

**Definitions and concept of Dynamical Reference Frame**

*Work in DRF-Iceland-pre project*

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**Reference frames - Definitions**

The terms dynamic, semi-dynamic and static reference frame are defined in various ways and can make discussion on the topic difficult. Alternative definitions with more or less the similar meanings are in use e.g static, plate fixed or epoch fixed and e.g. dynamic, kinematic, earth fixed, NNR fixed, global or 4D.

In this project, we define a *static reference frame* as areference frame given by the fixed coordinates of control stations or markers.

A *dynamic reference frame* (DRF) is a reference frame aligned to a global earth fixed reference frame, normally the latest International Terrestrial Reference Frame (at the moment ITRF2014). The coordinates in the DRF is by nature 4 dimensional, given by its 3D-spatial coordinate and its time tag. To compare and compile coordinates in the DRF a model of the crustal deformations is needed.

A *semi-dynamic reference frame* is just a static realization of a dynamic a reference frame at a certain epoch (realization epoch). A model of crustal deformations are used for bringing observations from the observation epoch to the realization epoch. The specific model do not need to be a part of the definition, but may be subject to updates. A *semi-dynamic reference frame* is sometimes also defined as a series of static realizations at different epochs.

**Dynamic Reference Frame – DRF**

High precision satellite positioning is a way to determine your position in the earth system based on time and satellite ephemerids. These parameters are linked to the rotating earth using the no-net-rotation criteria and continuous operating reference stations through their (ITRF-) coordinates. Physical positions in such a system are continuously changing coordinates. The corresponding reference frame is therefore often named Dynamic Reference Frame (DRF). To uniquely define positions in a DRF the coordinates need a time stamp, i.e. P=(x,y,z,t). Such a 4D-coordinate (3D positions plus time) is uniquely determined.

Satellite positioning, like GPS, gives 4D-coordinates directly in the DRF and with the accuracy of the positioning technique you are using. You have direct access to the reference frame without additional loss of accuracy. In principle, this is all you need to determine positions uniquely!

However, to compare, compile or describe the situation at a specific time, coordinates must be transformed to the same epoch using the description on how the coordinates change with time (deformation model). Coordinates of different objects will normally have different time tag in the DRF.

With this definition of the DRF, you do not need to think of crustal deformation processes in the determination of the coordinates in the reference frame. However, the observation method needs to give coordinates in the DRF (see examples below). The models of crustal deformations are still needed when you will compare coordinates and compile different data sets.

*Examples (How to access a coordinate in a DRF):*

*-PPP direct access*

*-DD access through the ITRF coordinates of your reference stations*

*-RTK direct access if the RTK-GNSS stations are in ITRF*

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

*i.e. all measured coordinates will be easily accessible in the same reference frame; local surveys, electronic devices, autonomous cars, GIS databases and high accurate geodetic time-series.*

One of the counterargument to a dynamic reference frames is that the concept of changing coordinates is difficult to understand. With the DRF the coordinates reflect the location to day and not at a reference epoch in the past or future. The coordinates are fixed (in space and time) and you do not need to change them.

Only when you will compare coordinates with different time stamp, the coordinates have to be transformed. Users are able to understand (and be aware of) that the earth crust is moving and that you need some deformation model in addition to compare points from different times. The deformation models become something that describe the dynamic world and something you apply when necessary - not a part of a “diffuse” reference frame.

It is important to note that both in the semi-dynamic reference frame and the DRF, precise knowledge about crustal deformation processes are fundamental. However, while the deformation model is used to transform coordinates back to the reference epoch in the semi-dynamic case, the deformation model is normally used to transform old coordinates to current epoch in the DRF. With the semi-dynamic approach, the transformation is done once and for all for each observation, while in the DRF case the transformation is done when you need to compare or compile coordinates.

The questions will then be: *how do we best deal with the earth’s dynamic nature for the different applications?*

With the DRF you only have to think of the deformation model when you need to compare positions. The same physical point measured at two different times will have different coordinates. To compare two different points you need a model for the movements in the global frame.

Our deformation models are continuously improving. With the DRF the newest and most accurate model can be used. Opposite traditional thinking where the deformation model at the measurement time (possibly outdated) is applied.

However, for some user groups a set of regularly updated fixed coordinates might be convenient. That means that a set of DRF-coordinate need to be fixed to a certain epoch (epoch realization), either by transformations/velocity models, new measurements or new adjustment. The realization of the dynamic/earth-fixed reference frame in Australia (ATRF) is using this approach, with regular update of the frame (aligned to ITRF). The update interval depend on the accuracy requirement. E.g. with a similar approach on Iceland and with a 5 cm accuracy requirement, the frame have to be updated each 2 years and after large earthquakes.

*Example (Australia):*

*GDA2020 will be an epoch-realization of ITRF2014 at epoch 2020.0. I.e. all reference coordinates are measured/or transformed to the same time t=2020.0. ATRF will be a time-series of reference frame with new fixed realizations of the reference frame at new epochs with regular time interval (epoch-realization of the reference frame).*

*Example (Iceland):*

*The new Icelandic reference frame ISN2016 will be a semi dynamic reference frame with epoch-realization at 2016.5. A new deformation model including patches will follow the ISN2016. Coordinates in a new possible DRF in Iceland is given with (x,y,z,t) where t is the epoch of your measurement. ISN2016 will, from the DRF perspective, just be an epoch realization of DRF at epoch 2016.5. The new deformation model will be as crucial in the DRF as in the ISN2016, but used differently.*

*Example:(Large construction projects)*

*Construction projects with limited spatial extension* *often defines their own reference frame through fix points. However, different construction machines might have direct access to ITRF through satellite positioning at current epoch. This is a source of confusion and might be fatal. With the DRF concept will fix points have coordinates in ITRF, but with at a fixed epoch and all relative measurements in the project will have coordinates with the same epoch. The problem is not solved with the DRF concept, but the differences can easily be explained by the time differences and managed by the deformation field.*

*Advantages of the DRF thinking:*

-(All) Coordinates can be determined directly in the reference frame

-Coordinates will have the accuracy of the measurements technique used, not degenerated by any transformations.

-To compare coordinates from different time, the latest and most accurate deformation model might be used.

-In the transition phase, traditional fixed reference frames can be implemented as a realization of the reference frame on a certain date (epoch-realization of the reference frame).

-The 4D concept is easier to understand than a reference frame with changing coordinates.

-With a 4D-reference frame the coordinates reflect the location at the time of measuring and not at a reference epoch in the past or future.

-The fundamental definition will be the same for all user groups, but with some adaptations for special applications. (e.g. fixed epoch-realizations)

**The difficult concept of a dynamic planet where everything is moving, can easily be managed by the time!**