# Application and Evaluation of ACDC Delay-Doppler processing over CryoSat-2 for Open-Ocean zones

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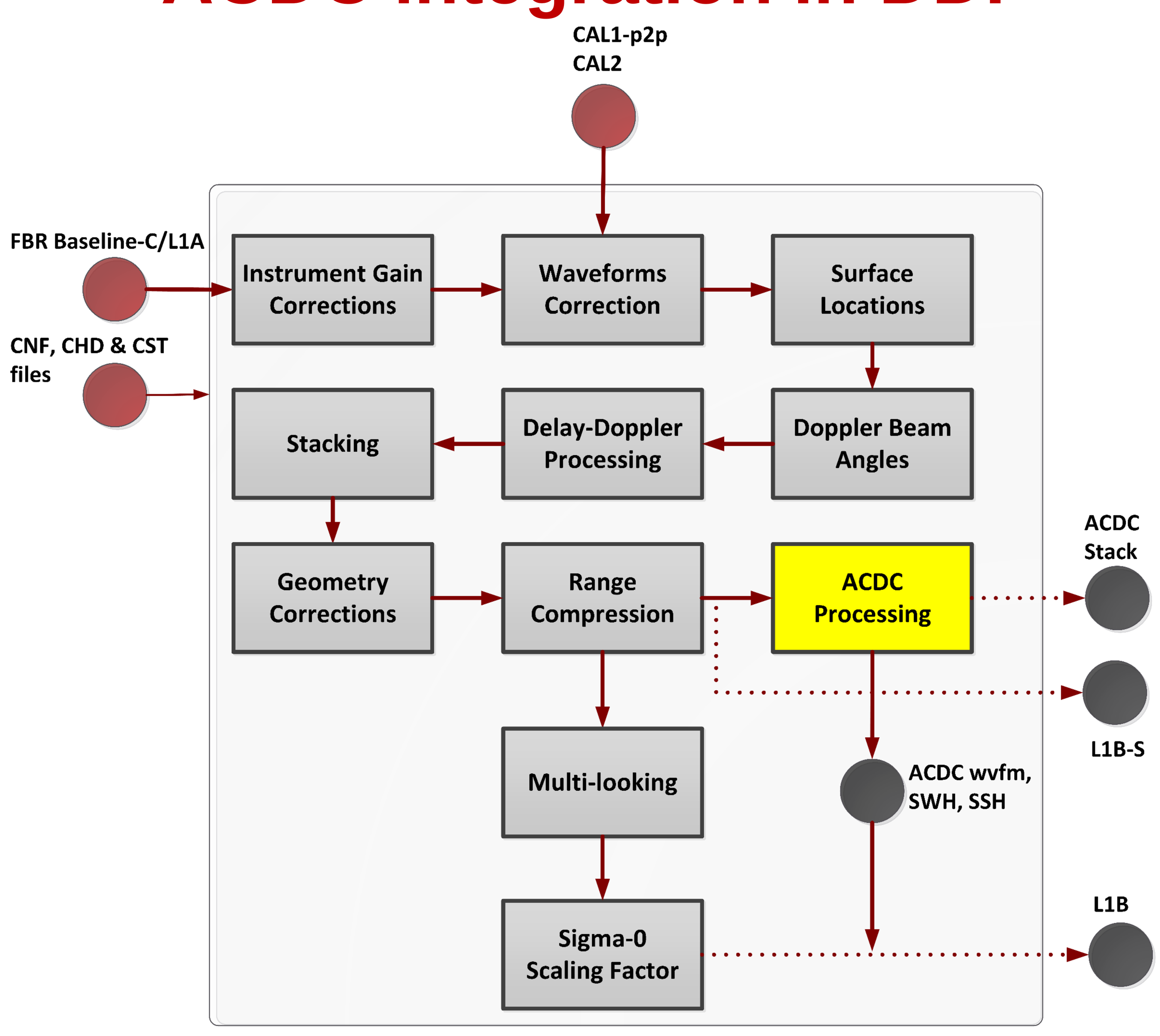
**This work is devoted to show the integration and operation of the ACDC (amplitude compensation and dilation compensation) technique in an isardSAT in-house developed Delay-Doppler processor (DDP). Preliminary results on the ACDC performance on real FBR CryoSat-2 data over open ocean zones are presented. ACDC algorithm was originally proposed by Chris Ray and isardSAT team within the Sentinel-6 project and applied at burst level [1]. In this work such processing algorithm is integrated at stack level once the geometry corrections have been applied. The combination of the ACDC processing within L1B and the implementation of the simpler ACDC retracker provides improved (less noisier) geophysical retrievals.**

