Scatterometer Response to Ocean Surface Winds and Waves

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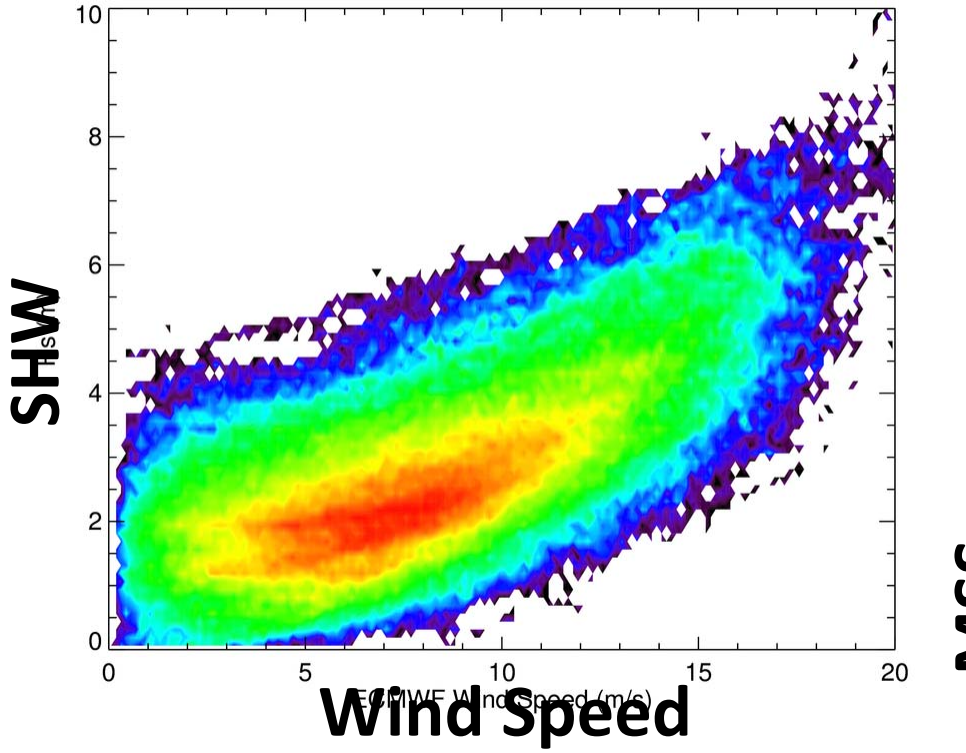
Presentation Outline

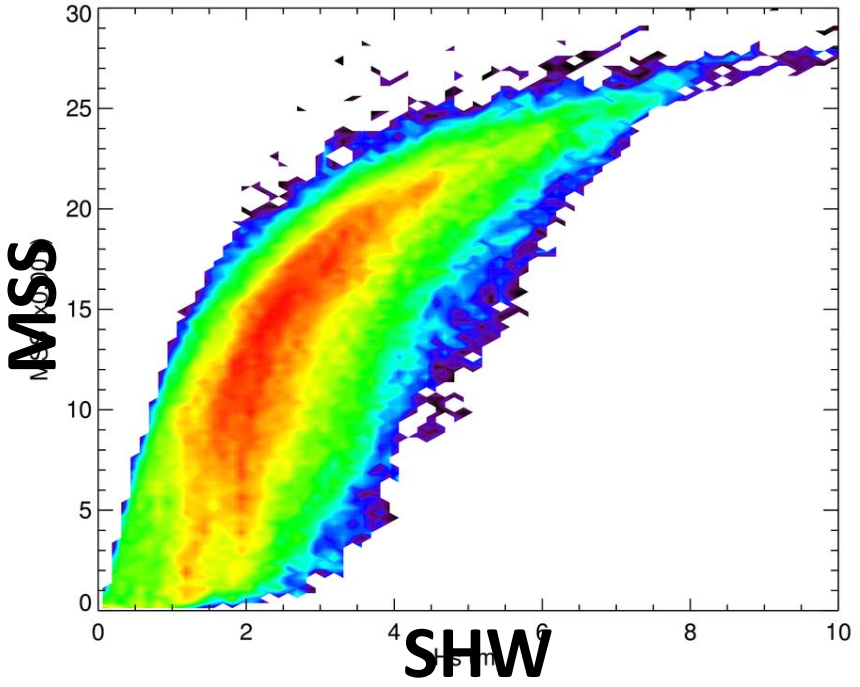
- Relationship between ocean surface wind and wave parameters
- Scatterometers data response to the different wave parameters
  - Significant Wave Height (SWH)
  - Whitecap Coverage
  - Mean Wave Direction
- Difference between Ku-band and C-band scatterometers

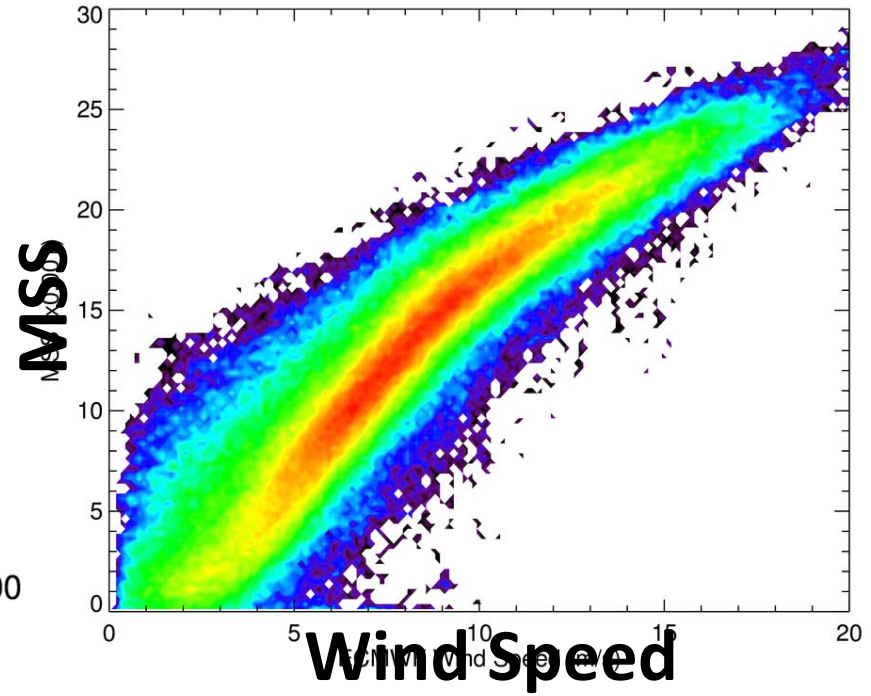
Dataset Overview

- Scatterometer Winds (as a proxy of NRCS)
  - Ku-Band: JPL Rapidscat: Level 2B 12.5km and 25km winds
  - C-Band: ASCAT-A,B: 25km (12.5km sampling) winds
- Model Winds data
  - 25km gridded ECMWF winds
- Waves data
  - Ifremer Wavewatch model:
    - ***Significant Wave Height, Hs (Full Spectrum, Wind Sea, First Swell)***
    - ***Mean Direction (Full Spectrum, Wind Sea, First Swell)***
    - ***Whitecap Coverage***
    - ***Mean-Square Slope (MSS)***
- Model winds and waves gridded data were spatially and temporally interpolated to scatterometer observations: July 2014 – Sep 2015 (15 months)

