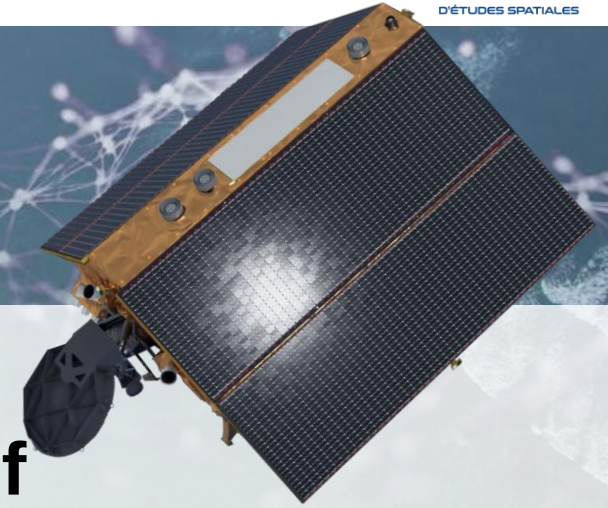




Multi-Mission External Calibration of Radar Altimeters Using Point Targets

isardSAT[®]

Adrián Flores de la Cruz¹, Albert Garcia-Mondéjar¹, Ferran Gibert¹, Mònica Roca i Aparici¹,
Michele Scagliola², Alessandro DiBella², Marco Fornari³

¹isardSAT, Ltd. ²ESA-ESRIN. ³ESA-ESTEC

1. Global Calibration Sites

Locations and characteristics of the transponders used for mission calibration.

2. Altimetry Data Processing Approaches

Fully Focused and Delay-Doppler methodologies.

3. Comparative Results

Performance assessment in Range, Datation, Across-track Resolution:

- CryoSat-2
- Sentinel-3A
- Sentinel-3B
- Sentinel-6

Performance assessment in Sigma0:

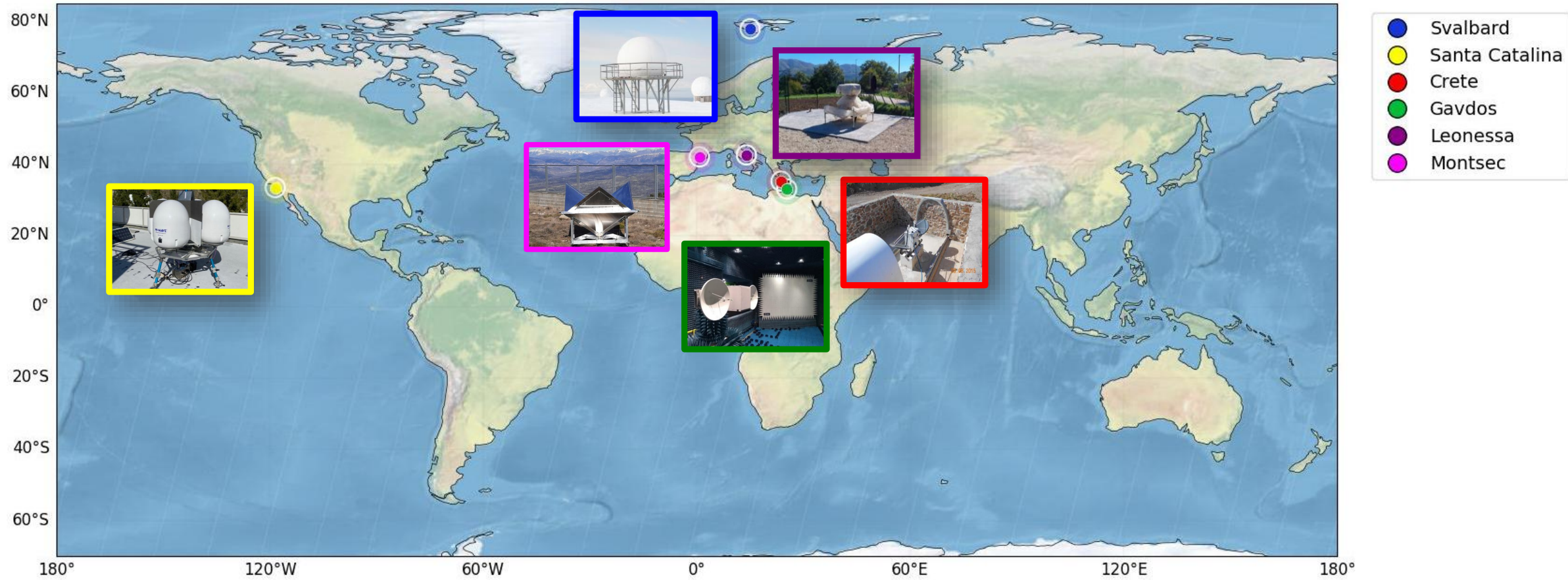
- Gavdos
- Montsec
- Leonessa

4. Key Conclusions

Main findings and implications for future altimetry missions

Global Calibration Sites

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Global Calibration Sites

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Site Location	Svalbard	Crete	Catalina	Leonessa	Gavdos	Montsec
Period	2005-	2013-	2020-	2020-	2021-	2021-
Bands	Ku	Ku	Ku & C	Ku	Ku	-
Antenna gain [dBi]	35.8	75-80	30.3 / 28.0	33.7 Tx., 31.3 Rx.	80	-
Beamwidth [°]	2.5	1.2	3 for Ku, 5 for C	3.2 Tx., 4.6 Rx.	1.2	-
Antenna diameter [m]	0.61	1.0	0.61	Horn antenna, 0.3	1.0	-
Auxiliary equipment	-	GNSS x2 Meteo x2, Radiometer	GNSS station	Automatic positioning & control system.	GNSSX3 MetoX3 DORIS	GNSS
Manufacturer	ULMO	TUC	JPL	Refurbished by RAME	TUC	isardSAT
Missions	CS2, S3A, S3B	CS2, S3A, S3B, S6	S3A, S6	S3A, S3B	CS2, S3A, S6	CS2, S3B, S6

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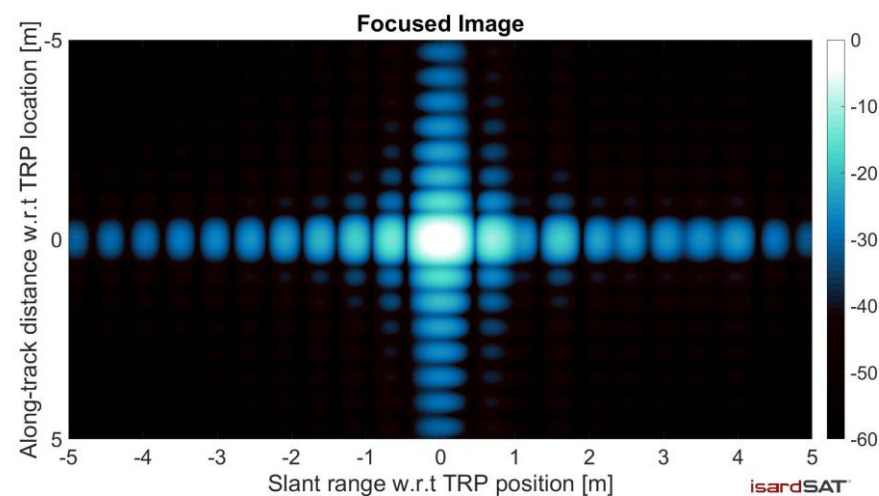
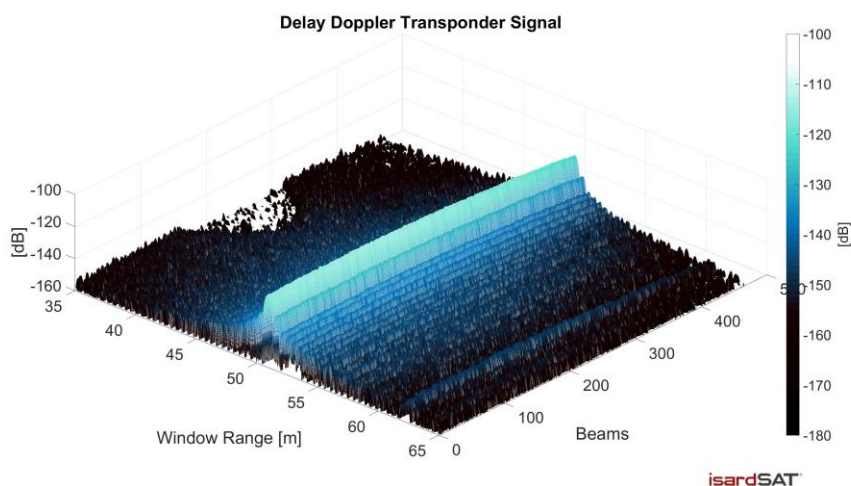
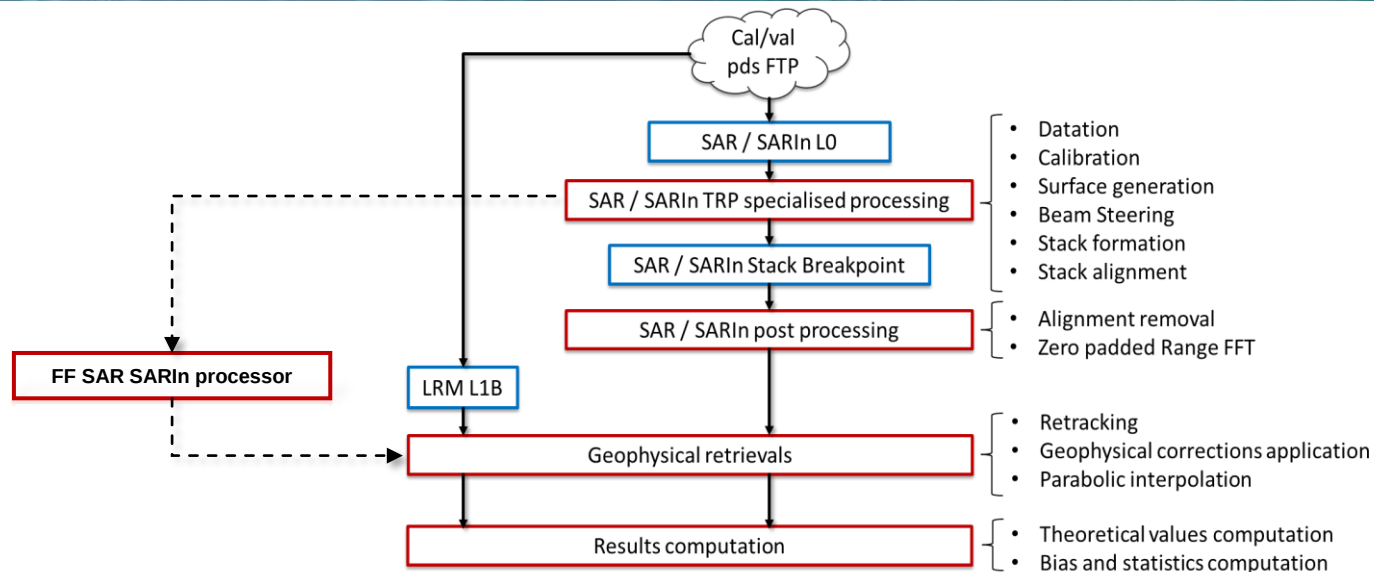
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Main findings and implications for future altimetry missions

Processing methods

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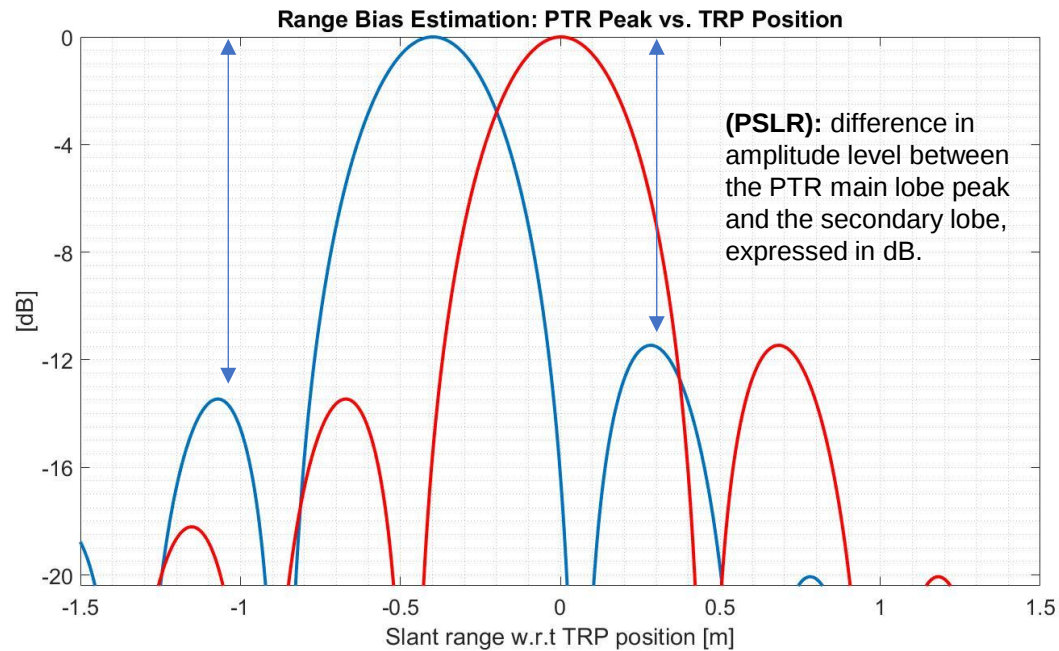
- Gavdos
- Montsec
- Leonessa

4. Key Conclusions

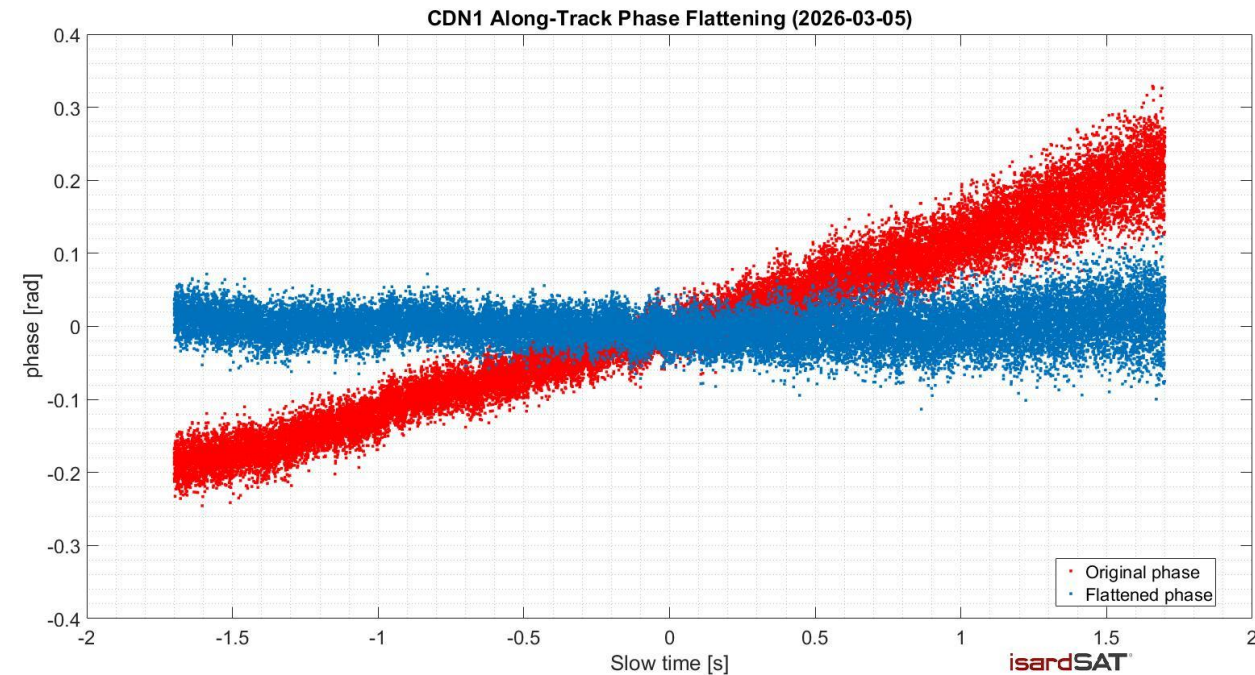
Main findings and implications for future altimetry missions

