CENTRE NATIONAL D'ÉTUDES SPATIALES

Jason-1 GDR-C POD reprocessing: standard selection and current status

L. Cerri[1], P. Perrachon[1], S. Houry[1], F. Mercier[1], J.P. Berthias[1]

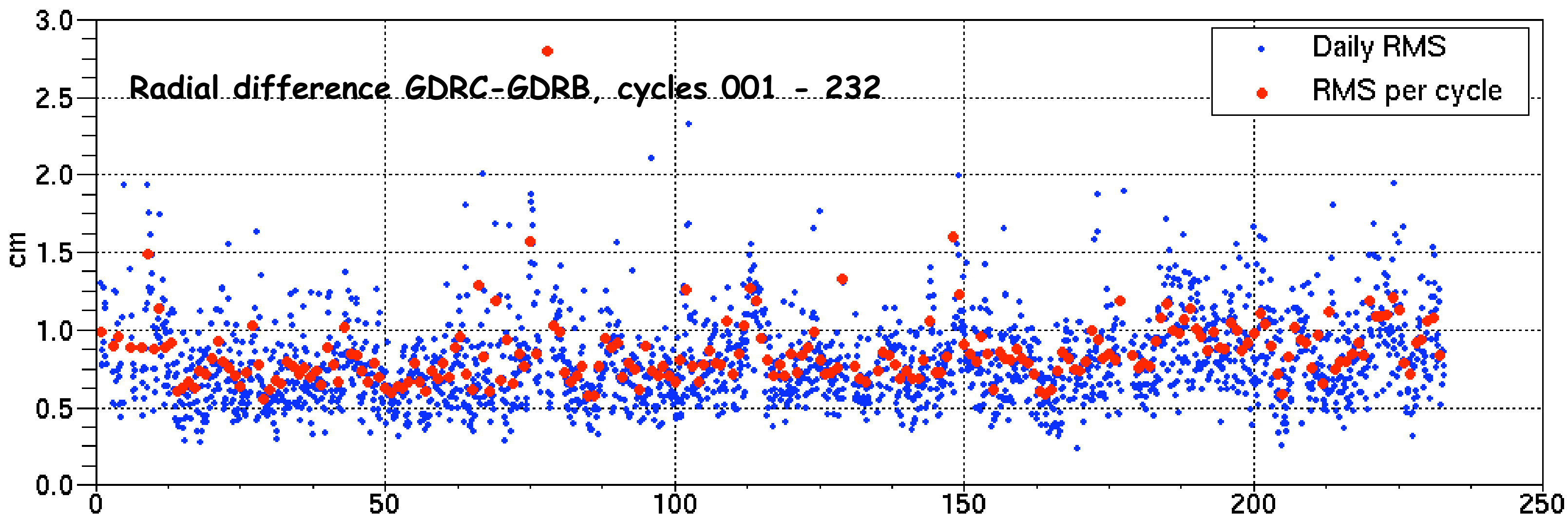
[1]*CNES, Toulouse, France*

OSTST Meeting , Nov. 10-12, 2008 - Nice

GDR-C standards summary

_ Complete reprocessing of Jason-1 cycles 1→240

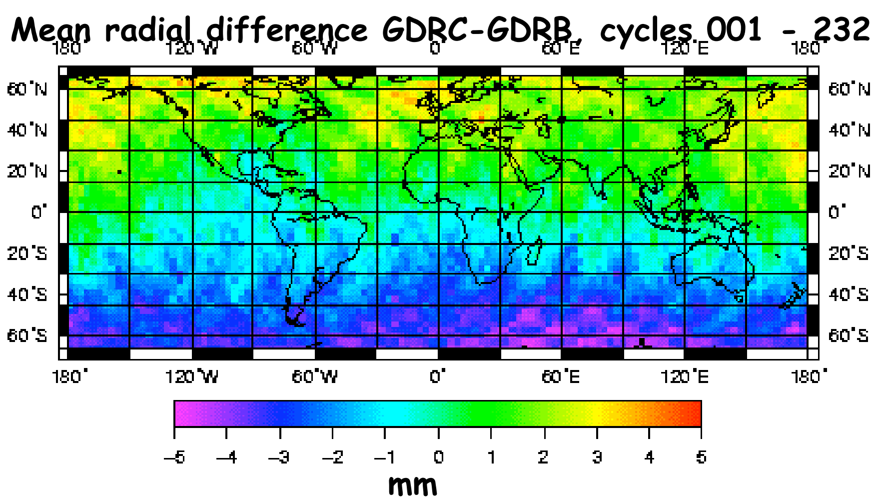
- Reference Frame: ITRF2005
- Time Varying Gravity: hydrology and atmospheric gravity (NCEP,IB)
- Weight of GPS wrt to SLR and Doris is reduced (more continuity when GPS tracking is reduced)
- Use of SAA model extended after the Doris instrument change

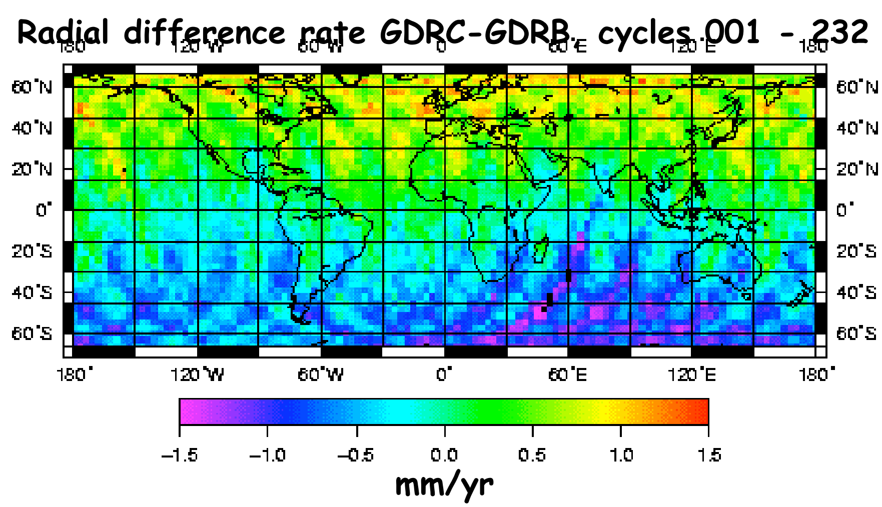


Comparison between GDR-C and GDR-B orbits

_ Reference frame : from ITRF2000 hybrid configuration to a fully consistent ITRF2005 configuration

- **SLRF2005 station coordinates and biases** (bias per pass is solved for a few stations)
- **DPOD2005 Doris coordinates**
- **GPS constellation:**
  - JPL solution (sp3, clk) @IGS (consistent with IGS05)
  - Ephemeris aligned by JPL to ITRF05 before GPS week 1400, clocks unchanged
- **Polar motion consistent with ITRF05**

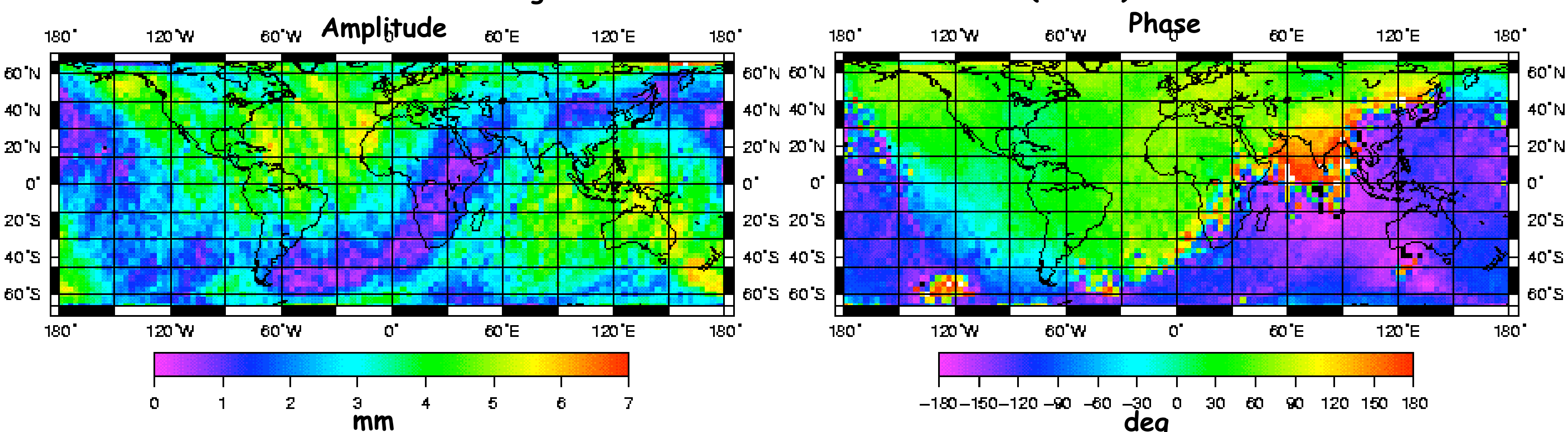




Comparison between GDR-C and GDR-B orbits

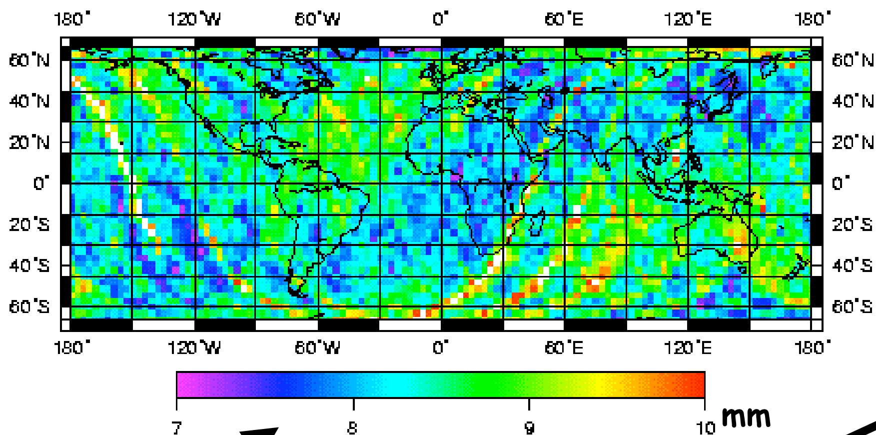
- Static gravity field: EIGEN-CG03C → EIGEN-GL04S
- Time varying components :
  - Annual + Semiannual (no drifts) from EIGEN-GL04S-ANNUAL model
  - Atmospheric gravity from AGRA files produced at GSFC
- These effects induce a time varying radial difference with an annual component that can reach 6 mm amplitude

Annual signal in radial difference GDRC-GDRB (1-232)

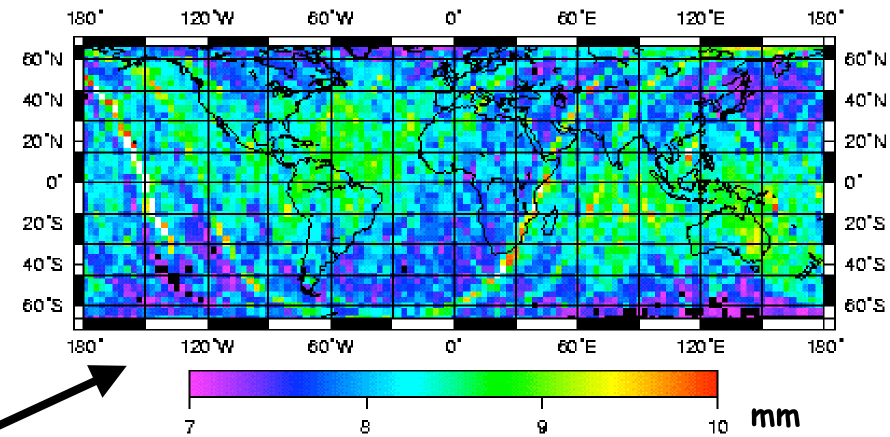


Comparison between GDR-C and GDR-B orbits

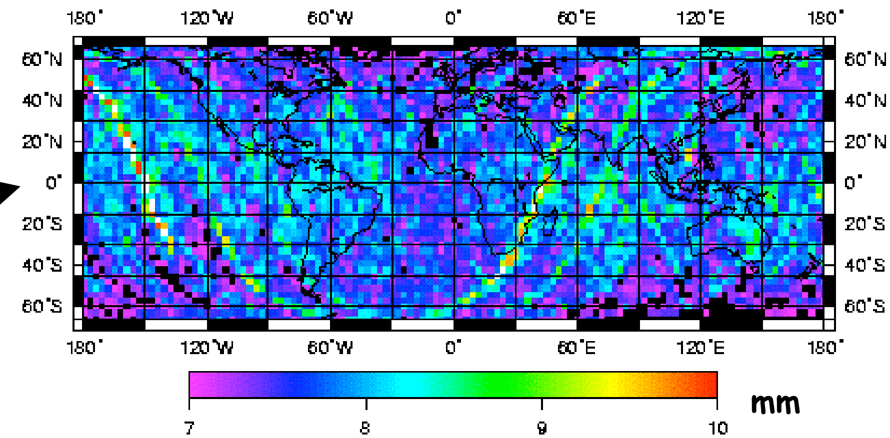
_ New ITRF + TVG are sufficient to explain most of the long term geographic difference between the two orbits



Initial RMS



RMS when bias and drift are removed

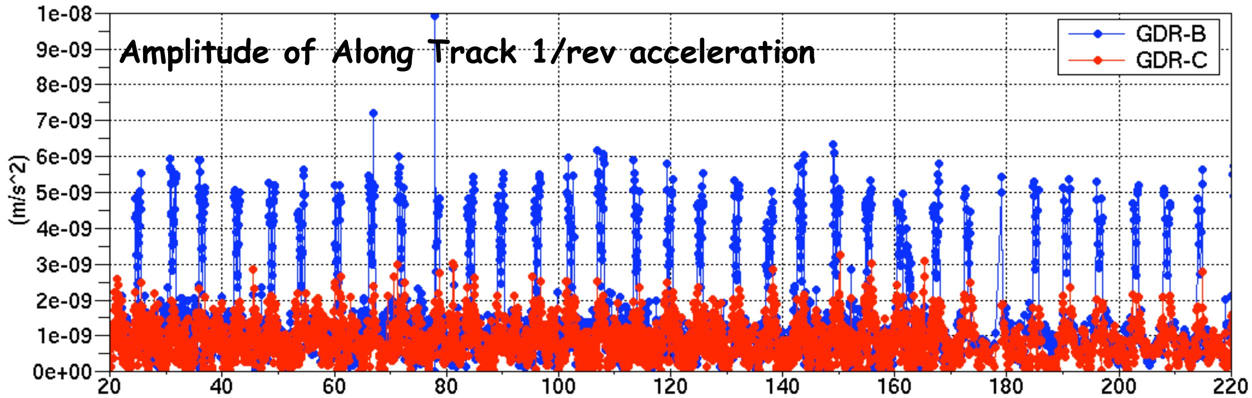


RMS when bias, drift and annual are removed

Other changes

_ **Measurement model**
- Updated emitter/receiver GPS phase maps
- LRA range correction not constant but dependent on the line-of-sight direction
- FES2004 Ocean loading and solid earth pole tide applied to all Doris/SLR station coordinates

