Monitoring the origin of the TRF with Space Geodetic Techniques

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Outline

- Introduction
- Review
- Results from Space Techniques
- Conclusions

Introduction

- Definition
- Practical Realization
- Sensitivity to sources of variability
- Observability from Space Techniques
- Current state (resolution & precision)

Geocenter Definition

- From Mechanics, at a certain epoch *t* :

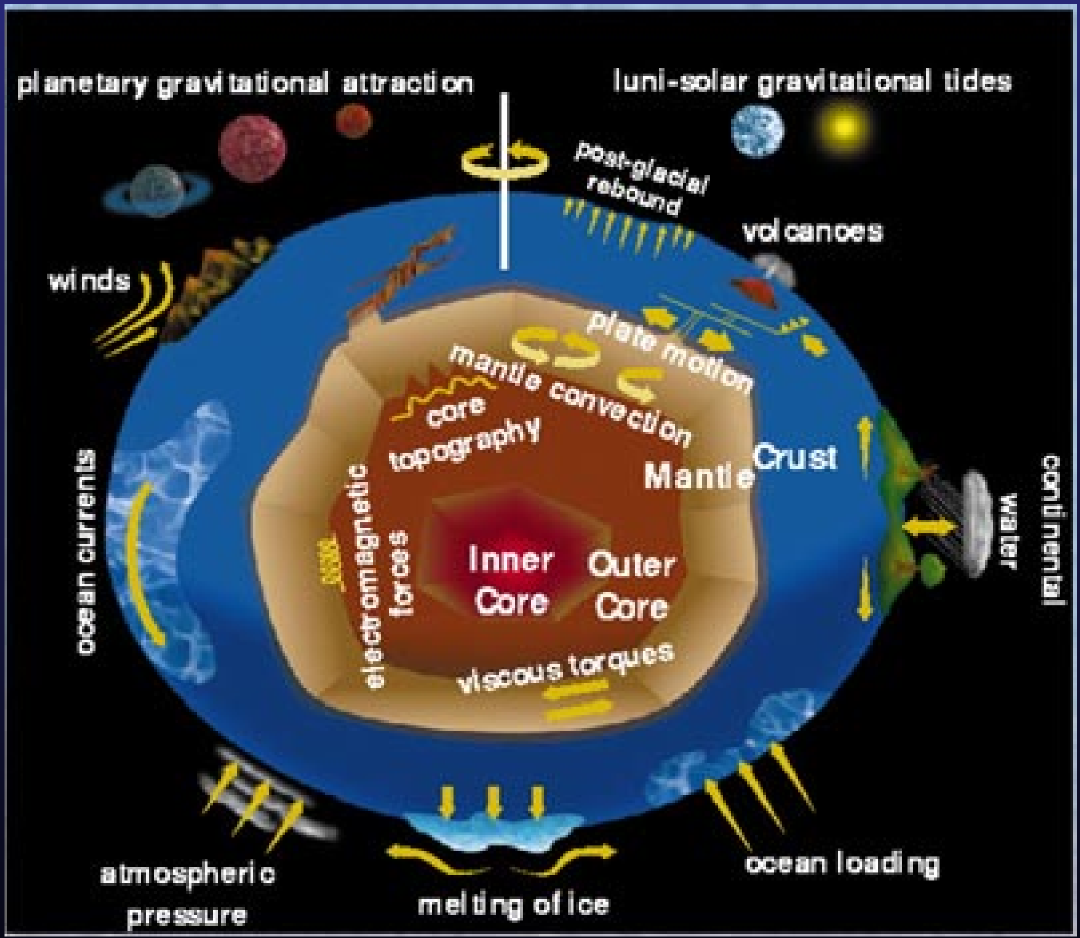
$$x_c = (1/M) \iiint x' dM$$

$$y_c = (1/M) \iiint y' dM$$

$$z_c = (1/M) \iiint z' dM$$

Temporal Variability

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



Observations & Models

- Remote sensing techniques from space are now steadily providing with ever increasing resolution and accuracy estimates of the various Earth system components (snapshots)
- We are still far from having a complete and satisfactory picture for all of the components
- Models are still very useful in providing us with estimates of the less reliably observed or the yet-to-be-observed components

