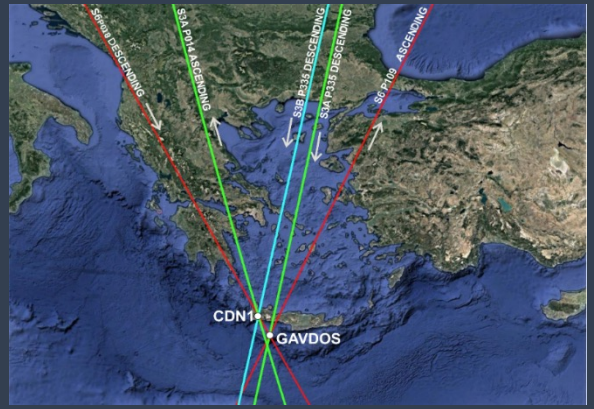
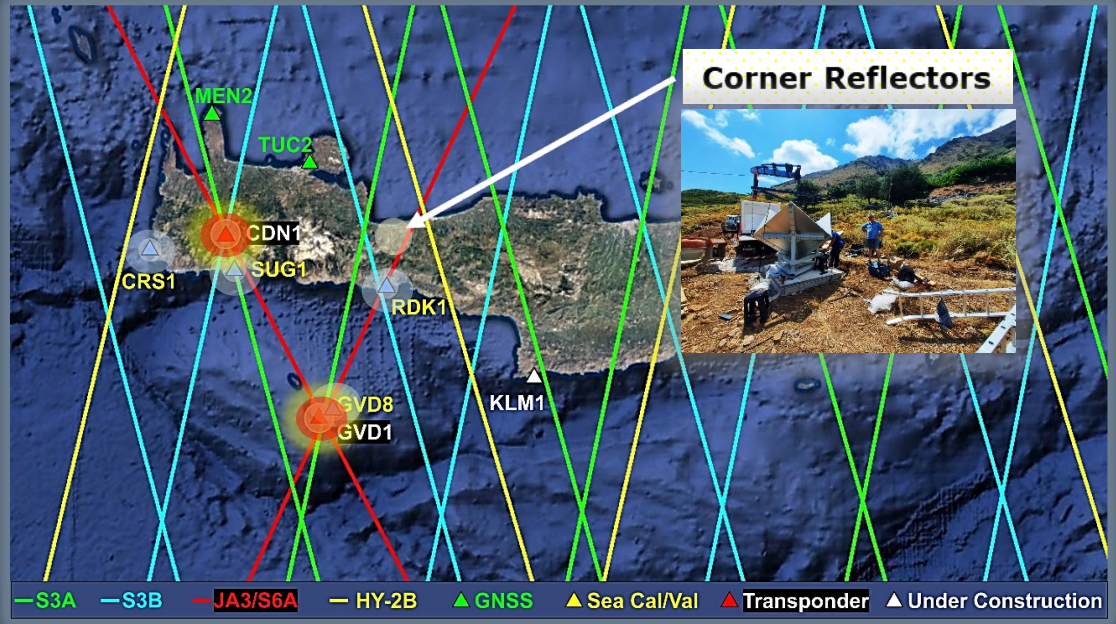
The ESA Permanent Facility for Altimetry Calibration in Crete: Advanced Services and Latest Cal/Val Results

Stelios Mertikas[1], Craig Donlon[2], Dimitrios Piretzidis[1,3], Costas Kokolakis[1,4], Robert Cullen[2], Pierre Femenias[4], Marco Fornari[5], Jerome Bouffard[4], Alessandro Di Bella[4], Francois Boy[6], Xenophon Frantzis[1], Achilles Tripolitsiotis[4], Mingsen Lin[7], Lei Yang[8],

(1) Technical University of Crete, Greece;
(2) ESA/ESTEC, Netherlands;
(3) Space Geomatica, Greece;
(4) ESA/ESRIN, Italy;
(5) RHEA for ESA, Netherlands;
(6) CNES, France;
(7) NSOAS, China;
(8) First Institute of Oceanography, China.

ESA Permanent Facility for Altimetry Calibration

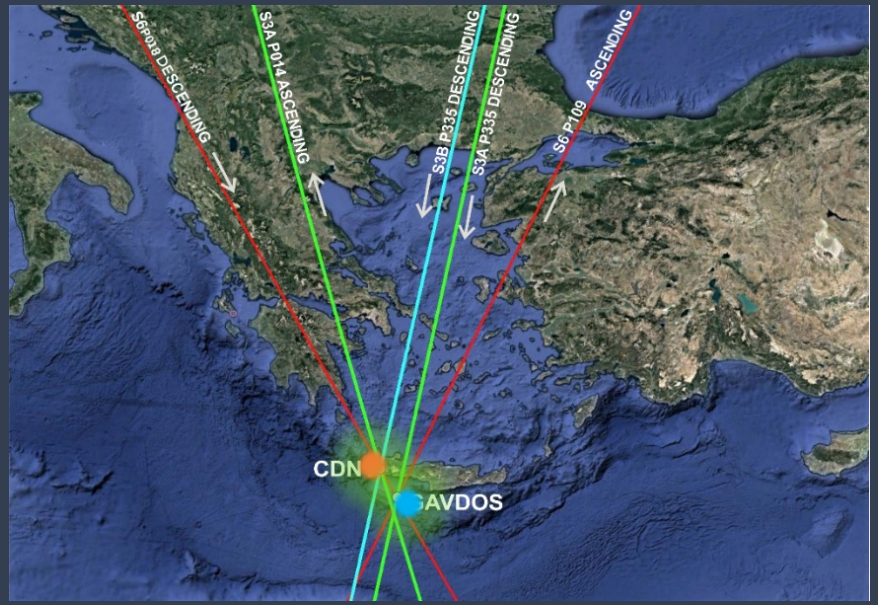




- ✓ 4 sea-surface, 2 transponder, 2 Corner Reflector Cal/Val sites,
- ✓ Crossovers with S3A, S3B, JA3, S6, CryoSat-2, AltiKa, SWOT, HY-2,…
- ✓ Frequent, Redundant, Confident results, Directional errors.

ESA Permanent Facility for Altimetry Calibration

Transponders at ESA PFAC, Crete



Crete (CDN1 Transponder)

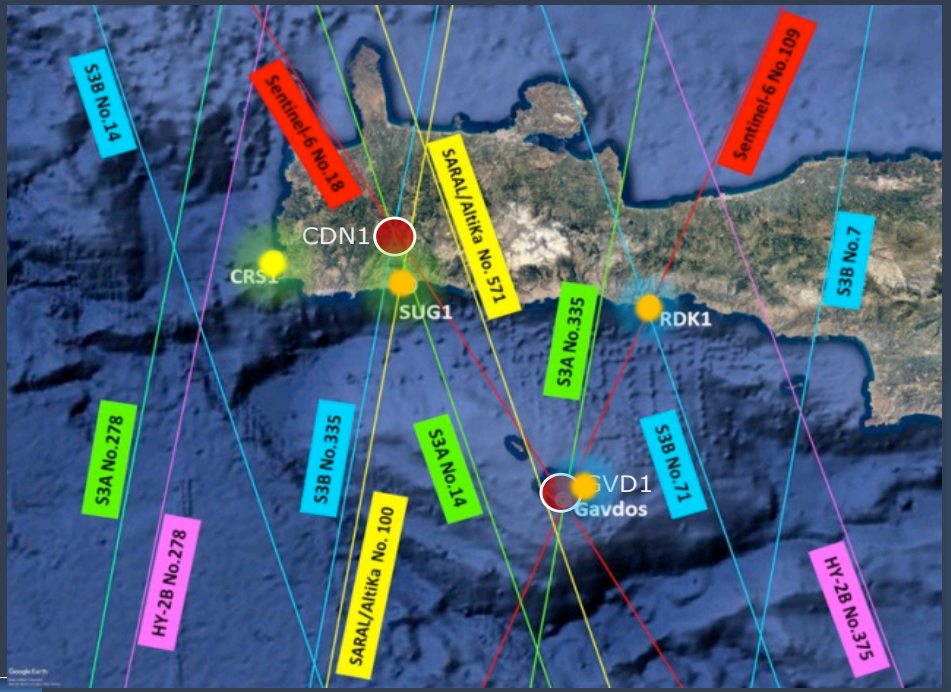
-Multiple Cross-over (S3A, S3B, JA3, S6, CryoSat-2, SWOT),
-Low clutter,
-Cross-calibration,
-Crystal clear signal of satellites.

