2017 ILRS TECHNICAL WORKSHOP

THE COPERNICUS SENTINEL-3 MISSION

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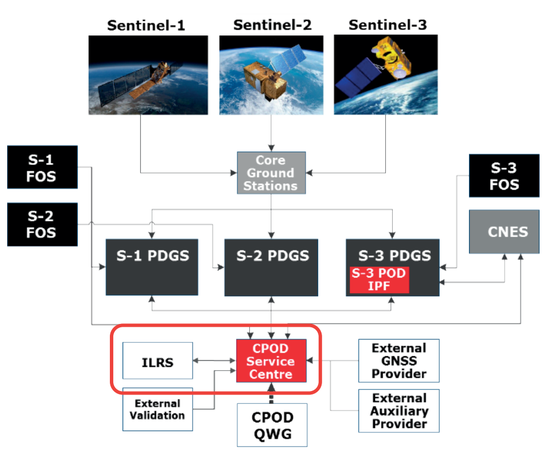
OVERVIEW OF THE COPERNICUS POD SERVICE

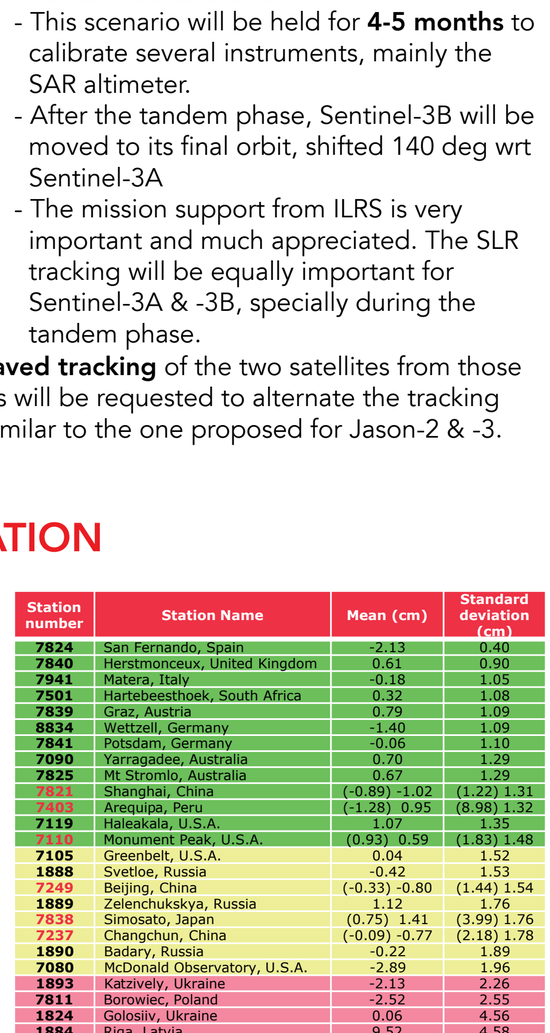
Copernicus program facts:
- A joint initiative of the **European Commission** and the **European Space Agency**
- Aims to establish an autonomous European Earth Observation capacity with different missions: Sentinel-1 to -6
- Copernicus POD Service in charge of Sentinel-1, -2 and -3

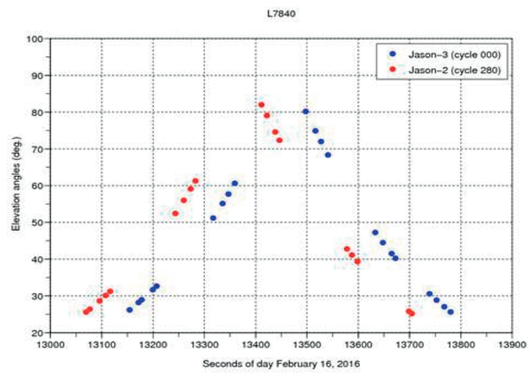
Copernicus POD Service facts:
- Part of the **PDGS Ground Segment** of the Sentinel missions
- In charge of the generation of **precise orbital products** and auxiliary data files
- **Developed** and **operated** by a **GMV-led consortium**
- **Location**: Operated on **GMV premises** (Tres Cantos, Spain)
- Based on **NAPEOS** (Navigation Package for Earth Orbiting Satellites)
- Responsible for the interface with the **ILRS Community**:
  - In charge of generating CPF orbit files
  - Main user of SLR measurements for independent orbit validation



