Modeling Changes for the ILRS Reanalysis for ITRF2013

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Outline

- ITRF2013 reanalysis initiated in Sept. 2013
- New ILRS improved models implementation
  - New gravity modeling
- New 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
- ILRS reanalysis delivery to ITRS

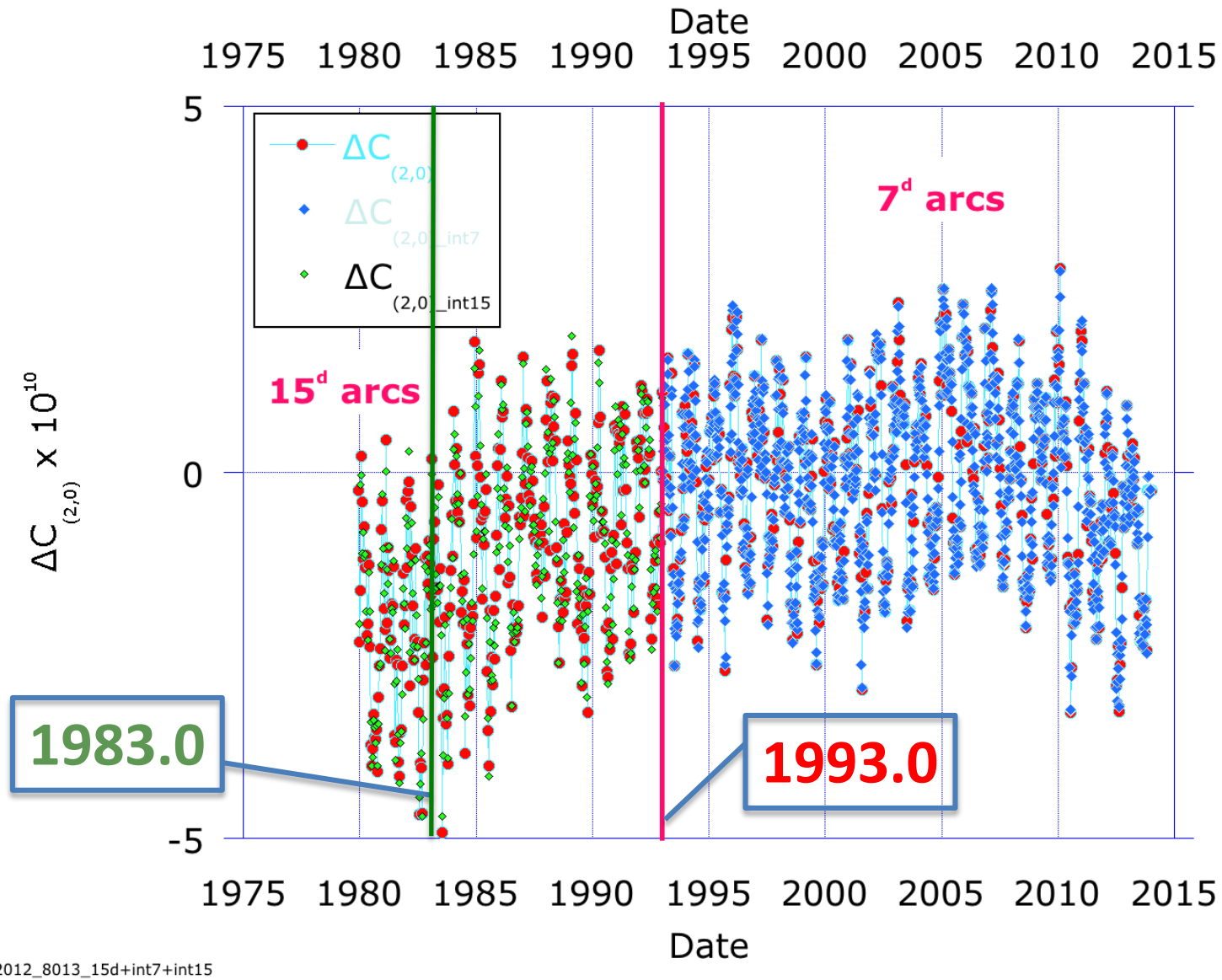
Reanalysis Kick-off (Sept. 2013)

- A reanalysis effort in response to the ITRF2013 solicitation was planned by the ILRS AWG during our Sept. 2013 meeting in Potsdam, Germany
- It was agreed to implement several new models and to have them validated before the reanalysis for the ITRF submission (discussed at EGU 2013)
- Considerable time and effort required from each AC / CC to develop the final ITRF delivery product
- The reanalysis starts with 1983, as with ITRF2008, and ends at the end of 2013.

What's New in Terms of Modeling - I

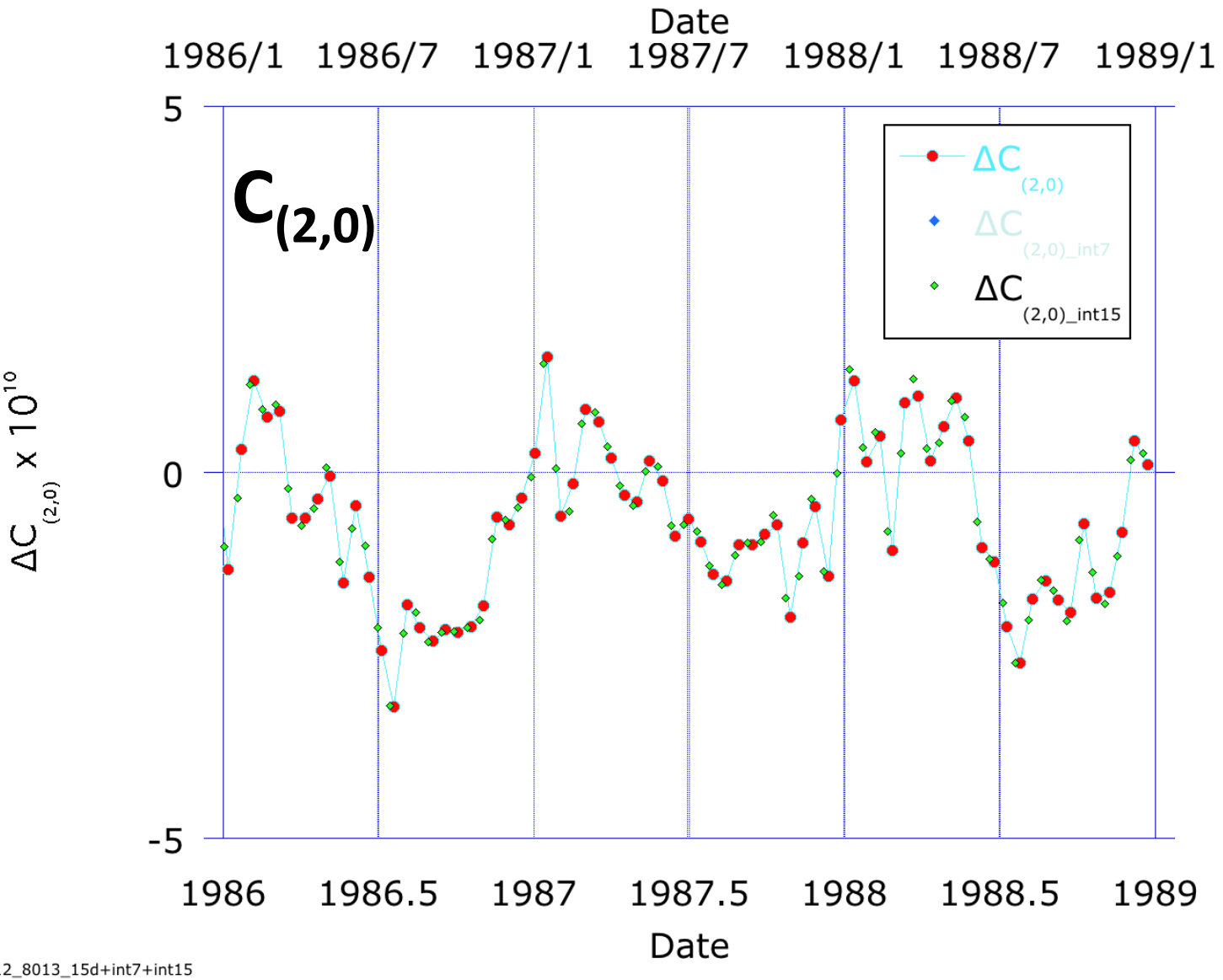
- New static gravitational model adopted by all ACs, some of which were still using EGM96:
  - **GGM05S**
- A consistent set of additional terms with significant temporal variation, derived using GGM05S as the static part and with the same standards from SLR tracking of multiple geodetic satellites by Minkang Cheng (CSR/UT):
  - $C_{(2,0)}$ & $C/S_{(2,1)}$ 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 rates however come from *Cheng et al., 1997*

