Compass Geodetic System

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Outline

- Introduction
- Definition of System
- Realization of System
- Summary

1、 Introduction

- The Compass Geodetic System (CGS) is to be used by BeiDou as its geodetic reference.
- The Compass Geodetic System is a geocentric coordinate system.
- To date the CGS has been realized twice, the second realization is underway, and will be finalized in the near future.

2、 Definition of System

1 Definition

The definition of the CGS follows the criteria outlined in IERS Technical Note 21. These criteria are repeated below:

◆ **Origin**: its origin being the center of mass for the whole earth, including oceans and atmosphere.

◆ **Scale**: the unit of length is meter (SI). the scale is consistent with the TCG time coordinate for a geocentric local frame.

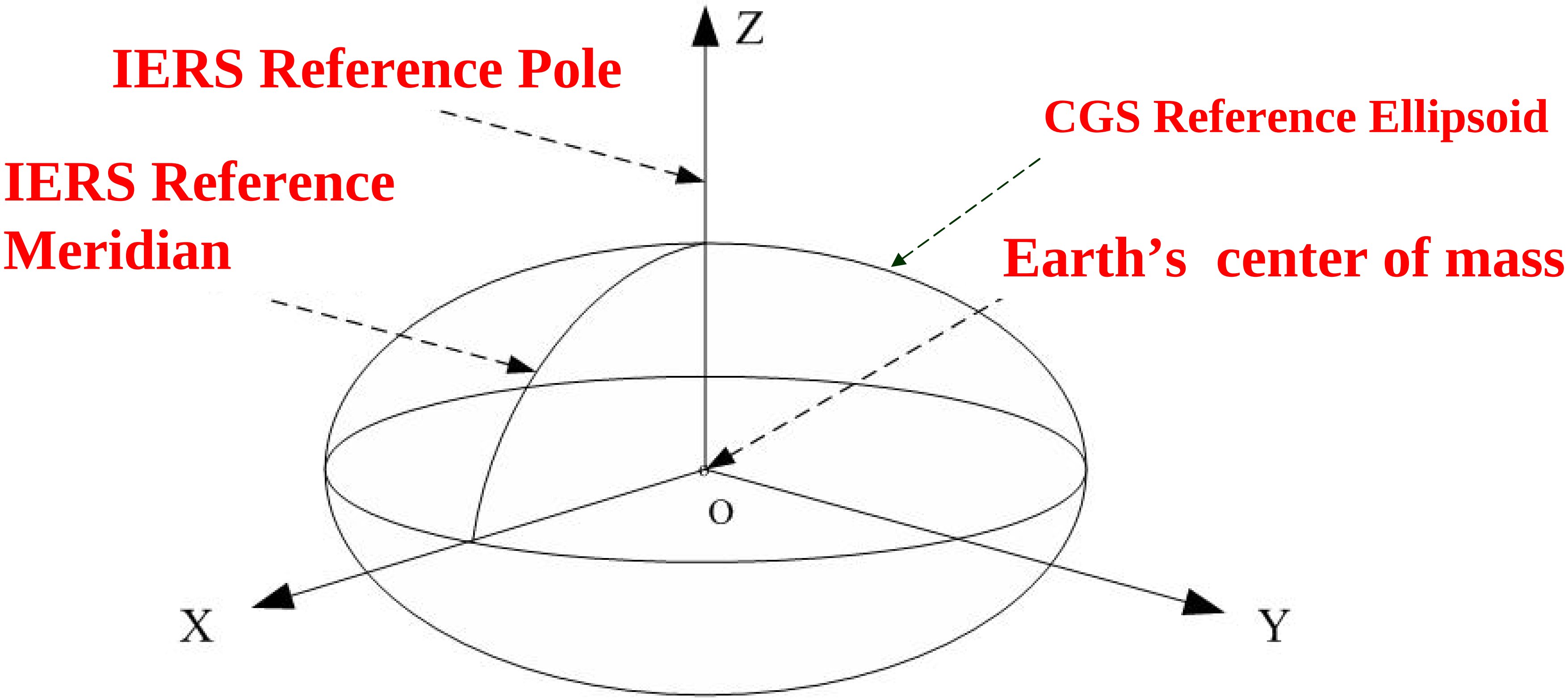
◆ **Orientation**: the orientation was initially given by the BIH orientation at 1984.0.

◆ **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.

2、 Definition of System

2 Definition

The Compass Geodetic System (CGS) is a right-handed, Earth-fixed orthogonal coordinate system.



