Deutsches Geodätisches Forschungsinstitut (DGFI-TUM)
Technische Universität München

2023 ILRS Analysis Standing Committee meeting

Mathis Bloßfeld[(1)] and Cinzia Luceri[(2)]

(Conveners)

(1) DGFI-TUM

(2) ASI/e-geos

Wednesday, April 26th, 2023, TU Vienna, 14:00 – 18:00 CEST

Seminarraum A (SEM A), Freihaus, yellow area, 2nd floor, Wiedner Hauptstrasse 8-10,

Today's agenda (to be approved)

1)	Last meeting + open Action Items	(CL, MB)	10 minutes
2)	Report from the IERS Directing Board	(MB)	15 minutes
3)	AC reports (SLR ACs +status of 2 new French ACs + LLR ACs)	(all)	80 minutes
4)	CC reports	(CL, EP)	30 minutes
	break		20 minutes
5)	SLRF2020 + new ILRS DHF + target signature model	(CL, EP)	15 minutes
6)	Transition to new official ILRS ASC products	(CL, MB)	15 minutes
7)	SSEM-X status	(CL)	15 minutes
8)	LARES-2 incorporation into official products	(CL, MB)	5 minutes
9)	LARES-PP	(MB)	10 minutes
10)	Any other business	(MB)	25 minutes

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Last meeting + open Action Items

- AIs from ASC meeting in Guadalajara, Spain in fall 2022

AI No.	Responsible Entity	Action Item Description	Deadline	
1	DGFI/BKG/GFZ	Daily&Weekly products from 07-08/2022 to be investigated (3D wrms too high)	ASAP	→ **status?**
2	DGFI/BKG/ESA	Geocenter and EOP from 10/2022 to be investigated	ASAP	→ **done**
3	BKG/ESA	daily&weekly Scale from 10/2022 to be investigated	ASAP	→ **done**
4	NGSF	daily&weekly Scale from 09/2022 to be investigated	ASAP	→ **status?**
5	ALL ACs + CCs	Deliver 2021&2022 **weekly solution (v415)** (SLRF2020)	31 December 2022	→ **done**
6	ALL ACs + CCs	Implement **v180 daily** operational products	January 2023 (TBC)	→ **ongoing; cf. 5), 6), and 7)**
7	ALL ACs + CCs	Implement **v80 weekly** operational products	January 2023 (TBC)	→ **ongoing; cf. 5), 6), and 7)**
8	ALL ACs + CCs	Implement **v280 weekly** operational products then switch-off v230 (date TBD)!	January 2023 (TBC)	→ **ongoing; cf. 5), 6), and 7)**
9	ALL ACs	Complete Re-Analysis 1993-2022 (SLRF2020, new DHF & IERSEOPC04 20), v85 series	March 2023	→ **to be started soon**
10	CCs	Release DHF Update + final list of reference models for the routine products and reanalysis	15 December 2022	→ **done**
11	ALL ACs	Submit v230 to current period and continue to submit weekly v230 solutions	ASAP	→ **(partly) done**

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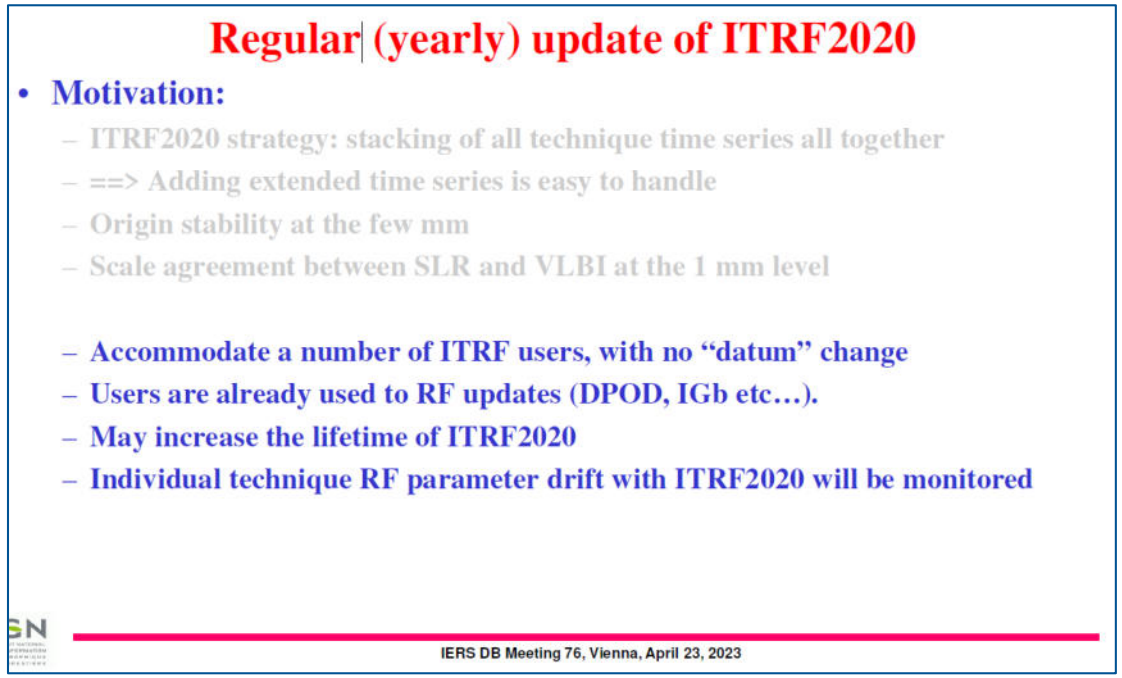
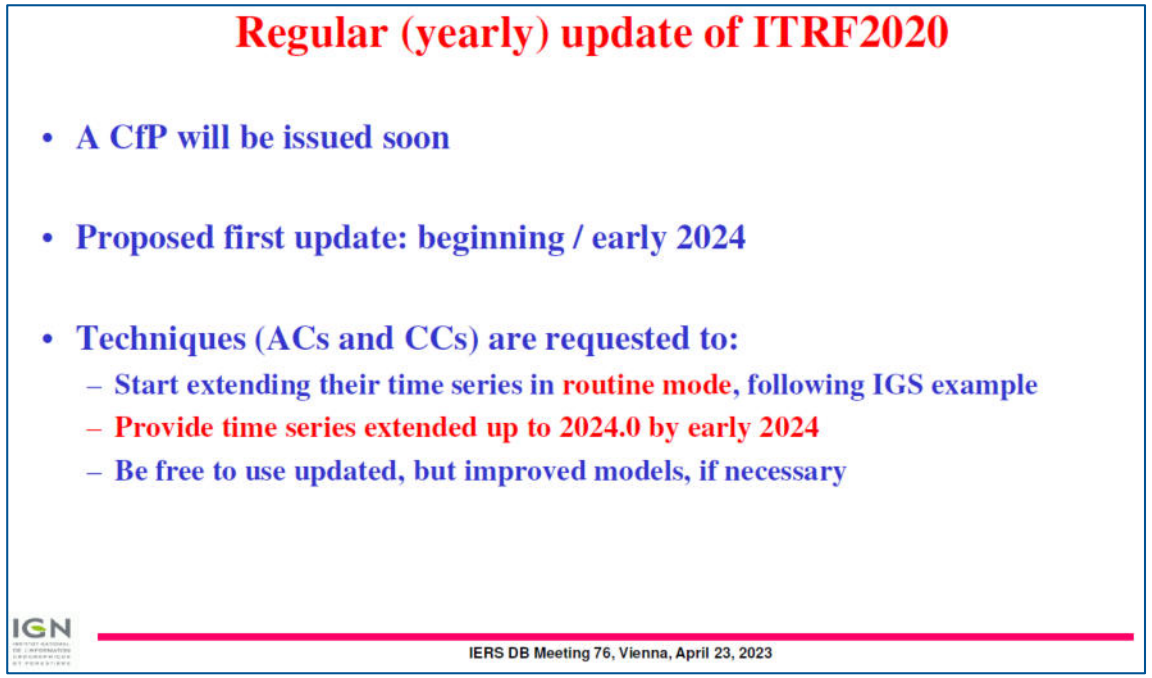
Report from the IERS DB

- IDS, IVS and IGS turn 20, 25, and 30 this year. ILRS was founded officially on Sep. 22nd, 1998 → 25 years this year!
- Proposal on ITRF updates by ITRS Center (slides presented by Z. Altamimi, ITRS Center)





- Any thoughts on this idea?
- GENESIS: is the IERS prepared to use such collocated observations in space? → new WG will be installed

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Status report of ACs

ILRS SLR ACs

- **ASI** (combined presentation with ASI CC; ILRS-A)
- **BKG**
- **DGFI-TUM**
- **ESA**
- **GFZ**
- **JCET** (combined presentation with JCET CC; ILRS-B)
- **NSGF**
- **GRGS + CNES** (2 new ACs!)

ILRS LLR ACs

- **IAA**
- **IFE**
- **LNF**

ASI AC&CC report

V. Luceri, A. Basoni , D. Sarrocco
e-GEOS S.p.A., ASI/CGS - Matera

G. Bianco
Agenzia Spaziale Italiana, CGS - Matera

ASI/CGS Activities since last ASC meeting

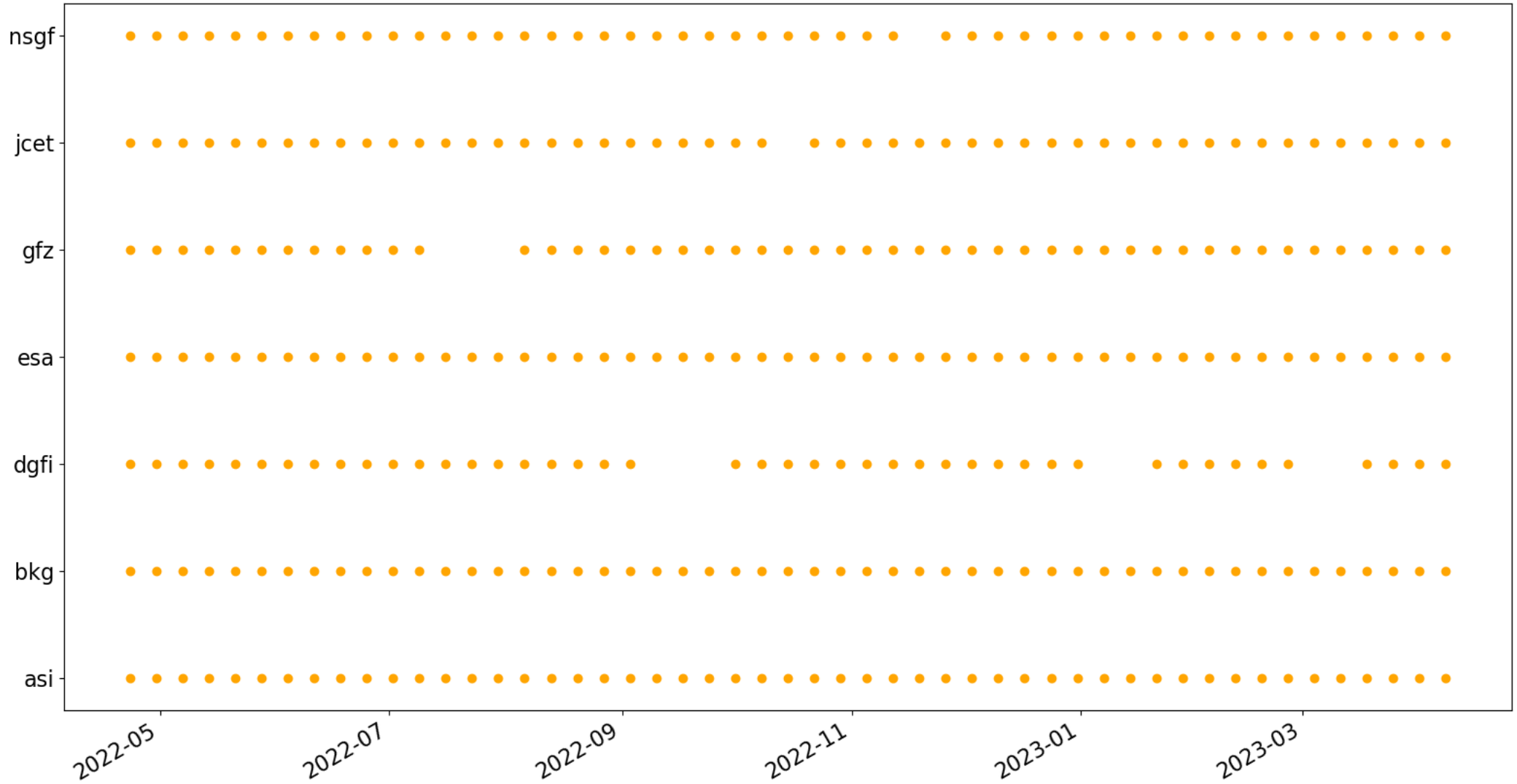
- ACs performance check
    - Product submissions
    - 3D wrms of the residuals w.r.t. SLRF (daily and weekly)
    - Scale
    - Geocenter motion
    - LOD
    - Orbits: RMS of residuals w.r.t. combination
    - ILRS ACs orbit agreement
- Activities to control systematic error, its modelling, update of Data Handling file and its use for new routine products.

Solution submissions

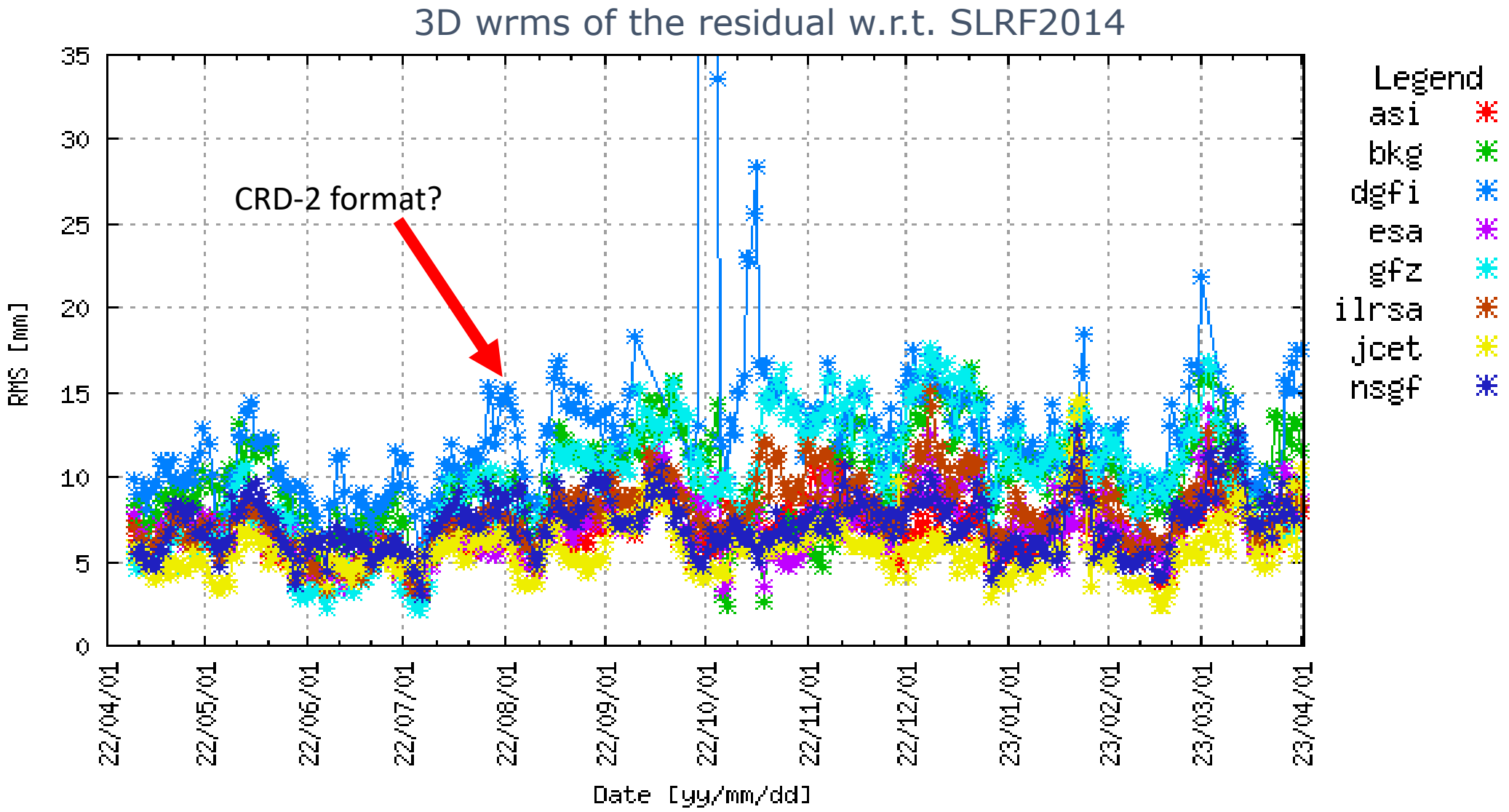
Daily (v170) ACs time series
2022/04/19 – 2023/04/19

Solution submissions

Weekly (v70) ACs time series
2022/04/19 – 2023/04/19



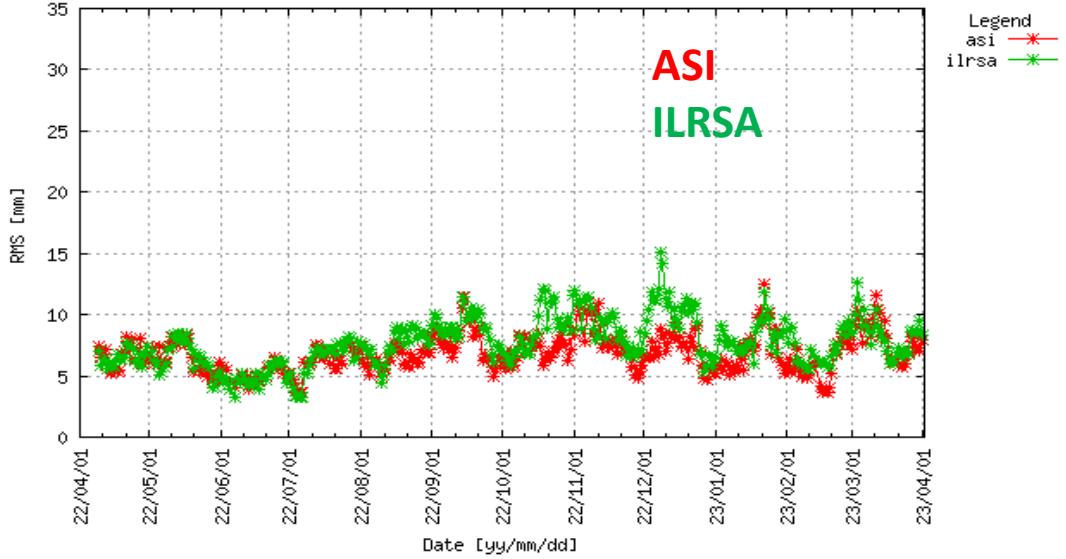
Stations coordinates from daily solutions

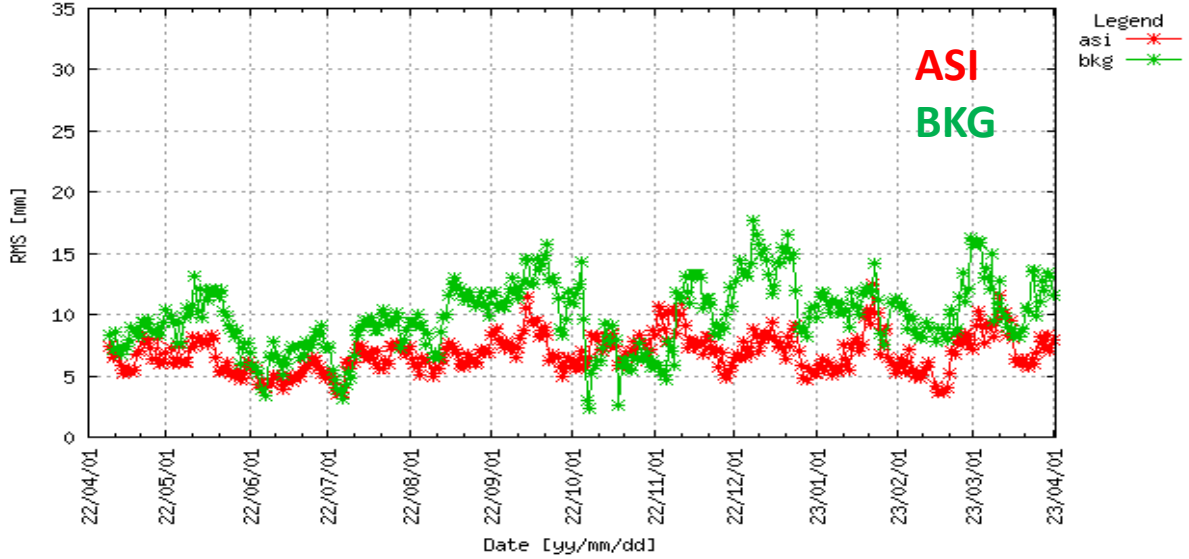


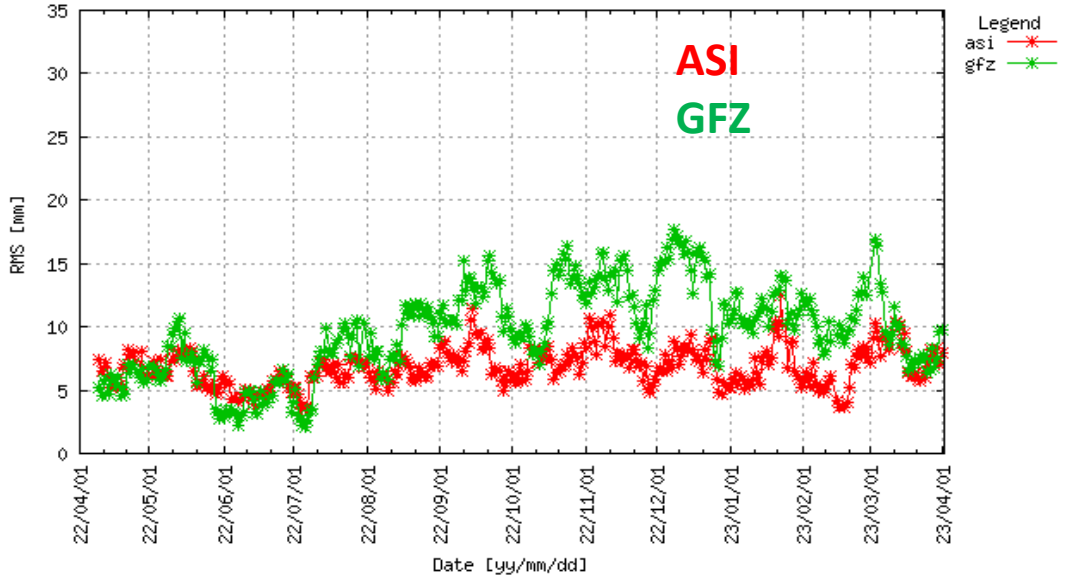
Stations coordinates from daily solutions

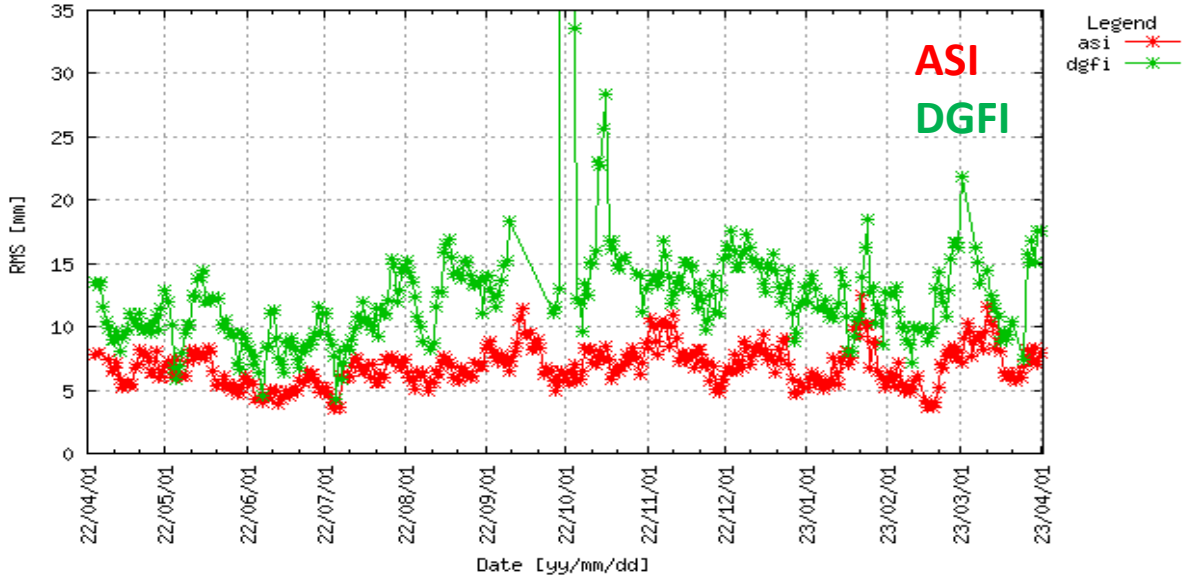
3D wrms of the residual w.r.t. SLRF2014

CORE SITES



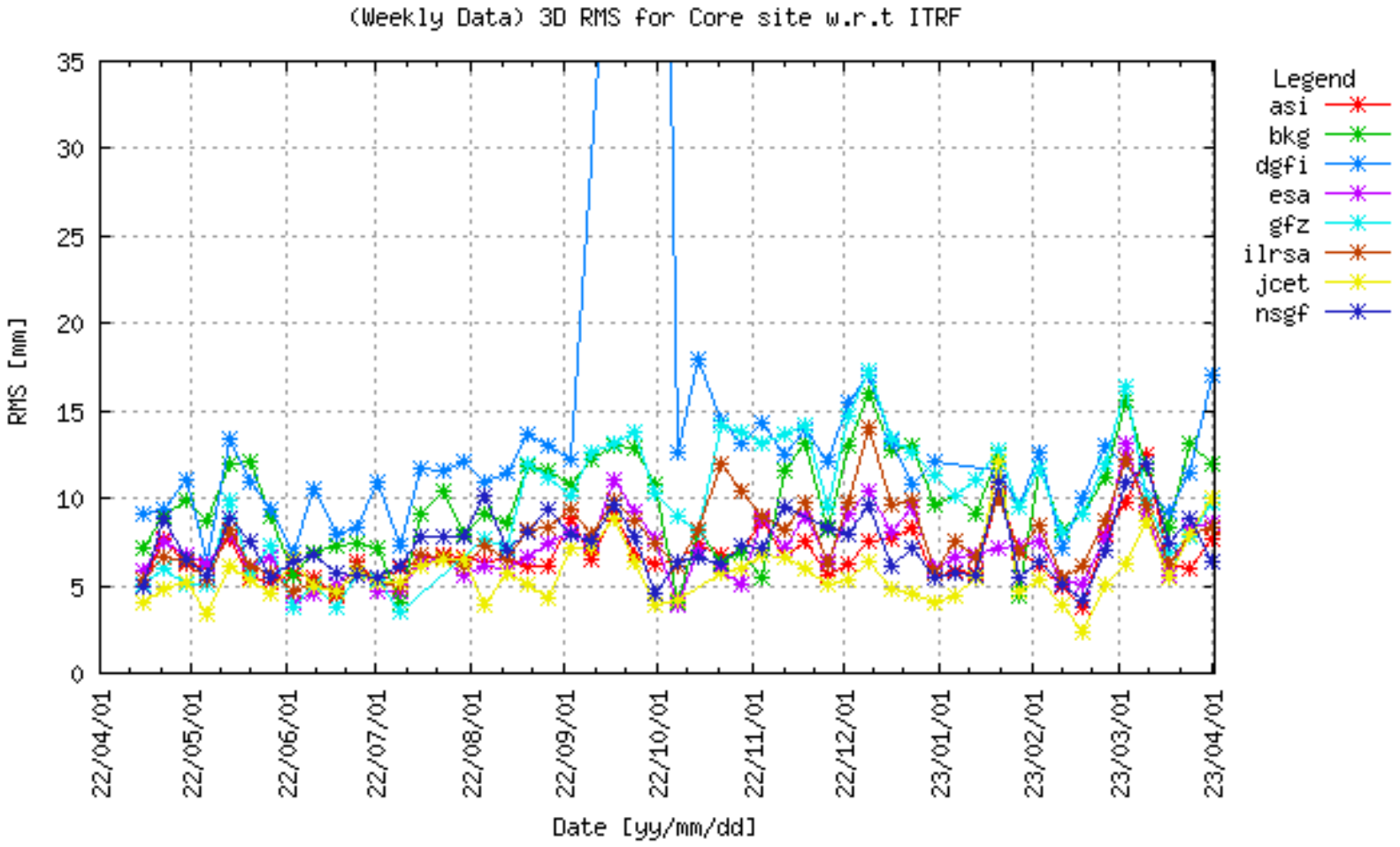




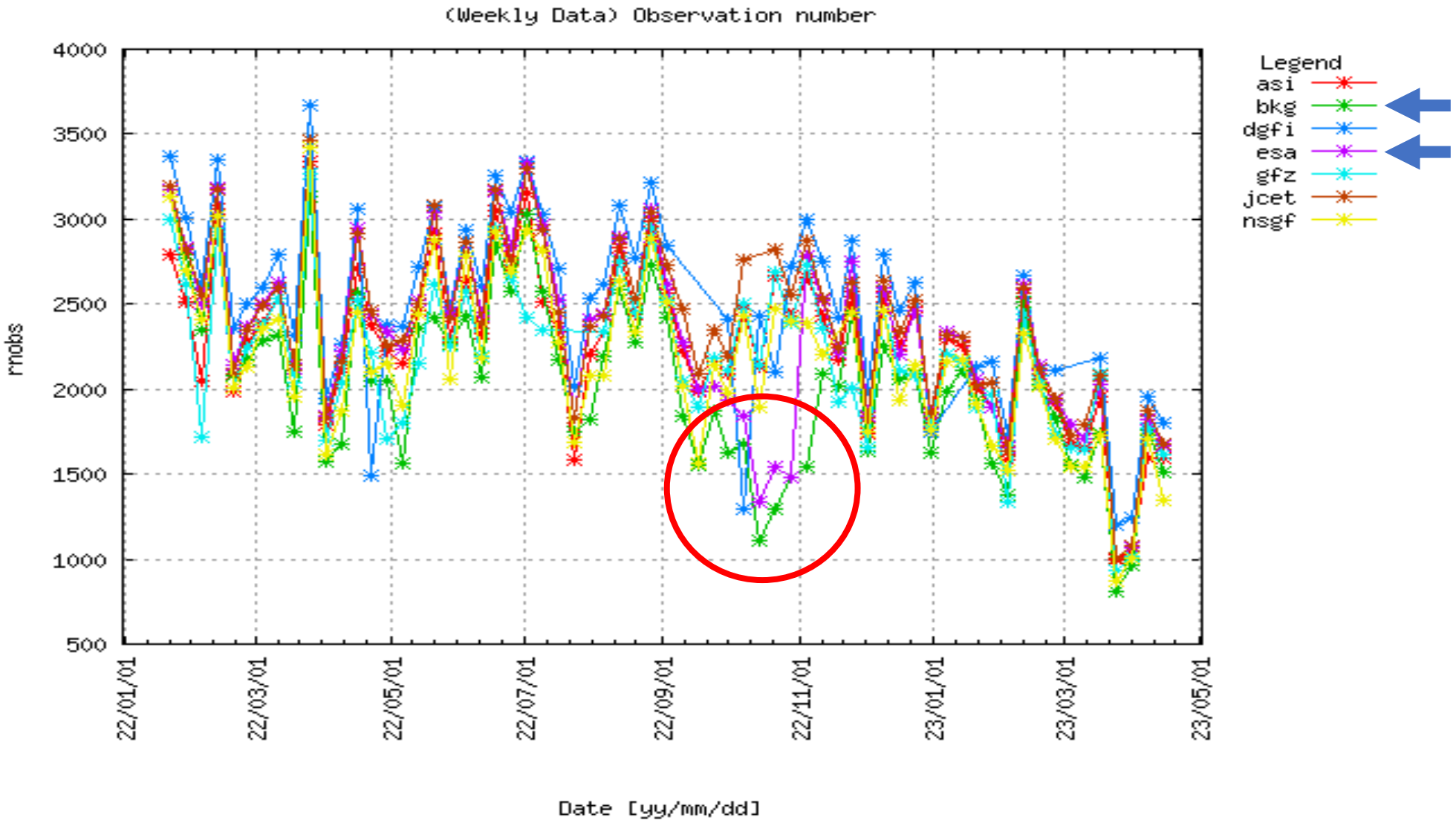


Stations coordinates from weekly solutions

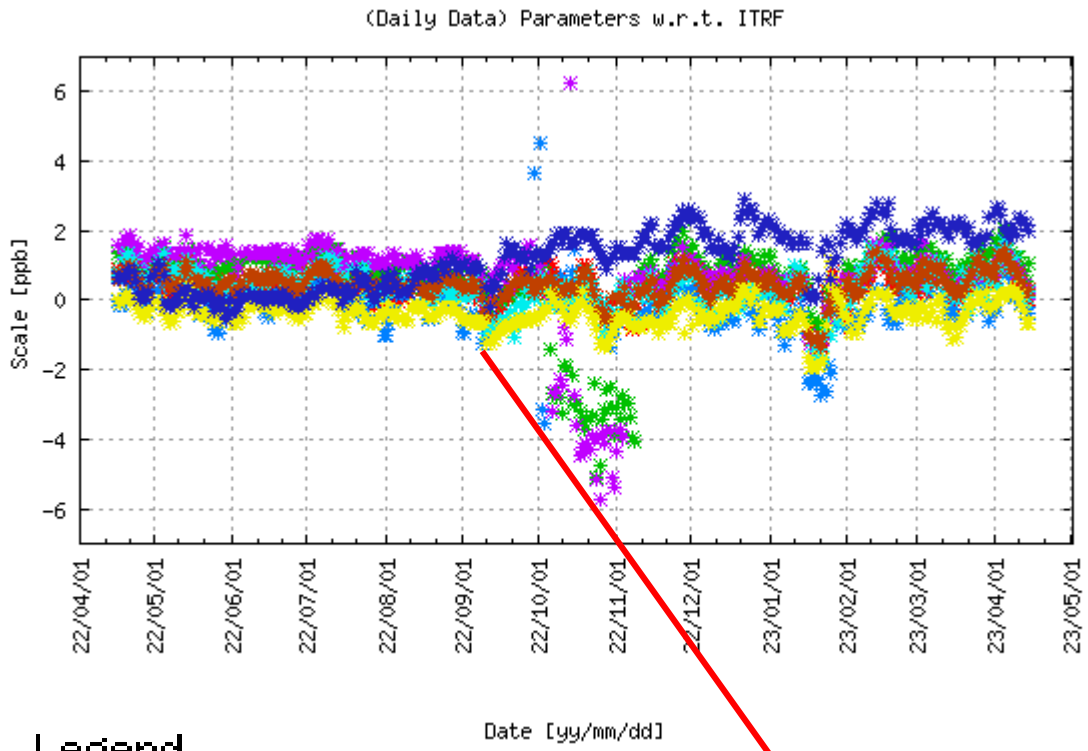
3D wrms of the residual w.r.t. SLRF2014
CORE SITES



