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Federal Ministry of Education and Research

LABEX G-EAU-THERMIE PROFONDE

GFZ Helmholtz Centre Potsdam

Ecole et Observatoire des Sciences de la Terre

ÍSOR Iceland GeoSurvey

University of Iceland

Landsvirkjun Power

GNS Science Te Pū Ao

GWR Instruments, Inc.

Helmholtz Association

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- Objectives and Methods
- Equipment deployment
- Preliminary results and perspectives

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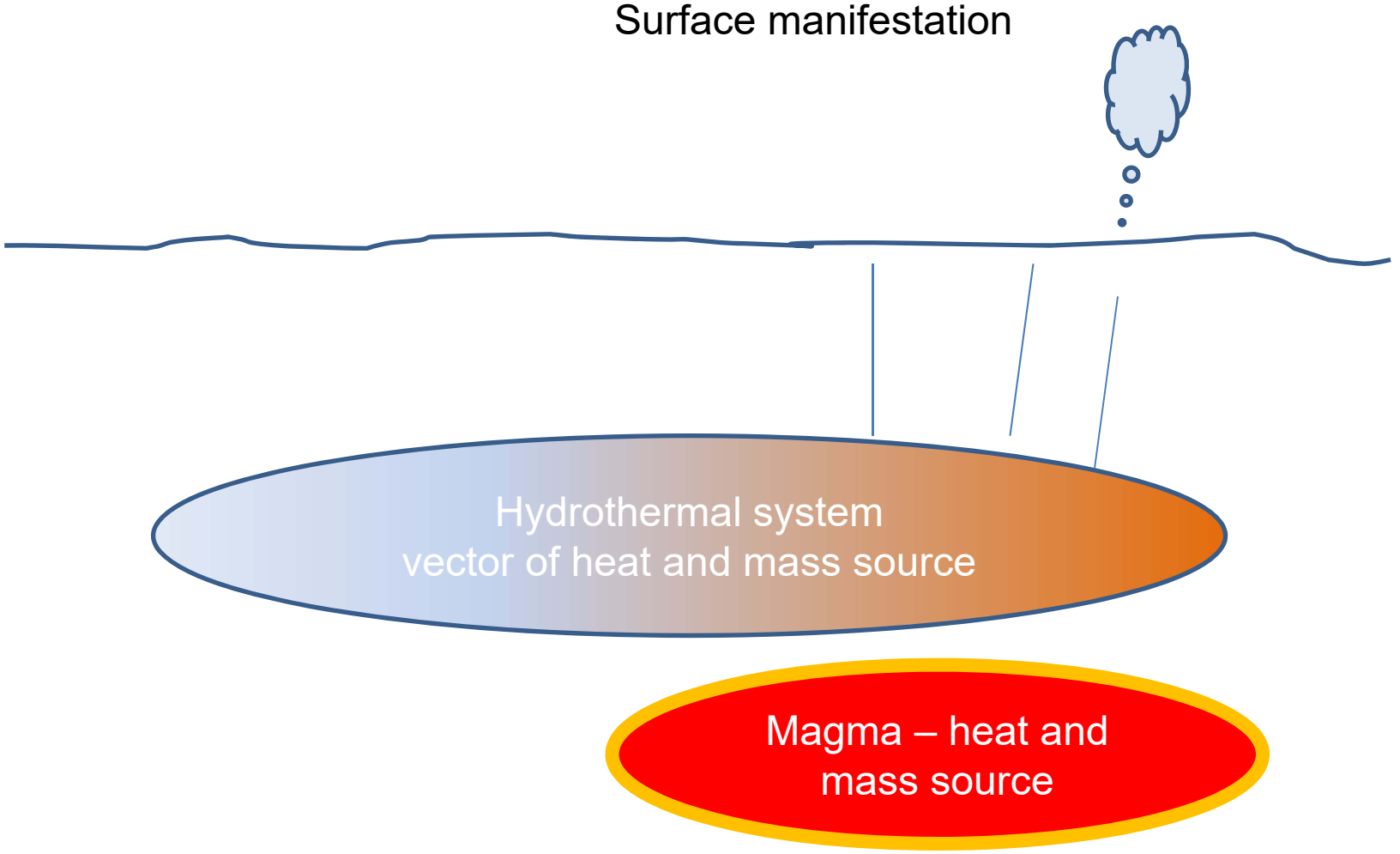
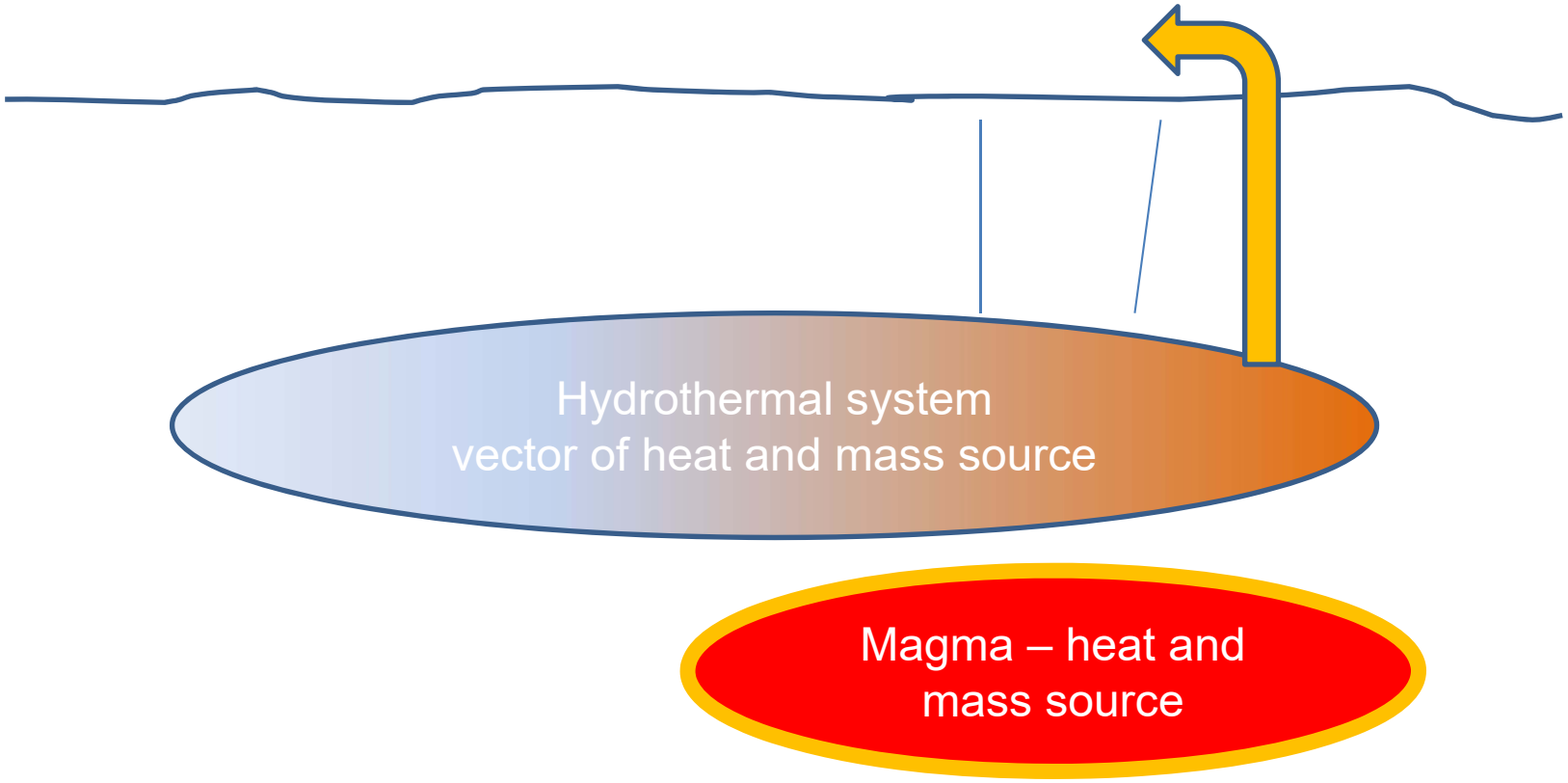

Surface manifestation
Hydrothermal system
vector of heat and mass source
Magma – heat and
mass source


