ICG-5, WG-D, 2010, Torino, Italy

Updates of CGCS 2000

Yuanxi YANG

China National Administration of GNSS and Applications (CNAGA)

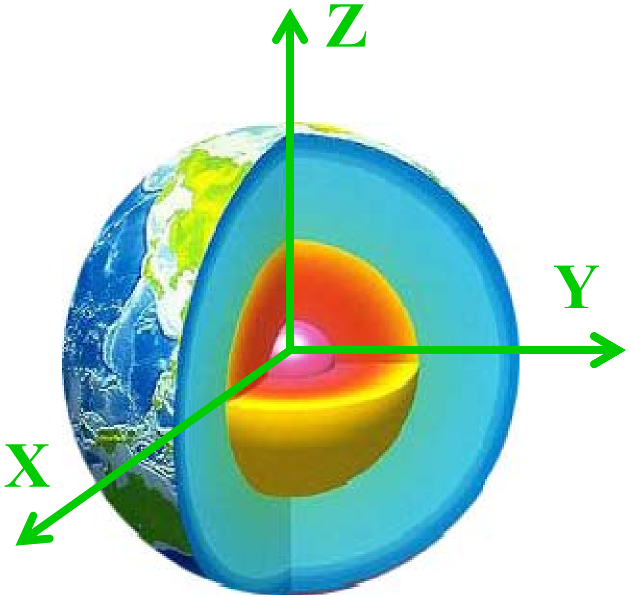
0 Comments on GNSS coordinate system

- **The same geocentric coordinate system has to be used (benefits for providers and users), because the satellites run around the geocenter.**
- **The same coordinate reference is needed (not the frame, it is impossible and unnecessary).**
- **Orbit parameters reflect reference frame.**
- **The dynamic effects should be considered in the coordinate system, otherwise the coordinates of tracking stations may be in error, result in orbit error----agreement to update coordinates by xx years?**

1. Background of CGCS 2000

Definition of CGCS 2000

- Global, three-dimensional;
- Right-handed, orthogonal;
- Geo-centered;
- Frame: ITRF97;
- Epoch: 2000.0;



- CTRF (Chinese Terrestrial Reference Frame)
    - Aligned to ITRF
    - Consistent with international standards

1. Background of CGCS 2000

Main Parameters of Reference Ellipsoid

Semi major axis:

a=6 378 137m

Gravitational constant:

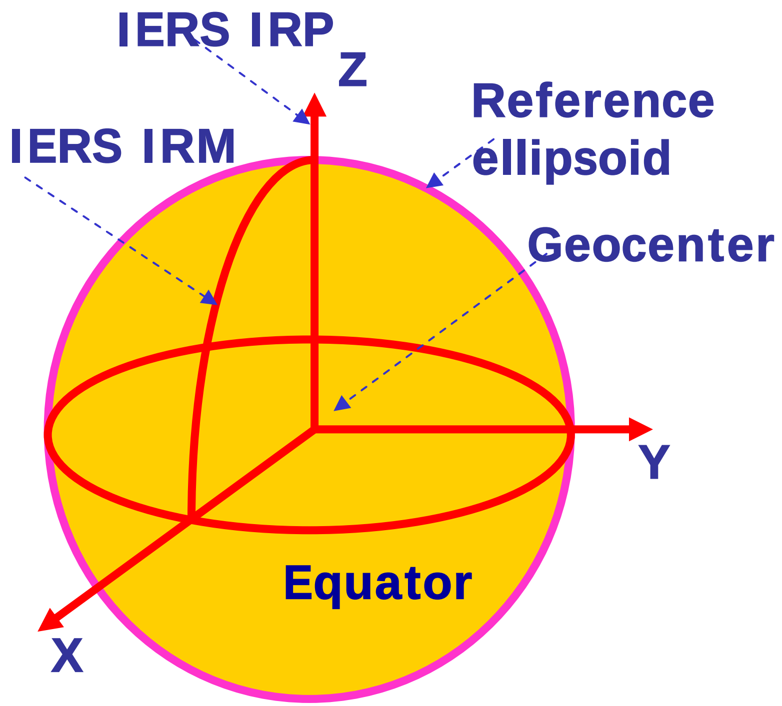
$GM=3.986004418\times10^{-14}m^{3}s^{-2}$

2nd drgree harmonic coefficient:

$J_2=0.001082629832258$

Mean angular velocity of the earth:

