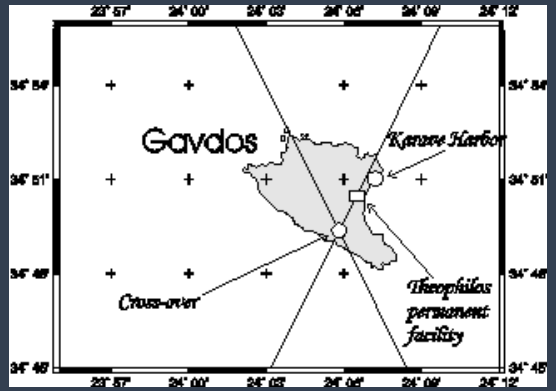
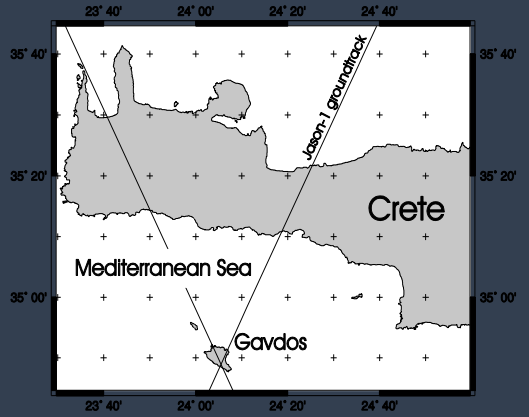
Current Cal/Val results on the performance of Jason-3, Sentinel-3 and HY-2B radar altimeters using transponder and sea-surface calibrations at the Permanent Facility for Altimetry Calibration in Gavdos/Crete.

Mertikas[1] S., C. Donlon[2], A. Tripolitsiotis[3], C. Mavrocordatos[2], P. Féménias[2], F. Borde[2], X. Frantzis[1], C. Kokolakis[3], D. Piretzidis[3], T. Guinle[4], F. Boy[4], M. Lin[5], Y. Jia[5], G. Vergos[5], R. Cullen[2], I. Tziavos[6]

[1]Technical University of Crete,
[2] European Space Agency,
[3]Space Geomatica, Greece,
[4]CNES, France
[5]NSOAS, China,
[6]Aristotle University of Thessaloniki, Greece.

Gavdos/Crete Permanent Cal/Val Facility





Permanent Facility For Altimetry Calibration

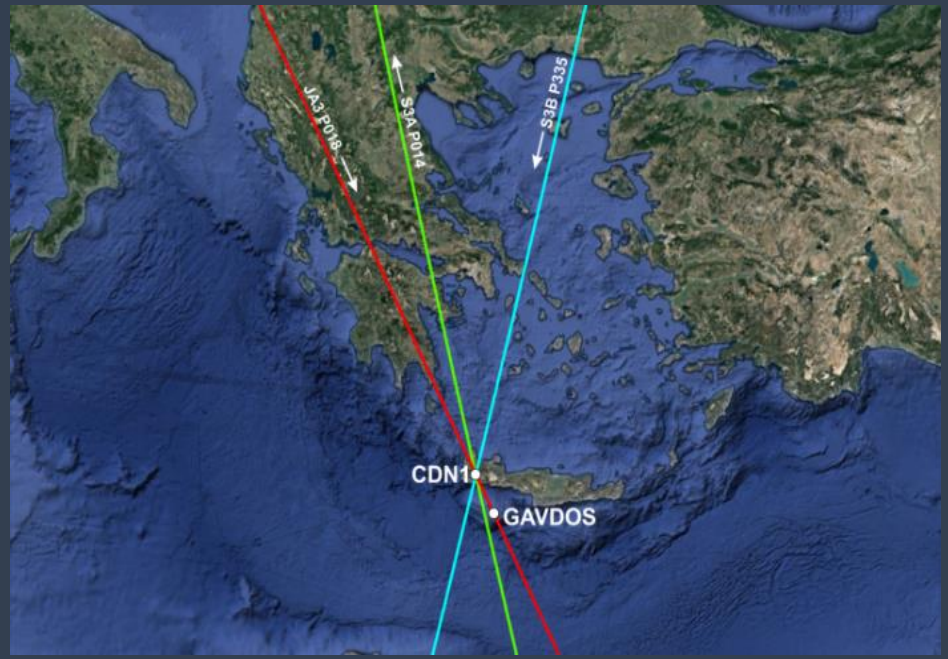
ESA Projects to support Operational Cal/Val Altimetry:

- **SERAC**: Support absolute Cal/Val for Sentinel-3,
- **FRM4S6**: Strengthen & maintain PFAC for Sentinel-6 Cal/Val.

Key Objectives:

- Calibrate altimeters at FRM Standards,
  - To absolute reference signals,
  - Traceable to SI-standards,
  - With different & redundant techniques (sea & land),
  - With various processes, diverse instrumentation & settings,
- Report FRM uncertainty for Cal/Val Results;
- Maintain & Upgrade PFAC with a 2nd transponder;
- Analyse performance against other missions.

