Вариации движения геоцентра по спутниковым данным

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The Conventional Terrestrial Reference System (CTRS) is commonly adopted implementation of the TRS. As currently defined (IERS Conventions 2003) the CTRS has these characteristics:

1) It is geocentric with its origin at the center of mass the whole Earth, including oceans and atmosphere;

2) The unit of length is the meter (SI). Its scale is that of the local Earth frame within a relativistic theory of gravitation;

3) its orientation was initially given by the Bureau Intrernational de l'Heure (BIN) orientation at 1984.0;

4) 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.

There are three commonly adopted origins of the terrestrial reference frames:

a) the center of mass the whole Earth, including atmosphere, oceans and surface groundwater (CM) - it is commonly used in space geodesy because satellite dynamics are sensitive only to CM;

b) the center of mass the solid Earth without mass load (CE) - it is used in certain theoretical geophysics studies (e.g., of the load Love numbers);

c) the center of figure of the outer surface of the solid Earth (CF). CF frame is often used in ground survey related disciplines, where the geometry between ground sites is the only measurable quantity.

Geocenter motion - this is vector offset of CF relative to CM.

The ITRF origin has attracted increasing attention for several reasons:

1) as more scientists study the dynamic deformation on seasonal and shorter timescales, the stability of the ITRF on those timescales becomes critical;

2) many studies require comparison between space geodetic solutions and solutions from other geophysical data or models (atmosphere, oceans, etc.). Consistency between the ITRF origin and the origins of other reference frames must be taken into account;

3) True geocenter variations can be detected by space geodesy and can be quantitatively compared with geophisical model predictions.

4) The dual character of the ITRF origin can easily cause confusion (desired nature of the ITRF2000 origin is CM. The realized nature of the ITRF2000 becomes CM in the long term, but CF on seasonal and short timescales).

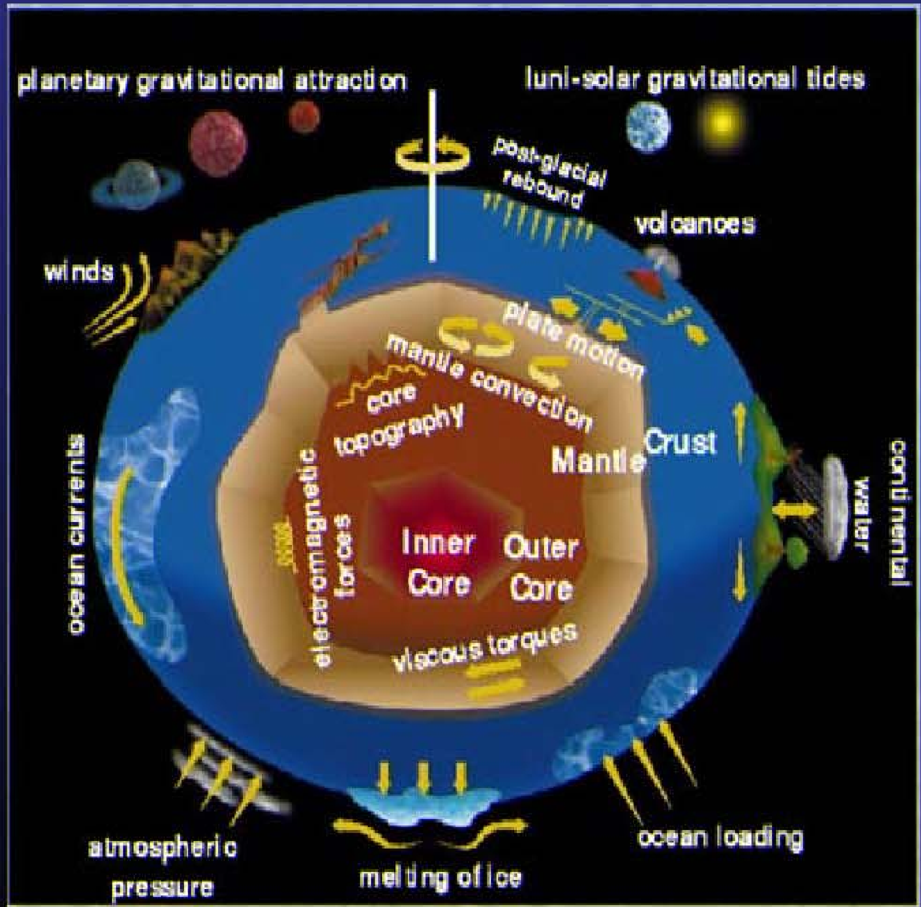
Observational approach of the Geocenter Motion

