Transponder and Sea-Surface Calibration of Satellite Altimeters at the Permanent Facility for Altimeter Calibration in west Crete, Greece

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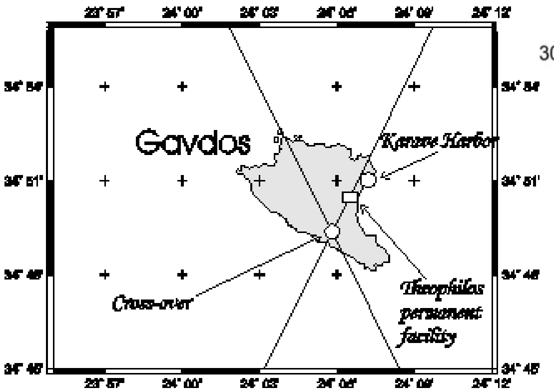
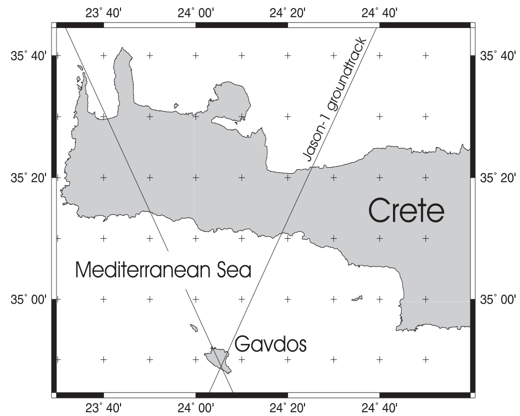
[6]Aristotle University of Thessaloniki, Greece,

→ 25 YEARS OF PROGRESS IN RADAR ALTIMETRY SYMPOSIUM

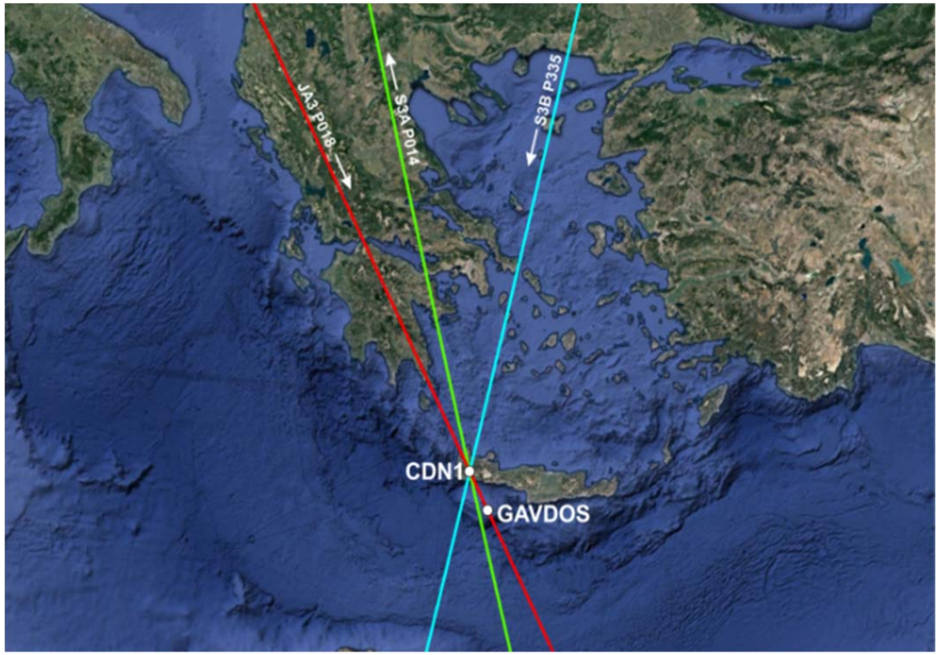
24–29 September 2018 | Ponta Delgada, São Miguel Island | Azores Archipelago, Portugal

