Realization of Terrestrial Reference Frame for GNSS

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OUTLINE

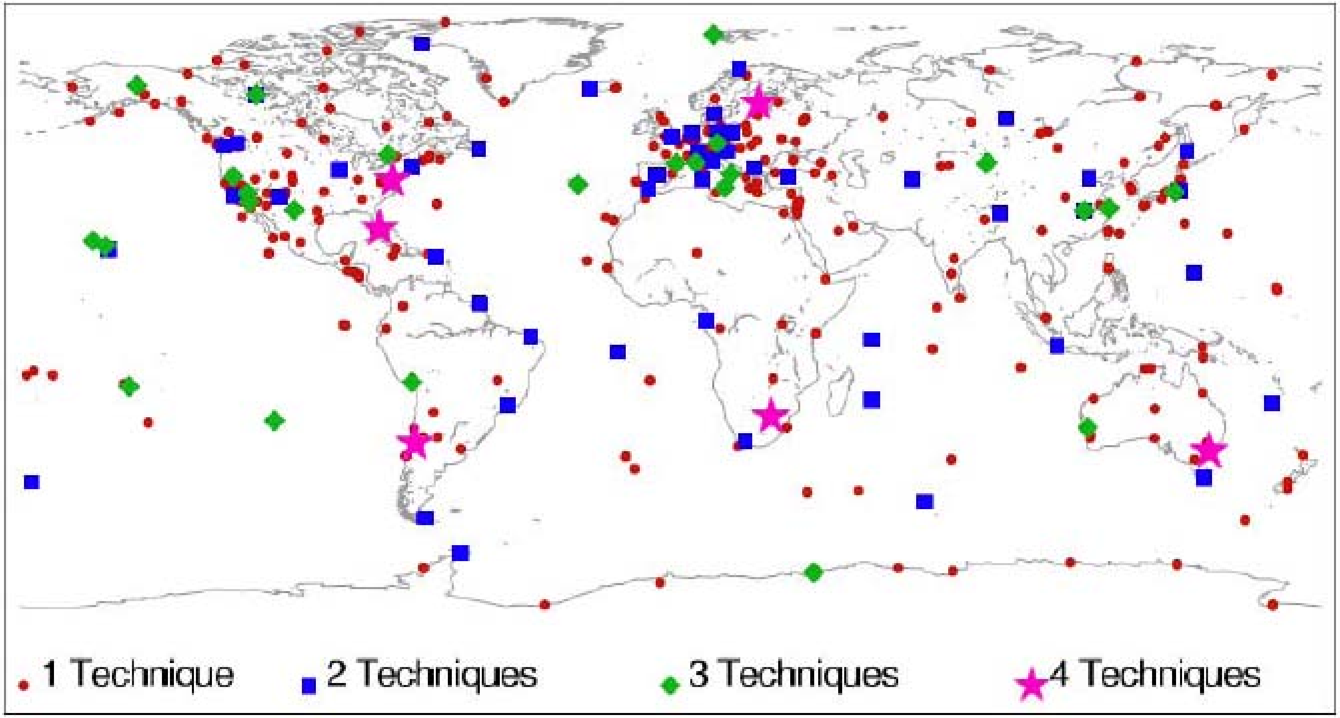
- Back Ground
- TRF Realization by Multi-techniques combination
  - A-optimal regularization
  - Intra-technique combination
  - Inter-technique combination
- Compass Reference Frame simulation
- Geocenter motion from GPS

BackGround

- TRF is a basic for GNSS, each system has to develop its TRF
- TRF is complicate in definition and realization
- TRF needs data and software support from global or regional area
- TRF Realization is an important step for GNSS
- TRF has to meet all kinds of application in deferent levels of precision

BackGround

- ITRF 2005



What's TRF

- TRF

  Reference Frame: Points with accurate xyz

  Inputs:

  Points with X Y Z, freedom (observed by GPS,VLBI,SLR)

  aprior information as EOP, some sites' coordinates

  Outputs: Points with XYZ and velocity field

  Transformation Parameters, EOP

  Purpose: determine how these points are consistent with each other, so that they are in a family

- Problem in Realization of TRF?

  points with freedom, Rank deficiency

Datum Estimation

- Minimum constriants

$$(N + k^2 B^T B)\hat{x} = b + k^2 B^T c$$

Over-constrained GPS NEQ ???