_ **Force model**
- Main deficiencies of Box and Wing SRP model were corrected



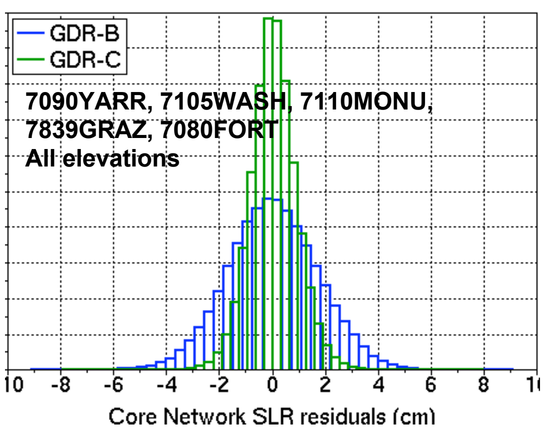
- Ocean pole tide added to the satellite dynamic model

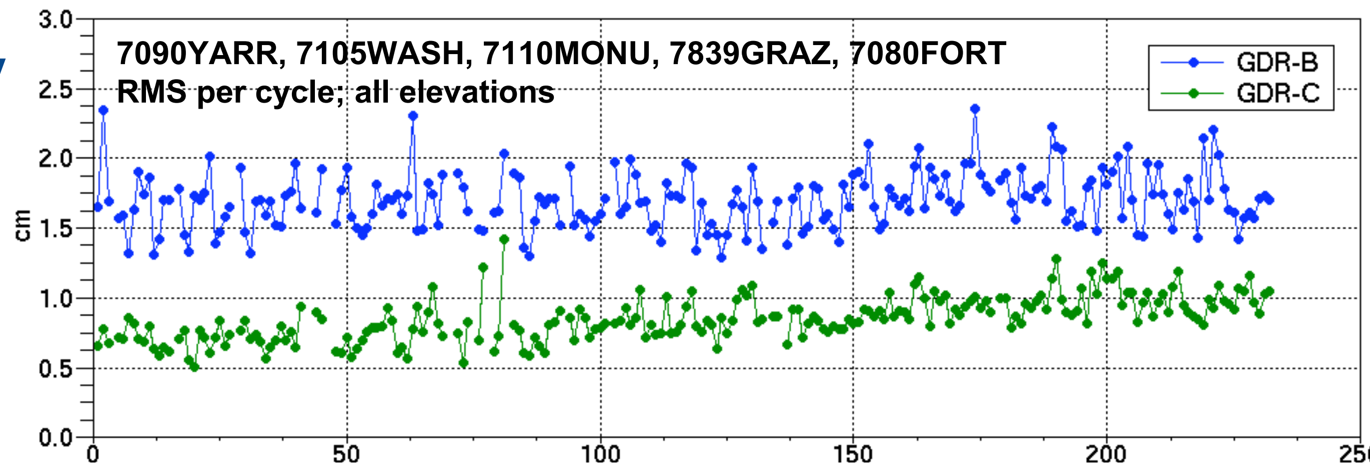
_ **Many independent tests (each one over many jason-1 cycles) were run to verify the impact of these changes ! (see backups for more details)**

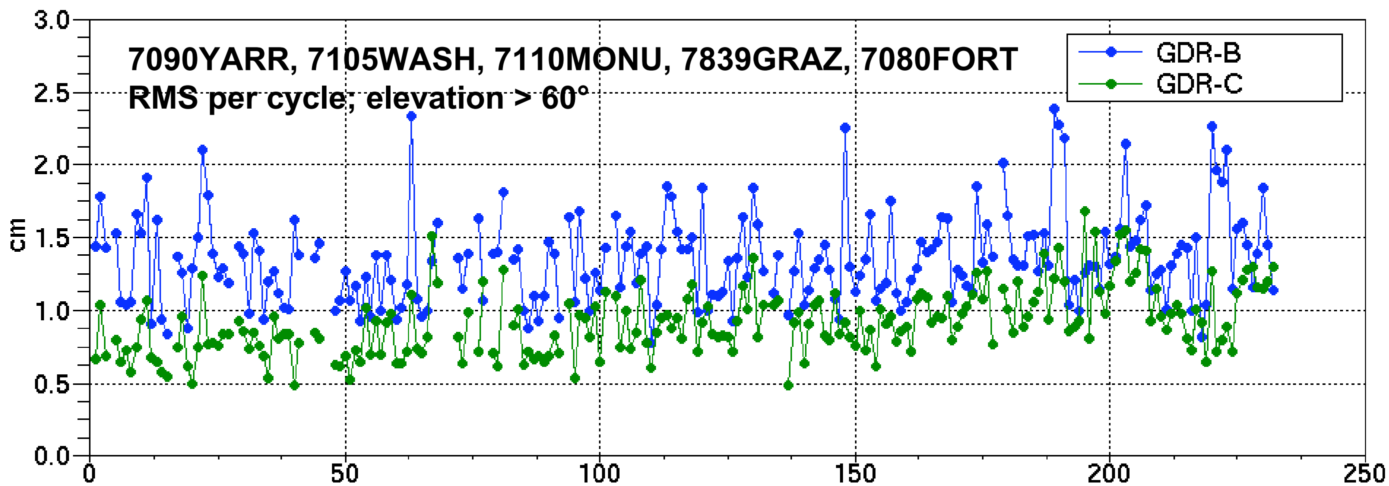
SLR residuals on GDR-B and GDR-C orbits

- Improved orbit accuracy cross- and along-track (new GPS-phase maps)
- Stronger relative weight of SLR measurements accentuates the improvement

Histogram of SLR residuals

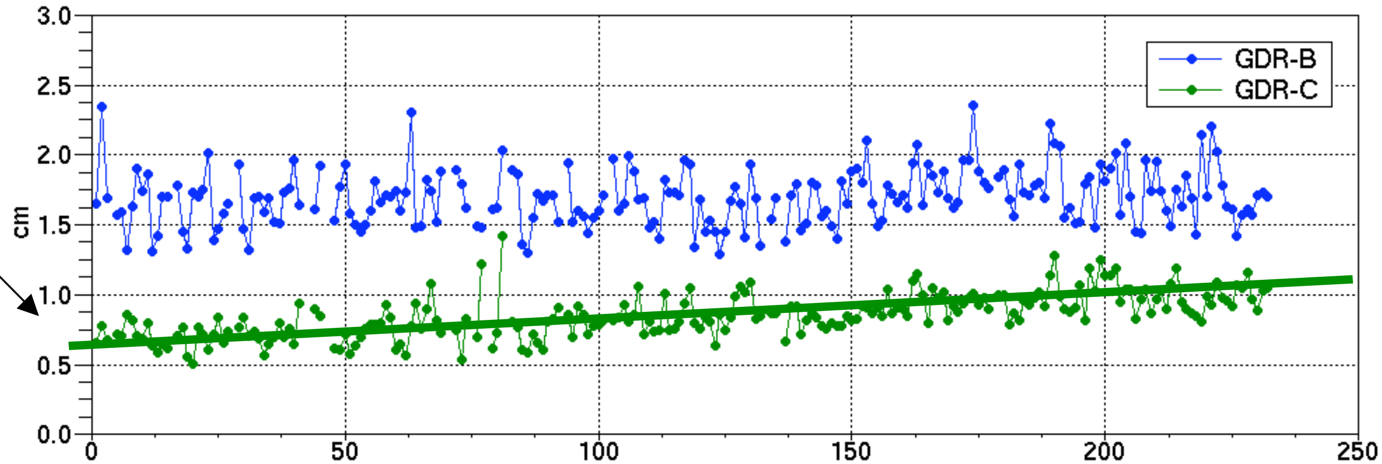




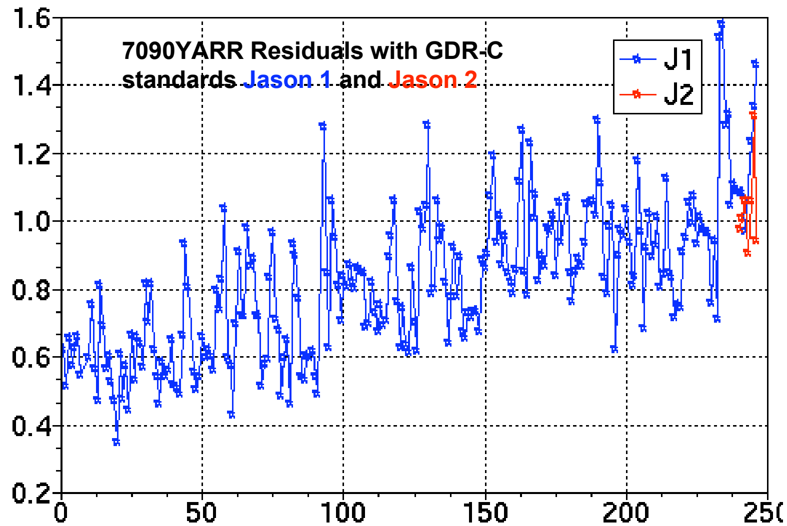


SLR residuals on GDR-B and GDR-C orbits

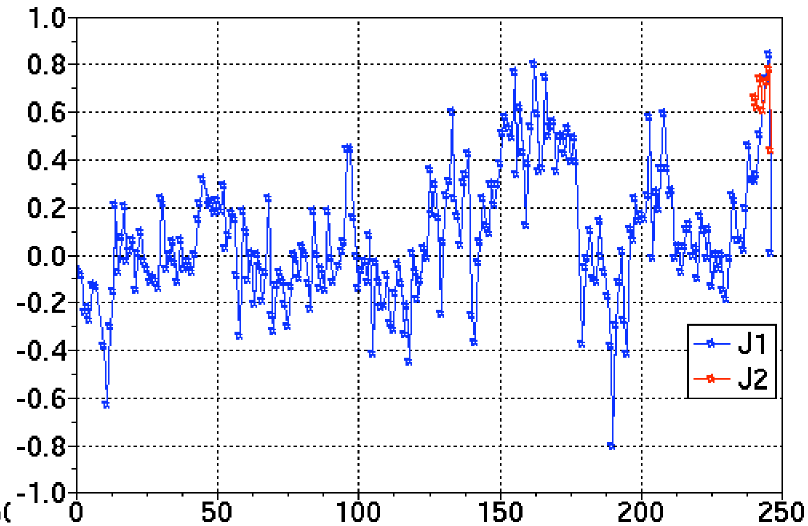
- Noticeable trend in the RMS of SLR residuals on reference stations
- Some indication of increasing “noise” for 7090YARR



L7090 RMS (cm)



L7090 MEAN (cm)

