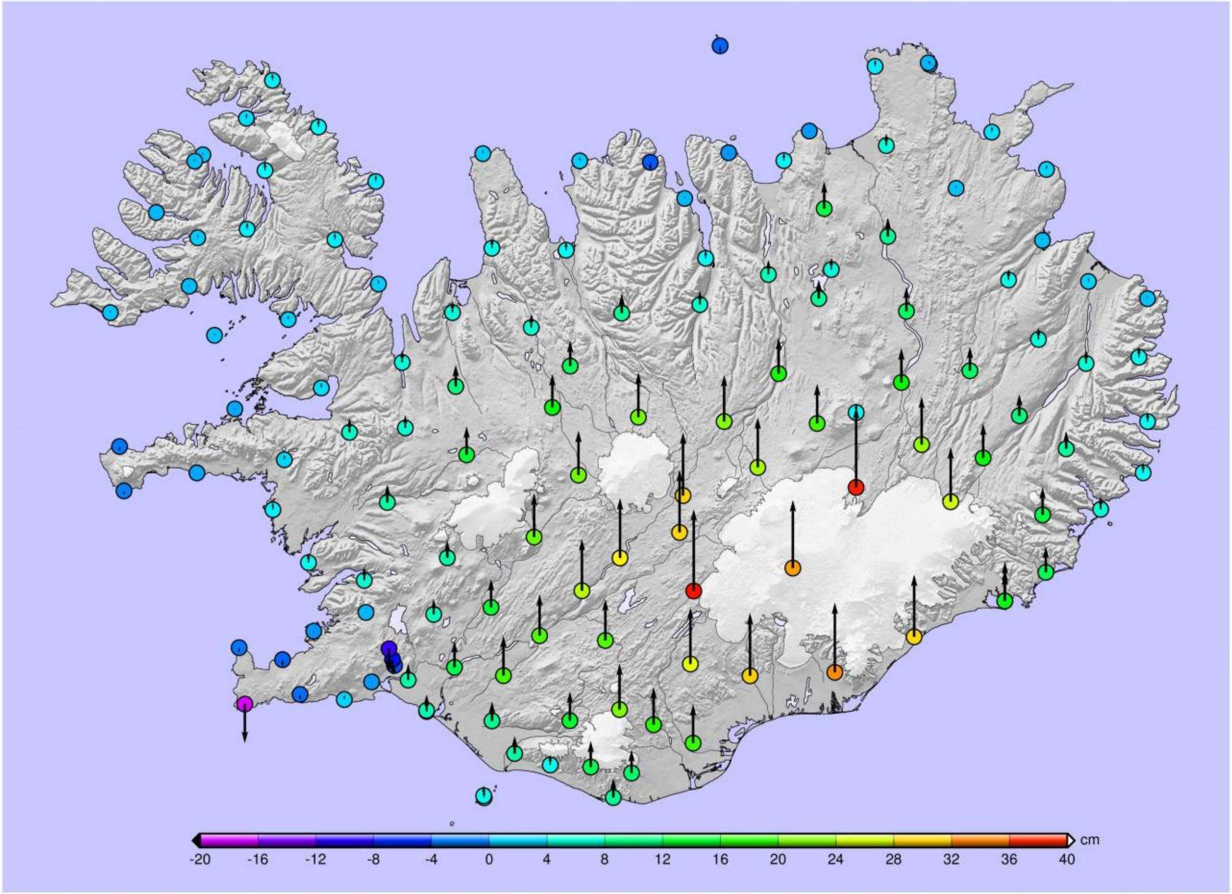
Why are we always changing datum’s

- Iceland is located on the plate boundaries of the Eurasian- and North American plate
- Our network is constantly deforming due to plate tectonics
- Also sudden local deformation due to earthquakes and volcanic eruptions
- Height changes because of melting of glaciers and geothermal power plants

ISN2016 vs. ISN2004 horizontal deformation



ISN2016 vs. ISN2004 vertical difference



What is needed to use ISN2016?

- Accurate transformations from the older ISN systems and some local systems
- Velocity model to handle regular crustal deformation
- Methods to handle sudden deformation like earthquakes and volcanic eruptions
- Ways to use complex transformations
- Access to the system through benchmarks and positioning service

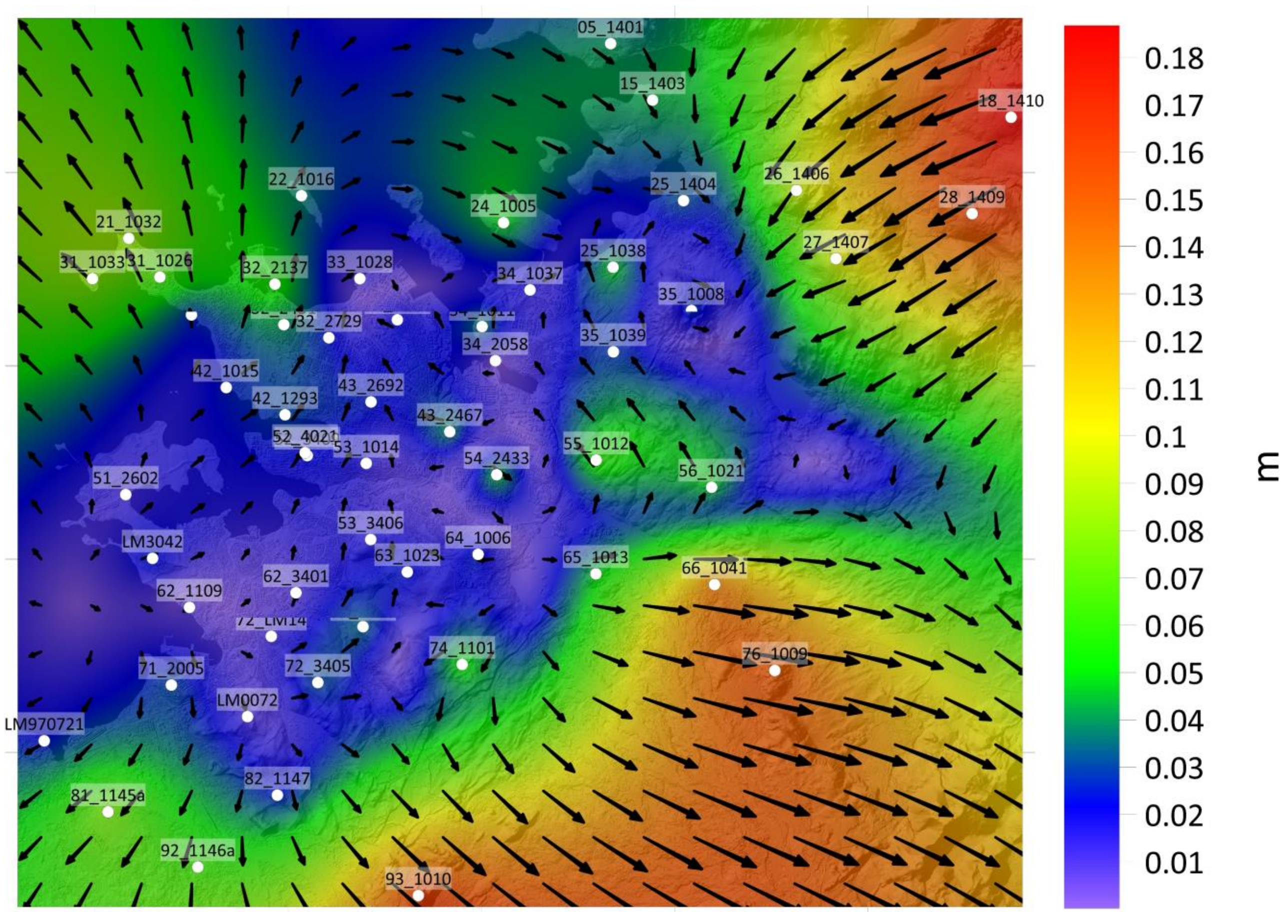
Transformations

- Transformations between the ISN datums are mainly based on the results of the ISNET campaigns
- Grid based transformations
- Accuracy
  - < 5 cm in stable areas
  - < 10 cm in areas close to the plate boundaries
  - > 10 cm in areas were we had earthquakes and large volcanic eruptions
- Some improvements can made with more data

Reykjavík local system

- An old 2D planar system still used in the capital area
- Causing problems when using GNSS
- In 2019 NLSI measured 55 points in Reykjavik area with GNSS
  - Original triangulation points + some extra points
- Two step approach
  - 4 parameter Helmert transformation
    - Plane and Gauss-Kruger
  - Grid transformation based on Kriging
- Transformation between Reykjavik local, ISN93 and ISN2016 is available in Cocodati

