Level-2 Assessment of Along-Track Antenna Pattern Compensation for SAR Altimetry

Salvatore Dinardo (He Space/EUMETSAT), Michele Scagliola (ARESYS srl), Marco Fornari (ESA/ESTEC), Jérôme Benveniste (ESA/ESRIN)

20-23 October 2015 OSTST, Reston VA

Presentation Outline

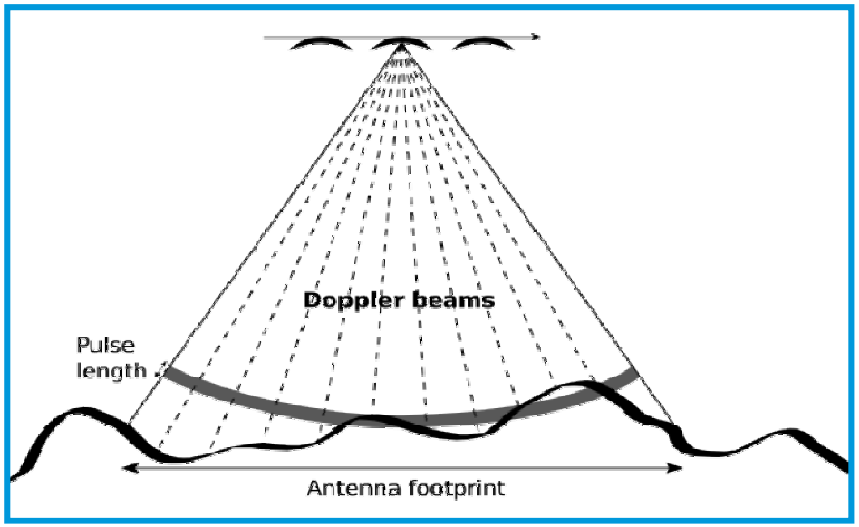
- Synthetic Aperture Radar altimetry
- Stack of single look echoes and multilooking
- Along-track antenna pattern compensation
- Experimental results on CryoSat-2 acquisitions over ocean
- Conclusions

Synthetic Aperture Radar Altimetry

SAR altimetry exploits the coherence of the emitted pulses so that:

1. Narrower antenna pattern is syntethized

2. More observations are gathered for each scattering area on Earth surface



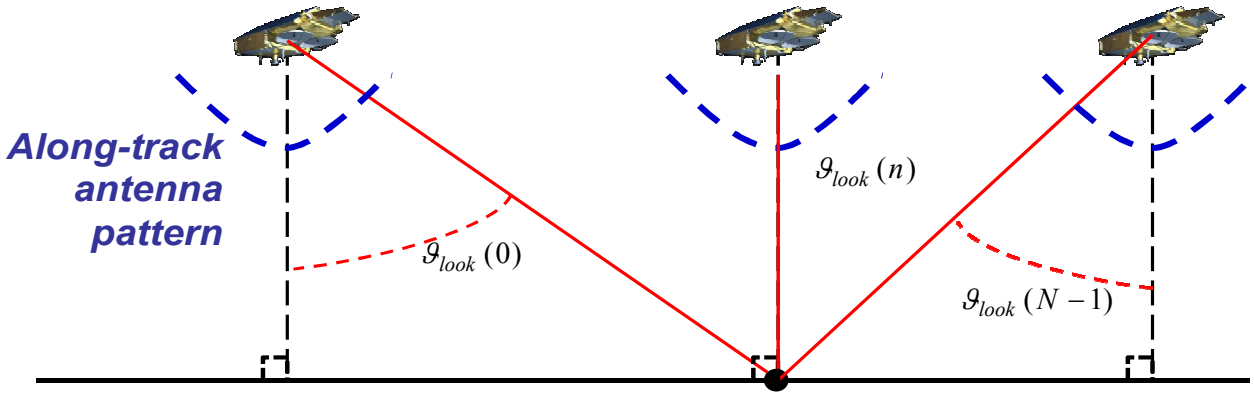
Improved along-track resolution

Higher speckle reduction

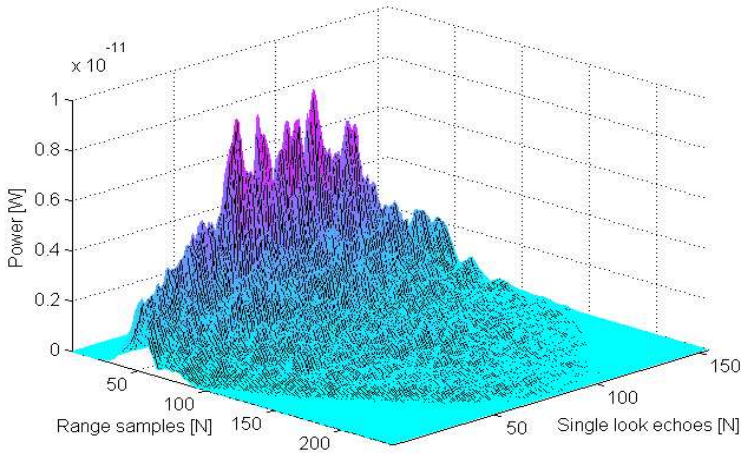
A further speckle reduction is achievable by compensating the along-track antenna pattern on the stack of single look echoes

Building the Stack of single look echoes

For each Surface Location it is accumulated a stack of single look echoes coming from the processed bursts during the time of visibility



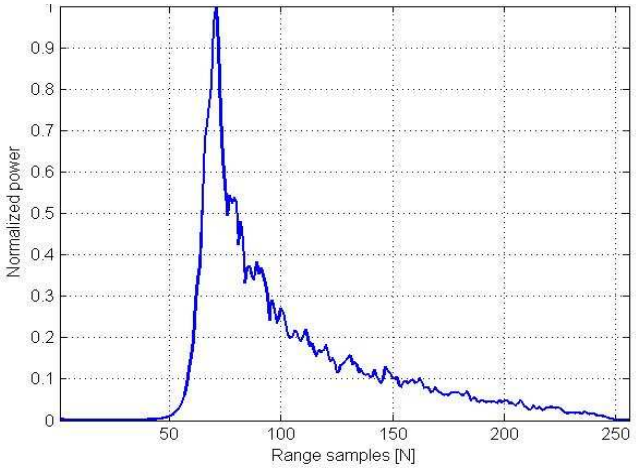
Stack for SAR over Ocean



Azimuth Averaging

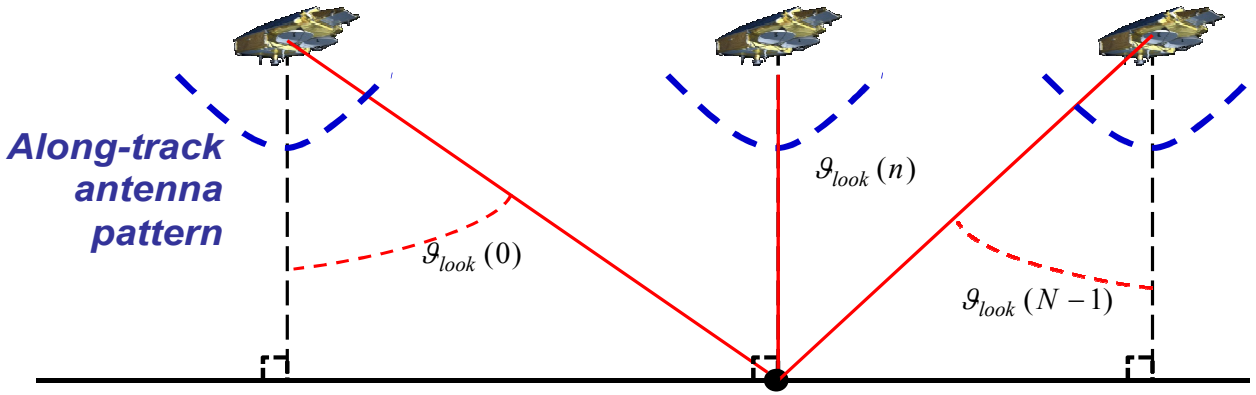
Exploiting statistical independence of looks, speckle noise is reduced

