Evaluation and validation studies of candidate ITRF2005 products

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Outline

- ITRF2005 performance on SLR
- SLR Network evolution
- ITRF2000 vs. ITRF2005
- SLR data before 1993
- 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.

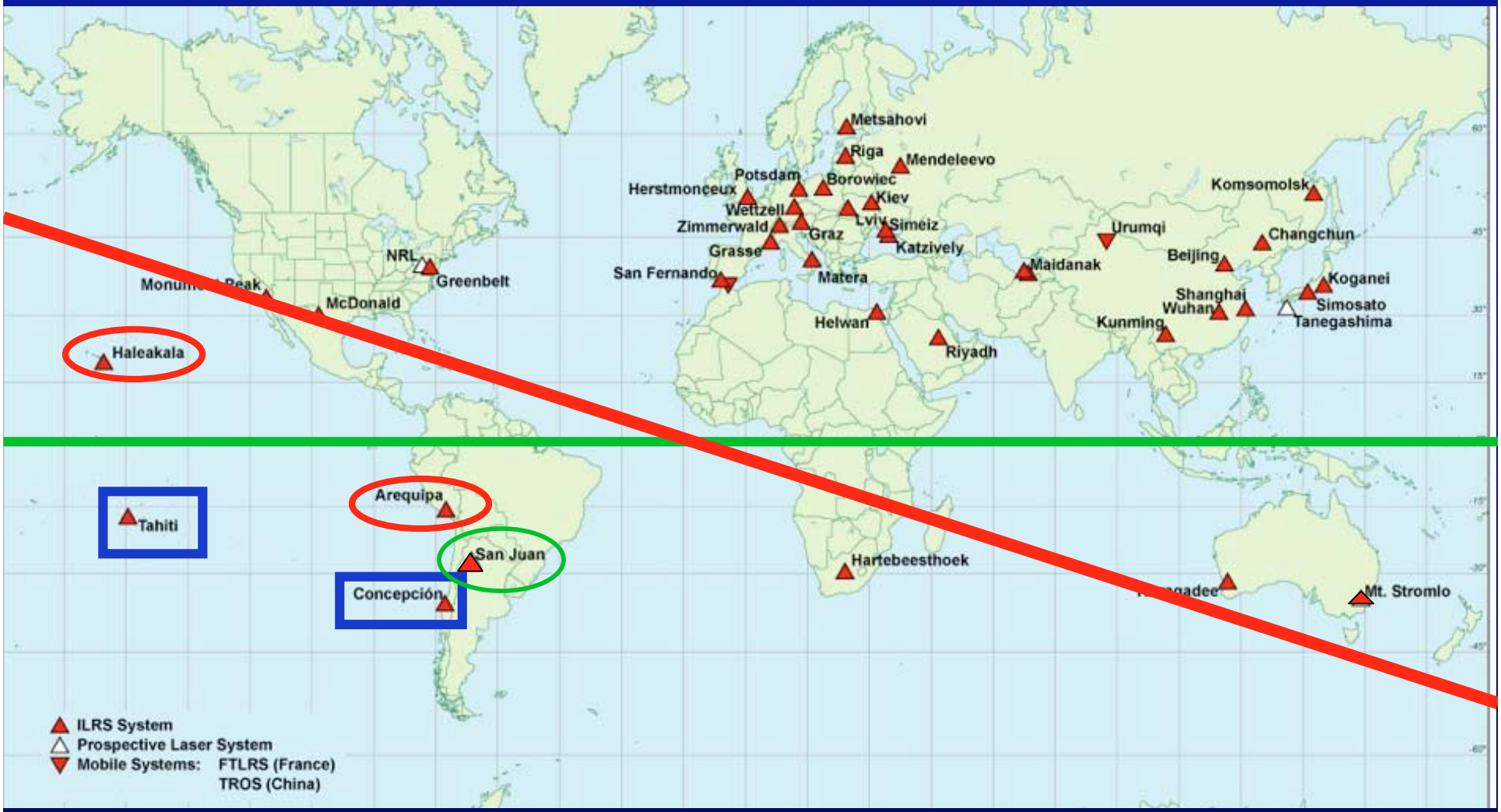
Terrestrial Reference Frame

- "State-of-the-art" realization of a TRS:

