ASI AC&CC report

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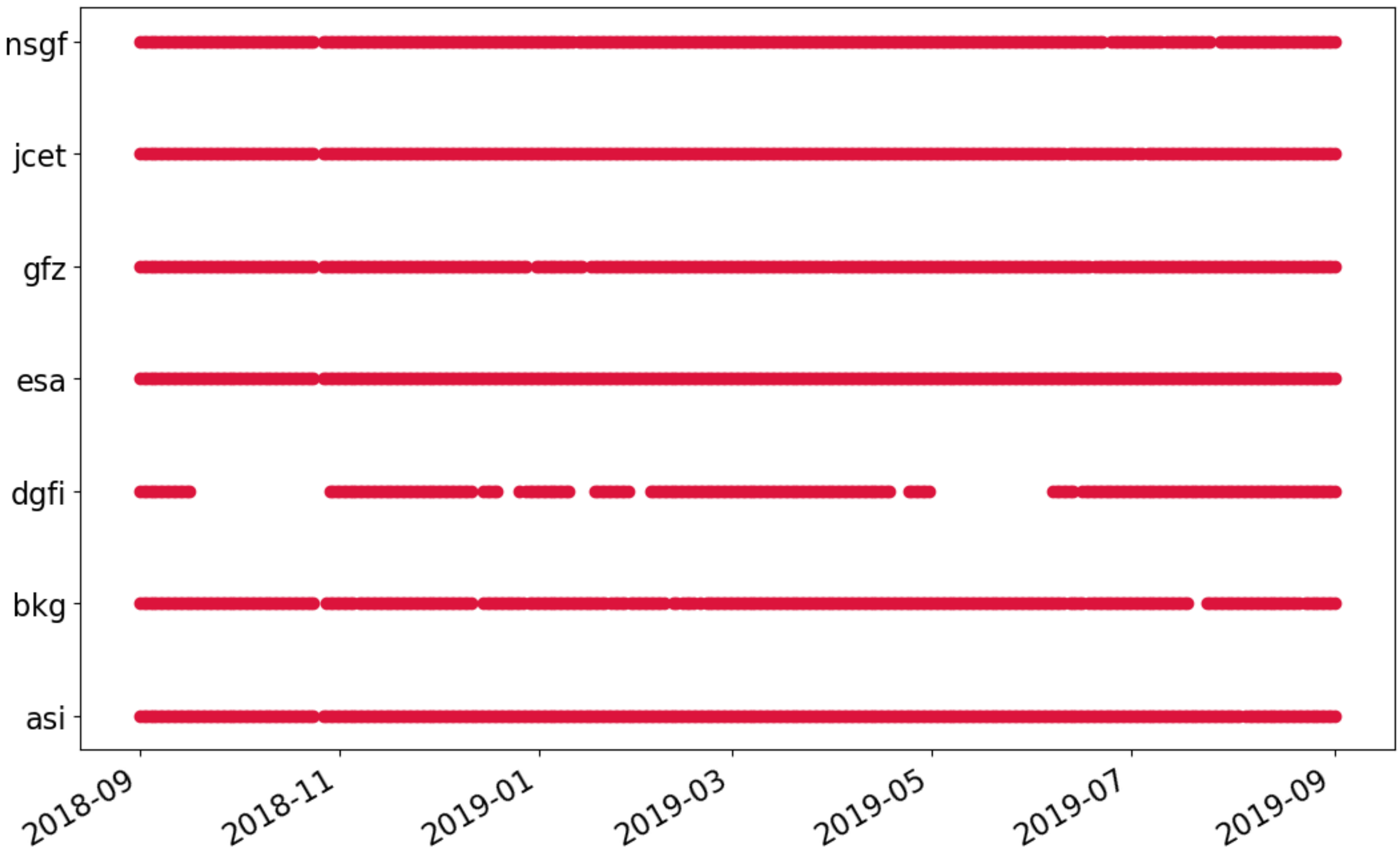
ILRS ASC Meeting, October 1st 2019, Paris

Activities since last ASC meeting

- ACs performance check
  - Data submissions
  - 3D wrms of the residuals w.r.t. SLRF (daily and weekly)
  - Scale factor
  - Geocenter motion
  - LOD
  - Combination scale factor
  - Orbits: RMS of residuals w.r.t. combination
  - ILRS ACs orbit agreement

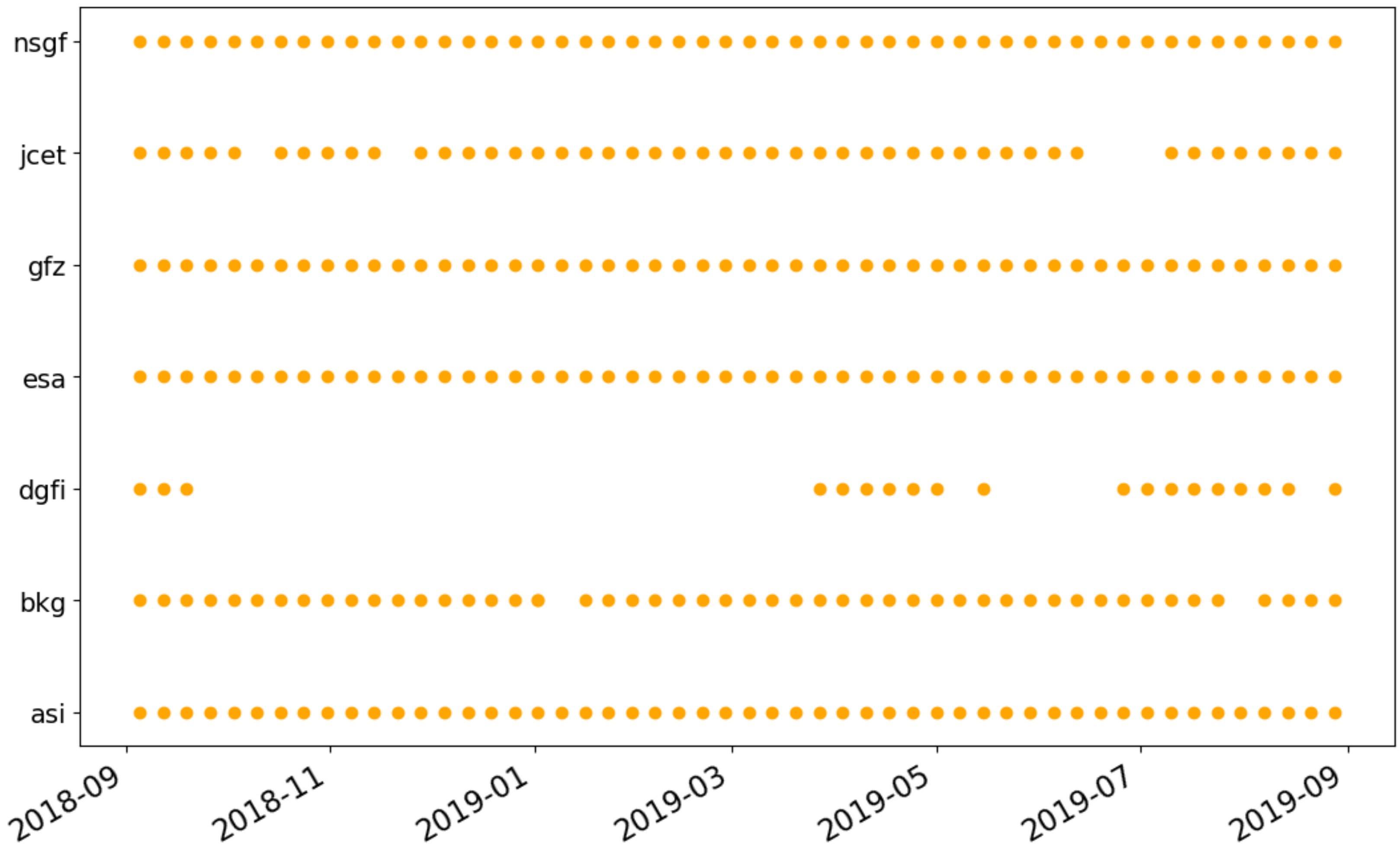
Data submissions

Daily (v170) ACs time series

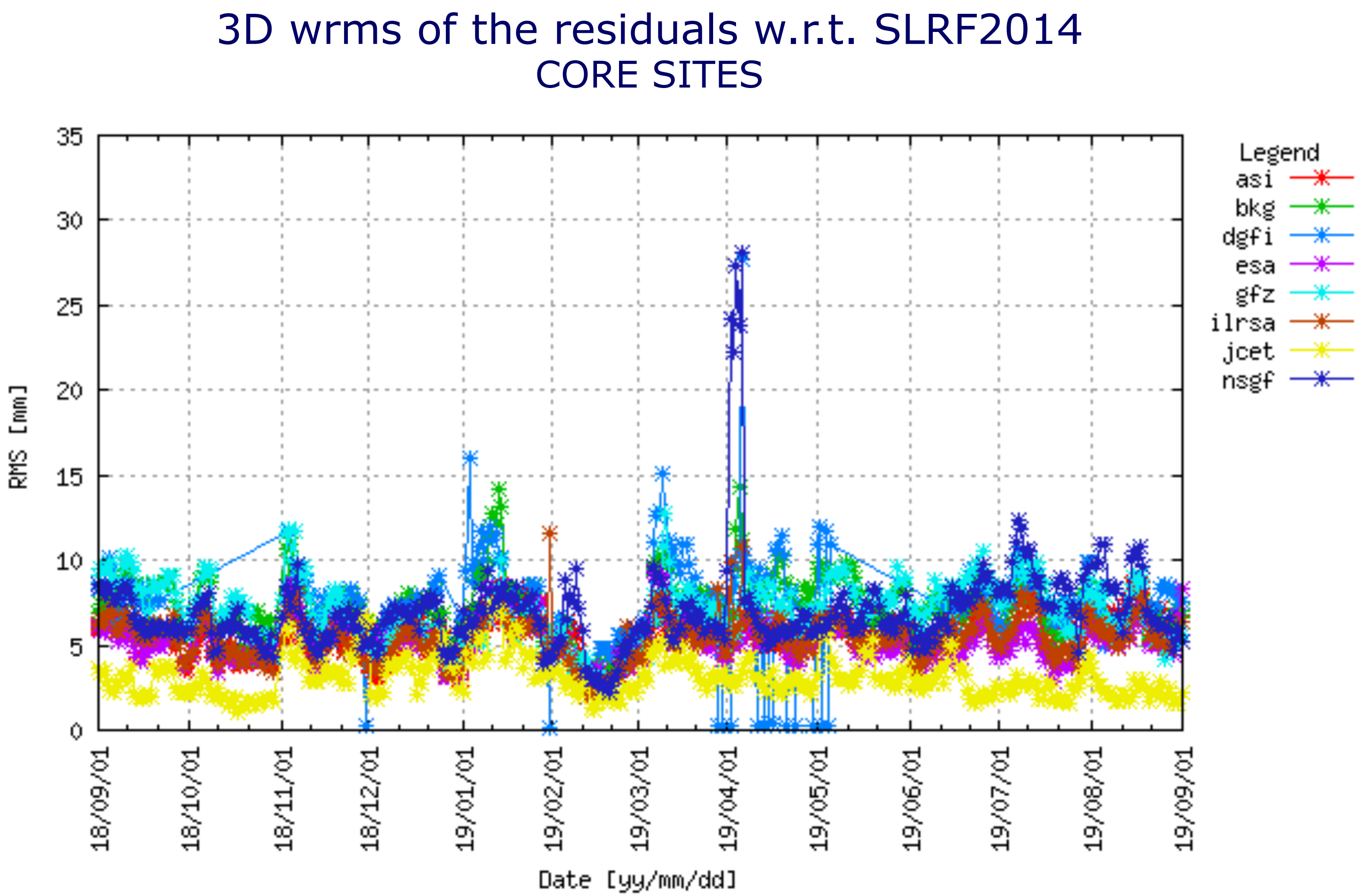


Data submissions

Weekly (v70) ACs time series

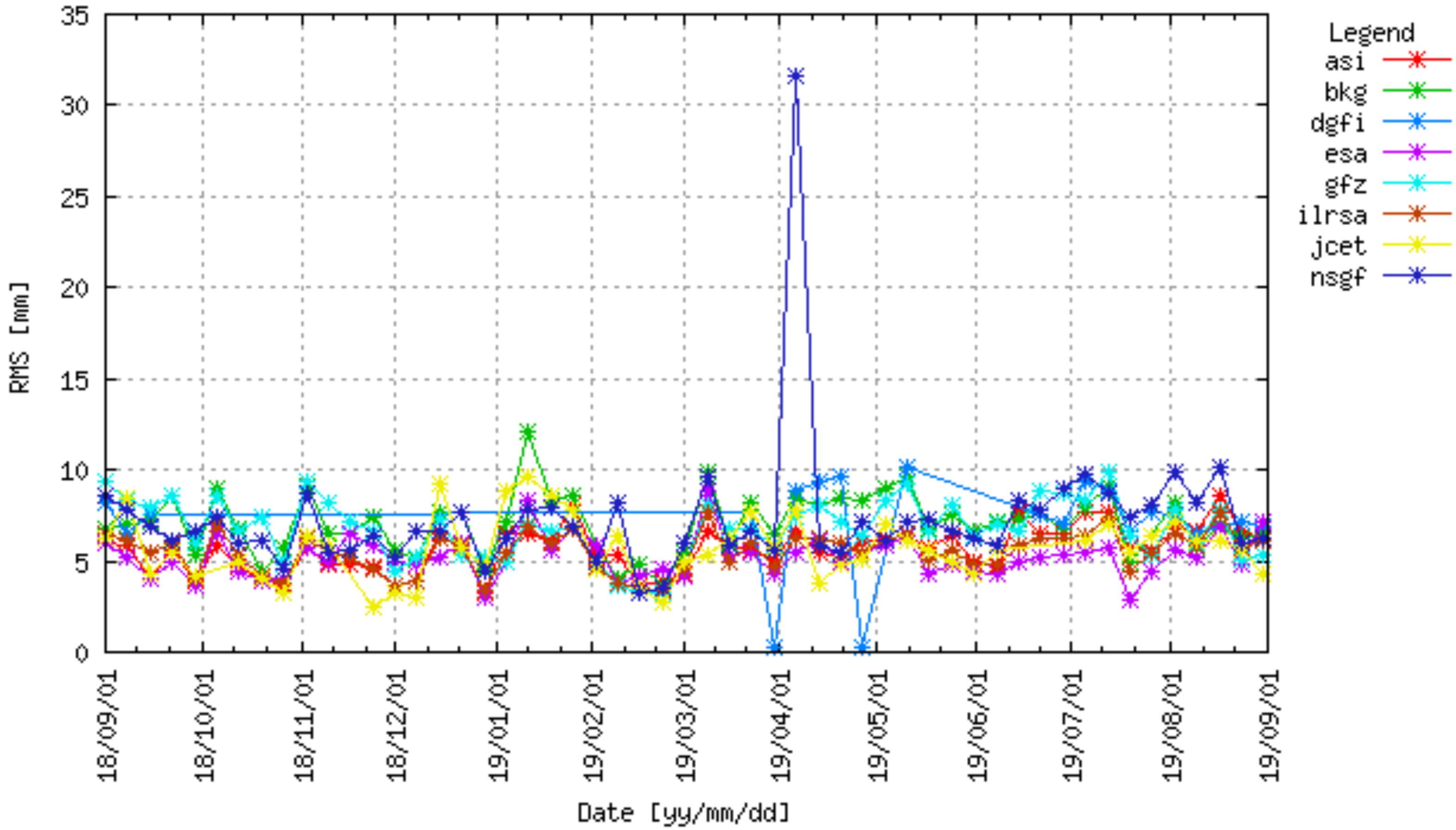


Stations Coordinates from Daily solutions

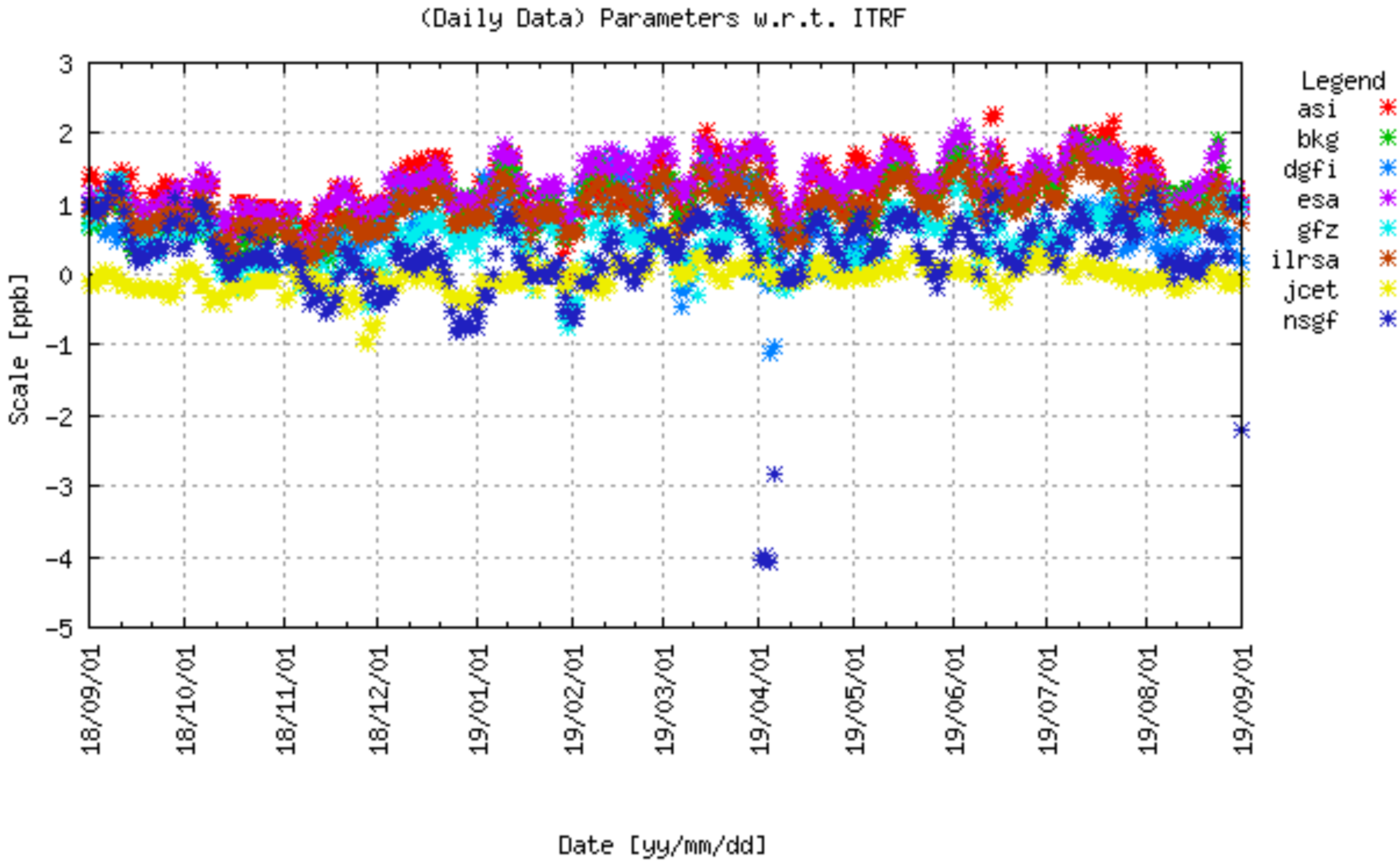


Stations Coordinates from Weekly solutions

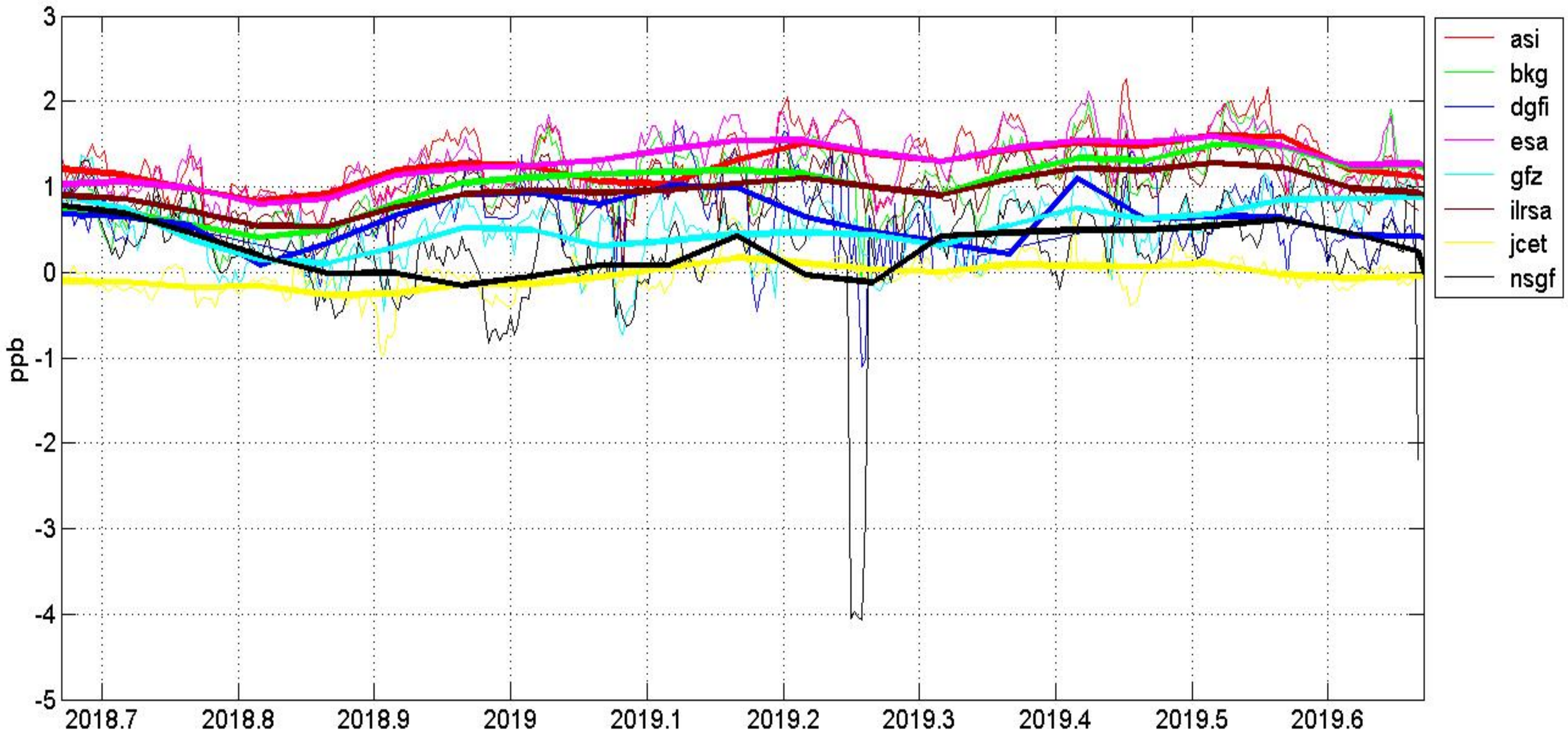
3D wrms of the residuals w.r.t. SLRF2014
CORE SITES



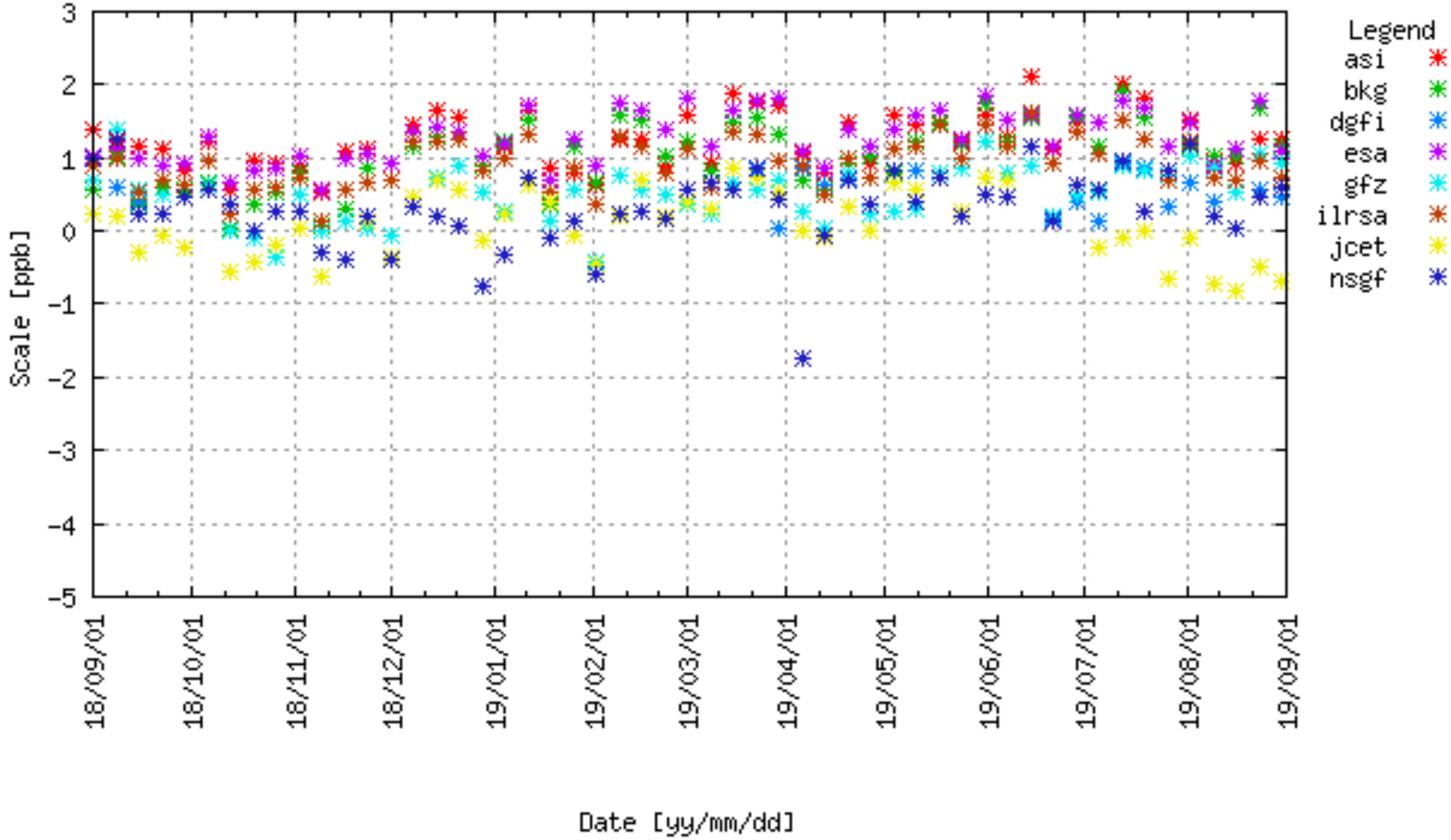
Scale from daily solutions



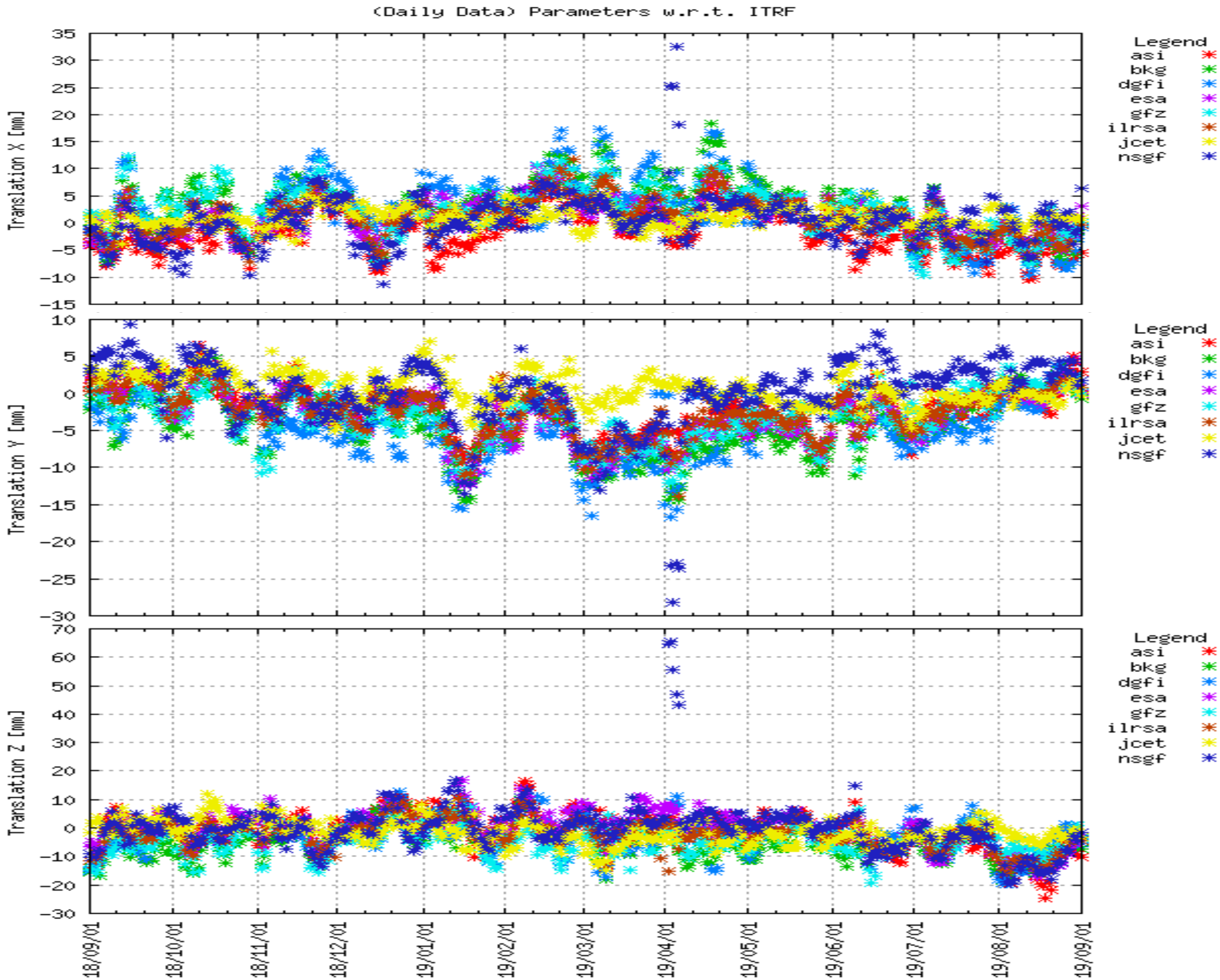
Scale from daily solutions (trend lines)



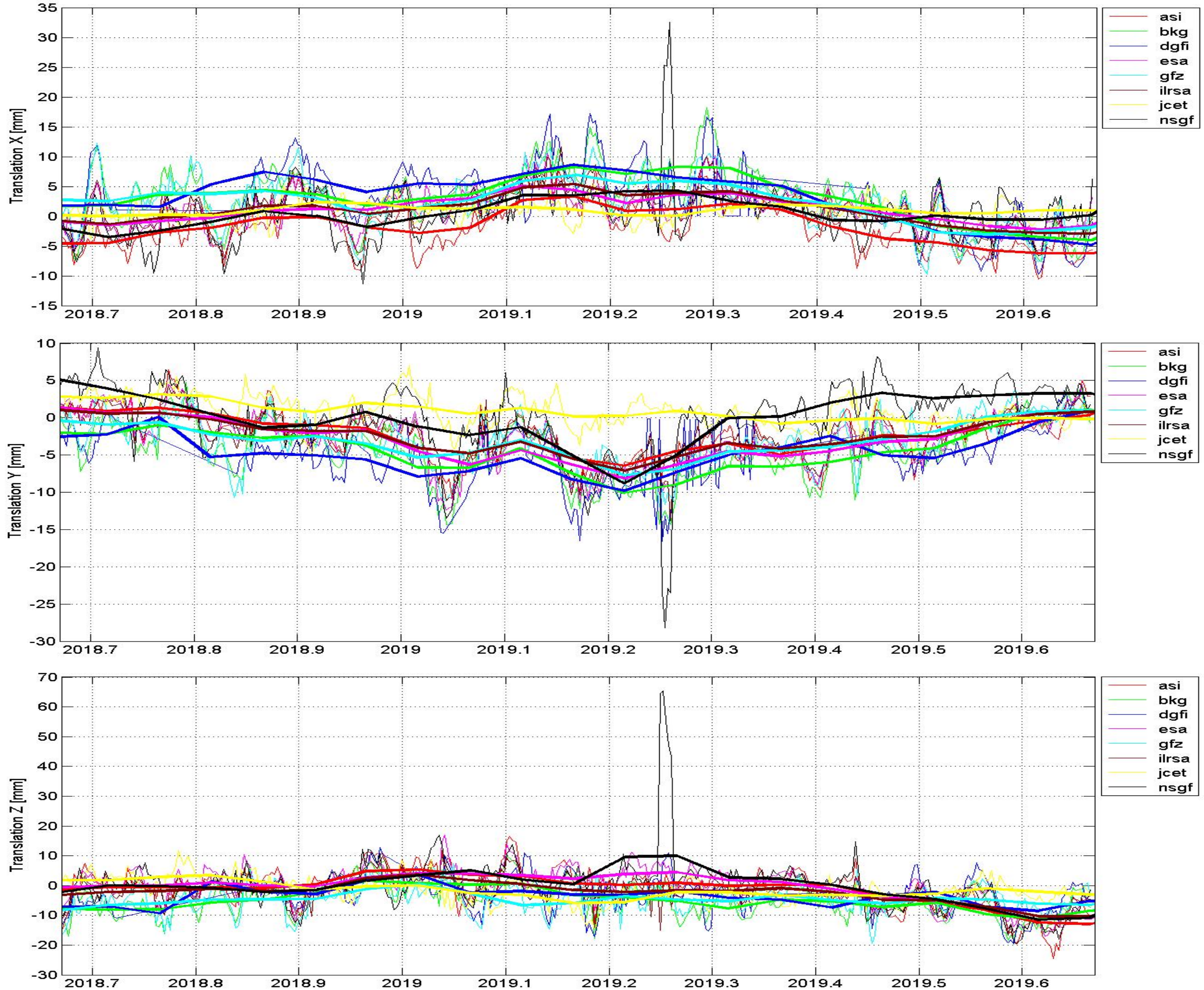
Scale from weekly solutions



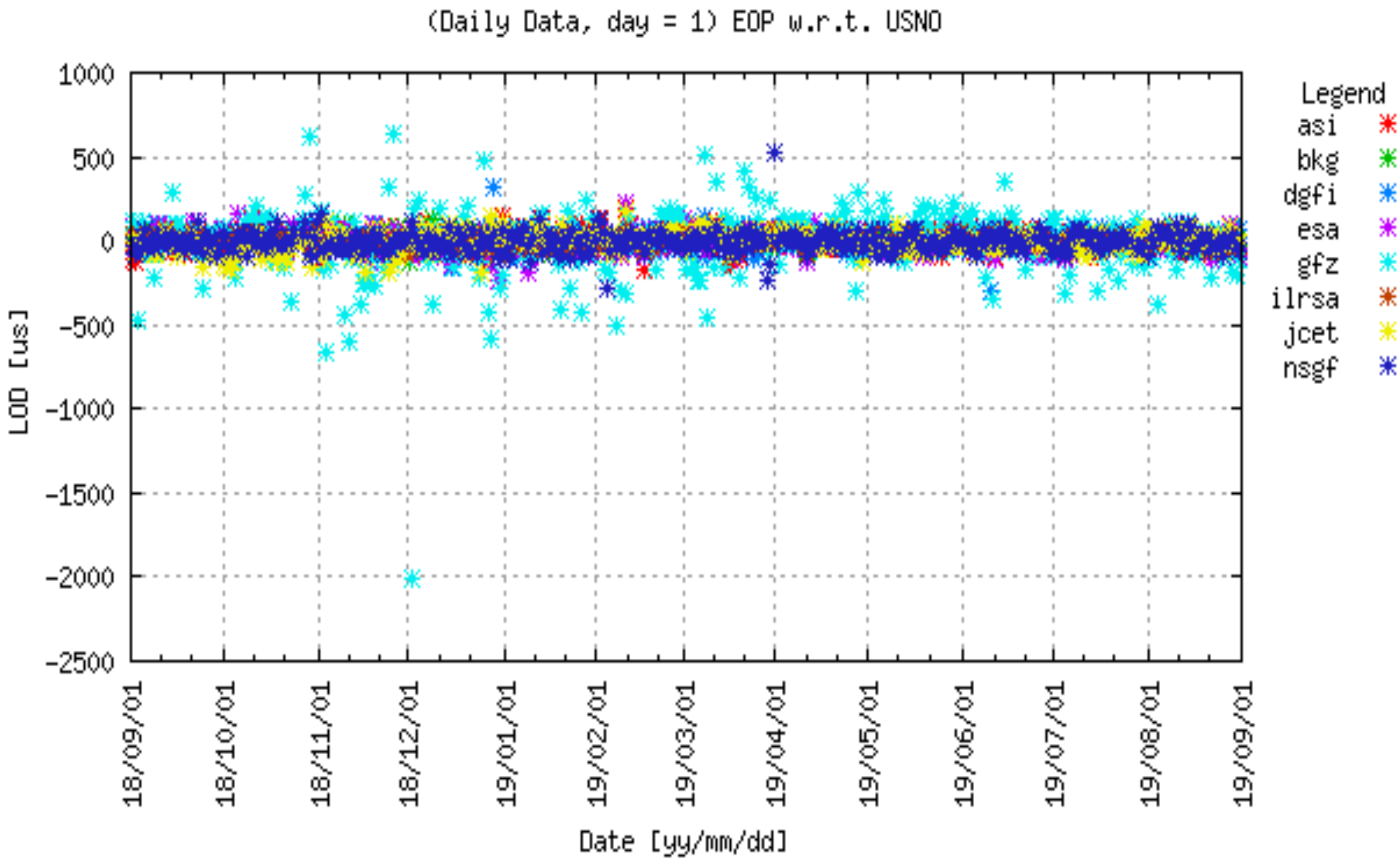
Geocenter motion from daily solutions



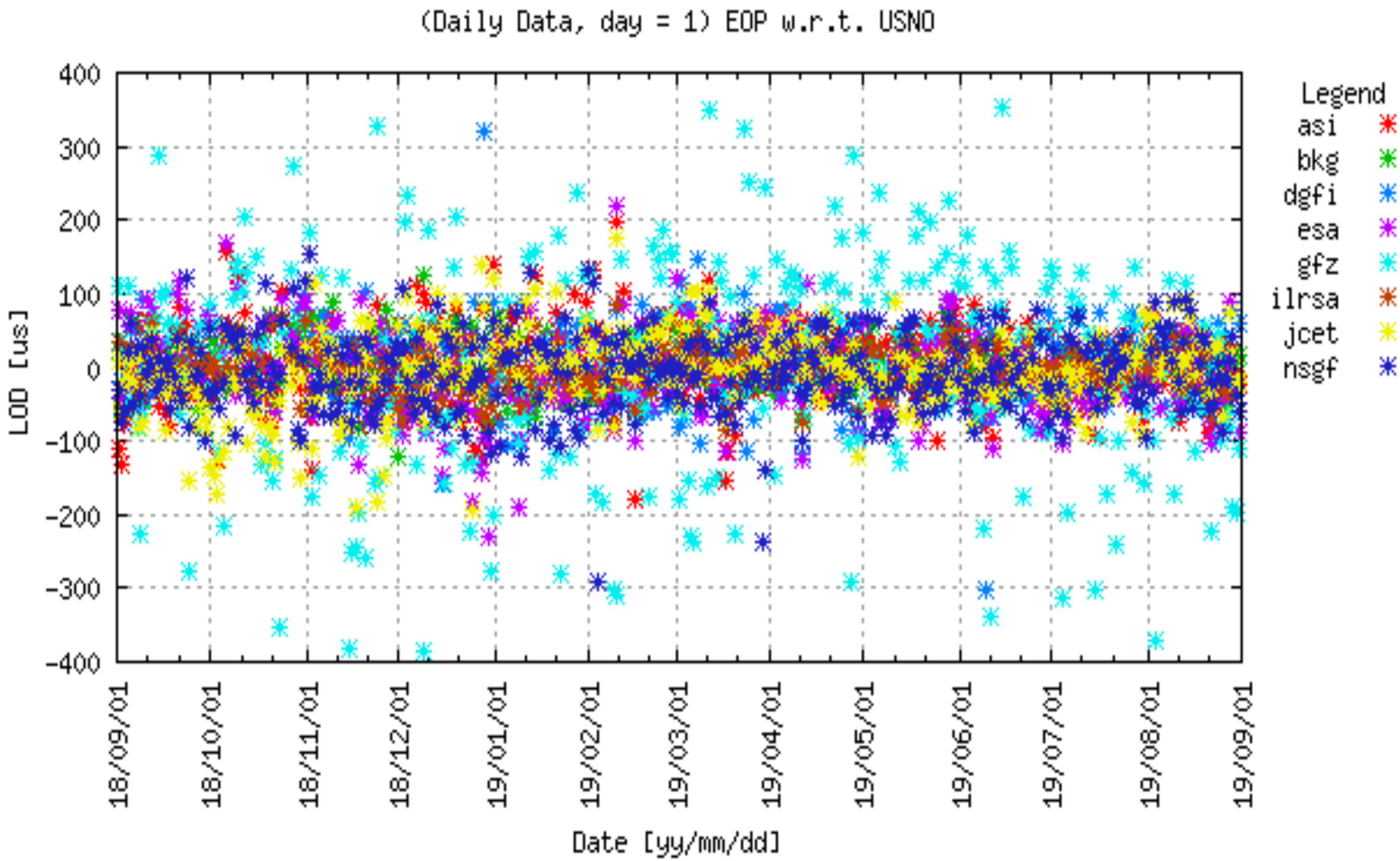
Geocenter motion from daily solutions (trend lines)



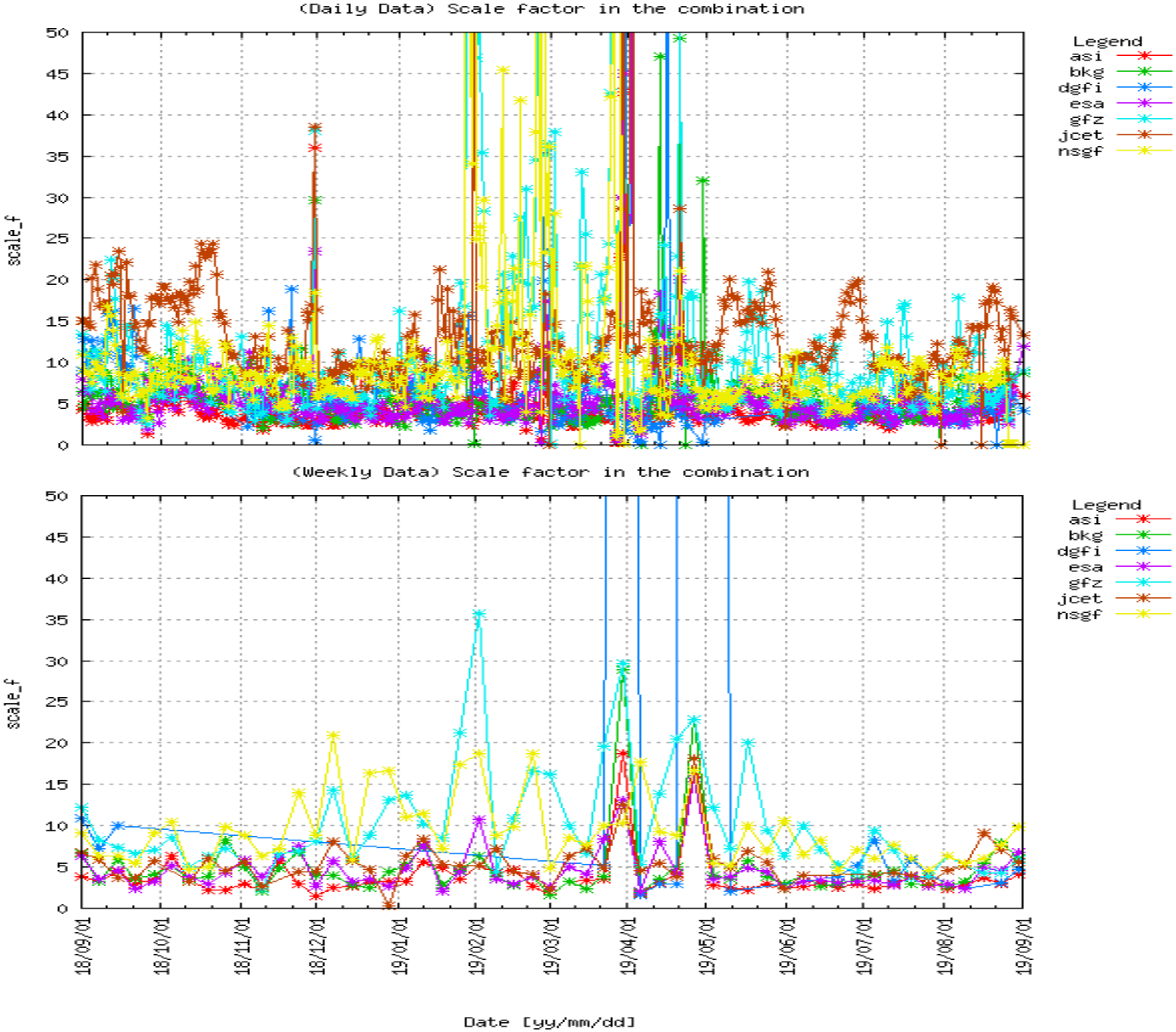
LOD from daily solutions



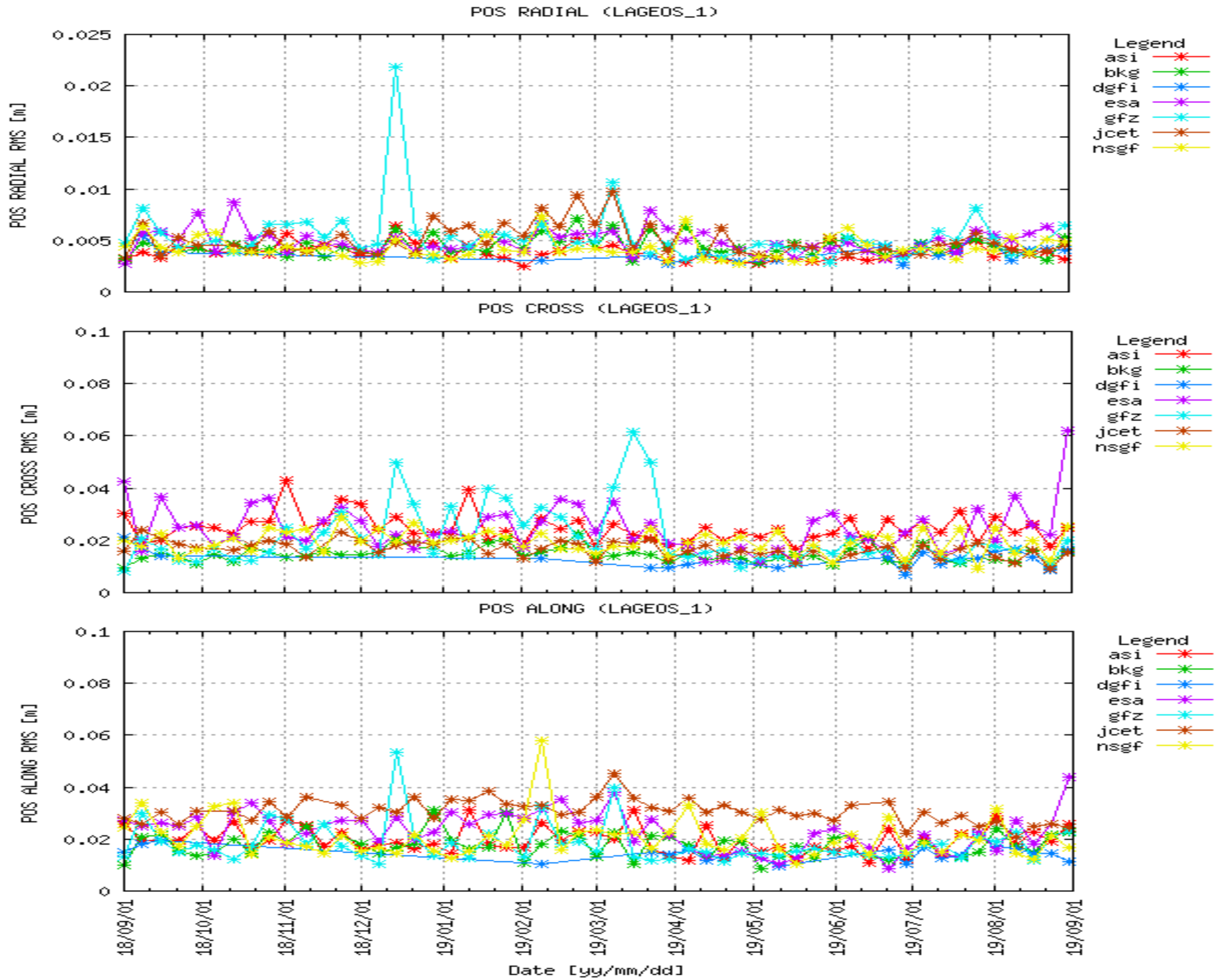
LOD from daily solutions - detail



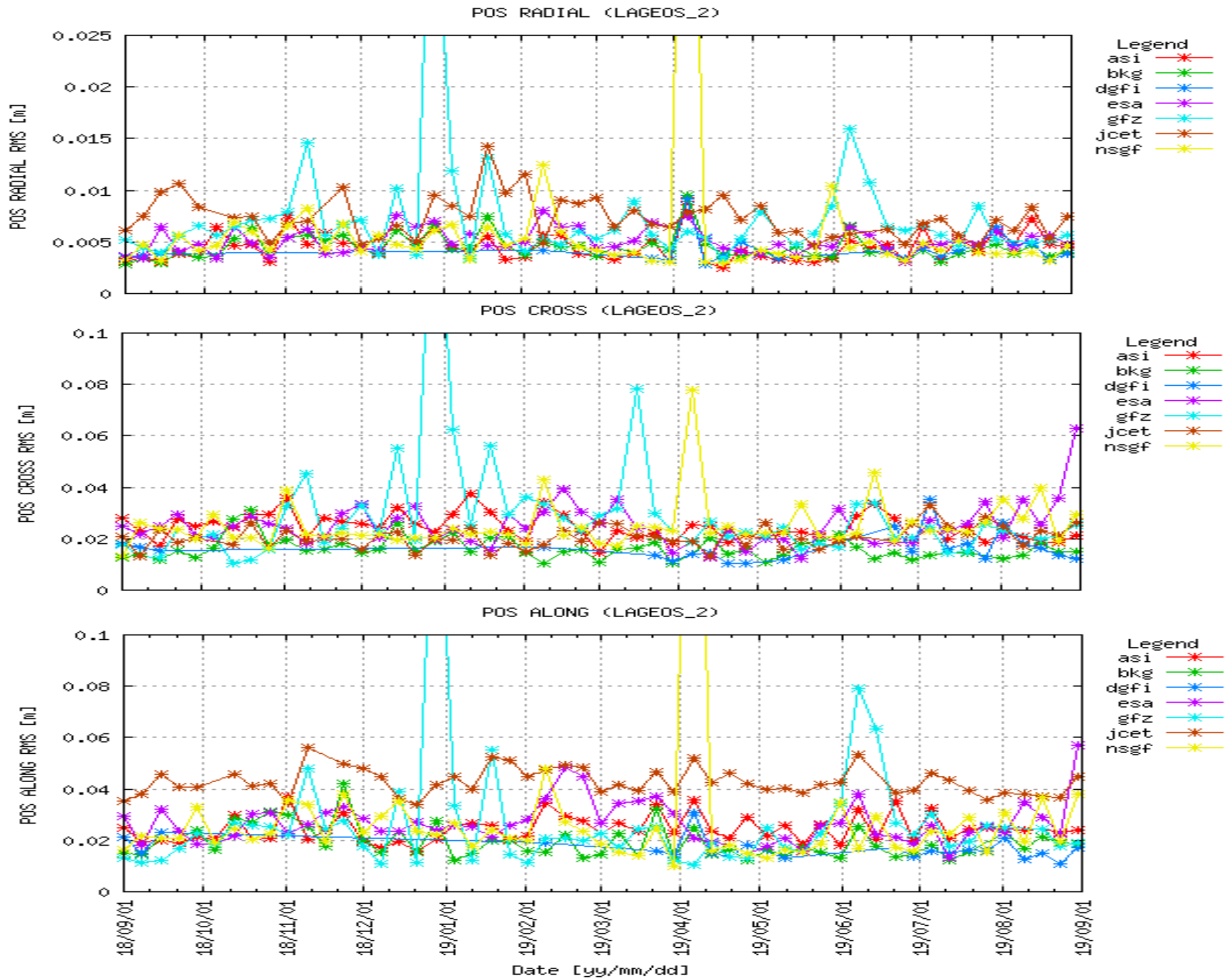
Combination scale factor



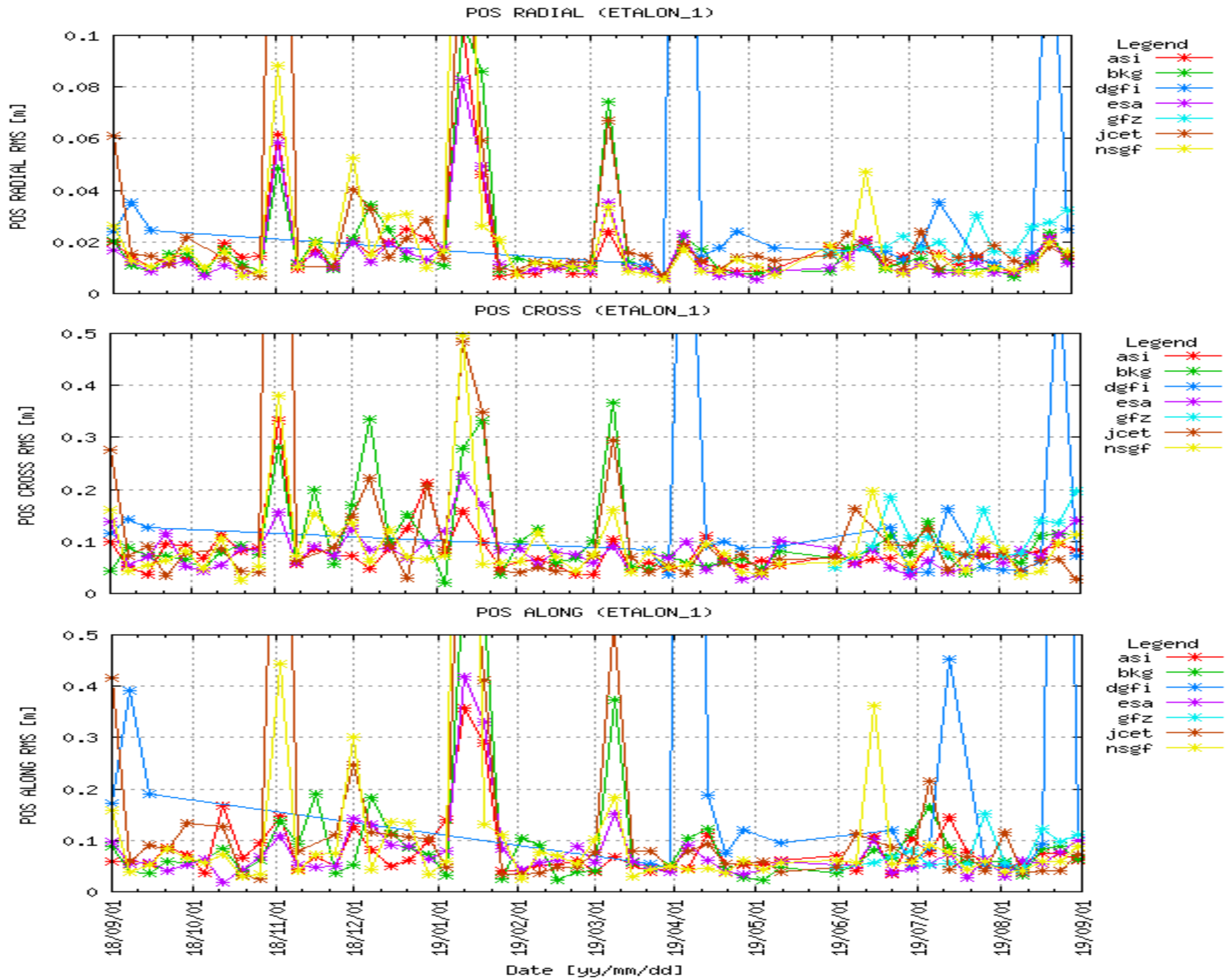
LAGEOS1 orbits – RMS of residuals w.r.t. combination