Practical Realization

- Terrestrial satellites are sensitive to the instantaneous location of the geocenter with respect to the tracking network polyhedron
- Frequent redefinition of the tracking site positions (e.g. monthly, weekly, or even daily averages) provide a time-series of realizations (Helmert/geometric)
- Alternatively, the averaged geocenter offsets can be estimated directly from the variation in the first degree terms of the gravitational model (dynamic)

Periodic Variability of the Geocenter

- Observations and models of the geophysical processes typically provide us with daily to monthly averages at this time
- With new missions in the planning stages, this can be soon improved

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Table 3. Geocenter Motion Seasonal Sinusoids Computed From the Combined Analysis of LAGEOS I and II Satellites, Atmosphere, Ocean, and Continental Water Storage[a]

		Annual		Semi-Annual	
Source	Axis	Amplitude, mm	Phase, deg	Amplitude, mm	Phase, deg
Atmosphere (IB)	x	0.55	104	0.23	90
ECMWF	y	1.31	91	0.38	217
Dong et al. [1997]	z	0.87	133	0.73	271
Atmosphere (IB)	x	0.40	165	0.30	270
GEOS-1	y	1.35	150	0.47	335
This paper	z	0.44	134	0.70	353
Oceans (ISO Model)	x	1.05	79	0.39	248
Dong et al. [1997]	y	0.09	121	0.29	282
	z	0.18	218	0.16	41
Oceans (T/P Model)	x	0.96	73	0.86	187
Chen et al. [1998]	y	0.97	52	0.73	173
	z	0.49	3	0.25	232
Oceans (POCM_4B)	x	0.89	92	0.24	117
No correction	y	0.40	130	0.23	22
	z	0.05	193	0.13	189
Oceans (POCM_4B)	x	0.83	95	0.24	111
Sea level adjustment	y	0.40	136	0.24	23
	z	0.14	220	0.09	182
Continental Hydrology	x	3.28	25	0.84	319
Dong et al. [1997]	y	2.94	185	0.94	48
	z	3.57	40	0.60	344
Continental Hydrology	x	1.28	44	0.15	331
(CDAS-I)	y	0.52	182	0.56	312
Chen et al. [1999]	z	3.30	43	0.50	75

Long Period Signals

Source	Magnitude	Induced motion	Ref.
Sea level	1.2 mm/y	0.064 ±0.02 mm/y	2
Ice sheets (G)	2 mm/y	0.046±0.20 mm/y	2
Tectonics	AMO-2	0.309±0.05 mm/y	2
Postglacial rebound	ICE-3G model	0.2 - 0.5 mm/y	1

- (1) : Marianne Greff-Lefftz (2000)
- (2) : Yu. Barkin (1997?)

Observations - SLR (CSR 12-day)

- 12-day averages since late 1992 and up to early 1997
- The 12-day averaging period results in increased noise in the series
- Long period trends compare well with geophysical predictions and other SLR series