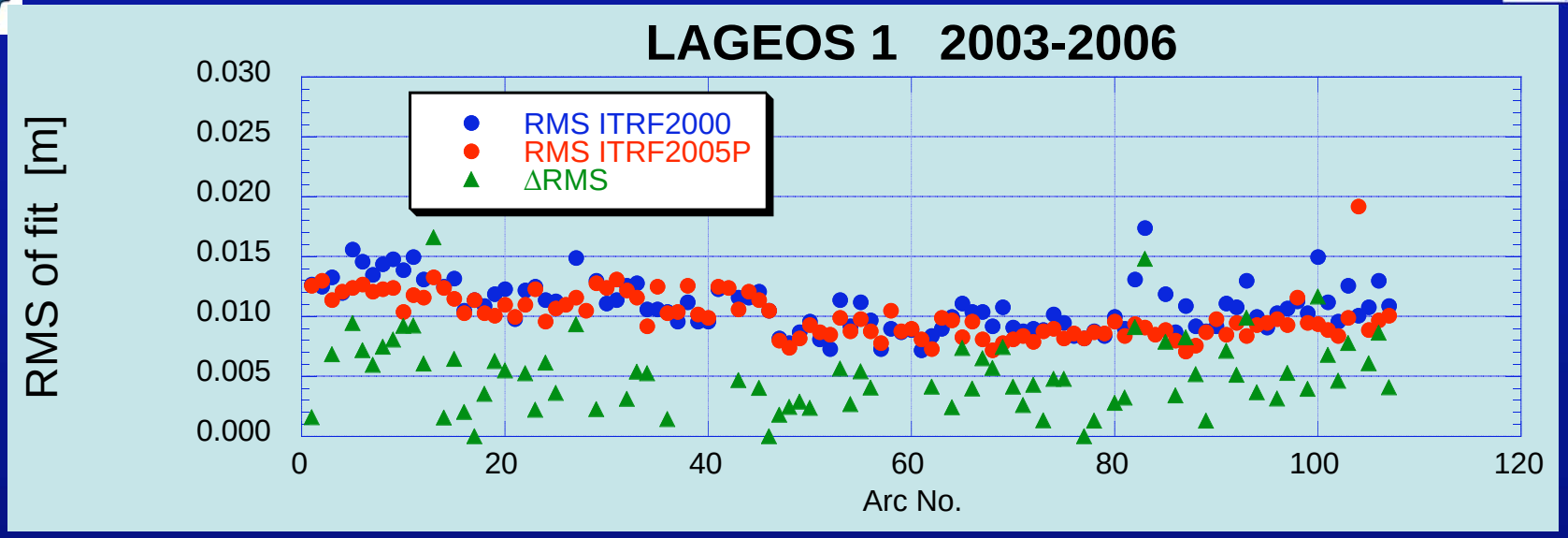
  ITRF2005 - *done! available !!*

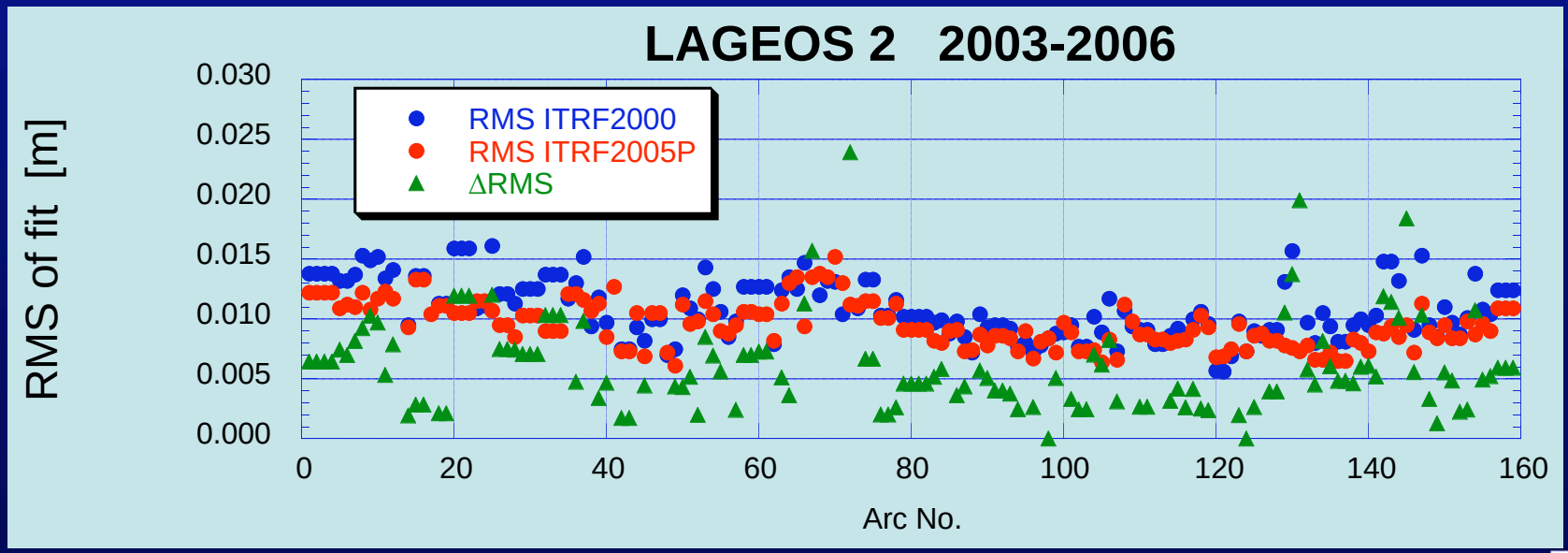
- Long-term stability (present and future) not well understood at present
- SLR, GPS, VLBI, DORIS are the primary contributing techniques, with unique aspects for each of them
- **SLR** is traditionally the primary technique to define the origin and along with VLBI, the scale of the TRF.