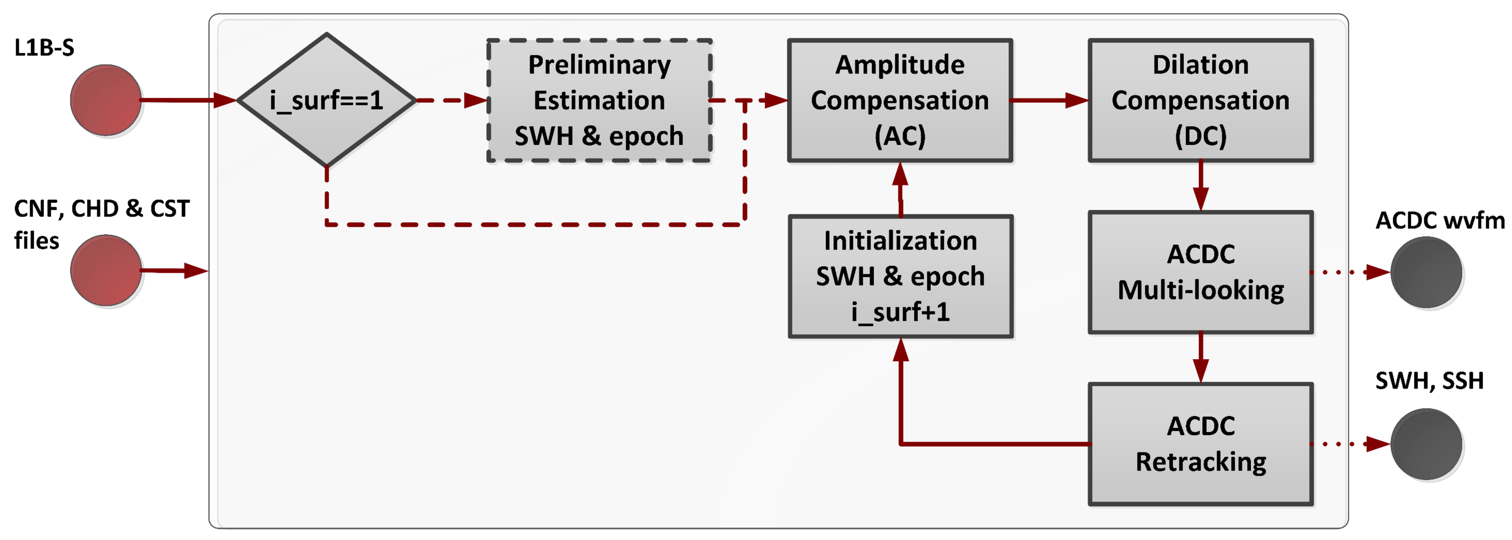
## ACDC integration in DDP




**DDP structure** change with stacking before geometry corrections allows an **easy integration of ACDC** processing → **conventional + ACDC stack (L1B-S)** are provided as optional products.

**L1B product** includes **geophysical retrievals** since a **simple** (lower computational load) **retracker** is integrated in the **ACDC processing**.

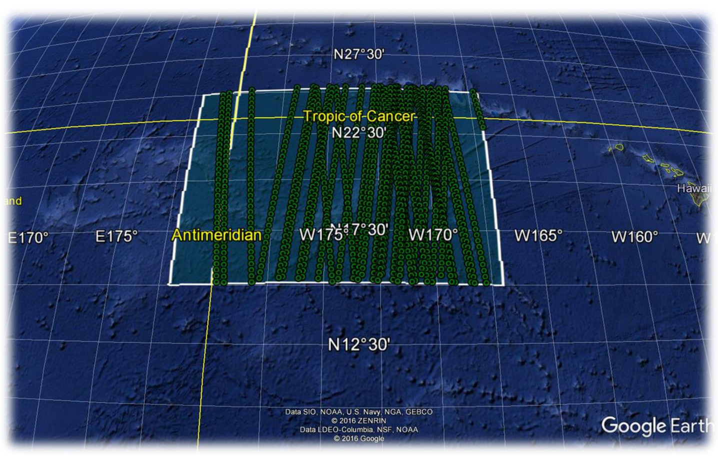
## ACDC implementation




**Initial estimates (first surface)** of **SWH & epoch** performed with **in-house implementation** of the **fully analytical SAR ocean model** (Chris Ray et al 2015, see [2]) → **synergy with L1B processing**

