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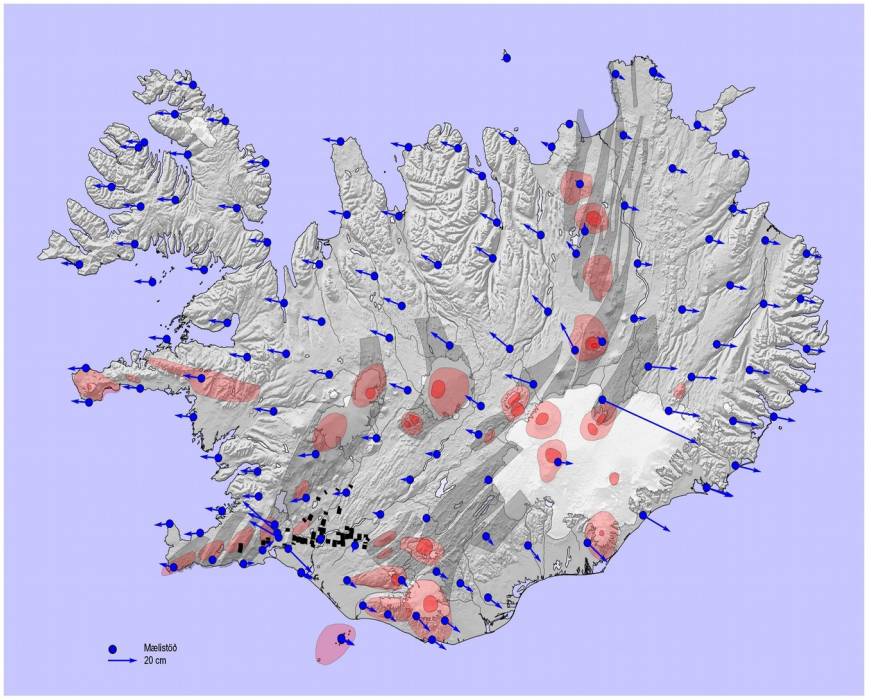
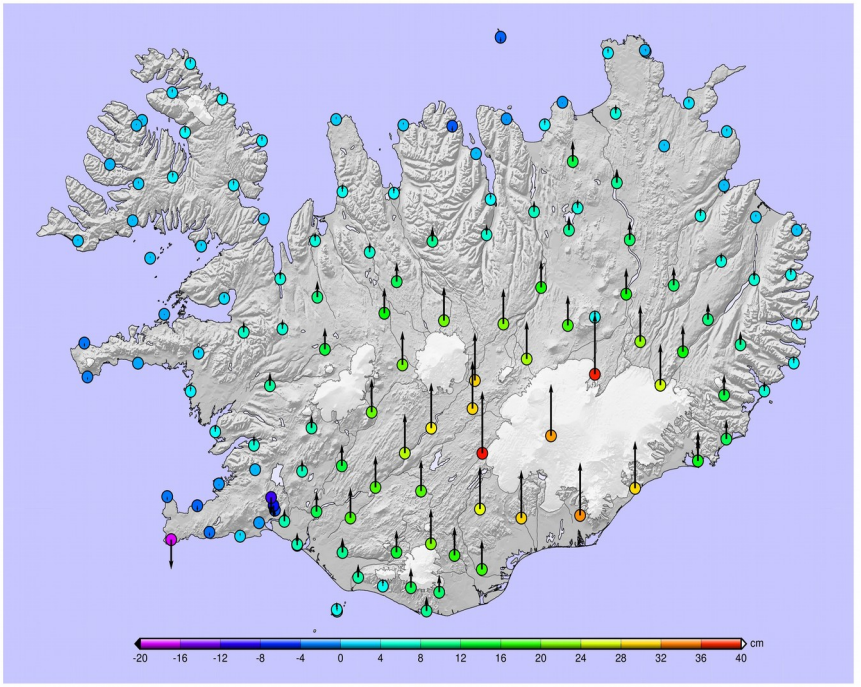
Dynamic reference frame in Iceland

EGU 2019, Vienna 8/4





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Background

- Scenario: Smartphones give positions within dm or cm accuracy
  - in real time
  - in a global and dynamic reference frame
- Autonomous driving sets new demands on the reference frame
- Australia has decided to implement a fully dynamic reference frame in 2020
- Is a static “plate fixed” reference frame the best solution for the users in the future?

The NKG-presidium initiated a pilot project on Dynamical Reference Frame: ***DRF-Iceland***