Multilooked waveform

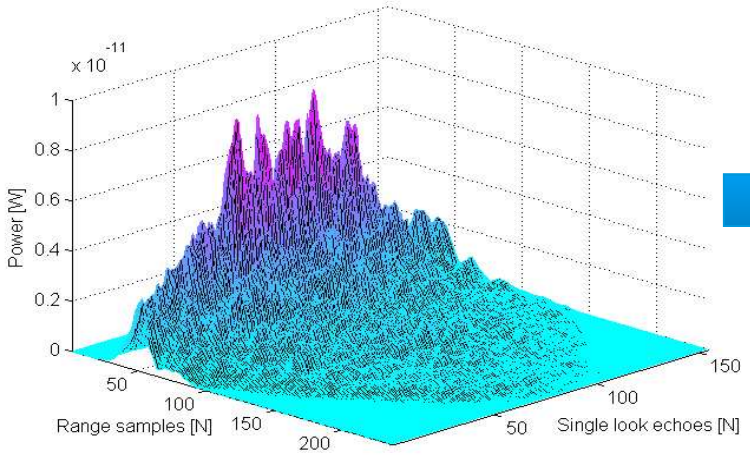


Delay- Doppler Beams Modulated by Along-Track Antenna Pattern

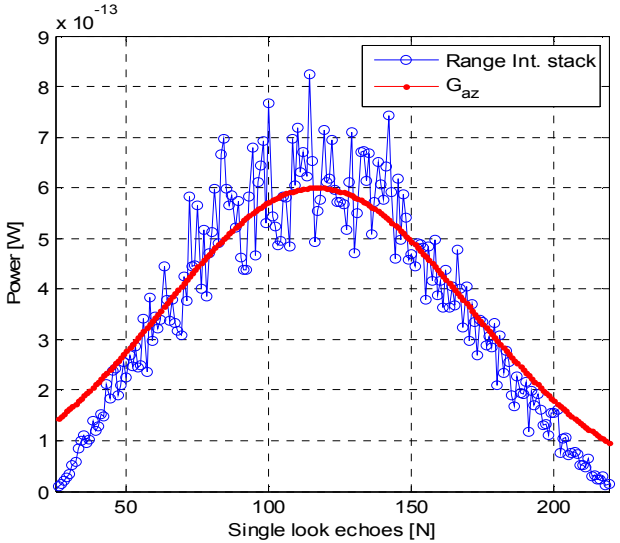
Each single look echo has been acquired for a different look angle, so that is scaled by the along track antenna pattern as function of the look angle.



Stack for SAR over Ocean

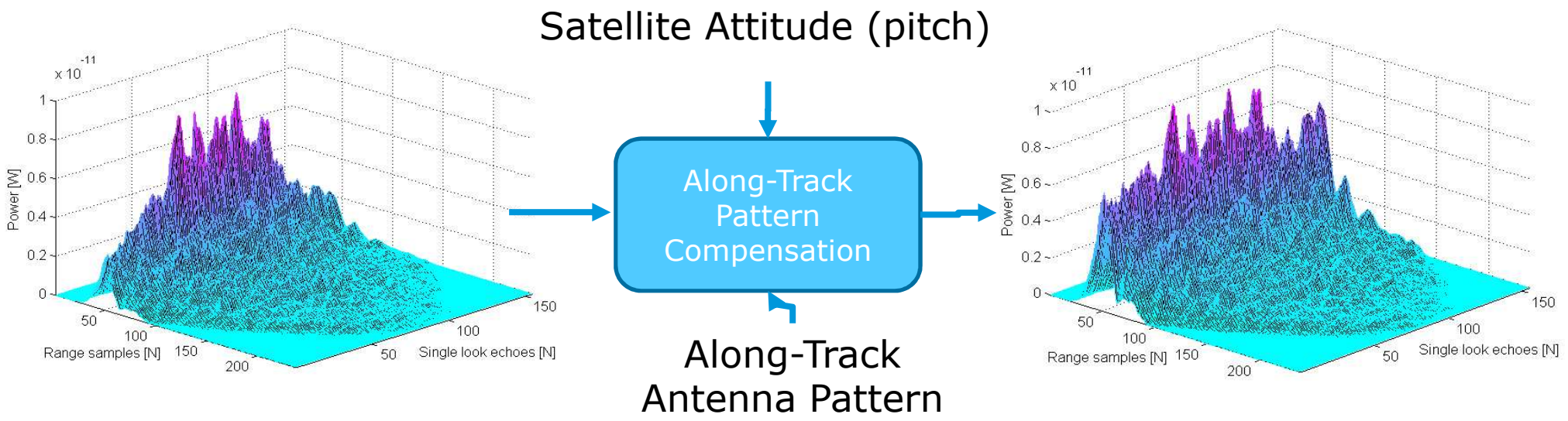


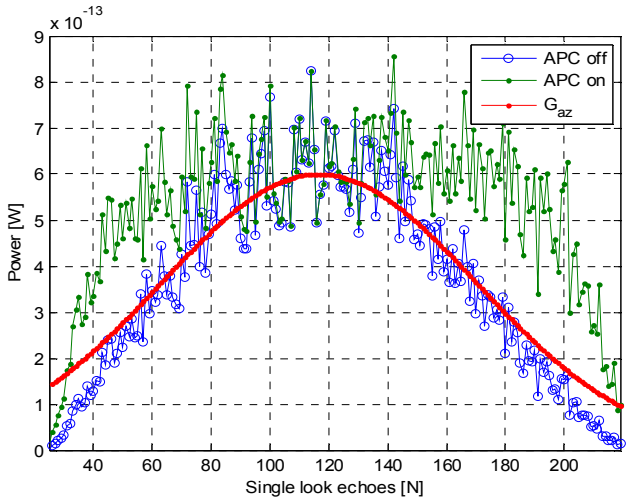
Range integration



being G_{az} the along-track antenna pattern

Along-Track Antenna Pattern Compensation (APC)





The speckle from all the single look echoes in the stack is raised approximately to the same power.
A better speckle reduction is expected.
In case APC is applied, Multilooked waveforms are built from ≈**180** Single Look Beams