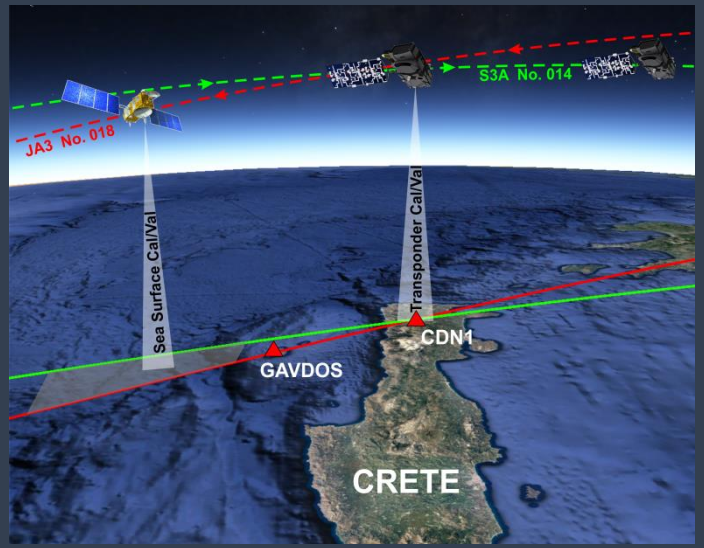
Land & Sea Calibrating Regions



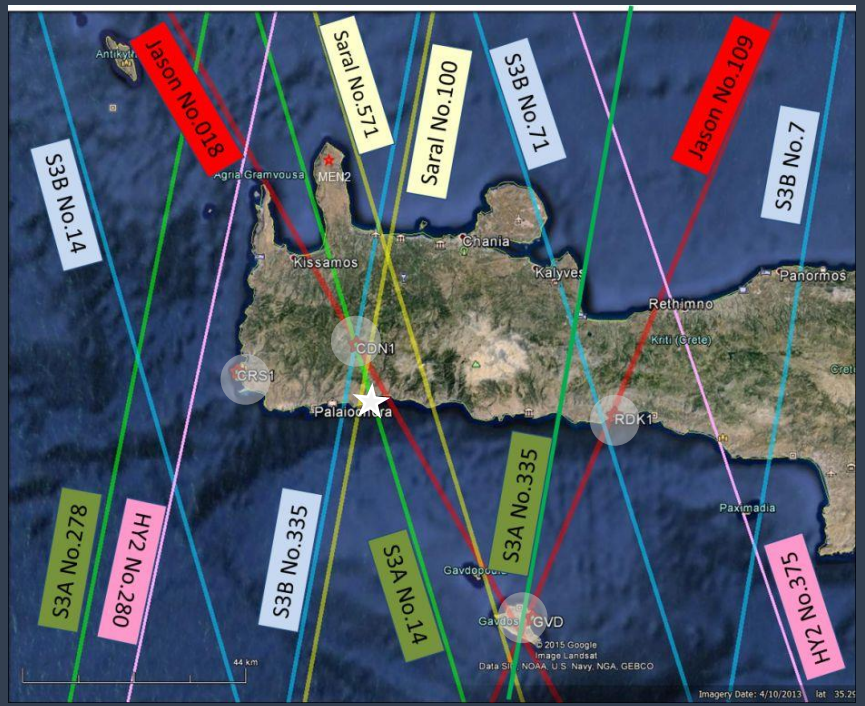
Transponder at CDN1 Cal/Val

Gavdos sea-surface Cal/Val

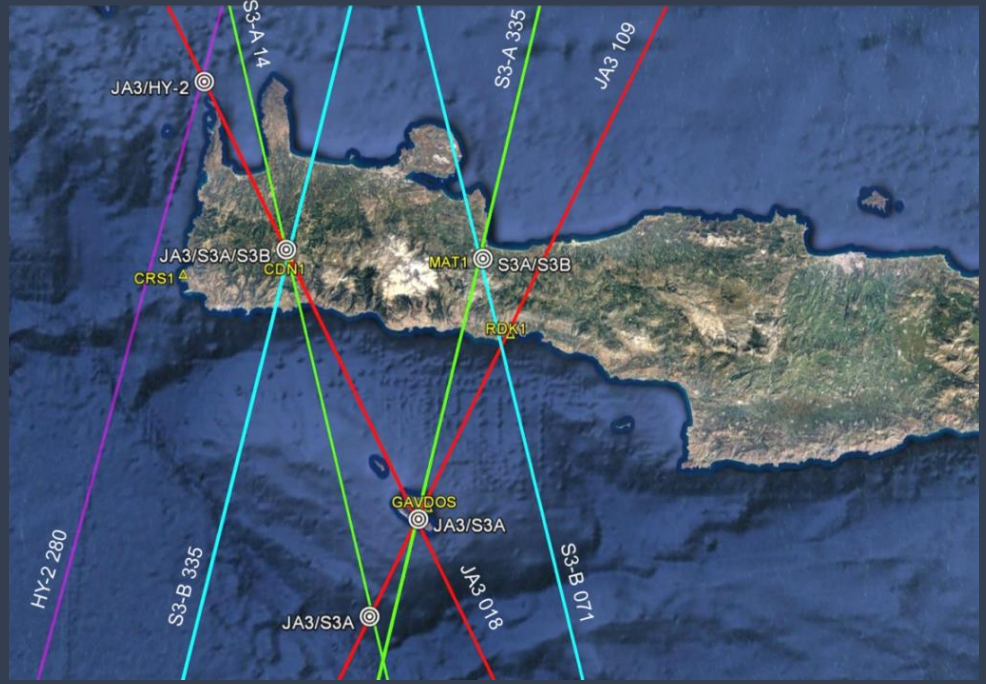
Groundtracks around Crete & Gavdos

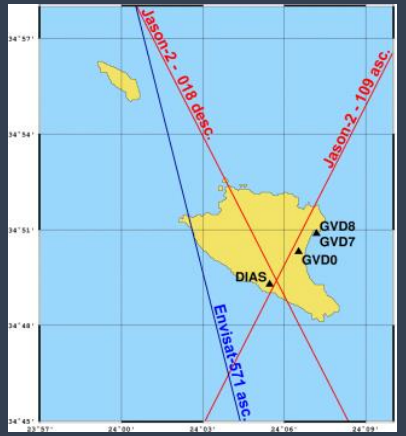


Transponder & Sea-Surface simultaneous

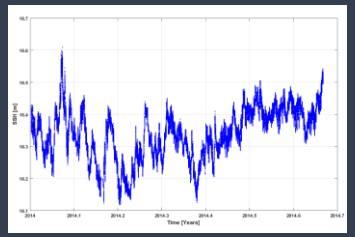


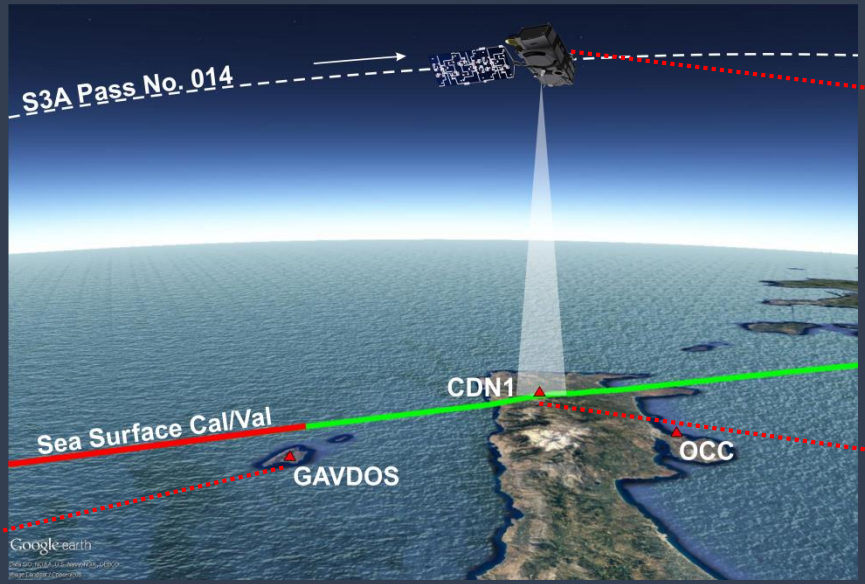
Major Cal/Val and crossover sites

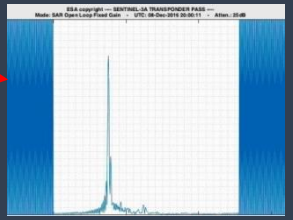


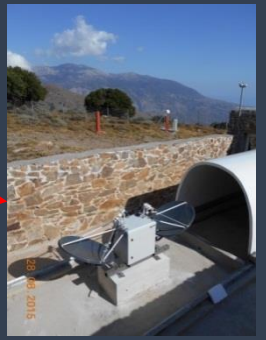


Simultaneous Transponder & Sea Cal/Val

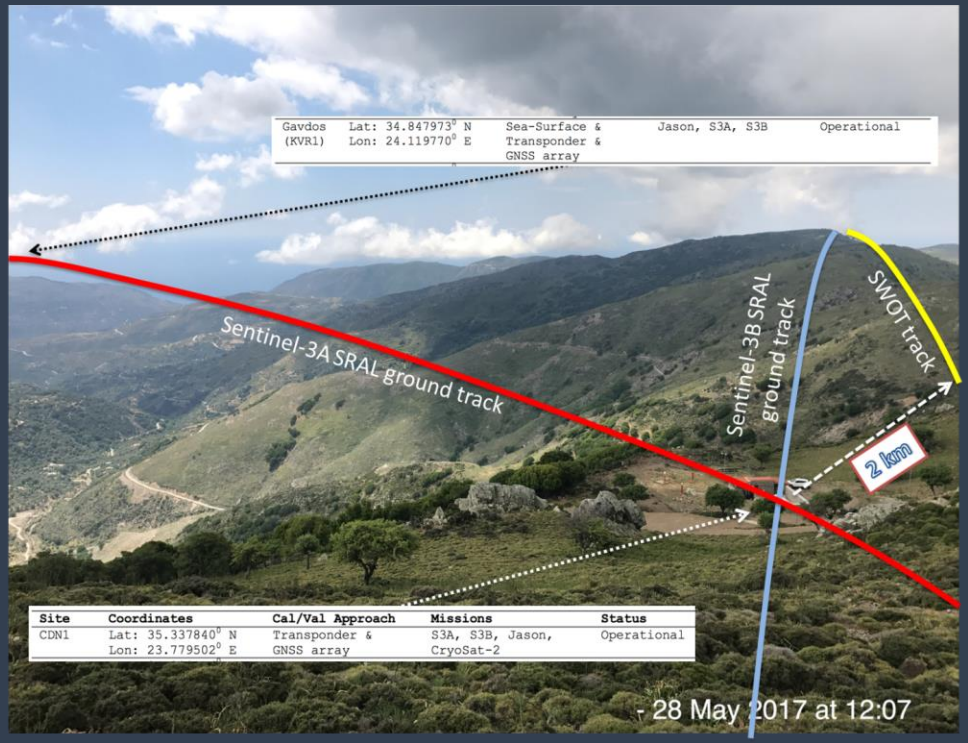




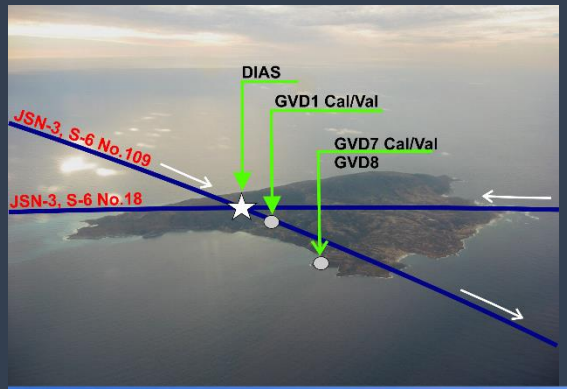


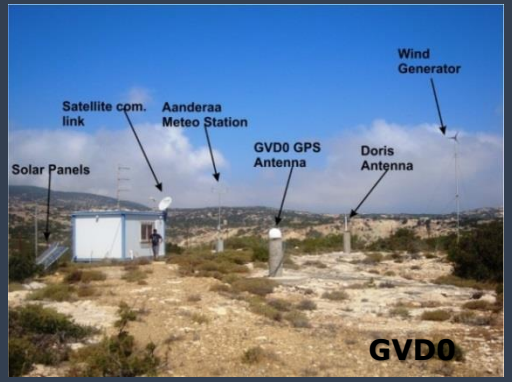


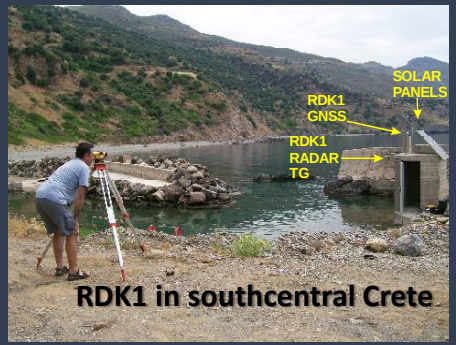
Transponder CDN1 Cal/Val Facility



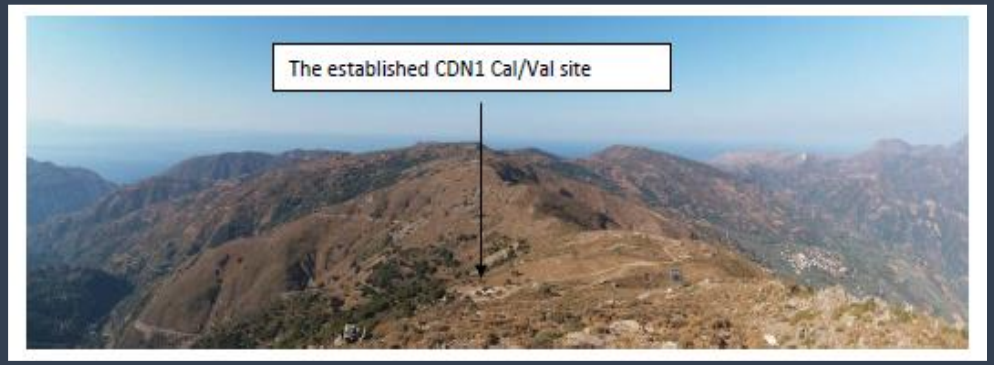
Sea-surface Cal/Val Facilities

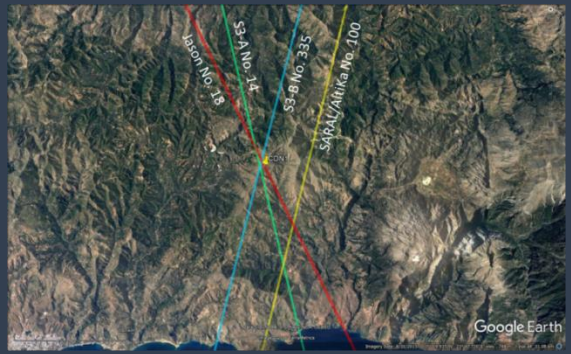




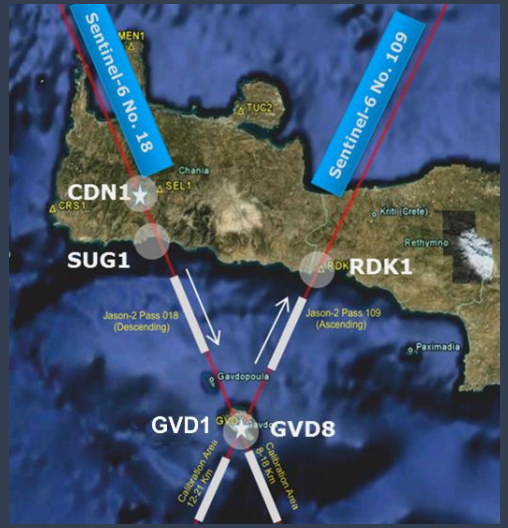


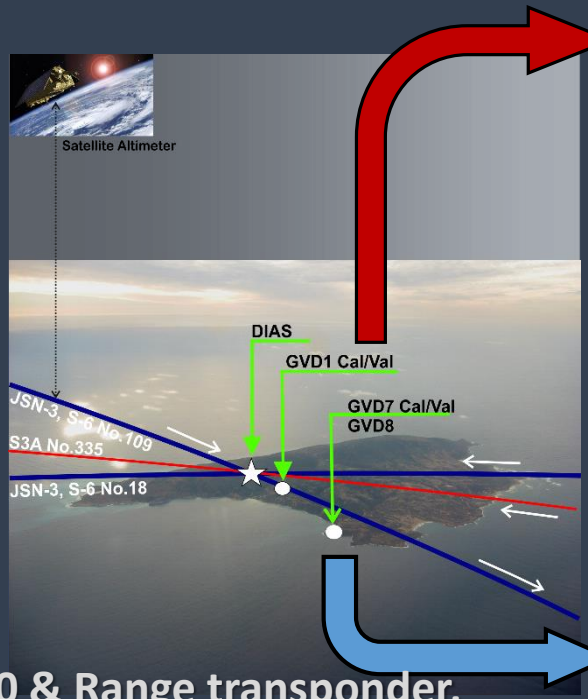
CDN1: ESA Altimeter Cal/Val site for S3 &S6