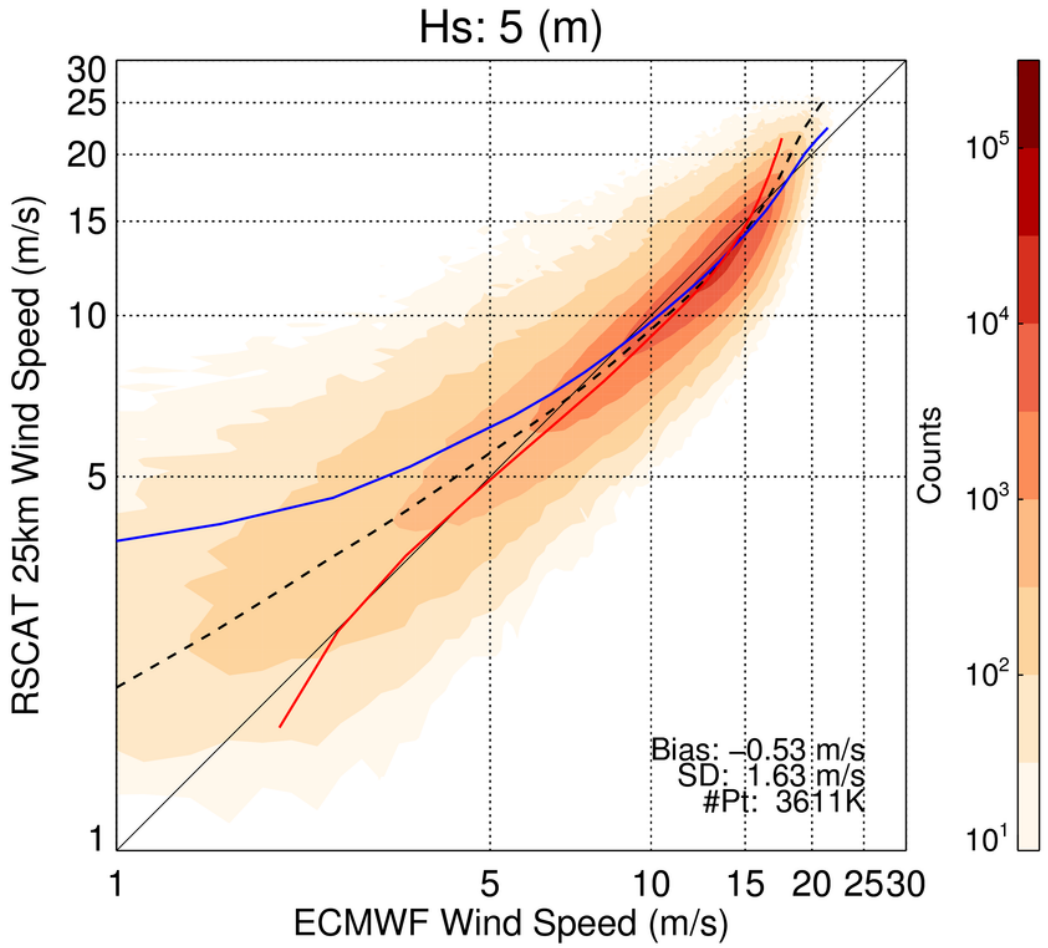
Wind, SWH and MSS Relationship







Scatter Density Plot Mean



Conditional PDF

$$E[Y \mid X = x_n] = \sum y_i \frac{f_{XY}(x_n, y_i)}{f_X(x_n)}$$

$$E[X \mid Y = y_n] = \sum x_i \frac{f_{XY}(x_i, y_n)}{f_Y(y_n)}$$

Conditional CDF

$$F_{Y|X}(y \mid x_n) = \frac{F_{XY}(x_n, y)}{F_X(x_n)}$$

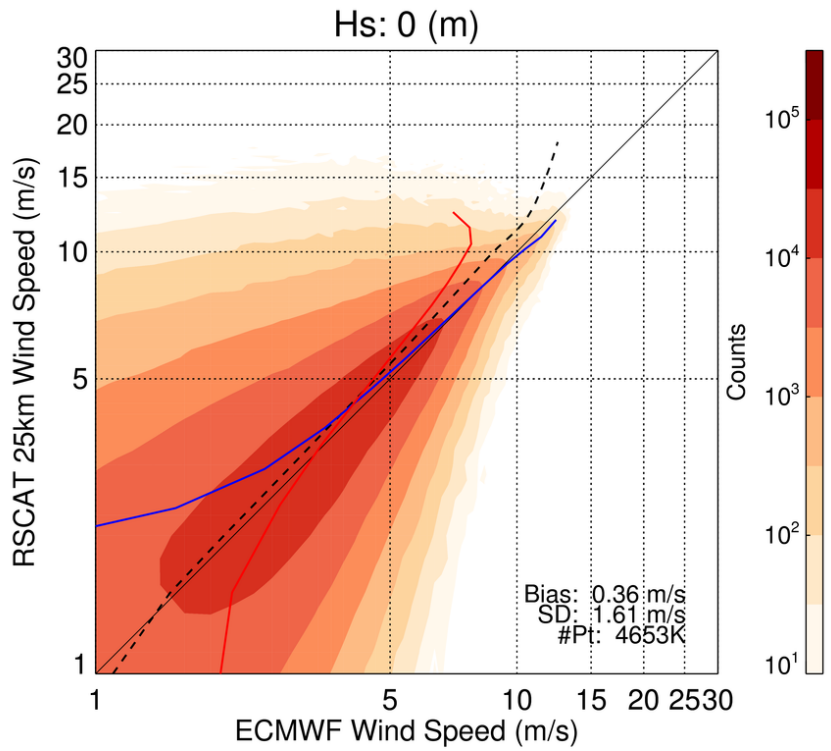
$$F_{X|Y}(x \mid y_n) = \frac{F_{XY}(x, y_n)}{F_Y(y_n)}$$

