Validation Exercise over German Bight

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OUTLINE

The presentation is structured in the following points:

- Introduction/Heritage
- Dataset Used
- Processing Configuration
- Validation Methods
- Results
- Conclusions

Document Purpose

The aim of this document is to respond to the CP40 project Action placed on ESRIN responsibility:

"Need for a Configuration Control for the SAMOSA Retracker:

It is necessary to put in place a configuration control for development and validation of the SAMOSA3 re-tracker;

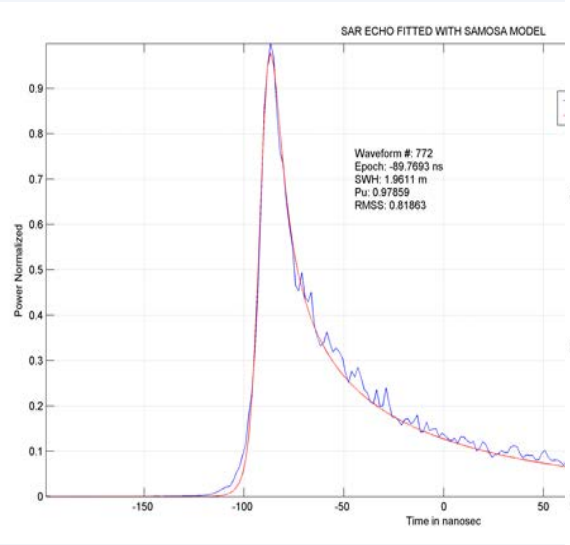
All Implementations of the SAMOSA retracker shall be:

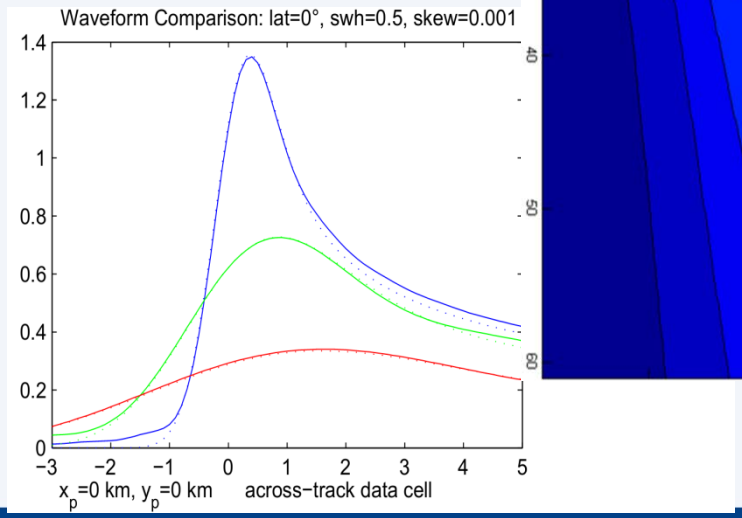
- validated by processing a benchmark Cryosat-2 input data set (to be defined).

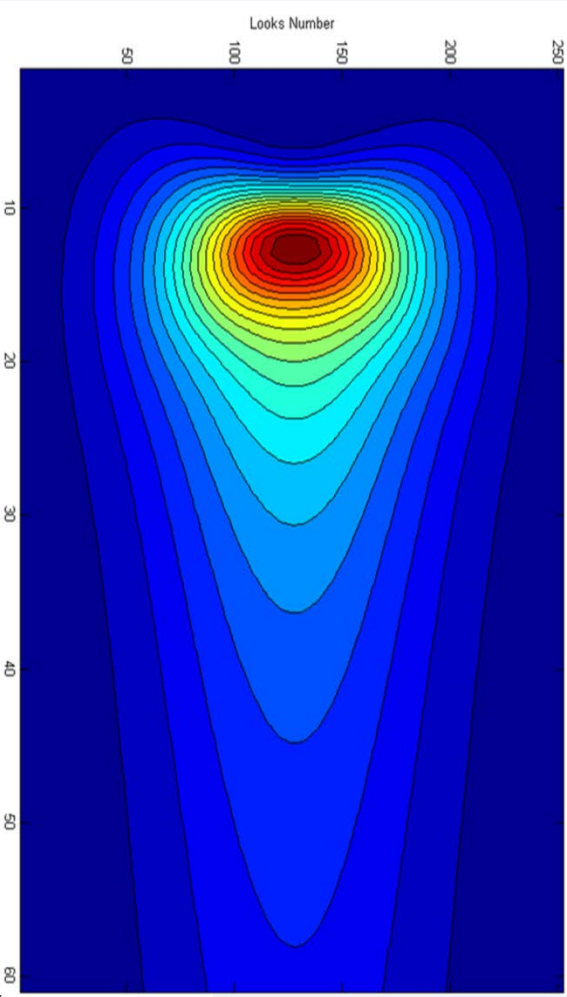
- and then applying an validation analysis method to be agreed (e.g. Calculation of SD in SSH and SWH at 20Hz and regression against buoy SWH?), reported in a validation document"

SAMOSA HERITAGE

- **SAMOSA MODEL**: Physically-based model developed by Starlab from first principles
- Analytical **(by Bessel Functions)** solutions to model the Delay Doppler Maps (DDM) for the full span of Doppler Frequencies
- Model depends on epoch, significant wave height, Pu, surface rms slope, and mispointing angle(s),
- The model independent variables are the Doppler Frequency and the Time Delay
- The waveforms are retracked by Bounded Least- Square Fitting Algorithm (**Levenberg-Marquard**)

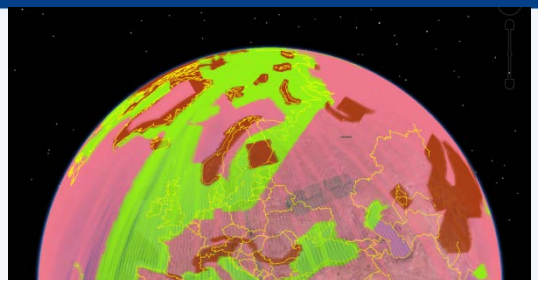






ESRIN KNOW HOW and SAR DATA PRODUCTION

ESRIN EOP-SER Section, for validation purposes and preparation to Sentinel-3 mission (**SAR Retracker Algorithm Definition**), implemented an ESRIN SAR Processor Prototype in order to Delay-Doppler process CryoSat FBR data and re-track Delay-Doppler Echoes



- SAR/SARin FBR/L1b DATA Archiving and Cataloguing
- SAR/SARin L1b & L2 Processor Prototype

-Input: CRYOSAR SAR FBR DATA

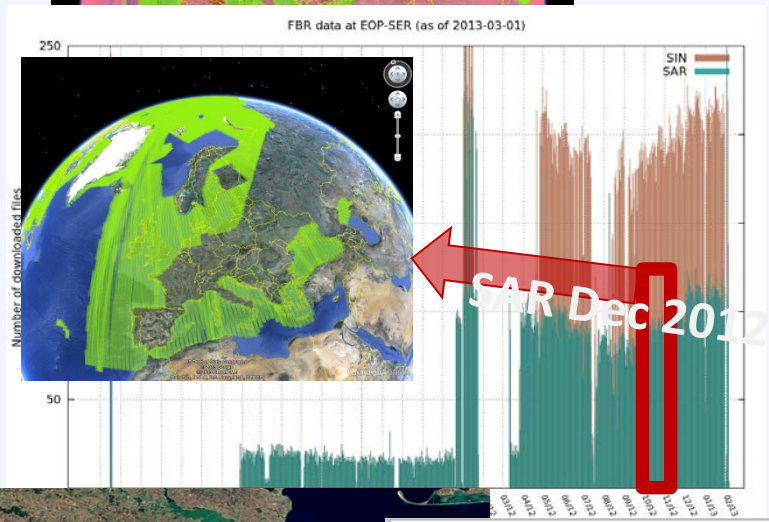
-Coding Language: MATLAB

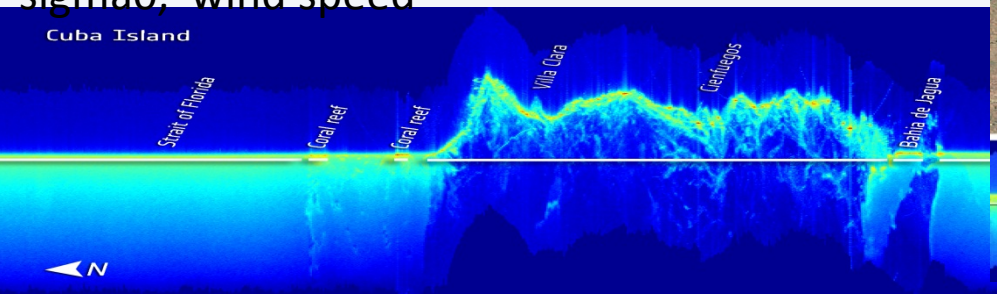
-At L1b, Standard Delay-Doppler Processing (**description on line in** https://wiki.services.eoportal.org/tiki-download_wiki_attachment.php?attId=2540)

