Validation of CryoSat-2 in SAR Mode data in the German Bight – Open Ocean

L. Fenoglio[1], S. Dinardo[2], R. Scharro[3], B. Lucas[4], A. Roland[5], M. Dutour[7], J. Benveniste[6], M. Becker[1]

[1)] Institute of Geodesy, Physical and Satellite Geodesy Section, TU Darmstadt

[2)] SERCO/ESA/ESRIN

[3)] ALTIMETRICS/NOAA

[4)] DEMOS/ESA/ESRIN

[5)] Institute for Hydraulic and Water Resources Engineering, TU Darmstadt

[6)] ESA/ESRIN

[7)] Laboratory of Satellite Oceanography, Rudjer Boskovic Institute, Zagreb, Croatia

Method of regional comparison

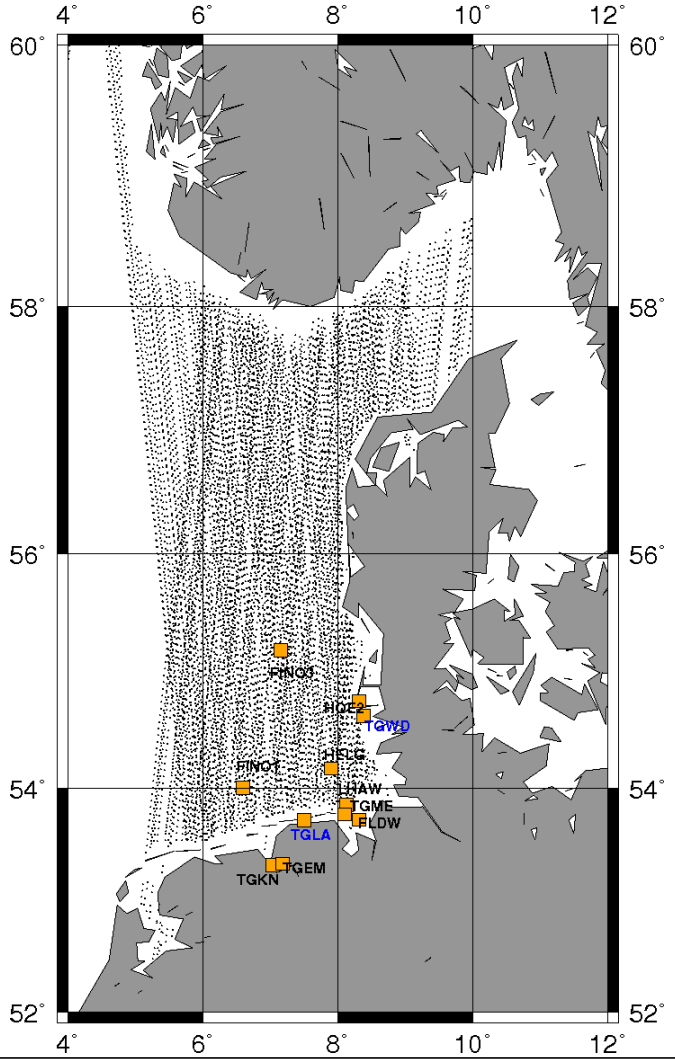
We compare SWH
SSH (SLA),
WIND SPEED (U10), Backscatter coeff.

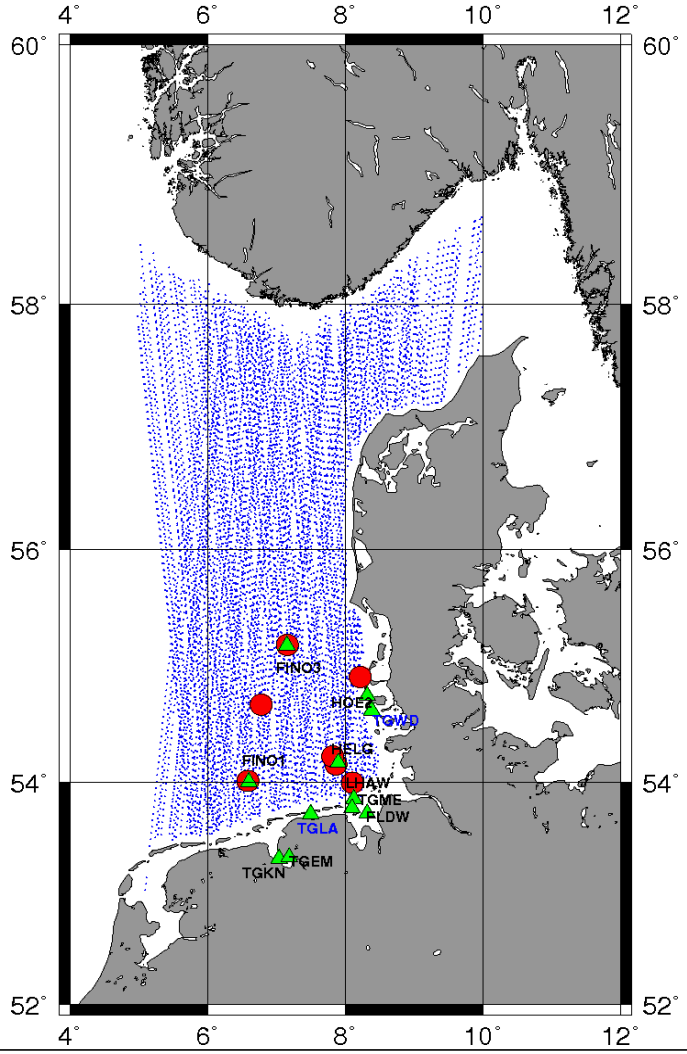
- **Inter-comparison of Altimetry data** :
  C2/PLRM versus C2/SAR along tracks

- **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

RADS PLRM ESRIN SAR

DATA IN OPEN OCEAN (> 10 KM FROM COAST)





Method of regional comparison

- **Wind Wave Modeling** :results of two common 3rd generation spectral wave models.

  SWH, U10 C2 versus WW3 model along tracks
  - **WW3 – ATNE IFREMER** regional model (IOGAWA project , WaveWatch III wave model and ECMWF wind fields 0.5 deg, 3 hour)
  - **BSH model** (uses WAM model, COSMO model wind field)

- **WW3** - operational wave forecasting at NCEP, forced with the ECMWF global forecast (0.25°) wind fields - no data assimilation

- **WAM** Federal Maritime and Hydrographic Agency (BSH) Institute for Coastal Research, Helmholtz Zentrum Geesthacht (HZG). The BSH model forced with the LM Model (7km; resolution) wind fields from the German Weather Service (DWD) and altimeter data was assimilated into the model

Method of regional comparison

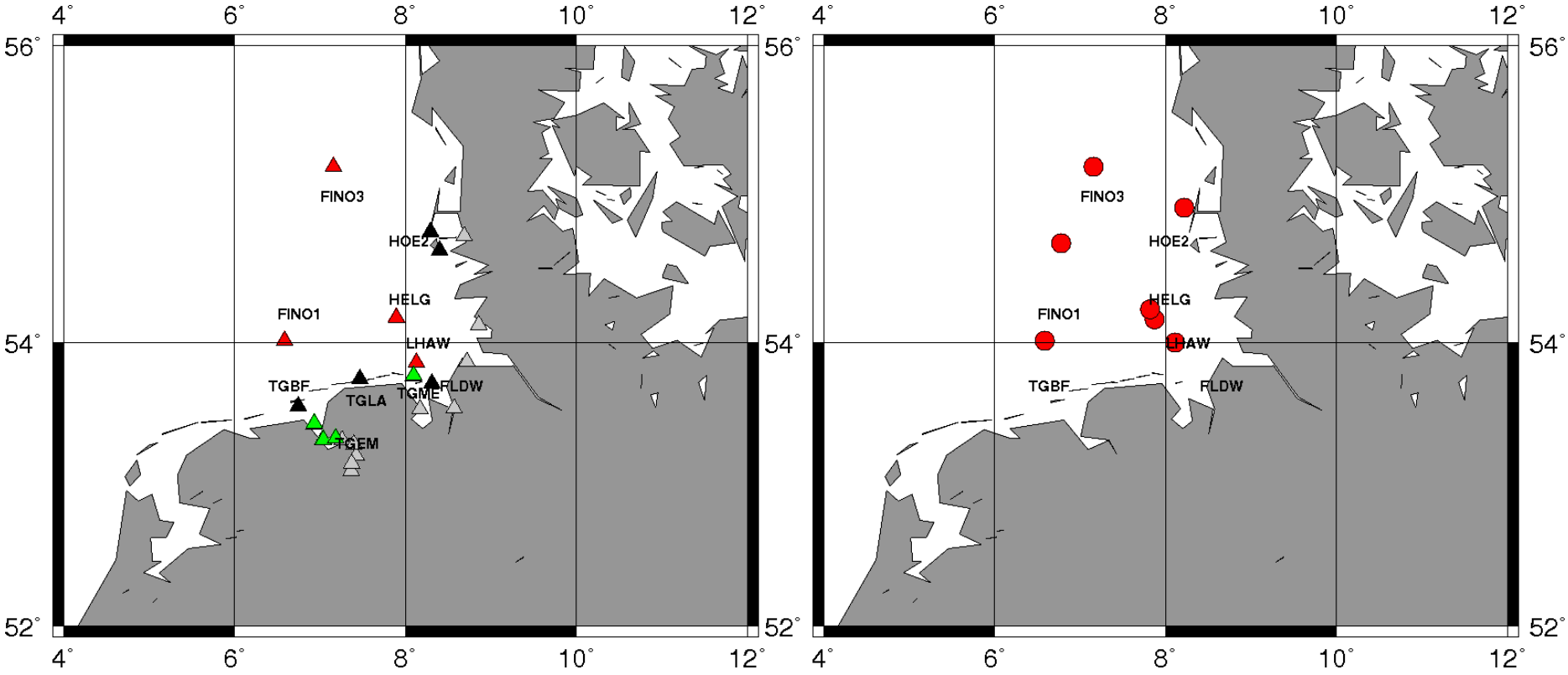
Statistical parameters :

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

We focus on **slope** (bias) and **scatter index** (scatter around this bias).

