Calibration of HY-2A Satellite Scatterometer with Ocean and Considerations of Calibration of CFOSAT Scatterometer

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- 2. Consideration of Calibration of CFOSAT SCAT
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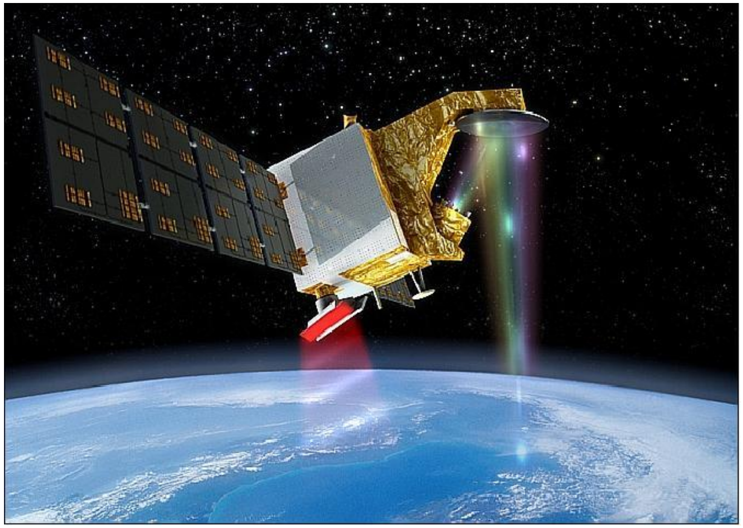
CFOSAT SCAT Mission Updates

- CFOSAT (Chinese-French Oceanic SATellite) is a China-France jointly developed oceanic satellite, CFOSAT has two radar payloads:
- Ku-band real aperture radar for measurement of directional ocean surface wave measurement (SWIM).
- Ku-band radar scattermeter (SCAT) for ocean surface wind vector measurement;

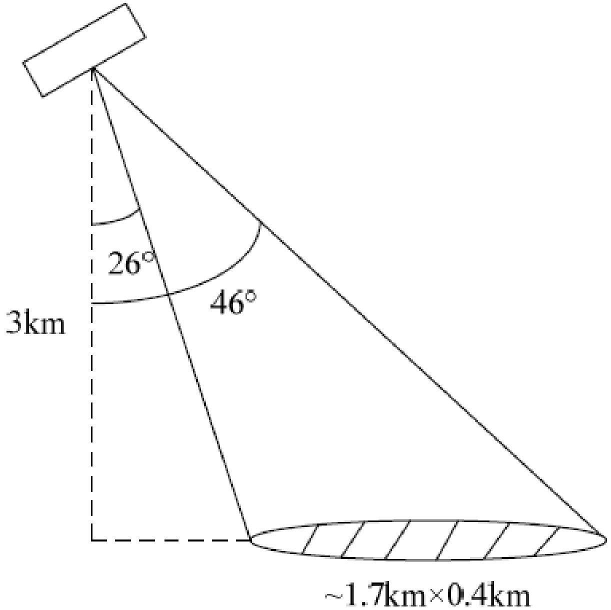


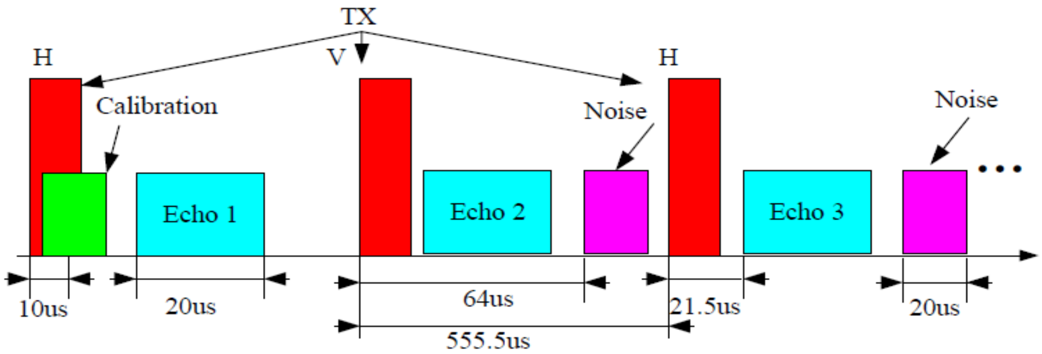
Milestones of CFOSAT SCAT

- Apr, 2010, Preliminary design review;
- Dec, 2010, Detailed design review;
- Jul, 2011, Satellite interface compatibility test and SCAT electrical performance test;
- Nov, 2011, Delivery of mechanical and thermal models;
- Oct, 2012, Airborne validation experiments at Yellow Sea, China.
- Jun, 2013, Environmental experiments
- Feb, 2014, Delivery of electrical models
- Apr, 2014, CFOSAT RM2/EMC Test
- 2018, Launch.

Airborne Validation Experiments

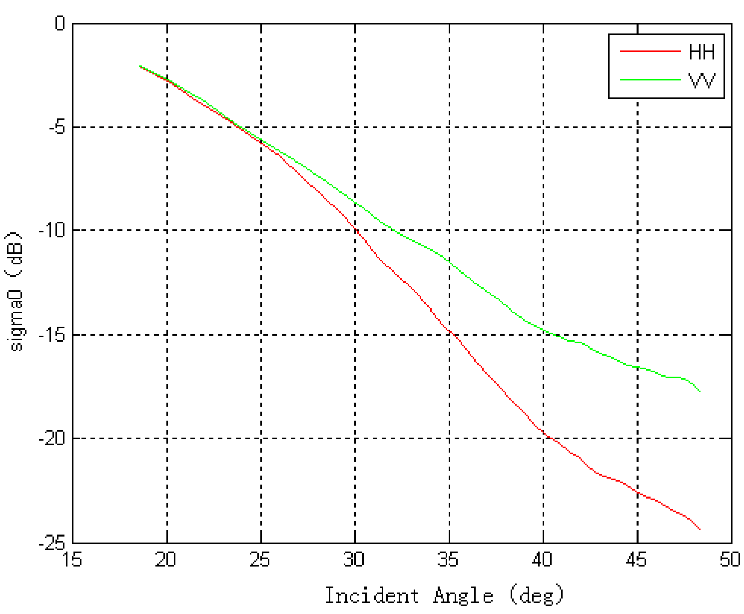
- To Validate the SCAT system design and reliability;
- Using all the instruments of the spaceborne scatterometer to except the power amplifier and the antenna.
- Software of SCAT is redesigned due to observation geometry of airborne platform.



