Russian Federal Space Agency (Roscosmos)
Central Research Institute for Machine Building, Federal State Unitary Enterprise (FGUP TSNIIMASH)
Information and Analysis Center for Positioning, Navigation and Timing (IAC PNT)

CURRENT STATUS OF GLOBAL TERRESTRIAL REFERENCE SYSTEMS IMPLEMENTED IN GNSS

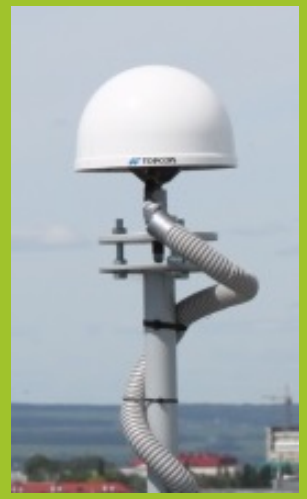
Igor Gusev, Olga Sanakina

VLBI

SLR

Space Geodesy Techniques

GNSS



DORIS

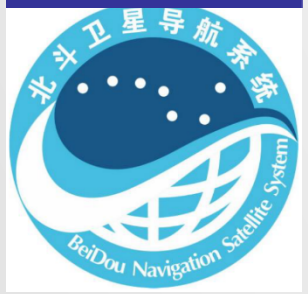
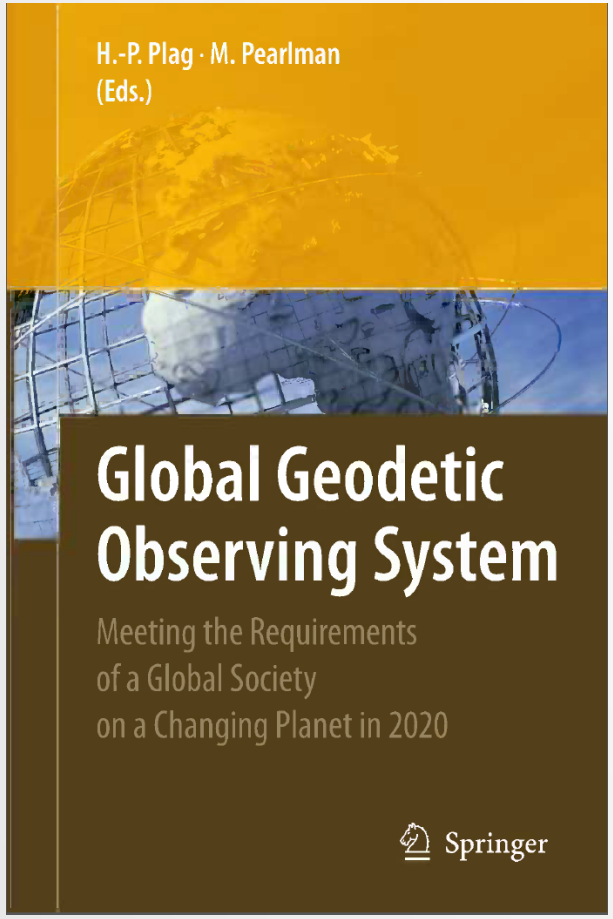


Table 1: TRF realized in GNSS

#	GNSS	TRF	Current Realization
1	GLONASS	PZ-90	PZ-90.11
2	GPS	WGS 84	WGS 84 (G1762)
3	Galileo	ITRS	GTRF14v01
4	BeiDou	CGCS2000	CTRF2000

FUTURE REQUIREMENTS



- accuracy < 1 mm,
- stability < 0.1 mm/yr, including geocenter;
- scale accuracy < 0.1 ppb,
- scale stability < 0.01 ppb/yr

THE INTERNATIONAL TERRESTRIAL REFERENCE SYSTEM AND FRAME (ITRS/ ITRF)