Hydrothermal system
vector of heat and mass source
Magma – heat and
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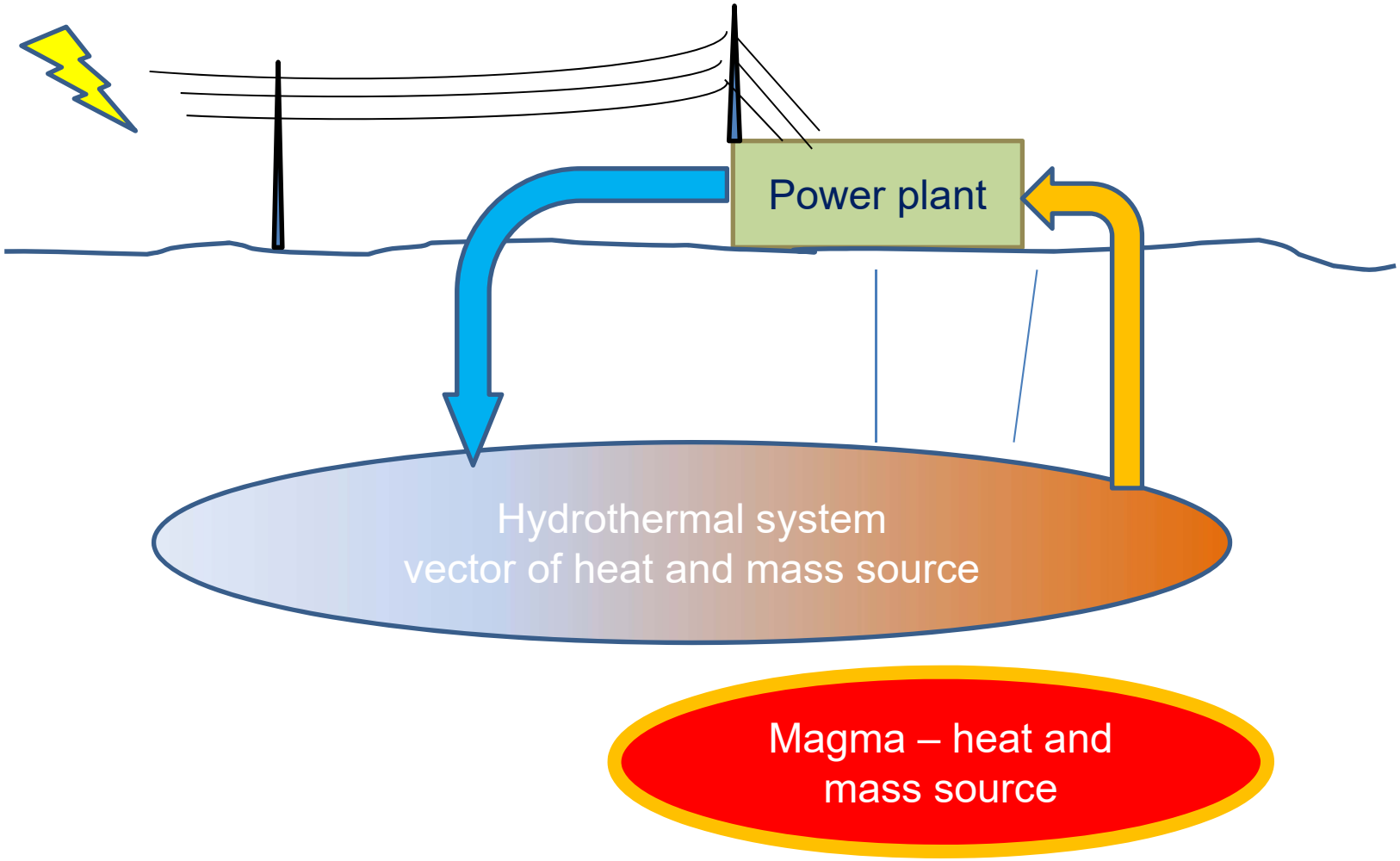
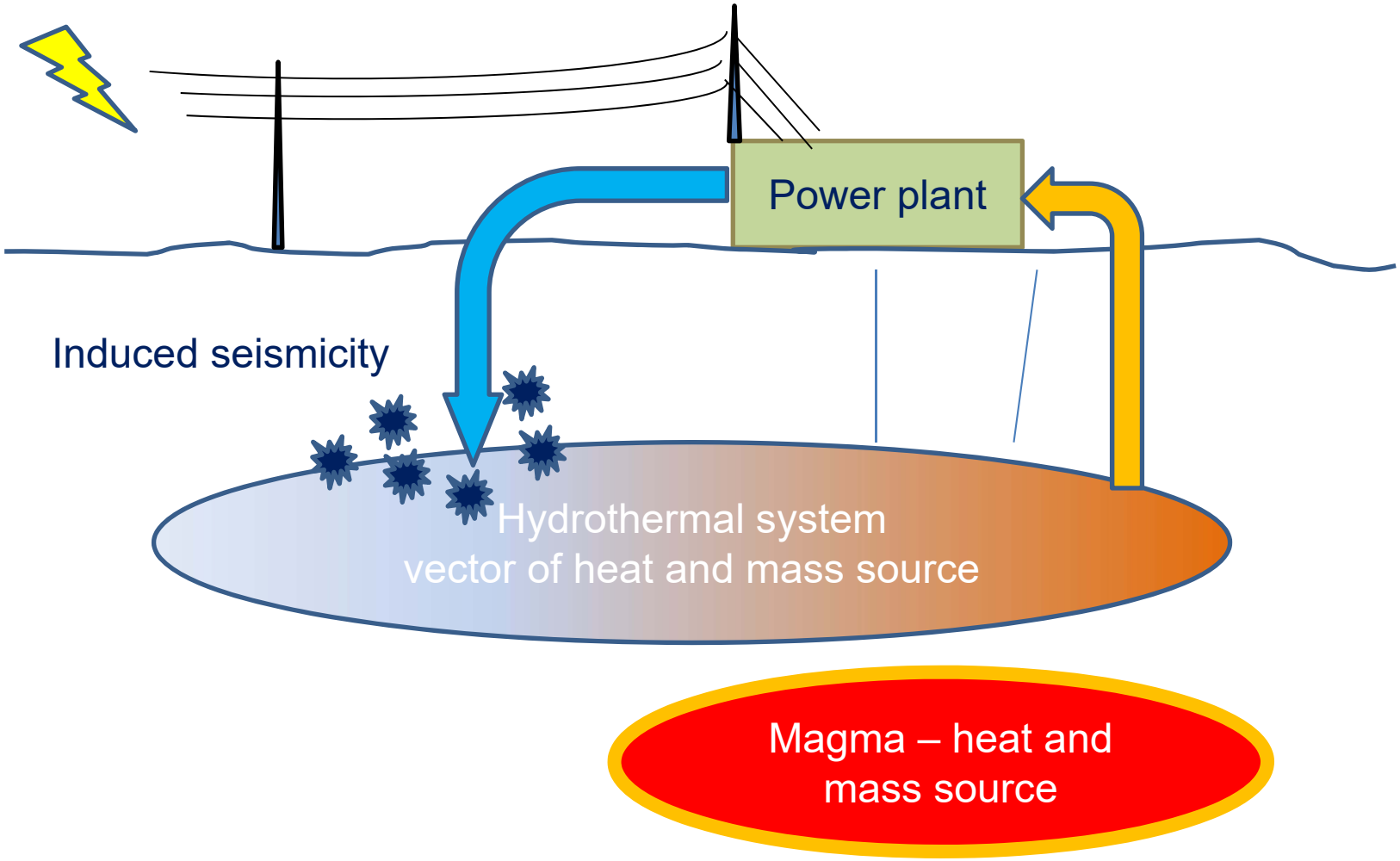

Power plant
Hydrothermal system
vector of heat and mass source
Magma – heat and
mass source


Power plant
Induced seismicity
Hydrothermal system
vector of heat and mass source
Magma – heat and
mass source