Equivalent Number of Looks

As a metrics to evaluate the speckle reduction on the Multi-looked waveform, the ***Equivalent Number of Looks*** has been used

The ENL is the estimate of the effective number of statistically independent looks and it is expected to be smaller than the number of averaged single look echoes

$$ENL(\tau) = \frac{E[W(\tau)]^2}{Var[W(\tau)]}$$

being $W(\tau)$ the multilooked waveform

Theoretical ENL has been computed in case of CryoSat-2 for:

- Number of single look echoes in stack = 180
- SAR Standard Processing (i.e. no APC) ≈ 159
- SAR processing with APC ≈ 180

APC gives a theoretical improvement of about 13% on the ENL around the waveform peak

Expected Improvement in measurement noise

1. ***Range noise:*** the uncertainty on the range measure is function of the number of statistically independent looks (*N*)

2. Recalling that Range noise can be modeled as

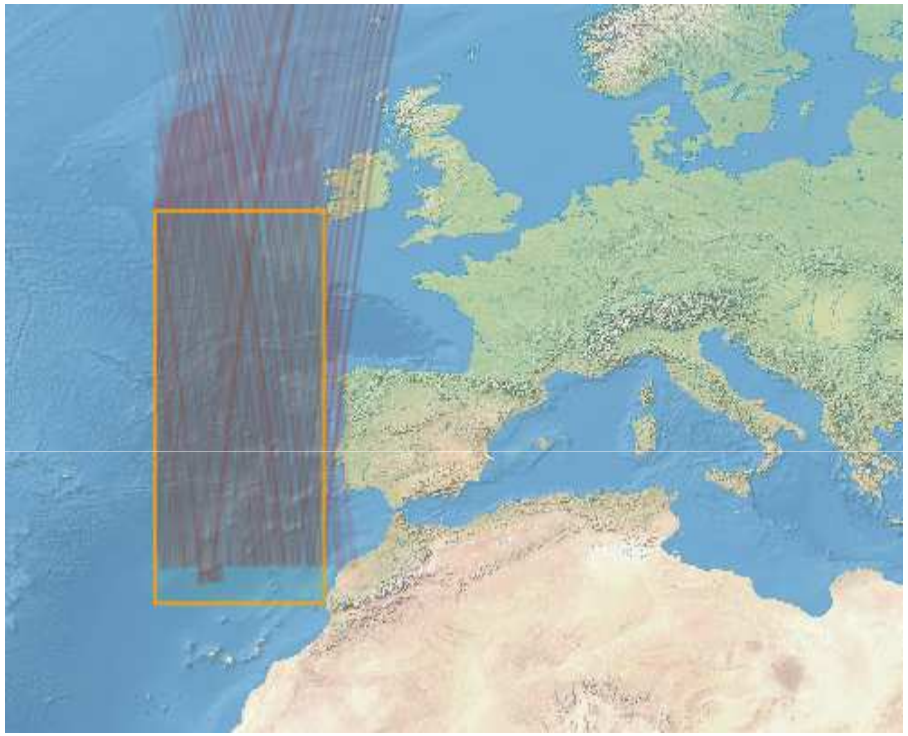
$$\sigma_h = \frac{\sigma_p}{0.8\sqrt{N_g \cdot N}}\left[1 + \frac{2}{SNR}\right]$$

Increasing the number of statistically independent looks (i.e. reducing the speckle noise) is expected to cause a decrease of the range noise

Region and Time of Interest

1620 CryoSat-2 SAR acquisitions in **5 years of mission** (2010/04->2015/08) over North-East Atlantic Ocean (no coastal data) have been processed in ESA-ESRIN GPOD CryoSat-2 service in order to produce 2 dataset to be compared:

- 20 Hz L1b & L2 Data with APC off
- 20 Hz L1b & L2 Data with APC on

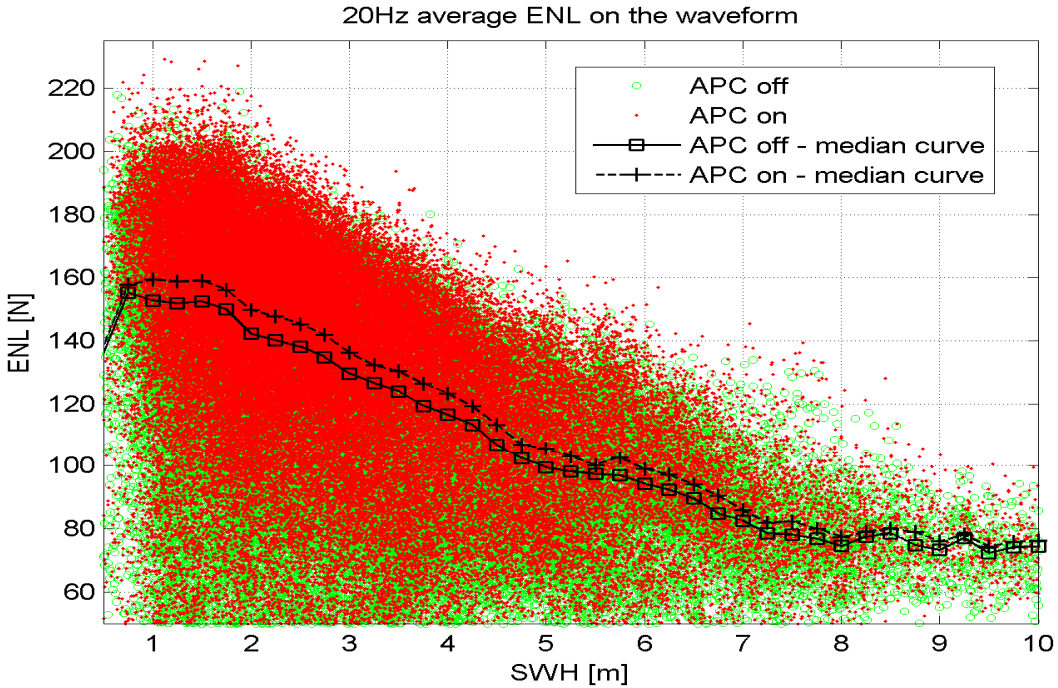


The performance of APC have been evaluated by comparison of the two datasets at:

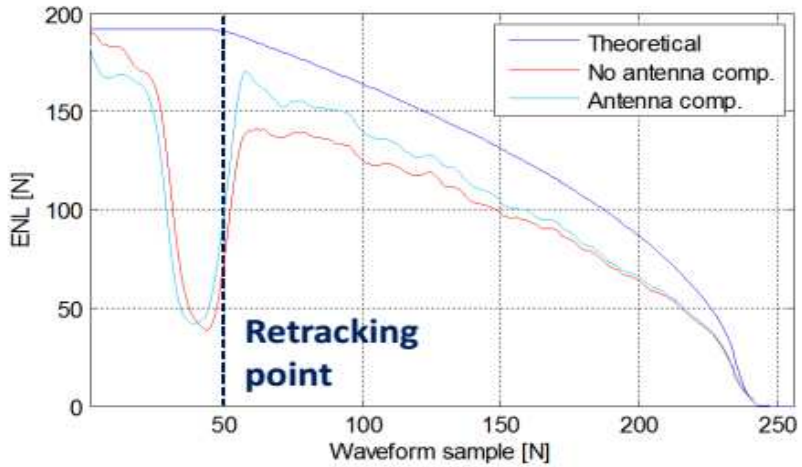
- Level1b (average ENL along the waveform)
- Level2 (SSH std, SWH std, Sigma0 std , Misfit plot, wave-number spectra)