Gavdos (GVD1 Transponder)

S3A, Sentinel-6 (A109 & D18), CryoSat-2
Sea-Surface Cal/Val

ESA Permanent Facility for Altimetry Calibration

Sea-surface infrastructure, Crete



CRS1 Cal/Val site (West Crete)

SUG1 Cal/Val site (South Crete)

Gavdos Cal/Val site

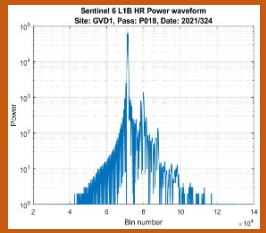
RDK1 Cal/Val site (South Crete)

Simultaneous Transponder & Sea-Surface Cal/Val

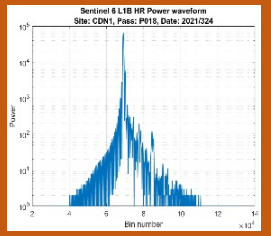
GeoMatLab

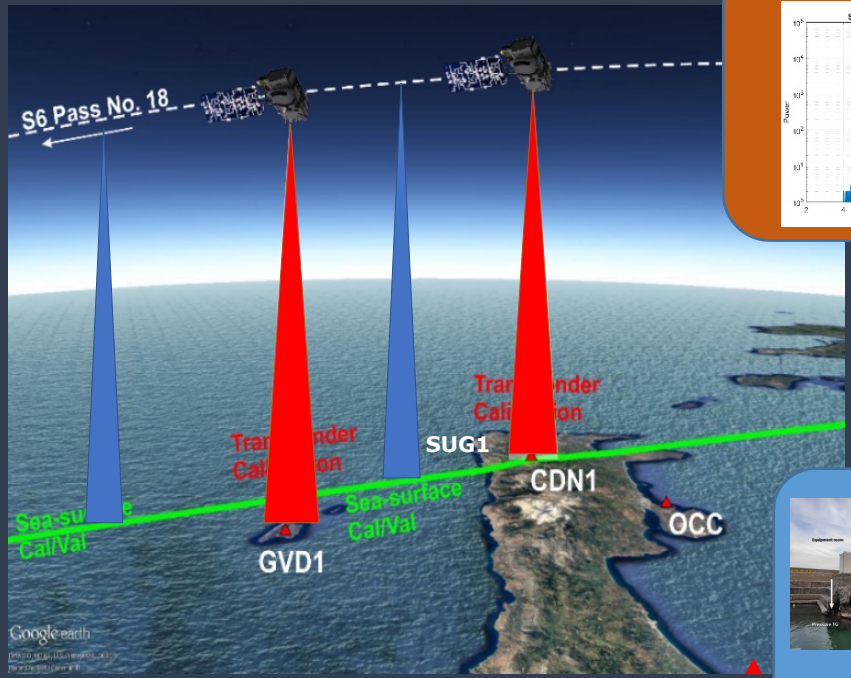
esa European Space Agency

GVD1 Transponder



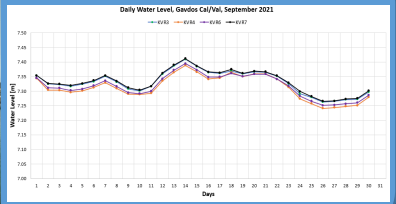
CDN1 Transponder



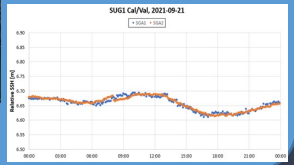


RDK1

Gavdos sea-surface



SUG1 sea-surface



Space Geomatics P.C.

OSTST Conference,
7-11 Nov 2023, PUERTO RICO

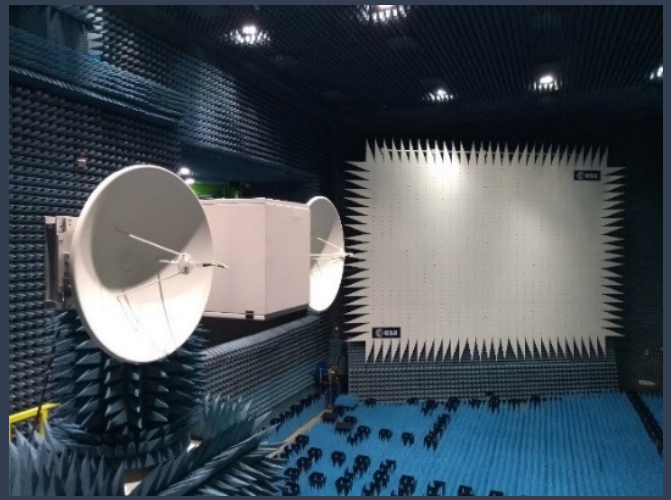
ESA Permanent Facility for Altimetry Calibration

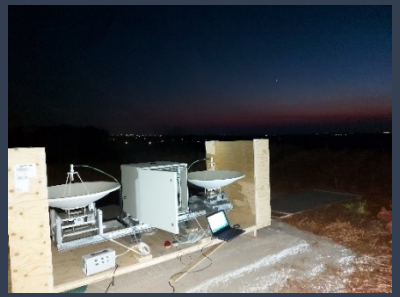
Gavdos transponder at GVD1 Cal/Val site

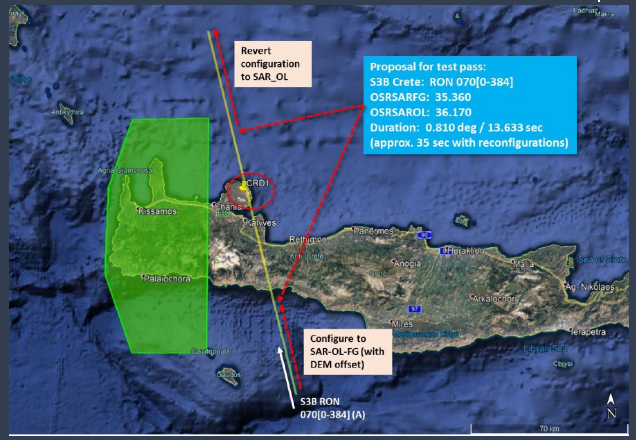
Transponder operational as of 11-Oct-2020.

DORIS Antenna.

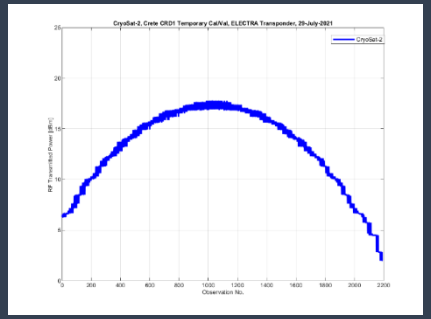
Characterization of ELECTRA Transponder

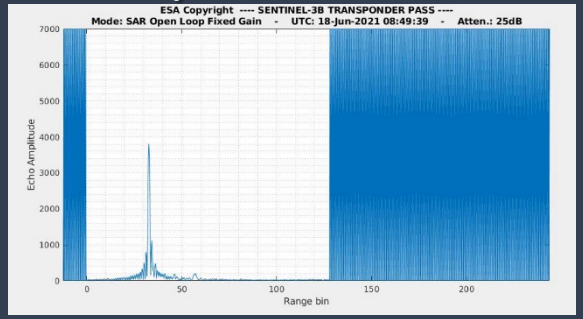




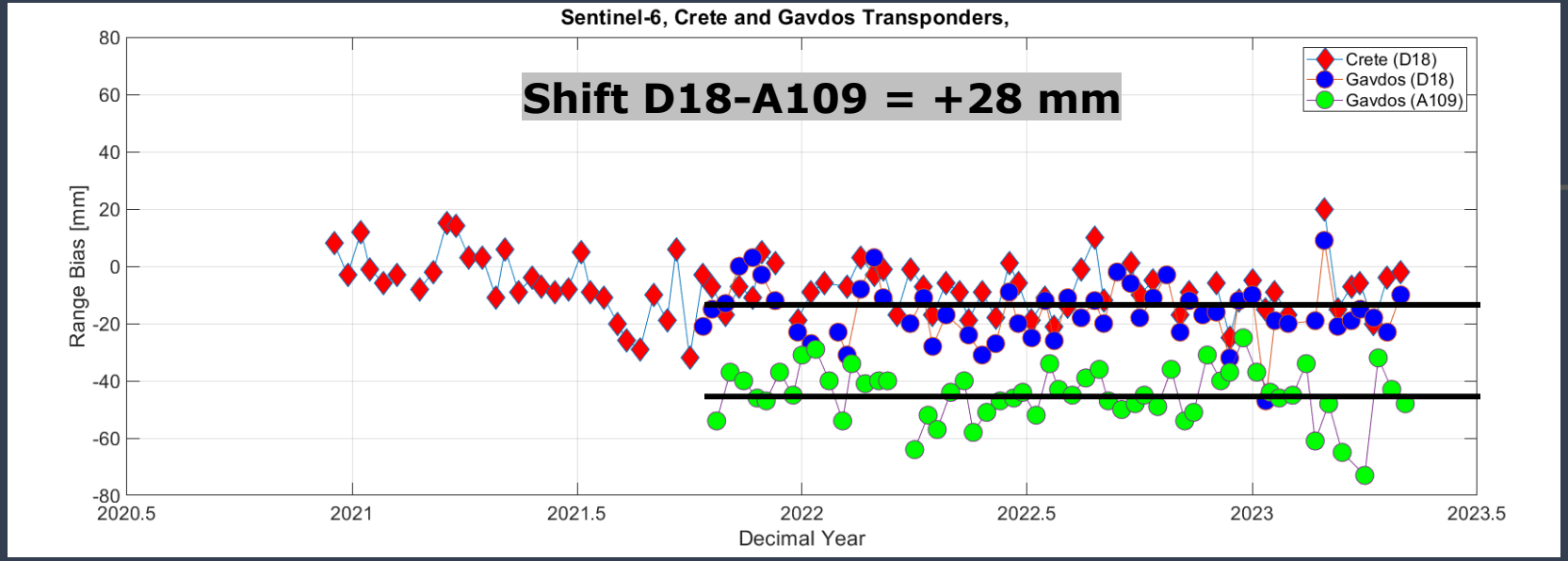


- Field Testing before deployment,
- S3B & CryoSat-2.