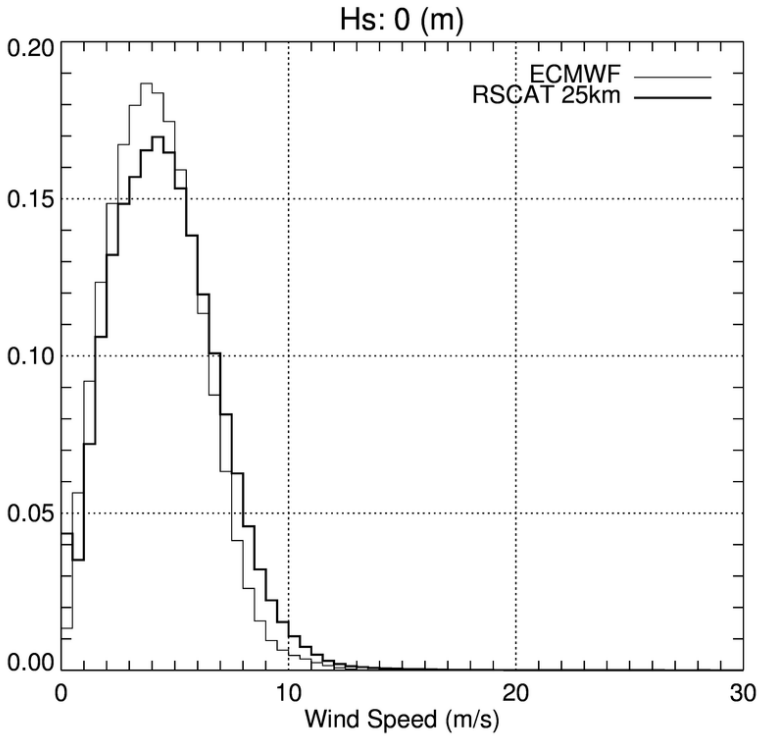
$$F_{Y|X}(y_n \mid x_n) = F_{X|Y}(x_n \mid y_n) \Rightarrow F_X(x_n) = F_Y(y_n)$$

$$y_n = F_Y^{-1}(F_X(x_n))$$

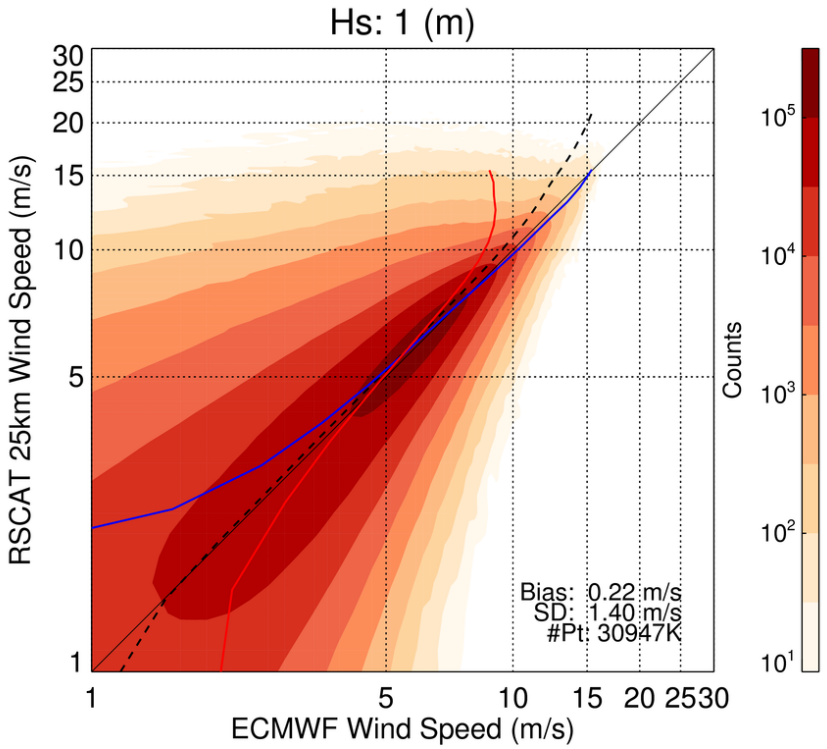
Ones should use conditional CDF to get correct scatter plot fit

Hs: 0 (m)


Hs: 0 (m)
RSCAT 25km Wind Speed (m/s)
ECMWF Wind Speed (m/s)
Counts
Bias: 0.36 m/s
SD: 1.61 m/s
#Pt: 4653K


Hs: 0 (m)
ECMWF
RSCAT 25km
Wind Speed (m/s)

Hs: 1 (m)


Hs: 1 (m)
RSCAT 25km Wind Speed (m/s)
ECMWF Wind Speed (m/s)
Counts
Bias: 0.22 m/s
SD: 1.40 m/s
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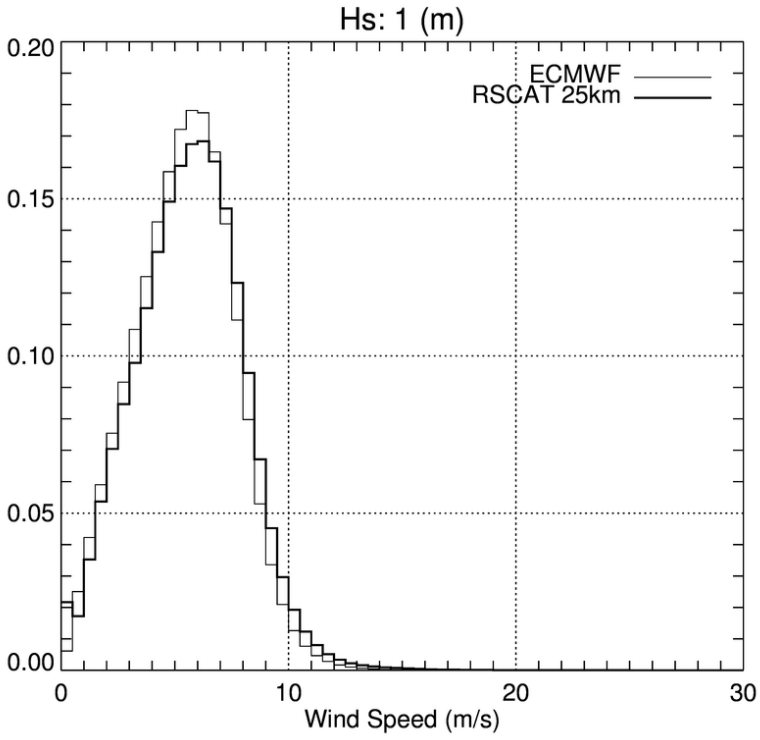
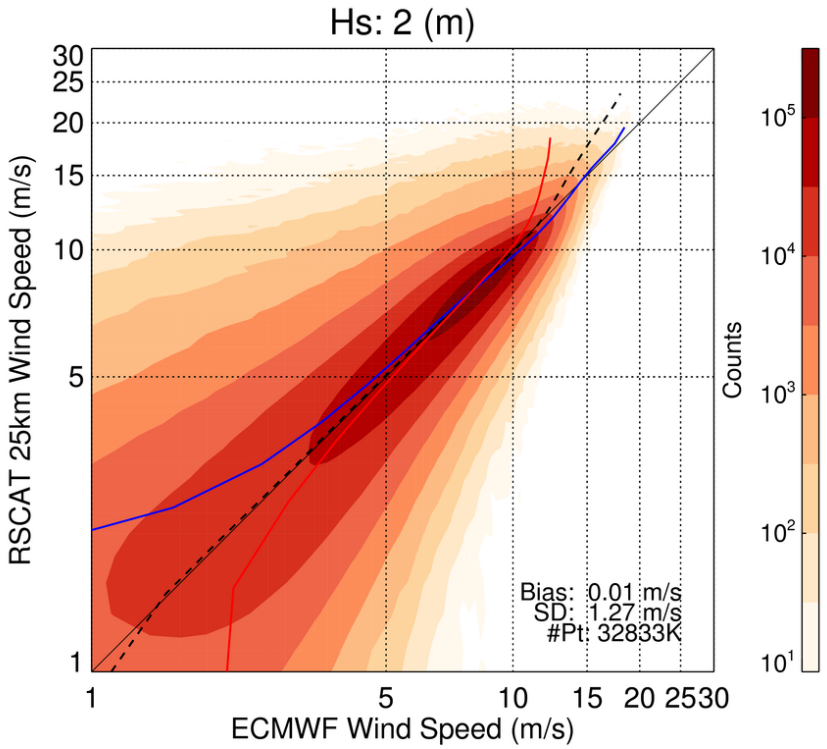