Method of regional comparison

- Interval : 2011-2012
- Region: German Bight-tracks with lon between 6-9 E(200 tracks)



SSH In-situ network SWH

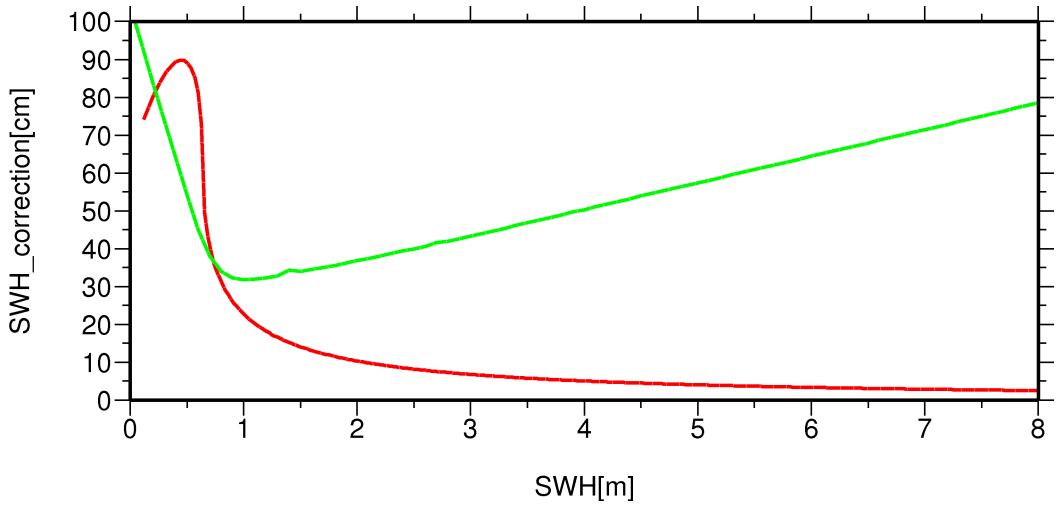
Comparison of SSH and SLA in open ocean (> 10 Km to coast)

- SSH and SLA C2/PLRM versus C2/SAR along tracks
  - Compare **uncorrected SSH (**no env. & geophysical corrections)
    - SAR_uncorr (platform bias 71 cm)
    - RADS : orbit – range + 0.247 (w.r.t. WGS84 ellipsoid)
  - Compare **corrected SLA** (w.r.t DUT10 MSL)
    - Corr_all = all corrections from SAR no SSB
    - SAR SLA = SSH_uncorr + corr_all - MSL_DUT10
    - SAR RADS : SSH_uncorr + corr_allSAR – MSL_DUT10

- SSH C2 versus in-situ GPS@TG at FINO3 platform
  - Compare **instantaneous SSHi** and **SLAi**=SSHi-MSL_DUT10

    Not applied :
    - Sea state bias
    - Ocean tide correction
    - inverse barometer (DAC) correction
    - Ocean part of pole tide correction

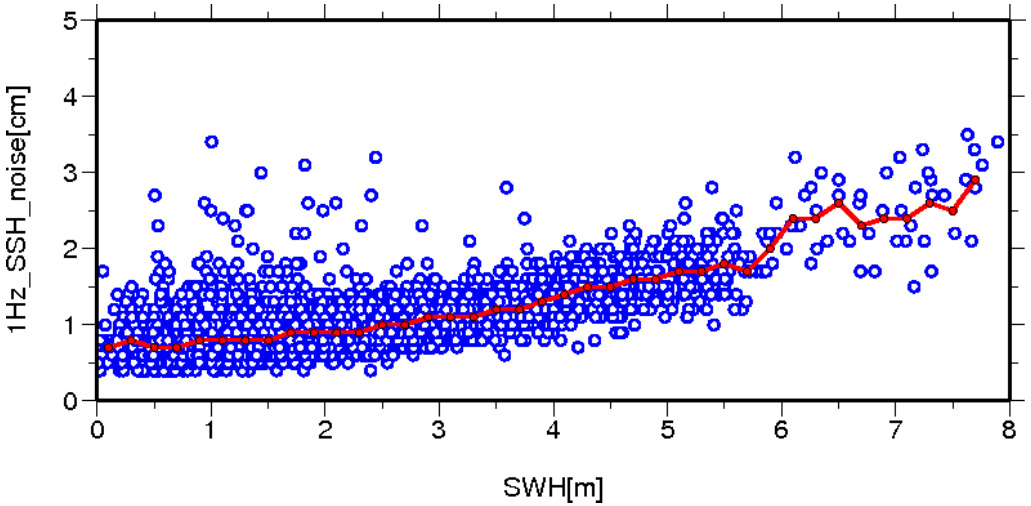
Two SWH Corrections Look up Tables for ESRIN SAR



- **1st Correction**: approximated SAR Echo Model, which Point Target Response (PTR) given by a gaussian Bell function as in RADS. We account for the different equivalent dimensionless PTR width σ_p used in RADS & ESRIN re-trackers (0.53 in RADS PLRM products and 0.38 in original ESRIN SAR products). Best agreement between PLRM/RADS and SAR $\sigma_{p.}$

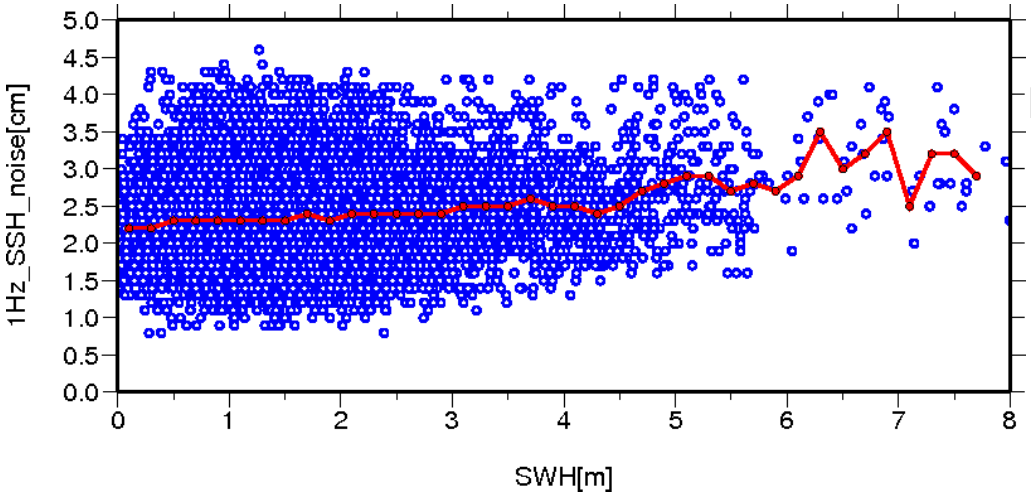
- **2nd Correction**: calculated by comparison vs. real numerical SAR Echo Model, hence this SWH correction is theoretically more sound.