RESULTS

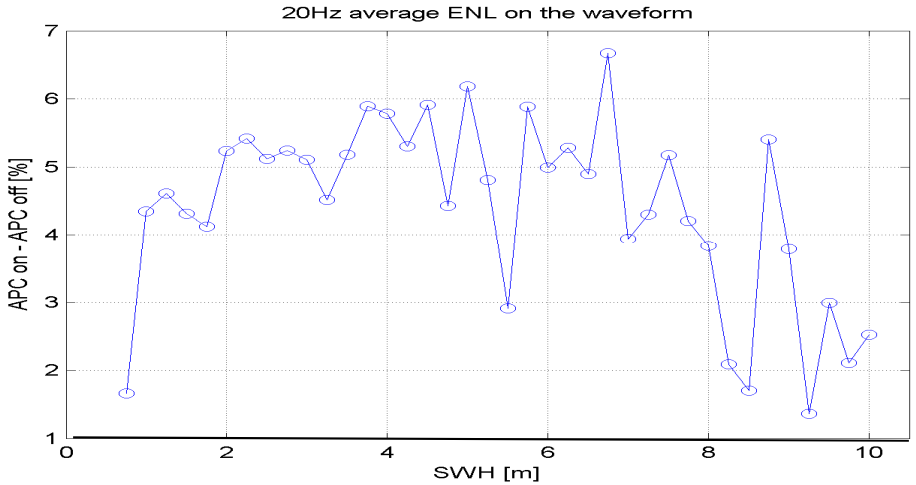
Average ENL on the 20Hz waveforms



- The ENL for APC on is always higher than that for APC off (increase about 5-6 %)
- The ENL is max for SWH approximately equal to 1 m
- The ENL decreases as SWH increases (expected behavior)