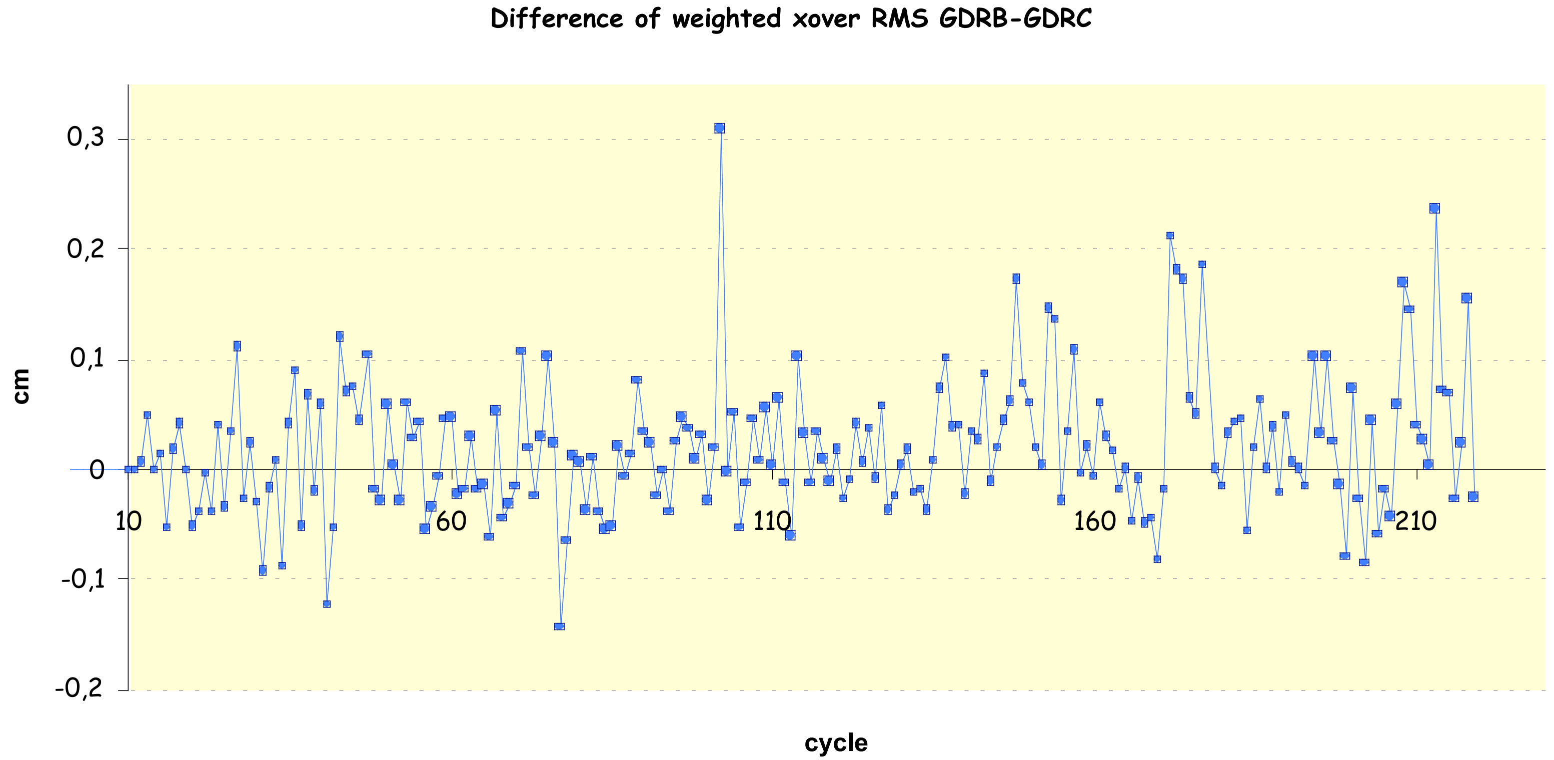


Crossover residuals

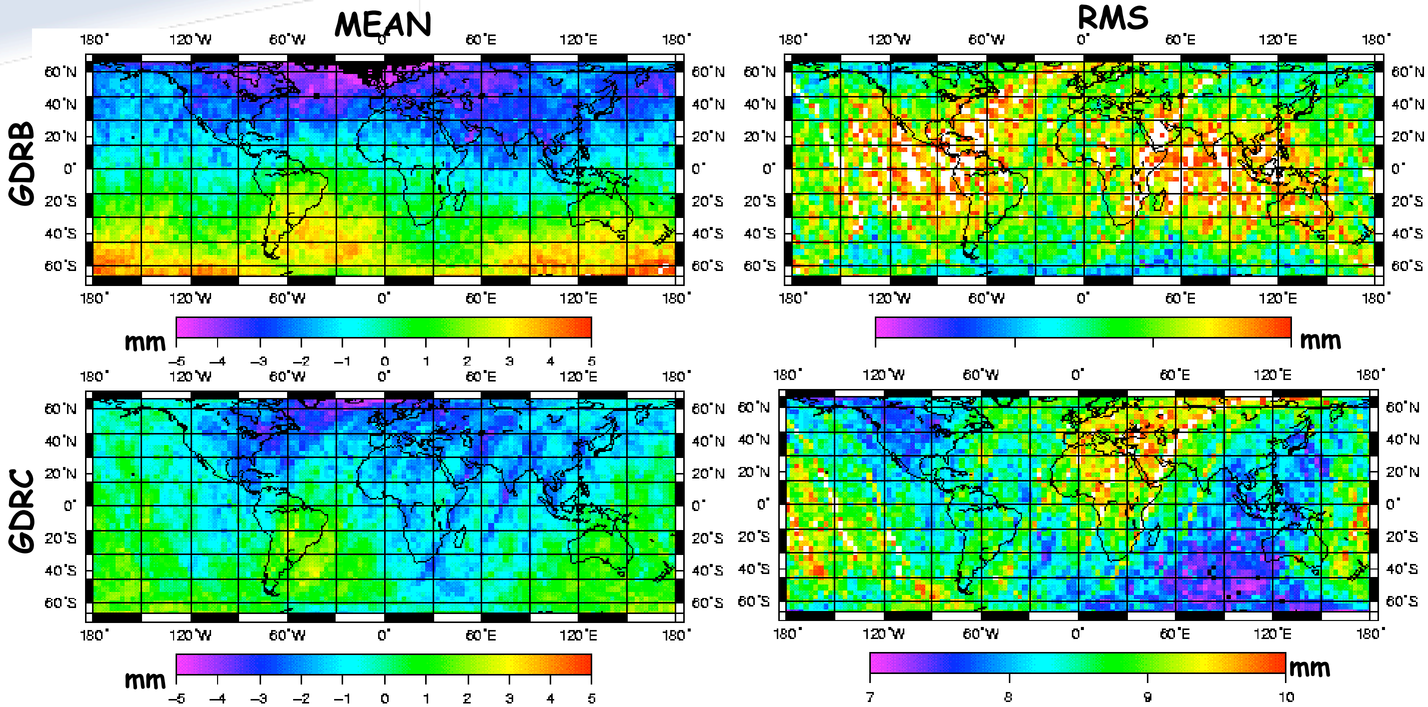
_ In general, not very sensitive to geographically correlated difference

_ Improvement is more significant toward the end of the series

- reduced GPS tracking, stronger degradation of GDR-B orbit without SAA model

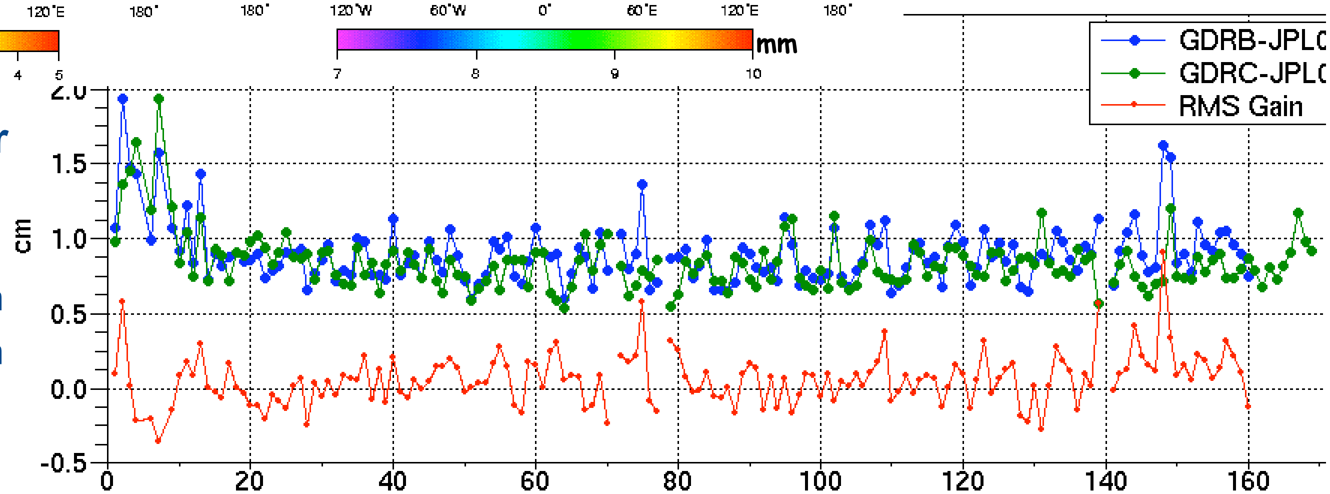


Difference with respect to JPL07A orbit



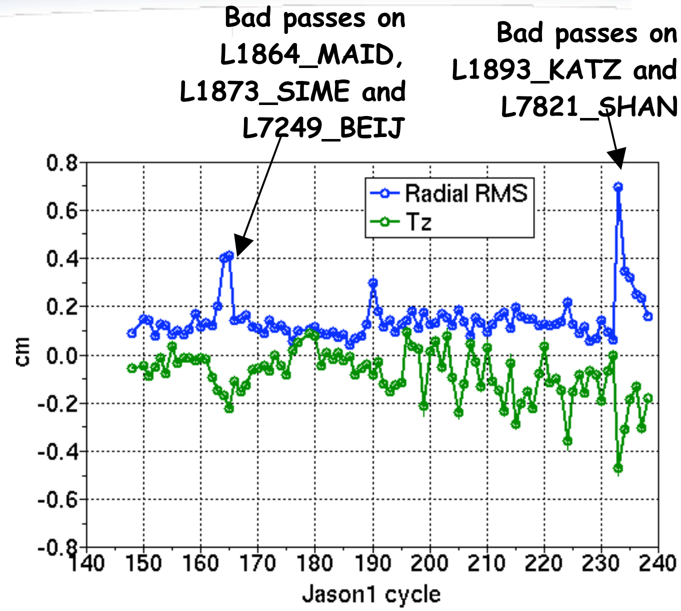
- The geographic distribution of radial RMS and mean are reduced
- Some patterns still remain

- The mean radial RMS per cycle is very slightly reduced
  - GDRB-JPL07A = 9.0 mm
  - GDRC-JPL07A = 8.4 mm

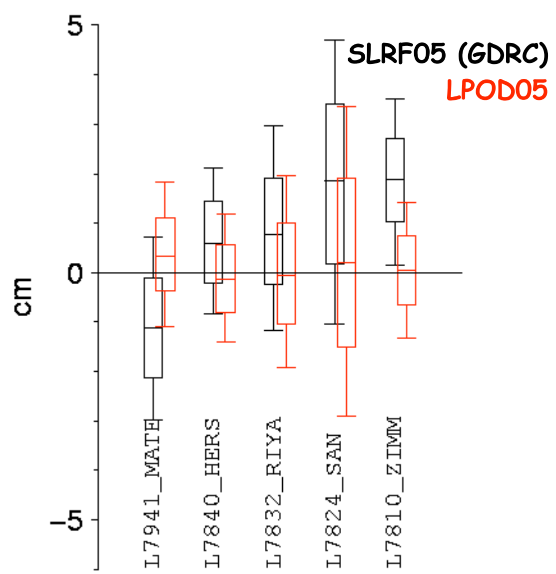


Known problems – SLRF2005

- The LPOD2005 solution is now available and corrects biases/coordinates of some important stations
- Test performed on Jason-1 cycles 138-239, with fixed station biases



Comparison of GDR-C reprocessed orbits wrt LPOD05 test orbits

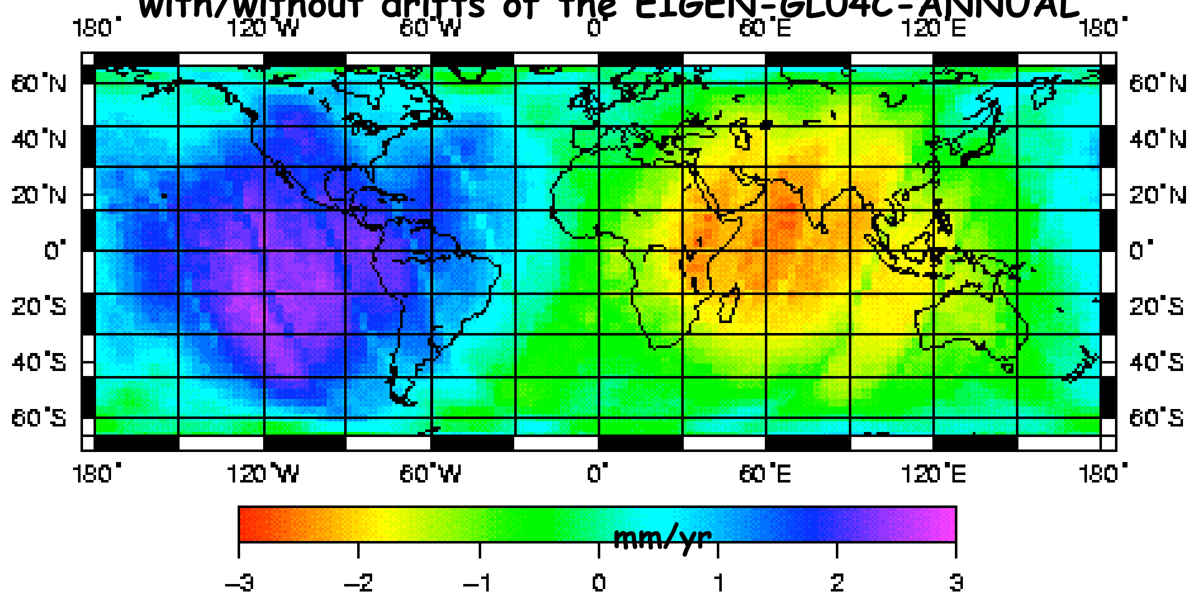


- The impact is small but not negligible
  - Bias on some stations was solved for on GDRC orbit and compensated for SLRF05 errors (ex. 7810ZIMM)
  - Biases should still be solved for some stations
- The operational POE will switch soon to LPOD2005

Known problems – long terms variations of gravity field

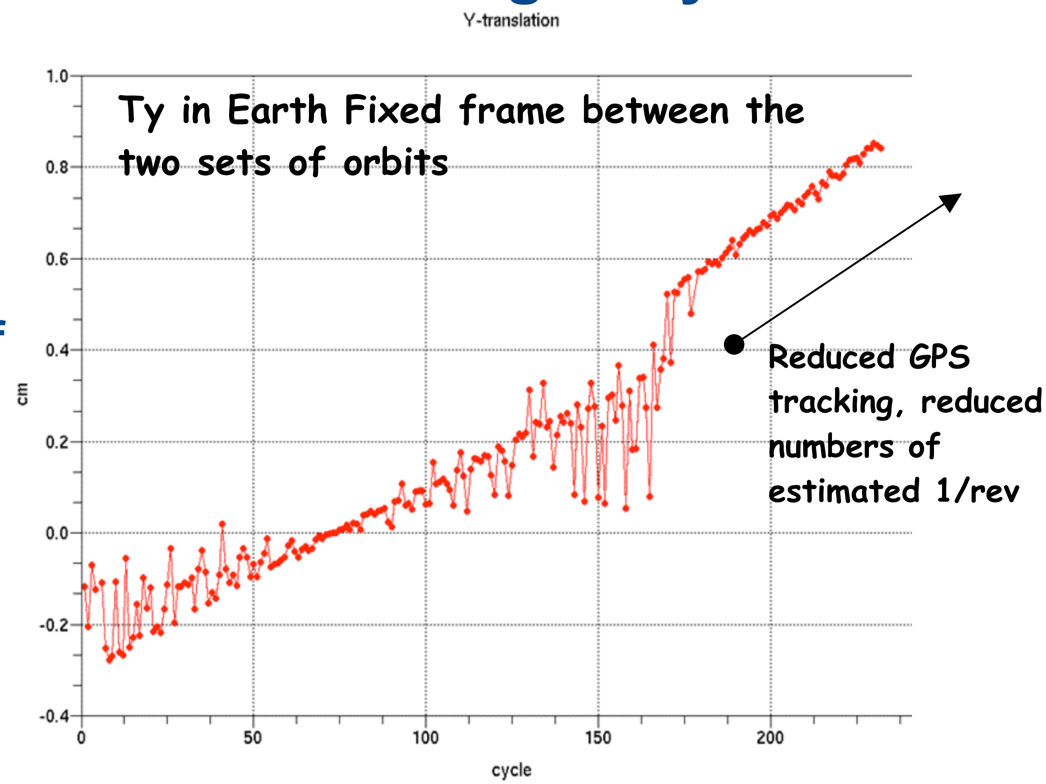
- It was finally decided not to take into account the drifts of the EIGEN-GL04C-ANNUAL TVG model for GDR-C orbits
  - Only drifts: zonals up to degree 4 and the C21/S21 as from IERS standards
- This decision was based on a lack of confidence in the extrapolated gravity model, and not on evident POD quality criteria

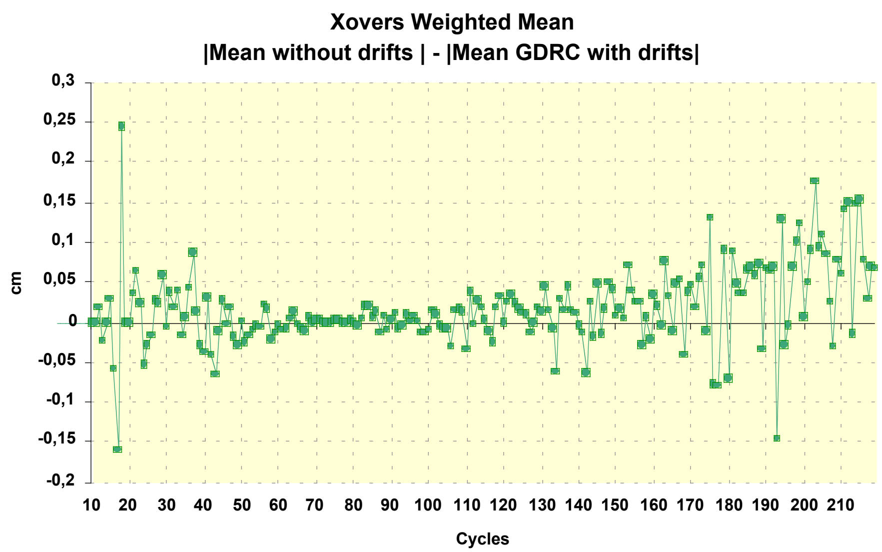
Radial difference rate between two sets of orbits (cycles 1-232) with/without drifts of the EIGEN-GL04C-ANNUAL



Known problems – long terms variations of gravity field

- The GDR orbit centering in the equatorial plane is sensitive to changes in the gravity field
- Even more with a typical Doris/SLR configuration (24 hr 1/rev instead of 12 hr)