Gavdos / Crete Permanent Cal / Val Facility

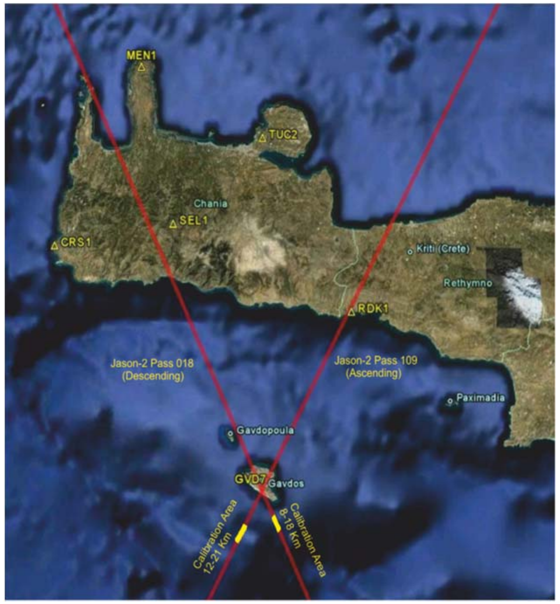




Land & Sea Calibrating Regions

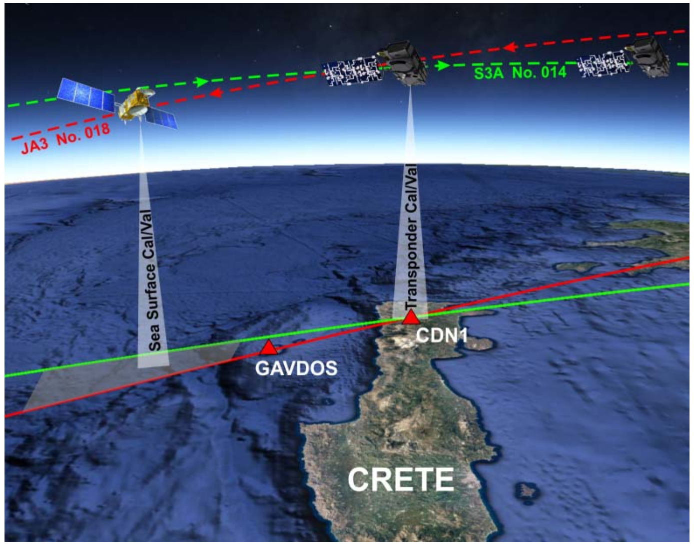


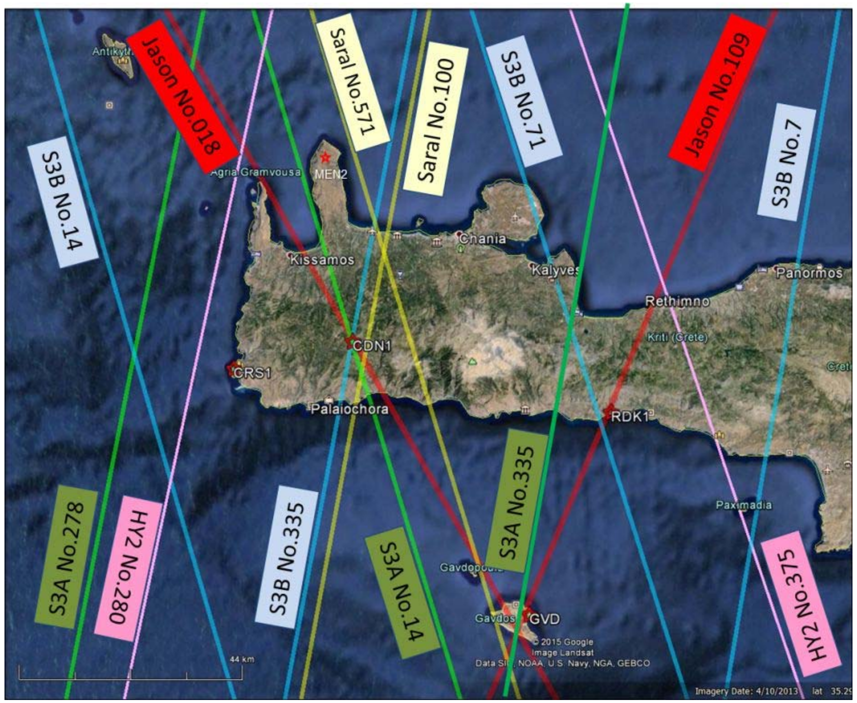
Transponder at CDN1 Cal / Val



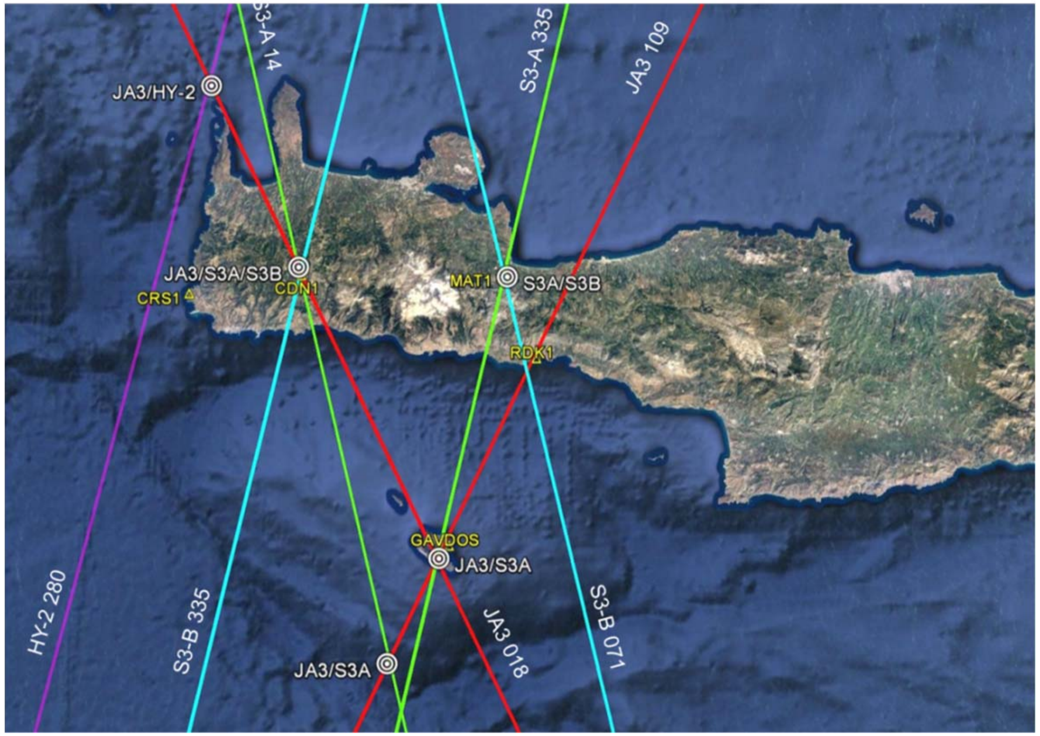
Gavdos sea-surface Cal / Val

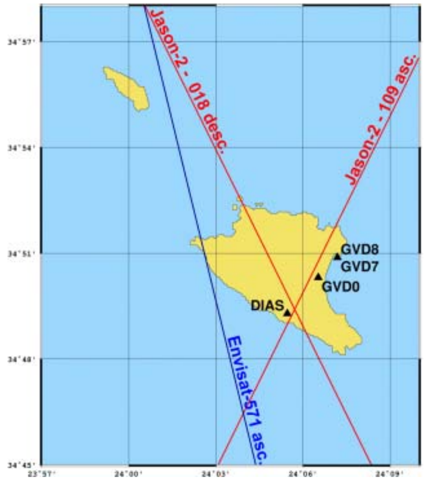
Groundtracks around Gavdos & Crete



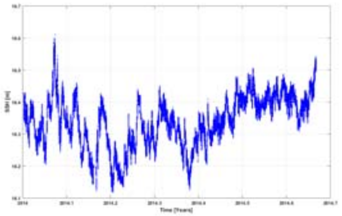


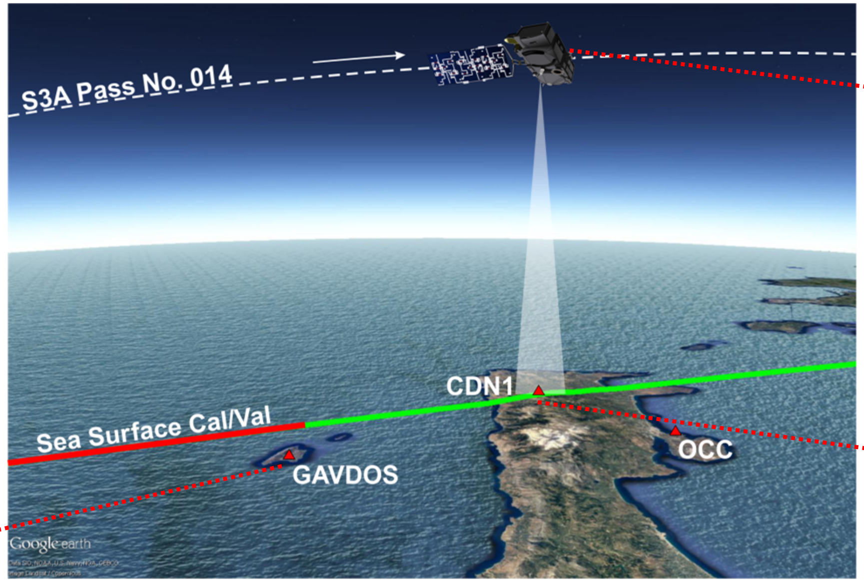
Major Cal / Val and crossover sites

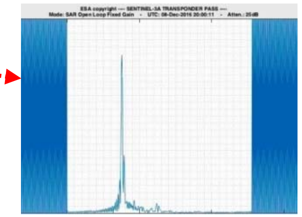




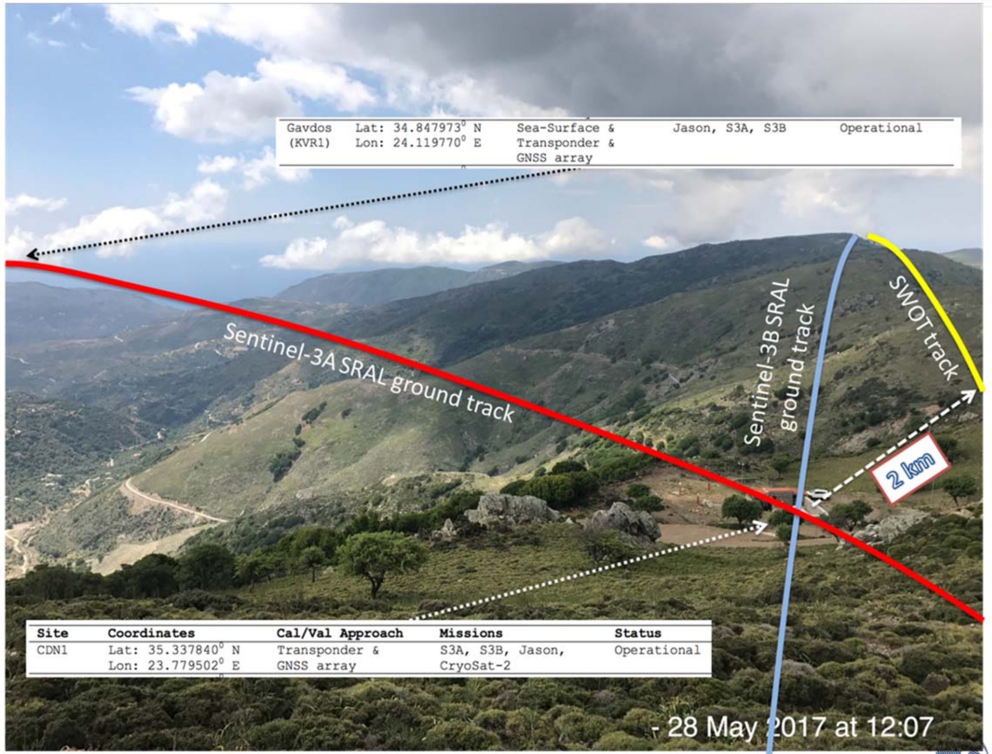
Simultaneous Transponder and Sea Cal / Val





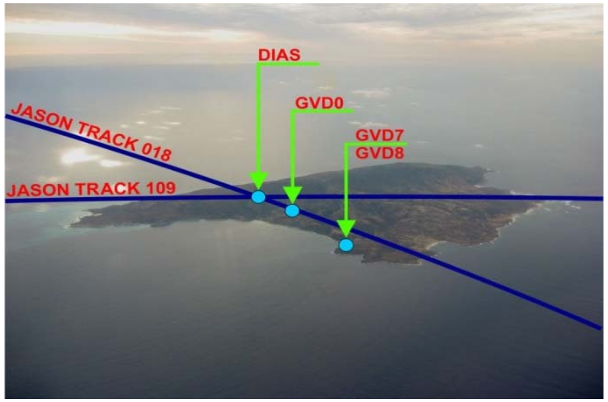


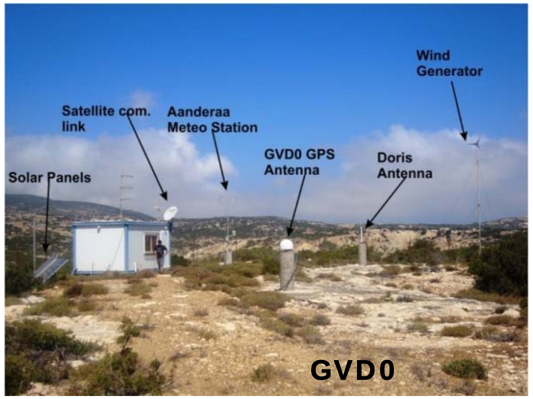
Transponder CDN1 Cal / Val Facility

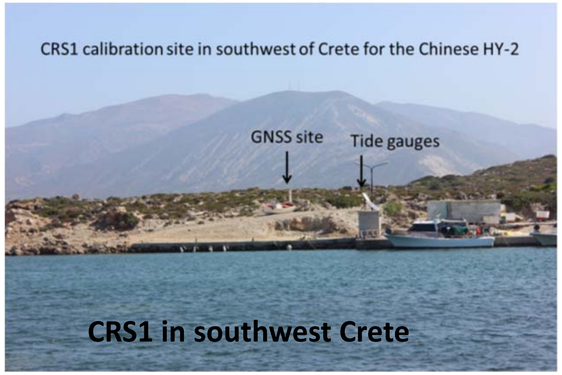


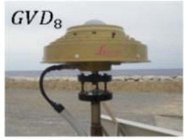
Site	Coordinates	Cal/Val Approach	Missions	Status
CDN1	Lat: 35.337840^0 N Lon: 23.779502^0 E	Transponder & GNSS array	S3A, S3B, Jason, CryoSat-2	Operational
Gavdos (KVR1)	Lat: 34.847973^0 N Lon: 24.119770^0 E	Sea-Surface & Transponder & GNSS array	Jason, S3A, S3B	Operational

