**Coordinate transformation between International Terrestrial Reference System and coordinates used for the islands Bonaire, St. Eustatius and Saba (BES)**

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Version: 17 december 2024



# 1 Introduction

## 1.1 Coordinate systems in the Caribbean Netherlands

The International Terrestrial Reference System (ITRS) is the official worldwide coordinate system. ITRS is prescribed by the United Nations and national and international standards. Precise orbits of Global Navigation Satellite Systems (GNSS) by the International GNSS Service (IGS) for use in Precise Point Positioning (PPP) are given in ITRS.

National and local coordinate systems are linked to ITRS via a regional system like the European Terrestrial Reference System 1989 (ETRS89) or are linked to ITRS directly. The islands Bonaire, St. Eustatius and Saba of the Caribbean Netherlands (Dutch: *BES-eilanden*) each have their own local coordinate system per island, called DPnet, and their own height systems, called KADpeil in Bonaire. St. Eustatius and Saba originally had two variants of the coordinate system, one for the topographic map and the other used for the cadastral map. The difference is a constant shift in the x-coordinate and a constant shift in the y-coordinate. For St. Eustatius, the coordinates of the topographic map are now used, also for the cadastral map. For Saba, the coordinates of the cadastral map are used, also for other purposes.

For storage and exchange of geo-information at sea, the International Hydrographic Organisation (IHO) has agreed upon World Geodetic System 1984 (WGS 84). WGS 84 is the coordinate system used by GPS, the GNSS of the United States' military. WGS 84 and coordinate systems of other GNSS are periodically aligned to ITRS. Since ellipsoidal heights in ITRS and WGS 84 are only geometrical and have no physical meaning, other height references are used too. Dienst der Hydrografie uses WGS 84 coordinates with the maritime reference surface Lowest Astronomical Tide (LAT) as chart datum and publishes the relation of LAT with the geoid model (EGM2008) for the Dutch part of the Caribbean Sea.

## 1.2 Coordinate transformation

Since 1 January 2021, the cadastral organisations of Bonaire, St. Eustatius and Saba are part of the Netherlands' Cadastre, Land Registry and Mapping Agency (Kadaster). Kadaster is working together with the Hydrographic Service of the Royal Netherlands Navy and Rijkswaterstaat in the Netherlands Partnership Geodetic Infrastructure (NSGI) to maintain the geodetic infrastructure.

This document is restricted to the transformation between ITRS and DPnet coordinates of the Caribbean Netherlands. It uses the ITRS realisation ITRF2014 for St. Eustatius and Saba. An older realisation is used for Bonaire, called Bonaire 2004, which corresponds to ITRF2000 at epoch 2001.00 within 0.1 metre. The realisation of WGS 84 currently used by GPS is WGS 84 G2139, which is aligned within a few centimetres to ITRS realisation ITRF2014 (and ITRF2020). The use of map projections like Universal Transverse Mercator (UTM) projection or Web Mercator projection are not described.

This document describes the parameters needed to implement the transformation for Bonaire, St. Eustatius and Saba. ITRS coordinates of fixed points are changing with about 1.8 cm per year due to tectonics of the Caribbean plate. Therefore, the transformation parameters are time-dependent. For Bonaire, the time-dependent parameters of the transformation are not yet determined.

For GIS and other applications where dynamic coordinates are inconvenient, we recommend to use ITRF2014 coordinates at epoch 2020.00 for St. Eustatius and Saba. This reference epoch is a convenient choice as the same epoch will be used by the expected new Caribbean Terrestrial Reference Frame 2022 (CATRF2022).

The precision of the transformation parameters for St. Eustatius and Saba is limited due to: (1) the short span of 1-2 years for the used times series of the used GNSS reference stations, (2) the low number of 6 first-order reference points (Dutch: *DP-punten*) that were measured per island, and (3) the discrepancies up to 0.05 m between GNSS measurements and original coordinates of the reference points. The expected 3D precision of the parameters is better than 0.1 metre up to the year 2030. Improved parameters will be computed when more measurement data become available. The projection and transformation parameters can be used with GNSS reference stations of IGS, NSGI or another reference for ITRF2014 coordinates. Use with a GNSS reference station in a different reference frame or with unknown epoch, will give inconsistent coordinates.

The transformation parameters for Bonaire provide 2D transformation for the reference frame and epoch in which the coordinates of the GNSS reference station of Kadaster Bonaire have been determined. The yearly change of the coordinates of this GNSS reference station and the corresponding yearly change of the transformation parameters is not known. The precision of the transformation parameters is better than 0.1 metre when used for 2D RTK measurements with the GNSS reference station of Kadaster Bonaire. The use of these parameters in GIS software or for GNSS surveying without the GNSS reference station of Kadaster Bonaire (e.g. PPP-RTK), would result in coordinates with an offset below 1 metre.

