OSTST 2017

Splinter Summary: Instrument Processing –Measurement and Retracking (SAR and LRM)

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Robert Cullen, Marco Fornari, Walter H.F. Smith

OSTST 2017: Instrument Processing

Start	Title
9:00	Progress on Retracked TOPEX Data for the Climate Data Record
9:15	Evaluating methods to improve the performance of Sentinel-3 SRAL SAR Altimetry in the Coastal and Open Ocean- The SCOOP Project
9:30	Investigation of SWH bias in SAR Altimetry mode
9:45	New stacking method for removing the SAR sensitivity to swell
10:00	Pulse-to-Pulse Correlation Effects on high PRF Low Resolution Mode Altimeters
10:15	Discussion
11:00	Convergent solutions for retracking conventional and Delay Doppler altimeter echoes
11:15	Along-Track Zero Padding for the Processing of Unfocused SAR Altimetry Waveforms
11:30	Covariant errors in ocean retrackers evaluated using along-track cross-spectra
11:45	Delay-Doppler Processing of altimetric SAR data over open ocean: precision evaluation of different algorithms
12:00	ALES+: Adapting a homogenous ocean retracker for satellite altimetry to sea ice leads, coastal and inland waters.
10:15	Discussion
Posters	Sentinel-6/Poseidon-4 altimeter end-to-end simulator to assess the global mission performances
	CryoSat SAR/SARin L1B products: BaselineC assessment and improvements towards BaselineD
	CryoSat/SIRAL Cal1 Calibration Orbits
	S6 P4 GPP: The Sentinel-6 Poseidon-4 Ground Processor Prototype. New simulation results.

Highlights from Instrument Processing (Measurement)

- A new version of TOPEX consistent with Jason ver E with retracking, regenerating many correction, new orbits, new environmental corrections, Jason-like format in netcdf is in work. Will settle issue of the WFF range calibration

- The outcomes of the Sentinel-3 SRAL SAR Altimetry in the Coastal and Open Ocean (SCOOP) project will include Characterization of S3 SAR mode performances in the coastal zone and open-ocean and an evaluation of enhancements to the Sentinel-3 SRAL processing.

- Investigation of swell effects and SWH bias in SAR
  - LR-RMC (new SAR stacking process) removes the swell induced effect and provides 10%-40% noise reduction
  - SWH bias is explained. L1B correction reduces the bias by 7cm. Better consistency with LRM data is expected.

Highlights from Instrument Processing (Measurement)

- The Adaptive retracker (physical model + IR + surface roughness + MLE) is now available for both SARM and LRM. Large benefits over ocean, leads and hydro.

- The ALES+ retracker (reduced waveform near leading edge based on sea state + surface roughness) improves the current standards of ERS-2 and Envisat in all the domains. Also useful over ocean/coastal/leads/hydro

- LRM Waveform correlation is most significant in the leading edge. The results show that there are significant improvements in the estimation of geophysical parameters by increasing the PRF from 2 to 9 kHz (study based on PLRM data analysis). There is a bias between 2 kHz and 9 kHz data synthesized from Sentinel-3 data.

- Covariant errors in ocean retrackers (LRM): parameters in retracking are always correlated. Net effect depends on both model (mainly, is attitude estimated) and estimation method. Effects most clearly seen in “spectral hump” region and wavelengths <~100 km

OSTST 2017 Key Points from Project Scientists

- 1 – Are our cal/val methods sufficient to verify the Jason-CS/Sentinel-6 global and regional mean sea level stability requirements?
- 2 – Considering the possibility of switching on the redundant altimeter on JCS/S6 during the cal/val phase with Jason-3. If feasible, what is the number of cycles that the redundant altimeter should operate?
- 3 – Alternative processing approaches such as fully-focused SAR processing are emerging. Will the current Sentinel-3 and Jason-CS/Sentinel-6 systems allow for novel processing approaches to be fully exploited?
- 4 – What would be the impact of descoping MLE3 fields in the baseline for JCS/S6 products (except for sigma0)?
- 5 – Would increasing the frequency of the Jason-3 AMR cold sky calibrations improve the long term stability?
- 6 – What are the open issues that affect the continuity between LRM and SAR modes from SWH, roughness, swell and their impacts on SSH?
- 7 – What areas should S6/JCS RAW SAR data (non-RMC) be collected (acquisition mask)?