SLR Network


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

LAGEOS 1 & 2 Orbit Fit with ITRF2005P





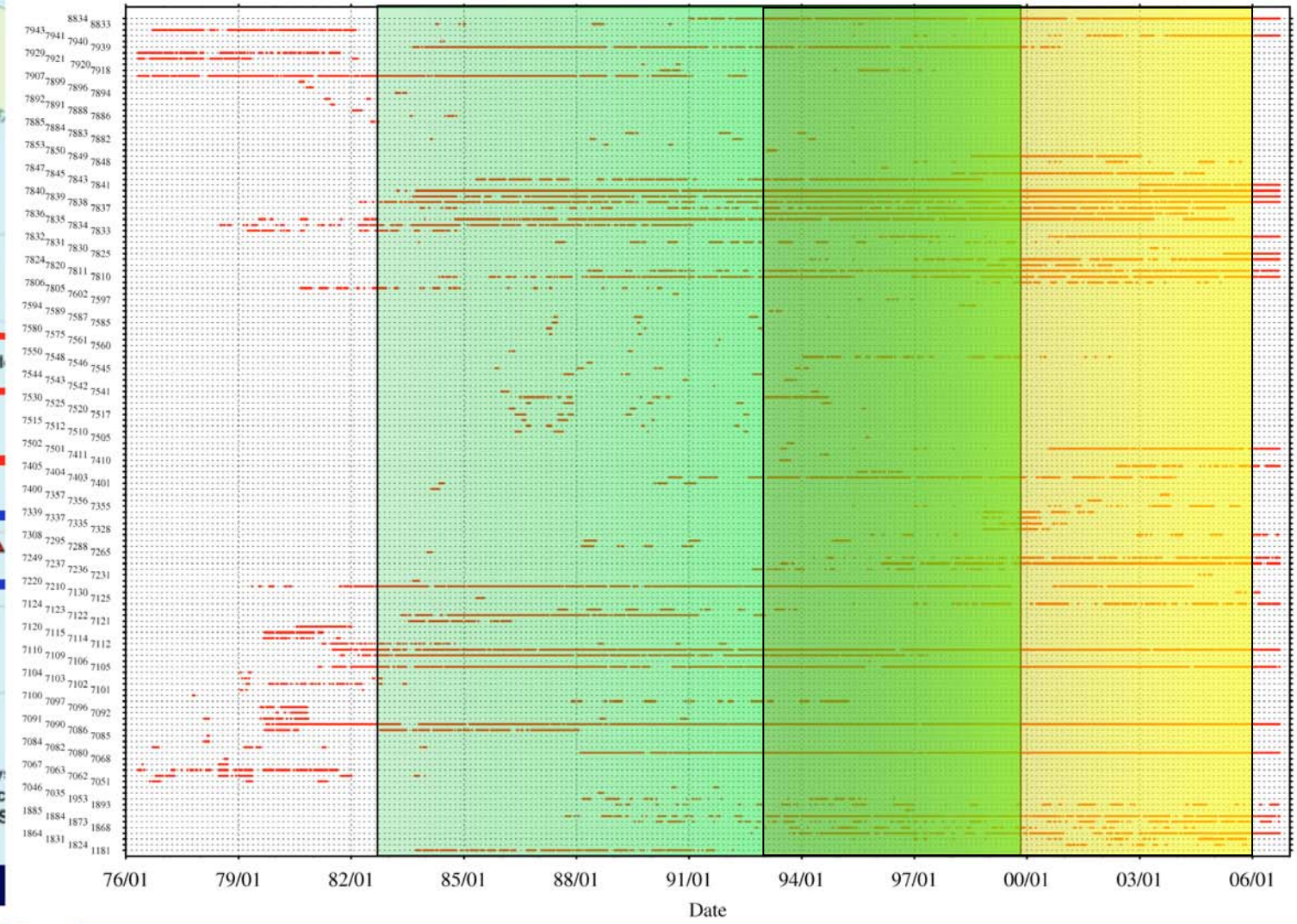
SLR POD tests

- The minute change in the weekly arcs indicates little or no improvement from the adoption of ITRF2005
- For some of the “strong” SLR sites, we even see a slight degradation, unlike the big improvements we saw with ITRF2000
- The scale difference between ITRF2000 and ITRF2005 at 2000.0 (~1.5 ppb) cannot be explained by either a GM-error (needs about $\Delta \approx 0.0025 \times 10^{9}$, totally unreasonable) or a LAGEOS CoM change (~20 mm, again unreasonable), and BOTH would have to apply!
- Testing ITRF2005 while using the Mendes-Pavlis atmospheric delay model results in a smaller scale difference to ITRF2000 (~0.4 ppb)

