

Towards the Optimization of SAR Altimetry Processing Over the Open Ocean

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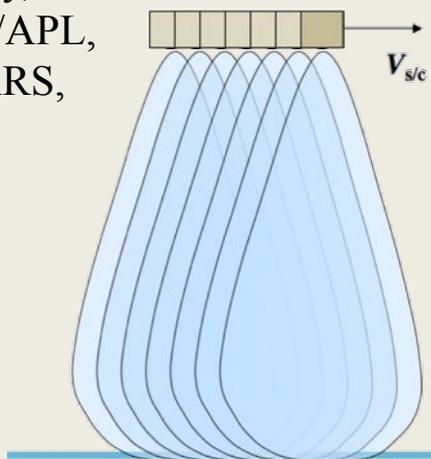
(3) UMD, United States



From Conventional to Focused SAR Altimetry

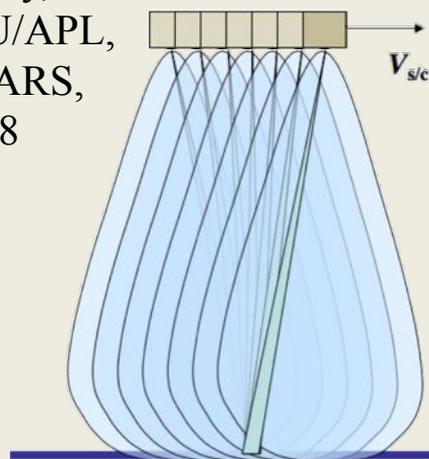
Conventional Altimeter

Image K.
Raney,
JHU/APL,
TGARS,
1998

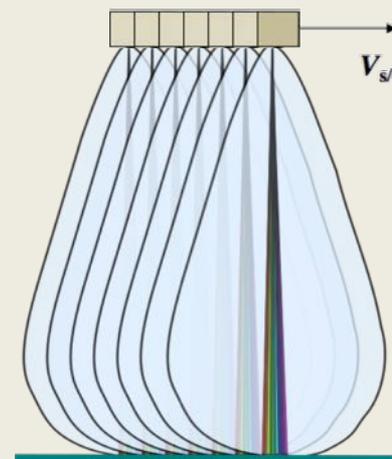


Delay-Doppler Altimeter

Image K.
Raney,
JHU/APL,
TGARS,
1998



Focused SAR Altimeter



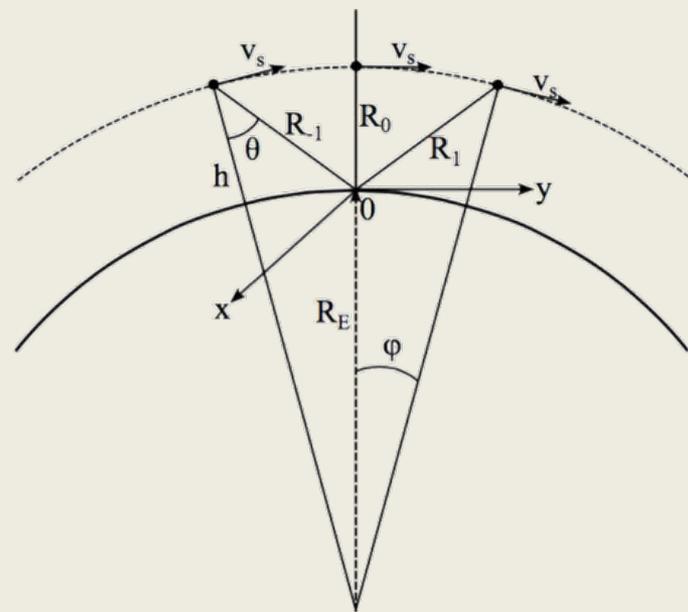
- Low Resolution Mode
- Pulse limited footprint (circular)
- 1.5 / 5 km res. depending on SWH
- Open burst operation
- PRF ~ 2 kHz
- ENL ~ 2000 looks/sec

- Unfocused SAR processing
- ~300 m resolution Along-Track
- Pulse limited across-track
- Closed Burst
- PRF ~ 18 KHz
- ENL ~ 2700-4000 looks/sec

- Fully Focused SAR processing
- Coherent processing for ~2 seconds
- Resolution Along-Track ~ 0.5 m
- Pulse limited across-track
- Closed/Open Burst
- PRF ~ 18 KHz
- ENL ~ 14000 looks/sec

Basics of FF-SAR Altimetry processing

- The Synthetic Aperture Radar (SAR) processing technique combines *coherently* the response of a single point on the surface during its entire illumination time by the radar.
- The target is processed with a synthetic “aperture” of several km.
- The achievable resolution is $L/2$, L = antenna length.
- Coherent processing both range migration and phase change correction occurring over the entire “aperture” (time when a point on the ground is visible to the radar, about 2 seconds, more than 10,000 pulse echoes). The resulting $\Delta x \approx 0.5$ m.
- The technique can be applied to any kind of SAR Altimeter, provided that the radar is coherent.
- Description of mathematical formulation, details of the processing, and application examples in [1].



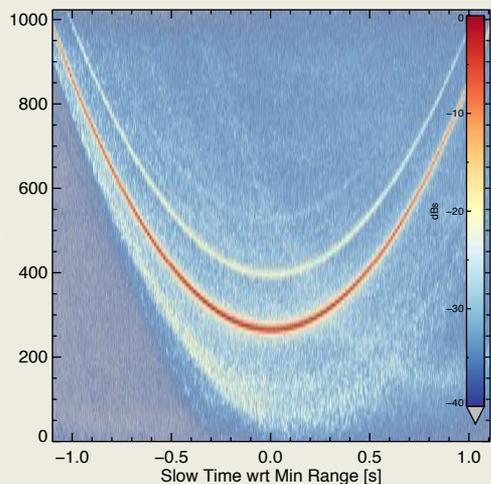
[1]: [IEEE TRANSACTIONS ON GEOSCIENCE AND REMOTE SENSING](#)

Fully Focused SAR Altimetry: Theory and Applications

Alejandro Egido, *Member, IEEE*, and Walter H. F. Smith

Basics of FF-SAR Altimetry processing

We demonstrated the FF-SAR Altimetry processing using CryoSat-2 FBR SAR Mode data over transponders, [1]:



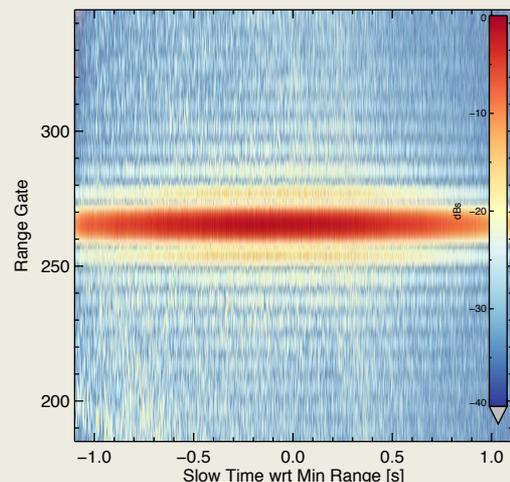
Data from CS2 over Svalbard TRP on 2014-05-06.
Range gates 8x over-sampled (128 zero-padded to 1024)

Range Curvature Migration Correction

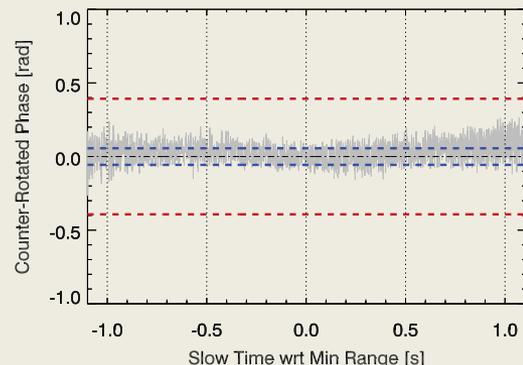
Range curvature migration correction (RCMC) removes the motion of a point on the ground as it appears in the radar's range window to align all echoes of all bursts on a common range delay.

