# Chinese Geodetic Coordinate Reference Frame 2000

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# 1. Overview on CTRF2000

- **What kind of geodetic reference coordinate system do we need for satellite navigation?**

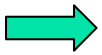
- **The satellite moves round the Earth mass center — the orbit of the satellite should be expressed in a geocentric terrestrial reference system (TRS).**

- **COMPASS orbit and navigation in China refer to CGCS 2000 — Chinese Geodetic Coordinate System, realized by CTRF 2000.**

# 1. Overview on CTRF2000

- **What does TRF serve for in navigation?**

**Terrestrial Reference Frame (TRF) in navigation**

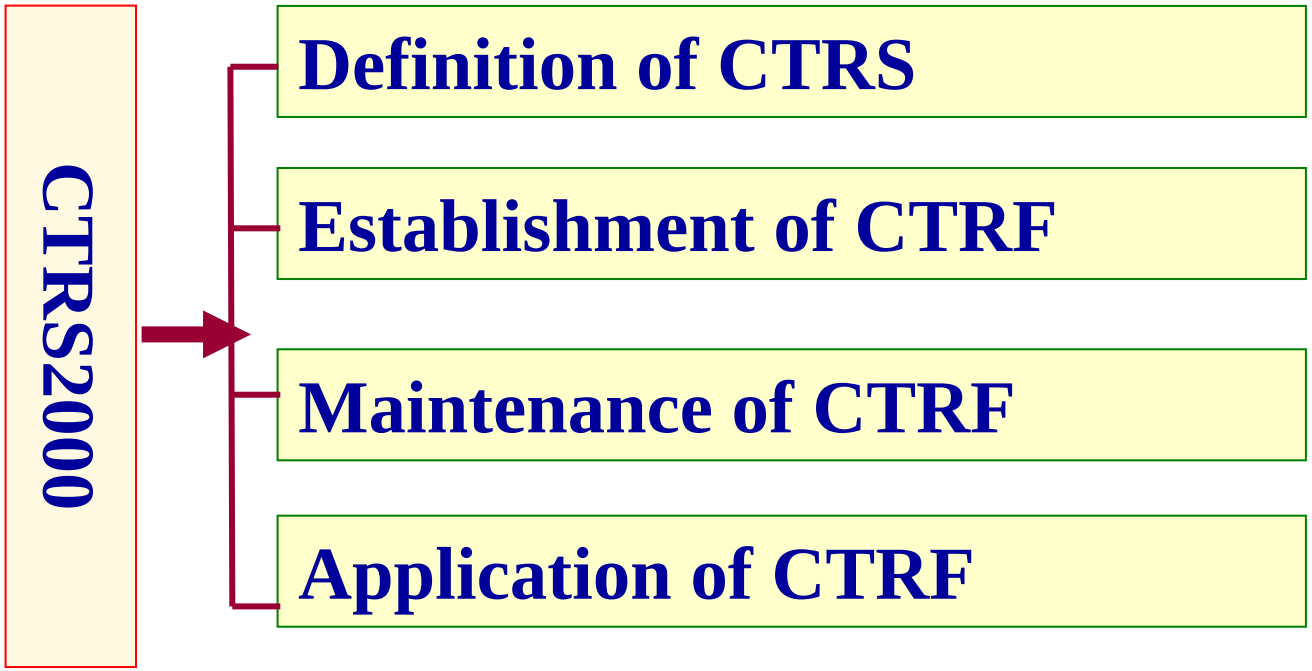


- **Tracking the satellite to determine the orbit**
- **Expressing the coordinate system of navigation system**
- **Augmenting in local area for satellite navigation**
- **…**