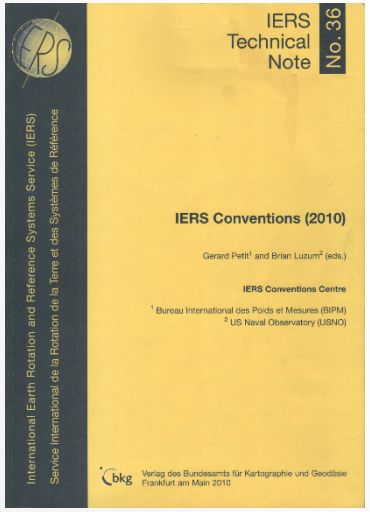
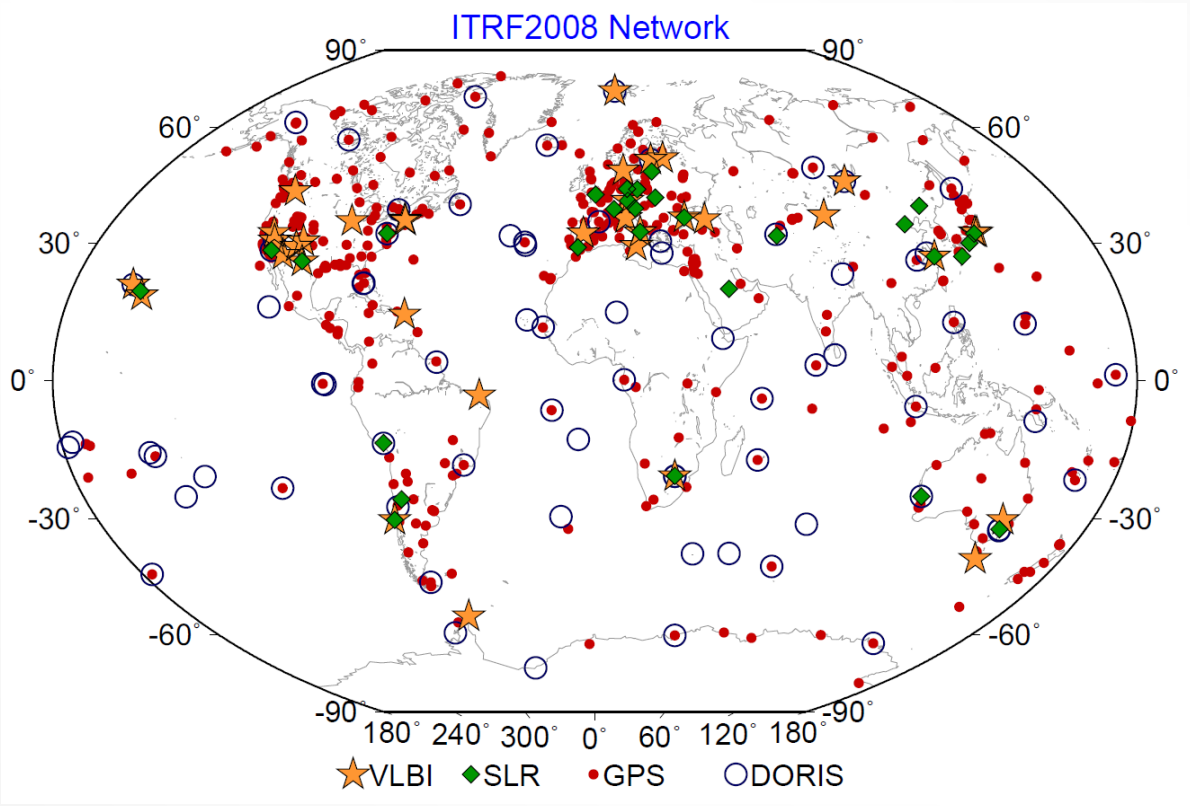


Table 2: ITRF2008 Accuracy

#	Parameter	Accuracy (m)
1	Origin	0.010
2	Scale	0.008



International Terrestrial Reference System

Responsible Organization: International Earth Rotation and Reference Systems Service (IERS)

Abbreviated System Name: ITRS

Coverage of System: Global

Type of System: 3-Dimensional

Brief Description

A spatial reference system co-rotating with the Earth in its diurnal motion in space. In such a system, positions of points attached to the solid surface of the Earth have coordinates which undergo only small variations with time, due to geophysical effects (tectonic or tidal deformations).

Definition of System

- **Origin**: It is geocentric, its origin being the center of mass for the whole Earth, including oceans and atmosphere
- **Scale**: The unit of length is the meter (SI). The scale is consistent with the TCG time coordinate for a geocentric local frame, in agreement with IAU and IUGG (1991) resolutions. This is obtained by appropriate relativistic modelling
- **Orientation**: Its orientation was initially given by the BIH orientation at 1984.0
- **Time Evolution**: The time evolution of the orientation is ensured by using a no-net-rotation condition with regards to horizontal tectonic motions over the whole Earth.

