Modeling Improvements in the ILRS Reprocessing for ITRF2013

E. C. Pavlis[1], V. Luceri[2], M. Kuzmicz-Cieslak[1], D. König[1] and G. Bianco[2]
[1]GEST/UMBC, Baltimore, MD, USA
[2]ASI/CGS, Matera, Italy

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Outline

- ITRF2013 reanalysis schedule
- Improved models implementation
  - New gravity modeling
  - Target array CoM offset correction model
  - Modified Mean Pole model of IERS MP series
- SLR network changes:
  - new sites, earthquakes near old sites → new coordinates & velocities
- Station data quality monitoring & systematic error modeling
- ITRF2013 reanalysis delivery to ITRS/IGN: *October 24, 2014*

ILRS Reanalysis Schedule

- First planning meeting of the ILRS AWG held in Potsdam, Germany, September 2013
- Agreed to implement and validate several new models before the reanalysis
- Considerable time and effort required from each AC / CC for the implementation of the models
- The reanalysis covers the period 1983 (as with ITRF2008), up to the end of 2013.

Model Improvement Areas

- Update of the *a priori* TRF (SLRF2008) to include new sites and better position/velocity estimates for tectonically active regions
- New time-dependent target signature model for LAGEOS and ETALON satellites ("COM offset")
- New static gravitational model and temporal variations for the 2nd degree/order terms
- Improved version of the IERS Mean Pole description (avoiding the fixed polynomial in the 2010 Conventions)
- Improved systematic error handling, extended to all sites and all of the period covered by the data

A priori TRF (SLRF2008)

- A final version of SLRF2008 (*ILRS version/extension of ITRF2008*) is used as the starting positions and velocities of our tracking sites for the re-analysis
  - ASI, DGFI and JCET developed, evaluated and validated tailored station solutions for about a dozen sites:
    - some that suffered major earthquakes and,
    - some that joined the network after the development of ITRF2008 and are not present in it.

Station with Updated Positions in SLRF2008

STATION		SLRF2008	ASI Solution	DGFI Solution
Altay	1879		X	
Arkhyz	1886			X
Baikonur	1887			X
Svetloe	1888			X
Zelenchukskaya	1889			X
Badary	1890	X		
Koganei	7308		X	
Tanegashima	7358	X		
Concepcion	7405		X	
San Juan	7406			X
Kunming	7820			X
Shanghai	7821			X
Simosato	7838			X

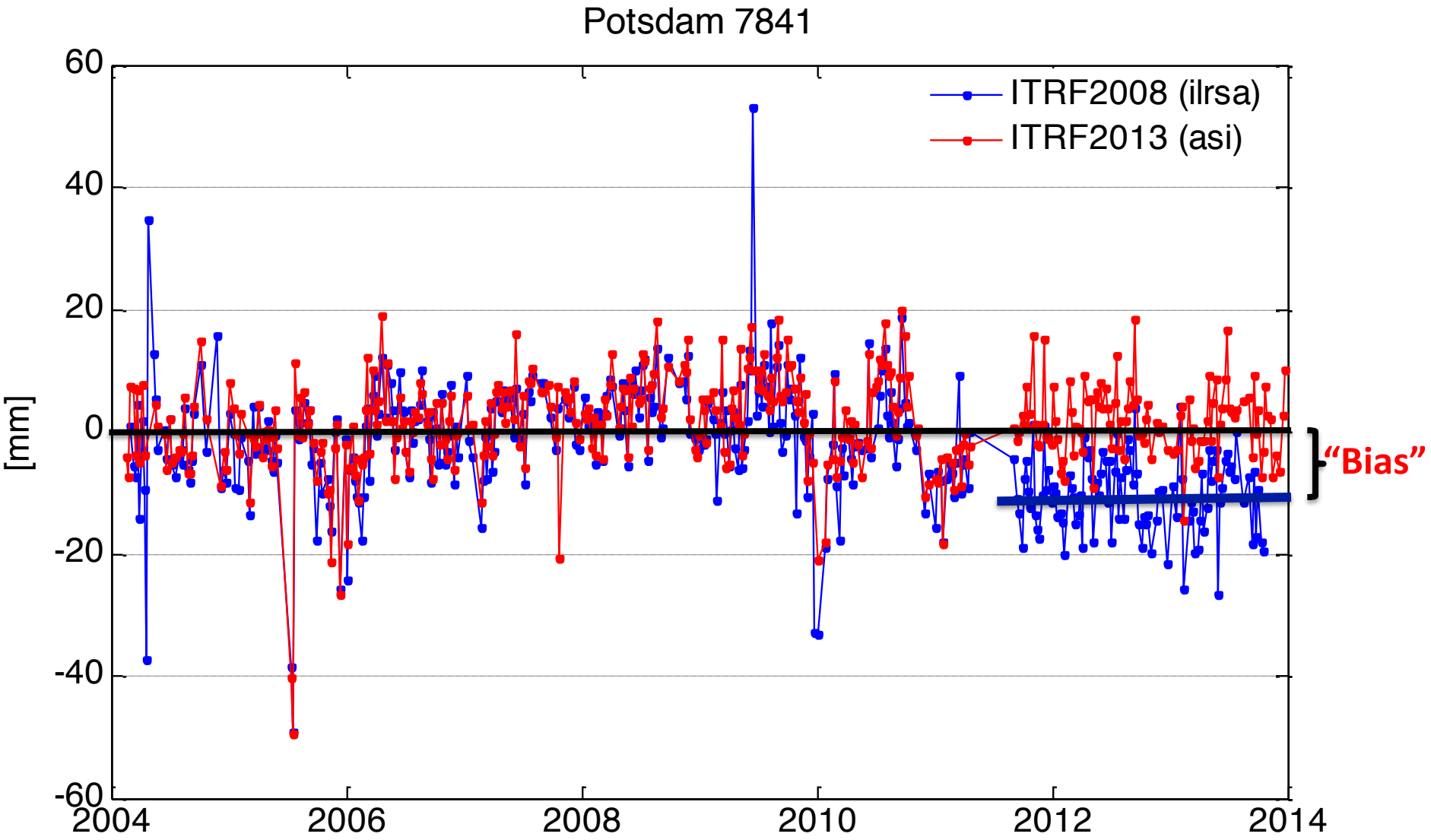
Target Signature Modeling

- In 2013 ILRS adopted a new model to account for the optical response of each target to different systems and modes of operation: the so-called “CoM offset”
  - It depends on:
    - The geometric/optical properties of the tracked s/c LRA
    - The ranging system installed at each site,
    - The raw data preprocessing scheme, and
    - The mode of operation of the system (single/few/multi photon)
- The application of the “CoM” correction is now **time-dependent** and applied by s/w using look-up tables that need frequent updates for new sites, etc.

Pre-2013 Center of Mass Offset Correction (Fixed)

Stn pad ID	Name	Pulse length (ps)	Detector	Regime (single, few, multi)	Editing Level (✕σ)	Calib. St. error (mm)	LAGEOS St. error (mm)	LAGEOS CoM range (mm)	LAGEOS CoM ADOPTED (mm)
1873	Simeiz	350	PMT	No CNTL	2.0	60	70	248-244	246
1879	Altay	150	PMT	No CNTL	2.5	20	36	254-248	251
1884	Riga	130	PMT	CNTLD s->m	2.0	10	15	252-248	250
7080	McDonald	200	MCP	CNTLD s->m	3.0	8.5	13	250-248	249
7090	Yaragadee	200	MCP	CNTLD f->m	3.0	4.5	10	250-248	249
7105	Greenbelt	200	MCP	CNTLD f->m	3.0	5	10	250-248	249
7110	Mon. Peak	200	MCP	CNTLD f->m	3.0	5	10	250-248	249
7119	Haleakala	200	MCP	CNTLD f->m	3	4.5	10	250-248	249
7124	Tahiti	200	MCP	CNTLD f->m	3.0	6	10	250-248	249
7237	Changchung	200	CSPAD	CNTLD s->m	2.5	10	15	250-245	248
7249	Beijing	200	CSPAD	No CNTL, m	2.5	8	15	255-247	251
7355	Urumqui	30	CSPAD	No CNTL	2.5	15	30	255-247	251
7358	Tanegashima	50	MCP	No CNTL	3	1.3	5	252-248	250
7405	Concepcion	40	CSPAD	CNTLD s	2.5	15	20	246-247	246
7406	San Juan	40	CSPAD	No CNTL	2.5	8	15	246-255	250
7501	Harteb.	200	PMT	CNTLD f->m	3.0	5	10	250-244	247
7806	Metsahovi	50	PMT	?	2.5	15	17	254-248	251
7810	Zimmerwald	60	CSPAD	CNTLD s->f	2.5	5	12	246-249	248
7811	Borowiec	40	PMT	No CNTL f	2.5	16	23	256-250	253
7824	San Fernando	100	CSPAD	No CNTL s->m	2.5	30	25	252-246	249
7825	Stromlo	10	CSPAD	CNTLD s->m	2.5	4	10	257-247	252
7832	Riyadh	100	CSPAD	CNTLD s->m	2.5	10	15	252-246	249
7835	Grasse	50	CSPAD	CNTLD s->m	2.5	6	15	255-246	250
7836	Potsdam	35	PMT	CNTLD s->m	2.5	10	20	256-252	254
7838	Simosato	100	MCP	CNTLD s->m	3.0	20	40	252-248	250
7839	Graz	35	CSPAD	No CNTL m	2.2	3	9	255-250	252
7839	Graz kHz	10	CSPAD	No CNTL s->f	2.2	3	9	255-250?	252
7840	Herstmonceux	100	CSPAD	CNTLD s	3.0	6	15	246-244	245
7840	Hx kHz	10	CSPAD	CNTLD s	-1.5,+2.5	3	9	245	245
7841	Potsdam 3	50	PMT	CNTLD s->f	2.5	10	18	254-248	251
7941	Matera	40	MCP	CNTLD m	3.0	1	5	252-248	250
8834	Wettzell	80	MCP	No CNTL f->m	2.5	10	20	252-248	250