For the height transformation between ellipsoidal height in Bonaire 2004 and physical height in the Bonaire height system (KADpeil), a geoid derived with high-resolution from the Earth Gravitational Model 2008 (EGM2008) is used. The EGM2008 tide-free geoid was found to agree within 0.1 metre with the difference in height of RTK measurements with the GNSS reference station of Kadaster Bonaire and levelling based KADpeil heights for most of the island, in particular in residential areas, and within 0.25 metre for the northwest of the island.

Due to the size of St. Eustatius and Saba, the geoid is modelled implicitly as a tilted plane by the datum transformation parameters. No additional geoid model is used for these coordinate transformations.

# 2 Parameters

## 2.1 ITRS

### 2.1.1 Ellipsoid

Parameters of GRS80 ellipsoid

| | |
|---|---|
| $a = 6378137 \text{ m}$ | half major (equator) axis of GRS80 ellipsoid |
| $f = 1/298.257222101$ | flattening of GRS80 ellipsoid (dimensionless) |

### 2.1.2 Map projections

Optional

## 2.2 Transformation from ITRS to DPnet

### 2.2.1 Bonaire

Parameters of 3D similarity transformation from Bonaire 2004 (≈ITRF2000 at fixed epoch 2001.00) to DPnet of Bonaire

| | |
|---|---|
| $t_X = +366.2685 \text{ m}$ | translation in direction of X axis |
| $t_Y = +114.9660 \text{ m}$ | translation in direction of Y axis |
| $t_Z = +776.6963 \text{ m}$ | translation in direction of Z axis |
| $\alpha = -101.62636 \cdot 10^{-6} \text{ rad} = -20.961941''$ | rotation angle around X axis |
| $\beta = -79.82070 \cdot 10^{-6} \text{ rad} = -16.464201''$ | rotation angle around Y axis |
| $\gamma = +69.20573 \cdot 10^{-6} \text{ rad} = +14.274706''$ | rotation angle around Z axis |
| $\delta = +12.80916 \cdot 10^{-6}$ | scale difference (dimensionless) |

*NB: The three rotation parameters ($\alpha$, $\beta$, $\gamma$) are for use with the formulas according to the "coordinate frame" convention that assumes the positive rotation direction to be anticlockwise. The signs of these parameters must be inverted for the alternative "position vector" convention.*

The transformation should be performed with full rotation matrix. A frequently used alternative formula with an approximated rotation matrix will cause errors of several decimetres.

### 2.2.2 St. Eustatius

Parameters of 3D similarity transformation and their yearly rates from ITRF2014 to DPnet of St. Eustatius

| | |
|---|---|
| $t_X = -1276.8187 \text{ m}$ | translation in direction of X axis |
| $t_Y = +2017.6083 \text{ m}$ | translation in direction of Y axis |
| $t_Z = -667.3989 \text{ m}$ | translation in direction of Z axis |
| $\alpha = +490.03015 \cdot 10^{-6} \text{ rad} = +101.075975''$ | rotation angle around X axis |
| $\beta = -1032.07065 \cdot 10^{-6} \text{ rad} = -212.879853''$ | rotation angle around Y axis |
| $\gamma = +332.27704 \cdot 10^{-6} \text{ rad} = +68.537059''$ | rotation angle around Z axis |
| $\delta = +431.78240 \cdot 10^{-6}$ | scale difference (dimensionless) |
| $\dot{t}_X = -0.00745 \text{ m}$ | yearly rate of translation in direction of X axis |
| $\dot{t}_Y = -0.00876 \text{ m}$ | yearly rate of translation in direction of Y axis |
| $\dot{t}_Z = -0.01401 \text{ m}$ | yearly rate of translation in direction of Z axis |
| $\dot{\alpha} = +0.000000 \cdot 10^{-6} \text{ rad} = +0.0000000''$ | yearly rate of rotation angle around X axis |

$\dot{\beta}$ $= +0.000000 \cdot 10^{-6}$ rad $= +0.0000000''$ yearly rate of rotation angle around Y axis
$\dot{\gamma}$ $= +0.000000 \cdot 10^{-6}$ rad $= +0.0000000''$ yearly rate of rotation angle around Z axis
$\dot{\delta}$ $= +0.000000 \cdot 10^{-6}$ yearly rate of scale difference (dimensionless)

$t_0 = 2020.00$ reference epoch (years)

*NB: The three rotation parameters and their yearly rates ($\alpha$, $\beta$, $\gamma$, $\dot{\alpha}$, $\dot{\beta}$, $\dot{\gamma}$) are for use with the formulas according to the "coordinate frame" convention that assumes the positive rotation direction to be anticlockwise. The signs of these parameters must be inverted for the alternative "position vector" convention.*

The transformation should be performed with full rotation matrix. A frequently used alternative formula with an approximated rotation matrix will cause errors of several decimetres.