Processing methods: Calibration Metrics Estimation

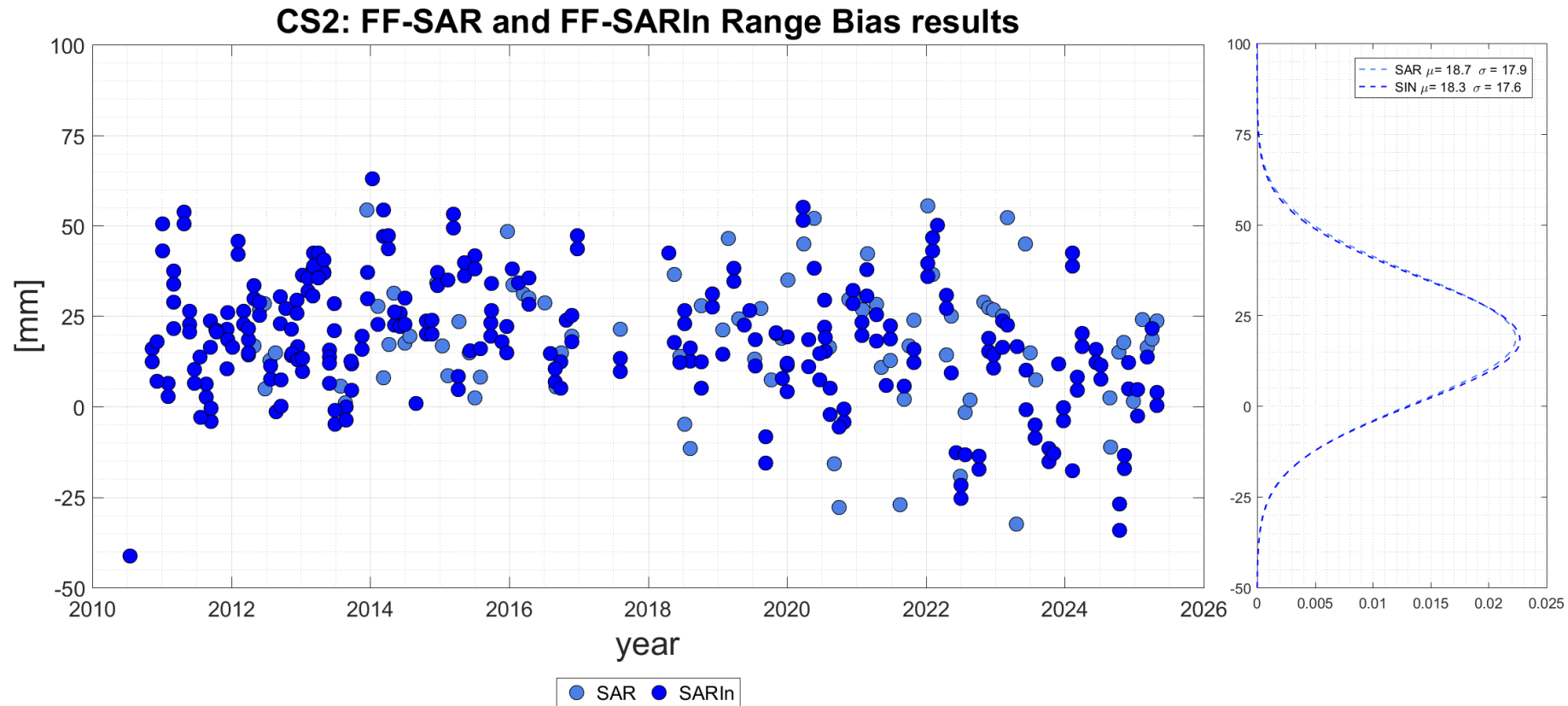
OSTST 2026

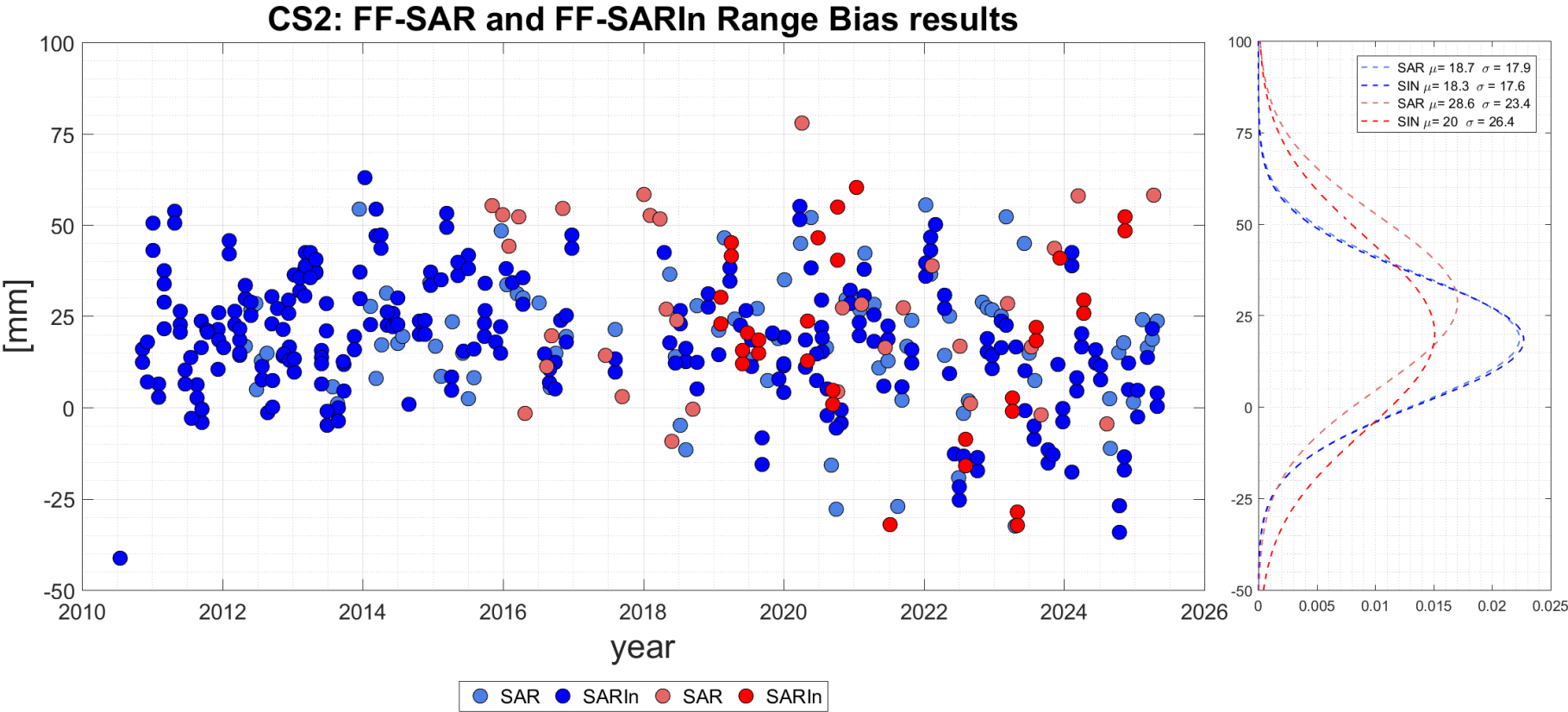


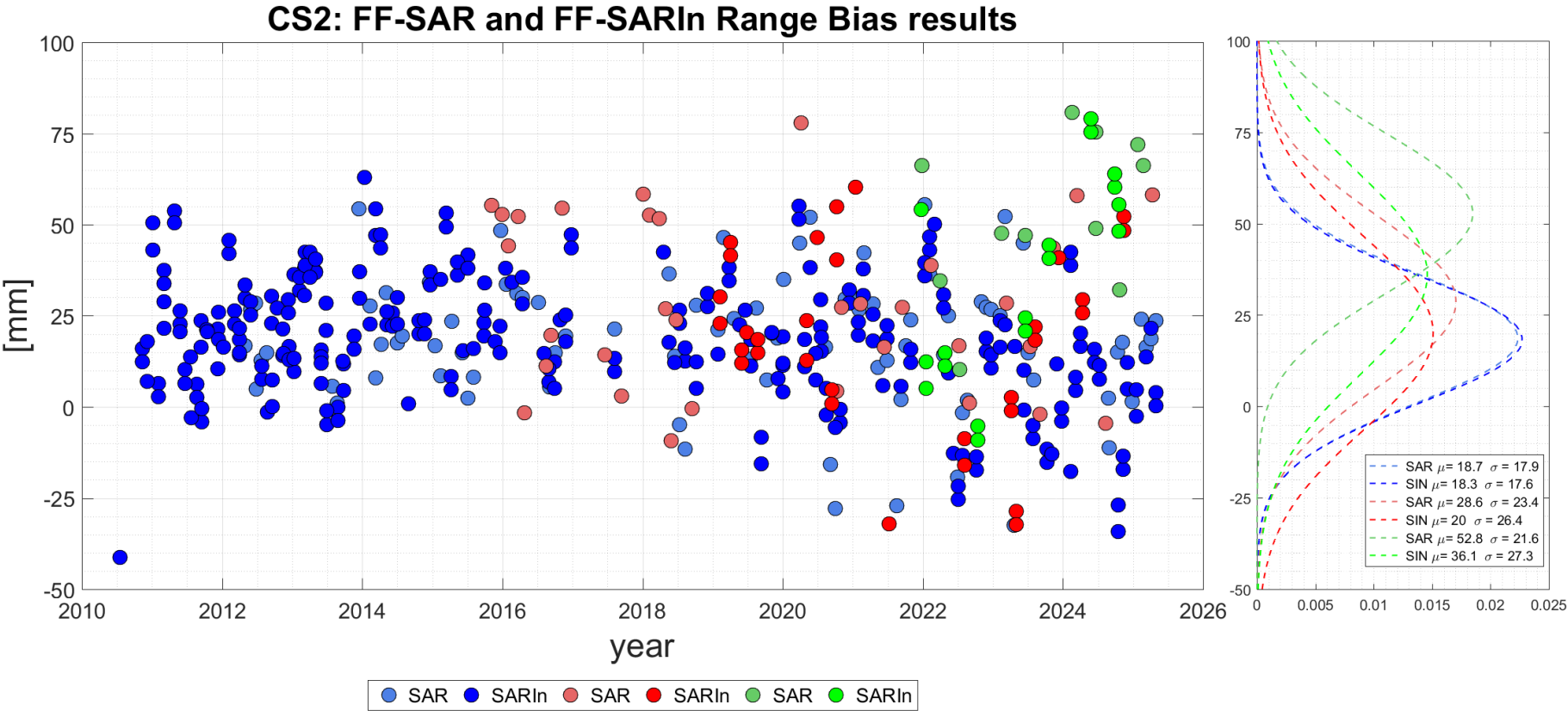
Range bias estimation: offset between the PTR peak position and the theoretical TRP location.

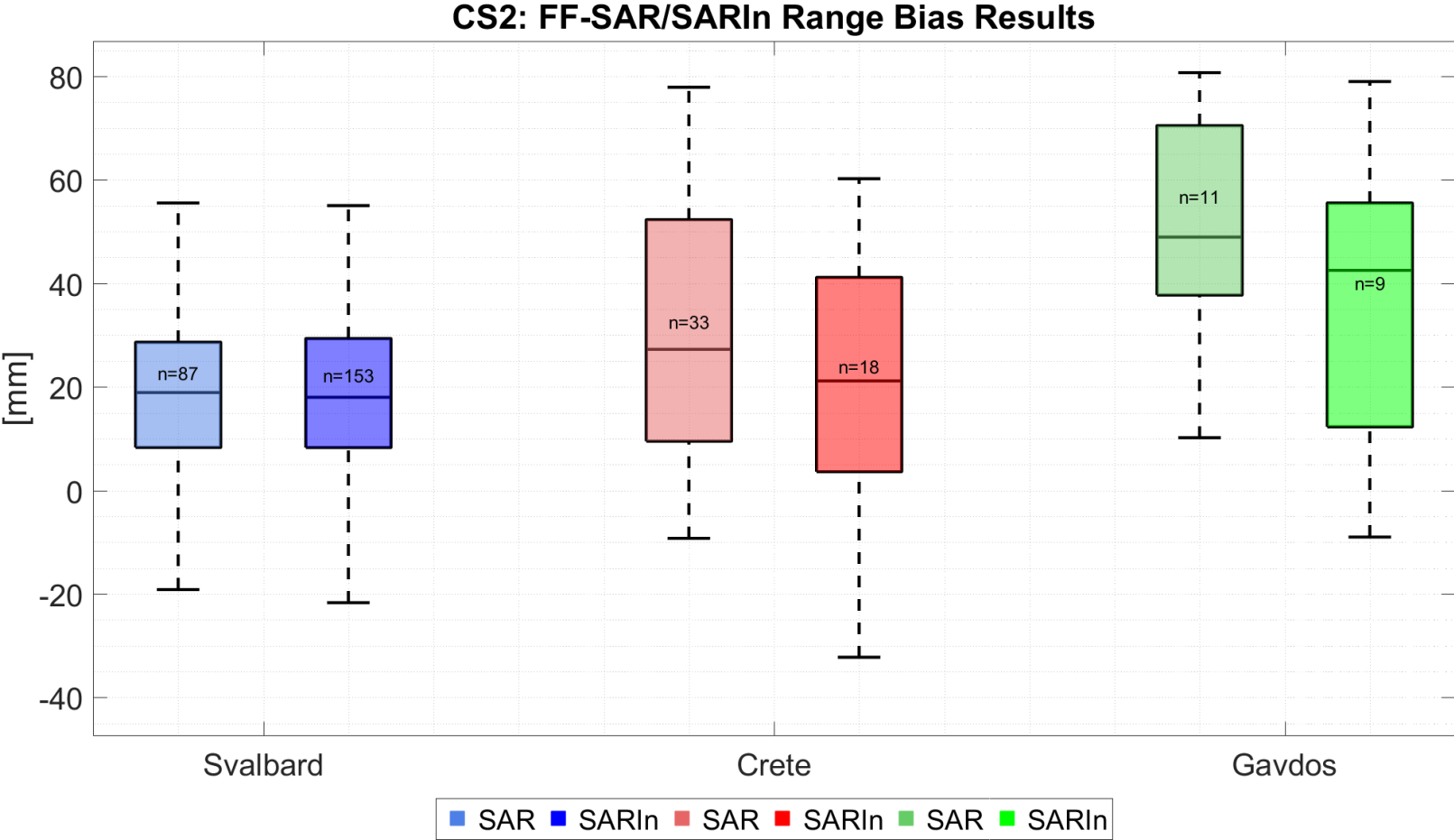


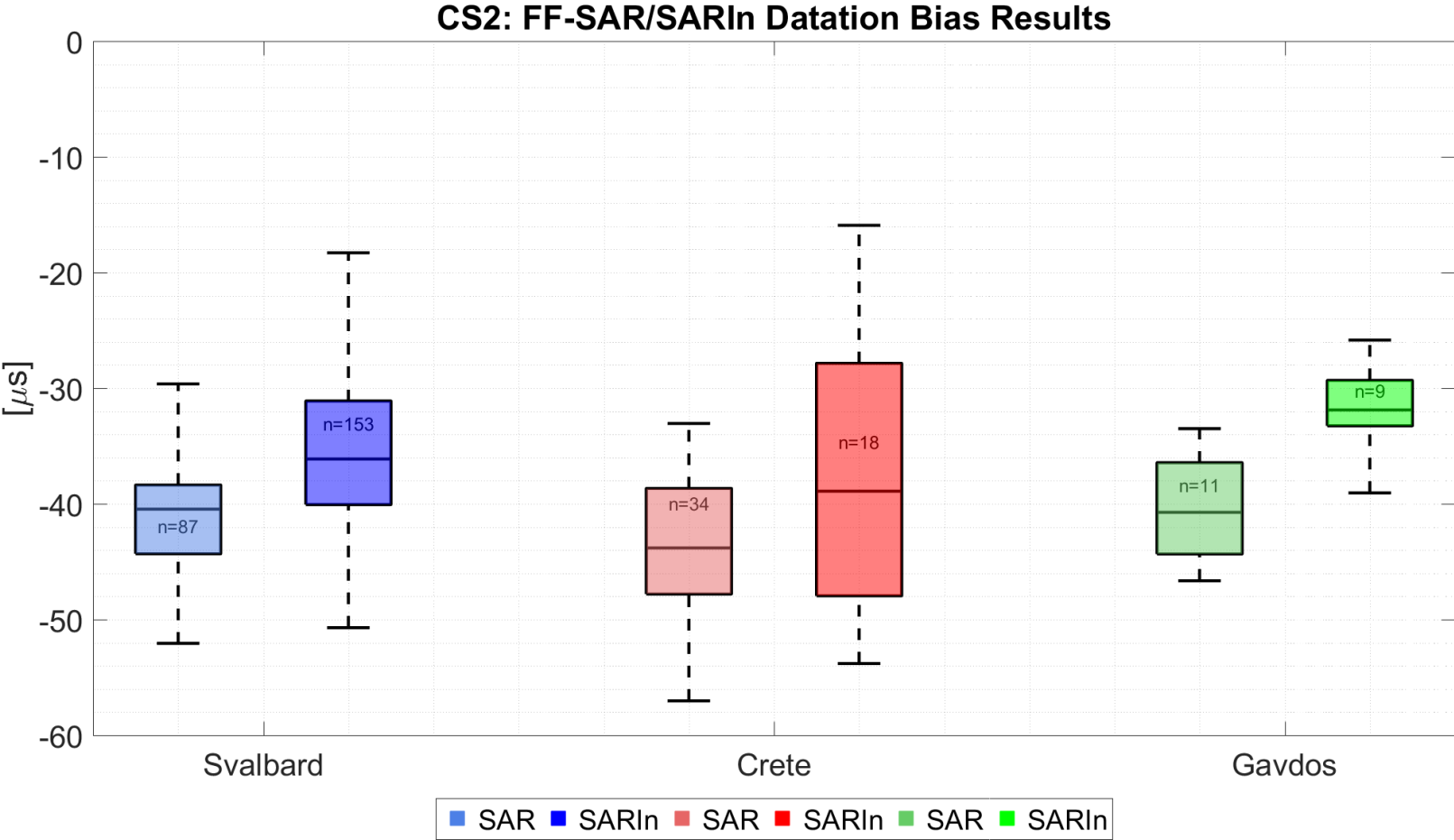
Datation bias estimation: phase flattening over the TRP response. The phase ramp is removed so that the residual phase remains constant around the TRP location.





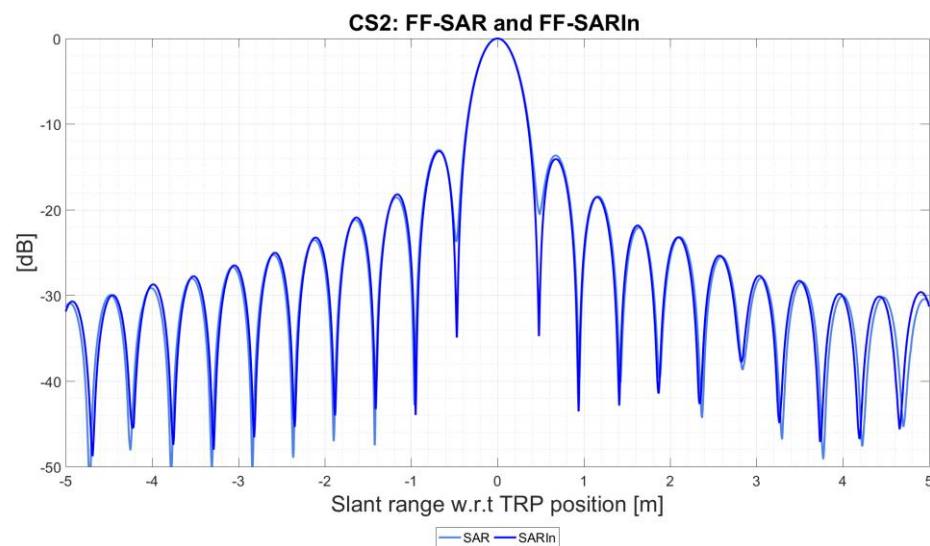
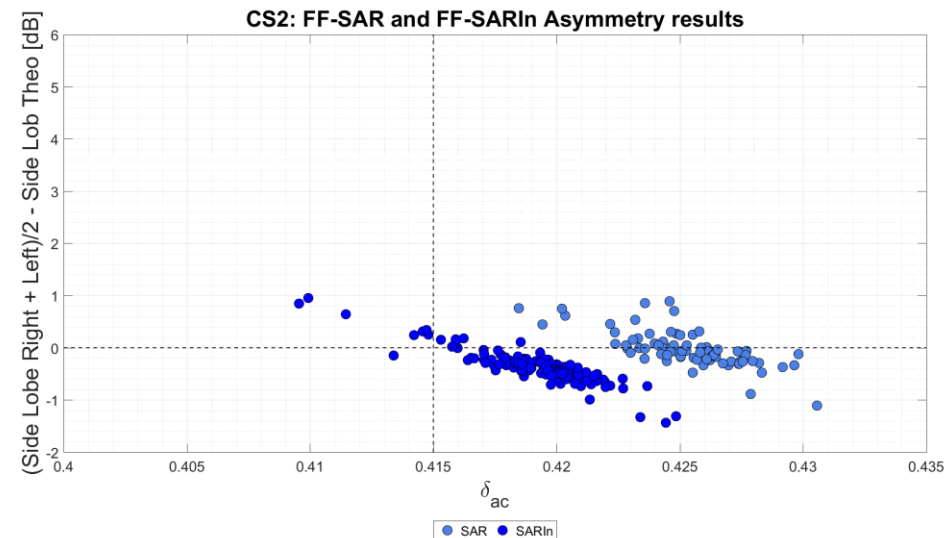
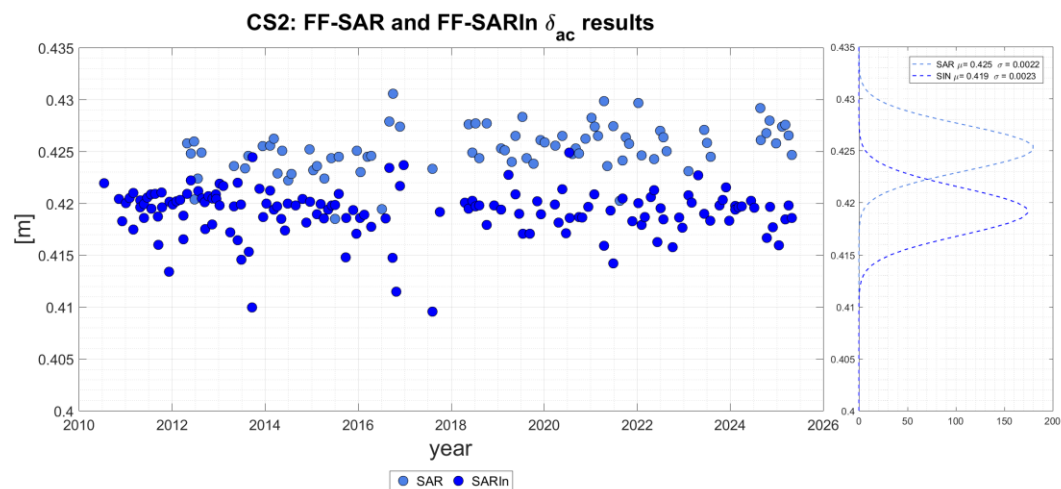


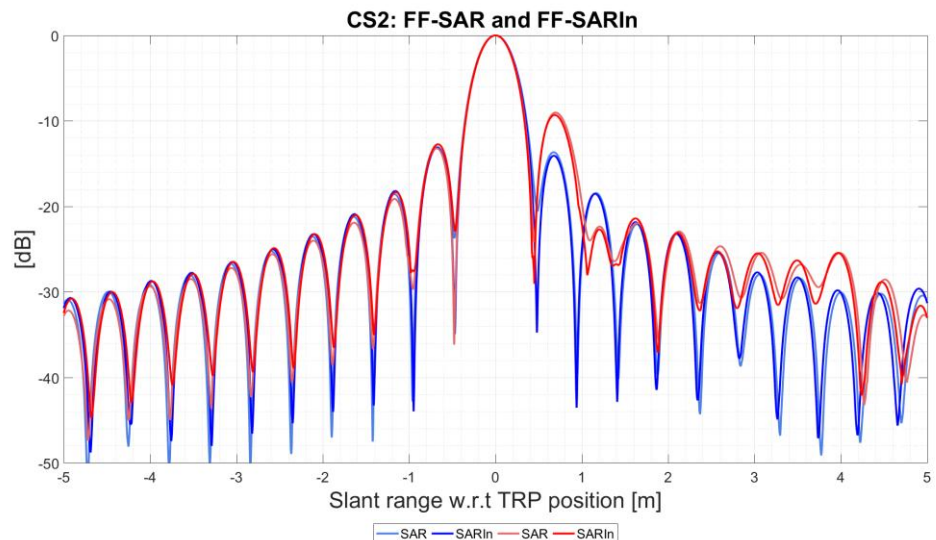
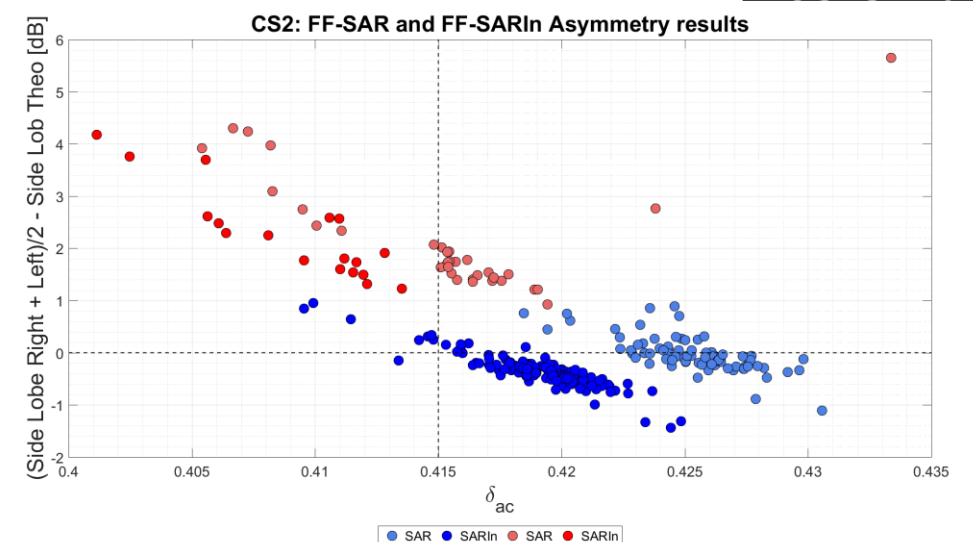
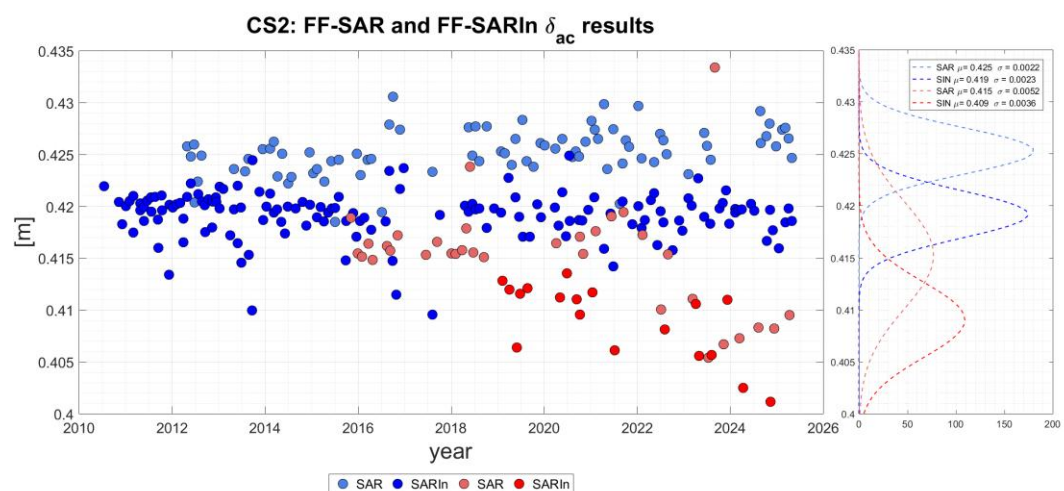