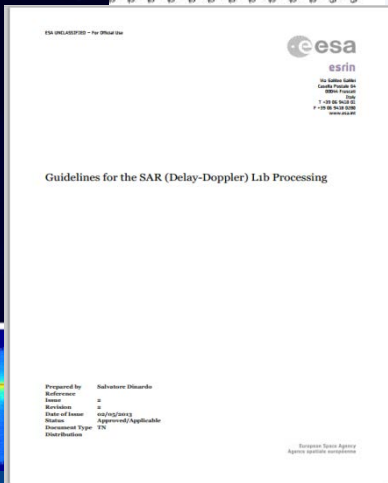
-At L2, Re-tracker with SAMOSA-Analytical Model using Levmar Least Square Estimator

-Output L1b → Radar Echogram

-Output L2 → SLA (W/O SSB), SSH , SWH, sigma0, wind speed



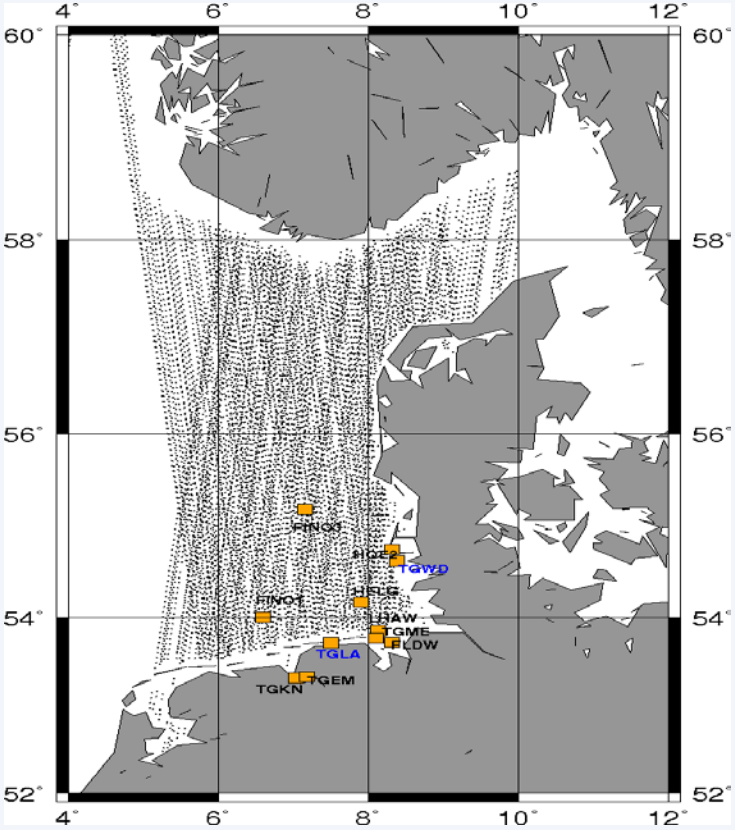




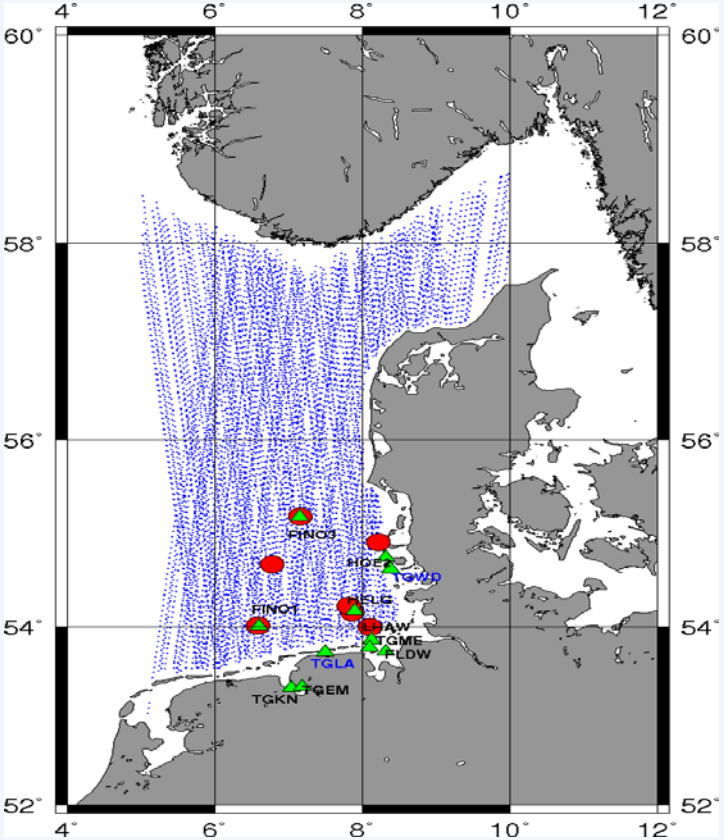
DATASET USED in the Validation

DATASET USED in GERMAN BIGHT

RADS PLRM (PSEUDO-LRM) 2011-2012



ESRIN SAR 2011-2012



- WE COMPARE ALTIMETERIC PARAMETERS (SLA, SWH, U10) IN SAR MODE (from ESRIN Processing) and IN PLRM MODE (from RADS Database) for 2011-2012 time
- DATA IN OPEN OCEAN ONLY (> 10 KM FROM COAST)

PROCESSING CONFIGURATION

PROCESSING CONF AT L1b

- A Pre-FFT Zero-Padding in range is applied in order to avoid aliasing for low-SWH conditions (Jansen's sampling)
- A Doppler weighting (Hamming) is applied only over land and in coastal zone (Distance to land >10 km => weighting off,Distance to land <10 km => weighting on)
- No Antenna Pattern Compensation is applied on the stack data
- Noisy Stack Looks ruled out from the multi-looking (stack thresolding)
- Multilooked waveform posted at same time tag than in CryoSat-2 Kiruna PDGS products

PROCESSING CONF AT L2

- SAMOSA Model generation: SAMOSA v3 (see last slide for ref)
- Roll/Pitch mis-pointings (from platform) in input to retracking scheme and platform values are compensated for biases
- Thermal Noise estimated a priori and fed as input in the re-tracking algorithm
- SAR Multilooked Echo Model generated using the same number of looks used in generating the SAR input Waveform
- Range PTR Alpha_p set to 0.513 (RADS PLRM Value)
- Slope/Vertical Speed Effect Switched on
- Sigma nought calculated from Pu inverting SAR Radar Equation and wind speed extracted from sigma nought using Envisat wind model after sigma0 mission inter-calibration

Method of regional comparison

- **We compare:**
  - SSH/SLA,
  - SWH,
  - WIND SPEED (U10),

- **Inter-comparison of Altimetry Data**:
  - C2/PLRM (extracted from RADS database) versus C2/SAR (processed in house at ESRIN) along tracks

- **In-situ data**:
  - SWH C2 versus in-situ SWH AWAC data (Acoustic Wave and Current Meter, BSH)
  - SSH C2 versus in-situ GPS@TG at FINO3 platform, Helgoland

Method of regional comparison

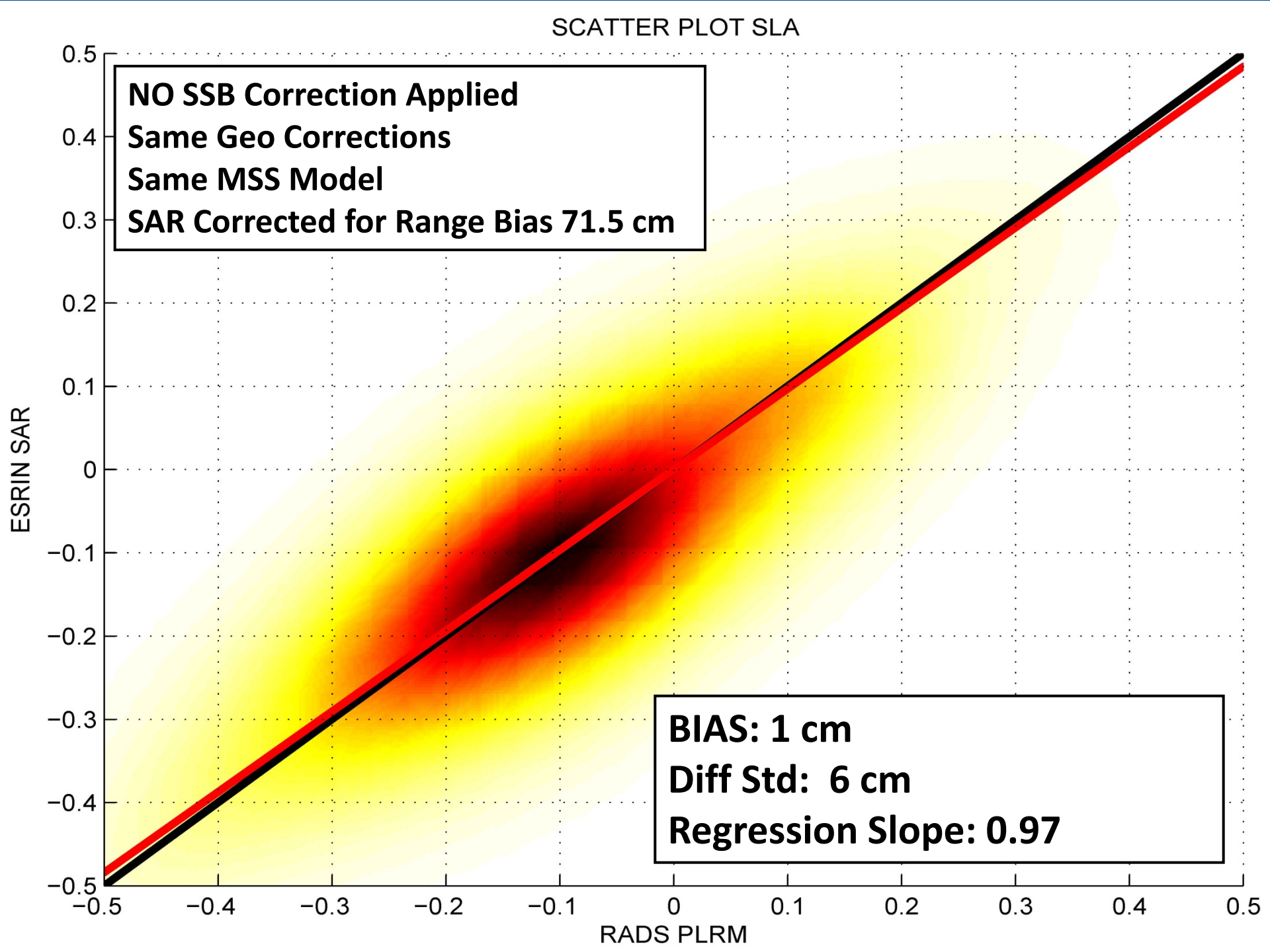
Statistical parameters to assess and compare:

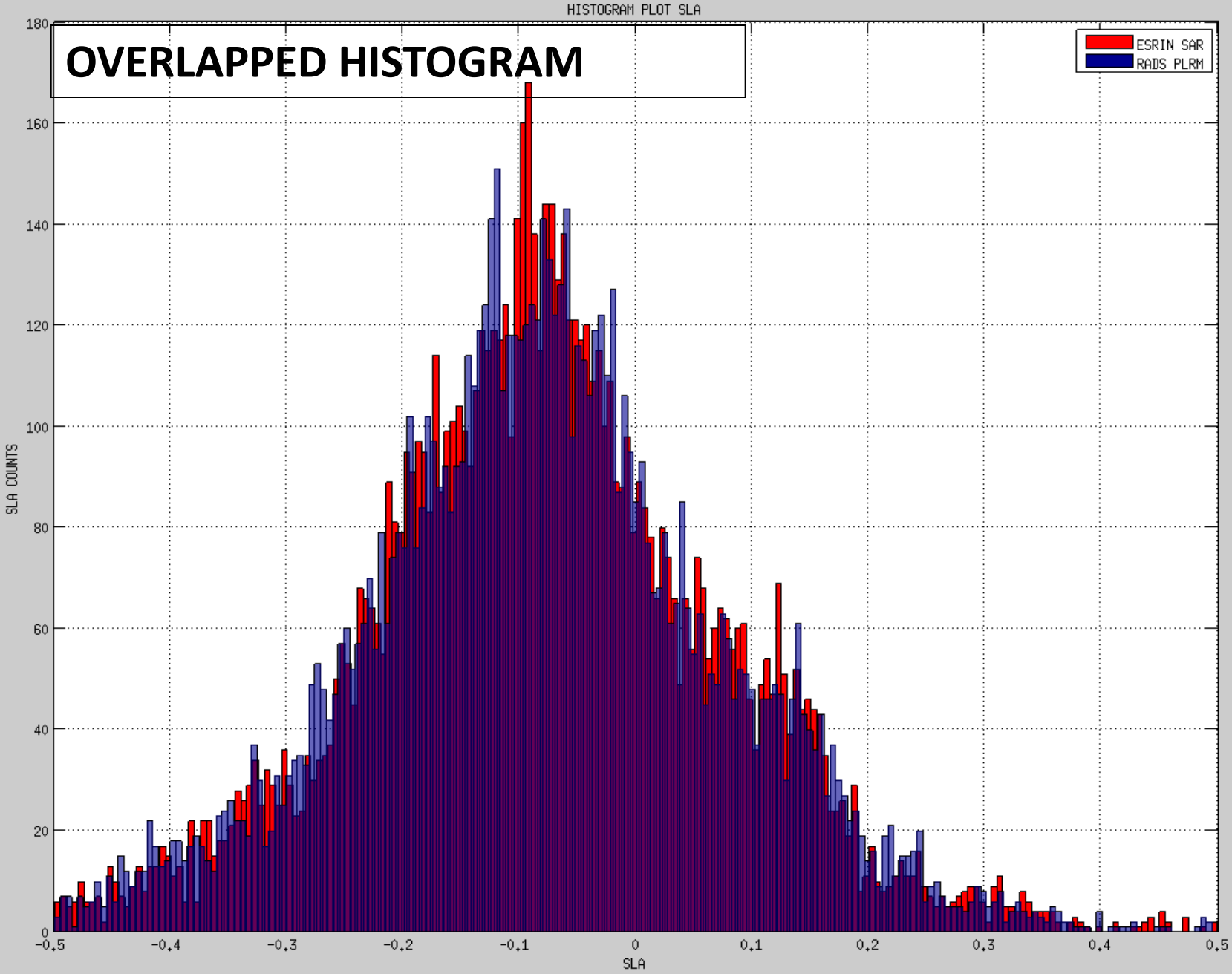
- **mean**
- **standard deviation** (of model, obs. and of their differences),
- **correlation**,
- **slope of the regression line** (SAR in y-axis, PLRM in x-axis),
- **scatter index** (SI, std of the data with respect to the best-fit line, divided by the mean observed value).

Corrections applied to SSH for comparison

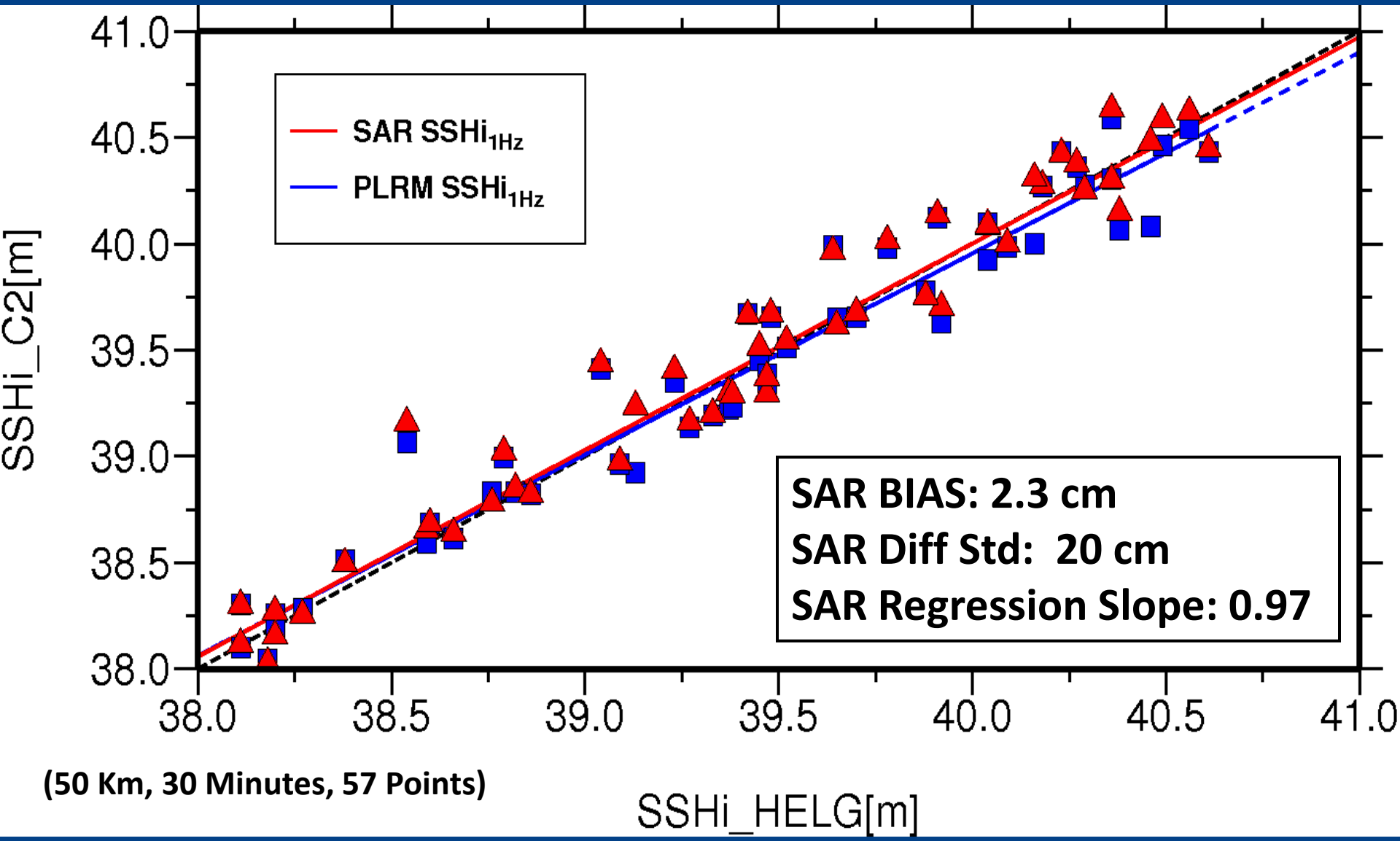
- SSH C2/PLRM versus C2/SAR along tracks
  - Compare SSH
    - no SSB applied for PLRM and SAR
    - Same MSS and geo-corrections
    - SAR: range bias 71.5 cm
    - RADS PLRM : orbit – range + 0.247 + correction to WGS84 ellipsoid
- SSH C2 versus in-situ GPS@TG at FINO3 platform
  - Not applied:
    - Sea state bias
    - Ocean Tide correction
    - inverse barometer (DAC) correction
    - Ocean part of pole tide correction

