The Global SLR Network and the origin and scale of the TRF in the GGOS era

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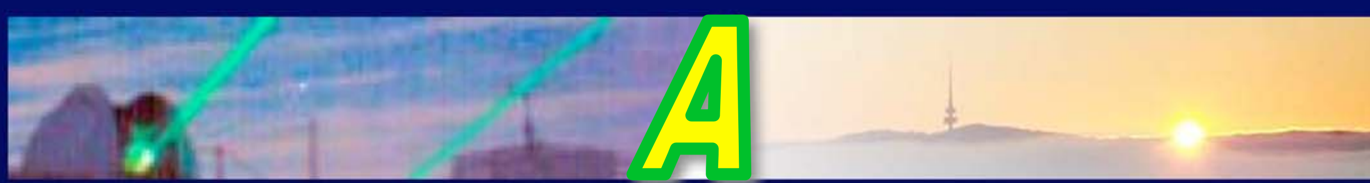

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Extending the Range
15-20 October 2006, Canberra, Australia

Outline

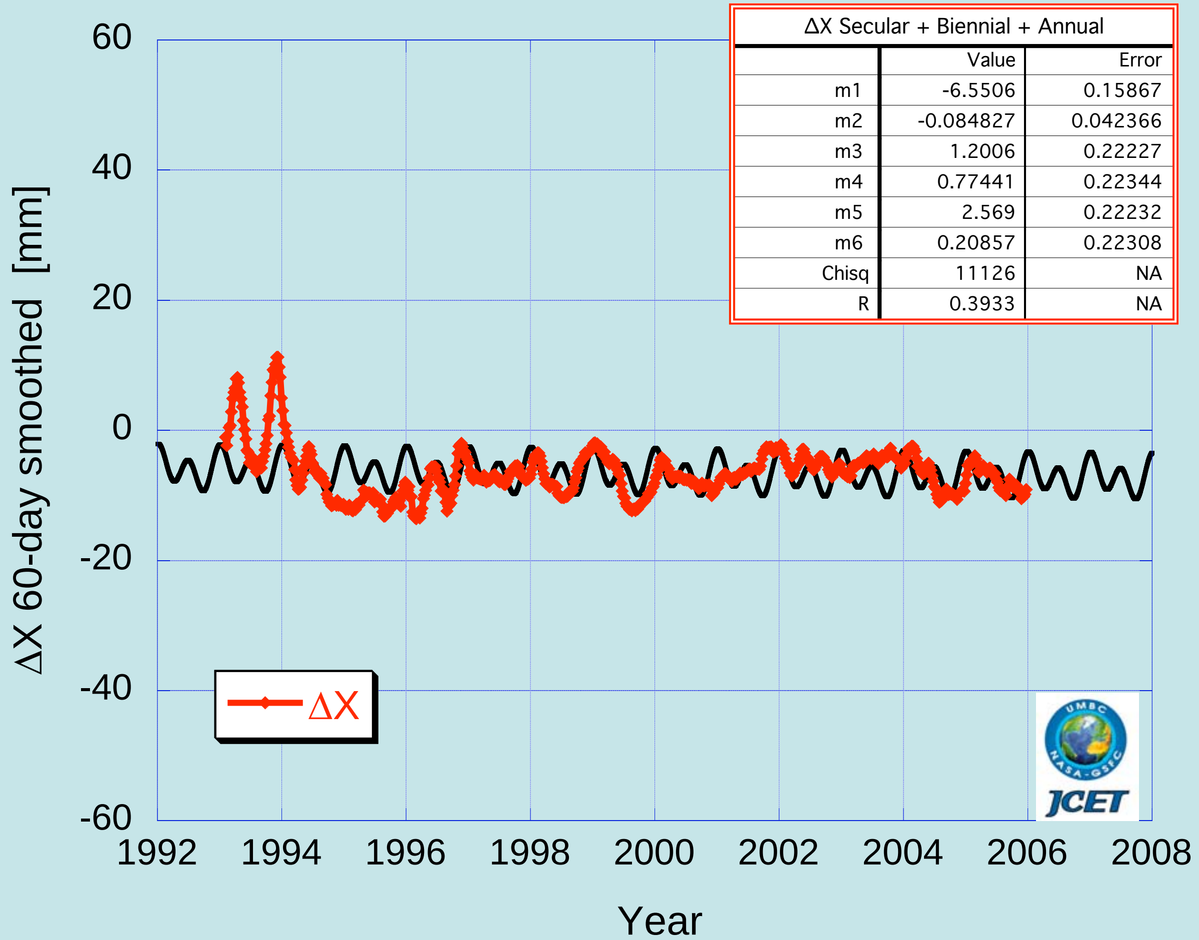
- Introduction
- SLR Observations of "geocenter"
- The spectrum of the *g*-series
- Factors affecting the robustness and reliability of the *g*-series
- Summary - Conclusions

We gratefully acknowledge the support of the ILRS and their network for making their SLR tracking data available to us for this study, as well as the GRACE Mission Project for the release of GSM results.

Motivation

- Examine the robustness of the TRF and the effect of changes in the Geodetic networks.
- TRF development via integrated application of space techniques, and ancillary data.
- National effort to support NASA's contribution to a Global Geodetic Observing System (NGGOS).
- International effort to support IAG's contribution to the GEOSS effort with a Global Geodetic Observing System (GGOS).

