ITRF2014: Preliminary results and ILRS contribution

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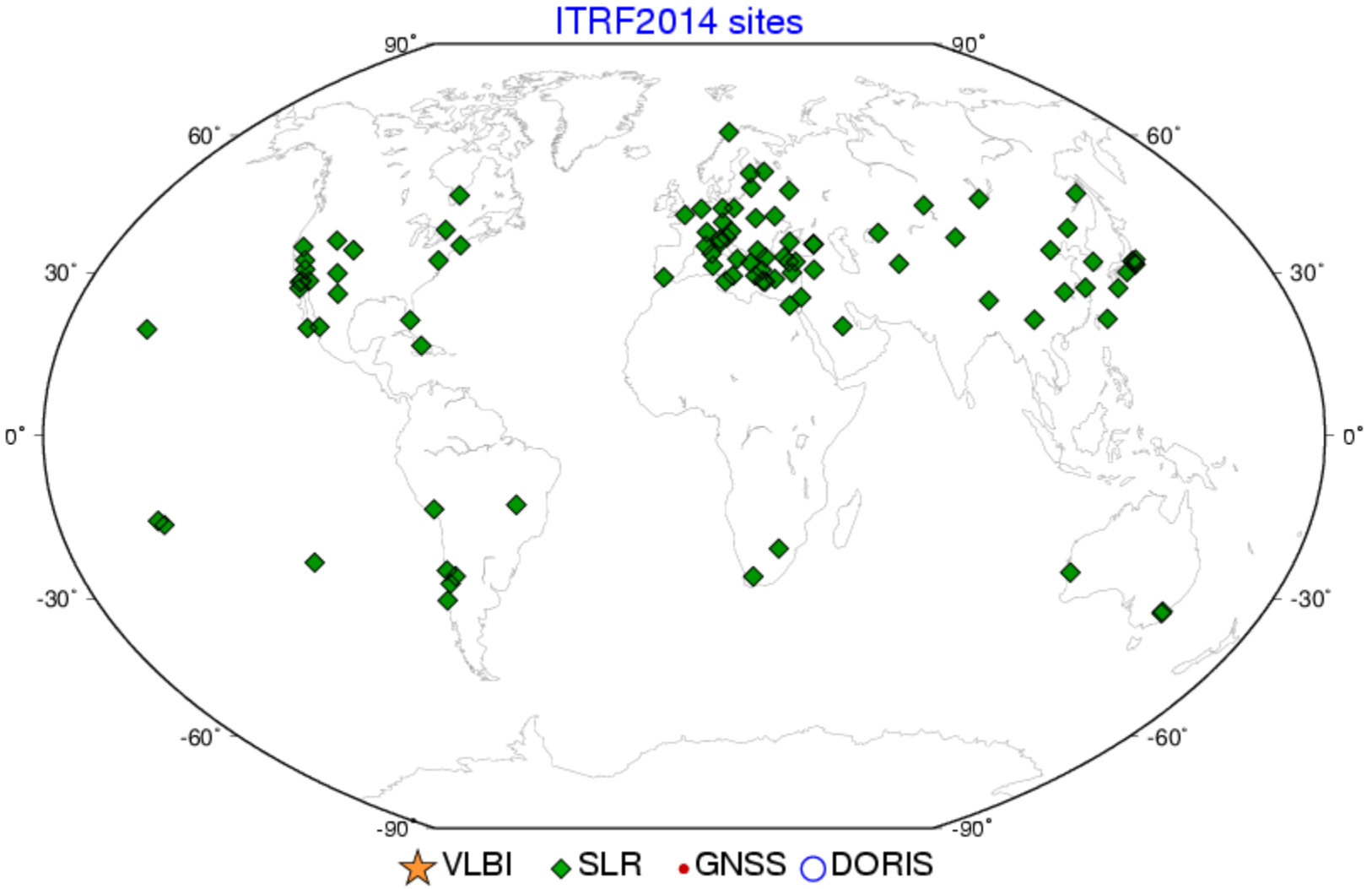
Key Points of ITRF2014

- **Linear & Non-linear motions**
  - **Periodic signals: seasonals (e.g. annual, semi-annual)**
  - **Post-seismic deformation**

Preliminary results, but close to final

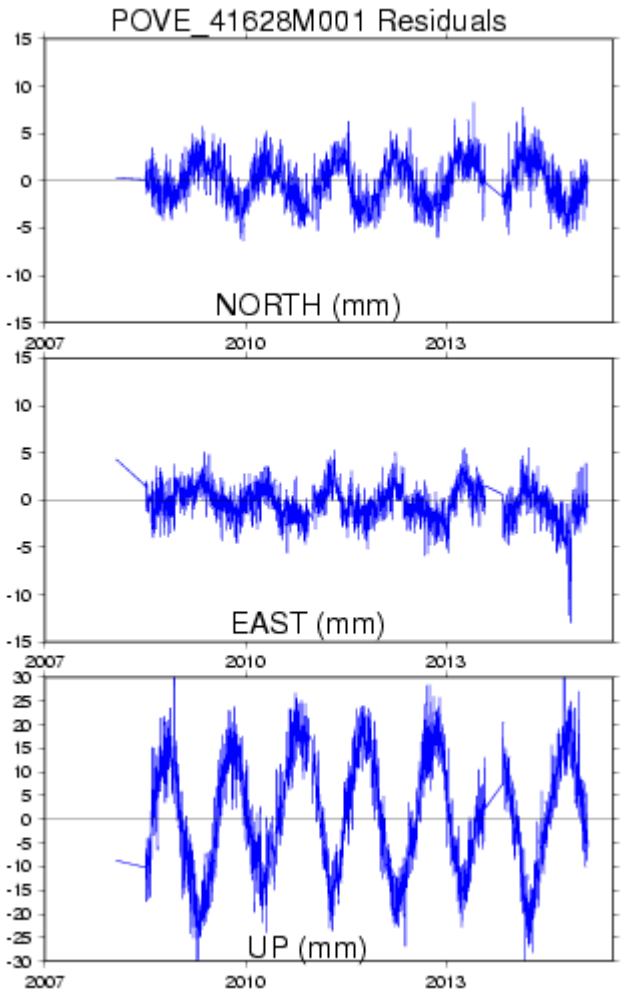
ITRF2014 : SLR



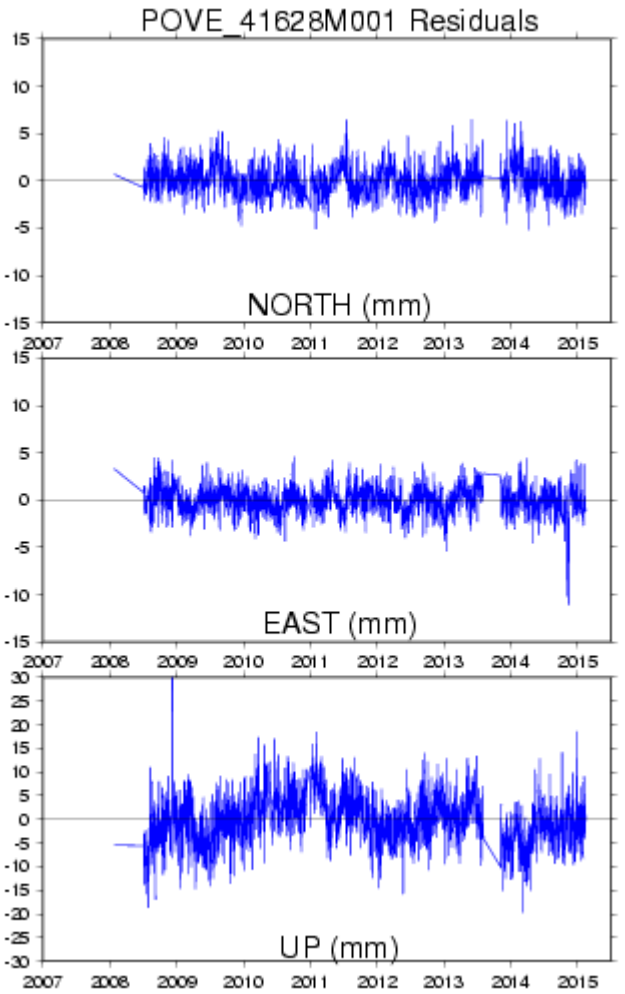
Periodic signals

POVE/ Brazil GNSS site

Standard residuals



Annual & semi-annual estimated

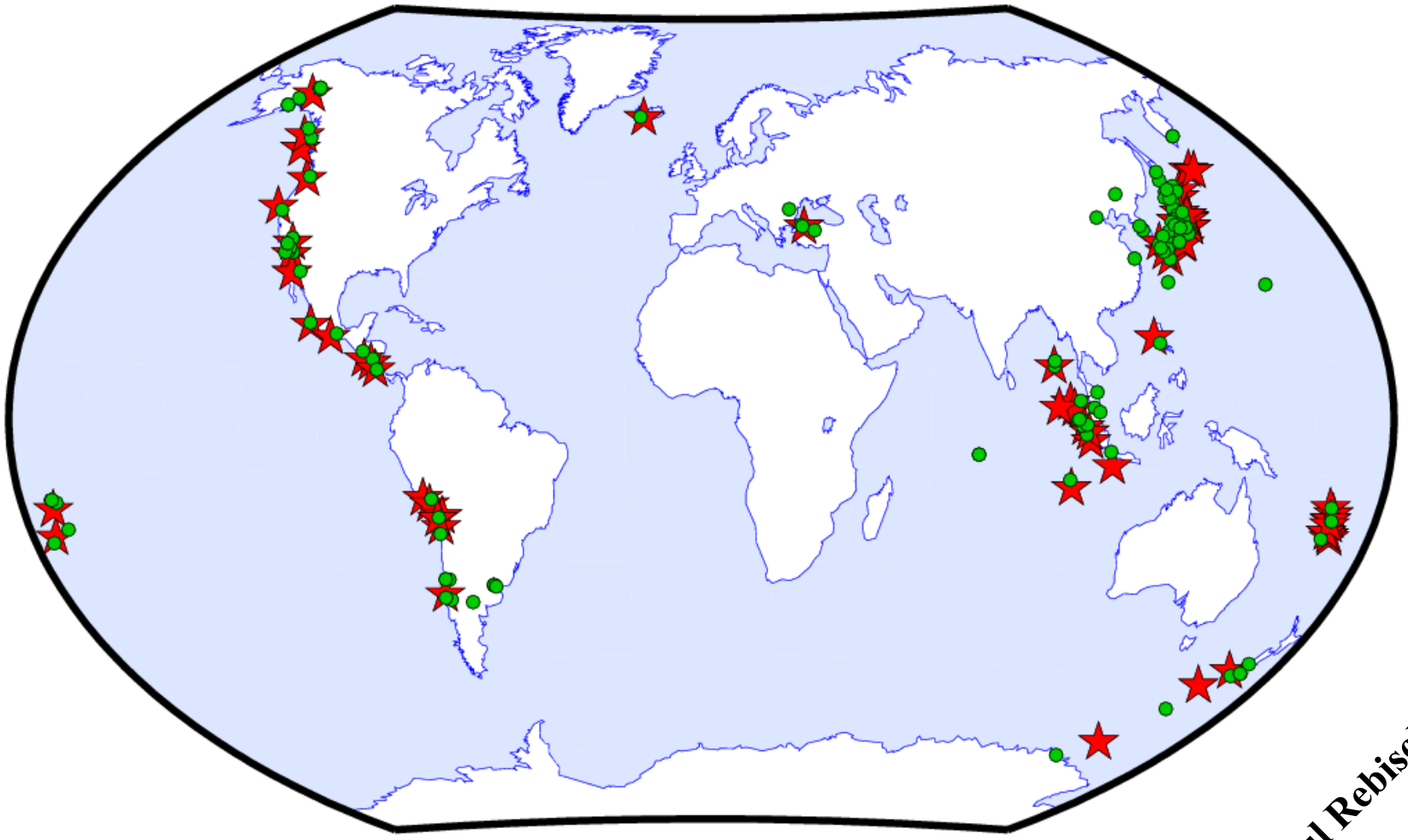


Post-Seismic Deformations

- Fitting parametric models using GNSS/GPS data
  - at all GNSS/GPS Earthquake sites
  - Apply these models for the 3 other techniques at Co-location EQ sites

- Parametric models:
  - Logarithmic
  - Exponential
  - Log + EXP
  - Two EXP

ITRF2014 Site affected by PSD



Red Stars: EQ Epicenters

Green circles: ITRF2014 sites

Artist: Paul Rebischung

Post seismic parametric models

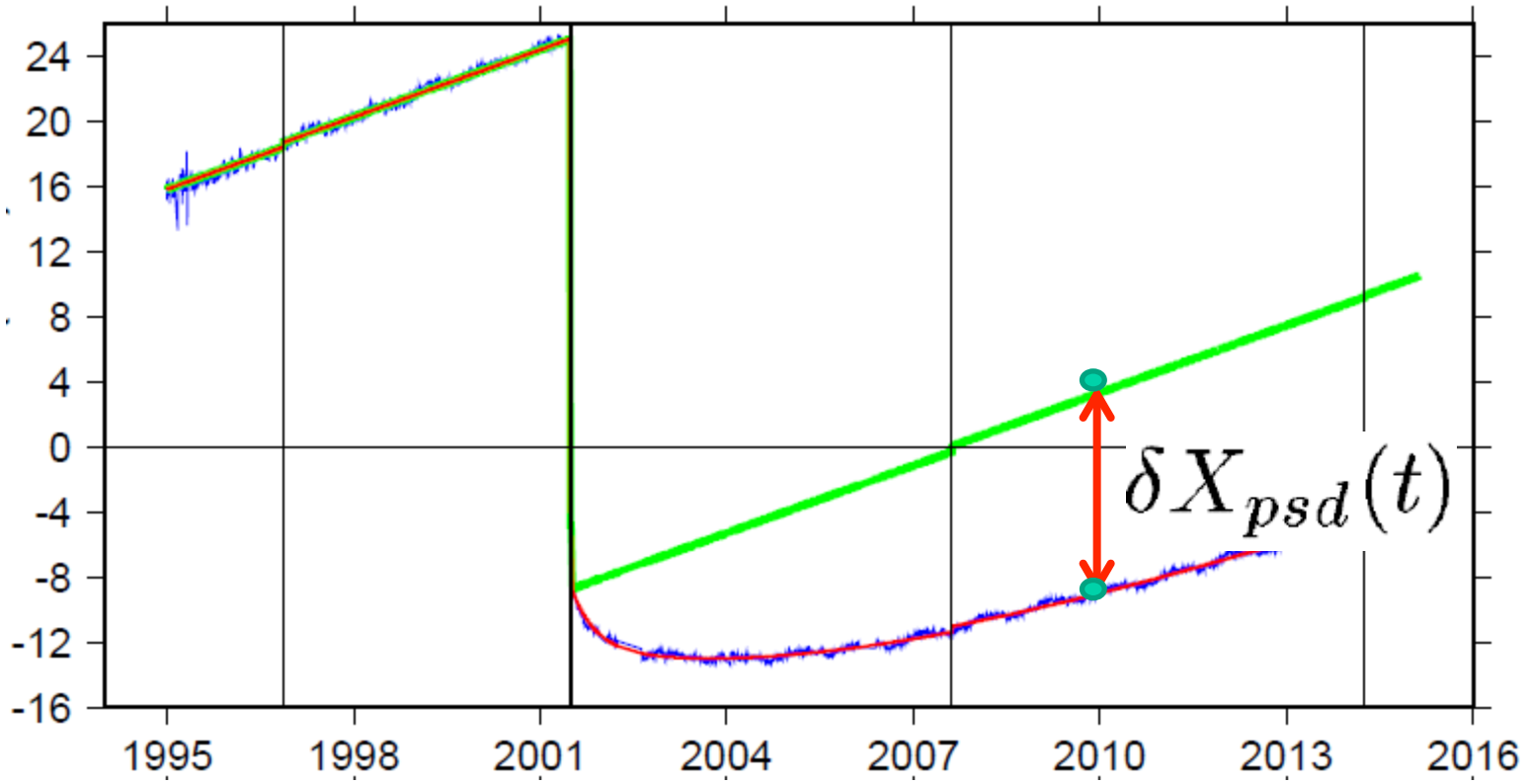
$$X(t) = X(t_0) + \dot{X}(t - t_0) + \delta X_{psd}(t)$$

$$X_{instantaneous}(t) = X(t_0) + \dot{X}(t - t_0) + \delta X_{psd}(t)$$

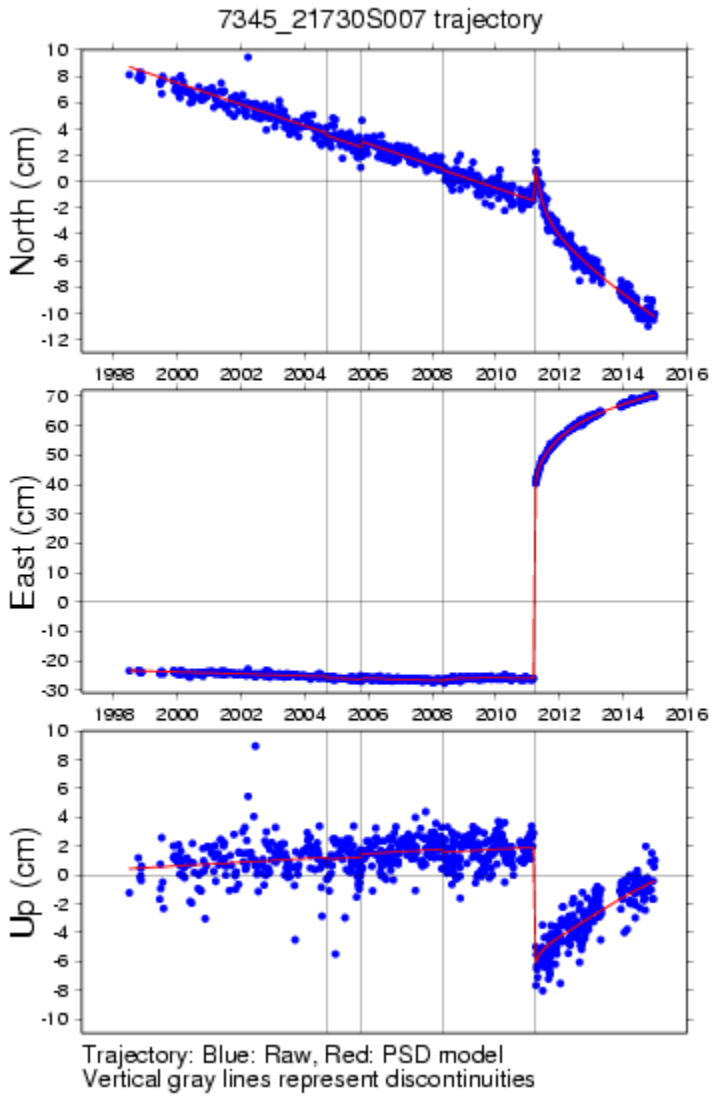
$$\delta L(t) = \sum_{i=1}^{n^l} A_i^l \log(1 + \frac{t - t_i^l}{\tau_i^l}) + \sum_{i=1}^{n^e} A_i^e (1 - e^{-\frac{t - t_i^e}{\tau_i^e}})$$

- **Sum up all EQ contributions**
- **Applications:**
- Propagate ITRF2014 stations positions from $\mathbf{t_0}$ to **t**: Should **Add (+)** the correction
- Apply the correction to a time series before stacking: Should **Subtract (-)** the correction

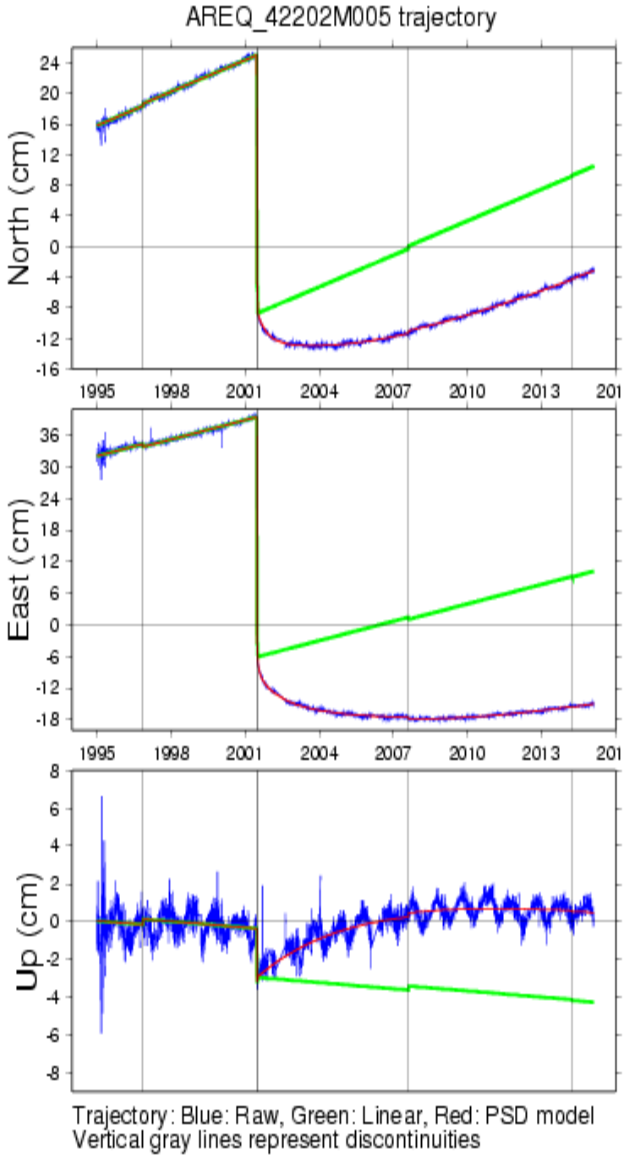
PSD Correction

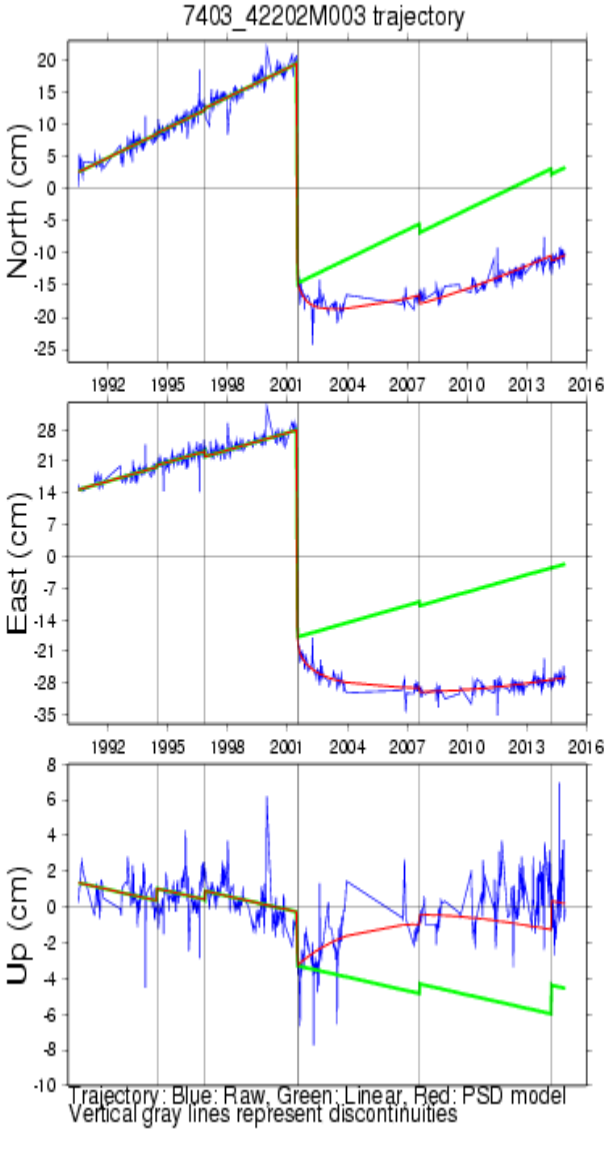


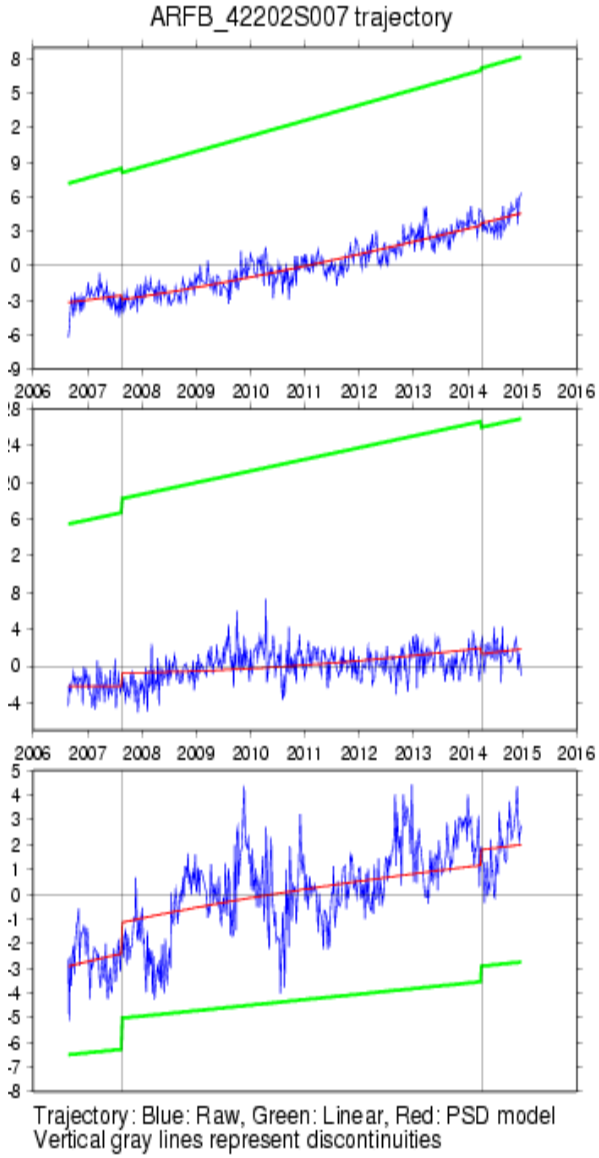
VLBI: Tsukuba PSD



Arequipa-GPS, SLR & DORIS

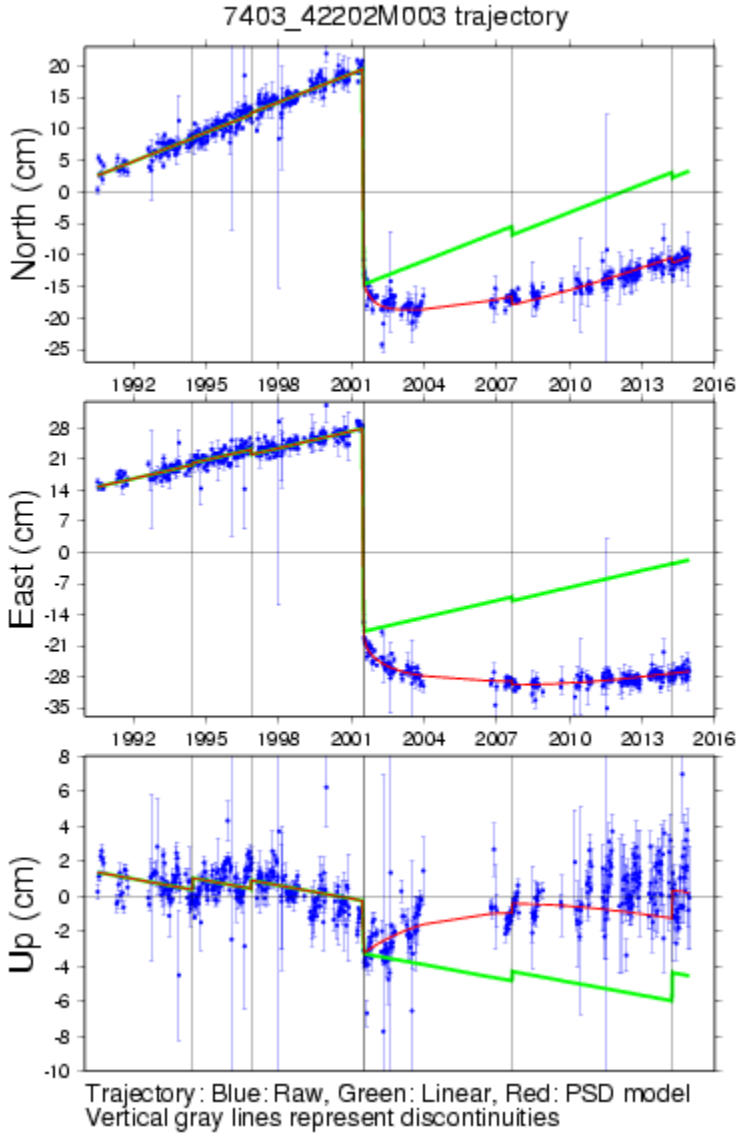




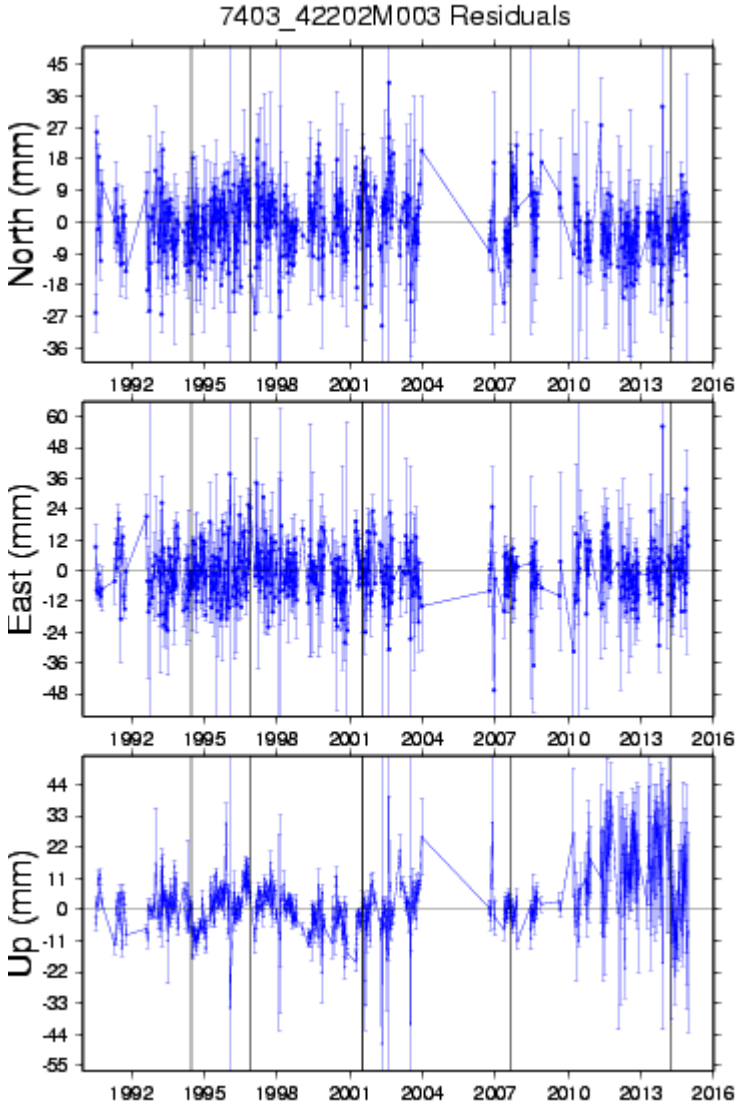


SLR station Arequipa

Trajectory

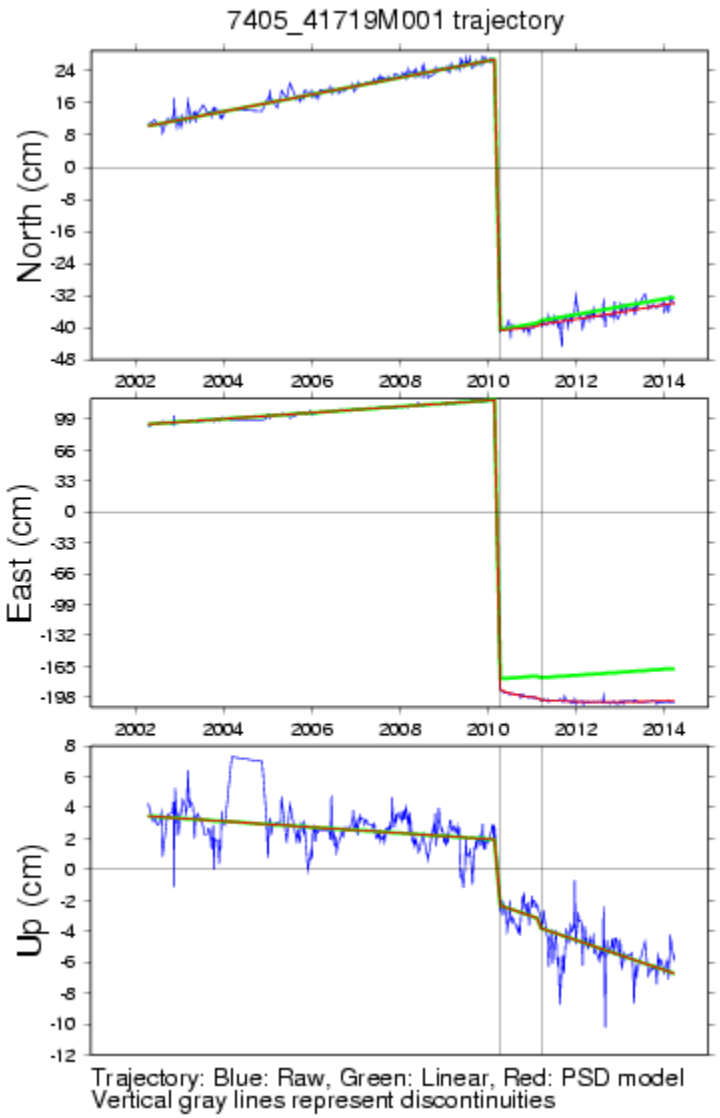


Residuals

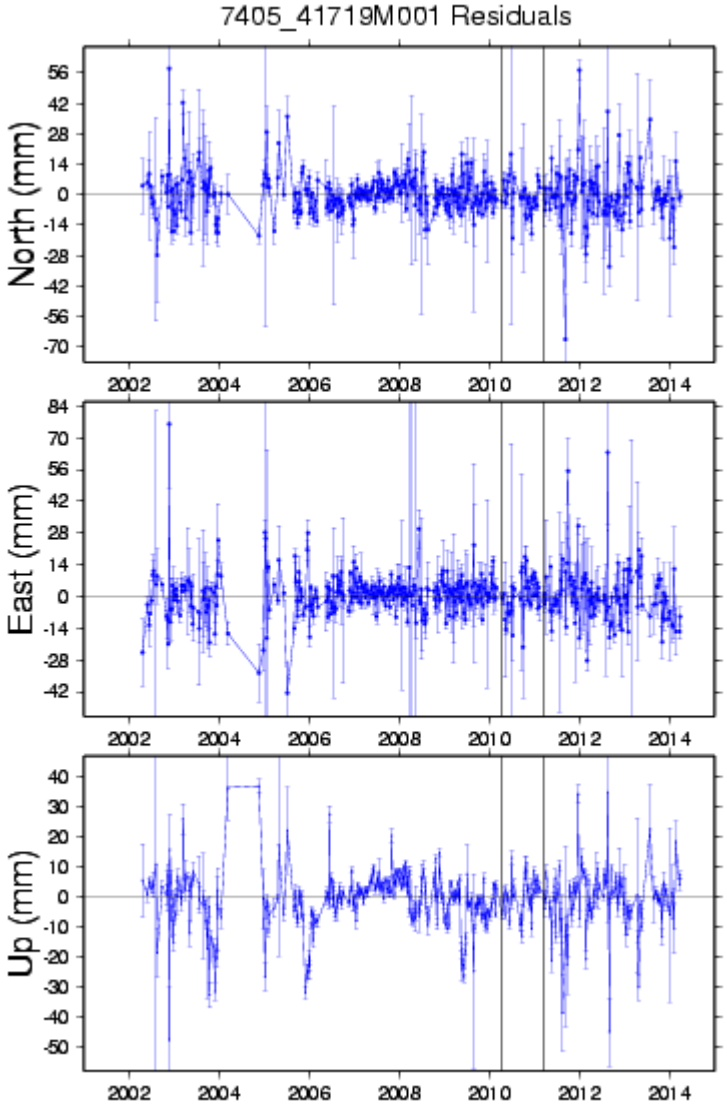


SLR station Concepcion

Trajectory

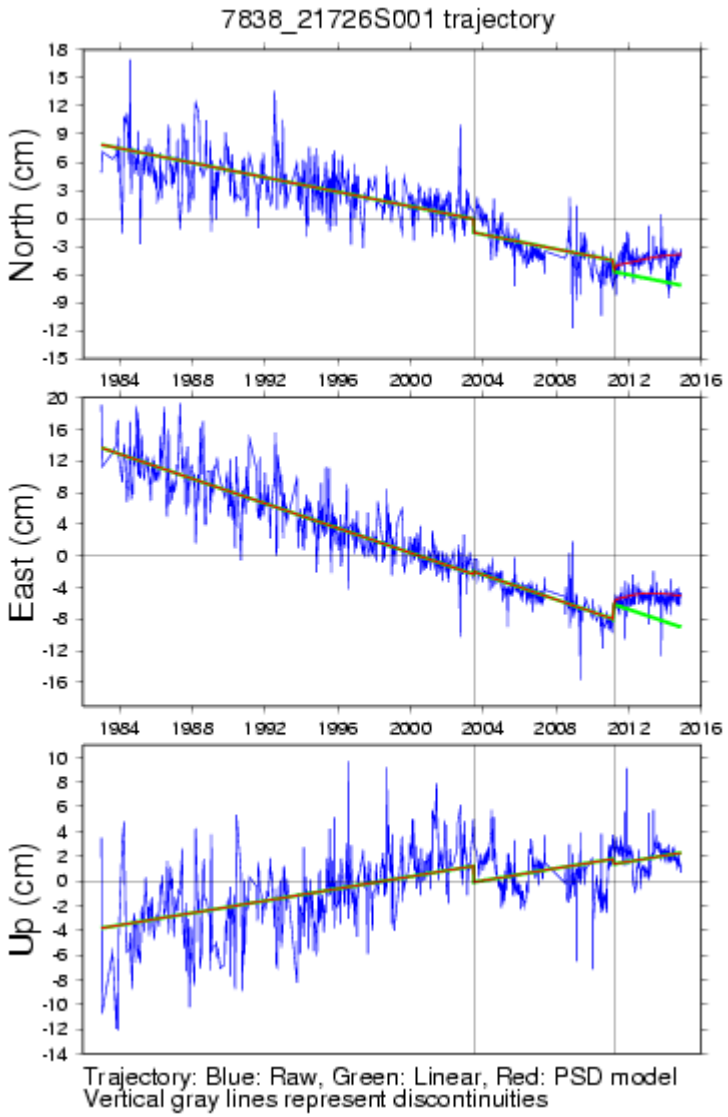


Residuals

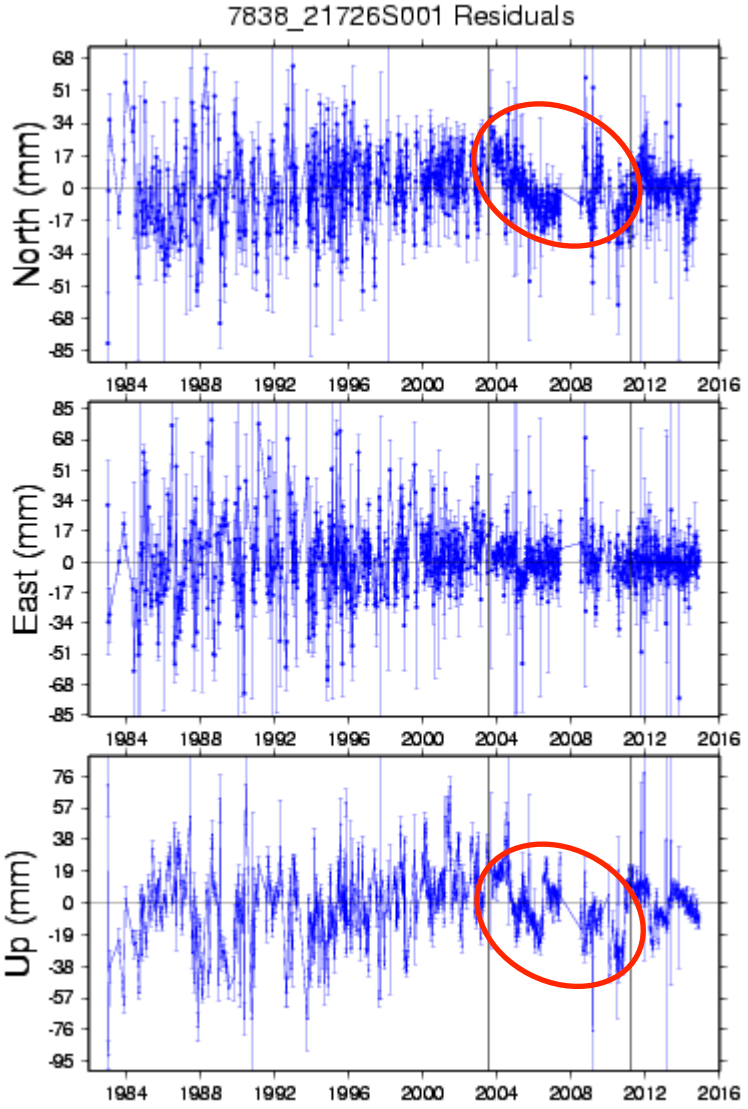


SLR station Simosato

Trajectory

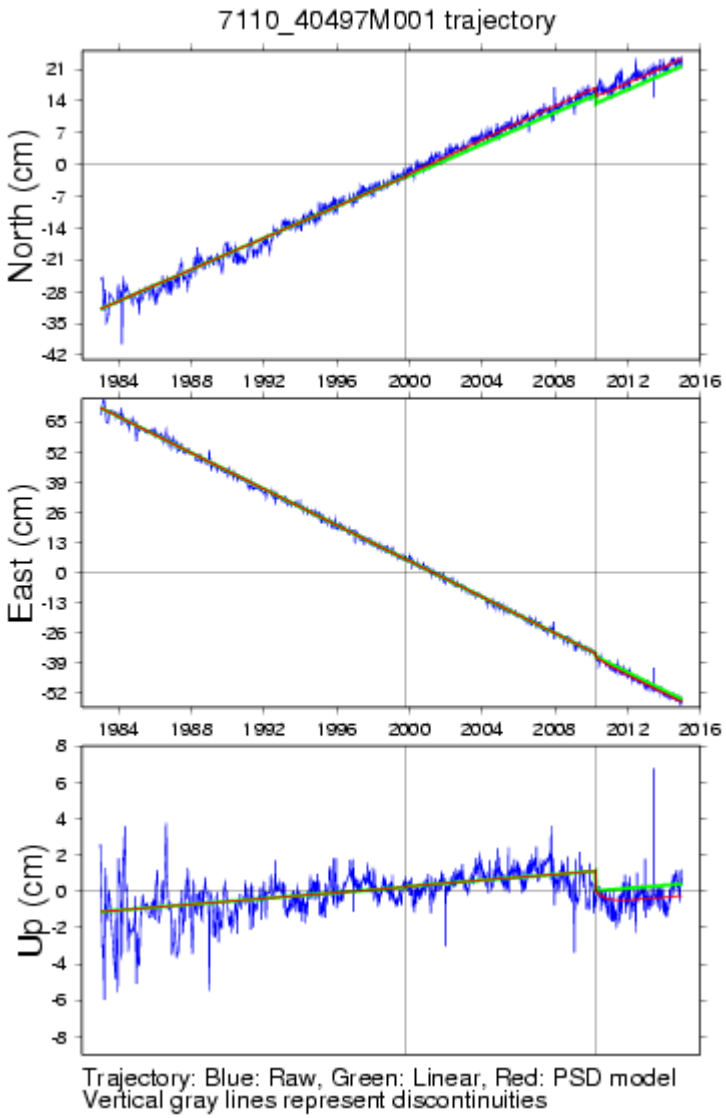


Residuals

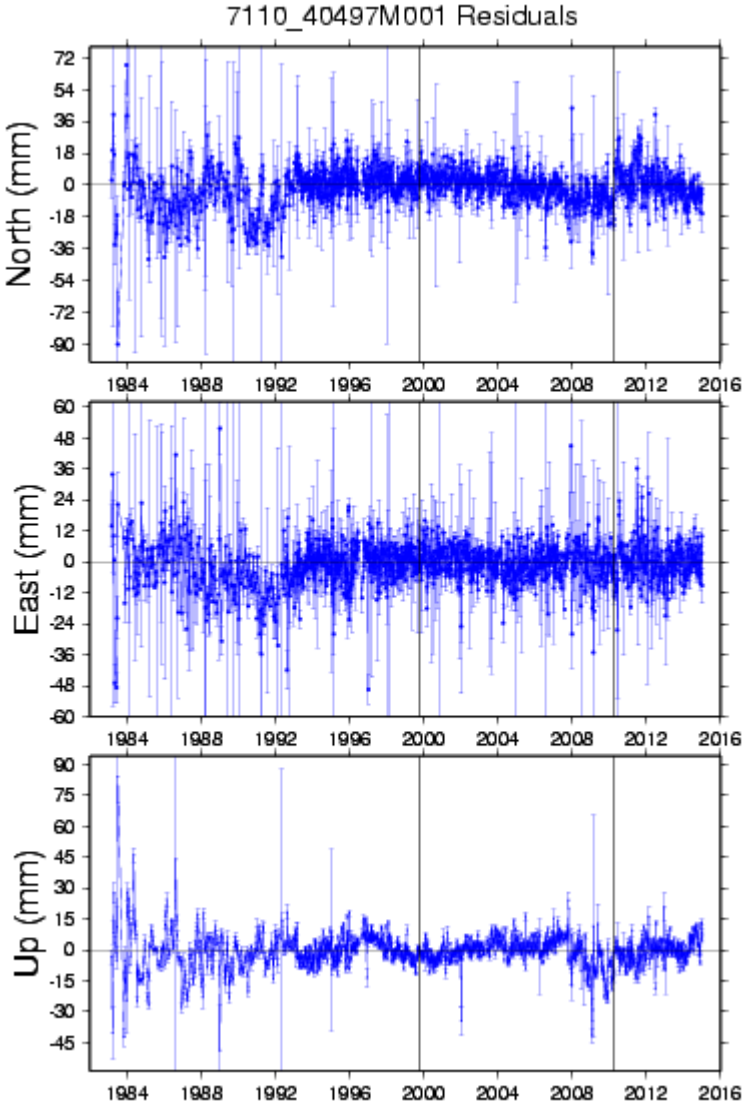


SLR station Monument Peak

Trajectory

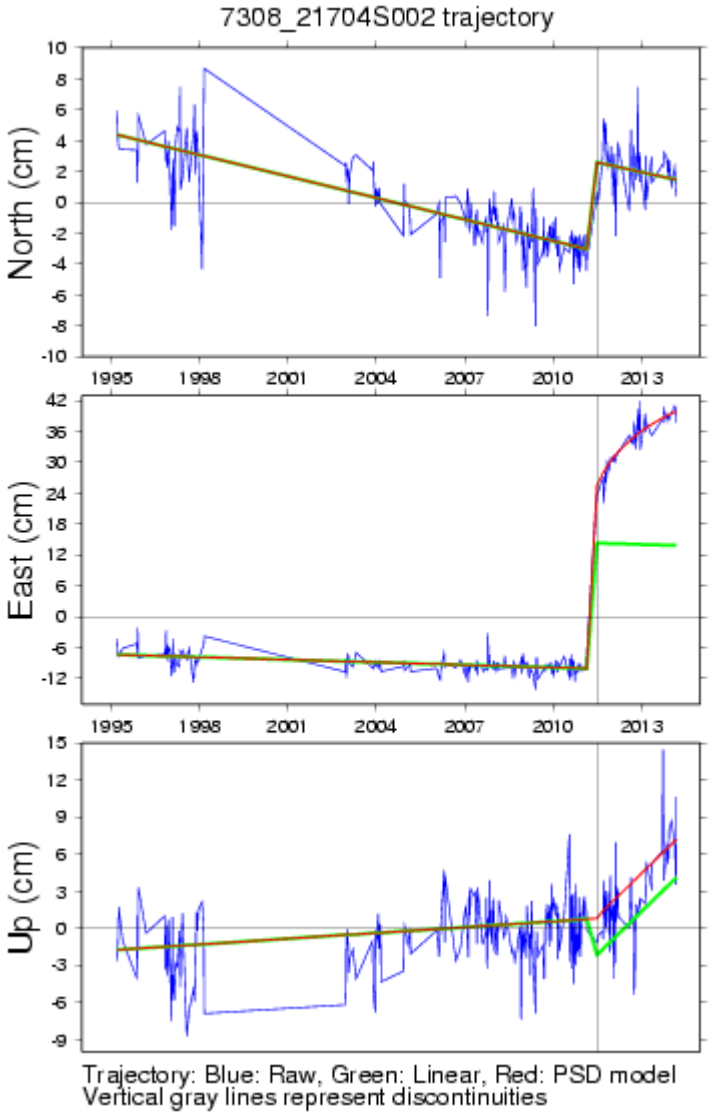


Residuals

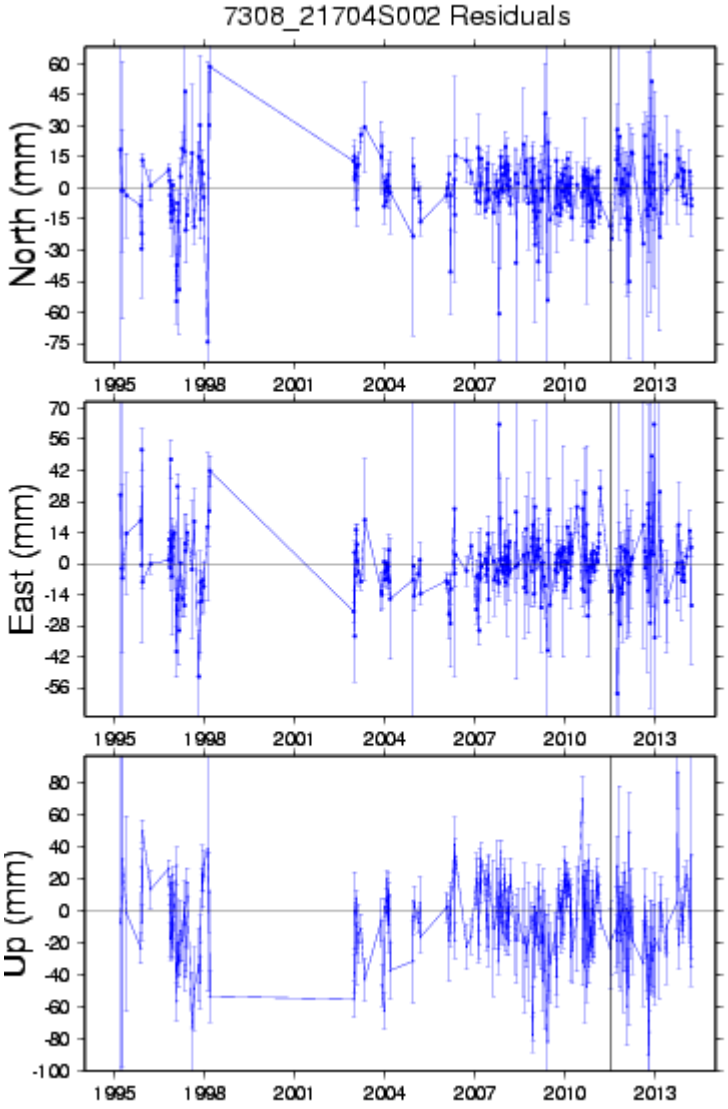


SLR station Koganei

Trajectory

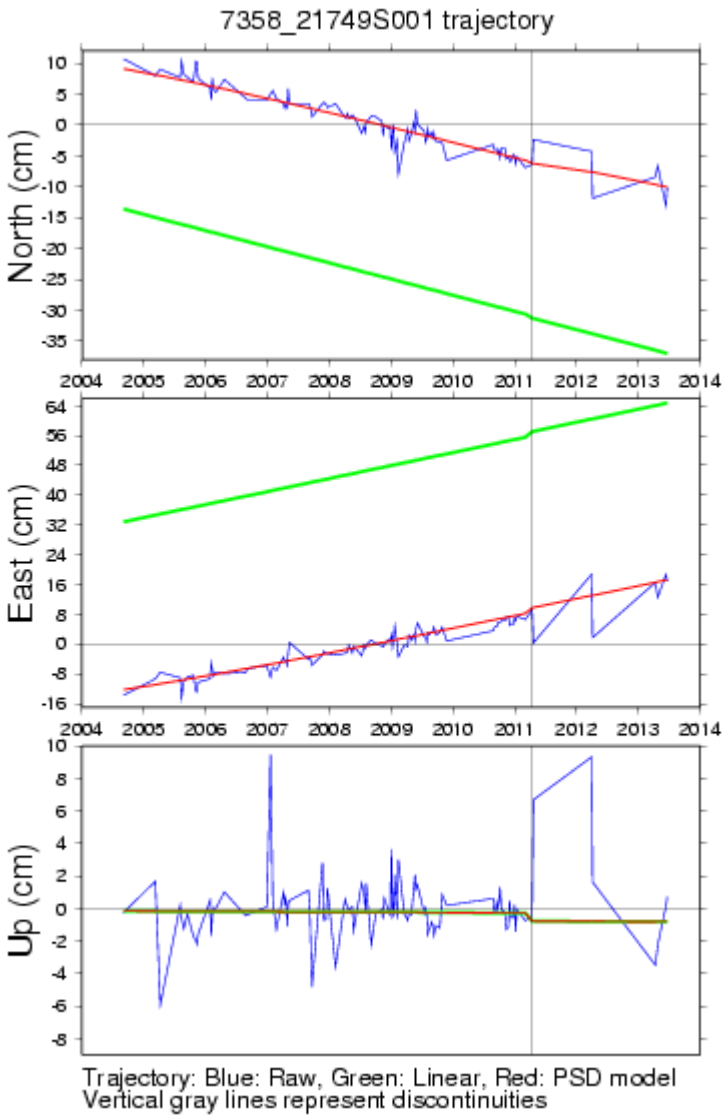


Residuals

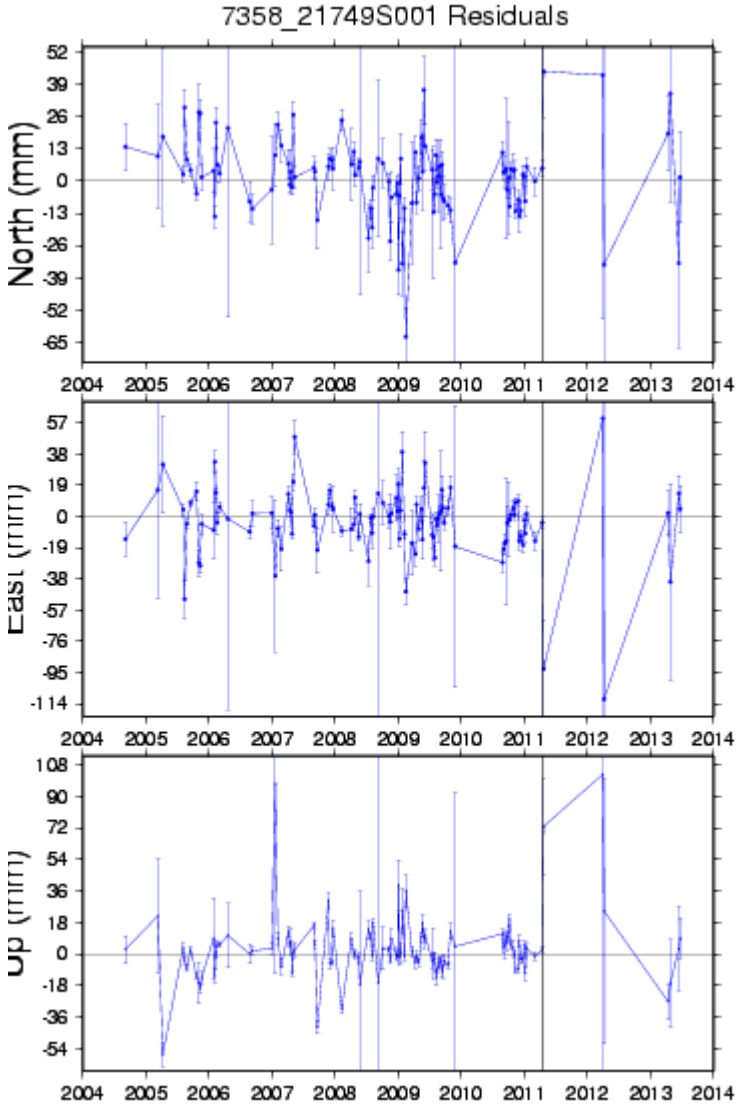


SLR station Tanegashima Island

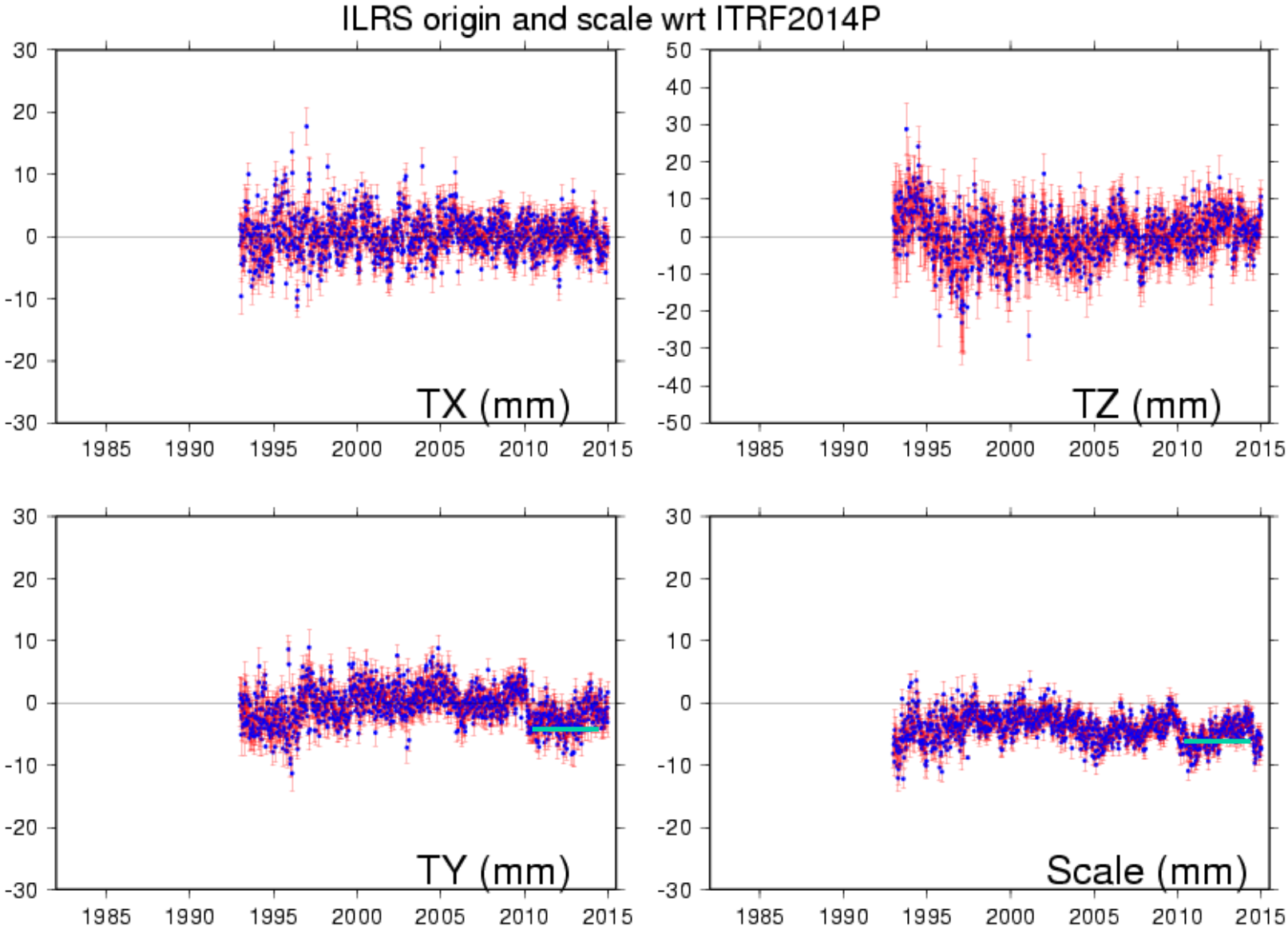
Trajectory



Residuals



SLR Origin & Scale WRT ITRF2014P



Consistency of ILRS SLR and ITRF2014P

Origin and Scale at epoch 2010.0 , and rates from ITRF2014P to ILRS Cumulative Solution