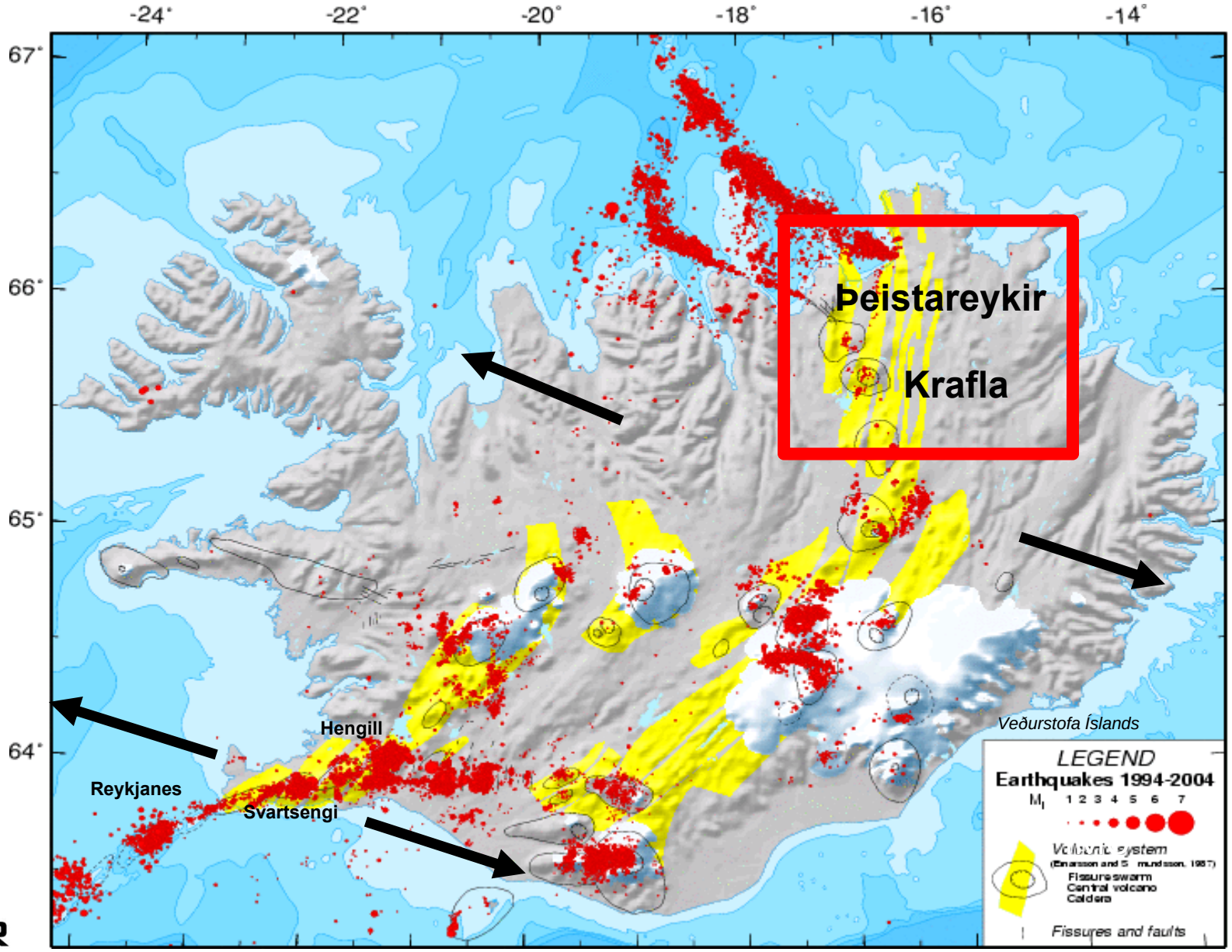
Scientific and pragmatic objectives

- Geothermal systems
  - Quantify fluid transfer used for electricity production
  - Find and quantify the recharge
  - Link induced seismicity to rate and mass production
  - Quantify underground permeability

  This project aims at helping management of the geothermal resource by understanding mass and stress transfer

- Volcanoes: challenges to interpret signals with respect to other signals (intruded mass unknown, structure unknown)

  This project helps constraining processes of mass and stress transfer for volcanic hazard assessment



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Geothermal Drilling in Þeistareykir

- Exploration drilling started in 2002 with drilling of wells ÞG-1 to ÞG-9
- Geophysical exploration:TEM resistivity measurements indicate size of 45 km2.
- Estimated power capacity of the area 270 MW. Based on resistivity and modelling.
- The plan is to utilize the area in two 45 MW steps
- In early 2016 directional drilling started, in order to fulfill the 90 MW
- In total 9 wells were drilled from early 2016 until late 2017 (ÞG-10 to ÞG-18)

Curtosy: Sylvía Rakel Guðjónsdóttir

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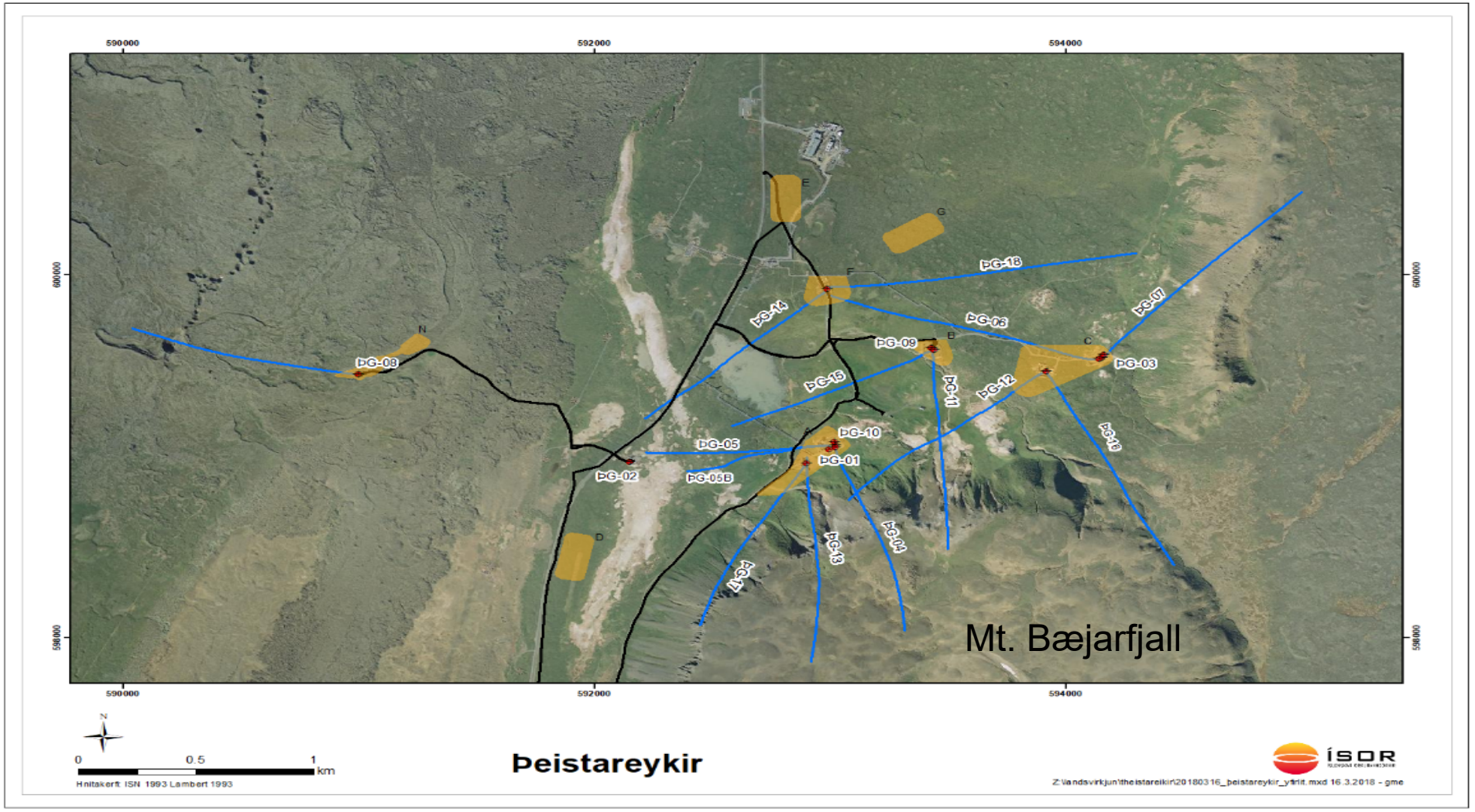
Geothermal Drilling in Þeistareykir



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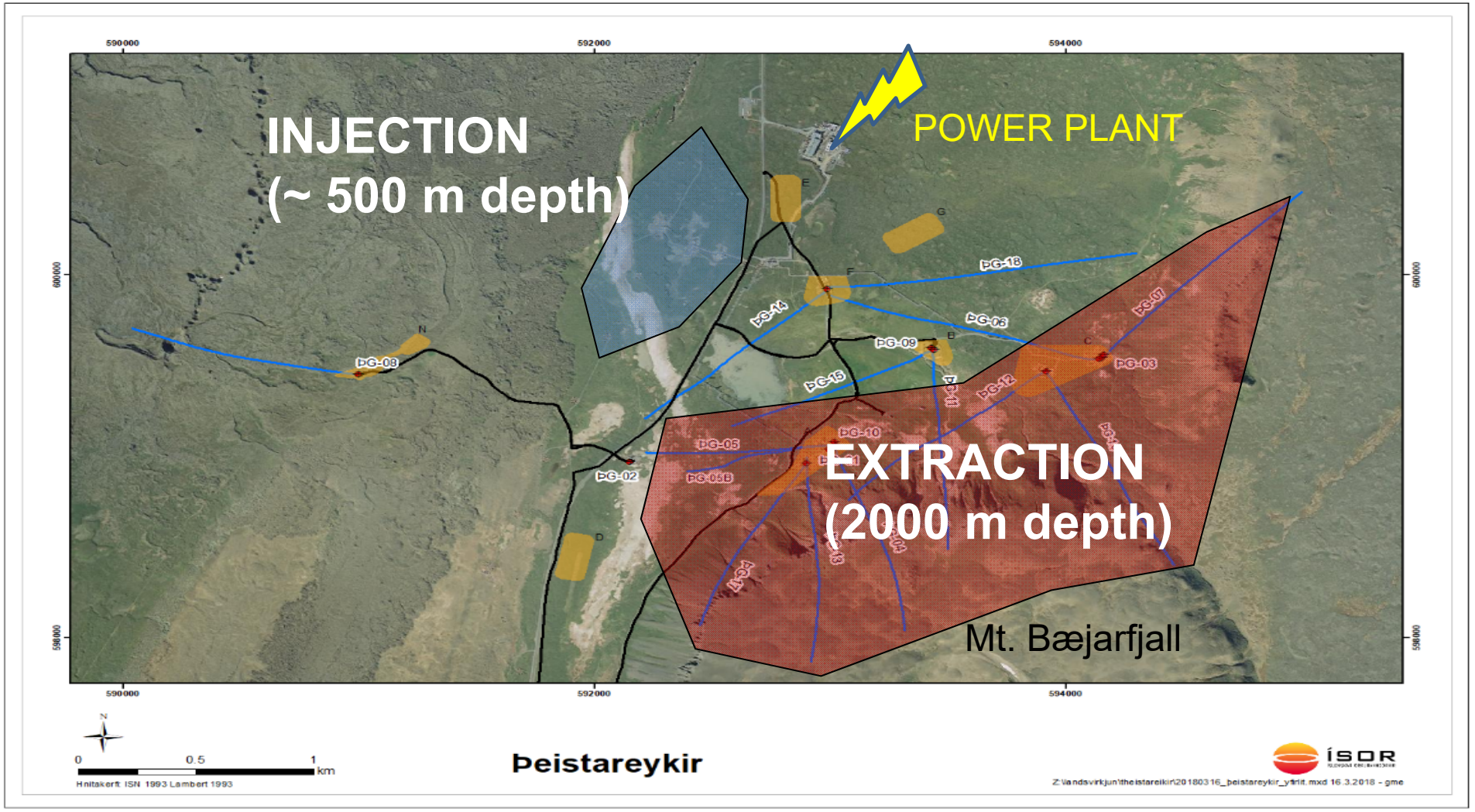
Geothermal Drilling in Þeistareykir