Coordinate System: Cartesian coordinates (X, Y, Z)

References:

- IERS Conventions (2010): http://tai.bipm.org/iers/convupdt/convupdt.html

International Terrestrial Reference Frame

Responsible Organization: International Earth Rotation and Reference Systems Service (IERS)

Abbreviated Frame Name: ITRF

Associated TRS: ITRS

Coverage of Frame: Global

Type of Frame: 3-Dimensional

Last Version: ITRF2008

Brief Description

The ITRF2008 is the current realization of the ITRS obtained by combination of VLBI, SLR, GPS and DORIS time series of station positions and Earth Orientation Parameters provided by the IAG Services (IVS, ILRS, IGS, IDS), together with local ties in co-location sites. The ITRF2008 is published by the ITRS product center of the IERS

Definition of Frame

- **Origin**: Zero translation and translation rate with respect to SLR long-term solution used in the ITRF2008 combination
- **Scale**: Zero scale and scale rate with respect to the mean scale of VLBI and SLR long-term solutions used in the ITRF2008 combination.
- **Orientation**: Zero rotation and rotation rate with respect to ITRF2005.
- **Time Evolution**: Zero rotation rate with respect to ITRF2005.

Coordinate System: Cartesian coordinates (X, Y, Z)

References:

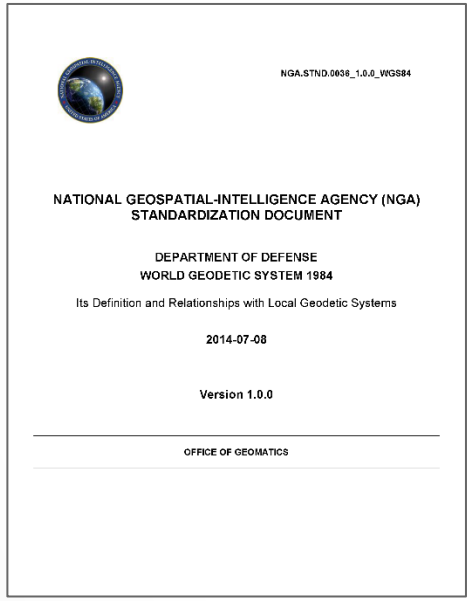
- http://itrf.ensg.ign.fr/ITRF_solutions/2008/ITRF2008.php

Transformation Parameters

Transformation parameters from ITRF2008 to past ITRFs. "ppb" refers to parts per billion (or 10^{-9}). The units for rate are understood to be "per year."

ITRF Solution	Tx (mm)	Ty (mm)	Tz (mm)	D (ppb)	Rx (mas)	Ry (mas)	Rz (mas)	Epoch
ITRF2005	-2.0	-0.9	-4.7	0.94	0.00	0.00	0.00	2000.0
rates	0.3	0.0	0.0	0.00	0.00	0.00	0.00	
ITRF2000	-1.9	-1.7	-10.5	1.34	0.00	0.00	0.00	2000.0
rates	0.1	0.1	-1.8	0.08	0.00	0.00	0.00	
ITRF97	4.8	2.6	-33.2	2.92	0.00	0.00	0.06	2000.0
rates	0.1	-0.5	-3.2	0.09	0.00	0.00	0.02	
ITRF96	4.8	2.6	-33.2	2.92	0.00	0.00	0.06	2000.0
rates	0.1	-0.5	-3.2	0.09	0.00	0.00	0.02	
ITRF94	4.8	2.6	-33.2	2.92	0.00	0.00	0.06	2000.0
rates	0.1	-0.5	-3.2	0.09	0.00	0.00	0.02	
ITRF93	-24.0	2.4	-38.6	3.41	-1.71	-1.48	-0.30	2000.0
rates	-2.8	-0.1	-2.4	0.09	-0.11	-0.19	0.07	
ITRF92	12.8	4.6	-41.2	2.21	0.00	0.00	0.06	2000.0
rates	0.1	-0.5	-3.2	0.09	0.00	0.00	0.02	
ITRF91	24.8	18.6	-47.2	3.61	0.00	0.00	0.06	2000.0
rates	0.1	-0.5	-3.2	0.09	0.00	0.00	0.02	
ITRF90	22.8	14.6	-63.2	3.91	0.00	0.00	0.06	2000.0
rates	0.1	-0.5	-3.2	0.09	0.00	0.00	0.02	
ITRF89	27.8	38.6	-101.2	7.31	0.00	0.00	0.06	2000.0
rates	0.1	-0.5	-3.2	0.09	0.00	0.00	0.02	
ITRF88	22.8	2.6	-125.2	10.41	0.10	0.00	0.06	2000.0
rates	0.1	-0.5	-3.2	0.09	0.00	0.00	0.02	