# 1. Overview on CTRF2000

- **What does Chinese Geodetic Coordinate System (CGCS) need?**

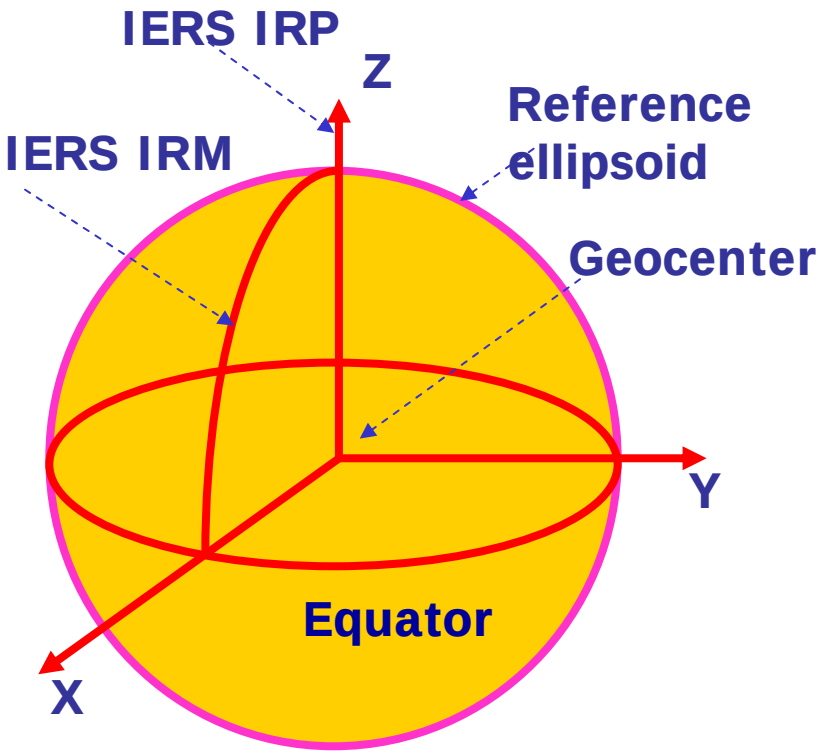
**---Definition, establishment, maintenance and applications.**



# 1. Overview on CTRF2000

## CGCS2000 meets the following rules of IERS :

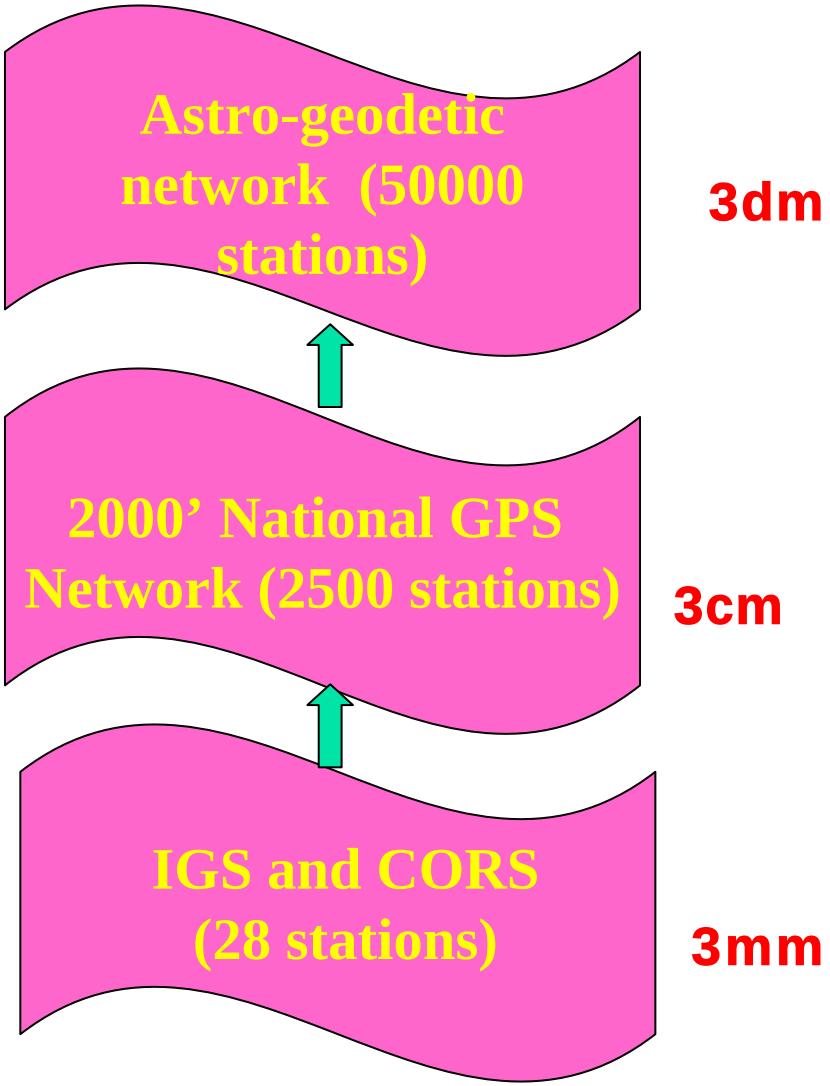
- Its **origin** is at the center of mass for the whole Earth, including oceans and atmosphere;
- **Unit of length**: meter SI, consistent with TCG (Geocentric Coordinate Time);
- The **orientation** is initially given by the BIH orientation at 1984;
- The time evolution in orientation will create no residual global orientation with regard to the crust.