δ_c results: Svalbard

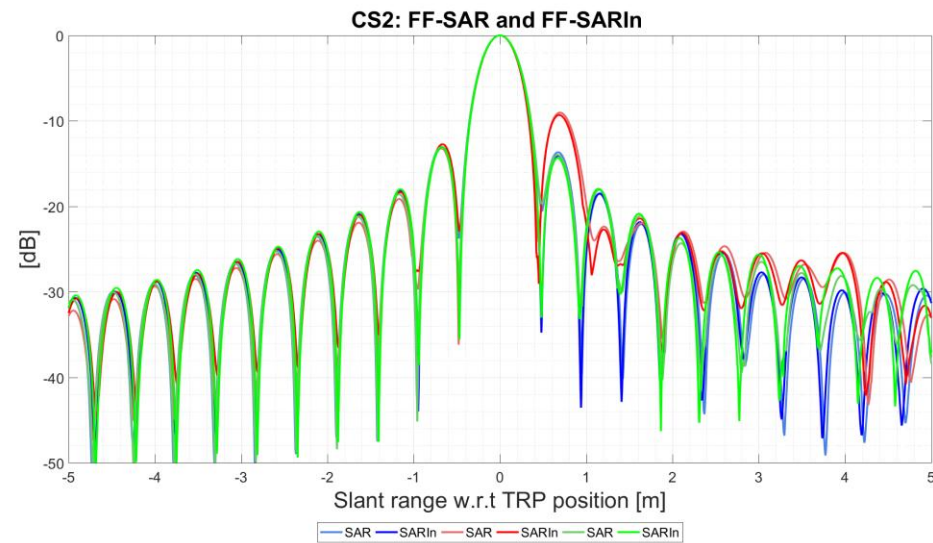
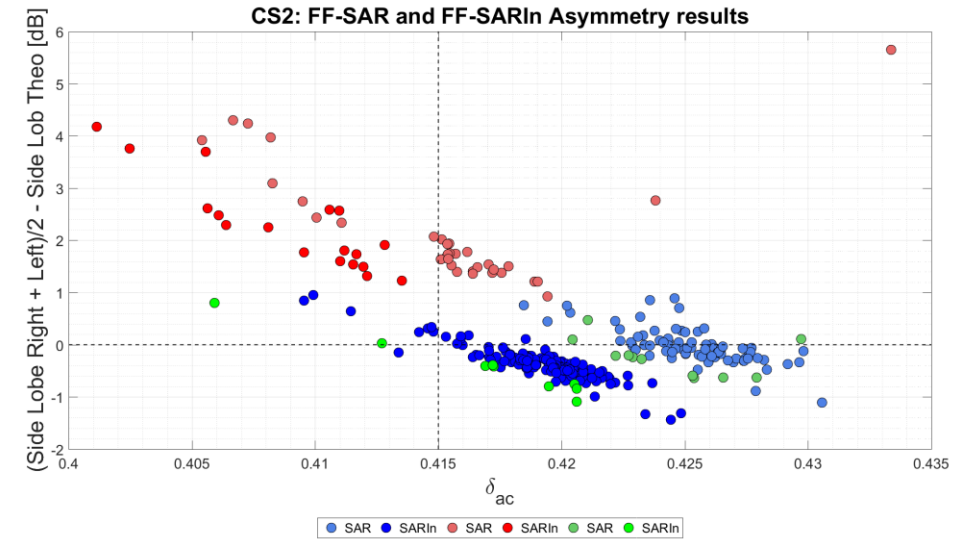
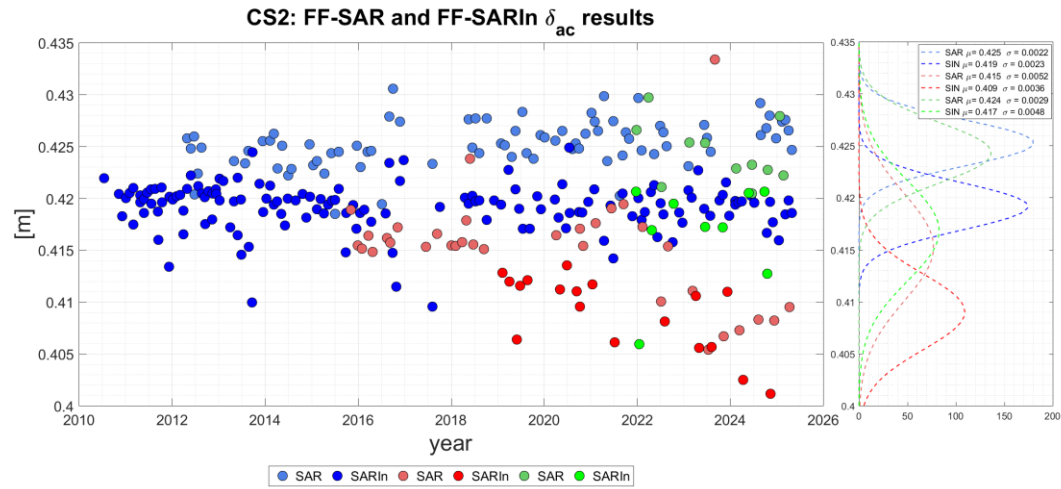
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δ_c results: Gavdos

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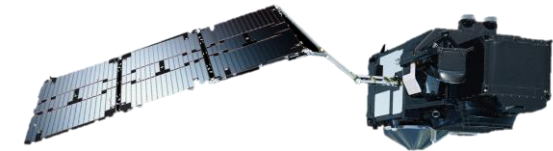
- CryoSat-2
- Sentinel-3A
- Sentinel-3B
- Sentinel-6

Performance assessment in Sigma0:

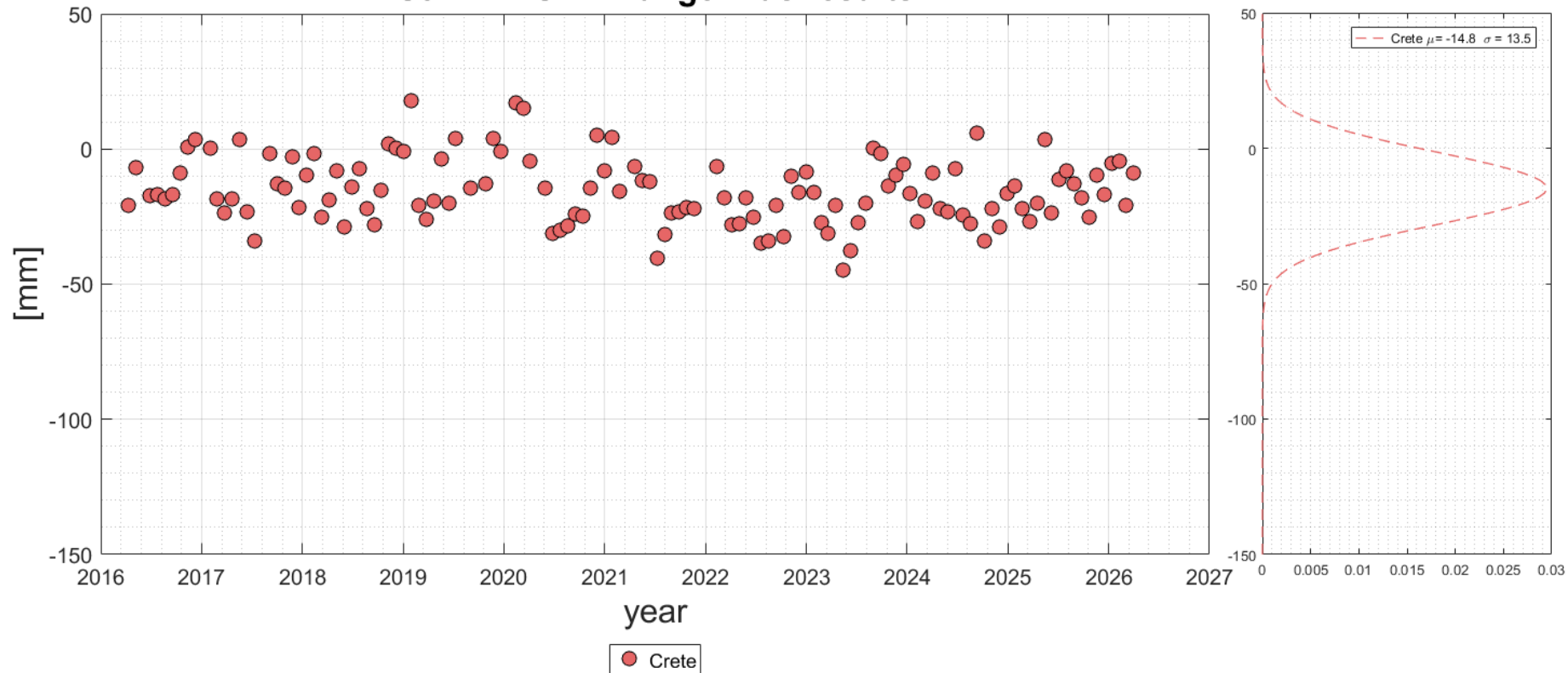
- Gavdos
- Montsec
- Leonessa

4. Key Conclusions

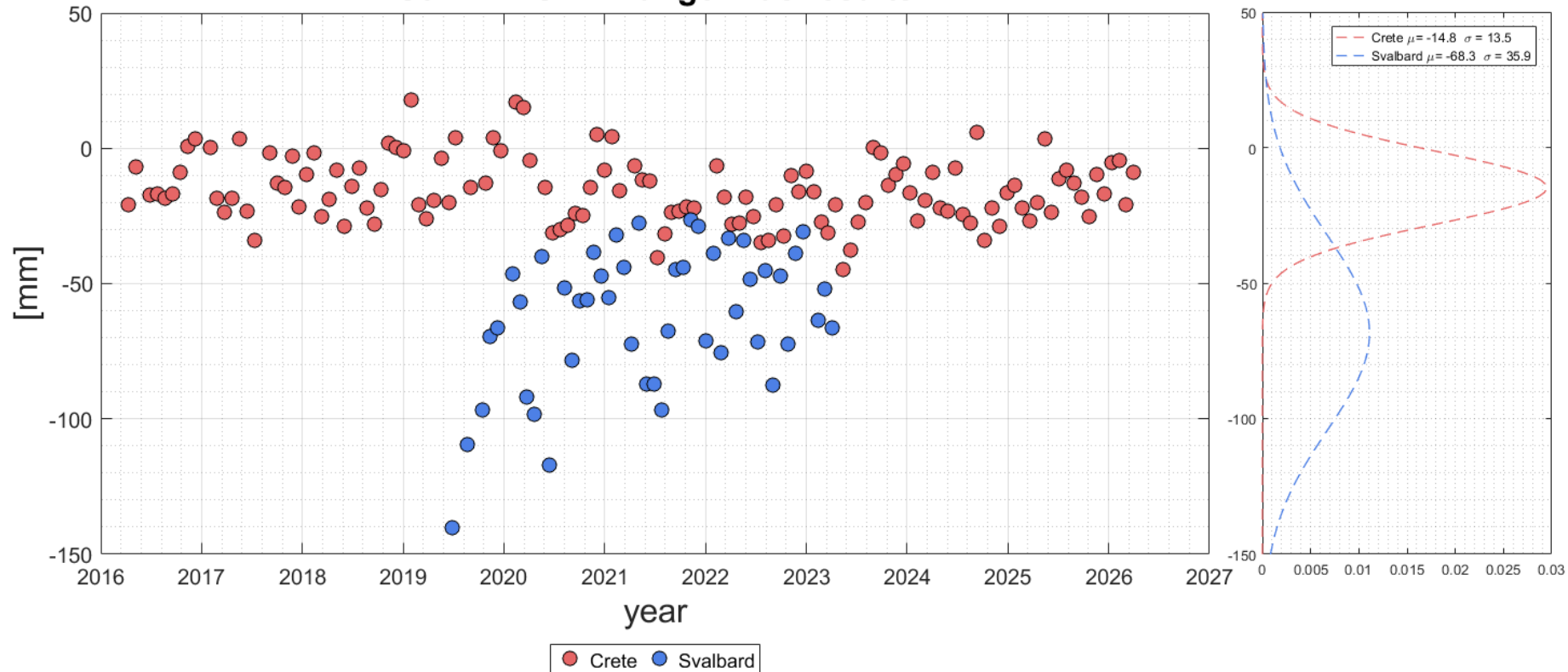
Main findings and implications for future altimetry missions