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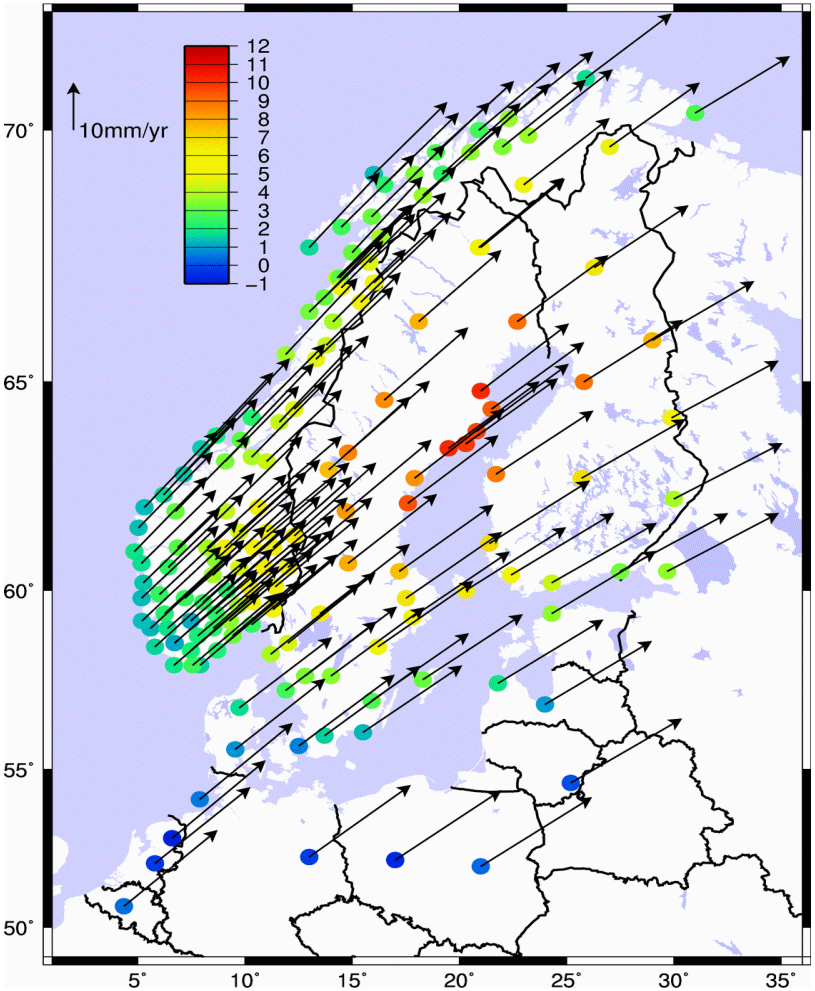
The earth and the Nordic countries are subject to crustal deformations that influence the reference frames



- Scandinavia has moved since ETRS was realized
  - ~50 cm to North-East
  - 0-20 cm Up
- ITRF and ETRS differ
- Should the reference frame follow the “stable”- plate or the global system?

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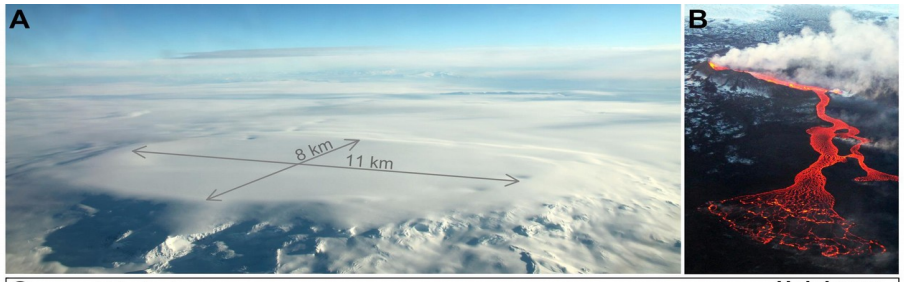
In Iceland the deformations are much more complex

-Two plates are drifting apart ~2-3 cm/year
-Deformations within the plates
-Earthquakes ~50 cm
-Volcanoes
-Melting graciers ~40 mm land uplift annually
~more than 10 mm/yr horizontally
-Geothermal power plants - subsidence



If we could handle the situation in Iceland, we could handle the situation in Scandinavia.

Important to have a common understanding of the definitions and vocabulary

-***Static RF*** ***(Plate fixed):***

The RF moves with the tectonic plate.
The coordinates (of physical objects) do not change with time.

-***Dynamic RF*** ***(Earth fixed, kinematic):***

The RF is fixed to the earth as a whole.
The RF does not move with the tectonic plates.
The spatial coordinates (of physical objects) change with time.

-***Semi-dynamic RF:***

Any possible combination of static and dynamic thinking.
E.g. A "time-series" of static reference frames
A static reference frame with a deformation model

Text for ISO/DIS 19111, (draft version 2018-08-28)

reference frame/datum
parameter or set of parameters that realize the position of the origin, the scale, and the orientation of a coordinate system

dynamic reference frame/dynamic datum
reference frame in which the defining parameters include time evolution

semi-dynamic is not mentioned in the document!

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Definitions: Dynamic Reference Frame

A *point* in a DRF is given by 4-parametres (x,y,z,t), where (x,y,z) is the spatial location in a global reference frame (e.g. ITRF) at epoch t.

A point (x,y,z,t) is:

-uniquely defined

and

- is given directly in the global reference frame
- have the accuracy of the measurements technique
- do not change over time

(but the coordinate of a physical object is different at different epochs)

In addition, we need:

- a *deformation model* to compile or compare coordinates with different epoch

NOTE:

Because of the time tagging you can:

- store coordinates in your database even though your deformation model is not updated (e.g. after a large earthquake)
- Can always use the latest and most precise deformation model

How to determine a position in a dynamic reference frame

Examples:

-PPP: direct determination in the DRF

-DD: determination through the ITRF coordinates of your reference stations

-RTK: direct determination if the RTK-GNSS stations are continuously updated in ITRF

-Positioning relative a local marker also works, but the time stamp will be the same as for the local markers.

i.e. all techniques determine positions in the same reference frame without transformations.

Ten pre-conditions for a DRF

1) A sufficiently dense active geodetic infrastructure (CORS) with known coordinates in a global reference frame (ITRF).

2) A way to distribute the reference frame to the users, e.g. positioning services.

3) Transformations to other reference frames.

4) Deformation models with sufficient accuracy to meet the future demands for comparison and compiling coordinates from different epochs.

5) Geodetic data archive able to store and handle dynamic coordinates.

6) GIS systems that are able to handle dynamic coordinates in general and in particular the time dimension of a dynamic reference frame and the various transformations needed.