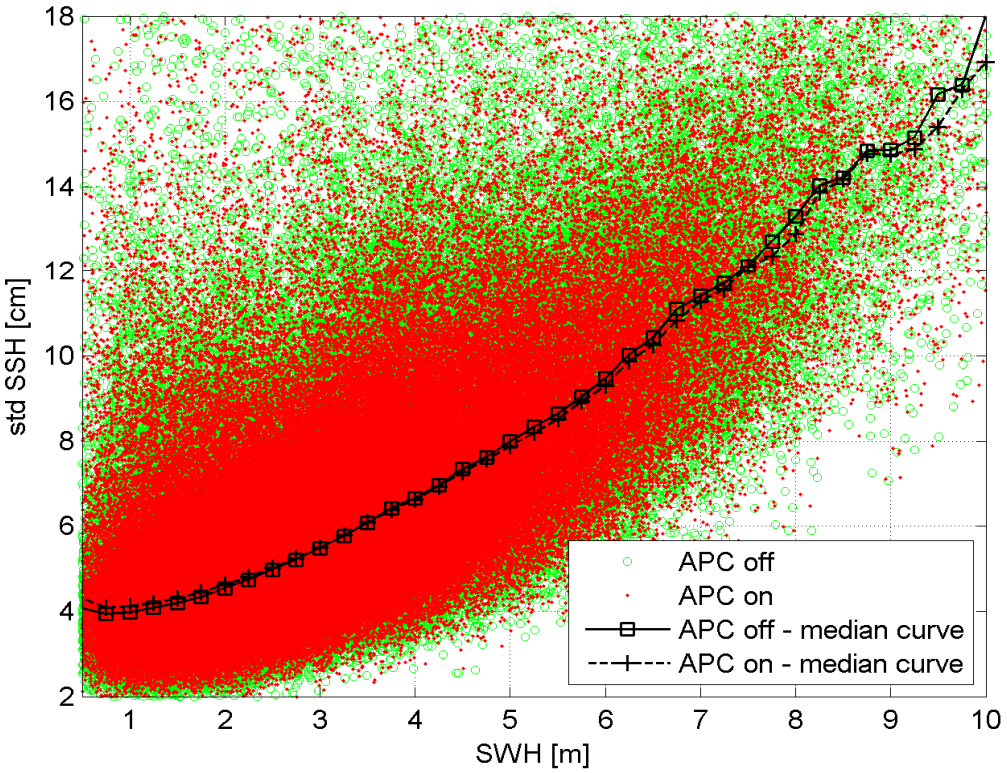


improvement

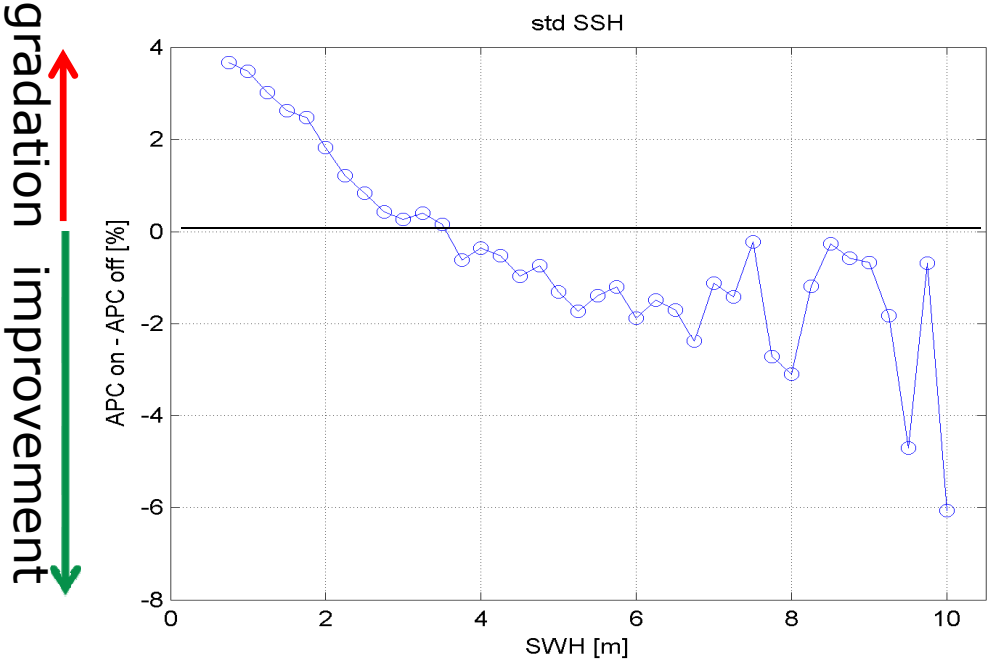


SSH Precision

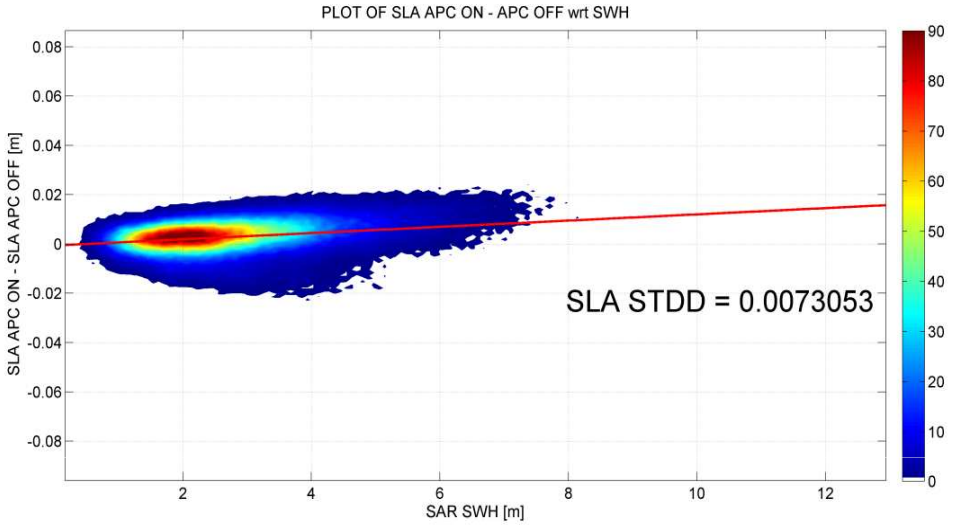
Using SAMOSA retracker on 20Hz waveforms and computing the 20 Hz SSH STD



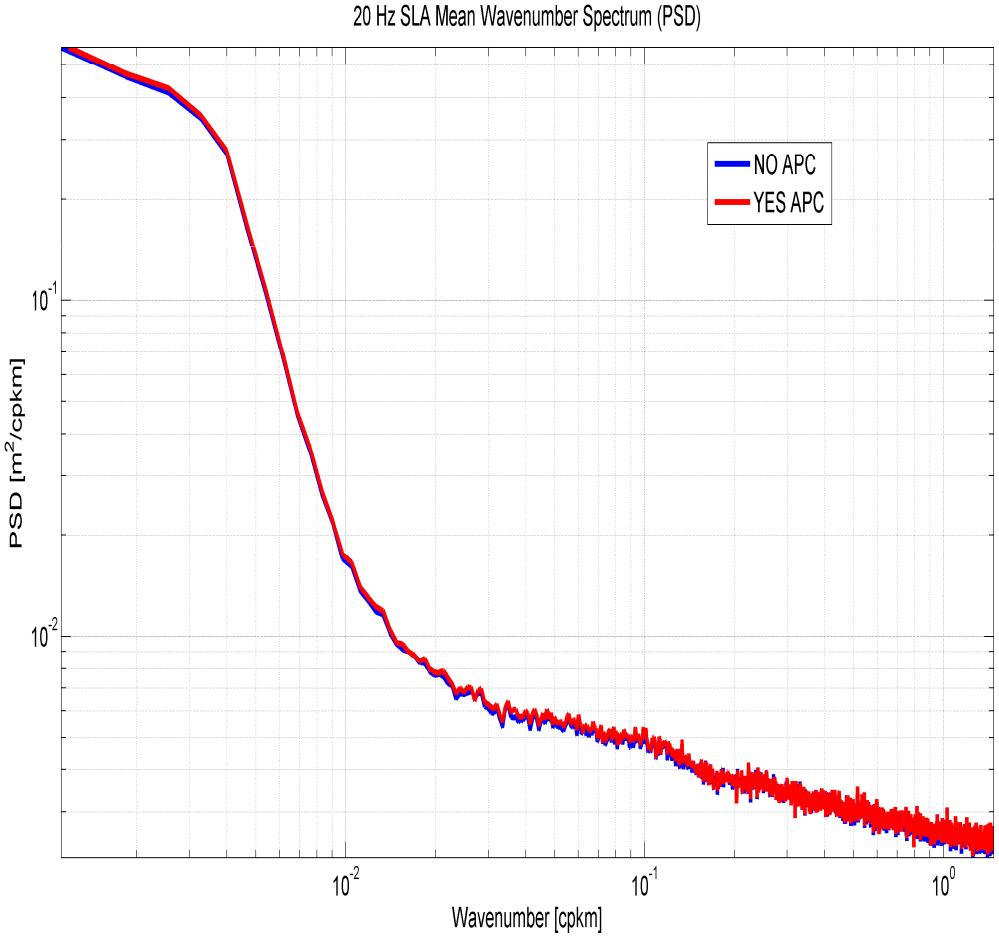
- SSH STD is an index of SSH precision
- SSH precision for APC ON is basically equivalent to that for APC ON



SSH Dispersion Plot & Wave Number SLA Spectrum

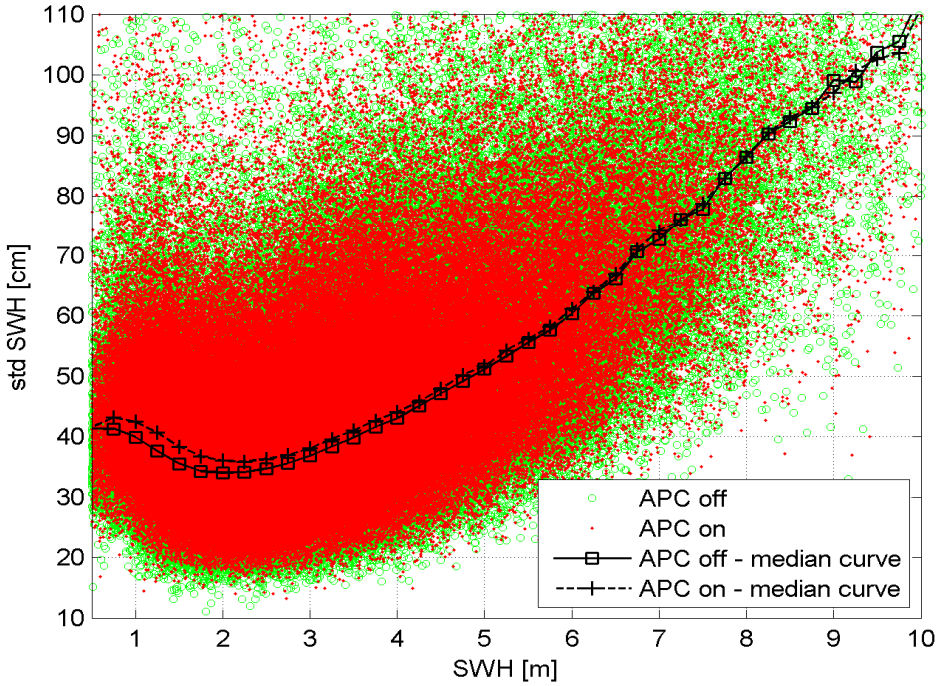


Wave Number SSH spectra with or without APC are equivalent, no major anomaly from the dispersion density plot

