Accuracy and Stability Assessment of the ILRS Stations Over Two Decades

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Abstract

The development of the ITRF depends on the quality of the contributions from the four geometric techniques. With the GGOS requirements for ITRF accuracy and stability becoming exceedingly stringent, ITRS requests that each technique generate and deliver an assessment of the performance of each system over time, covering as much of the period spanned by their contribution as possible. Since the ITRF relies on the combination of the techniques at the co-located sites, this information can be used to sort out cases where a discrepancy is observed between the techniques and the local survey information, isolating the most likely culprit and taking appropriate steps to avoid distorting the final result. In response to an ITRS request we have developed a historical qualification index based on the long-term and short-term performance information available to ILRS, a consistently-derived set of systematic error estimates from the analysis of LAGEOS and LAGEOS 2 SLR data and all the engineering information reported to ILRS by the stations. We propose to establish and maintain this index to serve as input to ITRS for the ITRF2013 development as well as for the future realizations.

ILRS MONTHLY GLOBAL REPORT CARD

DGFI HITO UNI. JCET MCC SHAO

Site Information		DGFI Orbital Analysis				Hitotsubashi Univ. Orbital Analysis				JCET Orbital Analysis				MCC Orbital Analysis				SHAO Orbital Analysis			
Station Location	Station Number	LAG NP RMS (mm)	short term (mm)	long term (mm)	% good LAG. NP	LAG NP RMS (mm)	short term (mm)	long term (mm)	% good LAG. NP	LAG NP RMS (mm)	short term (mm)	long term (mm)	% good LAG. NP	LAG NP RMS (mm)	short term (mm)	long term (mm)	% good LAG. NP	LAG NP RMS (mm)	short term (mm)	long term (mm)	% good LAG. NP
Baseline		10.0	20.0	10.0	95	10.0	20.0	10.0	95	10.0	20.0	10.0	95	10.0	20.0	10.0	95	10.0	20.0	10.0	95
Yarragadee	7090	3.7	15.6	1.8	100.0	2.0	7.5	1.9	100.0	3.2	14.8	2.8	99.8	2.4	16.6	2.9	98.3	1.7	15.2	2.0	91.9
Changchun	7237	4.2	26.7	4.7	99.1	3.1	25.2	2.8	99.7	3.1	28.6	3.5	96.8	4.1	30.9	10.5	96.4	3.1	32.3	10.0	90.3
Mount_Stromlo_2	7825	4.2	14.1	4.1	100.0	3.1	8.1	2.0	100.0	3.5	15.2	3.7	99.9	4.1	12.9	3.3	95.4	2.7	12.9	3.1	95.1
Zimmerwald_532	7810	3.1	11.6	7.8	99.9	1.4	5.4	3.1	99.8	2.1	13.0	7.8	99.9	2.6	13.6	3.2	98.3	1.5	11.2	3.7	95.0
Wettzell	8834	3.7	13.1	3.8	100.0	2.5	8.6	2.2	100.0	3.1	12.4	3.9	99.4	2.6	11.5	4.2	96.2	1.5	12.3	5.2	94.2
Graz	7839	2.5	11.2	2.9	100.0	0.8	4.4	1.8	100.0	1.9	11.7	4.9	98.5	1.9	12.0	4.5	98.0	0.7	9.3	2.5	95.5
Matera_MLRO	7941	2.6	12.0	4.7	99.9	1.2	6.0	2.6	100.0	2.1	12.4	4.4	100.0	1.8	14.3	3.7	99.5	2.1	32.0	3.6	97.6
Greenbelt	7105	4.5	12.9	1.2	99.9	2.2	6.6	1.1	99.8	3.3	11.5	1.7	99.2	2.5	16.6	1.8	97.0	2.3	13.5	1.8	91.0
Herstmonceux	7840	2.7	9.8	3.5	100.0	1.4	5.4	1.5	100.0	1.7	11.6	2.9	100.0	2.6	8.9	2.7	96.9	1.7	11.4	2.5	97.2
Monument_Peak	7110	5.8	17.2	5.3	99.7	3.8	12.3	2.0	99.7	5.7	20.5	4.9	98.0	3.9	20.5	3.9	94.4	3.5	14.6	6.2	91.0