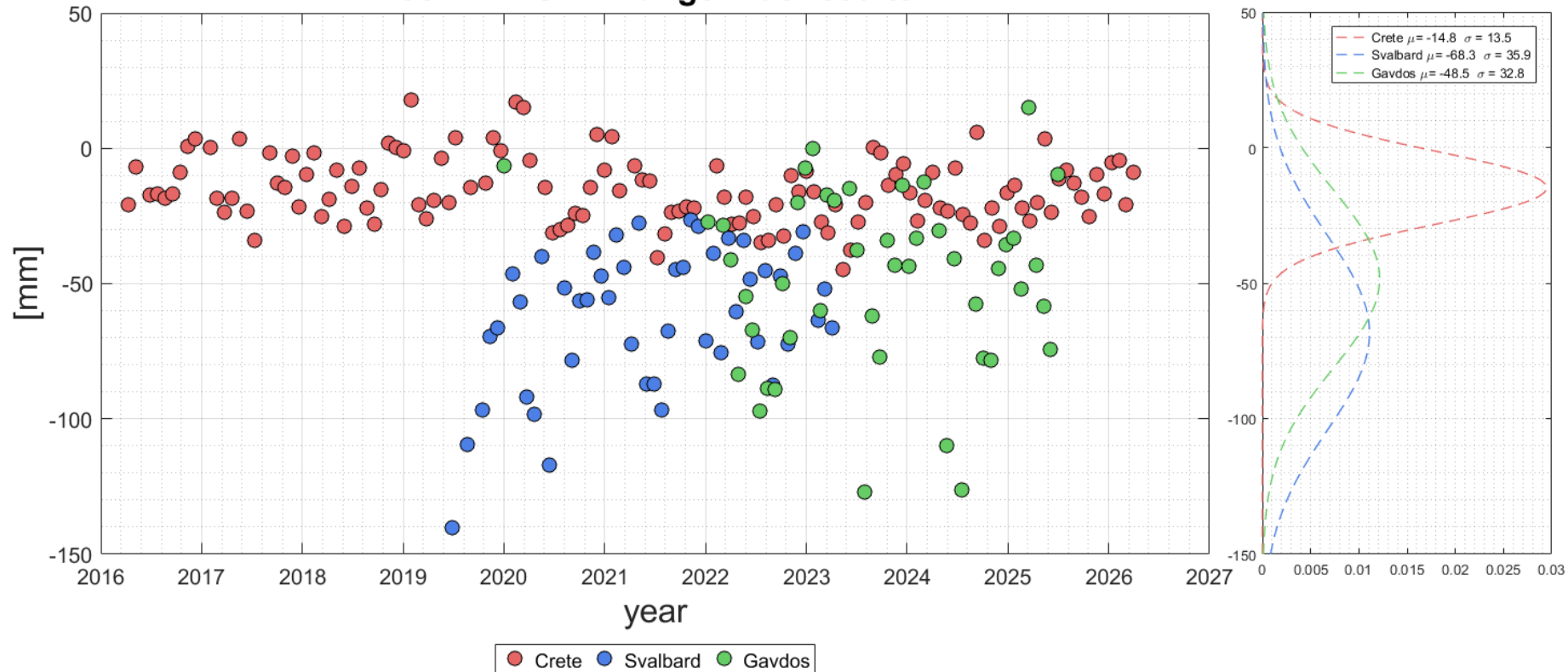
S3A: FF-SAR Range Bias results

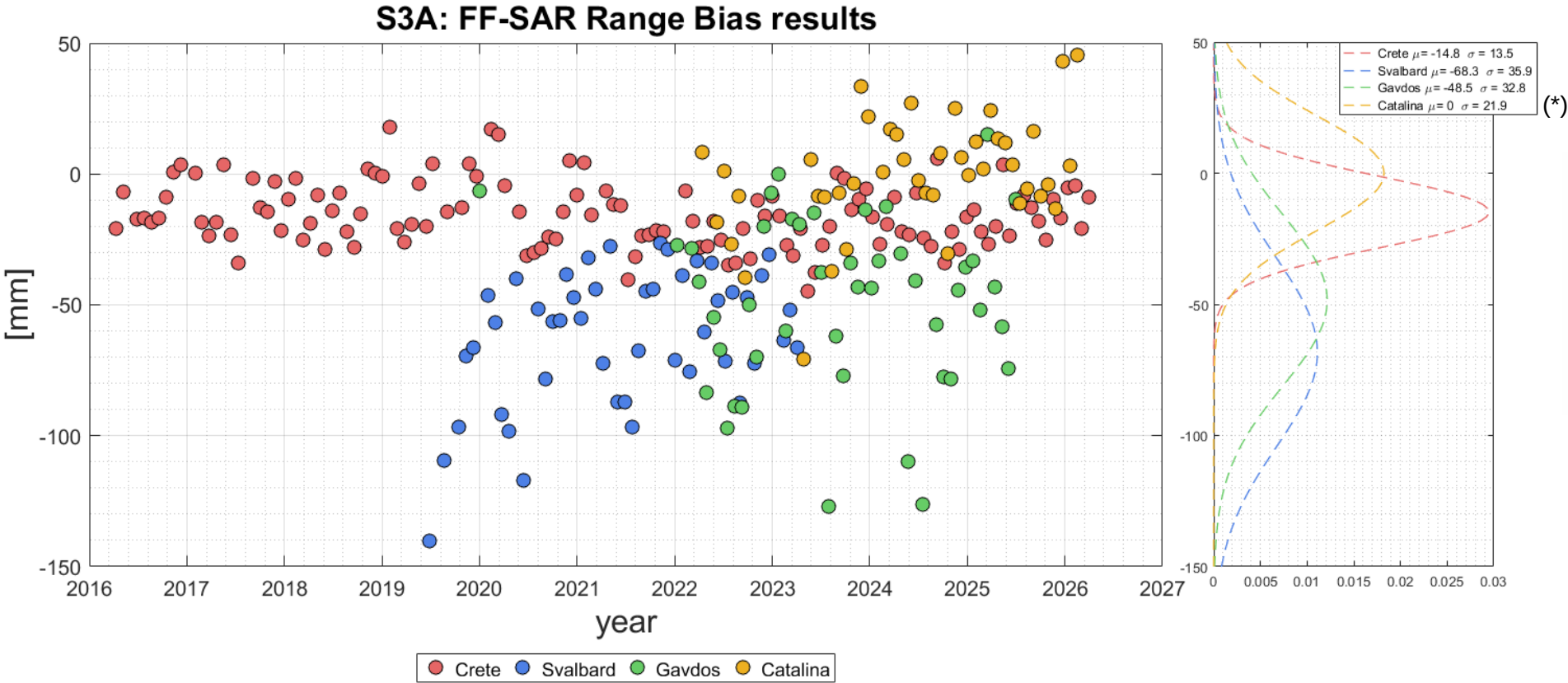


S3A: FF-SAR Range Bias results

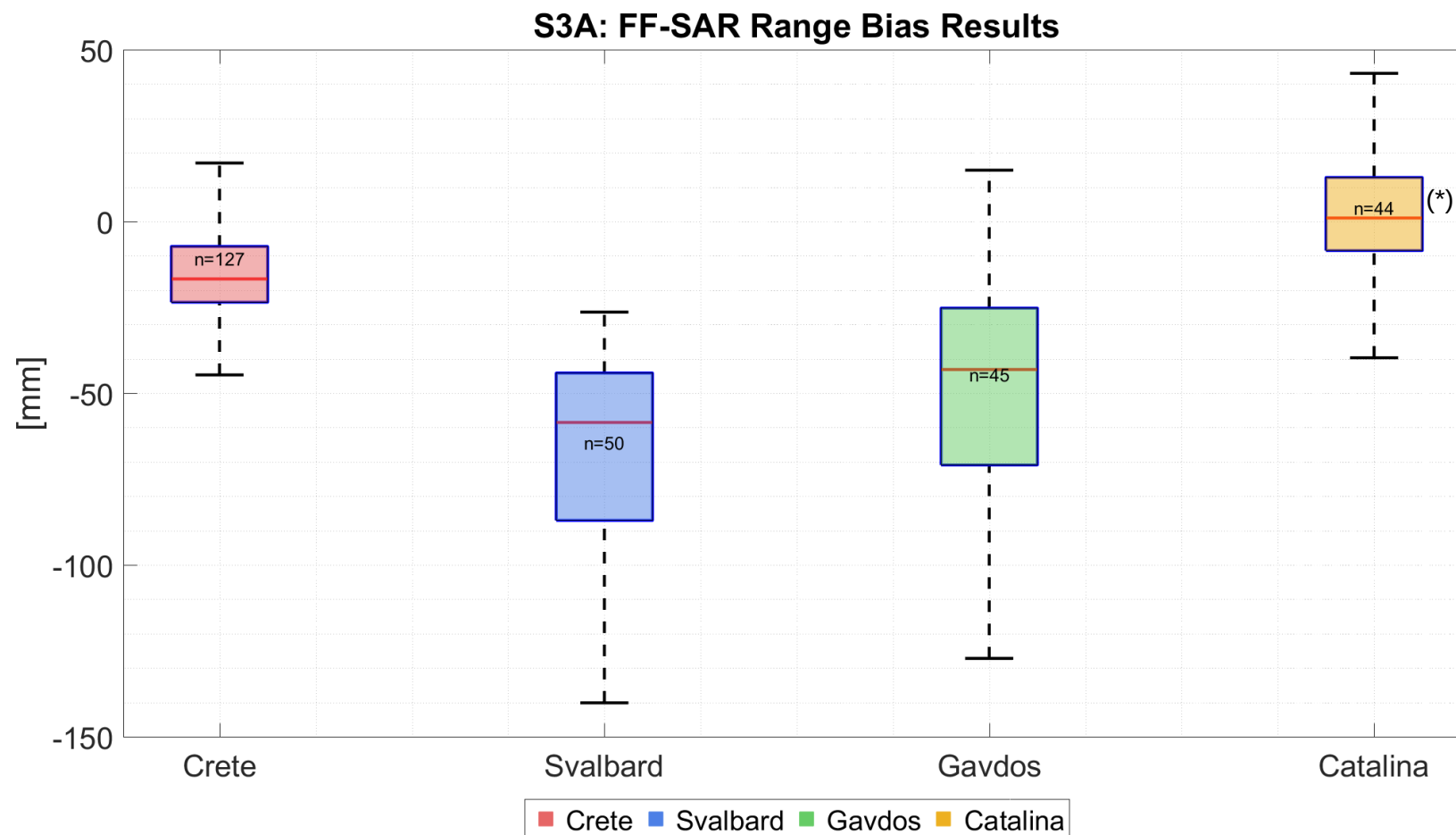


S3A: FF-SAR Range Bias results

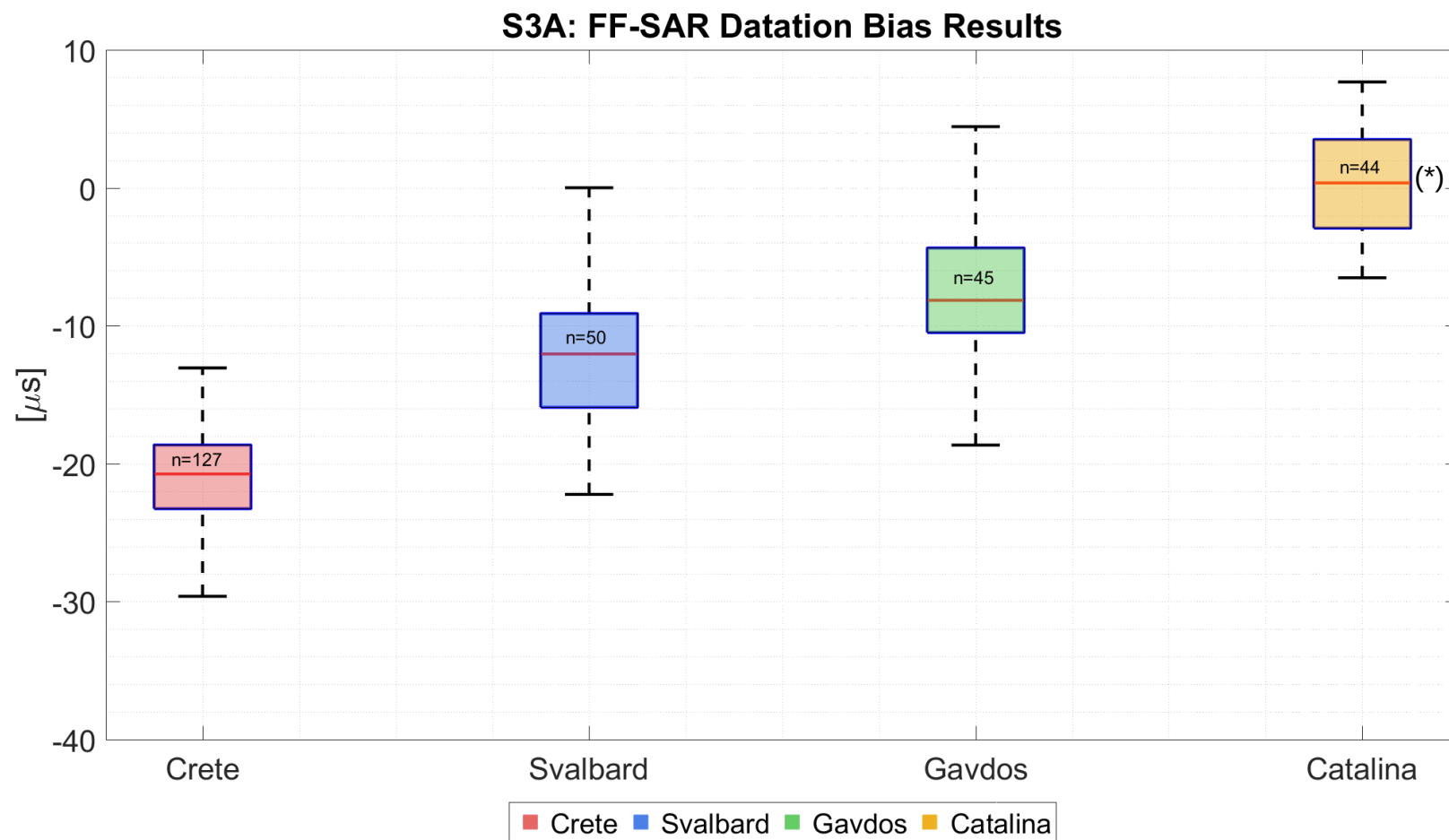




(*) The Santa Catalina transponder data are shown after mean removal for visualisation purposes



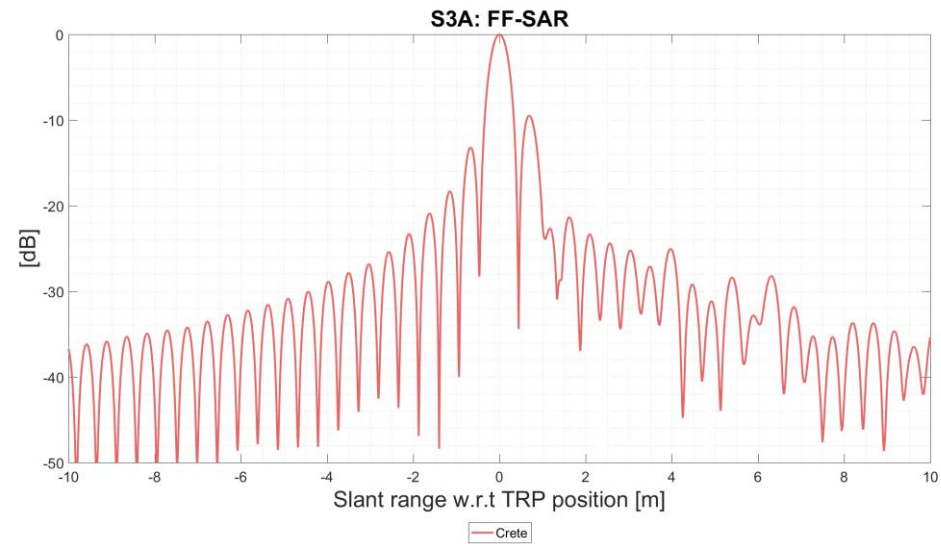
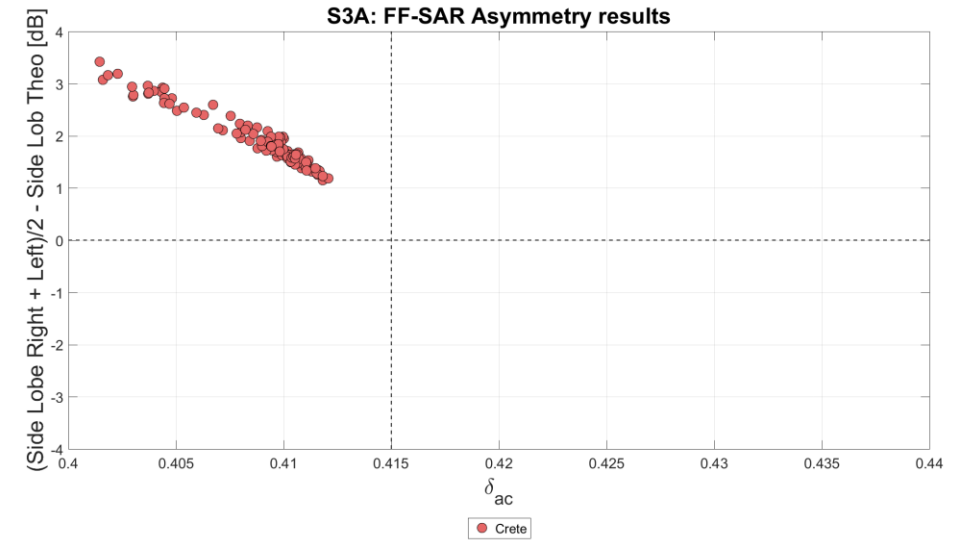
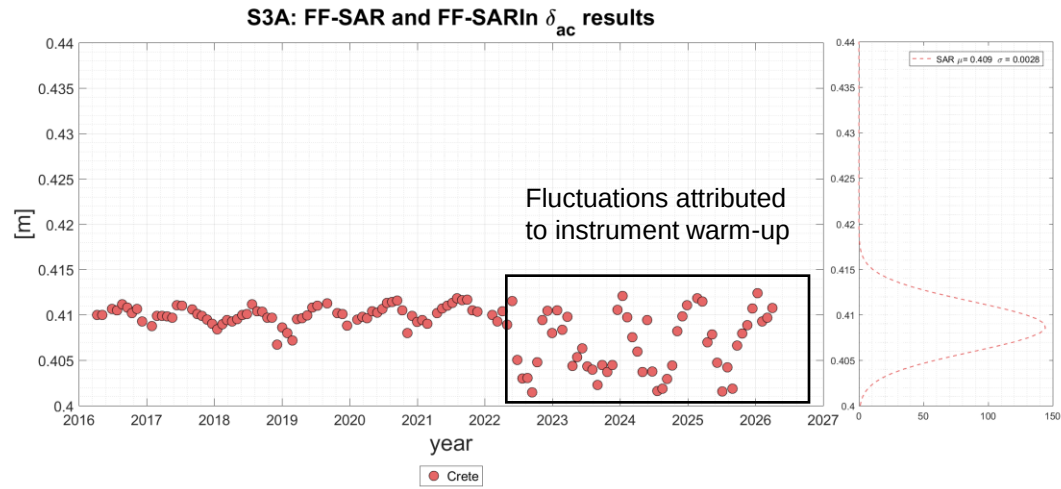
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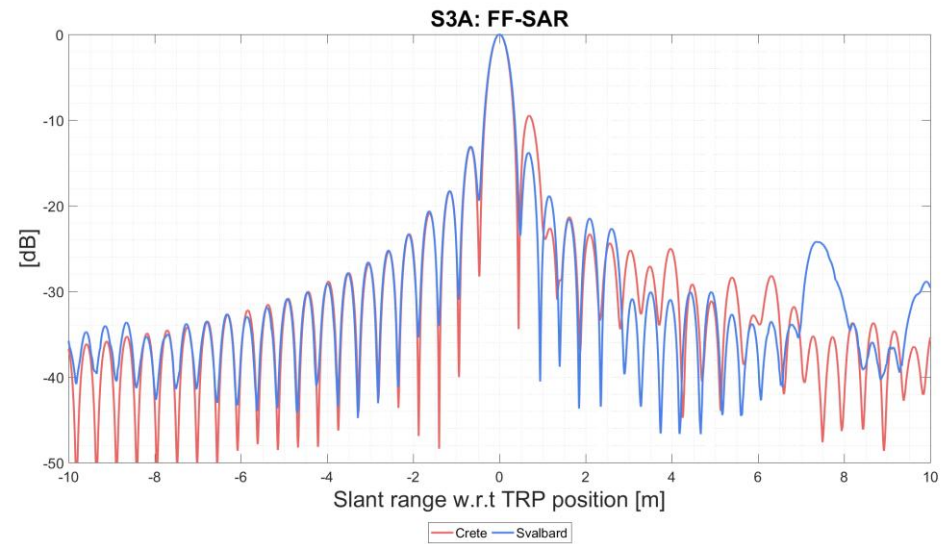
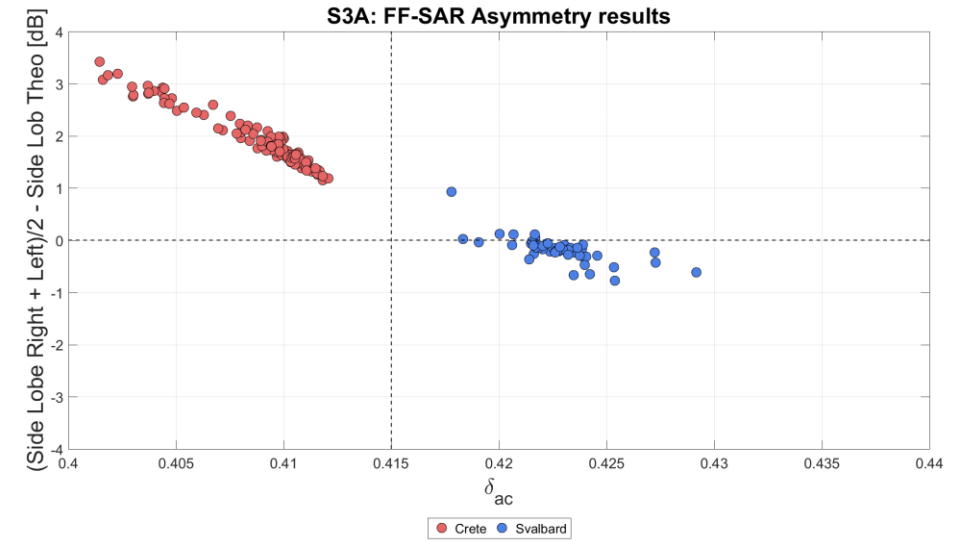
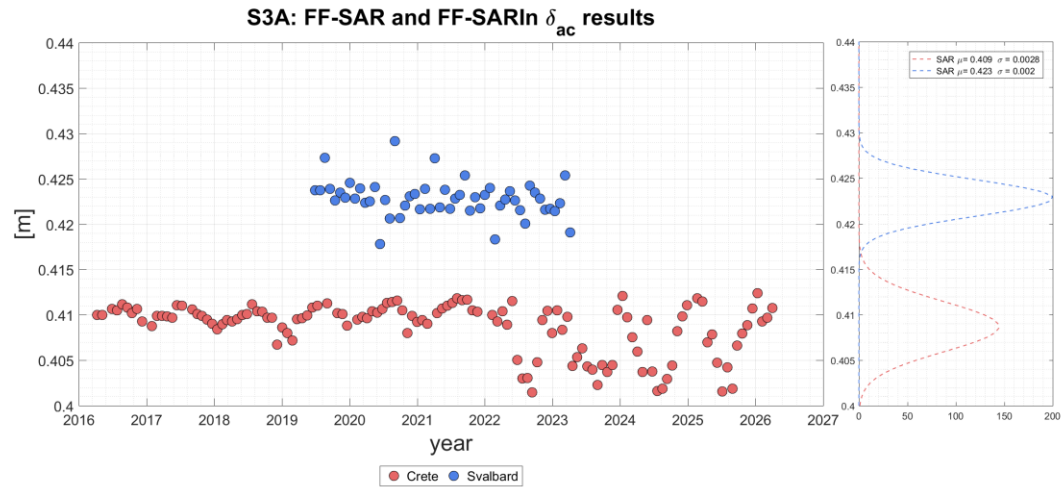
δ_c results: Crete

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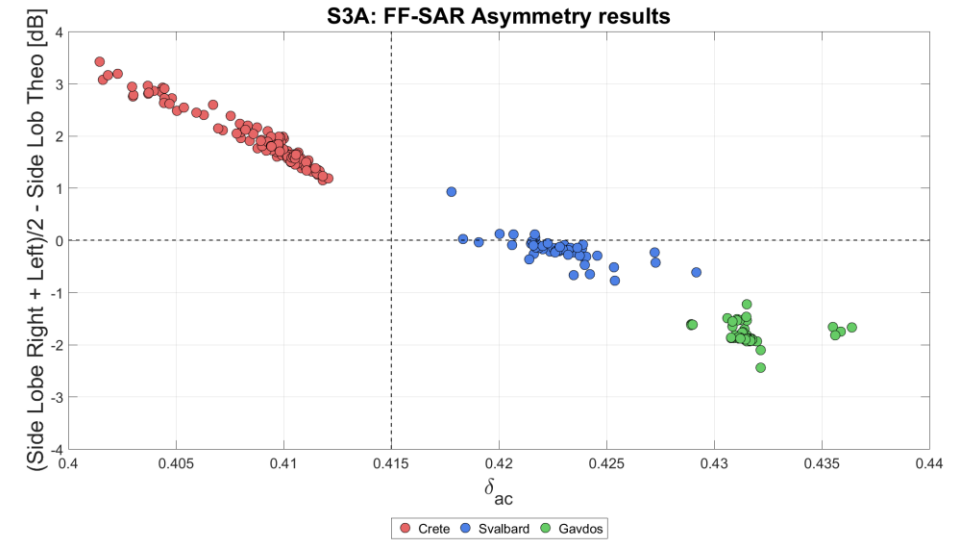
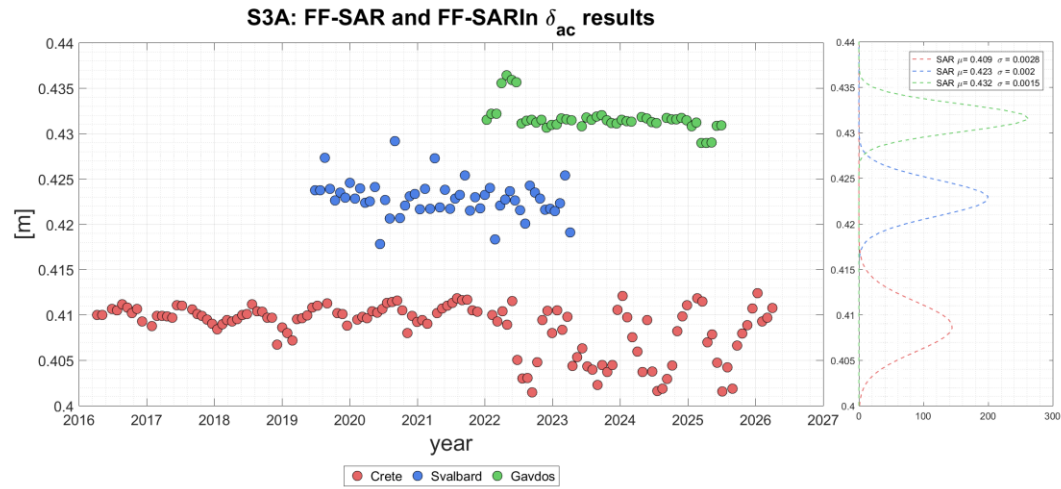
δ_c results: Svalbard

OSTST 2026



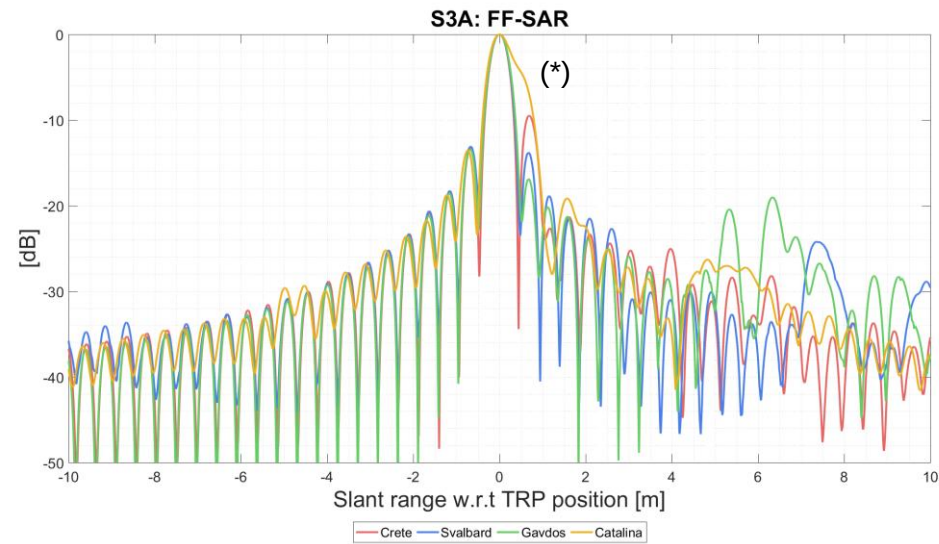
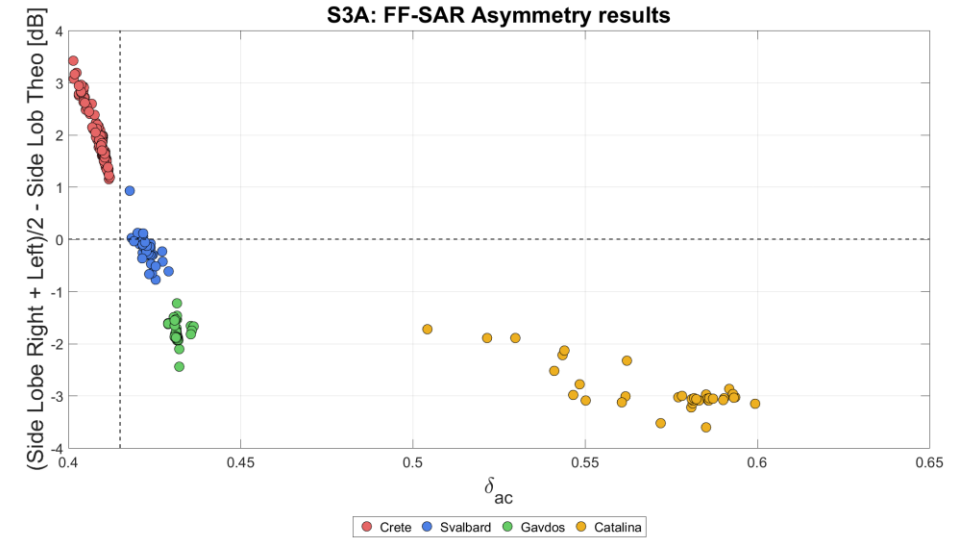
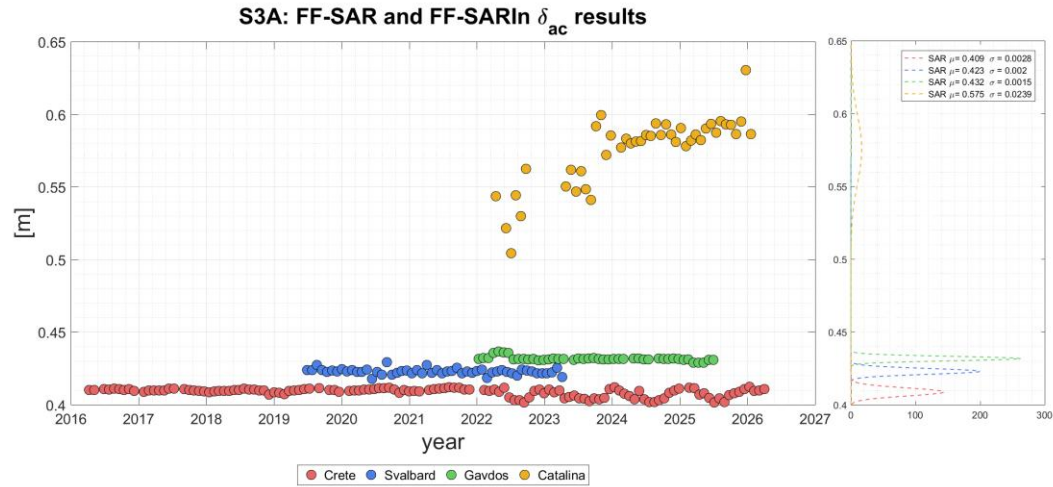
δ_c results: Gavdos

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δ_c results: Catalina

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(*) The main lobe is partially merged with the sidelobes, degrading the range resolution and affecting the symmetry of the PTR.

