Plan for a NKG-activity on Dynamic reference frames for 2018-2022

*D4 of the DRF-Iceland-S1 project*

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| Delivery description: The long-term goal of the NKG-activity will be a fully implemented DRF in Iceland. To achieve this goal the preconditions 1)-8) in Section 1.5 have to be in place. D4 will describe how this activity should be organized, e.g. the interaction between the activity and short-term project, reporting routines, commitment to resources, scope of activity. |

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| Version: 1.0 | Last change:  2019-01-31 | Authors:  Halfdan Pascal Kierulf and the DRF-Iceland team | Accepted by:  DRF-Iceland team |

**Project information**

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| Project name | Dynamic Reference Frame in Nordic and Baltic area (or Iceland) |
| Short name | DRF-Iceland |
| Project owner | Per Erik Opseth |
| Proposal maker and date | DRF-Iceland project group |

# Project objectives

## Background

There is a general growing need for geodetic reference frames that on national level supports the increased use of global positioning services. As of today most countries have developed and are maintaining their own national reference frame, and global satellite systems, such as GPS and Galileo, and global positioning services may not be directly compatible with national geospatial data in those frames, especially in the case of crustal deformations.

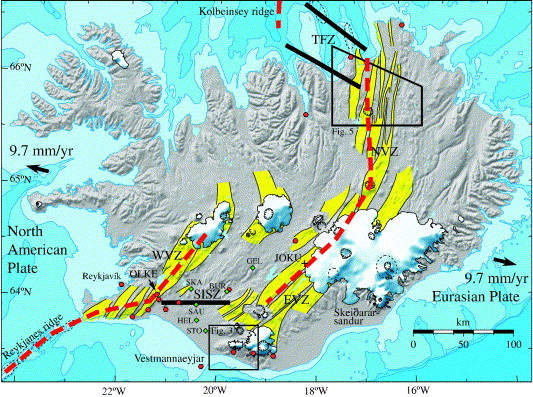
How to take full benefit of global services in practice is a subject for discussions and considerations. The current situation in Europe is that most countries have a regional static reference frame aligned to ETRS89. As ETRS89 is defined to be co-moving with the Eurasian plate, such reference does not enable a direct access to the reference frame through the GNSS system without some kind of time-dependent transformation.

Australia is meeting this future demand with another approach. They introduced a new reference frame in 2017 with epoch 2000.0 (GDA2020). In 2020 they will introduce a new national reference frame (ATRF) directly aligned to the latest International Terrestrial Reference Frame (ITRF 2014) and co-rotating with this global frame instead of the tectonic plate. In such a frame, the coordinates of a point fixed to the ground, will have coordinates changing with time and this is therefore often named a dynamic reference frame (DRF). New Zealand has chosen a way in between. Their national reference frame is static with reference epoch 2000.0, and a deformation model is closely integrated to allow transformation of a new observation to the reference epoch. Updates of both the reference frame and the velocity model are allowed to happen when necessary. This approach is often named semi-dynamic.

There is a growing awareness that static reference frames like the national realizations of ETRS89, are not the ideal solution for all purposes in the future. To be prepared for the future, the Nordic Geodetic Commission (NKG) initiated a pilot-project to gain knowledge and end up with a "Project proposal for implementation of a dynamic reference frame in Iceland".

Iceland has a very active and complex geodynamic situation, causing large non-homogenous crustal deformations. With its location at the Mid-Atlantic Ridge, it is lying on two different tectonic plates. It is also affected by deformations caused by active volcanoes, melting glaciers, and glacial isostatic adjustment (GIA) (see Illustration 1). Due to this situation, the traditional concept of static geodetic reference frames is difficult to maintain at the uncertainty level required by modern applications. It is therefore worthwhile to investigate how a dynamic reference frame could be implemented in Iceland.

In Fennoscandia and Balticum the geophysical deformation are mainly driven by plate tectonics and GIA. Both processes are slow and predictable, hence the deforming aspects of the reference frames, dynamic or not, are easier to handle. From a geodetic point of view: If we could resolve the situation in Iceland with its complexity, we could also handle the situation in Scandinavia. However, the fundamental differences between a static and dynamic reference frame remains also in Scandinavia.

Illustration 1: Geophysical processes affecting the Icelandic crust

The DRF-Iceland has gone through two phases, a pre-project and a project to establish the basic geodetic components of a DRF. The DRF-Iceland projects have mainly focused on Iceland and the geodetic parts of the DRF; Its definition, the realization and networks, distribution to users and the necessary transformations and deformation models to compare and compile coordinates.

This document describes a plan of how the work with DRF can be continued in the NKG community. What is the goal? How can we improve our reference frame and deformation models? How could we best implement it in GIS systems? What can we achieve now, what will be possible in the next NKG-period and what have to wait for the global development?