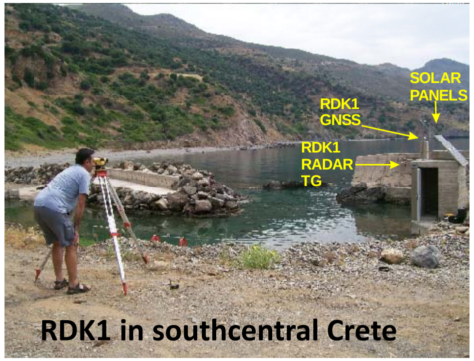
Sea-surface Cal / Val Facilities



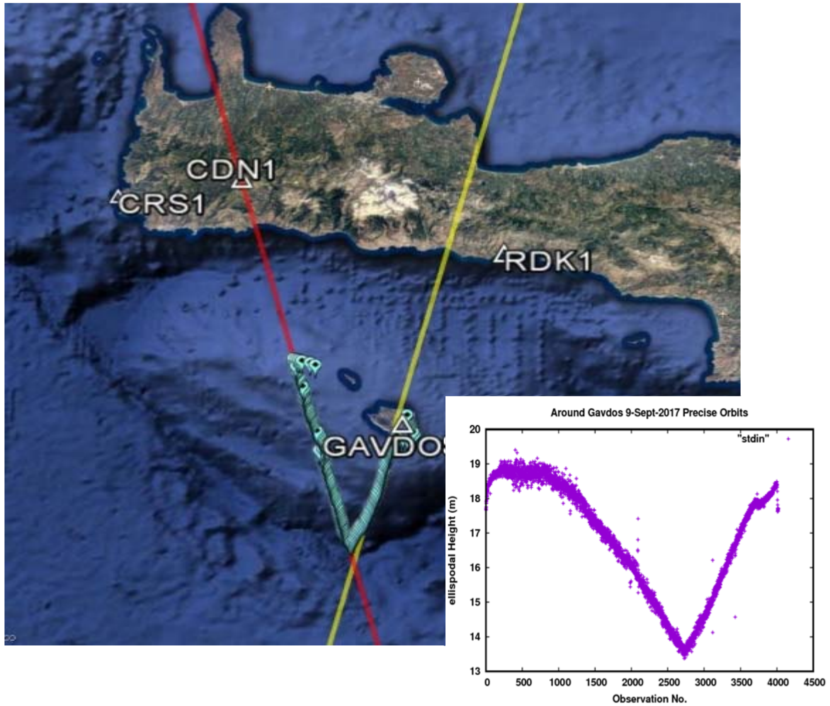




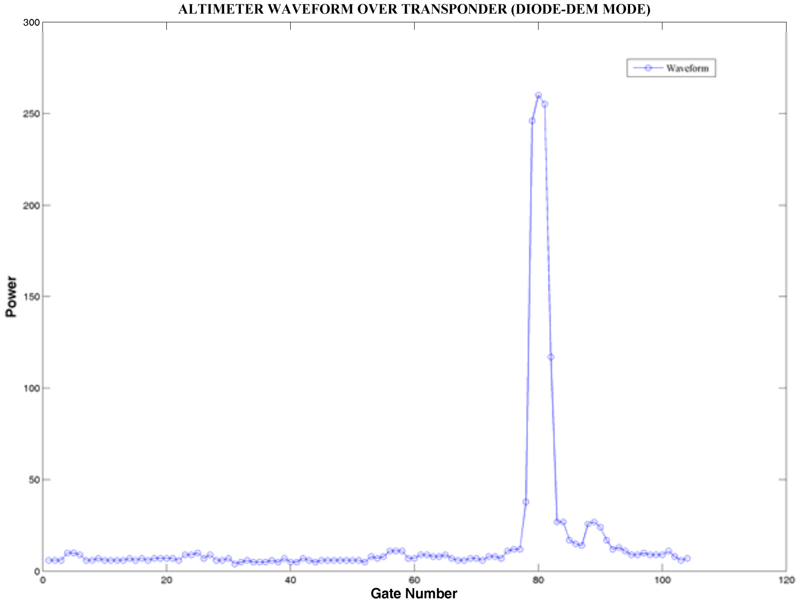




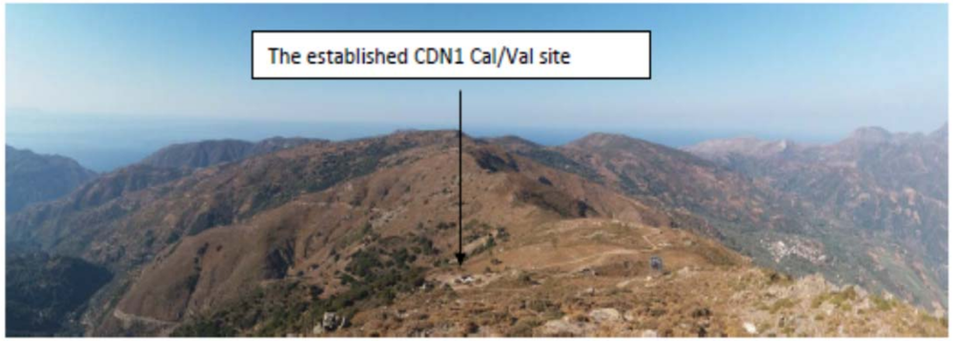
Boat Campaigns in Sept 2017



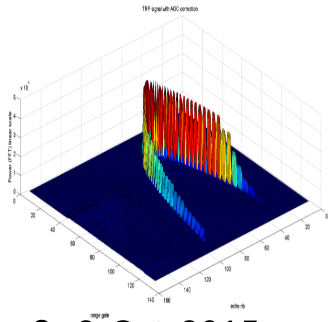
GVD3: Transponder Cal / Val in Gavdos



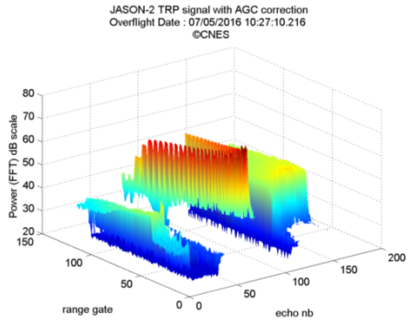
CDN1: ESA Sentinel-3 Altimeter Calibration



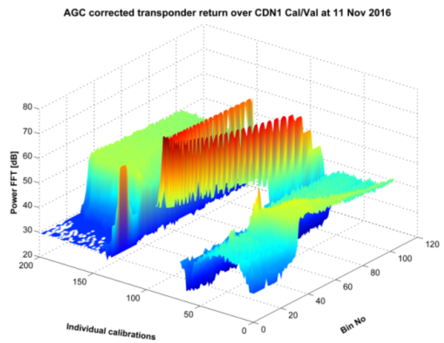
CDN1: Multi-Mission Transponder Calibrations