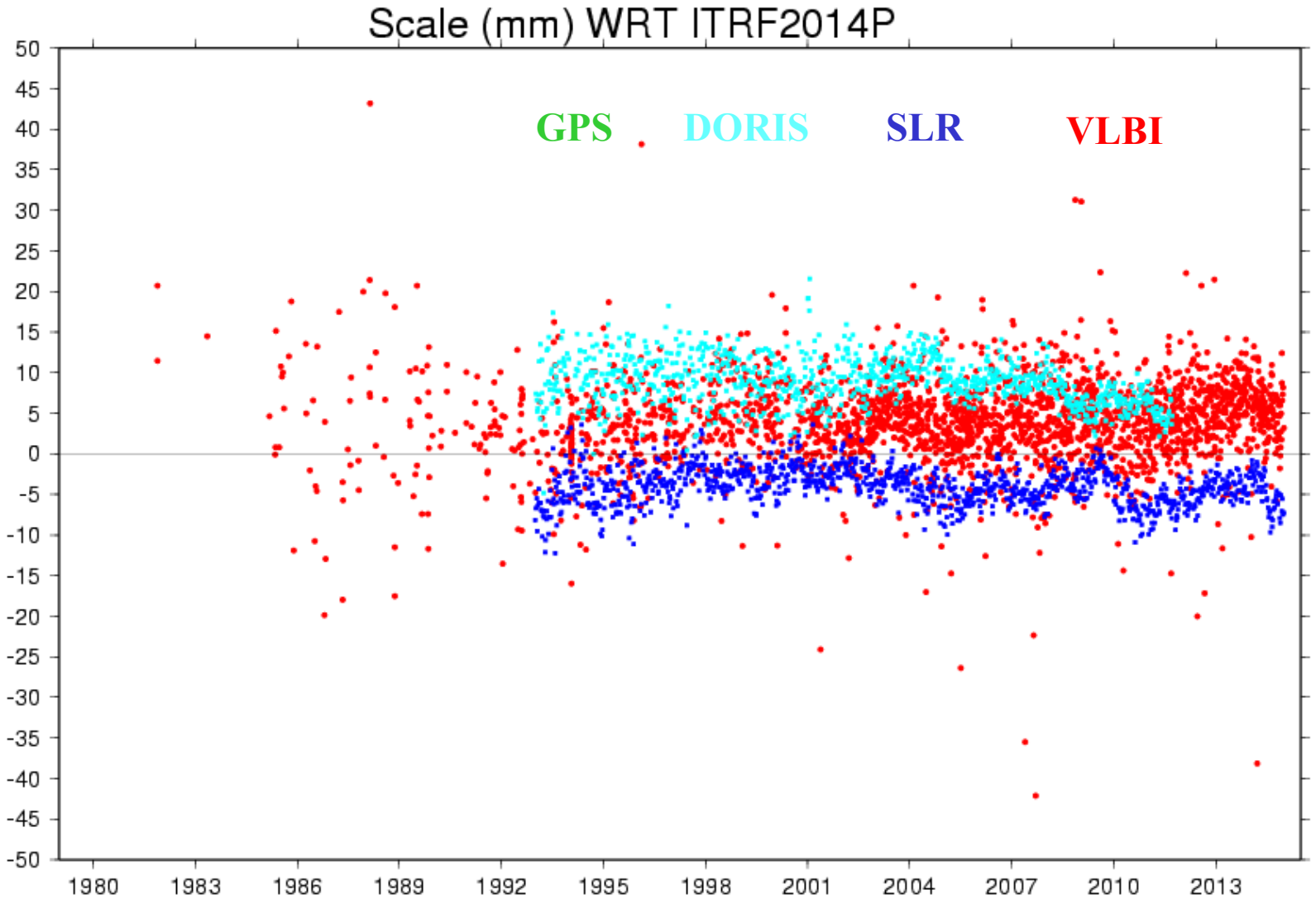
	Tx (mm)	Ty (mm)	Tz (mm)	Scale (ppb)
At 2010.0	**0.1** (±0.1)	**0.2** (±0.1)	**0.0** (±0.1)	**-0.72** (±0.02)
Rates (mm/yr)	**0.0** (±0.1)	**0.0** (±0.1)	**0.0** (±0.1)	**-0.01** (±0.01)

WRMS of fit

	East	North	Up
Positions (mm)	**0.7**	**0.9**	**0.4**
Velocities (mm/yr)	**0.4**	**0.4**	**0.2**

stations
133

VLBI, SLR, DORIS & GPS Scales wrt ITRF2014P



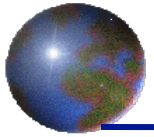
International Laser Ranging Service

ASI AC&CC
ITRF2014P evaluation

V. Luceri, B. Pace
eGEOS S.p.A., CGS – Matera

G. Bianco
Agenzia Spaziale Italiana, CGS - Matera

ILRS AWG Meeting, 24 October 2015, Matera



Outline

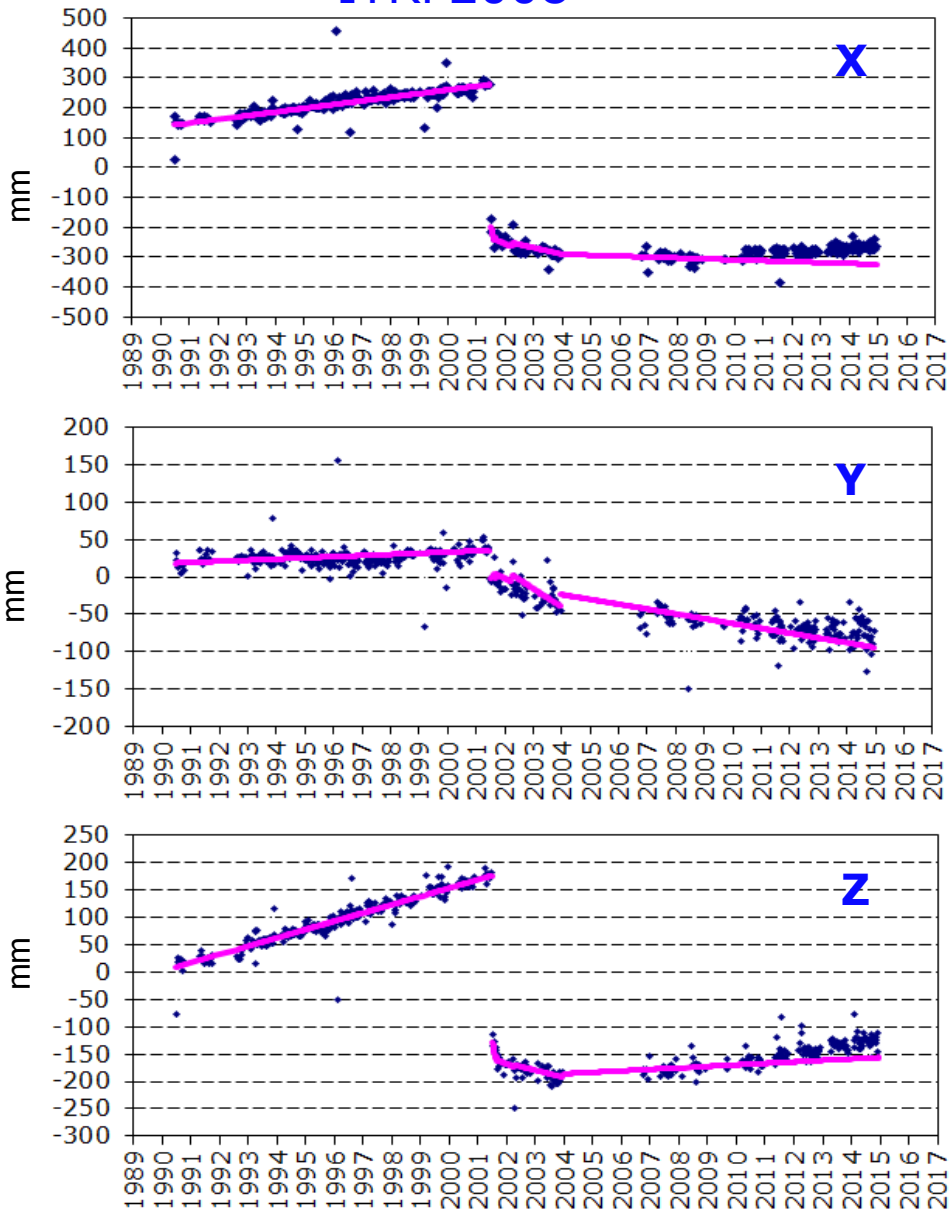
- Post-Seismic Deformation (PSD) Model
- Discontinuities
- 1983-2014 ILRSA v61 transformed into ITRF2014P (transformation into SLRF2008 already available)
- Analysis of SSC residuals
- Analysis of Helmert parameters (Translations&Scale)

ITRF2014P

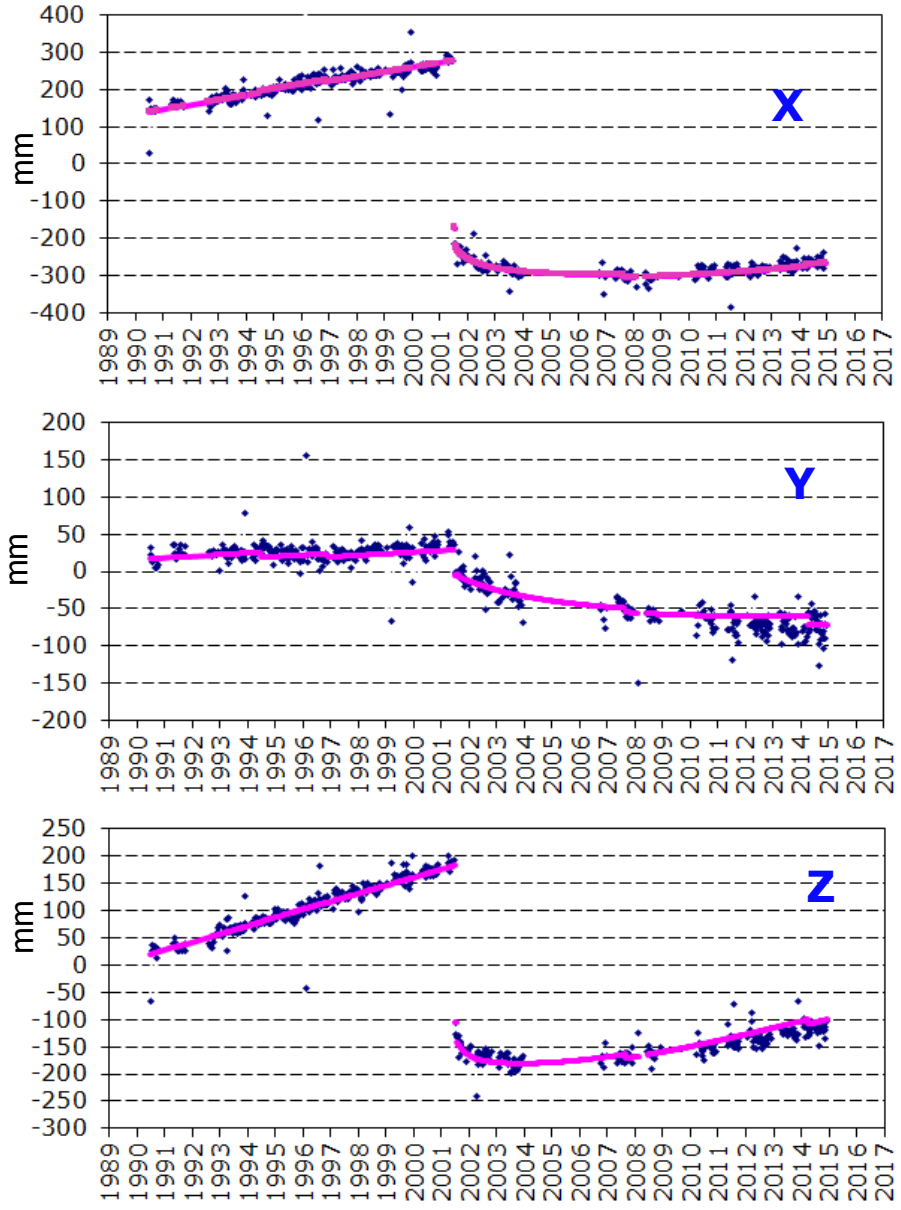
- The SINEX file with ITRF2014P and the discontinuity file are formally correct and usable
- The Post Seismic Deformation model source code and input file are easy to use and integrated into our processing chain.
- PSD is now implemented into the SW for the SLR data analysis, for the combination and for the solution comparison/checking.
- Discontinuities under discussion for some stations
- New ASI time series using ITRF2014P, analyzing the data from 2009 to 2014. No issue found.

PSD Model: 7403 Arequipa, Peru

ITRF2008

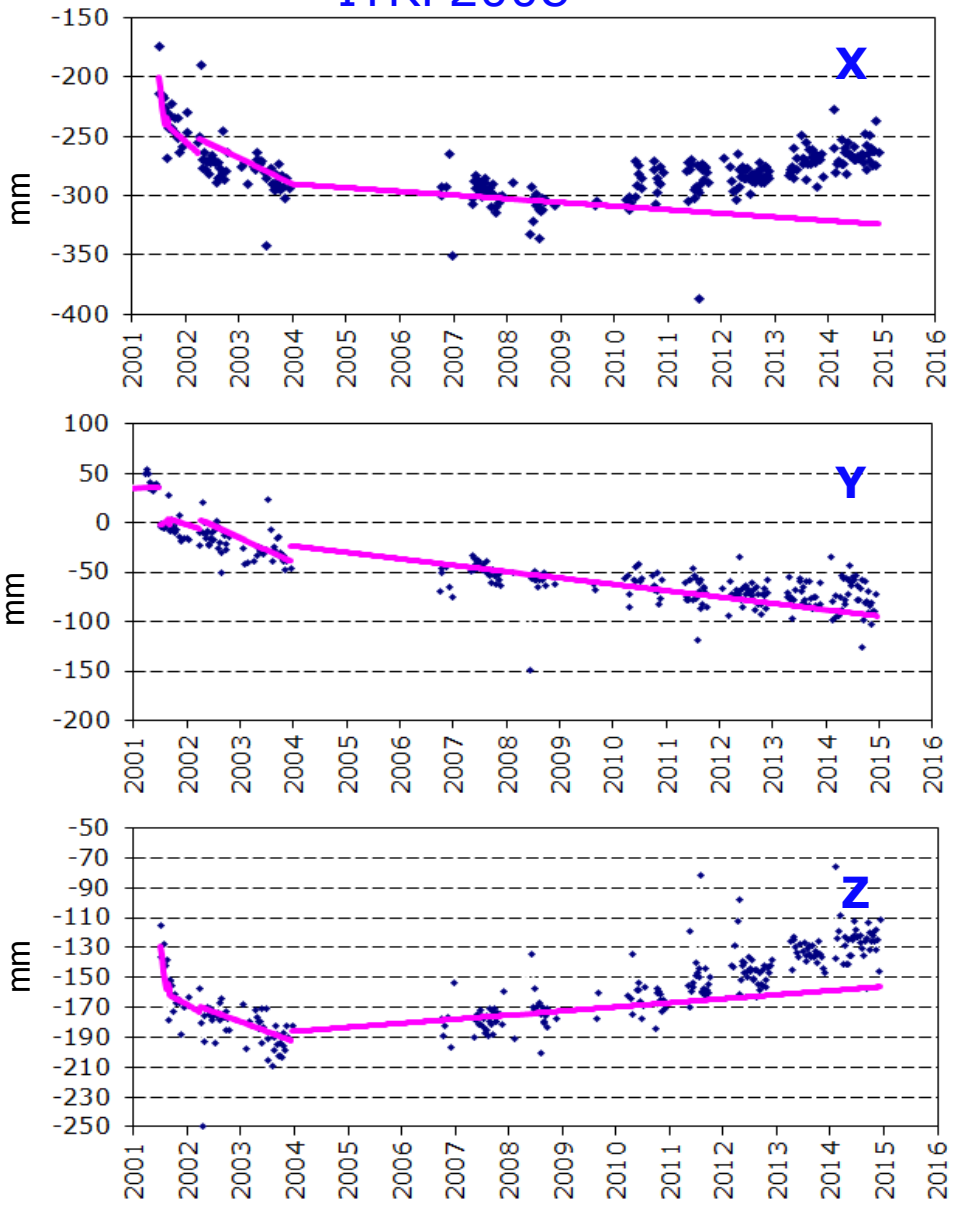


ITRF2014P

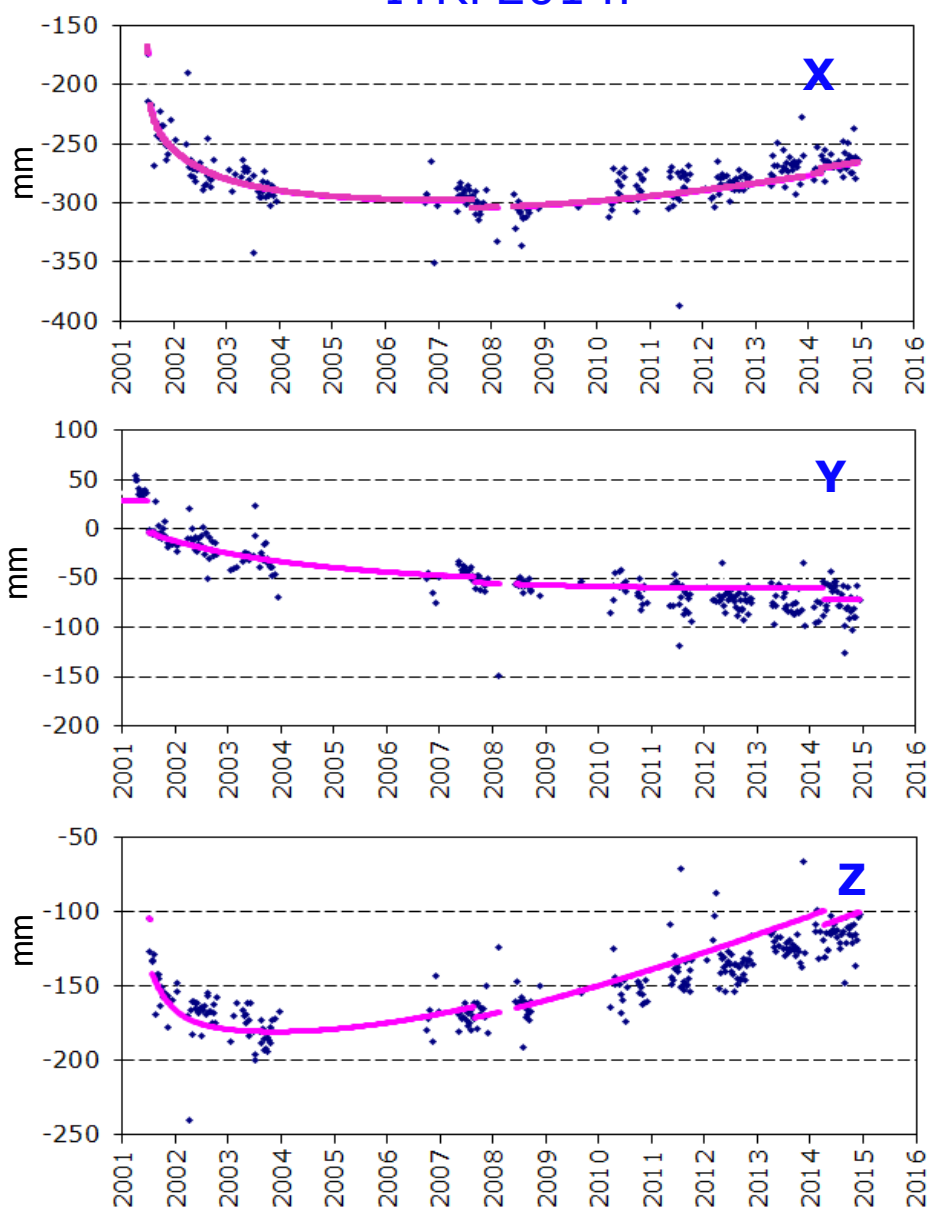


PSD Model: 7403 Arequipa, Peru

ITRF2008



ITRF2014P



Discontinuities in ITRF2014P

	Discontinuities					
	yyyy:doy	**yyyy:doy**	**yyyy:doy**	**yyyy:doy**	**yyyy:doy**	**yyyy:doy**
1868	2003:157					
1893	2008:298					
7110	1999:289 **E**	2010:092 **E**				
7122	1985:266	1991:087				
7124	2001:138					
7210	1989:263	1994:020	1999:216			
7237	2011:069 **E**					
7249	2011:031 **E**					
7307	1997:307					
7308	2011:056 **E**					
7358	2011:064 **E**					
7403	1994:161	1996:321	2001:166 **E**	2001:186	2007:230	2014:093
7405	2010:058 **E**	2011:038				
7406	2010:051					
7501	2012:098					
7811	2002:208					
7820	2002:098					
7821	2009:135	2010:028	2011:068 **E**			
7835	1990:078					
7837	1995:229					
7838	2003:100	2011:049 **E**				
7839	1995:332	1999:316				
7843	1992:126					
7907	1988:104					
8834	2000:343	2009:045				

E=earthquake

Questionable discontinuities

	Discontinuities					
	yyyy:doy	**yyyy:doy**	**yyyy:doy**	**yyyy:doy**	**yyyy:doy**	**yyyy:doy**
1868	2003:157					
1893	2008:298					
7110	1999:289 E	2010:092 E				
7122	1985:266	1991:087				
7124	2001:138					
7210	1989:263	1994:020	1999:216			
7237	2011:069 E					
7249	2011:031 E					
7307	1997:307					
7308	2011:056 E					
7358	2011:064 E					
7403	1994:161	1996:321	2001:166 E	2001:186	2007:230	2014:093
7405	2010:058 E	2011:038				
7406	2010:051					
7501	2012:098					
7811	2002:208					
7820	2002:098					
7821	2009:135	2010:028	2011:068 E			
7835	1990:078					
7837	1995:239					
7838	2003:100	2011:049 E				
7839	1995:332	1999:316				
7843	1992:126					
7907	1988:104					
8834	2000:343	2009:045				

+ 2010:058 E

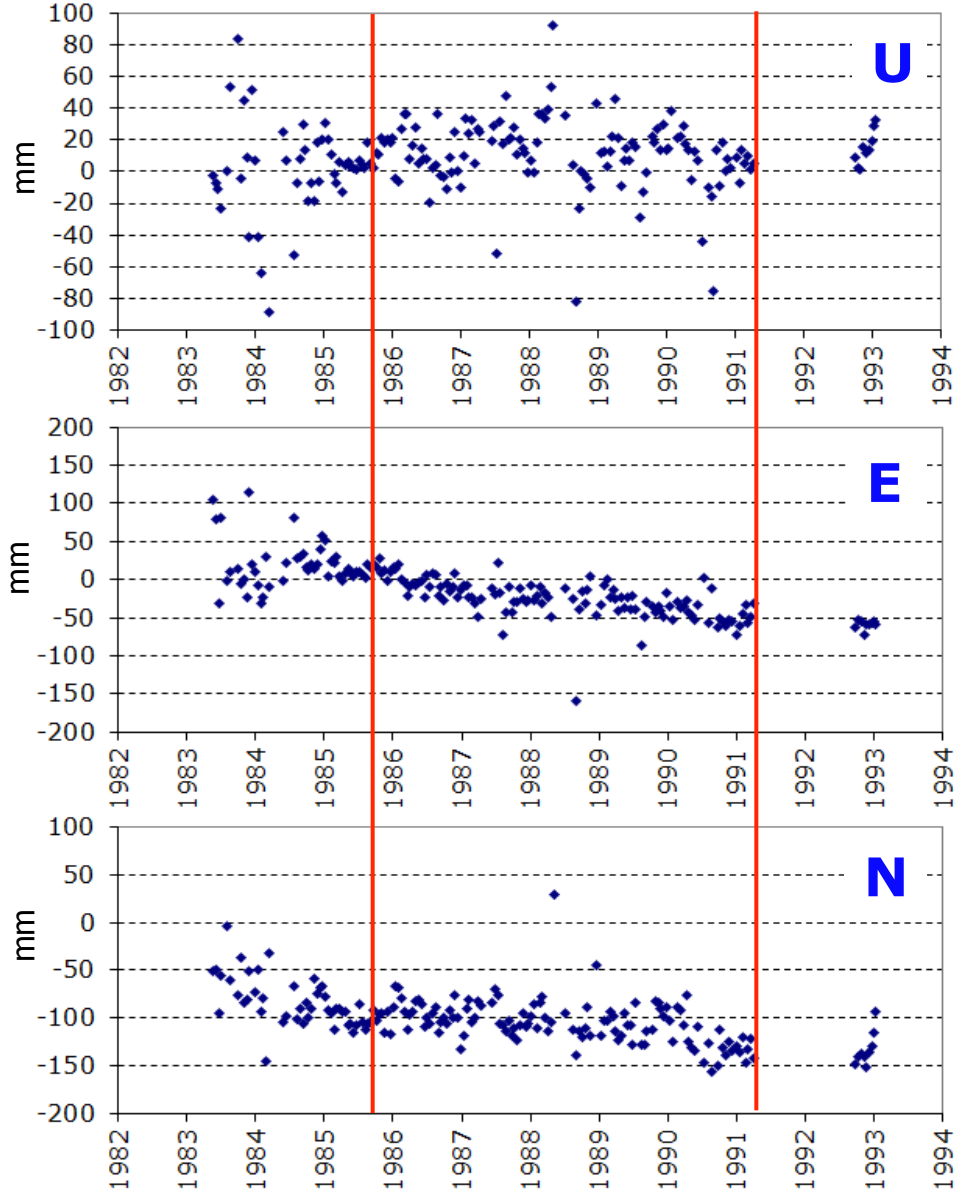
2004:249 E instead of

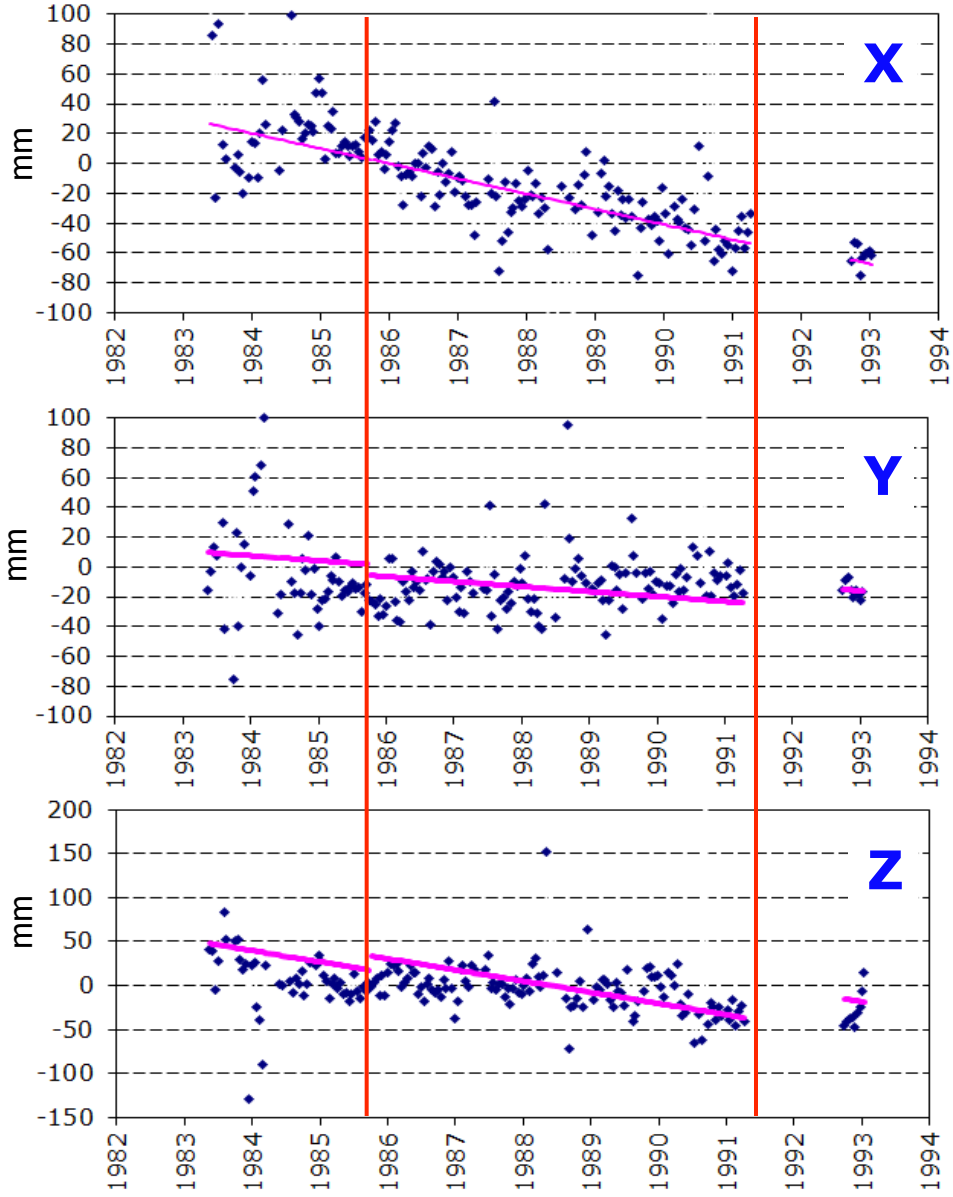
+ 1988

We see also a discontinuity for **1864** at 1997

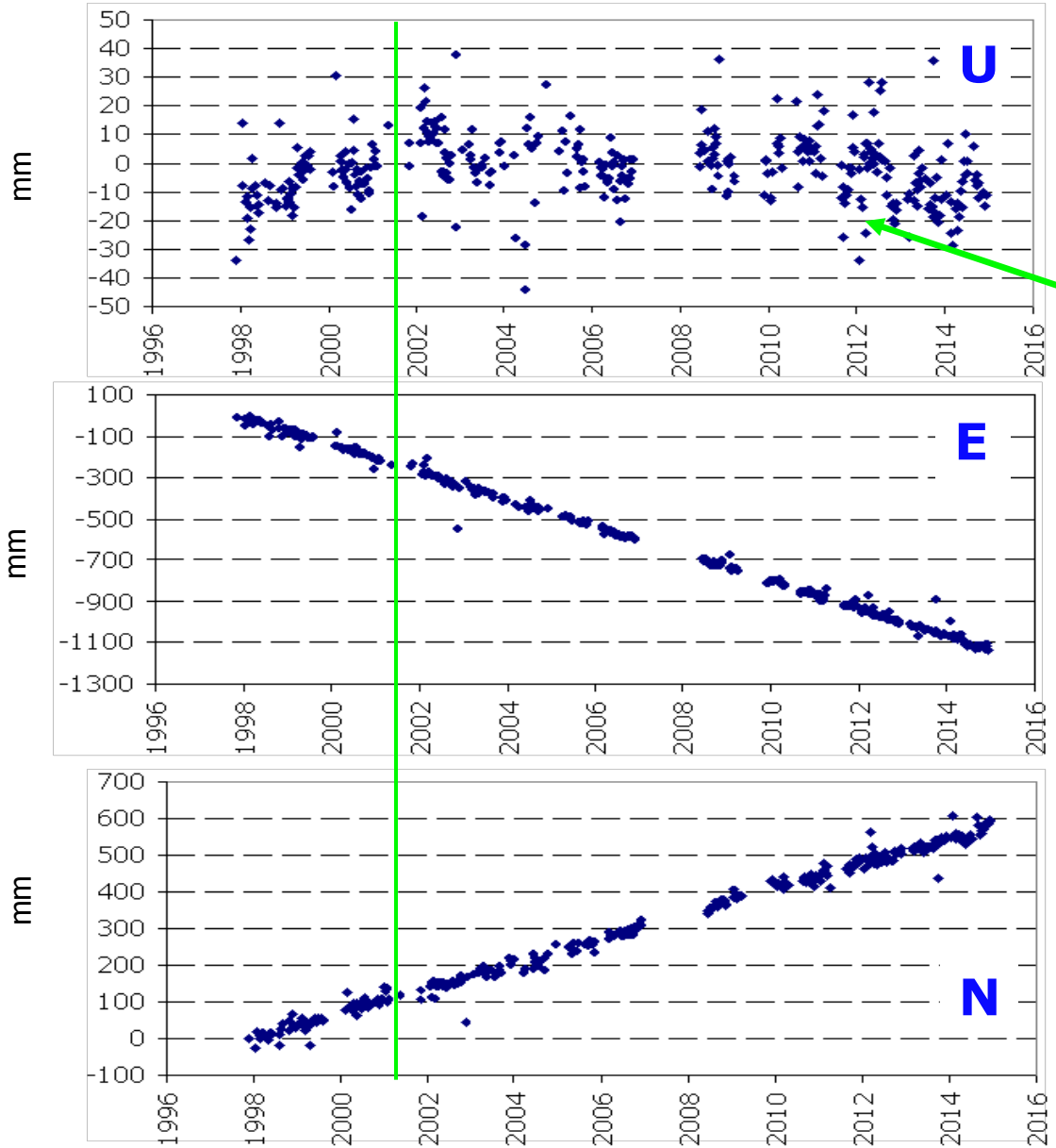
7122 Mazatlan

The scatter is large and the discontinuities are not so evident



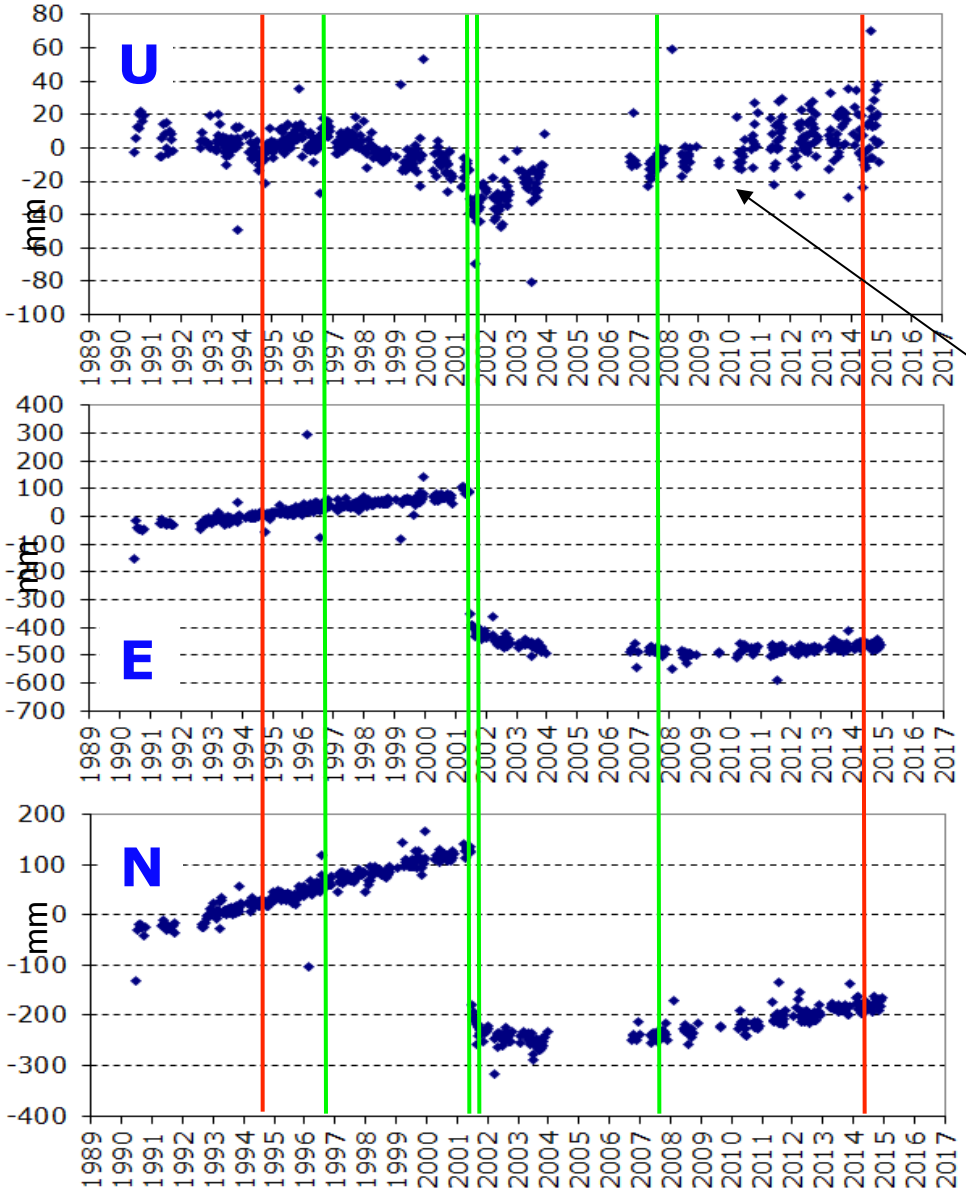


7124 Tahiti, French Polynesia



A discontinuity in 2012?

7403 Arequipa, Peru



- Discontinuities 1994:161 and 2014:093 are not obvious
- 1996 and 2007 Earthquakes are not considered in PSD model file

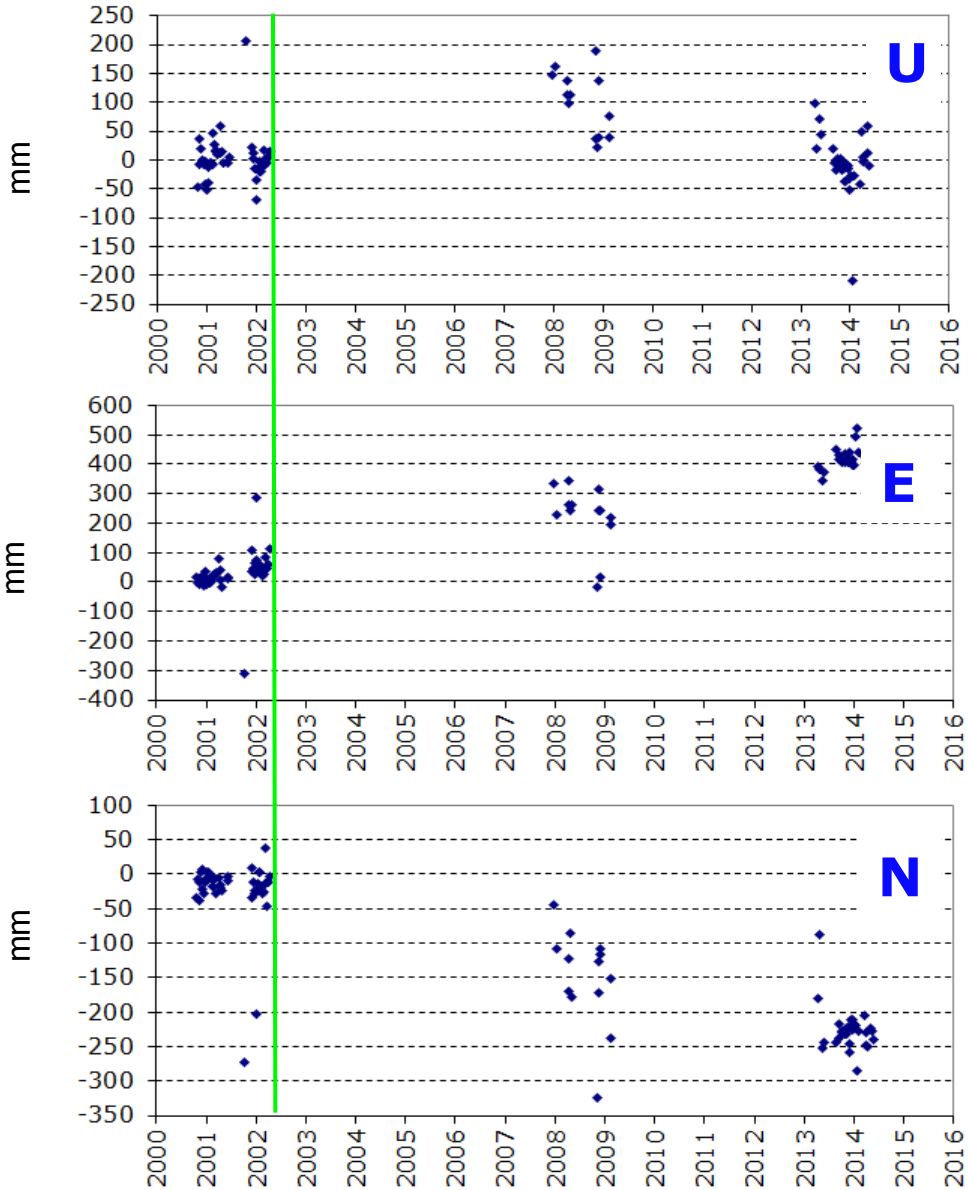
Chile Earthquake 2010:058?