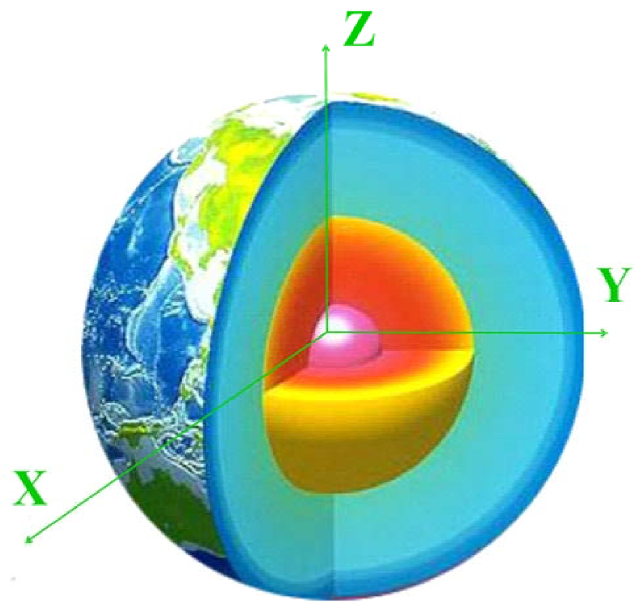
2、 Definition of System

3 Reference Ellipsoid

The reference ellipsoid the CGS uses is defined by the following four parameters:

Defining parameters of CGS Ellipsoid

Semi-major axis	$a = 6378137.0m$
Flattening	$f = 1:298.257222101$
Earth's gravitational constant	$GM = 3986004.418 \times 10^8 m^3 s^{-2}$
Earth's angular velocity	$\omega = 7292115.0 \times 10^{-11} rad\ s^{-1}$