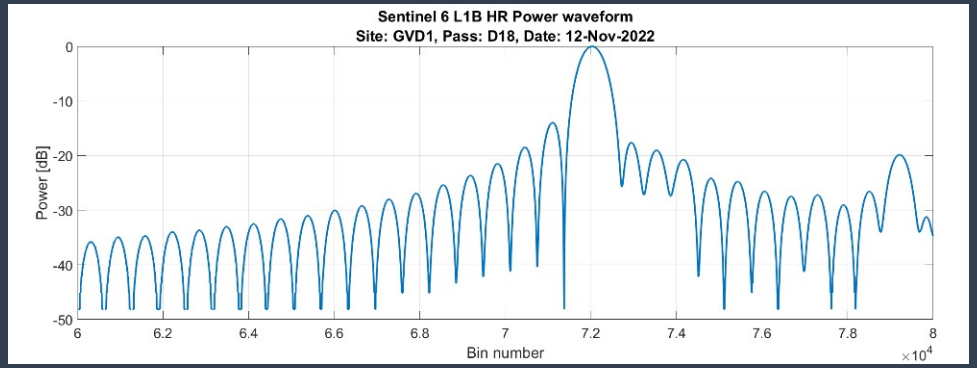


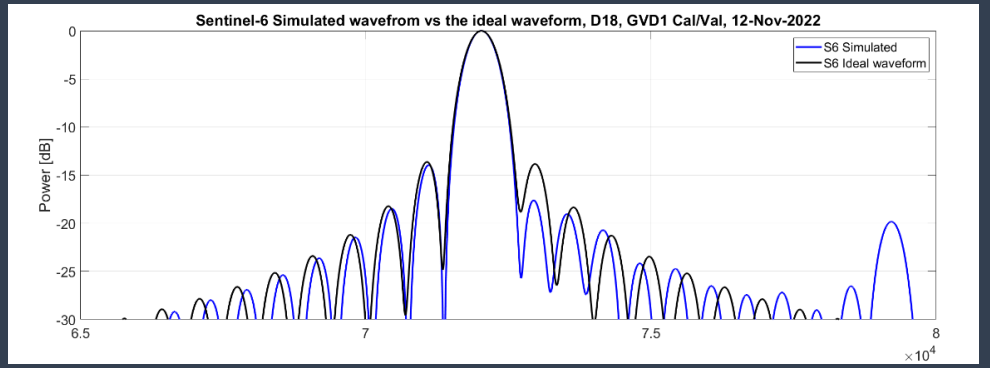
Sentinel-6 Transponder Cal/Val: Asymmetry Present



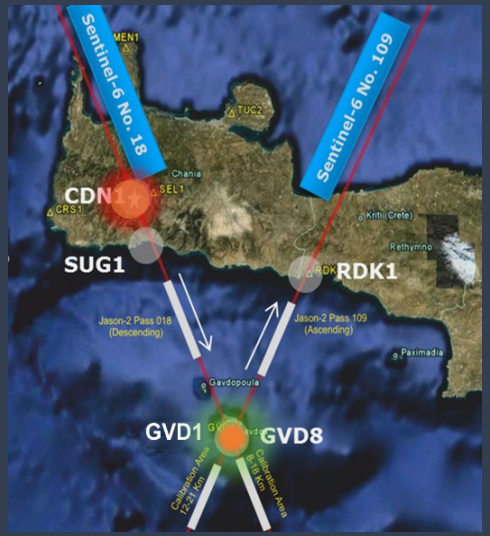
- Crete (D18): Range Bias = - 7 mm ± 1 mm, D18, NTC, POE, Cycles 4-70,
- Gavdos (D18): Range Bias = -10 mm ± 4 mm, D18, NTC, POE, Cycles 34-70,
- Gavdos (A109): Range Bias = -40 mm ± 5 mm, A109, NTC, POE, Cycles 34-69.

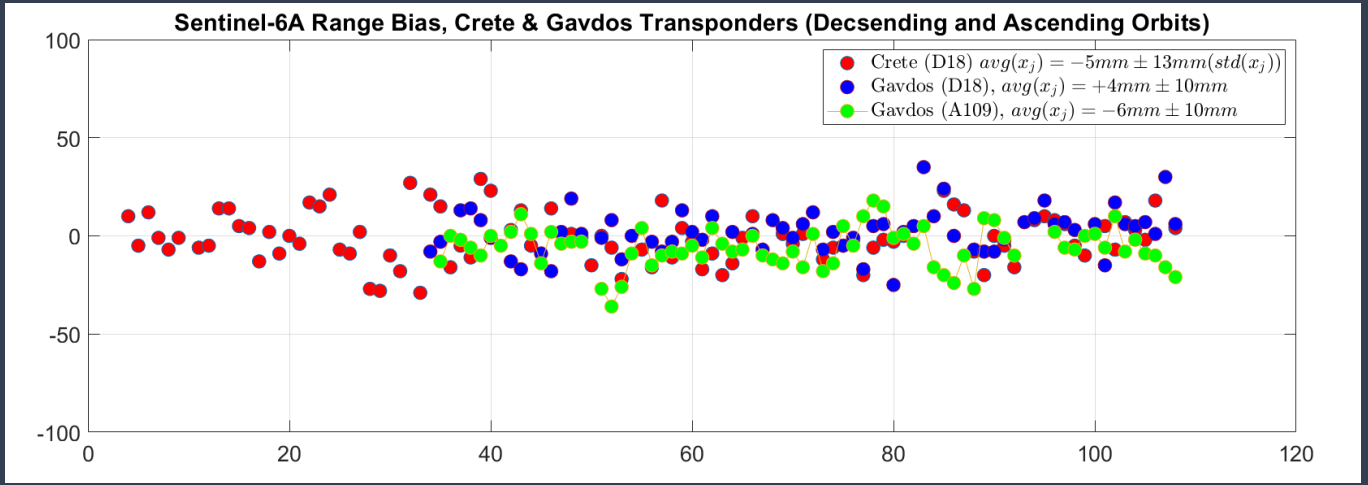
GVD1 Transponder: Asymmetry in Waveform Revealed





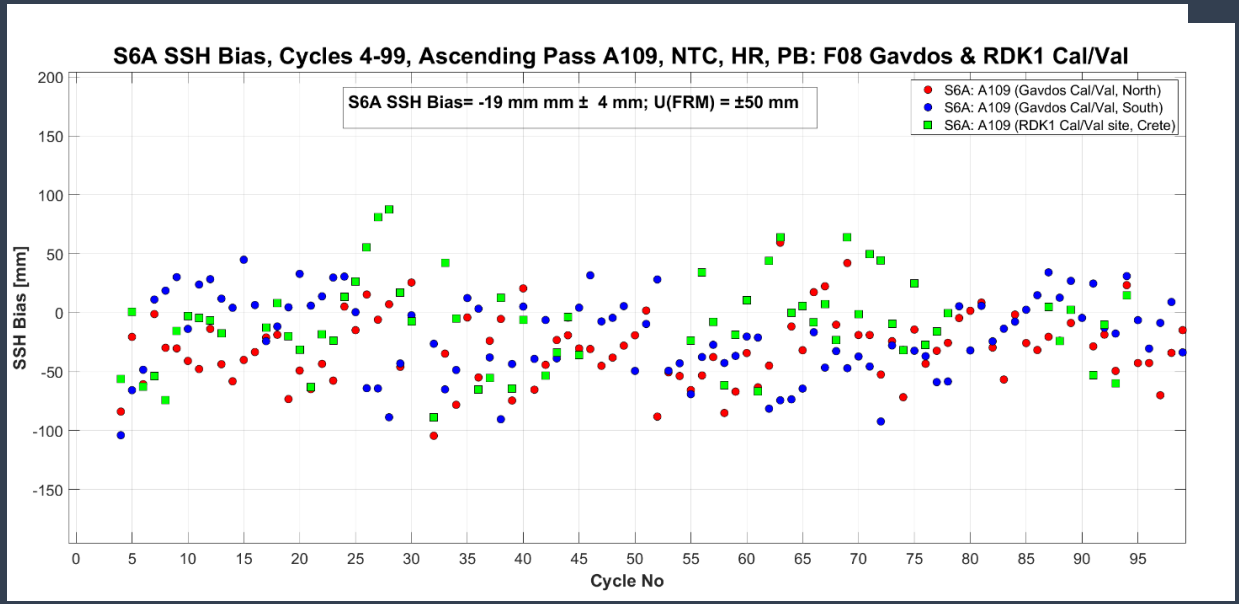
CDN1 & GVD1 Transponder Cal/Val: Sentinel-6