$\omega=7292115.0\times10^{-11}rad\ s^{-1}$



1. Background of CGCS 2000

- **Deduced Parameters of Reference Ellipsoid**

Semi minor axis: b=6 356 752.31414

1st eccentricity: e=0.0818191910428

2nd eccentricity: e'=0.0820944381519

Flattening: f=1/298.257222101 dif. 1/298.257223563

Ratio of the axes: a/b=1/0.996647189335

Mean radius of the ellipsoid: R_1=6371008.77138m

1. Background of CGCS 2000

Deduced Gravitational Parameters

Normal potential: $U_0=62636851.7149 m^2 s^{-2}$

Polar normal gravity: $\gamma_p=9.8321849402 ms^{-2}$

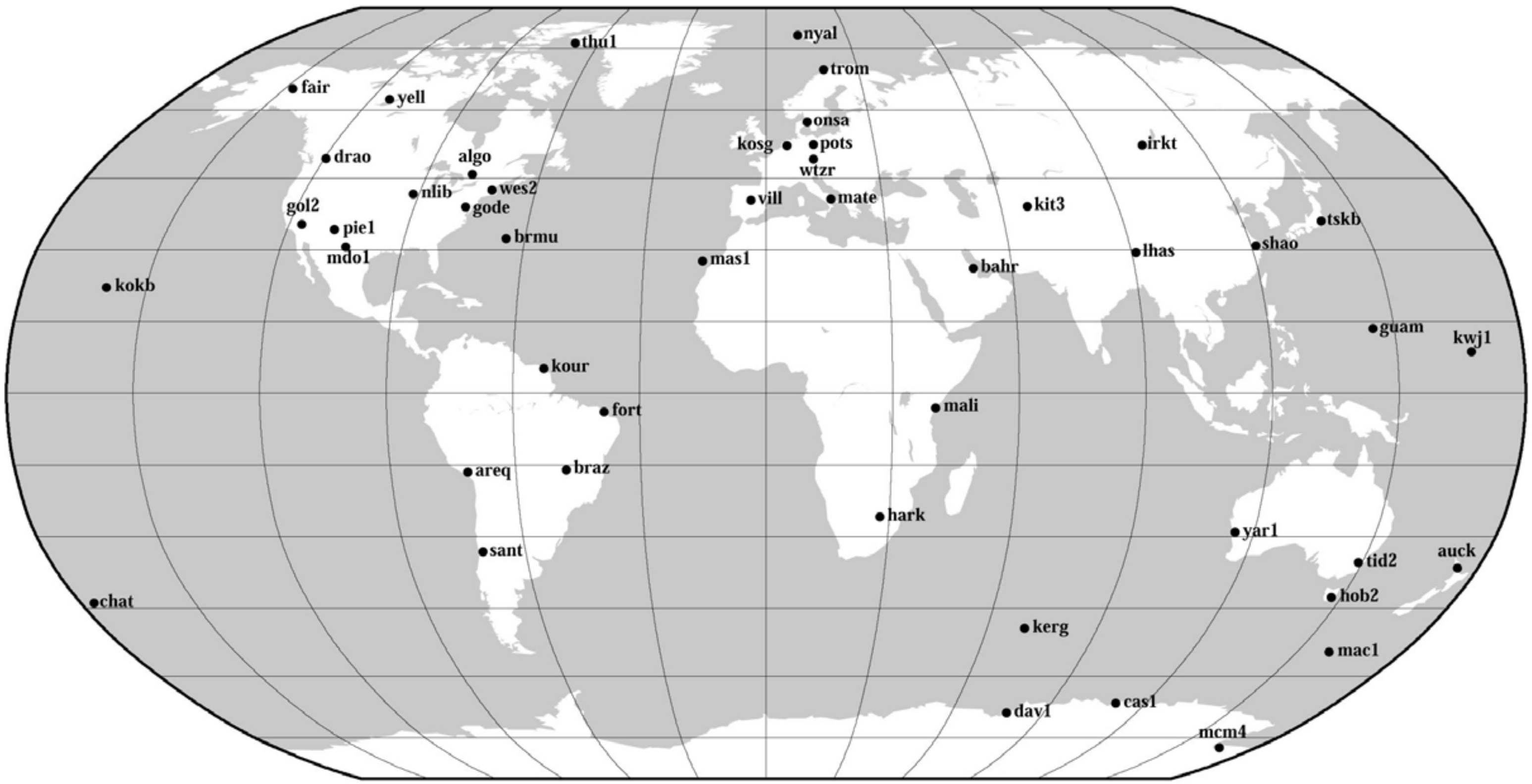
Equator normal gravity: $\gamma_e=9.7803253361 ms^{-2}$

Total mass of the earth: $M=5.9733328\times 10^{24} kg$

- **Consistency in definition and diversity in realization!----Benefit for compensate the systematic errors**

1. Background of CGCS 2000

■ IGS Stations used in CTRF computation



47 IGS stations were included in establishing CTRF 2000

1. Background of CGCS 2000

IGS stations in China

BJFS

CHAN

KUNM

LHAS

SHAO

URUM

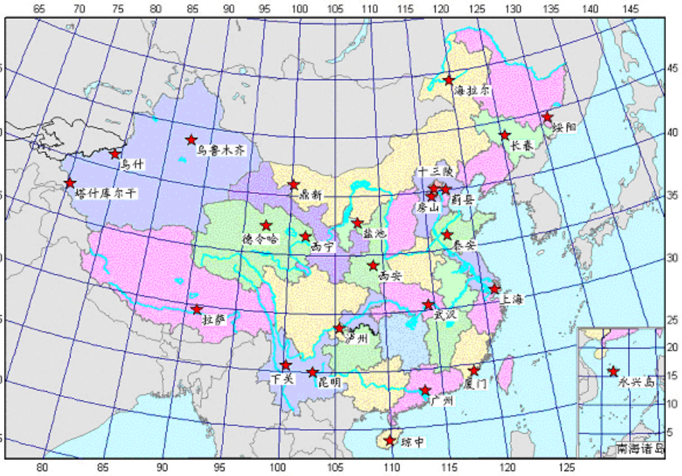
WUHN

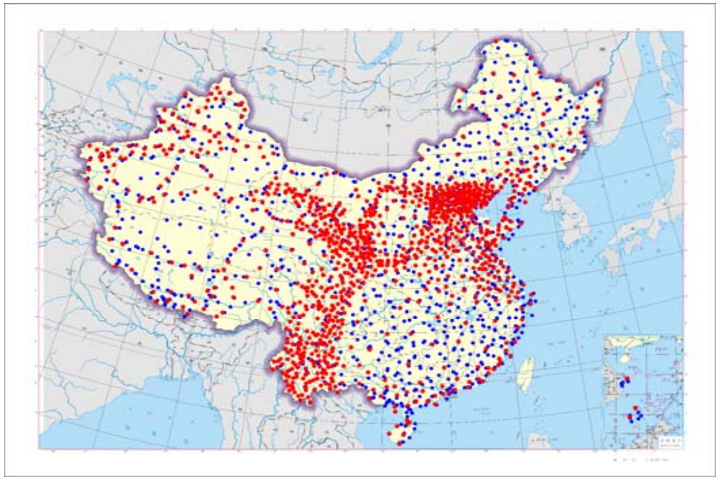
XIAN

1. Background of CGCS 2000

China Terrestrial Reference Frame (CTRF 2000)