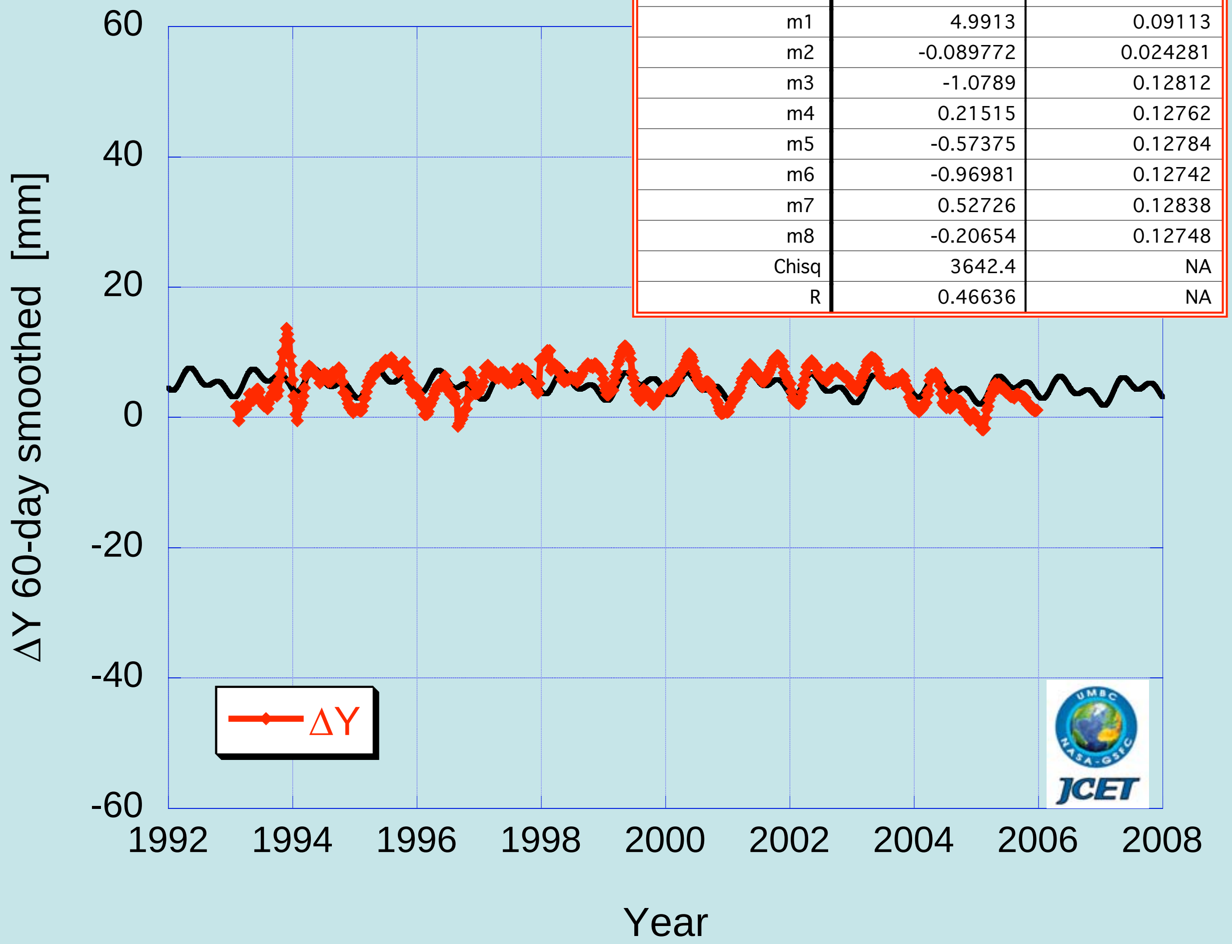
SLR “Geocenter” - X



ΔX Secular + Biennial + Annual

	Value	Error
m1	-6.5506	0.15867
m2	-0.084827	0.042366
m3	1.2006	0.22227
m4	0.77441	0.22344
m5	2.569	0.22232
m6	0.20857	0.22308
Chisq	11126	NA
R	0.3933	NA

SLR “Geocenter” - Y

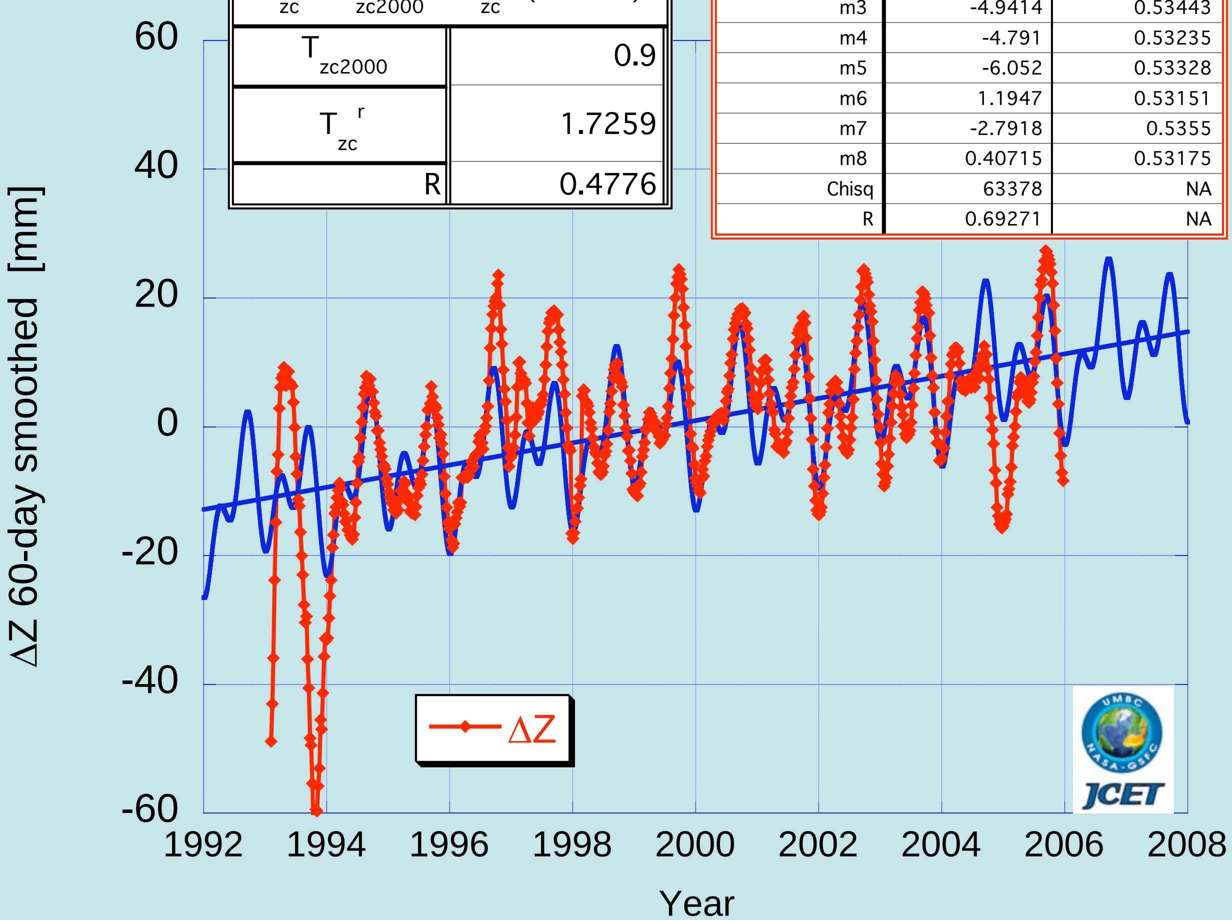


ΔY Secular + Biennial + Annual + Semi-annual		
	Value	Error
m1	4.9913	0.09113
m2	-0.089772	0.024281
m3	-1.0789	0.12812
m4	0.21515	0.12762
m5	-0.57375	0.12784
m6	-0.96981	0.12742
m7	0.52726	0.12838
m8	-0.20654	0.12748
Chisq	3642.4	NA
R	0.46636	NA

SLR “Geocenter” - Z

$T_{zc} = T_{zc2000} + T_{zc}^{r} * (t-2000)$	
T_{zc2000}	0.9
T_{zc}^{r}	1.7259
R	0.4776

ΔZ Secular + Biennial + Annual + Semi-annual		
	Value	Error
m1	0.91063	0.38014
m2	1.6981	0.10128
m3	-4.9414	0.53443
m4	-4.791	0.53235
m5	-6.052	0.53328
m6	1.1947	0.53151
m7	-2.7918	0.5355
m8	0.40715	0.53175
Chisq	63378	NA
R	0.69271	NA



Secular "geocenter" trends

Linear secular trends from estimated degree-1 harmonics:

$\Delta X = -\ 6.55 - 0.08480 \times (\,t - 2000\,)$ [mm]

$\Delta Y = \ \ 4.99 - 0.08977 \times (\,t - 2000\,)$ [mm]

$\Delta Z = \ \ 0.91 + 1.69810 \times (\,t - 2000\,)$ [mm]

Interpretation ...