# Goals

Establish a common Nordic DRF (DRF-NKG). That includes; regular/continuous update of the reference frame, sufficient accurate deformation model and the necessary routines for handling time evolution in GIS systems.

*To what extent this will be implemented in the individual countries as the reference frame for practical purposes, will be decided on national level. However, such a common DRF-NKG will ensure that the DRF is identical in the NKG area independent of the implementation level and national time lines.*

# Effect goals

NKG has the necessary competence and experience with reference frames, deformation models and GIS systems to handle future requirements for a reference frame for most practical and geodetic purposes.

## Outcome/Project goals

A uniform/consistent DRF for the Nordic and Baltic area. This implies a common NKG-AC solution of all CORS, a deformation model to compare and compile coordinates from different epochs and the necessary routines to handle dynamic coordinates in GIS systems.

## Consequences of not implementing

The geophysical setting in Iceland makes classical static reference frames difficult to maintain, and over time, they will deteriorate leaving an inaccurate reference frame that is not suitable for high precision land surveying. Consequently, new static reference frames has to be introduced regularly in Iceland. This is a considerable disadvantage to both land surveyors and users of geospatial data, as well as very costly for the local mapping authority.

By not implementing the dynamic reference frame in Iceland status quo is upheld and the known disadvantages of using a static reference frame will continue.

In the other Nordic countries, the geophysical processes are slower and more predictable and a static reference frame can keep a sufficient accuracy over longer time. This requires an accurate deformation model. However, the problem with inconstancy between the reference frame for the global positioning systems and the plate fixed static reference frames remains for all countries.

## Consequences for users

Implementation of a dynamic reference frame marks a paradigm shift. In a dynamic reference-frame, coordinates of fixed points on the earth vary over time.

This has many consequences for land surveyors and other users of geospatial data and they will have to adapt to this new situation. The payoff for the users is that they can do surveying with higher precision over longer time periods.

# Solution description

In a DRF, a location is described with four parameters: three parameters for the three-dimensional global position and one parameter for the time stamp of the observation (see e.g. A1 from the DRF-Iceland pre-project for details). With such a description, the co-ordinate of a fixed location on the ground will vary with time and hence a way to compare and compile coordinates with different reference epoch is necessary. The basis for a DRF will be the Continuous Operating Reference Stations (CORS) and their positions in a global terrestrial reference frame, e.g. ITRF2014. A DRF for practical purposes presupposes:

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.

Preconditions 1) to 10) have to be in place to have a well working DRF as the soul national reference frame in the future.

Many of these points are large and demanding and rely on the international development. E.g. 6) will require large development resources. However, with the announcement of the coming Australian dynamic reference frame it is expected that most GIS software vendors will be working on implementing the updated standards and improving their transformation tools. The time frame for this is unknown, however (see A4 from the DRF-Iceland pre-project for more details about DRF in GIS systems).

Legal foundation of geospatial information is regularized through the INSPIRE directive (2007/2/EC) (Point 7). It depends on various national juridical laws and regulations. Especially for the cadastre, it seems practically impossible to implement in a DRF. Partly because of this, the DRF will be supplemented by a static frame in foreseeable future (so called two-frame approach).

## Stakeholders

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| --- | --- |
| Stakeholder | Contribution, expectations and interest in the project |
| NMAs affected by the project |  |
| NKG | The various agencies under NKG will supply personnel |
| Land surveyors | Land surveyors will be affected by the project once the DRF is implemented |

# Project implementation

# The future organization of the NKG is at the moment not decided and it is therefore difficult to set up an exact plan for the management of the DRF-activity. The activity should be led by the NKG-DRF-team, consisting of at least one member from each country, keeping track of the long-term challenges for DRF in the NKG area. The team should be flexible, follow the international development carefully and be able to initiate sub projects to solve the necessary issues for a DRF. Below, is a list of 12 milestones for the activity, but other activities might be necessary as well.

## Milestones

1. Clarify the concepts and describe the merits of static, semi-dynamic and dynamic reference frames, including the “two frame concept” where ITRF and national realizations of ETRS89 are used in parallel for various applications.

2. Evaluate the different concepts as basis for our geospatial data sets and for various positioning and surveying techniques.

3. Develop the NKG analysis center for DRF needs, e.g. continuous coordinate updates of the Nordic and Baltic CORS (automated process?).

4. Establish routines to update rest of geodetic networks (by interpolation from CORS or prediction based on deformation models).

5. Setting up an RTK-service delivering DRF-coordinates in a test area.

6. Improve existing deformation models for the NKG-area and customize them for DRF and semi-DRF use.

7. Test of InSAR as a source for local deformations, and evaluate if local deformations are relevant in the velocity model.