- **The first order:** 28 CORS, which is the key frame of CGCS 2000 with mm accuracy.
- **The second order:** “2000’ national GPS network”, with about 2500 stations with cm accuracy.
- Realized using some IGS even distributed over the world.





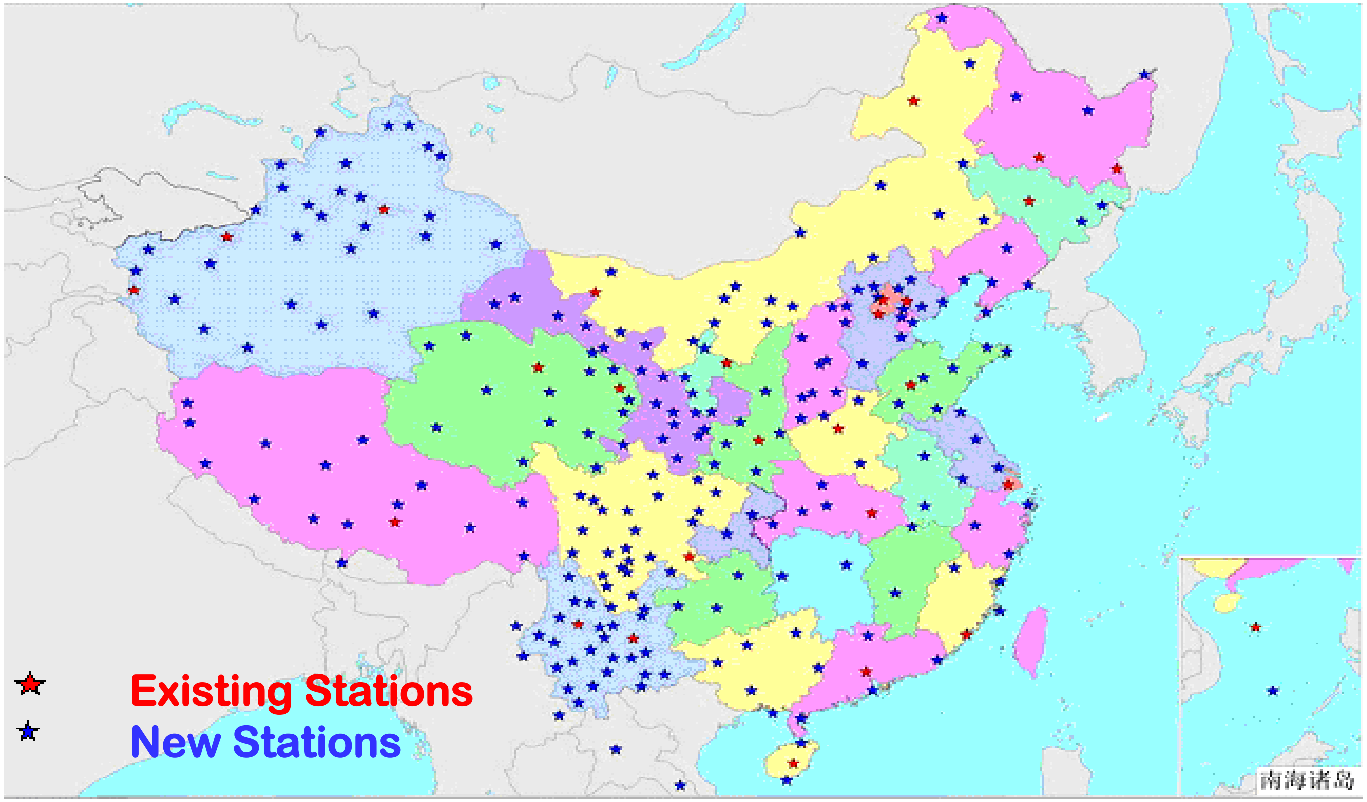
1. Background of CGCS 2000

Problems of CTRF 2000

- The accuracy of the CTRF 2000 is not so homogeneous, compared to the ITRF, because some old and low order GPS networks were integrated.
- Only 28 CORS and about 1000 monitoring stations with high accuracy were used in the CGCS2000.
- The geometry structure of 2000' GPS network is quite weak for vast territory in China.
- The positional velocities were not provided.
- The tracking stations of Beidou have not been integrated in the CTRF 2000.