RESULTS OVER OPEN SEA

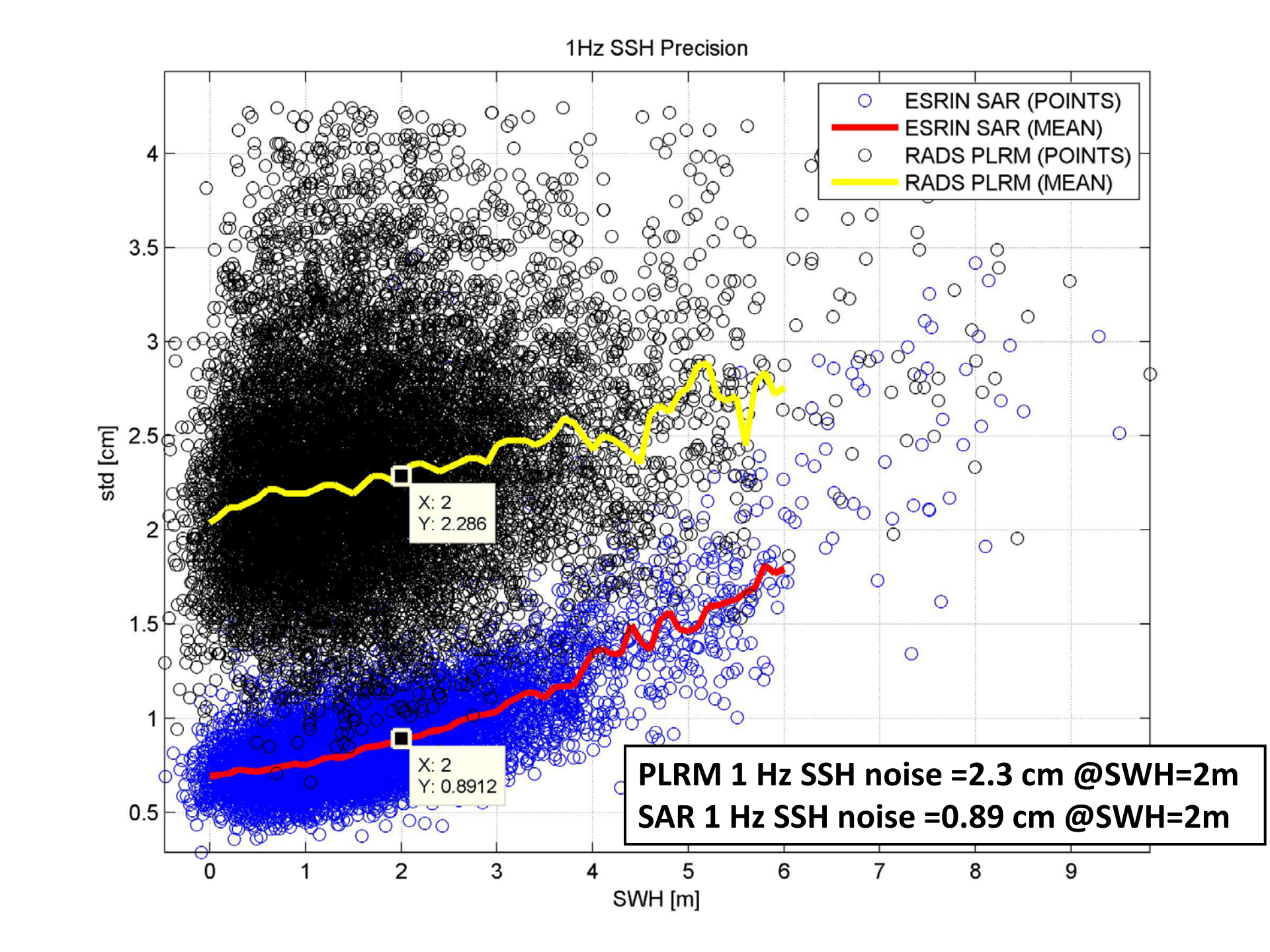

SCATTER PLOT SLA
NO SSB Correction Applied
Same Geo Corrections
Same MSS Model
SAR Corrected for Range Bias 71.5 cm
BIAS: 1 cm
Diff Std: 6 cm
Regression Slope: 0.97
ESRIN SAR
RADS PLRM
0.5
0.4
0.3
0.2
0.1
0
−0.1
−0.2
−0.3
−0.4
−0.5
−0.5
−0.4
−0.3
−0.2
−0.1
0
0.1
0.2
0.3
0.4
0.5

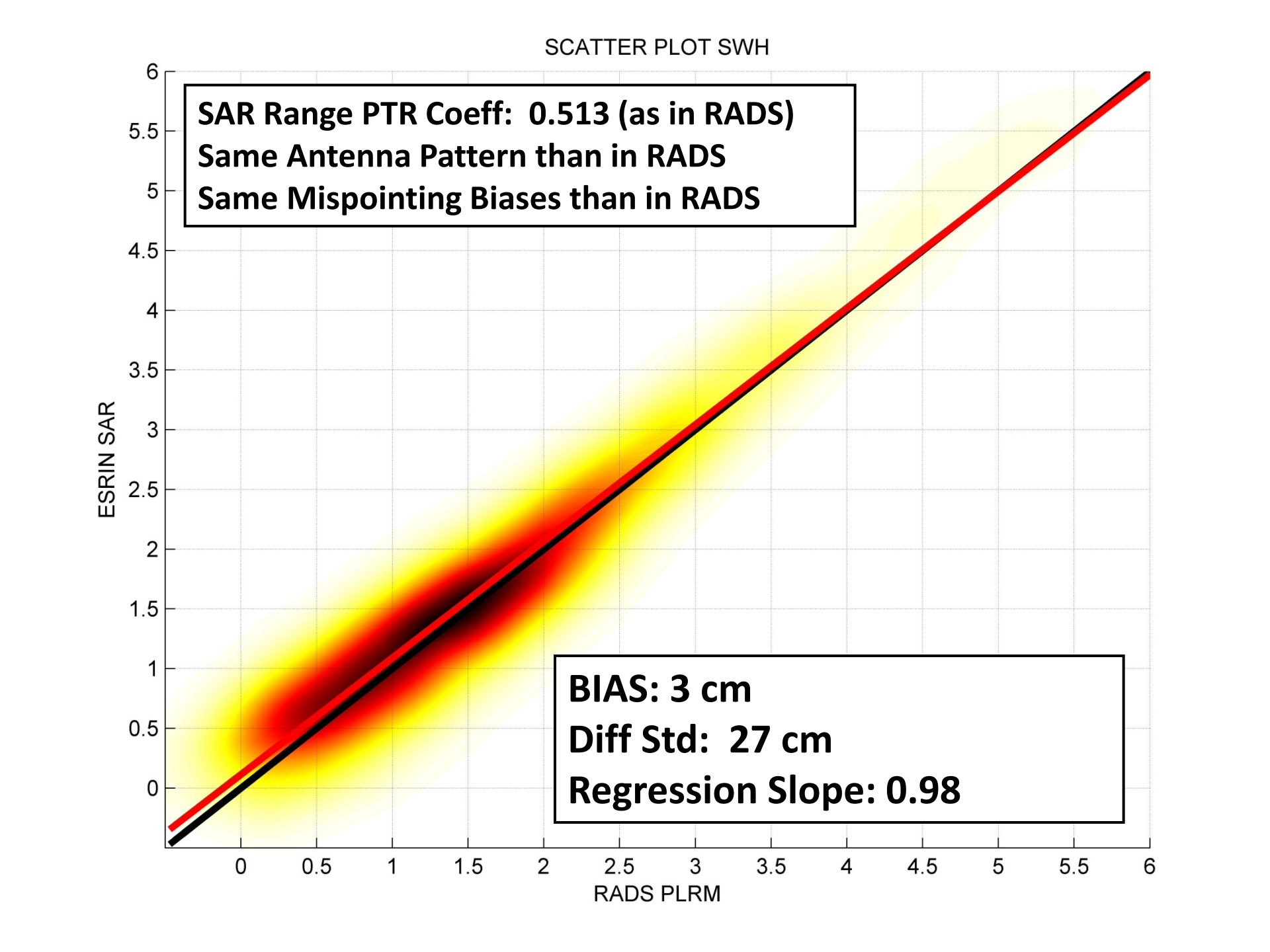

OVERLAPPED HISTOGRAM
HISTOGRAM PLOT SLA
ESRIN SAR
RADS PLRM
SLA COUNTS
SLA
0
20
40
60
80
100
120
140
160
180
-0.5
-0.4
-0.3
-0.2
-0.1
0
0.1
0.2
0.3
0.4
0.5