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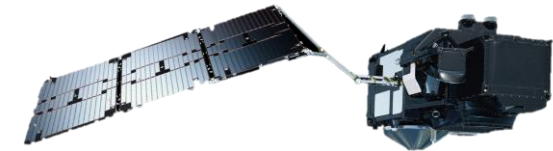
- CryoSat-2
- Sentinel-3A
- **Sentinel-3B**
- Sentinel-6

Performance assessment in Sigma0:

- Gavdos
- Montsec
- Leonessa

4. Key Conclusions

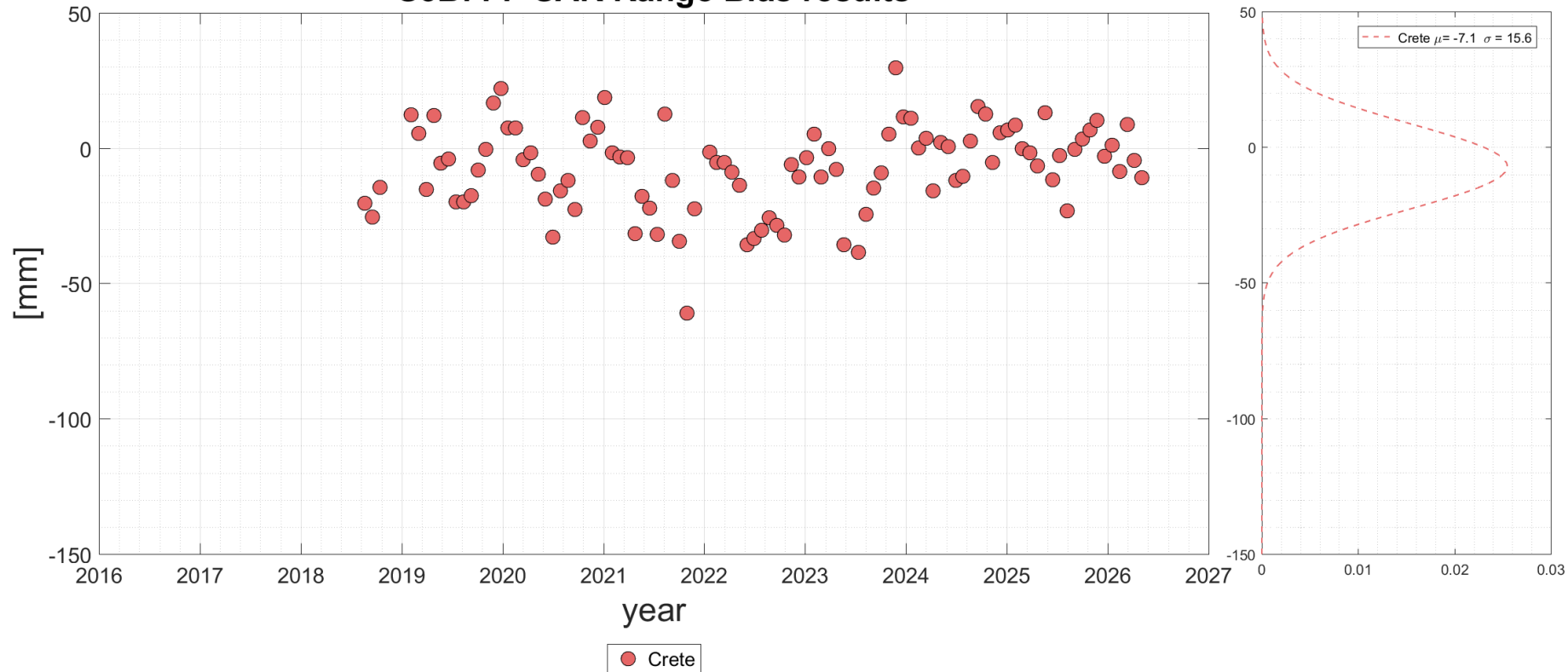
Main findings and implications for future altimetry missions



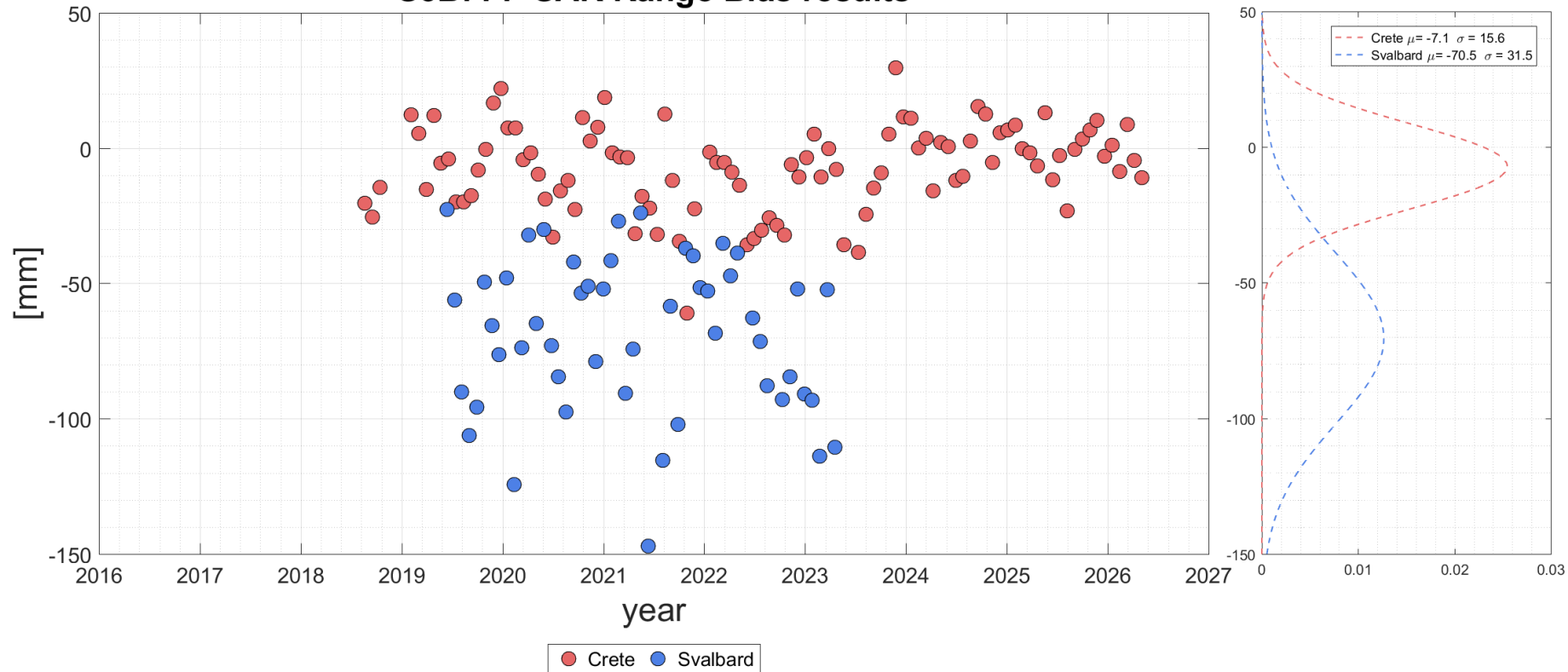
Range results: Crete

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S3B: FF-SAR Range Bias results



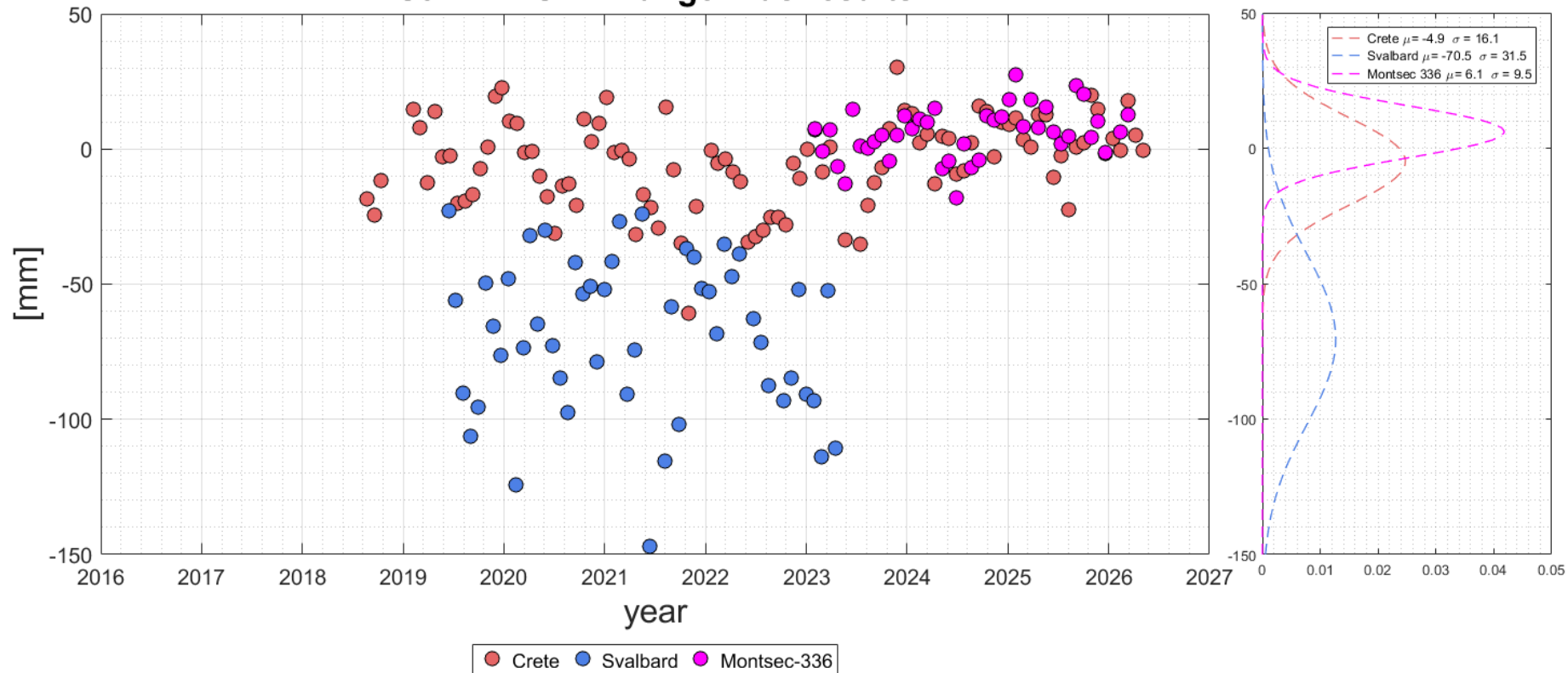
S3B: FF-SAR Range Bias results



Range results: Montsec 336

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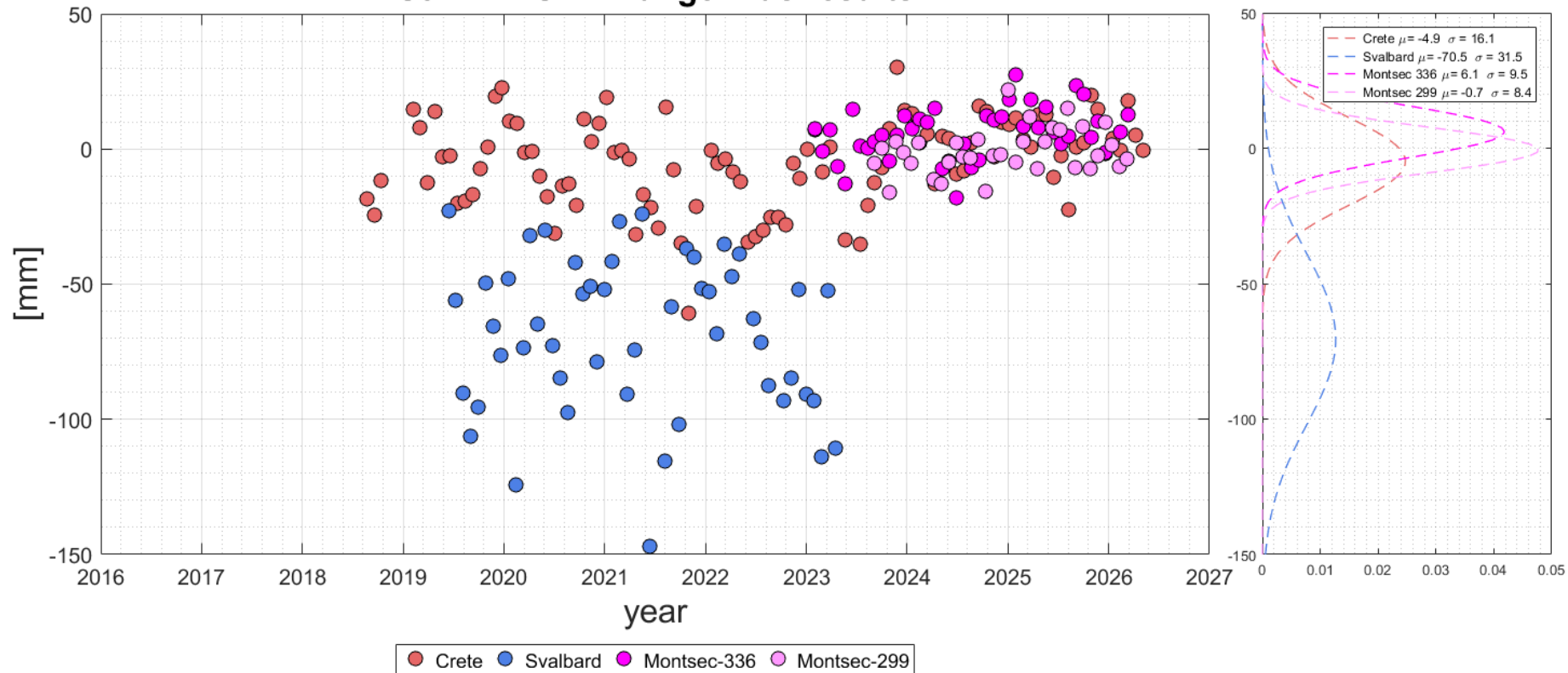
S3B: FF-SAR Range Bias results