2. Extended national CTRF stations

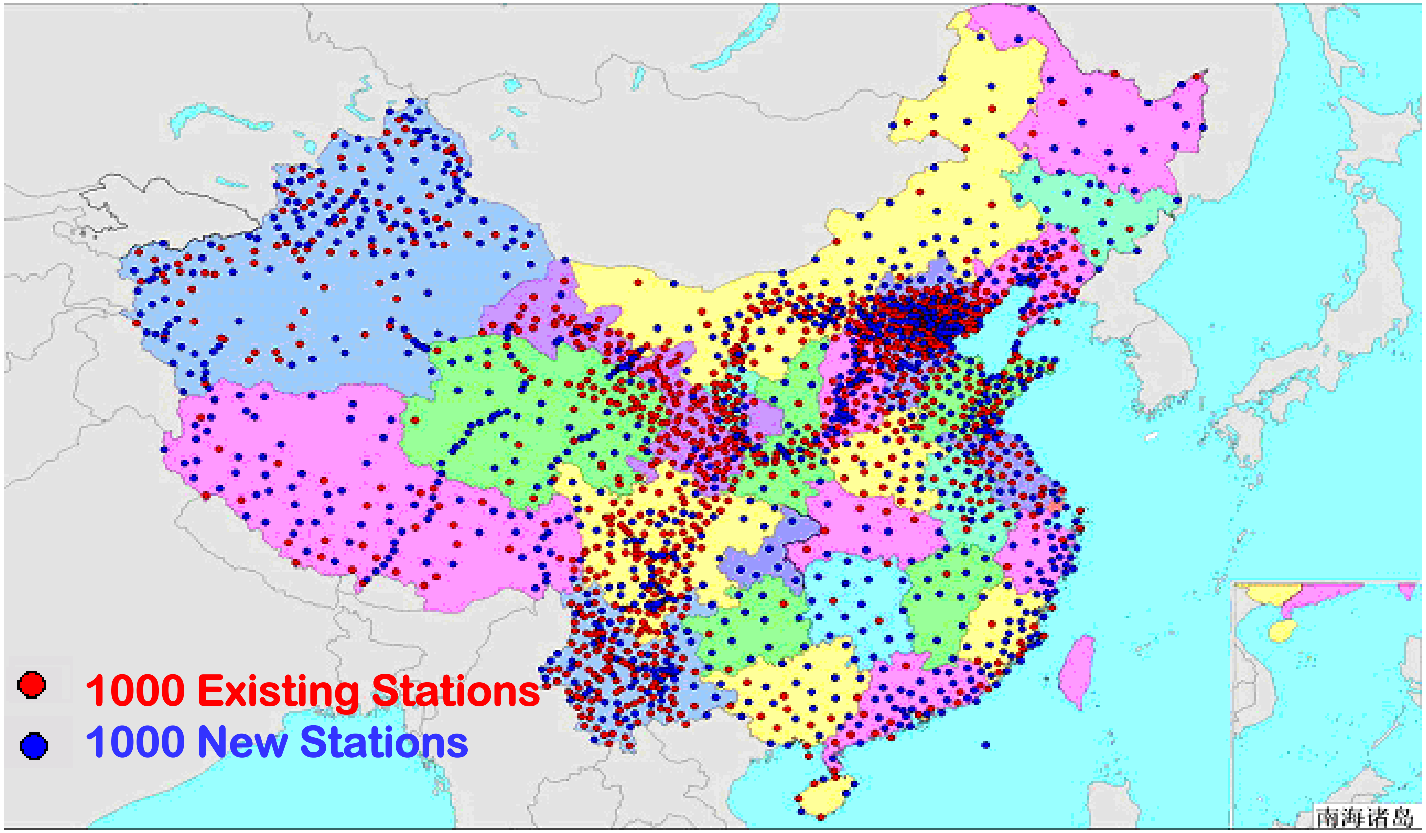
- CORS stations will be increased from 28 to 260



- 28 existing stations
- 3 co-located stations with VLBI, 6 co-located stations with fixed SLR and 232 new stations will be established.

2. Extended national CTRF stations

- Regional stations from 1000 to 2000



- ➢ 1000 existing regional stations
- ➢ 1000 stations will be established.

3. Coordinate Updating by Collocation

- **Velocities from Cartesian coordinates to local coordinates (Based on Euler vector)**

$$\dot{X} = \begin{bmatrix} v_x \\ v_y \\ v_z \end{bmatrix} = \begin{bmatrix} 0 & z & -y \\ -z & 0 & x \\ y & -x & 0 \end{bmatrix} \begin{bmatrix} \omega_x \\ \omega_y \\ \omega_z \end{bmatrix}$$

- **Neglecting the vertical component, we have the error equation**

$$\begin{bmatrix} v_n \\ v_e \end{bmatrix} = \begin{bmatrix} R\sin\lambda & -R\cos\lambda & 0 \\ -R\sin\varphi\sin\varphi & -R\sin\varphi\sin\varphi & R\cos\varphi \end{bmatrix} \begin{bmatrix} \omega_x \\ \omega_y \\ \omega_z \end{bmatrix}$$

$$V = A\hat{\omega} - L$$

3. Coordinate Updating with Collocation

- Considering the local variations of the velocities, we add a new term ***S*** (Signal) in the error equation, and get a collocation model based on Euler vector

$$\mathbf{V} = \mathbf{A}\hat{\omega} + \hat{\mathbf{S}} - \mathbf{L}$$

$$\mathbf{A}\hat{\omega} = \begin{bmatrix} R\sin\lambda & -R\cos\lambda & 0 \\ -R\sin\varphi\sin\varphi & -R\sin\varphi\sin\varphi & R\cos\varphi \end{bmatrix} \begin{bmatrix} \hat{\omega}_x \\ \hat{\omega}_y \\ \hat{\omega}_z \end{bmatrix}$$