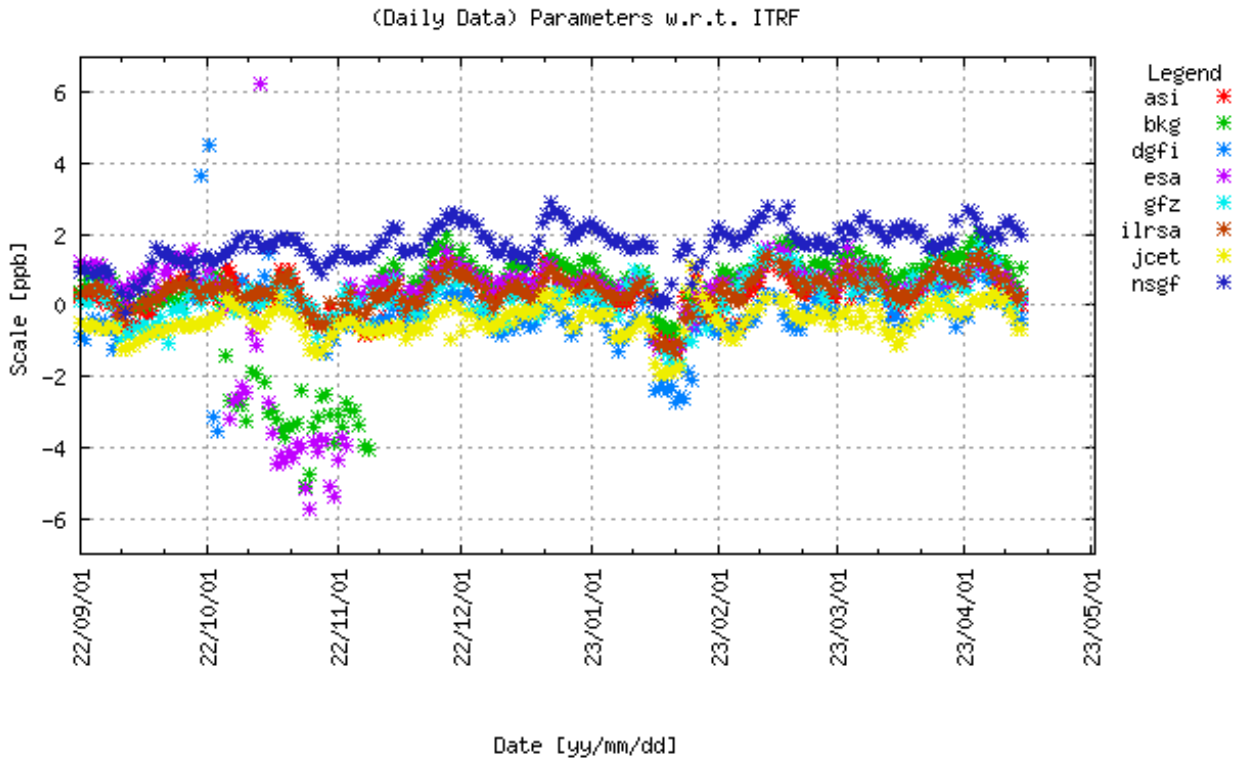
Number of observations for ACs



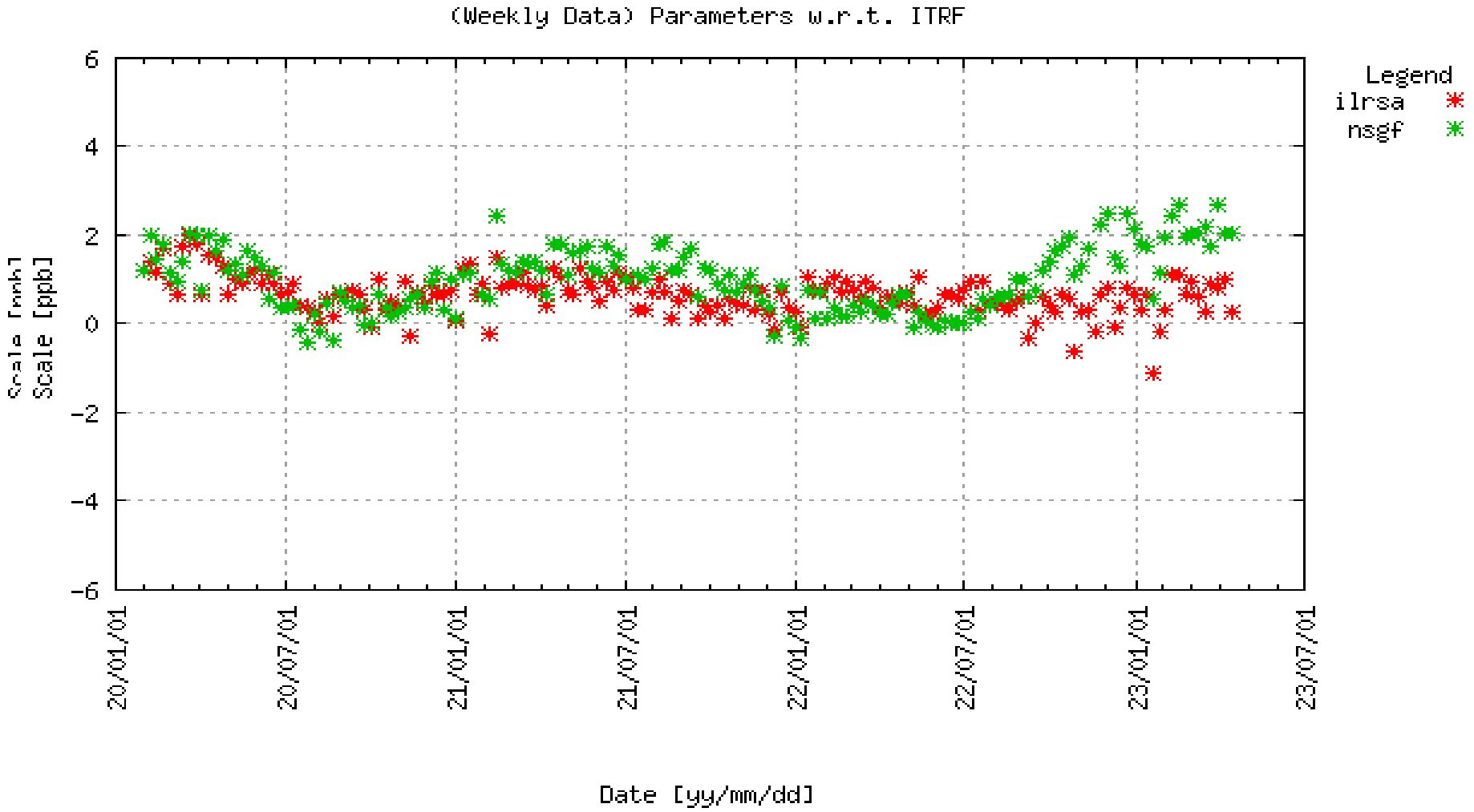
Scale from daily solutions



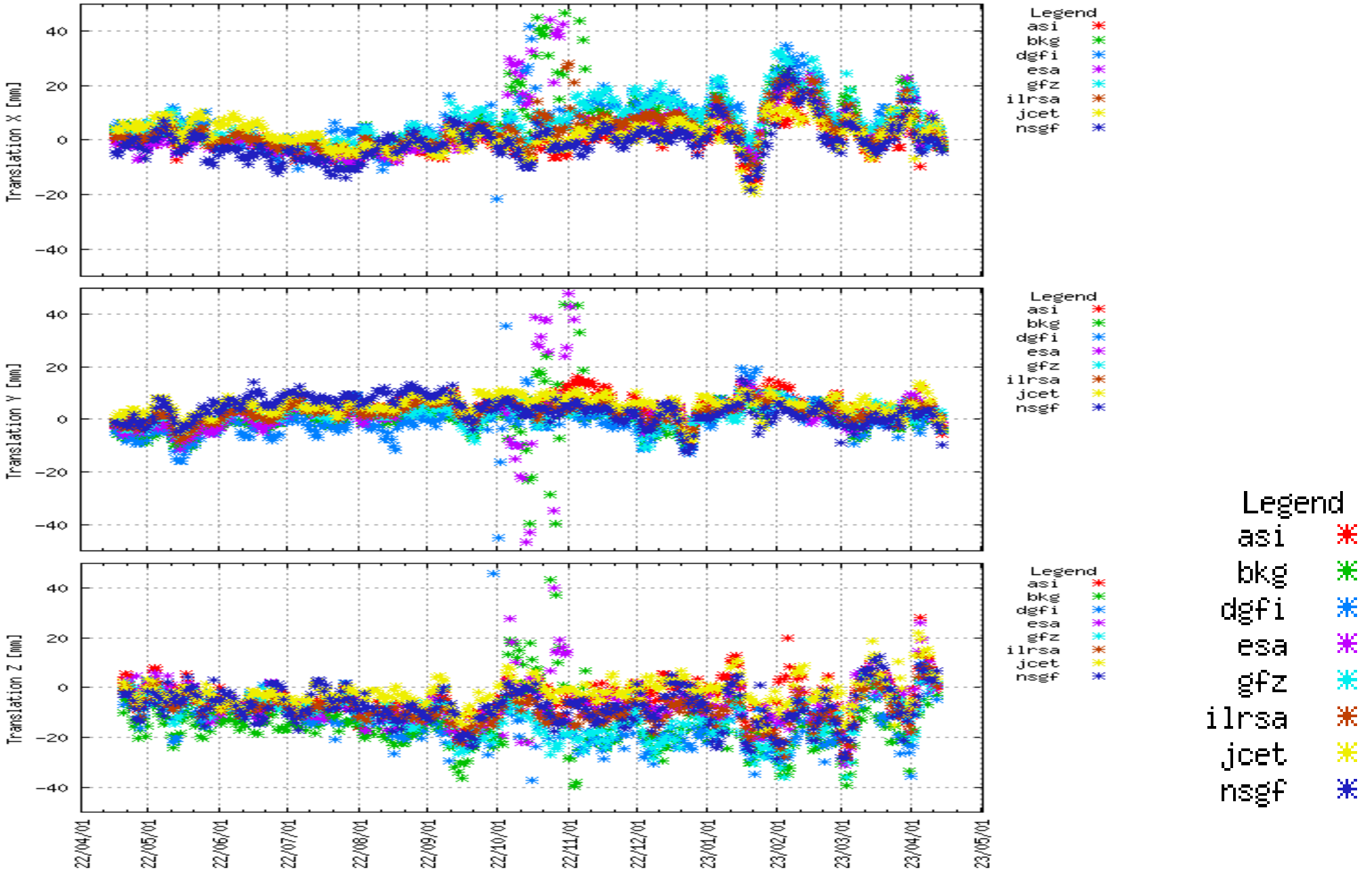
ZOOM



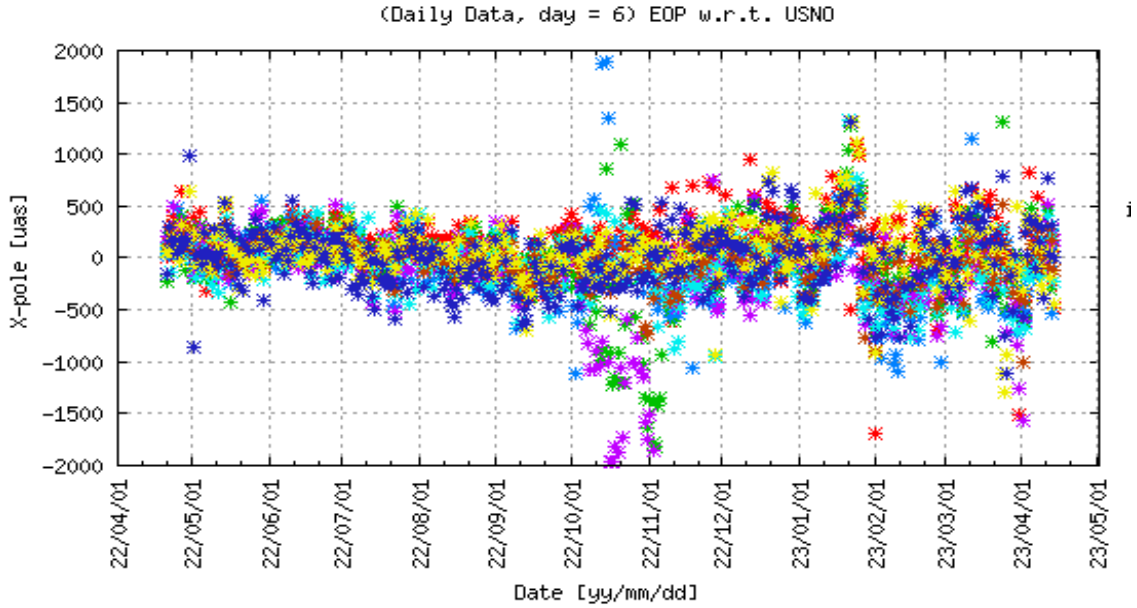
Scale from weekly solutions

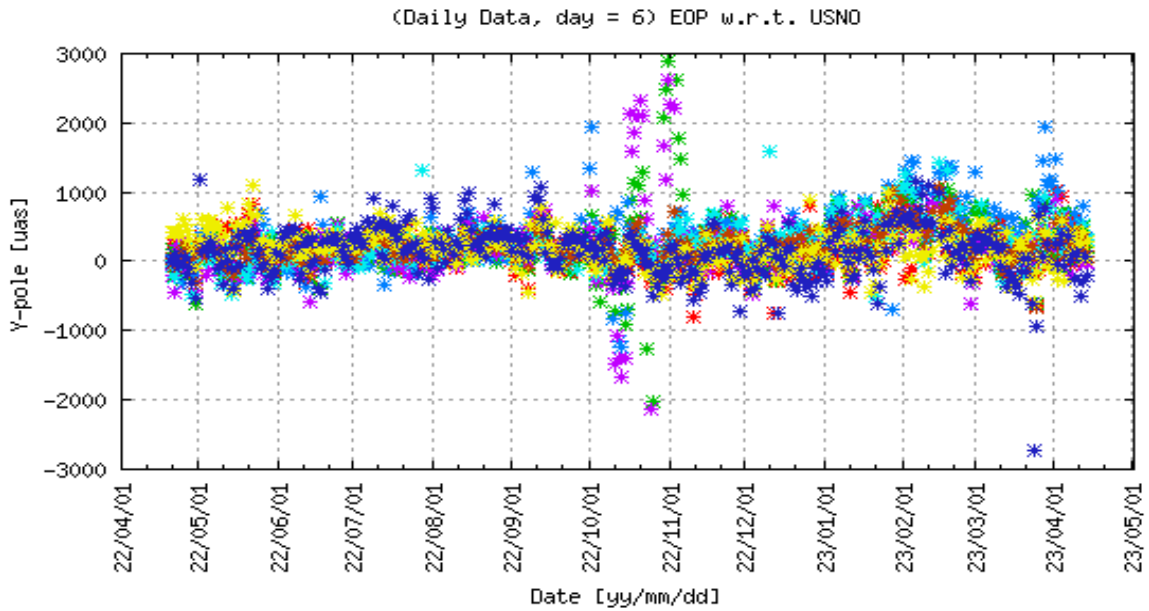


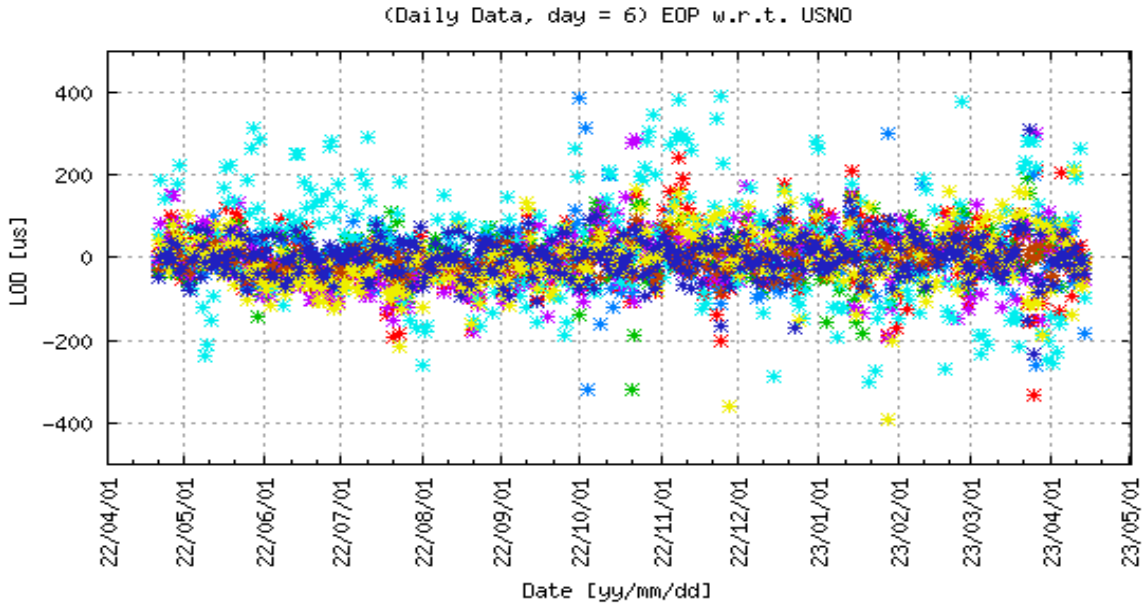
Geocenter motion from daily solutions



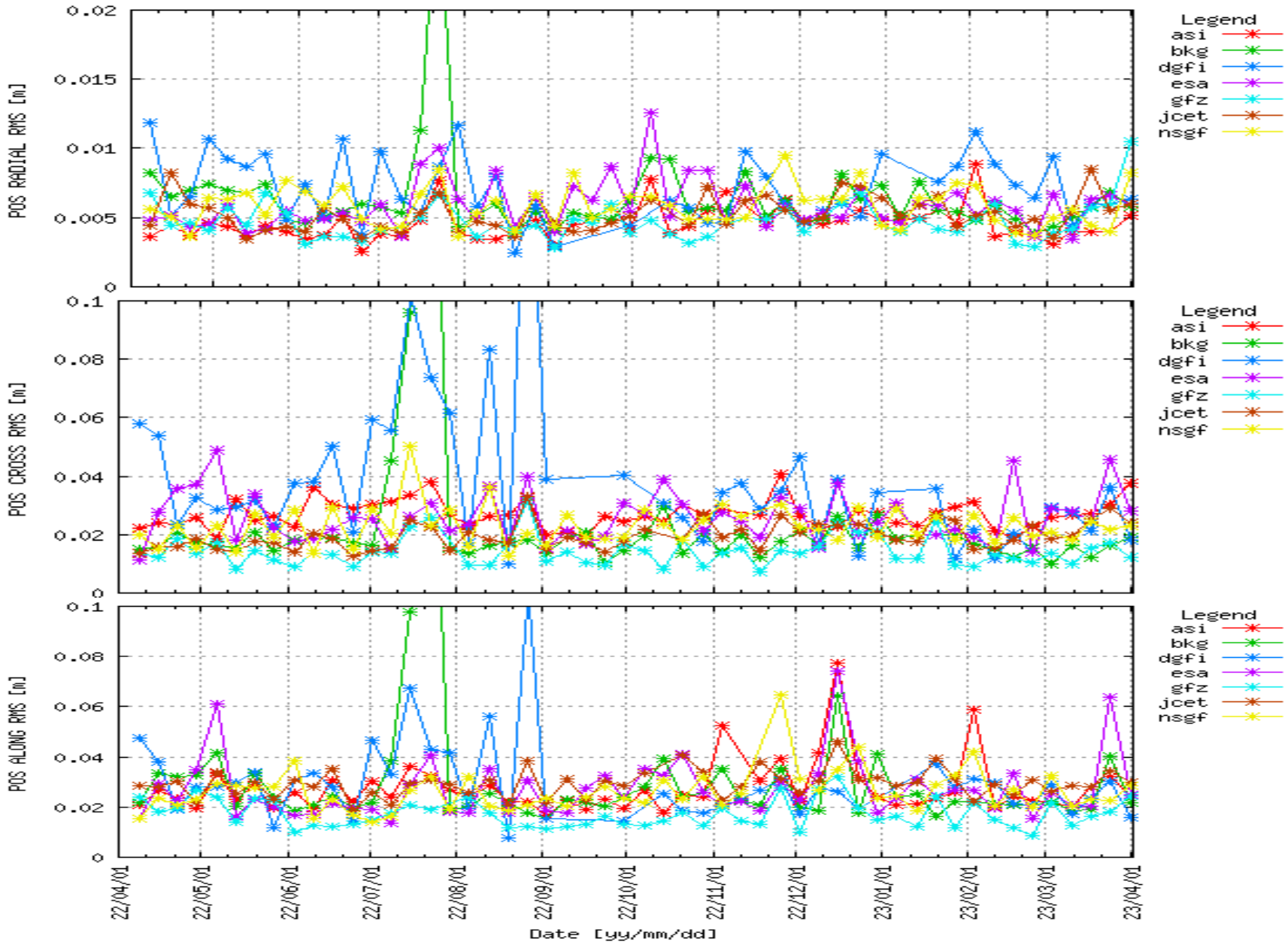
EOP from daily solutions



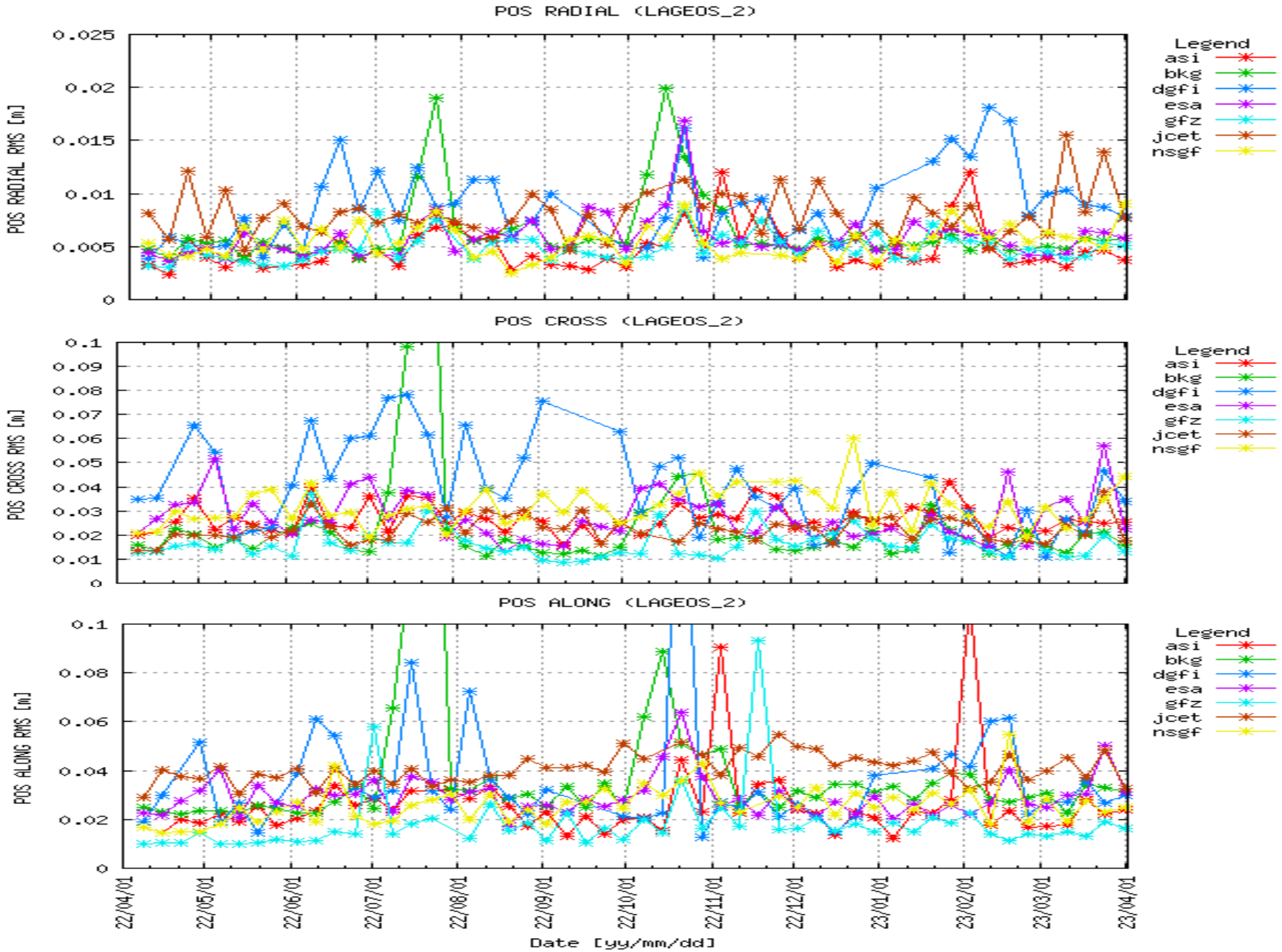




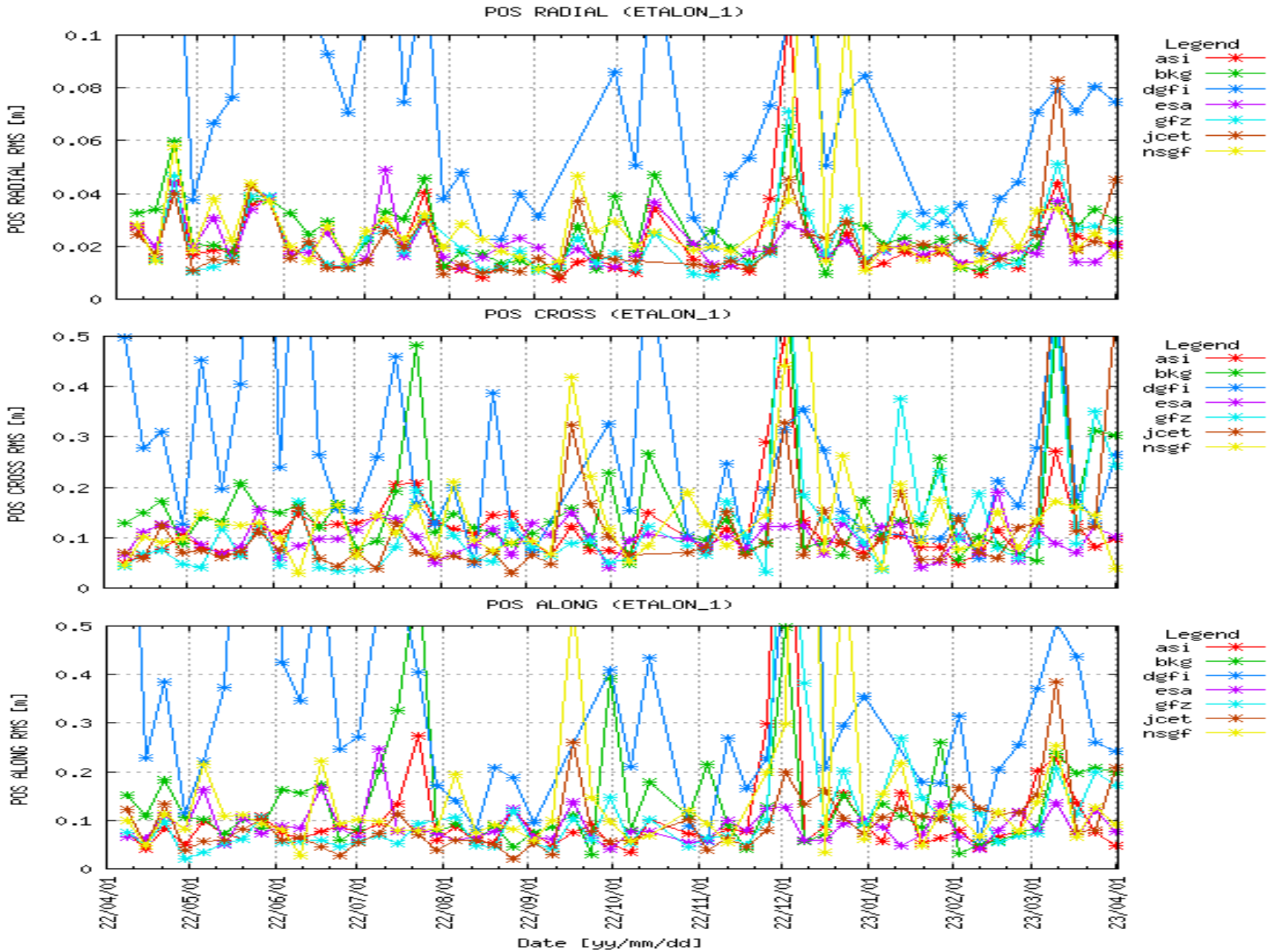
LAGEOS1 orbits – RMS of residuals w.r.t. combination



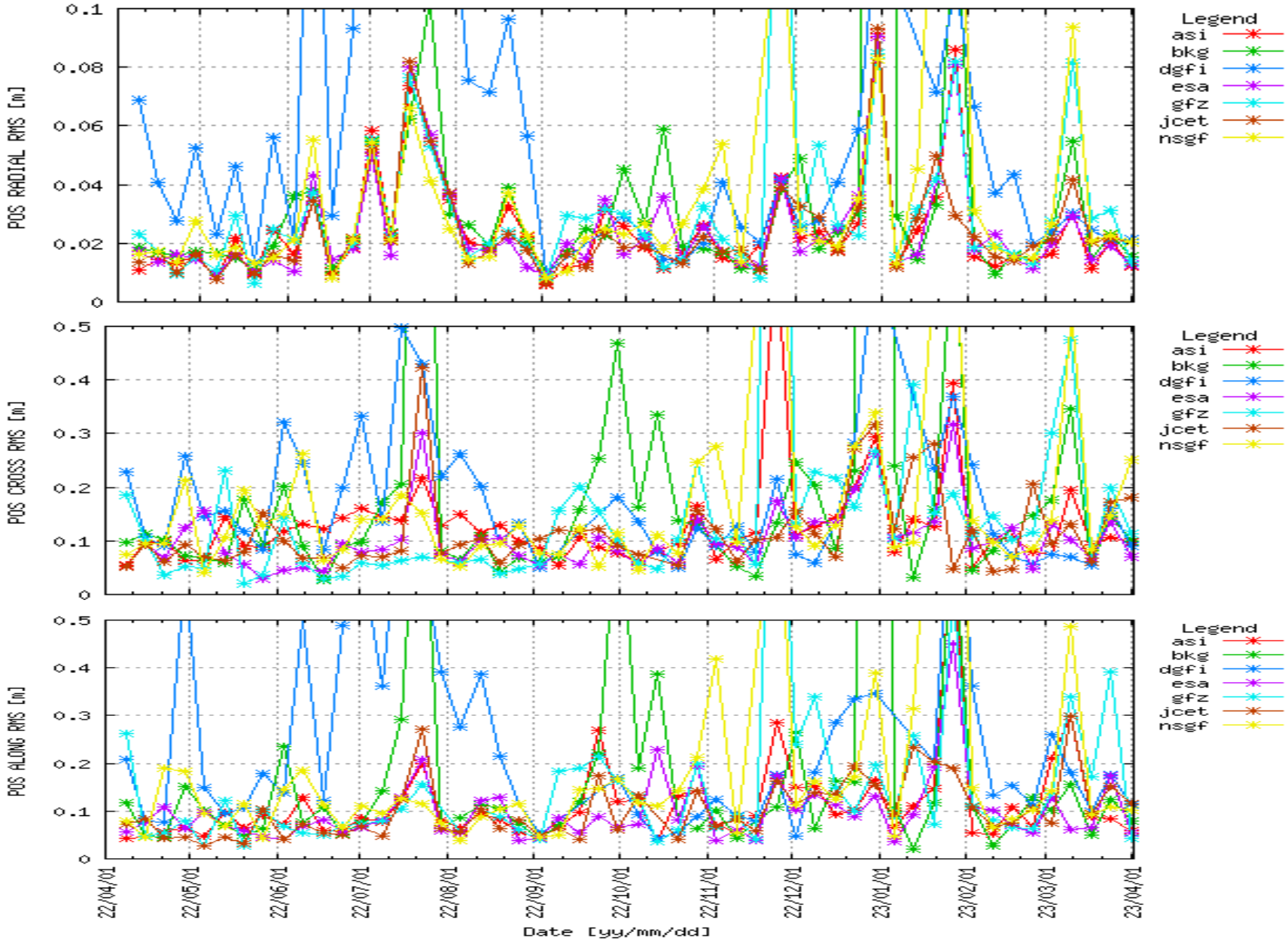
LAGEOS2 orbits – RMS of residuals w.r.t. combination



ETALON1 orbits – RMS of residuals w.r.t. combination



ETALON2 orbits – RMS of residuals w.r.t. combination



ILRS ACs orbit agreement

Satellite	Radial [mm]	Cross-track [mm]	Along-track [mm]
LAGEOS1	5.7	24.1	27.0
LAGEOS2	6.3	26.7	30.8
ETALON1	31.6	147.3	155.4
ETALON2	35.3	166.0	156.6

ALL ACs

Satellite	Radial [mm]	Cross-track [mm]	Along-track [mm]
LAGEOS1	5.5	22.2	26.6
LAGEOS2	5.9	24.8	29.9
ETALON1	23.1	128.2	119.2
ETALON2	30.9	165.3	143.5

without DGFI

Mean RMS over the period 2022/04/19-2023/04/19

Test v415 series for USNO

- All ACs delivered WEEKLY SINEXs for 2021 & 2022 based on the REPRO models and SLRF2020 and “draft” IERS EOPC04 20, v415 series.