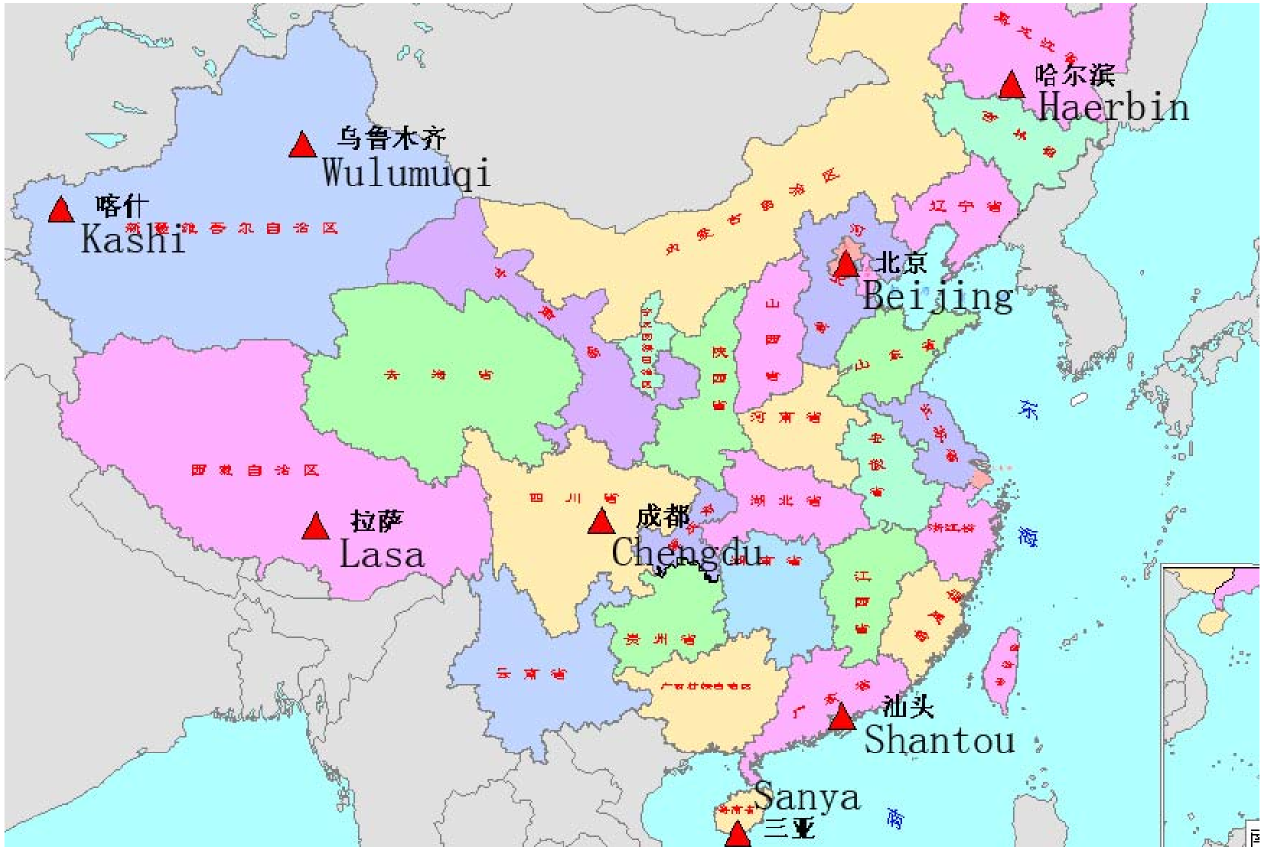
2、 Definition of System

Derived parameters of CGS Ellipsoid

Semi-minor axis	b = 6356752.3141m
Linear eccentricity	E = 521854.00970025m
First eccentricity squared	e^2=0.00669438002290
Second eccentricity squared	e'^2=0.00669438002290
Radius of sphere of equal volume	R = 6371000.7900m
Normal gravity potential of the ellipsoid	U_0 =62636851.7149 m^2s^{-2}
Second degree zonal harmonic coefficient	J_2 =0.1082629832258x10^{-2}
Normal gravity at the equator on the ellipsoid	γ_e =9.7803253361ms^{-2}
Normal gravity at the pole on the ellipsoid	γ_p =9.8321849379ms^{-2}
Normal gravity formula constant	k =0.00193185261931

3、 Realization of System

The CGS is materialized by the coordinates and velocities of BeiDou's monitor stations.



Monitor stations of BeiDou System

3、 Realization of System

1 Initial realization

- The initial realization of the CGS took place in 2007 ~2009 by using GPS technology.
- Within two years and a half, the monitor stations were visited site by site.
- During a site occupation, a GPS receiver observed GPS satellites for ~ 70 hours divided into 6 sessions.
- In some sites, a local survey had to done to tie the receiver to the monitor station.

3、 Realization of System

1 Initial realization

- In order to tie the CGS system to ITRF frame, GPS data for monitor stations were processed together with those for 4~6 surrounding CMONOC*/IGS stations, whose ITRF2000 coordinates were held fixed in the position estimation.
- As a result, the CGS is aligned to ITRF2000 frame. It is shown that the accuracy of the CGS system for each coordinate component is better than 10 cm.

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*CMONOC=Crustal Movement Observation Network of China

3、 Realization of System

Information on the site occupation and station positions in the 1st realization of CGS

Monitor station	Site occupation period	Epoch of station coordinates	Reference frame	CMONOC/IGS stations whose coordinates were fixed in position estimation
Bejing	Mar 26 ~Apr 06, 2007	2007.242	ITRF2000	BJFS,JIXN,HLAR,CHUN, YANC,HRBN
Chengdu	Dec 9~ Dec 22, 2008	2008.956	ITRF2000	DLHA,KMIN,WUHN,XIAA, XIAG,XNIN
Haerbin	June 25~ July 7, 2008	2008.503	ITRF2000	BJFS,CHUN,HLAR,HRBN, SUIY,TAIN
Kashi	May 16~ June 9, 2009	2009.404	ITRF2000	KIT3,POL2,SELE,URUM
Sanya	Dec 27~ Dec 30, 2008	2008.995	ITRF2000	QION,XIAM,SHAO,WUHN ,LUZH,KMIN
Shantou	Jan 3~ Jan 16, 2009	2009.014	ITRF2000	KUNM,LHAZ,SHAO,TCMS ,WUHN
Wulumuqi	Mar 14~ Mar 17, 2007	2009.135	ITRF2000	IRKM,NOVM,SELE,ULAB

3、 Realization of System

2 Second Realization

- The second realization started with a GPS observation campaign occurred in the period 16 - 31 December 2011, totaled 15 whole days.
- During this period GPS data were collected simultaneously at 7 reference stations co-located with respective monitor stations.
- A local tie between the reference and monitor stations was performed, also using GPS measurements.
- Note, the monitor station Lasa was directly tied to a IGS station ~ 2 km away, which is considered as a reference station.