- A-optimal

$$(N + \lambda \cdot I)\hat{x}$$

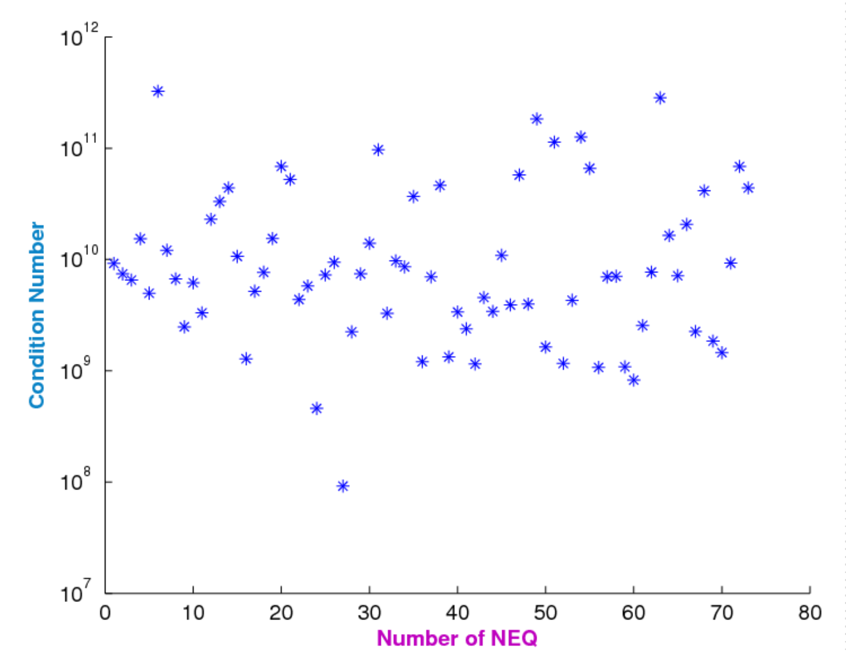
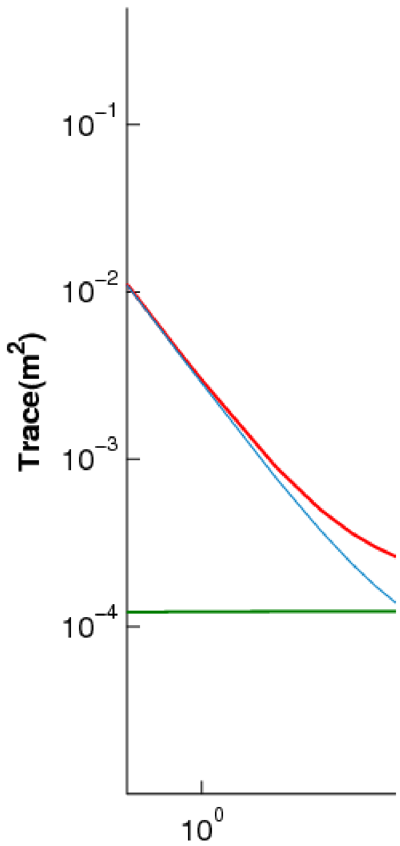


Fig. 1 Condition number of 78 GPS SINEX files

Regularization parameter



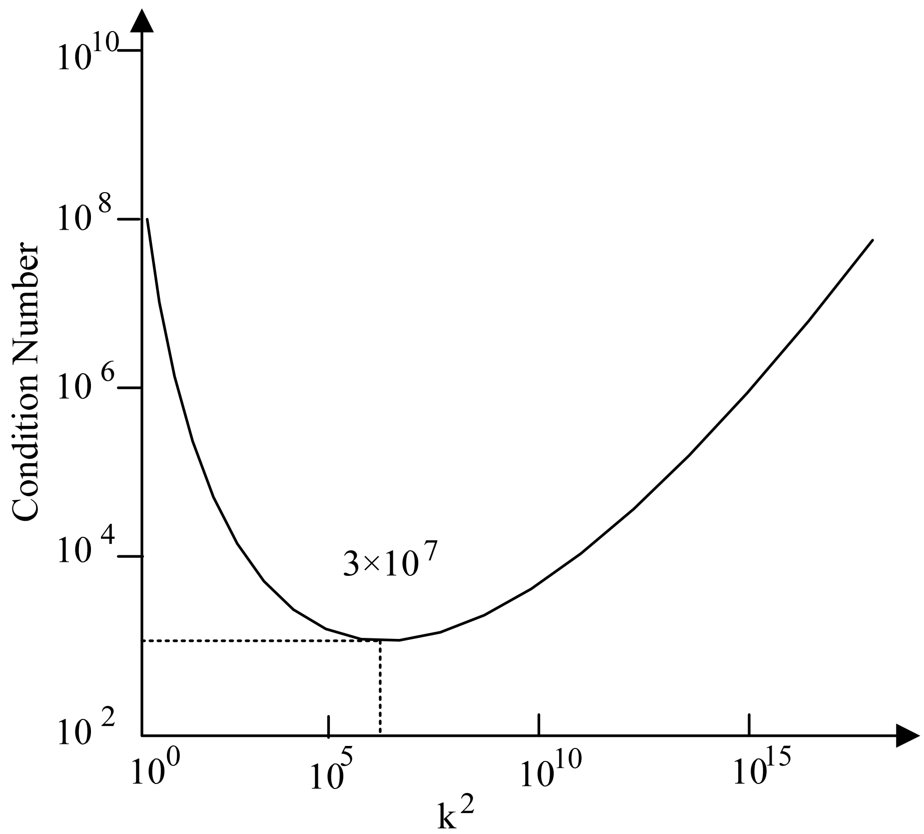
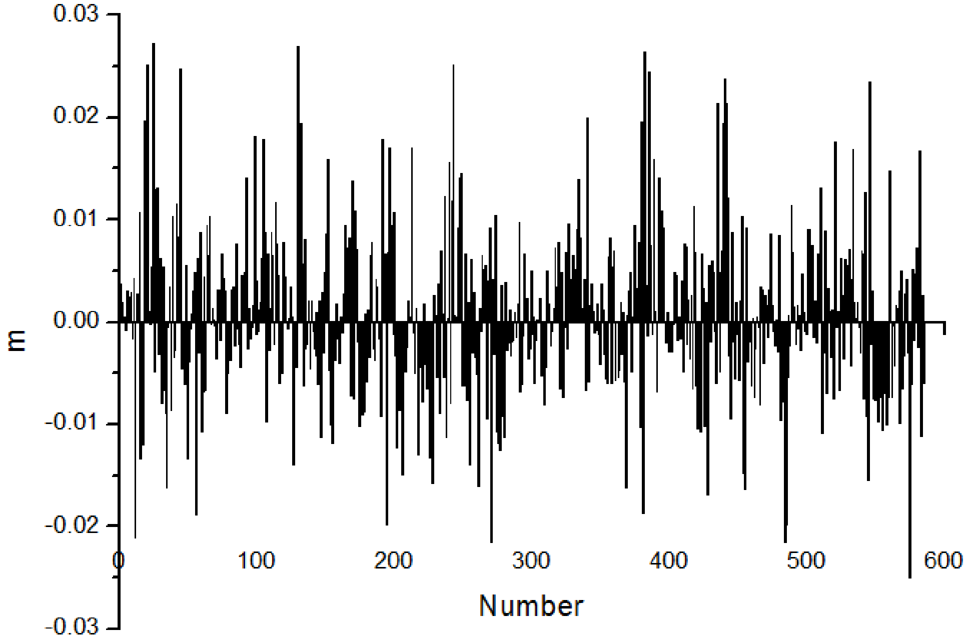


