Analysis-assessed SLR Range biases

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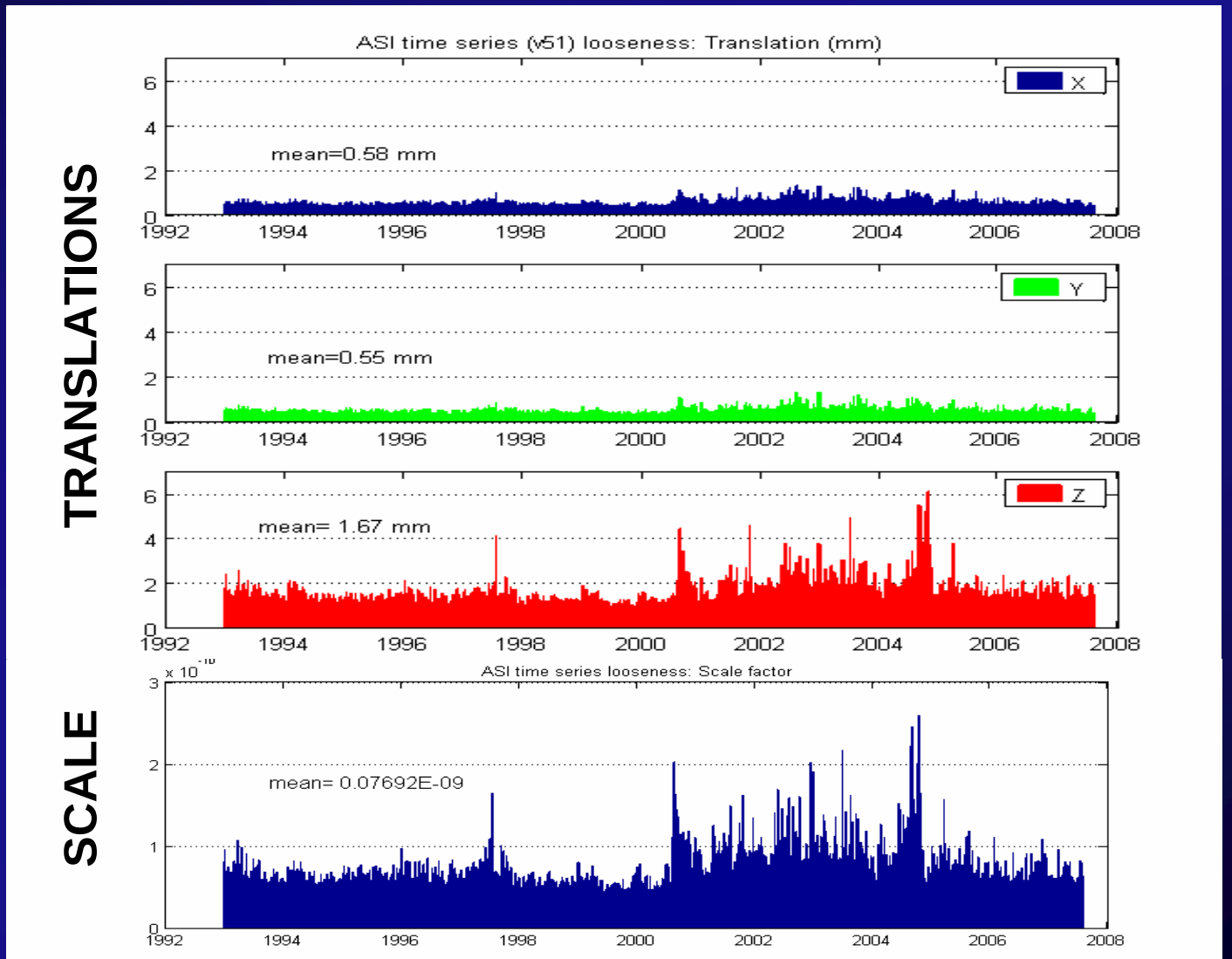
SLR biases

- SLR is a clean, absolute ranging technique with essentially ***two types of bias*** due to errors at the stations e.g. calibration and/or synchronization issues, hardware malfunctioning:
  - time biases, and
  - range biases
- The range bias is the most critical, being highly correlated with height over short periods
- The presence of intermittent biases can introduce jumps in the coordinate time series

SLR sensitivity to the TRF datum



ILRS range bias information sources

(1) Engineering bias report from CDDIS database and from the stations through SLRMail