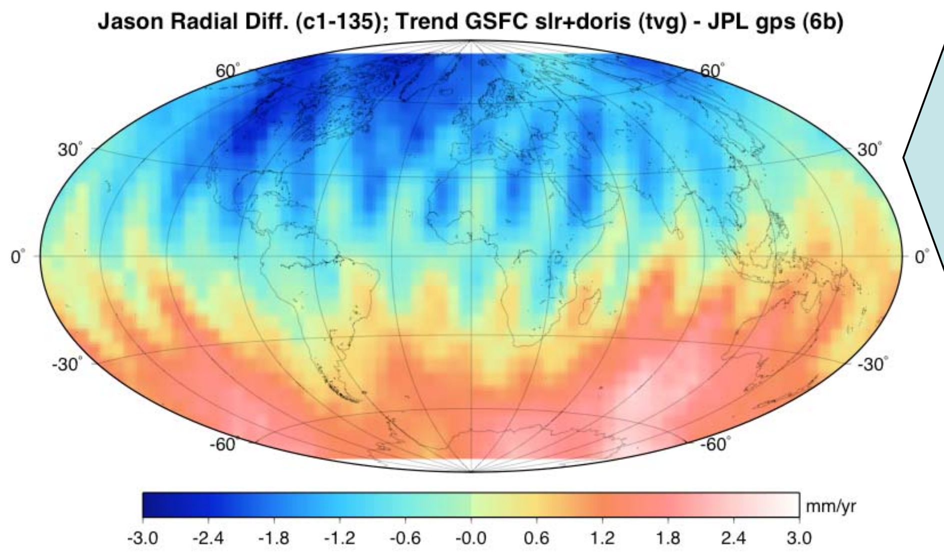
- Evolving network
- Uneven distribution of tracking sites
- Poor coverage of major tectonic plates...

Secular Geophysical Signals in ΔGeocenter

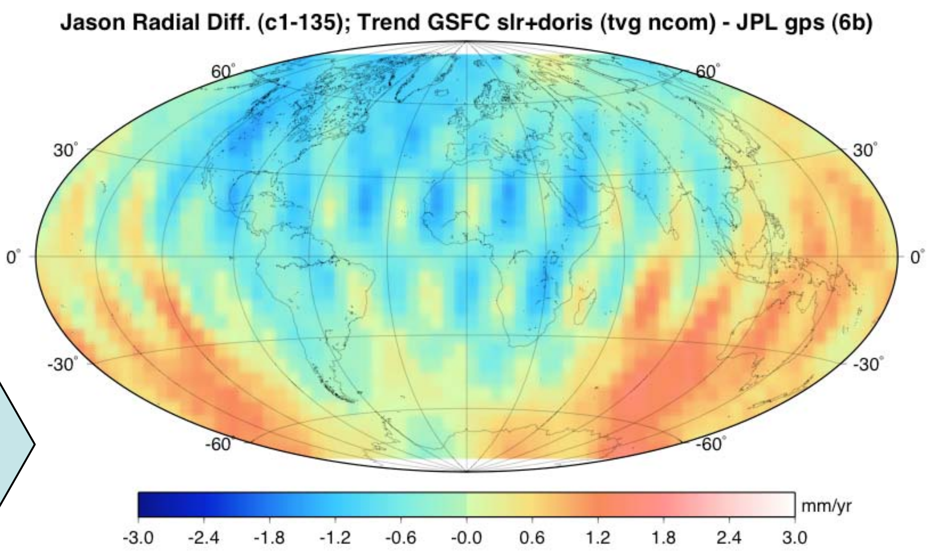
Source	**Magnitude**	**Induced motion**	**Ref.**
Sea level	1.2 mm/y	0.064 ±0.02 mm/y	2
Ice sheets (G)	2 mm/y	0.046±0.20 mm/y	2
Tectonics	AMO-2	0.309±0.05 mm/y	2
Postglacial rebound	ICE-3G	0.2 - 0.5 mm/y	1

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

Geocenter and Radial Orbit Error



Radial orbit Differences
GSFC(SLR+DORIS) - **JPL**(GPS)
WITHOUT Geocenter correction



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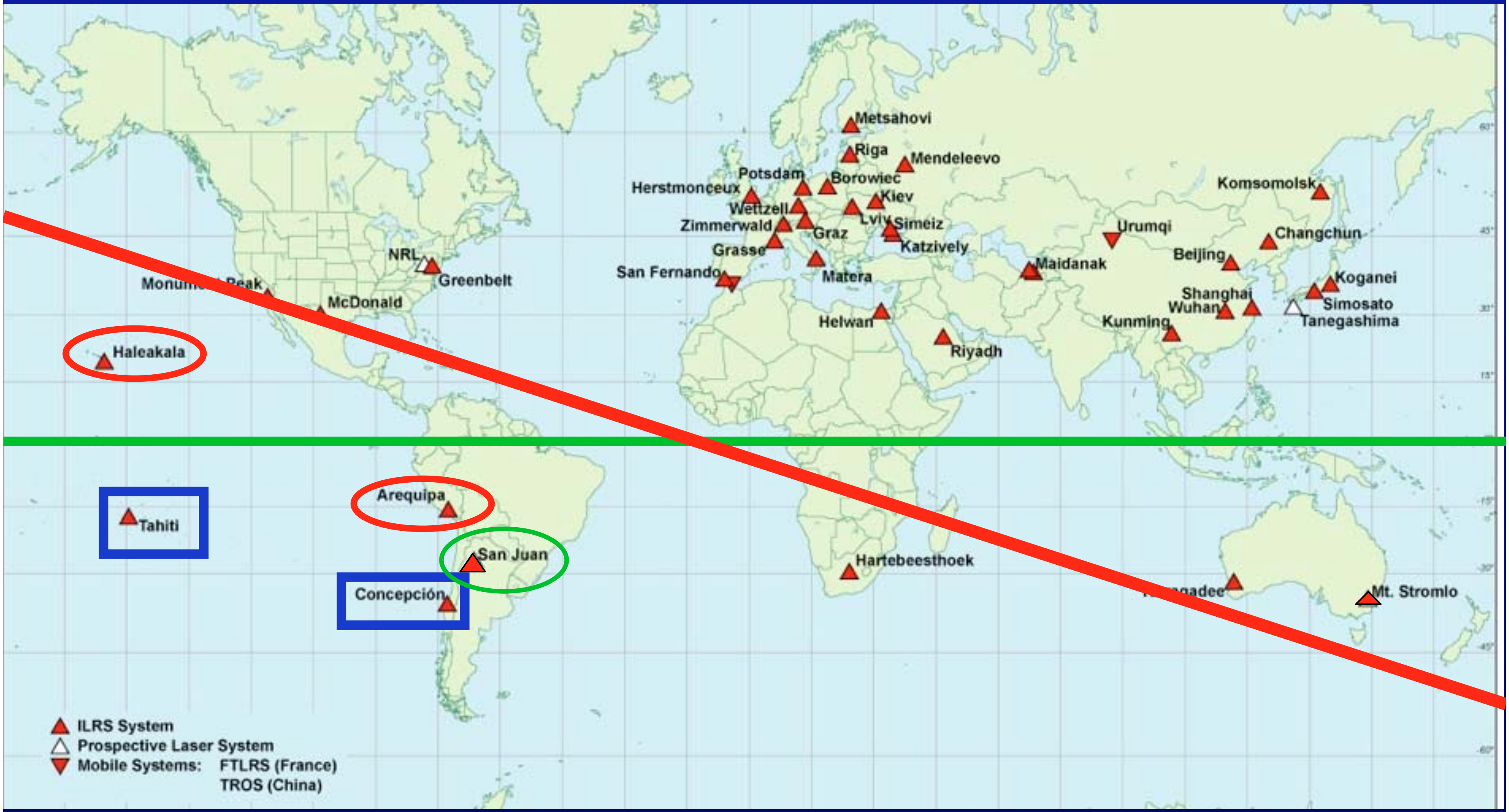
Radial orbit Differences
GSFC(SLR+DORIS) - **JPL**(GPS)
WITH Geocenter correction