3、 Realization of System

3 **Data Processing**

- **The GPS campaign data, combined with the 2007-2009 data are analyzed, aiming at achieving the coordinates and velocities for each monitor station.**
- **To reach this goal, four steps are taken:**

3、 Realization of System

3 Data Processing

- **First step: loosely constrained solutions to reference station coordinates are obtained by analyzing GPS data for 8 reference stations , together with those for 20 CMONOC stations and 18 IGS stations, utilizing GAMIT/GLOBK* software package .**

20 CMONOC stations : AHBB、BJFS、GSAX、HLHG、HNMY、LHAZ、NMAG、NMDW、NMER、NMWT、QION、QHBM、QHGE、XIAA、XIAM、XJHT、XJQH、XJRQ、XJWQ、YNTC

18 IGS stations: aira、chan、daej、gmsd、guam、iisc、irkt、kit3、kunm、lhaz、pol2、sele、suwn、tcms、tnml、tskb、twtf、usud

*GAMIT/GLOBK is a GPS analysis package developed at MIT and Scripps for the estimation of relative positions of ground stations and satellite orbits.

3、 Realization of System

3 Data processing

- **Second step**: **A time series of reference station position solutions are achieved by combining the solutions obtained in first step with H-files of ~150 globally distributed IGS stations and bring them into ITRF2008 frame defined by a set of the coordinates of 47 IGS core stations.**

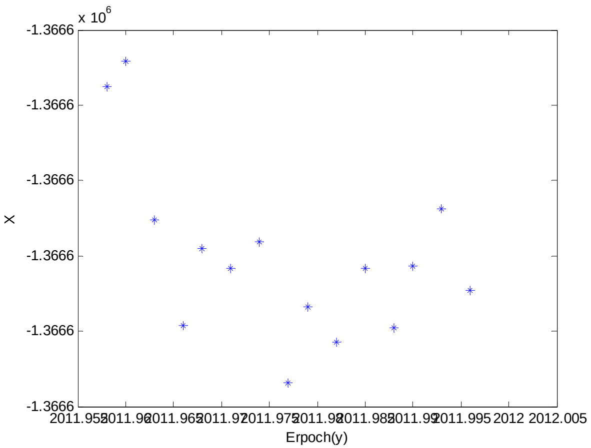
47 IGS core stations: ALGO、AREQ、AUCK、BAHR、BRAZ、BRMU、CAS1、CHAT、DAV1、DRAO、FAIR、FORT、GOL2、GODE、GUAM、HARK、HOB2、IRKT、KERG、KIT3、KOKB、KOSG、KOUR、KWJ1、LHAS、MAC1、MALI、MAS1、MATE、MCM4、MDO1、NLIB、NYAL、ONSA、PIE1、POTS、SANT、SHAO、TID2、THU1、TROM、TSKB、VILL、YELL、YAR1、WES2、WTZR

3、 Realization of System

3 Data processing

➢ **Third step: A time series of positions for each monitor station are generated by adding the local tie data to the coordinates of the corresponding reference station.**

Chengdu station



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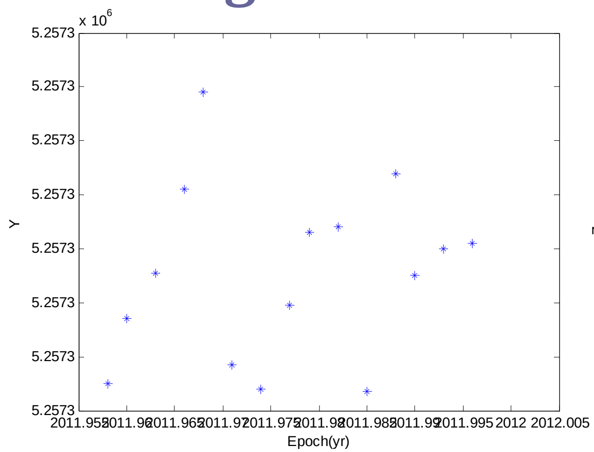

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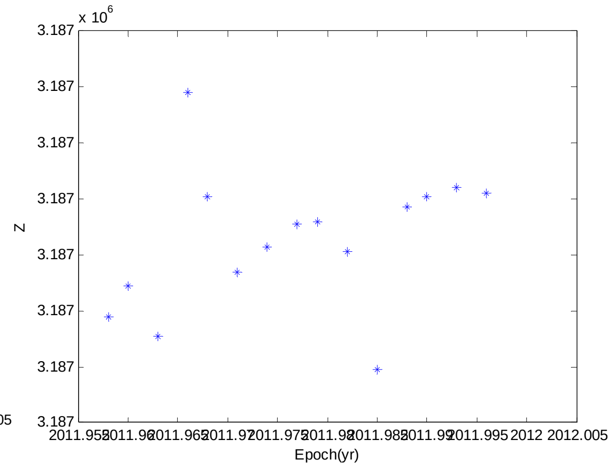