- There are two approaches to monitor the motion of the geocenter with space geodesy. The geometric approach was historically the first one to be used. The geometric approach consists of a direct comparison of short-term estimates of the network positions (e.g., monthly, bi-weekly, weekly and so on) with respect to a standard set of positions, usually derived from a much longer averaging period (e.g., several years). The geometric technique estimates the three Cartesian offsets as part of a seven-parameter transformation (Helmert transformation) is very sensitive to changes in the tracking network. This is understandable since stations can be inoperative at times due to repairs or upgrades and in case of SLR, due to poor weather.
- The second, dynamic approach relies on the estimation of the degree-one terms of the spherical harmonic expansion of the gravitational potential, which are directly proportional to the geocenter offsets.

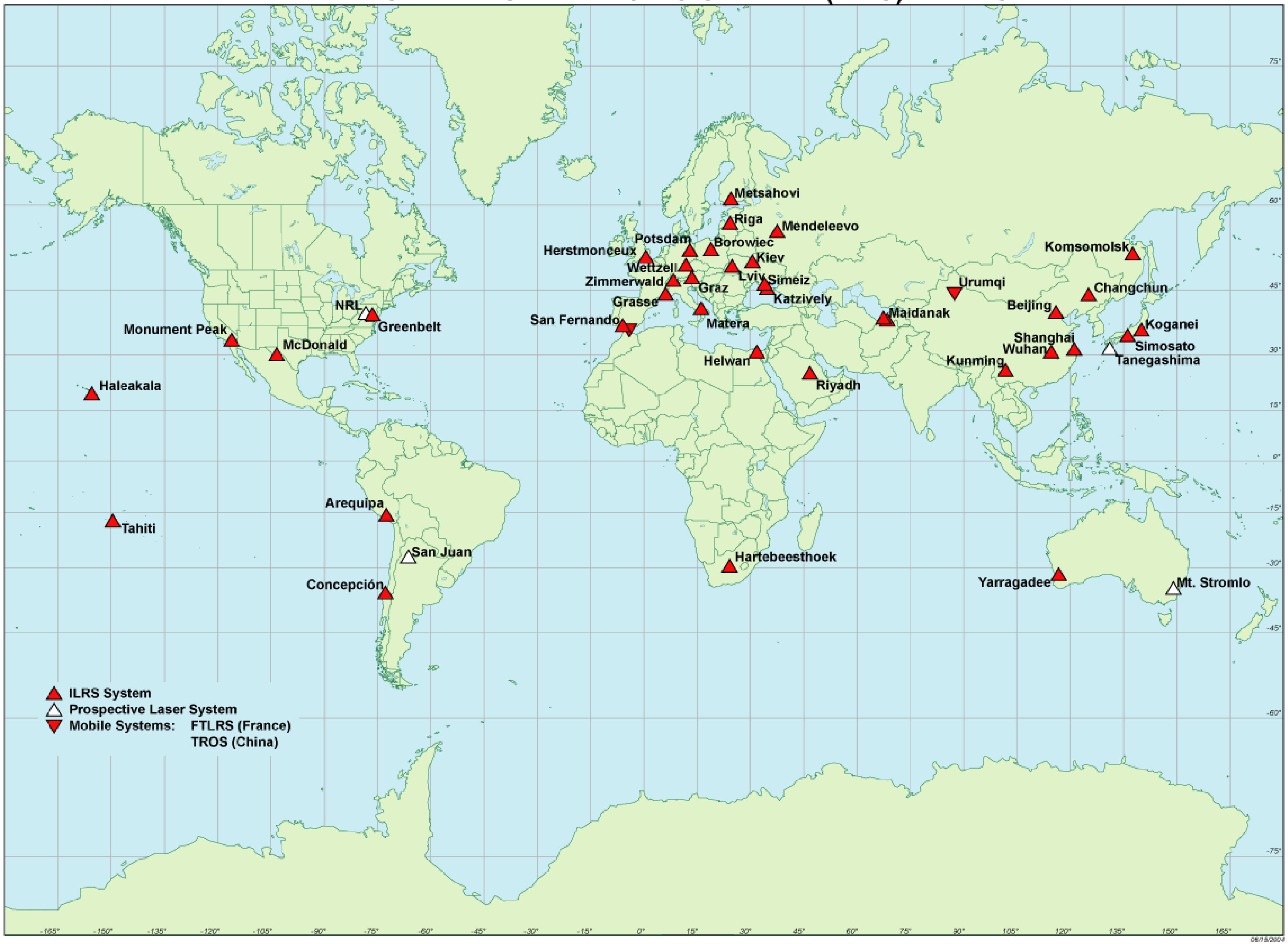
$$X_g = \sqrt{3} * R * C_{11}$$
$$Y_g = \sqrt{3} * R * S_{11}$$
$$Z_g = \sqrt{3} * R * C_{10} ,$$