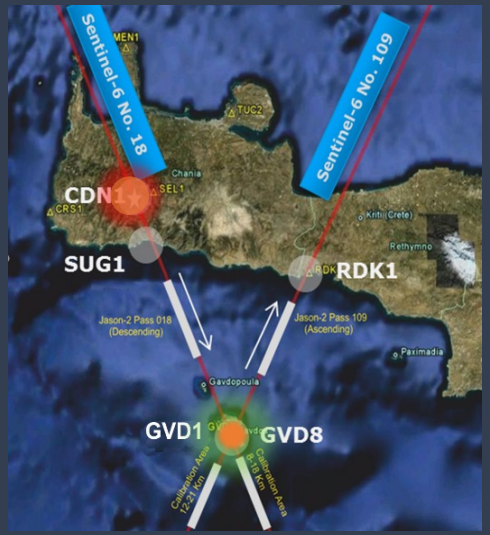
- Crete: Range Bias = – 5 mm ± 13 mm D18, NTC, (N= 91) [U(FRM)= ± 30mm],
- Gavdos: Range Bias = + 4 mm ± 10 mm D18, NTC, (N= 62),
- Range Bias = – 6 mm ± 10 mm A109, NTC, (N= 62).

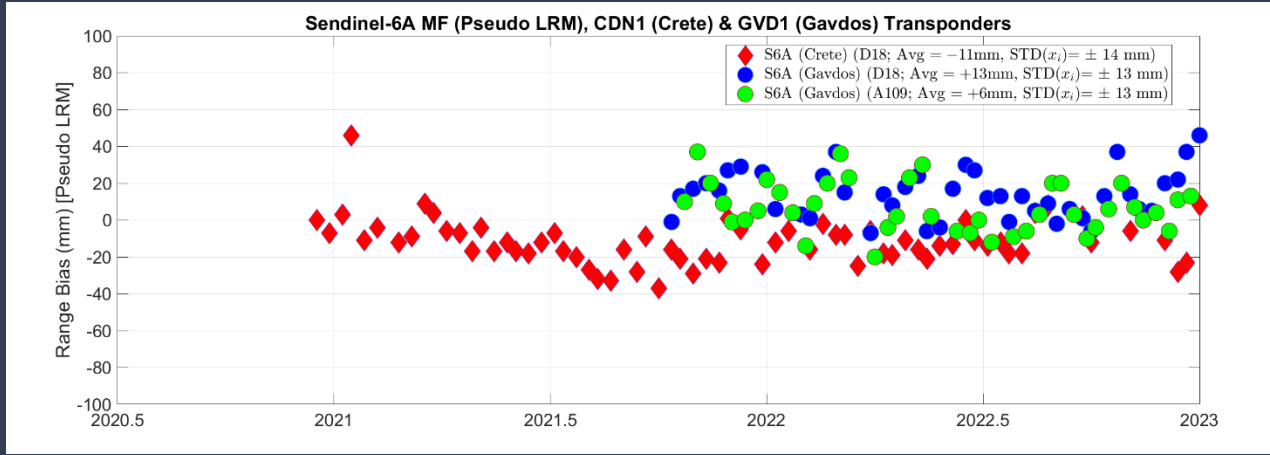
Sentinel-6A Sea-Surface Cal/Val: SUG1, RDK1, GVD8 Sites



- Grand AVG(D18) : SSH Bias = – 15 mm ± 5 mm ; U(FRM) = ± 50 mm,
- Grand AVG(A109): SSH Bias = – 19 mm ± 4 mm ; U(FRM) = ± 50 mm.

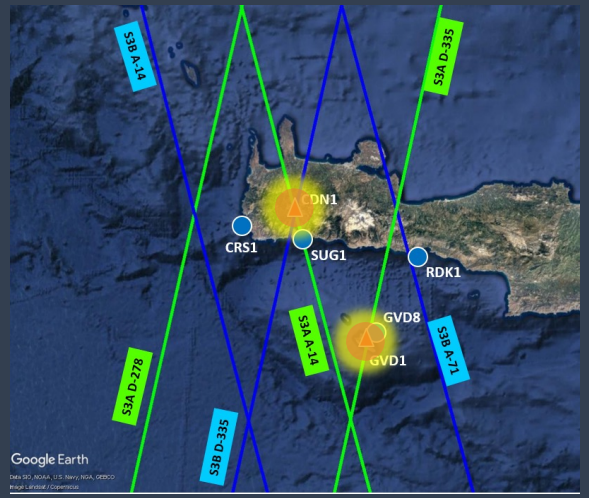
Sentinel-6A Transponder Cal/Val: Pseudo LRM

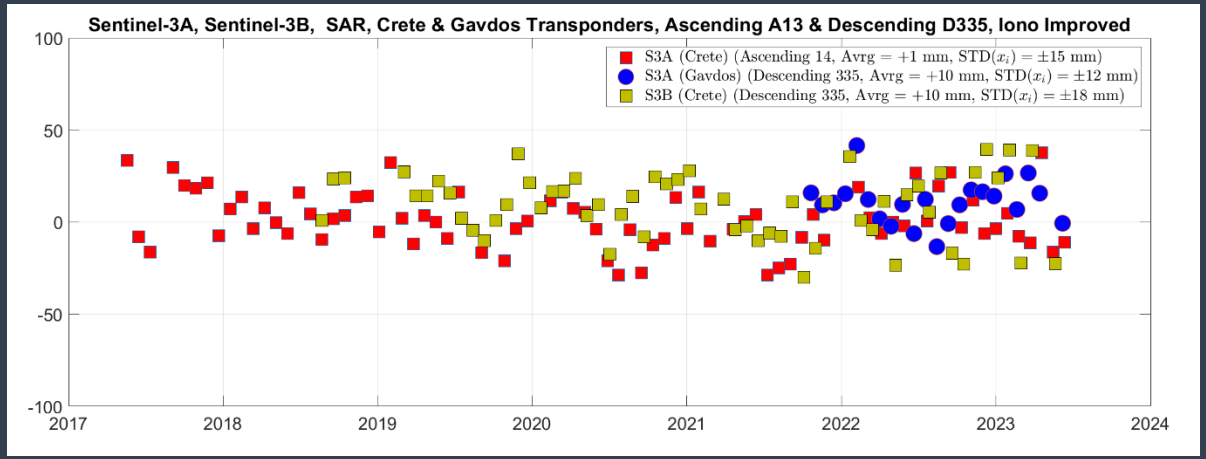




Crete: Range Bias = – 11 mm ± 2 mm D18 , (N= 76),
Gavdos: Range Bias = + 13 mm ± 1 mm D18 , (N= 42),
Range Bias = + 6 mm ± 2 mm A109, (N= 42).

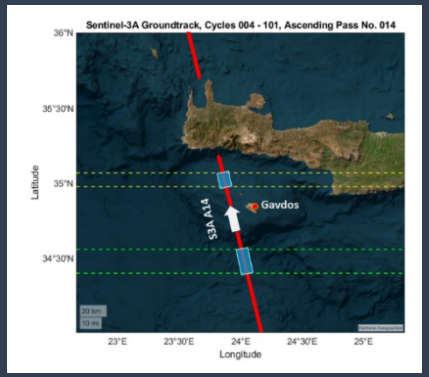
Sentinel-3A/3B Transponder Cal/Val (SAR): Crete & Gavdos

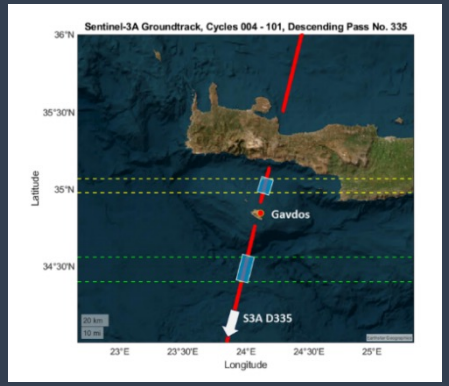


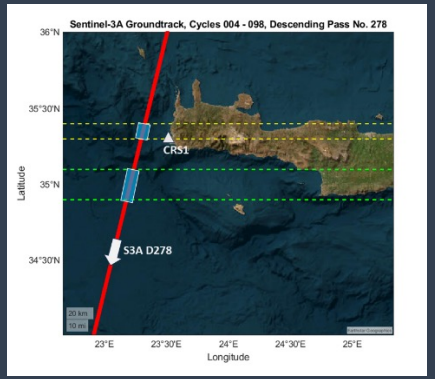


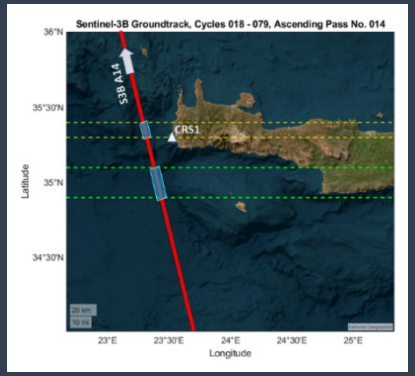
- S3A Range Bias (Crete) = +1 mm ± 15 mm [U(FRM)= ± 30mm], Ascend A14;
- S3A Range Bias (Gavdos) = +10 mm ± 12 mm, Descending D335,
- S3B Range Bias (Crete) = +10 mm ± 18 mm, Descending D335,