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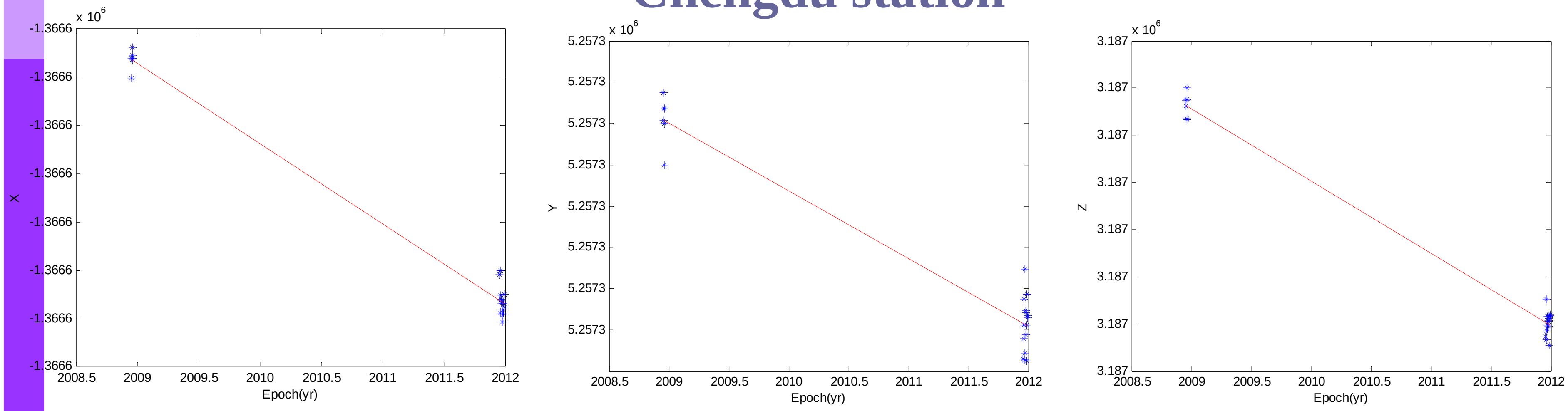
3、 Realization of System

3 Data processing

- **Last Step**: the coordinates at epoch 2012.0 and velocities are obtained by a linear regression analysis of the time series of monitor station positions.
- **This step ends up with the new frame we desired.**

Chengdu station



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3、 Realization of System

4 The CGS (2012)

- **The updated version of the CGS system is designated as "CGS (2012)", where the number in parentheses indicates the year during which the coordinates and velocities were implemented in the ephemeris computation process.**
- **The CGS (2012) includes a set of coordinates at epoch 2012.0 and velocities for 8 monitor stations.**
- **The standard deviations of coordinate and velocity component are less than 3 mm and 1.2 mm/yr respectively; the accuracies of coordinate and velocity are on the order of 1 cm and 2 mm/yr respectively.**

3、 Realization of system

4 The CGS (2012)

- The CGS (2012) is closely aligned to ITRF2008. There is no need of making a transformation between these two frames.
- In terms of datum definition, the CGS (2012) have the following properties:

- **Origin**: zero translation and translation rate with respect to ITRF2008.
- **Scale**: zero scale and scale rate with respect to ITRF2008.
- **Orientation**: zero rotation and rotation rate with respect to ITRF2008.
- **Time Evolution**: zero rotation rate with respect to ITRF2008.

4、 Summary

- BeiDou references the Compass Geodetic System (CGS), its definition strictly follows the specifications formulated by IERS.
- So far the CGS system has been realized twice. The CGS (2012) is closely aligned to ITRF2008.
- The accuracy of the CGS (2012) is on the order of 1 cm and 2 mm/yr respectively for the coordinate and velocity component.

Final remarks

- Previously, BeiDou was supposed to use the CGCS2000 as its geodetic reference. CGCS2000 stands for China Geodetic Coordinate System 2000, which is the current national coordinate system of China.
- But now it is decided that BeiDou use the Compass Geodetic System (CGS), instead of CGCS2000, as its coordinate system. Why do we need to make a change? Why does Beidou have its own coordinate system? The reason is simple:
- Such a change enables the realization of BeiDou' coordinate system to be much easier and more practical, this is because:

Final remarks (continued)

- The national coordinate system involves thousands of points, whereas BeiDou' coordinate system only involves a few of points (= the number of monitoring stations, at this stage, it is 8). Dealing with a few of points is relatively simple and easy!
- It is necessary, essential and unavoidable to separate the BeiDou' coordinate system from the national coordinate system. So we have the Compass Geodetic System. In the long run, this will benefit the realization and maintenance of BeiDou' coordinate system.

Thank you
for your attention!