WGS 84


NGA.STND.0036_1.0.0_WGS84

NATIONAL GEOSPATIAL-INTELLIGENCE AGENCY (NGA)
STANDARDIZATION DOCUMENT

DEPARTMENT OF DEFENSE
WORLD GEODETIC SYSTEM 1984

Its Definition and Relationships with Local Geodetic Systems

2014-07-08

Version 1.0.0

OFFICE OF GEOMATICS

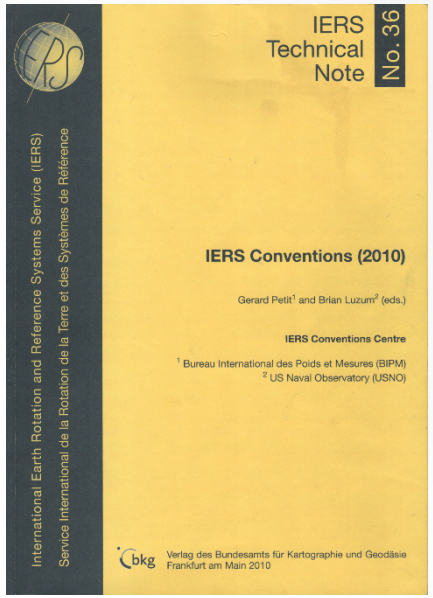


Table 3: WGS 84 Station Coordinate Updates

Name	Implementation date		Epoch	Accuracy
	GPS Broadcast Orbits	NGA Precise Ephemeris		
WGS 84	1987	1 Jan 1987	–	1-2 meters
WGS 84 (G730)	29 Jun 1994	2 Jan 1994	1994.0	10 cm/component rms
WGS 84 (G873)	29 Jan 1997	29 Sep 1996	1997.0	5 cm/component rms
WGS 84 (G1150)	20 Jan 2002	20 Jan 2002	2001.0	1cm/component rms
WGS 84 (G1674)	8 Feb 2012	7 May 2012	2005.0	<1cm/component rms
WGS 84 (G1762)	16 Oct 2013	16 Oct 2013	2005.0	<1cm/component rms

World Geodetic System 1984

Responsible Organization: National Geospatial-Intelligence Agency

Abbreviated Frame Name: WGS 84

Associated TRS: WGS 84

Coverage of Frame: Global

Type of Frame: 3-Dimensional

Last Version: WGS 84 (G1674)

Reference Epoch: 2005.0

Brief Description: WGS 84 is an Earth-centered, Earth-fixed terrestrial reference system and geodetic datum. WGS 84 is based on a consistent set of constants and model parameters that describe the Earth's size, shape, and gravity and geomagnetic fields. WGS 84 is the standard U.S. Department of Defense definition of a global reference system for geospatial information and is the reference system for the Global Positioning System (GPS). It is compatible with the International Terrestrial Reference System (ITRS).

Definition of Frame

- **Origin:** Earth's center of mass being defined for the whole Earth including oceans and atmosphere
- **Axes:**
  - Z-Axis = The direction of the IERS Reference Pole (IRP). This direction corresponds to the direction of the BIH Conventional Terrestrial Pole (CTP) (epoch 1984.0) with an uncertainty of 0.005″
  - X-Axis = Intersection of the IERS Reference Meridian (IRM) and the plane passing through the origin and normal to the Z-axis. The IRM is coincident with the BIH Zero Meridian (epoch 1984.0) with an uncertainty of 0.005″
  - Y-Axis = Completes a right-handed, Earth-Centered Earth-Fixed (ECEF) orthogonal coordinate system
- **Scale:** Its scale is that of the local Earth frame, in the meaning of a relativistic theory of gravitation. Aligns with ITRS
- **Orientation:** Given by the Bureau International de l'Heure (BIH) orientation of 1984.0
- **Time Evolution:** Its time evolution in orientation will create no residual global rotation with regards to the crust

Coordinate System: Cartesian Coordinates (X, Y, Z). WGS 84 (G1674) follows the criteria outlined in the International Earth Rotation Service (IERS) Technical Note 21. The WGS 84 Coordinate System origin also serves as the geometric center of the WGS 84 Ellipsoid and the Z-axis serves as the rotational axis of this ellipsoid of revolution. WGS 84 geodetic coordinates are generated by using its reference ellipsoid.

Defining Parameters: WGS 84 identifies four defining parameters. These are the semi-major axis of the WGS 84 ellipsoid, the flattening factor of the Earth, the nominal mean angular velocity of the Earth, and the geocentric gravitational constant as specified below.

