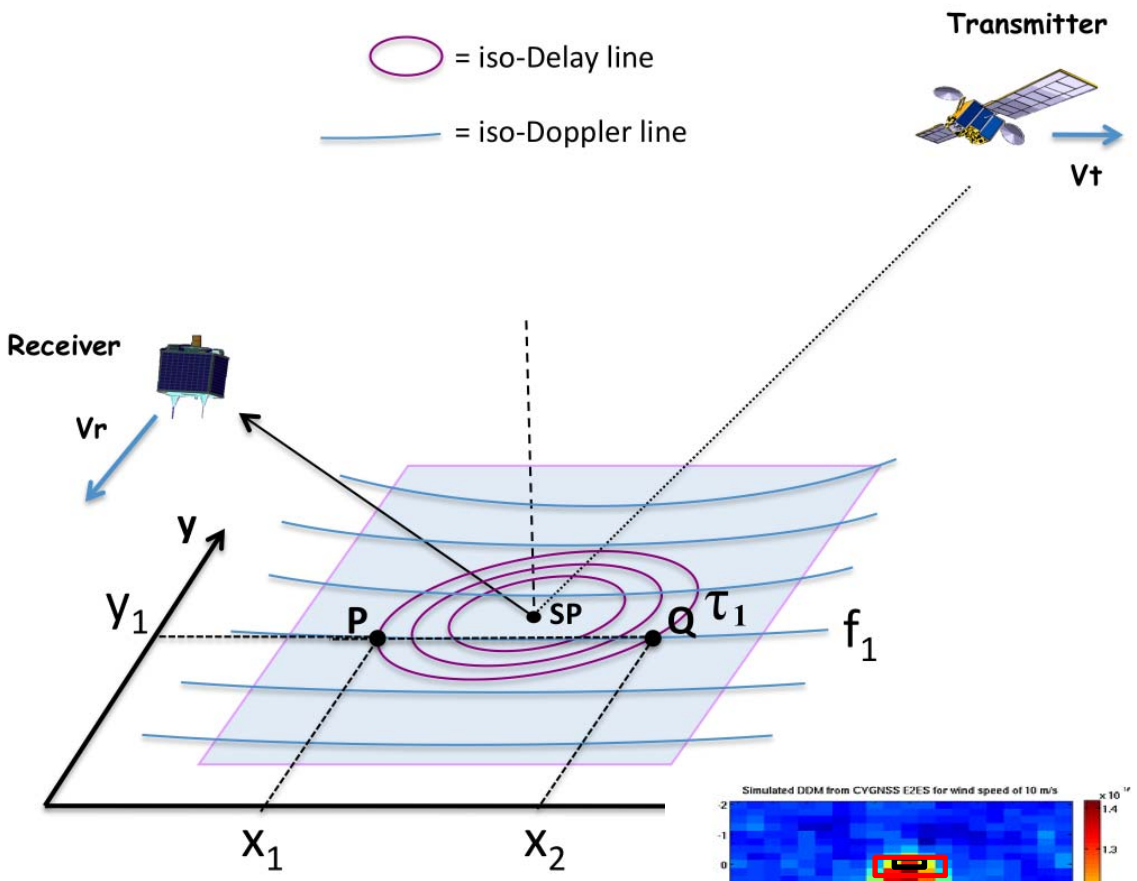
The GNSS Reflectometry Response to the Ocean Surface Winds

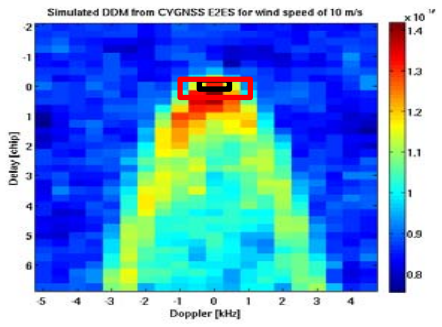
Zorana Jelenak, Seubson Soisuvarn, Faozi Said and Paul Chang

NOAA/NESDIS/STAR

Bi-Static Quasi-Specular Ocean Surface Scatterometry

- The measurement concept relies on bi-statically reflected signals transmitted from global navigation satellites.
- The unique range coded modulation of the GPS signals, allows for the mapping of received power as a function of both time- delay and Doppler frequency across the ocean surface.





TechDemoSat-1 with on Board GNSS-R Instrument (SGR-ReSi)

Launched 8 July 2014, satellite carries the first spaceborne GNSS-R receiver flown since UK-DMC over 10 years ago. First public data set released on March 5th, 2015

DDM measurements collected by SGR-ReSi in period between Sep 2014 – Feb 2015

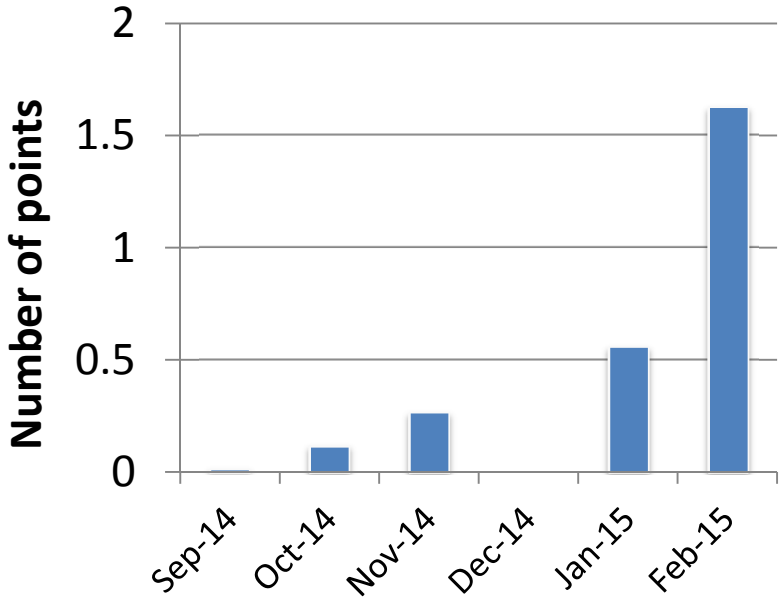
- Nadir-look antenna pattern
- Operate in unmonitored Automatic Gain Control (AGC) mode
- Use Signal-to-Noise Ratio as signal to overcome unmonitored gain issue
- Implemented conservative quality control to the DDMs
- CYGNSS will utilize a similar GNSS-R receivers as SGR-ReSI

To characterize GNSS-R sensitivity with geophysical parameters:

- Wind Speed, Significant Wave Height
- Sea Surface Temperature, Wind Direction, Rain

Matchup dataset

- Models (ECMWF, GDAS, Wavewatch, Reynolds)
- Satellites (ASCAT-A/B, Rapidscat, GMI)



SGR-ReSI DDMs

$$DDM_{Power} = k \cdot \frac{G_{ant}^{R}}{R_{tx}^{2} \cdot R_{rx}^{2}} \cdot \sigma^{0} \cdot A$$