Phase Migration Correction accounts for phase variations due to range and second order pulse compression effects (Residual Video Phase).

When phase is unwrapped the residual error is ~ 0.06 radian implies that the RMS range error in range amounts to ~ 0.1 mm !!



Phase Migration Correction

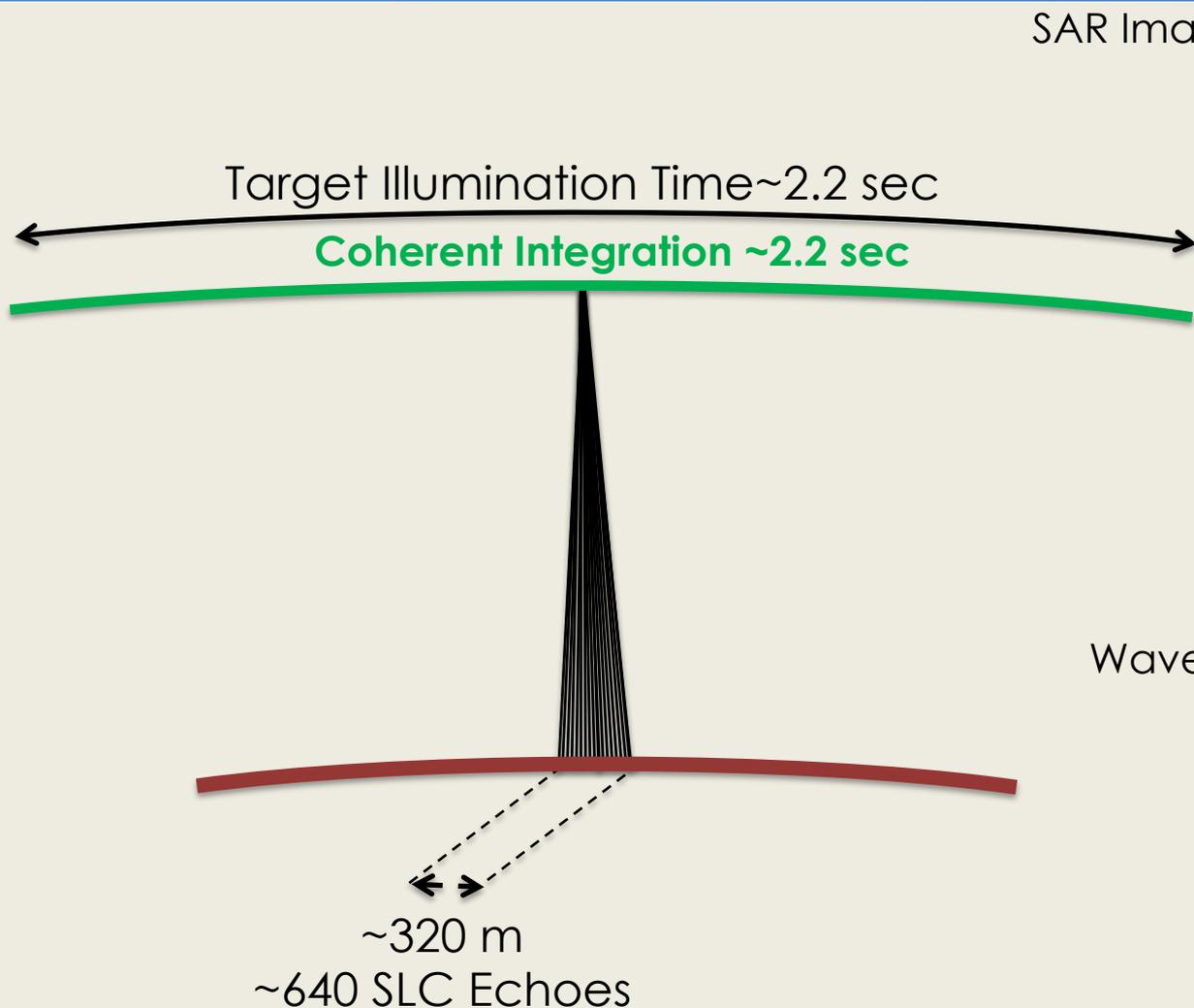


[1]: Fully Focused SAR Altimetry:
Theory and Applications

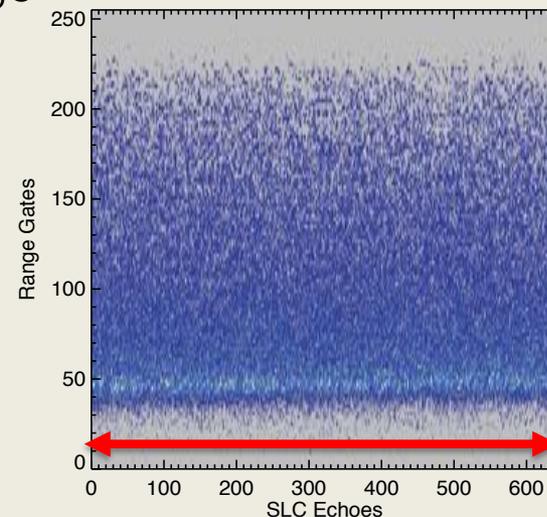
Alejandro Ezido, *Member, IEEE*, and Walter H. F. Smith