Precision SSH : SAR and RADS/PLRM



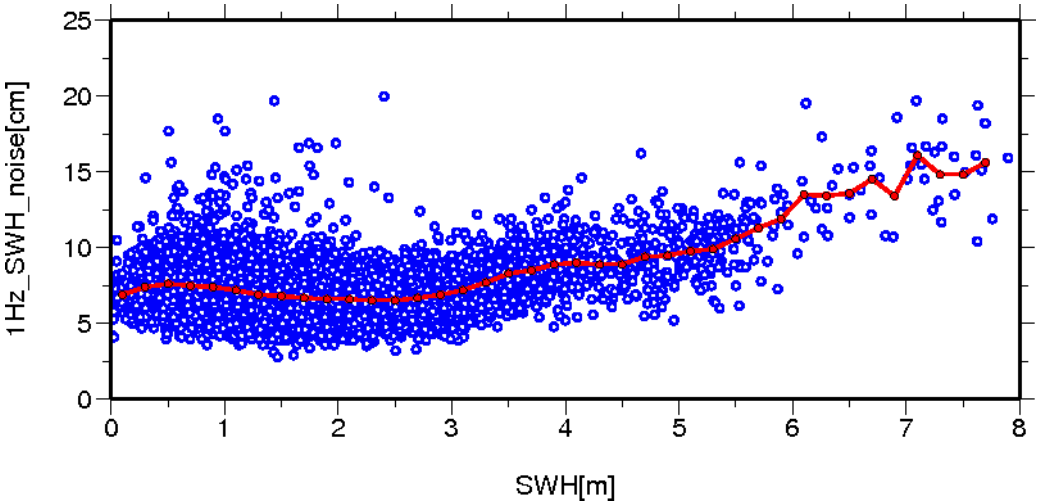
performace curves
SAR: 0.9 cm for 1 Hz SSH @SWH=2m

filtered out sigma (SSH) >4
(outliers due to ships,
off-shore platforms, etc)

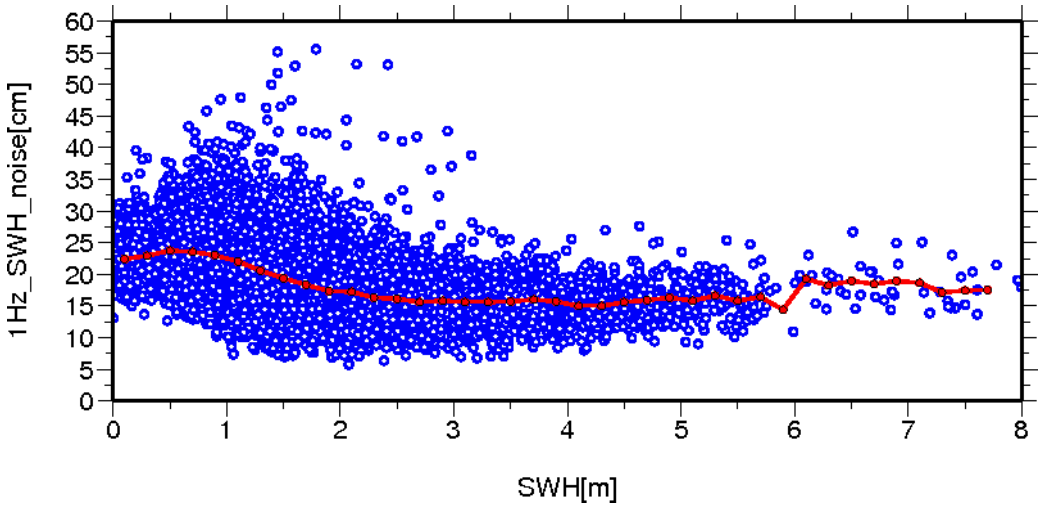


PLRM : 2.1 cm for 1 Hz SSH @SWH=2m

Precision SWH : SAR & PLRM

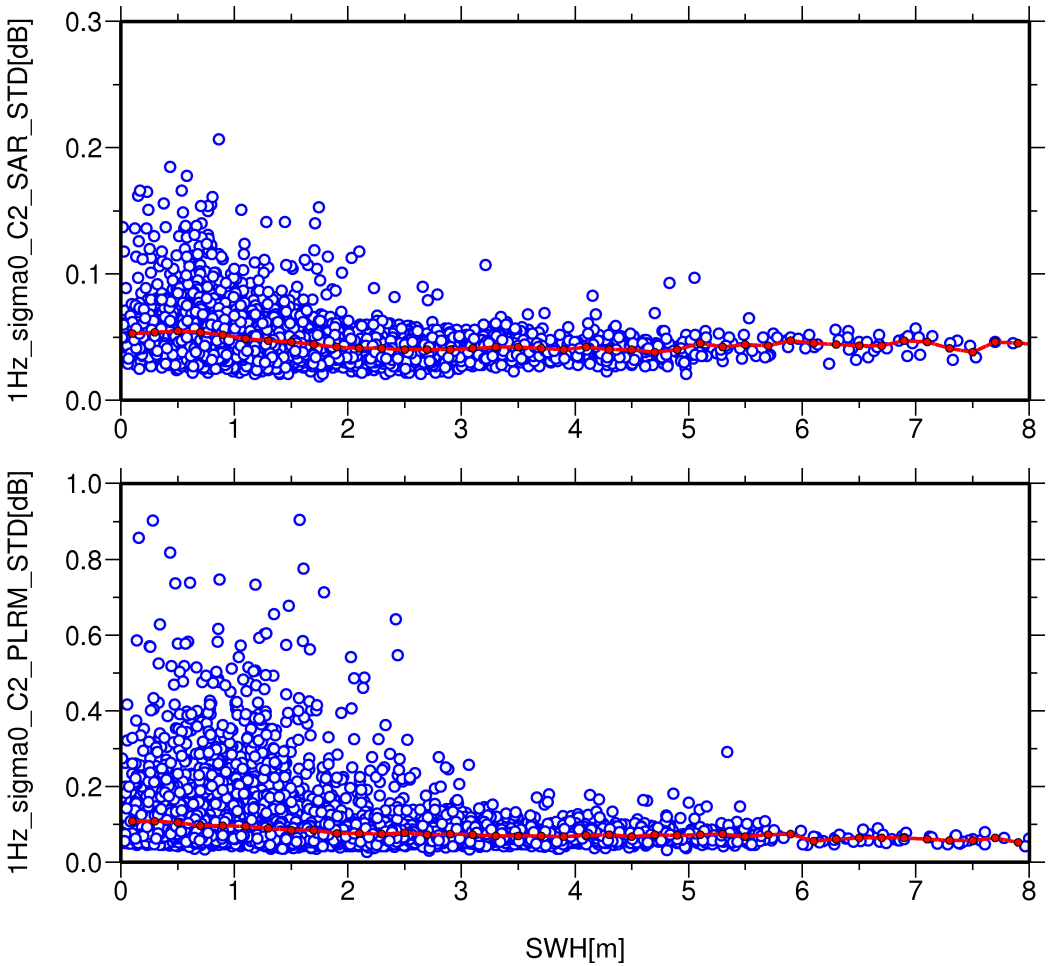


SAR : →
6.5 cm for 1 Hz SWH @SWH=2m
filtered out sigma (SWH) >20
(outliers due to ships,
off-shore platforms, etc)



PLRM: ->
15.2 cm for 1 Hz SWH @SWH=2m

Precision Backscatter: SAR and RADS/PLRM

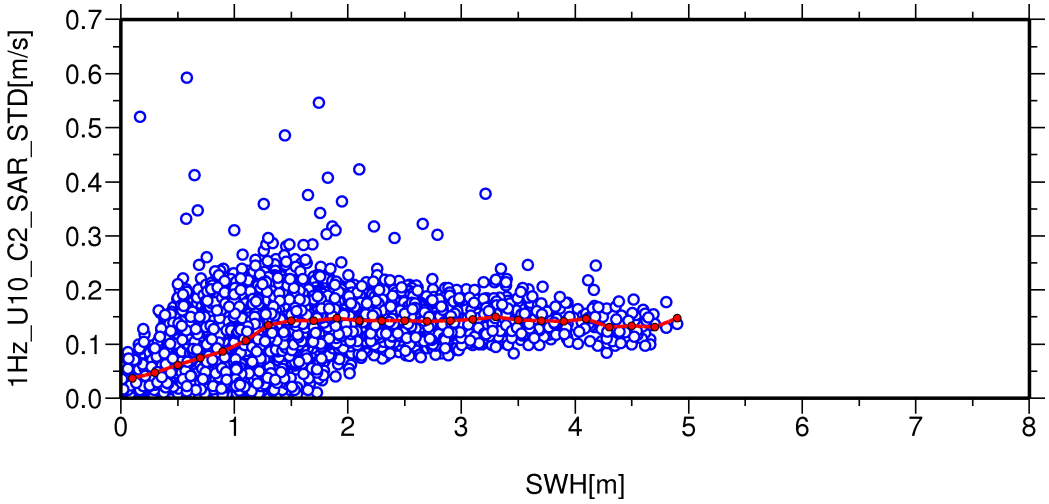


performace curves
SAR: 0.05 dB for 1 Hz sigma0 @SWH=2m

filtered out sigma (SSH) >4
(outliers due to ships,
off-shore platforms, etc)