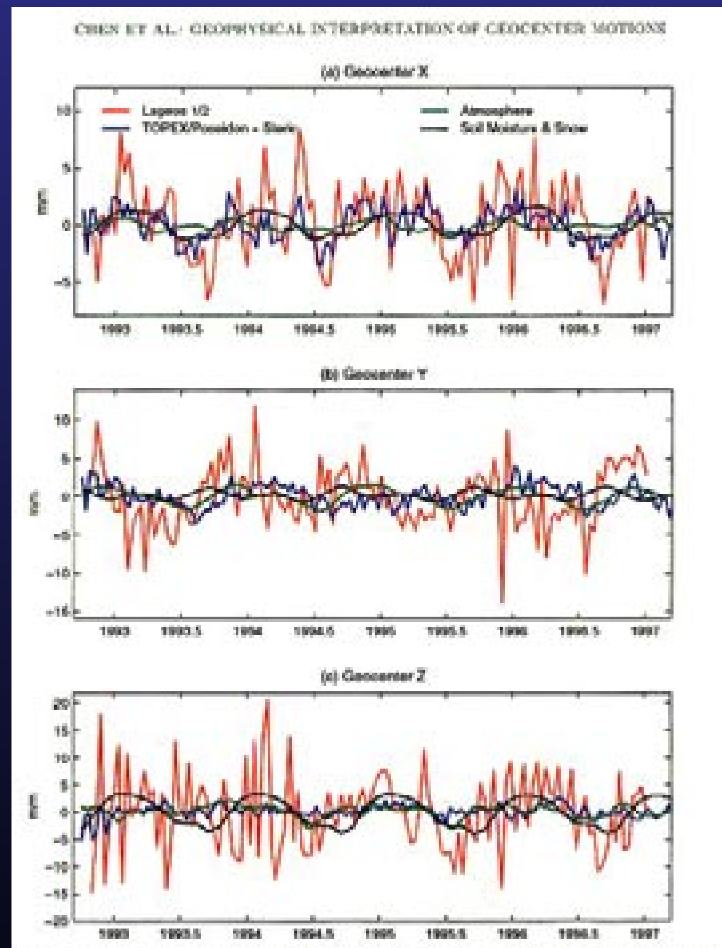
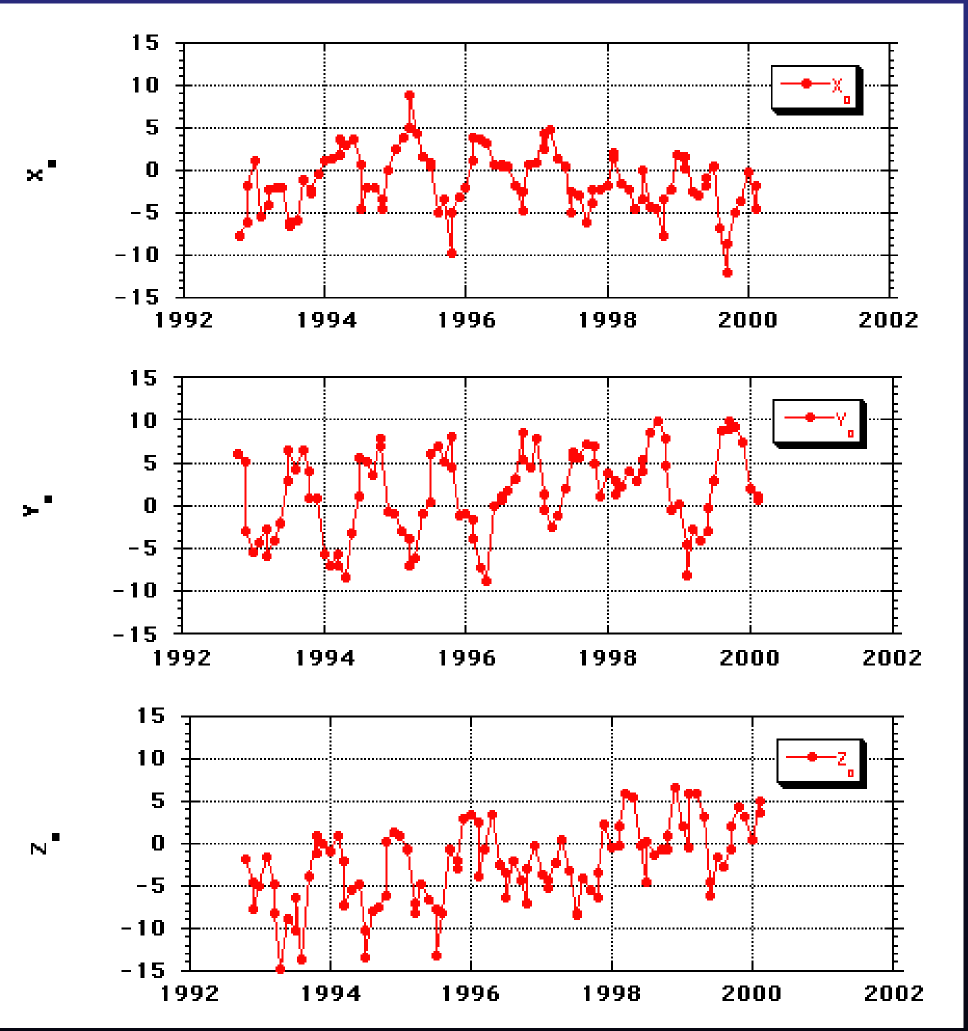


