Vertical Displacements at an earthquake station: MONUMENT PEAK

Peter Dunn and Van Husson

MONUMENT PEAK SLR and GNSS stations

Monument Peak is located close to the San Andreas fault

Large position shifts are expected and seen at times of large earthquakes.

Engineering changes can also result in apparent station position discontinuities.

The SLR Analysis Centers compensate for the engineering changes
and only assume discontinuities at known earthquake times

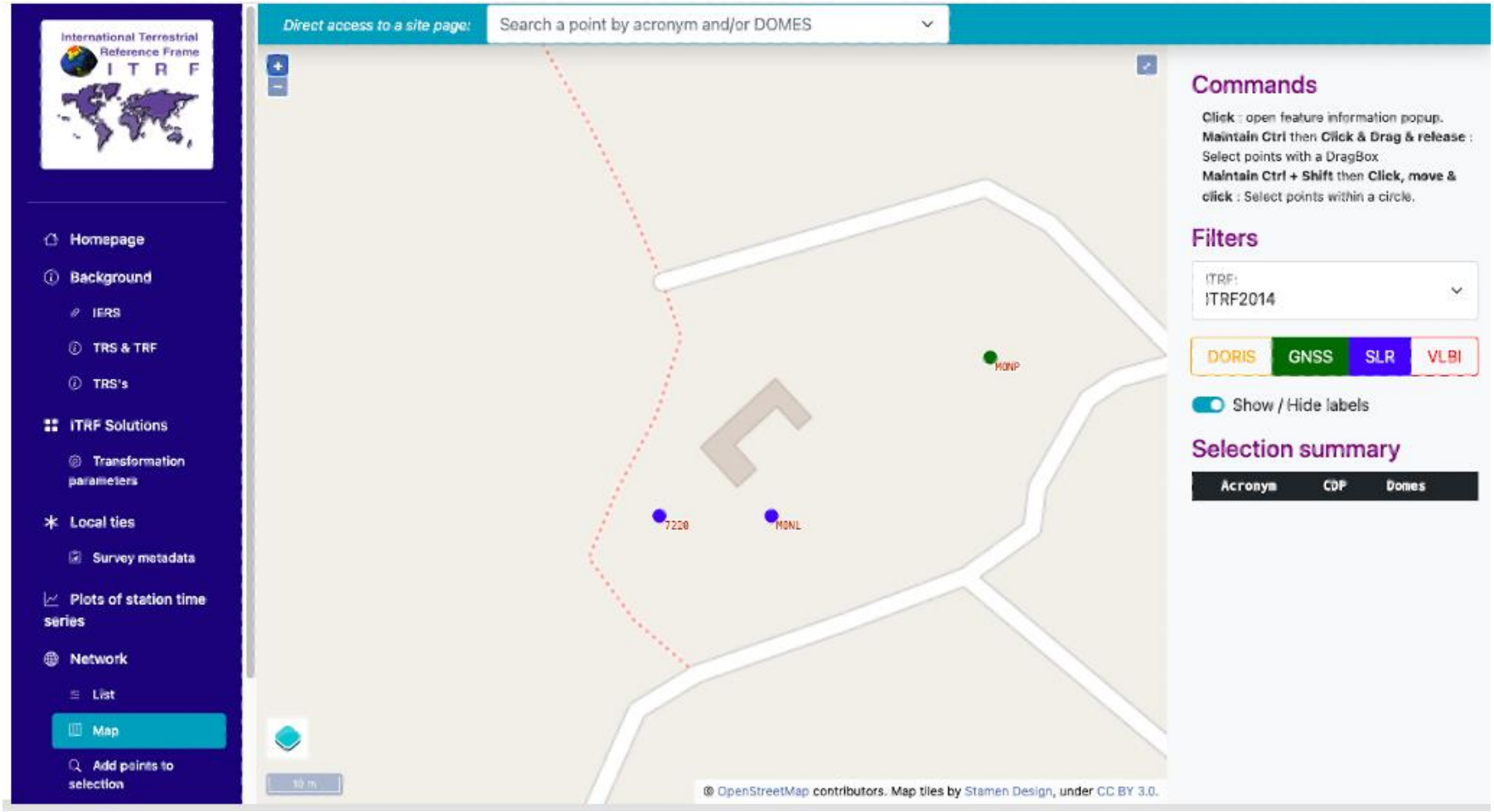
In contrast, GNSS Analysis Centers allow for frequent height shifts
which are modelled empirically.

We compare the behavior of two strong co-located systems.

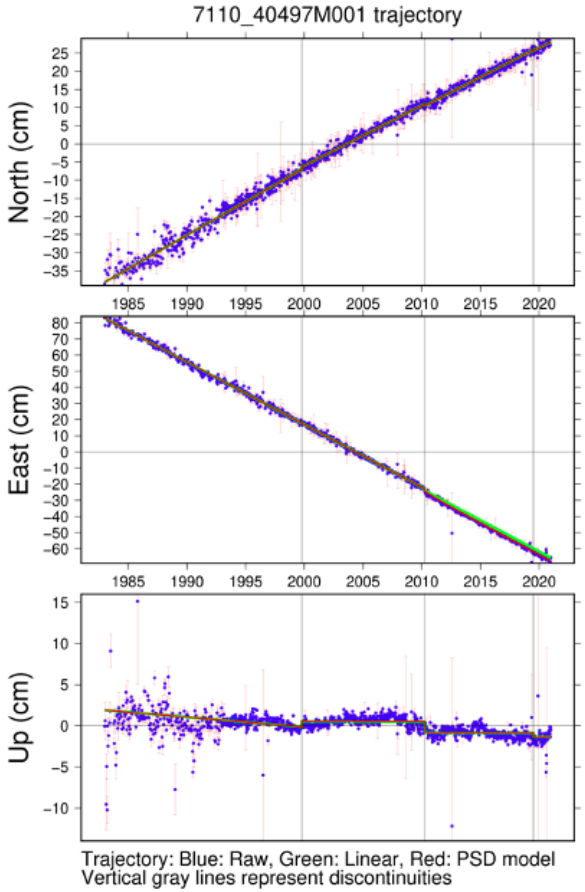
The SLR and GNSS stations each have different assignments
for the times of discontinuity events.

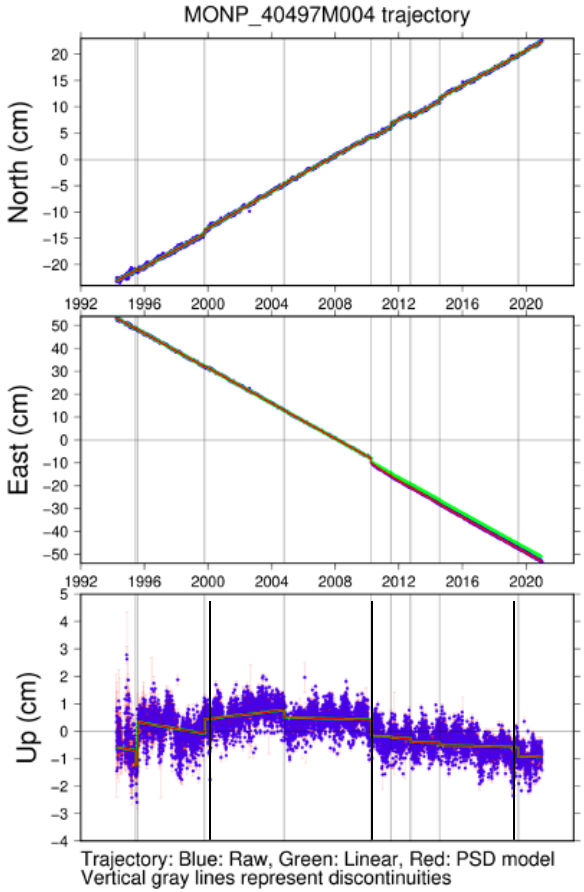
Reference
ITRF2020 [Data set]: Altamimi, Z., Rebischung, P., Collilieux, X., Métivier, L., Chanard, K. (2022) IERS ITRS Center Hosted by IGN and IPGP

MONUMENT PEAK SLR and GNSS stations



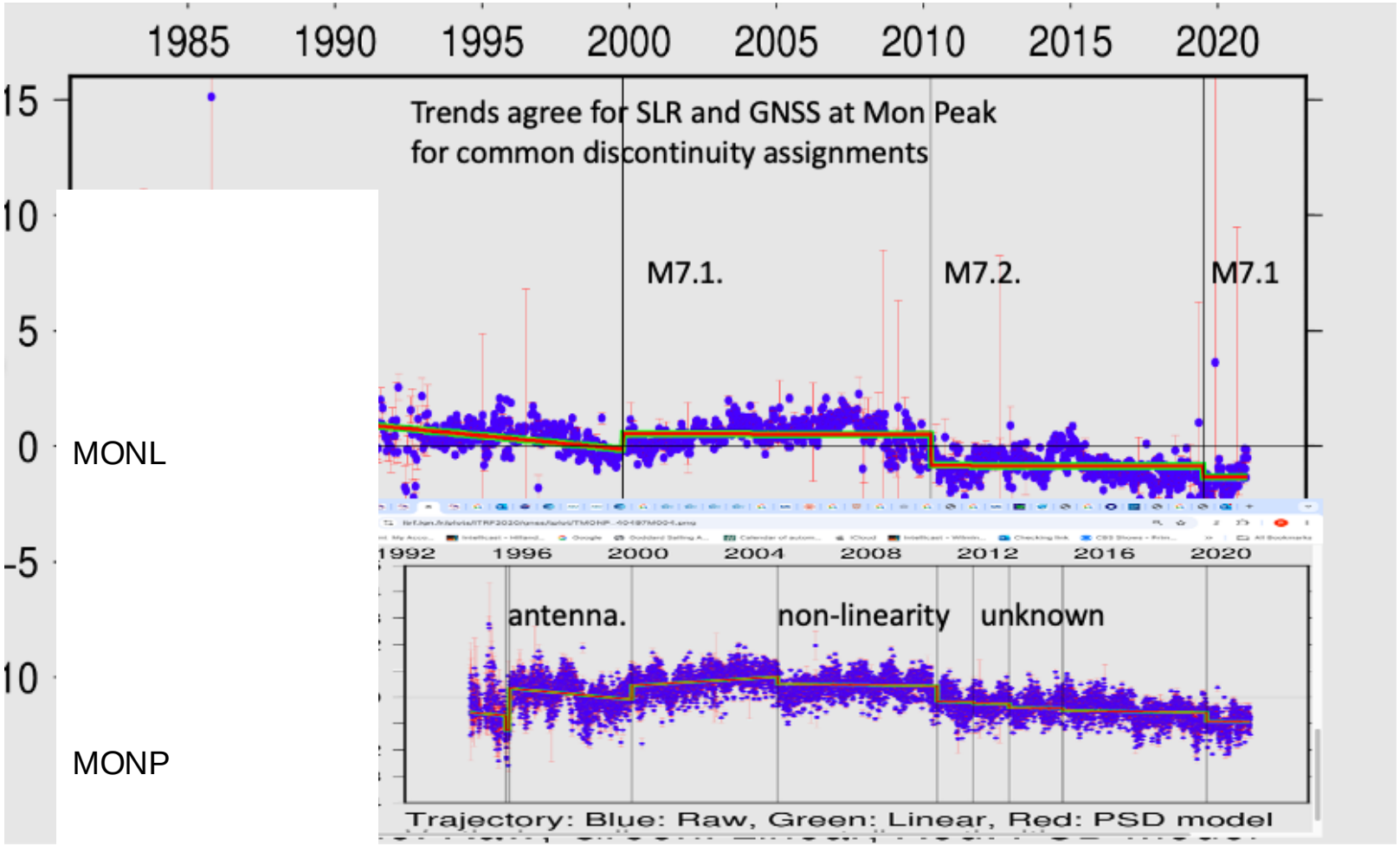
ITRF2020
MONL(SLR) and MONP(GNSS)





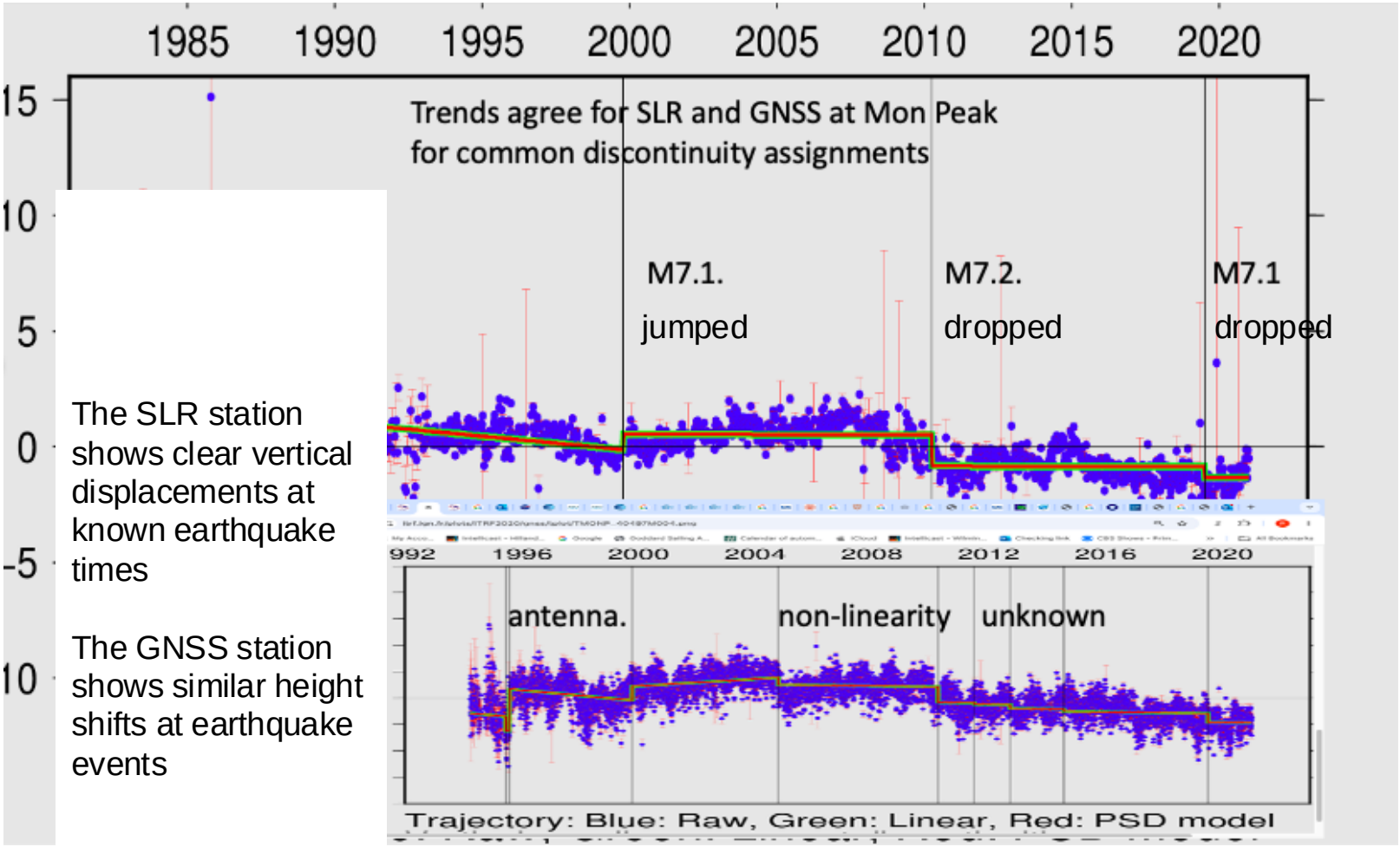
MONL/7110 and MONP show similar displacements at earthquake times

SLR and GNSS Heights on the same scale



SLR cf. GNSS: known earthquake discontinuities show matching vertical displacement

SLR and GNSS Heights on the same scale



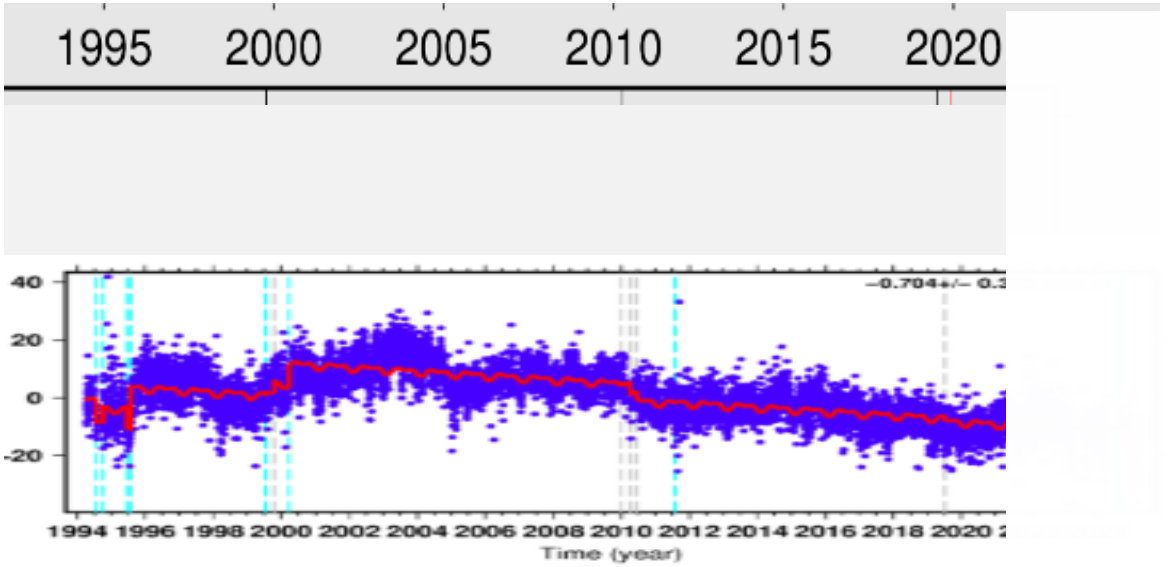
The SLR station shows clear vertical displacements at known earthquake times

The GNSS station shows similar height shifts at earthquake events

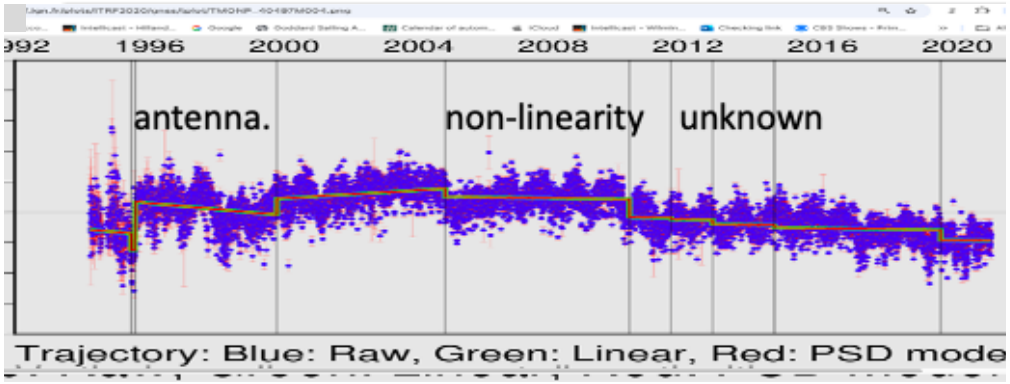
The GNSS height time series is interrupted by known and unknown discontinuities

GNSS Heights on the same scale

NGL



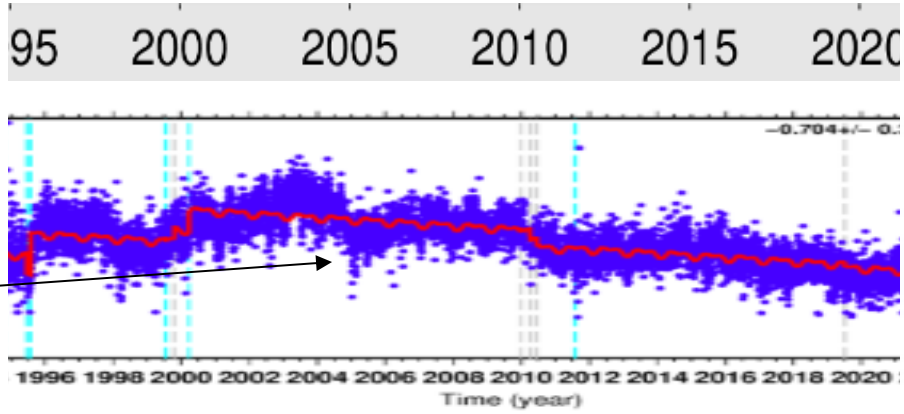
IGN



Nevada Geodetic Lab results have no 2005 discontinuity

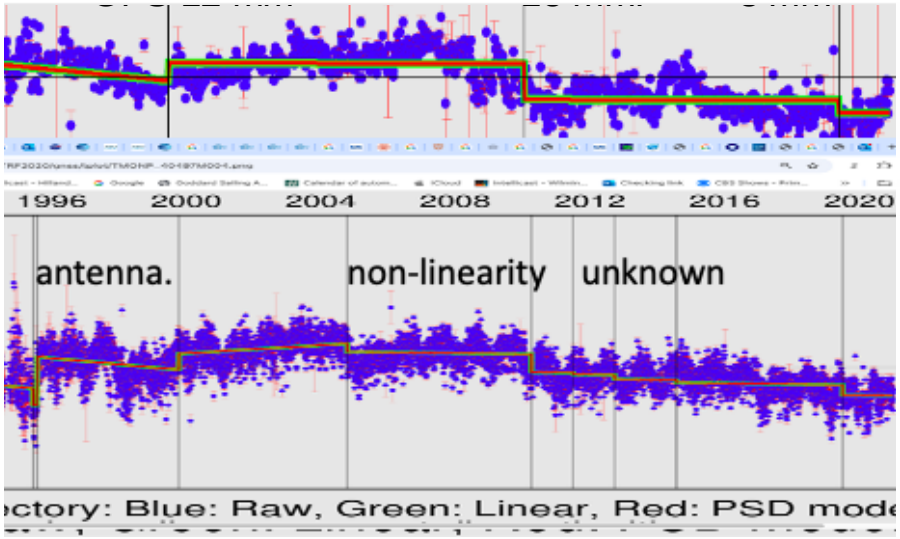
SLR and GNSS Heights on the same scale

NGL NGSS: no discontinuity:
shows downward displacement
In 2005



IGN SLR: no engineering discontinuities:
shows clear non-linear motion
between 2000 and 2010

IGN NGSS: with discontinuity for non-linearity
suggests engineering change
In 2005



NGL gives similar GNSS results (mostly)

Vertical Displacements at an active earthquake station: MOBLAS4

SUMMARY

MOB4 SLR (MONL) exhibits well-defined vertical motion between earthquakes.