Temporal Variability

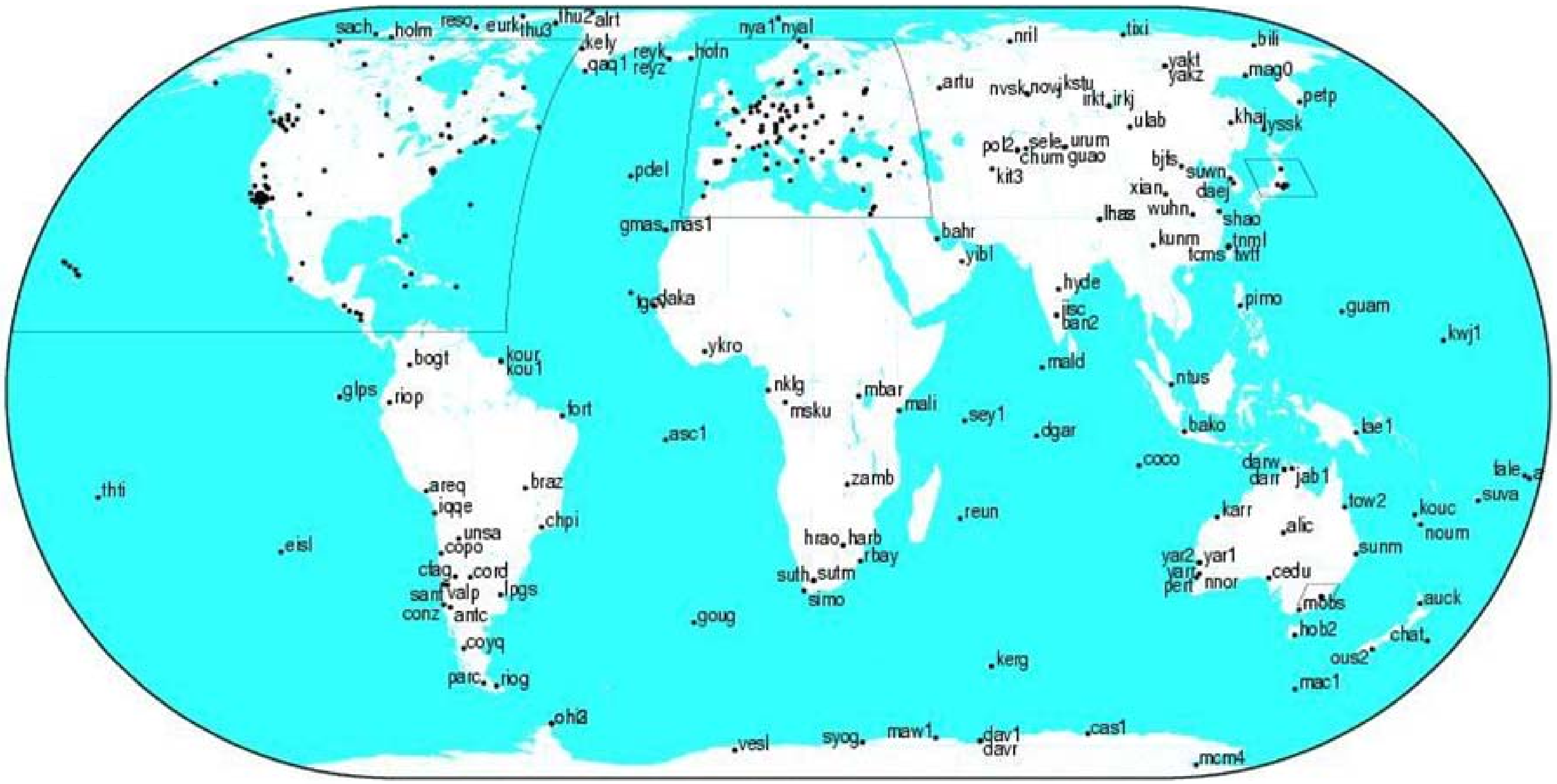
- Mass is in constant motion in the Earth system:
  - Solid Earth
  - Atmosphere
  - Hydrosphere
    - Oceans
    - Ice caps
    - Soil moisture
    - Rivers & lakes