Hartebeesthoek	7501	4.8	18.6	5.0	99.9	2.8	8.4	3.2	99.9	3.8	18.7	5.4	98.8	3.3	23.5	4.6	96.3	2.5	19.0	6.2	92.0
San_Juan	7406	15.9	44.1	9.5	97.5	5.6	33.0	10.7	96.0	7.2	33.0	8.3	79.2	7.4	30.5	9.0	91.5	8.7	32.3	11.9	90.4
Potsdam_3	7841	3.9	10.7	4.2	100.0	1.7	7.7	2.7	99.6	2.7	10.9	5.0	99.4	2.1	7.4	2.9	98.2				
Grasse_MEO	7845	4.2	14.1	3.1	100.0	2.6	9.6	3.1	100.0	3.5	13.3	2.6	100.0	3.1	12.9	3.3	97.5	2.1	14.0	2.9	94.3
Arequipa	7403	5.6	22.6	11.8	99.5	2.4	22.6	18.4	99.2	5.0	25.8	21.5	97.4	3.6	16.6	6.8	96.0	4.2	18.7	6.7	89.5
Shanghai_2	7821	8.0	44.8	19.7	99.4	3.8	43.9	18.8	100.0	4.1	46.2	24.6	94.1	5.0	46.6	21.5	97.5	2.6	31.5	19.6	95.0
Haleakala	7119	7.0	29.3	9.0	98.3	3.6	14.3	2.7	98.1	5.3	15.1	4.8	96.7	5.8	27.9	14.3	96.6	5.0	13.1	20.1	92.5
Simosato	7838	6.5	27.7	11.3	100.0	3.1	17.7	6.8	99.8	6.1	19.0	8.0	97.1	4.5	19.1	9.9	98.9	6.1	18.4	6.2	90.6
McDonald	7080	5.2	17.9	5.3	99.7	2.9	9.6	3.5	99.7	4.2	11.7	3.6	99.3	3.4	11.9	6.2	93.2	2.5	10.1	4.2	96.5
Kiev	1824	18.3	42.8	26.5	84.1	12.6	49.7	28.3	89.1	4.9	30.1	16.7	47.8	1271.8	44.6	33.8	87.8				
Katzively	1893	15.8	15.7	6.4	98.9	9.8	17.8	3.5	97.9	7.0	20.5	6.5	79.9	12.1	18.8	10.4	86.3	9.8	18.6	13.0	92.8
Concepcion_847	7405	9.0	40.8	11.7	99.1	1.6	50.3	8.7	100.0	9.9	57.3		87.5	2.6	38.8	14.6	100.0				
Arkhyz	1886	9.5	22.4	14.1	100.0	6.9	26.8	15.3	99.8	7.3	25.5	12.7	93.7	7.5	27.2	19.5	93.2				
Altay	1879	22.5	53.2	21.3	100.0									3.8	15.1	7.4	100.0				
Beijing	7249	5.9	19.5	13.2	100.0					5.7	17.8	11.4	98.3	5.2	32.4	15.4	98.6				
Simeiz	1873					30.2	31.6	24.1	98.7	7.1	35.4		57.1	25.6	42.4	29.1	93.6	20.5	27.4	10.5	88.7
Baikonur	1887	10.5	25.0	21.7	100.0	7.3	26.5	10.3	99.8	8.1	29.3	20.4	89.2	7.3	18.0	17.2	95.6				
Komsomolsk	1868	10.4	48.0	27.7	94.4	3.7	31.2	20.6	100.0					3.7	51.7	23.9	96.4				
Papeete	7124	4.9	17.3	9.4	100.0	2.5	7.8	3.8	100.0	4.0	13.2	4.3	99.5	3.8	20.4	7.6	100.0				
Badary	1890	6.1	14.8	9.8	92.3	5.2	12.4	8.5	100.0					6.4	17.3	22.4	91.3				
Zelenchukskya	1889					4.8	7.9	3.2	100.0												
Svetloe	1888					8.0	13.4		100.0												

Long-term RMS Averaged across AC and computed Std. Dev. about the mean

Short-term RMS Averaged across AC and computed Std. Dev. about the mean

ILRS NETWORK QUALITY CONTROL RESOURCES

ILRS since more than two decades has monitored the performance of individual stations through a Quality Control (QC) process. QC is based on the standardized analysis of the collected data by a dedicated group of Analysis Centers (AC). The results have been tabulated in what is known as the “Global Report Card”, originally released every three months, and now on a monthly basis:

http://ilrs.gsfc.nasa.gov/network/system_performance/global_report_cards/monthly/

Monitoring the statistics of each station’s calibration stability provides a metric for the quality of the collected NPs and their noise content. Fitting the data from the entire network in orbital arcs may further reveal systematic errors which sometimes arise from several sources, some of which cannot be detected through engineering QC procedures, such as those routinely performed on site, but only through a precise data analysis with the rest of the network data.