7) Legal foundation of dynamic reference frames (e.g. for cadastre).

8) Training and education of surveyors.

9) Training and education of GIS users.

10) Willingness of the users to take such a system into use.

Deliverables of the DRF-Iceland projects

DRF-Iceland pre-project

- Definitions of DRF
- Geodesy and geospatial data infrastructure in Iceland
- DRF in GIS

DRF-Iceland-S1

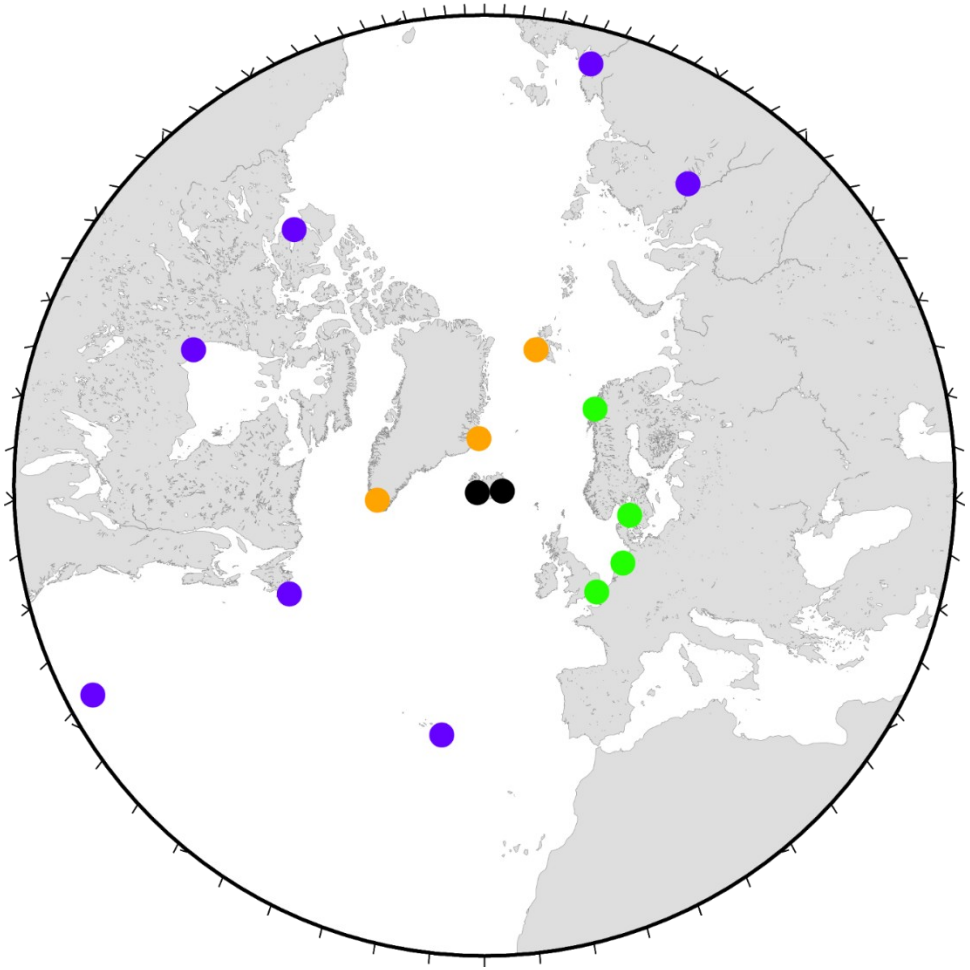
- WP1: Realization of DRF-Iceland
  - GNSS analysis strategy
  - Operationalization
  - Time-series analysis (velocities and deformations)

- WP2: Access to DRF (user perspective)
  - RTK with dynamic coordinates
  - PPP techniques

- WP3: Deformation model
  - Velocity fields and deformations
  - Implementation in GIS systems

- WP4: Plan for a long term NKG-activity

The reference frame realization will be based on the NKG-GNSS analysis center following EUREF



- But:
  - Include none European stations surrounding Iceland
  - Might be necessary with lower latency