Plate 1. The three components (a) X, (b) Y, and (c) Z of observed geocenter solutions from Lageos 1 and Lageos 2, along with the atmospheric, continental hydrological, and oceanic contributions.

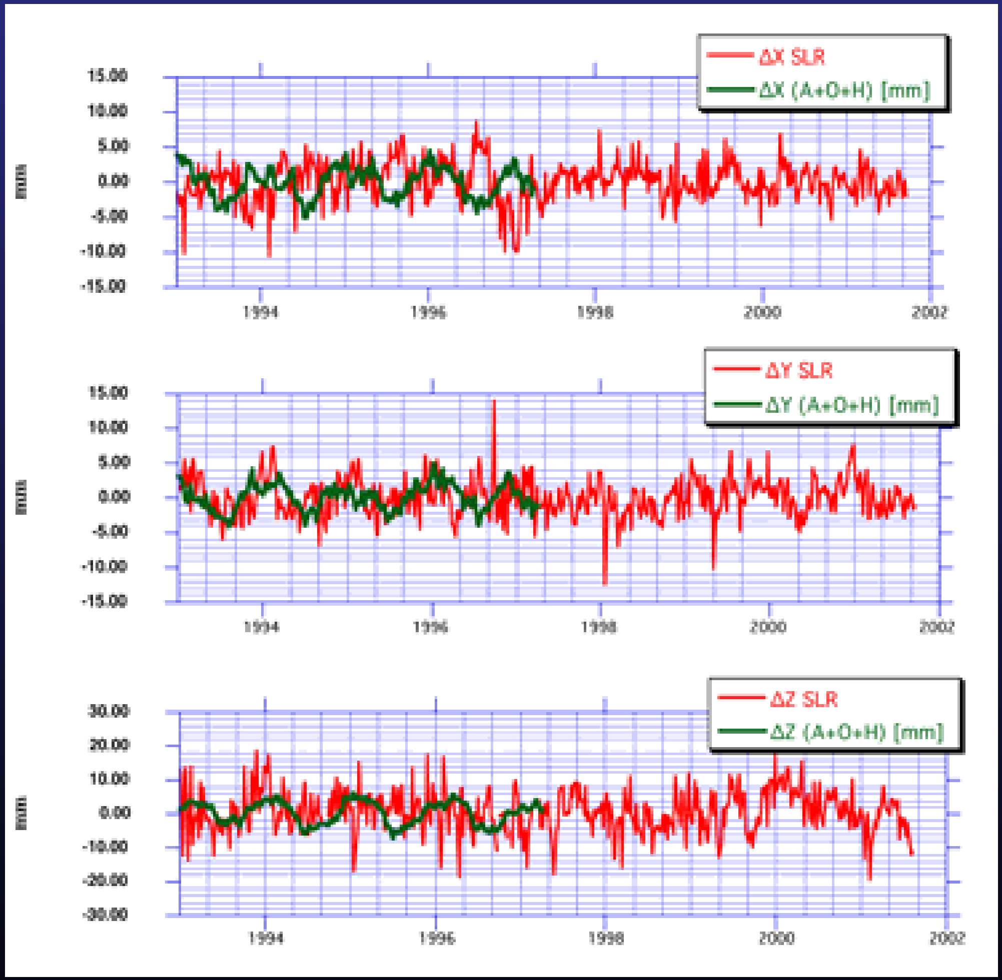
Observations - SLR (CSR monthly)

- Monthly estimates since late 1992 (evolving, ?)
- The monthly averaging period results in a clearer definition of the annual and semi-annual signals
- Order of magnitude of observed variations compares well with geophysical predictions and other SLR series



