Validation of Sentinel-3 waveforms over selected coastal areas

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Motivation

1. Importance of the **Sentinel-3** mission for monitoring sea level and inland water bodies
2. Need for continuous Calibration and Validation (Cal/Val) to ensure high-accuracy/quality altimetry measurements
3. The fundamental measurement, i.e., waveform shall be involved enough in Cal/Val process
4. Potential impact on derived geophysical products and water level measurements

Objectives of this study

1. Improve the quality of water level measurements from **Sentinel-3** altimetry.
2. How?
$$H = f(h, R) \tag{1}$$
h →POD and R →waveforms, coastal – lake
3. Validation of the waveforms and retrack them.
4. Evaluate the performance of different retracking scenarios in water level estimation.

Measurements/parameters used in Cal/Val activities

1. Instrument Cal:
   - Internal Cal: CAL1 and CAL2
   - Tracking mode Val, Open Loop and Closed Loop
   - External Transponder Cal, e.g., Crete
   - Cross Cal with other altimetry missions for e.g., SSH, SLA, SWH and Sigma0
   - Range Cal with in-situ gauge data, over dedicated CAL sites, Tide Gauge Network and ARGO
   - Cross-Cal of LRM and SAR modes with different scenarios
2. Product Validation: calibration with in-situ,
   - Val vs other Altimetry missions, SSH, SLA, SWH, WS and Geophysical Corr
   - Range Val vs in-situ measurements
   - Wind and wave product Val vs models
   - Global mission evaluation
   - Sea ice freeboard Val with CryoSat-2 data
   - **Waveform Val and water level variation estimation**

Waveform Val: Our Methodology

1. Waveform Modification
   - Defining a reference waveform farther offshore, e.g., distance 20 – 30 km
   - Subtract the reference waveform from each waveform and calculate the standard deviation, i.e., σ
   - Finding outlier powers and Re-construct them:

$$\bar{P}_C(i) = \frac{1}{2\sqrt{2}+4}\Big\{\big[P_C(i+1) + P_C(i-1) + P_{C+1}(i) + P_{C-1}(i)\big] + \frac{1}{\sqrt{2}}\big[P_{C+1}(i+1) + P_{C-1}(i-1) + P_{C+1}(i-1) + P_{C-1}(i+1)\big]\Big\} \tag{2}$$

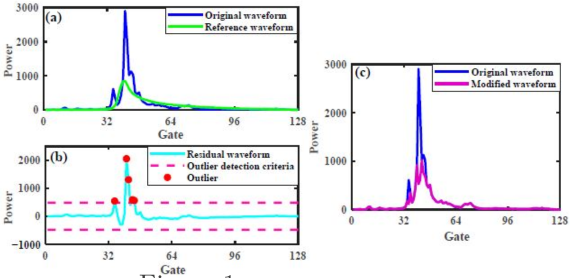


Figure 1: Waveform modification over Persian Gulf, RC 25

Waveform Val: Our Methodology

1. Waveform Decontamination:
   - Defining a reference waveform at 0 – 20 km from the coast for each satellite overpass
   - Detecting outliers based on the RMS:

$$\text{RMS} = \sqrt{\frac{\sum_{n=1}^{N}\sum_{i=1}^{M}\Delta P_n^2(i)}{NM}} \quad (3)$$

N: number of waveforms, M: number of gates and $\Delta P_n(i)$ is the difference with respect to the reference waveform.

