

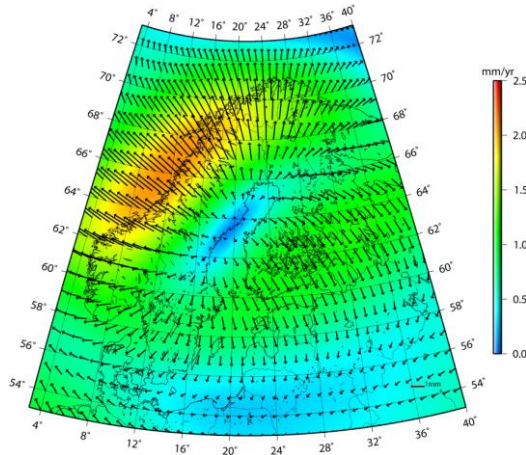
ETRS89 TRANSFORMATIONS IN FENNOSCANDIA (NKG TRANSFORMATION)

Pasi Häkli



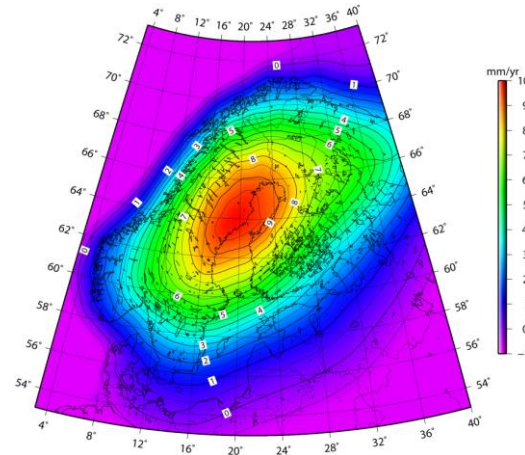
POST-GLACIAL REBOUND (GLACIAL ISOSTATIC ADJUSTMENT, LAND UPLIFT)

- **Post-glacial rebound (PGR)** changes coordinates in the Nordic-Baltic area, affects mostly to heights (up to 10 mm/yr) but small horizontal component as well
- Nordic Geodetic Commission (NKG) has developed some models and methodologies to account for the effect



NKG_RF03vel
intraplate model
velocities

← Horizontal
Vertical →



CONSEQUENCES OF THE PGR EFFECT

- Eventually static reference frame becomes too distorted - deformations must be accounted for somehow
 - Regular updates of static reference frame or semi-dynamic or dynamic reference frame
 - Time tag for the coordinates a prerequisite!
 - Good deformation model crucial
 - Common practices (standards) for utilizing the model needed
- Nordic-Baltic ETRS89 realizations mostly established in the 1990's
 - ~20 years of deformations compared to present-day coordinates
 - PGR effect cannot be neglected in accurate georeferencing applications and in the maintenance of national ETRS89 realizations

MOTIVATION

Project of the Nordic Geodetic Commission (NKG):

1. To ensure, improve and update the accurate transformations (incl. deformation model) from global ITRFs to the national ETRS89 realizations in the Nordic/Baltic area
 - Needed for most accurate georeferencing/geospatial data that is collected in a global frame (using e.g. GNSS) and needs to be stored in a national reference frame (semi-dynamic reference frame)
2. Establish an accurate and homogeneous common reference frame in the Nordic-Baltic-Arctic region e.g.:
 - expressing GNSS/levelling data in a common reference frame in order to evaluate new Nordic geoid model
 - cross-border applications

NKG2008 campaign - ITRF2008(2008.75)

Input coordinates in ITRF2008:

- Nordic Geodetic Commission (NKG) set up a Nordic-Baltic-Arctic GPS campaign in 2008

Nordic-Baltic common frame:

- Conventional frame of ETRS89: ETRF2000
- Conventional epoch in the Nordic-Baltic countries for land uplift: 2000.0

ETRF2000(2000.0)

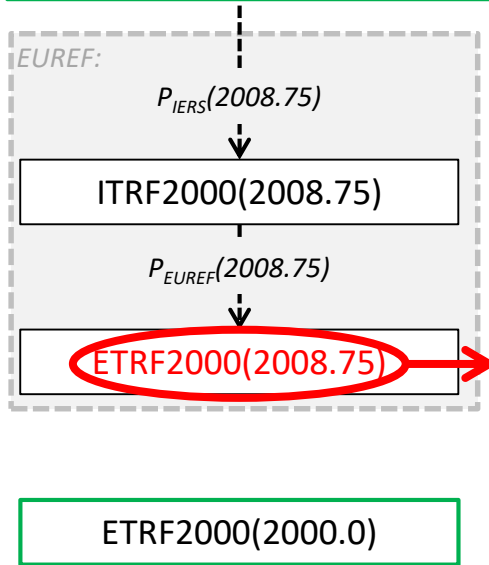
National coordinates in ETRS89:

- Different versions of ETRFyy and realization (reference) epochs tr

National ETRS89 realizations (epoch: t_r)

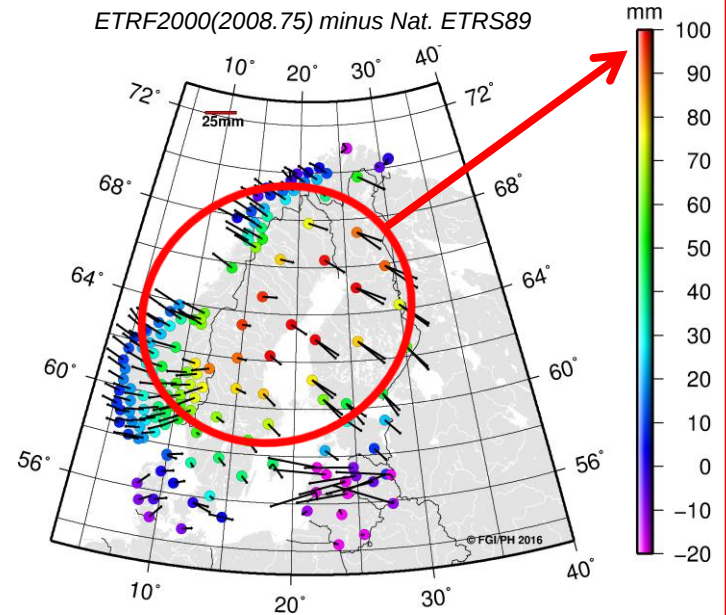
- | | |
|-------------------------|-------------------------|
| - DK: ETRF92(1994.704) | - EE: ETRF96(1997.56) |
| - FO: ETRF2000(2008.75) | - FI: ETRF96(1997.0) |
| - LV: ETRF89(1992.75) | - LT: ETRF2000(2003.75) |
| - NO: ETRF93(1995.0) | - SE: ETRF97(1999.5) |

NKG2008 campaign - ITRF2008(2008.75)



De facto EUREF (Tech.Note 1) transformation:

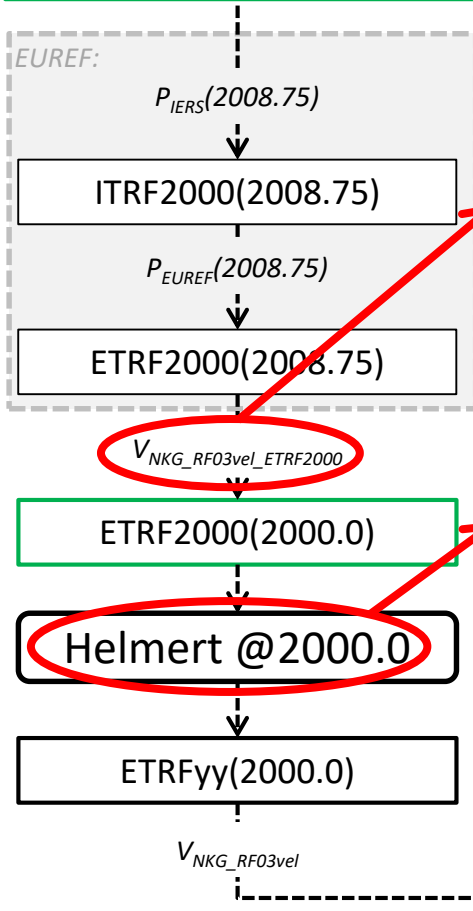
- No epoch/PGR correction
- NOT sufficient for cm-level access to the national realizations



National ETRS89 realizations (epoch: t_r)

- | | |
|-------------------------|-------------------------|
| - DK: ETRF92(1994.704) | - EE: ETRF96(1997.56) |
| - FO: ETRF2000(2008.75) | - FI: ETRF96(1997.0) |
| - LV: ETRF89(1992.75) | - LT: ETRF2000(2003.75) |
| - NO: ETRF93(1995.0) | - SE: ETRF97(1999.5) |

NKG2008 campaign - ITRF2008(2008.75)



NKG approach:

1. EUREF (memo) transformation

2. additional intraplate corrections

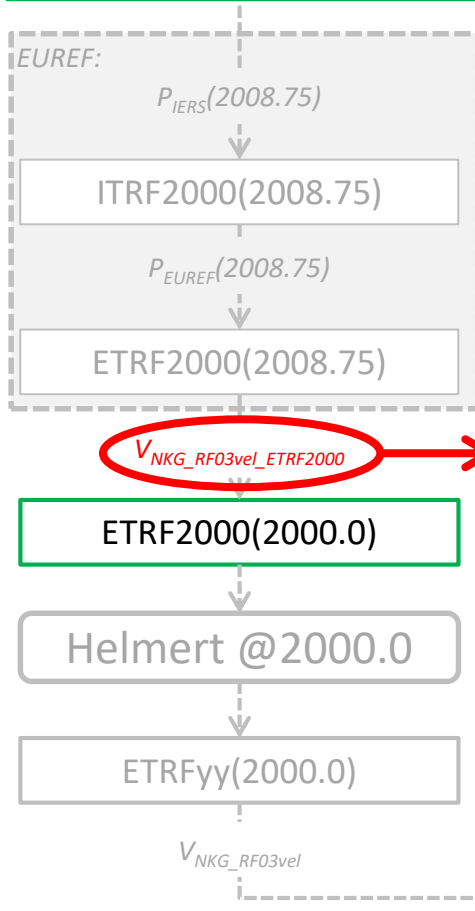
→ Common NKG reference frame aligned to ETRF2000(2000.0), designated as *NKG ETRF00*

3. transformation parameters between the *NKG ETRF00* and (intraplate-corrected) national ETRS89 coordinates

National ETRS89 realizations (epoch: t_r)