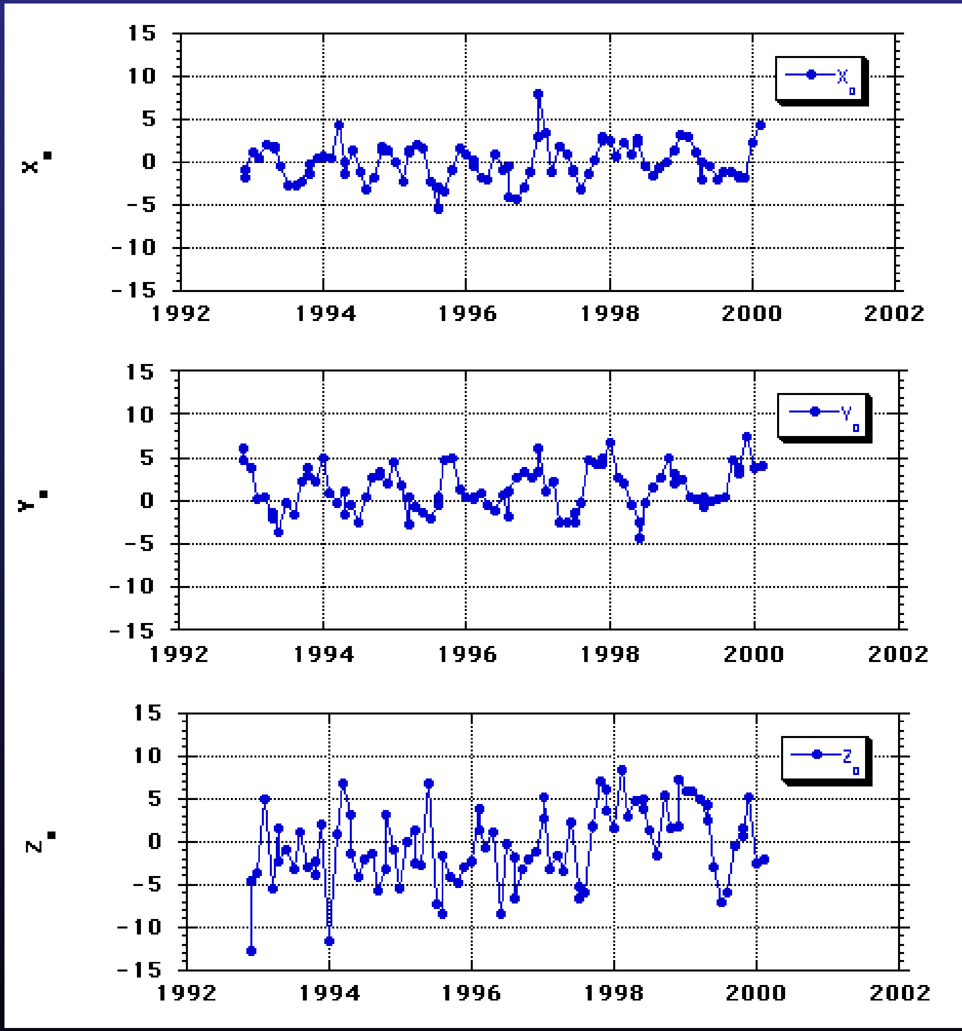
Observations - SLR (JCET weekly)

- Weekly estimates since 1993, secular trends removed
- Tracking network variations affect quality of results
- Order of magnitude of results consistent with predictions and other SLR series



