NESC Virtual Meeting

December 17, 2020, 14:00-16:00 UTC

Agenda

1. GASTON – ILRS support for the Galileo based project – **Clément Courde**
   - Discussion
2. Keeping the station history log current and a remainder on what system changes constitute data quarantine **-Van Husson**
3. Barometric Pressure Measurement Best Practices **-Van Husson**
4. Barometer drifting causes RB?? Case study: Graz SLR **- Wang Peiyuan**
5. Update on the upcoming ACES on the ISS **- Ulrich Schreiber**
6. ILRS Best Practice Guide
7. Any other NESC business
   - Offers for future items
   - NESC requests for presentations

GASTON – ILRS support for the Galileo based project

ILRS Networks and Engineering Standing Committee

December 2020

C. Courde

Description of the project

GASTON: GAlileo Survey of Transient Objects Network

Objectives and achievement :
The main goal of this project is to develop, perform and analyse data of a 3-months measurements campaign dedicated to search for Dark Matter (DM) transients using the Galileo constellation.

PI: Pacôme Delva

Partners: Observatoire de Paris, Observatoire Royal de Belgique, Geoazur-Observatoire de la Côte d’Azur

Funding : ESA H2020-038

Description of the ESA-GASTON project

- Recent investigation: Dark Matter (DM) could be on the form macroscopic structure (e.g. Earth-sized)
- Such structures could cross regularly the Earth !
  => New experiments in the Earth's neighborhood: Search for DM transient objects
- Our goal: Search for a coherent succession of glitches of atomic clocks onboard Galileo satellites in case of crossing

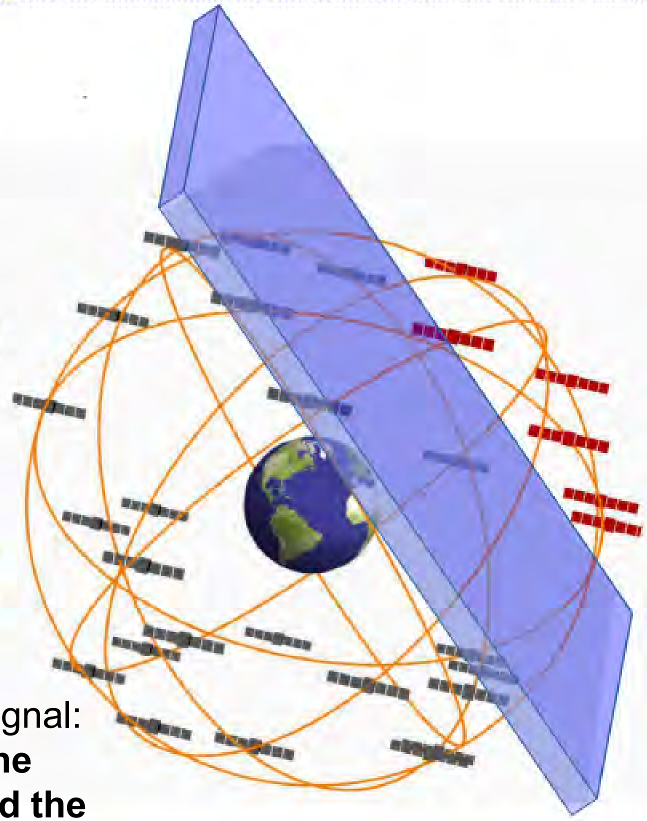
Stable H-maser onboard Galileo satellites

Deep study of systematic effects

3-month SLR campaign

Simplest case : planar structures called domain wall

A. Derevianko & M. Pospelov, Nature Phys. **10**, 2014



- The DM transient has almost no effect on the propagation of the laser signal: **SLR residuals can be used as a reference in order to disentangle the effect of the DM transient on the clocks and signal propagation, and the systematic effects due to orbital errors.**
- **Continuous SLR tracking** to a Galileo satellite **is required** by the investigation **to be happening at the exact moment a DM transient is detected**.

Description of the ESA-GASTON project

- Network of ILRS stations can contribute to the search of DM transients in the close neighborhood of the Earth !

  Signature: Perspective of an outstanding discovery

  Minimal result: Stronger experimental limits on the abundance and size of such DM transients