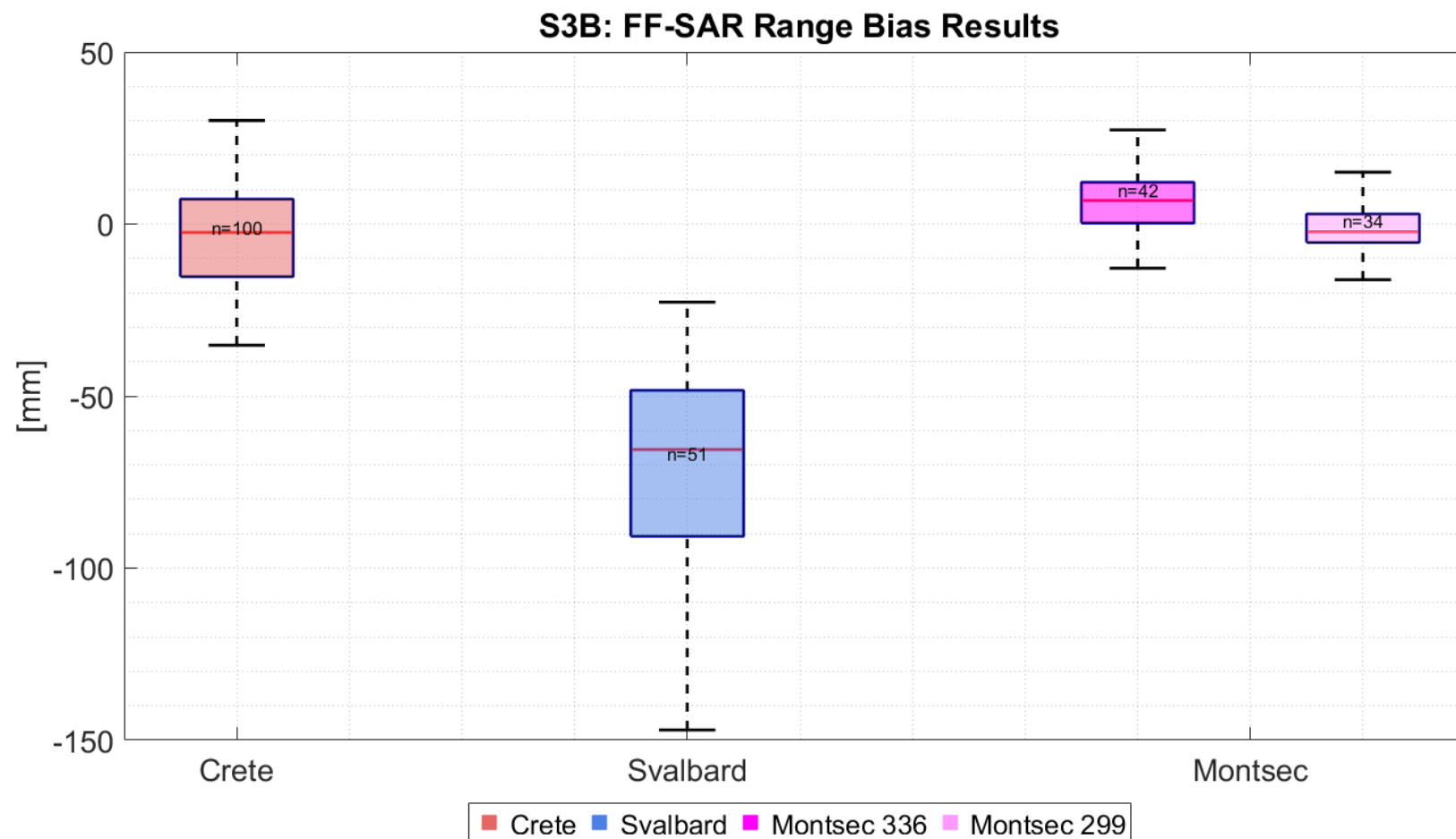


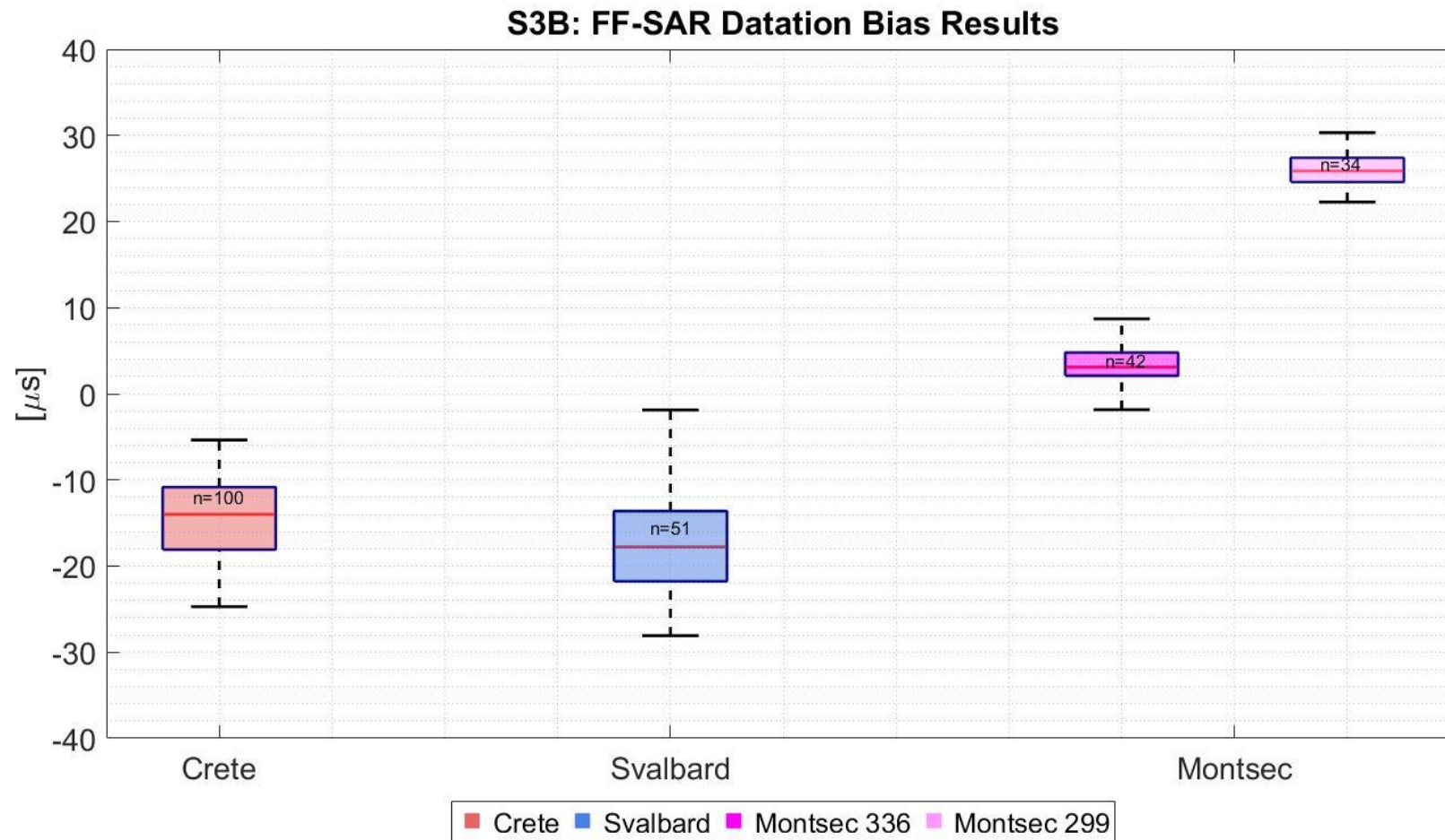
Range results: Montsec 299

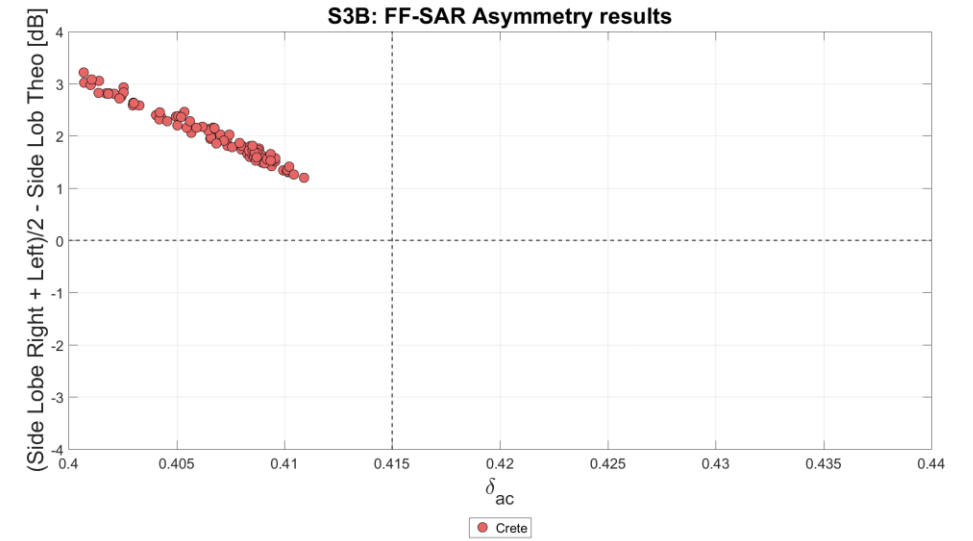
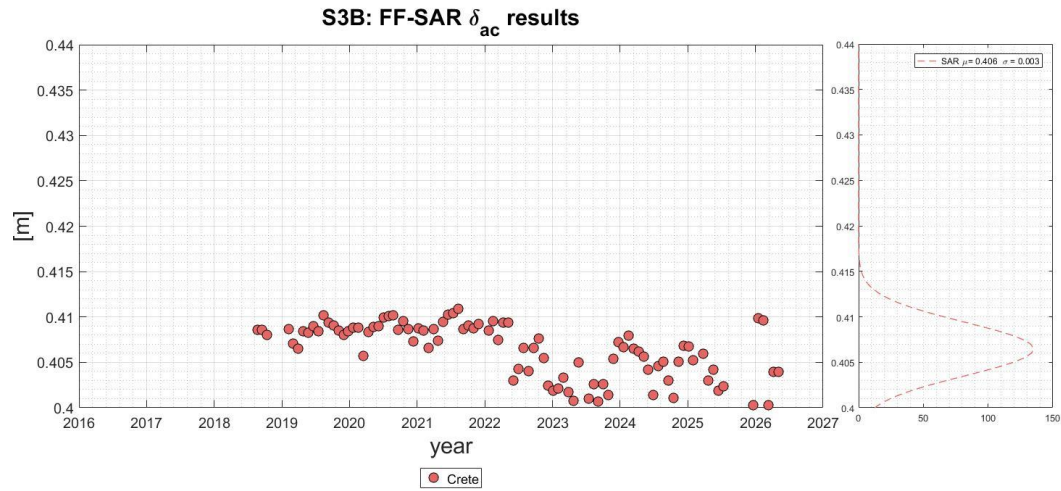
OSTST 2026

S3B: FF-SAR Range Bias results



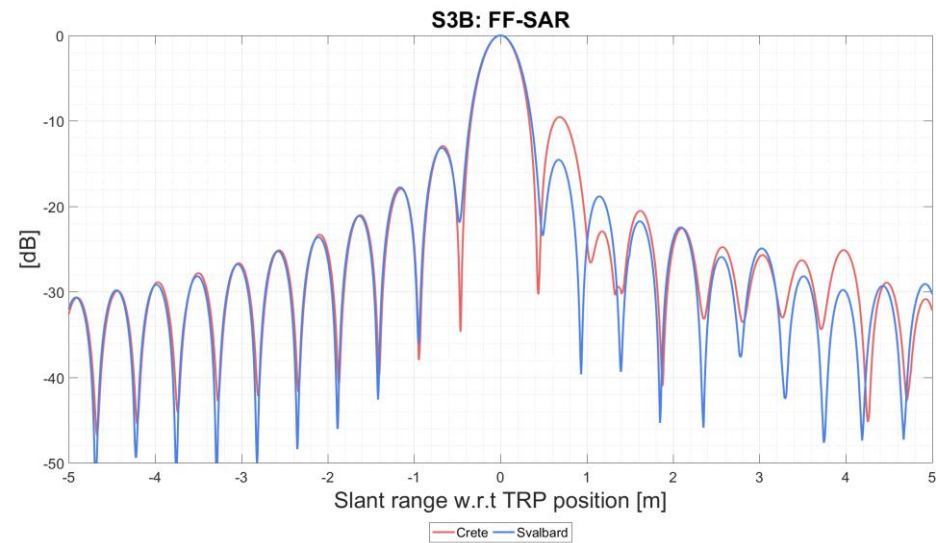
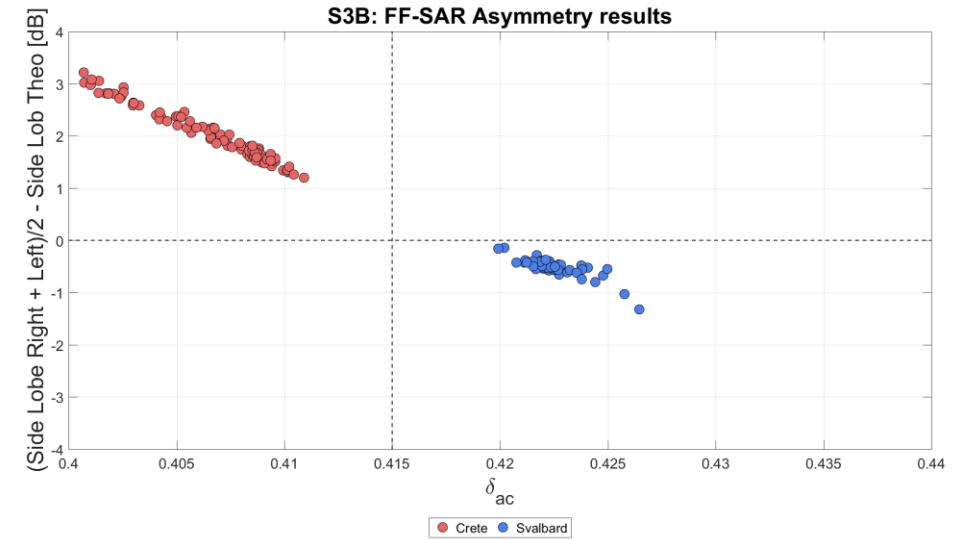
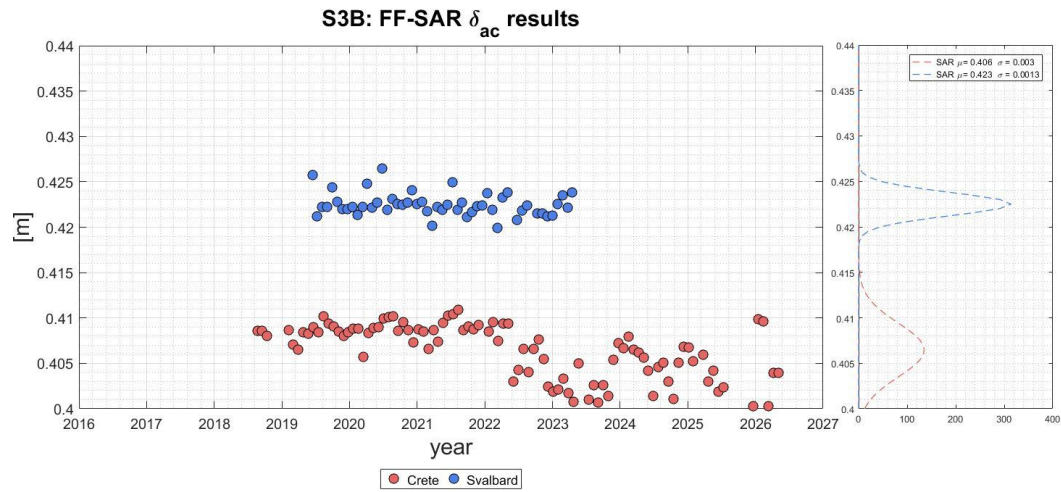


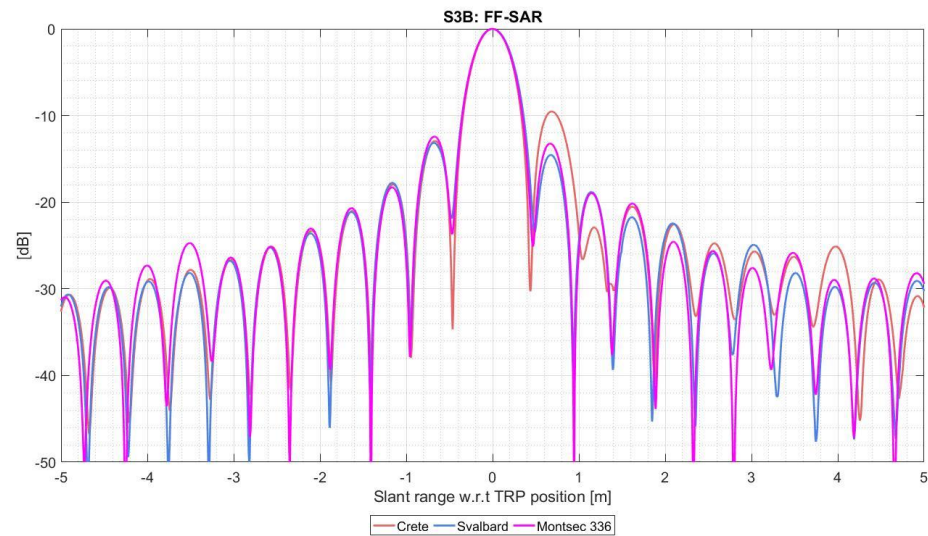
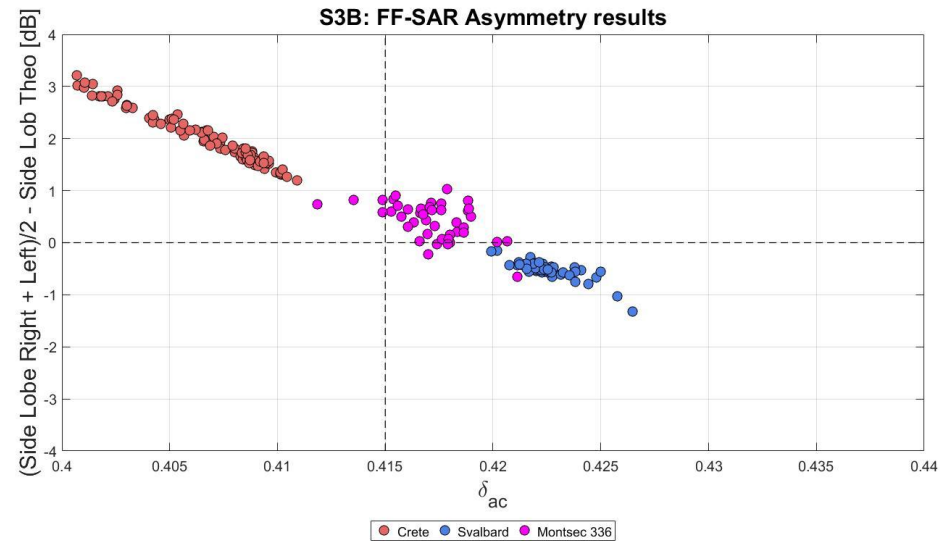
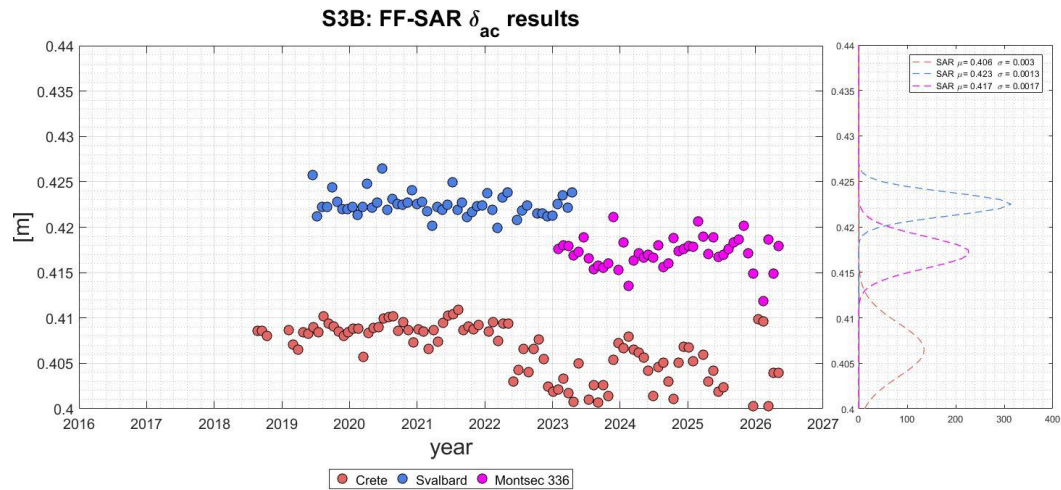


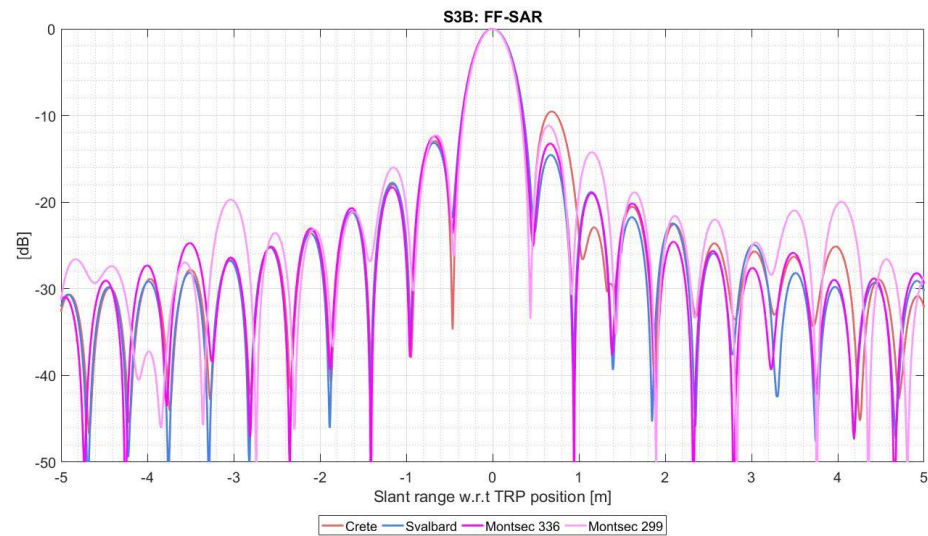
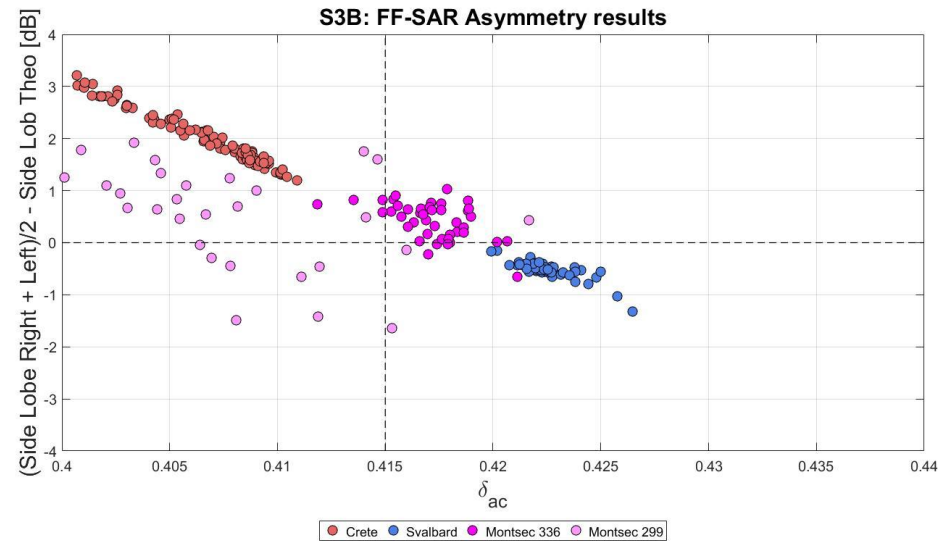
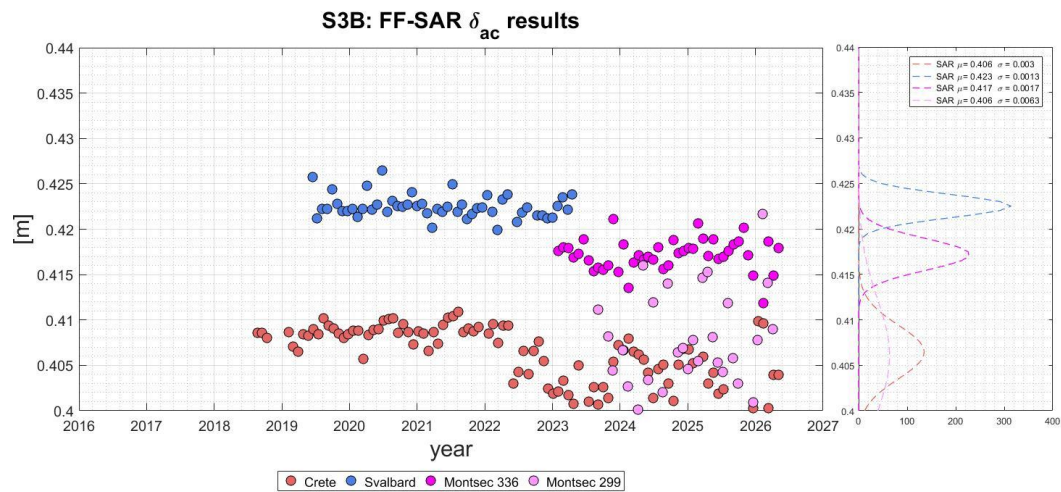


δ_c results: Svalbard

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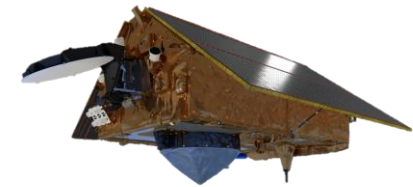
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- Sentinel-3A
- Sentinel-3B
- Sentinel-6