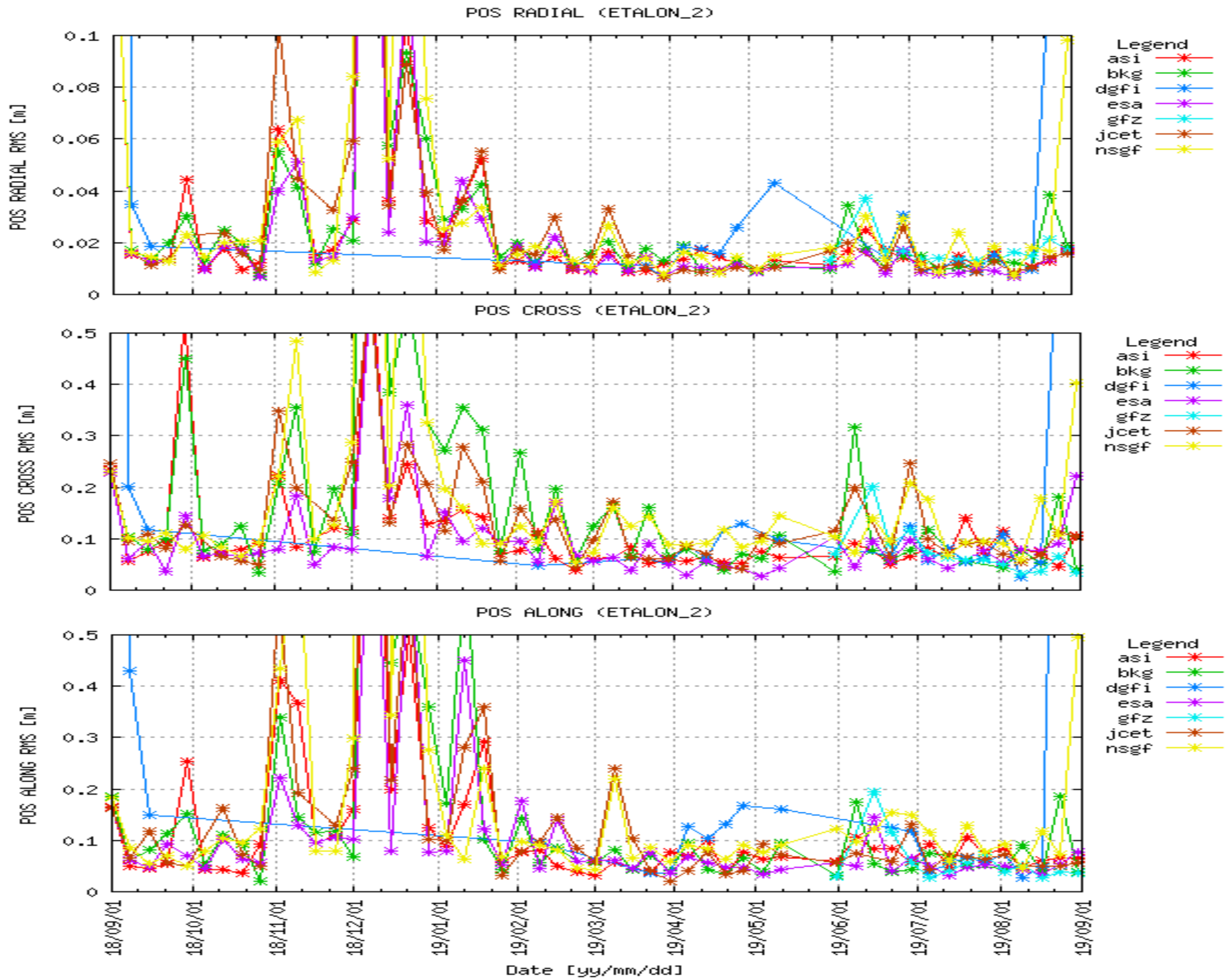
LAGEOS2 orbits – RMS of residuals w.r.t. combination



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



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



ILRS ACs orbit agreement

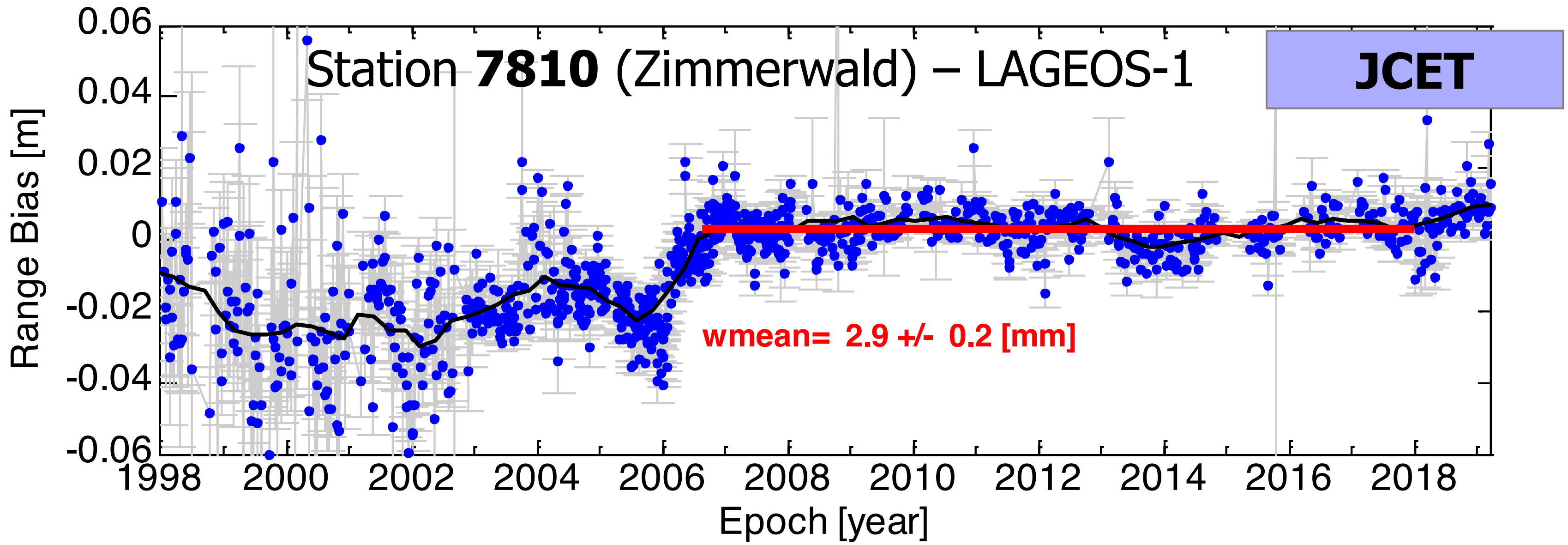
Satellite	Radial [mm]	Cross-track [mm]	Along-track [mm]
LAGEOS1	4,55	19,65	21,15
LAGEOS2	5,65	23,06	27,15
ETALON1	21,83	92,17	85,19
ETALON2	29,03	112,28	99,25

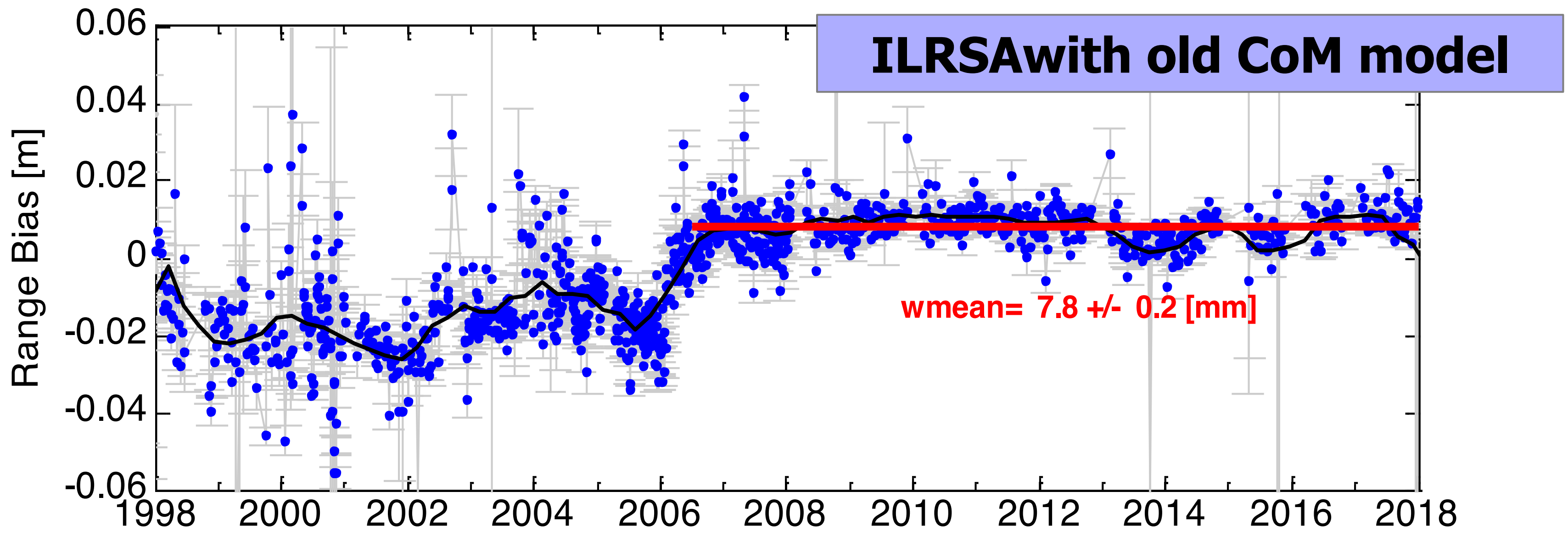
Mean RMS over the period 2018/09/01-2019/09/01

AC time series v230 uploaded at EDC

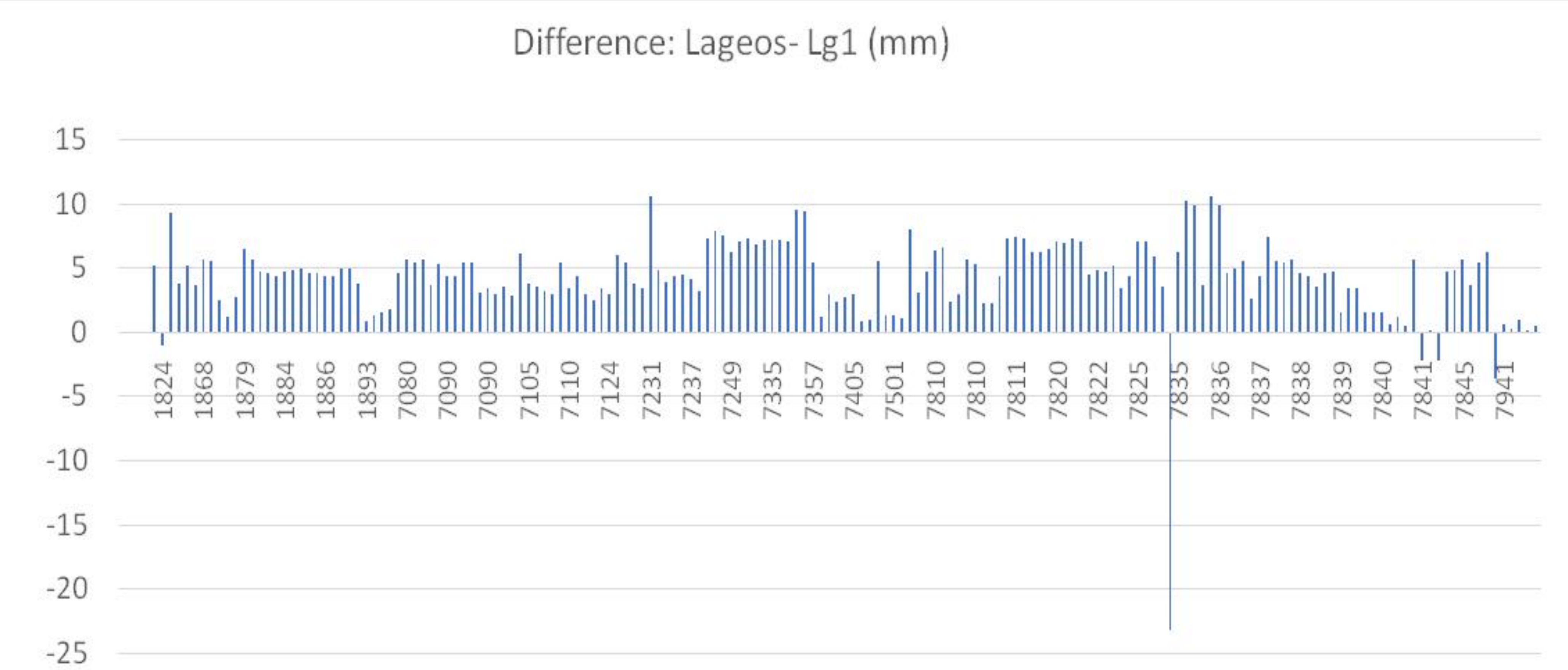
AC	Start	Stop	Submission date
ASI	1993.01.09	2019.06.29	25/09/2019
BKG	1993.01.09	2019.05.04	25/07/2019
DGFI	--	--	--
ESA	--	--	--
GFZ	--	--	--
JCET	1993.01.09	2019.03.30	25/07/2019
NSGF	1993.01.09	2019.07.27	06/09/2019

ILRS Pilot Project on systematic errors





CoM file comparison : LAGEOS



Old CoM model

7810	4/3/2008	31/12/2050	**249**

New CoM model

11/03/2003	03/02/2006	**243.4**
03/02/2006	18/02/2008	**243.7**
01/01/2002	18/02/2006	**246.8**
18/06/2006	18/02/2008	**246.7**
18/02/2008	01/01/2050	**244.7**

Thank you

Federal Agency for Cartography and Geodesy

BKG Report

D. Koenig (1), U. Meyer (2), R. Dach (2), D. Thaller (1)

(1) BKG

(2) AIUB

Activities

- PP_SSEM_EC_COM
  - Wettzell data updated
  - v230 SSEM PP series: solutions 01/1993-04/2019 submitted
- LARES
  - preliminary routine operations running, still experimental
  - close to be adopted
- HF-EOP model
  - implemented into Bernese, ready to be used
- Revised ASC analysis procedures
  - IERS secular pole applied
  - latest CoM file used
- Geophysical loading models
  - GNSS/SLR reprocessings currently carried out at BKG
- Analysis of PP_SSEM_EC/BKG ongoing
  - postponed
- Etalon orbits for 1993-1999
  - postponed

Activities

- ITRF202x reprocessing
  - CoM corrections used to be written into SINEX files
  - Initial proposal by R. Dach, further discussion by J. Rodríguez

Federal Agency for
Cartography and Geodesy

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Delayed NPT-CRD submission to EDC

Mathis Bloßfeld, Christian Schwatke

Deutsches Geodätisches Forschungsinstitut (DGFI-TUM)
Technische Universität München

10 October 2019

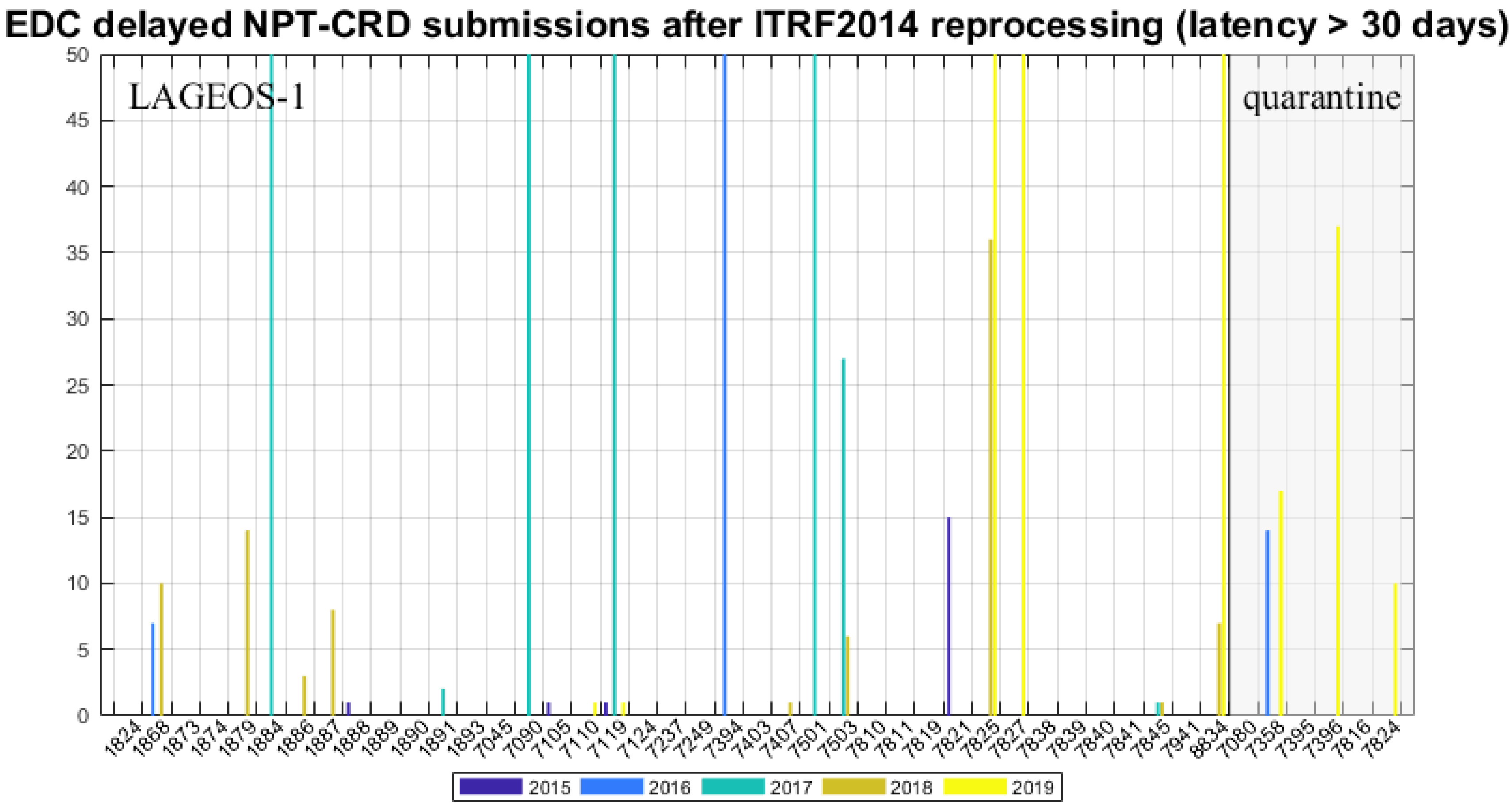
Content

- Stations within the ILRS network submit their computed normal points (NPs) in CRD format to either EDC or CDDIS
- Usual latency of the submission is up to 1 day
- Sometimes, stations resubmit NPs afterwards or even submit NPs with a long delay
- without an email send to ILRS, the ILRS Analysis Coordinator/CB is not aware of the new NPs!
- If ACs not mirror the entire EDC/CDDIS NPT-CRD data base and download only the most recent (daily/monthly) observation files, these NPs are not used in the ILRS contribution to ITRF2020 (or at least are not checked)!

➢ EDC database checked for delayed submissions (delay > 30 days) for LA-1/-2, Et-1/-2 and LRS

➢ Time period checked is 2015-2019 (period after ITRF2014 reprocessing)

LAGEOS-1



EDC delayed NPT-CRD submissions after ITRF2014 reprocessing (latency > 30 days)
LAGEOS-1
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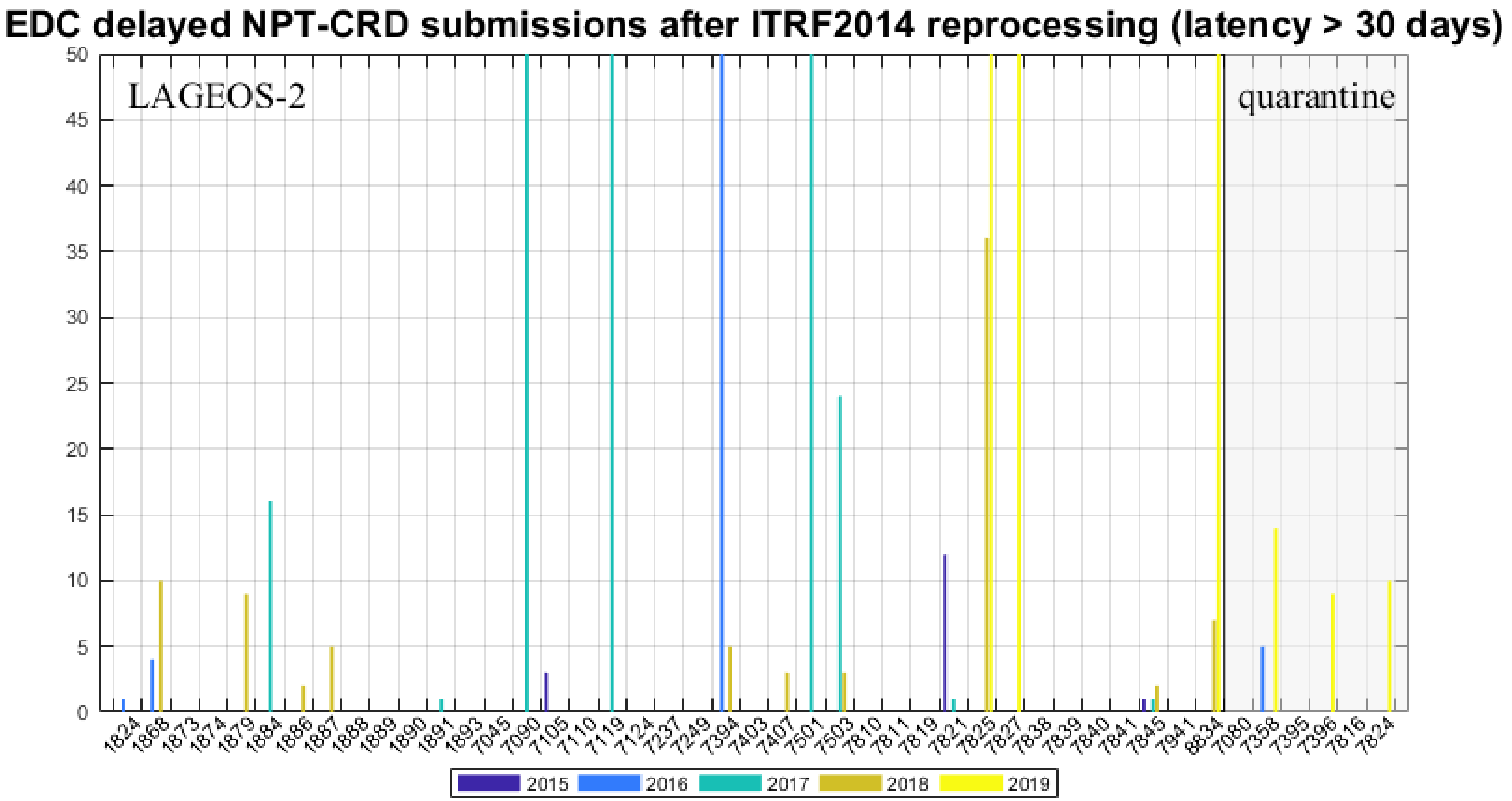
LAGEOS-2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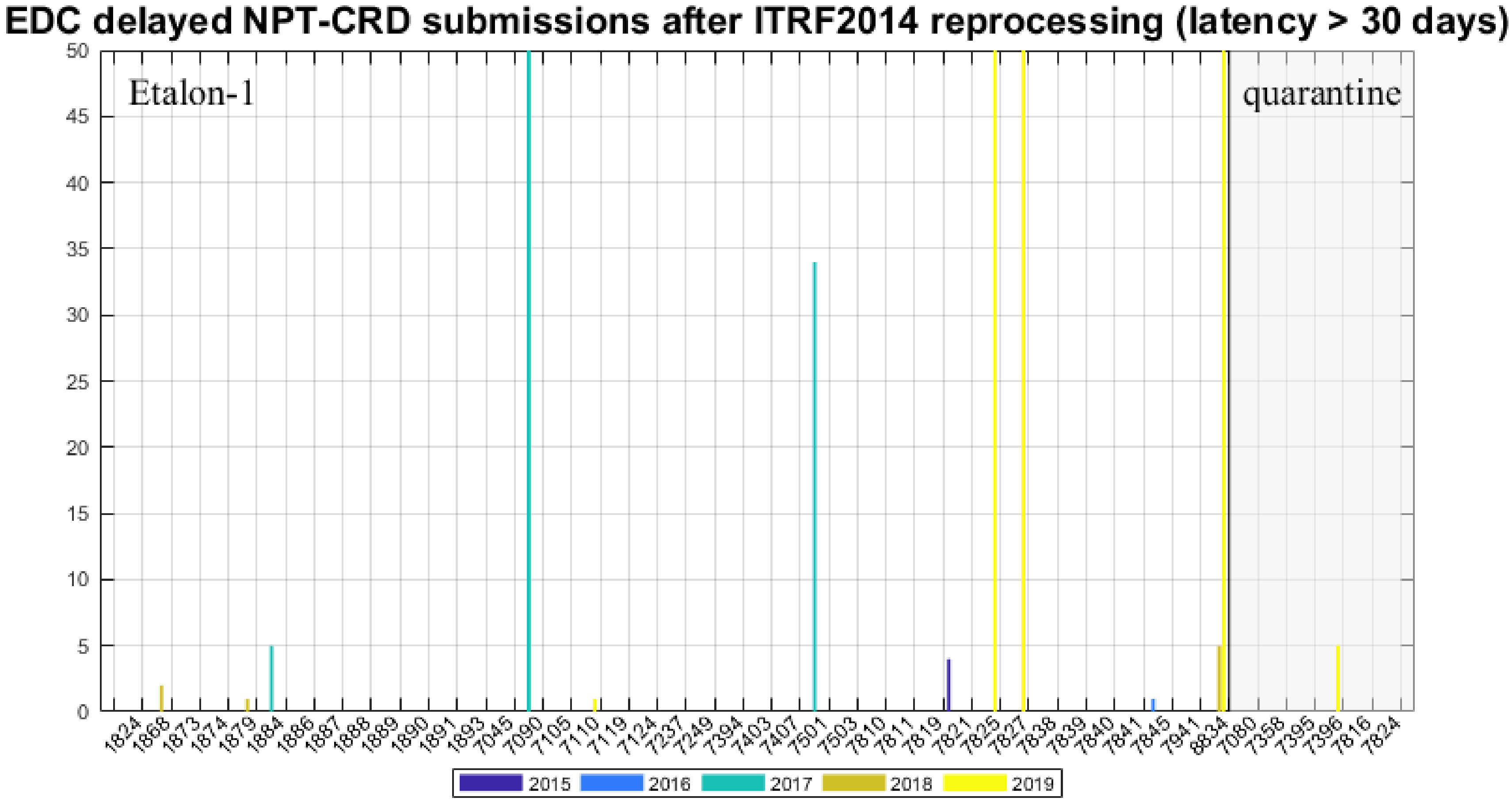
Etalon-1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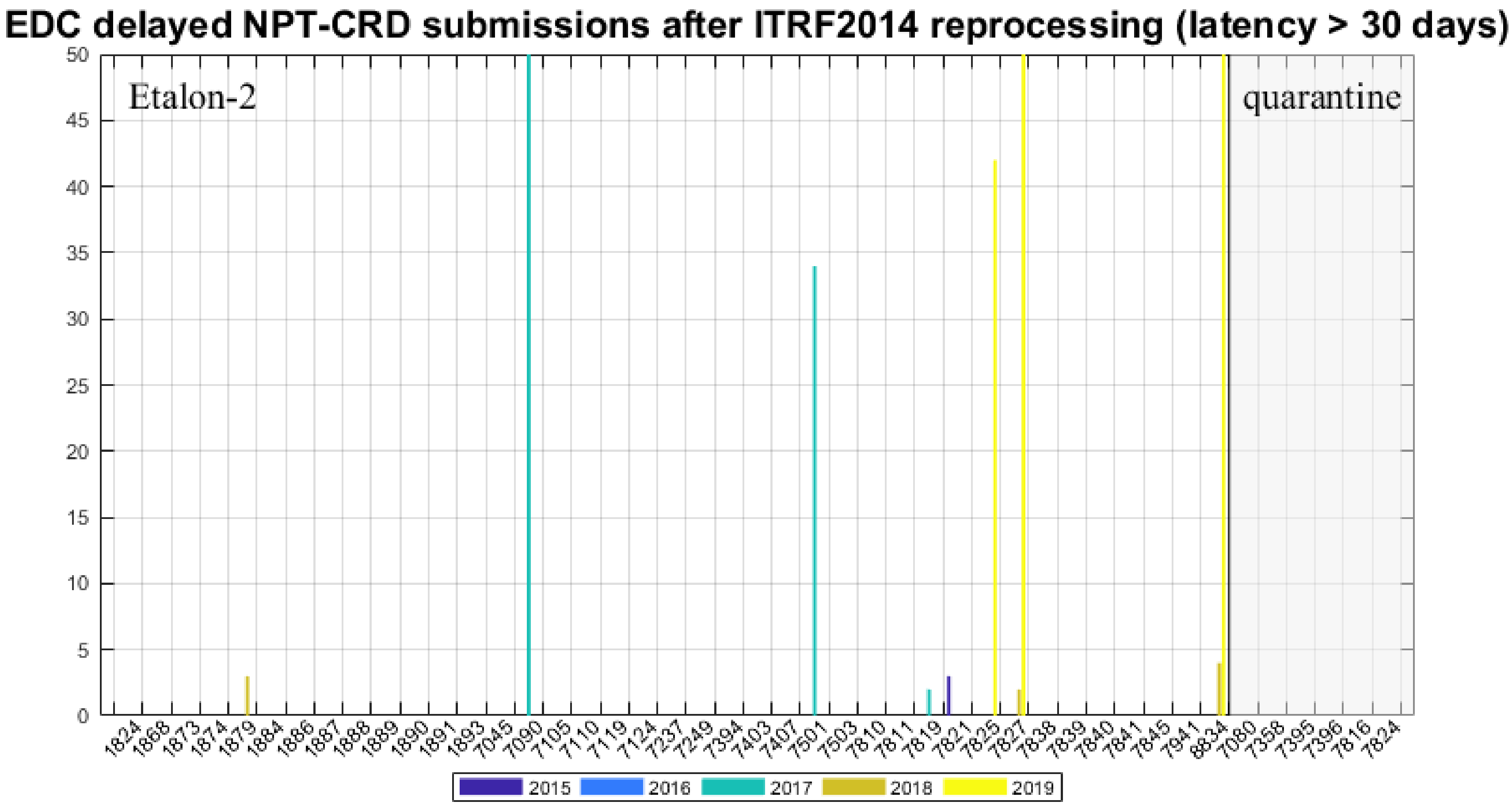
Etalon-2


EDC delayed NPT-CRD submissions after ITRF2014 reprocessing (latency > 30 days)
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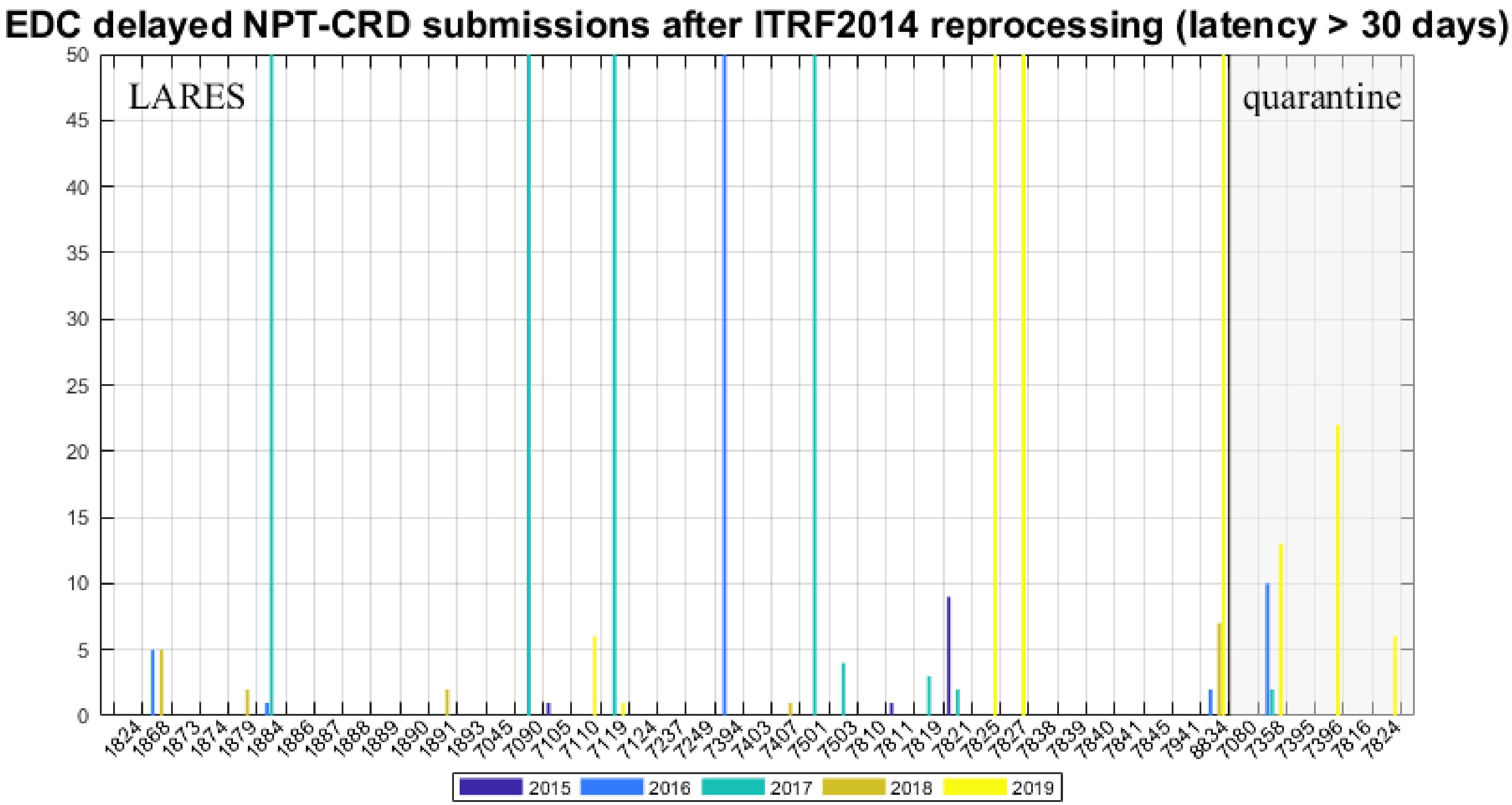
LARES



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2015
2016
2017
2018
2019

Remarks

- 8834 (WLRS), 7827 (SOSW) resubmitted NPs to all satellites after pressure bias correction in 2019 (SLR-Mail 7827)
- 7825 (Mt. Stromlo) also released new data in 2019 (SLR-Mail 2573).
- Other known resubmissions?
  - ➢ Maybe due to release of station from quarantine?

- If necessary, we can easily identify the exact passes which are newly submitted to EDC!

DGFI-TUM ILRS AC: status report

Mathis Bloßfeld

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Technische Universität München

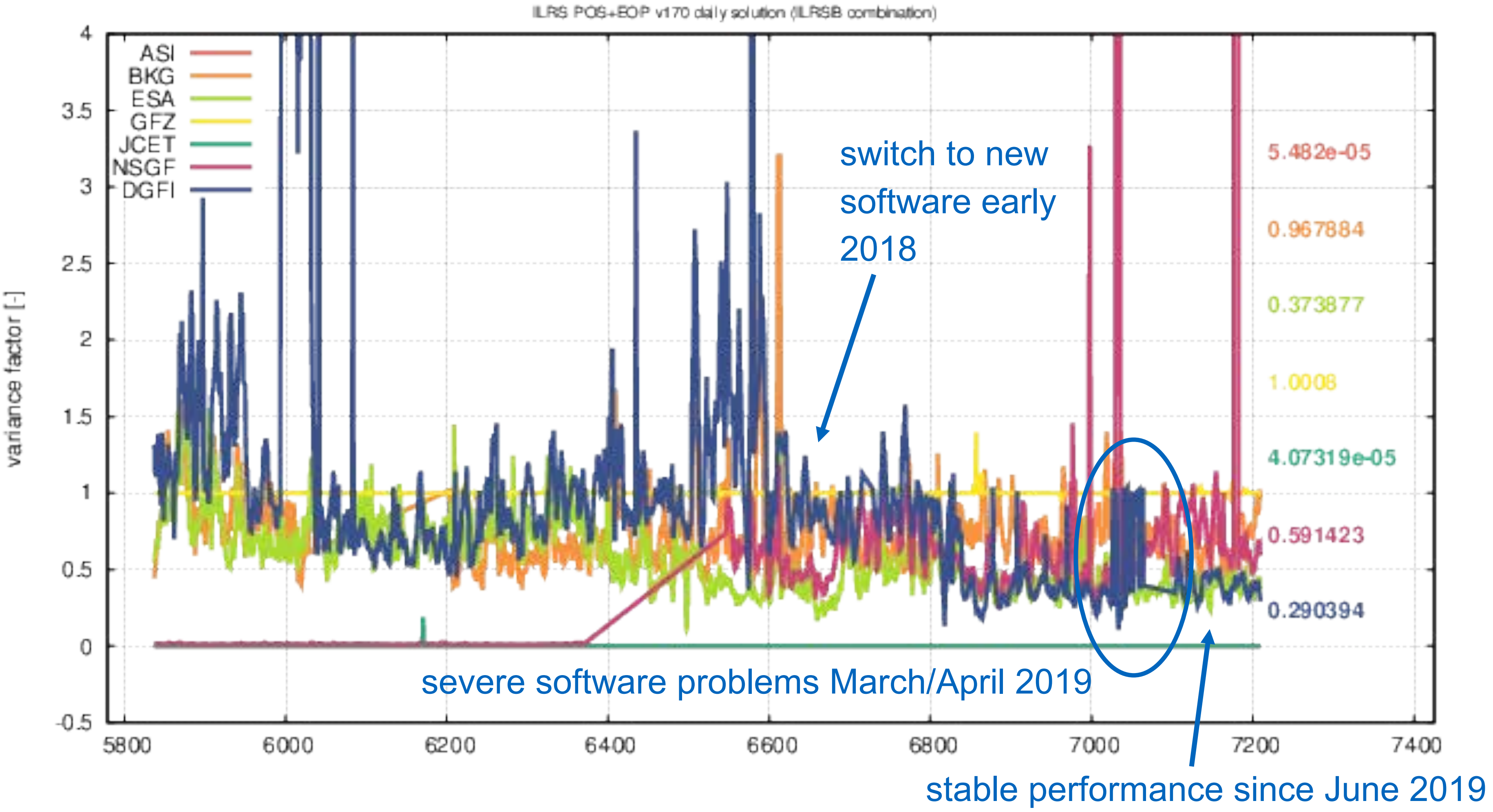
ILRS ASC meeting

Paris, France, 01 October 2019

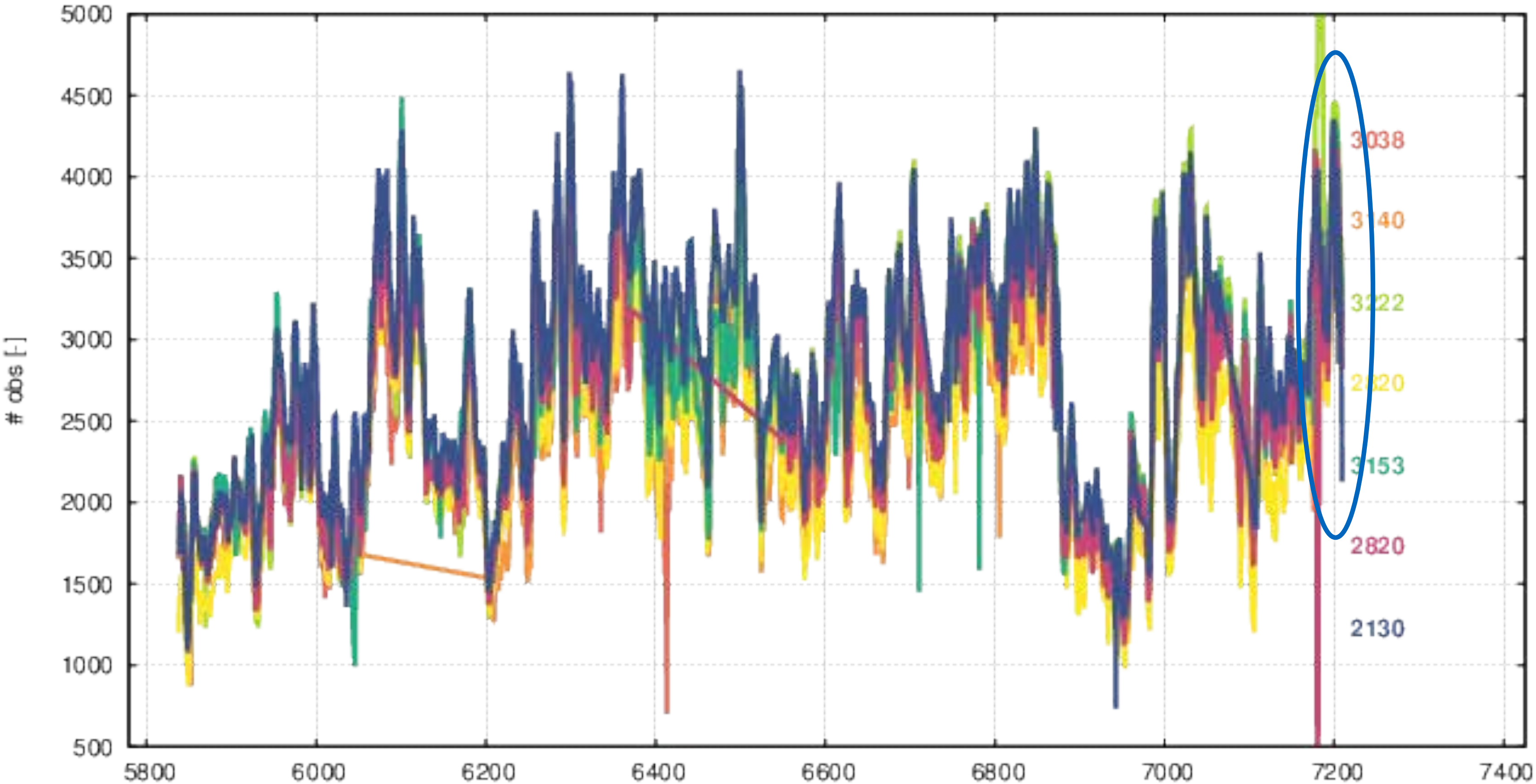
Content

- Current performance of DGFI-TUM's v170/v70 solutions
- CRD data download
- IERS HF-EOP WG (see presentation to HF-EOP WG)
- ILRS analysis procedures and modeling standards (operational and PPs)
- ILRS "cookbook"
- Future steps

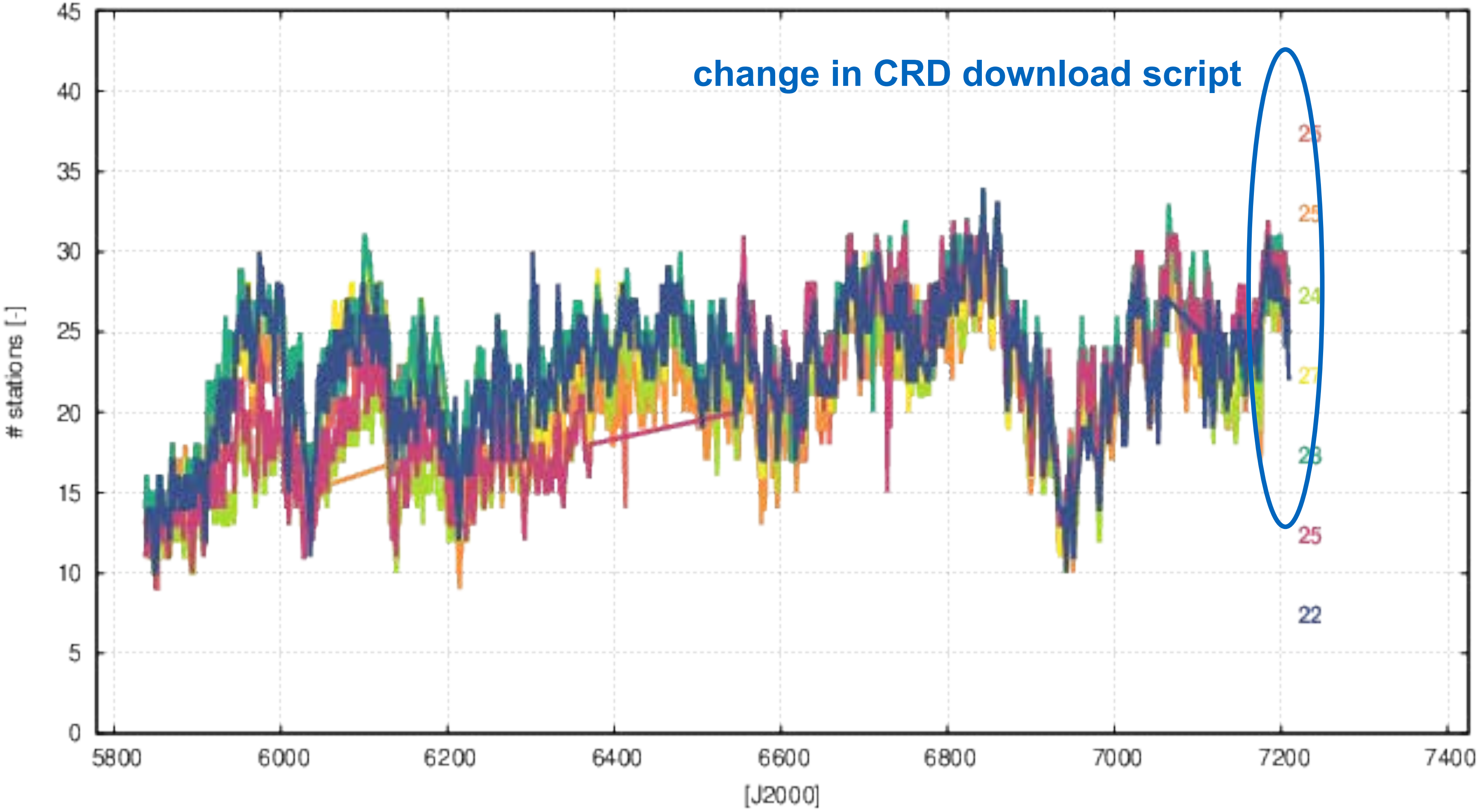
Current performance of DGFI-TUM's v170/70 solutions



Current performance of DGFI-TUM's v170/70 solutions



Current performance of DGFI-TUM‘s v170/70 solutions



CRD data download

- Up to now, only the most recent monthly CRD file was downloaded for ca. 18 satellites (spherical/non-spherical)
- Due to new data release of some stations (Wettzell, etc.) data base mirroring became necessary
- It turned out that **frequently, old data is submitted** to EDC/CDDIS (e.g., Sejong June/July 2019)
- What to do with this data?
  - **(A) Do not analyze it and wait for the next reprocessing**
  - **(B) Reprocess/combine the data and submit new v70 series?**
    - This would make it necessary for ILRS-A/-B to perform another combination of these weeks!

ILRS operational products and PPs

- DGFI-TUM contributed SLR results to the IERS adhoc HF-EOP working group leaded by J. Gipson (NASA GSFC)
- External presentation provided to group
- Recommendation by the group (based on analysis of all techniques): **Desai and Sibois 2019**

ILRS operational products and PPs

- Currently, DGFI-TUM contributes to the following ILRS products
  - **operational v170** time series
    - stable behavior since couple of months
    - last changes: data download scripts, a priori gravity field, two-color biases, …
  - **operational v70** time series
    - stable behavior since couple of months
    - same as for v170 time series
  - **SSEM PP v230** time series
    - recent model updates end of September 2019 (see next slide)
    - reprocessing underway, submission very soon
  - **LARES+grav. "v500"** time series
    - reprocessing nearly finished, submission very soon

ILRS operational and PP time series

ILRS product	TRF	CoM corrections	ILRS data handling file (DHF)	HF-EOP	EOP
v170	SLRF2014 (2017-10-24)	2018-11-14	2019-09-25	conventional (IERS2010)	mean pole (IERS2010)
v70	SLRF2014 (2017-10-24)	2018-11-14	2019-09-25	conventional (IERS2010)	mean pole (IERS2010)
v230	SLRF2014 (2017-10-24)	2019-09-03	2019-07-31 (via email)	Desai & Sibois 2019	secular (UAW2017)
“v500”	SLRF2014 (2017-10-24)	2019-09-03	future DHF?	Desai & Sibois 2019	secular (UAW2017)

ILRS a priori gravity field

- Should we use **one common gravity field model** within the ILRS ASC?
  - **NO**: systematic errors should be averaged within combination
  - **YES**: which a priori gravity field model should be used in the operational analysis or the ITRF2020 reprocessing?
    - model must be consistent to secular pole (UAW2017)
    - model should be include as much TVG parts as possible (important for LEOs)
- Recent gravity field models **consistent with secular pole**:
  - **GGM05c + TVG** (low d/o) provided by CRS recommended by ILRS (limited time span, no extrapolation with functional model)
  - **EIGEN-GRGS.RL04** (TVG up to d/o 90)
  - **GOCO06s** (TVG up to d/o 200)
  - **ITSG-Grace2018s** (TVG up to d/o 200)
- **Should the model be consistent to other techniques?**

ILRS ASC „cookbook“

- Is there a need for **one file** where all settings, models, etc. is documented for each operational product and each ILRS PP?
  - would help **newcomers** to manage their processing
  - would help **to monitor systematics** in the products
  - would help to **clarify things** between ASC meetings
  - would help to **increase efficiency/performance** of ILRS ASC

- I see a need for such a documentation here since, e.g., I simply didn’t know that I had to upload DGFI-TUM operational products to EDC and CDDIS!

Future steps

- Automated upload of products to CDDIS
- Revised handling of ILRS data handling file
- Reprocessing of all SLR data available (all sphericals and selected non-sphericals)
- Various software updates (OC/RI/CS)

- Since today, a new PhD student is working at DGFI-TUM; topic: combined SLR-/DORIS-POD

Impact of HF-EOP models on SLR products

Mathis Bloßfeld and Alexander Kehm

Technische Universität München
Deutsches Geodätisches Forschungsinstitut (DGFI-TUM)

IERS HF EOP ad-hoc working group
Munich, Germany, 2019-04-01

HF EOP model validation

Motivation

- Issue of high-frequency EOP models raised at IERS Unified Analysis Workshop 2017 in Paris
- John Gipson agreed to chair the ad-hos IERS WG on HF EOP
- Up to now, only GNSS and VLBI tests were forwarded to John

- This presentation summarizes some findings for SLR based on an analysis done with our s/w DOGS-OC/-CS
  - Is SLR at all sensitive to HF EOP variations?
  - Which parameters are affected by HF EOP variations?
  - Which model is the best?