THANKS, SIRAL 😊

Fully Focused SAR Processing

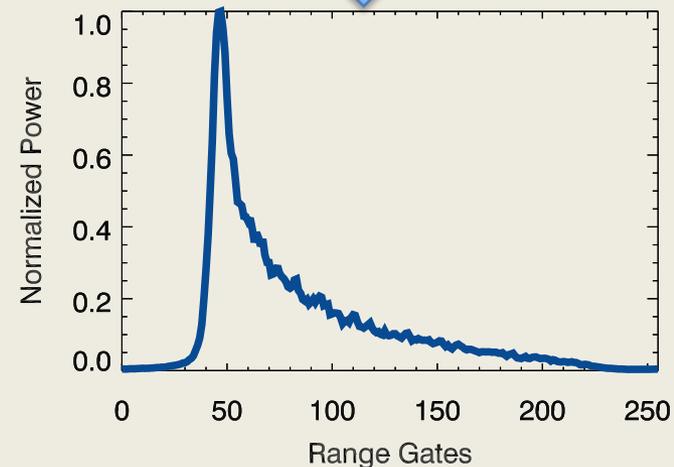


SAR Image

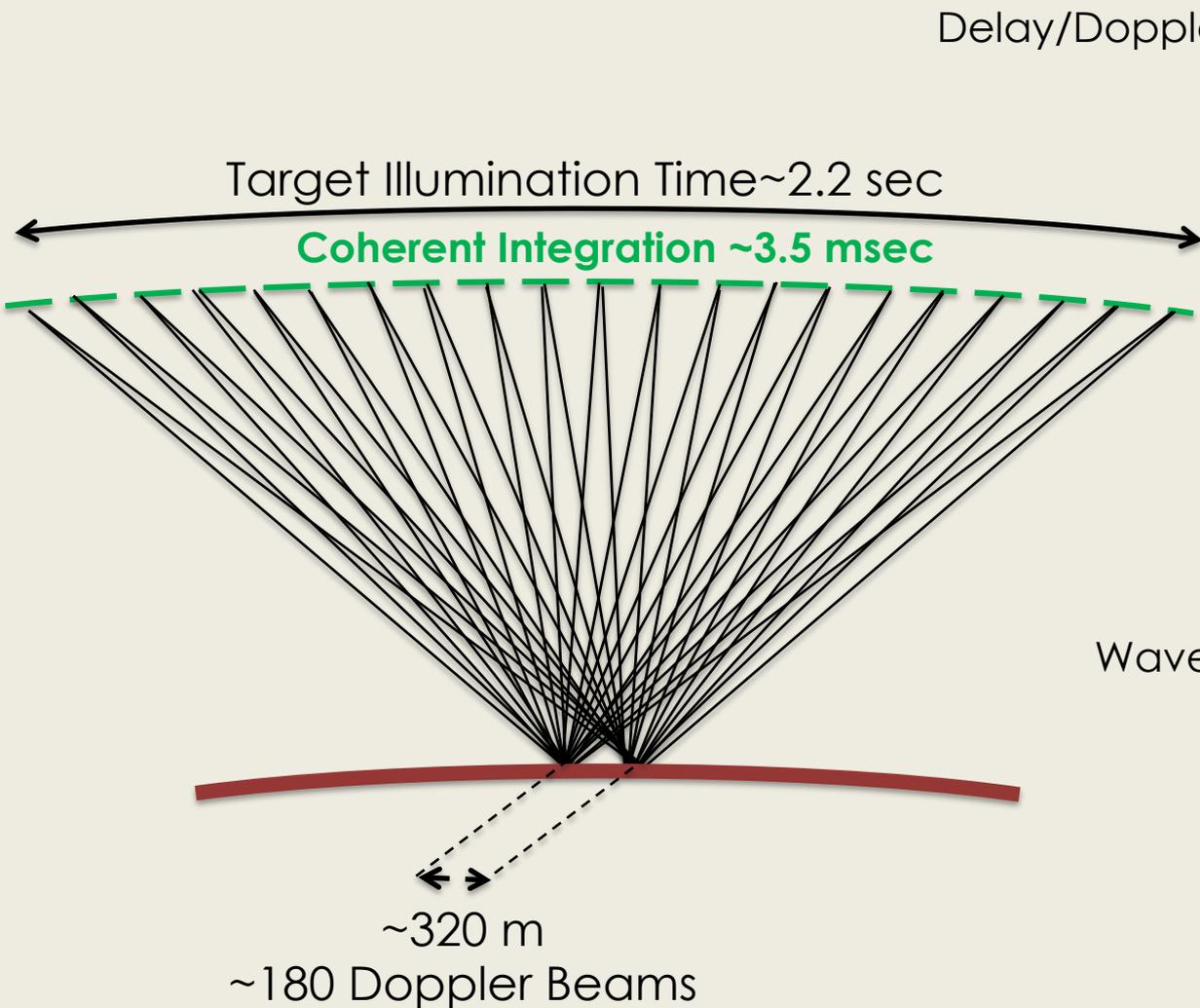


Multilooking

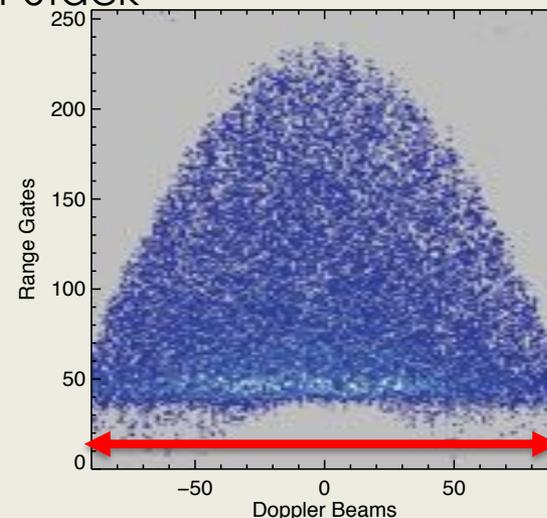
Waveform



Delay/Doppler Processing



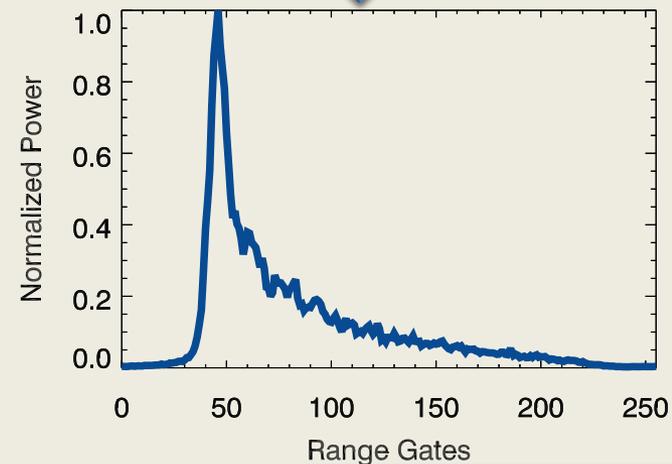
Delay/Doppler Stack



Multilooking



Waveform



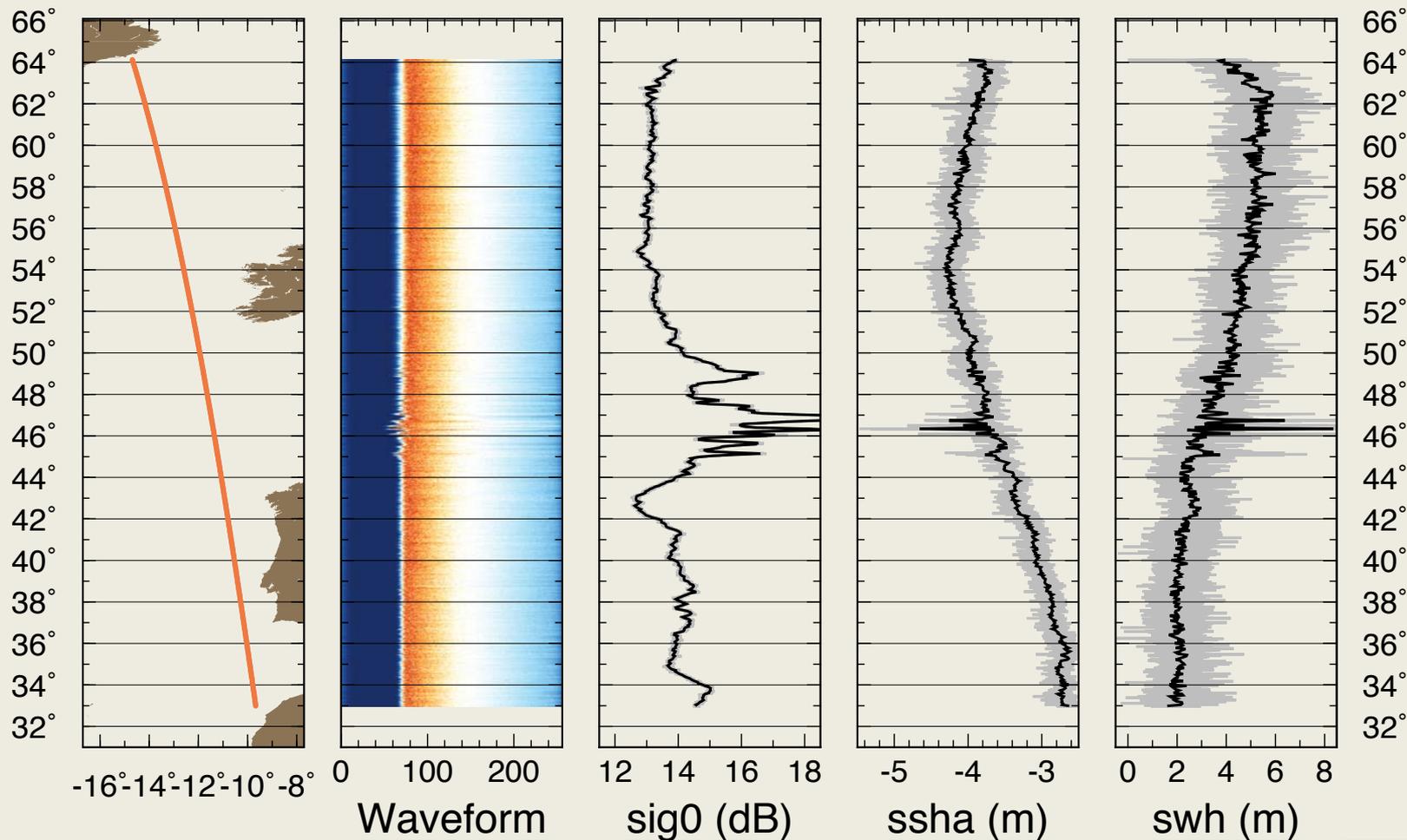


NOAA LSA SAR-Altimetry Processor

- SAR altimetry data processor developed in-house
- IDL Code pre-operational processor
- Sentinel-3 and Cryosat-2 capable
- Generation of experimental L1 and L2 data products in netcdf
- Great flexibility of configuration options:
 - Focused and unfocused (delay/Doppler) processing
 - Configurable coherent integration time
 - Windowing Along- Across- track
 - Configurable Zero-Padding