(2) Rapid, daily bias analysis report from the ILRS ACs

(3) Bias time series estimated from a multi-year solution

Daily Bias Report Example: JCET

#7090 Yarragadee 50107M001

# STA ID YY/MM/DD HH:MM SAT	A	GOOD OBS	RAW RMS [mm]	PREC EST [mm]	RANGE BIAS [mm]	RANGE BIAS SIGMA [mm]	TIME BIAS [us]	TIME BIAS SIGMA [us]	PASS DUR [MIN]	EDIT OBS	CALIB+ MEAN [mm]		CALIB SDEV [mm]	CALIB++ SHIFT [mm]		STPASS RMS [mm]	TEMP [K]	HUM %	PRES [hPa]	WLEN [nm]	S C H	S I	D F	ELEVATION MAX [degrees]	ELEVATION MIN [degrees]
70900513 7/11/26 07:50 A1		9	9.0	7.9	4.8	15.1	-53.2	3.1	12	0	15856	E	5	1	P	13	304.2	33.0	982.5	532.0	1	2	0	34.3	17.6
70900513 7/11/26 09:52 A1		13	27.5	4.4	25.6	11.5	-14.8	2.8	13	0	15855	E	5	-1	P	15	301.6	30.0	983.0	532.0	1	2	0	48.7	18.3
70900513 7/11/26 11:33 L1		9	15.9	8.3	-13.5	7.2	-3.9	1.9	14	0	15853	E	5	-2	P	7	296.8	42.0	983.9	532.0	1	2	0	36.5	32.1
70900513 7/11/26 11:58 A1		15	78.3	7.1	78.6	20.0	14.4	4.2	8	0	15853	E	5	-2	P	13	295.6	50.0	984.1	532.0	1	2	0	21.9	15.9
70900513 7/11/26 14:03 A1		17	144.7	9.6	144.9	22.0	21.2	4.4	7	0	15848	E	4	0	P	14	292.7	62.0	984.4	532.0	1	2	0	21.5	15.7
70900513 7/11/26 14:21 S1		5	927.3	40.4	-945.9	209.2	-24.1	41.4	1	0	15848	E	4	0	P	9	292.5	62.0	984.3	532.0	1	2	0	18.9	17.5
70900513 7/11/26 14:49 L1		15	13.4	3.5	14.5	3.5	-4.9	1.2	44	0	15849	E	4	0	P	9	291.7	61.7	983.8	532.0	1	2	0	59.5	19.7
70900513 7/11/26 15:43 L2		6	45.9	7.3	-45.3	7.5	-0.1	2.2	9	0	15849	E	4	0	P	9	291.8	59.0	983.7	532.0	1	2	0	37.9	19.5
70900513 7/11/26 16:04 A1		3	14.6	3.7	-8.2	44.9	0.6	8.7	0	0	15849	E	4	0	P	18	291.6	58.0	983.4	532.0	1	2	0	20.3	16.6
70900513 7/11/26 16:07 S1		22	191.3	89.0	163.7	42.4	121.1	21.3	10	0	15849	E	4	0	P	9	291.7	58.0	983.3	532.0	1	2	0	84.9	17.5
70900513 7/11/26 16:21 L2		6	20.9	5.4	20.2	6.0	0.8	2.1	12	1	15849	E	4	0	P	9	291.6	57.0	983.3	532.0	1	2	0	55.0	27.8
70900513 7/11/26 17:59 S1		11	378.4	75.9	378.1	182.9	142.5	28.9	4	0	15848	E	4	0	P	9	291.1	55.0	982.6	532.0	1	2	0	23.5	18.8
70900513 7/11/26 18:06 A1		29	104.0	28.0	-98.6	16.3	25.5	3.7	13	0	15848	E	4	0	P	13	291.0	55.0	982.7	532.0	1	2	0	47.0	16.8
70900513 7/11/26 18:28 L1		7	49.7	3.3	49.6	8.7	0.2	1.9	11	0	15848	E	4	0	P	8	290.8	56.0	982.5	532.0	1	2	0	20.3	17.5
70900513 7/11/26 19:23 E1		3	203.7	2.4	203.7	1043.2	-0.0	7.9	7	0	24376	E	6	3	P	20	289.8	57.0	982.4	532.0	1	2	0	56.9	52.6
70900513 7/11/26 19:44 E2		3	4075.7	166.0	4072.2	6539.8	-0.1	117.6	6	0	24376	E	6	3	P	26	289.6	59.0	982.3	532.0	1	2	0	42.0	40.2
70900513 7/11/26 19:59 L2		25	30.9	4.6	30.6	4.8	-3.2	1.9	46	0	15849	E	4	0	P	9	289.3	60.5	982.5	532.0	1	2	0	46.9	21.8
70900513 7/11/26 20:59 E1		4	127.6	4.5	127.5	1024.6	0.0	7.9	13	0	24382	E	6	-2	P	23	289.7	63.0	982.8	532.0	1	2	0	55.8	48.8
70900513 7/11/26 21:23 E2		3	7234.5	105.7	7233.5	5783.5	0.5	117.6	6	0	24382	E	6	-2	P	20	290.6	63.0	983.0	532.0	1	2	0	64.8	64.4
70900513 7/11/26 21:33 L1		5	35.4	12.6	31.7	7.0	13.9	1.5	33	0	15851	E	4	-2	P	8	291.7	56.0	983.1	532.0	1	2	0	28.4	19.7
70900513 7/11/26 23:33 S1		9	236.1	48.3	-231.6	133.9	-91.6	27.1	6	0	15851	E	4	1	P	8	296.0	37.0	983.4	532.0	1	2	0	46.8	18.0

#7237 Changchun 21611S001

# STA ID YY/MM/DD HH:MM SAT	A	GOOD OBS	RAW RMS [mm]	PREC EST [mm]	RANGE BIAS [mm]	RANGE BIAS SIGMA [mm]	TIME BIAS [us]	TIME BIAS SIGMA [us]	PASS DUR [MIN]	EDIT OBS	CALIB+ MEAN [mm]		CALIB SDEV [mm]	CALIB++ SHIFT [mm]		STPASS RMS [mm]	TEMP [K]	HUM %	PRES [hPa]	WLEN [nm]	S C H	S I	D F	ELEVATION MAX [degrees]	ELEVATION MIN [degrees]
72371901 7/11/26 08:49 L1		4	20.3	11.0	-20.3	6.6	5.0	1.8	14	0	9842	E	15	0	P	22	270.0	50.0	991.5	532.0	0	8	0	51.6	26.7
72371901 7/11/26 10:25 S1		9	521.7	76.0	493.8	75.1	124.9	20.6	4	0	9842	E	15	0	P	12	265.9	54.0	991.4	532.0	0	8	0	75.5	27.1
72371901 7/11/26 11:12 L2		7	39.7	14.8	36.8	4.8	-3.0	2.0	16	1	9842	E	15	0	P	18	265.2	56.0	991.2	532.0	0	8	0	79.9	34.6
72371901 7/11/26 12:07 L1		6	55.1	6.0	54.8	4.5	0.7	1.9	8	0	9842	E	15	0	P	15	264.9	59.0	991.0	532.0	0	8	0	66.2	51.5
72371901 7/11/26 12:18 S1		5	431.2	140.5	361.7	203.6	-72.2	43.4	1	0	9842	E	15	0	P	24	264.8	59.0	991.0	532.0	0	8	0	23.5	19.8
72371901 7/11/26 20:30 A1		13	34.9	15.8	32.9	16.7	34.2	4.4	6	0	9848	E	17	0	P	15	263.1	75.0	987.1	532.0	0	8	0	52.7	21.4