Parameter	Notation	Value
Semi-major Axis	a	6378137.0 meters
Flattening Factor of the Earth	1/f	298.257223563
Nominal Mean Angular Velocity of the Earth	ω	7292115×10^{-11} radians/second
Geocentric Gravitational Constant (Mass of Earth's Atmosphere Included)	GM**	$3.986004418 \times 10^{14}$ meter^3/second^2

**The value of GM for GPS users is 3.9860050×10^{14} m^3/sec^2 as specified in the references below.

References:

- NIMA Technical Report 8350.2 "Department of Defense, World Geodetic System 1984, Its Definition and Relationships with Local Geodetic Systems"
- Addendum to NIMA TR 8350.2: Implementation of the World Geodetic System 1984 (WGS 84) Reference Frame G1150
- NAVSTAR Global Positioning System Interface Specification (IS-GPS-200), NAVSTAR GPS Space Segment / Navigation User Interface.

Relationship with other reference systems:

WGS 84 (G1674) is aligned to ITRF2008 with the same epoch of 2005.0. The purpose of this alignment is to ensure scientific integrity and follow best practices. The ITRF incorporates multiple methods to realize the reference system such as satellite laser ranging and very-long-baseline interferometry that NGA does not include. Adjusting WGS 84 to ITRF allows the reference frame to take advantage of those methods without directly incorporating them into the coordinate determination software.

WGS 84 (G1674) adopted the values of NGA stations coordinates in the ITRF2008 reference frame with the exception of its stations located in Bahrain and Korea. Computations were performed to align the remaining WGS 84 reference stations to this network. For WGS 84 (G1674), all WGS 84 reference stations adopted ITRF2008 velocities of the station or nearby sites. The estimated accuracy of WGS 84 (G1674) is better than one centimeter overall for each of the reference frame station coordinates. The 7-parameter transformation from WGS 84 (G1674) to ITRF2008 is zero in all components. This is by design since WGS 84 (G1674) adopted ITRF2008 coordinates and velocities in common stations between the two reference frames in all but two exceptions. This process ensures that WGS 84 is aligned to ITRF2008 to better than one centimeter at initial WGS 84 (G1674) release.

Transformation Parameters

The parameters are defined from the listed reference frame to WGS 84 (G1674) at epoch 2005.0.

Reference Frame (reference frame epoch)	Tx (mm) (sigma)	Ty (mm) (sigma)	Tz (mm) (sigma)	D (ppb) (sigma)	Rx (mas) (sigma)	Ry (mas) (sigma)	Rz (mas) (sigma)
WGS 84 (G1150)# (2001.0)	-4.7 5.9	11.9 5.9	15.6 5.9	4.72 0.92	-0.52 0.24	-0.01 0.24	-0.19 0.22
ITRF2008* (2005.0)	0	0	0	0	0	0	0

The sign convention for the rotations Rx, Ry, and Rz is what NGA uses in its orbit comparison programs and is opposite to that of IERS Technical Note No. 36, Equation 4.3 and following.
*Zero by construction.

Notes:

The GPS reference system is WGS 84. GPS users directly receive WGS 84 coordinates from a GPS receiver if no changes to the reference frame are selected or made.

The software that generates GPS Broadcast orbits is updated at the beginning of each calendar year with an epoch at the half-year mark to account for plate tectonic motion. This method results in a yearly step-wise adjustment of WGS 84 coordinates delivered through GPS broadcast orbits. For example, GPS broadcast orbits at the time of this writing have an epoch of 2012.5.

Reference frame station locations are updated for any sudden displacement such as an earthquake. The DoD Precise GPS orbits generated by NGA incorporate plate motion by using the WGS 84 reference stations propagated forward using reference station velocities.

Future Plans:

NGA plans to conduct a WGS 84 reference frame network adjustment in early 2013 to incorporate IERS Conventions 2010 Technical Note 36 (TN 36). Note that WGS 84 will retain its four defining parameters of which some do not comply with TN 36. When completed, the newest realization of WGS 84 will be published, and NGA (formerly NIMA) Technical Report 8350.2 will be updated.

GTRF

Table 4: GTRF Realizations

#	GTRF	Released
1	GTRF07v00	Aug 2007
2	GTRF07v01	Nov 2007
3	GTRF08v01	Aug 2008
4	GTRF09v01	Apr 2009
5	GTRF13v01	May 2013
6	GTRF13v02	May 2013
7	GTRF14v01	Apr 2014

Galileo Terrestrial Reference Frame

Responsible Organization: European Space Agency (ESA)

Abbreviated Frame Name: GTRF

Associated TRS: ITRS

Coverage of Frame: Global

Type of Frame: 3-Dimensional

Last Version: GTRF09v01

Brief Description

The GTRF09v01 is the current GTRF prototype solution obtained by accumulating time series of station positions of 133 stations, including 13 Galileo Experimental Sensor Stations (GESS), using GPS observations. The GTRF09v01 was computed by the GGSP (Galileo Geodetic Service Provider) consortium.