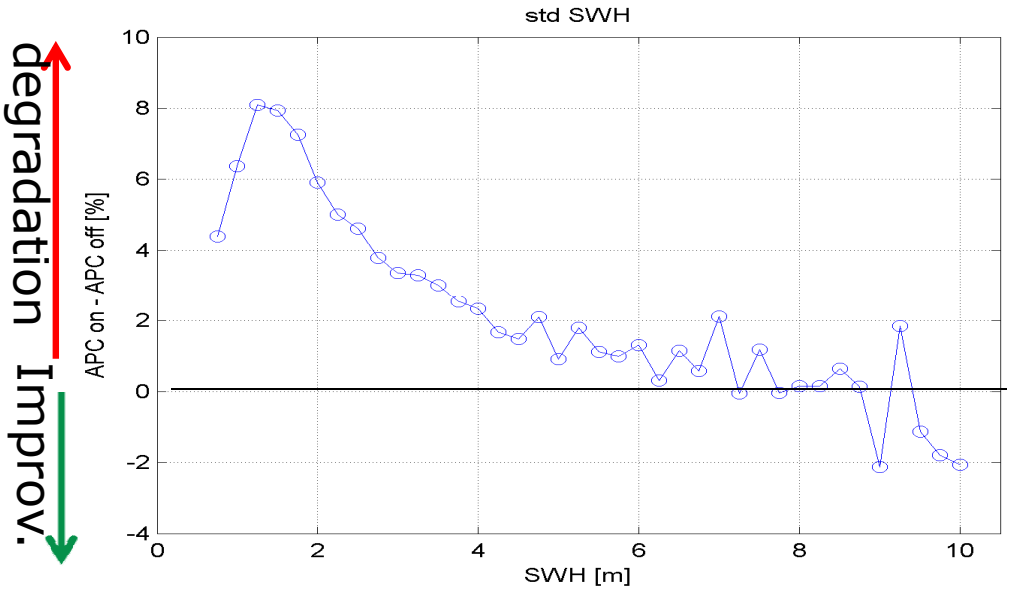


SWH Precision

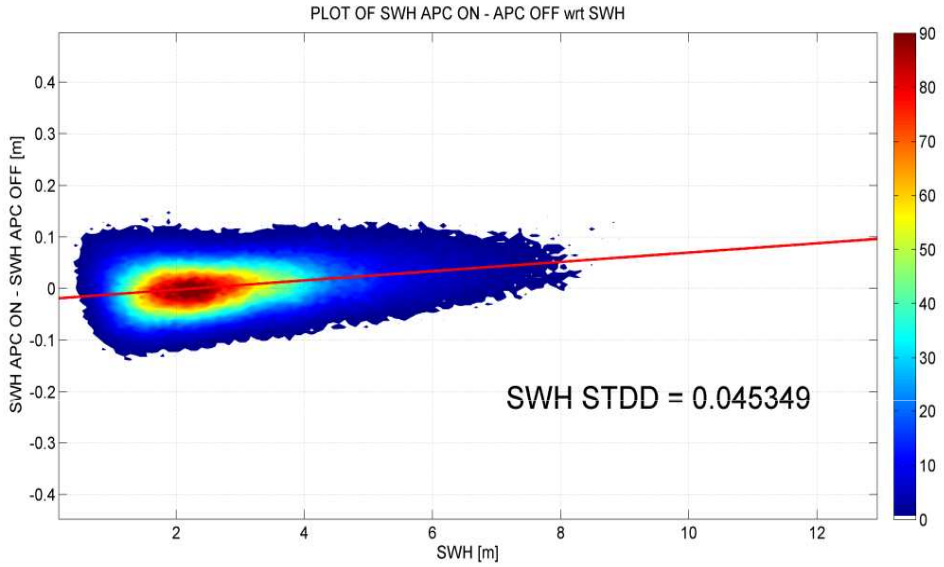
Using SAMOSA retracker on 20Hz waveforms and computing the 20 Hz SWH STD



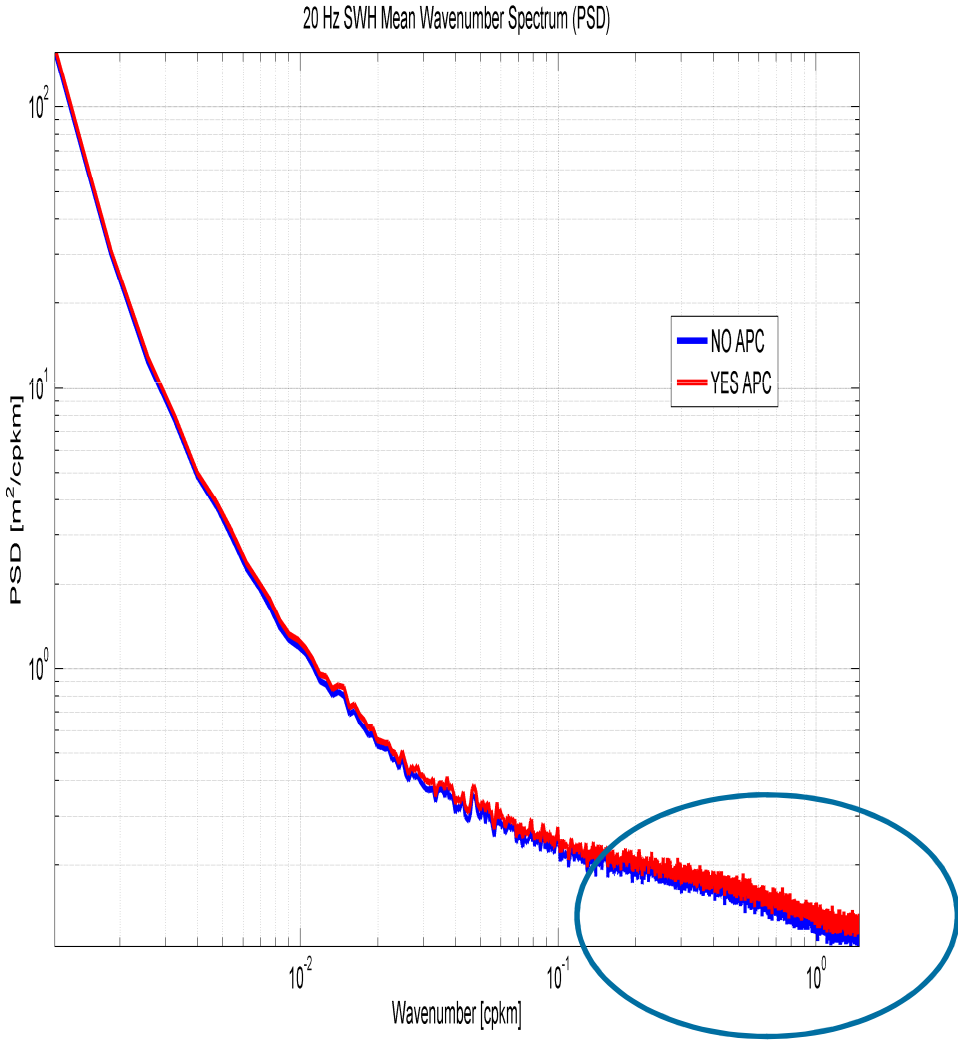
- SWH STD is an index of SWH precision
- The SWH precision for APC on is slightly worst than that for case APC off