- The mean of crossover residuals (inertial centering) is closer to 0 when the drifts are included in gravity field

Conclusion

_ GDR-C orbit is the most accurate GDR orbit to date

_ Next reprocessing will benefit from

- ITRF2008
- Completely reprocessed GPS ephemeris/clocks with consistent emitter/receiver maps

_ mm/yr radial accuracy on a local scale is not achieved with GDR dynamic orbits

- Improve modeling of long term TVG effects
- Review the current adopted strategy for the orbit's empirical parameterization

Backups

Detailed standards description

Detail of GDR-C standards 1/2

	GDR-B	GDR-C
Time Span	Cycle 1 to 232	Complete reprocessig
Reference System		
Polar motion and UT1	IERS bulletin C04 with IERS 1996 daily and sub-daily corrections	IERS bulletin C04 consistent with ITRF2005, with IERS 1996 sub-daily corrections
Doris coordinates	DPOD2000	DPOD2005
SLR coordinates	ITRF 2000 (with minor corrections for a few SLR stations)	SLRF2005, including station biases
Displacement of reference points		
Earth tides	IERS 2003 Solid Earth tides	Unchanged
Ocean loading	FES 1999 (SLR only)	FES 2004 (SLR and Doris)
Pole tides	Solid Earth Pole tide from IERS2003 (SLR only)	Solid Earth Pole tide from IERS2003 (SLR and DORIS)
Satellite reference		
Mass and center of gravity	Post-Launch values + variations generated by Control Center	
Attitude Model	Quaternions from control center, completed by nominal yaw steering law when necessary	Unchanged
Gravity		
Gravity field (static)	EIGEN-CG03C	EIGEN-GL04S
Gravity field (time varying)	Drifts from EIGEN-CG03C, on zonal harmonics up to degree 4	Annual+Semiannual 50x50 from EIGEN-GL04S-ANNUAL (Drifts are unchanged wrt to GDR-B orbits)
Earth tides	IERS 2003 Solid Earth tides	Unchanged
Pole tide	Solid Earth Pole tide from IERS2003	Solid Earth and Ocean Pole tide from IERS2003
Ocean tides	FES 2004 (all principal constituents, with admittance)	Unchanged
Atmospheric tides	Haurwitz & Cowley	Unchanged
Atmospheric gravity	None	NCEP-derived 20x20 field at 6 hr interval (AGRA service at GSFC)
Third bodies	Sun, Moon, Venus, Mars and Jupiter third bodies	Unchanged

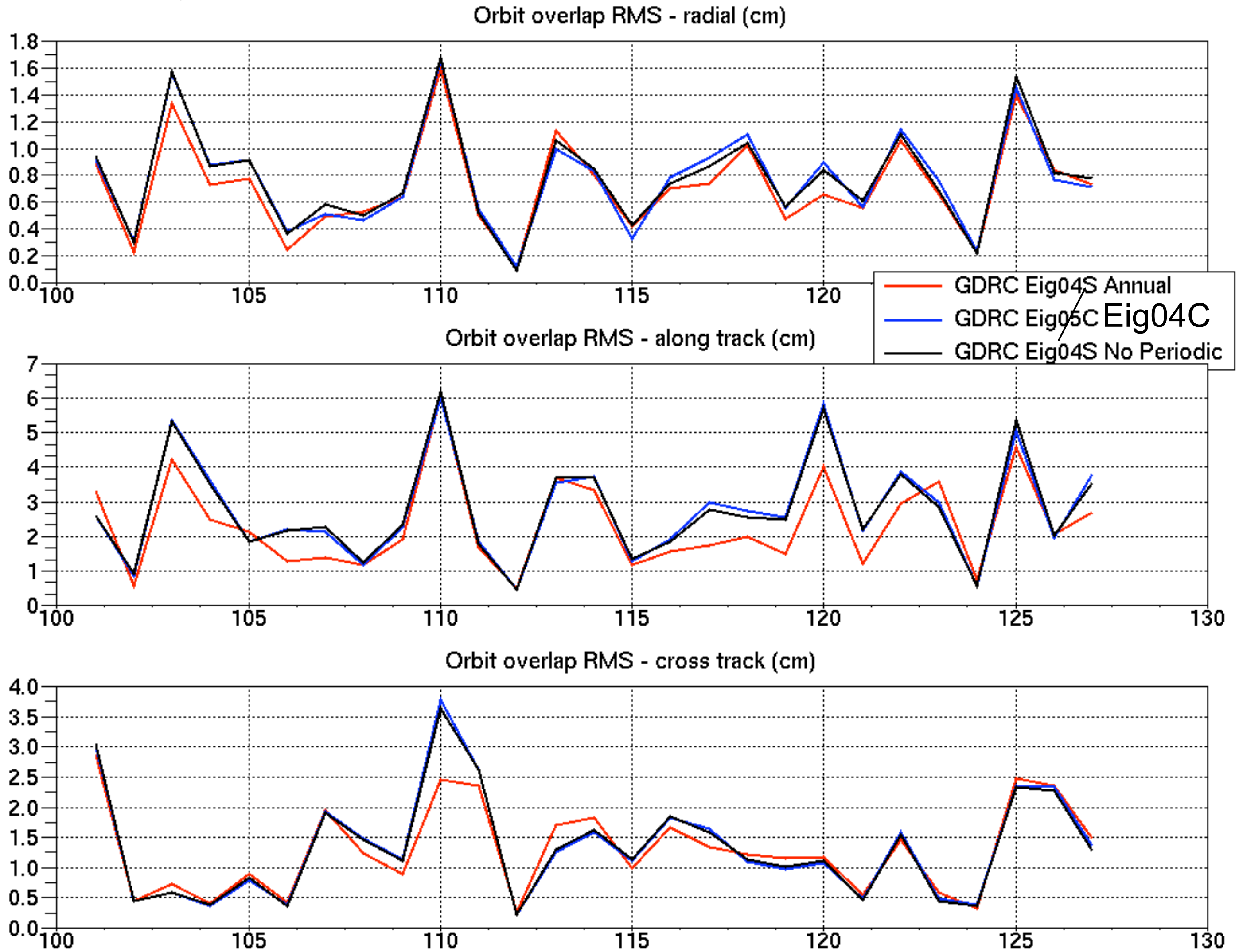
Detail of GDR-C standards 2/2

	GDR-B	GDR-C
Surface forces and empiricals		
Radiation Pressure model	Thermo-optical coefficient from pre-launch box and wing model, with smoothed Earth shadow model	Updates in coefficients of +Y,-Y and +X sides and in the value of the body-fixed X-force
Radiation pressure scale coefficient	Fixed to 0,97 (set to minimize the amplitude of 1/rev empiricals)	Unchanged
Earth radiation	Knocke-Ries albedo and IR satellite model	Unchanged
Atmospheric density model	DTM 94, with best available solar activity	Unchanged
Drag coefficients	Adjusted every two revolutions, with apriori loose constraint	Unchanged
1/rev empiricals	Every 12 hours (depending on GPS availability)	Unchanged
Doris		
Troposphere correction	CNET1 model, vertical bias adjusted per pass	Unchanged
Frequency	1 frequency bias adjusted per pass	Unchanged
South Atlantic Anomaly	SAA model applied before the instrument change	SAA model applied over the entire series
Weight	1.5 mm/s (for Jason-1 : underweighting of the SAA stations)	Unchanged
Datation bias (to compensate for along-track inconsistency of Doris orbits wrt SLR/GPS measurements)	6,0 μsec	6,0 μsec before instrument change (cycle 91) and 8,8 after
SLR		
Troposphere correction	Marini-Murray	Mendes-Pavlis
Retroreflector correction	Constant ranging correction	Elevation dependent ranging correction
Biases	Bias per pass solved for a few stations	Fixed biases consistent with SLRF2005, bias per pass solved for a few stations
Weight	Globally 10 cm (some SLR stations underweighted)	Unchanged
GPS		
Constellation ephemeris and clocks	JPL precise solution at IGS	Before GPS week 1400, JPL solution has been aligned with IGS05; clocks remain unchanged
Sampling for POD	5 min	Unchanged
Phase correction diagrams	Receiver only	Emitter / Receiver , updated
phase windup correction	Applied	Unchanged
Phase ambiguity	Floating ambiguity adjusted per pass	Unchanged
Receiver clock	Adjusted at every epoch	Unchanged
Weight	Phase: 1 cm / Code: 1 m	In order to have a more continous solution even after GPS failure, GPS weight has been reduced by a factor 10

Summary of tests for GDR-C tuning

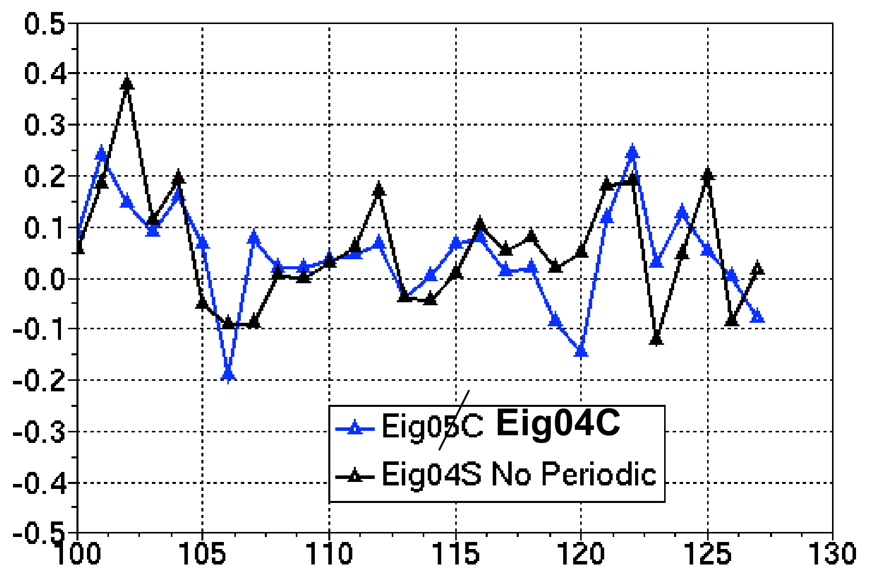
- Nominal 1/rev at 12 hr or 24 hr : 100-127 (1 series)
- Weight of D+L wrt GPS: 22-89 and 100-127 (4 series)
- Atmospheric gravity
  - SHDP and AOD1B RL03 : 22→99 (Hobart 2007)
  - AGRA: 100-127 (1 series)
- EIGEN-04S-ANNUAL with/without periodic terms: 100-127 (2 series)
- EIGEN-04S-ANNUAL with drifts: 1-233 (1 series)
- Doris time bias after second instrument change 100-127 (1 series)
- Box & Wing / UCL model 103-127 (3 series)

EIGENGL04S-ANNUAL Vs EIGENGL04C – 1/2

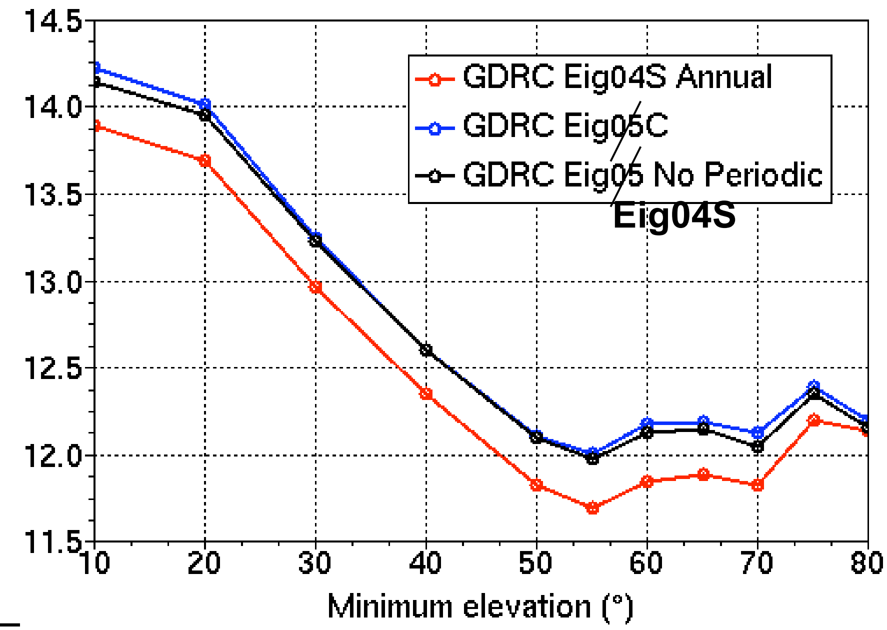


EIGENGL04S-ANNUAL Vs EIGENGL04C – 2/2

Xover RMS Difference relative to GDRC Eig04S_ANNUAL (mm)

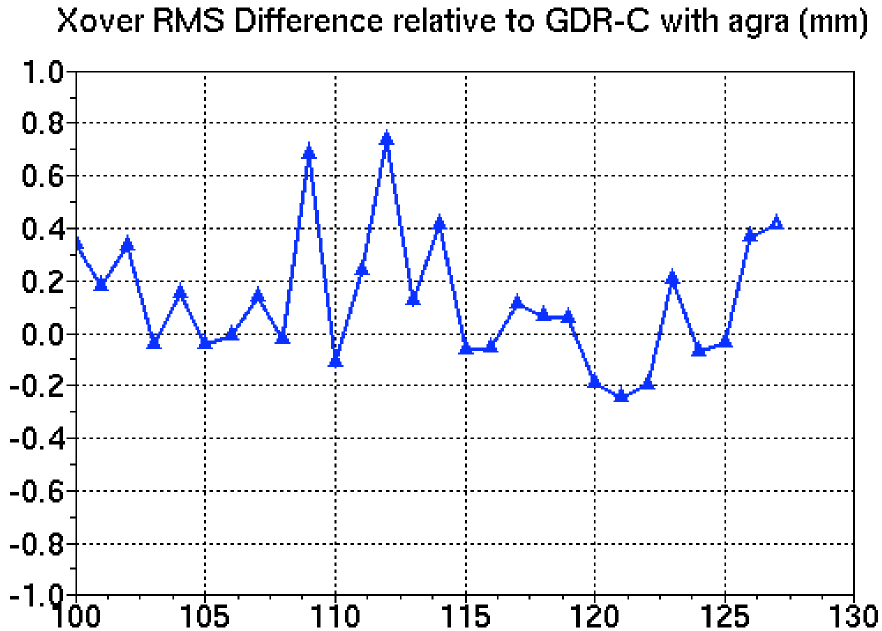


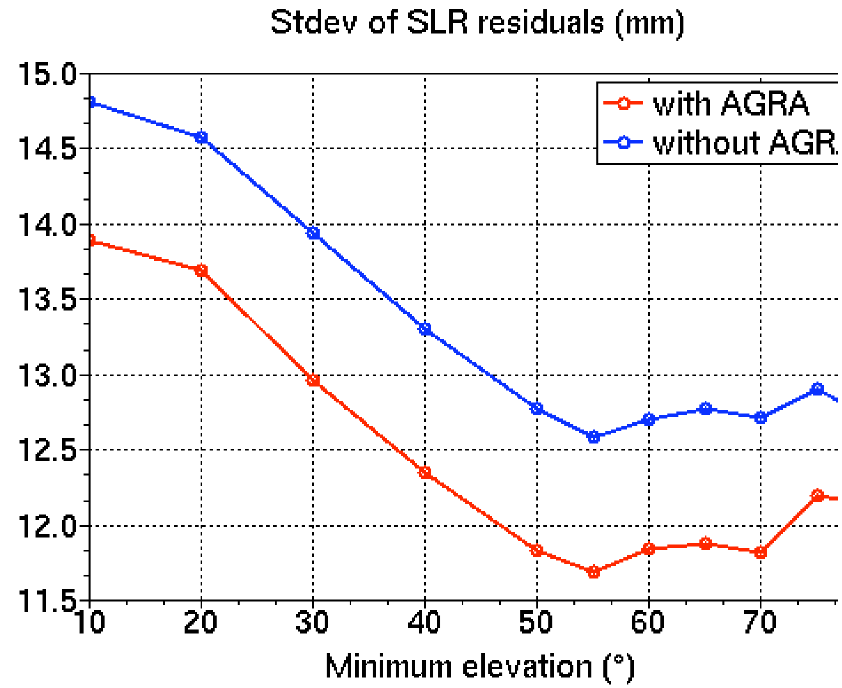
Stdev of SLR residuals (mm)