 - Zero Doppler focusing & timing bias adjustments
 - Configurable posting rate and multi-looking
 - Amplitude Compensation/ Delay Compensation
 - Modified SAMOSA retracker
- Optimized use of computational resources:
 - Memory efficient coding
 - Modular code...possibility to include further options in the future
 - New processing method for focusing improves speed by ~2 orders of magnitude.
 - Current speed...about 10 times real-time per CPU thread.
- To be installed in GPOD shortly!

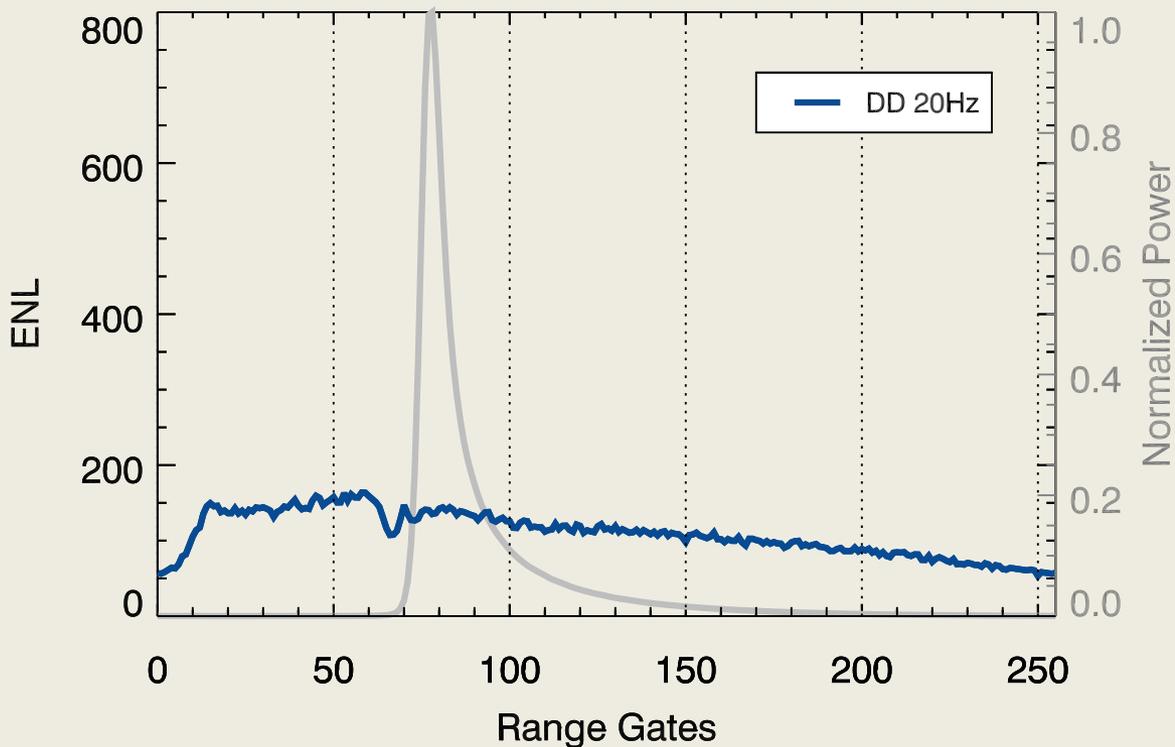
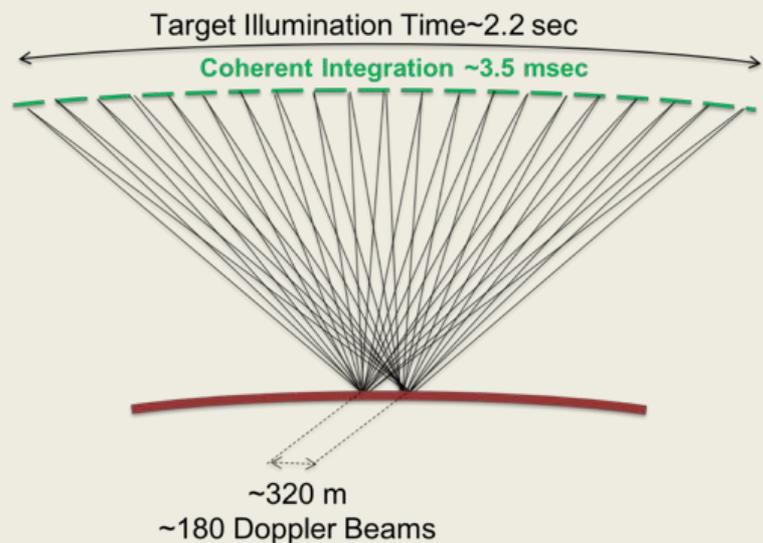
Effective Number of Looks Analysis

- Use of different processing configurations (FFSAR, dD, windows...)
- Data used: CryoSat-2 SAR Mode Baseline-C track over North-East Atlantic.
 - CS_LTA__SIR1SAR_FR_20120107T225227_20120107T230104_C001