A = GPS C/A-code effective area

σ^0 = Normalized BRCS

$$k = \frac{P_{tx} G_{ant}^{T} \lambda^{2}}{(4\pi)^{3} L_{atm}}$$

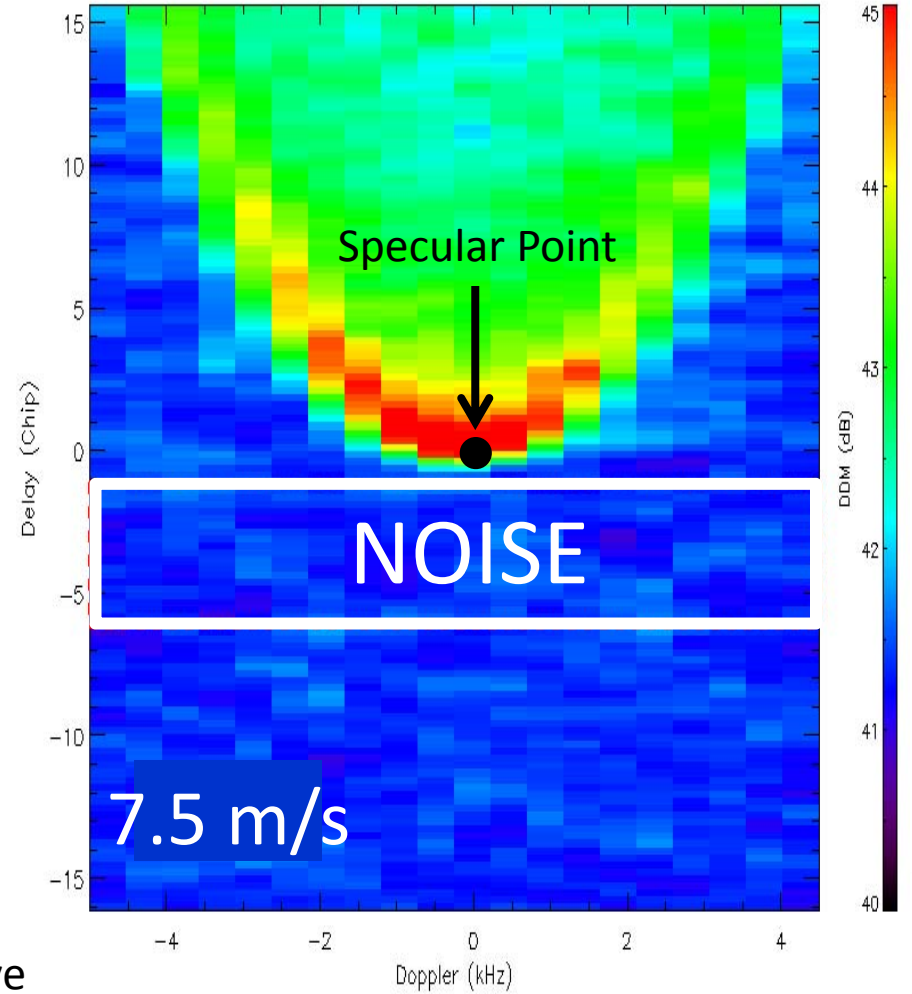
$$SNR = \frac{DDM_{Power+noise} - < noise >}{< noise >}$$

$$\boxed{CF = \frac{R_{tx}^{2} \cdot R_{rx}^{2}}{G_{ant}^{R}} \cdot \frac{1}{A}}$$

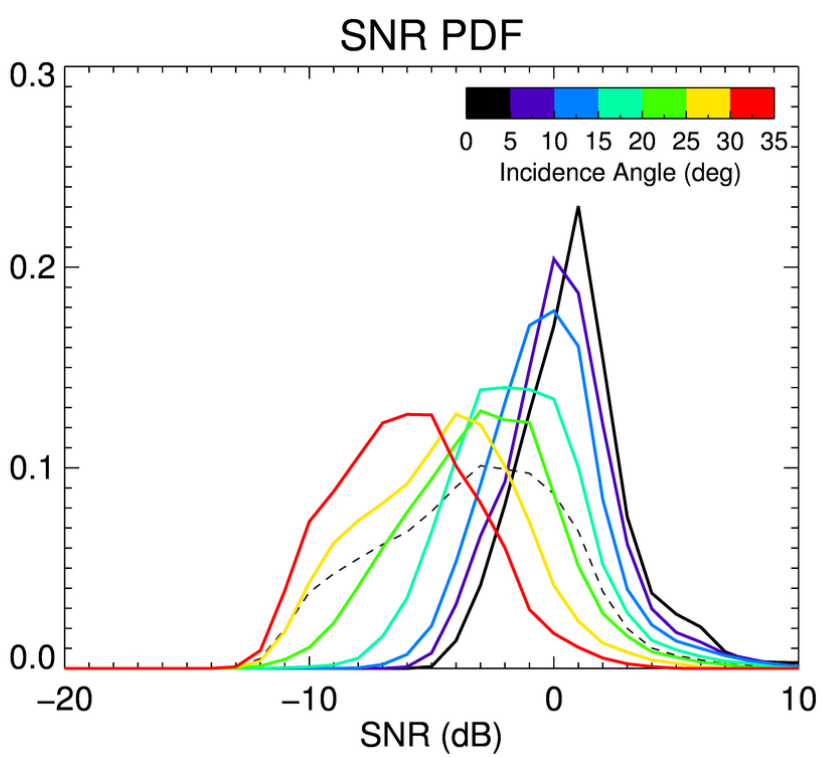
$$\boxed{SNR^{Norm} = CF \cdot SNR = \frac{k \cdot \sigma^{0}}{< noise >}}$$

Additional correction is implemented to remove residual antenna gain dependent in the signals