Station	*Nr*	*RMS (mm)*		
YARR_7090	*12879*	11,9	12,3	12,2
WASH_7105	*3407*	11,9	12,4	12,3
MONU_7110	*3711*	14,1	14,6	14,4
GRAZ_7839	*8616*	14,3	14,5	14,4
FORT_7080	*1310*	15,9	16,5	16,3
HERS_7840	*6462*	14,1	14,4	14,3
WETZ_8834	*6225*	16,9	17,4	17,4

Atmospheric contribution to the gravity field



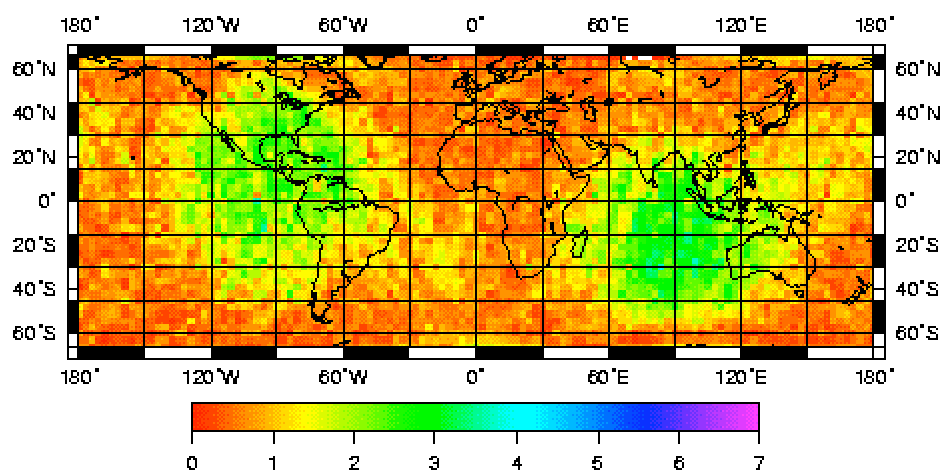


Station	Nr	RMS (mm)	
YARR_7090	12879	11,9	12,9
WASH_7105	3407	11,9	12,5
MONU_7110	3711	14,1	14,6
GRAZ_7839	8615	14,3	15,3
FORT_7080	1310	15,9	16,4
HERS_7840	6462	14,1	15,3
WETZ_8834	6225	16,9	17,9

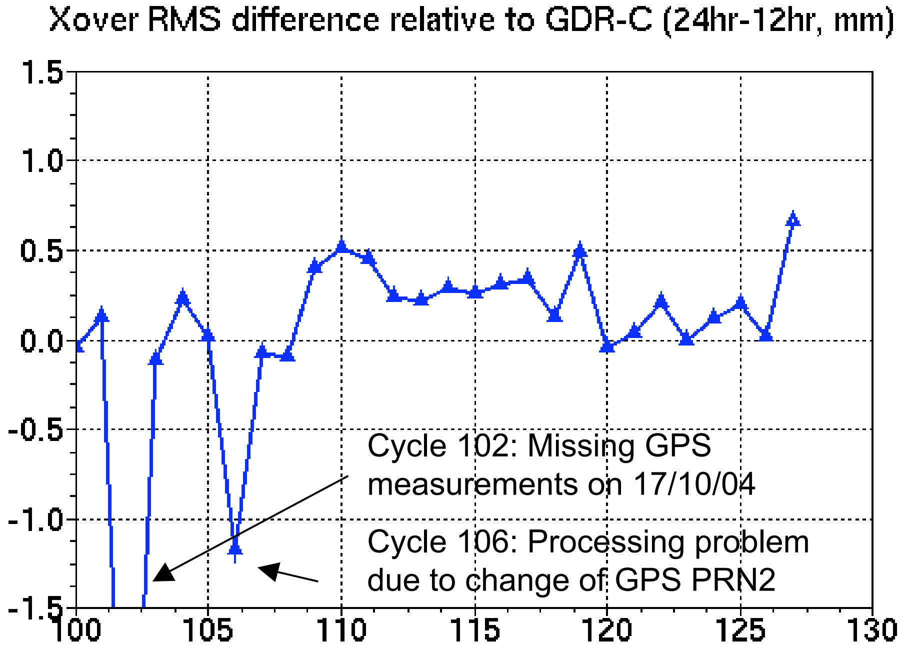
Atmospheric contribution to the gravity field

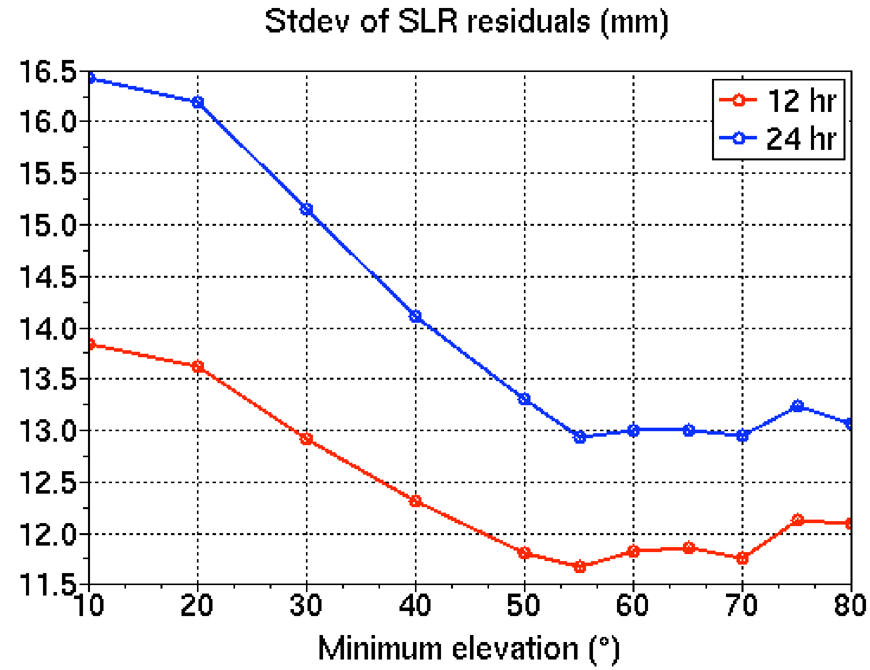
- Test with SHDP product (similar to AGRA) performed in preparation of the Hobart 2007 meeting (see presentation at POD splinter)

- Annual signal between two orbits series with/without SHDP



12 hr Vs 24 hr 1/rev forces





Station	Nr	RMS (mm)	
YARR_7090	13346	11,8	15,5
WASH_7105	3443	11,9	15,6
MONU_7110	3796	14,0	17,1
GRAZ_7839	8641	14,3	16,2
FORT_7080	1377	15,9	19,8
HERS_7840	6582	14,0	14,4
WETZ_8834	6370	17,0	20,0

LPOD2005 test

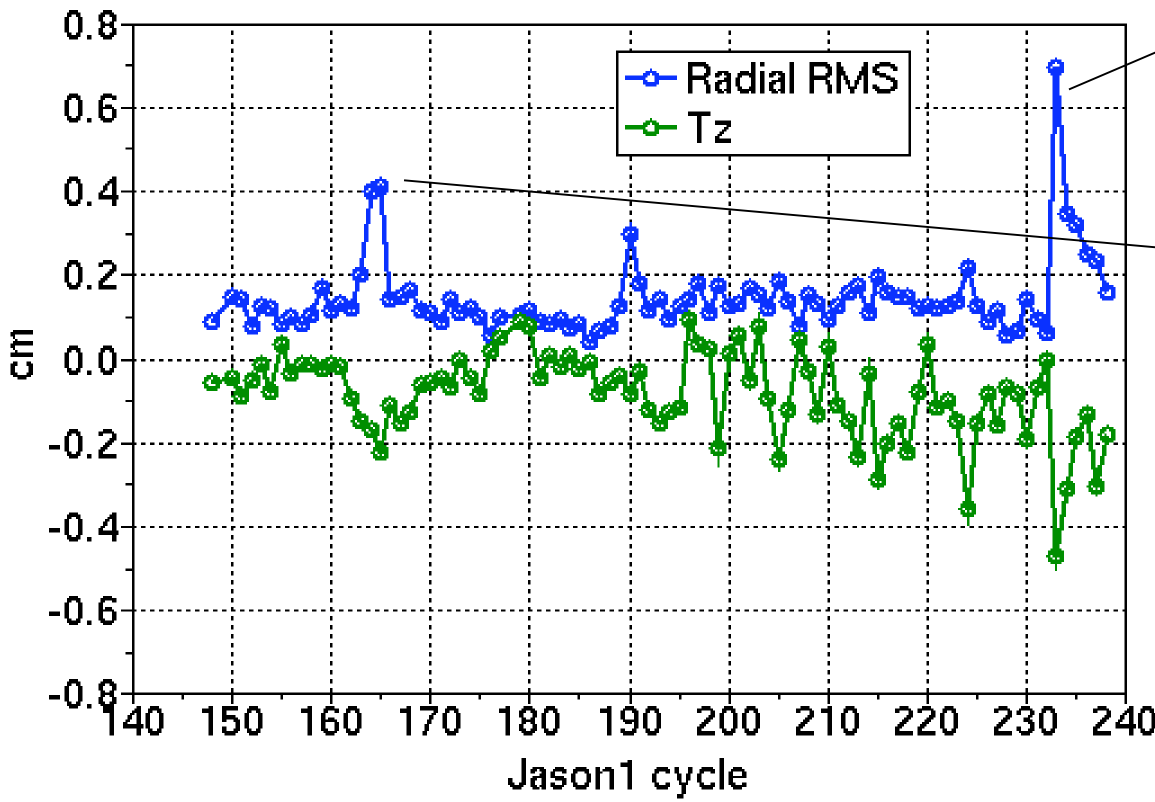
Test description (JASON-1)
(identical test as for JASON-2)

- Verify the impact of LPOD2005 on Jason-1 D+L+G dynamic POE
- Identical configuration except for SLR station coordinates and bias modeling
  - Current POE configuration (V01): SLRF2005 coordinates and biases; a bias per pass is solved for a few stations

  Vs

  - LPOD2005 (V02): coordinates and biases fixed to the suggested values

Orbit comparison 2 (per cycle)



Bad passes on L1893_KATZ and L7821_SHAN

Bad passes on L1864_MAID, L1873_SIME and L7249_BEIJ

In general the orbits stay close (<2mm RMS) with few exceptions due to bad passes with fixed bias on test V02

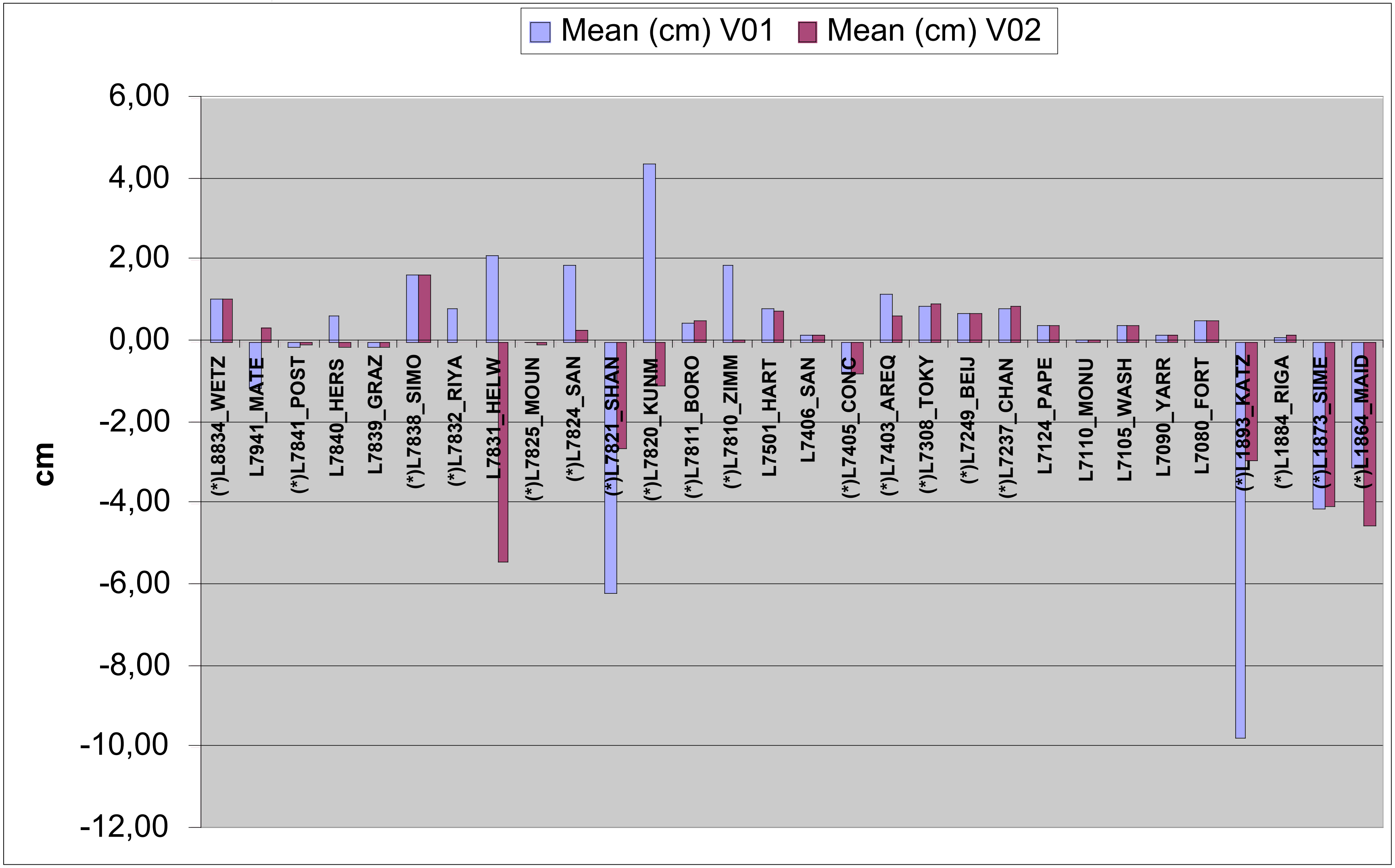
Post-fit SLR Residuals 1

(*) Indicates that a bias per pass was estimated in V01 test. The estimated value was then added back to the residuals to allow a direct comparison