INTERNATIONAL LASER RANGING SERVICE (ILRS) NETWORK



IGS NETWORK (362 sites)



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DORIS NETWORK (54 sites)

5 time series of geocenter solutions were used for comparison:

- ***- two DORIS solutions using data on SPOT2, SPOT3, SPOT4, SPOT5, TOPEX-POSEIDON, ENVISAT satellites:***

1.IGN/JPL analysis center weekly solution on span 1993.0 – 2006.9,
(ftp://cddis.gsfc.nasa.gov/pub/doris/products/geoc/ign/ign03wd01.geoc.Z);
2. INASAN analysis center weekly solution on span 1993.0 – 2006.6,
(ftp://cddis.gsfc.nasa.gov/pub/doris/products/geoc/ina/ina05wd02.geoc.Z);

- ***- one GPS global solution*:**

3. JPL analysis center daily solution on span 1993.0 - 2006.6,
(ftp://sideshow.jpl.nasa.gov/pub/mbn);

- ***- two SLR solutions:***

4. SCR LAGEOS 1,2 monthly solution on span 1993.0 - 2000.2,
(http://sbgg.jpl.nasa.gov);
5. SCR TOPEX/DORIS monthly solution on span 1993.0 - 2000.1,
(http://sbgg.jpl.nasa.gov);

$$J(t) = a_0 + b_0 t + A_0 \sin\left(\frac{2\pi}{P}(t - t_0) + \varphi_0\right),$$

A_0	- amplitude of the signal;
P	- period of the signal (in years);
φ_0	- initial phase of the signal;
a_0	- offset;
b_0	- trend;
t	- time;
t_0	- arbitrary initial time (we take t_0 - 1st January).