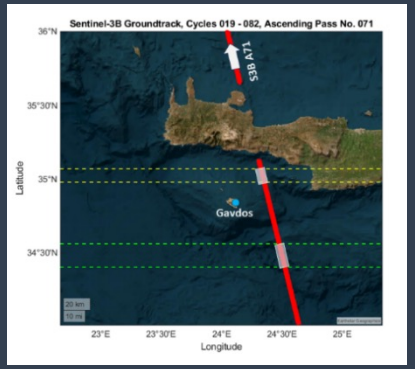
Sentinel-3: Sea-Surface Cal/Val Regions

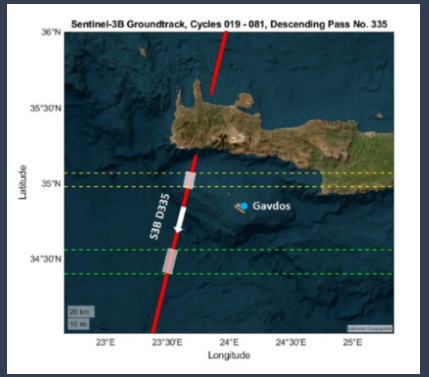




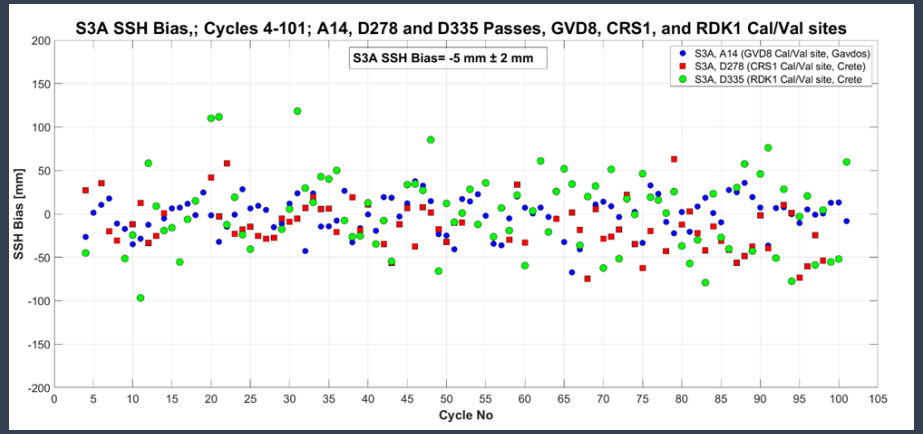


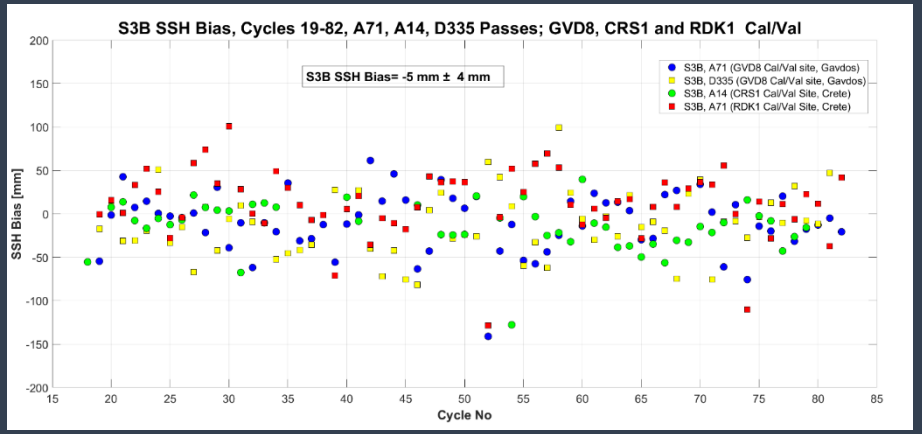






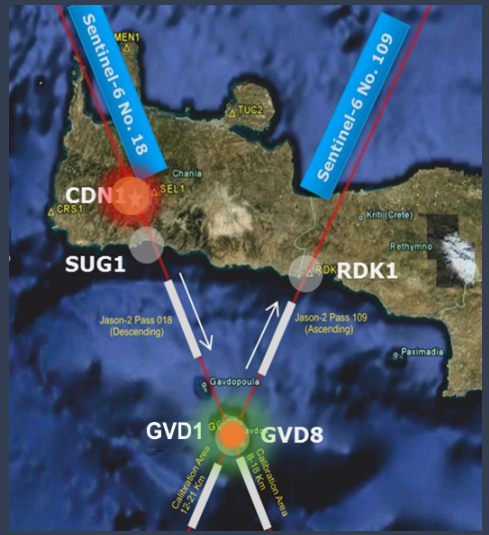
Sentinel-3A/3B Sea-Surface Cal/Val (SAR): Crete & Gavdos

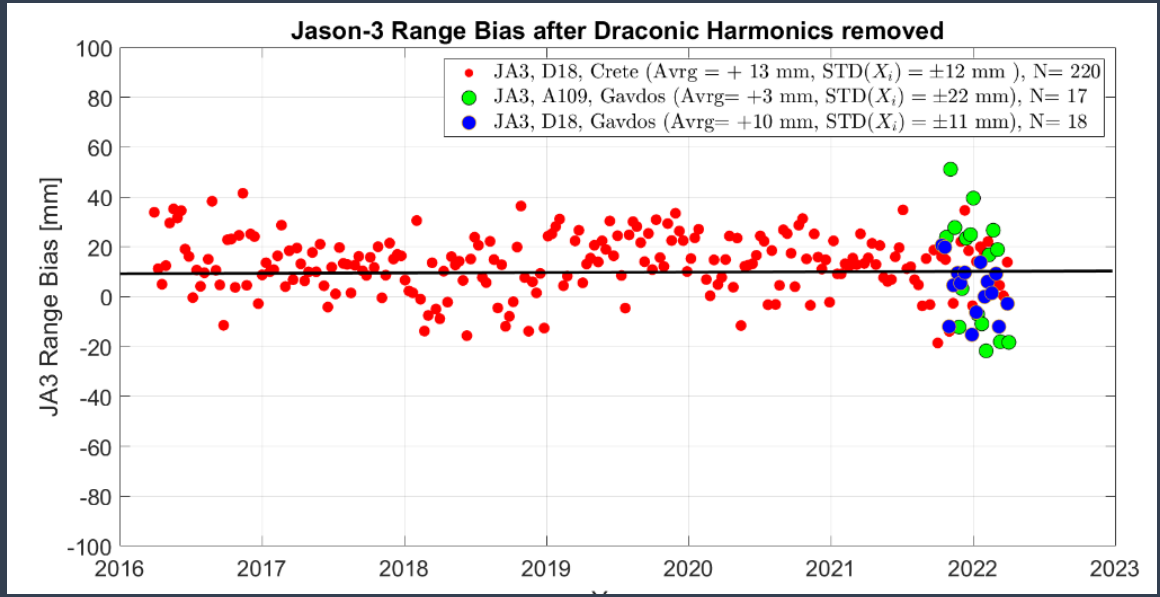




- S3A: Grand AVG: SSH Bias = – 5 mm ± 2 mm ; U(FRM) = ± 50 mm,
- S3B: Grand AVG: SSH Bias = – 5 mm ± 4 mm ; U(FRM) = ± 50 mm.