HF EOP models implemented in DOGS-OC

Model	Tides included	Libration included	Description
Artz_2011	96	Yes	VLBI model (Artz et al., 2011, DOI 10.1007/s00190-011-0457-z)
Artz_2012	96	Yes	GPS+VLBI model (Artz et al., 2012, DOI 10.1007/s00190-011-0512-9)
Desai	159	Yes	Desai and Sibois model
Gipson (no lib.)	70	No	John Gipson's VLBI tidal model (libration modeled acc. to IERS Conv. 2010 within DOGS-OC/-CS)
Gipson (lib.)	70	Yes	John Gipson's VLBI tidal model
EOT11a	71	Yes	Tidal correction model based on EOT11a (Jan Hagedoorn, GFZ)
FES2012	71	Yes	Tidal correction model based on FES2012 (Jan Hagedoorn, GFZ)
Hamtide	71	Yes	PREM tidal correction model by Jan Hagedoorn (GFZ)
IERS_2010	71	Yes	IERS2010 tidal correction model (IERS Conventions 2010)
Madzak	28	Yes	Altimetry-based ocean model tidal correction (Madzak et al. 2016, DOI: 10.1007/s00190-016-0919-4)

- In DOGS-OC, the sub-daily (high-frequency) EOP variations are modelled according to the IERS Conventions 2010.
  - Closure check: internal DOGS-OC-/CS and external IERS_2010 corrections should be identical

HF EOP model validation

SLR-only solution setup

- SLR observations to LAGEOS-1/-2, Etalon-1/-2
- weekly arcs between GS week 1564 (27.12.2009) and 2034 (30.12.2018) → 9 years

TEST 1: Precise Orbit Determination (POD)

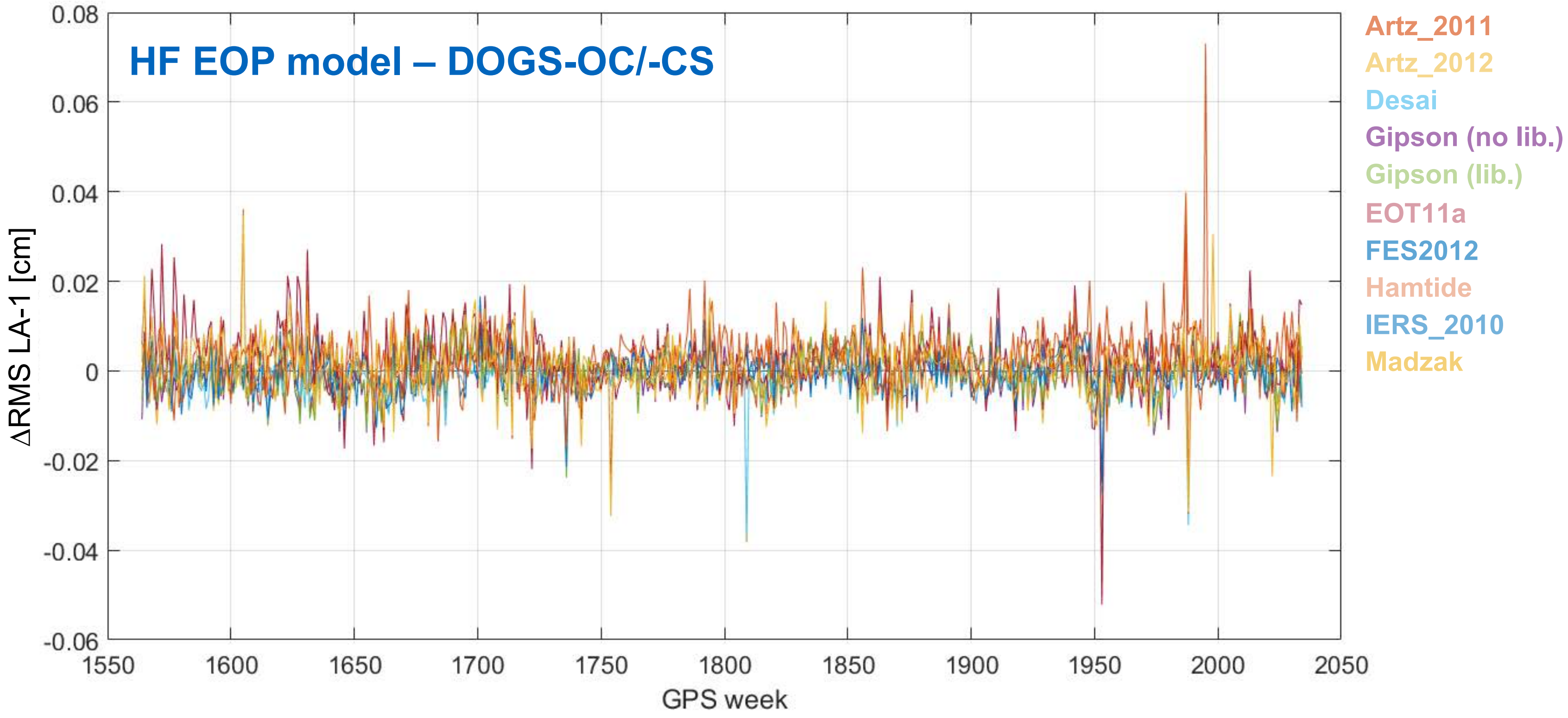
- Estimated parameters: initial state vector, SRP/ALB scaling factor, empirical accelerations (cosine/sine OPR in cross-/along-track + along-track daily polygon), TRF coordinates
- POD based on loose-constrained TRF solution

TEST 2: Estimation of ∆XPO, ∆ YPO, and ∆ LOD w.r.t. IERS 14 C04

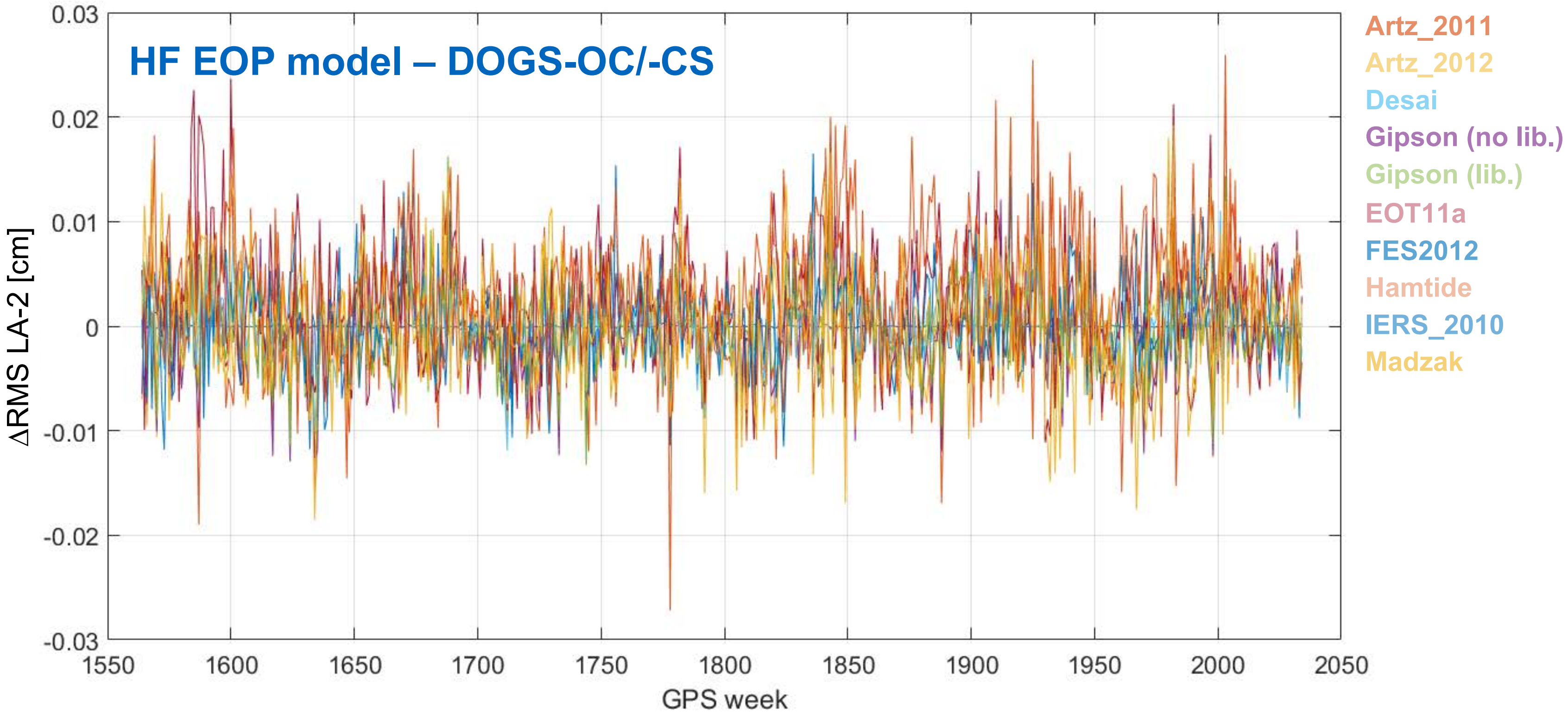
- Estimated parameters: TRF coordinates, XPO, YPO, LOD
- Datum realized weekly through NNR condition of ILRS core network

TEST 1

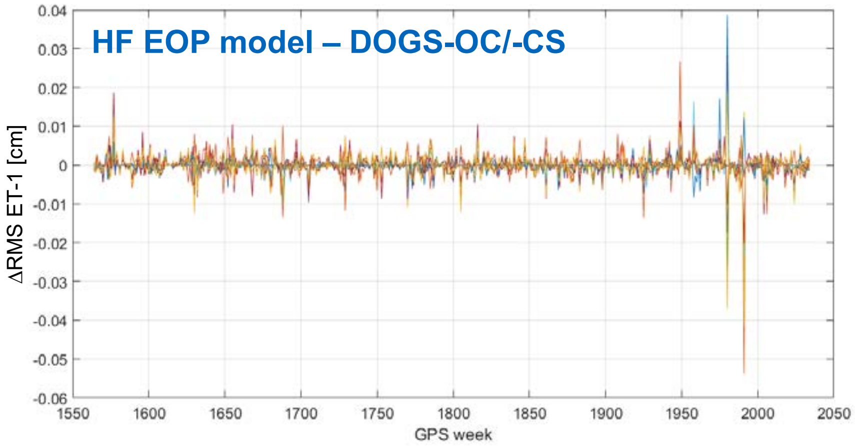
HF EOP impact on LA-1 SLR-RMS (obs. residuals)



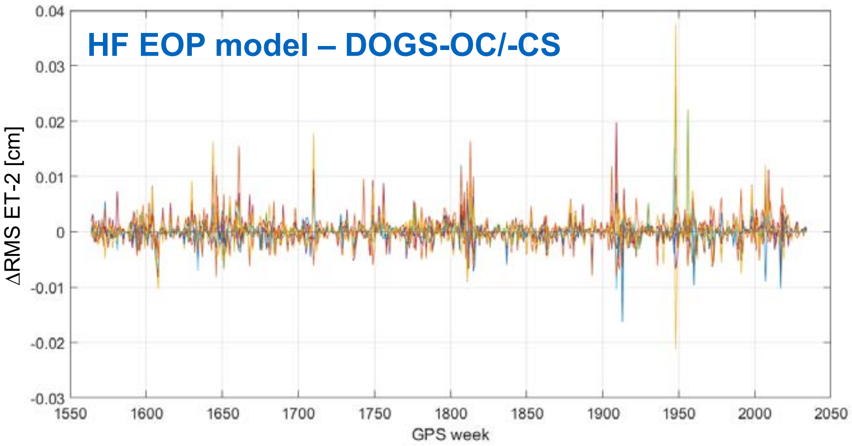
HF EOP impact on LA-2 SLR-RMS (obs. residuals)



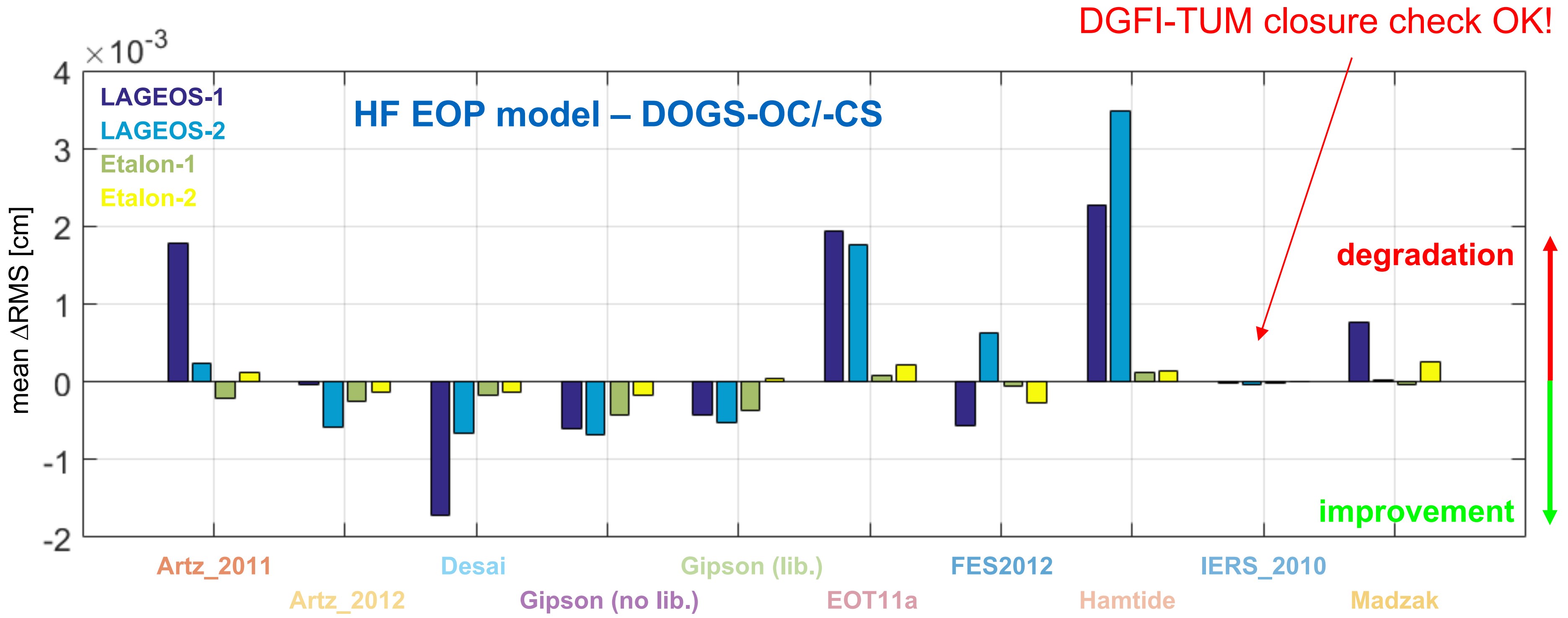
HF EOP impact on ET-1/-2 SLR-RMS (obs. residuals)



Artz_2011
Artz_2012
Desai
Gipson (no lib.)
Gipson (lib.)
EOT11a
FES2012
Hamtide
IERS_2010
Madzak



Mean HF EOP impact on SLR-RMS (obs. residuals)



HF EOP impact on SLR-RMS (obs. residuals)

Findings:

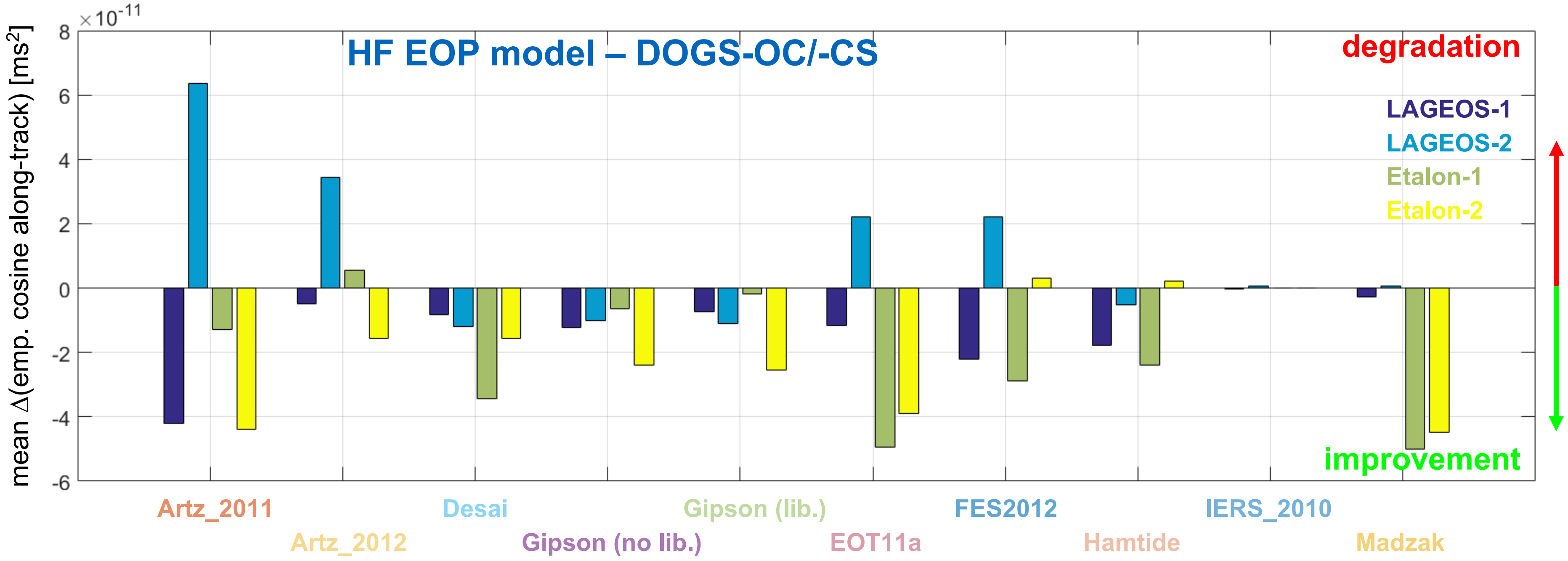
- ➢ Closure check for internal DOGS-OC/-CS and external IERS_2010 correction is OK
- ➢ Impact on RMS is rather small
- ➢ LAGEOS satellites are more affected than the Etalons
  - Impact of HF EOP does not depend on satellite altitude but on temporal distribution of observations during a day → higher impact on more dense LAGEOS observations
- ➢ Largest improvement of SLR-RMS obtained for **Desai** and **Gipson model**

HF EOP impact on orbit parameters

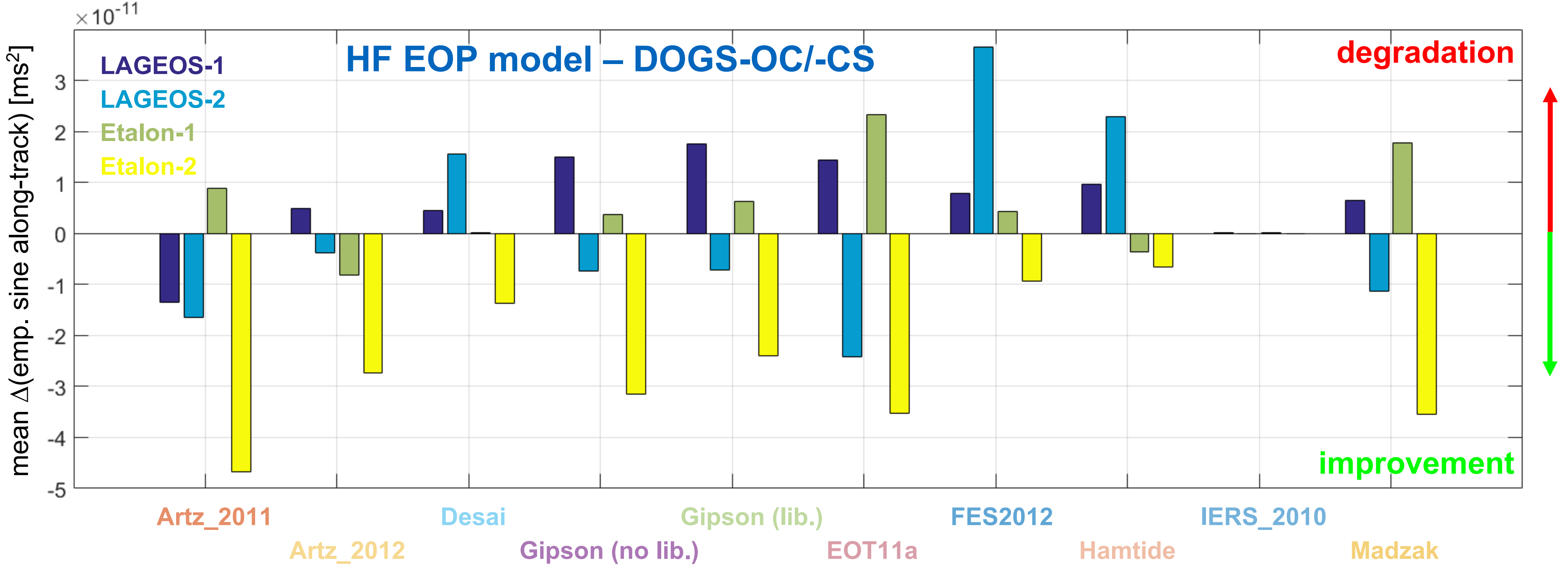
Evaluation criteria:

- Estimated empirical accelerations (cosine/sine OPR in cross-/along-track + along-track daily polygon) should be as small as possible
- Solar radiation pressure (SRP) and Earth albedo (ALB) scaling factors should be equal to one

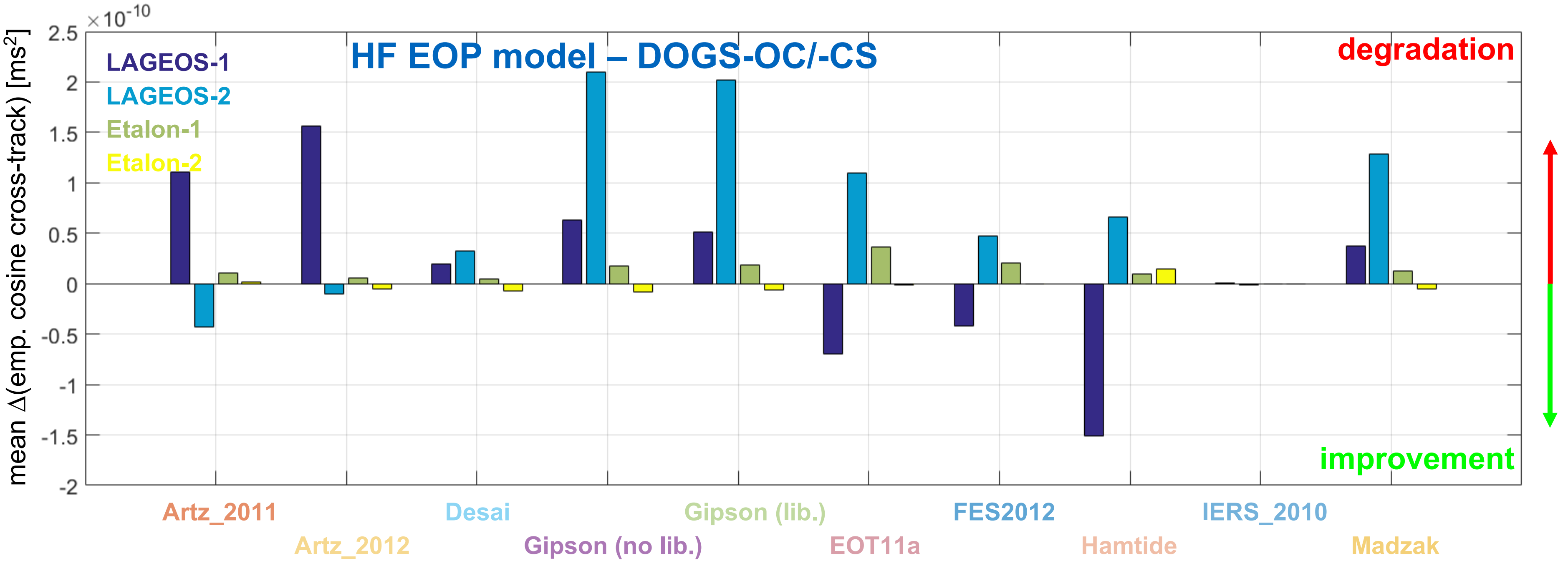
Mean HF EOP impact on emp. accelerations



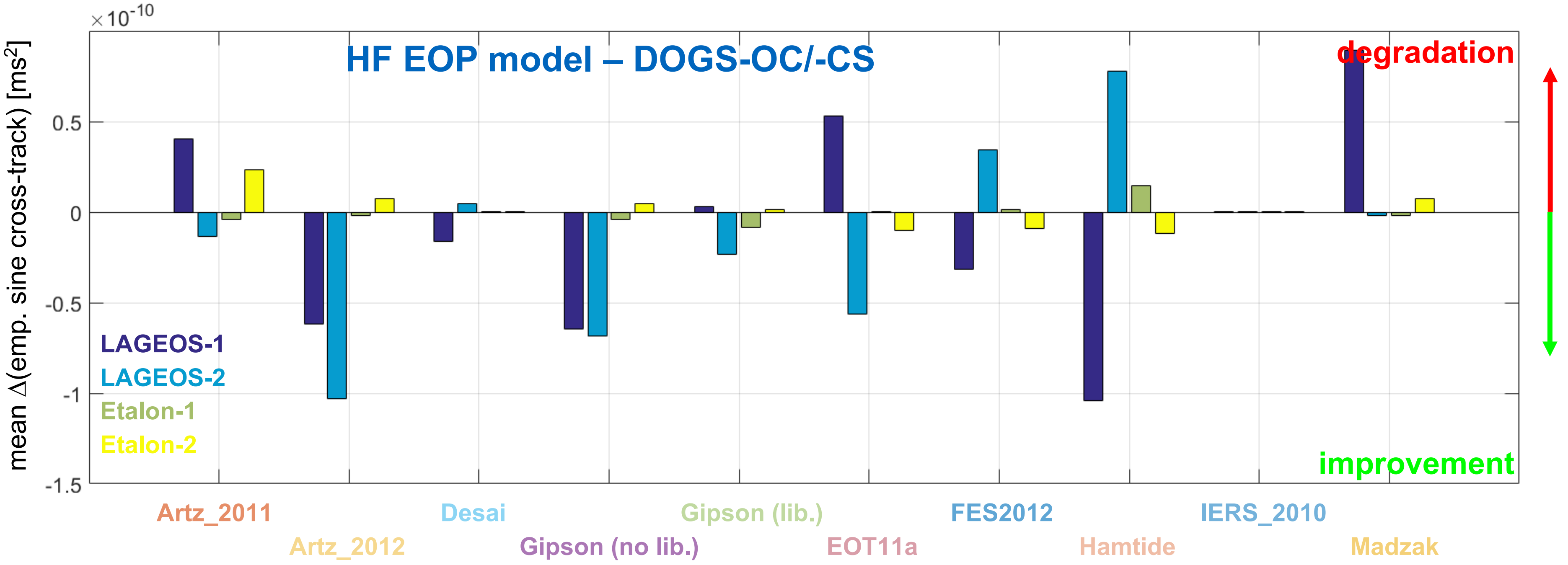
Mean HF EOP impact on emp. accelerations



Mean HF EOP impact on emp. accelerations



Mean HF EOP impact on emp. accelerations



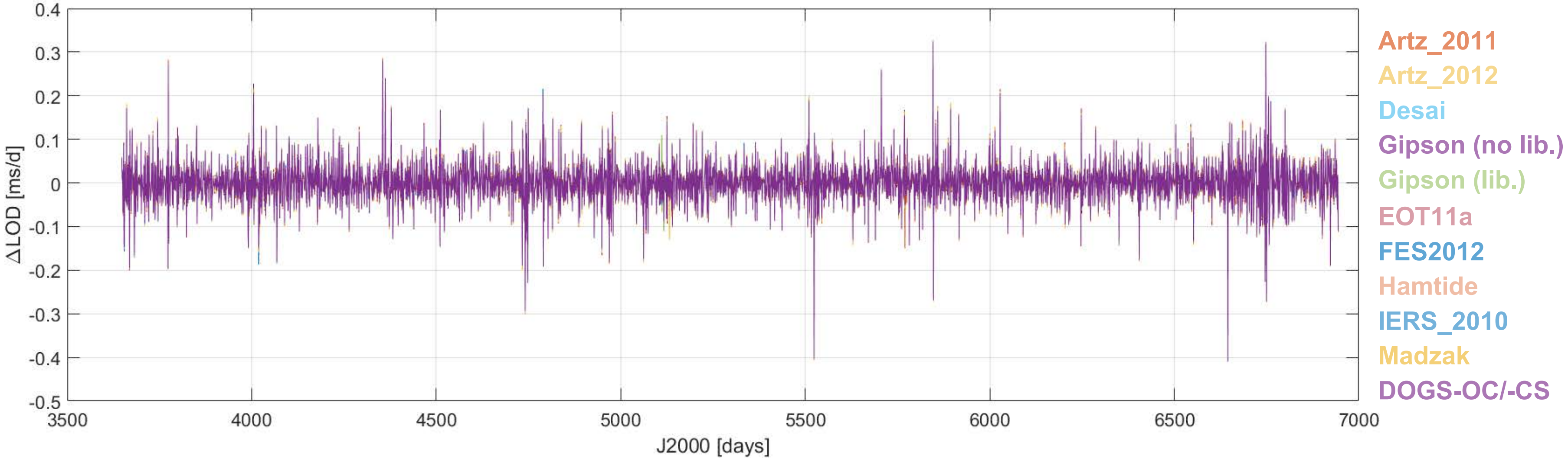
HF EOP impact on orbit parameters

Findings:

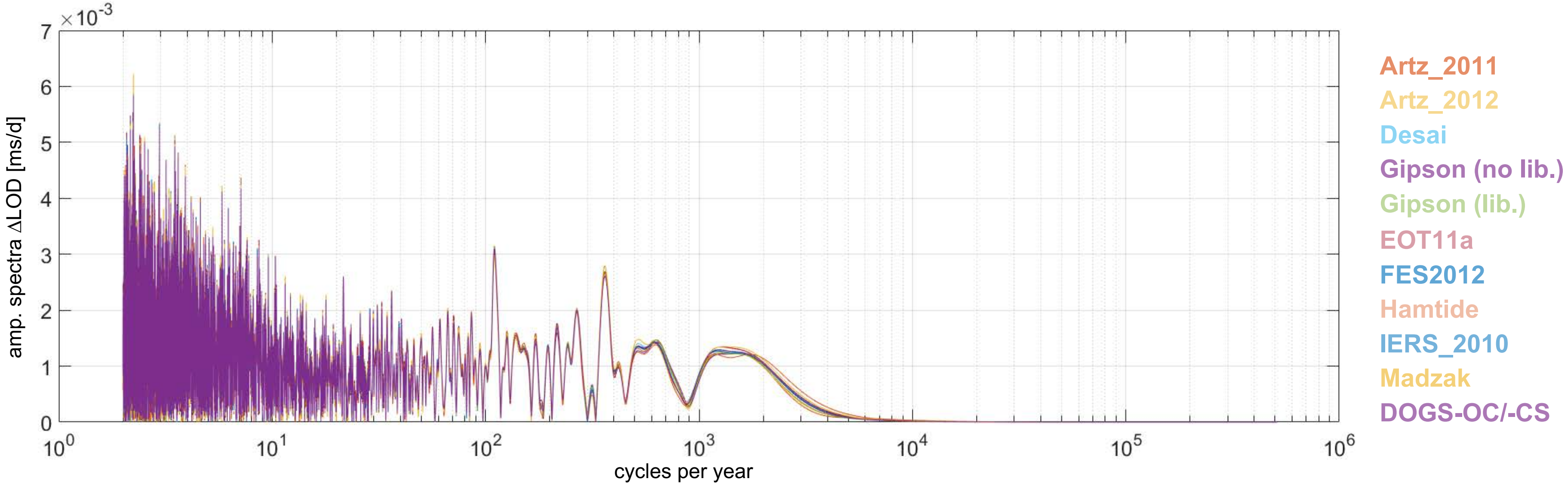
- cosine OPR along-track: Desai, Gipson, Hamtide, and Madzak beneficial
- sine OPR along-track: none clearly beneficial
- cosine OPR cross-track: none clearly beneficial
- sine OPR cross-track: Artz_2012 and Gipson beneficial
- along-track daily polygon: none clearly beneficial
- SRP and ALB scaling factors nearly not affected at all by HF EOP models

TEST 2

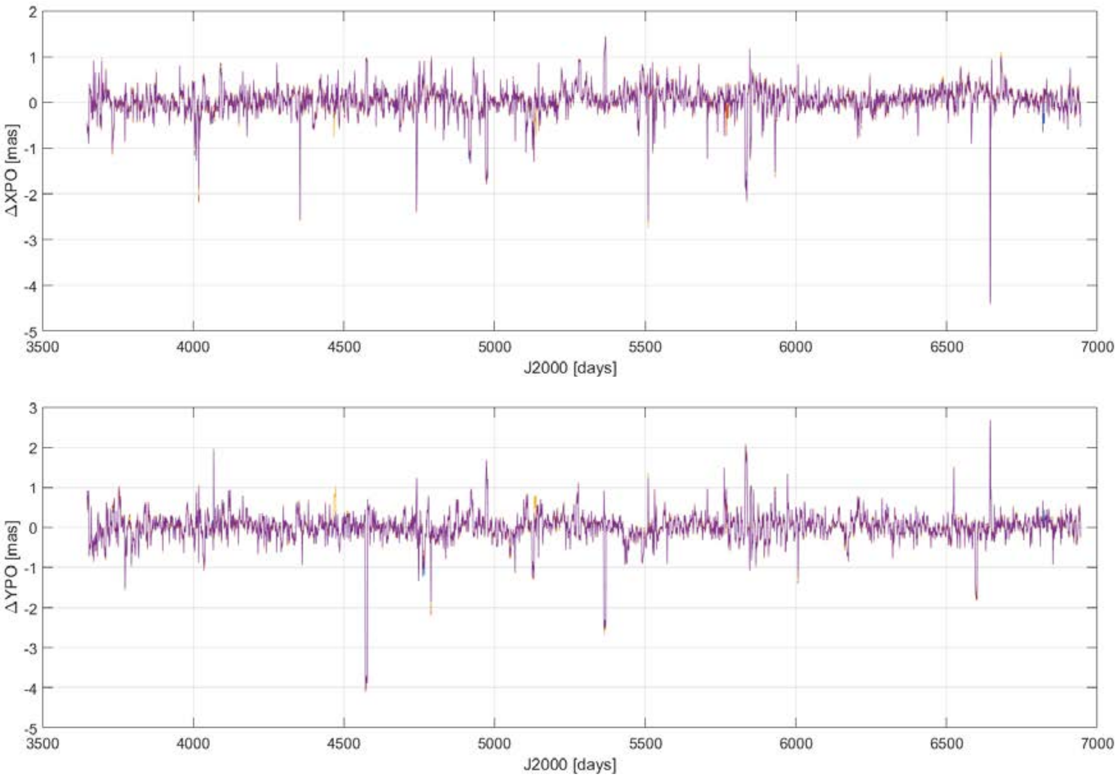
HF EOP impact on ΔLOD w.r.t. IERS 14 C04



HF EOP impact on ΔLOD w.r.t. IERS 14 C04 (spectra)

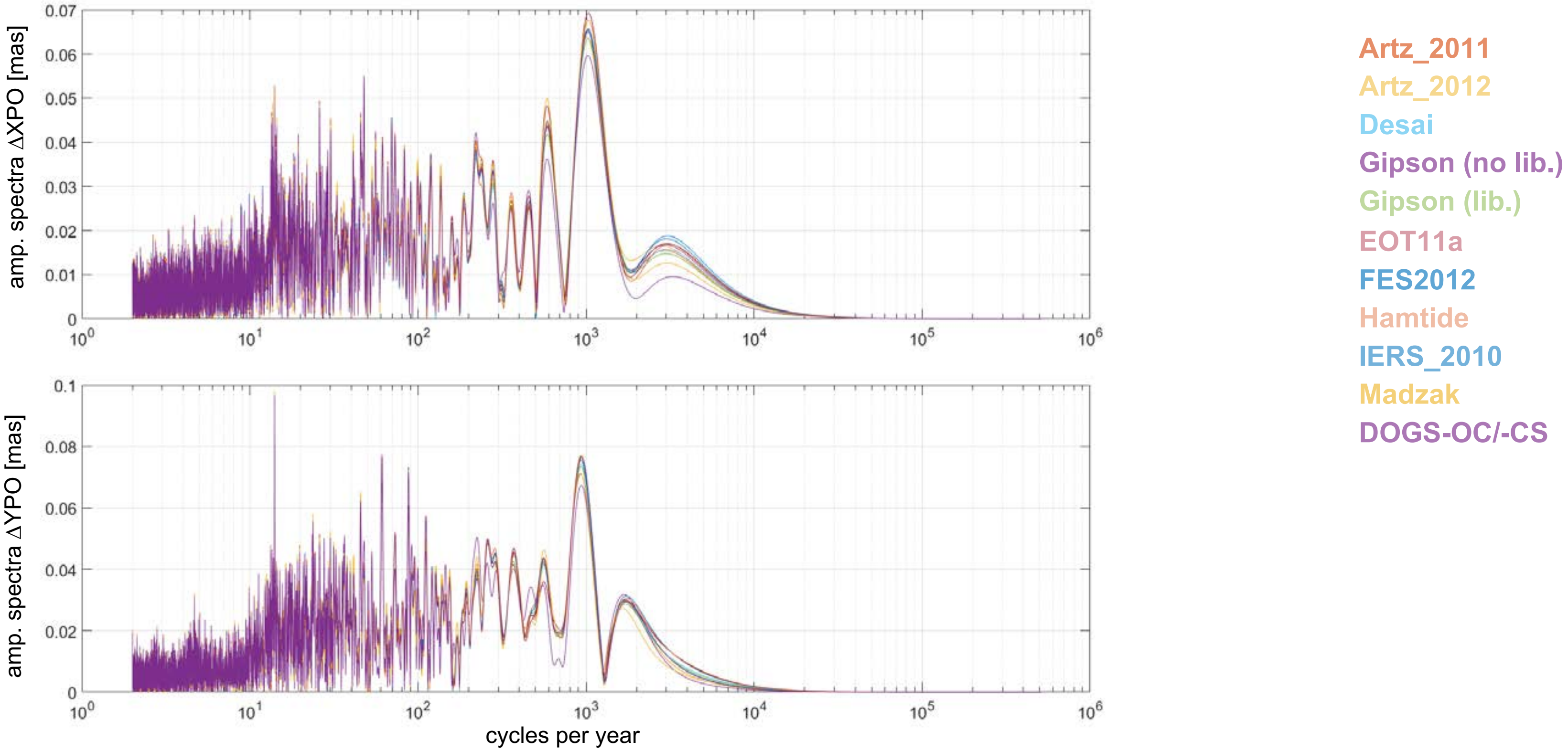


HF EOP impact on ΔXPO/ΔYPO w.r.t. IERS 14 C04



Artz_2011
Artz_2012
Desai
Gipson (no lib.)
Gipson (lib.)
EOT11a
FES2012
Hamtide
IERS_2010
Madzak
DOGS-OC/-CS

HF EOP impact on ΔXPO/ΔYPO w.r.t. IERS 14 C04 (spec.)



HF EOP impact on orbit parameters

Findings:

- ➢ no significant impact of HF EOP models on ERP at all

HF EOP model validation

Questions from the beginning:

- **Is SLR at all sensitive to HF EOP variations?**
  - Yes, the SLR orbits are sensitive whereas the final ERP do not differ at all
- **Which parameters are affected by HF EOP variations?**
  - RMS of the observation residuals and empirical accelerations are affected
- **Which model is the best?**
  - Desai and Gipson seem to perform slightly better than the rest

General recommendation:

- Within the SLR analysis, it doesn’t really matter which HF EOP model is used
- Desai seems to be favorable since it is a model based on external (non-geodetic) data

ESOC ILRS AC Status

Tim Springer

1/10/2019

Status

- In General doing a lot with/for ILRS
  - Recently more focussed on Galileo
- AC Status
  - Wettzell issue: TBD
  - V230 SSEM PP: Should be done next week
    - Agreement issue was resolved (tropo bug)?
  - 1 Year LARES: Not 100% sure about gravity field estimation
    - Should be resolvable in October
  - HF EOP: Done
  - Standards: Secular pole and CoM no issue
    - T2L2: TBD (if in data handling file then no problem)

GFZ AC Report

Margarita Vei, Rolf König, Patrick Schreiner

Content

- POSEOP
- SSEM PP
- HF EOP-model
- LARES SH
- CRD v2

Report (1)

- POSEOP
  - daily product nominal (short gap in last week due to relocation)
  - weekly product :
    - E1 and E2 orbits available since June 2019
    - Inclusion of E1 E2 1992 onwards in progress, for ITRF2020

- SSEM PP
  - Wettzell corrected data used
  - newest CoM model used
  - v230 ready (without HF EOP-model)

Report (2)

- HF EOP-model
  - implemented, still in testing phase

- LARES SH
  - 6 satellite gravity field solution 5x5 and C(6,1) ready (L1,L2,AJ,STE,STA,LA)
  - Solution with L1,L2,E1,E2,LA not yet tested
    - Need concrete guidelines and the a-priori constraints to test and go on with EOP and coordinate solution

- CRD v2
  - in progress

- New address
  - Claude-Dornier-Straße 1, 82234 Weßling

Lunar Laser Ranging Analysis at the Institute of Applied Astronomy RAS

Dmitry Pavlov
Laboratory of Ephemeris Astronomy, IAA RAS
dpavlov@iaaras.ru

iaaras.ru/en

ILRS Analysis Standing Committee Meeting
Observatoire de Paris, 1 October 2019

LLR Analysis at IAA RAS: Past and Present

Milestones

- 1987: IAA RAS founded in Leningrad, USSR (now St. Petersburg, Russia)
- 1998: IAA RAS united with the Institute of Theoretical Astronomy (ITA RAS). Ephemerides of Planets and the Moon (EPM) development continues at IAA
- 2013: release of EPM2011 with lunar physical libration
- 2016: release of EPM2015 with JPL DE430 lunar model (Folkner et al, 2014)
- 2017: release of EPM2017 (most recent version)

Present Activities

- Building high-precision numerical ephemeris of planets and the Moon (The next version will probably be EPM2019)
- Improving the model of orbital and rotational motion of the Moon

Observations

McDonald	1969-1985	3604 NPs (MINI). Source: POLAC.
Crimea	1982-1984	25NPs (MINI). Source: CrAO (raw data), James WIlliams and Dale Boggs (normal points). Published by IAA RAS.
MLRS1	1983-1988	631 NPs (MINI). Source: POLAC.
MLRS2	1988-2015	3653 NPs (MINI). Source: POLAC.
Haleakala	1984-1990	770 NPs (MINI). Source: POLAC.
OCA	1984-2005	Ruby laser: 1188 NPs, YAG laser: 8324 NPs (MINI). Source: POLAC.
OCA	2009-2019	MeO laser: 1930 NPs (MINI). Source: ASTROGÉO, Jean-Marie Torre.
OCA	2015-2019	IR laser: 4762 NPs (MINI). Source: ASTROGÉO, Jean-Marie Torre.
APO	2006-2016	2648 NPs (MINI). Source: Tom Murphy's webpage.
Matera	2003-2019	233 NPs (MINI, CRD). Source: POLAC, CDDIS
Wettzell	2018-2019	42 NPs (CRD). Source: CDDIS.

Model of the Lunar Physical Libration

- Torque from point masses in lunar gravitational field: Earth, Sun, Venus, Mercury, Mars, Jupiter
- Figure-figure torque between Earth's J2 and Moon
- Dynamic tensor of inertia: delayed dissipation from rotation and Earth tides
- C20, C22, C21, S21, S22 respond accordingly
- Inertia and torque from inner rotating liquid core (Williams et al, 2001)
- Torque from friction on the core-mantle boundary (ibid)

Compromises made for now

- Mean C21, S21, S22 are fixed to zero but S21 tends to be nonzero when made a determined parameter.
- Additional kinematic longitude libration terms with periods of 365, 206, and 1095 days (few mas).
- There is also a 6 year (2190 d) term present in the residuals.

Statistics of Residuals

Station	Timespan	Used	Rejected	One-way wrms, cm
McDonald	1970-1985	3552	52	20.1
Crimea	1982-1984	25	0	11.1
MLRS1	1983-1988	588	43	11.0
MLRS2	1988-2015	3224	429	3.4
Haleakala	1984-1990	751	19	5.8
OCA (Ruby)	1984-1986	1109	79	16.9
OCA (YAG)	1987-2005	8273	51	1.5
OCA (MeO)	2009-2019	1814	22	1.61
OCA (IR)	2015-2019	2797	43	1.30
APO	2006-2016	2610	38	1.50
Matera	2003-2019	219	14	3.1
Wettzell	2018-2019	42	0	1.06

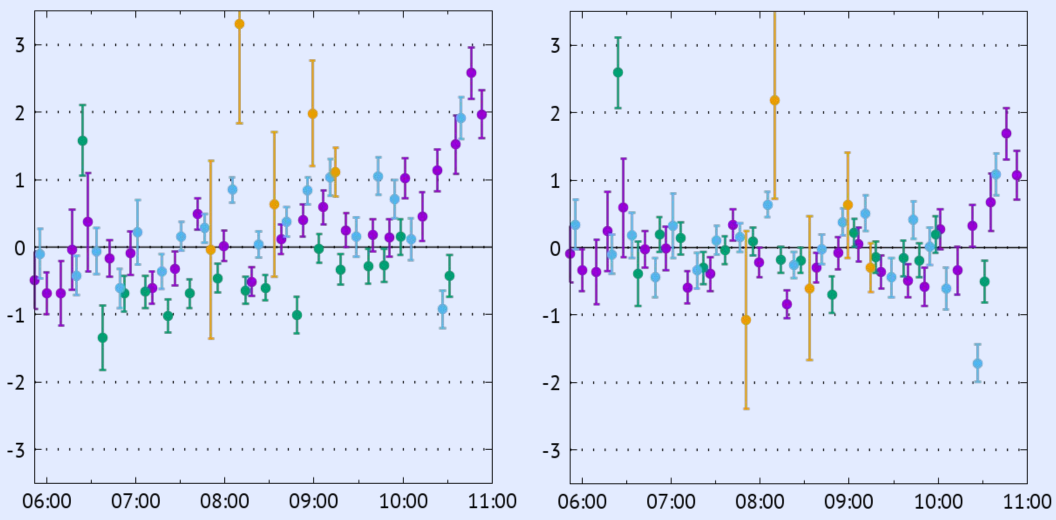
Is it possible to go down to 5 mm?

- ITRF2014 PSD models seemingly do not exist for Matera, Grasse, Wettzell, and Apache Point sites.
- Numerical model of optical signal propagation in atmosphere was once tried without success.
- Fancy model of intraday UT variations was tried, but the improvement of the solution was moderate.
- Daily adjustments of LOP/EOP help to a degree (next slide), but still leave room for improvement.

What else to do?

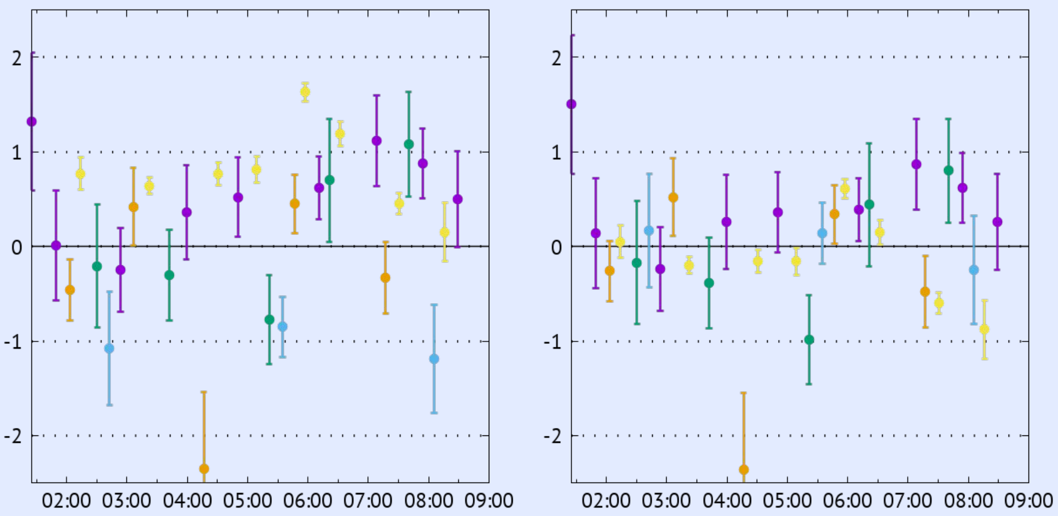
- A better lunar theory will certainly improve the overall statistics, fit long periods.
- Daily site offsets from GNSS or SLR solutions?

Daily adjustments of EOP, LOP and Δrange



Apache Point 15.04.2014

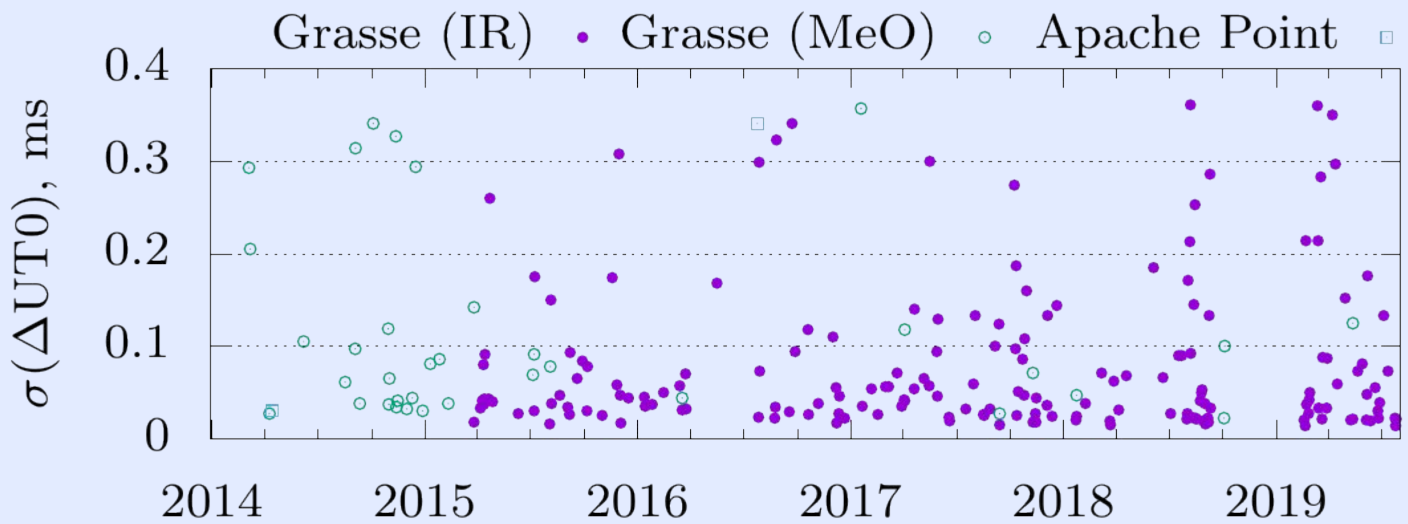
Rms of normal error: 4.3 mm
Wrms before adjustment: 8.4 mm.
Wrms after adjustment: 6.2 mm

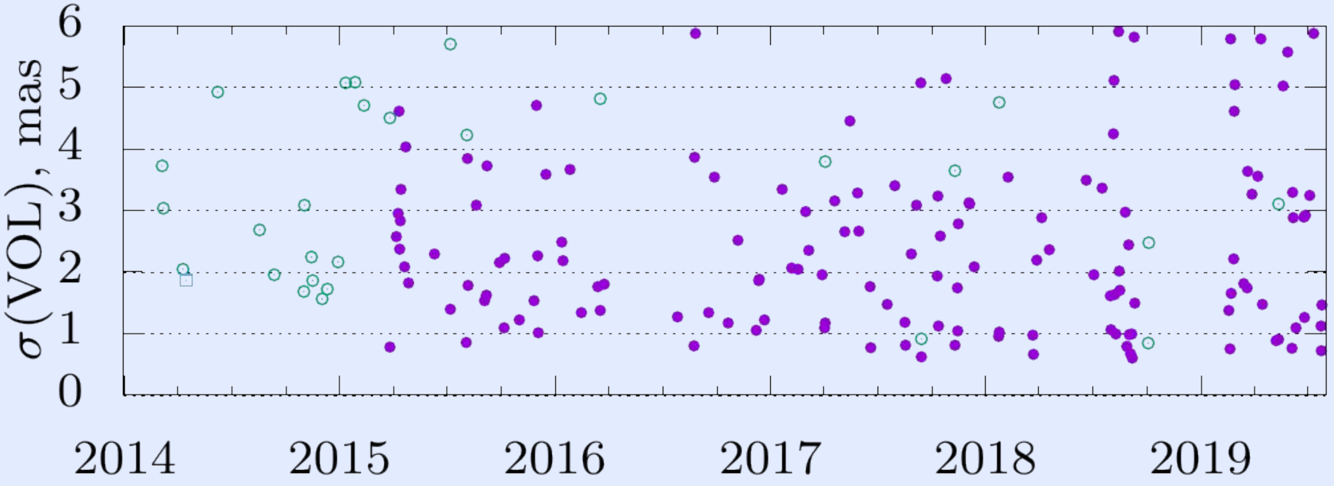


Grasse (IR) 21.10.2016

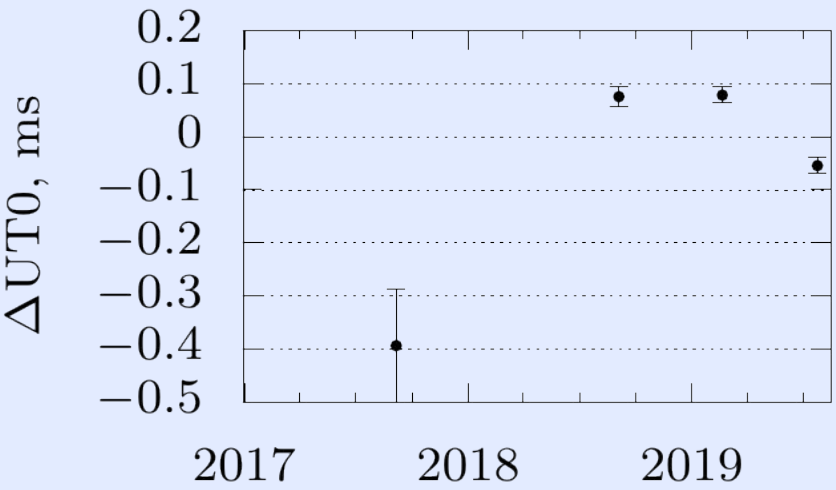
Rms of formal error: 4.5 mm
Wrms before adjustment: 8.5 mm.
Wrms after adjustment: 6.3 mm

Accuracy of ΔUT0 and VOL

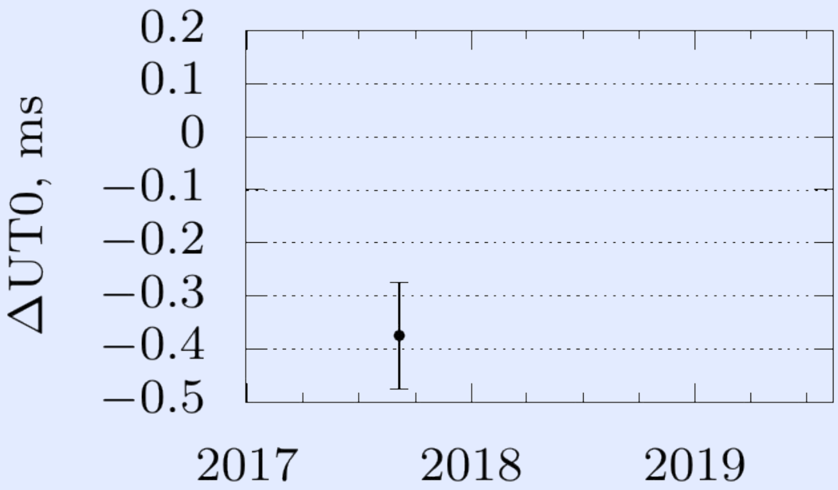




ΔUT0 outliers (outside 3σ)



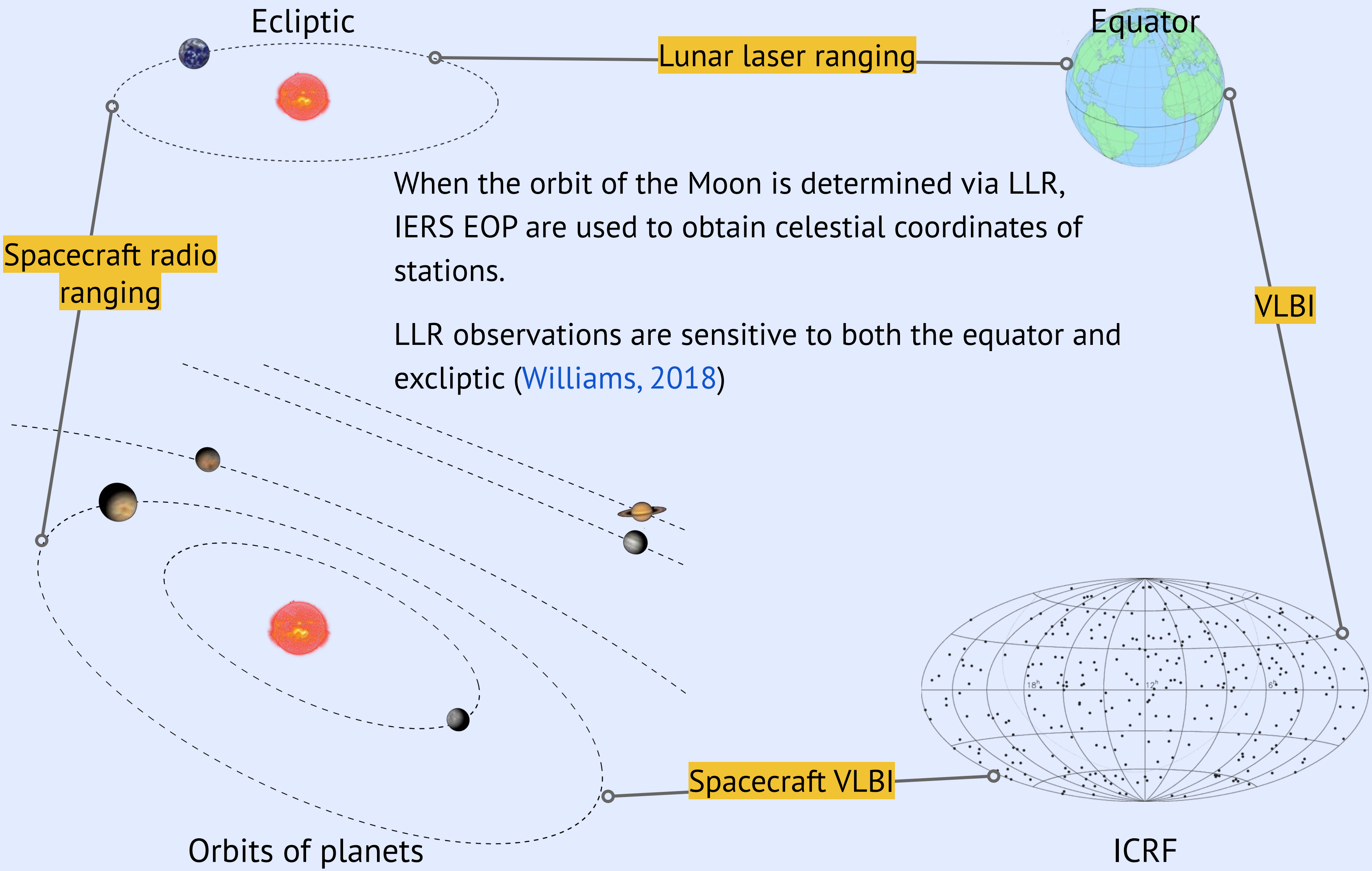
W.r.t. C04 series



W.r.t. Bulletin A

Maybe LLR will once again take part in EOP determination?