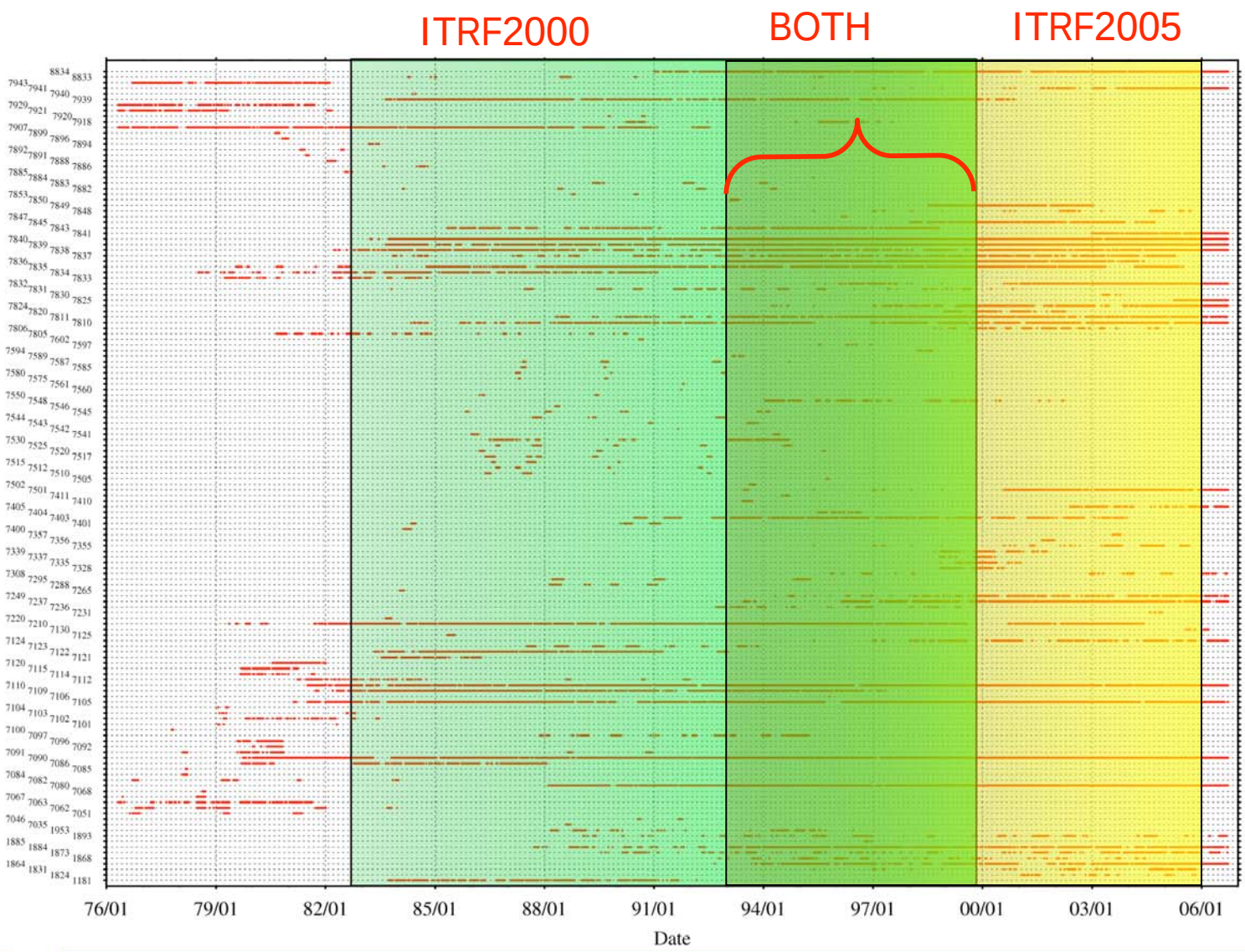
Alternative explanations

- Tests were made with LAGEOS and Starlette arcs to investigate the possible deficiency of the SLR model in the computation of the time delay, by a relativistic term of the order of ~0.69 ppb suggested by Neil Ashby.
- Discussions with Neil suggest that this is not an issue
- The tests though revealed an inconsistency between LAGEOS and Starlette, when using a scaled version of ITRF2005 that fits LAGEOS
- The use of ITRF2005 with recent ILRS weekly products indicates a scale degradation that is approaching 3 ppb in 2006 (and growing!)
- Finally, it was suggested that the lack of the early (pre-1993) SLR data from ITRF2005 may be the culprit behind the scale bias