#### 2.2.3 Saba

Parameters of 3D similarity transformation and their yearly rates from ITRF2014 to DPnet of Saba

| | |
|---|---|
| $t_X = -1137.8063$ m | translation in direction of X axis |
| $t_Y = +2066.1024$ m | translation in direction of Y axis |
| $t_Z = -110.2520$ m | translation in direction of Z axis |
| $\alpha = +1042.34209 \cdot 10^{-6}$ rad $= +214.998490''$ | rotation angle around X axis |
| $\beta = -2323.17020 \cdot 10^{-6}$ rad $= -479.188251''$ | rotation angle around Y axis |
| $\gamma = +800.92710 \cdot 10^{-6}$ rad $= +165.203074''$ | rotation angle around Z axis |
| $\delta = +402.48266 \cdot 10^{-6}$ | scale difference (dimensionless) |
| $\dot{t}_X = -0.00730$ m | yearly rate of translation in direction of X axis |
| $\dot{t}_Y = -0.00849$ m | yearly rate of translation in direction of Y axis |
| $\dot{t}_Z = -0.01351$ m | yearly rate of translation in direction of Z axis |
| $\dot{\alpha} = +0.000000 \cdot 10^{-6}$ rad $= +0.0000000''$ | yearly rate of rotation angle around X axis |
| $\dot{\beta} = +0.000000 \cdot 10^{-6}$ rad $= +0.0000000''$ | yearly rate of rotation angle around Y axis |
| $\dot{\gamma} = +0.000000 \cdot 10^{-6}$ rad $= +0.0000000''$ | yearly rate of rotation angle around Z axis |
| $\dot{\delta} = +0.000000 \cdot 10^{-6}$ | yearly rate of scale difference (dimensionless) |
| $t_0 = 2020.00$ | reference epoch (years) |

*NB: The three rotation parameters and their yearly rates ($\alpha$, $\beta$, $\gamma$, $\dot{\alpha}$, $\dot{\beta}$, $\dot{\gamma}$) are for use with the formulas according to the "coordinate frame" convention that assumes the positive rotation direction to be anticlockwise. The signs of these parameters must be inverted for the alternative "position vector" convention.*

The transformation should be performed with full rotation matrix. A frequently used alternative formula with an approximated rotation matrix will cause errors of several metres.

### 2.3 Transformation from DPnet to ITRS

#### 2.3.1 Bonaire

Parameters of 3D similarity transformation from DPnet of Bonaire to Bonaire 2004 (≈ITRF2000 at fixed epoch 2001.00)

| | |
|---|---|
| $t_X = -366.1939$ m | translation in direction of X axis |
| $t_Y = -115.0688$ m | translation in direction of Y axis |

$t_Z = -776.7039$ m — translation in direction of Z axis
$\alpha = +101.63188 \cdot 10^{-6}$ rad $= +20.963080''$ — rotation angle around X axis
$\beta = +79.81366 \cdot 10^{-6}$ rad $= +16.462749''$ — rotation angle around Y axis
$\gamma = -69.21384 \cdot 10^{-6}$ rad $= -14.276379''$ — rotation angle around Z axis
$\delta = -12.80900 \cdot 10^{-6}$ — scale difference (dimensionless)

*NB: The three rotation parameters ($\alpha$, $\beta$, $\gamma$) are for use with the formulas according to the "coordinate frame" convention that assumes the positive rotation direction to be anticlockwise. The signs of these parameters must be inverted for the alternative "position vector" convention.*

The transformation should be performed with full rotation matrix. A frequently used alternative formula with an approximated rotation matrix will cause errors of several decimetres.

### 2.3.2 St. Eustatius

Parameters of 3D similarity transformation and their yearly rates from DPnet of St. Eustatius to ITRF2014