From Thibaut: General View of Retracking

S(t, f)

Retracker = A model + an estimation method

A model

For LRM and SAR modes, the echoes can be expressed as the convolution (with different geometries) of 3 terms (Brown/Hayne model) :

$$S(t) = FFSR(t) \circledast PDF(t) \circledast PTR(t)$$ *in LRM*

$$S(t,f) = FFSR(t,f) \circledast PDF(t) \circledast PTR(t,f)$$ *in SAR*

t: time, f: doppler frequency (cf, Boy, 2016, TGRS)

- FSSR (Flat Sea Surface Response)
- PDF(Probability Density Function of the heights)
- PTR (Point Target Response: XT for LRM, XT & AT for SAR)

CNES/CLS have made the choice to derive the FSSR **analytically (LRM and SAR) and numerically (SAR)**
PTR and PDF are **always introduced numerically**

CNES Processing Prototype (CPP & S3PP)

Halimi's model published in TGRS, 2013

Instrument Processing Round Table

- **A process is needed to get improved methods validated and put into use to get improved products users.** Validation to include:
  - Methods (statistics, etc.), metrics, criteria, test data sets (regions; including in situ if possible; global desirable)
  - Independent assessment
  - Documentation, specifications
  - Path to use, reprocessing of previous data

- 4 – What would be the impact of descoping MLE3 fields in the baseline for JCS/S6 products (except for sigma0)?
  - To avoid confusion, it may be best to put MLE3 fields only in SGDR; basic/simple GDR to contain only recommended values

- 6 – What are the open issues that affect the continuity between LRM and SAR modes from SWH, roughness, swell and their impacts on SSH?
  - Swell effect can be removed with a different stacking
  - How to make full SAR SWH consistent with LRM is mainly solved

- 7 – What areas should S6/JCS RAW SAR data (non-RMC) be collected (acquisition mask)? -

Main discussion was to demonstrate that on-board RMC does not degrade the data quality (phase, signal accuracy) :

  - Analysis already performed by the project team
  - Test data are available.
  - Test by performing RMC on Sentinel-3 data
  - Insure that data can be transformed back to do full SAR processing without quality loss
  - RMC Technical description (high level) to be provided to users

Backup

New TOPEX RGDR Plan

- Use original SDR, GDR
  - Search for missing cycles, pass data to make record as complete as possible. Both SDR and GDR are needed in retracking.
- Revisit Retracking code, process
  - Investigate use of same PTR for Ku, C
  - Validate with simulations
- Include additional parameters on record
  - 20Hz Range at both Ku, C as available on SDR. With time tags, locations. (Corrections still at 1 Hz)
  - Key parameters for both original GDR and Retracked
- Regenerate some corrections, flags
  - Oscillator drift from long term fit (TBD)
  - Doppler shift and acceleration corrections (TBD from orbit or altimeter data)
  - Rain, ice flags with Jason-like algorithms
- Use latest POE from GSFC (ITRF2014), new environmental corrections & geophysical fields from CNES, reprocessed TMR data
- Refit SSB with all above improvements
- Update format to Jason ver E

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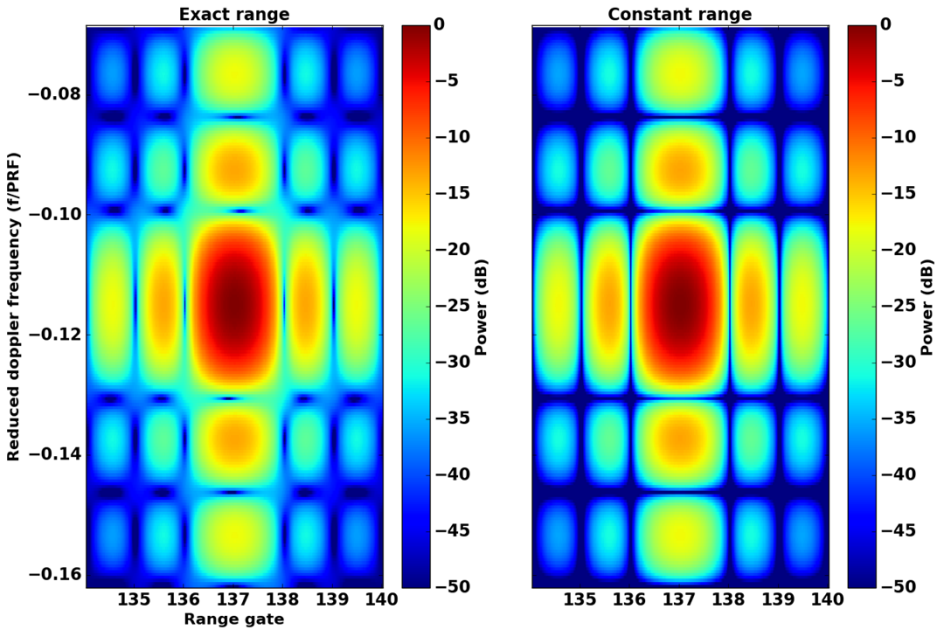
INVESTIGATION OF SWH BIAS IN SAR ALTIMETRY MODE (T. Moreau, CLS)

