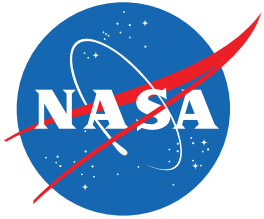


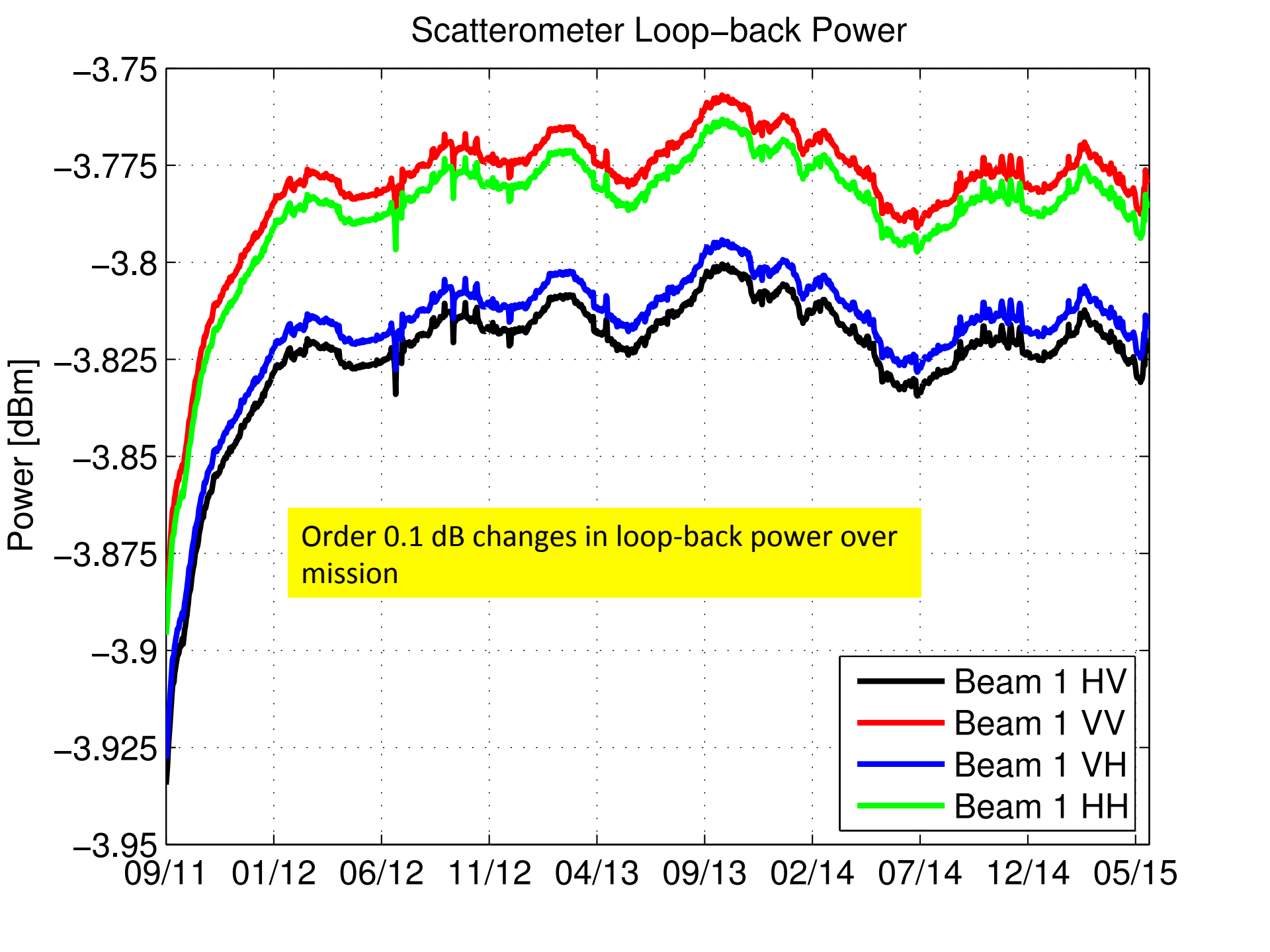
Aquarius Scatterometer Calibration

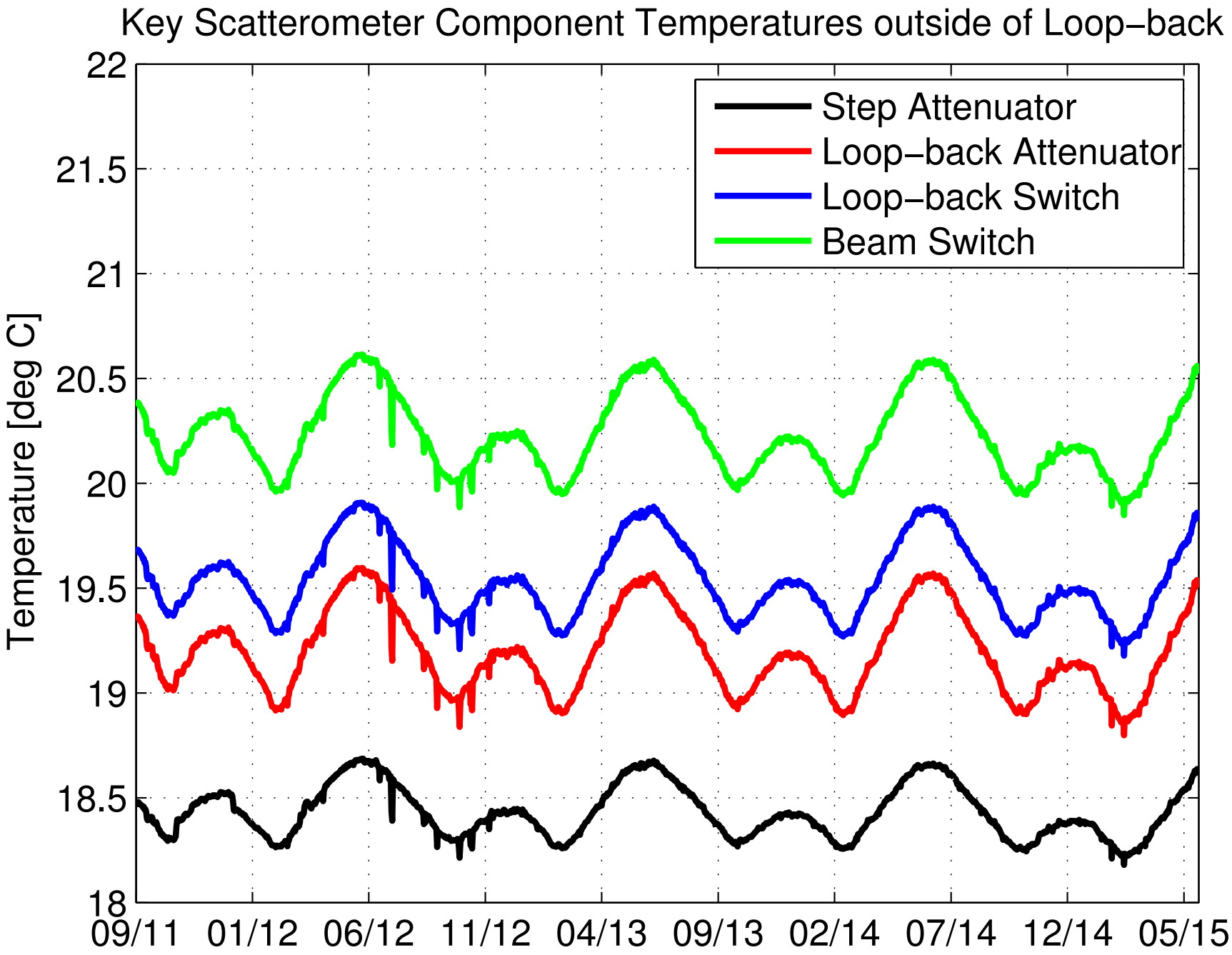
Fore, A., Neumann, G., Freedman, A., Chaubell, M., Tang, W., Hayashi, A., and Yueh, S.