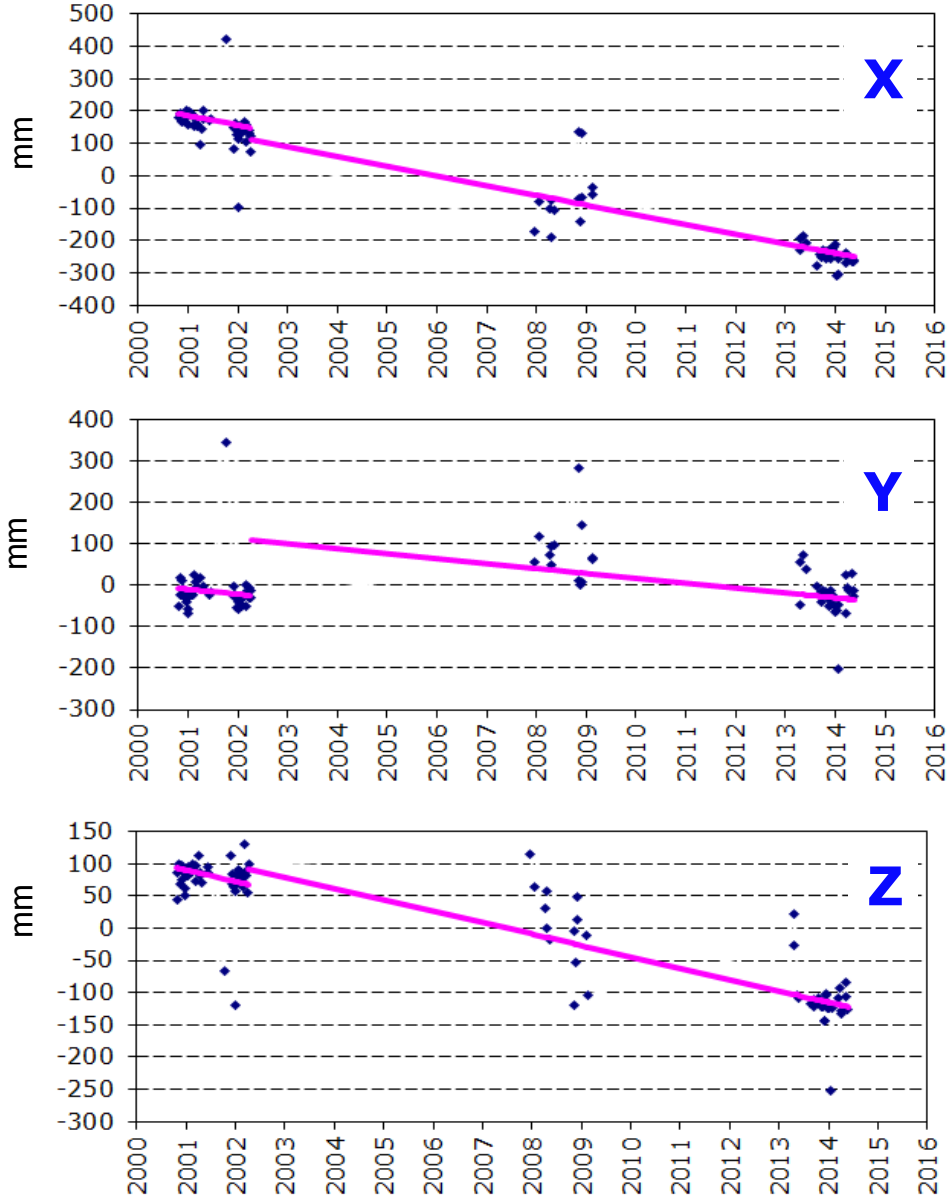
Registered Earthquake with M > 7

12 November 1996	7.7
23 June 2001	8.4
15 August 2007	8.0
25 September 2013	7.0

7820 Kunming, China

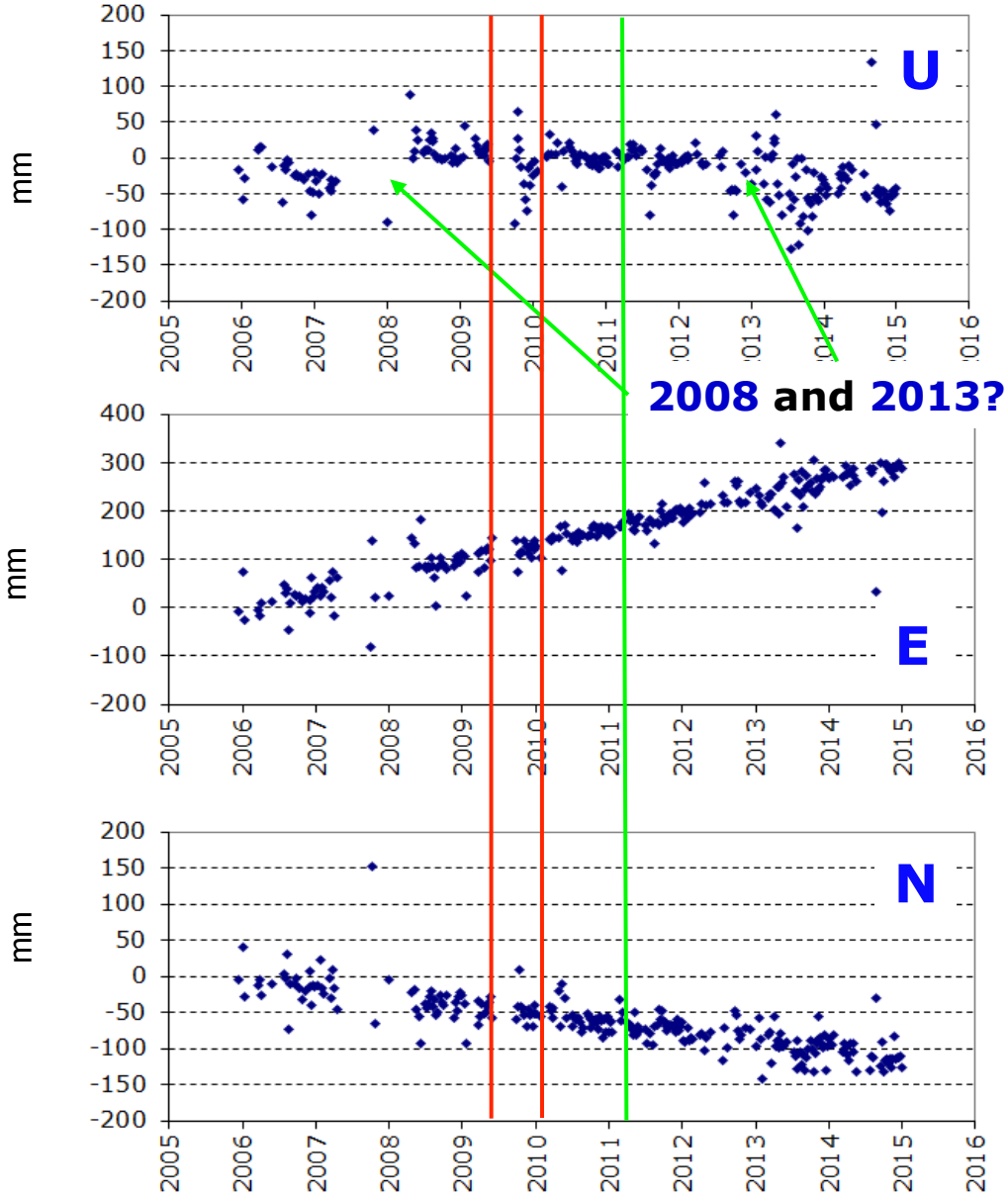
Noisy station with large gaps

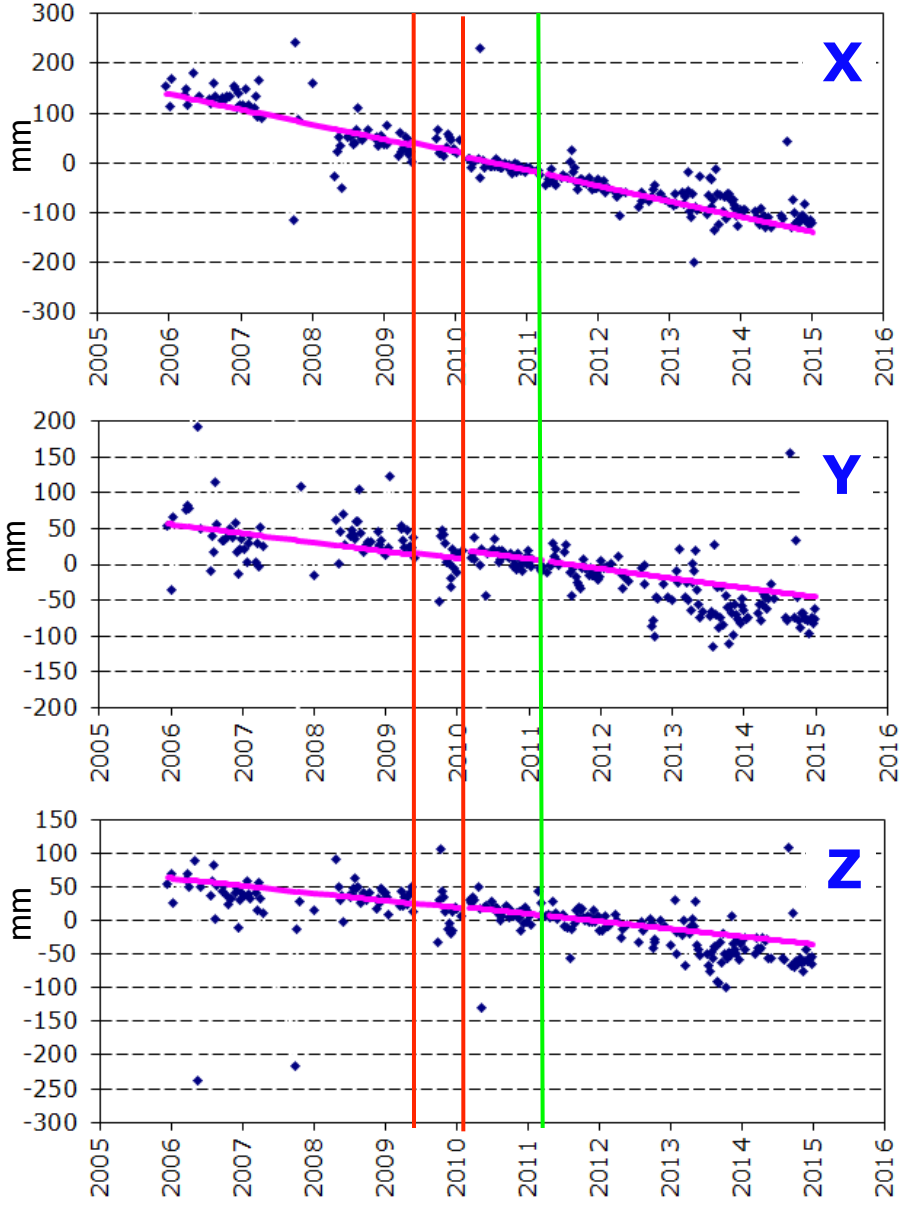




7821 Shanghai, China

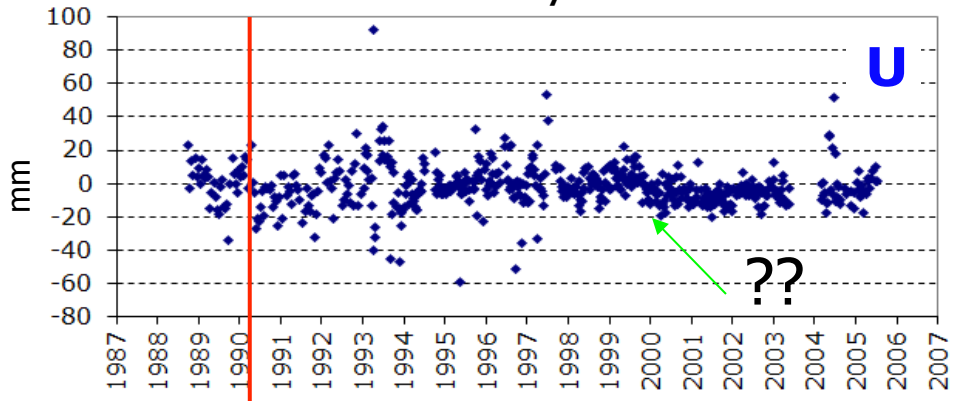
Discontinuities 2009:135 and 2010:028 are not obvious

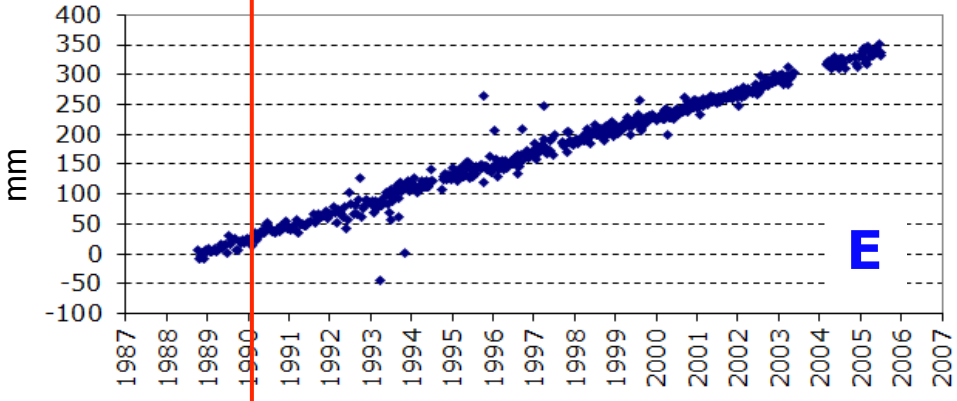


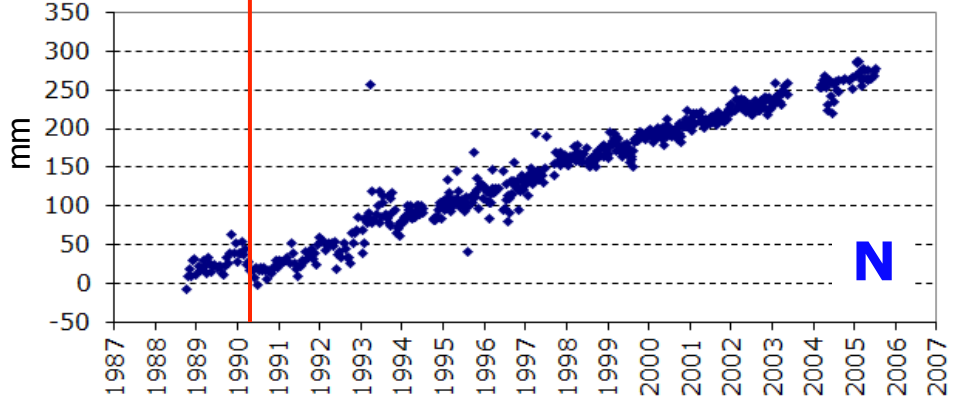


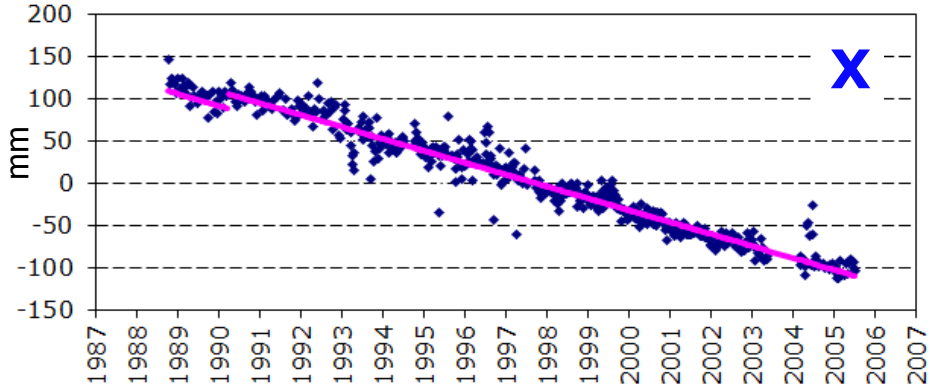
7835 Grasse, France

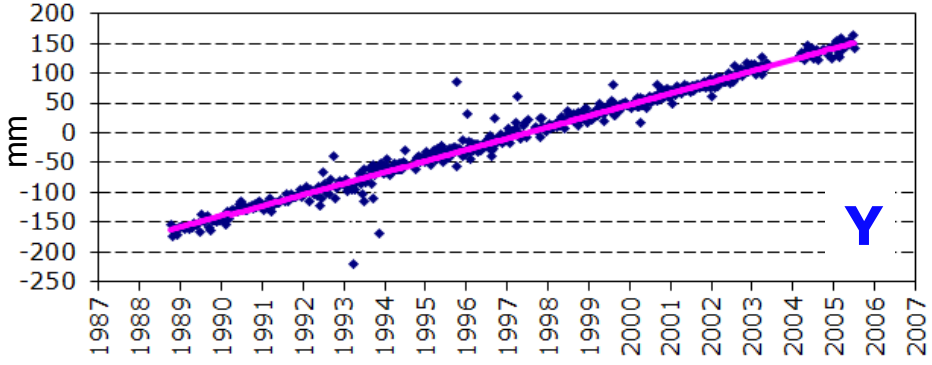
Real discontinuity in 1990?

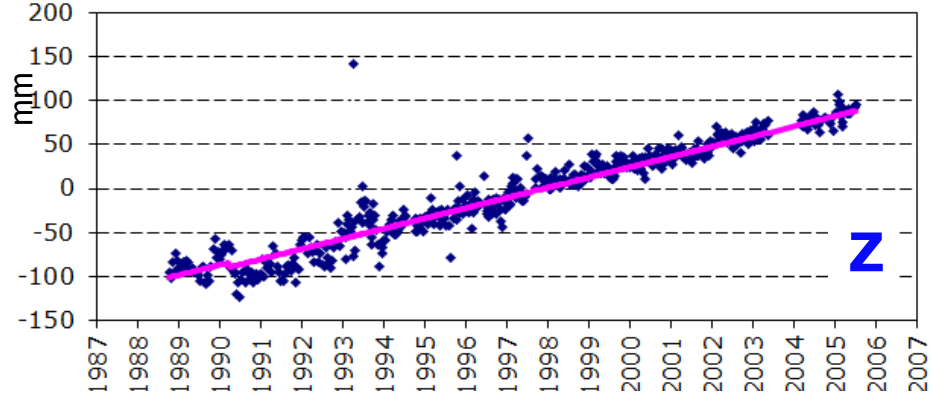






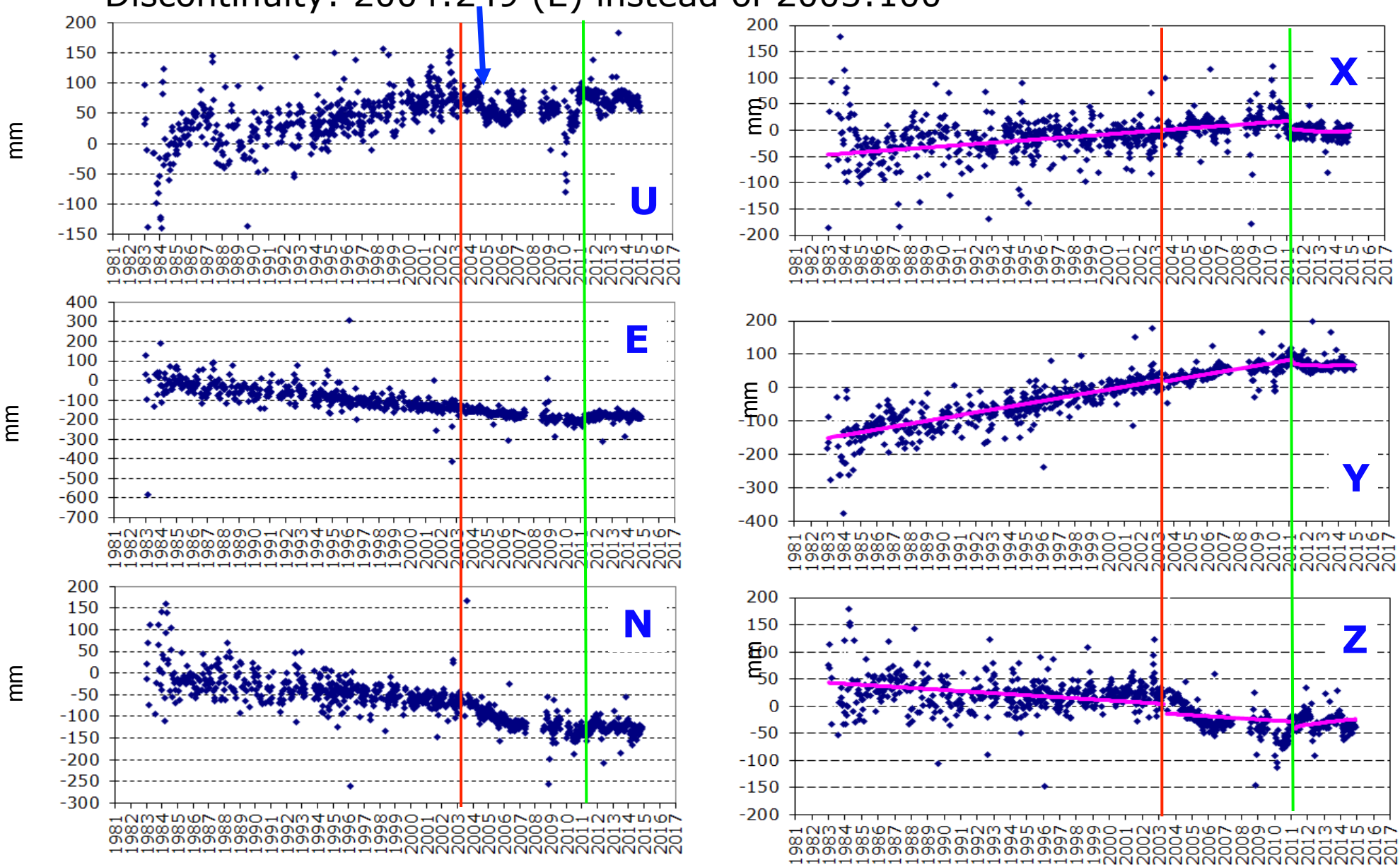




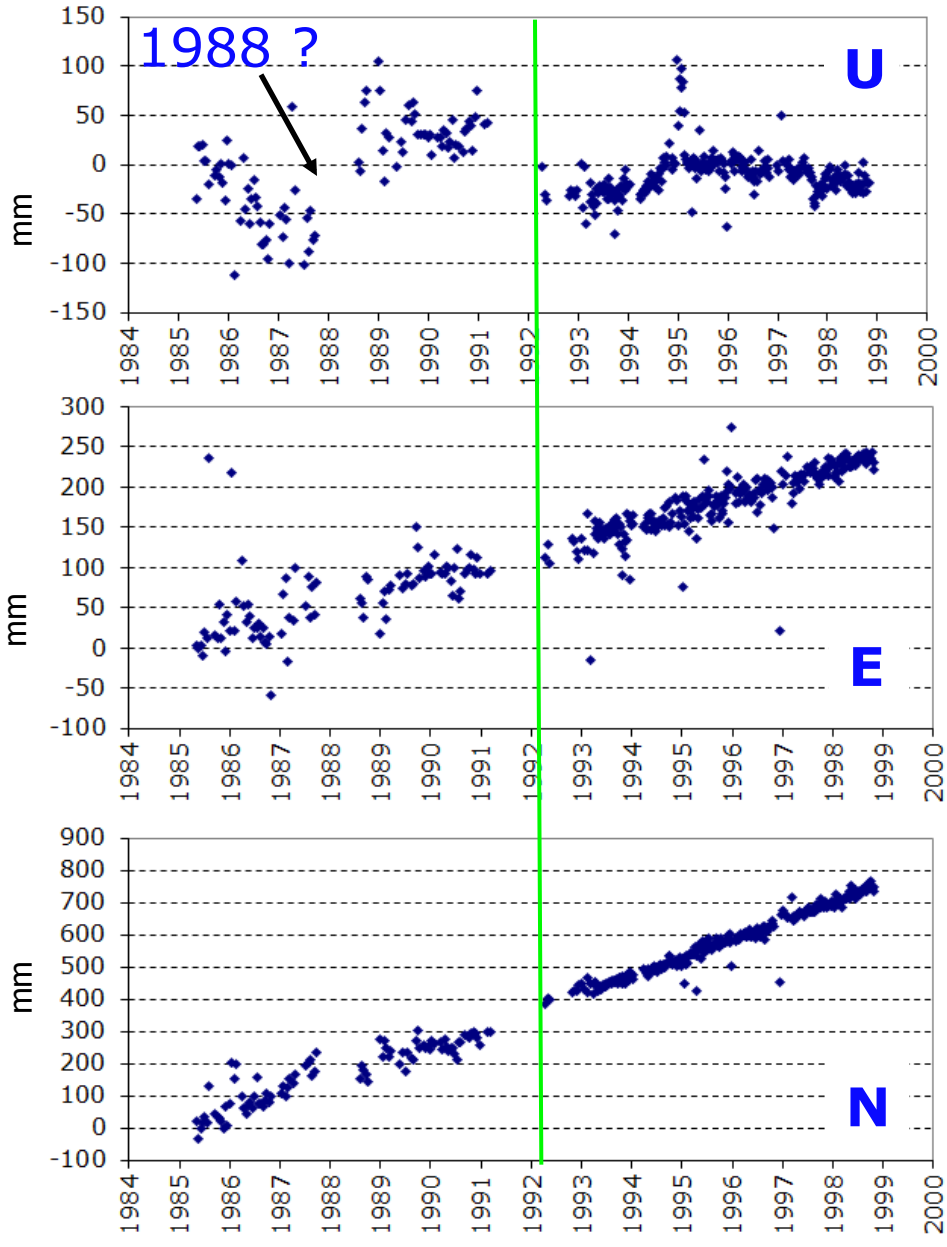


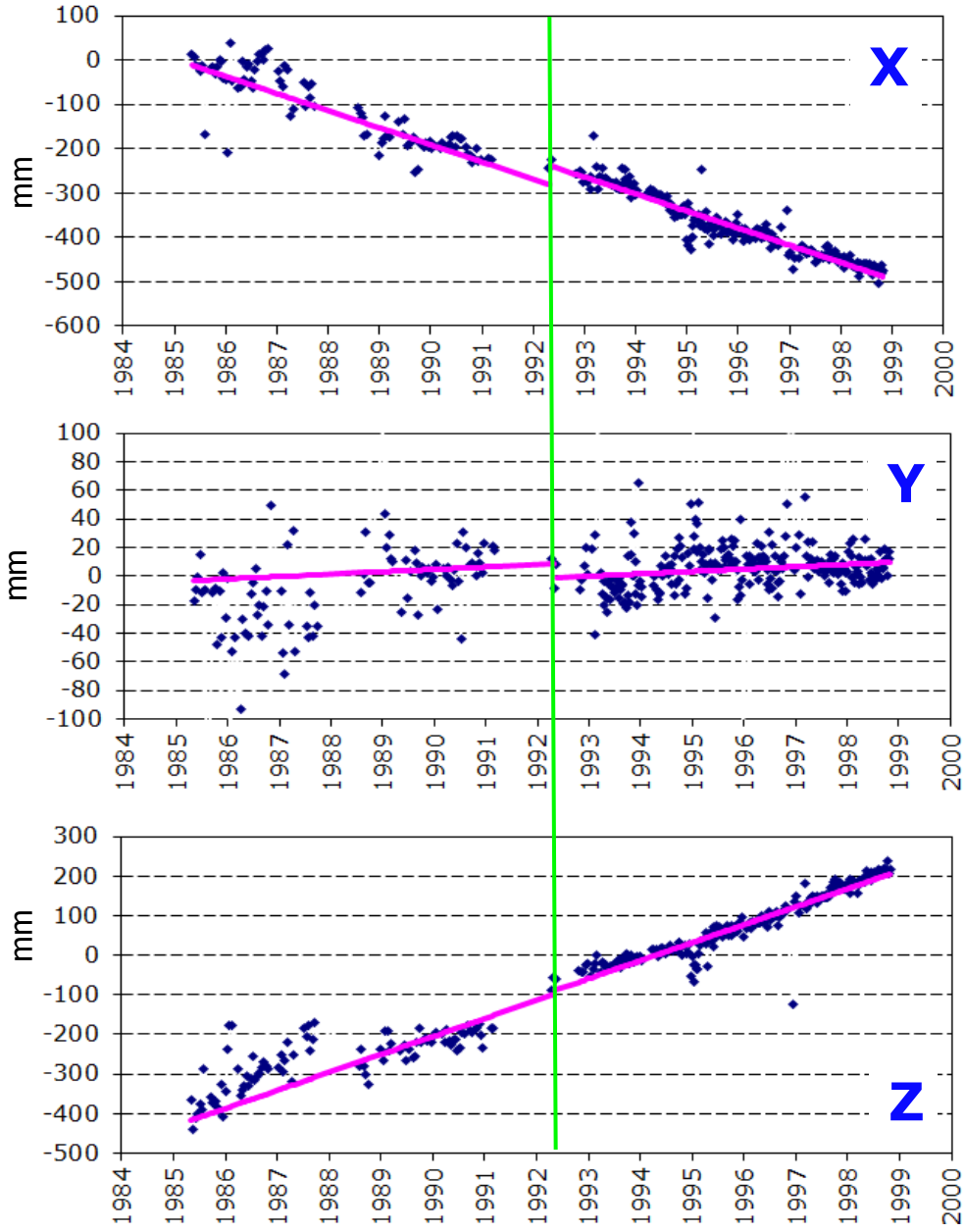
7838 Simosato, Japan

Discontinuity: 2004:249 (E) instead of 2003:100

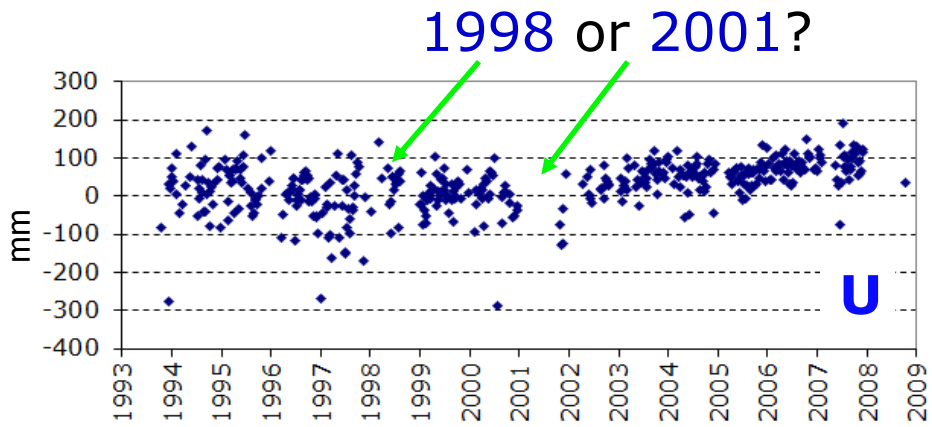


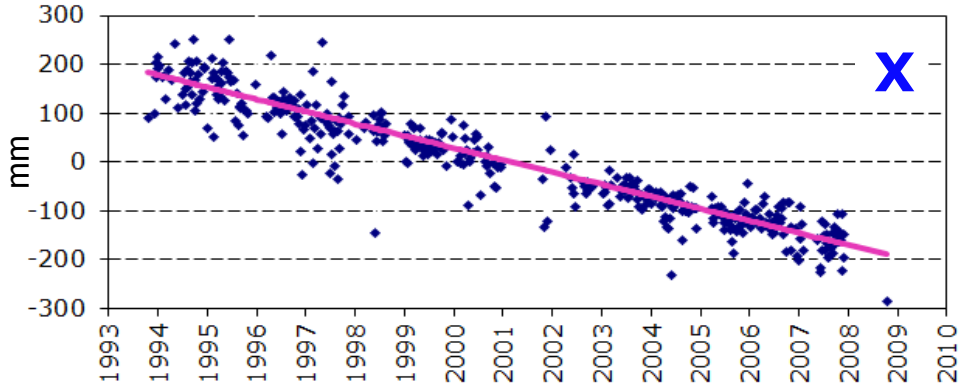
7843 Orroral, Australia

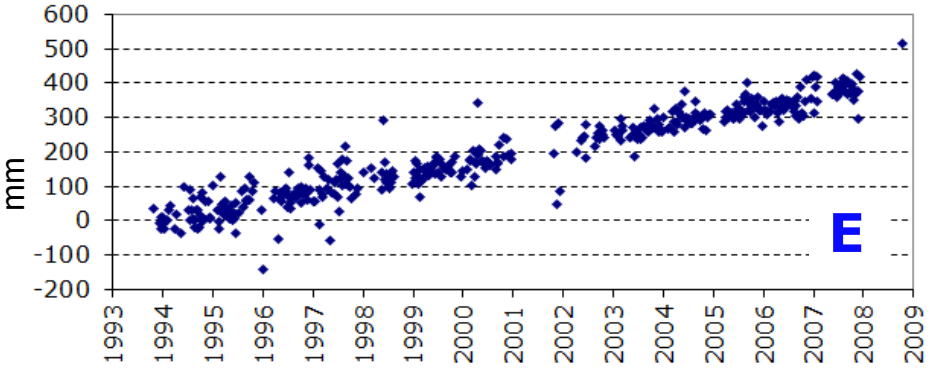


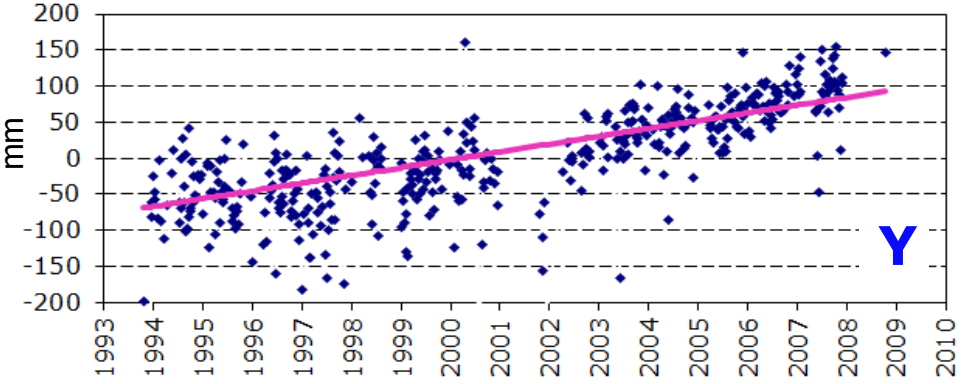


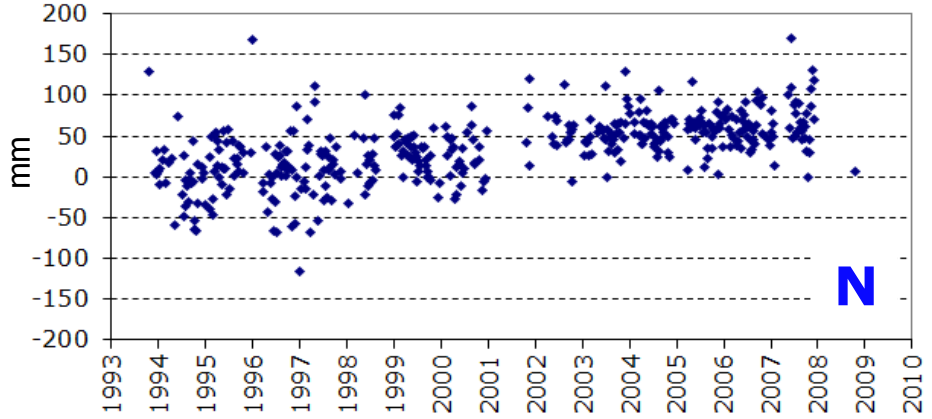
1864 Maidanak 1, Uzbekistan

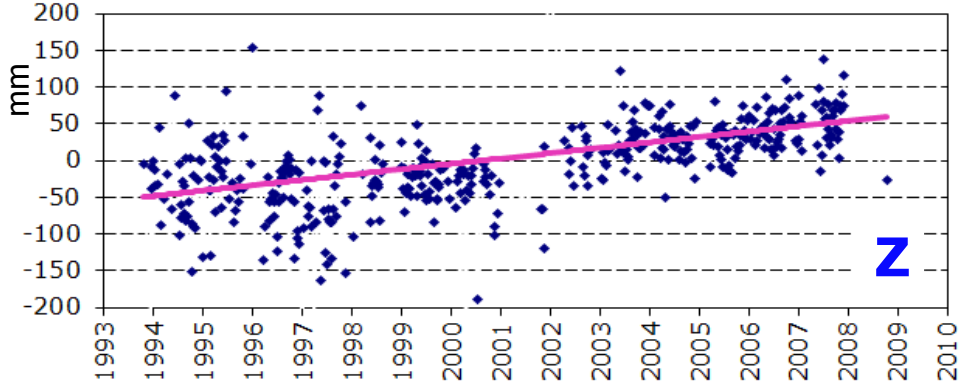






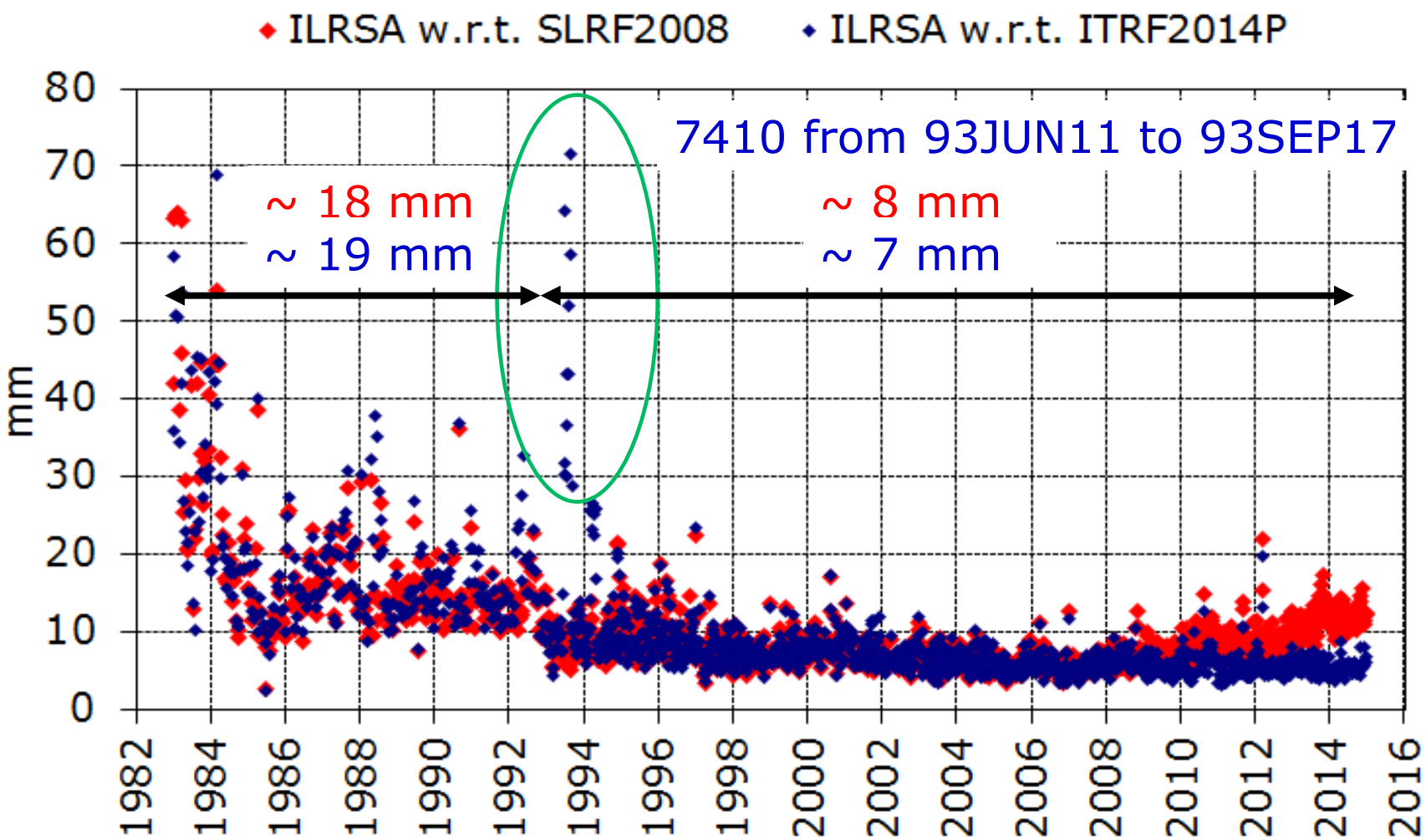




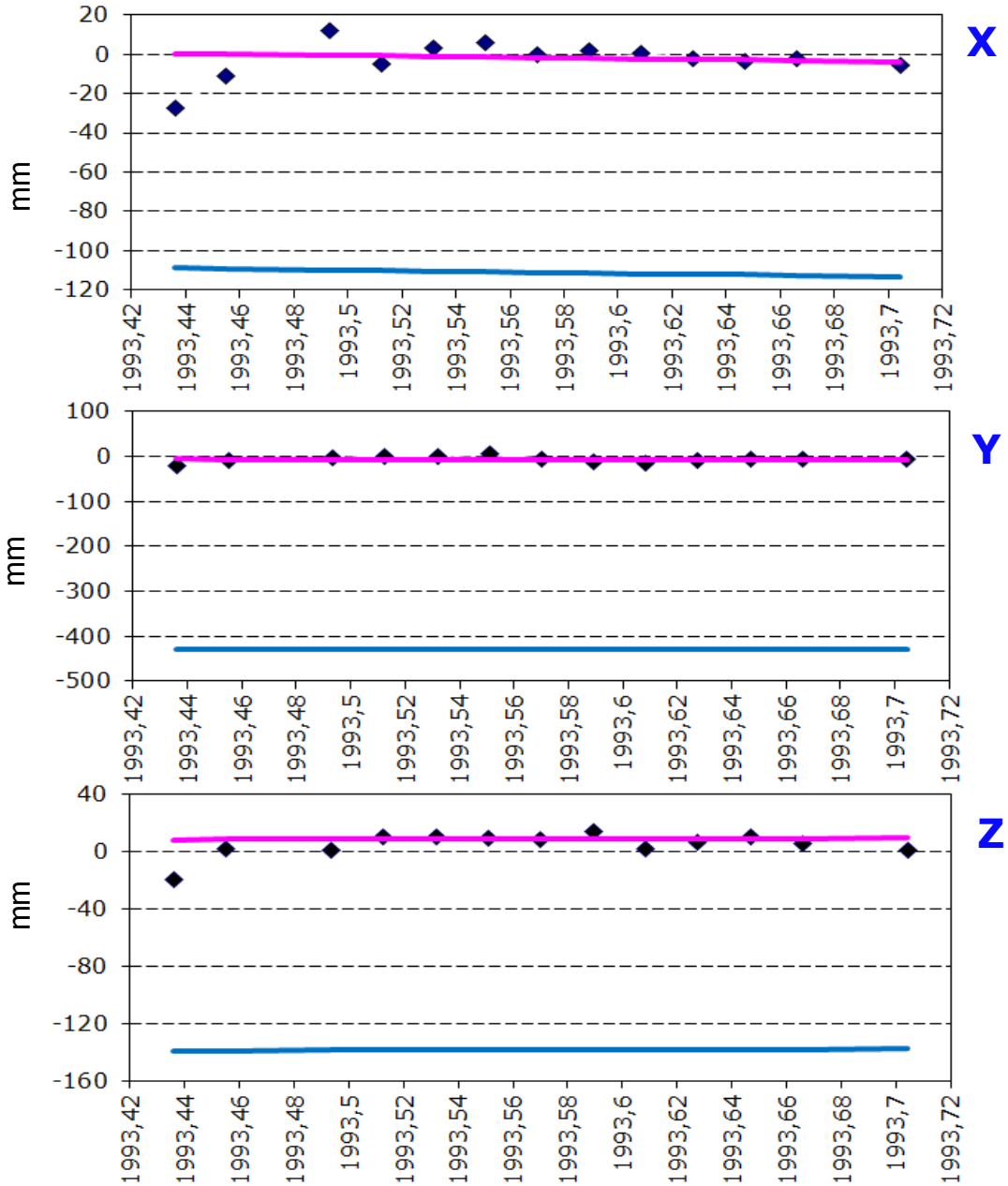


Site Coordinate Residuals

All Sites – 3D Residuals WRMS wrt ITRF



7410 Algonquin (93JUN11-93SEP17)

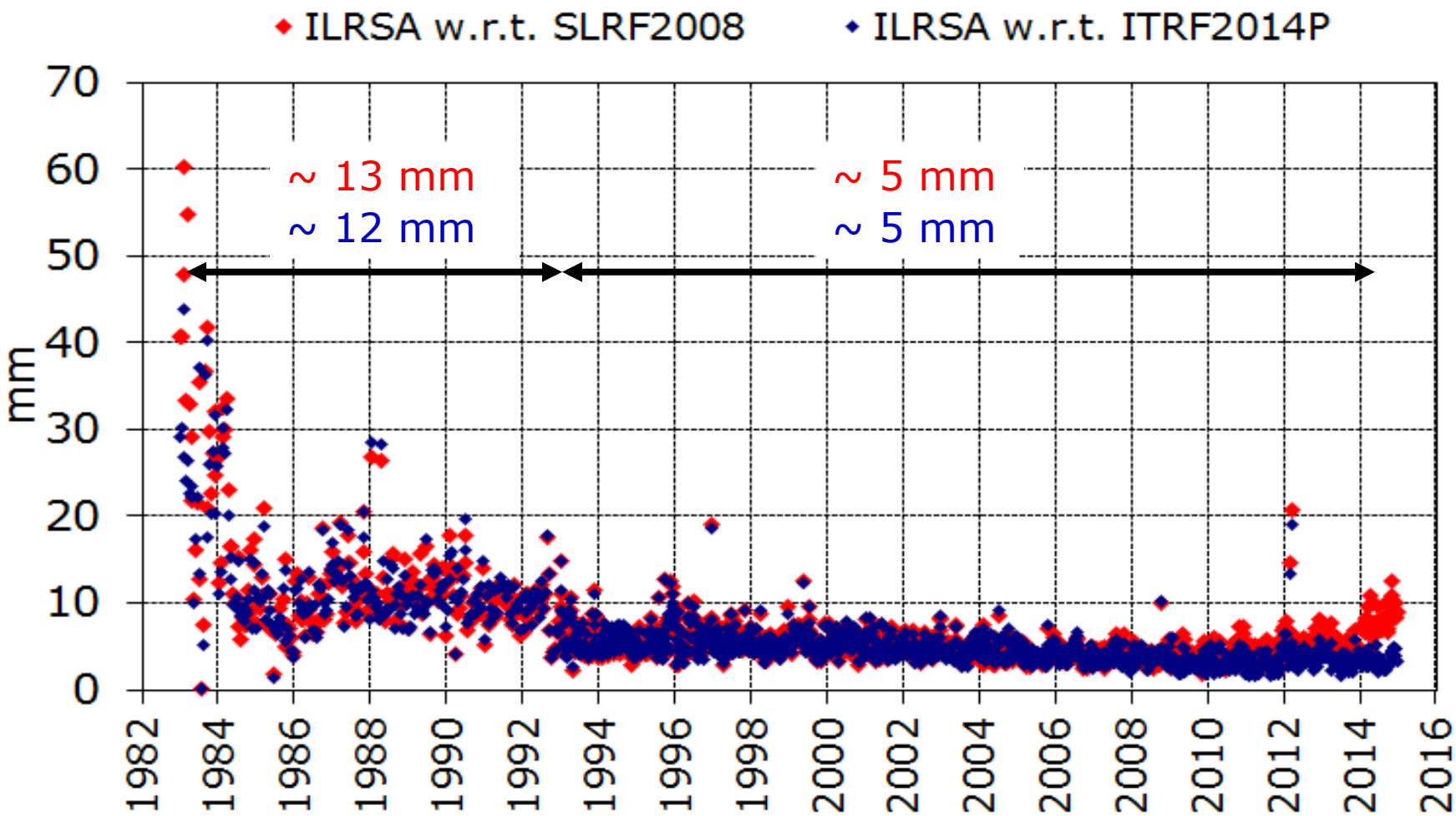


SLRF2008

ITRF2014P

Site Coordinate Residuals

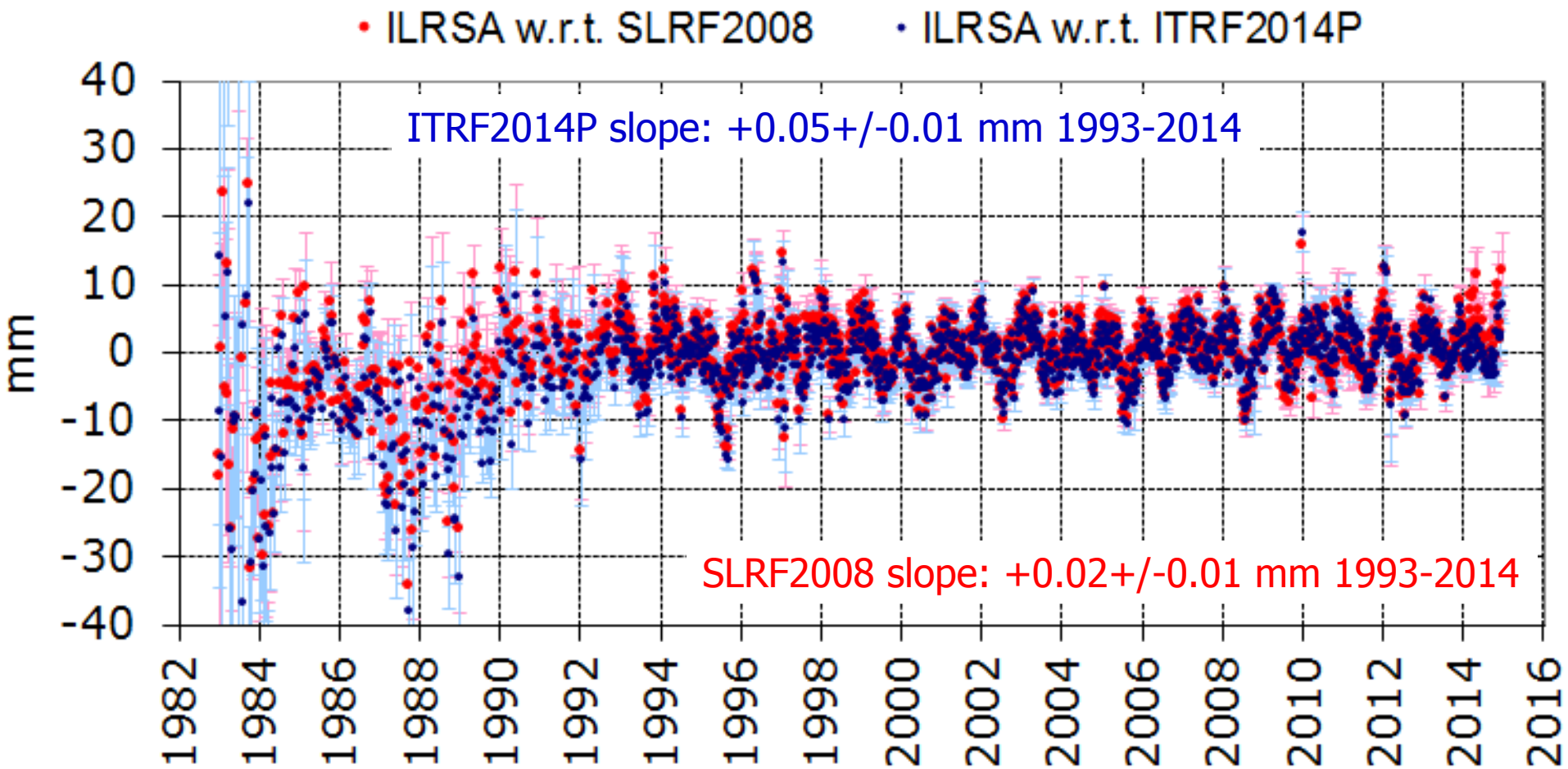
Core Sites – 3D Residuals WRMS wrt ITRF Frame



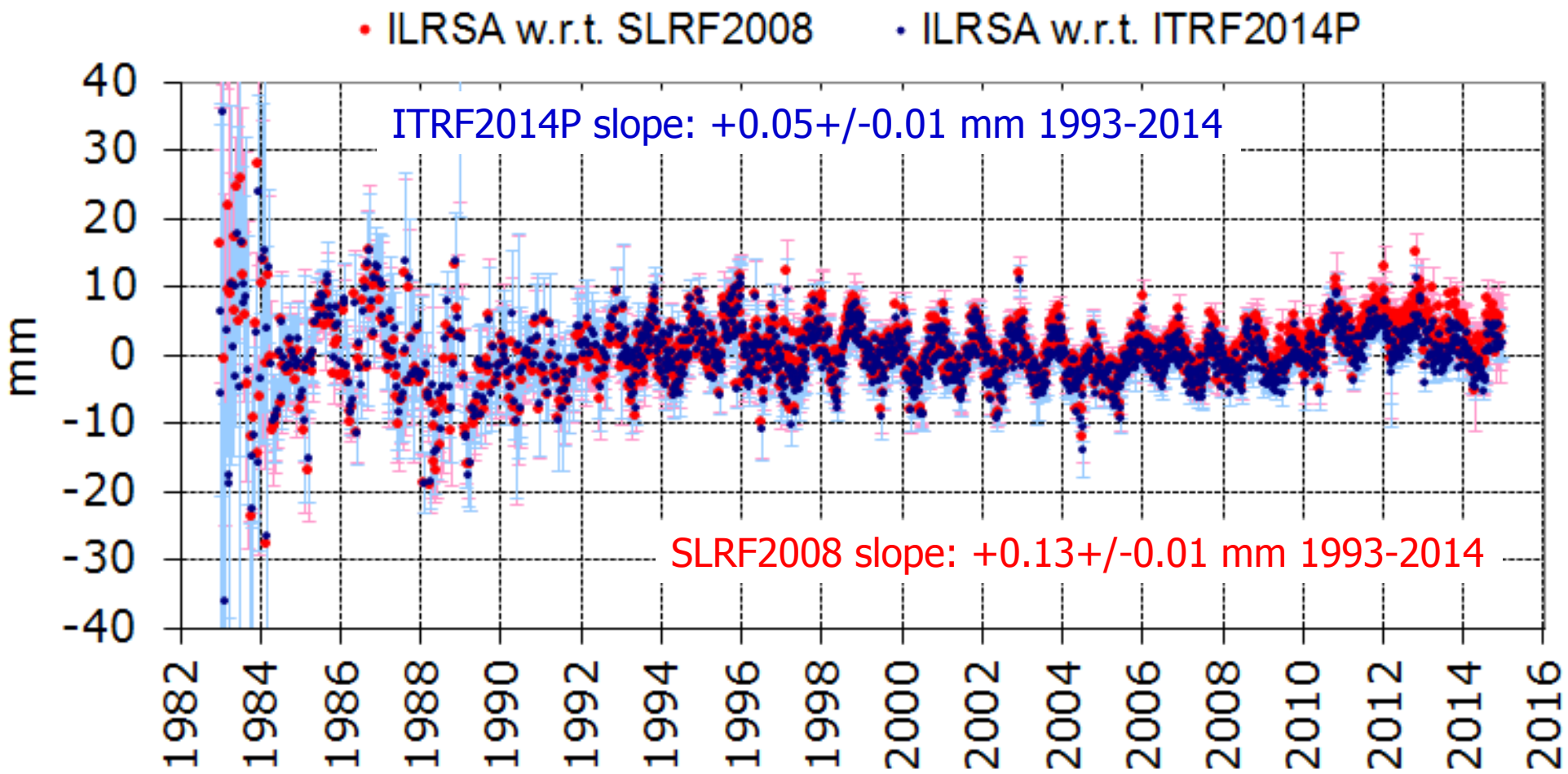
Site Coordinate Residuals - Statistics

	vs SLRF2008		vs ITRF2014P	
	Mean WRMS [mm]	**STD WRMS [mm]**	**Mean WRMS [mm]**	**STD WRMS [mm]**
All Sites	**9.7**	***6.2***	**9.0**	***6.5***
Core Sites	**6.5**	***4.9***	**6.0**	***4.3***

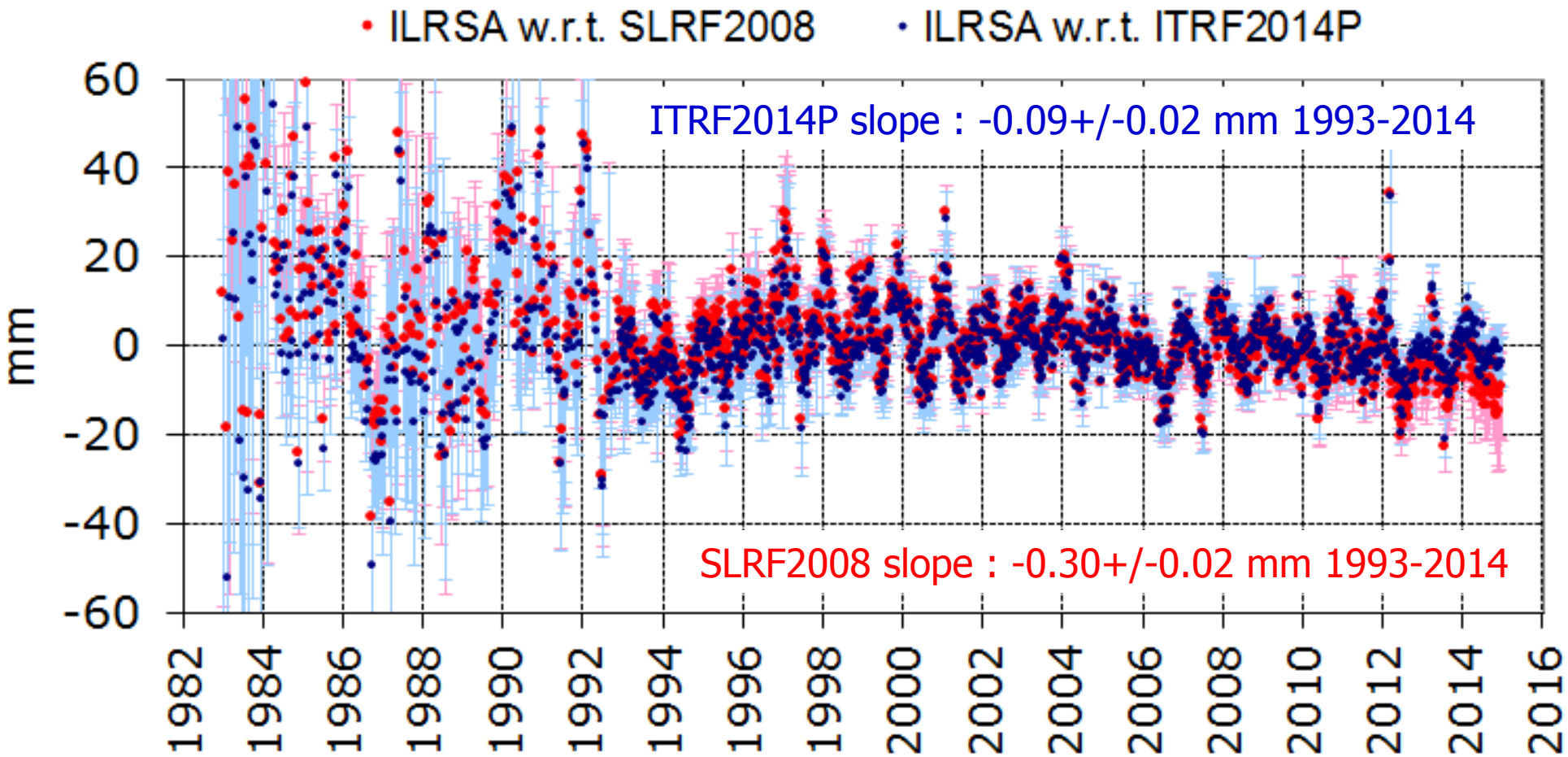
Helmert Translations: Tx



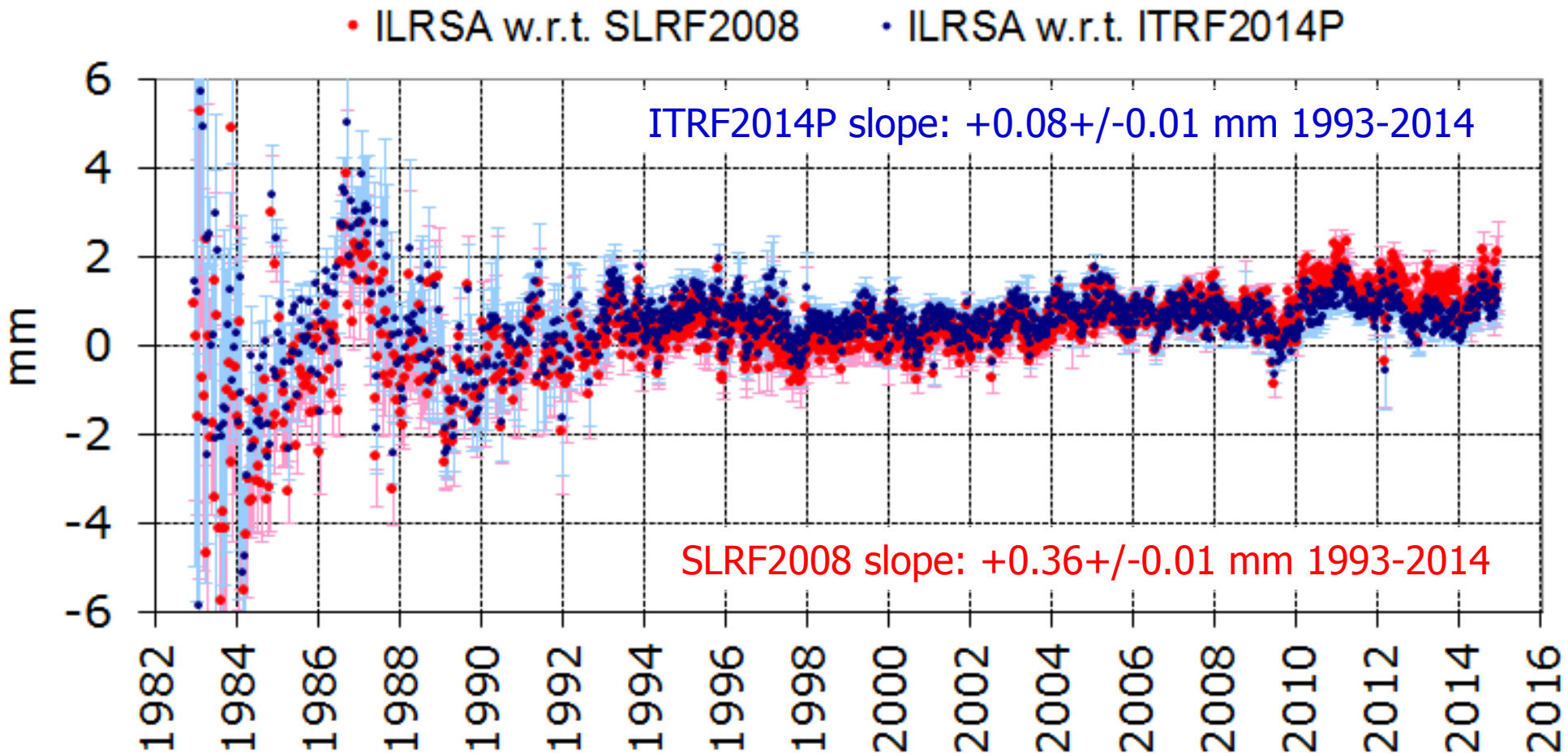
Helmert Translations: Ty



Helmert Translations: Tz



Helmert Scale



Helmert Parameters comparison

	vs SLRF2008 1983-2014			vs ITRF2014P 1983-2014		
	WRMS [mm]	Slope [mm/yr]	σslope [mm/yr]	WRMS [mm]	Slope [mm/yr]	σslope [mm/yr]
Tx	3.89	+0.06	*0.01*	3.85	+0.10	*0.01*
Ty	3.72	+0.11	*0.01*	3.39	+0.03	*0.01*
Tz	7.47	-0.37	*0.02*	6.84	-0.15	*0.02*
Sc	4.98	+0.34	*0.01*	4.98	+0.07	*0.01*

	vs SLRF2008 1993-2014			vs ITRF2014P 1993-2014		
	WRMS [mm]	Slope [mm/yr]	σslope [mm/yr]	WRMS [mm]	Slope [mm/yr]	σslope [mm/yr]
Tx	3.73	+0.02	*0.01*	3.62	+0.05	*0.01*
Ty	3.55	+0.13	*0.01*	3.26	+0.05	*0.01*
Tz	6.76	-0.30	*0.02*	6.31	-0.09	*0.02*
Sc	4.91	+0.36	*0.01*	4.85	+0.08	*0.01*

AWG plan for ITRF2014P evaluation

- The AWG plan is the generation of a combined ILRS solution for t.he period 2009-2014.