Fig. 3 Statistical quantities variations with regularization parameters

Fig. 2 Condition number variations with k^2

Results & Analysis

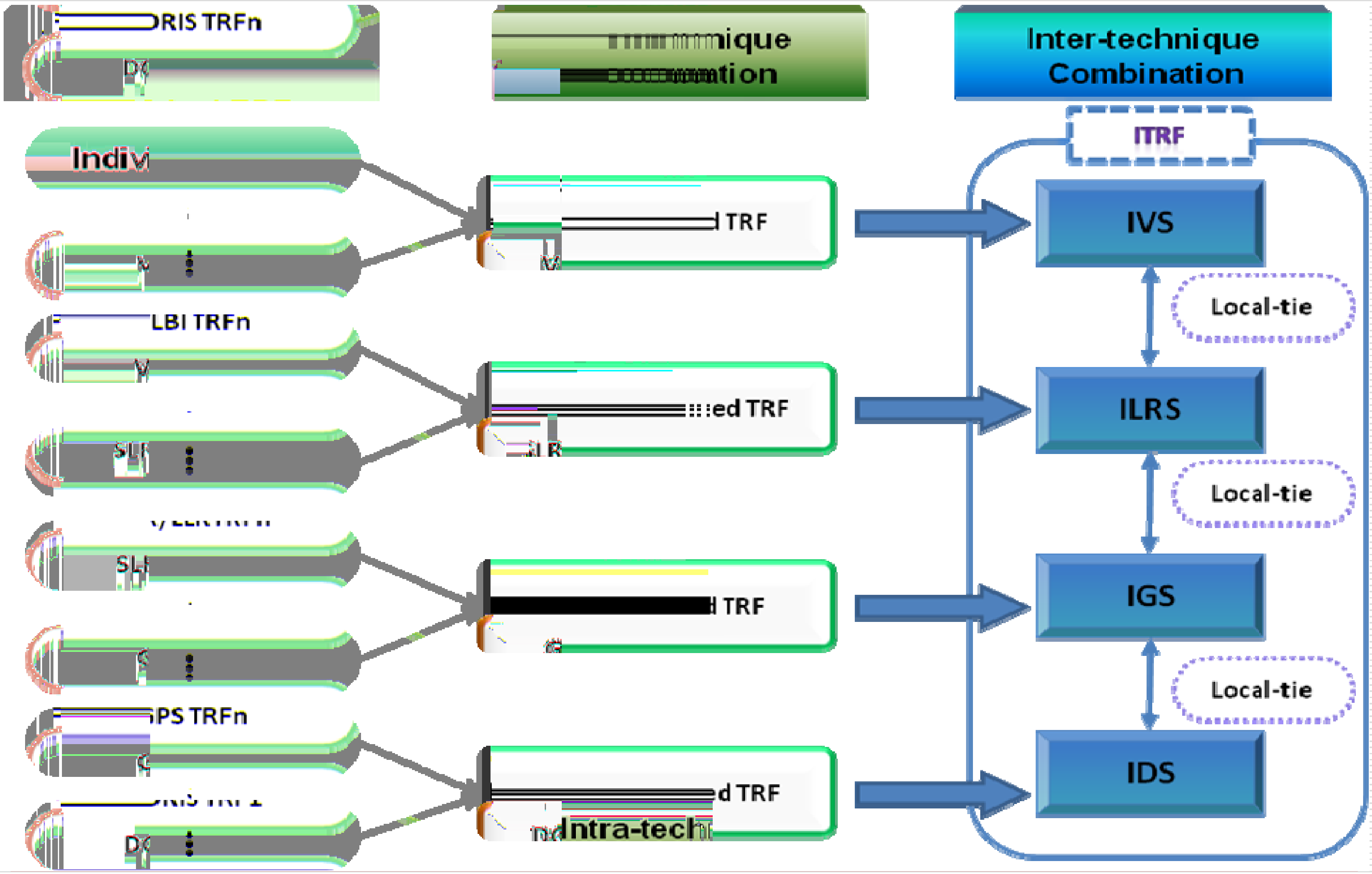
Fig. 4 Differences when $k^2=3*10^7, \lambda = 2198.21$



	X	Y	Z
<5mm	22.51%	9.76%	15.23%
5-10mm	72.38%	21.26%	45.99%
10-15mm	5.09%	48.62%	22.16%
15-20mm	0.02%	18.79%	15.62%
20-30mm	0.01%	1.53%	0.98%
>30mm	0.00%	0.05%	0.02%