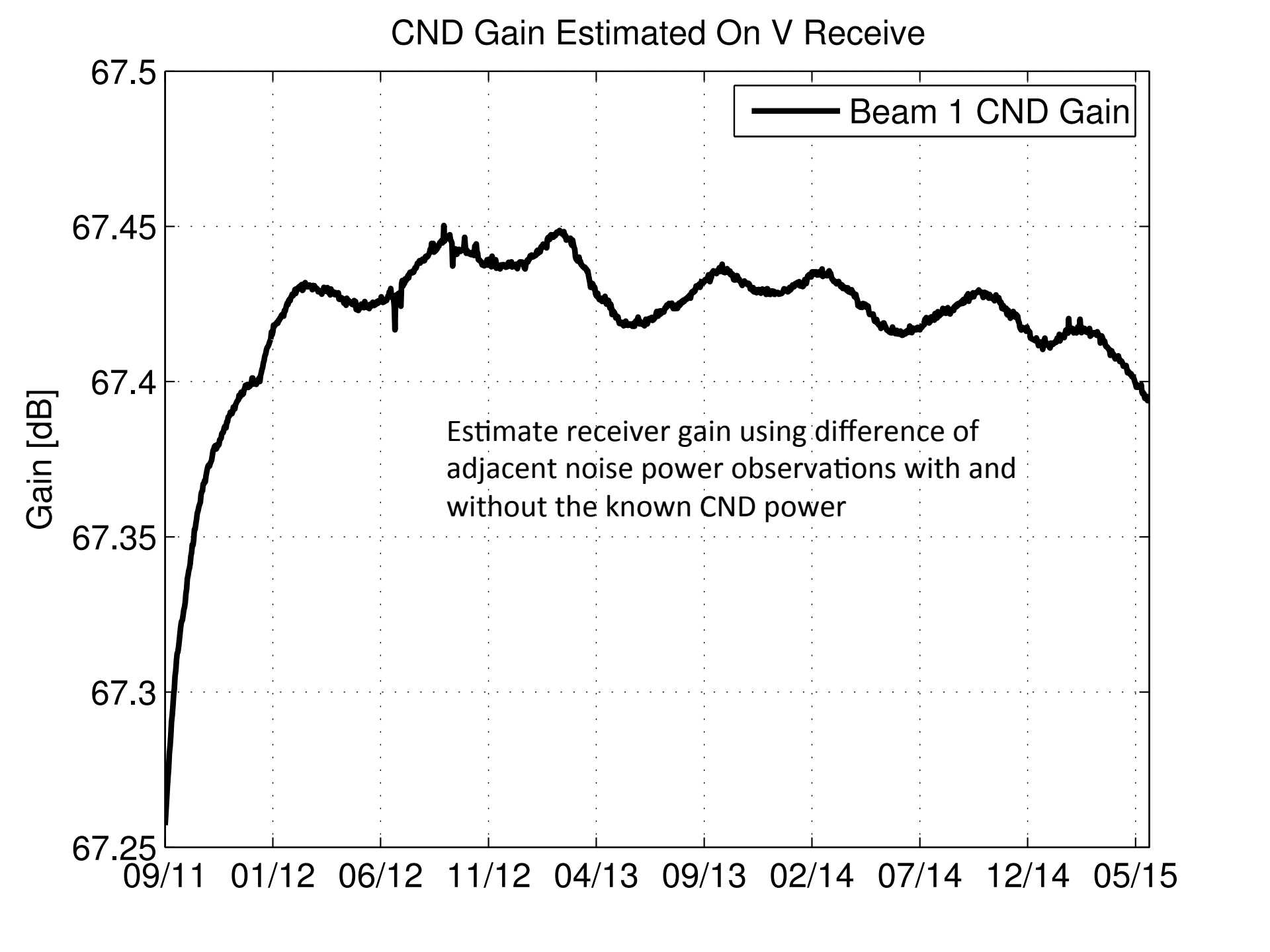
Jet Propulsion Laboratory, California Institute of Technology

