ESRIN EOP-SER Cryosat-2 Data Processing for CP40

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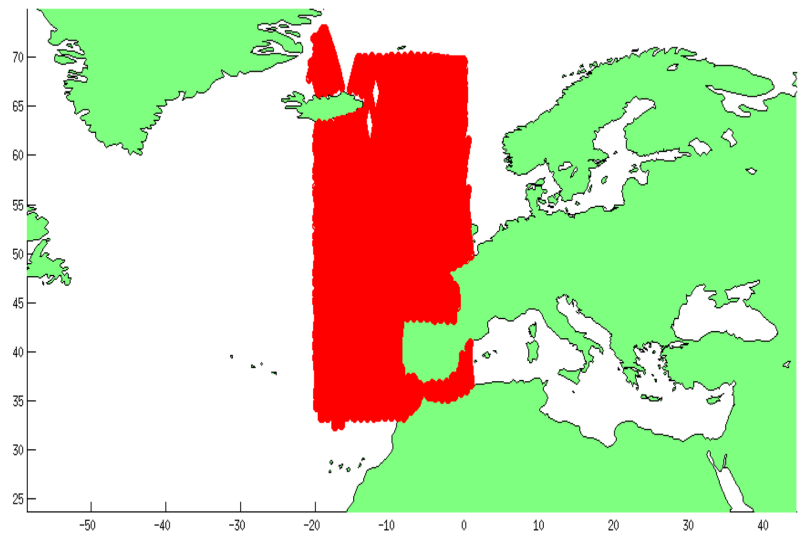
Summary of the data we produced (in last 6 months) for CP40 (in red) and community

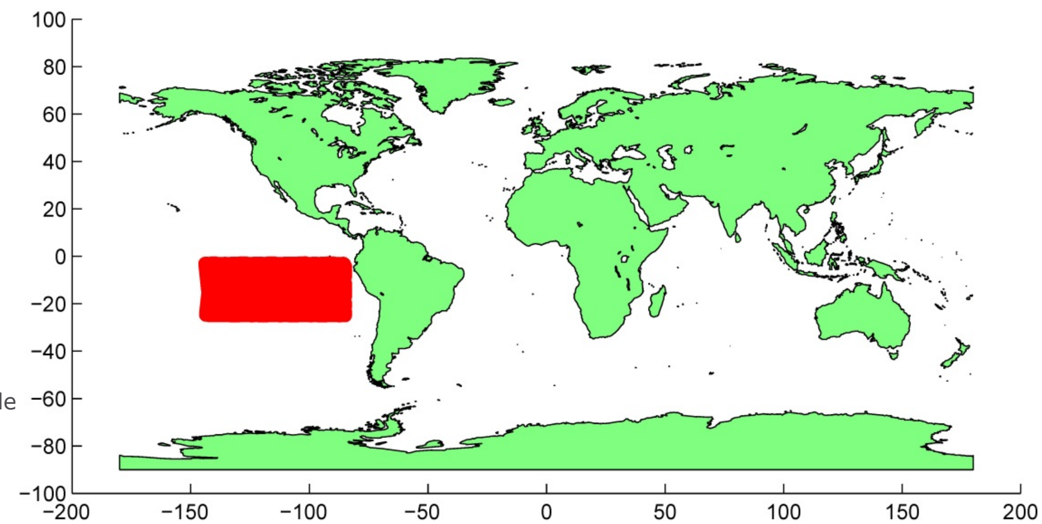
~14k tracks processed and delivered

Institution	Area	#Tracks
TUD (DE)	German Bight	900 (total 2900)
DTU (DK)	North Europe/Artic Ocean	1080
DTU (DK)	North Pacific	472
UC (ES)	South Spain	440
UH (DE)	Agulhas (South Africa)	1855
UH (DE)	South Pacific	3259
ECMWF (INT)	North W Atlantic	1100
NOC (UK) & CLS (FR)	South Pacific	Total 1540
NOC (UK) & CLS (FR)	North Atlantic	Total 1302

ESRIN CP40 Deliveries for Round Robin

- SAR L2 data (in netcdf format) delivered to CP40 team on 26/02/2014 on the South Pacific Box and North-East Atlantic Area (July 2012 and January 2013) for the round robin exercise
- Data processed thanks to the ESRIN implementation of the SAMOSA Re-tracker, run with CPP L1b Data as input and on a parallel computing platform (1 day of processing)
- Data re-delivered to CLS on 06/05/14 (after CP4O PM4) to correct post-processing bugs on sigma zero and misfit formula
- We delivered SAR L2 dataset generated from FBR in North Atlantic (out state of art for NOC) and a series of S-3 DPM-like dataset (NOC and CLS)
- On our side, still to improve compression method algorithm (i.e. from 20 Hz to 1 Hz)





SAMOSA Model Configuration for CP40 Round Robin Exercise

- Radar Parameter Table provided by CPP team
- Reference Ellipsoid: Topex/Poseidon
- SAR Echo's Model Used: SAMOSA 2
- Model Antenna Pattern: 2-D Gaussian with teta3b_X=1,095 deg, teta3db_Y=1,22 deg
- Thermal Noise: computed from Echo's leading edge early samples
- Mis-pointing angles in input, values from CPP products
- Range not corrected for Internal Path Delay and platform range bias
- Multi-looking: 212 Doppler Looks accumulated
- Scattering Amplitude Decay Rate (nu) set to zero
- Slope Effect set to zero, Skewness Effect set to zero
- Curve Best-Fitting Algorithm : **Bounded** Levenberg–Marquardt Least Square Estimator
- All reported in a configuration control document :

  http://www.satoc.eu/projects/samosa/samosa_config.html

Look-up Table for SAMOSA Model

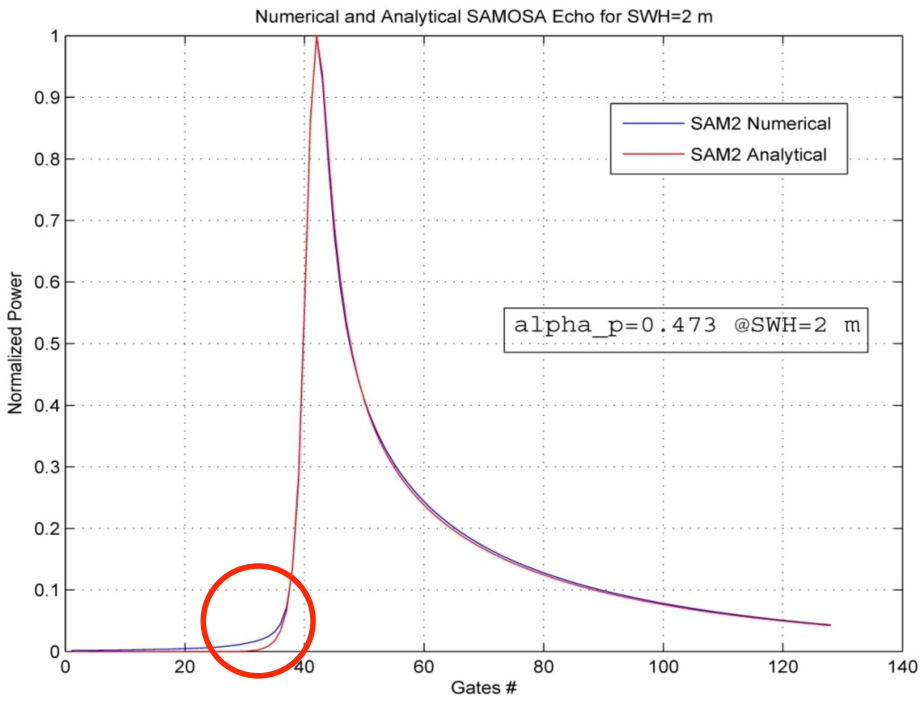
Gaussian Approximation for squared Delay-Doppler PTR in the SAMOSA **Analytical** Model

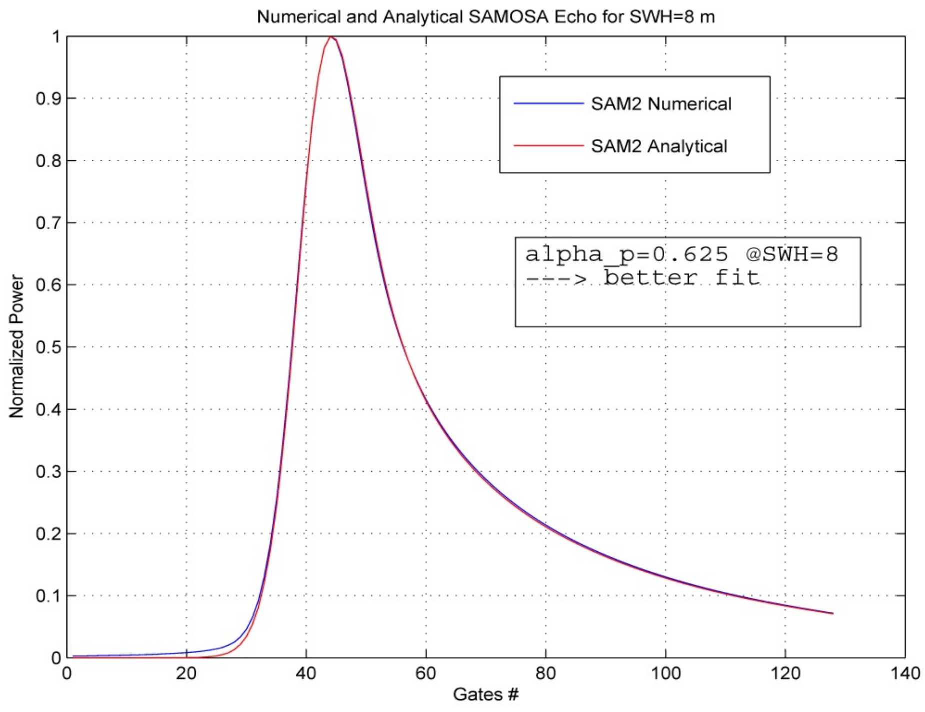
$$\mathrm{sinc}^2(x) \approx e^{-\left(\frac{x}{\sqrt{2}\cdot\alpha_p}\right)^2}$$

→ SAMOSA Model is function of alpha_p parameter (model's free parameter)

The question is: how to determine the best value for alpha_p ?

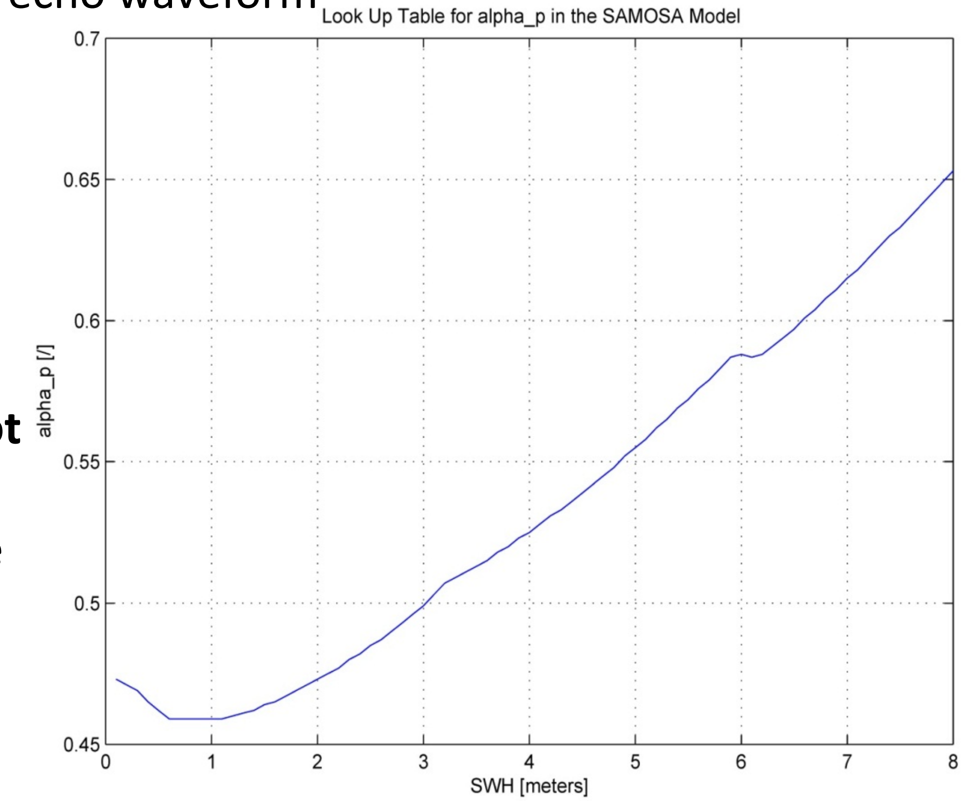
SAMOSA **Numerical** Model (SAMOSA Model not using the Gaussian approximation but a sinc^2 PTR and calculated solving numerical integration in 3-D space and time)





Look-up Table for SAMOSA Model

It is clear that the right value for alpha_p is function of SWH (i.e. sea state) --->
Using only one value for alpha_p, we will end up to have large trends in SWH (and range) measurements
The idea (very simple) is to the choose, for each SWH, the alpha_p value proving the best fit in rms term between the SAMOSA Numerical and the SAMOSA Analytical model.
This will be not a perfect work-around but will **mitigate** the trends without losing the **flexibility** to have a simple equation for the SAR echo waveform



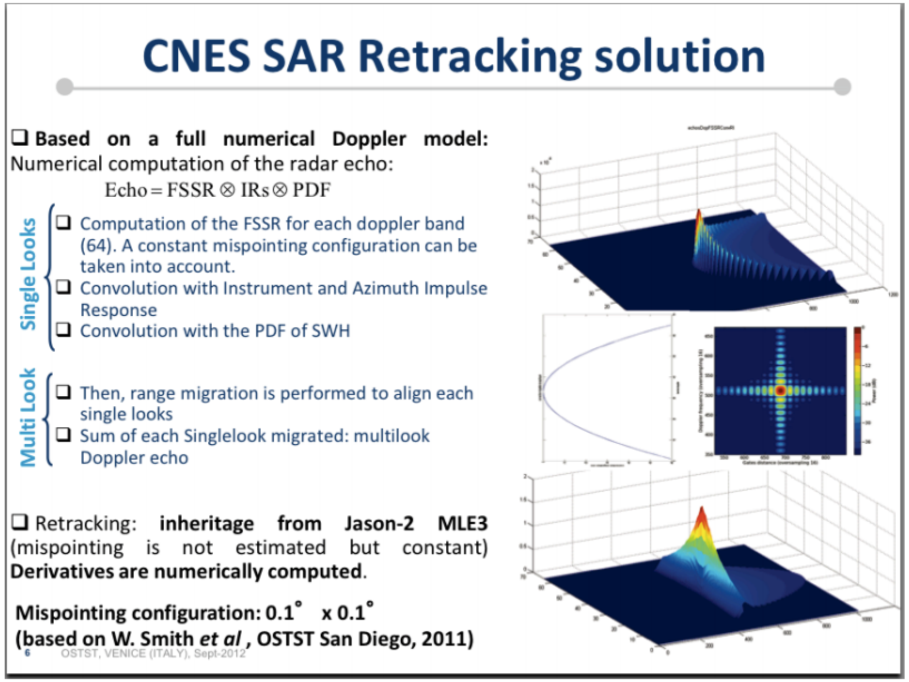
Once that the LUT (function of SWH) has been computed off-line, at run time (i.e. during re-tracking) we extract from the LUT the alpha_p value corresponding to the SWH under iteration
Hence, in order to calculate the LUT **we have not used at all any real CryoSat-2 data** (i.e. any L2 CPP data) but only information coming from the model.

SAMOSA DDM MASKING (STACK Peel)

SLIDES from Alejandro's Presentation at Porto CP40 PM (06/11/2013)

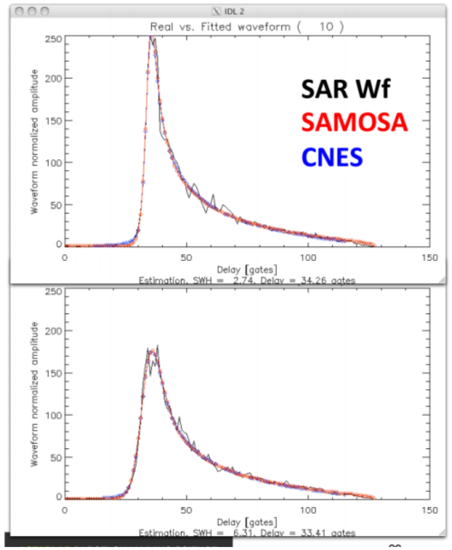
SAMOSA Model Updates (Round 4…)

- Antialiasing filter effect:



- Boy & Moreau, OSTST Venice 2012
- The antialiasing filter

Waveform Model Comparison – Round 4

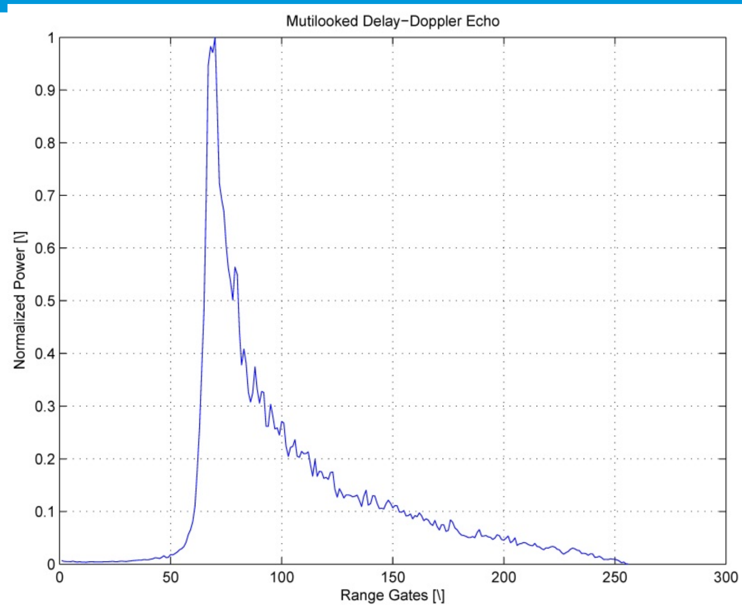


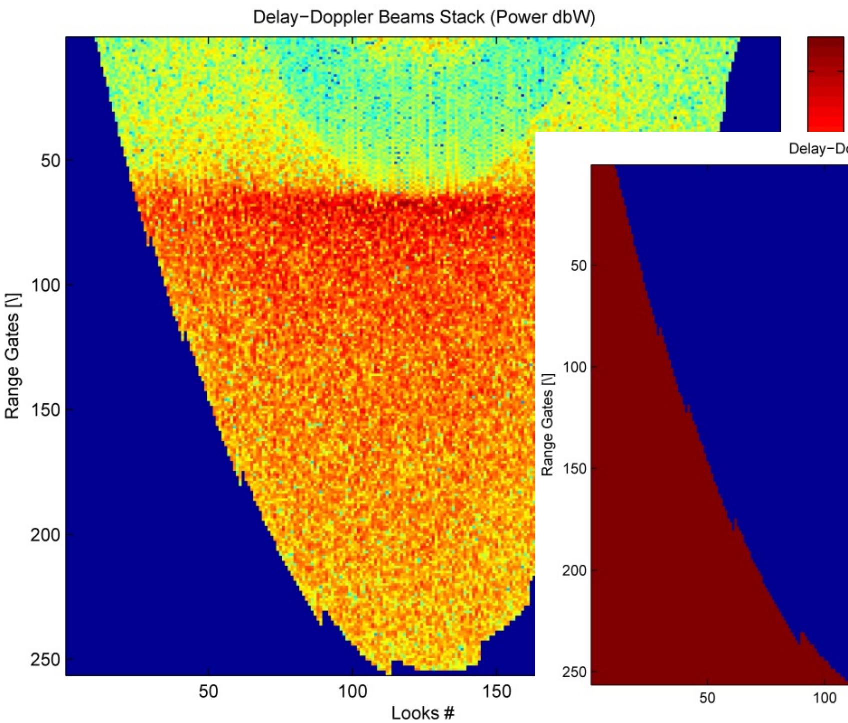
- Good correspondence on leading edge and trailing edge !
- Possible causes:
  - Thermal noise
  - PTR width…
  - Wrong Wf Normalization?
  - **Antialiasing filter effect…?**
    - **Probably…**
  - **Others…?**
- More work needs to be done…
- Retracking results to be consolidated