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Geophysical methods for tracking mass and stress in the reservoir

- Gravity methods (density, mass distribution)
  - Reservoir location
  - Sustainability of the reservoir (fluid extraction and recharge)
- Seismic methods (seismic velocities, attenuation, stress)
  - Fractures and reservoir location
  - Fluid content
  - Fluid dynamics
- Electromagnetic methods (resistivity)
  - Rock permeability, porosity, fractures and fissures
  - Temperature, Fluids
- Additional methods that may influence gravity:
  - Elevation, deformation (GNSS, tiltmeters, InSAR ...)
  - Hydrological parameters

INSTRUMENTATION

Gravity Meters

- 5 Gravity meters deployed since Decembre 2017
  - 3 @ Þeistareykir, 1 @ Krafla
  - 1 Reference station near Husavik, far from production/injection
    3 iGravs (superconducting from GFZ and GWR: 006, 015, 032)
    2 gPhoneX (128-GFZ and 061-GNS)
- 1 CG5 (relative gravity meter - EOST)
- 1 FG5 (absolute gravity meter - EOST)

Ground motion/Seismic network

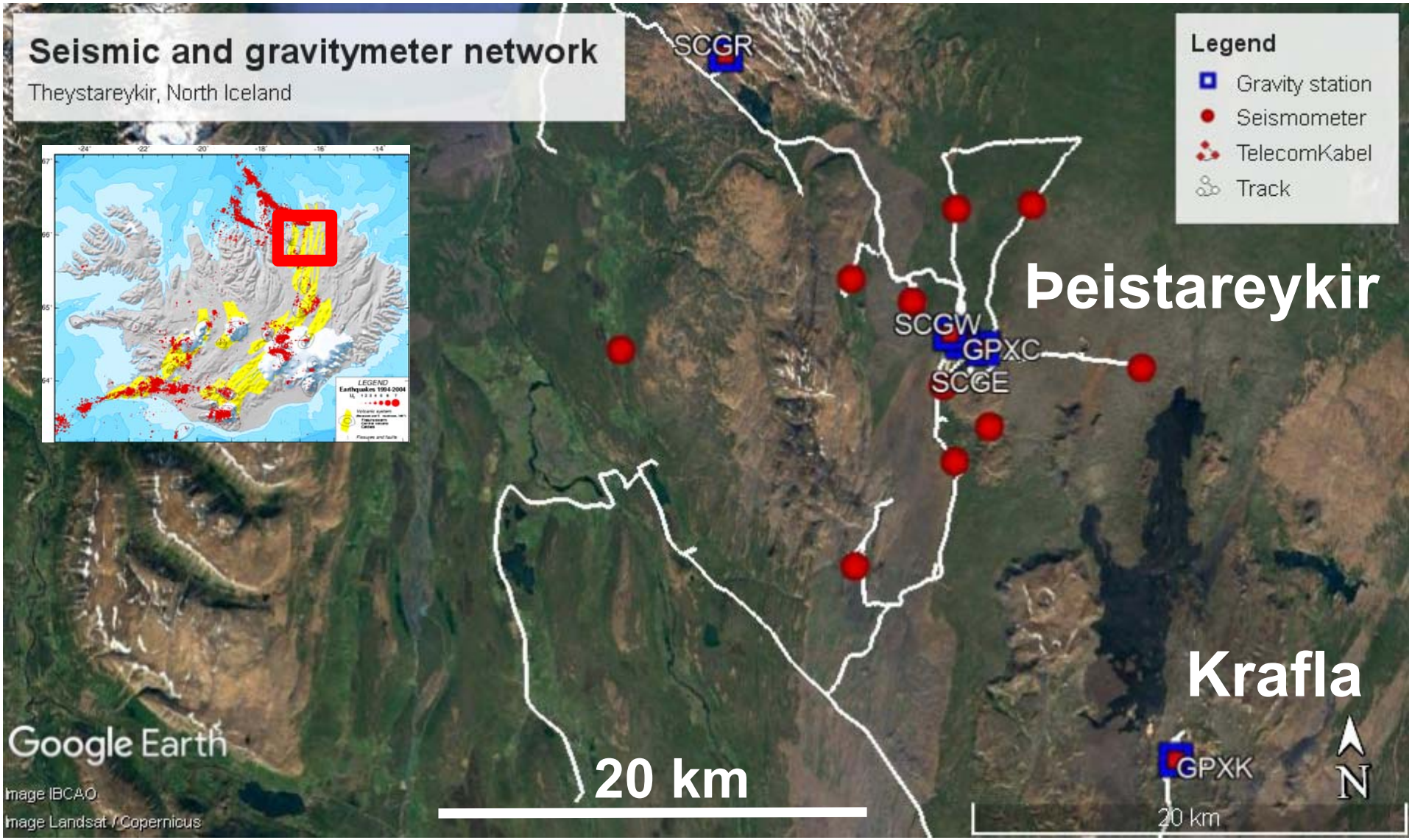
- 5 GNSS receivers
- 5 Tiltmeters
- 14 Trillium Compact and 14 Cube (GFZ)

Magneto-telluric

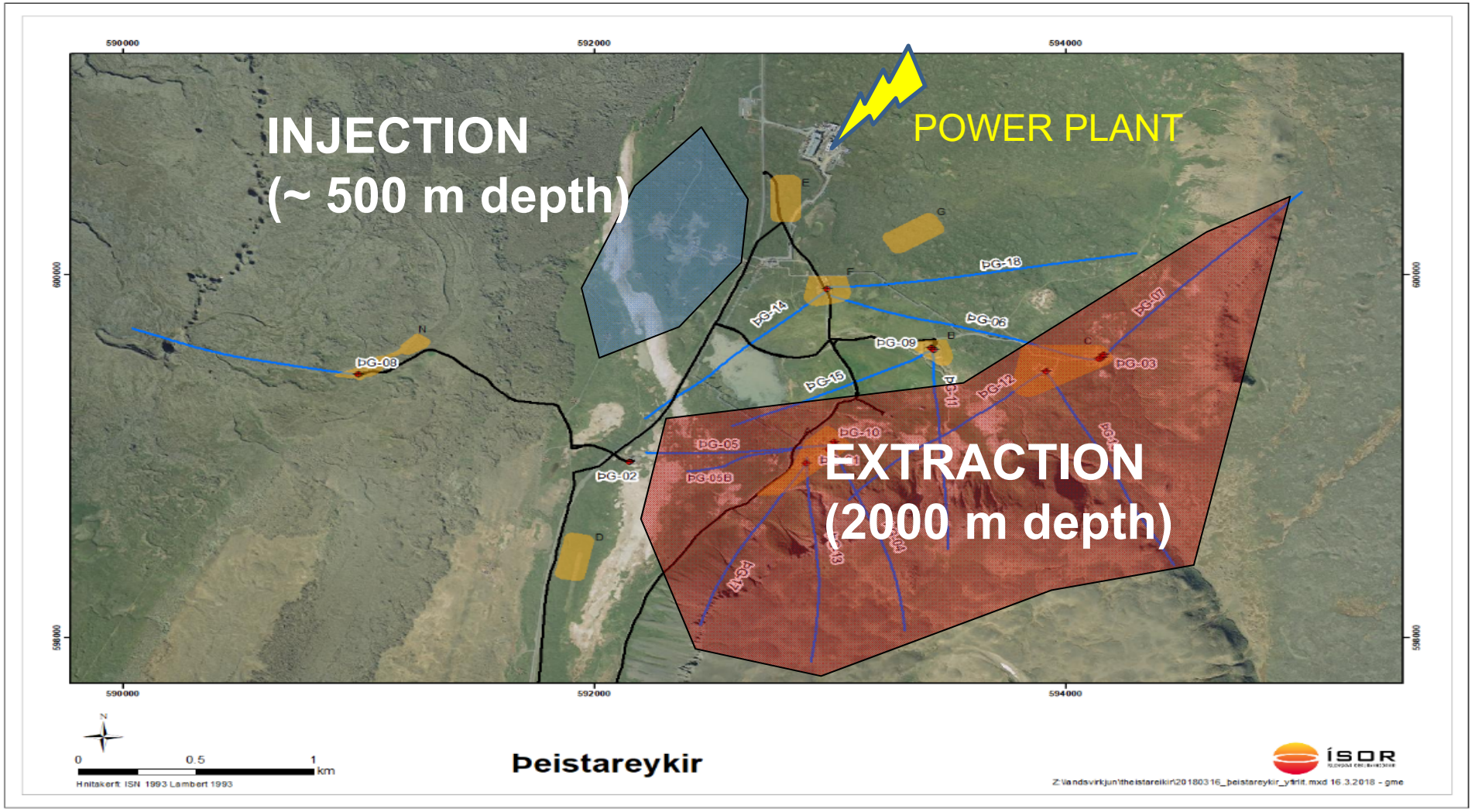
- 2 Magneto-telluric continuous stations