$$C_N(d) = \frac{38.33170}{1 + 0.651987 \cdot d^2}$$

$$C_E(d) = \frac{21.47733}{1 + 1.063019 \cdot d^2}$$

$$\hat{\omega} = (A^T P_L A)^{-1} A^T P_L L$$

$$\hat{S} = \Sigma_S B^T P_L (L - A\hat{\omega})$$

$$\hat{S}' = \Sigma_{S'S} \Sigma_S^{-1} \hat{S}$$

3. Coordinate Updating with Collocation

- Adaptive collocation

$$\Omega = V^T P_e V + \alpha \hat{S}^T P_S \hat{S} = \min$$

$$\begin{bmatrix} \hat{\omega} \\ \hat{S} \end{bmatrix} = \begin{bmatrix} A^T P_e A & A^T P_e B \\ B^T P_e A & B^T P_e B + \alpha P_S \end{bmatrix}^{-1} \cdot \begin{bmatrix} A^T P_e \dot{X} \\ B^T P_e \dot{X} \end{bmatrix}$$

$$\hat{\omega} = (A^T \overline{P}_L A)^{-1} A^T \overline{P}_L L$$

$$\hat{S} = \overline{\Sigma}_S B^T \overline{P}_L (\dot{X} - A\hat{\omega})$$

$$\overline{P}_L = (B\Sigma_S B^T/\alpha + \Sigma_e)^{-1} = \alpha(B\Sigma_S B^T + \alpha\Sigma_e)^{-1}$$

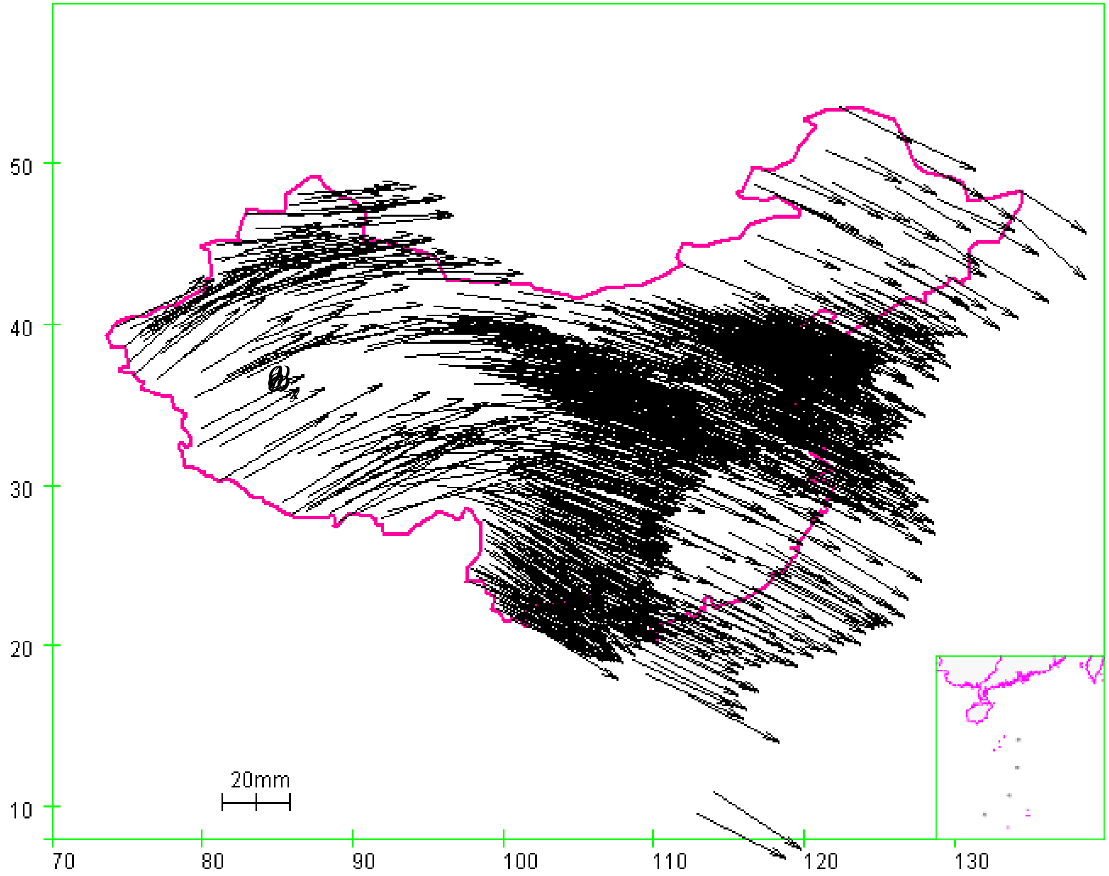
$$\hat{S}' = \overline{\Sigma}_{S'S} \overline{\Sigma}_S^{-1} \hat{S} = \frac{1}{\alpha} \Sigma_{S'S} (\frac{1}{\alpha} \Sigma_S)^{-1} \hat{S} = \Sigma_{S'S} \Sigma_S^{-1} \hat{S}$$

3. Coordinate Updating with Collocation

- Euler vector from different calculation model

Model	ω_x (Rad/Ma)	ω_y (Rad/Ma)	ω_z (Rad/Ma)	λ (°)	ϕ (°)	ω (°/Ma)
LS Euler Vector	-0.0004415	-0.0037950	0.0035848	-96.6	43.2	0.300
Collocation Model	0.0001159	-0.0042049	0.0031925	-88.4	37.2	0.302
Adaptive Collocation	0.0001367	-0.0041396	0.0032090	-88.1	37.7	0.300