- All SINEXs were combined and sent to IERS RS/PC at USNO for the final release of the IERS EOPC04 20 and Bulletin A (planned transition to the revised one aligned with ITRF2020 on March 30, 2023), the series can be downloaded from :

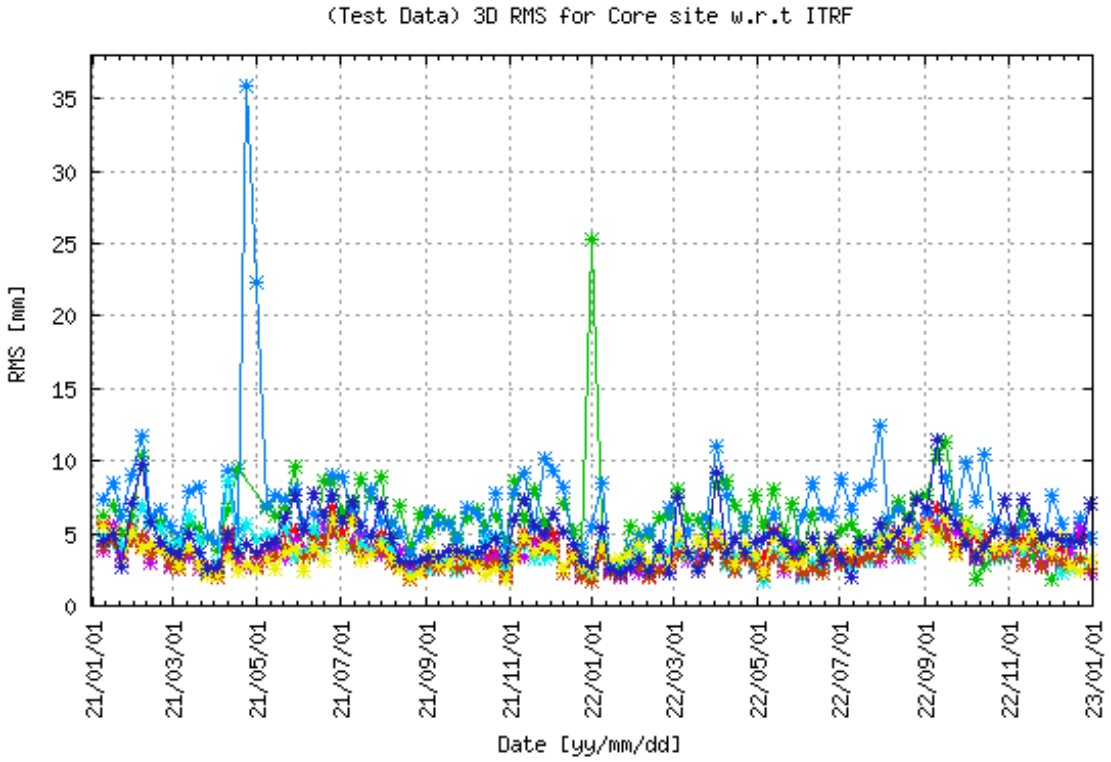
  ftp://edc.dgfi.tum.de/pub/slr/products/test/EOPC04_20draft_v415/

v415 SERIES for 2021 & 2022 UPLOADED on EDC

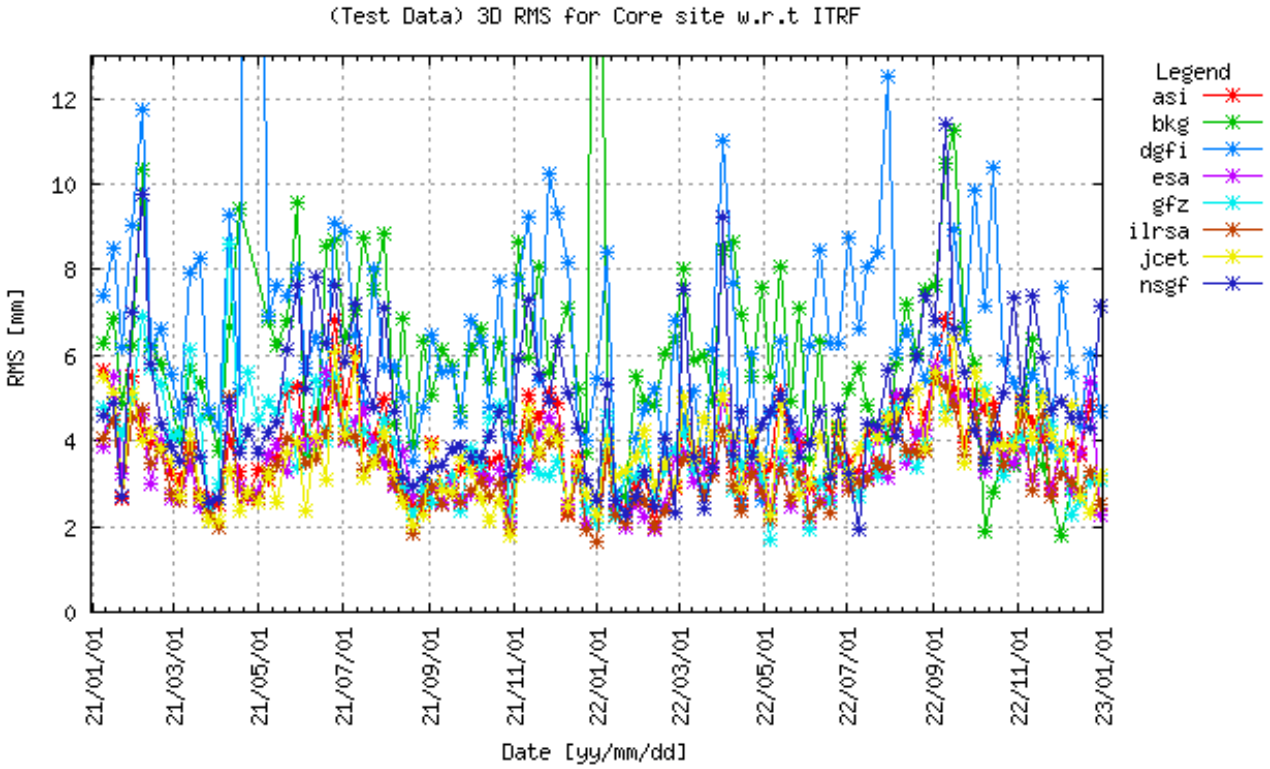
SINEX FILES by AC and CC

version	ASI	BKG	DGFI	ESA	GFZ	JCET	NSGF	ILRSA	ILRSB
v415	2023-02-10 (106 files)	2023-02-23 (102 files)	2023-02-08 (106 files)	2023-02-13 (106 files)	2023-01-18 (106 files)	2023-02-11 (107 files)	2023-02-12 (106 files)	2023-03-08 (104 files)	2023-03-06 (101 files)
First week	201226	210102	201226	201226	201226	201226	201226	210109	210109
Last week	221231	221210	221231	221231	221231	230107	221231	221231	221210

v415 3D-WRMS (core site)



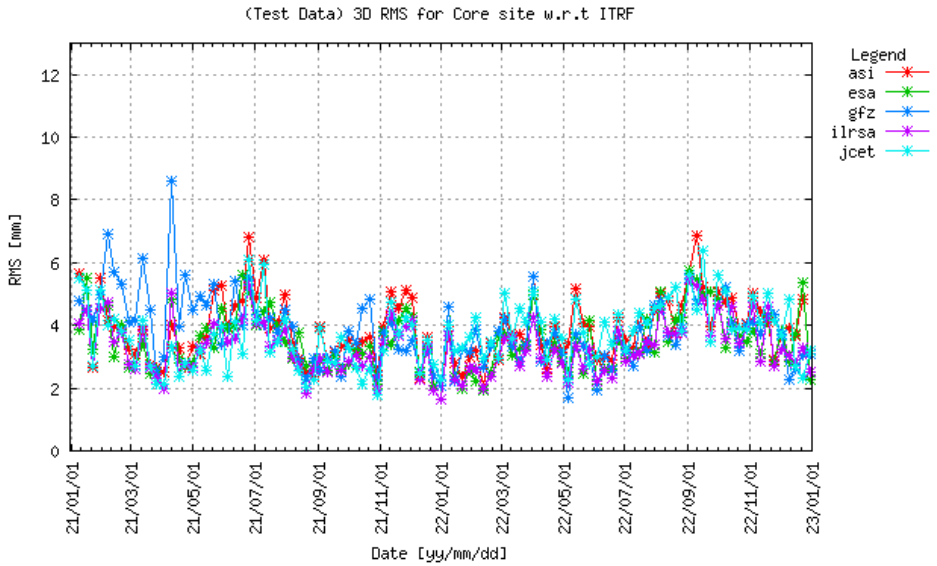
Scale: 0-35mm

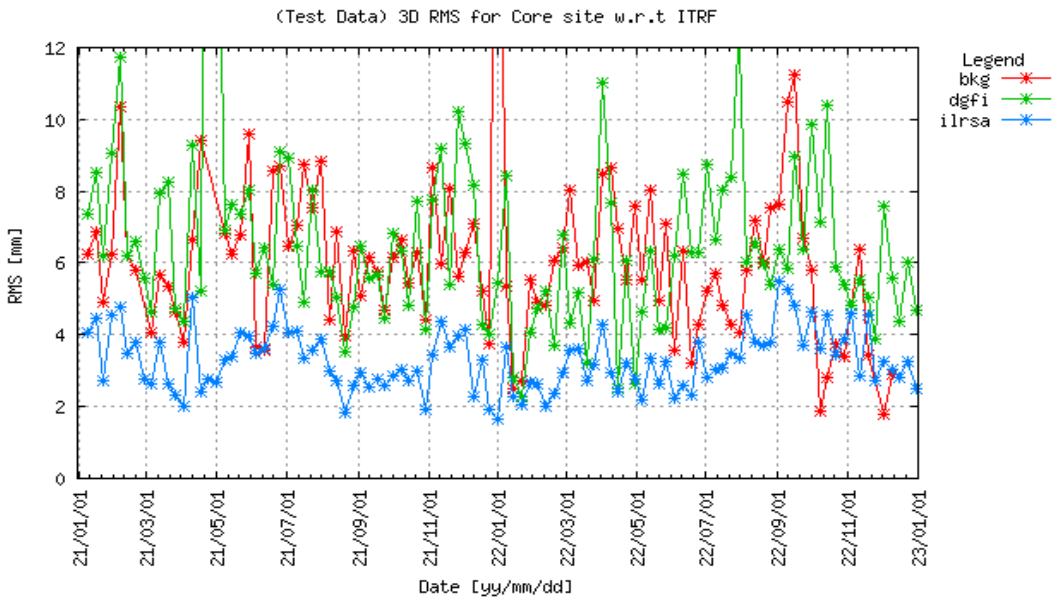


Scale: 0-12mm

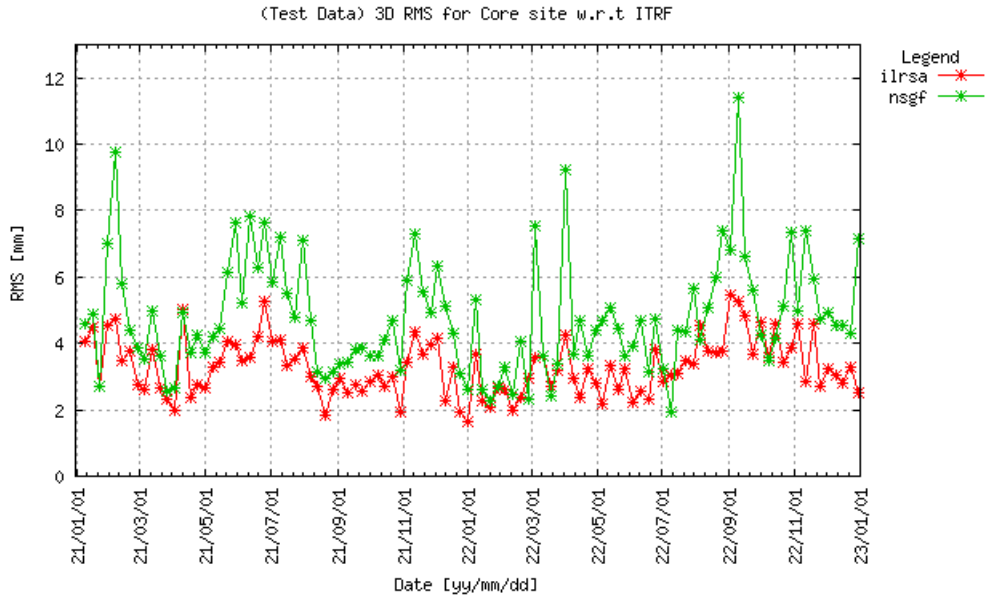
v415 3D-WRMS (core site)

ASI/ESA/GFZ/JCET - ILRSA





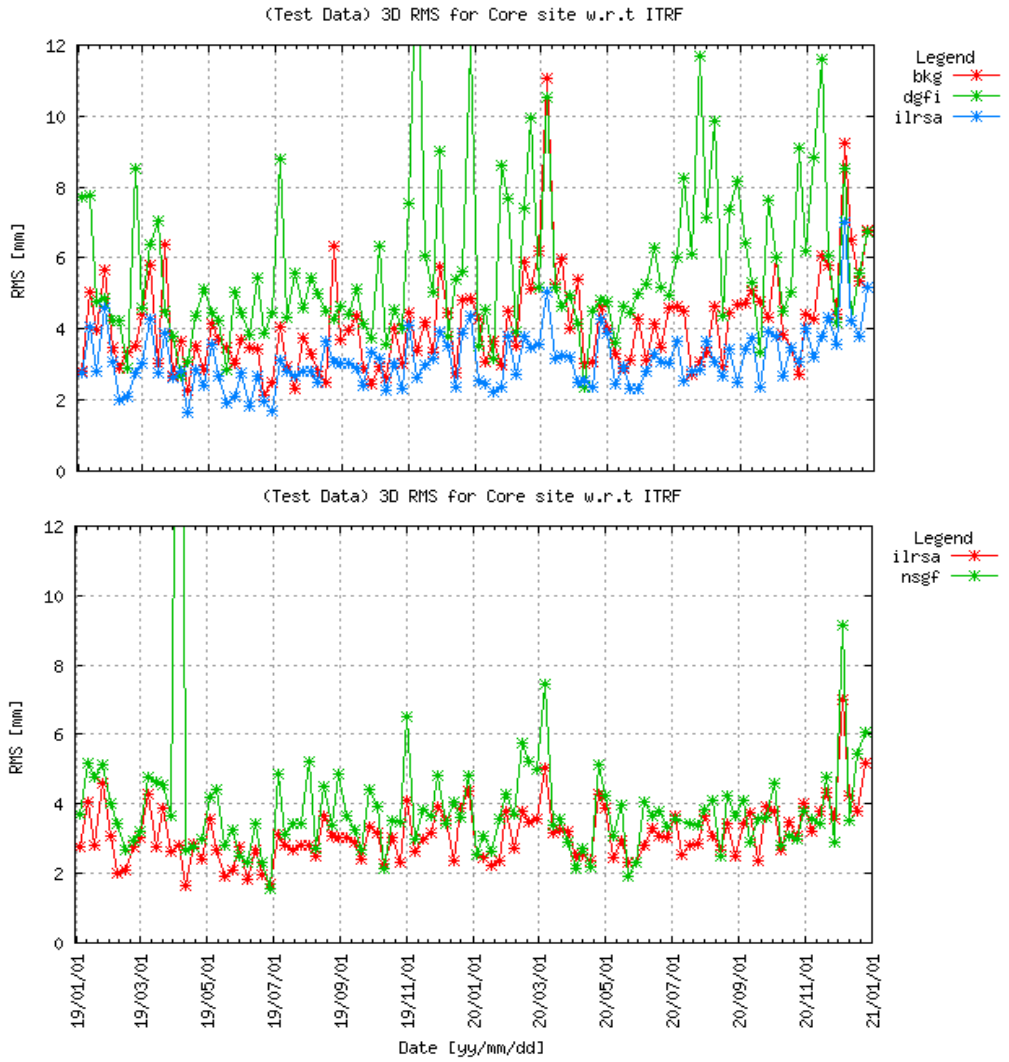
BKG/DGFI - ILRSA



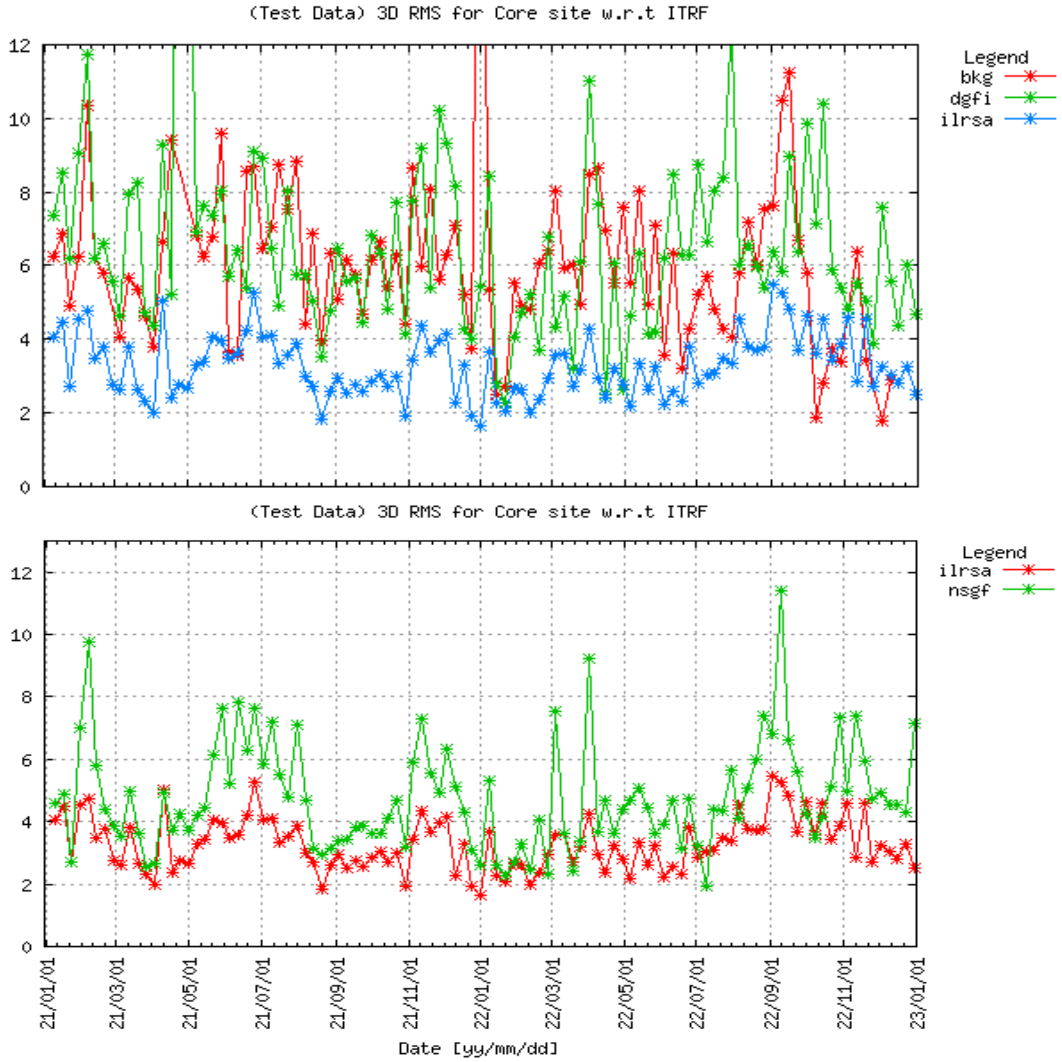
NSGF - ILRSA

v415 3D-WRMS compared with REPRO2020 (core site)

V410
2019 - 2021

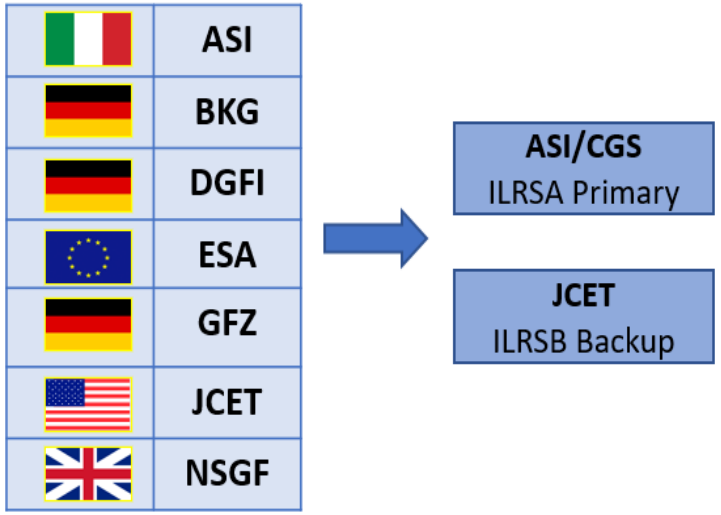


v415
2021 – 2023



ILRS Data Handling File

Station Systematic Error Modeling



- In 2015 ILRS launched a multi-year effort to address and resolve the SLR scale issue: Station Systematic Error Modeling Pilot Project (**SSEM PP**) to estimate RBIAS simultaneously with the station positions.

- Analysis since **01/1993.**
- Weekly estimation of coordinates, EOP and range biases RB
- Time frame for the Pilot Project: 1993 – 2020 for ITRF2020
- Data: LAGEOS , LAGEOS 2, ETALON1-2
- Time series with separate range biases for LAGEOS, combined for ETALON

Data Handling file used for ITRF2020 was the version 210416 (yymmdd), from january 1993 to december 2020

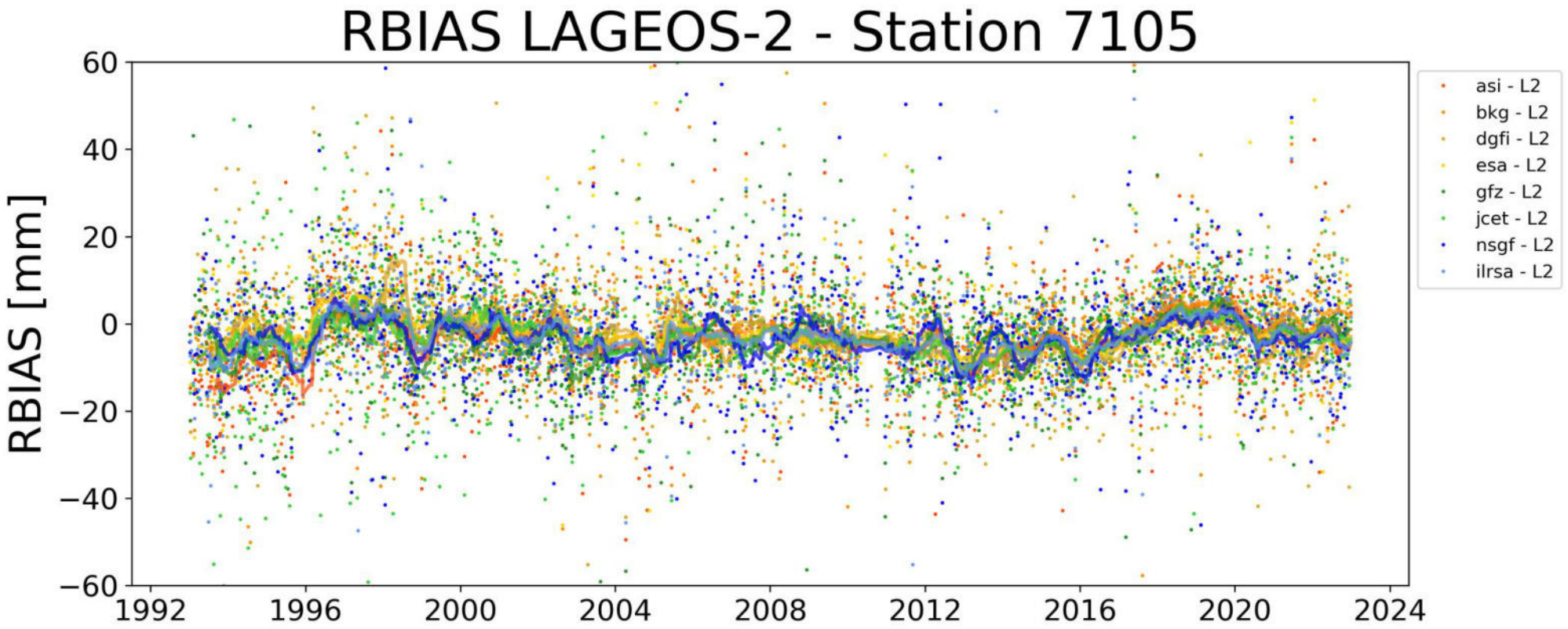
PP-SSEM solutions for DH file updated to end-2022

AC	# SINEXs v230	Start date	End date
ASI	1564	930206	221231
BKG	1545	930206	221231
DGFI	1567	930206	221231
ESA	1564	930206	221210
GFZ	1561	930206	221217
JCET	1529	930206	221231
NSGF	1557	930206	221210

All ACs to the current date 19/04/23 are delivering v230 product routinely to EDC server.

Operational Data Handling file

- All ACs delivered WEEKLY SINEXs to extend the time series (v23* series) to end-2022.
- All SINEXs were combined to update the DH file
- All ACs filled the gaps left until the present time.
- Set a weekly production chain of SSEM-like SINEXs file to routinely extend the RB time series (v230).



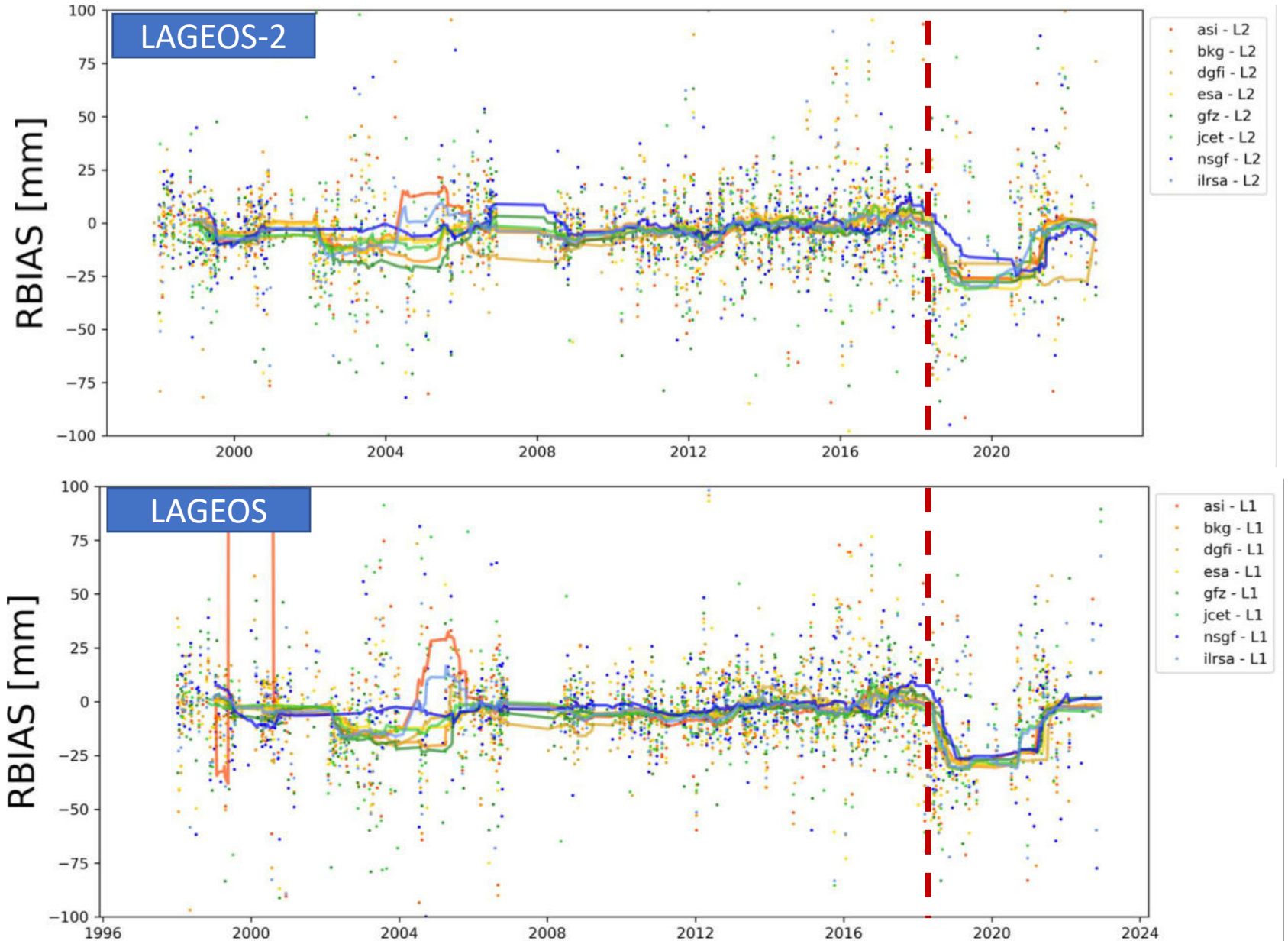
Operational Data Handling file

Major Updates

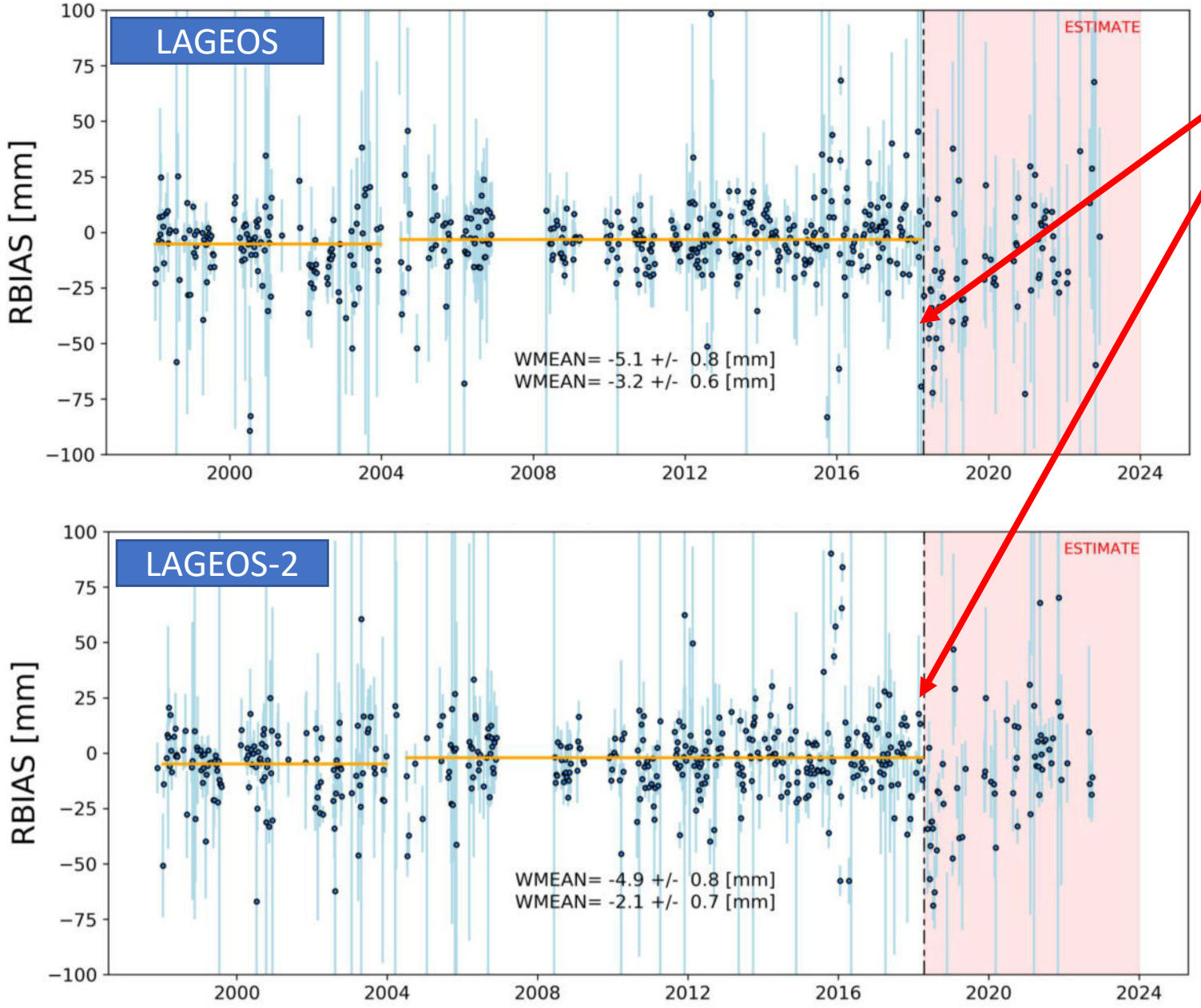
	ILRS_Data_Handling_File_REPRO2020_210416						ILRS_Data_Handling_File_REV_280323						
		Start	Stop	**Val**	**Sig**		Start	Stop	Val	Sig	DELTA	SIGMA	
L1	7124	18:021:00000	20:075:00000	-29,5	2,6		estimated after 15/4/2018, as indicated by Van Husson						
L1	7237						20:033:00000	00:000:00000	10.3	0.8	-10,3	0.8	additional interval
L1	7821	16:017:00000	20:145:00000	-6,9	0,8		16:017:00000	00:000:00000	-5.4	0.6	-1,5	0.6	
L1	7838	11:079:00000	18:287:00000	-5,3	0,7		11:079:00000	18:070:00000	-3.9	0.6	-1,4	0.6	
L1	7845	15:004:00000	21:001:00000	-6	0,4		15:004:00000	19:041:00000	-7.9	0.5	1,9	0.5	
L2	7124	18:021:00000	20:075:00000	-27,3	3,7		estimated after 15/4/2018, as indicated by Van Husson						
L2	7237						20:033:00000	00:000:00000	11.5	0.8	-11,5	0.8	
L2	7821	16:017:00000	20:145:00000	-4,2	0,8		16:017:00000	00:000:00000	-2.9	0.6	-1,3	0.6	
L2	7838	11:079:00000	18:287:00000	-4	0,7		11:079:00000	18:070:00000	-2.4	0.6	-1,6	0.6	
L2	7845	15:004:00000	21:001:00000	-3,8	0,4		15:004:00000	19:041:00000	-5.7	0.5	1,9	0.5	
EC	7105	17:036:00000	21:001:00000	17	0,8		17:036:00000	00:000:00000	13.6	0.7	3,4	0.7	
EC	7810	01:091:00000	21:001:00000	3	0,3		01:091:00000	16:080:00000	1.3	0.4			New discontinuity
EC	7825	04:221:00000	07:168:00000	-8,5	1		16:080:00000	22:051:00000	7.2	0.5			
EC	7845	08:349:00000	21:001:00000	-5,9	0,6		01:126:00000	04:270:00000	12.8	1.1	0	1.1	
EC	7849	98:186:00000	02:363:00000	-8,2	1,2		08:349:00000	17:022:00000	-8.7	0.7	2,8	0.7	