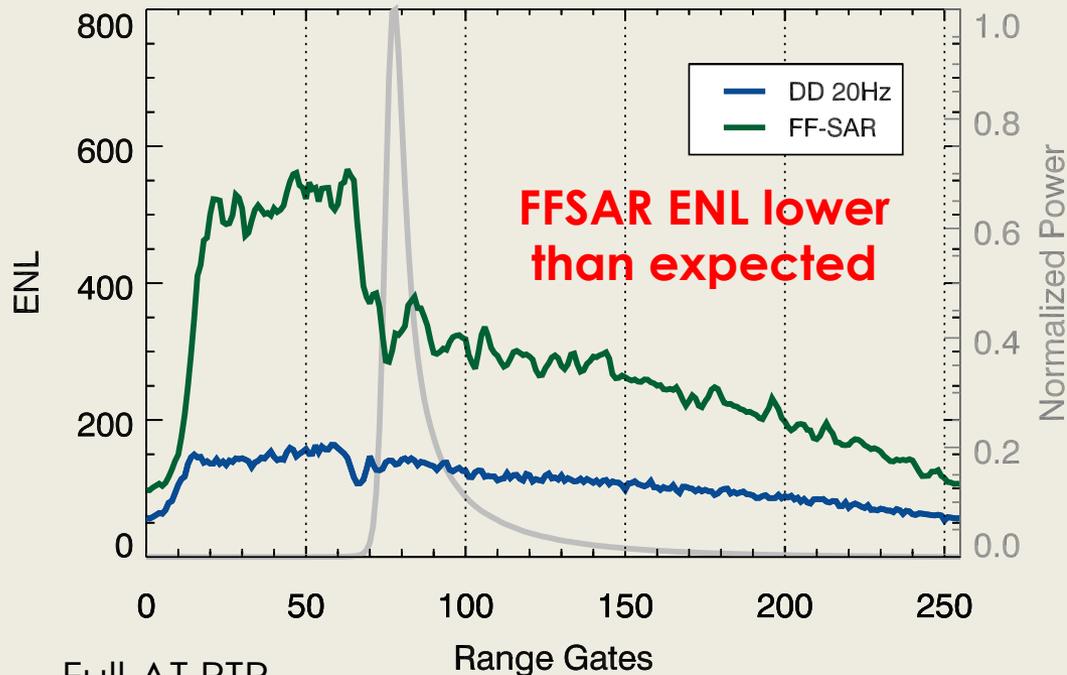
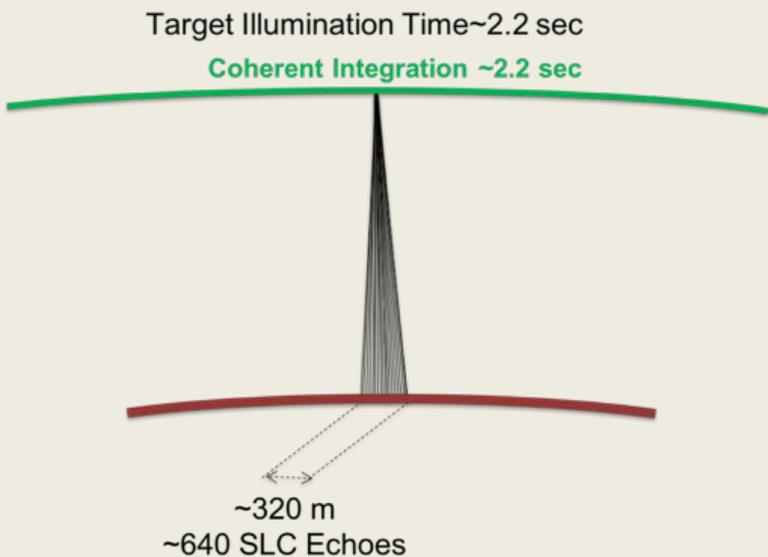
Effective Number of Looks Analysis

delay/Doppler Processing @ 20 Hz

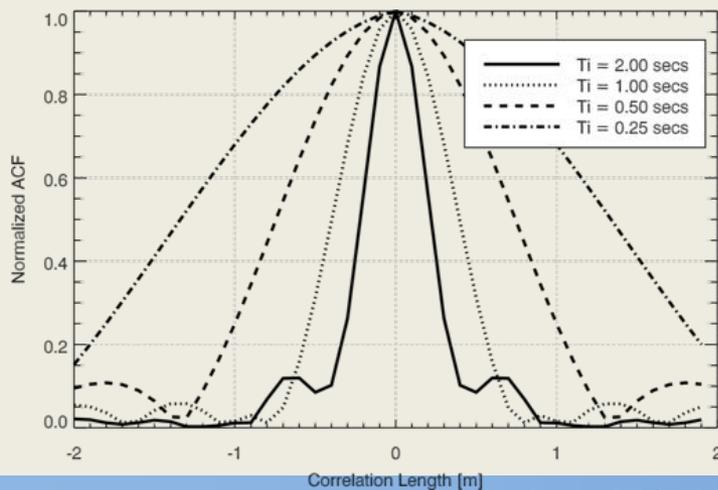


Effective Number of Looks Analysis

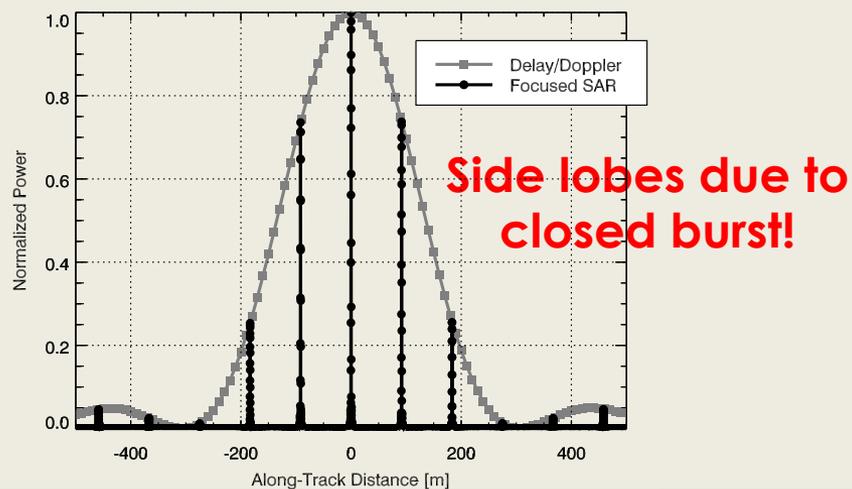
Fully Focused SAR Processing



Speckle Noise ACF (Wf peak)