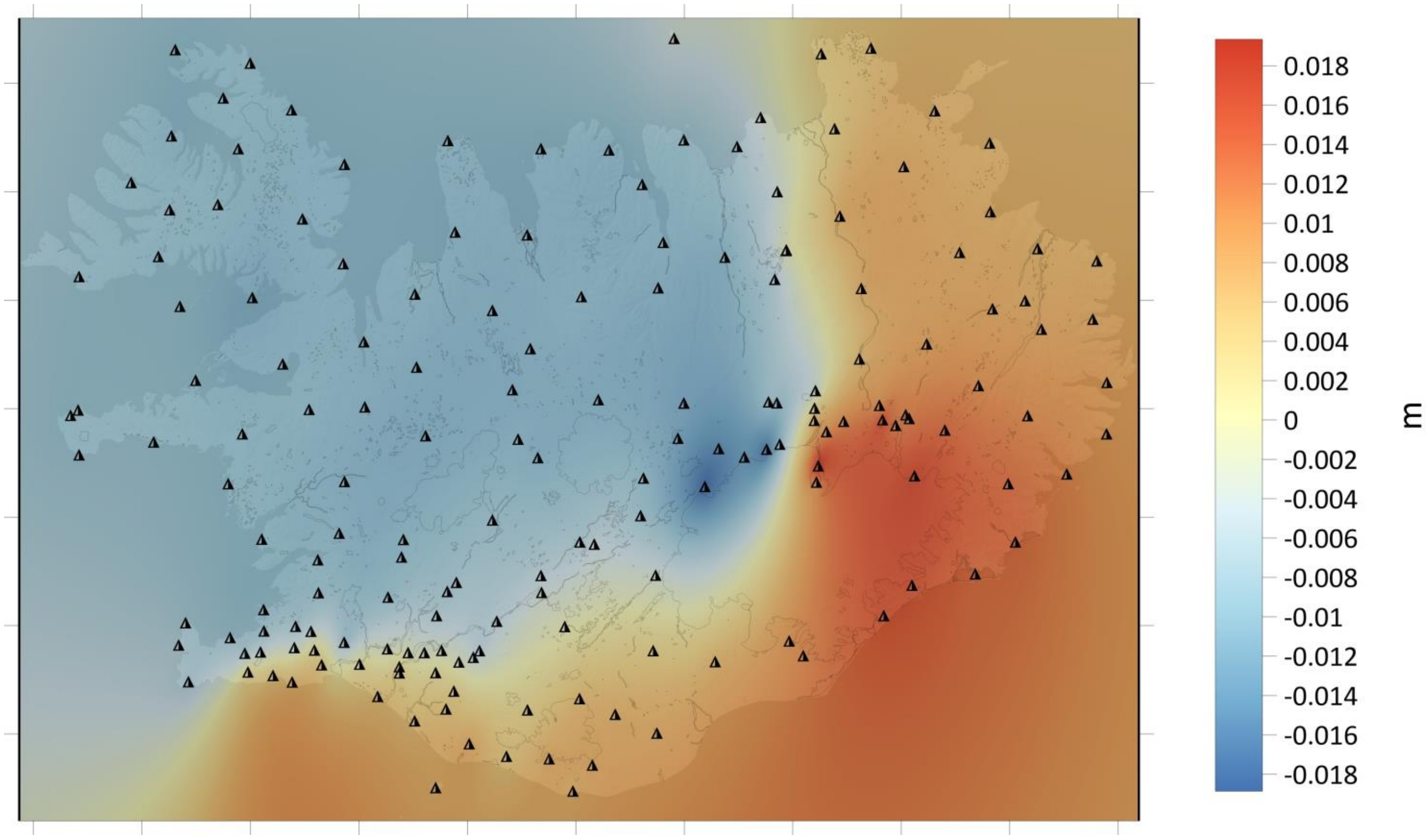
Reykjavik transformation grid



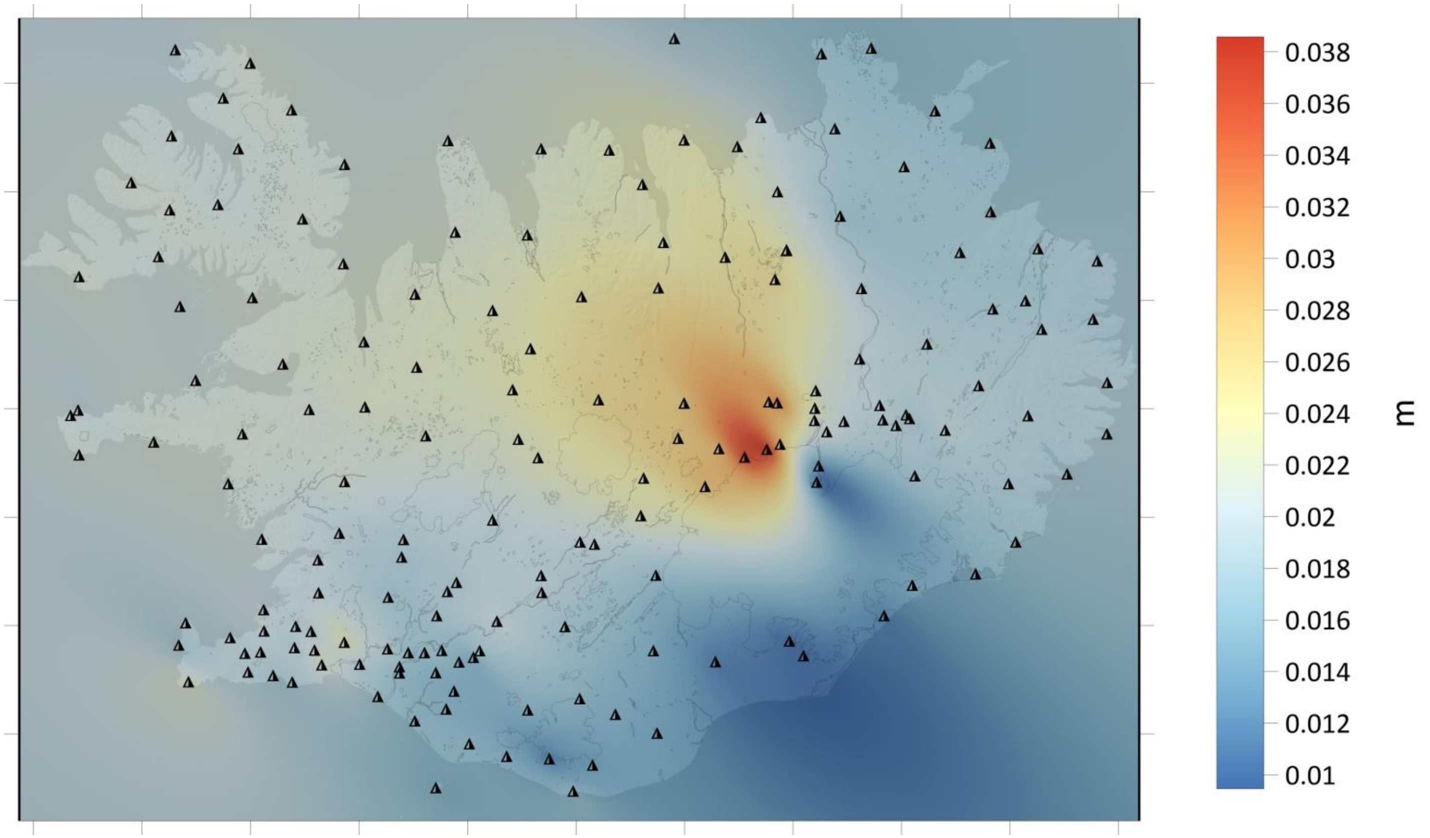
Secular velocity field

- The first version is based on 134 BM measurements and 41 time series with varying time span
- We are working on 2nd version
  - Velocities from around 50-60 more timeseries
  - Want to add plate spreading model and GIA model
  - Remove-restore
- For the last five years the land uplift around Vatnajökull has been decreasing
- Changes in vertical velocities up to 7 mm/year compared to the whole timeseries
- Also small changes in horizontal velocities