# 2. Structure of CTRF2000

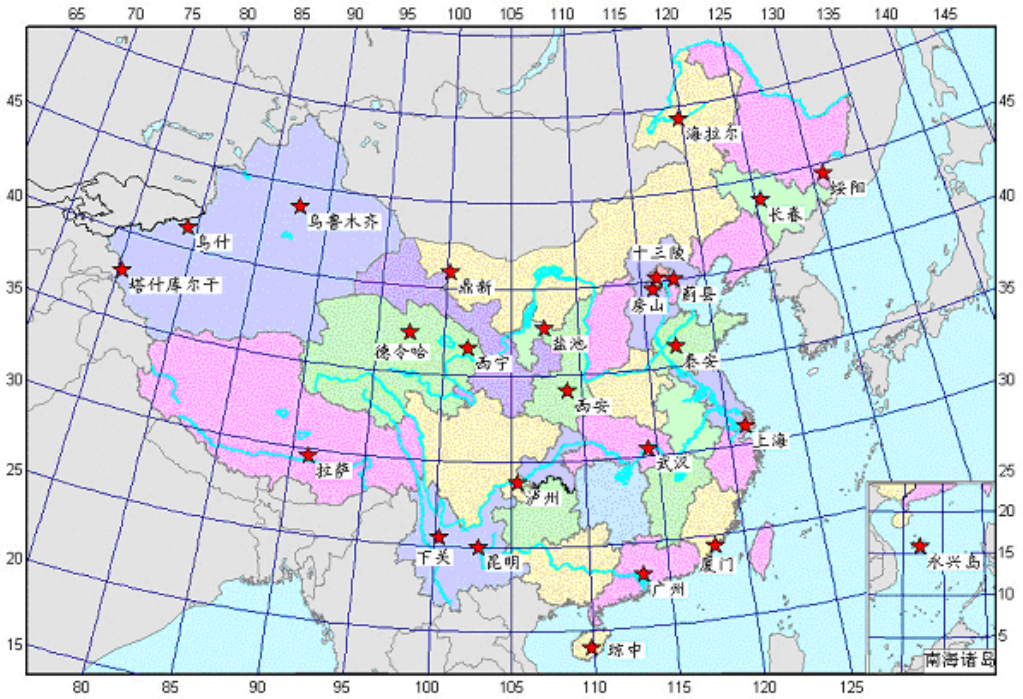
- **Reference Frame：ITRF1997;**
- **Epoch: 2000.0.**

- **The first order:** 28 CORS, which is the key frame of CGCS2000 with mm accuracy.
- **The second order:** "2000' national GPS network", with about 2500 stations with cm accuracy.
- **The third order:** National astro-geodetic network, with about 50,000 stations with 0.3m accuracy.



# 2.1 The first order frame——28 CORS

- The first order frame is composed of 28 continuous operational stations.
- An integrated adjustment of the CORS in China with selected IGS stations was carried out.
- The accuracy of the coordinates of the adjusted CORS is about 3mm.



# 2.2 The second order frame
# ——2000’ national GPS network

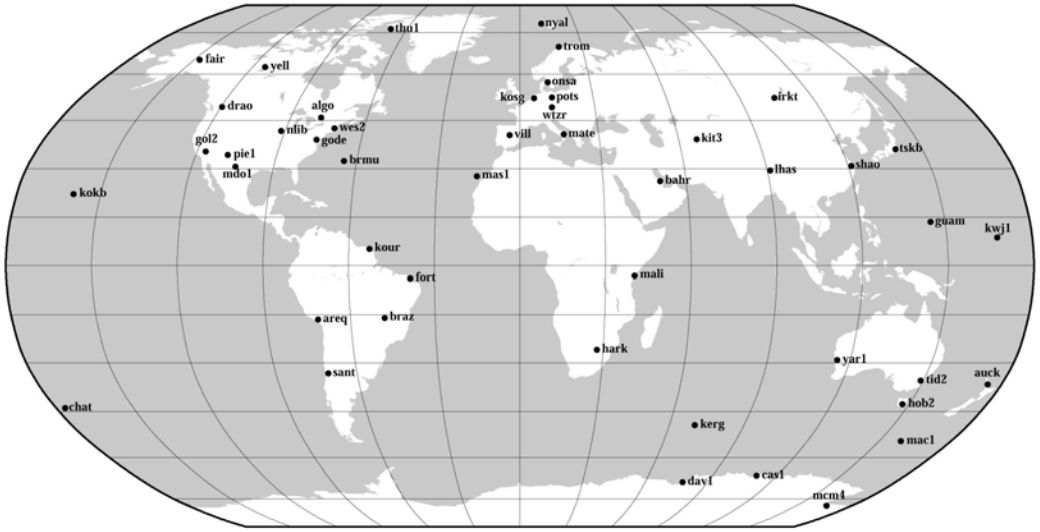
# 2.2 The Second Order Frame of CGCS 2000