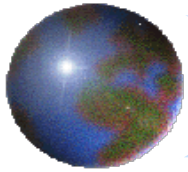
Agency	Time series	Submission date	Note
ASI	2009-2014	21 Oct 2015	
BKG	-		
DGFI	2009-2014	09 Oct 2015	
ESA	1993-2014	22 Oct 2015	
GRGS	2009-2014	23 Oct 2015	Without PSD model
GFZ	2009-2014	08 Oct 2015	
JCET	-		
NSGF	-		

ILRSA CC
Status of the SP3 files combination

B.Pace, V. Luceri
eGEOS S.p.A., CGS – Matera

G. Bianco
Agenzia Spaziale Italiana, CGS - Matera

ILRS AWG Meeting, 24 October 2015, Matera



Contents

- SP3 data evaluation
- Preliminary combination
- Next steps

SP3 data evaluation

- L51/L52/L53/L54 SP3 files from 150620 to 150926 available at CDDIS
- cross-evaluate their consistency (RAC)
- preliminary combination

Assumptions

- EF frame as in the ACs weekly solution
- UTC
- SP3c format
- 2’ POS/VEL L51/L52
- 15’ POS/VEL L53/L54

SP3 availability and assumptions adherence

AC	L51	L52	L53	L54
ASI	yes	yes	yes	yes
BKG	yes	yes	yes	yes
DGFI	yes	yes	-	-
ESA	yes	yes	yes	yes
GFZ	yes	yes	-	-
GRGS	**NO**	**NO**	**NO**	**NO**
JCET	yes	yes	yes	yes
NSGF	yes	yes	yes	yes

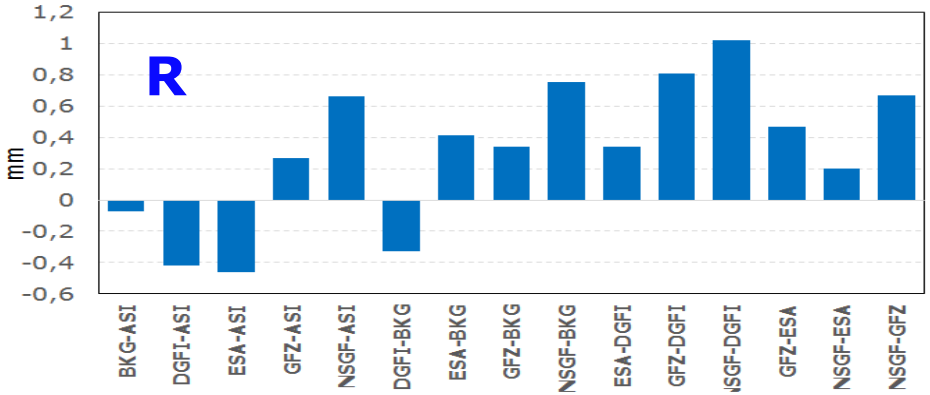
← Uploaded just 2 weeks ago

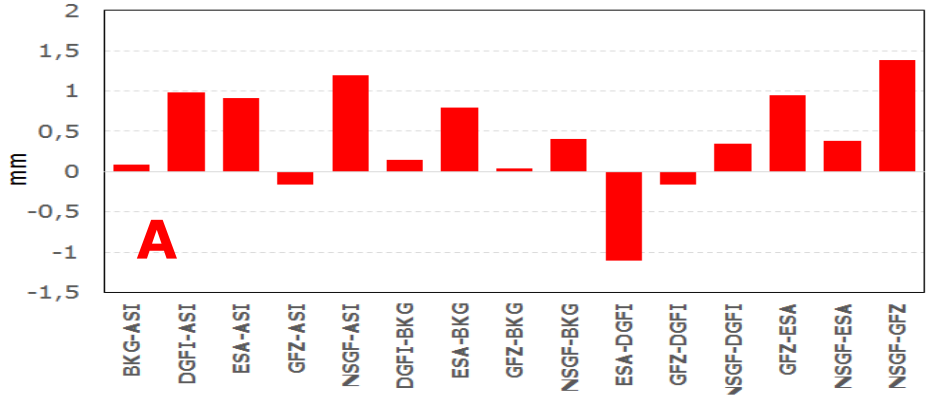
AC	Comments
DGFI	In LAGEOS1/2 sp3 files the “Number of Epochs” in the first line is 0.
BKG	In LAGEOS1/2 and ETALON1/2 sp3 files the name of Agency in the first line is CODE rather than BKG. **Epoch incorrect from 150711 (second = 0.00000020)**
ESA	- In LAGEOS1/2 and ETALON1/2 sp3 files the name of Agency in the first line is ESOC rather than ESA. - Format check NOK for L53/L54: the estimates are given every 5 min instead of 15 min.
NSGF	In LAGEOS1/2 and ETALON1/2 sp3 files the name of Agency in the first line is SGF rather than NSGF.

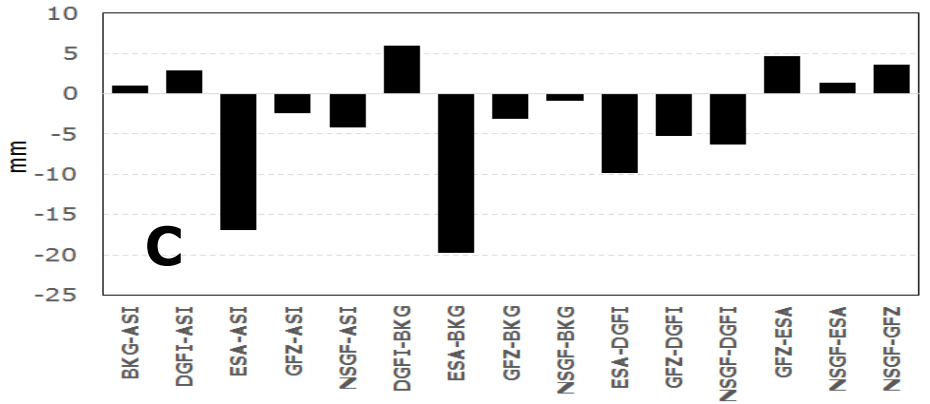
← OK

L51 – summary (150620-150926)

Mean







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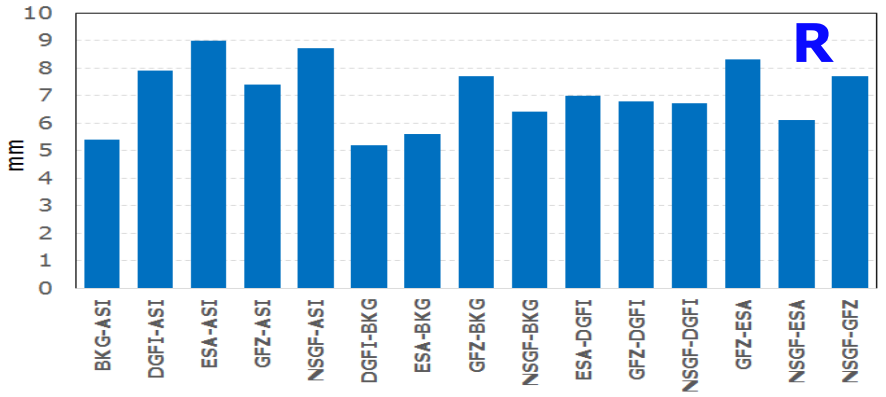
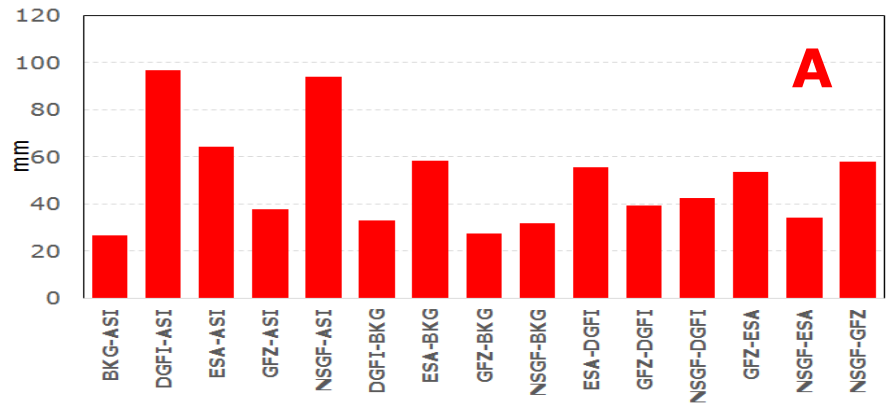
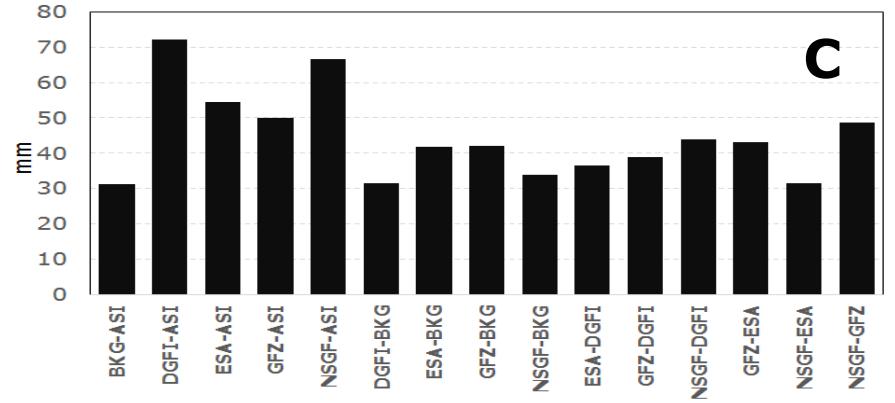
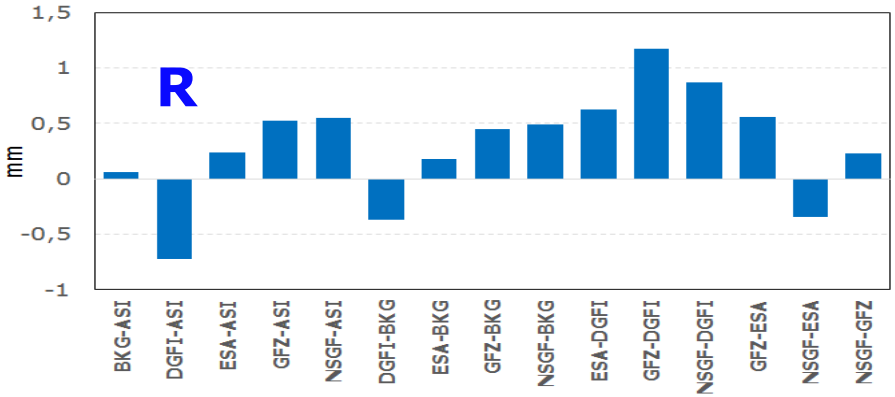


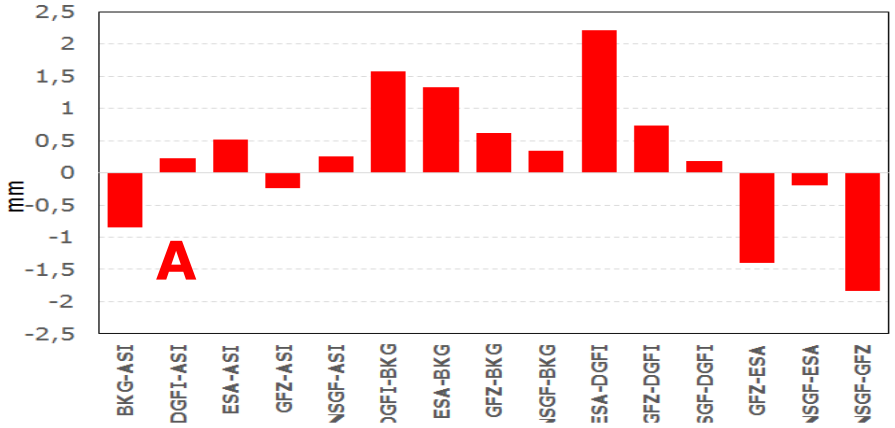


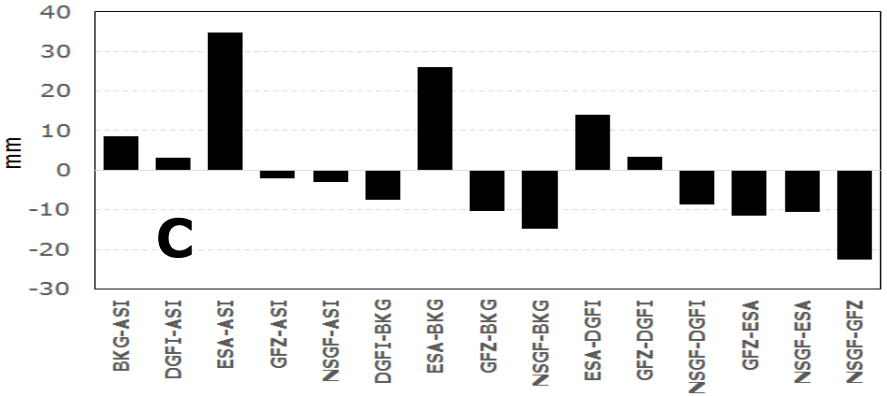


L52 – summary (150620-150926)

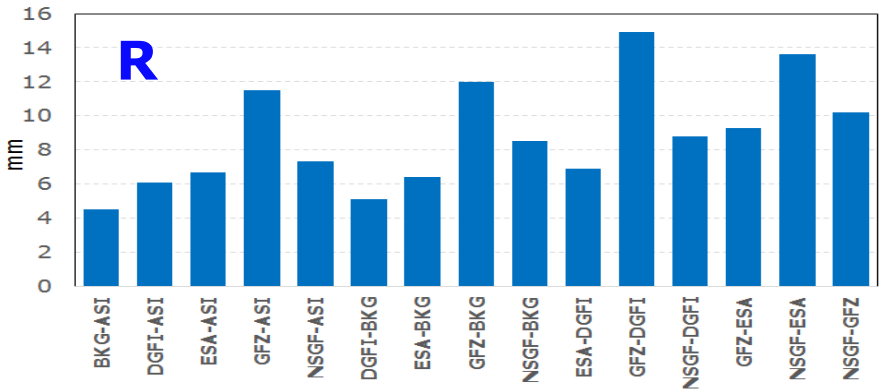
Mean

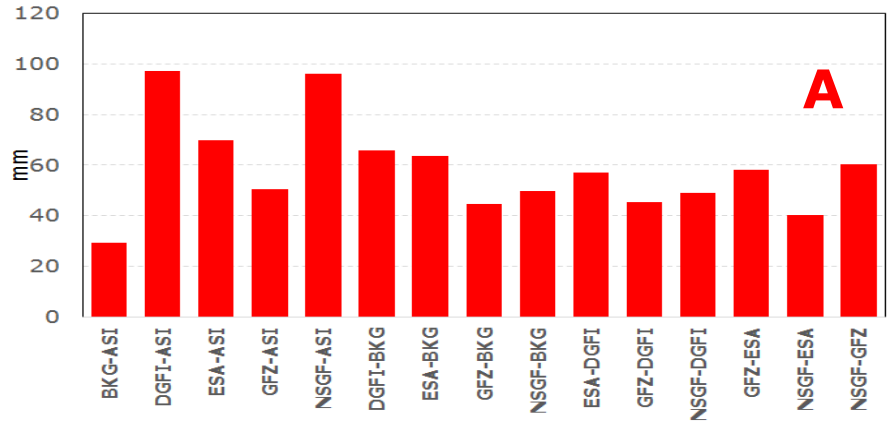


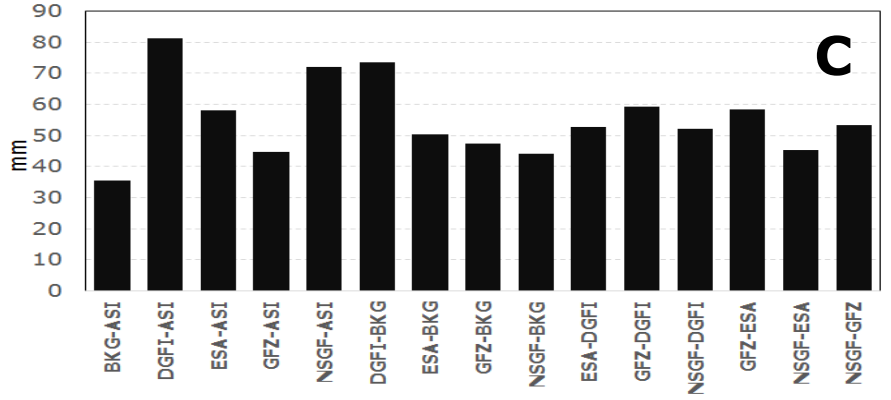




STD

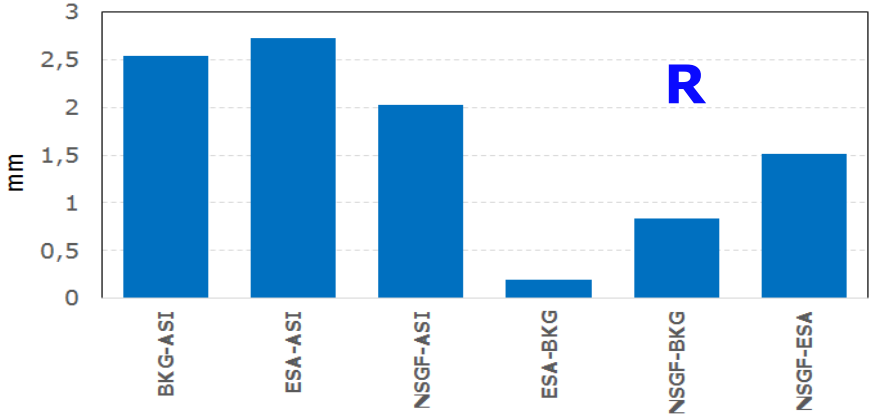


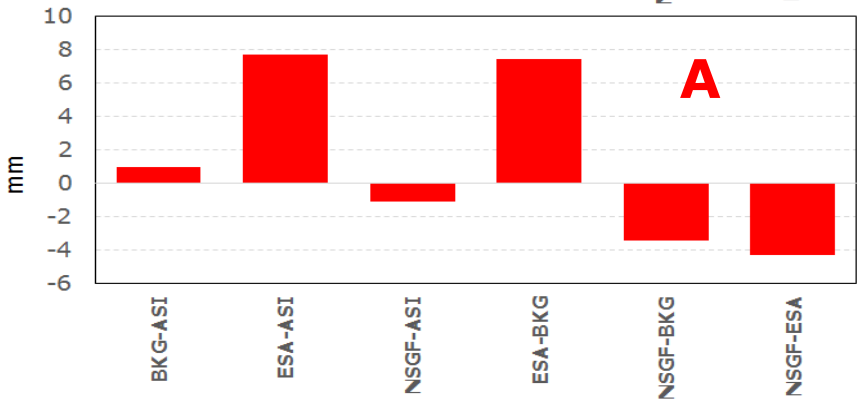


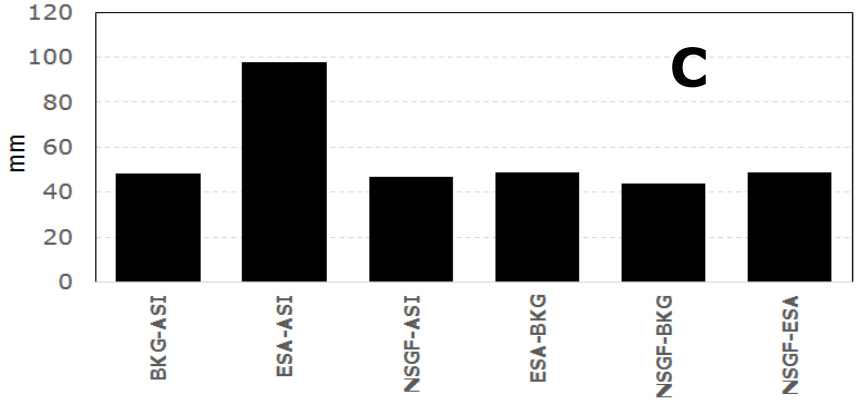


L53 – summary (150620-150926)

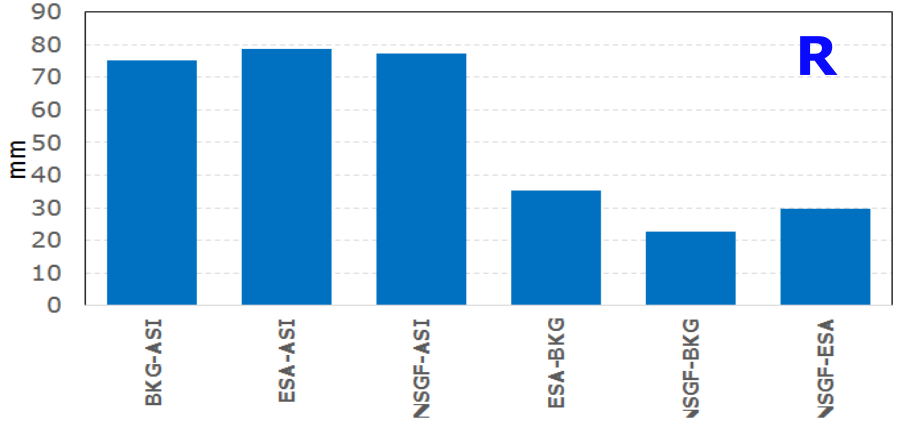
Mean

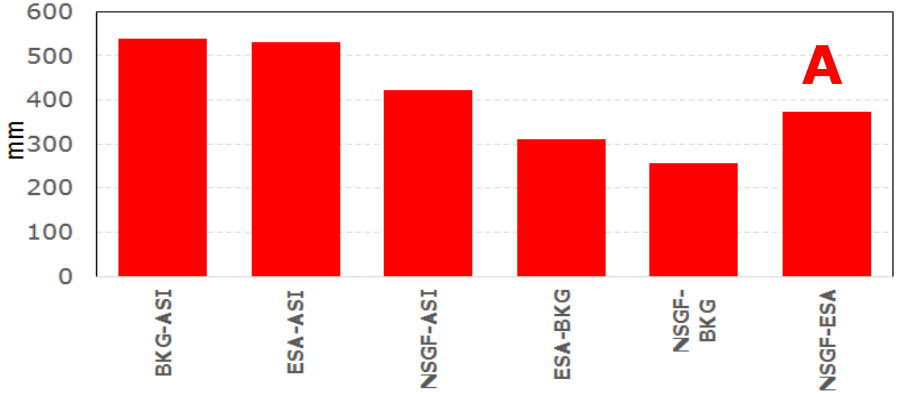


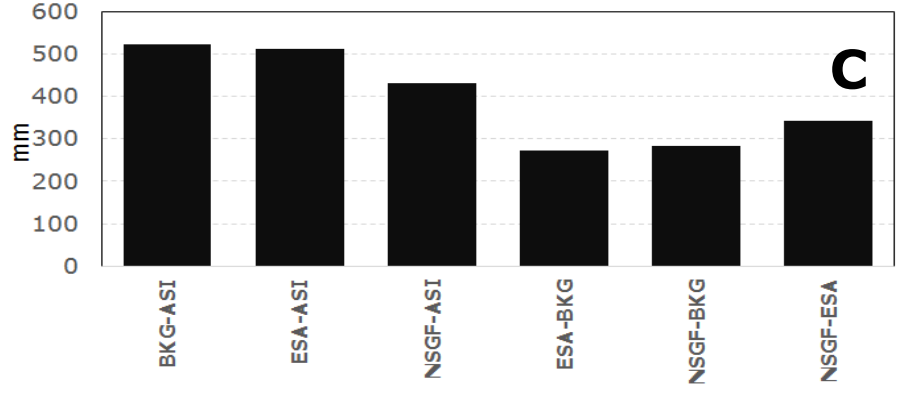




STD

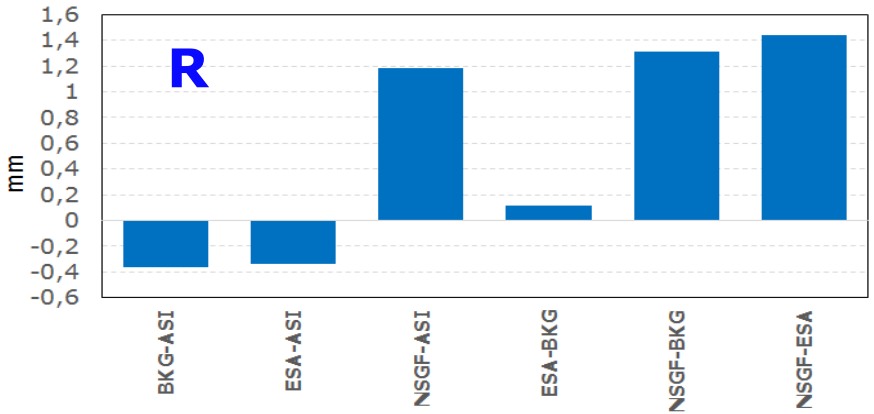


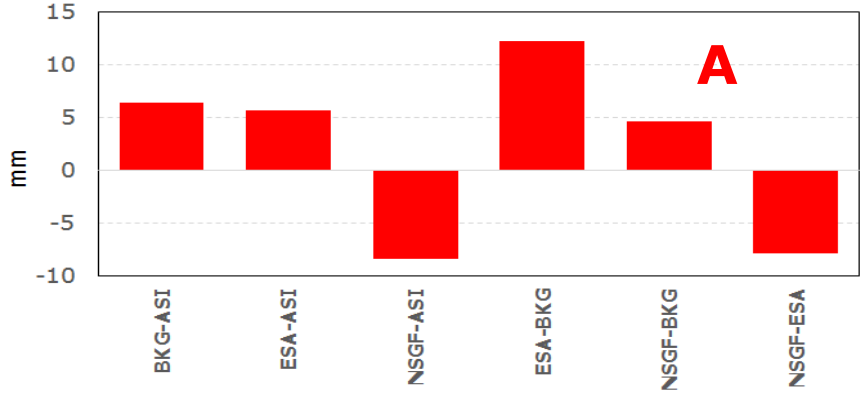


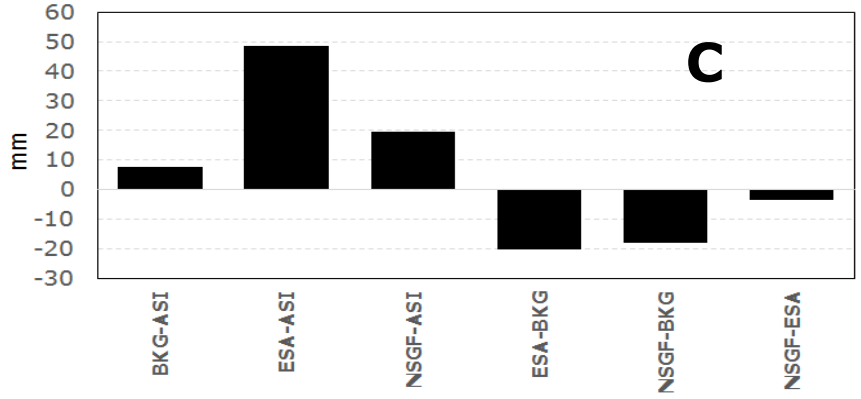


L54 – summary (150620-150926)

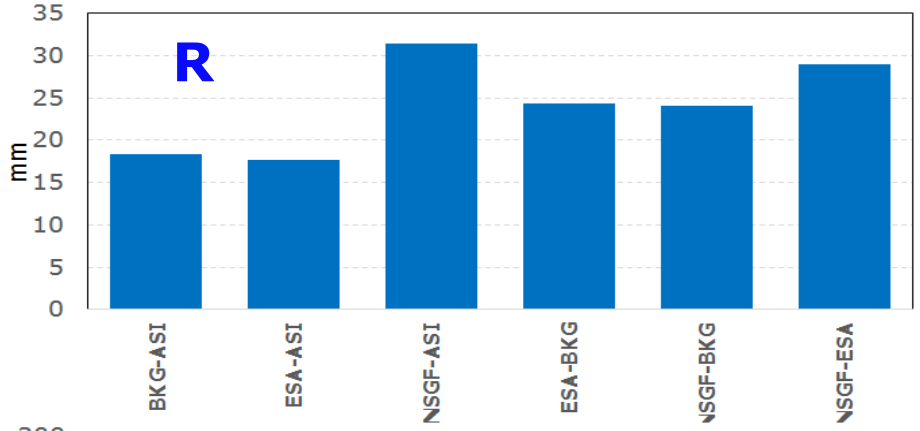
Mean

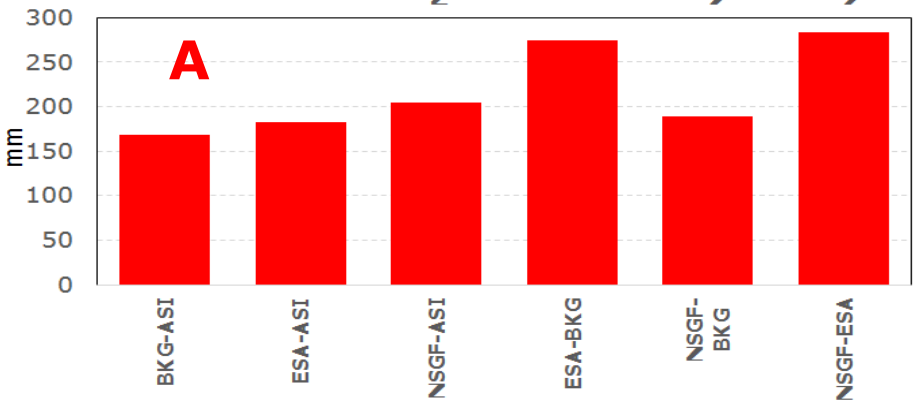


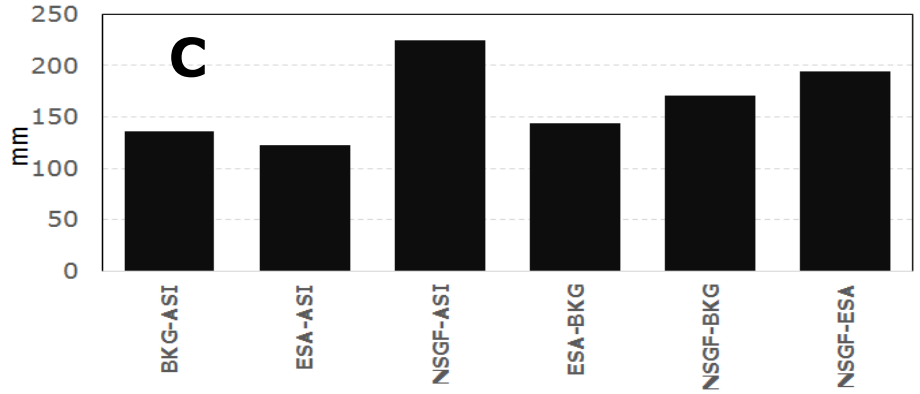




STD

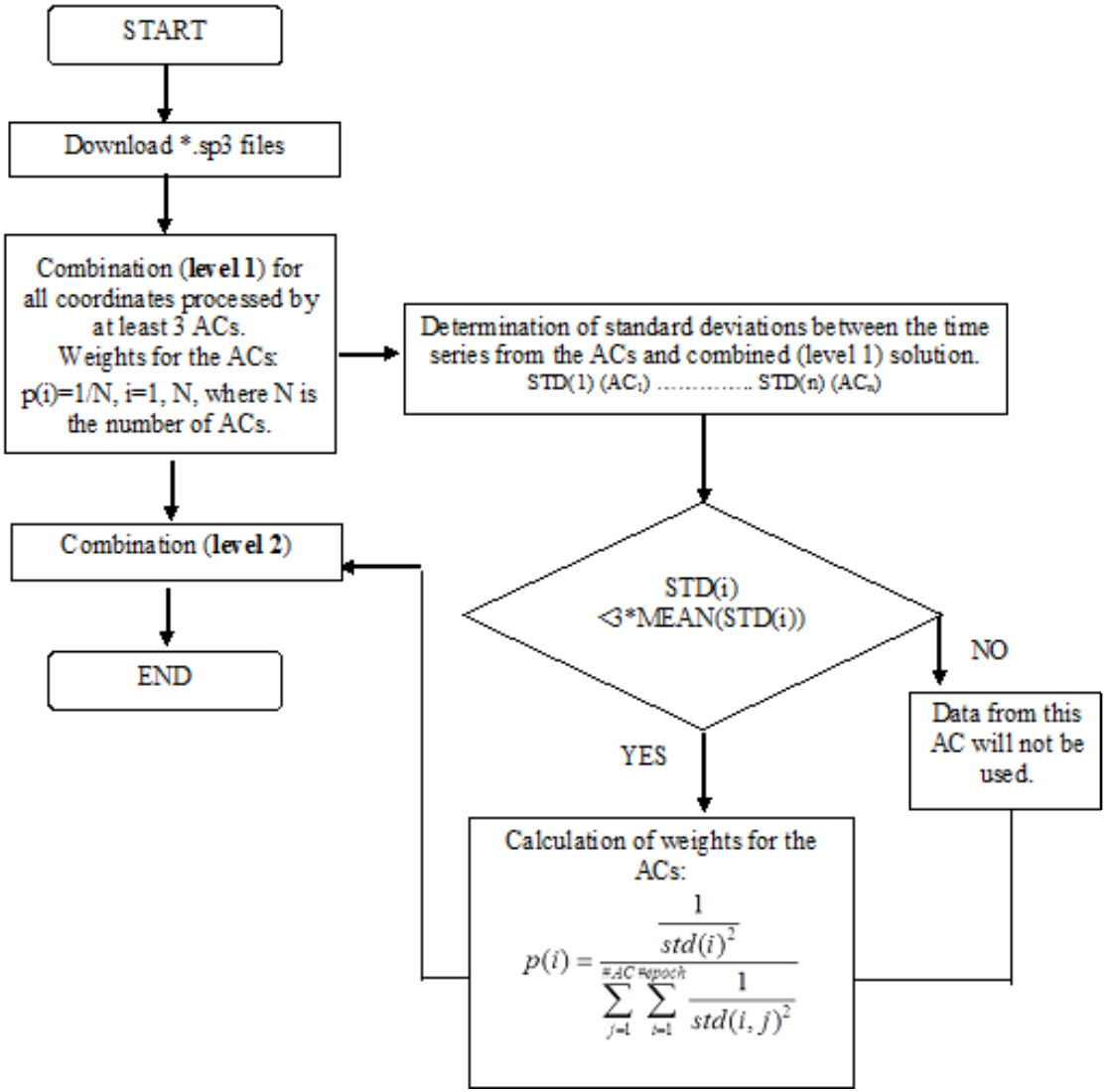






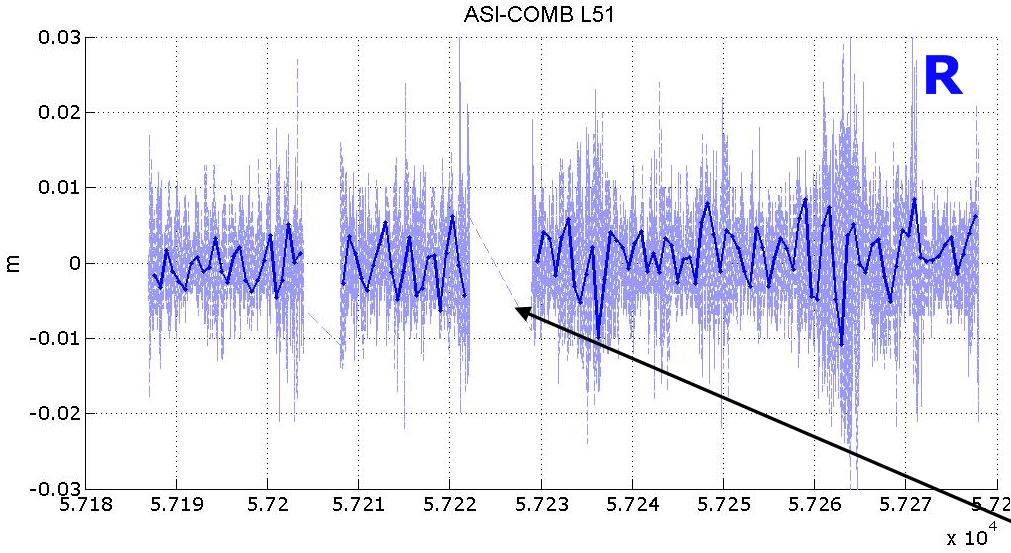
Combination strategy outline

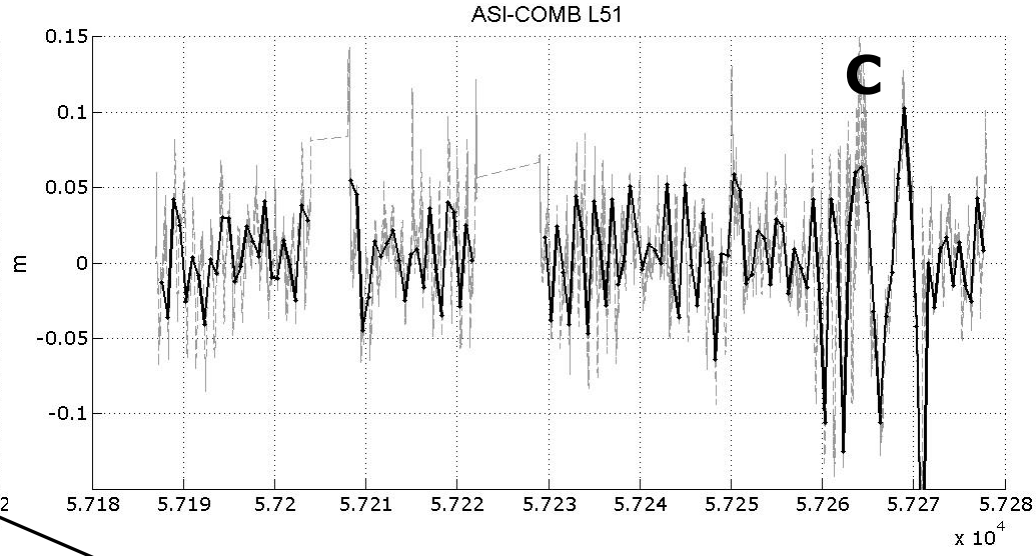
Assumption: each ILRS AC SP3 in AC weekly EF reference frame

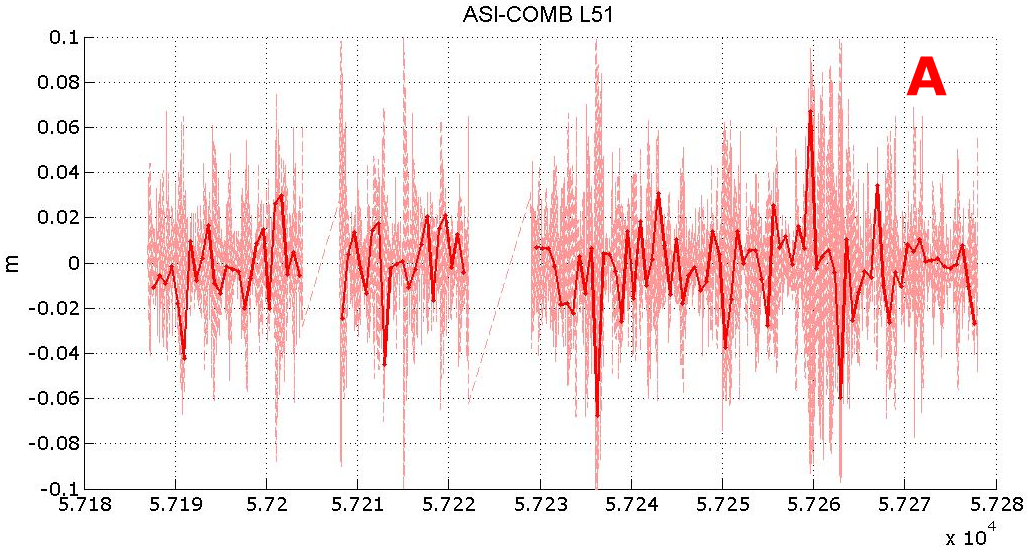


L51 ACs vs Combination

Test combination for L51 using **ASI**, BKG, DGFI, ESA, GFZ, NSGF





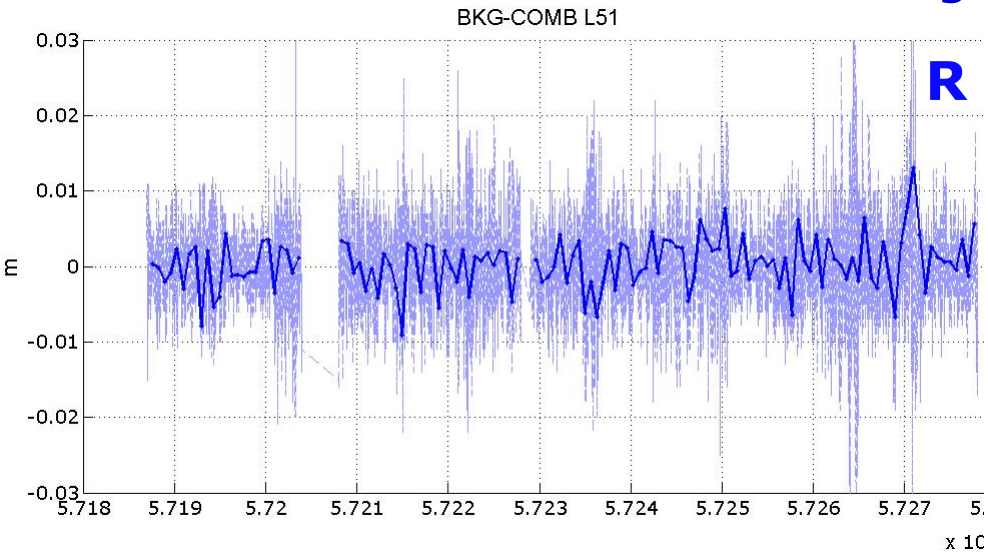


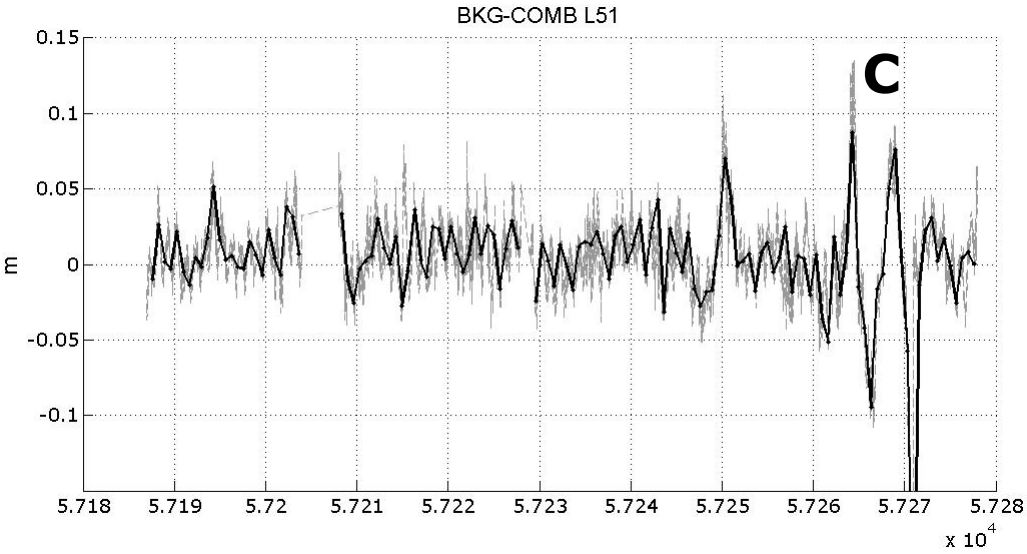
Gap to investigate

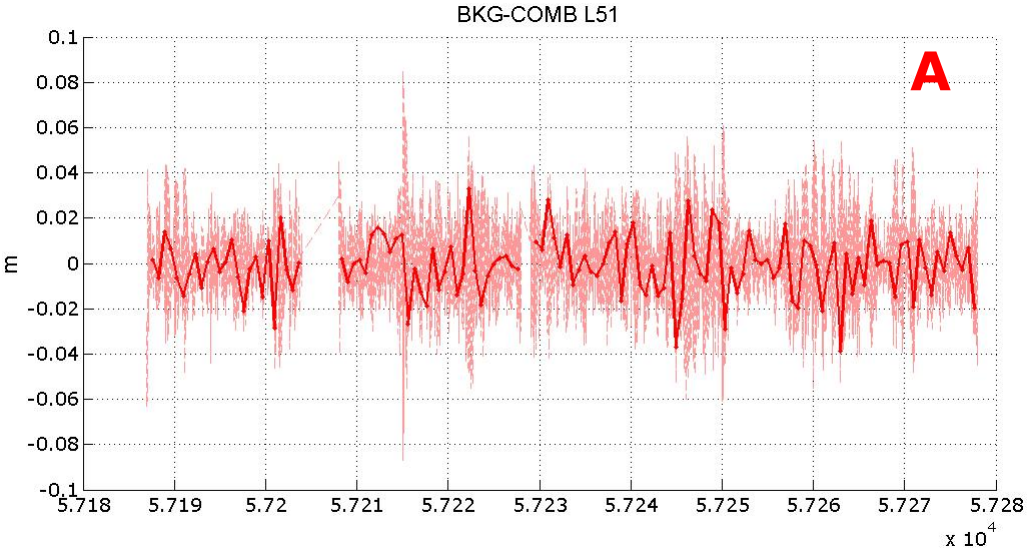
	MEAN [mm]	STD [mm]
R	0.2	5.8
A	-0.4	24.9
C	3.4	37.7

L51 ACs vs Combination

Test combination for L51 using ASI, **BKG**, DGFI, ESA, GFZ, NSGF



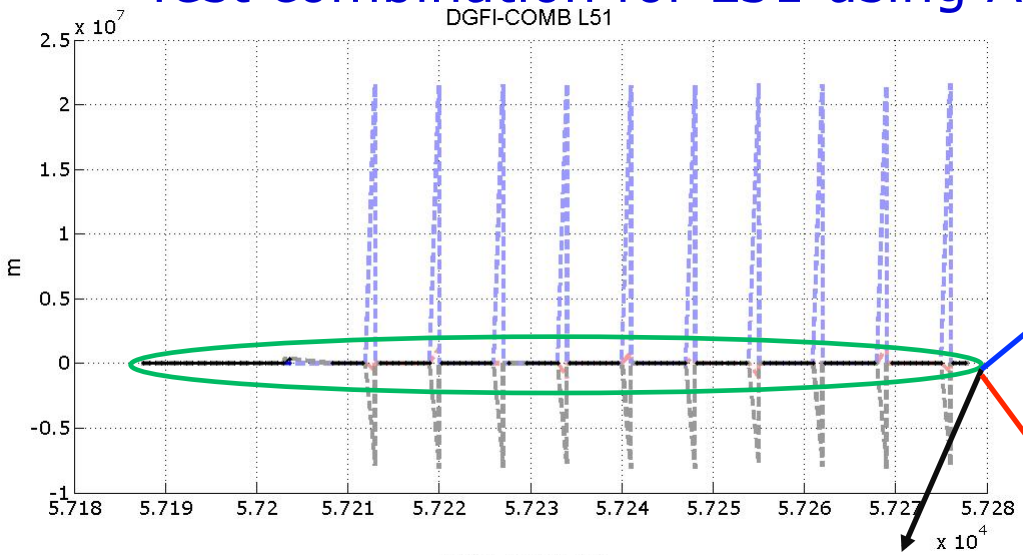


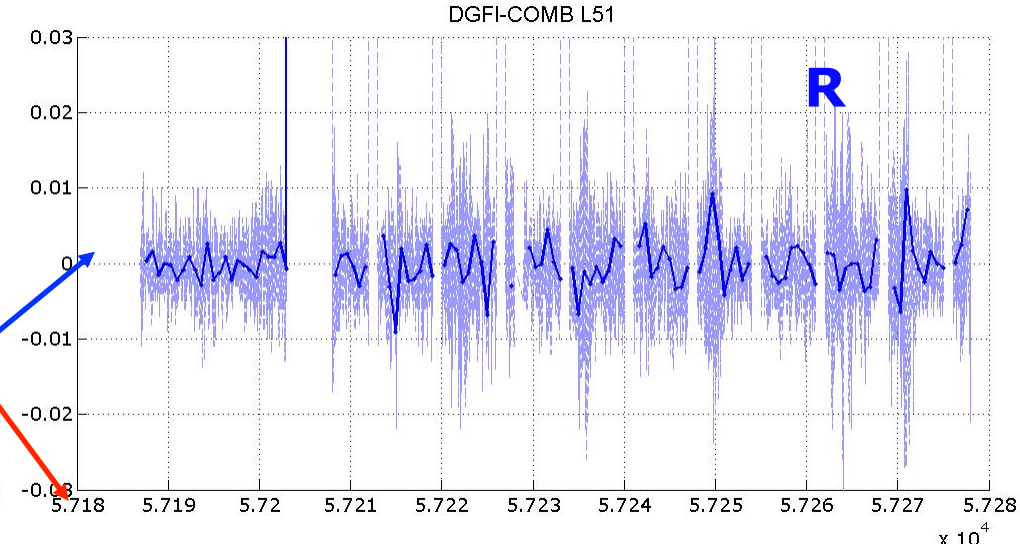


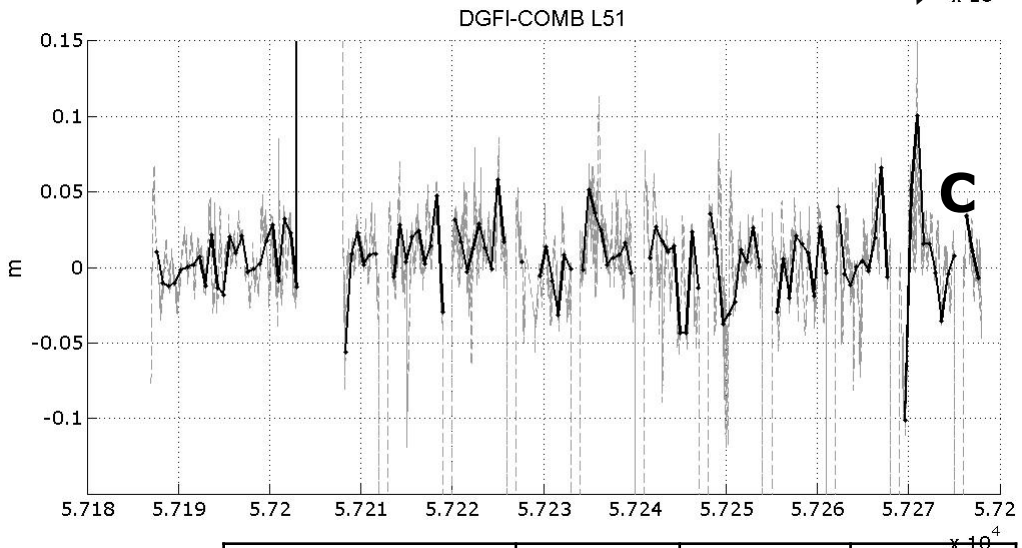
	MEAN [mm]	STD [mm]
R	0.2	5.4
A	-0.2	16.7
C	3.9	29.4