Environmental parameters

- 5 Meteorological sensors (P, T, Humidity, wind direction, snow height...)
- 150 Hydrological sensors


Seismic and gravitymeter network
Theystareykir, North Iceland
Legend
Gravity station
Seismometer
TelecomKabel
Track
SCGR
SCGW
GPXC
SCGE
Þeistareykir
Krafla
GPXK
Google Earth
Image IBCAO
Image Landsat / Copernicus
20 km
20 km
N

Mass transfer and gravimeter network



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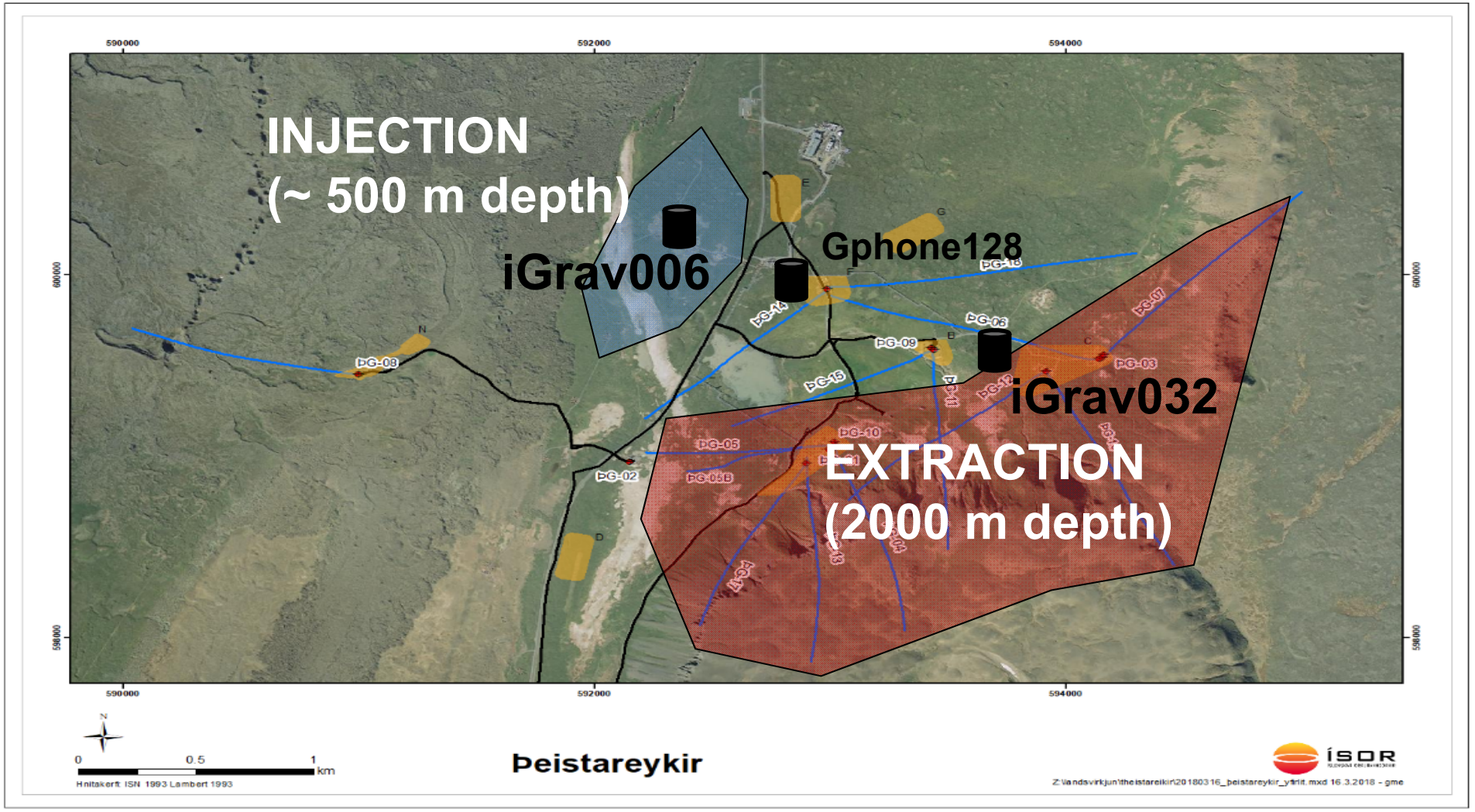
Mass transfer and gravimeter network



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iGrav015
SCGR
iGrav006
SCGW
Power Plant
gPhone128
GPXC
SCGE
iGrav032

June 2017 – Scouting – seismic and gravity stations

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July-August 2017 – pillar construction

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October 2017 – Containers transportation and deployment

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December 2017 – Gravimeters deployment


GWR
INSTRUMENTS

December 2017 – Having fun with the Helium bottle!