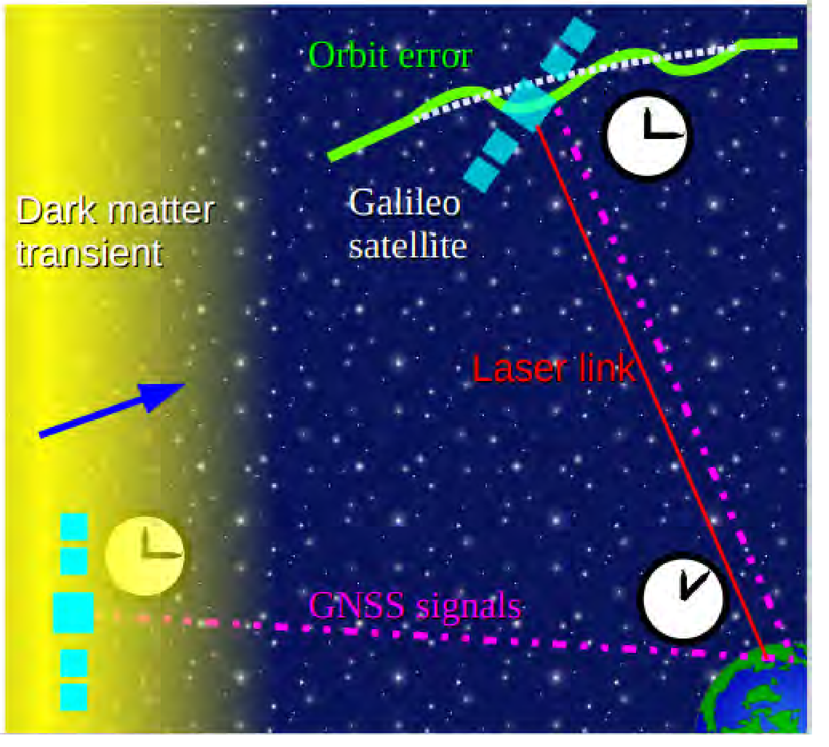
- Interest : to disentangle effects due to orbits from true Dark matter objects

  Comparison

  SLR residuals >< satellite clock estimates

  ⬇

  Help to discriminate radial orbit errors from potential DM transients



Methodology chosen

The **ideal methodology** to search for such transients using the Galileo constellation would be to always **have at least one ILRS station firing on a Galileo satellite**, during a three months campaign.

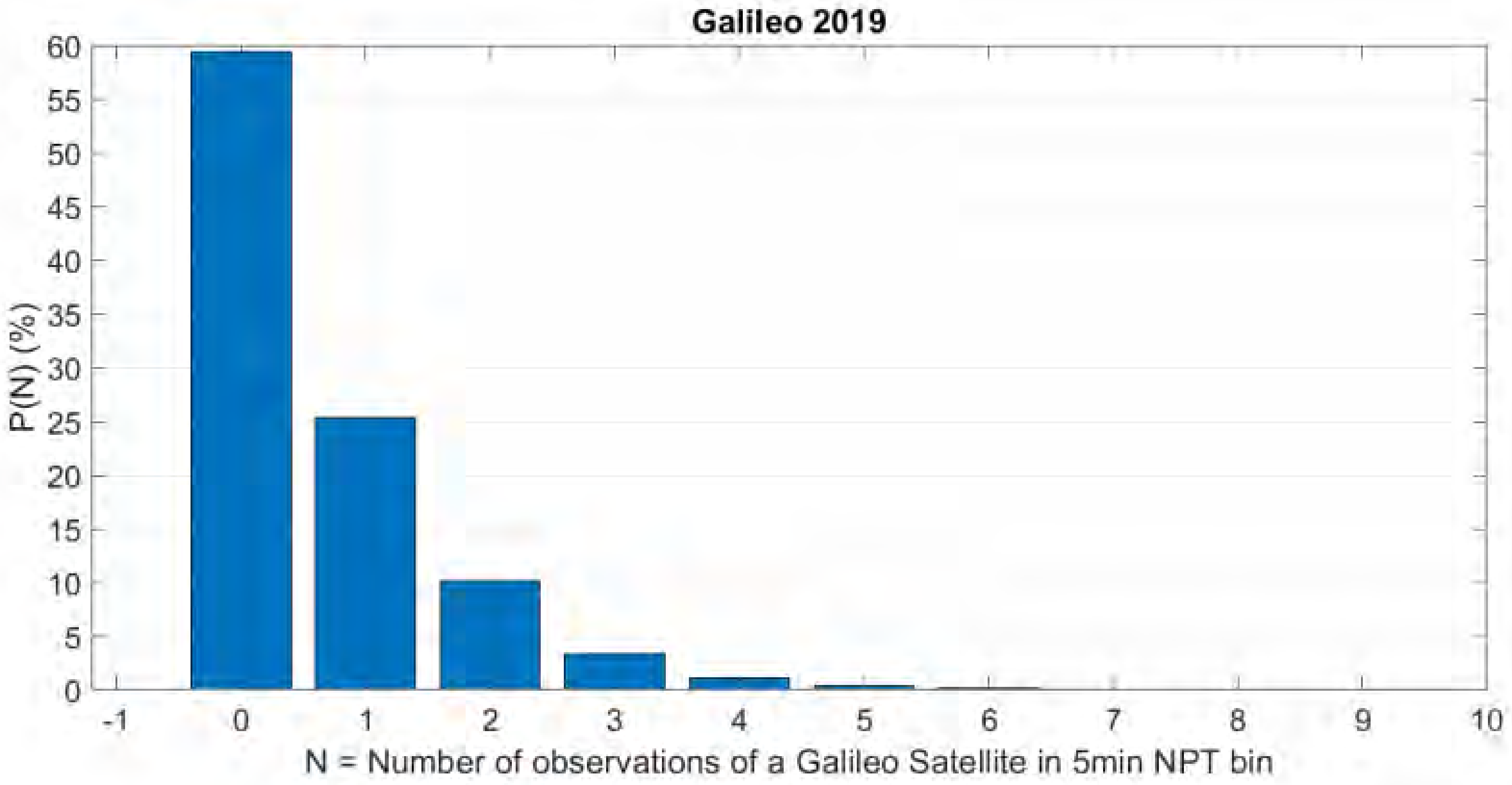
=> A look on the statistics from ILRS to have an idea of the situation during routine operations