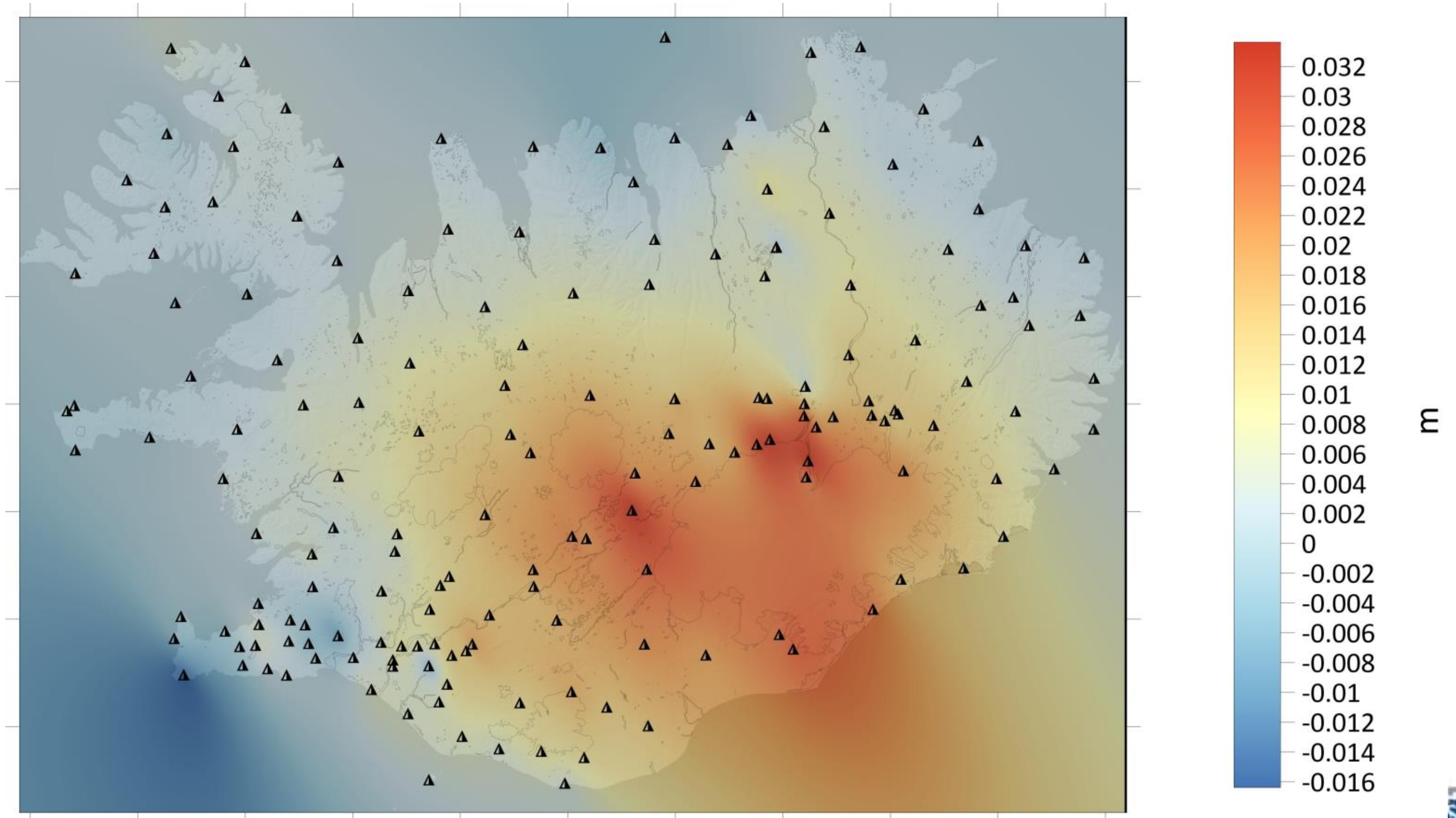
East-West velocity



Northward velocity



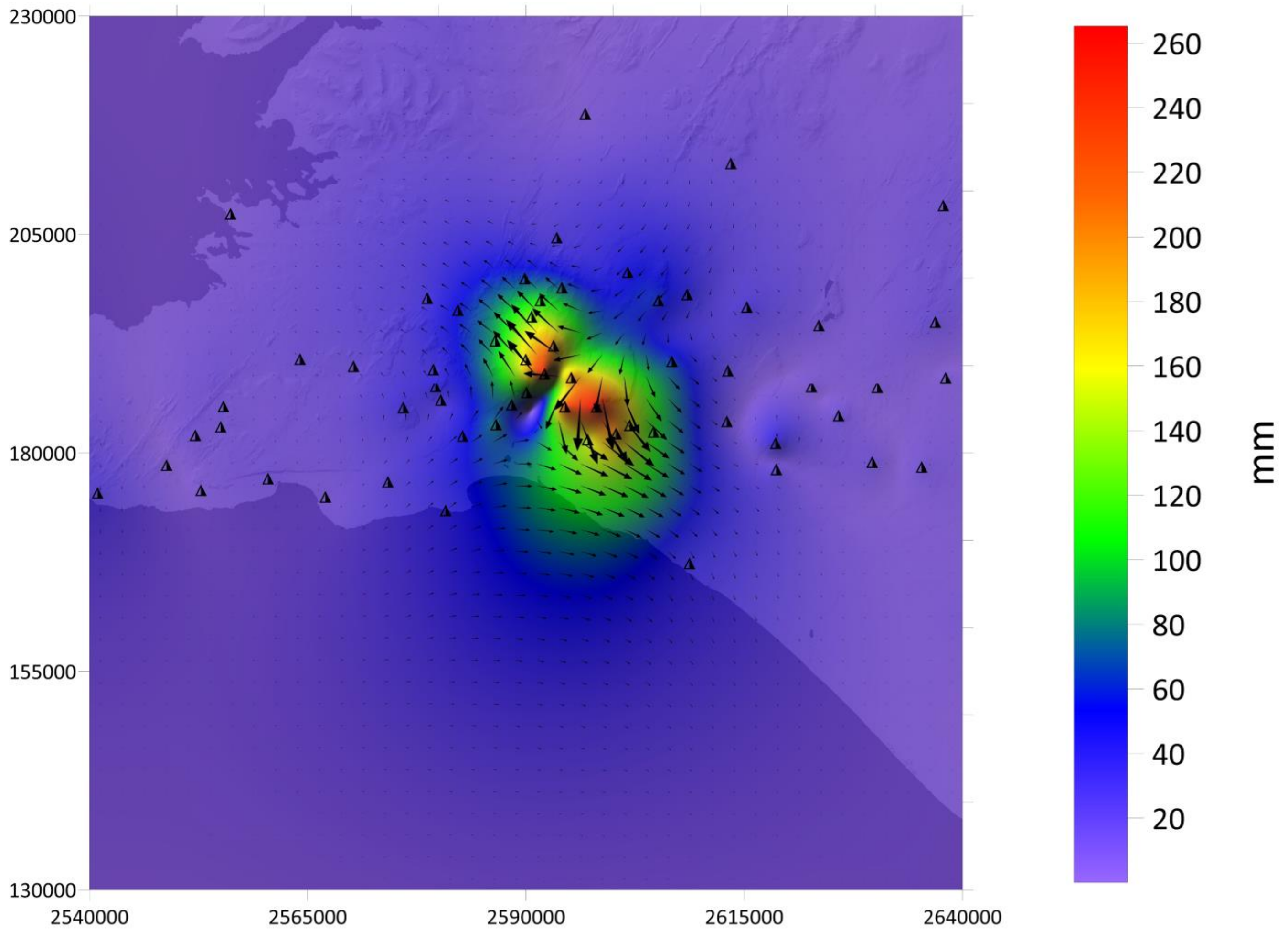
Vertical velocity



Earthquake patch (test)

- We've an earthquake patch for test purpose
  - Only Kriging
- Based on coseismal displacements of 74 GNSS benchmarks and timeseries
- From the paper The 2008 May 29 earthquake doublet in SW Iceland by J. Decriem et.al. from 2010
- Some dummy points to have zero displacement on the edges of themodel
- Works in PROJ

May 29th 2008 Earthquake patch



Transformations and models to the users

- All our models and transformations can be used with PROJ
- Our new transformation service Cocodati is based on PROJ
- Most of models are included in the PROJ European grid package also an init file with pipelines and explanations
- EPSG codes
- ISN2016 is now fully included in QGIS with grid transformations
  - A bit slow when using raster data and when working with online data with different datum

Transformations and models to the users

- Most geospatial data can be transformed using GDAL, both for ISN2016 and ISN_DRF
- ESRI is working on implementing ISN2016 and also Trimble

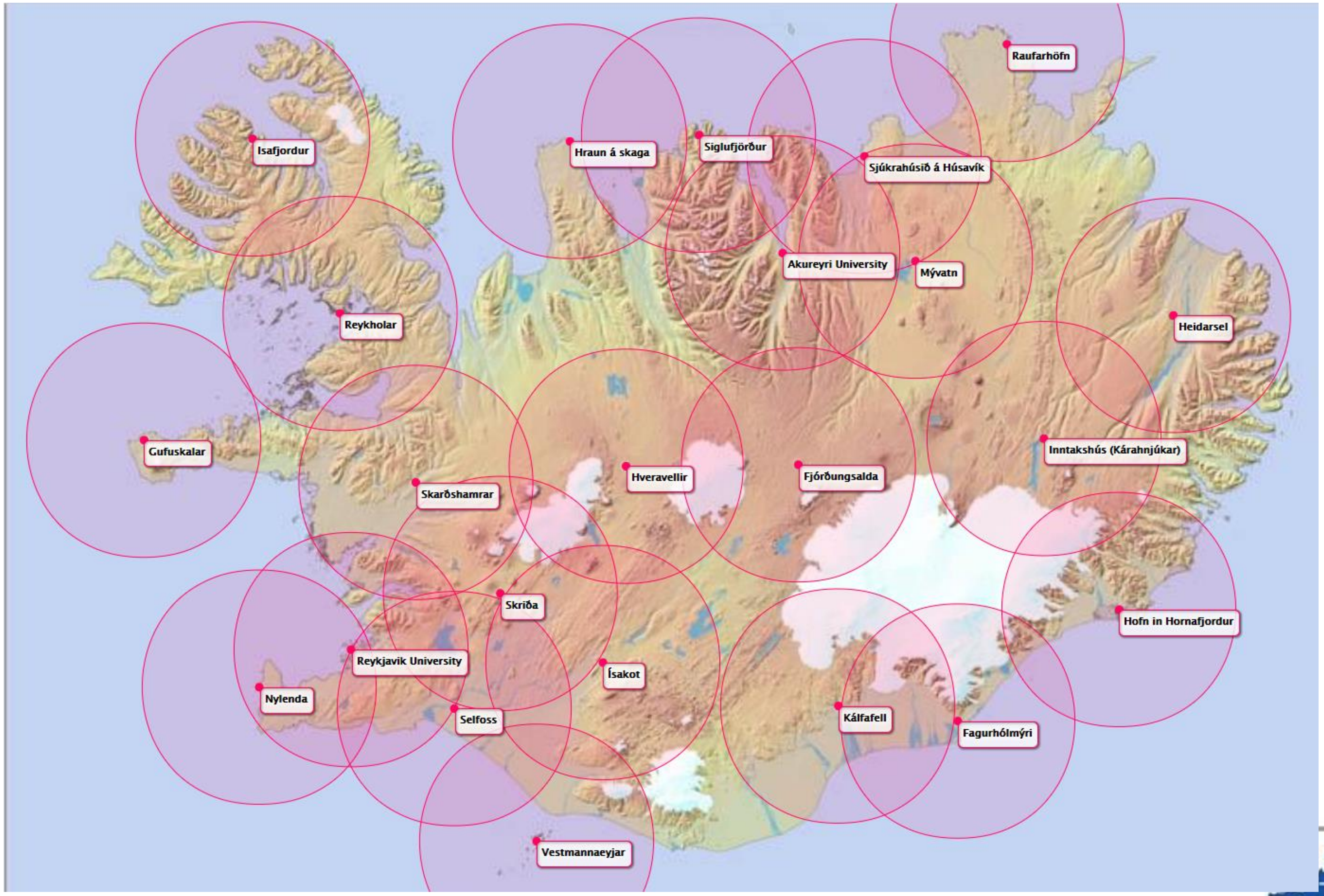
Processing service

- IceCORS PPS
    - Bernese processing
    - For static measurements more than 1 hour
    - Results in epoch of the measurement and in ISN2016
- SBPPS
    - Based on WASOFT
    - For shorter and kinematic observations
- Still in test phase but promising