Current release of DH file **230328**

Revised station behavior – station 7124 case



Revised station behavior – station 7124 case



New break at 18:105:00000

Revised station behavior – station 7124 case

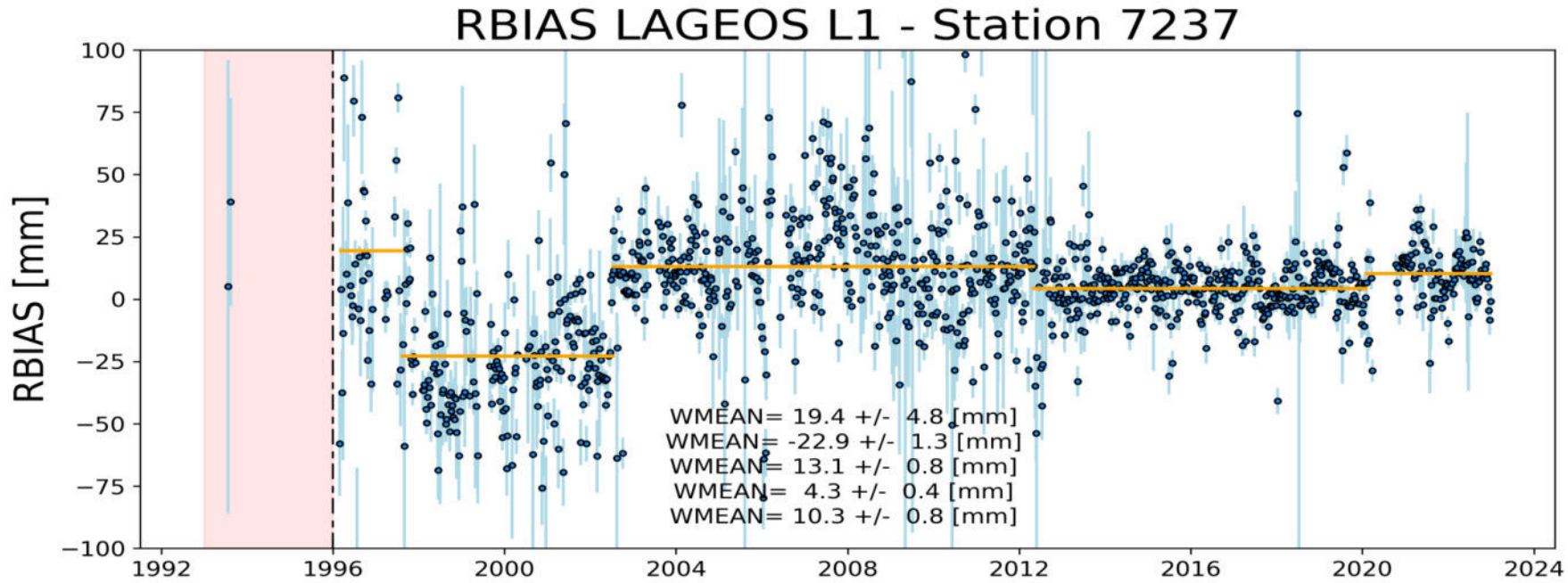
```
·7124·51··501·A·18:021:00000·20:075:00000·R·········-29.5·····2.6·············mm·
·7124·52··501·A·18:021:00000·20:075:00000·R·········-27.3·····3.7·············mm·
·7124·53··501·A·18:028:00000·20:075:00000·E·····································mm·
·7124·54··501·A·18:028:00000·20:075:00000·E·····································mm·

·7124·51··501·A·04:186:00000·18:105:00000·R··········-3.2·····0.6·············mm·
·7124·52··501·A·04:186:00000·18:105:00000·R··········-2.1·····0.7·············mm·
·7124·53··501·A·08:343:00000·18:105:00000·R··········12.1·····1.3·············mm·
·7124·54··501·A·08:343:00000·18:105:00000·R··········12.1·····1.3·············mm·
·7124·----·501·A·18:105:00000·00:000:00000·E·····································mm·
```

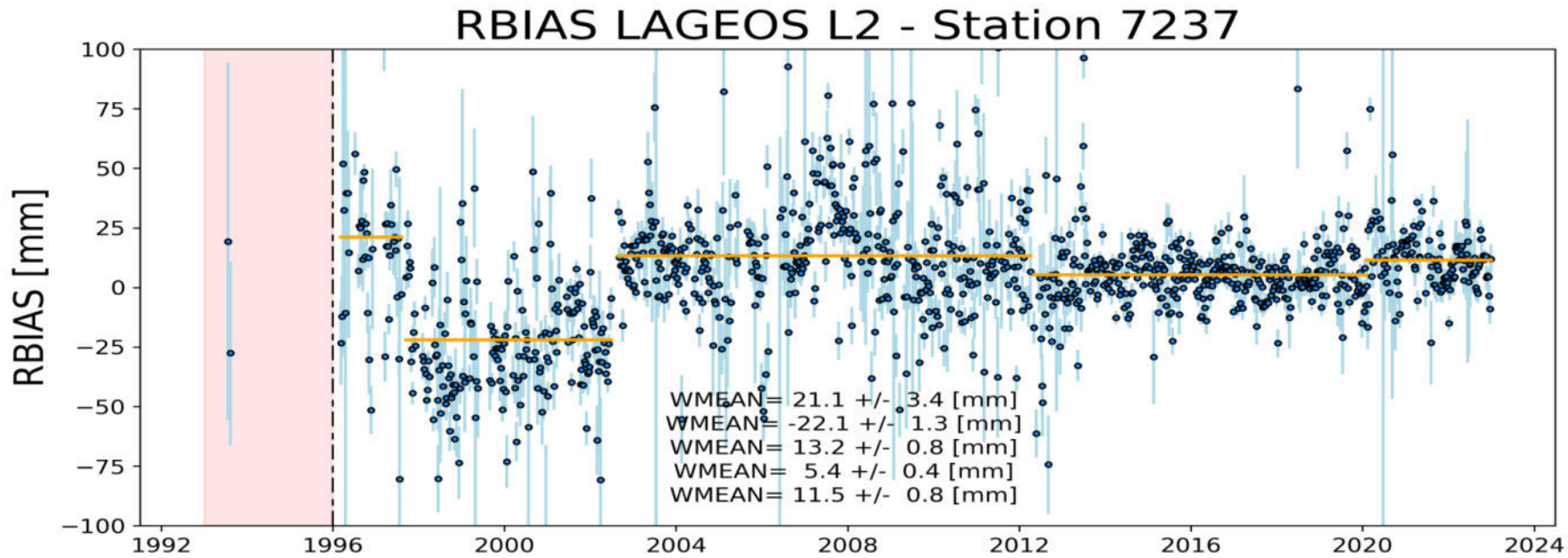
DH file for ITRF2020

Extended DH file to end-2022

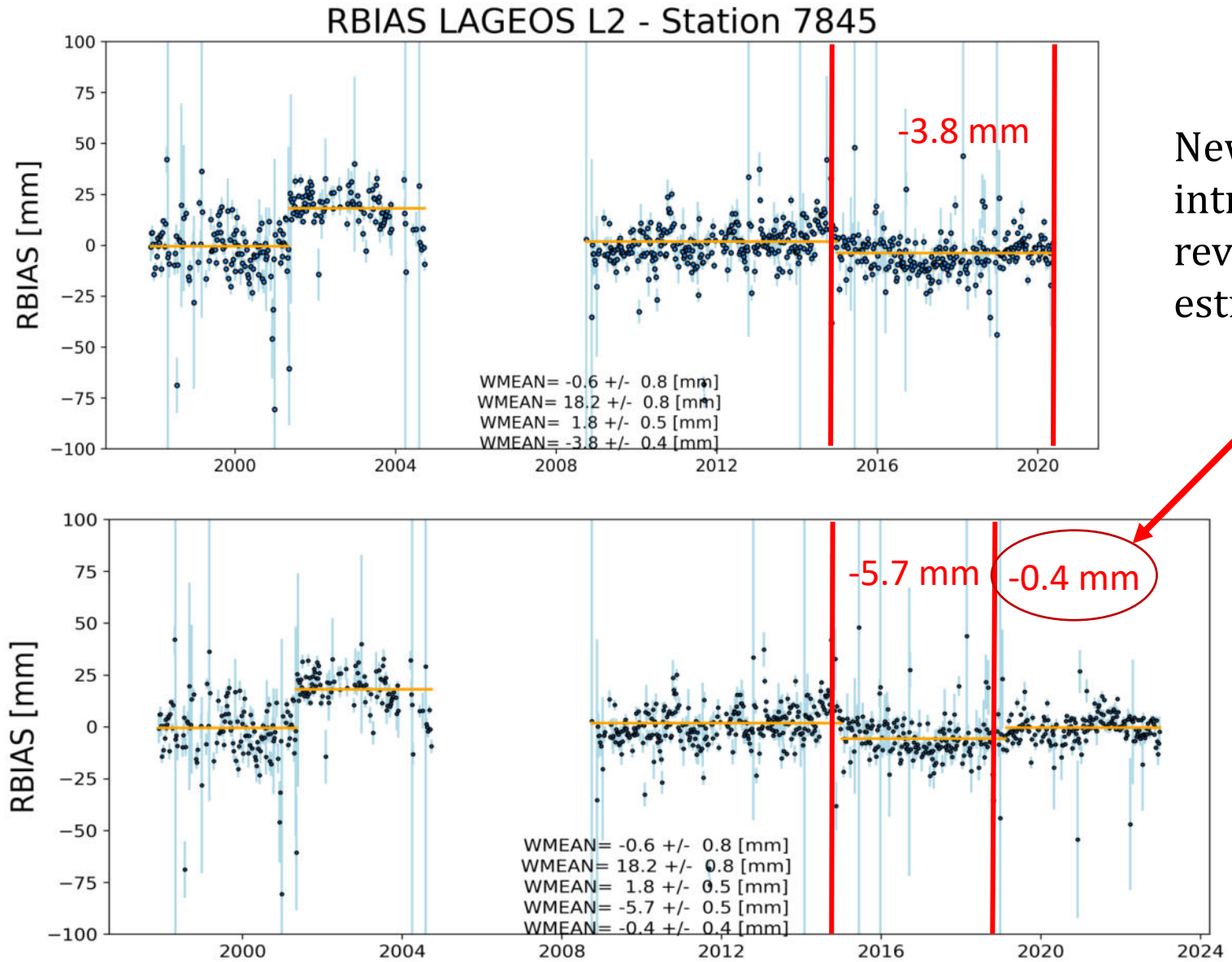
Same break point for all satellites

Estimation of the range bias for incoming data


RBIAS LAGEOS L1 - Station 7237
RBIAS [mm]
100
75
50
25
0
−25
−50
−75
−100
1992
1996
2000
2004
2008
2012
2016
2020
2024
WMEAN= 19.4 +/- 4.8 [mm]
WMEAN= -22.9 +/- 1.3 [mm]
WMEAN= 13.1 +/- 0.8 [mm]
WMEAN= 4.3 +/- 0.4 [mm]
WMEAN= 10.3 +/- 0.8 [mm]


RBIAS LAGEOS L2 - Station 7237
RBIAS [mm]
100
75
50
25
0
−25
−50
−75
−100
1992
1996
2000
2004
2008
2012
2016
2020
2024
WMEAN= 21.1 +/- 3.4 [mm]
WMEAN= -22.1 +/- 1.3 [mm]
WMEAN= 13.2 +/- 0.8 [mm]
WMEAN= 5.4 +/- 0.4 [mm]
WMEAN= 11.5 +/- 0.8 [mm]

Extended RB time series for Grasse



New discontinuities introduced with revision of long term estimates

New operational products

New ILRS routine products

- The SLRF2020 and associated DHF were sent to the 7 ACs involved in REPRO2020 (**28/03/2023**) as input for the new products (v80, v180 & v280):

  http://geodesy.jcet.umbc.edu/ILRS_ASC_RESOURCES/

- v80, v180 and v280 products are produced in parallel for 1-2 months with the current ones in order to check the new solutions.

- **DGFI,NSGF,ASI** to the current date 19/04/23 are routinely delivering v180 and v80 products to EDC server, **DGFI and ASI** are delivering v280 product too:

  /pub/slr/products/test/daily_v180
  /pub/slr/products/test/weekly_v80
  /pub/slr/products/test/ssem_v280

- Latency for v80 and v280:

sunday 1	.....	sat 7	sun 8	...	sat 14	sun 15	mon 16	tue 17	wed 18	.....
Data arc from 1 to 7								AC V80 V280 arc 1-7	CC V80V280 arc 1-7	

e-geos
AN ASI / TELESPAZIO COMPANY

International Laser Ranging Service

ASI
Agenzia Spaziale Italiana

Thank you

Federal Agency for Cartography and Geodesy

BKG
Wir geben Orientierung.

BKG Report

D. Koenig, U. Meyer (AIUB), D. Thaller

Overview

Work Done/Ongoing

- Processings done/implemented:
  v415 – submitted
  v230 – SSEM-X: operational
- New architecture of Unix machines
  new environment for s/w organisation + processing
- new Bernese version 5.4 released:
  installation process ongoing
  to be put into operation soon

Overview

ILRS Topics (Item (3) of Draft Minutes)

- Implementation of new analysis models
  - ready to be used:
    - SLRF2020
    - new DHF, IERS 20 C04
  - already in use:
    - TSM(220915)
    - new subdaily EOP model
- Parallel submission of v180, v80, and v280 products
  - pending
- Future plans:
  - transition to combination at the NEQ level (incl. LARES,…)
  - investigation of weighting and correlation aspects within multi-sat. comb.
  - establishing a website for product parameters

Report of the DGFI-TUM ILRS AC

Mathis Bloßfeld, Alexander Kehm

Deutsches Geodätisches Forschungsinstitut, Technische Universität München (DGFI-TUM)

ILRS ASC meeting – 2023-04-26

Implementation of new analysis models

- new ITRS realizations
  - **ITRF2020** (Altamimi et al., 2023) **+ respective metadata**
  - **DTRF2020** (Seitz et al., 2023) **+ respective metadata**
  - **JTRF2020** (Abbondanza et al., 2023)
  - **SLRF2020** (v1.0; Pavlis et al., 2023)
- new **IERS 20 C04** (Bizouard et al., 2023) + **sub-daily EOP model** (Desai and Sibois, 2016)
- new Earth gravity field models
  - **CNES_GRGS.RL05MF_combined_GRACE_SLR_DORIS** (J.-M. Lemoine et al., 2023)
  - **IAG COST-G fitted signal model** (Peter et al., 2022)
- new ocean tidal models
  - **EOT20** (Hart-Davis et al., 2021),
  - **FES2014** (Lyard et al., 2021
- handling and smoothing of **observed geomagnetic storm and solar flux indices** provided by the German Research Center for Geosciences (GFZ)

Parallel submission of v180, v80, v80(sp3c), and v280

- DGFI-TUM submits since April, 1st all official products in parallel mode
- model changes w.r.t. currently official versions
  - **SLRF2020 (version 230322)** instead of SLRF2014
  - **DHF (version 230328)** instead of DHF (version 200616)
  - updated **TS model (version 220915)**
  - **IERS 20 C04** instead of IERS 14 C04 as a priori EOP
  - **subdaily EOP model (Desai and Sibois, 2016)** instead of subdaily EOP model (Eanes, IERS Conventions)

Currently non-official products computed by DGFI-TUM

- cf. DGFI-TUM Annual Report 2022 (https://www.dgfi.tum.de/en/publications/annual-reports/)

Table 1.2: Routine and project-specific solutions computed by the DGFI-TUM ILRS AC during 2022.

ILRS code	description	file format
v170	daily LA-1/-2 and ET-1/-2 TRF and EOP solutions	SINEX
v70	weekly LA-1/-2 and ET-1/-2 TRF and EOP solutions	SINEX
v70-sp3c	weekly LA-1/-2 and ET-1/-2 orbit solutions	SP3C
—	daily orbit predictions for LA-1/-2 and ET-1/-2 and others	CPF(v2)
v230	weekly LA-1/-2 and ET-1/-2 TRF and EOP solutions (incl. biases)	SINEX
v450	prototype processing of v70 based on the new SLRF2020	SINEX

Besides the official products provided by DGFI-TUM to the ILRS Analysis Standing Committee, numerous other daily and weekly solutions are computed (cf. Tab. 1.3). According to the standards used for the v170 and v70 processing, DGFI-TUM routinely computes 10-satellite solutions comprising six additional spherical satellites compared to the standard ILRS 4-satellite solution. These satellites are LARES (LAser RElativity Satellite), LARES-2, Ajisai, Stella, Starlette, and Larets.

Table 1.3: Routine (in-official) solutions computed by the DGFI-TUM ILRS AC during 2022.

ILRS code	description	file format
—	daily 10-satellite TRF and EOP solutions	SINEX
—	weekly 10-satellite TRF and EOP solutions	SINEX
—	weekly GM solution based on 10 satellites	SINEX
—	weekly SH deg 1 solution based on 10 satellites	SINEX
—	weekly SH deg 2 solution based on 10 satellites	SINEX
—	weekly 10-satellite (reduced dynamic) orbit solutions	SP3C
—	daily orbit predictions for LARES, LARES-2, Ajisai, Stella, Starlette, Larets	CPF(v2)

Currently non-official products computed by DGFI-TUM

- Example: GM estimates based on 12-satellite solution compared to 4-satellite solution

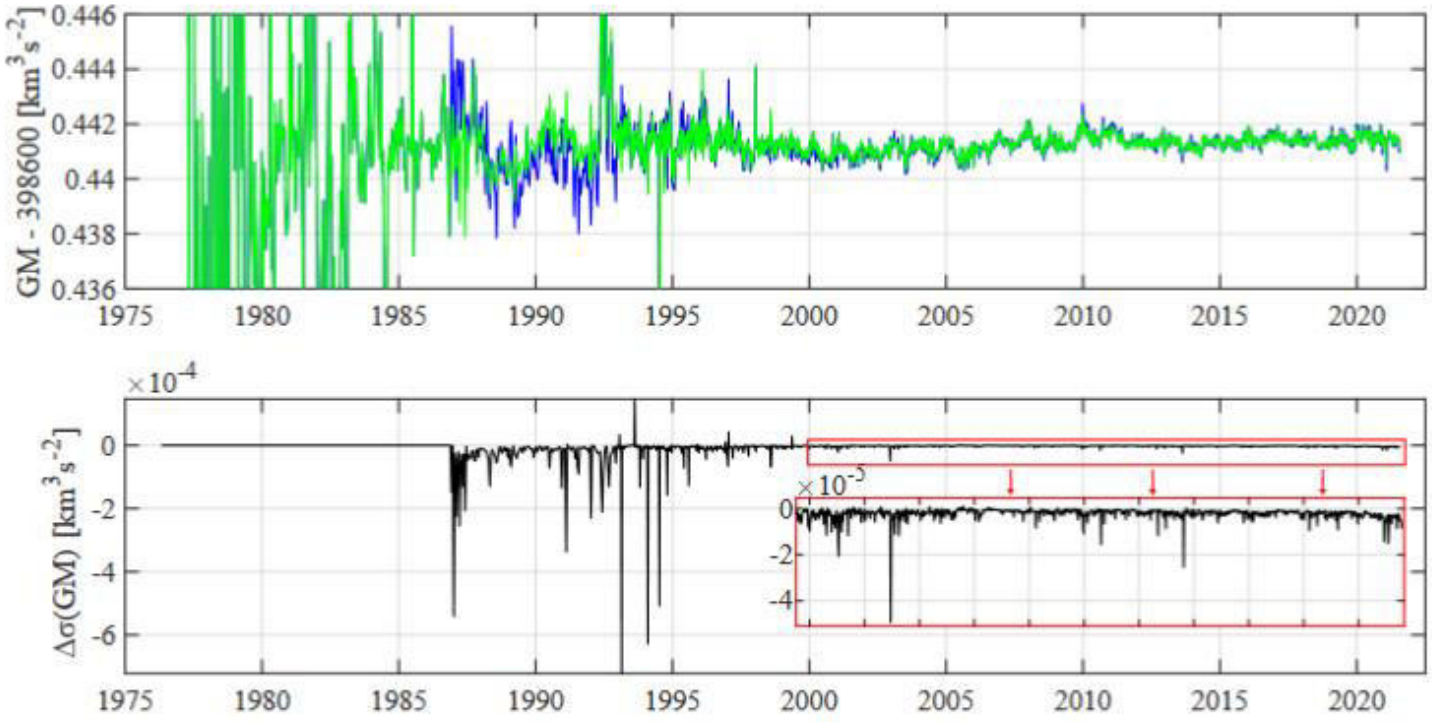


Figure 1.5: *Upper panel: 15-/7-daily GM estimates based on 4-satellite (LA-1/-2, ET-1/-2) and 12-satellite (four satellites + LARES, LARES-2, Ajisai, Stella, Starlette, Larets, BLITS, Westpac) solutions. SLR observations to BLITS and Westpac had been available only a few years in the past. Lower panel: STandard Deviation (STD) differences of 15-/7-daily GM estimates (12-sat. solution – 4-sat. solution). The red box shows the zoom on the STD differences since 2000.*

Future plans at DGFI-TUM

- revisit ocean tide modelling in DOGS
- revisit NTL application at observation level in DOGS
- work on pilot project for the inclusion of LARES
- Implementation of non-spherical satellites (TOPEX and Jason-1/-2/-3 already implemented) → focus on combined SLR/DORIS POD

ESOC ILRS AC Status

Tim Springer and Erik Schoenemann

26/04/2023

ESA UNCLASSIFIED - For Official Use

ESA ILRS AC Status (1/2)

- V230 (V231) solutions running manual
  - Never anticipated the ITRF2020 switch to take so long….
  - Hopefully, parallel submissions not too long….
- Ready for ITRF2020 (v80/v180/v280) solutions
  - Testing latest/final DH file looks fine
  - Submissions should start this week
- ITRF2020 reprocessing done (in December 2022)
  - IGS, ILRS, and IDS reprocessing with all ITRF2020 models and TRF
  - Was needed for the ESA internal ERP production switch from ITRF2014 to ITRF2020

ESA ILRS AC Status (2/2)

- LARES/LARES-2
  - LARES is included in our initial 21-day cleaning step since Feb 2012
  - LARES-2 included since August 2022
  - Both also in our ILRS reprocessing setup (but also only initial step)
  - Ready for fully including them
    - Need to check and validate our gravity field SINEX implementation

Status report of the ILRS AC at GFZ

Margarita Vei, Anton Reinhold, Patrick Schreiner

ILRS – ASC meeting 2023
Vienna April 26, 2023

1 Team

New team of the GFZ AC ILRS

Patrick Schreiner

Anton Reinhold
(Margarita leaving at the end of 2023)

2 Nominal Products

- Weekly and daily products in v70, v170
- SSEM_extended in v230

- New implementations
  - SINEX
    - Blocks RANGE, TIME, CoG
    - Excentricity now 4 decimals
  - DHF
  - SLRF2020

- v80, v180, v280 ready for parallel submission next week starting with file gfz.pos+eop.230401.vXX.snx.gz

3 Gravity Field

- We are about to switch to a new gravity field, i.e. EIGEN-6C4, 90x90
- and taking the time variable components from COST-G FSM for the mid-epoch of the arc
- Tests for a 10 year time period are ongoing before going online

4 Conclusion and Outlook

- Future plans:
  - Still looking for probable cause of LoD problem
  - Ready for the L1, L2 , E1, E2 , LR combination
    - 1. EOPs and STATION COORDINATES
    - 2. Harmonic Coefficients
    - waiting for ASC to decide the test period and the models to be used

The JCET AC/CC Report to the ILRS ASC

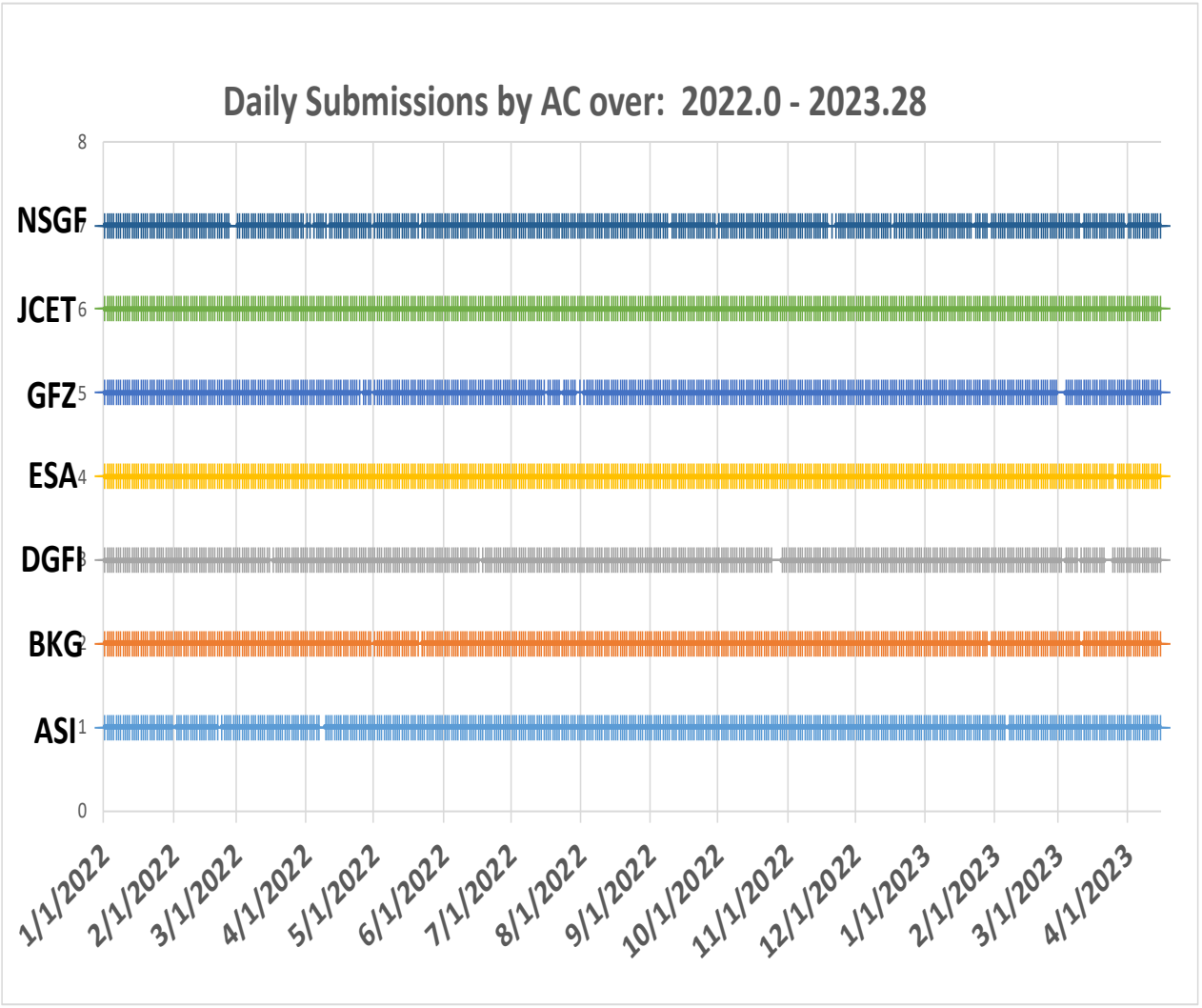
E. C. Pavlis, M. Kuzmicz-Cieslak and K. Evans

