
ITRF-NAD83 TRANSFORMATION & DEFINITION OF NAD83(CSRs)

Mike Craymer

Geodetic Survey Division, Natural Resources Canada

Tel 613-947-1829, Fax 613-992-6628

<mailto:craymer@nrcan.gc.ca>

<http://www.geod.nrcan.gc.ca/~craymer/nets/>

April 16, 1998

Revised 1998-04-22

Revised 1998-05-20

Revised 2001-06-11: For notation consistency with Craymer et al., 1999.

Revised 2001-08-18: Added ITRF96-97 based on agreed GSD/NGS values;
differences with adopted IGS values in IGS Mail #2342 are negligible.

Revised 2001-12-12: Revised entire paper; added ITRF97-00 transformation
as defined by the IERS.

The Geodetic Survey Division (GSD) of Natural Resources Canada and the U.S. National Geodetic Survey (NGS) have recently agreed on a new common scheme for transforming coordinates between the International Terrestrial Reference Frame (ITRF) and NAD83. This effectively unifies the definition of the NAD83 reference frame throughout both countries. This realization of NAD83 is denoted as NAD83(CSRs) in Canada and NAD83(NSRS) in the U.S.

The new transformation is based upon the transformation between NAD83 and ITRF96 at epoch 1997.0. The transformation of ITRF96 geocentric Cartesian coordinates (Xi,Yi,Zi) at epoch t to NAD83(CSRs98) coordinates (Xn,Yn,Zn) is defined by

$$\begin{aligned} X_n &= TX + (1+DS)*X_i - RZ(t)*Y_i + RY(t)*Z_i \\ Y_n &= TY + RZ(t)*X_i + (1+DS)*Y_i - RX(t)*Z_i \\ Z_n &= TZ - RY(t)*X_i + RX(t)*Y_i + (1+DS)*Z_i \end{aligned}$$

where

$$\begin{aligned} TX &= 0.9910 \text{ m} \\ TY &= -1.9072 \text{ m} \\ TZ &= -0.5129 \text{ m} \\ DS &= 0.00 \text{ ppb} \\ RX(t) &= -25.79 \text{ mas} + dRX*(1997.0-t) \\ RY(t) &= -9.65 \text{ mas} + dRY*(1997.0-t) \\ RZ(t) &= -11.66 \text{ mas} + dRZ*(1997.0-t) \end{aligned}$$

and

$$\begin{aligned} dRX &= 0.0532 \text{ mas/y} \\ dRY &= -0.7423 \text{ mas/y} \\ dRZ &= -0.0316 \text{ mas/y} \end{aligned}$$

The later parameters are rates of change of rotation from the observation epoch to the reference epoch (1997.0) of the ITRF96-NAD83 transformation. They represent the horizontal motion of the NAD83 reference frame due to the tectonic motion of the North American plate. The rotation rates are derived from the NUVEL1A plate motion model recommended by the IERS Conventions (2000) [McCarthy, 2001].

To transform between NAD83 and other realizations of ITRF, it is first necessary to apply an "incremental" transform to ITRF96. The parameters for these incremental ITRF transformations are obtained from the values adopted by the IERS [McCarthy, 2001]; see also the ITRF web site at

<ftp://lareg.ensg.ign.fr/pub/itrf/ITRF.TP>. The exception is for the transformation between ITRF96 and ITRF97 where a systematic translation exists at IGS stations. In this case, both GSD and NGS have adopted the official IGS transformation defined in IGS Mail #2342 (converted to epoch 1997.0). There are small differences between the IGS values and those we have adopted due to round off errors which are insignificant for practical purposes.

The following table summarizes the incremental ITRF transformation parameters:

From	To	t0	TX(cm)	TY(cm)	TZ(cm)	RX(mas)	RY(mas)	RZ(mas)	DS(ppb)
ITRF88	ITRF96	1988.0	-1.8	0.0	9.2	-0.1	0.0	0.0	-7.4
ITRF89	ITRF96	1988.0	-2.3	-3.6	6.8	0.0	0.0	0.0	-4.3
ITRF90	ITRF96	1988.0	-1.8	-1.2	3.0	0.0	0.0	0.0	-0.9
ITRF91	ITRF96	1988.0	-2.0	-1.6	1.4	0.0	0.0	0.0	-0.6
ITRF92	ITRF96	1988.0	-0.8	-0.2	0.8	0.0	0.0	0.0	0.8
ITRF93	ITRF96	1988.0	-0.6	0.5	1.5	0.39	-0.80	0.96	-0.4
+ rates of change			0.29	-0.04	-0.08	0.11	0.19	-0.05	0.0
ITRF94	ITRF96	1988.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ITRF96	ITRF97	1997.0	0.21	0.02	-1.00	0.125	-0.224	-0.061	0.935
+ rates of change			-0.07	0.01	-0.19	0.013	-0.015	0.000	0.192
ITRF97	ITRF00	1997.0	-0.67	-0.61	1.85	0.00	0.00	0.00	-1.55
+ rates of change			0.00	0.06	0.14	0.00	0.00	-0.02	-0.01

For a given transformation parameter P, its value at epoch t is obtained from:

$$P(t) = P(t_0) + dP \cdot (t - t_0)$$

where t0 is the reference epoch in the above table and dP is the rate of change of the parameter, and P(t0) is the parameter at the reference epoch, given in the above table. To transform between ITRF00 and ITRF96, it is necessary to take the sum of the transformation parameters for ITRF96-ITRF97 and ITRF97-ITRF00, both at epoch t. These transformation parameters can then be added with those between ITRF96 and NAD83/CSRS to give the full transformation from ITRFxx to NAD83/CSRS.

The above transformations have been implemented in a portable Fortran program called TRNOBS. It transforms GHOST and GeoLab coordinate and coordinate difference records between various ITRFs and NAD83(CSRS). TRNOBS is available via anonymous FTP from:

<ftp://ftp.geod.nrcan.gc.ca/pub/GSD/craymer/software/trnobs/>

NOTES

1) All of the above rotations are defined as clockwise rotations in a right-handed coordinate system following the convention used in IERS reports. Customary mathematical and geodetic convention is to use anti-clockwise rotations in right-handed systems.

2) The same transformation parameters have also been adopted by the U.S. National Geodetic Survey, except for ITRF reference frames prior to ITRF96. For more information about NGS's transformations, see their web page at <http://www.ngs.noaa.gov/CORS/metadata1/>.

3) For more information about the ITRF, see Boucher and Altamimi [1996] and Altamimi et al. [2001], or visit the ITRF web site at <http://lareg.ensg.ign.fr/ITRF/>.

REFERENCES

Altamimi et al. (2001). "The Terrestrial Reference Frame and the Dynamic Earth", EOS, Transactions, Vol. 82, No. 25, June 19, 2001.
<<http://www.geod.nrcan.gc.ca/new/html-public/GSDinfo/English/itrf2000.pdf>>

Boucher, Claude and Zuheir Altamimi (1996). "International Terrestrial Reference Frame", GPS World, September 1996.

McCarthy, Dennis D. (2000). "IERS Conventions (2000)". Draft IERS Technical Note, International Earth Rotation Service, Paris, August 2000.
<<http://maia.usno.navy.mil/conv2000.html>>

Craymer, M., R. Ferland and R. Snay (1999). "Realization and Unification of NAD83 in Canada and the U.S. via the ITRF", Proceedings of the International Symposium of the International Association of Geodesy, Section II, ♦Towards an Integrated Geodetic Observing System (IGGOS)♦, Munich, October 5-9, 1998. Revised 11 March 1999.