SWH Dispersion Plot & Wave Number SWH Spectrum

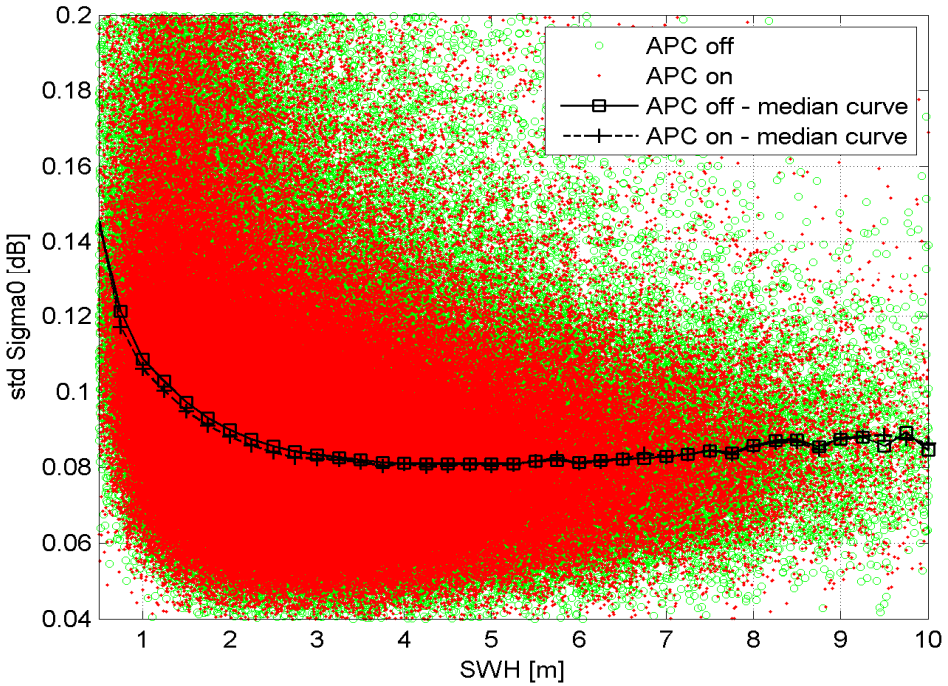


Wave Number SWH spectra with APC ON is **slightly** degraded (in term of spectral noise), no major anomaly from the dispersion density plot



Sigma0 Precision

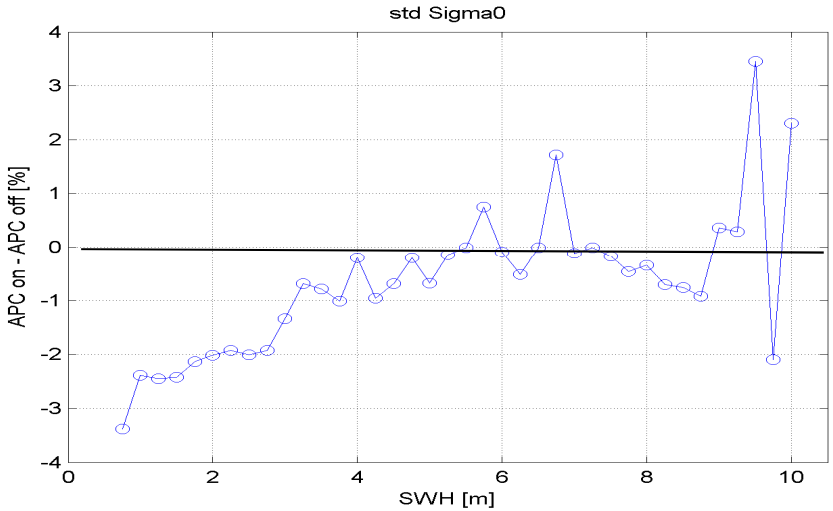
Using SAMOSA retracker on 20Hz waveforms and computing the 20 Hz Sigma 0 STD



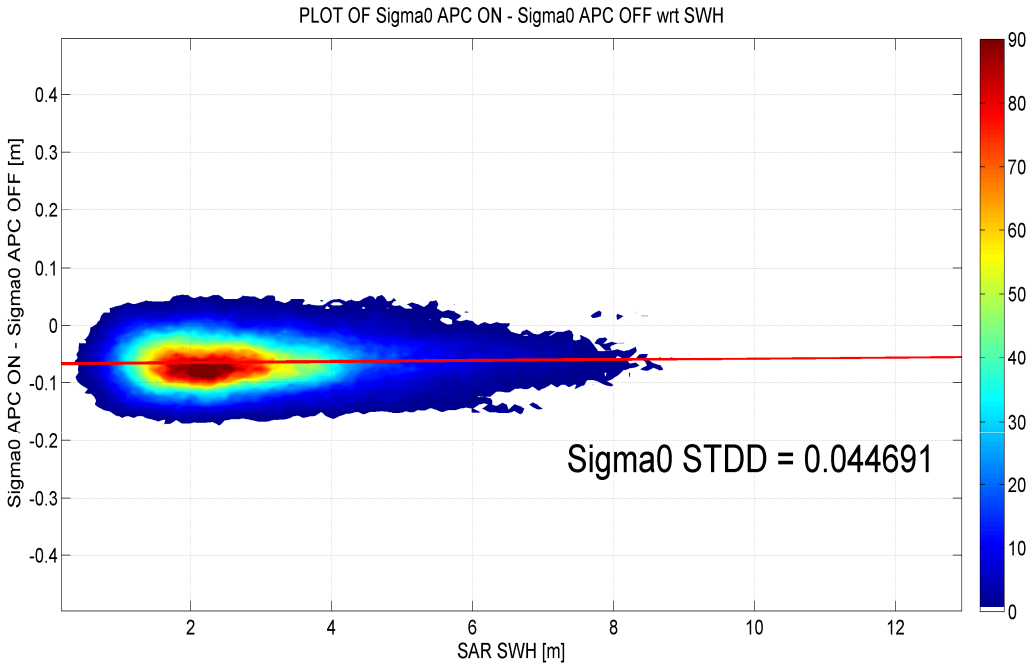
- Sigma 0 STD is an index of Sigma0 precision
- The Sigma0 precision for APC on is better than that for APC off, at any SWH