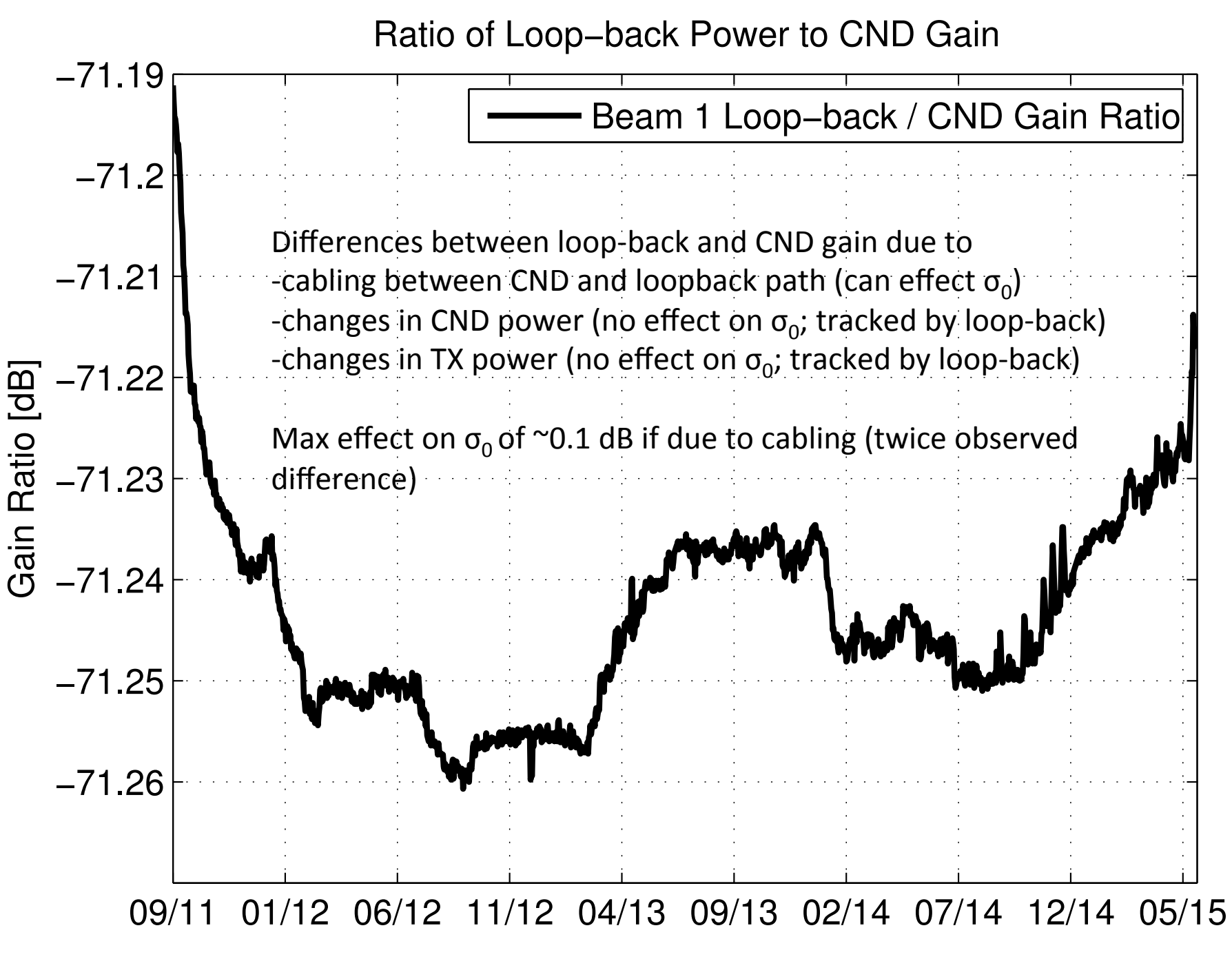
Aquarius Instrument Calibration

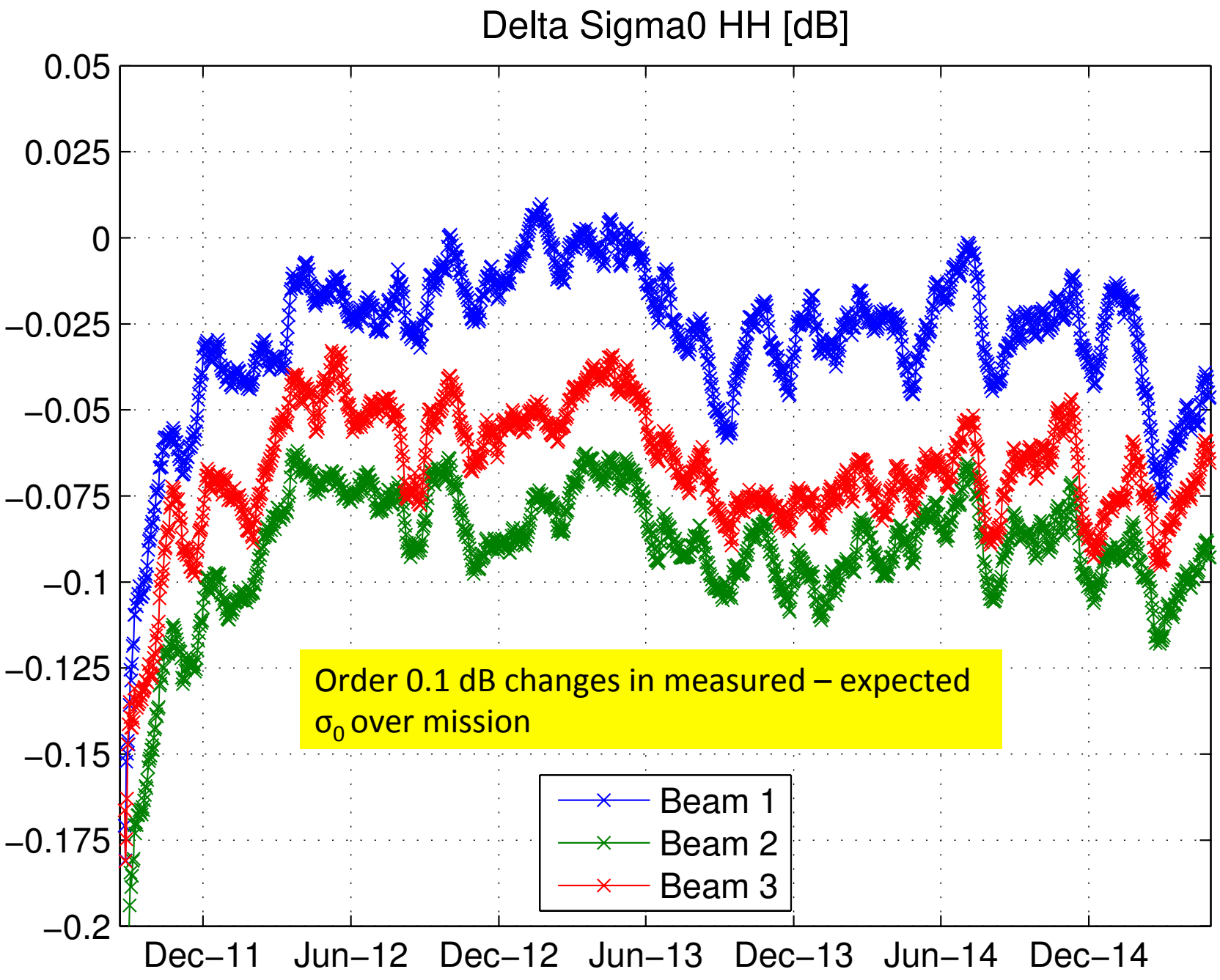
- Aquarius includes a loop back calibration feature
  - Tracks transmit power and receiver gain product.
  - Any variations within the loop back pathway are automatically corrected in σ_0 computation.
- Some key portions of hardware lie outside of loopback pathway
  - These are controlled thermally to ~ 0.5 deg C temperature variations.
  - Or designed to be insensitive to changing temperature.

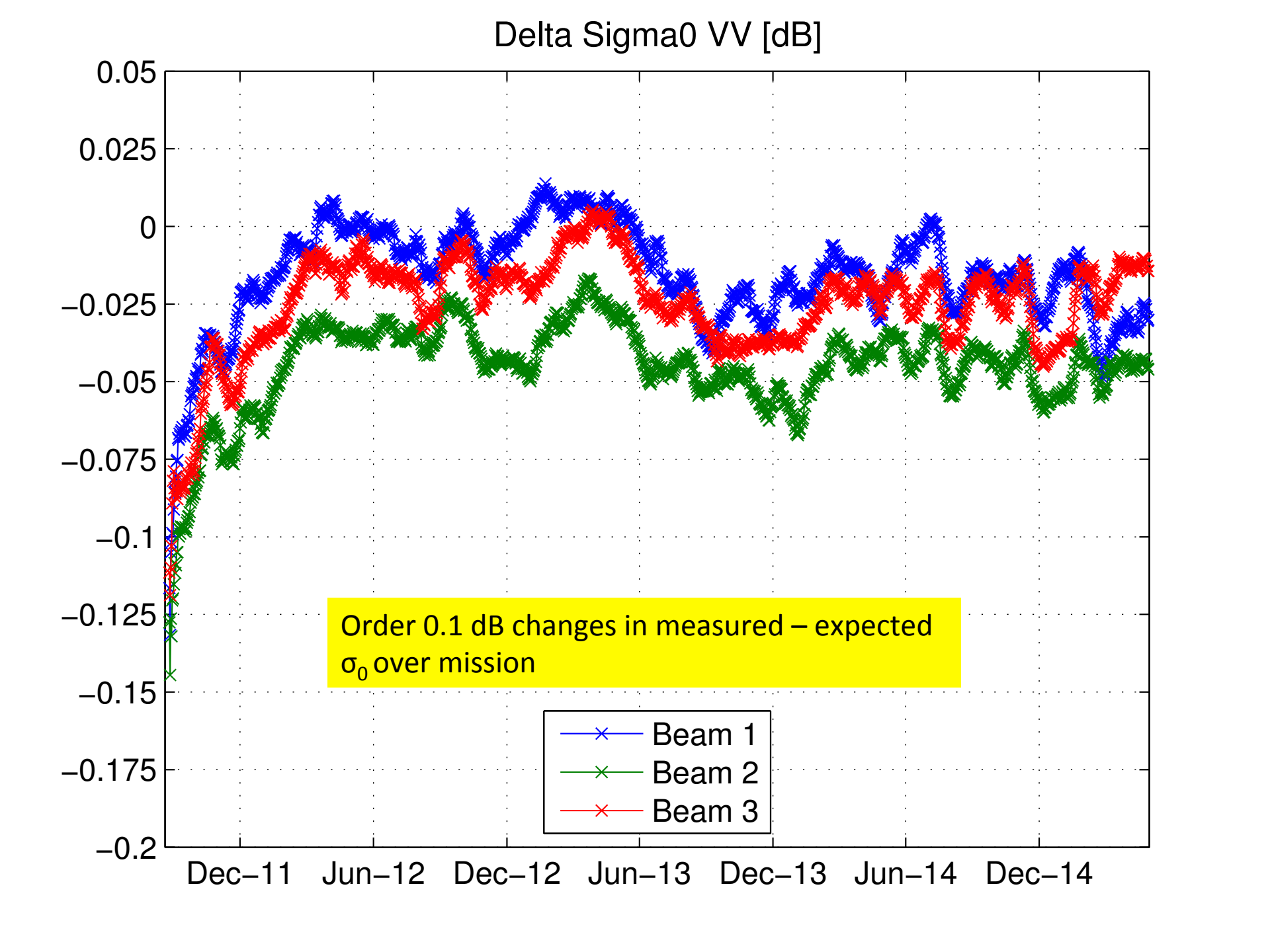

Scatterometer Loop−back Power
Power [dBm]
−3.75
−3.775
−3.8
−3.825
−3.85
−3.875
−3.9
−3.925
−3.95
09/11
01/12
06/12
11/12
04/13
09/13
02/14
07/14
12/14
05/15
Order 0.1 dB changes in loop-back power over mission
Beam 1 HV
Beam 1 VV
Beam 1 VH
Beam 1 HH


Key Scatterometer Component Temperatures outside of Loop−back
Temperature [deg C]
22
21.5
21
20.5
20
19.5
19
18.5
18
09/11
01/12
06/12
11/12
04/13
09/13
02/14
07/14
12/14
05/15
Step Attenuator
Loop−back Attenuator
Loop−back Switch
Beam Switch


CND Gain Estimated On V Receive
Beam 1 CND Gain
Gain [dB]
67.5
67.45
67.4
67.35
67.3
67.25
09/11
01/12
06/12
11/12
04/13
09/13
02/14
07/14
12/14
05/15
Estimate receiver gain using difference of adjacent noise power observations with and without the known CND power


Ratio of Loop–back Power to CND Gain
Beam 1 Loop–back / CND Gain Ratio
Differences between loop-back and CND gain due to
-cabling between CND and loopback path (can effect σ0)
-changes in CND power (no effect on σ0; tracked by loop-back)
-changes in TX power (no effect on σ0; tracked by loop-back)
Max effect on σ0 of ~0.1 dB if due to cabling (twice observed difference)
Gain Ratio [dB]
−71.19
−71.2
−71.21
−71.22
−71.23
−71.24
−71.25
−71.26
09/11
01/12
06/12
11/12
04/13
09/13
02/14
07/14
12/14
05/15