Network Evolution



SLR Network for ITRF2000/2005



The 1976-1993 data

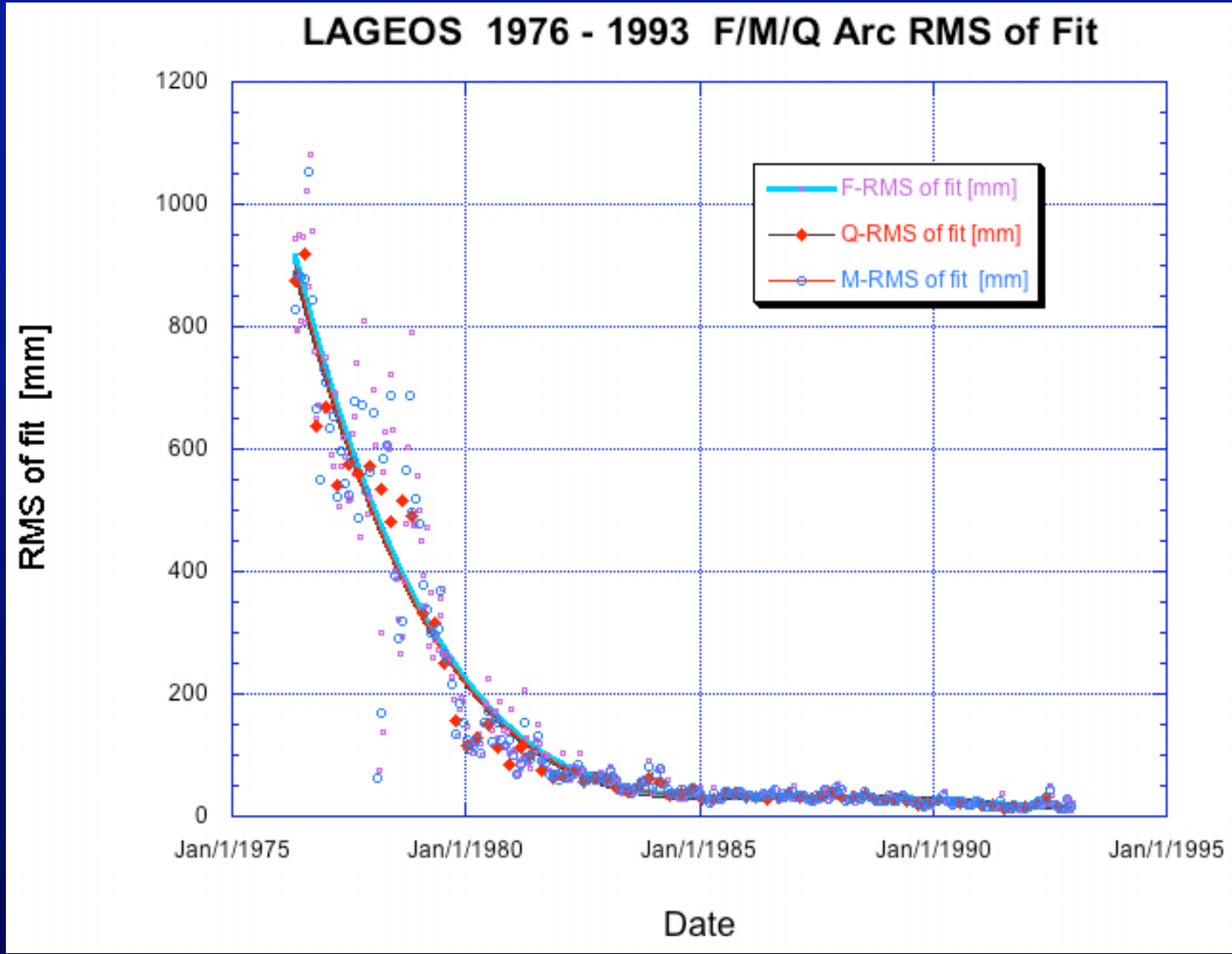
- We re-analyzed the early (pre-1993) SLR data using the same "conventions" and standards as for the 1993-present data set except that we decimated the data in batches of 2-week (fortnightly), 4-week (monthly) and 12-week (quarterly) data, since the data sparseness and the small number of stations do not allow for stable weekly arcs.

- The EOP that were adjusted as part of these solutions were also set at 5-day averages in the early years (up to 1983) and 3-day averages from 1983 to the beginning of 1993.

Extended SLR-only TRFs

- JCET 06 L97 : TRF from WEEKLY arcs, spans the same period that was contributed to ILRS combined product that was used in ITRF2005 (1993-2005).
- Extended solutions with 1976-1993 data to investigate their significance in the definition and evolution of the TRF scale:
  - JCET Q06 L19/20 : JCET 06 L97 extended with QUARTERLY arcs, with (a) equal weights L19, and (b) tuned weights L20.
  - JCET M06 L21/22 : JCET 06 L97 extended with MONTHLY arcs, with (a) equal weights L21, and (b) tuned weights L22.
  - JCET F06 L23/24 : JCET 06 L97 extended with FORTNIGHTLY arcs, with (a) equal weights L23, and (b) tuned weights L24.