Hs: 1 (m)
ECMWF
RSCAT 25km
Wind Speed (m/s)

Hs: 2 (m)


Hs: 2 (m)
RSCAT 25km Wind Speed (m/s)
ECMWF Wind Speed (m/s)
Counts
Bias: 0.01 m/s
SD: 1.27 m/s
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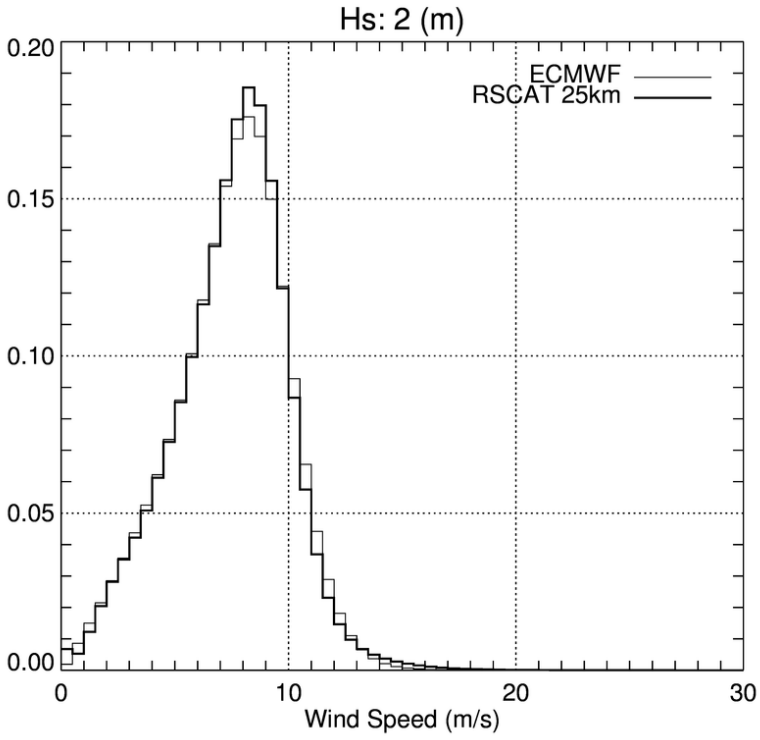
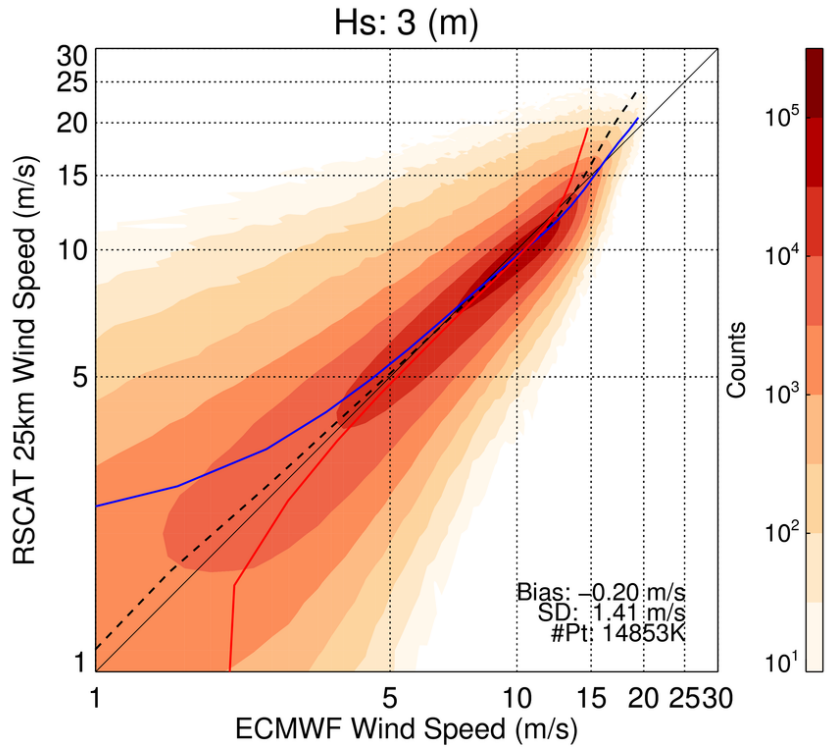
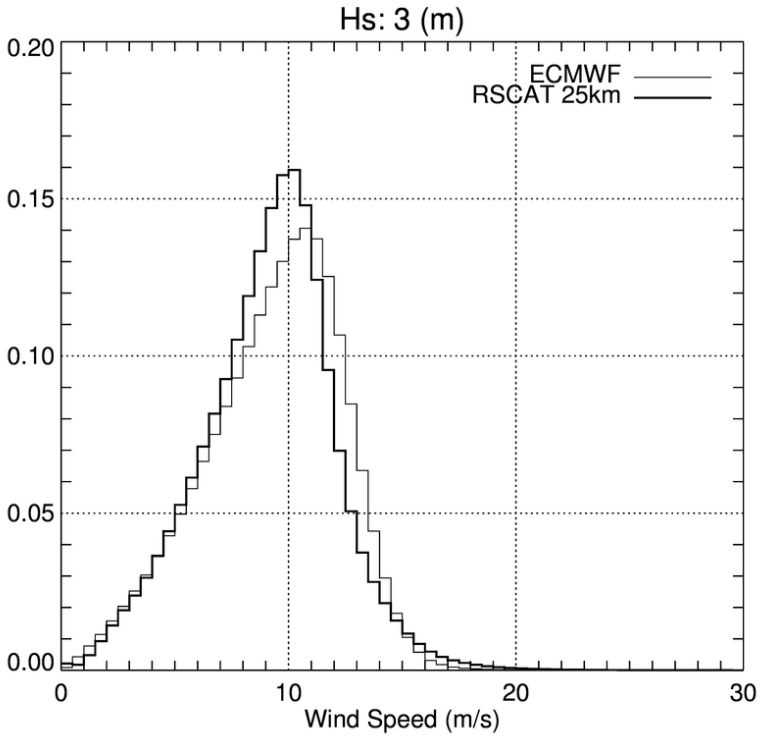
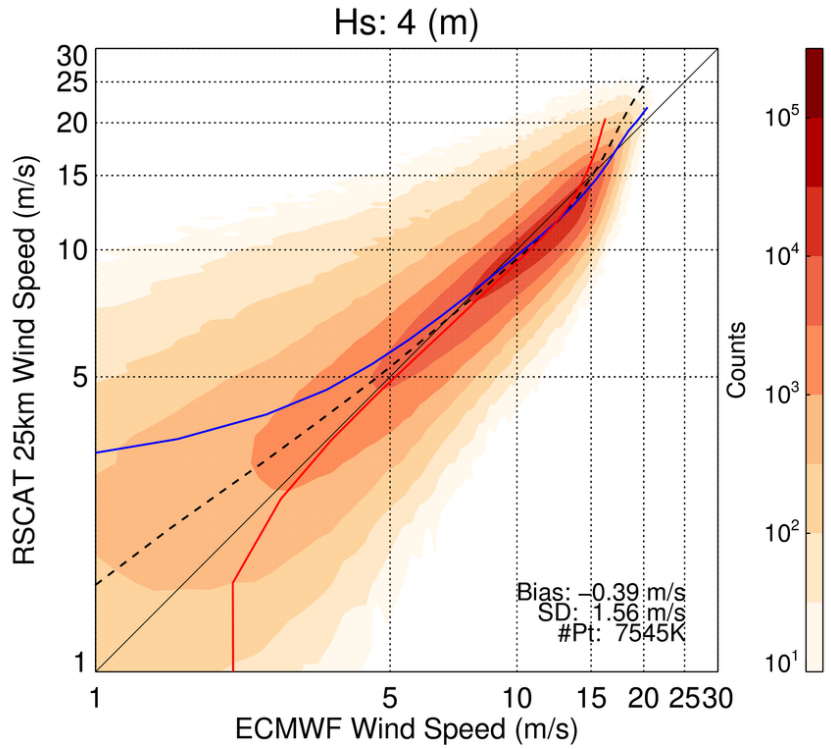