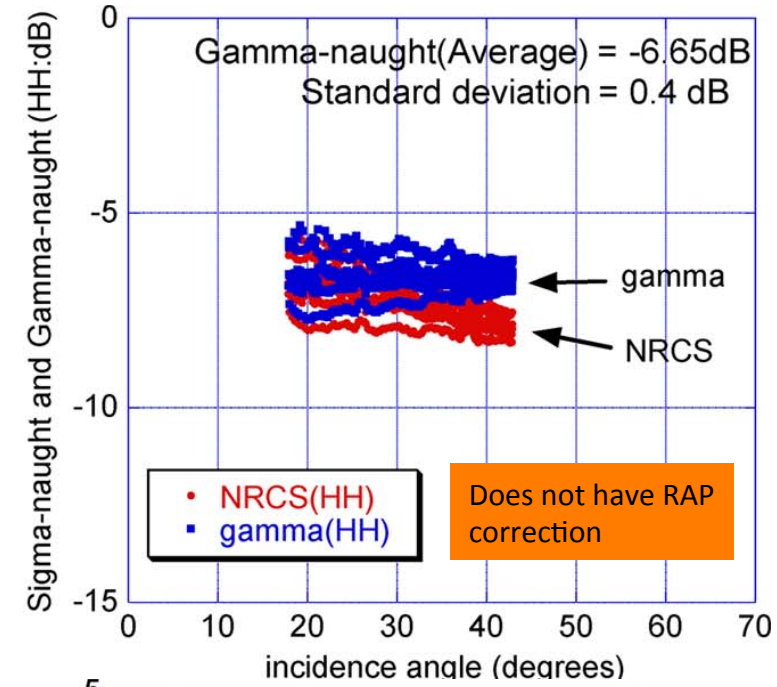

Delta Sigma0 HH [dB]
0.05
0.025
0
−0.025
−0.05
−0.075
−0.1
−0.125
−0.15
−0.175
−0.2
Dec−11
Jun−12
Dec−12
Jun−13
Dec−13
Jun−14
Dec−14
Order 0.1 dB changes in measured – expected σ0 over mission
Beam 1
Beam 2
Beam 3

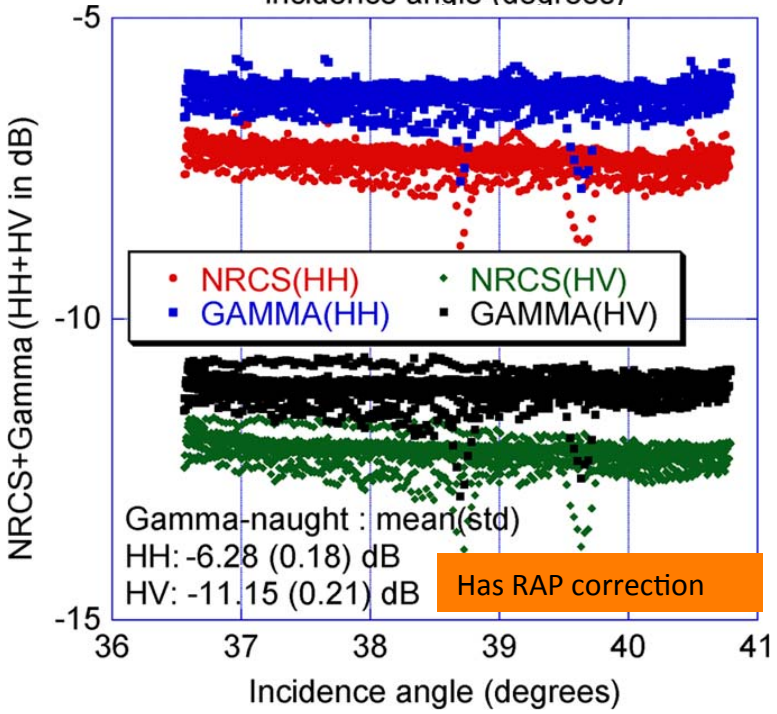

Delta Sigma0 VV [dB]
0.05
0.025
0
−0.025
−0.05
−0.075
−0.1
−0.125
−0.15
−0.175
−0.2
Dec−11
Jun−12
Dec−12
Jun−13
Dec−13
Jun−14
Dec−14
Order 0.1 dB changes in measured – expected σ0 over mission
Beam 1
Beam 2
Beam 3

Amazon γ_0

$$\gamma_0 = \sigma_0 / \cos(\theta_{inc})$$

- PALSAR found γ_0 values in the Amazon stable across 20-45 degrees in incidence angle*
  - Wet-dry seasonal difference of ~ 0.27 dB**
  - Wet season is approx. Nov-April.
- Best estimates are:
  - HH ~ -6.28 dB (std 0.18)
  - HV ~ -11.15 dB (std 0.21)
  - Not clear which season this is from!





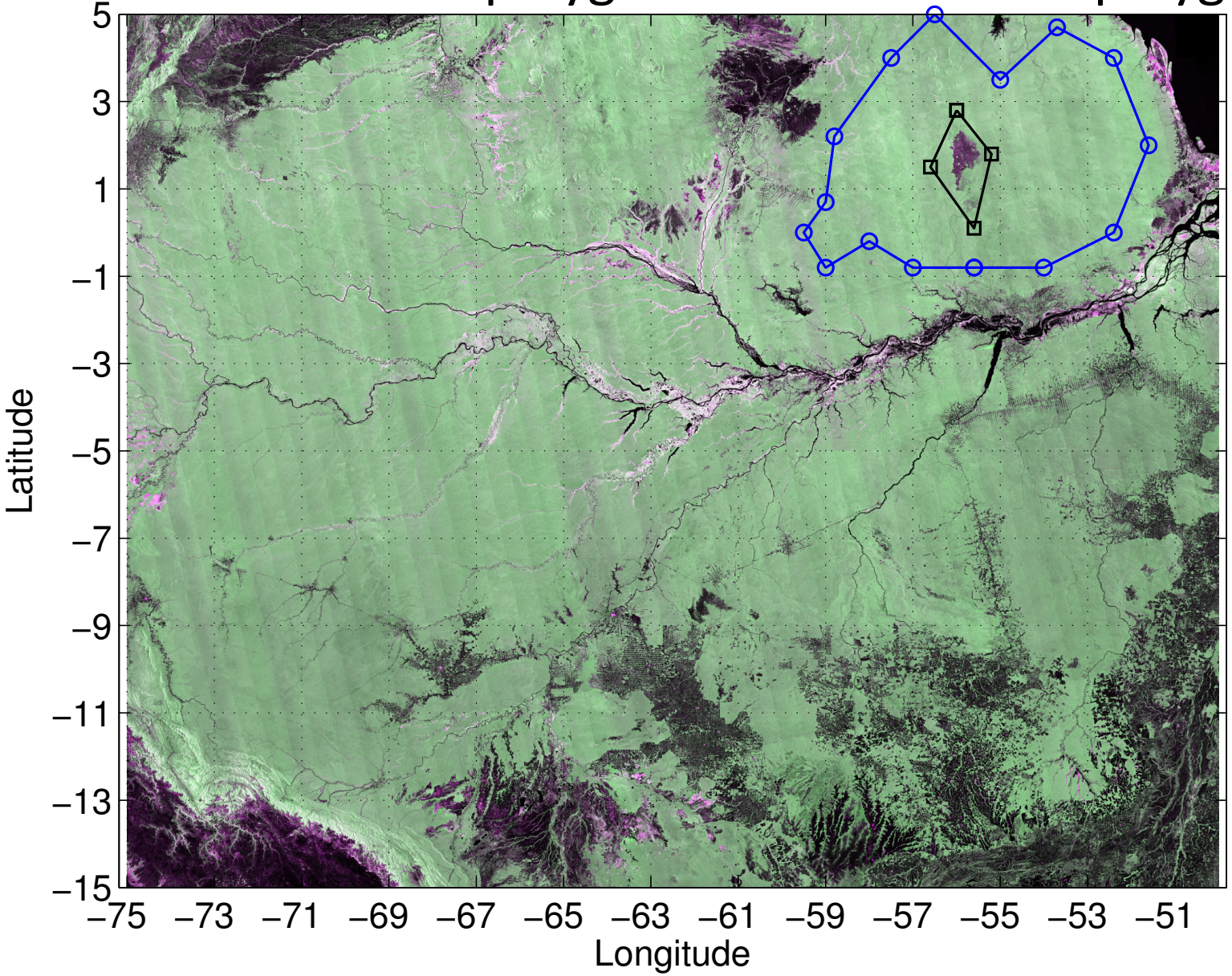
*M. Shimada, O. Isoguchi, T. Tadono, and K. Isono. Palsar radiometric and geometric calibration. Geoscience and Remote Sensing, IEEE Transactions on, 47(12):3915 – 3932, dec. 2009 (Images from this source)