$C_{(2,0)}$ Gravitational Modeling



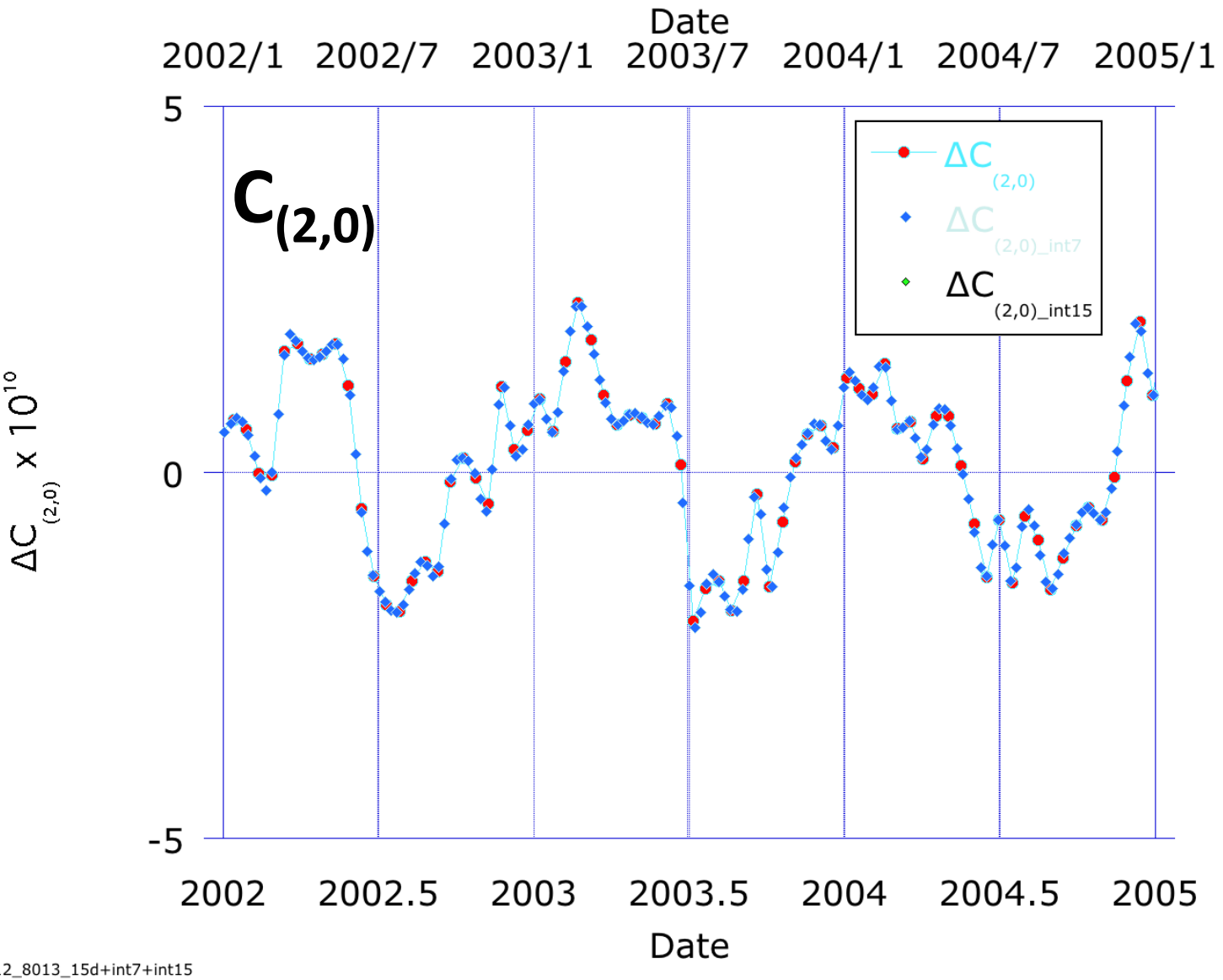
CS2012_8013_15d+int7+int15

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



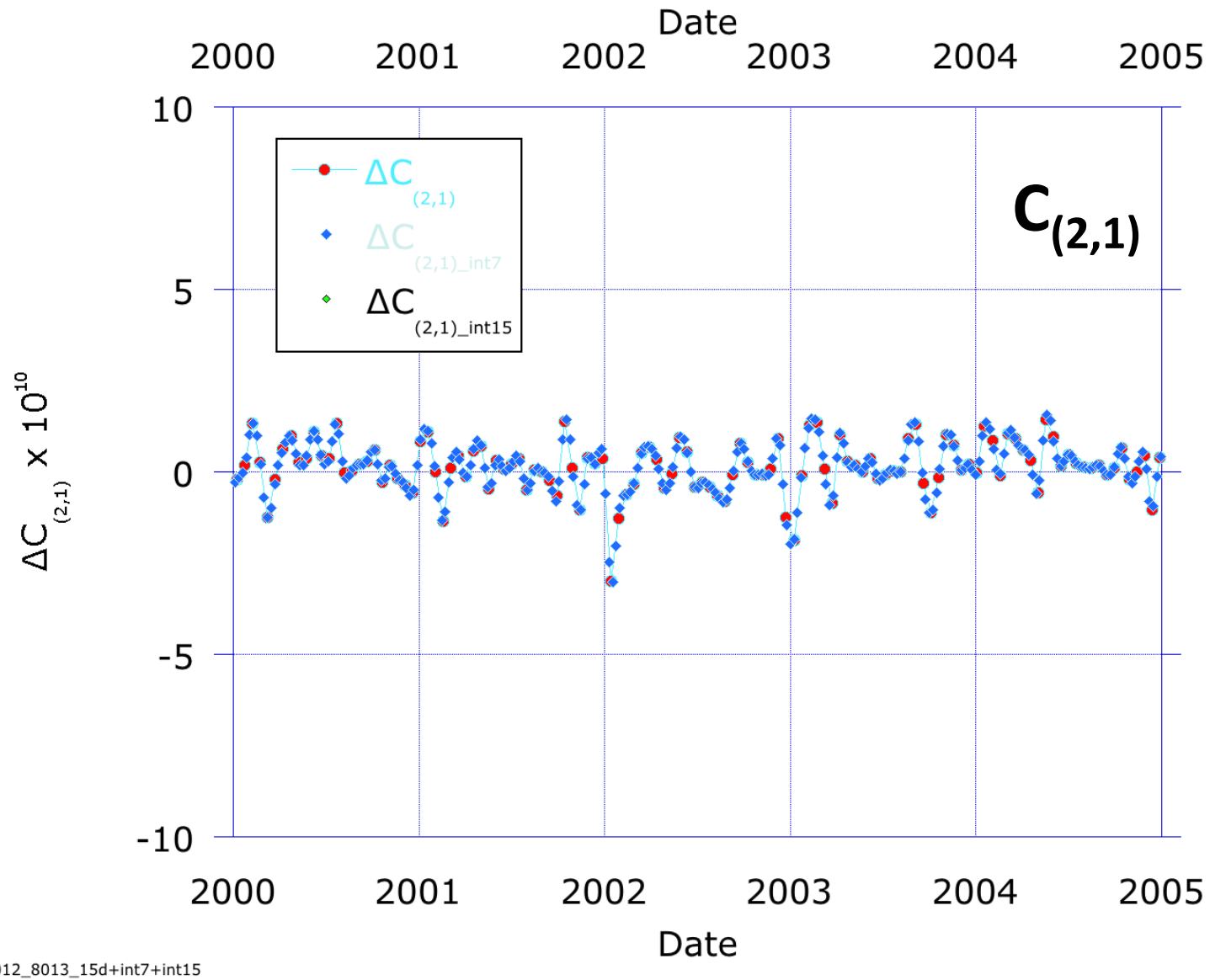
CS2012_8013_15d+int7+int15

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

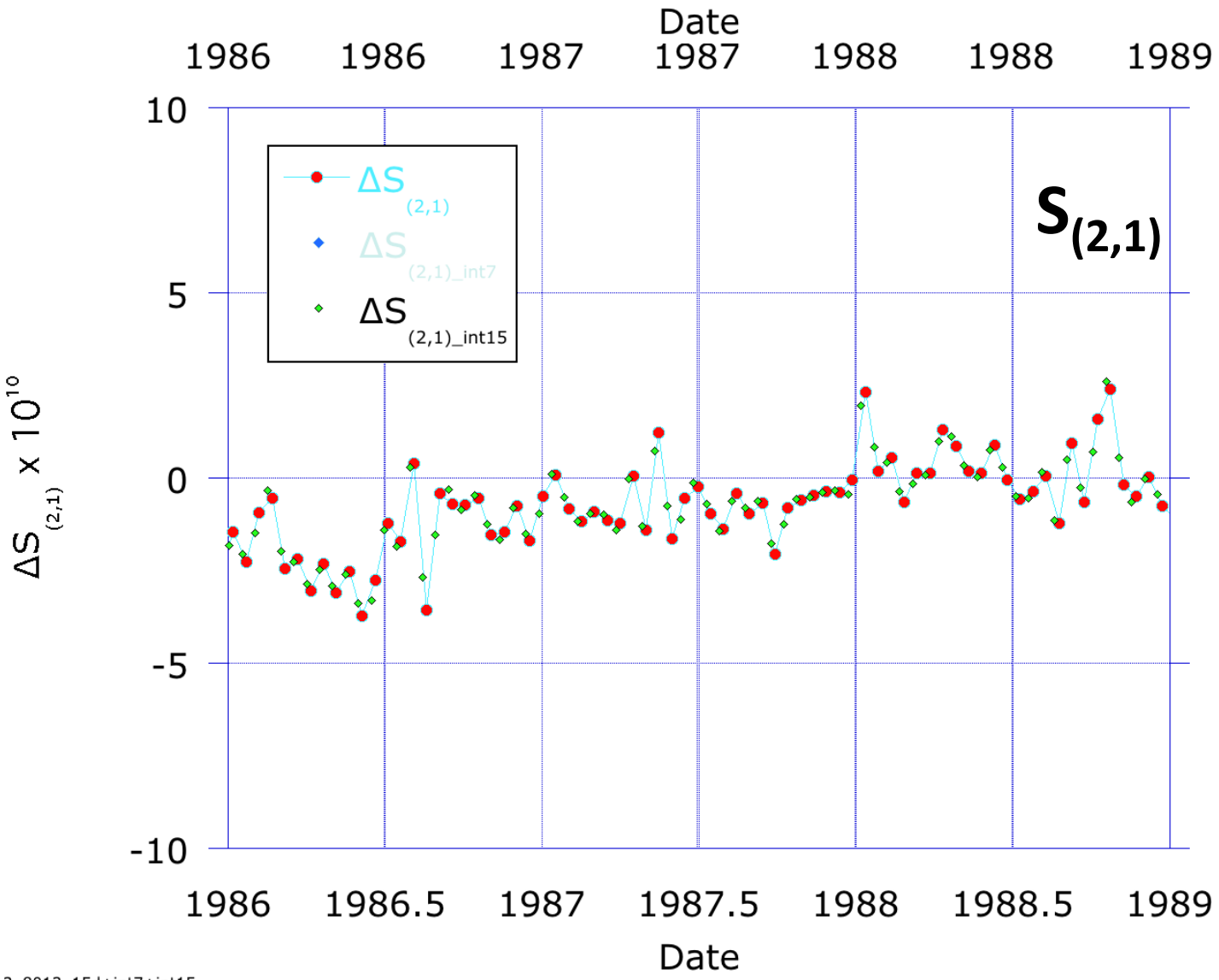


CS2012_8013_15d+int7+int15

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



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



CS2012_8013_15d+int7+int15

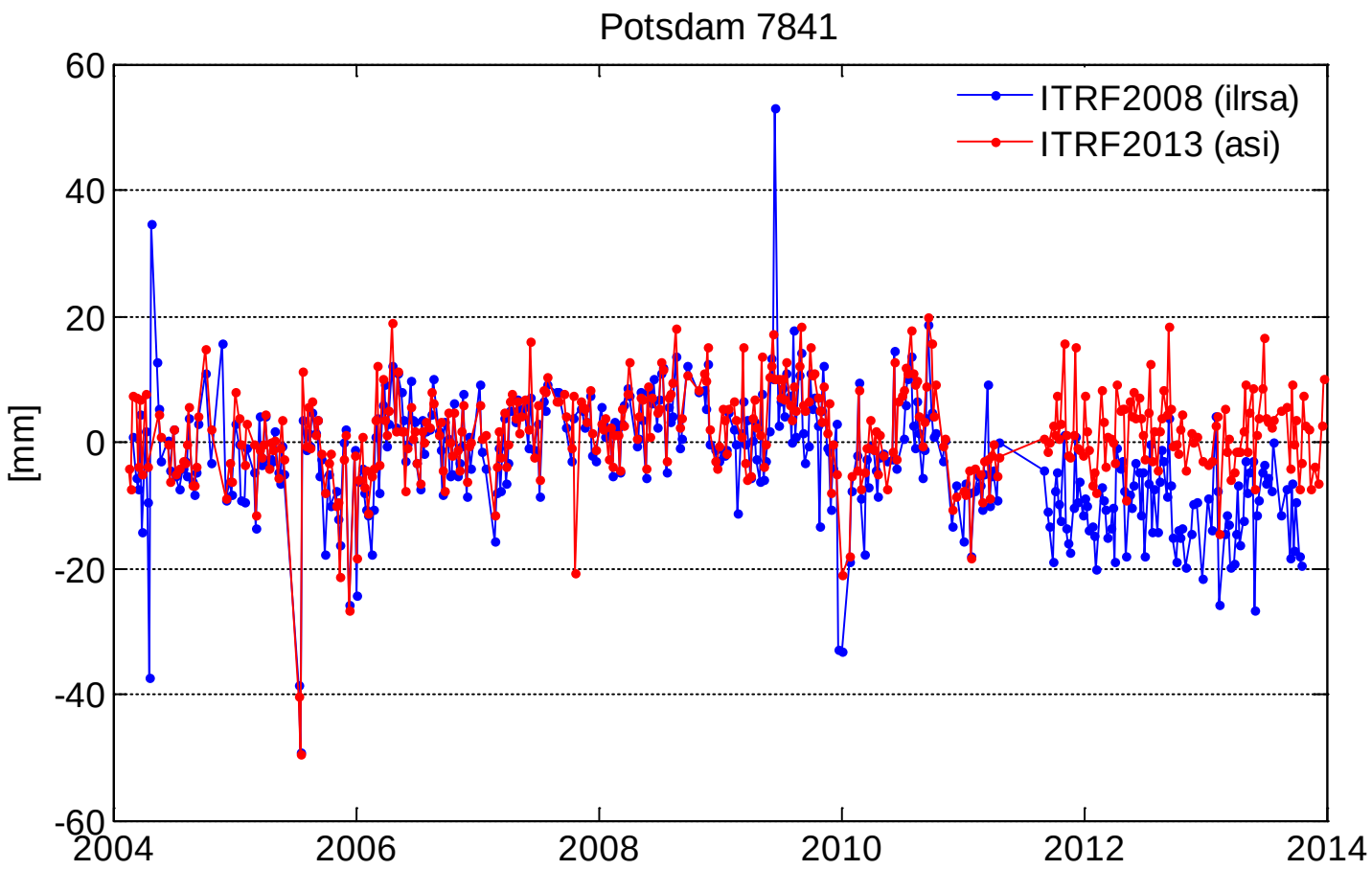
What's New in Terms of Modeling - II

- 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 geometry and optical properties of the LRA on the s/c being tracked,
    - The ranging system installed at each site,
    - The data preprocessing parameters, and
    - The mode of operation of the system
- i.e. the application of the "CoM" correction is now time-dependent and applied by s/w using look-up tables that often need updates for new sites