In ITRF2020, discontinuities are introduced at known earthquake occurrence times

The vertical displacements of SLR and GNSS (MONP) are in close agreement at earthquake discontinuity times.

MONP heights are also affected by unmodeled engineering changes

MONL only shows significant vertical displacement at known earthquake events.

The inter-seismic deformation signal between the two large earthquakes is also well-defined by the SLR observations.

The ITRF2020 model shows mild subsidence for the DORIS station (MOOB) in the two-year series preceding the 2010 M7.2 event.

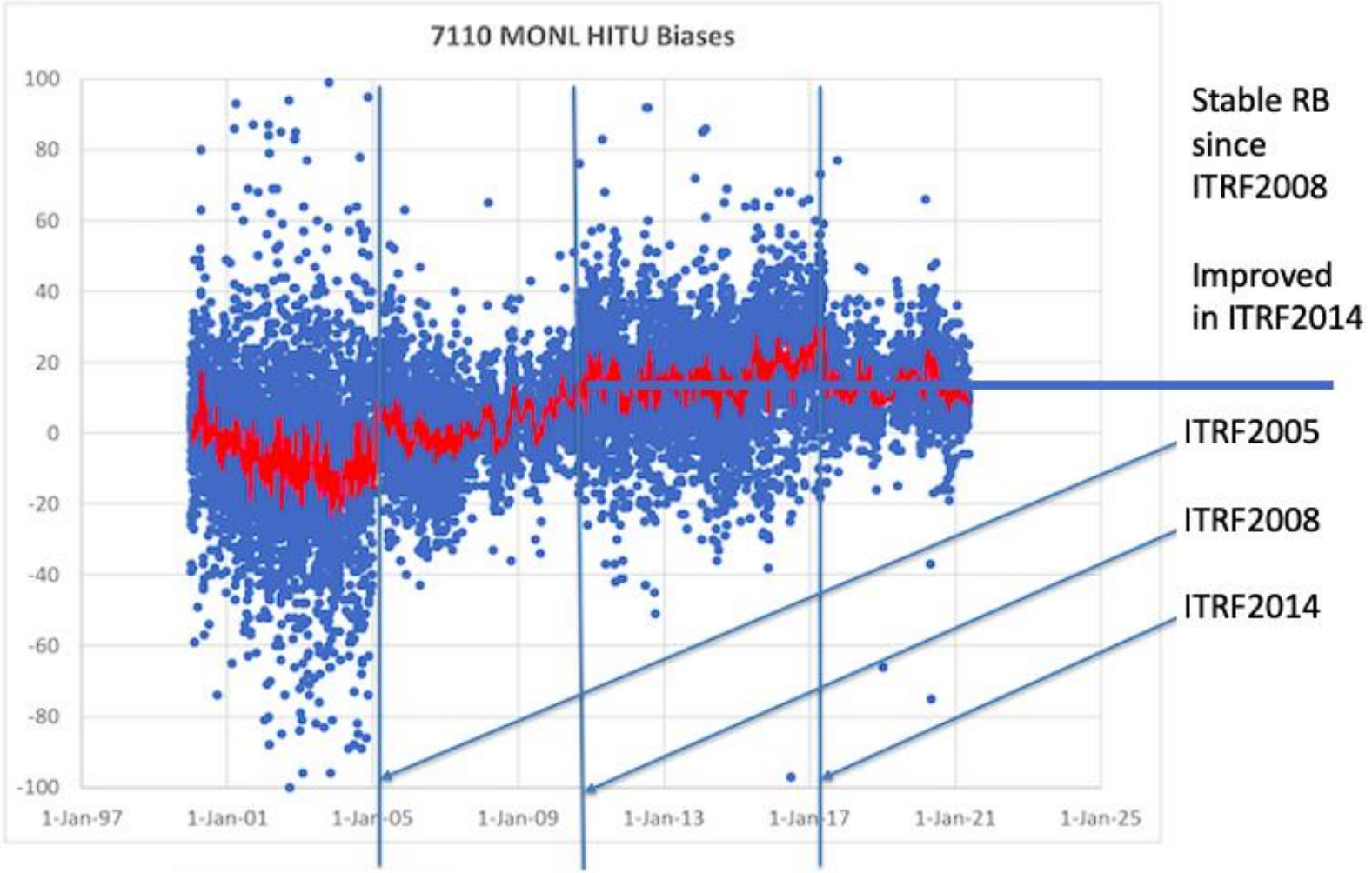
The DORIS results confirm the non-linear inter-seismic behavior observed by MONL.

Furthermore, the SGF SATAN SLR data analysis system confirms the long-term behavior of Monument Peak as a period of up-lift followed by subsidence.

This study suggests that short-term vertical positioning precision of the GNSS system can be successfully combined with SLR's accurate long-term resolution.

Thanks for Watching

MONL SLR Performance

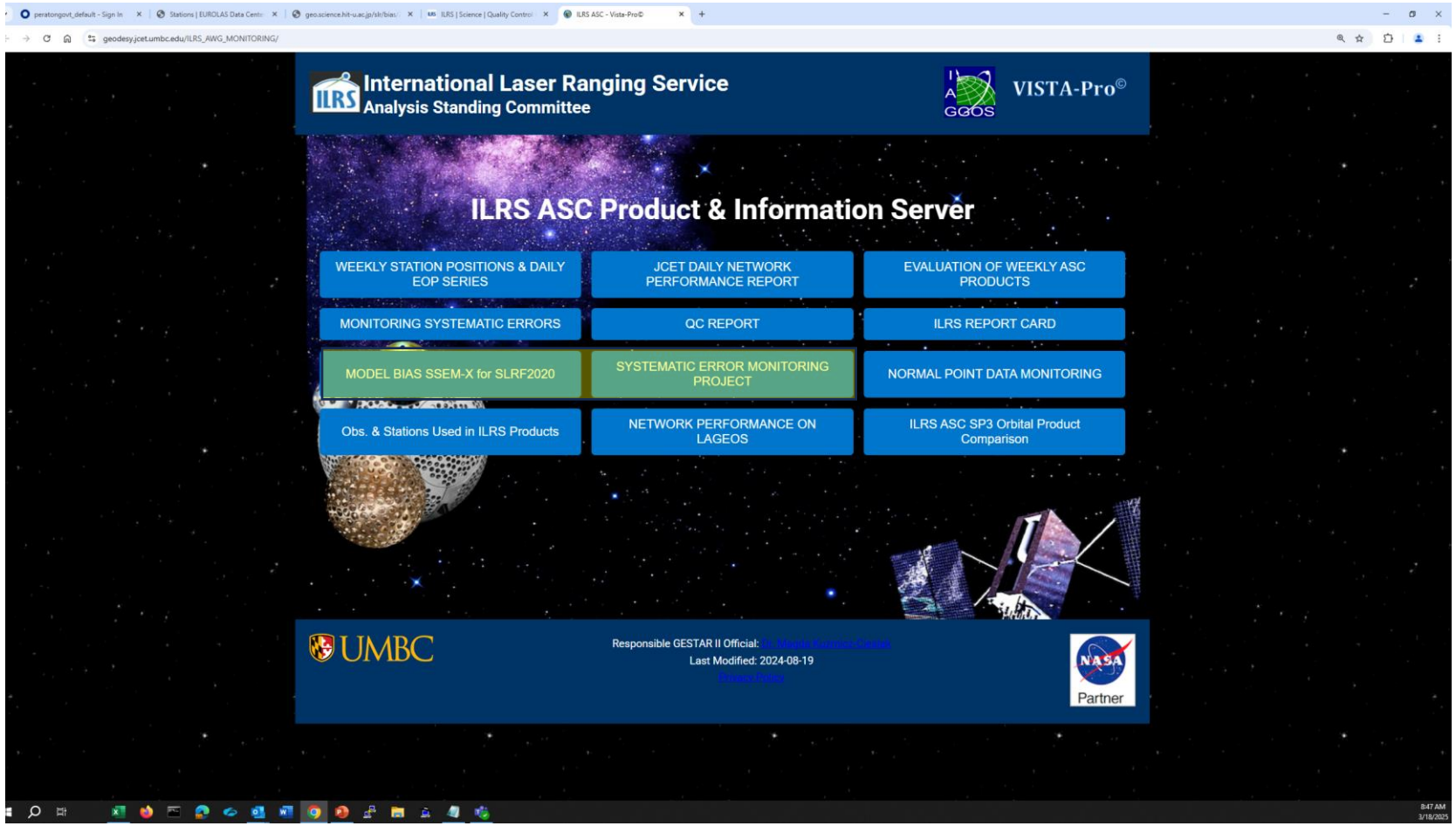


HITU RB Analysis shows that MOB4 SLR exhibits stable vertical behavior .

Investigation into ITRF2020_U2023 NASA SLR Height Discontinuities

Van S. Husson, Peter Dunn
ILRS QCB
24-Mar-2025

Analysis Tools from the JCET Website



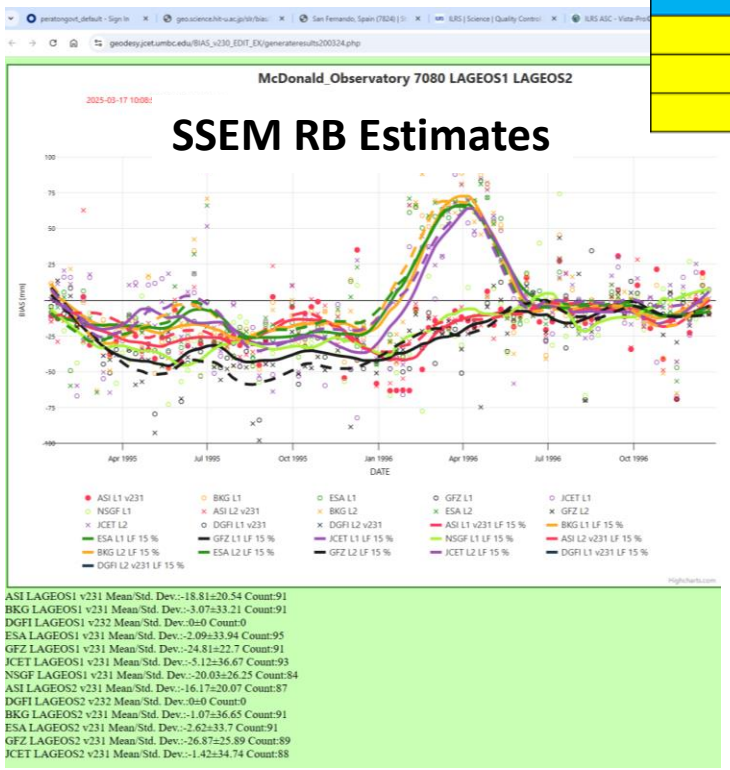
- The JCET website is a valuable resource for investigating SLR System performance issues
- The two tools that greatly assist in determining the root cause of ITRF2020 coordinate anomalies are the MODEL BIAS SSEM-X for SLR2020 and the SYSTEMATIC ERROR MONITORING PROHECT highlighted in green
- Magda is responsible for the development and maintenance of this website, and we are very thankful

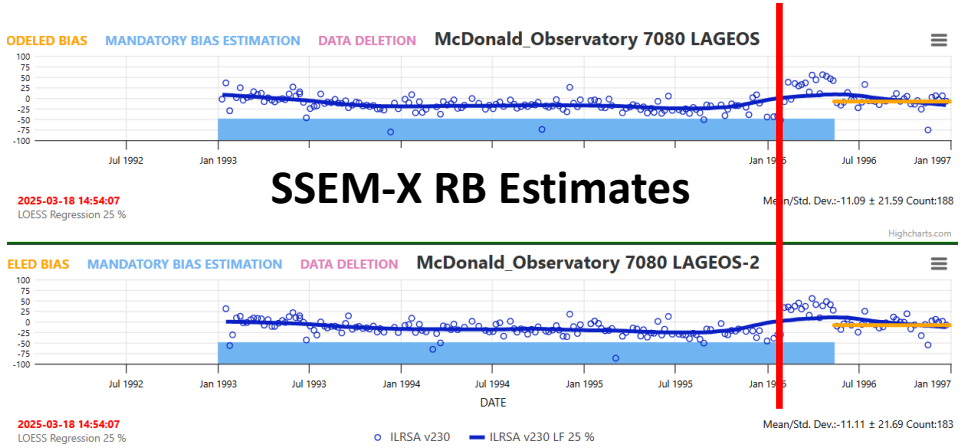
7080 MDOL DHF, Range Bias Estimates and ITRF2020 Station 'Up' Residuals

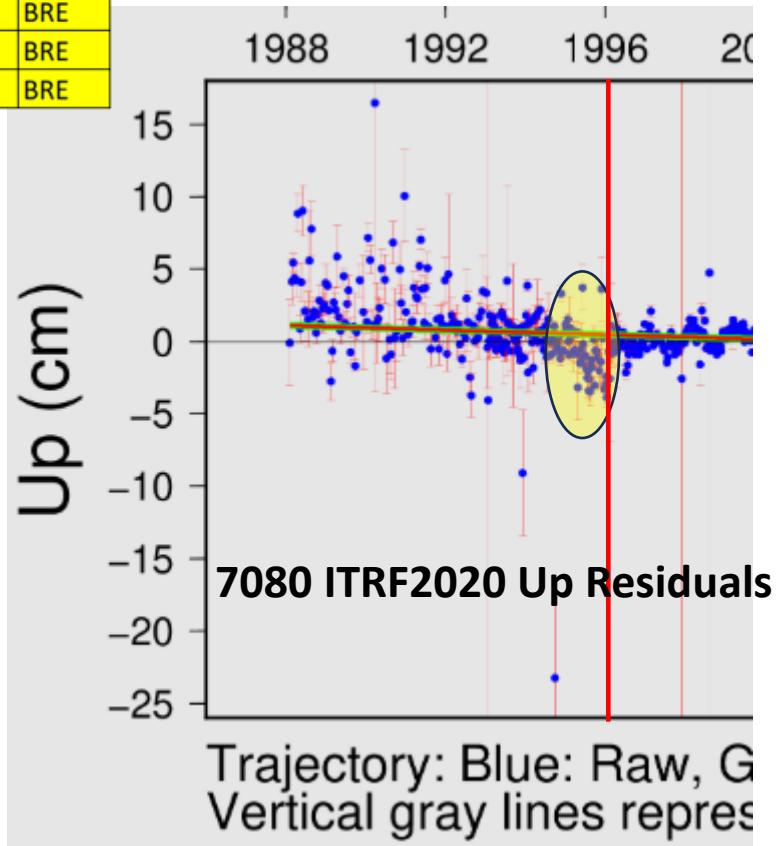
*COI	Pad	S			Start Da	End Da	Bias Co	Bi	S	Ra	UN	Com
	7080	51	501	A	93:001:00000	96:133:00000	E				mm	
	7080	52	501	A	93:001:00000	96:133:00000	E				mm	
	7080			A	95:065:00000	96:025:86400	P	-2.1			mB	BRE
	7080			A	96:026:00000	96:115:86400	P	-10.3			mB	BRE
	7080			A	96:116:00000	96:129:72000	P	-9.7			mB	BRE

Legend
Esitmate
Pressure Error

Legend	
51	LAGEOS-1
52	LAGEOS-2
	all Satellites

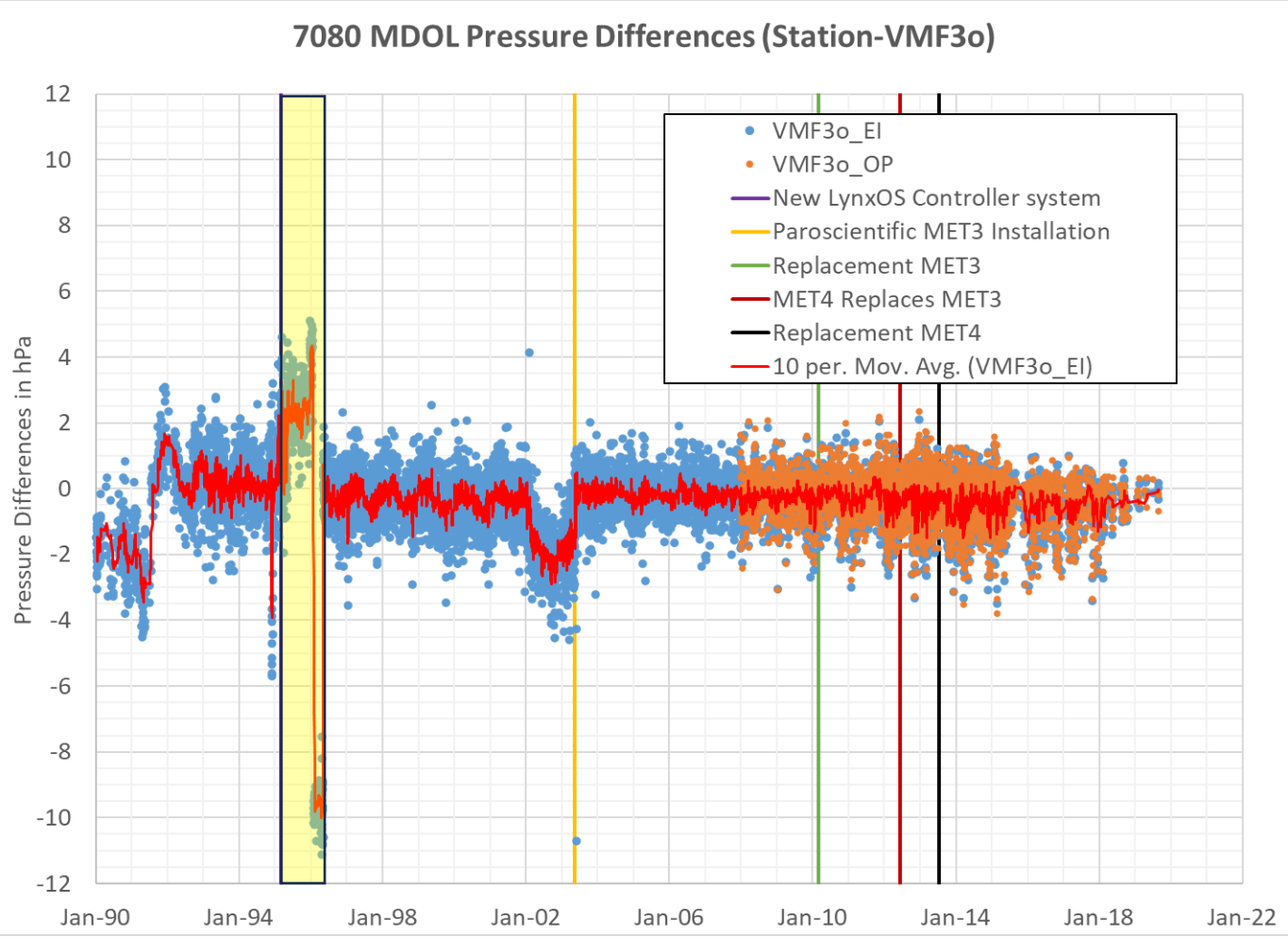






- There was an actual 14 mBar change in the barometric pressure on 25-Jan-1996 (see next 2 slides). Since biases were to be 'estimated' according to the DHF, it appears half the Analysis Centers applied barometric corrections prior to computing a range bias and the others didn't (see SSEM RB Estimates chart, middle left chart), which induced a discontinuity in the SSEM-x RBs, which in turn induced a height discontinuity