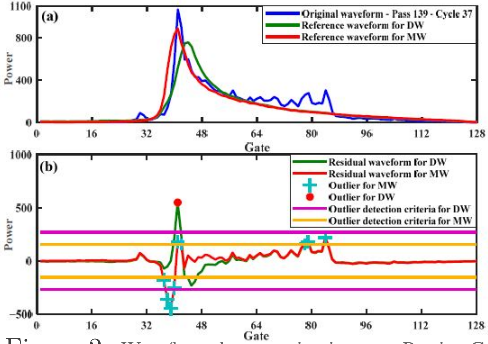
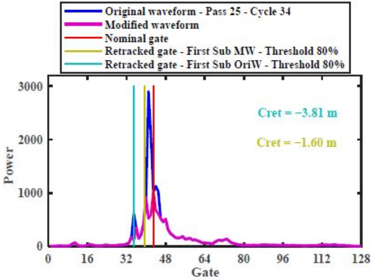
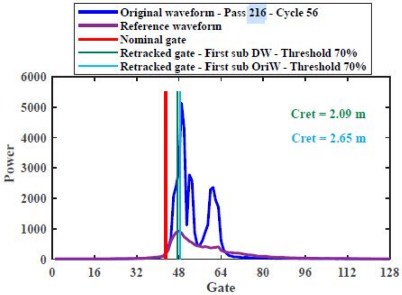


Figure 2: Waveform decontamination over Persian Gulf, track 139, RC 37

Waveform Retracking: Our Scenarios

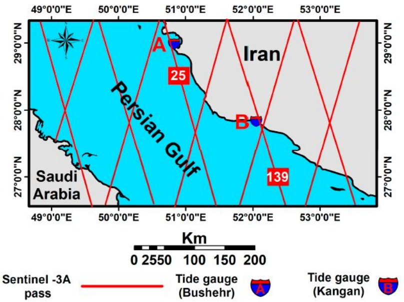
1. Original Waveforms
   - Full-waveform
   - Sub-Waveform:first sub-waveform
2. Modified Waveforms
   - Full-waveform
   - Sub-Waveform:first sub-waveform
3. Decontaminated Waveforms
   - Full-waveform
   - Sub-Waveform:first sub-waveform



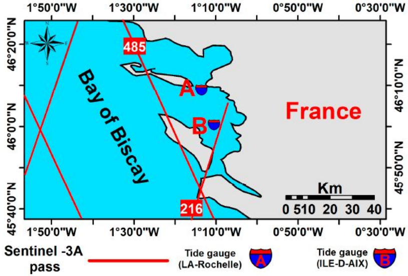


Study areas and dataset

1. Persian Gulf



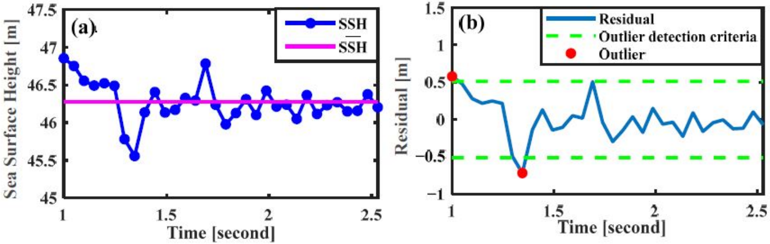
2. Biscay Bay



3. Data: S3 SRAL SR_1_ SAR and SAR L2

Validation of retracked water level variations

1. Instantaneous water level estimation for each satellite overpass and remove outliers, e.g., track 485, RC 39 Biscay Bay:



2. Build up water level variation for each pass from median values of Instantaneous water level
3. Remove outliers and bias in compare with tide gauge data and estimate RMS value for each scenario

Numerical Results from L2 Products

Table 1: RMS values (cm) between water level variations derived from L2 products and tide gauge

Coastal Area	Pass	OCOG	Ocean	Ice Sheet	Sea Ice
Persian Gulf	25 139	32 12	39 14	37 12	57 28
Biscay Bay	216 485	114 9	149 9	109 9	162 20

Numerical Results from Our Methodology: Original Waveform

Table 2: RMS values (cm) between water level from first sub/full-waveform retracked with Threshold and tide gauge