TANDEM CONSTELLATION: SENTINEL-3A & -3B

- **Sentinel-3A** was launched in 16th February 2016 and **Sentinel-3B** is planned to be launched in Feb/March 2018. The mission will be developed by **ESA**; and jointly operated by **ESA** and **EUMETSAT**
- Both satellites are identical. For fulfilling the demanding **Precise Orbit Determination (POD) requirements** (2-3 cm in radial direction), it carries two GPS receivers, a DORIS receiver and a laser retro-reflector for Satellite Laser Ranging (SLR).
- **Main applications**: monitor Earth's oceans, land, ice and atmosphere to study large-scale global dynamics and provide near-real time information for ocean and weather forecasting
- **Main instruments**: Radar Altimeter (SRAL), Ocean and Land Colour Instrument (OLCI), Sea Land Surface Temperature Radiometer (SLSRR), and Micro Wave Radiometer (MWR)





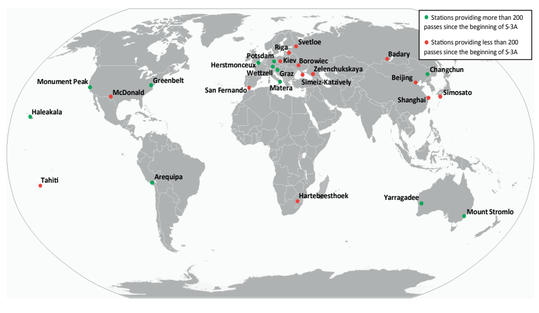
- During its commissioning phase, it will fly only 30 sec apart form Sentinel-3A → **Tandem Constellation**
- This scenario will be held for **4-5 months** to calibrate several instruments, mainly the SAR altimeter.
- After the tandem phase, Sentinel-3B will be moved to its final orbit, shifted 140 deg wrt Sentinel-3A
- The mission support from ILRS is very important and much appreciated. The SLR tracking will be equally important for Sentinel-3A & -3B, specially during the tandem phase.
- Sentinel-3 project will request to ILRS for **interleaved tracking** of the two satellites from those SLR stations able to perform it. The other stations will be requested to alternate the tracking evenly between both satellites. This scenario is similar to the one proposed for Jason-2 & -3.

ILRS STATIONS STATISTICS – SENTINEL-3A

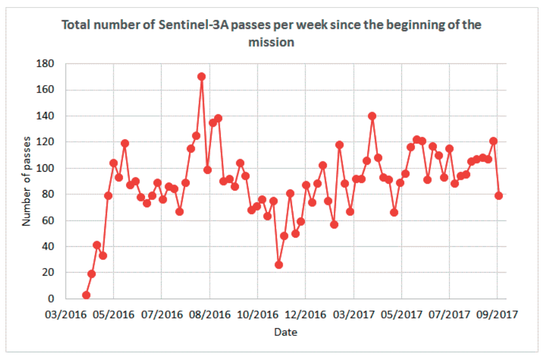
SLR is a key technique to calibrate the GPS and DORIS instruments and the overall POD processing chain. A decent amount of SLR tracking data is needed for the entire mission to perform regular checks of the biases that could exist between different tracking techniques.

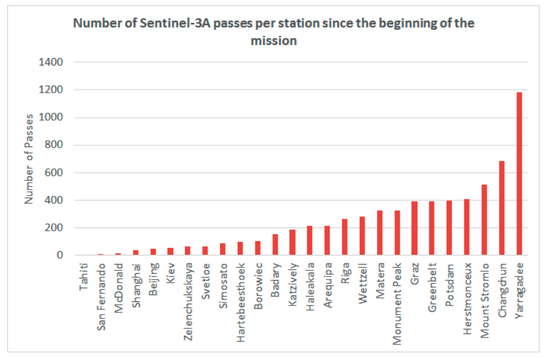
Status and performance of the S-3A SLR processing are presented focusing on the station quality assessment.

More than one year of operational data has been analysed. SLR



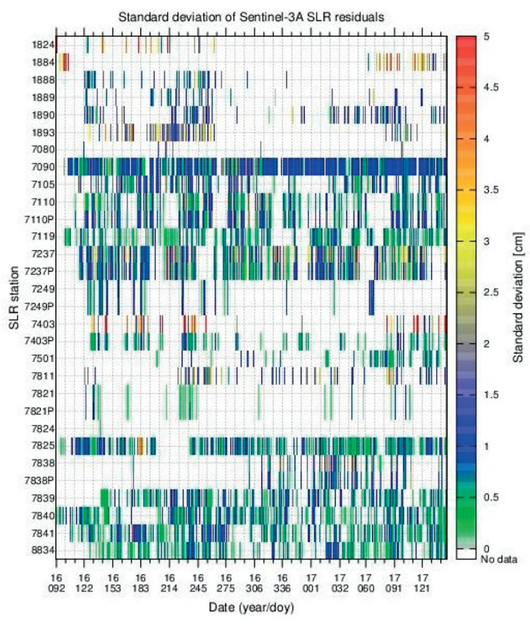
Map with statistics on ILRS stations tracking Sentinel-3A. Only those that signed the Sentinel-3 tracking agreement based on power restrictions are included.