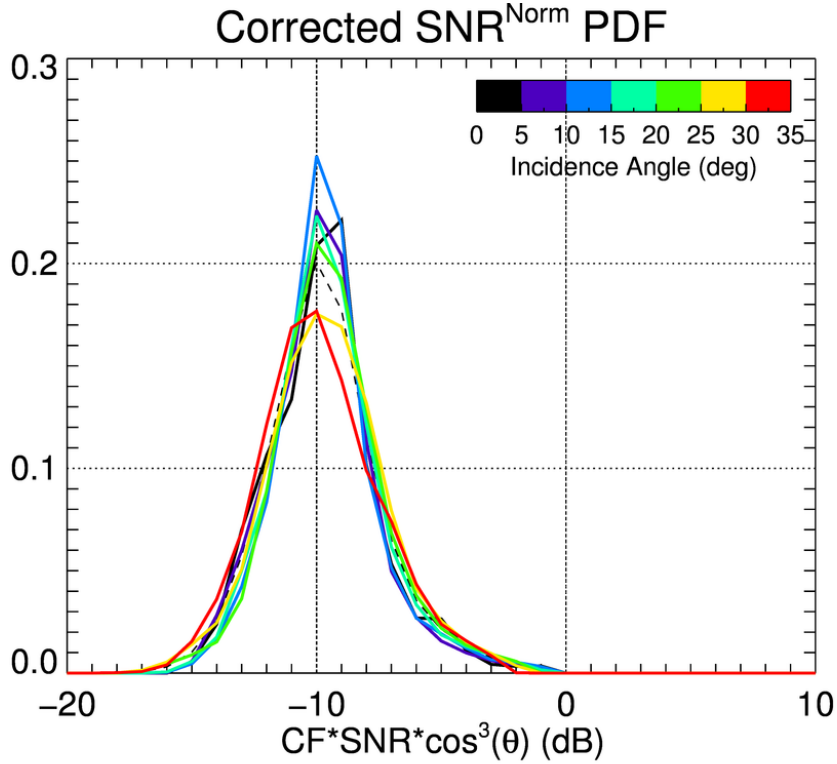
$DDM_{Power+Noise}$



SGR-ReSI Signals PDF



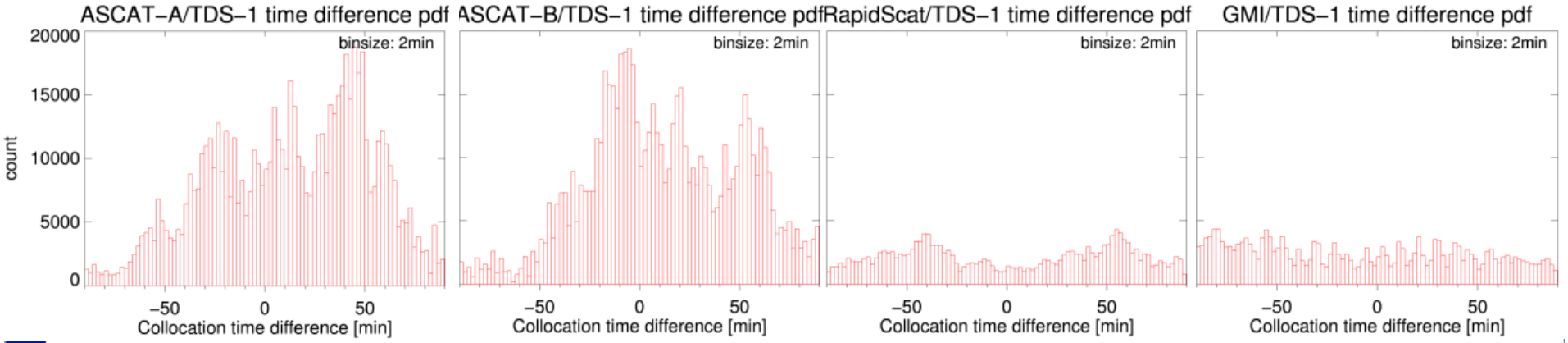
Before Correction



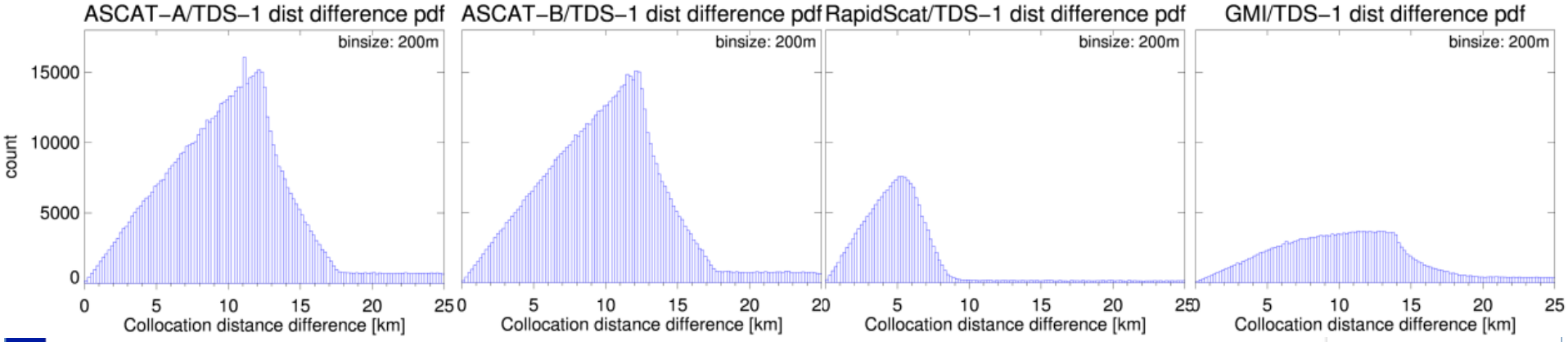
After Correction

Satellite Matchup Histogram

Time Difference

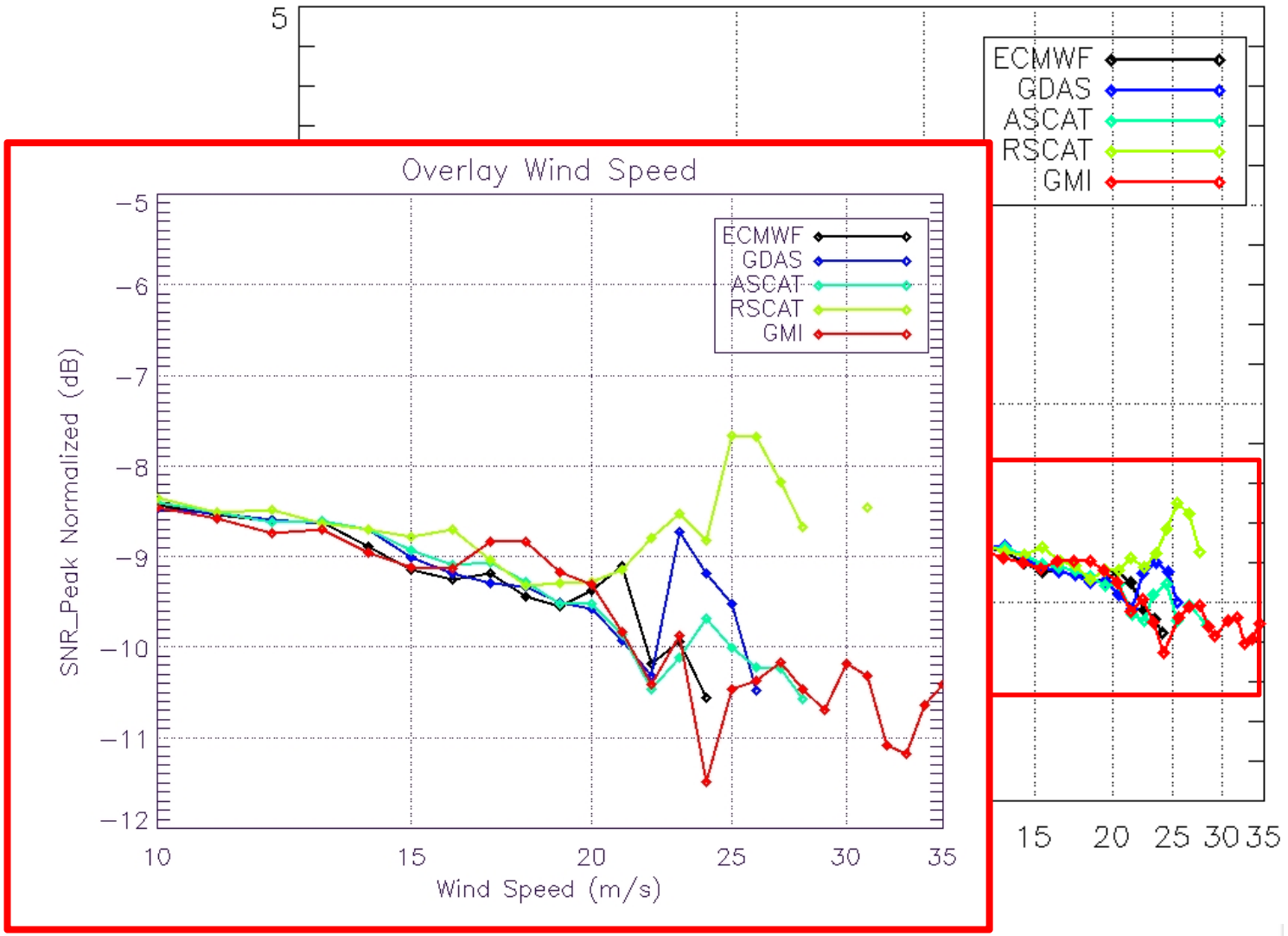