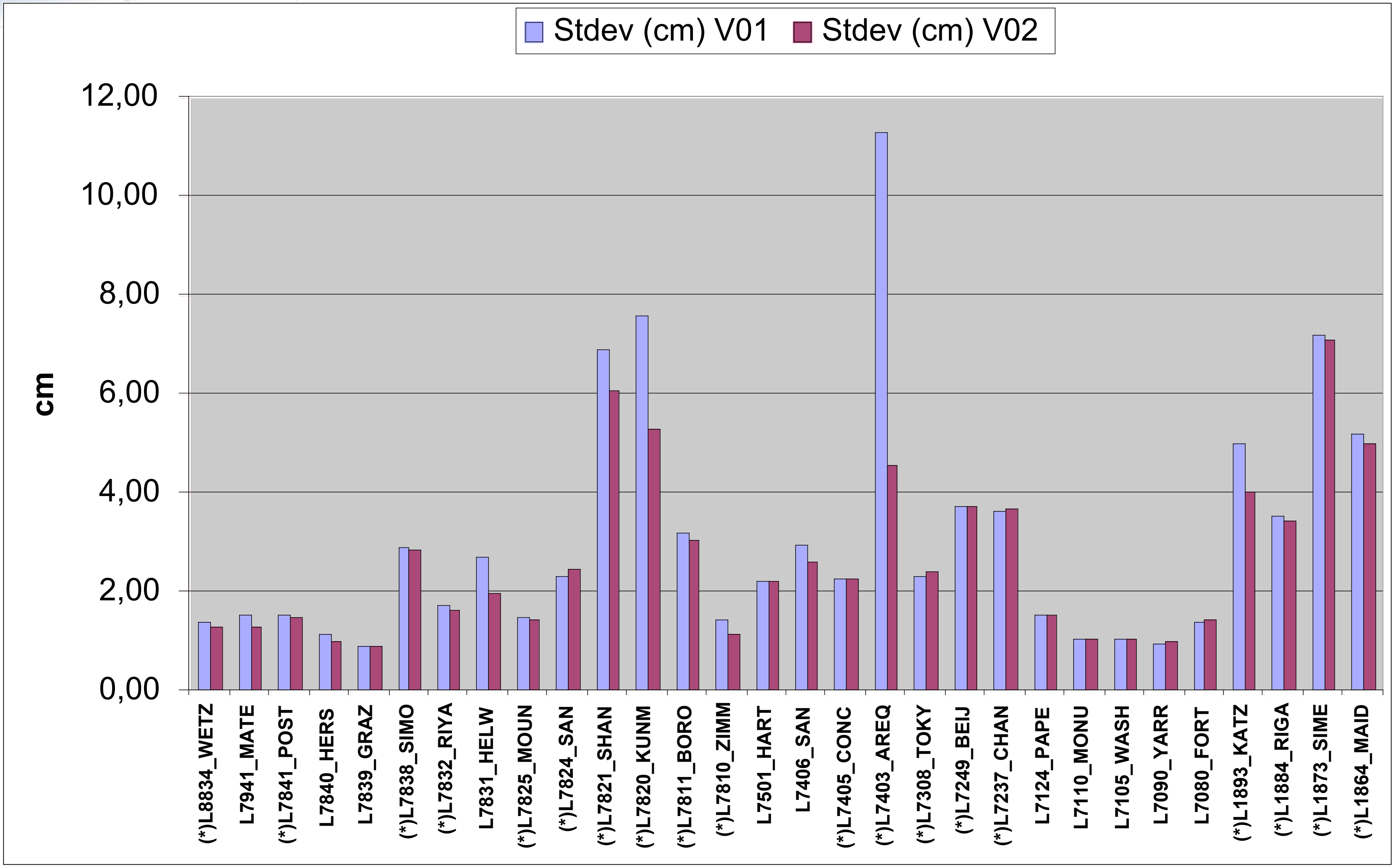
Black lines indicate stations whose coordinates are modified by LPOD2005

			Mean (cm)		Median (cm)		Stdev (cm)		RMS (cm)	
Station	Weight	Points	V01	V02	V01	V02	V01	V02	V01	V02
(*)L8834_WETZ	0,3	22212	1,03	1,05	0,98	1,01	1,39	1,29	1,73	1,67
L7941_MATE	0,7	13900	-1,14	0,36	-1,13	0,32	1,51	1,26	1,89	1,31
(*)L7841_POST	0,5	13605	-0,17	-0,10	-0,24	-0,16	1,55	1,47	1,56	1,48
L7840_HERS	1	29608	0,62	-0,12	0,60	-0,14	1,14	1,01	1,30	1,02
L7839_GRAZ	1	33501	-0,16	-0,12	-0,17	-0,13	0,90	0,88	0,92	0,89
(*)L7838_SIMO	0,1	4873	1,67	1,66	1,59	1,59	2,88	2,85	3,33	3,30
(*)L7832_RIYA	0,2	18016	0,83	-0,01	0,76	-0,05	1,72	1,63	1,91	1,63
L7831_HELW	0,1	11	2,10	-5,46	2,64	-5,73	2,68	1,99	3,31	5,78
(*)L7825_MOUN	0,8	28407	-0,03	-0,06	-0,09	-0,12	1,49	1,42	1,49	1,42
(*)L7824_SAN	0,1	11721	1,86	0,25	1,86	0,19	2,32	2,47	2,97	2,48
(*)L7821_SHAN	0,5	744	-6,19	-2,67	-5,83	-2,74	6,89	6,06	9,26	6,62
(*)L7820_KUNM	0,1	500	4,40	-1,08	5,03	-0,19	7,58	5,29	8,75	5,40
(*)L7811_BORO	0,5	2989	0,48	0,50	0,19	0,28	3,21	3,03	3,25	3,07
(*)L7810_ZIMM	0,7	59961	1,86	0,05	1,89	0,05	1,42	1,13	2,34	1,13
L7501_HART	0,1	10280	0,78	0,77	0,80	0,79	2,19	2,21	2,32	2,34
L7406_SAN	0,1	13738	0,14	0,15	0,31	0,20	2,93	2,62	2,94	2,62
(*)L7405_CONC	0,1	12598	-0,78	-0,80	-0,86	-0,88	2,26	2,25	2,39	2,39
(*)L7403_AREQ	0,3	340	1,14	0,61	-1,44	0,89	11,31	4,56	11,35	4,59
(*)L7308_TOKY	0,1	2288	0,87	0,94	0,67	0,72	2,32	2,40	2,48	2,58
(*)L7249_BEIJ	0,1	5790	0,68	0,70	0,55	0,59	3,74	3,73	3,80	3,79
(*)L7237_CHAN	0,1	14750	0,83	0,87	0,91	0,97	3,65	3,66	3,75	3,77
L7124_PAPE	0,5	1457	0,39	0,39	0,37	0,37	1,52	1,53	1,57	1,58
L7110_MONU	1	18919	0,05	0,06	0,03	0,05	1,03	1,05	1,03	1,05
L7105_WASH	1	13924	0,37	0,40	0,33	0,36	1,05	1,05	1,11	1,13
L7090_YARR	1	67423	0,18	0,17	0,19	0,18	0,95	0,97	0,97	0,99
L7080_FORT	1	5184	0,49	0,50	0,49	0,50	1,40	1,41	1,48	1,49
(*)L1893_KATZ	0,1	6325	-9,81	-2,97	-9,79	-2,81	4,99	4,04	11,01	5,01
(*)L1884_RIGA	0,2	6388	0,12	0,18	-0,16	-0,06	3,52	3,41	3,52	3,42
(*)L1873_SIME	0,1	325	-4,14	-4,08	-3,43	-3,37	7,19	7,11	8,29	8,19
(*)L1864_MAID	0,1	1360	-3,14	-4,54	-3,40	-4,69	5,20	4,98	6,08	6,74

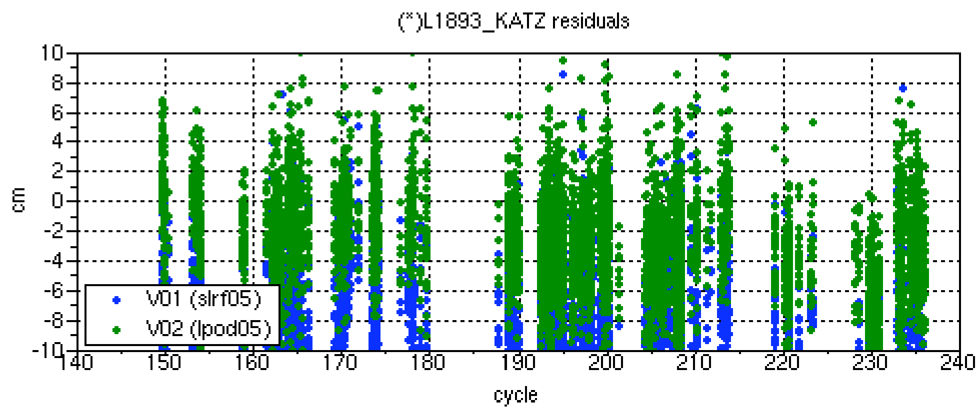
Post-fit SLR Residuals 2 (Mean)

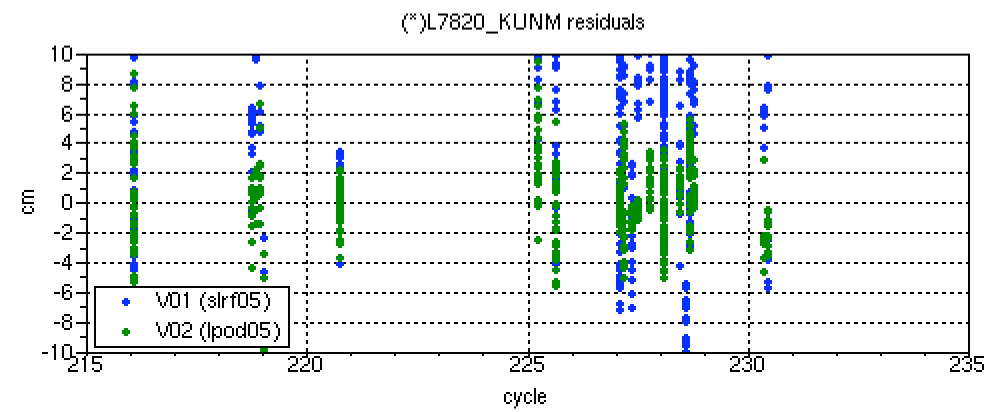


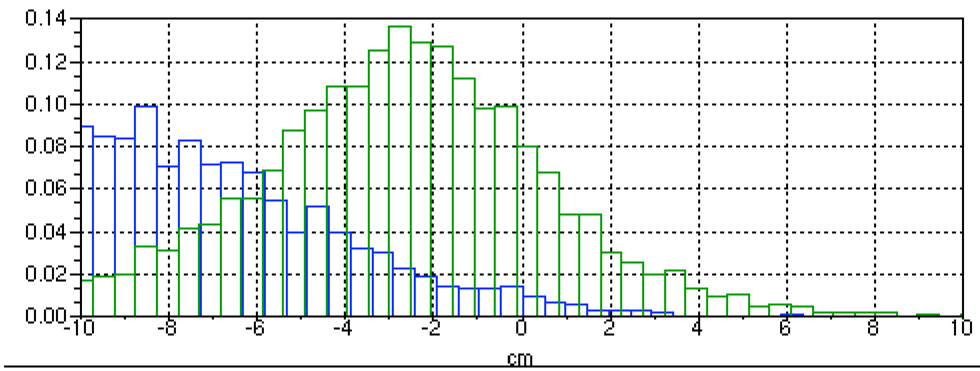
Post-fit SLR Residuals 2 (StDev)

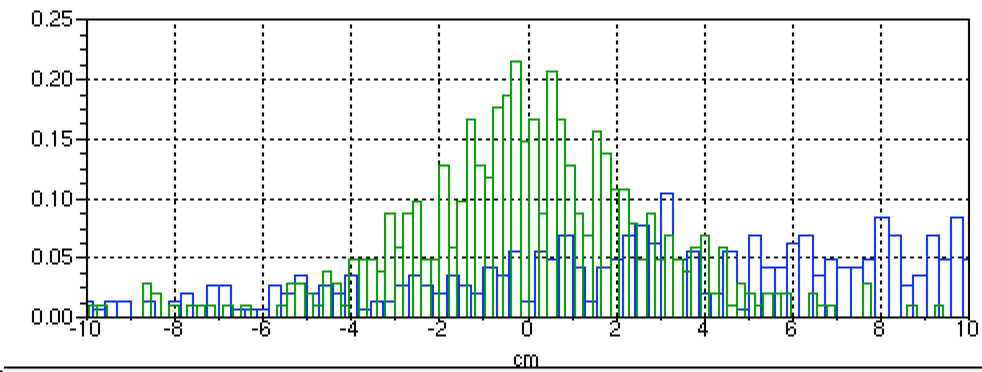


1893 / 7820

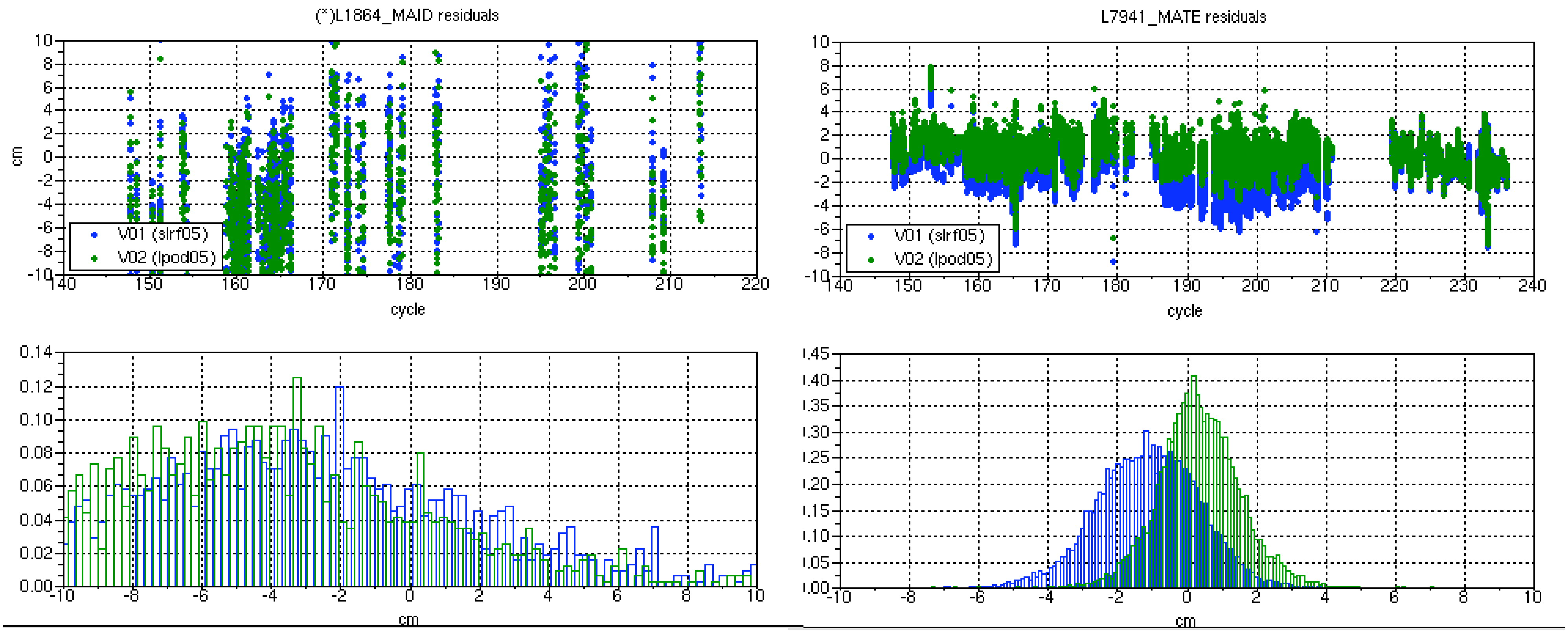

(*)L1893_KATZ residuals
cm
cycle
V01 (slrf05)
V02 (lpod05)