PLRM : 0.1 dB for 1 Hz sigma0 @SWH=2m

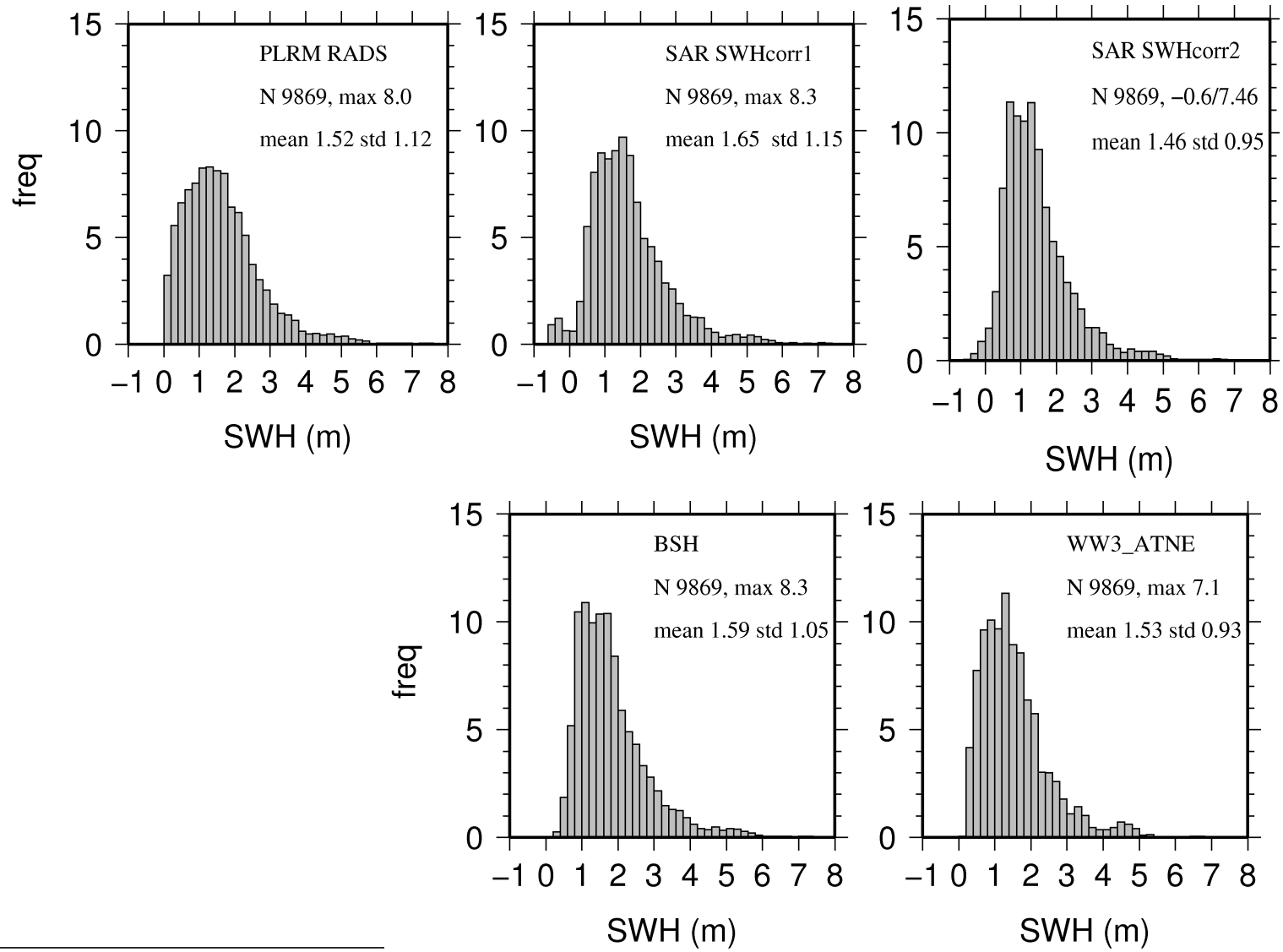
Precision U10: SAR



performace curves
SAR: 15 cm/s for 1 Hz sigma0 @SWH=2m

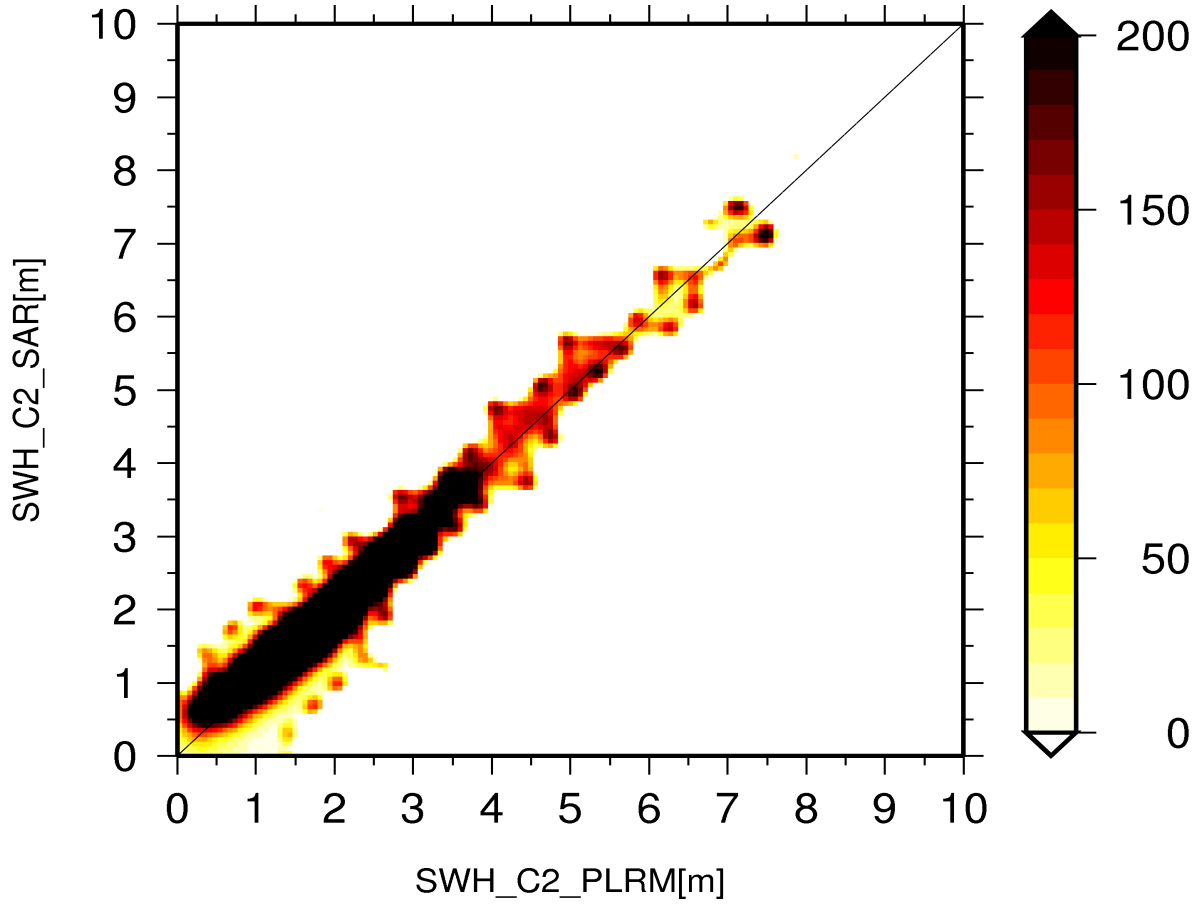
filtered out sigma (SSH) >4
(outliers due to ships,
off-shore platforms, etc)