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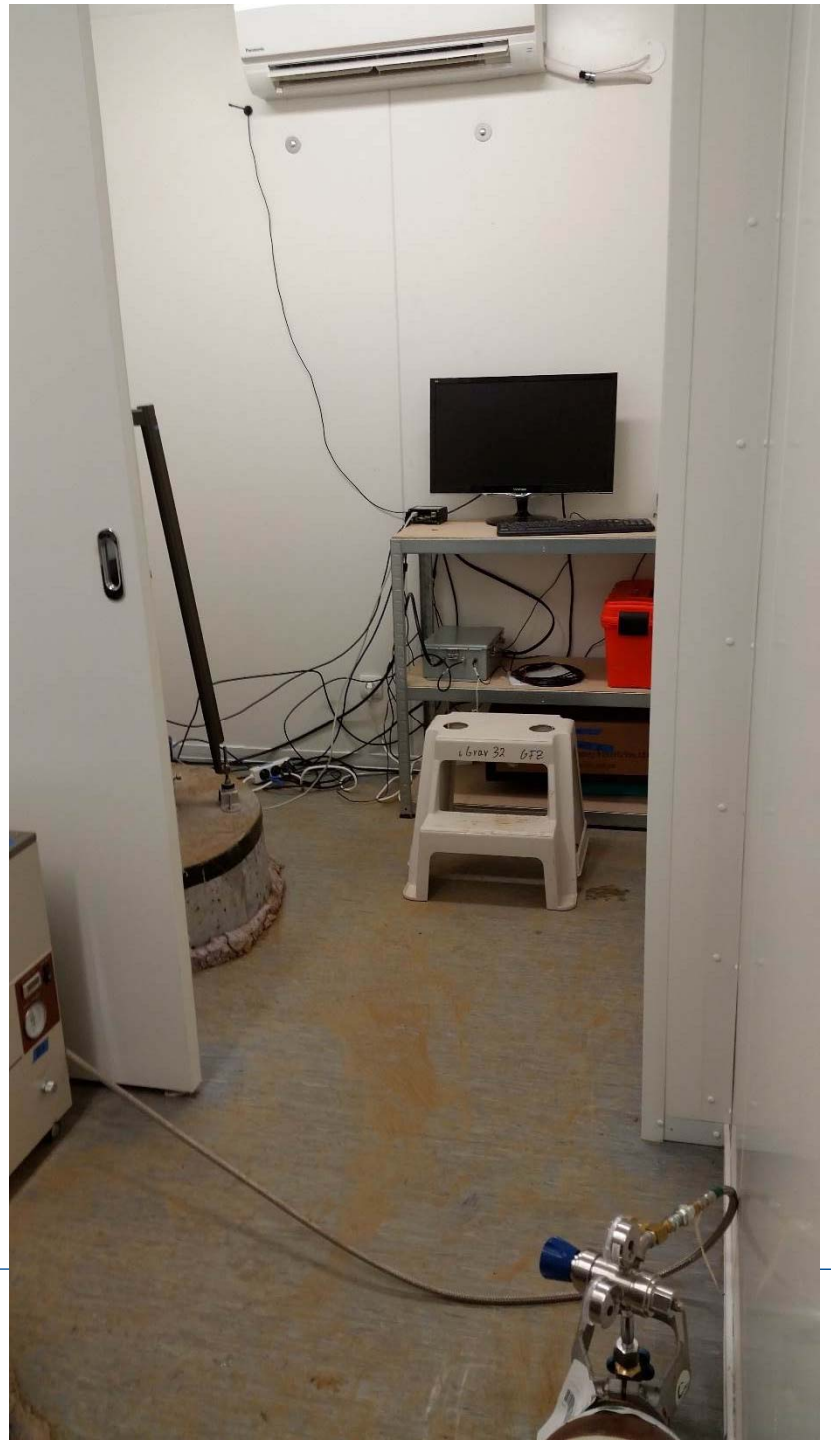
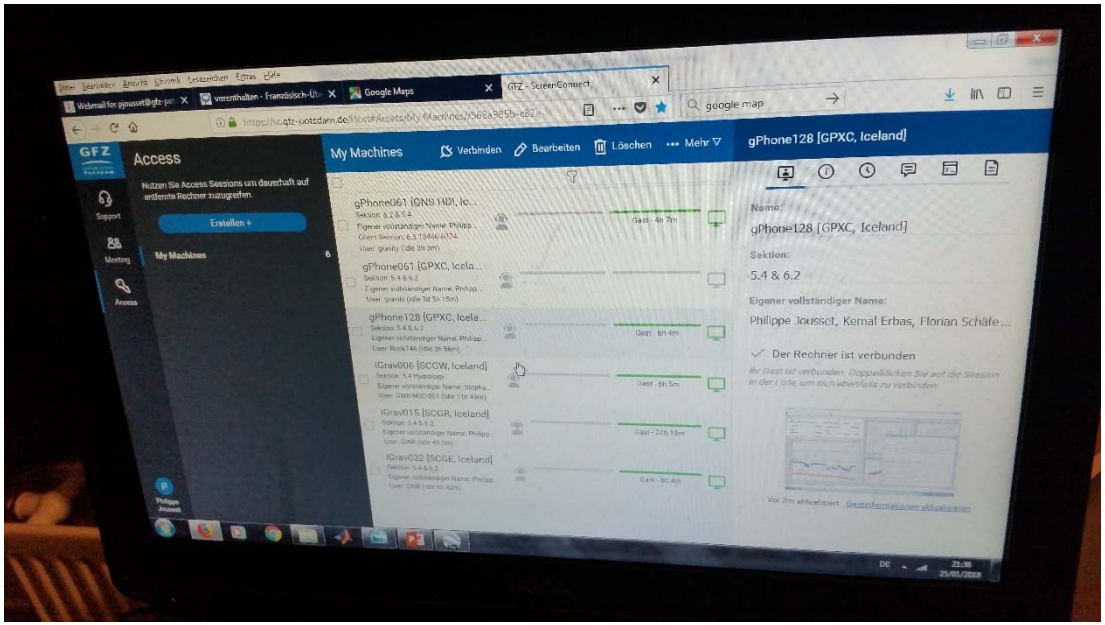
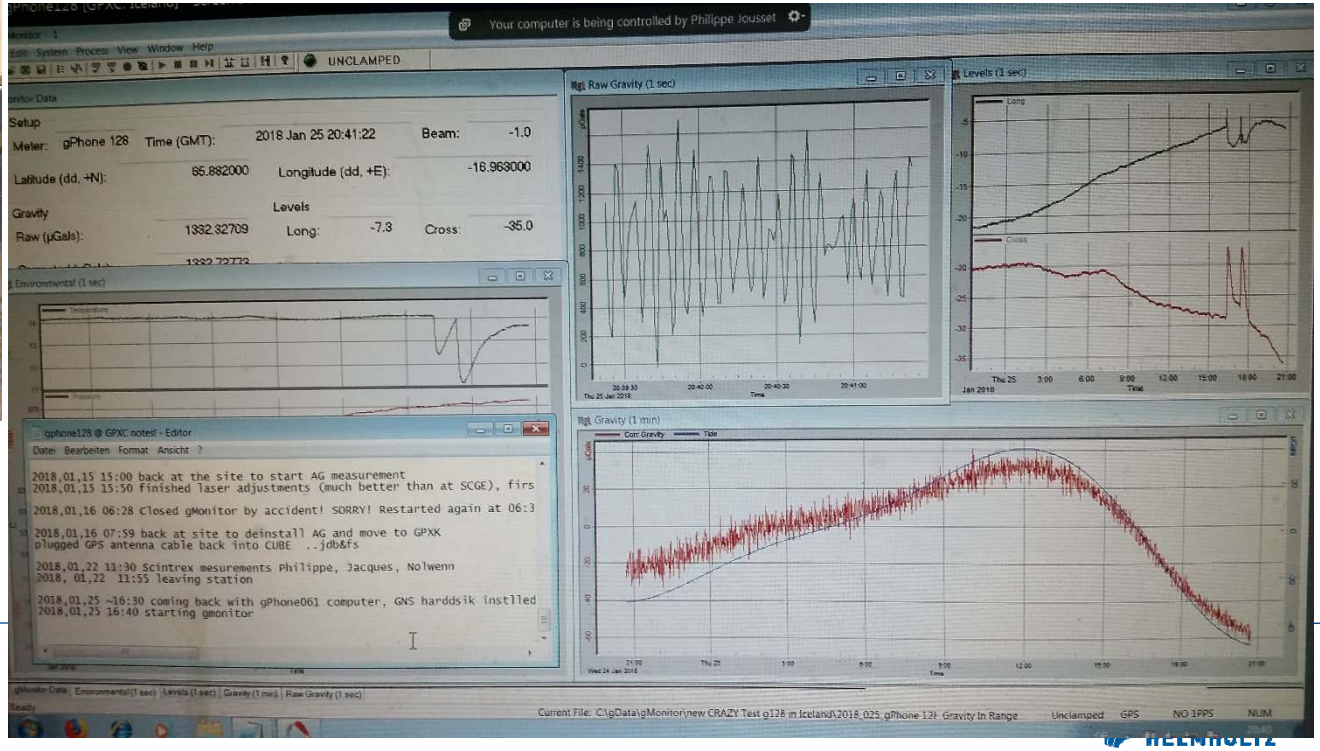
Sensors,
Compressor,
Helium bottle
Cooling system
Communication (wifi),
....

Ready to operate!



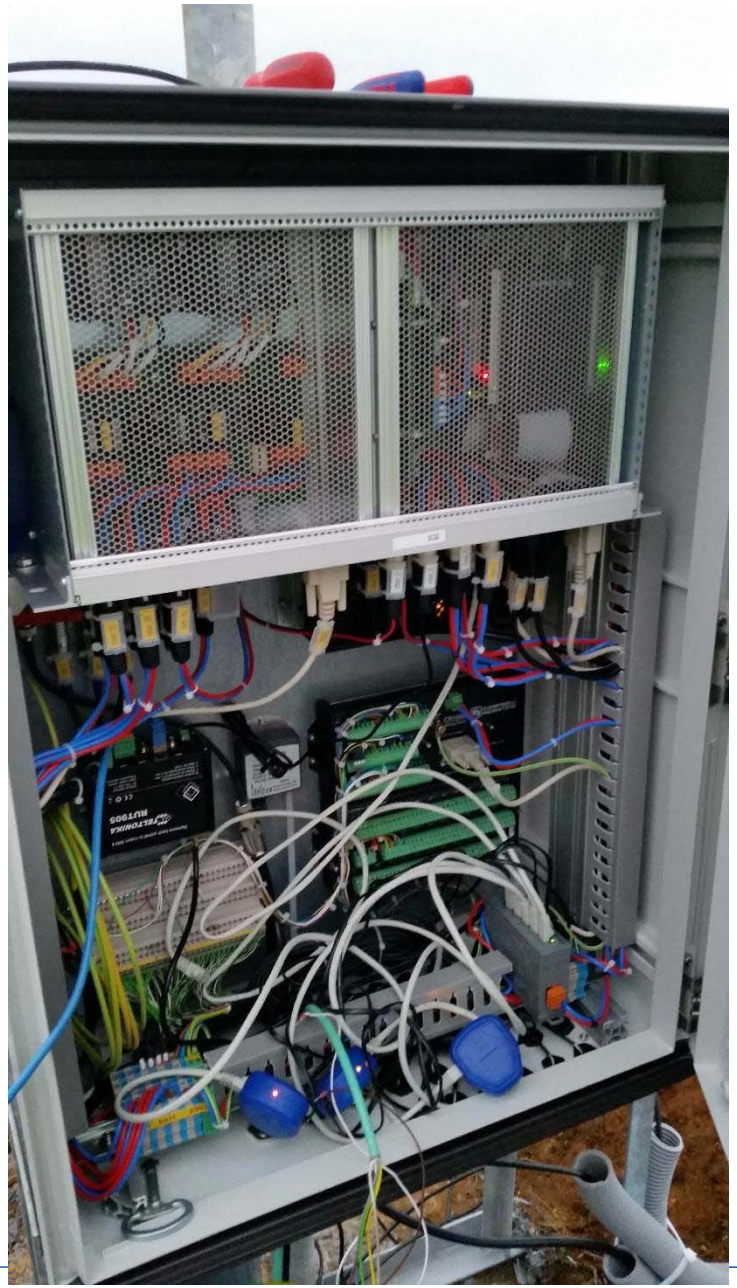
Remote control of the stations via wifi and/or SIM card