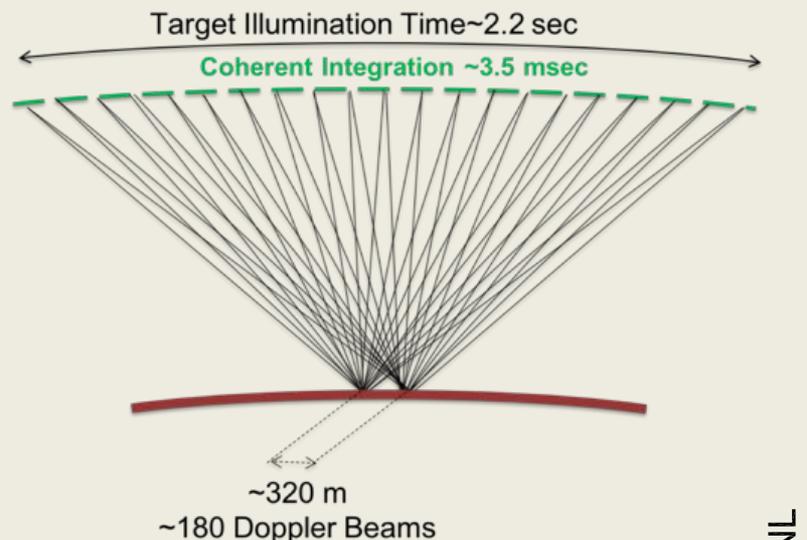
Full AT PTR



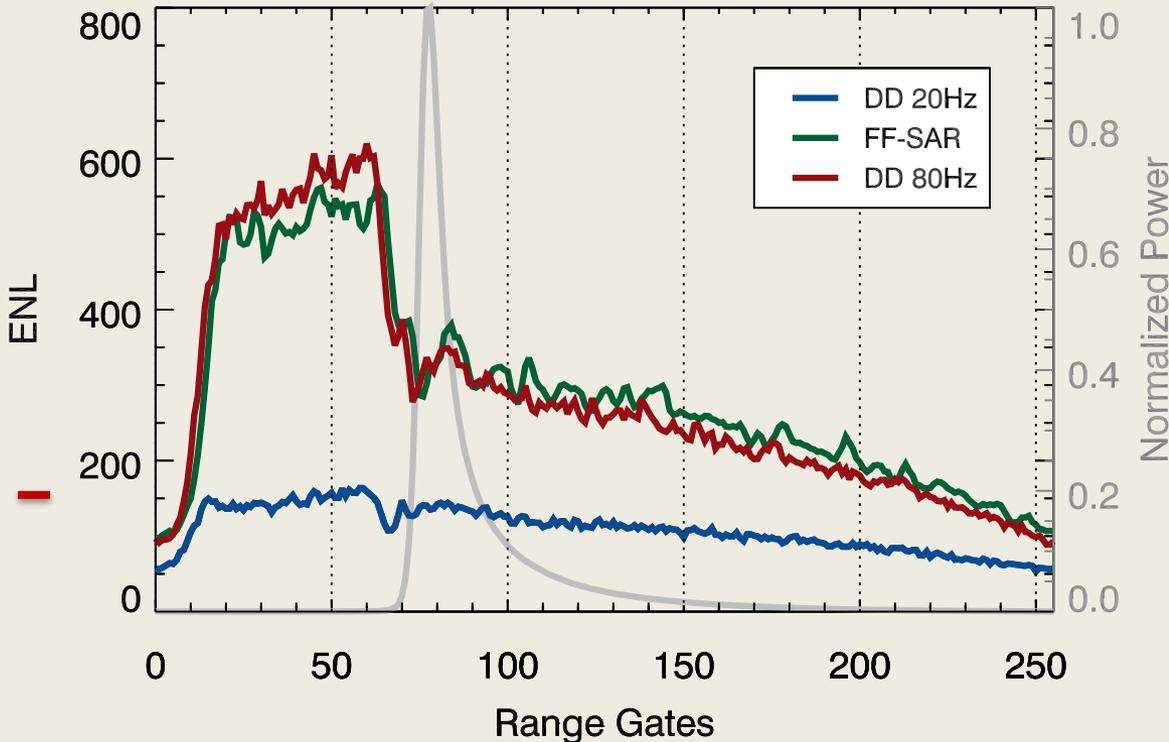
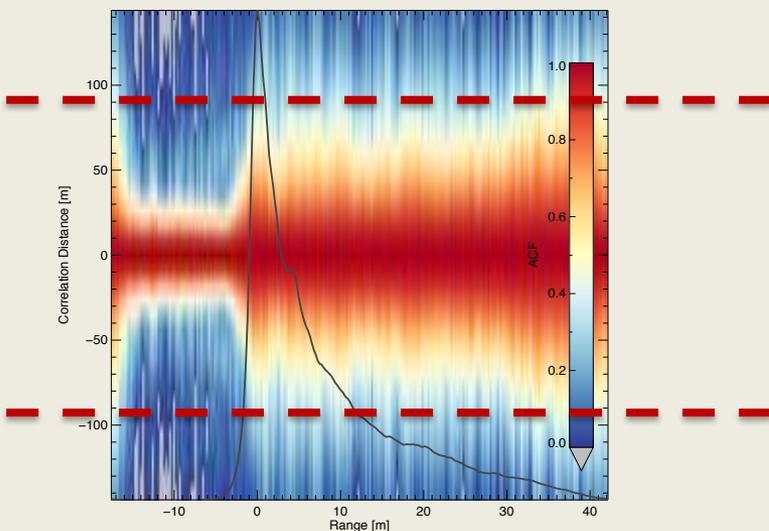
Effective Number of Looks Analysis

delay/Doppler Processing @ 80 Hz

SAR Altimetry @ 80 Hz
Salvatore Dinardo, et al
CAW-7



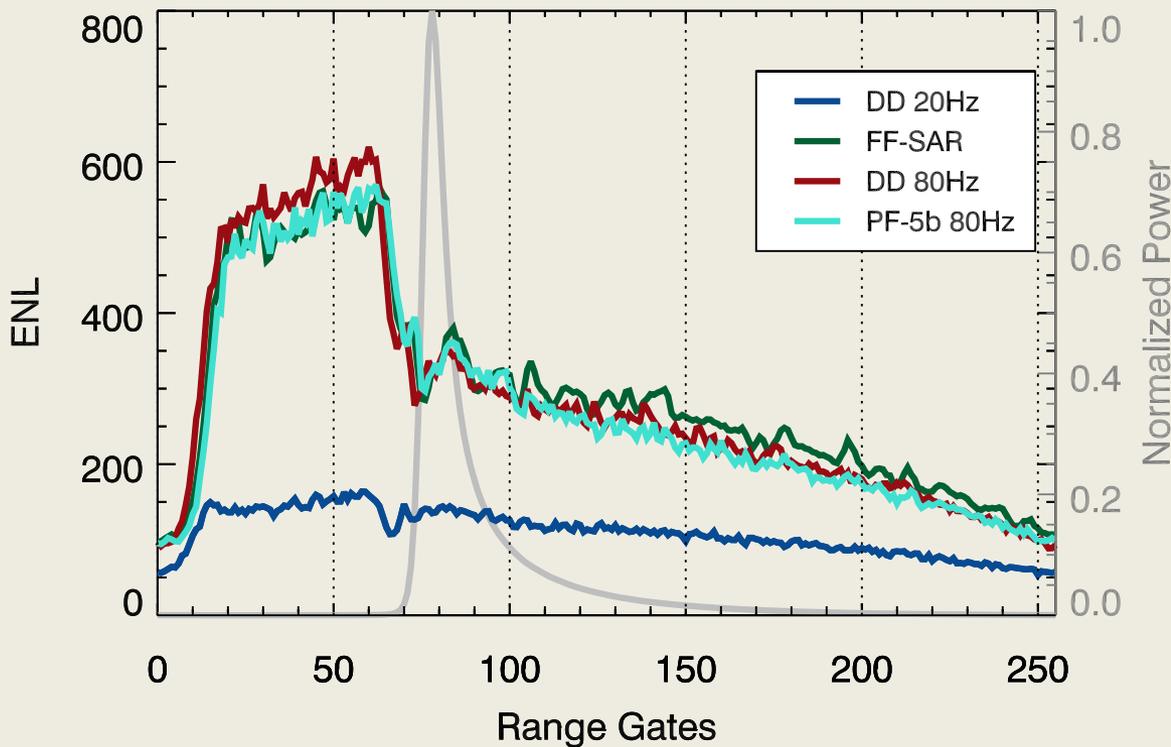
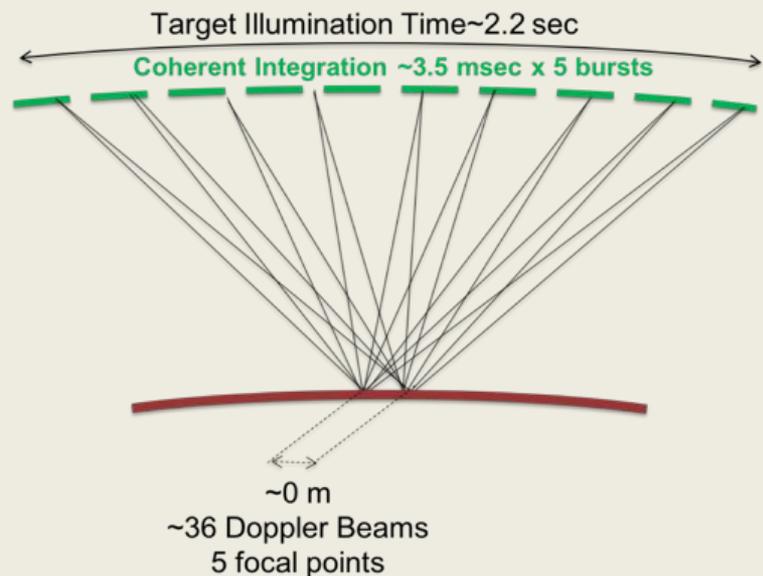
Speckle Noise ACF



Decorrelation distance is much shorter than along-track resolution!