Early LAGEOS SLR data 1976-1993



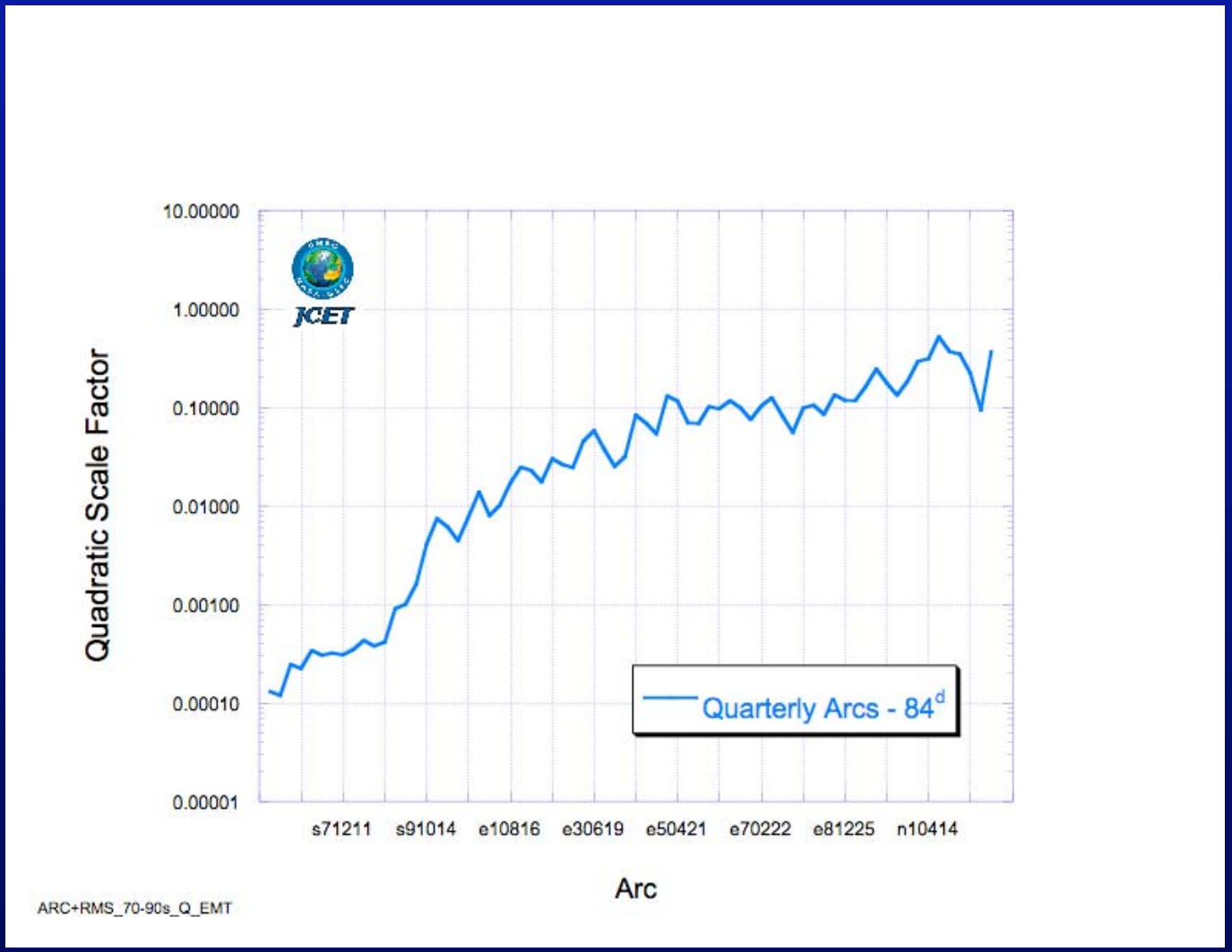
Helmert Transformations

JCET 06 L97 vs. ITRF2000				JCET 06 L97 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]

The hypothesis tested:

- If the non-inclusion of the early (pre-1993) SLR data in ITRF2005 is indeed the reason for the scale bias, then solutions that do include that data should decrease the bias by ~ 1 ppb.

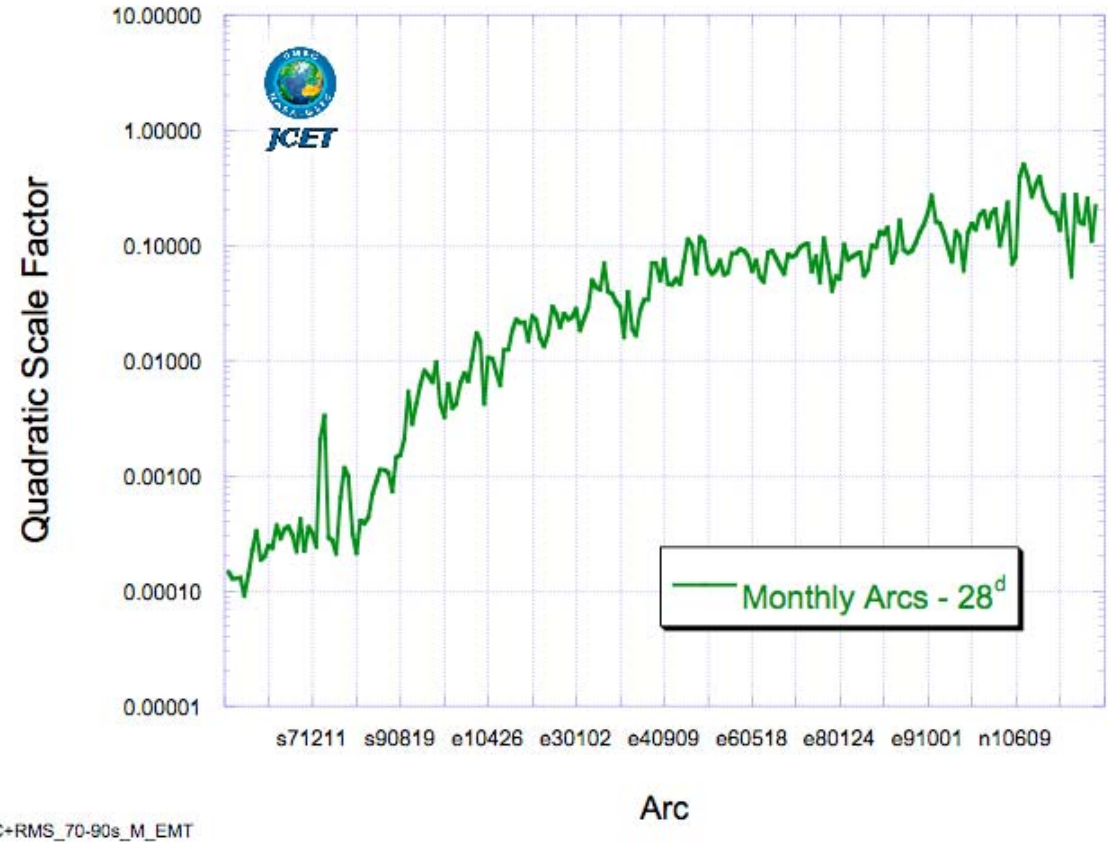
Optimal Weight Factors (Q)