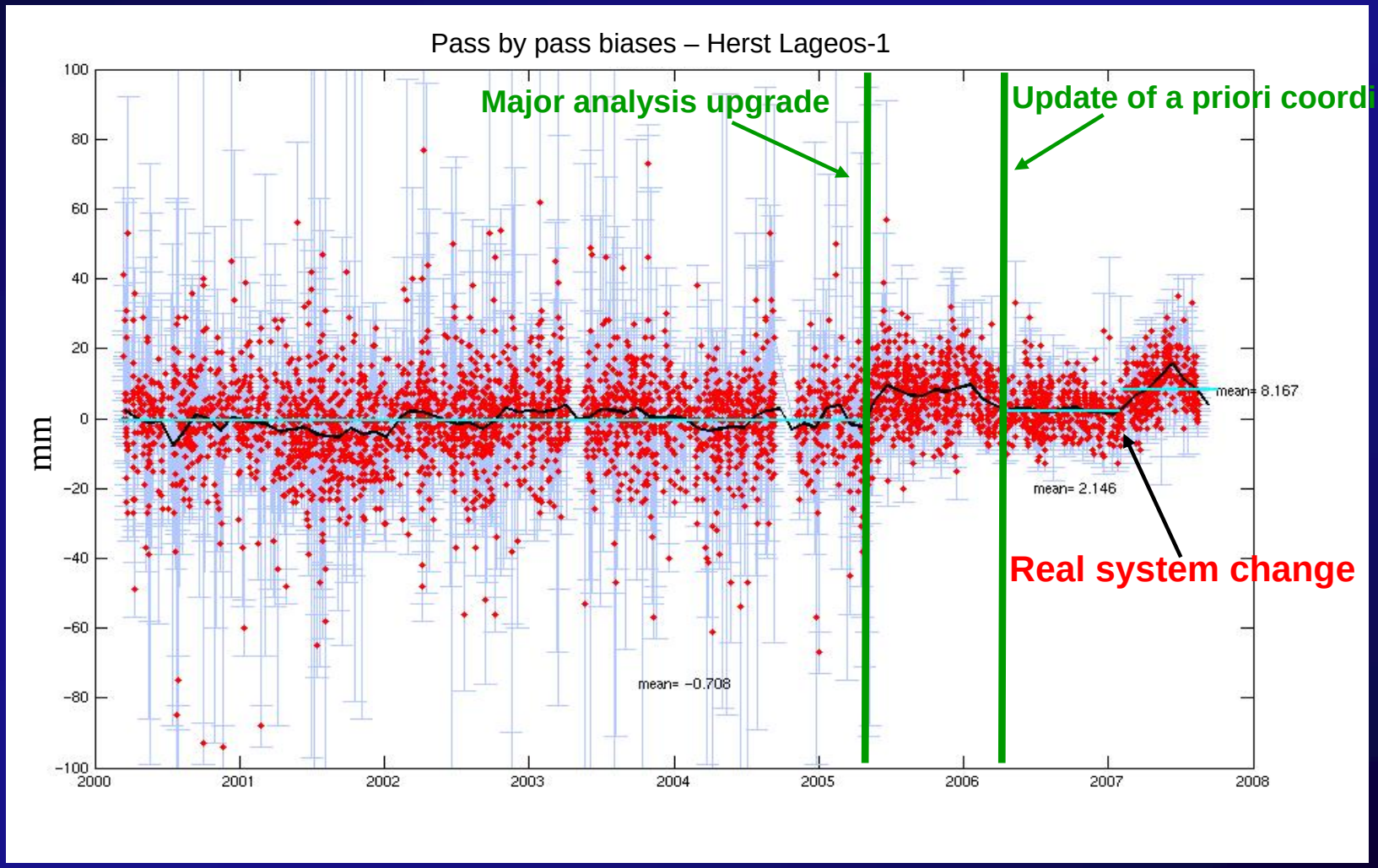
#7249 Beijing 21601S004

# STA ID YY/MM/DD HH:MM SAT	A	GOOD OBS	RAW RMS [mm]	PREC EST [mm]	RANGE BIAS [mm]	RANGE BIAS SIGMA [mm]	TIME BIAS [us]	TIME BIAS SIGMA [us]	PASS DUR [MIN]	EDIT OBS	CALIB+ MEAN [mm]		CALIB SDEV [mm]	CALIB++ SHIFT [mm]		STPASS RMS [mm]	TEMP [K]	HUM %	PRES [hPa]	WLEN [nm]	S C H	S I	D F	ELEVATION MAX [degrees]	ELEVATION MIN [degrees]
72496101 7/11/26 10:24 S1		17	112.3	65.7	75.1	100.4	173.3	16.6	7	0	17984	E	10	0	P	11	276.0	35.0	1017.9	532.0	2	3	0	56.7	24.1
72496101 7/11/26 11:11 L2		21	20.8	8.2	-19.1	3.0	-12.5	1.3	38	0	17984	E	10	0	P	12	275.5	40.0	1017.9	532.0	2	3	0	74.4	32.2
72496101 7/11/26 12:03 L1		5	22.3	10.9	19.5	4.5	1.5	2.0	9	0	17984	E	10	0	P	12	275.2	40.0	1017.5	532.0	2	3	0	72.8	45.4
72496101 7/11/26 12:13 S1		16	508.2	142.8	468.5	108.0	223.7	17.0	8	0	17984	E	10	0	P	11	273.7	47.0	1017.2	532.0	2	3	0	49.7	18.8
72496101 7/11/26 15:13 L2		16	70.5	10.3	69.8	5.4	-3.1	1.5	33	0	17984	E	9	0	P	15	274.2	36.0	1016.8	532.0	2	3	0	41.4	25.2
72496101 7/11/26 20:28 A1		26	82.7	16.2	80.7	14.7	41.7	3.6	12	0	17969	E	6	0	P	21	274.8	30.0	1014.8	532.0	2	3	0	44.9	15.3

#7403 Arequipa 42202M003

# STA ID YY/MM/DD HH:MM SAT	A	GOOD OBS	RAW RMS [mm]	PREC EST [mm]	RANGE BIAS [mm]	RANGE BIAS SIGMA [mm]	TIME BIAS [us]	TIME BIAS SIGMA [us]	PASS DUR [MIN]	EDIT OBS	CALIB+ MEAN [mm]		CALIB SDEV [mm]	CALIB++ SHIFT [mm]		STPASS RMS [mm]	TEMP [K]	HUM %	PRES [hPa]	WLEN [nm]	S C H	S I	D F	ELEVATION MAX [degrees]	ELEVATION MIN [degrees]
74031304 7/11/26 13:15 S1		5	707.6	70.6	-697.1	150.7	-26.2	27.4	3	0	3432	E	5	3	P	7	292.8	25.0	762.2	532.0	1	8	0	47.9	23.2
74031304 7/11/26 13:35 L2		4	36.1	17.8	-31.4	5.0	1.4	2.2	6	1	3432	E	5	3	P	6	293.6	24.0	762.2	532.0	1	8	0	63.9	57.7
74031304 7/11/26 14:06 L1		1	---------	---------	----------	---------	------	------	----	0	3432	E	5	3	P	1	294.3	19.0	762.1	532.0	1	8	0	42.5	42.5
74031304 7/11/26 19:23 A1		7	298.4	13.1	294.3	22.4	-9.1	5.4	4	0	3434	E	5	-2	P	7	295.8	26.0	760.2	532.0	1	8	0	40.1	34.4

Daily Bias Report Example: HIT-U



Weekly Mean Bias Report

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********************************************************************************
SLR Electronic Report      Wed Nov 21 14:15:04 CET 2007       Message No. 8995
********************************************************************************
Author: Werner Gurtner
Subject: ILRS Combined Range Bias Report 21-Nov-2007


                    ILRS Combined Range Bias Report
                    *******************************

                  2007-11-07 00:00 UT - 2007-11-21 00:00 UT

                  Compiled by: SLR Observatory Zimmerwald
                  Date       : 2007-11-21 12:30 UT
                  E-Mail     : Werner.Gurtner@aiub.unibe.ch
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1 2 3 4 5