**Parameter estimates** of the **previously processed waveforms** are used to make **initial estimate** for the **ACDC processing of next waveforms**

## AOI & Methodology




(*) Tracks used in the ACDC evaluation over the central pacific mask of CryoSat-2

- 37 tracks over **Central Pacific-year 2013**
- DDP processing baseline:
  - **Zero-padding** + **Hamming** in **along-track** (across-track weighting can be considered**)** + samples to **zero avoided in ML** + **edge beams masking** ($-0.6 \leq \theta_{look} \leq 0.6$)
- Conventional retracker [2] vs ACDC
  - Root mean square error (**RMSE**) w.r.t **smoothed version** (**sliding window of 20** samples) over track [SSH & SWH]

## ACDC modeling

Two-step compensation:

1. **Along- and across-track amplitude compensation** to equalize the Doppler and range-dependent weighting
2. **Across-track dilation compensation** to correct for the waveform widening when moving away from the central beam

**Mean backscattered power** in a range-bin $k$ & Doppler beam $l$ [2]

$$P_{k,l} = B_{k,l} \cdot \sqrt{g_l} \cdot f_0\left(g_l \cdot (k - k_0)\right)$$

Antenna & Surface pattern

$$g_l = \left(\sigma_{ac}^2 + \left(2 \cdot \sigma_{al} \cdot \frac{L_x^2}{L_y^2}\right)^2 + \left(\frac{H_s}{4 \cdot L_z}\right)\right)^{-\frac{1}{2}}$$

*Doppler-dependent dilation*

$$f_n(x) = \int_0^{\infty} (u^2 - x)^n \cdot e^{-\frac{(u^2-x)^2}{2}} du$$

*Basis functions*

**1) Amplitude Compensated Mean backscattered power** in a range-bin $k$ & Doppler beam $l$

$$P_{k,l}^{AC} = \frac{P_{k,l}}{B_{k,l} \cdot \sqrt{g_l}} = f_0\left(g_l \cdot (k - k_0)\right)$$

**2) Compensation** of a **Doppler-dependent range dilation** w.r.t **central Beam**

$$\kappa_{k,l} = \frac{g_l \cdot (k - k_0)}{g_0} \quad \Rightarrow \quad P_{k,l}^{ACDC} = f_0\left(g_0 \cdot \kappa_{k,l}\right)$$

Ideally there is **no variation** of the **ACDC stack** in the **along-track direction** → move from **2-D map to a 1-D representation** (↑↑ samples for fitting)

**3) ACDC Multilooking** with a Gaussian weighting $\omega(x)$ (**averaging samples with similar DC range-** win. size of $\delta$)

$$\Psi_n^{ML-ACDC} = \frac{\sum_{k,l} \omega(\kappa_{k,l} - n\delta)\, P_{k,l}^{ACDC}}{\sum_{k,l} \omega(\kappa_{k,l} - n\delta)}$$