Pre-2013 Center of Mass Offset Correction

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



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 of which had suffered major earthquakes in recent years and some which had joined the network after the development of ITRF2008 and are not present in it.
- The majority of the updates refer to stations that were recently introduced in the network and did not exist during the development of ITRF2008 and some sites that were recently affected by earthquakes.

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

Other Modified Models

- The IERS Conventions 2010 have a Mean Pole model in the form of a polynomial that was fit to one release of the official IERS Mean Pole series (ca. 2012)

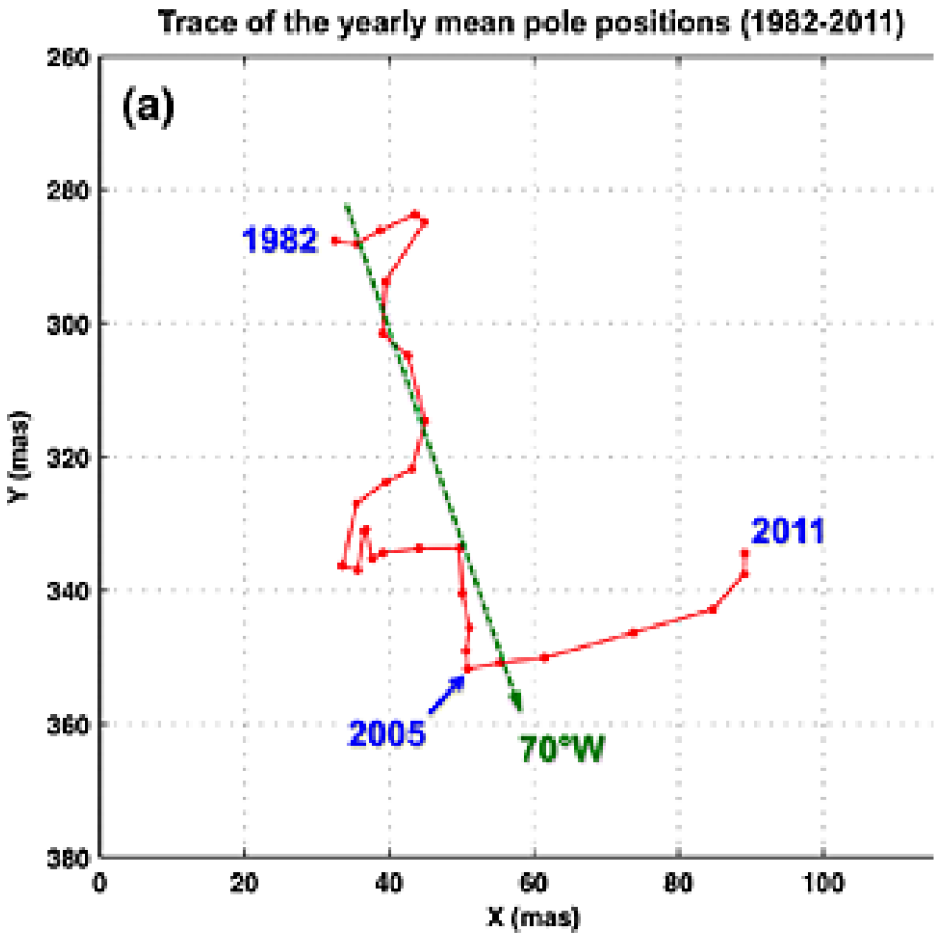
- Recent changes (ca. 2005) in the nearly linear MP motion require that we are flexible and be able to adapt the “model” to such changes as they happen, since extrapolation over many years is not adequate