7090 YARL Yarragadee			DGFI		MCC		HIT-U		SAO		JCET	
	sc	wl	rb	pr	rb	pr	rb	pr	rb	pr	rb	pr
7090 2007-11-11 01:42 L1		532	-10	4	-6	2	15	2	-8	3	25	8
7090 2007-11-11 02:31 L2		532	-2	4	13	1	16	3	-17	4	21	8
7090 2007-11-11 14:13 L1		532	7	4	0	2	14	2	-20	0	29	5
7090 2007-11-11 16:07 L2		532	7	3	5	2	10	2	-10	3	11	9
7090 2007-11-11 17:44 L1		532	43	4	11	2	5	2	6	1	42	4
7090 2007-11-11 20:12 L2		532	-7	3	-1	1	8	2	13	3	17	5
7090 2007-11-11 21:12 L1		532	13	4	4	3	9	3	-5	2	55	4
7090 2007-11-12 00:30 L1		532	-6	3	-5	2	10	2	-10	4	11	6
7090 2007-11-12 00:48 L2		532	-9	2	7	2	13	2	-12	2	4	5
7090 2007-11-12 18:46 L2		532	9	1	10	1	11	1	1	0	9	1
7090 2007-11-12 22:50 L2		532	28	3	13	2	12	0	-13	1	-10	4
7090 2007-11-12 23:16 L1		532	-17	3	-4	1	5	1	-34	1	8	6
7090 2007-11-13 11:40 L1		532	-1	4	0	1	13	2	3	2	-13	1
7090 2007-11-13 16:42 L2		532	-7	3	-14	0	16	2	3	1	9	8
7090 2007-11-13 20:32 L2		532	2	4	75	3	5	2	9	2	20	4
7090 2007-11-13 21:44 L1		532	102	8	1	2	22	2	-3	3	87	8
7090 2007-11-14 01:00 L2		532	-20	1	4	1	15	1	-8	0	34	2
7090 2007-11-14 01:20 L1		532	-10	4	7	3	12	2	-23	3	27	10
7090 2007-11-14 05:23 L2		532	-37	5	-2	4	3	3	-65	3	-31	11
7090 2007-11-14 13:44 L1		532	2	5	3	4	3	2	-15	5	-14	6
7090 2007-11-14 14:52 L2		532	-16	9	-8	2	14	2	-3	7	-52	11
7090 2007-11-14 17:13 L1		532	22	3	10	2	2	1	16	2	95	8
7090 2007-11-14 18:30 L2		532	10	3	1	3	1	2	1	3	61	7
7090 2007-11-14 20:28 L1		532	-30	2	2	3	10	2	23	2	113	10
7090 2007-11-14 22:58 L2		532	65	2	16	2	12	1	14	1	23	5

7105 GODL Greenbelt			DGFI		MCC		HIT-U		SAO		JCET	
	sc	wl	rb	pr	rb	pr	rb	pr	rb	pr	rb	pr
7105 2007-11-07 02:08 L1		532	-11	4			1	3	-18	4	-7	3
7105 2007-11-07 03:50 L2		532	-8	2			1	2	6	5	-10	6
7105 2007-11-08 04:20 L1		532	-49	2			8	1	4	1		
7105 2007-11-08 06:12 L2		532	-30	3			7	1	0	1		
7105 2007-11-09 02:45 L1		532	-6	3	-21	1	9	1	-23	1		
7105 2007-11-09 04:16 L2		532	25	2	-8	1	5	1	1	2		

7110 MONL Monument Peak			DGFI		MCC		HIT-U		SAO		JCET	
	sc	wl	rb	pr	rb	pr	rb	pr	rb	pr	rb	pr
7110 2007-11-13 16:52 L1		532	0	6	6	3	13	4	-1	4	-8	4
7110 2007-11-13 18:24 L2		532	-8	9	-2	11	-4	9	1	8	-15	9
7110 2007-11-14 15:43 L1		532	-8	3	1	2	4	1	-10	1	-63	5
7110 2007-11-14 19:14 L1		532	13	3	2	2	12	1	-2	1	45	3
7110 2007-11-14 20:30 L2		532	-29	4	-4	3	-7	3	-18	3	-26	6
7110 2007-11-15 17:56 L1		532	16	5			5	2	-10	1		
7110 2007-11-15 18:52 L2		532	-47	10			-14	7	-29	9		

7119 HA4T Haleakala			DGFI		MCC		HIT-U		SAO		JCET	
	sc	wl	rb	pr	rb	pr	rb	pr	rb	pr	rb	pr
7119 2007-11-07 21:34 L2		532	-96	6			-1	0	102	4		
7119 2007-11-09 19:08 L1		532	-6	3	-5	5	-1	2	-23	2		
7119 2007-11-09 21:30 L2		532	-40	4	-11	4	2	3	101	1		
7119 2007-11-09 22:42 L1		532	-19	5	-22	5	0	1	-17	5		
7119 2007-11-10 01:31 L2		532	-13	3	-10	3	6	2	18	16		
7119 2007-11-10 21:14 L1		532	3	5	-28	2	8	1	-17	4		
7119 2007-11-10 23:27 L2		532	-37	4	-13	3	2	2	55	7		
7119 2007-11-12 01:38 L2		532	-234	5	-15	6	9	5	-304	0	21	7
7119 2007-11-12 18:36 L1		532	21	2	1	2	19	1	38	1	-19	4
7119 2007-11-15 21:30 L1		532	-4	4			-9	2	2	1		
7119 2007-11-15 22:02 L2		532	47	4			0	2	42	19		
7119 2007-11-16 02:10 L2		532	-278	3			20	2	0	3		
7119 2007-11-17 22:13 L2		532	40	4			6	2	46	7		
7119 2007-11-18 21:10 L1		532	43	4			2	1	37	1	33	7
7119 2007-11-19 00:30 L2		532	-182	4			6	3	10	2	36	5
7119 2007-11-19 19:34 L1		532	18	6			3	2	30	2	12	6

Multi-year range bias monitoring

Multi-year solution, actually with LAGEOS 1/2 only

- CDDIS Bulletin
- SLRMail

- Site Log
- Info from the stations

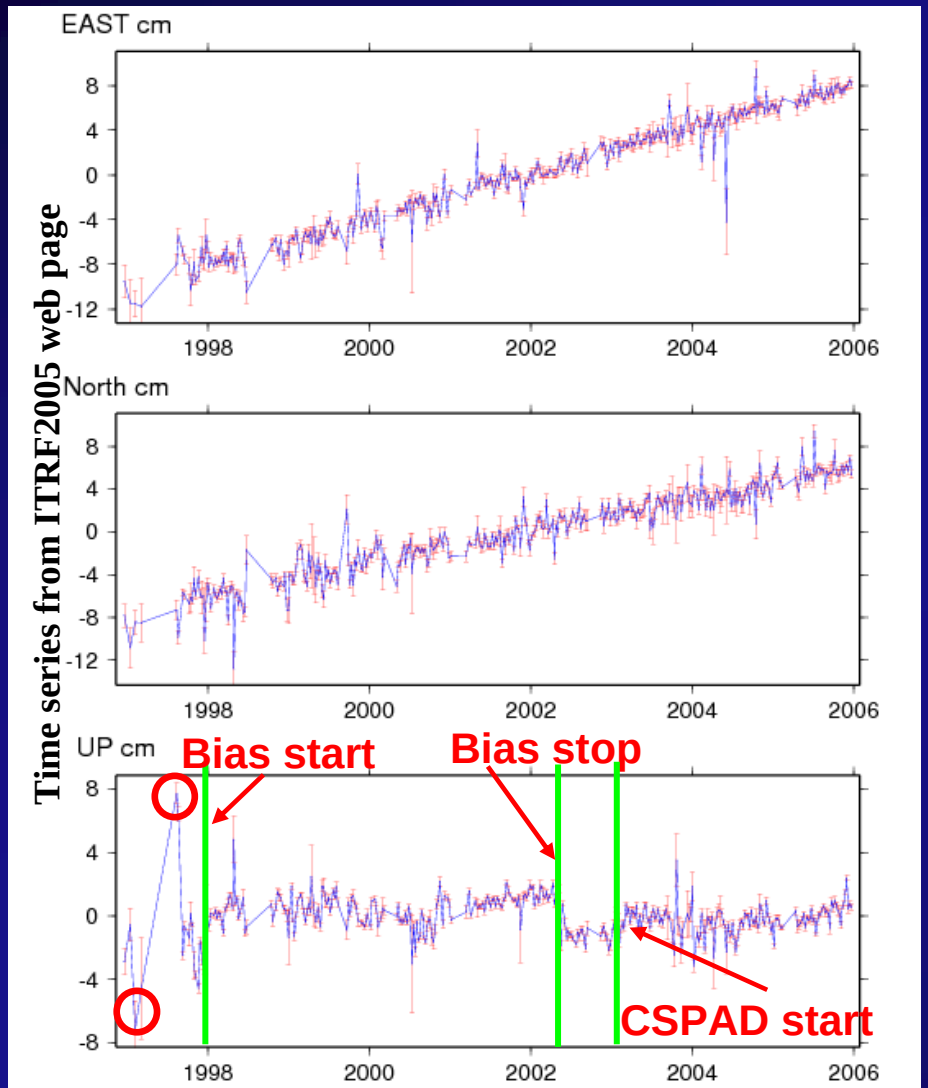
Definition of:

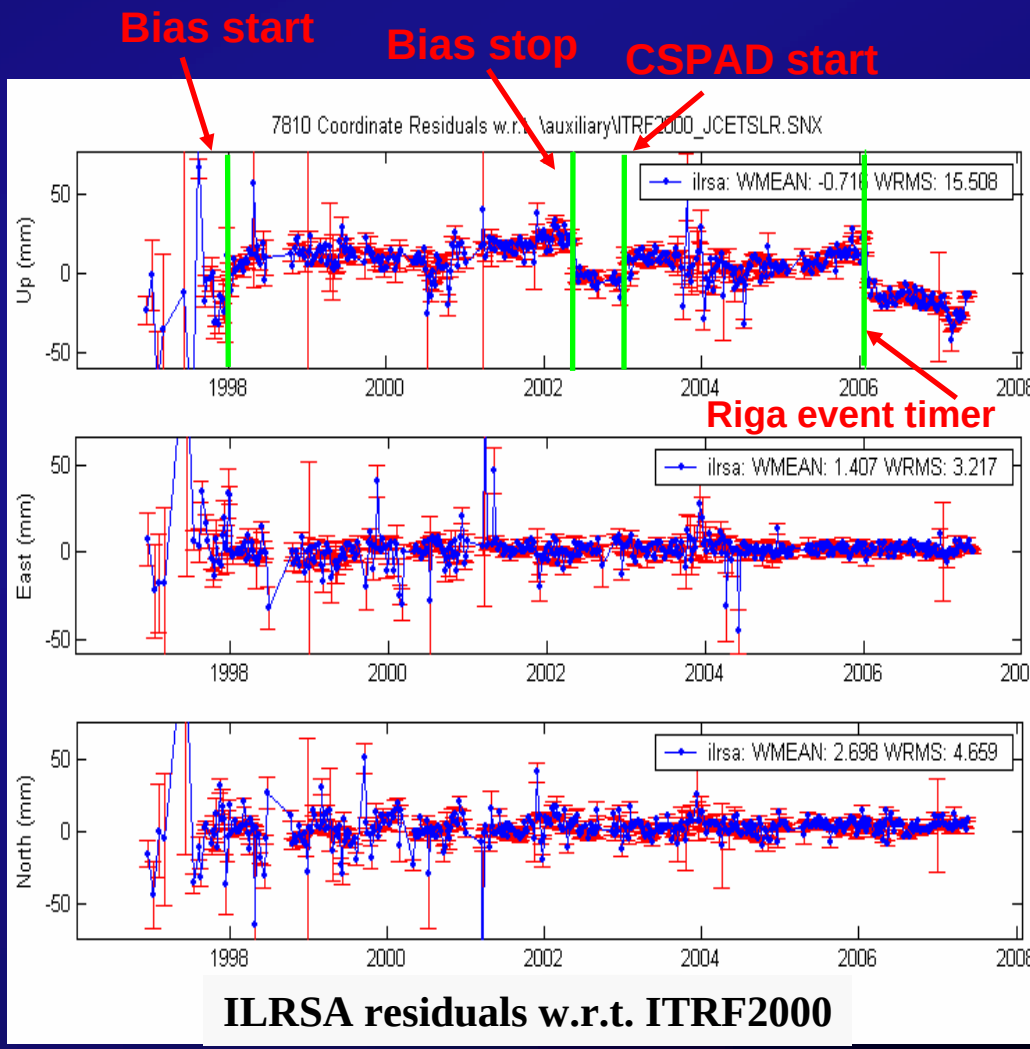
- **unrecoverable data to be edited**
- **sites requiring bias estimation**
- **bias to be applied**

Range bias estimation from ASI06 solution

- The biases are estimated from a multi-year solution spanning January 1983 to July 2007
- The solution is loose and SSC/SSV are estimated over the entire time span
- One bias estimated every 15 days after the SSC/SSV/EOP adjustment
- The biases are one-way and should be subtracted from the observations