Tracking the system performance over the past three months gives a “short-term metric”, while averaging over longer periods, such as the past year, characterizes the “long-term performance” of the system. Every AC uses a different piece of s/w and analysis approach, resulting in slightly different estimates of the RMS error for the same data batches. Lack of a higher standard for absolute comparison is overcome by forming the average of the performance indices estimated by each AC and computing the standard deviation of these estimates about the mean. This metric is one of the elements used to characterize a systems’ stability and the lack or presence of systematics over time.

OUR APPROACH FOR SYSTEM PERFORMANCE CHARACTERIZATION

The ILRS AWG has long adopted a policy in estimating systematic measurement errors for the tracking sites, separating the network in “Core” and “Associate” sites, and in general avoiding estimation for the core sites, unless a real problem is detected through the daily QC process or reported directly by the station crew.

The QC process qualifies the data and the system performance on the basis of the currently available best set of station positions and velocities (usually the ITRFXXXX model), which however do suffer from errors themselves, thus “biasing” our results to some extent. Model deficiencies will further bias our analysis, however, these would affect all stations at a similar level, although errors for some models do have a geographically correlated nature. It is thus clear that the “long-term performance” index as it is represented by the quarterly or monthly Global Report Cards, should be taken with more than a grain of salt, and it should be accompanied by some time series of estimated systematic errors (e.g. measurement or timing biases, etc.) and good understanding of the quality of the underlying (fixed) position of each site.

JCET has developed a data base of weekly resolution measurement error estimates for all active sites in the ILRS network and for all four main target satellites used in the ILRS operational products: LAGEOS 1 & 2, and ETALON 1 & 2. The estimates are based on the SLRF2008 reference frame, which does have significant deficiencies when it comes to new sites (operational after the end of 2008) or even for some sites with a very small data contribution into the ITRF2008 (which SLRF2008 is based on). Recent improvements in SLRF2008 will soon be implemented and a revised version of the data base will provide a more realistic picture of the errors for all ILRS systems, throughout the period covered by this data base: 1993 to present.

During the development of the previous ITRF model, the AWG compiled a detailed list of documented measurement errors at each tracking site and adopted a standard way of addressing these in the analysis. Some of the information was derived from station logs, some from station emails, others from communications with the station crew. All that information has been logged in a data base which is maintained by DGFI and accessible through their web site:
http://ilrs.dgfi.badw.de/fileadmin/data_handling/ILRS_Data_Handling_File.snx

Additionally, the AWG determined through analysis a number of systematic errors that were found present in the data and for most of which the stations could not identify a reason for their existence. All of this information is still valid and will be used as input for the characterization of the relative stability and fidelity of each site over time, with respect to the rest of the network. The end product of this process will only be available after we have agreed on the revised SLRF2008 release, the reassessment of the measurement errors obtained from a reanalysis of the data for the affected stations (mostly those entering the network in 2009 and later), and it will have the form of a relative weight for each site versus the entire network over the time span 1993 to present.