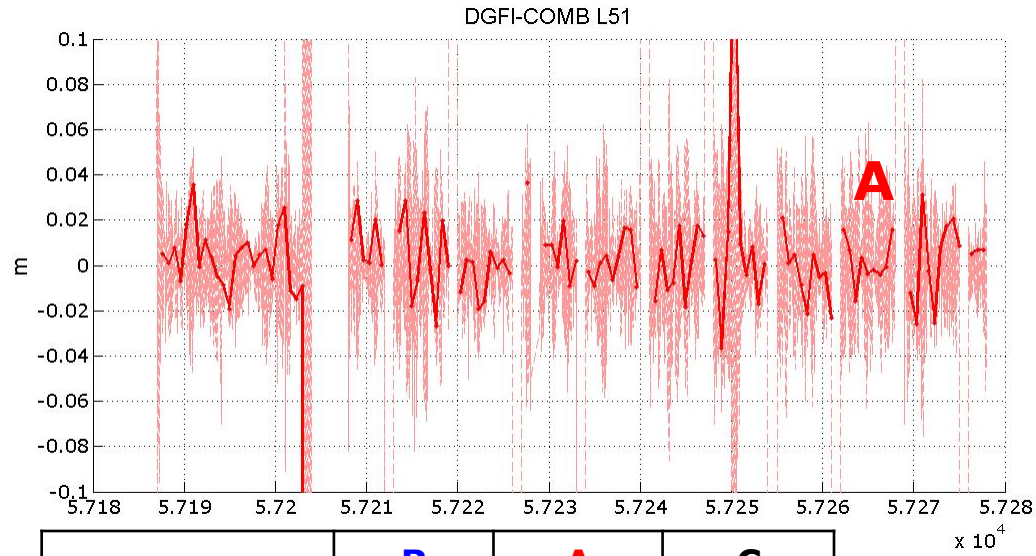
L51 ACs vs Combination

Test combination for L51 using ASI, BKG, **DGFI**, ESA, GFZ, NSGF







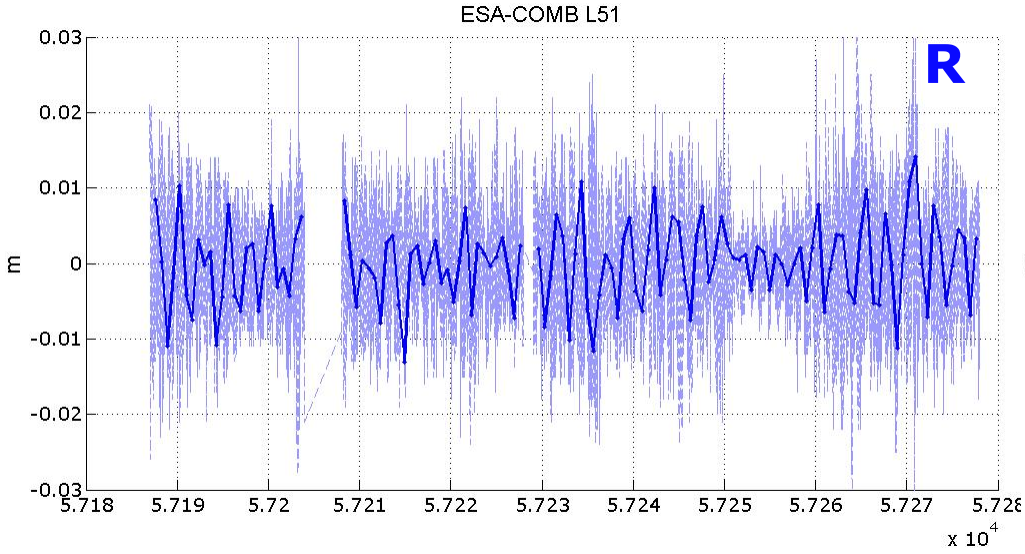


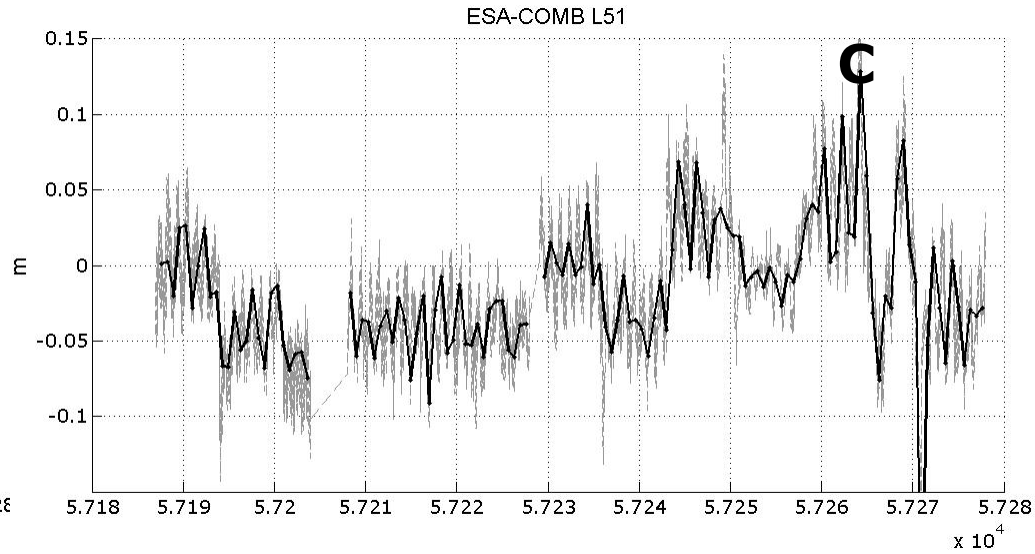
	R	A	C
MEAN [mm]	2.1	-0.9	3.3

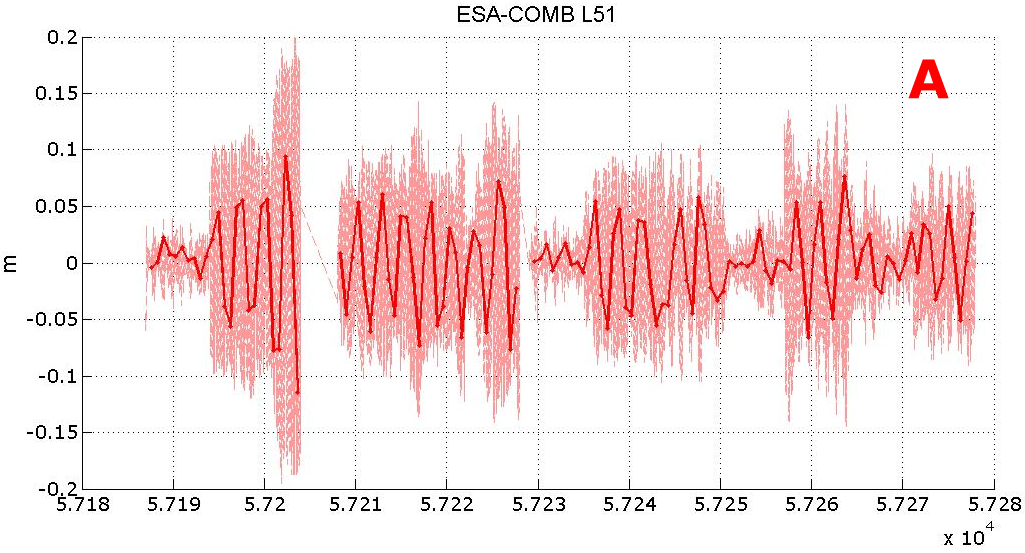
	R	A	C
STD [mm]	6.6	14.5	20.2

L51 ACs vs Combination

Test combination for L51 using ASI, BKG, DGFI, **ESA**, GFZ, NSGF



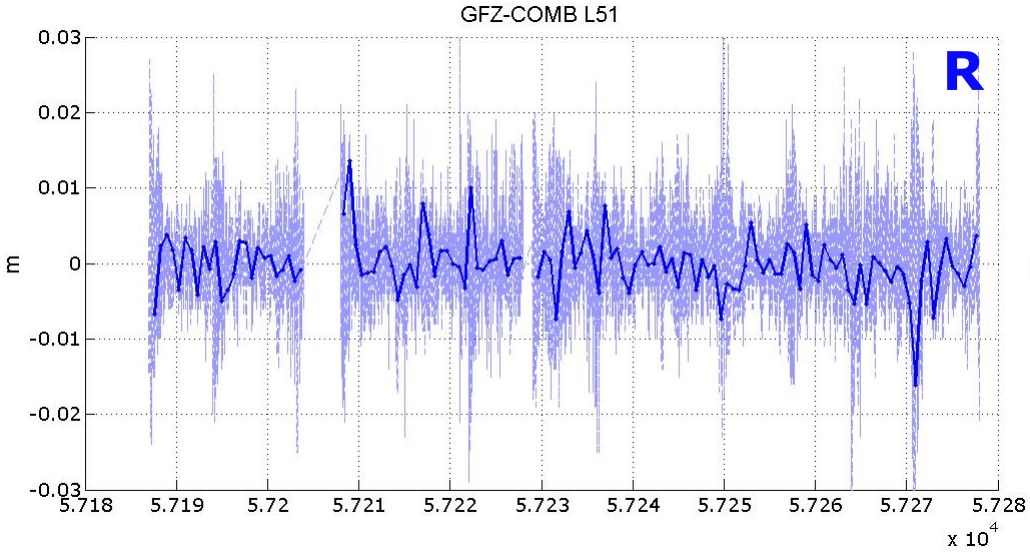


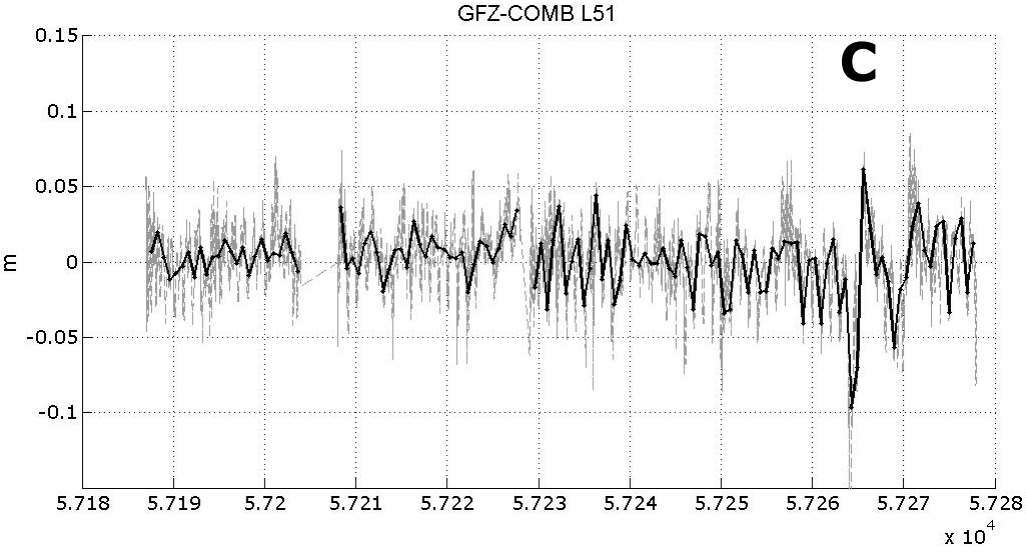


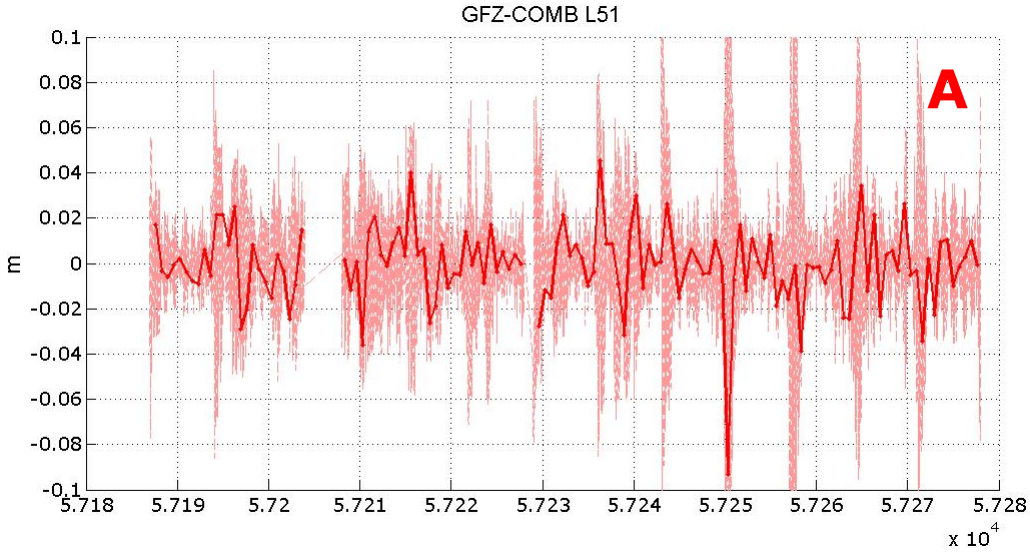
	MEAN [mm]	STD [mm]
R	-0.3	7.5
A	0.5	54.2
C	-15.8	42.7

L51 ACs vs Combination

Test combination for L51 using ASI, BKG, DGFI, ESA, **GFZ**, NSGF



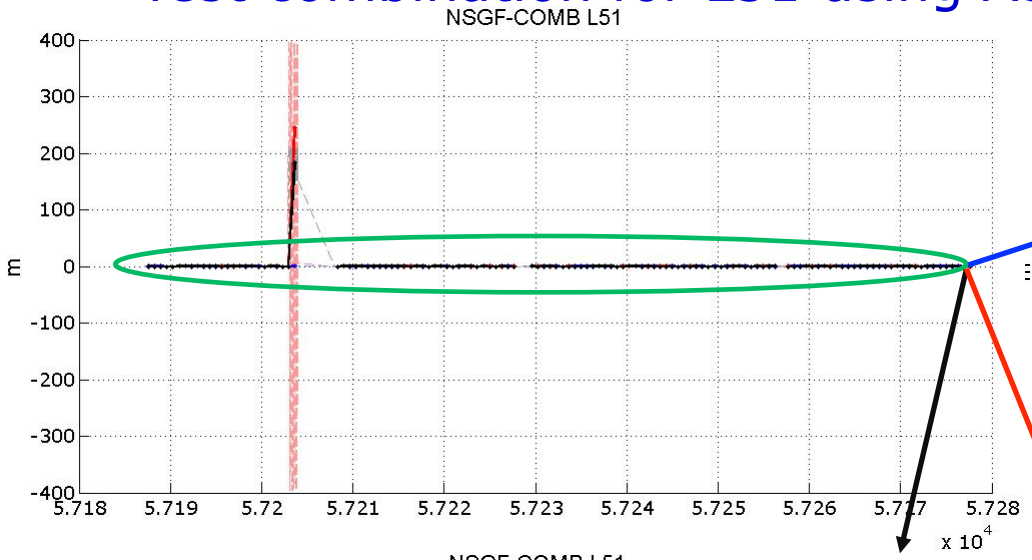


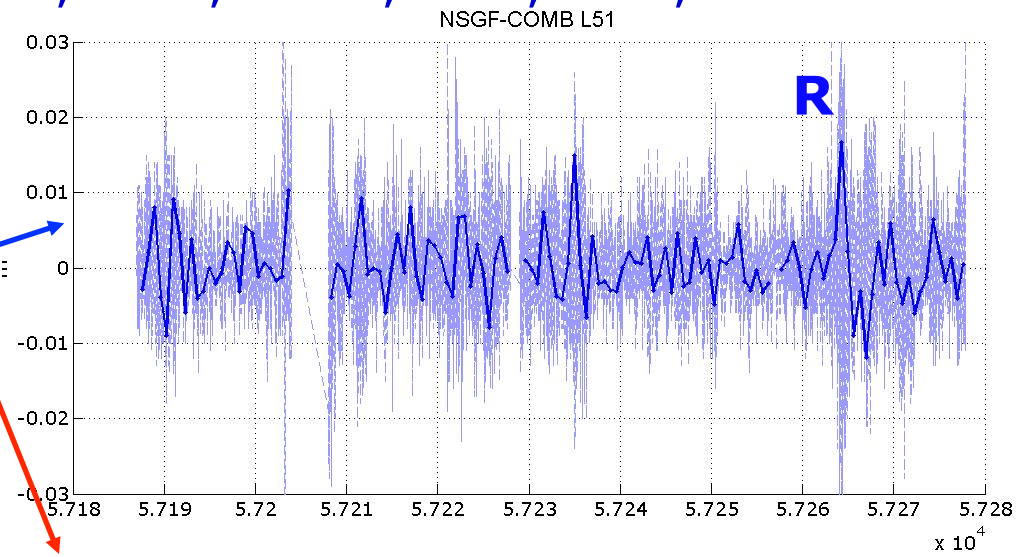


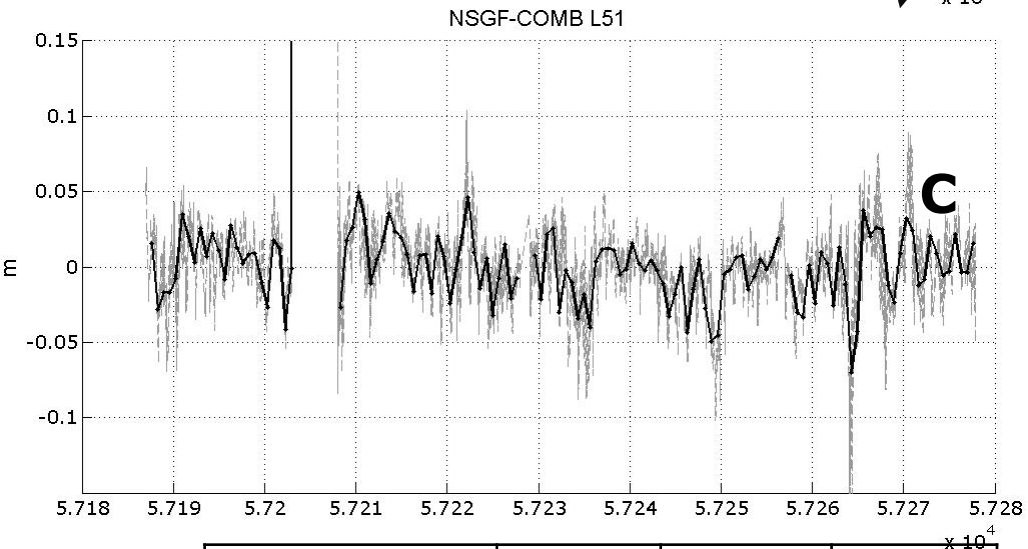
	MEAN [mm]	STD [mm]
R	0.4	5.8
A	-0.1	25.3
C	0.8	25.3

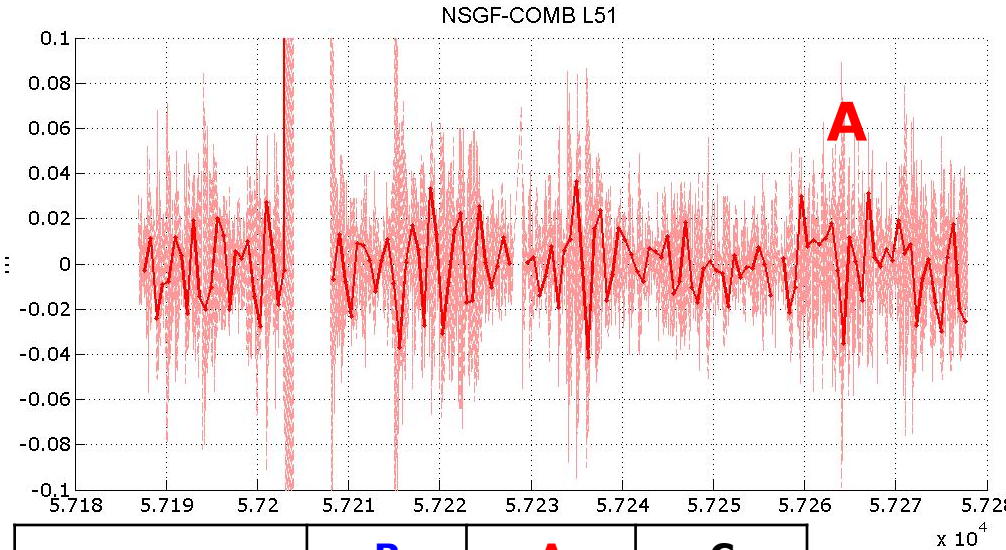
L51 ACs vs Combination

Test combination for L51 using ASI, BKG, DGFI, ESA, GFZ, **NSGF**







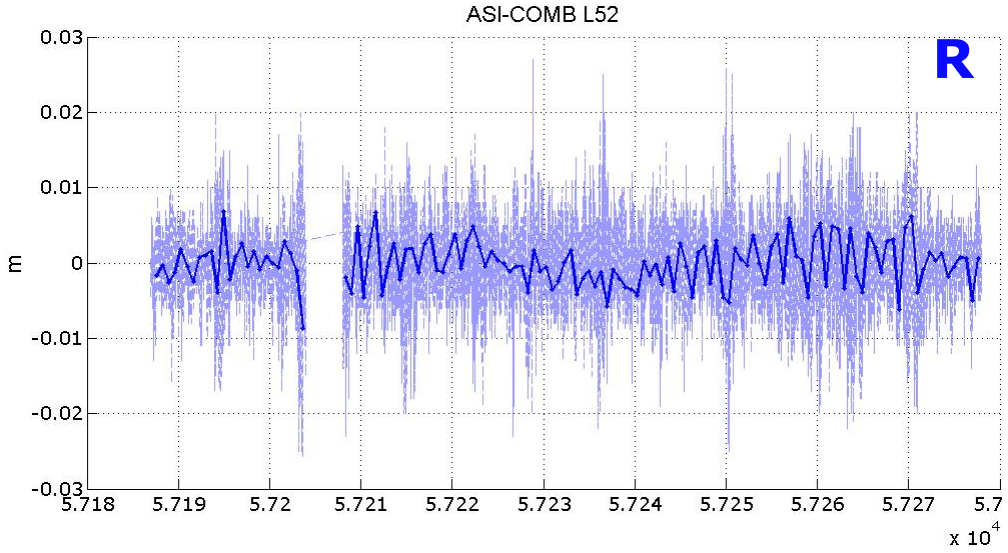


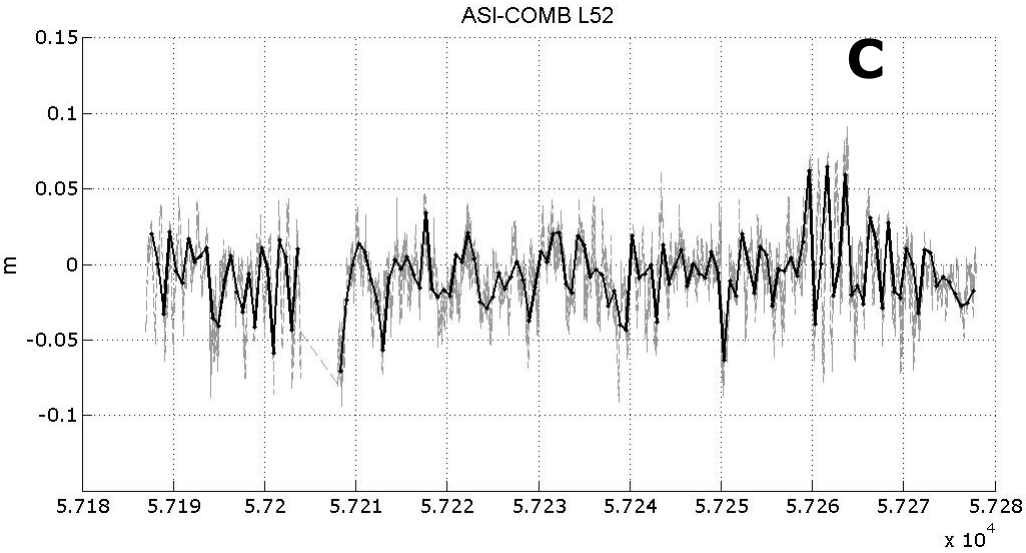
	R	A	C
MEAN [mm]	**0.4**	**1.0**	**-3.3**

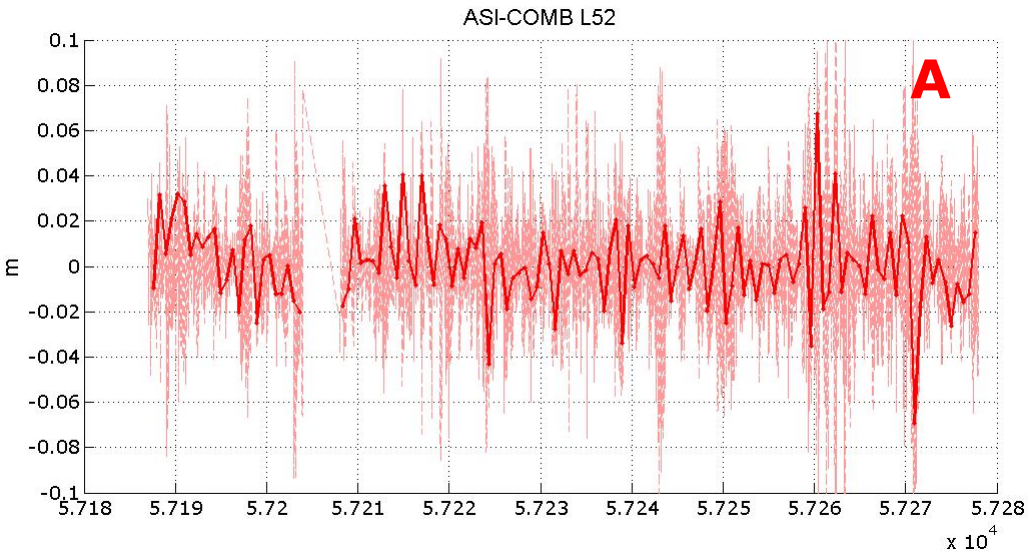
	R	A	C
STD [mm]	**6.3**	**18.3**	**21.7**

L52 ACs vs Combination

Test combination for L52 using **ASI**, BKG, DGFI, ESA, GFZ, NSGF



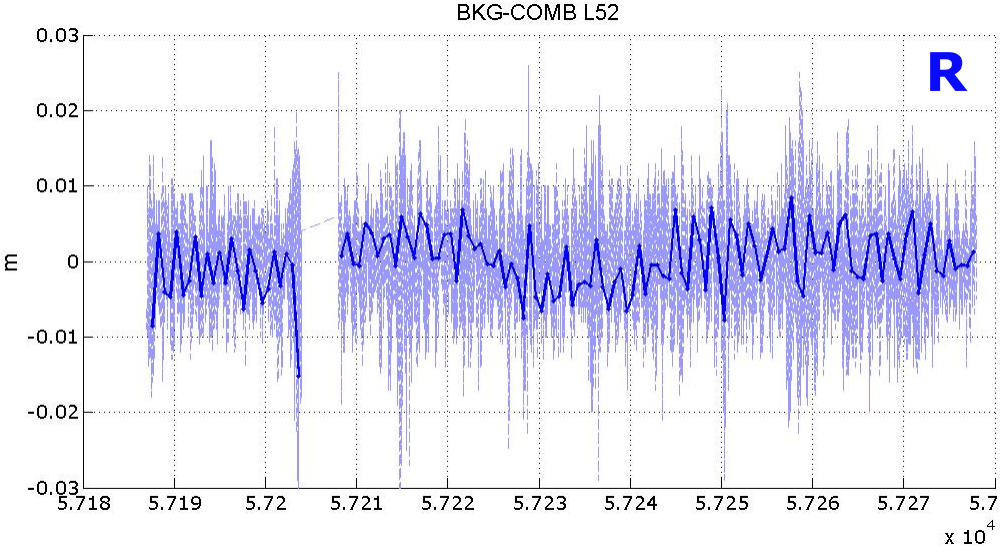


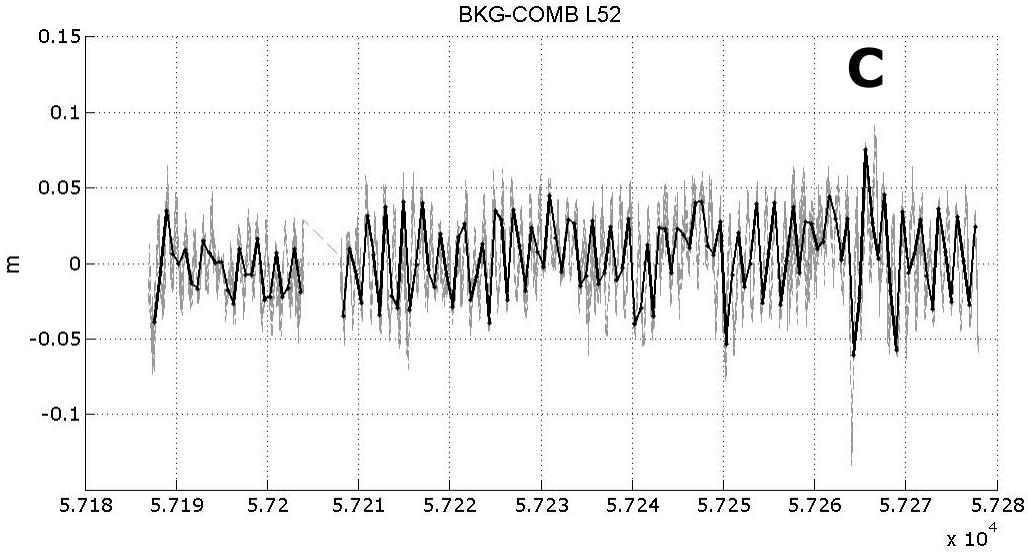


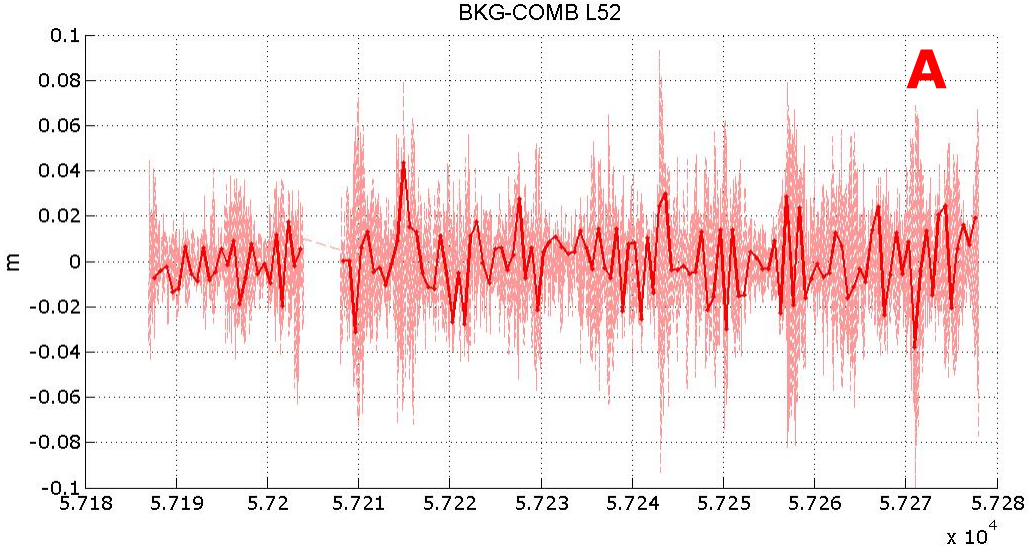
	MEAN [mm]	STD [mm]
R	-2.3	5.1
A	0.1	42.9
C	-7.2	23.7

L52 ACs vs Combination

Test combination for L52 using ASI, **BKG**, DGFI, ESA, GFZ, NSGF



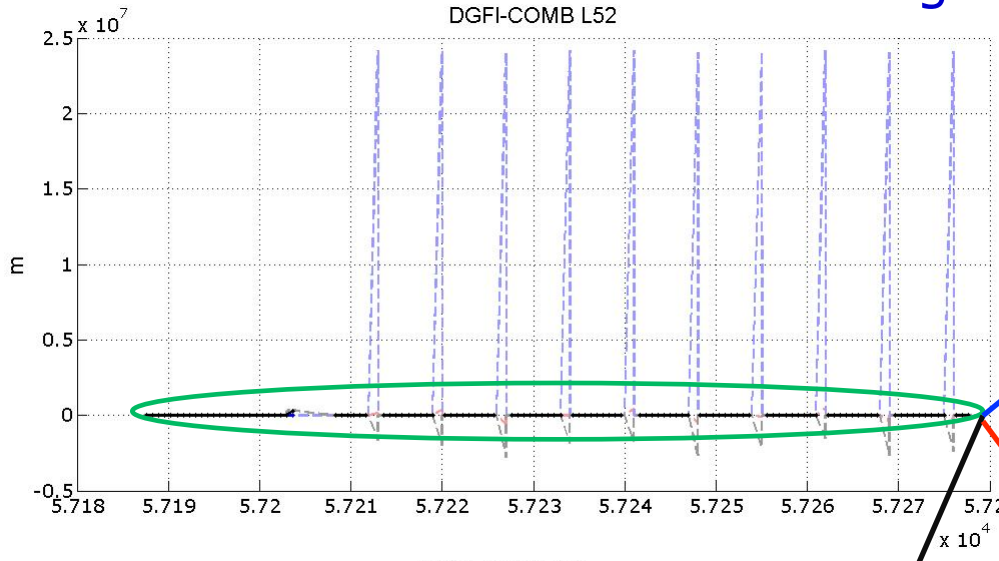


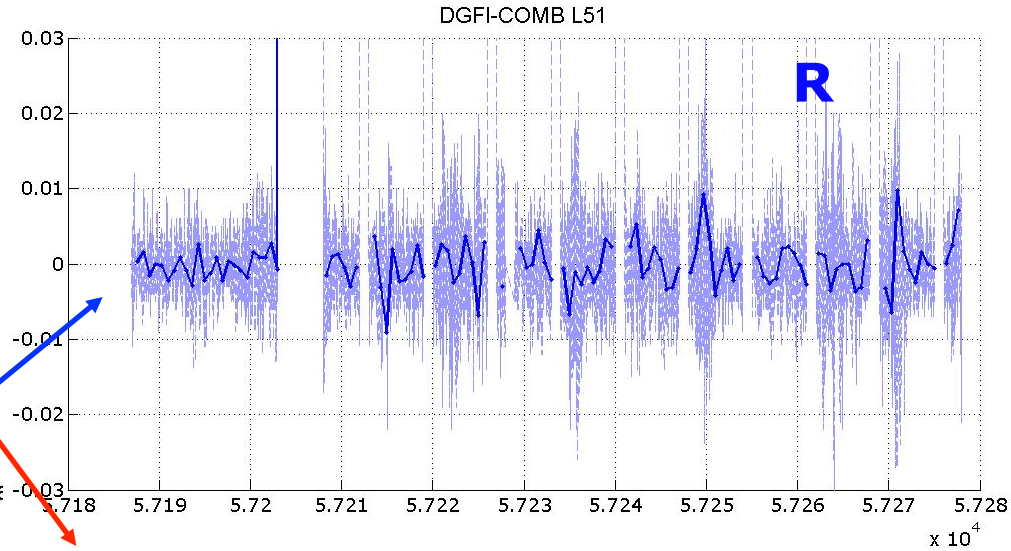


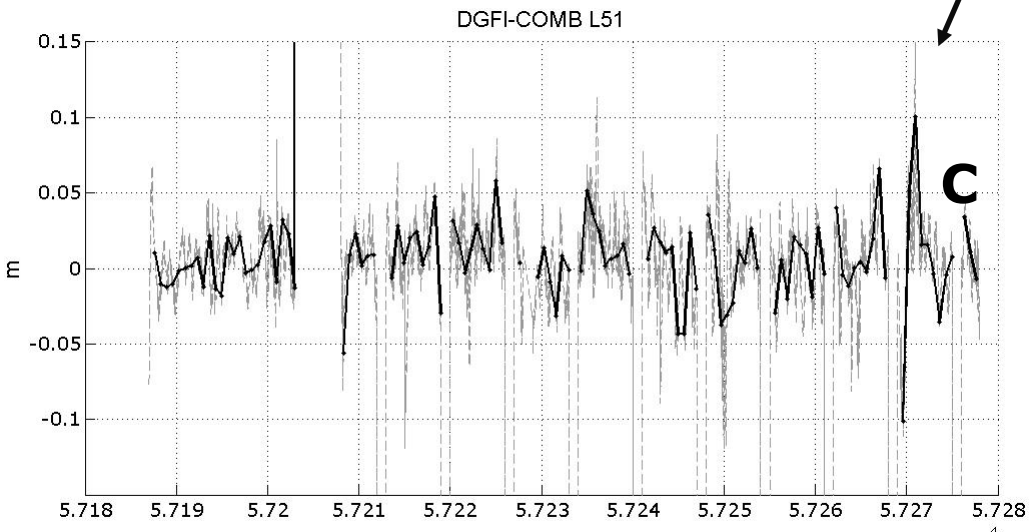
	MEAN [mm]	STD [mm]
R	-0.1	5.9
A	-0.8	21.1
C	1.8	25.6

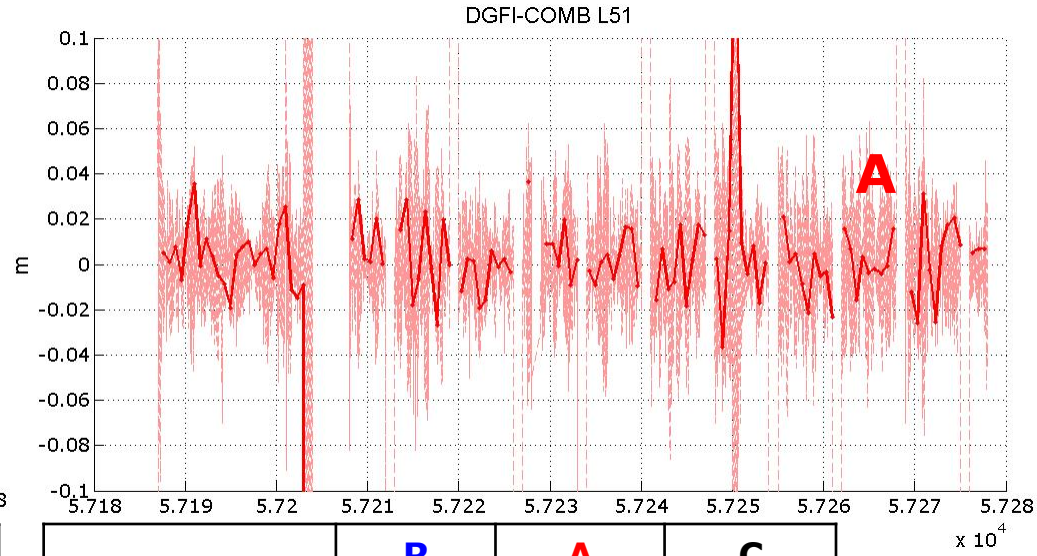
L52 ACs vs Combination

Test combination for L52 using ASI, BKG, **DGFI**, ESA, GFZ, NSGF







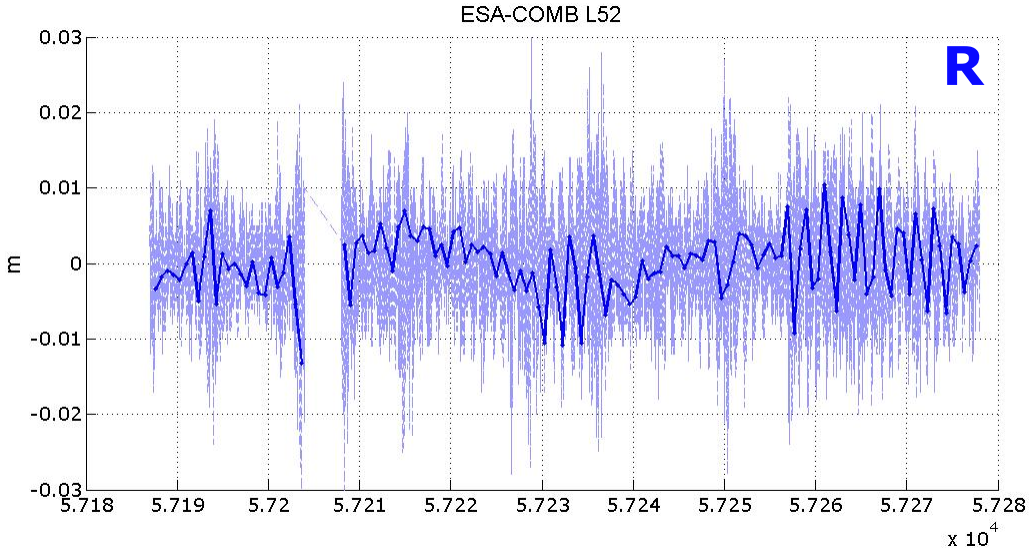


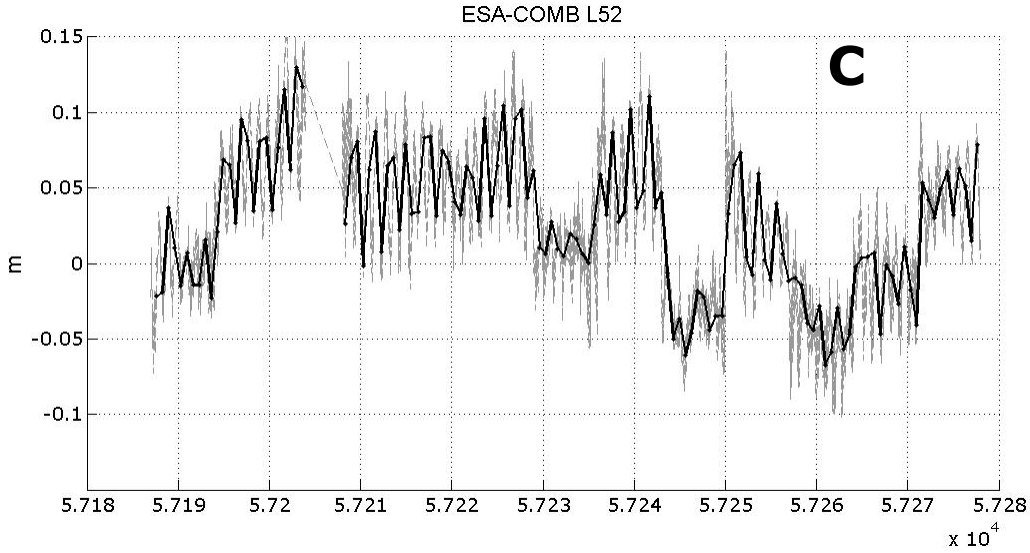
	R	A	C
MEAN [mm]	**0.4**	**0.9**	**-3.0**

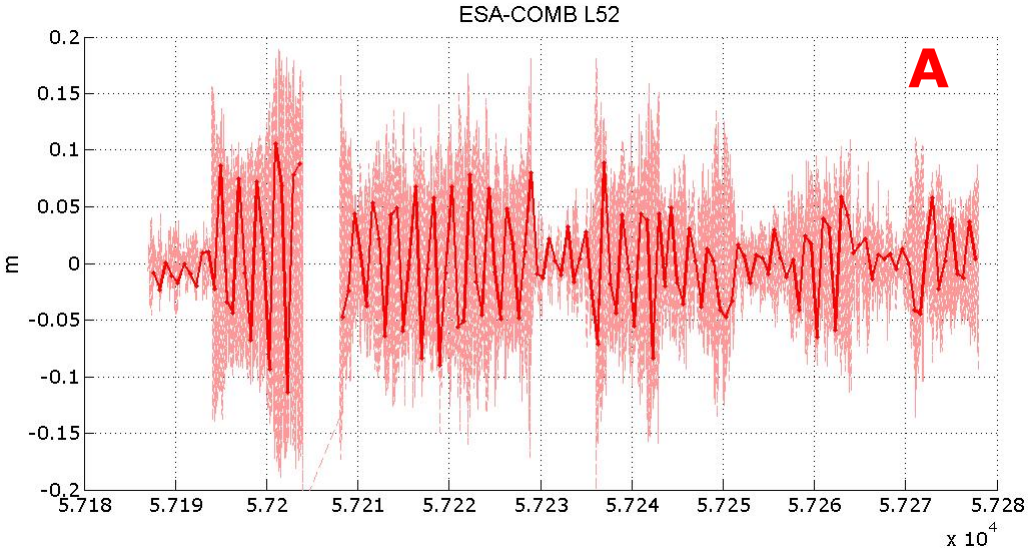
	R	A	C
STD [mm]	**5.2**	**20.1**	**23.5**

L52 ACs vs Combination

Test combination for L52 using ASI, BKG, DGFI, **ESA**, GFZ, NSGF



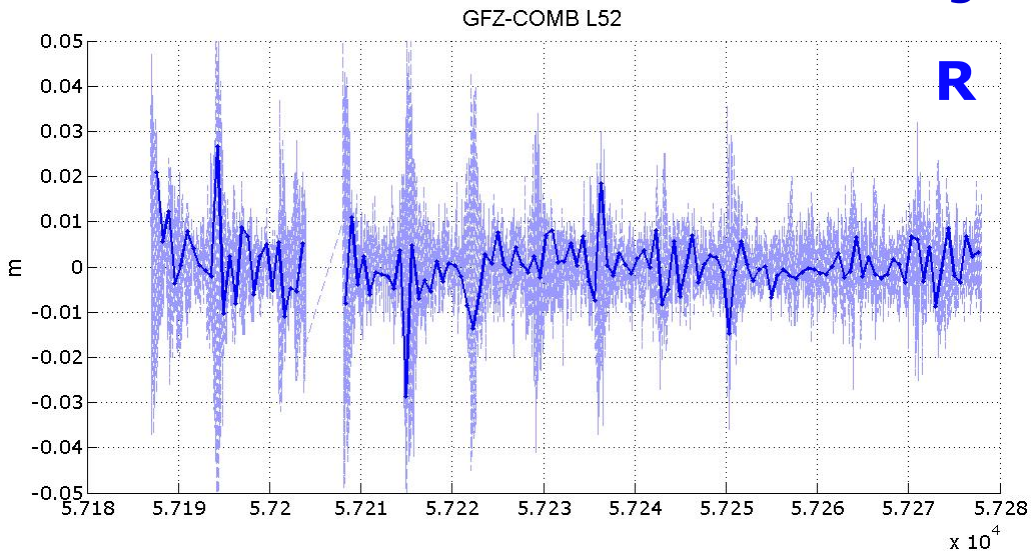


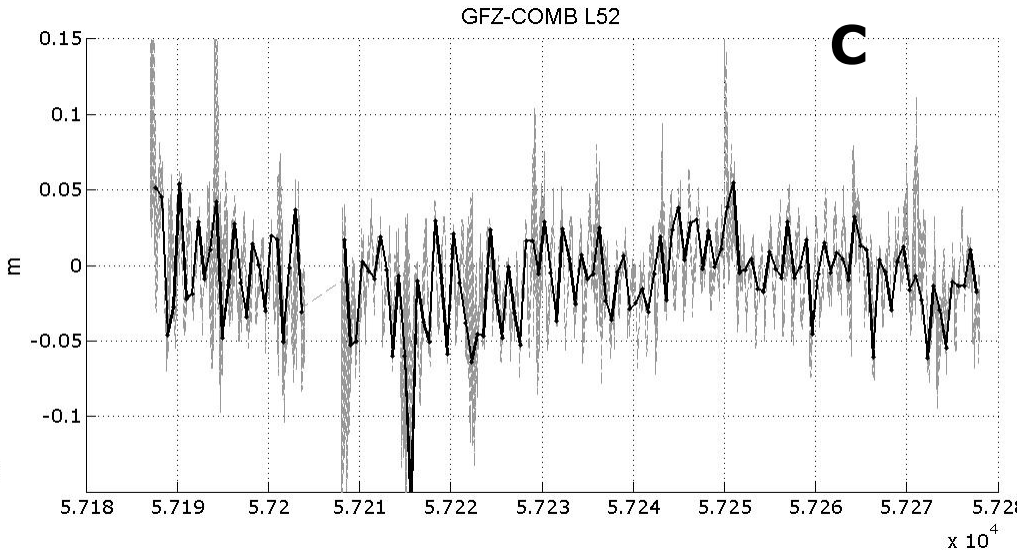


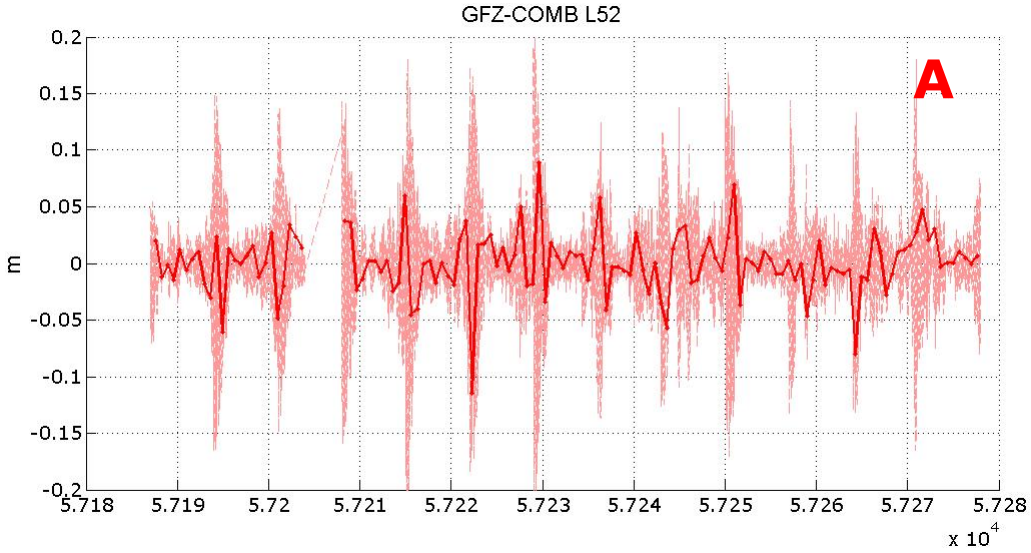
	MEAN [mm]	STD [mm]
R	-0.3	6.4
A	0.5	58.8
C	26.3	47.1

L52 ACs vs Combination

Test combination for L52 using ASI, BKG, DGFI, ESA, **GFZ**, NSGF



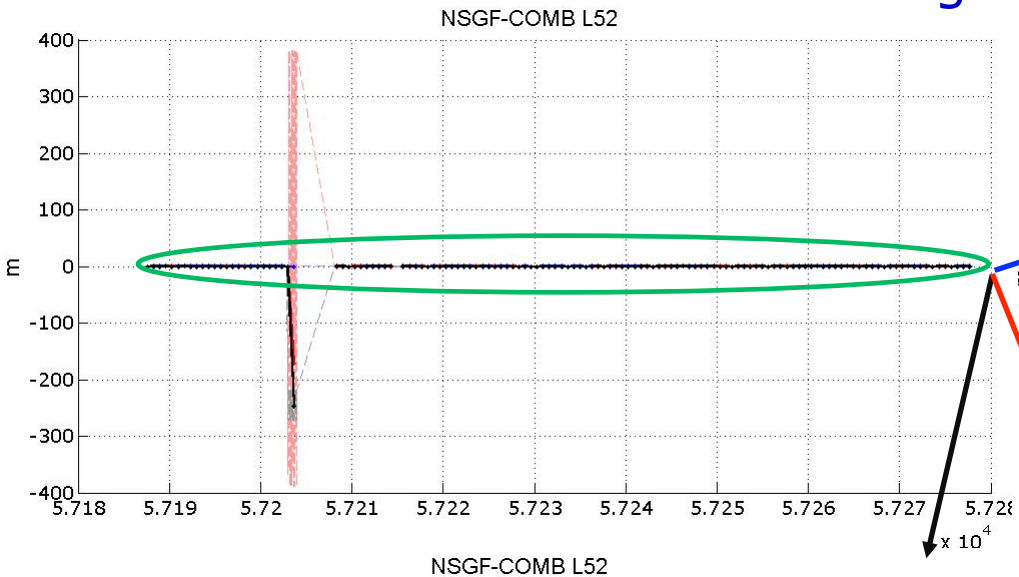


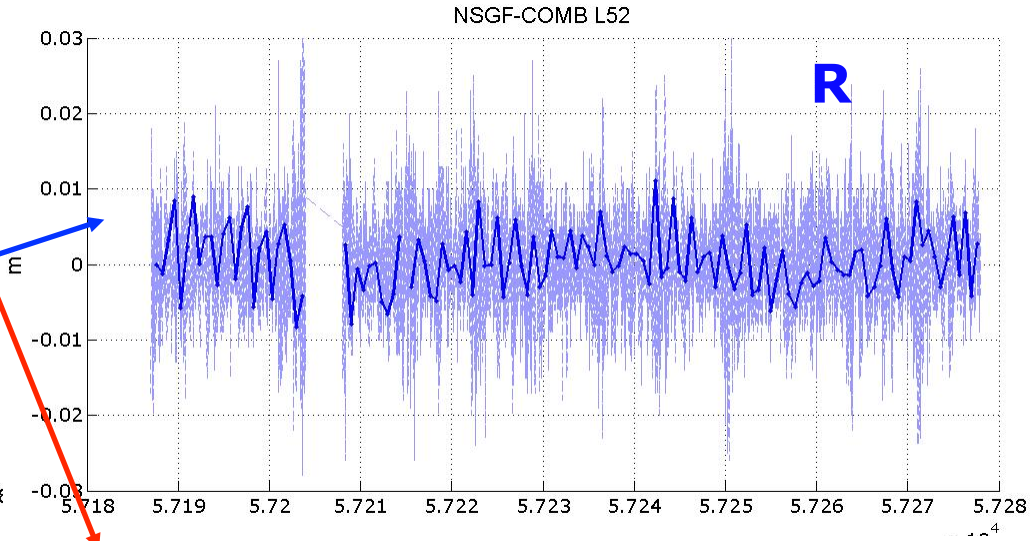


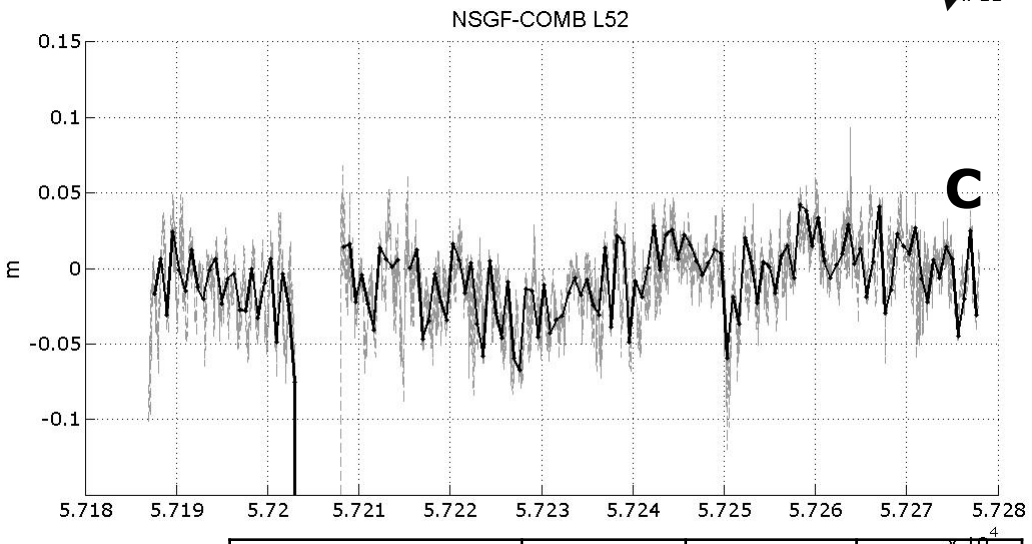
	MEAN [mm]	STD [mm]
R	0.2	9.6
A	-0.4	40.7
C	-7.9	33.9

