BeiDou Coordinate System And Its First Realization

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Outline

- **Introduction**
- **Definition of BDCS**
- **First Realization of BDCS**
- **Summary**

1 Introduction

In August 2017, China Satellite Navigation Office issued Beidou Navigation Satellite System(BDS) Signal in Space Interface Control Document (ICD), in which Beidou Coordinate System(BDCS) will replace CGCS2000 and be adopted as its geodetic reference system.

Why?

1 Introduction

□ **Main Consideration**

BDS monitor stations

VS

Bejing	Haerbin
Sanya	Wulumuqi
Chengdu	Kashi
Shantou	Lasa
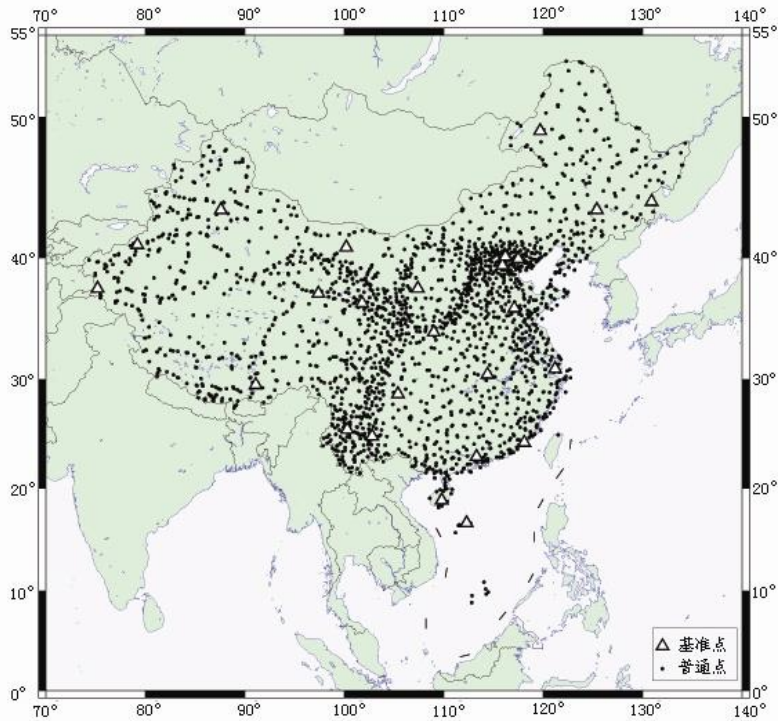
CGCS2000 reference stations

1 Introduction

☐ **Principles**

✓ **Advanced and Scientific**
✓ **BDCS should be aligned to the latest ITRF.**

2 Definition of BDCS

□ **Name**

　　To differentiate the updated realizations, BDCS（W***）is presented, where W*** indicates BeiDou week, for example BDCS（W465）, which means the new frame is adopted from BeiDou week 465.