ANALYSIS OF ACCURACY – SLR RESIDUALS

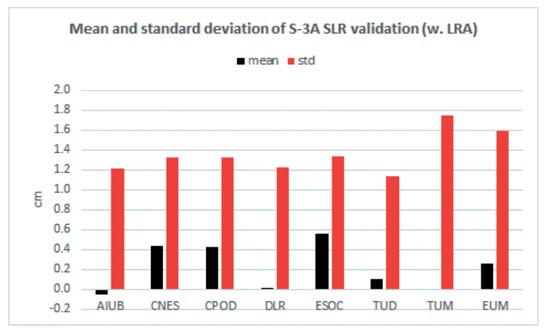
Standard deviation of S-3A SLR residuals



The SLR stations marked with a "P" have been corrected with the "Post-Seismic Deformation (PSD)"

Mean and standard deviation of S-3A SLR validation per centre

- A SLR validation was performed based on the final station list form 1st April 2016 to 31st May 2017 using all QWG S-3A orbits.
- ITRF2014 station coordinates were used.



- Laser Retroreflector Array (LRA) corrections were applied for this validation.
- Mean values are between -0.05 cm and 0.56 cm
- St. deviation are between 1.13 cm and 1.75 cm
- EUM orbits were only available from 01/10/2016 to 31/05/2017 and TUM orbits from 01/02/2017 to 31/05/2017.

SLR STATION LIST FOR VALIDATION

- 25 stations all around the world have been tracking S-3A since the beginning of the mission.
- Some of them provide better results than others.
- Some of them have tracked the satellite more times than others (from 12 to 19860 normal points)
- The proper application of the Post-Seismic Displacement file in connection with the SLRF2014 coordinates has been implemented by PosiTim. The table on the right shows the results of a SLR validation for the S-3A NTC orbits over the entire mission time. The standard deviation of four stations affected by PSD has improved whereas it is slightly worse for two of them.
- Moreover, the quality of the SLR stations has been assessed based on the statistics from ILRS analysis centres of other satellites' observations (such as Lageos 2) to estimate the station range biases.

Station number	Station Name	Mean (cm)	Standard deviation (cm)
7824	San Fernando, Spain	-2.13	0.40
7840	Herstmonceux, United Kingdom	0.61	0.90
7941	Matera, Italy	-0.18	1.05
7501	Hartebeesthoek, South Africa	0.32	1.08
7839	Graz, Austria	0.79	1.09
8834	Wettzell, Germany	-1.40	1.09
7841	Potsdam, Germany	-0.06	1.10
7090	Yarragadee, Australia	0.70	1.29
7825	Mt Stromlo, Australia	0.67	1.29
7821	Shanghai, China	(-0.89) -1.02	(1.22) 1.31
7403	Arequipa, Peru	(-1.28) 0.95	(8.98) 1.32
7119	Haleakala, U.S.A.	1.07	1.35
7110	Monument Peak, U.S.A.	(0.93) 0.59	(1.83) 1.48
7105	Greenbelt, U.S.A.	0.04	1.52
1888	Svetloe, Russia	-0.42	1.53
7249	Beijing, China	(-0.33) -0.80	(1.44) 1.54
1889	Zelenchukskya, Russia	1.12	1.76
7838	Simosato, Japan	(0.75) 1.41	(3.99) 1.76
7237	Changchun, China	(-0.09) -0.77	(2.18) 1.78
1890	Badary, Russia	-0.22	1.89
7080	McDonald Observatory, U.S.A.	-2.89	1.96
1893	Katzively, Ukraine	-2.13	2.26
7811	Borowiec, Poland	-2.52	2.55
1824	Golosiiv, Ukraine	0.06	4.56
1884	Riga, Latvia	9.52	4.58

*In red the stations affected by the PSD corrections
**In brackets, the results without PSD corrections

- To make the SLR analysis comparable within the Copernicus POD QWG, a common list of SLR stations is selected based on the following criteria:
  - Number of normal points in the S-3A lifetime
  - Std. deviation of preliminary Sentinel-3A orbit validation
  - Range biases of Lageos2 analysis
  - Mean of Jason-2 SLR residuals
  - Exclusion of stations affected by PSD (for the time being, because not yet all QWG members have implemented the application in their SW packages).

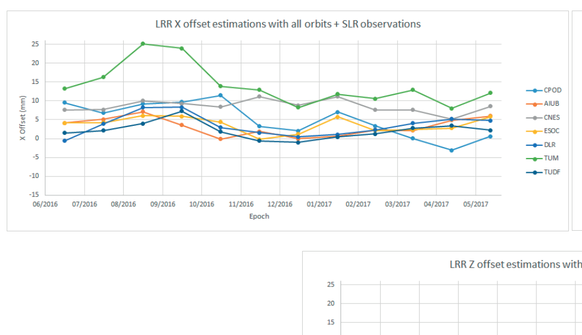
Station number	Station Name
7840	Herstmonceux, United Kingdom
7941	Matera, Italy
7501	Hartebeesthoek, South Africa
7839	Graz, Austria
8834	Wettzell, Germany
7841	Potsdam, Germany
7090	Yarragadee, Australia
7119	Haleakala, U.S.A.
7105	Greenbelt, U.S.A.