(*)L7820_KUNM residuals
cm
cycle
V01 (slrf05)
V02 (lpod05)

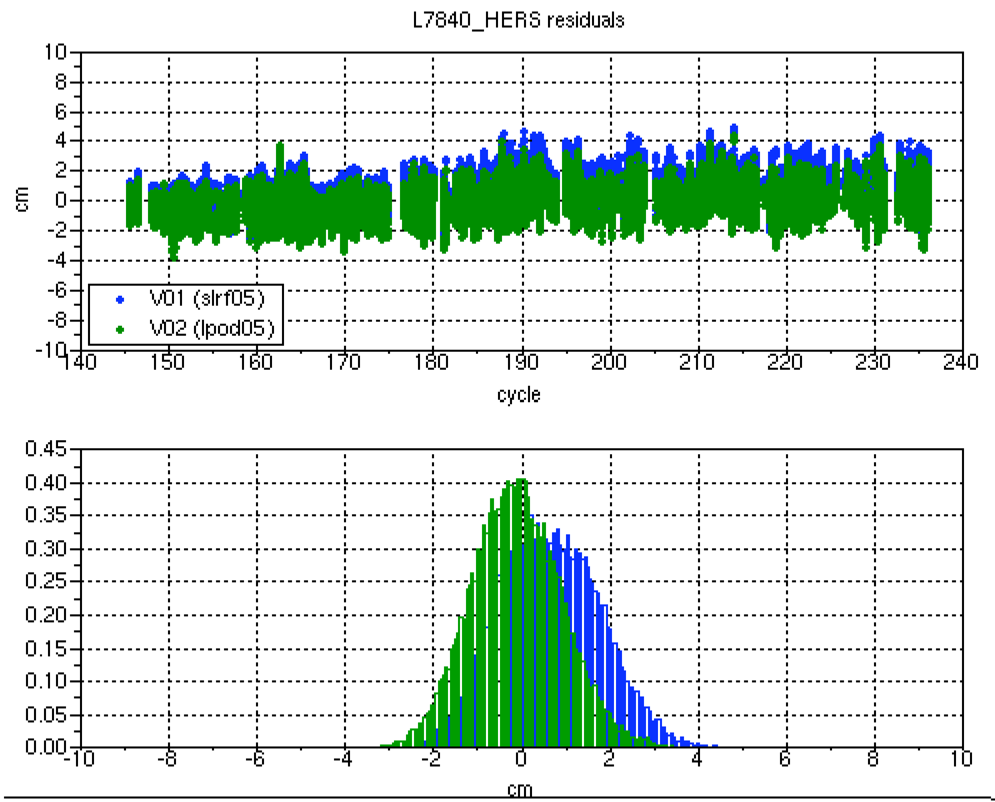

cm

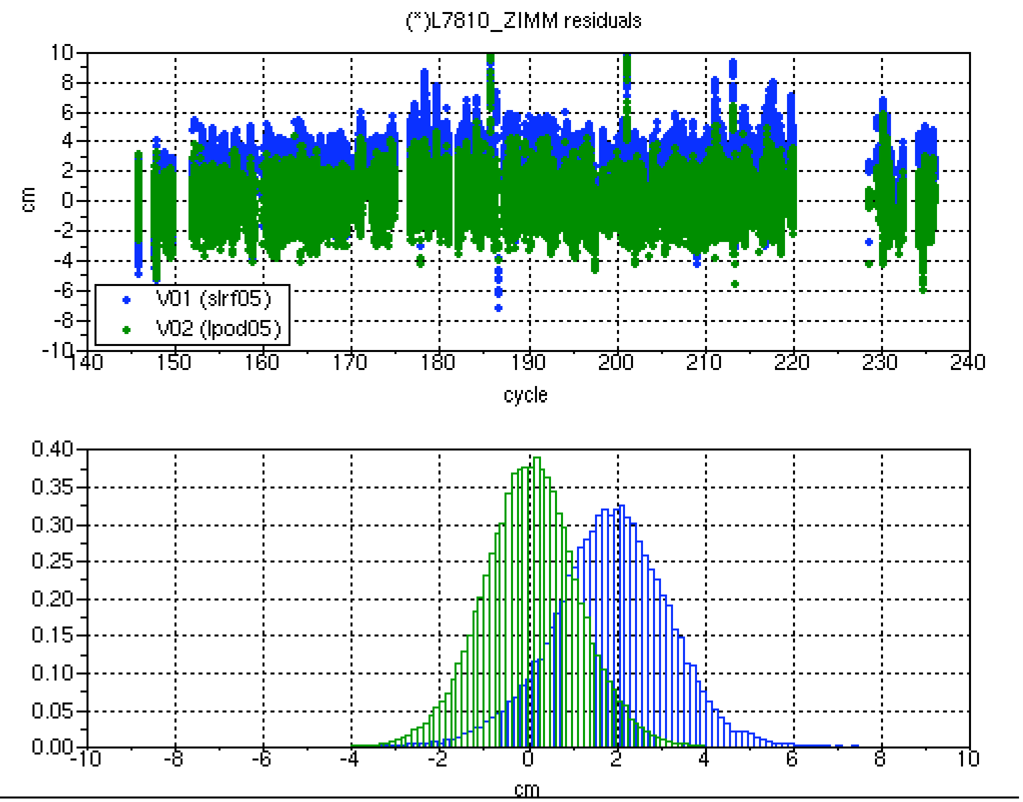

cm

7941 / 1864

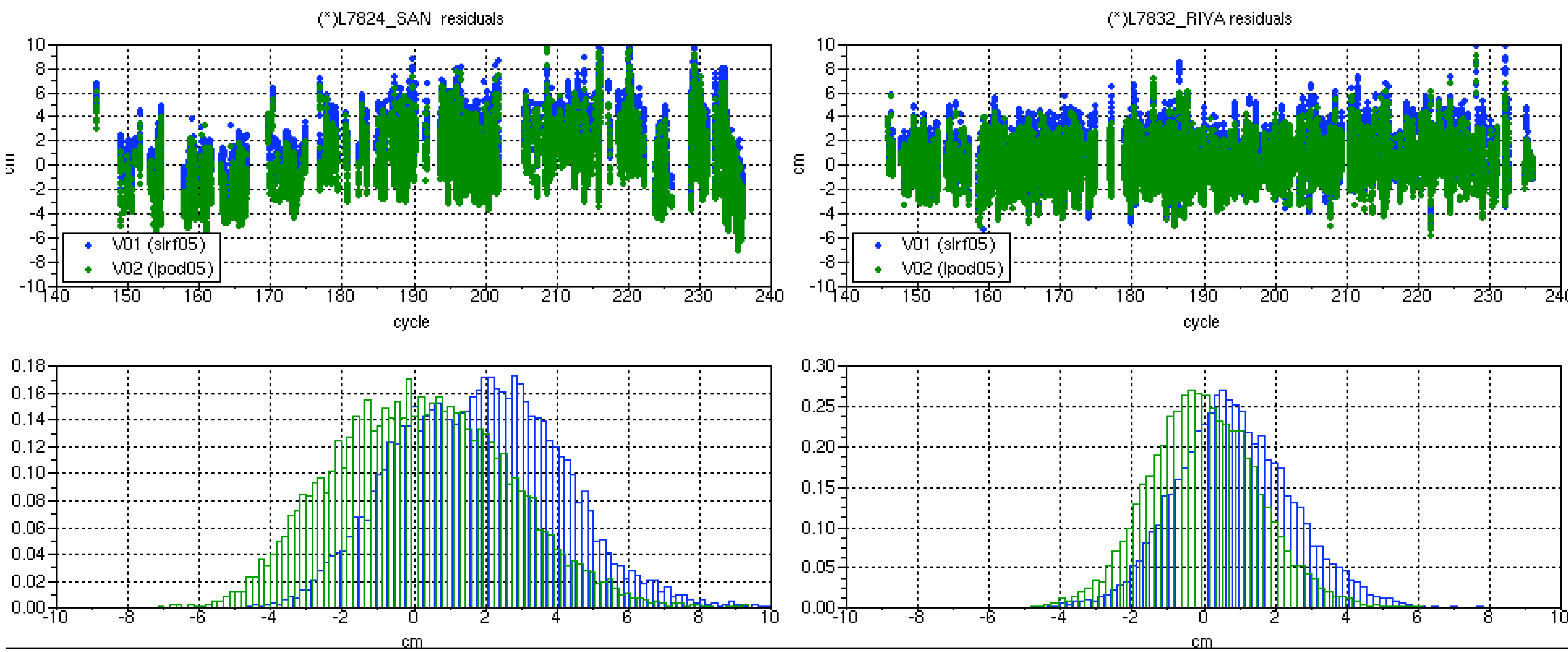

(*)L1864_MAID residuals
L7941_MATE residuals
cm
cycle
V01 (slrf05)
V02 (lpod05)
cm

7840 / 7810

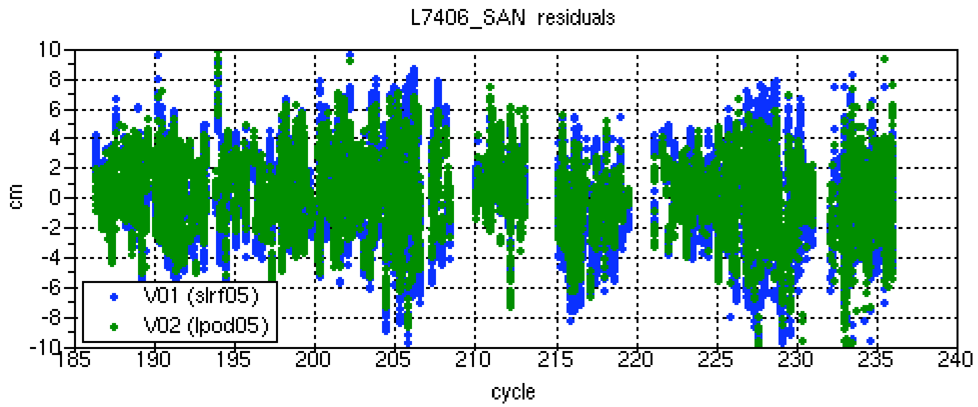

L7840_HERS residuals
cm
cycle
V01 (slrf05)
V02 (lpod05)
cm

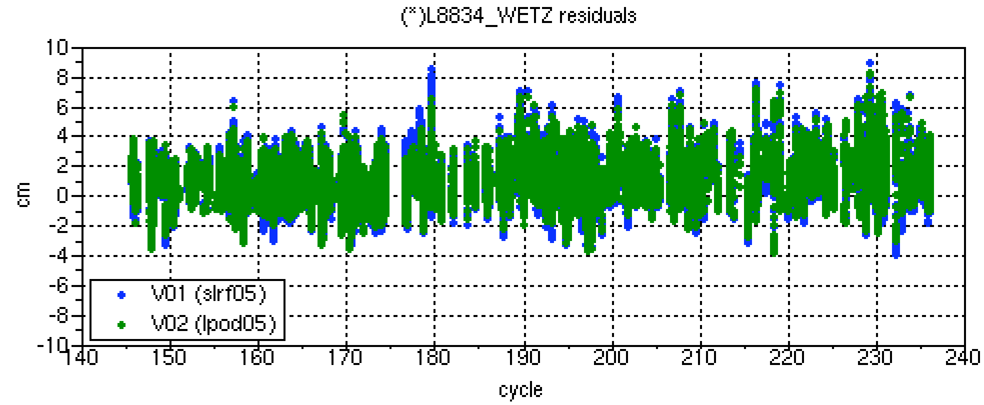

(*)L7810_ZIMM residuals
cm
cycle
V01 (slrf05)
V02 (lpod05)
cm

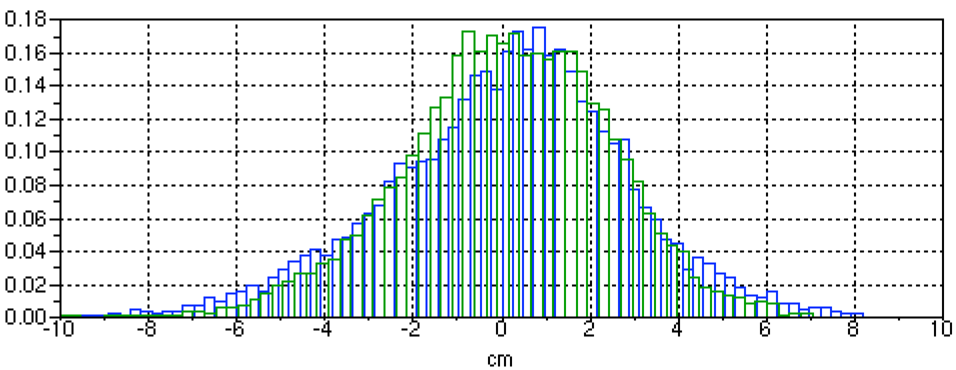
7824 / 7832

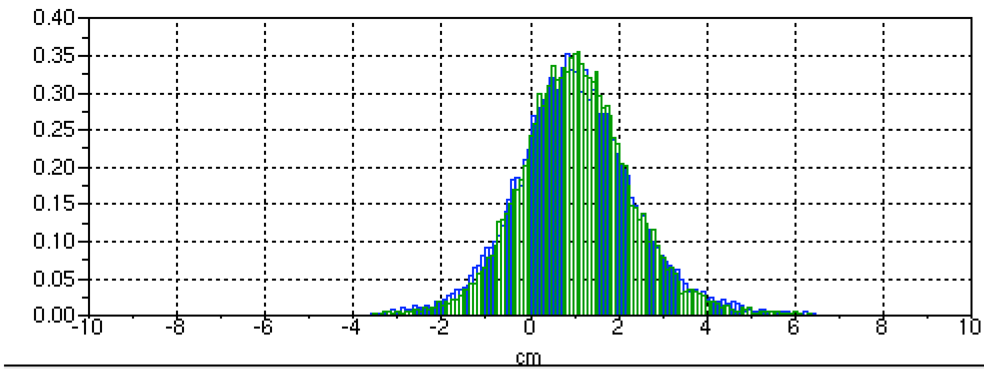

(*)L7824_SAN residuals
(*)L7832_RIYA residuals
V01 (slrf05)
V02 (lpod05)
V01 (slrf05)
V02 (lpod05)
cycle
cycle
cm
cm
cm
cm