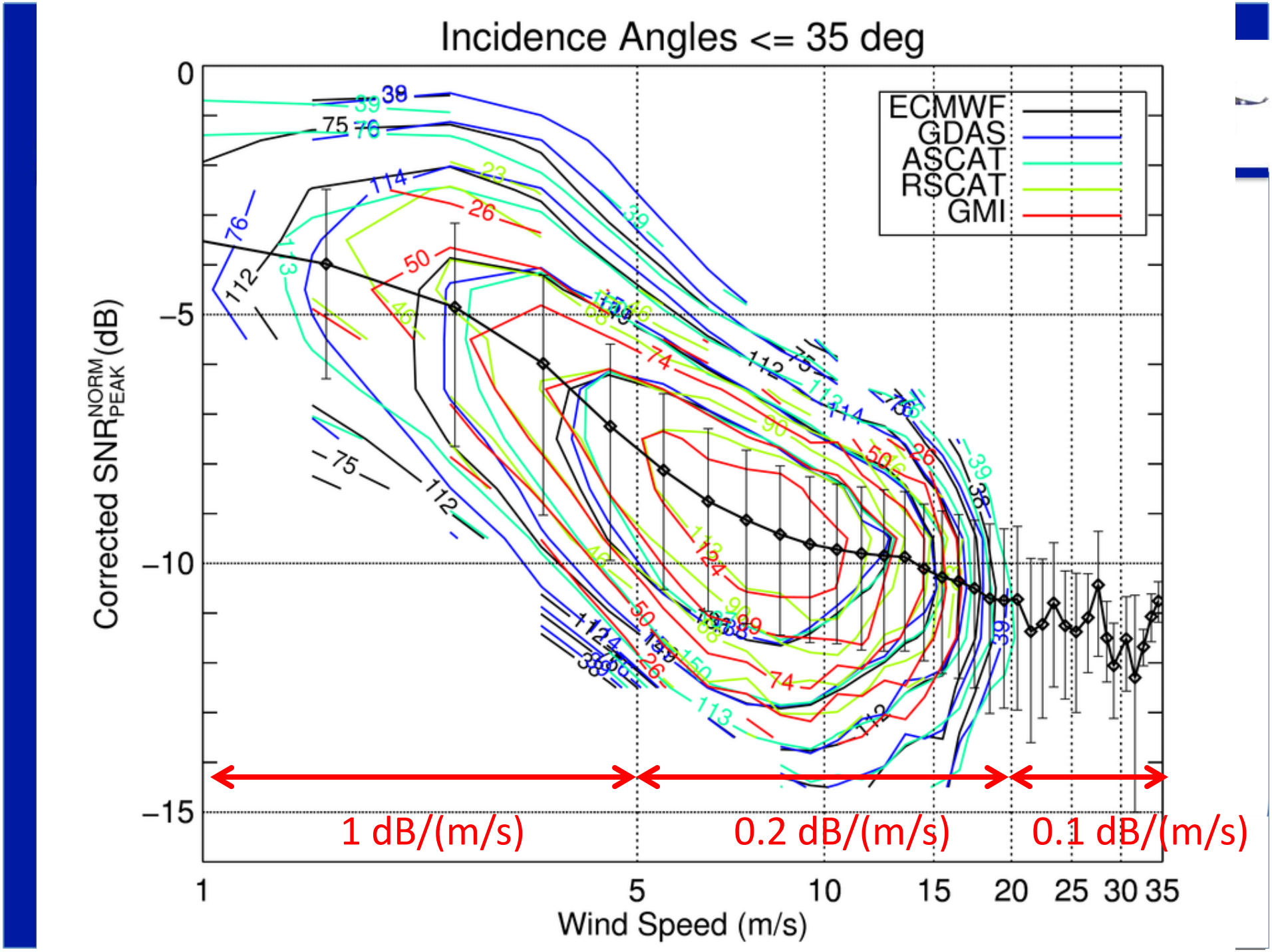
Space Difference



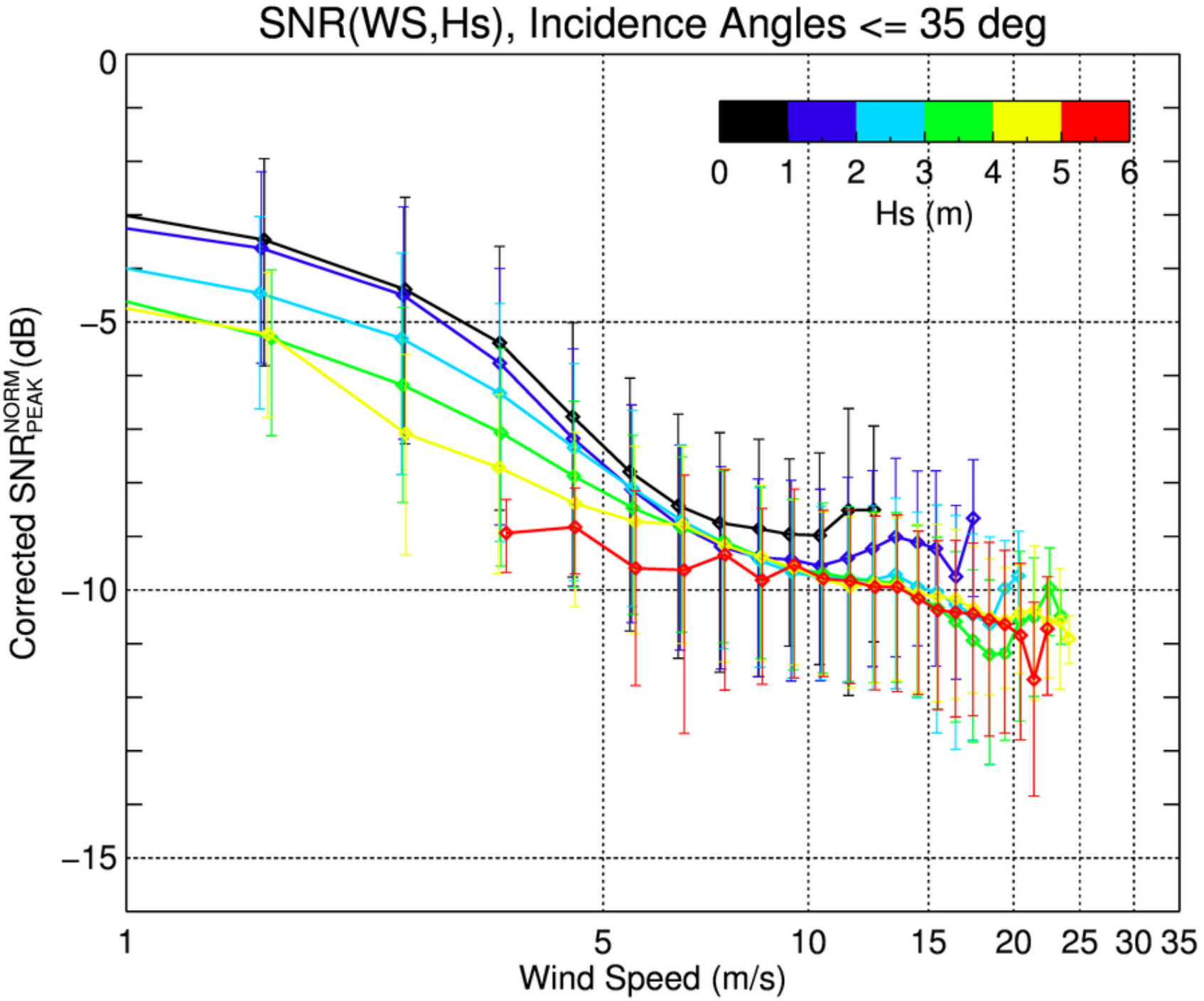
Wind Speed Response

Wind Speed Dependence

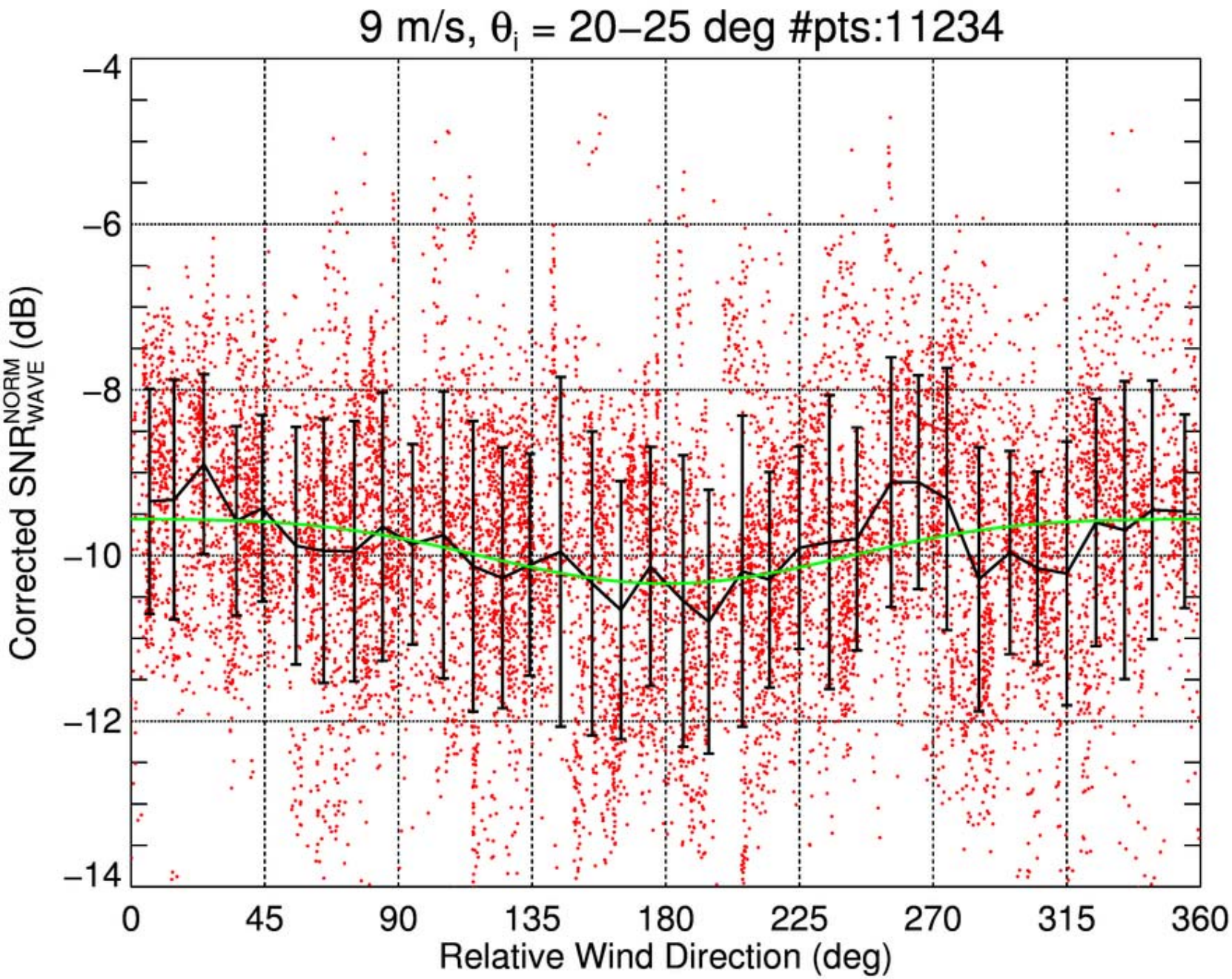



Incidence Angles <= 35 deg
ECMWF
GDAS
ASCAT
RSCAT
GMI
Corrected SNR$^{NORM}_{PEAK}$ (dB)
0
−5
−10
−15
1
5