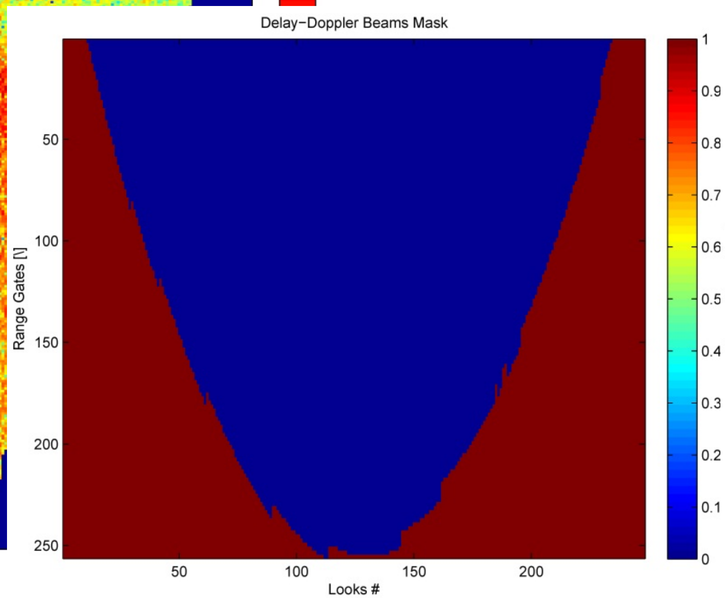
SAMOSA DDM MASKING (STACK Peel)

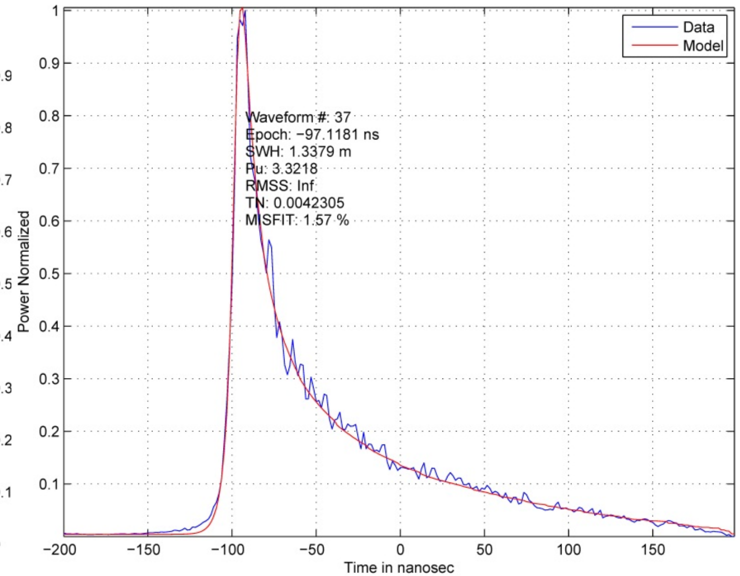
Due to the limited size of the radar receiving window (60 meters), after range alignment operation, the Delay –Doppler beam Stack gets filled with zeroes

At L2, a 1/0 mask is applied on Delay Doppler Map to build a echo waveform with tail decaying to zero









SAMOSA DDM MASKING (STACK PEEL)

Re-tracking CPP L1b dataset, we build an approximated 1/0 mask:

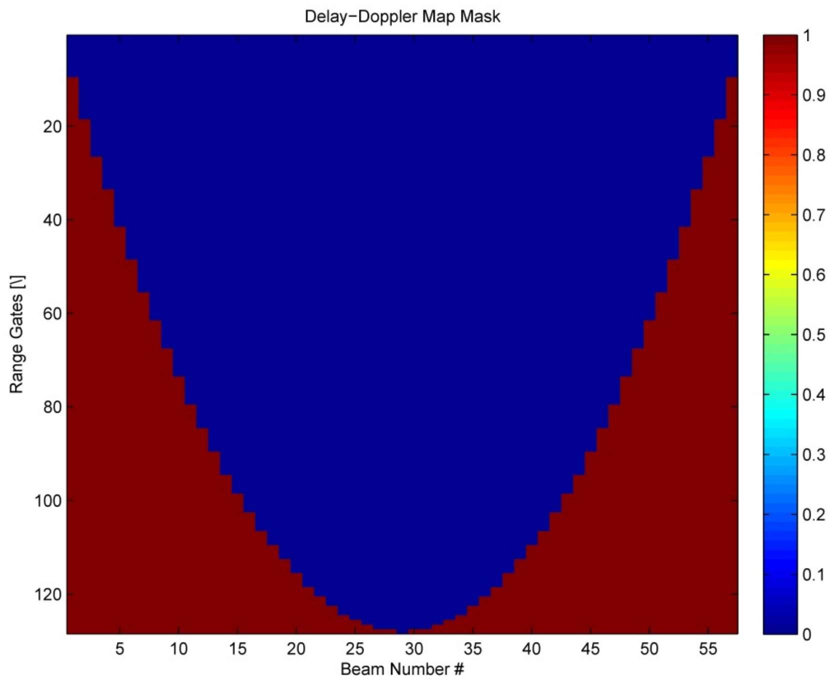
$$\delta R_l = H \cdot \left(\sqrt{1 + \alpha_E \cdot \left(\frac{L_x \cdot l}{H} \right)^2} - 1 \right) \quad \text{with } l = -32,..,31$$

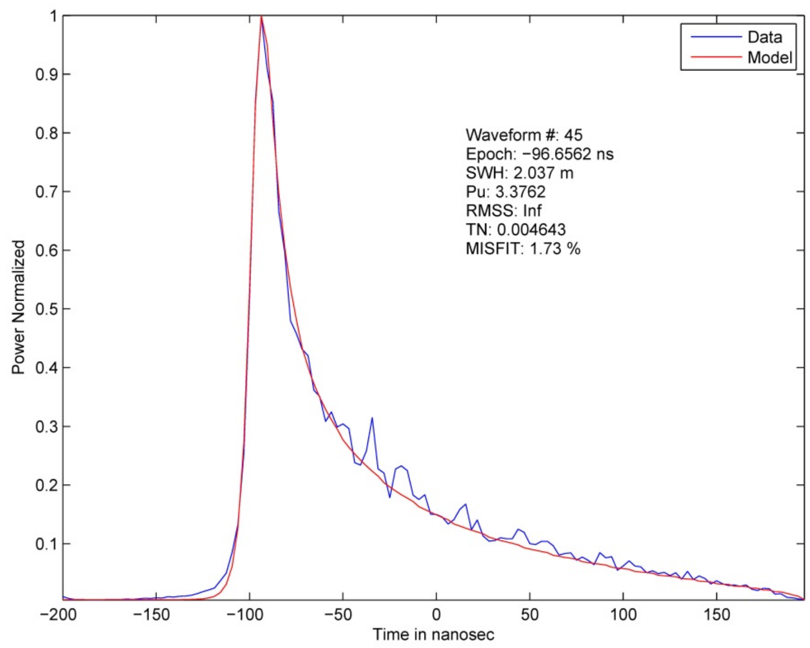
$$\delta r_k = \frac{c_0}{2 \cdot B_r} \left[N_s - 1, -1, 0 \right] \quad \text{with } k = 1,..,128$$

for each column l, zeroes are placed in range gates (k,l) for which holds the relation:

$$\delta r_k \leq \delta R_l \quad \text{with } k = 1,..,128$$

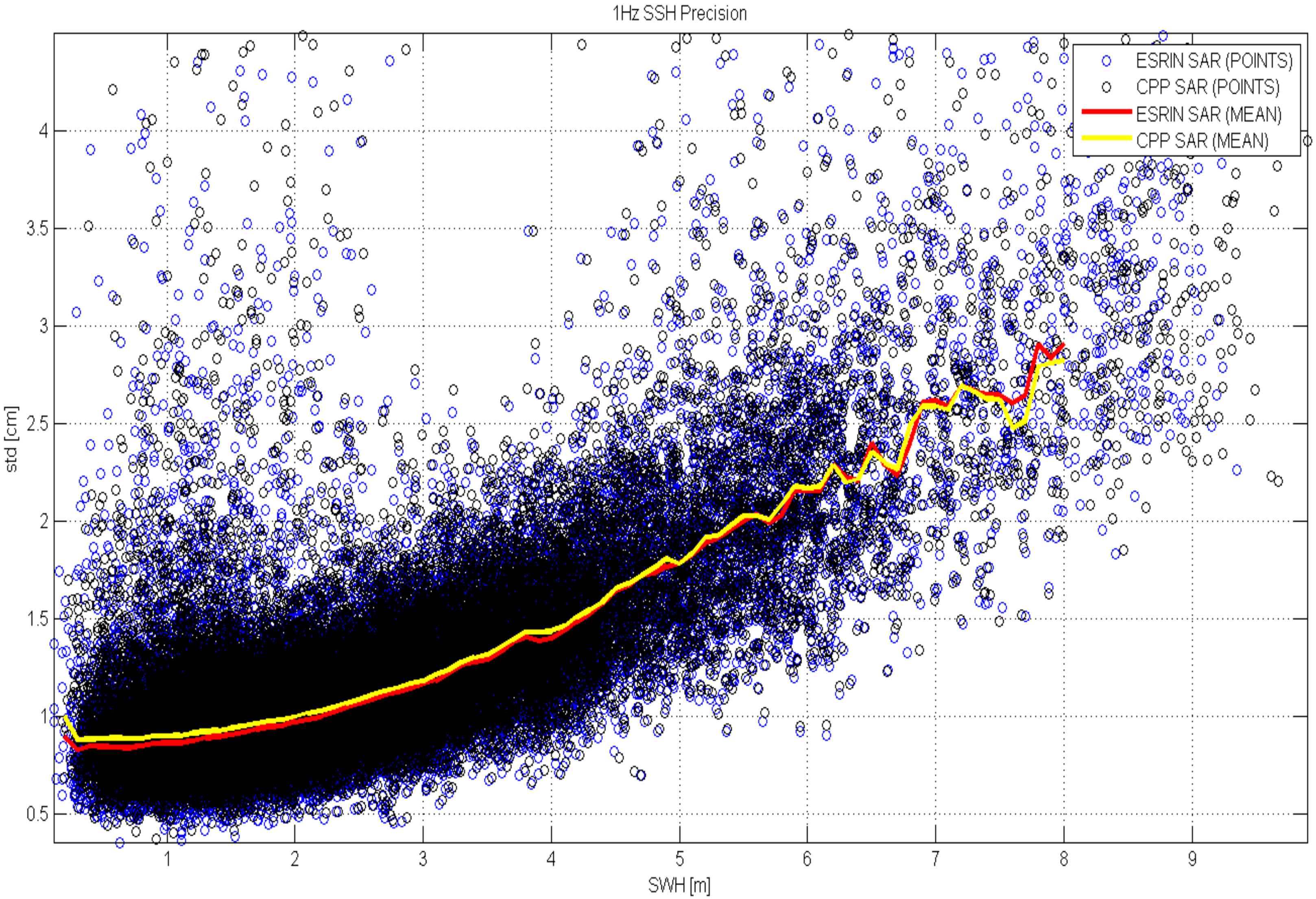
c_0	**vacuum speed light**
B_r	Received Bandwidth
N_s	Number of Range gates (128)
H	Orbital Altitude
L_x	Along Track Resolution
α_E	Earth Sphericity Factor
l	Along Track Beam Index (-32->31)
k	Range Gate



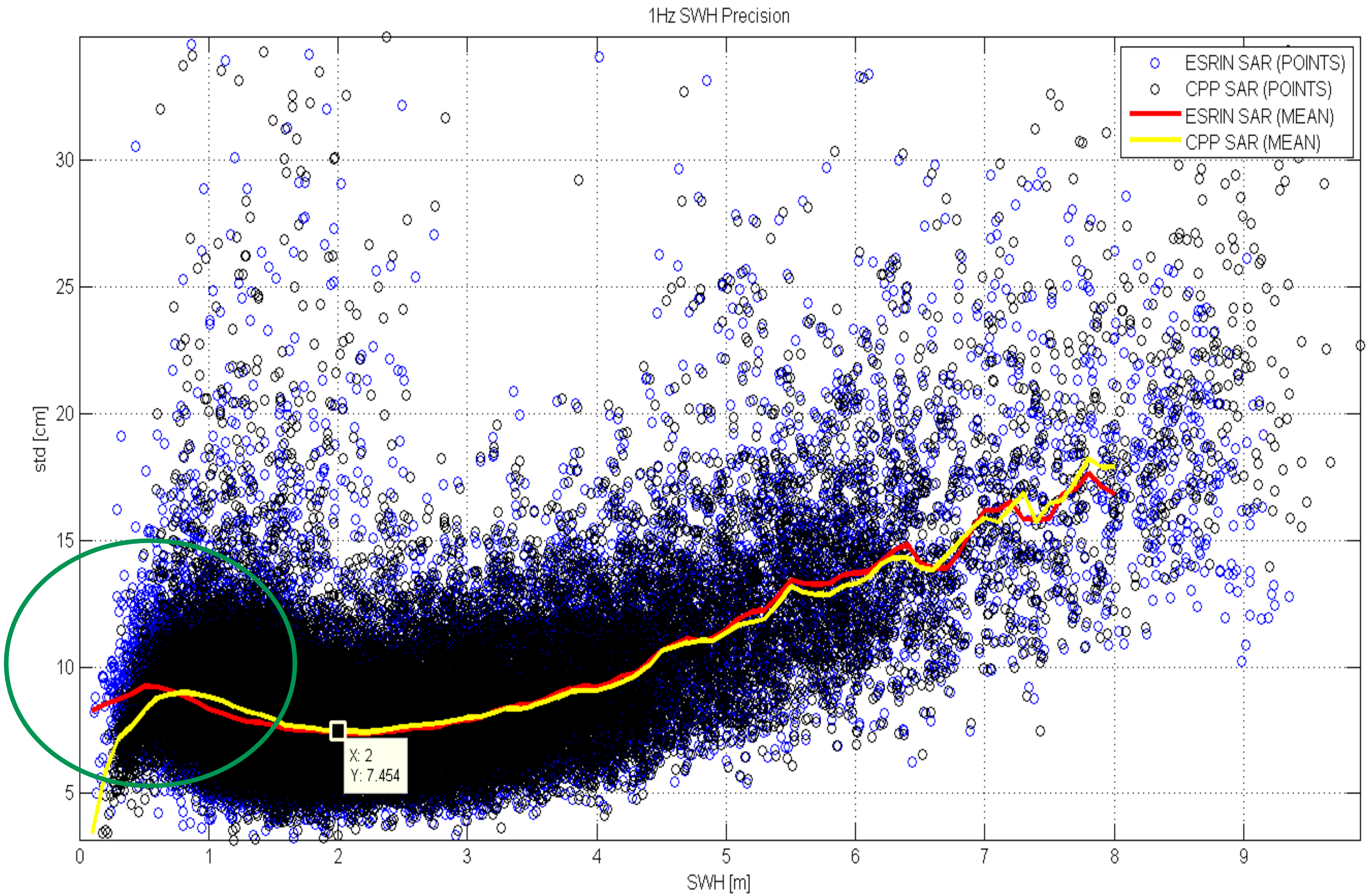


RESULTS SAR CPP vs ESRIN SAR SAMOSA in North Atlantic / South Pacific

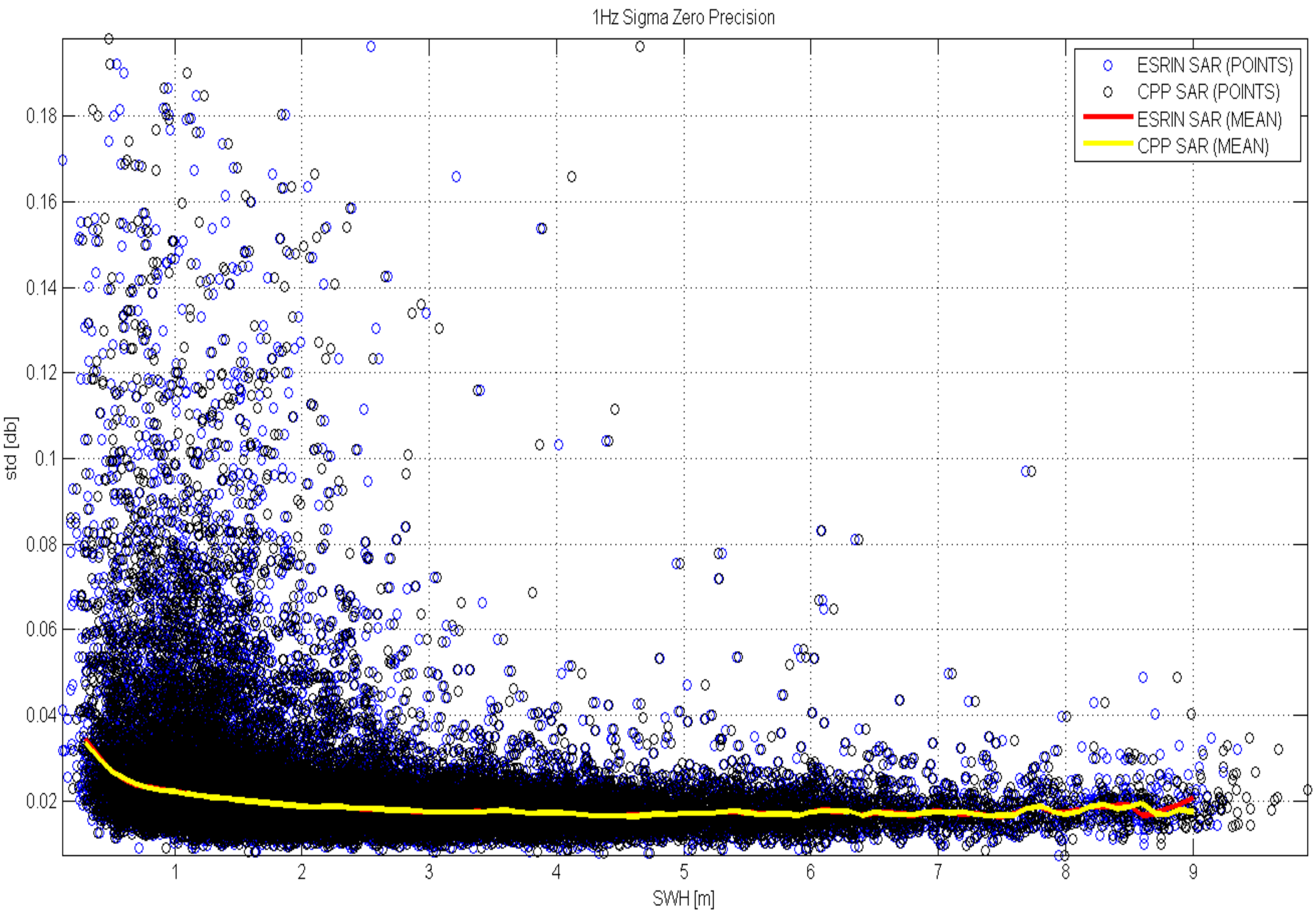
SSH PERFORMANCE CURVE (North Atlantic Open Sea 1 Hz noise)