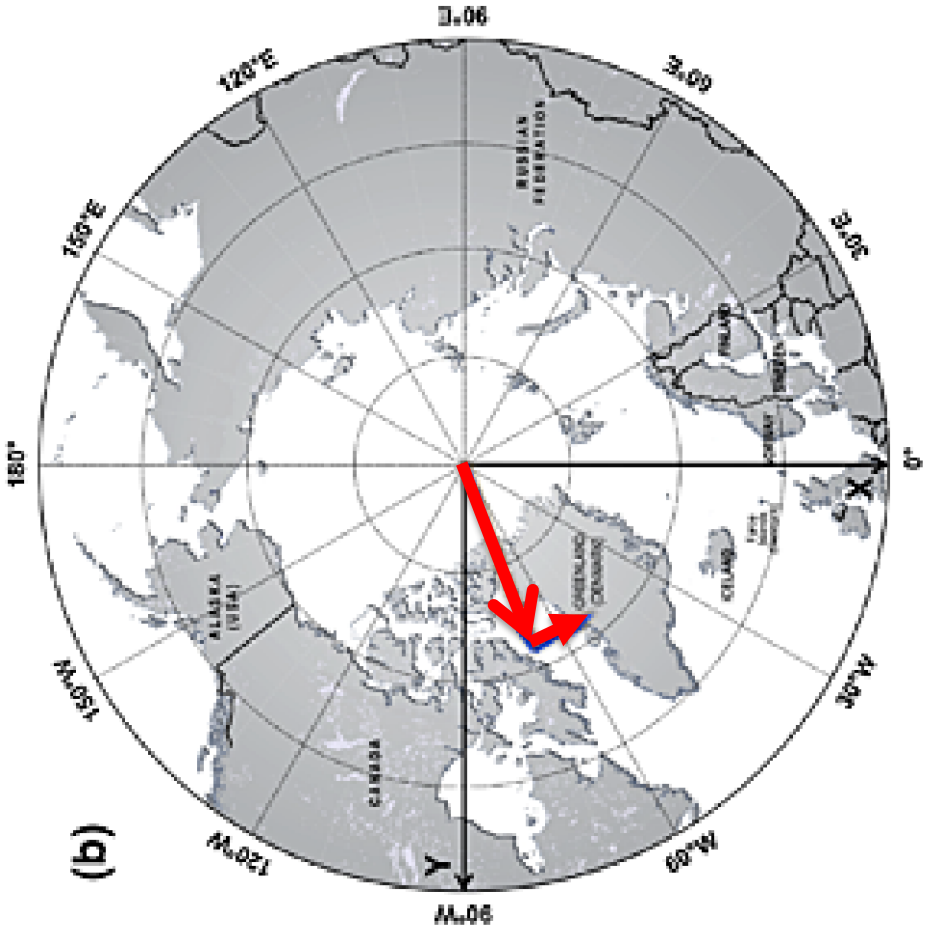
- A daily series of the MP coordinates and their rates based on the interpolated/extrapolated IERS MP series was adopted, instead of the fixed polynomial version in the IERS 2010 Conventions

Rapid ice melting drives Earth's pole to the east

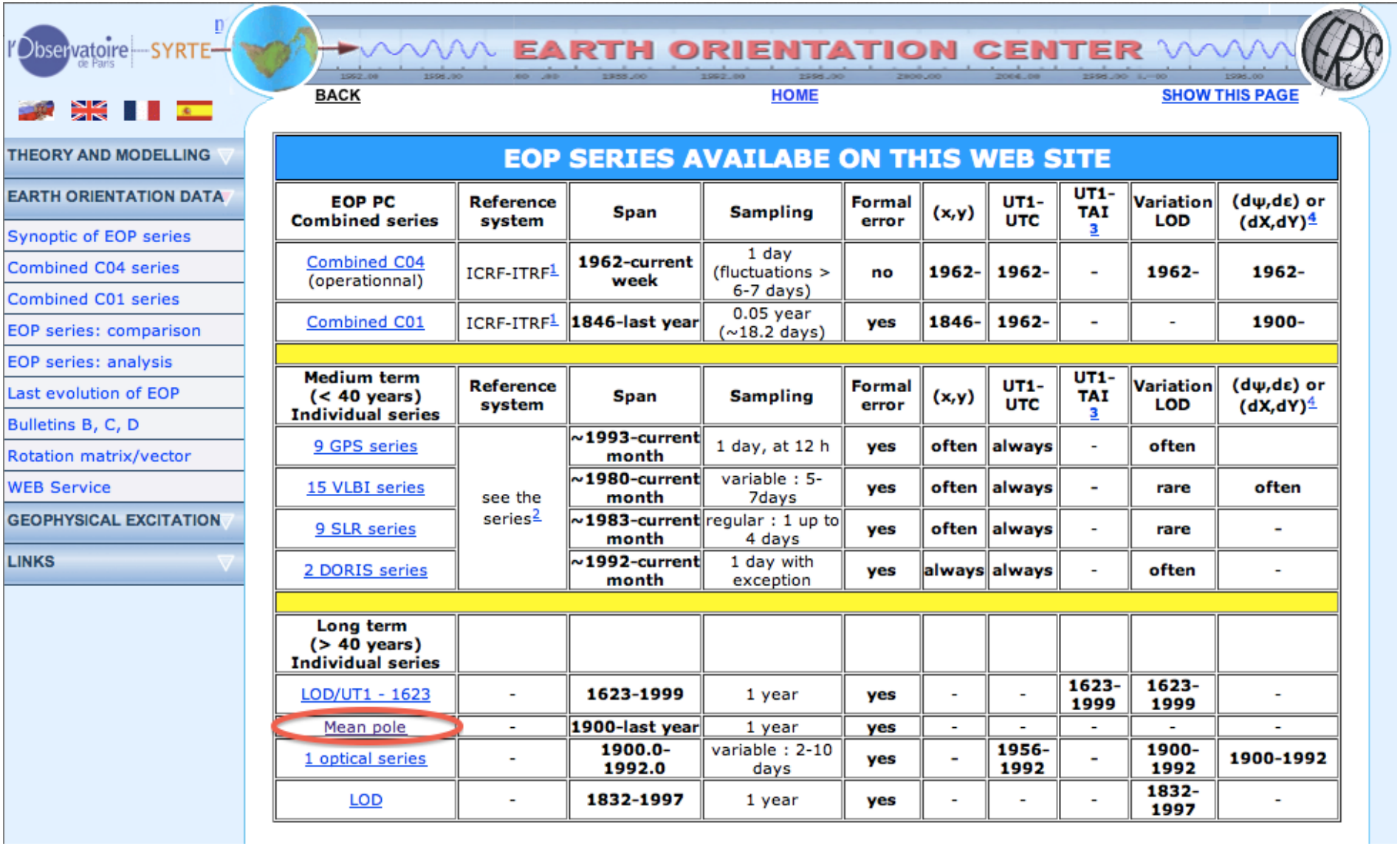
J. L. Chen[1], C. R. Wilson[1,2], J. C. Ries[1], B. D. Tapley[1]

DOI: 10.1002/grl.50552





IERS Mean Pole Series



Observatoire de Paris – SYRTE

EARTH ORIENTATION CENTER

BACK HOME SHOW THIS PAGE

THEORY AND MODELLING

EARTH ORIENTATION DATA

- Synoptic of EOP series
- Combined C04 series
- Combined C01 series
- EOP series: comparison
- EOP series: analysis
- Last evolution of EOP
- Bulletins B, C, D
- Rotation matrix/vector
- WEB Service