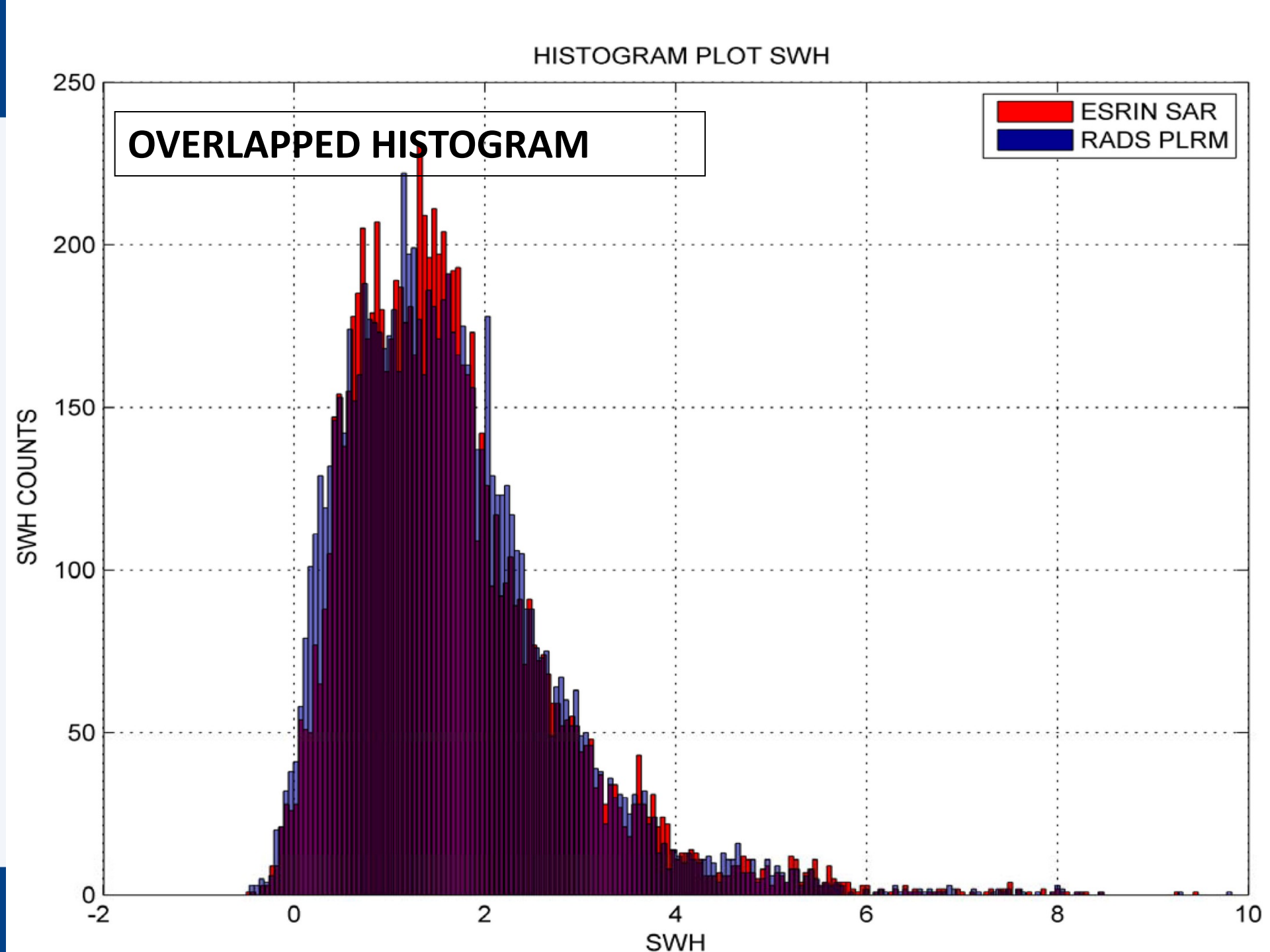
Validation against in situ data: SSH



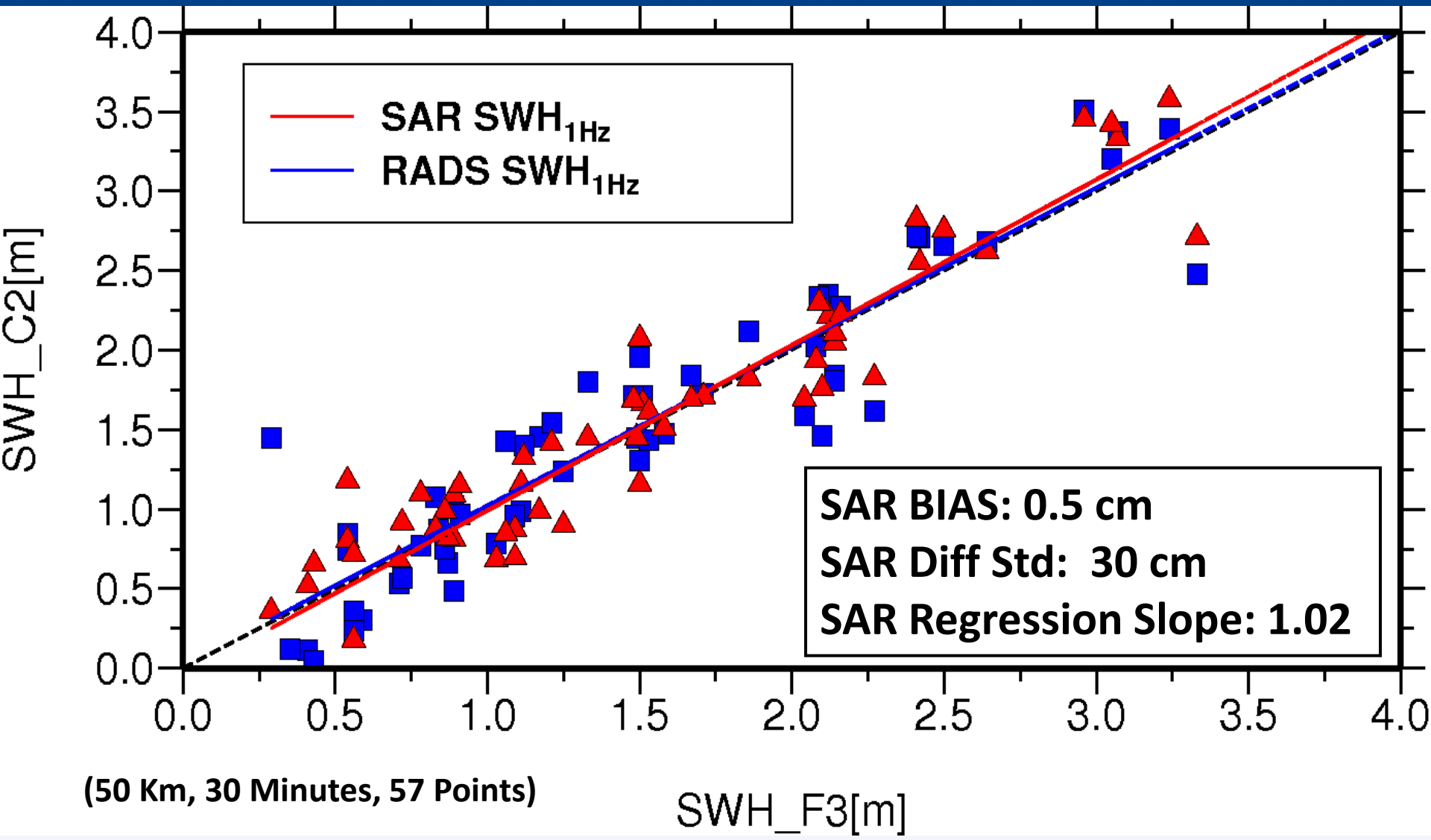
(50 Km, 30 Minutes, 57 Points)


1Hz SSH Precision
ESRIN SAR (POINTS)
ESRIN SAR (MEAN)
RADS PLRM (POINTS)
RADS PLRM (MEAN)
X: 2
Y: 2.286
X: 2
Y: 0.8912
std [cm]
SWH [m]
0.5
1
1.5
2
2.5
3
3.5
4
0
1
2
3
4
5
6
7
8
9
PLRM 1 Hz SSH noise =2.3 cm @SWH=2m
SAR 1 Hz SSH noise =0.89 cm @SWH=2m