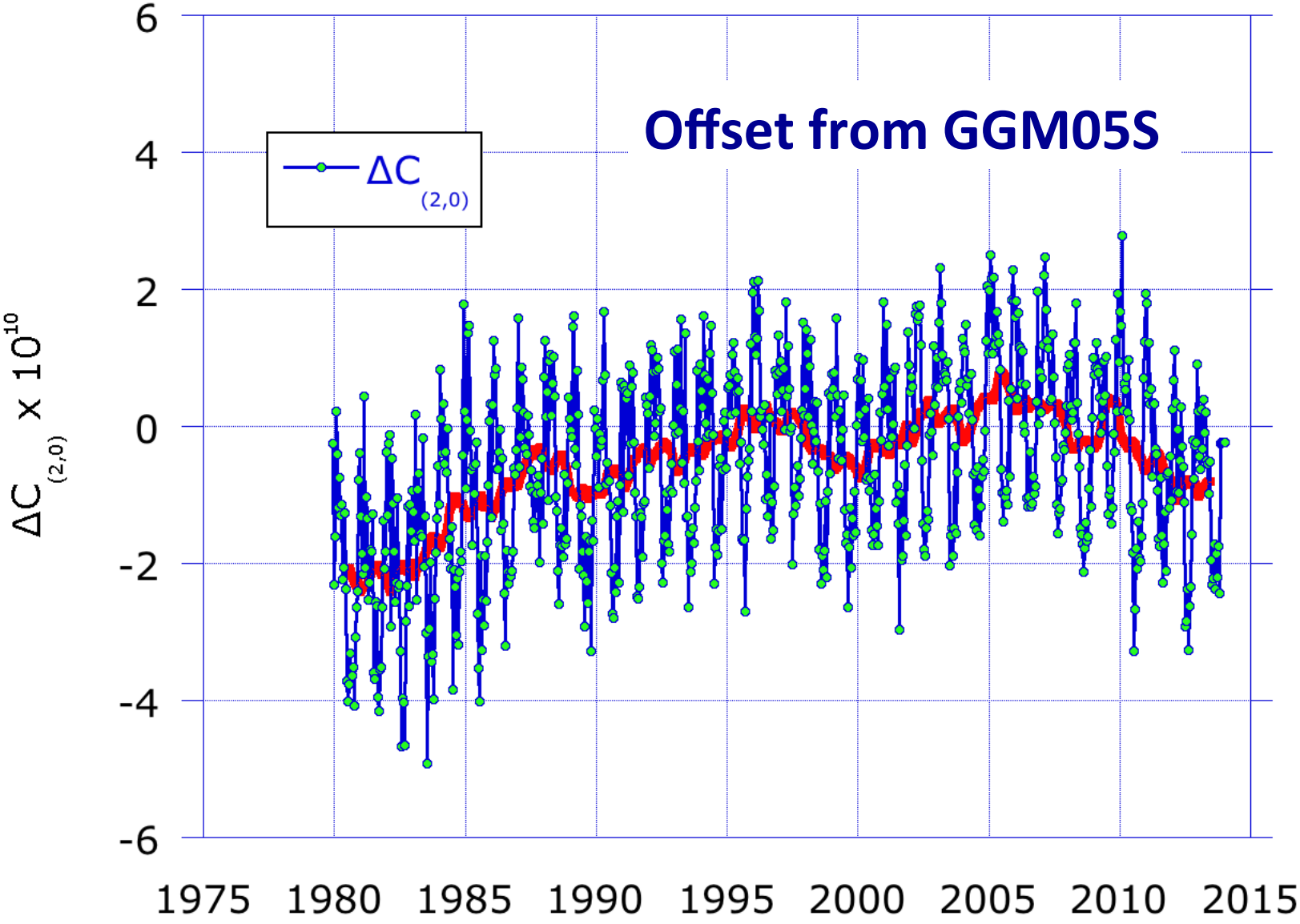
Improvements due to the new Satellite CoM Model



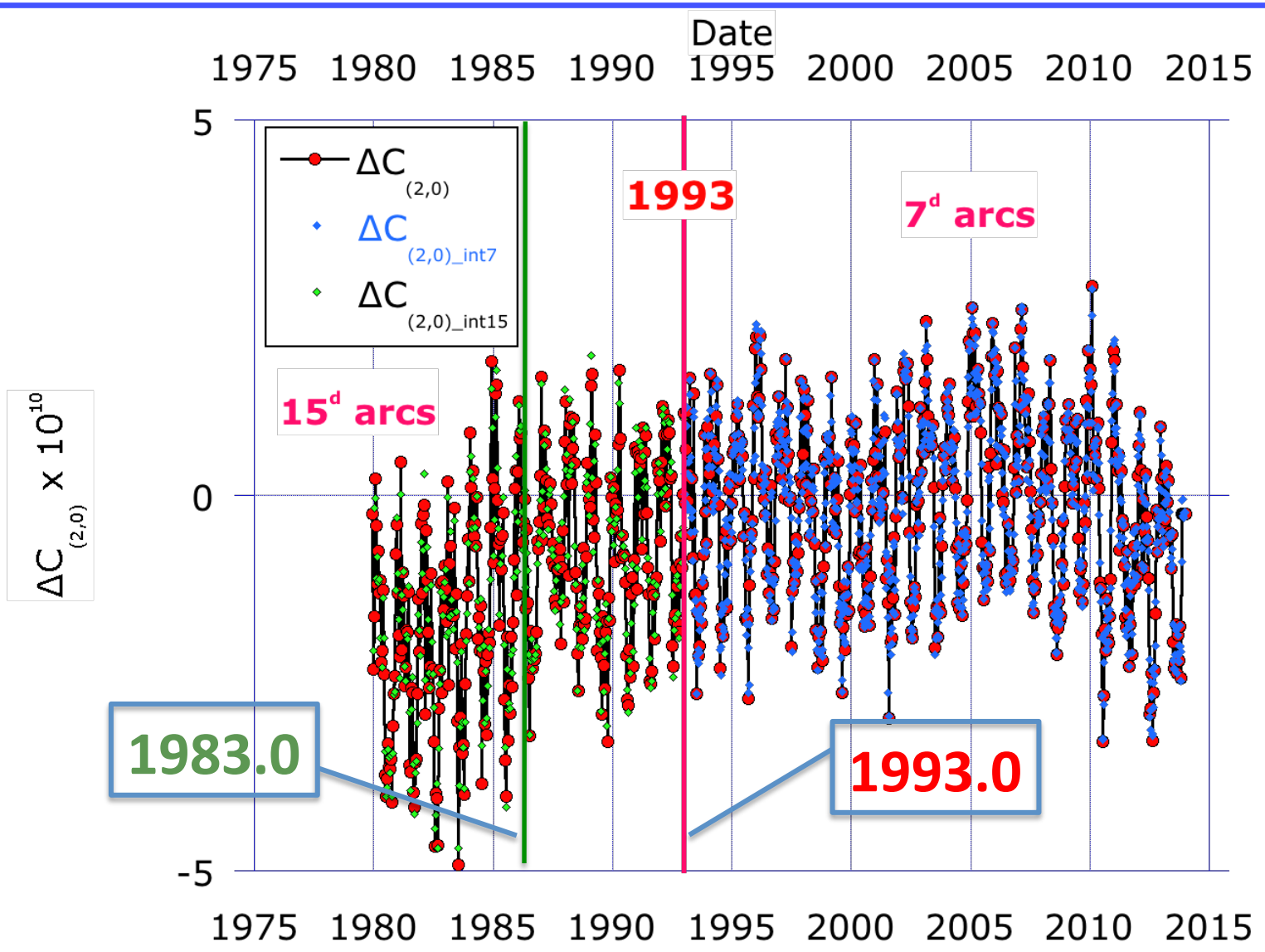
Gravitational Modeling

- New static gravitational model adopted by all ACs:
  - **GGM05S** from the GRACE project
- A consistent set of additional terms with significant temporal variation, derived from SLR tracking of multiple geodetic satellites by Minkang Cheng (CSR/UT), using GGM05S as the background static part and using the same standards :
  - $C_{(2,0)}$ & $C/S_{(2,1)}$ from CSR's 15^d series, interpolated/evaluated at mid-arc epoch of our 15^d arcs (1983 - 1992) and our 7^d arcs (1993 – 2013)
  - The nominal zonal terms' values for degree 3-6 for our use come from CSR's GGM05S, their linear rates however come from *Cheng et al., 1997*