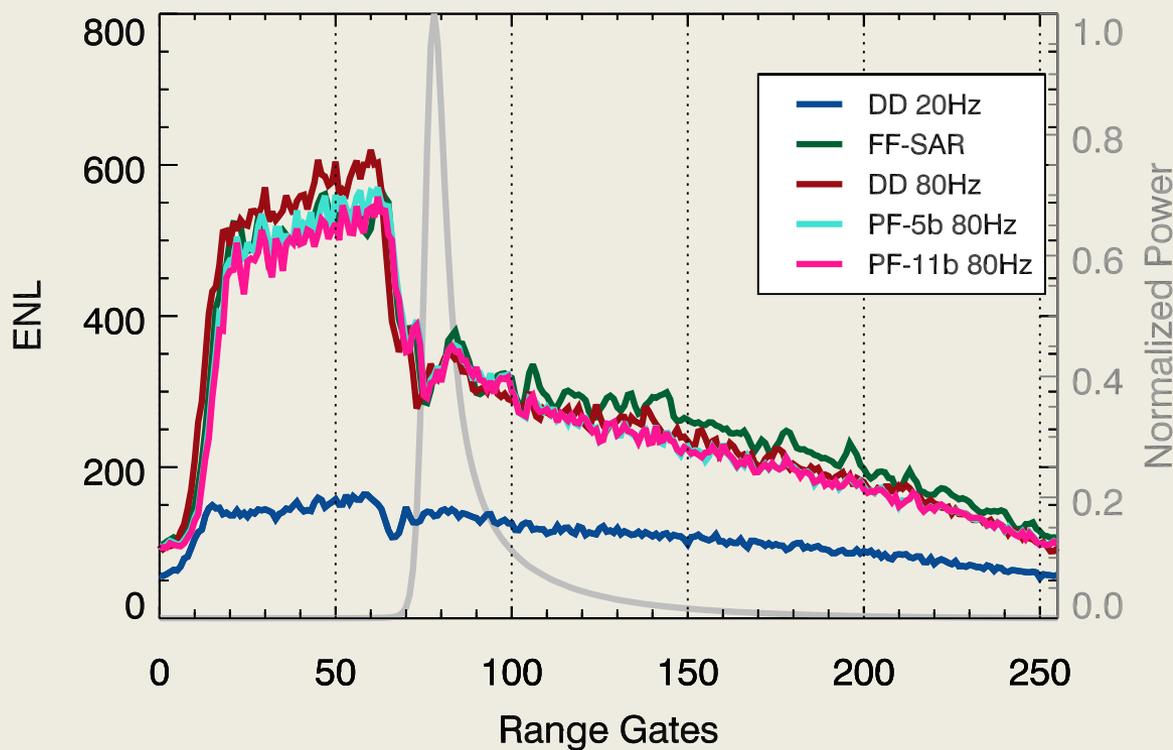
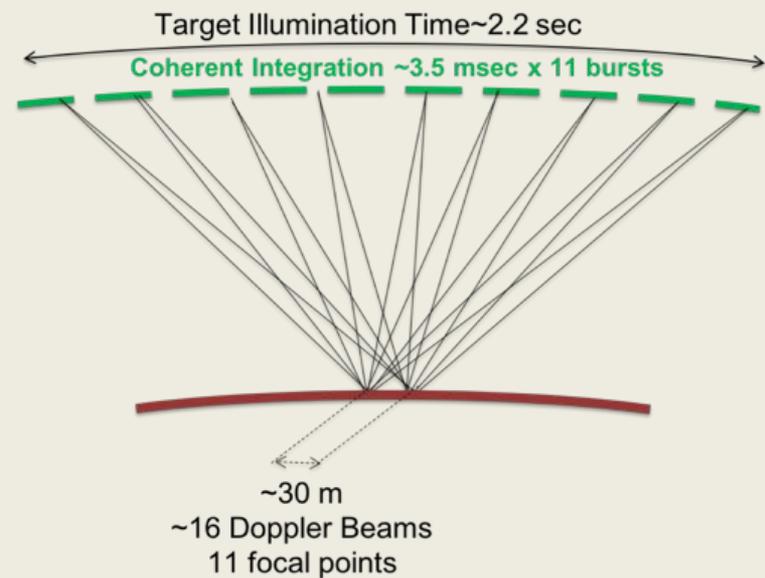
Effective Number of Looks Analysis

5 bursts Partial Focusing @ 80 Hz



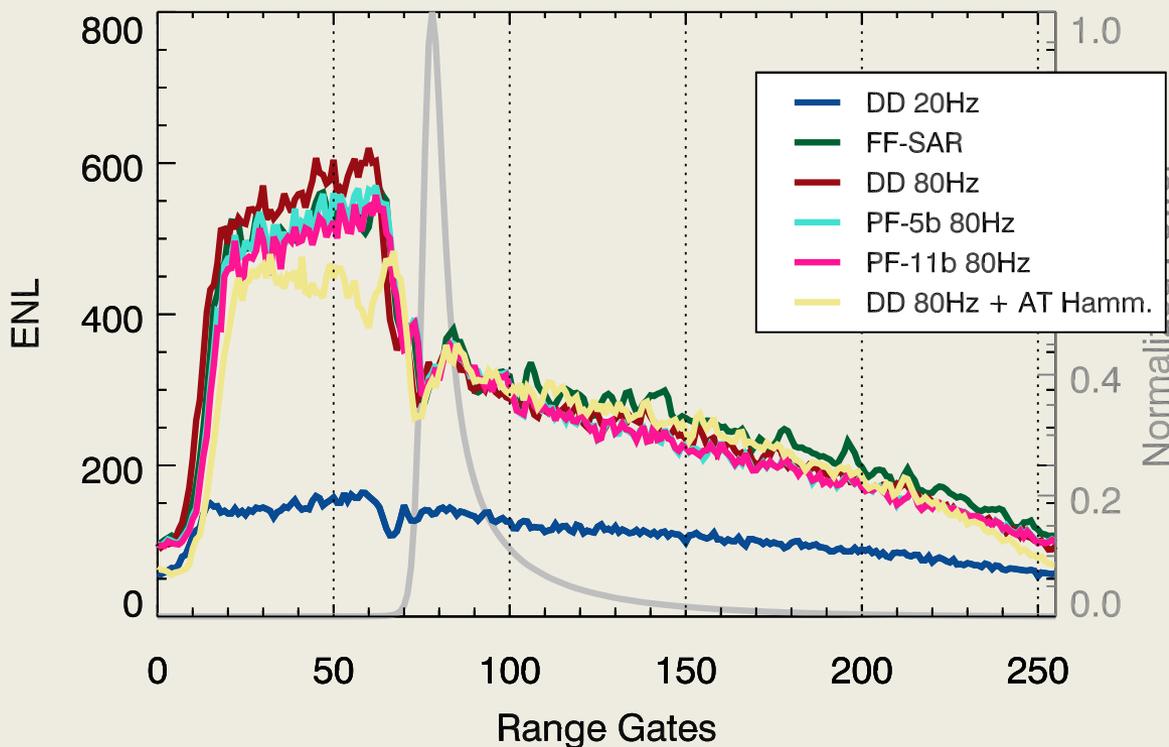
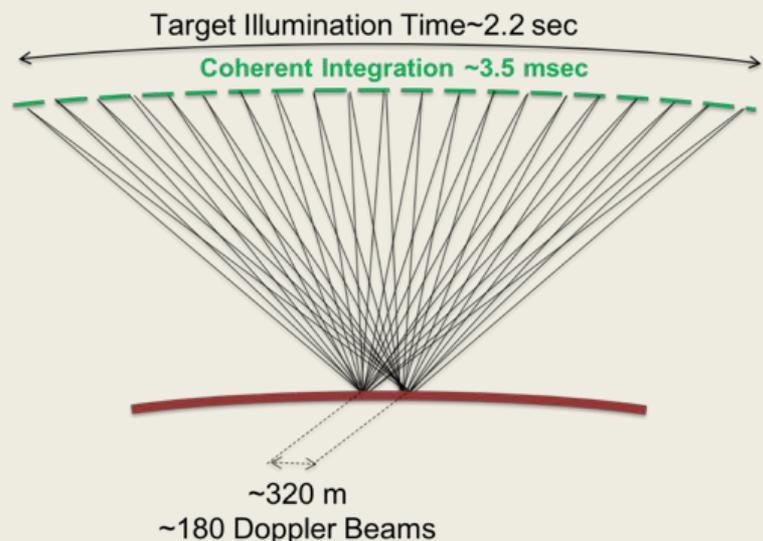
Effective Number of Looks Analysis