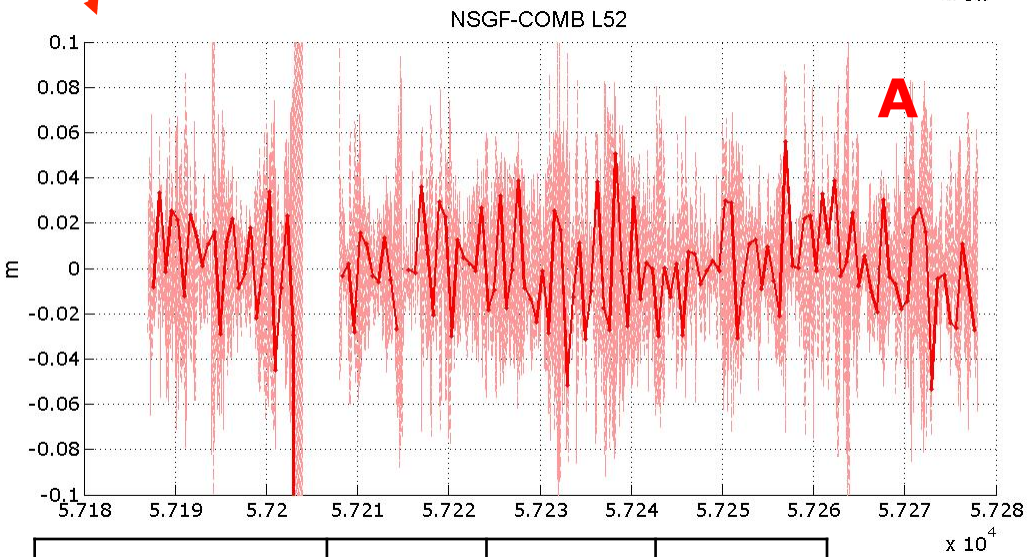
L52 ACs vs Combination

Test combination for L52 using ASI, BKG, DGFI, ESA, GFZ, **NSGF**







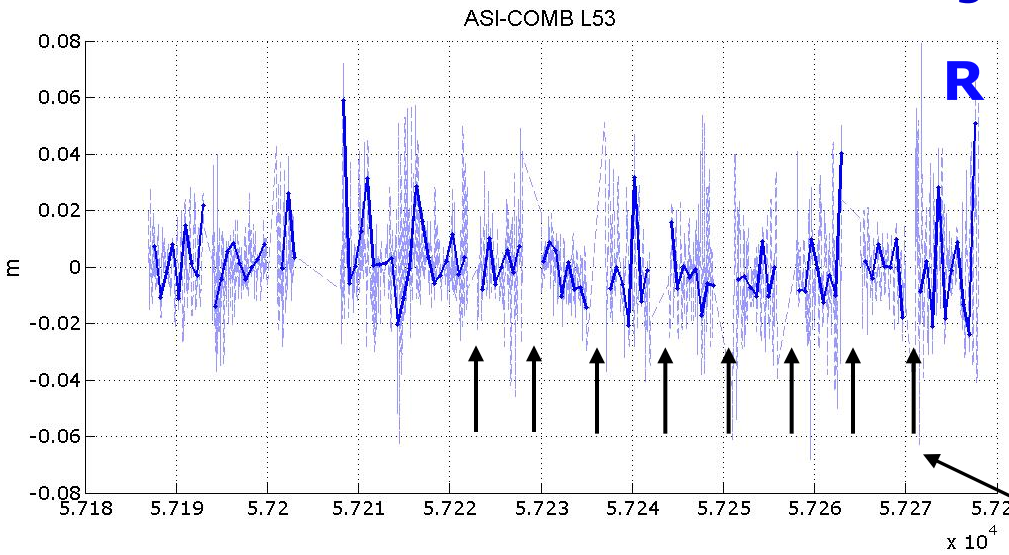


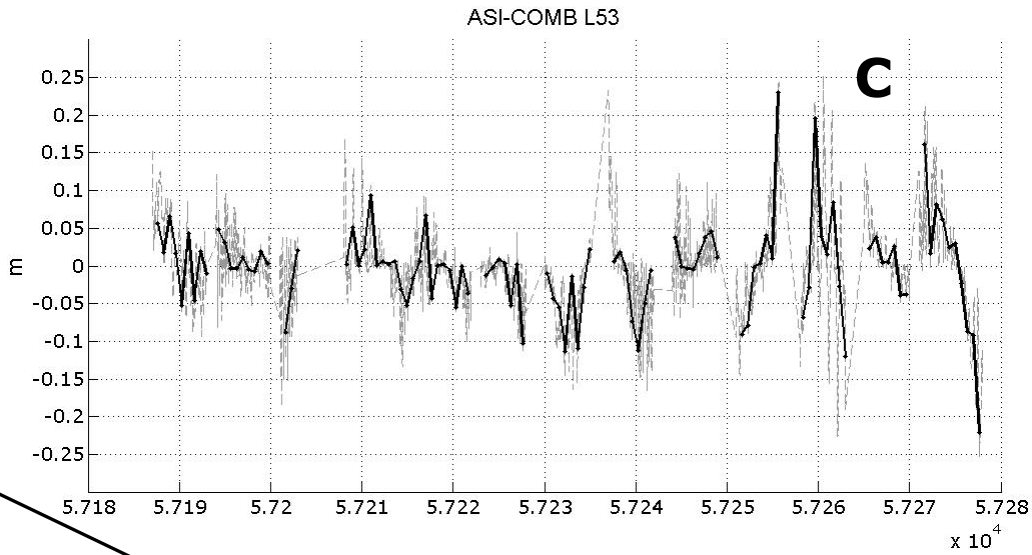
	R	A	C
MEAN [mm]	**0.2**	**-0.4**	**0.3**

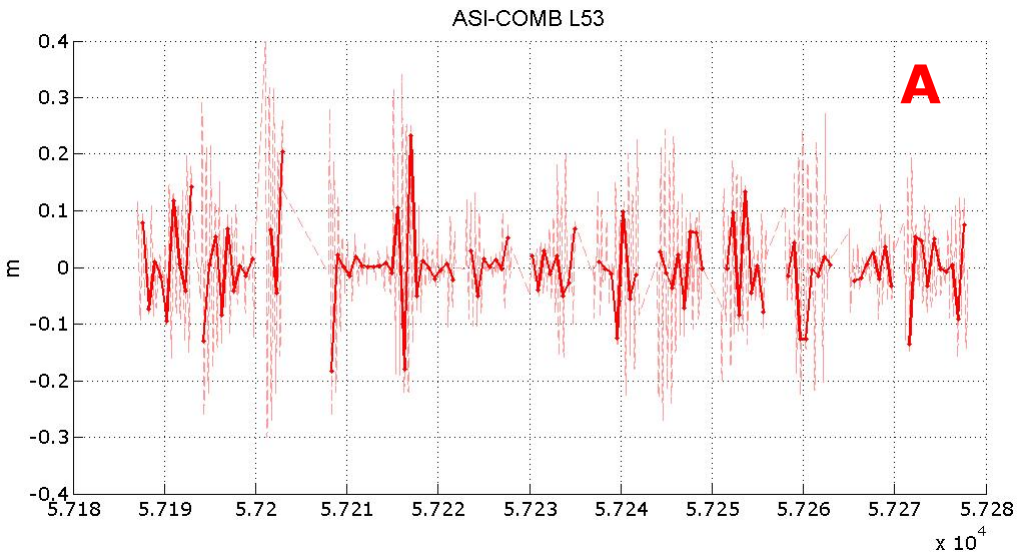
	R	A	C
STD [mm]	**6.1**	**22.3**	**19.2**

L53 ACs vs Combination

Test combination for L53 using **ASI**, ESA, NSGF





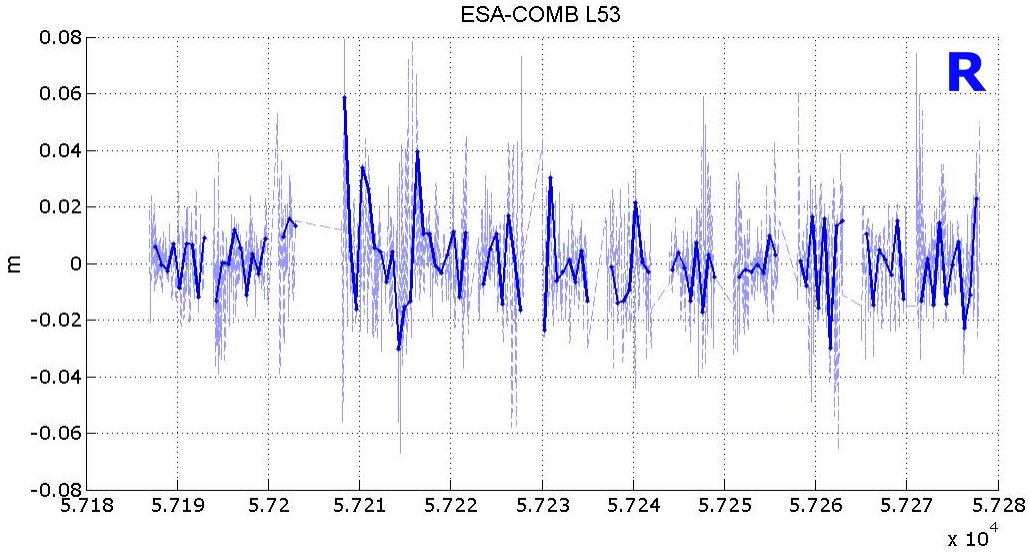


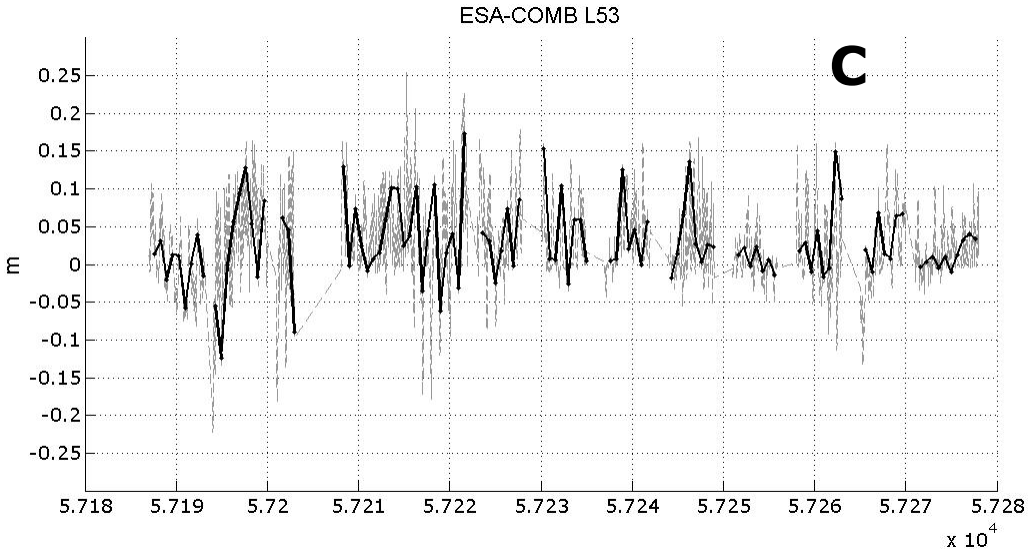
Gaps to investigate for all ACs (#AC < 3: NSGF excluded, BKG not considered for wrong epochs)

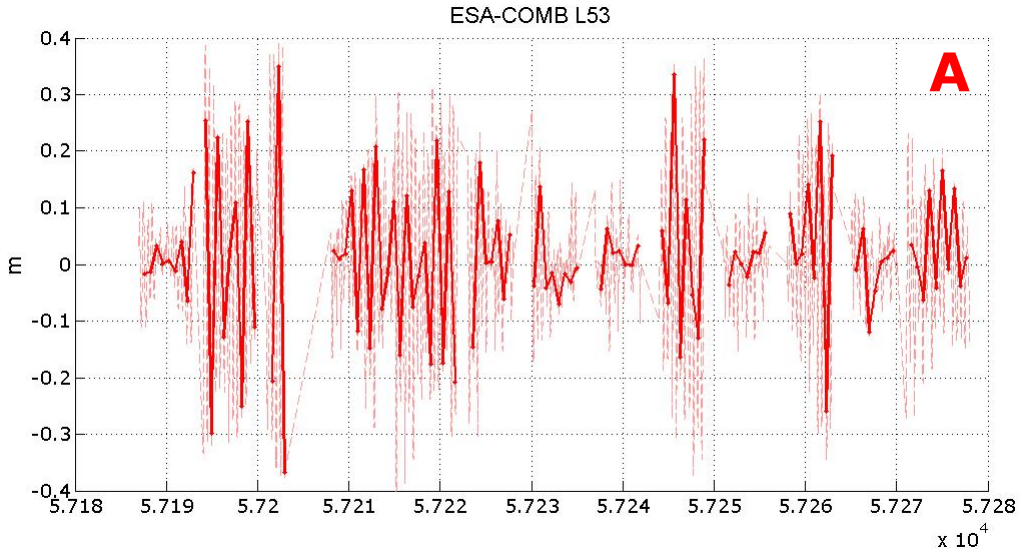
	MEAN [mm]	STD [mm]
R	3.5	14.6
A	3.1	78.5
C	-1.3	59.3

L53 ACs vs Combination

Test combination for L53 using ASI, **ESA**, NSGF



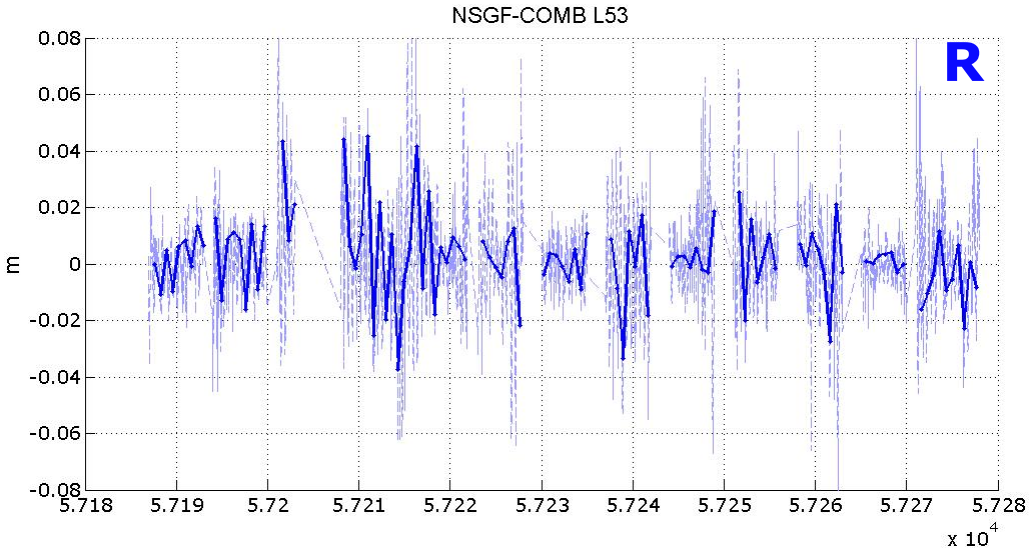


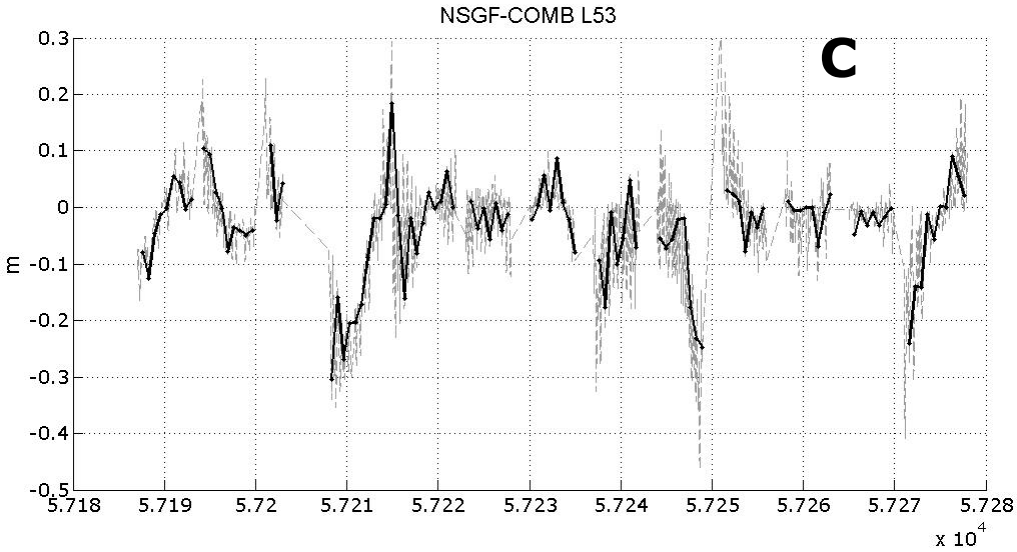


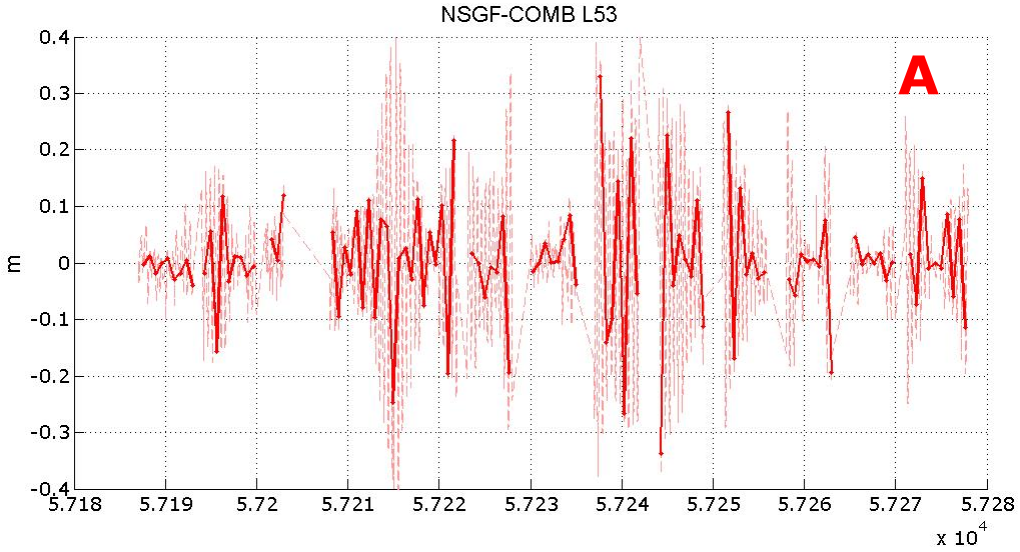
	MEAN [mm]	STD [mm]
R	1.6	17.4
A	0.7	107.0
C	-35.5	91.0

L53 ACs vs Combination

Test combination for L53 using ASI, ESA, **NSGF**



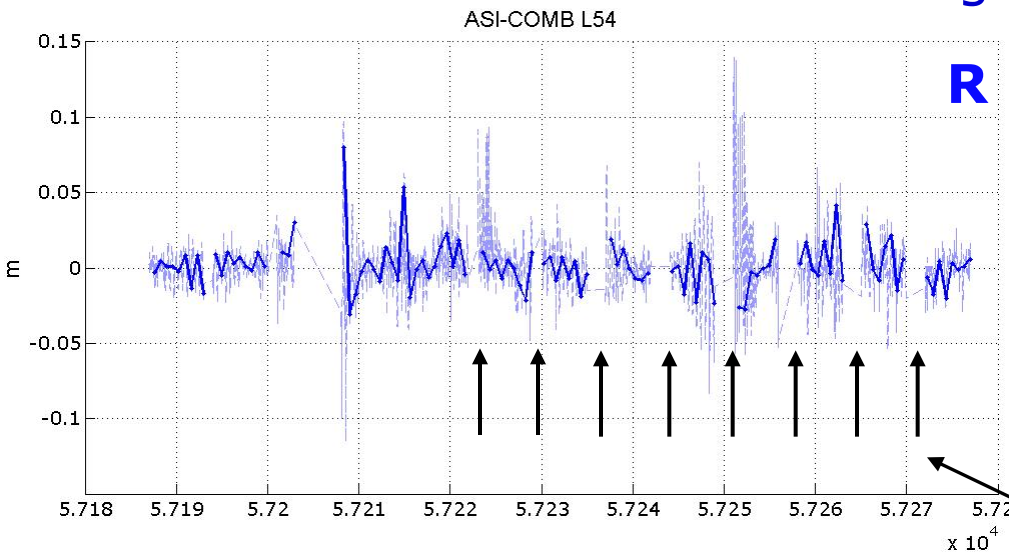


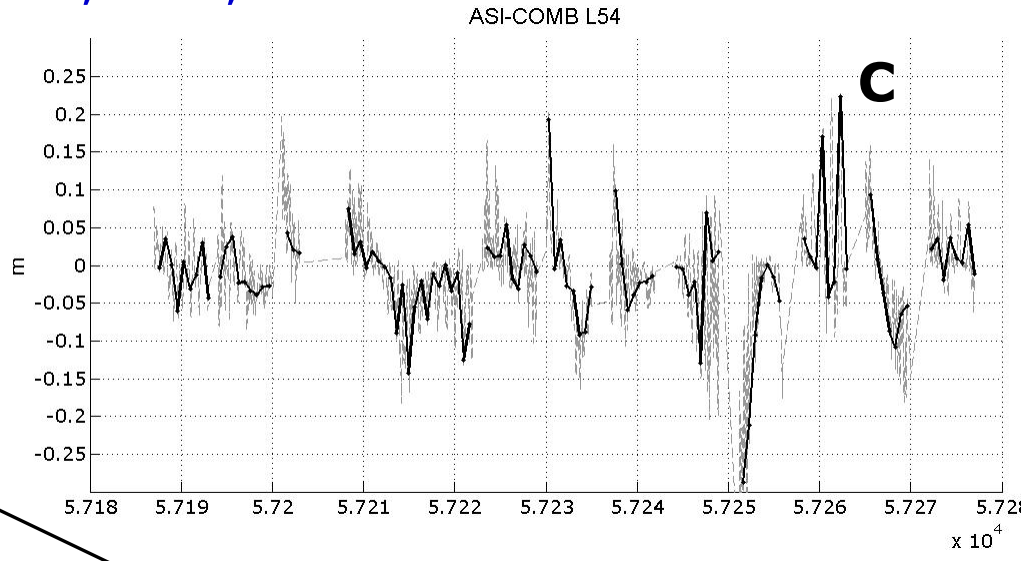


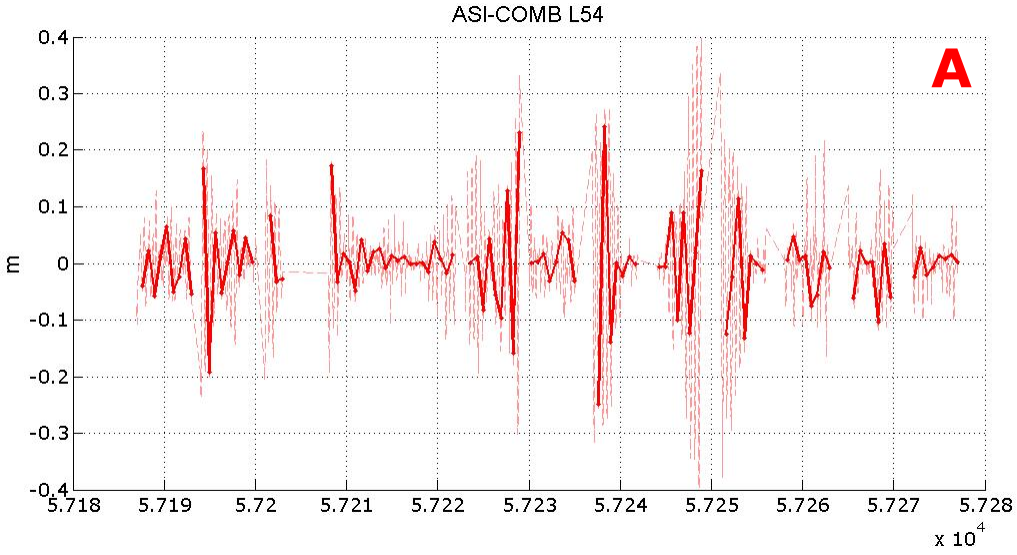
	MEAN [mm]	STD [mm]
R	0.1	15.6
A	-5.7	132.0
C	-35.5	102.0

L54 ACs vs Combination

Test combination for L54 using **ASI**, ESA, NSGF





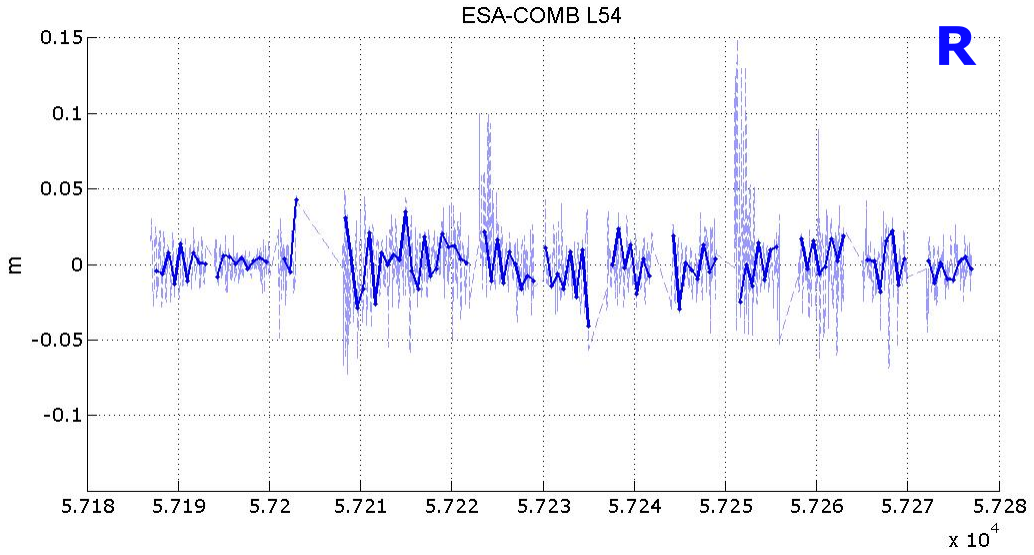


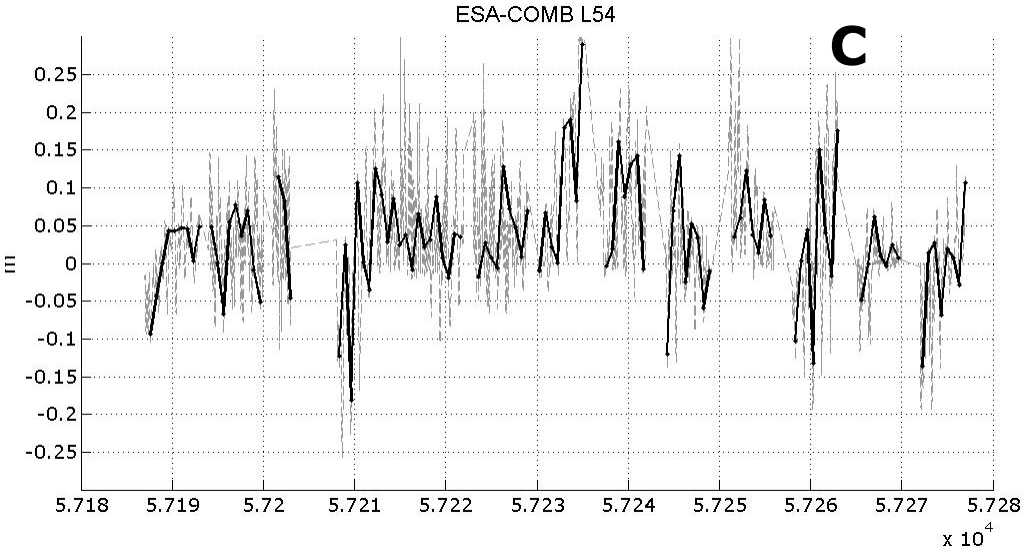
Gaps to investigate for all ACs (#AC < 3: NSGF excluded, BKG not considered for wrong epochs)

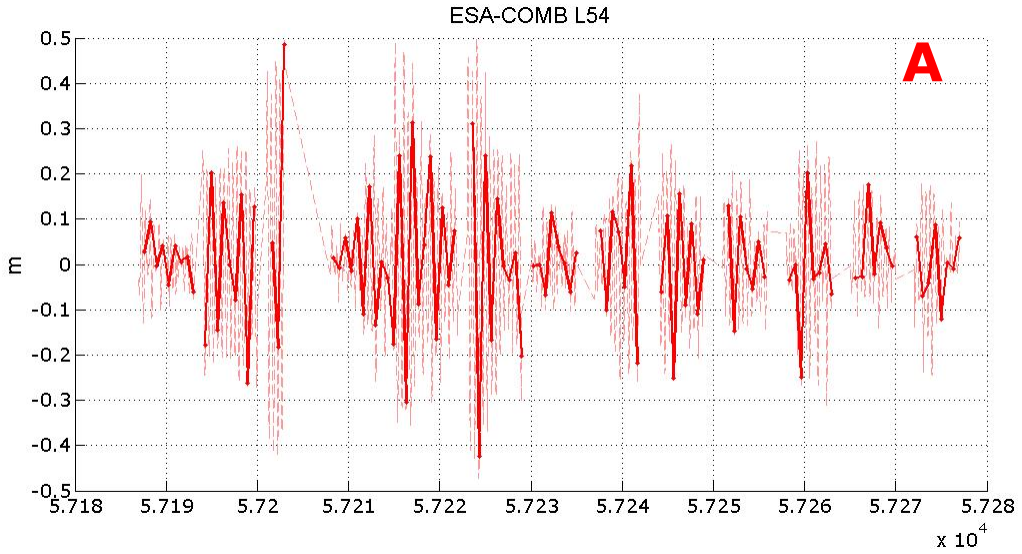
	MEAN [mm]	STD [mm]
R	1.0	17.7
A	-1.0	80.7
C	-12.5	66.9

L54 ACs vs Combination

Test combination for L54 using ASI, **ESA**, NSGF



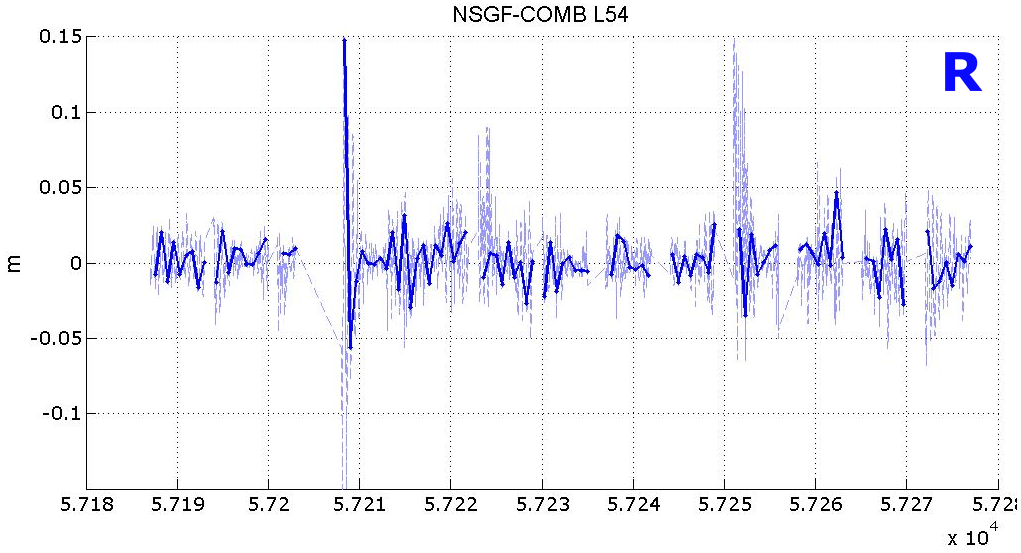


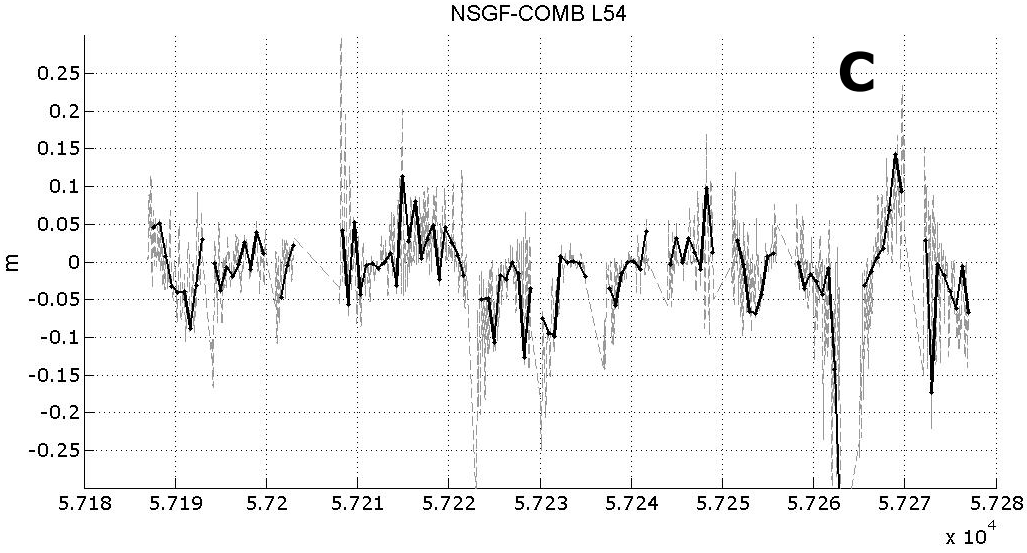


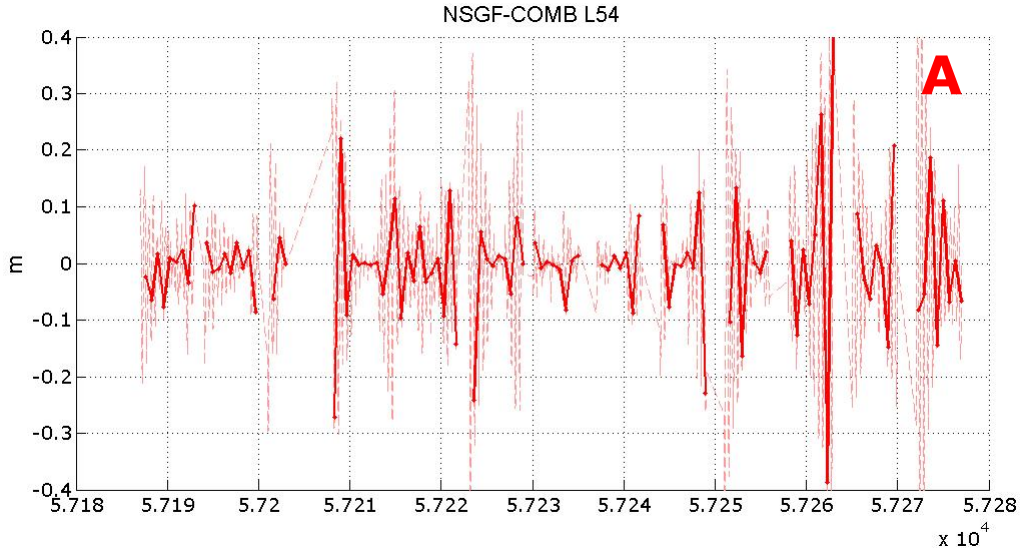
	MEAN [mm]	STD [mm]
R	1.6	21.5
A	-1.8	108.0
C	-11.2	61.8

L54 ACs vs Combination

Test combination for L54 using ASI, ESA, **NSGF**







	MEAN [mm]	STD [mm]
R	0.5	20.2
A	6.6	119.0
C	-10.6	72.0

Next steps

- Check JCET and GRGS orbit solutions;
- Produce weekly combined orbit files;
- Produce sum files;
- Evaluate the quality and stability of this solution.

DGFI AC Report

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Munich
email: horst.mueller@*tum.de*

DGFI contribution ITRF2014P evaluation

- Version v70 delivered October 09 2014, updated Oct. 12

- ITRF2014P stations coordinates with non linear station velocities
  - Weekly sinex files from 2009 to 2015
  - Using fixed ITRF2014P station coordinates to compute orbit from 1983 to 2015
  - Comparison with the same orbit processed using SLRF2008

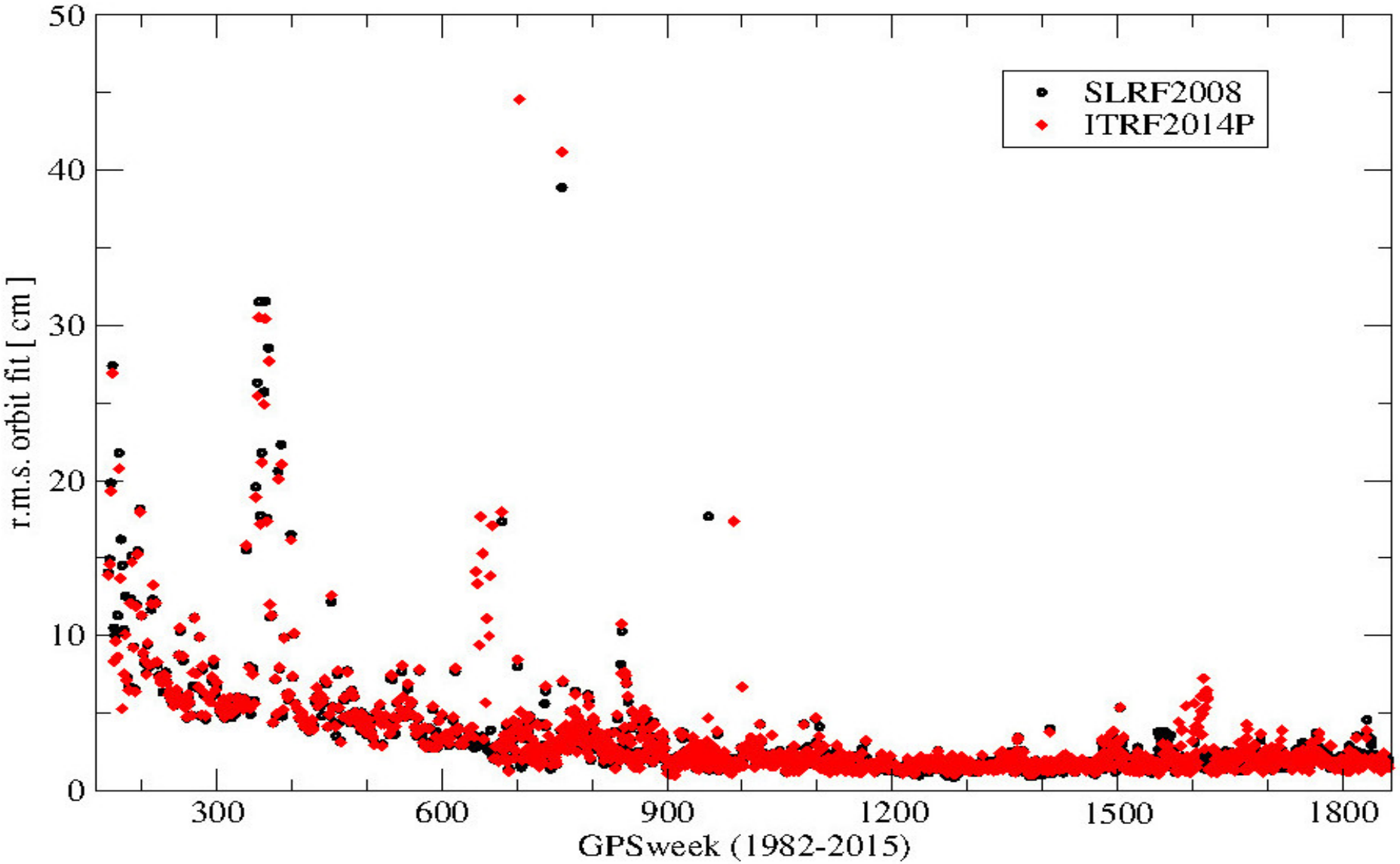
ITRF2014P evaluation

- Processing of Lageos arcs with fixed coordinates (including non linear station velocities)
  - Same input as for delivered sinex files
  - ITRF2014P is generally better than SLRF2008
  - Only Problems in GPSweeks 1580 1620 with Concepcion
    - ITRF2014P coordinates produce

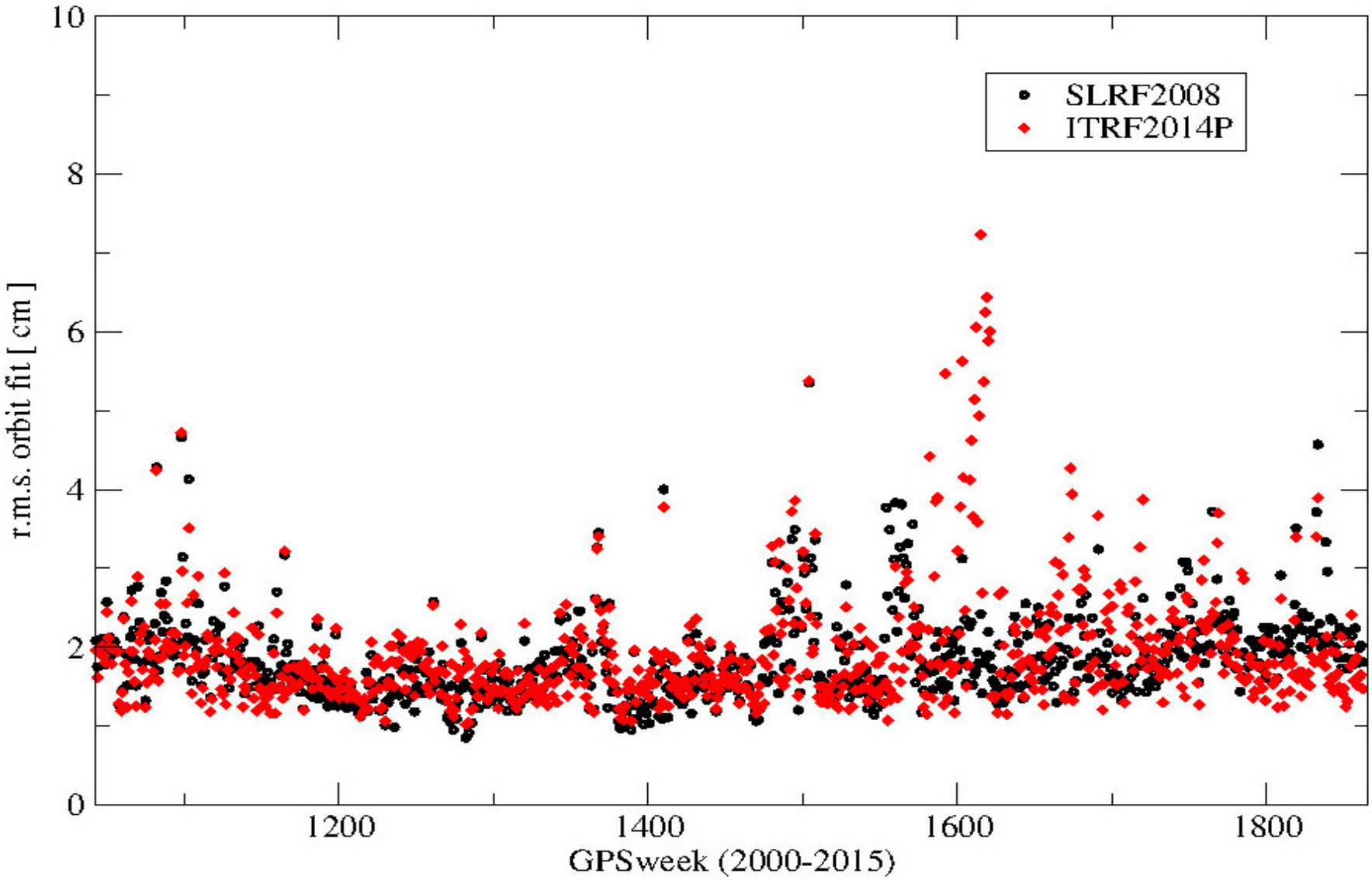
- Main difference 20 weeks after the earthquake in Chile 2010

	ITRF2014P	slrf2008
• Mean r.m.s. orbit fit: Lageos1: (1983-2015)	3.17 +- 3.37	3.02 +- 3.14
(2000–2015)	1.92 +- 0.74	1.84 +- 0.54
Lageos2: (1993-2015)	2.23 +- 1.17	2.14 +- 0.95

ITRF2014P evaluation



ITRF2014P evaluation



Data Handling File Update

Regular update if necessary:

Last update: Sep 30 2015, new stations

Comment block contains reason for update

ILRS AWG meeting
ESOC status

T. Springer, C. Flohrer,
R. Zandbergen, W. Enderle
Matera, Italy 24-10-2015

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Routine activities

- Routine ILRS solutions:
    - Weekly solutions (V35)
    - Daily rapid solutions (V130)
- Were also are a full analysis centre for the IDS and IGS
    - IGS: Final, Rapid, Ultra-rapid, and real-time
    - IDS: Final solutions
- Reprocessing for ILRS, IGS, and IDS becoming almost “routine”
- Initial developments for becoming an IVS analysis centre

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ITRF2014P Evaluation

- Build in the handling of the Post Seismic Displacements (PSD) functions
- Reprocessed 1983 to 2015 because all results were lost due to disk crash (for ITRF2014P 1993 to 2015 used)
    - Reprocessed first using “old” setup (input for ITRF2014)
    - Reprocessed second time with ITRF2014P without PSD
    - Reprocessed third time with ITRF2014P with PSD
        - Results submitted last Thursday including a short document with our first impressions
- Further ITRF2014P evaluation plans:
    - Use for IDS and IGS reprocessing
    - Use for ILRS reprocessing for 1983 to 1992 timeframe
        - In this scope add missing stations to ESOC processing

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ESOC ILRS AC Status (1)

- For reprocessing some improvements were made to our processing
  - Station specific weights
  - Handling of data issues (biases, exclusions) based on input SINEX
    - These improvements will become part of our routine processing when we switch to the ITRF2014
- Updated AC analysis description file send to ILRS and also description included in SINEX
- Need to add some missing stations (mainly the "recent" Russian stations)
    - We have made a software improvement allowing us to detect that there are stations in the tracking data which are not in our database, this feature was lacking
    - Stations will be added when switching to ITRF2014

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ESOC ILRS AC Status (2)

- Reprocessing Specials:
  - Mean pole handling
    - Software modification needed to make this fully automatic
  - C20, C21 and S21 coefficients
    - Software modification needed to make this fully automatic
- In both cases main issues that need to be defined:
  - Location of the input files
  - Format of the input files
  - Availability, accessibility and reliability have to be very good!

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Further work and interests

- Continue ITRF2014P evaluation
    - Using GNSS and DORIS
- Detailed analysis of our reprocessing time series
    - Station: coordinates, biases, residuals
    - Satellite: SRP parameter, CPR parameters
- Use of ETALON to get a better understanding of and handle on the SRP environment for the GNSS satellites in general and GLONASS in particular
- Interesting signals in the time series of the satellite dynamical parameters
    - Following slides show two examples
    - Most likely caused by the known thermal/rotation effects

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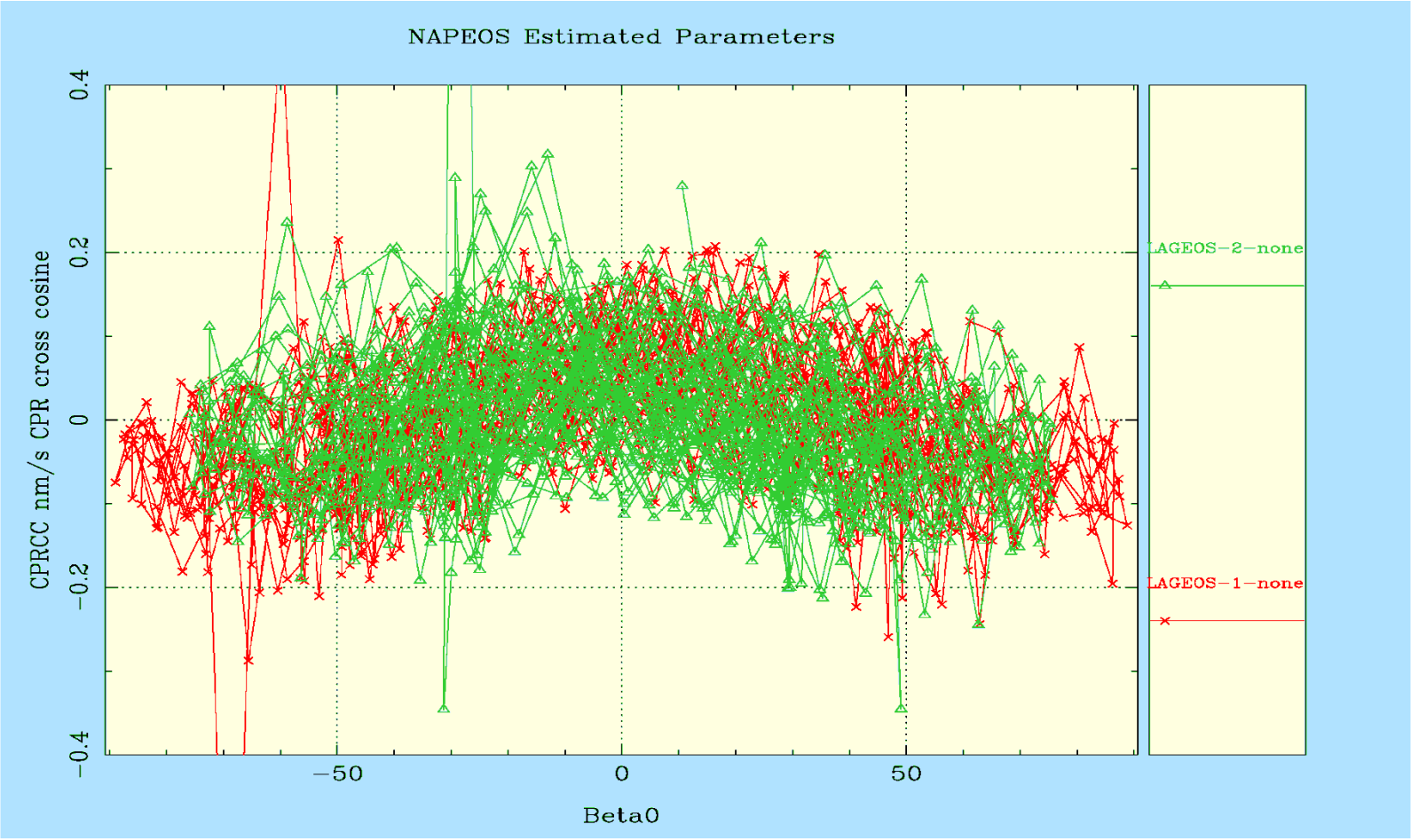
LAGEOS Cross-track cosine term



European Space Agency

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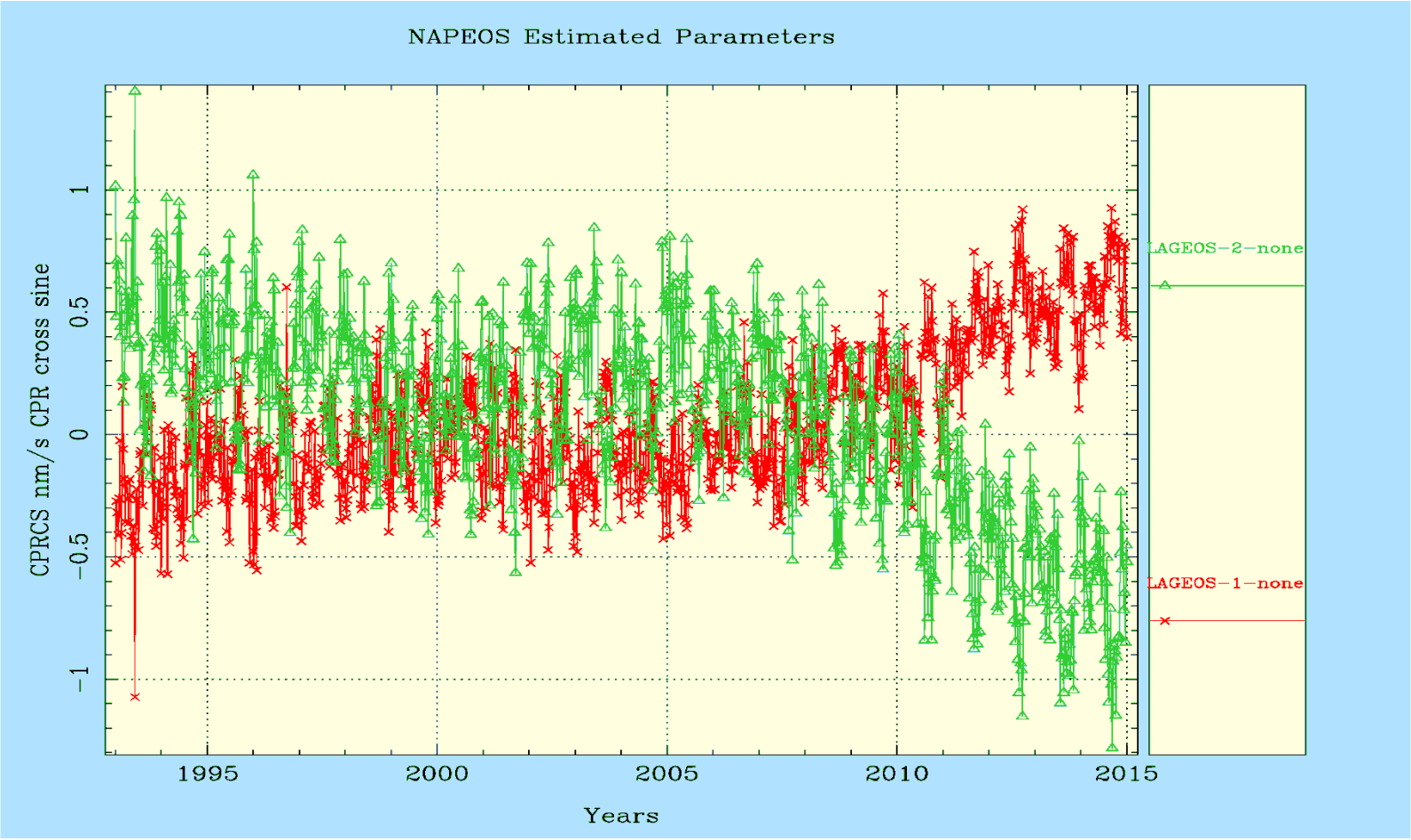
LAGEOS Cross-track sine term



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Conclusions

- ESA/ESOC very interested in SLR data
  - Efforts in our group are increasing
  - Focus still strongly on GNSS and ESA missions but SLR is getting more interest
- Will continue our ITRF2014P evaluation
  - Possibly some issues with the PSD functions
  - Could still be an implementation issue on our side
  - Need to do IGS/GNSS and IDS/DORIS analysis

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ITRF2014P Evaluation

Tim Springer

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PSD Functions

- For 10 ILRS stations PSD functions are included in the ITRF2014P
- We have implemented the PSD functions in our software
- Cross checked with the examples as provided by Zuheir
- Validation based on our ILRS reprocessing
- In one of the steps of our ILRS reprocessing we keep the station positions fixed. The residuals from this run we have used as one of the means to further validate the PSD functions
    - For 8 our of 10 stations the residual RMS went downs significantly.
    - For 2 stations (7403 and 7405) a significant increase is observed and for 7403 even a clear signal appears in the residuals
- For 7405 (CONZ) we observe an increase of the residuals over time which indicates that the station position accuracy may be degrading over time
- For 7403 (AREQ) the situation is more interesting, see next slides….