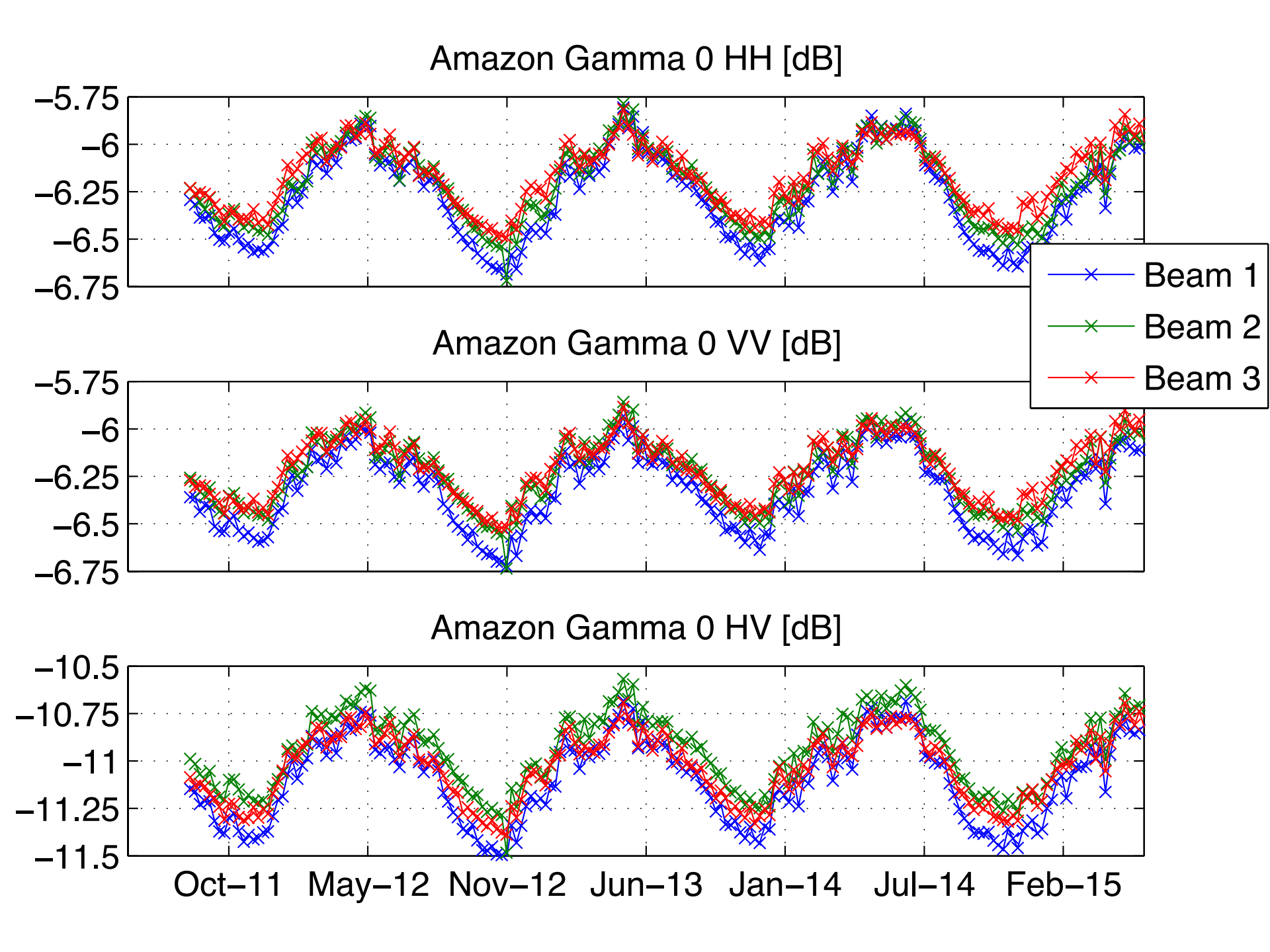
**M. Shimada. Long-term stability of l-band normalized radar cross section of amazon rainforest using the jers-1 sar. Canadian Journal of Remote Sensing, 31(1): 132–137, 2005.

RAP correction is range antenna pattern correction

Regions used in γ_0 Analysis

Include data in blue polygon and not in black polygon




Amazon Gamma 0 HH [dB]
−5.75
−6
−6.25
−6.5
−6.75
Amazon Gamma 0 VV [dB]
−5.75
−6
−6.25
−6.5
−6.75
Amazon Gamma 0 HV [dB]
−10.5
−10.75
−11
−11.25
−11.5
Oct−11
May−12
Nov−12
Jun−13
Jan−14
Jul−14
Feb−15
Beam 1
Beam 2
Beam 3

Bias compared to PALSAR

PALSAR values: HH: -6.28 dB; HV: -11.15 dB

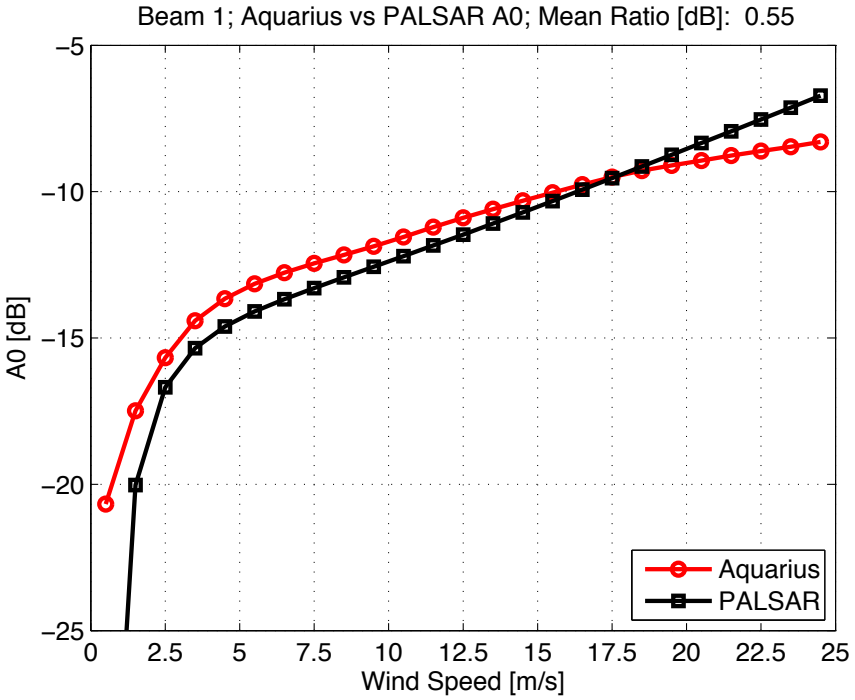
Asc / Dec	Beam 1	Beam 2	Beam 3
All HH	0.03	0.03	0.07
Ascending HH	0.06	0.01	0.01
Descending HH	-0.01	0.04	0.15
All VV	-0.02	0.04	0.07
Ascending VV	0.00	0.02	0.05
Descending VV	-0.05	0.07	0.08
All HV	0.07	0.17	0.10
Ascending HV	0.09	0.17	0.10
Descending HV	0.05	0.19	0.16

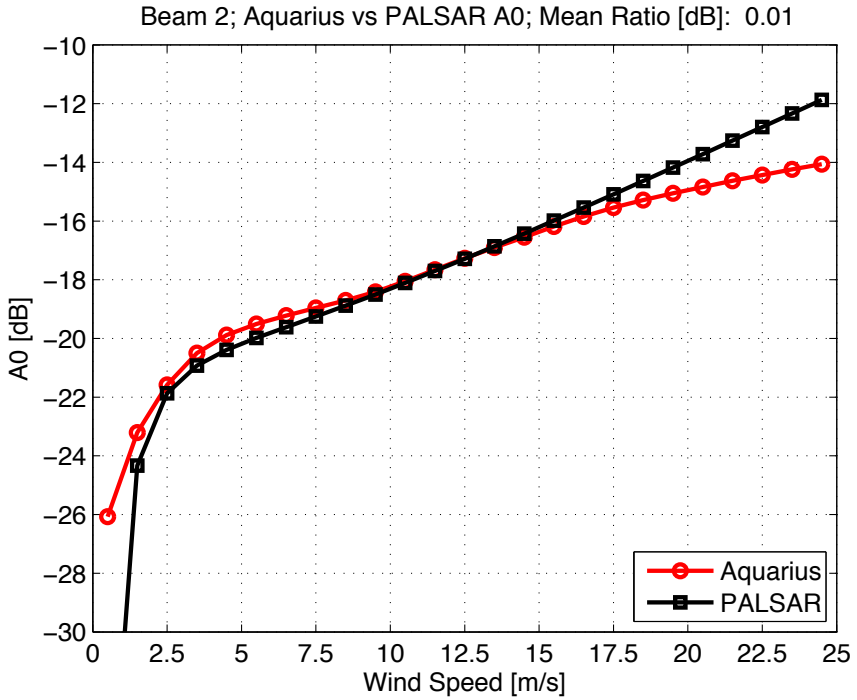
No significant ascending / descending difference