Jason-3 Transponder Cal/Val (LRM)

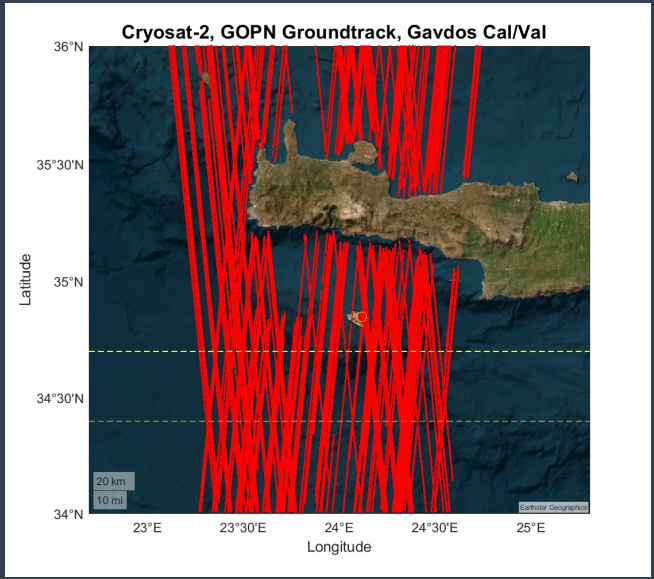


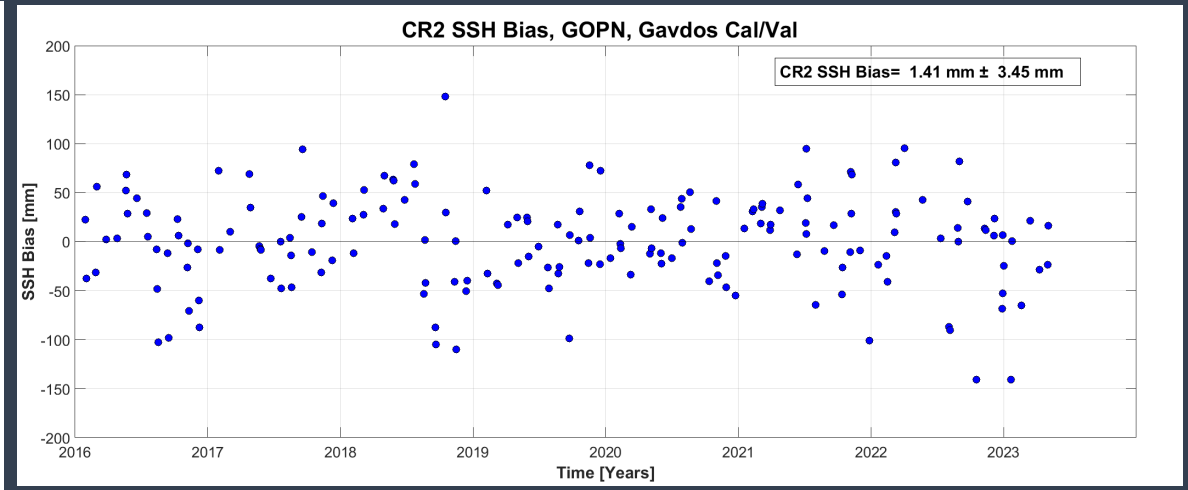


- Crete: Range Bias = + 13 mm ± 12 mm D18 , (N= 220),
- Gavdos: Range Bias = + 3 mm ± 22 mm D18 , (N= 17),
- Range Bias = 10 mm ± 11 mm A109, (N= 18).

CryoSat-2 Sea-surface Cal/Val: GOPN

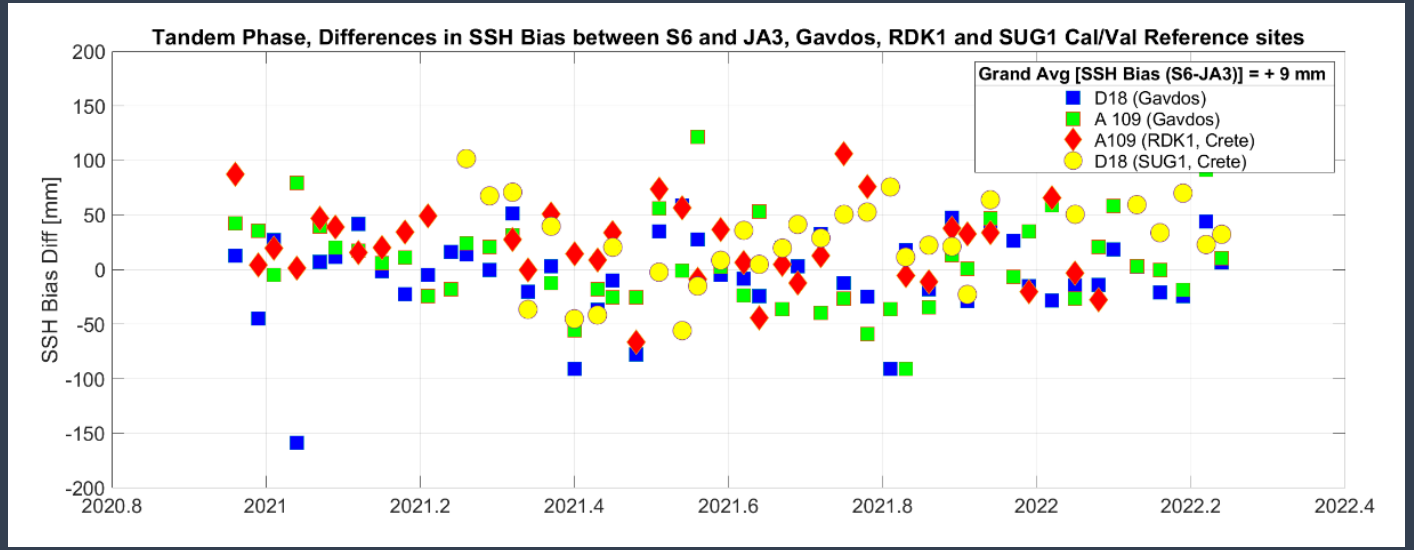
GOPN: Geophysical Ocean Products SARIn





- CS2 (GOPN) Bias = 1 mm ± 4 mm [U(FRM)= ± 50mm,
- Baseline-D Ice Products

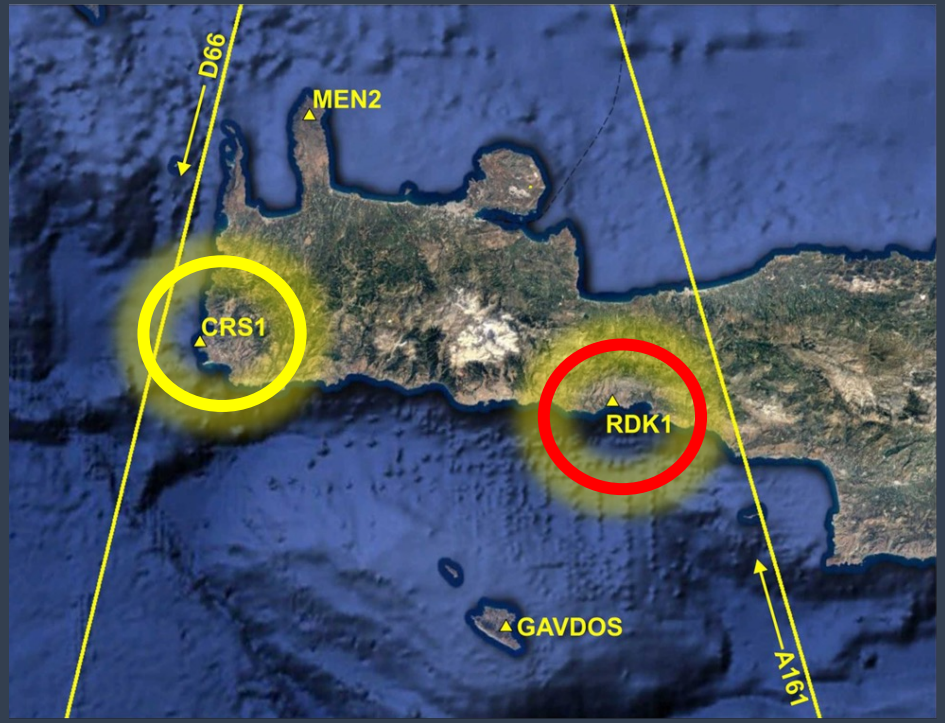
Difference in Range Bias [S6-MF minus Jason-3]



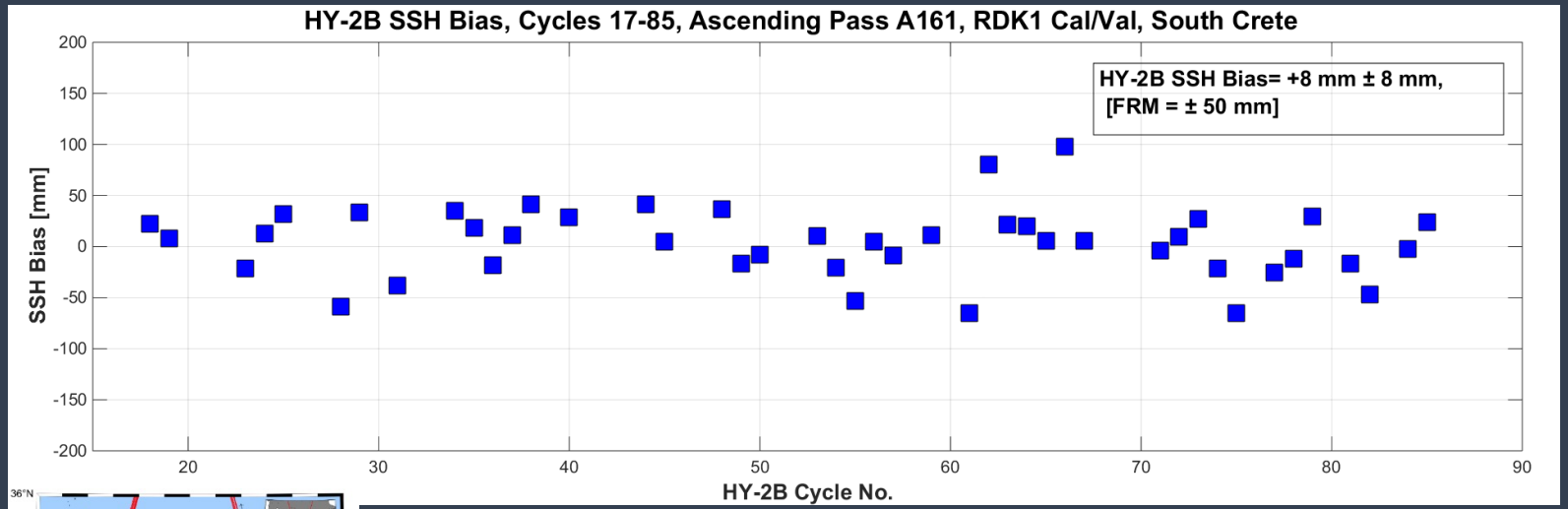
S6-JA3 (Crete, D18) = - 18 mm ± 10 mm,
S6-JA3 (Gavdos, D18) = - 17 mm ± 16 mm.