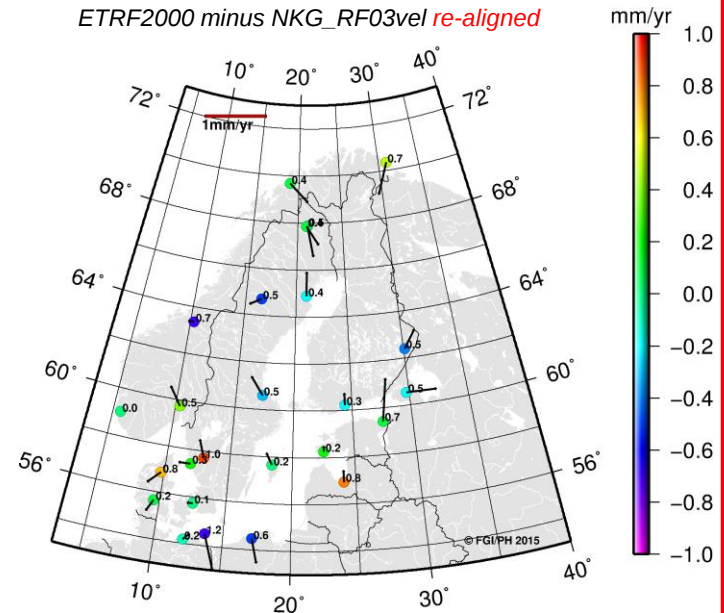
- | | |
|-------------------------|-------------------------|
| - DK: ETRF92(1994.704) | - EE: ETRF96(1997.56) |
| - FO: ETRF2000(2008.75) | - FI: ETRF96(1997.0) |
| - LV: ETRF89(1992.75) | - LT: ETRF2000(2003.75) |
| - NO: ETRF93(1995.0) | - SE: ETRF97(1999.5) |

NKG2008 campaign - ITRF2008(2008.75)



Accuracy of the intraplate velocity model:

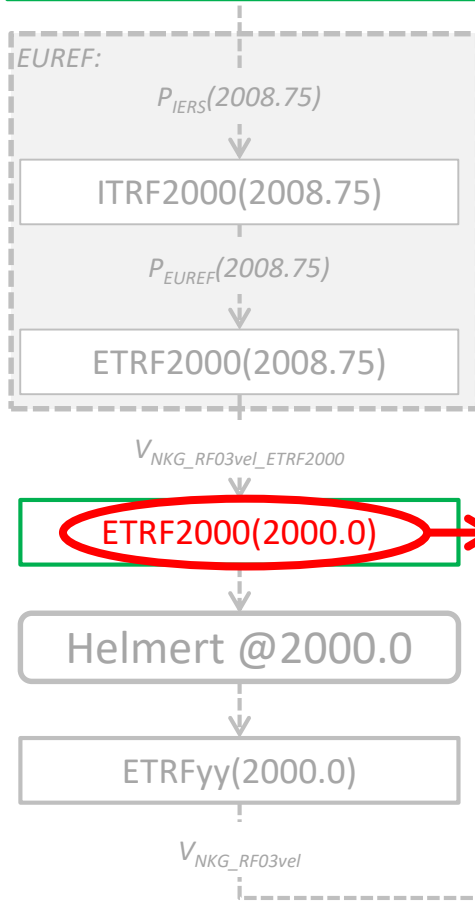
- Intraplate corrections are applied in ETRF2000 → should be consistent with **ETRF2000 velocities** (EPN cumulative solution of class A stations used as a reference)
- RMS (NEU): 0.34/0.18/0.42 mm/yr**



National ETRS89 realizations (epoch: t_r)

- DK: ETRF92(1994.704)
- FO: ETRF2000(2008.75)
- LV: ETRF89(1992.75)
- NO: ETRF93(1995.0)
- EE: ETRF96(1997.56)
- FI: ETRF96(1997.0)
- LT: ETRF2000(2003.75)
- SE: ETRF97(1999.5)

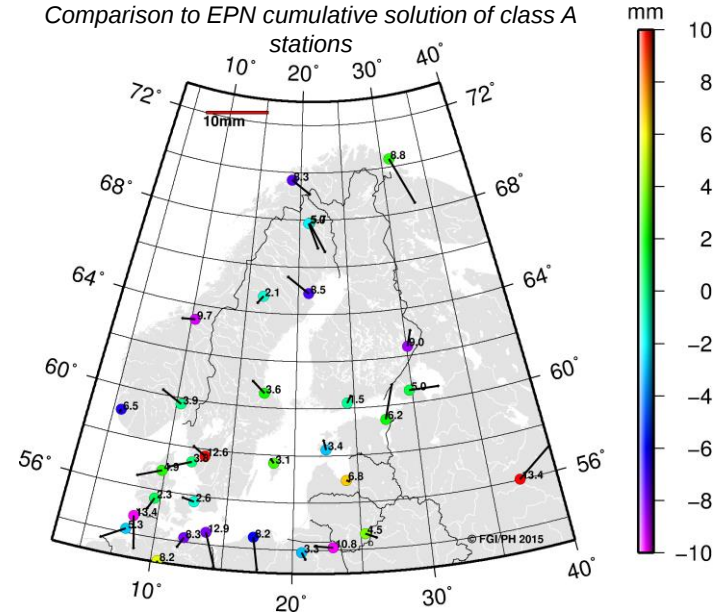
NKG2008 campaign - ITRF2008(2008.75)



Common NKG reference frame alignment:

RMS (NEU):

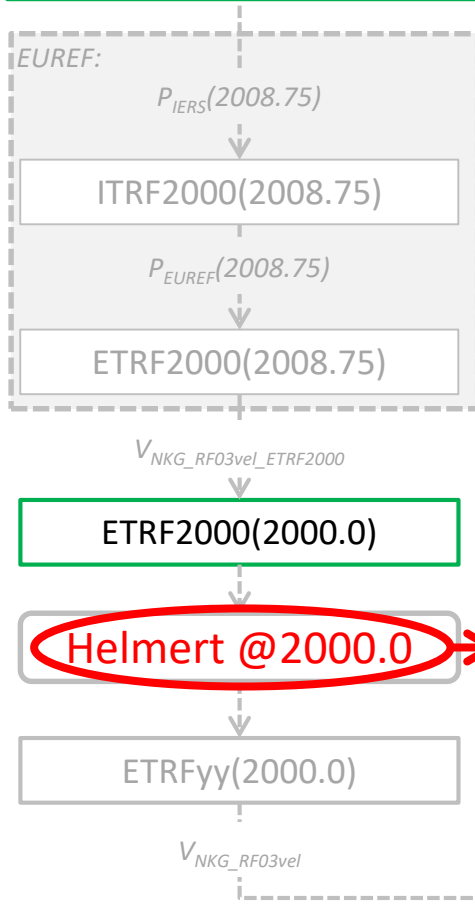
- Initial GNSS solution in IGB08(2008.75): 1/1/3 mm
- Common RF in **ETRF2000(2000.0): 3.5/2.4/5.4 mm**



National ETRS89 realizations (epoch: t_r)

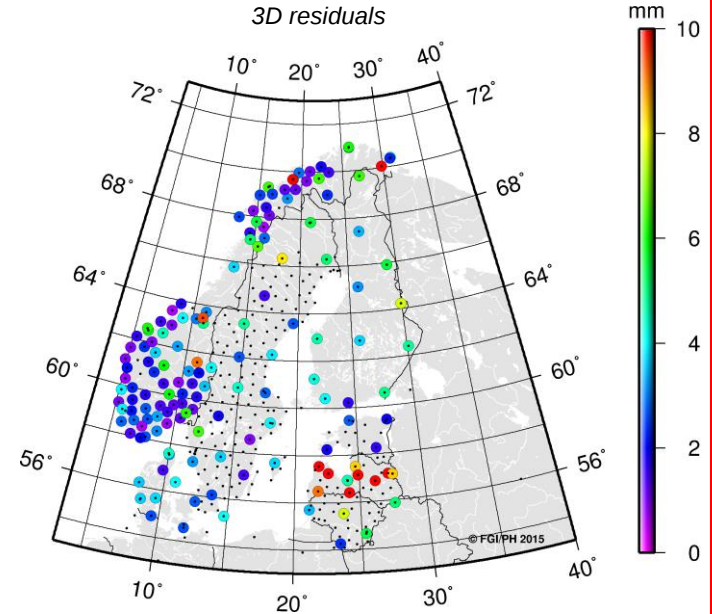
- DK: ETRF92(1994.704)
- FO: ETRF2000(2008.75)
- LV: ETRF89(1992.75)
- NO: ETRF93(1995.0)
- EE: ETRF96(1997.56)
- FI: ETRF96(1997.0)
- LT: ETRF2000(2003.75)
- SE: ETRF97(1999.5)

NKG2008 campaign - ITRF2008(2008.75)



Transformation residuals (country-wise):

- Reflect the consistency of input coordinates (NKG2008 and national ETRS89) and used deformation model
- Mostly some mm-level