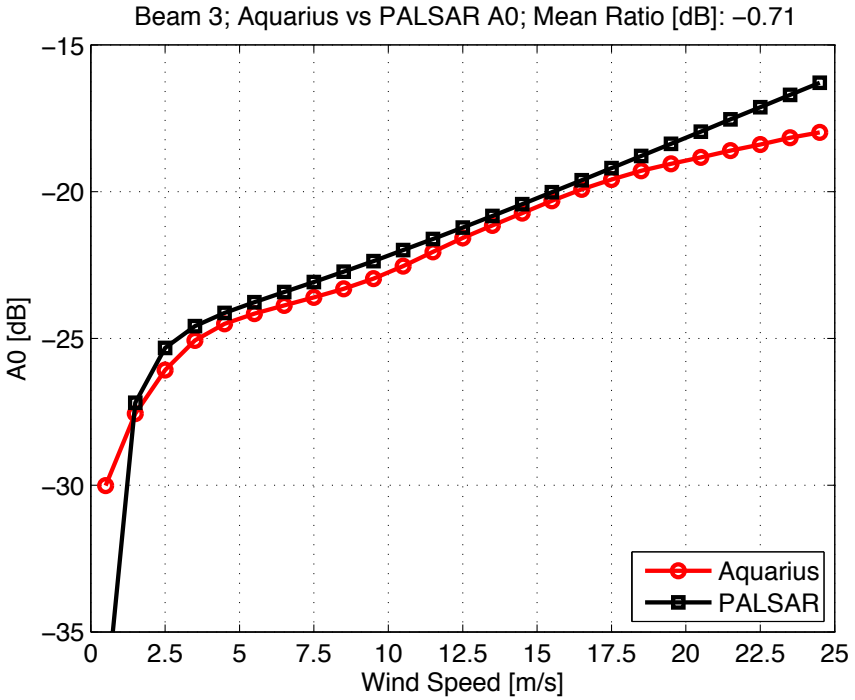
Ocean Comparison
Aquarius HH / PALSAR HH

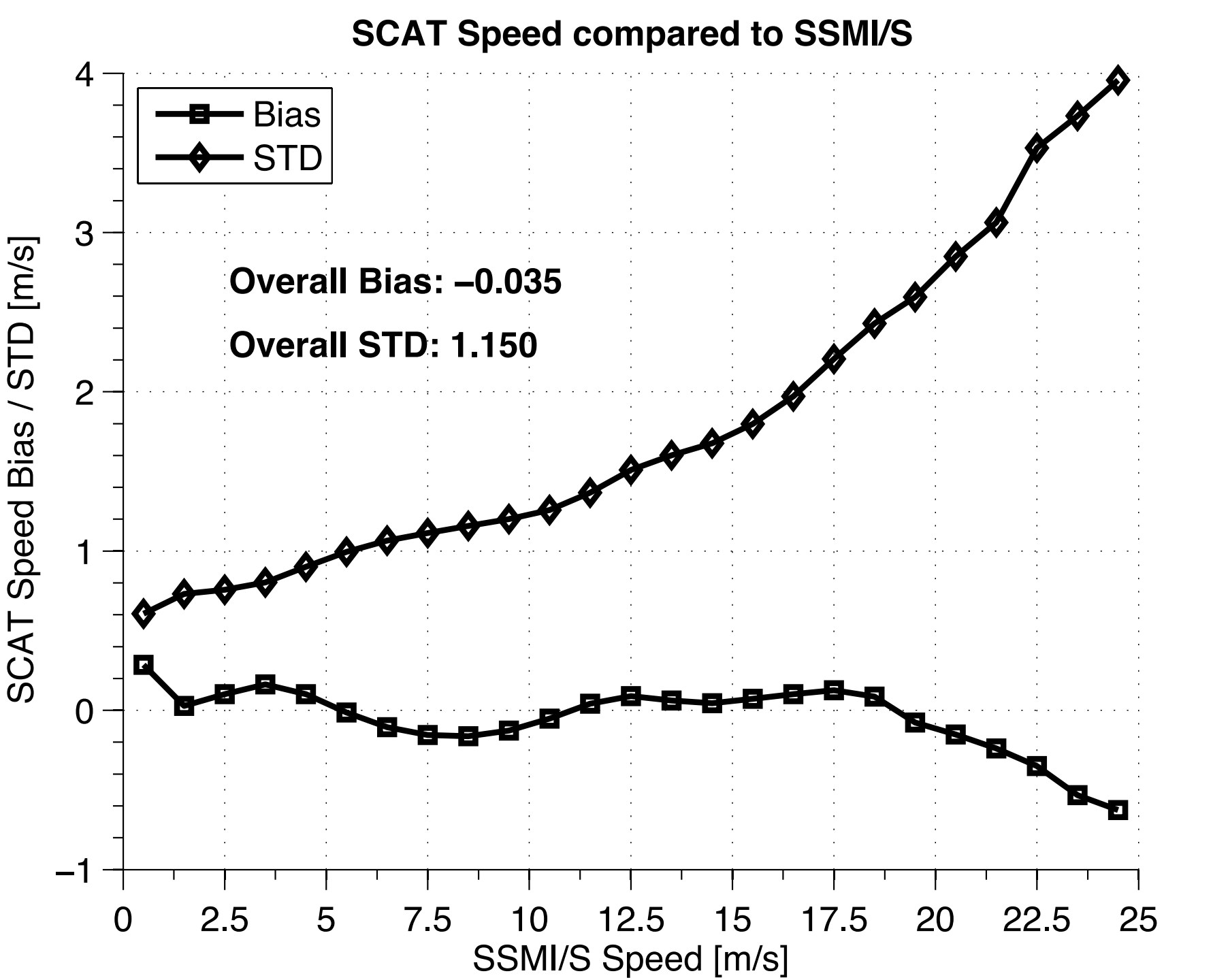
Plot of PALSAR HH GMF (black square) and our Aquarius HH GMF (red o).
-Compute wind speed PDF weighted mean ratio of Aquarius GMF divided by PALSAR GMF.