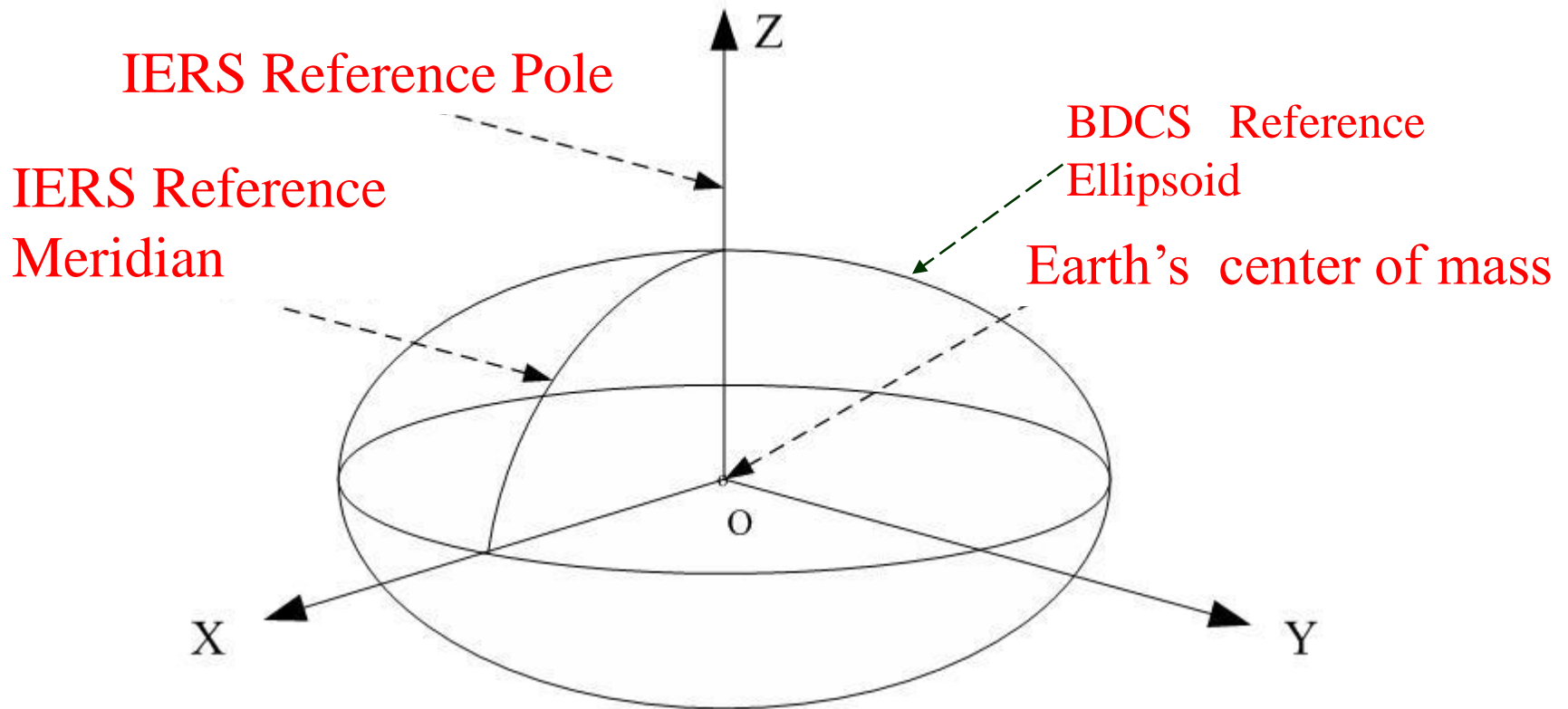# 2 Definition of BDCS

❑ **Definition**

✓ Origin: 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.

✓ Orientation: conform to the recommendation of BIH.

✓ time evolution: no-net-rotation with regards to horizontal tectonic motions over the whole earth.
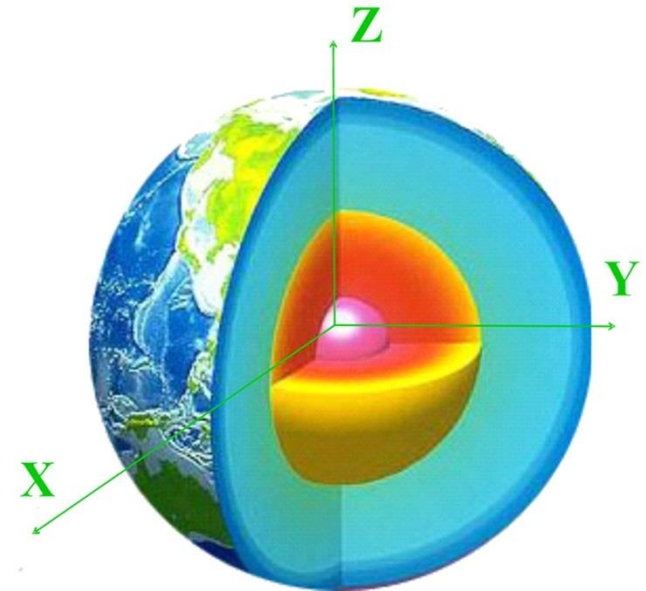
2 Definition of BDCS