10
15
20
25
30
35
Wind Speed (m/s)
1 dB/(m/s)
0.2 dB/(m/s)
0.1 dB/(m/s)

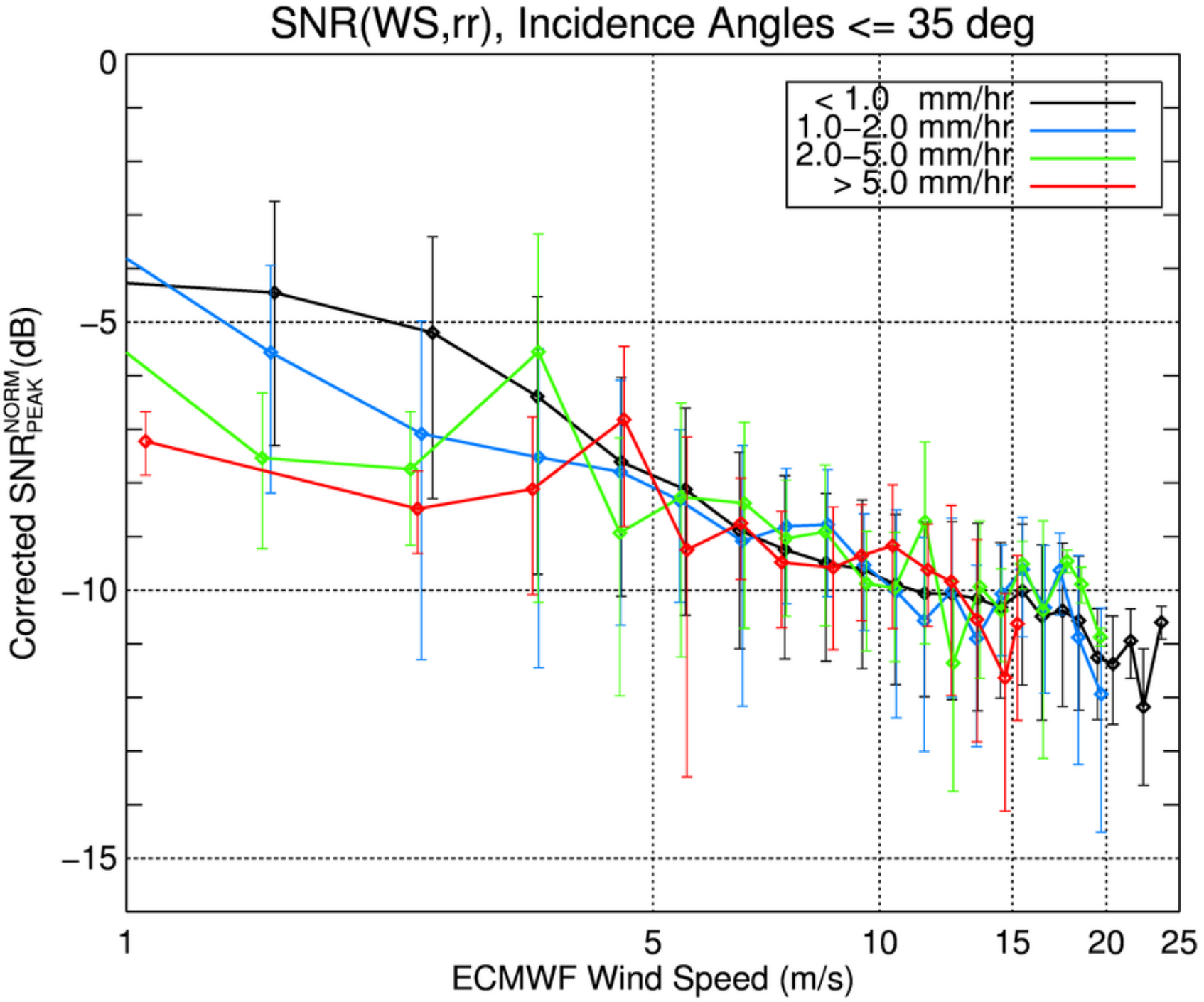
Significant Wave Height Response


SNR(WS,Hs), Incidence Angles <= 35 deg
0
−5
−10
−15
Corrected SNR$_{PEAK}^{NORM}$(dB)
1
5
10
15
20
25
30
35
Wind Speed (m/s)
0
1
2
3
4
5
6
Hs (m)