SOLUTION		Span	X				Y				Z			
			Annual		Semiannual		Annual		Semiannual		Annual		Semiannual	
			A, mm	Ph, deg	A, mm	Ph, deg	A, mm	Ph, deg	A, mm	Ph, deg	A, mm	Ph, deg	A, mm	Ph, deg
DORIS	IGN /JPL (weekly)	1993.0 – 2006.9	6.4 ± 0.3	93.5 ± 3.0	1.0 ± 0.3	180.0 ± 17.7	5.9 ± 0.1	309.3 ± 4.6	1.6 ± 0.3	277.9 ± 13.5	30.3 ± 1.1	289.2 ±4.5	23.6 ± 1.5	349.8 ± 5.2
	INASAN (weekly)	1993.0 – 2006.6	6.6 ± 0.3	103.0 ± 4.6	5.2 ± 0.4	5.1 ± 10.4	5.2 ± 0.1	322.9 ± 5.8	1.4 ± 0.5	227.1 ± 0.8	29.3 ± 1.1	287.6 ± 4.4	10.9 ± 0.5	325.7 ± 13.0
GPS	JPL (daily)	1993.0 – 2006.6	2.2 ± 0.1	294.4 ± 7.8	15.5 ± 0.2	354.2 ± 1.0	4.6 ± 0.2	279.6 ± 3.0	1.8 ± 0.2	178.6 ± 6.6	7.9 ± 0.3	108.6 ± 4.7	5.5 ± 0.1	140.0 ± 7.5
SLR	SCR – LAGEOS 1,2 (monthly)	1993.0 – 2000.2	3.1 ± 0.5	17.6 ± 4.9	1.1 ± 0.5	19.2 ± 13.2	5.5 ± 0.5	197.9 ± 2.6	0.8 ± 0.5	16.0 ± 18.5	3.6 ± 0.5	82.8 ± 6.5	1.4 ± 0.6	197.1 ± 12.2
	SCR - TOPEX /DORIS (monthly)	1993.0 – 2000.1	1.8 ± 0.4	47.8 ± 0.5	1.5 ± 0.2	170.7 ± 11.7	2.8 ± 0.1	130.3 ± 6.1	0.4 ± 0.1	295.1 ± 38.0	2.3 ± 0.8	66.0 ± 8.0	3.8 ± 0.8	195.4 ± 6.8
PREDICTED														
Dong et al. [1997]			4.2	224	0.83	30	3.2	339	0.43	26	3.5	235	1.1	313
Chen et al. [1999]			2.4	244	0.75	181	2.0	270	0.89	221	4.1	228	0.5	238
Bouille et al. [2000]			1.6	236			1.8	309			3.1	254		

Table 1. Measured and predicted seasonal variations of geocenter motion

SOLUTION		Span	bias			trend		
			X, mm	Y, mm	Z, mm	X, mm/yr	Y, mm/yr	Z, mm/yr
DORIS	IGN /JPL (weekly)	1993.0 – 2006.9	2.4 ± 0.5	8.5 ± 0.6	- 36.1 ± 3.1	-1.8 ± 0.1	0.3 ± 0.1	5.2 ± 0.4
	INASAN (weekly)	1993.0 – 2006.6	6.8 ± 0.7	10.3 ± 0.6	- 31.0 ± 3.2	-2.1 ± 0.1	0.1 ± 0.1	3.5 ± 0.3
GPS	JPL (daily)	1993.0 – 2006.6	5.5 ± 0.6	8.5 ± 0.5	- 32.2 ± 1.2	-0.2 ± 0.1	-0.8 ± 0.1	3.0 ± 0.1
SLR	SCR – LAGEOS 1,2 (monthly)	1993.0 – 2000.2	- 0.7 ± 0.5	-0.9 ± 0.5	- 6.8 ± 0.6	-0.2 ± 0.1	0.7 ± 0.1	1.2 ± 0.2
	SCR - TOPEX / DORIS (monthly)	1993.0 – 2000.1	- 0.4 ± 0.3	0.5 ± 0.3	- 2.2 ± 0.9	0.1 ± 0.1	0.2 ± 0.1	0.6 ± 0.2