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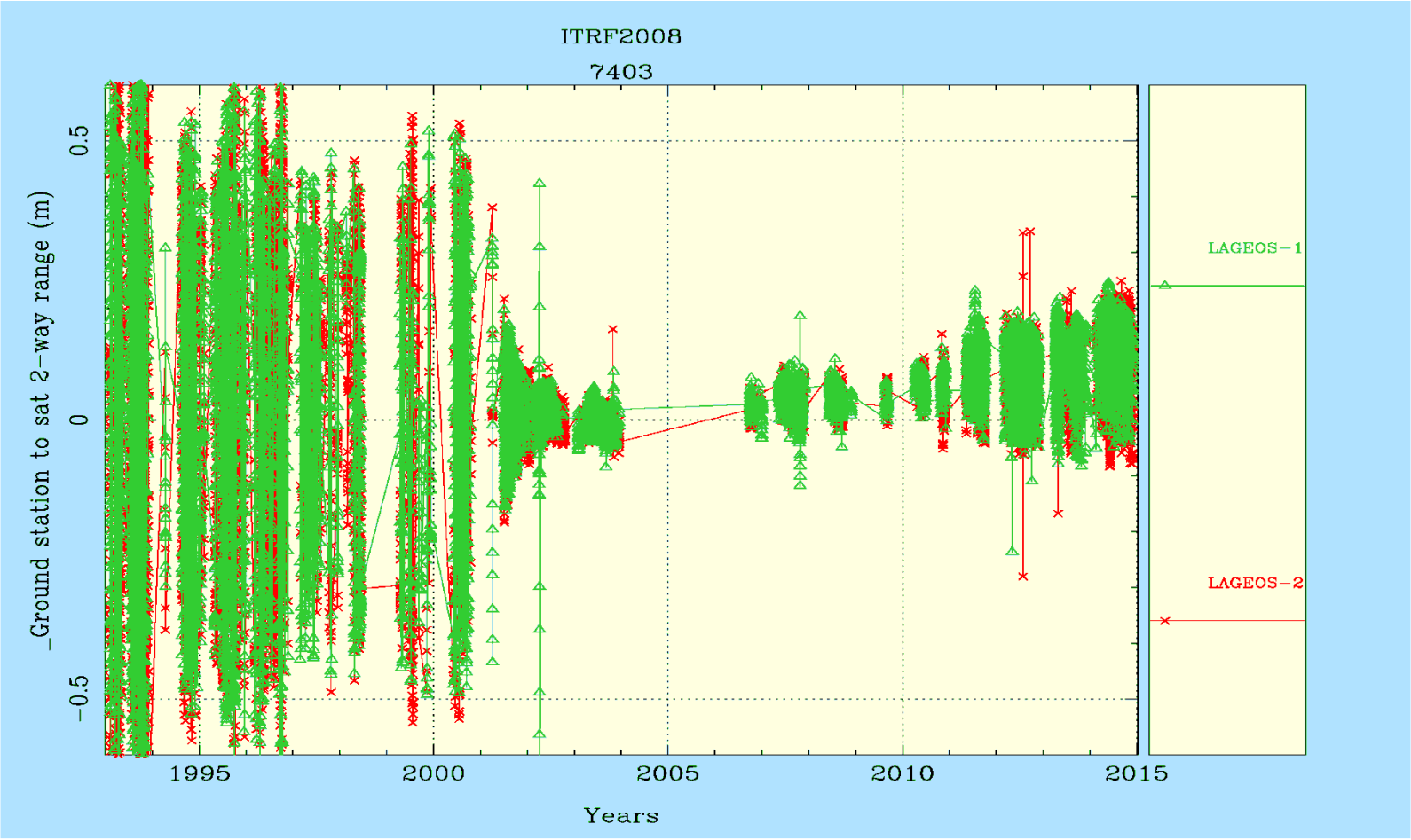
7403 (AREQ) PSD Issue?



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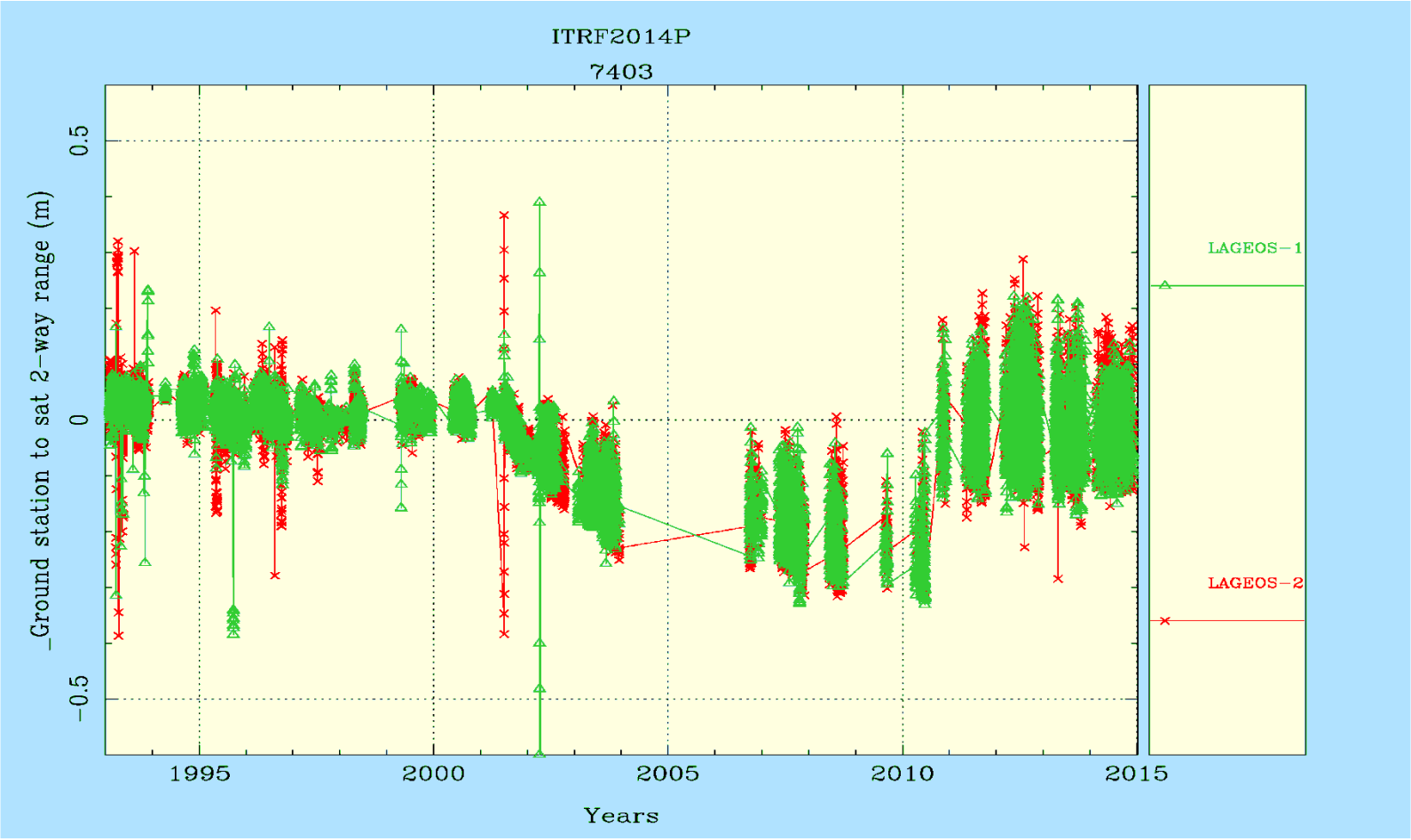
7403 (AREQ) PSD Issue?



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7403 (AREQ) PSD Issue?

- ITRF2008 solution
  - Incorrect coordinates used before 2001, consequently large residuals, due to an error in our set-up
  - From 2001 to 2015 one set of coordinates and velocities used which seemed to work OK, but the residuals are growing!
- ITRF2014P solution:
  - Period before 2001 looks fine! But 2001 to 2010/Sep not good
  - After 2010/Sept looks good
    - But note: from 2010/Sept Range bias estimated for 7403!
    - Average value of bias -43 mm
  - But also here residuals growing over time…

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7403 (AREQ) Discontinuities

```
7403  A    1 L 00:000:00000 94:160:01996 P - EQ (PR)
7403  A    2 L 94:160:01996 96:317:61184 P - EQ (PR)
7403  A    3 L 96:317:61184 01:174:73994 P - EQ (PR)
7403  A    4 L 01:174:73994 01:188:34724 P - EQ (PR)
7403  A    5 L 01:188:34724 07:227:85258 P - EQ (PR)
7403  A    6 L 07:227:85258 14:091:85607 P - EQ (PR)
7403  A    7 L 14:091:85607 00:000:00000 P -  (PR)
7403  A    1 L 00:000:00000 00:000:00000 V -  (PR)
```

```
42202M003 7403              GPS 7403       1          1942808.274 -5804069.671 -1796915.273 0.004 0.004 0.004 I
42202M003                                                   0.0125       0.0021       0.0147 0.000 0.000 0.000 I
42202M003 7403              GPS 7403       2          1942808.280 -5804069.678 -1796915.271 0.004 0.003 0.003 I
42202M003                                                   0.0125       0.0021       0.0147 0.000 0.000 0.000 I
42202M003 7403              GPS 7403       3          1942808.274 -5804069.683 -1796915.272 0.003 0.002 0.002 I
42202M003                                                   0.0125       0.0021       0.0147 0.000 0.000 0.000 I
42202M003 7403              GPS 7403       4          1942807.835 -5804069.713 -1796915.559 0.034 0.018 0.025 I
42202M003                                                   0.0125       0.0021       0.0147 0.000 0.000 0.000 I
42202M003 7403              GPS 7403       5          1942807.800 -5804069.709 -1796915.592 0.002 0.001 0.002 I
42202M003                                                   0.0125       0.0021       0.0147 0.000 0.000 0.000 I
42202M003 7403              GPS 7403       6          1942807.793 -5804069.714 -1796915.599 0.001 0.001 0.001 I
42202M003                                                   0.0125       0.0021       0.0147 0.000 0.000 0.000 I
42202M003 7403              GPS 7403       7          1942807.797 -5804069.726 -1796915.609 0.003 0.005 0.003 I
42202M003                                                   0.0125       0.0021       0.0147 0.000 0.000 0.000 I
```


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7403 (AREQ) PSD Issue?

- Results before 2001 improved significantly
  - Due to error in our 2008 set-up we used incorrect coordinates and velocities
- Results after 2001 seem to be worse
  - Our 2008 set-up used only a single position and velocity vector for the period and seemed to perform OK, but residuals are increasing over time indicating some issue with the accuracy of the station position/velocity
  - The ITRF2014P set-up uses 4 position vectors and 1 velocity vector from 2001 and two PSD functions. Clear signal shows up in our residuals. After 2010 the signal disappears due to the estimation of a (weekly) range bias
- Conclusions
  - Handling 7403 using just a single position and velocity vector of the SLR2008 worked better then handling the station with the current ITRF2014P set-up!
  - We will carefully validate the AREQ station in our IGS/GNSS analysis and see if something similar may be observed there. If for the GNSS analysis things are fine the issue must be with the SLR data. If something similar is observed for IGS/GNSS it must be an ITRF2014P issue.

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ITRF2014P Evaluation

T.A. Springer

European Space Operations Centre, Darmstadt, Germany

1 Comments

1.1 Introduction

Below some comments regarding the ITRF2014P based on the experience gathered with the implementation into the NAPEOS software and the evaluation of the results. I have have two main comments. Firstly, the equation given for the station position over time is incomplete. On first glance this is just a minor issue but on second glance it actually reflects the fundamental difference of the ITRF2014 w.r.t. previous ITRF releases. And this aspect does (did) have a significant impact when implementing the ITRF2014P into our software.

Below we first discuss the issue of the incomplete equation. This is followed by a discussion of the more fundamental change (or should we say issue or even problem?) we noticed in this ITRF2014P.

1.2 Equation problem

The equation (1) as given in the document ITRF2014P-psd-model-eqs-IGN.pdf is obviously not completely correct. It is given as:

$$X(t) = X(t_0) + \dot{X}(t - t_0) + \delta X_{psd}(t) \tag{1}$$

This, however, would mean that for $t = t_0$ we get:

$$X(t_0) = X(t_0) + \delta X_{psd}(t_0)$$

Which clearly leads to the contradiction that $X(t_0) \neq X(t_0)$. So the correct equation, also making it more similar to the way the velocity is handled, seems to be:

$$X(t) = X(t_0) + \dot{X}(t - t_0) + \delta X_{psd}(t) - \delta X_{psd}(t_0) \tag{2}$$

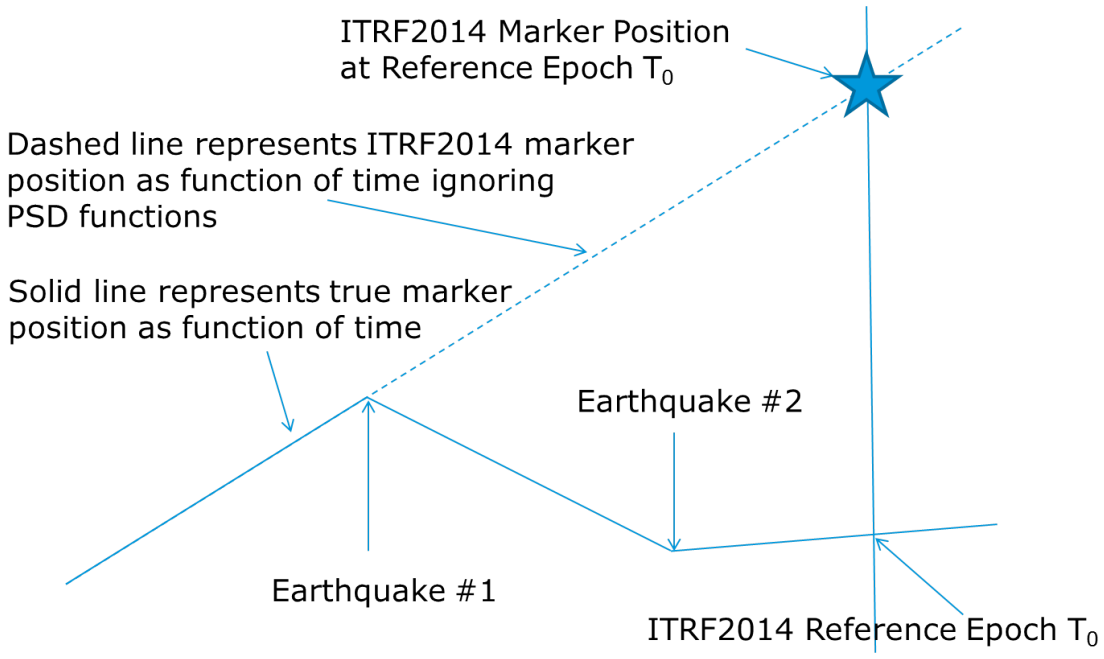


Figure 1: Example of station position evolution over time with earthquakes

With this equation we then also get the correct answer for $t = t_0$, namely:

$$X(t_0) = X(t_0)$$

However, is this really correct now!? The discussion below will show that this equation does not deliver what we (may) want!

1.3 Fundamental Change

With the introduction of the post seismic deformation (PSD) functions there is a fundamental change in the ITRF namely that the coordinates as given in the ITRF SINEX file are no longer necessarily close to the actual physical location of the marker. Differences in the order of meters are present, but only for Earthquake sites, i.e. sites for which PSD functions are given. The reason for this is illustrated in figure 1.

Figure 1 shows the schematic time evolution of an fictious station suffering from two earthquakes. The way the ITRF2014 represents such a station is by estimating:

- At least one station position vector, but more likely three
- One single velocity vector

- Two PSD functions, one valid from the time of Earthquake #1 and a second one valid from the time of Earthquake #2

As a consequence the estimated velocity vector will be based solely on the time series of the station until the first Earthquake. From the first Earthquake any deviation from the estimated velocity vector will be absorbed (modeled) by the estimated PSD function. And after Earthquake 2 the PSD function #2 will reflect the velocity difference compare to the velocity given by the velocity vector and PSD function #1. As a consequence the marker position as given in the ITRF2014 SINEX may deviate significantly from the actual physical location. With figure 1 I have tried to schematically reflect what is going one. In this figure the "star" reflects the marker position as given by the ITRF2014 at its reference epoch (2010.0), the solid line represents the true physical position and the dashed line represent the time evolution of the position based on the ITRF2014 position and velocity but ignoring the PSD functions. The ITRF2014 position, velocity and PSD functions together should (and do) coincide with the solid line of course. So the disturbing issue here is that there may be very significant differences between the location as given in the ITRF2014 SINEX files compare to the true physical location, even at the reference epoch of the ITRF2014. This is not really a problem but it is a completely new feature which may (and I think actually will) surprise many users!

So knowing this lets turn back to our equation 2.

$$X(t) = X(t_0) + \dot{X}(t - t_0) + \delta X_{psd}(t) - \delta X_{psd}(t_0)$$

We already established that for t_0 this will give us the position $X(t_0)$. However, this would give us the location of the "star" in figure 1 wereas we would like to get a point on the solid line. So although our equation is mathematically correct it does not really deliver what it should. The issue is that with the ITRF2014 the $X(t)$ and the $X(t_0)$ have become fundamental different things. The $X(t_0)$ now represent the position of the station on the "dashed" line whereas the $X(t)$ is intended to represent the station position on the solid line. Consequently, the error is by naming these two things the same (X) where they are actually fundamentally different. So we have to define a new variable, lets call it I, and with that we may write:

$$X(t) = I(t_0) + \dot{I}(t - t_0) + \delta I_{psd}(t)$$

Note that the variable I was selected as it both reflects "ITRF" as well as "imaginary" (punn intended).

So essentially with the ITRF2014 we need the following equation to convert ITRF2014 positions to true positions (and visa versa):

$$X(t) = I(t_0) + \dot{I}(t - t_0) + \delta I_{psd}(t) \tag{3}$$

From this equation we may derive the equation to convert a true station position at time t_1 to a true station postion at time t_2, which gives:

$$X(t_2) = X(t_1) + \dot{I}(t_2 - t_1) + \delta I_{psd}(t_2) - \delta I_{psd}(t_1)$$

Although this is all trivial and straight forward, mathematically speaking, this may not be so simple when implementing it into your software. With the new "definition" used for the ITRF2014 we have "gained" and additional complexity in that besides the fact that we have to distinquish between "marker" and "instrument" coordinates we now also have to distinquish between the "true" marker position and the "ITRF" (or "imaginary") marker position. For all people not dealing with software implementation this will not matter but for all the software engineers out there I urge you all to take a carefull look at what ITRF2014 is now giving you and how you will handle that in your software... The biggest pitfall being the case where you use your own a priori coordinate set, which are typically "true" coordinates", but then you convert them from "imaginary" to "true" (applying the PSD effect). So you will have to add an identifier to specify what type your coordinates are: "true" or "imaginary" to avoid incorrectly applying the PSD correction(s).

2 Conclusions

We believe to have successfully implemented the ITRF2014P in the ESA/ESOC NAPEOS software. However, the switch from "true" position to "imaginary" did cause significant issues in the implementation and some careful design considerations had to be made. The quality of the ITRF2014P seems to be fine based on rerunning our ILRS reprocessing (1993-2015). As next validation step we will use the ITRF2014P for our IGS reprocessing.

Our main comments/concerns are:

- Fundamental change in that ITRF2014 now provides "imaginary" positions rather then "true" positions, which is particularly important from a software implementation point of view
- The PSD functions do contain a velocity component, the velocity given in the ITRF2014 for earthquake sites reflects only the velocity of the site for the time before the first Earthquake
- For Earthquake sites the coordinates found in the SINEX file for the reference epoch 2010.0 do NOT reflect the true position of the site, the PSD function(s) must be taken into account
- The PSD functions have infinite duration. Would make more sense to only have them valid from earthquake n to earthquake n+1.

So although the ITRF2014P may be used in the way it has been distributed I would have preferred it if it would have more closely followed the "old" scheme of providing "true" station positions. Basically for Earthquake sites I would have preferred a "model" that for a station with n earthquakes would consists out of $n+1$ sets of coordinates, velocities, and (where necessary) PSD functions. Each of these three components (coordinate, velocity, and PSD) being valid only for the period between Earthquake n and n+1. Of course I am very well aware that the involvement of PSD functions will automatically mean that the given positions become "imaginary" positions rather than "true" positions. But the effect would be much smaller than it is with the current implementation/definition. It would basically be an enhancement of the velocity model from a "constant" velocity model to a higher order model.

Last but not least I would like to state that the significant change in the ITRF "model" should have been communicated well in advance of the (preliminary) release of the ITRF2014. Especially in view of the large delay there was in generating the ITRF2014 there was ample time to provide an example of what was planned. The amount of time given for the evaluation of the ITRF2014 might have been enough if it would just have been a mere change of the coordinate and velocity values, but with the inclusion of the new PSD model the time given was not enough.

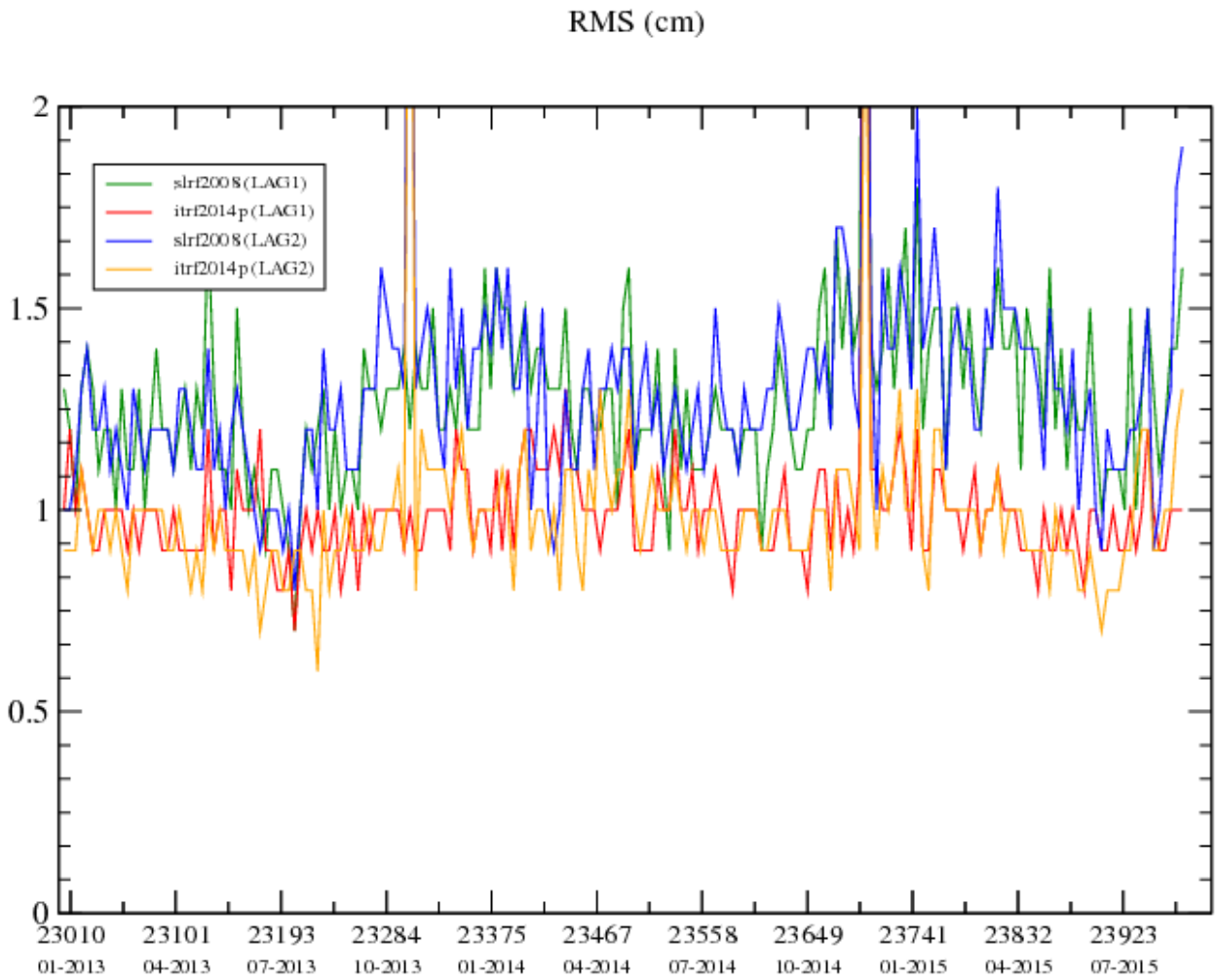
AWG GRGS ILRC AC

Florent Deleflie[1], Franck Reinquin[2],
and David Coulot[3,1]

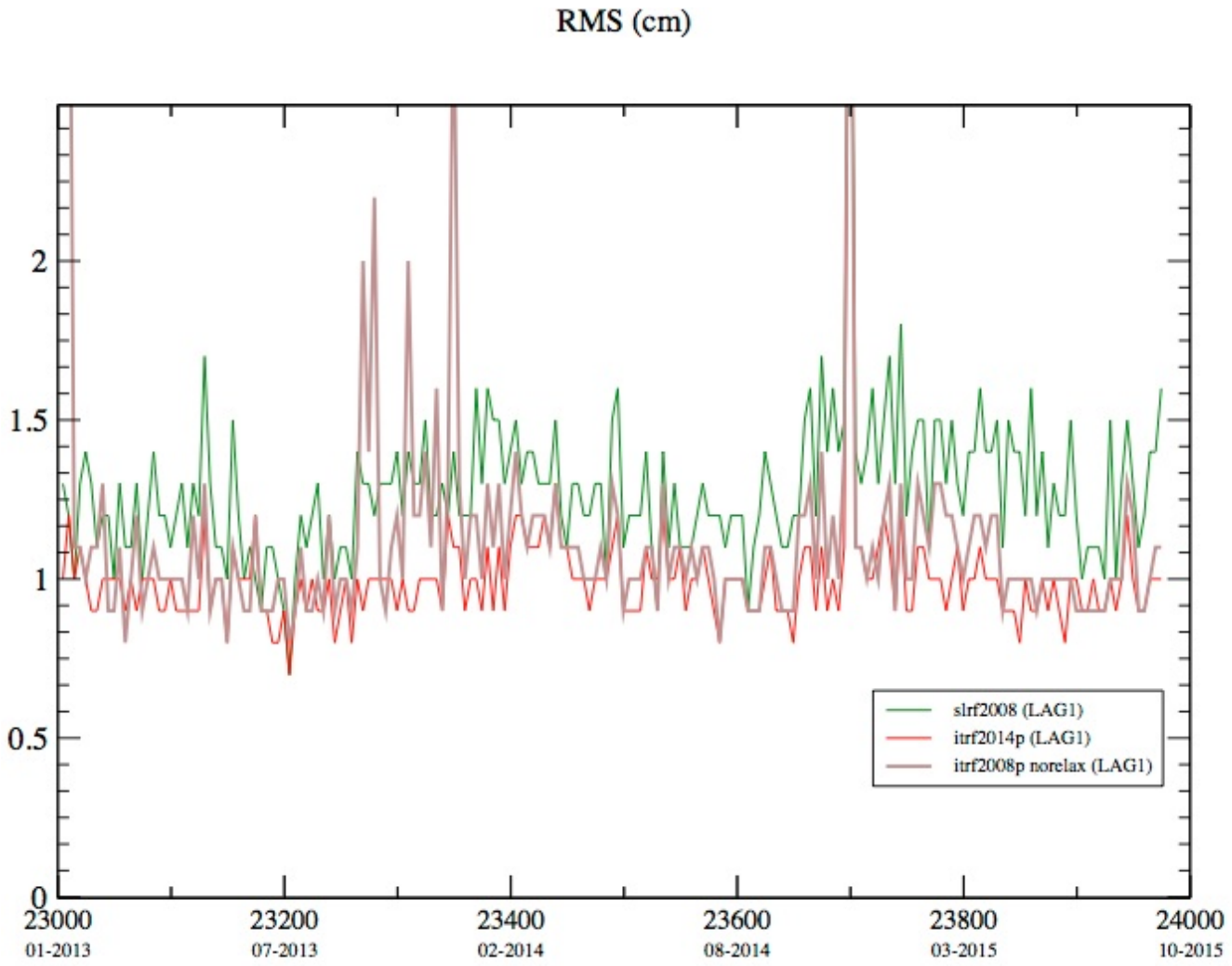
[1] Institut de Mécanique Céleste et de Calcul des Ephémérides/GRGS, Paris
[2] Centre National d'Etudes Spatiales/GRGS,Toulouse, France
[3] IGN/LAREG/GRGS, Université Paris Diderot, Paris, France

24th October, 2015

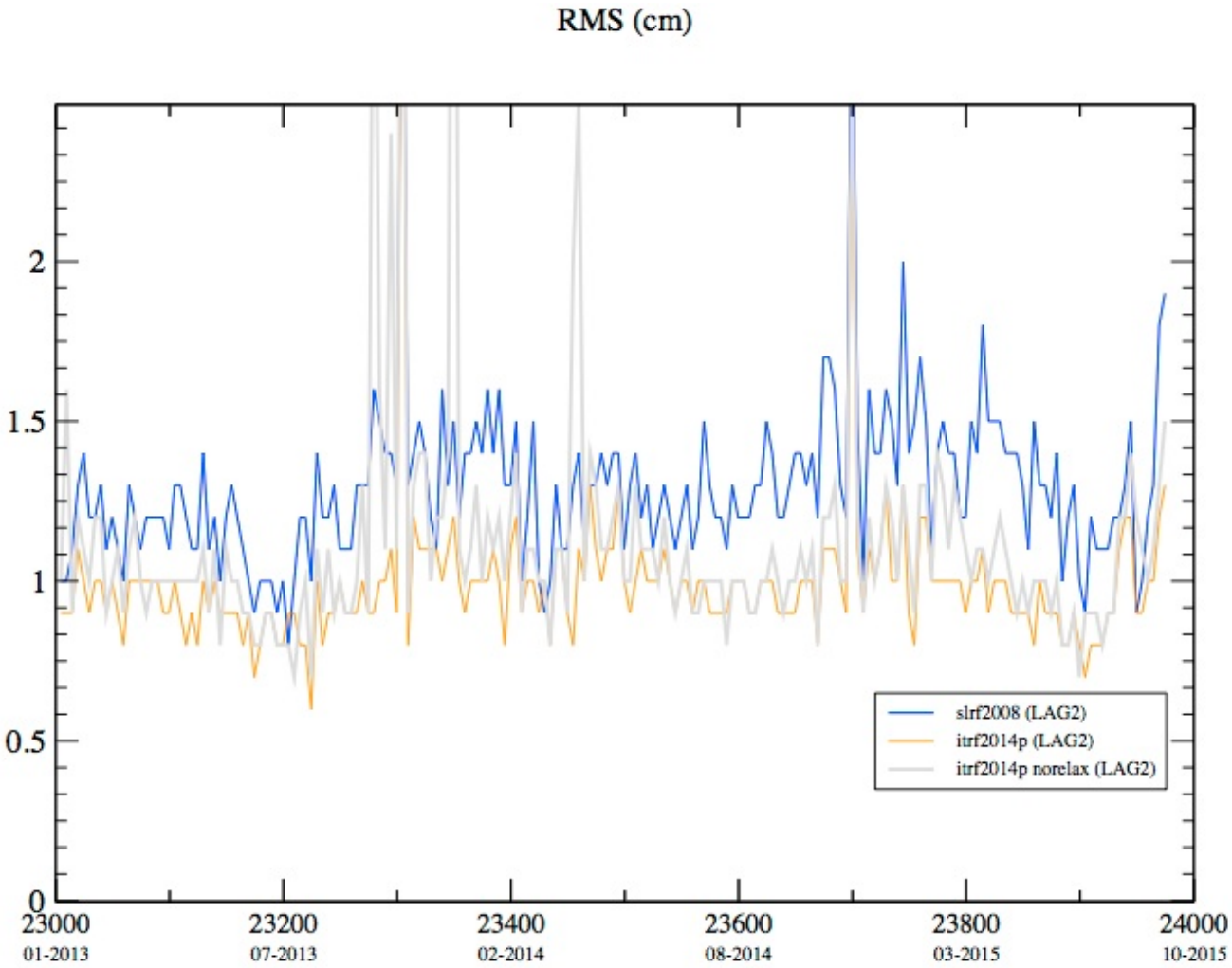
ITRF2008 (SLRF2008) / ITRF2014P: global results



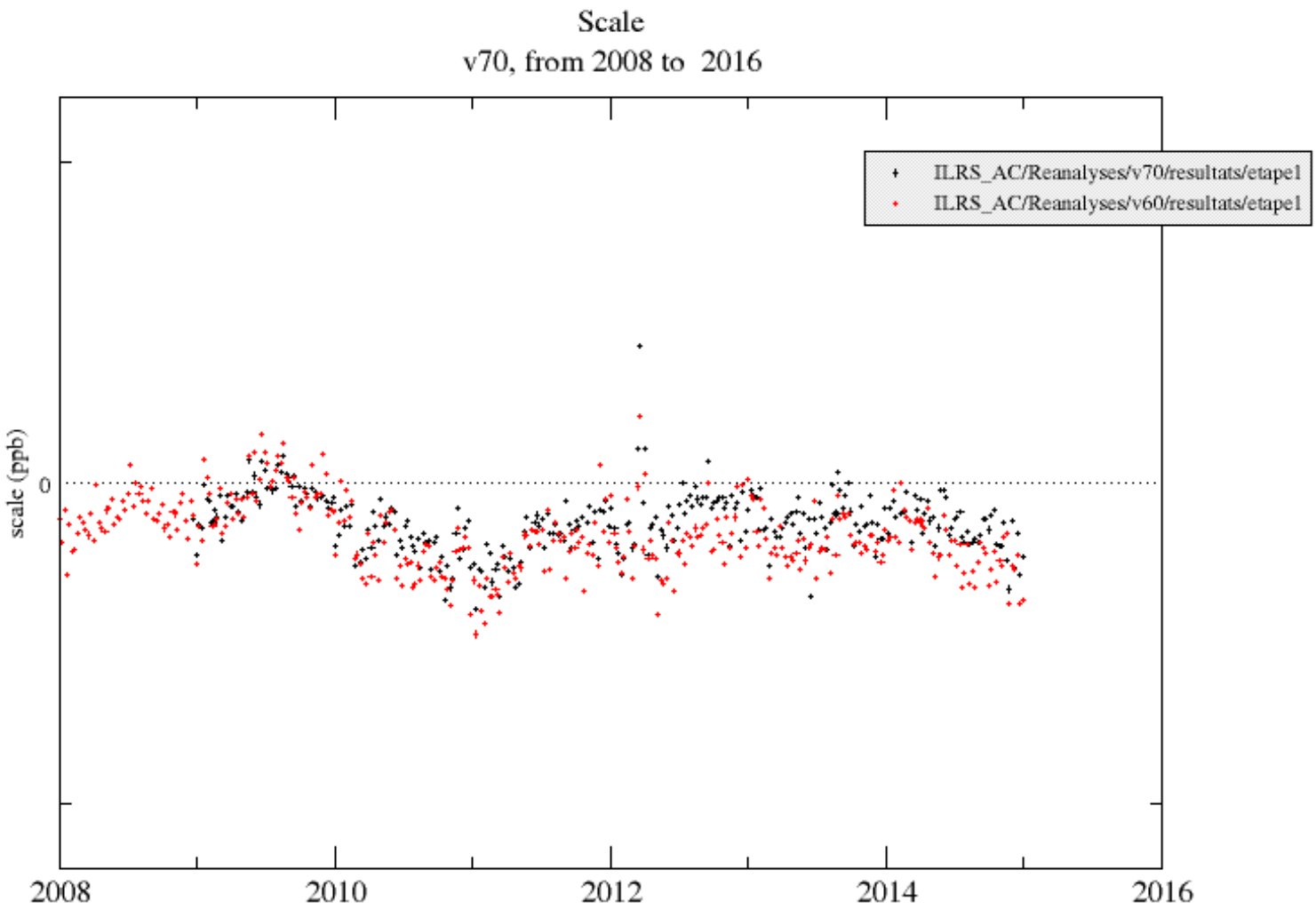
ITRF2008 (SLRF2008) / ITRF2014P: LAG1 w.&w/o PSD



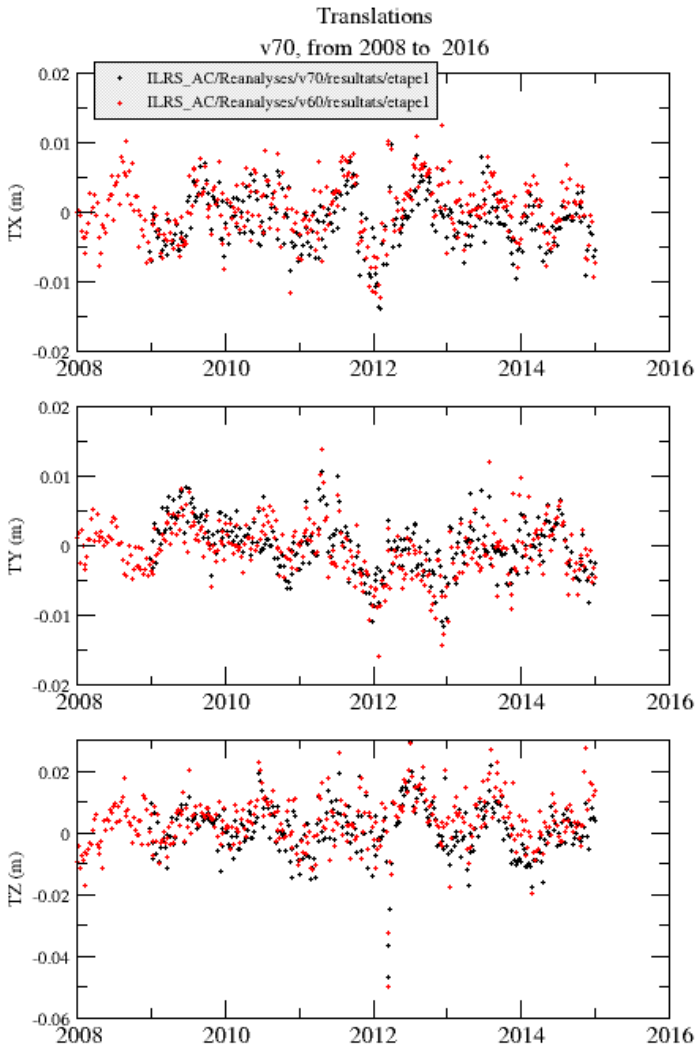
ITRF2008 (SLRF2008) / ITRF2014P: LAG2 w.&w/o PSD



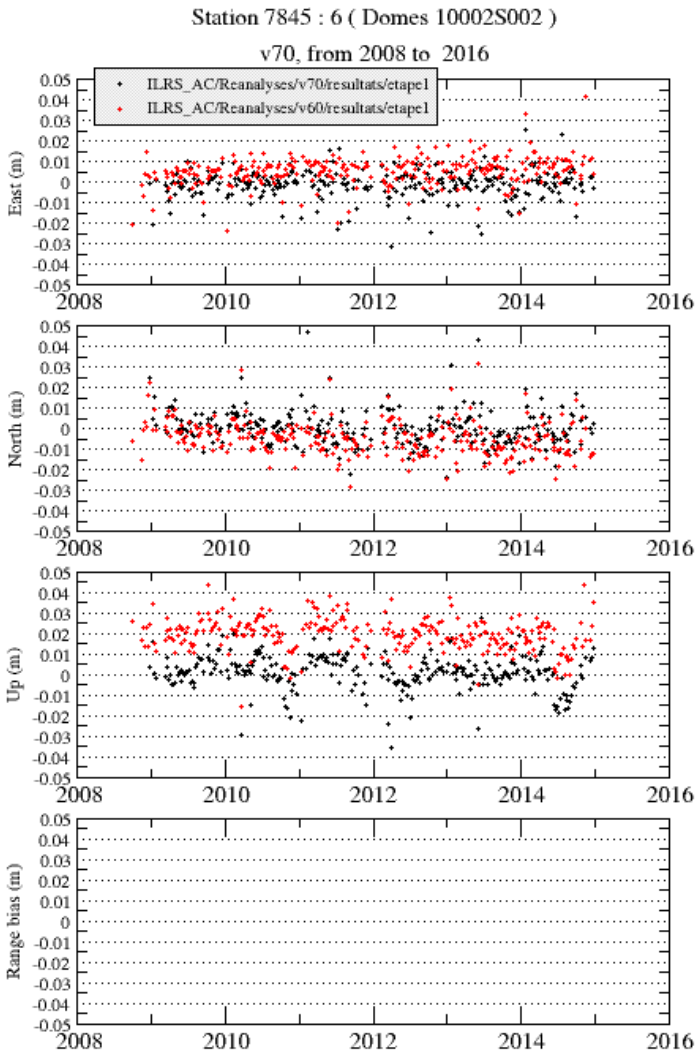
ITRF2008 (SLRF2008) / ITRF2014P: scale



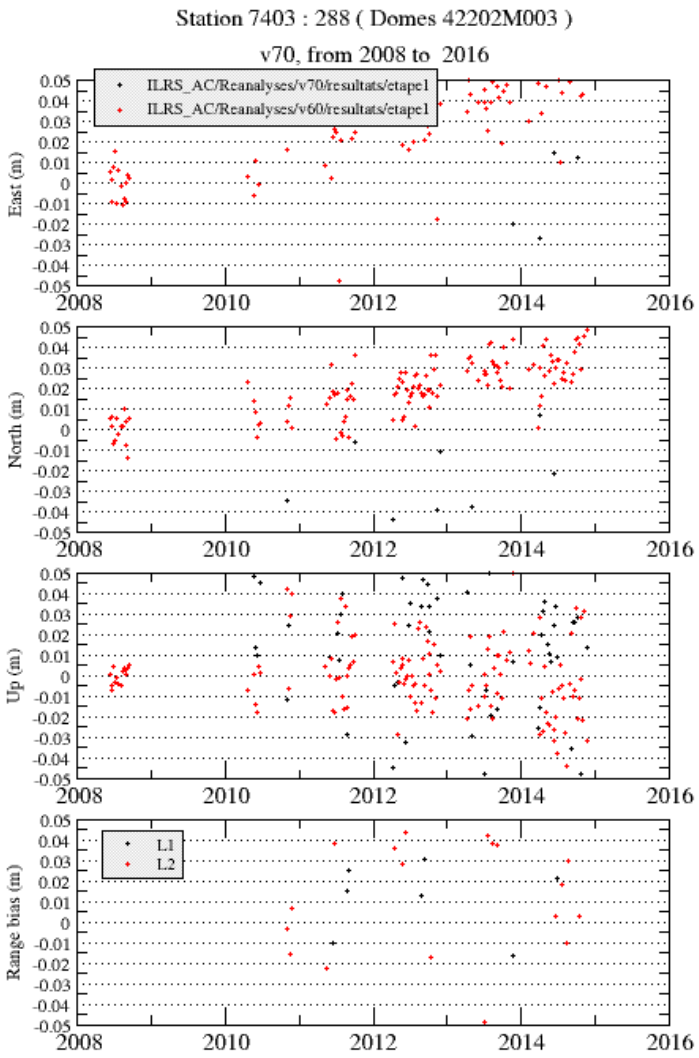
ITRF2008 (SLRF2008) / ITRF2014P: translations



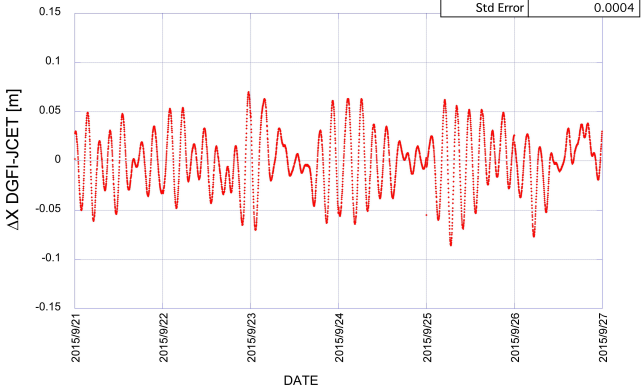
ITRF2008 (SLRF2008) / ITRF2014P: SSC



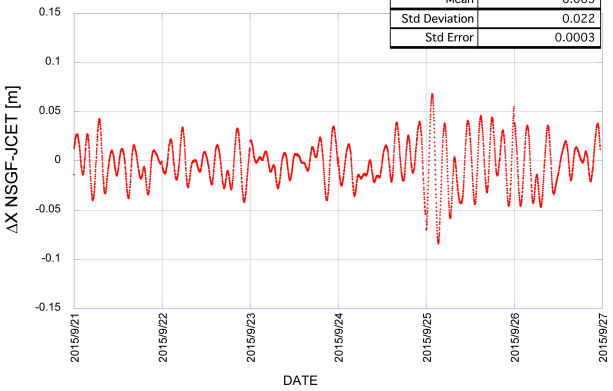
ITRF2008 (SLRF2008) / ITRF2014P: SSC



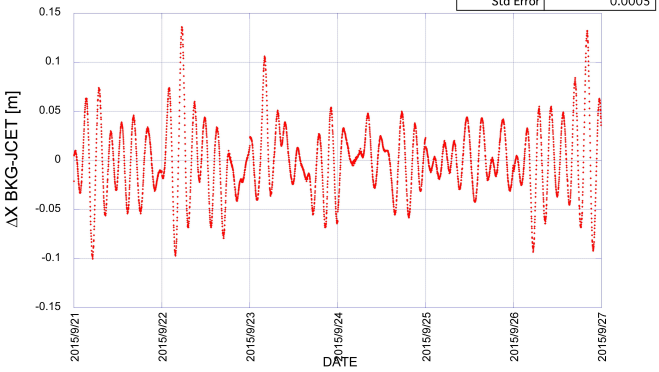
	ΔX DGFI-JCET [m]
Minimum	-0.086
Maximum	0.07
Points	4320
Mean	-0.001
Std Deviation	0.03
Std Error	0.0004



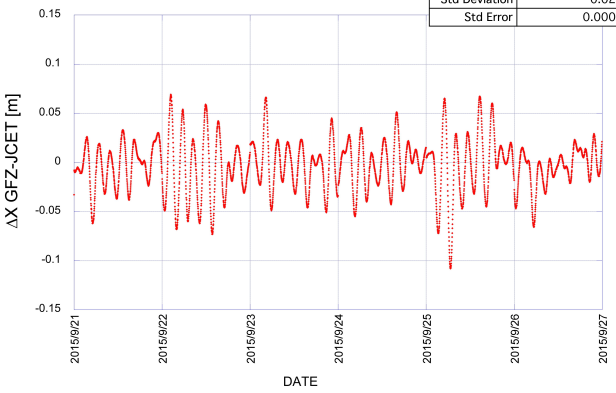
	ΔX NSGF - JCET [m]
Minimum	-0.084
Maximum	0.068
Points	4305
Mean	-0.003
Std Deviation	0.022
Std Error	0.0003



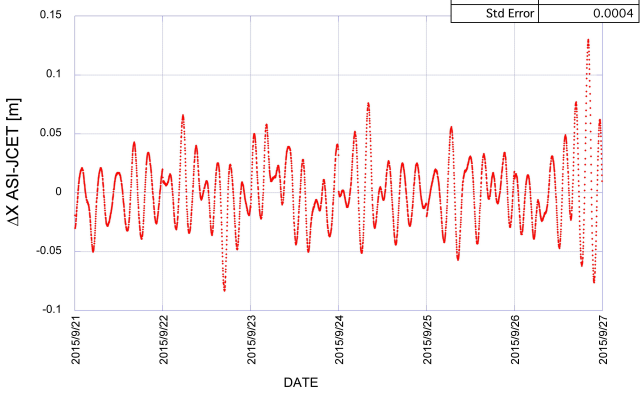
	ΔX BKG-JCET [m]
Minimum	-0.1
Maximum	0.136
Points	4320
Mean	-7.152e-05
Std Deviation	0.0366
Std Error	0.0005



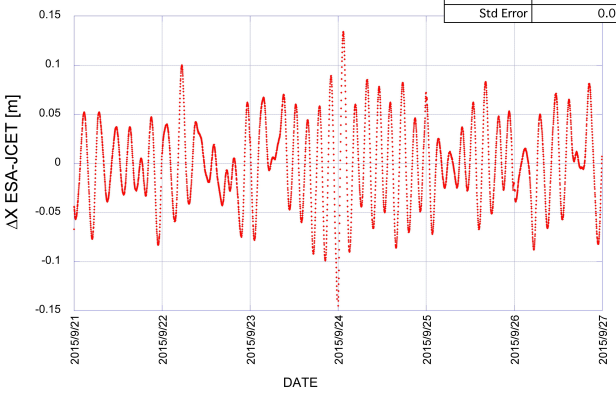
	ΔX GFZ-JCET [m]
Minimum	-0.108
Maximum	0.069
Points	4320
Mean	-0.003
Std Deviation	0.027
Std Error	0.0004



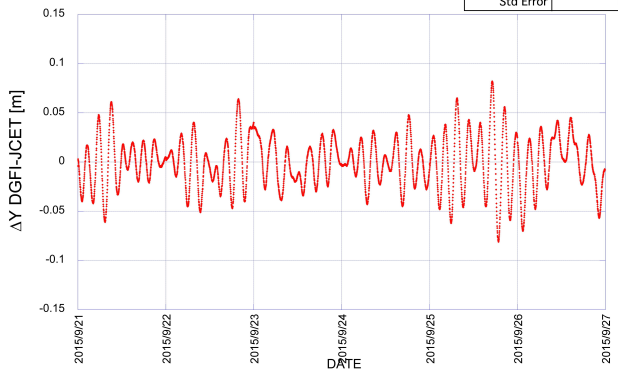
	ΔX ASI-JCET [m]
Minimum	-0.083
Maximum	0.13
Points	4320
Mean	0.001
Std Deviation	0.028
Std Error	0.0004



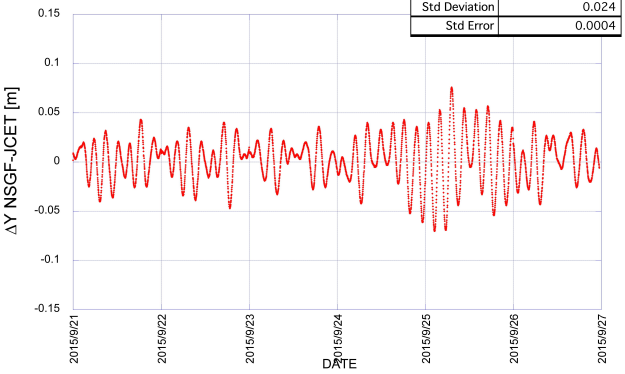
	ΔX ESA-JCET [m]
Minimum	-0.163
Maximum	0.134
Points	4320
Mean	-0.0005
Std Deviation	0.043
Std Error	0.0006



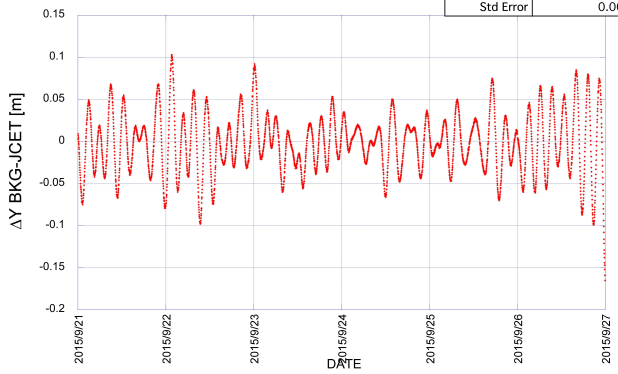
	ΔY DGFI-JCET [m]
Minimum	-0.081
Maximum	0.082
Points	4320
Mean	-0.0004
Std Deviation	0.026
Std Error	0.0004



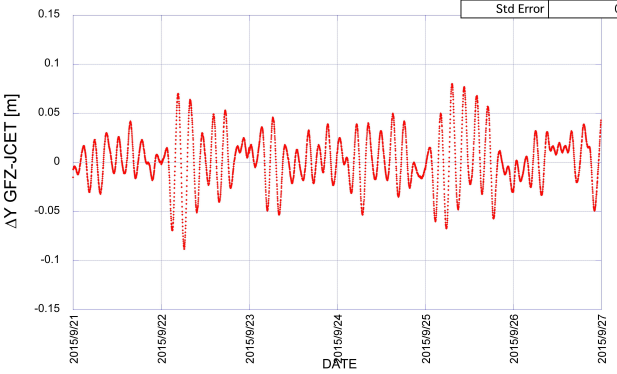
	ΔY NSGF - JCET [m]
Minimum	-0.07
Maximum	0.076
Points	4305
Mean	0.002
Std Deviation	0.024
Std Error	0.0004