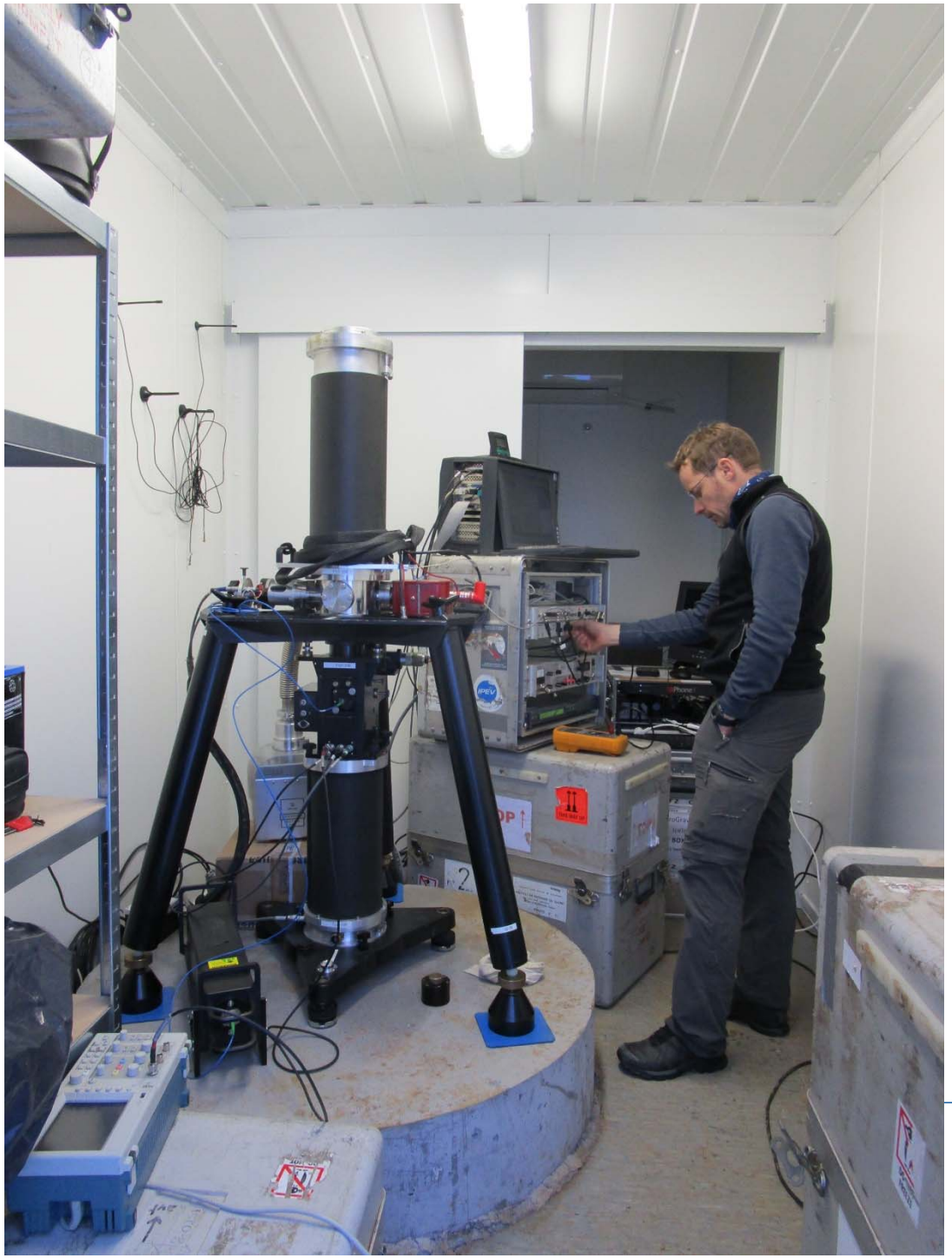




October 2017 – Deploying ROMPS et other sensors

Remote
Operating
Monitoring
Permanent
System





August 2017/ December 2017
Absolute gravity measurements
On the second pillar of each container

Ney campaign summer 2018

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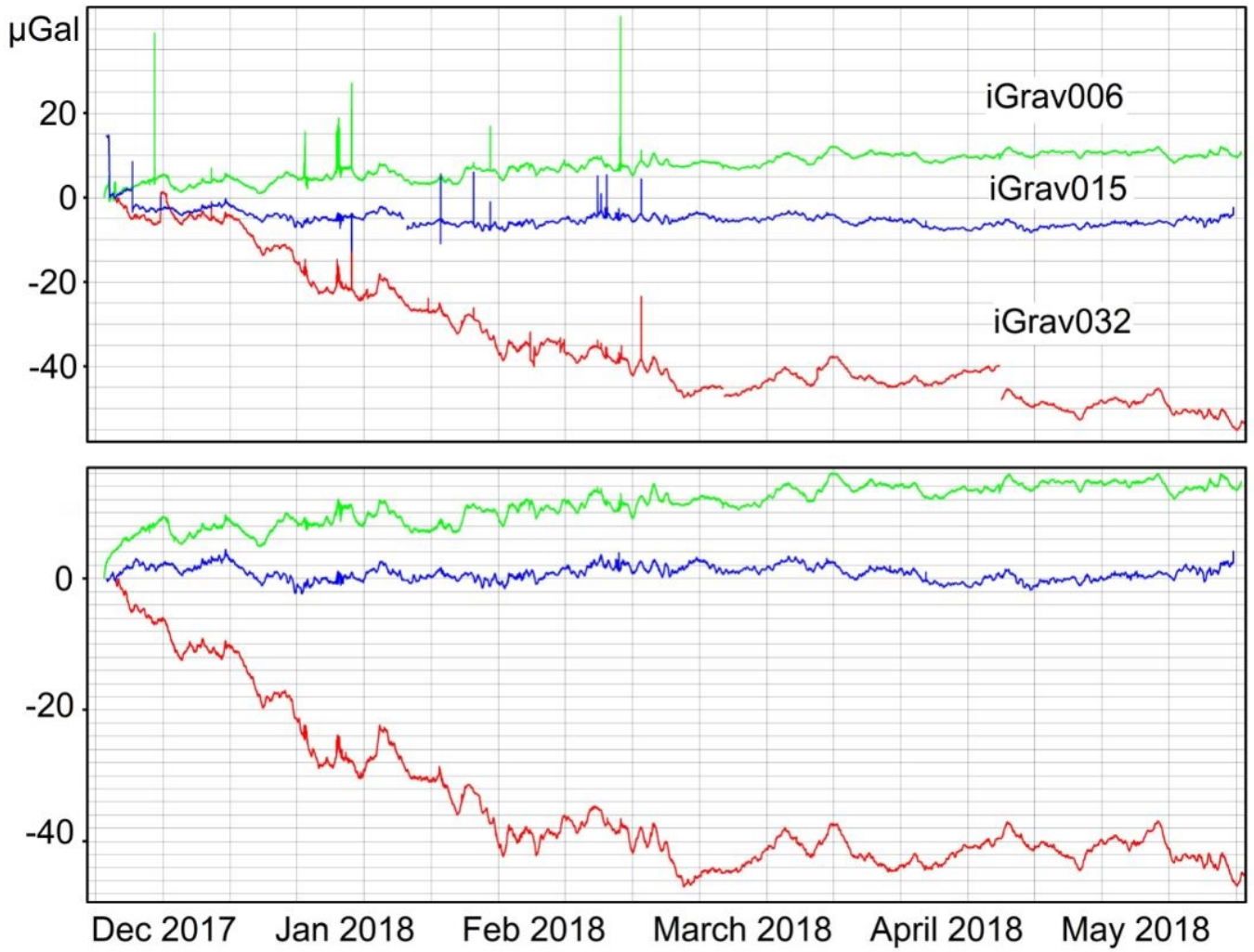
Repeated gravity measurement on the second pillar

Residuals of iGravs (top uncorrected, bottom corrected for spikes and steps)

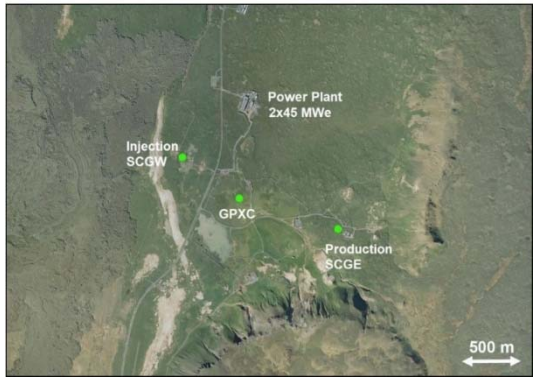
- **Scale factors** from calibration measurements at Strasbourg (FG5 and iOSG23)