Statistics from ILRS

5 min time bin over the year 2019
60% of the time: No Observation of a Galileo satellite
25% of the time, 1 satellite is observed

We need to reduce the time without an observation of Galileo satellite

Challenge => try coordination of observations between SLR station



Strategy proposal for the GASTON SLR campaign

1) Ask the ILRS stations to participate to the 3 months campaign on a voluntary basis
2) Ask the station to deliver CRD and FRD data
3) Reduce the number of target to the satellites with the best clocks: GASTON Galileo list on the right
4) Raise the Galileo satellites equipped with the best clocks in the ILRS priority list
5) Ask the voluntary stations to install the Eurostat station status display
6) Ask the stations to check a dedicated webpage made by OCA (under construction: https://ocatools.oca.eu/galileo/) showing from the Eurostat data, the number of Galileo satellites tracked in real time. The webpage warns the stations when no Galileo is tracked and promote the station to move on one of the Galileo satellite. A color code shows the status in real time: red when no Galileo is tracked, orange when only one station tracked, yellow when two stations tracked a Galileo satellites, green when three or more stations tracked a Galileo.
7) To challenge the ILRS stations, a statistic will be done and displayed every week to show the Galileo time coverage. The most contributing station of the week will be displayed and the most contributing station over the whole campaign will win a surprise gift from Grasse SLR station.

Table 4: List of PHM with their ADEV at 30s and 15360s

Satellite name	SV ID	ADEV ($\tau = 30$s)	ADEV($\tau = 15360$s)
GSAT0102	E12	2.973e-13	1.475e-14
GSAT0103	E19	2.814e-13	6.837e-15
GSAT0203	E26	2.924e-13	4.575e-15
GSAT0205	E24	2.703e-13	3.321e-15
GSAT0206	E30	3.079e-13	1.441e-14
GSAT0207	E07	2.695e-13	2.088e-14
GSAT0208	E08	3.027e-13	6.713e-15
GSAT0209	E09	2.724e-13	7.160e-15
GSAT0210	E01	2.704e-13	5.531e-15
GSAT0211	E02	2.837e-13	1.5459e-14
GSAT0212	E03	2.858e-13	7.890e-15
GSAT0213	E04	2.813e-13	8.866e-15
GSAT0214	E05	2.862e-13	7.296e-15
GSAT0215	E21	2.793e-13	9.884e-15
GSAT0216	E25	2.915e-13	1.210e-14
GSAT0217	E27	2.900e-13	1.494e-14
GSAT0218	E31	2.960e-13	1.076e-14
GSAT0219	E36	2.765e-13	1.102e-14
GSAT0220	E13	2.803e-13	5.2544e-15
GSAT0221	E15	2.664e-13	1.057e-14
GSAT0222	E33	2.960e-13	9.225e-15

To resume

What ?

Try to have continuously at least one SLR station firing on one of the Galileo satellite equipped with passive hydrogen maser

When ?

A three months campaign starting from January or February

Who ?

ILRS stations on a voluntary basis. GRSM will be dedicated to the GASTON campaign and will track as most as possible Galileo satellites but …. We need the contribution of the other ILRS stations when the weather is not good at Grasse and during maintenance interruption.

How ?

Please track a Galileo satellite when you check on https://ocatools.oca.eu/galileo/ that there is no station in current tracking on Galileo

Discussion and question

- What need to be implemented for the best coordination ? Weather forecasting, share the tracking schedule for each participating station ?

- Is the live tracking status sufficient for the coordination ? Software for the real-time coordination between station: Which system ? Eurostat ? Other solution ?

- When start the GASTON campaign ? January or February

- Which station will win the special price ?



ILRS Networks and Engineering Standing Committee

December 17, 2020

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ILRS Station Procedures

- **Station Change History Log Procedure:**
  - https://ilrs.gsfc.nasa.gov/network/site_procedures/configuration_files.html
- **Why is it important to keep your station change history and site log current?**
  - Any system change has the potential to introduce a range and/or time bias and therefore, this information is crucial for the ILRS analysts to treat your data appropriately (e.g. when computing a time series of station coordinates), and
  - Some system changes (e.g. laser, detector, sigma editing level, etc.) can impact satellite Center of Mass (CoM) corrections
- **Station Quarantine Procedure:**
  - https://ilrs.gsfc.nasa.gov/network/site_procedures/quarantine_changestation.html
  - If a station has been offline for an extended period of time (> 90 days)
  - If there was a major system change (e.g. 10 Hz to kHz laser)