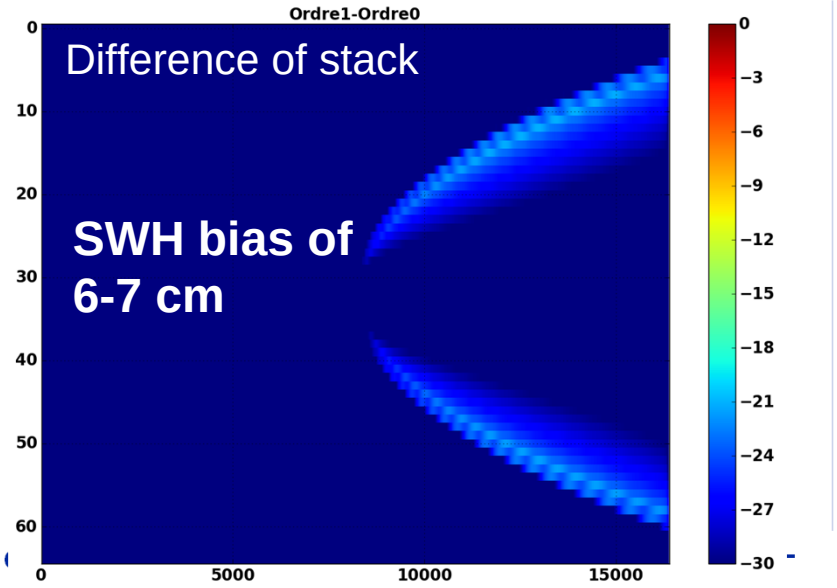
Nominal ocean SAR-mode processing uses inappropriate 2D-IR model => overestimation of the SWH

On-going investigations would confirm those results and assess the impact of this inconsistency on estimates

Correction may be done at Level-1 or Level-2 processing

We expect to improve the consistency data/model to make possible the use of maximum-likelihood method (Adaptive retracker) with SAR-mode data and individual Doppler echoes



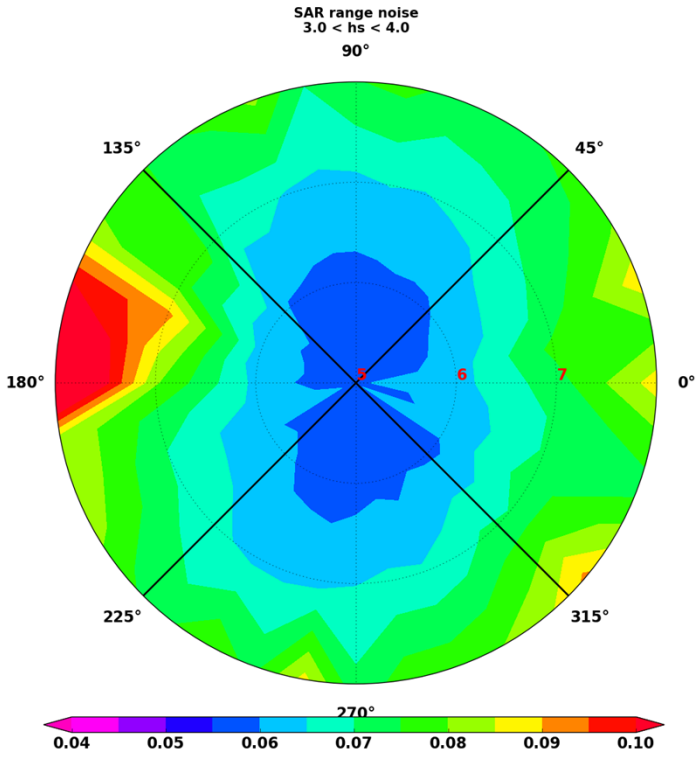


New stacking method for removing the SAR sensitivity to swell (F. Boy, CNES)