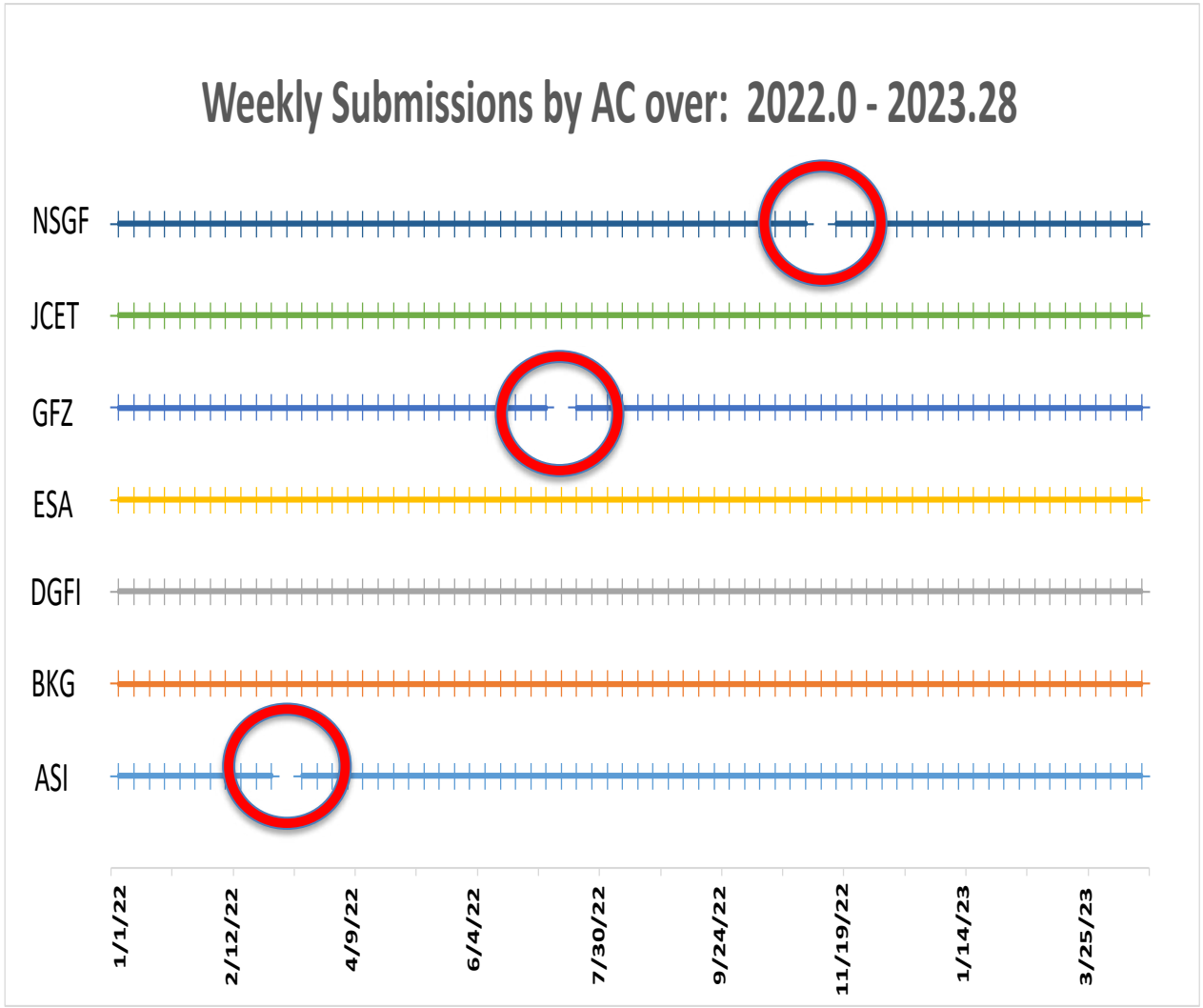
EGU2023 ILRS ASC Virtual Meeting
April 26, 2023

Outline

- Operational Products Status Report
- Weekly Combination Series Evaluation
- LARES-2 Data Analysis and Evaluation
- Modeling Updates & ASC Products Standards Description
- Other topics

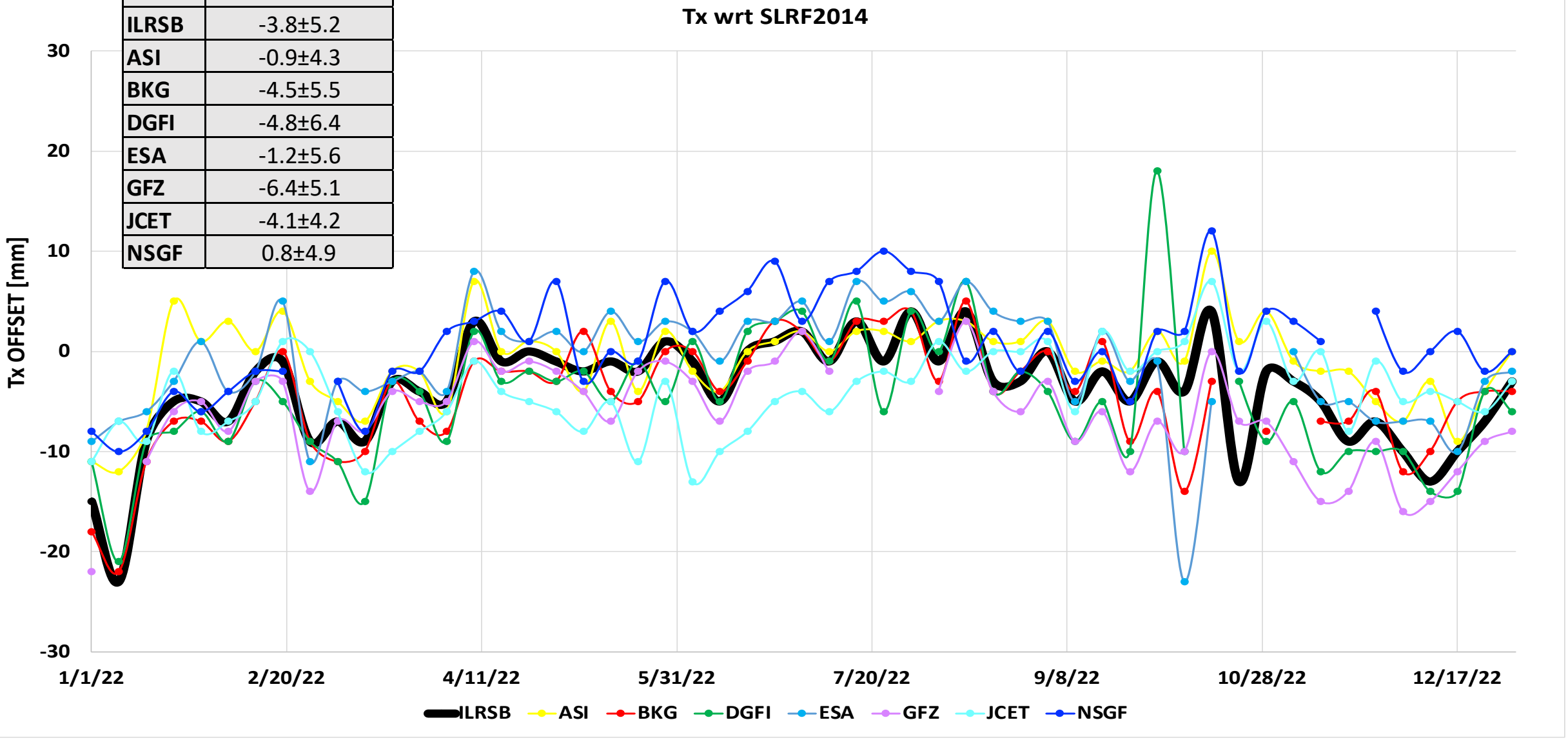
Daily & Weekly Product Submissions





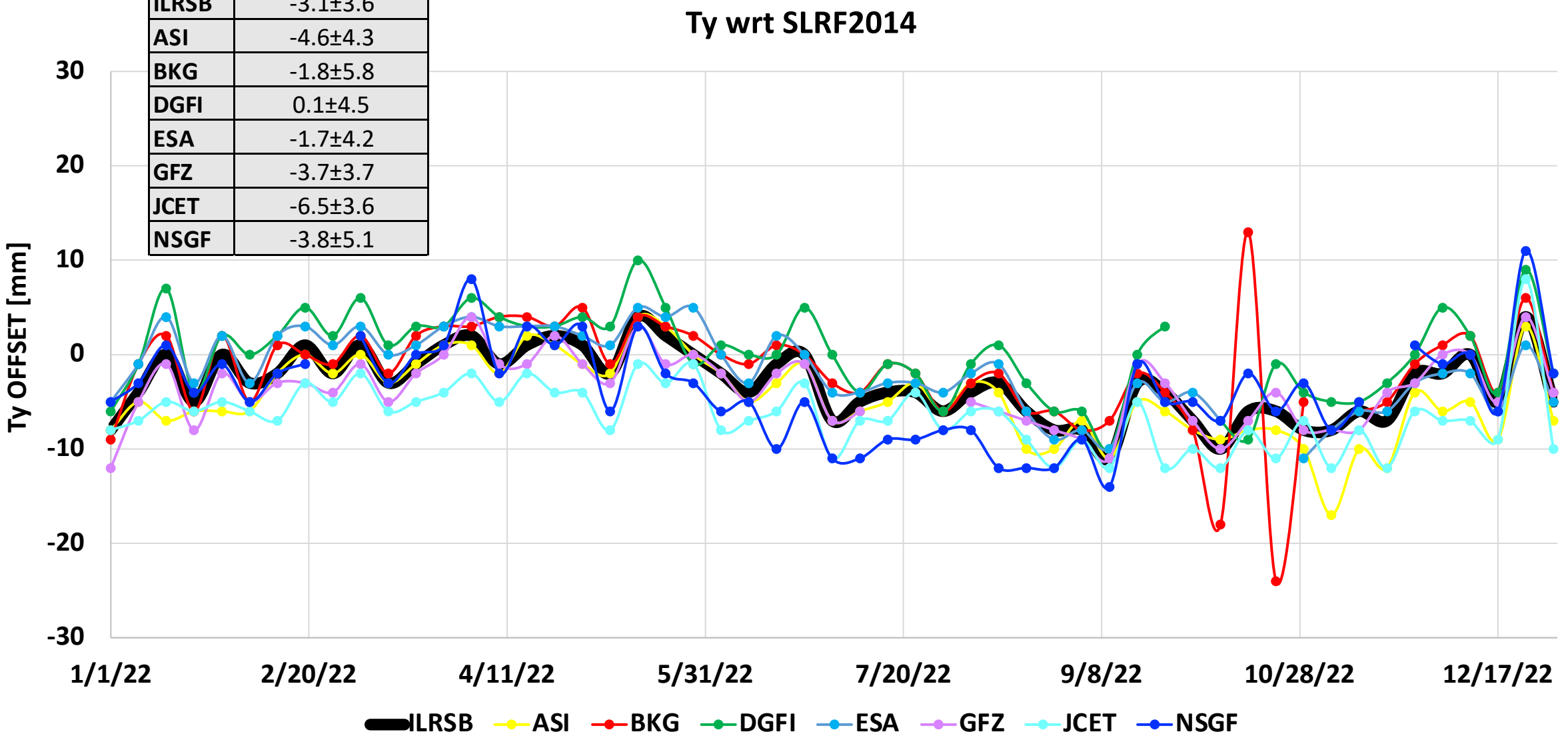
T_X Offset wrt SLRF2014

AC	Mean ± StdDev
ILRSB	-3.8±5.2
ASI	-0.9±4.3
BKG	-4.5±5.5
DGFI	-4.8±6.4
ESA	-1.2±5.6
GFZ	-6.4±5.1
JCET	-4.1±4.2
NSGF	0.8±4.9



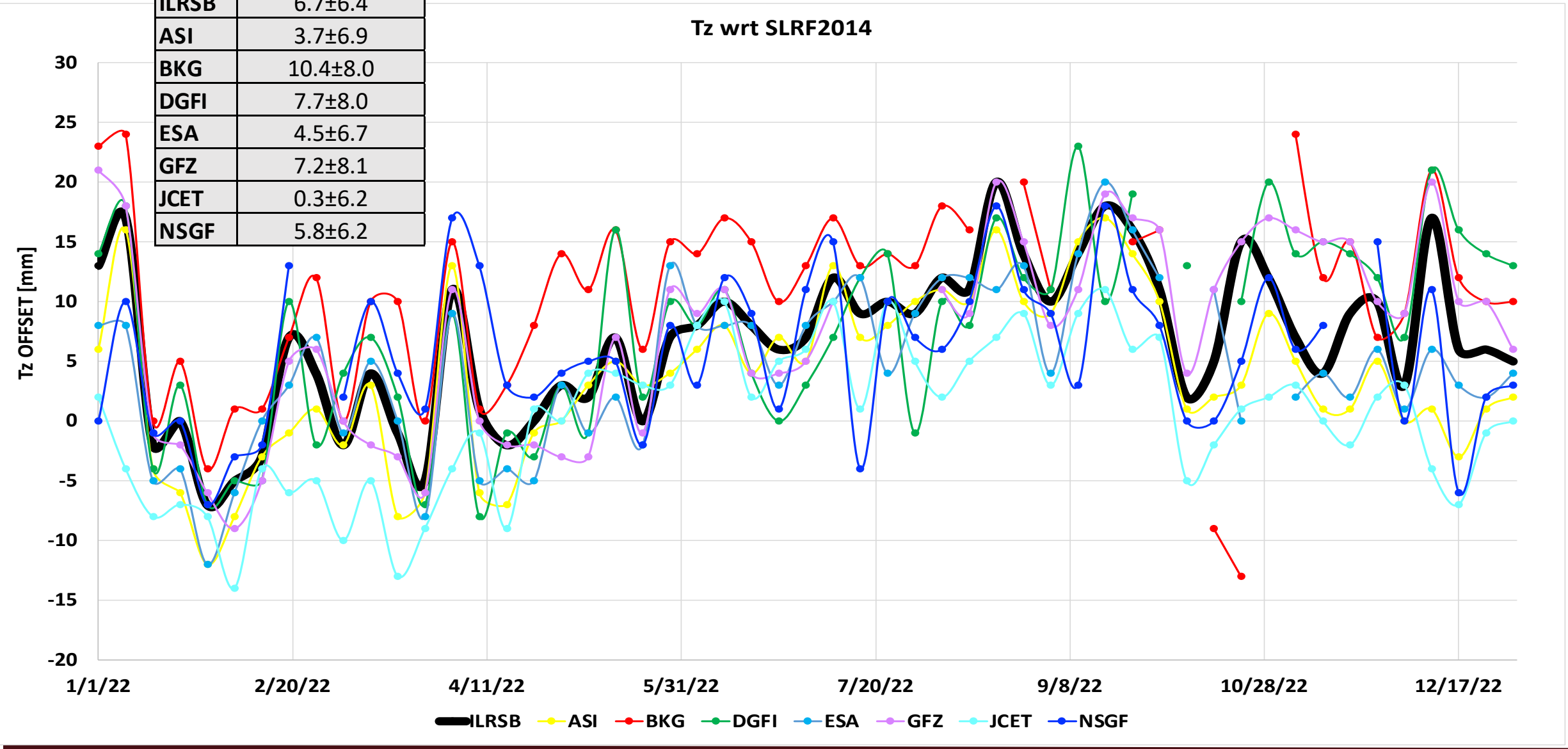
T_Y Offset wrt SLRF2014

AC	Mean ± StdDev
ILRSB	-3.1±3.6
ASI	-4.6±4.3
BKG	-1.8±5.8
DGFI	0.1±4.5
ESA	-1.7±4.2
GFZ	-3.7±3.7
JCET	-6.5±3.6
NSGF	-3.8±5.1



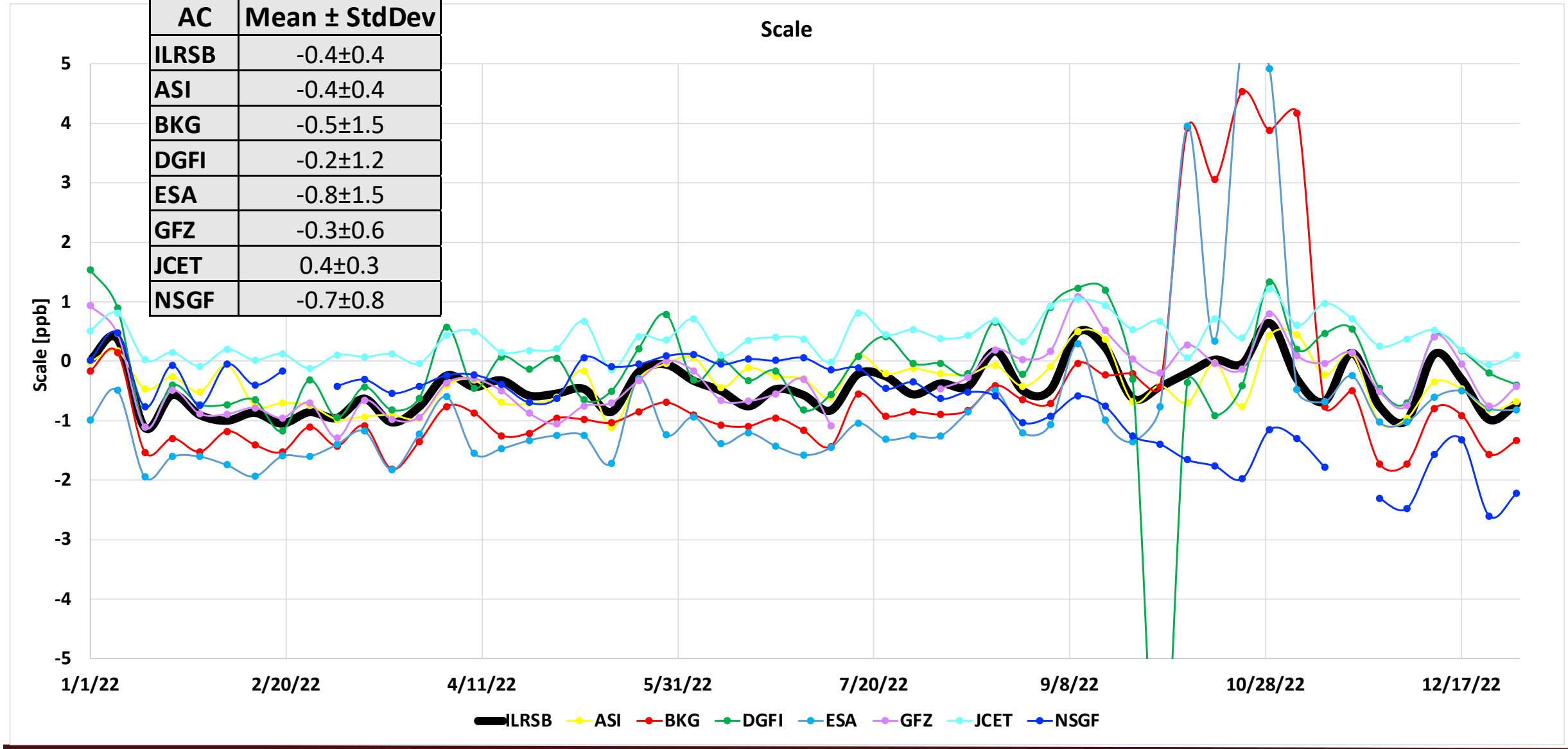
T_z Offset wrt SLRF2014

AC	Mean ± StdDev
ILRSB	6.7±6.4
ASI	3.7±6.9
BKG	10.4±8.0
DGFI	7.7±8.0
ESA	4.5±6.7
GFZ	7.2±8.1
JCET	0.3±6.2
NSGF	5.8±6.2



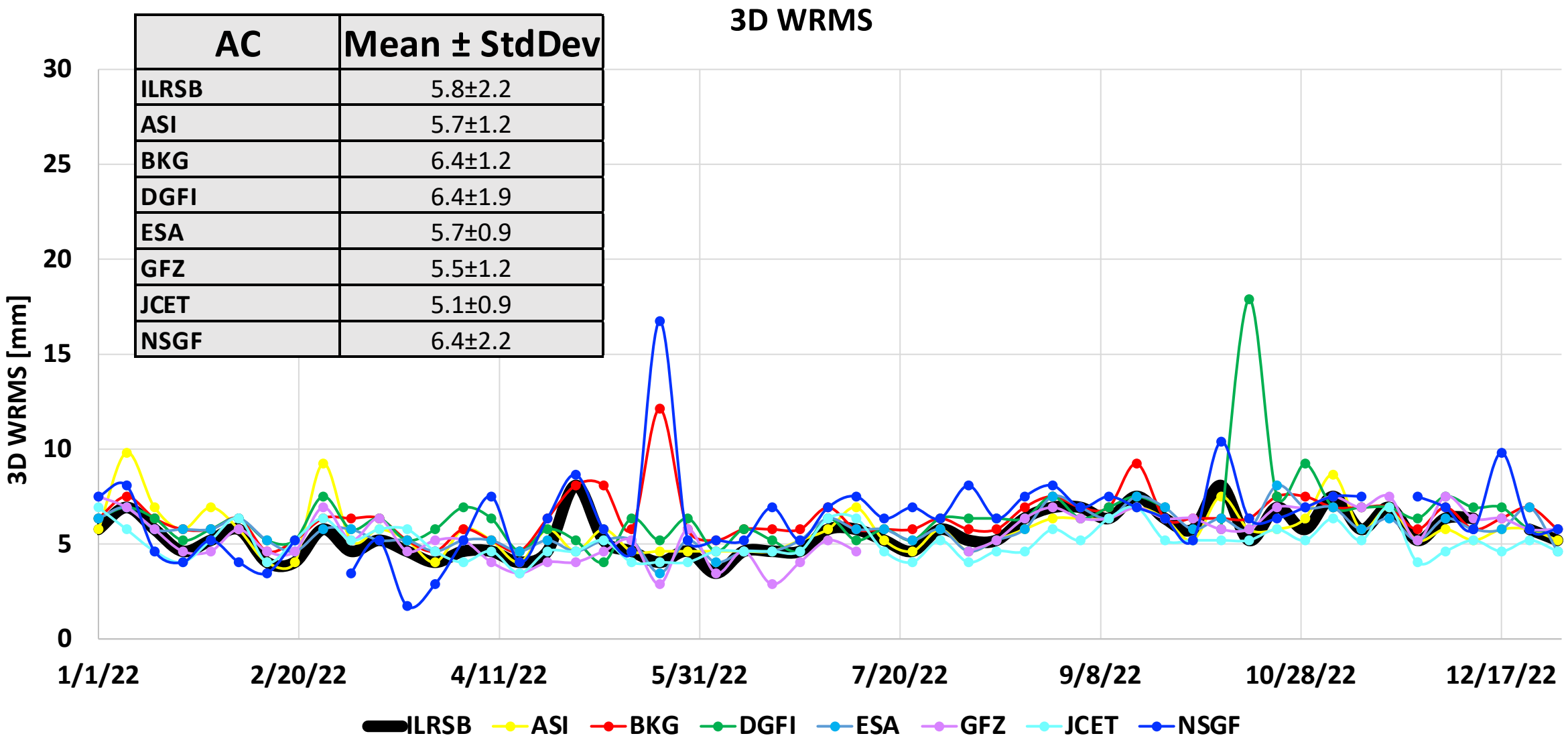
Scale Offset wrt SLRF2014

AC	Mean ± StdDev
ILRSB	-0.4±0.4
ASI	-0.4±0.4
BKG	-0.5±1.5
DGFI	-0.2±1.2
ESA	-0.8±1.5
GFZ	-0.3±0.6
JCET	0.4±0.3
NSGF	-0.7±0.8



3D-WRMS of Core Sites wrt SLRF2014

AC	Mean ± StdDev
ILRSB	5.8±2.2
ASI	5.7±1.2
BKG	6.4±1.2
DGFI	6.4±1.9
ESA	5.7±0.9
GFZ	5.5±1.2
JCET	5.1±0.9
NSGF	6.4±2.2



Special Series Combination Product: v415

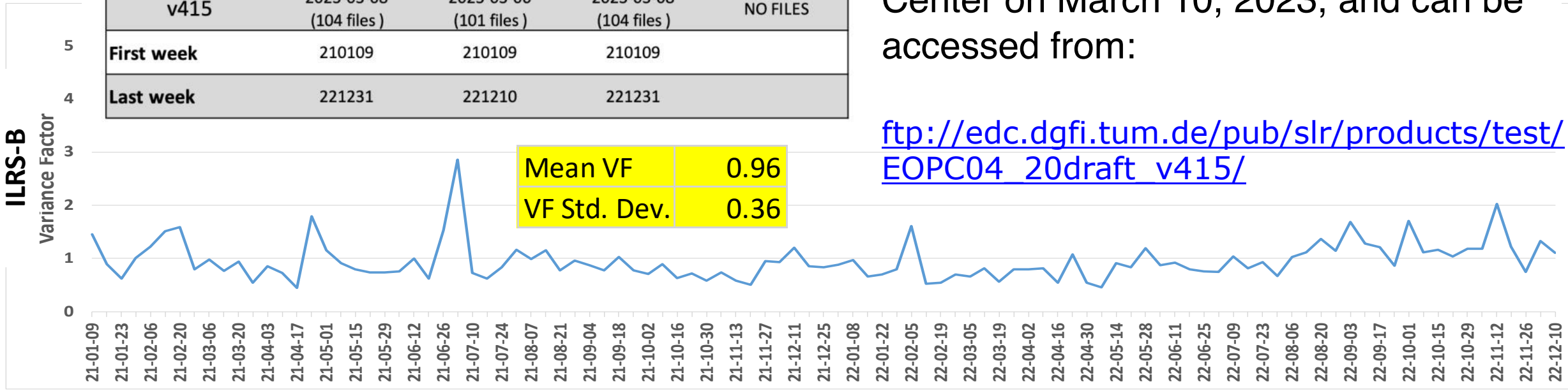
Pleiades /nobackup/mkuzmicz/COMBO_v415/

version	ASI	BKG	DGFI	ESA	GFZ	JCET	NSGF	ILRSA	ILRSB
v415	2023-02-10 (106 files)	2023-02-23 (102 files)	2023-02-08 (106 files)	2023-02-13 (106 files)	2023-01-18 (106 files)	2023-02-11 (107 files)	2023-02-12 (106 files)	2023-03-08 (104 files)	2023-03-06 (101 files)
First week	201226	210102	201226	201226	201226	201226	201226	210109	210109
Last week	221231	221210	221231	221231	221231	230107	221231	221231	221210

version	ILRSA eop	ILRSB eop	ILRSA sum	ILRSB sum
v415	2023-03-08 (104 files)	2023-03-06 (101 files)	2023-03-08 (104 files)	NO FILES
First week	210109	210109	210109	
Last week	221231	221210	221231	

The official (ILRS-A) and the back-up (ILRS-B) submitted to EDC ILRS Data Center on March 10, 2023, and can be accessed from:

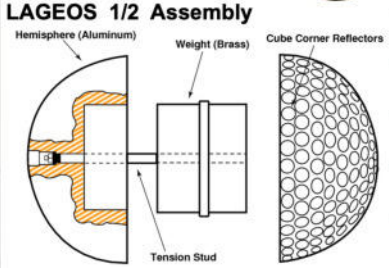
ftp://edc.dgfi.tum.de/pub/slr/products/test/EOPC04_20draft_v415/

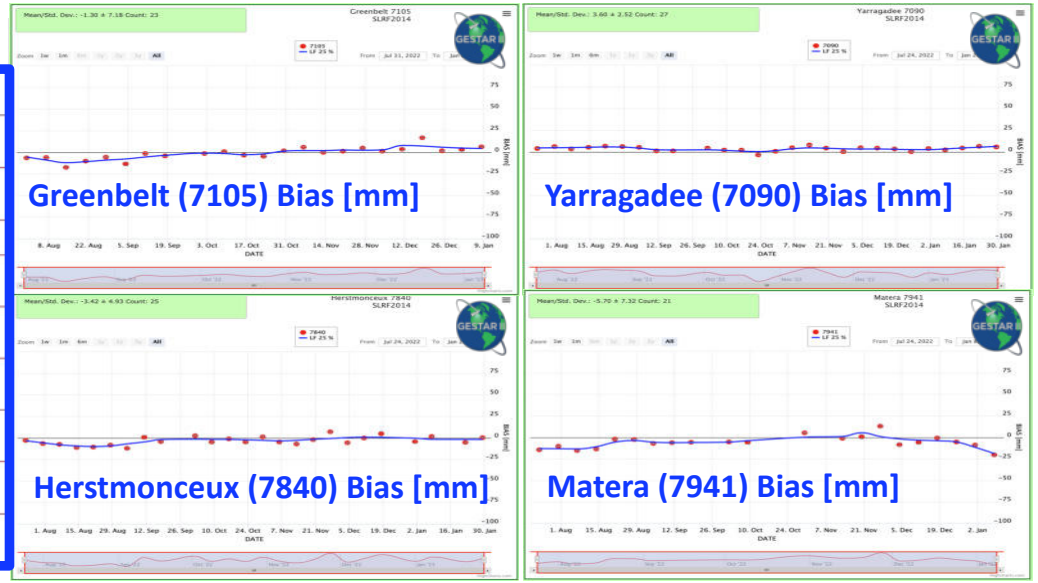


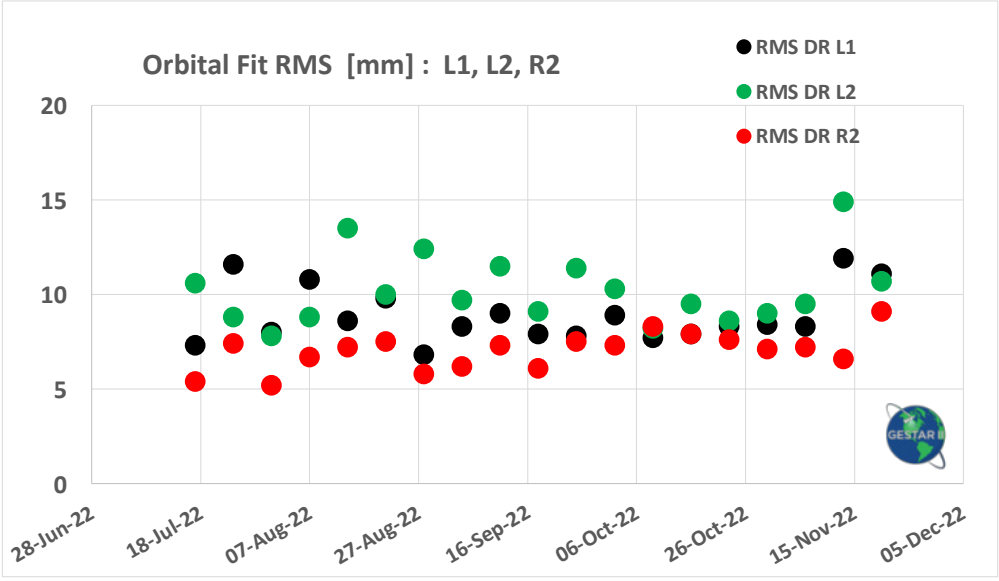
Initial Analysis of LARES-2 SLR Data (AGU f'2022)

Satellite Design: LAGEOS 1/2 vs LARES vs LARES-2

	LAGEOS 1/2	LARES	LARES-2
Launch Year:	• 1976 (L1) • 1992 (L2)	2012	2022
Mass:	• 406.9 kg (L1) • 405.3 kg (L2)	386.8 kg	294.8 kg
Diameter:	600 mm	364 mm	424 mm
Body:	Assembly	Single piece	Single piece
Material(s):	Al alloy hemispheres; Brass alloy core	Tungsten alloy (ρ = 18000 kg/m^3)	Nickel alloy
Diameter of CCRs	1.5 in	1.5 in	1.0 in
Number of CCRs:	426	92	303
Eccentricity:	• 0.0045 (L1) • 0.0135 (L2)	0.0005	0.0003
Altitude:	• 5860 km (L1) • 5620 km (L2)	1430 km	5856 km



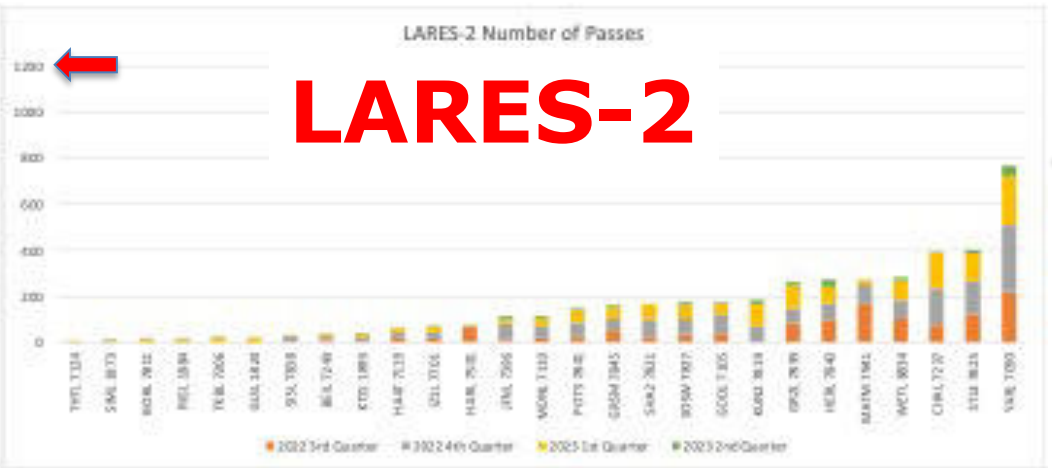




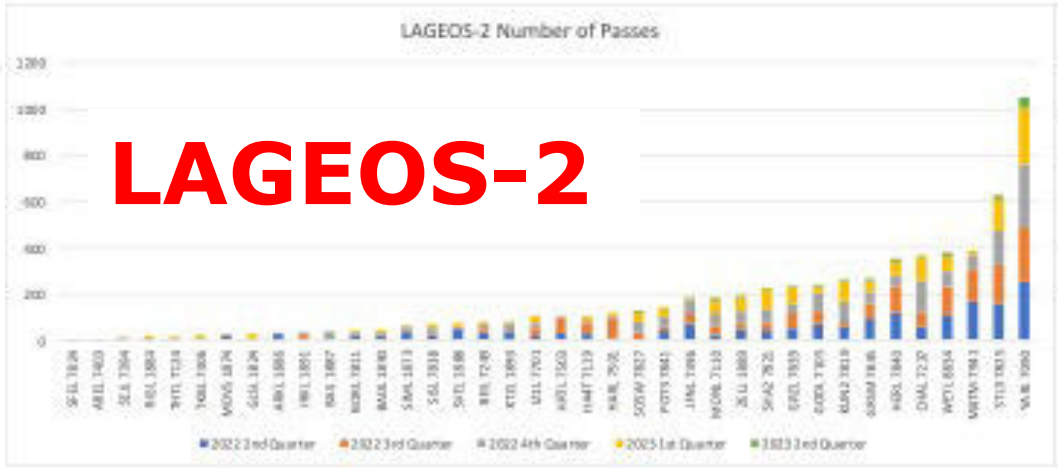
- LARES-2 was launched on July 13, 2022, to support relativity tests and geodetic science products, mainly the ITRF;
- Successfully tracked since launch, by most of the ILRS network;
- The nominal target correction of 174 mm and the free adjustment of station-dependent biases reassessed that for most stations the nominal value is only very few mm off the truth;
- The improved design and materials of LARES-2 deliver very small and stable biases across the network, and will result in an extremely stable and accurate scale for future ITRF models;
- The core ILRS systems fit the data at a few mm: ~5-6 mm;
- LARES-2 data will become part of the ILRS official analysis over the next couple of months.