Change History Log Status

System	Location Name, Country	Last Change (yyyy-ddd)
1824	Golosiiv, Ukraine	2014-283
1868	Komsomolsk-na-Amure, Russia	No station log available
1873	Simeiz, Ukraine	No station log available
1874	Mendeleevo 2, Russia	No station log available
1879	Altay, Russia	No station log available
1884	Riga, Latvia	2020-305
1886	Arkhyz, Russia	No station log available
1887	Baikonur, Kazakhstan	No station log available
1888	Svetloe, Russia	No station log available
1889	Zelenchukskya, Russia	No station log available
1890	Badary, Russia	No station log available
1891	Irkutsk, Russia	No station log available
1893	Katzively, Ukraine	No station log available
7090	Yarragadee, Australia	2020-283
7105	Greenbelt, Maryland	2020-288
7110	Monument Peak, California	2020-197
7119	Haleakala, Hawaii	2020-312
7124	Tahiti, French Polynesia	2020-125
7237	Changchun, China	2018-100
7249	Beijing, China	No station log available
7358	Tanegashima, Japan	No station log available

System	Location Name, Country	Last Change (yyyy-ddd)
7394	Sejong City, Republic of Korea	No station log available
7395	Geochang, Republic of Korea	No station log available
7396	Wuhan, China	No station log available
7403	Arequipa, Peru	2015-346
7407	Brasilia, Brazil	No station log available
7501	Hartebeesthoek, South Africa	2020-332
7503	Hartebeesthoek, South Africa	No station log available
7810	Zimmerwald, Switzerland	2020-212
7811	Borowiec, Poland	No station log available
7819	Kunming, China	No station log available
7821	Shanghai, China	2019-223
7824	San Fernando, Spain	2016-289
7825	Mt Stromlo, Australia	2018-264
7827	Wettzell, Germany	2020-115
7838	Simosato, Japan	2020-174
7839	Graz, Austria	2019-070
7840	Herstmonceux, United Kingdom	2020-269
7841	Potsdam, Germany	2020-337
7845	Grasse, France (LLR)	No station log available
7941	Matera, Italy (MLRO)	2017-338
8834	Wettzell, Germany (WLRS)	2019-155

Legend
No station log
latest update is within past 2 years
latest update is more than 2 years old

Barometric Pressure Measurement Best Practices

- The tropospheric refraction correction is sensitive to barometric pressure
  - A 1 millibar error induces an elevation dependent error: 7 and 3 mm at 20 and 90 degrees of elevation; respectively
  - An undetected barometric error impacts range bias and/or station height determinations
- Common issues with barometric measurements
  - Barometric sensors can drift over time
  - A barometric sensor change can induce a barometric offset
  - Barometric measurement updates stop resulting in frozen barometric pressures
  - The barometric sensor is not located at the same height as the system reference point and the height difference is unmodeled in the data processing
    - A 1 meter difference is height is ~0.1 millibar difference in pressure

Barometric Pressure Measurement Best Practices

- Follow manufacturer's maintenance procedures
- Calibrate your barometric sensor at least once a year
- Account for any height difference between the sensor and the system reference point in the data processing
- Install a second barometric sensor in order to make redundant measurements and regularly compare the results
- Report any barometric anomalies to the ILRS Central Bureau at ilrs-cb@lists.nasa.gov

BAROMETER DRIFTING CAUSES RB ??

SLR Graz (7839)