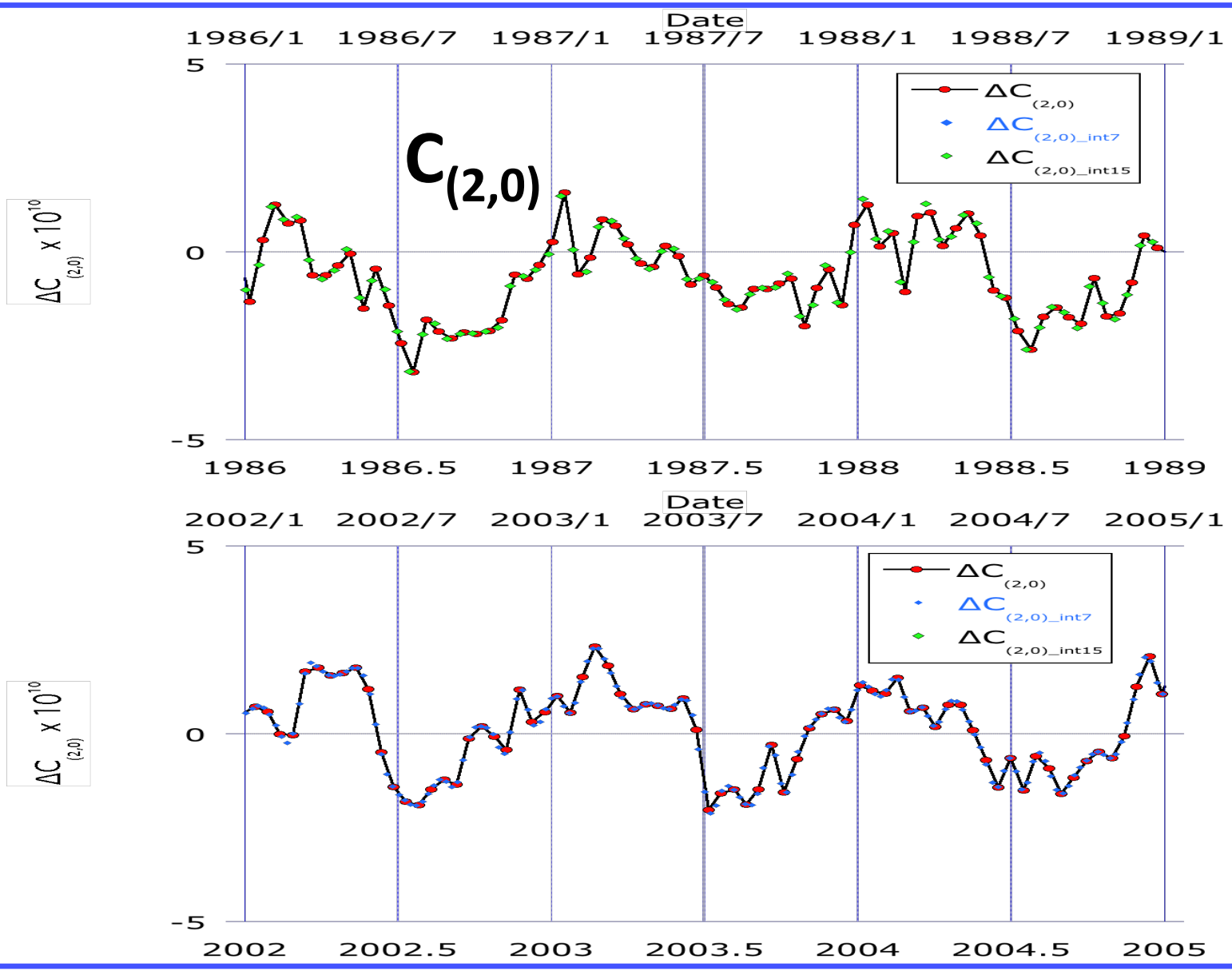
Earth Oblateness Variations



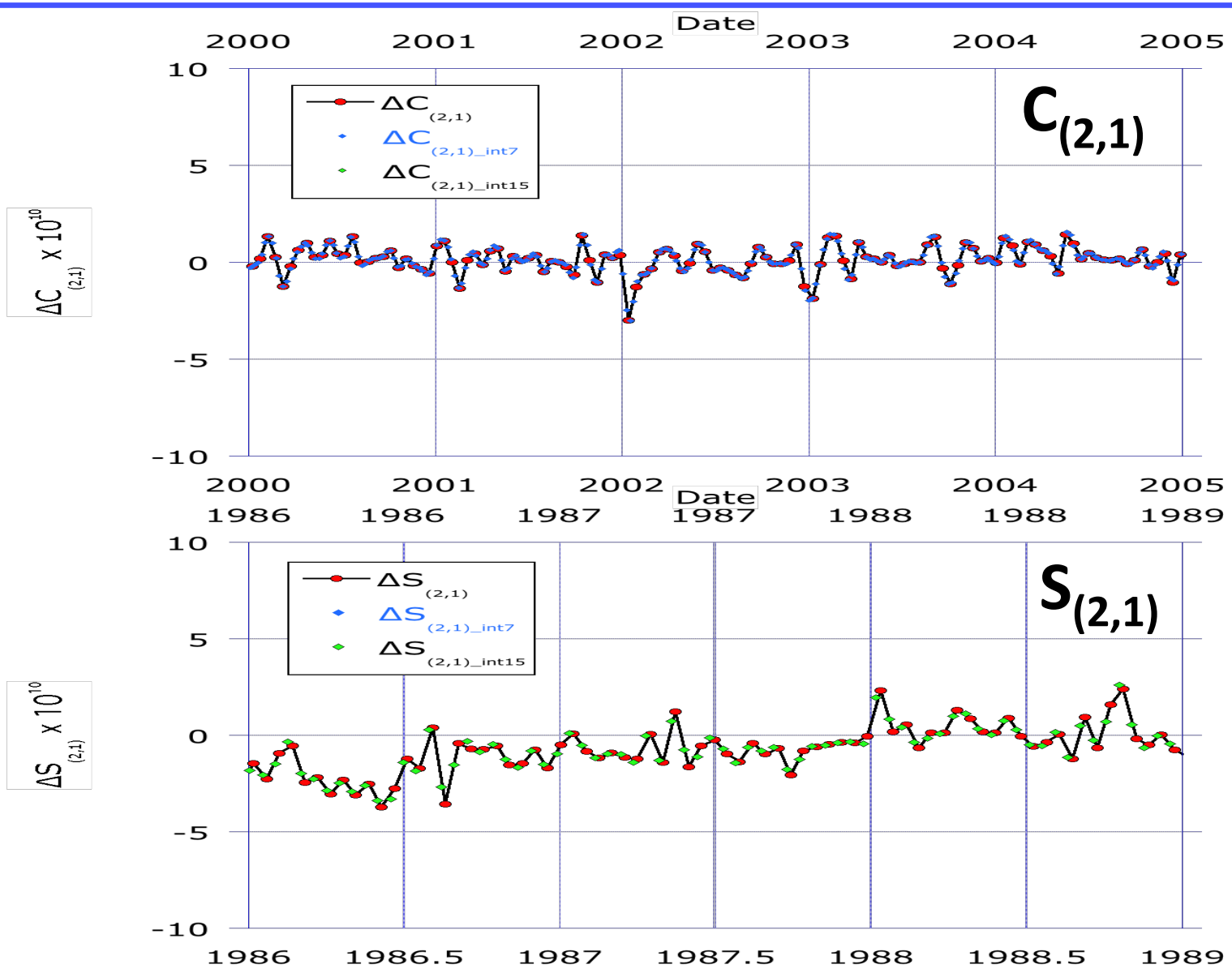
$C_{(2,0)}$ Time Series



$C_{(2,0)}$ Interpolation 15^d & 7^d arcs



$C/S_{(2,1)}$ Interpolation 15^d & 7^d arcs



Mean Pole Model

- The IERS Conventions have a Mean Pole model in the form of a polynomial that was fit to one release of the official IERS Mean Pole (MP) series (ca. 2010)

- Changes (ca. 2005) in the nearly linear MP motion require that we are flexible and adapt the "model" to such changes, since extrapolation from a fixed polynomial fit is inadequate

- A daily series of the MP coordinates and their rates based on the interpolated/extrapolated IERS MP series was adopted, **instead of the fixed polynomial** version in the IERS 2010 Conventions

Rapid ice melting drives Earth's pole to the east

J. L. Chen[1], C. R. Wilson[1,2], J. C. Ries[1], B. D. Tapley[1]

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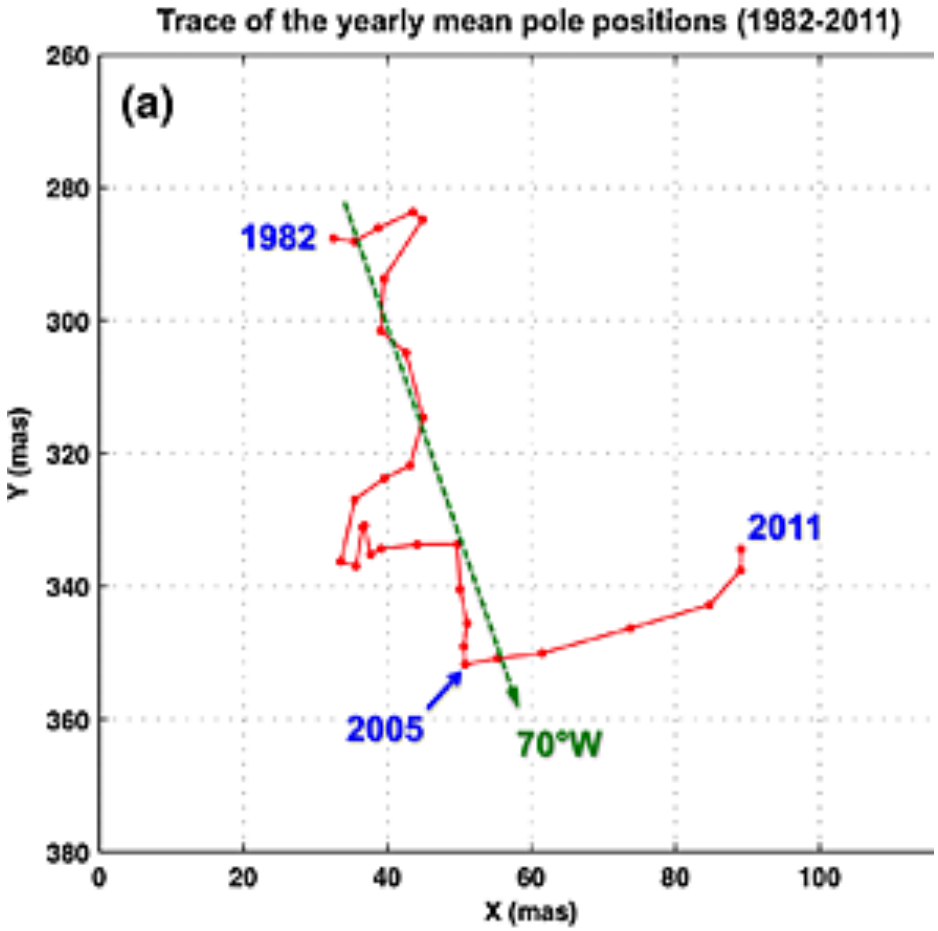
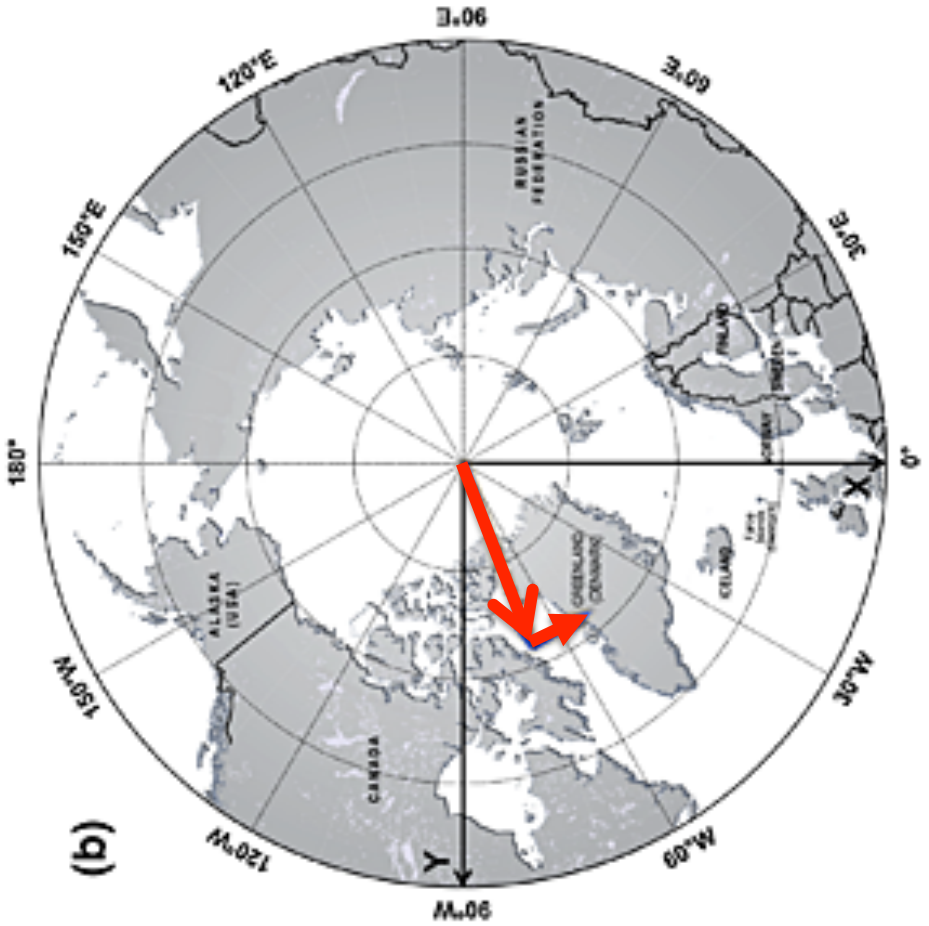
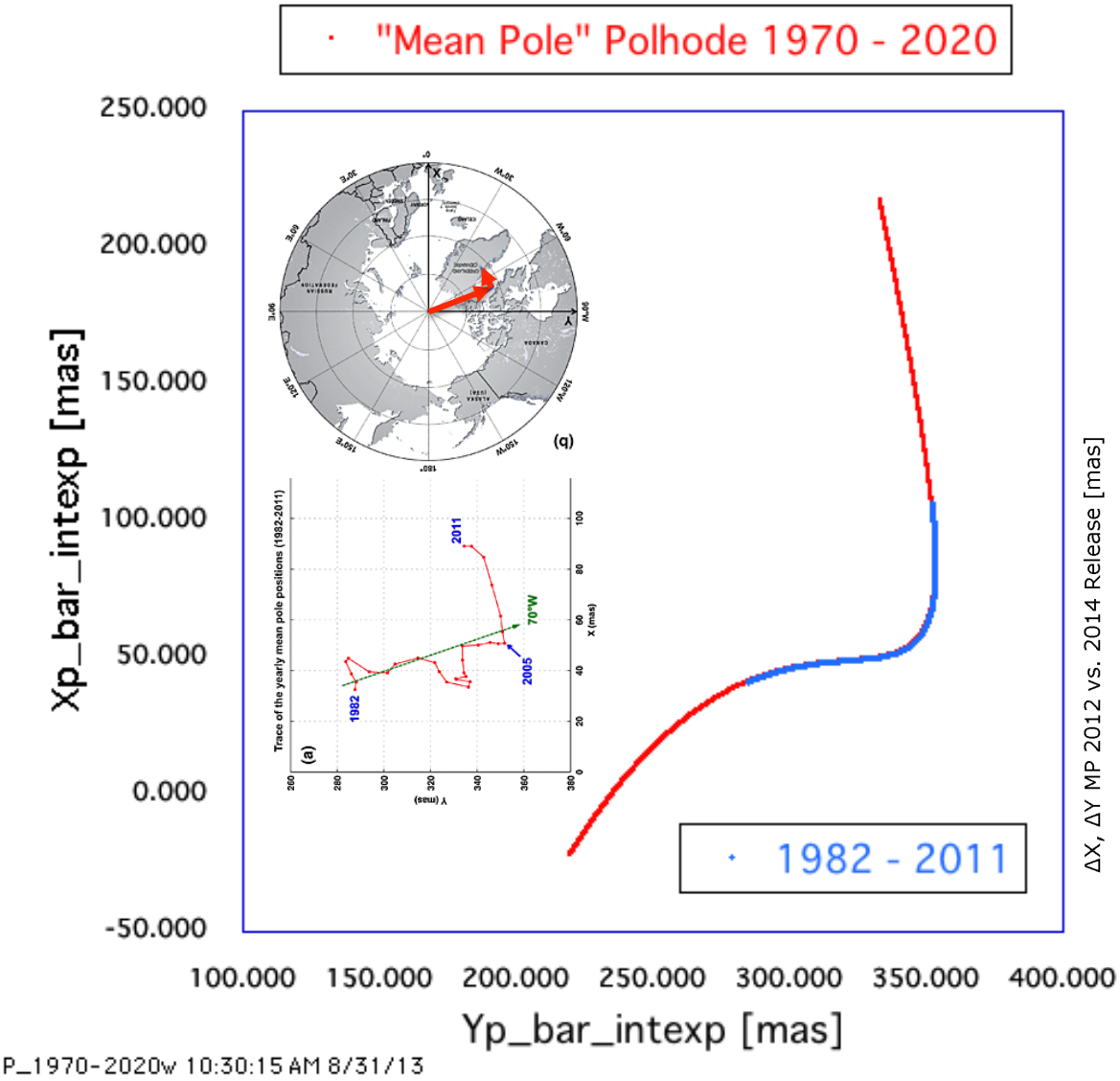
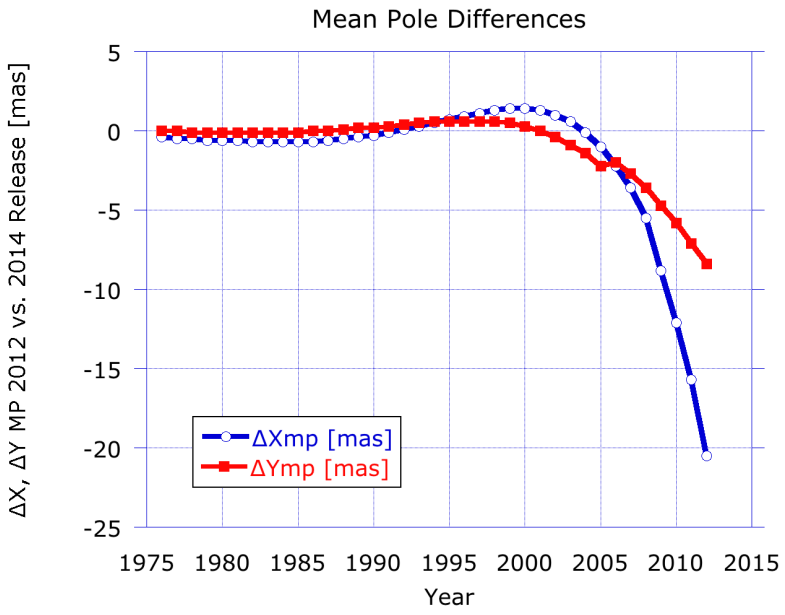