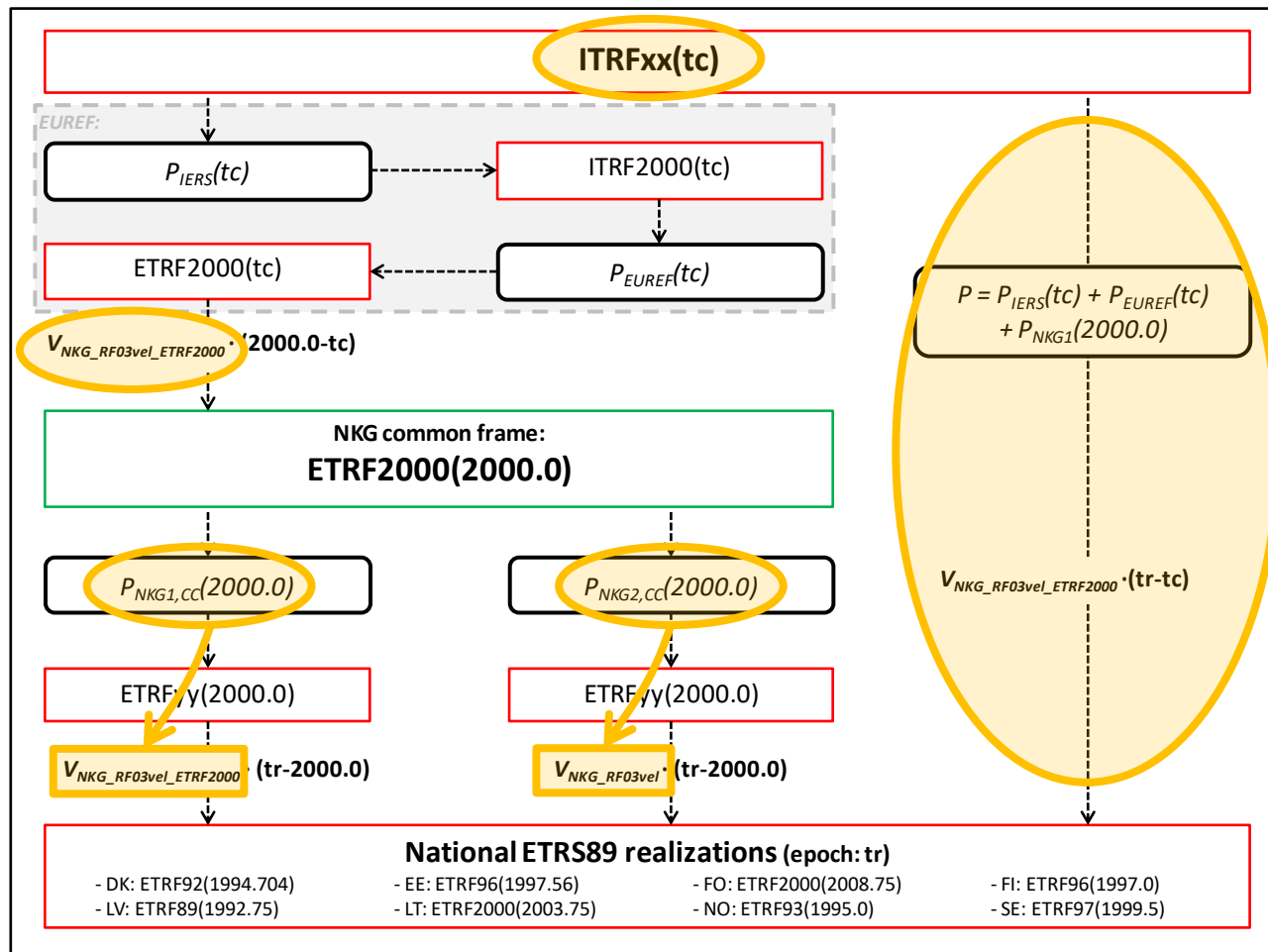


National ETRS89 realizations (epoch: t_r)

- DK: ETRF92(1994.704)
- FO: ETRF2000(2008.75)
- LV: ETRF89(1992.75)
- NO: ETRF93(1995.0)
- EE: ETRF96(1997.56)
- FI: ETRF96(1997.0)
- LT: ETRF2000(2003.75)
- SE: ETRF97(1999.5)

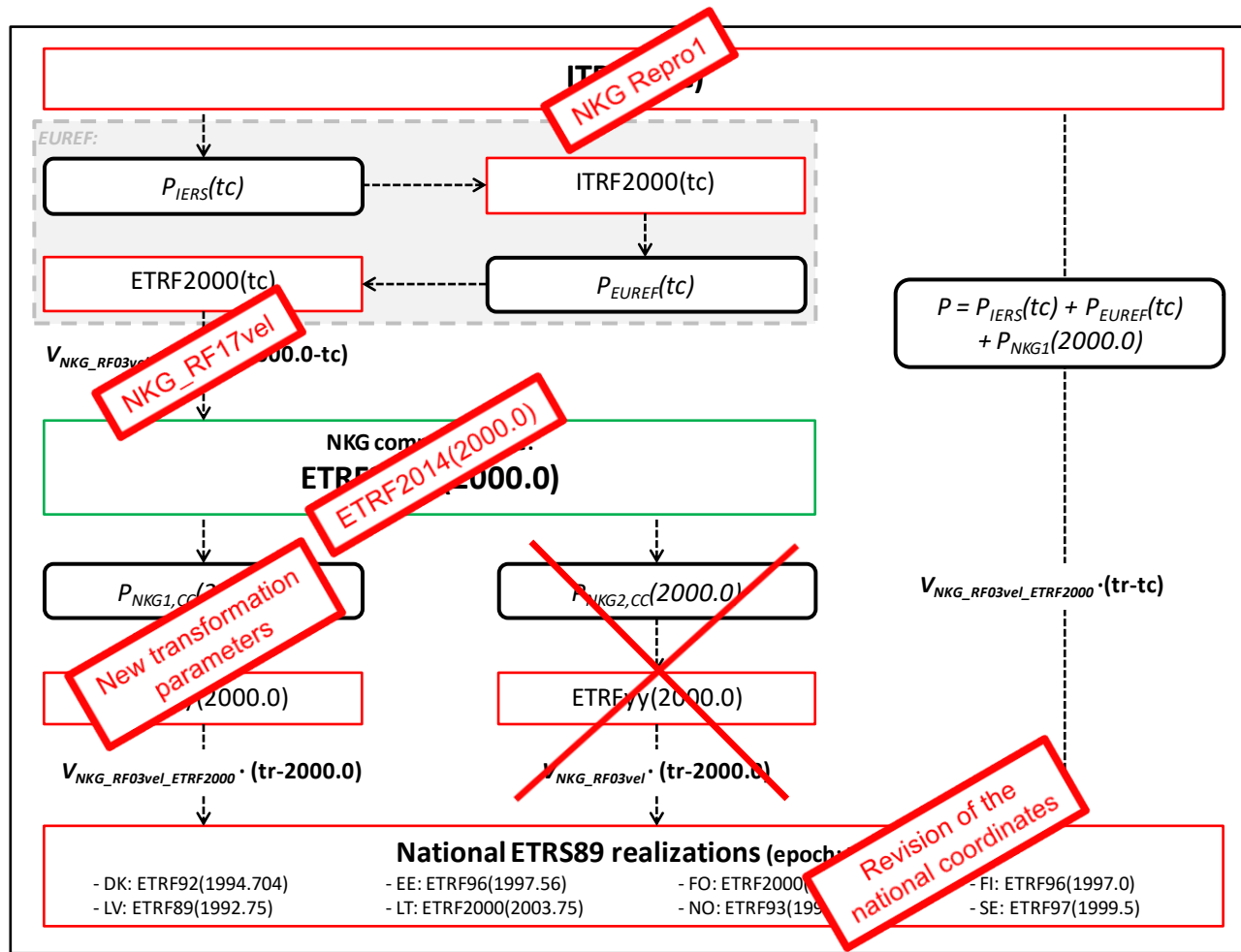
NKG(2008) transformation

- Supports all ITRF realizations and epochs
- Includes intraplate corrections and national transformation parameters to enable (sub-)cm level accuracies
- Includes several steps but can be simplified by summation of parameters and corrections
- **IMPLEMENTED IN PROJ!**



NKG(2019) transformation

- NKG transformation will be updated soon
- ITRF coordinates (as input for parameter estimation) updated – based on time series
- Updated intraplate model
- National ETRS89 coordinates revised
- New transformation parameters
- Will be implemented in PROJ as well



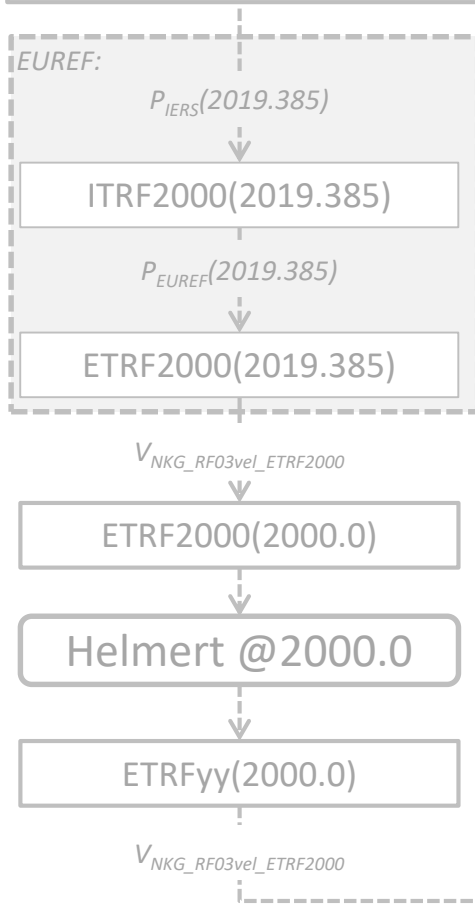
PROJ

Example **step-by-step**: ITRF2014@t_obs → EUREF-EST97



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ITRF2014 coordinates



Location: Mustamäe tee 51, Tallinn → lat=59.421, lon=24.698, h=25

Epoch: 2019-05-21 12:00:00 → t=2019.385

Convert geodetic coordinates to cartesian

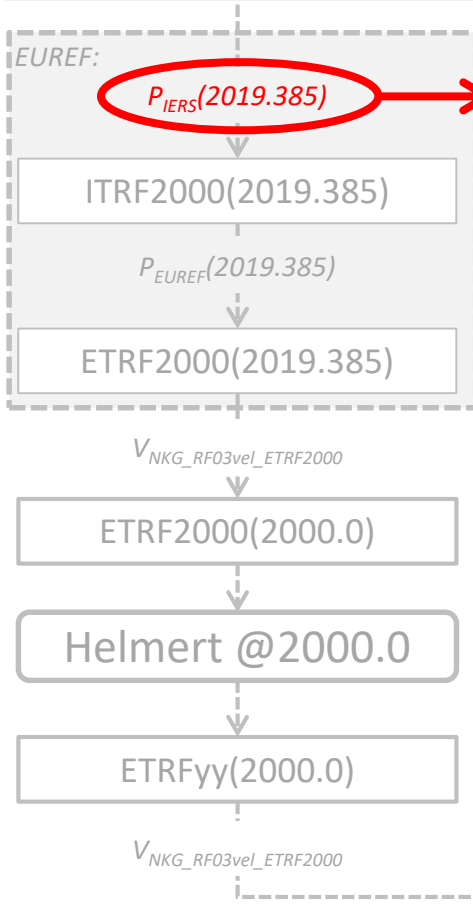
> echo 59.421 24.698 25 | **cct** -t 2019.385 -c2,1,3 +proj=cart +ellps=GRS80

2955257.5973 1359141.6460 5467964.5254 2019.3850

National ETRS89 realizations (epoch: t_r)

- | | |
|-------------------------|-------------------------|
| - DK: ETRF92(1994.704) | - EE: ETRF96(1997.56) |
| - FO: ETRF2000(2008.75) | - FI: ETRF96(1997.0) |
| - LV: ETRF89(1992.75) | - LT: ETRF2000(2003.75) |
| - NO: ETRF93(1995.0) | - SE: ETRF97(1999.5) |

ITRF2014(2019.385)