Peiyuan Wang, Georg Kirchner,

Michael Steindorfer, Franz Koidl

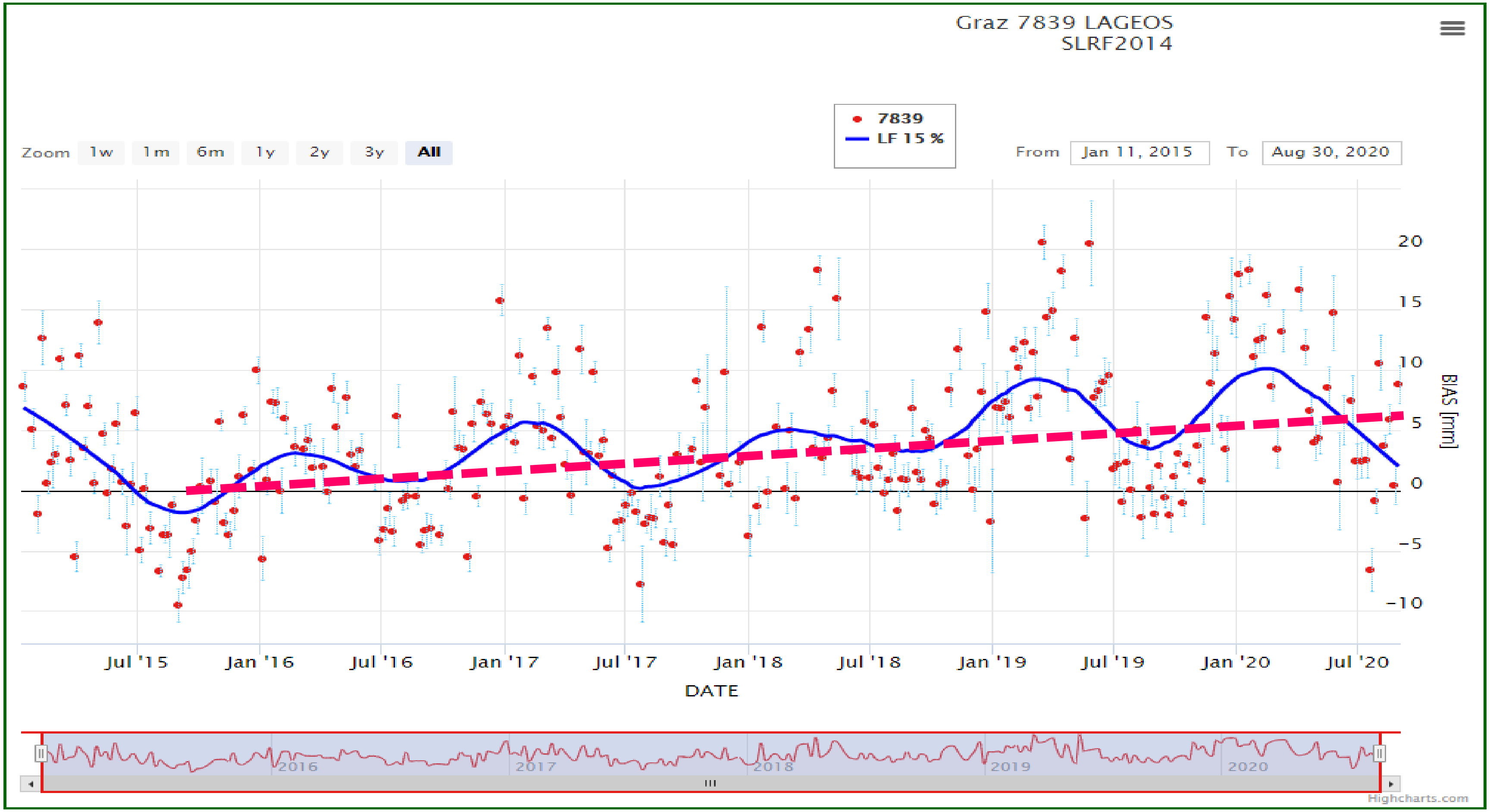
peiyuan.wang@oeaw.ac.at

MOTIVATION

- Graz: a linear increasing bias from 2015, with seasonal oscillations

(email from Erricos C. Pavlis)

MONITORING SYSTEMATIC ERRORS AT ILRS STATIONS



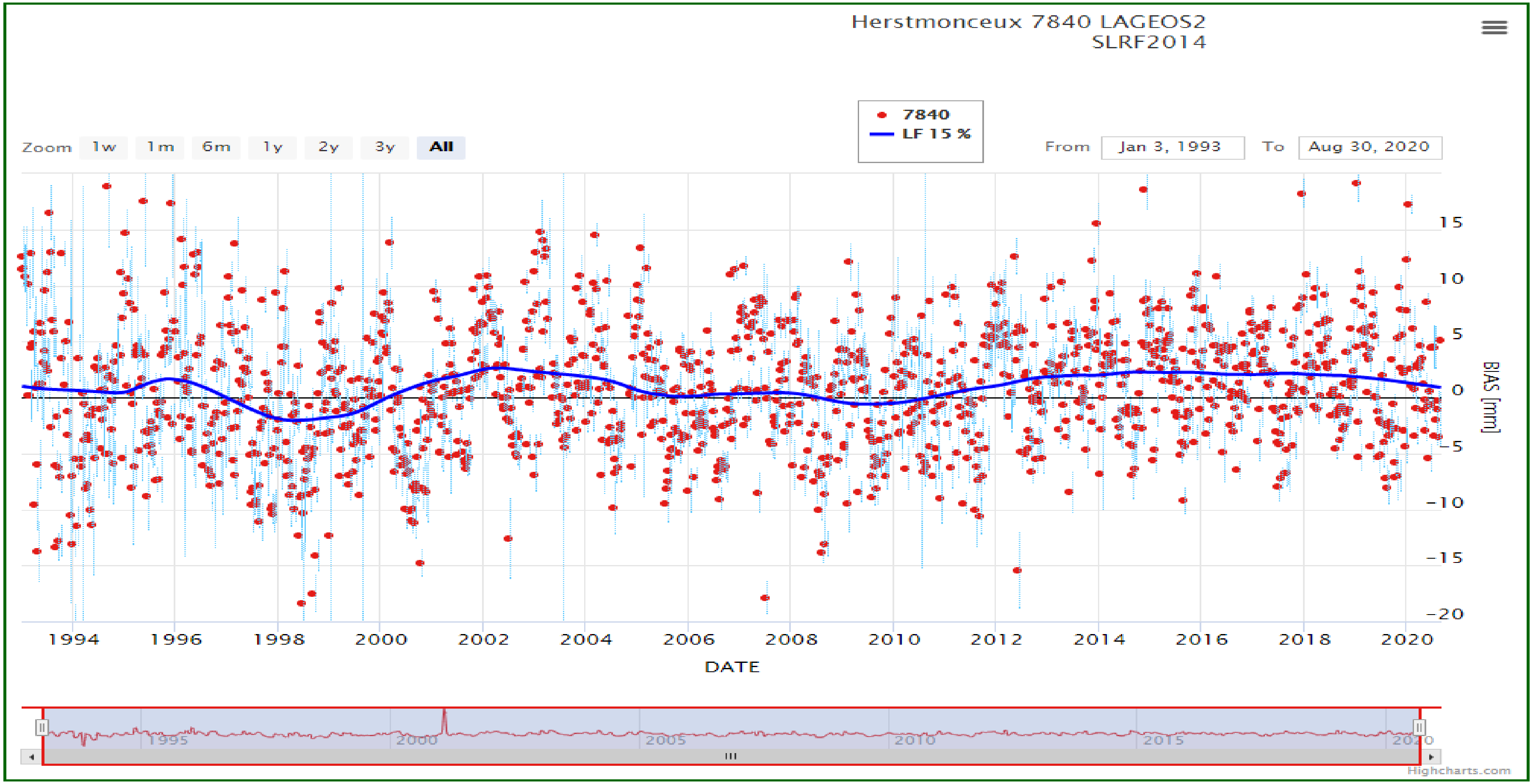
http://geodesy.jcet.umbc.edu/ILRS_AWG_MONITORING/