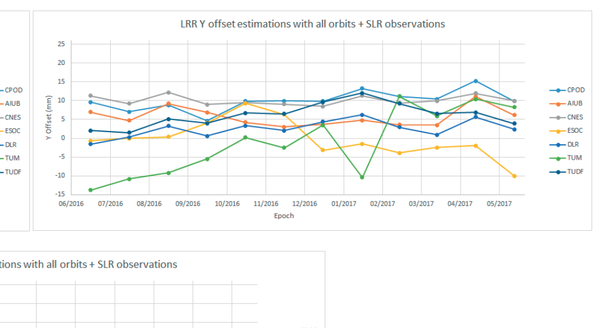
LRR POSITION ESTIMATION WITH SLR OBSERVATIONS

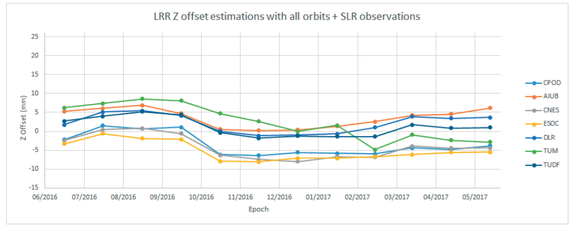
- The Laser Retro Reflector (LRR) position has been estimated by fixing the S-3A orbits coming from all the QWG centres and minimising the SLR observations residuals.
- The computational timespan starts on 01/06/2016 and ends on 01/06/2017.
- Current position is X=1134.03 mm, Y=637.905 mm, Z=801.18 mm with respect to satellite axis.
- The obtained average offsets per centre are summarized in the table below:

	CPOD	AIUB	CNES	ESOC	DLR	TUM	TUDF	AVERAGE
LRR X offset (mm)	5.02	3.14	8.59	3.73	3.52	14.10	2.11	**5.74**
LRR Y offset (mm)	9.97	5.65	10.10	-0.29	2.53	-1.05	6.17	**4.73**
LRR Z offset (mm)	-3.49	3.57	-4.16	-5.18	2.14	2.34	1.14	**-0.52**

- The differences may be attributed to different modelling aspects of the software packages

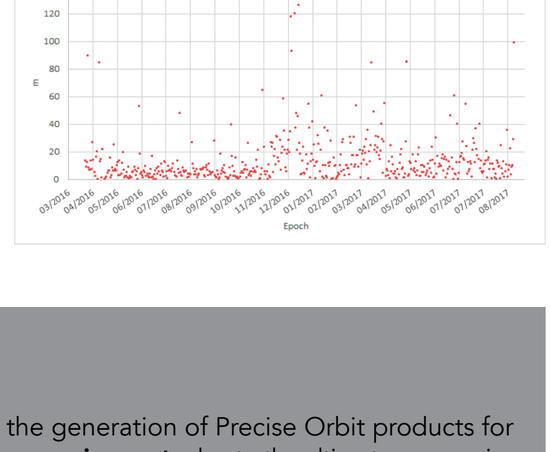






ANALYSIS OF ACCURACY – CPF FILES

- **Consolidated Prediction Format (CPF)** files delivered to the ILRS Community are based on an orbit propagation from the STC product for 5 days into the future.
- Accuracy of the CPF files is assessed by comparison to the STC product with the coverage of the first predicted day of the CPF. Results show that the CPFs accuracy is typically below **20 m 3D RMS**.



CONCLUSIONS

- **The Copernicus POD Service** is responsible for the generation of Precise Orbit products for the Sentinel-3 mission with **very demanding accuracy requirements** due to the altimetry processing.
- The **Copernicus POD Service** serves as the **interface** with the ILRS Community, and is in charge of the generation of the CPF orbit files with the adequate latency and accuracy requirements. Moreover, it is responsible for the routinely use of the **SLR measurements** from all stations to validate the generated orbital products to ensure that there are no unexpected biases which might have a negative impact on the altimeter results.
- **Sentinel-3B** will fly in **Tandem formation** with Sentinel-3A during its commissioning phase to calibrate several instruments. An **interleaved tracking** in long passes will be much appreciated during this phase to estimate relative biases.
- A **common list of SLR stations** for the Copernicus QWG has been developed based on the number of observations, the quality of the SLR analysis, the PSD correction results and the statistics of ILRS analysis centres (e.g. the range biases of Lageos2 and residuals mean of Jason-2 SLR).

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