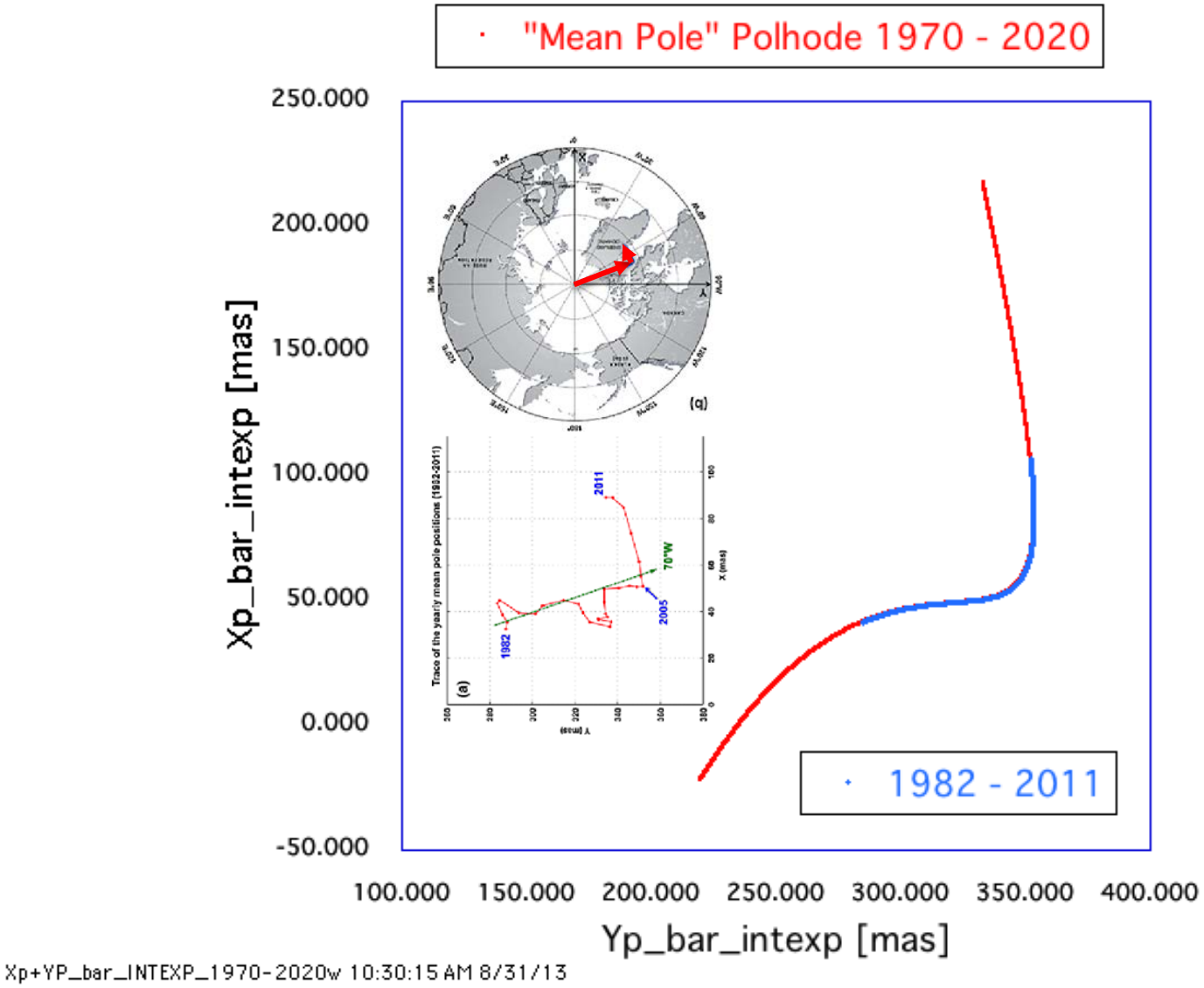
GEOPHYSICAL EXCITATION

LINKS

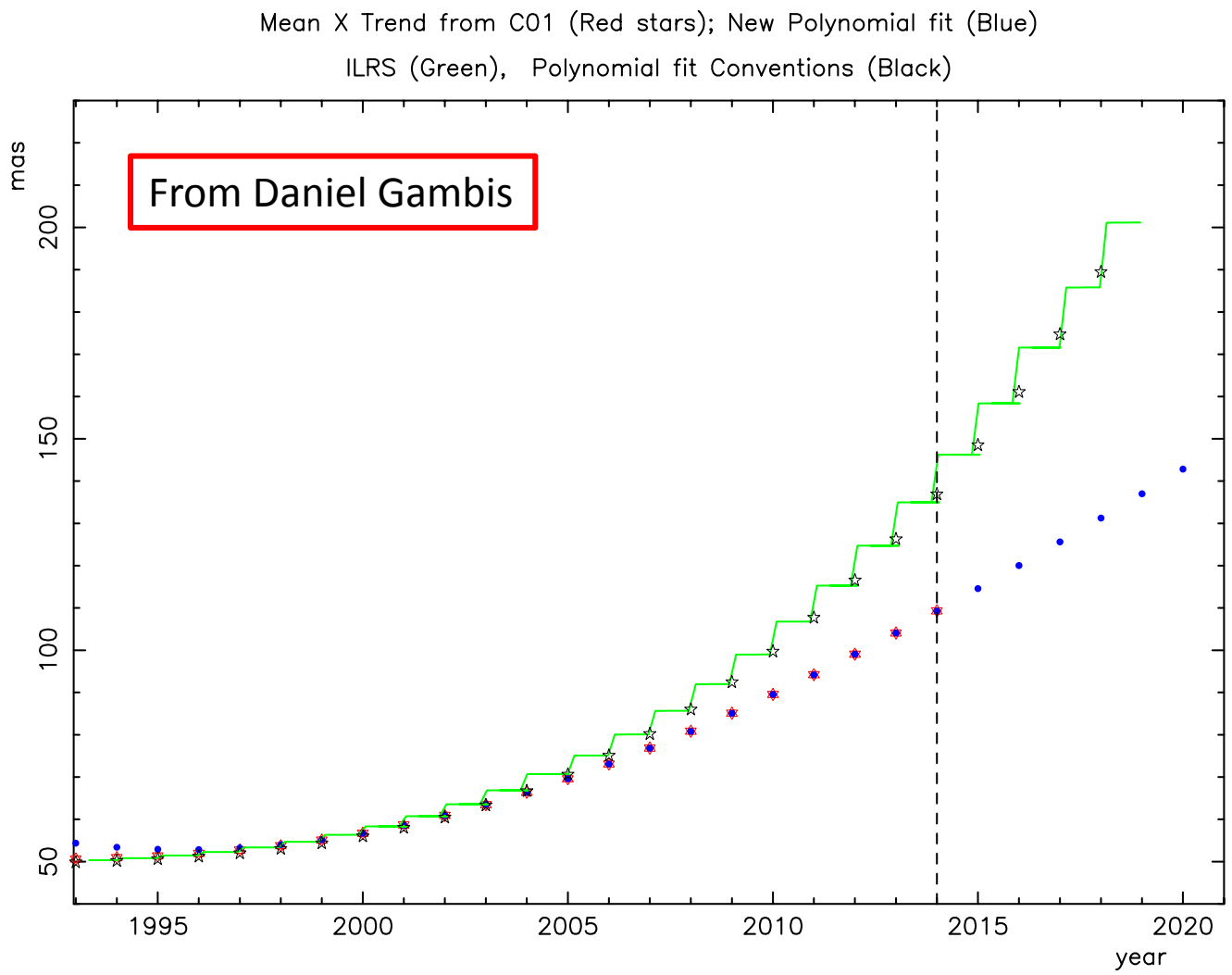
EOP SERIES AVAILABE ON THIS WEB SITE

EOP PC Combined series	Reference system	Span	Sampling	Formal error	(x,y)	UT1-UTC	UT1-TAI [3]	Variation LOD	(dψ,dε) or (dX,dY) [4]
Combined C04 (operationnal)	ICRF-ITRF [1]	1962-current week	1 day (fluctuations > 6-7 days)	no	1962-	1962-	-	1962-	1962-
Combined C01	ICRF-ITRF [1]	1846-last year	0.05 year (~18.2 days)	yes	1846-	1962-	-	-	1900-
Medium term (< 40 years) Individual series	**Reference system**	**Span**	**Sampling**	**Formal error**	**(x,y)**	**UT1-UTC**	**UT1-TAI [3]**	**Variation LOD**	**(dψ,dε) or (dX,dY) [4]**
9 GPS series	see the series [2]	~1993-current month	1 day, at 12 h	yes	often	always	-	often	
15 VLBI series		~1980-current month	variable : 5-7days	yes	often	always	-	rare	often
9 SLR series		~1983-current month	regular : 1 up to 4 days	yes	often	always	-	rare	-
2 DORIS series		~1992-current month	1 day with exception	yes	always	always	-	often	-
Long term (> 40 years) Individual series									
LOD/UT1 - 1623	-	1623-1999	1 year	yes	-	-	1623-1999	1623-1999	-
Mean pole	-	1900-last year	1 year	yes	-	-	-	-	-
1 optical series	-	1900.0-1992.0	variable : 2-10 days	yes	-	1956-1992	-	1900-1992	1900-1992
LOD	-	1832-1997	1 year	yes	-	-	-	1832-1997	-