SLR Network



Metsahovi
Riga
Mendeleevo
Potsdam
Borowiec
Herstmonceux
Kiev
Wettzell
Zimmerwald
Lviv
Simeiz
Graz
Grasse
Katzively
NRL
Greenbelt
San Fernando
Matera
McDonald
Haleakala
Helwan
Riyadh
Maidanak
Urumqi
Komsomolsk
Changchun
Beijing
Koganei
Shanghai
Wuhan
Simosato
Tanegashima
Kunming
Arequipa
Tahiti
San Juan
Concepción
Hartebeesthoek
Mt. Stromlo
ILRS System
Prospective Laser System
Mobile Systems: FTLRS (France)
TROS (China)

Plausible Causes

- If the evolution of the SLR network over the years causes all or part of the observed trends, then **sub-set solutions** could give some indication of that.
- Similarly, if the distribution of the stations is to blame, adding sites where needed should resolve the issue (**simulations**).

Adopted strategy

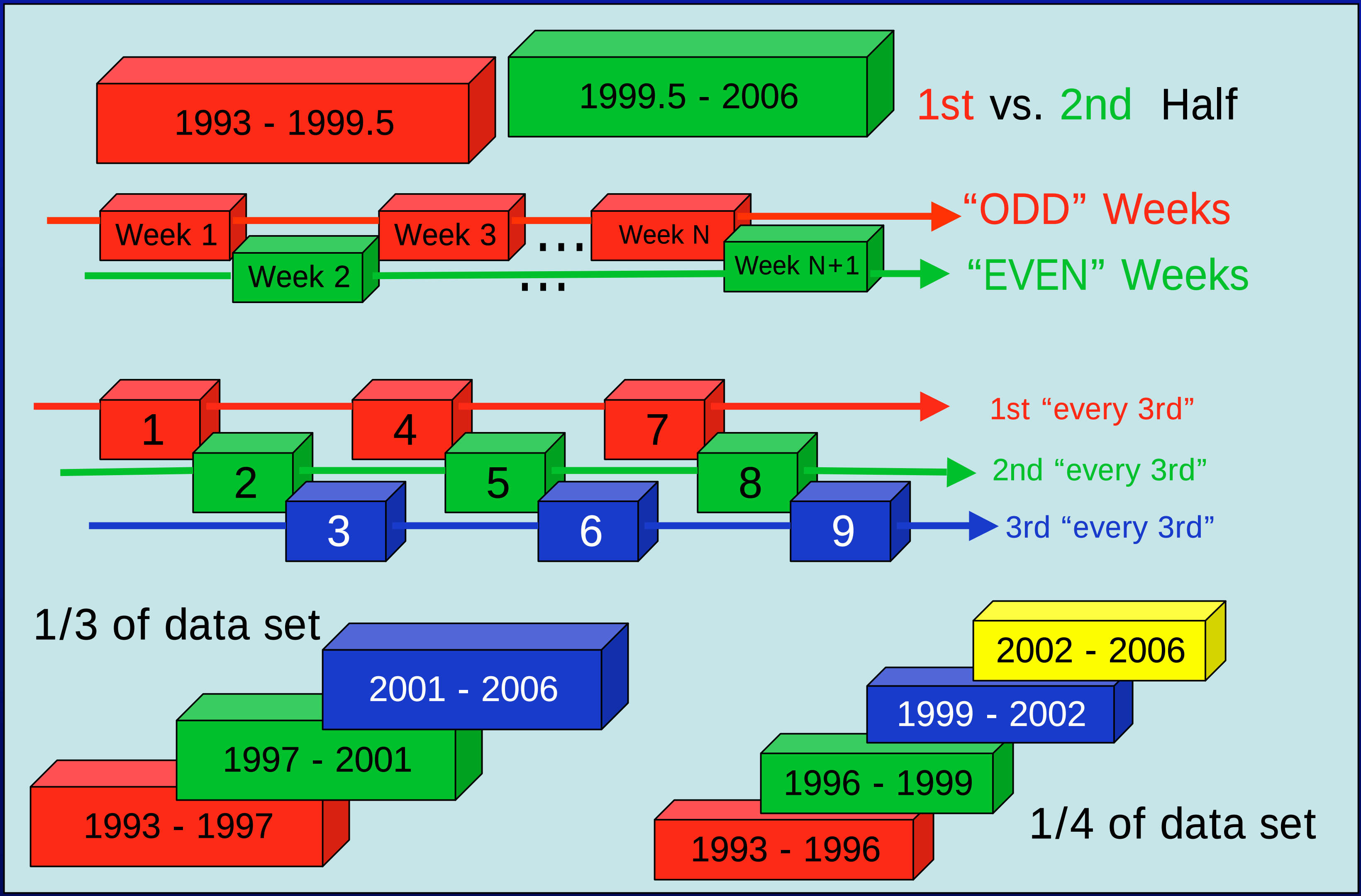
- **At this stage we have some answers to the first postulated question, by means of a large number of sub-set solutions for the TRF origin and its seasonal variations.**

- The second question is still being investigated, in a concerted simulation effort involving several institutions and most of the space geodetic data types, predominantly though, SLR and VLBI.