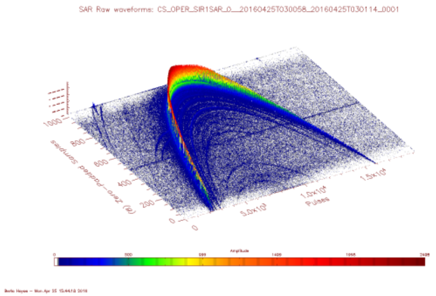
Jason-2, 2-Oct-2015



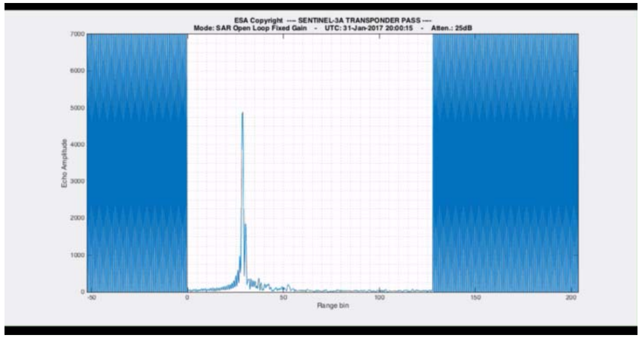
Jason-2, 7-May-2016



Jason-3, 11-Nov-2016

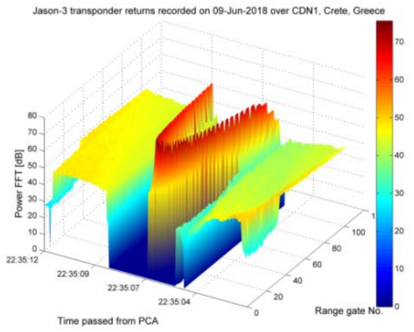


CryoSat-2, 25-Apr-2016

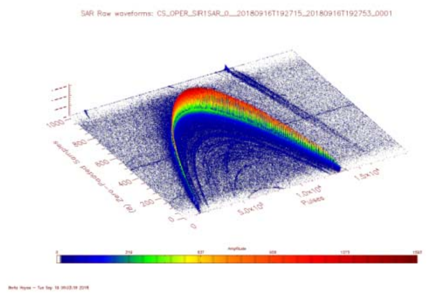


Sentinel-3A, 31-Jan-2017

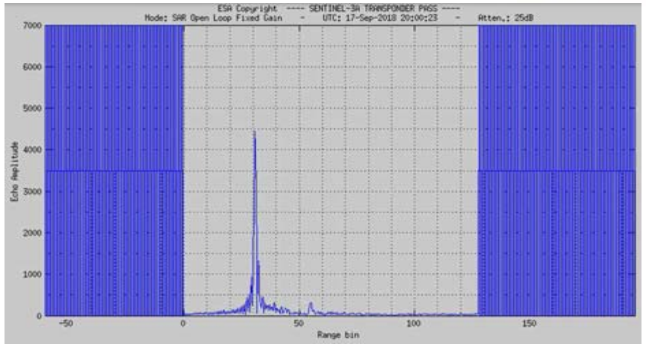
Recent Transponder Calibrations

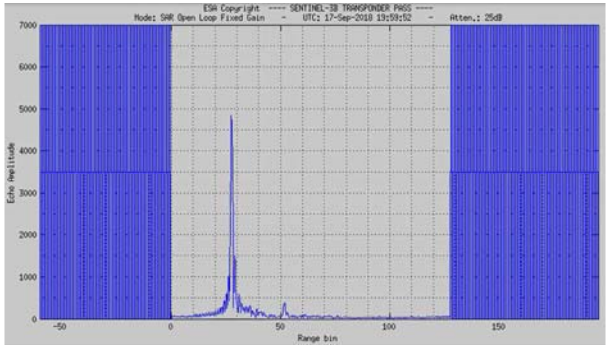


Jason-3, 9-June-2018



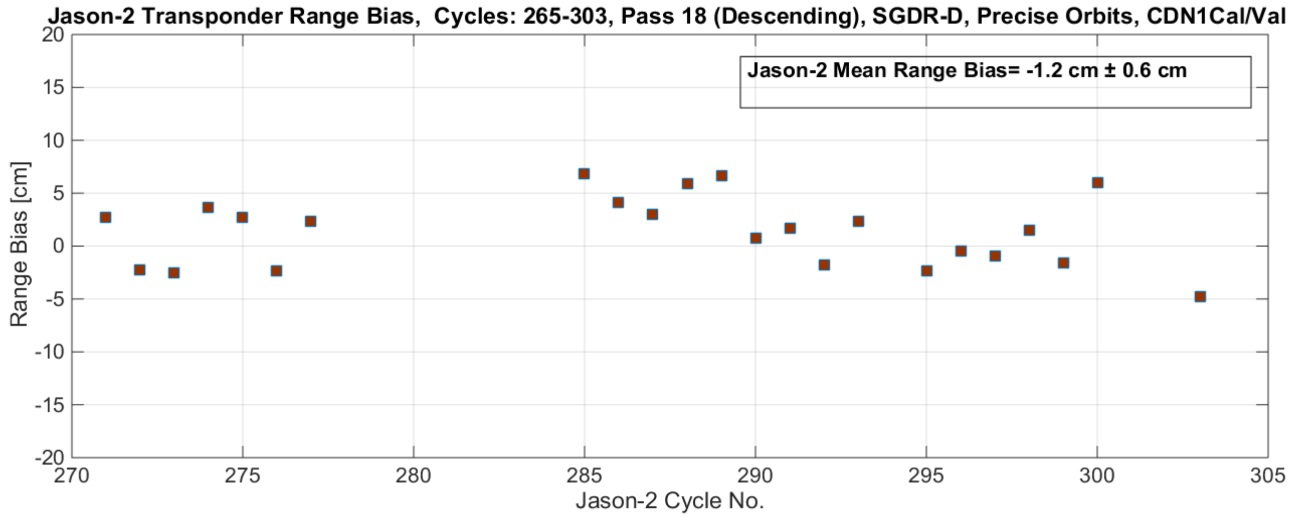
CryoSat-2, 16-Sept-2018





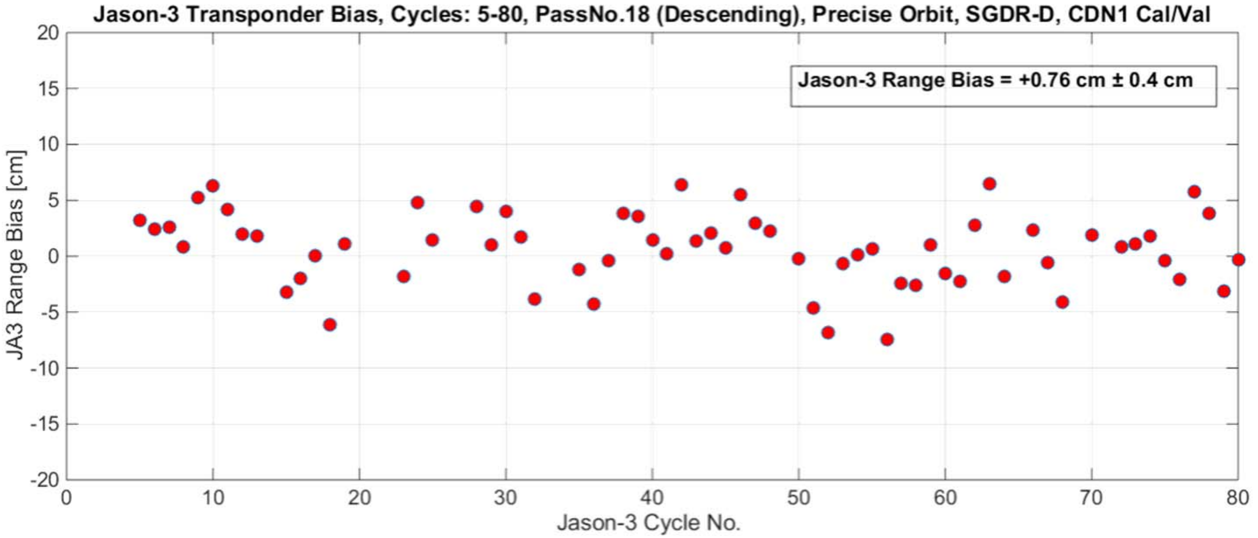
Sentinel-3A (up) & **Sentinel-3B** (down)**,** 17-Sept-2018

JA-2 Transponder Cal / Val: Pass No.18



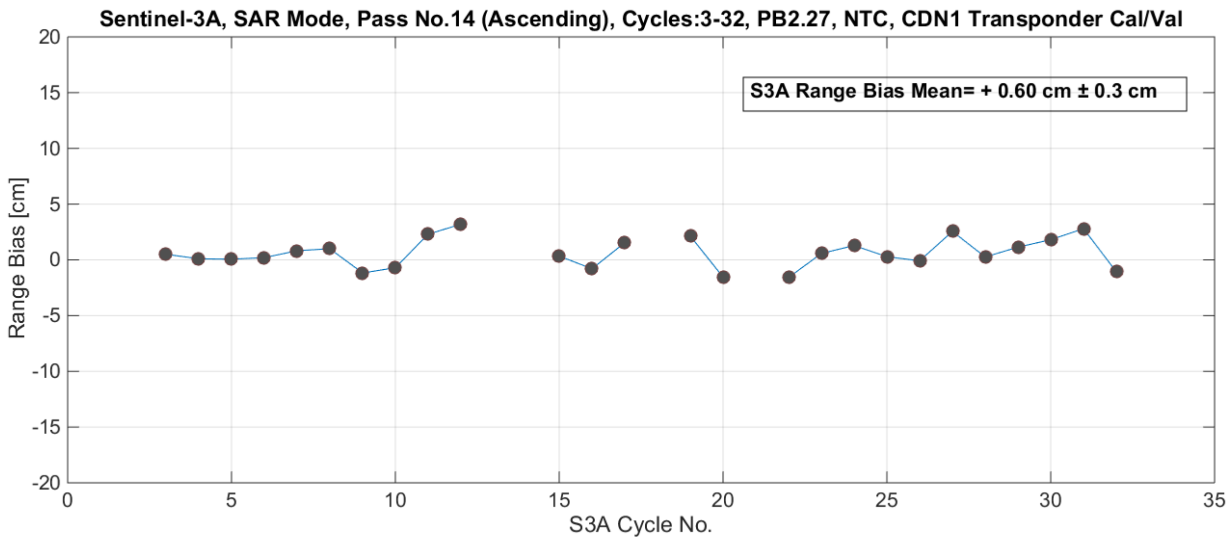
- Descending Pass No. 18, in 2015 and in 2016 (in Tandem with Jason-3),
- Precise Orbit [POE], Sensor-GDR-D,
- Range Bias B= **-12 mm ± 6 mm**,
- Variations may be due to **yaw steering** applied in Jason-2 & Jason-3.