Positioning service: IceCORS

- We have 23 stations at the moment, final design is about 33 stations
- Only part owned by NLSI
- Also using stations from the geophysical society
- Some stations are GPS only
- We're using GNSMART from Geo++
- Data for Post Processing, VRS data and Network RTK
- The service is free of charge

IceCORS – Today



Two frame approach in GNSMART

- We've been testing two frame approach for our RTK system
- Using module called GNTRSRVR
  - Use a residual grid between epochs 2016.5(IGS14) and the current reference coordinates in GNSMART
  - Send out two different streams, with and without the grid correction
  - Requires regular update of coordinates and residual grid
- Using SSR2OSR
  - Coordinates kept in ISN2016
  - ISN_DRF coordinates created with SSR
  - Question about accuracy of ISN2016 coordinates when time goes by

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RTK network using Geo++ GNSMART

PRIMARY TASK (The GNSS errors must be precisely modeled and monitored to resolve ambiguities)

SSM: All error sources build up the State Space Model

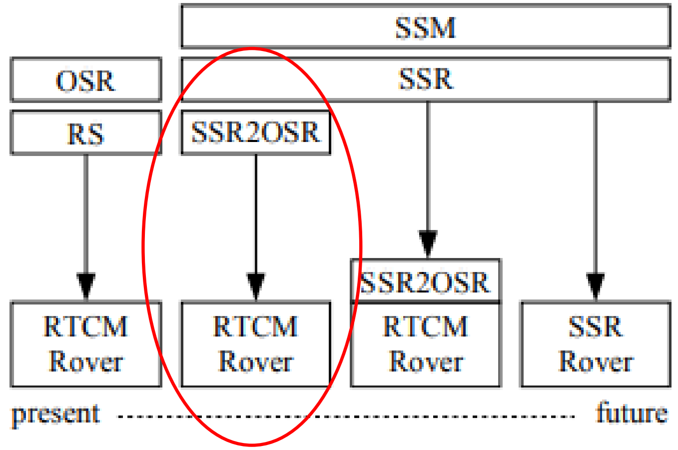
SECONDARY TASK (For any time and location within the covered network area the computation of correction data from SSM, which represent the GNSS errors for an individual rover site)

OSR: Observation Space Representation (transforming state parameters into observations or observation corrections)

SSR: State Space Representation (also the actual state-space data can be used for the representation of the complete GNSS state)

RS: Reference Station

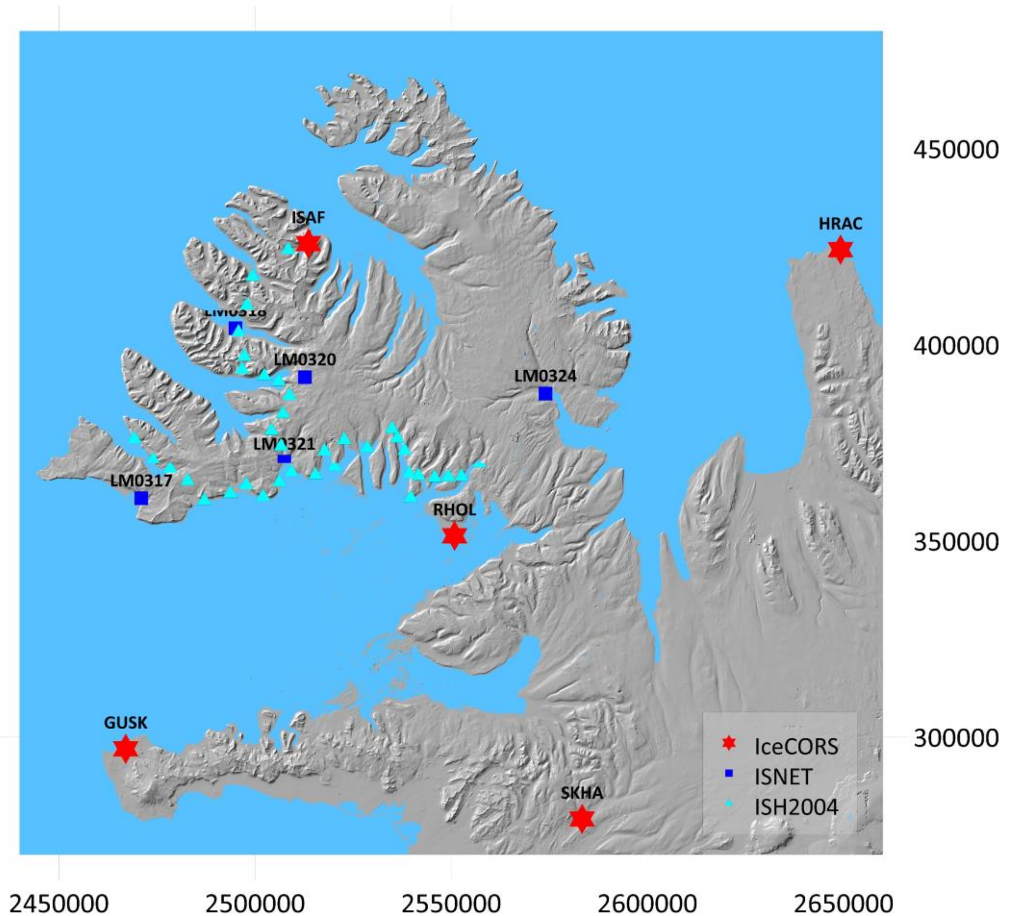
SSR2OSR: Conversion from SSR to OSR



Vestfjords 2019 campaign

- 41 benchmarks were measured with static GNSS in October 2019
- Observation time around 40 hours at each point
- Network RTK measurements were done at same points during the campaign using Trimble R10
  - SSR for 5 seconds, 30 seconds and 5 minutes
  - VRS for 30 seconds
- The distance between IceCORS stations are in some cases over 100 km and the landscape is sometimes challenging for GNSS

Stations in the VES2019 campaign



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Data processing

- The static data was processed using Bernese 5.2
- Using NKG_AC settings + some extra IGS stations
- Results were in the centre epoch of the campaign
  - Estimated accuracy around 3-4 mm in plane and 7mm in height
- The results were also transformed to ISN2016 using the preliminary velocity model to compare with the VRS results

Network RTK compared to Static Results

SSR 5 seconds

Value	dEast	dNorth	dHeight
Max	0.036	0.039	0.068
Min	-0.042	-0.039	-0.105
Average	-0.002	0.002	-0.016
StDev	0.014	0.019	0.039
RMS	0.015	0.019	0.042

SSR 30 seconds

Value	dEast	dNorth	dHeight
Max	0.034	0.049	0.044
Min	-0.034	-0.040	-0.099
Average	-0.001	0.002	-0.021
StDev	0.014	0.020	0.040
RMS	0.014	0.020	0.045

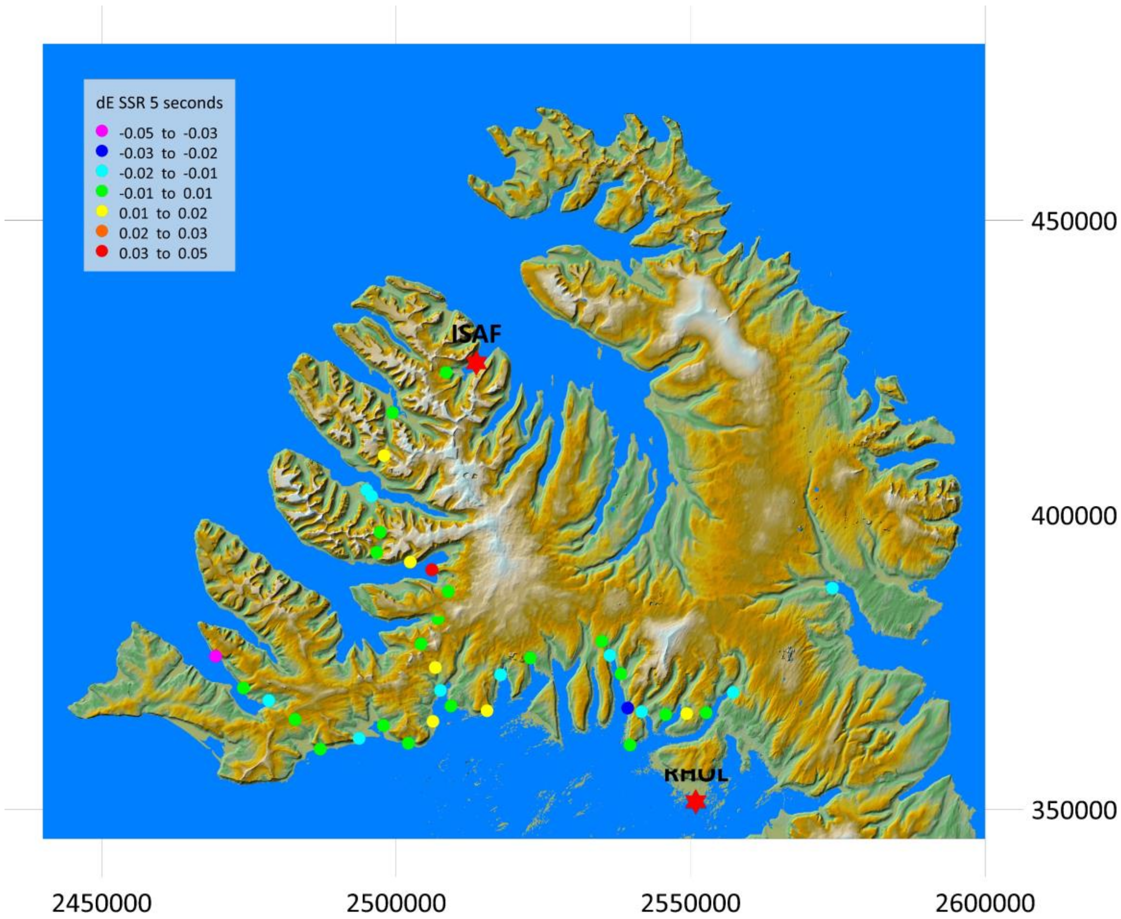
SSR 5 minutes

Value	dEast	dNorth	dHeight
Max	0.022	0.034	0.046
Min	-0.023	-0.029	-0.066
Average	-0.003	0.002	-0.013
StDev	0.012	0.014	0.031
RMS	0.012	0.014	0.034