Hs: 2 (m)
ECMWF
RSCAT 25km
Wind Speed (m/s)

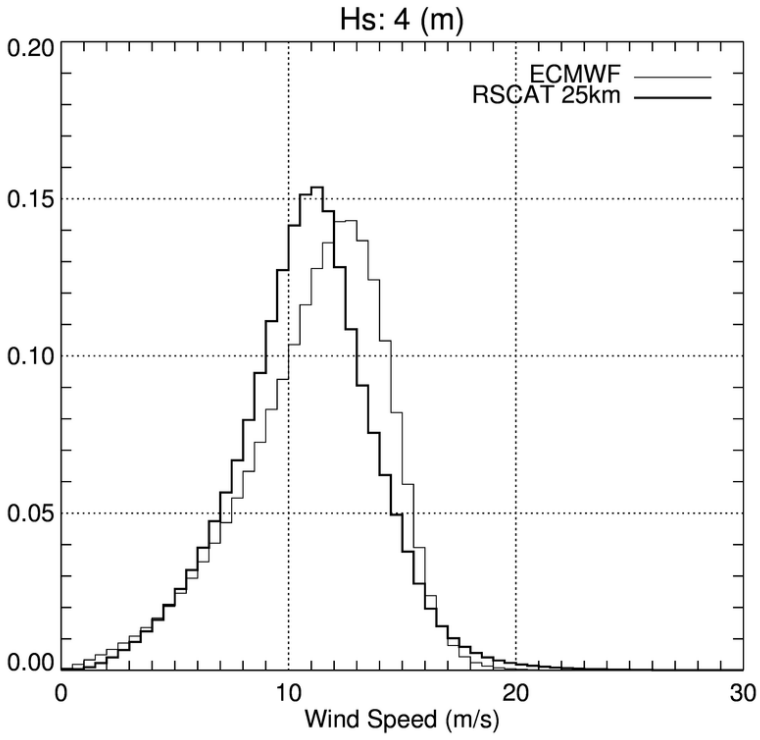
Hs: 3 (m)


Hs: 3 (m)
RSCAT 25km Wind Speed (m/s)
ECMWF Wind Speed (m/s)
Counts
Bias: –0.20 m/s
SD: 1.41 m/s
#Pt: 14853K

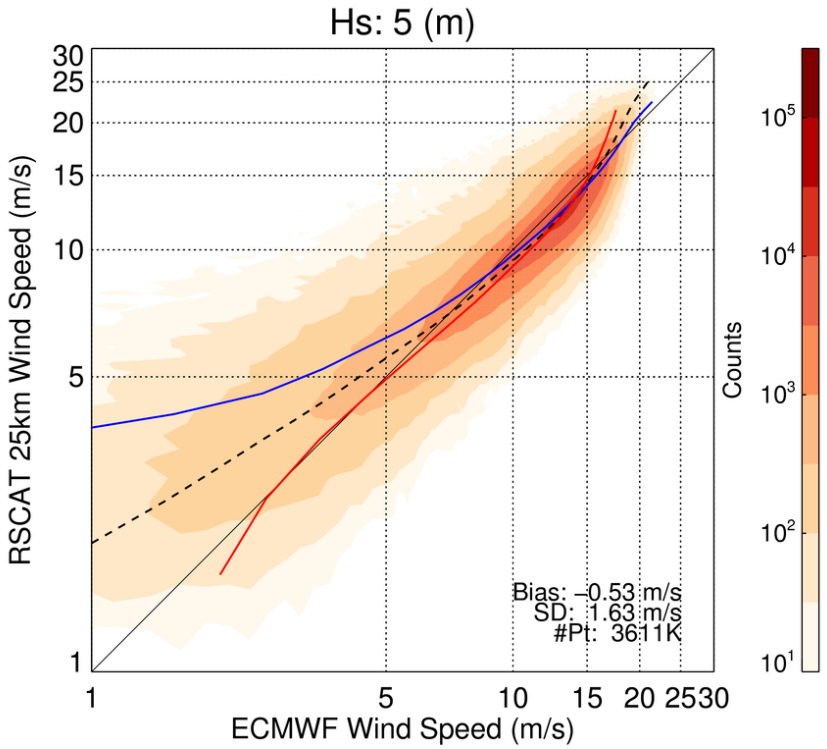

Hs: 3 (m)
ECMWF
RSCAT 25km
Wind Speed (m/s)