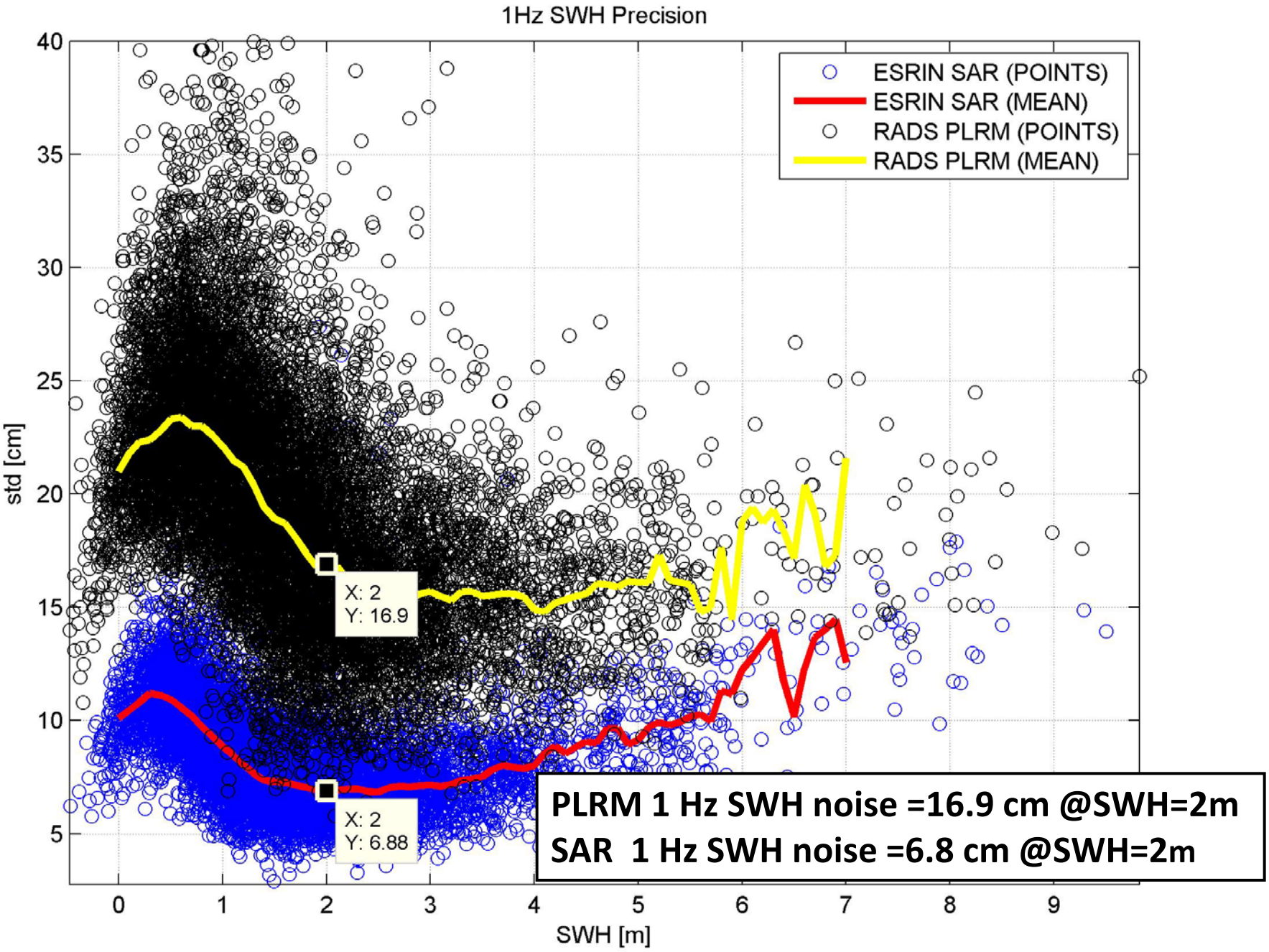

SCATTER PLOT SWH
SAR Range PTR Coeff: 0.513 (as in RADS)
Same Antenna Pattern than in RADS
Same Mispointing Biases than in RADS
BIAS: 3 cm
Diff Std: 27 cm
Regression Slope: 0.98
ESRIN SAR
RADS PLRM
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
5.5
6