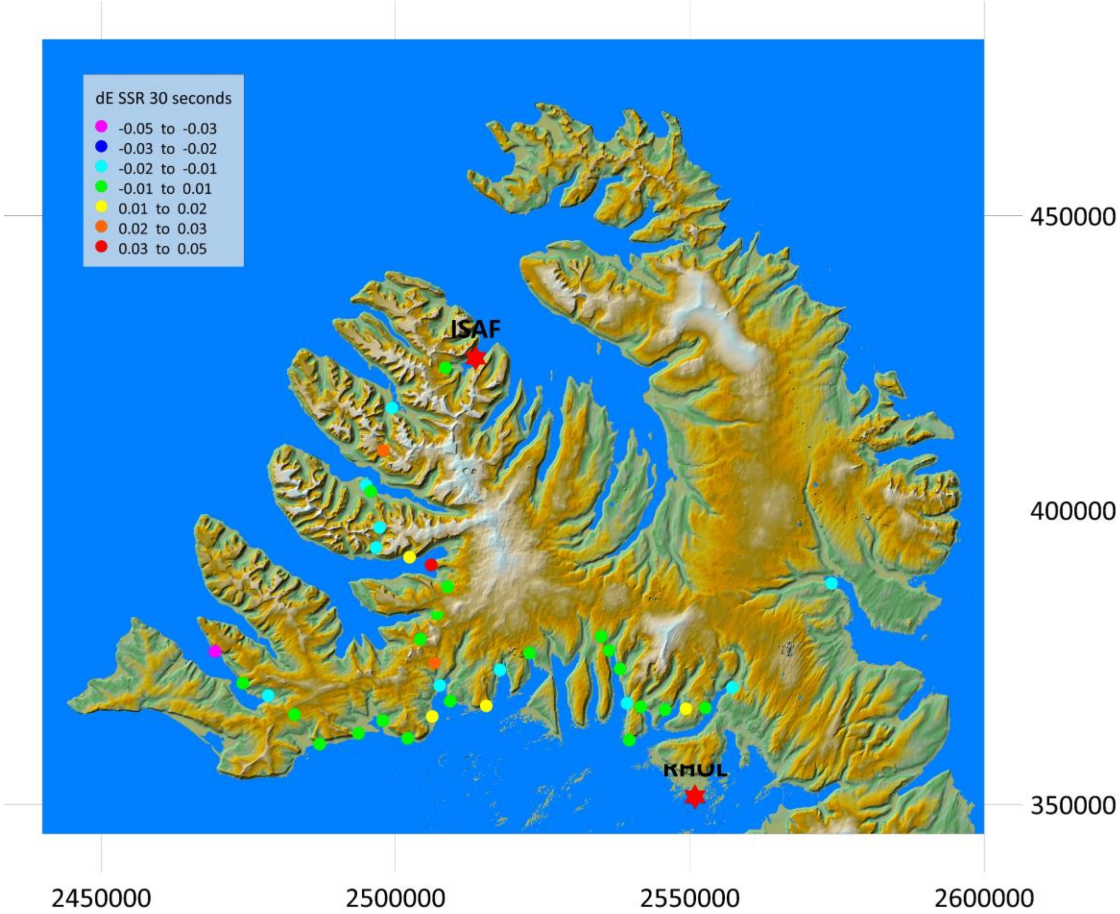
VRS 30 seconds

Value	dEast	dNorth	dHeight
Max	0.021	0.032	0.029
Min	-0.025	-0.023	-0.124
Average	-0.001	0.004	-0.023
StDev	0.013	0.014	0.040
RMS	0.013	0.015	0.046

