# USING CORNER REFLECTORS FOR ALTIMETRY CALIBRATION

11/09/2023 OSTST San Juan, Puerto Rico

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# **Motivation**

Feasibility

**\*** "small" CR now detectable with FFSAR (signal-to-clutter ratio)

Interest

- Relatively inexpensive, with weak maintenance
- Relative easy installation
- Not band-dependent
- **\therefore** No signal amplification  $\rightarrow$  suitable for sigma0 calibration?

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# **Sentinel-3 experimentation description**

#### **CR** Design

- Square-side trihedral CR
  - L = 2m
     RCS = <sup>12πL<sup>4</sup></sup>/<sub>λ<sup>2</sup></sub> = 61 dBm<sup>2</sup> for Ku band
- Manufactured in 2019 with Luntech





#### Specification

- Under Sentinel-3 tracks
- Near from Toulouse
- Weak clutter
- Local topography
- Mas Perdu in Pech David (Toulouse)
  - Distance to theoretical track: 1.56 km
  - OLTC update with Mas Perdu location
- Deployement: 10/08/2020
- About one year of data





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2D PTR



 But full stack method is too noisy for the CR

## Back projection

2 algorithms for FFSAR
Additional noise for the clutter level estimation with omegakappa





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2D PTR



 But full stack method is too noisy for the CR Back projection

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- Gibert at al. (2023) DOI:10.1109/TGRS.2023.3239988
- Mertikas et al. in preparation
  - CNES/CLS contribution for calibration with CR

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#### **Results on Sentinel-3 data**



- Calibration parameters in line with TRP estimations
- High stability of the estimations, even for sigma0
  - Suitable for sigma0 calibration?

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## **No band dependency**



Seen on SWOT swath, in Ka band

#### **Montsec Corner Reflector facility**

- Being aware of FFSAR opportunity for radar altimeter calibration improvement, back to 2021 isardSAT designed a square-side trihedral reflector
  - ~1.4m side, RCS 54.9 dB
- Location selected for permanent ubication: Montsec Astronomical Observatory (Lleida, Catalonia)
  - Low clutter ensured
  - Monitored area
  - Close to Sentinel-6, Sentinel-3B (A/D cross-over) and CryoSat-2 ground tracks



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# **Data availability**

- As of today,
  - More than two years of Sentinel-6 passes (since September 2021)
  - Cryosat-2 analysed since December 2022
  - Sentinel-3B tracking windows adjusted in February 2023 track 336 and recently for track 299, already under regular monitoring.
  - GNSS station recently installed to by the Catalan Cartographic and Geological Institute (ICGC) to provide geophysical corrections and ground movement monitoring



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### **Sentinel-6 MF: 2 years of data**

- Results essentially in terms of:
  - Range and datation bias
  - Radar cross section (RCS)
  - Impulse response function characterisation



IEEE TRANSACTIONS ON GEOSCIENCE AND REMOTE SENSING, VOL. 61, 2023

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A Trihedral Corner Reflector for Radar Altimeter Calibration

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## Sentinel-6 MF: improved PTR with antenna model

- A recent correction by S. Dinardo based on antenna model allows to generate more symmetric PTR
  - Correction tested with Sentinel-6 data with the Montsec Corner Reflector
  - Now first side lobe average difference is below 0.01 dB (before: 0.76 dB)



SEE: A complex correction for the End to End Range Impulse Response of S6 – S6VT2023\_001 S. Dinardo

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# **Sentinel-6 MF: CR vs TRP**

- Compared over series with same length and integration time (3.4s)
- Equivalent performances in terms of range and datation bias



SEE: SENTINEL-6 PERFORMANCE FROM TRANSPONDER GROUP – Thu, 16:30-16:45 A. Garcia-Mondéjar

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# **Sentinel-3B**

- Cross-over consistency to be assessed in some months from now
  - Just few points for track 299
- Same range bias as in Sentinel-6?
  - > Attributed to residual error in corner vertex determination.
  - > New vertex measurement campaign by end of this month with improved techniques.

		CRF-S6	CRF S3B 336	CRF S3B 299
Range bias [cm]	Mean	3.29	3.08	2.04
	Std	1.07	0.97	
Datation bias [µs]	Mean	-2.44	3.5	28.19
	Std	2.31	2.1	
Radar Cross Section [dB]	Mean	54.01	53.65	
	Std	0.37	0.40	
#Passes		64 NTC	10 NTC (+1 STC)	2 NTC (+1 STC)

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# **CryoSat-2**

- Both SAR/SARin modes analysed
- Capability to extract Angle of Arrival
- Cross-track distance effects under assessment



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## **Portable corner reflector**

- A portable corner of 1m-side diamond shape has been built with the purpose to support investigation of new corner reflector sites and demonstrate new reflector-based calibration capabilities.
  - RCS around 45 dB
- Measurement campaign has been carried out during Summer 2023
  - Deployed close to S6, S3 A/B ground tracks
  - Variate set of locations: forest, mountain, coast...



SEE: Radar altimetry calibration with Corner Reflectors: Current Status and Future Plans -CVL2023\_005 F. Gibert

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#### **Portable corner reflector**



Along-track distance w.r.t CR location [m]

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# Conclusion

- Corner reflectors have demonstrated to be accurate tools for radar altimeter monitoring
  - Performance equivalent to active transponders
- High stability of the estimations, even for sigma0
  - Suitable for sigma0 calibration
- Calibration parameters in line with TRP estimations
  - Complementary solution to transponder for calibration
- ♦ Not band-dependent  $\rightarrow$  CR seen on SWOT swath
  - Ideal calibration tool for calibration/calibration of future mission Cristal
- The site selection is critical for corner reflector success
  - The CNES CR has shown potential for S3A altimeter monitoring.
  - > The Montsec Corner Reflector facility in the Pyrenees has shown its potential after 2-year series of Sentinel-6 data
  - The Montsec CR has been included in the S3MPC as an official calibration site.
  - Portable corner reflectors may be useful tools to evaluate future emplacements

#### What next?

- Keep accumulating data over the Montsec CR to investigate residuals and achieve sub-cm range bias std.
- Other site for CNES CR: under a S6 cross-over in the Pyrenees. On-going.

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