SWH : SAR & PLRM & MODELS



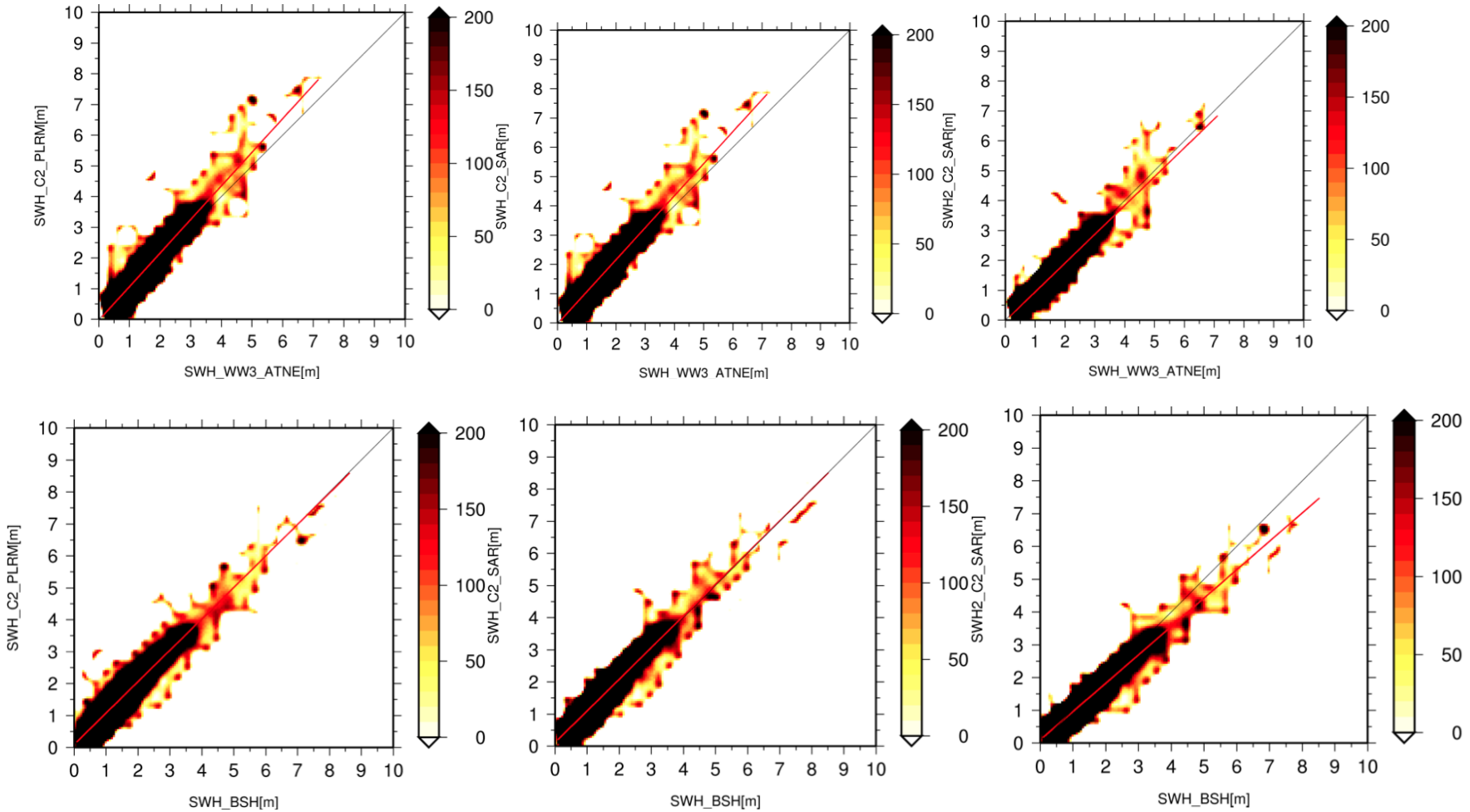
SWH

PLRM/RADS versus ESRIN/SAR correction 1



SWH

PLRM ESRIN/SAR SWHcorr1 ESRIN/SAR SWHcorr2



Best agreement with BSH, altimeter overestimates if WW3 as truth

SWH

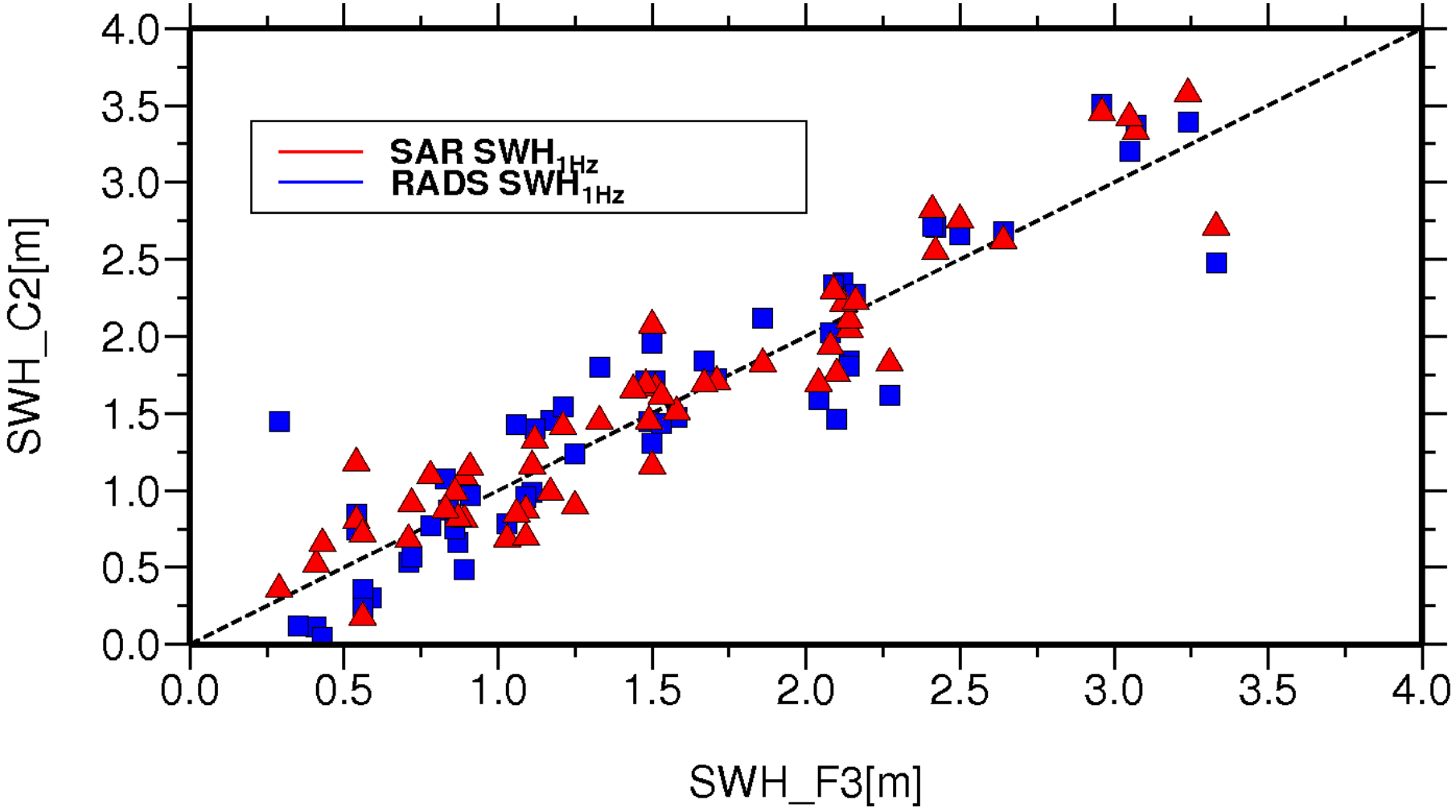
Statistics versus Models

Table 1. Statistics of 1Hz SWH (m from CryoSat SAR mode SAR and PLRM in open ocean

	mean	std	rms	cor	slop	SI	NP
PLRM SWH	1.52	1.12	1.82				9868
SAR SWHcor1	1.65	1.15	2.00				
SAR SWHcorr2	1.46	0.95	1.74				
SAR SWHori	1.84	1.00	2.09				
WW3_ATNO swh	1.53	0.93	1.79				
BSH SWH	1.59	1.05	1.90				
PLRM-WW3_ATNO SWH	0.11	0.38	0.39	0.940	1.09	0.24	
SAR-WW3_ATNO SWHcor1	0.13	0.38	0.40	0.942	1.09	0.24	
SAR-WW3_ATNO SWHcor2	-0.08	0.32	0.33	0.944	0.96	0.20	9868
PLRM-BSH SWH	0.07	0.35	0.36	0.947	0.98	0.22	9745
SAR- BSH SWHcor1	**0.09**	**0.34**	**0.35**	**0.950**	**0.98**	**0.21**	**9745**
SAR-BSH SWHcor2	**-0.12**	**0.32**	**0.34**	**0.955**	**0.87**	**0.18**	**9748**
SAR-PLRM SWHcor1	0.02	0.30	0.30	0.962	0.96	0.18	9898
SAR-PLRM SWHcor2	0.19	0.30	0.33	0.966	0.84	0.15	9898