LAGEOS 1 & 2, LARES-2 and Etalon Passes Used 2022-2023

1200

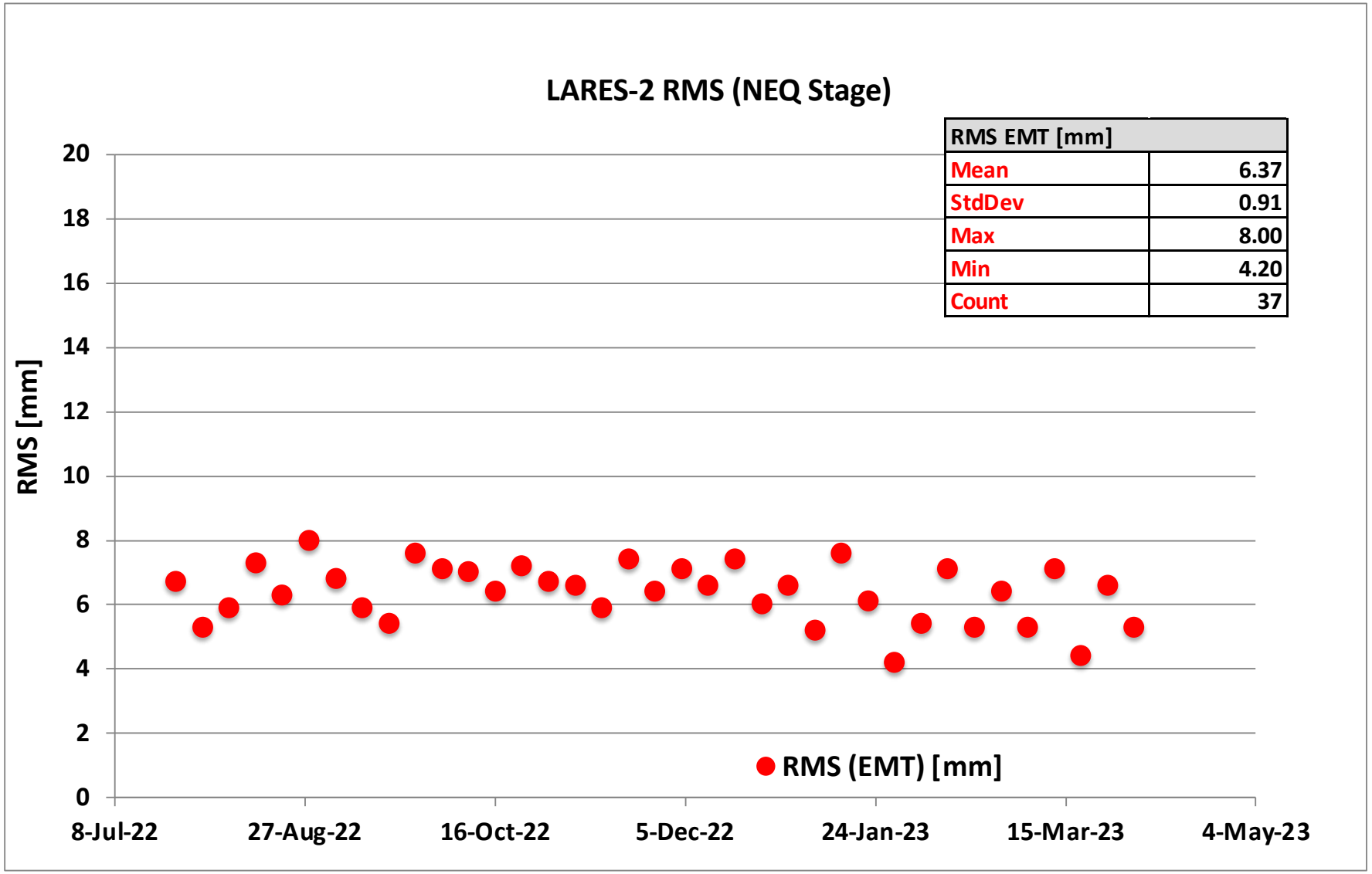


800



LAGEOS 1 & 2, LARES-2 and Etalon Passes Used 2022-2023

- Nine months of LARES-2 data analyzed using the LAGEOS-tailored modeling, applying the nominal CoG correction of 174 mm and adjusting a weekly averaged bias per station;
- Size, mass, etc. taken from mission's documents as in the submitted ILRS MSRF.



ILRS ASC Product Standards & Models - 1

GEOMETRY

ILRS-ASC product	Series Designator (April 2023)	TRF (SLRF2020 release)	Target Signature Model (CoG corrections)	ILRS Data Handling file release date	A priori EOP Series	Secular pole model	HF-EOP
Official Products							
Daily POS+EOP	**v180**	2022 (loosely constrained)	2022-09-15	2023	IERS Bulletin A (estimated)	secular pole (UAW2017)	Desai and Sibois (2019)
Weekly POS+EOP	**v80 / v85**	2022 (loosely constrained)	2022-09-15	2023	IERS Bulletin A (estimated)	secular pole (UAW2017)	Desai and Sibois (2019)
Weekly Orbits	**v80**	2022 **(release, fixed to a priori)**	2022-09-15	2023	IERS Bulletin A **(EOP fixed to a priori)**	secular pole (UAW2017)	Desai and Sibois (2019)
Pilot Project Products							
SSEM PP POS+EOP*	**v230**	2020-04-28 (orientation loosely constrained)	2020-06-08	REPRO2020 version	IERS 14 C04 (estimated)	secular pole (UAW2017)	Desai and Sibois (2019)
SSEM-X POS+EOP	**v280**	2022 (loosely constrained)	2022-09-15	2023	IERS 20 C04 (estimated)	secular pole (UAW2017)	Desai and Sibois (2019)
LARES & Gravity PP	**v300**	2022 (orientation loosely constrained)	2022-09-15	2023	IERS 20 C04 (estimated)	secular pole (UAW2017)	Desai and Sibois (2019)
LARES & Gravity PP with NT Loading Corrections	**v310**	2022 (orientation loosely constrained)	2022-09-15	2023	IERS 20 C04 (estimated)	secular pole (UAW2017)	Desai and Sibois (2019)
LARES-2 "PP" (v80/v180 Variants)	**v350/v360**	2022 (loosely constrained)	2022-09-15	2023	IERS 20 C04 (estimated)	secular pole (UAW2017)	Desai and Sibois (2019)
Discontinued Products							
REPRO 2020	**v400/v401/…**	2020-04-28 (orientation loosely constrained)	2020-06-08	2021-01-27 (via email)	IERS 14 C04 (estimated)	secular pole (UAW2017)	Desai and Sibois (2019)

* **NOTE:** To be discontinued once v280 becomes operational

Release: 2023.04.26

ILRS ASC Product Standards & Models - 2

POTENTIAL

ILRS-ASC product	Series Designator (April 2023)	Gravitational corrections ATM. & OCN. (AOD)	Static Gravity model	Time Varying Gravity model (TVG)	Earth & Ocean Tide models	Ocean Loading model
Official Products						
Daily POS+EOP	**v180**	None	GGM05C	JCET2023	IERS Conventions 2010 & GOT4.10c/FES2014/etc.	GOT4.10c / FES2014c
Weekly POS+EOP	**v80 / v85**	None	GGM05C	JCET2023	IERS Conventions 2010 & GOT4.10c/FES2014/etc.	GOT4.10c / FES2014c
Weekly Orbits	**v80**	None	GGM05C	JCET2023	IERS Conventions 2010 & GOT4.10c/FES2014/etc.	GOT4.10c / FES2014c
Pilot Project Products						
SSEM PP POS+EOP*	**v230**	None	GGM05C	JCET2018	IERS Conventions 2010 & GOT4.10c/FES2014/etc.	GOT4.7
SSEM-X POS+EOP	**v280**	None	GGM05C	JCET2023	IERS Conventions 2010 & GOT4.10c/FES2014/etc.	GOT4.10c / FES2014c
LARES & Gravity PP	**v300**	ON ORBIT ONLY: GGFC ERA5 & TUGO-m or AOD1B-RL06, etc.	GGM05C	JCET2023	IERS Conventions 2010 & GOT4.10c/FES2014/etc.	GOT4.10c / FES2014c
LARES & Gravity PP with NT Loading Corrections	**v310**	GGFC ERA5 & TUGO-m or AOD1B-RL06, etc.	GGM05C / EIGEN-GRGS.RL04.MD*	JCET2023	IERS Conventions 2010 & GOT4.10c/FES2014/etc.	GOT4.10c / FES2014c
LARES-2 "PP" (v80/v180 Variants)	**v350/v360**	ON ORBIT ONLY: GGFC ERA5 & TUGO-m or AOD1B-RL06, etc.	GGM05C / EIGEN-GRGS.RL04.MD*	JCET2023	IERS Conventions 2010 & GOT4.10c/FES2014/etc.	GOT4.10c / FES2014c
Discontinued Products						
REPRO 2020	**v400**	ON ORBIT ONLY: GGFC ERA5 & TUGO-m or AOD1B-RL06, etc.	GGM05C / EIGEN-GRGS.RL04.MD*	JCET2021	IERS Conventions 2010 & GOT4.10c/FES2014/etc.	GOT4.10c / FES2014c

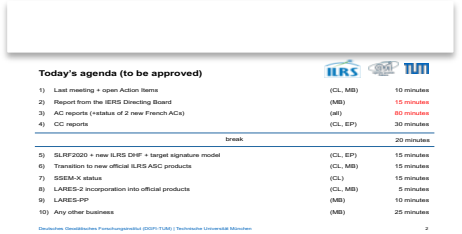
*** NOTE:** To be discontinued once v280 becomes operational

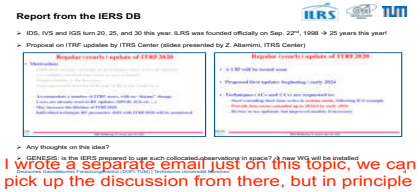
Release: 2023.04.26

*Provided you use the NEW IERS (2018) « linear mean pole convention » version of the model !!!

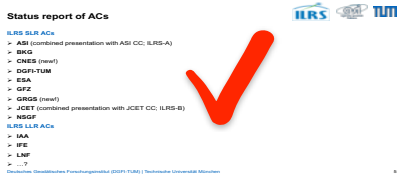
*We may switch to GOT5 and a comparable FES model when avaialble

General Comments on ASC Discussion Topics

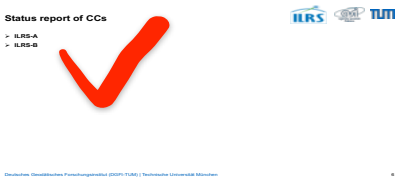




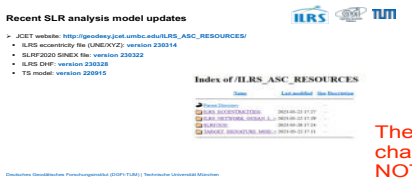
I wrote a separate email just on this topic, we can pick up the discussion from there, but in principle I think this was exactly what we were envisioning when we started delivering the WEEKLY products years ago, only none of the ITRS CCs took advantage of our product…

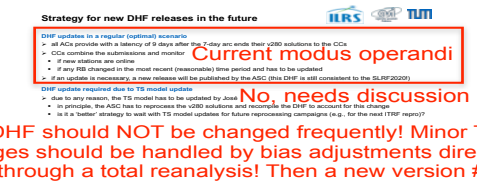


These are JCET slides that I have UPDATED and plan to deposit on our RESOURCES website. UPDATE them please!



May need update!

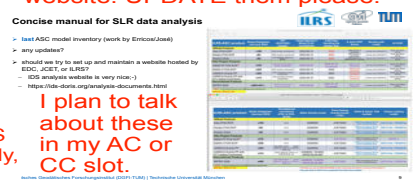




Current modus operandi

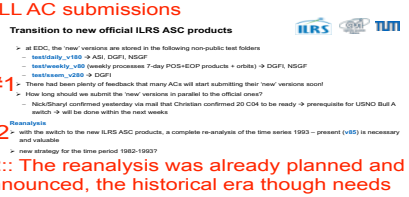
No, needs discussion !!!

The DHF should NOT be changed frequently! Minor TS changes should be handled by bias adjustments directly, NOT through a total reanalysis! Then a new version # can be assigned.



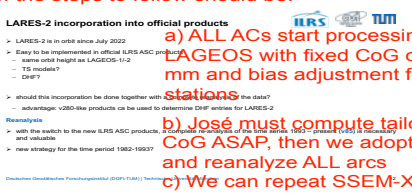
I plan to talk about these in my AC or CC slot.

#1:: We need at least 4 weeks with ALL AC submissions



#2:: The reanalysis was already planned and announced, the historical era though needs special attention and an SSEM treatment

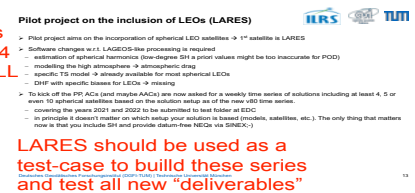
For the LARES-2 incorporation the order of the steps to follow should be:



a) ALL ACs start processing as LAGEOS with fixed CoG of 174 mm and bias adjustment for ALL stations

b) José must compute tailored CoG ASAP, then we adopt it and reanalyze ALL arcs

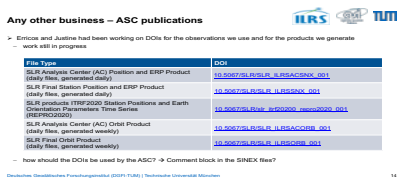
c) We can repeat SSEM-X arcs (v280) for the LARES-2 period AFTER we have USED the new CoG!



LARES should be used as a test-case to buildd these series and test all new "deliverables" or estimates (e.g. gravitational SHs)

We will need a complete list of s/c parameters for each these "10" targets to be sure we ALL use the same parameters (will go into resources site).

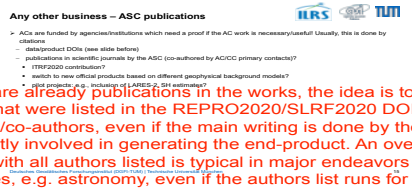
The last comment is true once we have ensured everyone is on the same page, until then, we should ALL use the same models, etc.



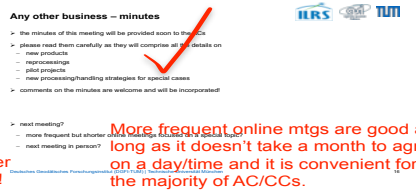
That is correct and we will continue this work and even establish these DOIs for the PAST ITRF/SLRF models!

I suggest that you remove these "DOIs" that you listed, they are NOT those we use here, the DOI is assigned by the organization that has the ability to assign DOIs, NASA/CDDIS in this case. If these get circulated users might start looking for them and will be pissed off when they find they do not exist!

Just leave the list of products that we want to assign DOIs for.



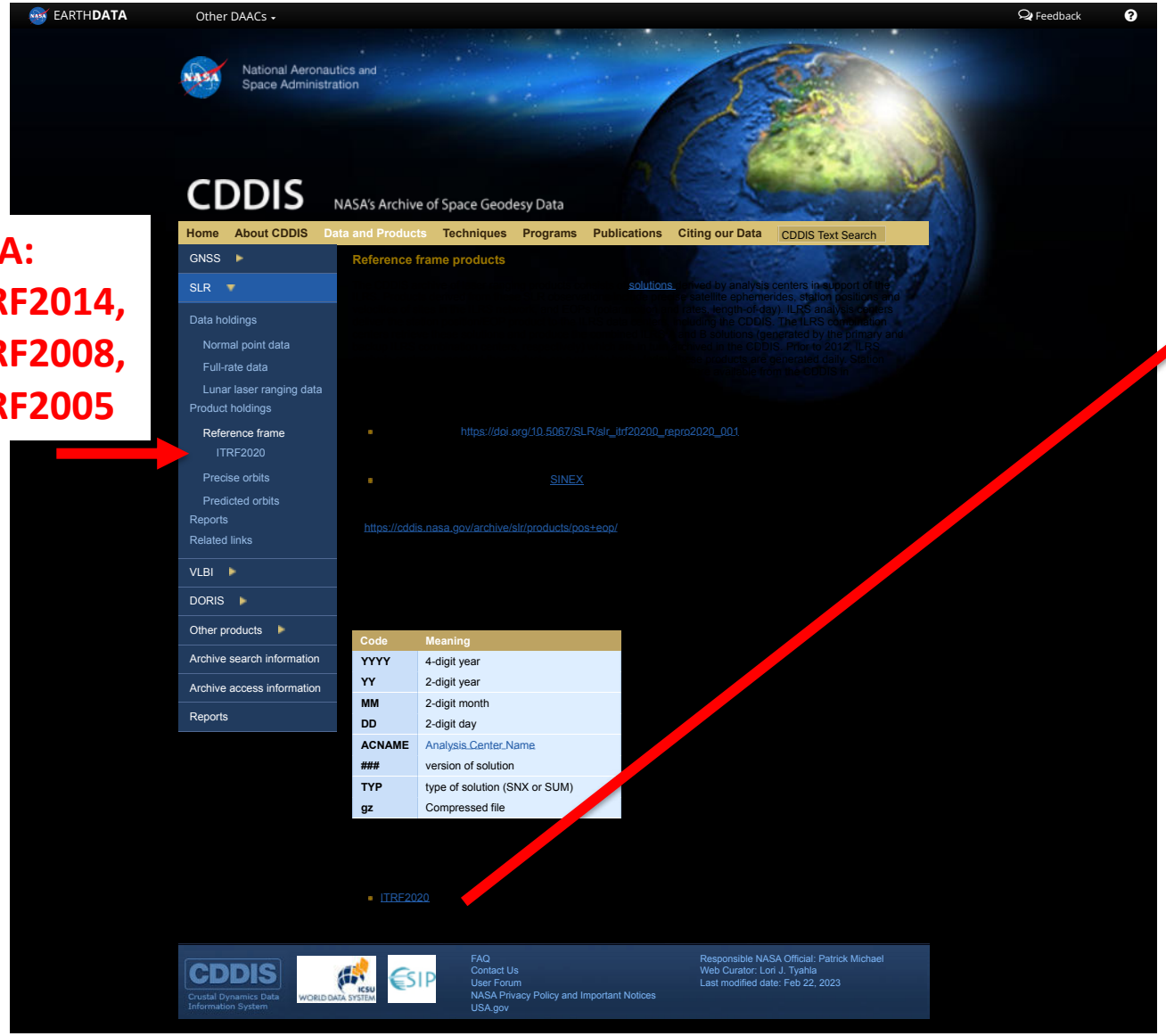
There are already publications in the works, the idea is to list all those that were listed in the REPRO2020/SLRF2020 DOI as authors/co-authors, even if the main writing is done by those inherently involved in generating the end-product. An overview paper with all authors listed is typical in major endeavors in other sciences, e.g. astronomy, even if the authors list runs for pages! Each AC/CC can also write a paper focused on their own work, with details.



More frequent online mtgs are good as long as it doesn't take a month to agree on a day/time and it is convenient for the majority of AC/CCs.

CDDIS Reference Frame Page & DOI

TBA:
ITRF2014,
ITRF2008,
ITRF2005



NSGF AC report

ILRS Analysis Standing Committee Meeting 2023, Vienna, Austria

Andreja Susnik (1), Graham Appleby (2)

(1) BGS Space Geodesy Facility, Herstmonceux Castle, UK; (2) BGS Honorary Research Associate, SGF;

British Geological Survey

Natural Environment Research Council

NSGF AC activities

- Finished, ongoing & todo

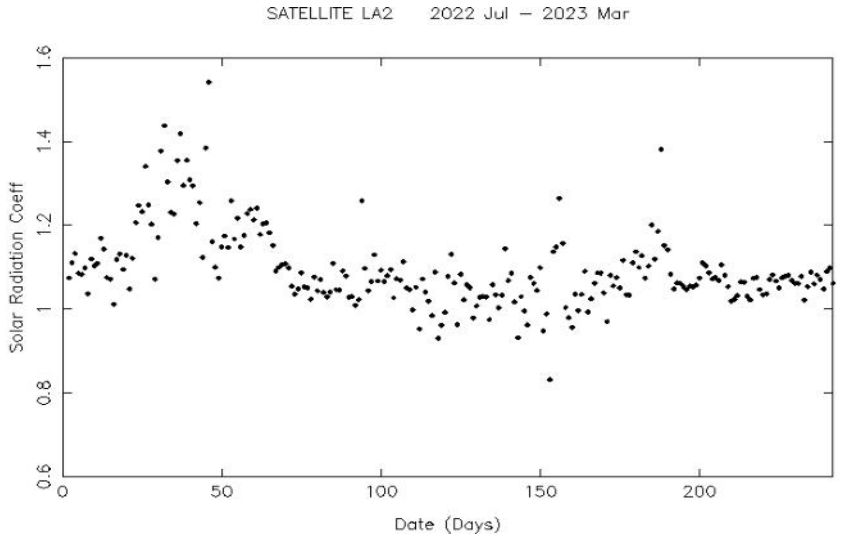
Solution	Submission	Status
v80	weekly (with 10 day delay; snx + orbits)	(routinely since 18 April 2023)
v180	daily	(routinely since 18 April 2023)
v230	weekly	(routinely since January 2023)
v415	two submissions (on 22/12/2022 and end of February);	√
v280	ongoing	X

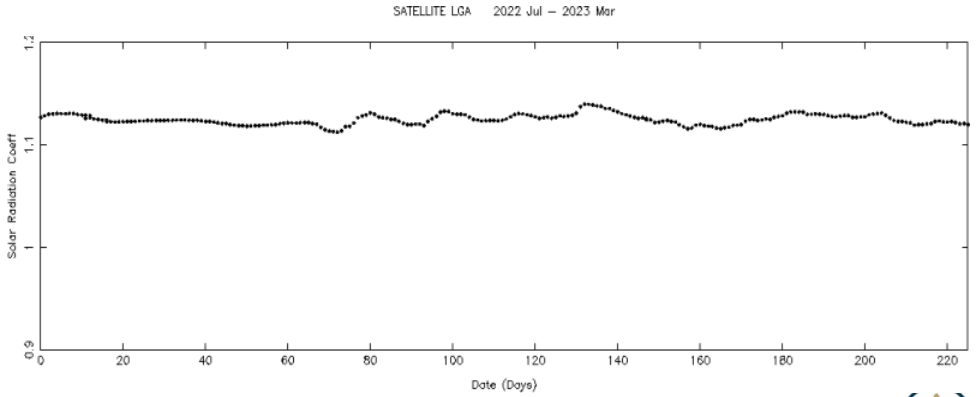
In addition to operational weekly orbit solutions in sp3 format for LAGEOS 1/2 and Etalon 1/2:
- daily orbit solutions in sp3 format for Lares-2, Lares, Ajisai, Stella and Starlette

NSGF AC activities

Ongoing:

- LOD implementation fix → problem was/is in subroutine for UT1/LOD regularization. (TODO: internal reprocessing using the latest models).
- Lares-2 implemented in the software, currently in testing phase for weekly solutions.

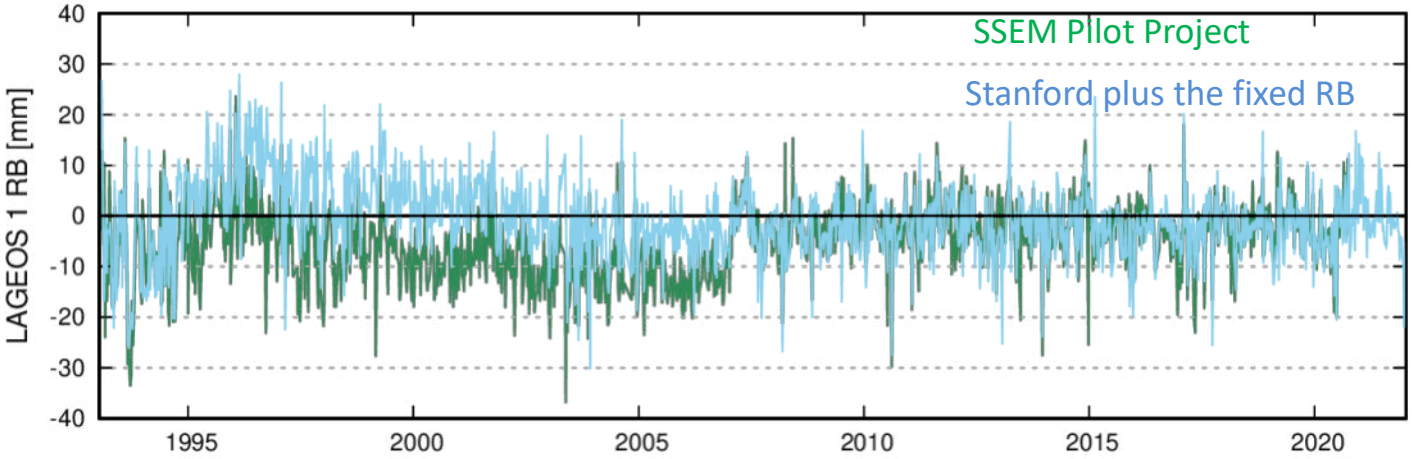




NSGF AC activities

Done:

- range-dependent (satellite) plus fixed (calibration) errors imposed by the Stanford counters for HERL station were not properly ‘handled’ in our software for SSEM project and ITRF2020 repro -> will have an impact on the mean range-bias values for data_handlng file! How are other AC’s ‘treating’ HERL station for period 1995-2007?



Susnik et.al. Determination and analysis of Herstmonceux geodetic heights for the period between 1984 and 2022; 22nd IWLR, Yebes, Spain

NSGF AC activities

Ongoing:

- Investigation into scale issue in v70 and v170
- moving to new machine/OS (mid-June 2023);

Todo:

- analysis of data from other stations that used Stanford counters;
- testing DTRF2020 (expected end of May 2023);
- …

Current status of the CNES and GRGS analysis centers for the ILRS

ASC Meeting, Vienna 2023

The two ACs in a nutshell

- CNES :
  - Development and internal assessment started in March 2022
  - Operational production of orbits (v70) and sinex (v170) started in January 2023, but no official submissions have been done yet
  - As of today, five satellites are processed (Lageos-1, Lageos-2, Etalon-1, Etalon-2 and LARES)
  - Software : GINS (version 22_2) and DYNAMO
  - People in charge : Franck Reinquin and Adrian Banos Garcia

- GRGS :
  - First new submissions of orbits and sinex in 2019 and 2020 respectively
  - Regular submissions of daily and weekly sinex started in March 2021 (only one day missing ever since)
  - As of today, two operational analysis schemes (@ IMCCE/OP and IGN) : use of CRD, CRD_v2, new DHF
  - Software : GINS (version 17_2, but soon upgraded) and LOCOMOTIV
  - People in charge : Florent Deleflie, Stéphane Vallant and Arnaud Pollet

cnes

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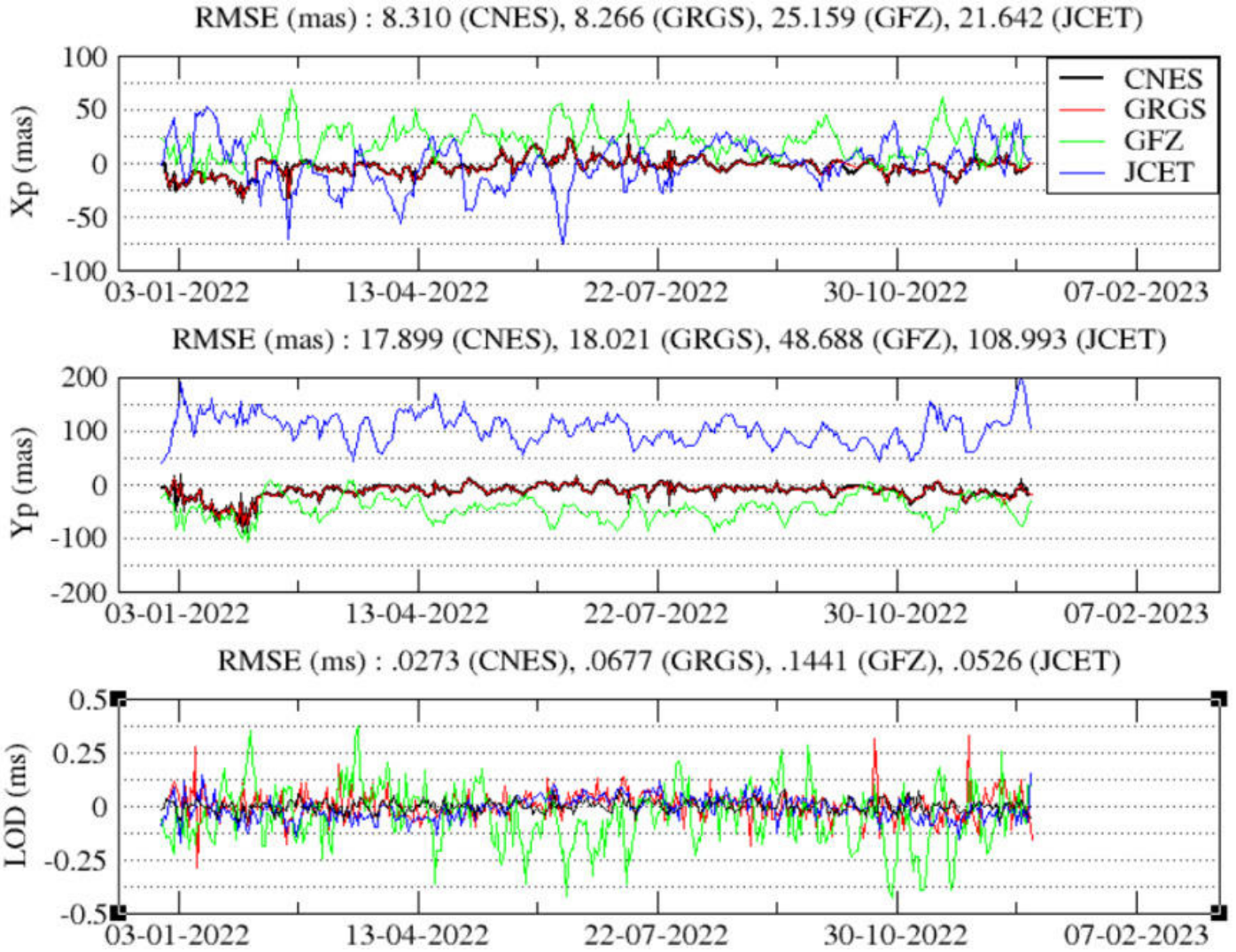
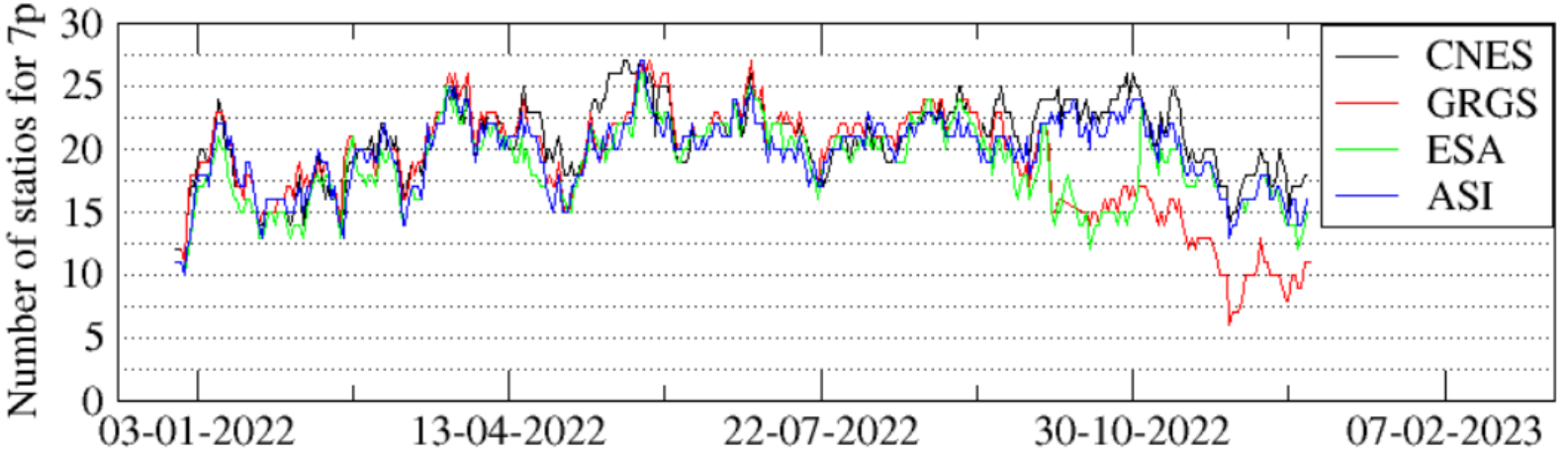
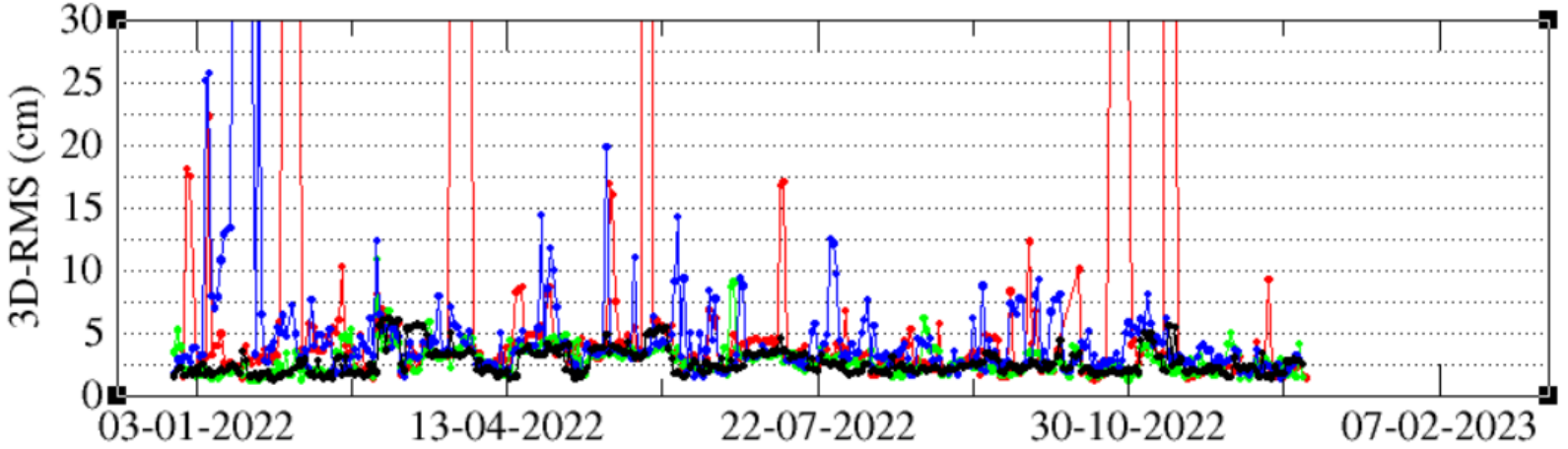
Earth orientation parameters wrt. ILRSA combination



CNES Xp & Yp wrt. IERSC04 : ~ 0.3 mas = 1 cm

Number of stations and rms-3D residuals wrt. ITRF2020





CNES = 2.66 cm ESA = 2.74 cm

GRGS = 9.20 cm ASI = 5.09 cm

Origin and Scale wrt. ITRF2020

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Conclusions and perspectives

- CNES :
  - Solution on par with others ACs
  - Ready to switch to the SLRF2020 standards and have an external evaluation
- GRGS :
  - Same as CNES

To be confirmed

- Does the operational solution include as many satellites as possible or are they fixed?
- Are there models that are compulsory fixed for everyone (e.g. gravity field)?
- Deadline for operational submissions ?