HISTOGRAM PLOT SWH
OVERLAPPED HISTOGRAM
ESRIN SAR
RADS PLRM
SWH COUNTS
SWH
250
200
150
100
50
0
-2
0
2
4
6
8
10

Validation against in situ data: SWH

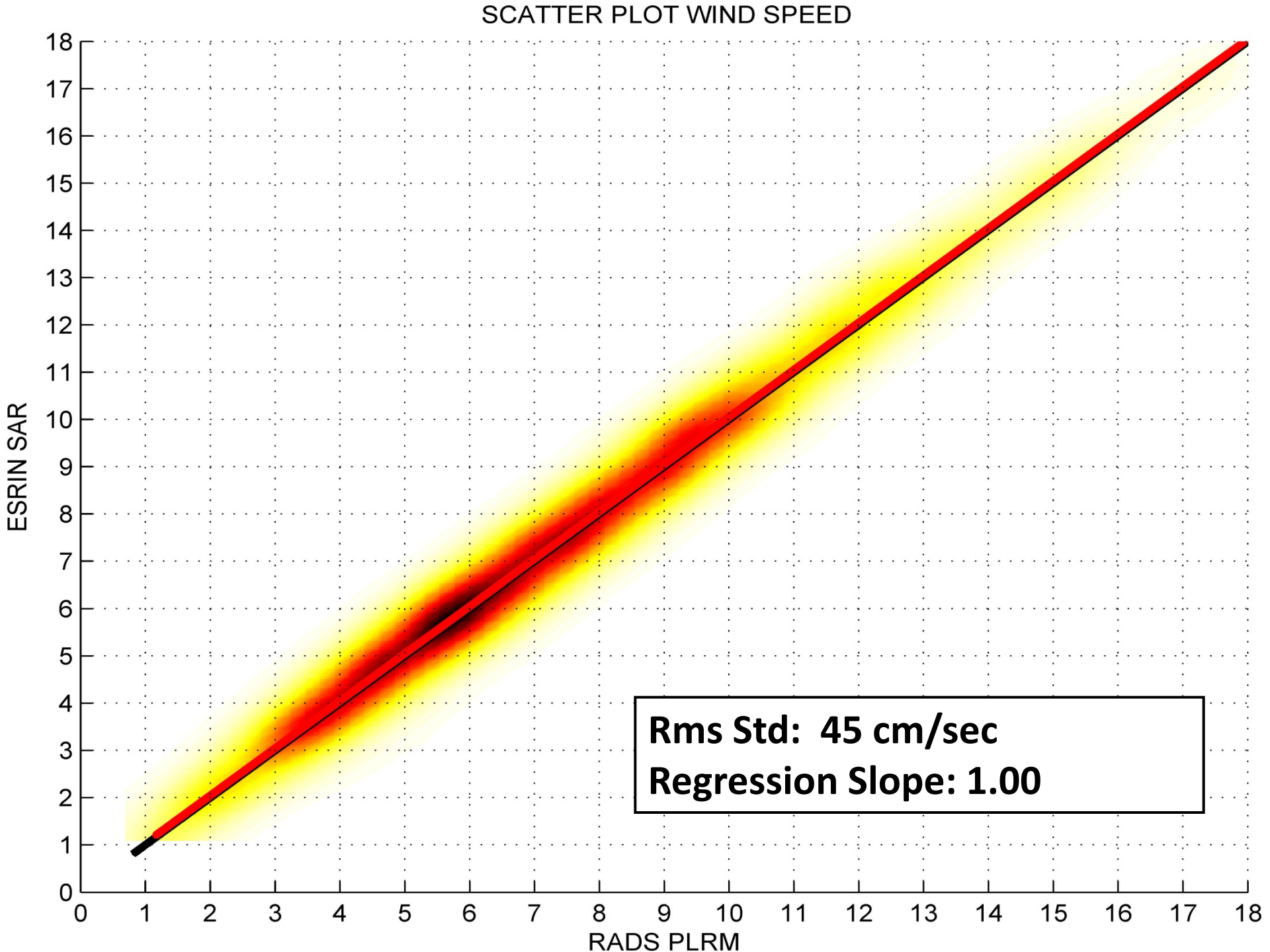


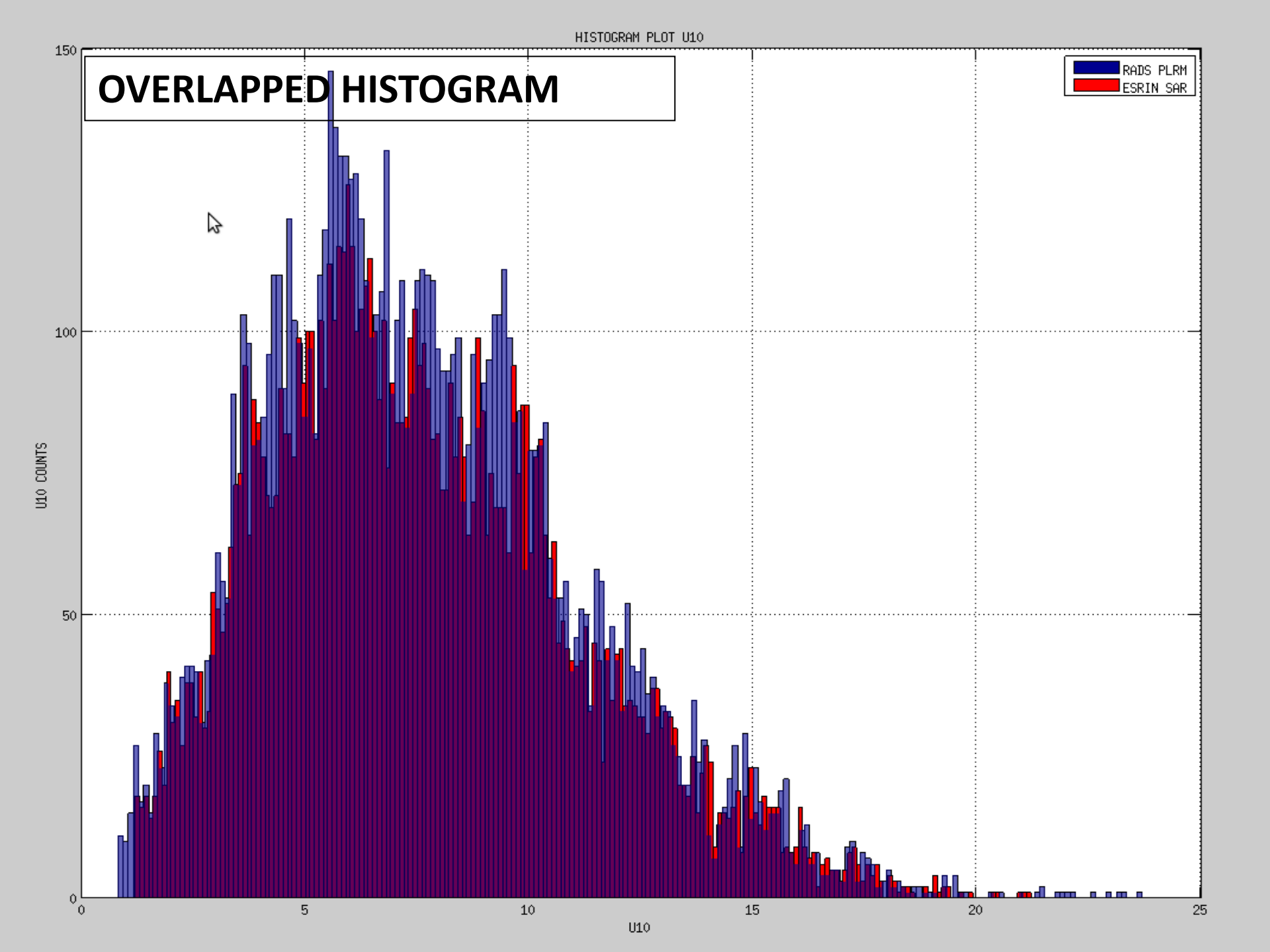
(50 Km, 30 Minutes, 57 Points)


1Hz SWH Precision
ESRIN SAR (POINTS)
ESRIN SAR (MEAN)
RADS PLRM (POINTS)
RADS PLRM (MEAN)
X: 2
Y: 16.9
X: 2
Y: 6.88
std [cm]
SWH [m]
40
35
30
25
20
15
10
5
0
1
2
3
4
5
6
7
8
9
PLRM 1 Hz SWH noise =16.9 cm @SWH=2m
SAR 1 Hz SWH noise =6.8 cm @SWH=2m

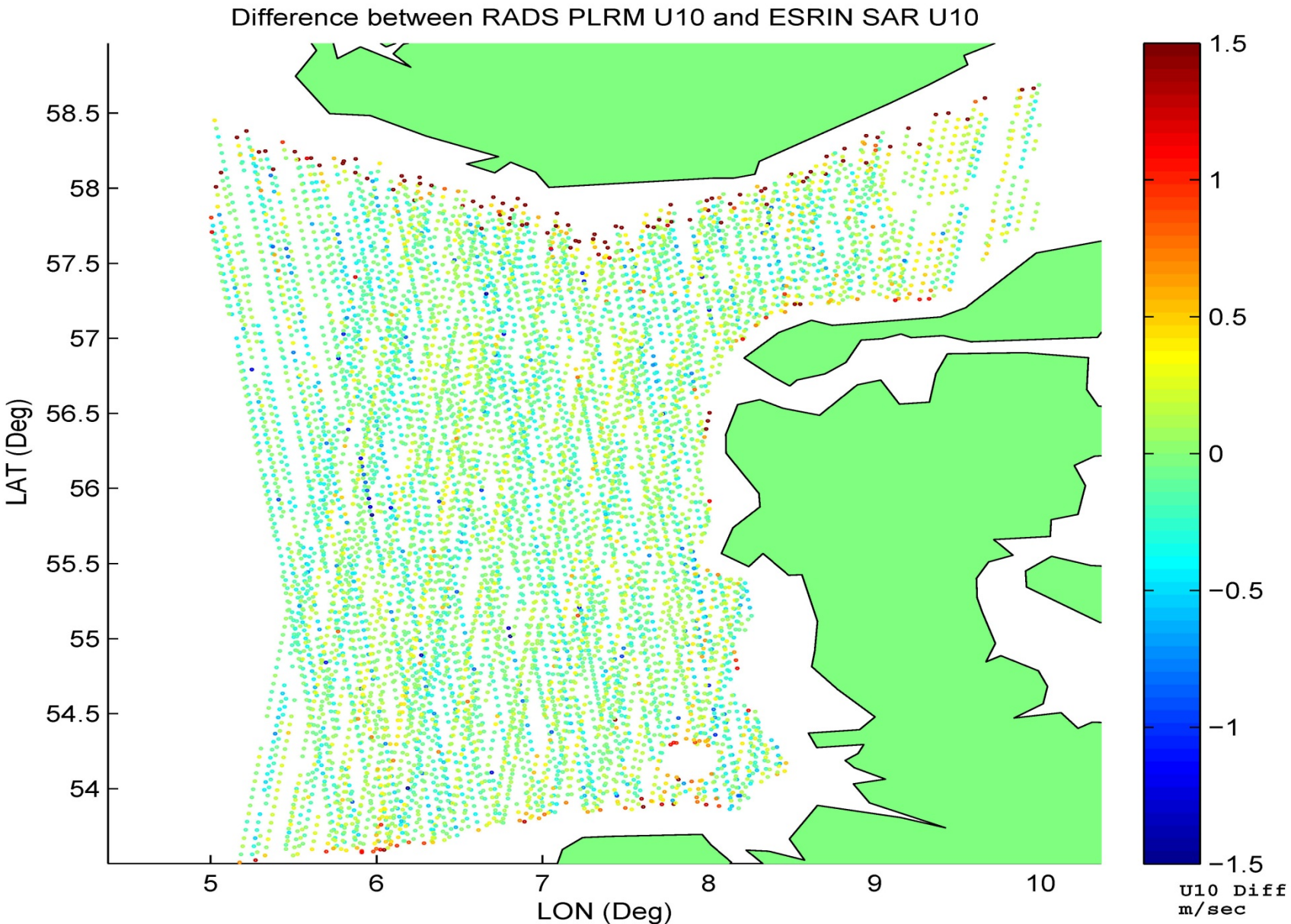
WIND SPEED RETRIEVAL

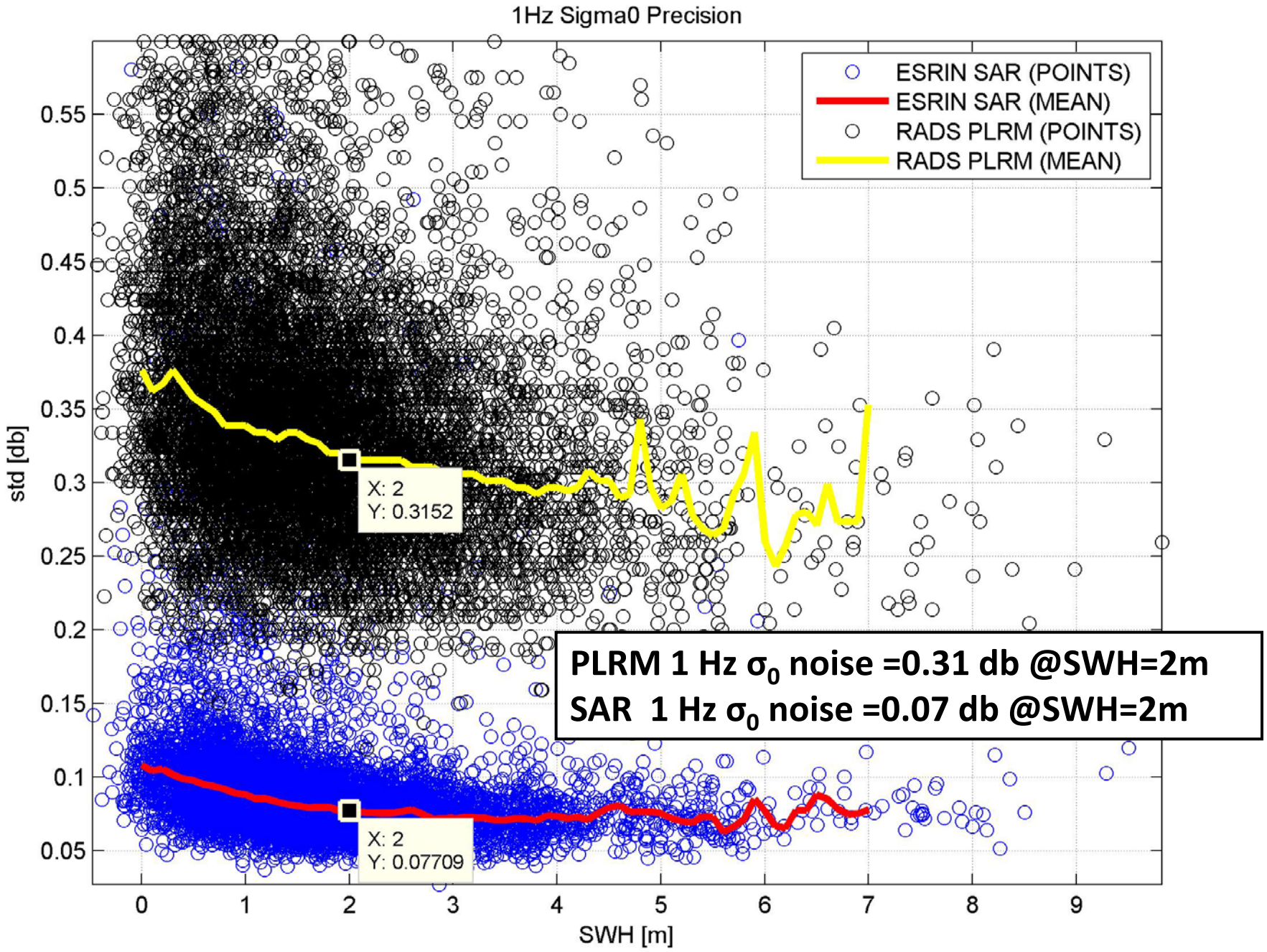
- **Received Power Level corrected for AGC, AGC setting & PTR Gain Drift (thanks M. Fornari)**
- Sigma nought calculated from **Pu** inverting **SAR Radar Equation (i.e. now using SAR Footprint);**
- CryoSat sigma nought compensated for a bias (**-3.5 db**) to align Envisat to CryoSat mission (**Mission Inter-calibration**)
- Finally, Wind Speed extracted from sigma nought using **the same wind model than Envisat (Abdalla's Model)**