Helmert Transformation Results (Q)

JCET 06 L97 vs. ITRF2005			JCET Q06 L20 vs. ITRF2005		
Dx =	1.25 +/-	0.91 [mm]	Dx =	1.72 +/-	0.96 [mm]
Dy =	8.37 +/-	0.91 [mm]	Dy =	7.28 +/-	0.95 [mm]
Dz =	-6.59 +/-	0.86 [mm]	Dz =	-30.54 +/-	0.90 [mm]
Ds =	-0.87 +/-	0.13 [ppb]	Ds =	-0.91 +/-	0.14 [ppb]
Rx =	0.05 +/-	0.04 [mas]	Rx =	-0.72 +/-	0.04 [mas]
Ry =	-0.07 +/-	0.04 [mas]	Ry =	0.43 +/-	0.04 [mas]
Rz =	0.32 +/-	0.03 [mas]	Rz =	-0.22 +/-	0.03 [mas]
Dxd =	-1.22 +/-	0.85 [mm/y]	Dxd =	-1.47 +/-	0.90 [mm/y]
Dyd =	1.37 +/-	0.85 [mm/y]	Dyd =	1.67 +/-	0.89 [mm/y]
Dzd =	1.89 +/-	0.65 [mm/y]	Dzd =	1.94 +/-	0.68 [mm/y]
Dsd =	0.05 +/-	0.12 [ppb/y]	Dsd =	0.07 +/-	0.13 [ppb/y]
Rxd =	0.12 +/-	0.03 [mas/y]	Rxd =	0.13 +/-	0.03 [mas/y]
Ryd =	0.02 +/-	0.03 [mas/y]	Ryd =	0.02 +/-	0.03 [mas/y]
Rzd =	0.01 +/-	0.03 [mas/y]	Rzd =	0.03 +/-	0.03 [mas/y]

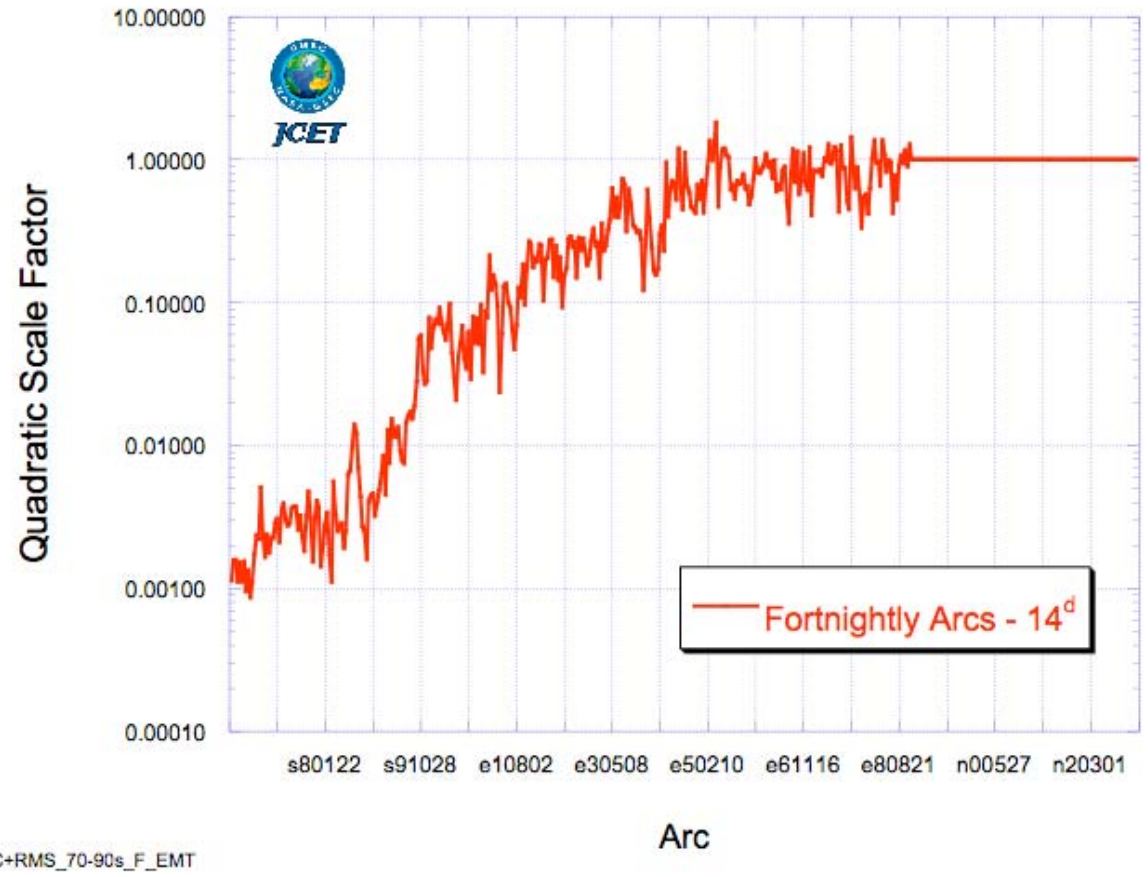
Optimal Weight Factors (M)