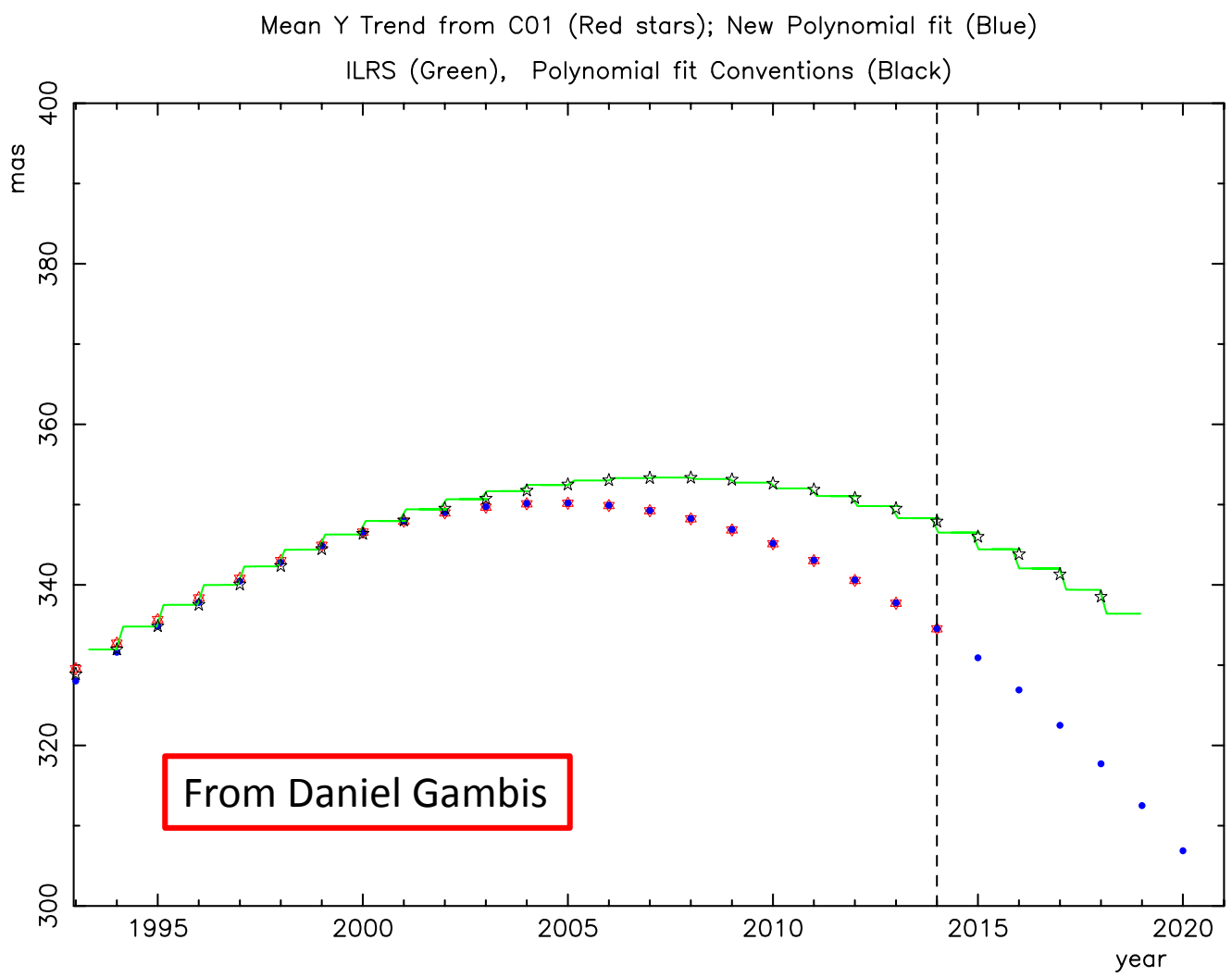
Realistic Mean Pole Model (IERS EOP Series)



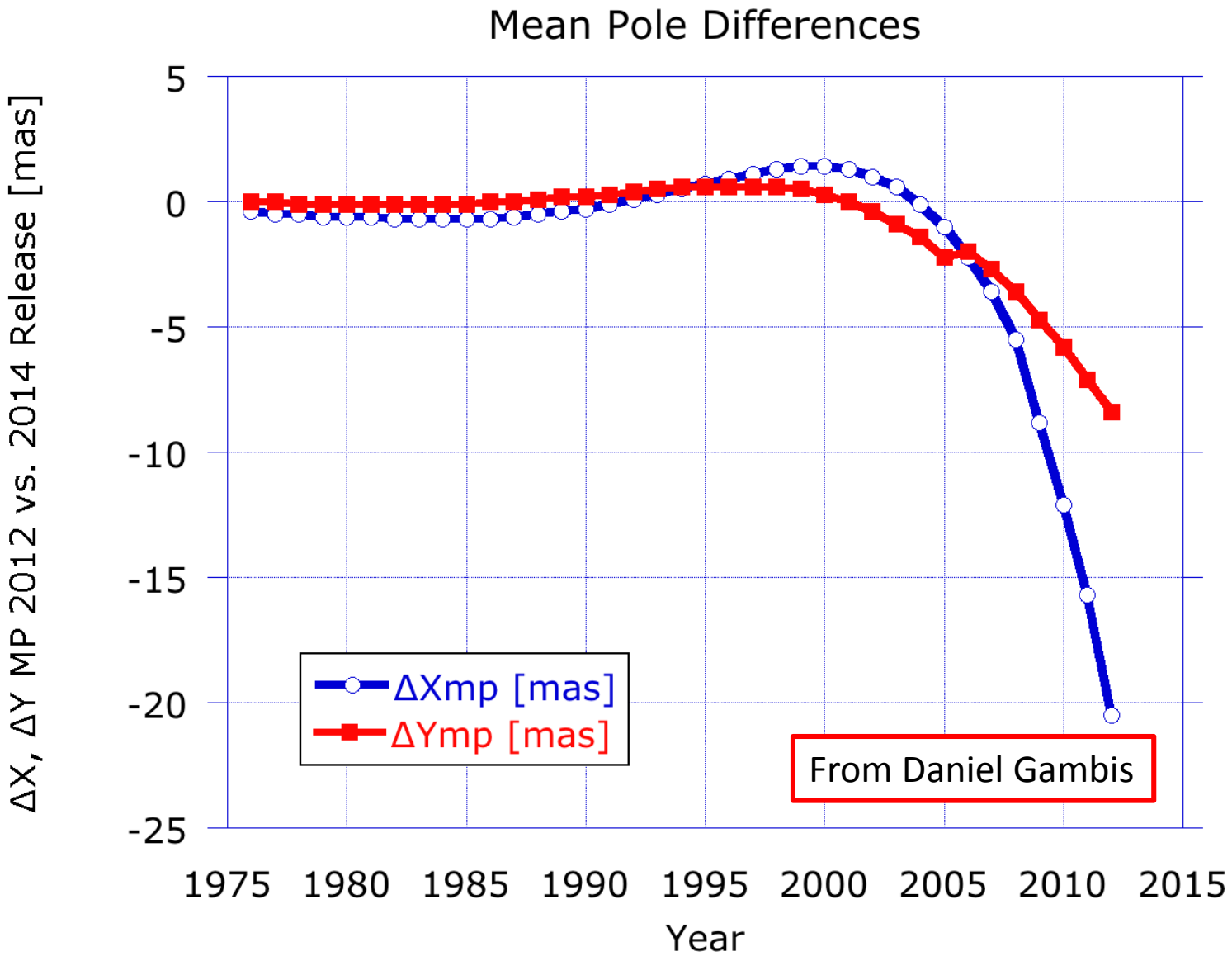
X-Mean Pole Differences: IERS Series 2012 vs 2014