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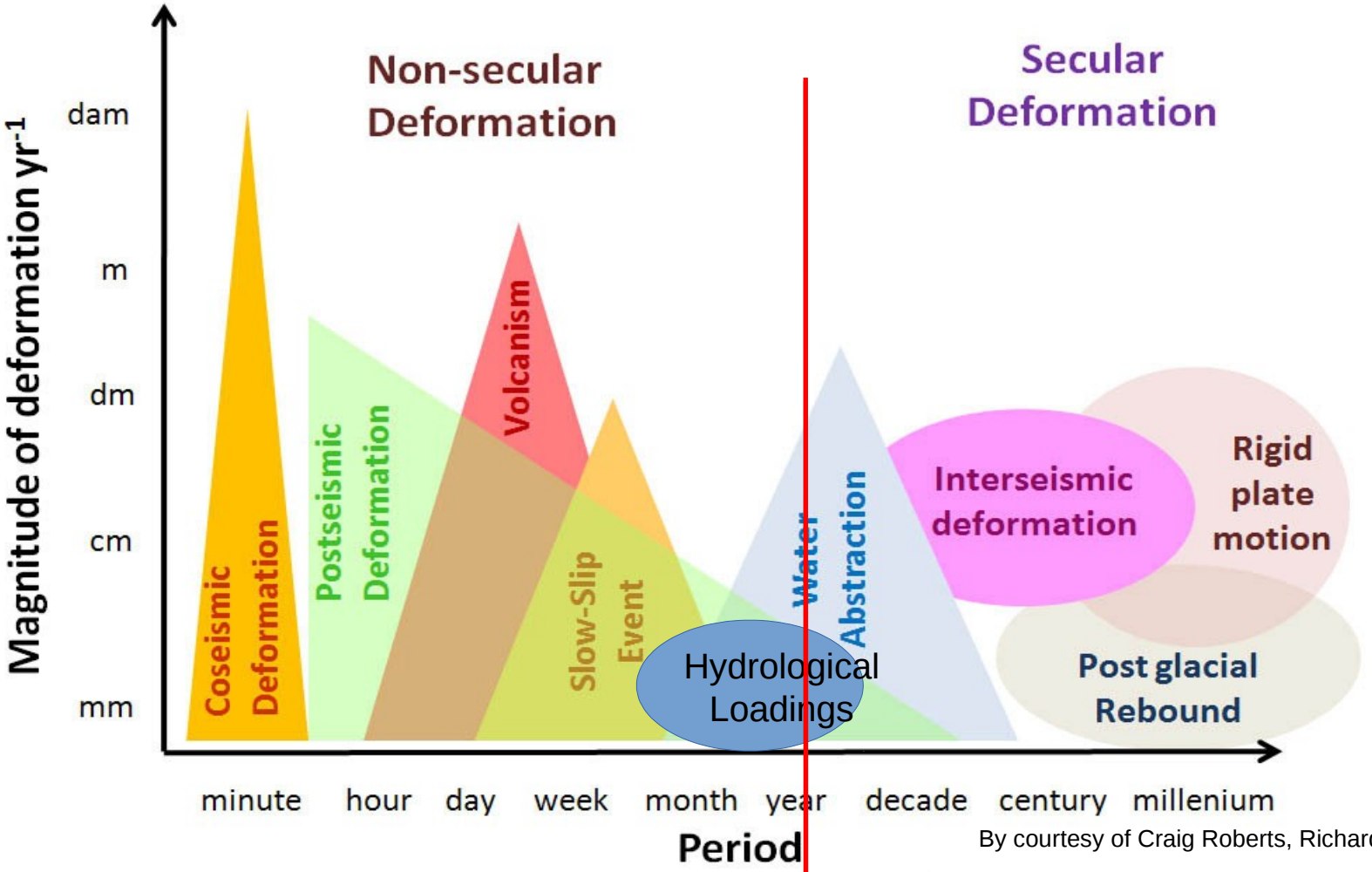
We need a way to handle crustal deformation!



By courtesy of Craig Roberts, Richard Stanaway et at.

From: Stanaway etal. 2012

Deformation model
Patches or ...

Velocity field

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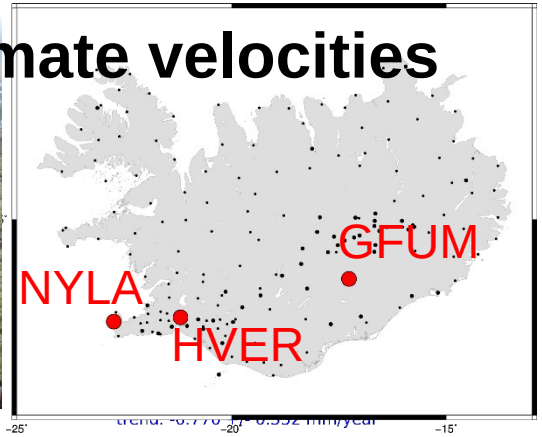
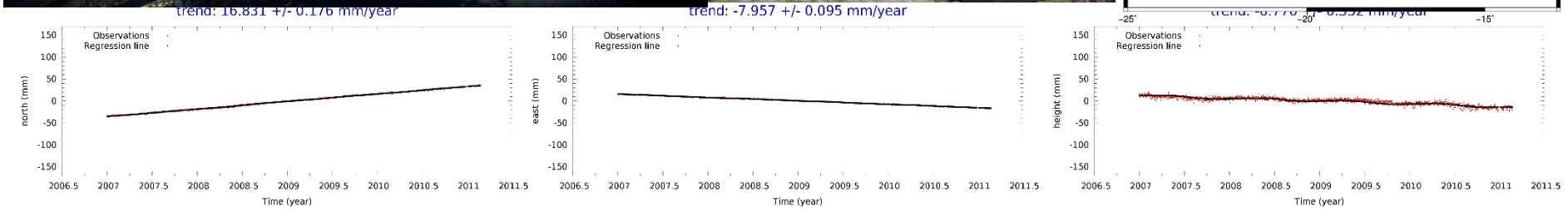
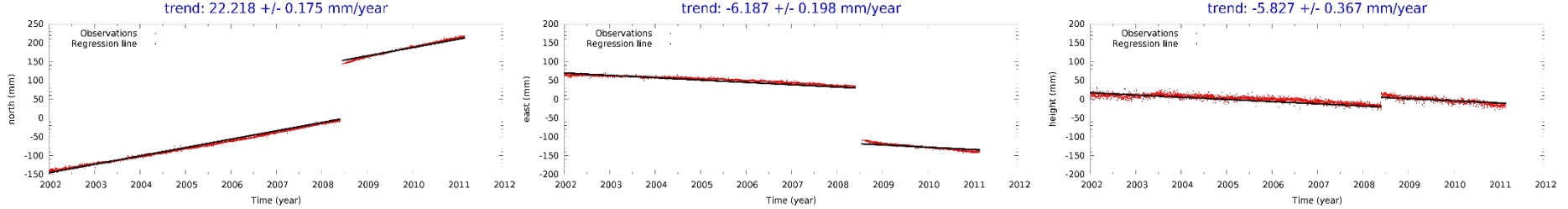
GNSS time-series are our main tool to estimate velocities and deformations