Realistic Mean Pole Model (IERS EOP Series)



Mean Pole Differences: IERS Series 2010 vs 2014



From Daniel Gambis

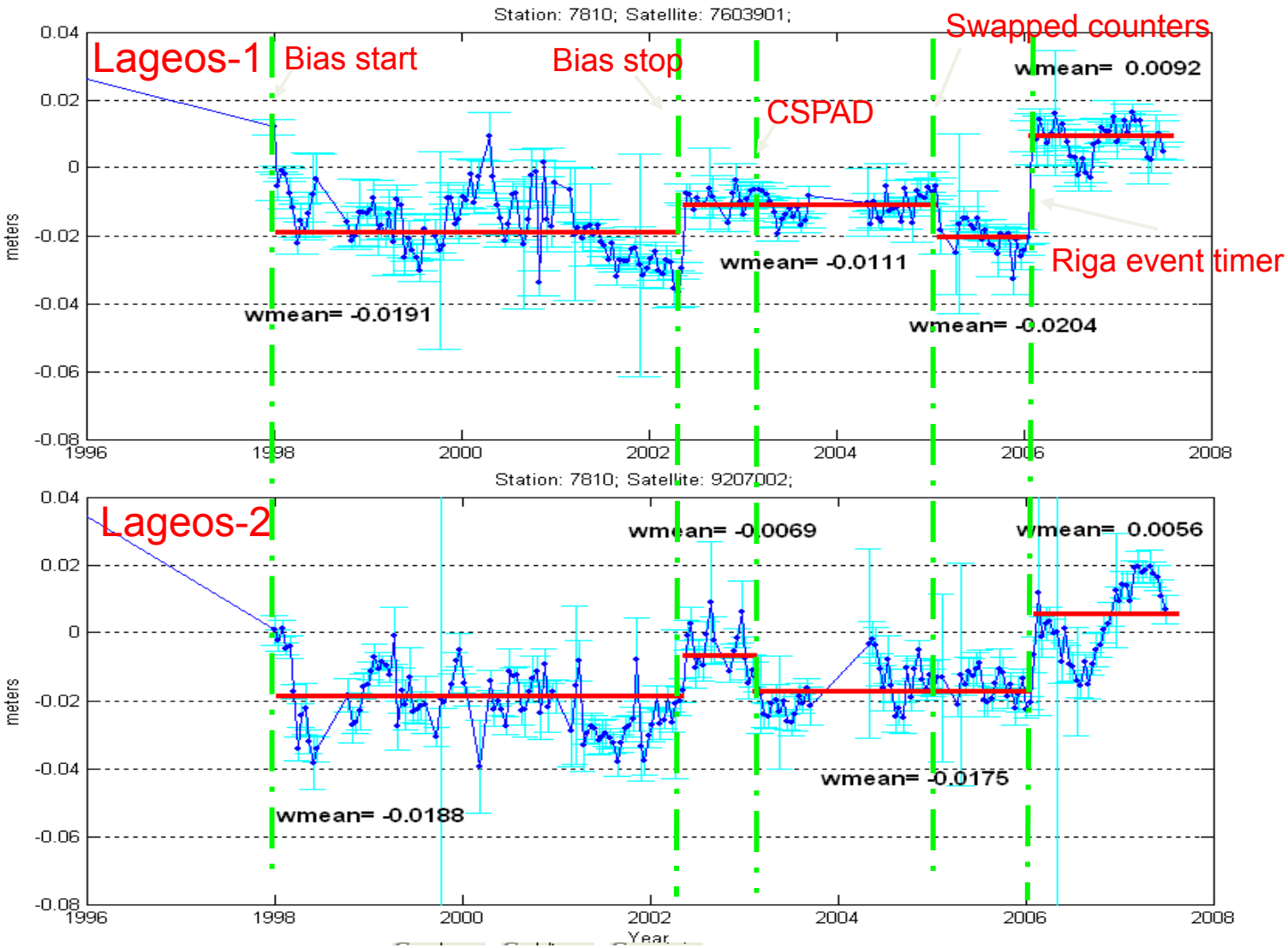
Station Systematic Error Modeling

- The ILRS initiated a thorough investigation of the station-dependent systematic errors since the development of ITRF2008, leading to significant improvement and consistency of the product we deliver to ITRS