Performance assessment in Sigma0:

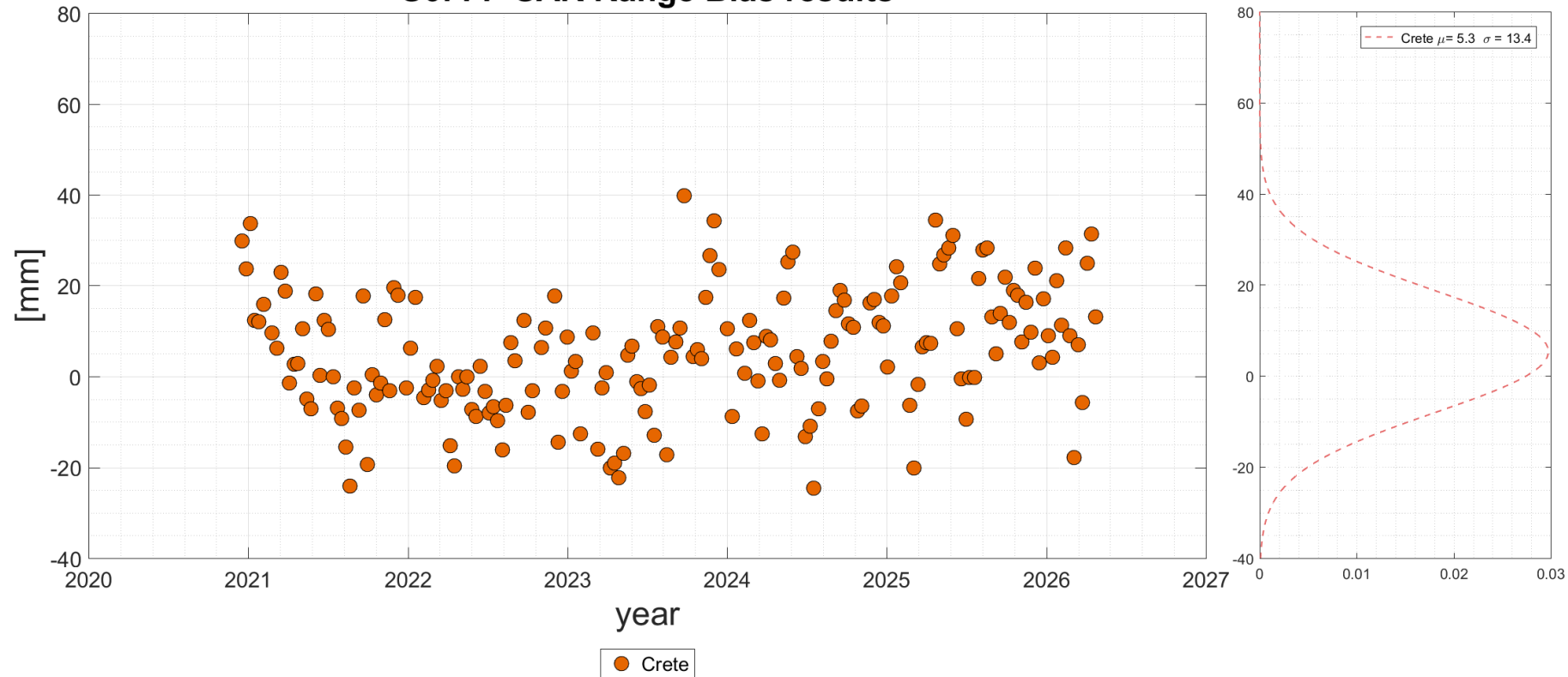
- Gavdos
- Montsec
- Leonessa

4. Key Conclusions

Main findings and implications for future altimetry missions



S6: FF-SAR Range Bias results



Range results: Gavdos Ascendig

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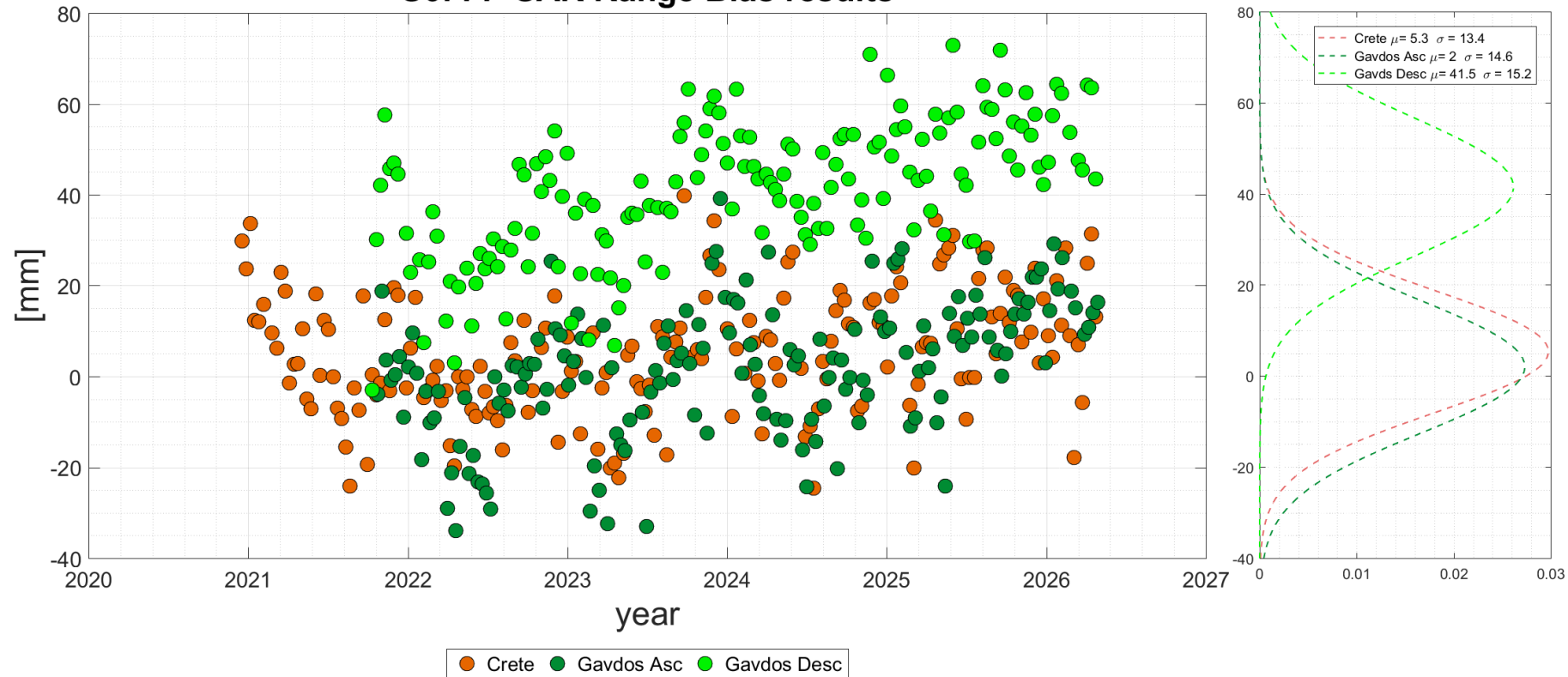
S6: FF-SAR Range Bias results



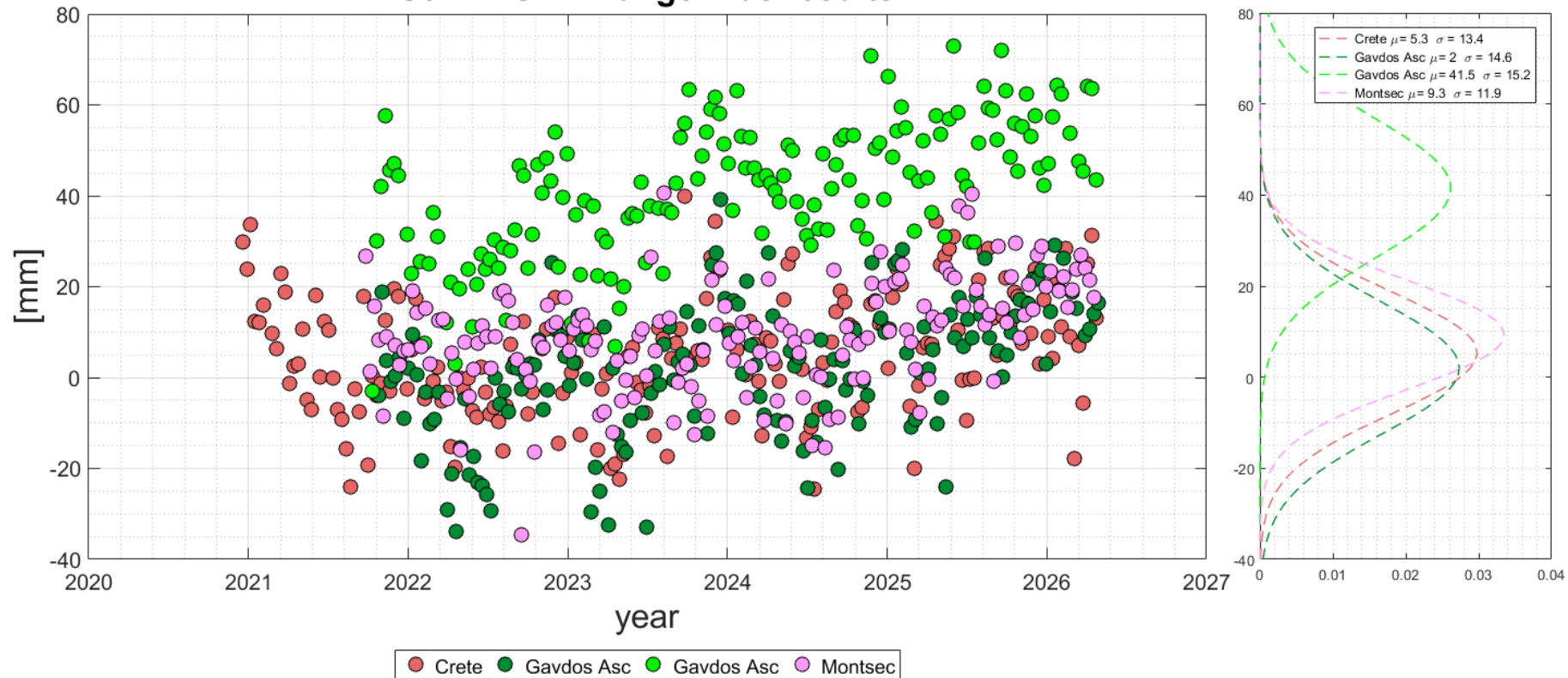
Range results: Gavdos Descending

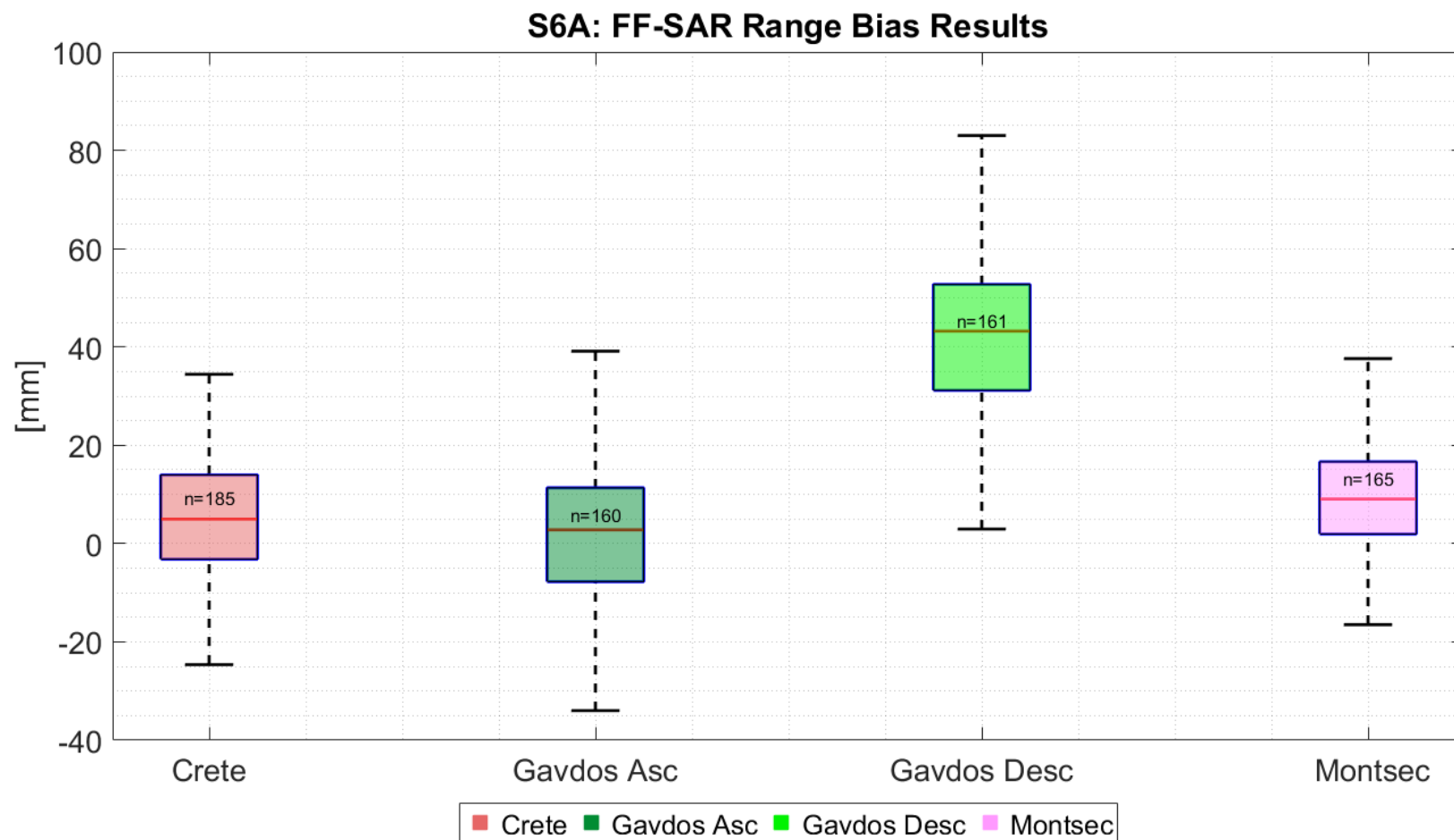
OSTST 2026

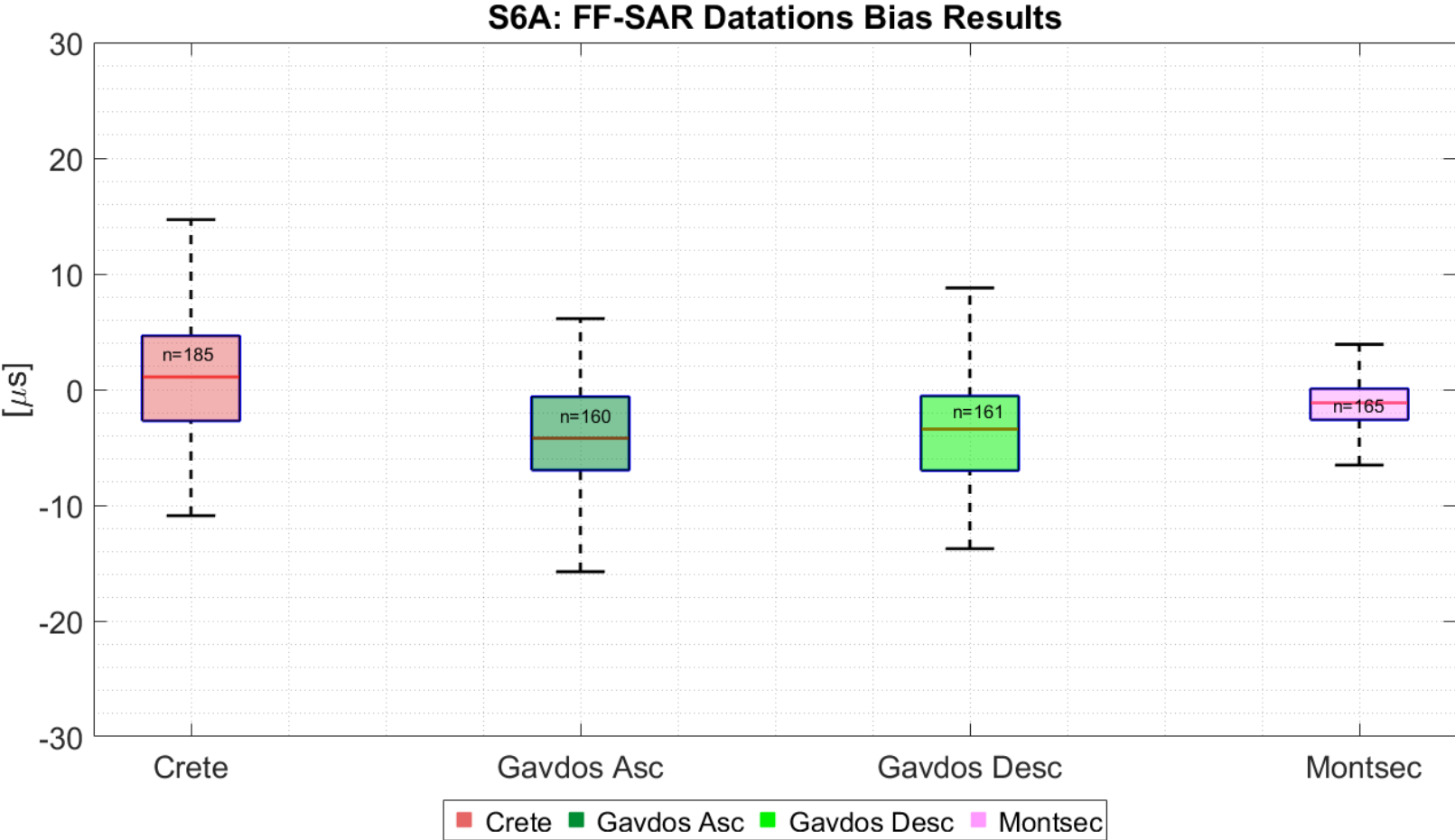
S6: FF-SAR Range Bias results

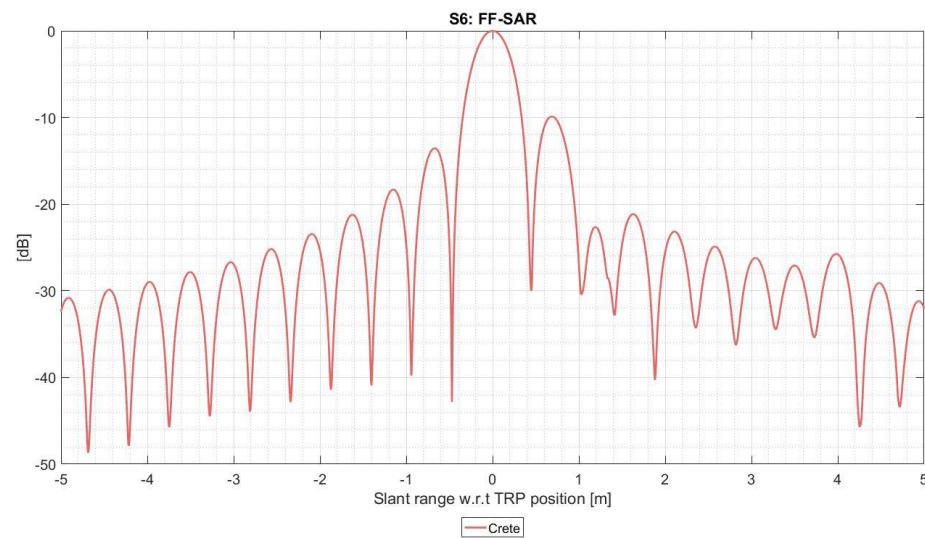
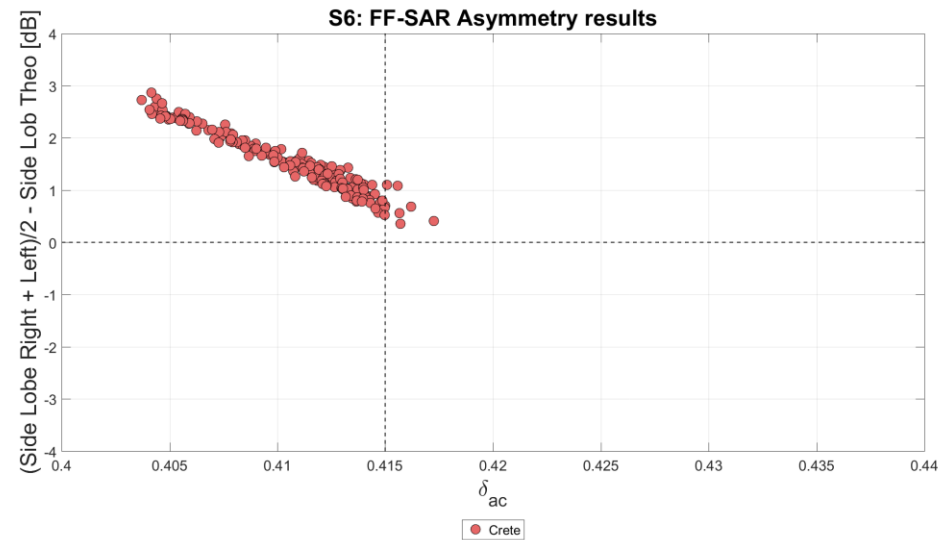
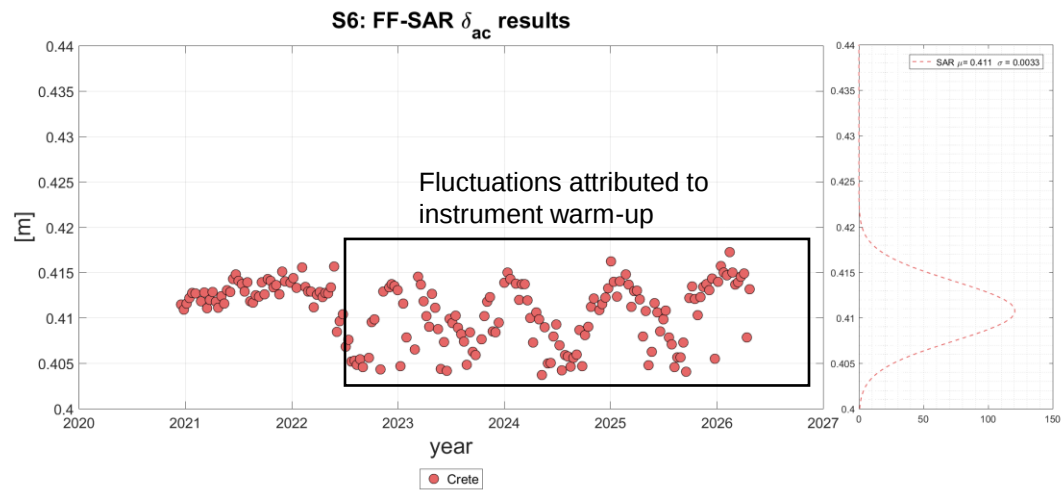