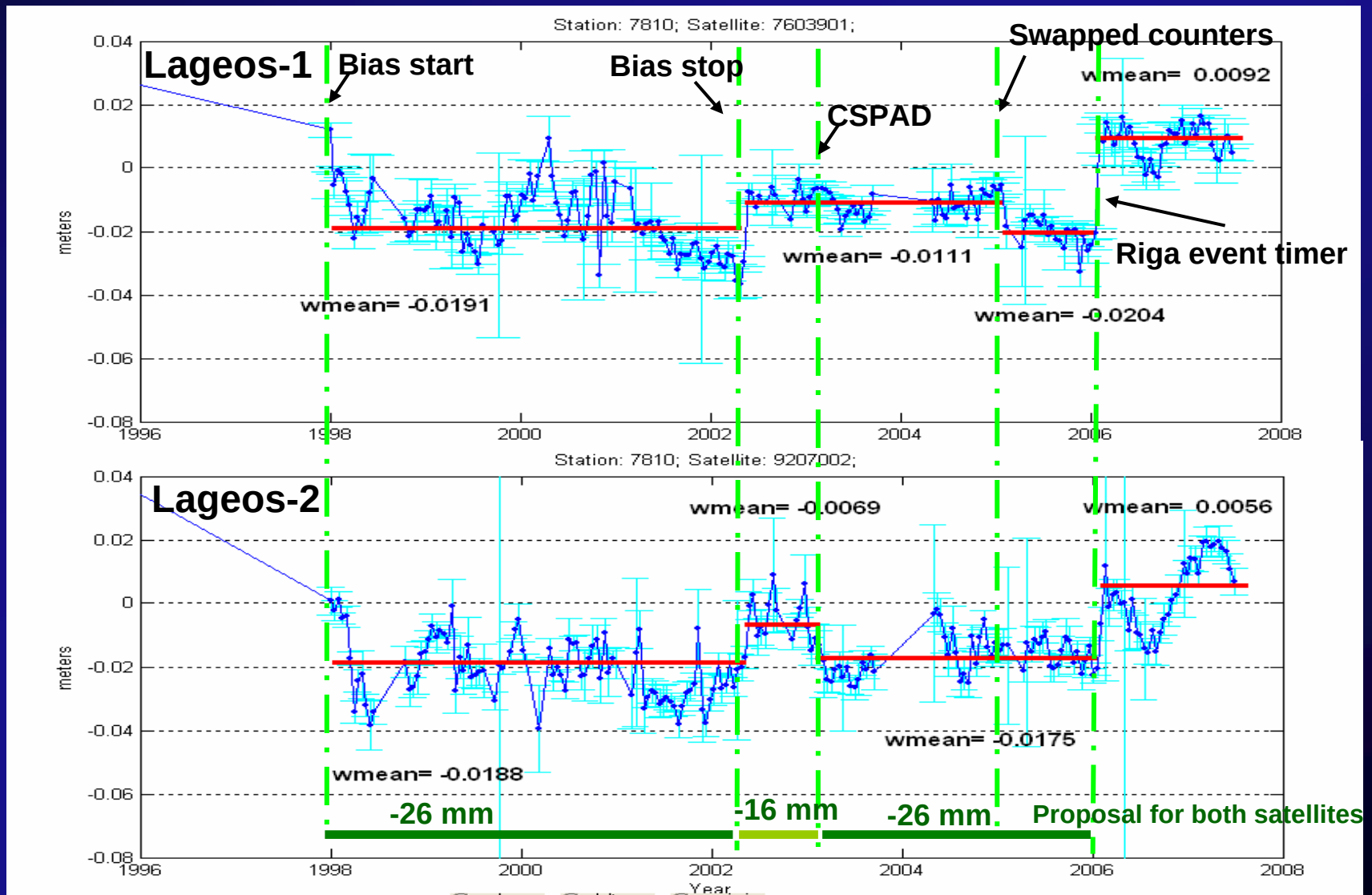
Zimmerwald coordinate time series





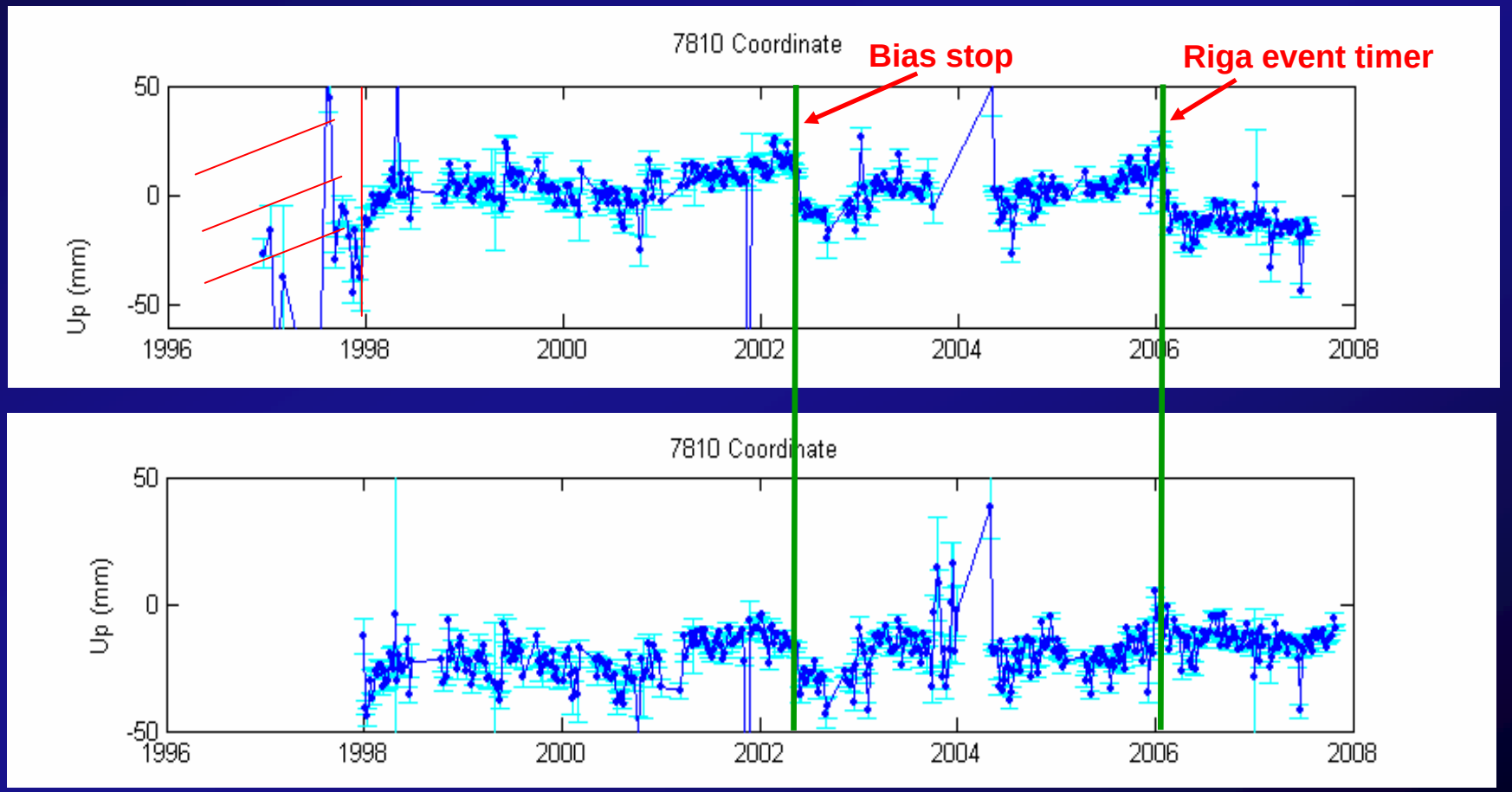
ILRSA residuals w.r.t. ITRF2000