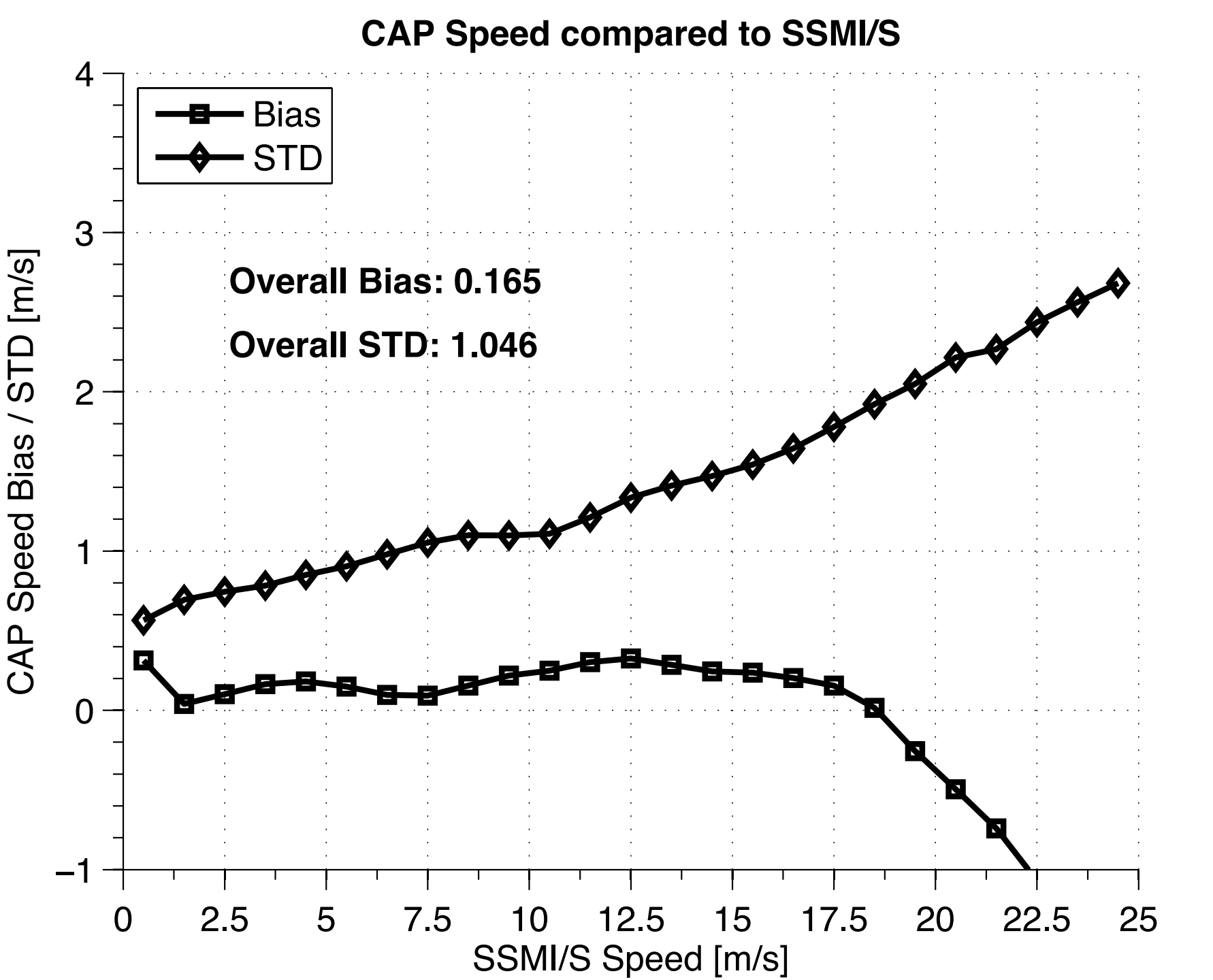
Beam	1	2	3
Mean Ratio [dB]	0.55	0.01	-0.71








SCAT Speed compared to SSMI/S
Bias
STD
Overall Bias: –0.035
Overall STD: 1.150
SCAT Speed Bias / STD [m/s]
SSMI/S Speed [m/s]
4
3
2
1
0
–1
0
2.5
5
7.5
10
12.5
15
17.5
20
22.5
25


CAP Speed compared to SSMI/S
Bias
STD
Overall Bias: 0.165
Overall STD: 1.046
CAP Speed Bias / STD [m/s]
SSMI/S Speed [m/s]
4
3
2
1
0
−1
0
2.5
5
7.5
10
12.5
15
17.5
20
22.5
25

Triple-Collocation Results

The scatterometer-only wind speed product has performance within 0.2 m/s RMS of RapidSCAT

	Bias	Slope	RMS Error
SSMI	0	1	0.6670
RapidScat	0.4440	0.9525	0.7333
SCAT 4.0	-0.1193	1.0184	0.9531

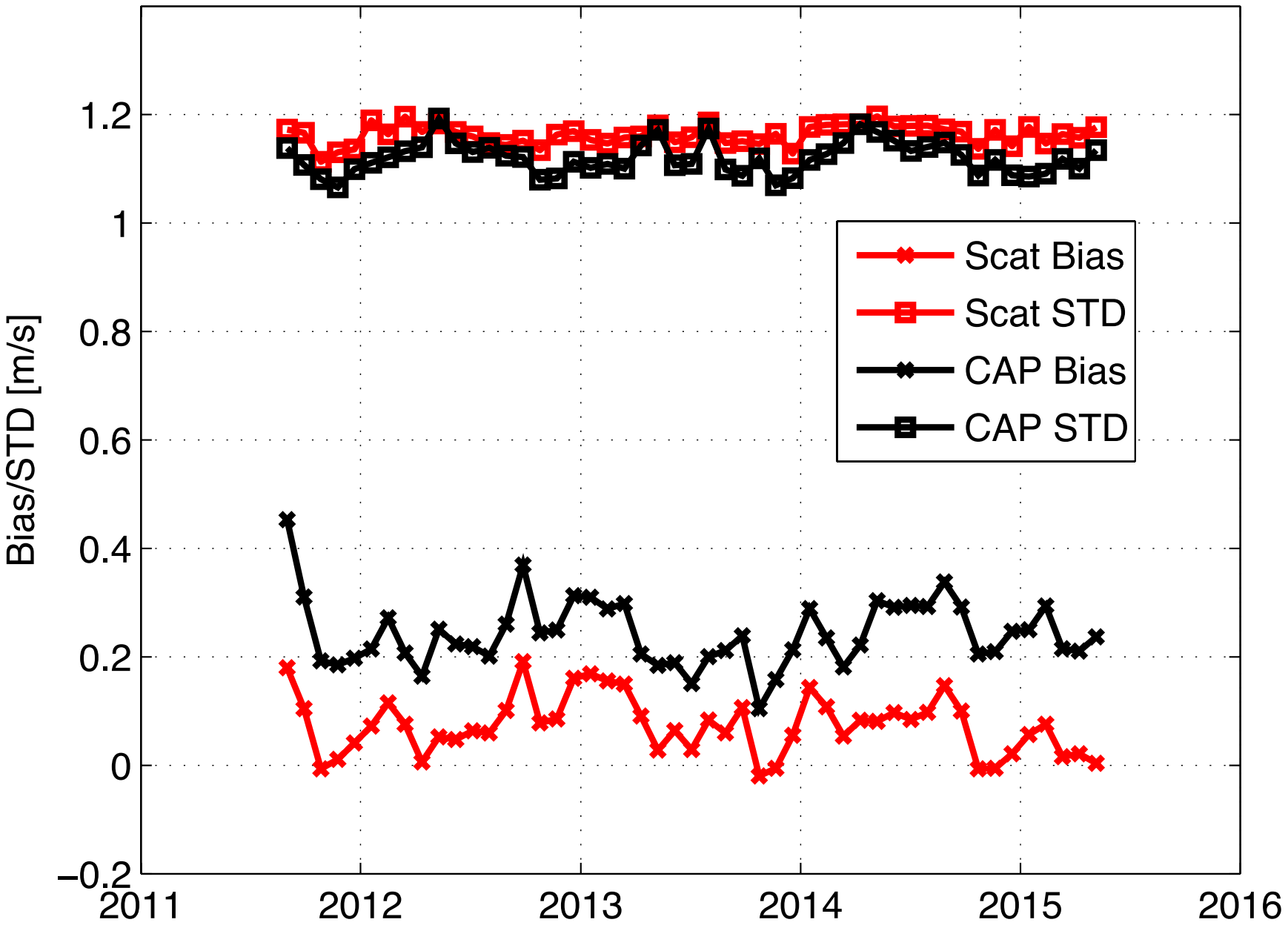
	Bias	Slope	RMS Error
SSMI	0	1	0.6715
RapidScat	0.4395	0.9532	0.7295
CAP 4.0	-0.3214	1.0752	0.8953

Triple-Collocation Results (CAP)

The vector triple-collocation results suggest that the CAP wind direction is not as good as that from RapidScat.

U Component	Bias	Slope	RMS Error
ECMWF	0	1	0.8107
RapidScat	-0.0997	0.9912	1.1487
CAP 4.0	-0.0273	1.0309	1.3924