ÖAW IWF

MOTIVATION

- Herstmonceux 7840: no drift, only seasonal oscillations

MONITORING SYSTEMATIC ERRORS AT ILRS STATIONS



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

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INVESTIGATIONS

➢ Barometric pressure comparison (ZAMG: Central Austrian MET Office)

Inv.	Co-location	Time span	Sample rate	Devices			
				ZAMG BM35	SLR Met3A	Vaisala PTU330	ParoScientific 740-16B
1	No	5 years	3 sps/day	√	√		
2	ZAMG	3 days	Every 10 min	√		√	
3	ZAMG	7 days	Every 10 min	√			√
4	Lustbühel (Device Height)	5 days	Every 1 min		√	√	√
5	Lustbühel (Invar Point)	Two comparisons 2015 and 2020			√	√	

➢ Temperature and humidity comparison

Inv.	Co-location	Time span	Sample rate	Devices		
				ZAMG EE33-M	SLR Met3A	Vaisala PTU330
6	ZAMG	3 days	Every 10 min	√		√
7	Lustbühel	5 days	Every 1 min		√	√
8	Lustbühel	Two comparisons 2015 and 2020			√	√

BM35(ZAMG)

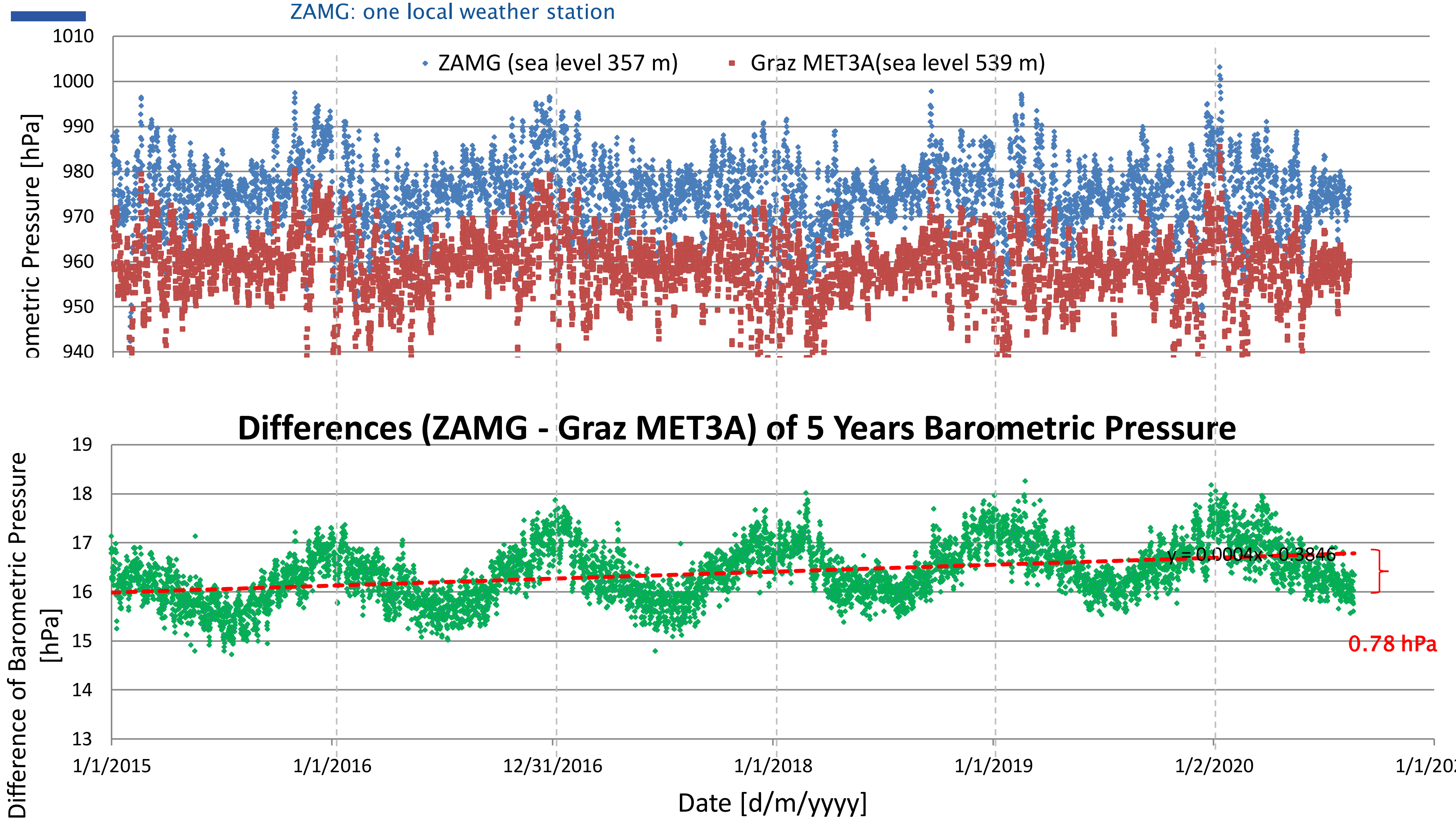

EE33-M(ZAMG)


ParoScientific 740-16B
(laser room for comparison)


Vaisala PTU330
(SP-DART)


Met3A
(SLR)

INV1: 5 YEARS BAROMETRIC PRESSURE



- The differences between ZAMG and Graz SLR Met3A drifting upward – 0.78 hPa
- The differences oscillating with a period of year: max. Winter, min. – Summer
- 1 hPa jitters of differences

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BAROMETER COMPARISON

- In 2015
  - -- Vaisala ≈ MET3A, diff. avg.: ~ 0.062 hPa
- Over 5 years
  - -- MET3A is drifting (downward) from ZAMG value – 0.78 hPa over 5 years
- Recently
  - -- Vaisala ≈ ZAMG: 0.0 hPa – 0.2 hPa
  - -- Vaisala > MET3A diff agv.: ~ 0.70 hPa

BM35
(ZAMG)