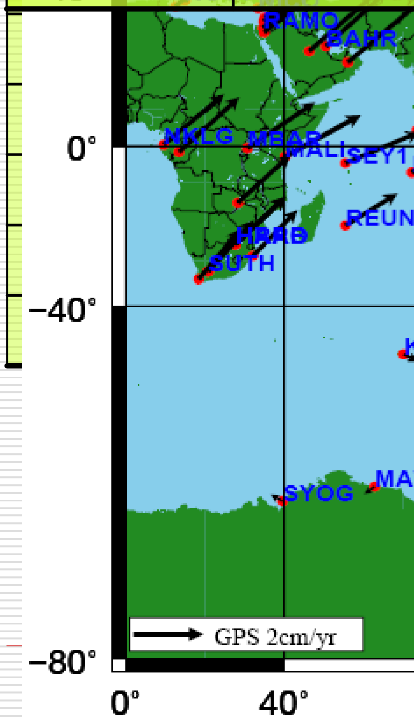
Coordinate differences between two individual datum constrains are within 3cm, and 98% of them less than 2cm

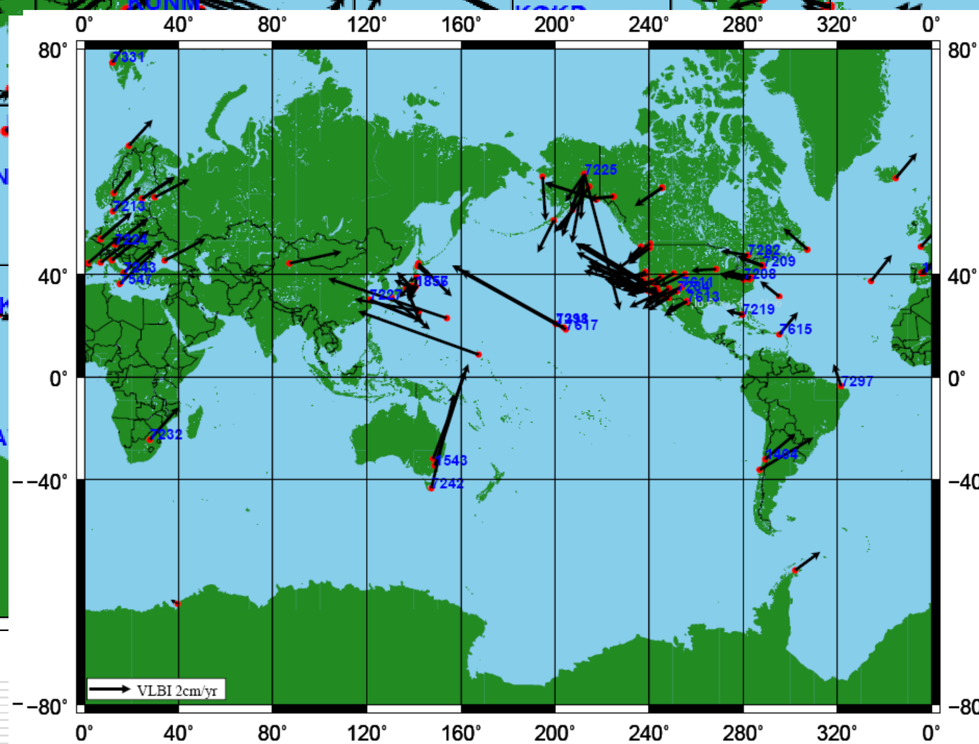
Combination Strategy



Intra-technique combination

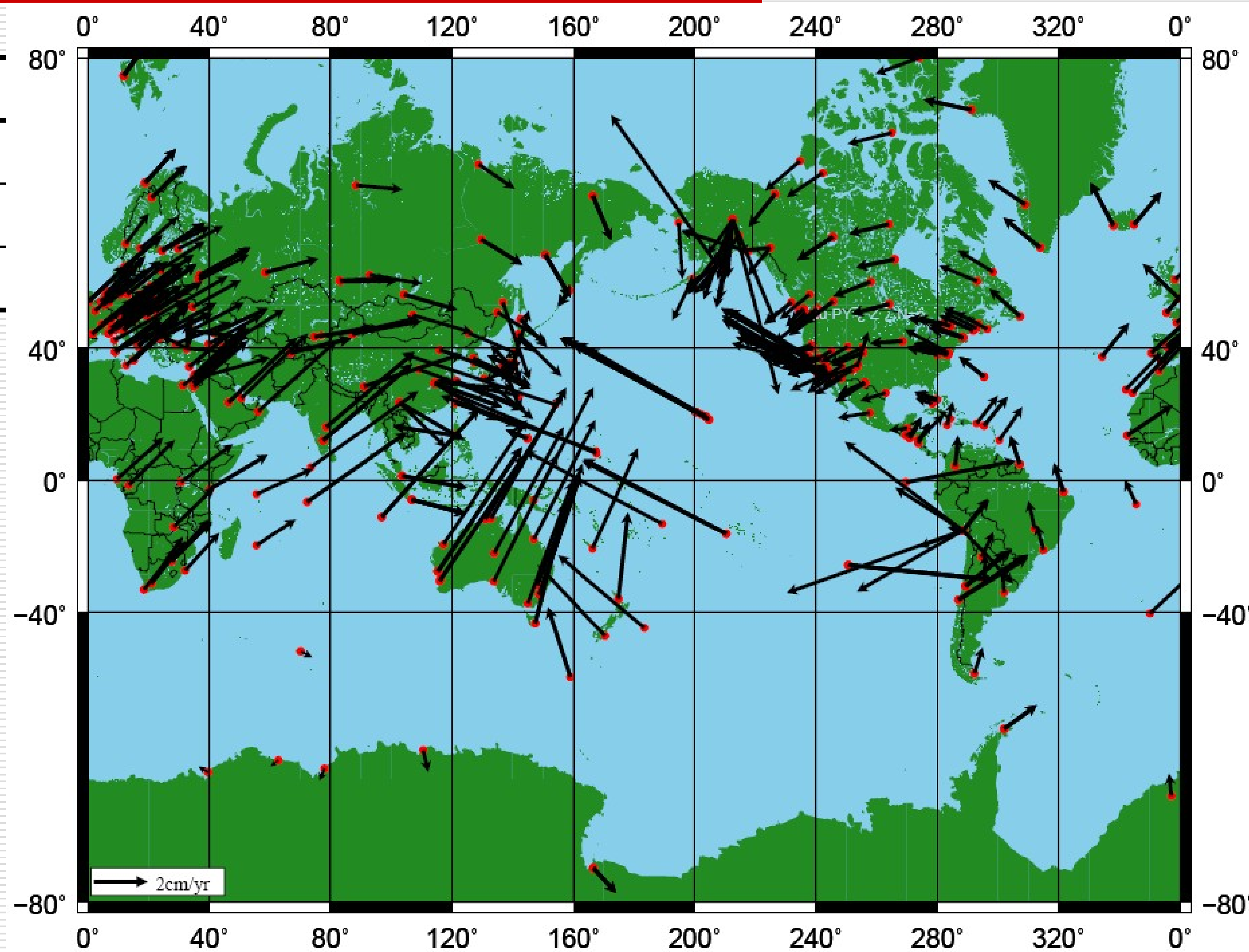
AC	Data-span	Station	SINEX	Constraints	Source
ASI	1993-2009	18	2.0	Loose constraint	cddis
DGFI	1993-2009	17	2.0	Loose constraint	cddis
GFZ	1993-2009	11	2.0	Loose constraint	cddis
JCET	1993-2009	20	2.0	Loose constraint	cddis
NSGF	1993-2009	15	2.0	Loose constraint	cddis