degradation

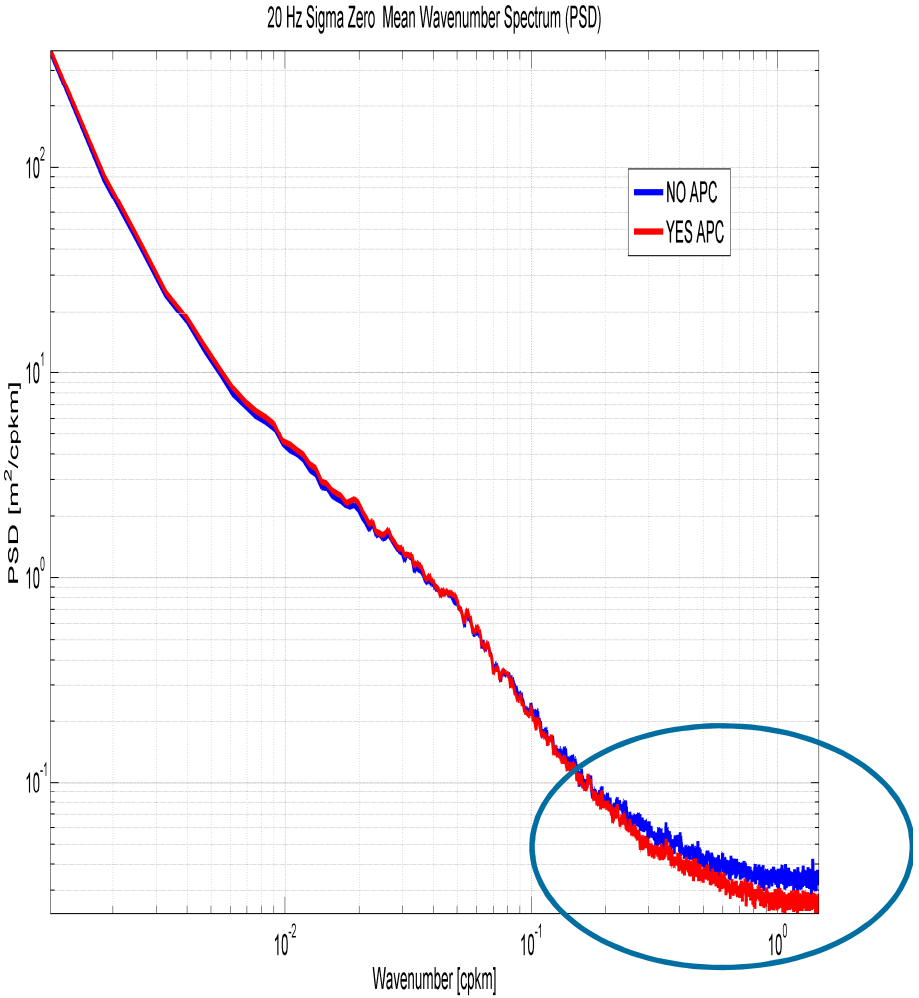
Improv.



Sigma0 Dispersion Plot & Wave Number Sigma0 Spectrum

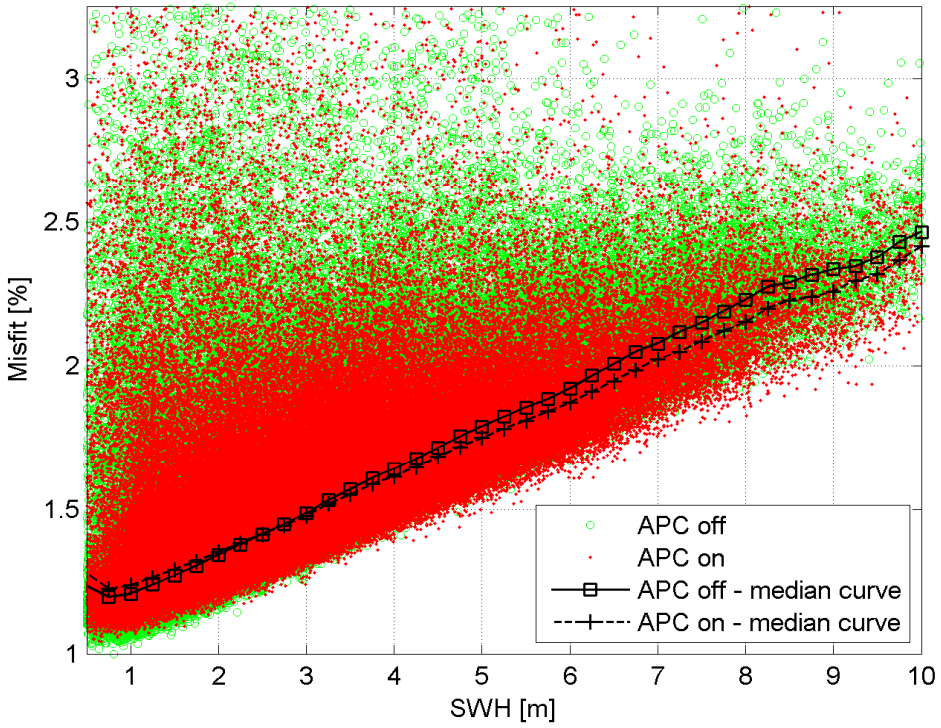


Wave-Number Sigma0 spectrum with APC ON shows lower spectral noise , no major anomaly from the dispersion density plot a part for a static bias (0.07 db)

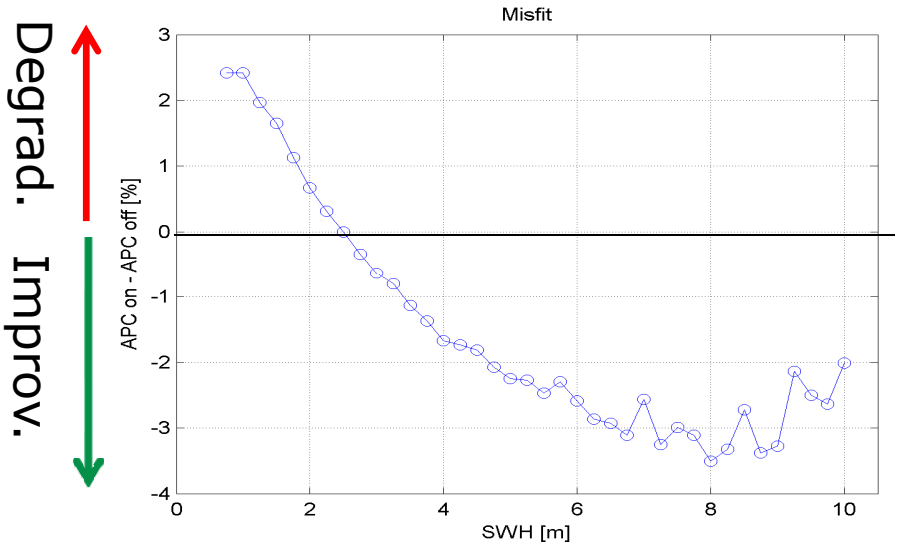


Misfit between Waveform and Model

Using SAMOSA retracker on 20Hz waveforms and computing misfit between waveform model and waveform data



- Misfit, i.e. the RMSE between the 20Hz waveform and the model waveform
- The misfit for APC on is lower than that for APC off for high SWH and higher for low SWH



Conclusions and Way Forward

1. Along-track antenna pattern compensation has been presented as a technique in SAR altimetry processing to increase the speckle reduction
2. From experimental results, it has been verified that APC leads to:
    a. An **increase** of the number of statistically independent looks (i.e. a speckle reduction) on the 20Hz multi-looked waveforms
    b. An **improvement** on Level2 parameters strictly related to the radiometric accuracy (i.e. Sigma0)
    c. No clear improvement on SSH and **slightly degradation** for SWH
3. APC performance can be still improved working on:
    1. Along-track antenna pattern model
    2. Increasing the accuracy of pitch information

For more details, refer to *"An Extended Analysis Of Along-track Antenna Pattern Compensation For SAR Altimetry"* M. Scagliola; S. Dinardo; M. Fornari; to be included in proceedings of IGARSS 2015