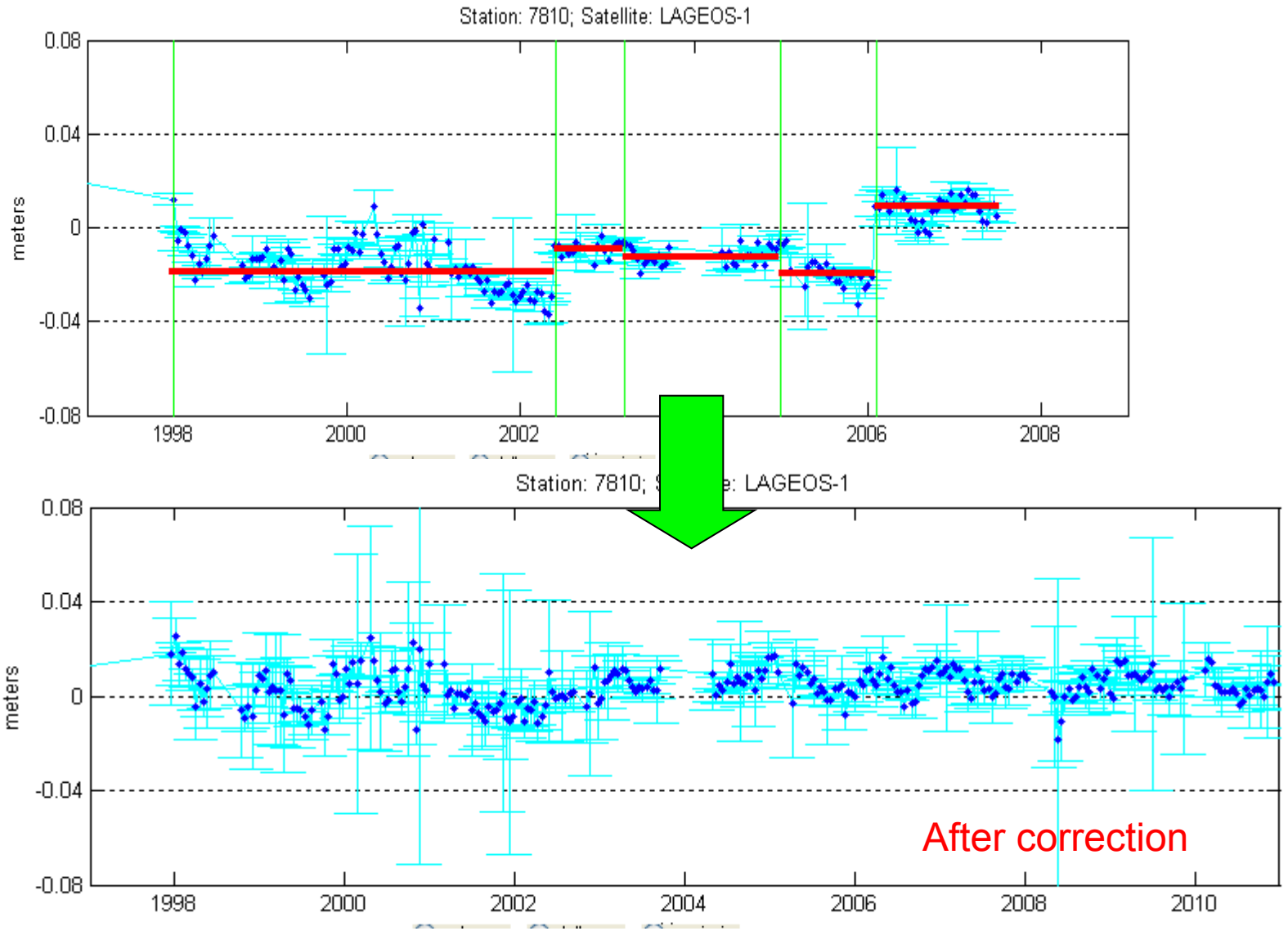
- Since several years we maintain a time series of weekly-averaged systematic error estimates for all active sites (since 1993), which is used to notify stations of sudden changes with respect to the adopted reference frame

- Starting late last year, the ILRS replaced the outdate way the stations reported changes to the community with a more efficient and simple way, readily accessible to users: the Station History Change records (archived at the DCs)