4. Coordinate velocities from Euler Vector

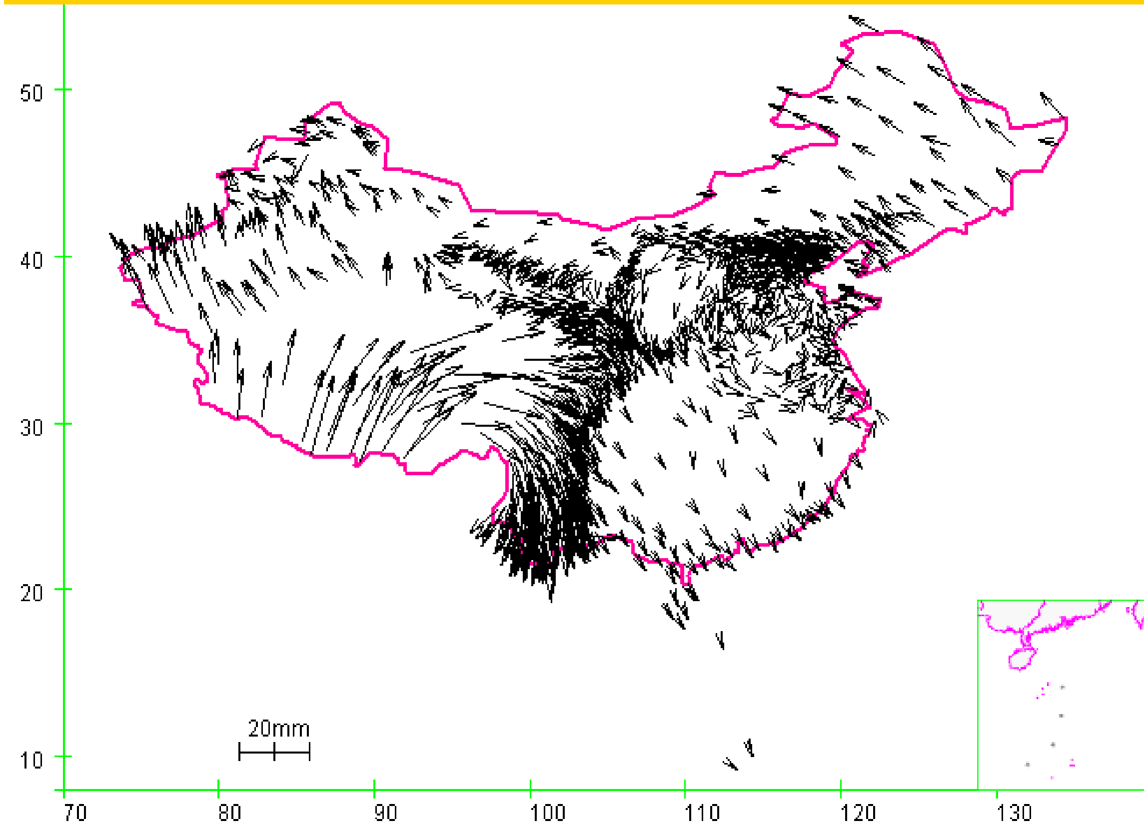


- ✓ 1041 stations with velocity accuracy better than 3mm/y are employed in Euler vector estimation.
- ✓ 29 CORS are acted as checking stations which are not included in the velocity estimation.

- ✓ The CRTF station movements are generally in eastern direction. The velocities of the western part are much larger than those of eastern part.