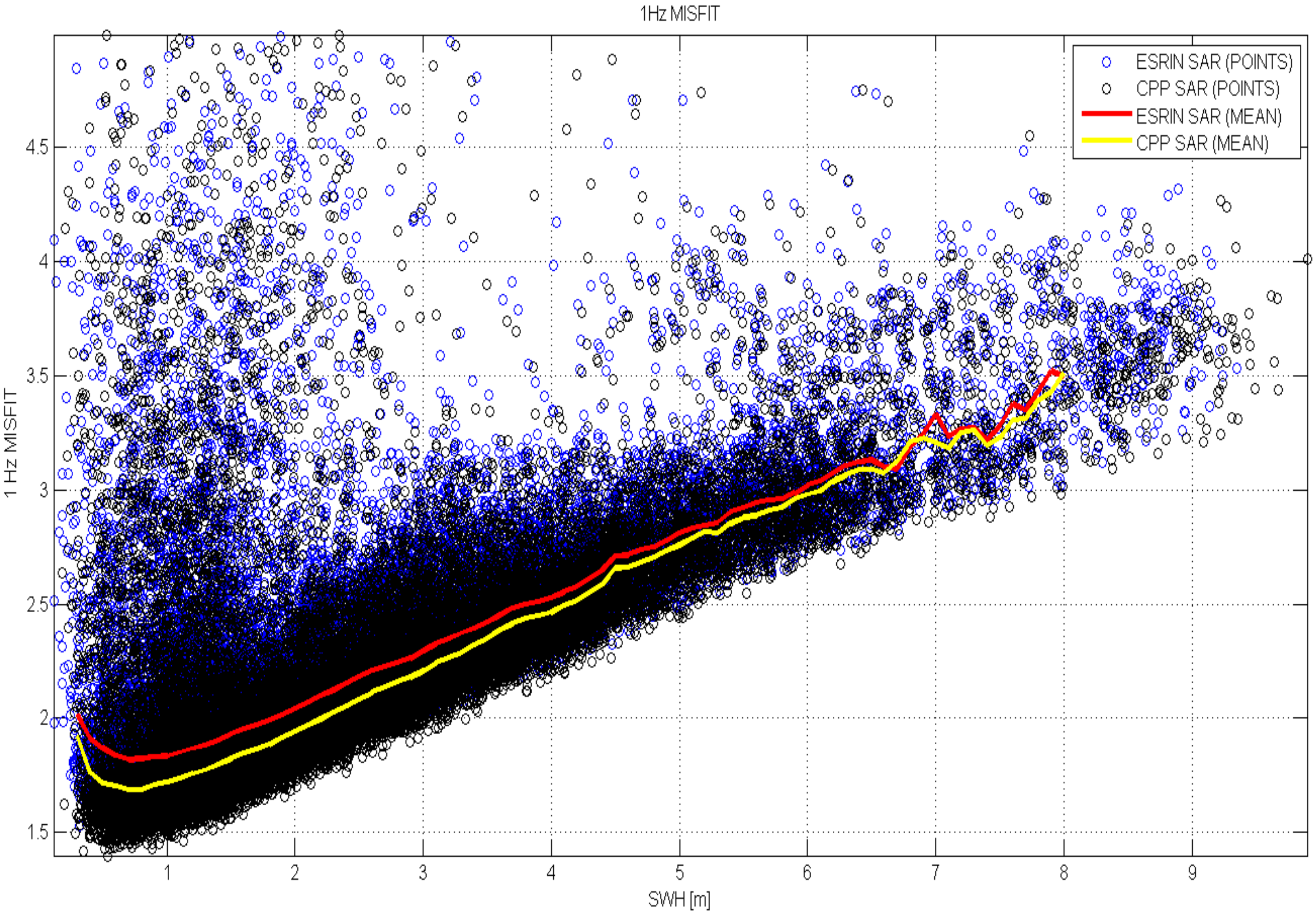
SWH PERFORMANCE CURVE (North Atlantic Open Sea 1 Hz noise)

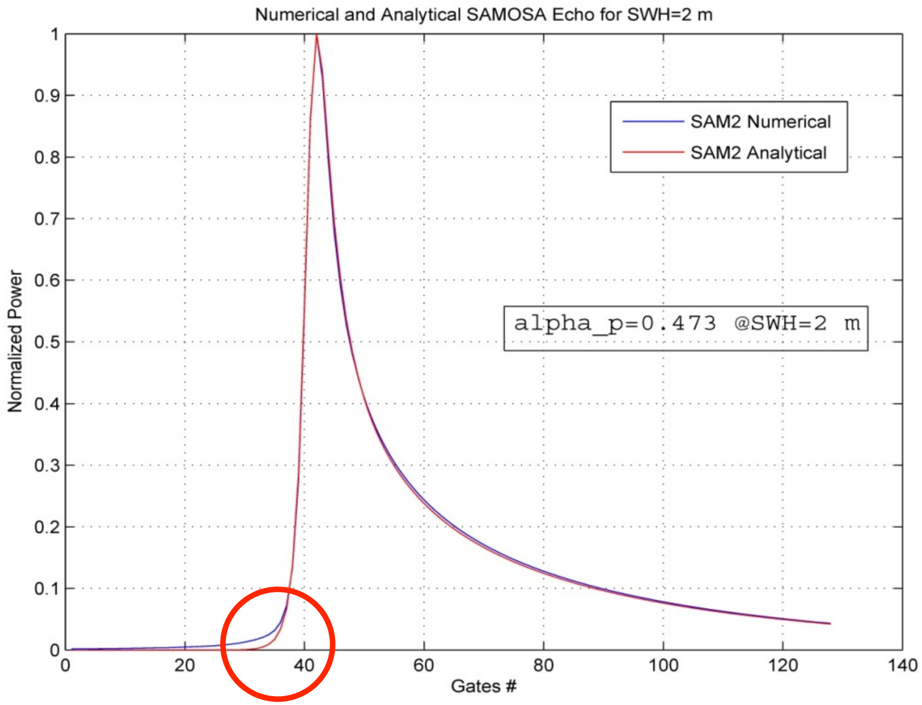


Sigma Zero PERFORMANCE CURVE (North Atlantic Open Sea 1 Hz noise)

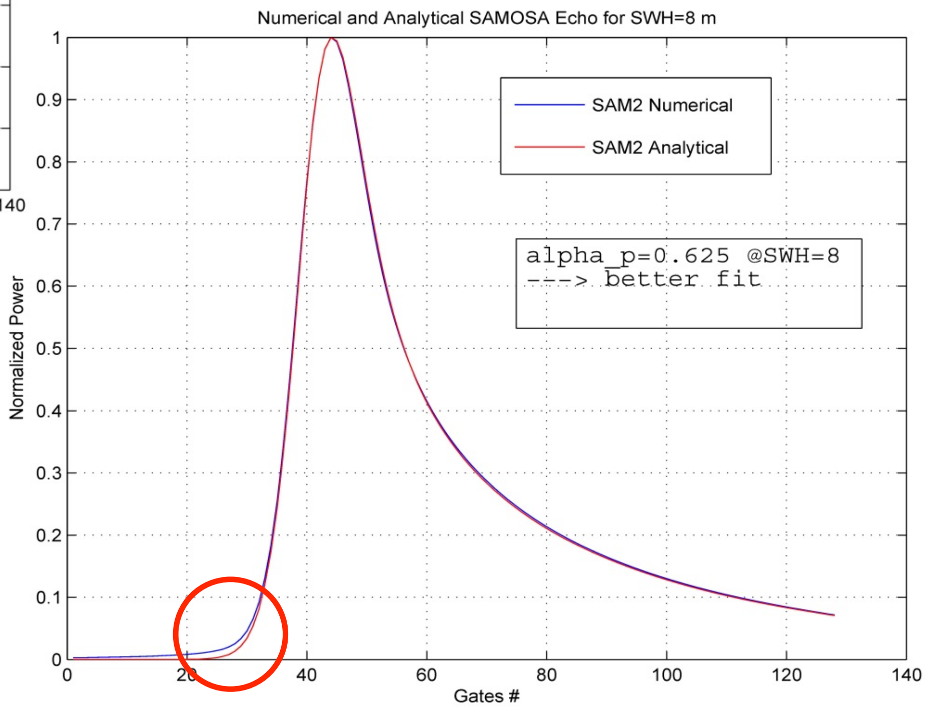


Misfit CURVE (North Atlantic Open Sea 1 Hz noise)





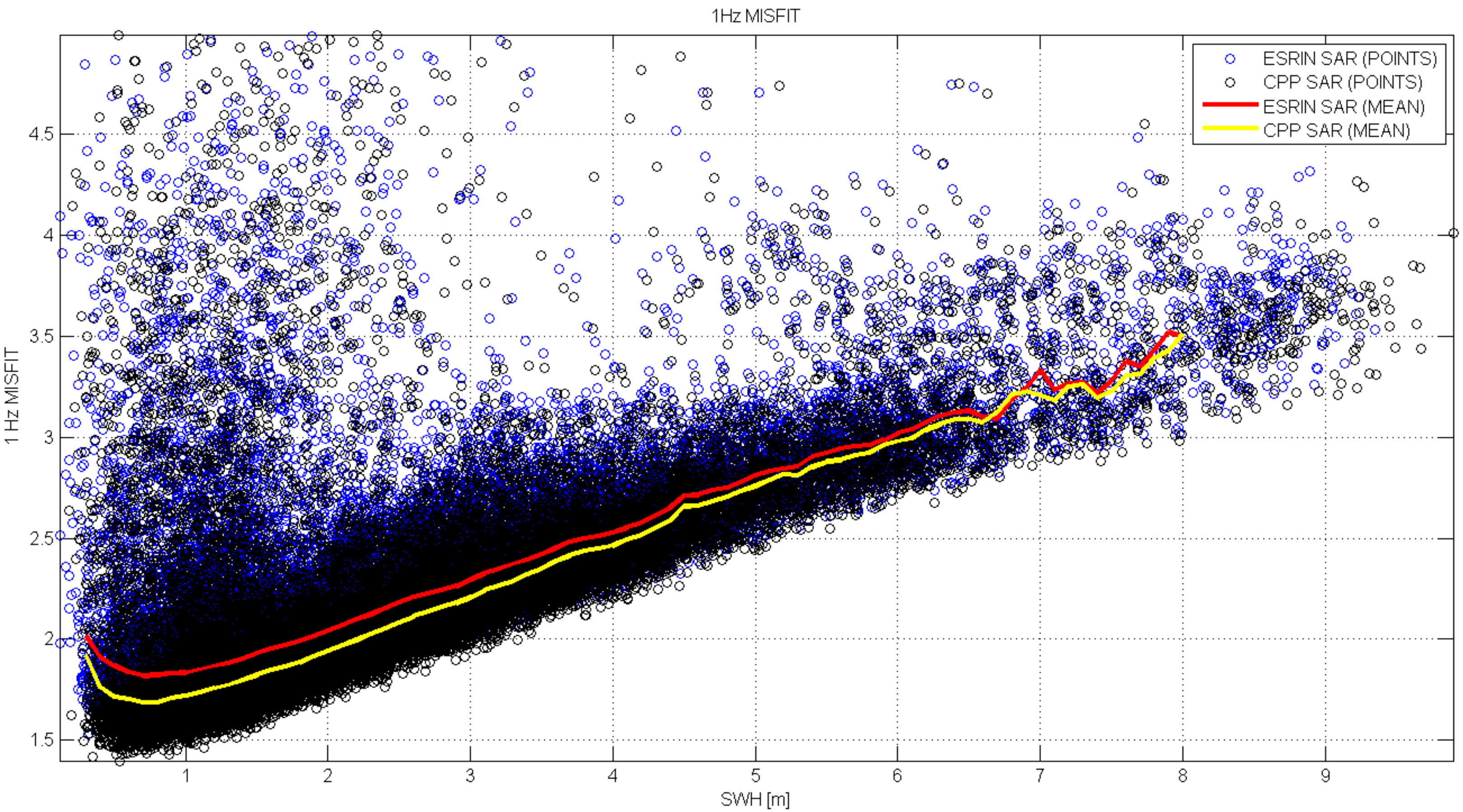
Numerical and Analytical SAMOSA Echo for SWH=2 m
SAM2 Numerical
SAM2 Analytical
alpha_p=0.473 @SWH=2 m
Normalized Power
Gates #



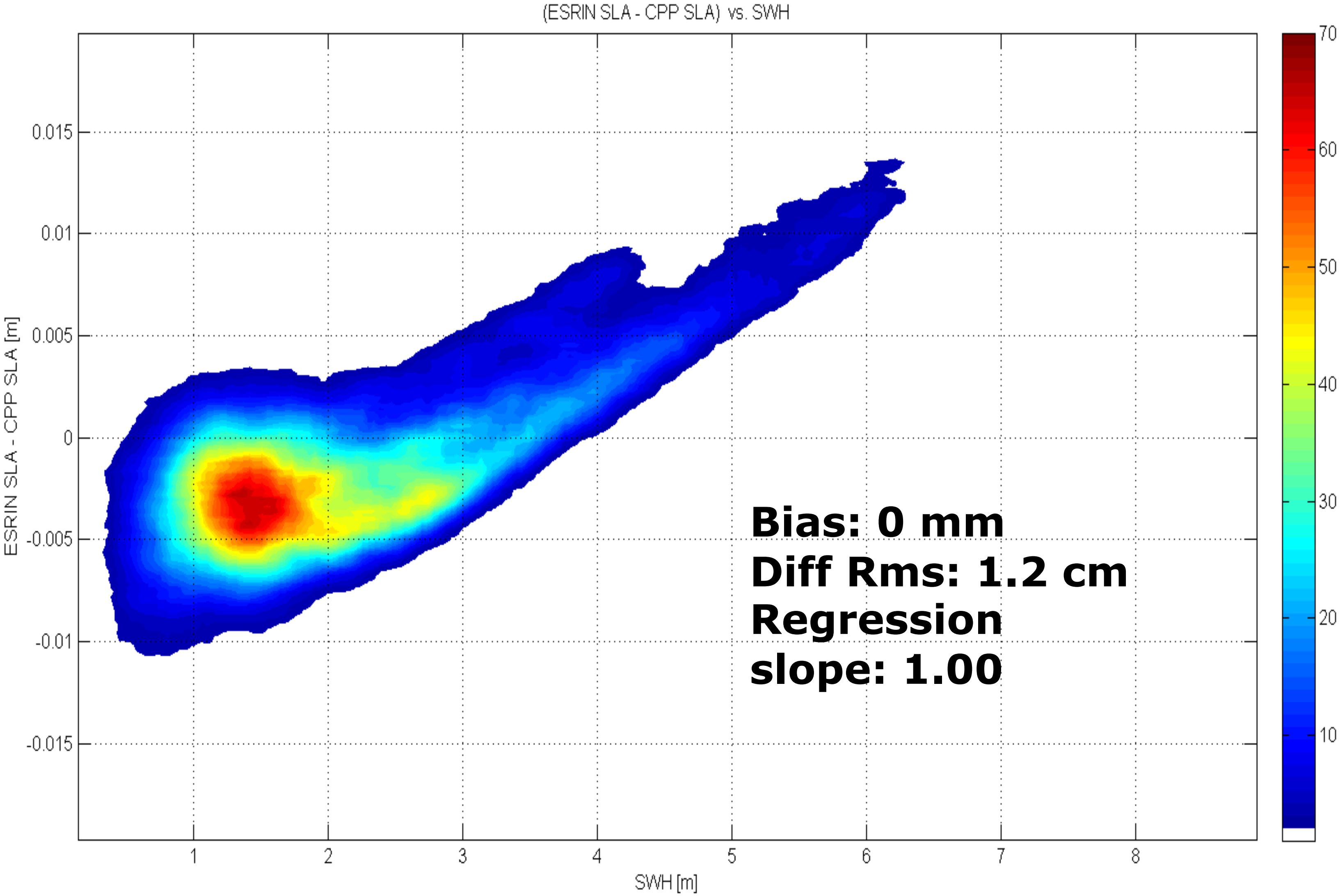
Numerical and Analytical SAMOSA Echo for SWH=8 m
SAM2 Numerical
SAM2 Analytical
alpha_p=0.625 @SWH=8
---> better fit
Normalized Power
Gates #

ency

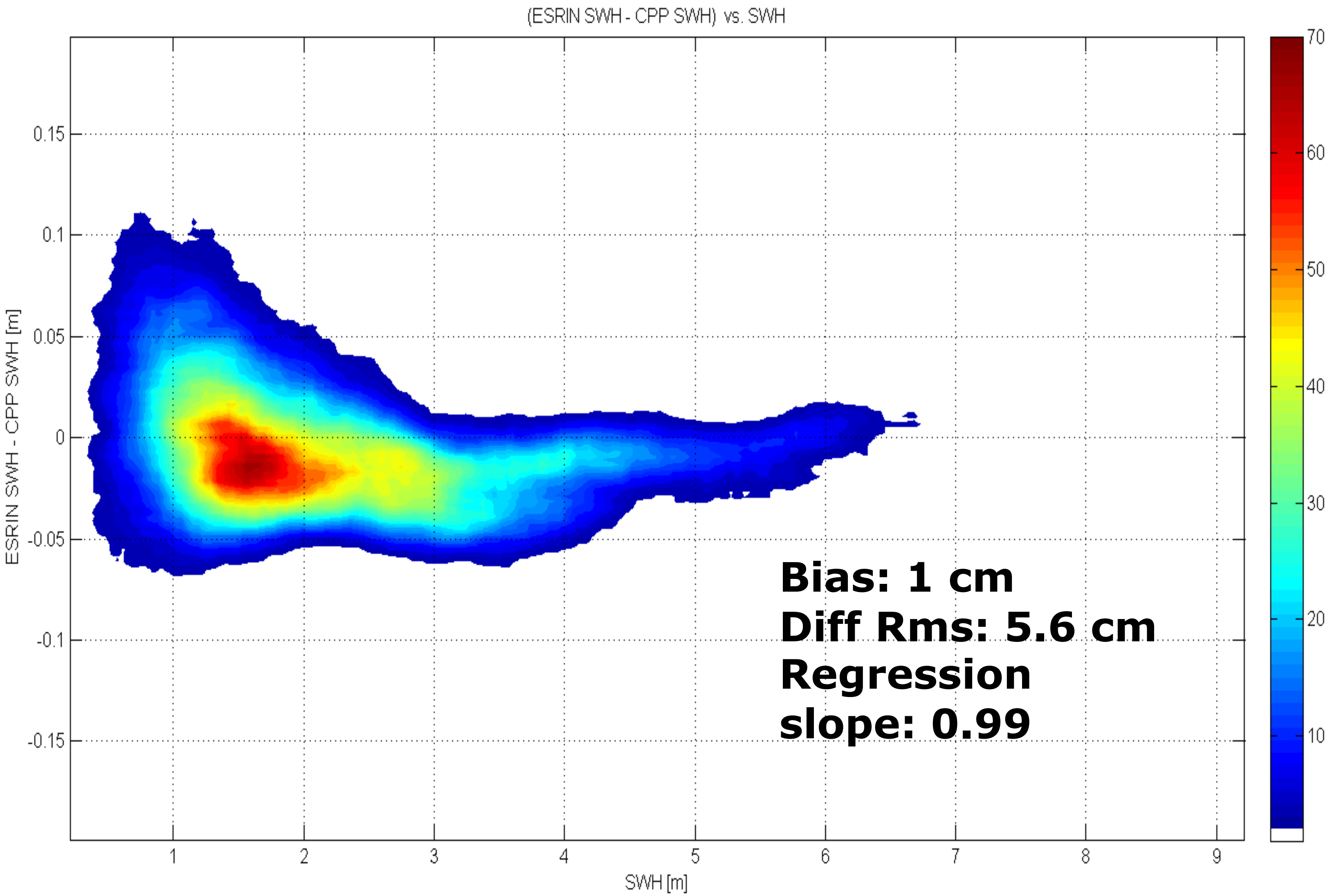
Misfit CURVE (North Atlantic Open Sea 1 Hz noise)