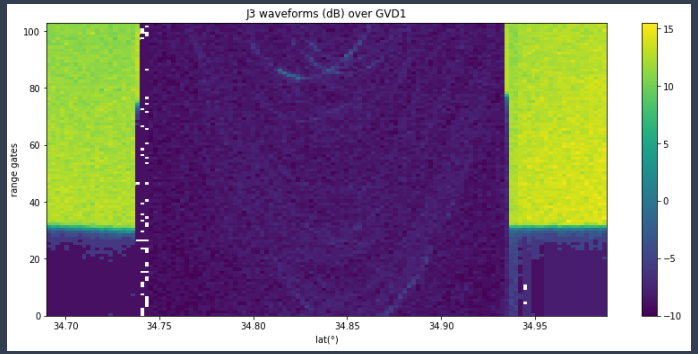
GVD1: ESA Sentinel-6 Altimeter Calibration



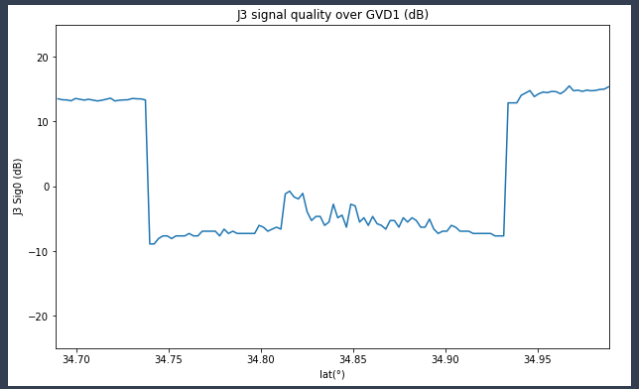


Developing new Sigma-0 & Range transponder,
For operational redundancy,
Be ready in Q1 2021 (Covid-19 might delay).

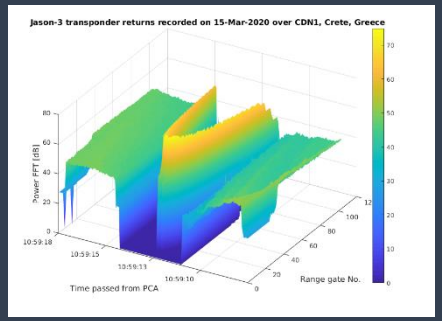
Jason-3 Signal Quality over GVD1 Cal/Val



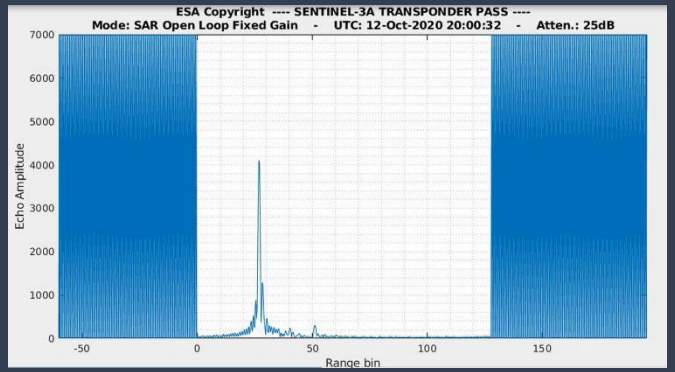
- Jason-3 signal quality monitored over GVD1;
- Signal clutter is below 0 dB;
- Better than the one observed over CDN1.



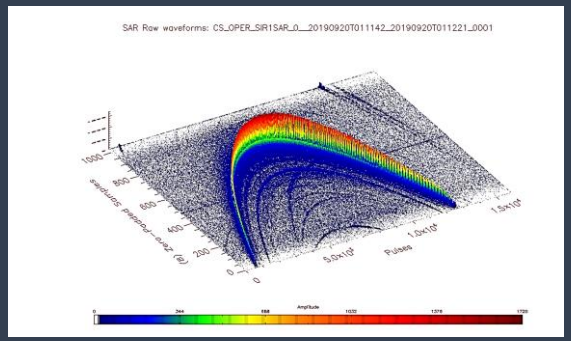
Transponder Calibrations at CDN1 Cal/Val