5. Comparison of Various Models

■ Residuals transformed by LS Euler vector

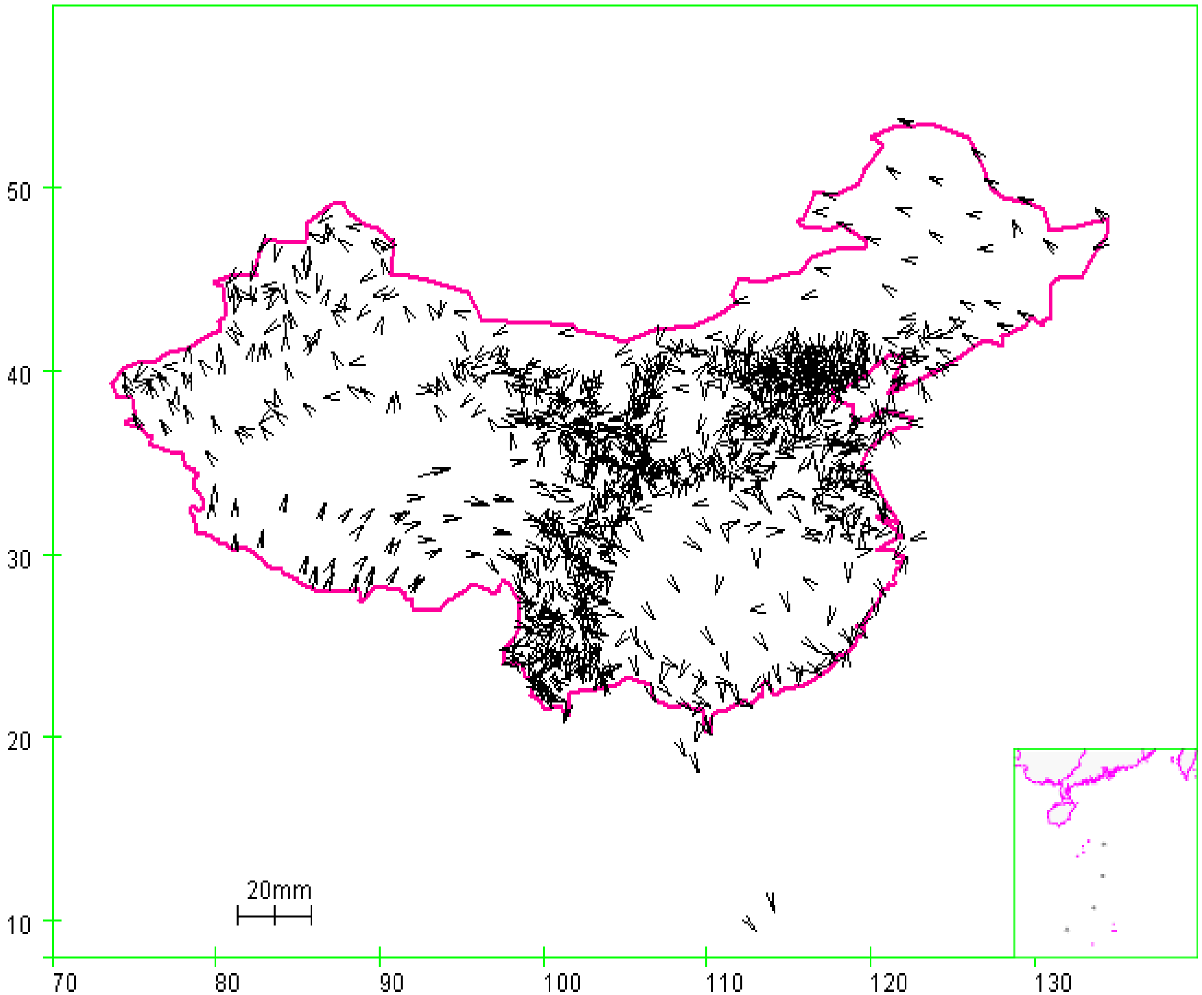


- The residuals have significant regional trend marked by 104° of longitude. The residuals in western part are much larger than those of eastern part.

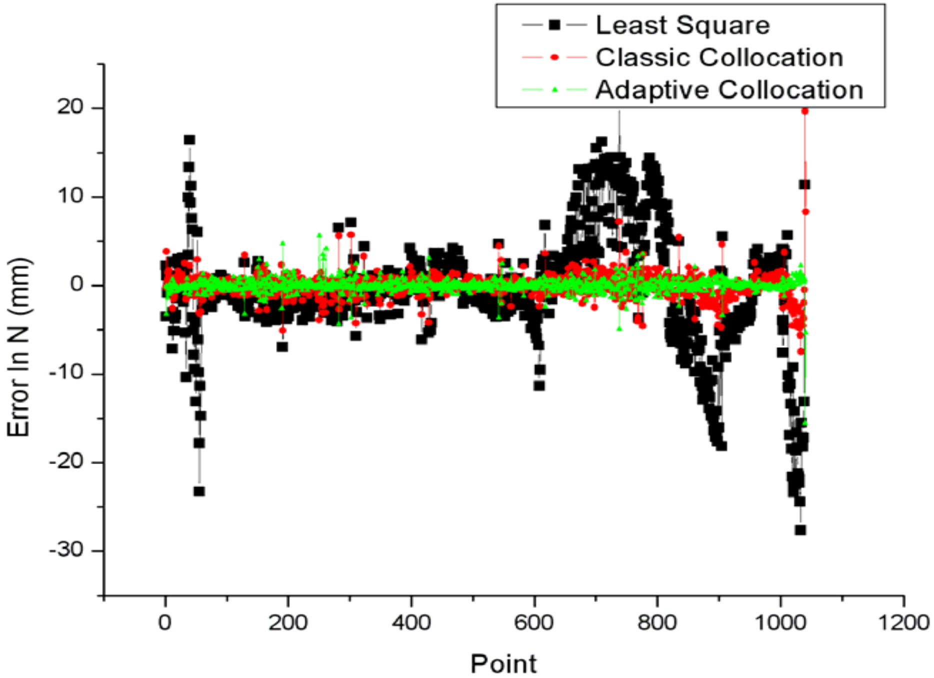
- In the Northwest, the residuals are in the northeastern direction; The Northeast are in west-north direction; and in the South, the residuals are in northwestern direction but not significant.