Sub-set solutions

- The SLR data set from 1993 to present was used to obtain the 13^+-year solution shown earlier.
- Next, we generated 18 solutions using the same set of *weekly* normal equations, using various selection schemes:
  - First vs. second half of the data
  - Selecting "every other week"
    ...every 3rd week
    ...every 4th week
  - First vs. second vs. third 1/3 of the data
  - First vs. second vs. third vs. fourth 1/4 of the data

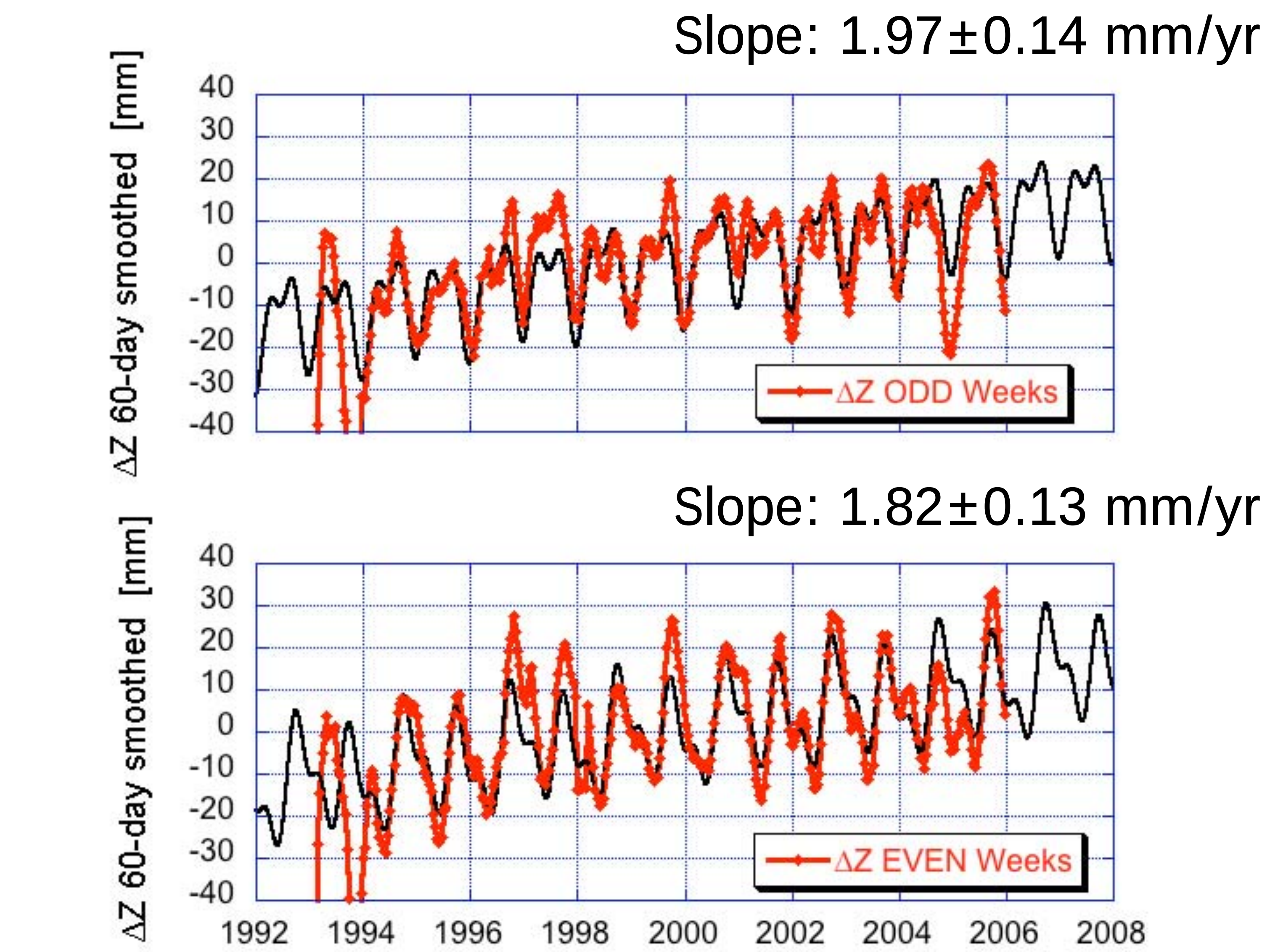
The data decimation scheme



TRF Subset Solutions

Case	ΔX [mm]	$\sigma_{\Delta X}$ [mm]	ΔY [mm]	$\sigma_{\Delta Y}$ [mm]	ΔZ [mm]	$\sigma_{\Delta Z}$ [mm]	3D |Δ| mm	$\sigma_{3D\,\Delta}$ mm
3 **Odd**	-8.37	±10.91	19.25	±10.78	-4.20	±10.32	**21**	**± 17**
4 **Even**	-12.62	± 8.93	5.15	± 8.82	-12.50	± 8.44	**18**	**± 16**
5 **@ 3rd**	-7.92	± 18.84	-3.87	±18.61	3.56	±17.82	**10**	**± 31**
6	-7.61	± 8.66	19.78	± 8.56	-15.33	± 8.19	**26**	**± 16**
7	-11.36	± 10.41	9.03	±10.28	-11.58	± 9.84	**19**	**± 17**
8 **@ 4th**	-15.62	± 21.76	43.27	±21.49	16.57	±20.57	**49**	**± 36**
9	-17.75	± 18.87	16.31	±18.63	-29.03	±17.84	**38**	**± 33**
10	-6.61	± 17.18	-5.50	±16.97	-11.56	±16.24	**14**	**± 29**
11	-16.72	± 12.01	1.32	±11.86	-9.92	±11.36	**19**	**± 21**
1 **1/2**	-41.20	±35.82	6.26	±35.38	-10.10	±33.86	**43**	**± 61**
2	1.74	± 6.76	8.06	± 6.68	7.28	± 6.39	**11**	**± 11**
12 **1/3**	-49.10	± 22.39	52.74	±22.11	2.73	±21.16	**72**	**± 38**
13	-3.07	± 8.21	-13.72	± 8.11	5.90	± 7.76	**15**	**± 14**
14	-16.95	± 14.20	5.72	±14.06	4.28	±13.40	**18**	**± 24**
15 **1/4**	-60.49	± 23.68	57.43	±23.39	7.48	±22.39	**84**	**± 40**
16	18.65	± 31.40	-57.81	±30.88	-6.19	±29.50	**61**	**± 53**
17	-0.27	± 18.01	-4.74	±17.79	15.72	±17.03	**16**	**± 31**
18	2.07	± 12.29	7.16	±12.18	1.73	±11.60	**8**	**± 21**

Secular trends from sub-set solutions



Remarks on Sub-Network Solutions

- On average *each g*-component not better than 6-8 mm
- 1993-present SLR data are significantly non-uniform.
- Steady improvement over the years, but even 10-fold differences possible.
- Secular trends from same data span agree at ~7-10%
- Secular trends from different spans suffer from the changes in the network and can differ up to 100%
- Seasonal variations' magnitudes seem stable
- More than ~10 years needed for robust results.