Coastal Area	Pass	10%	20%	30%	40%	50%	60%	70%	80%	90%
Persian Gulf	25	21/54	21/31	20/26	20/28	20/29	20/31	19/32	19/32	18/32
	139	15/288	14/56	13/38	14/14	13/13	13/12	12/12	12/12	11/12
Biscay Bay	216	19/35	17/33	17/49	15/58	15/72	13/86	13/113	13/124	13/137
	485	10/10	9/10	9/9	9/9	9/9	9/9	9/9	9/9	10/9

Numerical Results from Our Methodology: Modified Waveform

Table 3: RMS values (cm) between water level from first sub/full waveform retracked with Threshold and tide gauge

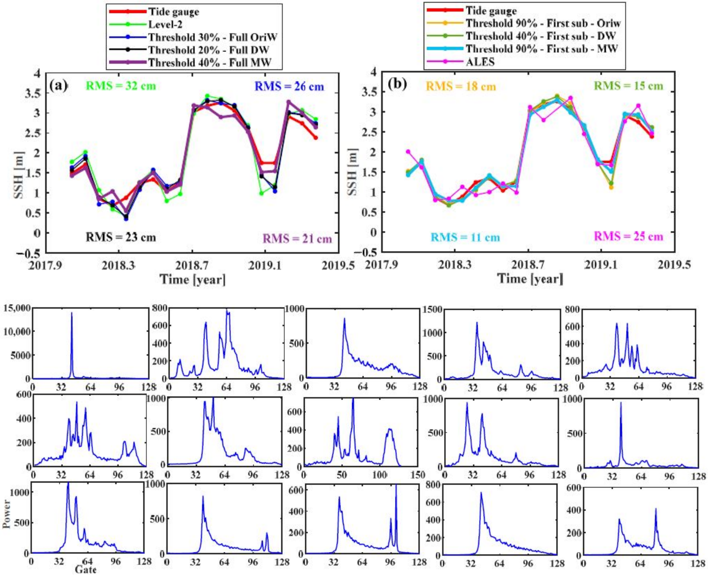
Coastal Area	Pass	10%	20%	30%	40%	50%	60%	70%	80%	90%
Persian Gulf	25	14/44	14/44	15/33	19/21	19/24	16/29	12/33	11/34	11/33
	139	21/299	15/116	17/40	16/14	14/15	14/14	14/15	15/13	14/14
Biscay Bay	216	24/28	23/25	21/32	21/44	20/55	21/74	20/91	20/113	21/126
	485	14/38	15/25	12/20	10/18	10/16	11/11	12/9	14/9	17/10

Numerical Results from Our Methodology: Decontaminated Waveform

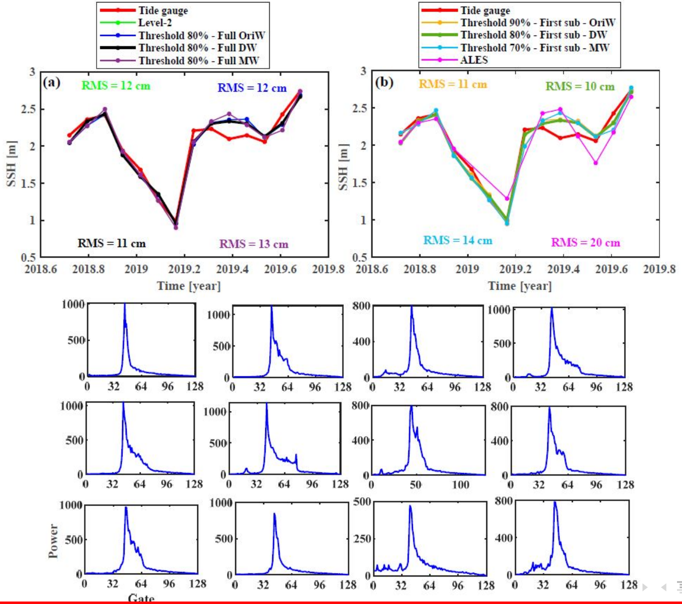
Table 4: RMS values (cm) between water level from first sub/full waveform retracked with Threshold and tide gauge