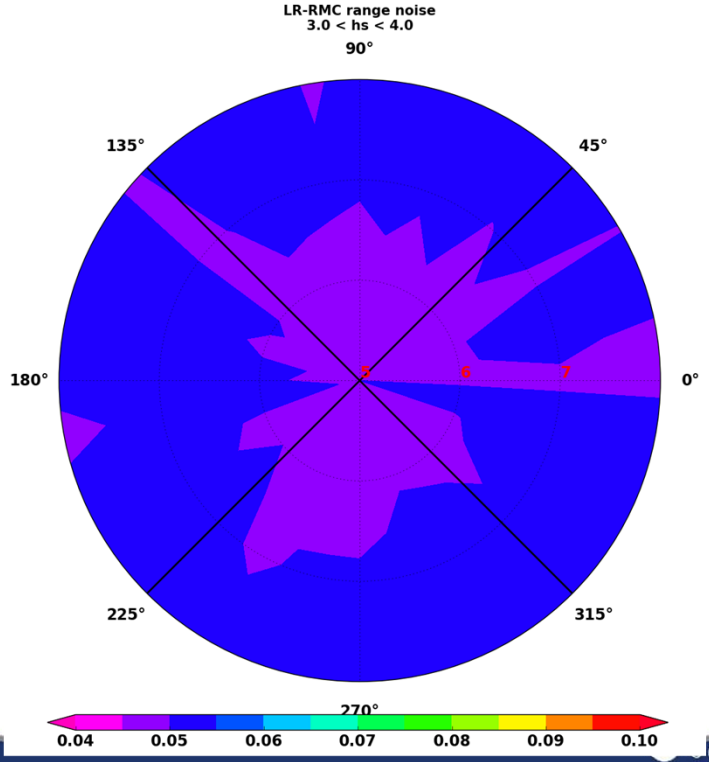
LR-RMC offers a major improvement over open ocean:

- No bias at global scales
- 10%-40% noise reduction on Range and SWH
- Stable performances whatever swell conditions

Current SAR processing



LR-RMC processing



Pulse-to-Pulse Correlation Effects on High PRF Low Resolution Mode Altimeters (A. Egido, NOAA)

- In this study we have analyzed the pulse-to-pulse correlation of low resolution mode (LRM) pulse-limited altimeter waveforms.
- We have based our study on PLRM data obtained from CryoSat-2 SAR Mode FBR data.
- The pulse-to-pulse correlation changes depending on the waveform region:
  - For tl
  - For tl

Please Walter, could you provide one slide as a summary of Alejandro's presentation?

- This leads to a steadily increasing effective number of looks (ENL) in the waveform trailing edge, even for PRFs as high as 18 kHz.
- To determine the effect of the partial pulse-to-pulse correlation, we have processed and retracked 5 full years of CryoSat-2 SAR Mode data in a PLRM fashion with different PRFs.
- The results show that there are significant improvements in the estimation of geophysical parameters by increasing the PRF from 2 to 9 kHz.
  - Up to 25% for SSH and SWH, and up to 35% for sigma-0 and mispointing angle.
- The estimation of SSH and SWH at 9 kHz are biased with respect to the 2 kHz estimations. These errors would need to be accounted for and corrected.
  - This was linked to the use of an unweighted MLE4 retracker for waveforms with different statistics along the range gates. Future work implies the use of an weighted retracker.

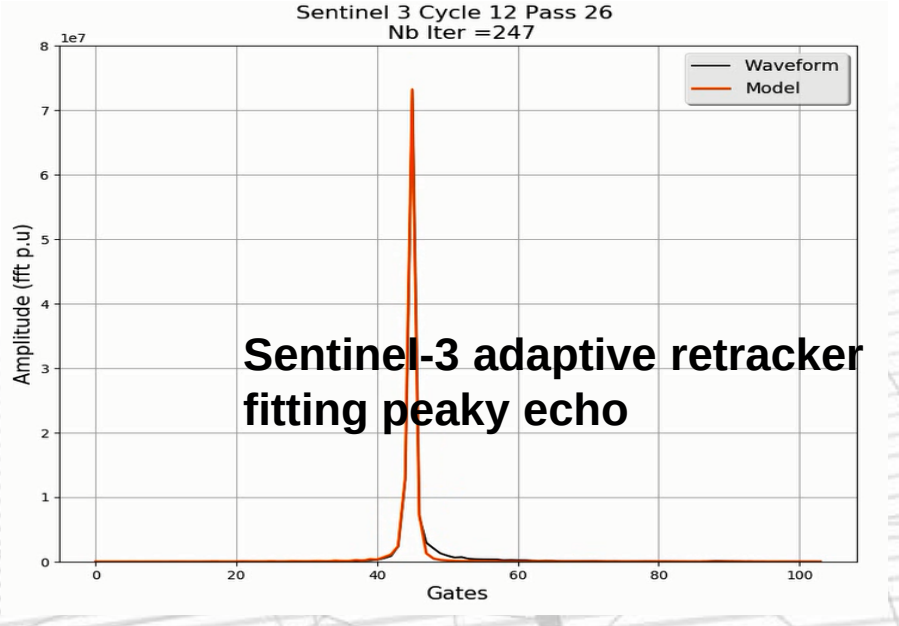
Convergent solutions for retracking conventional and Delay Doppler altimeter echoes (P. Thibaut, CLS)