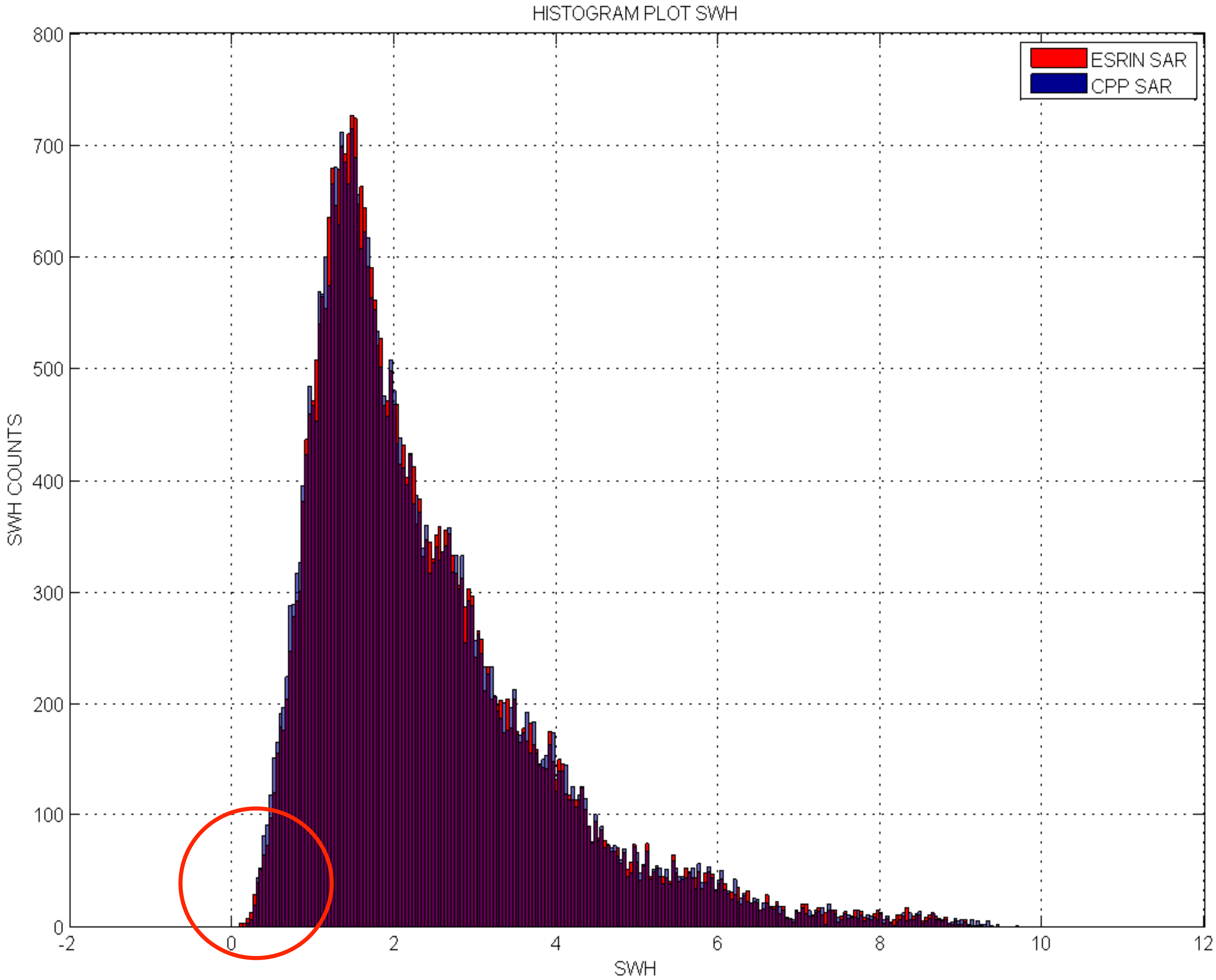


Dispersion/Density Plot for SLA (North Atlantic Open Sea 1 Hz)



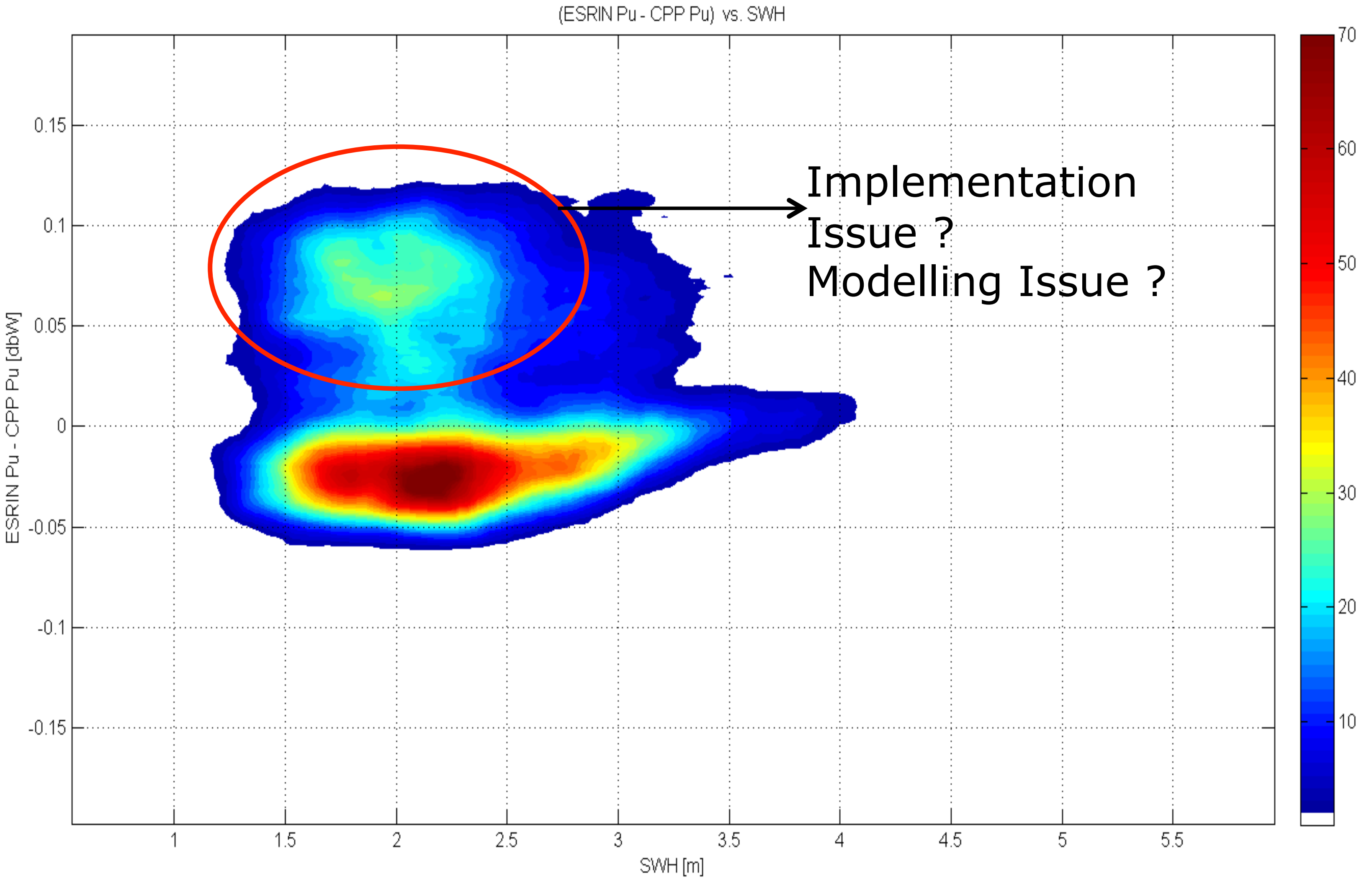
Dispersion/Density Plot for SWH (North Atlantic Open Sea 1 Hz)



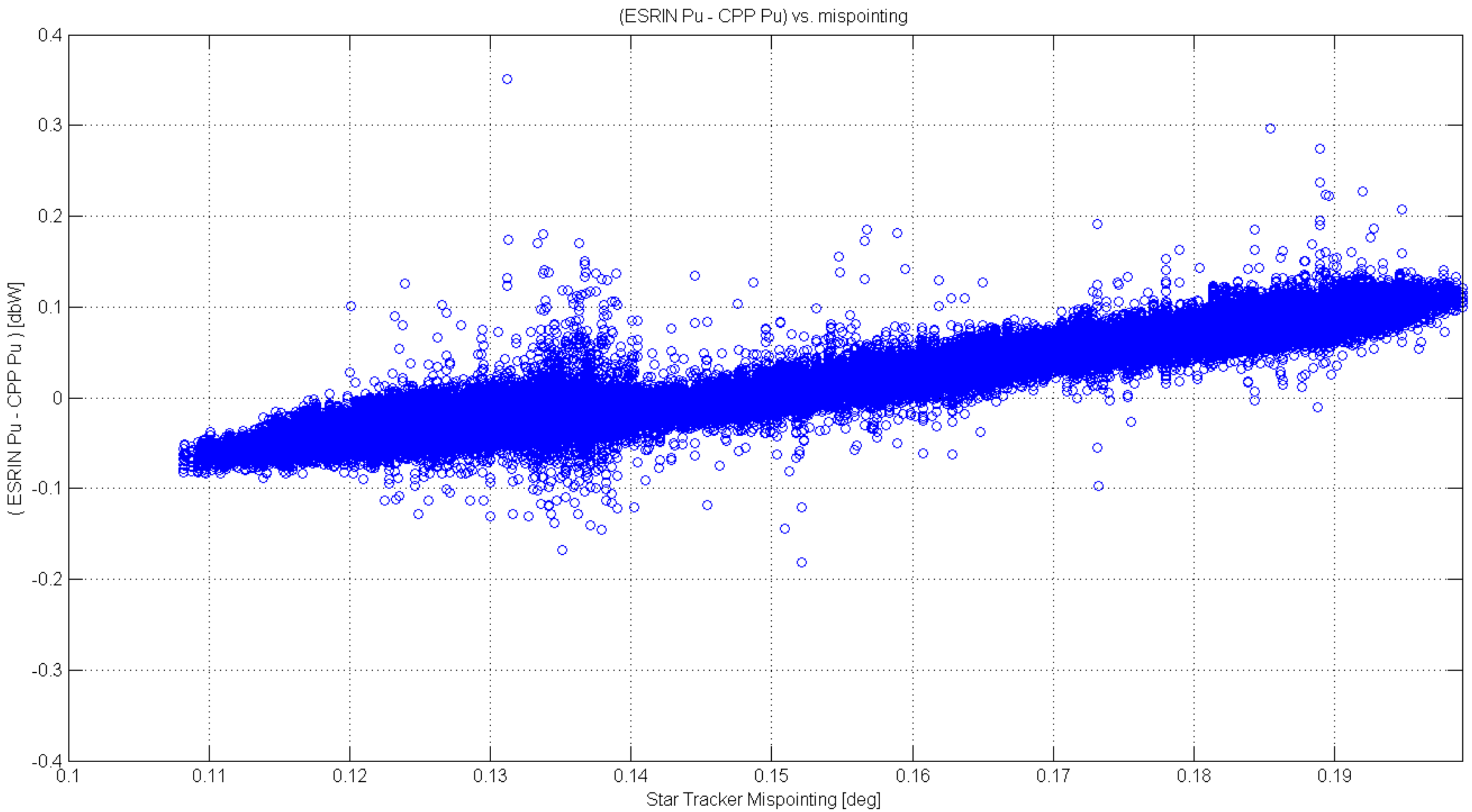


HISTOGRAM PLOT SWH
ESRIN SAR
CPP SAR
SWH COUNTS
SWH
800
700
600
500
400
300
200
100
0
-2
0
2
4
6
8
10
12

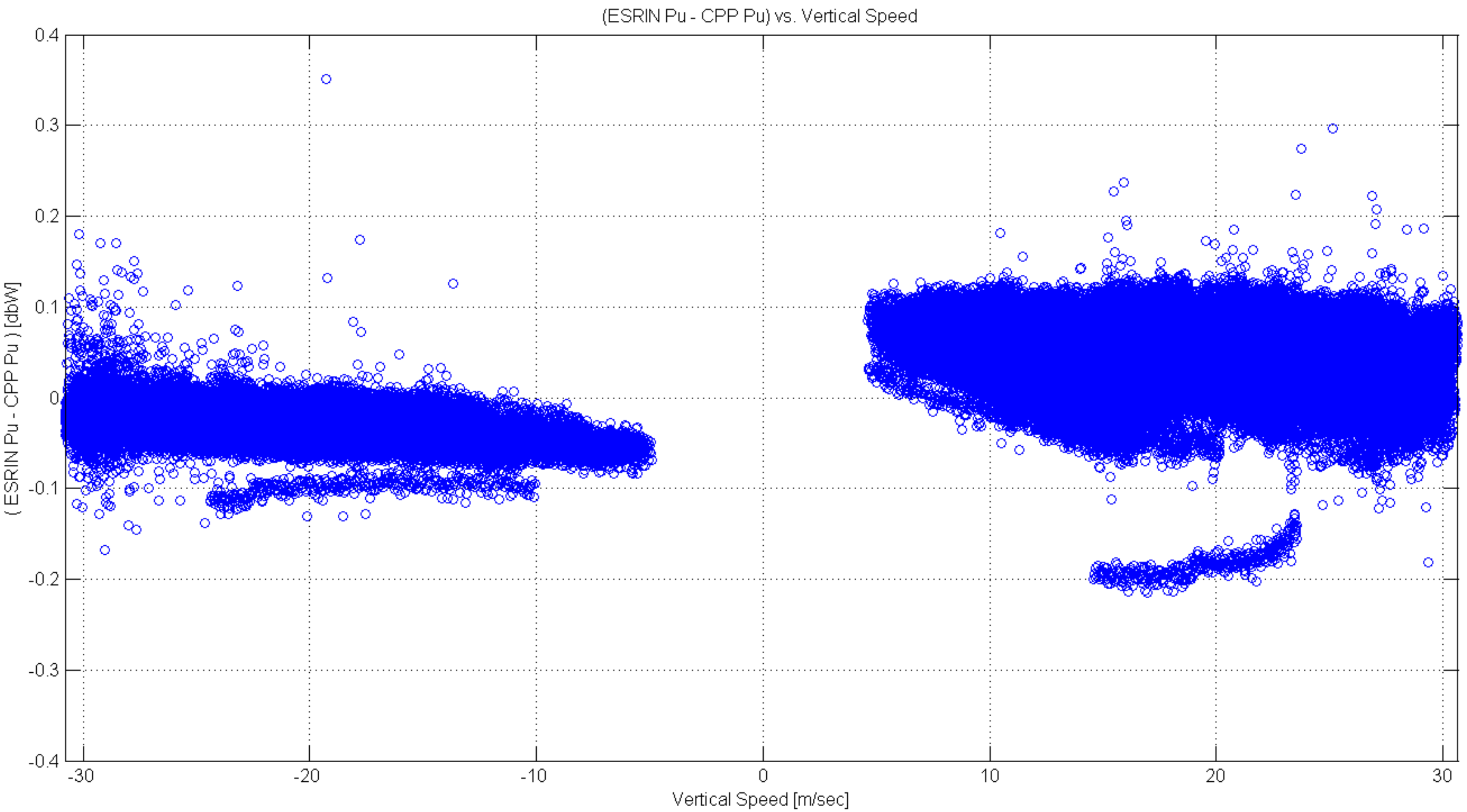
Dispersion/Density Plot for Pu – Waveform Power (South Pacific at 1 Hz) vs. SWH



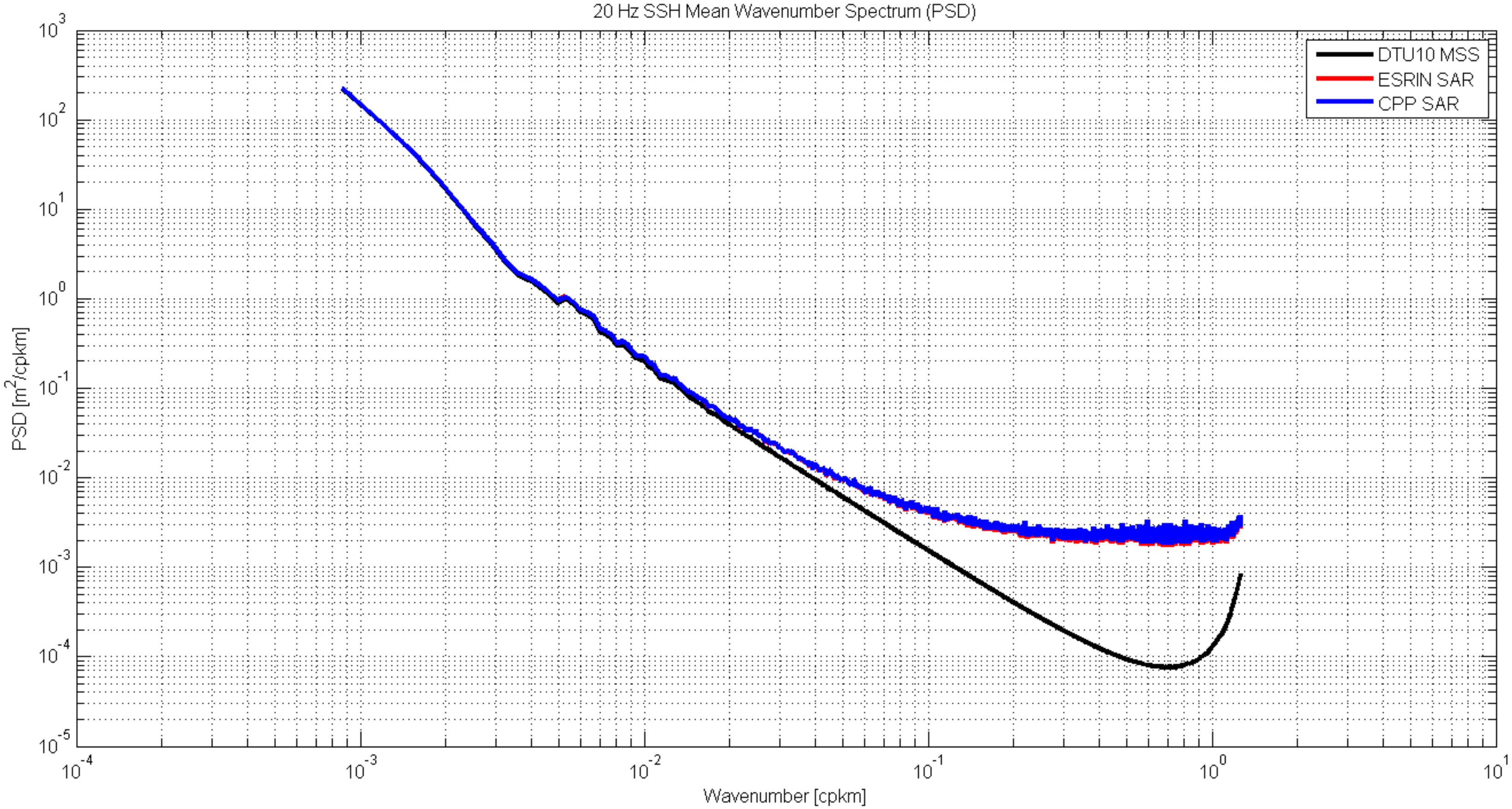
Dispersion Plot for Pu vs. mispointing – Waveform Power (South Pacific)