Definition of Frame

- **Origin**: Zero translation and translation rate with respect to ITRF2005
- **Scale**: Zero scale and scale rate with respect to ITRF2005
- **Orientation**: Zero rotation and rotation rate with respect to ITRF2005.
- **Time Evolution**: Zero rotation rate with respect to ITRF2005.

Coordinate System: Cartesian coordinates (X, Y, Z)

References:

- http://www.ggsp.eu/ggsp_home.html

Transformation Parameters

Transformation parameters from GTRF09v01 to other frames. "ppb" refers to parts per billion (or 10^{-9}). The units for rate are understood to be "per year."

ITRF Solution	Tx (mm)	Ty (mm)	Tz (mm)	D (ppb)	Rx (mas)	Ry (mas)	Rz (mas)	Epoch
ITRF2005	(ZEROS BY CONSTRUCTION)							
ITRF2008	2.0	0.9	4.7	-0.94	0.00	0.00	0.00	2000.0
rates	-0.3	0.0	0.0	0.00	0.00	0.00	0.00	

CGCS2000

Table 5: Precision of Alignment BDS/GPS Stations to ITRF 2008

	Position RMS	Velocity RMS
Horizontal	< 3 mm	< 0.5 mm/yr
Vertical	< 9 mm	< 1.3 mm/yr

China Terrestrial Reference Frame 2000

Responsible Organization: National Bureau of Surveying and Geo-information

Abbreviated Frame Name: CTRF 2000

Associated TRS: ITRS

Coverage of Frame: Global

Type of Frame: 3-Dimensional

Last Version: CTRF 2000 (2000.0)

Reference Epoch: 2000.0

Brief Description: China Geodetic Coordinate System 2000 (CGCS 2000) is an Earth-centered, Earth-fixed terrestrial reference system and geodetic datum. CGCS 2000 is based on a consistent set of constants and model parameters that describe the Earth's size, shape, gravity and geomagnetic fields. CGCS 2000 is the standard Chinese geodetic reference system for geospatial information and BeiDou/COMPASS. It is compatible with the International Terrestrial Reference System (ITRS). The reference frame of CGCS 2000 is CTRF 2000, which is maintained by 28 CORS stations and more than 2500 GPS stations.

Definition of Frame

- **Origin:** Zero translation and translation rate with respect to ITRF1997
- **Scale:** Zero scale and scale rate with respect to ITRF1997
- **Orientation:** Zero rotation and rotation rate with respect to ITRF1997.
- **Time Evolution:** Zero rotation rate with respect to ITRF1997.

Coordinate System: Cartesian Coordinates (X, Y, Z)

Defining Parameters: CGCS 2000 identifies four defining parameters.

Parameter	Notation	Value
Semi-major Axis	a	6378137.0 meters
Flattening Factor of the Earth	1/f	298.257222101
Nominal Mean Angular Velocity of the Earth	ω	7292115×10^{-11} radians/second
Geocentric Gravitational Constant (Mass of Earth's Atmosphere Included)	GM	$3.986004418 \times 10^{14}$ meter^3/second^2

References:

Chen J 1999. Consideration of improving and updating Chinese geodetic coordinate system. In: Collection of Geodesy, Beijing: Press of Surveying and Mapping (in Chinese)
Wei Z. 2003. National geodetic coordinate system: to next generation. Geomatics and Information Science of Wuhan University. 28(2): 138-143 (in Chinese)
Yang Y 2009. Chinese geodetic coordinate system 2000. Chinese Science Bulletin. 54: 2714-2721.

Relationship with other reference systems:

Future Plans:

China Bureau of National Surveying and Geo-information plans to conduct a new GPS network adjustment for updating CTRF 2000 in the second half of 2012 based on the ITRF 2008. Note that CGCS 2000 will retain its four defining parameters of which some do not comply with TN 36. When completed, the updated frame of CGCS 2000 will be open to use in China.