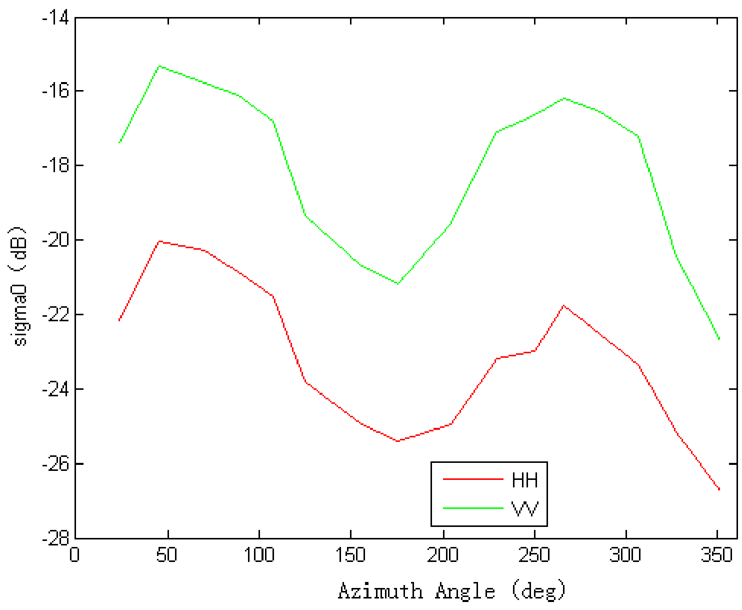


Airborne Validation Experiments

Test Results of Airborne Scatterometer



Sigma0 vs. incident angles



Sigma0 vs. azimuth angles

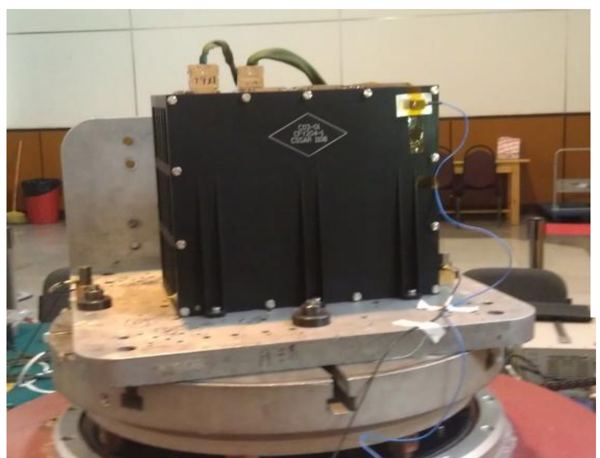
Airborne Validation Experiments

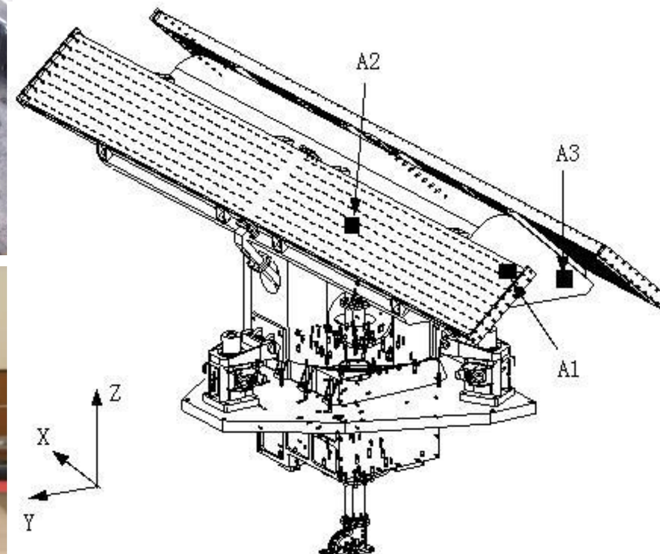
Retrieval Results Compared with real time wind vectors and HY-2A Scatterometer

Date	Airborne Scatterometer	HY-2A Scatterometer	Real time wind vectors (Measured on ships)	Wind Vector Errors
2012-11-2	4.8 m/s@28°	5.6 m/s@43°	5.0 m/s@30°	0.2 m/s@2°
2012-11-7	3.4 m/s@104°	-	3.5 m/s@112°	0.1 m/s@8°
2012-11-8	4.3 m/s@174°	5.0 m/s@141°	4.8 m/s@168°	0.5 m/s@6°
2012-11-12	11.0 m/s @105°	-	11.6 m/s @112°	0.6m/s @7°
2012-11-14	6.4 m/s @159°	6.1 m/s @175°	7.1 m/s @177°	0.7 m/s @18°
2012-11-17	11.0 m/s @124°	-	11.5 m/s @135°	0.5m/s@11°

Environmental Experiments

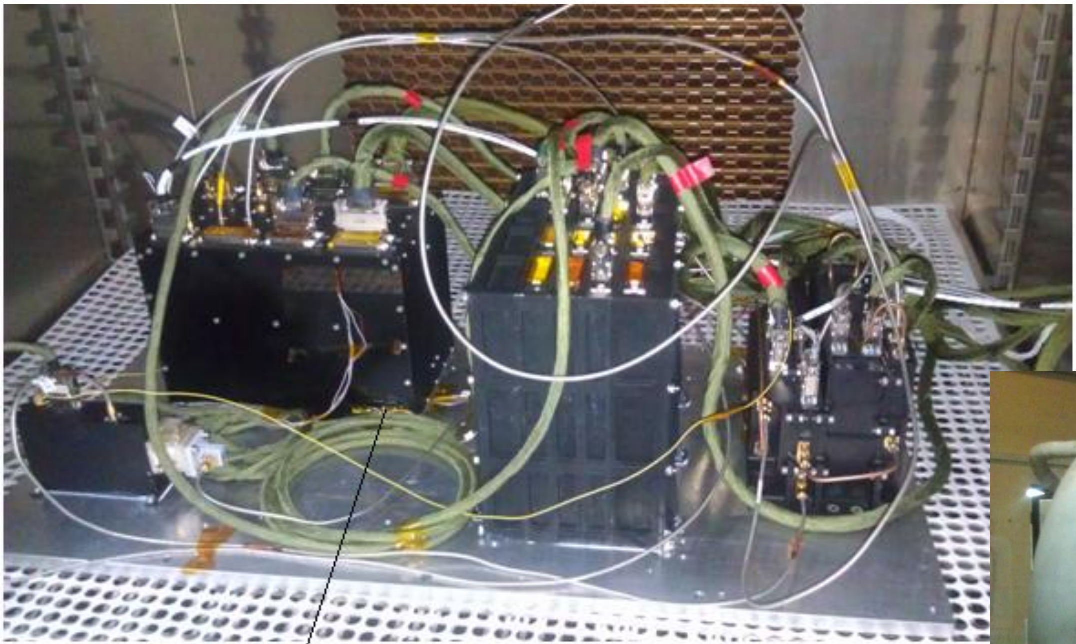
Random Vibration, Sine Vibration and Shock Tests





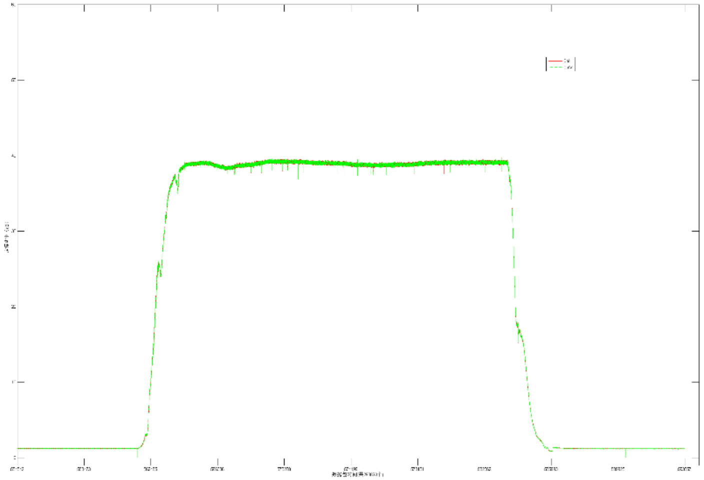
Environmental Experiments

Thermal Test and Thermal Vacuum Tests



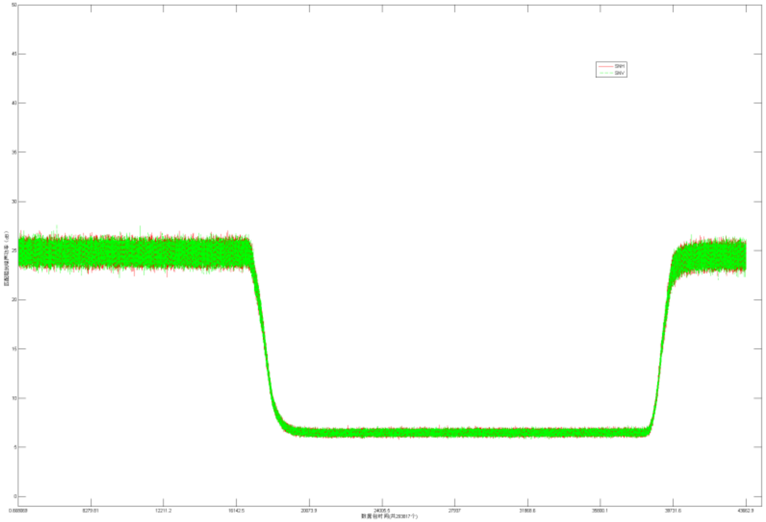
Environmental Experiments

The Calibration signal and Internal Noise during thermal test (one cycle)