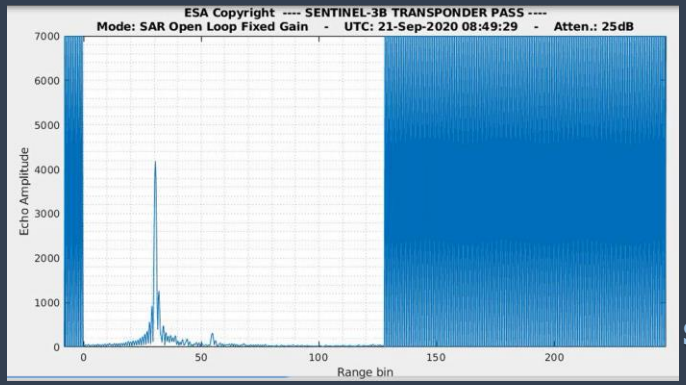
Jason-3, 15-March-2020



Sentinel-3A 12-Oct-2020

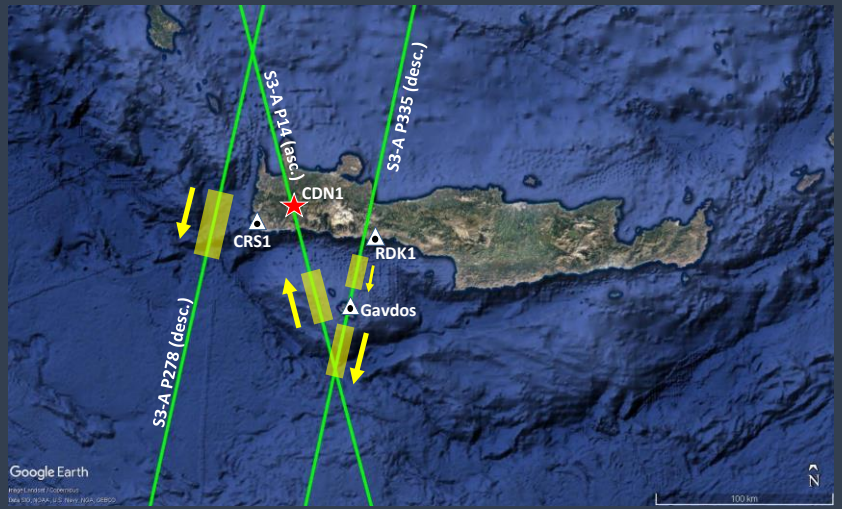


CryoSat-2, 20-Sept-2019



Sentinel-3B 21-Sept-2020

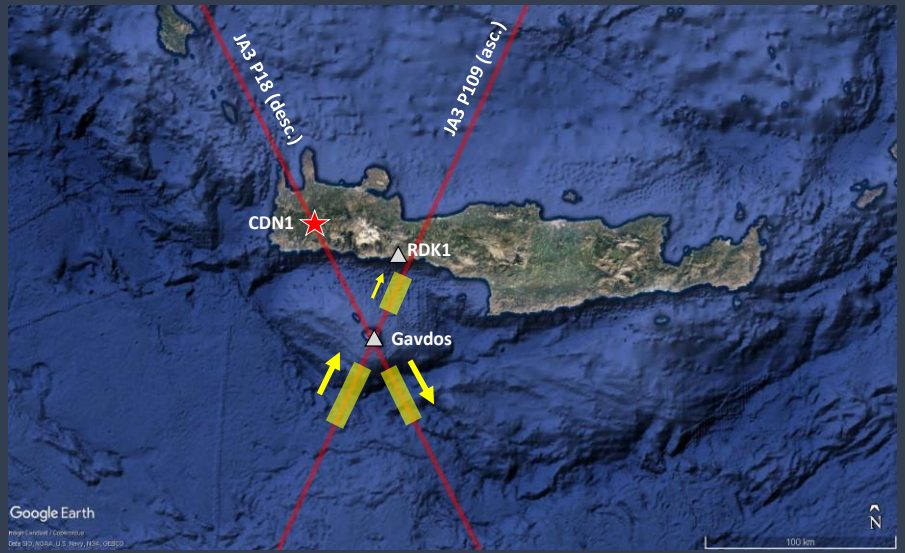
Sentinel-3 Cal/Val over Crete



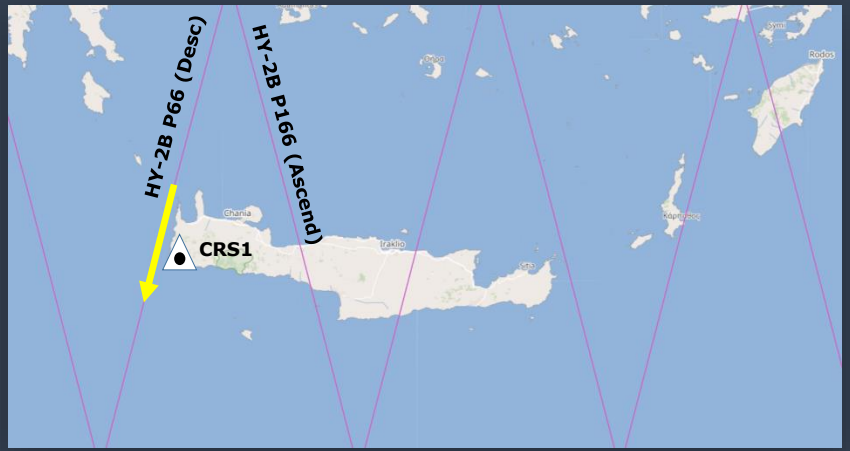
Sentinel-3A

Sentinel-3B

Jason-3 & HY-2B Cal/Val over Crete

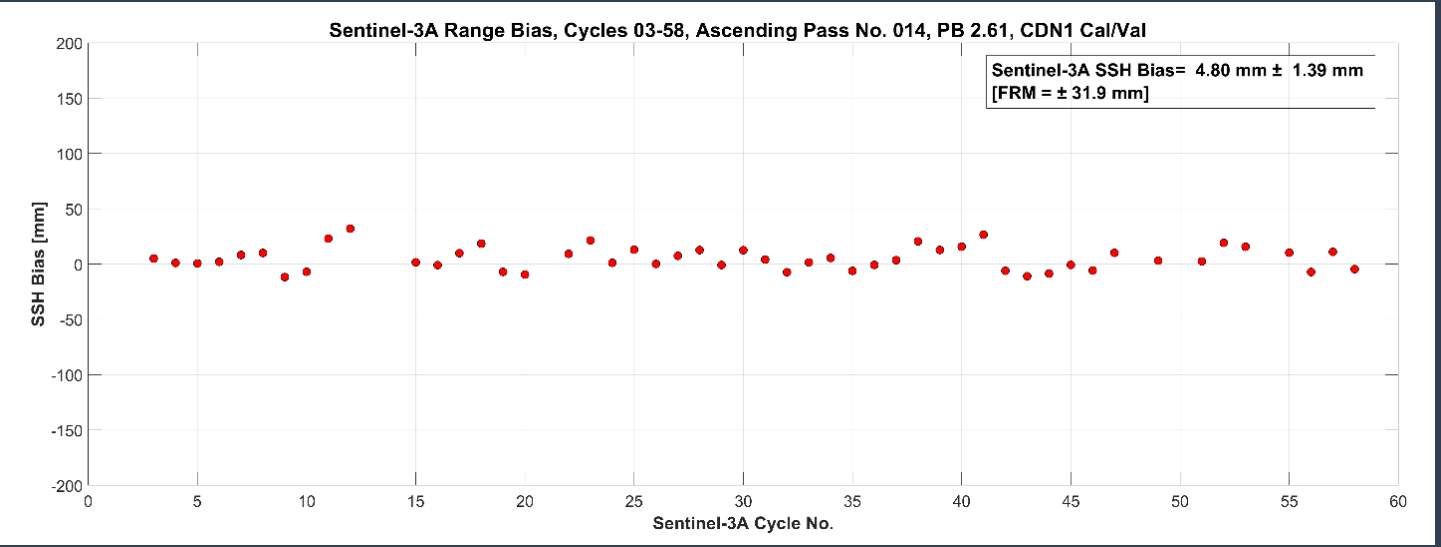


Jason-3



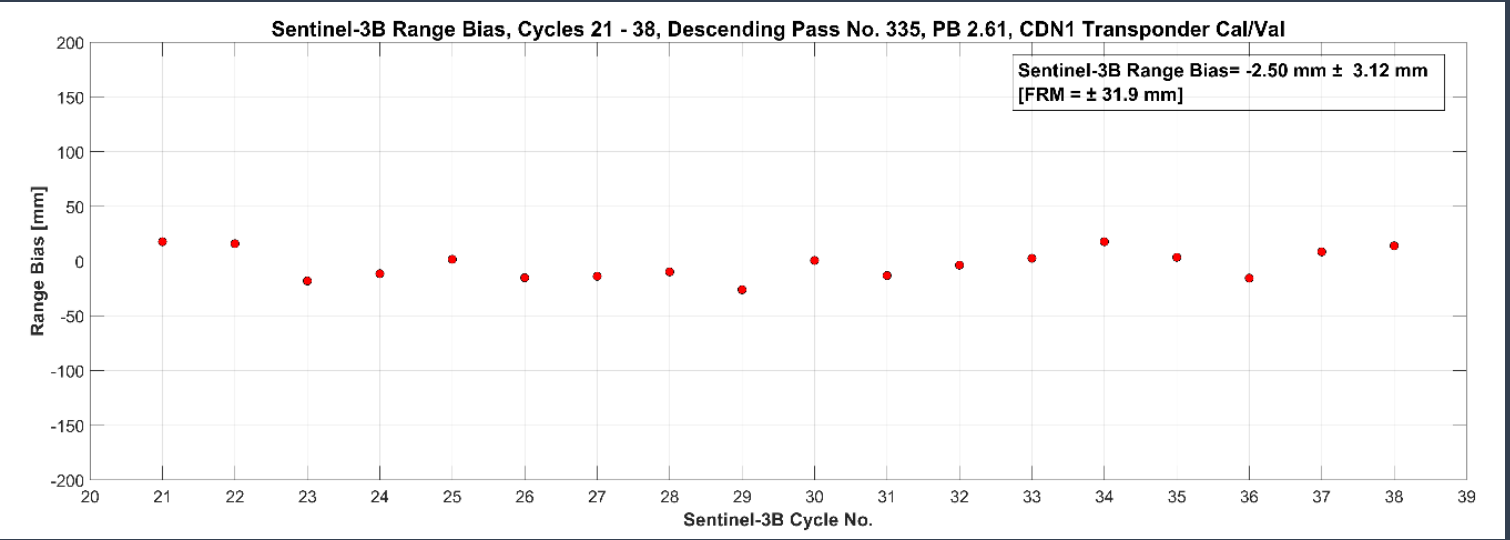
HY-2B

S3A Transponder Cal/Val (CDN1): Pass No.14



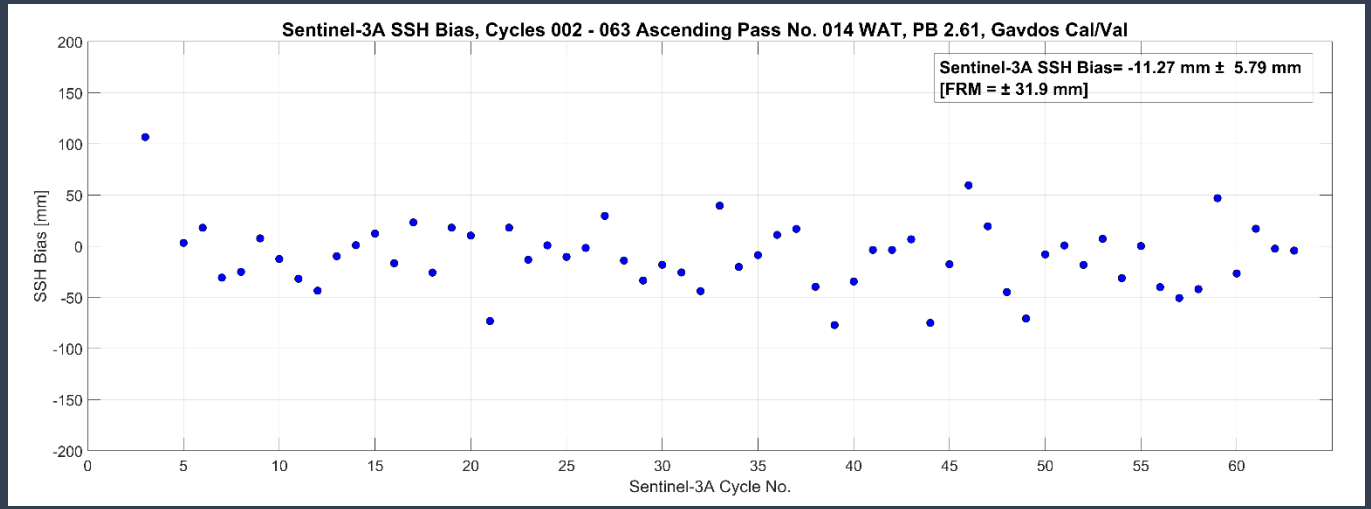
- S3A Ascending Pass No. 14, Cycles: 3-58
- NTC, Processing Baseline: 2.61,
- Transponder Range Bias **B= +4.8 mm ± 1.4 mm (FRM Uncertainty ± 32 mm) ,**

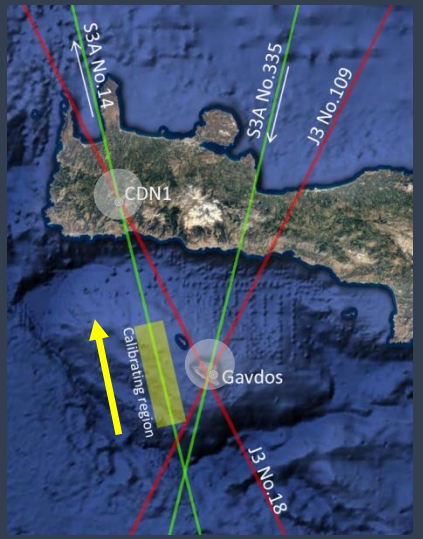
S3B Transponder Cal/Val (CDN1): Pass No.335



- S3B Descending Pass No. 335, Cycles 21 – 38 (nominal orbit)
- NTC, Processing Baseline: 1.33,
- Transponder Range Bias **B= -2.5 mm ± 4 mm (FRM Uncertainty ± 32 mm) ,**

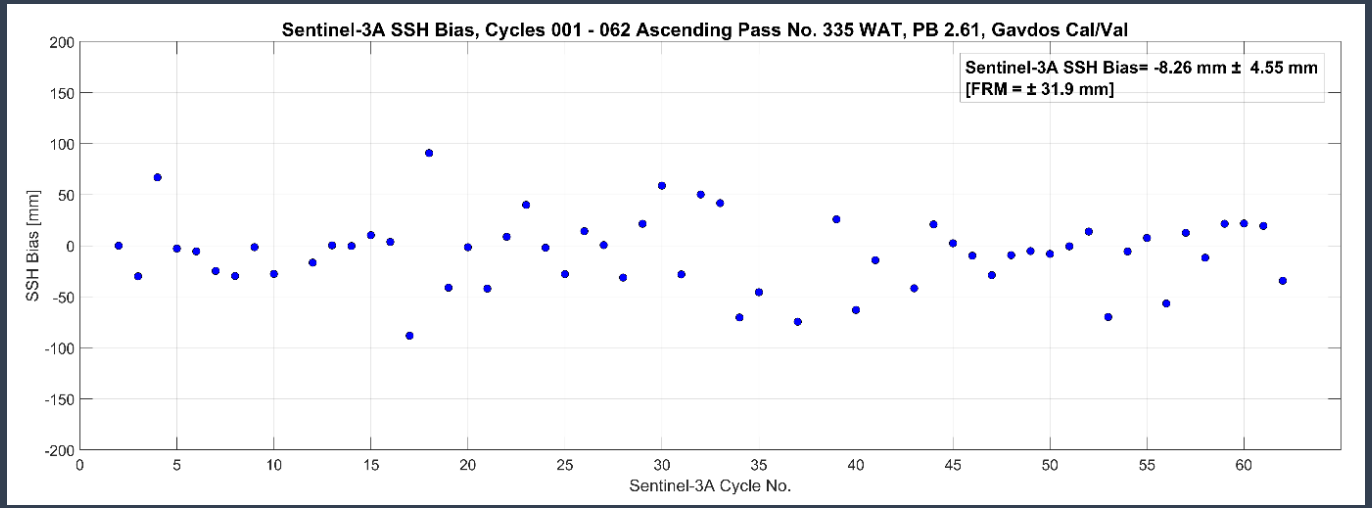
S3A SSH Bias: Pass No. 14 (Ascending)