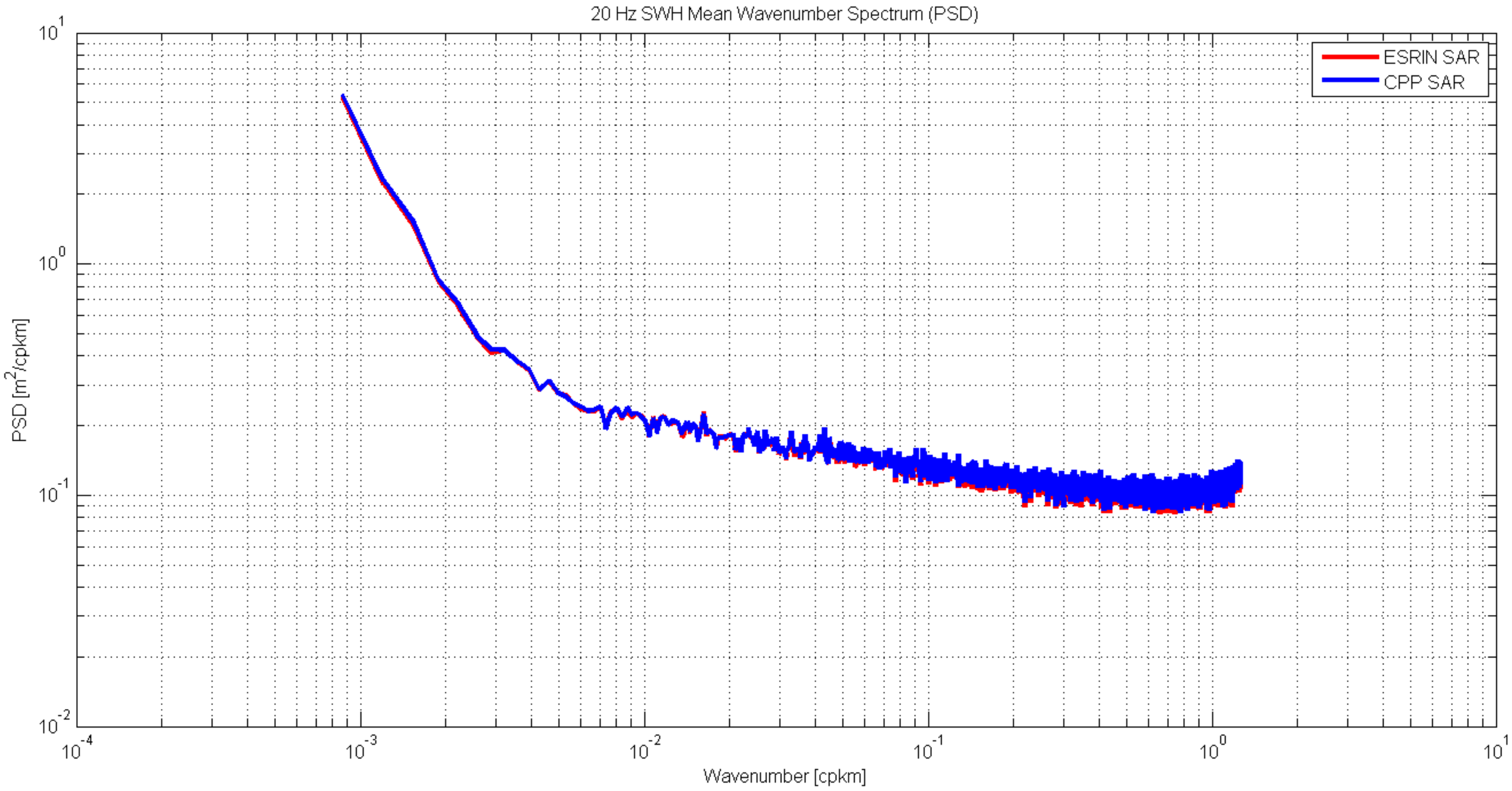
Dispersion Plot for Pu – Waveform Power (South Pacific) vs. Vertical Speed



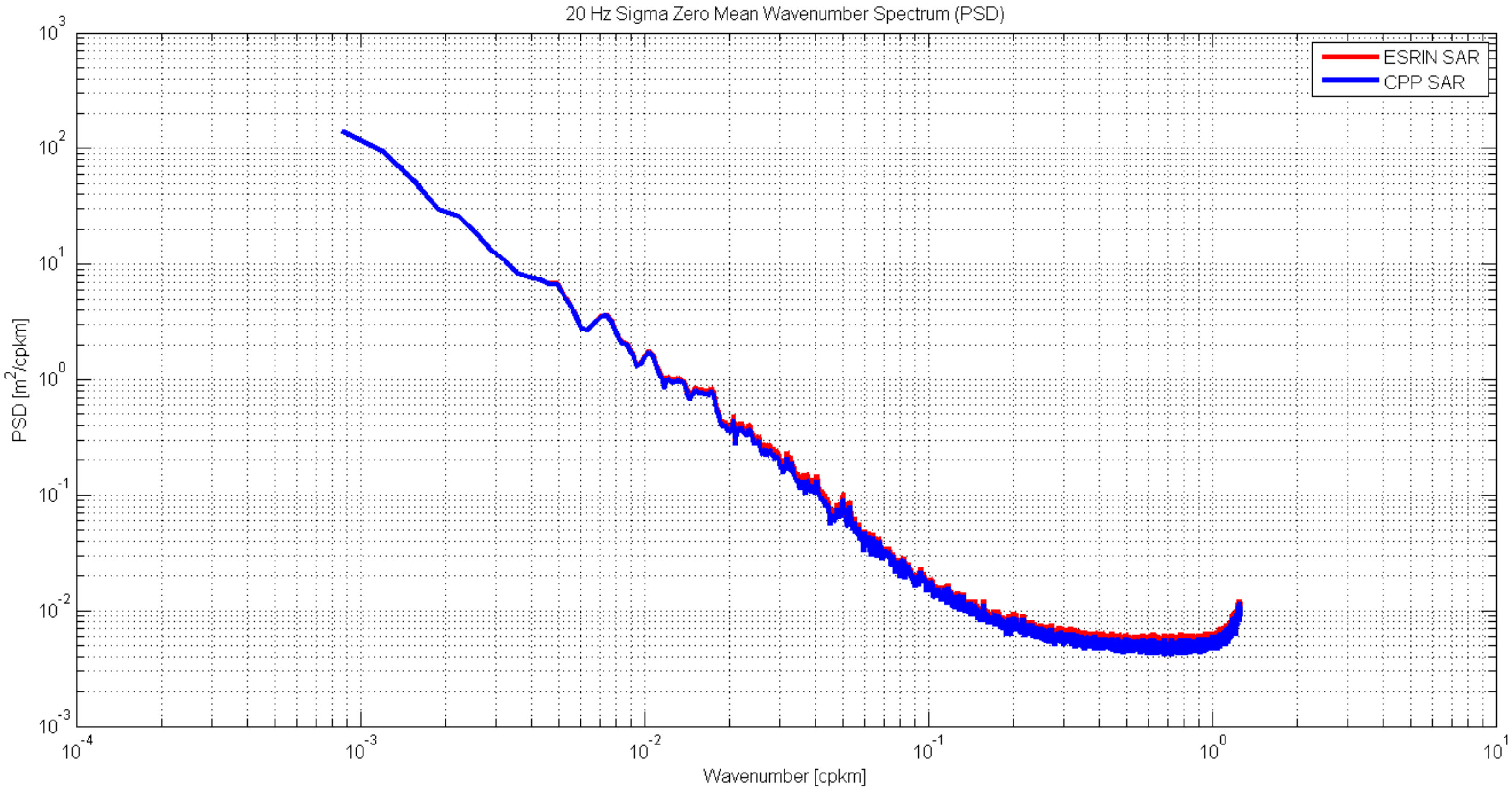
Wavenumber Spectrum SSH South Pacific 20 Hz



Wavenumber Spectrum SWH South Pacific 20 Hz

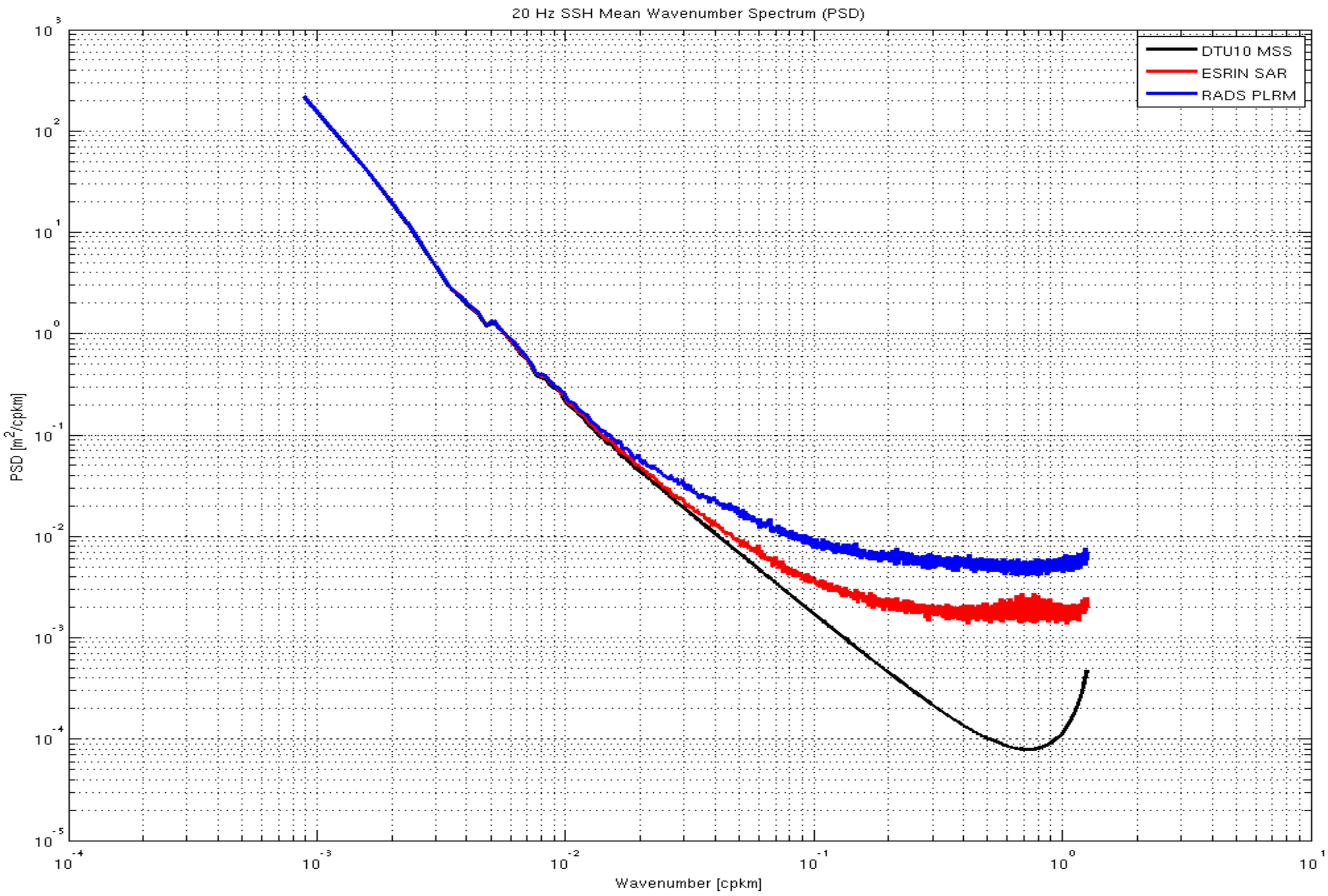


Wavenumber Spectrum Sigma Zero South Pacific 20 Hz

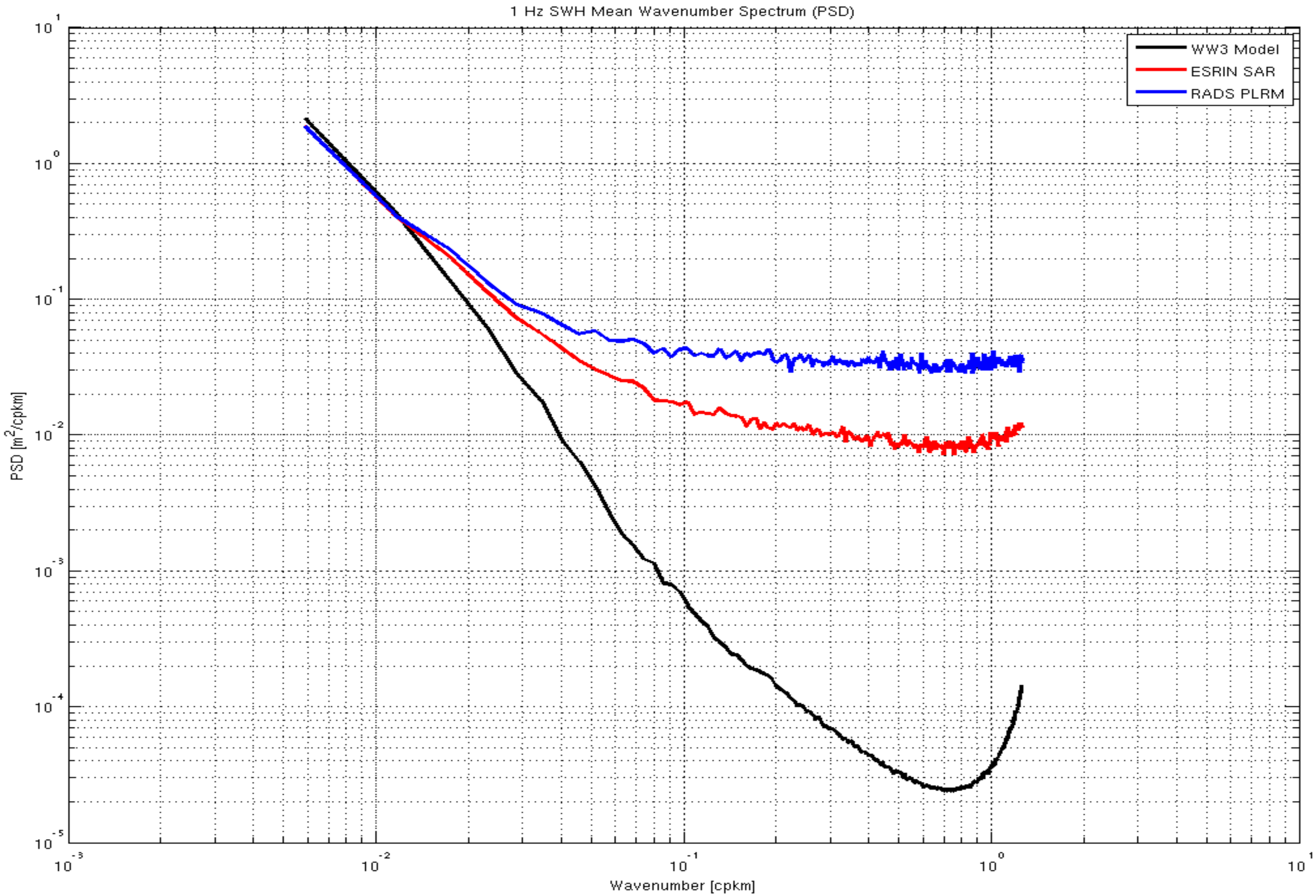


Spectra SAR SAMOSA vs RADS PLRM (South Pacific, 2 months)

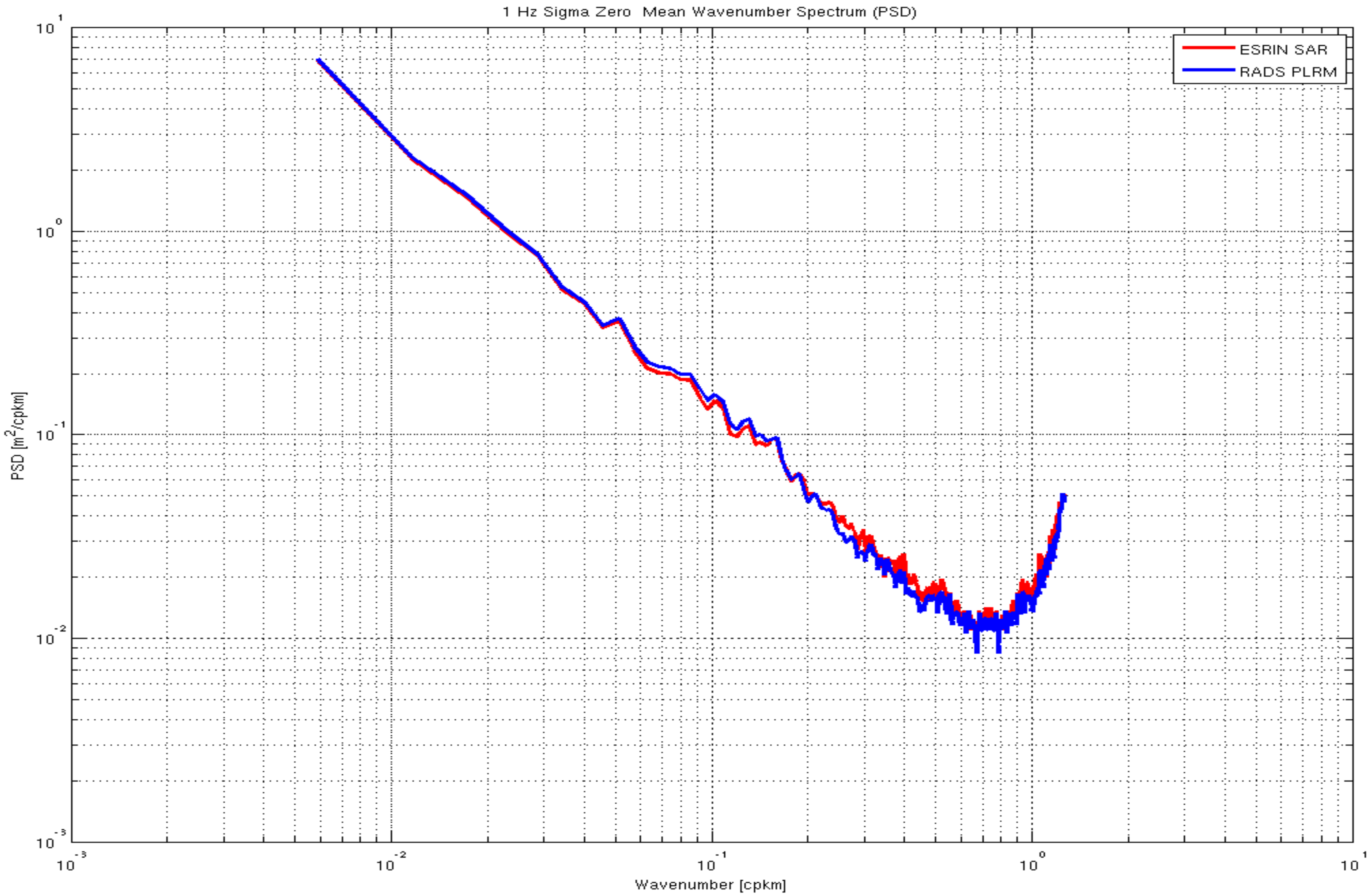
South Pacific SSH Spectrum: RADS RDSAR vs ESRIN SAR