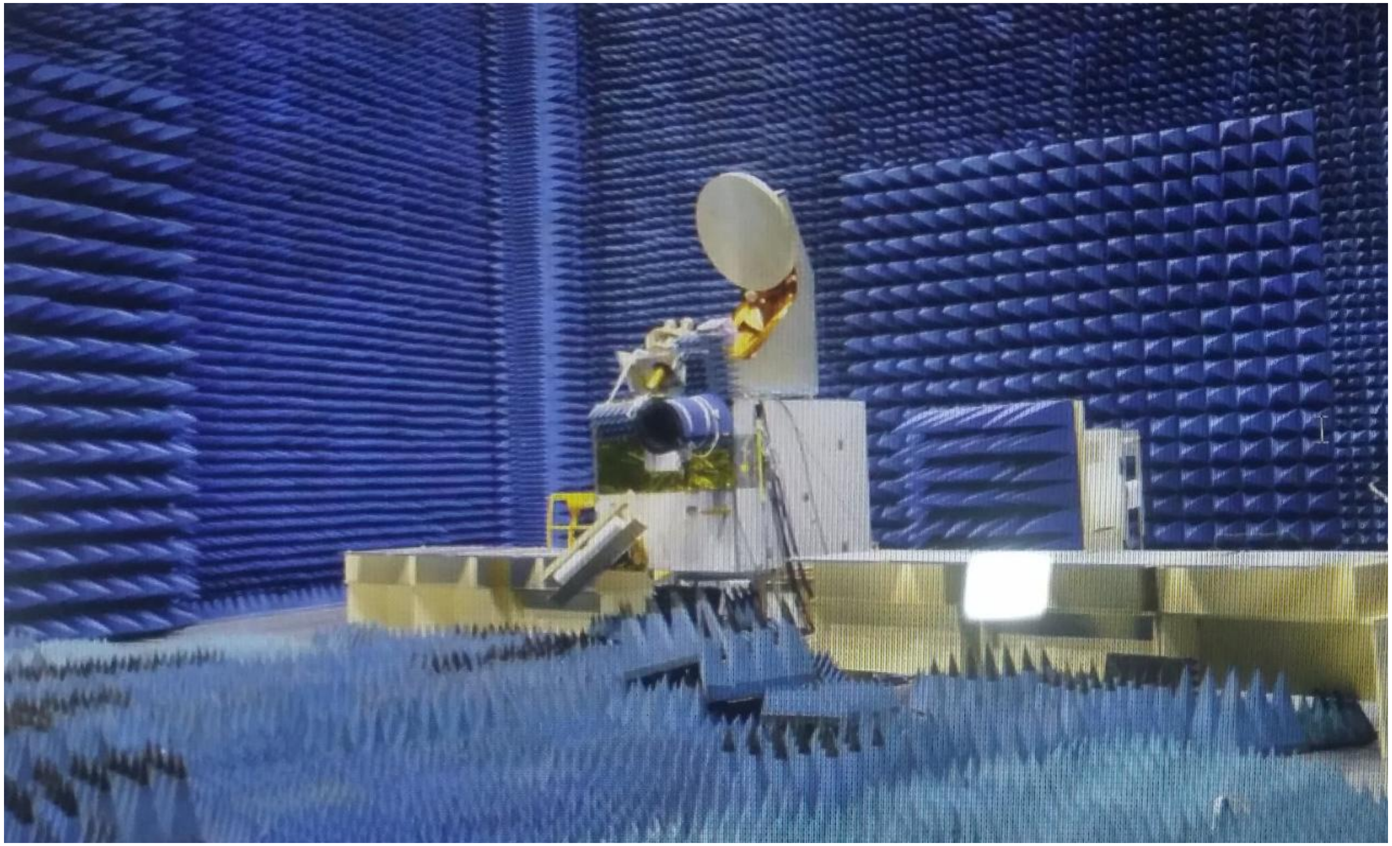
Calibration signal changes at different temperatures

Internal Noise changes at different temperatures



CFOSAT RM2/EMC Test

Satellite configuration in the EMC chamber



Calibration of CFOSAT SCAT

Internal Calibration

--Fluctuations of Tx power and Rx gain

--Fluctuations of Rx noise level

--Fluctuations of Rx transfer characteristics

External Calibration

--In-orbit antenan gain pattern, especially the elevation part

--Fluctuations of insert loss during the antenna rotation

--Satellite attitude errors

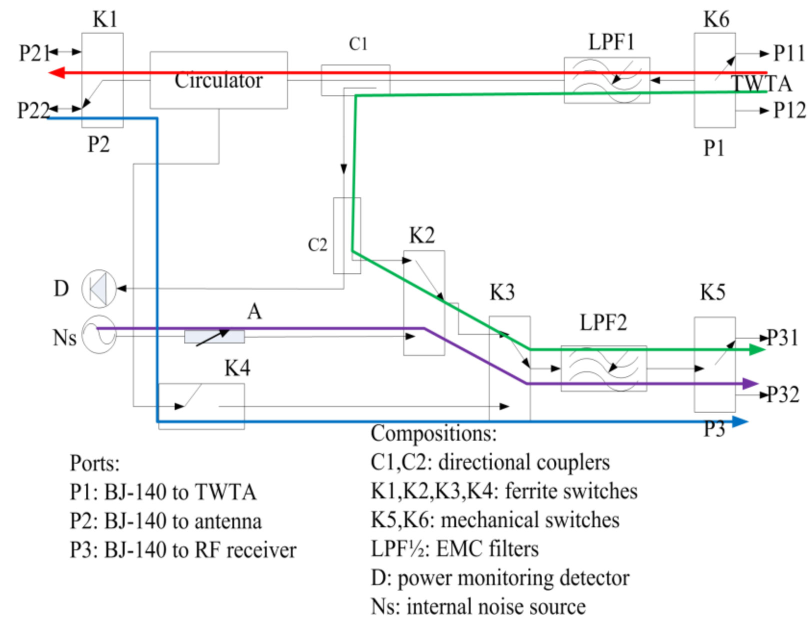
Calibration of CFOSAT SCAT

--The programmable gain controller inside the receiver has a repetitive precision of 0.1dB ;

--The measurement precisions for passive part of the transmitting/receiveing channel are both less than 0.05dB;

--The clutter by coupling outside the calibration loop is more than 20dB lower than the power coupled from the internal calibration loop, which leads to uncertainty of about 0.05dB.

--The fluctuation of the insertion loss of the rotary joint has a residual of less than 0.05dB;



The overall internal calibration error is better than 0.15dB

Calibration of CFOSAT SCAT

External Calibration

Purpose:

--Calibration of in-orbit antenna pattern;

--Calibration of fluctuations of insert loss of rotary joint

--Estimation of satellite attitude errors

Possible Solutions:

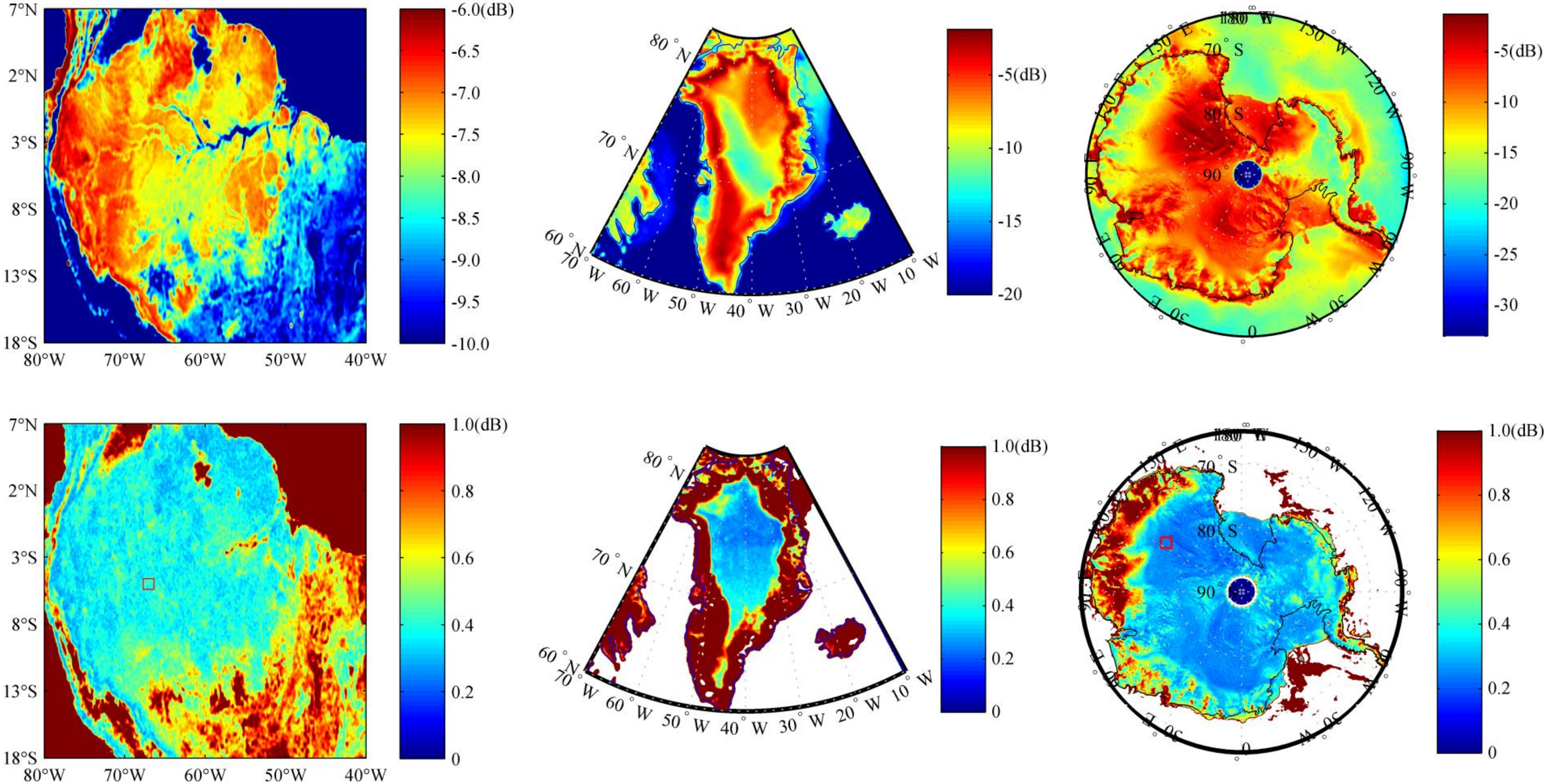
--Natural area-extended target with uniform Sigma-0