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vs. ITRF2000	vs. ITRF2005
Dx = -8.82 +/- 1.02 [mm]	Dx = 1.25 +/- 0.91 [mm]
Dy = 3.21 +/- 1.01 [mm]	Dy = 8.37 +/- 0.91 [mm]
Dz = -5.65 +/- 0.95 [mm]	Dz = -6.59 +/- 0.86 [mm]
Ds = 0.52 +/- 0.15 [ppb]	Ds = -0.87 +/- 0.13 [ppb]
Rx = -0.24 +/- 0.04 [mas]	Rx = 0.05 +/- 0.04 [mas]
Ry = 0.06 +/- 0.04 [mas]	Ry = -0.07 +/- 0.04 [mas]
Rz = 0.15 +/- 0.03 [mas]	Rz = 0.32 +/- 0.03 [mas]
Dxd = 0.75 +/- 0.95 [mm/y]	Dxd = -1.22 +/- 0.85 [mm/y]
Dyd = 0.56 +/- 0.94 [mm/y]	Dyd = 1.37 +/- 0.85 [mm/y]
Dzd = 3.10 +/- 0.73 [mm/y]	Dzd = 1.89 +/- 0.65 [mm/y]
Dsd = -0.10 +/- 0.14 [ppb/y]	Dsd = 0.05 +/- 0.12 [ppb/y]
Rxd = 0.12 +/- 0.03 [mas/y]	Rxd = 0.12 +/- 0.03 [mas/y]
Ryd = -0.02 +/- 0.03 [mas/y]	Ryd = 0.02 +/- 0.03 [mas/y]
Rzd = 0.02 +/- 0.03 [mas/y]	Rzd = 0.01 +/- 0.03 [mas/y]

TRF Scale

GM Estimates and Uncertainty

GM_{IERSc} = 398600.441500 x 10^9 [m^3/s^2]

GM_{SLR1} = 398600.441659 x 10^9 [m^3/s^2] ($W_{1993-2006}$)

GM_{SLR2} = 398600.441634 x 10^9 [m^3/s^2] ($F_{1976-2006}$)

GM_{SLR3} = 398600.441634 x 10^9 [m^3/s^2] ($M_{1976-2006}$)

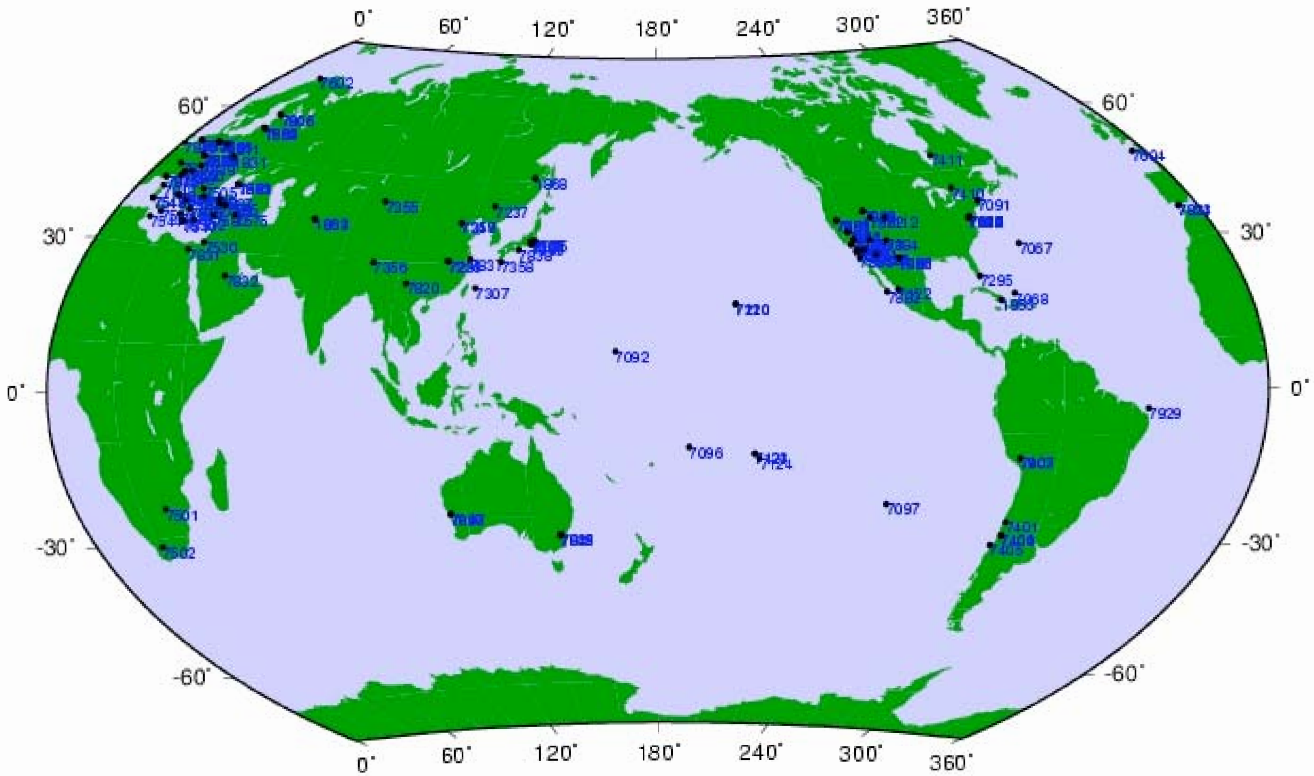
GM_{SLR4} = 398600.441633 x 10^9 [m^3/s^2] ($Q_{1976-2006}$)

$\sigma_{GM\ SLR}$ = 0.000026 x 10^9 [m^3/s^2]

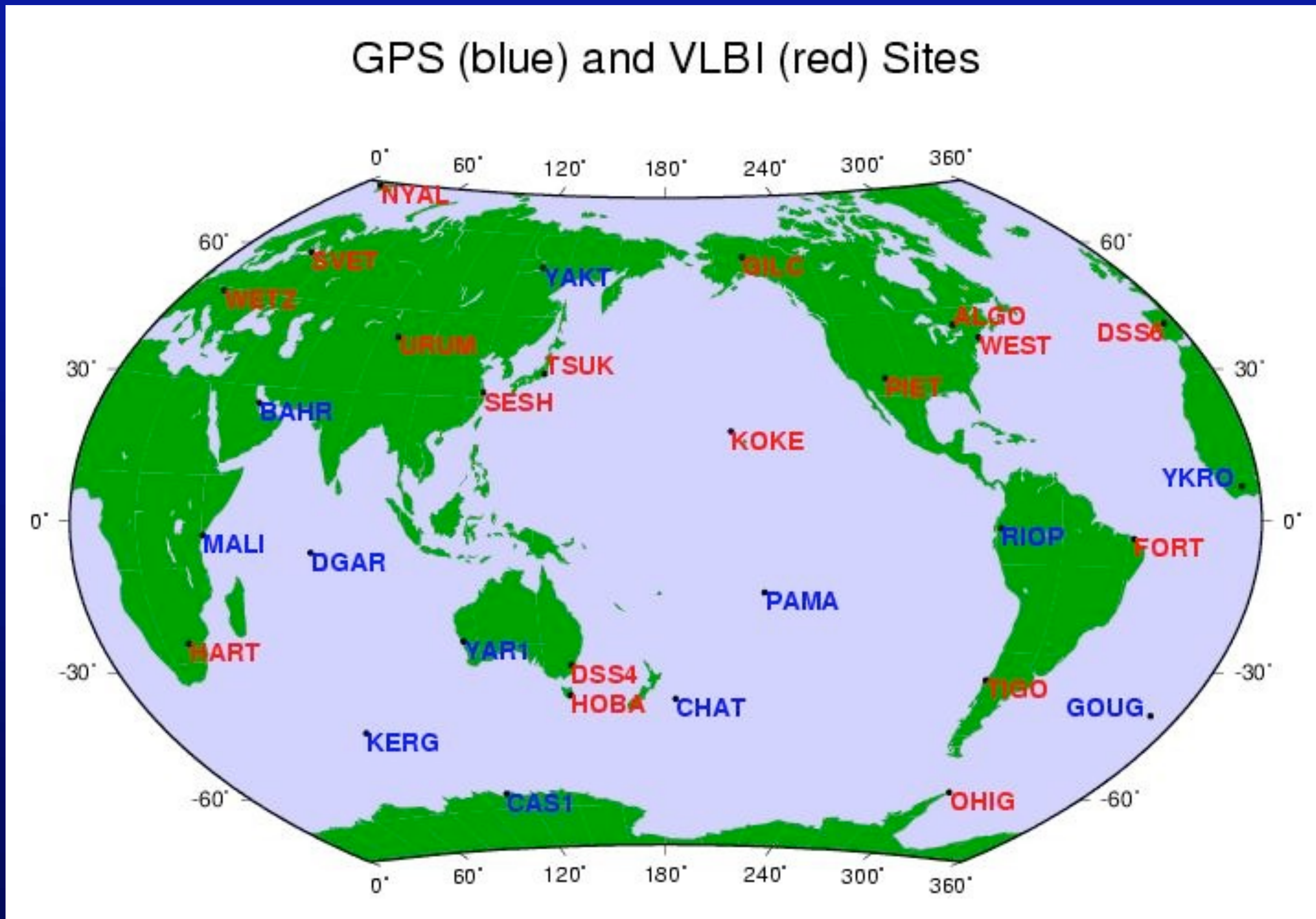
3 σ TRF scale at ≈ 0.2 parts in 10^9 (≈1.3 mm)