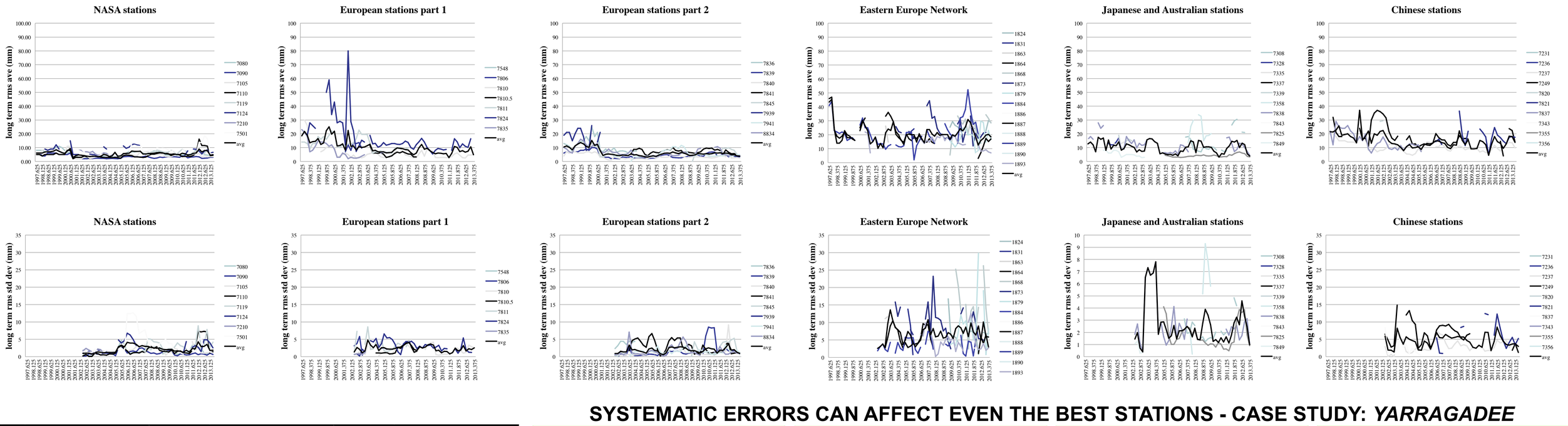
ILRS AWG LIST OF DATA DELETIONS★

LIST OF DATA TO BE DELETED

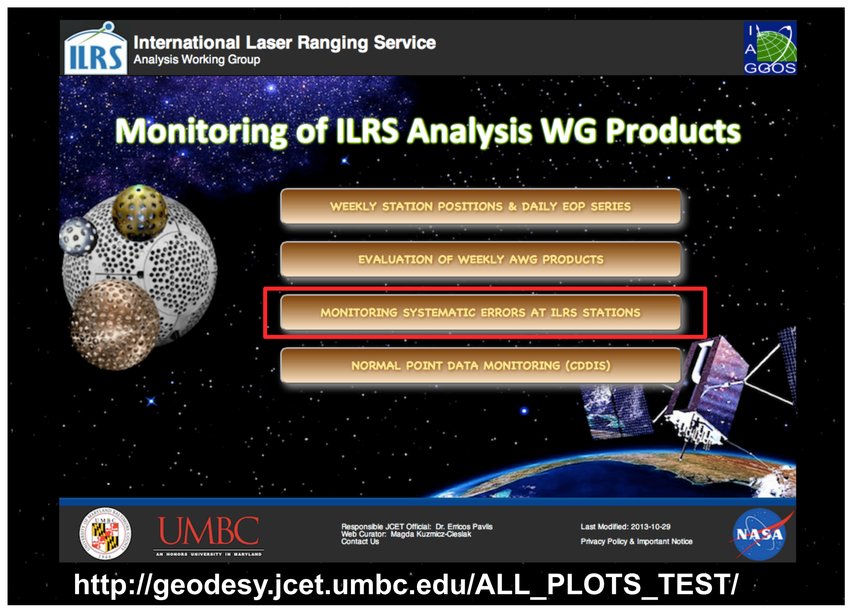
Site No.	Wav	Core NonCore in V50	Solve ?	Model ?	bias in sol V50	SOLUTION PROPOSAL	Source
1863	G	NC	NO	NO	--	data before 1994.0	
1873	G	NC	NO	NO	--	data before 1995.0	
1884	G	NC	NO	NO	1993.0 ->	data before august 1994	
1893	G	NC	NO	NO	--	data before 1998.0	CDDIS
7112	G	NC	NO	NO	--	data before 1985.0	
7123	G	NC	NO	YES	--	data from 25 to 30 august, 1988 (3 m bias) data on may 12, 1993 (> 500 meter bias)	
7236	G	NC	NO	NO	--	data after 1998.0 (a few acquisitions)	
7237	G	NC	NO	NO	--	data before 1996.0	
7249	G	NC	NO	NO	--	data before 1999.0	
7355	G	NC	NO	NO	--	use only data in 2003	
7510	G	NC	NO	NO		data from 920623 to 920930 to be deleted	CDDIS
7585	G	NC	NO	NO		data from 920623 to 920930 to be deleted	CDDIS
7810	B	C	NO	YES	--	data from dec 18, 1996 to dec 29, 1997	
7811	G	NC	NO	YES	1993.0 -1994.0	data before 1993:202	CDDIS
7820	G	NC	NO	NO	--	data before 2000:291	CDDIS
7824	G	NC	NO	NO	--	data before 1996	
7831	G	NC	NO	YES	--	data before 1984	
7832	G	C	NO	NO	__	data before 1998	
7835	G	NC	NO	YES	--	data before oct 1988	
7837	G	C	NO	NO	__	data before 1990	
7841	G	NC	NO	NO	--	data before feb 19, 2004	