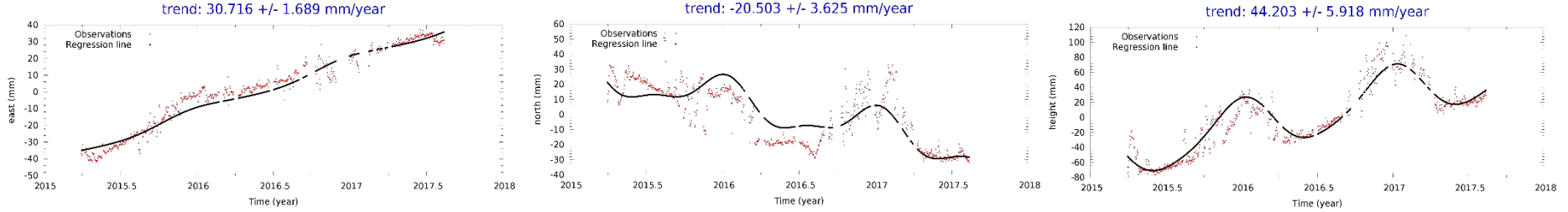


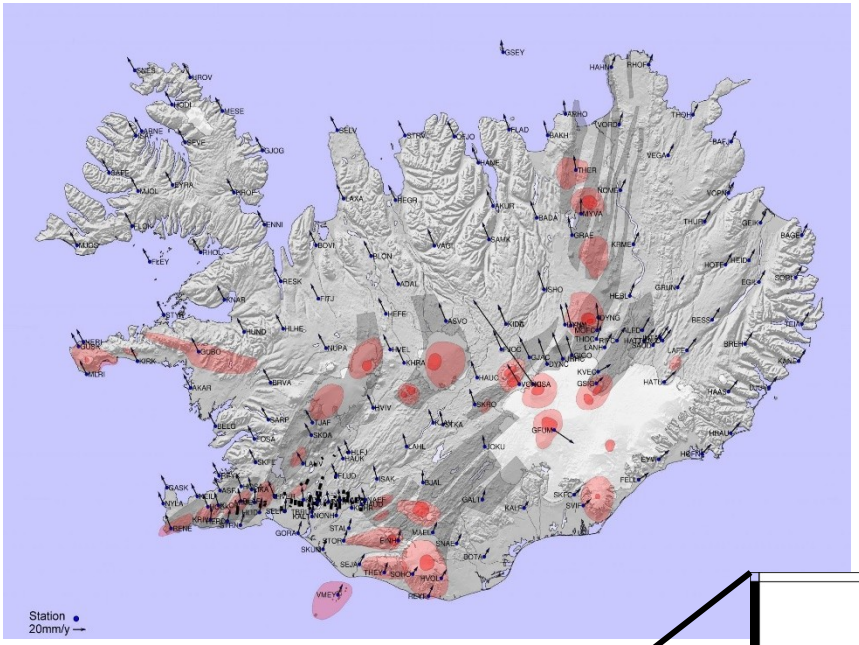


HVER: Earth quakes (co- and post-seismic deformations)