S6: FF-SAR Range Bias results



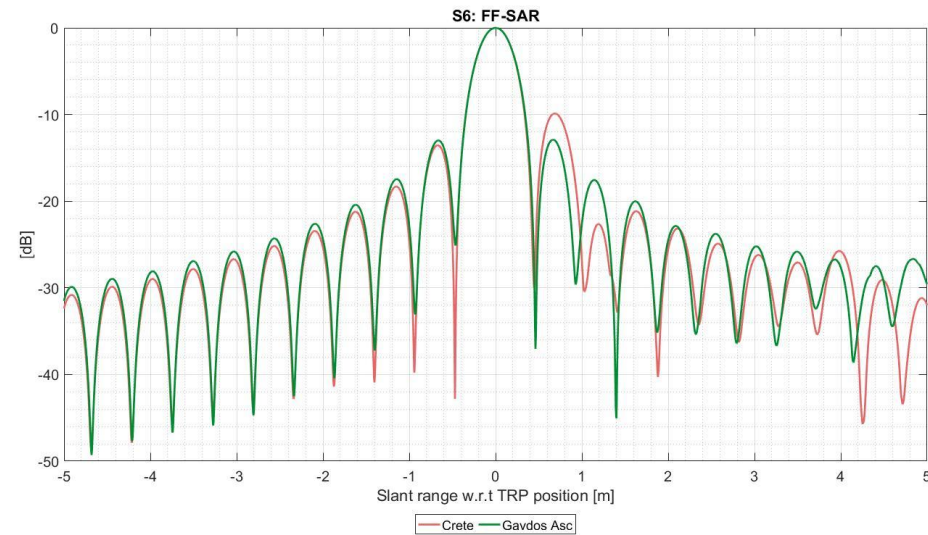
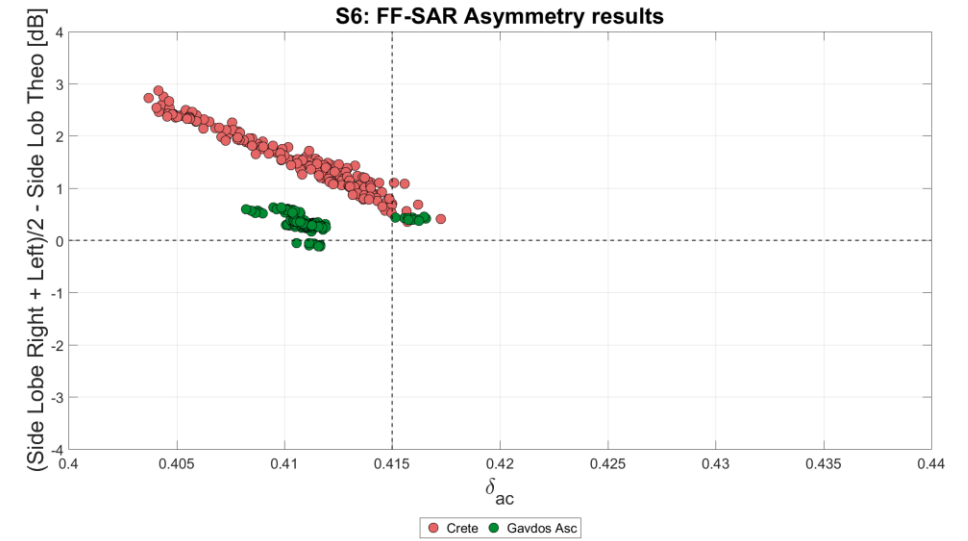
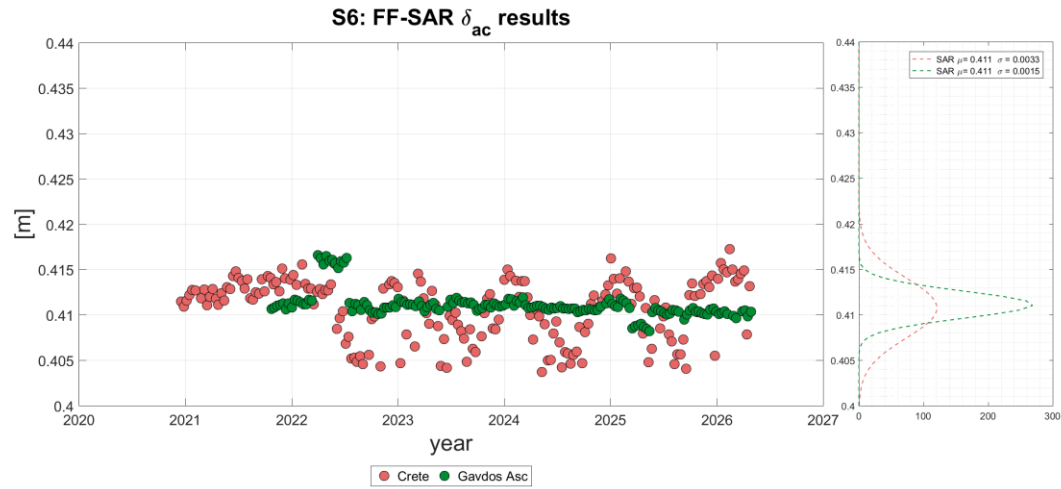






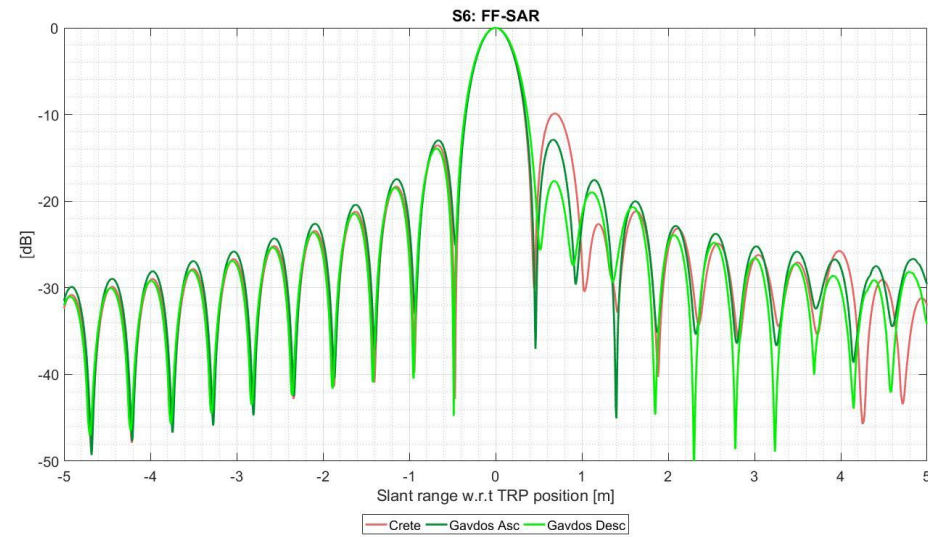
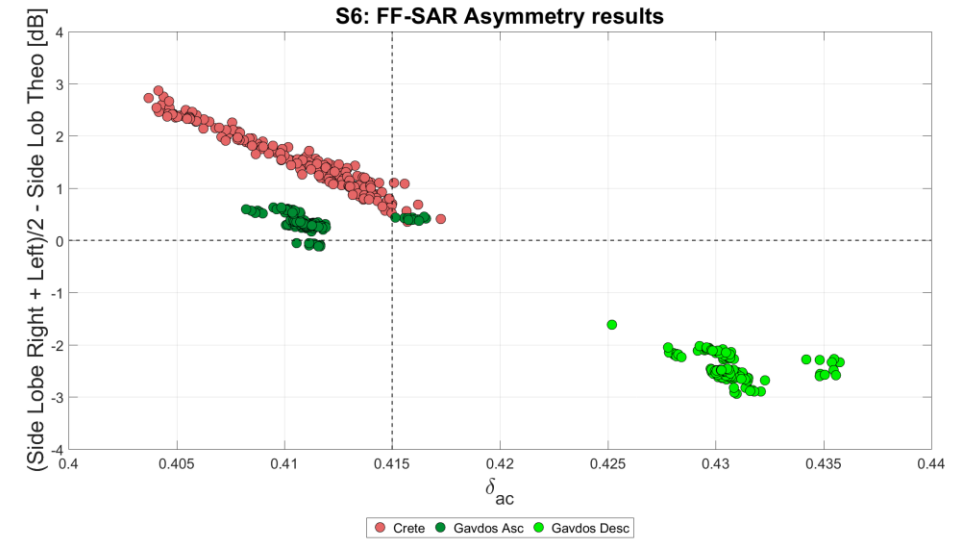
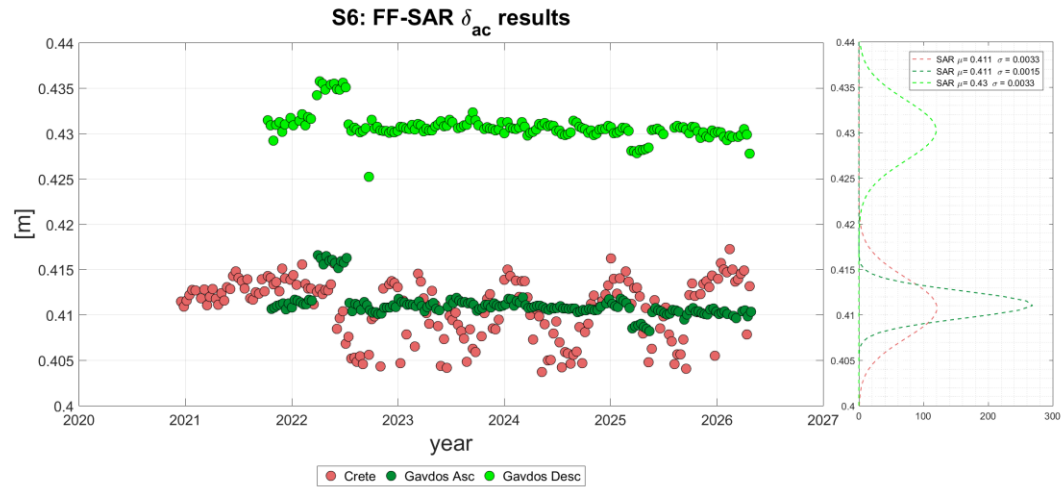
δ_c results: Gavdos Ascending

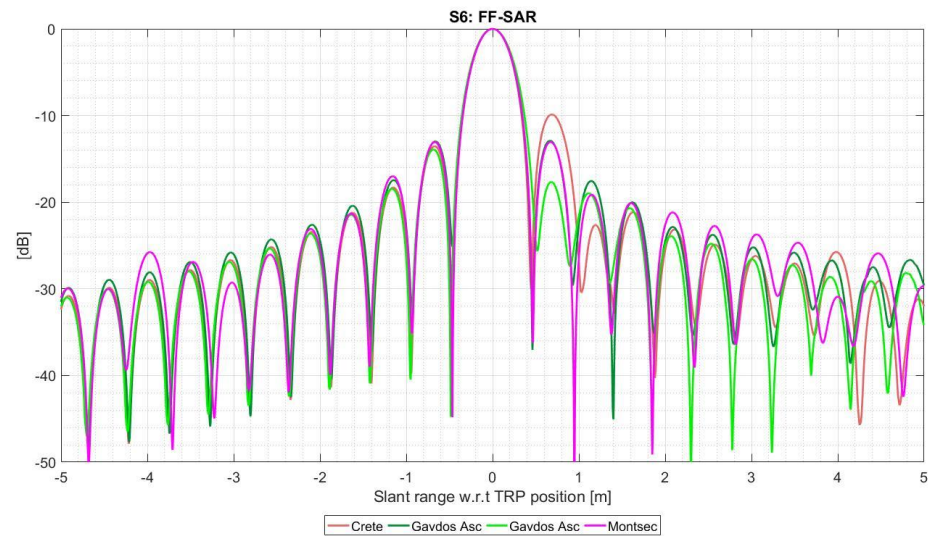
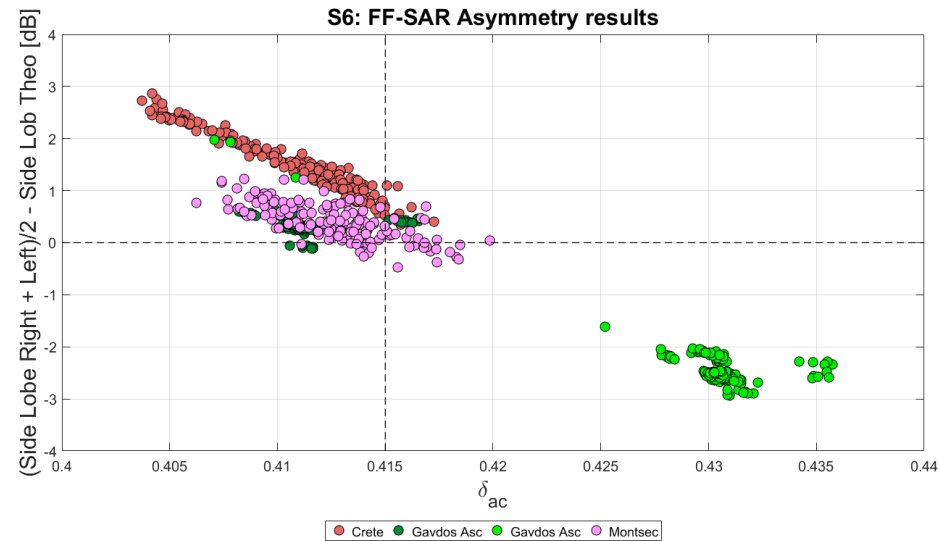
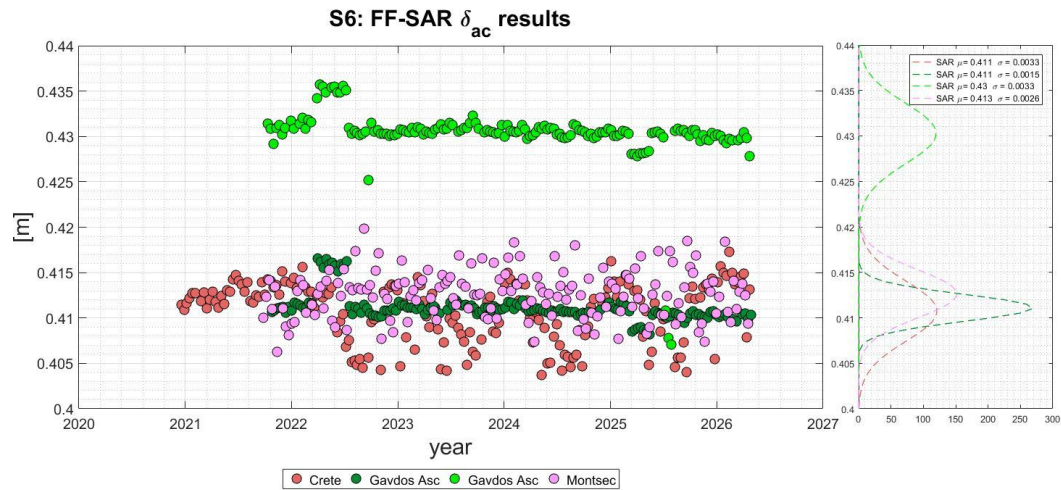
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δ_c results: Gavdos Descending

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1. Global Calibration Sites

Locations and characteristics of the transponders used for mission calibration.

2. Altimetry Data Processing Approaches

Fully Focused and Delay-Doppler methodologies.

3. Comparative Results

Performance assessment in Range, Datation, Across-track Resolution:

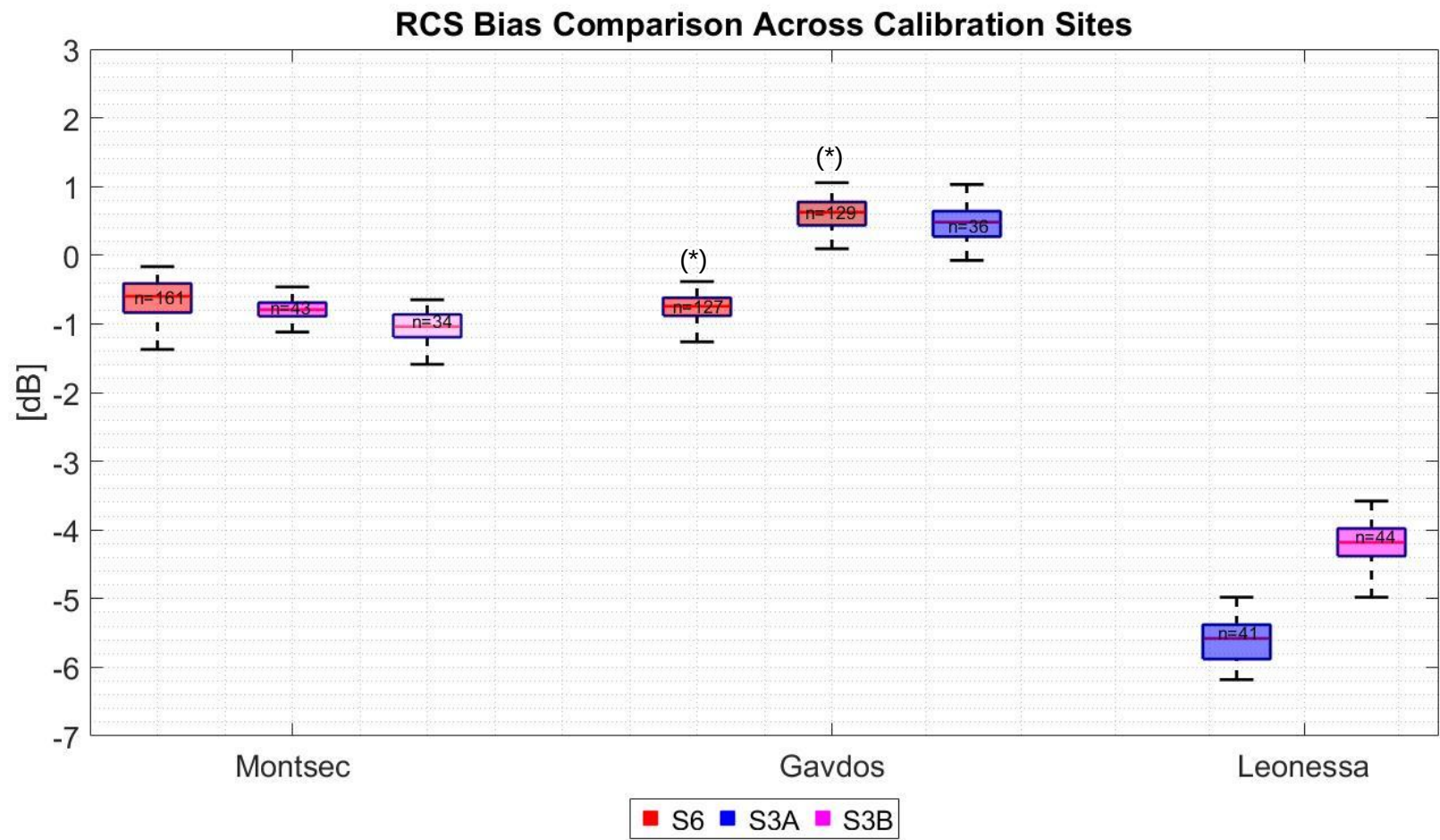
- CryoSat-2
- Sentinel-3A
- Sentinel-3B
- Sentinel-6

Performance assessment in Sigma0:

- Gavdos
- Montsec
- Leonessa

4. Key Conclusions

Main findings and implications for future altimetry missions



(*) Gavdos data after mid-2025 were excluded due to TRP attenuation tests

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4. Key Conclusions

Main findings and implications for future altimetry missions

- Transponders remain key assets for the external calibration and long-term monitoring of satellite altimetry missions.
- Range, datation, and sigma0 biases provide robust metrics for cross-mission consistency and stability assessment.
- Fully Focused (FF) processing delivers a significant improvement in datation precision compared with conventional Delay-Doppler processing.
- PTR shape variations at some TRP sites can affect the stability assessment of the non-calibrated altimeter path.
- The transponder network continues to play a crucial role in ensuring the quality and harmonisation of current and future altimetry missions.
- The same analysis will be extended to new corner reflector sites, including ALX-1/2, Calern, Uscla, Ger and SANAE
- Special thanks to all TRP teams for their continuous support, maintenance efforts, and provision of auxiliary data.

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