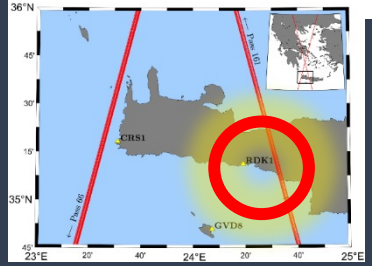
Sinusoid variations caused by JA3 yaw rotations.

HY-2B Sea-Surface Cal/Val over Crete



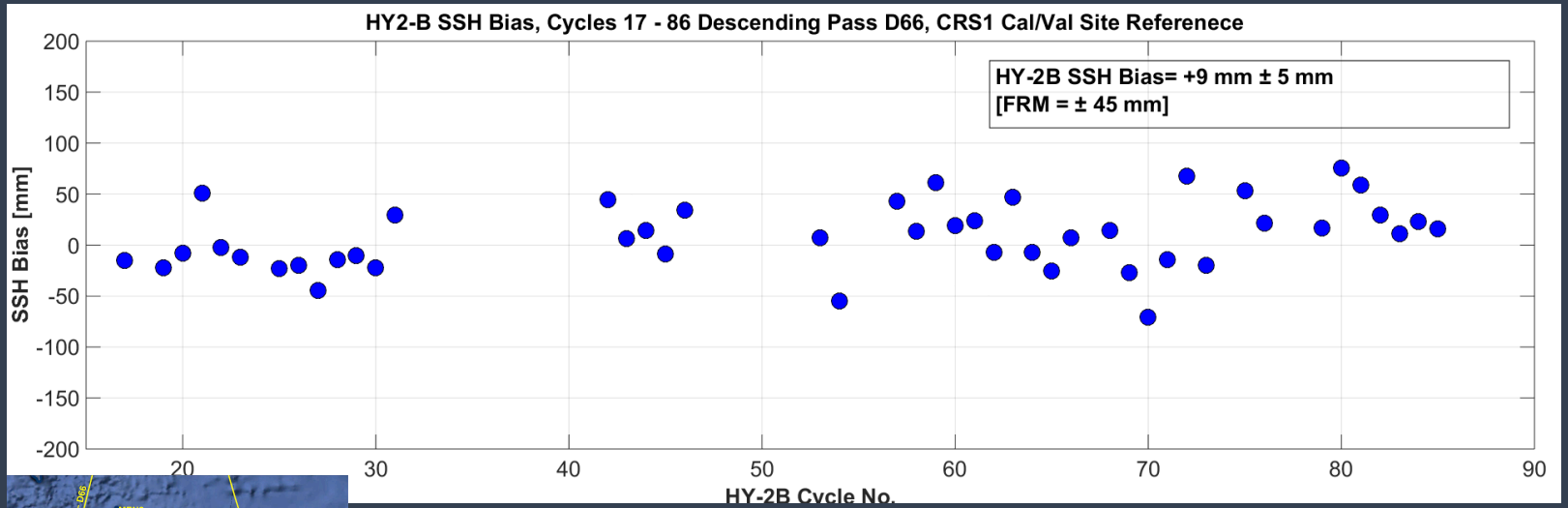
HY-2B, Crete, RDK1 Cal/Val Results



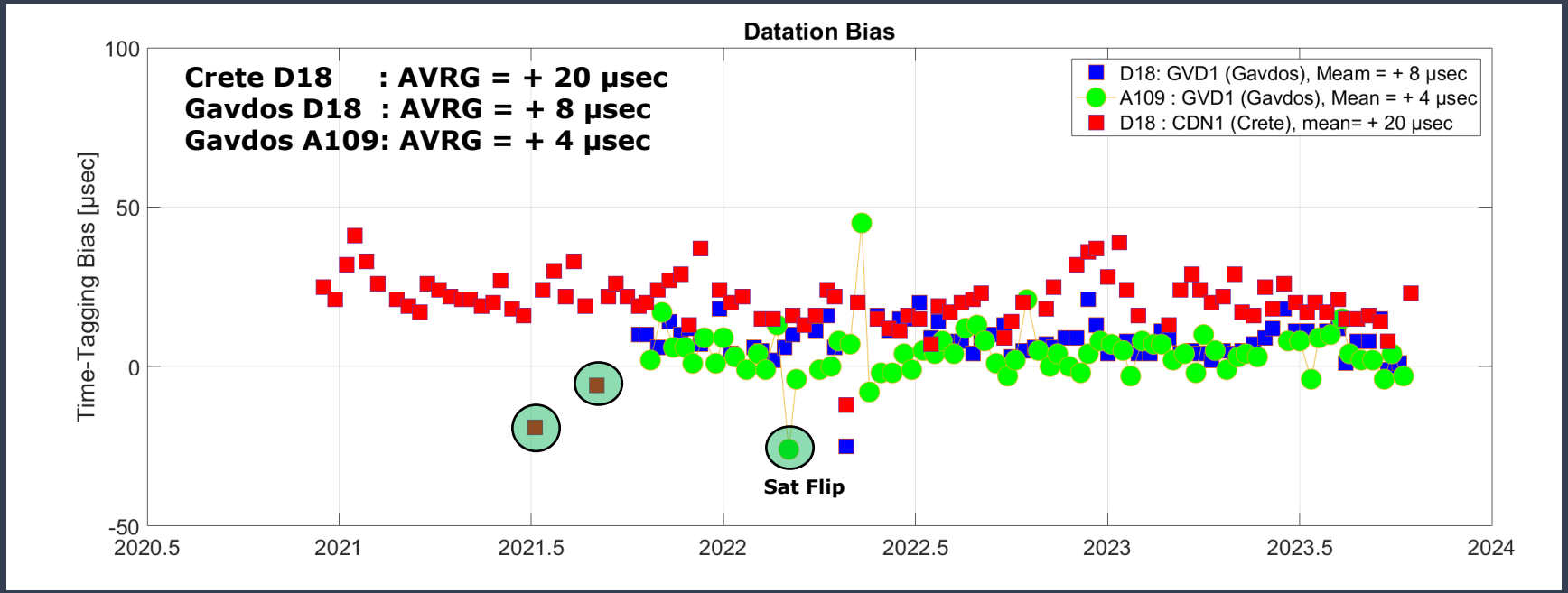


- HY-2B: Mean SSH Bias: +8 mm ± 8 mm,
- FRM Uncertainty : ± 50 mm

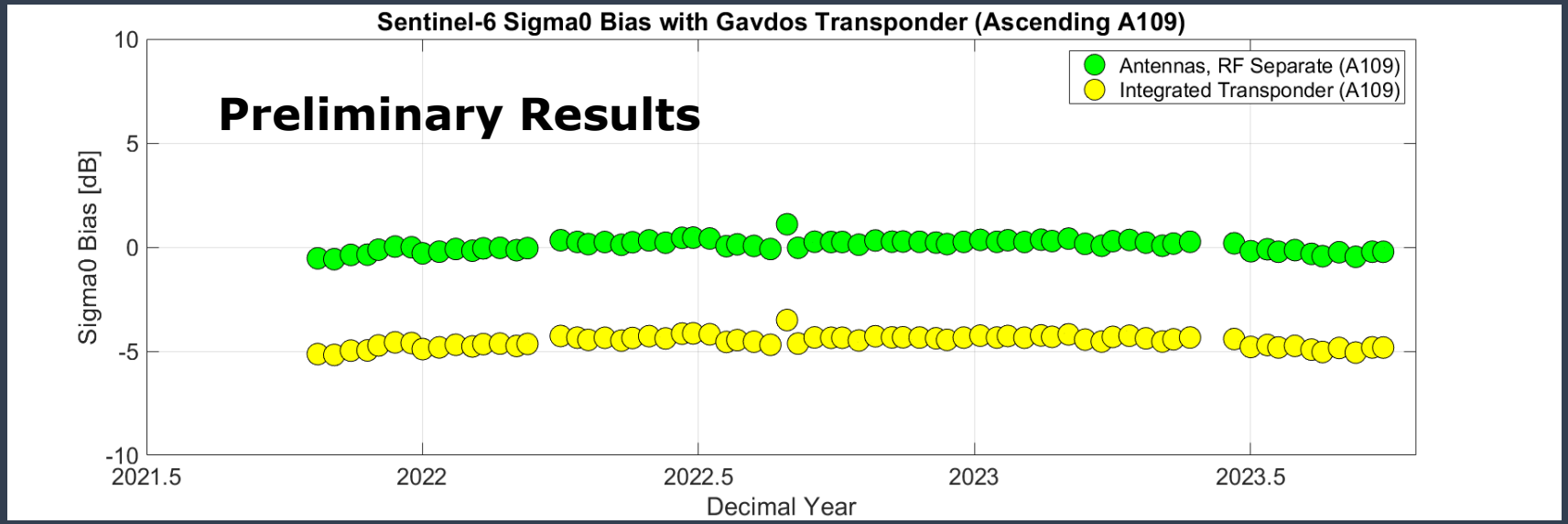
HY-2B, Crete CRS1 Cal/Val Results (D66)