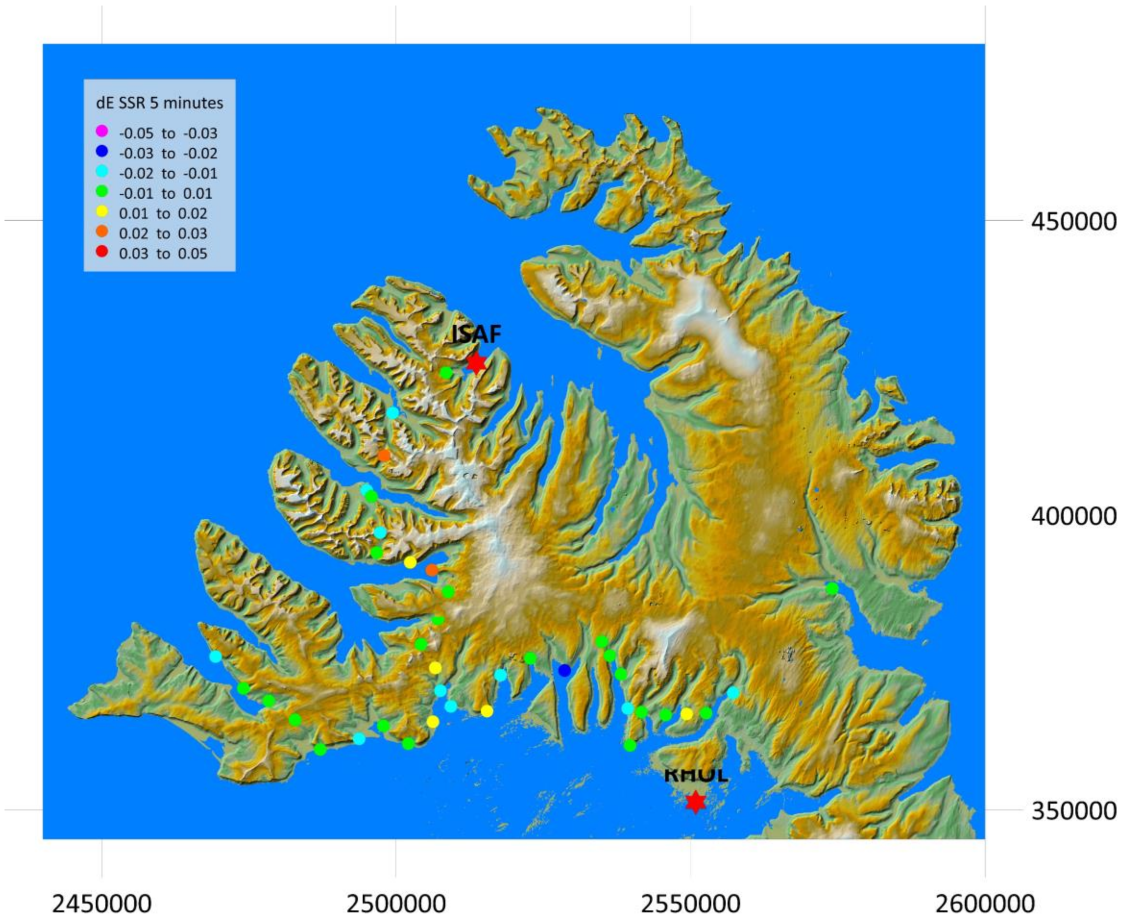
dE SSR 5 seconds



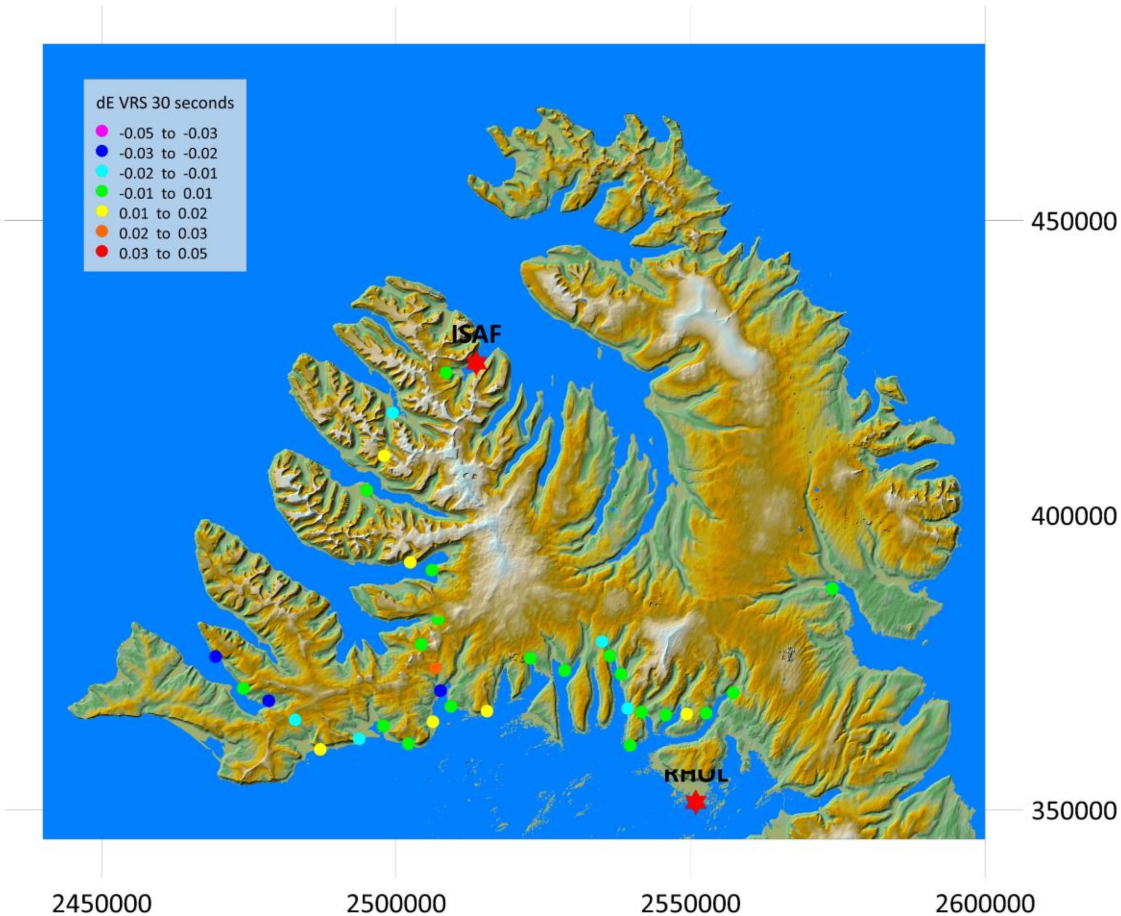
dE SSR 30 seconds



dE SSR 5 minutes



dE VRS 30 seconds



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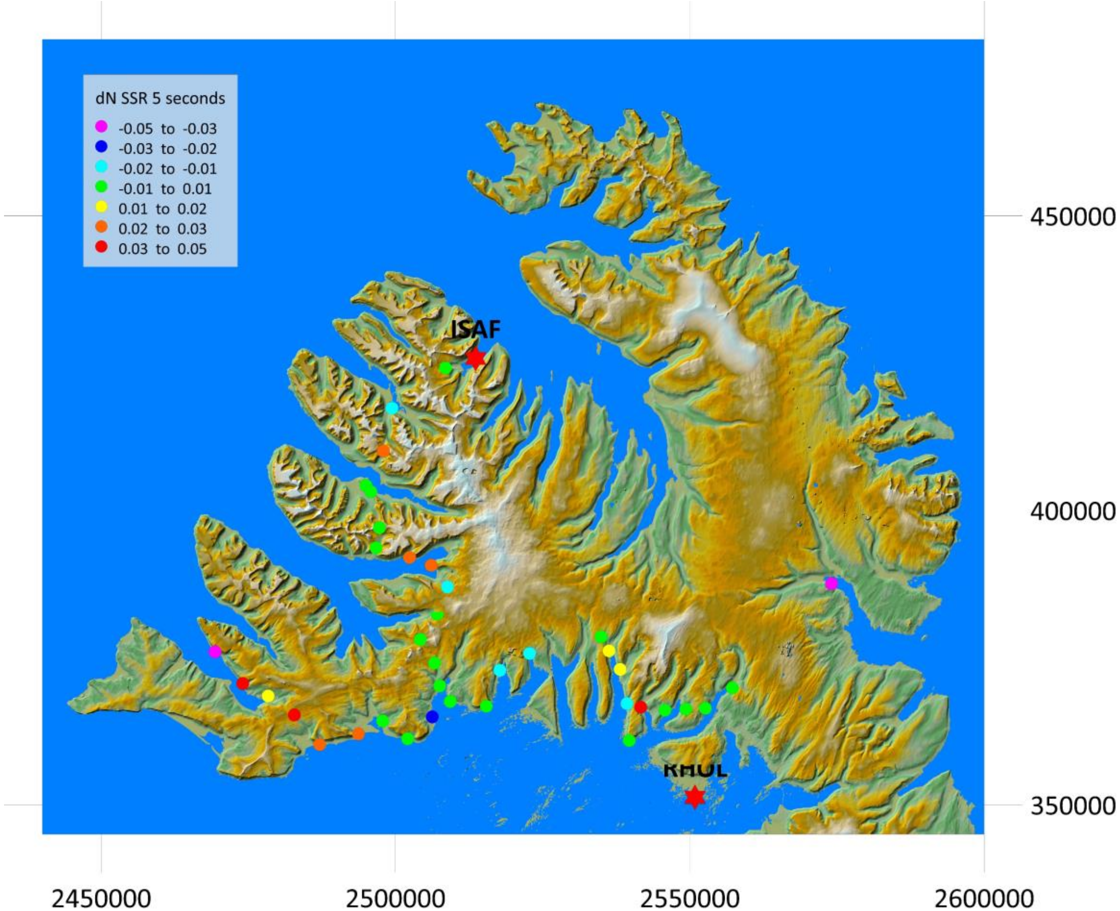
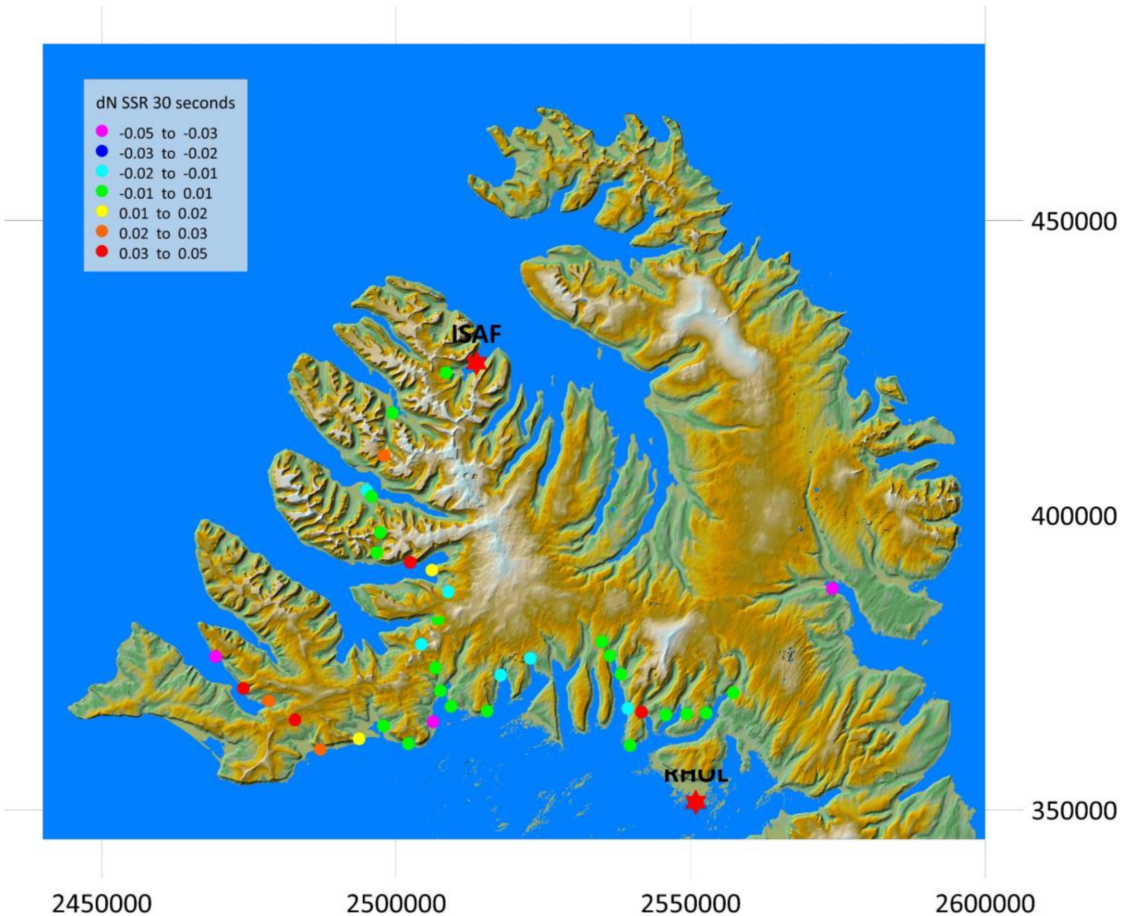
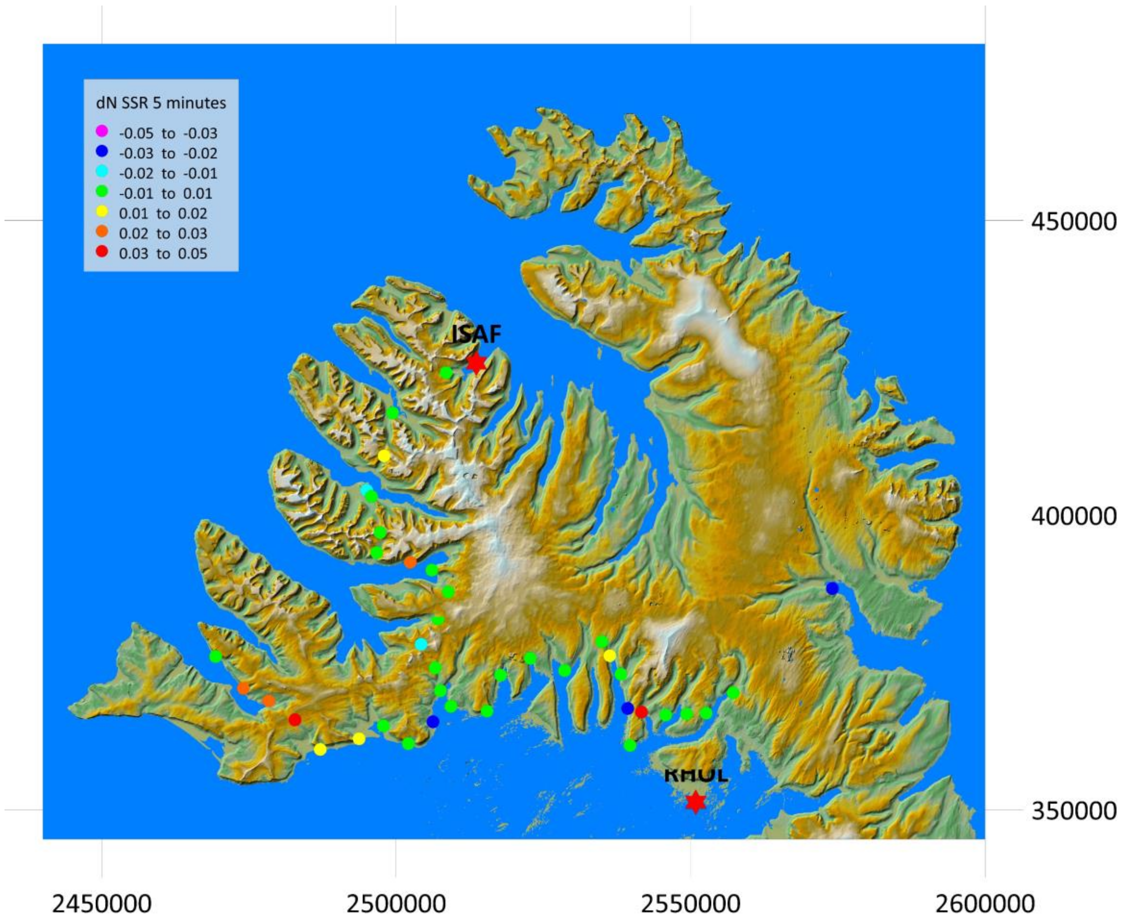
dN SSR 5 seconds