| | |
|---|---|
| $t_X = +1276.2485$ m | translation in direction of X axis |
| $t_Y = -2016.6406$ m | translation in direction of Y axis |
| $t_Z = +667.4403$ m | translation in direction of Z axis |
| $\alpha = -489.68745 \cdot 10^{-6}$ rad $= -101.005288''$ | rotation angle around X axis |
| $\beta = +1032.23330 \cdot 10^{-6}$ rad $= +212.913401''$ | rotation angle around Y axis |
| $\gamma = -331.77143 \cdot 10^{-6}$ rad $= -68.432770''$ | rotation angle around Z axis |
| $\delta = -431.59604 \cdot 10^{-6}$ | scale difference (dimensionless) |
| $\dot{t}_X = +0.00743$ m | yearly rate of translation in direction of X axis |
| $\dot{t}_Y = +0.00875$ m | yearly rate of translation in direction of Y axis |
| $\dot{t}_Z = +0.01402$ m | yearly rate of translation in direction of Z axis |
| $\dot{\alpha} = +0.000000 \cdot 10^{-6}$ rad $= +0.0000000''$ | yearly rate of rotation angle around X axis |
| $\dot{\beta} = +0.000000 \cdot 10^{-6}$ rad $= +0.0000000''$ | yearly rate of rotation angle around Y axis |
| $\dot{\gamma} = +0.000000 \cdot 10^{-6}$ rad $= +0.0000000''$ | yearly rate of rotation angle around Z axis |
| $\dot{\delta} = +0.000000 \cdot 10^{-6}$ | yearly rate of scale difference (dimensionless) |
| $t_0 = 2020.00$ | reference epoch (years) |

*NB: The three rotation parameters and their yearly rates ($\alpha$, $\beta$, $\gamma$, $\dot{\alpha}$, $\dot{\beta}$, $\dot{\gamma}$) are for use with the formulas according to the "coordinate frame" convention that assumes the positive rotation direction to be anticlockwise. The signs of these parameters must be inverted for the alternative "position vector" convention.*

The transformation should be performed with full rotation matrix. A frequently used alternative formula with an approximated rotation matrix will cause errors of several decimetres.

### 2.3.3 Saba

Parameters of 3D similarity transformation and their yearly rates from DPnet of Saba to ITRF2014

| | |
|---|---|
| $t_X = +1138.7432$ m | translation in direction of X axis |
| $t_Y = -2064.4761$ m | translation in direction of Y axis |
| $t_Z = +110.7016$ m | translation in direction of Z axis |

$\alpha\ = -1040.48388 \cdot 10^{-6}\ \text{rad} = -214.615206''$ rotation angle around X axis
$\beta\ = +2324.00304 \cdot 10^{-6}\ \text{rad} = +479.360036''$ rotation angle around Y axis
$\gamma\ = \ \ -798.50729 \cdot 10^{-6}\ \text{rad} = -164.703951''$ rotation angle around Z axis
$\delta\ = \ \ -402.32073 \cdot 10^{-6}$ scale difference (dimensionless)

$\dot{t}_X = +0.00726\ \text{m}$ yearly rate of translation in direction of X axis
$\dot{t}_Y = +0.00848\ \text{m}$ yearly rate of translation in direction of Y axis
$\dot{t}_Z = +0.01353\ \text{m}$ yearly rate of translation in direction of Z axis
$\dot{\alpha}\ = +0.000000 \cdot 10^{-6}\ \text{rad} = +0.0000000''$ yearly rate of rotation angle around X axis
$\dot{\beta}\ = +0.000000 \cdot 10^{-6}\ \text{rad} = +0.0000000''$ yearly rate of rotation angle around Y axis
$\dot{\gamma}\ = +0.000000 \cdot 10^{-6}\ \text{rad} = +0.0000000''$ yearly rate of rotation angle around Z axis
$\dot{\delta}\ = +0.000000 \cdot 10^{-6}$ yearly rate of scale difference (dimensionless)

$t_0\ = 2020.00$ reference epoch (years)

*NB: The three rotation parameters and their yearly rates ($\alpha$, $\beta$, $\gamma$, $\dot{\alpha}$, $\dot{\beta}$, $\dot{\gamma}$) are for use with the formulas according to the “coordinate frame” convention that assumes the positive rotation direction to be anticlockwise. The signs of these parameters must be inverted for the alternative “position vector” convention.*

The transformation should be performed with full rotation matrix. A frequently used alternative formula with an approximated rotation matrix will cause errors of several metres.

## 2.4 DPnet

### 2.4.1 Ellipsoid

Parameters of International 1924 (Hayford) ellipsoid

$a = 6378388\ \text{m}$ half major (equator) axis of International 1924 ellipsoid
$f\ = 1/297$ flattening of International 1924 ellipsoid (dimensionless)

*NB: This ellipsoid is used for the conversion between geocentric Cartesian coordinates and geographic coordinates as well as for the map projection.*

### 2.4.2 Map projection Bonaire

Parameters of Transverse Mercator projection for DPnet of Bonaire

$\varphi_0\ = 12°\ 10'\ 50.37123''\ \text{N}$ latitude of central point
$\lambda_0\ = 68°\ 15'\ 06.48821''\ \text{W}$ longitude of central meridian
$k\ \ = 1$ scale factor (dimensionless)
$x_0\ = 23209.56\ \text{m}$ false Easting
$y_0\ = 21423.99\ \text{m}$ false Northing