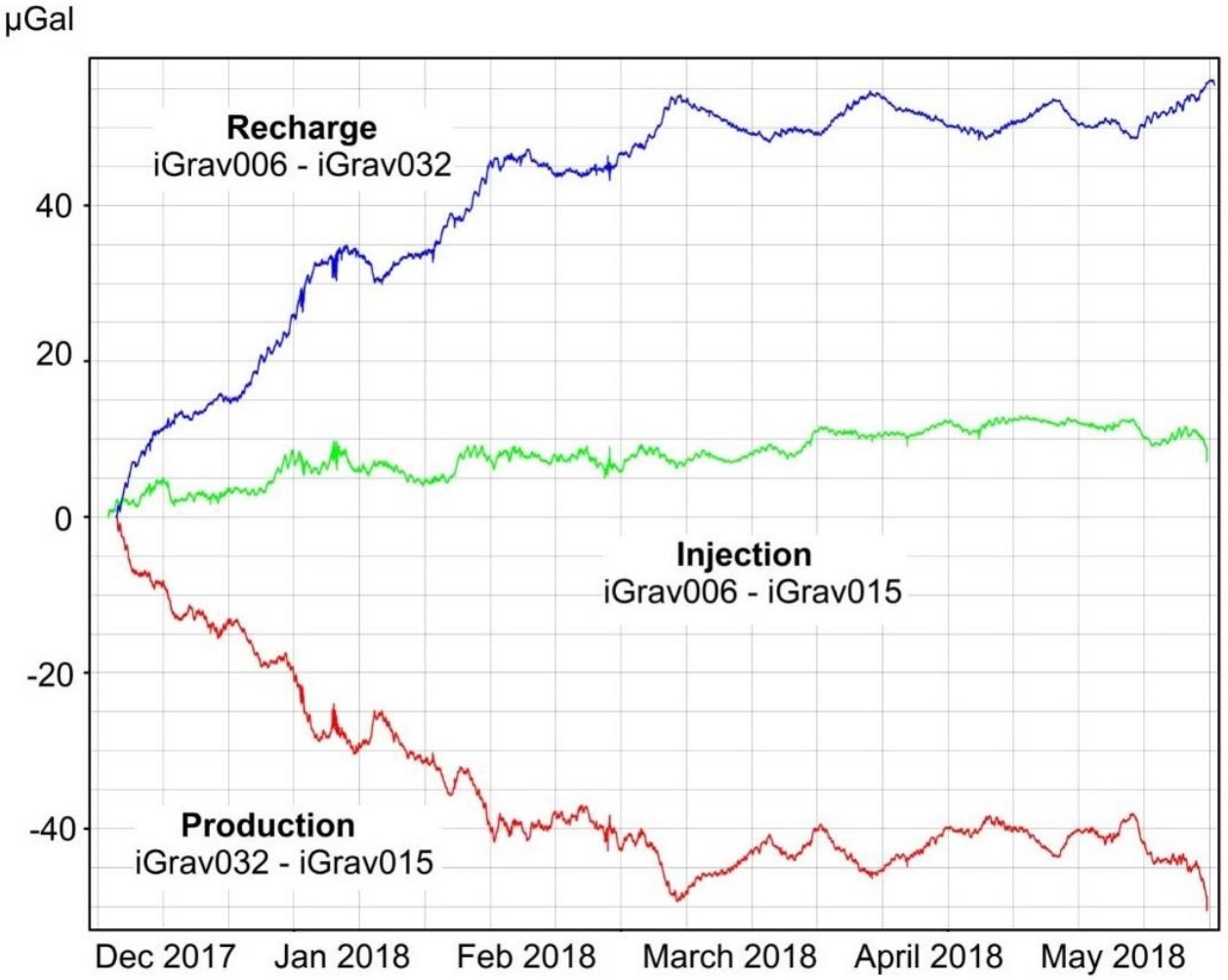
- **Tidal analysis** with ETERNA 3.4
- 6 months models for each station
- Incl. air pressure correction



Gravity differences – of residuals (tides and pressure corrected)

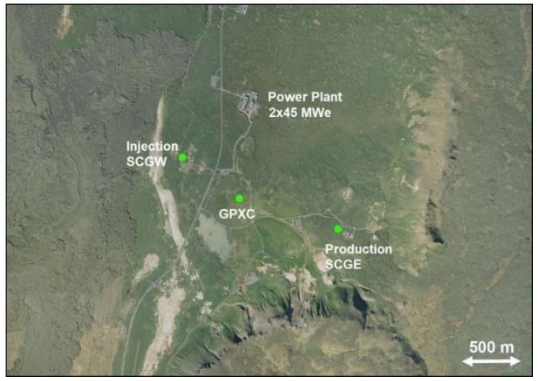
- iGrav006 = **SCGW**est (injection site)
- iGrav032 = **SCGE**ast (production site)
- iGrav015 = **SCGR**eference

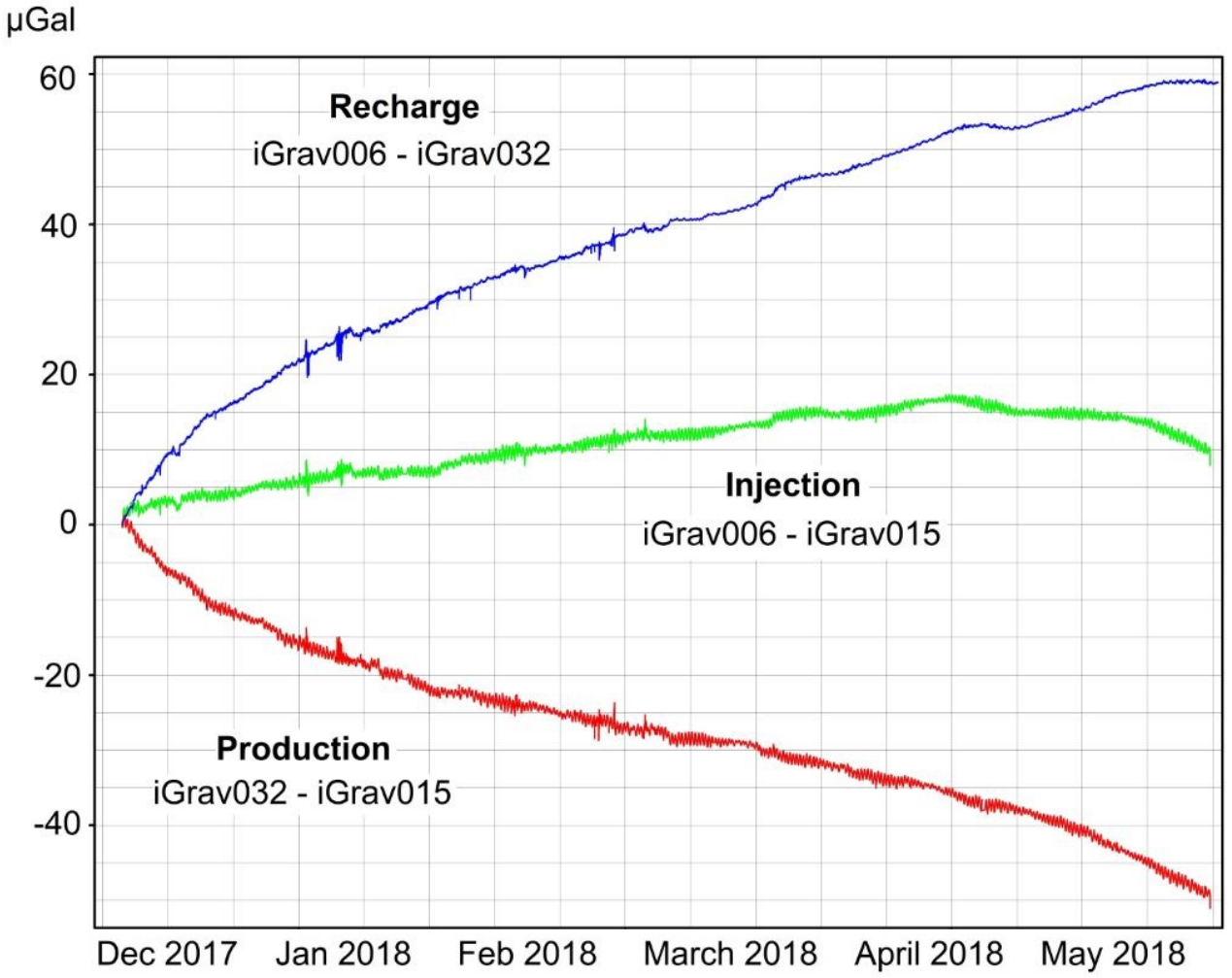




Gravity differences – of calibrated raw gravity (no tidal and pressure correction)

- iGrav006 = **SCGW**est (injection site)
- iGrav032 = **SCGE**ast (production site)
- iGrav015 = **SCGR**eference





Final remarks

• **Sub-complete set of measurements**
gravity, seismicity, deformation, EM, useful for geothermal research and monitoring

• **Complementary method of gravity measurements:**
  - **Repeated (Scintrex) / Continuous (iGrav, gPhones)**
  - **Relative/absolute (FG5)**

• **Small drift of the iGravs – checked together in Strasbourg (France) with other superconducting gravity meters at a well characterized site.**

• **First results suggest what we expect, however clear need for further investigations, perform all corrections and compare with injection/production data**

Final remarks

- **Sub-complete set of complementary observations , useful for mass and stress research and monitoring**
  - gravity,
  - ground motion,
  - ground displacement,
  - EM
  - environmental observations

- **Bring information about geothermal reservoir location and provides information for sustainability**

- **Provides constraints on processes of fluid transfer**

Perspectives

Confirm signals - Check drifts with second set of absolute gravity measurements (this summer)

Computations of Earth tide models and admittances
Comparison with seismic activity, EM, other signals

Introducing the new
Abolute Quantum Gravimeter

- **absolute**
- **continuous record**
- **repeatability < 2 microgal**
- **low power**

Takk fyrir !

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