**4) Simpler ACDC waveform retracker**

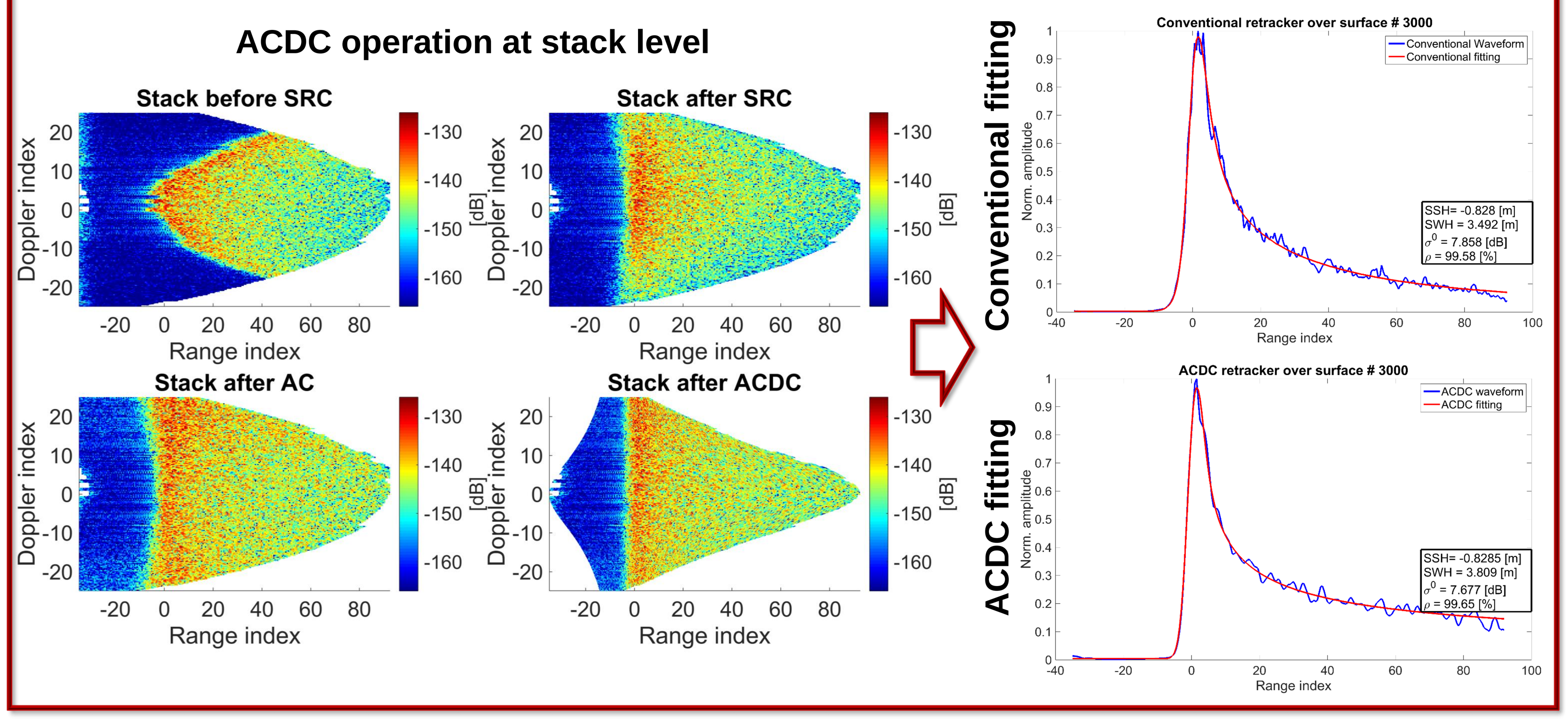
$$\Psi_n^{model} = P_1 \cdot f_0\left(P_2 \cdot (n - P_3)\right)$$