- A **consistant approach** has been derived for retracking conventional and Delay Doppler measurements, either for open-ocean or specular surfaces
  - Physical model accounting for Impulse Responses
  - Roughness of the surface has been introduced in the models
  - Speckle noise statistics accounted for allowing to use a true likelihood criterium in the optimization process (Nelder Mead optimization method)

- **Large benefits for open ocean**
  - Huge noise reduction for SWH and range (30% to 60% for SWH in LRM/DD)
  - No need to use LUT corrections
  - Better estimation over blooms/rain/internal waves events

- **and for sea ice and for hydrology**.

Ongoing studies to quantify the impact on radar freeboard and ice thickness estimations.



Along-Track Zero Padding for the Processing of Unfocused SAR Altimetry Waveforms (C. Buchhaupt, TU Darmstadt)

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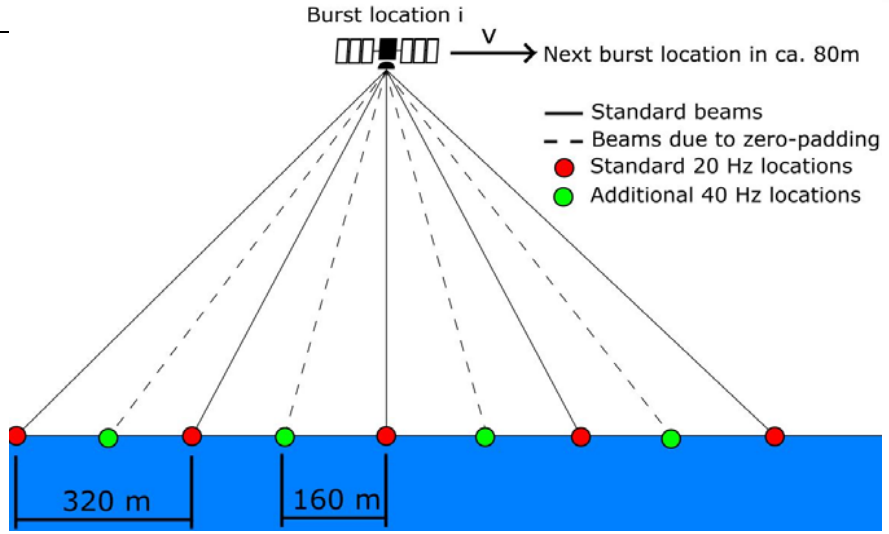
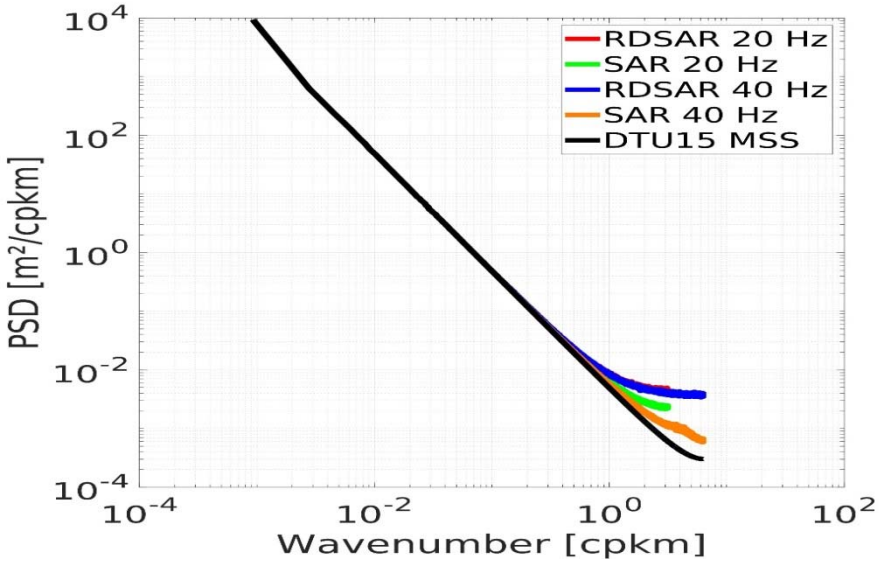
- Zero-Padding of the bursts before the along-track FFT leads to additional beams not available in standard 20 Hz surface locations
- A surface sampling rate of 40 Hz allows to use these additional beams
- Small improvement of precision for SLA (ca. 10-20%) is observable for 40 Hz unfocused SAR data
- Spectral analysis shows significant improvements for SWH, SSH, sigma0 derived from the 40 Hz SAR