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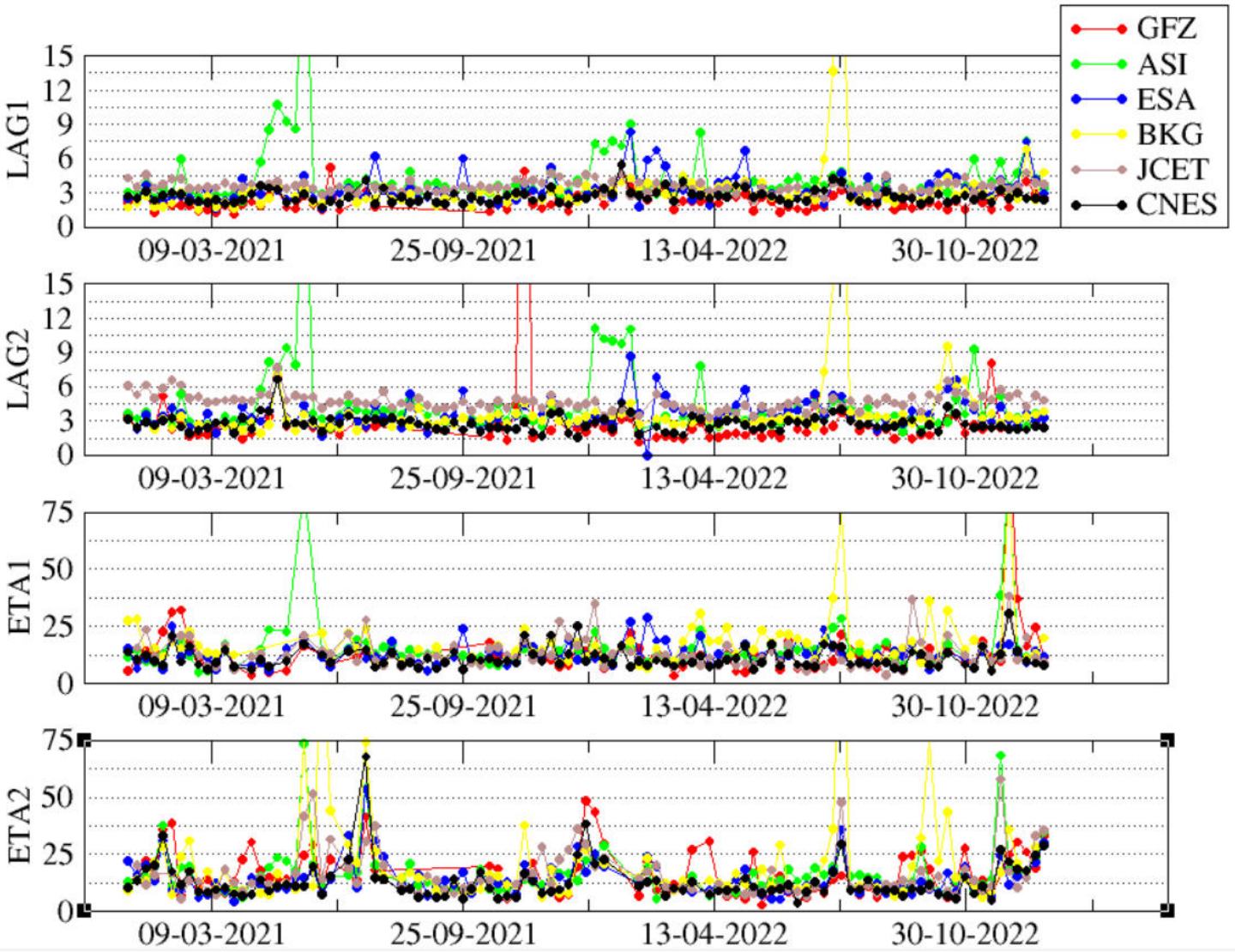
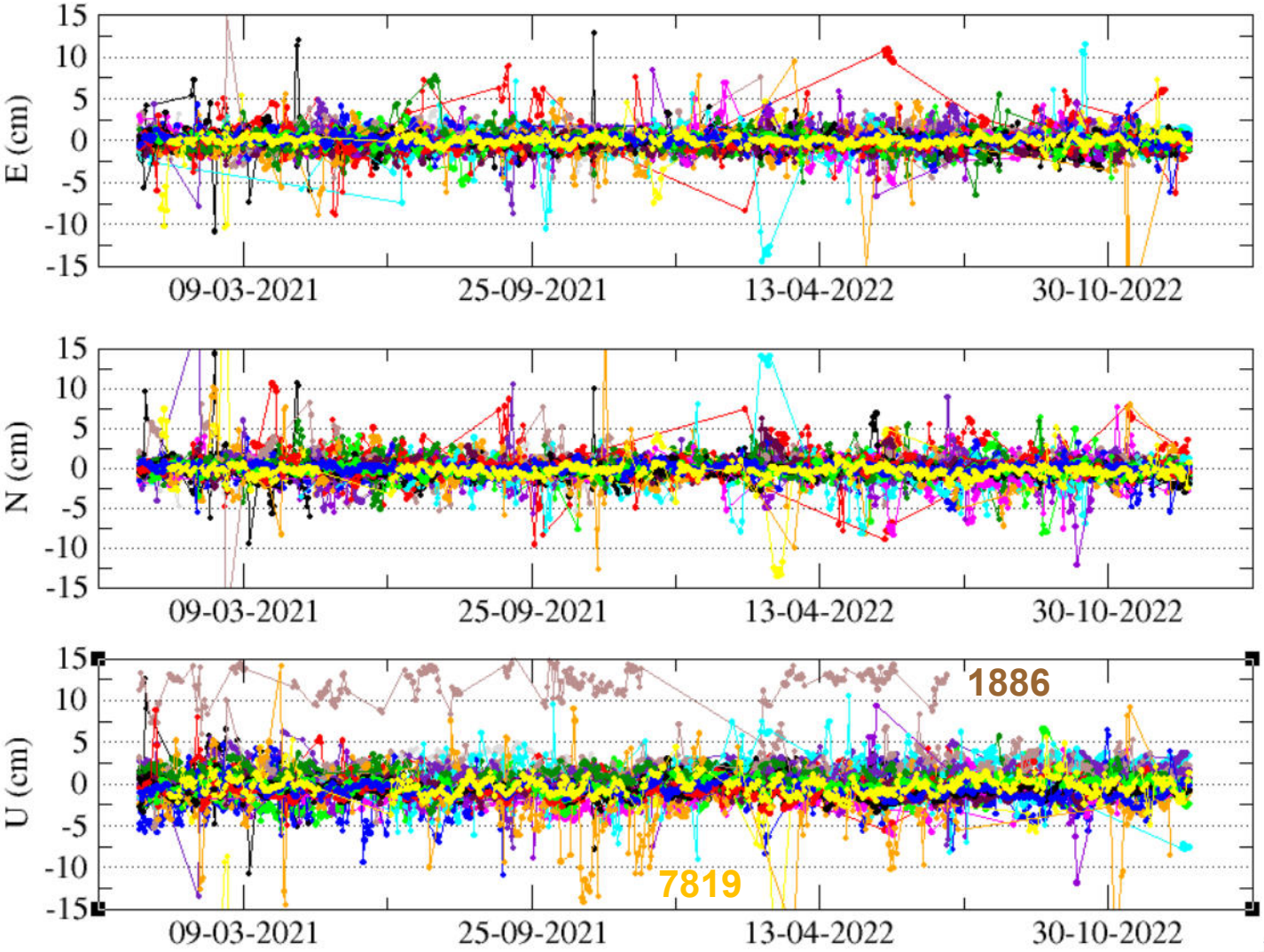
Back-up slide : orbits' rms-3D wrt. ILRSA combined orbit



Back-up slide : CNES stations residuals wrt. ITRF2020



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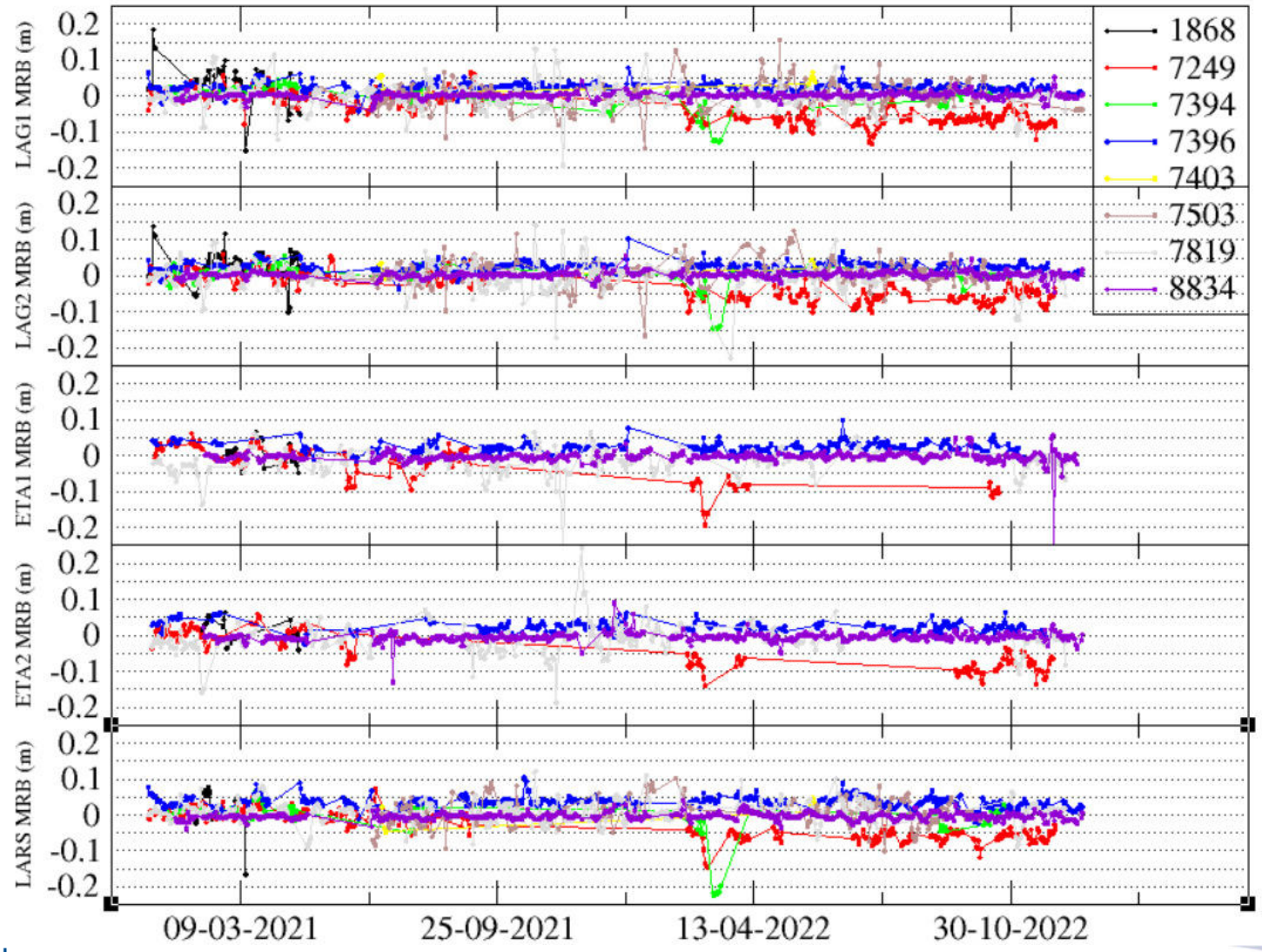
Back-up slide : CNES range biases



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Institute of Applied Astronomy RAS
Lunar Analysis Center

E.I.Yagudina, M.V. Vasilyev
Saint-Peterbursg, Russia

Areas of Interest

- IAA RAS routinely produces lunar and planetary ephemeris EPM
- IAA RAS participates in the programs for the development of LLR facilities on the Earth and in space
- IAA RAS provides ephemerides of the Moon, Sun and planets to the national Astronomical Yearbook and national space programs
- IAA RAS works with other analysis centers and LLR observatories to improve the lunar dynamical model and provide the best lunar reference frame

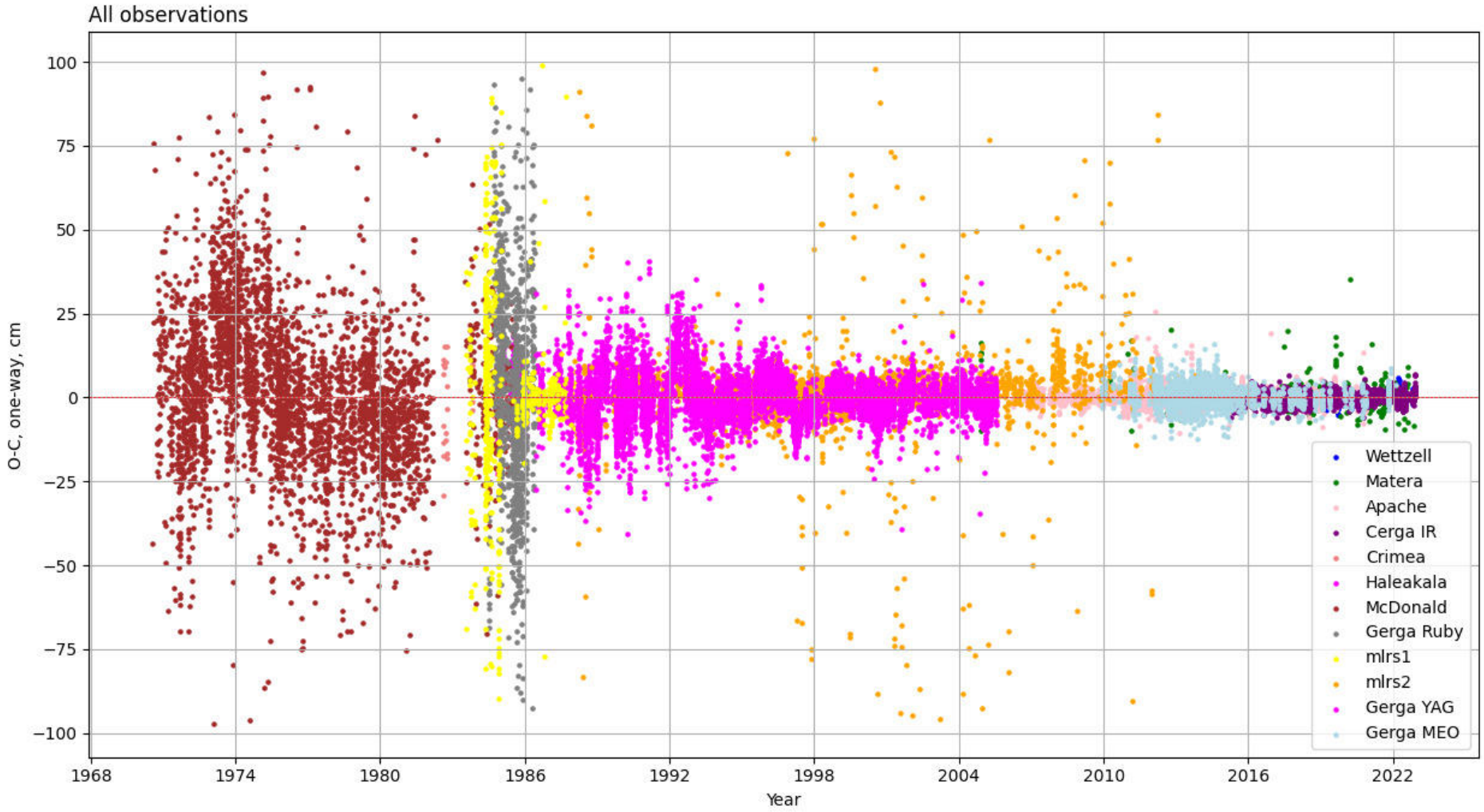
Recent Progress and Analysis Center Improvements

- Model of the orbital-rotational motion of the Moon by Krasinsky was used till 2015. Now the dynamical model of the Moon in EPM is based on DE430 model.
- 31589 LLR observations (1970-2022) are the basis of the latest lunar ephemeris – EPM2022
- Two versions of the lunar ephemeris have been prepared since 2020: EPM2021 and EPM2022

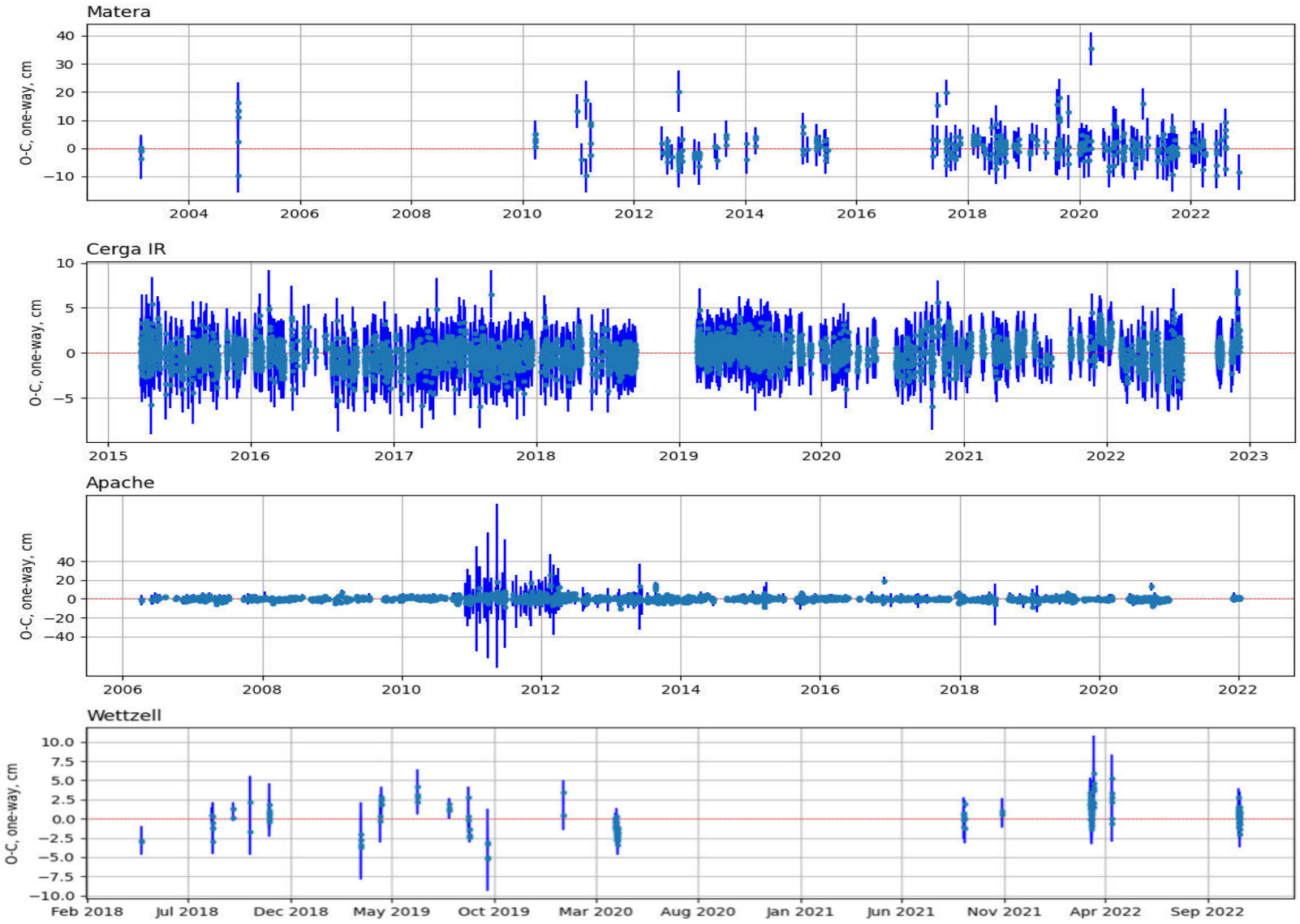
EPM2022 parameters

- initial coordinates and velocity components of the Moon for epoch JD2446000.5 ;
- Euler angles and their rate of change for a given epoch;
- initial angular velocity of rotation of the Earth's core;
- delay of lunar tides;
- The sum of the Earth-Moon masses;
- Compression ratio of the lunar core **f_c**;
- coefficient of friction between the core and the crust **K_v** /C;
- number of Lava Moon **h_2**;
- dynamic parameters $\beta=(C-A)/B$, $\gamma=(B-A)/C$;
- tidal delay τ;
- Moon potential parameters;
- position of five lunar reflectors A11, A14, A15, L1, L2;
- observation station positions: Haleakala/McDonald/MLRS1/MLRS2, Cerga, Apache(Apollo), Matera, Wettzell;
- three additional dissipative tidal terms for the Moon;
- 28 shifts (biases) are not modeled shifts of observed values.

EPM2022 residuals



EPM2022 residuals depending on the LLR station



EPM parameters in progress

	Parameters	EPM2019	EPM2021	EPM2022
1	Moon X	−137136473.790 ± 0.035 m	-137136473.600 ± 0.033 m	137136473.540 ± 0.033 m
2	Moon Y	−311514604 .073 ± 0.039 m	-311514603.992± 0.036 m	-311514604.030 ±0.036 m
3	Moon Z	−141738600.463 ± 0.065 m	−141738600.888 ± 0.059 m	-141738600.845 ± 0.059 m
4	Moon v_x	962372276.46 ± 0.08 μm/sec	962372276.70 ± 0.07 μm/sec	962372276.75 ± 0.07 μm/sec
5	Moon v_y	−375608190.10 ± 0.09 μm/sec	-375608189.49 ± 0.09 μm/sec	-375608189.35 ± 0.01 μm/sec
6	Moon v_z	−268439309.87 ± 0.04 μm/sec	-268439309.80 ± 0.04 μm/sec	-268439309.75 ± 0.04 μm/sec
7	ω_{cx}	$(-882.7 \pm 1.8) \cdot 10^{-6}$ rad/day	$(- 887.5 \pm 1.6) \cdot 10^{-6}$ rad/day	$(-886.4 \pm 1.6) \cdot 10^{-6}$ rad/day
8	ω_{cy}	$(-6500 \pm 4) \cdot 10^{-6}$ rad/day	$(-6505.0 \pm 3.6) \cdot 10^{-6}$ rad/day	$(-6504.0 \pm 3.5) \cdot 10^{-6}$ rad/day
9	ω_{cz}	$(229.82 \pm 0.03) \cdot 10^{-3}$ rad/day	$(229.95 \pm 0.02) \cdot 10^{-6}$ rad/day	$(229.94 \pm 0.01) \cdot 10^{-6}$ rad/day
10	φ	$(-5823800 \pm 1) \cdot 10^{-8}$ rad	$(-5823800 \pm 1) \cdot 10^{-8}$ rad	$(-5823800 \pm 1) \cdot 10^{-8}$ rad
11	θ	$(395116 \pm 1) \cdot 10^{-8}$ rad	$(395116 \pm 1) \cdot 10^{-8}$ rad	$(395116 \pm 1) \cdot 10^{-8}$ rad

EPM parameters in progress

	Parameters	EPM2019	EPM2021	EPM2022
12	ψ	$(128918873 \pm 3) \cdot 10^{-8}$	$(128918873 \pm 3) \cdot 10^{-8}$	$(128918873 \pm 2) \cdot 10^{-8}$
13	$\dot{\varphi}$	-74.533 ± 0.001"/day^{-1}	-74.536 ± 0.007"/day^{-1}	-74.536 ± 0.007"/day^{-1}
14	$\dot{\theta}$	-37.0246 ± 0.0002"/day^{-1}	-37.0248 ± 0.0001"/day^{-1}	-37.0253 ± 0.0001"/day^{-1}
15	$\dot{\psi}$	47501.849 ± 0.001"/ day^{-1}	47501.852 ± 0.001"/ day^{-1}	47501.853 ± 0.001"/ day^{-1}
16	β	$(631020.6 \pm 0.3) \cdot 10^{-9}$	$(631022.1 \pm 0.2) \cdot 10^{-9}$	$(631022.0 \pm 0.3) \cdot 10^{-9}$
17	γ	$(227738.2 \pm 0.3) \cdot 10^{-9}$	$(227738.9 \pm 0.3) \cdot 10^{-9}$	$(227738.6 \pm 0.3) \cdot 10^{-9}$
18	τ	0.096 ± 0.001 day	0.096 ± 0.001 day	0.094 ± 0.001 day
19	h_2	0.0425 ± 0.0004	0.0428 ± 0.0004	0.0429 ± 0.0004
20	$M_E + M_M$	403503.2364 ± 0.0001 km^{3}s^2	403503.2364 ± 0.0001 km^{3}s^2	403503.2362 ± 0.0001 km^{3}s^2
21	k_v / C_T	$(15.9 \pm 0.1) \cdot 10^{-9}$ day^{-1}	$(16.4 \pm 0.1) \cdot 10^{-9}$ day^{-1}	$(16.4 \pm 0.1) \cdot 10^{-9}$ day^{-1}
22	f_c	$(0.260 \pm 0.002) \cdot 10^{-3}$	$(0.256 \pm 0.003) \cdot 10^{-3}$	$(0.254 \pm 0.002) \cdot 10^{-3}$

EPM2022 and INPOP21a comparison

Parameter	INPOP2021a	EPM2022	INPOP21a − EPM2022
f_c-core compression ratio	2.8E-04	2.5E-04	0.3E-04
C_{32} −moon potential - parameter	4.84E-06	4.94E-06	-0.1E-06
h_2 Moon – Love number	4.23E-02	4.31E-02	-0.08E-02
k_v/C_T -core friction coefficient oh bark	1.62E-08	1.65E-08	-0.03E-08
τ_m - lunar tidal delay (days)	9.6E-02	9.3E-02	0.03E-02
Rotational delays of the earth tides τ_{R1} days , τ_{R2} days	8.02E-03 2.82E-03	7.71E-03 2.85E-03	0.31E-03 0.03E-03

EPM: WRMS in progress

Stations	EPM 2021				EPM 2022			
	Years	Numer of nor. points.	Discarded	wrms (cm)	Years	Number of Nor.points	Discarded	wrms (cm)
McDonald	1970-1985	3588	34	**21.4**	1970-1985	3588	34	**21.5**
MLRS1	1983-1988	631	46	**8.8**	1983-1988	631	46	**8.9**
MLRS2	1988-2015	3669	389	**3.4**	1988-2015	3669	389	**3.6**
Haleakala	1984-1990	770	23	**5.1**	1984-1990	770	23	**5.2**
Cerga Ruby	1984-1986	1112	3	**16.6**	1984-1986	1112	3	**16.7**
Cerga YAG	1987-2005	8316	39	**2.3**	1987-2005	8316	39	**2.3**
Cerga MeO	2009 -2022	2097	0	**1.4**	2009 -2022	2097	0	**1.5**
Cerga IR	2015-2022	6047	3	**1.1**	2015-2022	6847	7	**1.2**
Apache	2006-2022	3916	77	**1.3**	2006-2022	3901	78	**1.4**
Matera	2003-2022	375	2	**3.2**	2003-2022	421	2	**3.2**
Wettzell	2018-2022	229	0	**1.6**	2018-2022	212	0	**1.5**

Technical Challenges

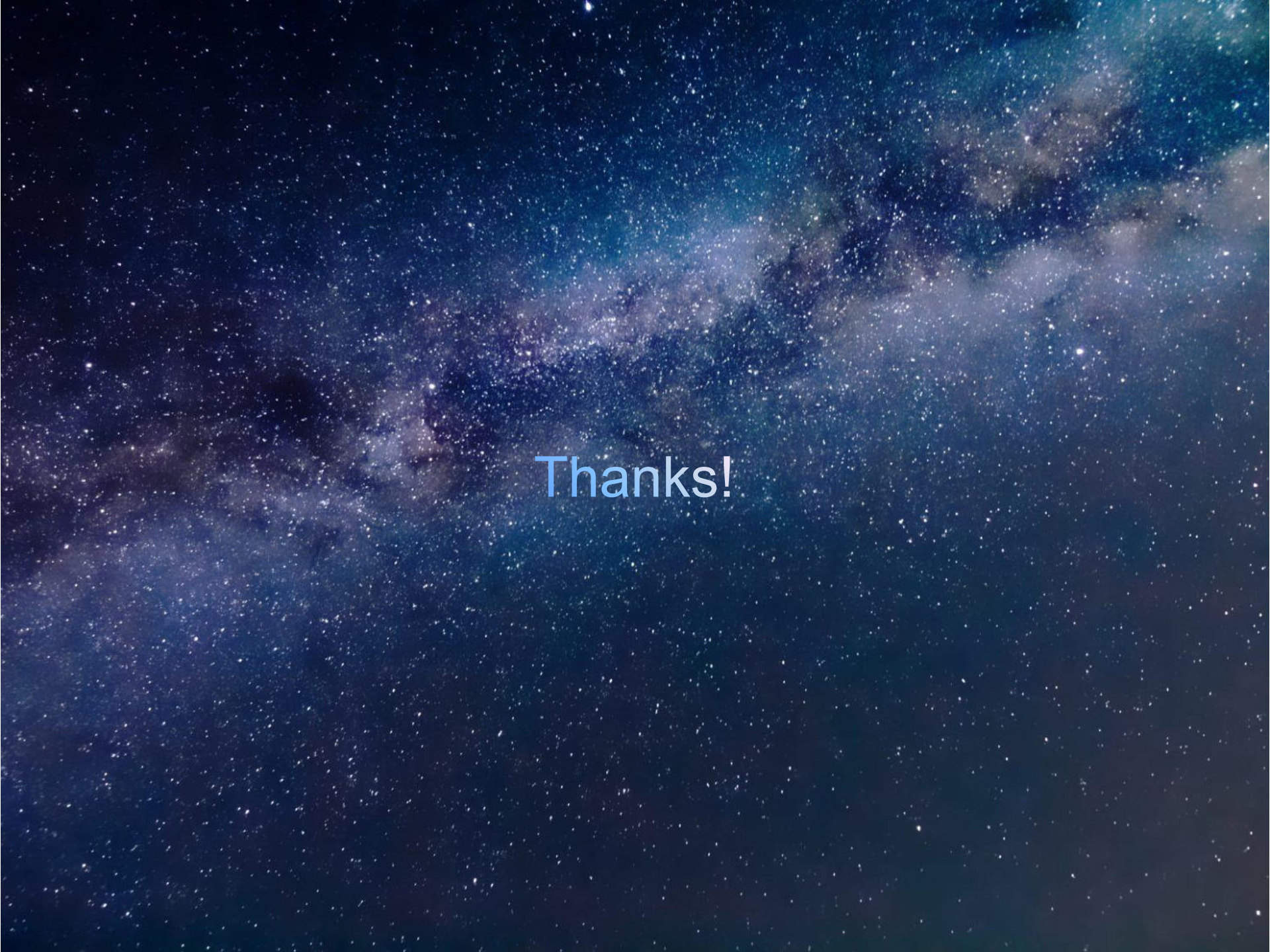
- IAA RAS continues work to maintain the new Russian LLR station. However, the construction is still being delayed, mainly due to the optical part of the station.
- IAA RAS is currently not engaged in the LRR processing, since the Chinese colleagues have not yet sent new data covering a longer time interval.