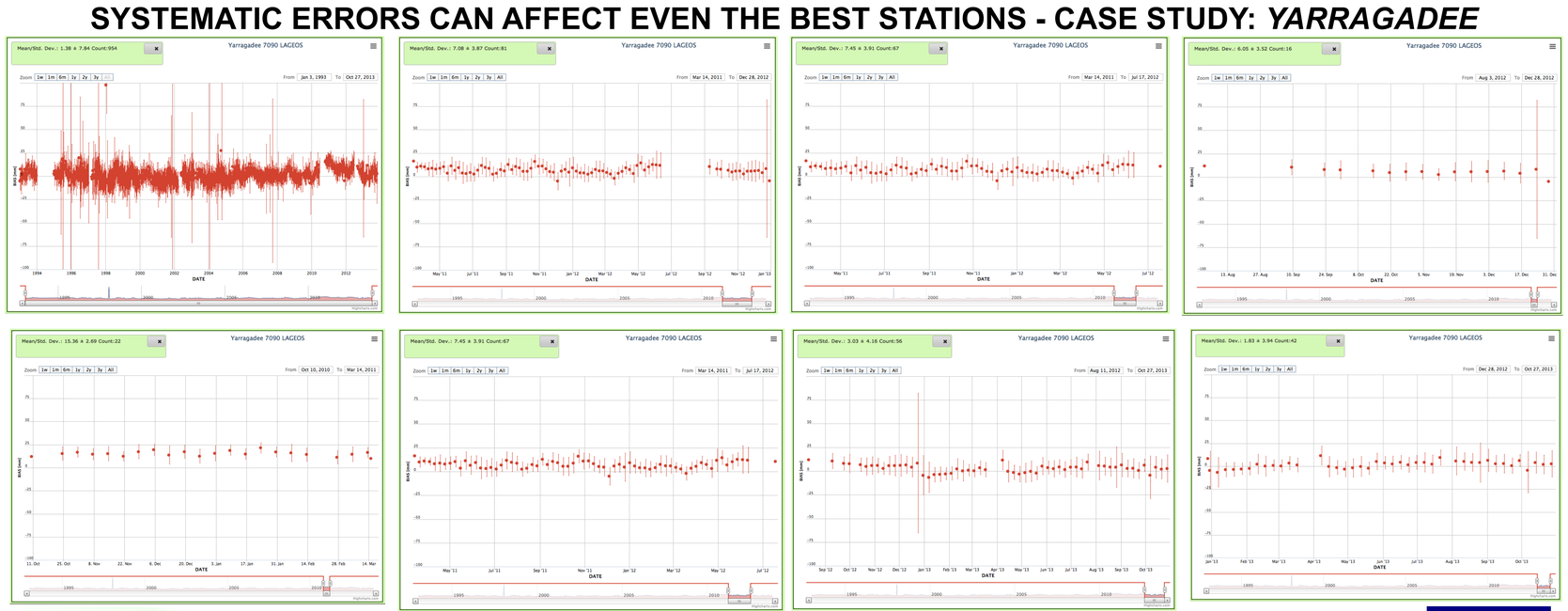
★List adopted prior to the development of the ITRF2008 product

LONG-TERM RMS AVERAGE VALUES (TOP CHARTS) AND THEIR STANDARD DEVATIONS (BOTTOM CHARTS) BY REGION
COLOR LINES ARE FOR INDIVIDUAL STATIONS – BLACK LINE IS THE AVERAGE OVER ALL STATIONS



SYSTEMATIC ERRORS CAN AFFECT EVEN THE BEST STATIONS - CASE STUDY: *YARRAGADEE*





We gratefully acknowledge the support of the ILRS and their network for making their SLR tracking data available to us for this study and NASA’s financial support through Grant NNX11AI44G.

Averaging over long periods of time can easily mask short-term deviations which sometimes even the local crew cannot explain. Note the large and significant error from **Oct.2010 to March 2011**: **15.4 ± 2.7 mm**