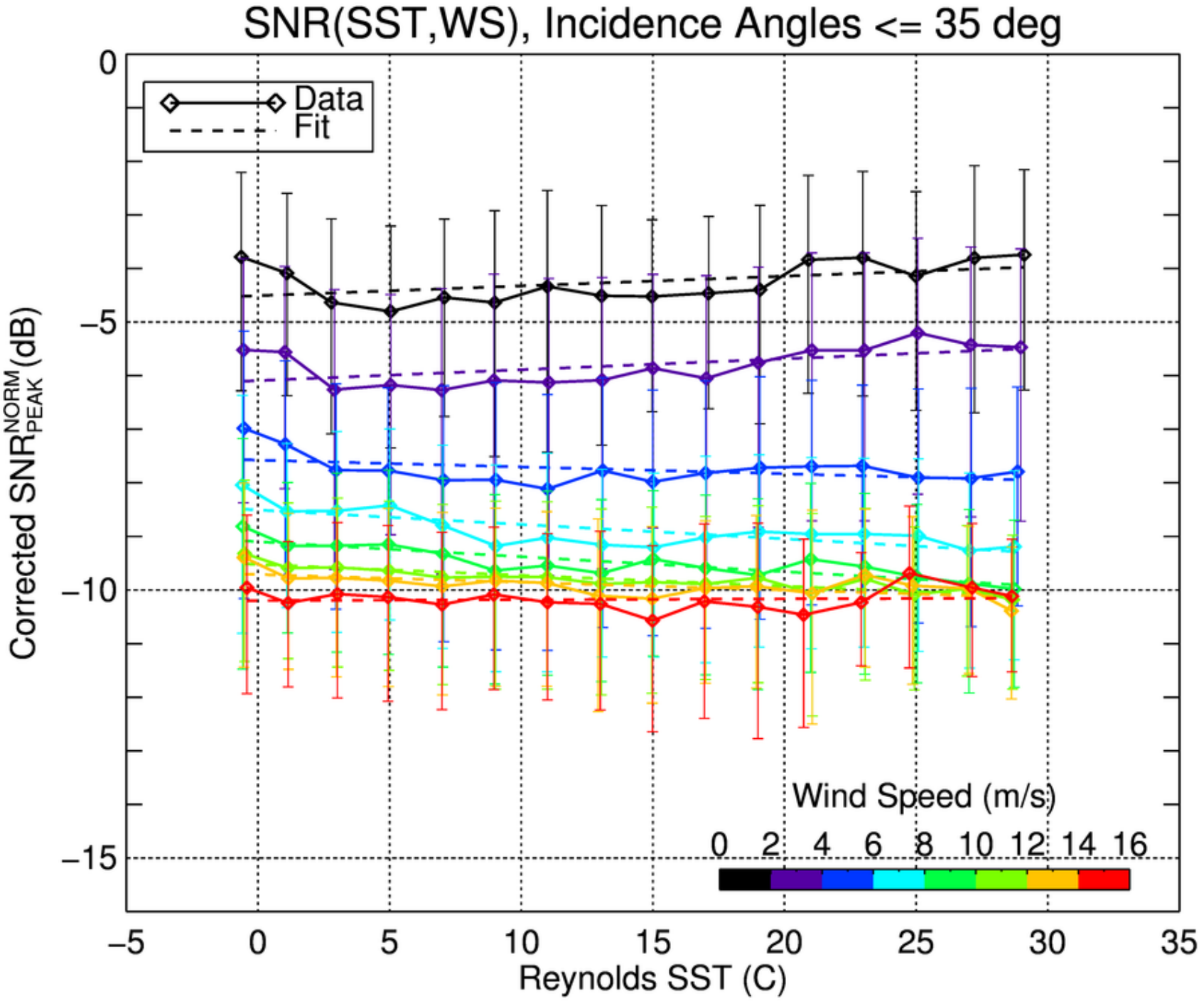
Wind Direction Response


9 m/s, θi = 20–25 deg #pts:11234
Corrected SNR WAVE NORM (dB)
−4
−6
−8
−10
−12
−14
0
45
90
135
180
225
270
315
360
Relative Wind Direction (deg)

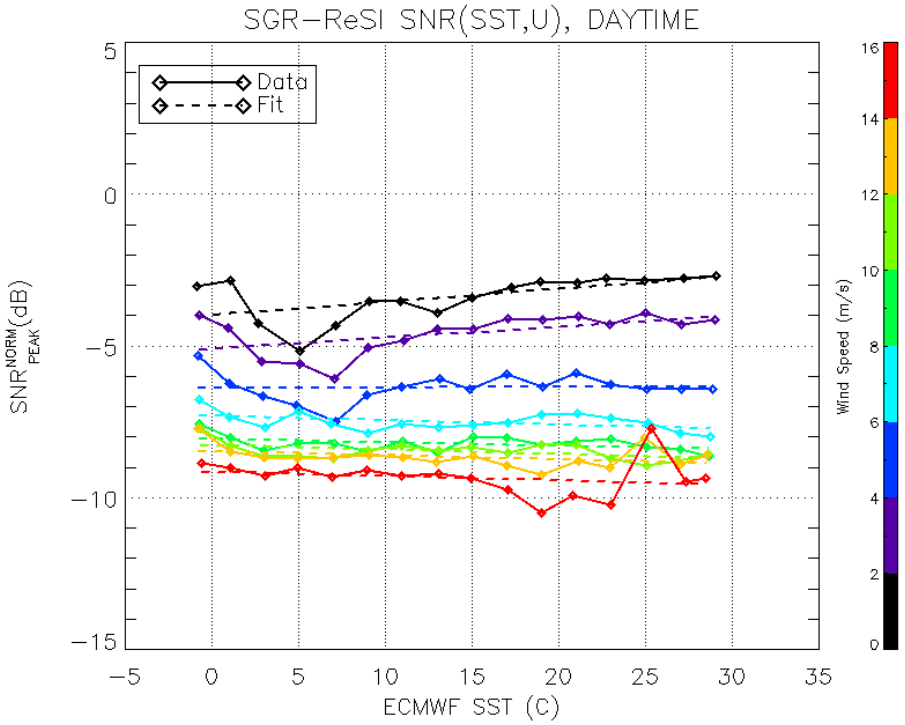
Rain Rate Response

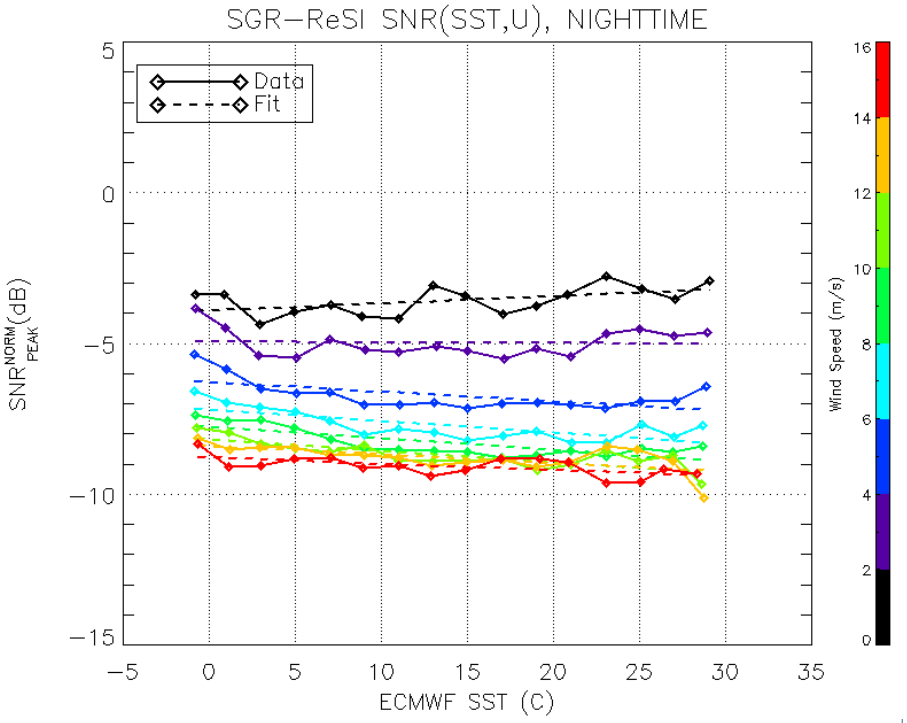

SNR(WS,rr), Incidence Angles <= 35 deg
< 1.0 mm/hr
1.0–2.0 mm/hr
2.0–5.0 mm/hr
> 5.0 mm/hr
Corrected SNR$^{NORM}_{PEAK}$(dB)
0
−5
−10
−15
1
5
10
15
20
25
ECMWF Wind Speed (m/s)