Table 2. Measured biases and trends time series of the geocenter motion

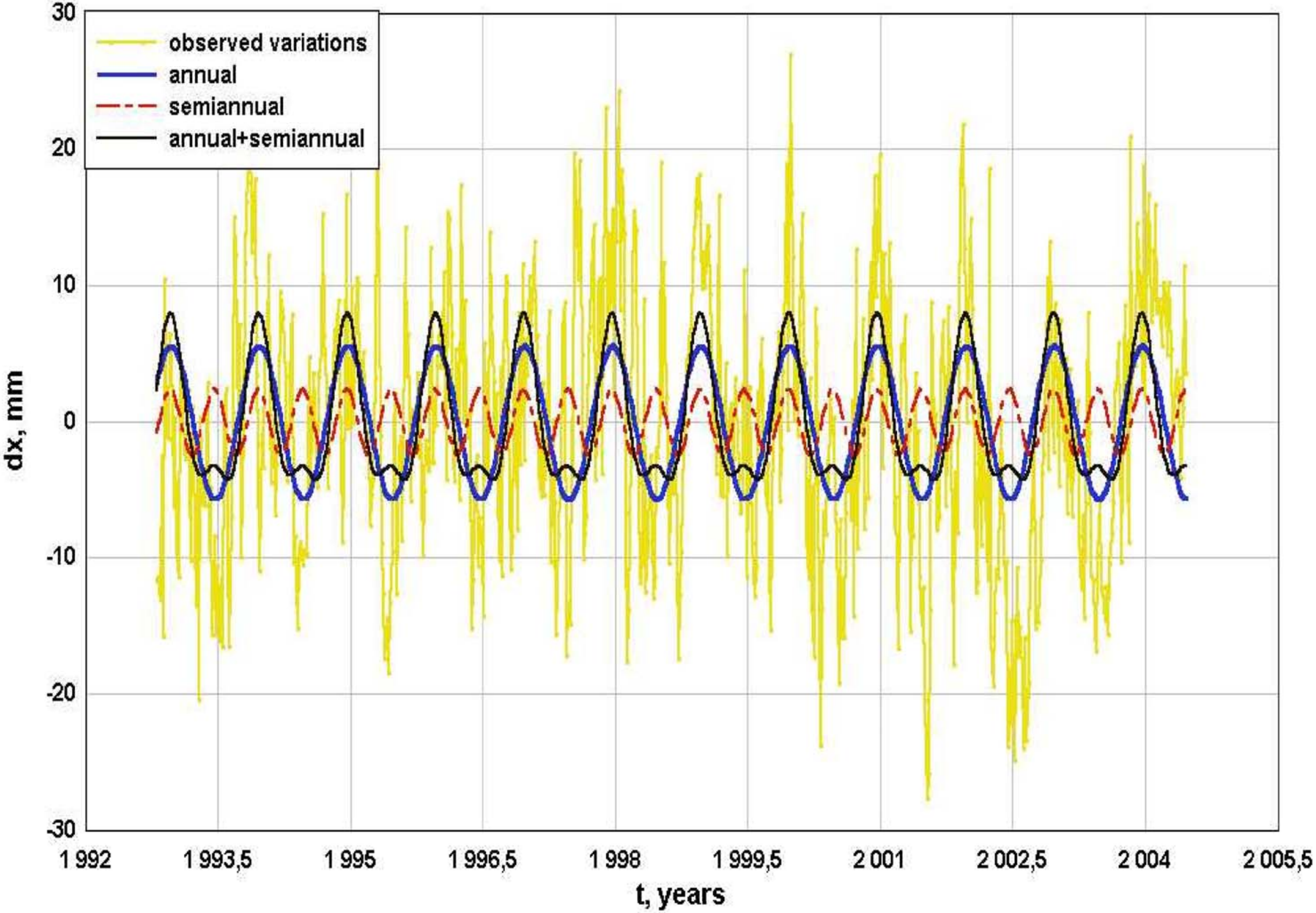

Fig. 1. DORIS weekly geocenter variations (TX component) compared to ITRF00 with superimposed annual, semiannual, annual+semiannual