Best agreement with BSH, altimeter overestimates if WW3 as truth

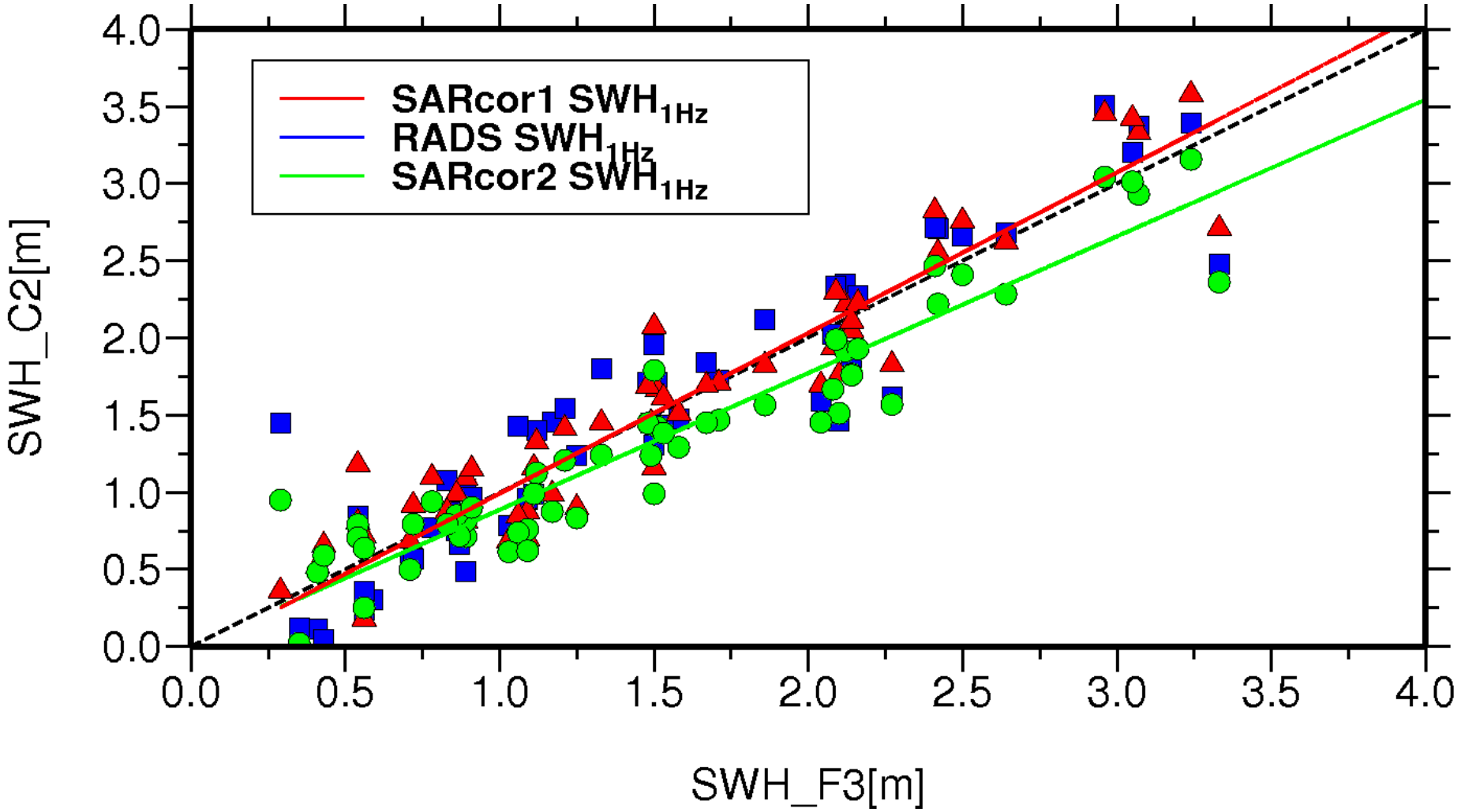
SWH comparison with In-situ FINO3



many SWHs are lower than 1 meter

(50 Km, 30 Minutes, 57 Points)

SWH comparison with In-situ FINO3



(50 Km, 30 Min)

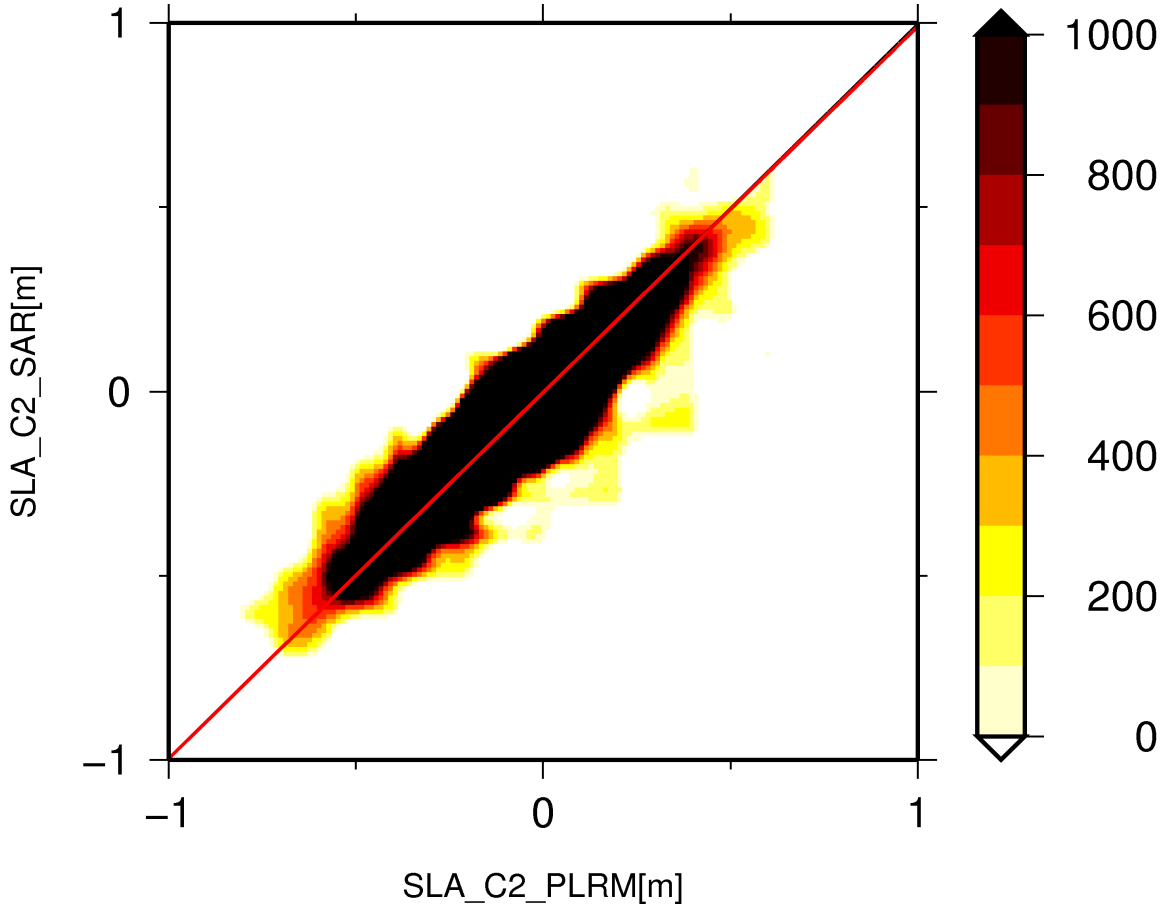
many SWHs are lower than 1 meter

SWH comparison with In-situ FINO3

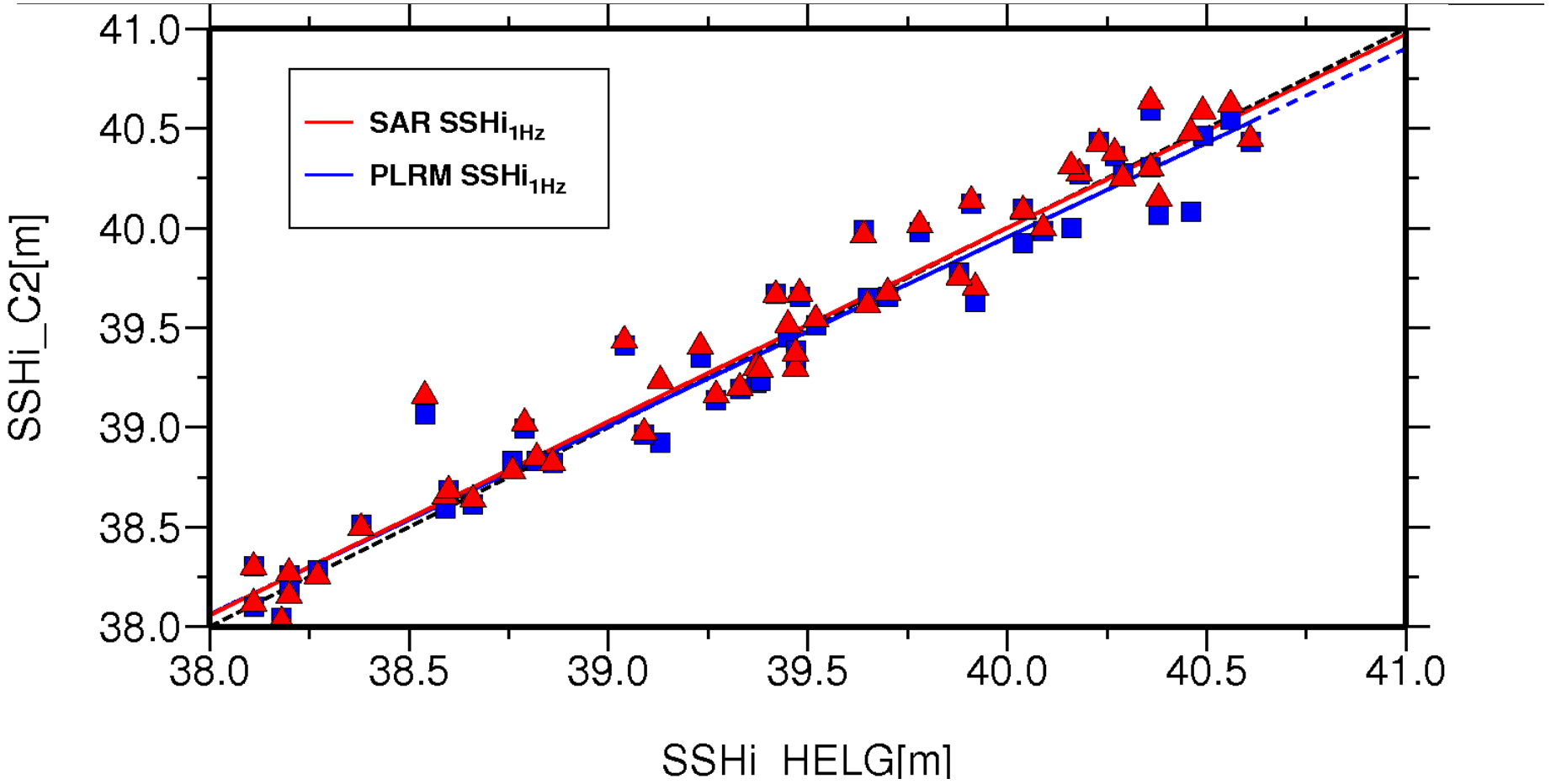
Table 2. Statistics of 1Hz SWHs (m) and SSH (m) from CryoSat SAR mode and in-situ AWAC and radar tide gauge measurements at FINO3

	mean	std	rms	cor	slop	SI	NP
PLRM SWH	1.52	0.93	1.78				57
SAR SWHcor1	1.51	0.95	1.78				57
FINO3 SWH	1.50	0.95	1.73				57
PLRM-FIN3 SWH	0.02	0.33	0.33	0.935	0.99	0.22	57
SAR-FIN3 SWHcor1	0.005	0.30	0.30	0.947	1.02	0.20	57
SAR-FIN3 SWHcor2	-0.2	0.27	0.32	0.954	0.89	0.16	57
SAR-PLRM SWHcor1	-0.01	0.29	0.29	0.951	0.97	0.19	57