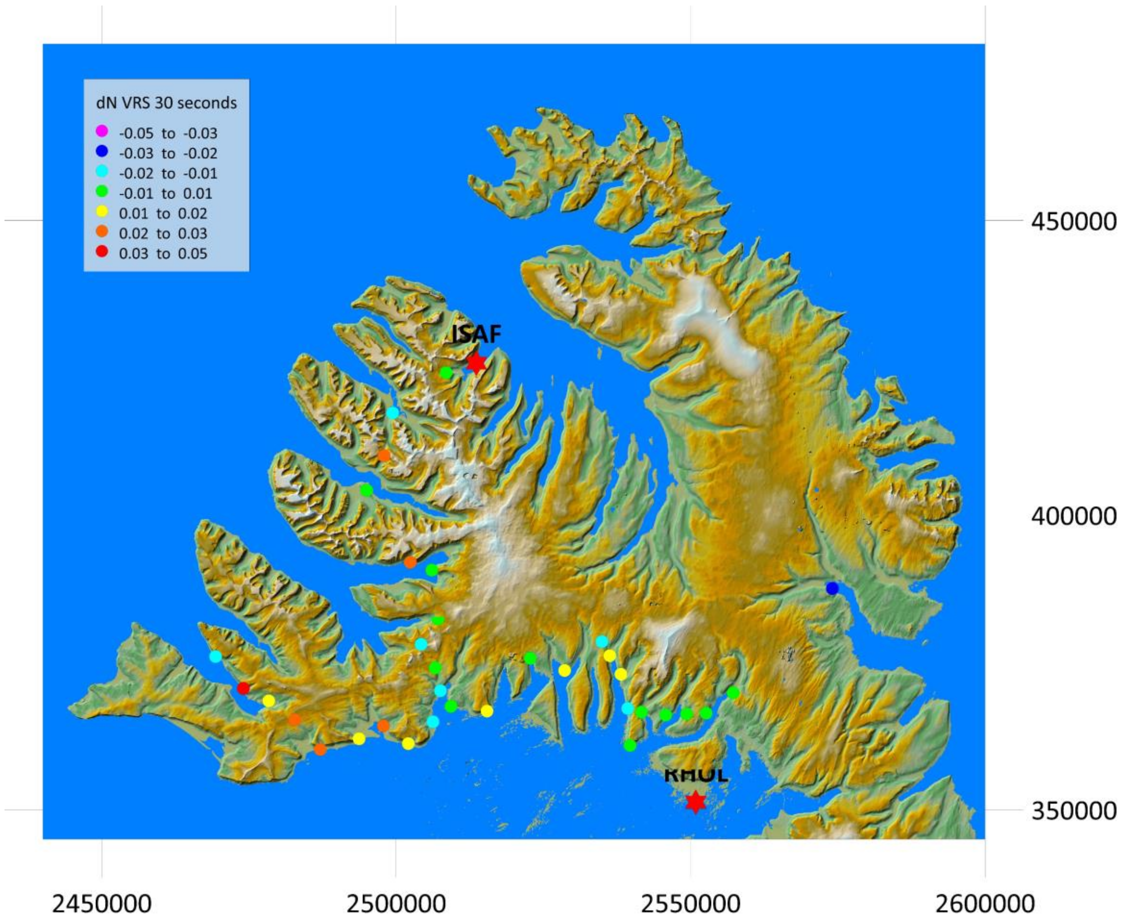
dN SSR 30 seconds



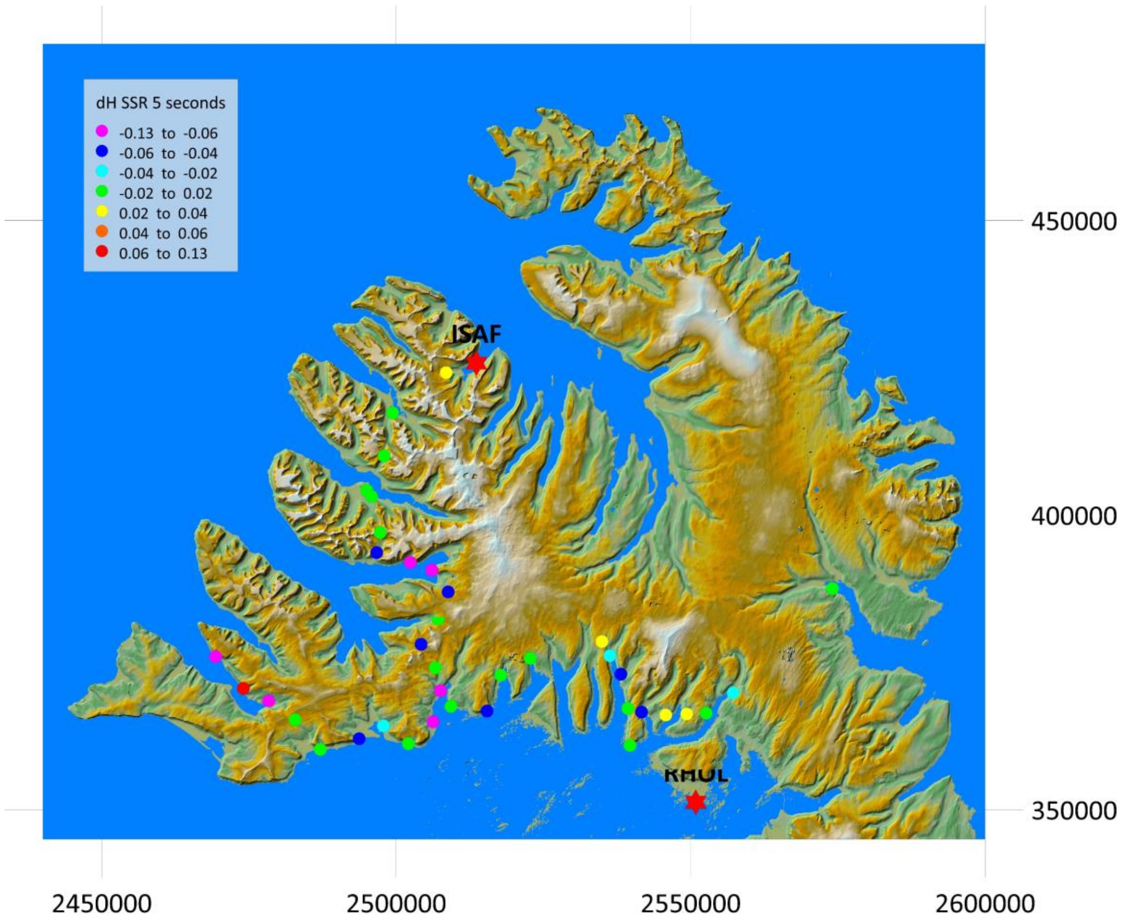
dN SSR 5 minutes



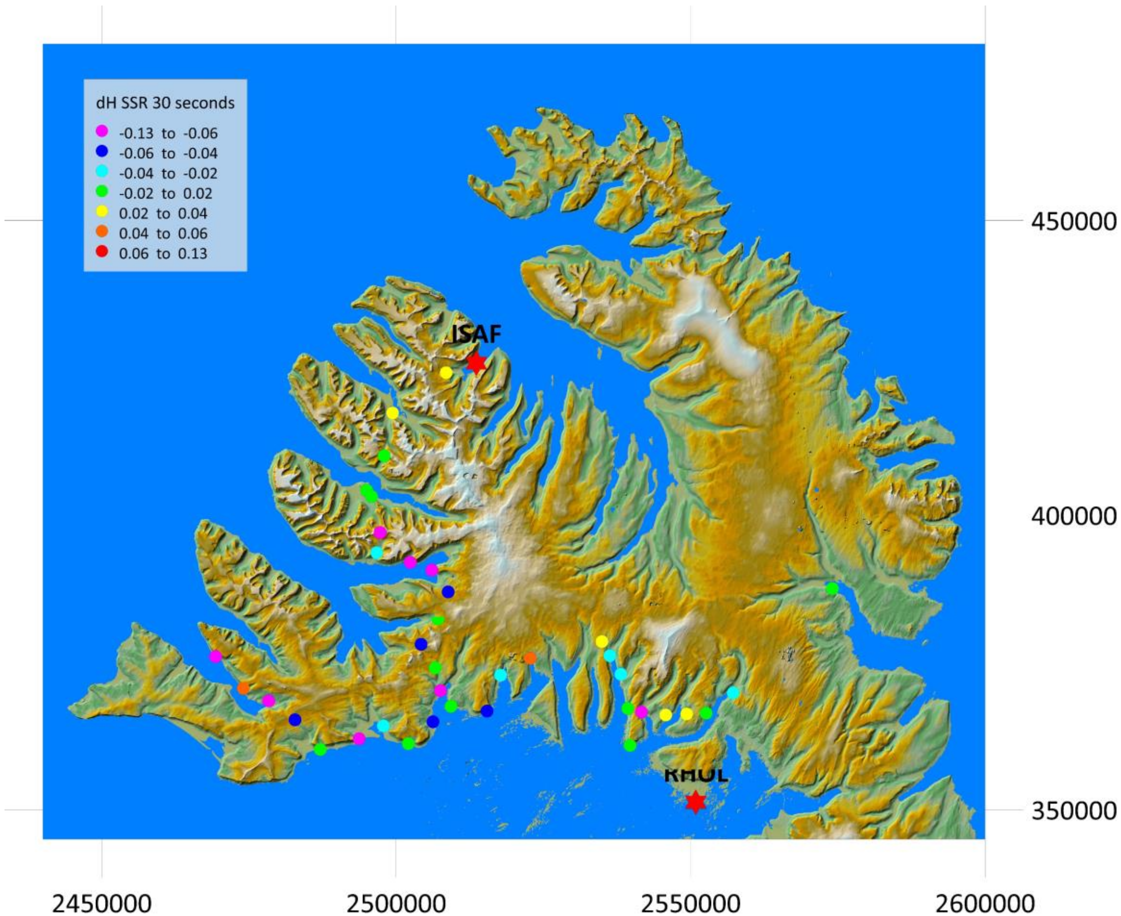
dN VRS 30 seconds



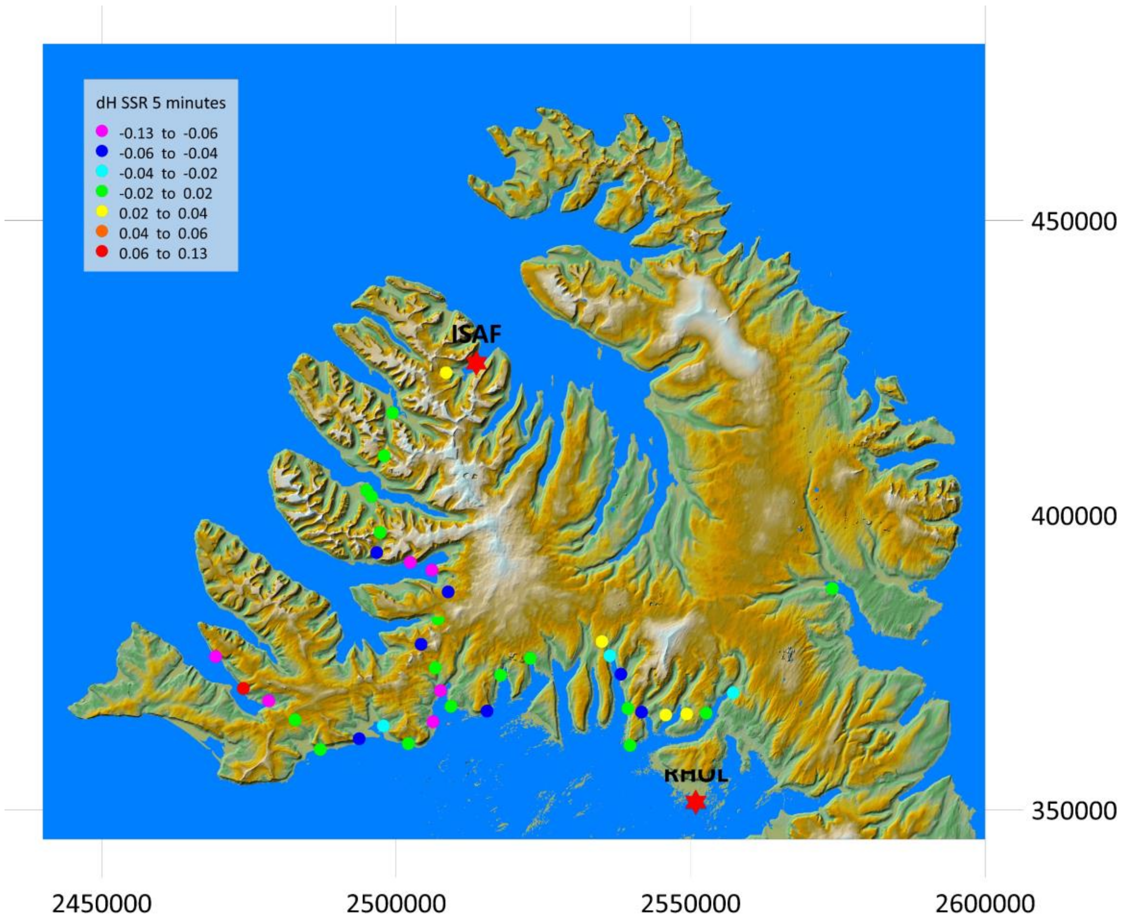
dH SSR 5 seconds



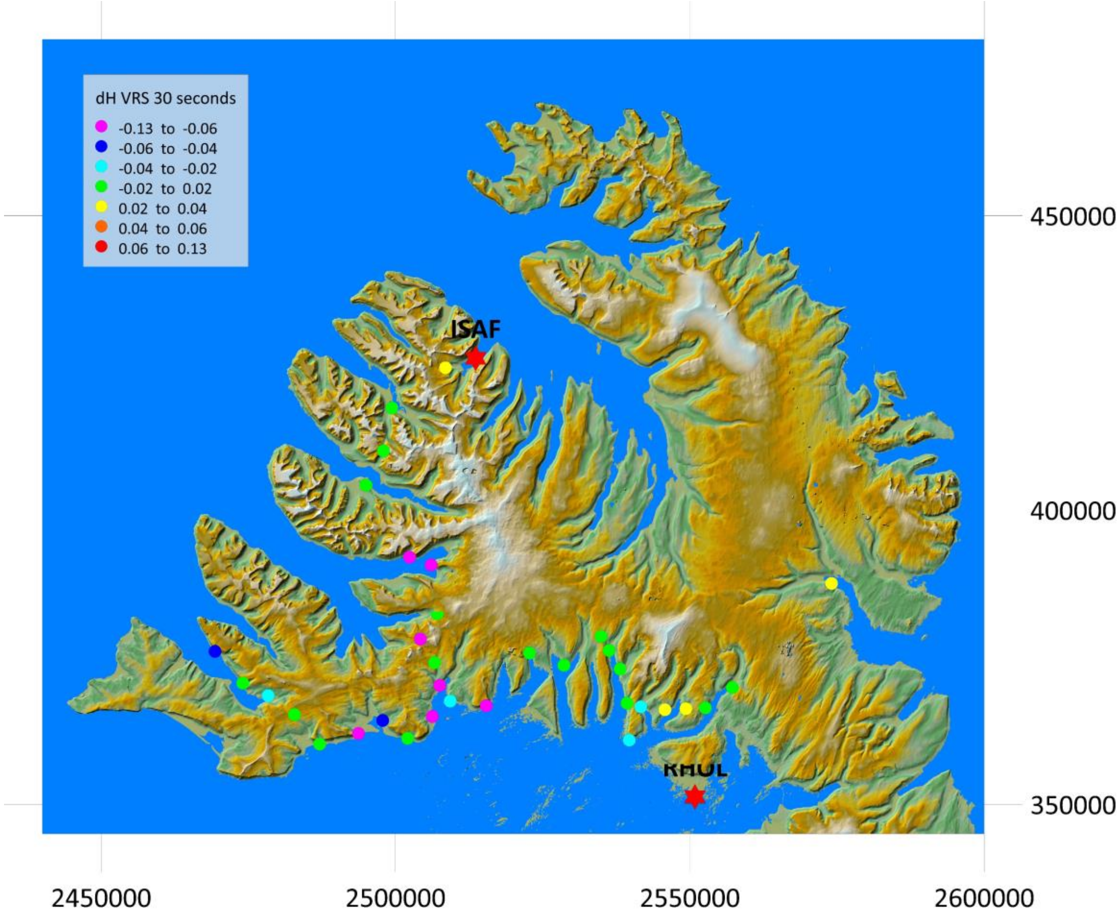
dH SSR 30 seconds



dH SSR 5 minutes



dH VRS 30 seconds



Conclusions

- The accuracy of the Network RTK is like one would suspect in a sparse network
- Larger errors further away from IceCORS stations and in challenging locations
- High negative error in height component more frequent than positive
  - Multipath or bad fix?
- Little difference between 5 and 30 seconds observations in SSR but clear improvement when measuring for 5 minutes
- Plans to do similar test in the south western part of Iceland were we have more network density, but also some more geophysical challenges

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Thank you

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