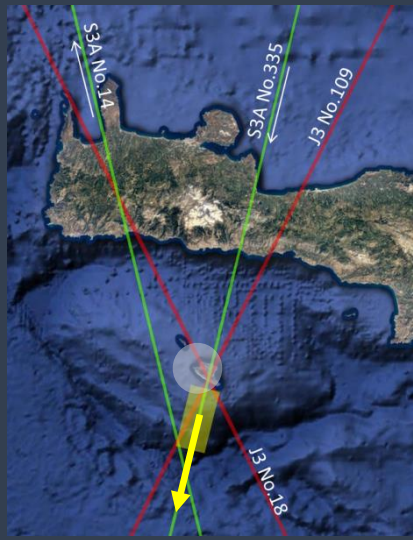




- S3A Ascending Pass No. 14, Cycles: 2-63
- WAT, NTC, Processing Baseline: 2.61,
- Sea-Surface Height Bias **B= -11 mm ± 6 mm (FRM ± 32 mm)** ,

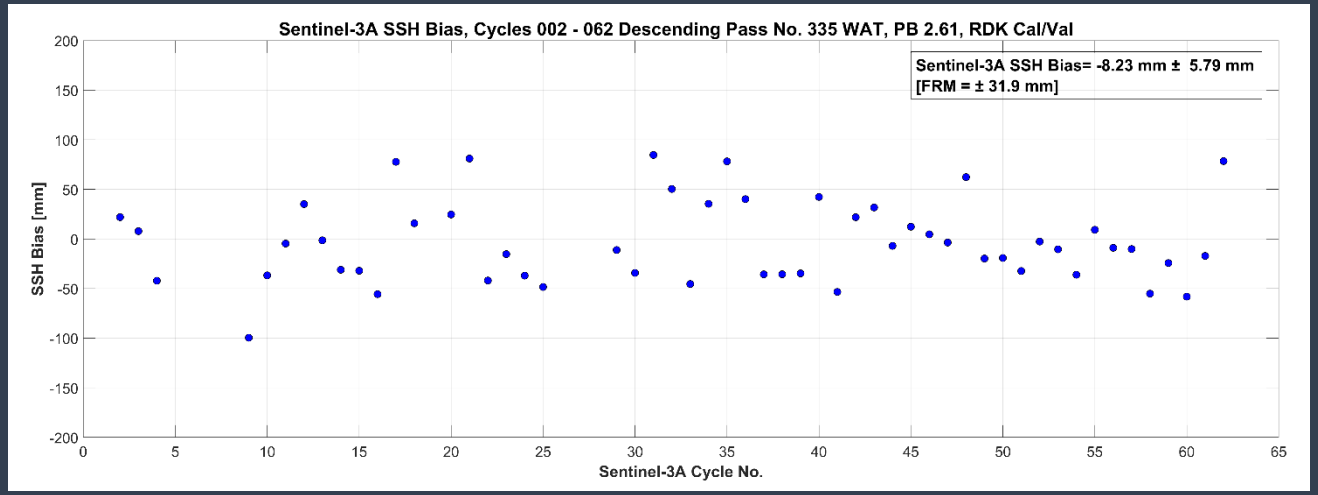
S3A SSH Bias: Pass No. 335 (Descending)

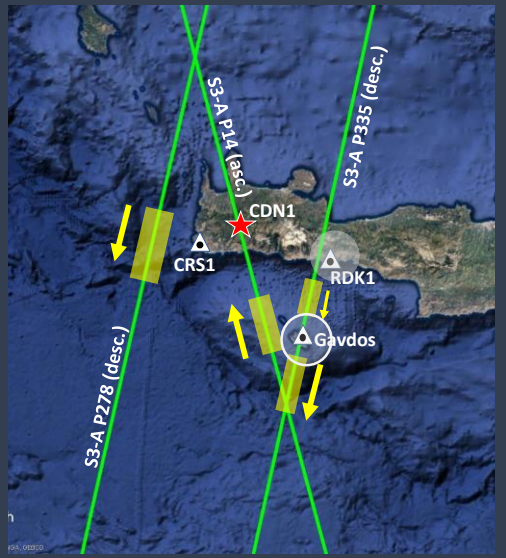




- S3A Descending Pass No. 335, Cycles: 2-62, Gavdos Cal/Val
- WAT, NTC, Processing Baseline: 2. 61,
- Sea-Surface Height **Bias B= -8 mm ± 4 mm** (FRM ± 32 mm) ,

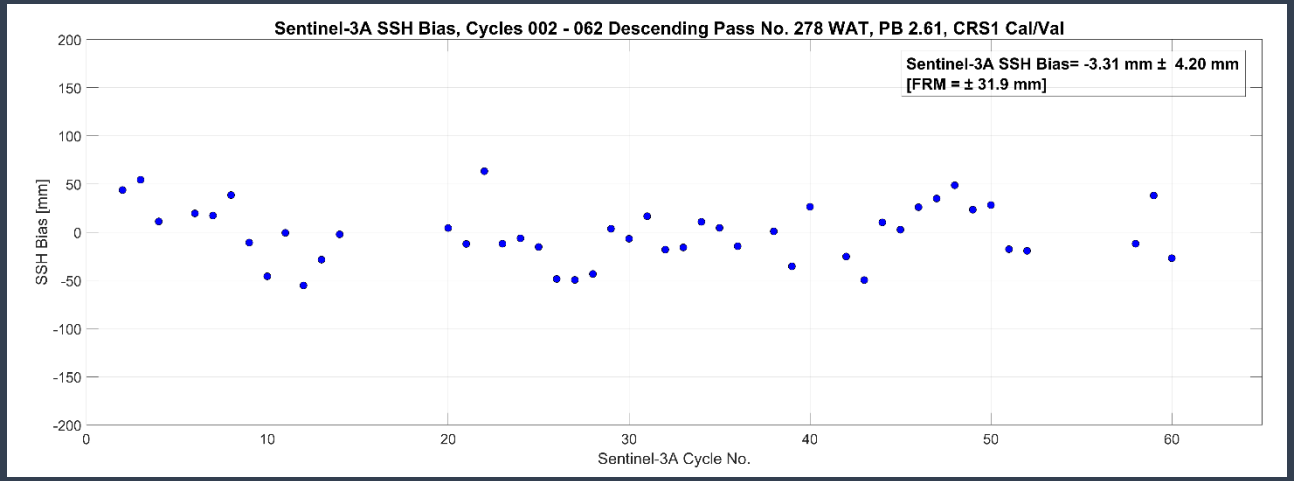
S3A SSH Bias: Pass No. 335 (Descending) (2)

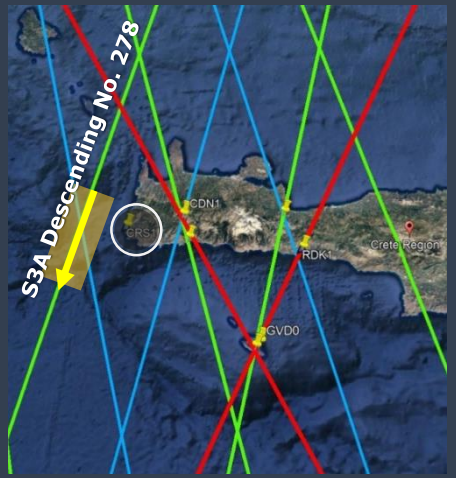




- S3A Descending Pass No. 335, Cycles: 2-62, RDK1 Cal/Val
- WAT, NTC, Processing Baseline: 2. 61,
- Sea-Surface Height **Bias B= -8 mm ± 6 mm** (FRM ± 32 mm) ,

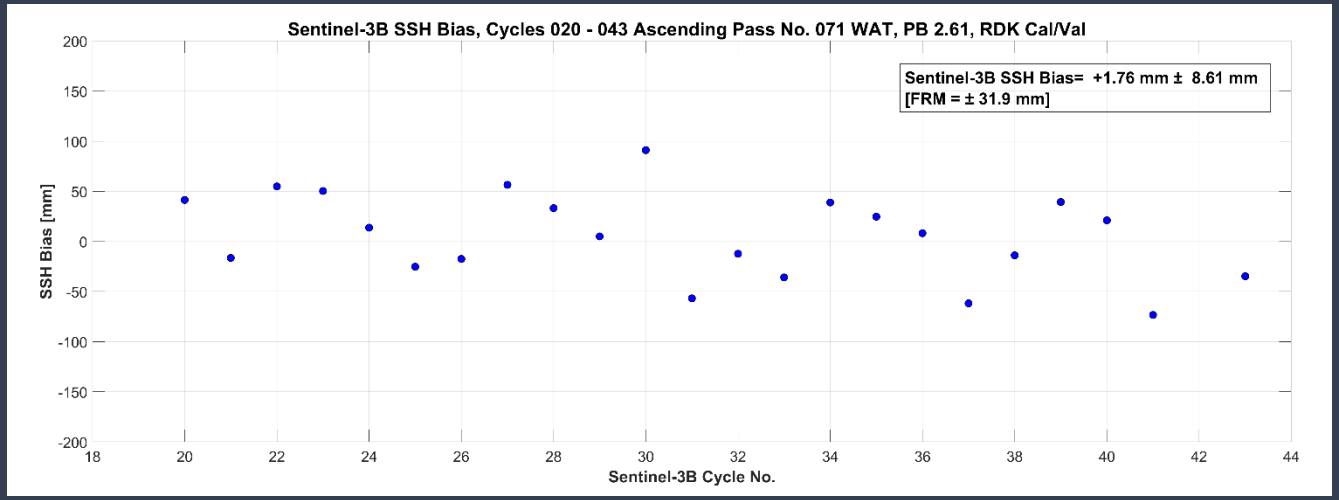
S3A SSH Bias: Pass No. 278 (Descending)

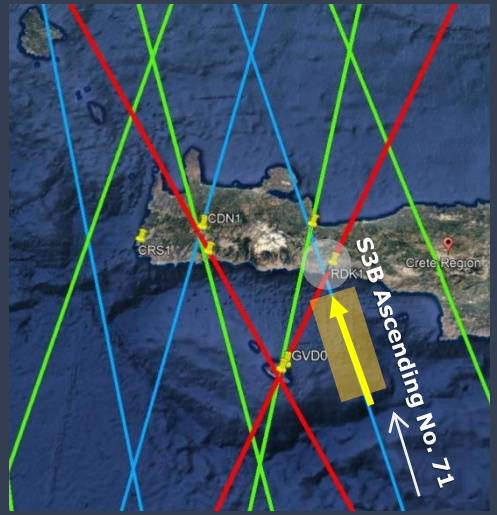




- S3A Descending Pass No. 335, Cycles: 2-62, CRS1 Cal/Val
- WAT, NTC, Processing Baseline: 2. 61,
- Sea-Surface Height **Bias B= -3 mm ± 4 mm** (FRM ± 32 mm) ,