Vaisala PTU330
(SP-DART)
Bought 2015
Last calibration Oct. 2020

Met3A
(SLR)

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WHAT REASON ???

MARINI–MURRAY model: MET offset vs. Dis(1 way)

- Barometric Pressure
  - **1 hPa – 6.6 mm (EL= 13°)**
  - **1 hPa – 4.0 mm (EL= 45°)**
  - **1 hPa – 3.9 mm (EL= 85°)**
- Temperature
  - **1 °C – about 0.2 mm (EL=45°)**
- R.Humidity
  - **1 % - about 0.07 mm (EL=45°)**

MET3A vs. Vaisala

	Differences	Corresponding RB [mm]	
Barometric pressure [hPa]	0.7	2.7 - 4.6	MET3A < Vaisala

CURRENT AND NEXT

1, Data (since 2015) corrected

-- a correction model confirmed by Erricos C. Pavlis

-- data replacement is done at EDC, updating (no reaction required, will send out an information)

2, Installed a newly calibrated Vaisala PTU300 (site log updated, CB approved)

3, Order a new Vaisala with two barometers for comparison

4, Re-start the real-time comparison with 3 or 4 barometers from different companies

5, Suggestions:

-- should take care if only one barometer/ fr. one company

-- calibrate MET device regularly or compare with others

-- use useful tool-- http://geodesy.jcet.umbc.edu/ILRS_AWG_MONITORING/

Highly accurate optical time transfer

Atomic Clock Ensemble in Space

System Requirements for ranging to the ISS

Objectives

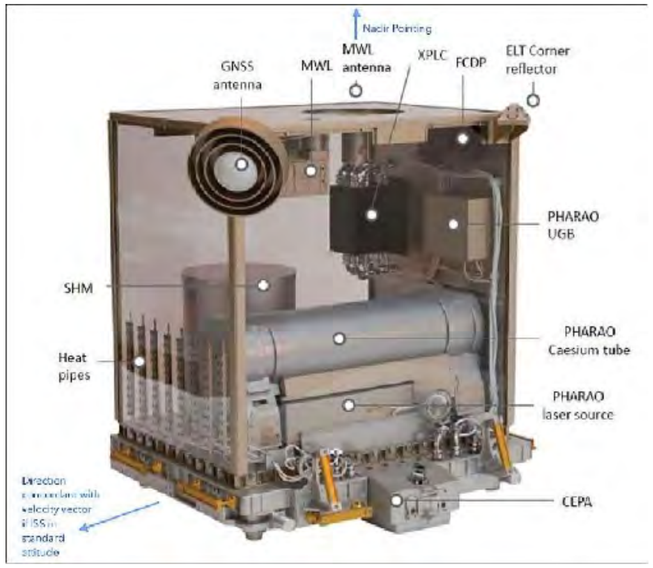
Time itself is not used in space geodesy, because it is hard to track the phase consistently

Result: The combination between different space geodetic techniques on the observation level is not satisfactory

Evidence to this effect is the discussion about scale discrepancies between SLR and VLBI