11 bursts Partial Focusing @ 80 Hz



Effective Number of Looks Analysis

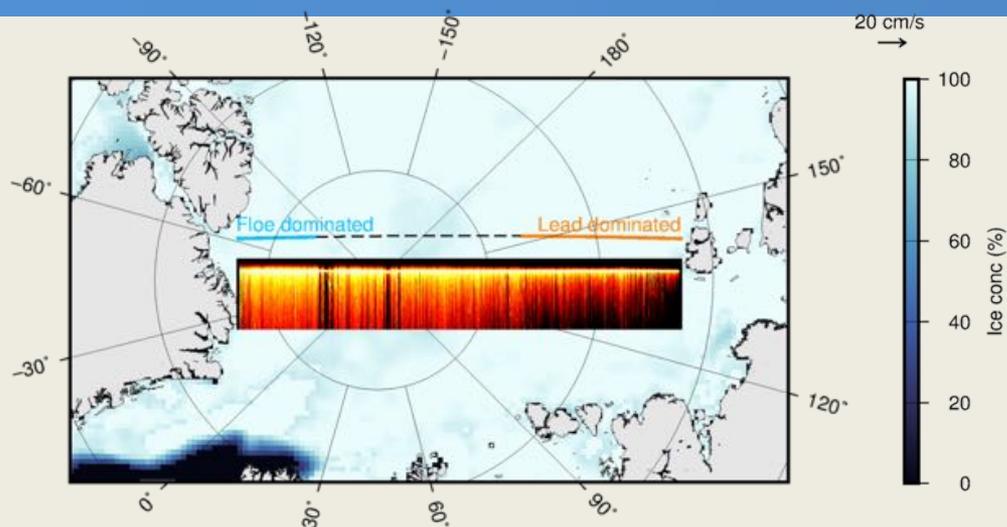
delay/Doppler Processing + Hamming Window AT @ 80 Hz



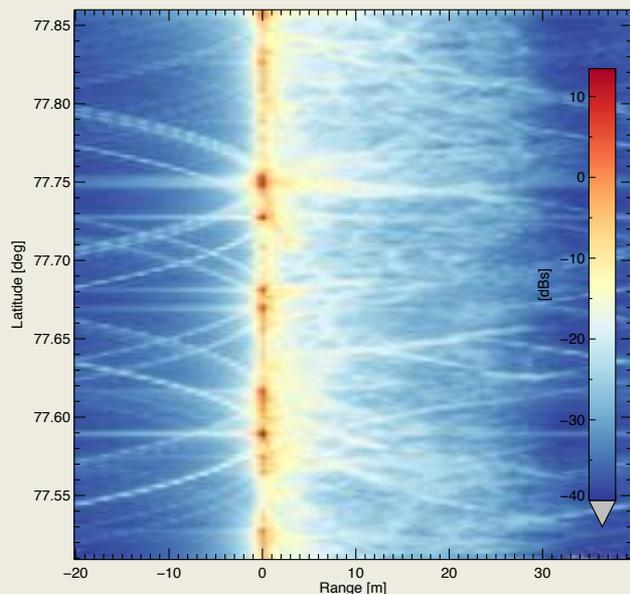
Hamming Window AT has NO apparent effect on ENL over the open ocean

The case for an AT Hamming window

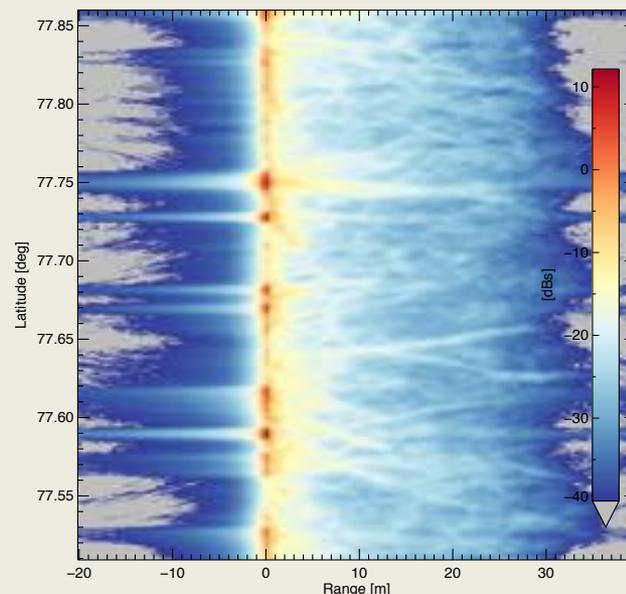
CryoSat Track over sea-ice
 “Golden Days”
 26th March 2014:



Delay/Doppler No Window:



Delay/Doppler AT Hamming Window:



- Continuous development of SAR processing tools at NOAA/LSA
- In this work we have investigated different processing configurations to try to achieve the highest possible Effective Number of Looks (ENL)
- FF-SAR effectively achieves the highest ENL, but quite comparable to dD@80Hz
- Partial focusing the aperture provides comparable results to classical dD@80Hz
- Along-track Hamming windowing the echoes burst-by-burst does not have a noticeable effect on the ENL
 - Important to keep consistency between open ocean and sea-ice!
- The results presented here would indicate that the ocean behaves like a wheat field...classical example for perfectly uniform random distributed target.
- K. Raney in [2] states that in the case of a wheat field:
 - *“for a given radar and scene, the SNR is constant as processor focus and coherence are varied, assuming that all available data are used”*

[2]:
IEEE TRANSACTIONS ON GEOSCIENCE AND REMOTE SENSING, VOL. GE-23, NO. 3, MAY 1985

Theory and Measure of Certain Image Norms in SAR

R. KEITH RANEY, SENIOR MEMBER, IEEE

Conclusions

- But wait... we “kinda” know that the ocean is not a wheat field!
 - $\text{Sigma}0 > 0\text{dB}$
 - Complex cross-correlation of echoes exists!
- Future work entails investigating this issue to determine if partial coherency of echoes can be exploited to increase ENL even further