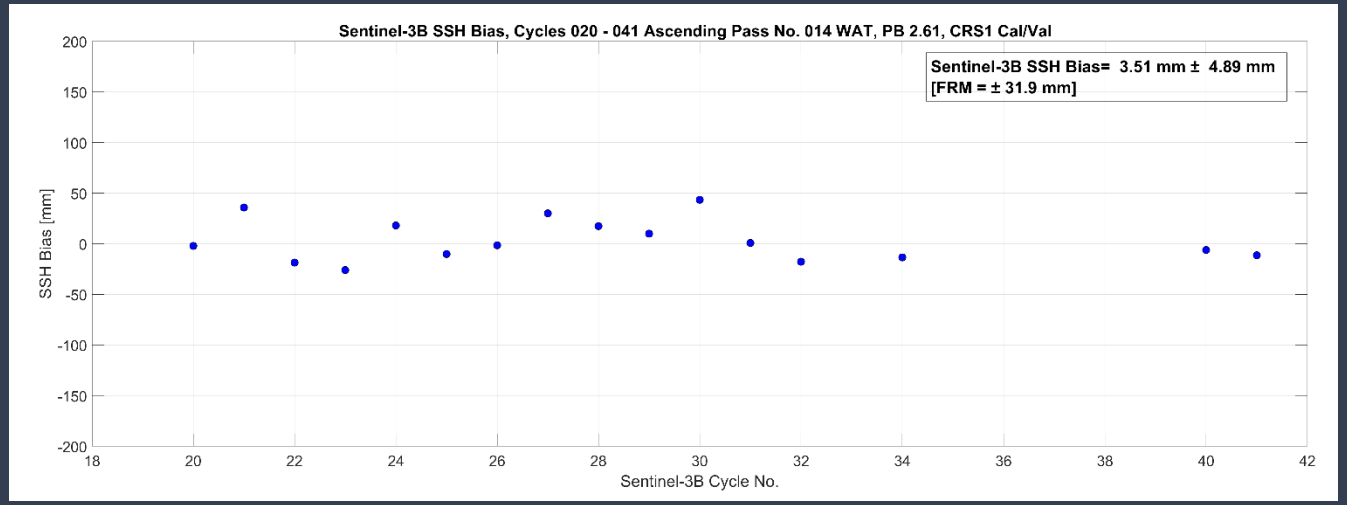
S3B SSH Bias: Pass No. 71 (Ascending)

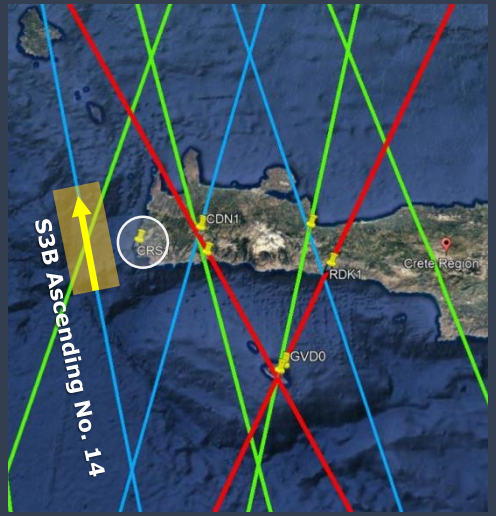




- S3B Ascending Pass No. 71, Cycles: 20 - 43
- WAT, NTC, Processing Baseline 1.33,
- Sea-Surface Height Bias B= +2 mm ± 9 mm (FRM ± 32 mm) ,

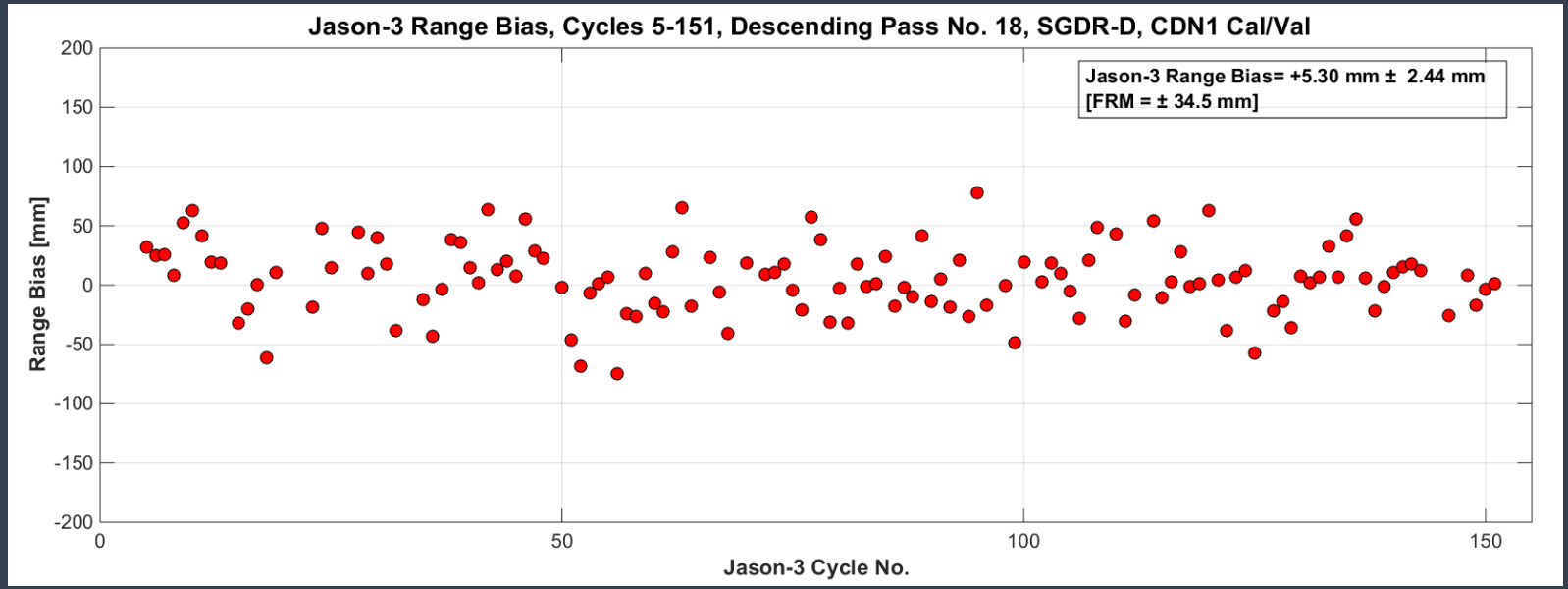
S3B SSH Bias: Pass No. 14 (Ascending)





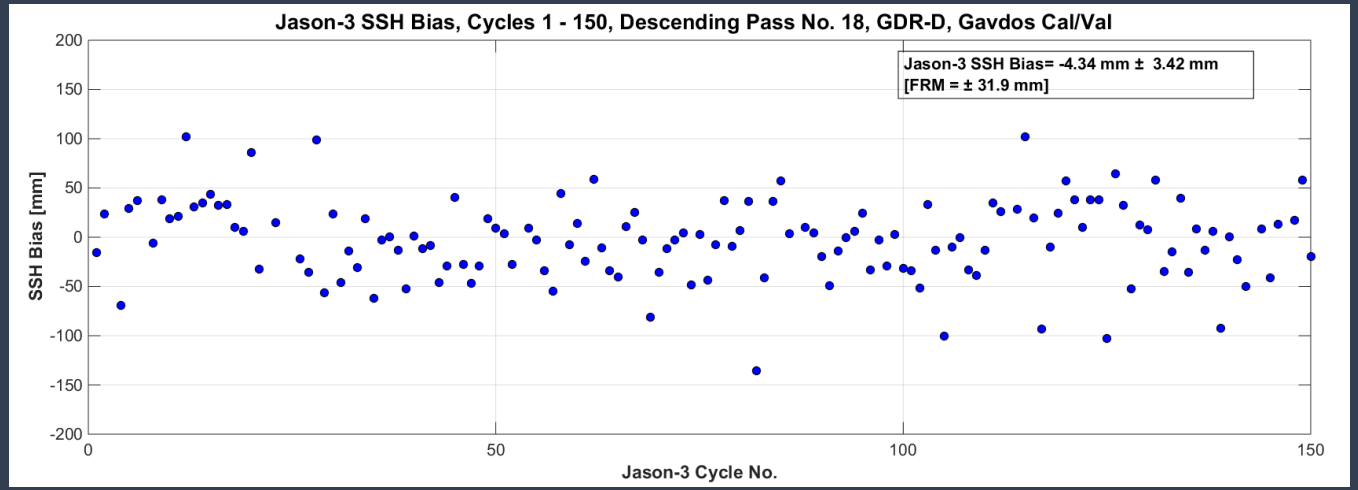
- S3B Ascending Pass No. 14, Cycles: 21-41
- WAT, NTC, Processing Baseline: 1.33,
- Sea-Surface Height Bias B= +3.5 mm ± 5 mm (FRM ± 32 mm) ,

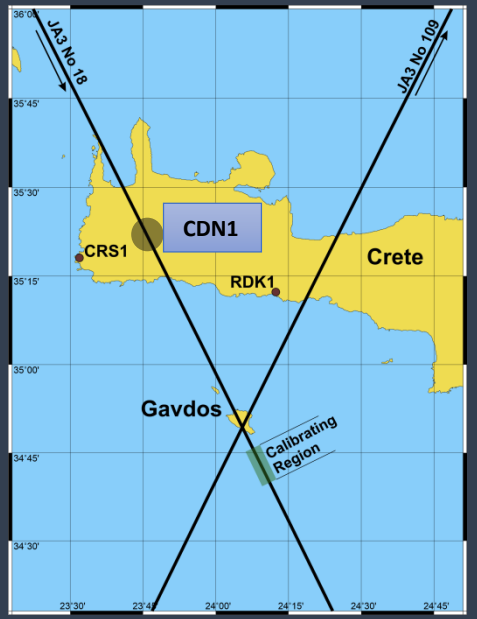
JA3 Transponder Cal/Val: Pass No.18



- Jason-3 Descending Pass No. 18, Cycles: 5-150
- SGDR-D, POE,
- Transponder Range Bias **B= +5.3 mm ± 2.5 mm** (FRM ± 34 mm) ,