☐ **Definition**

2 Definition of BDCS

□ **Ellipsoid**

Defining parameters of BDCS Ellipsoid

Semi-major axis	a = 6378137.0m
Flattening	f = 1:298.257222101
Geocentric 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 BDCS

Derived parameters of BDCS 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	$U_0 = 62636851.7149 \ m^2 s^{-2}$
Second degree zonal harmonic coefficient	$J_2 = 0.1082629832258 \times 10^{-2}$
Normal gravity at the equator on the ellipsoid	$\gamma_e = 9.7803253361 ms^{-2}$
Normal gravity at the pole on the ellipsoid	$\gamma_p = 9.8321849379 ms^{-2}$
Normal gravity formula constant	$k = 0.0019318526193l$

3 First Realization of BDCS

- ✓ **the collection of geophysical models and parameters**
- ✓ **positions and velocities for the monitoring stations**
- ✓ **satellite ephemerides**
- ✓ **corresponding EOPs**

3 First Realization of BDCS

BDCS monitor stations

| Bejing	Chengdu	Haerbin	Kashi
Sanya	Shantou	Wulumuqi	Lasa

3　First Realization of BDCS

❑　**Time span of data**

✓　The initial observation: in 2007 ~2009, one station after another.

✓　The second observation: in December 2011, the joint campaign , totaled 15 whole days.

✓　The third observation: in April 2014, the joint campaign, totaled 15 whole days.

✓　The fourth observation: in 2016, regional joint survey.

3 First Realization of BDCS

❑ **Data processing**
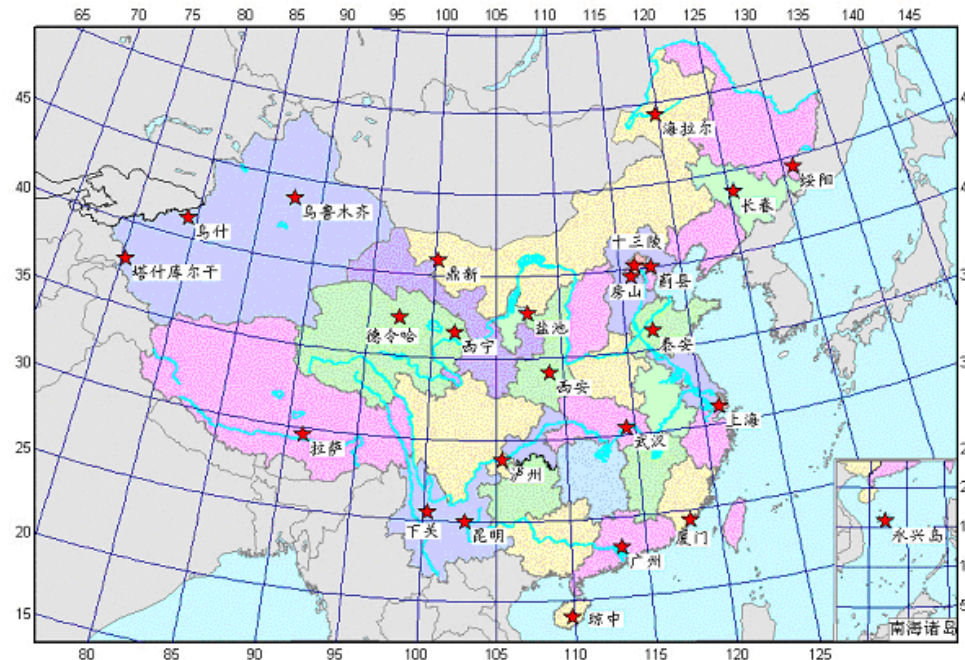
➢ First step: loosely constrained solutions