- The CTRF 2000 is mainly expressed by 2000' National GPS Network
  - 1. The frame and epoch of the GPS network 2000
    - Frame: ITRF97; Epoch: 2000.0.
  - 2. What are the initial constraints?
    - 47 IGS stations are selected to define the reference frame;
    - The coordinates of IGS stations with 1 $\sigma$ are introduced in the integrated adjustment of GPS networks;
    - The coordinates are reduced into the epoch 2000.0 according to their velocities.

# 2.2 The Second Order Frame of CGCS 2000

2000’ GPS network

IGS stations



# 2.2 The Second Order Frame of CGCS 2000

- **3. How to deal with the functional and stochastic model errors?**

**Systematic parameters are introduced in functional model**

⇩

**Variance component estimation based on the improved functional model**

⇩

**Robust estimation is applied to the improved functional model**

⇩

**To control the cross error influences**

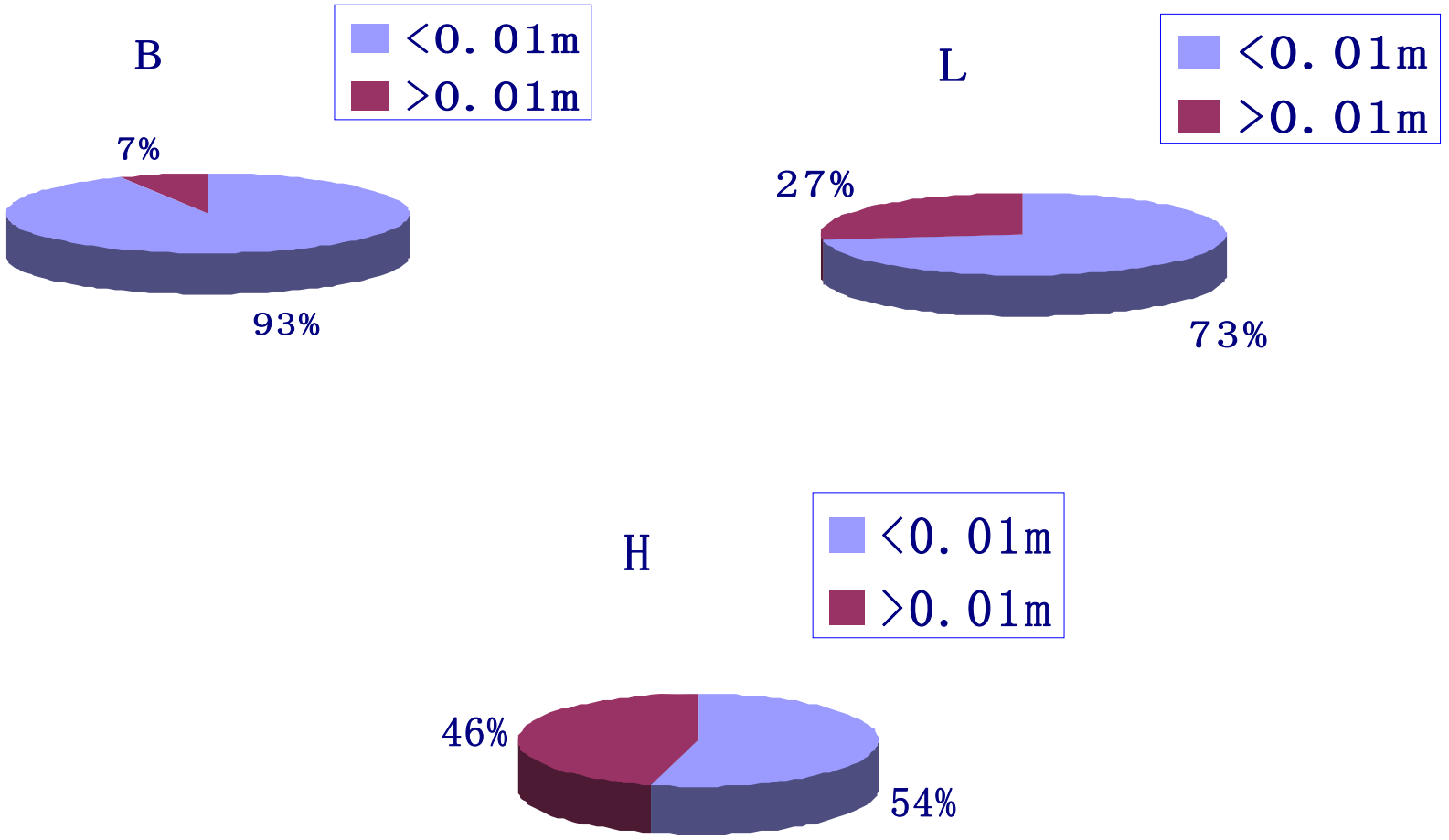
# 2.2 The Second Order Frame of CGCS 2000