7080 MDOL Barometric Analysis Six-Hour Differences



- ❑ **Five different sensors have been used to measure the barometric pressure**
- ❑ **Using the VMF data, it is easy so identify sudden changes in the average 6 hours pressures**
- ❑ **The Paroscientific MET3 sensor was installed on 17-May-2003 which stabilized the observed 6-hour differences except for an obvious outlier on 30-May-2003**
- ❑ **The current ILRS Data Handling File (6-Feb-2025) only has barometric corrections for the period highlighted in yellow**

7080 MDOL Barometric Error Models

Current ILRS DHF

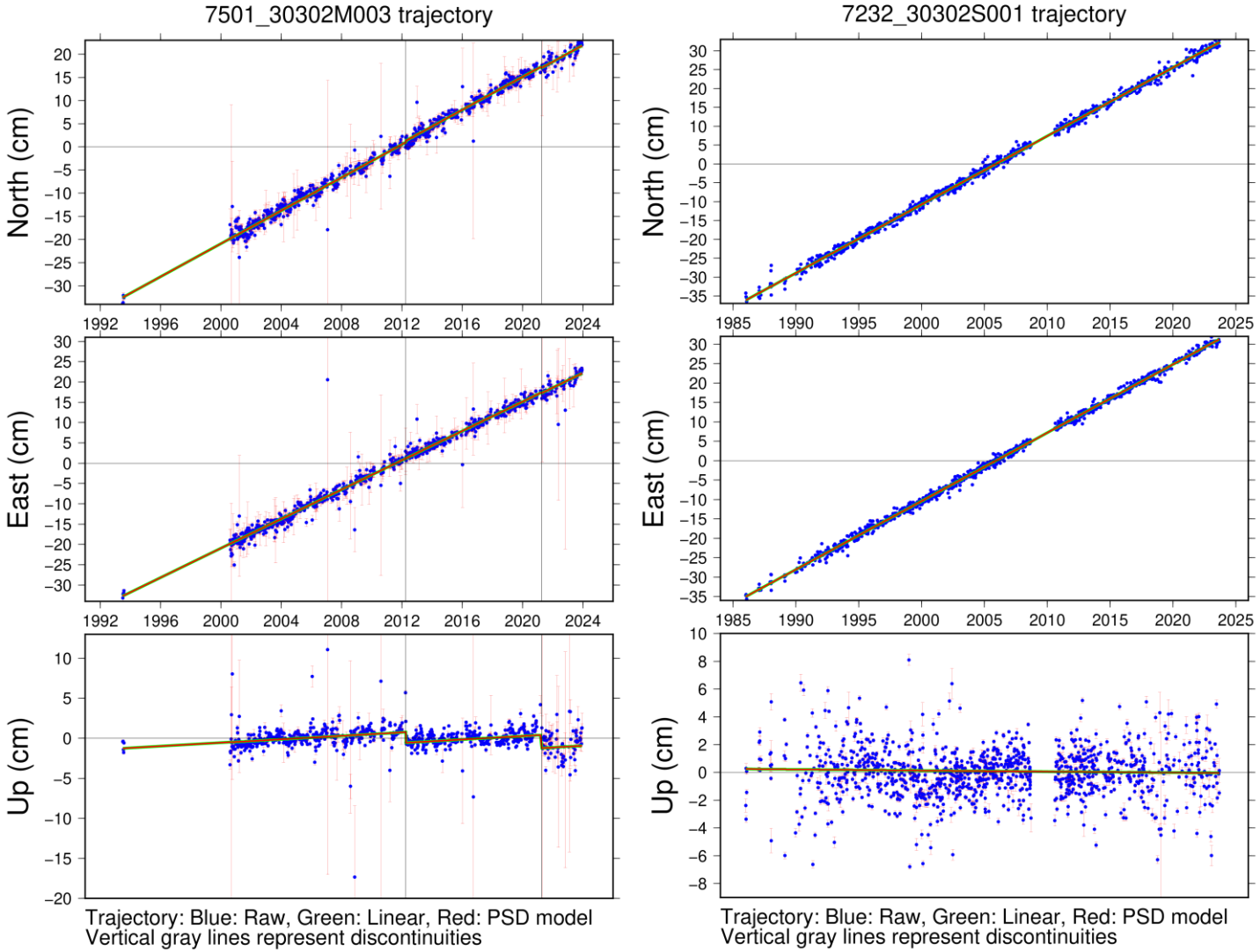
*COI	Pad_	S			Start Da	End Da	Bias Co	Bi	S	Ra	UN	Com
	7080			A	95:065:00000	96:025:86400	P	-2.1			mB	BRE
	7080			A	96:026:00000	96:115:86400	P	-10.3			mB	BRE
	7080			A	96:116:00000	96:129:72000	P	-9.7			mB	BRE

Future ILRS DHF

	7080			A	90:001:00000	91:199:00000	P	-1.8	0.5		mB	BRE
	7080			A	94:333:54000	94:335:32400	P	-4.6	0.5		mB	BRE
	7080			A	95:065:00000	95:362:08100	P	2.4	0.5		mB	BRE
	7080			A	95:362:08100	96:025:86400	P	4.4	0.5		mB	BRE
	7080			A	96:026:00000	96:129:72000	P	-9.4	0.5		mB	BRE
	7080			A	02:038:00000	03:137:00000	P	-1.7	0.5		mB	BRE
	7080			A	03:150:26340	03:150:43200	P	-11.5	1.0		mB	BRE

- ❑ There is a typo in the sign (- versus +) of the first barometric correction in the current DHF
- ❑ The proposed corrections are based on VMF comparisons

Hartebeesthoek ITRF2020_U2023 SLR and VLBI Station Residuals



- 7501 is SLR (MTLRS in 1993 and MOBLAS-6 since 2000) and 7232 is VLBI
- There are two unknown discontinuities (>10mm) in the 7501 'Up' residuals. The SLR height rate is slightly positive while the VLBI height rate is flat
- The two 7501 unknown height discontinuities were in April 2012 and 2021; respectively

7501 HARL Data Handling File Range Biases Instructions

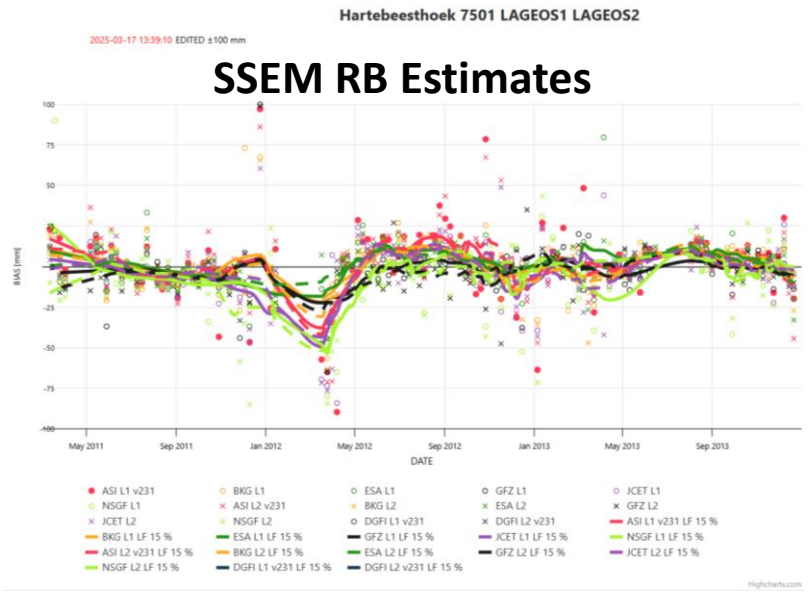
*COD	Pad_ic	S		PT	Start Date	End Date	Bias Code	Bias	STD	Rate	UNIT	Comments
	7501	51	501	A	00:219:00000	17:050:00000	R	1.7	0.3		mm	
	7501	51	501	A	17:057:00000	19:041:00000	R	6	0.6		mm	
	7501	51	501	A	19:041:00000	21:001:00000	R	13.1	1.1		mm	
	7501	52	501	A	00:219:00000	17:050:00000	R	2.1	0.3		mm	
	7501	52	501	A	17:057:00000	19:041:00000	R	6.8	0.7		mm	
	7501	52	501	A	19:041:00000	21:001:00000	R	13	1.1		mm	
	7501	51	501	A	21:001:00000	00:000:00000	E				mm	
	7501	52	501	A	21:001:00000	00:000:00000	E				mm	
*	7501			A	12:071:00000	12:073:64080	R	-66			mm	
*	7501			A	12:074:21600	12:074:79200	R	-66			mm	
*	7501			A	12:077:57600	12:079:08400	R	-66			mm	
*	7501			A	12:079:36000	12:080:05400	R	-66			mm	
*	7501			A	12:080:14400	12:089:75600	R	-66			mm	
*	7501			A	12:090:43000	12:092:07800	R	-66			mm	
*	7501			A	12:092:64800	12:094:28800	R	-66			mm	

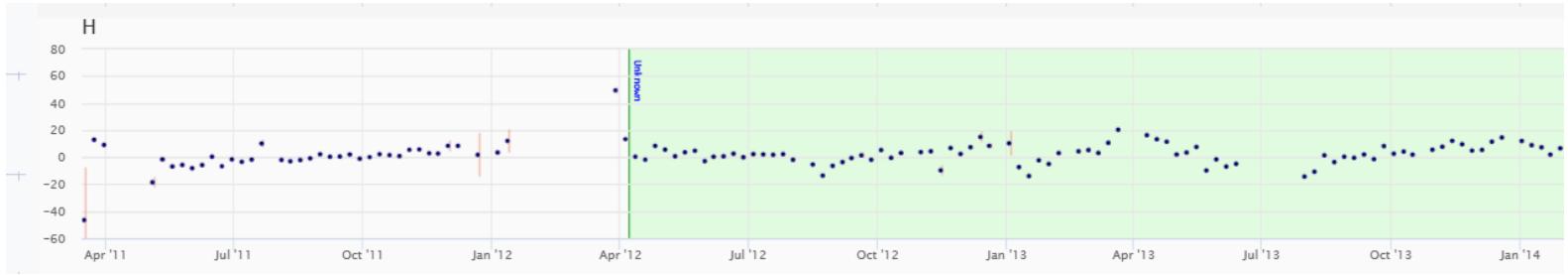
Legend	
51	LAGEOS-1
52	LAGEOS-2
	all Satellites

Legend	
R	Apply
E	Estimate

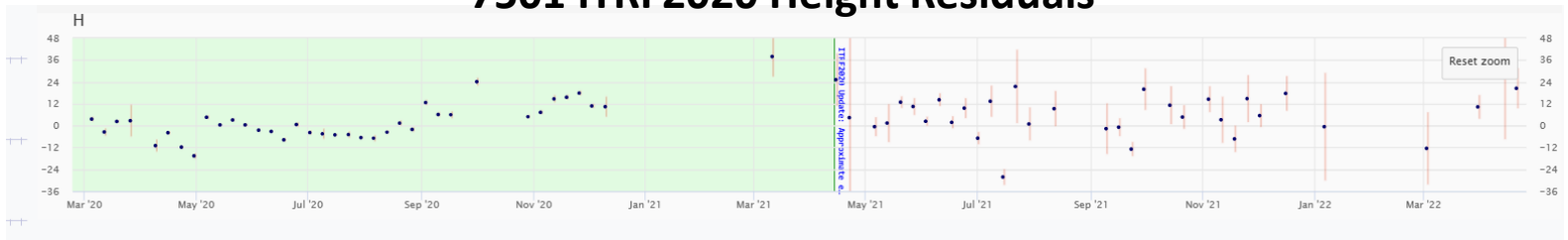
- According to the DHF, a constant range bias (1.7 and 2.1 mm) were to be applied to all LAGEOS-1 and -2 data; respectively, from 6-Aug-2000 to 19-Feb-2017
- MOBLAS-6 had a laser failure in January 2012 and was offline until 12-Mar-2012. During their down time, the onsite target range of their 'legacy' operational target was modified by 66 mm, inducing a -66 mm range bias on data taken using that target. Also, in March 2012 they started ranging intermittently to a new ground target and why some passes in March and early April 2012 were biased by -66mm and some were not. The switched exclusively to their a new calibration target on 5-Apr-2012
- According to the DHF, applying the intermittent -66mm range biases were optional; marked by an asterisk '*' in the first field

7501 HARL Range Bias Estimates and ITRF2020 Station "Up" Residuals

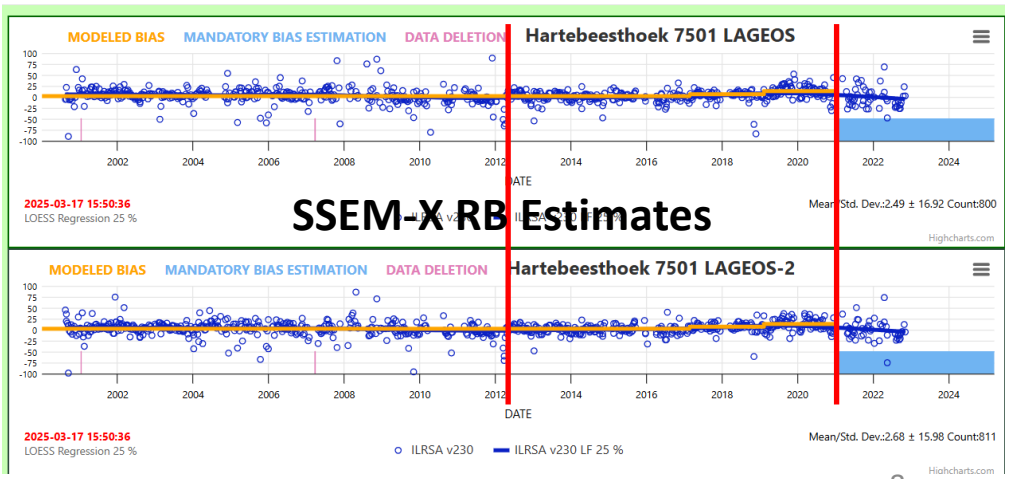




7501 ITRF2020 Height Residuals



- The two 7501 unknown height discontinuities were in April 2012 and 2021; respectively. The 7501 LAGEOS data was more sparse post April 2021, evidenced by the larger error bars
- The SSEM RBs were different pre and post April 2012, but a constant RB was modelled, so the range bias change was absorbed in the station height, inducing a discontinuity
- LAGEOS range biases were held fixed at +13 mm prior to April 2021 and were to be estimated after that. Did that bias treatment induce the height discontinuity. See next slide



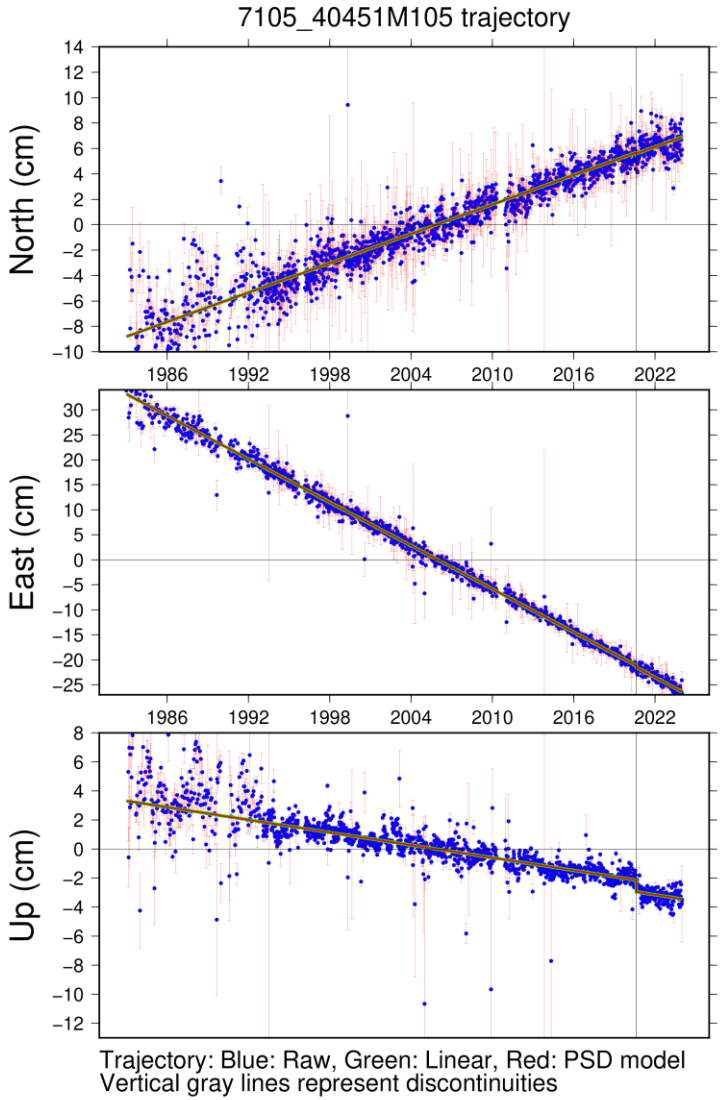
SSEM-X RB Estimates

7501 HARL LAGEOS-1 Passes per Hour and Year

7501 HARL LAGEOS-1 Passes per Hour per Year																									
GMT	Local	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
0	2		4	2	27	5	11	19	15	5	14	11	16	27	21	29	24	8	21	25	21	31	15	2	18
1	3		2	8	20	5	4	18	17	3	15	8	10	24	17	23	19	11	16	18	14	19	14	11	10
2	4		2	4	21	12	5	22	7	1	7	7	5	20	18	13	18	13	14	23	22	18	8	6	14
3	5		3	6	19	13	10	19	10	6	18	5	4	15	17	9	20	11	13	8	14	12	7	8	5
4	6		1	7	15	12	2	18	9	2	10		2	11	10	5	14		4	4	3	2			1
5	7		2	8	18	9	1	14	2	3	7	1	5	12	4	9	8		1		1				
6	8		17	9	19	8	6	14	3	7	1	2	4	6	7	4	5		1						
7	9		14	11	17	6	2	9	4	2		1	3	5	10	5	8	1	1						
8	10		11	9	14	0	3	7	1	2	2	2	9	8	10	7	7	1	1						
9	11	1	16	6	13	1	7	3	4	9		3	9	8	14	9	4	2	1						
10	12	1	12	16	12		8		4	3	5	4	12	4	10	15	4	1	1		1				
11	13		16	15	8	3	4		5	4	2		10	6	7	16	1			2					
12	14	2	8	17	2	3	7		3	6	2	1	14	2	5	13			1						
13	15		8	16	15	6	7	2	5	4	2		18	4	7	14			3						
14	16		13	18	12	8	5	8	2	4	5		12	6	5	17		1	3		1				
15	17	1	8	39	18	14	4	16	4	5	7		17	10	9	19			9		5	5			2
16	18	6	16	38	31	9	12	27	5	14	16	2	22	16	13	24	7	5	16	5	17	17		7	8
17	19	4	20	34	30	11	20	24	6	8	13	5	29	16	20	27	12	8	24	9	24	27	2	5	6
18	20	3	22	28	24	12	23	29	2	8	14	5	32	26	20	34	17	5	35	19	22	25	13	6	13
19	21	6	16	28	29	5	17	31	2	8	24	12	31	17	16	25	26	5	27	20	17	26	8	6	13
20	22	5	22	27	34	7	19	26	3	5	20	11	30	25	14	26	30	4	25	29	14	26	8	2	12
21	23	5	17	18	35	3	9	27	2	3	14	11	25	24	16	31	30	6	20	26	25	22	8	6	18
22	0	0	4	6	30	2	12	34	12	3	17	9	24	26	25	28	27	4	18	25	15	25	17	5	16
23	1		6	12	25	2	6	22	11	3	21	11	11	23	15	21	16	9	20	18	17	20	8	8	17
Total		34	260	382	488	156	204	389	138	118	236	111	354	341	310	423	297	95	275	231	233	275	108	72	153