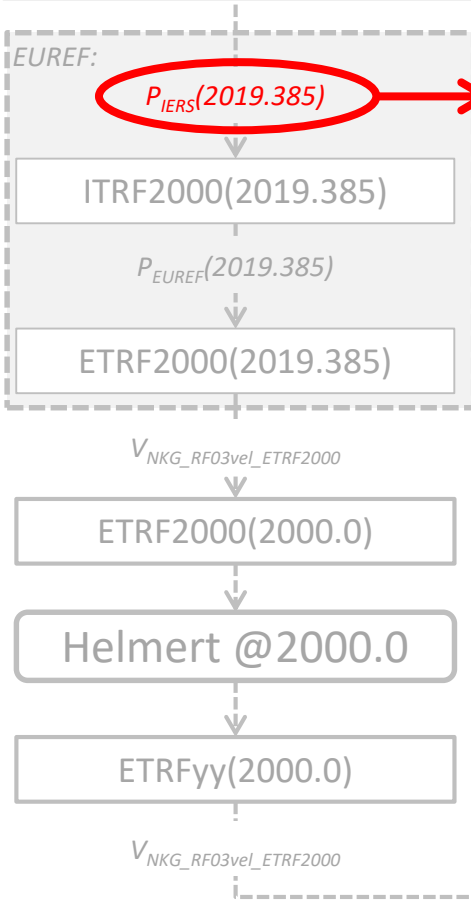
Helmert transformation: **+proj=helmert**

- **+<x/ly/z/s/rx/ry/rz/dx/dy/dz/ds/drx/dry/drz>**
- **+convention=coordinate_frame/position_vector** (New in version 5.2.0.)
Indicates the *convention to express the rotational terms* when a 3D-Helmert / 7-parameter more transform is involved. As soon as a rotational parameter is specified (one of rx, ry, rz, drx, dry, drz), convention is required. This parameter is ignored when only a 3-parameter (translation terms only: x, y, z), 4-parameter (3-parameter and theta) or 6-parameter (3-parameter and their derivative terms) is used. The result obtained with parameters specified in a given convention can be obtained in the other convention by negating the rotational parameters (rx, ry, rz, drx, dry, drz).
- **+t_epoch=<value>**
Central epoch of transformation given in decimal year. Only used *spatiotemporal transformations*.
- Units: translations [m], rotations [arcsec], scale [ppm]

National ETRS89 realizations (epoch: t_r)

- | | |
|-------------------------|-------------------------|
| - DK: ETRF92(1994.704) | - EE: ETRF96(1997.56) |
| - FO: ETRF2000(2008.75) | - FI: ETRF96(1997.0) |
| - LV: ETRF89(1992.75) | - LT: ETRF2000(2003.75) |
| - NO: ETRF93(1995.0) | - SE: ETRF97(1999.5) |

ITRF2014(2019.385)



1. ITRF2014→ITRF2000@t=2019.385 (14 parameters by IERS, see: http://itrf.ign.fr/doc_ITRF/Transfo-ITRF2014_ITRFs.txt)

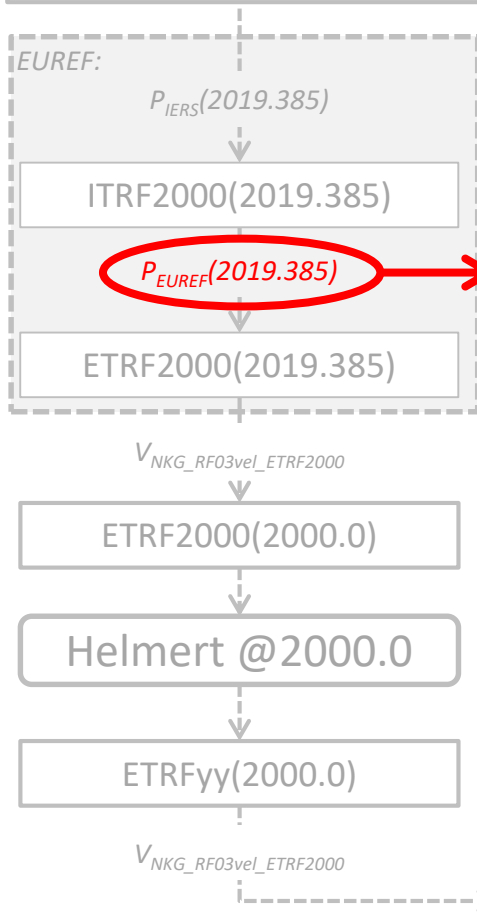
```
> echo 2955257.5973 1359141.6460 5467964.5254 2019.3850 | cct +ellps=GRS80  
+proj=helmert +x=0.0007 +y=0.0012 +z=-0.0261 +s=0.00212 +rx=0 +ry=0 +rz=0  
+dx=0.0001 +dy=0.0001 +dz=-0.0019 +ds=0.00011 +drx=0 +dry=0 +drz=0  
+t_epoch=2010.0 +convention=position_vector
```

2955257.6083 1359141.6524 5467964.4987 2019.3850

National ETRS89 realizations (epoch: t_r)

- DK: ETRF92(1994.704)
- EE: ETRF96(1997.56)
- FO: ETRF2000(2008.75)
- FI: ETRF96(1997.0)
- LV: ETRF89(1992.75)
- LT: ETRF2000(2003.75)
- NO: ETRF93(1995.0)
- SE: ETRF97(1999.5)

ITRF2014(2019.385)



1. ITRF2014→ITRF2000@t=2019.385

2. ITRF2000→ETRF2000@t=2019.385 (6 (14) parameters by EUREF, see EUREF Technical Note 1, eq. 2 and Table 1: <http://etrs89.ensg.ign.fr/pub/EUREF-TN-1.pdf>)

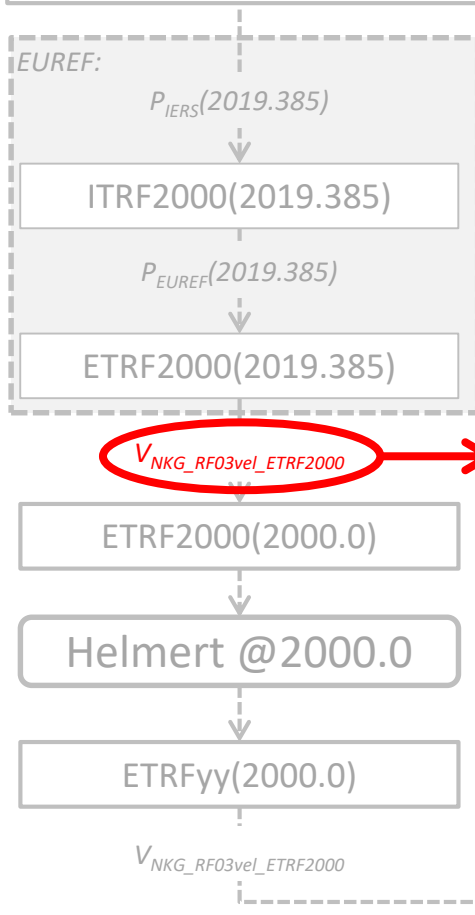
```
> echo 2955257.6083 1359141.6524 5467964.4987 2019.3850 | cct +proj=helmert  
+x=0.054 +y=0.051 +z=-0.048 +drx=0.000081 +dry=0.000490 +drz=-0.000792  
+t_epoch=1989.0 +convention=position_vector
```

```
2955258.2156 1359141.2934 5467964.2536 2019.3850
```

National ETRS89 realizations (epoch: t_r)

- DK: ETRF92(1994.704)
- EE: ETRF96(1997.56)
- FO: ETRF2000(2008.75)
- FI: ETRF96(1997.0)
- LV: ETRF89(1992.75)
- LT: ETRF2000(2003.75)
- NO: ETRF93(1995.0)
- SE: ETRF97(1999.5)

ITRF2014(2019.385)



Kinematic datum shifting utilizing a deformation model:

+proj=deformation

- The deformation model is represented as a grid of velocities in three dimensions. For a given coordinate, (X, Y, Z) , velocities (V_X, V_Y, V_Z) can be interpolated from the gridded model. The **time span between t_{obs} and t_c** determine the magnitude of the coordinate correction:

$$\begin{pmatrix} X \\ Y \\ Z \end{pmatrix}_B = \begin{pmatrix} X \\ Y \\ Z \end{pmatrix}_A + (t_{obs} - t_c) \begin{pmatrix} V_X \\ V_Y \\ V_Z \end{pmatrix}$$

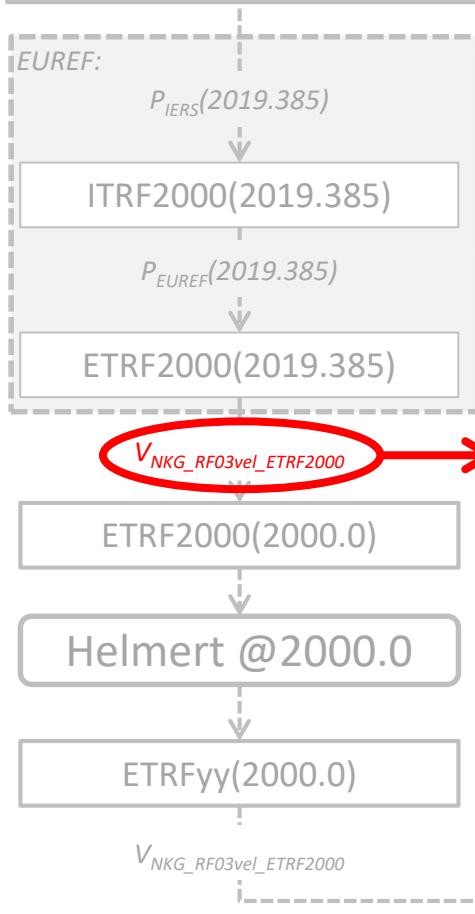
- Corrections are done in cartesian space.** Coordinates of the gridded model are typically in ENU (east, north, up) space. The conversion from ENU space to cartesian space is done in the following way:

$$\begin{pmatrix} X \\ Y \\ Z \end{pmatrix} = \begin{pmatrix} -\sin \phi \cos \lambda N - \sin \lambda E + \cos \phi \cos \lambda U \\ -\sin \phi \sin \lambda N + \sin \lambda E + \cos \phi \sin \lambda U \\ \cos \phi N + \sin \phi U \end{pmatrix}$$

National ETRS89 realizations (epoch: t_r)

- DK: ETRF92(1994.704)
- FO: ETRF2000(2008.75)
- LV: ETRF89(1992.75)
- NO: ETRF93(1995.0)
- EE: ETRF96(1997.56)
- FI: ETRF96(1997.0)
- LT: ETRF2000(2003.75)
- SE: ETRF97(1999.5)

ITRF2014(2019.385)



Kinematic datum shifting utilizing a deformation model:

+proj=deformation

+xy_grids=<list>

Comma-separated list of grids to load. If a grid is prefixed by an @ the grid is considered optional and PROJ will not complain if the grid is not available. Grids for the horizontal component of a deformation model are expected to be in **CTable2 format** (see <https://gdal.org/>)

+z_grids=<list>

Comma-separated list of grids to load. If a grid is prefixed by an @ the grid is considered optional and PROJ will not complain if the grid is not available. Grids for the vertical component of a deformation model are expected to be in **GTX format** (see <https://gdal.org/>)

+t_epoch=<value>

Central epoch of transformation given in decimal years. Will be used in conjunction with the observation time from the input coordinate to determine dt .