## ■ 4. Results of the GPS network 2000

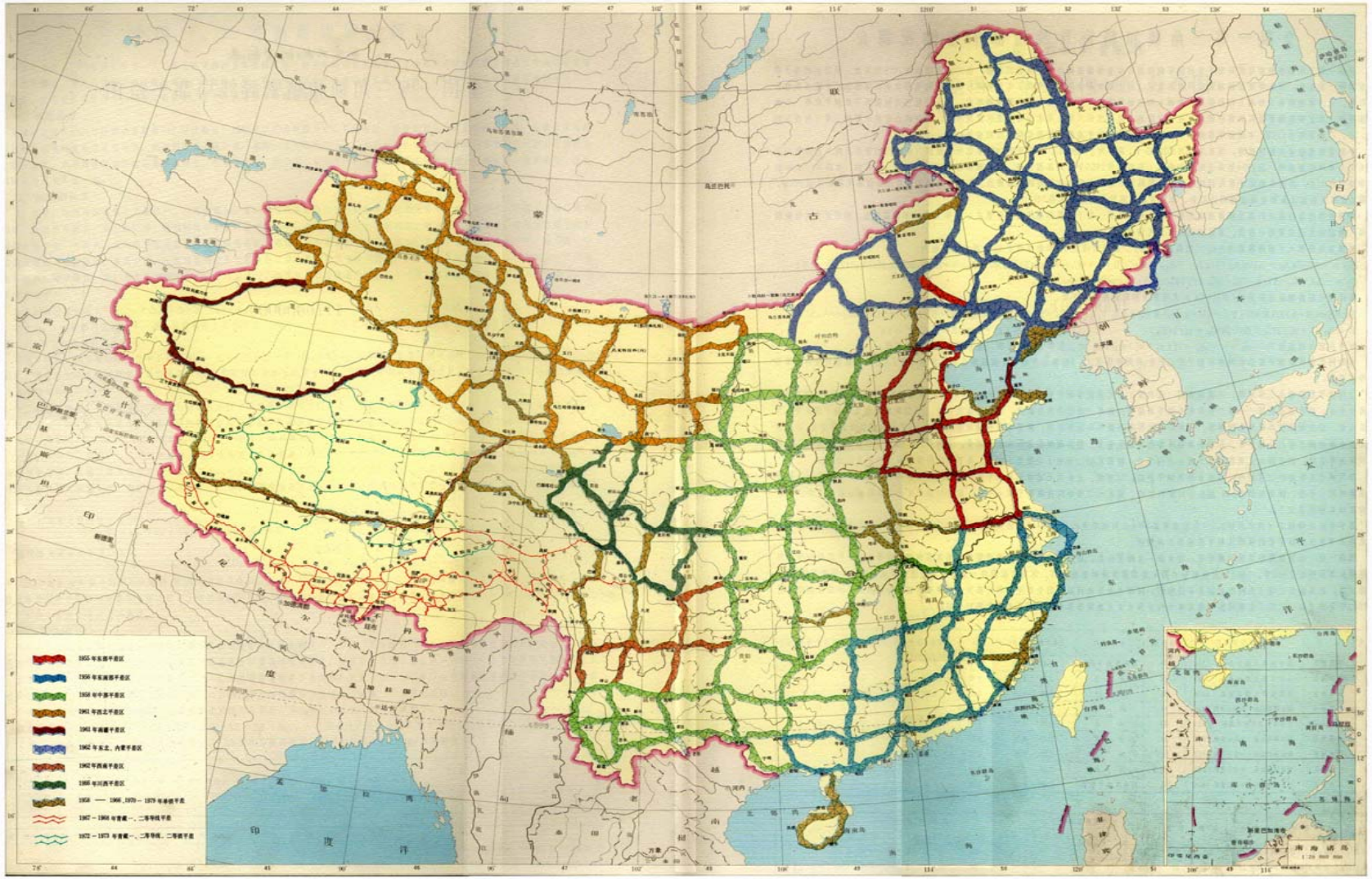
| | X/cm | Y/cm | Z/cm | B/cm | L/cm | H/cm | Position |
|---|---|---|---|---|---|---|---|
| Mean<br>Std | 0.90 | 1.57 | 1.06 | 0.37 | 0.77 | 1.92 | 2.13cm |