- Accurate range bias determination relies upon adequate LAGEOS data yield with good spatial and temporal resolution
- Noticed than since 2014, there is a noticeable reduction in daylight LAGEOS ranging and a large drop off in system performance in 2021, when range biases are to be estimated

7105 GODL ITRF2020 Height Residuals and DHF



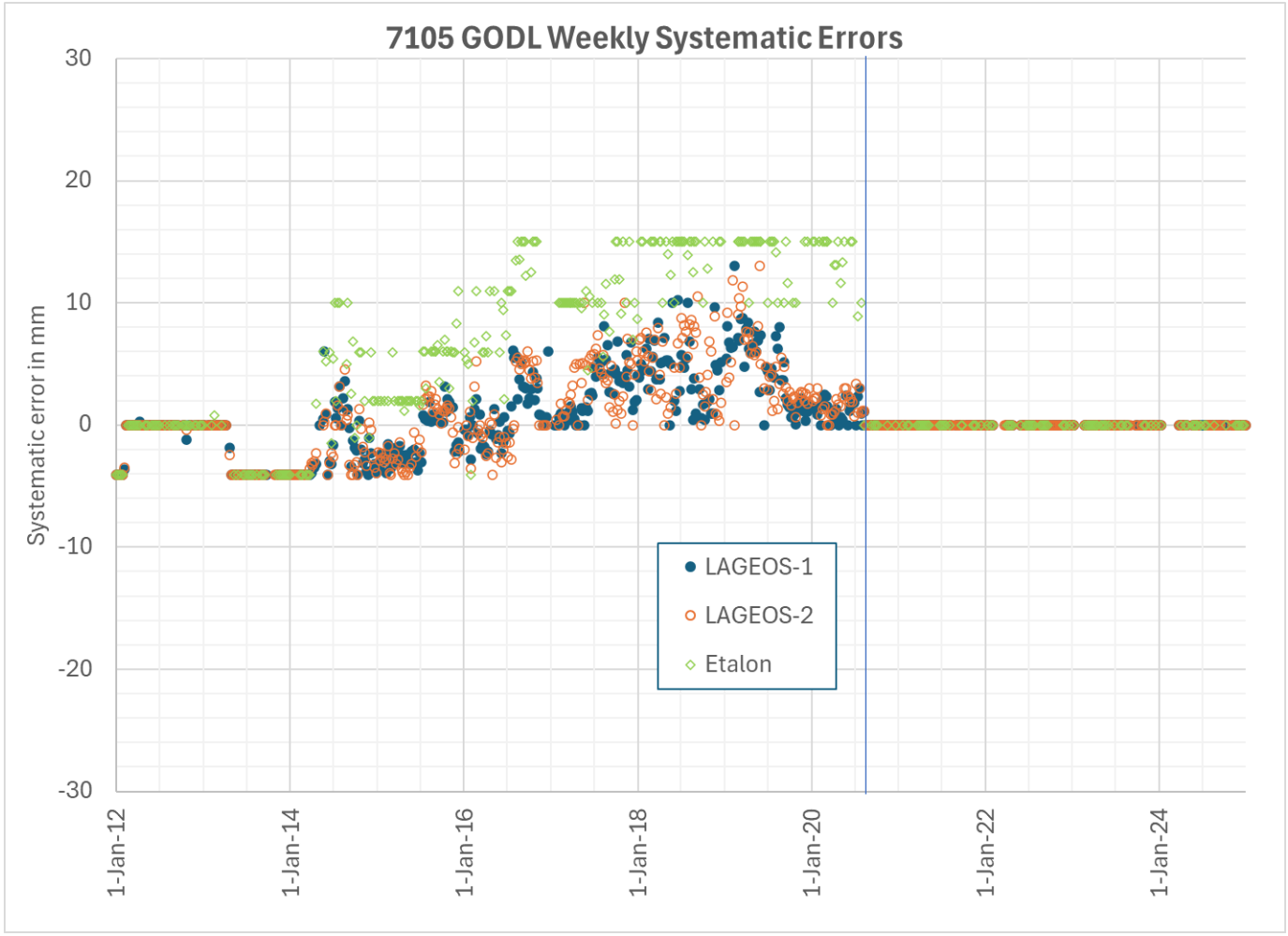
*CODE	Pad_id	S		PT	Start Date	End Date	Bias Co	Bias	STD	Rate	UNIT	Comme
	7105	51	501	A	93:017:00000	95:253:00000	R	-6.3	0.7		mm	
	7105	52	501	A	93:017:00000	95:253:00000	R	-6.2	0.6		mm	
	7105	51	501	A	96:056:00000	98:193:00000	R	3.4	0.7		mm	
	7105	52	501	A	96:056:00000	98:193:00000	R	3	0.7		mm	
	7105	51	501	A	98:193:00000	10:122:00000	R	-2.9	0.3		mm	
	7105	52	501	A	98:193:00000	10:122:00000	R	-2.9	0.3		mm	
	7105	51	501	A	10:339:00000	17:029:00000	R	-7.1	0.3		mm	
	7105	52	501	A	10:339:00000	17:029:00000	R	-6	0.3		mm	
		51			17:029:00000	20:047:00000						
		52			17:029:00000	20:047:00000						
	7105	51	501	A	20:047:00000	00:000:00000	R	-5.1	0.4		mm	
	7105	52	501	A	20:047:00000	00:000:00000	R	-4.3	0.4		mm	

Legend
no range bias estimation , not in DHF
apply fixed Range Bias

Legend	
51	LAGEOS-1
52	LAGEOS-2

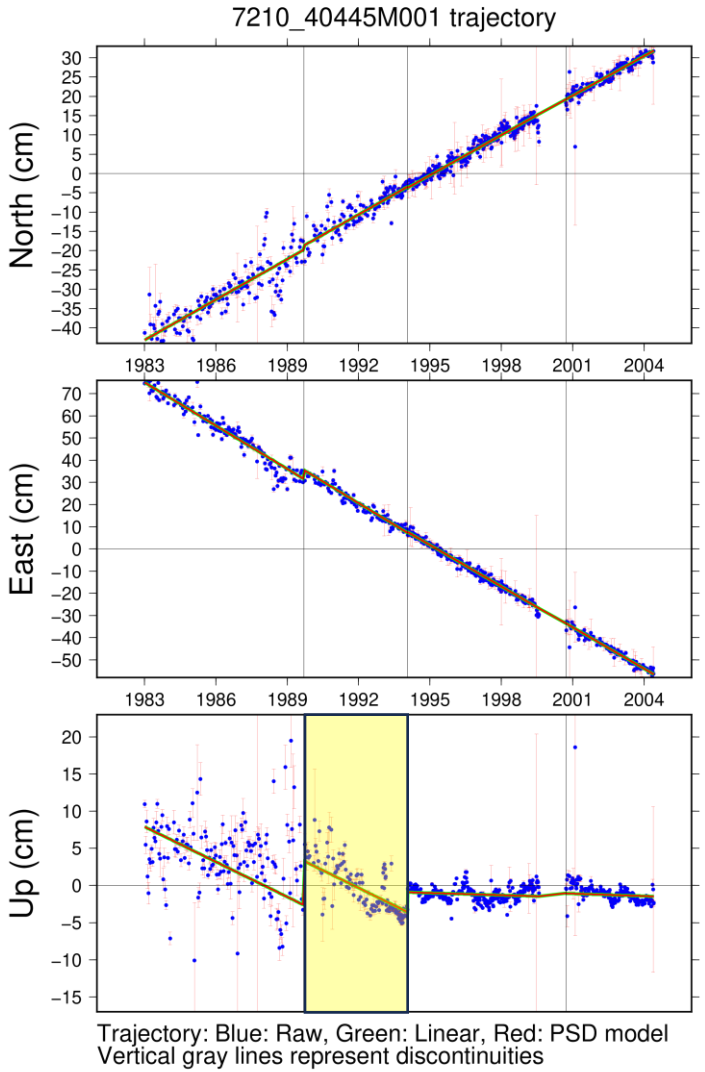
- ❑ **There is an 8 mm ‘unknown’ discontinuity in the 7105 ITRF2020_U2023 height residuals on 20-August-2020**
- ❑ **Based on the DHF, a -5.1 and -4.3 mm LAGEOS-1 and -2 range bias; respectively, are to be applied starting on 16-Feb-2020, 6 months before the height discontinuity**

7105 GODL Systematic Errors based on Engineering Tests



- Here is a weekly time series of 'known' 7105 GODL systematic errors based on engineering ground tests (i.e. PMT Tests) along with HP5370B vs Event Timer comparison results
- 7105 GODL PMT voltage variations and their impact were discussed at the March 2020 QCB meeting. On 14-Aug-2020, the 7105 GODL PMT voltage systematic error was eliminated by taking calibrations at the same PMT voltage as the corresponding satellite data. However; the DHF indicates a change in the LAGEOS Range Bias (RB) 6 months prior. The discontinuity in the ITRF2020_U2023 station height was just a few days later (20-Aug-2020). This is no coincidence since the 'real' change in RB was not modelled and was absorbed into the station height

7210 HALL ITRF2020 Height Residuals



- There are three discontinuities in the 7210 HOLL ITRF2020 height residuals. The first two discontinuities are quite large (i.e. a few cm)
- The 7210 HOLL HP5370A Time Interval Unit (TIU) was on internal frequency from August 1989 to 21-Jan-1994
- A frequency error will be range dependent and will drift linearly over time
- Based on the height residuals from 1983 to 1989, the station's HP5370A may have been on internal frequency. The lead engineer liked keeping the TIU on internal frequency because it yielded the best single shot RMSs
- The height residuals post 21-Jan-1994 to 1999 were not very stable, more on that later

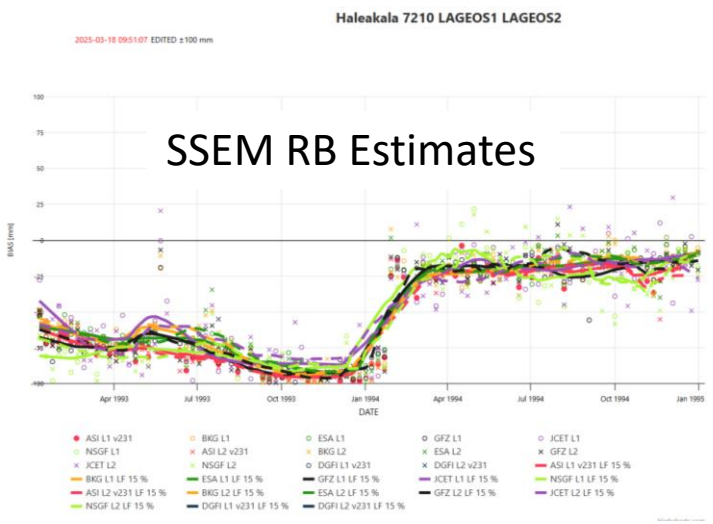
7210 HALL DHF Entries and SSEM Range Biases

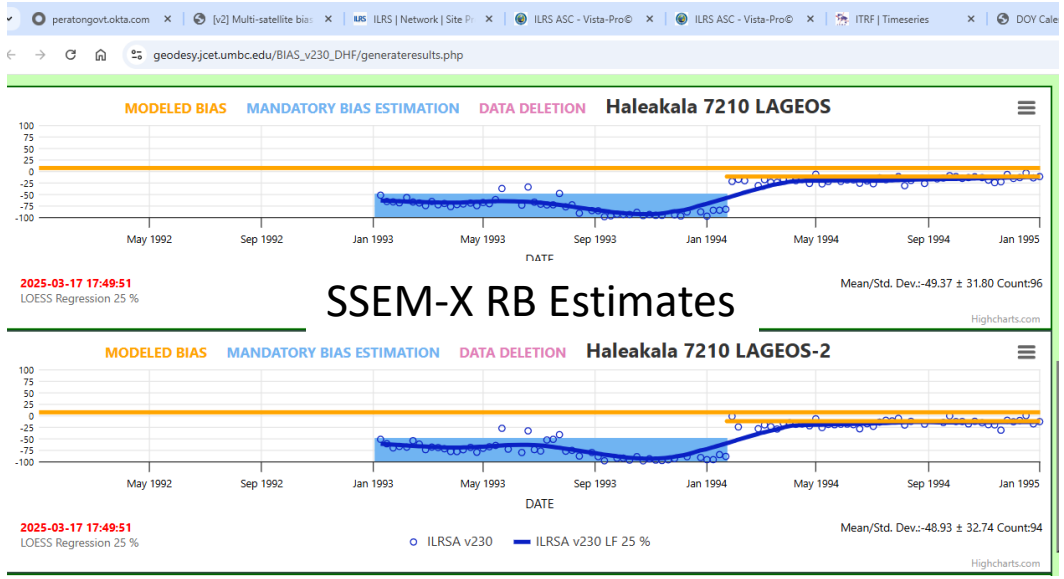
*COI	Pad_id	S		PT	Start Date	End Date	Bias Code	Bias	STD	Rate	UNIT	Comments
	7210			A	83:001:00000	87:255:00000	R	25			mm	
	7210			A	87:255:00000	93:001:00000	R	-37			mm	
	7210	51	501	A	93:003:00000	94:023:00000	E				mm	
	7210	51	501	A	94:023:00000	99:220:00000	R	-12	0.7		mm	
	7210	51	501	A	00:261:00000	04:158:00000	R	6.5	0.6		mm	
	7210	52	501	A	93:003:00000	94:023:00000	E				mm	
	7210	52	501	A	94:023:00000	99:220:00000	R	-12.7	0.7		mm	
	7210	52	501	A	00:261:00000	04:158:00000	R	6.6	0.7		mm	

Legend	
51	LAGEOS-1
52	LAGEOS-2
	all Satellites

Legend	
R	Appy
E	Estimate

- **Based on the DHF, a constant Range Bias (RB) of -37 mm is to be applied to all 7210 satellite between 12-Sep-1987 and 1-Jan-1993**
- **Between 1-Jan-1993 to 23-Jan-1994, the LAGEOS RBs are to estimated**
- **Post 23-Jan-1994, a constant RB (+6.5/+6.6 mm) is to be applied**



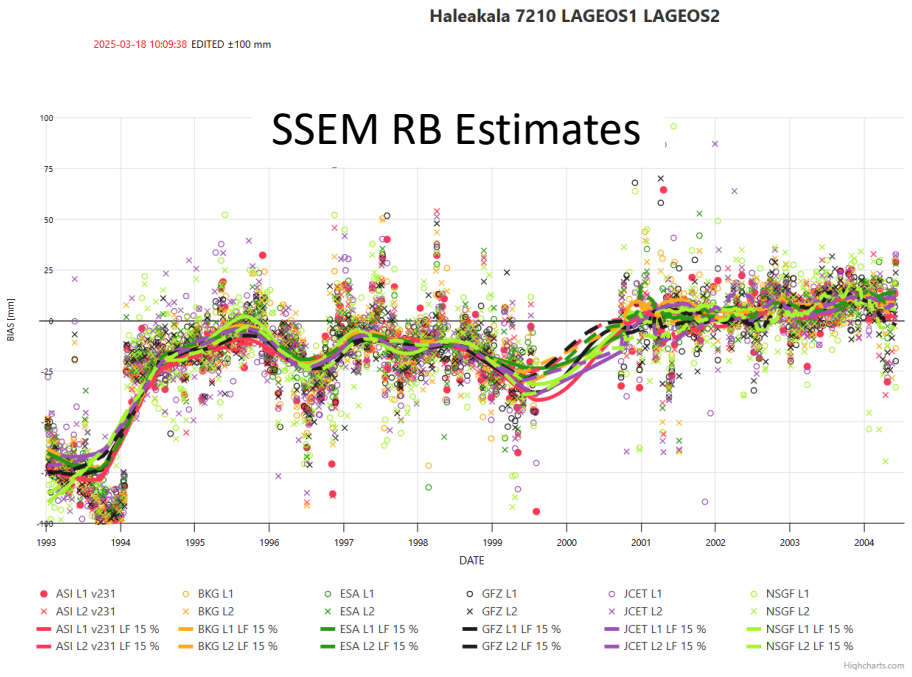


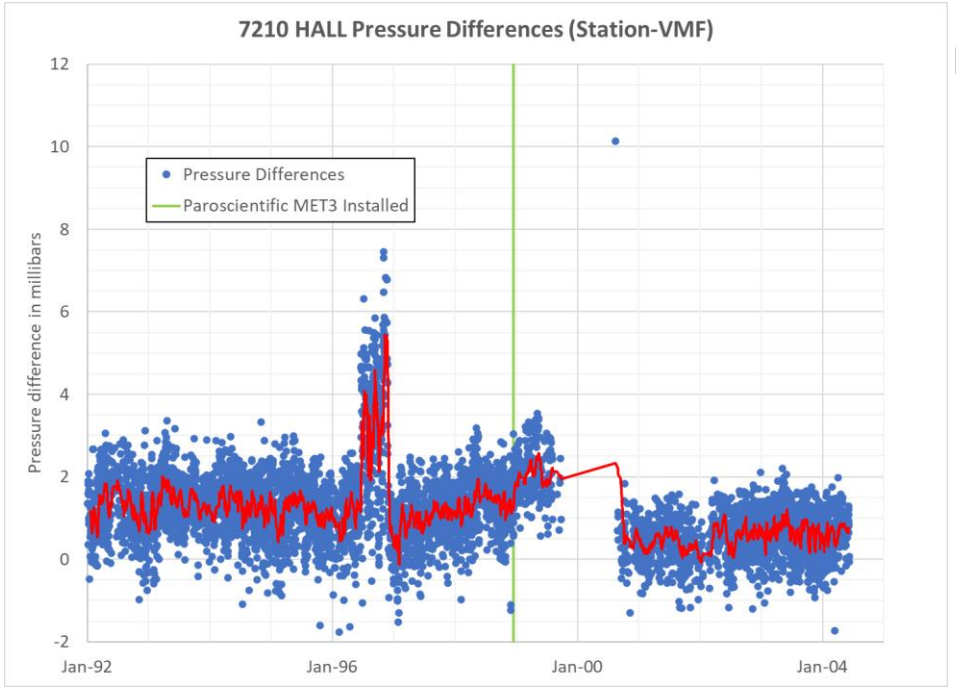
7210 HALL DHF Entries and SSEM Range Biases

*COI	Pad_id	S		PT	Start Date	End Date	Bias Code	Bias	STD	Rate	UNIT	Comments
	7210			A	83:001:00000	87:255:00000	R	25			mm	
	7210			A	87:255:00000	93:001:00000	R	-37			mm	
	7210	51	501	A	93:003:00000	94:023:00000	E				mm	
	7210	51	501	A	94:023:00000	99:220:00000	R	-12	0.7		mm	
	7210	51	501	A	00:261:00000	04:158:00000	R	6.5	0.6		mm	
	7210	52	501	A	93:003:00000	94:023:00000	E				mm	
	7210	52	501	A	94:023:00000	99:220:00000	R	-12.7	0.7		mm	
	7210	52	501	A	00:261:00000	04:158:00000	R	6.6	0.7		mm	

Legend	
51	LAGEOS-1
52	LAGEOS-2
	all Satellites

Legend	
R	Appy
E	Estimate





- **Based on the DHF a constant LAGEOS-1 and LAGEOS-2 RB of -12 and -12.7 mm; respectively, is to be applied to all data between 23-Feb-1994 and 6-Aug-1999**
- **Based on SSEM results the range bias had some obvious variations during this period (‘94 to ‘99). The negative dip in SSEM range biases in 1996 were caused by a unmodeled change in the station’s barometric pressures**

Summary

- **The handling of biases in ITRF2020 has resulted in some discontinuities in NASA SLR heights**
  - Any SLR coordinate height error will induce an ‘apparent’ range bias in SLR short arc analysis (e.g. HITU or JCET results) and in altimeter mission analysis results
- **Estimating a fixed range bias will not remove all the systematic trends caused by a barometric or frequency error**
  - Known elevation, range and range-rate dependent errors should be applied ‘a priori’ before estimating a range bias
- **Good temporal and spatial LAGEOS (1,2) and LARES-2 coverage is needed to accurately separate range bias from station height**
  - Is 200 passes/year on each ITRF satellite enough data?