SLR has a special role in this, because it is a two-way technique

Optical time transfer probes the potential of making time accessible for a relativistic space geodesy by SLR



Requirements: (redundant) eye-safety at all times

Challenging Einstein on the ISS: ACES takes a step ahead

- ACES is scheduled for Launch on Space X in the 2nd half of 2021
- Restricted target: Wettzell obtained (laser safety) clearance recently
- The Transponder SC is propagating the requirements to particular stations - exquisite timing is required
- Missions SC has to expect the tracking request shortly: (we are currently collecting a signature from ESA)
- In order to reduce weight and power, the complexity of the time transfer is on the ground station
- Most notable is the requirement for the control of the laser fire epoch and to record the start epoch with ps- resolution

Chance for the community to compare MWL and SLR ranging

System Assessment

- Due to the Dual Use SLR + LLR on one system the conditions at the WLRS are rather involved
- Low Power Single Use Systems are a lot simpler since they are always eye-safe
- The Wettzell case serves as a template for every other station
- When a system is eye-safe at all times, there is no eye-safety hazard
- SLR only on 532 nm (in order to avoid conflict with visiting vehicles)
- Adherence to Go/NoGo flag
- Laser fire control in order to hit the rangegate (100 Hz)
- We then go straight to the experimental requirement:

Time and frequency:	link to a good clock
	no variable delay
SLR:	Start epoch to ≈ 1 ps
	Stop epoch ≈ 1 ps
Calibration:	System delay split to TX and RX
	(calibration procedure by I. Prochazka)

We have a spreadsheet to calculate the eye-safety

Laser System					
Name	ACES Ground Laser Station Wettzell				
Description	YAG				
Z136 Standard	Z136.1-2014				
Analysis Type	Single Wavelenth				
Laser					
Wavelength	532 nm				
Waveform	MP: 1.2e-011 s at 20s^-1				
Pulse Mode	MultiPulse				
Pulse Width	12 ps				
PRF	20Hz				
Laser System Operating Mode		ELT Mode	ELT Mode - failure condition small divergence	Standard Ranging **except** ISS	Standard Ranging **except** ISS
Energy per pulse	mJ	1	1	100	100
Beam Distribution	Gaussian				
Beam Profile	Circular				
Beam Geometry					
Divergence	**half-angle in µrad**	200	50	200	50
Divergence	half-angle in rad	0.0002	0.00005	0.0002	0.00005
Source	point source				
VisibilityConditions					
Distance Laser - Observer	km	400	400	400	400
Eye Exposure Duration	0.25s				
MPE per ANSI for 1.2e-11 pulse	J/cm²	2.00E-07	2.00E-07	2.00E-07	2.00E-07
MPE per ANSI for 0.25sec exposure	J/cm²	6.36E-04	6.36E-04	6.36E-04	6.36E-04
MPE per single pulse for 0.25sec exposure	MPE/5 pulses per 0.25sec interval	1.27E-04	1.27E-04	1.27E-04	1.27E-04
MPE limit to be used	J/cm²	2.00E-07	2.00E-07	2.00E-07	2.00E-07
atmospheric attenuation (Transmission 60 to 80%)	per ANSI-Z136.6 C4.1.3. Upward directed Beam	0.8	0.8	0.8	0.8
Transmission loss by masking of laser beam by secondary mirror of the telescope (6.25%)		9.40E-01	9.40E-01	9.40E-01	9.40E-01
Transmission of transmit telescope and laser beam steering optics in the laboratory (>23 optical surfaces)		7.50E-01	7.50E-01	7.50E-01	7.50E-01
Radiant exposure at ISS distance **(crew unaided eye)**	energy (in J) * transmission / ((tan half-angle * distance (in cm))^2 * pi) [J/cm²]	2.80511E-12	4.48817E-11	2.80511E-10	4.48817E-09

Impact of crew using Telescope					
Objective Diameter	mm	400	400	400	400
Objective Entry Surface	cm²	1256.637061	1256.637061	1256.637061	1256.637061
Exit diameter	mm	8	8	8	8
Exit diameter surface	cm²	0.502654825	0.502654825	0.502654825	0.502654825
Optics power		50	50	50	50
optical efficiency	90%	0.9	0.9	0.9	0.9
Energy entering Objective	[J] Radiant exposure at ISS distance * surface Objective	3.525E-09	5.64E-08	3.525E-07	5.64E-06
exiting at 8mm diameter	energy * 0.9	3.1725E-09	5.076E-08	3.1725E-07	5.076E-06
radiant exposure exiting Objective	[J/cm²] energy exiting objective/ surface Exit	6.31149E-09	1.00984E-07	6.31149E-07	1.00984E-05
Eye limit aperture	diameter in cm	0.7	0.7	0.7	0.7
Eye limit aperture	surface in cm²	0.3848451	0.3848451	0.3848451	0.3848451
Eye Energy (MPE)	in J (based on 5 pulses per 0.25sec)	7.70E-08	7.70E-08	7.70E-08	7.70E-08
Radiant exposure energy (Eye)	[J] radiant exposure exiting Objective * Eye Surface	2.43E-09	3.89E-08	2.43E-07	3.89E-06