GFUM: Volcanoes and melting glaciers

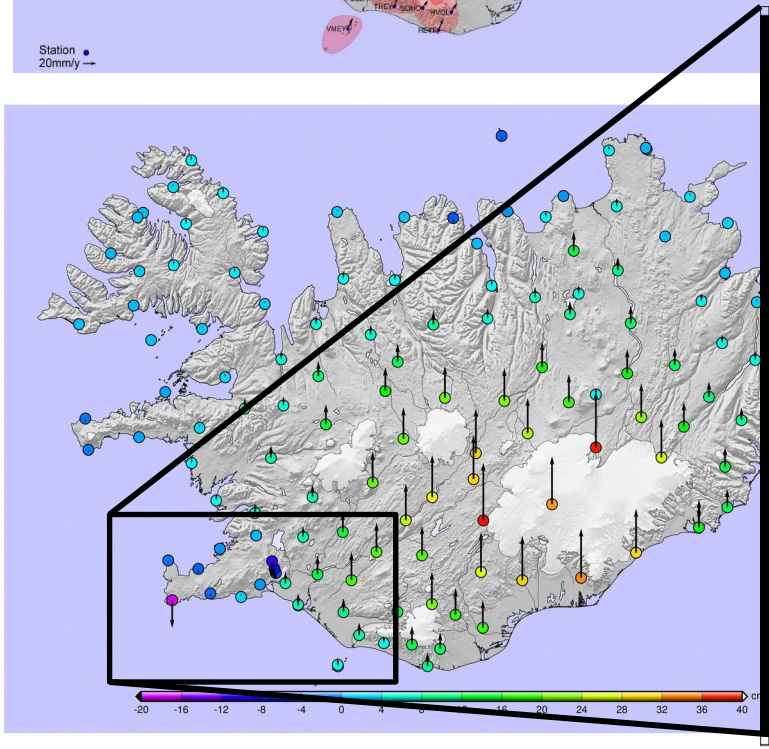


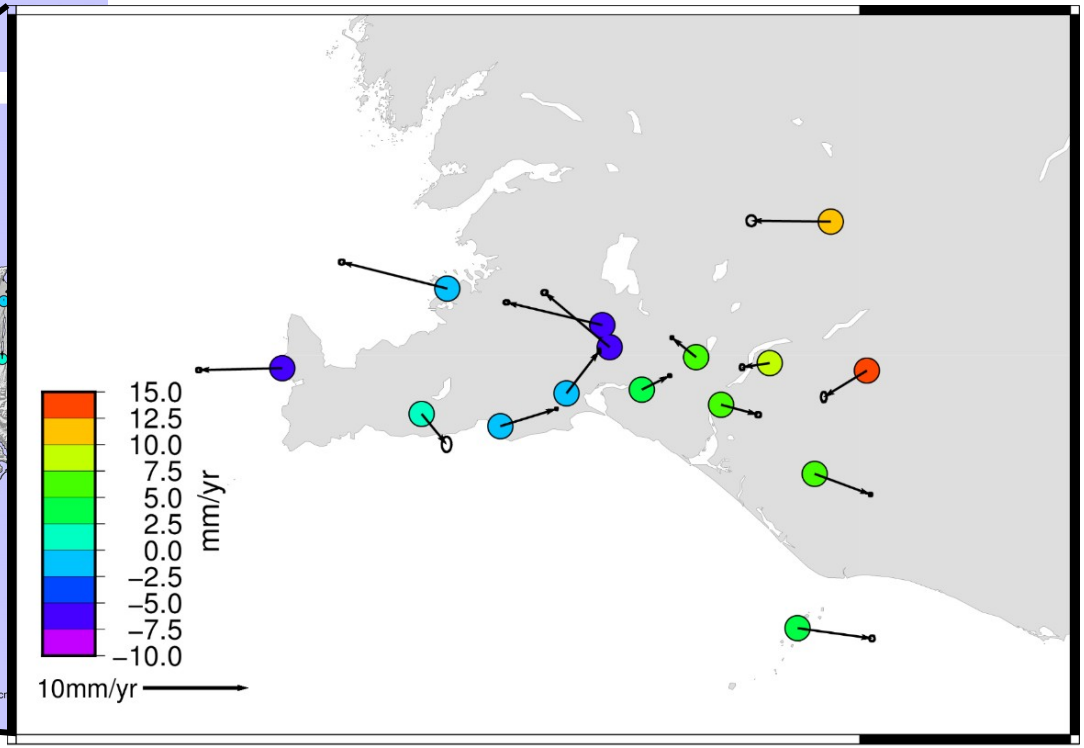


GNSS velocities are input for the velocity field

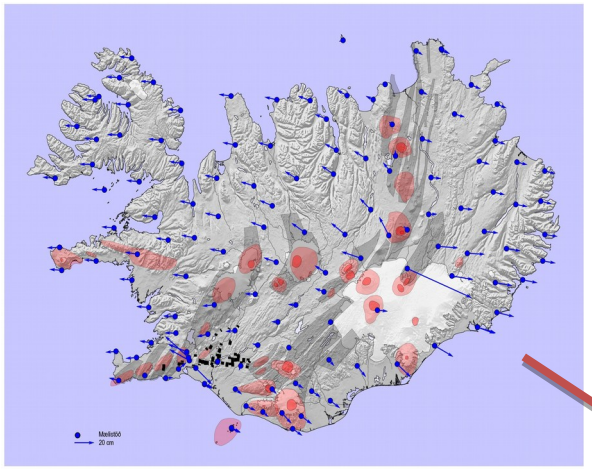
- In Fennoscandia colocation works well
- In Iceland the situation is more complex

- Colocation with geophysical constraints





Collocation with geophysical constraints



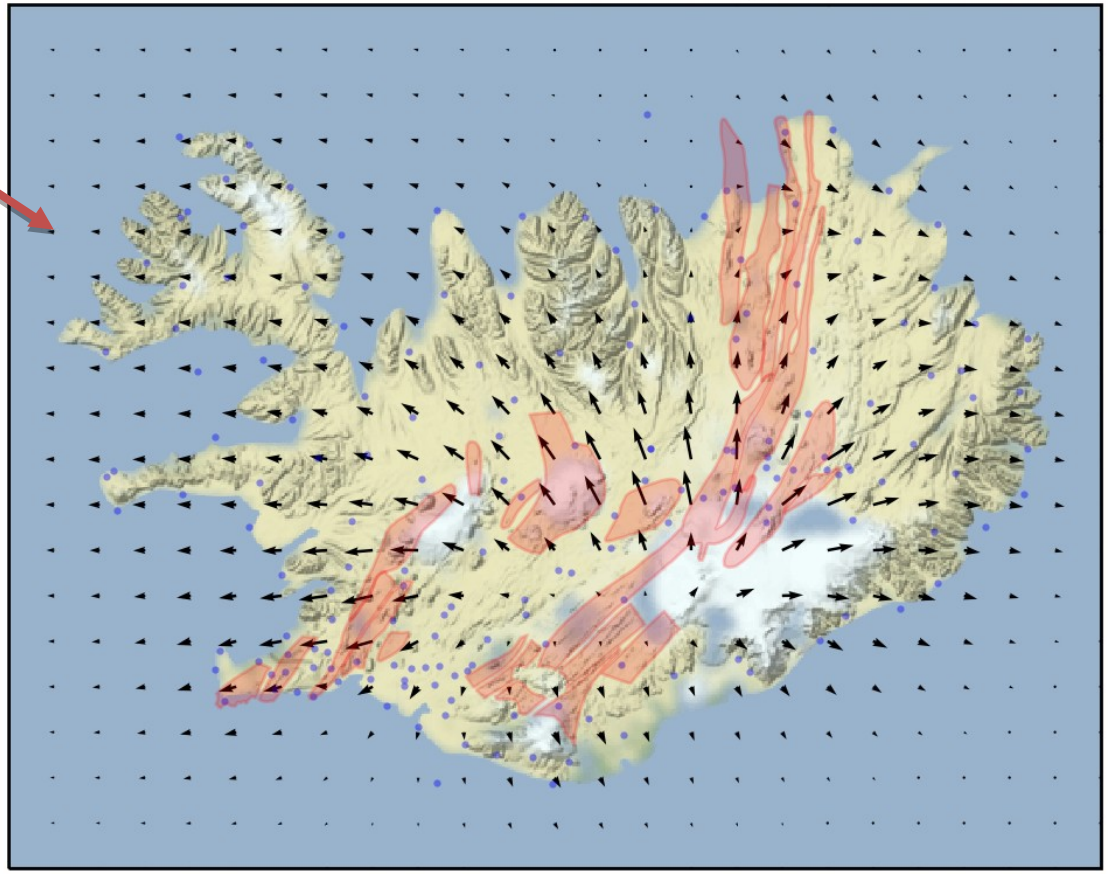
Idea:

Modify the distance in d_{ij} in the covariance function:

$$C_{ij} = \sigma^2 \exp\left(-\frac{\log 2}{D} d_{ij}\right)$$

Co-variance function needs to be positive-definite!

Collocation model modified using fault zones



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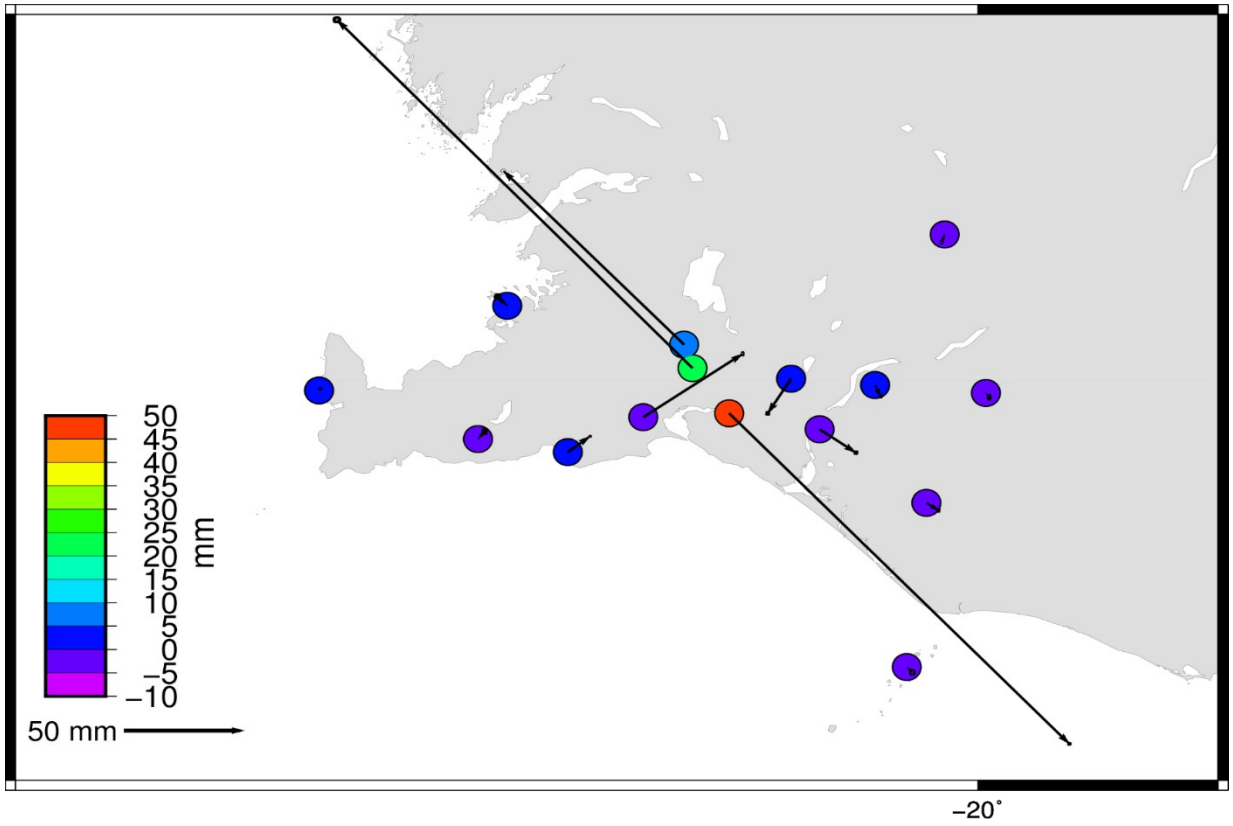
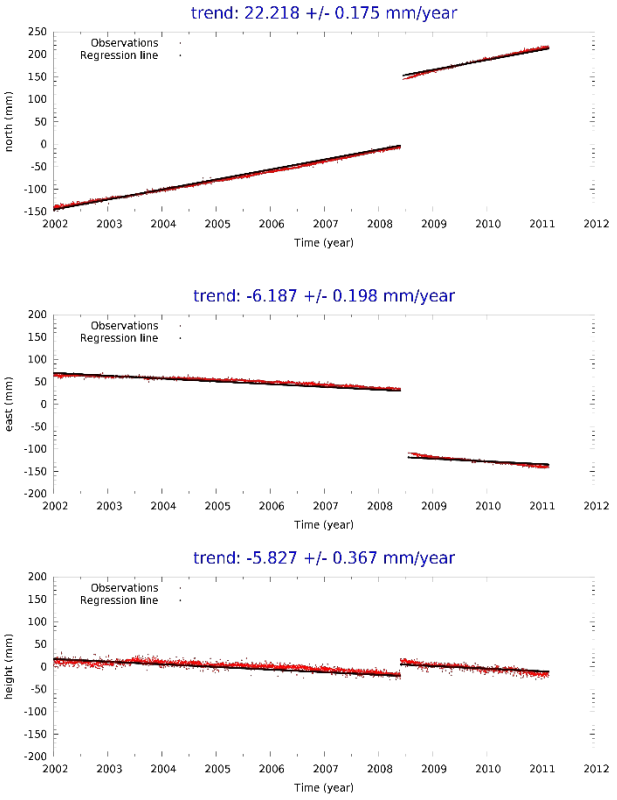
- **In 2008 it was an earth quake in the Reykjavik area**