South Pacific SWH Spectrum: RADS RDSAR vs ESRIN SAR



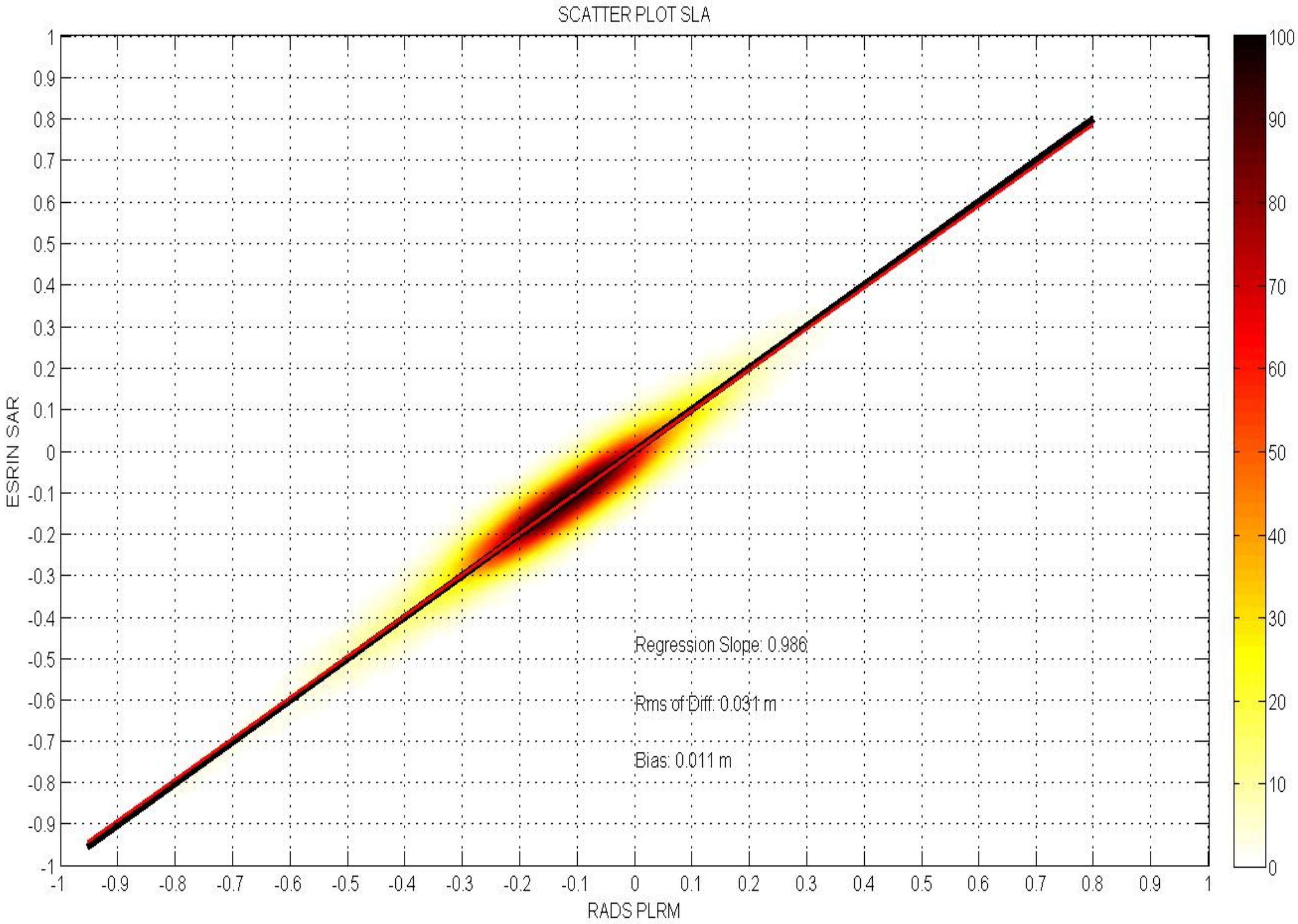
South Pacific Sigma zero Spectrum 1 Hz: RADS RDSAR vs ESRIN SAR



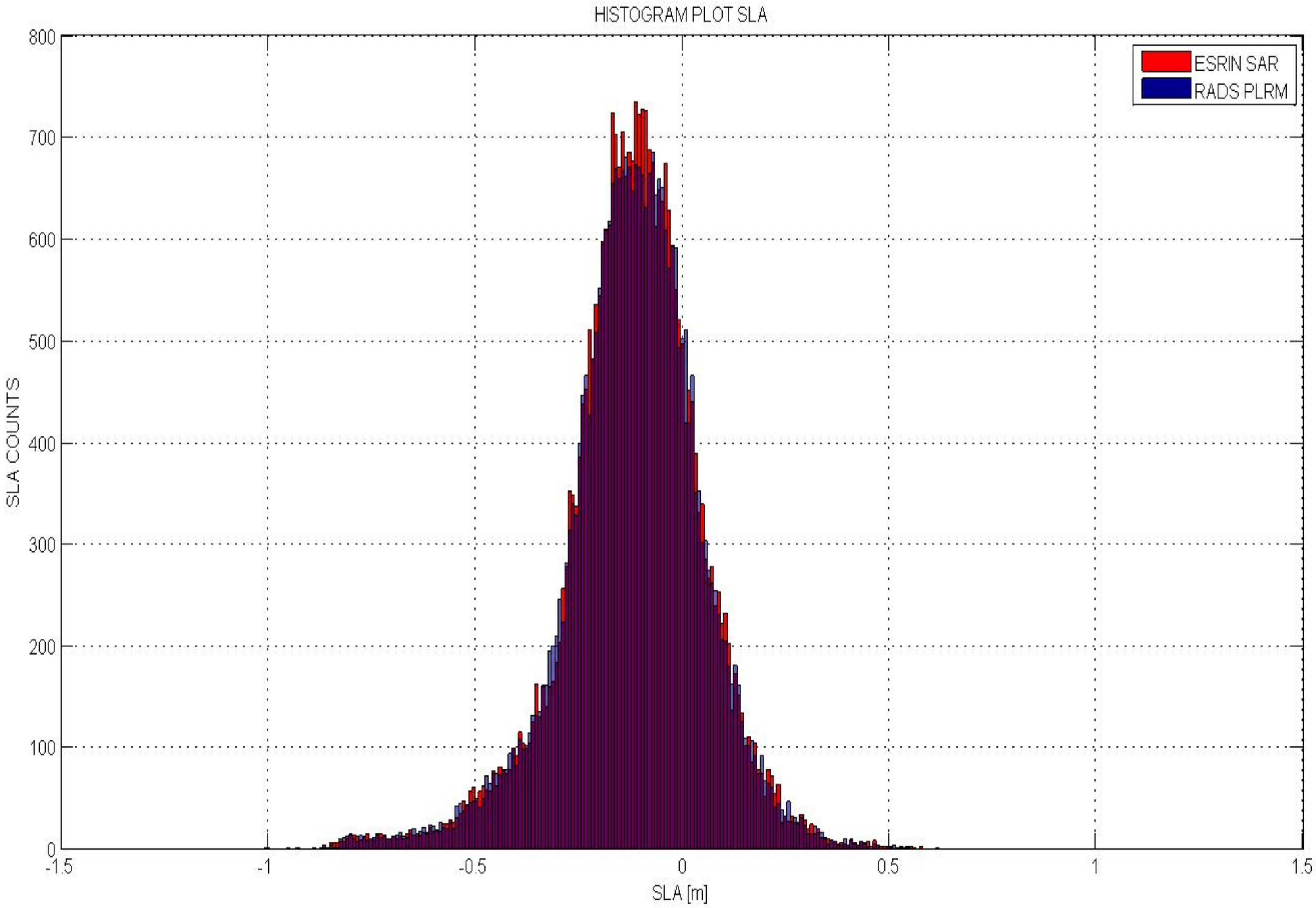
L2 Results SAR SAMOSA vs RADS PLRM (German Bight, 4 years) work with Luciana and Remko

Sea Level Anomaly

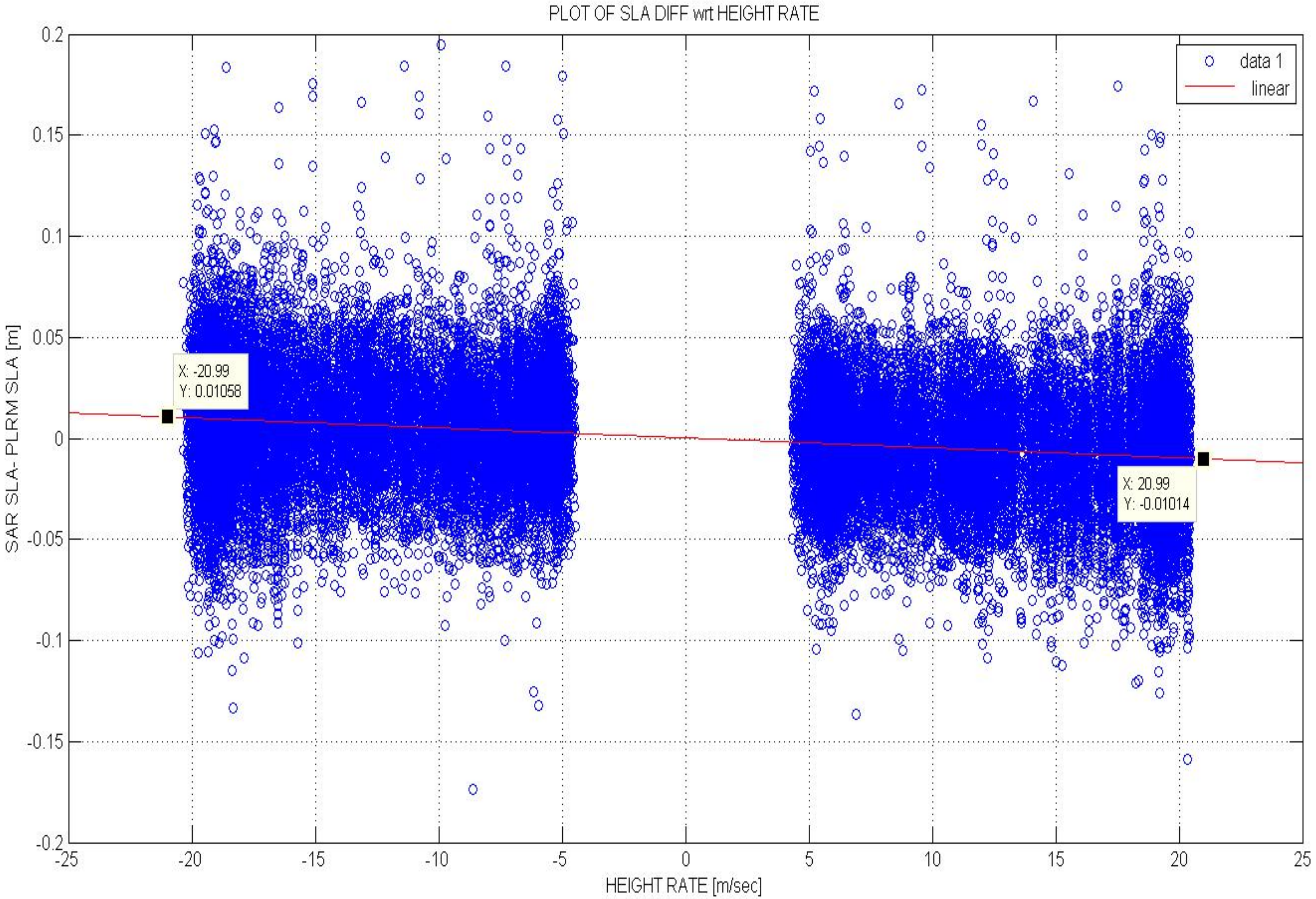
Sea Level Anomaly Scatter Plot SAR vs PLRM



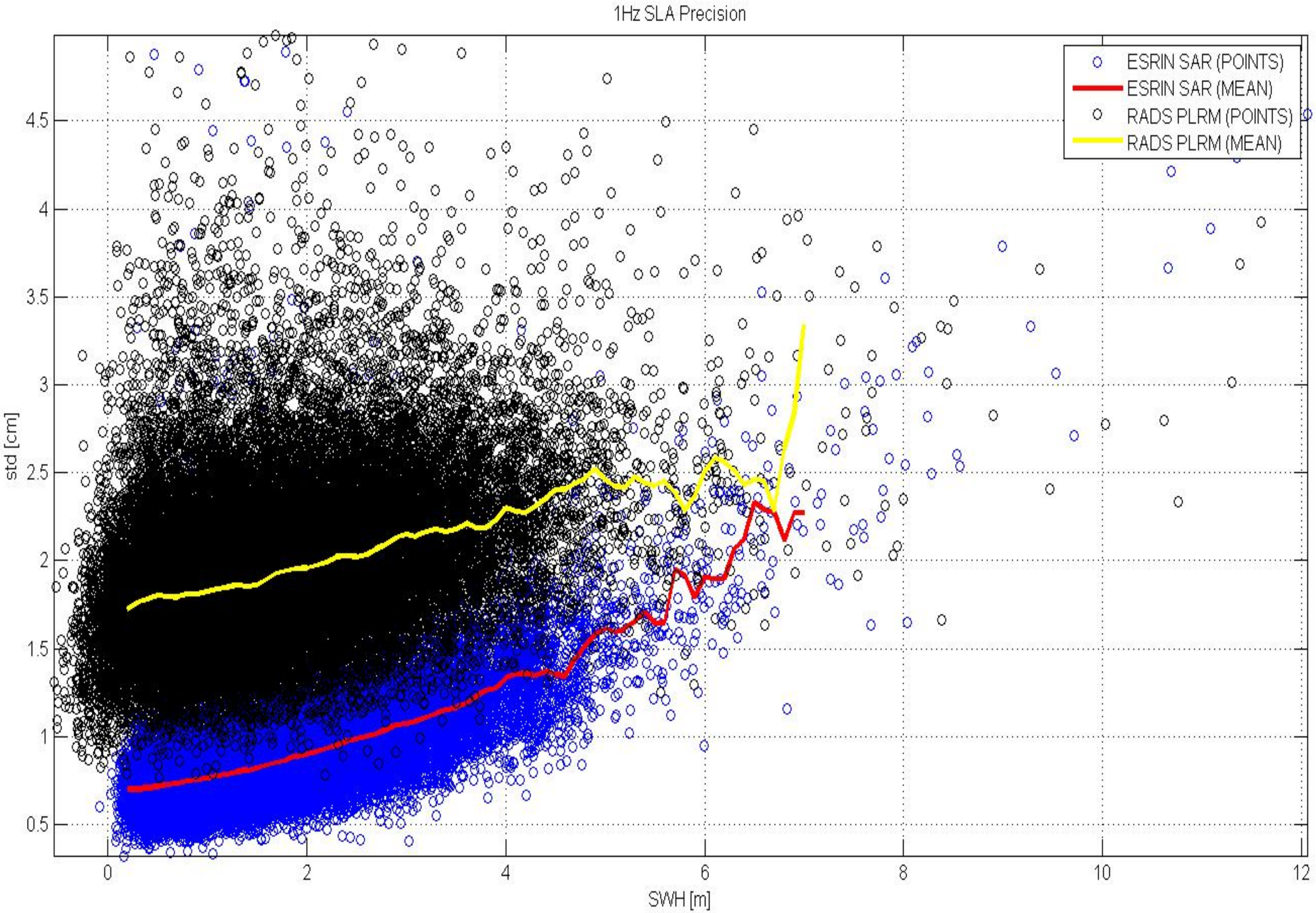
Sea Level Anomaly Histogram Plot: SAR vs PLRM