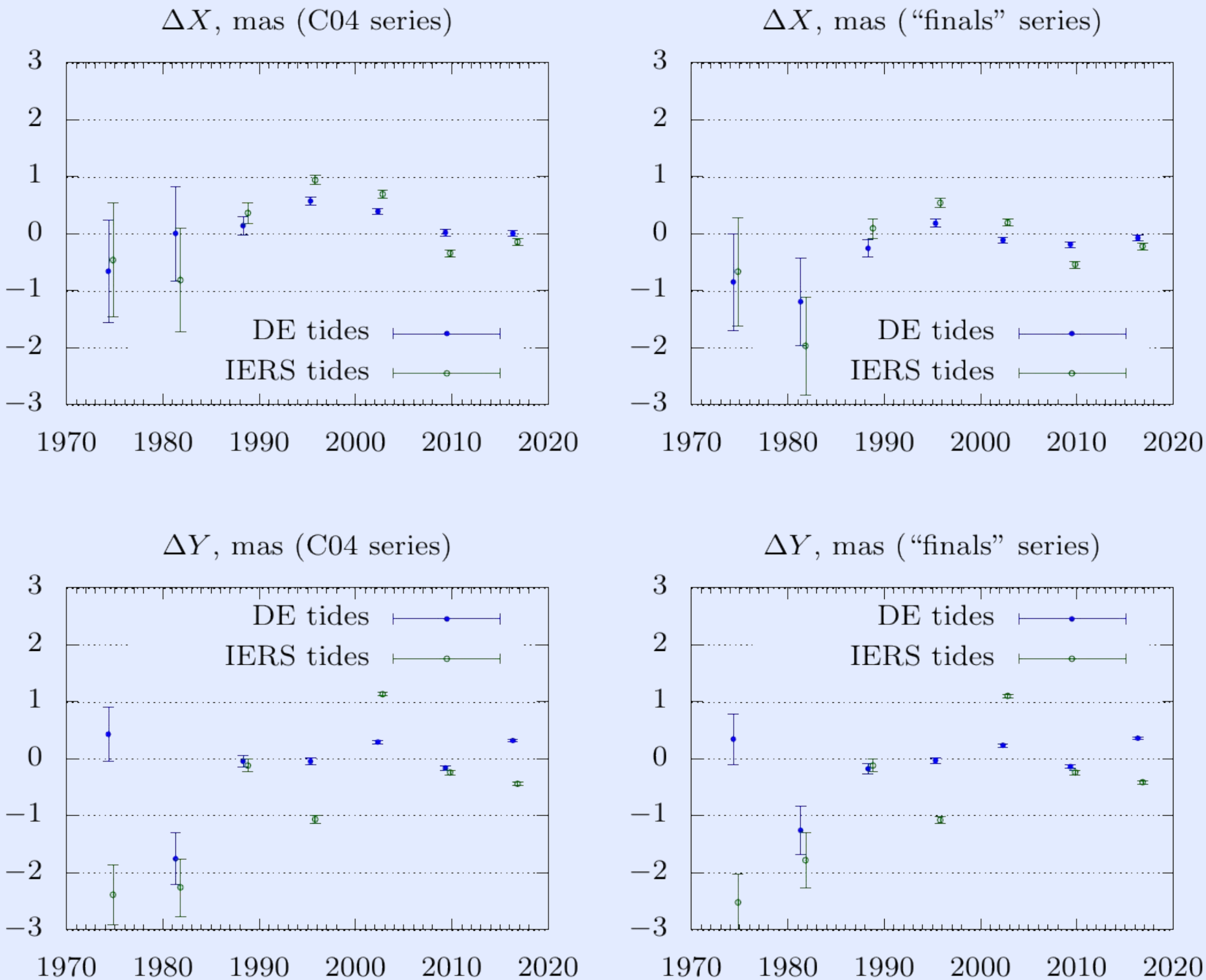
Ephemeris-ICRF sub-mas tie via LLR (concept)



When the orbit of the Moon is determined via LLR, IERS EOP are used to obtain celestial coordinates of stations.

LLR observations are sensitive to both the equator and excliptic (Williams, 2018)

Ephemeris-ICRF sub-mas tie via LLR (reality)



Conclusion

- Thanks to Wettzell Observatory for the new data of a very good quality!
- Modern LLR is able to detect inaccuracies in modern EOP series (probably).
- LLR is potentially capable of tying the Earth-Moon system to ICRF (and hence, the whole ephemeris frame to ICRF) with sub-mas accuracy, but that is not possible with the present accuracy of the celestial pole EOP series.
- More research is needed in the area of Earth-Moon dynamical system: lunar tides, Earth tides, Earth gravitational potential, lunar core.
  - Visible kinematic corrections may be related to the problems with tides or liquid core.

Recent papers

- Yagudina et al. Processing and analysis of lunar laser ranging observations in Crimea in 1974-1984. Proceedings of the IWLR (2018)
- Kurdubov et al. Earth–Moon very-long-baseline interferometry project: modelling of the scientific outcome. MNRAS (2019)
- D. Pavlov. Role of lunar laser ranging in realization of terrestrial, lunar, and ephemeris reference frames. On review in JoG (2019).

Preparation for ITRF2020

ITRS Center

ITRF2020: Call for Participation (CfP)

- **Draft circulated among IERS DB Thursday, Dec 06, 2018**
  - **List of suitable model updates in the annex of the CfP**

- **Comments were welcome until January 10, 2019**
  - **No comments received**

- **The CfP is now final & posted at the ITRF Website :**

http://itrf.ign.fr/doc_ITRF/CFP-ITRF2020.pdf

ITRF2020 Inputs by TCs: specific model updates are strongly requested

- All techniques to use the recommended HF-EOP model
- IGS: up to date GNSS force models to be used
- IDS: Improve analysis strategy, DORIS-specific model updates : SRP & SAA
- IVS: modeling the gravitational deformation for as many antennas as possible, possibly refine the thermal expansion modeling
- ILRS: SLR range biases to be handled/estimated
  - All RB parameters need to be included in weekly SINEX files

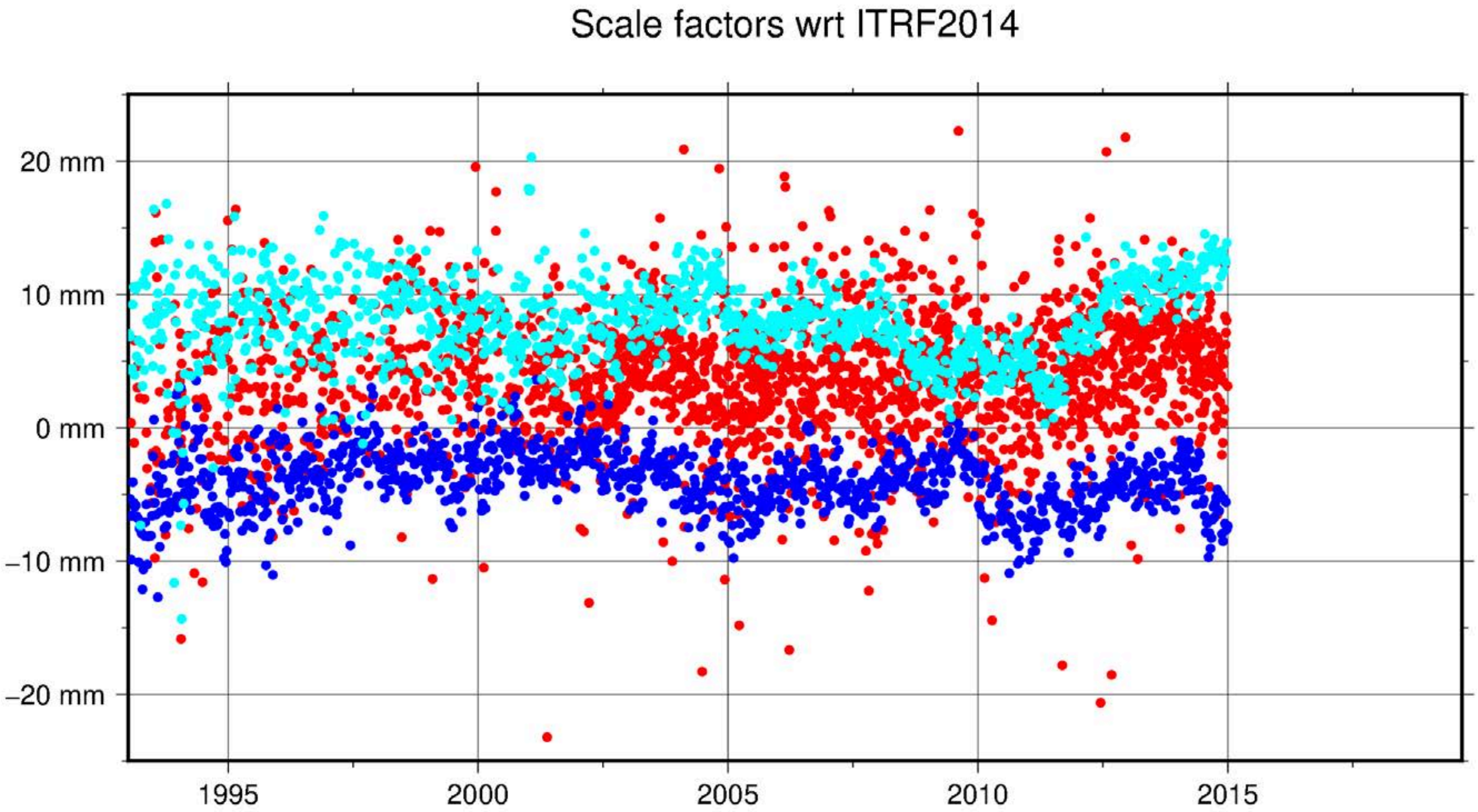
SLR range biases ↔ GNSS satellite z-PCOs

- GNSS satellite PCOs are included as constrained parameters in IGS SINEX files:

```
+SOLUTION/APRIORI
*Index _Type_ Code Pt Soln _Ref_Epoch__ Unit S __Apriori Value______ _Std_Dev___
  1048 SATA_X G063 LC    1 19:209:43185 m    0 0.394000000000000E+00 .100000E-02
  1049 SATA_Y G063 LC    1 19:209:43185 m    0 0.000000000000000E+00 .100000E-02
  1050 SATA_Z G063 LC    1 19:209:43185 m    0 0.150180000000000E+01 .100000E-02
  1051 SATA_X G061 LC    1 19:209:43185 m    0 0.130000000000000E-02 .100000E-02
  1052 SATA_Y G061 LC    1 19:209:43185 m    0 0.000000000000000E+00 .100000E-02
  1053 SATA_Z G061 LC    1 19:209:43185 m    0 0.728800000000000E+00 .100000E-02
-SOLUTION/APRIORI
*-------------------------------------------------------------------------------
+SOLUTION/ESTIMATE
*Index _Type_ Code Pt Soln _Ref_Epoch__ Unit S __Estimated Value____ _Std_Dev___
  1048 SATA_X G063 LC    1 19:209:43185 m    0 0.394037783403547E+00 .960842E-03
  1049 SATA_Y G063 LC    1 19:209:43185 m    0 -.208998511291004E-03 .992813E-03
  1050 SATA_Z G063 LC    1 19:209:43185 m    0 0.150178830270448E+01 .999270E-03
  1051 SATA_X G061 LC    1 19:209:43185 m    0 0.204653414875446E-02 .970243E-03
  1052 SATA_Y G061 LC    1 19:209:43185 m    0 -.118169152427016E-02 .994756E-03
  1053 SATA_Z G061 LC    1 19:209:43185 m    0 0.728806917166219E+00 .999464E-03
-SOLUTION/ESTIMATE
```

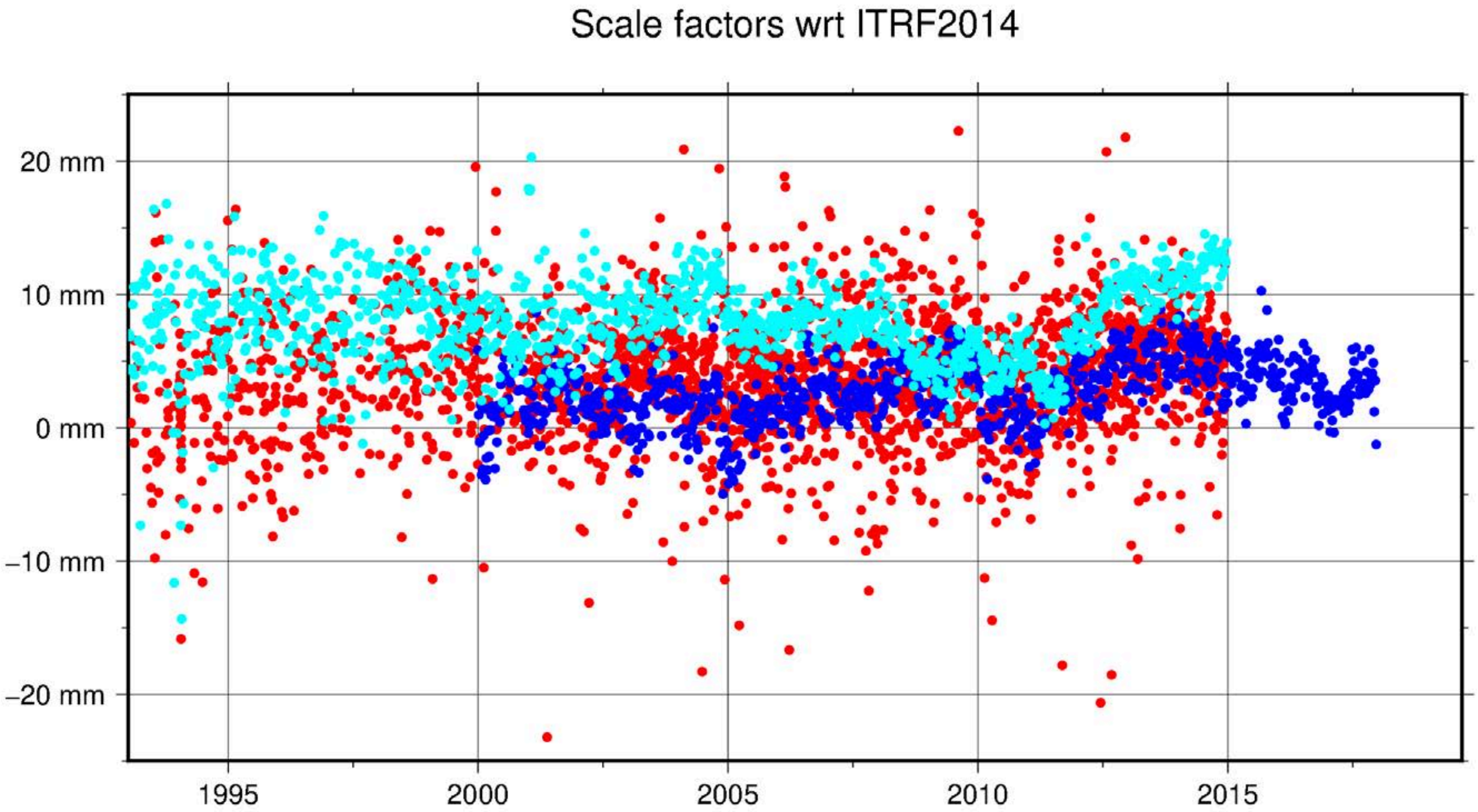
- This allows:
  - Re-evaluating satellite z-PCOs as needed
    (e.g., for new satellites, for consistency with new ITRF…)
  - Generating solutions consistent with any set of satellite z-PCOs
  - Without having to re-run the whole analysis
    (Back-substitution can be done directly in the normal equation.)

Illustration: IGS terrestrial scale



●●● VLBI contribution to ITRF2014 + 4.4 + 0.11 (t – 2010) mm
●●● SLR contribution to ITRF2014 – 4.4 – 0.08 (t – 2010) mm
●●● DORIS contribution to ITRF2014 + 7.2 – 0.11 (t – 2010) mm

Illustration: IGS terrestrial scale

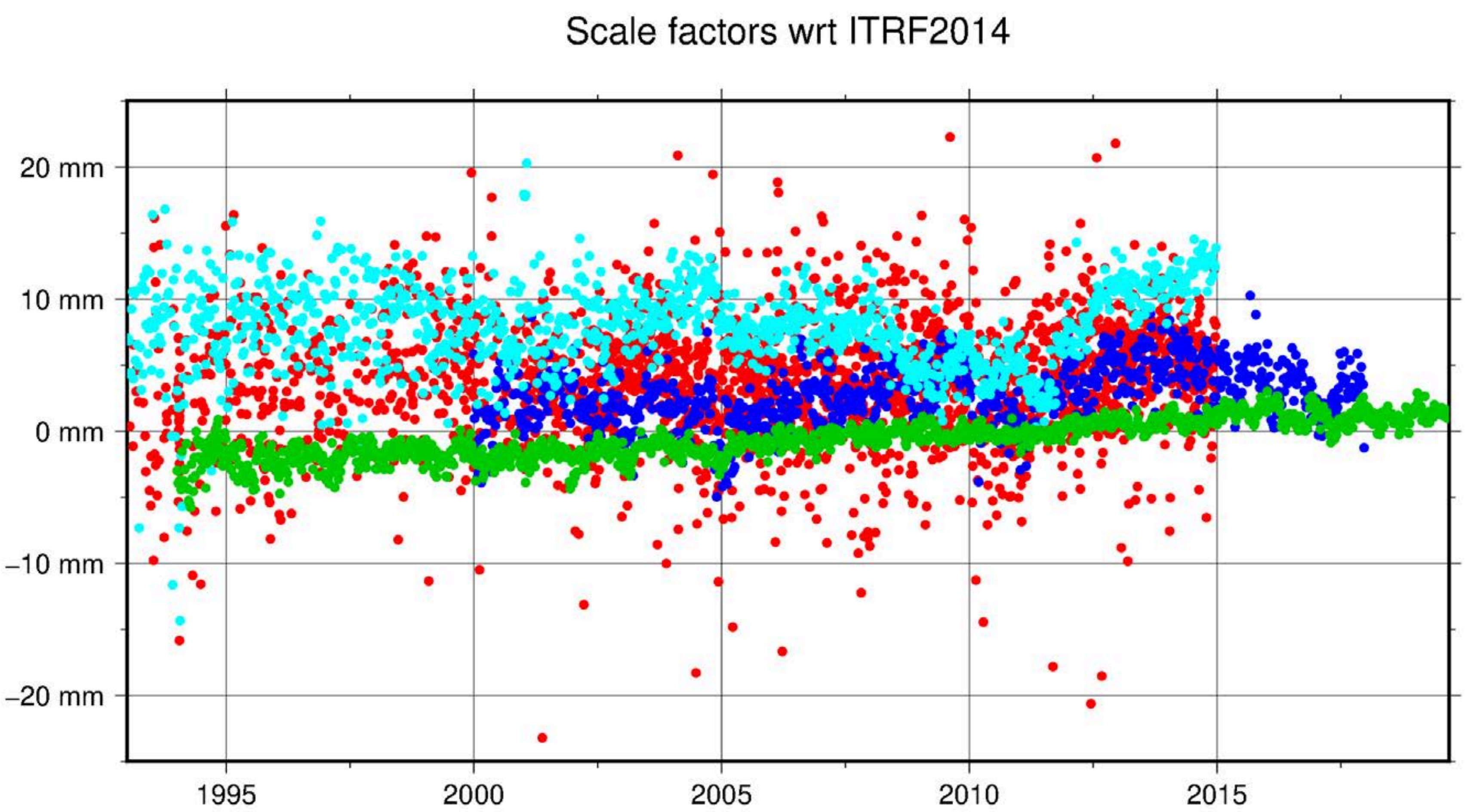


●●● VLBI contribution to ITRF2014 + 4.4 + 0.11 (t – 2010) mm

●●● SLR ASI solution – new range biases + 2.9 + 0.16 (t – 2010) mm

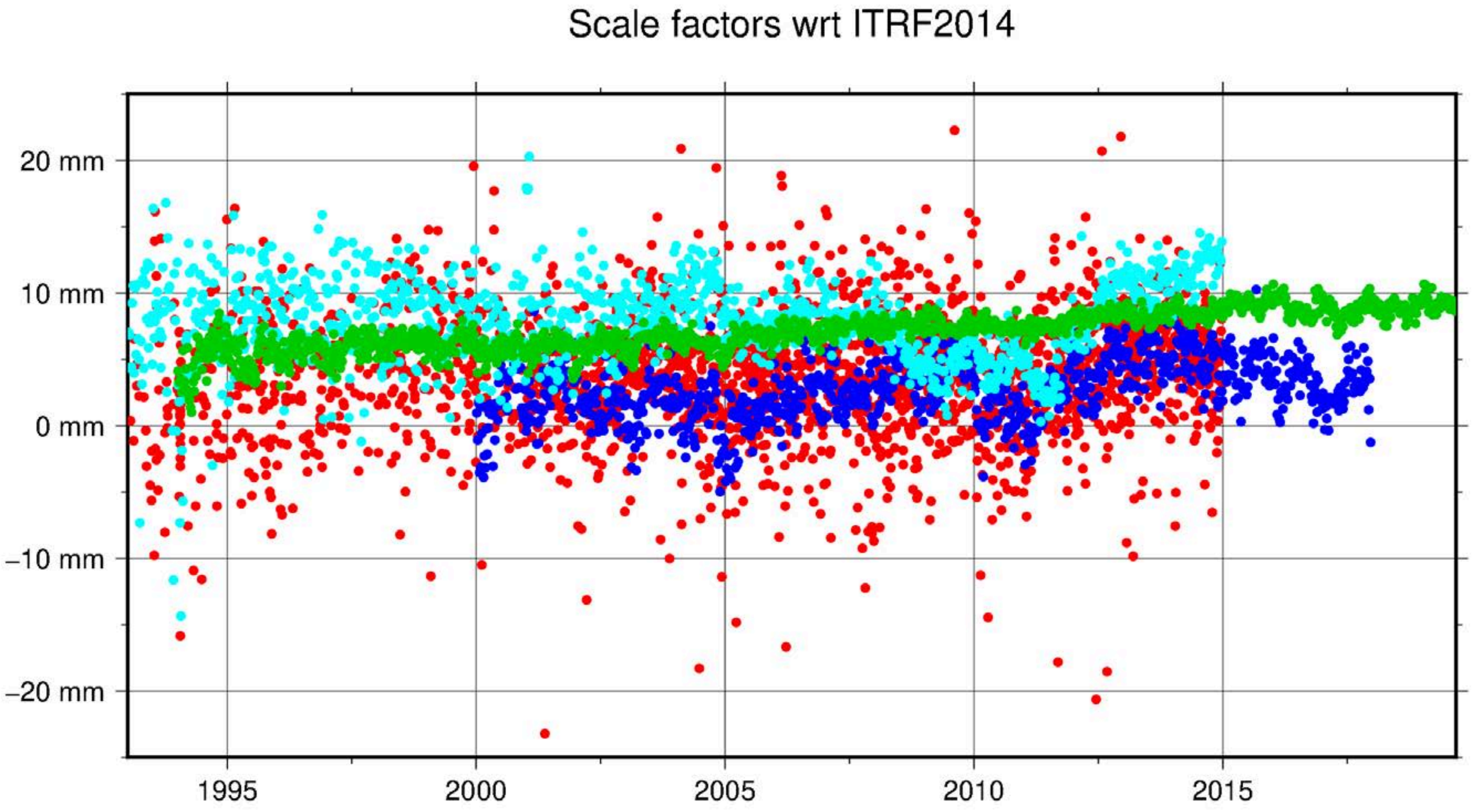
●●● DORIS contribution to ITRF2014 + 7.2 – 0.11 (t – 2010) mm

Illustration: IGS terrestrial scale



●●● VLBI contribution to ITRF2014	+ 4.4 + 0.11 (t – 2010)	mm
●●● SLR ASI solution – new range biases	+ 2.9 + 0.16 (t – 2010)	mm
●●● DORIS contribution to ITRF2014	+ 7.2 – 0.11 (t – 2010)	mm
●●● igs14.atx-based IGS combined solutions	– 0.1 + 0.18 (t – 2010)	mm

Illustration: IGS terrestrial scale



•••	VLBI contribution to ITRF2014	+ 4.4 + 0.11 (t – 2010) mm
•••	SLR ASI solution – new range biases	+ 2.9 + 0.16 (t – 2010) mm
•••	DORIS contribution to ITRF2014	+ 7.2 – 0.11 (t – 2010) mm
•••	igsR3.atx-based IGS combined solutions	+ 7.7 + 0.17 (t – 2010) mm

SLR range biases ↔ GNSS satellite z-PCOs

- SLR range biases (of all stations) could similarly be included in ILRS SINEX files:

```
+SOLUTION/APRIORI
*Index _Type_ Code Pt Soln _Ref_Epoch__ Unit S __Apriori Value______ _Std_Dev___
* 1 - core stations (range biases constrained to 0.1 mm)
     1 RBIAS  7090 LC    1 11:151:67023 m    2  0.00000000000000e+00 1.00000e-04
     2 RBIAS  7237 LC    1 11:152:44825 m    2  0.00000000000000e+00 1.00000e-04
     3 RBIAS  7406 LC    1 11:152:11148 m    2  0.00000000000000e+00 1.00000e-04
* 2 - other stations
     4 RBIAS  7501 LC    1 11:153:03624 m    2  0.00000000000000e+00 0.00000e+00
     5 RBIAS  7810 LC    1 11:151:31871 m    2  0.00000000000000e+00 0.00000e+00
-SOLUTION/APRIORI
*-------------------------------------------------------------------------------
+SOLUTION/ESTIMATE
*Index _Type_ Code Pt Soln _Ref_Epoch__ Unit S __Apriori Value______ _Std_Dev___
* 1 - core stations (range biases constrained to 0.1 mm)
     1 RBIAS  7090 LC    1 11:151:67023 m    2 -1.85280854053706e-06 9.97932e-05
     2 RBIAS  7237 LC    1 11:152:44825 m    2  5.90768938077550e-06 9.99958e-05
     3 RBIAS  7406 LC    1 11:152:11148 m    2  1.15140818800998e-05 9.99326e-05
* 2 - other stations
     4 RBIAS  7501 LC    1 11:153:03624 m    2 -9.48272553599114e-04 1.71051e-03
     5 RBIAS  7810 LC    1 11:151:31871 m    2  3.92183534261174e-02 5.25327e-03
-SOLUTION/ESTIMATE
```

- This would allow:
  - Flexible re-evaluations of range biases as needed
  - Easy back-substitutions
  - A rigorous handling of range biases / SLR scale information in the ITRF combination

ITRF2020: Augmented Parametric RF

Regularized position

$$X(t) = \underbrace{X(t_0) + \dot{X}.(t - t_0)}_{\text{Regularized position}} + \delta X(t)_{PSD} + \delta X(t)_S$$

∑ Post-Seismic Deformations

∑ Seasonal Signals of all frequencies, estimated for all techniques
Caution: significant discrepancies between techniques

Toward ITRF2020:

- $\delta X(t)_{PSD}$ **Will be refined for all stations subject to major earthquakes**
- $\delta X(t)_S$ **Will be provided, all expressed in CM-SLR, with their uncertainties as a function of technique agreements at co-location sites**

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Summary

- **General agreement of all techniques regarding proposed effects and model updates to be considered for the reprocessing**

- **CfP disseminated, available at the ITRF Website:**
  - **http://itrf.ign.fr/doc_ITRF/CFP-ITRF2020.pdf**
- **In preparation for ITRF2020, the ITRS Center may**
  - **Request specific solutions for testing purposes, e.g.**
    - **SLR range biases estimated**
    - **New HF-EOP model applied**
    - **Others TBD**
- **ITRF2020:**
  - **PSD parametric models will be refined**
  - **Annual & semi-annual signals will be provided in the CM-SLR, with uncertainties as a function of technique agreements.**

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The JCET AC/CC Report to the ILRS ASC

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

44th ILRS ASC Meeting

Paris, France,

Oct. 1, 2019

Outline

- Operational Products Status Report
- Station Systematic Error Monitoring Project
- Etalon 1 & 2 Tracking Campaign Plans
- Modeling Updates in view of the ITRF2020 reanalysis
- Planning for the use of SLR @ GNSS data in a future product

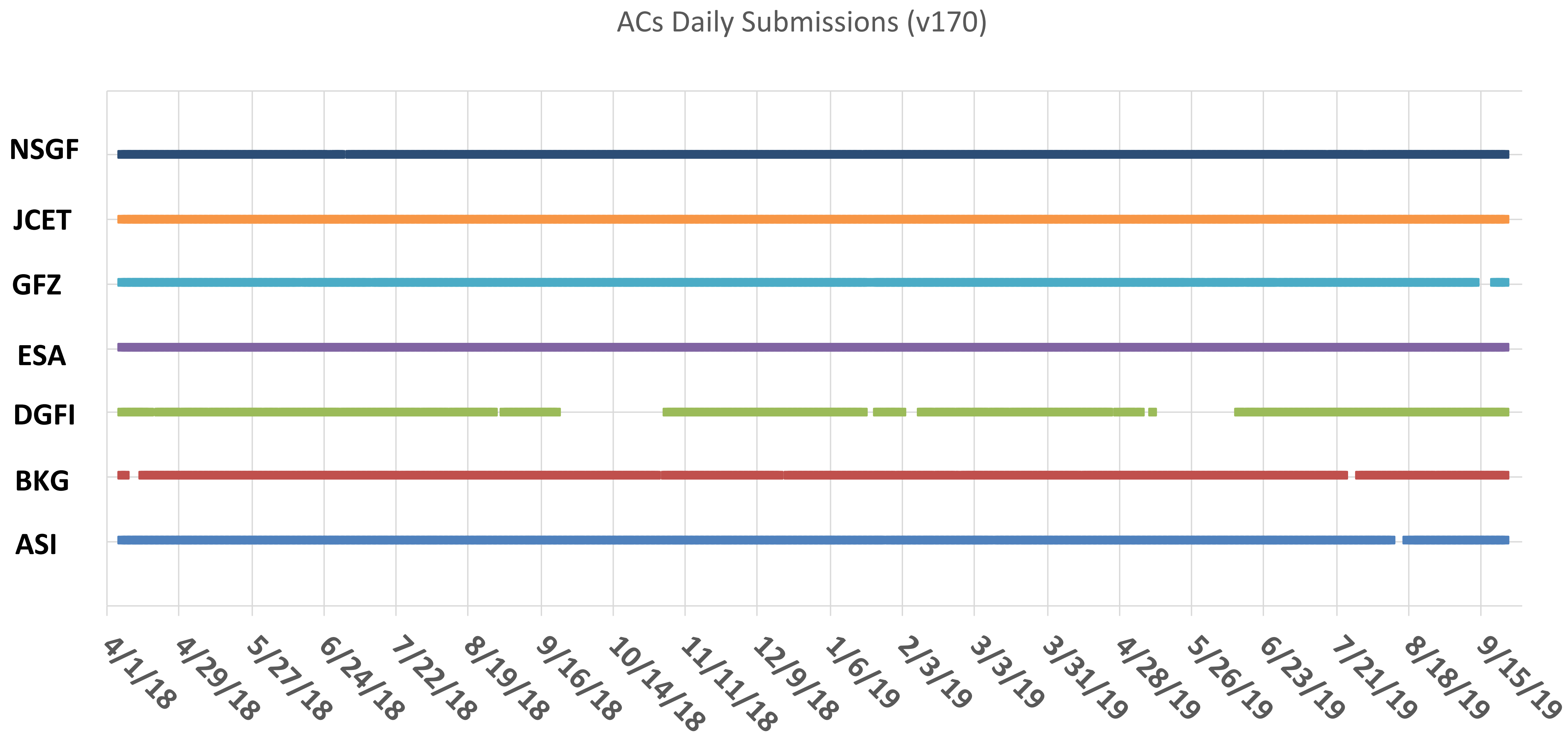
JOGSILR Articles Lineup for Printed Version

- Preface to the second Special Issue on Laser Ranging
- The ILRS: Approaching twenty years and planning for the future
- Geodetic Satellites: A High Accuracy Positioning Tool
- Lunar Laser Ranging - A Tool for General Relativity, Lunar Geophysics and Earth Science
- Information Resources Supporting Scientific Research for the International Laser Ranging Service
- The Next Generation of Satellite Laser Ranging Systems
- NASA's Satellite Laser Ranging Systems for the 21st Century
- Modernizing and Expanding the NASA Space Geodesy Network to Meet Future Geodetic Requirements
- Future SLR station networks in the framework of simulated multi-technique terrestrial reference frames
- **Impact of network constraining on the terrestrial reference frame realization based on SLR observations to LAGEOS**
- Satellite Laser Ranging to Low Earth Orbiters - Orbit and Network Validation
- Rapid Response Quality Control Service for the Laser Ranging Tracking Network
- **Transitioning the NASA SLR network to Event Timing Mode for reduced systematics, improved stability and precision**
- **Systematic errors in SLR Data and their impact on the ILRS products**
- Time Bias Service: Analysis and Monitoring of Satellite Orbit Prediction Quality
- Operating two SLR Systems at the Geodetic Observatory Wettzell - from local survey to space ties
- Time and laser ranging: A window of opportunity for geodesy, navigation and metrology
- Laser and Radio Tracking for Planetary Science Missions - A Comparison
- Assessment of the impact of one-way laser ranging on orbit determination of the Lunar Reconnaissance Orbiter
- Overview of Applications of Satellite Laser Ranging and Laser Time Transfer in BeiDou Navigation Satellite System
- Solar orbital thermo-optical characterization of an innovative GNSS retroreflector array
- Version of a glass retroreflector satellite with a sub-millimeter "target error"
- **Studies on the materials of LARES 2 satellite**

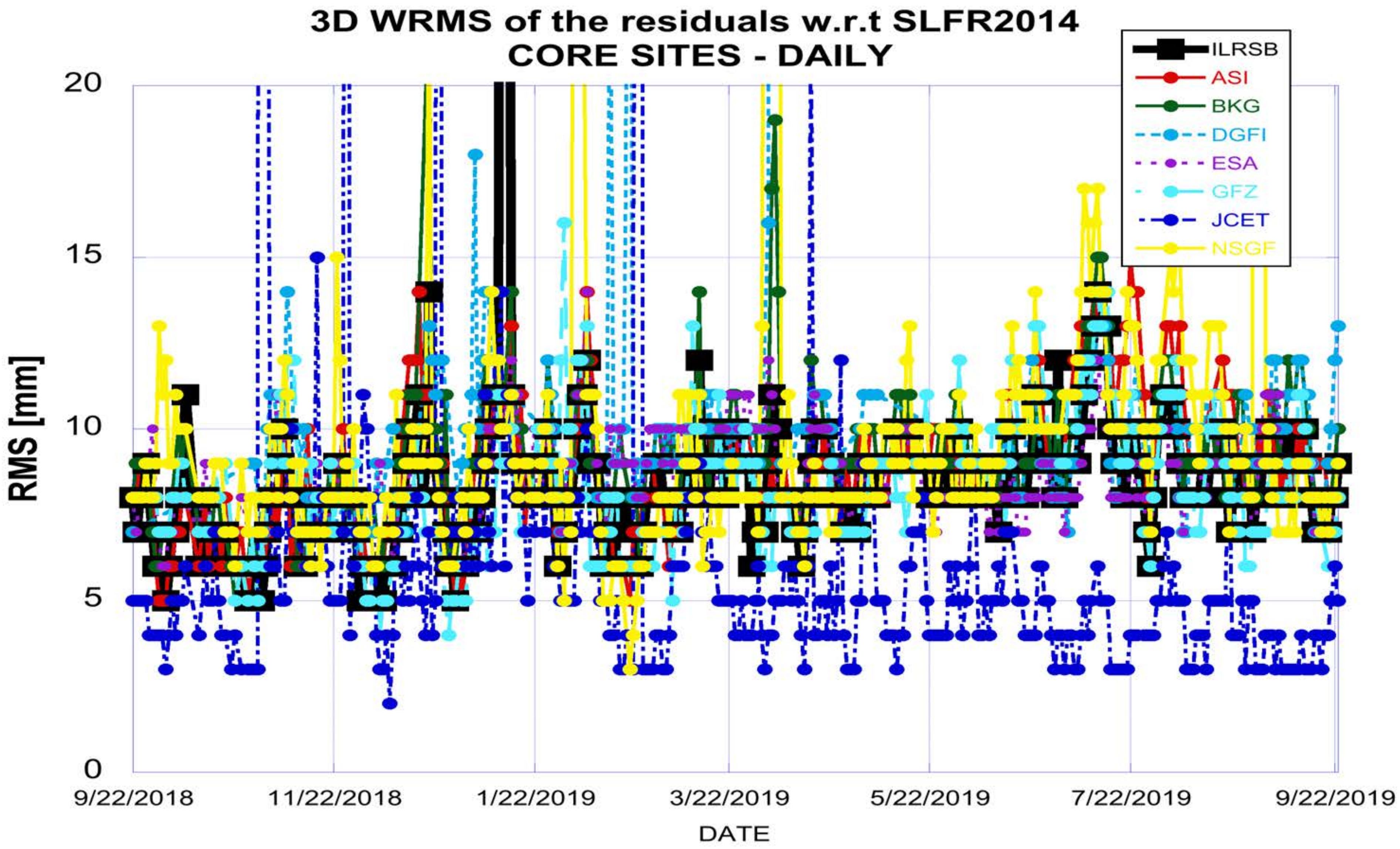
Operational Products Status

- Daily and Weekly series delivered (nearly) routinely by 7 of the eight ACs
- With the routinely contributing ACs down to seven, it is important that all ACs make an effort to deliver their contributions regularly, to maintain the quality of our products!
- ACs that do not participate in test PPs and demonstrate their ability to deliver quality products, delay us from wrapping up PPs and moving to the next phase or PP.
- We hope to see GRGS recover and return to operational status soon.
- No further progress on SHAO’s initiative to become an AC.

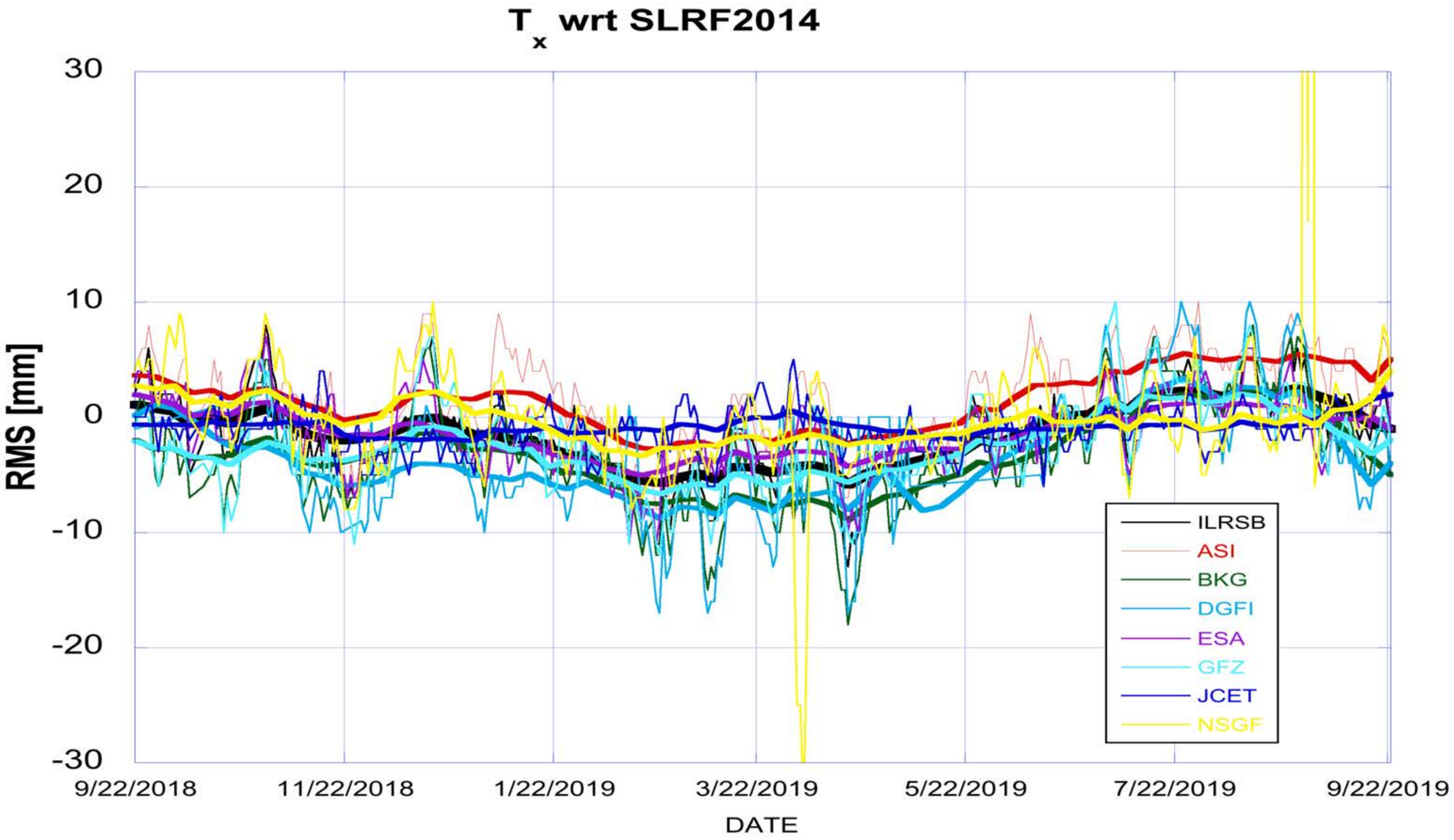
Daily Product Submissions



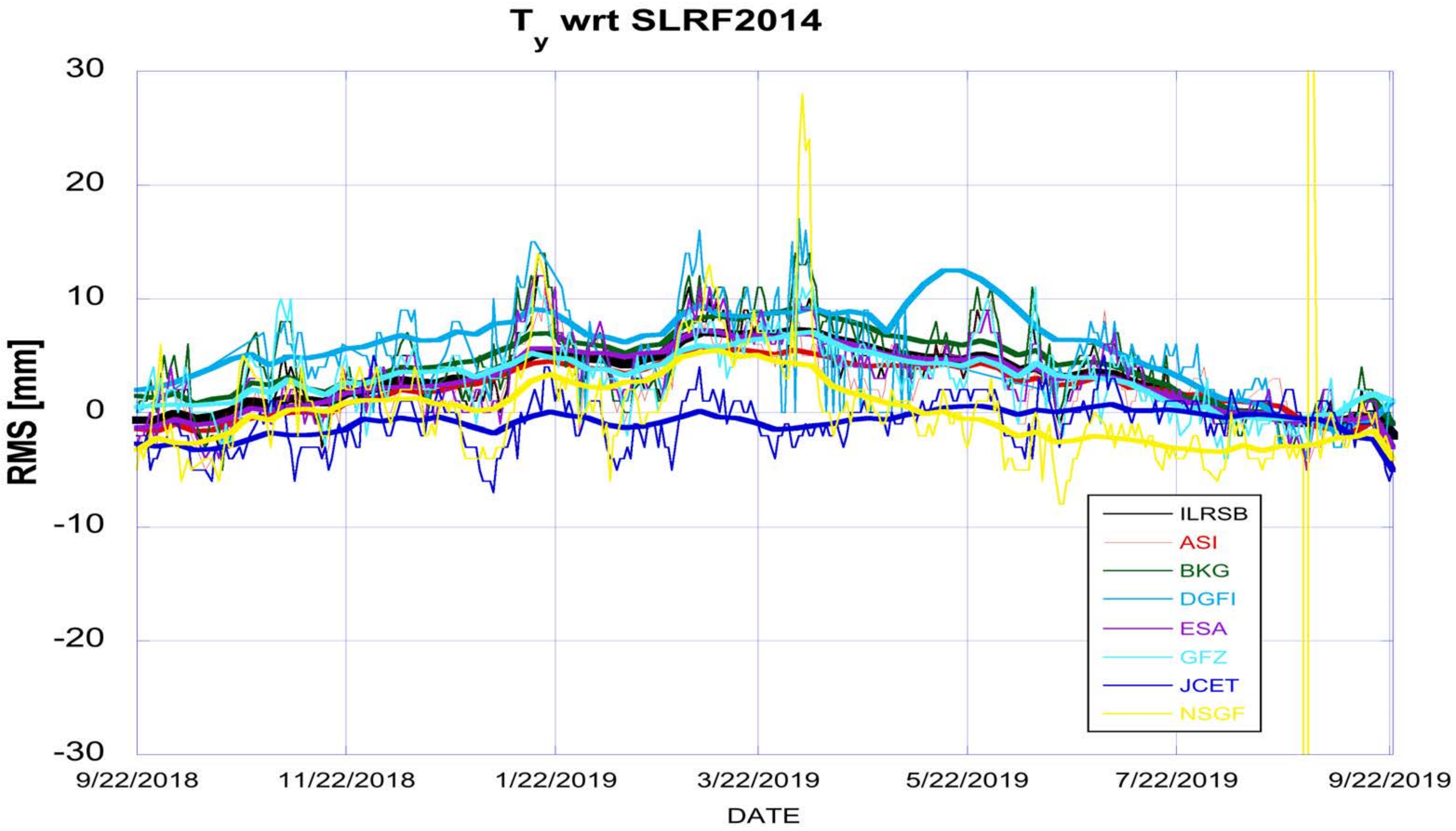
Daily Product Submissions



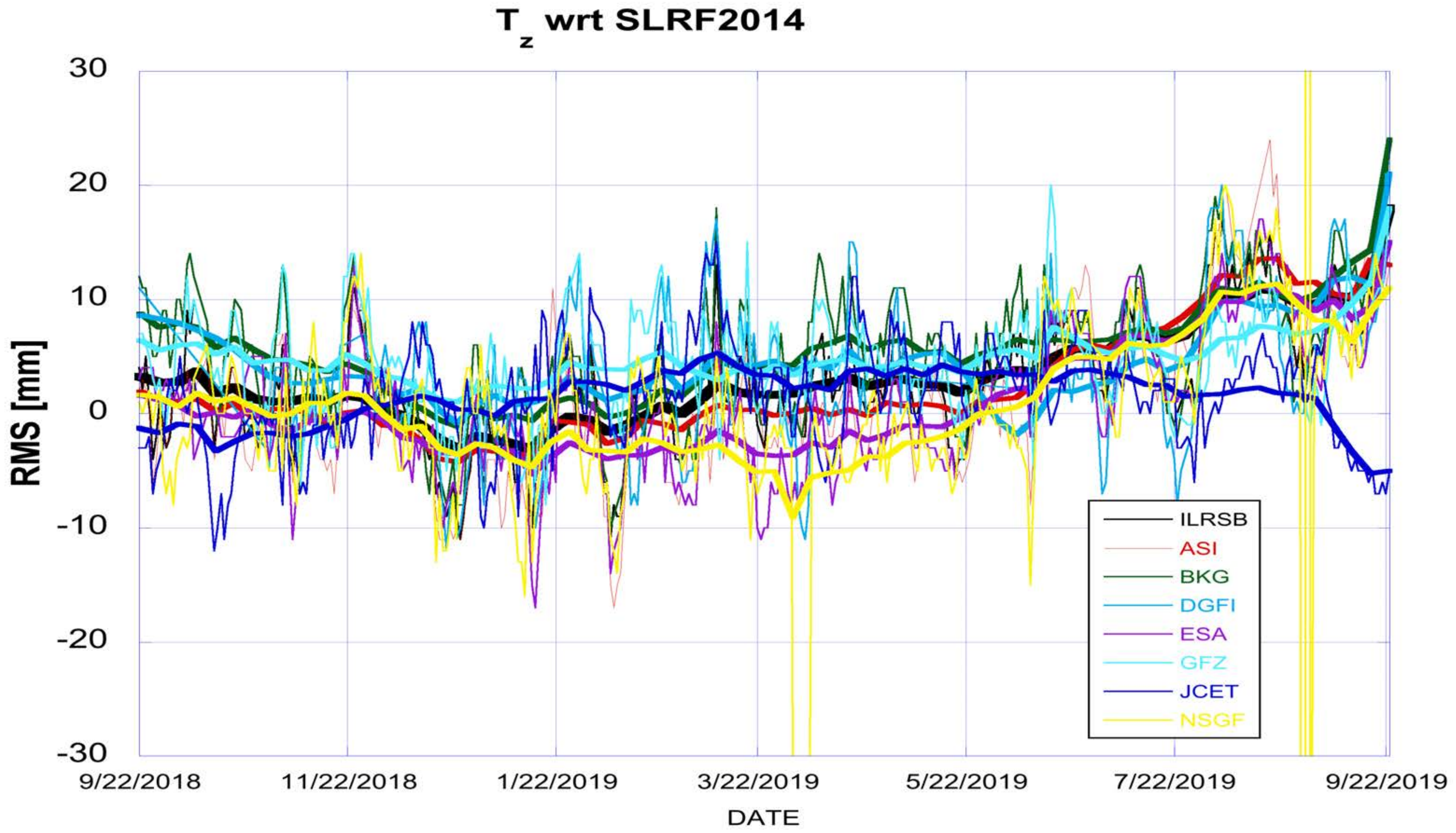
Daily Product Submissions



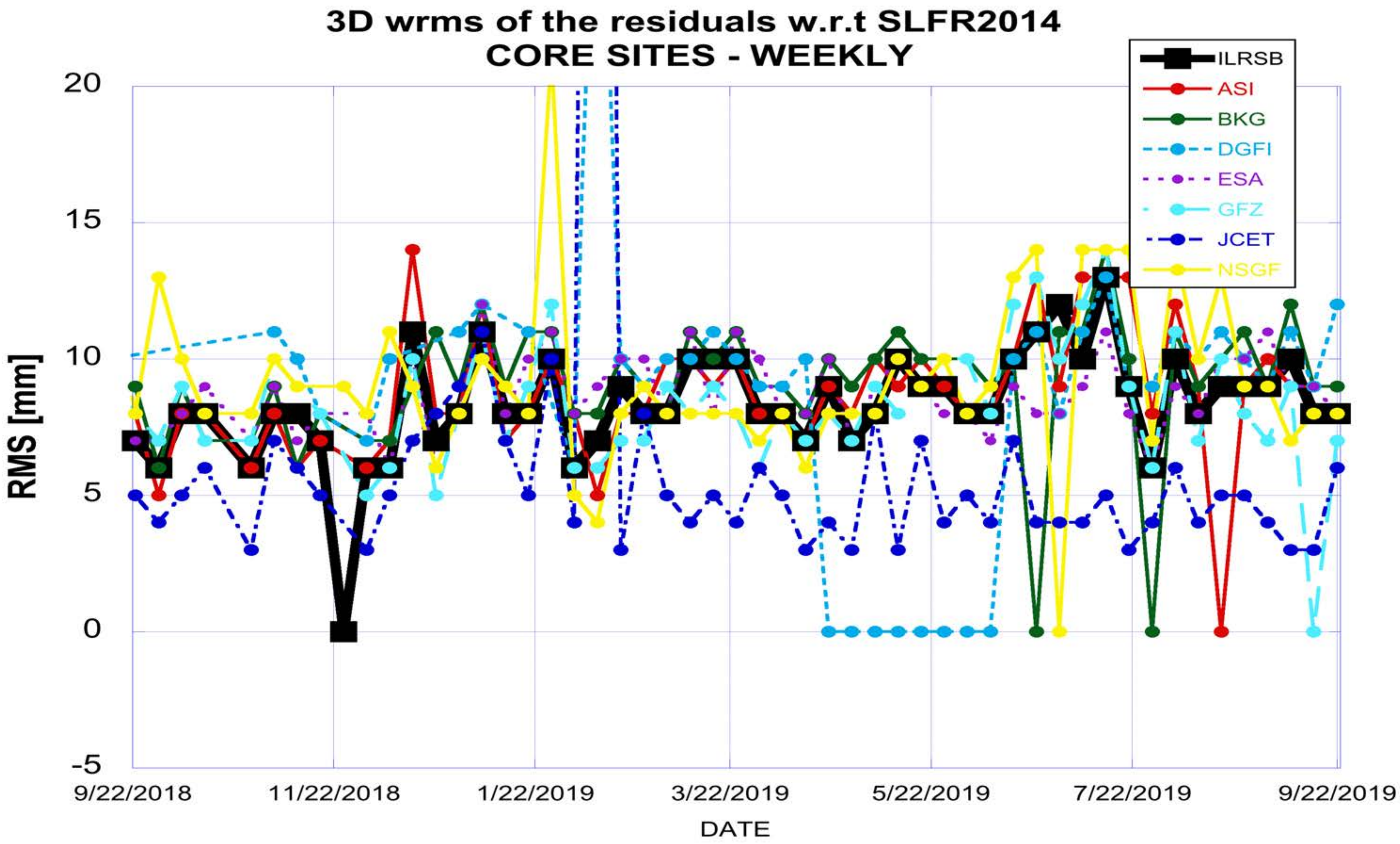
Daily Product Submissions



Daily Product Submissions



Weekly Product Submissions



Currently Quarantined Sites

Quarantine Stations

Station	Code	Site	DC	SOD	DOMES	First Data	Last Data	
7080	MDOL	McDonald Observatory, Texas	NASA	70802419	40442M006	1993-06-11	2019-08-29	25 day(s)
7358	GMSL	Tanegashima, Japan	NASA	73588901	21749S001	2004-09-01	2019-07-25	60 day(s)
7395	GEOL	Geochang, Republic of Korea	EDC	73956501	23910S001	0000-00-00	0000-00-00	None day(s)
7396	JFNL	Wuhan, China	EDC	73964701	21602S008	2019-06-24	2019-09-21	2 day(s)
7816	UROL	Stuttgart, Germany	EDC	78165201	10916S001	0000-00-00	0000-00-00	None day(s)
7824	SFEL	San Fernando, Spain	EDC	78244502	13402S007	1999-04-08	2019-09-22	1 day(s)

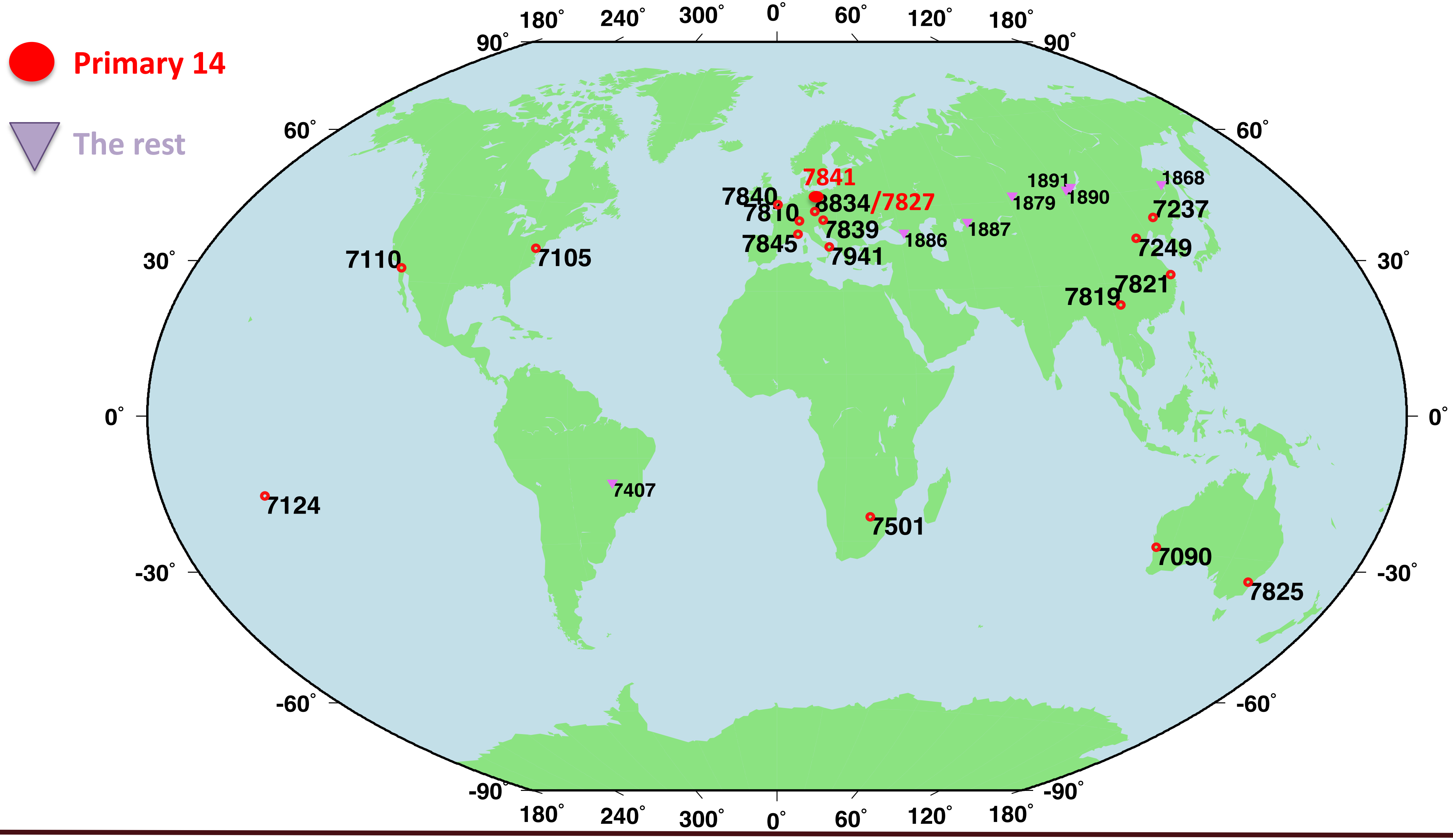
- Tow sites (**in RED**) are actively undergoing validation of their data;
- Two “engineering” sites (**above in PURPLE**) that have yet to submit any data (no need for official validation, but may request it if they want to see the quality of their data assessed);
- McDonald is sending data very sporadically
- McDonald has reached ”end of operations” phase, so no need to proceed with validation.