*NB: The International 1924 (Hayford) ellipsoid is used.*

### 2.4.3 Map projection St. Eustatius

Parameters of Transverse Mercator projection for DPnet of St. Eustatius

| | |
|---|---|
| $\varphi_0 = 0°$ | latitude of central point |
| $\lambda_0 = 63°\ \mathrm{W}$ | longitude of central meridian |
| $k = 0.9996$ | scale factor (dimensionless) |
| $x_0 = 500000\ \mathrm{m}$ | false Easting |
| $y_0 = 0\ \mathrm{m}$ | false Northing |

*NB: The International 1924 (Hayford) ellipsoid is used.*

The coordinates of the former cadastral map of St. Eustatius have a constant offset of −499421.45 m for the x-coordinate and −1930396.26 m for the y-coordinate.

### 2.4.4 Map projection Saba

Parameters of Transverse Mercator projection for DPnet of Saba

| | |
|---|---|
| $\varphi_0 = 0°$ | latitude of central point |
| $\lambda_0 = 63°\ \mathrm{W}$ | longitude of central meridian |
| $k = 0.9996$ | scale factor (dimensionless) |
| $x_0 = 29973.97\ \mathrm{m}$ | false Easting |
| $y_0 = -1947925.94\ \mathrm{m}$ | false Northing |

*NB: The International 1924 (Hayford) ellipsoid is used.*

The coordinates of the former topographic map of Saba have a constant offset of +470026.03 m for the x-coordinate and +1947925.94 m for the y-coordinate.

## 2.5 Height system

### 2.5.1 Geoid Bonaire

The height transformation from ellipsoidal height in Bonaire 2004 to physical height in the Bonaire height system (KADpeil) is based on the geoid model BONGEO2004, derived with high-resolution from the EGM2008 tide-free spherical harmonic model. The grid is supplied in three data formats, in tab-separated value ASCII text file format (.txt), in binary VDatum file format (.gtx) and in binary GeoTIFF file format (.tif). The supplied geoid grid files all have the same bounds and spacing.

Parameters of tab-separated value ASCII text (.txt) quasi-geoid grid files and of binary VDatum (.gtx) and GeoTIFF (.tif) geoid grid files

| | |
|---|---|
| $\varphi_{min} = +11°$ | latitude of southern bound of correction grid |
| $\varphi_{max} = +16°$ | latitude of northern bound of correction grid |
| $\lambda_{min} = -71°$ | longitude of western bound of correction grid |
| $\lambda_{max} = -67.5°$ | longitude of eastern bound of correction grid |
| $\Delta_\varphi = 0.0125° = 45''$ | latitude spacing of correction grid, corresponding to about 1.4 km |
| $\Delta_\lambda = 0.0125° = 45''$ | longitude spacing of correction grid, corresponding to about 1.4 km |

*NB: Since GeoTIFF files are often used for raster images and the grid values are valid for the pixel centre in Geodetic TIFF Grids, the bounds of the GeoTIFF may appear slightly larger (half the spacing on all sides of the grid).*

### 2.5.2 Geoid St. Eustatius

No geoid is used. The ellipsoidal height in DPnet can be used as physical height in the St. Eustatius height system. If specification of a geoid is needed, a null grid can be used.

### 2.5.3 Geoid Saba

No geoid is used. The ellipsoidal height in DPnet can be used as physical height in the Saba height system. If specification of a geoid is needed, a null grid can be used.