All-time SLR Network

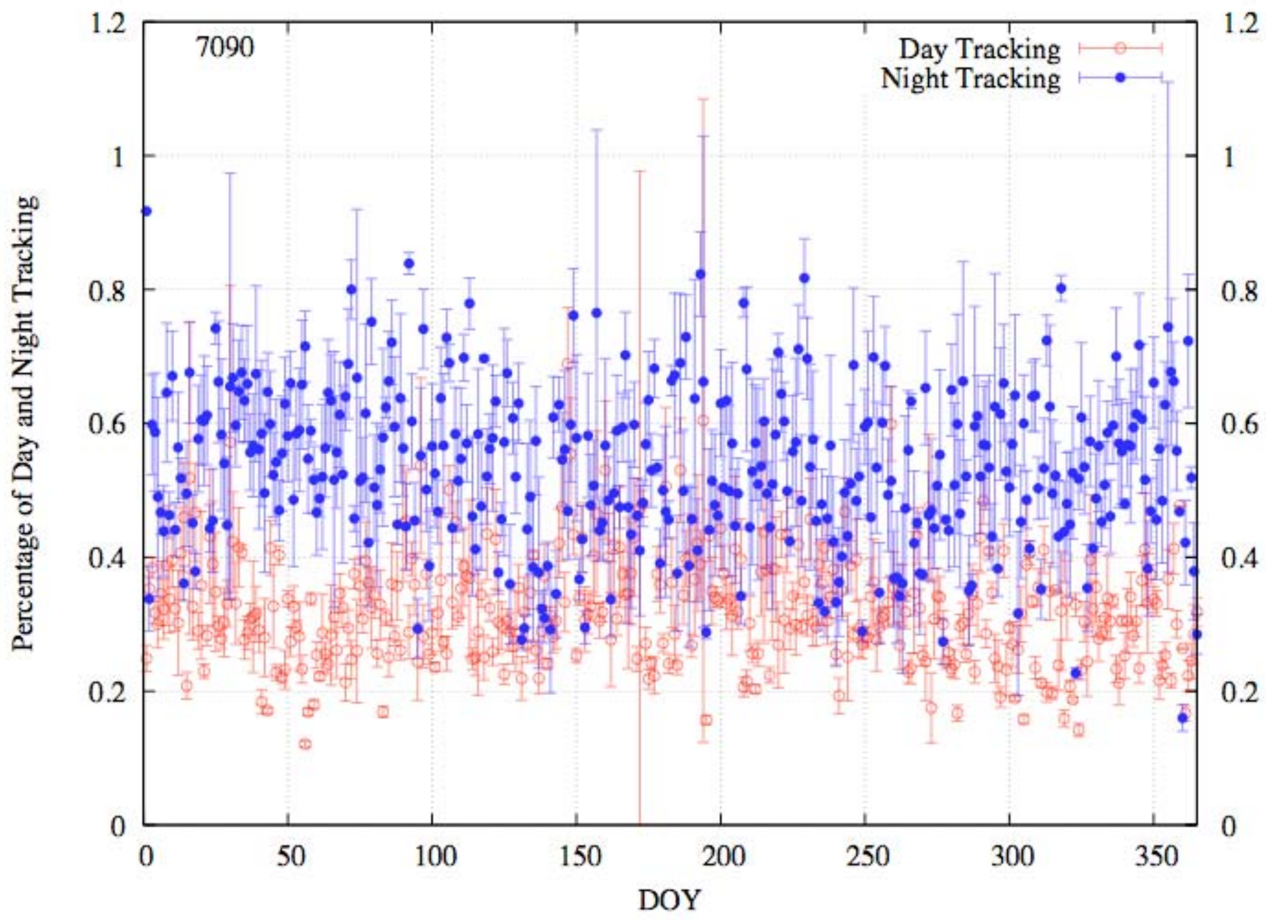
SLR sites ITRF2000 + ITRF2005



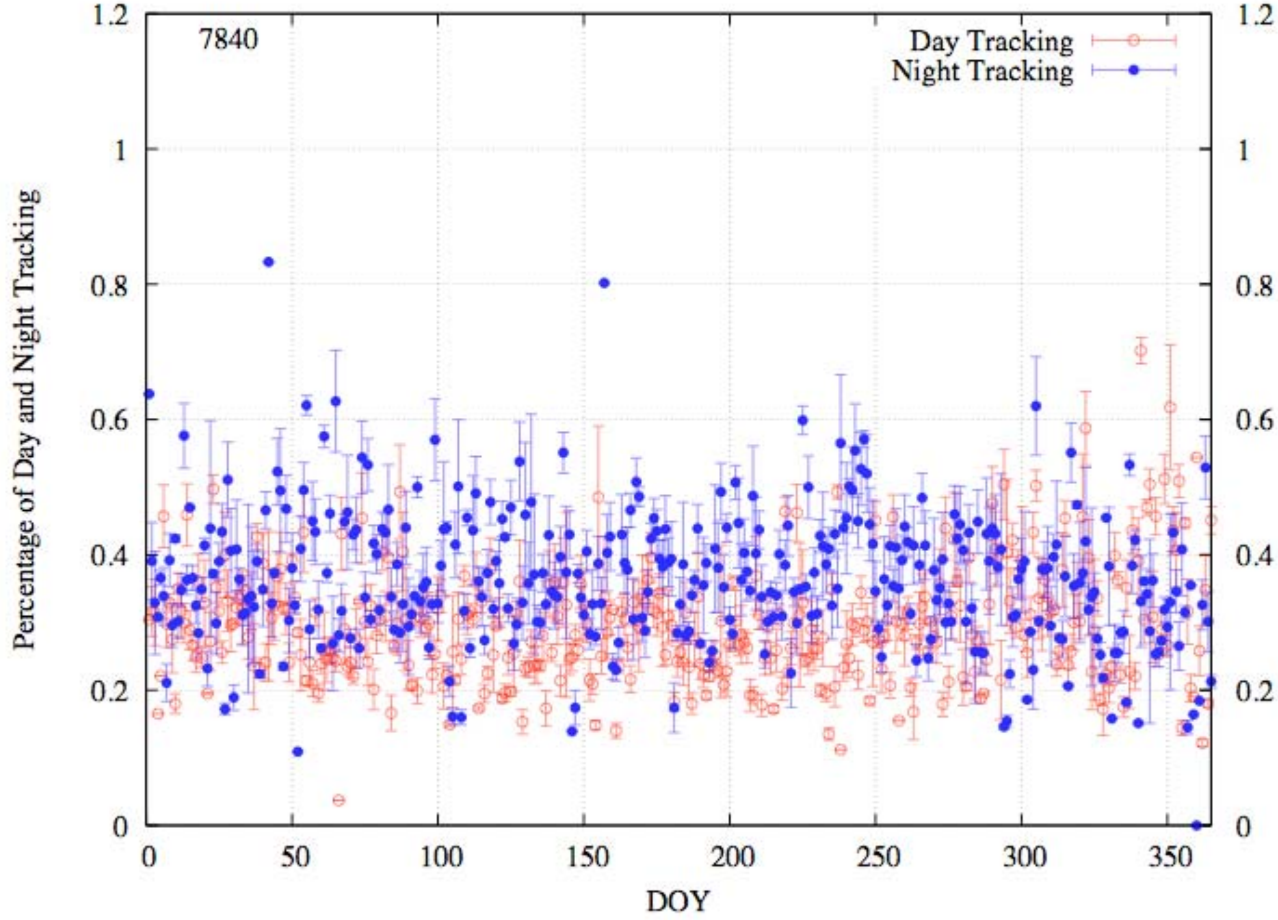
Simulation Network (SLR+VLBI)



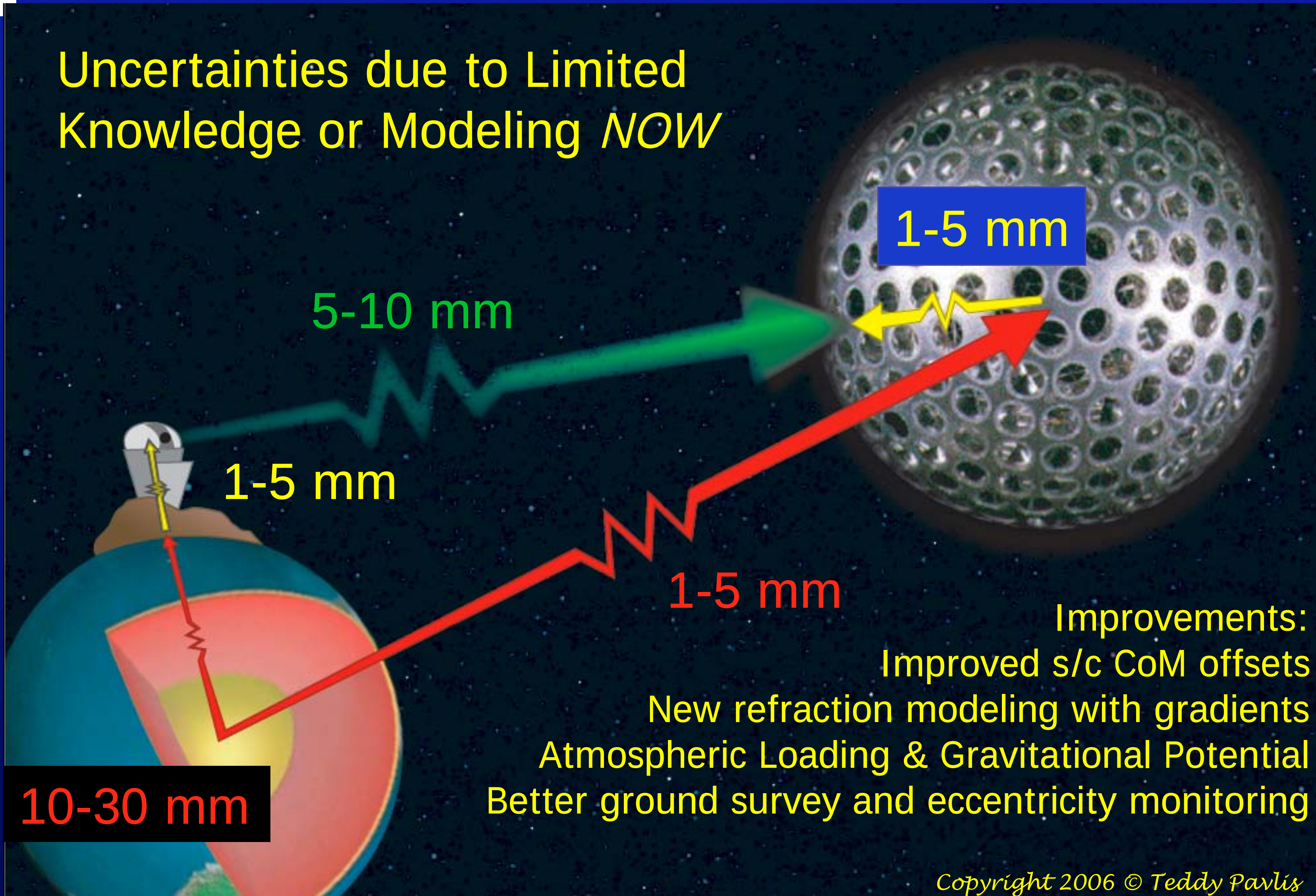
13 yr Tracking History - 7090



13 yr Tracking History - 7840



SLR Analysis Revisited



Summary - Conclusions I

- SRL defines the geocenter at present with an accuracy that is not better than ~10 mm at epoch
- Time evolution of the geocenter depends strongly on the evolution and performance of the tracking network (especially the "secular" part)
- Secular trends in the geocenter time series are stable at ~10% when half the data are utilized, but degrade rapidly after further decimation (temporal stability at best, ~0.2-0.3 mm/yr)

Summary - Conclusions II

- The present *g*-series do reflect the effect of the changing network (reality) and to that extent, incorporating them in orbital computations produce improved centering of the resulting orbits, removing a significant part of the geographically correlated trends
- A complete rationalization of the secular changes requires extensive simulations, where in a first step:
  - we must reproduce the results seen here with the real data set, and in a second step,
  - we augment the present network with future sites and investigate their impact on the geocenter series

TRF from SLR

Thank you

... more results by the Fall AGU