Sea Level Anomaly Dispersion Plot: vs Height Rate

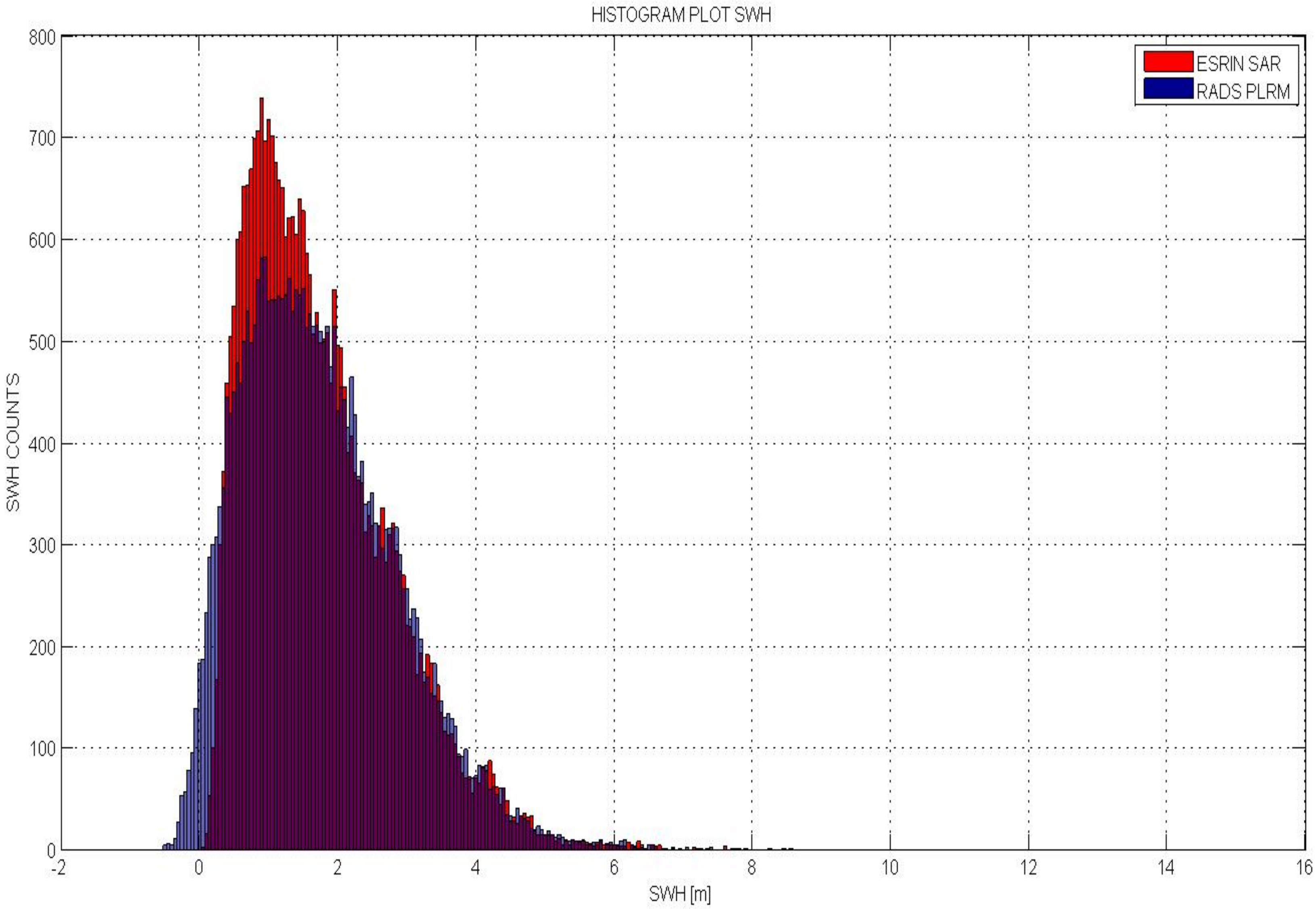


Sea Level Anomaly Performance Plot: SAR vs PLRM

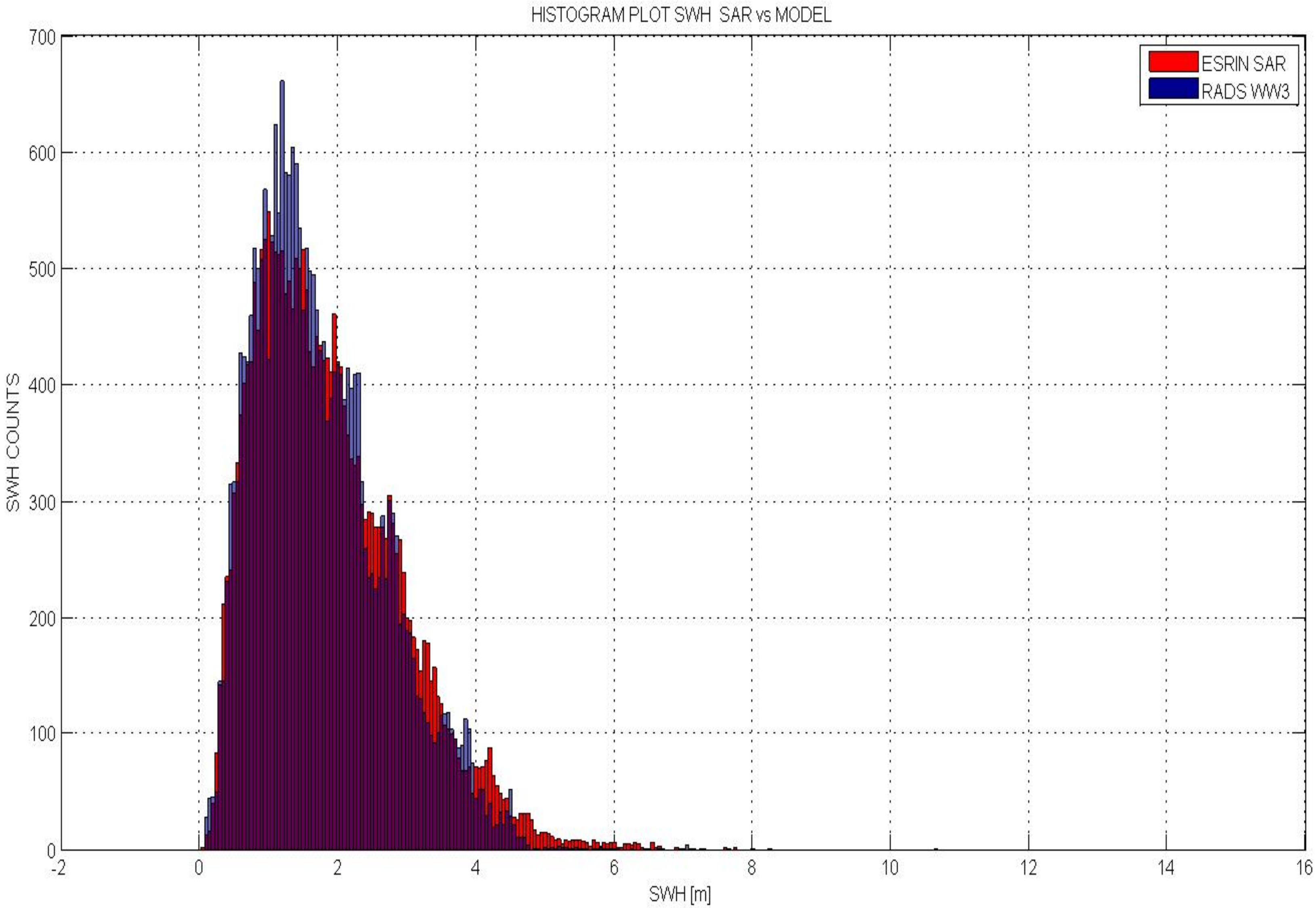


Significant Wave Height

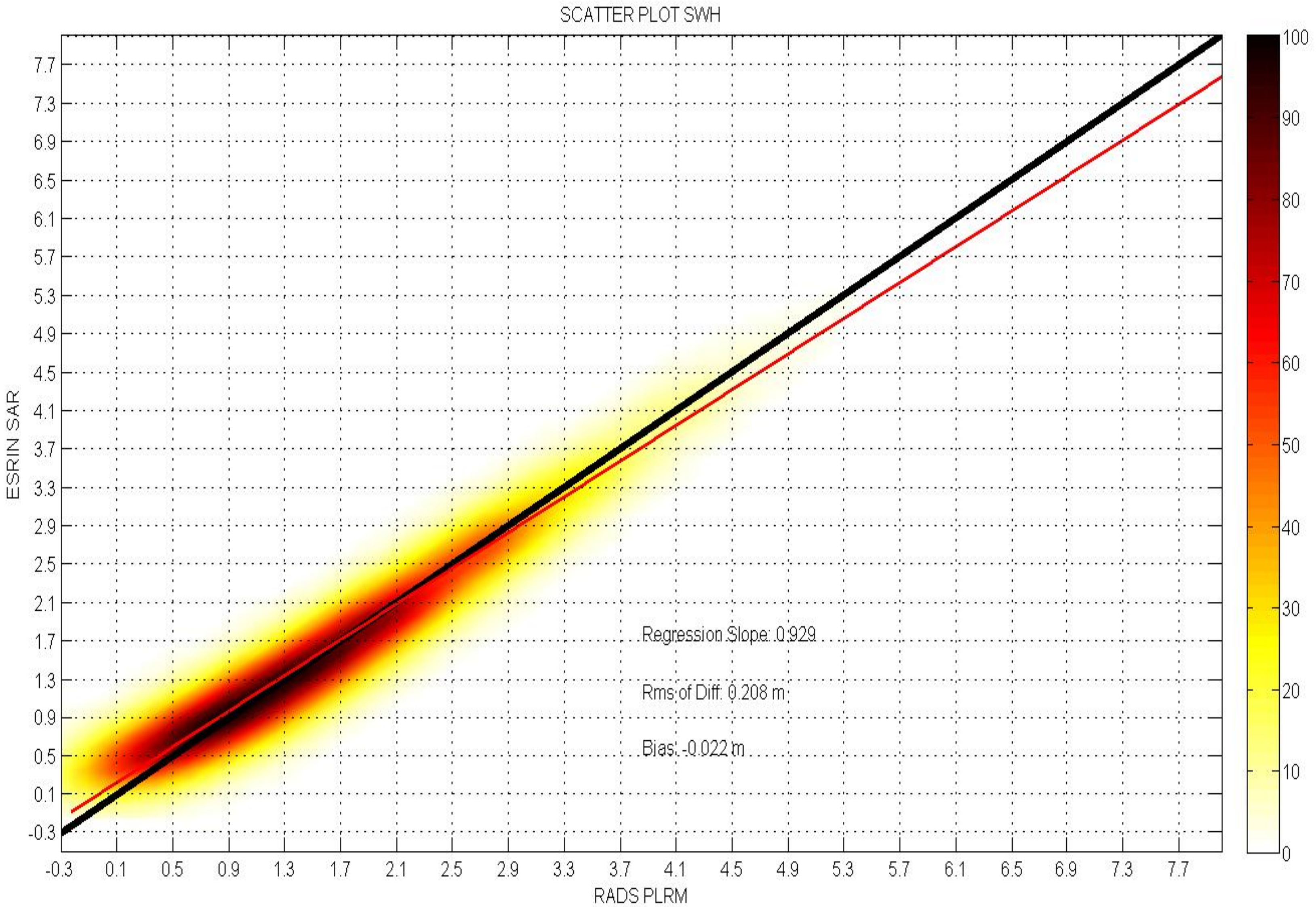
SWH Histogram Plot: SAR vs PLRM

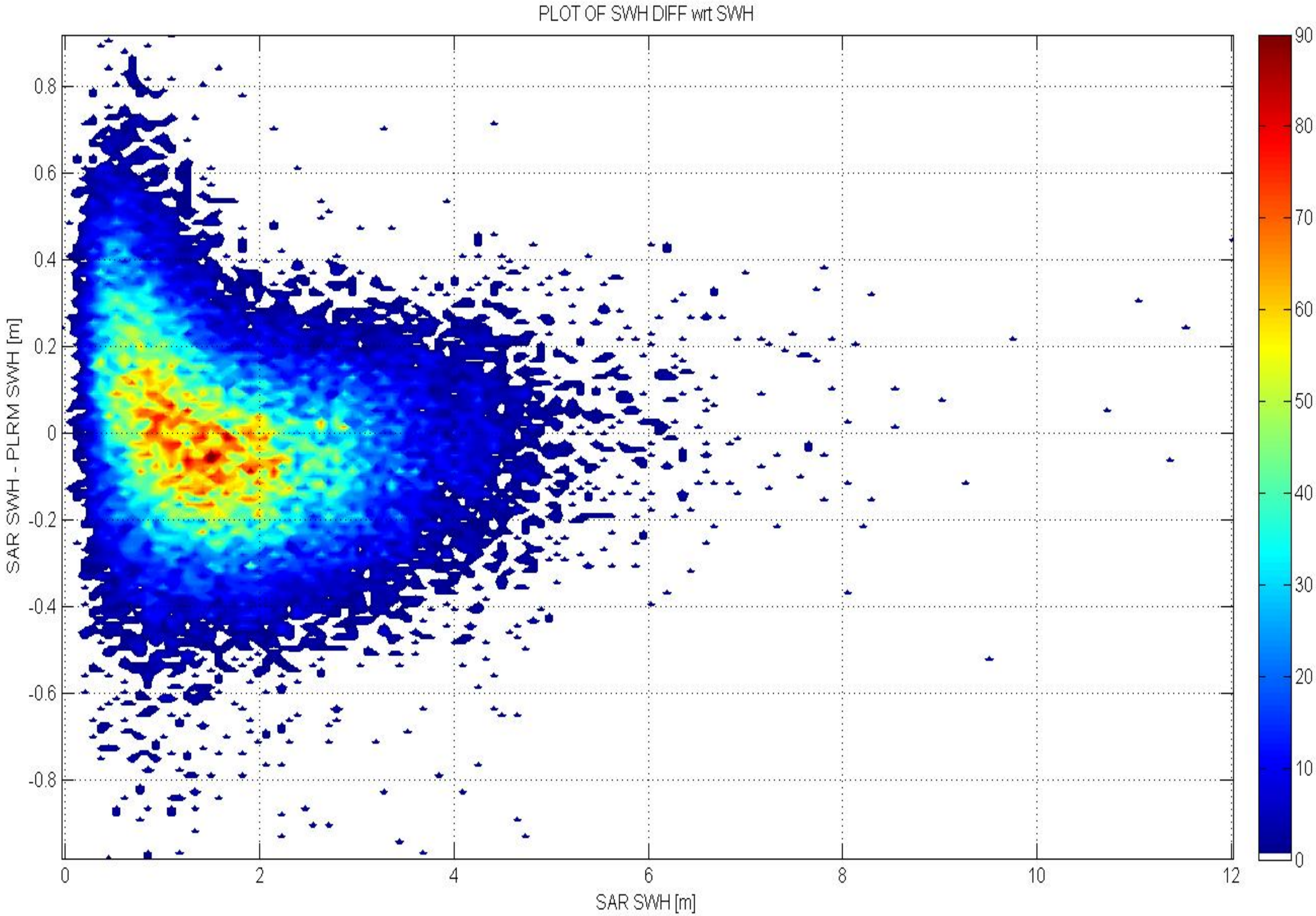


SWH Histogram Plot: SAR vs WW3 Model

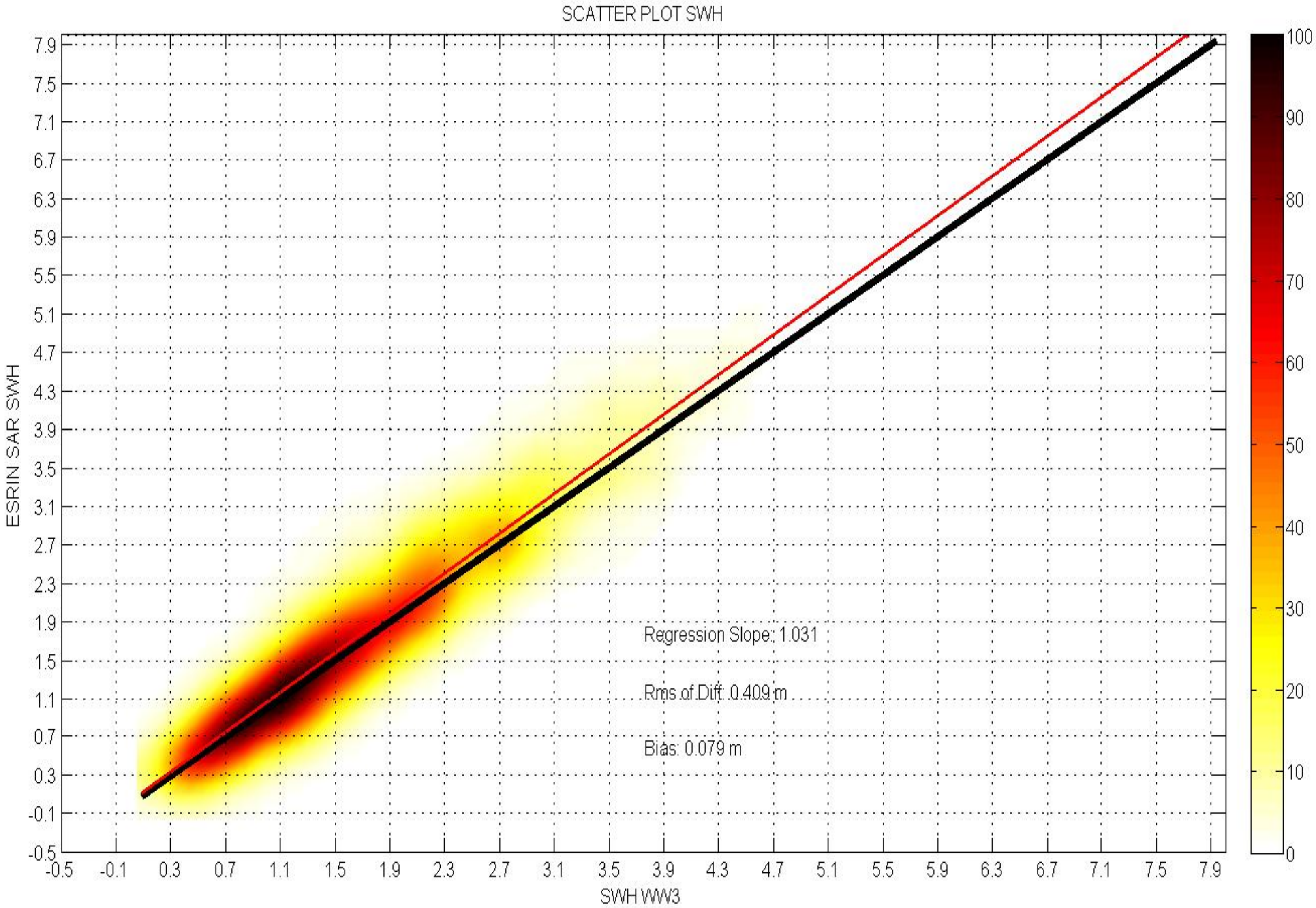


Significant Wave Height Scatter Plot SAR vs PLRM

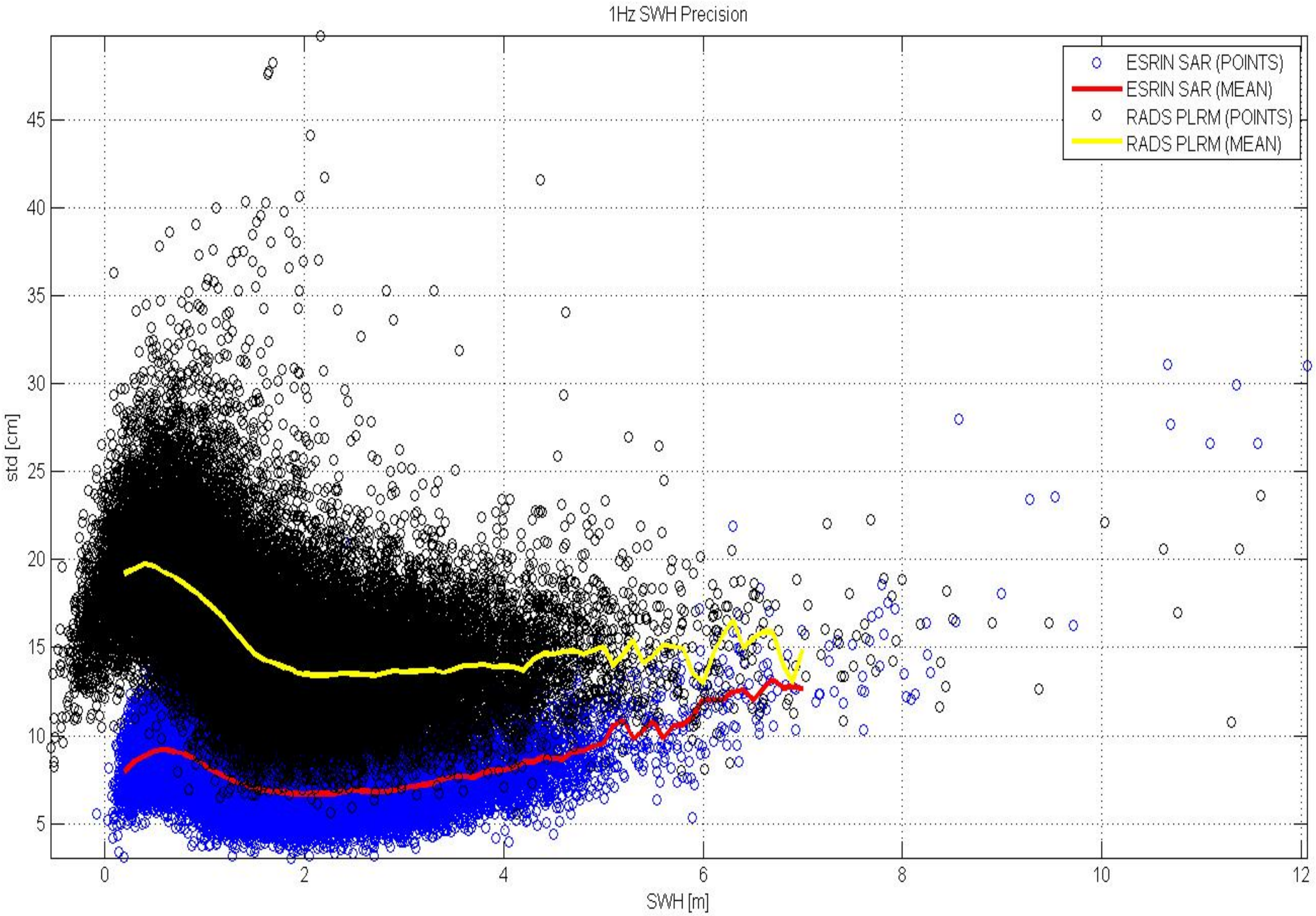



PLOT OF SWH DIFF wrt SWH
SAR SWH - PLRM SWH [m]
SAR SWH [m]
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
0
2
4
6
8
10
12
90
80
70
60
50
40
30
20
10
0