- Average standard deviation for **horizontal position** is about **0.5cm**;
- Average standard deviation for **height** is about **2cm**;
- Average standard deviation for 3D position is better than **2.5cm**.

# 2.2 The Second Order Frame of CGCS 2000



# 2.3 The third order frame
## ——Astro-geodetic network



# 2.3. The Third Order Frame of CGCS 2000 ---Astro-Geodetic Network

- The third order frame of CGCS 2000 is the astro-geodetic network with about 50 000 stations.
- The astro-geodetic network itself cannot be employed as reference frame.
- Combined adjustment of astro-geodetic network and 2000' GPS network can provide unified coordinates of stations in a given reference system.
- The combined adjustment can improve the coordinate accuracy of the astro-geodetic network in controlling of the high accurate GPS network.

# 2.3. The Third Order Frame of CGCS 2000 ---Astro-Geodetic Network

## ■ 1. Main strategies of the adjustment

| | |
|---|---|
| Coordinate datum | The uncertainty of the coordinates of the GPS network 2000 was given 1σ to propagate the datum |
| Crust deformation and other systematic errors | Parameters to compensate the systematic errors are introduced |
| Effects of outliers | Outlier diagnosis and robust estimation are used |
| Inconsistent inner precision | Variance component estimation (VCE) is used |

# 2.3. The Third Order Frame of CGCS 2000 ---Astro-Geodetic Network

## ■ 1. Main strategies of the adjustment

### (1) Datum and systematic errors

- **2000’ GPS network acts as a reference of the combined adjustment, thus the coordinates given by the combined adjustment will refer to the same datum as that of the 2000’ GPS net.**
- **The systematic errors of the astro-geodetic network are mainly controlled by the GPS network.**

# 2.3. The Third Order Frame of CGCS 2000 ---Astro-Geodetic Network

## ■ 1. Main strategies of the adjustment

### (2) Functional model of the combined adjustment

- The parameters are the 3D coordinates.
- The height fixed 3D model is employed if the stations have no vertical angle measurements.
- Some systematic parameters are introduced in the functional model:

----1 orientation parameter is introduced to adjust the orientation error;

----8 scale parameters are introduced to compensate distance errors.

# 2.3. The Third Order Frame of CGCS 2000 ---Astro-Geodetic Network

## ■ 1. Main strategies of the adjustment

### (3) Stochastic model

- The initial weights are the inverses of the variances;
- Variance component estimation is applied to the combined adjustment in order to adjust the inhomogeneous accuracies of the measurements.
- By iteration 2 times, all the variance components are nearly equal to 1 (the prior assumption value).