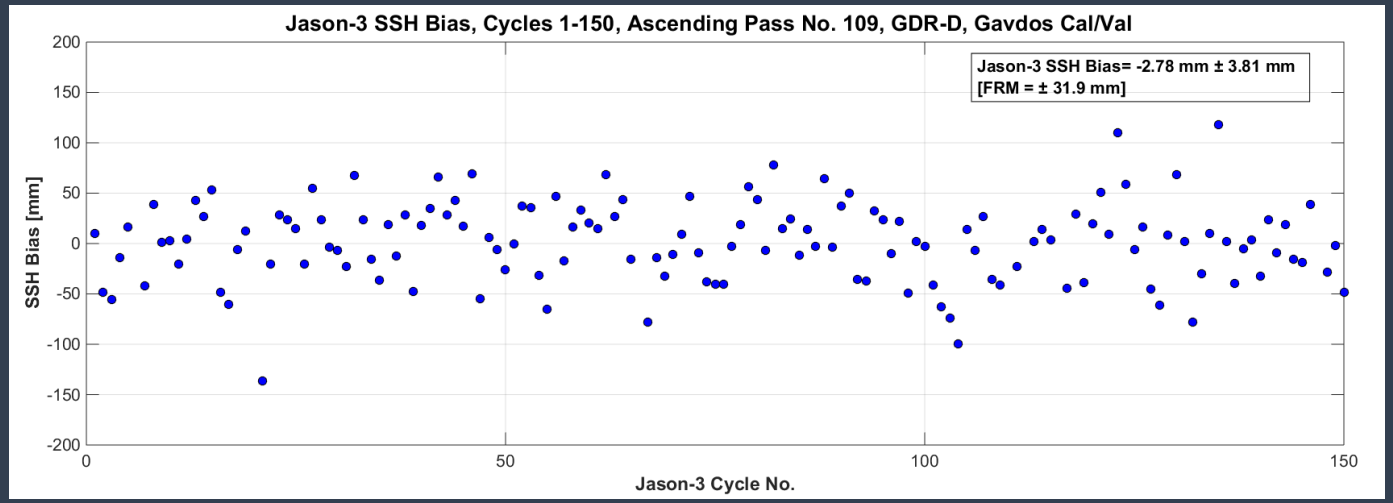
JA3 Sea-Surface Cal/Val: Pass No.18

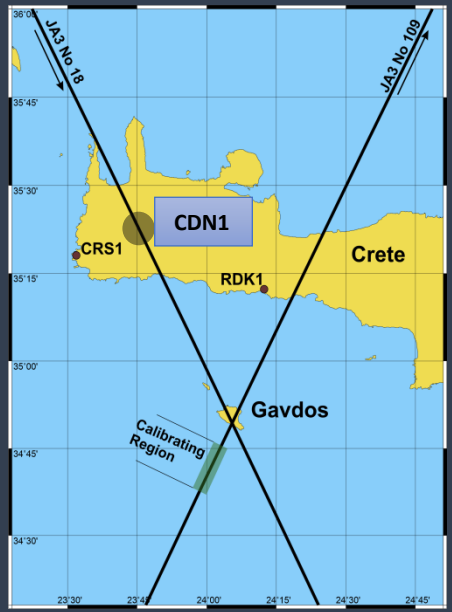




- Jason-3 Descending Pass No. 18, Cycles: 1-150
- SGDR-D, POE,
- Sea-Surface Height Bias **B= – 4.3 mm ± 3 mm** (FRM ± 32 mm) ,

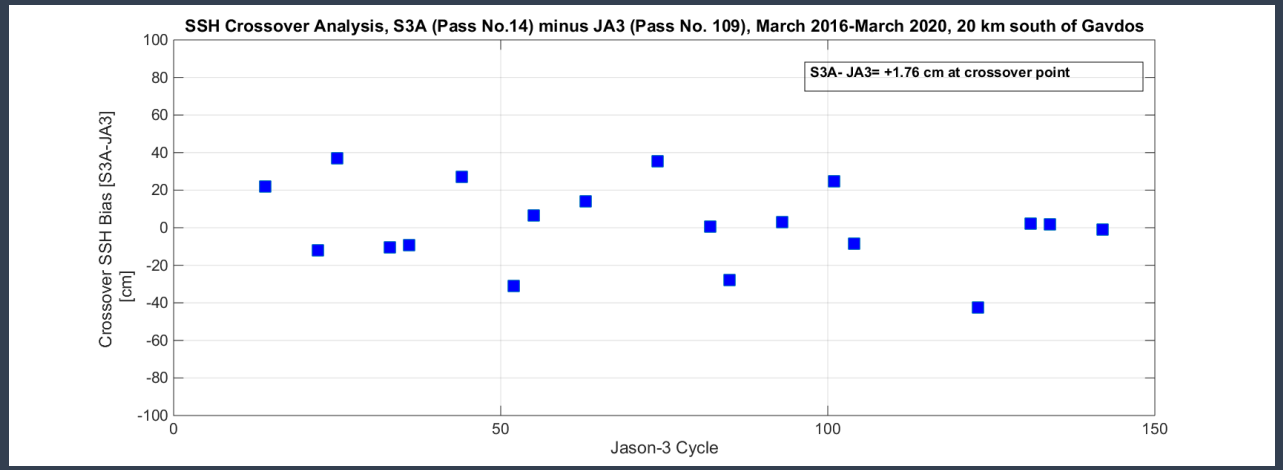
JA3 Sea-Surface Cal/Val: Pass No.109

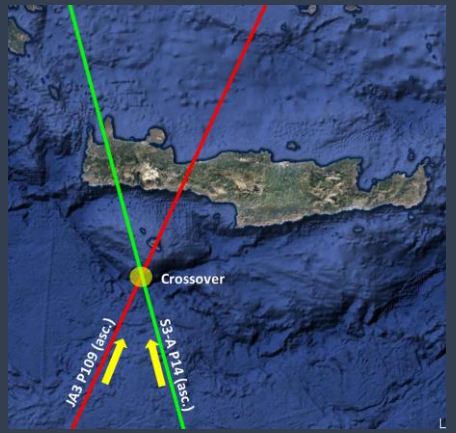




- Jason-3 Ascending Pass No. 109, Cycles: 1-150
- SGDR-D, POE,
- Sea-Surface Height **Bias B= -2.8 mm ± 3.8 mm** (FRM ± 32 mm) ,

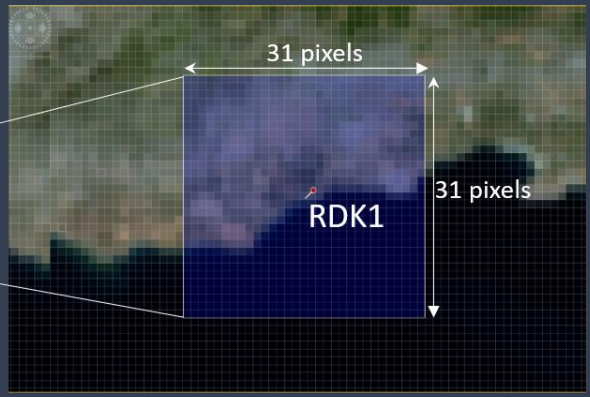
Crossover Analysis: S3A and JA3



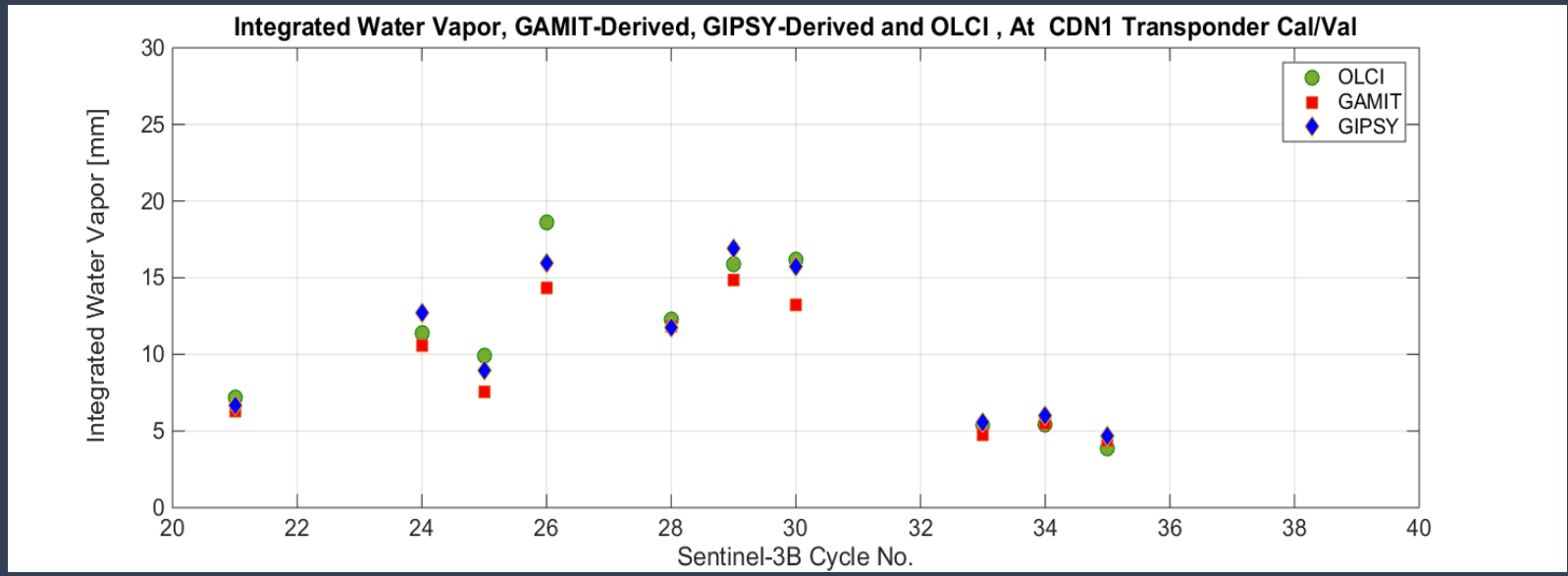


- Sentinel-3A P14 wrt Jason-3 P109;
- Temporal distance < 2 days;
- Period: 3-2016 – 3-2020;
- 19 overpasses;
- Sentinel-3A measures SSH ~ 2cm higher than Jason-3.