$P_2 = g_0(H_s) \rightarrow \tilde{H}_s = g_0^{-1}(P2)$

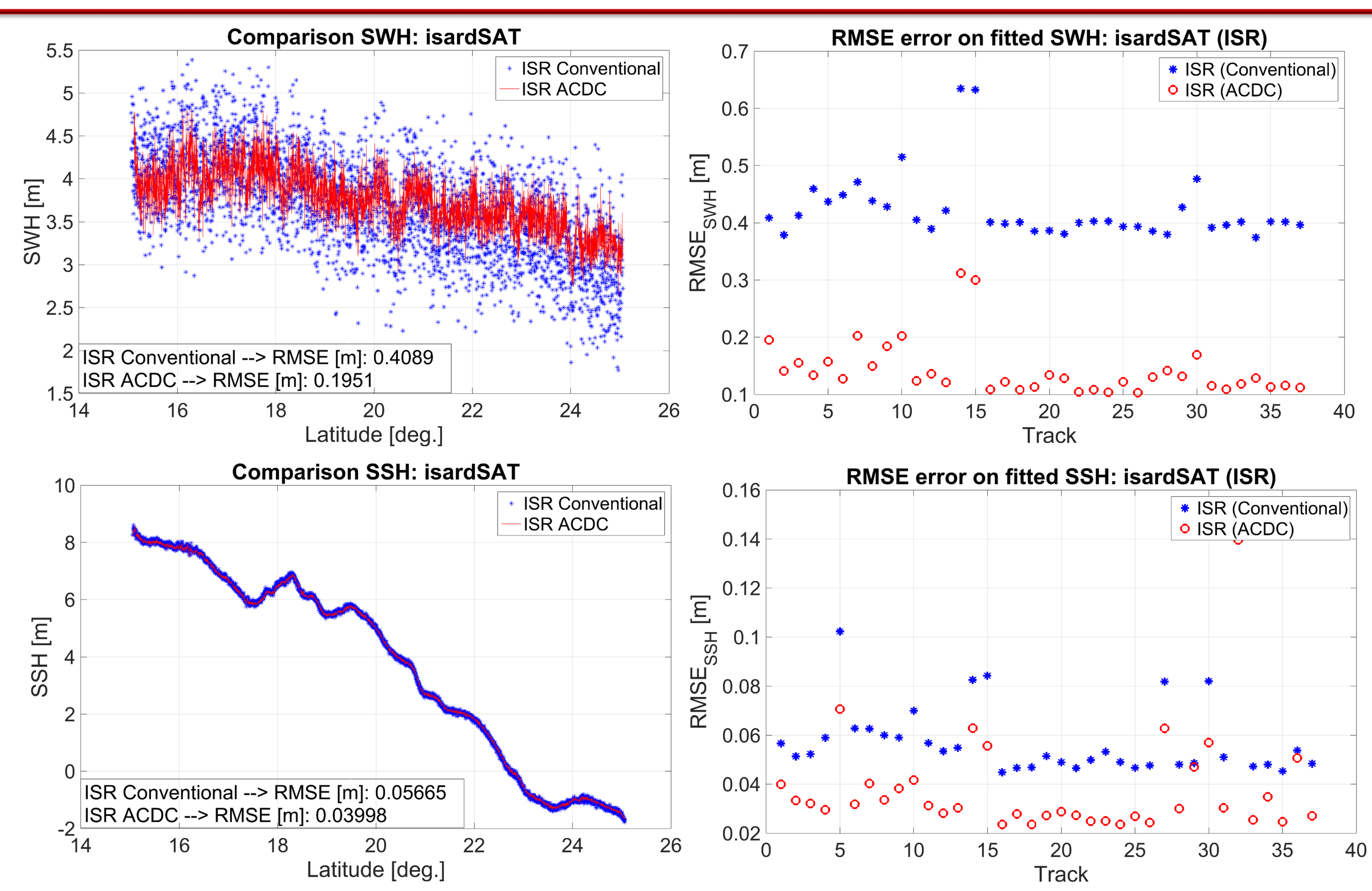
*Estimated dilation → SWH estimate*

$P_3 \rightarrow \tilde{k}_0 = k_0 + P_3$

*Residual epoch → correct initial epoch for ACDC operation*




## Validation Results




## Conclusions

- Implementation and **integration of ACDC** processing at **stack level** → L1B with geophysical retrievals
- **Preliminary validation** of **ACDC** integrated at **stack level** with **CryoSat-2** data **vs fully analytical SAR** ocean retracker
  - **Improved SSH** (a factor of **1.5-2** in terms of **RMSE**)
  - **Improved SWH** (a factor of **3-4** in terms of **RMSE**)
  - Further **analysis of biases** on SWH required to **tune** the impact of **PTR modeling (ground-truth data)** and possible impact of wrong estimates of roll & pitch (could be improved through ACDC as in [3])

## References

[1] C. Ray *et al.*, "Amplitude and Dilation Compensation of the SAR Altimeter Backscattered Power," in *IEEE Geoscience and Remote Sensing Letters*, vol. 12, no. 12, pp. 2473-2476, Dec. 2015.

[2] C. Ray *et al.*, "SAR Altimeter Backscattered Waveform Model," in *IEEE Transactions on Geoscience and Remote Sensing*, vol. 53, no. 2, pp. 911-919, Feb. 2015.

[3] C. Ray *et al*, "A New Method to Determine the Antenna Pointing directly from Altimeter SAR mode Data", in *Ocean Surface Topography Science Team Meeting*, Reston (USA), 20-23 Oct. 2015.