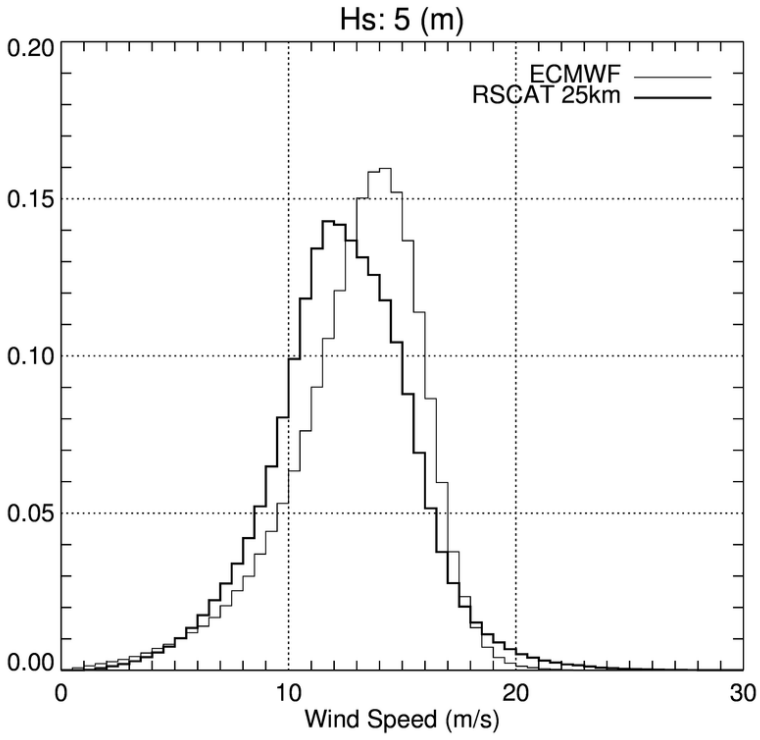
Hs: 4 (m)


Hs: 4 (m)
RSCAT 25km Wind Speed (m/s)
ECMWF Wind Speed (m/s)
Counts
Bias: –0.39 m/s
SD: 1.56 m/s
#Pt: 7545K

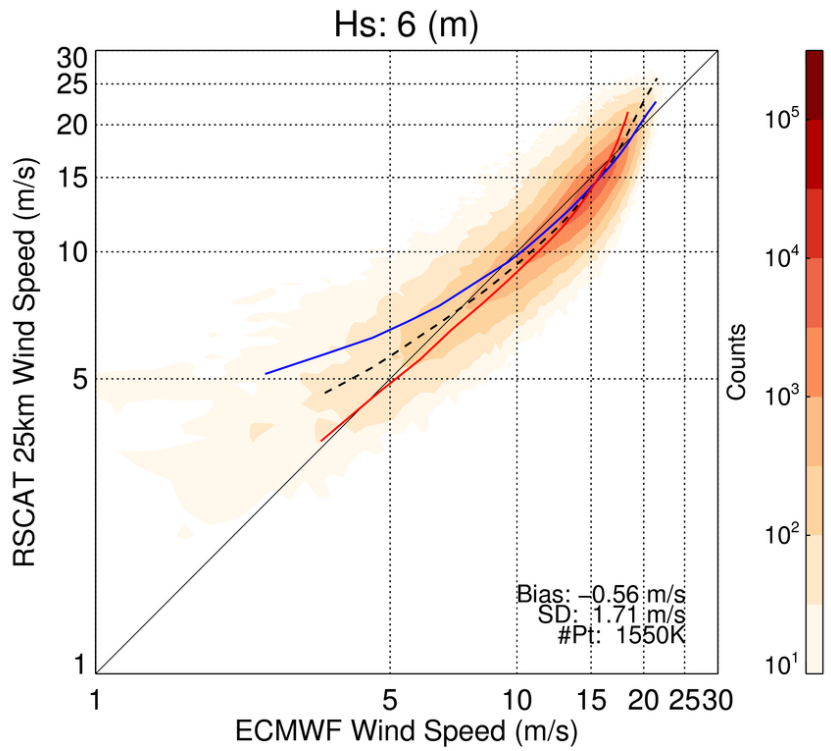

Hs: 4 (m)
ECMWF
RSCAT 25km
Wind Speed (m/s)

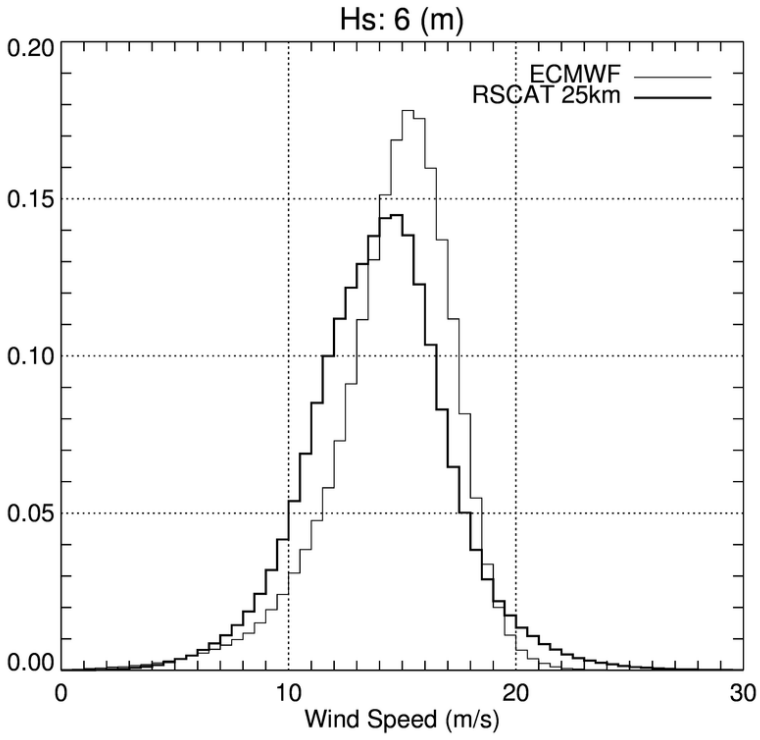
Hs: 5 (m)


Hs: 5 (m)
RSCAT 25km Wind Speed (m/s)
ECMWF Wind Speed (m/s)
Counts
Bias: –0.53 m/s
SD: 1.63 m/s
#Pt: 3611K

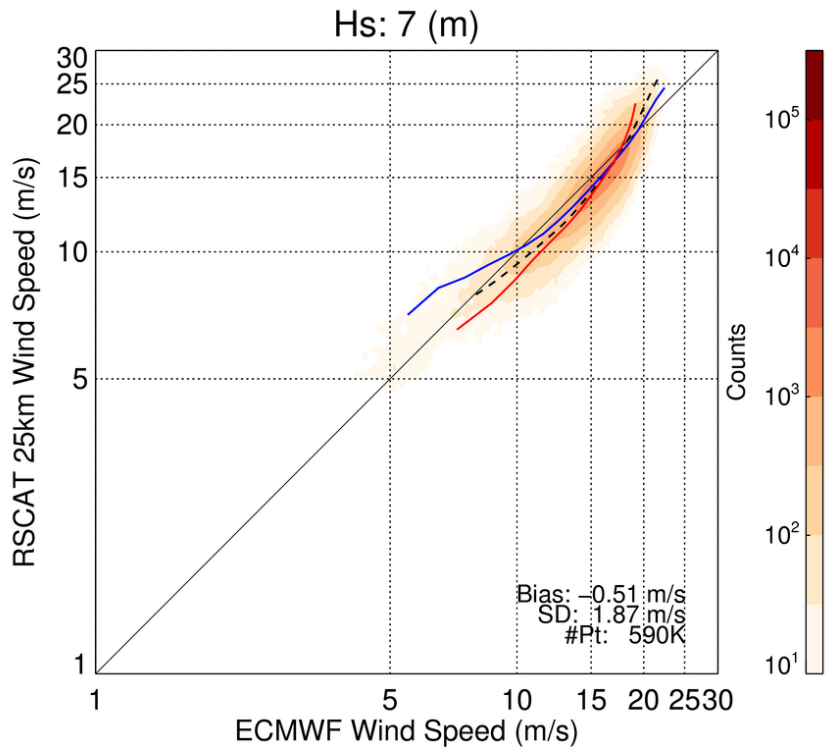

Hs: 5 (m)
ECMWF
RSCAT 25km
Wind Speed (m/s)