7406 / 8834


L7406_SAN residuals
V01 (slrf05)
V02 (lpod05)
cm
cycle


(*)L8834_WETZ residuals
V01 (slrf05)
V02 (lpod05)
cm
cycle

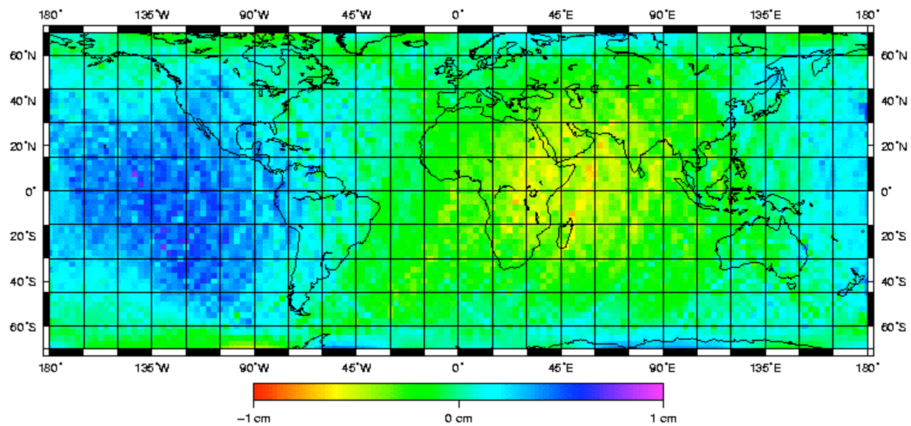

cm


cm

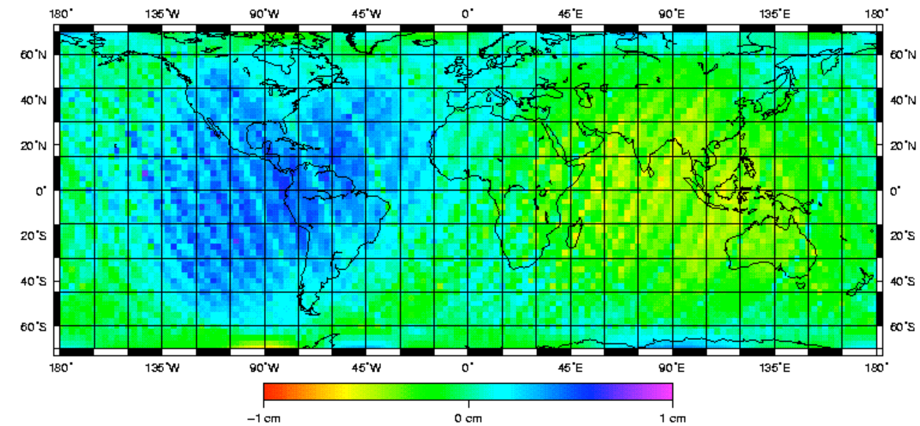
Drifts/No drifts backups

Radial difference looks like Y-bias, with some exceptions

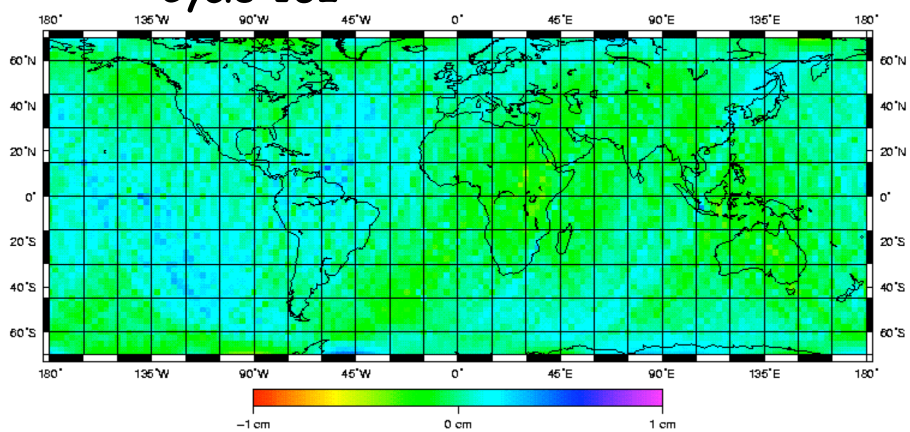
Cycle 151 All Tracks – Mean



Cycle 153 All Tracks – Mean



Cycle 152 All Tracks – Mean

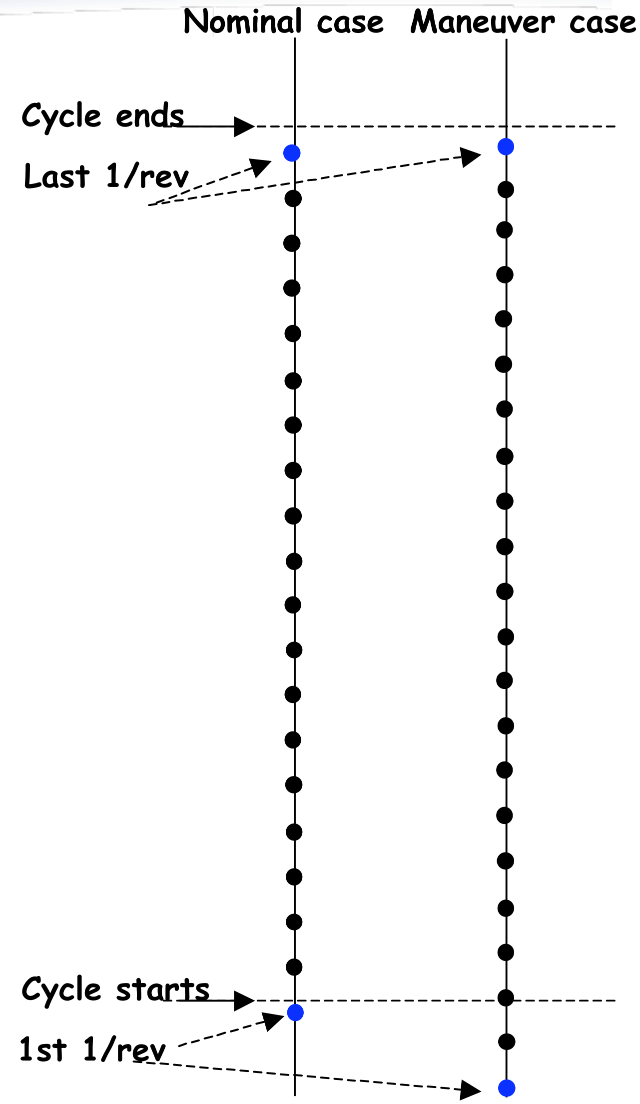


- Difference almost completely attenuated on cycle 152 …

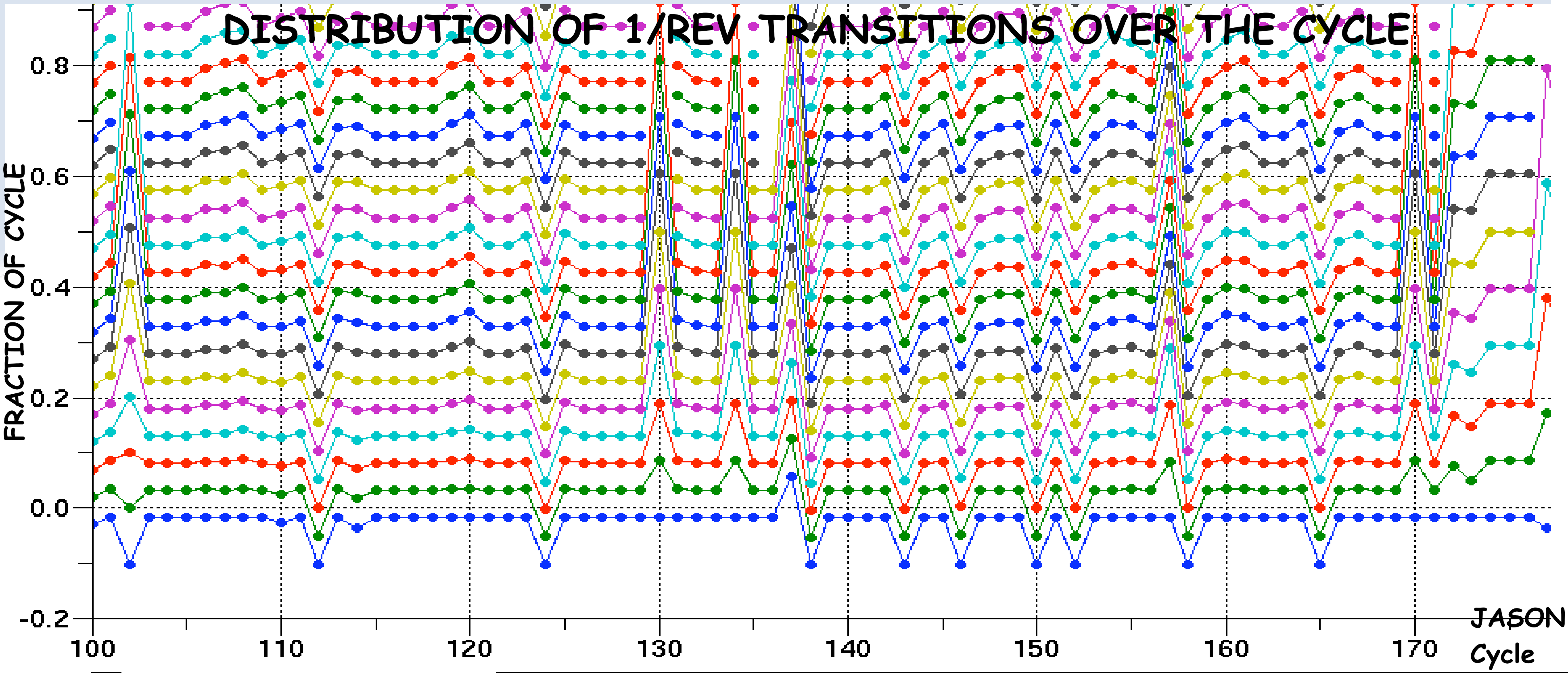
The impact varies from cycle to cycle

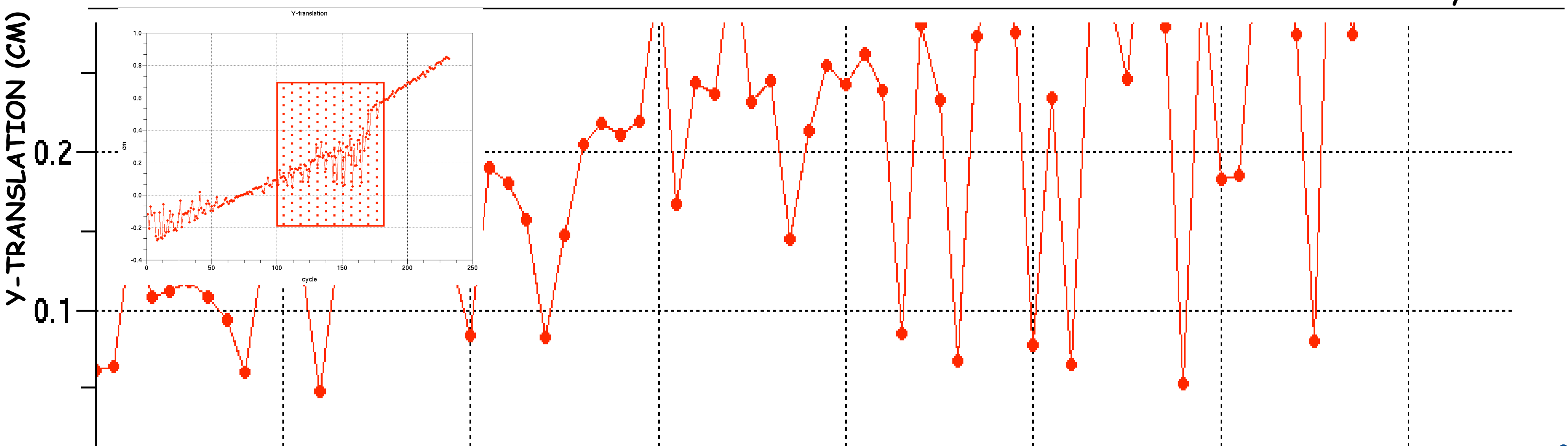
- The impact of changes in the gravity field on the orbit depends on how the 1/rev empirical forces are distributed over the cycle
- Nominally, 1/rev forces are adjusted every 12 hr starting from the beginning of the arc (the arc starts 4hr before the cycle)
- But
  - Solving for maneuvers at the beginning of the cycle obliges to start the arc earlier (1 day margin instead of 4 hours)
  - The number of adjusted 1/rev is reduced when tracking is reduced
  - Attitude events within the cycle break the regular distribution of 1/rev

➔ The orbit response to changes (or errors) in the gravity field is not the same one cycle to another



DISTRIBUTION OF 1/REV TRANSITIONS OVER THE CYCLE





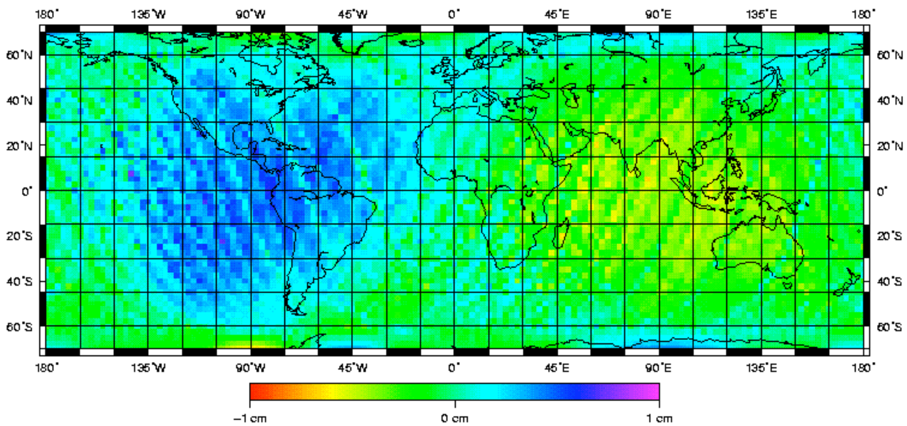
Example on cycle 153

_ With the standard 12hr 1/rev

_ With 12hr 1/rev phased wrt to the cycle

Expected difference: Drift – No drifts

All Tracks – Mean



Attenuated difference: Drift – No drifts

All Tracks – Mean