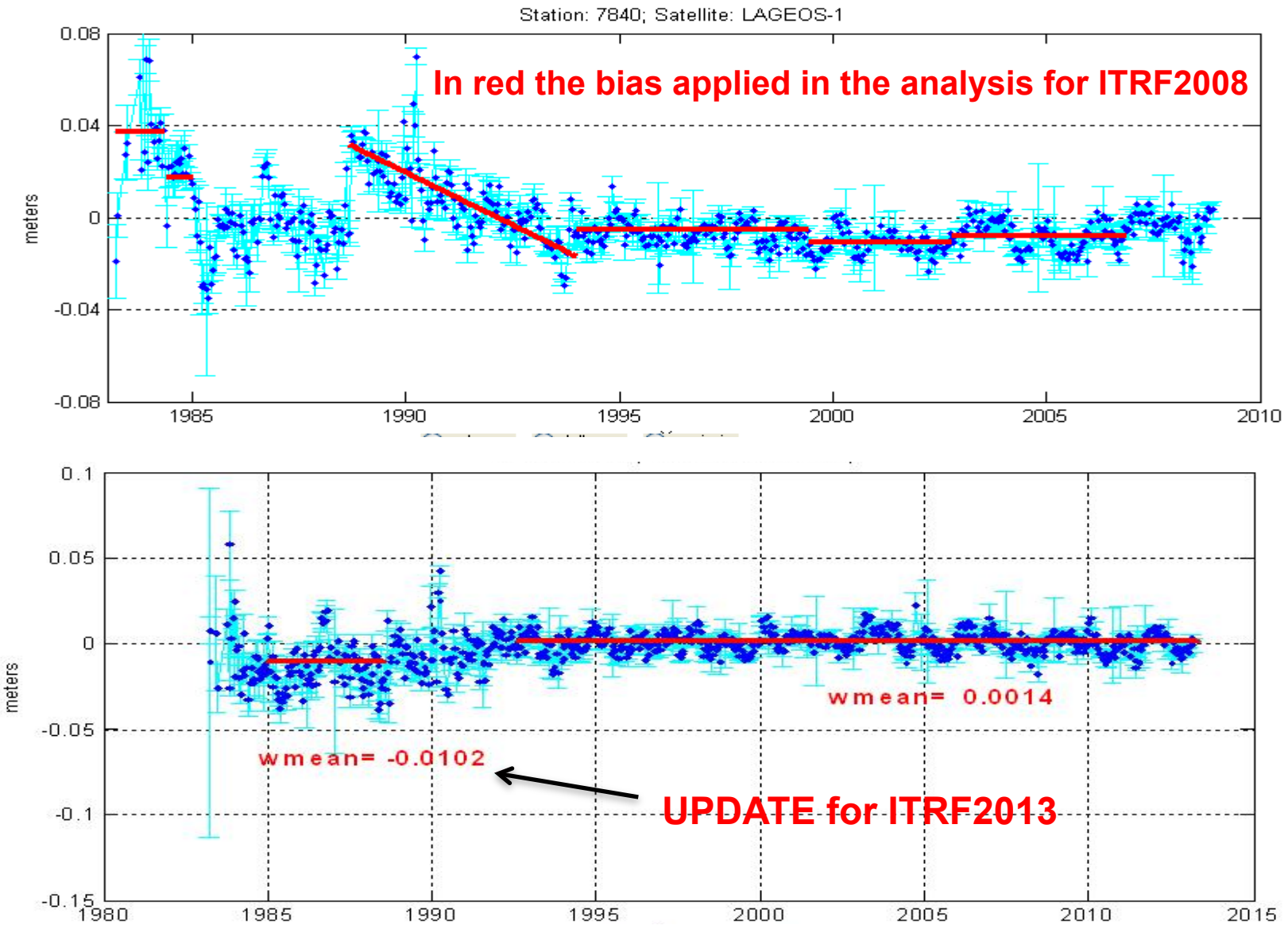
Zimmerwald Systematics



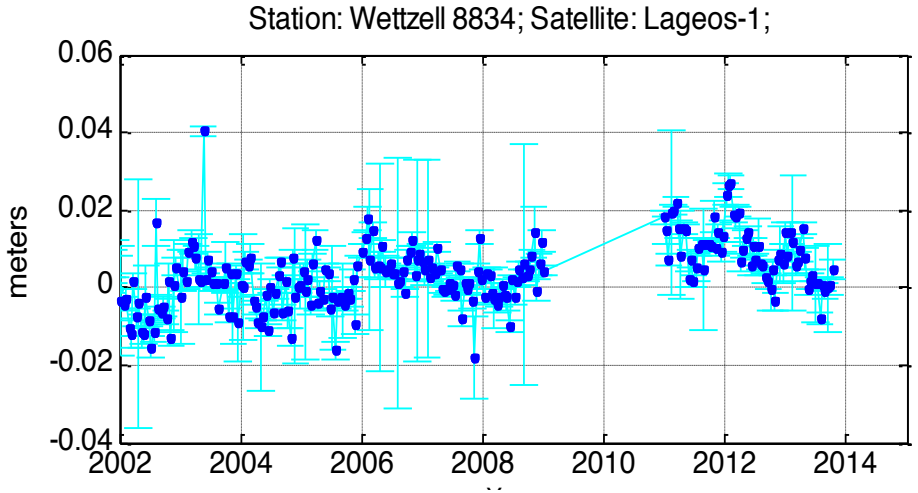
Zimmerwald Systematics



Herstmonceux Systematics

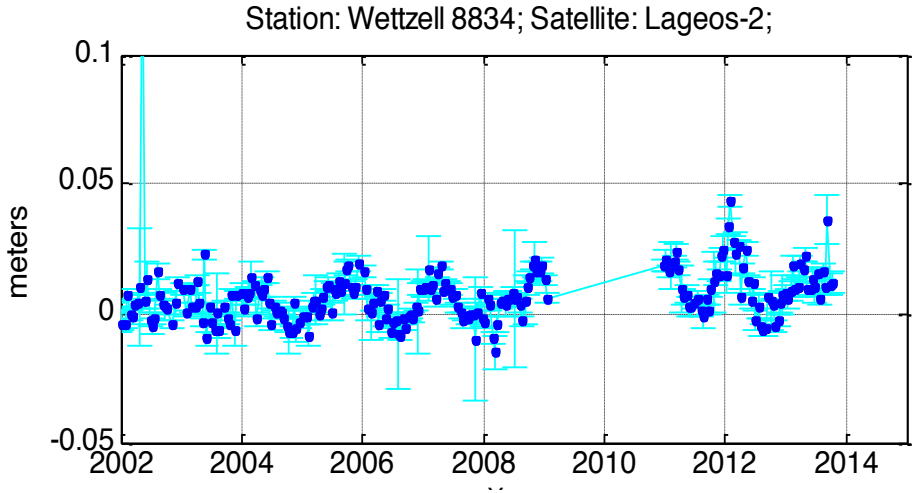


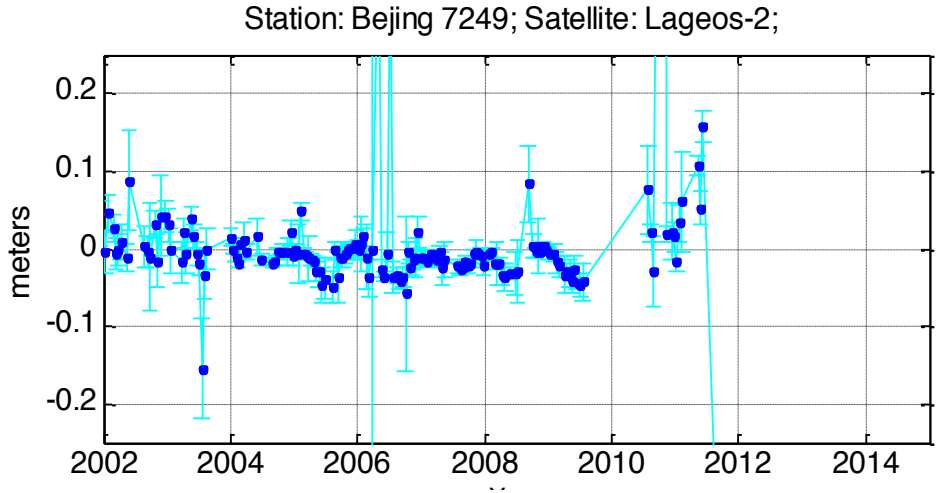
Routine Systematics Estimation



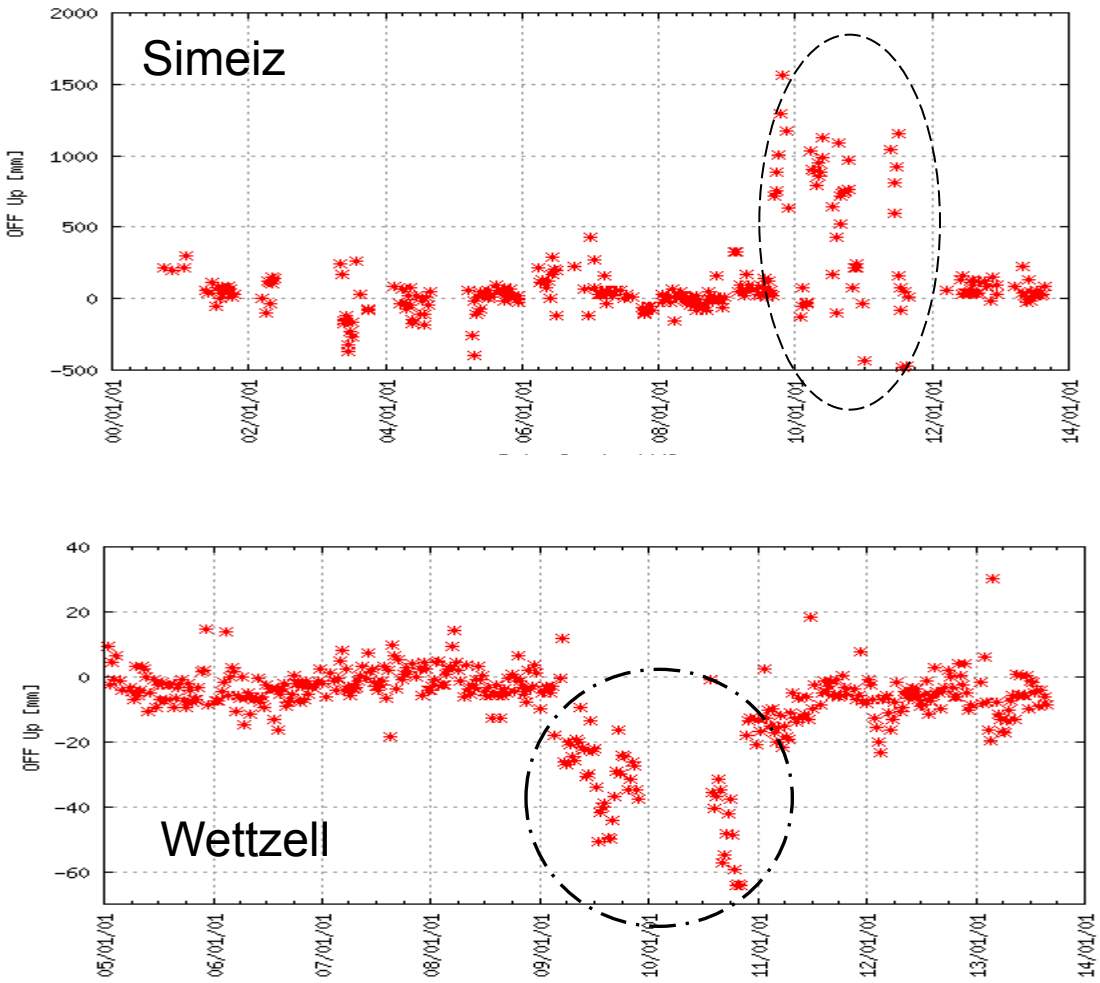
Active stations requiring estimation of a correction:

1864 --- mm A 00:000:00000 00:000:00000
1868 --- mm A 00:000:00000 00:000:00000
7249 --- mm A 12:067:00000 00:000:00000
7308 --- mm A 00:000:00000 00:000:00000
7403 --- mm A 10:265:00000 00:000:00000
7820 --- mm A 12:001:00000 00:000:00000
7821 --- mm A 09:148:00000 10:069:00000
8834 --- mm A 10:319:00000 00:000:00000