NASA SLR Local Site Survey Issues

Van Husson

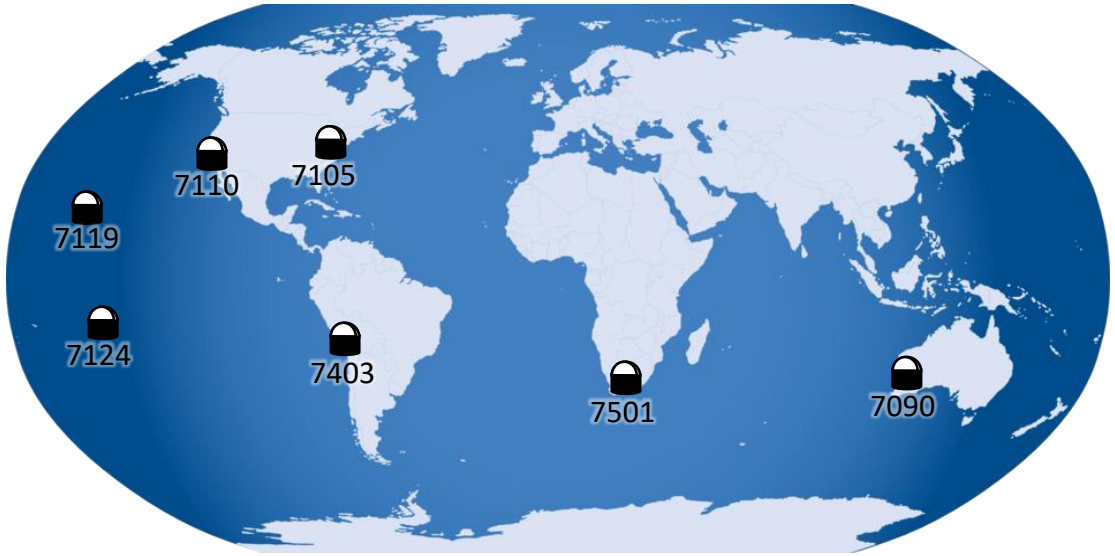
ILRS QCB 24-Mar-2025

Current Active NASA SLR Systems in ITRF2020

- **MOBile LAser ranging Systems 4-8 (MOBLAS 4-8):**
  - MOBLAS 4 at Monument Peak, USA (7110, MONL);
  - MOBLAS-5 at Yarragadee, Australia (7090, YARL)
  - MOBLAS-6 at Hartebeesthoek, South Africa (7501, HARL)
  - MOBLAS-7 at Greenbelt, USA (7105, GODL)
  - MOBLAS-8 at Tahiti, French Polynesia (7124, THTL)
- **Transportable Laser Ranging Systems 3-4 (TLRS 3-4)**
  - TLRS-3 at Arequipa, Peru (7403, AREL)
  - TLRS-4 at Haleakala, USA (7119, HA4T)

Calibration Pier

NASA Monument



NASA SLR Calibration Pier

Figure 1

Figure 2

Figure 3

Figure 4

- NASA SLR systems utilize concrete calibration piers, located within a few hundred meters, for operational calibrations and system characterization tests
- Each NASA SLR calibration pier has a force-centering device which is designed to accept an adapter (Figure 1). For SLR operations, a calibration prism is mounted on the adapter (Figures 2 and 3). During a survey, surveying instrumentation is mounted on the calibration pier adapter (Figure 4)
- NGS and IGN survey reports contain the calibration pier distances from the System Reference Point (SRP) to the top center of the pier, but these distances require two mm level adjustments (prism height and depth) for use in NASA SLR data reduction
- *Photos from the May 2018 NGS Monument Peak Local Survey Report*

NASA SLR Calibration Pier Adapter

Disassembled

O-Ring

Prism

Assembled

- Pictured here are the components that make up the calibration pier adapter. Each adapter has a serial number and an associated prism depth. Prism depths can vary up to several mm. The prisms at some sites may accumulate moisture and must be removed and dried
- *Photos courtesy of MOBLAS-7*

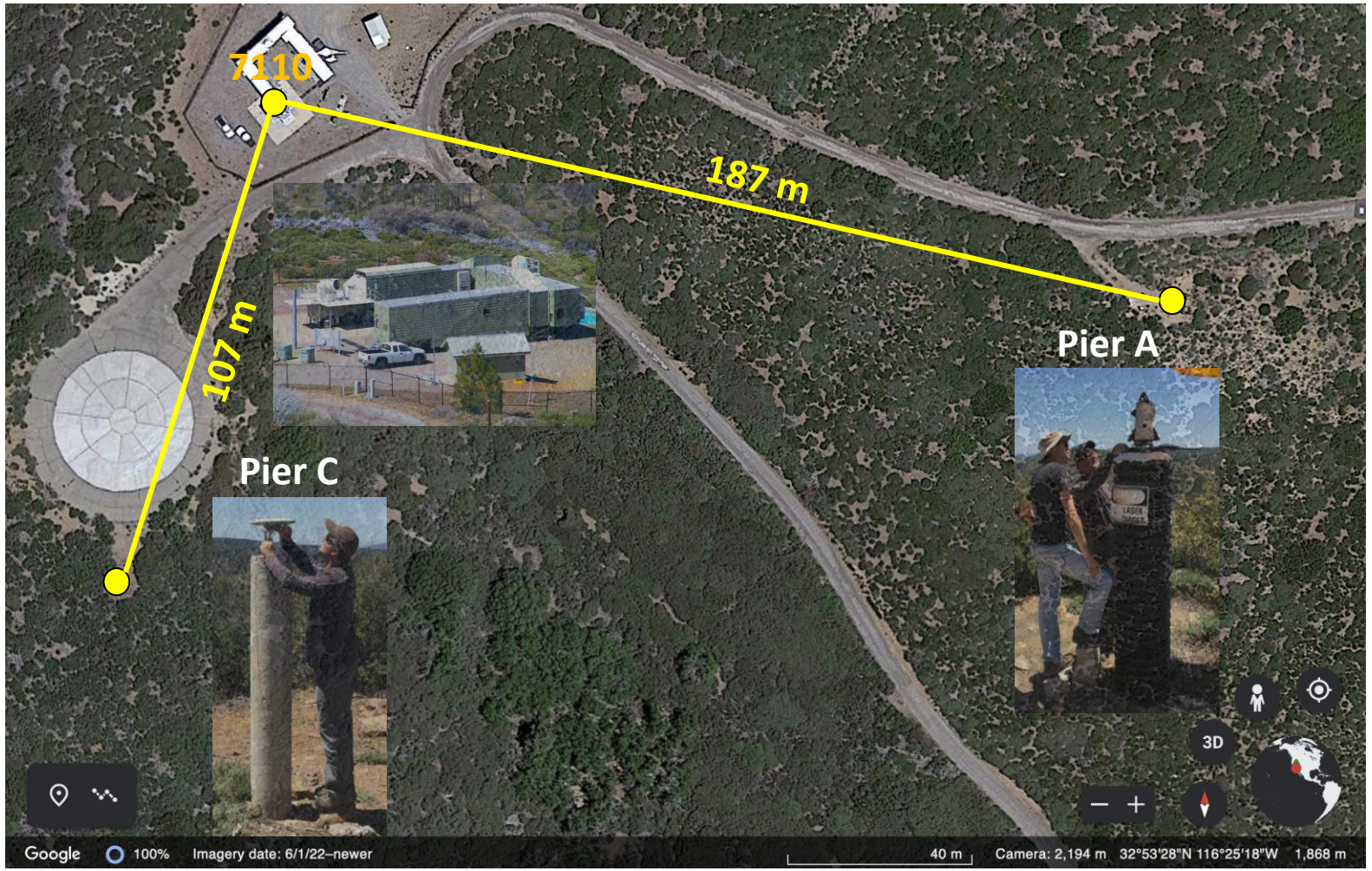
NASA SLR Local Survey Summary (since 2002)

Location	Mark	System	Date of Surveys	Conducted By	System Eccs	Calibration Piers	Calibration Targets
Monument Peak	7110	MOBLAS 4	May-2018	NGS	Yes	Yes	2
			Nov-2011	NASA	Yes	Yes	
Yarragadee	7090	MOBLAS 5	Jun-2024	GA	Yes	Yes	3
			Jun-2021	GA	Yes	Yes	
			Mar-2014	GA	Yes	Yes	
			Jul-2010	GA	Yes	Yes	
Hartebeesthoek	7501	MOBLAS 6	Feb-2014	IGN/NASA	Yes	Yes	2
			Aug-2003	IGN	Yes	Yes	
Greenbelt	7105	MOBLAS 7	Jun-2024	NGS	Yes	Yes	3
			Aug-2012	NGS/NASA	Yes	Yes	
			Mar-2008	NASA	Yes	Yes	
Tahiti	7124	MOBLAS 8	Oct-2007	IGN	Yes	No	2
			Jan-2002	NASA	Yes	Yes	
Arequipa	7403	TLRS-3	Jan-2013	IGN	No	Yes	3
			May-2007	NASA	Yes	Yes	
Haleakala	7119	TLRS-4	Mar-2019	NGS	No	Yes	1
			May-2013	NASA	Yes	Yes	

Legend

IGN: National Geographical Institute, France
NGS: National Geodetic Survey, USA
GA: Geoscience Australia
NASA: National Aeronautics and Space Administration

MOBLAS-4 at 7110 MONL (Monument Peak)



- **MOBLAS-4 has two calibration targets A and C separated by more than 90 degrees. Target A is prime**
- **Pier C is near a heliport and therefore should not be used for operations**
- *Pier photos from the May 2018 NGS Monument Peak Local Survey Report*

Monument Peak Site Information from the ITRF website

Monument Peak SLR GNSS VLBI DORIS

Site informations

Site name	Monument Peak
Country	UNITED STATES OF AMERICA
Longitude	-116.42
Latitude	32.892
Tectonic plate	PACIFIC

Points information and selection :

Add point(s) to the selection

Code	cdp	Domes	Description	ITRF 94	96	97	2000	2005	2008	2014	2020	2020 u2023
7220	7220	40497M002	ARIES ORION STA 7220-1981									
7274	7274	40497M003	NCMN 1983 mobile VLBI NGS disk									
MONB		40497S008	DORIS antenna Reference point (Starec type)									
MONL	7110	40497M001	ORT station 7110-1981 standard NASA disk									
MONP		40497M004	PGGA MARK									
MOOB		40497S009	DORIS antenna reference point (Starec type)									
		40497S007	LASER TLRS-1 72201103 (TL0133)/IAR									
		40497M005	Domed brass screw on the DORIS concrete pillar									
		40497S001	GODDARD MOBILE LASER / IAR (ML0308)									
		40497S004	LASER TLRS-1 72201102 (TL0132)/IAR									
		40497S003	LASER TLRS-1 72201101 (TL0124)/IAR									
		40497S006	LASER MOBLAS-4 / IAR (ML0406)									
		40497S002	GODDARD MOBILE LASER / IAR (ML0404)									
		40497S005	LASER TL0134									

- **Reference: https://itrf.ign.fr/en/site/404111**
- **Other Space Geodetic Techniques: GNSS and DORIS, no active VLBI (last VLBI data Nov 1990)**
- **ITRF2020 Local Ties**
  - NASA 1999: 7110(SLR), MONP(GNSS)
  - IGN 2005: MONB (DORS), MONP(GNSS), MOOB(DORIS)
  - NGS 2018: 7110(SLR), MONP(GNSS)
  - No local ties with the legacy VLBI system

7110 MONL System Eccentricities and Calibration Target Ranges

System Eccentricities (2011 and 2018)

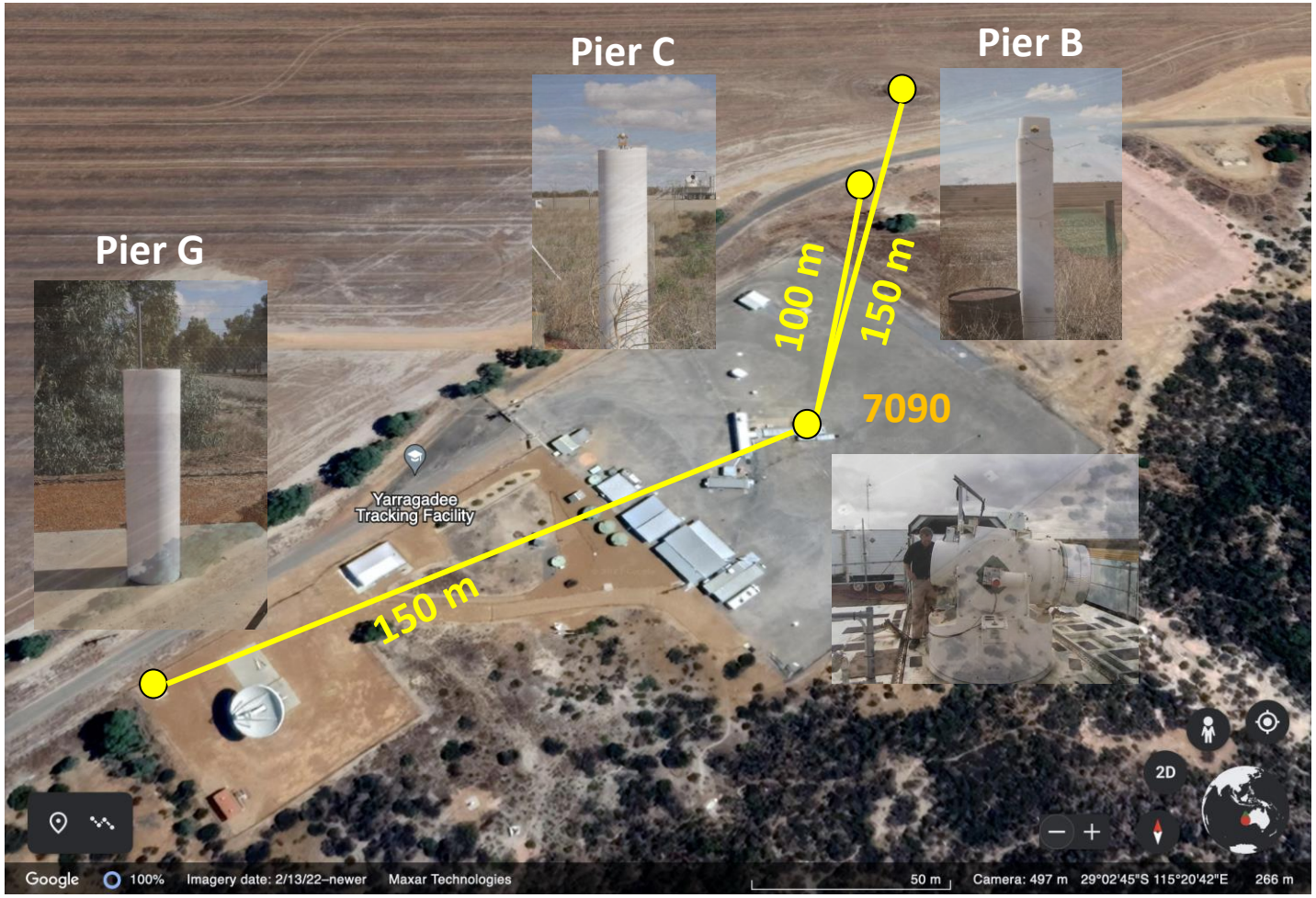
Pad	Point	Point2	Laser	Start	End	UNE	Up(m)	North(m)	East(m)	Delta Up (mm)	Delta North (mm)	Delta East (mm)	SOD
7110	A	1	L	11:317:00000	18:136:86399	UNE	3.1900	-0.0260	-0.0180				71100412
7110	A	1	L	18:137:00000	00:000:00000	UNE	3.1895	-0.0242	-0.0148	-0.5	1.8	3.2	71100412

Target Ranges (2011 and 2018)

Date	Target A (Prime) Range (m)	Target A Change (mm)	Target C Range (m)	Target C Change (mm)
1-Nov-11	187.0028		107.3720	
1-May-18	186.9969	-5.9	107.3747	2.7

- **The November 2011 survey was published within 1-2 weeks of the taking the measurements, while the May 2018 survey report was published a few months later in September 2018.**
- **The System Reference Point (SRP) and both calibration piers moved a few mm between the two surveys. Were these changes sudden, gradual or episodic? Even if the calibration piers are stable, any movement of the SRP will result in a calibration target change. Should a change in eccentricities warrant a SOD change even if the station didn't actually 're-occupy' the monument?**

MOBLAS-5 at 7090 YARL (Yarragadee)



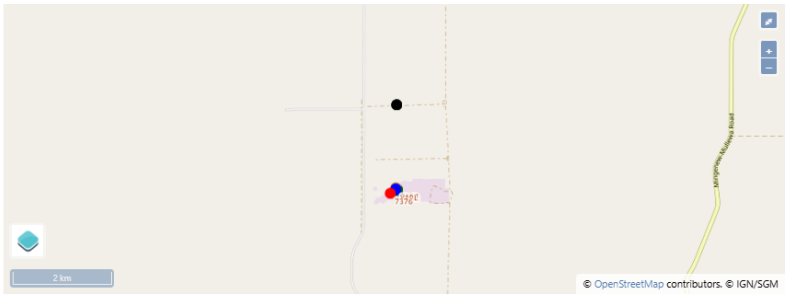
- **MOBLAS-5 has three calibration targets B, C, & G. Target B is prime**
- **Target G has a concrete pad, but targets B & C do not**
- *Pier photos courtesy of MOLBAS-5*

Yarragadee Site Information from the ITRF Website

Yarragadee **VLBI** **SLR** **GNSS** **DORIS**

Site informations

Site name	Yarragadee
Country	AUSTRALIA
Longitude	115.35
Latitude	-29.047
Tectonic plate	AUSTRALIAN



Points information and selection :

Add point(s) to the selection

	Code	cdp	Domes	Description	ITRF 94	96	97	2000	2005	2008	2014	2020	2020 u2023
☐	7376	7376	50107S012	12M Patriot radio telescope - Intersection of axes of a permanent VLBI antenna									
☐	7847	7847	50107S009	PSLR									
☐	YAR2		50107M004	Mark 7090-RM4									
☐	YAR3		50107M008	Intersection of the top of the stainless steel plate with the vertical axis of a 5/8" threaded pin.									
☐	YARA		50107S006	DORIS antenna ref. pt (Alcatel type)									
☐	YARB		50107S010	DORIS antenna ref. pt (Starec type)									
☐	YARL	7090	50107M001	MOBLAS 7090 brass disk									
☐	YARR		50107M006	Plate on secondary GPS mark/centre of base of 5/8" spigot of GPS antenna / AU053									
☐	YASB		50107S011	DORIS antenna ref. pt (Starec type)									
☐			50107M005	DORIS ground mark / Centre punch mark in a brass pin set in concrete									
☐			50107M007	DORIS mark / Top and centre of a 5/8 inch spigot put on top and centre of a 250mm diametre stainless steel plate, set in the top of a 400mm diametre concrete pillar of 1.5m high									
☐			50107S005	ROGUE SNR-8/DM R/L1 15-DEC-90 -									
☐			50107S007	LASER MOBLAS-5 / IAR (ML0511,0513)									

- **Reference: https://itrf.ign.fr/en/site/501007**
- **Other Space Geodetic Techniques: VLBI, GNSS and DORIS**
- **ITRF2020 Local Ties**
  - GA 2003: YAR2(GNSS), YARR(GNSS), 7090(SLR), YARB(DORIS), YASB(DORIS)
  - GA 2010: YAR2(GNSS), YARR(GNSS), 7090(SLR), YASB(DORIS), YAR3(GNSS), 7376(VLBI)