Etalon 1 & 2 Campaign Project Summary

Erricos C. Pavlis, Carey Noll and Magda Kuzmizc-Cieslak

July 31, 2019

Network of Selected Stations (all)



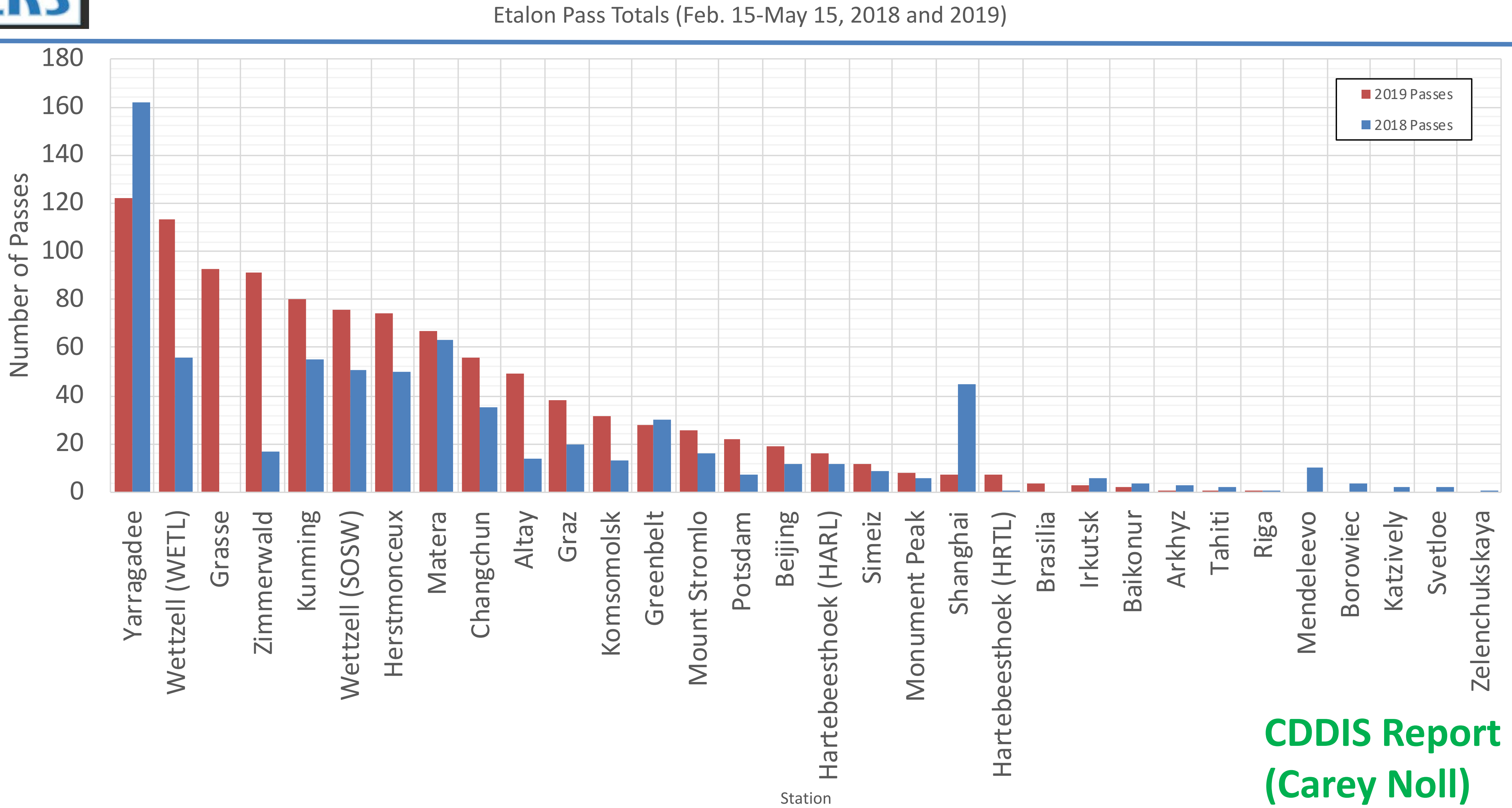
Summary

- We collected more data overall
- The network can be split in two tiers of stations based on NP data collected:
  - The top 12 and
  - The rest
- Of the top producers, Yarragadee, WLRS, MLRO, ZimLAS and MeO showed a consistent increased yield every week, although the weather did play a role in the observed variations.
- Of the remaining top producers, most averaged low NP weekly yields (~15 NPs), although a few (e.g. Hx, SOSW, Graz) did demonstrate on one occasion that they are capable of delivering similar amounts of data as the top sites in their tier:
  - This points to weather conditions as the possible culprit for their overall low yield.
- For the bottom tier sites with the single-digit weekly yield we will have to wait for the in-depth analysis to see if these few points make any contribution to the products (e.g. due to the geographical location of these sites). Otherwise it will probably be better for these sites to focus on other targets.
- Based on the 3-month tracking in 2018 and 2019, we deduced the equivalent annual yield for the network for these two years. It is clear that whether we use the mean or the median as a criterion, the 2019 results could be double (or more) the amount of the 2018 data set (see last slide). From this point of view the campaign is clearly a success.

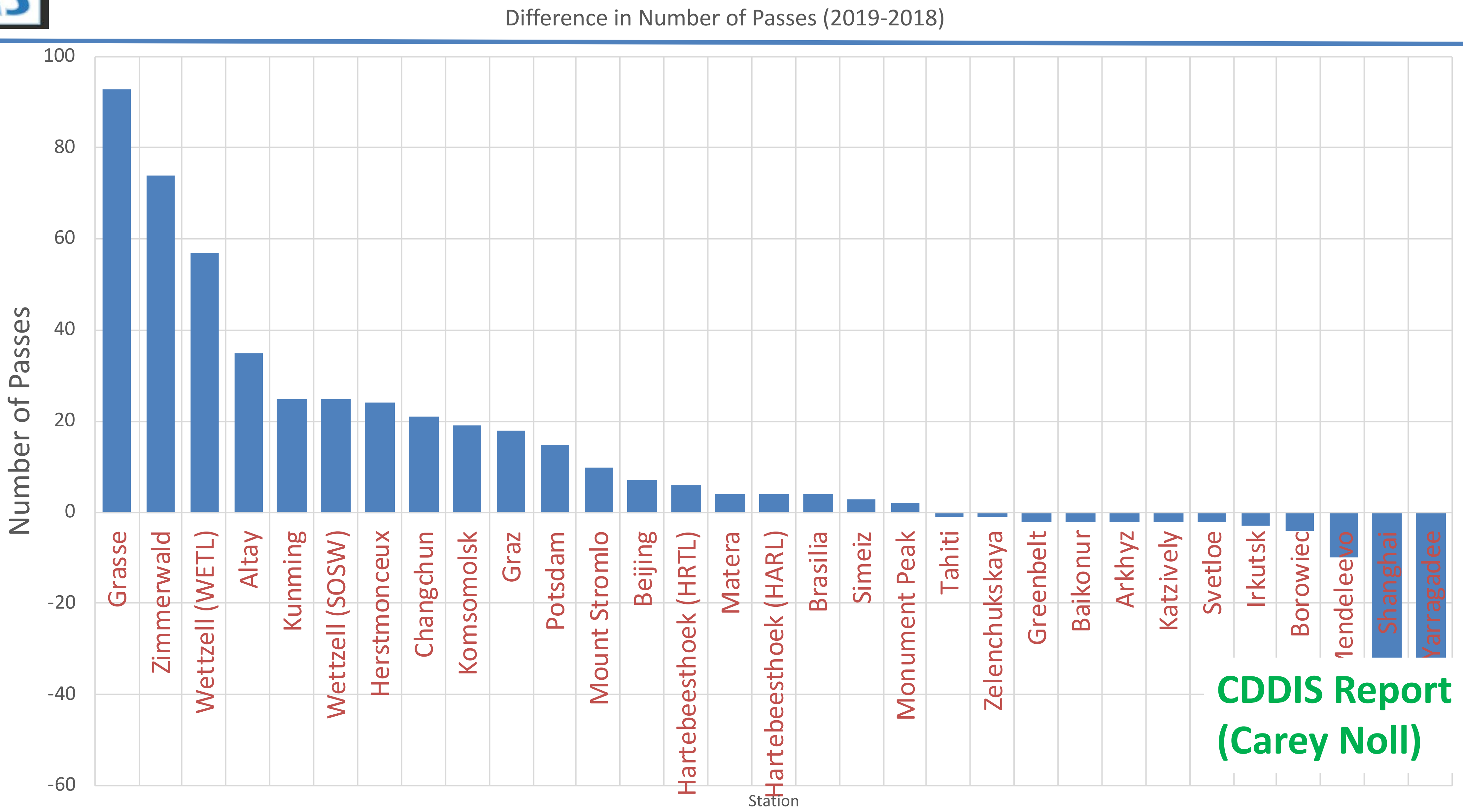
Improvement over 2018 (same time period)

- The comparison to the IERS C04 definitive series for the period of the campaign in 2019 and the same period in 2018 shows a significant reduction of the differences

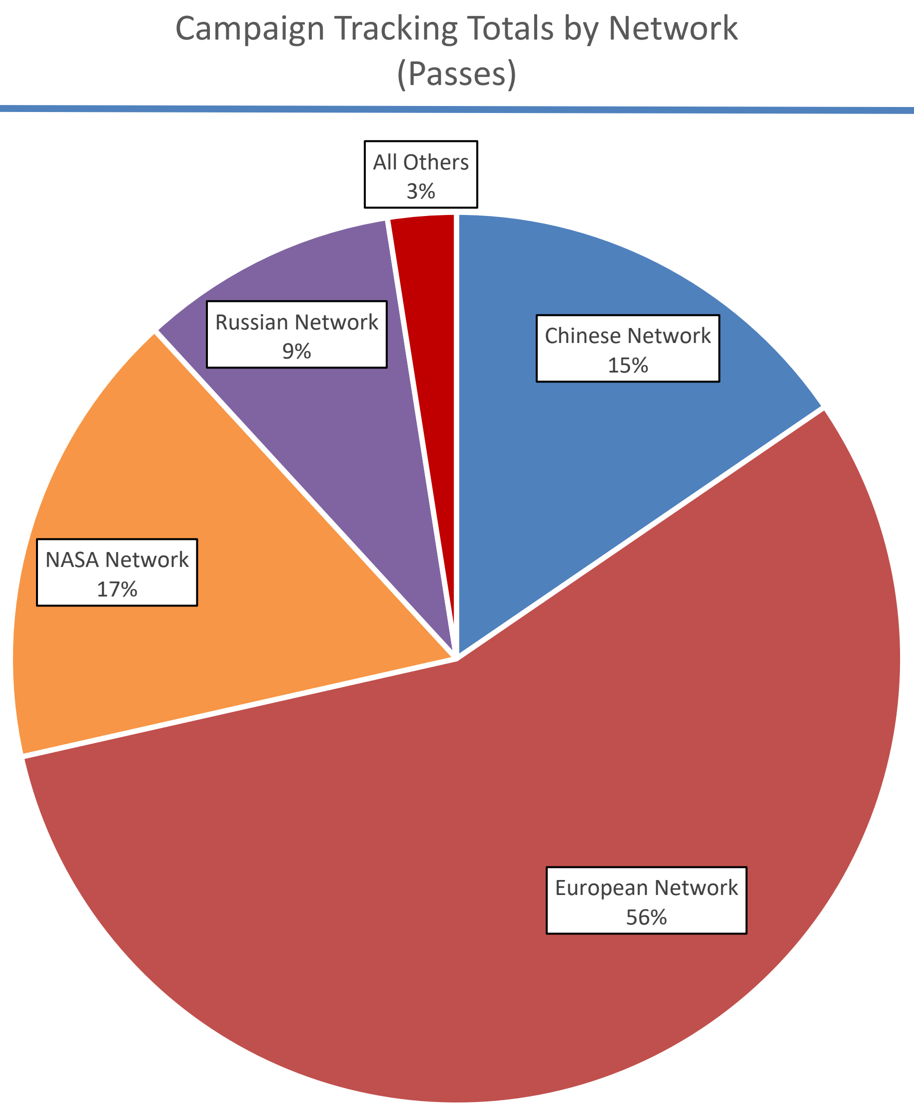
- The RMS scatter about the mean difference is reduced by:
  - X-component: **-37 %**
  - Y-component: **-18 %**
  - LOD: **-15 %**

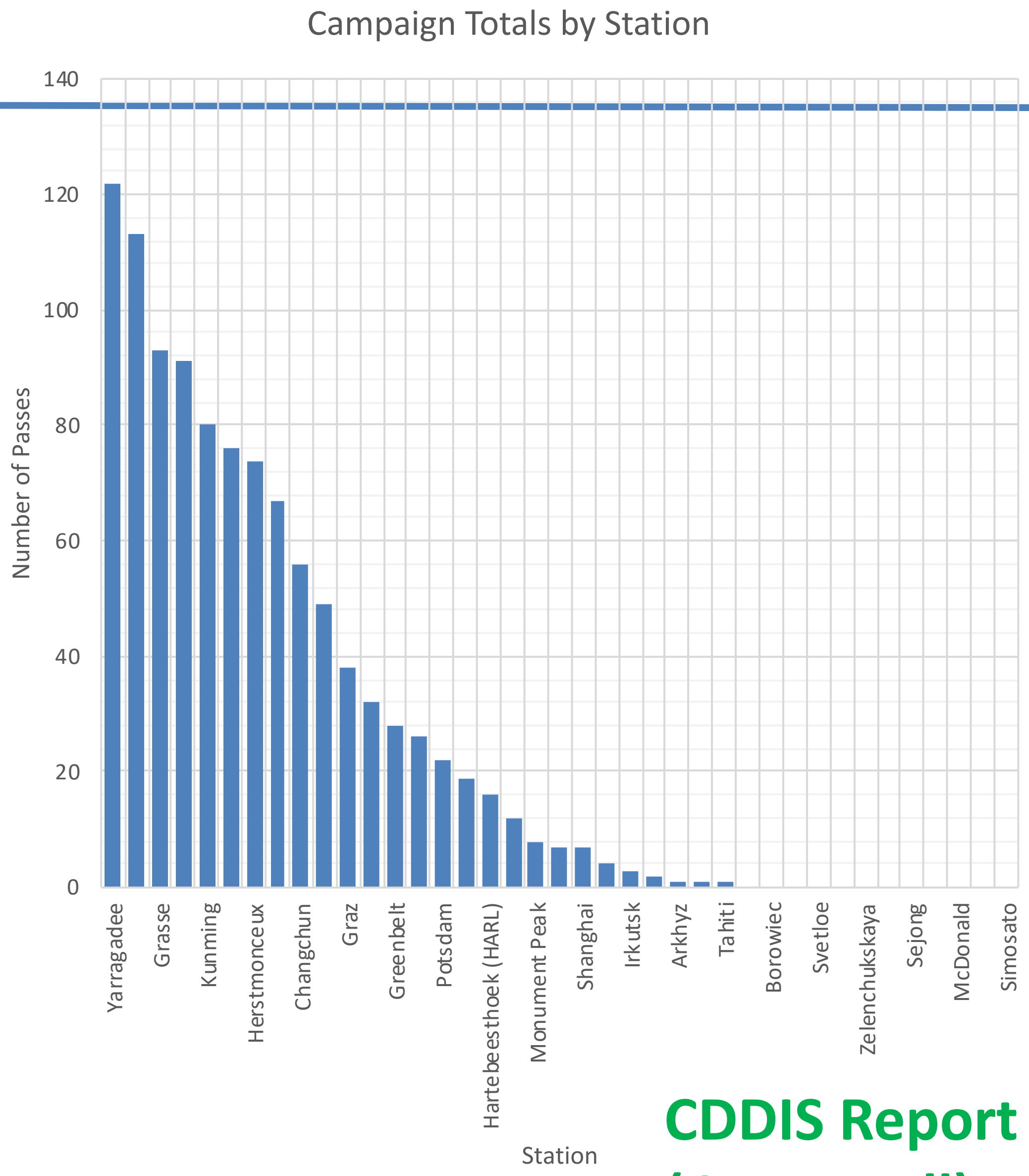


CDDIS Report (Carey Noll)



CDDIS Report (Carey Noll)

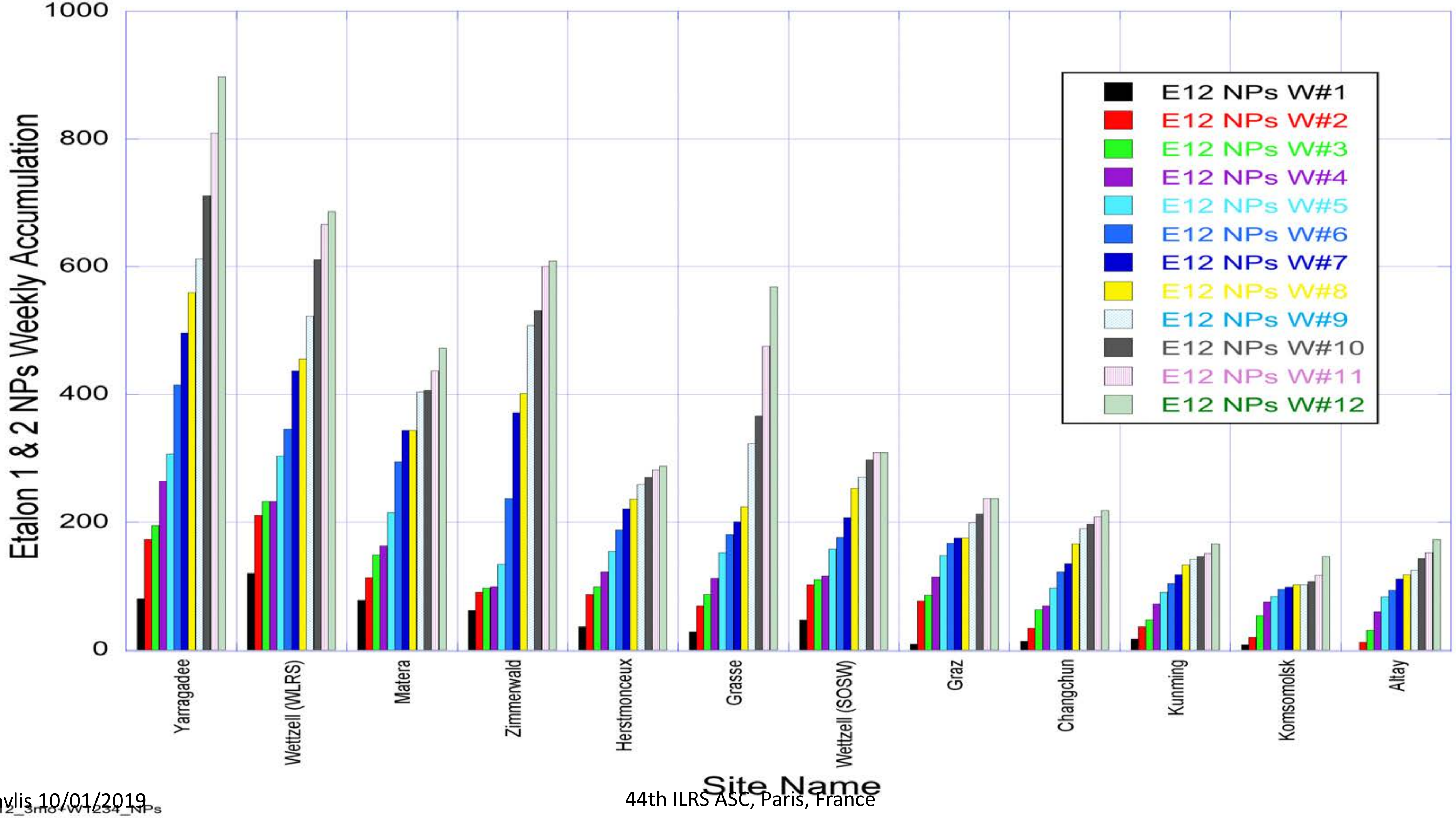




CDDIS Report (Carey Noll)

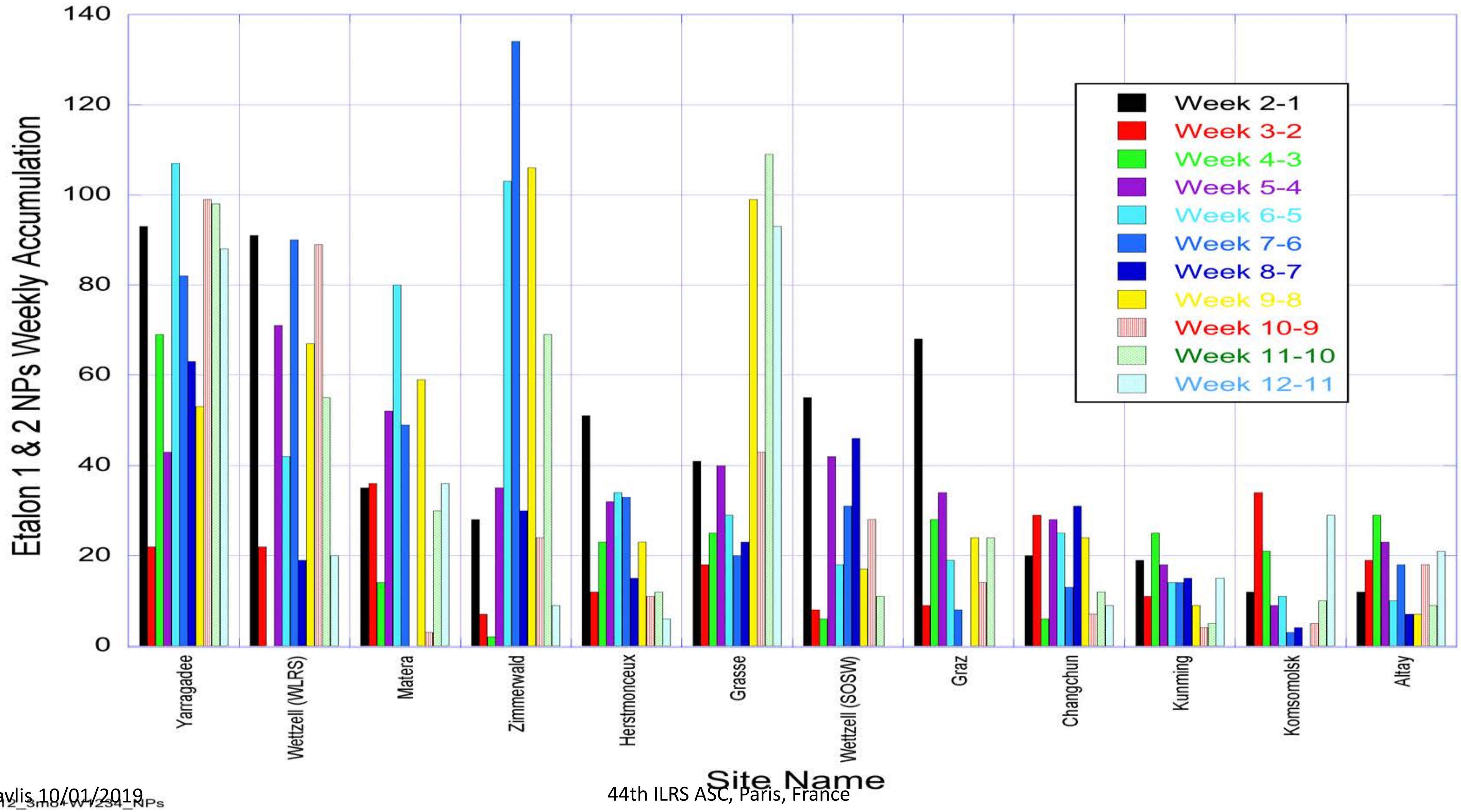
Etalon 1 & 2 Campaign 2019 Data Yield (02/15-05/15)

◆ Weekly Accumulation: **Top 12 Data Producer Stations**



Etalon 1 & 2 Campaign 2019 Data Yield (02/15-05/15)

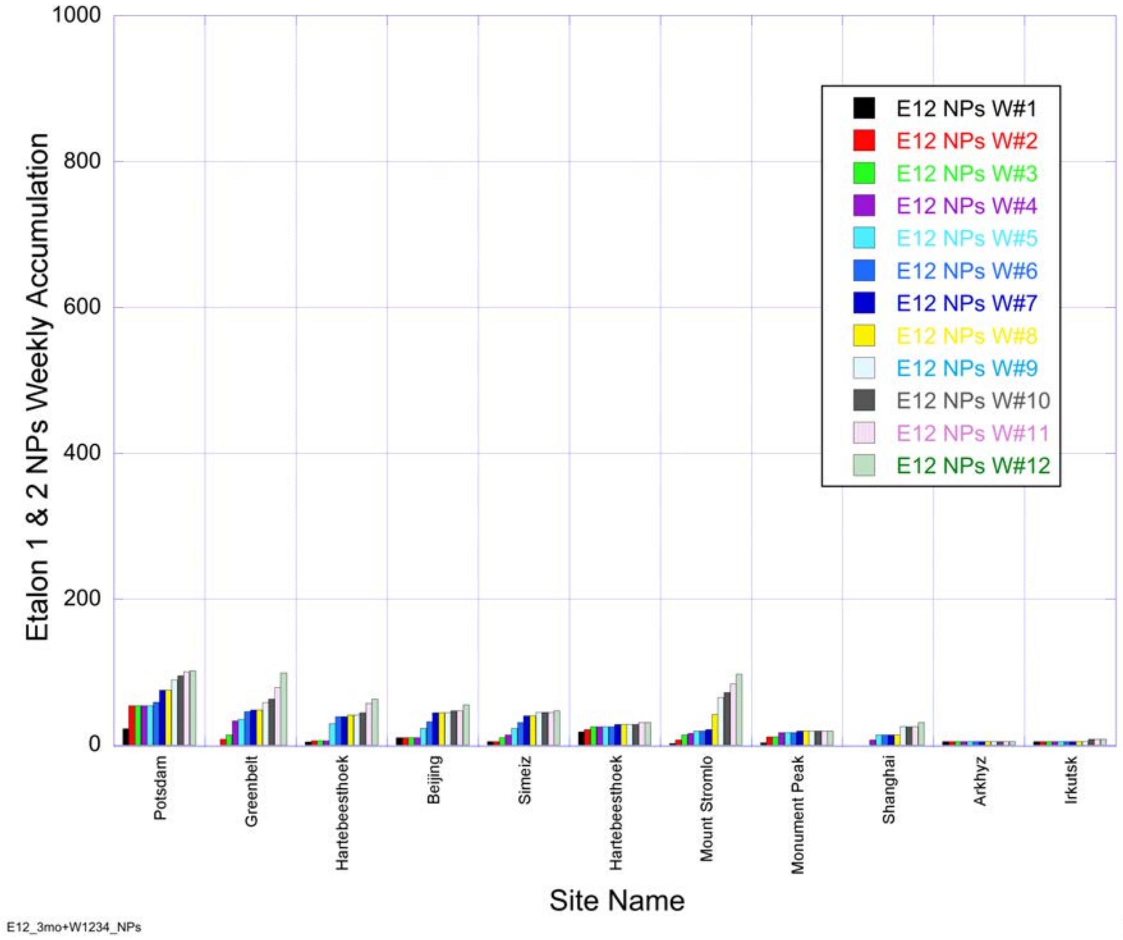
◆ Weekly Increments: **Top 12 Data Producer Stations**



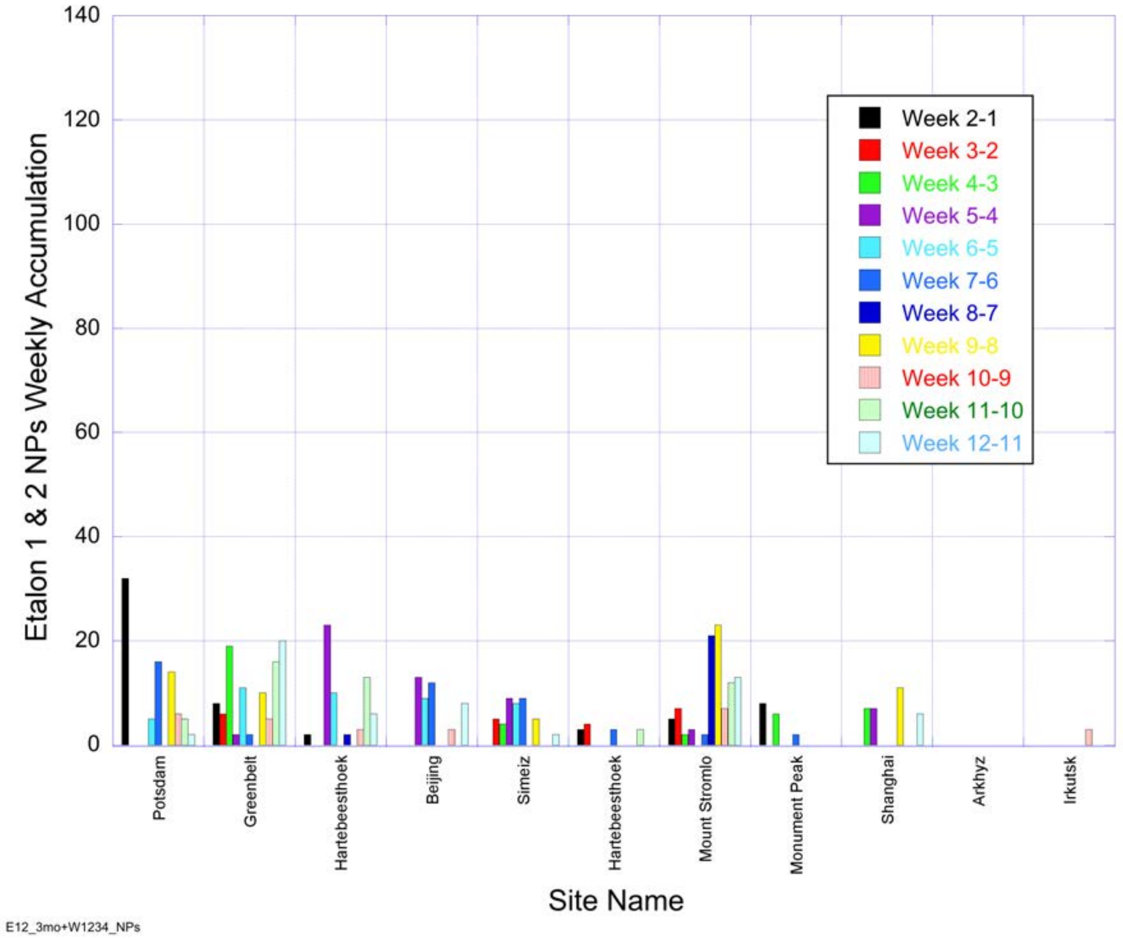
Etalon 1 & 2 Campaign 2019 Data Yield (02/15-05/15)

Low Data Yield Stations

Weekly Accumulation

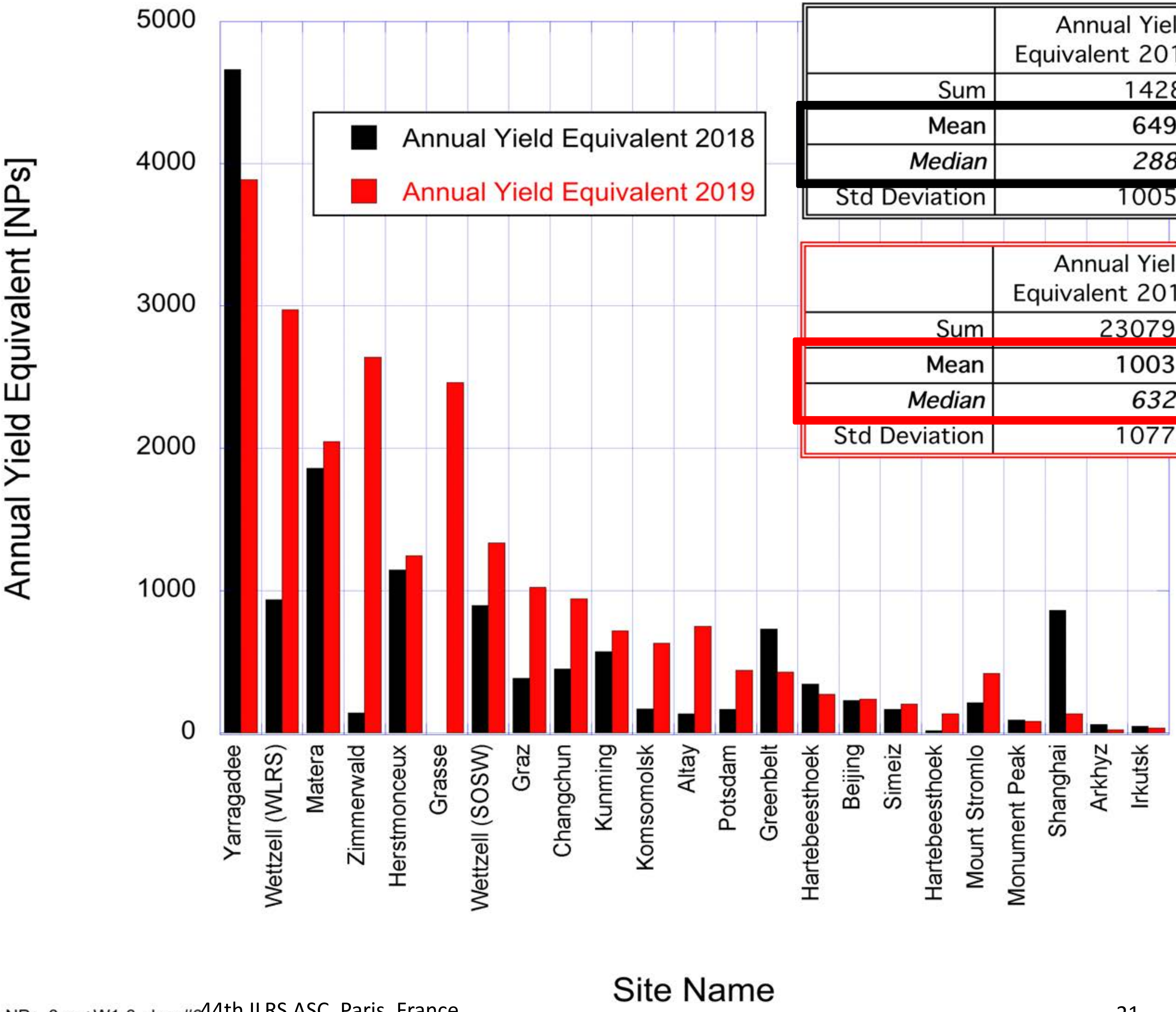


Weekly Increments



Etalon 1 & 2 Campaign 2019 Data Yield (02/15-05/15)

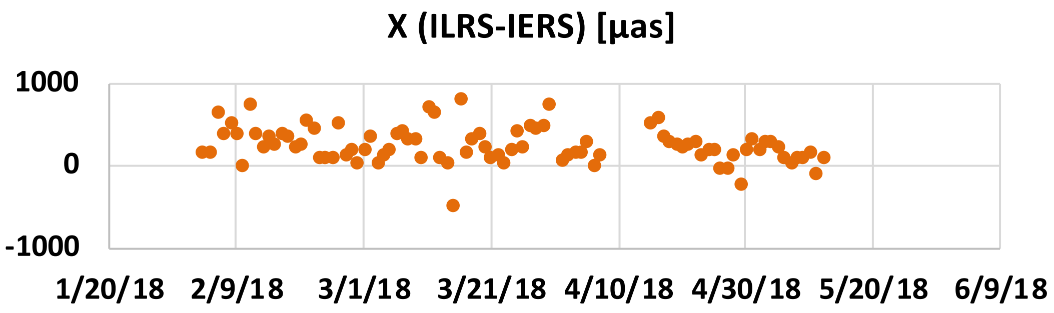
Annual data yield equivalent for 2018 and 2019, assuming the same weekly data yield as for the first three months of 2018 and over the 3-month campaign period of 2019.

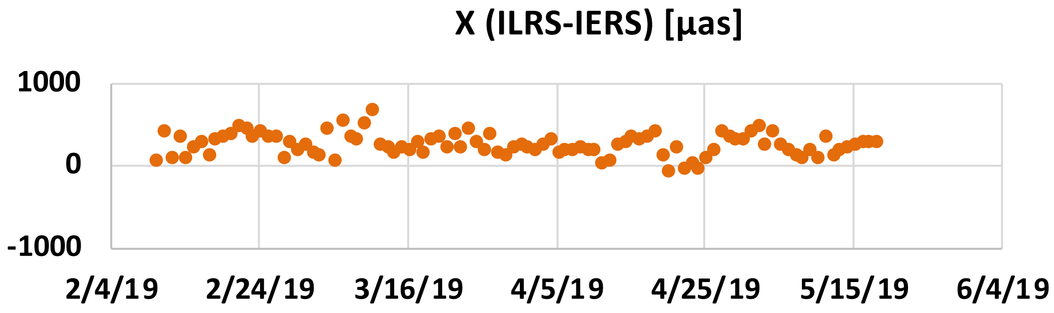


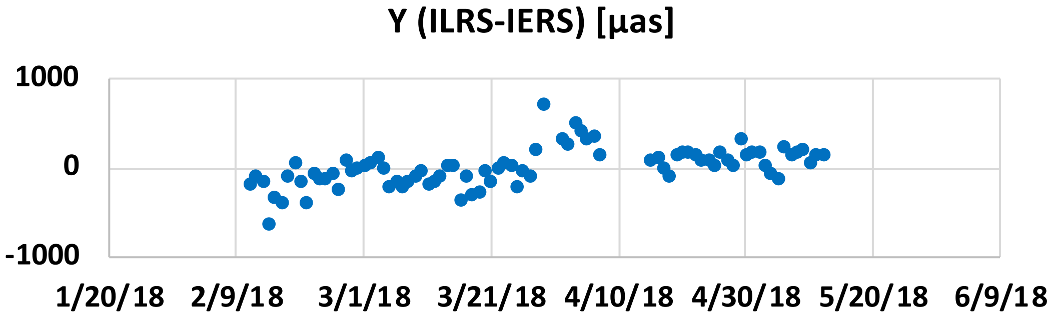
	Annual Yield Equivalent 2018
Sum	14287
Mean	649.4
Median	*288.2*
Std Deviation	1005.5

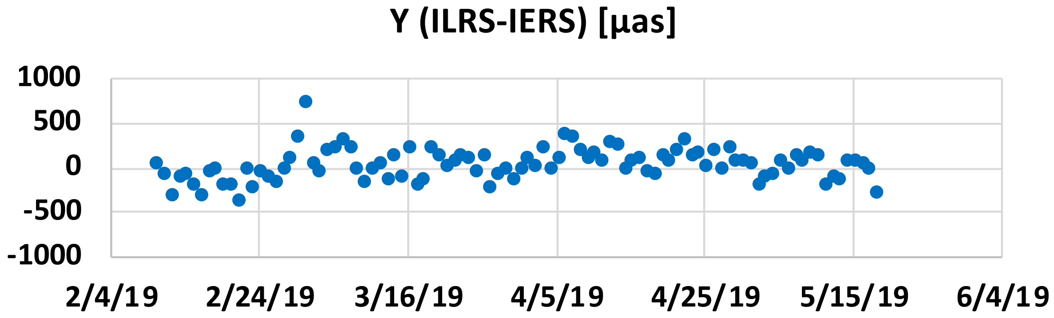
	Annual Yield Equivalent 2019
Sum	23079.3
Mean	1003.4
Median	*632.7*
Std Deviation	1077.5

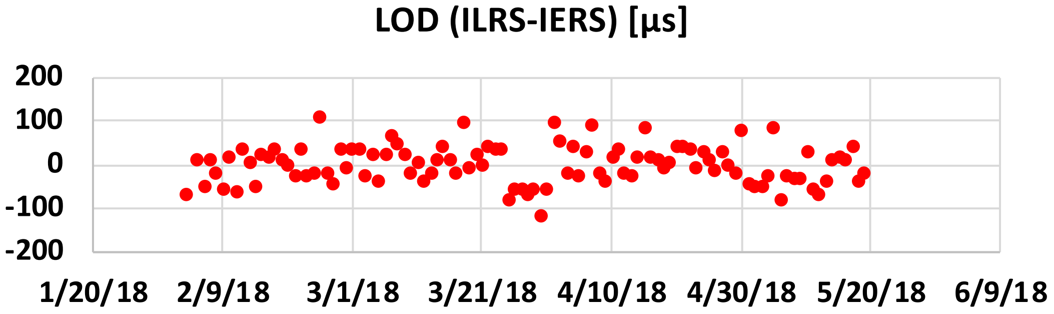
EOP Comparison for 2018 and 2019 Results

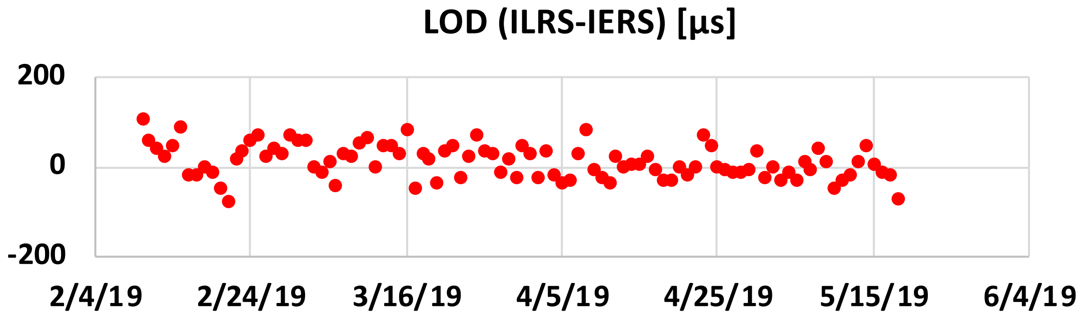












EOP Comparison Statistics for 2018 and 2019

2018 Non-Campaign Period

CASE	MEAN	STD	RMS
X (ILRS-IERS) [µas]	237.106	213.361	318.177
Y (ILRS-IERS) [µas]	-14.677	211.007	210.230
LOD (ILRS-IERS) [µs]	-3.409	43.595	43.521

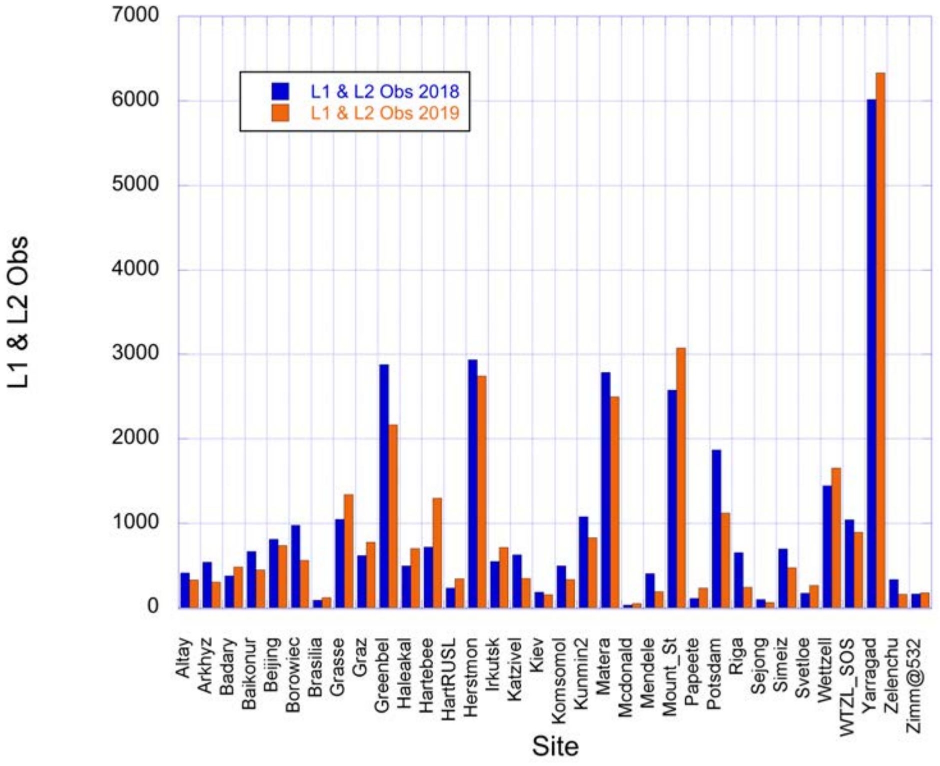
-37%
-18%
-15%

2019 Campaign Period

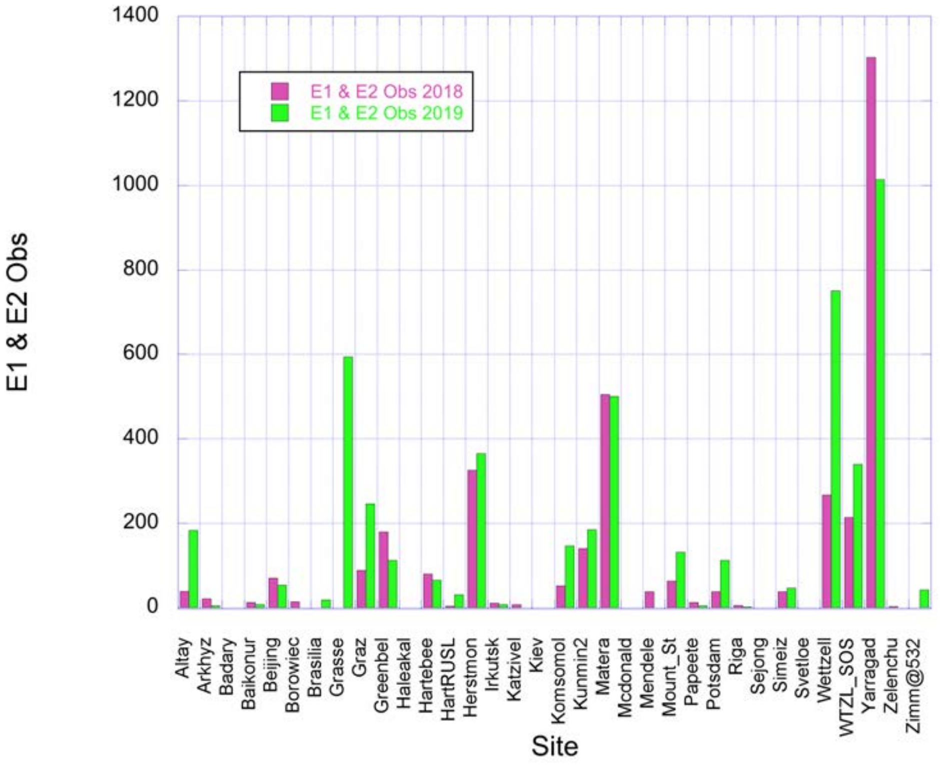
CASE	MEAN	STD	RMS
X (ILRS-IERS) [µas]	246.291	134.835	280.453
Y (ILRS-IERS) [µas]	19.722	172.845	173.088
LOD (ILRS-IERS) [µs]	6.590	36.875	37.274