5. Comparison of Various Models

Residuals transformed by collocation model

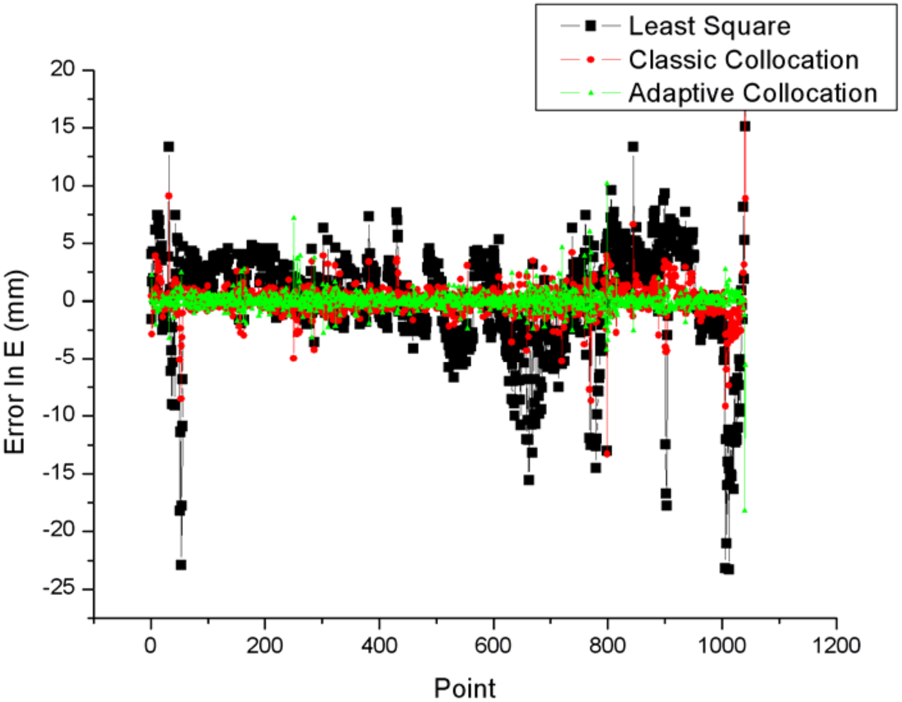


- The local trends of the residuals transformed by collocation model nearly disappear.

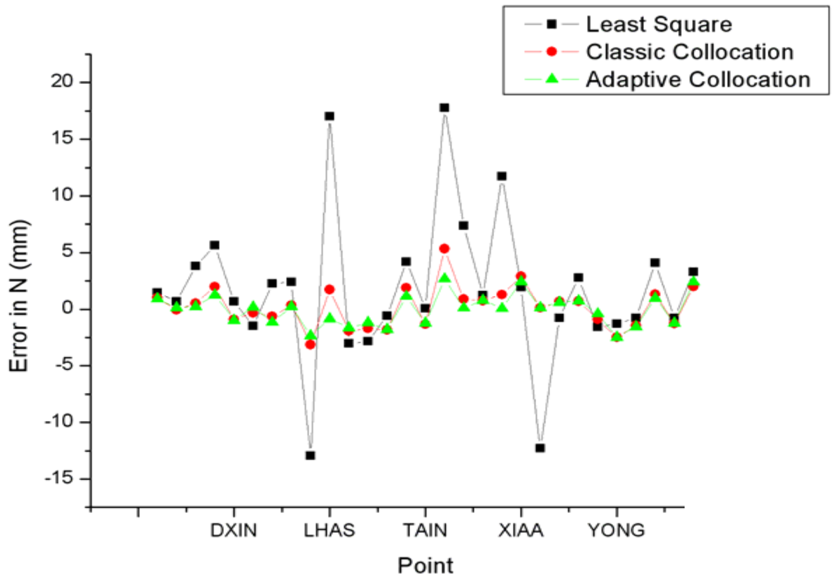


Residuals in N direction

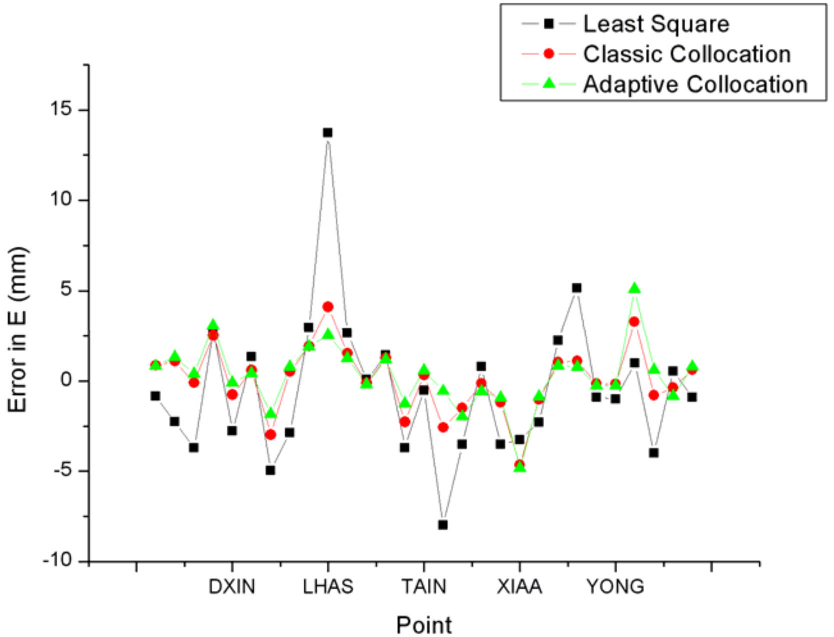
Residuals in E direction



Outside Checking



Discrepancy in N direction
In Checking stations



Discrepancy in E direction
In Checking stations

5. Comparison of Various Models

RMS calculated by the 29 CORS（mm）

Scheme	Component	Max	Min	Mean	RMS
Euler vector model	E (mm)	13.72	-7.99	-0.49	3.92
	N (mm)	17.78	-12.94	1.73	6.59
Collocation model	E (mm)	4.10	-4.66	0.07	1.81
	N (mm)	5.35	-3.13	0.19	1.78
Adaptive Collocation	E (mm)	5.10	-4.83	0.28	1.76
	N (mm)	2.68	-2.50	-0.06	1.35

6. Future development of CTRF

- **Much more National CORS station will be established (CORS belong to various provinces will be integrated).**
- **Multi GNSS (inc. Beidou) with their multi frequencies will be applied in the frame maintenance.**
- **The coordinate frame will be updated.**
- **Non of the geodynamic model can be used in updating the Chinese coordinate reference frame.**
- **Local and regional geodynamic effects should be taken into account in the updating of the coordinate reference frame.**
- **Collocation method can be a choice for updating the reference frame.**

Thank you!