Significant Wave Height Scatter Plot SAR vs WW3



SWH Level Anomaly Performance Plot: SAR vs PLRM

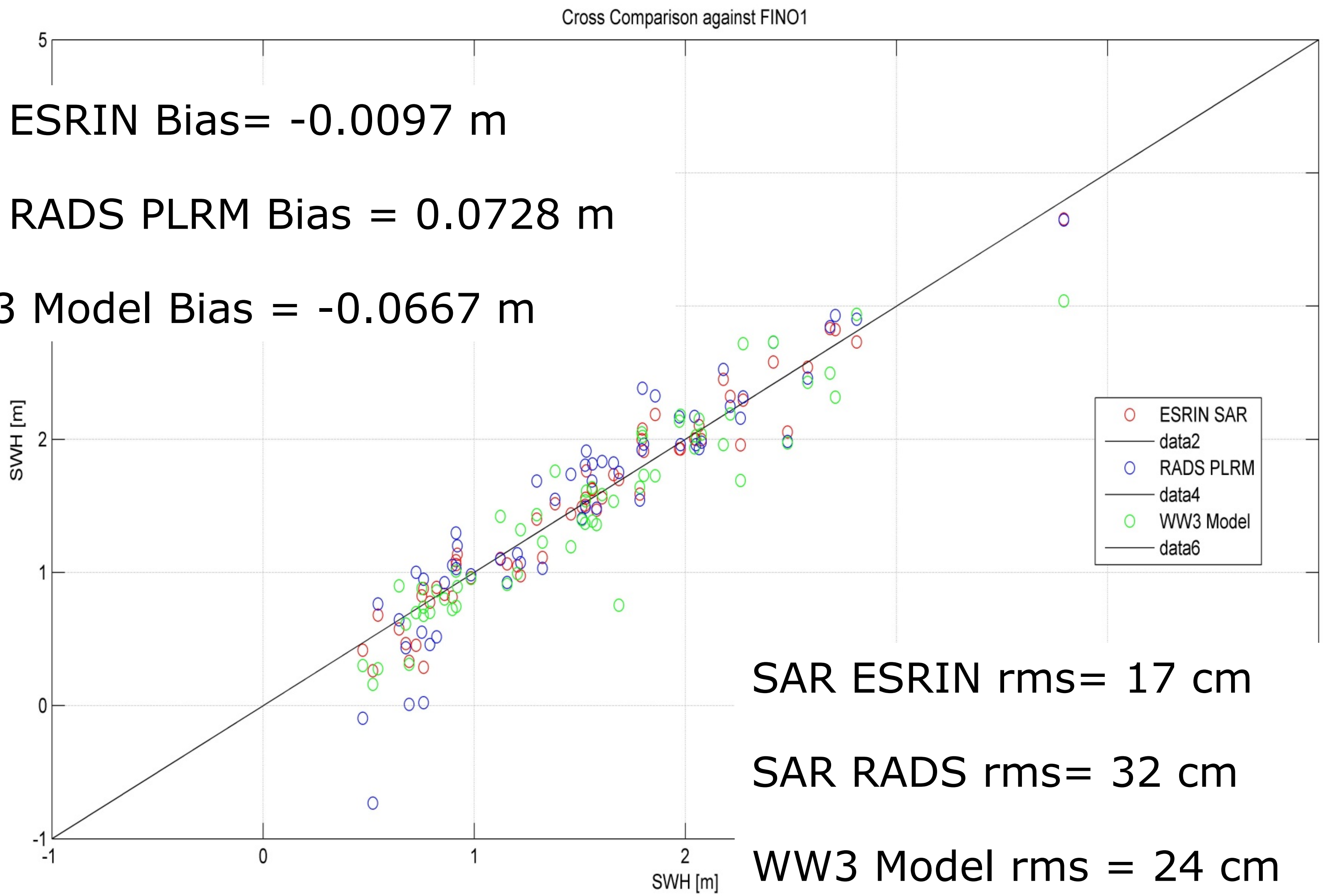


Cross Comparison against FINO1 Buoy (40 km distance lag, 30 min time lag, 58 points)

SAR ESRIN Bias= -0.0097 m

SAR RADS PLRM Bias = 0.0728 m

WW3 Model Bias = -0.0667 m



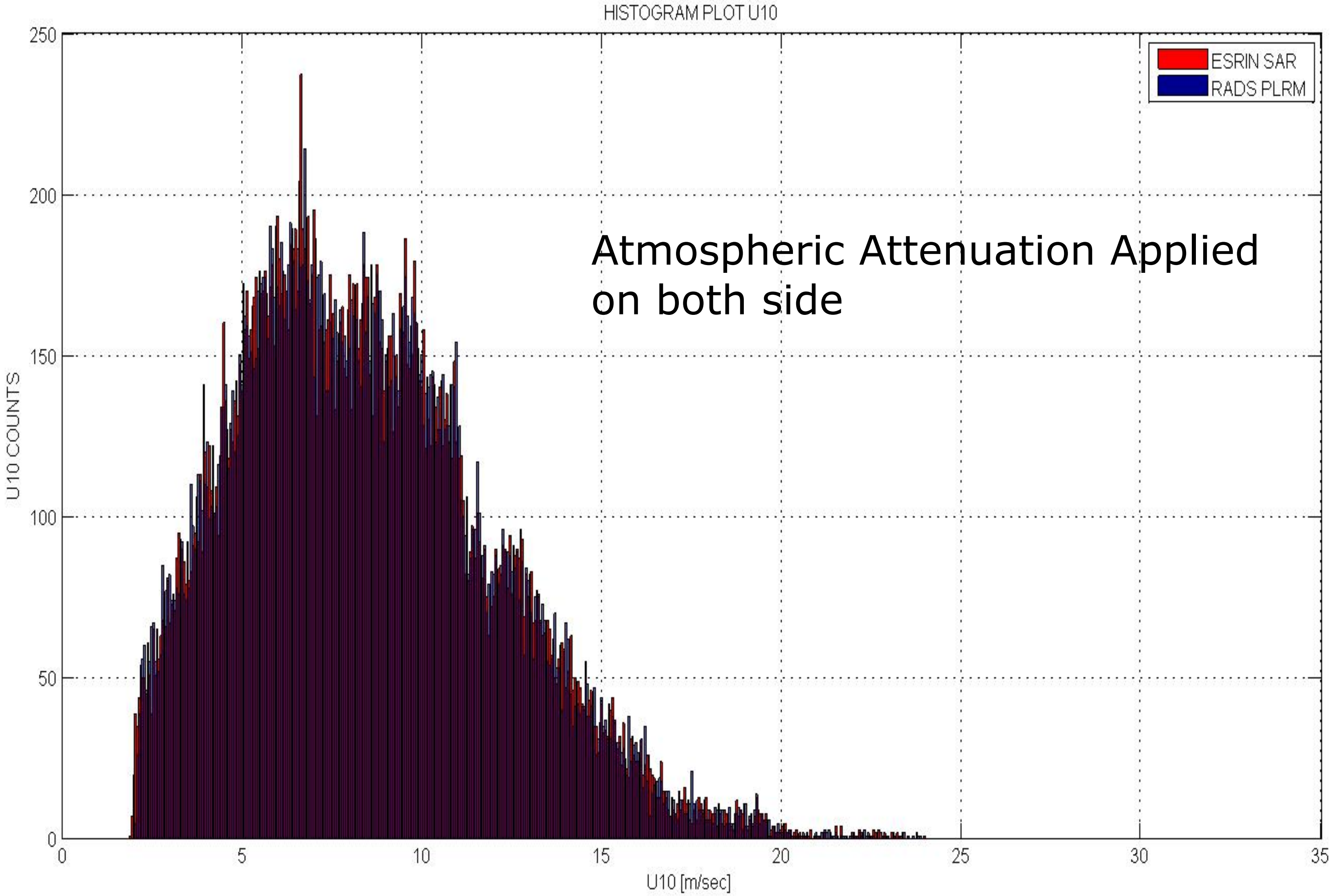
SAR ESRIN rms= 17 cm

SAR RADS rms= 32 cm

WW3 Model rms = 24 cm

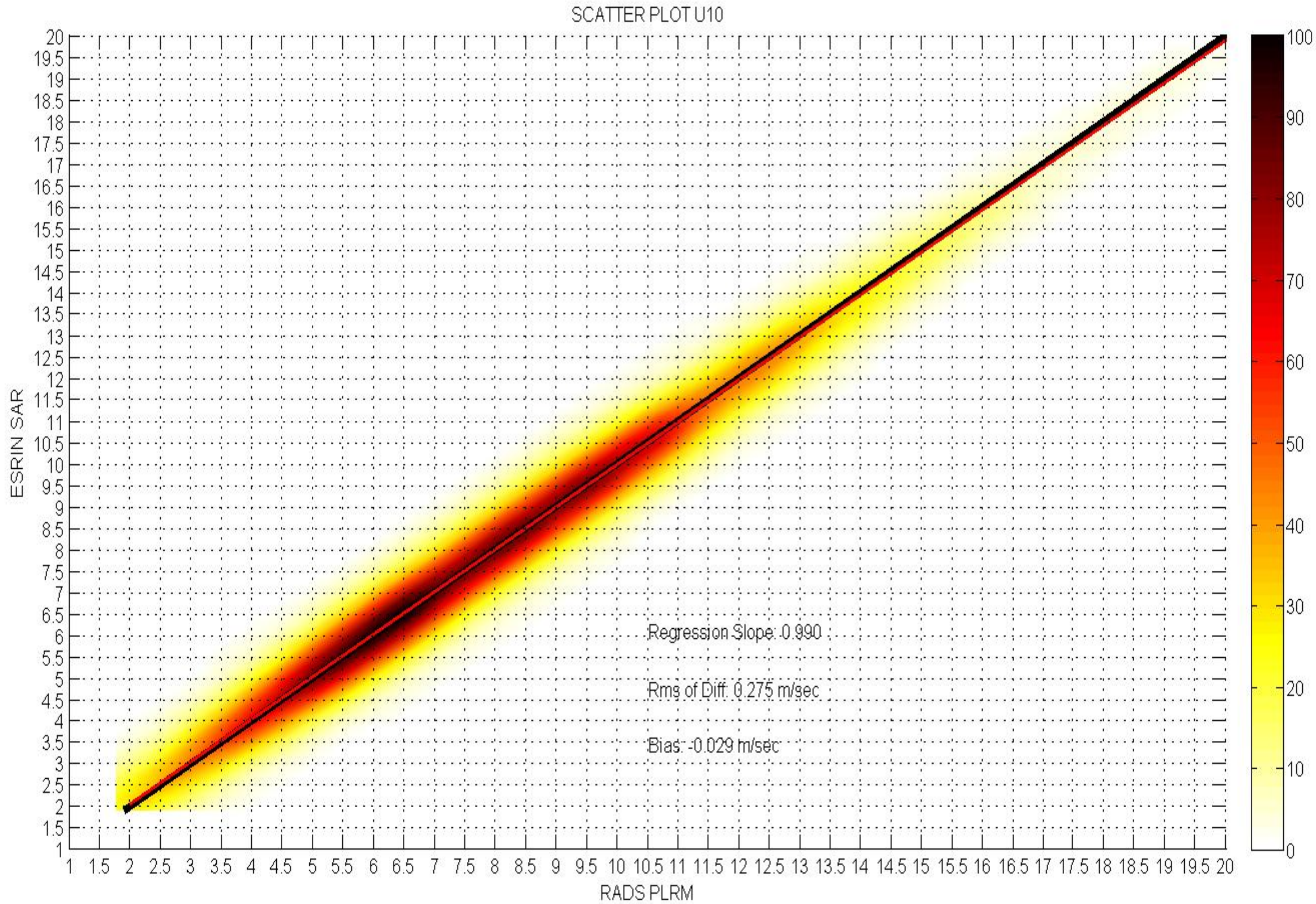
Wind Speed

U10 Histogram Plot: SAR vs PLRM

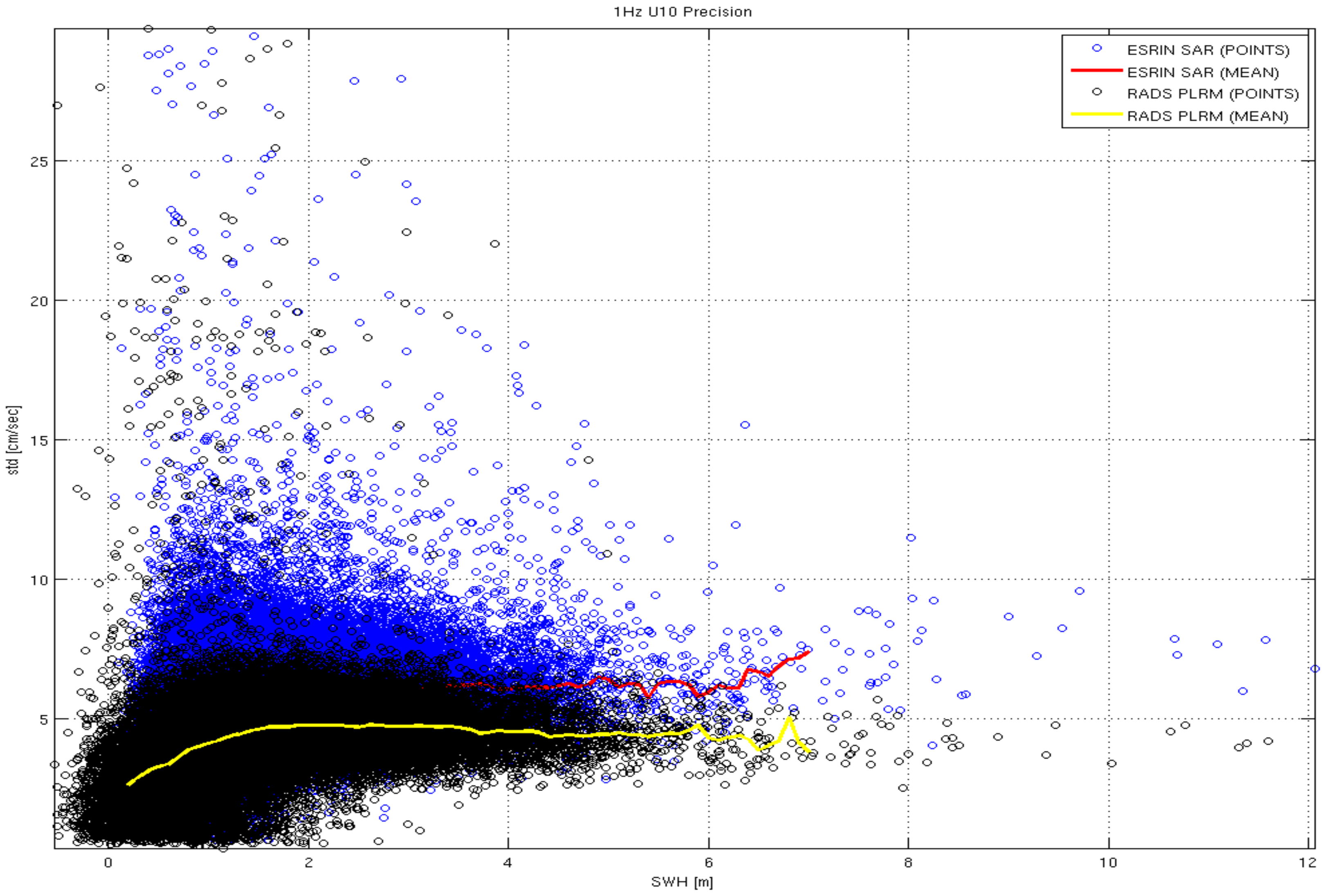


Atmospheric Attenuation Applied on both side

U10 Scatter Plot: SAR vs PLRM



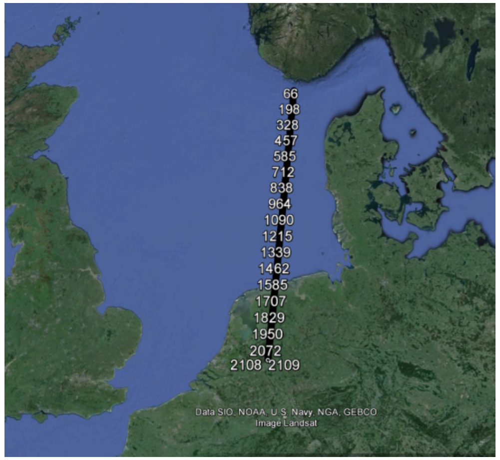
U10 Performance Curve: RADS RDSAR vs ESRIN SAR

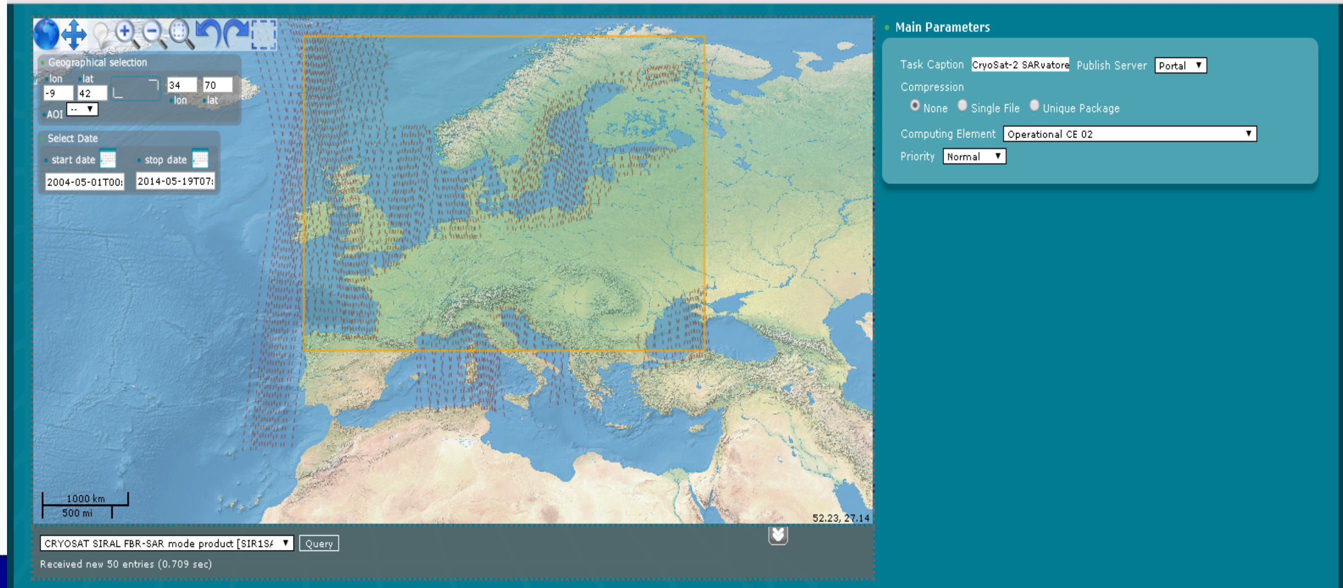


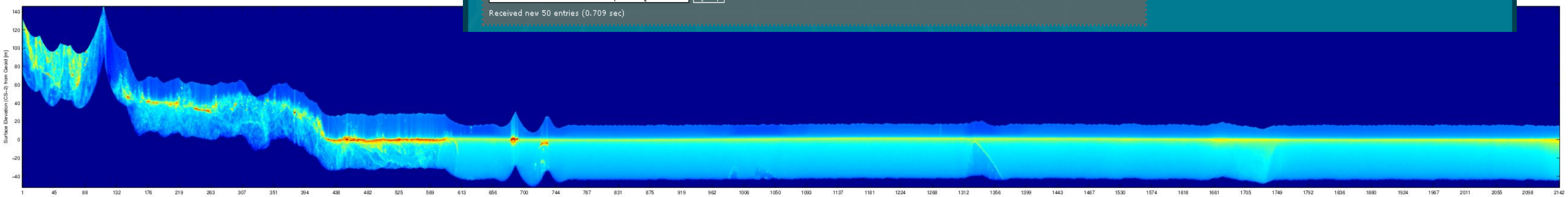
Importance to provide to the scientific community

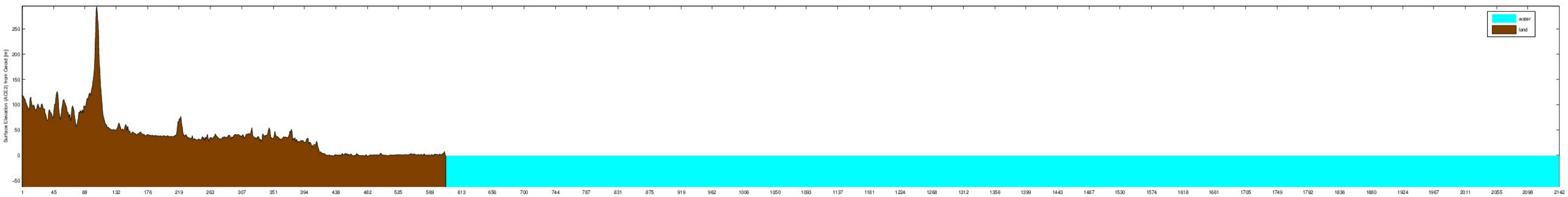
SAR Processing On Demand Service available at:

https://gpod.eo.esa.int/services/CRYOSAT_SAR/









Conclusions

- **Nowadays, SAR Processing is a mature technique (at L1b and L2)**
- **Near Perfect Agreement between Analytical Solution (ESRIN SAM) and Numerical Solution (CNES CPP)**
- **Very good agreement wrt RADS PLRM (degraded classical altimetry) wrt in situ data and wrt model data**
- **Actually, only big thing missing is the sea state bias**
- **Big thanks to CNES for providing L1b CPP (something not planned at CP4O kick off) and Remko for RADS data, Luciana for model and in situ data**