Sea Surface Temperature Response


SNR(SST,WS), Incidence Angles <= 35 deg
Data
Fit
Corrected SNR$_{PEAK}^{NORM}$ (dB)
0
−5
−10
−15
−5
0
5
10
15
20
25
30
35
Reynolds SST (C)
Wind Speed (m/s)
0 2 4 6 8 10 12 14 16

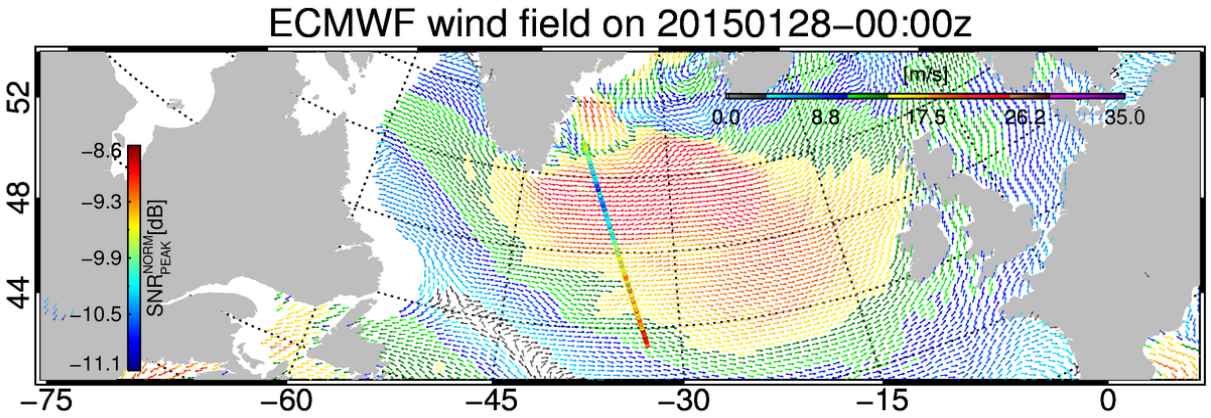
Day and Night Time Differences



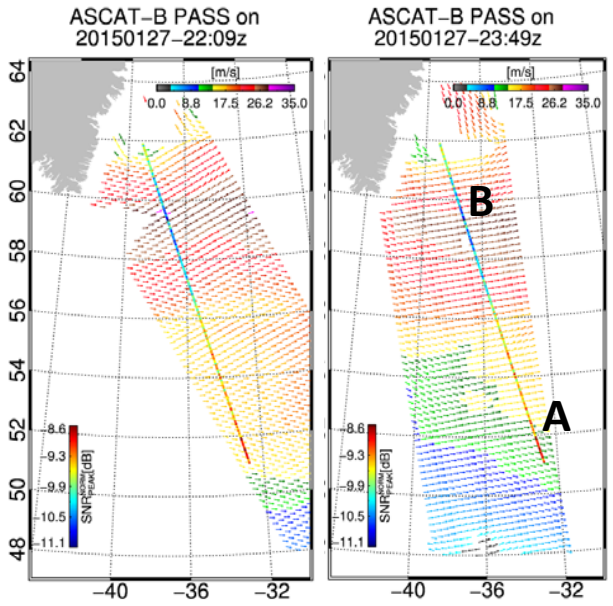


Case Studies

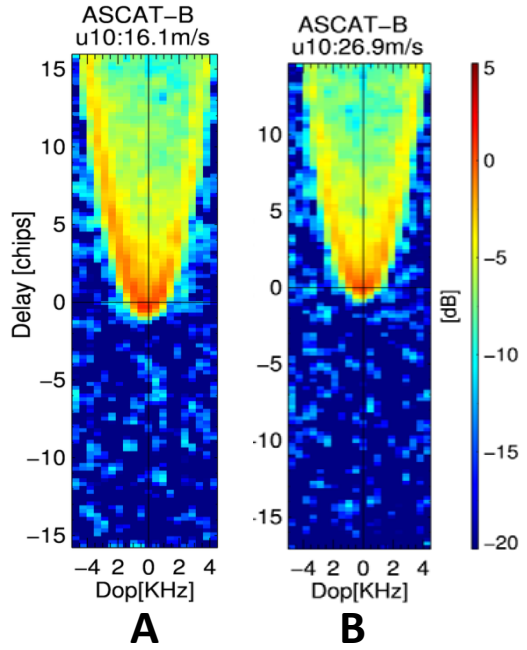
Case Study 1 – North Atlantic Extratropical Cyclone



ECMWF wind field over the North Atlantic showing an extratropical cyclone with TDS-1 pass (23:16Z) overlaid

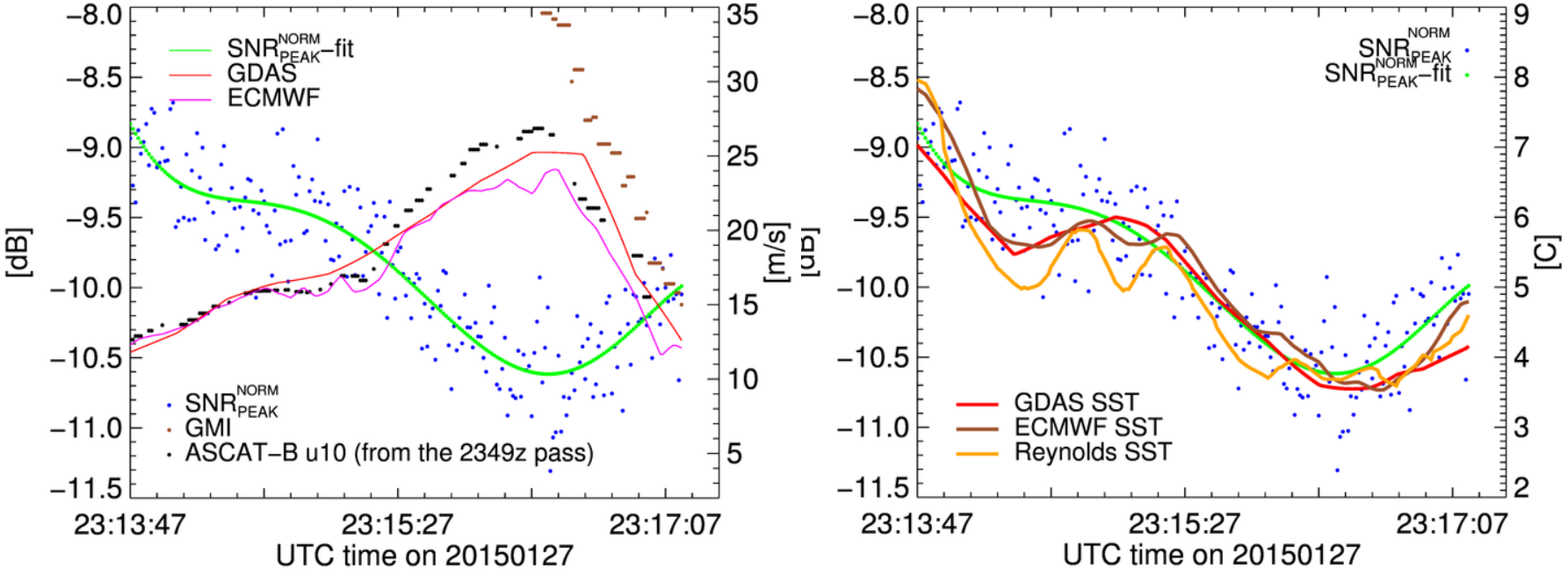


Two successive ASCAT-B passes



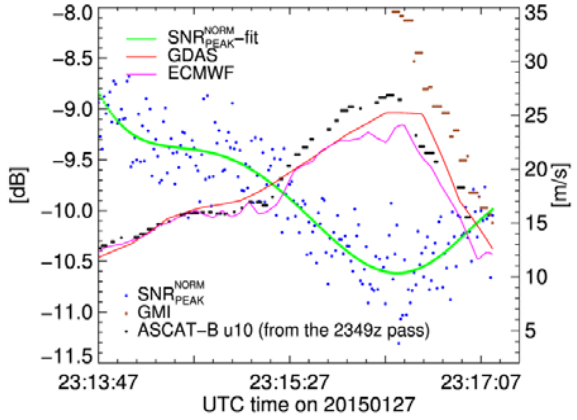
DDMs from points A and B along the TDS-1 transect for 16.1 m/s and 26.9 m/s, respectively. This case illustrates that there is still good sensitivity at the higher wind speeds.