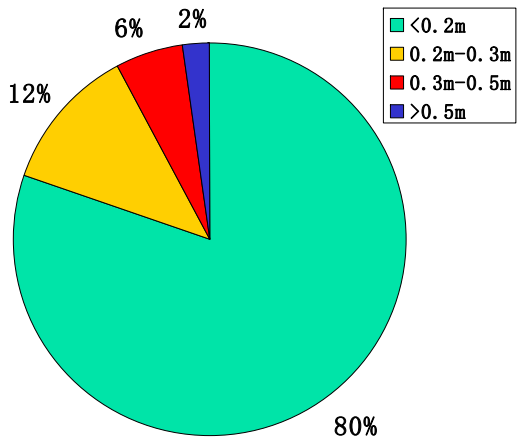
# 2.3. The Third Order Frame of CGCS 2000 ---Astro-Geodetic Network

## ■ 2. The results and quality

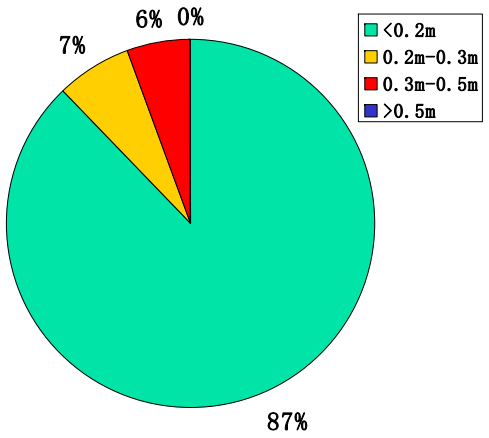
### ■ Precision of 3D position

- The standard deviations of 38693 (80.2%) stations are smaller than 0.2m;
- Std of 44384 (92.1%) stations are smaller than 0.3 m;
- Average std is 0.15m.

3D positional std

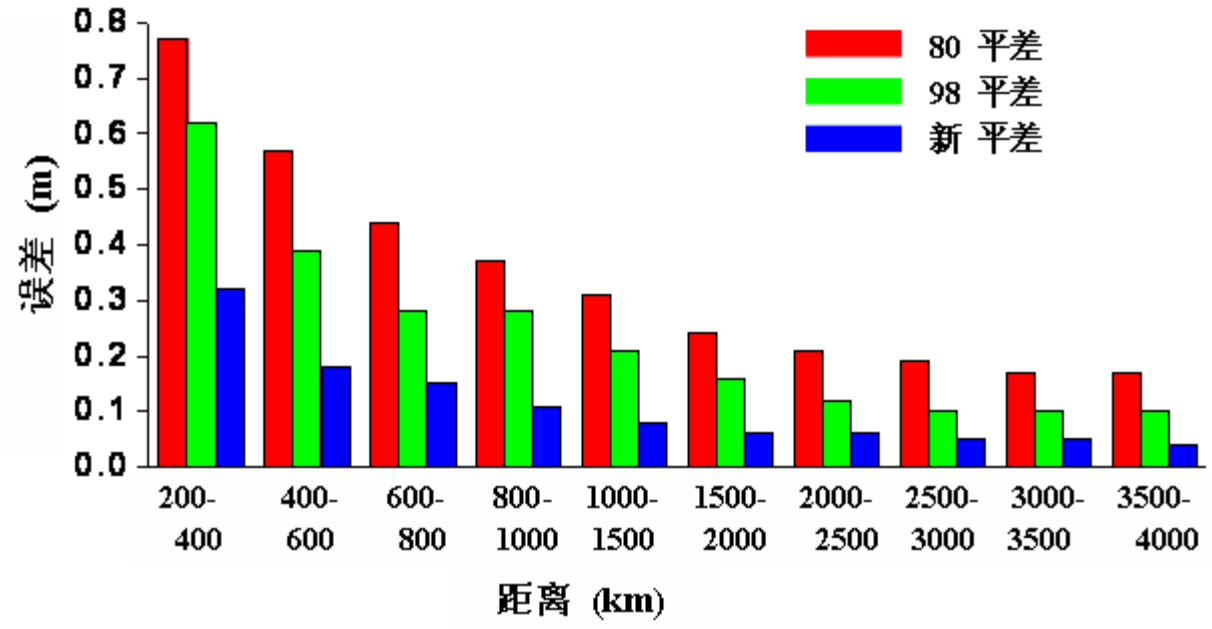



Horizontal std



# 2.3. The Third Order Frame of CGCS 2000 ---Astro-Geodetic Network

- **Relative precision comparison with old adj. (ppm)**




**The relative precision is 1/4-1/2 as much as that of the adjustment carried out in 1980 and 1998.**

# 2.3. The Third Order Frame of CGCS 2000 ---Astro-Geodetic Network

## ■ 3. Main achievements of the project

- **The geodetic measurements lasting more than 70 years in China are integrated and adjusted.**
- **The reference datum is unified, and some systematic error influences are controlled.**
- **The CTRF 2000 has been established and strengthened with higher precision and more density.**
- **The relative precision is 4 times better than that of the project carried out in 1980.**