--Calibration ground stations

--NOC will be used to improve the wind retrieval quality

Calibration of CFOSAT SCAT

Several homogenenous areas over land are analyzed.(2009 QuikSCAT SIR)



Calibration of CFOSAT SCAT

Several homogenenous areas over land are analyzed using HY-2 L1B data

Region	Pass	VV Polarization		HH Polarization	
		Average (dB)	Std Dev	Average (dB)	Std Dev
Amazon	Asc	-8.35	0.43	-7.67	0.41
	Des	-8.14	0.40	-7.29	0.42
Congo	Asc	-8.34	0.43	-7.94	0.43
	Des	-7.94	0.39	-7.38	0.41
Antarctic	Asc	-5.55	0.40	-5.65	0.40
	Des	-5.47	0.39	-5.66	0.41
Greenland	Asc	-5.20	0.39	-5.83	0.36
	Des	-5.14	0.30	-5.64	0.36
Sahara	Asc	-22.48	0.84	-21.57	0.85
	Des	-22.53	0.87	-21.58	0.90

Calibration of CFOSAT SCAT

Models: $\sigma^0_{\text{meas,n}}(\text{dB}) = \sigma^0_{\text{tr}}(L_n, \theta_n, \text{Asc/Des}) + \Delta\sigma^0_G(L_n, b_n, t_n, \text{Asc/Des}) + \Delta\sigma^0_{\text{noise}}$

$$\Delta\sigma^0_G = \Delta\sigma^0_{abs} + \Delta\sigma^0_r$$

speed direction

$$\sigma^0_{\text{meas,n}} = \sigma^0_{\text{eff}}(\theta_n) + \Delta\sigma^0_r(b_n, \theta_n)$$

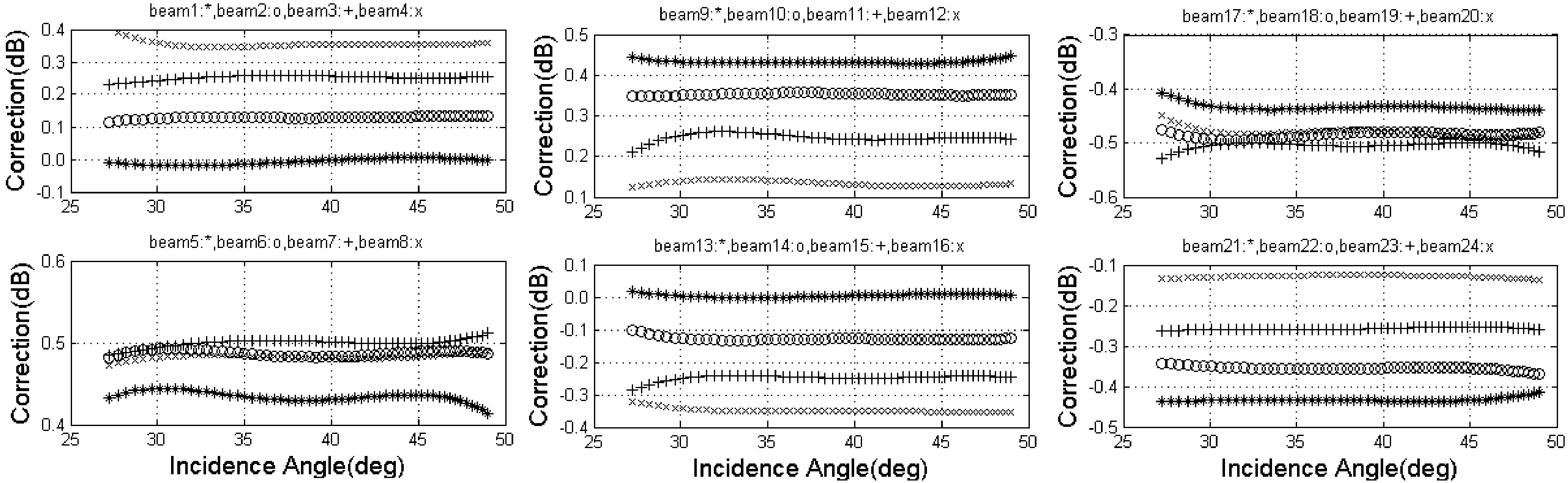
fourth order polynomial fitting (Long, Skouson, *TGRS*, 1996)

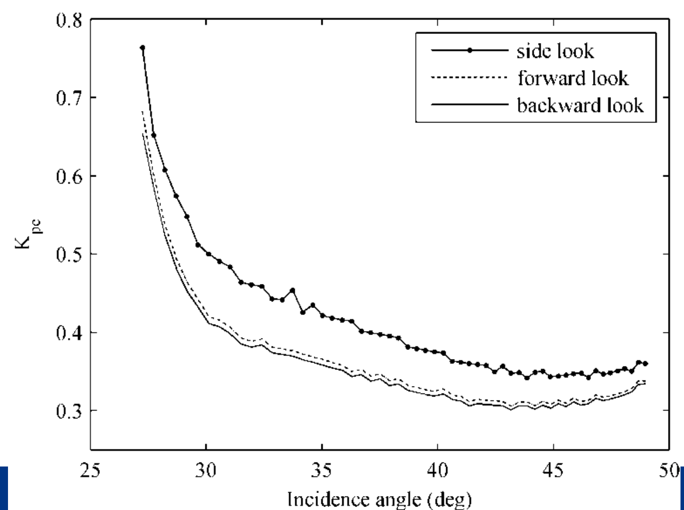
$$\sigma^0_{\text{meas}} = c(0,k) + c(1,k)\theta_n + c(2,k)\theta_n^2 + c(3,k)\theta_n^3 + c(4,k)\theta_n^4$$

$$c(i,k) = c_{\text{eff}}(i,k) + c_r(i,k)$$

In order to characterize the azimuthal-dependent bias (mainly casued by the rotary joint), the azimuth angles of the antenna beam are separated into 24 bins, which are sufficient for correcting the expected relative bias.

Simulation Results (STD<0.1dB)





Satellite attitude

$$F_1\left(\theta_r,\theta_y,\theta_p\right)=\frac{1}{N_m}\sum_{i=1}^{N_m}\left(G_{\mathrm{MEAS}}(\theta_N(i),\varphi_N(i))-G_{\mathrm{NOM}}(\theta_{\mathrm{ACT}}(i),\varphi_{\mathrm{ACT}}(i))\right)^2$$

Antenna gain pattern

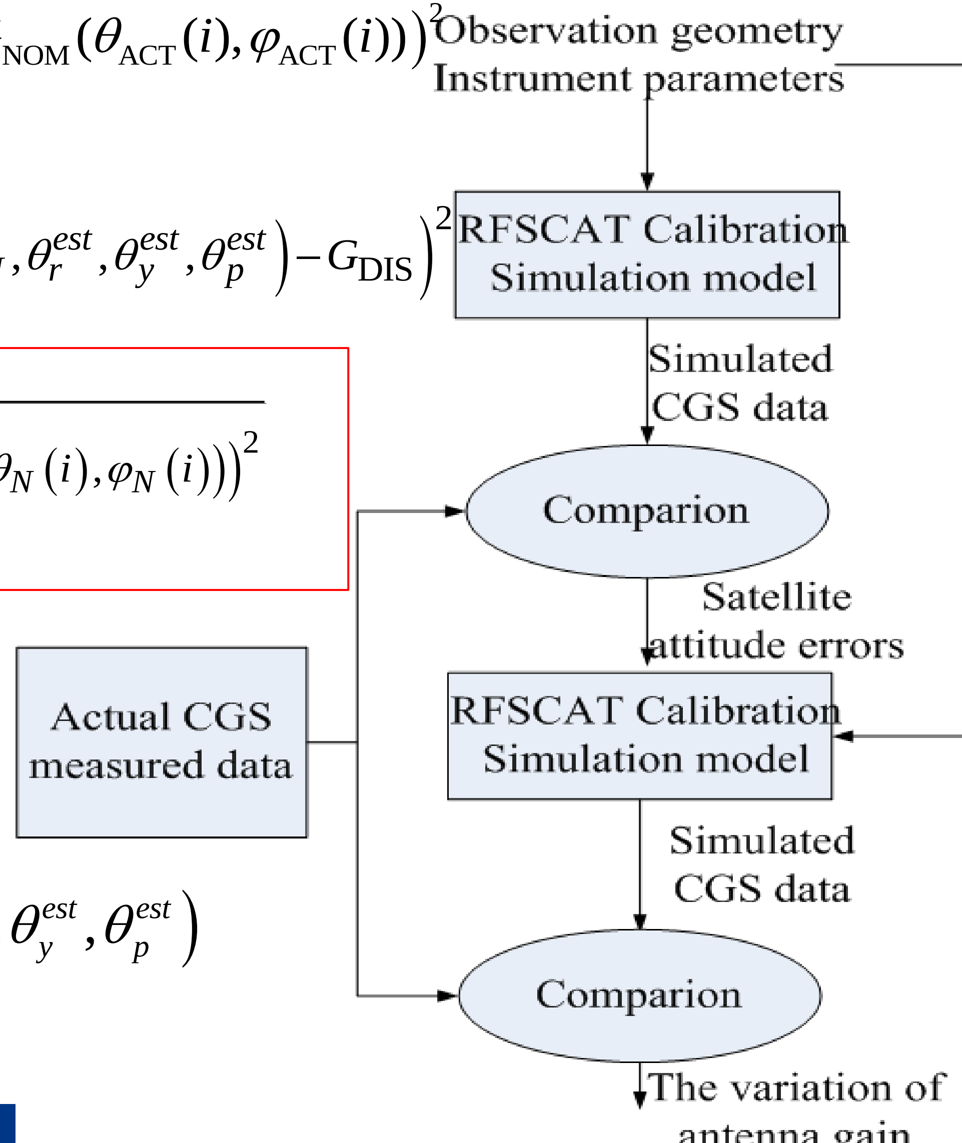
$$F_2\left(c_{\mathrm{nm}}\right)=\frac{1}{N_m}\sum^{N_m}\left(G_{\mathrm{MEAS}}\left(\theta_N,\varphi_N\right)-G_{\mathrm{NOM}}\left(\theta_N,\varphi_N,\theta_r^{est},\theta_y^{est},\theta_p^{est}\right)-G_{\mathrm{DIS}}\right)^2$$