8. Testing algorithms that combines GNSS time-series, geophysical models (especially GIA) and InSAR (if found useful in M7) to carry out a high-resolution deformation model in Iceland and in another test area.

9. Develop the necessary routines (e.g. in PROJ) to handle dynamic coordinates in GIS systems.

10. Finalizing the Icelandic case study and draw conclusions.

11. Define a new test area (outside Iceland) and set up a full-scale test of a dynamic GIS.

12. Outreach work – setting up a common campaign to convince the owners of the geospatial data.

13. Study: User analysis: What is the need for dynamic reference frames and when do they need to be implemented?

14. Study: How to organize the geospatial data to make an efficient upgrade of the reference frame when needed

15. Study: How to deal with dynamic cadaster data? What about legislation?

### Comments on the milestones

Basically with M-3 and M-6 we have a common Nordic Baltic NKG-DRF. The level of implementation will then vary from country to country and the importance of many of the other milestones depend on this implementation level. We are close to have the necessary deformation models for Fennoscandia and Baltic and a reasonable background velocity field for Iceland (assuming a successful D3.3 in DRF-Iceland-S1). NKG-AC is already functioning and will be the backbone for M-3, but it might be necessary with shorter latency and more CORS included both regionally and globally.

Legal foundation of geospatial information is regularized through the inspire directive. It depends on various national juridical laws and regulations. Especially for cadastre, it seems practically impossible to implement in a DRF. Partly because of this, the DRF will be supplemented by a static frame in foreseeable future (so called two-frame approach). The DRF-Iceland project group therefore believes that a thorough assessment of the legal issues is not worthwhile at the current stage. However, some consideration of legal implication will be performed under point M-1 and M-2.

## Organization

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| Roles | *Navngitt ressurs. Bidrag i prosjektet. Nødvendig kompetanse* |
| Project owner |  |
| Steering committee (evt.) |  |
| Project manager |  |
| Project participants |  |
| Reference group |  |

## Estimated costs

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| --- | --- | --- | --- |
| Deliverable | Type of cost | Cost | Specification/comment |
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| Total cost  (with internal resources) |  |  |  |
| Total cost  (without internal resources) |  |  |  |

# Appendix

## DRF-Iceland pre-project

The DRF-Iceland pre-project started the spring 2017 after initiativ from the NKG-presidium. The idea with the pre-study was to be prepeared for the future, gain knowledge and to end up with a project proposal for implementation of a dynamic reference frame at iceland. The pre-project ended in August 2017. During this project it become clear that parts of the project was not realistic to achive in forseable future and the project was adjusted acordingly. The outcome of the of pre-project was four reports/documents describing the current situation and a plan for furtheractivities until the NKG-GA-2018 meeting. These documents are:

*A1-Dynamic\_reference\_frames.docx* (Definition and explanation of the concept of dynamic reference frame.)

*A2-geodesy\_in\_iceland.docx* (An overview of geodesy in Iceland, including infrastructure, deformation processes and reference frames.)

*A3-spatial\_Data\_Infrastructure\_in\_Iceland.docx* (A short introduction to spatial data in Iceland.)

A4-GIS\_and\_dynamic\_reference\_frames.docx (A short introduction to the challenges that arise in GIS with the introduction of dynamic reference frames.)

*DRF-Iceland\_project\_proposal\_v1.0.doc*

## Results DRF-Iceland-S1 project

The DRF-Iceland-S1 project was divided in four work-packages; WP1: Realization of DRF-Iceland, WP2: Access to DRF, WP3: Deformation model and WP4: Plan for a long term NKG-activity. Each work package consists of several deliverables in total 12, of which six (D3.1 and D3.2 was merged together) are written reports, two were test services and three contains analysis results. The deliverables are listed below. For more details about the individual deliverables see the description in the *DRF-Iceland\_project\_proposal\_v1.0.*doc from the pre-project or go to the individual documents.

D1.1: Specification of the GNSS analysis strategy and reference frame realization for the DRF-Iceland (D)

D1.2: Set up an operational GNSS analysis of Icelandic CORS (S)

D1.3: Determine a preliminary secular velocity field for the Icelandic GNSS stations (R)

D1.4: Time-series analysis for determination of velocities and deformations of Icelandic GNSS stations (R)

D2.1: Review of the RTK software options with respect to the requirements of dynamic coordinates in a DRF (D)

D2.2: Implementing a test-RTK service delivering DRF coordinates (S)

D2.3: Review of the quality of global PPP for positioning (D)

D3.1: Description of concept for deformation model (D)

D3.2: Description of concepts for handling secular motions and deformation events (D)

D3.3: Determination of a preliminary deformation model (R)

D3.4: Description of how to implement deformation model in GIS systems (D)

D4: Document describing the plan for the NKG-activity 2018-2022 (D)