Compare corrected SLA (w.r.t DUT10 MSL)

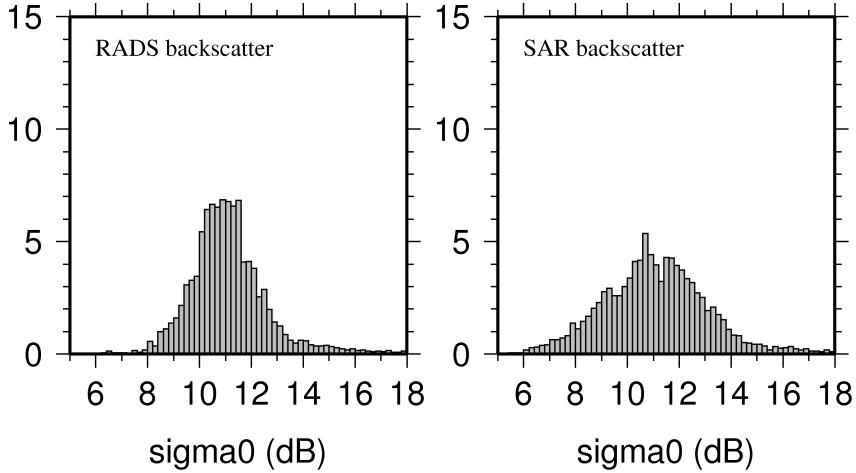


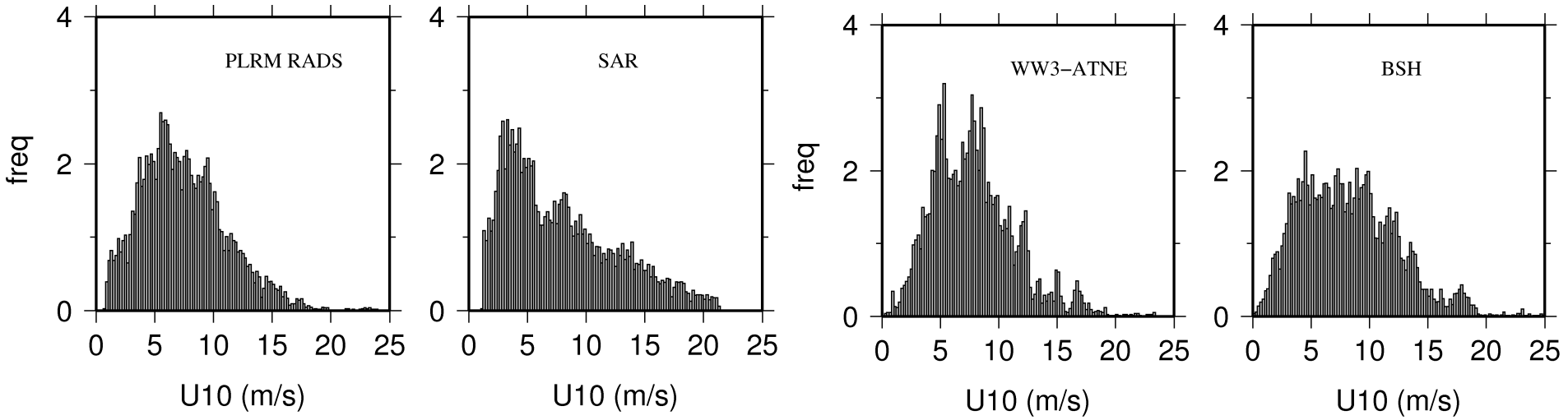
Instantaneous SSH comparison with in-situ HELGOLAND (50 Km, 30 Min)



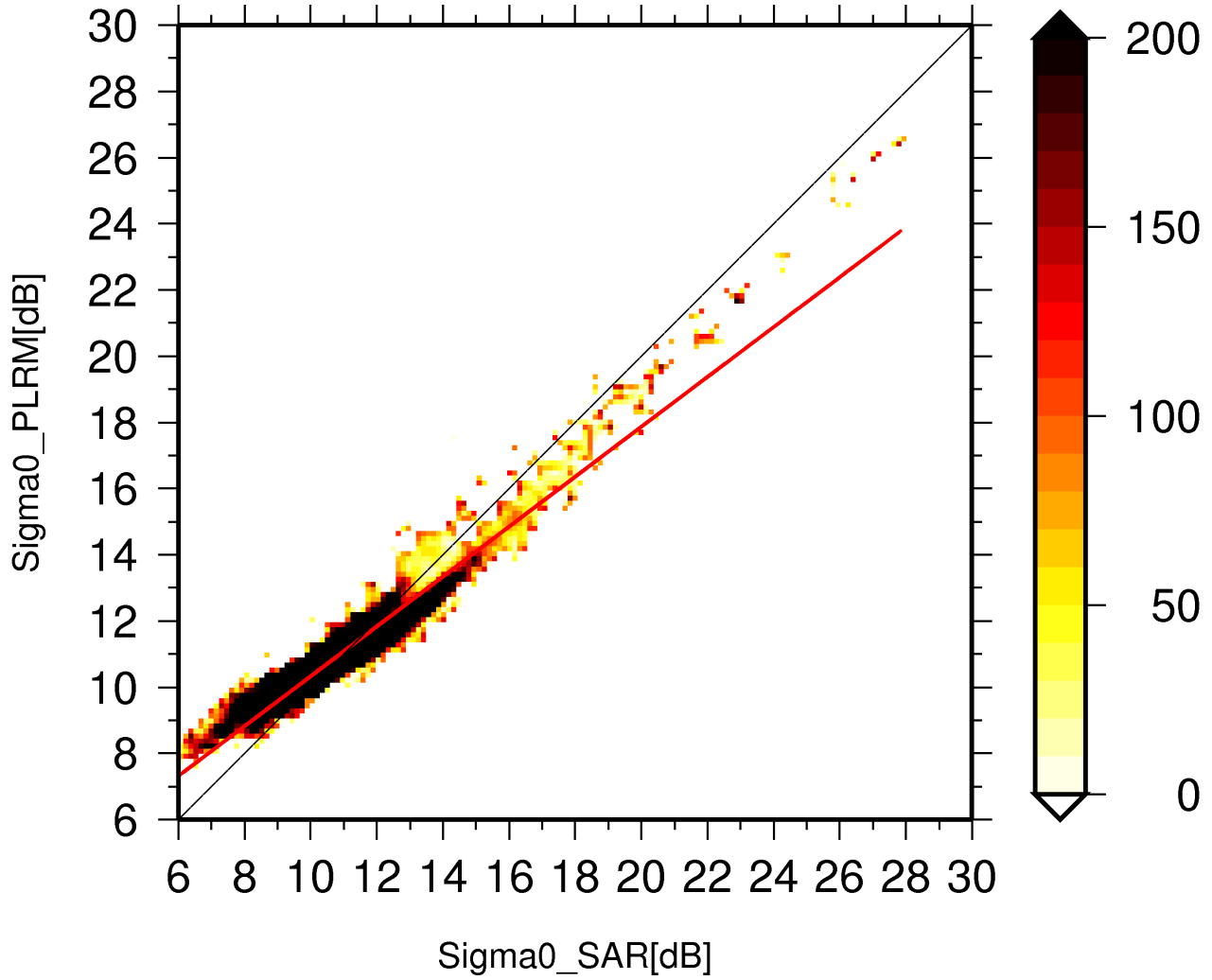
Open ocean > 10 km from land	mean	std	rms	cor	slop	SI	NP
SAR-HELG ssh	0.023	0.198	0.198	0.978	0.971	0.005	63
PLRM-HELG ssh	-0.002	0.208	0.206	0.976	0.946	0.005	63