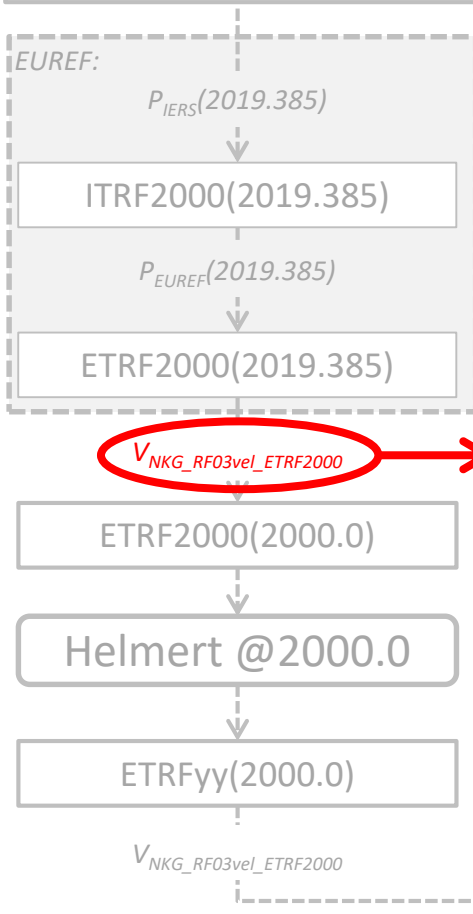
+dt=<value> (New in version 6.0.0.)

Time difference in decimal years. Useful when no observation time is available in the input coordinate or when a deformation for a specific timespan needs to be applied in a transformation.

National ETRS89 realizations (epoch: t_r)

- | | |
|-------------------------|-------------------------|
| - DK: ETRF92(1994.704) | - EE: ETRF96(1997.56) |
| - FO: ETRF2000(2008.75) | - FI: ETRF96(1997.0) |
| - LV: ETRF89(1992.75) | - LT: ETRF2000(2003.75) |
| - NO: ETRF93(1995.0) | - SE: ETRF97(1999.5) |

ITRF2014(2019.385)



1. ITRF2014→ITRF2000@t=2019.385

2. ITRF2000→ETRF2000@t=2019.385

3. ETRF2000@t=2019.385→ETRF2000@t=2000.0 (using NKG deformation model NKG_RF03vel_ETRF2000)

> echo 2955258.2156 1359141.2934 5467964.2536 2019.3850 | **cct** +ellps=GRS80
+proj=deformation +t_epoch=2000.0 +xy_grids=nkgrf03vel_realigned_xy.ct2
+z_grids=nkgrf03vel_realigned_z.gtx +inv

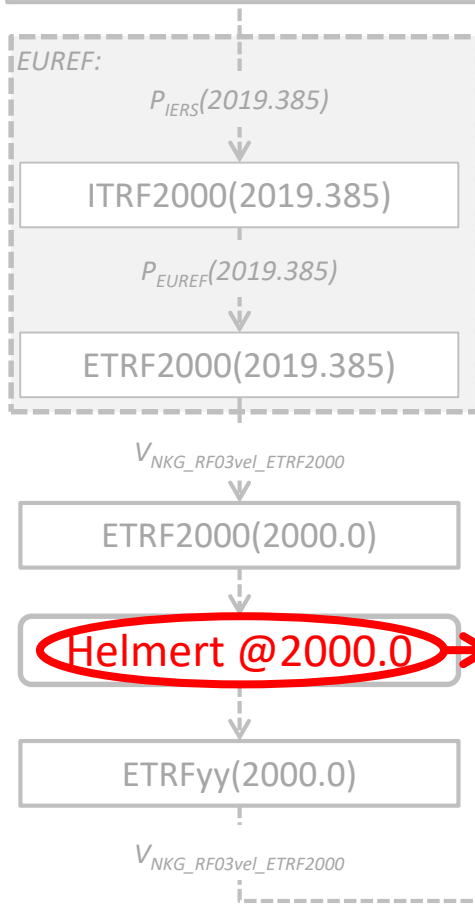
2955258.1812 1359141.2732 5467964.2258 2019.3850

Note: The **timestamp of the resulting coordinate is still 2019.385**. The observation time is always kept unchanged as it would otherwise be impossible to do the inverse transformation.

National ETRS89 realizations (epoch: t_r)

- DK: ETRF92(1994.704)
- EE: ETRF96(1997.56)
- FO: ETRF2000(2008.75)
- FI: ETRF96(1997.0)
- LV: ETRF89(1992.75)
- LT: ETRF2000(2003.75)
- NO: ETRF93(1995.0)
- SE: ETRF97(1999.5)

ITRF2014(2019.385)



1. ITRF2014→ITRF2000@t=2019.385

2. ITRF2000→ETRF2000@t=2019.385

3. ETRF2000@t=2019.385→ETRF2000@t=2000.0

4. ETRF2000→ETRF96@t=2000.0 (using national transformation parameters for Estonia: $P_{NKG1.EE}$ given in <https://doi.org/10.1515/jogs-2016-0001>)

> echo 2955258.1812 1359141.2732 5467964.2258 2000.0000 | **cct +proj=helmert**
 +x=0.12194 +y=0.02225 +z=-0.03541 +s=-0.005626 +rx=0.00227196 +ry=-
 0.00323934 +rz=0.00247008 +convention=position_vector

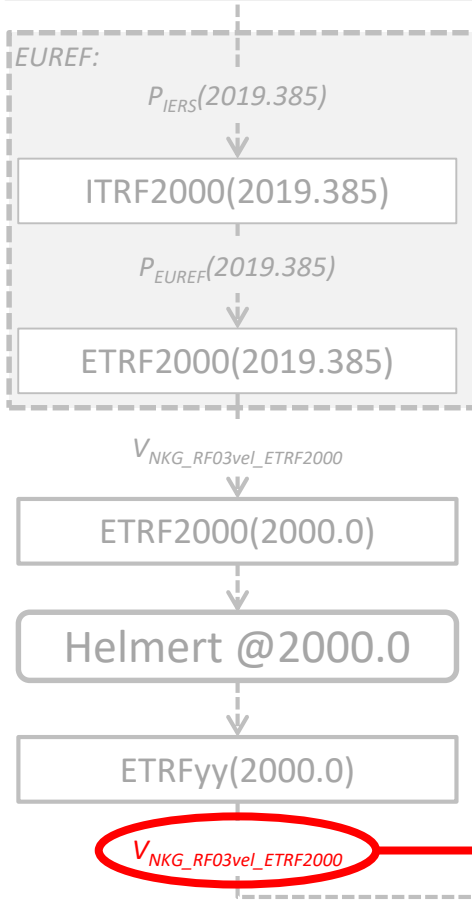
2955258.1844 1359141.2630 5467964.2210 2000.0000

Helmert @2000.0

National ETRS89 realizations (epoch: t_r)

- DK: ETRF92(1994.704)
- EE: ETRF96(1997.56)
- FO: ETRF2000(2008.75)
- FI: ETRF96(1997.0)
- LV: ETRF89(1992.75)
- LT: ETRF2000(2003.75)
- NO: ETRF93(1995.0)
- SE: ETRF97(1999.5)

ITRF2014(2019.385)



1. ITRF2014→ITRF2000@t=2019.385

2. ITRF2000→ETRF2000@t=2019.385

3. ETRF2000@t=2019.385→ETRF2000@t=2000.0

4. ETRF2000→ETRF96@t=2000.0

5. ETRF96@t=2000.0→ETRF96@t=1997.56 (using NKG deformation model NKG_RF03vel_ETRF2000)

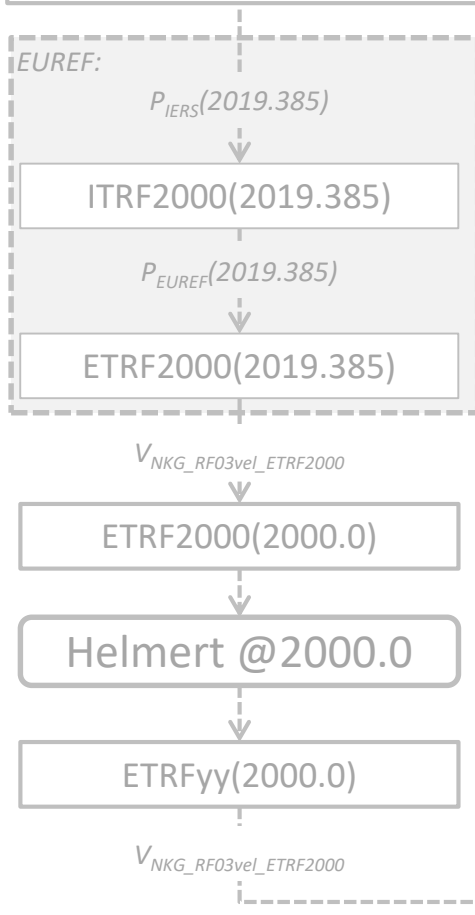
> echo 2955258.1844 1359141.2630 5467964.2210 2000.0000 | **cct +proj=deformation +t_epoch=1997.56 +xy_grids=nkgrf03vel_realigned_xy.ct2 +z_grids=nkgrf03vel_realigned_z.gtx +inv**

2955258.1801 1359141.2605 5467964.2175 2000.0000

National ETRS89 realizations (epoch: t_r)

- DK: ETRF92(1994.704)
- FO: ETRF2000(2008.75)
- LV: ETRF89(1992.75)
- NO: ETRF93(1995.0)
- **EE: ETRF96(1997.56)**
- FI: ETRF96(1997.0)
- LT: ETRF2000(2003.75)
- SE: ETRF97(1999.5)

ITRF2014(2019.385)



1. ITRF2014→ITRF2000@t=2019.385

2. ITRF2000→ETRF2000@t=2019.385

3. ETRF2000@t=2019.385→ETRF2000@t=2000.0

4. ETRF2000→ETRF96@t=2000.0

5. ETRF96@t=2000.0→ETRF96@t=1997.56

Coordinate difference EUREF-EST97 – ITRF2014(2019.385):

→ $dN_{tot} = -0.474$, $dE_{tot} = -0.594$, $dU_{tot} = -0.078$ [m]