JA-3 Transponder Cal/Val: Pass No.18



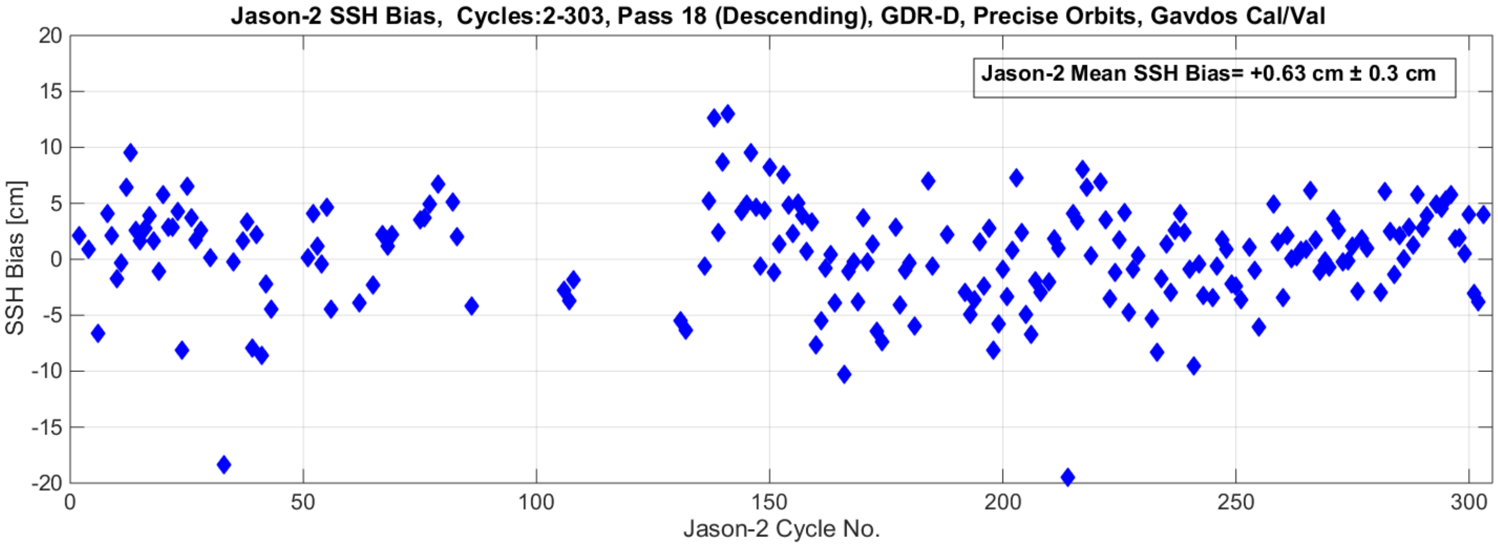
- Descending Pass No. 18, Cycles: 5-80
- Precise Orbit, Sensor-GDR-D,
- Range Bias B= **+0.76 cm ± 0.4 mm**,

S3A Transponder Cal / Val: Pass No.14



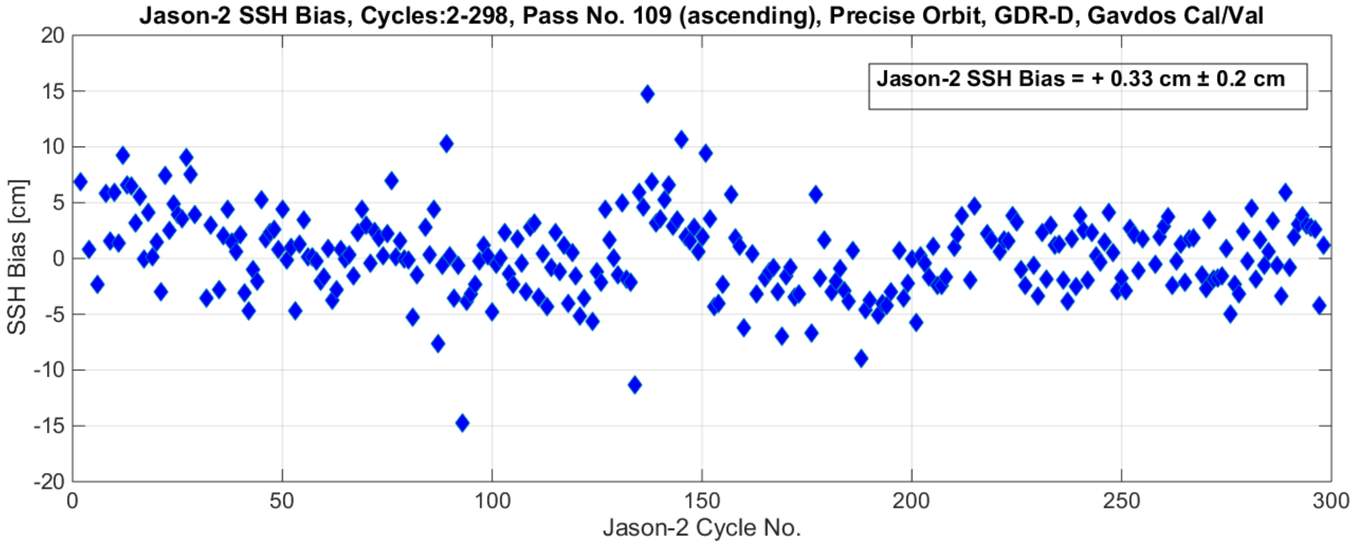
- Ascending Pass No. 14, Cycles: 3-32
- WAT, NTC, Processing Baseline: 2.27,
- Range Bias **B= +0.60 cm ± 0.3 cm**,

JA-2 Sea-Surface Bias: Pass No.18



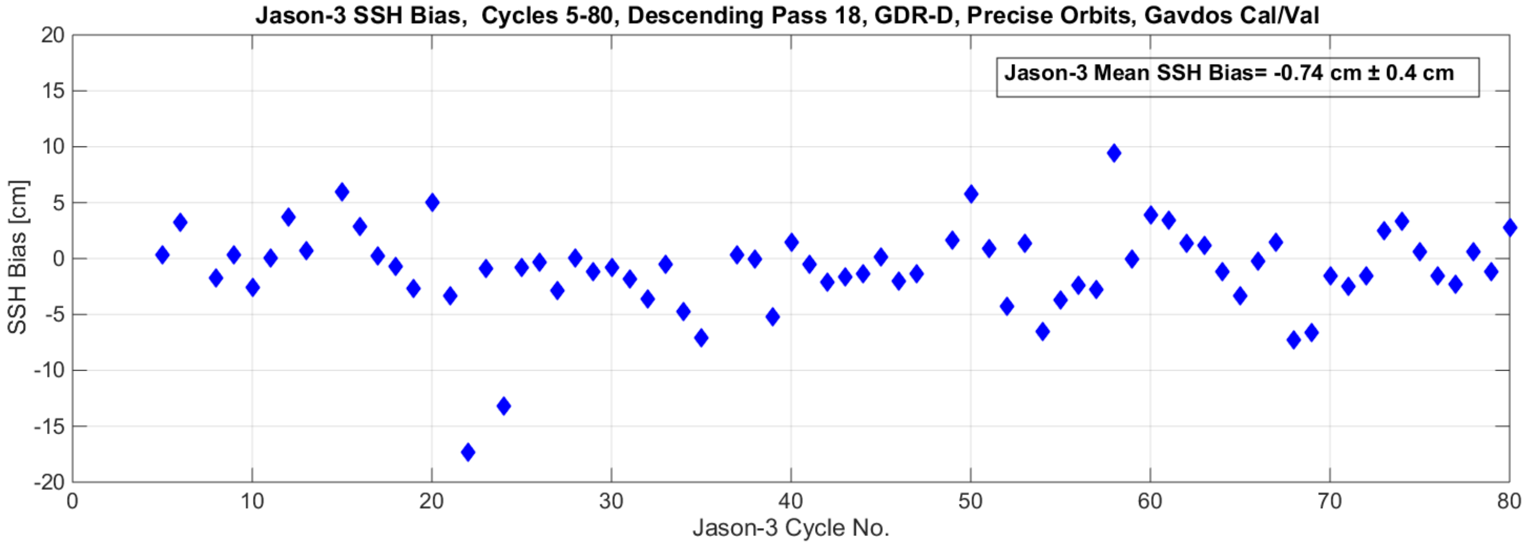
- Descending Pass No. 18, Cycles: 2-303
- Precise Orbit [POE], Sensor-GDR-D,
- Sea-Surface **Bias B= +6.3 mm ± 3 mm**,

JA-2 Sea-Surface Bias: Pass No.109



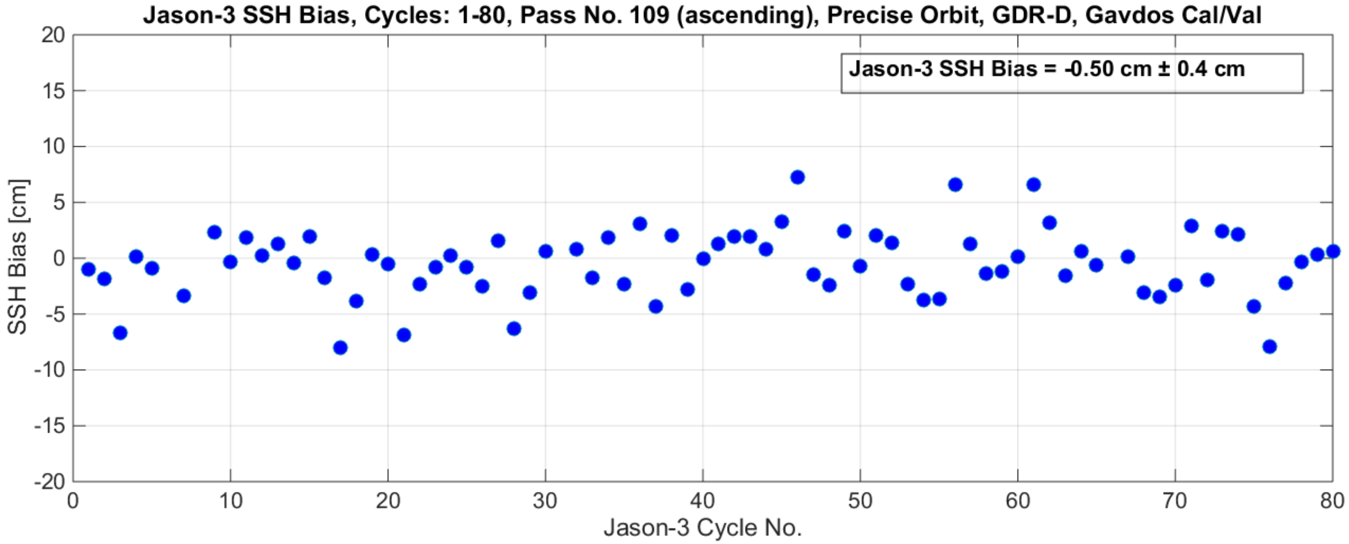
- Ascending Pass No. 109, Cycles: 2-298
- Precise Orbit [POE], Sensor-GDR-D,
- Sea-Surface Bias B= **+3.3 mm ± 2 mm**,