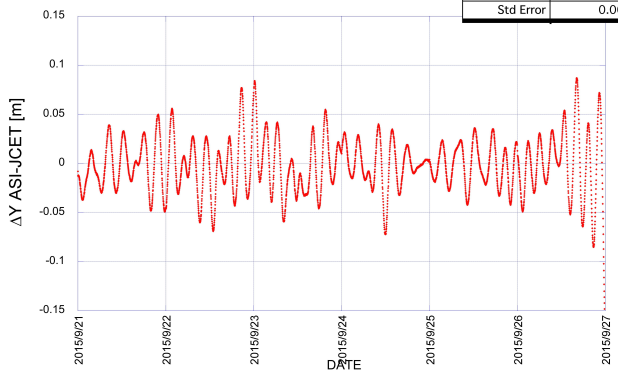
	ΔY BKG-JCET [m]
Minimum	-0.165
Maximum	0.103
Points	4320
Mean	-0.001
Std Deviation	0.036
Std Error	0.0005



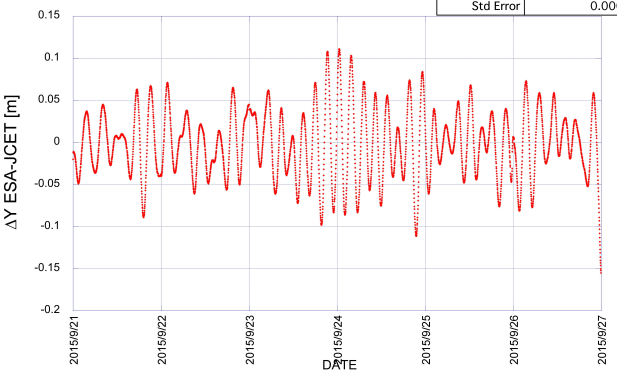
	ΔY GFZ-JCET [m]
Minimum	-0.088
Maximum	0.08
Points	4320
Mean	0.002
Std Deviation	0.026
Std Error	0.0004



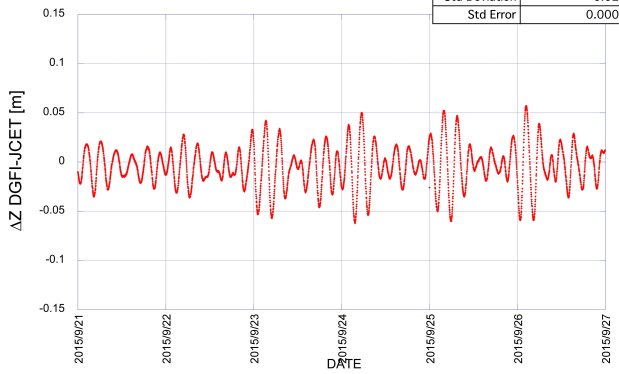
	ΔY ASI-JCET [m]
Minimum	-0.167
Maximum	0.087
Points	4320
Mean	-0.002
Std Deviation	0.029
Std Error	0.0004



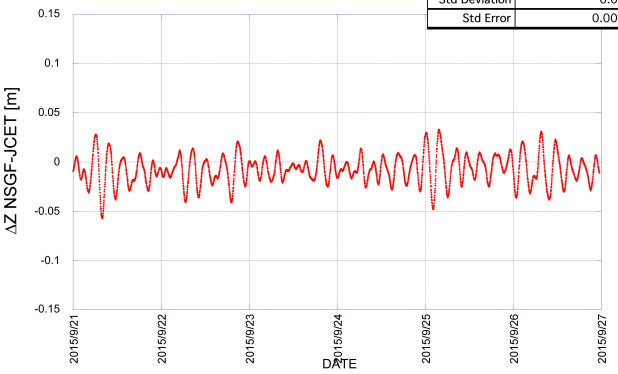
	ΔY ESA-JCET [m]
Minimum	-0.155
Maximum	0.111
Points	4320
Mean	-0.001
Std Deviation	0.041
Std Error	0.0006



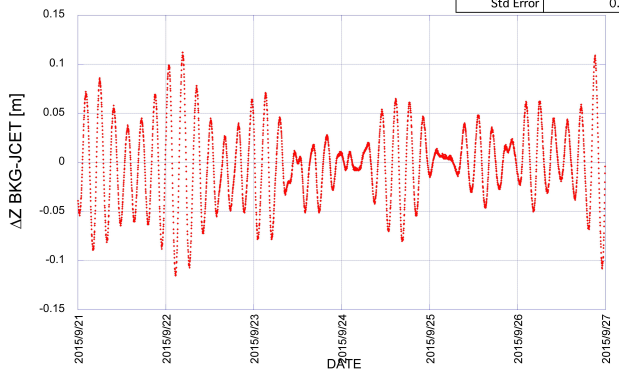
	ΔZ DGFI-JCET [m]
Minimum	-0.062
Maximum	0.057
Points	4320
Mean	-0.004
Std Deviation	0.021
Std Error	0.0003



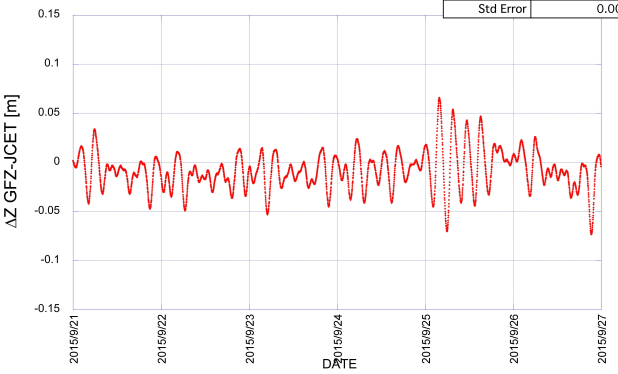
	ΔZ NSGF - JCET [m]
Minimum	-0.057
Maximum	0.033
Points	4305
Mean	-0.007
Std Deviation	0.015
Std Error	0.0002



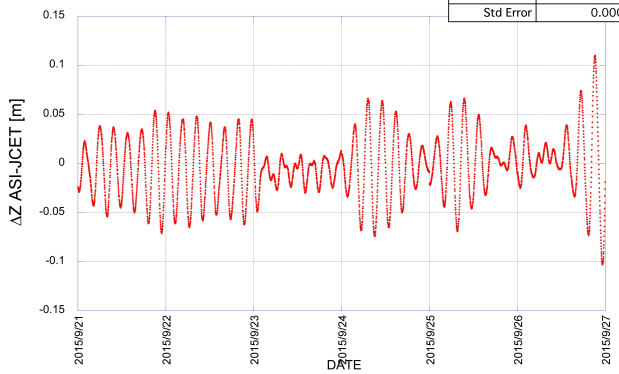
	ΔZ BKG-JCET [m]
Minimum	-0.115
Maximum	0.112
Points	4320
Mean	-0.0017
Std Deviation	0.039
Std Error	0.0006



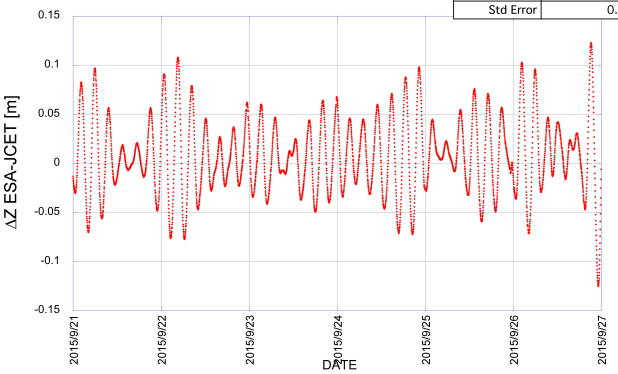
	ΔZ GFZ-JCET [m]
Minimum	-0.073
Maximum	0.066
Points	4320
Mean	-0.008
Std Deviation	0.019
Std Error	0.0003



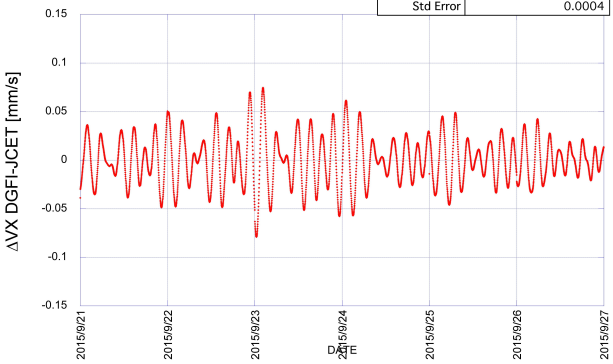
	ΔZ ASI-JCET [m]
Minimum	-0.103
Maximum	0.11
Points	4320
Mean	-0.003
Std Deviation	0.032
Std Error	0.0005



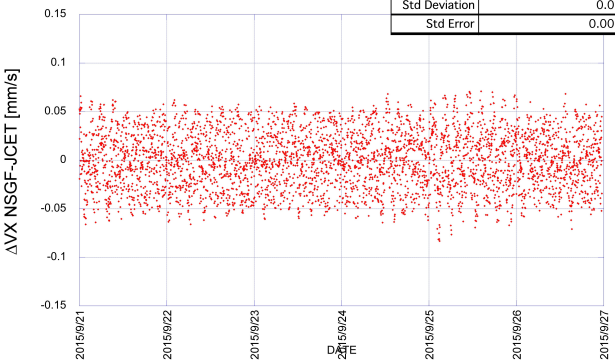
	ΔZ ESA-JCET [m]
Minimum	-0.125
Maximum	0.123
Points	4320
Mean	0.007
Std Deviation	0.039
Std Error	0.0005



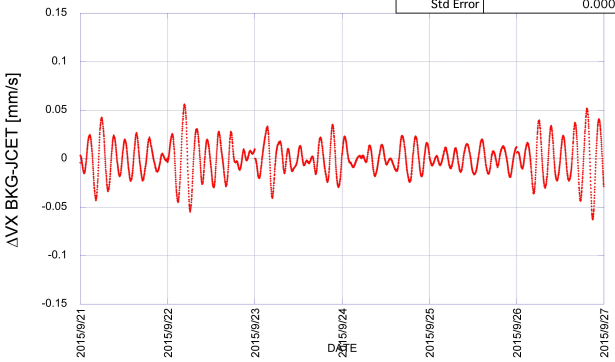
	ΔVX DGFI-JCET [mm/s]
Minimum	-0.079
Maximum	0.075
Points	4320
Mean	6.59e-05
Std Deviation	0.025
Std Error	0.0004



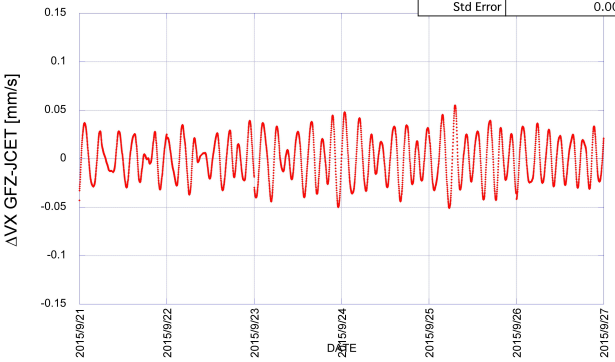
	ΔVX NSGF - JCET [mm/s]
Minimum	-0.083
Maximum	0.071
Points	4305
Mean	-8.37e-05
Std Deviation	0.029
Std Error	0.0004



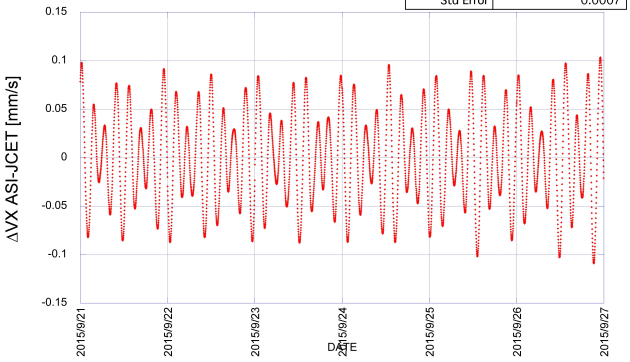
	ΔVX BKG-JCET [mm/s]
Minimum	-0.063
Maximum	0.056
Points	4320
Mean	6.507e-05
Std Deviation	0.0177
Std Error	0.0003



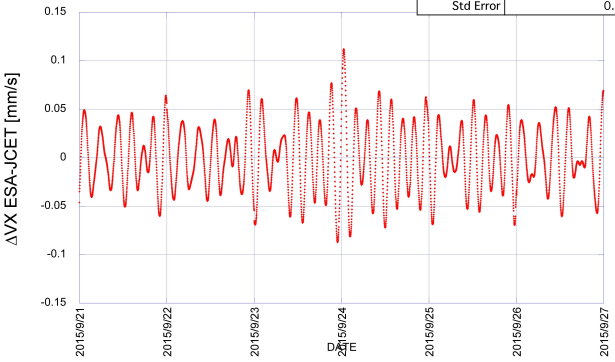
	ΔVX GFZ-JCET [mm/s]
Minimum	-0.051
Maximum	0.055
Points	4320
Mean	8.523e-05
Std Deviation	0.022
Std Error	0.0003



	ΔVX ASI-JCET [mm/s]
Minimum	-0.1091
Maximum	0.1034
Points	4320
Mean	0.0007
Std Deviation	0.0482
Std Error	0.0007



	ΔVX ESA-JCET [mm/s]
Minimum	-0.0871
Maximum	0.112
Points	4320
Mean	0.0002
Std Deviation	0.034
Std Error	0.0005



ΔVY ASI-JCET [mm/s]	
Minimum	-0.1116
Maximum	0.102
Points	4320
Mean	-0.0003
Std Deviation	0.045
Std Error	0.0007

ΔVY ESA-JCET [mm/s]	
Minimum	-0.08
Maximum	0.08
Points	4320
Mean	-0.0004
Std Deviation	0.033
Std Error	0.0005

ΔVY BKG-JCET [mm/s]	
Minimum	-0.062
Maximum	0.046
Points	4320
Mean	-0.0003
Std Deviation	0.018
Std Error	0.0003

ΔVY GFZ-JCET [mm/s]	
Minimum	-0.0495
Maximum	0.0581
Points	4320
Mean	7.104e-05
Std Deviation	0.02
Std Error	0.0003

ΔVY DGFI-JCET [mm/s]	
Minimum	-0.068
Maximum	0.0726
Points	4320
Mean	-3.78e-05
Std Deviation	0.023
Std Error	0.0003

ΔVY NSGF - JCET [mm/s]	
Minimum	-0.079
Maximum	0.082
Points	4305
Mean	0.001
Std Error	0.0004

ΔVZ ASI-JCET [mm/s]	
Minimum	-0.041
Maximum	0.063
Points	4320
Mean	4.59e-05
Std Deviation	0.015
Std Error	0.0002

ΔVZ ESA-JCET [mm/s]	
Minimum	-0.07
Maximum	0.09
Points	4320
Mean	6.22e-05
Std Deviation	0.022
Std Error	0.0003

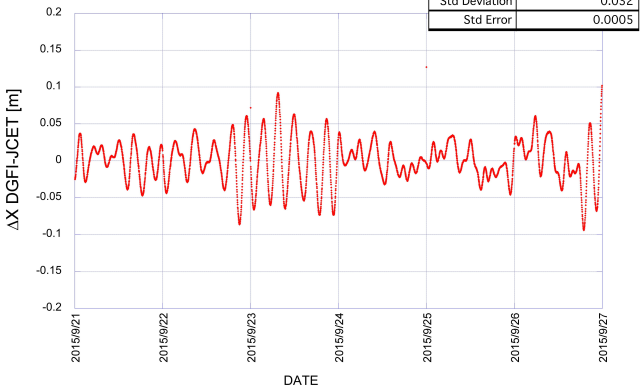
ΔVZ BKG-JCET [mm/s]	
Minimum	-0.055
Maximum	0.067
Points	4320
Mean	7.36e-05
Std Deviation	0.018
Std Error	0.0003

ΔVZ GFZ-JCET [mm/s]	
Minimum	-0.04
Maximum	0.05
Points	4320
Mean	0.0002
Std Deviation	0.018
Std Error	0.0003

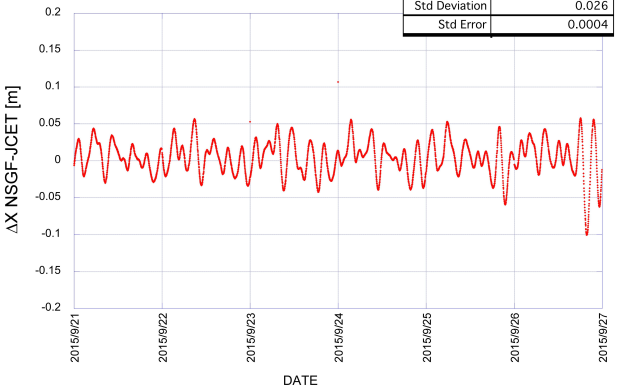
ΔVZ DGFI-JCET [mm/s]	
Minimum	-0.043
Maximum	0.045
Points	4320
Mean	0.0002
Std Deviation	0.02
Std Error	0.0003

ΔVZ NSGF - JCET [mm/s]	
Minimum	-0.063
Maximum	0.066
Points	4305
Mean	5.98e-05
Std Deviation	0.028
Std Error	0.0004

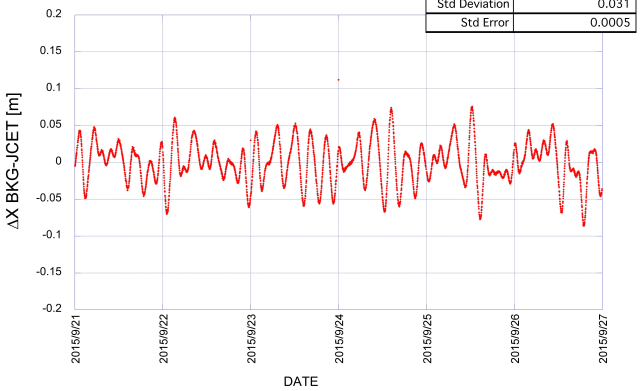
	ΔX DGFI - JCET [m]
Minimum	-0.311
Maximum	0.485
Points	4320
Mean	-2.56e-05
Std Deviation	0.032
Std Error	0.0005



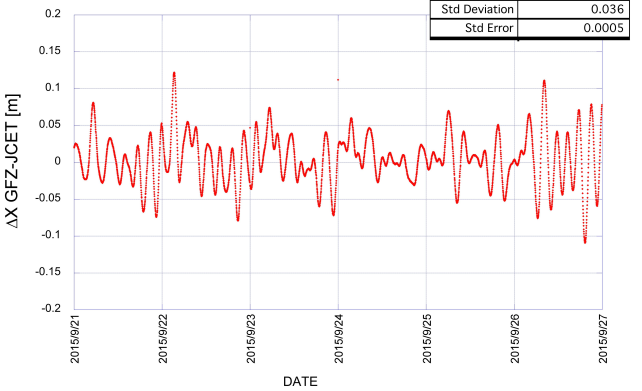
	ΔX NSGF - JCET [m]
Minimum	-0.323
Maximum	0.46
Points	4320
Mean	0.004
Std Deviation	0.026
Std Error	0.0004



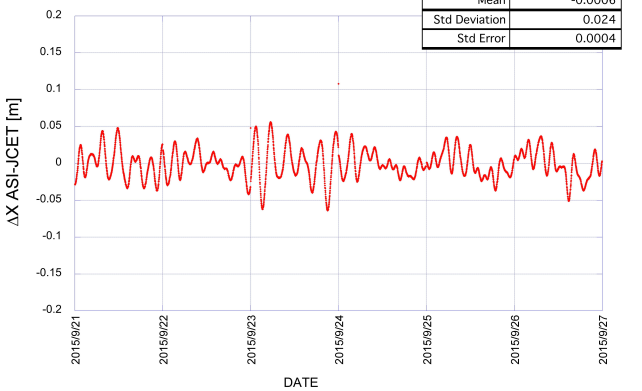
	ΔX BKG - JCET [m]
Minimum	-0.319
Maximum	0.485
Points	4320
Mean	-0.0005
Std Deviation	0.031
Std Error	0.0005



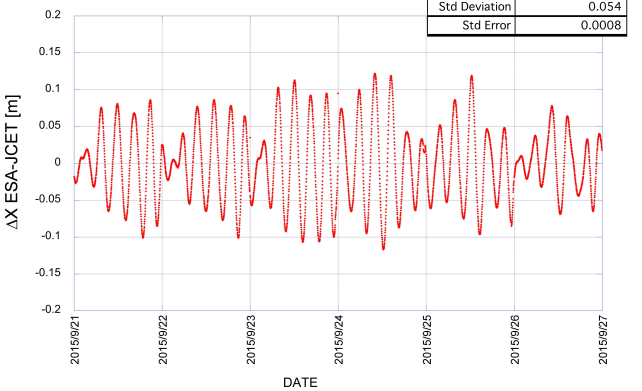
	ΔX GFZ - JCET [m]
Minimum	-0.302
Maximum	0.479
Points	4320
Mean	0.004
Std Deviation	0.036
Std Error	0.0005



	ΔX ASI - JCET [m]
Minimum	-0.307
Maximum	0.472
Points	4320
Mean	-0.0006
Std Deviation	0.024
Std Error	0.0004



	ΔX ESA - JCET [m]
Minimum	-0.294
Maximum	0.443
Points	4320
Mean	-0.0005
Std Deviation	0.054
Std Error	0.0008



ΔY ASI - JCET [m]	
Minimum	-1.073
Maximum	1.077
Points	4320
Mean	0.0004
Std Deviation	0.039
Std Error	0.0006

ΔY ESA - JCET [m]	
Minimum	-1.038
Maximum	1.055
Points	4320
Mean	-0.0002
Std Deviation	0.063
Std Error	0.001

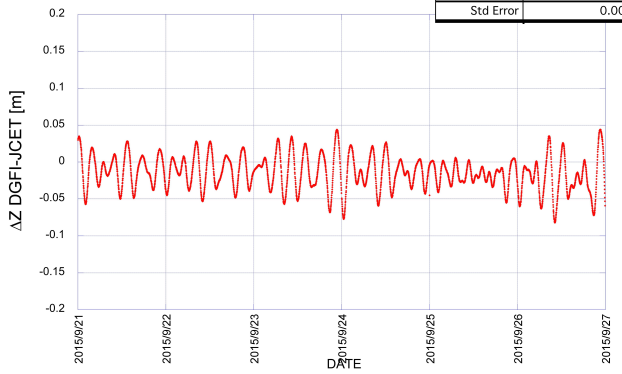
ΔY BKG - JCET [m]	
Minimum	-1.082
Maximum	1.114
Points	4320
Mean	0.0006
Std Deviation	0.045
Std Error	0.0007

ΔY GFZ - JCET [m]	
Minimum	-1.087
Maximum	1.106
Points	4320
Mean	-0.002
Std Deviation	0.047
Std Error	0.0007

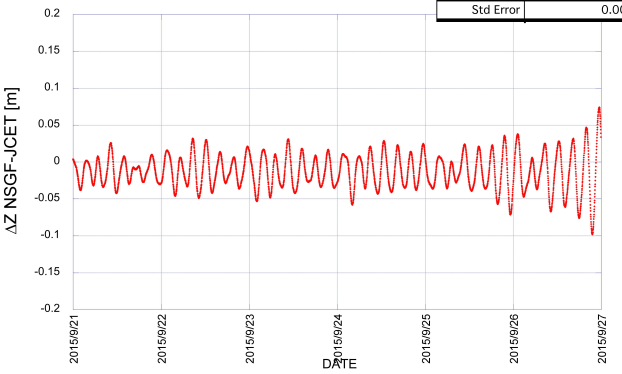
ΔY DGFI - JCET [m]	
Minimum	-1.05
Maximum	1.108
Points	4320
Mean	0.0003
Std Deviation	0.045
Std Error	0.0007

ΔY NSGF - JCET [m]	
Minimum	-1.064
Maximum	1.072
Points	4320
Mean	-0.003
Std Deviation	0.042
Std Error	0.0006

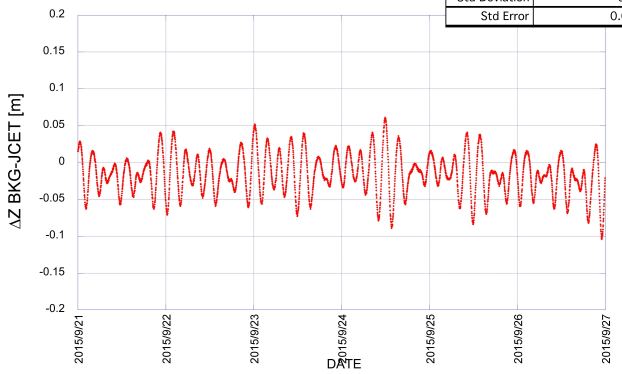
	ΔZ DGFI - JCET [m]
Minimum	-0.082
Maximum	0.044
Points	4320
Mean	-0.014
Std Deviation	0.023
Std Error	0.0004



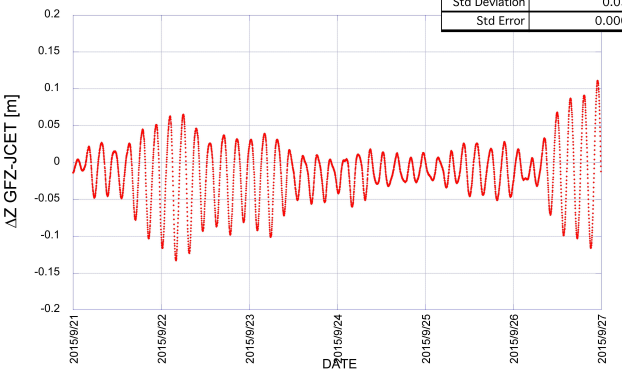
	ΔZ NSGF - JCET [m]
Minimum	-0.098
Maximum	0.074
Points	4320
Mean	-0.012
Std Deviation	0.024
Std Error	0.0004



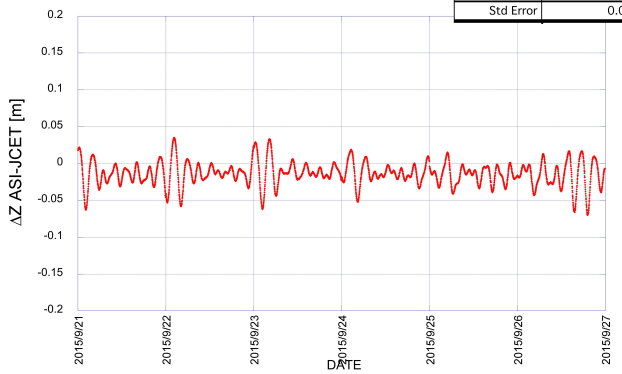
	ΔZ BKG - JCET [m]
Minimum	-0.104
Maximum	0.061
Points	4320
Mean	-0.015
Std Deviation	0.028
Std Error	0.0004



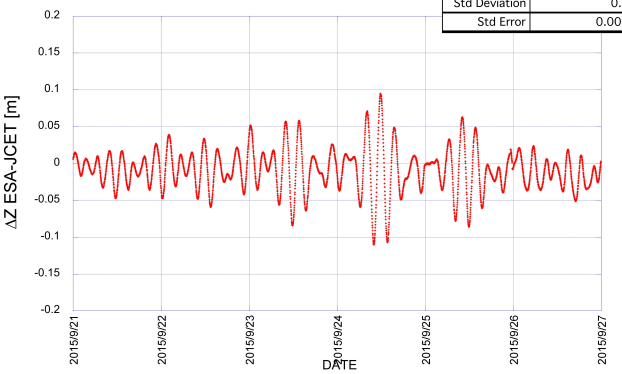
	ΔZ GFZ - JCET [m]
Minimum	-0.133
Maximum	0.111
Points	4320
Mean	-0.013
Std Deviation	0.039
Std Error	0.0006



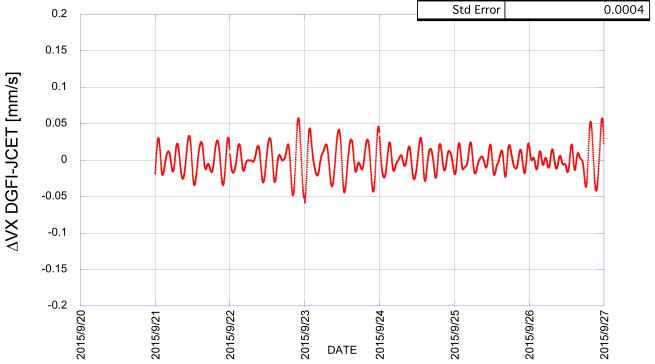
	ΔZ ASI - JCET [m]
Minimum	-0.07
Maximum	0.035
Points	4320
Mean	-0.014
Std Deviation	0.016
Std Error	0.0002



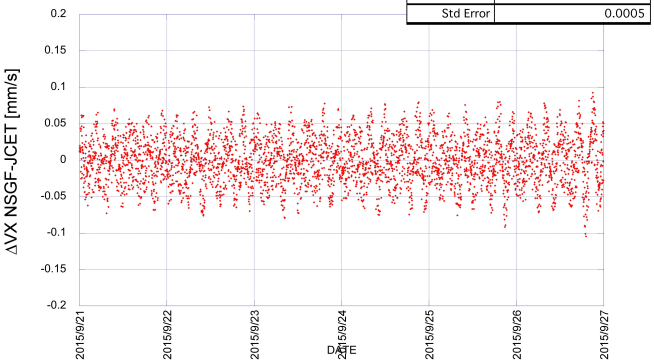
	ΔZ ESA - JCET [m]
Minimum	-0.11
Maximum	0.095
Points	4320
Mean	-0.009
Std Deviation	0.03
Std Error	0.0004



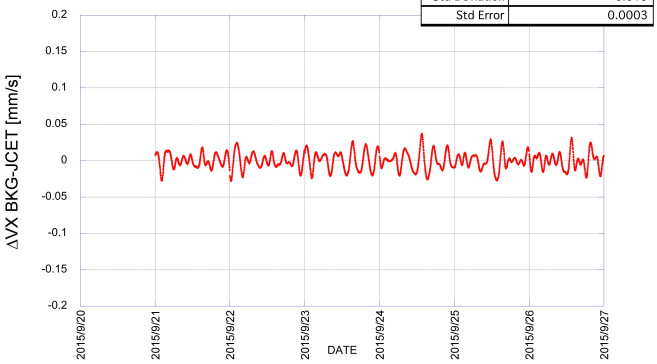
	ΔVX DGFI - JCET [mm/s]
Minimum	-0.41
Maximum	0.381
Points	4320
Mean	0.0003
Std Deviation	0.023
Std Error	0.0004



	ΔVX NSGF - JCET [mm/s]
Minimum	-0.437
Maximum	0.457
Points	4320
Mean	-0.0003
Std Deviation	0.035
Std Error	0.0005

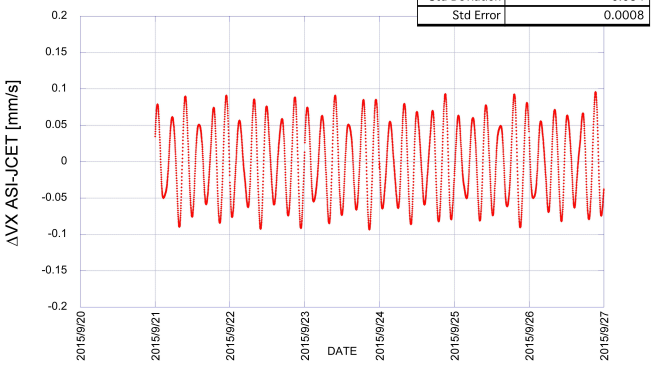


	ΔVX BKG - JCET [mm/s]
Minimum	-0.438
Maximum	0.430
Points	4320
Mean	-6.98e-05
Std Deviation	0.019
Std Error	0.0003

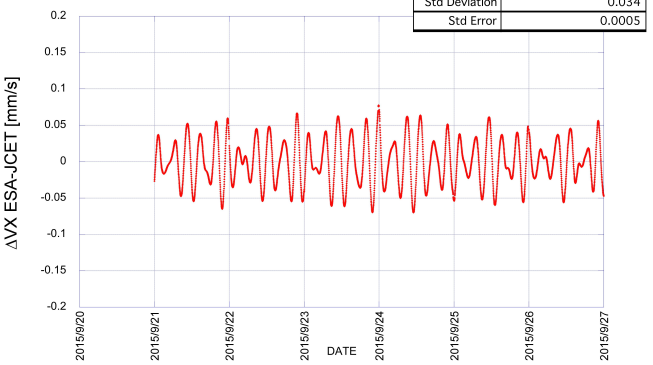


	ΔVX GFZ - JCET [mm/s]
Minimum	-0.401
Maximum	0.382
Points	4320
Mean	0.0002
Std Deviation	0.027
Std Error	0.0004

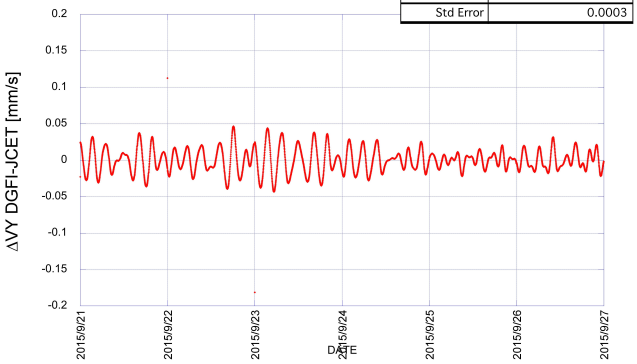
	ΔVX ASI - JCET [mm/s]
Minimum	-0.443
Maximum	0.429
Points	4320
Mean	0.0001
Std Deviation	0.054
Std Error	0.0008



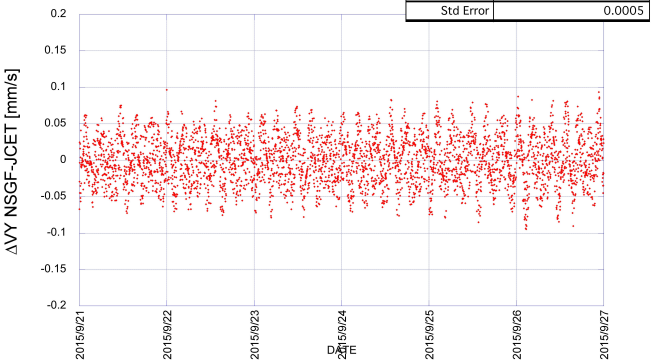
	ΔVX ESA - JCET [mm/s]
Minimum	-0.394
Maximum	0.377
Points	4320
Mean	6.878e-05
Std Deviation	0.034
Std Error	0.0005



	ΔVY DGFI - JCET [mm/s]
Minimum	-0.339
Maximum	0.405
Points	4320
Mean	-2.02e-05
Std Deviation	0.02
Std Error	0.0003

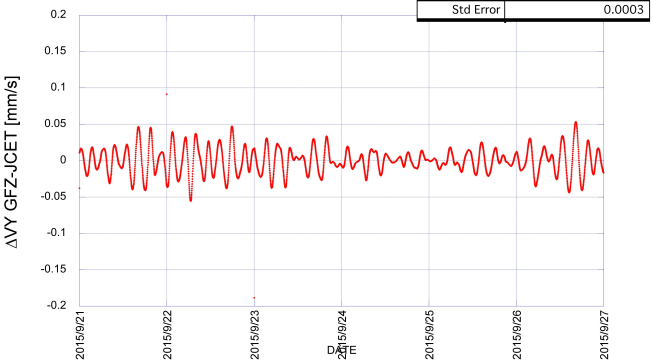


	ΔVY NSGF - JCET [mm/s]
Minimum	-0.392
Maximum	0.426
Points	4320
Mean	-0.0001
Std Deviation	0.034
Std Error	0.0005

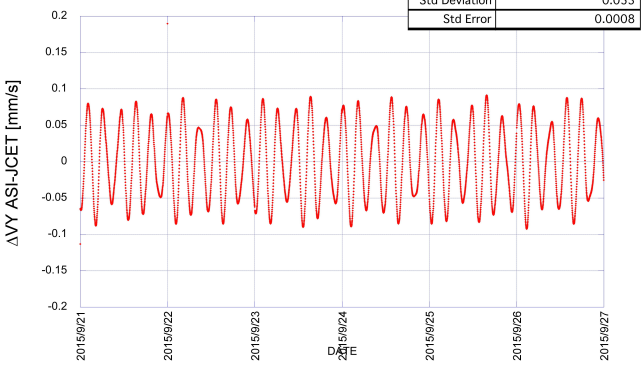


	ΔVY BKG - JCET [mm/s]
Minimum	-0.324
Maximum	0.404
Points	4320
Mean	2.12e-06
Std Deviation	0.02
Std Error	0.0002

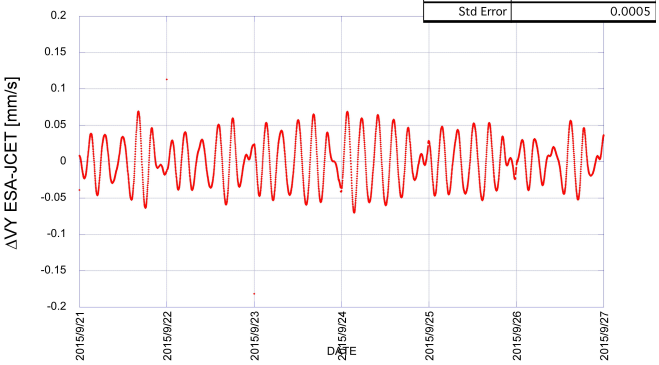
	ΔVY GFZ - JCET [mm/s]
Minimum	-0.341
Maximum	0.421
Points	4320
Mean	5.30e-05
Std Deviation	0.02
Std Error	0.0003



	ΔVY ASI - JCET [mm/s]
Minimum	-0.390
Maximum	0.452
Points	4320
Mean	0.0004
Std Deviation	0.053
Std Error	0.0008



	ΔVY ESA - JCET [mm/s]
Minimum	-0.312
Maximum	0.403
Points	4320
Mean	4.37e-05
Std Deviation	0.033
Std Error	0.0005



ΔVZ ASI - JCET [mm/s]	
Minimum	-0.025
Maximum	0.023
Points	4320
Mean	-7.53e-05
Std Deviation	0.008
Std Error	0.0001

ΔVZ ESA - JCET [mm/s]	
Minimum	-0.047
Maximum	0.046
Points	4320
Mean	0.0003
Std Deviation	0.02
Std Error	0.0003

ΔVZ BKG - JCET [mm/s]	
Minimum	-0.039
Maximum	0.034
Points	4320
Mean	-6.74e-05
Std Deviation	0.014
Std Error	0.0002

ΔVZ GFZ - JCET [mm/s]	
Minimum	-0.083
Maximum	0.061
Points	4320
Mean	6.77e-05
Std Deviation	0.031
Std Error	0.0005

ΔVZ DGFI - JCET [mm/s]	
Minimum	-0.053
Maximum	0.047
Points	4320
Mean	-8.62e-05
Std Deviation	0.024
Std Error	0.0004

ΔVZ NSGF - JCET [mm/s]	
Minimum	-0.078
Maximum	0.081
Points	4320
Mean	0.0009
Std Deviation	0.029
Std Error	0.0004

SP3C ΔOrbit [AC_i – JCET]

Week of 9/21 – 9/27 2015

LAGEOS - 1												
AC	X [m]		Y [m]		Z [m]		VX [mm/s]		VY [mm/s]		VZ [mm/s]	
	Mean	Std. Dev	Mean	Std. Dev	Mean	Std. Dev	Mean	Std. Dev	Mean	Std. Dev	Mean	Std. Dev
ASI - JCET	0.001	0.028	-0.002	0.029	-0.003	0.032	0.001	0.048	-3.00E-04	0.045	4.59E-05	0.015
BKG - JCET	-7.15E-05	0.037	-0.001	0.036	-0.002	0.040	6.51E-05	0.018	-2.96E-04	0.018	7.36E-05	0.018
DGFI - JCET	-0.001	0.030	-4.25E-04	0.027	-0.004	0.021	0.000	0.025	-3.78E-05	0.023	2.19E-04	0.019
ESA - JCET	-0.001	0.043	-0.001	0.041	0.008	0.039	2.29E-04	0.034	-3.70E-04	0.033	6.22E-05	0.022
GFZ - JCET	-0.003	0.027	0.002	0.026	-0.008	0.020	8.52E-05	0.022	7.10E-05	0.020	1.64E-04	0.018
NSGF - JCET	-0.003	0.022	0.002	0.024	-0.007	0.015	-8.37E-05	0.029	0.001	0.029	5.98E-05	0.028
LAGEOS - 2												
AC	X [m]		Y [m]		Z [m]		VX [mm/s]		VY [mm/s]		VZ [mm/s]	
	Mean	Std. Dev	Mean	Std. Dev	Mean	Std. Dev	Mean	Std. Dev	Mean	Std. Dev	Mean	Std. Dev
ASI - JCET	-0.0006	0.024	0.0004	0.039	-0.0137	0.016	0.0001	0.054	0.0004	0.053	-0.0001	0.008
BKG - JCET	-0.0005	0.031	0.0006	0.045	-0.0153	0.028	-0.0001	0.019	2.20E-06	0.015	-0.0001	0.014
DGFI - JCET	-2.50E-05	0.032	0.0003	0.045	-0.0139	0.023	0.0003	0.023	-2.02E-05	0.019	-0.0001	0.024
ESA - JCET	-0.0005	0.054	-0.0002	0.063	-0.0086	0.029	0.0001	0.034	4.37E-05	0.033	0.0003	0.022
GFZ - JCET	0.0042	0.036	-0.0025	0.047	-0.0134	0.039	0.0002	0.027	0.0001	0.020	0.0001	0.031
NSGF - JCET	0.0044	0.026	-0.0033	0.042	-0.0123	0.024	-0.0003	0.035	-0.0001	0.034	0.0009	0.029

ILRS AC work at SGF Herstmonceux

Graham Appleby, Jose Rodriguez

SGF Herstmonceux, UK

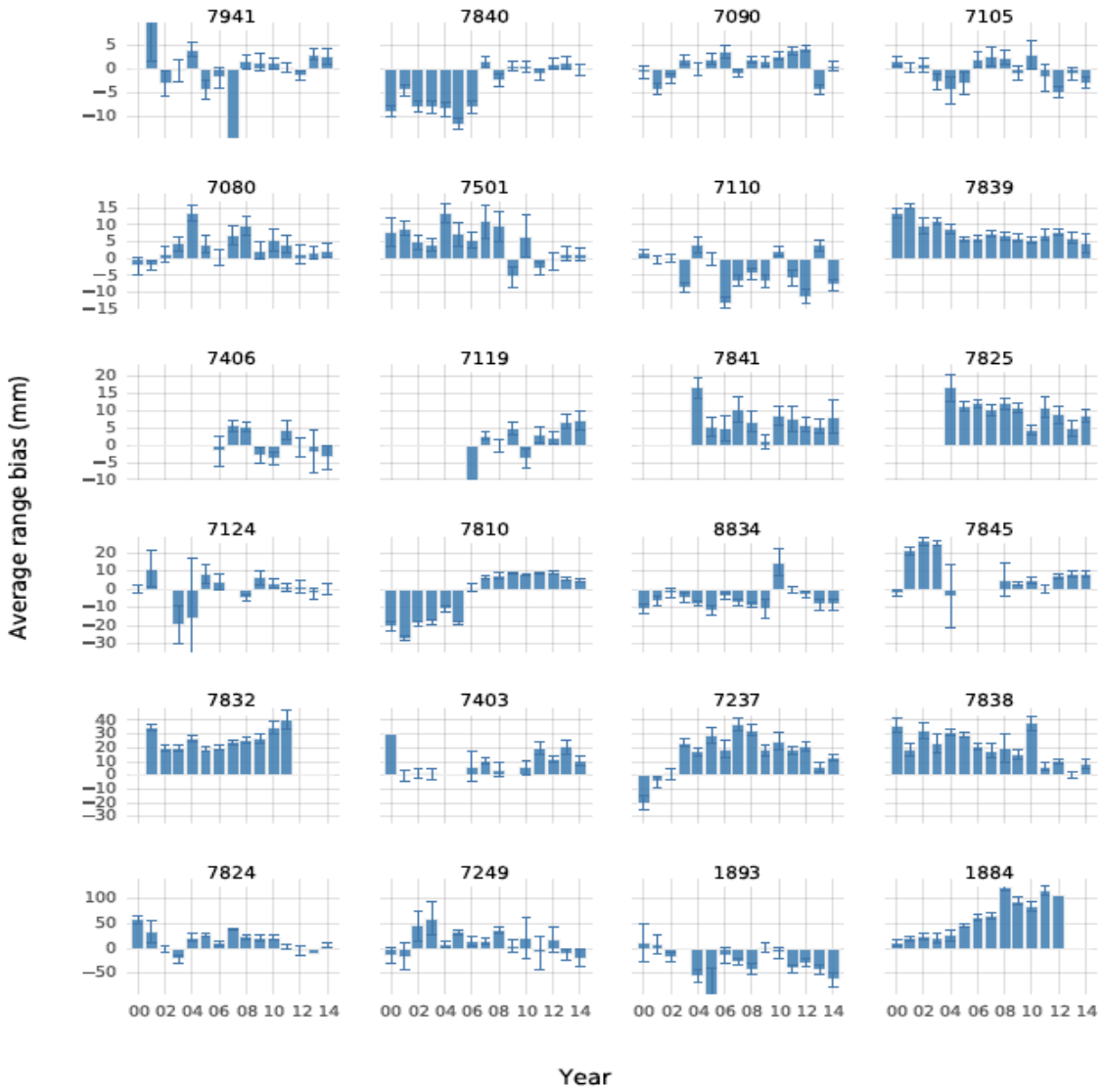
Test of ITRF2014P

- PSD s/w and data tables implemented in SATAN
- Solutions computed for 2006-2015 with ITRF2014P a-priori
  - Small problem (with 7810) under investigation
- Otherwise, no problems encountered
  - Should be able to deliver SINEX very soon
- Gravity field – estimation implemented, SINEX-write to be done

SGF Herstmonceux
Additional test of ITRF2014P

- Laser ranging solutions from 2000 to 2015.0 were previously computed using both ILRS-recommended RB and all-station RB estimation
- A-priori coordinates: SLRF2008
- Summary of RB results from all-RB solutions:

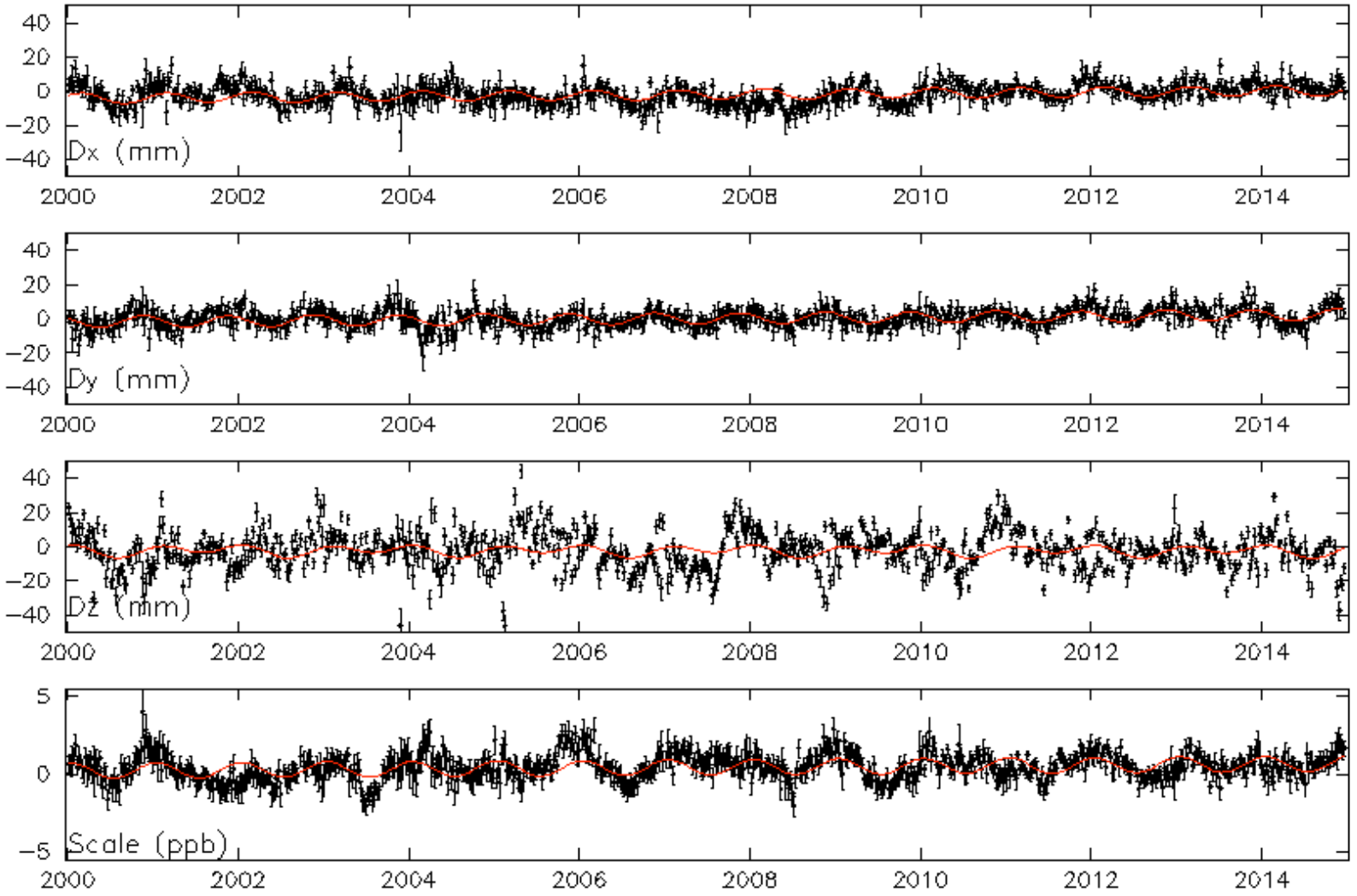
One-year av RB solutions for major sites – zero a-priori



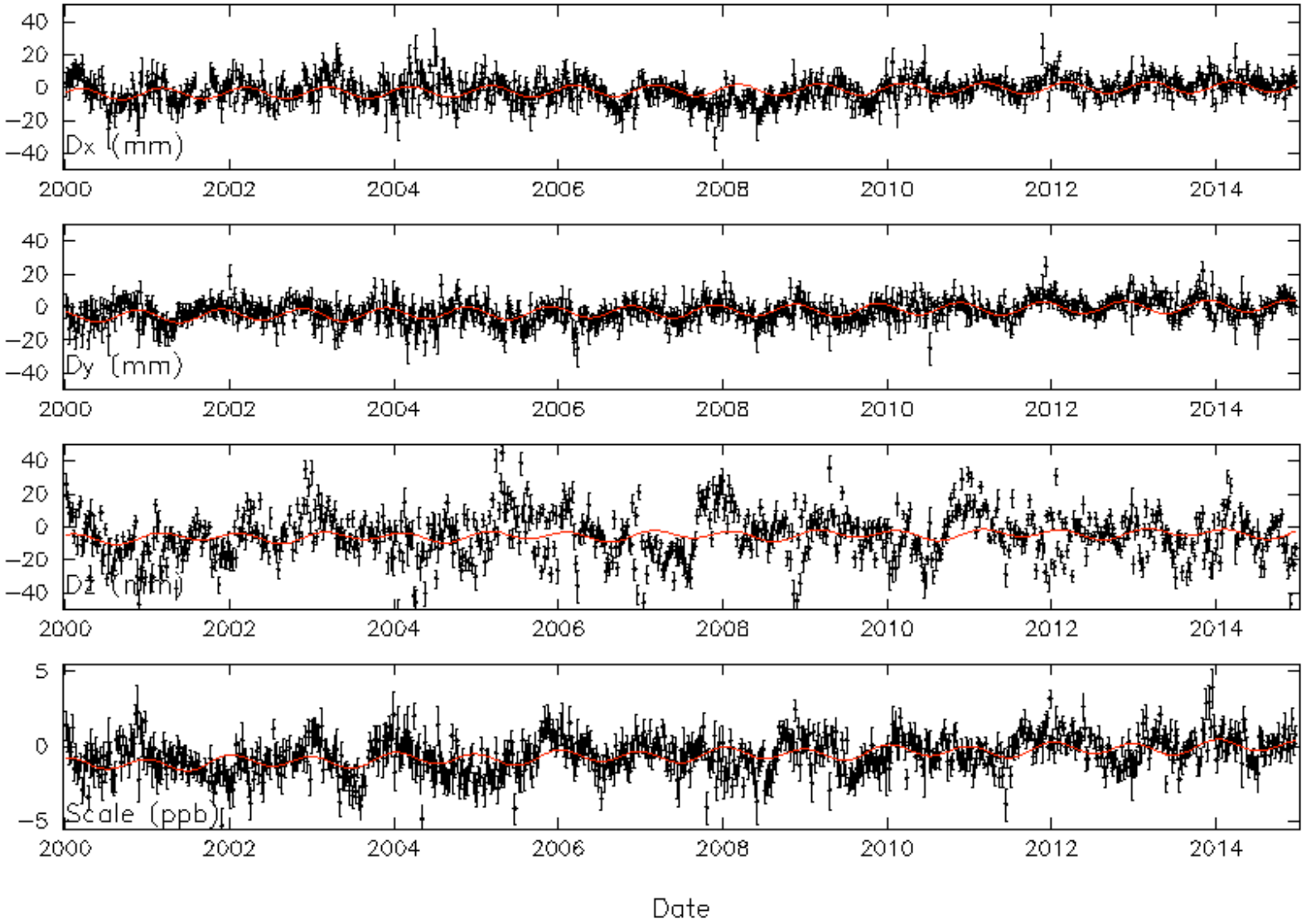
Comparison with ITRF2014P

- Then weekly SINEX solutions mapped onto ITRF2014P
  - 7-parameter iterative solutions
  - comparing each week each station XYZ with that computed at weekly epoch from ITRF2014P
- Sense of comparison is ITRF2014P – NSGF
- Plots of translations and scale for ILRS-RB and ALL-RB comparisons:

Translations and scale wrt ITRF2014P: 'ILRS standard'



Translations and scale wrt ITRF2014P: ‘all RB’ solutions



Numerical results (ppb)

(constant, linear, annual and semi-annual terms fitted to time series)

	ILRS-RB		ALL-RB	
Scale	**+0.22**	**0.05**	**-1.21**	**0.08**
Scale rate	+0.03	0.006	+0.09	0.009

Conclusion

- Weekly L1 & L2 Solutions for 2000-2015.0

- 'standard' AWG-agreed RB solutions
  - scale agrees with ITRF2014P (0.2ppb diff)
- 'all RB' solutions:
  - Scale difference 1.2ppb => ITRF2014P 'too small'

- Very similar results to our previous comparison with ITRF2008