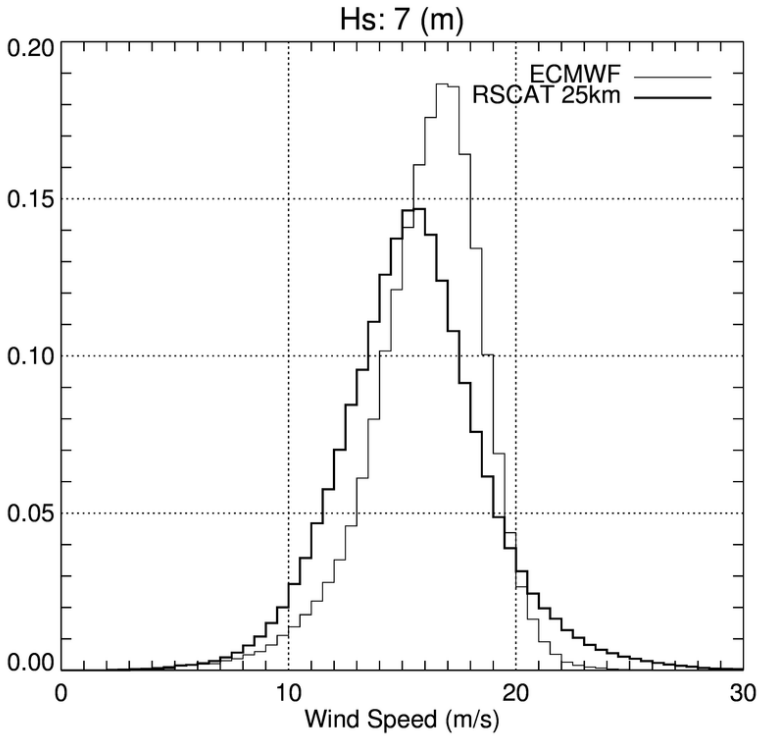
Hs: 6 (m)


Hs: 6 (m)
RSCAT 25km Wind Speed (m/s)
ECMWF Wind Speed (m/s)
Counts
Bias: –0.56 m/s
SD: 1.71 m/s
#Pt: 1550K

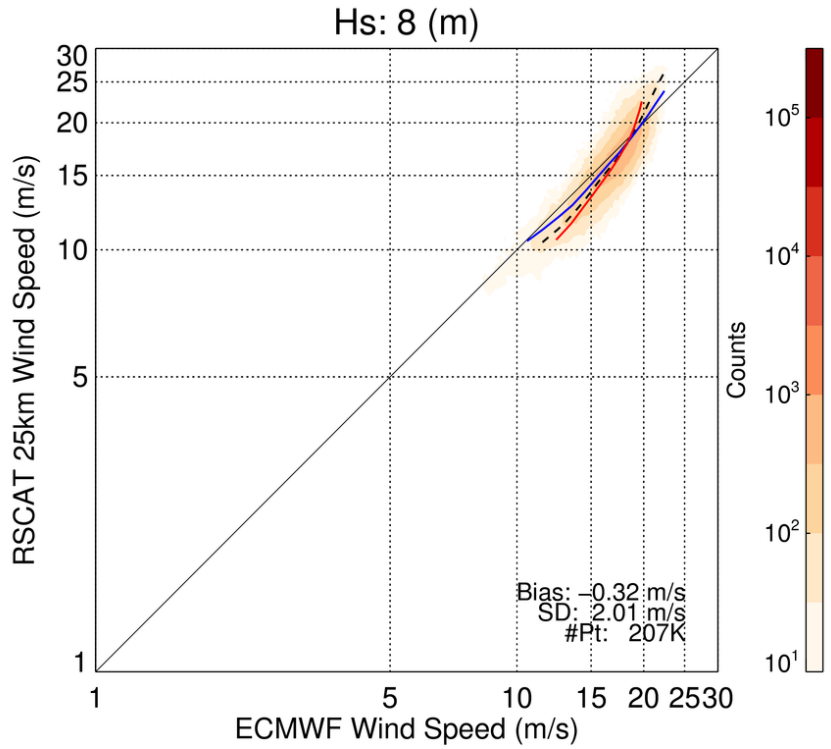

Hs: 6 (m)
ECMWF
RSCAT 25km
Wind Speed (m/s)

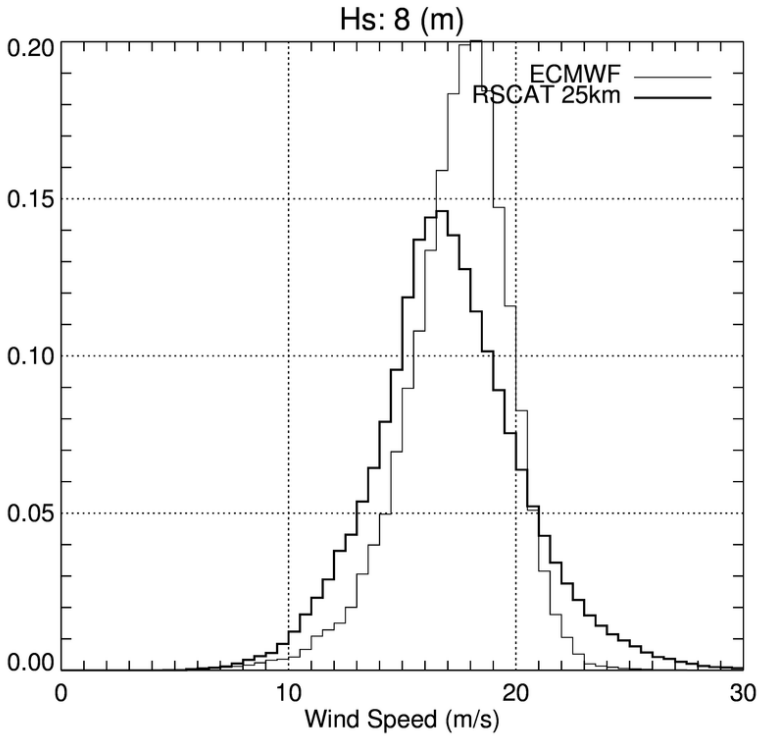
Hs: 7 (m)


Hs: 7 (m)
RSCAT 25km Wind Speed (m/s)
ECMWF Wind Speed (m/s)
Counts
Bias: –0.51 m/s
SD: 1.87 m/s
#Pt: 590K