JA-3 Sea-Surface Bias: Pass No.18



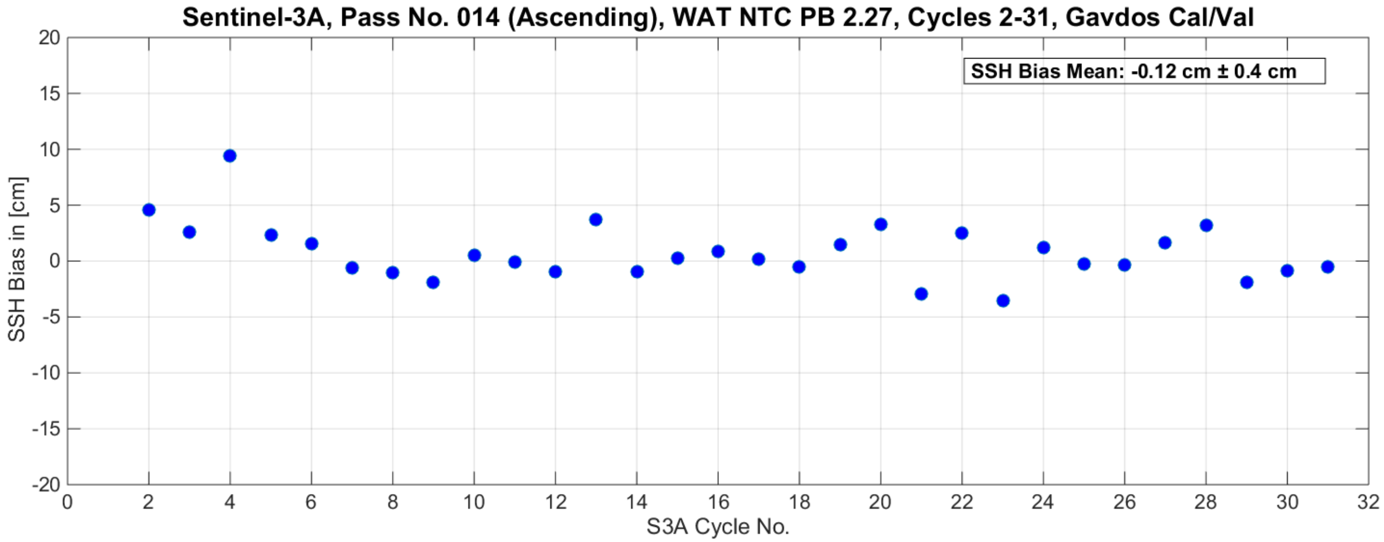
- Descending Pass No. 18, Cycles: 5-80
- Precise Orbit [POE], Sensor-GDR-D,
- Range Bias **B= -7.4 mm ± 4 mm**,

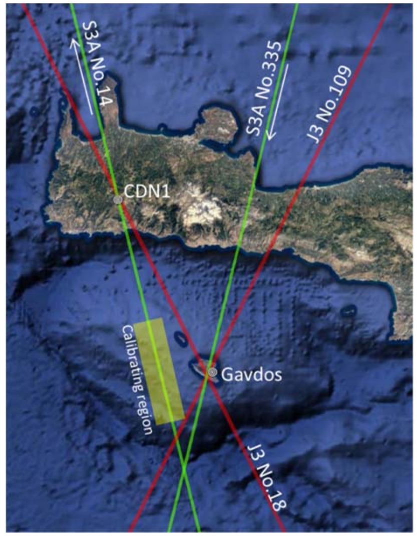
JA-3 Sea-Surface Bias: Pass No.109



- Ascending Pass No. 109, Cycles: 1-80
- Precise Orbit [POE], Sensor-GDR-D,
- Range Bias **B= -5.0 mm ± 4 mm,**

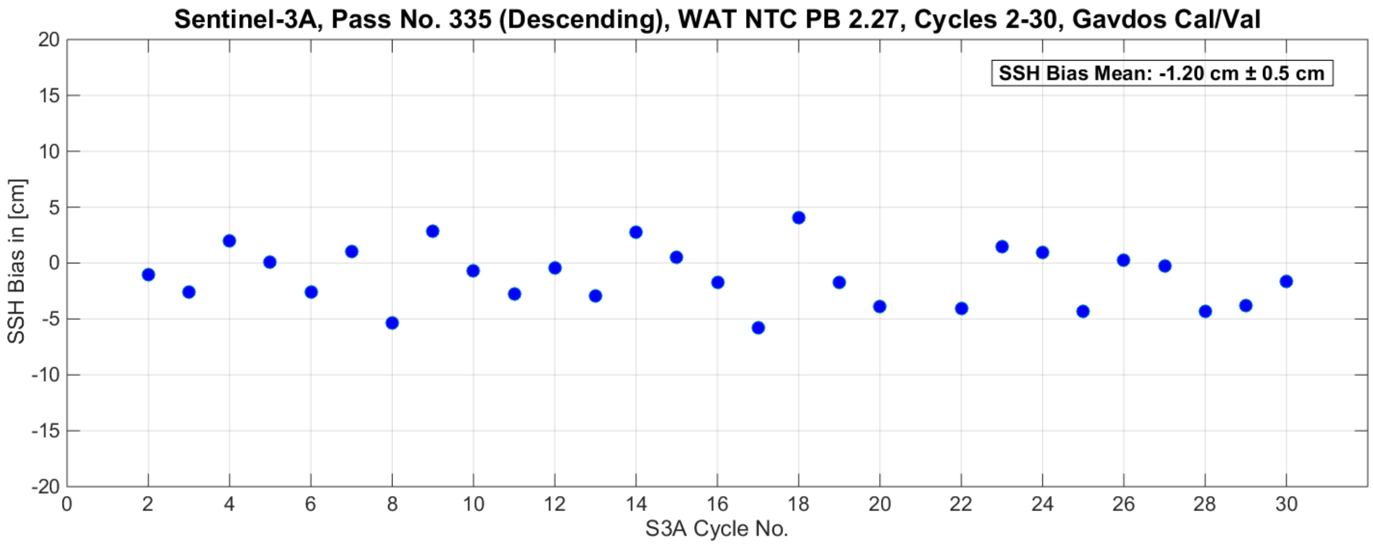
S3A SSH Bias: Pass No. 14

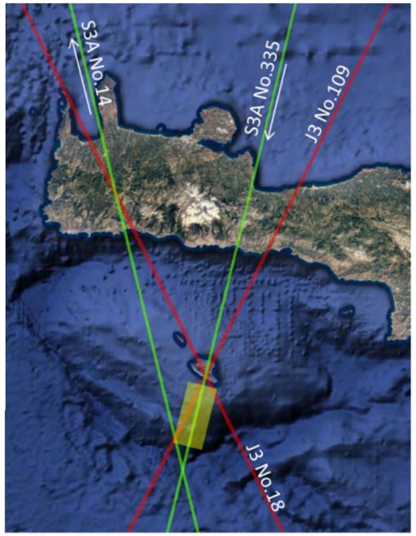




- Ascending Pass No. 14, Cycles: 2-31
- WAT, NTC, Processing Baseline: 2.27,
- Sea-Surface Height Bias **B= -1.2 mm ± 4 mm**,