→ $dN_{def} = 0.023$, $dE_{def} = -0.004$, $dU_{def} = -0.050$ [m]

National ETRS89 realizations (epoch: t_r)

- | | |
|-------------------------|------------------------------|
| - DK: ETRF92(1994.704) | - EE: ETRF96(1997.56) |
| - FO: ETRF2000(2008.75) | - FI: ETRF96(1997.0) |
| - LV: ETRF89(1992.75) | - LT: ETRF2000(2003.75) |
| - NO: ETRF93(1995.0) | - SE: ETRF97(1999.5) |

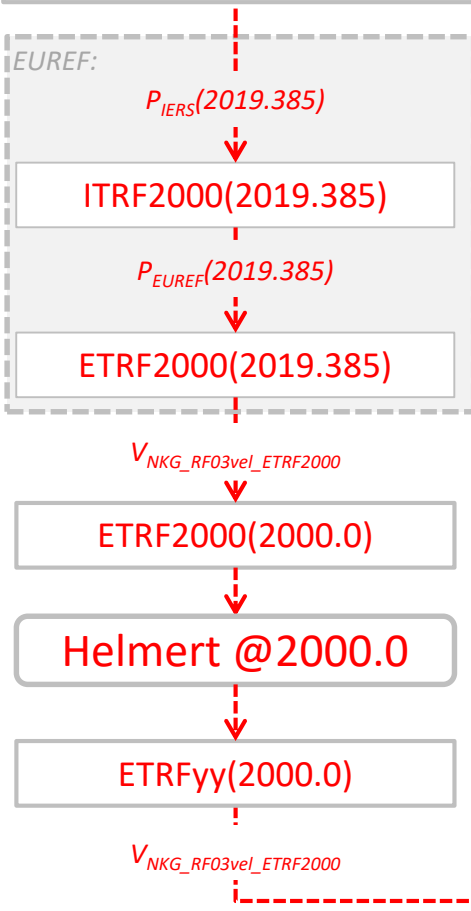
PROJ

Example **using pipelines**: ITRF2014@t_obs → EUREF-EST97



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ITRF2014(2019.385)



The pipeline operator: +proj=pipeline

With the pipeline operation it is possible to perform several operations after each other on the same input data. This feature makes it possible to create transformations that are made up of more than one operation, e.g. performing a datum shift and then applying a suitable map projection. A pipeline is made up of a number of steps, with each step being a coordinate operation in itself. By connecting these individual steps sequentially we end up with a concatenated coordinate operation.

+step

Separate each step in a pipeline

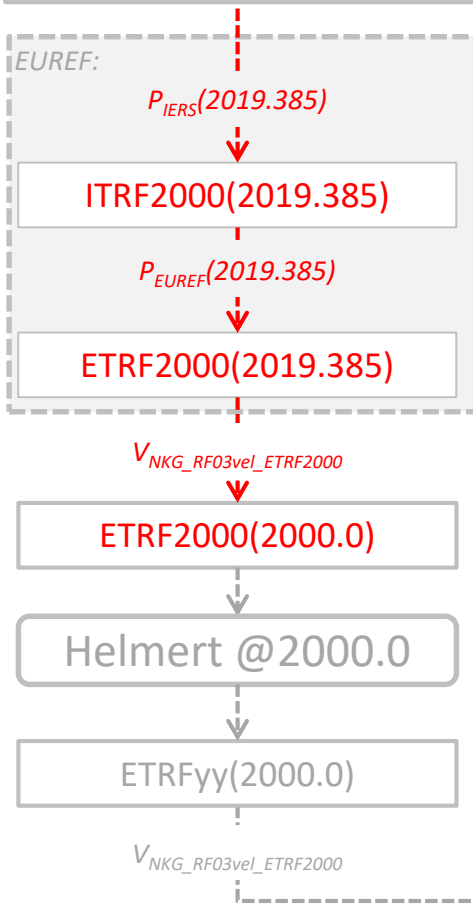
Rules for pipelines:

1. Pipelines must consist of at least one step
2. Pipelines can only be nested if the nested pipeline is defined in an init-file
3. Pipelines without a forward path can't be constructed (e.g. projection Urmaev V does not have an inverse operation defined)
4. Parameters added before the first '+step' are global and will be applied to all steps
5. Units of operations must match between steps

National ETRS89 realizations (epoch: t_r)

- | | |
|-------------------------|------------------------------|
| - DK: ETRF92(1994.704) | - EE: ETRF96(1997.56) |
| - FO: ETRF2000(2008.75) | - FI: ETRF96(1997.0) |
| - LV: ETRF89(1992.75) | - LT: ETRF2000(2003.75) |
| - NO: ETRF93(1995.0) | - SE: ETRF97(1999.5) |

ITRF2014(2019.385)



Pipeline 1: ITRF2014@2019.385 → NKG_ETRF00 (common NKG frame)

```
> echo 59.421 24.698 25 | cct -t 2019.385 -c2,1,3 +ellps=GRS80 +proj=pipeline \
```

```
+step +proj=cart \
```

```
+step +proj=helmert +x=0.0007 +y=0.0012 +z=-0.0261 +s=0.00212 +dx=0.0001 +dy=0.0001  
+dz=-0.0019 +ds=0.00011 +t_epoch=2010.0 +convention=position_vector \
```

```
+step +proj=helmert +x=0.054 +y=0.051 +z=-0.048 +drx=0.000081 +dry=0.000490 +drz=-  
0.000792 +t_epoch=1989.0 +convention=position_vector \
```

```
+step +proj=deformation +t_epoch=2000.0 +xy_grids=nkgrf03vel_realigned_xy.ct2  
+z_grids=nkgrf03vel_realigned_z.gtx +inv
```

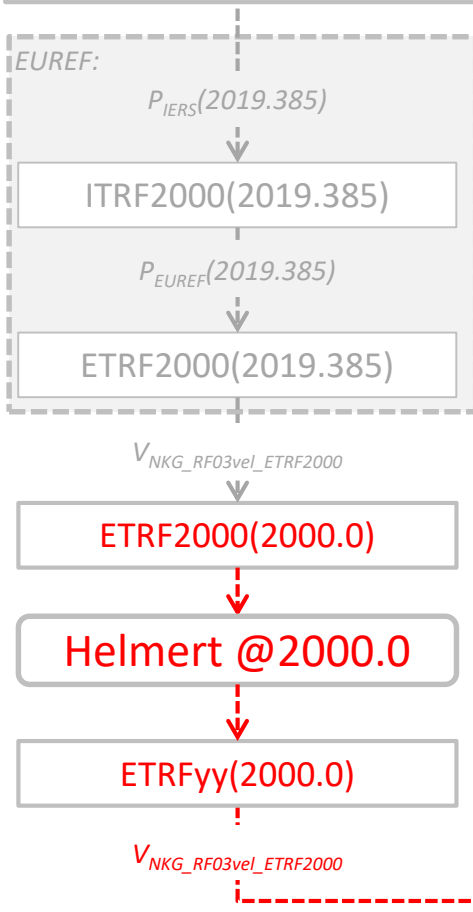
2955258.1812 1359141.2732 5467964.2258 2019.3850

Note: The **timestamp of the resulting coordinate is still 2019.385**. The observation time is always kept unchanged as it would otherwise be impossible to do the inverse transformation.

National ETRS89 realizations (epoch: t_r)

- DK: ETRF92(1994.704)
- FO: ETRF2000(2008.75)
- LV: ETRF89(1992.75)
- NO: ETRF93(1995.0)
- **EE: ETRF96(1997.56)**
- FI: ETRF96(1997.0)
- LT: ETRF2000(2003.75)
- SE: ETRF97(1999.5)

ITRF2014(2019.385)



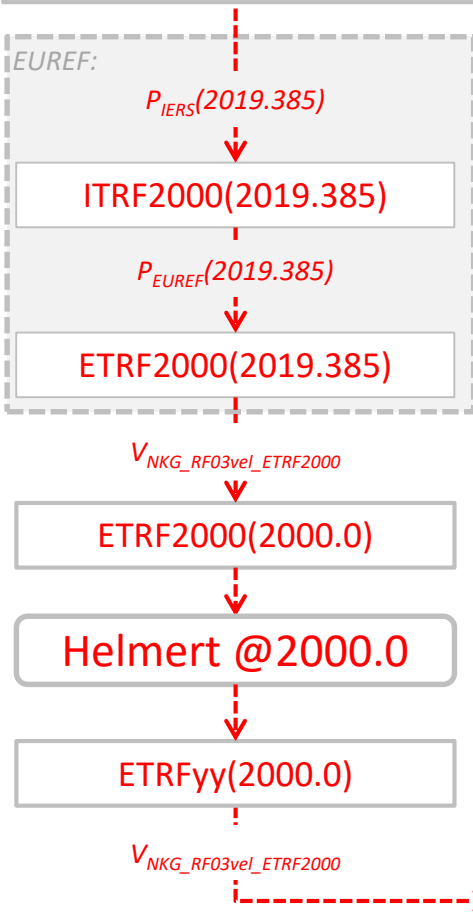
Pipeline 2: NKG ETRF00→EUREF-EST97

```
> echo 2955258.1812 1359141.2732 5467964.2258 2000.0 | cct +ellps=GRS80 +proj=pipeline \
+step +proj=helmert +x=0.12194 +y=0.02225 +z=-0.03541 +s=-0.005626 +rx=0.00227196 +ry=-
0.00323934 +rz=0.00247008 +convention=position_vector \
+step +proj=deformation +t_epoch=1997.56 +xy_grids=nkgrf03vel_realigned_xy.ct2
+z_grids=nkgrf03vel_realigned_z.gtx +inv
2955258.1800 1359141.2604 5467964.2175 2000.0000
```

National ETRS89 realizations (epoch: t_r)

- DK: ETRF92(1994.704)
- FO: ETRF2000(2008.75)
- LV: ETRF89(1992.75)
- NO: ETRF93(1995.0)
- EE: ETRF96(1997.56)
- FI: ETRF96(1997.0)
- LT: ETRF2000(2003.75)
- SE: ETRF97(1999.5)

ITRF2014(2019.385)