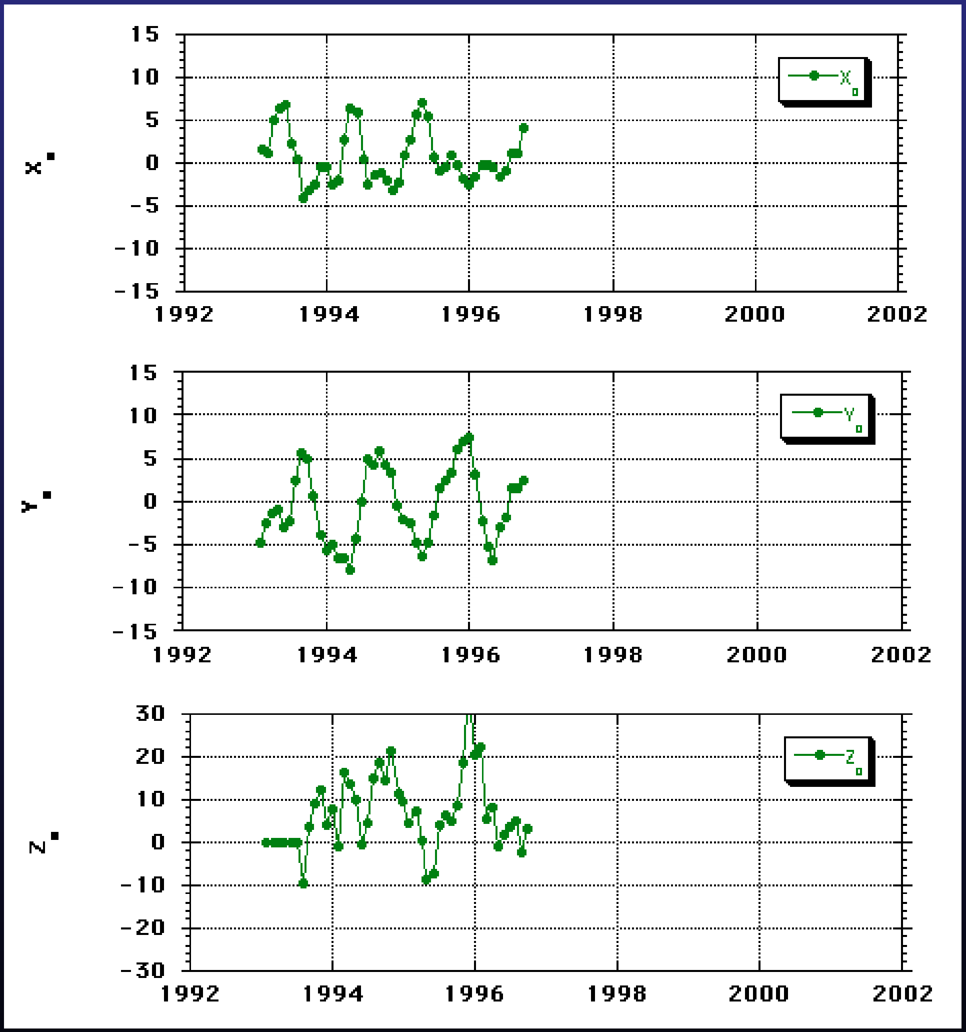
Observations - SLR+DORIS (CSR)

- Monthly estimates since late 1992
- The addition of a second type of data from another satellite (T/P) changes the amplitude of the annual and semi-annual signals as well as the secular trends
- In general, the observed variations are reduced in comparison with the CSR SLR-only series