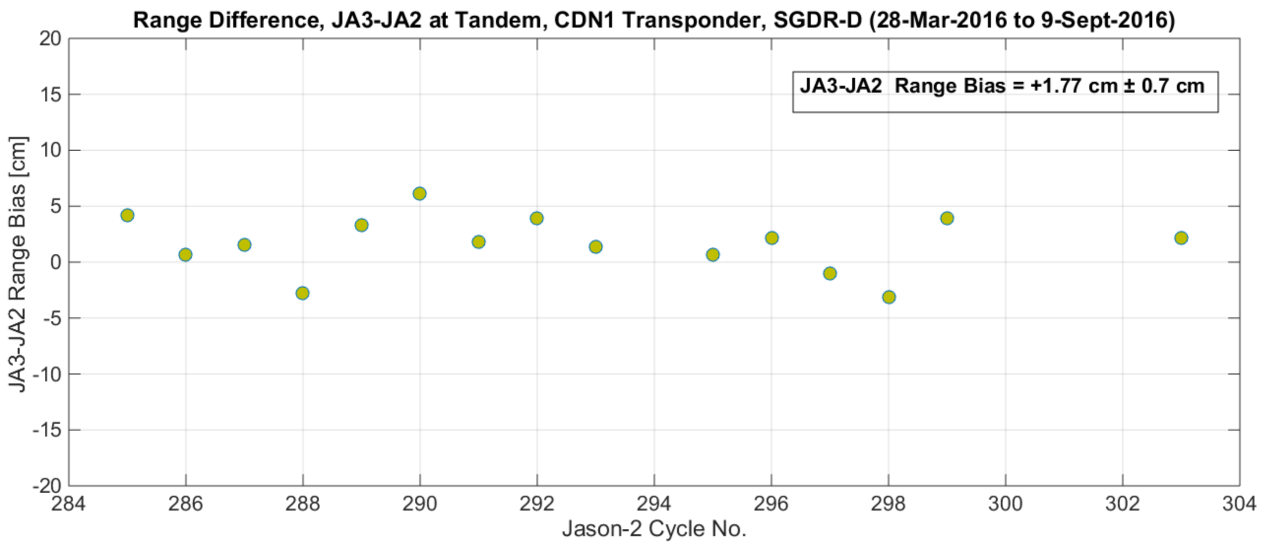
S3A SSH Bias: Pass No. 335





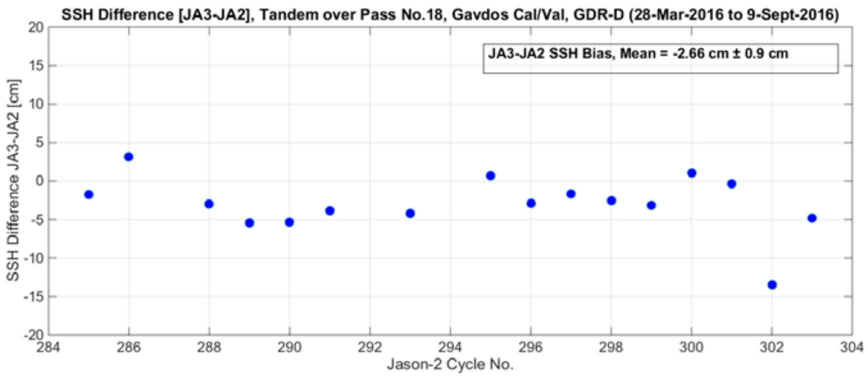
- Descending Pass No. 335, Cycles: 1-30
- WAT, NTC, Processing Baseline: 2.27,
- Sea-Surface Bias **B= -12.0 mm ± 5 mm**,

Transponder: JA-3 vs JA-2 (Tandem)

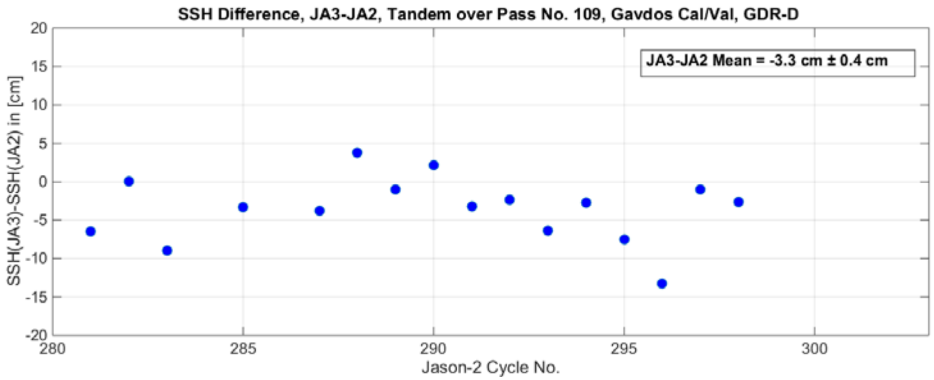


- Descending Pass No. 18, Cycles: 285-303
- **Tandem mission** 28-Mar-2016 to 9-Sept-2016
- Range Difference **[JA3-JA2]= +17.7 mm ± 7 mm**,

SSH: JA-3 vs JA-2 (Tandem)

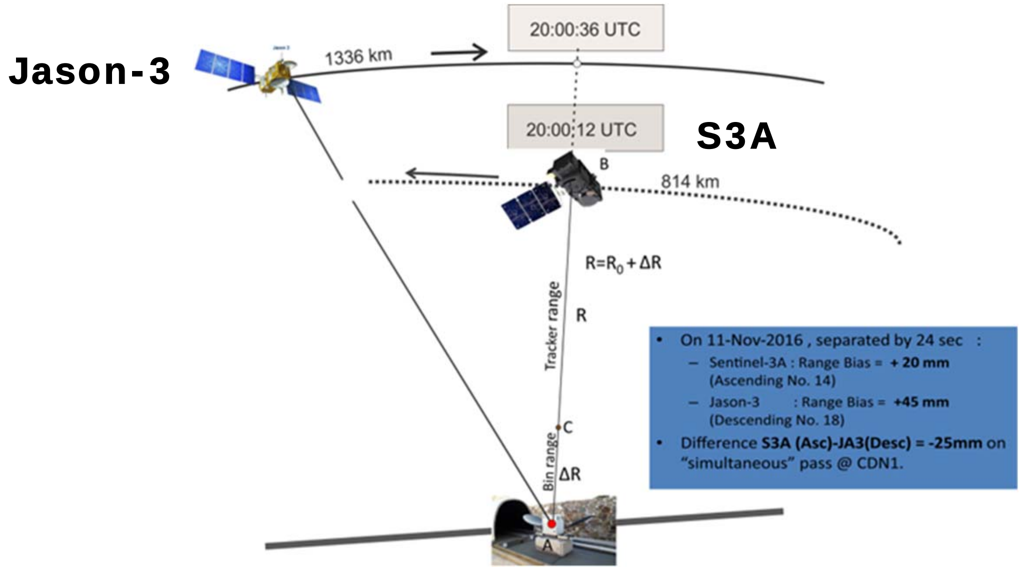


Descending Pass No. 18, Cycles: 285-303
Tandem mission 28-Mar-2016 to 9-Sept-2016
SSH [JA3-JA2]= **-26.6 mm ± 9 mm**,



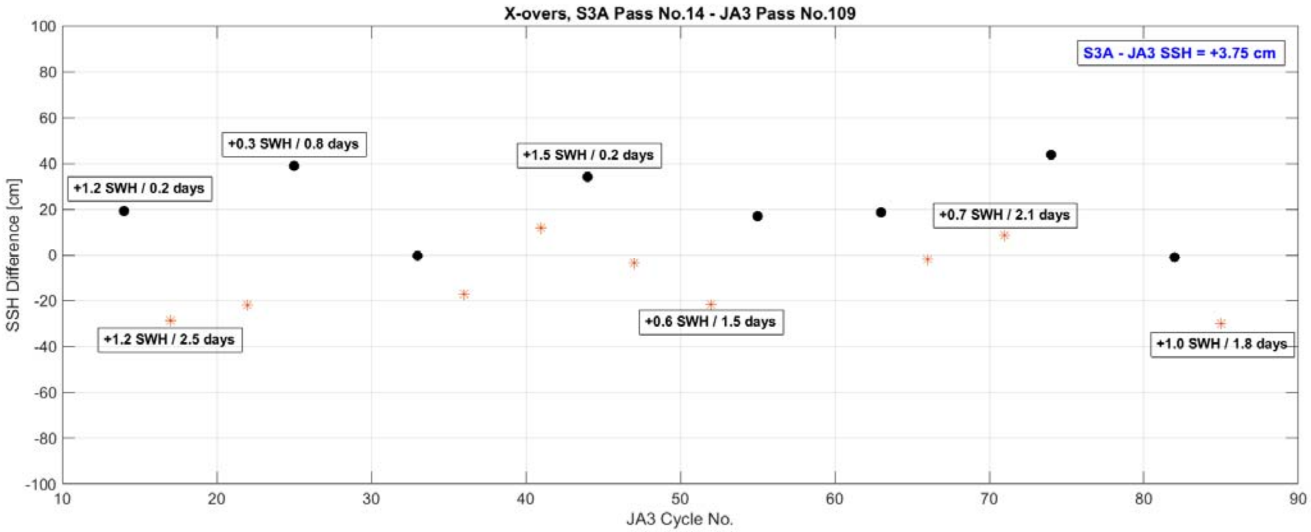
- Ascending Pass No. 109, Cycles: 280-298
- SSH **[JA3-JA2]= -33.0 mm ± 4 mm**,

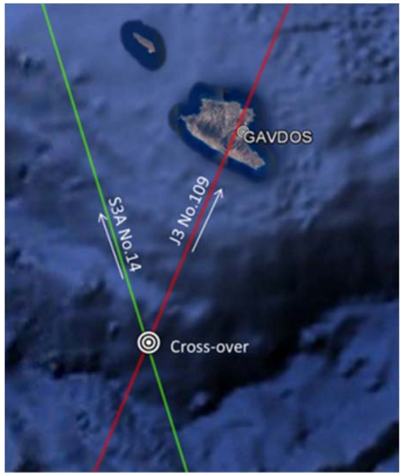
Transponder: S3A vs JA-3



- 11-Nov-2016:
- Simultaneous Sentinel-3A & Jason-3 over CDN1 and Gavdos Cal/Val sites;
- Range Diff. [S3A-JA3] **= -25 mm**