U10 and sigma0 : SAR & PLRM

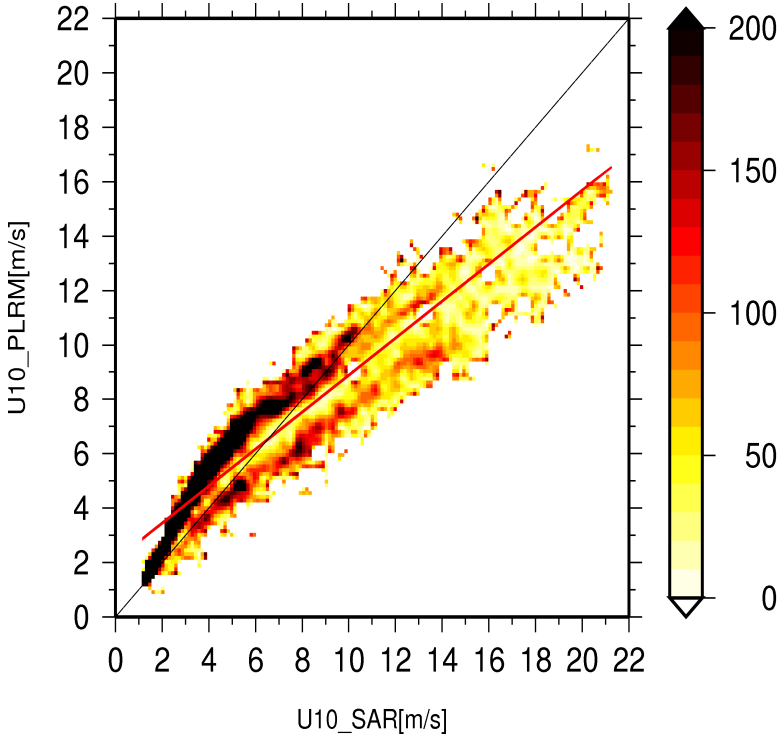


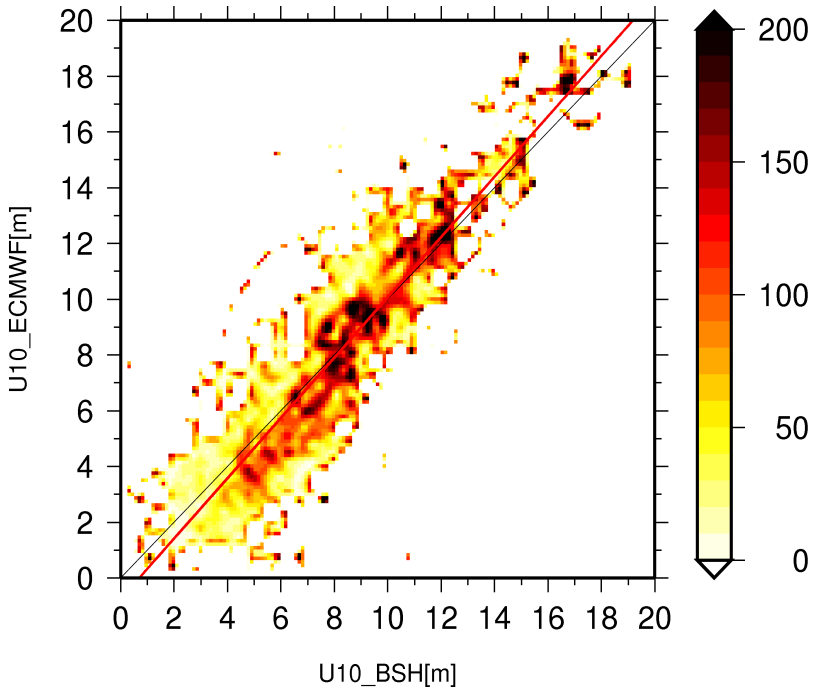


Backscatter coefficient (sigma0)



U10


U10_PLRM[m/s]
U10_SAR[m/s]
0 2 4 6 8 10 12 14 16 18 20 22
200
150
100
50
0


U10_ECMWF[m]
U10_BSH[m]
0 2 4 6 8 10 12 14 16 18 20
200
150
100
50
0

U10

Statistics versus Models

Table 4. Statistics of 1Hz SWH (m), SSH (m), SLA (m), WS (m/s) and from CryoSat SAR mode SAR and PLRM in open ocean

	mean	std	rms	cor	slop	SI	NP
RADS WS	7.61	3.49	8.37				9608
BSH WS	8.11	4.07	9.07				9608
ECMWF WS	7.28	3.54	8.09				7505
RADS-BSH WS	-0.50	1.6	1.7	0.922	0.791	0.17	9608
RADS-ECMWF WS	-0.55	1.26	1.37	0.937	0.939	0.16	7505
ECMWS-BSH WS	-0.11	1.59	1.59	0.926	1.082	0.20	7341
SAR-RADS WS	-0.29	1.8	1.82	0.93	0.67	0.16	9718

Best agreement between PLRM/RADS altimeter and ECMWF winds in slope

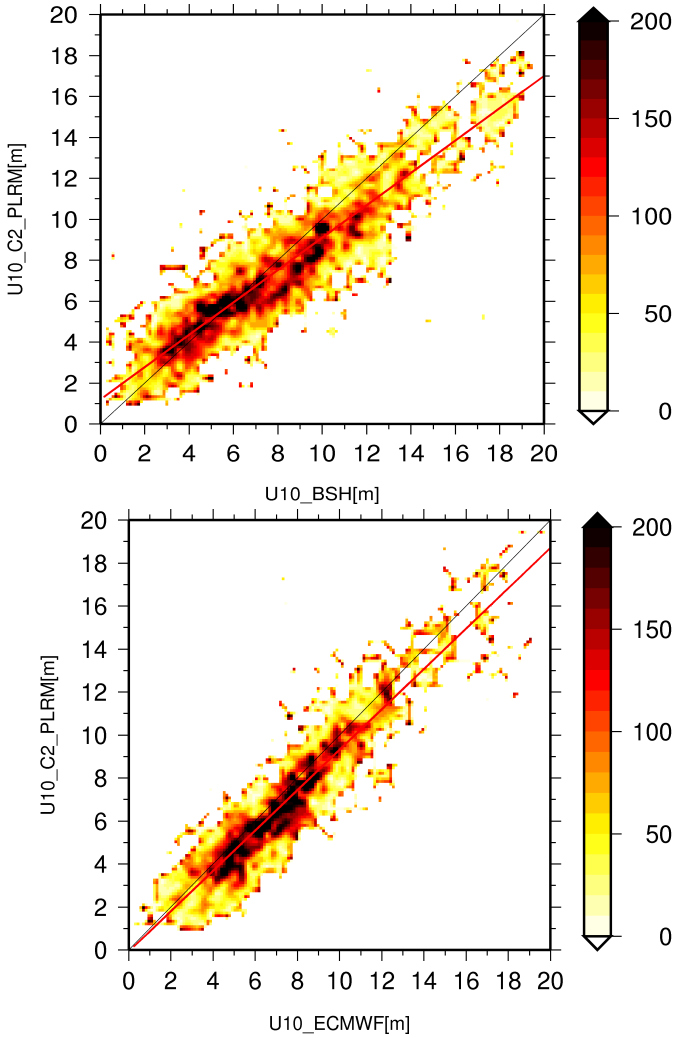
U10

- the ECMWF wind speeds are **lower** than the DWD wind speed

- **the wind fields of the local model of the DWD overestimate the wind velocities** whereas the ECMWF wind fields have no significant BIAS wrt the PLRM winds

- Note: the ECMWF wind model assimilates altimeter winds

- If we assume ECMWF correct
- DWD overestimates the U10
- SAR overestimates the U10



Conclusions – Altimeter Validation

- **Absolute regional** Validation of **range & SWH** via **GNSS-TG** & **altimetry**
- Noise:
  - ESRIN SAR 1Hz (0.9 cm for SSH **&** 6.5 cm for SWH **&** 0.05 db for sigma0, @SWH=2m)
  - RADS PLRM 1Hz (2.1 cm for SSH **&** 15.2 cm for SWH **&** 0.1 dB for sigma0 @SWH=2m)

- **SWH**

➢ **Cross-cal PLRM-SAR:** better results with SAR

  ➢ higher difference with corr2, 2 cm (corr1/corr2 : 2/20 cm)

➢ **Models: WW3** more suitable for CAL/VAL as it does not assimilate altimetric SWH - the BSH dataset is not statistically independent – better fit

  - Both PLRM and SAR with first correction overestimate WW3 model for big waves.
  - SAR with second correction underestimate the WW3 model.

  ➢ **IN-SITU** : as above with in-situ FINO3 data (cor1/**cor2**:

    - bias=0/**-20** cm, r=0.95/**0.96**, std=30/**27** cm, Over-/Under-estimation)

Conclusions Altimeter Validation

- **WIND**
- **U10 ECMWF** has **no significant BIAS** wrt PLRM,
- U10 BSH/DWD **overestimate** the c2 U10, however **SWHs of PLRM underestimate the WW3 SWHs** and agree better with BSH.

- **SSH**
  - **Regional** SSH uncorrected PLRM and SAR (mean/std 0.2/4 cm)
  - **In-situ** Helgoland instantaneous SSH
    - similar results from PLRM and SAR: under-estimation wrt TG

      bias/std : 0/20.6 cm (PLRM), -2/19.8 cm (SAR)

- **Costal region** to be analysed in details