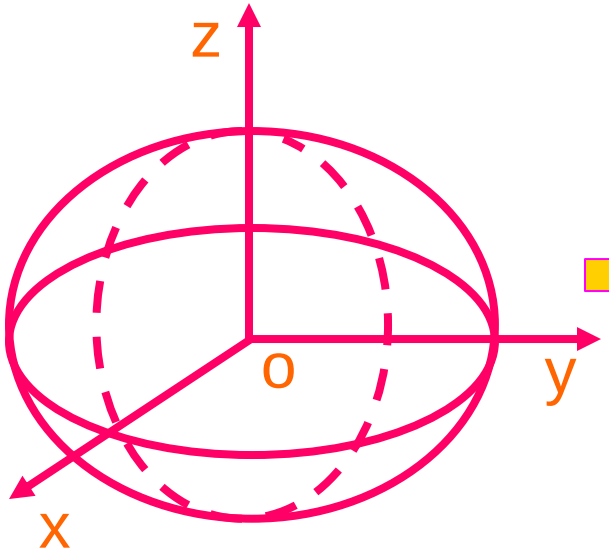
# 3. Main technical progress of the CTRF 2000

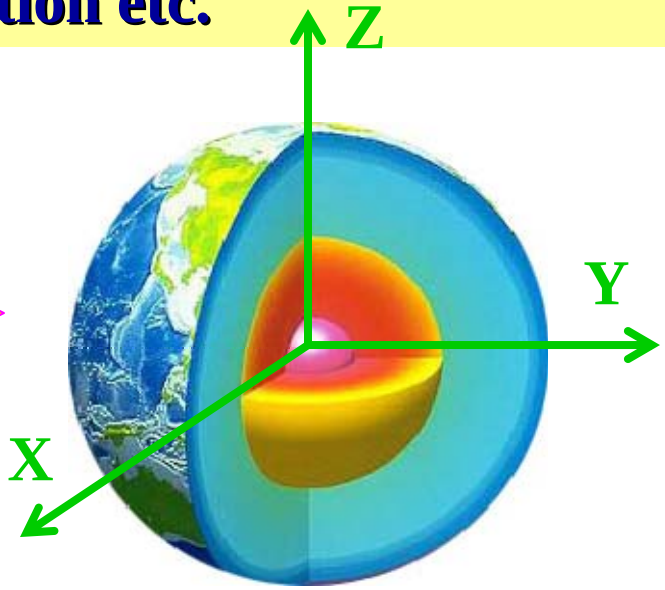
- 2D+1D geodetic networks

- 3D geodetic network
- It is suitable for space geodesy

- Non geocentric coordinate system

- Geocentric coordinate system
- It is suitable for aerospace and navigation etc.



# 3. Main technical progress of the CTRF 2000

- **Original accuracy 5-10m.** ⇒ **New accuracy 3cm-0.3m**
- **Inhomogeneous accuracy of the frame with the error more than 10m in the boundary area of the country.** ⇒ **Homogeneous accuracy without significant systematic errors (the error of boundary stations is about 0.5m)**
- **Least squares adj.** ⇒ **LS + VC + robust estimations**
  **Reliability has been improved**

**CGCF2000 is an alignment of ITRF, it will be updated to new ITRF series.**

# 4. Main problems of CTRF 2000

- **The accuracy of the CTRF is not so homogeneous, compared to the ITRF.**
- **The CTRF 2000 cannot provide accurate velocities at present stage.**
- **There are many continuously operating reference stations (CORS) in China have not been integrated in the unified coordinate frame, which results in sources waste and the datum confusion.**
- **The fundamental control stations are too few, the structure of 2000' GPS network is quite weak for the large territory.**

# 4. Main problems of CTRF 2000

- **The structure of the CTRF in the west part of the country is very weak.**
- **The control stations in the overlapping areas of lands and seas are less.**
- **The geodetic control stations in island and reef are nearly empty.**
- **The tracking stations of COMPASS have not integrated in the CGCF 2000, which will be modified in the future.**

# 4. Main problems of CTRF 2000

- **Conclusion**

**CGCS — has got great progress**

**— heavy tasks to strengthen and maintain**

**— a long way to go!**

Thank you for your attention