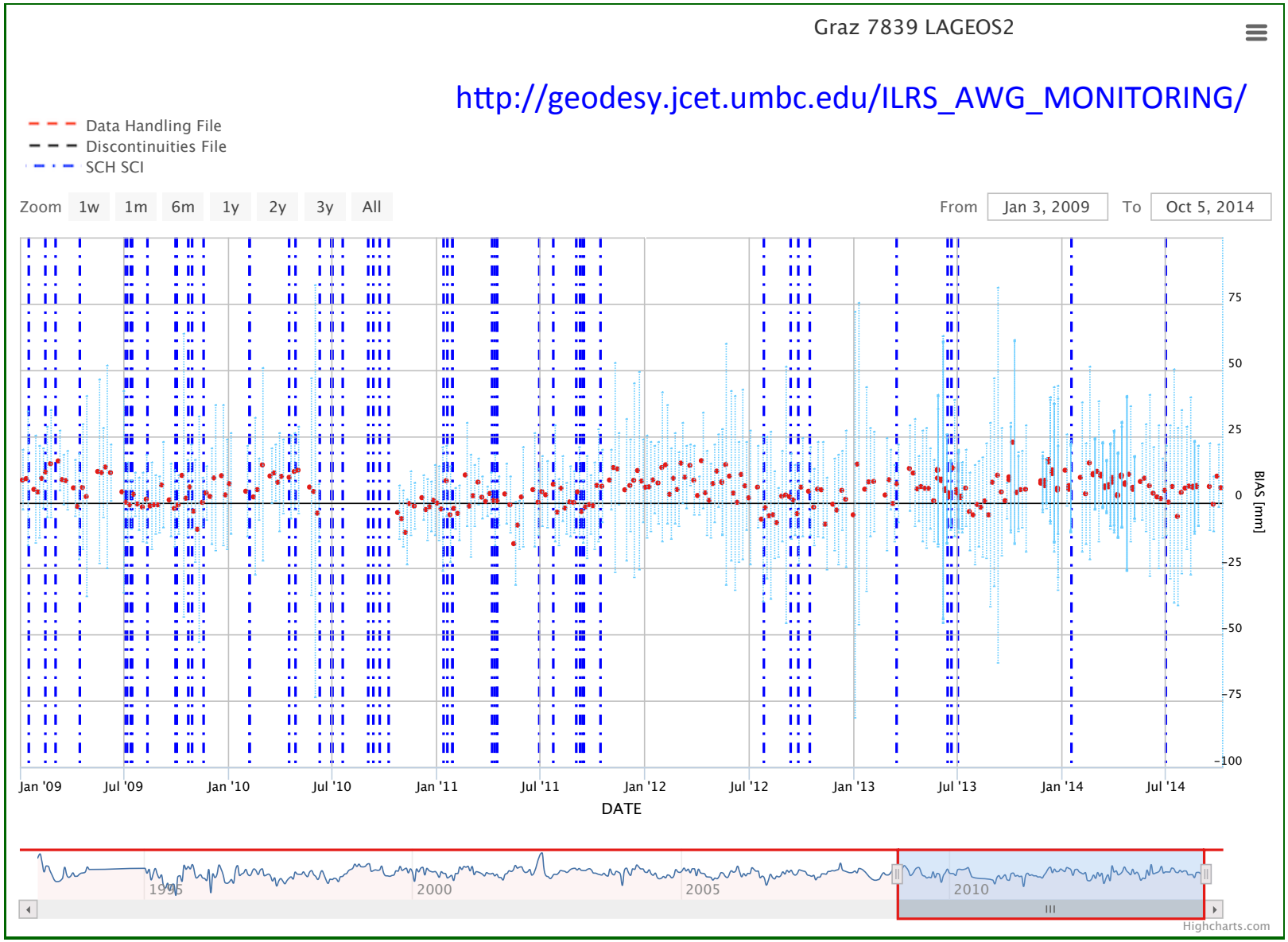




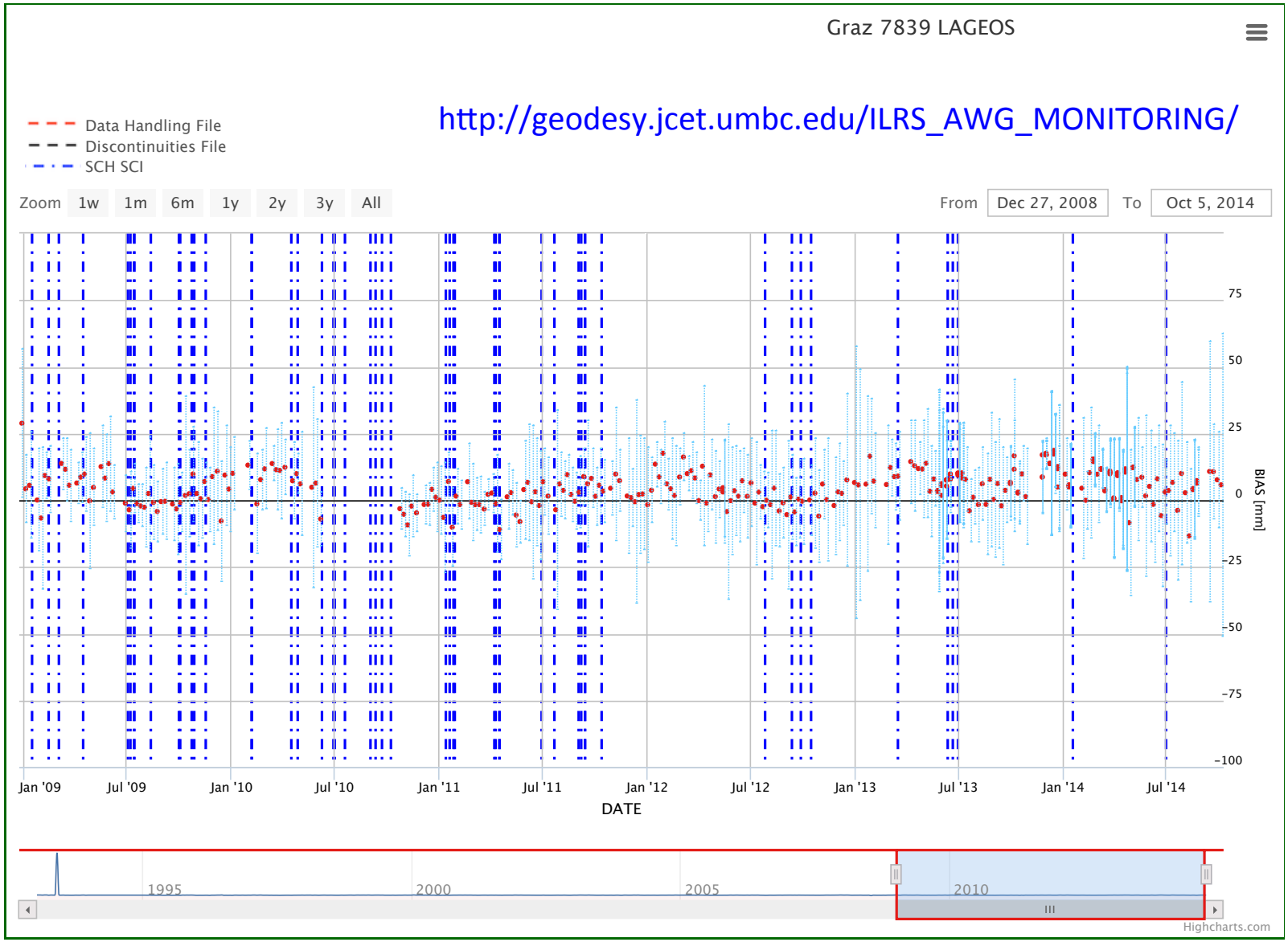
Unrecoverable Errors



Tracking of System Configuration Changes

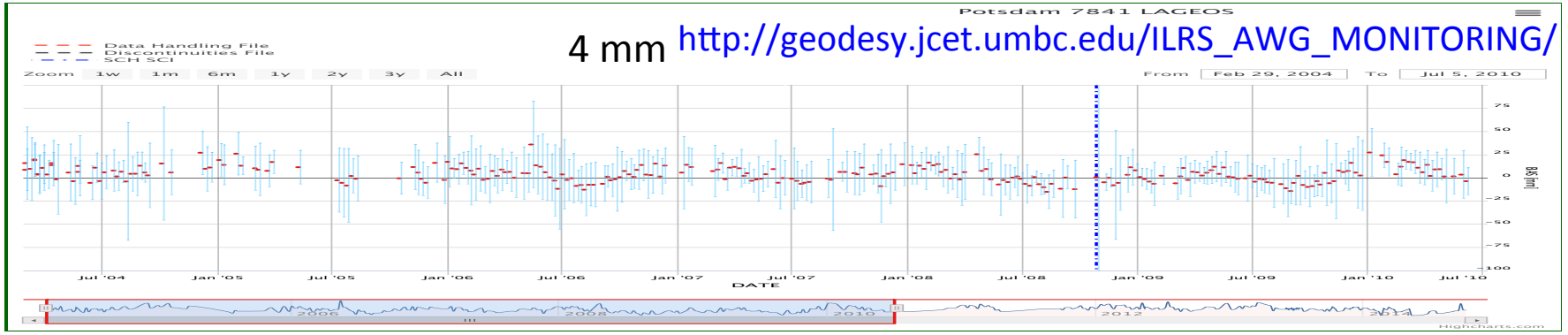


Tracking of System Configuration Changes

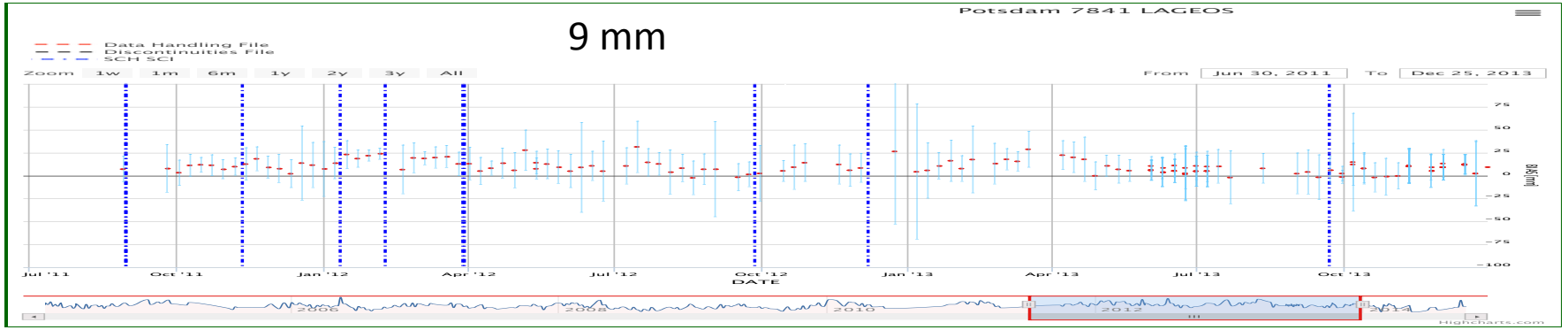


Tracking of System Configuration Changes

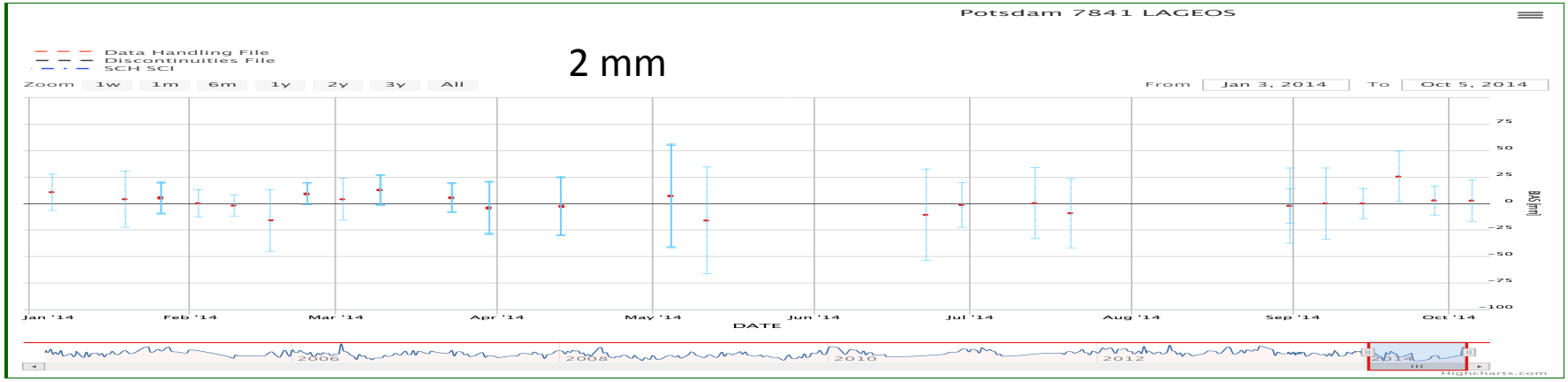
4 mm http://geodesy.jcet.umbc.edu/ILRS_AWG_MONITORING/