One pipeline: ITRF2014@2019.385 → EUREF-EST97

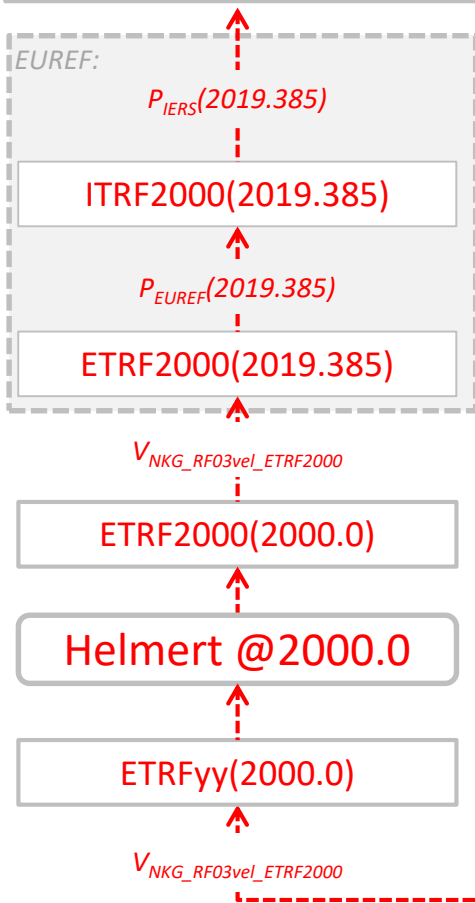
```
> echo 59.421 24.698 25 | cct -t 2019.385 -c2,1,3 +ellps=GRS80 +proj=pipeline \  
+step +proj=cart \  
+step +proj=helmert +x=0.0007 +y=0.0012 +z=-0.0261 +s=0.00212 +dx=0.0001 +dy=0.0001 +dz=-0.0019 \  
+ds=0.00011 +t_epoch=2010.0 +convention=position_vector \  
+step +proj=helmert +x=0.054 +y=0.051 +z=-0.048 +drx=0.000081 +dry=0.000490 +drz=-0.000792 \  
+t_epoch=1989.0 +convention=position_vector \  
+step +proj=deformation +t_epoch=2000.0 +xy_grids=nkgrf03vel_realigned_xy.ct2 \  
+z_grids=nkgrf03vel_realigned_z.gtx +inv \  
+step +proj=helmert +x=0.12194 +y=0.02225 +z=-0.03541 +s=-0.005626 +rx=0.00227196 +ry=-0.00323934 +rz=0.00247008 +convention=position_vector \  
+step +ellps=GRS80 +proj=deformation +dt=2.44 +xy_grids=nkgrf03vel_realigned_xy.ct2 \  
+z_grids=nkgrf03vel_realigned_z.gtx +inv
```

2955258.1800 1359141.2605 5467964.2175 2019.3850

National ETRS89 realizations (epoch: t_r)

- DK: ETRF92(1994.704)
- FO: ETRF2000(2008.75)
- LV: ETRF89(1992.75)
- NO: ETRF93(1995.0)
- EE: ETRF96(1997.56)
- FI: ETRF96(1997.0)
- LT: ETRF2000(2003.75)
- SE: ETRF97(1999.5)

ITRF2014(2019.385)



One pipeline backwards: EUREF-EST97 → ITRF2014@2019.385

```
> echo 2955258.1800 1359141.2605 5467964.2176 2019.3850 | pcr +ellps=GRS80 +proj=pipeline \
+step +ellps=GRS80 +proj=deformation +dt=2.44 +xy_grids=nkgrf03vel_realigned_xy.ct2
+z_grids=nkgrf03vel_realigned_z.gtx \ # +inv removed
+step +proj=helmert +x=0.12194 +y=0.02225 +z=-0.03541 +s=-0.005626 +rx=0.00227196 +ry=-
0.00323934 +rz=0.00247008 +convention=position_vector +inv \
+step +proj=deformation +t_epoch=2000.0 +xy_grids=nkgrf03vel_realigned_xy.ct2
+z_grids=nkgrf03vel_realigned_z.gtx \ # +inv removed
+step +proj=helmert +x=0.054 +y=0.051 +z=-0.048 +drx=0.000081 +dry=0.000490 +drz=-0.000792
+t_epoch=1989.0 +convention=position_vector +inv \
+step +proj=helmert +x=0.0007 +y=0.0012 +z=-0.0261 +s=0.00212 +dx=0.0001 +dy=0.0001 +dz=-0.0019
+ds=0.00011 +t_epoch=2010.0 +convention=position_vector +inv \
+step +proj=cart +inv \
24.6980000009 59.4210000001 25.0000 2019.3850
```

National ETRS89 realizations (epoch: t_r)

- DK: ETRF92(1994.704)
- FO: ETRF2000(2008.75)
- LV: ETRF89(1992.75)
- NO: ETRF93(1995.0)
- EE: ETRF96(1997.56)
- FI: ETRF96(1997.0)
- LT: ETRF2000(2003.75)
- SE: ETRF97(1999.5)

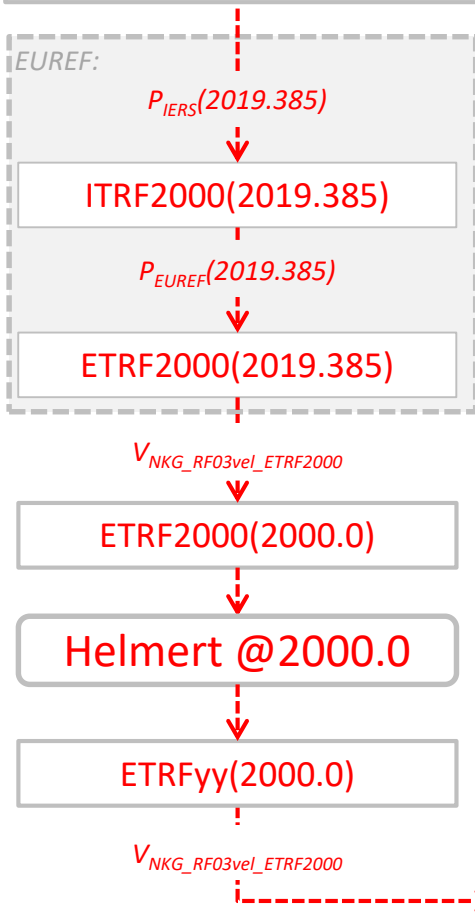
PROJ

Example **using parameter files**: ITRF2014@t_obs → EUREF-EST97



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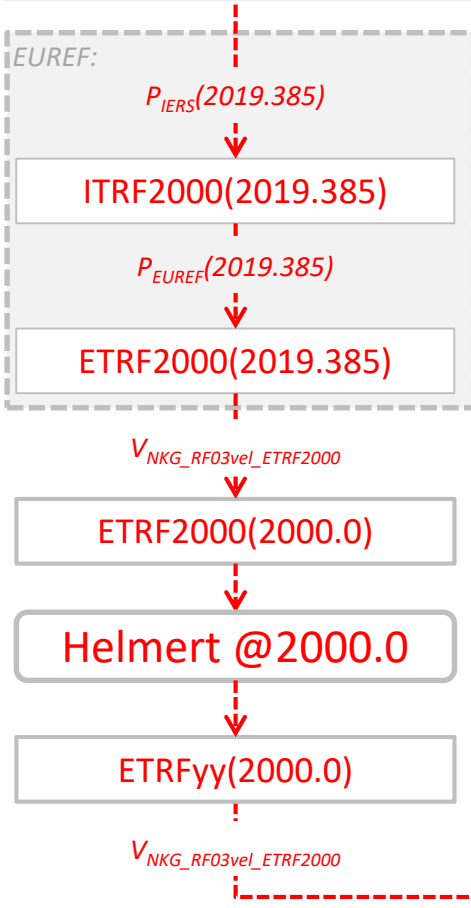
Resource files: +init

- A number of files containing **preconfigured transformations** and default parameters for certain projections are bundled with the PROJ distribution. Init files contains preconfigured proj-strings for various coordinate reference systems and the defaults file contains default values for parameters of select projections.
- In addition to the bundled init-files the PROJ.4 project also distribute a number of packages containing transformation grids and additional init-files not included in the main PROJ package.
 - The **proj-datumgrid package** provides transformation grids that are essential for many of the predefined transformations in PROJ. Which grids are included in the package can be seen on the proj-datumgrid repository as well as descriptions of those grids. In addition to the default proj-datumgrid package regional packages are also distributed. These include grids and init-files that are valid within the given region.
- A number of init files come pre-bundled with PROJ but it is also possible to add your own **custom init files**. PROJ looks for the init files in the directory listed in the PROJ_LIB environment variable.

National ETRS89 realizations (epoch: t_r)

- | | |
|-------------------------|------------------------------|
| - DK: ETRF92(1994.704) | - EE: ETRF96(1997.56) |
| - FO: ETRF2000(2008.75) | - FI: ETRF96(1997.0) |
| - LV: ETRF89(1992.75) | - LT: ETRF2000(2003.75) |
| - NO: ETRF93(1995.0) | - SE: ETRF97(1999.5) |

ITRF2014(2019.385)



Resource files: +init

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Installation Using PROJ Applications Coordinate operations Resource files Geodesic calculations Development Community FAQ Glossary References

Docs » Download

Download

Here you can download current and previous releases of PROJ. We only supply a distribution of the source code and various resource file archives. See [Installation](#) for information on how to get pre-built packages of PROJ.

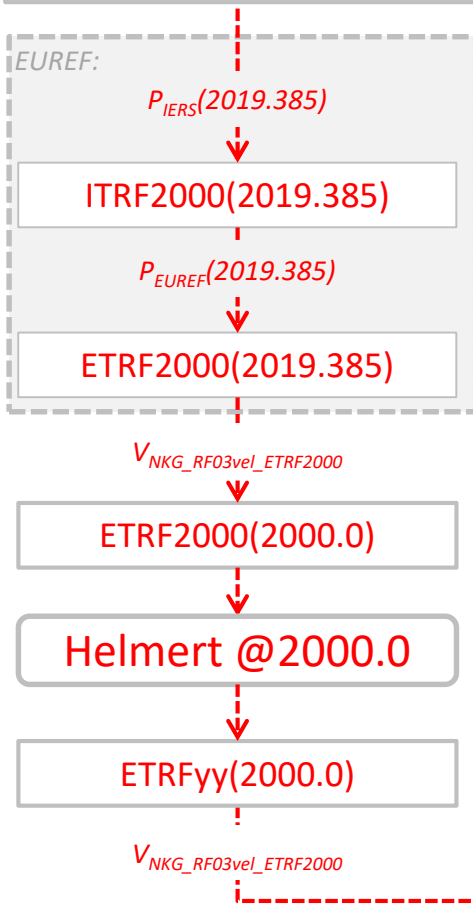
Current Release

- 2019-05-15 proj-6.1.0.tar.gz (md5)
- 2018-09-15 proj-datumgrid-1.8.zip
- 2019-03-01 proj-datumgrid-europe-1.3.zip
- 2019-03-01 proj-datumgrid-north-america-1.2.zip
- 2018-03-01 proj-datumgrid-oceania-1.0.zip
- 2019-03-01 proj-datumgrid-world-1.0.zip
- PDF Manual proj.pdf