Sentinel-6 MF Time Tagging Bias

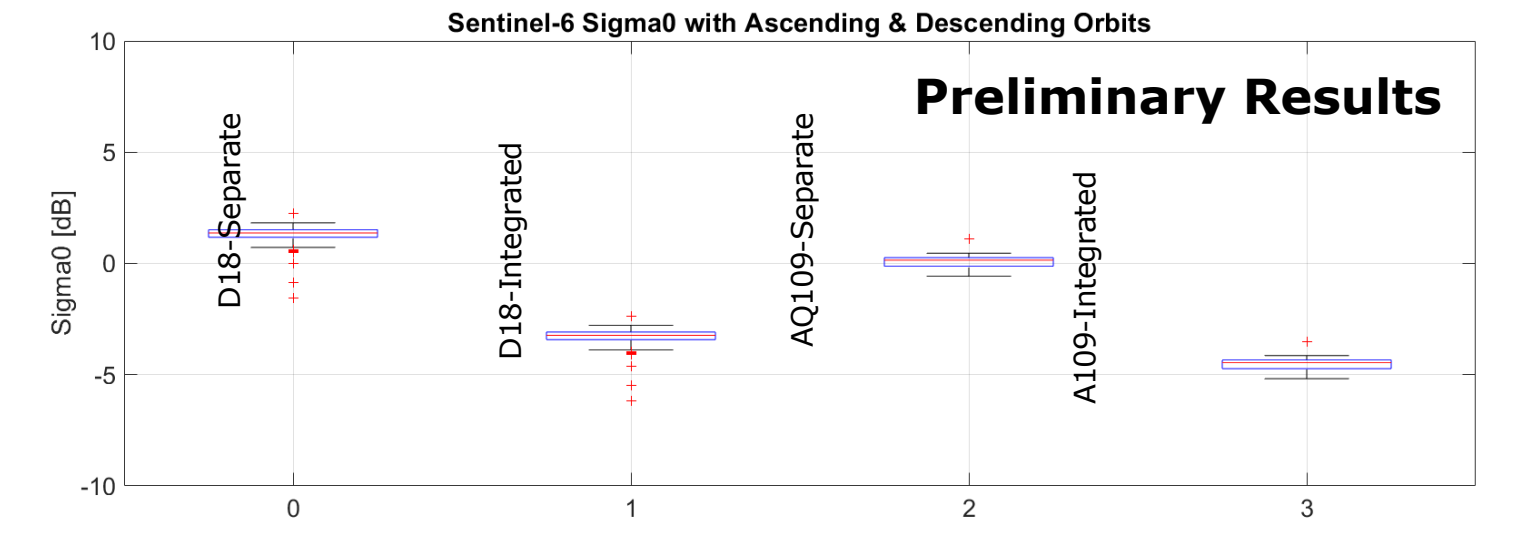


Sentinel-6 Sigma0 Bias, Ascending A109: Prelim Results



(Separate antenna & RF) Sigma0 Bias (A109): AVRG = + 0.08 dB ± 0.03 dB,
(Integrated Transponder) Sigma0 Bias (A109): AVRG : —4.52 dB ± 0.03 dB,

Sentinel-6 Sigma0 Bias: Summary



- Integrated Transponder with Antennas & RF : includes
  - (a) Circular Polarization mismatch, (b) RCS corrections, (c) Loss of adapters used in testing.
- D18 Cal/Val results are noisy with outliers,
- Waveform asymmetry may influence sigma0 Cal/Val Results.

TPX: Transponder Working Group Setup

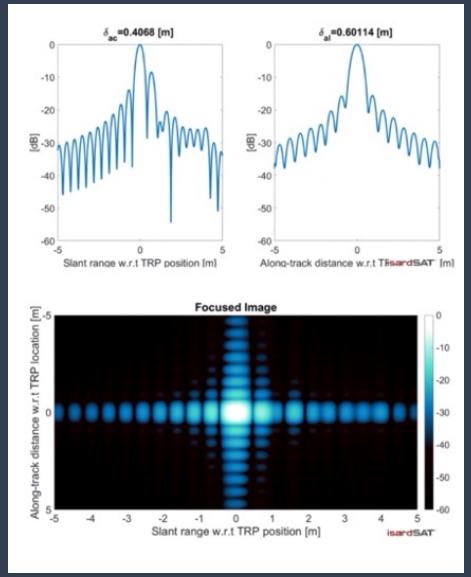
- **Joint Processing Evaluation (See presentation by IsardSAT)**

Led by ESA/ESTEC [Craig Donlon, Marco Fornari]:

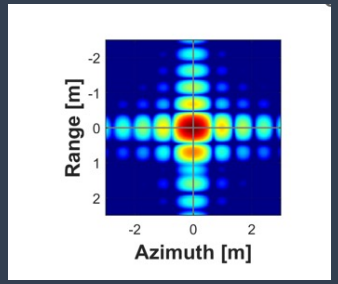
- Technical University of Crete, Space Geomatica, Greece;
- IsardSAT, Catalonia;
- ARESYS, Italy;
- CLS & CNES, France;
- Eumetsat;
- NOAA, USA;
- JPL, USA.

Transponder Working Group

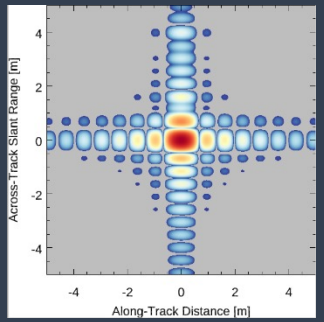
isardSAT



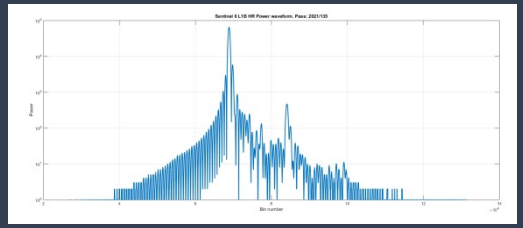
Aresys

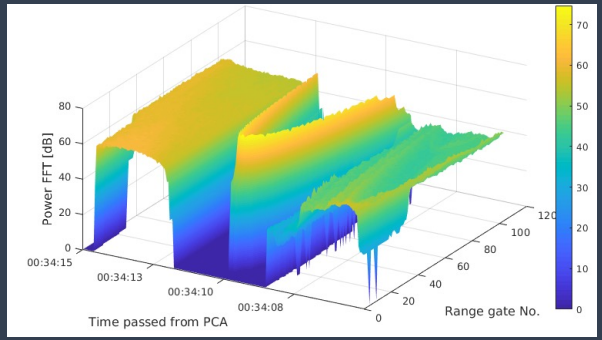


NOAA

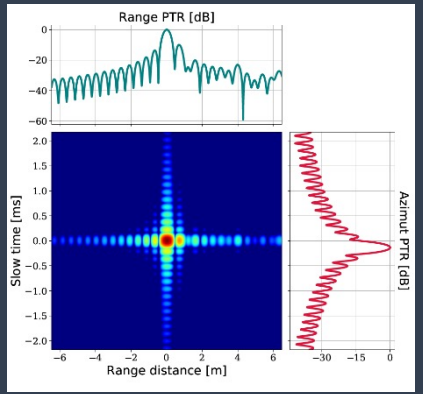


TUC/Space Geomatica





CNES/CLS



Concluding Remarks

ESA Permanent Facility for Altimetry Calibration:

- Transponder & Sea-Surface Ground infrastructure,
- Diverse Instrumentation, Settings & Processing,
- Ascending & Descending orbits (Directional Errors),
- Different satellites & Results are cross-examined,
- Reliability & confidence on results has been built up;
- Patterns & structures in transponder results understood;
- Data & Results are screened for their quality, daily and monthly;
- Ground reference connected to absolute time;
- Uncertainty Budget in FRM Standards.

Acknowledgments

FRM4S6 & S3MPC