$$\mathrm{RMS}=\sqrt{\frac{1}{N_m}\sum_{i=1}^{N_m}\left(G_{\mathrm{MEAS}}\left(\theta_N(i),\varphi_N(i)\right)-G_{\mathrm{MODEL}}\left(\theta_N(i),\varphi_N(i)\right)\right)^2}$$

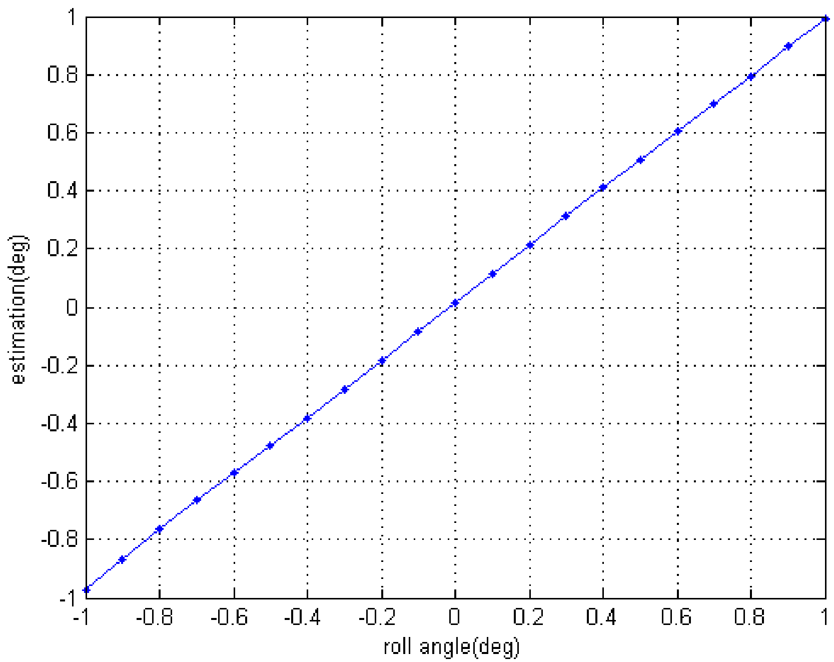
Fluctuations of insert loss of rotary joint

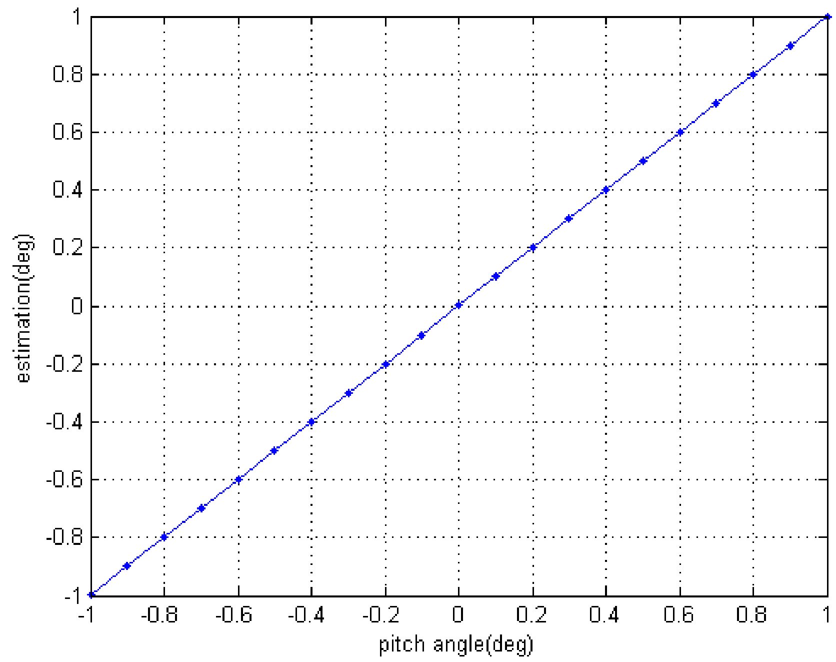
$$F_3\left(d_k\right)=\frac{1}{N_m}\sum_{i=1}^{N_m}\left(G_{\mathrm{DIF}}(i)-\sum_{k=1}^{N}d_k\phi^k(i)\right)^2$$

$$G_{\mathrm{DIF}}=G_{\mathrm{MEAS}}\left(\theta_N,\varphi_N\right)-G_{\mathrm{NOM}}\left(\theta_N,\varphi_N,\theta_r^{est},\theta_y^{est},\theta_p^{est}\right)-\sum_m\sum_n c_{\mathrm{nm}}\theta_{\mathrm{ACT}}^m\varphi_{\mathrm{ACT}}^n$$



Considertions of Calibration of CFOSAT SCAT

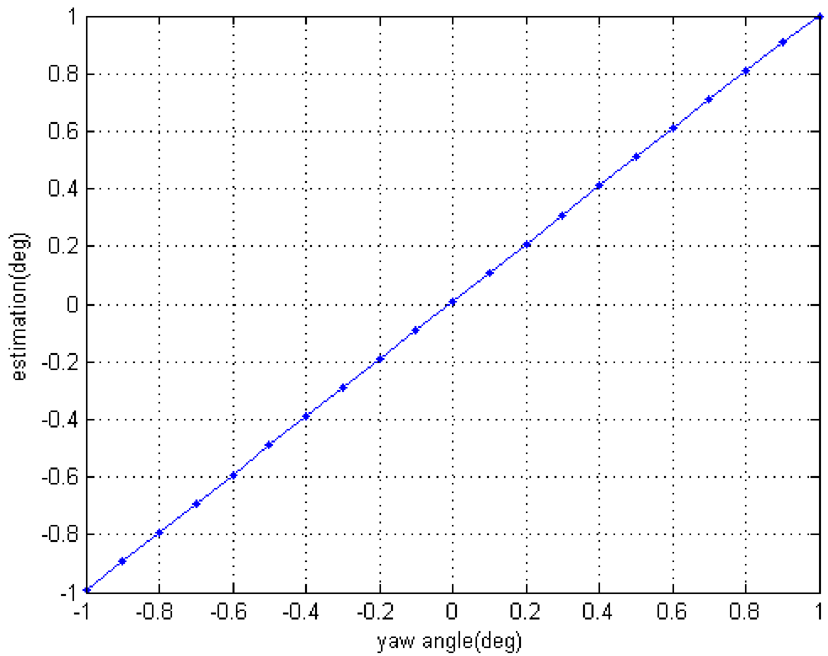


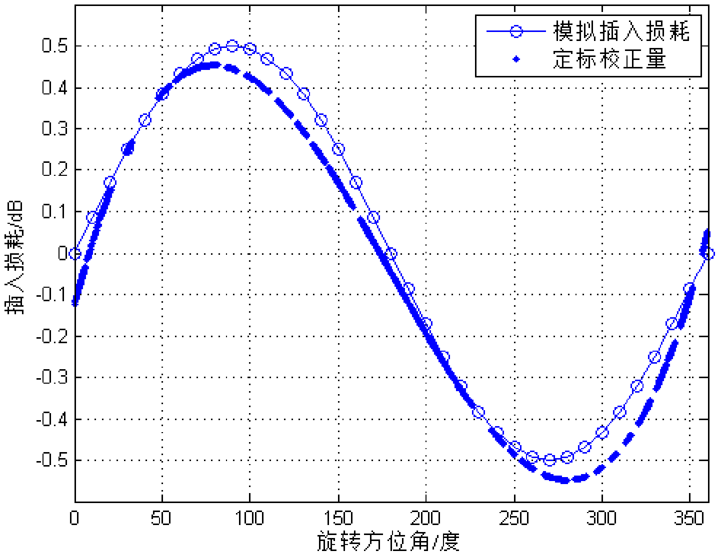


The STD of **roll** angle estimation is<0.02deg

The STD of **pitch** angle estimation is<0.001deg

Considertions of Calibration of CFOSAT SCAT





The STD of **yaw** angle estimation is<0.01deg

The estimation result of the loss due to rotary joint(STD<0.05dB)