## Appendix 1: Diagrams

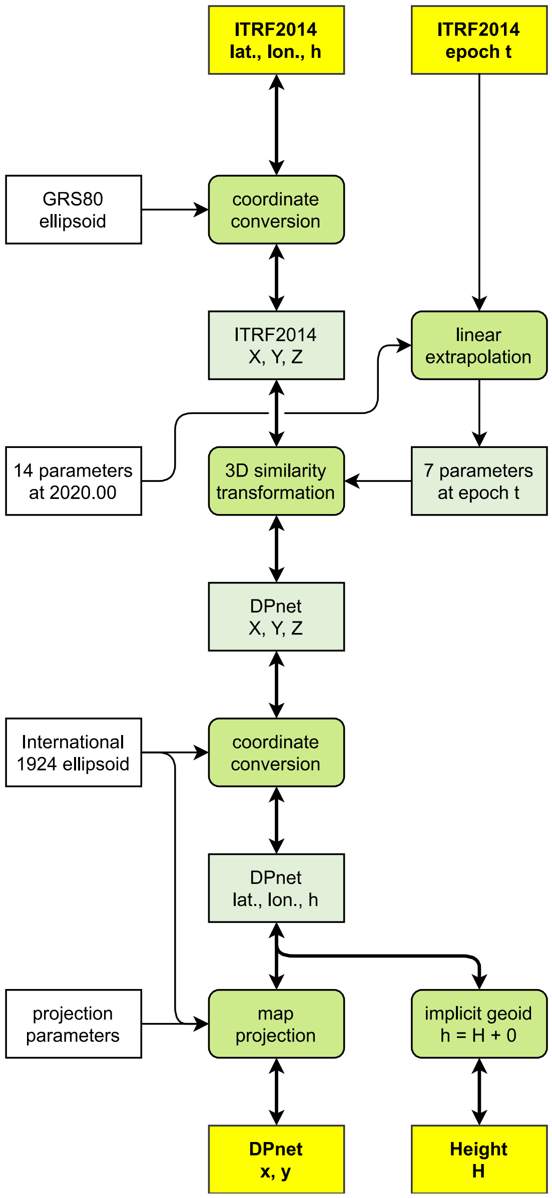


Figure A1.1 Time-dependent 3D transformation procedure for St. Eustatius and Saba.

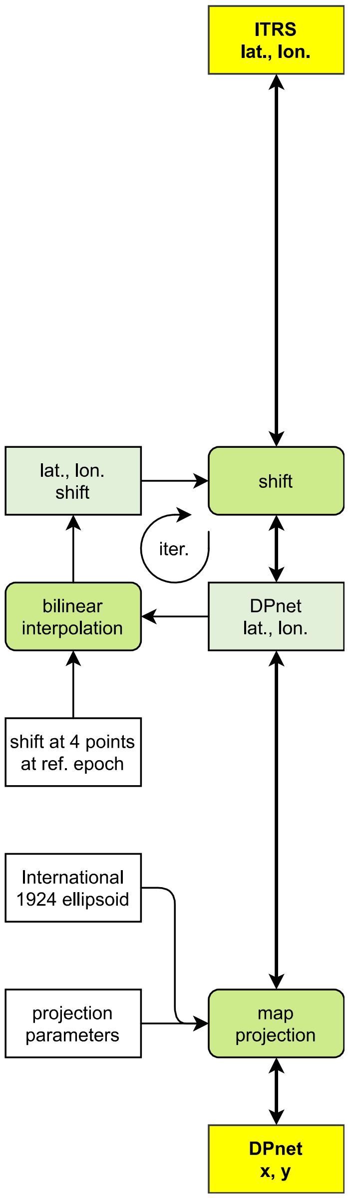


Figure A1.2 Procedure of 2D approximation PROJ4-style string (Section A3.2).