Inter-technique Combination

TC	Source
IGS	cddis
IVS	cddis
ILRS	cddis



TRF Simulation Test

- Coordinate System Defintion
  - ITRS definition
  - IERS 2003
- NetWork
  - Global distributed permanent stations
- Simulation data

AC	SINEX files	Data-span
AIUB	28 Weeks	2007-2008
ESA	28 Weeks	2007-2008
GFZ	28 Weeks	2007-2008
Software	PowerADJ-→PANDA	
Remarks: GPS weeks from 1399 to 1402, 1419 to 1422, 1431 to 1434, 1443 to 1446, 1460 to 1463, 1471to 1474, 1483 to 1486		

Results

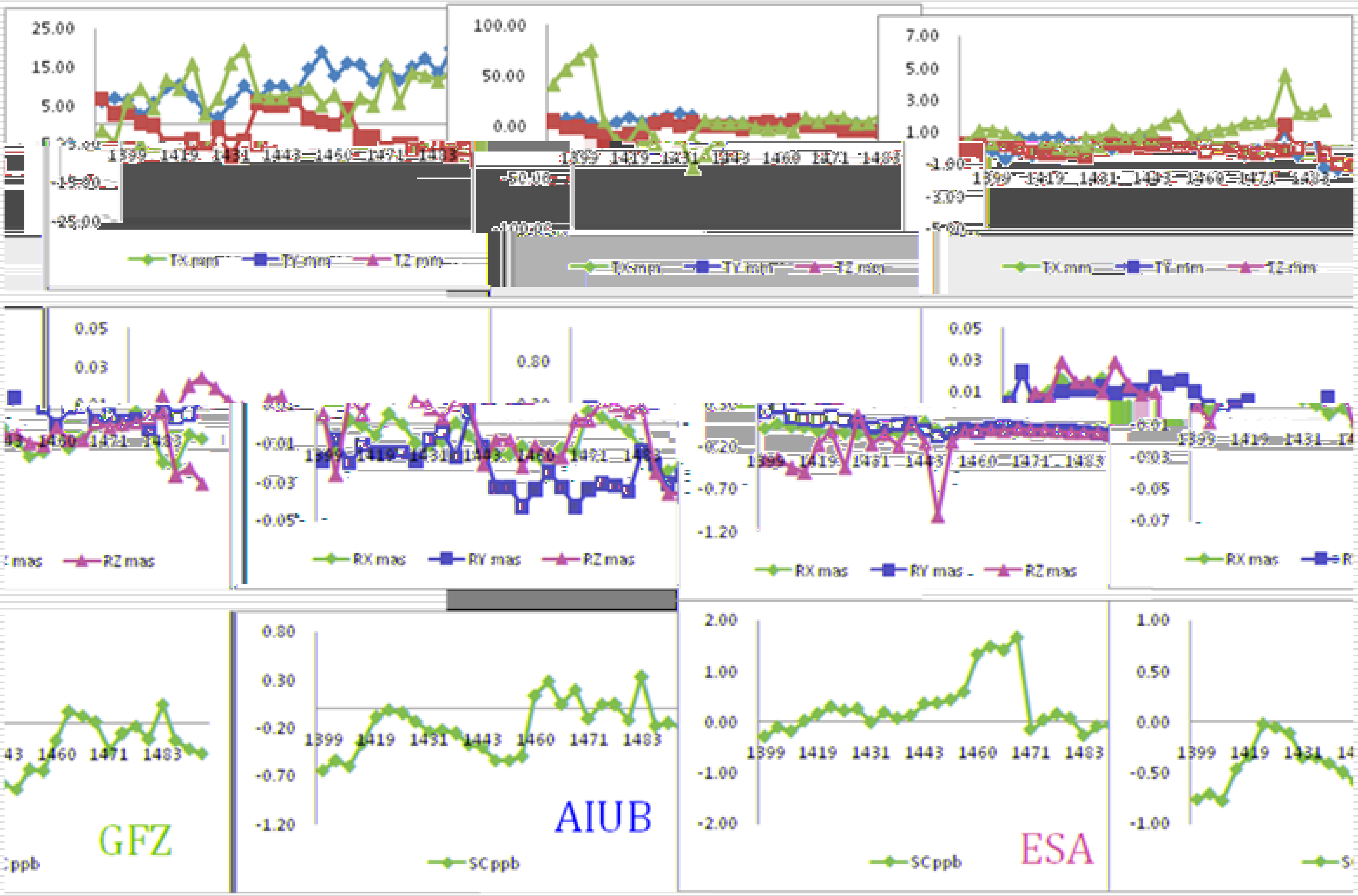
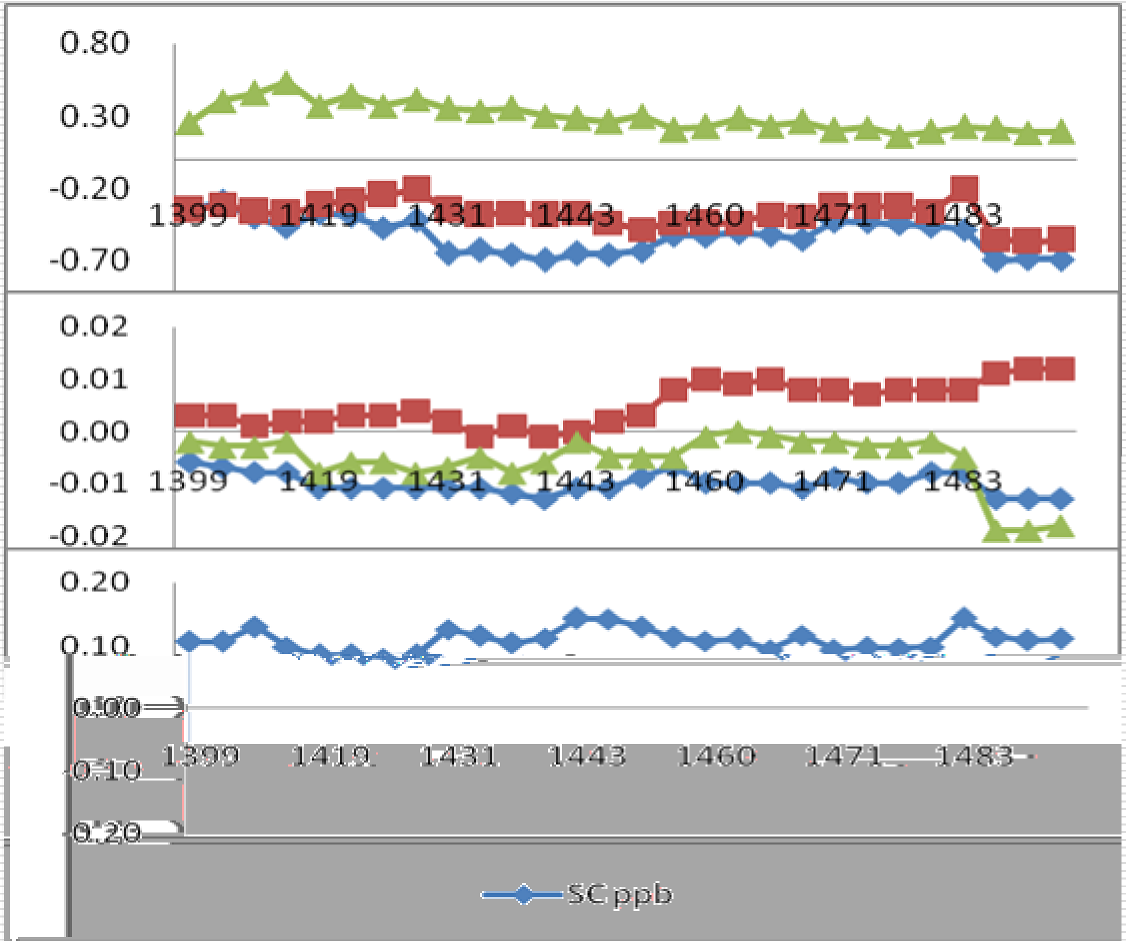


Fig. 5 Transformation parameters of each AC wrt intra-technique combination(WHU)

Analysis



good consistency wrt ITRF2005

Fig. 6 Transformation parameters of WHU wrt ITRF2005

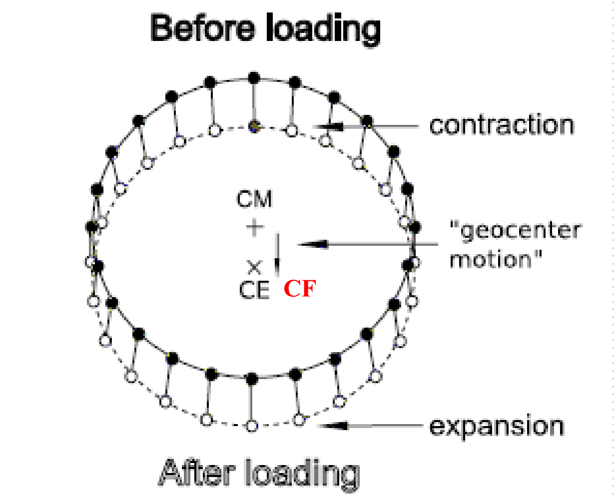
Why Geocenter Motion?