Zimmerwald range bias (blue) from ASI06 solution

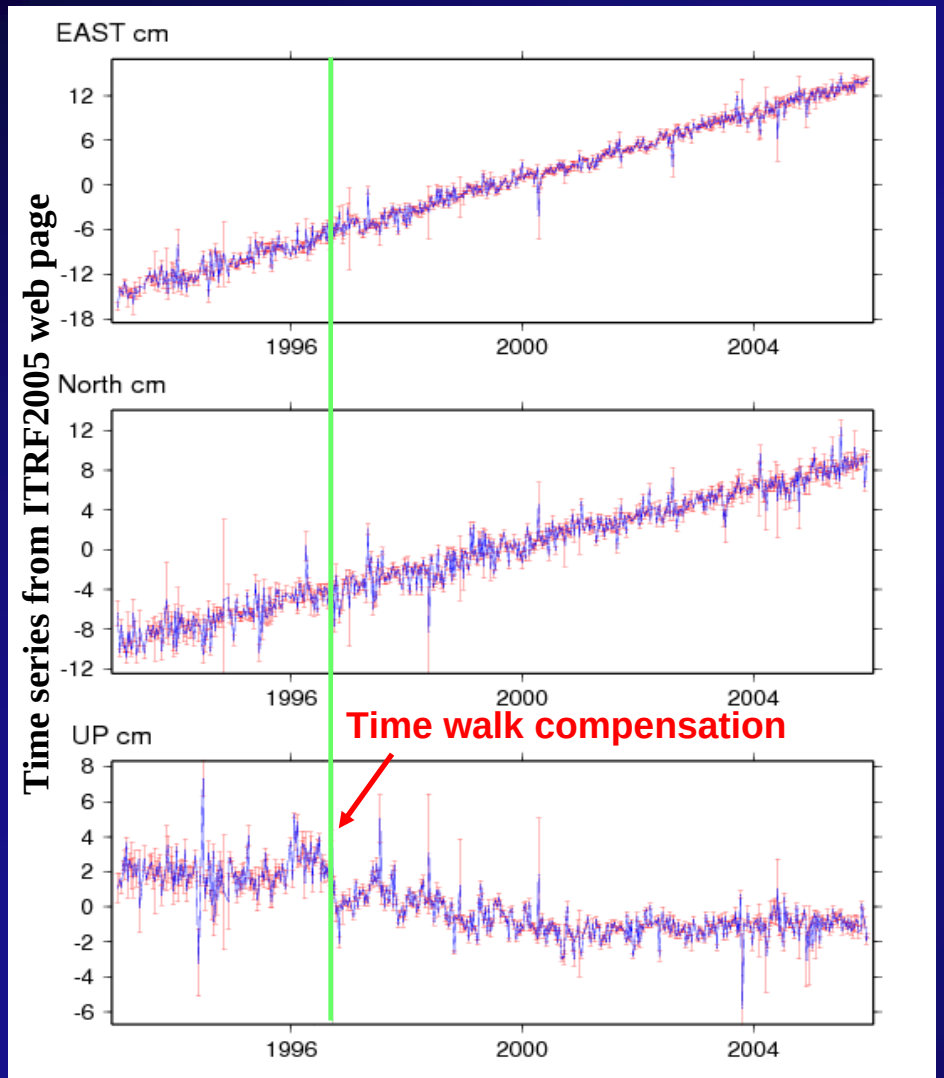


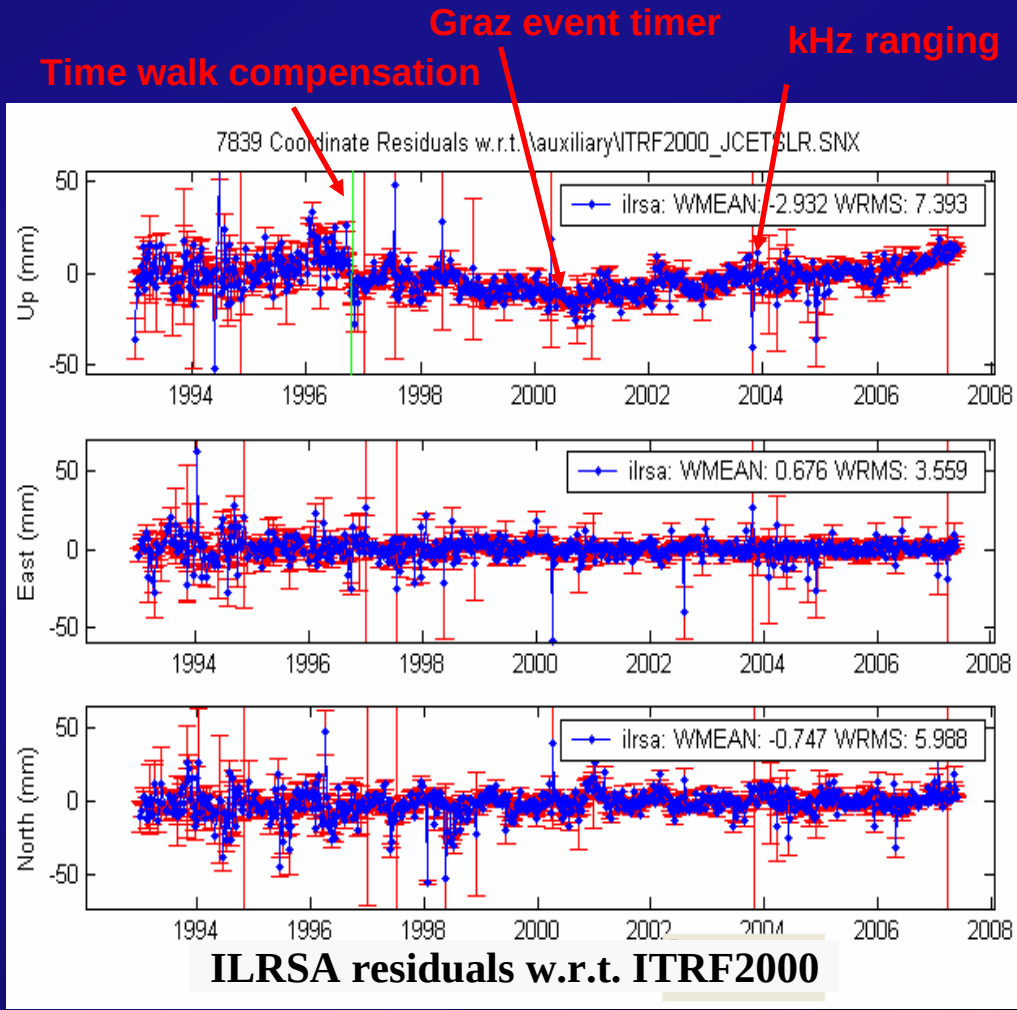
Zimmerwald height before and after bias application