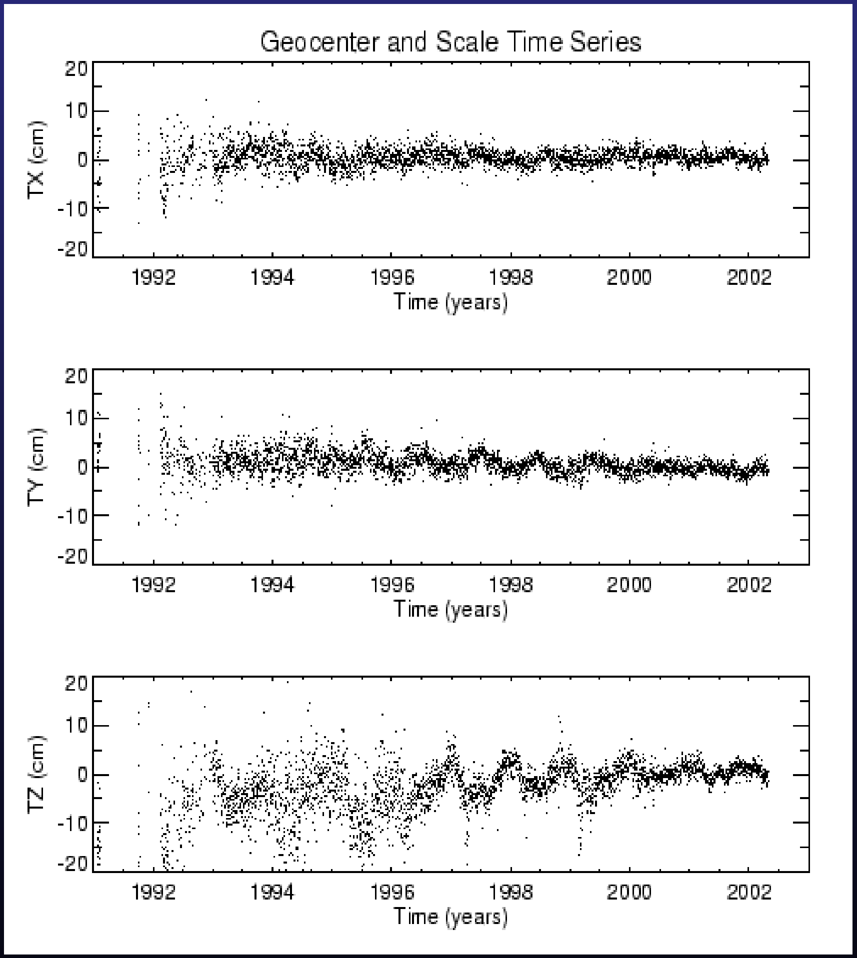
Observations - DORIS (CNES)

- Monthly series for 1993 - 1996
- With only four years of results we can infer only tentative conclusions
- The amplitude of the annual and semi-annual signals seem more similar to the LAGEOS-only results than to the CSR SLR+DORIS series
- Z-component less reliable

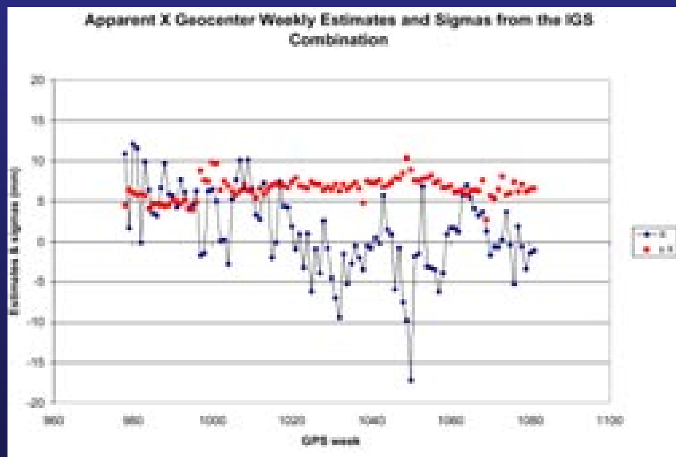


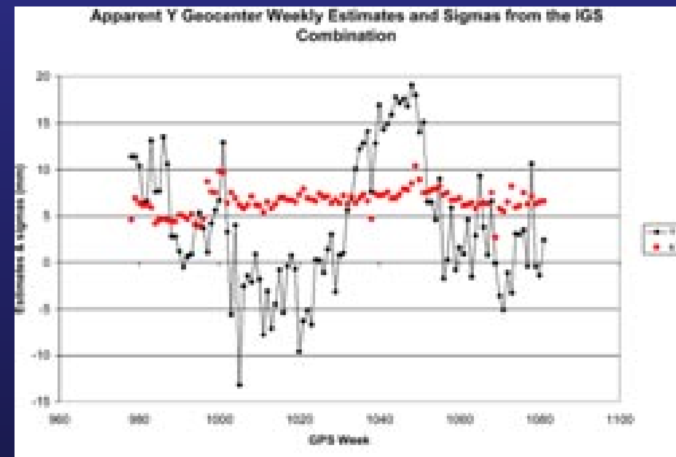
Observations - GPS (JPL Daily)