PZ-90

System of Geodetic Parameters "Parametry Zemli 1990"

Responsible Organization: Ministry of Defense of the Russian Federation

Abbreviated Frame Name: PZ-90

Associated TRS: PZ-90

Coverage of Frame: Global

Type of Frame: 3-Dimensional orthogonal

Last Version: PZ-90.11

Reference Epoch: 2010.0

Brief Description

"Parametry Zemli 1990"* is a system of geodetic parameters including fundamental geodetic constants, the Earth ellipsoid parameters, the Earth gravity field parameters, the geocentric coordinate system, and the transformation parameters to other reference systems. The PZ-90.11 is the state geocentric coordinate system introduced by the Russian Federation Government Decree 1463 of December 28, 2012, and has been used for geodetic support of orbital missions and navigation since January 15, 2014. The PZ-90 Coordinate System is a basis for geodetic support of the GLObal NAvigation Satellite System (GLONASS).

Definition of Frame

- **Origin:** Earth's center of mass being defined for the whole Earth including oceans and atmosphere.
- **Axes:**

  Z-axis is directed to the Conventional Reference Pole that was defined by the International Earth Rotation and Reference Systems Service (IERS) and Bureau International de l'Heure (BIH);

  X-axis is directed to the intersection point of the equatorial plane and the Zero Meridian defined by BIH;

  Y-axis completes a right-handed system.
- **Scale:** Conforms to the current state of knowledge of the speed of light, the geocentric gravitational constant as well as to the precision of the satellite laser ranging instruments.
- **Orientation:** Conforms to the Recommendations of BIH.
- **Evolution:** Zero rotation rate with respect to the ITRF2008.

PZ-90.11 is agreed with ITRF2008.

* In English "The Earth Parameters 1990".

Coordinate System: Orthogonal Cartesian Coordinates (*X*, *Y*, *Z*). The PZ-90 Coordinate System origin also serves as the geometric center of the PZ-90 ellipsoid and the *Z*-axis is its minor axis. The geodetic coordinates (latitude, longitude, height) are computed using this PZ-90 Earth's ellipsoid.

Defining Parameters: PZ-90 is defined by four fundamental parameters: the semi-major axis, the flattening factor of the Earth ellipsoid, gravitational constant (mass of Earth's atmosphere included), and the angular velocity of the Earth.

Parameter	Notation	Unit	Value
Semi-major Axis	a	m	6 378 136.0
Flattening Factor of the Earth Ellipsoid	α	–	1/298.25784
Gravitational Constant (Mass of Earth's Atmosphere Included)	fM	m^3/s^2	$398\,600.4418\times10^9$
Angular Velocity of the Earth	ω	rad/s	$7.292\,115\times10^{-5}$

References: "Parametry Zemli 1990" (PZ-90.11): Reference document. – Moscow: Military Topographic Department of the General Staff of Armed Forces of the Russian Federation, 2014, 52 p.†

Relationship with other reference systems: Transformation parameters of reference systems are obtained based on the differences between the coordinates of the same sites, defined in both systems.

Transformation Parameters: Transformation parameters and their root-mean-square errors for PZ-90, PZ-90.02, PZ-90.11, WGS 84 (G1150) and ITRF2008.

#	From	To	ΔX (m)	ΔY (m)	ΔZ (m)	ω_X (mas)	ω_Y (mas)	ω_Z (mas)	m (10^{-6})	Epoch
1	PZ-90	PZ-90.02	–1.07 ±0.10	–0.03 ±0.10	+0.02 ±0.10	0	0	–130 ±10	–0.220 ±0.020	2002.0
2	WGS 84 (G1150)	PZ-90.02	+0.36 ±0.10	–0.08 ±0.10	–0.18 ±0.10	0	0	0	0	2002.0
3	PZ-90.11	ITRF2008	–0.003 ±0.002	–0.001 ±0.002	+0.000 ±0.002	+0.019 ±0.072	–0.042 ±0.073	+0.002 ±0.090	–0.000 ±0.0003	2010.0