CM

$$X_{CM}(t) = \frac{\iiint_V x(t)dm}{\iiint_V dm}$$

CF

$$X_{CF}(t) = \frac{\iiint_\Omega x(t)dm}{\iiint_\Omega dm}$$



From Lavallee,2006

Ideal realization of CF

$$\begin{cases} T(t_0) = 0 \\ \Delta T = 0 \end{cases}$$

Origin of ITRF

$$\begin{cases} T(t_0) = 0 \\ \dot{T} = 0 \end{cases}$$

- No perfect geophysical models available to constrain $\Delta T = 0$
- ΔT : long-term, seasonal, residuals
- $\dot{T} = 0$ is long-term constraint, and in this case geocenter motion mainly shows seasonal variations

Degree-one deformation approach

- Data and preprocessing
  - IGS reprocessed weekly SINEX : 2000.0~2010.0
  - Network: 132 reference frame stations of IGS05
  - Linear velocity and jumps : IGS05_repro.snx

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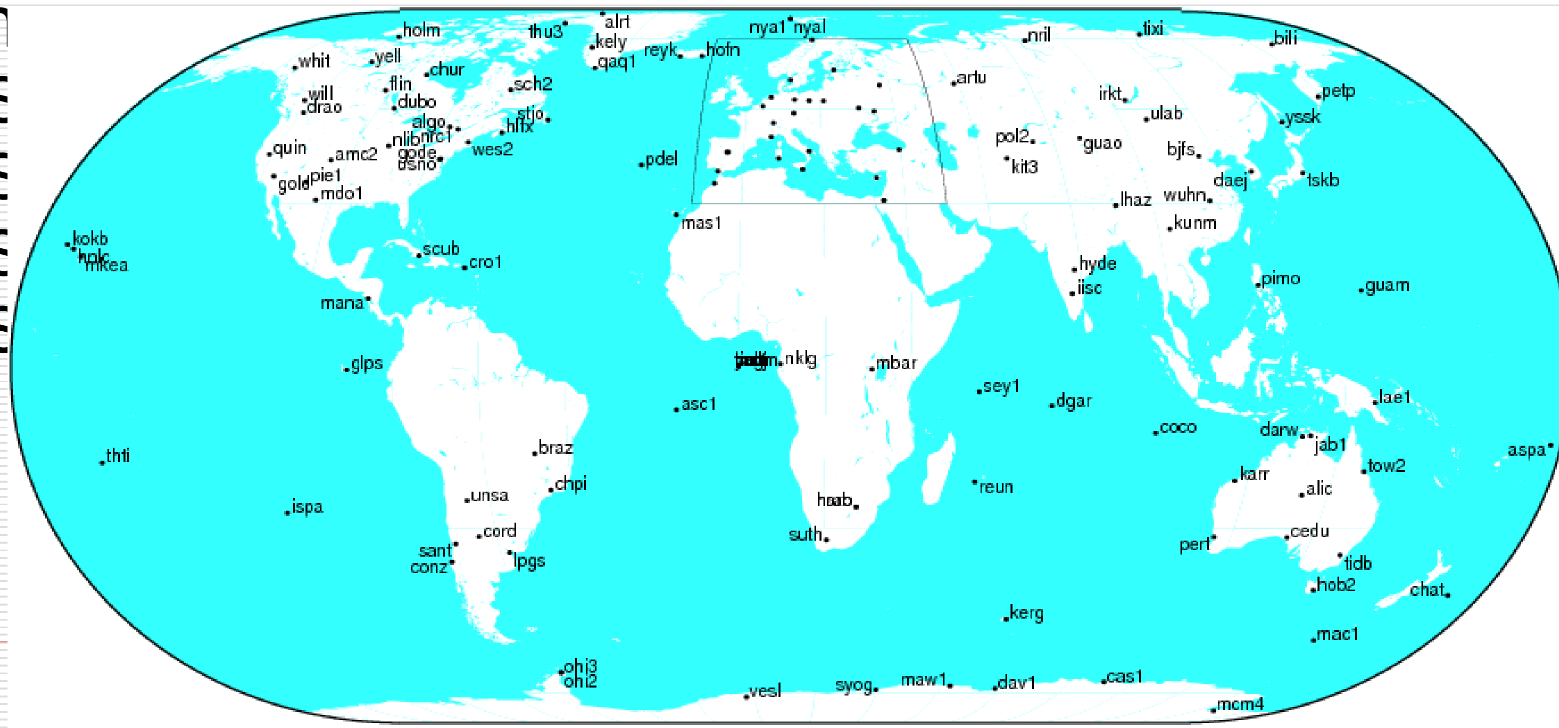