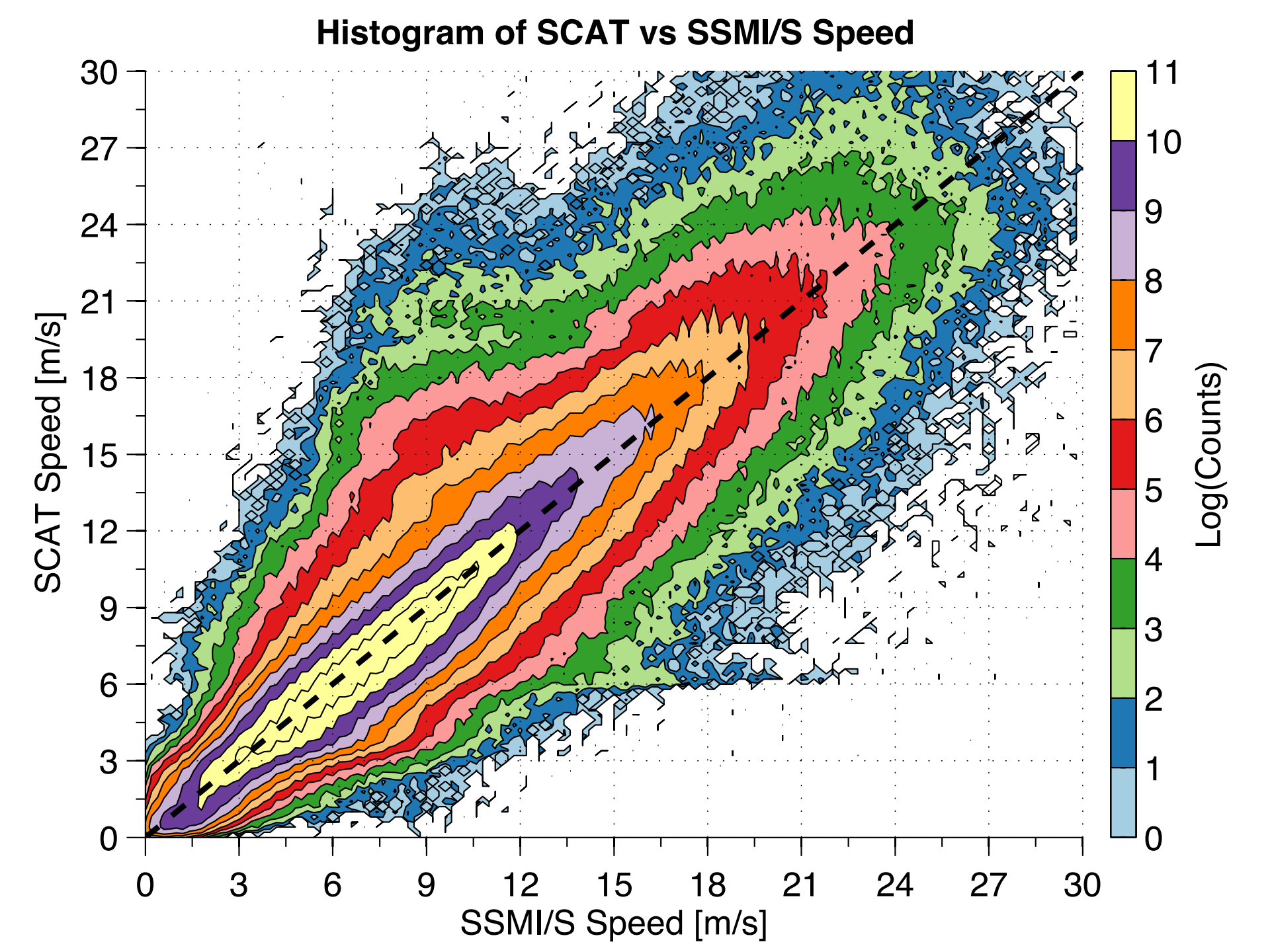
V Component	Bias	Slope	RMS Error
ECMWF	0	1	0.8187
RapidScat	0.0427	1.0265	1.4584
CAP 4.0	-0.0305	1.0383	1.5944

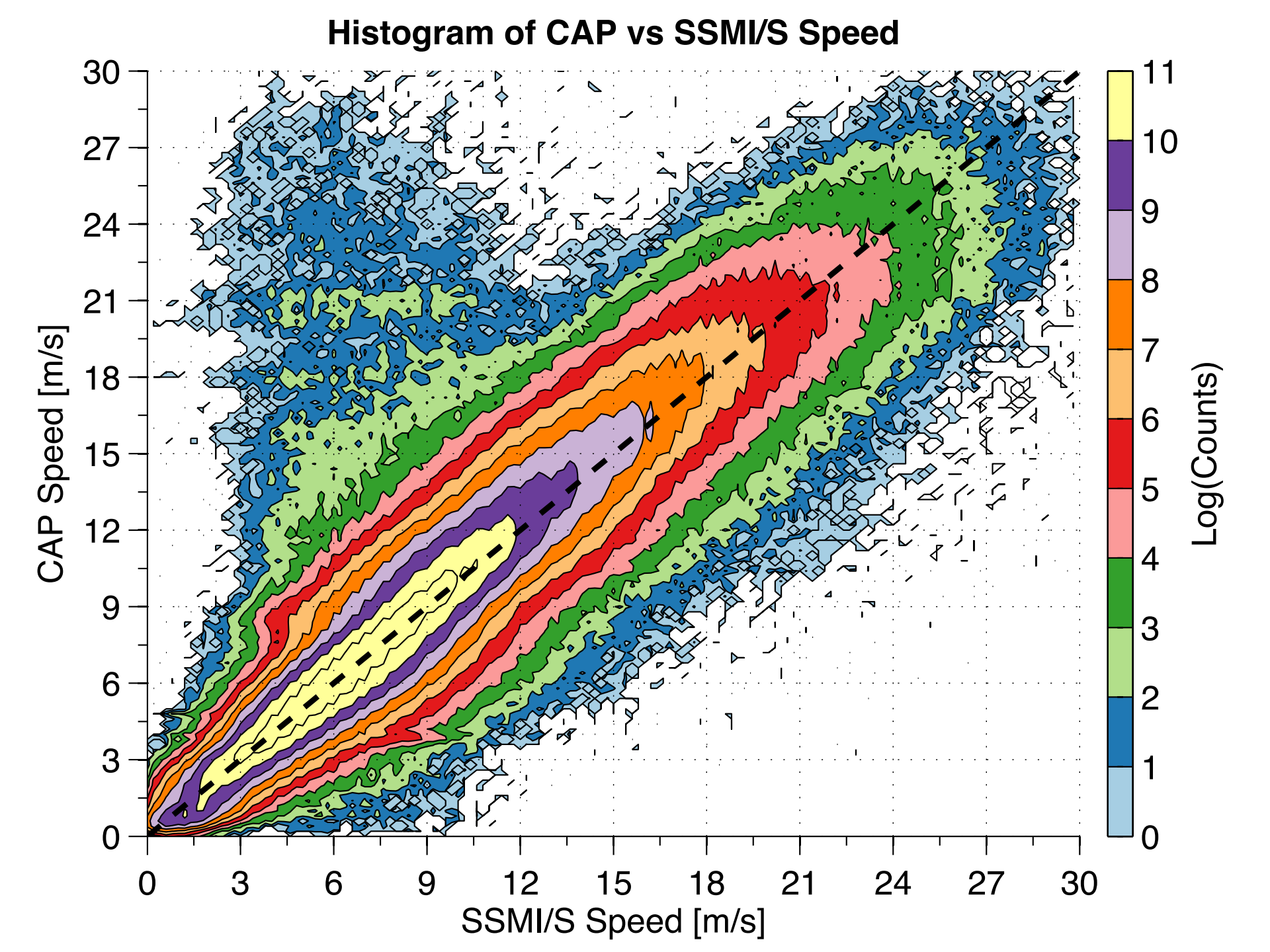

Wind Speed Bias/STD as compared to SSMI/S
Bias/STD [m/s]
1.2
1
0.8
0.6
0.4
0.2
0
−0.2
2011
2012
2013
2014
2015
2016
Scat Bias
Scat STD
CAP Bias
CAP STD

Summary

- Aquarius is a stable source of calibrated L-band backscatter over the mission.
  - Stability:
    - Instrument only predicts worst-case of 0.1 dB
    - Measured – model shows order 0.1 dB drift – corrected for in V4.0 data
- Aquarius is calibrated to be consistent with PALSAR
  - Amazon:
    - We find no significant ascending descending difference.
    - Seasonal variation of 0.5 dB over Amazon.
  - Ocean:
    - Comparison of Aquarius and PALSAR model functions shows they are calibrated to the 1 dB level.
    - Various factors can explain the residual differences (ancillary wind speed used, …etc.).
  - Aquarius has been used as reference for SMAP radar calibration.
- Aquarius provides a wind speed product with accuracy approaching that from previous Ku and C-band scatterometers.

Backups


Histogram of SCAT vs SSMI/S Speed
SCAT Speed [m/s]
SSMI/S Speed [m/s]
Log(Counts)
0
3
6
9
12
15
18
21
24
27
30
0
1
2
3
4
5
6
7
8
9
10
11


Histogram of CAP vs SSMI/S Speed
CAP Speed [m/s]
SSMI/S Speed [m/s]
Log(Counts)
0
3
6
9
12
15
18
21
24
27
30
0
1
2
3
4
5
6
7
8
9
10
11

PALSAR Found γ_0^{HH} = -6.28 dB and γ_0^{HV} = -11.15 dB
Histograms of Aquarius γ_0 For the Three Beams