Simulation Results of CGS

CAL Window	RFSCAT Work mode	CGS	Estimation error of Attitude(deg)				Rotary joint loss (dB)	Antenna gain(dB)
			Pointing error	Roll	Yaw	Pitch		
13 day	Normal mode	T_1	0.005	0.002	0.008	0.003	0.08	0.12
		T_2	0.004	0.001	0.007	0.002	0.04	0.10
		T_1+T_2	0.004	0.001	0.007	0.002	0.05	0.09
13 day	Only VV or HH mode	T_1	0.005	0.002	0.008	0.003	0.09	0.16
		T_2	0.004	0.001	0.007	0.002	0.04	0.11
		T_1+T_2	0.004	0.001	0.007	0.002	0.05	0.09
26 day	Normal mode	T_1	0.005	0.001	0.008	0.002	0.05	0.11
		T_2	0.004	0.001	0.007	0.002	0.05	0.06
		T_1+T_2	0.004	0.001	0.007	0.001	0.05	0.06

Simulation Results of CGS

$$\Delta\theta_{\text{point}} = \sqrt{\left(\Delta\theta_r\right)^2 + \left(\Delta\theta_y\right)^2 + \left(\Delta\theta_p\right)^2}$$

Less than 0.05dB

$$10\log_{10}\left(1+\frac{\Delta G_{\text{slant}}}{G}\right) = 10\log_{10}\left(1+\frac{2\Delta R}{R}\right)$$

The slant range to the near swath edge for the SCAT on CFOSAT is always greater than 570km. The bias error (100m) of slant range introduced into angenna gain error will be less than 0.0015dB

Atmospheric loss would be mainly related with oxygen content and water vapor density in the Clear sky. It would be reasonable to assume that one-way loss in the loss is about 0.0065dB/km under the condition that relative humidity is 30% lower. The variation of atmospheric loss after compensation is about 0.04dB

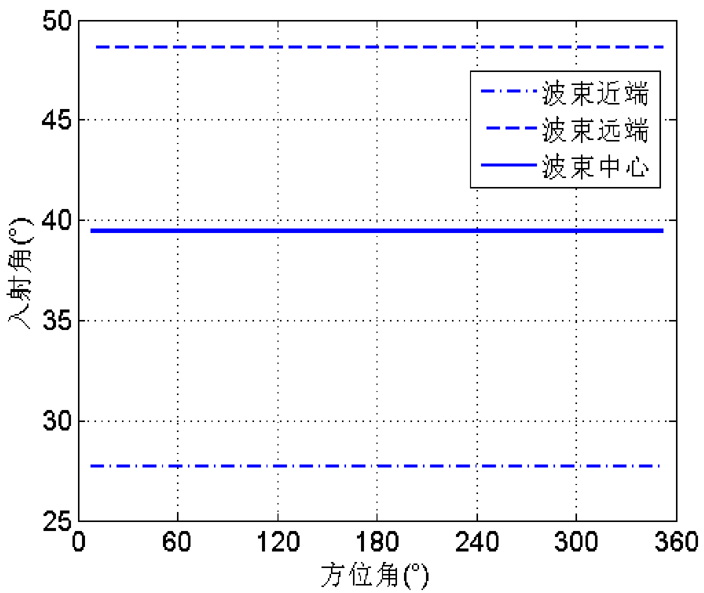
$$\Delta\sigma^0_{\text{scat}} = \sqrt{\left(\Delta\sigma^0_{\text{point}}\right)^2 + \left(\Delta\sigma^0_{\text{DIS}}\right)^2 + \left(\Delta\sigma^0_{L}\right)^2 + \left(\Delta\sigma^0_{\text{slant}}\right)^2 + \left(\Delta\sigma^0_{\text{CGS}}\right)^2 + \left(\Delta\sigma^0_{\text{atm}}\right)^2}$$

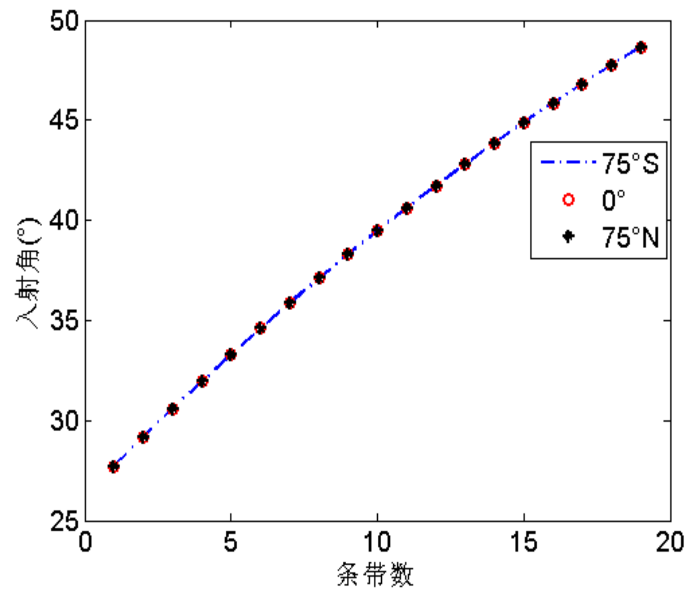
Less than 0.2dB

Considertions of Calibration of CFOSAT SCAT

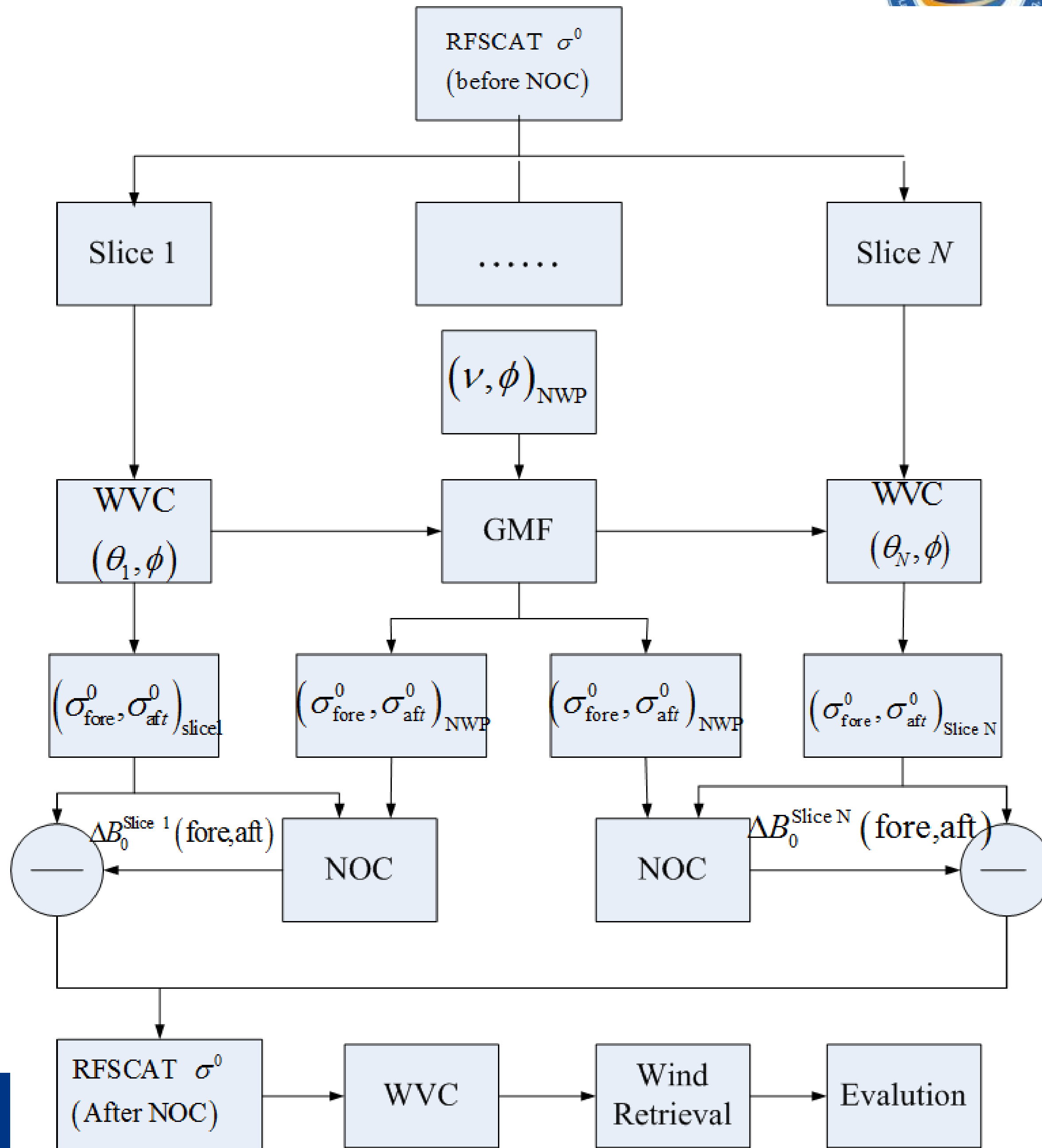
NWP Ocean Calibration (NOC):

Signals are averaged into 15 km spaced slice along-elevation. A slice can be regarded a special pencil-beam. Thus, rotating Fanbeam scatterometer can be divided into a combinations of series rotating pencil-beam. The NOC technique used for rotating pencil-beam scatterometer will be adopted for the calibration of RFSCAT.