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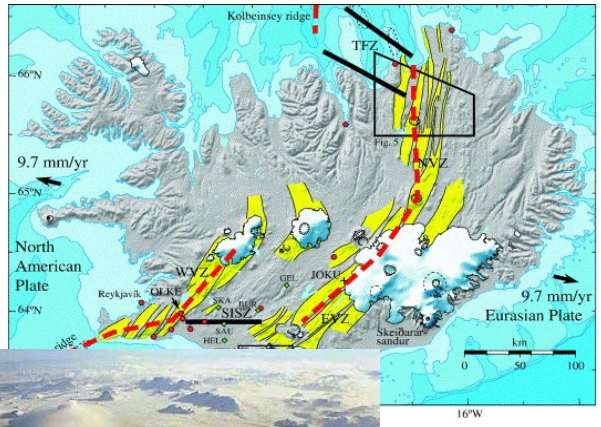
Various models and measurements are necessary to make a good deformation model



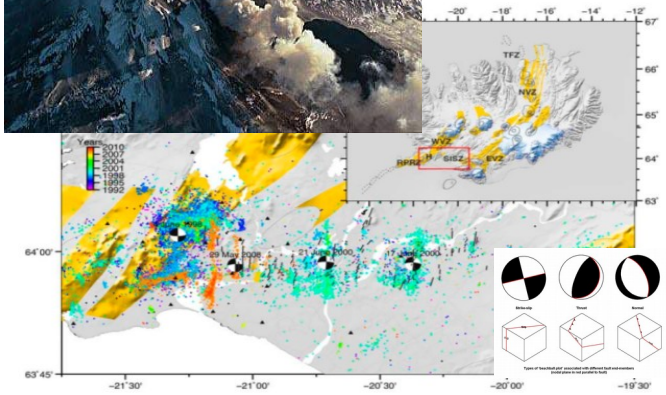
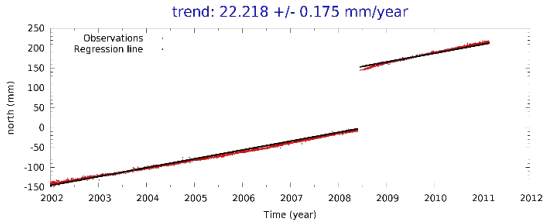
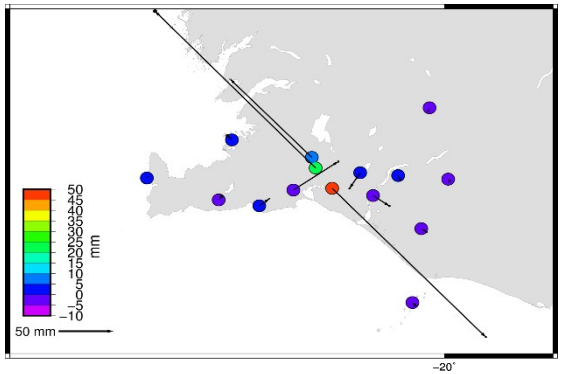
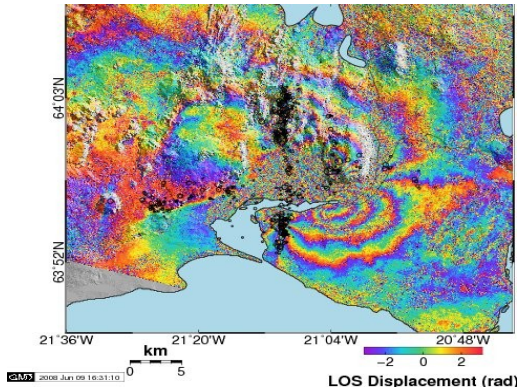


Figure 1. Seismicity within the South Iceland Seismic Zone and Hengill Triple Junction (H), 1992–2009. Event locations







InSAR

GNSS

Geophysical models

The ultimate goal:
A spatial and temporal continuous deformation model, automatically updated in real time

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DRF in GIS

Key question: How should the time dimension be handled in GIS!
(14-paremater transformations, Velocity fields, Time dependent deformations, Patches)

- Necessary routines are implemented in PROJ and available
- But not adopted in existing GIS software

Proj is is a commonly used transformation library used in several GIS applications e.g. QGIS

- Updating map databases:
  - How will web services work in a dynamic reference frame?
  - Huge amounts of data which is not feasible to transform on the fly.
  - Should it be transformed and updated to “current epoch” with regular intervals?
    - How often? Every week, month or year?

Some conclusions from the DRF-Iceland project

- Deformation model and velocity field is mandatory regardless of type of reference frame
- User groups will request a reference frame homogeneous over boarders and consistent with global positioning systems
- For legal issues e.g. cadastre and inspire directive, a static reference frame is mandatory in foreseeable future.
-
- A two frame approach might be an alterative (like Australia)
- How can we approach the users of the reference frame?