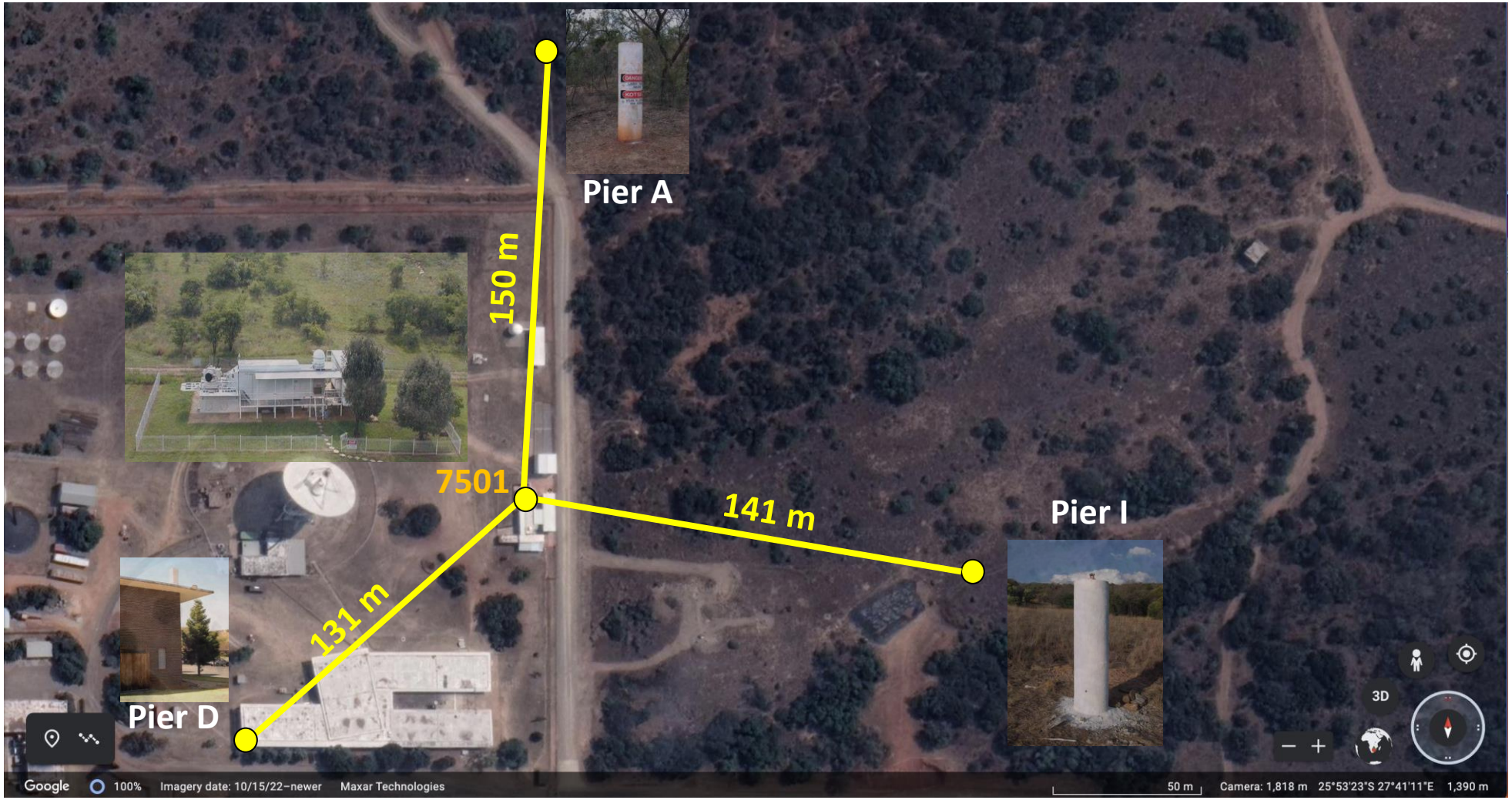
7090 YARL System Eccentricities and Status of Survey Reports

System Eccentricities (2007, 2010, 2014)

*SITE	PT	SOLN	T	Data Start	Data End	UNE	Up (m)	North (m)	East (m)	Delta Up (mm)	Delta North (mm)	Delta East (mm)	SOD
7090	A	1	L	07:151:00000	10:195:86399	UNE	3.1823	-0.0062	0.0190				70900513
7090	A	1	L	10:196:00000	14:079:86399	UNE	3.1820	-0.0068	0.0164	-0.3	-0.6	-2.6	70900513
7090	A	1	L	14:080:00000	00:000:00000	UNE	3.1827	-0.0064	0.0194	0.7	0.4	3.0	70900513

- The 2010, 2014, and 2021 survey reports were never published even though the ITRF has local ties from the 2010 that were used in ITRF2020 and the 2010 and 2014 eccentricities were published in the 7090 Site Log. The June 2024 final survey report is still pending. The preliminary 2024 report appears to have some inaccuracies in the prism constants that are necessary to compute the calibration distances
- Currently, GA only has a single surveyor, who was not involved in the previous surveys from 2010, 2014, and 2021. The surveyors that did the 2010, 2014 and 2021 are no longer employed

MOBLAS-6 at 7501 HARL (Hartebeesthoek)



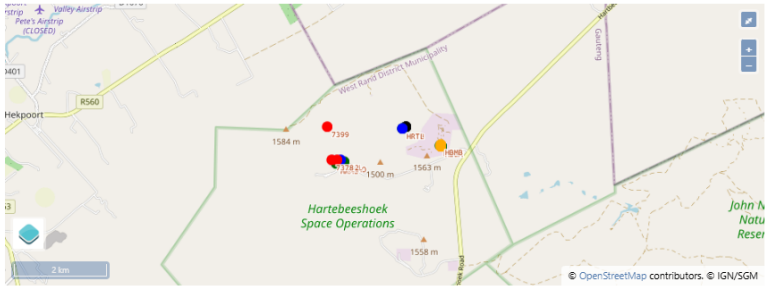
- **MOBLAS-6 has several calibration targets. Target A is now obscured by the ROSCOSMOS SLR system (7503). Prime Target D is on a building roof top**
- *Pier photos from the 2014 IGN Hartebeesthoek Local Survey Report*

Hartebeesthoek Site Information from the ITRF Website

Hartebeesthoek **SLR** **GNSS** **VLBI** **DORIS**

Site informations

Site name	Hartebeesthoek
Country	SOUTH AFRICA
Longitude	27.68
Latitude	-25.883
Tectonic plate	AFRICAN



Points information and selection :

Add point(s) to the selection

	Code	cdp	Domes	Description	ITRF 94	96	97	2000	2005	2008	2014	2020	2020 u2023
☐	7232	7232	30302S001	26m VLBI antenna ref. pt.	●	●	●	●	●	●	●	●	●
☐	7378	7378	30302S009	Intersection of rotation axes of a 15m VLBI antenna	●	●	●	●	●	●	●	●	●
☐	7399	7399	30302S011	Intersection of axes of a permanent VLBI antenna	●	●	●	●	●	●	●	●	●
☐	HARB		30302M009	Brass mark on a concrete pad	●	●	●	●	●	●	●	●	●
☐	HARK		30302M007	Survey and Mapping Rogue bench mark	●	●	●	●	●	●	●	●	●
☐	HARL	7501	30302M003	SLR mark 1993	●	●	●	●	●	●	●	●	●
☐	HART		30302M002	Engraved plate below ROGUE antenna	●	●	●	●	●	●	●	●	●
☐	HBKA		30302S202	DORIS 1 antenna ref. pt. (Alcatel type)	●	●	●	●	●	●	●	●	●
☐	HBLA		30302S005	DORIS 2 antenna ref. pt. (Alcatel type)	●	●	●	●	●	●	●	●	●
☐	HBLB		30302S006	DORIS antenna ref. pt. (Starec type)	●	●	●	●	●	●	●	●	●
☐	HBMB		30302S008	DORIS antenna reference point (starec type)	●	●	●	●	●	●	●	●	●
☐	HRAG		30302M010	Reference point of a forced antenna device, fixed on a wall	●	●	●	●	●	●	●	●	●
☐	HRAO		30302M004	KRUGERSDORP/SS6TRI MONUMENT	●	●	●	●	●	●	●	●	●
☐	HRTB		30302M011	Reference point of a forced centering antenna mount fixed on top of a concrete pillar	●	●	●	●	●	●	●	●	●
☐	HRTL	7503	30302S010	Intersection of the rotation axes of a permanent SLR telescope	●	●	●	●	●	●	●	●	●
☐	●		30302M008	Brass mark on top of a steel pole	●	●	●	●	●	●	●	●	●
☐	●		30302M006	DORIS 2 mark	●	●	●	●	●	●	●	●	●
☐	●		30302M005	DORIS 1 mark	●	●	●	●	●	●	●	●	●

- **Reference: https://itrf.ign.fr/en/site/303001**
- **Other Space Geodetic Techniques: VLBI, GNSS and DORIS**
- **ITRF2020 Local Ties**
  - IGN 2003: HRAO(GNSS), 7232(VLBI), 7501(SLR), HARB(GNSS), HBKB(DORIS), HBKA(DORIS), HBLA(DORIS)
  - IGN 2014: 7378(VLBI), 7232(VLBI), 7501(SLR), HBMB(DORIS), HARB(GNSS)

7501 HARL System Eccentricities

System Eccentricities (2000, 2003, 2014)

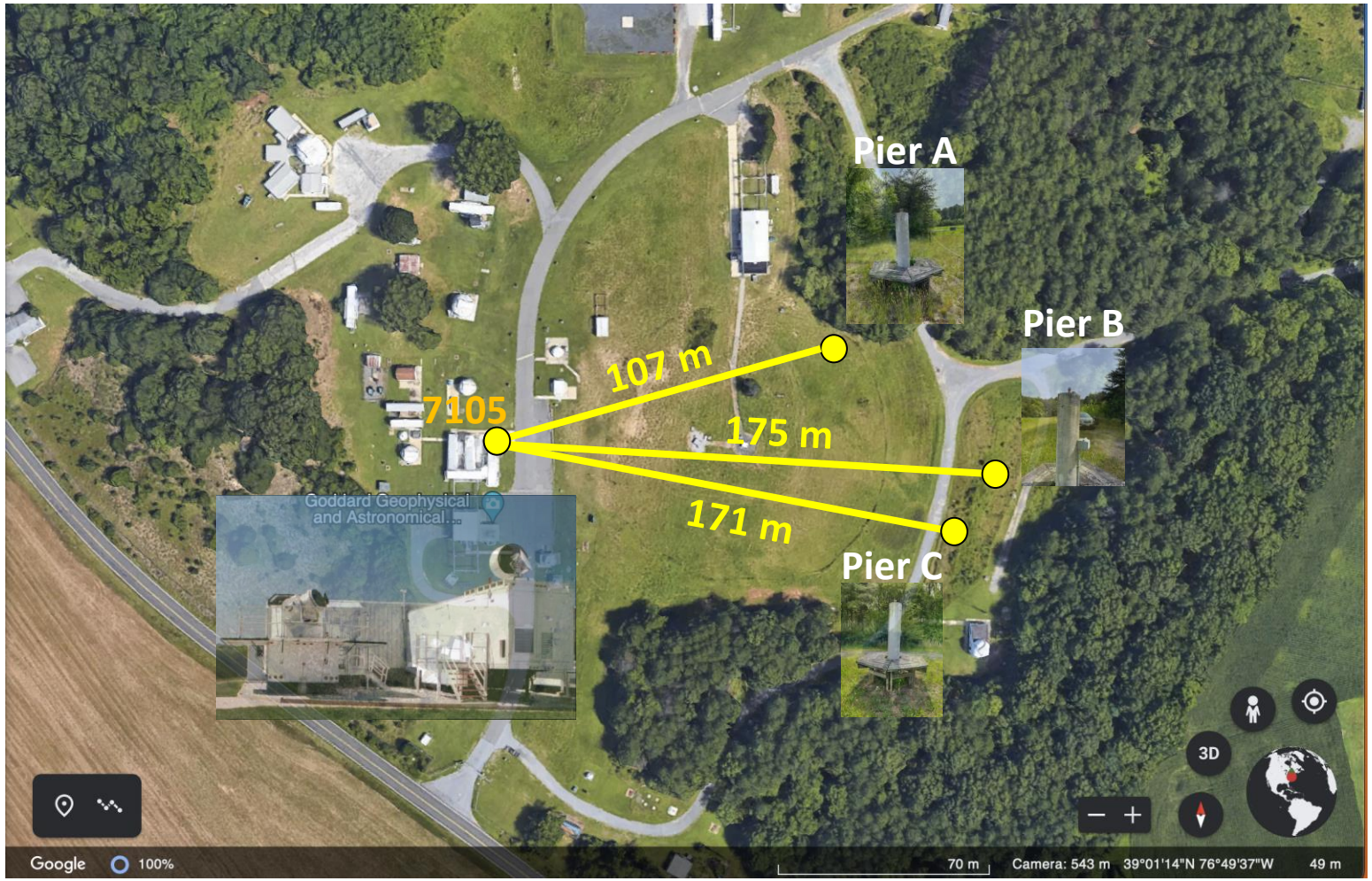
Pad	Point	Point2	Laser	Start	End	UNE	Up(m)	North(m)	East(m)	Delta Up (mm)	Delta North (mm)	Delta East (mm)	SOD
7501	A	1	L	00:122:00000	03:202:86399	UNE	3.2280	-0.0030	-0.0060				75010602
7501	A	1	L	03:203:00000	14:089:86399	UNE	3.2271	-0.0006	-0.0060	-0.9	2.4	0.0	75010602
7501	A	1	L	14:090:00000	00:000:00000	UNE	3.2236	-0.0029	-0.0071	-3.5	-2.3	-1.1	75010602

The IGN 2014 survey data was reprocessed again by IGN in 2021 using updated Comp3D (v5.19) software

	X (m)	Y (m)	Z (m)	Delta X (NASA-IGN) (mm)	Delta Y (NASA-IGN) (mm)	Delta Z (NASA-IGN) (mm)
IGN 2014 Processing	2.5712	1.3416	-1.4096			
NASA 2014 Processing	2.5720	1.3420	-1.4120	0.8	0.4	-2.4
IGN 2021 Processing	2.5702	1.3406	-1.4102	-1.8	-1.4	1.8

- **NASA and IGN both participated in the 2014 survey, but their estimated system eccentricities were slightly different. The NASA results were rounded to the nearest mm. Any change in system eccentricities also impacts the calibration distance**

MOBLAS-7 at 7105 GODL (Greenbelt)



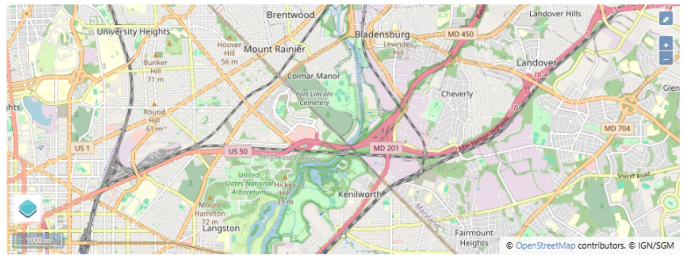
- **MOBLAS-7 has three calibration targets, Target C is prime**
- **The new SGSLR system uses Target A as its prime target**
- *Pier photos by Van Husson*

Greenbelt Site Information from the ITRF Website

Washington GNSS SLR VLBI DORIS

Site informations

Site name	Washington
Country	UNITED STATES OF AMERICA
Longitude	-76.82
Latitude	39.021
Tectonic plate	NORTH AMERICAN



Points information and selection :

Add point(s) to the selection

Code	cdp	Domes	Description	ITRF 94	96	97	2000	2005	2008	2014	2020	2020 u2023
7063	7063	40451M112	STALAS fixed Laser standard NASA disk									
7064	7064	40451M107	Mobile SLR 7064 standard NASA disk									
7065	7065	40451M108	Mobile SLR 7065 standard NASA disk									
7083	7083	40451M122	SLR mark standard NASA disk									
7100	7100	40451M106	Mobile SLR 7100-1977 standard NASA disk									
7101	7101	40451M101	MOBLAS 7101-1977 standard NASA disk									
7102	7102	40451M102	Mobile SLR 7102-1978 standard NASA disk									
7103	7103	40451M103	Mobile SLR 7103-1978 standard NASA disk									
7104	7104	40451M104	Mobile SLR 7104-1978 standard NASA disk									
7106	7106	40451M113	SLR mark									
7108	7108	40451M125	Mark SGP 7108-1993									
7622	7622	40451S177	Intersection of axes of a permanent VLBI2010 12m antenna									
7889	7889	40451M118	SLR mark 7889 1981 standard NASA disk									
7899	7899	40451M111	TLRS 7899-1980 standars NASA disk									
7917	7917	40451M119	SLR mark 7917 Steel plate SAO-3									
7918	7918	40451M120	SLR mark standard NASA disk									
7919	7919	40451M121	SLR mark standard NASA disk									
7920	7920	40451M117	SLR mark 7125-B standard NASA disk									
8213	8213	40451M115	SLR mark									
GO1L	7125	40451M114	SLR mark 7125 1985 standard NASA disk									
GO4T	7130	40451M116	SLR mark 7130 1985 standard NASA disk									
GODE		40451M123	GPS Mark East (JPL 4006)									
GODL	7105	40451M105	MOBLAS -7 7105-1981 standard NASA disk									
GODN		40451M127	Reference point of a forced centering SCIGN antenna mount on top of a deep dill braced monument									
GODR		40451M129	Reference point of a forced SCIGN antenna mount on top of a steel pillar									
GODS		40451M128	Reference point of a forced centering SCIGN antenna mount on top of a deep dill braced monument									
GODW		40451M124	GPS Mark West (JPL 4005)									
GREB		40451S176	DORIS antenna ref. pt (Starec type)									
GRFB		40451S178	DORIS antenna ref. pt (Starec type)									
GUSN		40451M126	Mark at the center and base of a forced centering supporting cylinder fixed on a rod in a mortar rooftop parapet of the Time Service department building.									
NRL1		40451S301	US Naval Research Laboratory - Ashtech Choke ring antenna reference point									
NRL2		40451M302	Intersection of antenna mount's base plate and mounting mast (5/8-inch screw)fixed on the NRL Building 53 rooftop									
USN1		40451S006	Roof of USNO Bldg 78/3S-02-TSADM(SN#12)/ARP 21-DEC-2000 - present									
USN5		40451S007	USNO Time Service department building roof - Baseball diamond shaped aluminum structure - AOAD/M_T ARP									
USN9		40451S009	USNO Time Service department building roof - Baseball diamond shaped aluminum structure - Left Field Position with Topcon CR-G5 Antenna									
USNO		40451S003	Roof of USNO Bldg 52/AOAD/M_T(SN#309)/ARP 24-APR-1997 - present									
USNX		40451S004	Roof of USNO Bldg 78/3S-02-TSADM(SN#12)/ARP 15-OCT-1998 - 26-AUG-1999									
WDC2		40451S005	NIMA GPS antenna ASH7009368_M 1122 /ARP									
WDC4		40451S008	GPS antenna ASH7009368_M 1122 /ARP. Roof of USNO building									
WDC6		40451S010	NGA GPS antenna ITT3750323 SCIS, SN 117 / ARP									
		40451M006	Top and axis of a stainless steel plate on top of a concrete pillar									
		40451M110	Greenbelt north GEOS(GSFC) GORF									
		40451M130	Top and axis of a screw fixed on a stainless steel plate on top of a concrete pillar									

- **Reference: https://itrf.ign.fr/en/site/404051**
- **Other Space Geodetic Techniques: VLBI, GNSS and DORIS**
- **ITRF2020 Local Ties**
  - NASA 2008: GODE (GNSS), 7105 (SLR), GREB (DORIS)
  - NGS 2012 GODE (GNSS), GRFB (DORIS), 7105 (SLR)
  - VLBI systems are missing from the local ties above