SLR Data Comparison for 2018 vs 2019

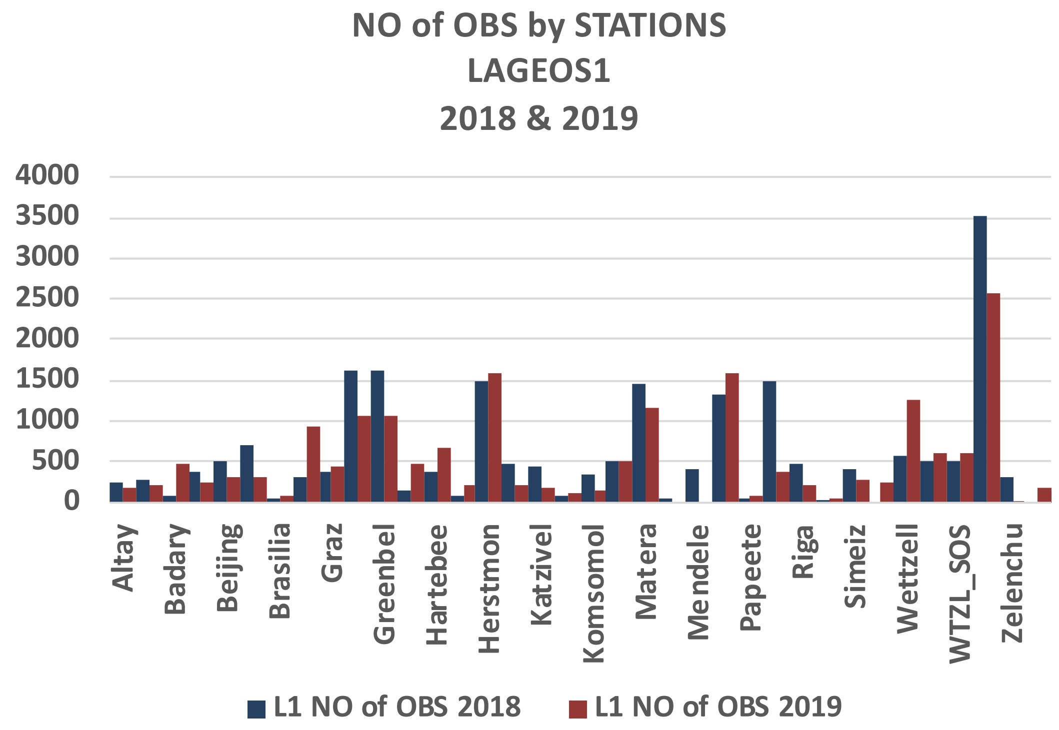
2018 vs 2019 LAGEOS – 1 & 2 Data



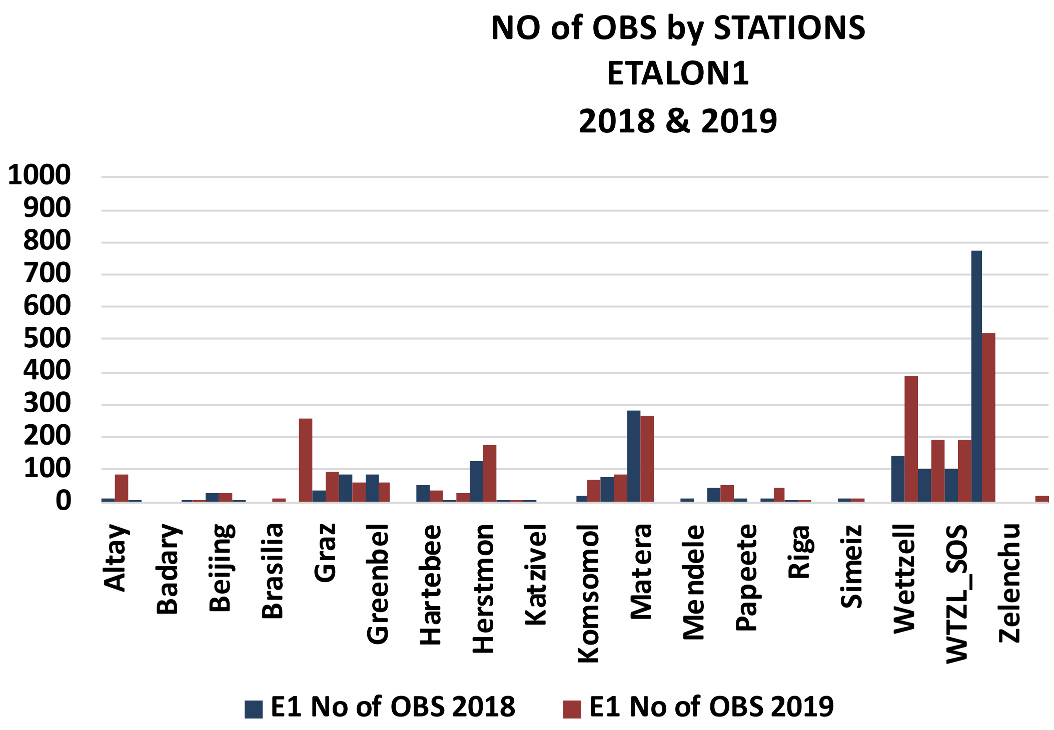
2018 vs 2019 Etalon – 1 & 2 Data



2018 vs 2019 LAGEOS - 1 Data

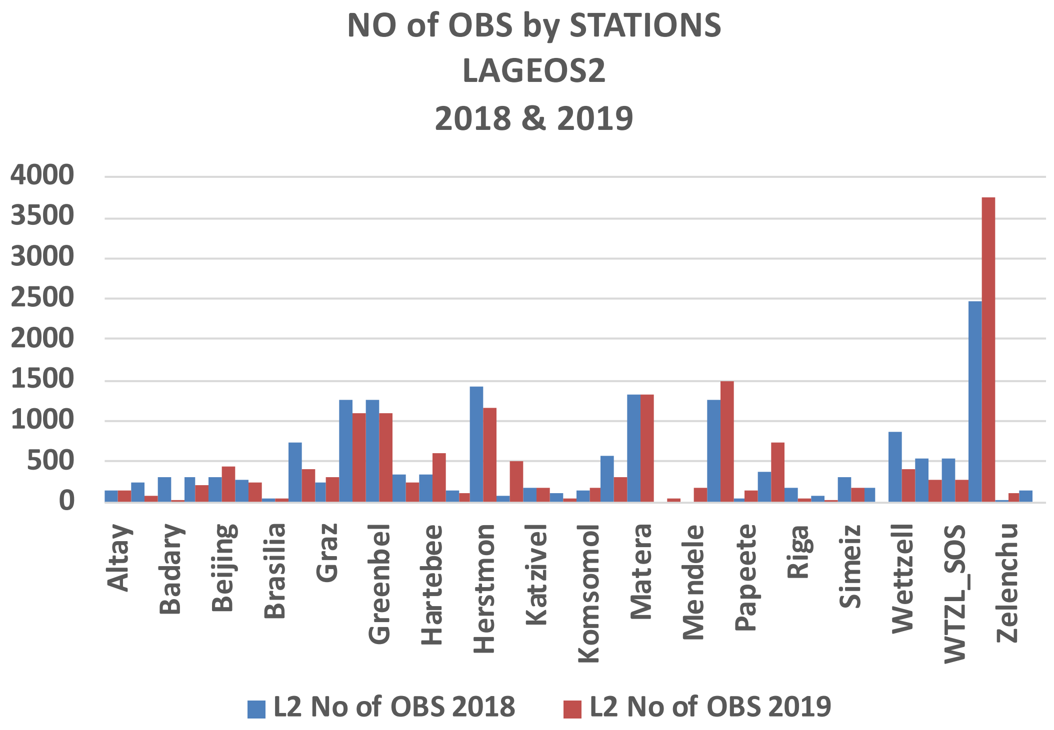


2018 vs 2019 Etalon -1 Data

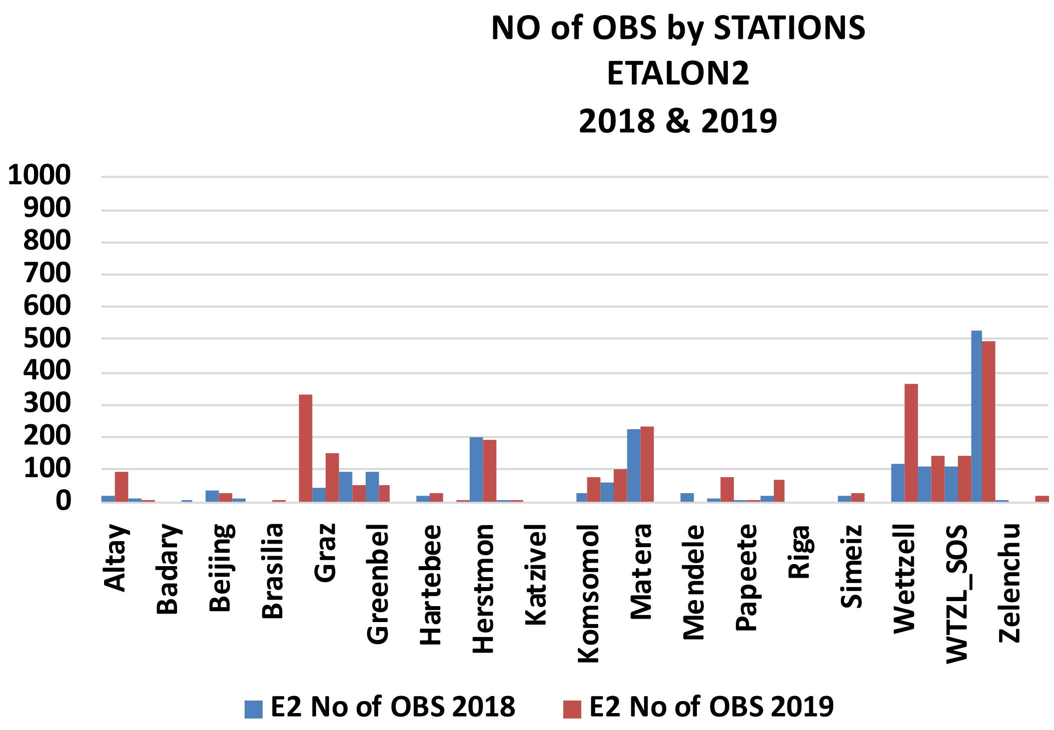


SLR Data Comparison for 2018 and 2019

2018 vs 2019 LAGEOS - 2 Data

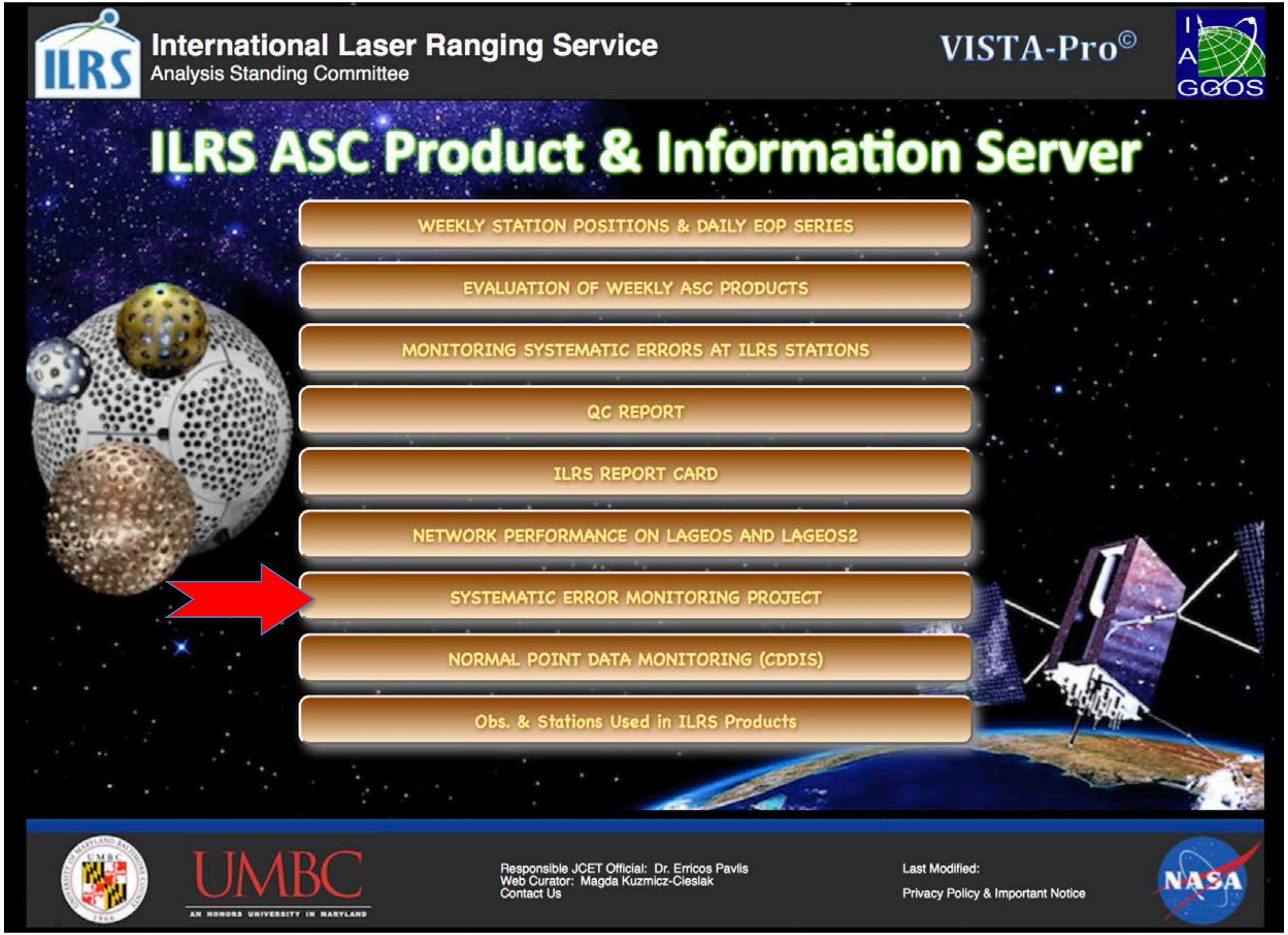


2018 vs 2019 Etalon - 2 Data



Station Systematic Error Monitoring-SSEM Project

JCET Portal UPDATE - 1



Station Systematic Error Monitoring Project

Station Systematic Errors Estimated from SLR DATA
Reanalysis Project Results since 1993

LAGEOS ESTIMATE	LAGEOS-2 ESTIMATE	COMBINED ESTIMATE ETALON1&2
☐ **ASI v230**	☐ **ASI v230**	☐ **ASI v230**
☐ **BKG v230**	☐ **BKG v230**	☐ **BKG v230**
☐ **JCET v230**	☐ **JCET v230**	☐ **JCET v230**
☐ **NSGF v230**	☐ **NSGF v230**	☐ **NSGF v230**

Start (MM-DD-YYYY): 1-01-2015

End Date (MM-DD-YYYY) 12-31-2019

Station 7840 Herstmonceux

Plot Size Minimum Maximum

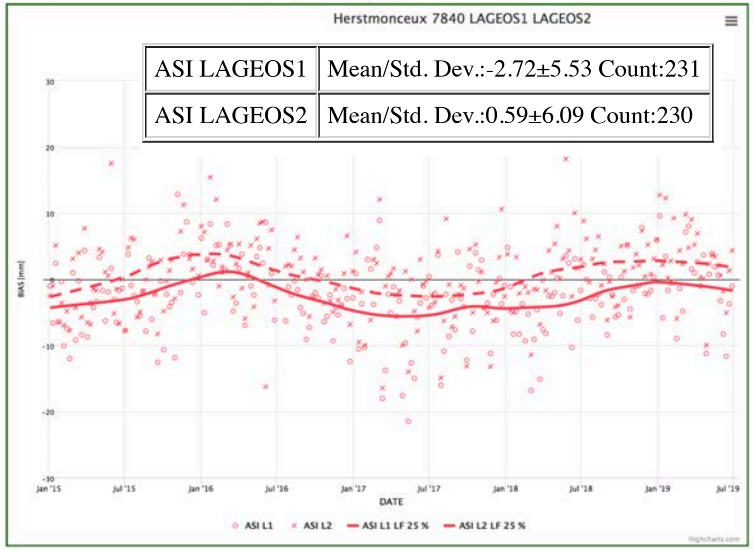
Y axis -30 30

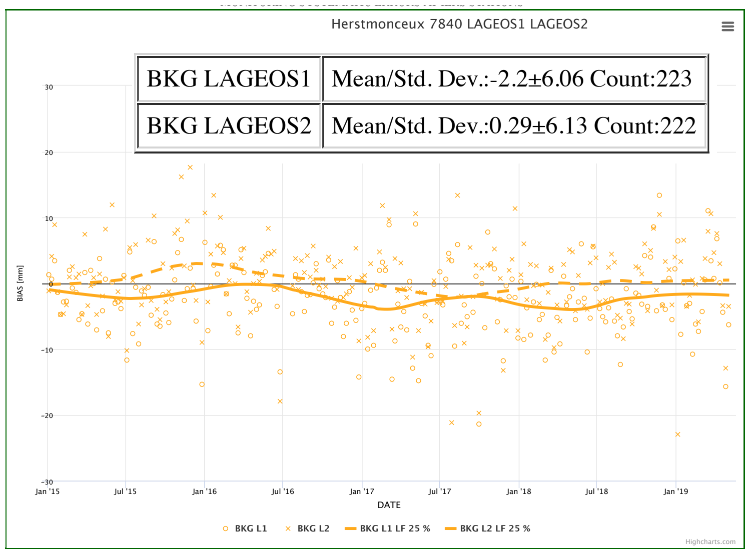
LOESS regression 25 %

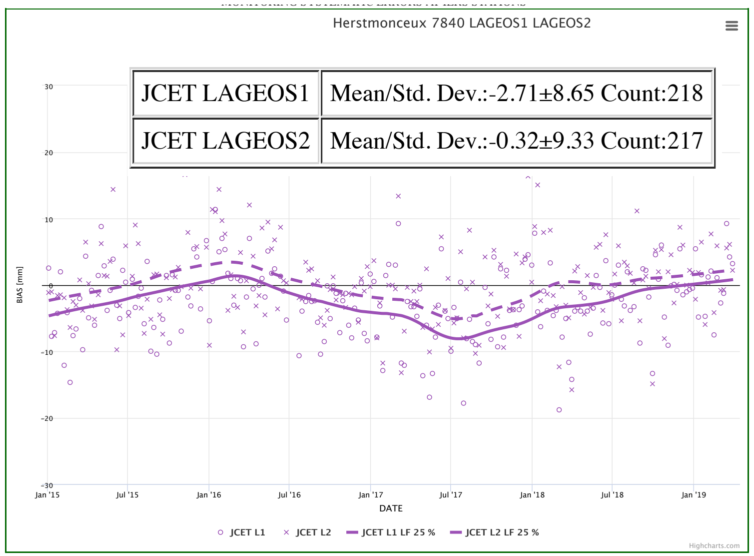
☐ SHOW STATION EVENTS LARGER THAN (SELECT BETWEEN 1-4) 0

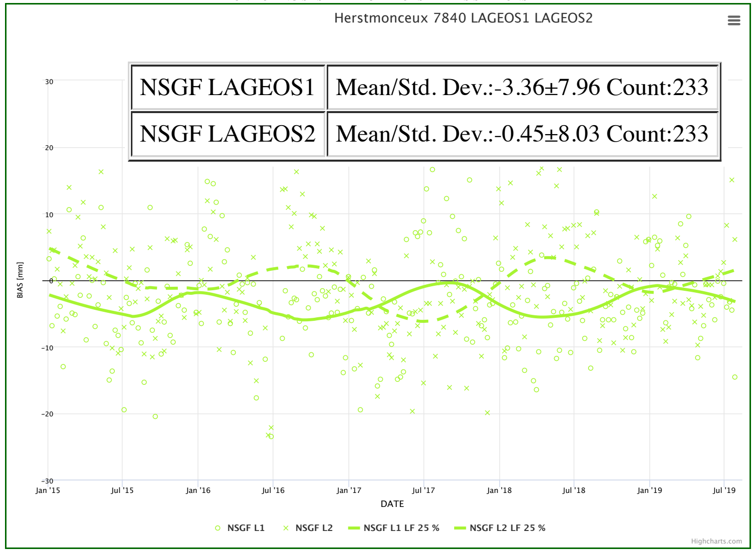
Submit Reset form

SSEM PP Results: Error in Herstmonceux ΔCoM?

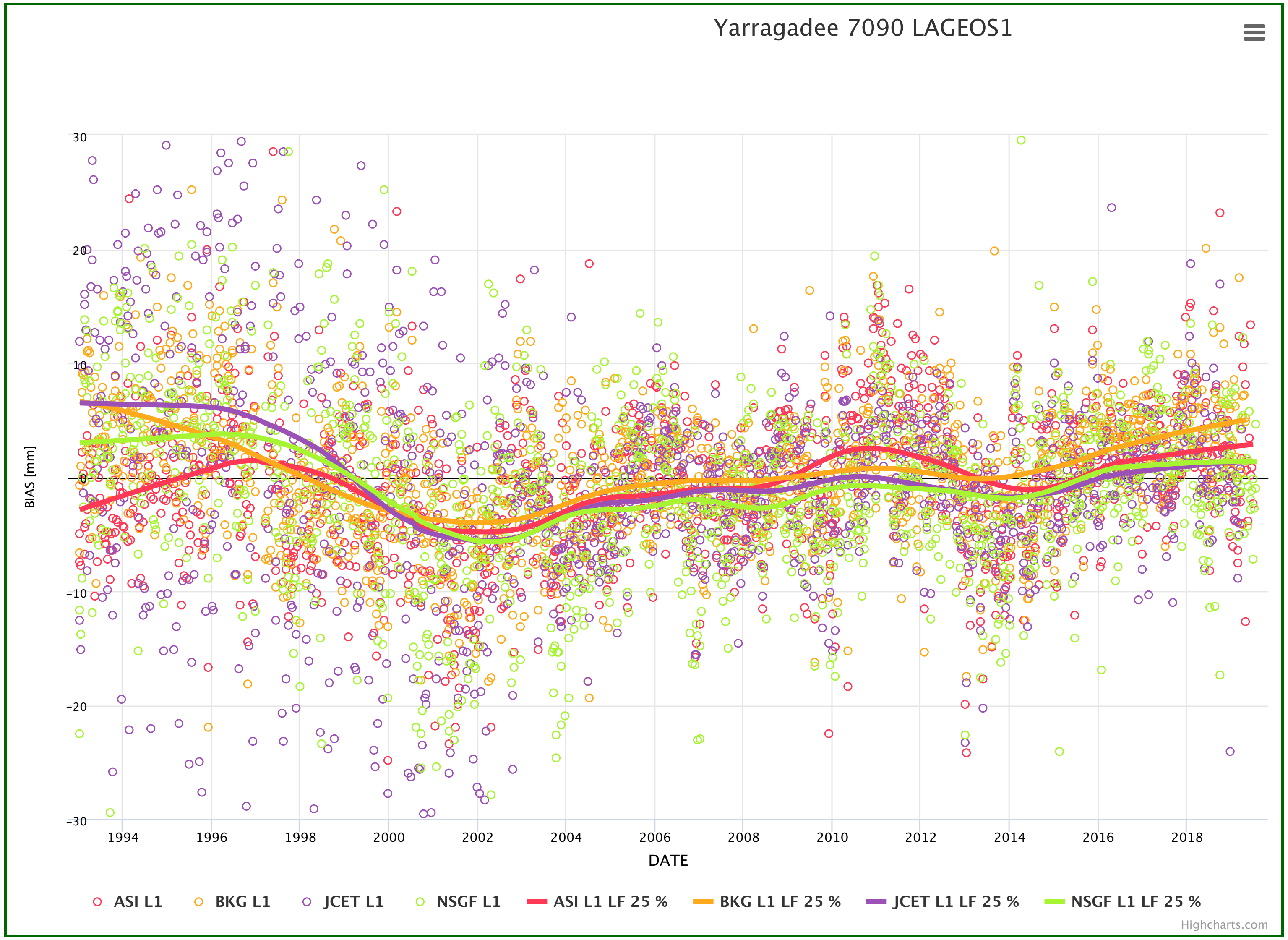




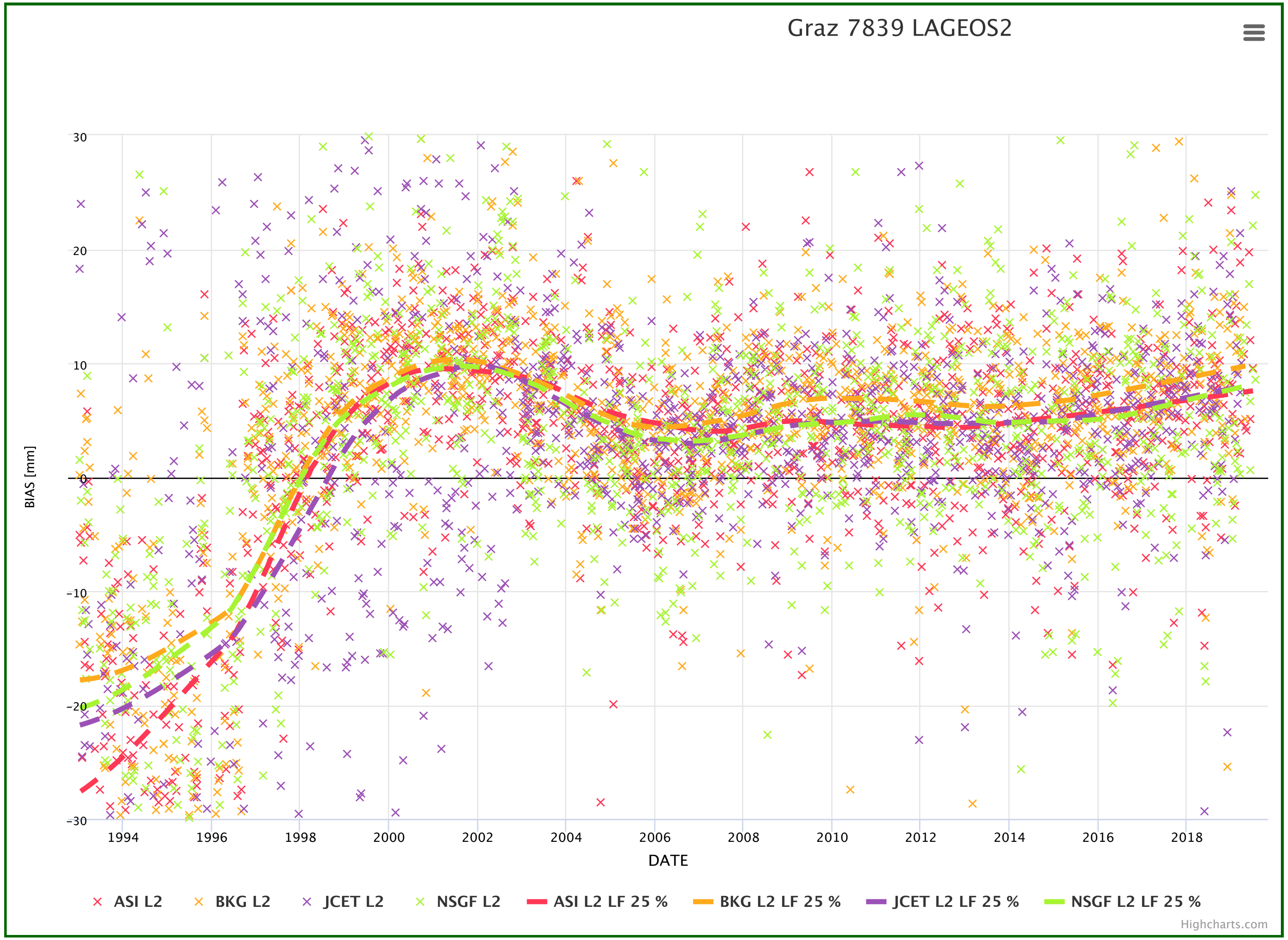




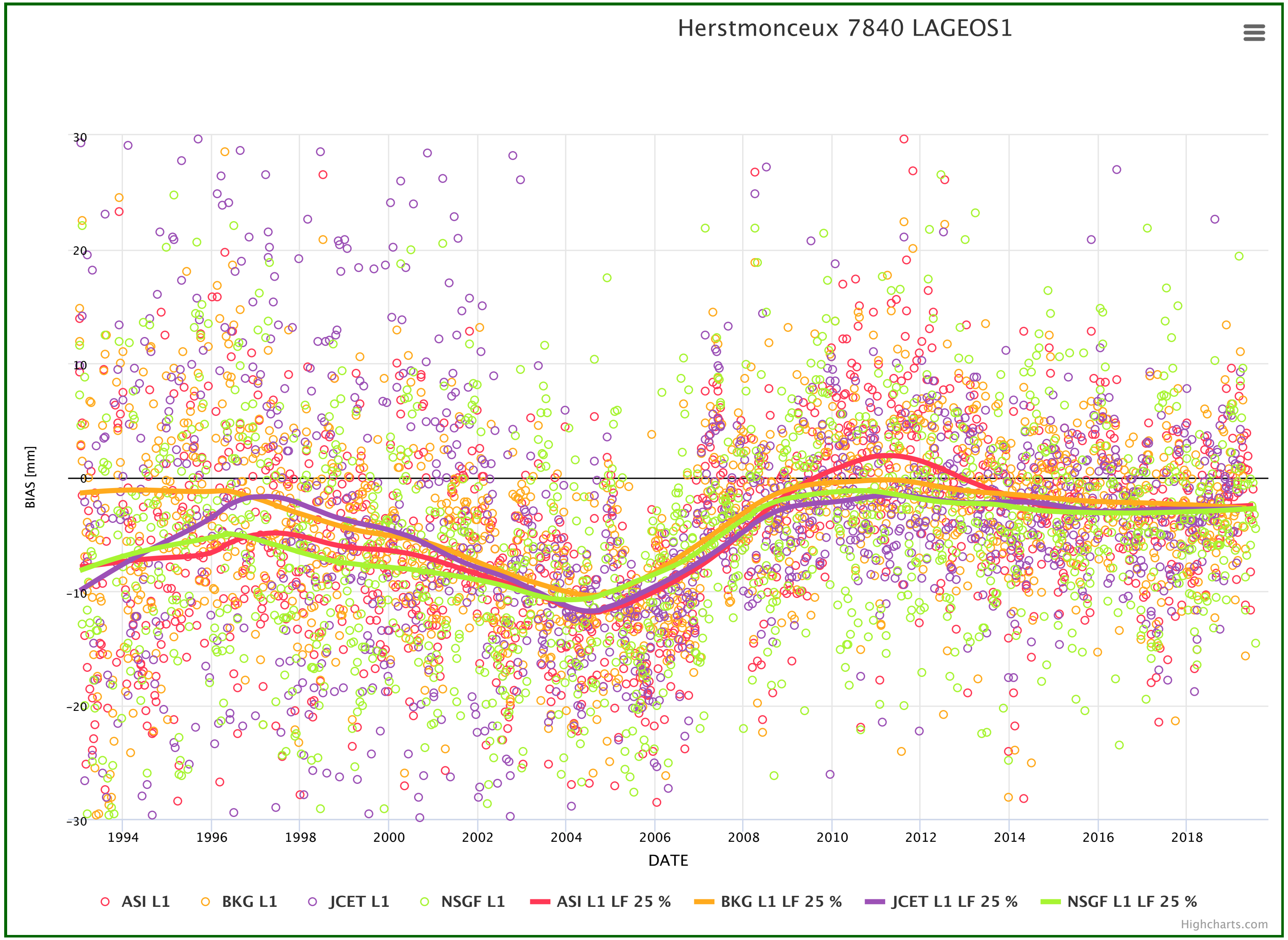
Station Systematic Error Project Results 1



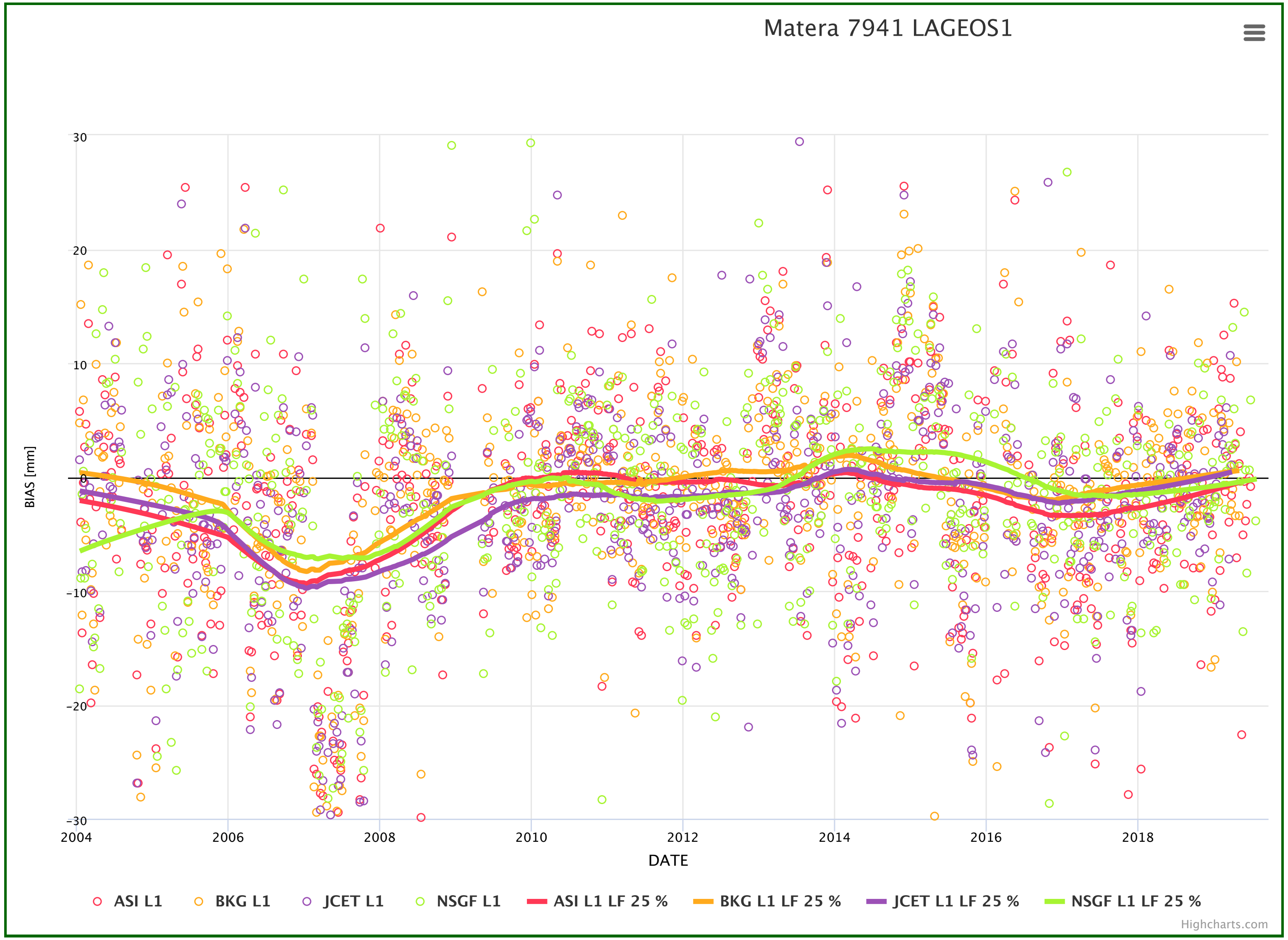
Station Systematic Error Project Results 2



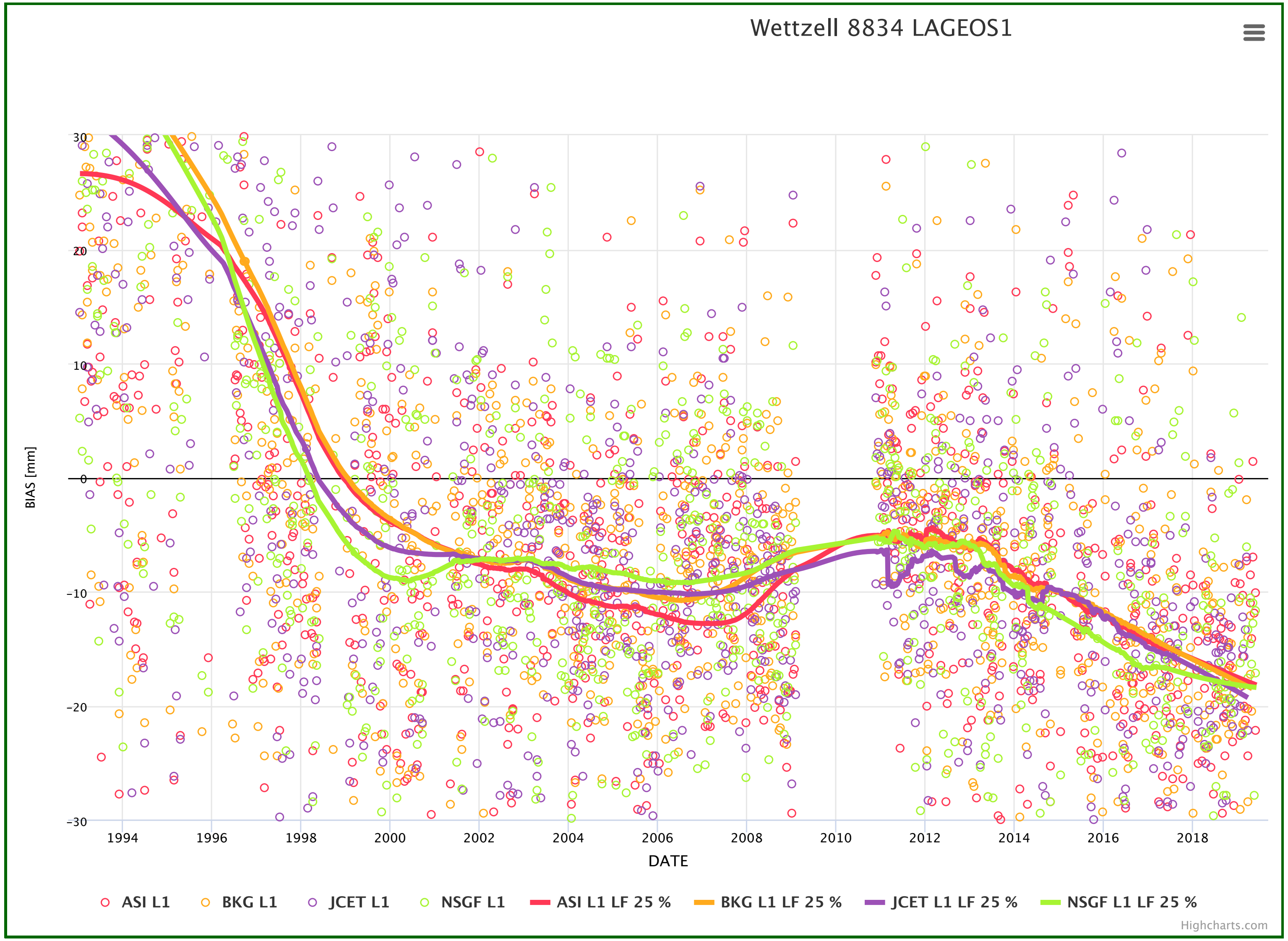
Station Systematic Error Project Results 3



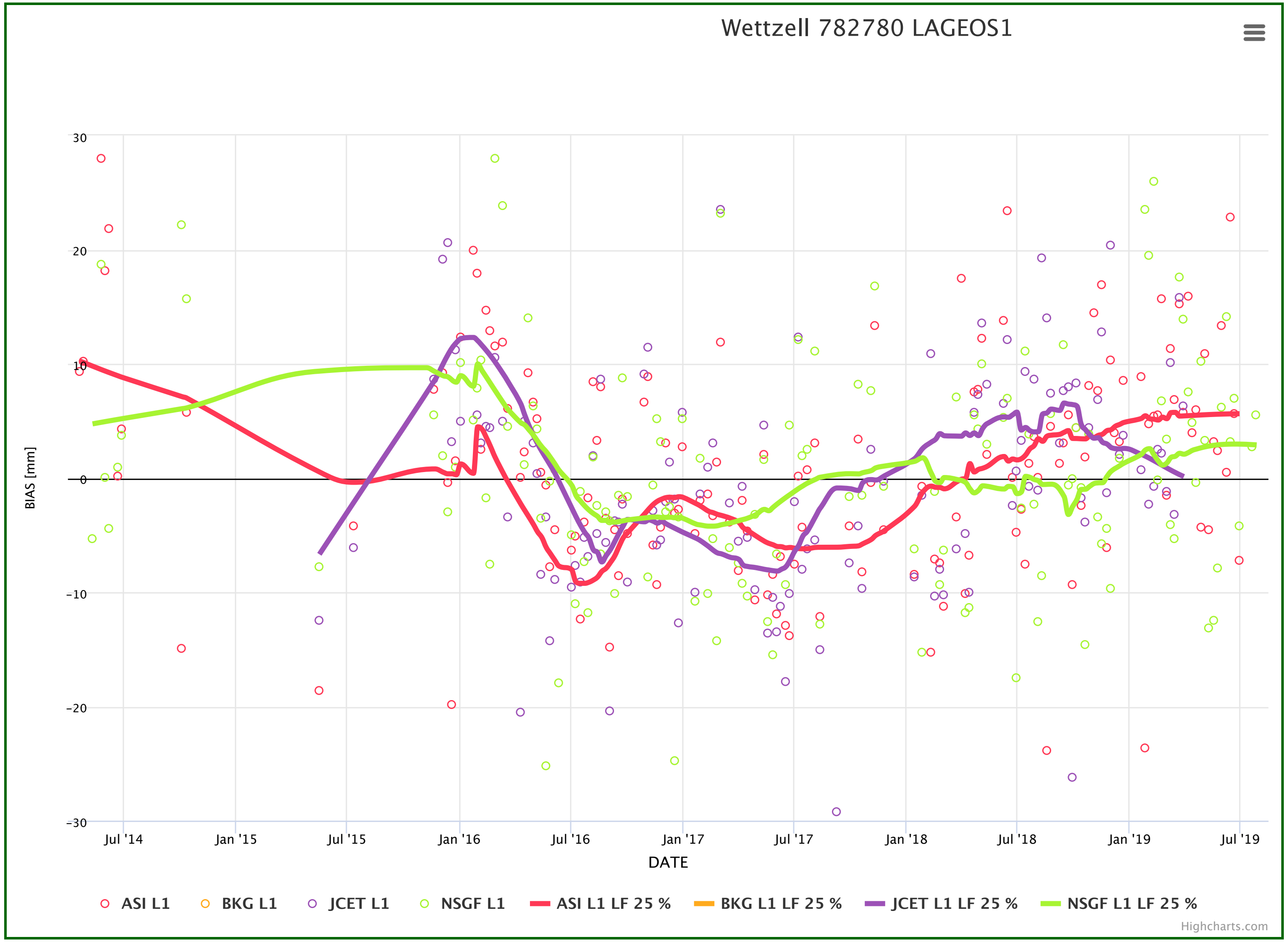
Station Systematic Error Project Results 4



Station Systematic Error Project Results 5



Station Systematic Error Project Results 6



Station Systematic Error Monitoring-SSEM Project -2

- We need to evaluate the results from ALL ACs and subsequently review the combined result for each LAGEOS;
- The combined time series will be reviewed for each system at each site and the goal here is to identify the "breaks" due to logged activities at the site (e.g. from their HST logs);
- At a next step we will need to discuss* with the stations any additional "events" identified in their time series, to rationalize the adoption of additional corrections (NEW RESULTS FROM NASA NETWORK, Van Husson's recent investigations);
- The adopted long-term mean biases will be applied a priori;
- We will need to do a "dry run" for 1-2 months, then move to an operational phase by March 1, 2020 or wait after the EGU**???**

* We already have had discussions up to ~2014, so we have most of the answers by now

NEW BIAS, TIMING BIAS & CoM CORRECTION BLOCK

GNSS SINEX Block Examples of Information

RECEIVER

```
+SITE/RECEIVER
*SITE PT SOLN T DATA_START__ DATA_END____ DESCRIPTION_________ S/N__ FIRMWARE___
ABMF  A     1 P 18:288:00000 18:290:86370 LEICA GR25          ----- -----------
ABPO  A     1 P 18:288:47700 18:288:86370 SEPT POLARX5        ----- -----------
```

ANTENNA

```
+SITE/ANTENNA
*SITE PT SOLN T DATA_START__ DATA_END____ DESCRIPTION_________ S/N__
ABMF  A     1 P 18:288:00000 18:290:86370 TRM57971.00     NONE -----
ABPO  A     1 P 18:288:47700 18:288:86370 ASH701945G_M    SCIT -----
```

ANT. PHASE CENTER

```
+SITE/GPS_PHASE_CENTER
*                           UP____ NORTH_ EAST__ UP____ NORTH_ EAST__
*DESCRIPTION_________ S/N__ L1->ARP(M)__________ L2->ARP(M)__________
3S-02-TSADM     NONE ----- 0.2543 0.0024 0.0031 0.2839 0.0005 0.0035 IGS14_2022
AOAD/M_B        NONE ----- 0.0598 0.0007 -.0005 0.0883 -.0003 -.0007 IGS14_2022
AOAD/M_T        DUTD ----- 0.0878 0.0003 -.0001 0.1190 0.0008 0.0002 IGS14_2022
```

ECCENTRICITY

```
+SITE/ECCENTRICITY
*                                             UP______ NORTH___ EAST____
*SITE PT SOLN T DATA_START__ DATA_END____ AXE ARP->BENCHMARK(M)_________
ABMF  A     1 P 18:288:00000 18:290:86370 UNE   0.0000   0.0000   0.0000
ABPO  A     1 P 18:288:47700 18:288:86370 UNE   0.0083   0.0000   0.0000
```

SATELLITE ID#

```
+SATELLITE/ID
*SITE PR COSPAR___ T DATA_START__ DATA_END____ ANTENNA_____________
G063 01 2011-036A P 11:197:00000 00:000:00000 BLOCK IIF
G061 02 2004-045A P 04:311:00000 00:000:00000 BLOCK IIR-B
```

s/c ANT. PHASE CENTER

```
+SATELLITE/PHASE_CENTER
*SITE L SATA_Z SATA_X SATA_Y L SATA_Z SATA_X SATA_Y MODEL_____ T M
G063 1 1.5018 0.3940 0.0000 2 1.5018 0.3940 0.0000 IGS14_2022 A E
G061 1 0.7288 0.0013 -.0011 2 0.7288 0.0013 -.0011 IGS14_2022 A E
```

Proposal for a SINEX Block with Corrections/Biases

MODIFIED
Jose's VERSION:
ARC Start-End
USED

```
*         1         2         3         4         5         6         7         8
*234567890123456789012345678901234567890123456789012345678901234567890123456789012345678901234567890
*-------------------------------------------------------------------------------
+SITE/BIAS
*SITE PT SOLN T DATA_START__ DATA_END____ RANGE_BIAS TIME_BIAS____   COM_CORR
 1873 L1  501 L 18:288:00000 18:295:00000    -0.0193    -0.0193456     0.1234
 1873 L2  501 L 18:288:00000 18:295:00000    -0.0193    -0.0193456     0.1234
 1879 L1  501 L 18:288:00000 18:295:00000     0.0193    -0.0193456     0.1234
 1879 L2  501 L 18:288:00000 18:295:00000     0.0193    -0.0193456     0.1234
```

Or:
ABOVE VERSION
WITHOUT DATES
INCREASED
Tbias PRECISION

```
*         1         2         3         4         5         6         7         8
*234567890123456789012345678901234567890123456789012345678901234567890123456789012345678901234567890
*-------------------------------------------------------------------------------
+SITE/BIAS
*SITE PT SOLN T RANGE_BIAS TIME_BIAS____   COM_CORR
 1873 L1  501 L    -0.0193    -0.0193456     0.1234
 1873 L2  501 L    -0.0193    -0.0193456     0.1234
 1879 L1  501 L     0.0193    -0.0193456     0.1234
 1879 L2  501 L     0.0193    -0.0193456     0.1234
```

CURRENT T_{bias}
ENTRIES
IN DH FILE (µs)

```
*CODE PT_ UNIT T _DATA_START_ __DATA_END__ M __E-VALUE___ STD_DEV _E-RATE__ _CMNTS_
 1824 --- us   A 10:126:00000 10:127:00000 T      -17.750   1.000    0.0000 -------
 1824 --- us   A 10:132:00000 10:133:00000 T       -5.750   1.000    0.0000 -------
 1824 --- us   A 12:084:68460 12:085:00000 T      -24.400   5.000    0.0000 -------
 1873 --- us   A 09:059:00000 09:110:00000 T      -21.750  50.000   -0.2600 c.drift
 1873 --- us   A 09:324:00000 10:095:00000 T        2.000  50.000    0.0750 c.drift
 1873 --- us   A 10:096:00000 10:159:00000 T        6.150  50.000    0.4000 c.drift
 1873 --- us   A 10:350:00000 11:064:00000 T     -380.000  50.000   -9.0000 c.drift
```

Preliminary Results on a Proposal to Add Troposheric Refraction Horizontal Gradient Modeling

Proposal based on a recent paper:

Journal of Geodesy
https://doi.org/10.1007/s00190-019-01287-1

ORIGINAL ARTICLE

Check for updates

Troposphere delay modeling with horizontal gradients for satellite laser ranging

M. Drożdżewski[1] · K. Sośnica[1] · F. Zus[2] · K. Balidakis[2]

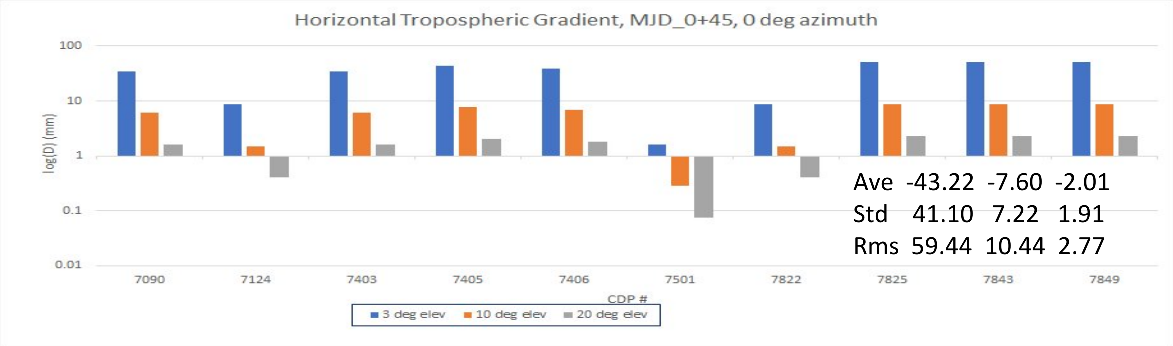
Received: 4 March 2019 / Accepted: 7 August 2019

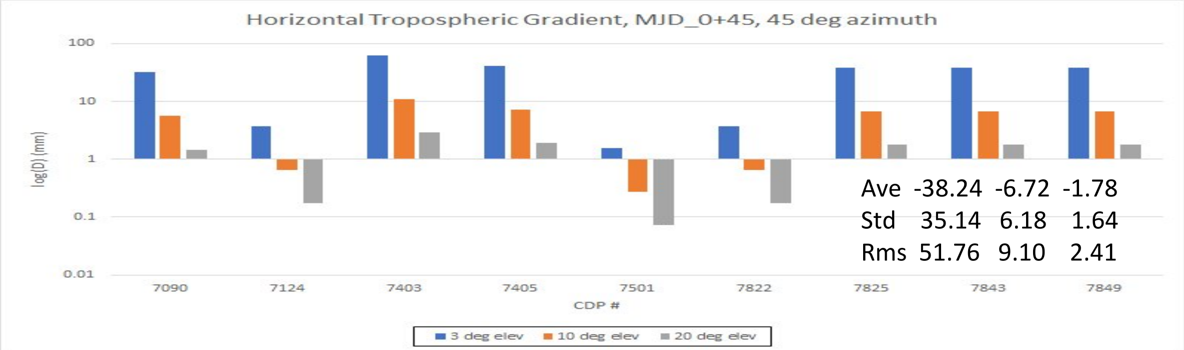
Proposed Model Tests with GEODYN and v230 SSEM Series (v232)

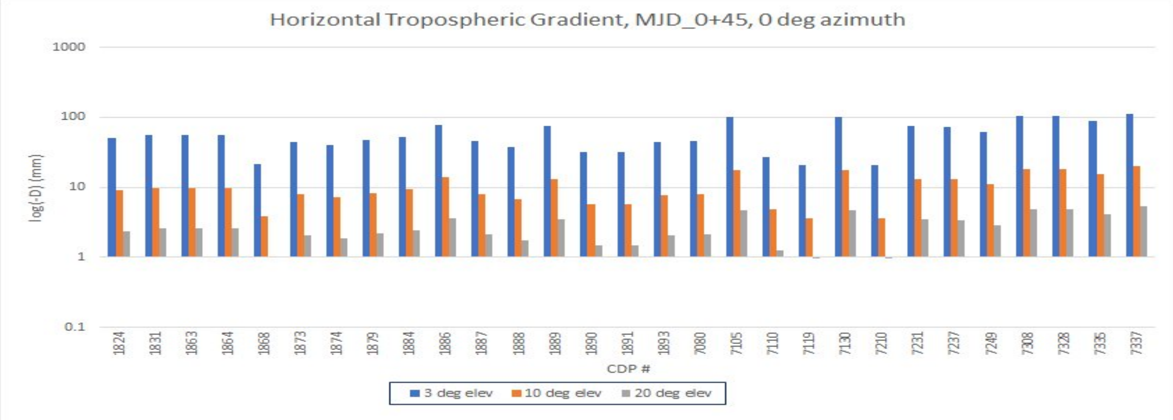
- We implemented the proposed model in Geodyn and reanalyzed the 2015 to present data set as in the v230 series;
- We evaluated the model at all active ILRS systems for 0°, 45° and 90° Azimuth, and Elevation 3°, 10° and 20°, for 4 dates in a year covering the four seasons;
- We compared the estimated biases from the two series and created a data base for visualization of the results;
- A comparison of the statistics of the two series of estimates shows that the biases are affected to a fraction of 1 mm in the mean and less than 1 μm in RMS, i.e. the scatter of the two series is unchanged at that level;
- These results indicate that at present the current model is not providing us the expected improvement seen by earlier studies when the ACTUAL meteorological fields were used to generate the gradients;
- We propose not to proceed with the adoption of the current version for the ITRF2020 reanalysis and wait for an improved version that will be based on actual meteorological fields.