Future plans

- The routine processing of the LLR observations should continue. The next, improved version of EPM, including improved lunar ephemeris, is scheduled for release in 2023.
- Testing general relativity with LLR.

AAC Personnel

- Dmitry Ivanov (dvi@iaaras.ru): head of IAA RAS
- Alexander Ipatov (ipatov@iaaras.ru): scientific director of the IAA RAS
- Elena Pitjeva (evp@iaaras.ru): head of the Laboratory of Ephemeris Astronomy, responsible for EPM ephemeris overall.
- EleonoraYagudina(eiya@iaaras.ru), Margarita Lebedeva(ma.Lebedeva@iaaras.ru): responsible for implementation of the lunar part of EPM.
- Ivan Dolgakov (ia.dolgakov@iaaras.ru): responsible for online ephemeris service (http://iaaras.ru/en/dept/ephemeris/online/), the online LLR pointing service (http://iaaras.ru/en/dept/ephemeris/llr-pointing/) and LLR O-C web service (http://iaaras.ru/en/dept/ephemeris/llr-oc/).


Thanks!

Report of the Lunar Analysis Center: Institut für Erdmessung/ Forschungseinrichtung Satellitengeodäsie (IFE/FESG), Germany

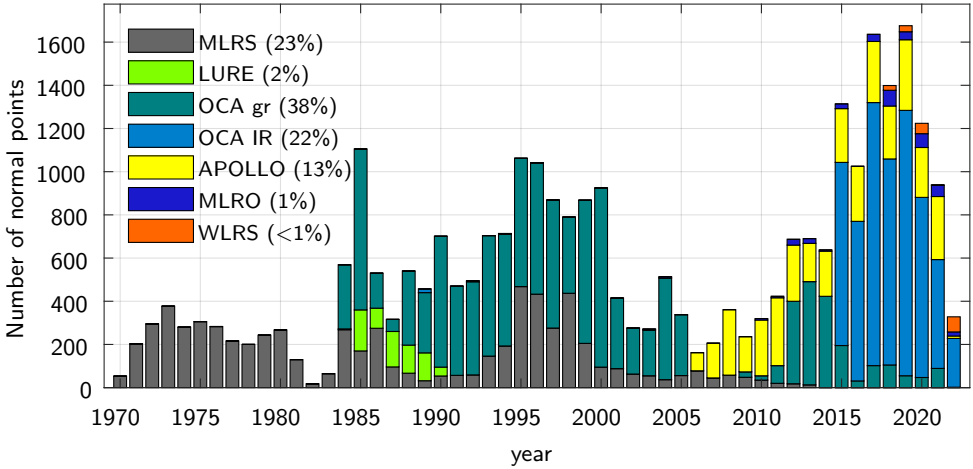
Liliane Biskupek[1], **Jürgen Müller**[1]
Ulrich Schreiber[2]

[1]Institute of Geodesy (IfE), Leibniz University Hannover

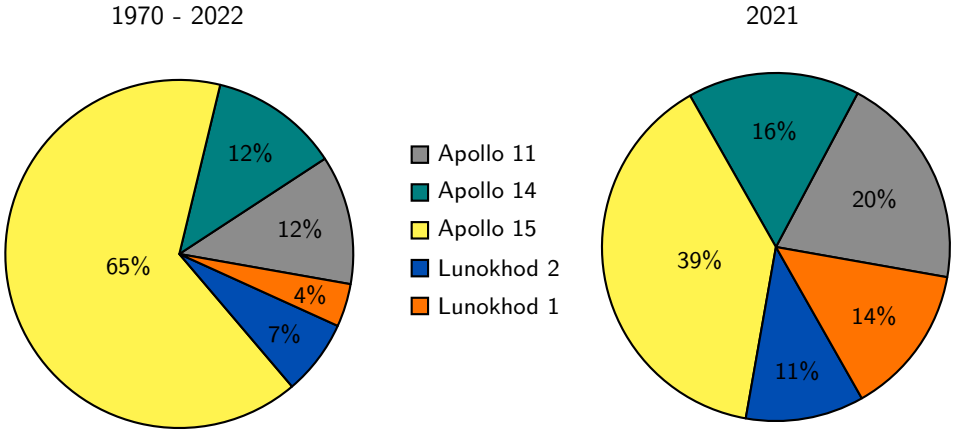
[2]Forschungseinrichtung Satellitengeodäsie, Geodetic Observatory Wettzell, Technical University Munich

Distribution of the normal points over 52 years

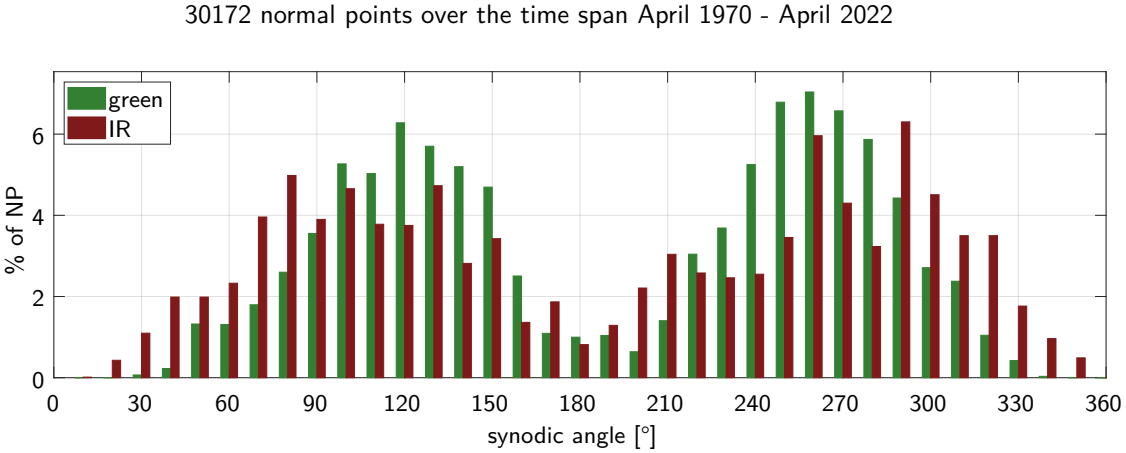
30172 normal points over the time span April 1970 - April 2022, only in CRD 1 format



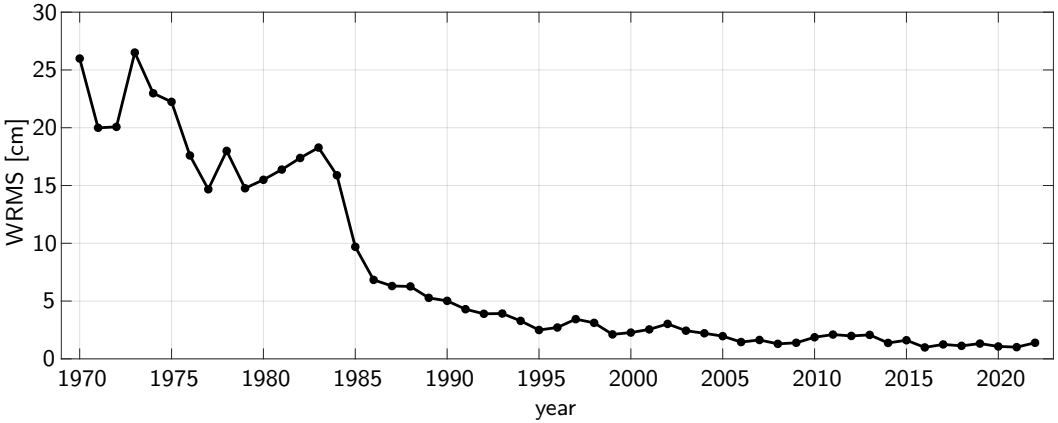
Distribution of the normal points over the reflectors



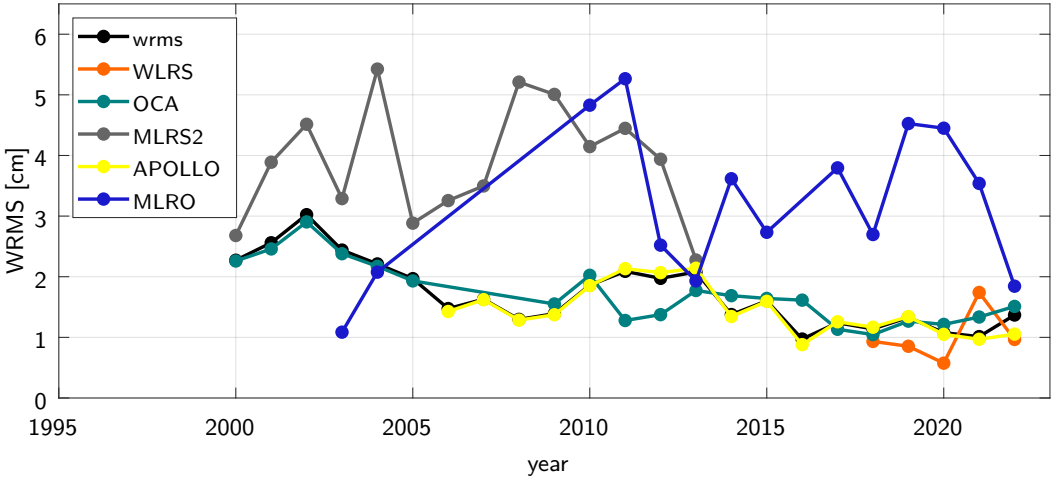
Distribution of the normal points over the synodic month



Residuals from LLR analysis at IfE



Residuals from LLR analysis at IfE by station



Recent analysis and research topics

changing ephemeris calculation

- before: successive calculation from 1969 on (1-way, 1969-2023)
- problem: errors are accumulated over time span (high accurate ephemeris/low accurate NPs $\leftrightarrow$ lower accurate ephemeris/high accurate NPs)
- now: ephemeris starting from 2000 (2-way, 2000-1969 and 2000-2023)

Relativity Tests

- equivalence of active/passive gravitational mass
- Singh et al, 2023, PRL, under review

Earth orientation parameters

- for x_p, y_p uncertainty better then 0.7 mas
- for ΔUT1 from the highly accurate OCA data uncertainty about 20 µs
- Singh et al, 2022, ASR

Differential Lunar Laser Ranging

- new station planned at Table Mountain observatory in California
- simulation of range differences
- improving parameters of Lunar interior and rotation
- combination with LLR
- Zhang et al, 2022, A&A

Conclusion and outlook

- LLR analysis benefits greatly from improved LLR data, especially from IR NPs with high number of NPs per night and better distribution over the synodic month and the reflectors

next steps:

- implementation of CRD 2 format in the analysis to use all new LLR NPs
- extension of the analysis model for celestial pole offsets
- combination of VLBI and LLR for EOP

Thank you!

Contribution to the ILRS ASC Meeting

by the INFN-LNF's SCF_Lab Team
(contributed by Luca Porcelli, Marco Muccino, Lorenza Mauro, Michele Montanari, and Simone Dell'Agnello)

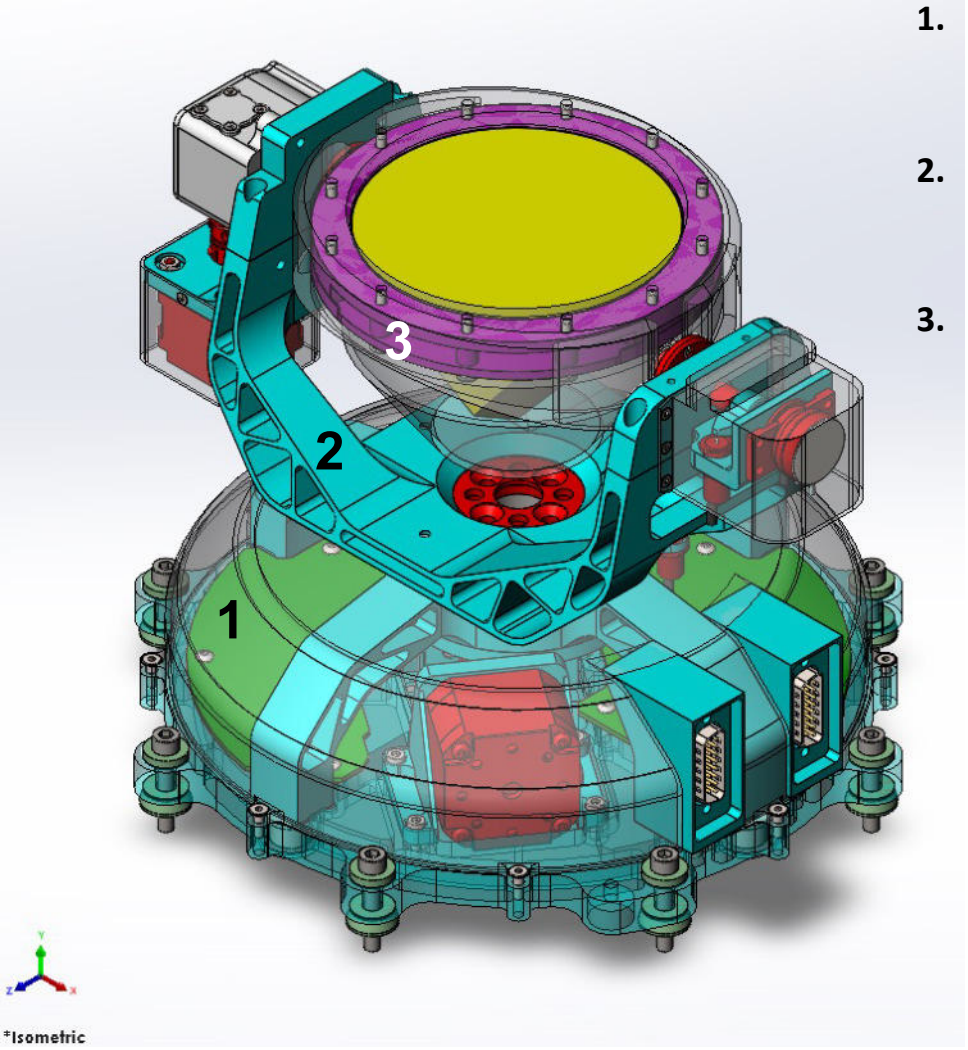
An off-topic presentation?!

We would like to introduce ‘MoonLIGHT+MPAc’:

- The 1st lunar laser retroreflector (as far as we know) with active dual pointing actuators.
- MoonLIGHT (Moon Laser Instrumentation for General relativity/geophysics High-accuracy Tests): INFN-LNF next-generation lunar laser retroreflector.
- MPAc (MoonLIGHT Pointing Actuator).
- ESA-MoonLIGHT for NASA-CLPS/PRISM-1A (CP-11) mission in 2024 to Reiner Gamma Swirl (7N, 59W) (NASA-ESA MoU signed in early 2022); INFN-LNF work supported by ESA Contract n. 4000129000/19/NL/TFD and ASI Agreement n. 2019-15-HH.0.

The following three slides are courtesy of *Muccino, M., et al., Probing Gravity with Next-generation Lunar Laser Ranging (LLR) & Lunar Surface Laser Ranging (LSLR), Lunar GW Detection Meeting, Bangalore, India, April 2023*.

MPAc (MoonLIGHT Pointing Actuator) in a nutshell



1. **Azimuth frame or base frame** contains most of the electronics and the "Azimuth" actuator, a stepper motor with an ideal range of movements from 0° to 180°, around the normal to the lander deck surface. These movements are confined by two limit switches.
2. **Elevation frame** holds the CCR housing and contains the "Elevation" actuator, a stepper motor with an ideal range of movements up to ±90° around an axis parallel to the lander deck. The space of movements is confined by two limit switches.
3. **CCR Housing** is a completely passive block that holds the retroreflector **MoonLIGHT** and contains its integration structure. The housing defines a coordinate system where the normal to the CCR front face points in the direction of the Earth, after pointing operations. In this direction the FoV must be free of obstructions in a cone of semi-aperture of 45° with respect to the axis of the CCR.

Color	Material	Finish	Absorptivity	Emissivity	Mass (Kg)
Cyan	AA6061	Surtec 650	0.13	0.06	~ 1.6
White	AA 6061	MAP® SG121FD white paint	0.18	0.88	~0.7
Yellow	Fused Silica	/	0.01	0.90	~0.6
Red	AISI 316	/	0.45	0.14	~0.95 *
Light green	FR4	/	Unknown	Unknown	~0.02
Green	35N	/	Unknown	Unknown	TBC
Purple	PCTFE (Kel-F)	/	0.5	0.92	0.08

Total Mass	**4.3 kg + 20% margin = 5.2 kg**
Dimensions (h × w × d)	**312.5 × 312.5 x 312.5 mm^3**

Courtesy of Muccino, M., et al. 2023.

Fundamental Physics Tests with MoonLIGHT/NGLR

The aim is to obtain highly accurate measurements of the Earth-Moon distance to investigate:

I. **The Equivalence Principle:** measuring the difference in acceleration of Earth and Moon due to Sun.

II. **The variation of $\dot{G}/G$** that can relate the expansion of the solar system in relation to the external universe.

III. **Test of theories of gravity:** through estimates of the PPN parameters from LLR measurements can test theories proposed for acceleration of distant galaxies which is closely tied to ideas about dark energy.

Gravitational measurement	Apollo/Lunokhod LLR accuracy (~ few cm)	Next generation LLR accuracy (~1 mm)	Time scale	Ultimate goal LLR accuracy (~0.1 mm)
WEP	$\left\|\frac{\Delta a}{a}\right\| < 1.4 \times 10^{-13}$	10^{-14}	Few years	10^{-15}
SEP	$\|\eta\| < 4.4 \times 10^{-4}$	3×10^{-5}	Few years	3×10^{-6}
β	$\|\beta - 1\| < 1.1 \times 10^{-4}$	10^{-5}	Few years	10^{-6}
$\frac{\dot{G}}{G}$	$\left\|\frac{\dot{G}}{G}\right\| < 9 \times 10^{-13} yr^{-1}$	5×10^{-14}	~ 5 years	5×10^{-15}
Geodetic precession	6.4×10^{-3}	6.4×10^{-4}	Few years	6.4×10^{-5}
$1/r^2$ deviation	$\|\alpha\| < 3 \times 10^{-11}$	10^{-12}	~ 10 years	10^{-13}

- J. G. Williams et al. Phys. Rev. Lett. 93, 261101 (2004)
- M. Martini, S. Dell'Agnello, Springer, DOI 10.1007/978-3-319-20224-2_5 (2016)
- Currie, D. G. et al. (2013), Acta Astronautica 68, 667–680
- H. Haviland et al., The Lunar Geophysical Network Landing Sites Science Rationale (2021), arXiv:2107.06451
- Biskupek, L., Müller, J., and Torre, "*Benefit of New High-Precision LLR Data for the Determination of Relativistic Parameters*", Universe, 7, 34 (2021)
- S. Turyshev et al., NASA BPS Division's "Lunar Surface Science Workshop Fundamental and Applied Lunar Surface Research in Physical Sciences", August 2021

Courtesy of Muccino, M., et al. 2023.

Today's agenda

1)	Last meeting + open Action Items	(CL, MB)	10 minutes
2)	Report from the IERS Directing Board	(MB)	15 minutes
3)	AC reports (SLR ACs +status of 2 new French ACs + LLR ACs)	(all)	80 minutes
4)	**CC reports**	(CL, EP)	30 minutes
	break		20 minutes
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6)	Transition to new official ILRS ASC products	(CL, MB)	15 minutes
7)	SSEM-X status	(CL)	15 minutes
8)	LARES-2 incorporation into official products	(CL, MB)	5 minutes
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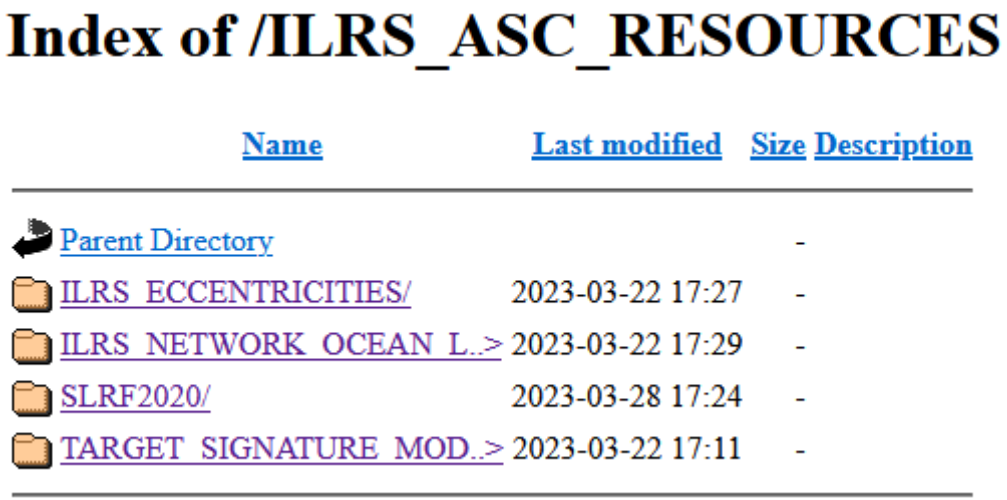
Recent SLR analysis model updates

- JCET website: **http://geodesy.jcet.umbc.edu/ILRS_ASC_RESOURCES/**
  - ILRS eccentricity file (UNE/XYZ): **version 230314**
  - SLRF2020 SINEX file: **version 230322**
  - ILRS DHF: **version 230328**
  - TS model: **version 220915**



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SLRF2020/	2023-03-28 17:24	-	
TARGET_SIGNATURE_MOD..>	2023-03-22 17:11	-	

Strategy for new DHF releases in the future

DHF updates in a regular (optimal) scenario

- all ACs provide with a latency of 9 days after the 7-day arc ends their v280 solutions to the CCs
- CCs combine the submissions and monitor
  - if new stations are online
  - if any RB changed in the most recent (reasonable) time period and has to be updated
- if an update is necessary, a new release will be published by the ASC (this DHF is still consistent to the SLRF2020!)

DHF update required due to TS model update

- due to any reason, the TS model has to be updated by José
  - in principle, the ASC has to reprocess the v280 solutions and recompile the DHF to account for this change
  - is it a 'better' strategy to wait with TS model updates for future reprocessing campaigns (e.g., for the next ITRF repro)?

DHF update required due to late NP submission by any SLR station

- occasionally, some SLR stations submit NPs with a large latency (several days to weeks)
- when does the ASC have to update the DHF? Do we need a reprocessing strategy for such cases?

Concise manual for SLR data analysis

- **last** ASC model inventory (work by Erricos/José)
- any updates?
- should we try to set up and maintain a website hosted by EDC, JCET, or ILRS?
  - IDS analysis website is very nice;-)
  - https://ids-doris.org/analysis-documents.html

ILRS ASC Products Description 2023 - GEOMETRY (1 page)

ILRS-ASC product	Series Designator (January 2023)	TRF (SLRF2020 release)	Target Signature Model (CoG corrections)	ILRS Data Handling file release date	A priori EOP Series	Secular pole model	HF-EOP
Official Products							
Daily POS+EOP	**v180**	2022 (loosely constrained)	2022-09-15	2022	IERS Bulletin A (estimated)	secular pole (UAW2017)	Desai and Sibois (2019)
Weekly POS+EOP	**v80**	2022 (loosely constrained)	2022-09-15	2022	IERS Bulletin A (estimated)	secular pole (UAW2017)	Desai and Sibois (2019)
Weekly Orbits	**v80**	2022 **(release, fixed to a priori)**	2022-09-15	2022	IERS Bulletin A **(EOP fixed to a priori)**	secular pole (UAW2017)	Desai and Sibois (2019)
Pilot Project Products							
SSEM PP POS+EOP*	**v230**	2020-04-28 (orientation loosely constrained)	2020-06-08	2019-07-31 (via email)	IERS 14 C04 (estimated)	secular pole (UAW2017)	Desai and Sibois (2019)
SSEM-X POS+EOP	**v280**	2022 (loosely constrained)	2022-09-15	2022	IERS 20 C04 (estimated)	secular pole (UAW2017)	Desai and Sibois (2019)
LARES & Gravity PP	**v300**	2022 (orientation loosely constrained)	2022-09-15	2022	IERS 20 C04 (estimated)	secular pole (UAW2017)	Desai and Sibois (2019)
LARES & Gravity PP with NT Loading Corrections	**v310**	2022 (orientation loosely constrained)	2022-09-15	2022	IERS 20 C04 (estimated)	secular pole (UAW2017)	Desai and Sibois (2019)
Discontinued Products							
REPRO 2020	**v400/v401/...**	2020-04-28 (orientation loosely constrained)	2020-06-08	2021-01-27 (via email)	IERS 14 C04 (estimated)	secular pole (UAW2017)	Desai and Sibois (2019)

* NOTE: To be discontinued once v280 becomes operational

Release: 2022.11.04

ILRS ASC Products Description 2023 - POTENTIAL (1 page)

ILRS-ASC product	Series Designator (January 2023)	Gravitational corrections ATM. & OCN. (AOD)	Static Gravity model	Time Varying Gravity model (TVG)	Earth & Ocean Tide models	Ocean Loading model
Official Products						
Daily POS+EOP	**v180**	None	GGM05C	JCET2022	IERS Conventions 2010 & GOT4.10c/FES2014/etc.	GOT4.10c / FES2014c
Weekly POS+EOP	**v80**	None	GGM05C	JCET2022	IERS Conventions 2010 & GOT4.10c/FES2014/etc.	GOT4.10c / FES2014c
Weekly Orbits	**v80**	None	GGM05C	JCET2022	IERS Conventions 2010 & GOT4.10c/FES2014/etc.	GOT4.10c / FES2014c
Pilot Project Products						
SSEM PP POS+EOP*	**v230**	None	GGM05C	JCET2018	IERS Conventions 2010 & GOT4.10c/FES2014/etc.	GOT4.7
SSEM-X POS+EOP	**v280**	None	GGM05C	JCET2022	IERS Conventions 2010 & GOT4.10c/FES2014/etc.	GOT4.10c / FES2014c
LARES & Gravity PP	**v300**	ON ORBIT ONLY: GGFC ERA5 & TUGO-m or AOD1B-RL06, etc.	GGM05C	JCET2022	IERS Conventions 2010 & GOT4.10c/FES2014/etc.	GOT4.10c / FES2014c
LARES & Gravity PP with NT Loading Corrections	**v310**	GGFC ERA5 & TUGO-m or AOD1B-RL06, etc.	GGM05C / EIGEN-GRGS.RL04.MD*	JCET2022	IERS Conventions 2010 & GOT4.10c/FES2014/etc.	GOT4.10c / FES2014c
Discontinued Products						
REPRO 2020	**v400**	ON ORBIT ONLY: GGFC ERA5 & TUGO-m or AOD1B-RL06, etc.	GGM05C / EIGEN-GRGS.RL04.MD*	JCET2021	IERS Conventions 2010 & GOT4.10c/FES2014/etc.	GOT4.10c / FES2014c

* NOTE: To be discontinued once v280 becomes operational

Release: 2022.11.04

*Provided you use the NEW IERS (2018) « linear mean pole convention » version of the model !!!

*We may switch to GOT5 and a comparable FES model when avaialble

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Transition to new official ILRS ASC products

- at EDC, the ‘new’ versions are stored in the following non-public test folders
  - **test/daily_v180** → ASI, DGFI, NSGF
  - **test/weekly_v80** (weekly processes 7-day POS+EOP products + orbits) → DGFI, NSGF
  - **test/ssem_v280** → DGFI
- There had been plenty of feedback that many ACs will start submitting their ‘new’ versions soon!
- How long should we submit the ‘new’ versions in parallel to the official ones?
  - Nick/Sharyl confirmed yesterday via mail that Christian confirmed 20 C04 to be ready → prerequisite for USNO Bull A switch → will be done within the next weeks

Reanalysis

- with the switch to the new ILRS ASC products, a complete re-analysis of the time series 1993 – present (**v85**) is necessary and valuable
- new strategy for the time period 1982-1993?

Today's agenda

1)	Last meeting + open Action Items	(CL, MB)	10 minutes
2)	Report from the IERS Directing Board	(MB)	15 minutes
3)	AC reports (SLR ACs +status of 2 new French ACs + LLR ACs)	(all)	80 minutes
4)	CC reports	(CL, EP)	30 minutes
	break		20 minutes
5)	SLRF2020 + new ILRS DHF + target signature model	(CL, EP)	15 minutes
6)	Transition to new official ILRS ASC products	(CL, MB)	15 minutes
7)	**SSEM-X status**	(CL)	15 minutes
8)	LARES-2 incorporation into official products	(CL, MB)	5 minutes
9)	LARES-PP	(MB)	10 minutes
10)	Any other business	(MB)	25 minutes

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LARES-2 incorporation into official products

- LARES-2 is in orbit since July 2022
- Easy to be implemented in official ILRS ASC products
  - same orbit height as LAGEOS-1/-2
  - TS models?
  - DHF?

- should this incorporation be done together with a complete reanalysis of the data?
  - advantage: v280-like products ca be used to determine DHF entries for LARES-2

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Pilot project on the inclusion of LEOs (LARES)

- Pilot project aims on the incorporation of spherical LEO satellites → 1st satellite is LARES
- Software changes w.r.t. LAGEOS-like processing is required
  - estimation of spherical harmonics (low-degree SH a priori values might be too inaccurate for POD)
  - modelling the high atmosphere → atmospheric drag
  - specific TS model → already available for most spherical LEOs
  - DHF with specific biases for LEOs → missing
- To kick off the PP, ACs (and maybe AACs) are now asked for a weekly time series of solutions including at least 4, 5 or even 10 spherical satellites based on the solution setup as of the new v80 time series.
  - covering the years 2021 and 2022 to be submitted to test folder at EDC
  - in principle it doesn't matter on which setup your solution is based (models, satellites, etc.). The only thing that matters now is that you include SH and provide datum-free NEQs via SINEX;-)

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Any other business – ASC publications

- Erricos and Justine had been working on DOIs for the observations we use and for the products we generate
  - work still in progress

File Type	DOI
SLR Analysis Center (AC) Position and ERP Product (daily files, generated daily)	10.5067/SLR/SLR_ILRSACSNX_001
SLR Final Station Position and ERP Product (daily files, generated daily)	10.5067/SLR/SLR_ILRSSNX_001
SLR products ITRF2020 Station Positions and Earth Orientation Parameters Time Series (REPRO2020)	10.5067/SLR/slr_itrf20200_repro2020_001
SLR Analysis Center (AC) Orbit Product (daily files, generated weekly)	10.5067/SLR/SLR_ILRSACORB_001
SLR Final Orbit Product (daily files, generated weekly)	10.5067/SLR/SLR_ILRSORB_001

  - how should the DOIs be used by the ASC? → Comment block in the SINEX files?

Any other business – ASC publications

- ACs are funded by agencies/institutions which need a proof if the AC work is necessary/useful! Usually, this is done by citations
  - data/product DOIs (see slide before)
  - publications in scientific journals by the ASC (co-authored by AC/CC primary contacts)?
    - ITRF2020 contribution?
    - switch to new official products based on different geophysical background models?
    - pilot projects: e.g., inclusion of LARES-2, SH estimates?

Any other business – minutes

- the minutes of this meeting will be provided soon to the ACs
- please read them carefully as they will comprise all the details on
  - new products
  - reprocessings
  - pilot projects
  - new processing/handling strategies for special cases
- comments on the minutes are welcome and will be incorporated!

- next meeting?
  - more frequent but shorter online meetings focused on a special topic?
  - next meeting in person?