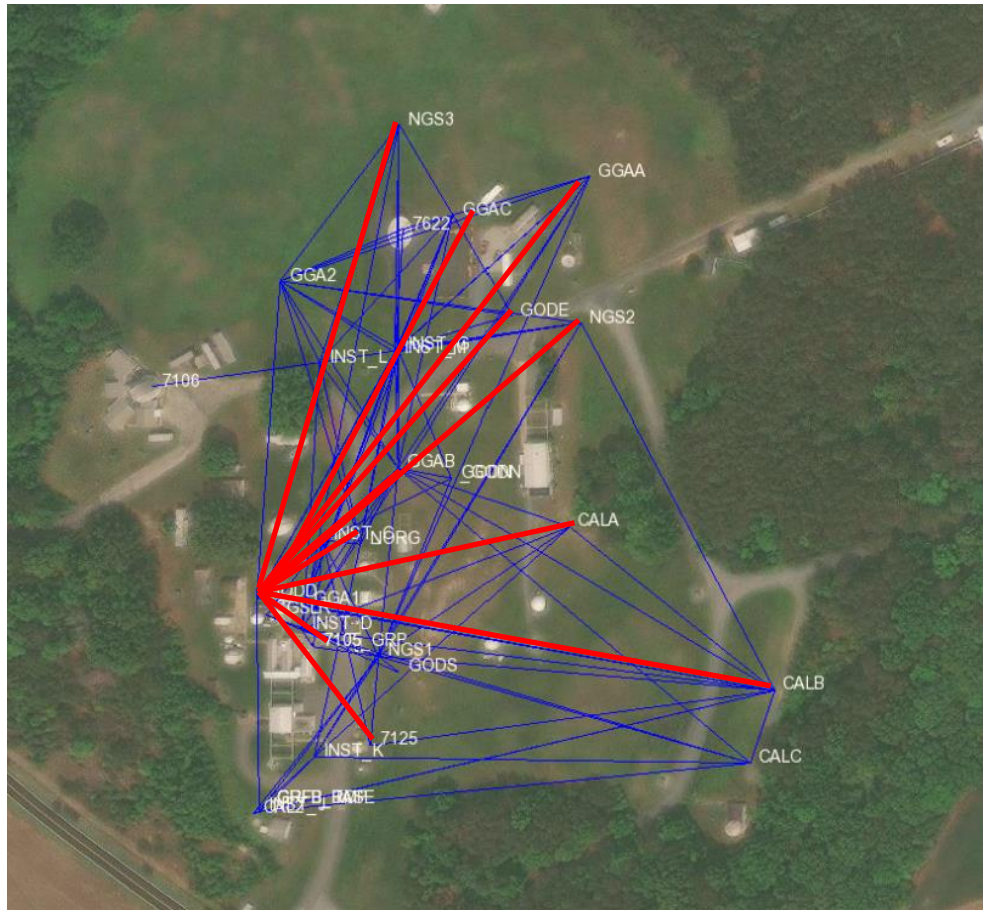
7105 GODL System Eccentricities

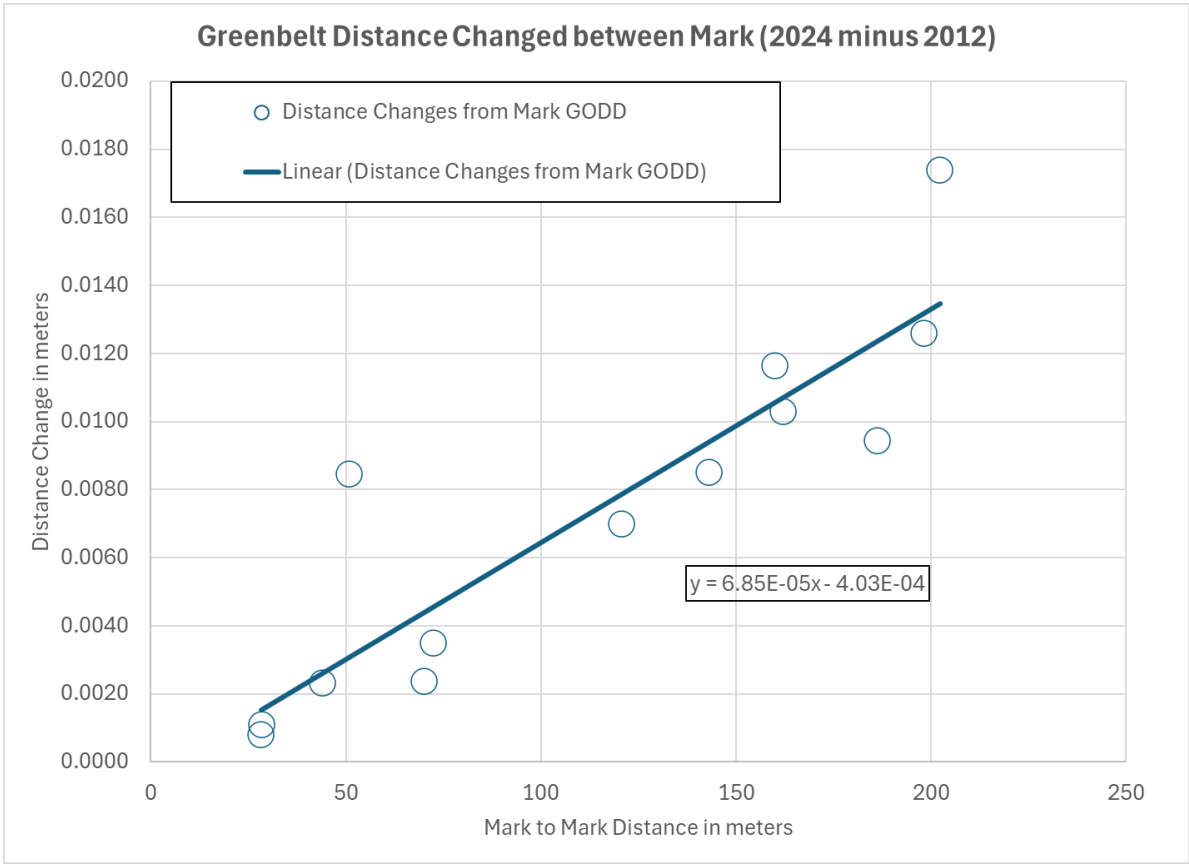
System Eccentricities (1999, 2012, 2024)

Pad	Point	Point2	Laser	Start	End	UNE	Up(m)	North(m)	East(m)	Delta Up (mm)	Delta North (mm)	Delta East (mm)	SOD
7105	A	1	L	99:032:00000	12:151:86399	UNE	3.1380	-0.0070	-0.0340				71050725
7105	A	1	L	12:152:00000	00:000:00000	UNE	3.1379	-0.0087	-0.0327	-0.1	-1.7	1.3	71050725
7105	A	2	L	Still under investigation		UNE	3.1393	-0.0090	-0.0328	1.4	-0.3	-0.1	71050725

- ❑ **See next slide for more information why the 2024 NGS survey is still under investigation**

Greenbelt Baselines from GODD to other Marks





- There appears to be a scale issue between the two NGS surveys since the Greenbelt baselines in red have all gotten longer by parts in E-05

MOBLAS-8 at 7124 THTL (Tahiti)

- **In 2007, IGN didn't survey targets A and C because they were not visible from most points due to vegetation growth. Also, they did not survey prime target B because the calibration pier is enclosed in a metal casing to prevent theft of the prism**
- **IGN also did a survey of the FTLRS system at Tahiti in 2011, but that survey did not include MOBLAS-8**
- **The last time the calibration targets were surveyed was 2002**
- *Photos from the 2007 IGN Tahiti Local survey and MOBLAS-8*

Tahiti Site Information from the ITRF Website

Papeete (Tahiti) DORIS GNSS SLR

Site informations

Site name	Papeete (Tahiti)
Country	SOCIETE ISLANDS
Longitude	-149.61
Latitude	-17.555
Tectonic plate	

Points information and selection :

Add point(s) to the selection

Code	cdp	Domes	Description	ITRF 94	96	97	2000	2005	2008	2014	2020	2020 u2023
FAA1		92201M012	Top and centre of a plate embedded on top of a geodetic concrete pillar									
GTHT		92201M014	Mark at the center and base of a forced centering supporting cylinder fixed on a plate on top of a concrete pillar									
PAMA		92201M003	IGN brass mark									
PAMB		92201S009	DORIS antenna ref. pt (Starec type) 19-08-1993 - 28-09-1993									
PAPB		92201S007	DORIS antenna ref. pt. (Starec type)									
PAPE		92201M011	MARK PAPE ON CONCRETE PILLAR									
PAQB		92201S008	DORIS 2 antenna ref. pt. (Starec type)									
PAUB		92201S010	DORIS antenna reference point (Starec type)									
TAH2		92201S011	GPS ARP ASH700936B_M 12108									
TAHI		92201M006	12 MM DOMED MARK UGP1									
TAHT		92201M013	NGA GPS tracking station - Top and centre of a brass mark embedded in a concrete block									
THTF	7822	92201M017	Top and center of a geodetic ground marker embedded in a concrete slab									
THTG		92201M016	Top and center of a geodetic mark embedded on the edge of a terrace roof									
THTI		92201M009	IGS mark THTI on a terrace roof									
THTL	7124	92201M007	MOBLAS-8 7124-1997 Standard NASA disk									
		92201M004	DORIS 1 mark (under PAPB)									
		92201S003	ASHTECH/L1 22-JAN-91 - 13-FEB-91-									
		92201M010	Brass disks cemented in concrete/GPS Station 85414									

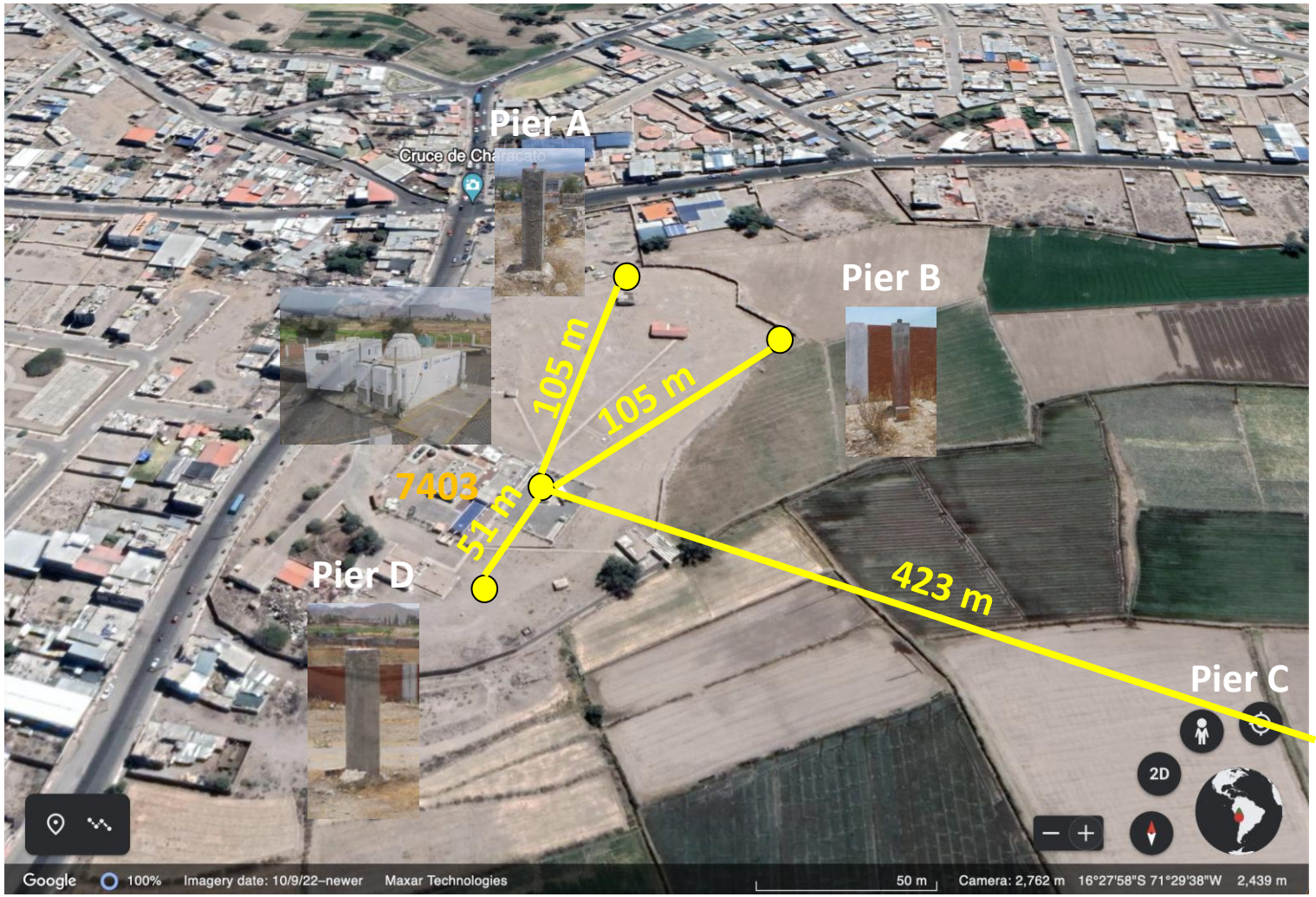
- **Reference: https://itrf.ign.fr/en/site/922001**
- **Other Space Geodetic Techniques: GNSS and DORIS, no VLBI**
- **ITRF2020 Local Ties**
  - IGN 2007: THTI(GNSS), 7124(SLR), PAPB(DORIS), PAQB(DORIS), PATB(DORIS)
  - IGN 2011: THTI(GNSS), PATB(DORIS), 7822(SLR)

7124 THTL System Eccentricities

Pad	PT	SOLN	T	Data Start	Data End	UNE	Up (m)	North (m)	East (m)	Delta Up (mm)	Delta North (mm)	Delta East (mm)	SOD
7124	A	1	L	97:213:00000	99:348:86	UNE	3.1450	-0.0120	0.0110				71240801
7124	A	1	L	99:349:00000	07:275:86	UNE	3.1430	-0.0150	0.0110	-2.0	-3.0	0.0	71240802
7124	A	1	L	07:276:00000	00:000:00	UNE	3.1410	-0.0150	0.0100	-2.0	0.0	-1.0	71240802

- ❑ **The SOD was incremented in 1999 but not 2007**
- ❑ **The calibration targets have not been surveyed since 2002**

TLRS-3 at 7403 AREL (Arequipa)



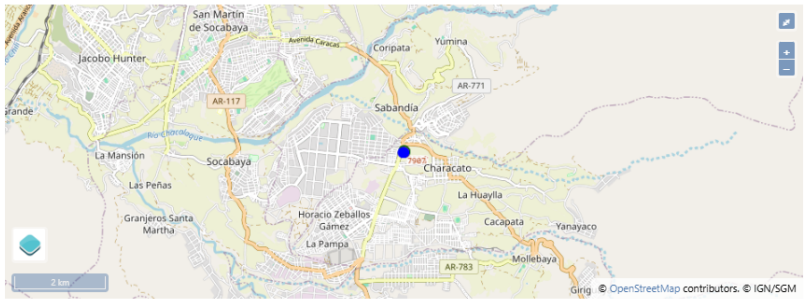
- **TLRS-3 was removed from the 7403 monument in 2004 and 2006 it was placed back over the monument making the monument no longer visible**
- **NASA and IGN conducted local survey in 2007 and 2013; respectively, but system eccentricities could not be measured directly because the monument 7403 was not visible. In the 2013 IGN survey, the legacy primary Pier C was not surveyed**
- *Photos from the 2013 IGN Arequipa Local Survey Report*

Arequipa Site Information from the ITRF Website

Arequipa **GNSS** **DORIS** **SLR**

Site informations

Site name	Arequipa
Country	PERU
Longitude	-71.49
Latitude	-16.466
Tectonic plate	SOUTH AMERICAN



Points information and selection :

Add point(s) to the selection

	Code	cdp	Domes	Description	ITRF 94	96	97	2000	2005	2008	2014	2020	2020 u2023
☐	7403	7403	42202M003	Mark SLR	●	●	●	●	●	●	●	●	●
☐	7907	7907	42202S001	SAO-2 fixed laser	●	●	●	●	●	●	●	●	●
☐	AREA		42202M006	DORIS 1 mark	●	●	●	●	●	●	●	●	●
☐	AREA		42202S005	DORIS antenna ref. pt (Alcatel type)	●	●	●	●	●	●	●	●	●
☐	AREB		42202M007	Concrete pillar / mark (DORIS 2)	●	●	●	●	●	●	●	●	●
☐	AREB		42202S006	DORIS antenna ref. pt. (Starec type)	●	●	●	●	●	●	●	●	●
☐	AREG		42202M008	Top and axis of a brass mark embedded in a concrete pillar	●	●	●	●	●	●	●	●	●
☐	AREV		42202M005	Reference point of an antenna mount on top of a 0.7m concrete pillar.	●	●	●	●	●	●	●	●	●
☐	AREB		42202S007	DORIS antenna Reference Point (Starec type)	●	●	●	●	●	●	●	●	●
☐			42202M001	BM. CHR-5 5 1961	●	●	●	●	●	●	●	●	●
☐			42202M004	East satellite 1961 Mar. Ref. 1	●	●	●	●	●	●	●	●	●
☐			42202M002	East satellite 1961 Mar. Ref. 2	●	●	●	●	●	●	●	●	●
☐			42202M009	NASA GSFC brass disk stamped 7403 RM2 89	●	●	●	●	●	●	●	●	●
☐			42202M010	Aux Satellite 1958 - IGM Peru	●	●	●	●	●	●	●	●	●

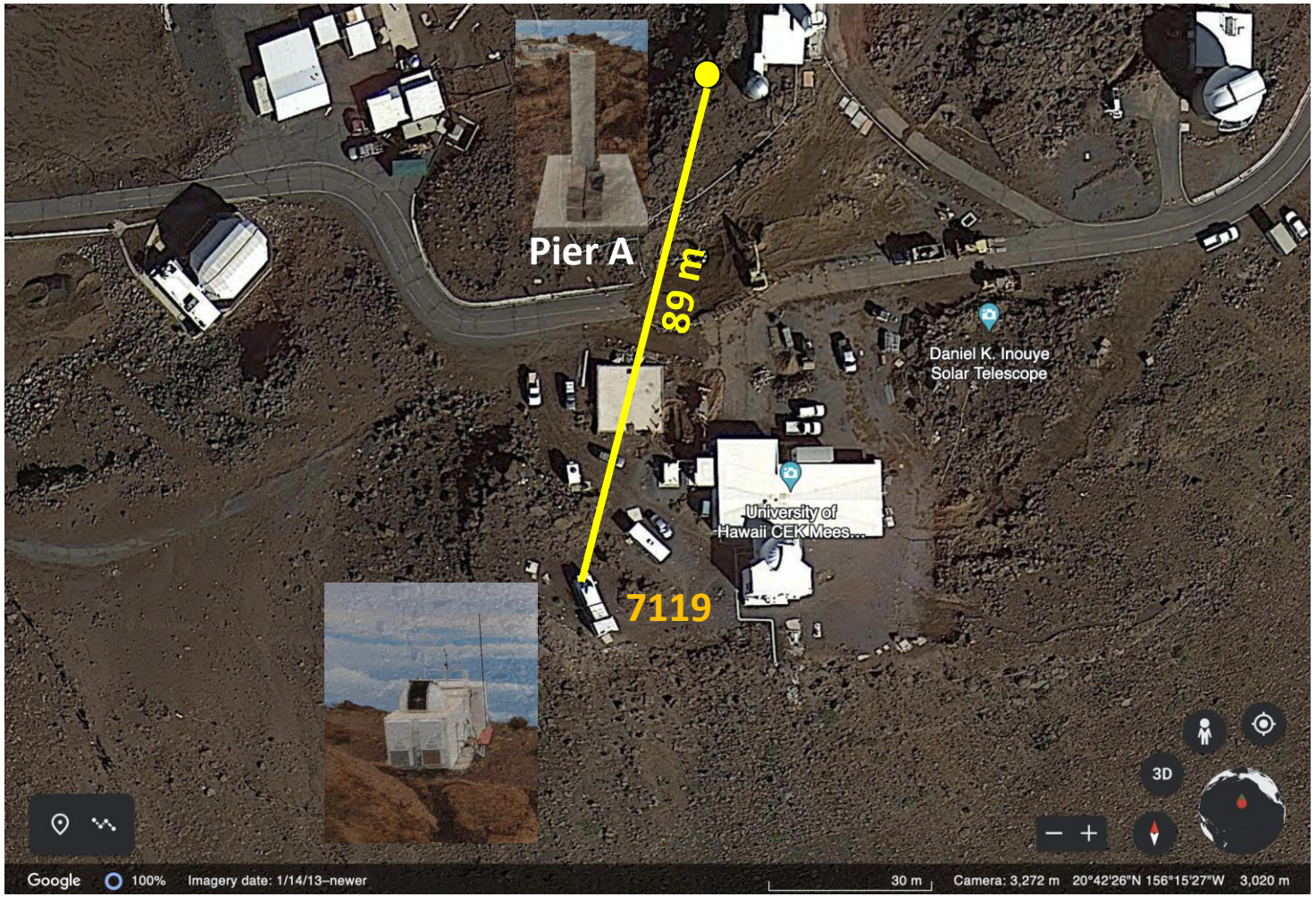
- **Reference: https://itrf.ign.fr/en/site/422002**
- **Other Space Geodetic Techniques: GNSS and DORIS, no VLBI**
- **ITRF2020 Local Ties**
  - IGN 1995: 7403(SLR), AREQ(GNSS)
  - NASA 2007: AREQ(GNSS), ARFB(DORIS), 7403(SLR)
  - IGN 2013: AREQ(GNSS), ARFB(DORIS), 7403(SLR)