Past Releases

- 2019-03-01 proj-6.0.0.tar.gz
- 2018-09-15 proj-5.2.0.tar.gz
- 2018-06-01 proj-5.1.0.tar.gz
- 2018-04-01 proj-5.0.1.tar.gz
- 2018-03-01 proj-5.0.0.tar.gz
- 2016-09-02 proj-4.9.3.tar.gz

ITRF2014(2019.385)



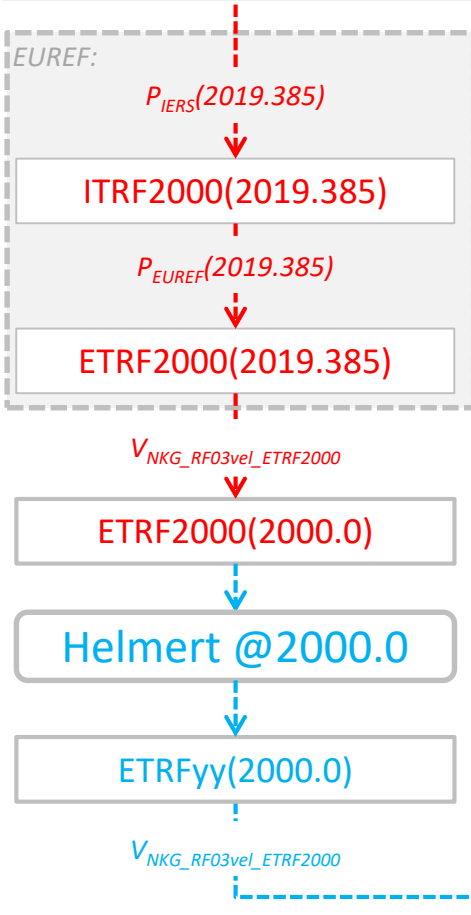
Examples of resource files:

- Included in PROJ installation package:
 - Parameter files: e.g. ITRF2014, ITRF2008, NAD83,...
 - Grid files: EGM96 geoid model,...
- Additional datum package - Europe:
 - Parameter and grid files: e.g. **NKG**, Denmark, Great Britain, France (overseas territories), Sweden (geoid model), etc...
- External datumgrid files should be extracted under share\proj in PROJ's installation folder
 - Conda installs by default: C:\Users\<user>\AppData\Local\Continuum\miniconda2\Library

National ETRS89 realizations (epoch: t_r)

- | | |
|-------------------------|------------------------------|
| - DK: ETRF92(1994.704) | - EE: ETRF96(1997.56) |
| - FO: ETRF2000(2008.75) | - FI: ETRF96(1997.0) |
| - LV: ETRF89(1992.75) | - LT: ETRF2000(2003.75) |
| - NO: ETRF93(1995.0) | - SE: ETRF97(1999.5) |

ITRF2014(2019.385)



NKG parameter file (<https://proj4.org/download.html> > proj-datumgrid-europe-1.2.zip >

NKG

> echo

29552

> echo

+in

29552

> echo

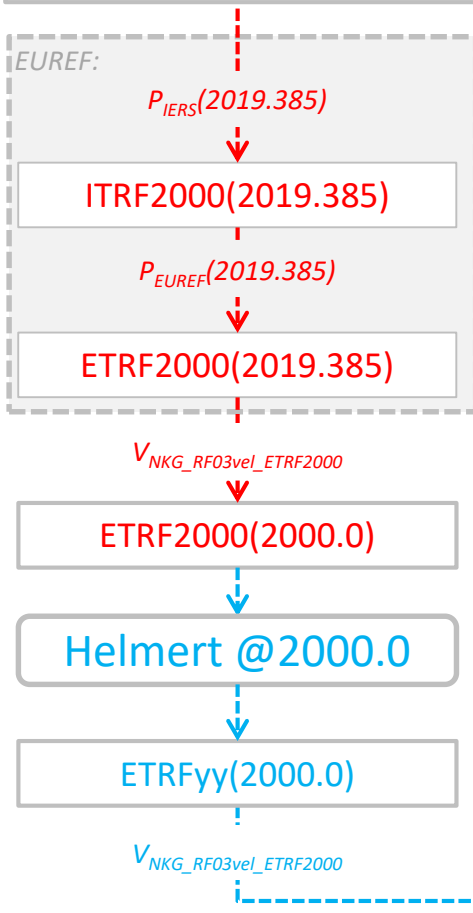
24.69

> echo

29552

```
C:\Users\ph\Desktop\NKG - Notepad++
File Edit Search View Encoding Language Settings Tools Macro Run Plugins Window ?
NKG
31 #####
32
33 # NKG ETRF00 -> ITRF2008
34 <ITRF2008> prq1 = pipeline ellps = GRS80
35
36 # NKG ETRF00@2000.0 -> ETRF00@t_obs
37 step prq1 = deformation t_epoch = 2000.0
38 xy_grids = nkgrf03vel_realigned_xy.ct2
39 z_grids = nkgrf03vel_realigned_z.gtx
40
41 # ETRF00@t_obs -> ITRF2000@t_obs
42 step init = NKG:ITRF2000_ETRF2000 inv
43
44 # ITRF2000@t_obs -> ITRF2008@t_obs
45 step init = ITRF2008:ITRF2000 inv
46
47
48
49 # NKG ETRF00 -> ITRF2014
50 <ITRF2014> prq1 = pipeline ellps = GRS80
51
52 # NKG ETRF00@2000.0 -> ETRF00@t_obs
53 step prq1 = deformation t_epoch = 2000.0
54 xy_grids = nkgrf03vel_realigned_xy.ct2
55 z_grids = nkgrf03vel_realigned_z.gtx
56
57 # ETRF00@t_obs -> ITRF2000@t_obs
58 step init = NKG:ITRF2000_ETRF2000 inv
59
60 # ITRF2000@t_obs -> ITRF2014@t_obs
61 step init = ITRF2014:ITRF2000 inv
62
63 # ITRF2000 -> ETRF2000
64 # Source: Specifications for reference frame fixing in the analysis of a
```

ITRF2014(2019.385)



NKG parameter file (<https://proj4.org/download.html> > proj-datumgrid-europe-1.2.zip > NKG + grids: nkgrf03vel_realigned_xy.ct2 and nkgrf03vel_realigned_z.gtx):

```
> echo 59.421 24.698 25 | cct -t 2019.385 -c2,1,3 +proj=cart +ellps=GRS80
```

```
2955257.5973 1359141.6460 5467964.5254 2019.3850
```

```
> echo 2955257.5973 1359141.6460 5467964.5254 | cct -t 2019.3850 +init=NKG:ITRF2014 +inv
```

```
2955258.1812 1359141.2732 5467964.2258 2019.3850
```

```
> echo 2955258.1812 1359141.2732 5467964.2258 | cct -t 2000.00 +init=NKG:EE
```

```
24.6979895409 59.4209957480 24.9223 2000.0000
```

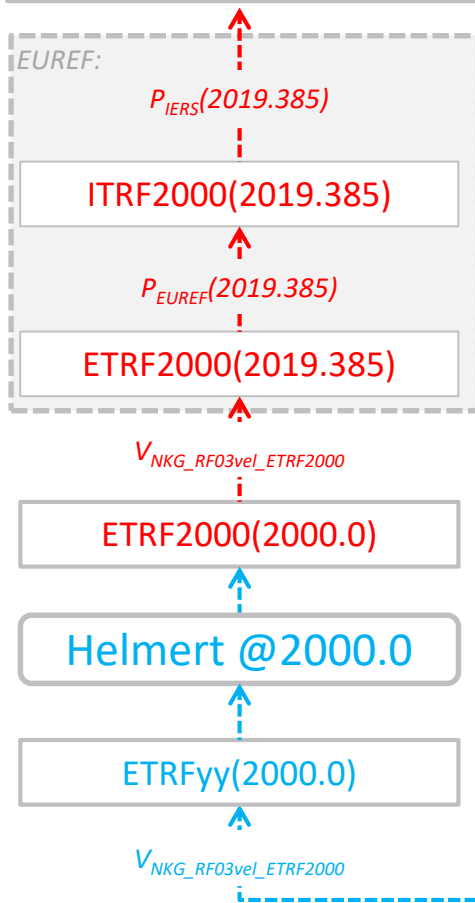
```
> echo 24.6979895409 59.4209957480 24.9223 2000.0000 | cct +proj=cart +ellps=GRS80
```

```
2955258.1800 1359141.2604 5467964.2175 2000.0000
```

National ETRS89 realizations (epoch: t_r)

- DK: ETRF92(1994.704)
- FO: ETRF2000(2008.75)
- LV: ETRF89(1992.75)
- NO: ETRF93(1995.0)
- **EE: ETRF96(1997.56)**
- FI: ETRF96(1997.0)
- LT: ETRF2000(2003.75)
- SE: ETRF97(1999.5)

ITRF2014(2019.385)



NKG parameter file (<https://proj4.org/download.html> > proj-datumgrid-europe-1.2.zip > NKG + grids: nkgrf03vel_realigned_xy.ct2 and nkgrf03vel_realigned_z.gtx):

Backwards: EUREF-EST97→ITRF2014@2019.385

```
> echo 2955258.1800 1359141.2604 5467964.2175 2000.0000 | cct +proj=cart +ellps=GRS80 +inv
```

```
24.6979895407 59.4209957483 24.9223 2000.0000
```

```
> echo 24.6979895407 59.4209957483 24.9223 2000.0000 | cct +init=NKG:EE +inv
```

```
2955258.1812 1359141.2732 5467964.2258 2000.0000
```

```
> echo 2955258.1812 1359141.2732 5467964.2258 2019.3850 | cct +init=NKG:ITRF2014 # +inv removed
```

2955257.5973 1359141.6460 5467964.5254 2019.3850

National ETRS89 realizations (epoch: t_r)

- DK: ETRF92(1994.704)
- EE: ETRF96(1997.56)
- FO: ETRF2000(2008.75)
- FI: ETRF96(1997.0)
- LV: ETRF89(1992.75)
- LT: ETRF2000(2003.75)
- NO: ETRF93(1995.0)
- SE: ETRF97(1999.5)

SUMMARY

- NKG transformation can be used to transform accurately between global (ITRFxx@tc), common Nordic-Baltic and national ETRS89 reference frames and is available to users within PROJ
 - NKG transformation can be performed as steps but more easily using parameter files
- There will be an update to NKG transformation in near future:
 - Based on new ITRF2014 coordinates and revised national ETRS89 coordinates
 - New intraplate/land uplift/PGR/GIA model
 - As soon as it is ready, it will implemented to PROJ as well

THANK YOU!



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