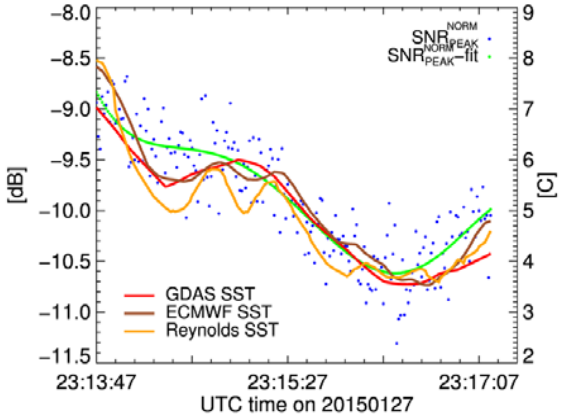
Signals Time Series



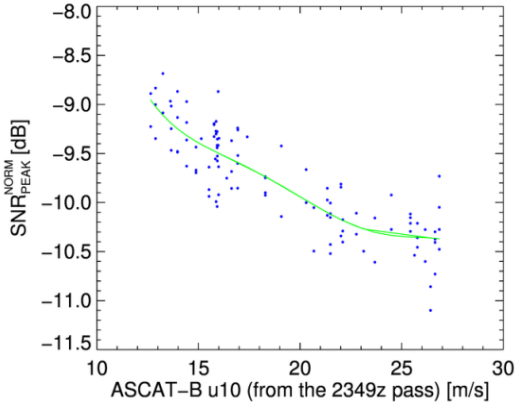
Case Study 1 – North Atlantic Extratropical Cyclone (Continued)

Time series plots along the TDS-1 transect showing wind speeds (left) and SST (right)

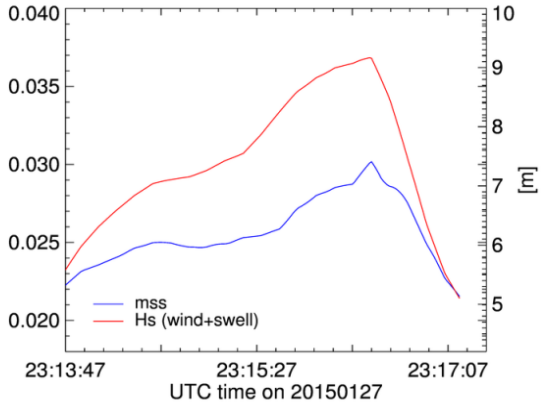




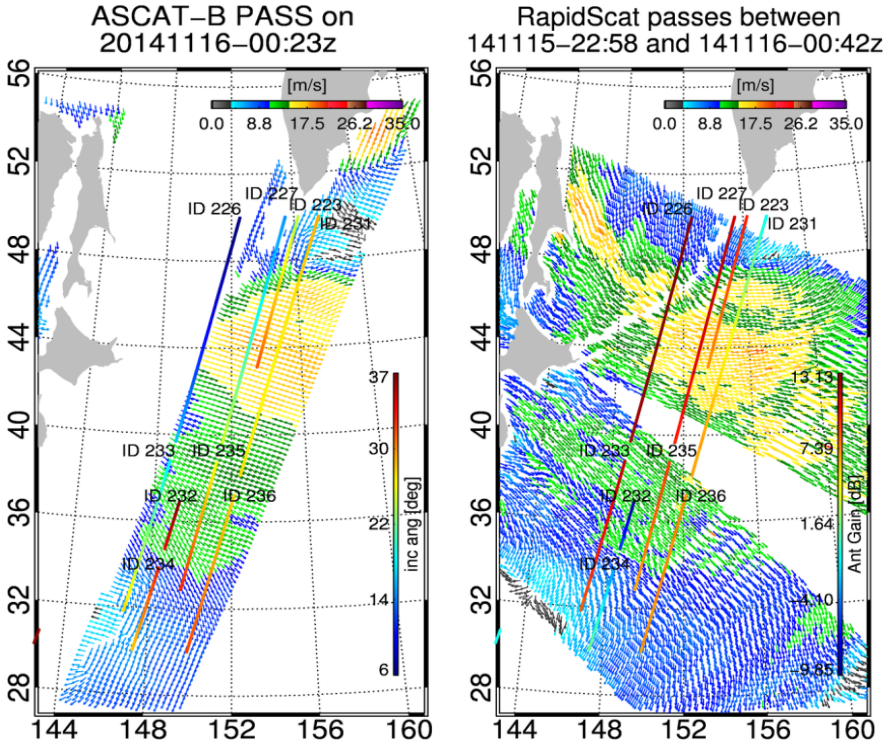
SNR_{norm_peak} values along the transect plotted against the ASCAT-B wind speeds



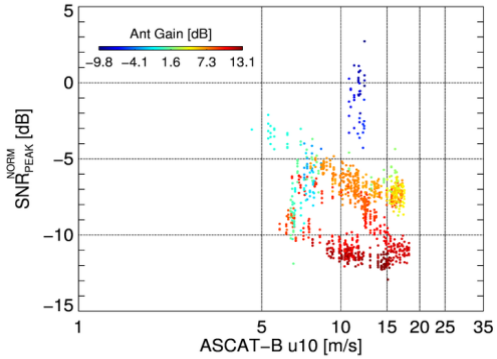
MSS and H_S values along the TDS-1 transect



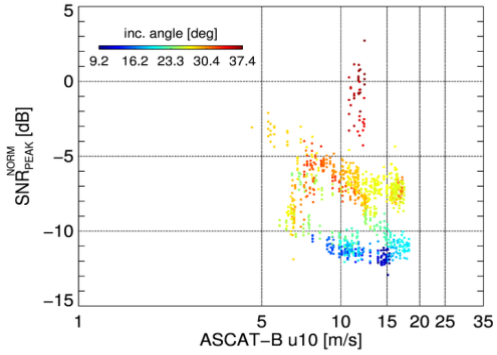
Case Study 2 – Wind Speeds and Geometries



Multiple transects over a varying wind shown in ASCAT-B (left) and RapidScat (right)



SNR_{norm_peak} for all transects as a function of gain



SNR_{norm_peak} for all transects as a function of incidence angle

Conclusions

- SGR-ReSI measurements show sensitivity to wind speeds up to 20 m/s and there still appeared to be sensitivity to 35 m/s.
- A dependence on larger waves was observed for winds < 6m/s and dominant by swell.
- Some dependence on SST was observed with positive slope for winds less than ~ 4 m/s and slightly negative for winds > 4.
- There appear to be a weak wind directional signal
- Sensitivity with rain is still inconclusive.

S. Soisuvarn, Z. Jelenak, F. Said, P. S. Chang and A. Egido, "The GNSS Reflectometry Response to the Ocean Surface Winds and Waves," under review for publication, 2016