7403 AREL System Eccentricities

Pad	PT	SOLN	T	Data Start	Data End	UNE	Up (m)	North (m)	East (m)	Delta Up (mm)	Delta North (mm)	Delta East (mm)	SOD
7403	A	1	L	90:165:00000	90:297:86399	UNE	2.6830	0.0130	-0.0110				74031301
7403	A	1	L	91:085:00000	91:288:86399	UNE	2.7010	0.0180	-0.0160	18.0	5.0	-5.0	74031302
7403	A	1	L	92:196:00000	04:031:86399	UNE	2.6951	0.0112	-0.0046	-5.9	-6.8	11.4	74031303
7403	A	1	L	06:244:00000	09:216:86399	UNE	2.6790	0.0140	-0.0020	-16.1	2.8	2.6	74031304
7403	A	1	L	09:217:00000	10:264:86399	UNE	2.6790	0.0140	-0.0020	0.0	0.0	0.0	74031305
7403	A	1	L	10:265:00000	00:000:00000	UNE	2.6790	0.0140	-0.0020	0.0	0.0	0.0	74031306

- **The eccentricities for the last 3 SODs are all the same**

TLRS-4 at 7119 HA4T (Haleakala)



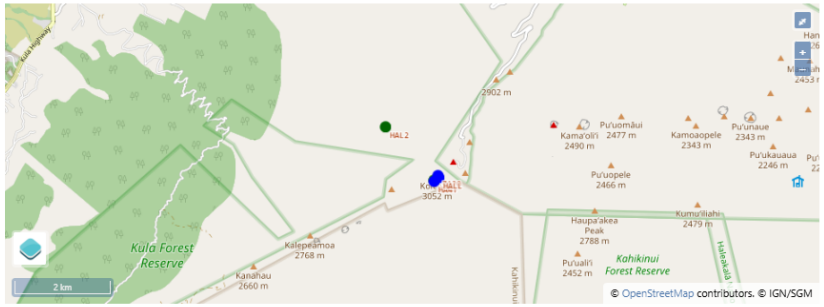
- ❑ TLRS-4 only has one calibration target that is visible
- ❑ NGS conducted a local survey in 2019; but system eccentricities could not be measured directly because the monument 7119 was not visible

Haleakala Site Information from the ITRF Website

MAUI **SLR** **GNSS**

Site informations

Site name	MAUI
Country	UNITED STATES OF AMERICA
Longitude	-156.26
Latitude	20.707
Tectonic plate	PACIFIC



Points information and selection :

Add point(s) to the selection

	Code	cdp	Domes	Description	ITRF 94	96	97	2000	2005	2008	2014	2020	2020 u2023
☐	7120	7120	40445M002	MOBLAS 7120 (1980)	●	●	●	●	●	●	●	●	●
☐	HA4T	7119	40445M004	Marker under SLR telescope on the summit of Haleakala. Local number 71191401	●	●	●	●	●	●	●	●	●
☐	HA4T	7119	40445S009	Permanent SLR instrument - Intersection of axes	●	●	●	●	●	●	●	●	●
☐	HAL1		40445M006	Reference point of a SCIGN antenna mount on short (1m) concrete pillar.	●	●	●	●	●	●	●	●	●
☐	HAL2		40445M007	Reference point of a self centring antenna SCIGN mount on 1.99 m short -driven to resistence- braced monument (SDBM type).	●	●	●	●	●	●	●	●	●
☐	HALL	7210	40445S005	LLR Haleakala transmitter	●	●	●	●	●	●	●	●	●
☐	HALL	7210	40445M001	HOLLAS fixed carriage bolt	●	●	●	●	●	●	●	●	●
☐	MAO0		40445M005	Reference point of a forced antenna device fixed on top of a pyramidal steel mast	●	●	●	●	●	●	●	●	●
☐	MAUI		40445S008	Ashtech Dorne-Margolin chokering antenna S/N: 12610 / ARP center of base of pre-amplifier	●	●	●	●	●	●	●	●	●

- **Reference: https://itrf.ign.fr/en/site/404045**
- **Other Space Geodetic Techniques: GNSS, no DORIS, no VLBI**
- **ITRF2020 Local Ties**
  - NASA 2006: MAUI(GNSS), 7119(SLR), 7210(SLR)
  - NGS 2019: MAUI(GNSS), 7119(SLR)

7119 HA4T System Eccentricities

Pad	PT	SOLN	T	Data Start	Data End	UNE	Up (m)	North (m)	East (m)	Delta Up (mm)	Delta North (mm)	Delta East (mm)	SOD
7119	A	1	L	06:250:00000	11:088:86399	UNE	2.6320	0.0010	0.0020				71191401
7119	A	1	L	11:089:00000	13:134:86399	UNE	2.6320	0.0010	0.0020	0.0	0.0	0.0	71191402
7119	A	1	L	13:135:00000	00:000:00000	UNE	2.6304	0.0029	0.0032	-1.6	1.9	1.2	71191402

- **Consistency of SOD changes**

Issues

- ❑ Do we need to refine the process when a new SOD should be assigned for NASA SLR systems?
- ❑ Survey reports are not always timely and are local surveys are less frequent post 2004
- ❑ Local ties are not always accurate
- ❑ Loss of surveying expertise at NASA and GA

Handling of Fullrate Data from LE Systems

Van S Husson

24-Mar-2025

Stations using a Leading Edge (LE) Filter

Geodetic Satellite Edit Criteria from Site Logs

Station	Marker	LAGEOS-1/-2	LARES-2	LARES	Aiisai	Stella/Starlette	Etalon-1/-2
Graz	7839	20 mm LE	20 mm LE	2.2 σ	20 mm LE	2.2 σ	2.2 σ
Shanghai	7821	20 mm LE	2.2 σ	2.2 σ	2.2 σ	2.2 σ	2.2 σ
Changchun	7237	20 mm LE	20 mm LE	20 mm LE	2.5 σ	20 mm LE	2.5 σ
Izana	7701	20 mm LE	2.2 σ	2.2 σ	300 mm LE	2.2 σ	2.2 σ
Tsukuba	7306	20 mm LE	2.2 σ	2.2 σ	300 mm LE	2.2 σ	2.2 σ
Yebes	7817	2.2 σ	2.2 σ	2.2 σ	2.2 σ	2.2 σ	2.2 σ

LAGEOS Fullrate Filters and the Filter Flag

Station	Marker	LAGEOS-1/-2	Fullrate Data Filter	Noise and Excluded Returns
Graz	7839	20 mm LE	20 mm LE	No
Shanghai	7821	20 mm LE	20 mm LE	No
Changchun	7237	20 mm LE	20 mm LE	No
Izana	7701	20 mm LE	2.2 σ	No
Tsukuba	7306	20 mm LE	2.2 σ	No
Yebes	7817	20 mm LE	2.2 σ	Yes

- **The site log information can't always be trusted**
- **There is no standardization of the edit criterion for the geodetic satellites**
- **No standardization of which satellite returns should be included in the FullRate (FR) data; and use of the Filter Flag**
  - Jose has proposed +/- 5 sigma in the past. At the Kunming workshop, Linda Geisser proposed all systems "provide the fullrate data including all returns within a limit of (e.g. 5*sigma)"

ILRS QCB Meeting

03/24/2024

Claudia Carabajal & Mike Pearlman

Agenda

Van:
- Investigation into ITRF2020_U2023 NASA SLR Height Discontinuities
- NASA SLR Local Site Survey Issues
- Handling of Fullrate Data from Systems with Leading Edge (LE) Filters

Peter:
- Vertical Displacements at an earthquake station:MONUMENT PEAK

Alex
- Station Survey on use of Priority List

Claudia/Mike:
- Updates from the ILRS CB

Station News

- San Fernando back in operations, soon to submit data for quarantine analysis. Submitted Site Survey for review. Van reviewed and sent to Zuher Altamimi. New occupation number, requested DOMES. Data will be corrected and submitted for quarantine analysis soon.
- Xian Station submitted Site Log to EDC, working on the station page. Will submit data for quarantine analysis soon.

- Other updates provided by Van Husson (Peraton).
- See the ILRS website for the full data quarantine policy as it stated on the website: https://ilrs.gsfc.nasa.gov/network/site_procedures/quarantine_procedure.html

Station News

- Succession of the Director of the Swiss Optical Ground Station and Geodynamics Observatory (SwissOGS) in Zimmerwald announced.

The following events took place since 2022:

  - Since July 18, 2022, the SwissOGS has been jointly led by Prof. Dr. Thomas Schildknecht (Direc-tor) and Prof. Dr. Lucia Kleint (Vice-Director) in preparation for Thomas Schildknecht's retirement in September 2025.
  - On February 1, 2024, Lucia Kleint became Associate Professor (Extraordinaria) of the Phil.-nat.-Faculty of the University of Bern.
  - On February 1, 2025, following discussions with the executive board of the University and the management of the Astronomical Institute, Thomas Schildknecht will step down as Director after 15 years and Lucia Kleint will become the new Director of the SwissOGS.

Lucia Kleint received her Ph.D. degree in 2010 from ETH Zürich. She subsequently worked at the National Center for Atmospheric Research and at the Lockheed Martin Solar and Astrophysics lab (USA) until 2014, when she returned to Europe to work on ESA's Solar Orbiter mission. From 2017, she headed Europe's largest solar telescope and later the whole German Solar Observatory on Tenerife. In 2020, she was awarded a PRIMA grant, with which she became an assistant professor at the Department of Com-puter Science at the University of Geneva. Her current research group at the University of Bern, consisting of 10 members and funded by third-party sources including an ERC grant, focuses on astronomical instrumentation, machine learning, and the physics of Space Weather.

Mission Updates/New Missions

- Received MSRF from Hideki Yamada from JAXA, for "**QPS-SAR**", was approved for tracking.

QPS-SAR approved for support. Mission sent list of stations they want to participate with restricted tracking. Missions contacted to verify parameters for the draft agreements.

The campaign period is tentatively scheduled for August 2025. The exact campaign period will be announced in advance via email.

ID	Code	Location Name, Country	Wavelength	unit	MaxEnergy	unit	PulseWidth	unit	MaxRepRate	unit	Full Beam Divergence min	Full Beam Divergence max	unit	final Beam Diameter	unit	Transimit Efficiency	ReceiveEfficiency
7249	BEIL	Beijing, China	532	nm	1	mJ	10	ps	1000	Hz	103	103	"	0.002	m	0.7	0.7
7306	TKBL	Tsukuba, Japan	532	nm	0.26	mJ	7	ps	1000	Hz	5	7	"	0.06	m	0.9	0.5
7394	SEJL	Sejong City, Republic of Korea	532	nm	2.5	mJ	50	ps	5000	Hz	5	200	"	0.08	m	0.923	0.649
7396	JFNL	Wuhan, China	532	nm	1.5	mJ	38	ps	4000	Hz	82.5	108	"	0.0017	m	0.95	0.9
7503	HRTL	Hartebeesthoek, South Africa	532	nm	2.5	mJ	300	ps	300	Hz	10	30	"	0.03	m	0.66	0.5
7821	SHA2	Shanghai, China	532	nm	<1	mJ	20	ps	5000	Hz	8	60	"	0.06	m	0.5	0.15
7839	GRZL	Graz, Austria	532	nm	0.5	mJ	10	ps	2000	Hz	3	200	"	0.1	m	0.7	0.3
7840	HERL	Herstmonceux, United Kingdom	532	nm	1.5	mJ	25	ps	1000	Hz	30	200	"	0.03	m	0.7	0.7
			~~1064~~	~~nm~~	~~1~~	~~mJ~~	~~10~~	~~ps~~	~~1000~~	~~Hz~~	~~x~~	~~200~~	~~"~~	~~0.03~~	~~m~~	~~0.7~~	~~0.7~~
			532	nm	1	mJ	10	ps	1000	Hz	30	200	"	0.03	m	0.7	0.7
7841	POT3	Potsdam, Germany	532	nm	0.7	mJ	10	ps	2000	Hz	x	90	"	0.15	m	0.8	0.4

Mission Updates/New Missions

- Nano FF 1-2 Mission launched in December 2023, aimed at advancing proximity operations in low Earth orbit, funded by the German Aerospace Center (DLR) and developed by Technische Universität Berlin.

The NanoFF mission consists of two 2U-CubeSats designed to demonstrate precise relative navigation and control, leveraging GNSS-based positioning, inter-satellite communication, and autonomous formation-keeping algorithms. A key focus of NanoFF is to ensure collision-free operations while executing controlled maneuvers in close proximity, making it a critical step towards future satellite servicing and inspection applications. **Support to start in June 2025.**

- We received a MSRFs for **QZS-6** from JAXA because each satellite has slightly different features and parameters that the other QZS satellites in the constellations.

This is one of 3 additional satellites that will be added to the QZSS constellation from the Government of Japan Cabinet Office. QZSS has been operating as a 4-satellite constellation since November 2018. 3 satellites are visible at all times from Asia-Oceania. They can be used in an integrated way with GPS ensuring a sufficient number of satellites for stable, high-precision positioning.

To improve position stability, one quasi-zenith satellite, one geostationary satellite, and one quasi-geostationary satellites will be added, to create a seven-satellite constellation. This is one of those three satellites. QSS/NEC will be providing the predictions. Support for the mission was requested beginning within two months after launch, anticipated in early February of 2025, with an expected mission lifetime of 15 years; MSRF sent to MSC Co-Chairs. **The campaign period is tentatively scheduled from April 25 to June 27, 2025.**

Mission Updates/New Missions

- **Engineering Test Satellite-9:** Contacted JAXA colleagues about ETS-9 (Engineering Test Satellite-9, https://www.satnavi.jaxa.jp/files/project/ETS-9/en/) mission, which requested access to CDDIS to test prediction files. The mission's planned launch is in 2025. ETS-9 is a demonstration satellite to achieve next generation geostationary satellite communication that will be internationally competitive, which will verify communication technology that meets market needs, and satellite bus (platform) technology to load communication instruments. The mission has a designed life of 16 years (Except payload), mass of 4.9 t, it will have an automated geostationary orbit at 36,000 km, larger power/Advanced heat control technology > 25kW, with Mitsubishi Electric Corporation as the primary contractor. It is the first Japanese geostationary satellite equipped with GPS receivers (Japan-made) for laborsaving autonomous orbital transfer and orbital maneuvering.

  Conceptual Design of Japan's Engineering Test Satellite-9, October 2017, DOI: 10.2514/6.2017-5427.

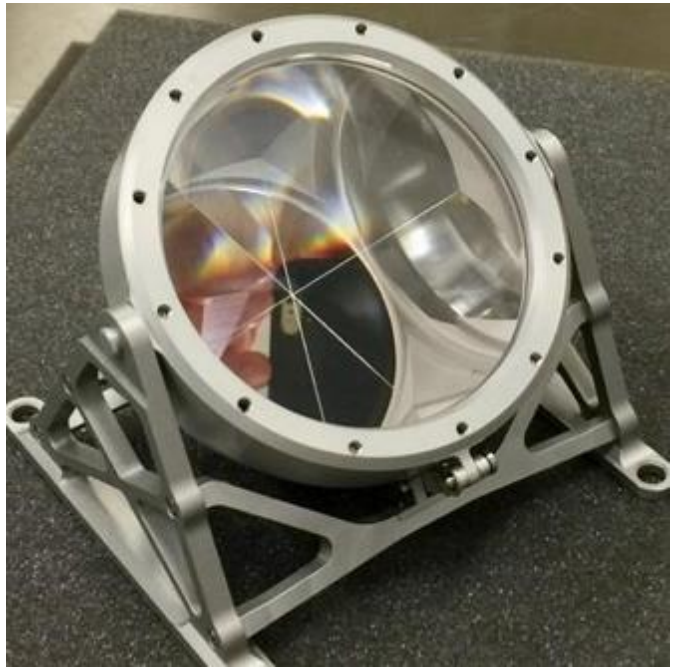
- **ICESat-2:** Updated the agreement from the ICESat-2 mission for Herstmonceux to track with the new laser. Tony Martino signed. Sent the signed agreement to the Station/Mission.

Mission Updates/New Missions

- **Sentinel-6B satellite:** Received MSRF from Marc Gaset, Copernicus Ground Segment System Engineer, Satellite System Ground Segments Division – EUMETSAT (incremental submission to the one approved by ILRS on May 28, 2020 for the Sentinel-6A).
- The Sentinel-6B/Jason-CSB is the follow-on to the TOPEX/POSEIDON, Jason-1, Jason-2, Jason-3 and Sentinel-6A/Jason-CSA satellites (clone of Sentinel-6A, high-precision ocean altimetry measurements). The Jason-CS Programme – established by Declaration EUM/C/83/15/Dcl.I – constitutes EUMETSAT's direct contribution to the funding, development and implementation of the Sentinel-6/Jason-CS mission, which also involves ESA, the EU, NOAA, NASA, and CNES. A secondary objective of Sentinel-6/Jason-CS is to collect high resolution vertical temperature profiles, using the GNSS Radio-Occultation sounding technique, to assess temperature changes in the troposphere and stratosphere and support Numerical Weather Prediction. Planned to have 5.5 years lifetime each (plus 2 years consumables).
- **The Sentinel-6B/Jason-CS-B satellite will be launched in November 2025** to guarantee adequate overlap with Sentinel-6A/Jason-CS-A and provide full continuity of service until 2030 and beyond. Sentinel-6B is a clone of Sentinel-6A. It is the same satellite. There may be minor changes to the tracking point offsets, or CofM. The satellite will first fly tandem with S6A for calibration/validation purposes. Then S6A will be moved to another orbit, probably an interleaved orbit. Then S6B will become the official satellite providing altimeter sea surface height measurements on the TOPEX ground track.
    - Satellite Laser Ranging for the Sentinel-6/Jason-CS mission: accurate orbit determination is a fundamental requirement for achieving the Jason-CS mission objectives. The SLR data play such an important role in two ways:
        - (1) by providing robust tracking information to complement GNSS and DORIS
        - (2) by providing a unique and unambiguous verification of the absolute radial orbit accuracy.

Mission Updates/New Missions

- NGLR-1 mission that was approved by the ILRS GB. Mission was informed. Firefly Aerospace's Blue Ghost Mission 1 successfully Launched at1:11 a.m. EST on January 15, 2025 and began its 45-Day transit to the Moon. The NGLS-1 mission will be contacted. Preparing to support the mission.\ https://fireflyspace.com/missions/blue-ghost-mission-1/



Next Generation Lunar Retroreflector (NGLR-1), University of Maryland

March 2, 2025, 3:08 am CST: First Image on the Moon and successful landing

Blue Ghost captured its first Moon image after successfully landing! The image shows the Moon's surface and a top-down view of the lander's RCS thrusters (center) with a sun glare on the right side. The X-band antenna was successfully deployed, allowing to rapidly downlink high-definition imagery and videos and transmit payload science data back to Earth.

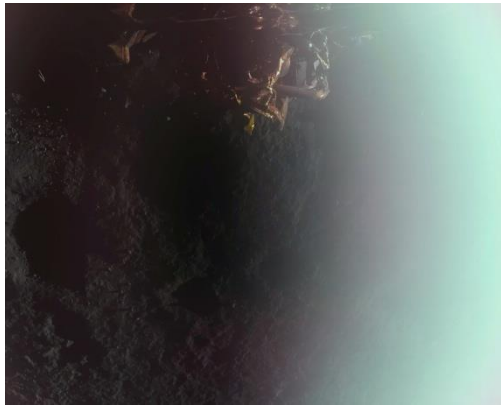


Image captured by Blue Ghost shows its shadow on the surface and Earth on the horizon. Credit: Firefly Aerospace

Credit: Firefly Aerospace

LLR stations have successfully ranged: Grasse, Wettzell, Apache Point.

Working on improving communication between analysis and stations.