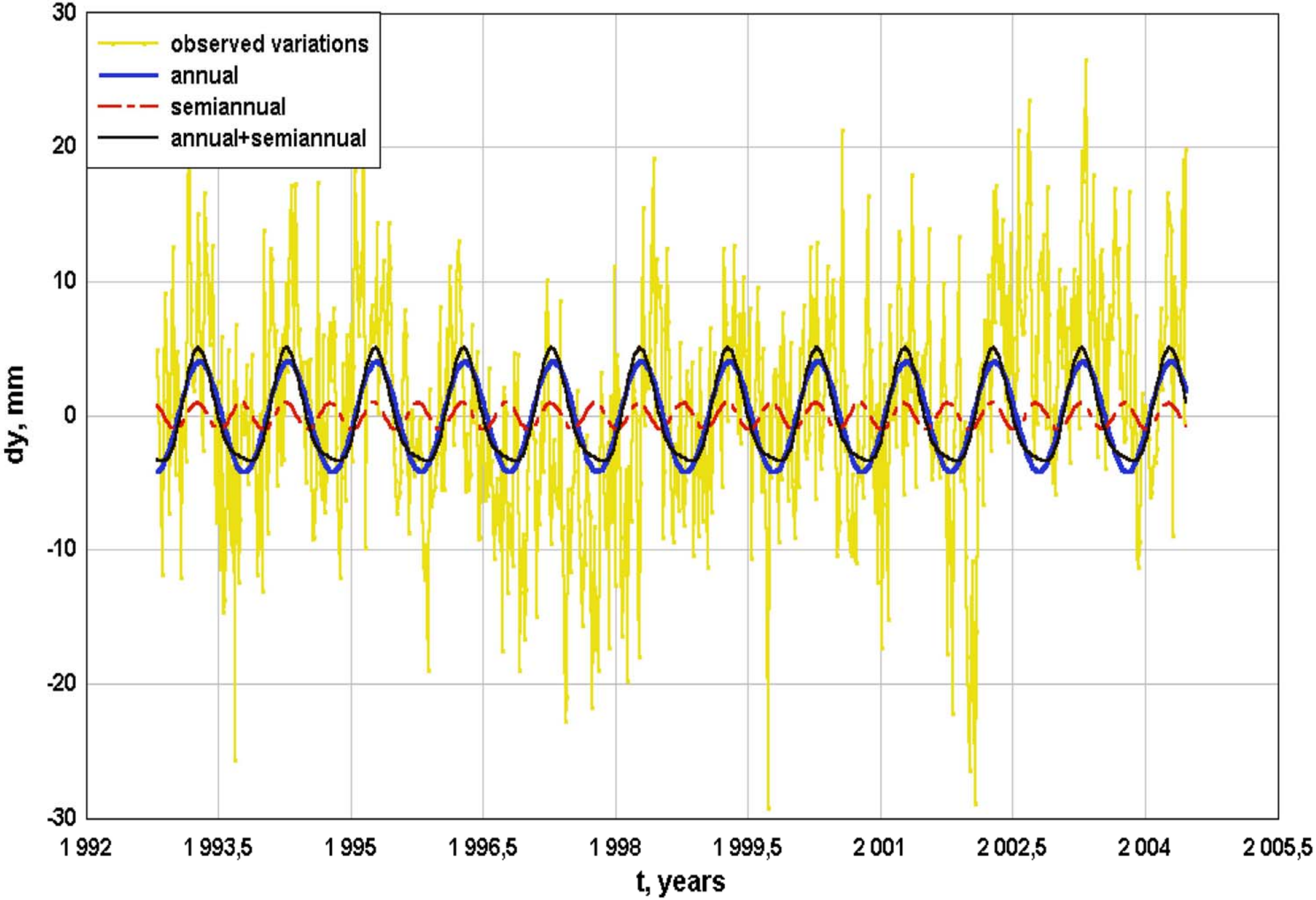

Fig. 2. DORIS weekly geocenter variations (TY component) compared to ITRF00 with superimposed annual, semiannual, annual+semiannual