- 8 reference stations (not monitor stations)
- 27 CMONOC stations
- 64 IGS stations .
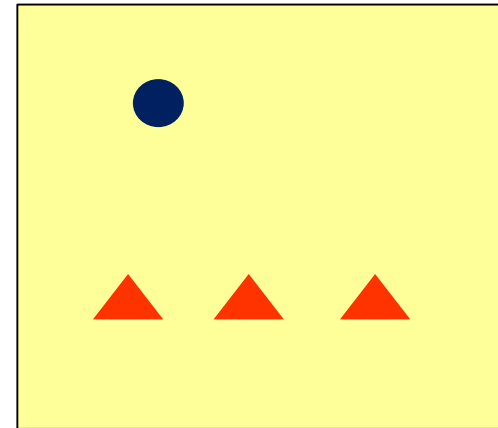
*CMONOC=Crustal Movement Observation Network of China
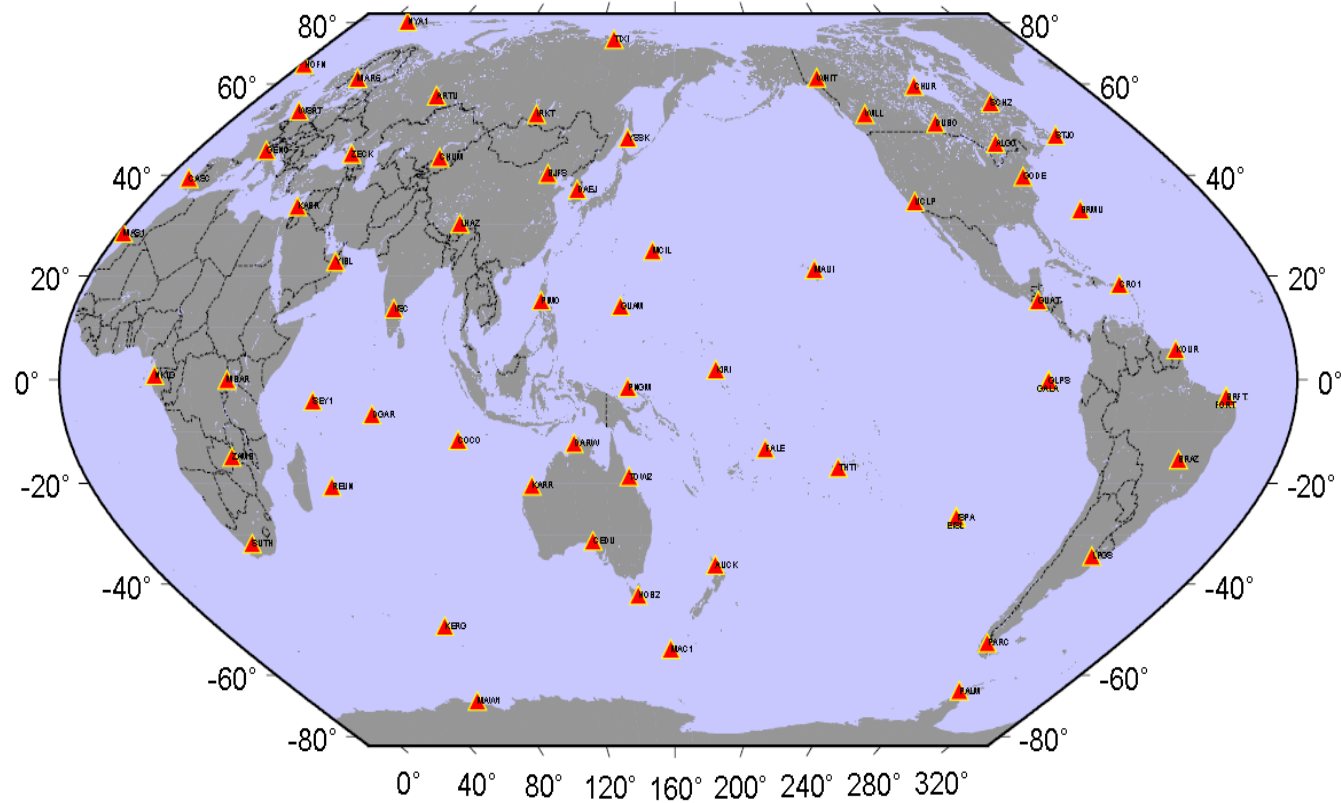
3 First Realization of BDCS