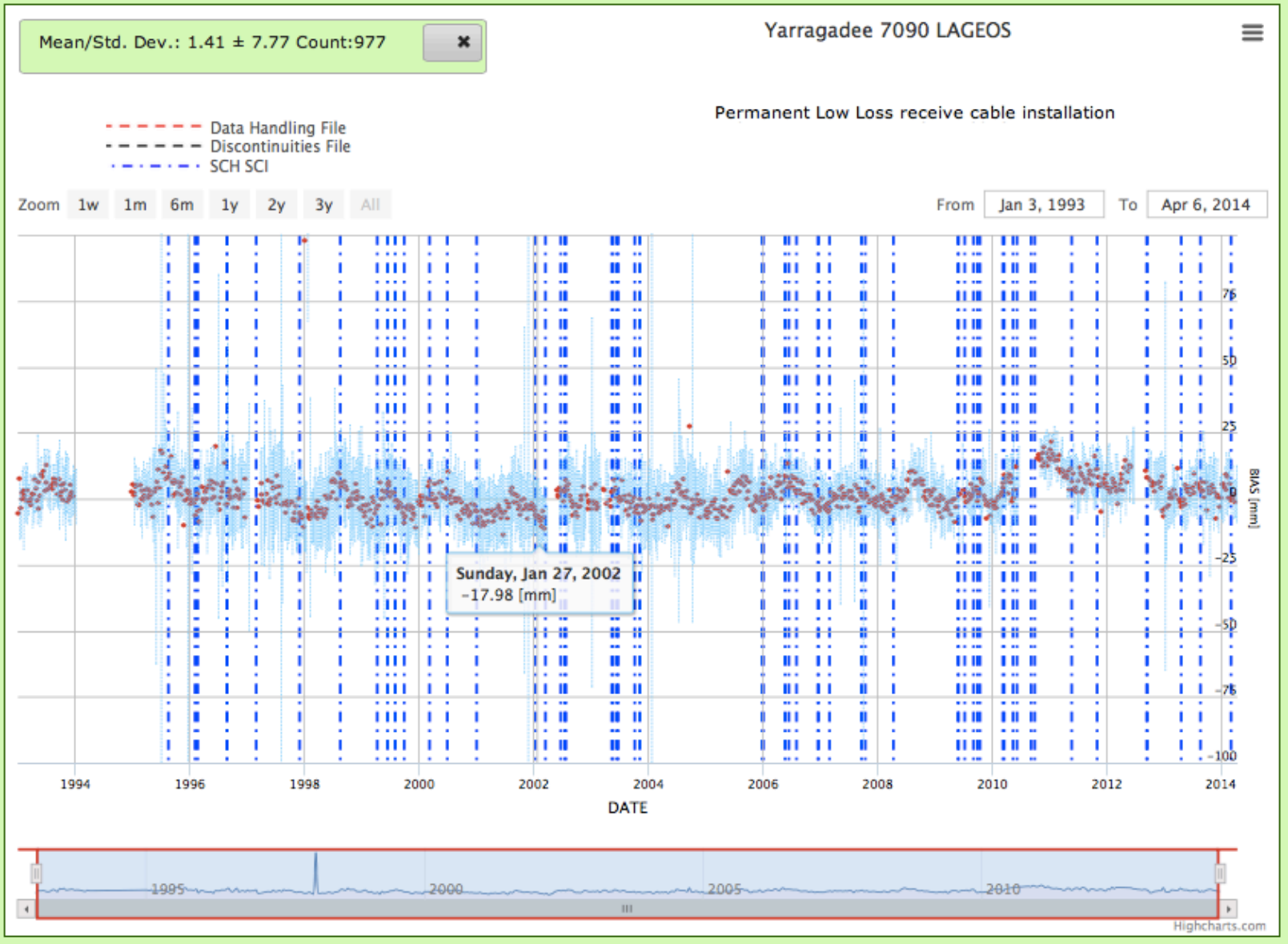
Y-Mean Pole Differences: IERS Series 2012 vs 2014



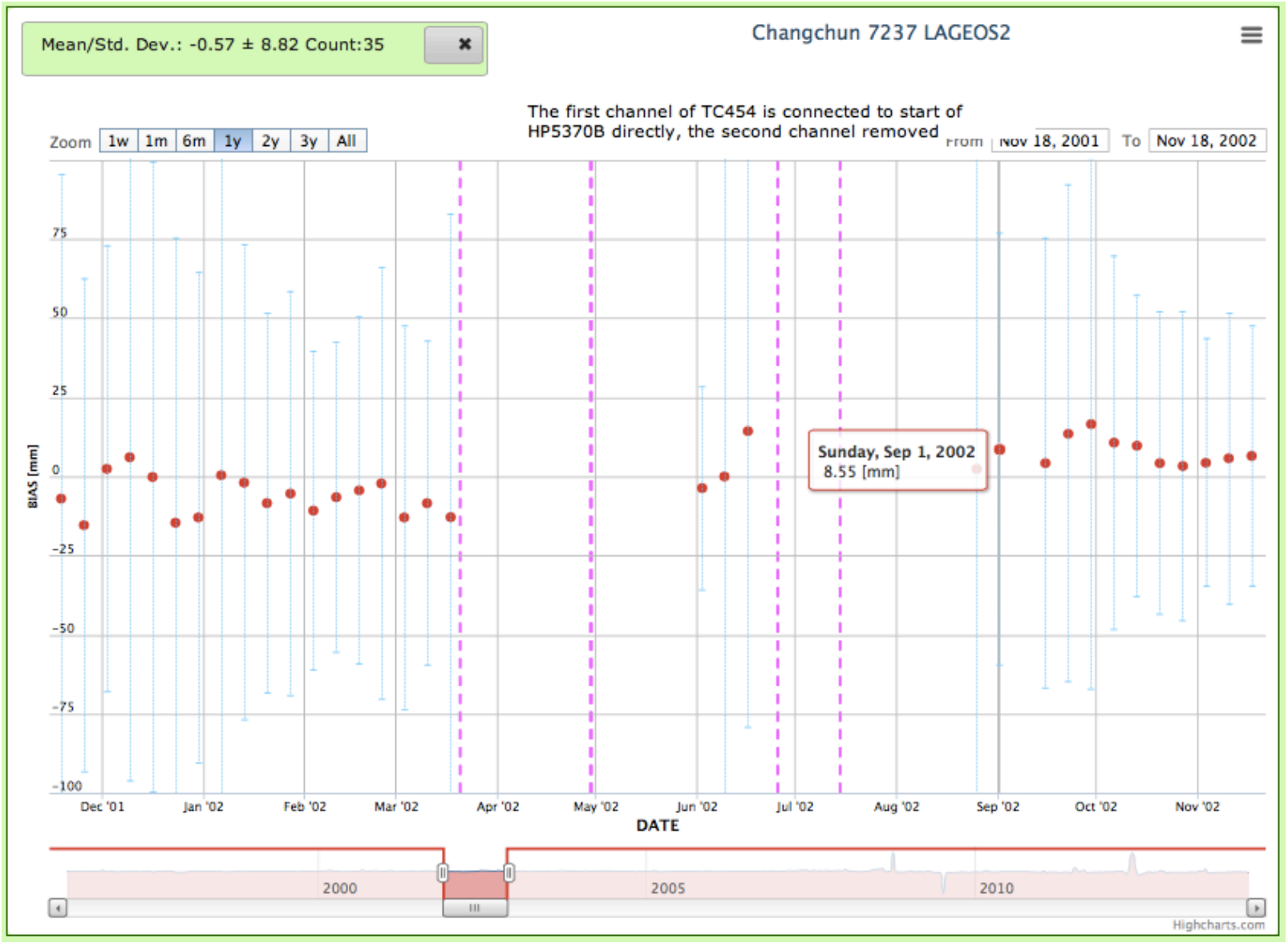
Mean Pole Differences: IERS Series 2012 vs 2014



Online Systematic Error Monitoring



Tracking of System Configuration Changes



Status of ILRS Effort for ITRF2013 Reanalysis

- New models implemented and systematic error adjustment rules strictly adhered to by all ACs
- All SLR data in the period 1993 to 2013 re-analyzed under the new standards and SINEX submitted by six (6) ACs
- The re-analysis of the 1983 to end of 1992 data set and the corresponding SINEX series delivered by fewer ACs
- One AC will deliver their contribution before the end of July
- Test combination series are developed at ASI and JCET to identify any issues with individual contributions
- A preliminary product can be delivered to ITRS soon
- Assuming no catastrophic events, final complete delivery should be at ITRS by mid-August, 2014

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
- Deliver a preliminary ILRS combination to ITRS in July and discussion of results if any adjustments are required
- ITRS will notify the ILRS AWG of any new “breaks” that they deem appropriate in the series and we will reach consensus
- If necessary, ILRS delivers selected new SINEXs from ACs and a new combination from the CCs to ITRS for the final ITRF2013 development (after we receive feedback from ITRS)

Thank you!

ILRS Data Handling File

- **http://ilrs.dgfi.badw.de/data_handling/ILRS_Data_Handling_File.snx**

```
=SNX 2.00 DGF 13:067:00000 ALL 76:120:00000 00:000:00000 L 00000 2
*-------------------------------------------------------------------------------
+FILE/REFERENCE
 RELEASE DATE        2013/03/08
 DESCRIPTION         range, time and pressure biases to be applied to SLR tracking
                     data and periods not to be used in analysis.

 INPUT               Corrections to SLR tracking data collected from
                     various tables at CDDIS and resolutions from the ILRS/AWG

 OUTPUT              ILRS SINEX file with data handling recommentations

 CONTACT             Horst Mueller <mueller@dgfi.badw.de>
 CONTACT             Margarita Vei <vei@gfz-potsdam.de>
-FILE/REFERENCE
*-------------------------------------------------------------------------------
+FILE/COMMENT

Last Updated: Mar. 08 2013  Simeiz (1873)  big range bias
              Feb. 21 2013  Zimmerwald (7810) back to standard processing
              Feb. 18 2013  Zimmerwald (7810) in quarantine due to longer break
              Jan. 08 2013  Russian stations, 1887, 1888, 1889, 1890 no longer in quarantine
              Nov. 12 2012  San Juan (7406) back to normal
              Oct. 24 2012  San Juan (7406) with big range biases since Oct. 13 2012
              Sep. 07 2012  Riga (1884) and Simeiz data released from quarantine
              Aug. 07 2012  Riga (1884) CRD data put into quarantine
              Aug. 05 2012  Monument Peak (7110) big time bias
              Jun. 15 2012  Tahiti (7124) data released from quarantine
              Jun. 05 2012  Russian stations, 1887, 1888, 1889, 1890 are in quarantaine
              May. 23 2012  Handling of Beijing data (7249), bias estimation starting 12/03/07
              May. 16 2012  reference to ILRS station upgrades file
              May. 15 2012  Tahiti (7124) put to quarantine (12/05/14), due to receiver upgrade
              Apr. 12 2012  Arequipa (7403) and Monument Peak (7110) data released from quarantine
              Mar. 14 2012  Moblas 4, Monument Peak, (7110) big range bias starting: 12/02/23
              Feb. 06 2012  Delete Observations for Haleakala (7119) 12/01/30-12/01/31
              Oct. 06 2011  Range bias estimation for 7821 (Shanghai) 11/05/28-10/09/03
              Sep. 30 2011  Problem with Matera 7941 Sep.24 18:00 - Sep.25 8:00 2011
              Sep. 21 2011  Exclude Simeiz data starting July 2011, increasing time bias
              Nov. 18 2010  mandatory Bias correction for Wettzell (starting March 2009)
              Nov. 12 2010  Bias correction for Arequipa (7403) added
              Sep. 15 2010  -20cm range bias for Haleakala July and August 2010
              Aug. 12 2010  100 ms time bias for MLRO from doy 221 to 223 2010 included
              Apr. 23 2010  corrections of errors detected by F. Deleflie
              Apr. 15 2010  all corrections from Van's tables at cddis added

*-------------------------------------------------------------------------------
```