Flow of RFSCAT NOC



Calibration of HY-2A SCAT

NWP Ocean Calibration (NOC) Stoffelen, *J. Atm. Ocean. Tech.* 1999

NOC may be applied over a large portion of the globe and consequently Provide accurate results over a relatively short period.

NOC has been applied successfully for the calibration of ASCAT and OSCAT at KNMI.

Dataset:

--L2A: December 1-31, 2012,
25km resolution 76WVC
provided by NSOAS

--L2B: processed at NSSC using OWDP

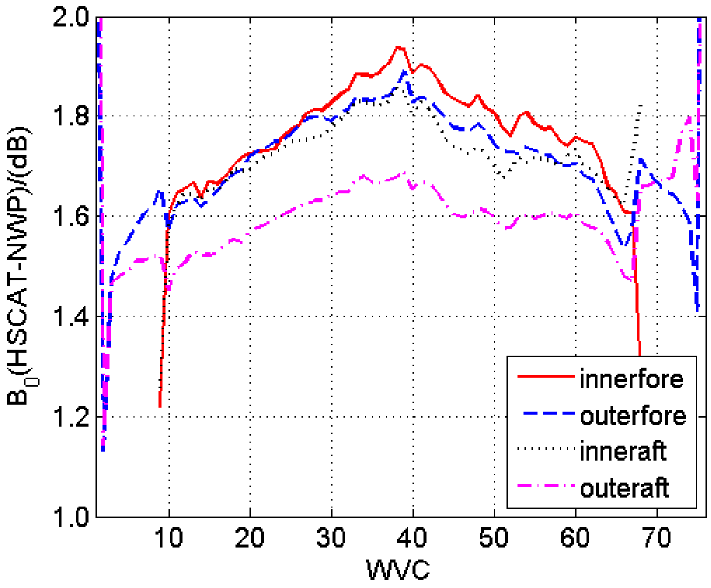
NWP Winds:ECMWF NWP equivalent neutral winds