Preliminary results from ASI time series



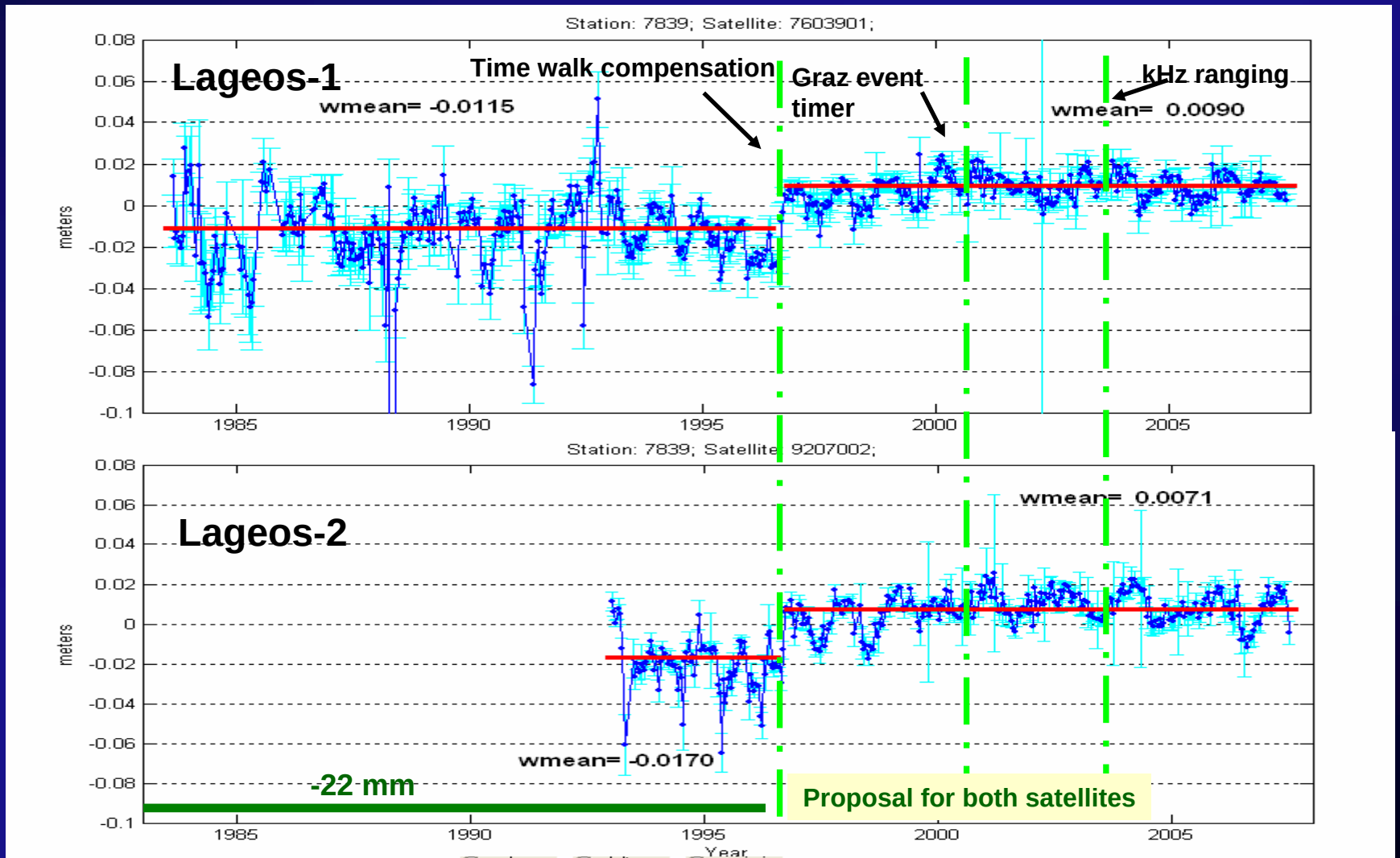
Graz coordinate time series





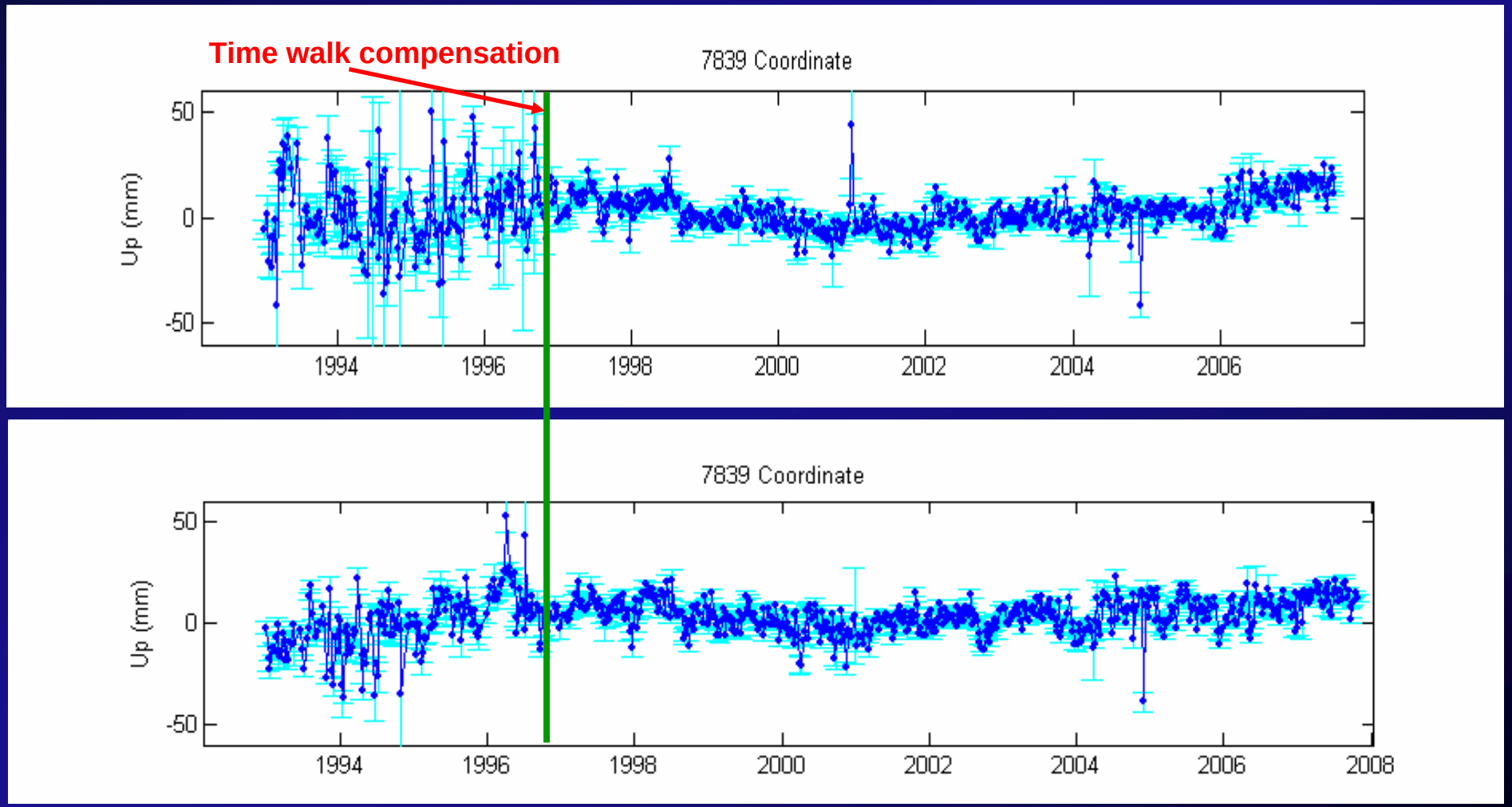
ILRSA residuals w.r.t. ITRF2000

Graz range bias from ASI06 solution



Graz height before and after bias application

Preliminary results from ASI time series



ILRS range bias monitoring

Engineering bias report from CDDIS repository and from the stations through SLRMail

- Sometimes stations are not aware of existing biases and need to be supported by the analysis

Rapid, daily analysis bias report from the ILRS ACs

- Discrepancy between AC bias reports are still present and ILRS is in the process of harmonization
- AC bias reports are generally not homogeneous over years and have a partial temporal coverage

Bias time series estimated from multi-year solution

- A long term analysis overcome the two problems and gives a complete, homogeneous detection of the biases decorrelating them from heights

Conclusions

- The re-analysis of the entire data span for the ILRS official product requires the adoption of the site range bias to avoid artificial jumps in the coordinate time series
- The bias estimation in the weekly standard ILRS product weakens the solution and corrupts the coordinate (mostly the UP)
- Multi-year analysis is necessary to define:
  - Bad data
  - Sites requiring bias estimation
  - Bias to be applied
- The biases of some stations are not completely clear
- Historic data are obviously more problematic and info collected at CDDIS are really a precious source