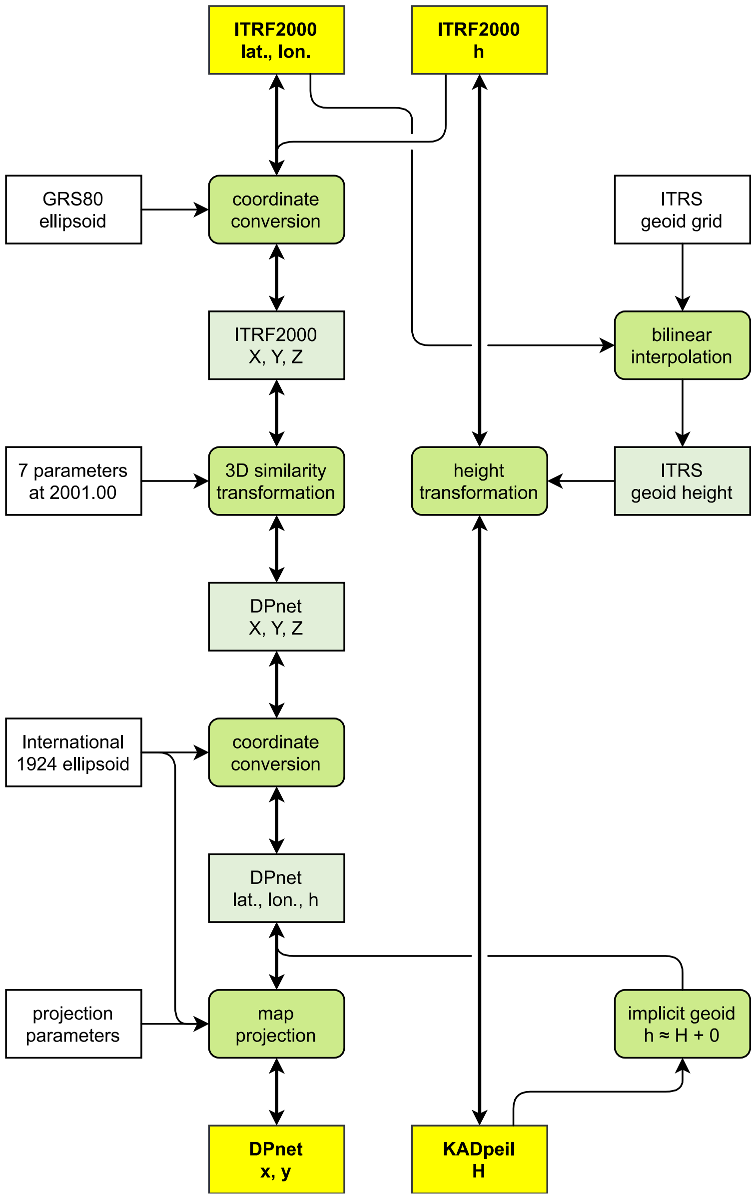


Figure A1.3 3D transformation procedure at reference epoch for Bonaire.

## Appendix 2: Test points

To test for blunders in an implementation of the transformation the coordinates of the test points below can be used.

Test points for the transformation between ITRF2014 and DPnet

| | latitude (°) or x (m) | longitude (°) or y (m) | height (m) | epoch |
|---|---|---|---|---|
| Bonaire 2004 (≈ITRF2000 at 2001-01-01) | 12.149707220 | -68.253725923 | -14.9436 | 2001.00 |
| ITRF2014 at 2020-01-01 | unknown | unknown | unknown | 2020.00 |
| ITRF2014 at 2022-07-02 | unknown | unknown | unknown | 2022.50 |
| Bonaire DPnet + Bonaire height | 23000.0000 | 18000.0000 | 10.0000 | any |

| | latitude (°) or x (m) | longitude (°) or y (m) | height (m) | epoch |
|---|---|---|---|---|
| ITRF2014 at 2020-01-01 | 17.492677034 | -62.980541749 | 58.1197 | 2020.00 |
| ITRF2014 at 2022-07-02 | 17.492677366 | -62.980541500 | 58.1197 | 2022.50 |
| St. Eustatius DPnet + St. Eustatius height | 502000.0000 | 1934000.0000 | 100.0000 | any |
| St. Eustatius former cadastral map coordinates | 2578.5500 | 3603.7400 | 100.0000 | any |

| | latitude (°) or x (m) | longitude (°) or y (m) | height (m) | epoch |
|---|---|---|---|---|
| ITRF2014 at 2020-01-01 | 17.627494963 | -63.234771976 | 257.5641 | 2020.00 |
| ITRF2014 at 2022-07-02 | 17.627495284 | -63.234771733 | 257.5641 | 2022.50 |
| Saba DPnet + Saba height | 5000.0000 | 1000.0000 | 300.0000 | any |
| Saba former topographic map coordinates | 475026.0300 | 1948925.9400 | 300.0000 | any |

## Appendix 3: Implementation using open source library PROJ

The recommended open source library is PROJ version 7 or newer. Commands for the cct program of PROJ are given. A workaround for a PROJ.4-style string is provided too.

### A3.1 3D transformation with PROJ pipeline

A3.1.1 Bonaire

ITRS coordinates can be transformed to DPnet and height system of Bonaire with the commands below. Since the velocity of Bonaire is not yet determined, the transformation is only valid for the reference epoch 2001.00.

From Bonaire 2004 (≈ITRF2000 at fixed epoch 2001.00) to DPnet and height system of Bonaire

```
cct -I -o output.txt +proj=pipeline +step +proj=push +v_3 +step +proj=tmerc +inv
+lat_0=12.180658675 +lon_0=-68.251802281 +k_0=1 +x_0=23209.5600 +y_0=21423.9900 +ellps=intl +step
+proj=cart +ellps=intl +step +proj=helmert +x=-366.1939 +y=-115.0688 +z=-776.7039 +rx=20.963080
+ry=16.462749 +rz=-14.276379 +s=-12.80900 +convention=coordinate_frame +exact +step +proj=cart
+inv +ellps=GRS80 +step +proj=vgridshift +grids=bq_nsgi_bongeo2004.tif +omit_fwd +step +proj=pop
+v_3 +step +proj=vgridshift +inv +grids=bq_nsgi_bongeo2004.tif +step +proj=axisswap +order=2,1
+step +proj=unitconvert +xy_in=rad +xy_out=deg input.txt
```

For the inverse transformation from DPnet and height system of Bonaire to ITRS, the option `-I` should be omitted.

A3.1.2 St. Eustatius

ITRS coordinates can be transformed to DPnet and height system of St. Eustatius with the commands below. Since the transformation is time-dependent, the recommended epoch is specified with the option `-t` (otherwise the epoch should be added to each input point as a fourth coordinate).