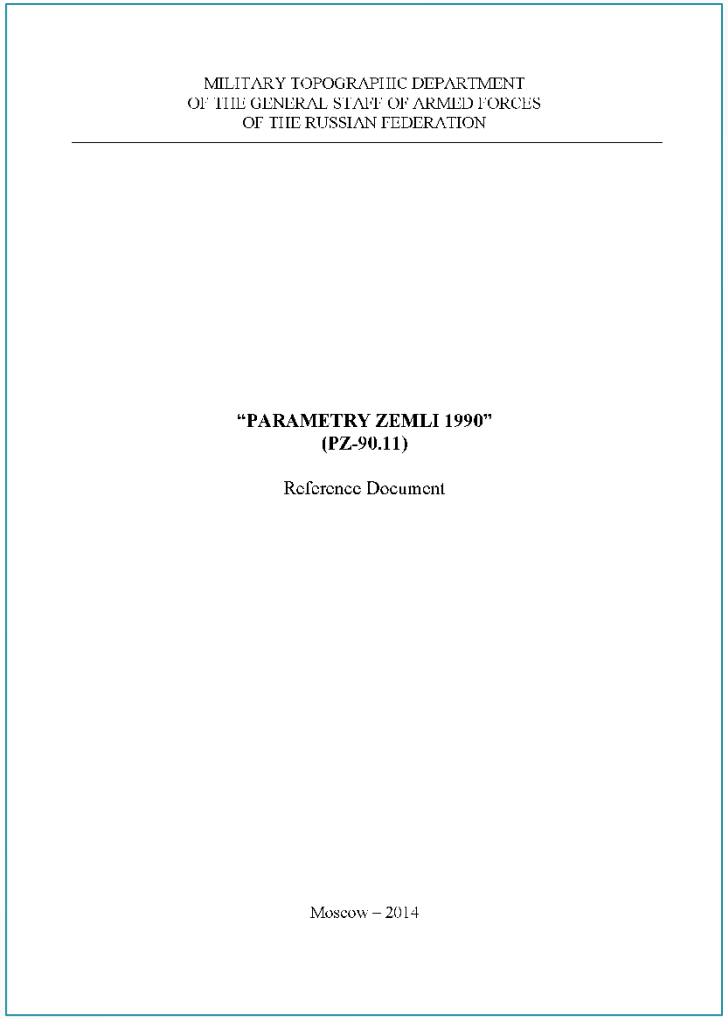
Notes: PZ-90 is the GLONASS geodetic basis. The PZ-90 Coordinate System is also used for orbital mission support and navigation. From the GLONASS satellites, users directly receive coordinates in PZ-90 and time in the GLONASS time scale.

Future Plans: The new version of "Parametry Zemli 1990" Coordinate System (PZ-90.11) is adopted in the Russian Federation. It has been implemented into GLONASS geodetic support. The PZ-90.11 monitoring is to be provided and user access is to be granted to the coordinates of a number of the PZ-90.11 sites based on the monitoring results.

† The English version is to follow and to be published on the websites of the Ministry of Defense of the Russian Federation and the Federal Space Agency.

Table 6: Accuracy of implementations of PZ–90

Version	Released	Epoch	Accuracy of absolute position, m	Accuracy of relative position, m
PZ-90	1990	—	1-2	0.3-0.5
PZ-90.02	2005	2002	0.3-0.5	0.02-0.03
PZ-90.11	2011	2010	0.05	0.005-0.01



MILITARY TOPOGRAPHIC DEPARTMENT
OF THE GENERAL STAFF OF ARMED FORCES
OF THE RUSSIAN FEDERATION

“PARAMETRY ZEMLI 1990”
(PZ-90.11)

Reference Document

Moscow – 2014

References:

“Parametry Zemli 1990” (PZ-90.11): Reference document. – Moscow: Military Topographic Department of the General Staff of the Armed Forces of the Russian Federation, 2014, 52 p.
http://structure.mil.ru/files/pz-90.pdf

UN Resolution A/RES/69/266
A Global Geodetic Reference Frame for Sustainable Development

1. Notes with appreciation the establishment of a working group by the Committee of Experts on Global Geospatial Information Management to develop a global geodetic road map that addresses key elements relating to the development and sustainability of the global geodetic reference frame;
2. Encourages Member States and relevant international organizations to enhance global cooperation in providing technical assistance, especially for capacity development in geodesy for developing countries, with the aim of ensuring the development, sustainability and advancement of a global geodetic reference frame;
3. Urges Member States to implement open sharing of geodetic data, standards and conventions, on a voluntary basis, to contribute to the global reference frame and regional densifications through relevant national mechanisms and intergovernmental cooperation, and in coordination with the International Association of Geodesy;
4. Also invites Member States to commit to improving and maintaining appropriate national geodetic infrastructure as an essential means to enhance the global geodetic reference frame;
5. Further invites Member States to engage in multilateral cooperation that addresses infrastructure gaps and duplications towards the development of a more sustainable global geodetic reference frame;
6. Invites Member States to develop outreach programmes that make the global geodetic reference frame more visible and understandable to society.

CONCLUSIONS

- The implementation of all international agreements will allow to establish a global geodetic reference frame that meets all the advanced requirements of accuracy, availability and efficiency for sustainable global development.
- A Global Geodetic Reference Frame is critical to future positioning and navigation with GNSS.
- Exploitation of multiple systems to support increased demands of a wide range of users and long-term stability would be facilitated by, if not require, use of interoperable reference systems consistent with conventions, constants and models of the International Terrestrial Reference System.

Thank you!

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