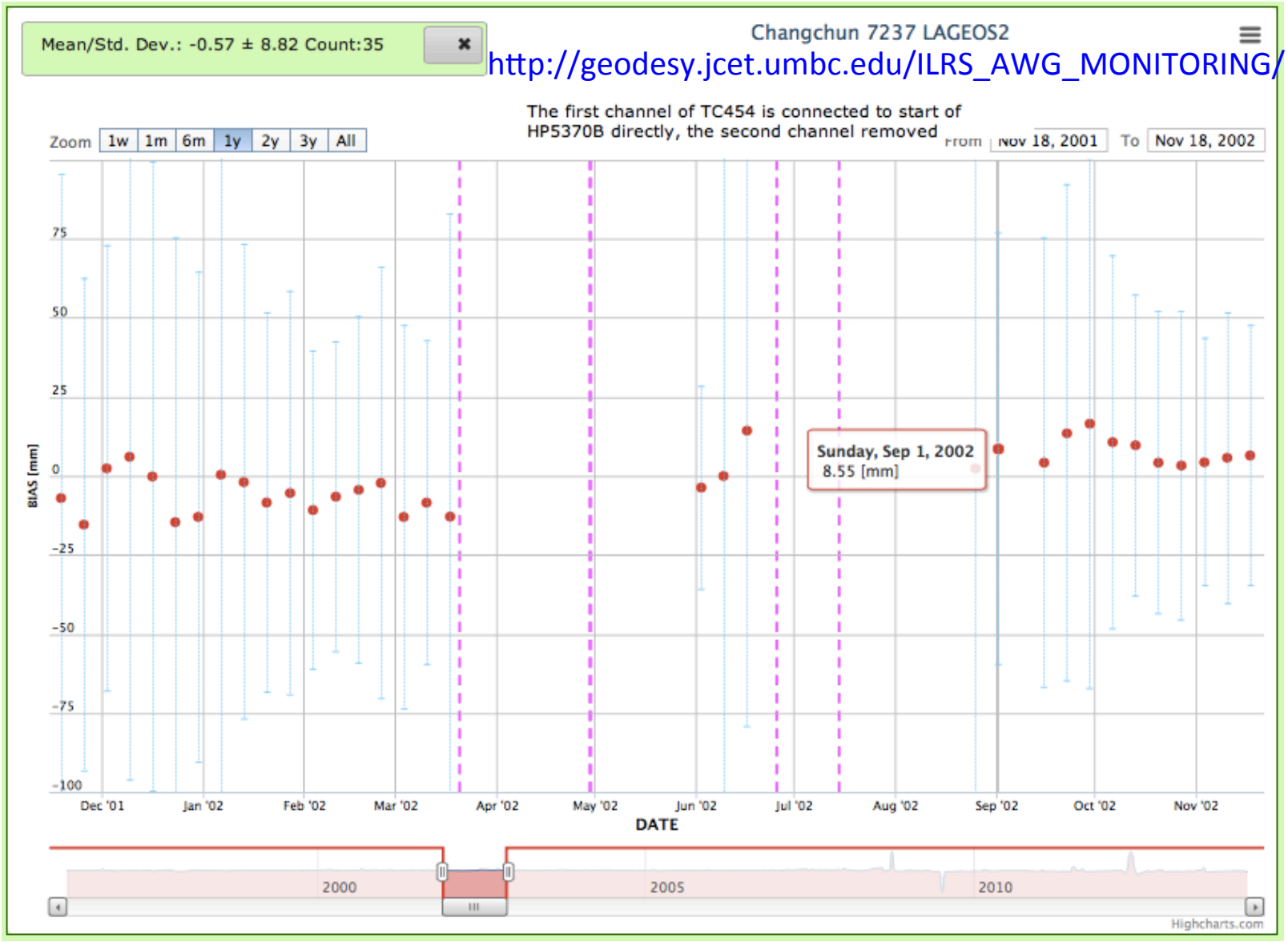
9 mm



2 mm



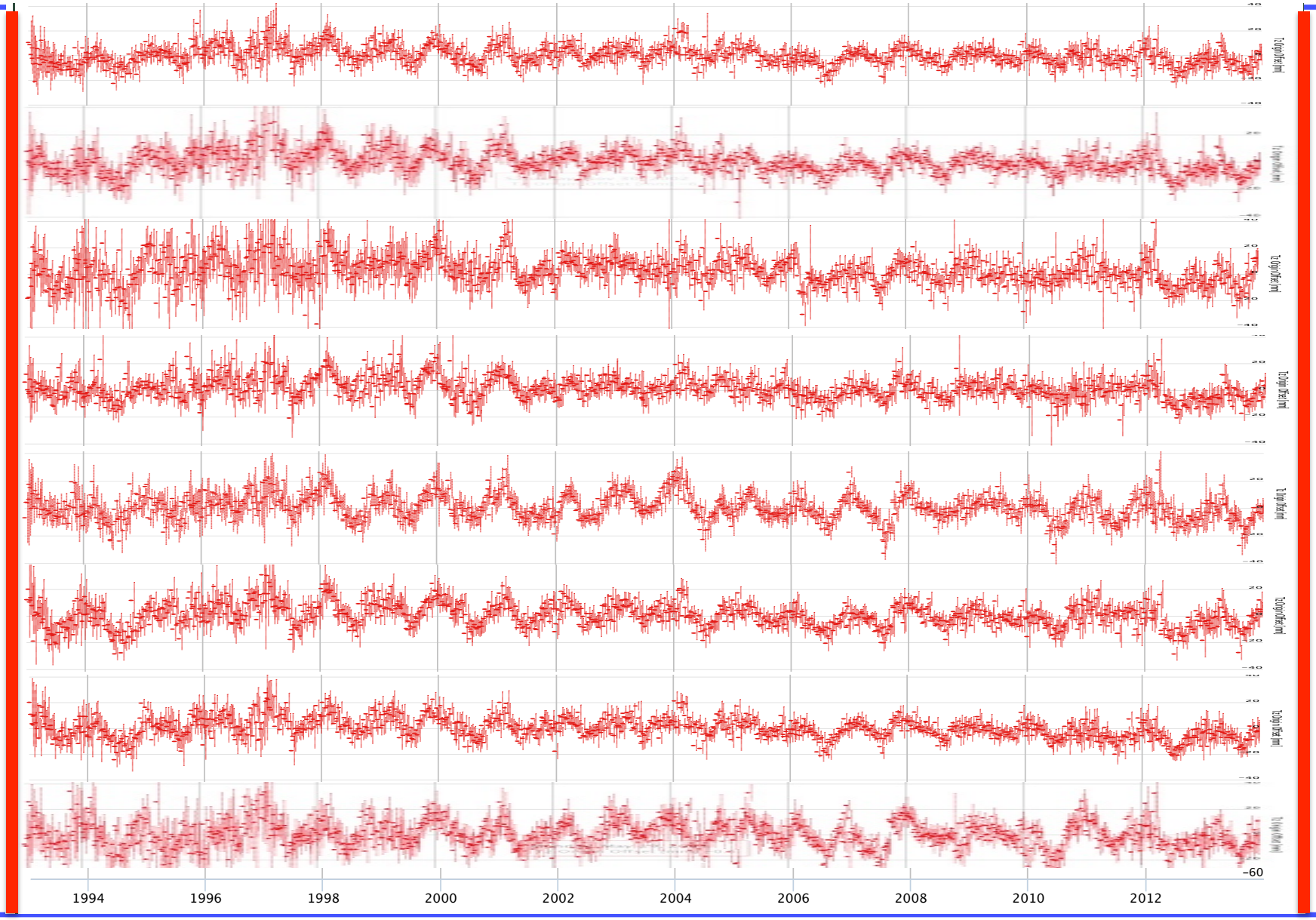
Tracking of System Configuration Changes



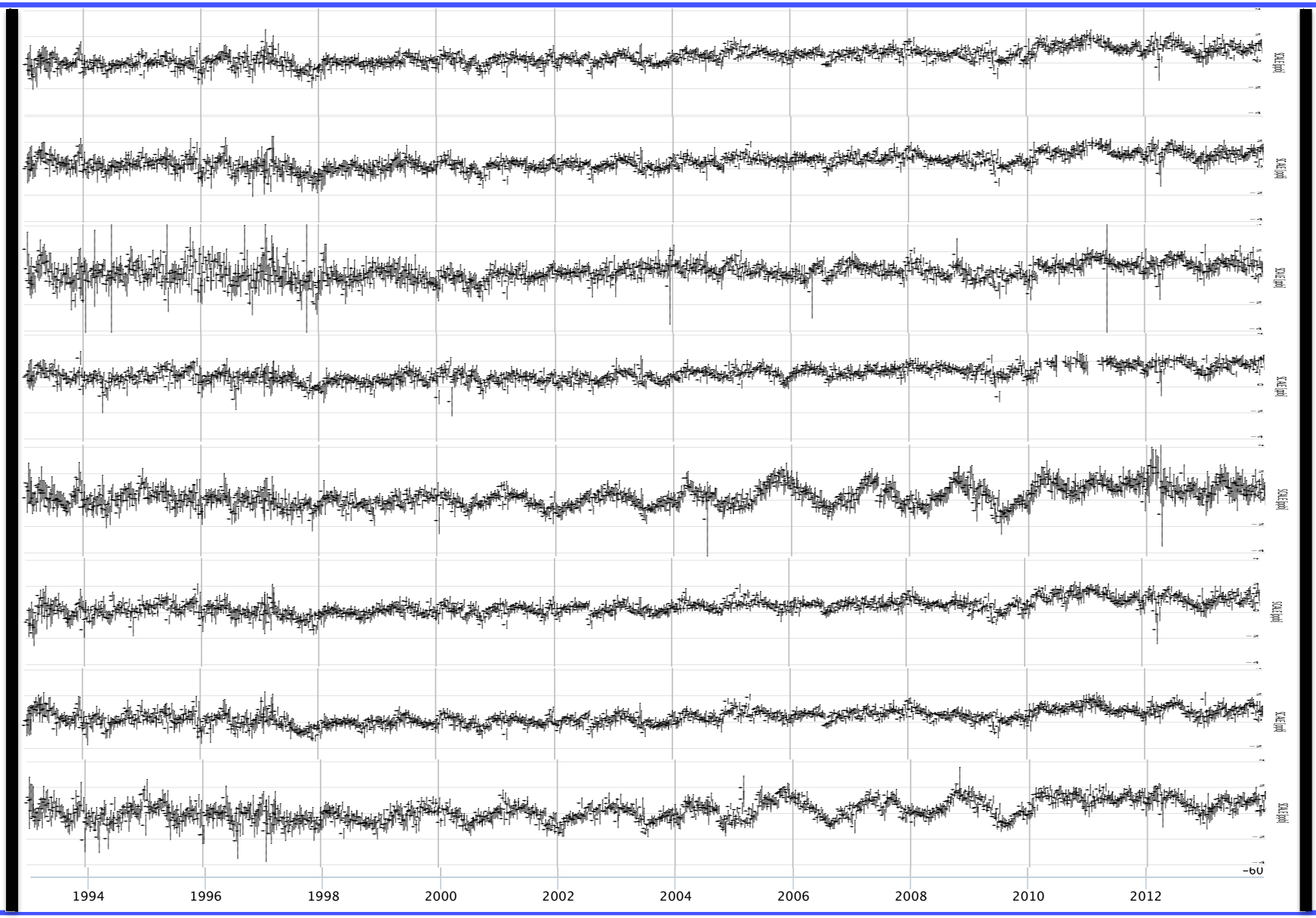
Current Results for 1993-2013

- The ILRS generates a single combined product for the ITRS and a back-up combination as an internal check
- The back-up combination product is generated using independent s/w and a different approach, based on the deconstrained normal equations and a variance component estimation for the relative weight estimation between the individual AC contributions
- The two series that cover the main period 1993-2013 indicate an agreement below their formal error estimates
- The result of the implemented improvements is better seen when comparing the time series from individual ACs

SLR TRF Origin: Z-Component wrt SLRF2008



SLR TRF Scale wrt SLRF2008



Official & Back-up Combination Results

SCALE [ppb] (mean/std. dev.)		
Contribution from:	**ILRS-A**	**ILRS-B**
ASI	0.41 ± 0.60	0.44 ± 0.61
BKG	0.51 ± 0.56	0.49 ± 0.57
DGFI	0.46 ± 0.65	0.43 ± 0.63
ESA	0.95 ± 0.56	0.91 ± 0.54
GFZ	0.23 ± 0.75	0.13 ± 0.72
GRGS	0.40 ± 0.57	0.34 ± 0.54
JCET	0.37 ± 0.54	0.40 ± 0.54
NSGF	0.19 ± 0.77	0.17 ± 0.76
COMBINATION	**0.52 ± 0.54**	**0.52 ± 0.72**

Official & Back-up Combination Results

ILRS-A TRF Origin Offsets [mm]			
Contribution from:	**X (mean/std. dev.)**	**Y (mean/std. dev.)**	**Z (mean/std. dev.)**
ASI	0.94 ± 4.14	1.03 ± 3.94	-0.32 ± 7.49
BKG	0.71 ± 4.45	0.74 ± 3.88	-0.29 ± 8.13
DGFI	-2.99 ± 5.62	-1.11 ± 5.41	2.20 ± 10.58
ESA	1.11 ± 4.14	1.31 ± 4.00	1.05 ± 7.93
GFZ	1.06 ± 4.86	0.75 ± 4.13	0.61 ± 9.19
GRGS	0.61 ± 4.40	1.21 ± 4.34	0.31 ± 8.93
JCET	0.69 ± 4.01	1.19 ± 4.25	-0.15 ± 8.12
NSGF	1.14 ± 5.66	0.76 ± 5.09	-0.40 ± 10.66
ILRS-A	**0.69 ± 3.93**	**1.01 ± 3.75**	**0.14 ± 7.34**

ILRS-B TRF Origin Offsets [mm]			
Contribution from:	**X (mean/std. dev.)**	**Y (mean/std. dev.)**	**Z (mean/std. dev.)**
ASI	0.96 ± 4.15	0.94 ± 3.94	-0.60 ± 7.44
BKG	1.50 ± 4.96	0.37 ± 3.83	-1.25 ± 8.88
DGFI	-2.51 ± 6.39	-1.05 ± 5.51	1.15 ± 10.73
ESA	2.17 ± 4.67	0.65 ± 3.88	-0.38 ± 8.24
GFZ	1.89 ± 5.09	0.26 ± 4.16	-0.41 ± 9.72
GRGS	1.10 ± 4.54	0.92 ± 4.30	-0.19 ± 8.91
JCET	0.72 ± 4.09	1.11 ± 4.25	-0.51 ± 8.12
NSGF	1.81 ± 5.88	0.50 ± 4.87	-1.64 ± 11.29
ILRS-B	**-0.95 ± 6.19**	**0.59 ± 4.02**	**-0.39 ± 8.24**

Summary

- The ILRS AWG implemented new models and data screening
- The adoption of these changes caused some delay at some ACs that had to modify their code to implement them
- Delivery of 1983-2013 ILRS combination to ITRS last week
- ITRS will notify the ILRS AWG of any new “breaks” that we deem appropriate in the series and we will reach consensus
- If necessary, ILRS will deliver selected new SINEXs from ACs and a new combination from the CCs to ITRS.
- Development of an ITRF2014 under discussion—ILRS committed to support this within the foreseeable timeframe

We would like to thank the eight individual ILRS Analysis Centers for their support of the ILRS products and their sponsoring organizations, and…

Thank you!