Globe buoys data

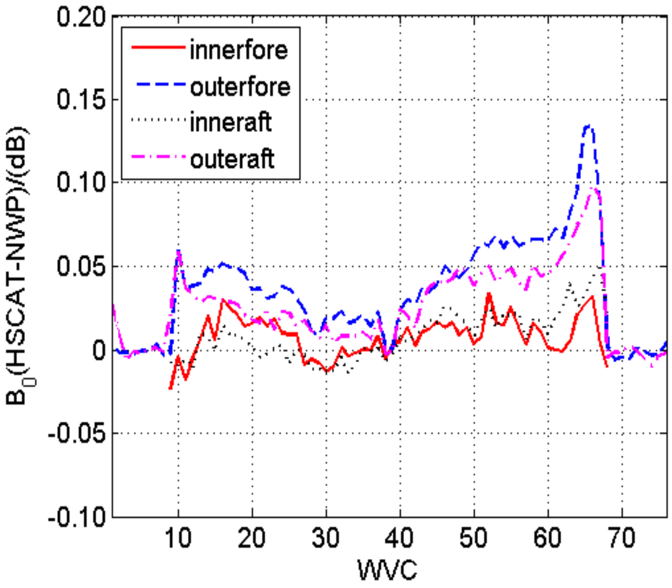
GMF: NSCAT-3

Calibration of HY-2A SCAT

December 1-7 2012
NOC correction coefficients

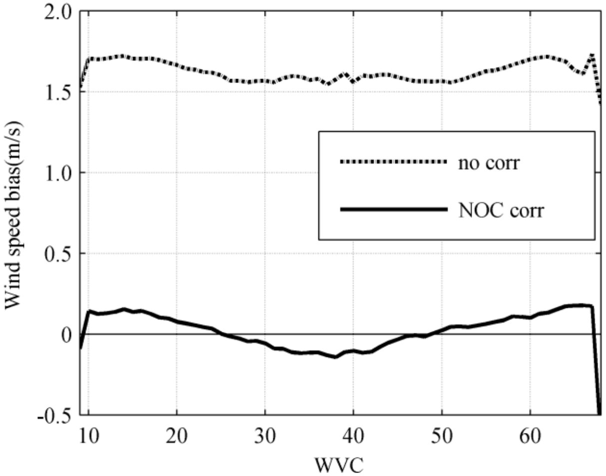


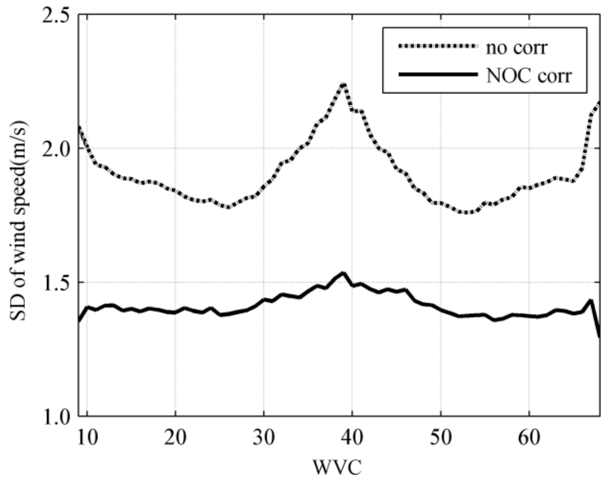
December 2012
Residual after NOC

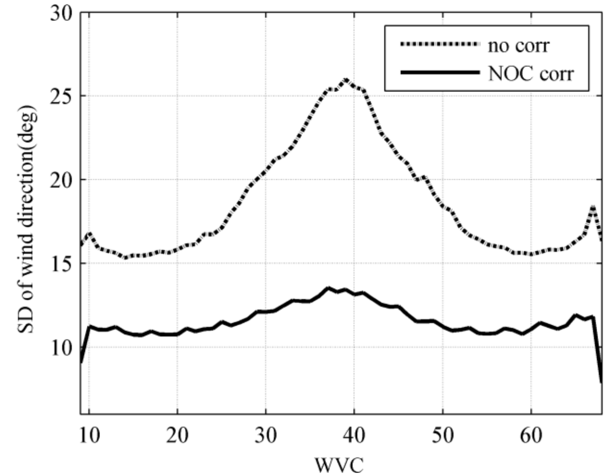


HY-2A SCAT CALIBRATION RESULTS

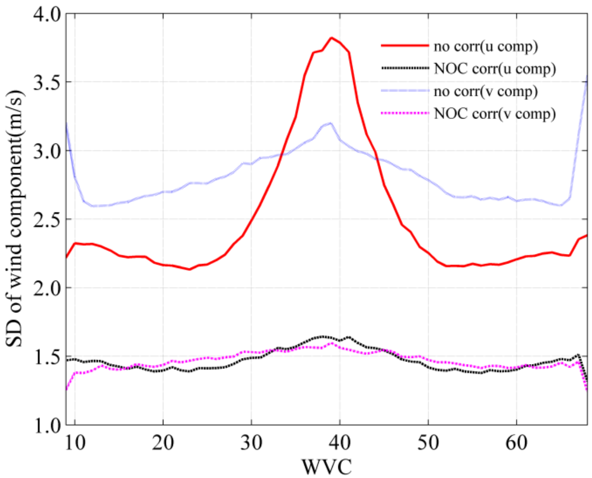
December 2012
L2B after NOC vs ECMWF

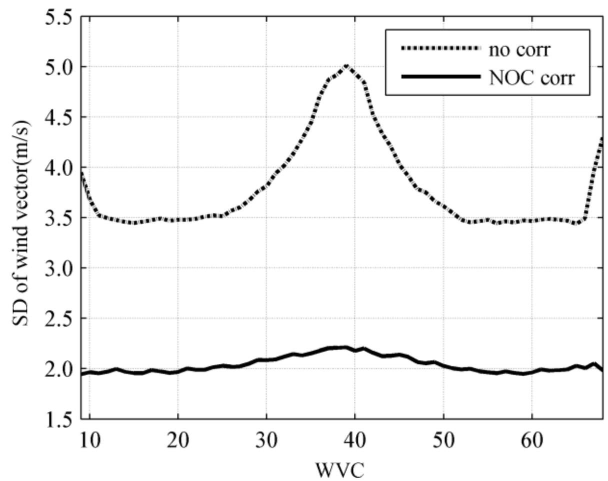






ECMWF winds>4m/s



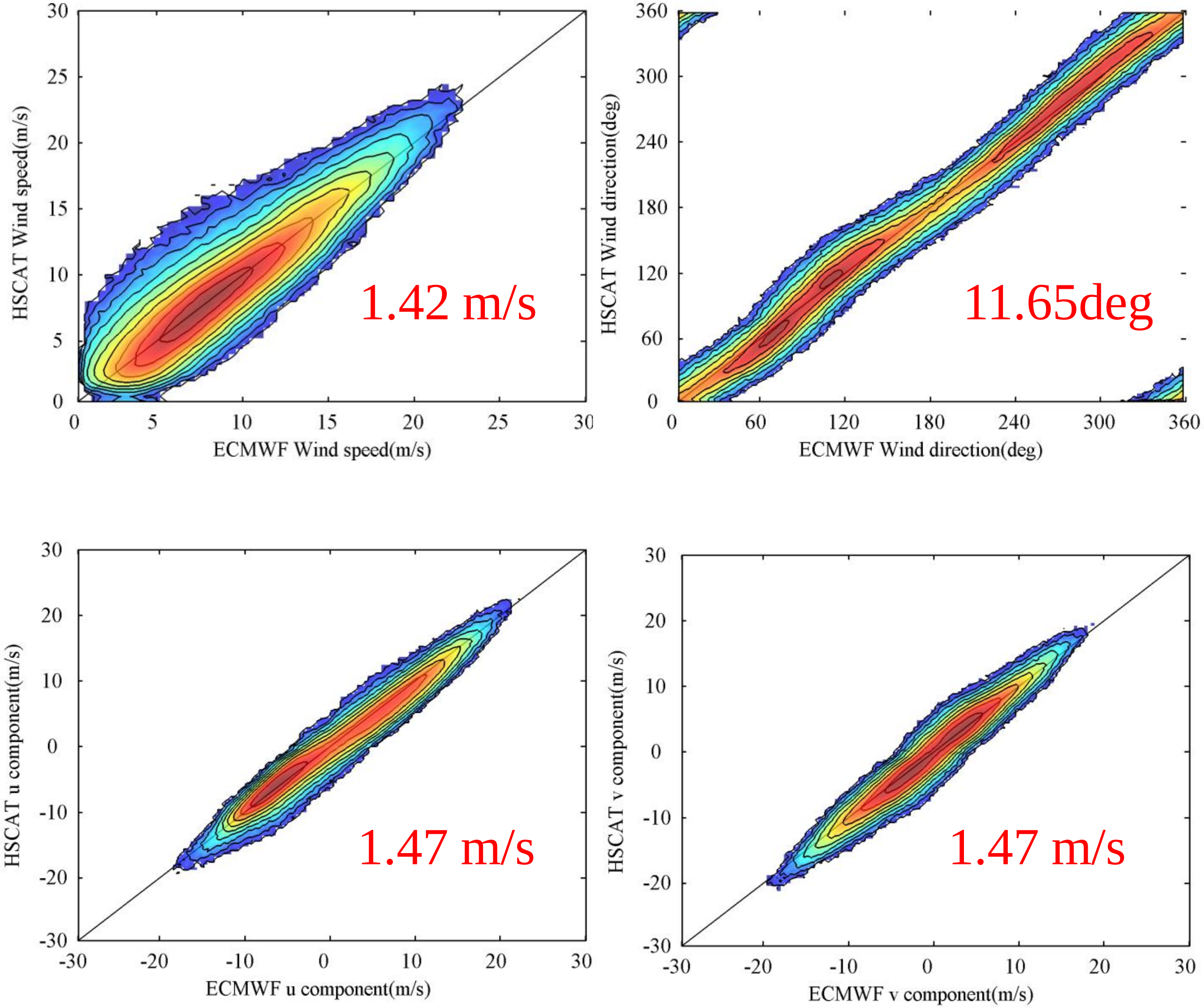


ECMWF winds>4m/s

Nssc

HY-2A SCAT CALIBRATION RESULTS

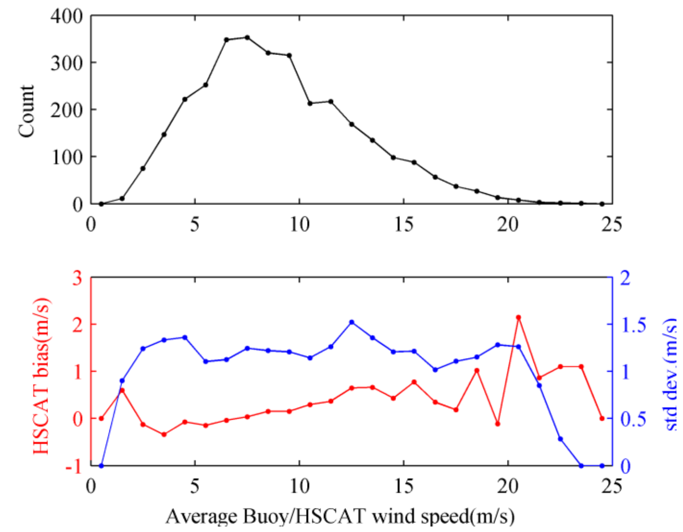
December 2012
L2B after NOC vs ECMWF

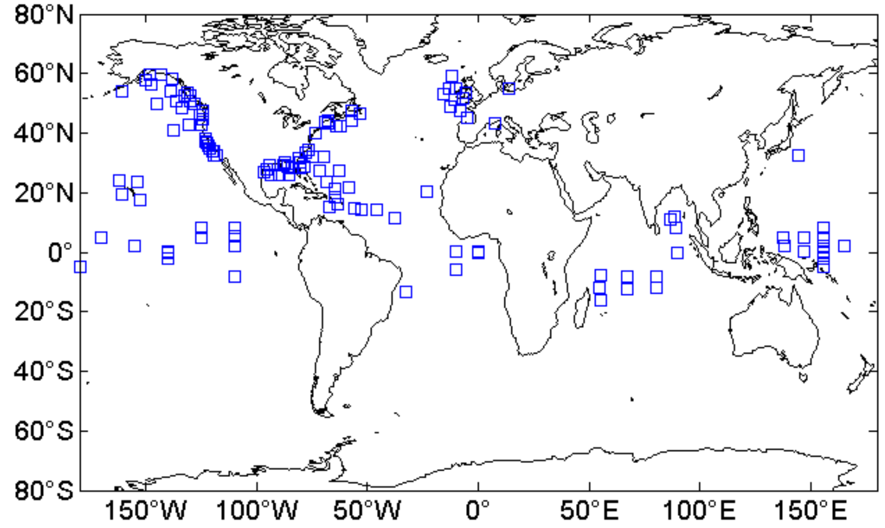


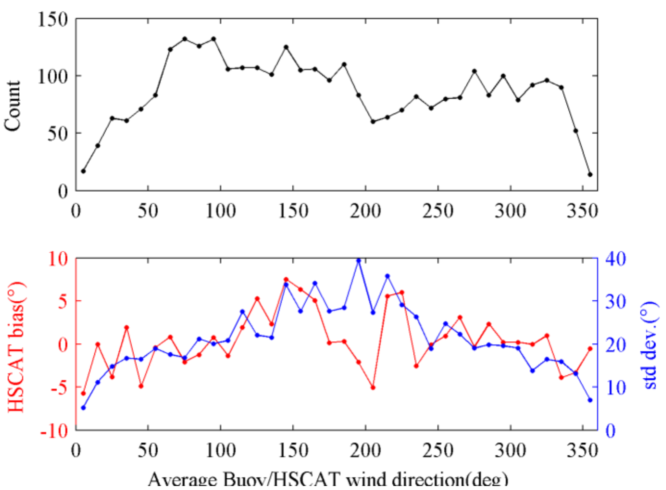
Nssc

HY-2A SCAT CALIBRATION RESULTS

December 2012
L2B after NOC vs Buoys







	collocation	Speed bias(m/s)	Speed STD(m/s)	Direction STD(deg)	Wind vector STD(m/s)
No corr	3112	1.93	1.93	18.40	4.64
NOC corr	3112	0.17	1.23	14.88	2.93

Thanks for your attention!