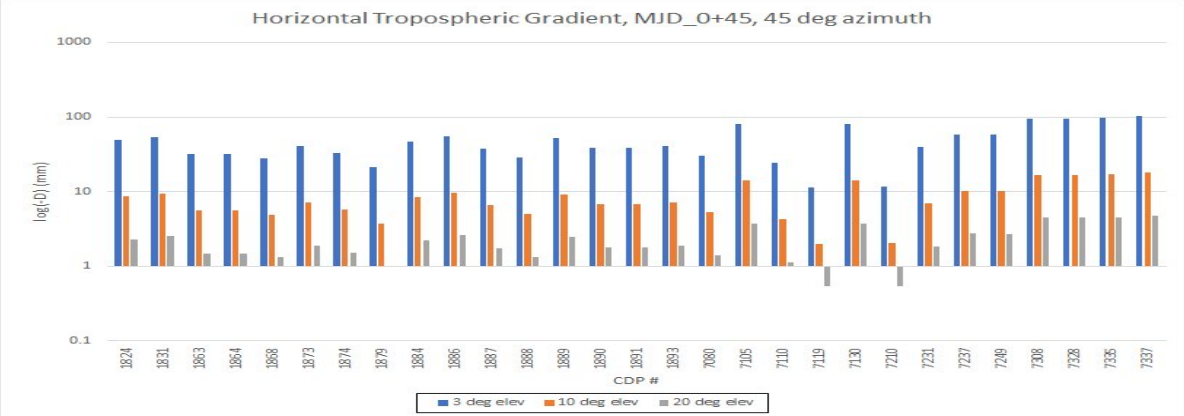
MJD_0+45 days, 0 Az

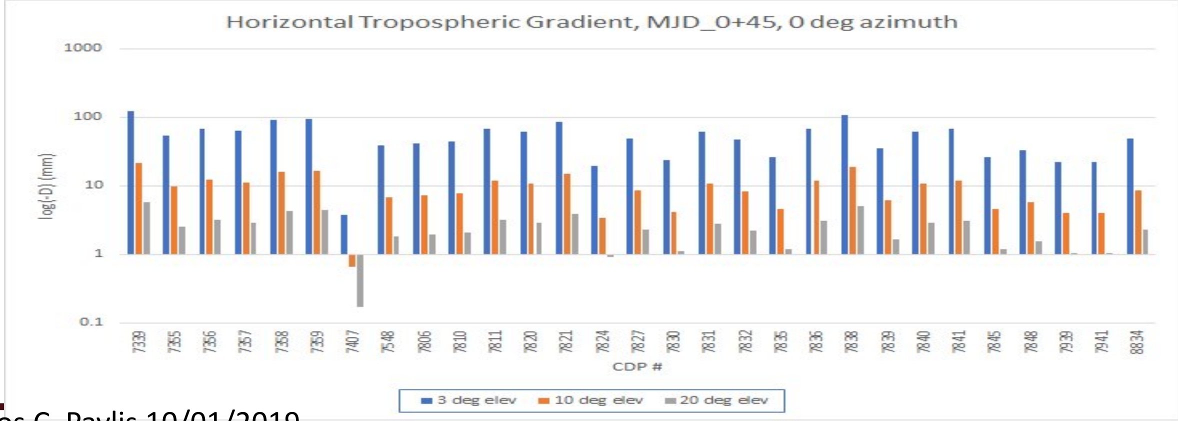
MJD_0+45 days, 45 Az

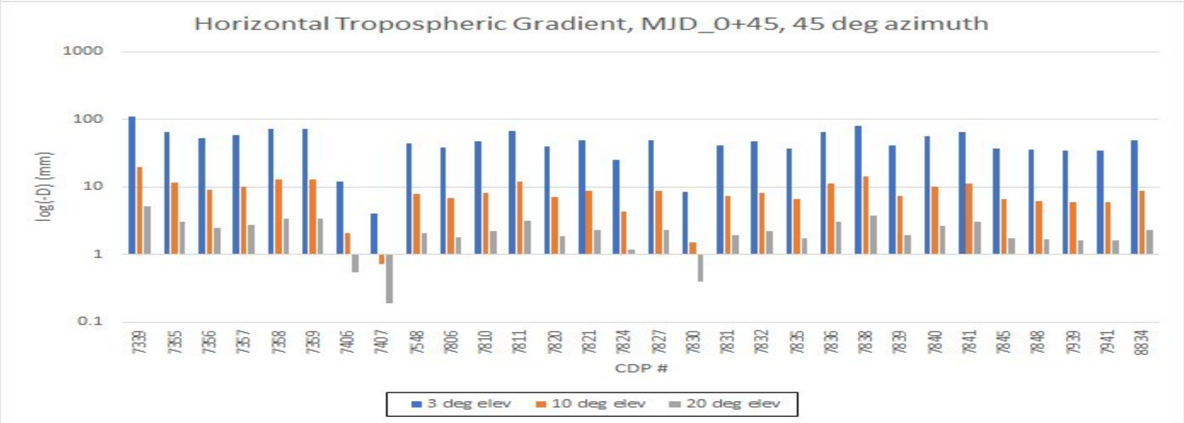






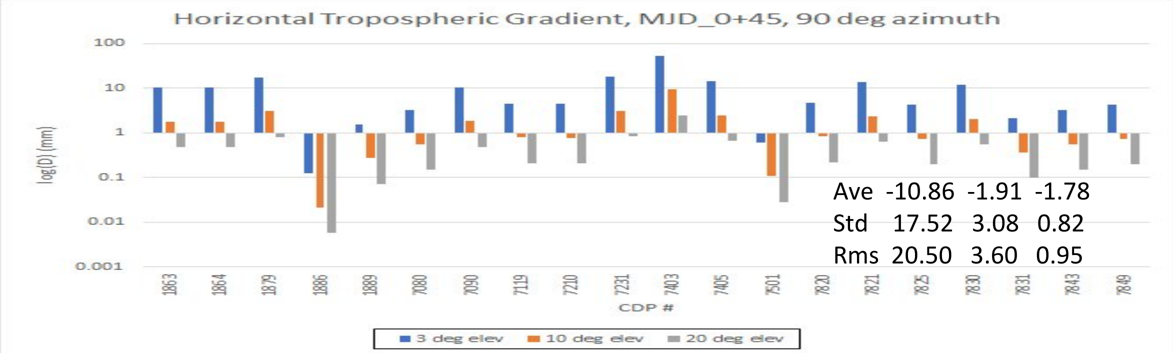


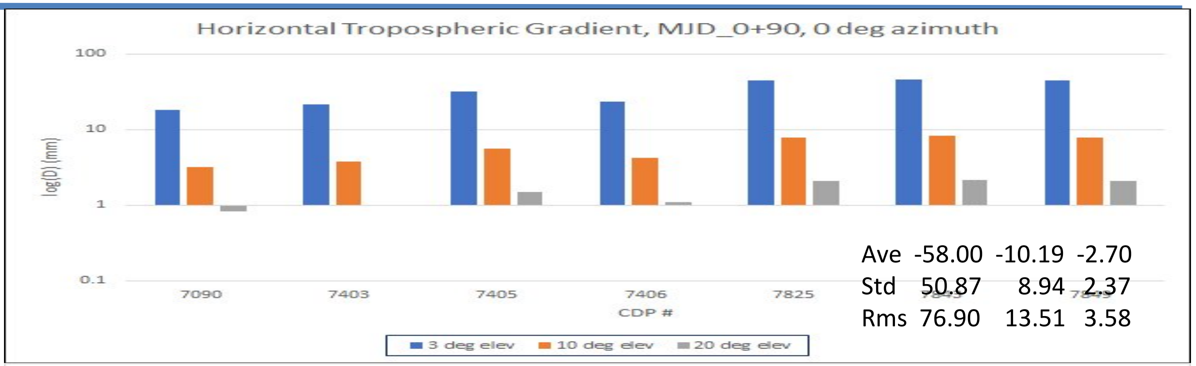


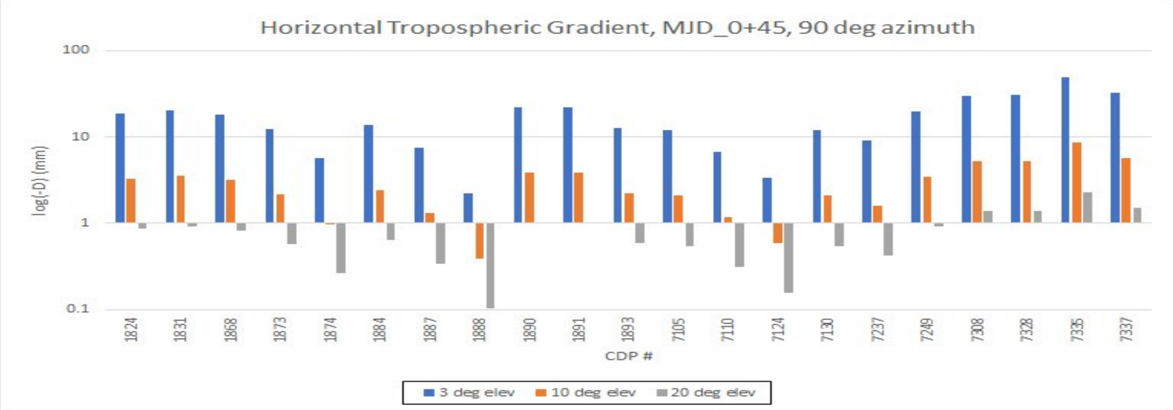


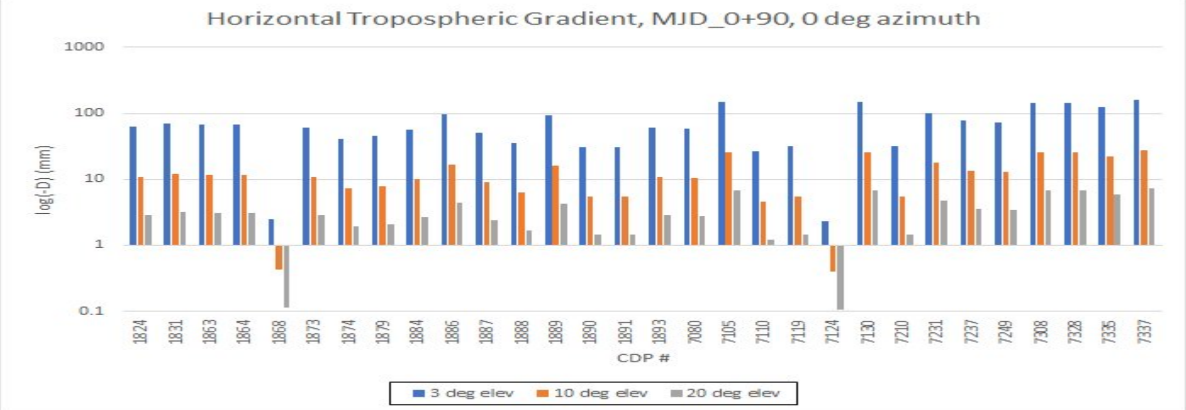
MJD_0+45 days, 90 Az

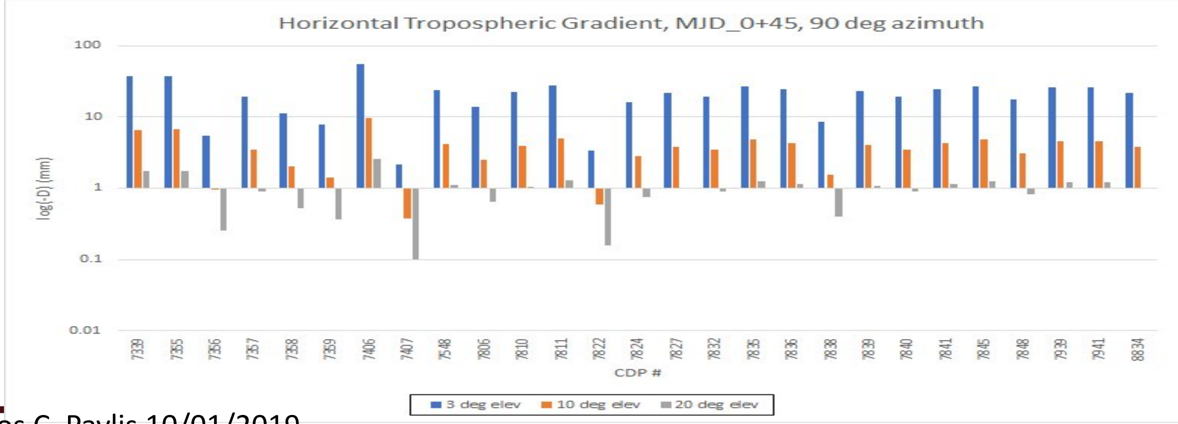
MJD_0+90 days, 0 Az

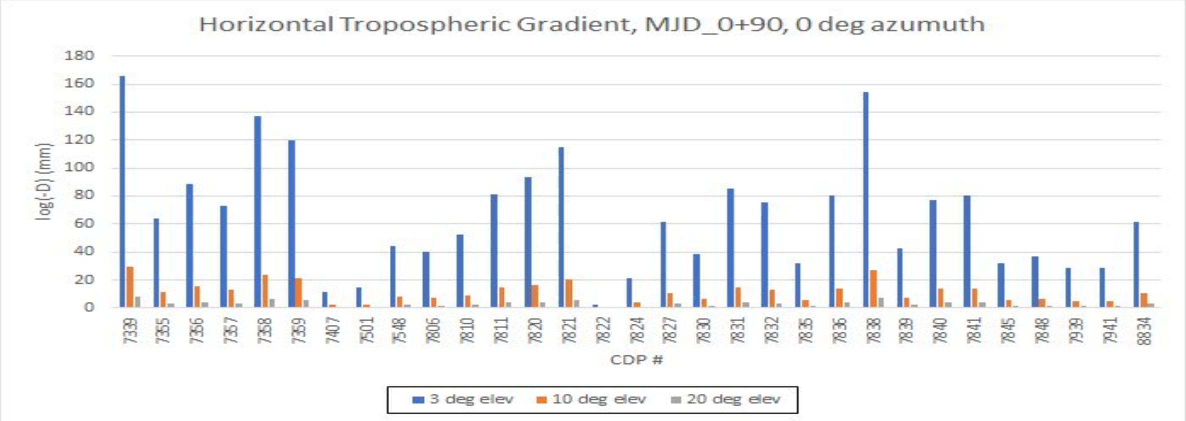






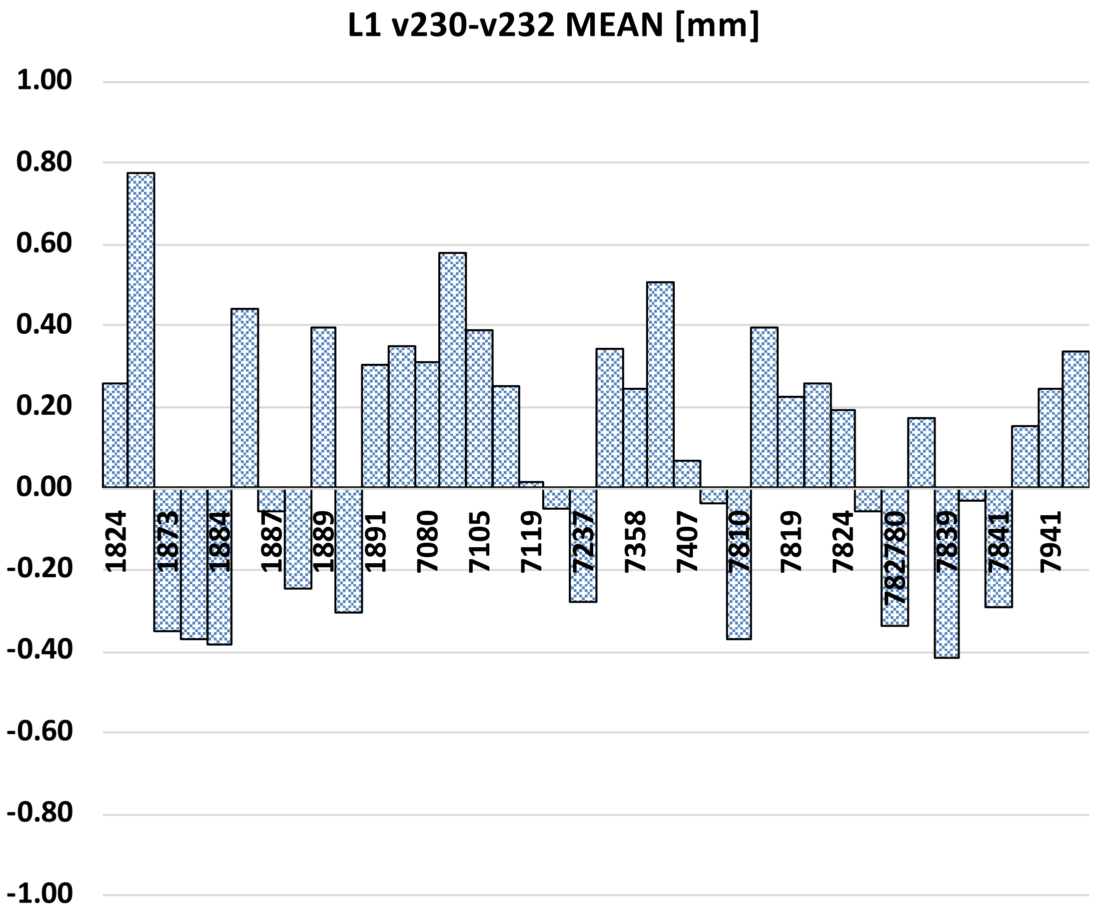




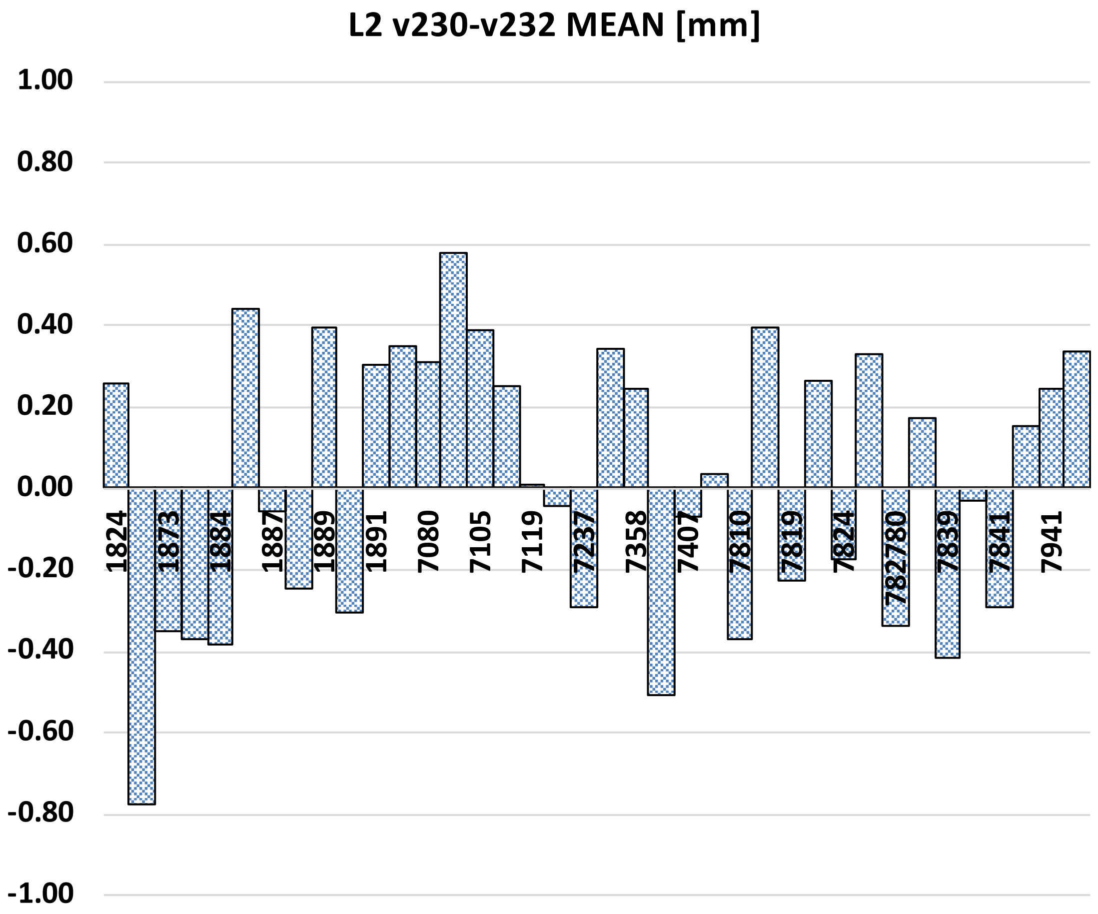


Differences in the mean bias estimate

LAGEOS

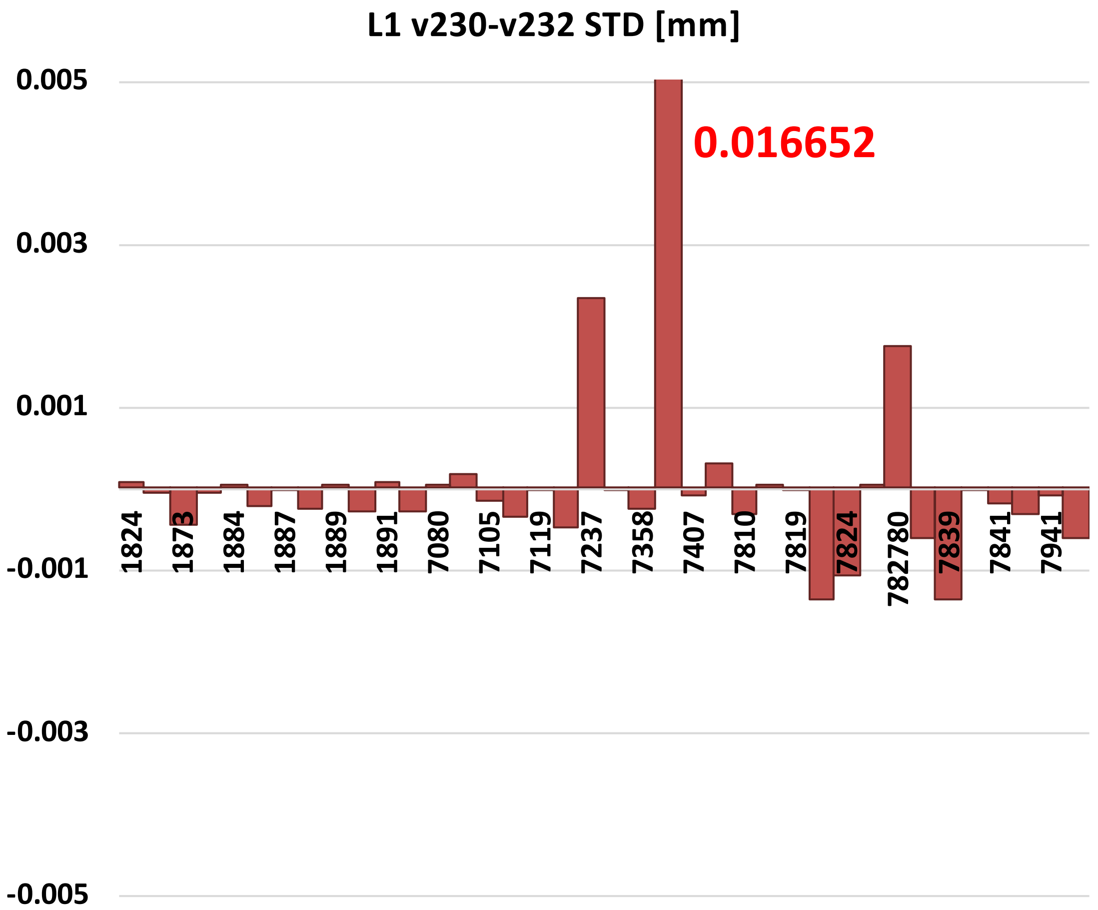


LAGEOS - 2

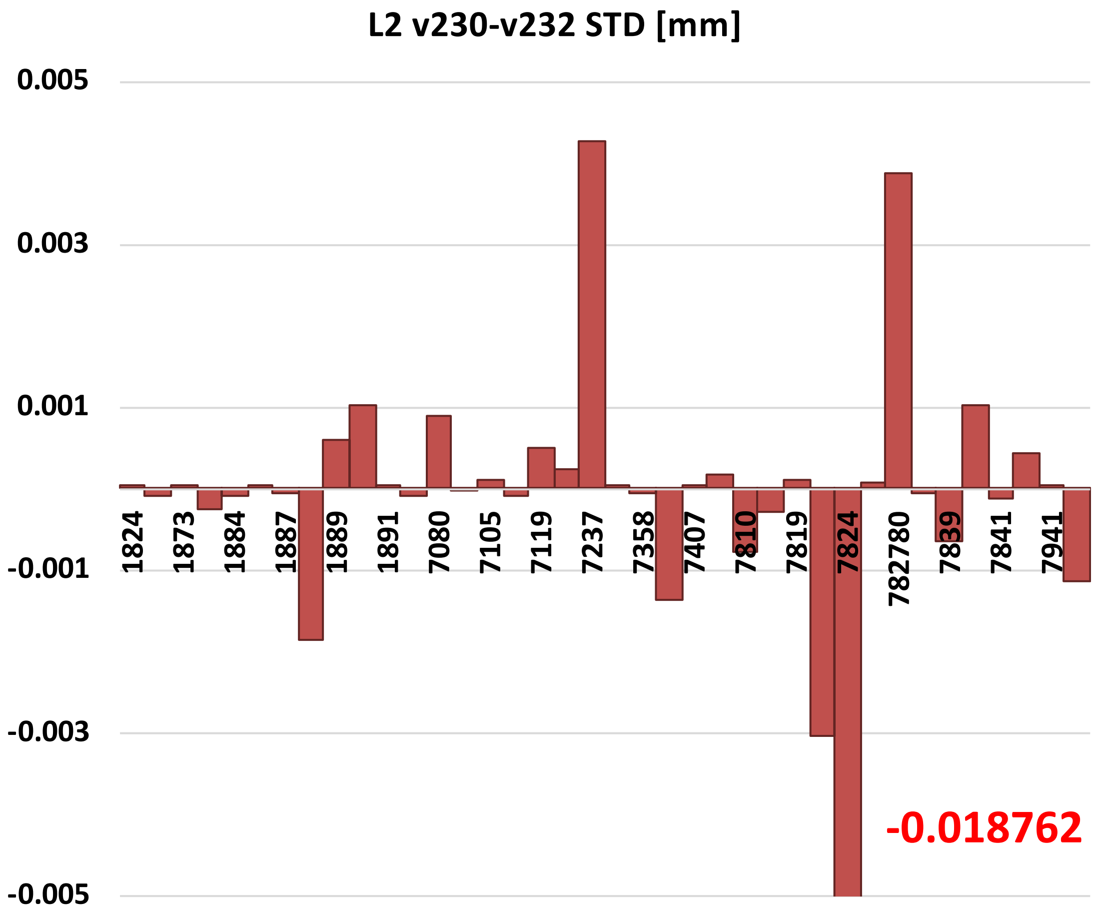


Std. Dev. of the estimated bias differences

LAGEOS



LAGEOS - 2



ILRS 2016-2018 Report Status (Carey Noll)

ILRS 2016-2018 Report Contributions

7	Combination/Analysis/Associate Analysis/Lunar Center Reports				
	Introduction to ILRS products		Erricos/Cinzia	5 pages	Carey drafted
		What data products does SLR produce?			
		What new data products are in process?			
		What are the major issues and limitations?			
	CC/AC/AAC/LAAC Reports, including:		CCs/ACs/AACs/LAACs	2-3 pages each	
		Name of center			
		List of personel			
		Areas of interest			
		Progress over the last 3 years			
		Plans and challenges			
		Contact name/address/email/website of center			
		Photos/graphs/etc.			
		Publications			

AC Reports	**Report Received?**
BKG	Y
DGFI	
ESA	
GFZ	Y
ASI	
JCET	
NERC	
CC Reports	
ASI	
JCET	

Annex

Etalon Visibility Graphs for Proposed Campaign Stations

Site Selection for the SSEM Project

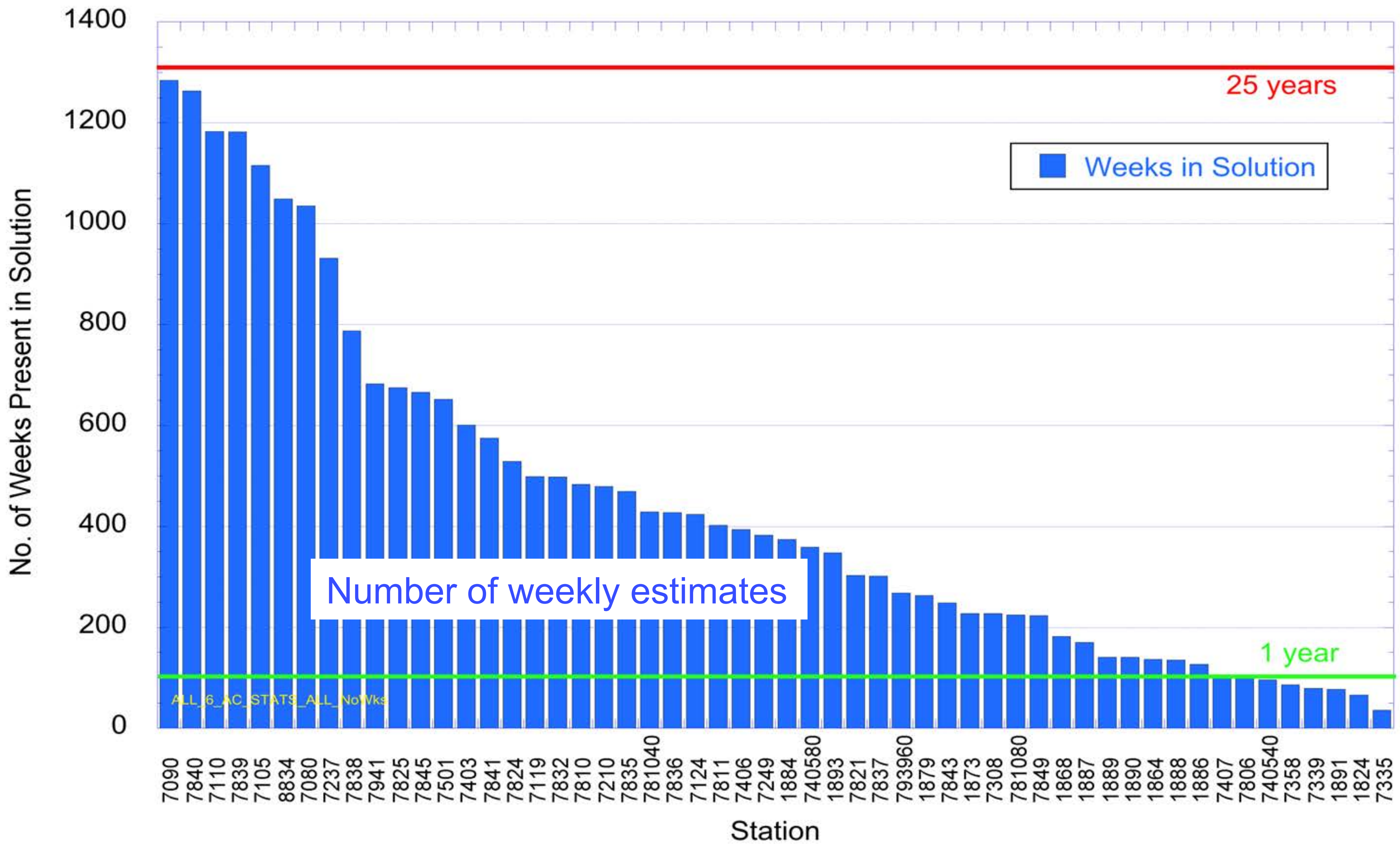
1824 Golosiiv
~~1831 Lviv~~
~~1863 Maidanak 2~~
1864 Maidanak 1 2003.0->
1868 Komsomolsk-na-Amure 2008.0 ->
1873 Simeiz 2001.0 ->
1879 Altay
1884 Riga
~~1885 Riga~~
1886 Arkhyz
1887 Baikonur
1888 Svetloe
1889 Zelenchukskya
1890 Badary
1891 Irkutsk
1893 Katzively
~~1953 Santiago~~
7080 McDonald Obs.
7090 Yarragadee
~~7097 Easter I~~
7105 Greenbelt
7110 Monument Peak
7119 Haleakala
7122 Mazatlan

7124 Easter I
7124 Tahiti
~~7125 Greenbelt~~
~~7130 Greenbelt~~
7210 Haleakala
~~7231 Wuhan~~
7236 Wuhan
7237 Changchun
7249 Beijing
~~7295 Richmond~~
7308 Koganei
~~7328 Koganei~~
7335 Kashima 99/04-00/05
~~7337 Miura~~
7339 Tateyama
~~7355 Urumqi~~
~~7356 Lhasa~~
~~7357 Beijing-A~~
7358 Tanegashima
~~7359 Daedeok~~
~~7394 Sejong~~
7403 Arequipa
~~7404 Santiago~~
7405 Conc@423
7405 Conc@847

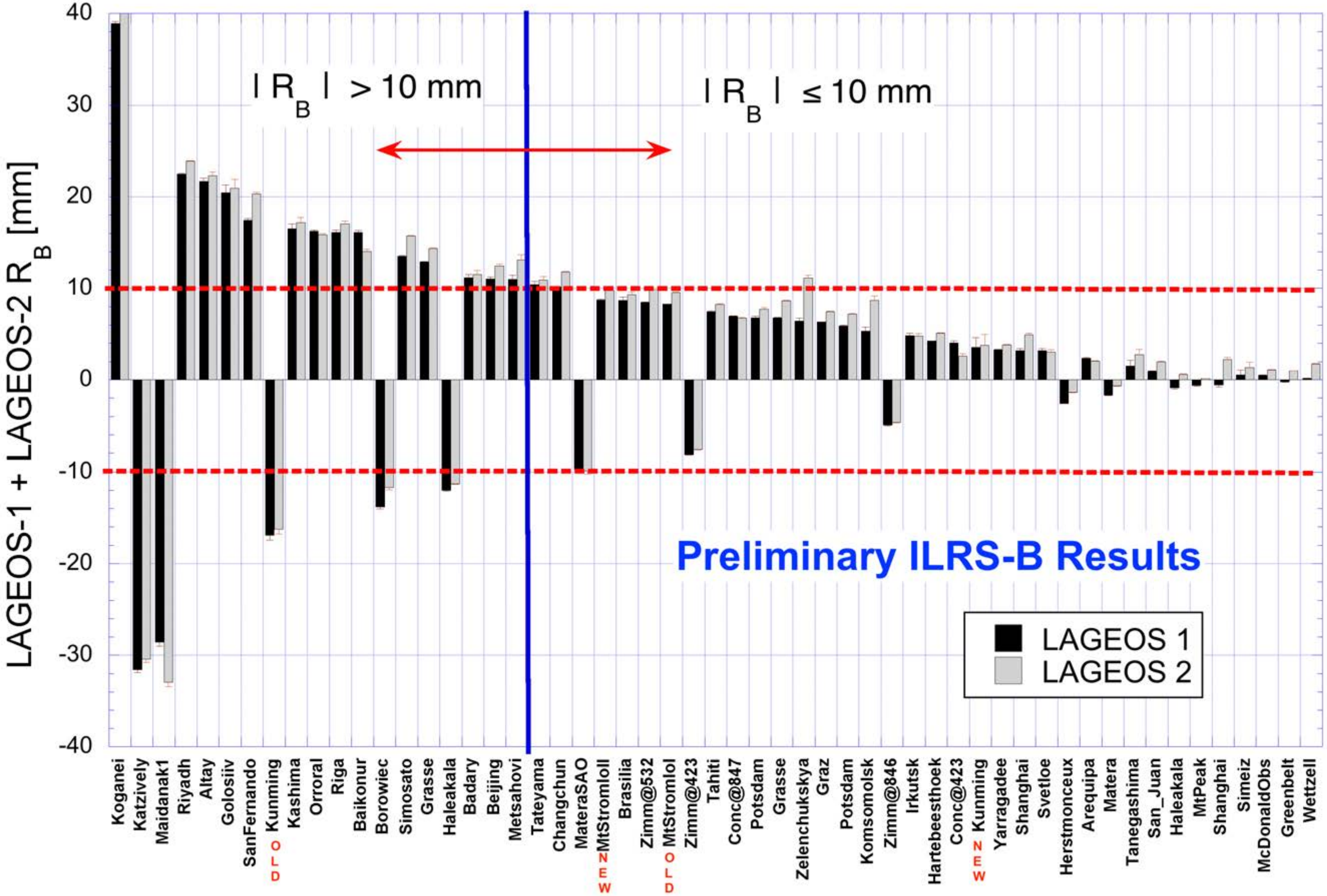
7406 San Juan → 2013.0
7407 Brasilia
~~7410 Algonqui~~
~~7411 La Grand~~
7501 Hartebeesthoek
~~7502 Sutherla~~
~~7525 Xrisokel~~
~~7530 Bar Giyy~~
~~7545 Punta Sa~~
~~7548 Cagliari~~
~~7597 Wettzell~~
7806 Metsahovi 99/09->
7810 Zimm@423
7810 Zimm@532
7810 Zimm@846
7811 Borowiec
7819 Kunming
~~7820 Kunming~~
7821 Shanghai
~~7822 Tahiti~~
~~7823 San Fernando~~
7824 San Fernando
7825 Mt Stromlo
~~7830 Chania~~
~~7831 Helwan~~

7832 Riyadh
7835 Grasse
7836 Potsdam
7837 Shanghai
7838 Simosato
7839 Graz
7840 Herstmonceux
7841 Potsdam
7843 Orroral
7845 Grasse
~~7848 Ajaccio~~
7849 Mt Stromlo
~~7850 Mcdonald~~
~~7882 Cabo San~~
~~7883 Ensenada~~
~~7884 Albuquer~~
~~7918 Greenbelt~~
7939 Matera
7941 Matera
~~8833 Kootwijk~~
8834 Wettzell

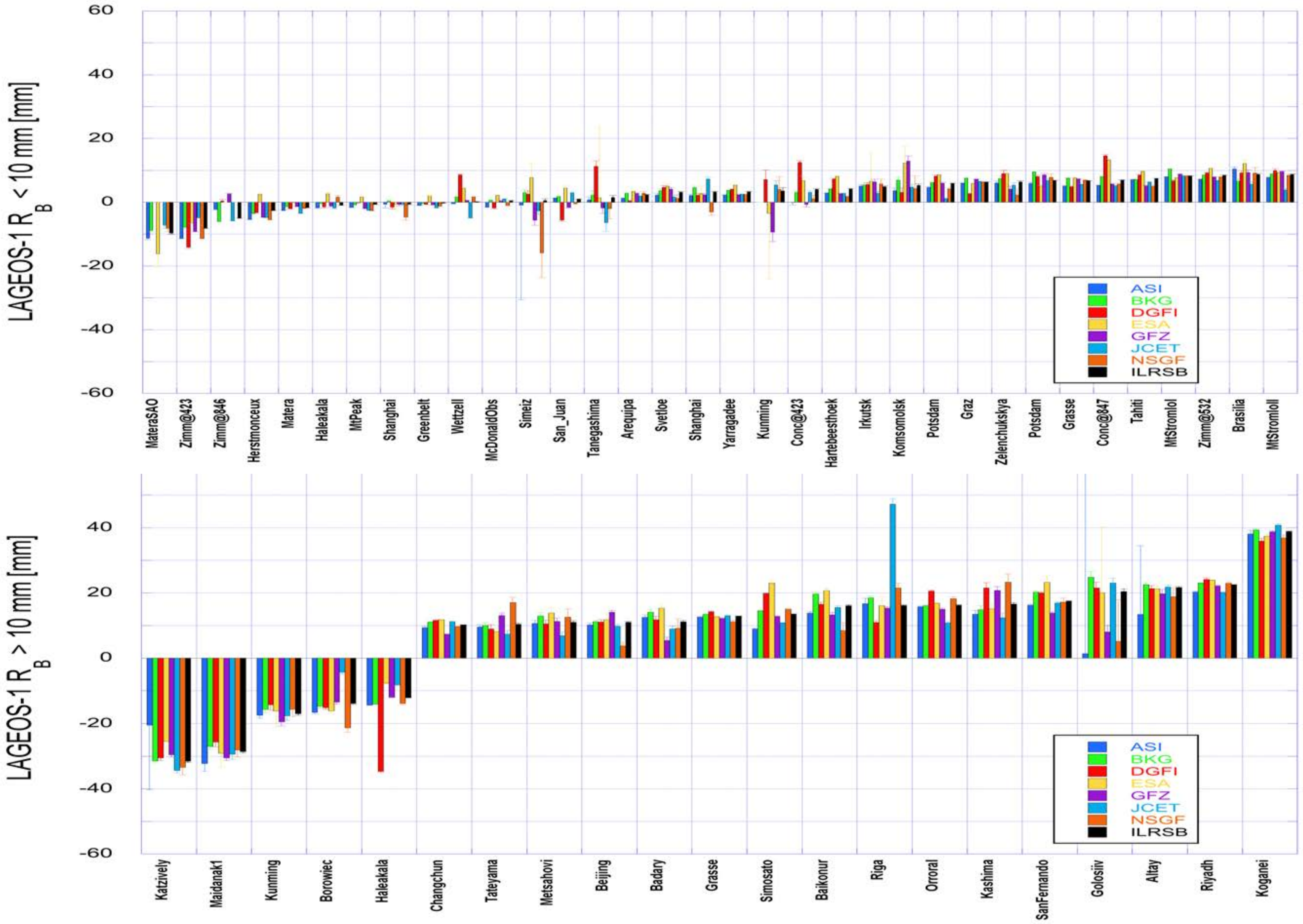
Site Participation in the SSEM Project



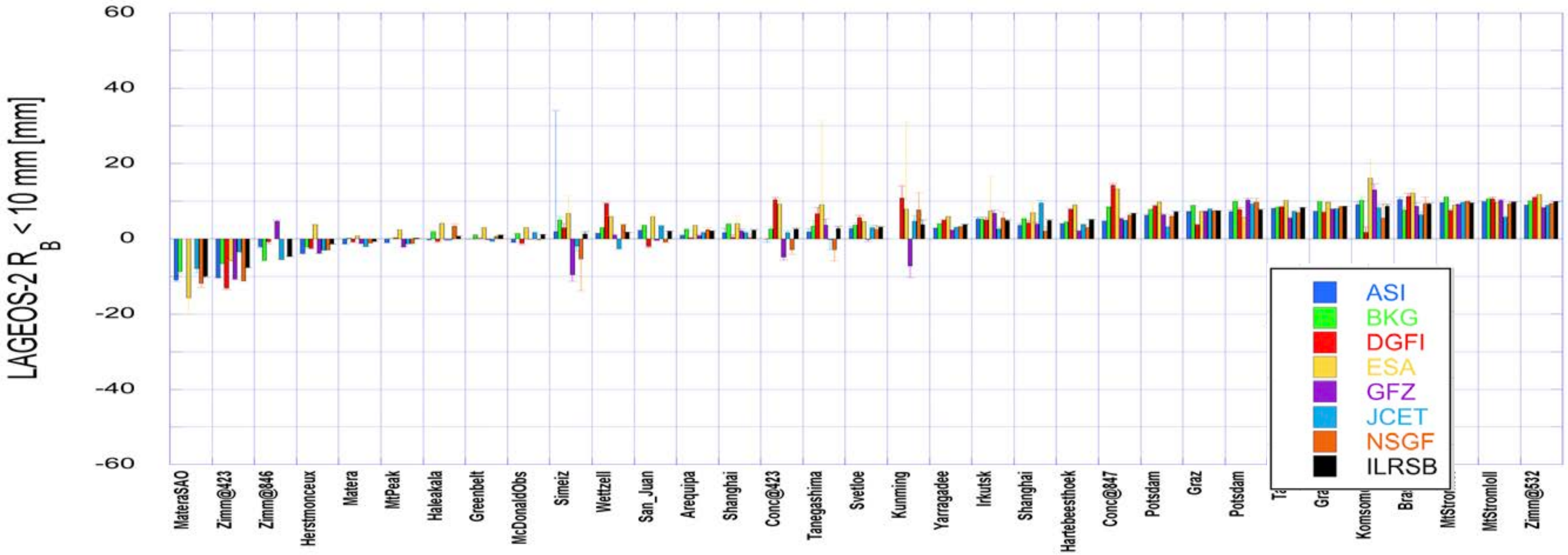
Long-term Systematic Errors LAGEOS1/2

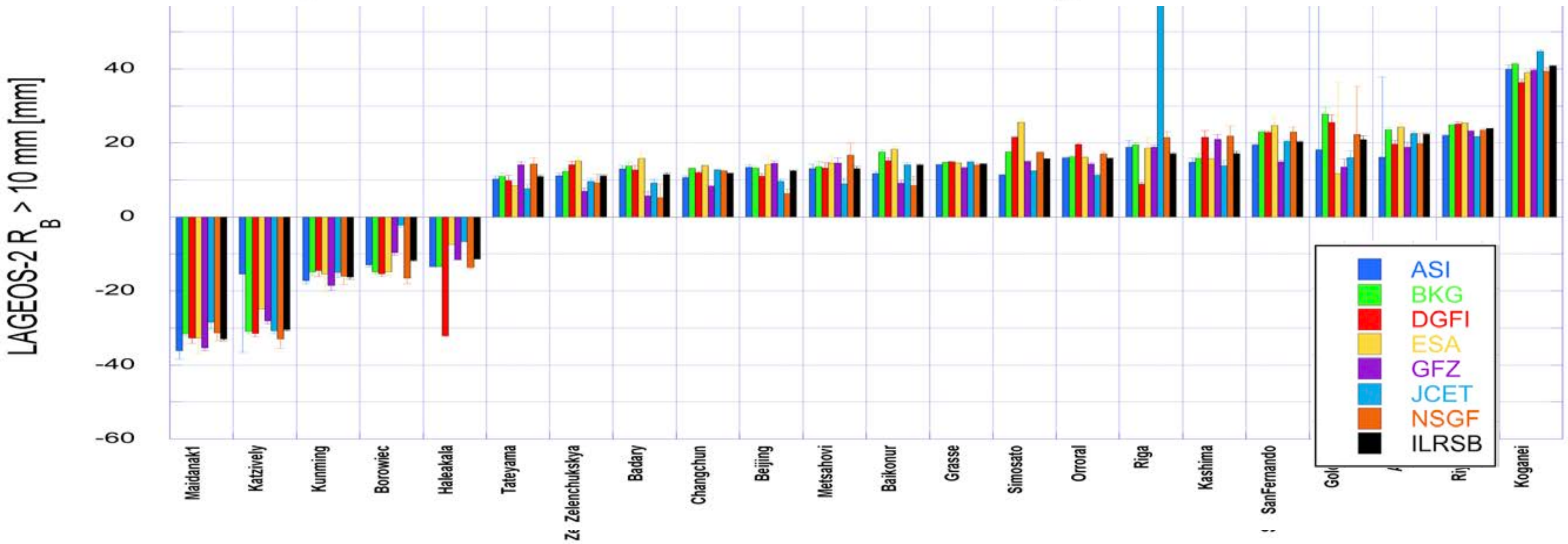


Long-term Systematic Errors LAGEOS



Long-term Systematic Errors LAGEOS-2



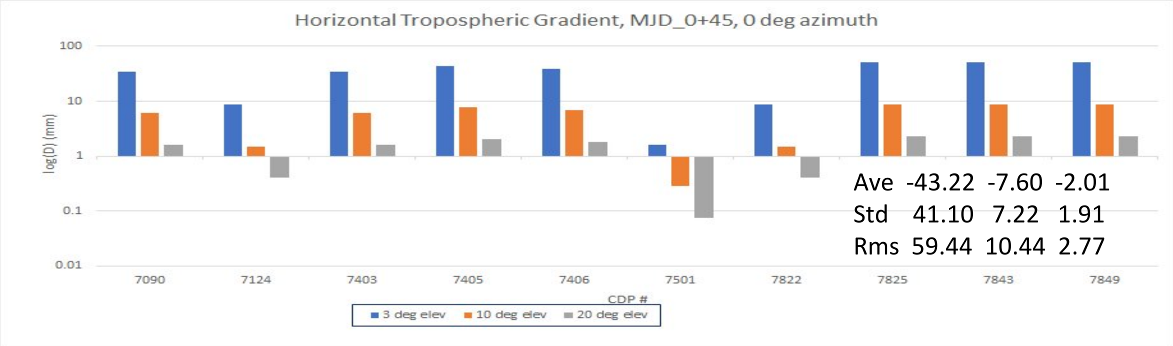


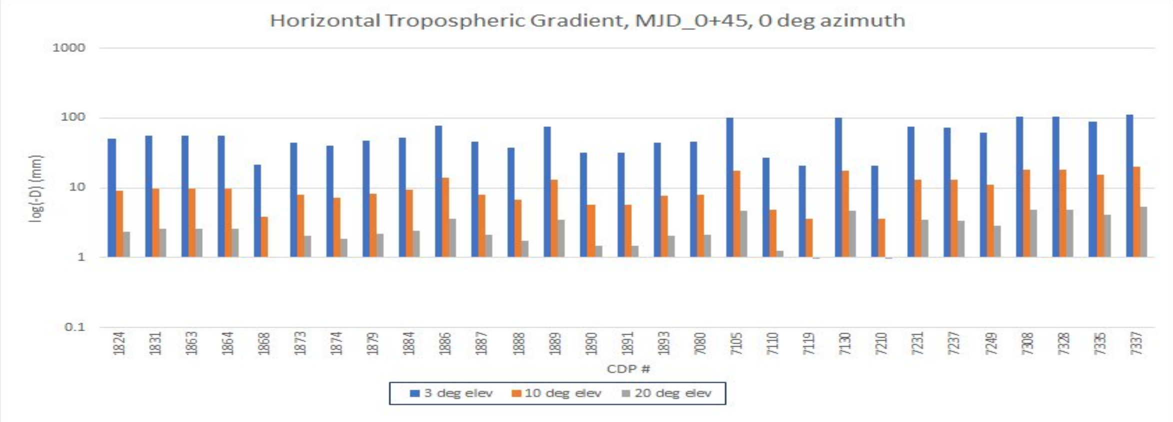
ILRS Network Sites Supporting Etalon Campaign

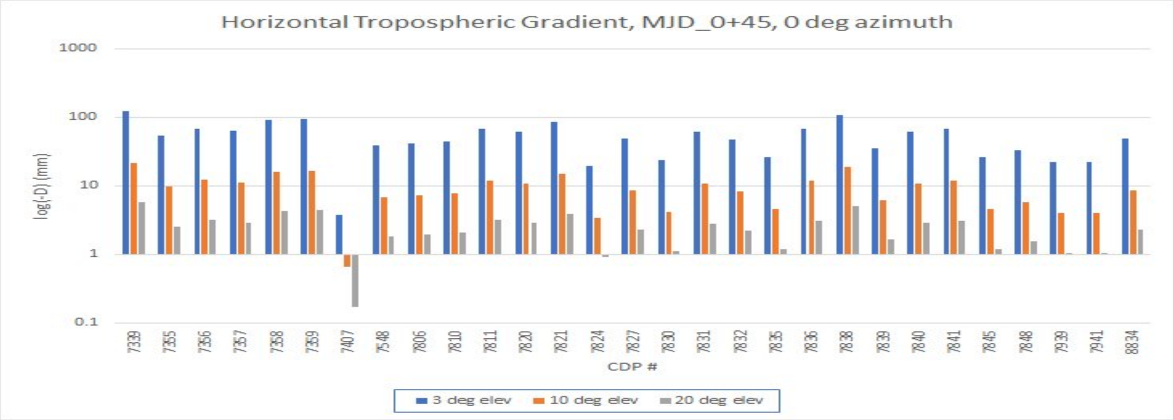
Site Name	Station ID#
Zimmerwald	7810
Wettzell (WETL)	8834
Yarragadee	7090
Herstmonceux	7840
Matera	7941
Graz	7839
Wettzell (SOSW)	7827
Grasse	7845
Potsdam	7841
Mount Stromlo	7825
Changchun	7237
Shanghai	7821
Beijing	7249
Hartebeesthoek (HARL)	7501
Kunming	7819
Monument Peak	7110
Tahiti	7124
Greenbelt	7105
Brasilia	7407
Irkutsk	1891
Altay	1879
Komsomolsk	1868
Badary	1890
Arkhyz	1886
Baikonur	1887

Normal Points		Total	
Site Name	Sta.	Etalon	Netw.
Yarragadee	7090	414	N
Wettzell (WI	8834	346	E
Matera	7941	295	E
Zimmerwald	7810	237	E
Herstmonceu	7840	188	E
Grasse	7845	181	E
Wettzell (SO	7827	176	E
Graz	7839	167	E
Changchun	7237	122	C
Kunming	7819	104	C
Komsomolsk	1868	95	R
Altay	1879	93	R
Potsdam	7841	59	E
Greenbelt	7105	46	N
Hartebeesth	7501	39	N
Simeiz	1873	32	E
Beijing	7249	31	C
Hartebeesth	7503	25	R
Mount Strom	7825	19	O
Monument P	7110	17	N
Shanghai	7821	14	C
Arkhyz	1886	5	R
Irkutsk	1891	5	R
Arequipa	7403	0	N
Badary	1890	0	R
Baikonur	1887	0	R
Borowiec	7811	0	E
Brasilia	7407	0	R
Haleakala	7119	0	N
Katzively	1893	0	E
Kiev	1824	0	E
McDonald	7080	0	N
Mendeleevo	1874	0	R
Riga	1884	0	E
Sejong	7394	0	O
Simosato	7838	0	O
Svetloe	1888	0	R
Tahiti	7124	0	N
Zelenchukska	1889	0	R
Totals:	0	2,710	