❑ Data processing

27 CMONOC stations

3 First Realization of BDCS

□ **Data processing**

64 IGS Stations

3 First Realization of BDCS

❑ Data processing

➤Second step: minimum constrains solutions

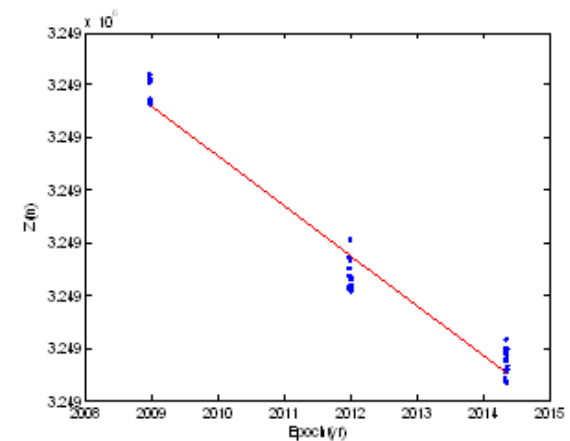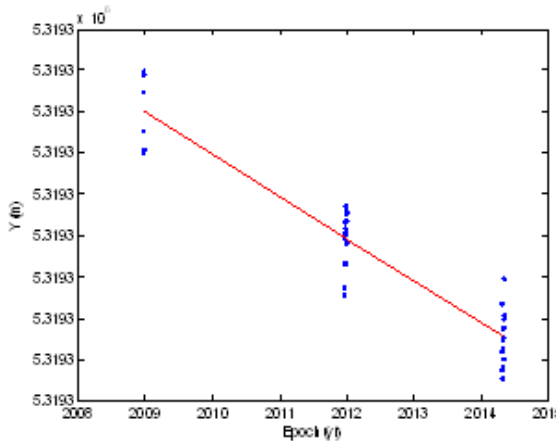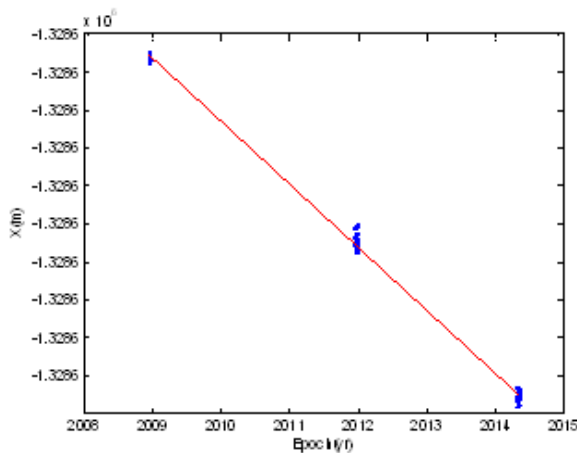Coordinates of montor stations are aligned to ITRF2014 over a set of 64 IGS core stations.

$$\hat{X} = X_{apr} + \left(N + B^T \Sigma_\theta^{-1} B \right)^{-1} \left[K + B^T \Sigma_\theta^{-1} B \left(X_R - X_{apr} \right) \right]$$

3 First Realization of BDCS

❑ **Data processing**

➤ Third step: positions time series

Local tie data were added to the coordinates of reference stations.