From ITRF2014 at epoch 2020.00 to DPnet and height system of St. Eustatius

```
cct -I -t 2020.00 -o output.txt +proj=pipeline +step +proj=utm +inv +zone=20 +ellps=intl +step
+proj=cart +ellps=intl +step +proj=helmert +x=1276.2485 +y=-2016.6406 +z=667.4403 +rx=-101.005288
+ry=212.913401 +rz=-68.432770 +s=-431.59604 +dx=0.00743 +dy=0.00875 +dz=0.01402 +t_epoch=2020.00
+convention=coordinate_frame +exact +step +proj=cart +inv +ellps=GRS80 +step +proj=axisswap
+order=2,1 input.txt
```

For the inverse transformation from DPnet and height system of St. Eustatius to ITRS, the option `-I` should be omitted.

From DPnet of St. Eustatius to coordinates of former cadastral map of St. Eustatius

```
cct -I -o output.txt +proj=affine +xoff=499421.4500 +yoff=1930396.2600 input.txt
```

For the inverse transformation from coordinates of the former cadastral map to DPnet, the option `-I` should be omitted.

A3.1.3 Saba

ITRS coordinates can be transformed to DPnet and height system of Saba with the commands below. Since the transformation is time-dependent, the recommended epoch is specified with the option `-t` (otherwise the epoch should be added to each input point as a fourth coordinate).

From ITRF2014 at epoch 2020.00 to DPnet and height system of Saba

```
cct -I -t 2020.00 -o output.txt +proj=pipeline +step +proj=tmerc +inv +lat_0=0 +lon_0=-63
+k_0=0.9996 +x_0=29973.97 +y_0=-1947925.94 +ellps=intl +step +proj=cart +ellps=intl +step
+proj=helmert +x=1138.7432 +y=-2064.4761 +z=110.7016 +rx=-214.615206 +ry=479.360036 +rz=-
164.703951 +s=-402.32073 +dx=0.00726 +dy=0.00848 +dz=0.01353 +t_epoch=2020.00
+convention=coordinate_frame +exact +step +proj=cart +inv +ellps=GRS80 +step +proj=axisswap
+order=2,1 input.txt
```

For the inverse transformation from DPnet and height system of Saba to ITRS, the option `-I` should be omitted.

From DPnet of Saba to coordinates of former topographic map of Saba

```
cct -I -o output.txt +proj=affine +xoff=-470026.0300 +yoff=-1947925.9400 input.txt
```

For the inverse transformation from coordinates of the former topographic map to DPnet, the option `-I` should be omitted.

### A3.2 2D approximation PROJ4-style string

A PROJ4-style string with a 3D similarity transformation (`+towgs84` option) can not be used for precise transformation, because it uses approximate formulas of a 3D Helmert transformation that give an error of several centimetres for Bonaire, several decimetres for St. Eustatius and several metres for Saba due to the exceptionally large rotation angles. As a workaround, a grid shift file can be used. Grids in the NTv2 file format (.gsb) are provided with this document for St. Eustatius and Saba. The PROJ4-style strings below provide 2D approximations of the transformations at the recommended fixed epoch. The difference with the exact formulas is below 0.1 m.

A3.2.1 Bonaire

ITRS coordinates can be transformed to DPnet of Bonaire with the commands below. This approximate 2D transformation is only valid at the recommended epoch 2001.00.

PROJ 4-style string of DPnet of Bonaire in PROJ≥6

```
+proj=tmerc +lat_0=12.180658675 +lon_0=-68.251802281 +k_0=1 +x_0=23209.5600 +y_0=21423.9900
+ellps=intl +towgs84=-366.1939,-115.0688,-776.7039,-20.963080,-16.462749,+14.276379,-12.80900
+type=crs
```

A3.2.2 St. Eustatius

ITRS coordinates can be transformed to DPnet of St. Eustatius with the commands below. Since this approximate 2D transformation does not take into account that the transformation is time-dependent, it is only valid at the recommended epoch 2020.00. Note that the grid shift files (.gsb) must be available in the appropriate directory.

PROJ 4-style string of DPnet of St. Eustatius in PROJ≥6

```
+proj=utm +zone=20 +ellps=intl +nadgrids=seutrans2020.gsb +type=crs
```

A3.2.3 Saba

ITRS coordinates can be transformed to DPnet of Saba with the commands below. Since this approximate 2D transformation does not take into account that the transformation is time-dependent, it is only valid at the recommended epoch 2020.00. Note that the grid shift files (.gsb) must be available in the appropriate directory.

PROJ 4-style string of DPnet of Saba in PROJ≥6

```
+proj=tmerc +lat_0=0 +lon_0=-63 +k=0.9996 +x_0=29973.97 +y_0=-1947925.94 +ellps=intl
+nadgrids=sabtrans2020.gsb +type=crs
```