Covariant errors in ocean retrackers evaluated using along-track cross-spectra (W. Smith, NOAA)

- Sea state bias is not a constant percentage; it is wavelength- and retracker-dependent.
- The "s errors.
- Fitting (SWA) introduces σ² error.
- Overall, ALES has the best noise spectrum (low covariant errors, low/moderate SSB)
- PEACHI Nelder-Mead minimizes SSHA variance but at the cost of strong correlation with SWH and new and larger SSB.

Please Walter, could you provide one slide as a summary of your presentation

Delay-Doppler Processing of altimetric SAR data over open ocean: precision evaluation of different algorithms (E. Makhoul, IsardSAT)

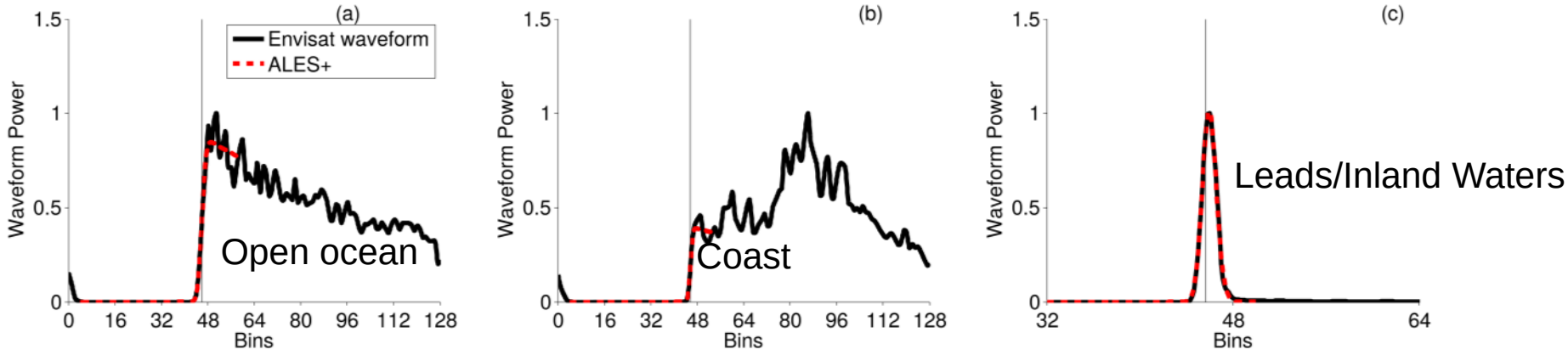
- Understand how the SAR mode can be efficiently exploited to improve performance of altimetric products (processing)
- **Comparative** assessment in terms of **precision**:
  - Conventional **S-3/CS-2** processing baseline
  - Amplitude Compensation & Dilation Compensation (**ACDC**)

- Precision performance comparative study of different DDP :
  - Very good noise performance in SWH for conventional (25-35 cm for SWH 1.5-4 m)
  - CS-2 including and not the zeros in ML show similar results
  - S-3 degraded performance compared to CS-2 (1 cm degradation on SSH and 5 cm in SWH)
  - ACDC shows the best performance in SSH and SWH precision (improvement of 2 cm in SSH and 10-15 cm in SWH)

Deutsches Geodätisches Forschungsinstitut (DGFI-TUM)
Technische Universität München

ALES+: Adapting a homogenous ocean retracker for satellite altimetry to sea ice leads, coastal and inland waters

(M. Passaro, Technische Universität München).



- ALES+ is a quick, non-computational demanding and effective way of retracking altimetry echoes from open ocean, leads, inland waters and coast.
- ALES+ improves the current standards of ERS-2 and Envisat in all the domains
- First applications: A DTU/TUM gridded Artic and Antarctic SSH product is available from Sea Level CCI