CDJC01 X, Y, Z coordinate series

3 First Realization of BDCS

❑ **Data processing**

➤ Last Step: the coordinates at any epoch can be obtained by linear regression.

$$
\begin{cases}
X(t) = X_0 + v_X \times (t - 2010.0) \\
Y(t) = Y_0 + v_Y \times (t - 2010.0) \\
Z(t) = Z_0 + v_Z \times (t - 2010.0)
\end{cases}
$$

3 First Realization of BDCS

❑ **Accuracy**

Comparison of the coordinates and velocities

stations	dx(m)	dy(m)	dz(m)	dvx(m/a)	dvy(m/a)	dvz(m/a)
CDJC01	-0.0004	0.0018	-0.0005	0.0001	0.0005	-0.0003
CDJC02	-0.0004	0.0016	-0.0009	0.0001	0.0010	0.0002
CDJC03	-0.0005	0.0015	-0.0019	0.0002	0.0010	0.0021
HEBJC01	-0.0020	0.0042	0.0024	-0.0010	0.0022	0.0018
HEBJC02	-0.0021	0.0041	0.0020	-0.0008	0.0024	0.0024
HEBJC03	-0.0024	0.0047	0.0024	-0.0004	0.0016	0.0020
…	…	…	…	…	…	…
RMS	0.002	0.002	0.004	0.003	0.002	0.002

3 First Realization of BDCS
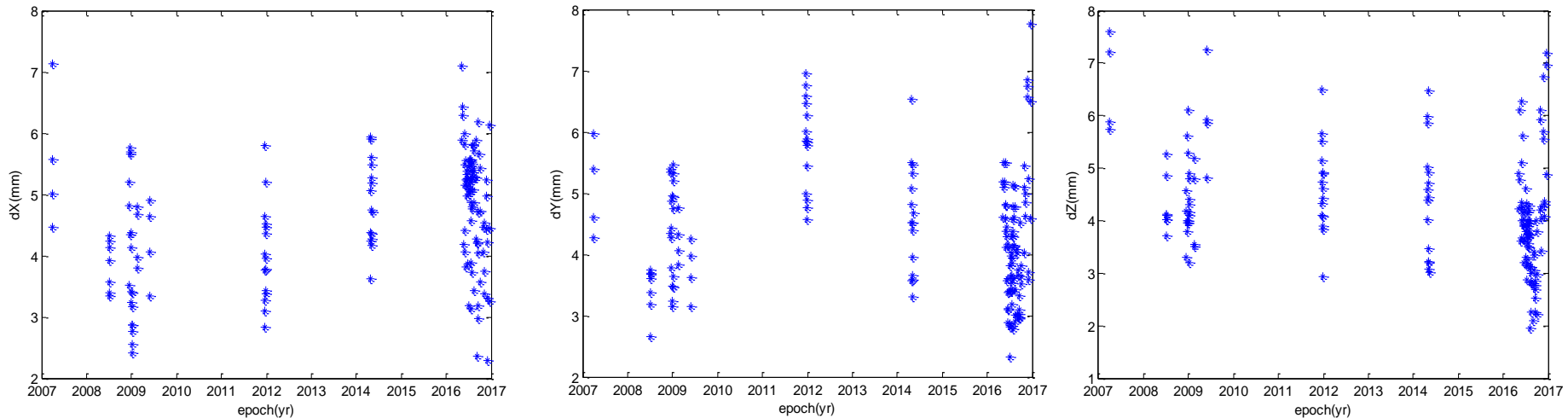
❑ **Accuracy**

RMS of differences between calculated coordinates and ITRF2014 coordinates of 64 IGS stations

The accuracy of monitor station coordinates is better than 1 cm.

4 Summary

- BDCS will replace CGCS2000 as BDS's geodetic reference system.

- The definition of BDCS is the same as that of CGCS2000, but the realization is separate.

- The first realization of BDCS is aligned to ITRF2014, and the accuracy of the coordinates is superior to 1 cm.

- BDCS will pave the way for the interoperation between BDS and other GNSS.

THANK YOU!

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