Coastal Area	Pass	10%	20%	30%	40%	50%	60%	70%	80%	90%
Persian Gulf	25	20/57	17/23	16/25	15/29	18/30	19/28	19/30	19/34	18/40
	139	15/-	15/-	14/-	14/14	13/13	12/13	11/11	10/11	11/11
Biscay Bay	216	17/28	14/40	12/54	10/86	11/109	12/131	11/143	11/157	13/181
	485	9/10	9/9	9/9	9/9	8/8	8/8	8/8	9/8	10/9

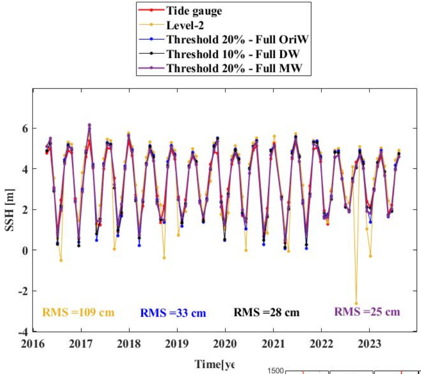
Persian Gulf track 25 L2 and L1b Retracking Scenarios

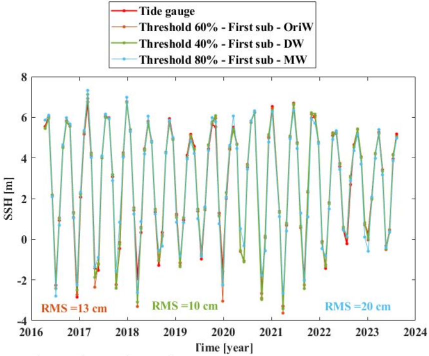


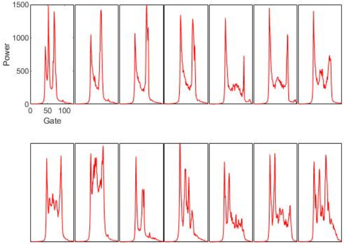
Persian Gulf track 139 L2 and L1b Retracking Scenarios



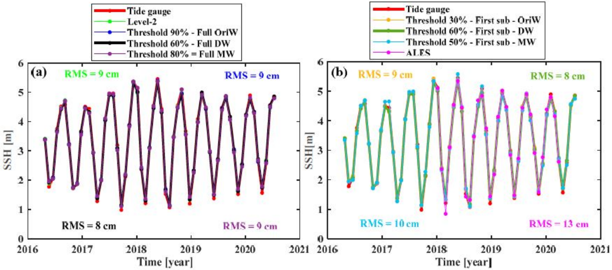
Biscay Bay track 216 L2 and L1b Retracking Scenarios

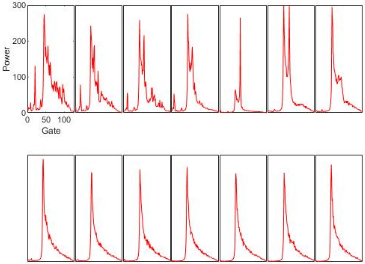






Biscay Bay track 485 L2 and L1b Retracking Scenarios





Conclusion

1. To have qualified water level variations in coastal areas, especially where waveforms are corrupted, retracking of the waveforms are necessary.
2. The first meaningful sub-waveform outperforms the full-waveforms in retracked water level estimation.
3. The first meaningful sub-waveform in the decontaminated waveforms show a better result (for3 of 4 tracks).
4. Our sub-waveform retracking scenarios outperform the ALES methodology.
5. Decontaminated and modified scenarios in full-waveform retracking have a slightly better performance than full-waveform retracking in the original waveform.

Suggestion:

1. Consider the waveform in the Cal/Val of Sentinel-3C
2. Implement our methodology for validation of Sentinel-3C waveforms in Call/Val activities

Many thanks for your attention