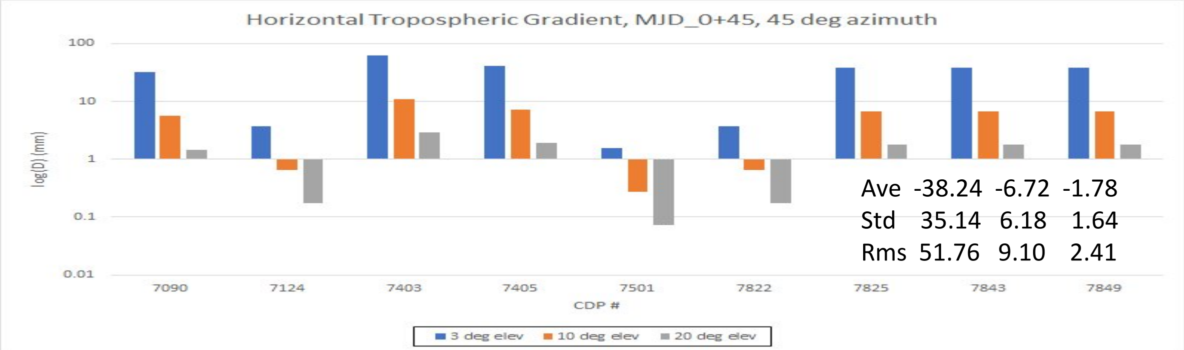
MJD_0+45 days, 0 Az

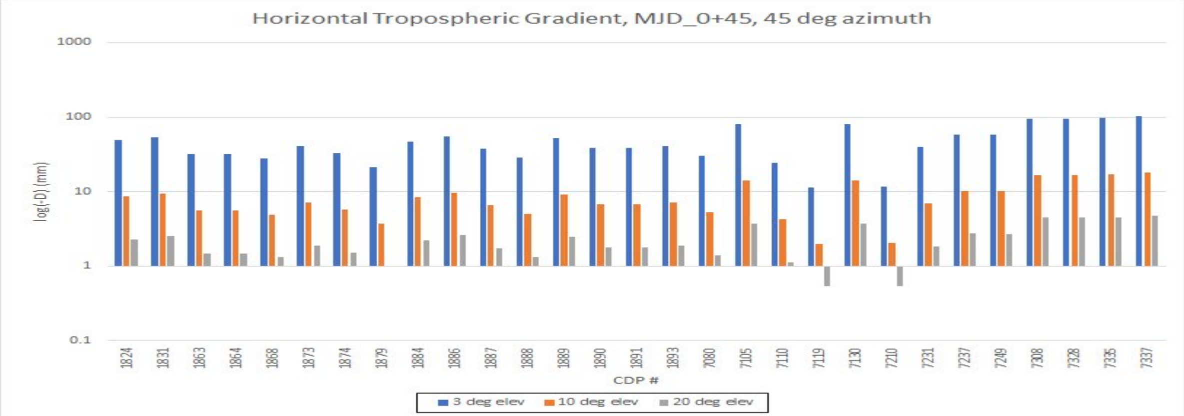


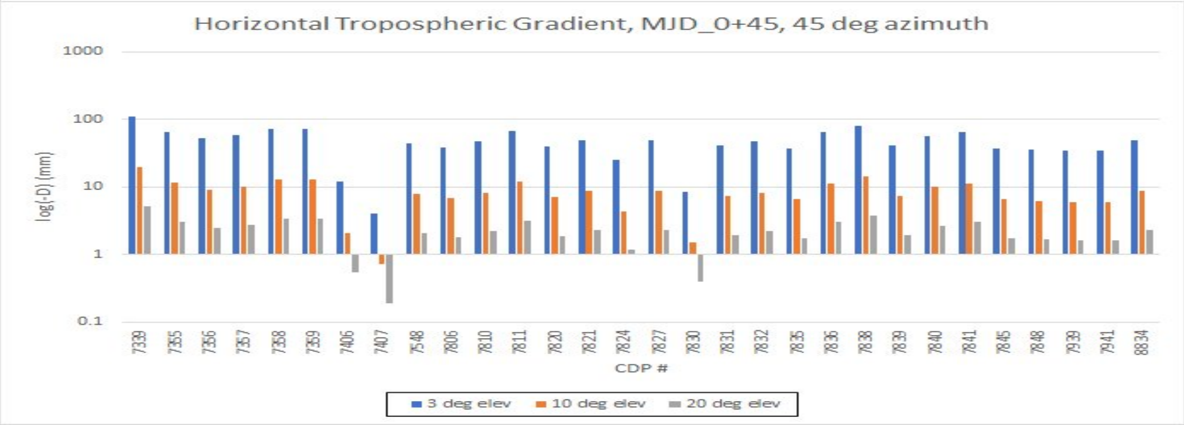




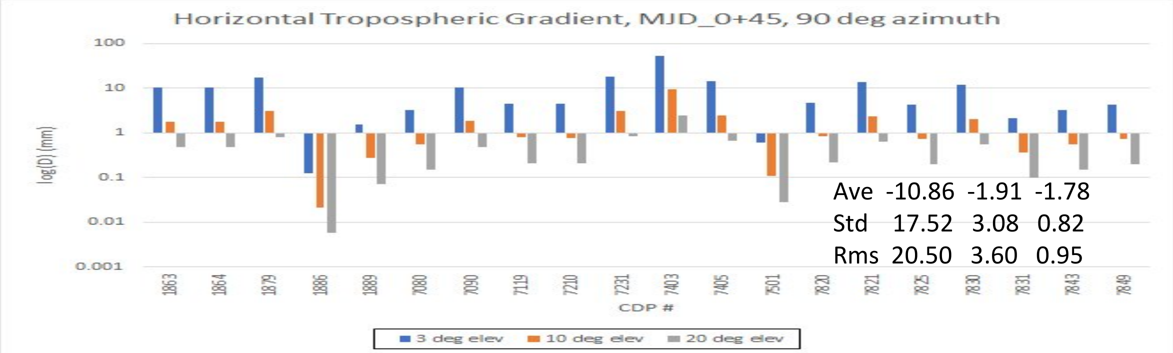
MJD_0+45 days, 45 Az

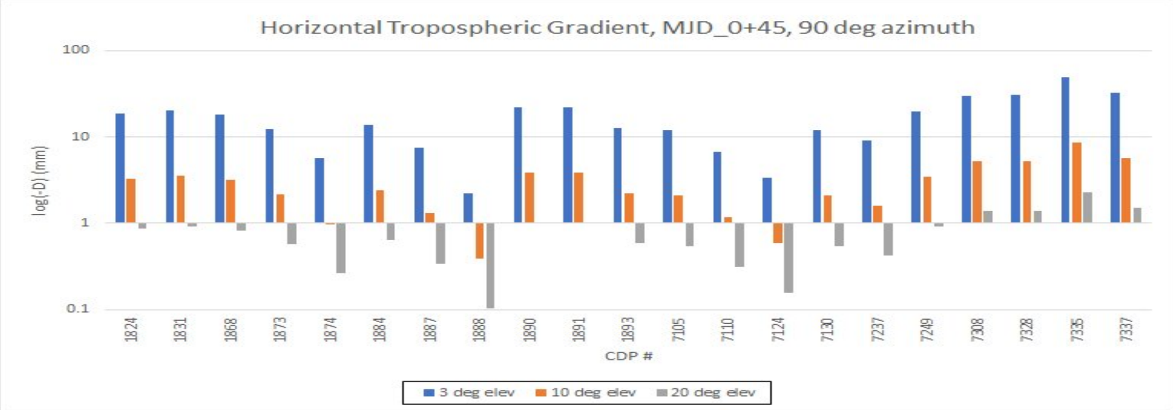


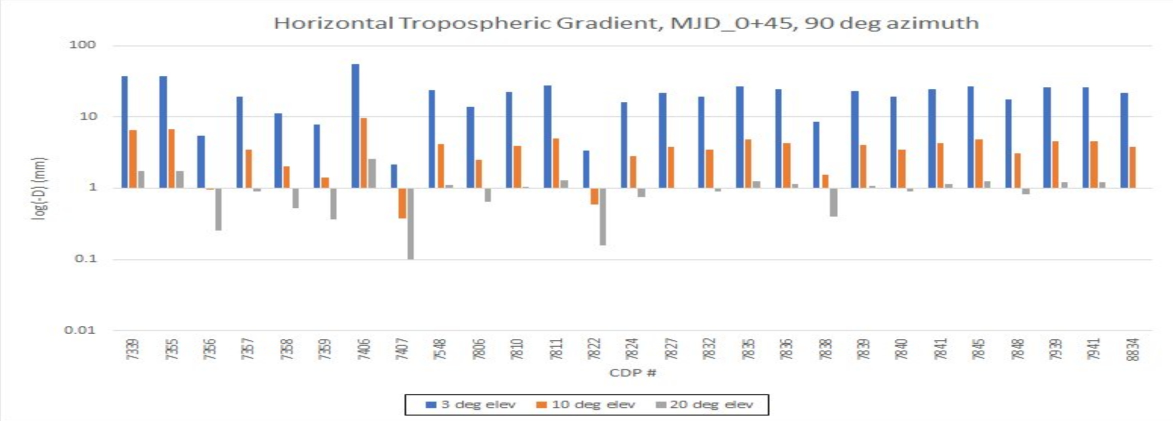




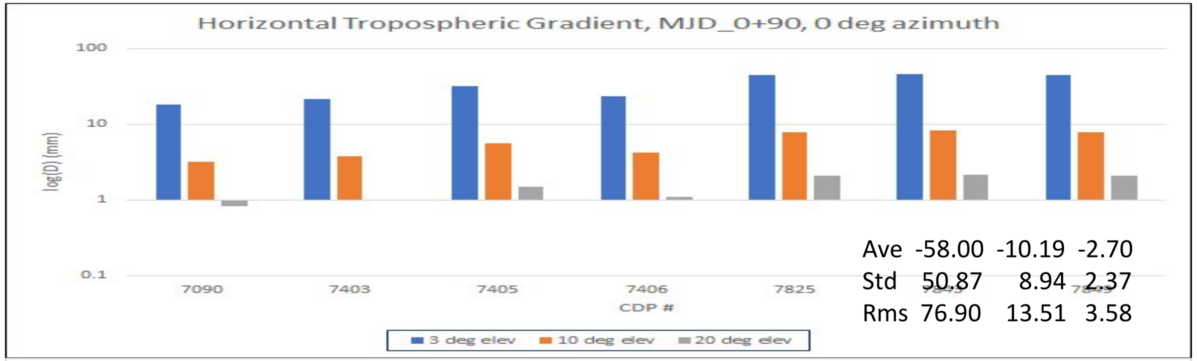
MJD_0+45 days, 90 Az

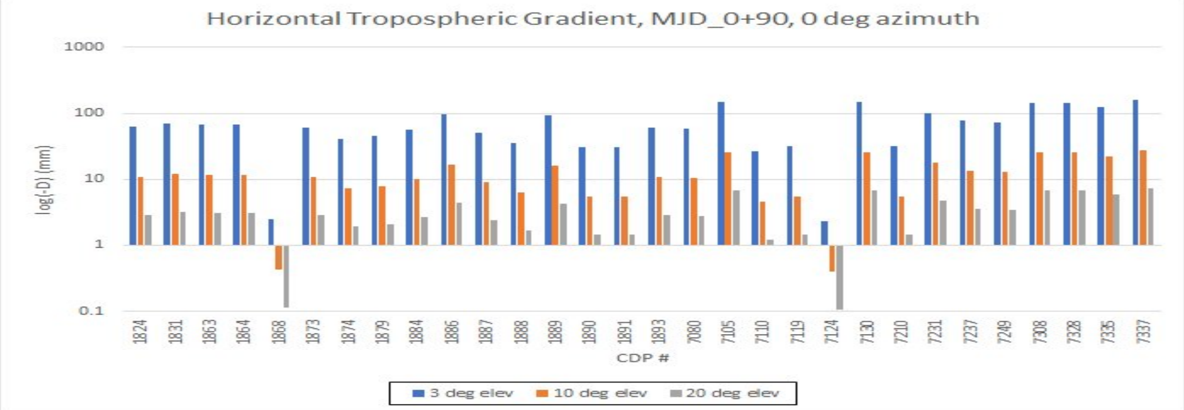


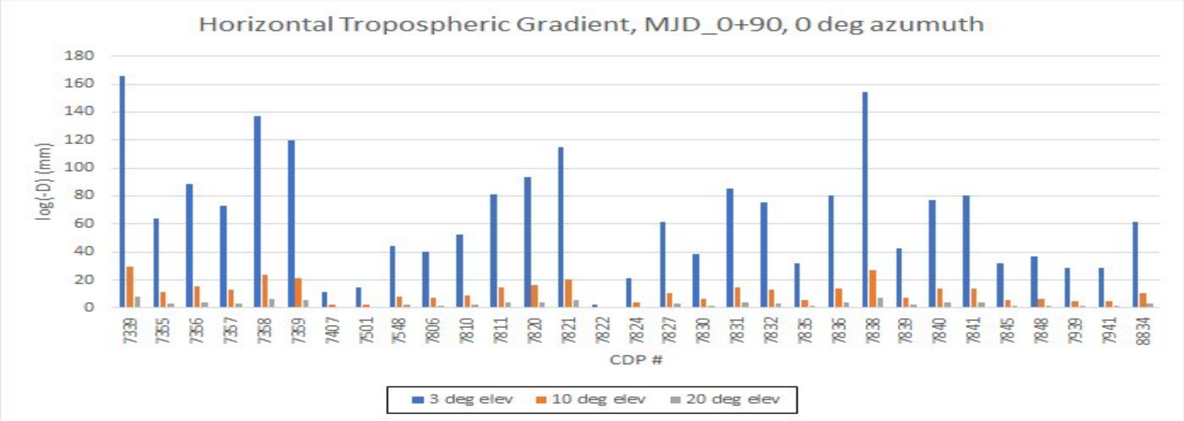




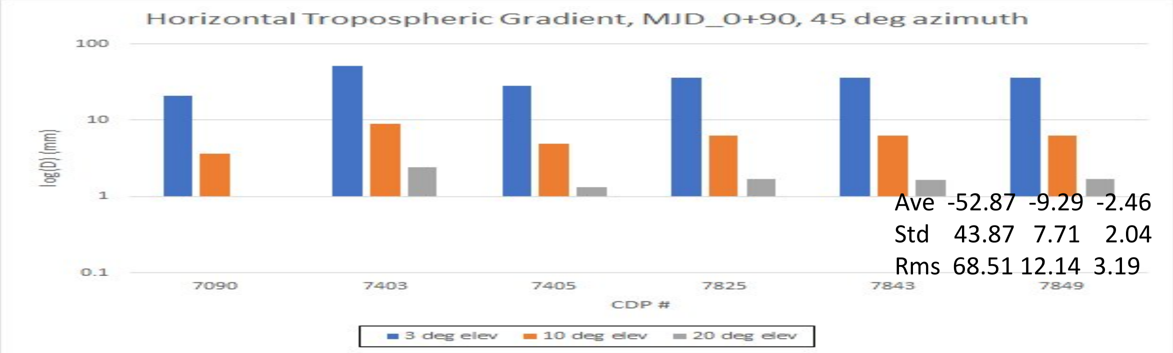
MJD_0+90 days, 0 Az

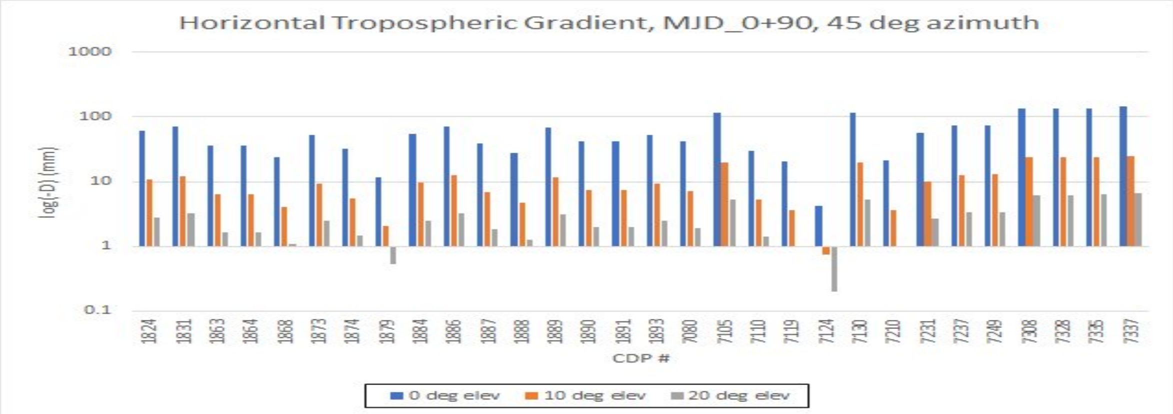


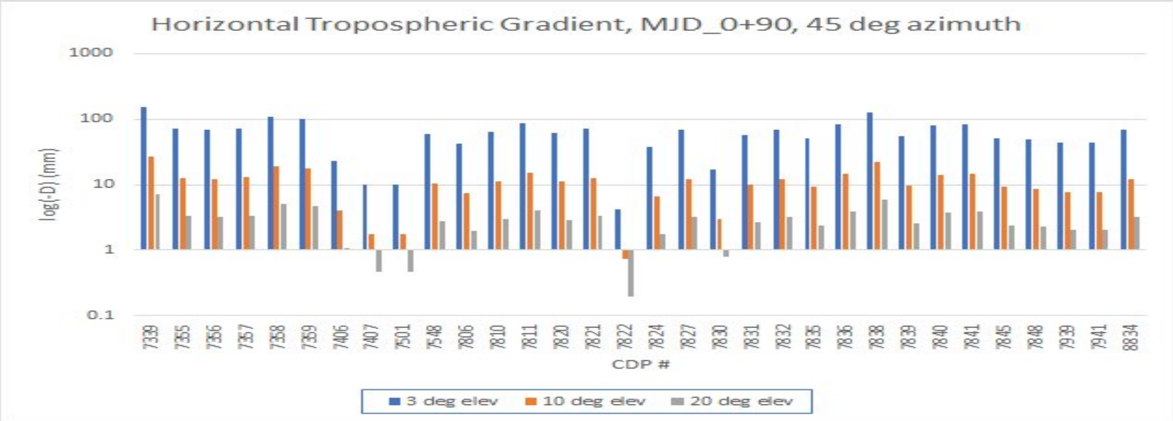




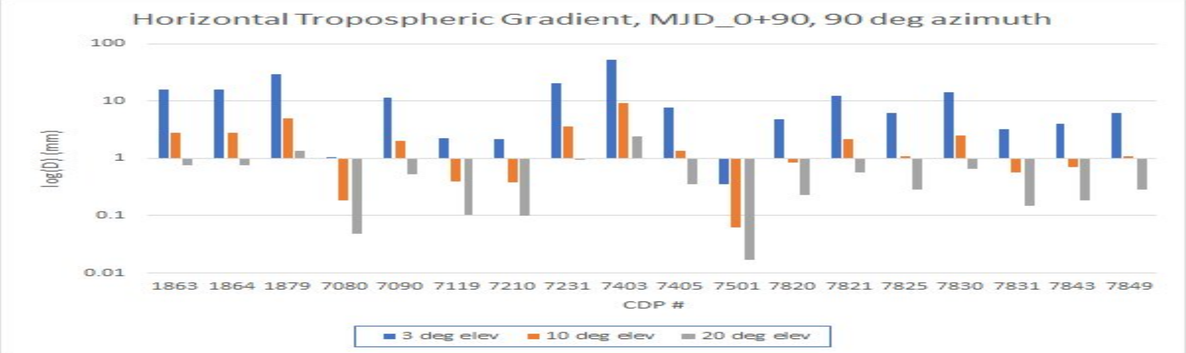
MJD_0+90 days, 45 Az

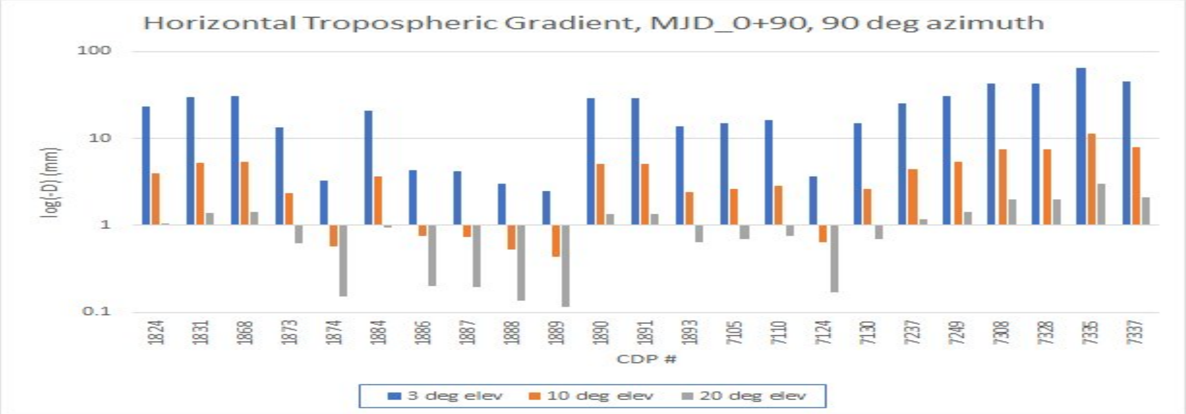


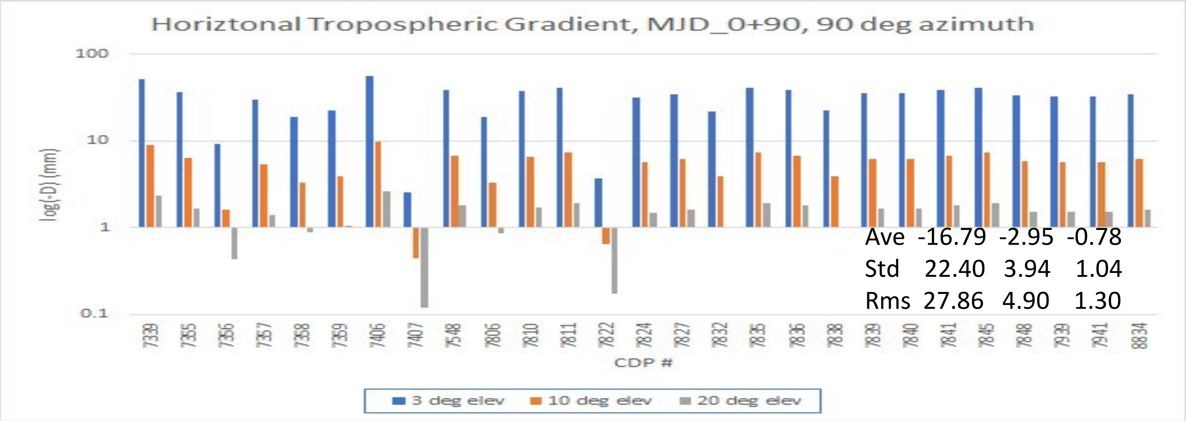




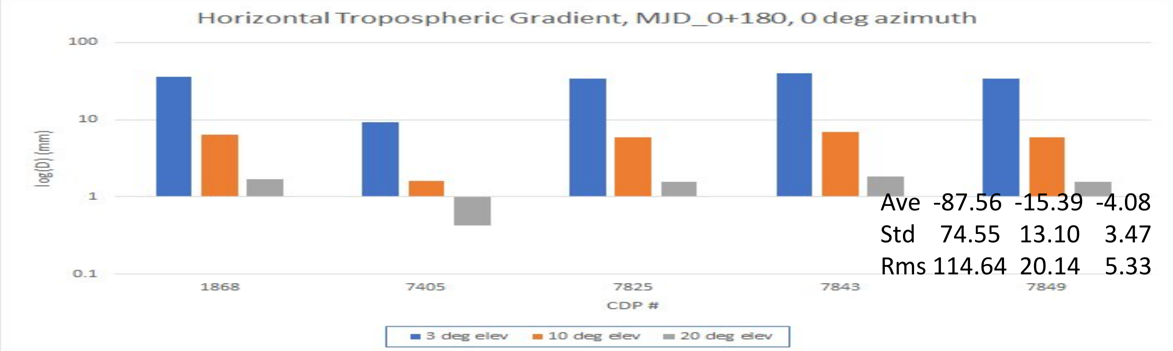
MJD_0+90 days, 90 Az

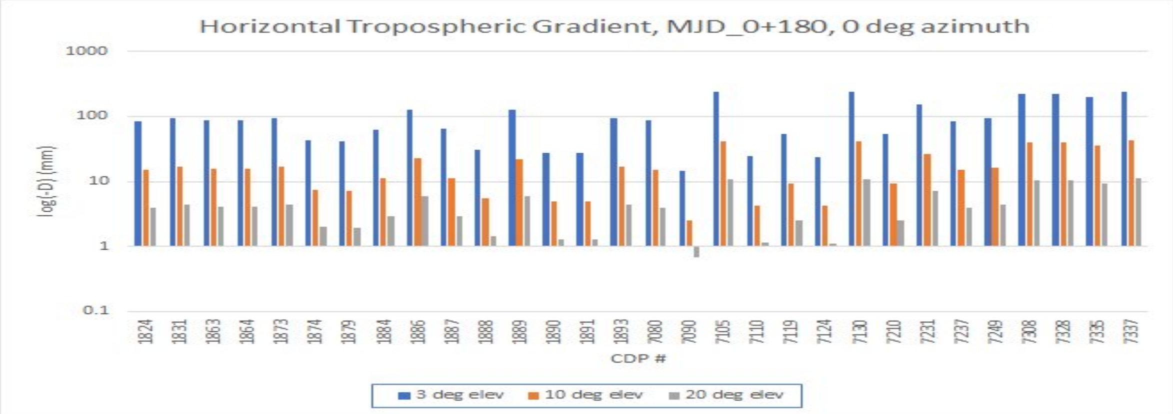


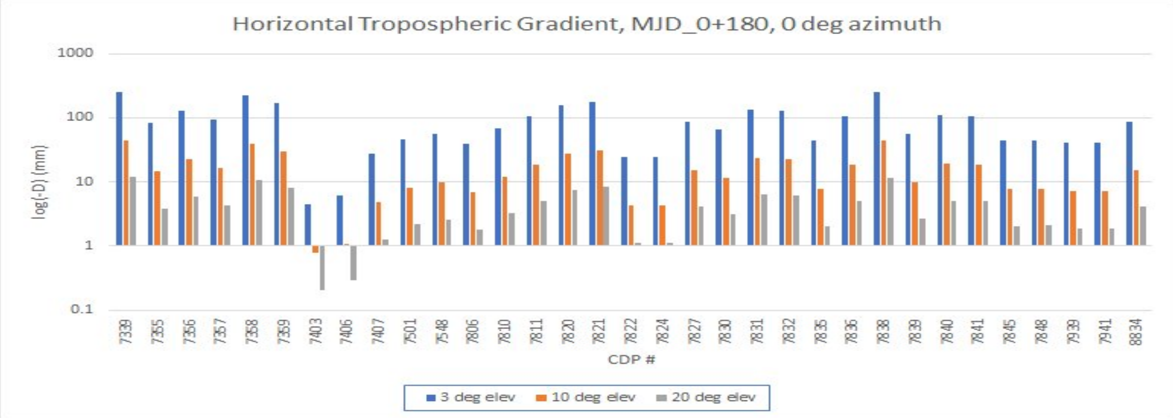




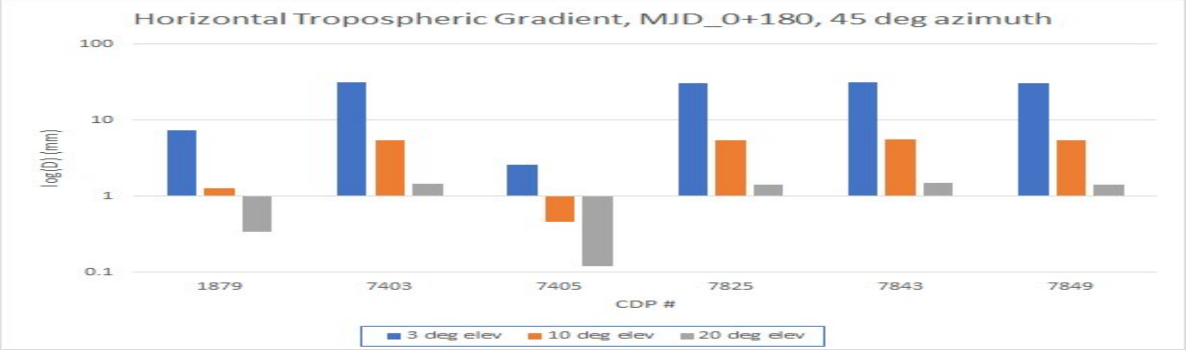
MJD_0+180 days, 0 Az

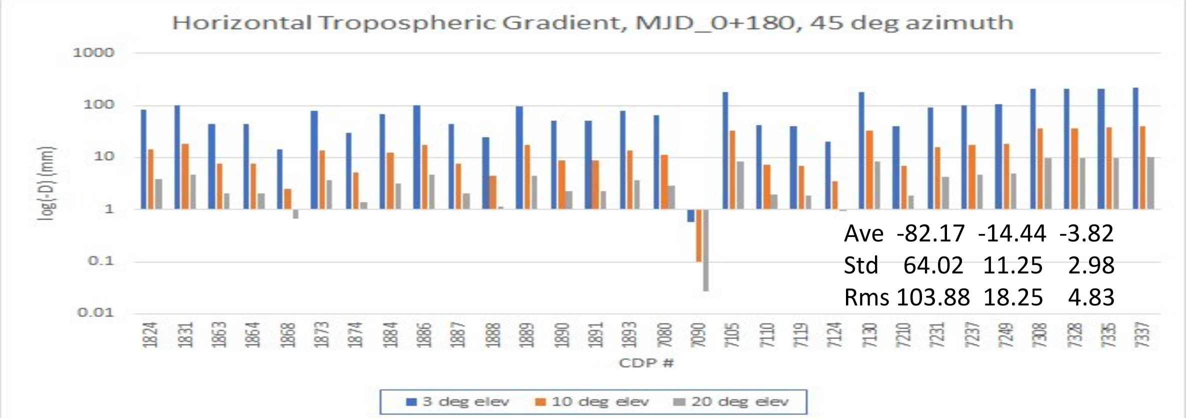


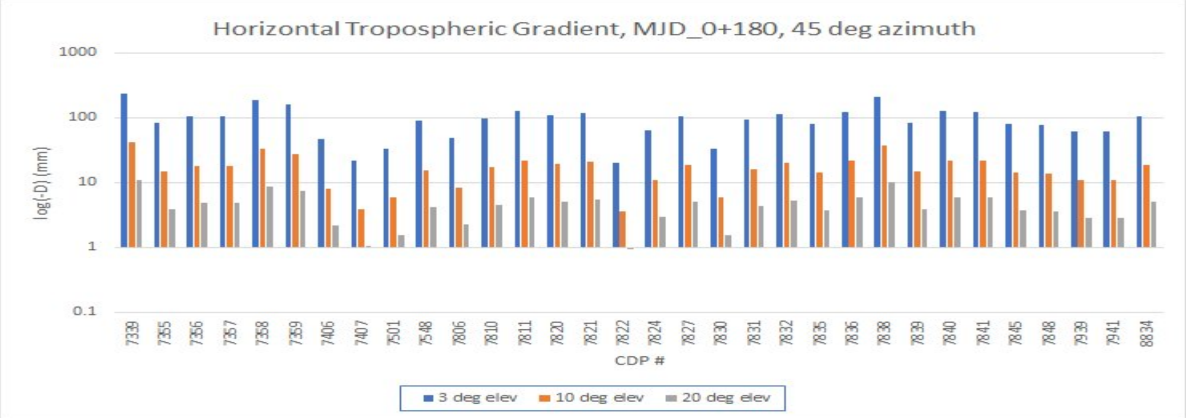




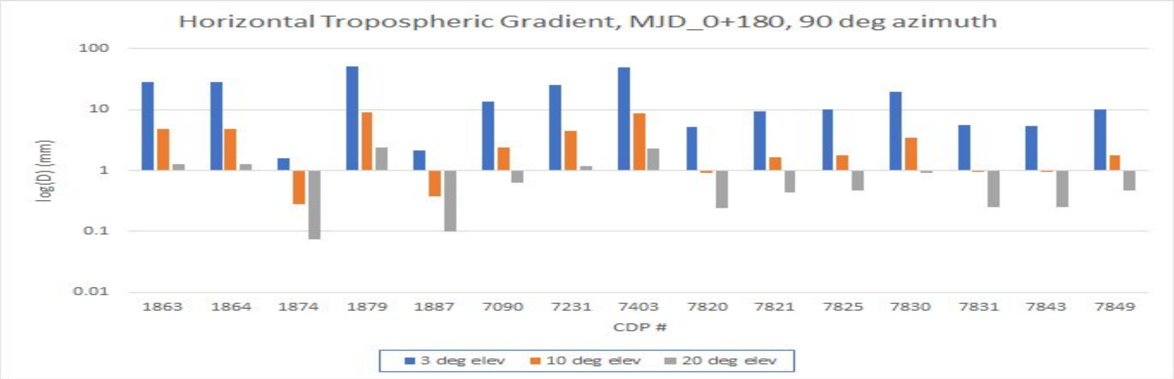
MJD_0+180 days, 45 Az

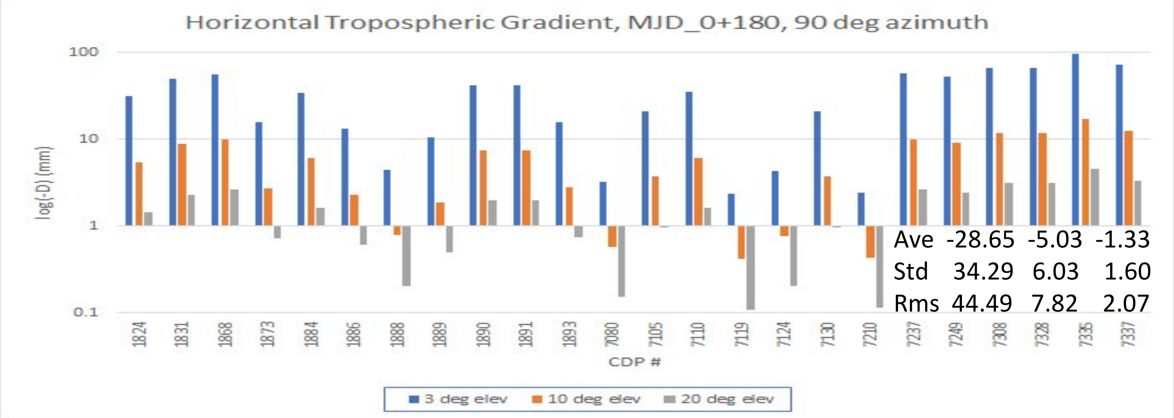


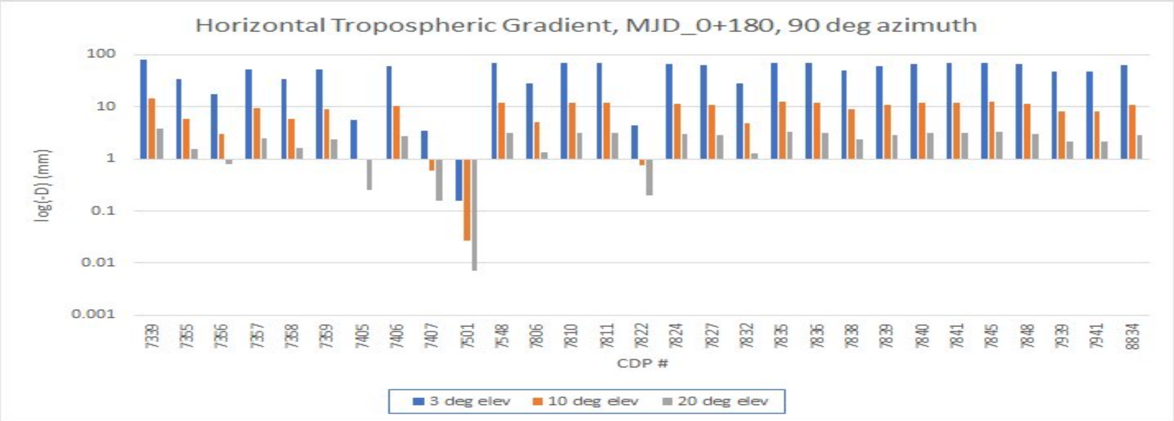




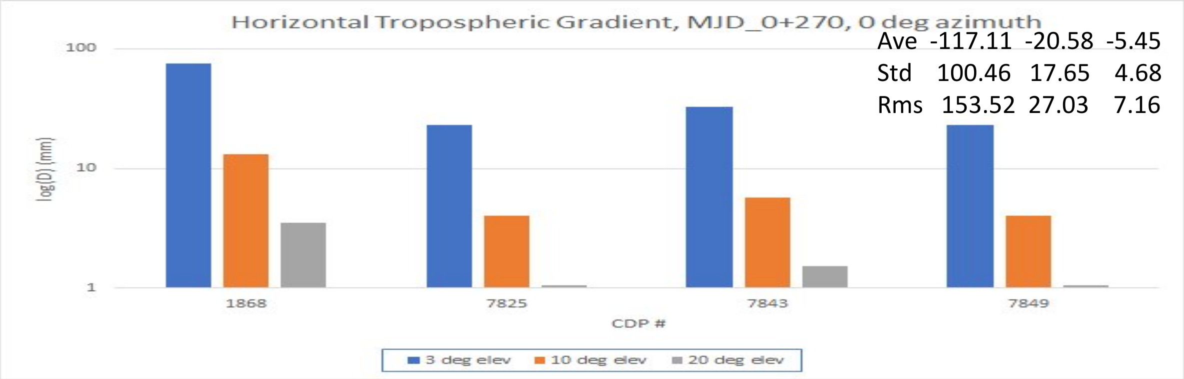
MJD_0+180 days, 90 Az

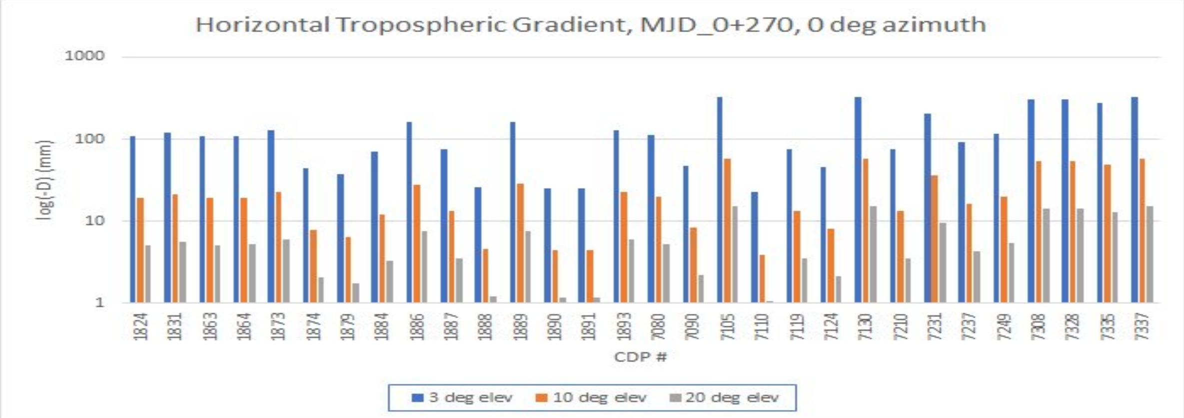


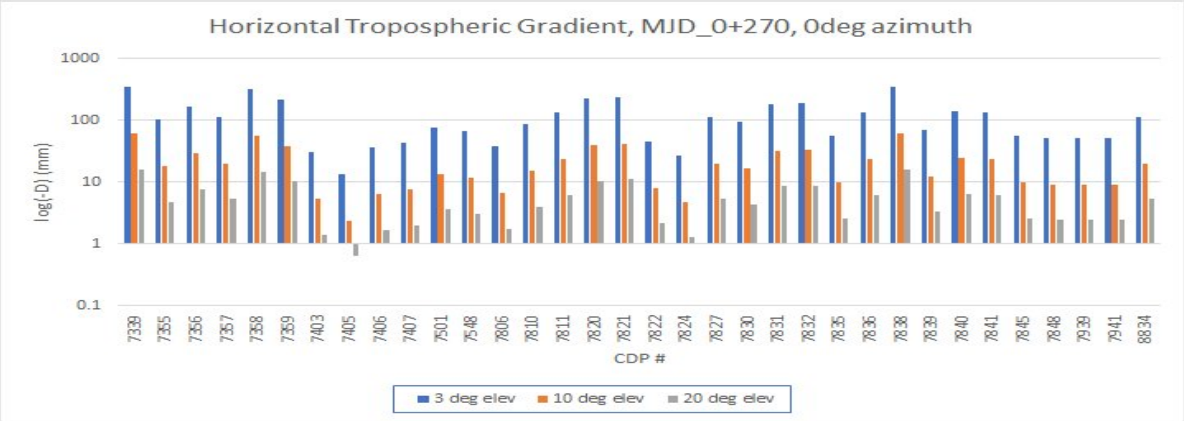




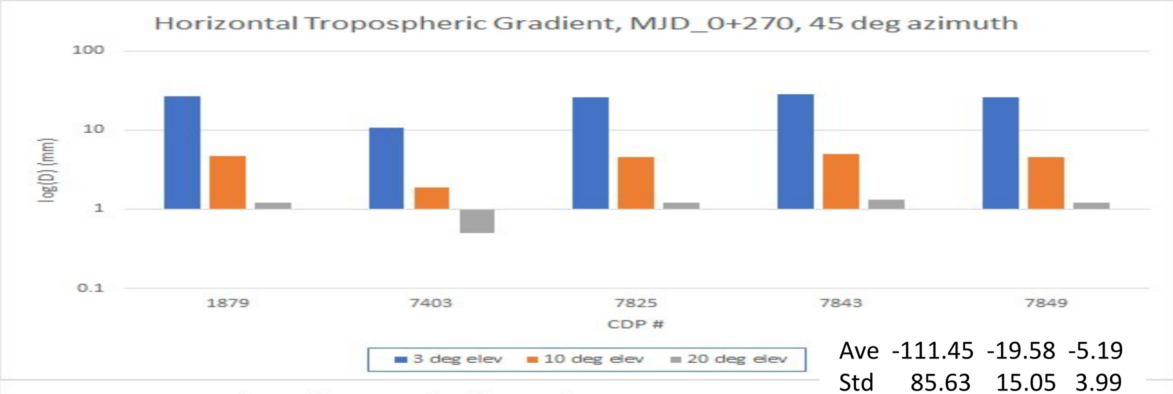
MJD_0+270 days, 0 Az



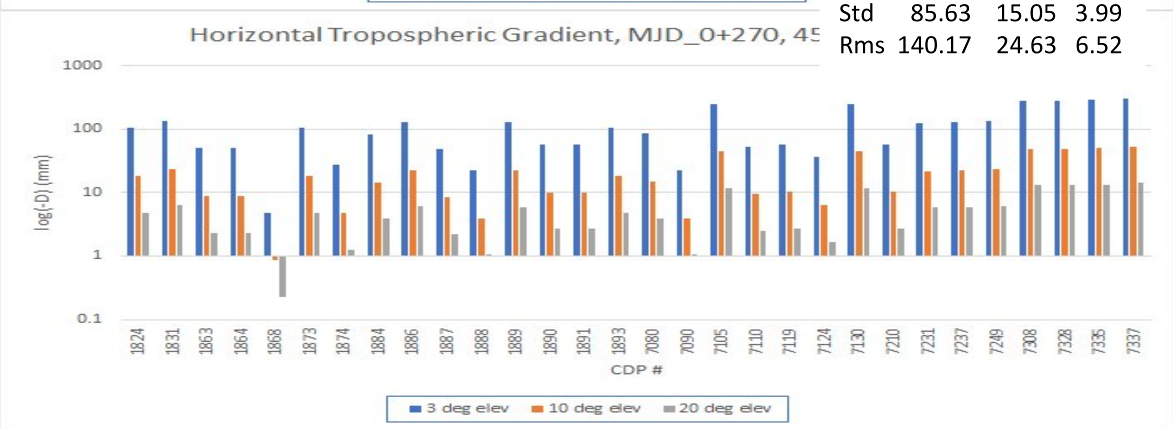


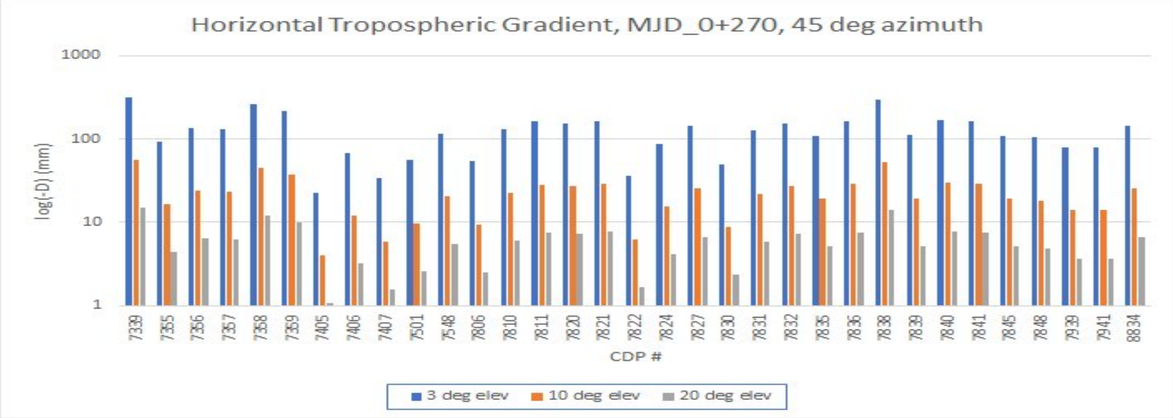


MJD_0+270 days, 45 Az

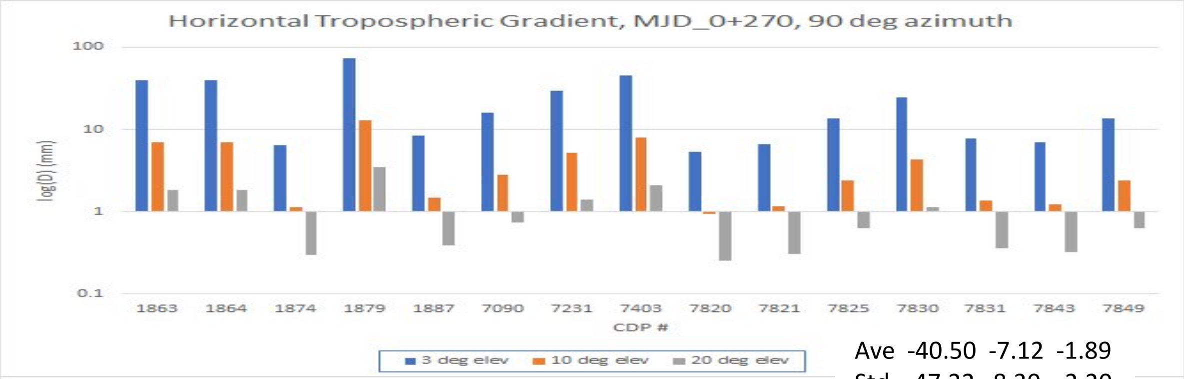


Ave	-111.45	-19.58	-5.19
Std	85.63	15.05	3.99
Rms	140.17	24.63	6.52

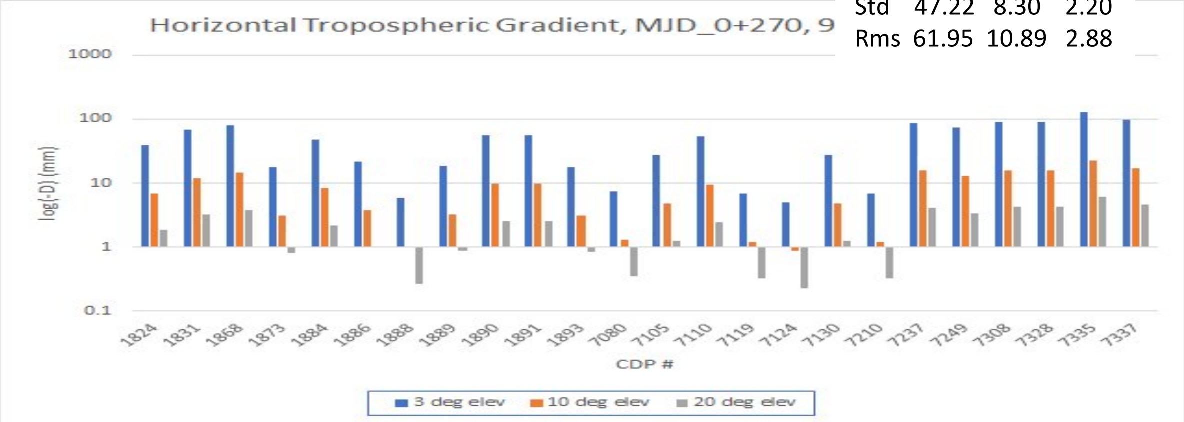


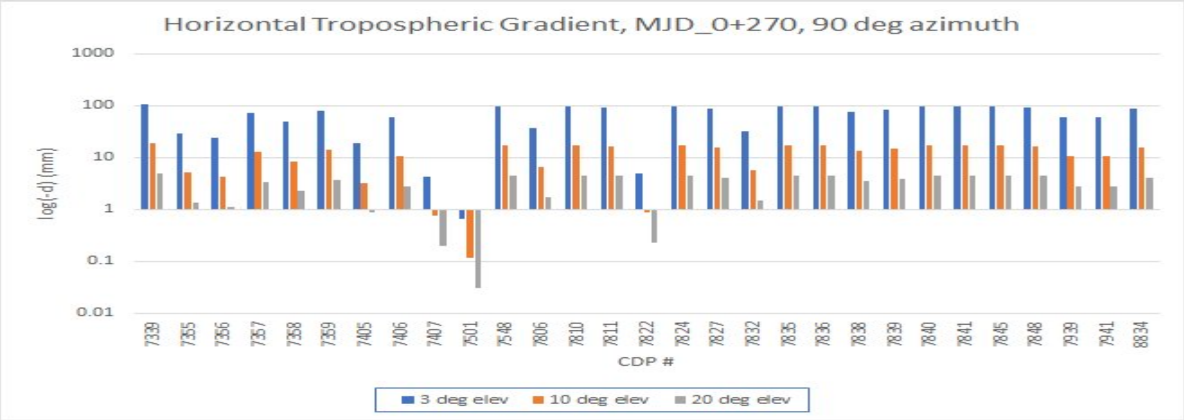


MJD_0+270 days, 90 Az



Ave	-40.50	-7.12	-1.89
Std	47.22	8.30	2.20
Rms	61.95	10.89	2.88





ILRS Analysis Committee meeting NSGF report

José Rodríguez, Graham Appleby
Space Geodesy Facility, UK

30th September 2019, Paris

Homework

DONE:

- NP re-downloaded to include corrected Wettzell and Mt Stromlo data
- IERS secular pole, T2L2 TB, CoM model
- v230 SSEM PP solutions

TO DO:

- 1-year LARES + low degree gravity
- High frequency EOP model implementation

CoM

- I will compute value for new 8834 system configuration. J. Heckl provided some data for this
- Plenty of debug info from J. Ries and A. Couhert about the tables (thanks!). Working on it (unimportant for the purposes of the PP)
- Tables should be online soon, no more major changes expected, just polishing usage info
- Reminder: latest version is **190904** (important fixes for two stations!)

Other: SINEX corrections block

- Proposal based on examples provided by R. Dach (thanks!)
- Dedicated block for all three possible corrections
- Official 3-char satellite code in its own field (https://cddis.nasa.gov/sp3c_satlist.html)
- RB and TB here are of course a priori, not estimates (can be zero)

```
*        1         2         3         4         5         6         7         8
*23456789012345678901234567890123456789012345678901234567890123456789012345678901234567890
*-------------------------------------------------------------------------------
+SITE/CORRECTIONS
*                                              COM_CORR__ RANGE_BIAS TIME_BIAS_
*SITE PT SOLN T DATA_START__ DATA_END____ SAT (m)_______ (m)_______ (ms)______
 1873  A  501 L 18:288:00000 18:290:86370 LG1     0.2468    -0.0193     0.1234
 1873  A  501 L 18:288:00000 18:290:86370 LG2     0.2441    -0.0193     0.1234
 1873  A  501 L 18:288:47700 18:288:86370 ET1     0.5796    -0.0193     0.1234
 1873  A  501 L 18:288:47700 18:288:86370 ET2     0.5796    -0.0193     0.1234
 1873  A  501 L 18:288:47700 18:288:86370 LAS     0.1302    -0.0193     0.1234
 1873  A  501 L 18:288:47700 18:288:86370 STR     0.0765    -0.0193     0.1234
 1873  A  501 L 18:288:47700 18:288:86370 STL     0.0765    -0.0193     0.1234
 1873  A  501 L 18:288:47700 18:288:86370 AJI     0.9926    -0.0193     0.1234
```

Other: SINEX corrections block

- M.Blossfeld: alternative already in use by DGFI
- CoM dedicated block, one line per station, all satellites

```
[...]

  occup no CoM(LA1) CoM(LA2) CoM(ET1) CoM(ET2) [m]
  18734901    0.243    0.243    0.565    0.565
  18799401    0.251    0.251    0.558    0.558 default values used!
  18879701    0.251    0.251    0.558    0.558 default values used!
  71100412    0.246    0.245    0.583    0.583
  71191402    0.251    0.251    0.558    0.558 default values used!
  72371901    0.244    0.243    0.559    0.559
  74072701    0.251    0.251    0.558    0.558 default values used!
  78106801    0.243    0.241    0.563    0.563
  78113802    0.247    0.246    0.566    0.566
  78212801    0.251    0.251    0.558    0.558 default values used!
  78259001    0.251    0.251    0.558    0.558 default values used!
  78393402    0.247    0.247    0.571    0.571
  78457801    0.243    0.242    0.568    0.568
  79417701    0.249    0.249    0.595    0.595
-FILE/COMMENT
```

Other: horizontal gradients

- Implemented horizontal gradients model from WUELS (Drożdżewski 2019)
- Example Fortran module provided by Krzysztof S. (thanks!)
- (very) preliminary test may identify some (modest) gains
- 1 year LG1/LG2/LAS, with/without horizontal gradients, with/without RB

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Standard (no RB)

	#NP	mad (mm)
LAS	79133	11.3
LG1	76521	10.8
LG2	65682	8.3

Standard (RB)

	#NP	mad (mm)
LAS	79283	10.8
LG1	76212	8.7
LG2	65416	7.6

Horizontal gradients (no RB)

	#NP	mad (mm)
LAS	79177	11.3
LG1	76475	9.9
LG2	65912	8.5

Horizontal gradients (RB)

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LAS	79294	10.1
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Other: accumulated progress :)

- Comparison of our latest reanalysis to solutions from 5 years ago (ITRF14 vintage)
- Changes, updates, upgrades, corrections in the latest years, e.g.:

  Updated geopotential, TVG, tides, AOD
  LOD estimation fix
  Improved screening (robust outlier detection, stricter criteria for station acceptance)
  Improved iteration policy (robust stats for rejection, orbit re-estimation per iteration)
  Improved OPR parameterisation (contraints and t. steps tweaks, decoupled params)
  T2L2 TB corrections
  New shadow function (R. Robertson 2015, 10.1007/s10569-015-9637-0)
  Station weighting (based on absolute values of mean RB estimates)
  Updated atmospheric model (NRLMSISE00)
  Bugs...

Other: accumulated progress :)

- Comparison of our latest reanalysis to solutions from 5 years ago (ITRF14 vintage)

2014 solution

	# NP	mad [mm]
ET1	119683	11.9
ET2	112761	13.3
LG1	1277283	11.9
LG2	1177880	11.9

(65 stations, 1993-2014)

2019 solution

	# NP	mad [mm]	
ET1	112441	8.2	(**-3.7**)
ET2	105384	8.9	(**-4.4**)
LG1	1484046	8.9	(**-3.0**)
LG2	1387612	8.2	(**-3.7**)

(94 stations, 1993-2014)

Other: accumulated progress :)

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LG2	1387612	8.2	(**-3.7**)

(94 stations, 1993-2014)

2019 solution (ALL sats)

	# NP	mad	rms
7080	88652	7.7	10.2
7090	433740	7.0	8.5
7105	139484	6.8	8.0
7501	86291	8.3	9.7
7810	242331	7.9	9.4
7839	176085	6.2	7.2
7840	221080	7.3	8.0
7841	38720	7.3	8.3
7941	122912	7.1	8.1
8834	129510	9.9	12.3


Thank you