SSH Crossover: S3A vs JA-3





- Crossover analysis south of Gavdos
- Black circles: Crossover almost the same day;
- Red star: Crossover time difference more than 2 days
- SSH Difference (S3A – JA3): **+3.75 cm**

SSH Bias: S3A vs S3B (Tandem)

GeoMatLab

Pass No.14

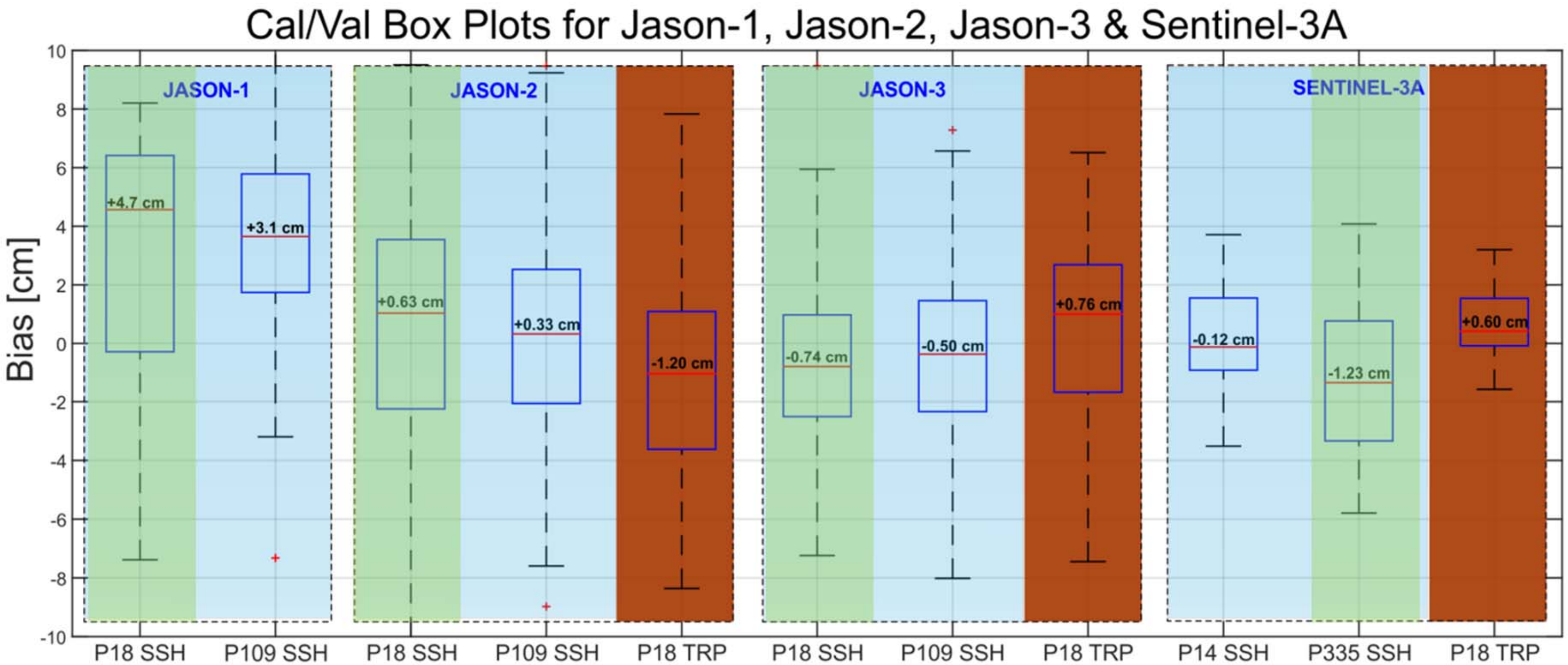
S3A Cycle	S3A SSH Bias	S3B Cycle	S3B SSH Bias	Diff [S3B-S3A]
33	1.96	10	3.97	2.01 cm
34	-0.60	11	1.19	1.79 cm
35	-0.70	12	-2.62	-1.92 cm
			Mean	+ 0.63 cm

Pass No.335

S3A Cycle	S3A SSH Bias	S3B Cycle	S3B SSH Bias	Diff [S3B-S3A]
32	0.49	9	3.92	**3.43 cm**
33	2.31	10	1.06	**-1.25 cm**
34	-3.97	11	-3.80	**0.17 cm**
			Mean	**+ 0.79 cm**

- S3B in tandem with S3A (30 sec apart);
- WAT, NTC, PB 2.27;
- **SSH [S3B-S3A]: + 1 cm** (based on 3 cycles only)

Transponder vs Sea-Surface: JA1,2,3, S3A



Summary of Cal / Val in Values

Sea-Surface Cal / Val

Satellite	Ascending	Descending	Average	Cycles
Jason-1	+35.0 mm (No.109)	+47.0 mm (No.18)	**+ 41.0 mm**	70-100
Jason-2	+3.3 mm (No.109)	+6.3 mm (No.18)	**+4.8 mm**	2-303
Jason-3	-5.0 mm (No.109)	- 7.4 mm (No.18)	**- 6.2 mm**	1-80
Sentinel-3A	-1.2 mm (No.14)	-12 mm (No.335)	**-6.6 mm**	1-32

Transponder Cal / Val

Satellite	Data	Descending	Cycles
JA-2	SGDR-D, POE	- 12.0 mm (No.18)	267-303
JA-3	SGDR-D, POE	**+ 7.6 mm** (No.18)	5-80
S-3A	SAR, NTC, PB 2.27	**+ 6.0 mm** (No. 14)	3-32

Fiducial Reference Measurements for Altimetry

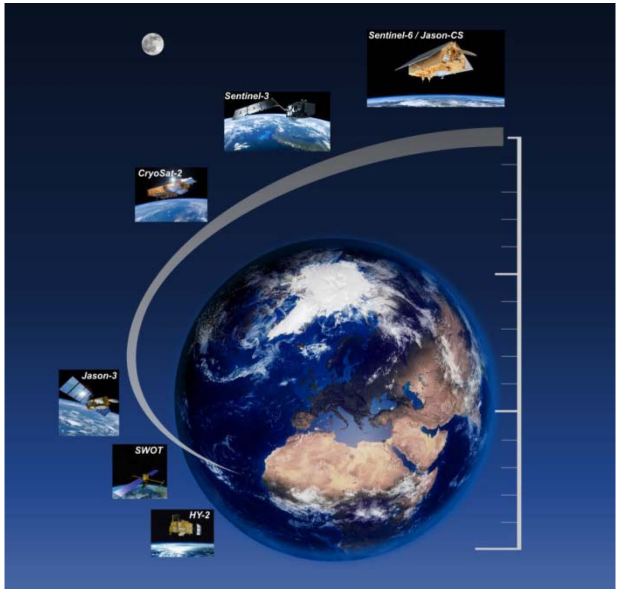
What is FRM for Altimetry Calibration?

- Cal/Val results connected to an undisputed reference,
- Measurement uncertainty based on:
    - Evaluation of each element contributing to uncertainty,
    - Documented and unbroken chain of calibrations,
    - Connect final uncertainty to SI-traceable
    - measurements (speed of light, absolute time, etc.),

What is the desired FRM result?

- Earth observation reliable in the long term,
- Comparable world-wide,
- Impervious to instrument, setting, location, conditions, ….
- Build up objective and reliable record for Climate Change,

What resources are available to achieve FRM?



Cal/Val Uncertainty Analysis for SSH Bias

Error Constituent	Variance Estimate	Standard Uncertainty
GNSS height	0.10 mm	± 0.10 mm
GNSS receiver	6.00 mm	± 3.50 mm
GNSS ARP	2.00 mm	± 2.00 mm
Water level	1.30 mm	± 1.30 mm
TGzero point	0.15 mm	±1.00 mm
TG vertical alignment	2.40 mm	± 1.40 mm
TG certificate	5.50 mm	± 5.50 mm
Leveling	0.13 mm	± 0.12 mm
Monumentation	1.10 mm	± 0.64 mm
Vertical misalignment	1.00 mm	± 0.60 mm
Leveling observer	1.00 mm	± 0.60 mm
Leveling instrument/method	1.00 mm	± 0.60 mm
TP reading	1.00 mm	± 0.60 mm
MSS	33.00 mm	± 33.00 mm
MDT	85.00 mm	± 85.00 mm
Geoid	80.00 mm	± 46.20 mm
Processing	0.50 mm	± 0.30 mm
Geoid slope	10.00 mm	± 5.80 mm
Unaccounted effects	20.00 mm	± 11.00 mm
Uncertainty (RMS)		**± 36.16 mm**

Roadmap to Cal / Val altimetry Standardization

- Select a standard **atomic time** & coordinate **reference system** for all altimetry;
- Define essential observations & instruments to support the Cal/Val;
- Define “benchmark calibrating parameters”,
- Characterize and calibrate instruments before in the field;
- Institute the fundamental **metrology standards** to build trust in Cal/Val;
- Define error constituents in Cal/Val,
- Document procedures to reporting uncertainty budgets for Cal/Val;
- Describe standards, protocols and characterization procedures;
- Regulate the way of global distribution of Cal/Val sites on the globe;
- Establish data formatting, archiving and distribution, and
- Be prepared for future satellite altimetry Cal/Val.

Acknowledgements

- European Union;
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- Danish Space Center.