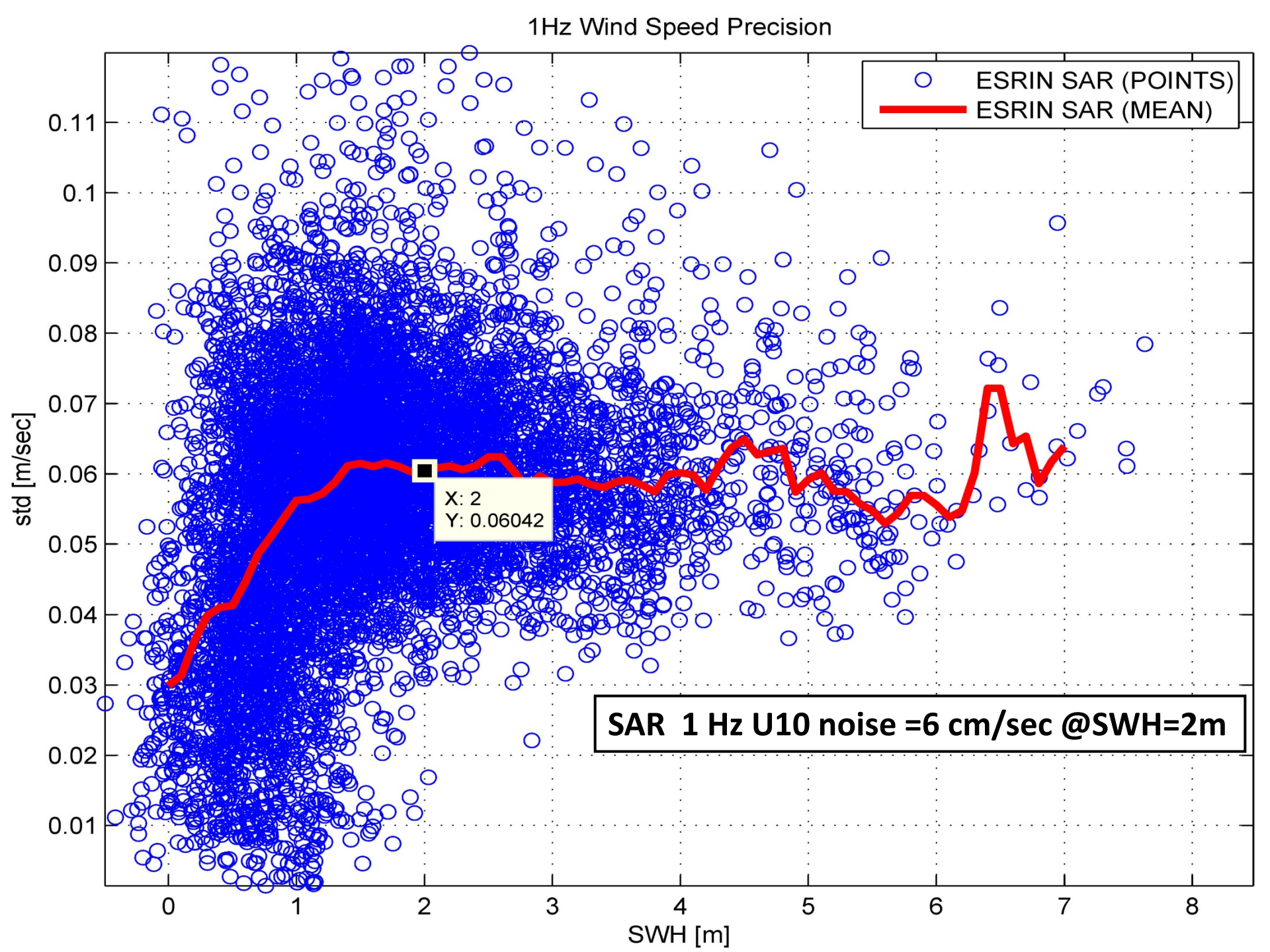

SCATTER PLOT WIND SPEED
ESRIN SAR
RADS PLRM
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
Rms Std: 45 cm/sec
Regression Slope: 1.00


HISTOGRAM PLOT U10
OVERLAPPED HISTOGRAM
RADS PLRM
ESRIN SAR
U10 COUNTS
U10
0
50
100
150
0
5
10
15
20
25

Wind Speed Differences SAR vs. PLRM




1Hz Sigma0 Precision
ESRIN SAR (POINTS)
ESRIN SAR (MEAN)
RADS PLRM (POINTS)
RADS PLRM (MEAN)
X: 2
Y: 0.3152
X: 2
Y: 0.07709
PLRM 1 Hz σ0 noise =0.31 db @SWH=2m
SAR 1 Hz σ0 noise =0.07 db @SWH=2m
std [db]
SWH [m]
0.55
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
1
2
3
4
5
6
7
8
9


1Hz Wind Speed Precision
ESRIN SAR (POINTS)
ESRIN SAR (MEAN)
X: 2
Y: 0.06042
SAR 1 Hz U10 noise =6 cm/sec @SWH=2m
std [m/sec]
SWH [m]
0.11
0.1
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
1
2
3
4
5
6
7
8

CONCLUSIONS

❑ **ESRIN SAR 1Hz Noise @SWH=2m:**

- 0.899 cm for SSH
- 6.8 cm for SWH
- 0.077 db for Sigma nought
- 6 cm/sec for U10

❑ **RADS PLRM 1Hz Noise @SWH=2m:**

- 2.3 cm for SSH
- 16.9 cm for SWH
- 0.31 db for Sigma nought

❑ **SSH/SLA**

Good consistency between SAR and PLRM (bias 1cm, std 6 cm, slope 0.97)
Std wrt in-situ data at comparable level in SAR mode (19.8 cm) than in PLRM mode (20 cm)

❑ **SWH**

Good consistency between SAR and PLRM (bias 3 cm, std 27 cm, slope 0.98)
Std wrt in-situ data at comparable level in SAR mode (30 cm) and in PLRM mode (33 cm)

❑ **U10**

Very Good consistency between SAR and PLRM (std 40 cm/sec, slope 1.00)

EPILOGUE

The regional validation in open sea in the German Bight shows that the RADS PLRM and the ESRIN SAR data are in general good agreement. There is no significant bias in SSH/SWH in both processing methods. The SSH/SWH/U10 SAR data are more precise than the corresponding PLRM values, as expected.

The analysis at the FINO3 and Helgoland platform using over 57 passes in 2011-2012 shows similarly appreciable good consistency for SWH/SSH from the altimeter solutions and in-situ measurements. The SAR data feature a slightly better behaviour with respect to in situ measurements than RADS Data.

List of References

- **Guidelines for the SAR (Delay-Doppler) L1b Processing, v2.2, Salvatore Dinardo, Technical Note, ESA/ESRIN (https://wiki.services.eoportal.org/tiki-download_wiki_attachment.php?attId=2540)**
- **SAR Altimeter Backscattered Waveform Model, C.Ray et al, TGRS (to be submitted)**
- **Detailed Processing Model (DPM) of the Sentinel-3 SAR Altimeter Ocean Waveform Retracker ,v2.2, SAMOSA Team**
- **A Validation Exercise for CryoSat-2 in SAR Mode in the German Bight Area, Fenoglio et al, CryoSat Third User Workshop Proceeding, SP-717**
- **Validation of CRYOSAT-2 in SAR Mode in the German Bight Area, Living Planet Symposium Proceeding, (to be submitted)**