- Long record of daily estimates: 1992-2002
- Variable quality over the years
- Order of magnitude larger variation compared to predictions and other techniques

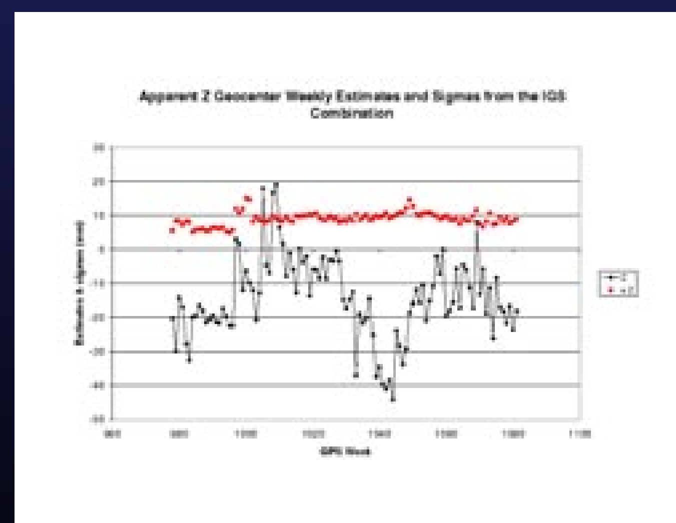


Observations - GPS (IGS Weekly)





- GPS Weeks 980 - 1080
- Short and noisy series
- Order of magnitude of variations larger than predictions and weekly SLR results



Observations vs. Predictions

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Table 3. Geocenter Motion Seasonal Sinusoids Computed From the Combined Analysis of LAGEOS I and II Satellites, Atmosphere, Ocean, and Continental Water Storage[a]

Source	Axis	Annual Amplitude, mm	Annual Phase, deg	Semi-Annual Amplitude, mm	Semi-Annual Phase, deg
LAGEOS I/II Solution	x	2.18	31	1.08	164
Eanes et al. [1997]	y	3.20	151	0.77	213
	z	2.79	45	0.38	13
Sum Oceans (POCM_4B-	x	1.88	76	0.16	287
SLA)+Atm (GEOS-1)+	y	2.19	158	1.15	333
Hydro. [*Chen et al.*, 1999]	z	3.18	51	0.83	28
Sum Oceans (POCM_4B-	x	3.42	43	0.83	312
SLA)+Atm (GEOS-1)+	y	4.44	171	1.41	25
Hydro. [*Dong et al.*, 1997]	z	3.43	47	1.21	348
Sum Oceans (POCM_4B-	x	2.36	72	0.38	83
SLA)+Atm (ECMWF)+	y	1.78	118	0.62	298
Hydro. [*Chen et al.*, 1999]	z	3.28	59	0.26	282
Sum Oceans (POCM_4B-	x	3.90	45	0.56	350
SLA)+Atm (ECMWF)+	y	3.50	158	0.79	46
Hydro. [*Dong et al.*, 1997]	z	3.49	54	1.03	299

[a] The amplitudes are in units of millimeters and the phases are in units of degrees from January 1 using a sine convention.

Atmosphere (IB)	x	0.55	104	0.23	90
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Summary and Conclusions

- Periodic and secular variations of the geocenter observed by all of the satellite positioning techniques (SLR, DORIS, GPS)
- The tracking data quality, the tracking site distribution and the averaging period affect the resulting estimates at levels higher than their formal error statistics (2-3 mm)
- Annual and semi-annual signals in the observed series correlate well with geophysical predictions, except for the case of continental hydrology (most difficult to model)
- Improvement of the gravitational model from Gravity Mapping missions (CHAMP, GRACE and GOCE) will remove the mismodeling now lumped into these estimates
- Adding more satellite targets (e.g. ETALONs) can enhance the quality of the results, if some error sources associated with satellite signature can be controlled