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http://igscb.jpl.nasa.gov/

Results

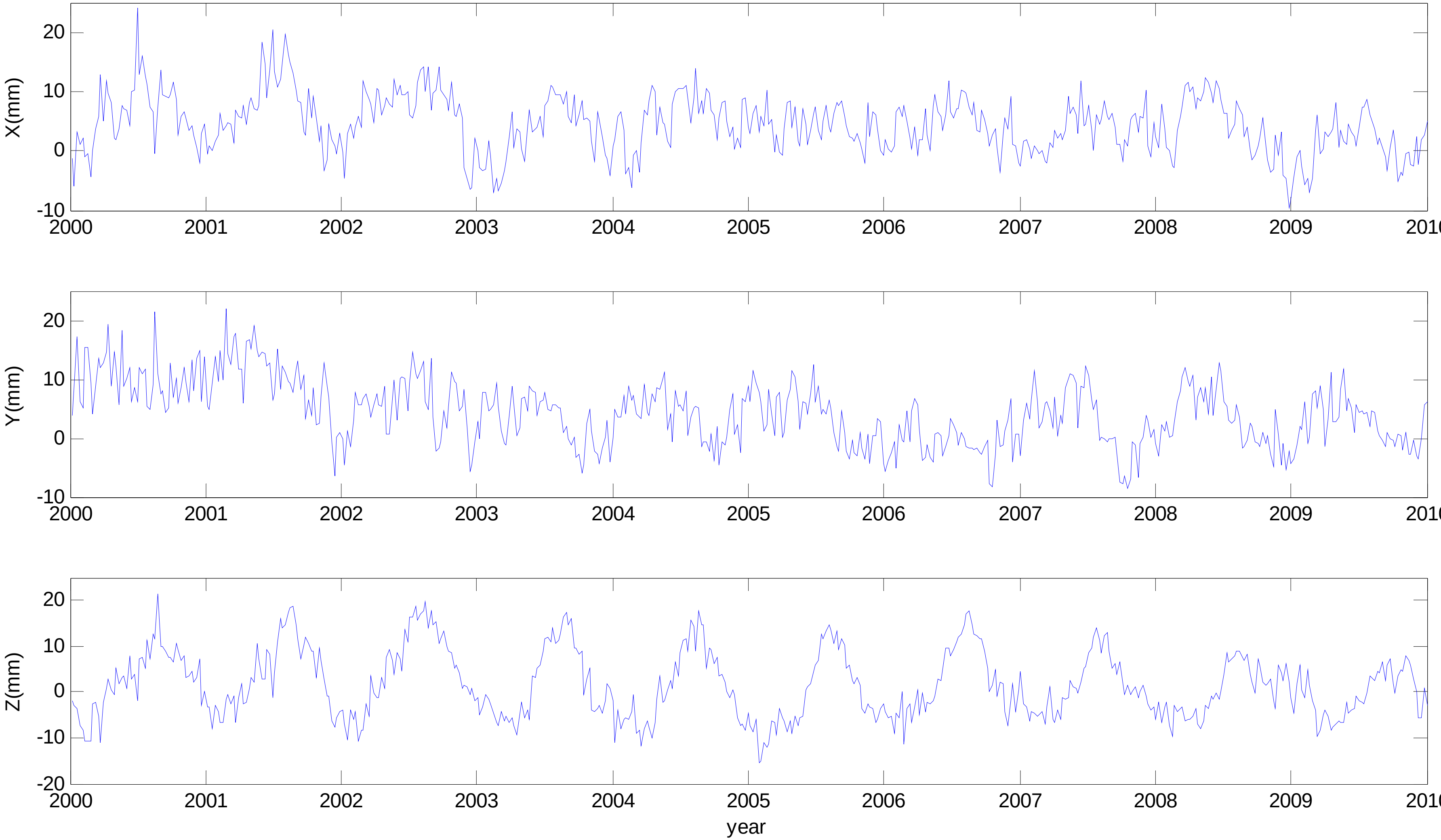

Fig. 7 Geocenter motion time series from scheme 2

Annual terms analysis

	x		y		z	
	Amplitude,mm	Phase,deg	Amplitude,mm	Phase,deg	Amplitude,mm	Phase,deg
scheme 1	3.68 ± 0.2	259 ± 3	2.96 ± 0.1	330 ± 2	8.49 ± 0.2	229 ± 1
scheme 2	3.72 ± 0.2	261 ± 4	3.06 ± 0.1	331 ± 2	8.95 ± 0.2	228 ± 1
scheme 3	3.56 ± 0.2	261 ± 4	3.18 ± 0.1	334 ± 2	8.52 ± 0.2	228 ± 1
scheme 4	3.58 ± 0.2	262 ± 4	3.12 ± 0.1	336 ± 2	8.96 ± 0.2	228 ± 1
scheme 2[b]	3.92 ± 0.3	256 ± 4	2.45 ± 0.2	327 ± 2	9.86 ± 0.2	230 ± 1
ig1	1.93 ± 0.2	89 ± 6	2.49 ± 0.1	144 ± 3	1.98 ± 0.3	294 ± 8
Lavallee,2006[c]	3.57 ± 0.3	219 ± 5	2.44 ± 0.3	289 ± 7	9.93 ± 0.3	240 ± 1
Dong,2003[d]	2.1 ± 0.3	224 ± 7	3.3 ± 0.3	297 ± 6	7.1 ± 0.3	232 ± 3
SLR[e]	2.60	229	3.00	320	3.55	231

[a] Am…
[b] A…
[c] Ta…
[d] Ta…
[e] Av… 03…

Comparison with other GPS results

✓ Amplitude in X and Y direction agree with Lavallee, but the phase is different up to 40 degeree

✓ The phase of scheme 2[b] are clearly smaller than scheme 2 in X and Y direction, encouraging to guess that phase in X and Y direction is likely not stable and that in earlier stage may be smaller

Comparisons between four schemes

✓ Degree-two mass load has **limited** effects on the annual terms, only at the level of sub-millimeter

✓ Rotation parameter has **little** effects on the annual terms

Comparison with SLR

✓ Amplitude and phase of scheme 2 are larger in X direction, both amplitude and phase in Y direction and phase in Z direction show good consistency with SLR; but amplitude in Z direction show large differences.

Discussions

- TRF Realization with GNSS, data processing technique development for Multi-GNSS era, need steps forward
- TRF alignment to international standard, need push through more application projects for GNSS performance refining, IGS as an successful experience, we need make it forward.
- We realized the estimation of geocenter motion, annual amplitude and phase of by degree-one approach is consistent with those published
- Geocenter motion is the basic problem for TRF realization for high precision applications
- Multi-space technology is important to realize TRF for GNSS

THANK YOU !!!