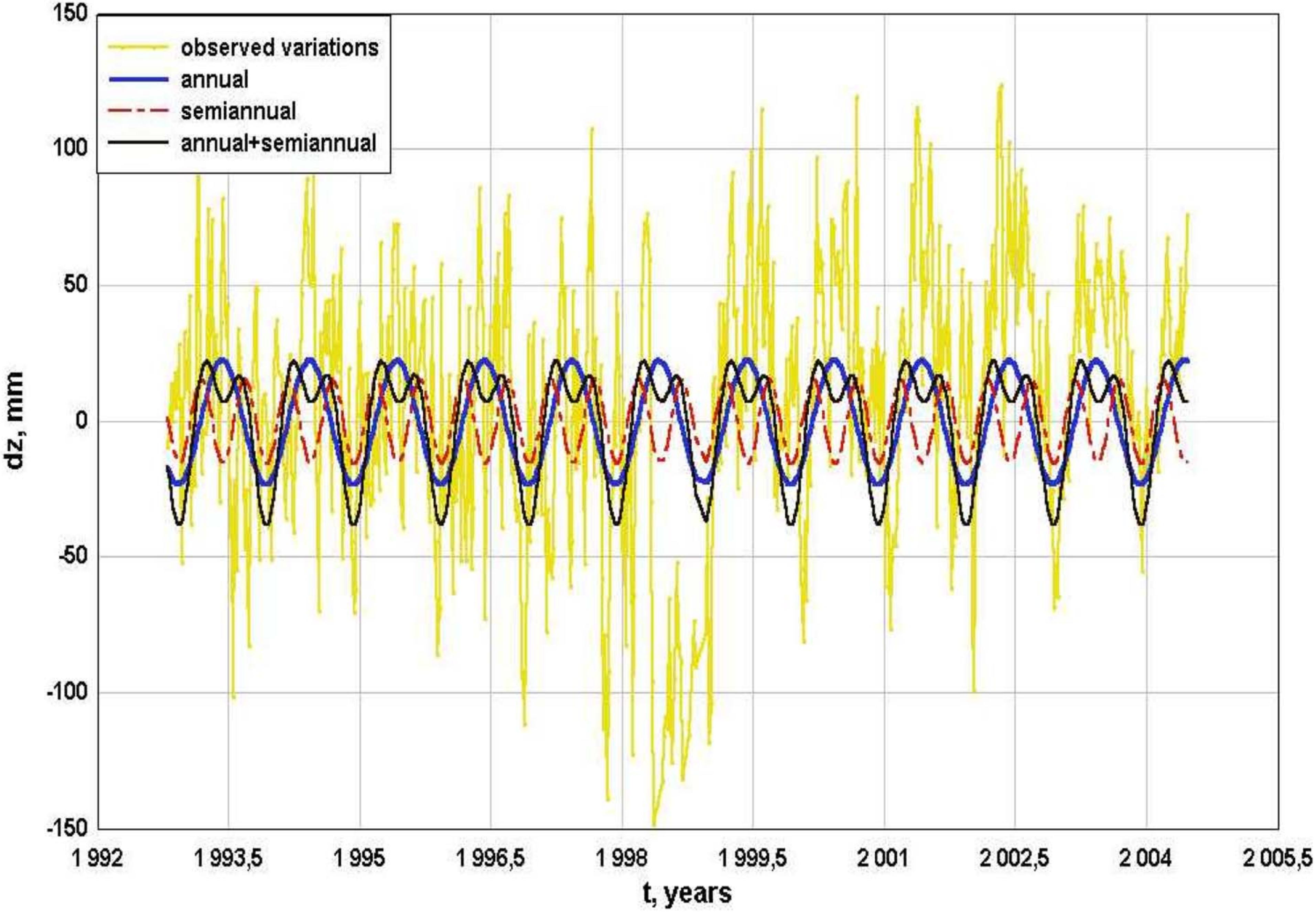

Fig. 3. DORIS weekly geocenter variations (TZ component) compared to ITRF00 with superimposed annual, semiannual, annual+semiannual

Conclusions

SLR, DORIS and GPS space geodesy techniques are sensitive to the variations of geocenter in different degree. The SLR solution has results the closest compare with the predicted solutions. GPS and DORIS solutions have a slightly higher amplitudes for *x* and *y* components compare with the SLR and considerably higher for *z* component. It is confirm the lower quality geocenter determination from the geometric method, though degree-1 deformation approach [*Dong et al., 2003*] gives more reasonable estimates for amplitudes and phases of GPS geocenter time series, which are consistent with SLR results and geophysical predictions.

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