Wet Tropo via Radiometer, GPS, OLCI

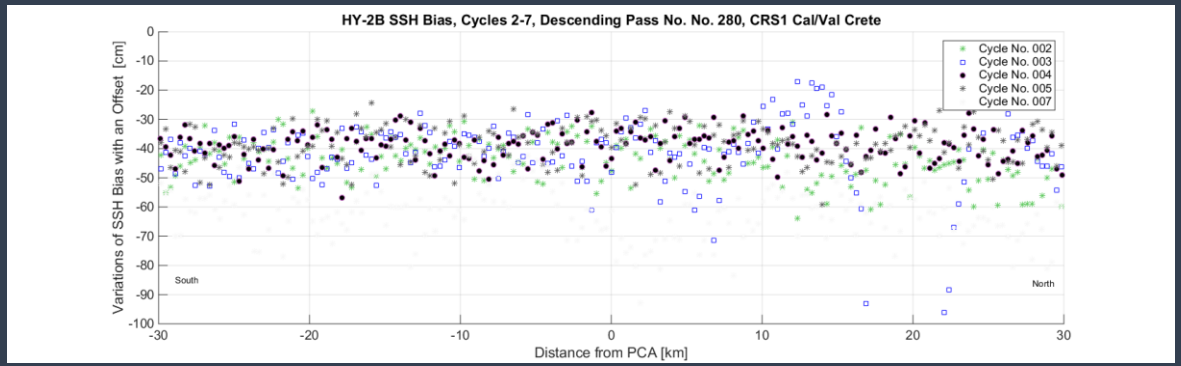


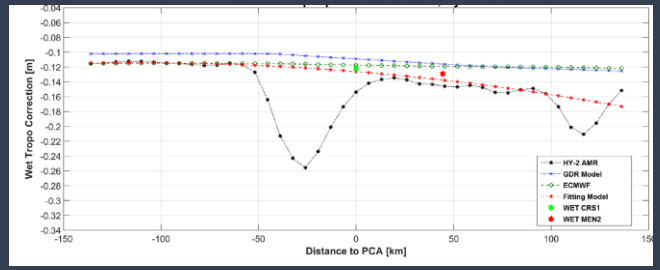
GNSS vs S3B OLCI Wet Path Delays



- Sentinel-3B OLCI IWV products concurrent with GNSS during transponder Cal/Val,
- Two GNSS processing strategies,
- Agreement at less than cm level.

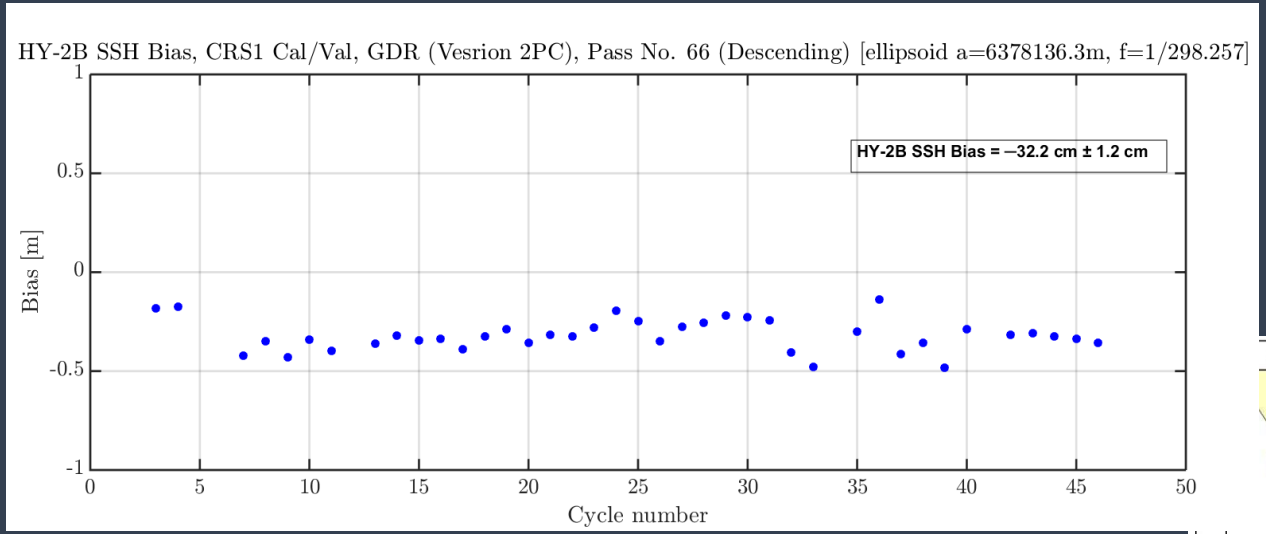
HY-2B Bias, Initial Results @ CRS1 Cal/Val (2019)

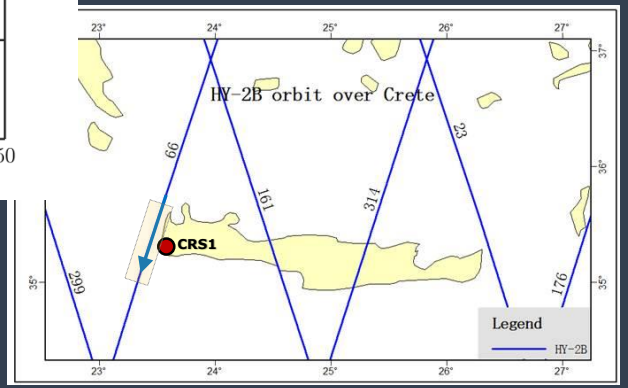




- HY-2B Descending Pass No. 66, Cycles: 2-7,
- Preliminary Results,
- Corrections still need to be applied properly,
- **Bias seems stable at this stage.**

HY-2B SSH Bias, CRS1 Cal/Val, Pass No.66





HY-2B Descending Pass No. 66, Cycles: 2-46,
Preliminary Results for SSH Bias (HY-2B)= **-32.2 cm ± 1.2 cm**,
Bias shift (~ 30 cm) under investigation, but Cal/Val results stable.

Cal/Val Summary

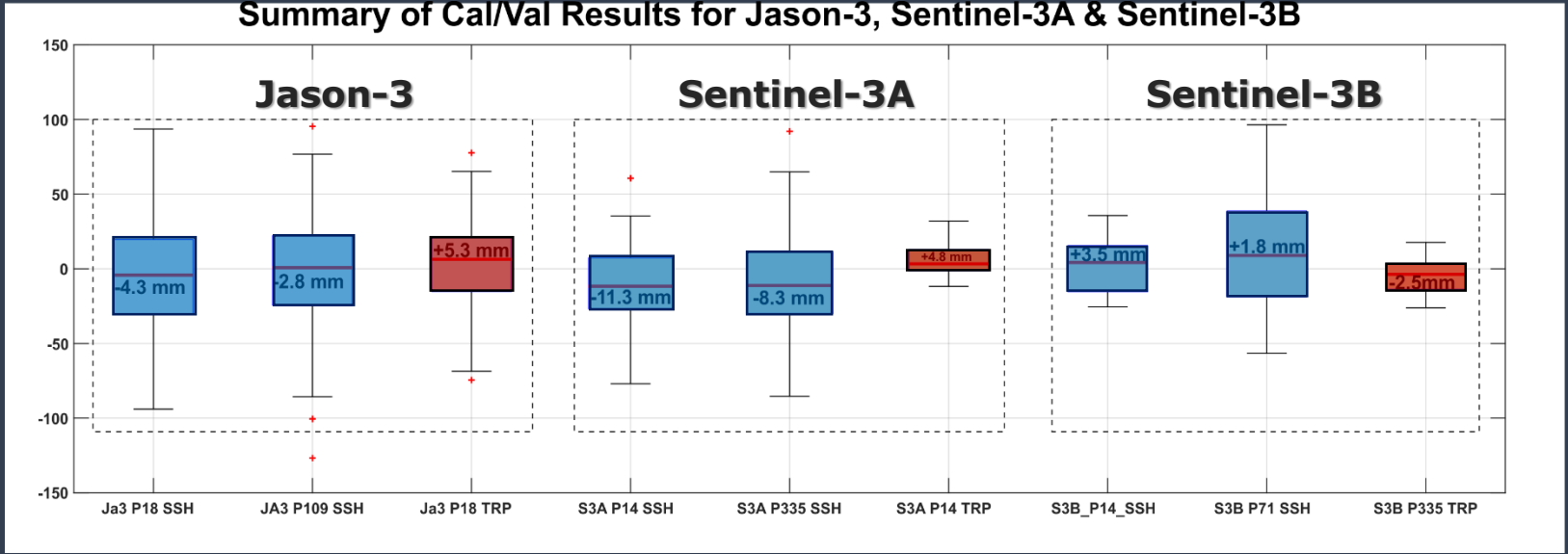
Sea-Surface Cal/Val

Satellite	Ascending	Descending	Average	Cycles
Sentinel-3A	-12 mm (No.14)	-8.0 mm (No.335 GVD1, RDK1) -3.0 mm (No. 278)	-7.75 mm	2-63
Sentinel-3B	+1.76 mm (No.71)	+3.51 mm (N0.14)	+2.64 mm	20-43
Jason-3 HY-2 B	-2.8 mm (No.109)	-4.30 mm (No.18) -322 mm (No. 66)	- 3.55 mm	1-150 2-44

Transponder Cal/Val

Satellite	Data	Descending	Cycles
S-3A	SAR, NTC, PB 2.61	+ 4.8 mm (No. 14)	3-58
S-3B	SAR, NTC, PB 2.61	- 9.0 mm (No. 14)	3 [Tandem]
S-3B	SAR, NTC, PB 2.61	- 2.5 mm (No. 335)	21-38 [Nominal]
JA-3	SGDR-D, POE	+ 5.3 mm (No.18)	5-151

Cal/Val Results Summary in Boxplots



Outlook for altimetry Cal/Val at FRM Standards

New Strategy to achieve:

- Reliable,
- Long-term,
- Consistent,
- Undisputable altimetry products.

ESA Effort to reach:

- Uniform and Absolute,
- Standardization of Earth observation,
- Uncertainty on metrology standards,
- Trust on data we produce (multiple teams processing/Sharing data),
- Correct information to Pubic,
- Right decisions for Policies.

FRM4ALT Documentation

- Donlon, C. Fiducial Reference Measurements for Altimetry (FRM4ALT). In Proceedings of the Presented at the International Review Workshop on Satellite Altimetry Cal/Val Activities & Applications, Chania, Greece, 23–26 April 2018
- Mertikas, S.; Donlon, C.; Matsakis, D.; Mavrocordatos, C.; Altamimi, Z.; Kokolakis, C.; Tripolitsiotis, A. (2020) *Fiducial Reference Systems for Time and Coordinates in Satellite Altimeter*. Advances in Space Research , doi: 10.1016/j.asr.2020.05.014.
- Mertikas, S.; Donlon, C.; Vuilleumier, P.; Cullen, R.; Féménias, P.; Tripolitsiotis, A. (2019) *An Action Plan towards Fiducial Reference Measurements for Satellite Altimetry*. Remote Sensing, 11(17), 1993, doi: 10.3390/rs11171993.
- Mertikas, S & R. Pail (2019). *Fiducial Reference Measurements for Altimetry*. Springer International Publishing, International Association of Geodesy Symposia #150.
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