Helmert Transformation Results (M)

JCET 06 L97 vs. ITRF2005			JCET M06 L22 vs. ITRF2005		
Dx =	1.25 +/-	0.91 [mm]	Dx =	2.49 +/-	0.95 [mm]
Dy =	8.37 +/-	0.91 [mm]	Dy =	7.40 +/-	0.94 [mm]
Dz =	-6.59 +/-	0.86 [mm]	Dz =	-8.89 +/-	0.89 [mm]
Ds =	-0.87 +/-	0.13 [ppb]	Ds =	-0.89 +/-	0.14 [ppb]
Rx =	0.05 +/-	0.04 [mas]	Rx =	-0.04 +/-	0.04 [mas]
Ry =	-0.07 +/-	0.04 [mas]	Ry =	-0.02 +/-	0.04 [mas]
Rz =	0.32 +/-	0.03 [mas]	Rz =	0.23 +/-	0.03 [mas]
Dxd =	-1.22 +/-	0.85 [mm/y]	Dxd =	-1.59 +/-	0.89 [mm/y]
Dyd =	1.37 +/-	0.85 [mm/y]	Dyd =	1.66 +/-	0.88 [mm/y]
Dzd =	1.89 +/-	0.65 [mm/y]	Dzd =	1.69 +/-	0.67 [mm/y]
Dsd =	0.05 +/-	0.12 [ppb/y]	Dsd =	0.07 +/-	0.13 [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 =	0.01 +/-	0.03 [mas/y]	Rzd =	0.03 +/-	0.03 [mas/y]

Optimal Weight Factors (F)



ARC+RMS_70-90s_F_EMT

Helmert Transformation Results (F)

JCET 06 L97 vs. ITRF2005			JCET F06 L23 vs. ITRF2005		
Dx =	1.25 +/-	0.91 [mm]	Dx =	1.40 +/-	1.01 [mm]
Dy =	8.37 +/-	0.91 [mm]	Dy =	5.22 +/-	1.00 [mm]
Dz =	-6.59 +/-	0.86 [mm]	Dz =	-22.65 +/-	0.95 [mm]
Ds =	-0.87 +/-	0.13 [ppb]	Ds =	-1.02 +/-	0.15 [ppb]
Rx =	0.05 +/-	0.04 [mas]	Rx =	-0.51 +/-	0.04 [mas]
Ry =	-0.07 +/-	0.04 [mas]	Ry =	0.29 +/-	0.04 [mas]
Rz =	0.32 +/-	0.03 [mas]	Rz =	-0.05 +/-	0.03 [mas]
Dxd =	-1.22 +/-	0.85 [mm/y]	Dxd =	-1.42 +/-	0.95 [mm/y]
Dyd =	1.37 +/-	0.85 [mm/y]	Dyd =	2.16 +/-	0.94 [mm/y]
Dzd =	1.89 +/-	0.65 [mm/y]	Dzd =	-5.36 +/-	0.72 [mm/y]
Dsd =	0.05 +/-	0.12 [ppb/y]	Dsd =	0.07 +/-	0.14 [ppb/y]
Rxd =	0.12 +/-	0.03 [mas/y]	Rxd =	-0.08 +/-	0.03 [mas/y]
Ryd =	0.02 +/-	0.03 [mas/y]	Ryd =	0.15 +/-	0.03 [mas/y]
Rzd =	0.01 +/-	0.03 [mas/y]	Rzd =	-0.13 +/-	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] ($W_{1993\text{-}2006}$)

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

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

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

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

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

Summary - Conclusions I

- ITRF2005 improves the position/velocity estimates for some sites that had short histories or were missing entirely from ITRF2000, but in general, it is in conflict with the scale preferred by the SLR primary targets.
  - Examination of various possibilities to explain the scale bias with some error(s) in the SLR models or analysis gave no new results apart from the already known correction in the atmospheric delay
  - Although the older data (1976-1993) are of much lower quality and from a generally sparser network, we did test the hypothesis that their absence in ITRF2005 was the reason for the scale bias.

Summary - Conclusions

- Addition of older SLR data, resulting in an extension of the network from 1976 all the way to 2006, results in a stronger definition of the scale and scale-rate wrt the previous TRF realization, ITRF2000, from the 30 year network.
  - The addition of the 1976-1992 SLR data does not modify the scale and scale rate of the SLR-only TRF wrt either ITRF2000 or ITRF2005 to eliminate the SLR-VLBI inconsistency
  - Test cases of ITRF2005 must be generated including the new data to investigate directly a possible reduction in the scale inconsistency between SLR and VLBI within ITRF2005, although this seems highly unlikely

ITRF2005P Evaluation

... more results for ITRF2005D soon!