ILRS Data Handling File (cont.)

```
+SOLUTION/DATA_HANDLING
*CODE PT_ UNIT T _DATA_START_ __DATA_END__ M __E-VALUE___ STD_DEV ___COMMENTS_____
*-------------------------------------------------------------------------------
*  list of sites with mandatory arc dependent biases to be estimated
*-------------------------------------------------------------------------------
 1864 --- mm   A 00:000:00000 00:000:00000 E
 1868 --- mm   A 00:000:00000 00:000:00000 E
 1953 --- mm   A 00:000:00000 00:000:00000 E
 7548 --- mm   A 00:000:00000 00:000:00000 E
 7308 --- mm   A 00:000:00000 00:000:00000 E
 7810 --- mm   B 00:000:00000 00:000:00000 E                    Infrared only
 7845 --- mm   A 00:000:00000 00:000:00000 E
 7403 --- ms   A 10:265:00000 00:000:00000 E                    small remaining range bias
 8834 --- mm   A 09:050:00000 00:000:00000 E                    laser problems
 7821 --- mm   A 09:148:00000 10:069:00000 E                    unknown range bias
 7249 --- mm   A 12:067:00000 00:000:00000 E                    small remaining range bias
*-------------------------------------------------------------------------------
*  list of mandatory range biases to be applied on observation (ILRS/AWG Oct 2007)
*  with updates from ILRS/AWG reprocessing results
*-------------------------------------------------------------------------------
 1873 --- mm   A 95:001:00000 00:001:00000 R      -270.00
 7080 --- mm   A 88:001:00000 89:349:00000 R       -40.00
 7080 --- mm   A 90:094:00000 93:031:00000 R        25.00         source CDDIS
 7080 --- mB   A 95:065:00000 96:026:00000 P        -2.10         source CDDIS
 7080 --- mB   A 96:026:00000 96:116:00000 P       -10.30         source CDDIS
 7080 --- mB   A 96:116:00000 96:130:00000 P        -9.70         source CDDIS
 7109 --- mm   A 00:000:00000 88:347:00000 R        10.00         ILRS/AWG 09/05/06
 7109 --- mm   A 97:009:00000 97:018:00000 R       164.90         source CDDIS
 7110 --- mm   A 84:001:00000 84:136:00000 R        30.00
 7110 --- mm   A 87:300:00000 88:025:00000 R        30.00
 7110 --- mm   A 96:240:00000 96:277:00000 R       163.60         source CDDIS
 7122 --- mm   A 84:122:00000 87:074:00000 R        30.00
 7123 --- mm   A 87:195:00000 87:282:00000 R       -30.00         source CDDIS
```

ILRS Data Handling File (cont.)

```
*-------------------------------------------------------------------------------
*   list of data to be deleted
*-------------------------------------------------------------------------------
 1863 ---      A 00:000:00000 94:001:00000 X
 1864 ---      A 02:070:00000 02:101:00000 X
 1873 ---      A 00:000:00000 95:001:00000 X
 1873 ---      A 11:182:00000 12:153:00000 X                    increasing time bias
 1873 ---      A 13:056:00000 13:064:00000 X                    big range bias
 1884 ---      A 00:000:00000 94:212:00000 X
 1893 ---      A 00:000:00000 98:001:00000 X
 7105 ---      A 99:119:18000 99:122:52740 X
 7105 ---      A 06:336:18000 06:342:10800 X                    Time unit fail
 7110 ---      A 12:054:00000 12:081:00000 X                    large range bias
 7110 ---      A 12:214:10000 12:216:57600 X                    big time bias (100 msec)
 7112 ---      A 00:000:00000 85:001:00000 X
 7119 ---      A 10:182:00000 10:273:86400 X                    uncorrected range bias
 7119 ---      A 12:030:70800 12:031:00900 X                    Wrong Pressure Reading
 7123 ---      A 88:238:00000 88:248:00000 X                    3m range bias
 7123 ---      A 93:132:00000 93:132:86400 X                    > 500m range bias
 7124 ---      A 02:122:00000 02:183:63240 X                    bias, translator not used
 7236 ---      A 00:000:00000 98:001:00000 X
 7237 ---      A 00:000:00000 96:001:00000 X
 7249 ---      A 00:000:00000 99:001:00000 X
 7249 ---      A 99:011:64898 99:215:00000 X                    at 100's level unrecov. biases
 7249 ---      A 12:001:00000 12:066:00000 X                    bias problems after system upgrade
 7355 ---      A 00:000:00000 03:001:00000 X
 7355 ---      A 04:001:00000 00:000:00000 X
 7403 ---      A 01:175:73994 01:266:00000 X                    Earth quake
 7403 ---      A 11:293:00000 11:365:00000 X                    data problems
 7406 ---      A 12:287:00000 12:307:00000 X                    big range bias > 2.5 m
 7510 ---      A 92:175:00000 92:274:00000 X
```

ILRS Data Handling File (cont.)

```
*=============================================================================
*  list of data corrections converted from CDDIS data base (Van Husson's tables)
*-----------------------------------------------------------------------------
 1864 --- mB   A 90:270:00000 00:359:00000 P      -6.8     1.0
 1868 --- mm   A 99:319:37380 99:319:69060 R    1500.00    15.
 1884 --- mm   A 94:213:00000 97:244:00000 R     -75.0
 1884 L51 mm   A 99:214:70680 99:214:74280 R    -5650.0    30.0   unstable range bias
 1884 L51 mm   A 99:215:78780 99:217:03660 R    -4150.0    30.0   unstable range bias
 1884 L51 mm   A 99:217:68940 99:217:85140 R    -5650.0    30.0   unstable range bias
 1884 L51 mm   A 99:219:71520 99:219:75120 R    -4150.0    30.0   unstable range bias
 1884 L51 mm   A 99:219:84420 99:219:88020 R    -5650.0    30.0   unstable range bias
 7090 --- ms   A 98:355:00000 98:355:86400 T     0.3875
 7105 L51 mm   A 99:339:23505 99:339:27105 R    -9221.0    20.0   frozen pressure
 7105 --- mB   A 99:058:21180 99:058:37180 P      -2.00     1.0   frozen pressure
 7105 L52 mB   A 99:038:09540 99:038:13140 P      -4.00     1.0   frozen pressure
 7105 L52 mB   A 99:060:34860 99:060:53100 P      021.0     1.0   frozen pressure
 7109 --- ms   A 97:009:00000 97:012:00000 T      -.0024          clock drift
 7109 --- ms   A 97:012:00000 97:015:00000 T      -.0025          clock drift
 7109 --- ms   A 97:015:00000 97:018:00000 T      -.0026          clock drift
 7110 L52 mm   A 99:004:68700 99:004:72300 R   15548.00     2.0
 7110 --- mm   A 03:143:00000 03:191:46800 R   -2.90000     .10
 7210 --- ms   A 94:347:00000 94:347:86400 T      .0015          stat. clock drift
 7210 --- ms   A 99:210:00000 99:211:00000 T      -.0124          SLRmails #0396,#0398
 7210 --- ms   A 99:211:00000 99:215:00000 T      -.0154          SLRmails #0396,#0398
 7210 --- ms   A 99:215:00000 99:216:00000 T      -.0269          SLRmails #0396,#0398
 7210 --- ms   A 99:216:00000 99:217:00000 T      -.0308          SLRmails #0396,#0398
 7237 L51 mm   A 99:291:34500 99:291:38100 R      995.0    15.0   miss calibrated
 7237 L51 mm   A 99:291:71460 99:291:75060 R      995.0    15.0   miss calibrated
 7237 L51 mm   A 99:299:70140 99:299:73740 R      995.0    15.0   miss calibrated
 7237 L51 mm   A 99:308:51500 99:308:55100 R     -995.0    15.0   miss calibrated
```