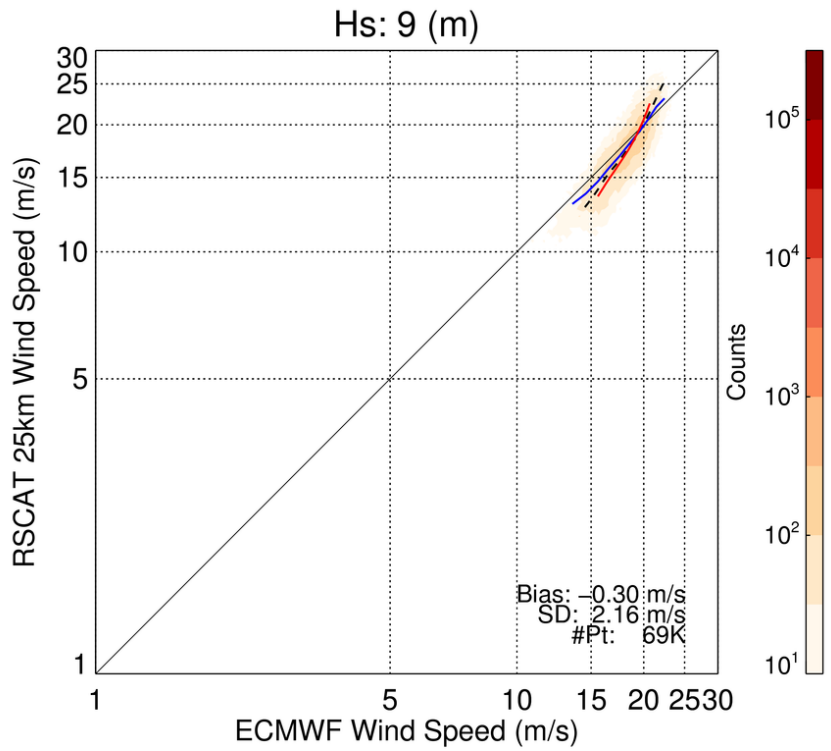

Hs: 7 (m)
ECMWF
RSCAT 25km
Wind Speed (m/s)

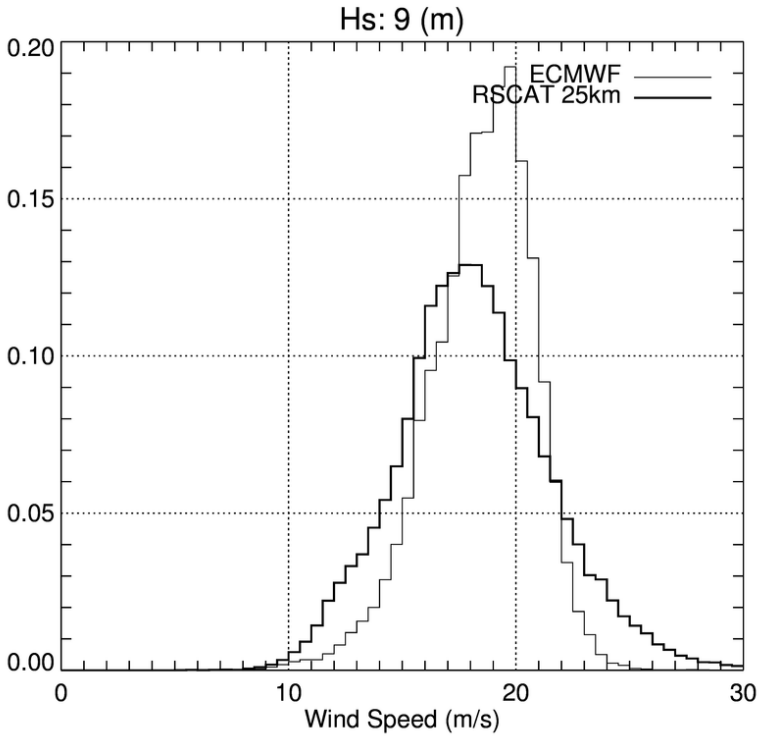
Hs: 8 (m)


Hs: 8 (m)
RSCAT 25km Wind Speed (m/s)
ECMWF Wind Speed (m/s)
Counts
Bias: –0.32 m/s
SD: 2.01 m/s
#Pt: 207K

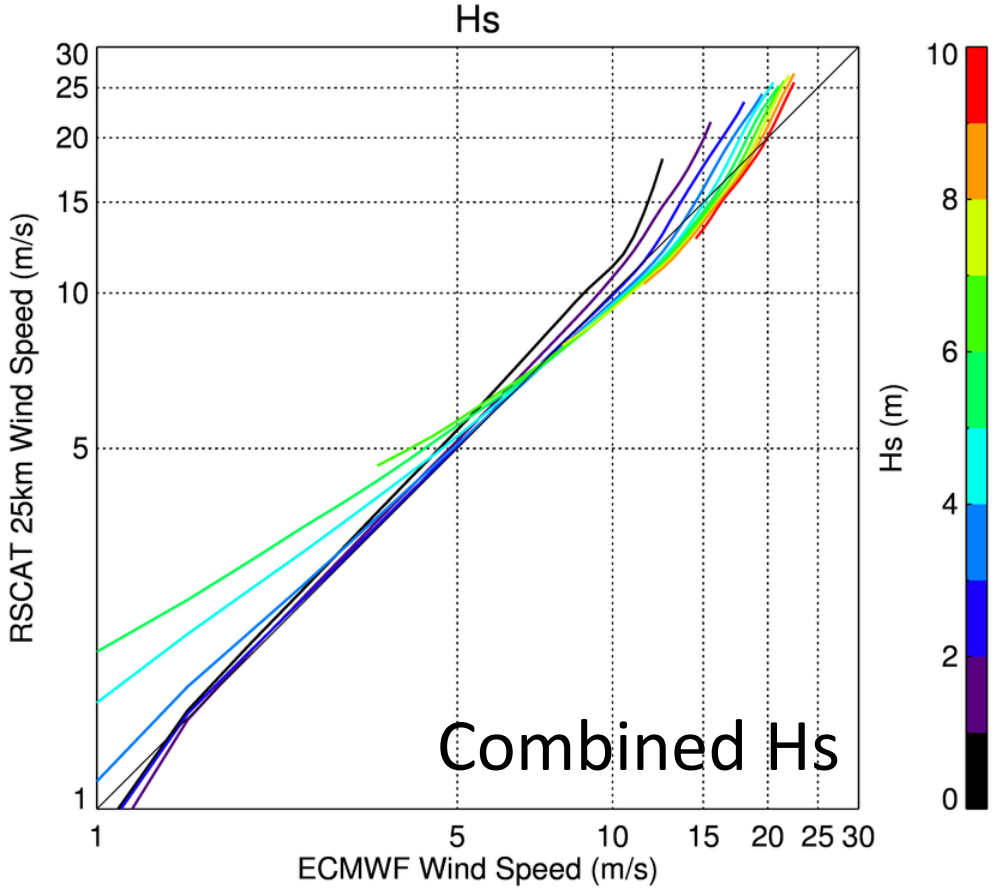

Hs: 8 (m)
ECMWF
RSCAT 25km
Wind Speed (m/s)

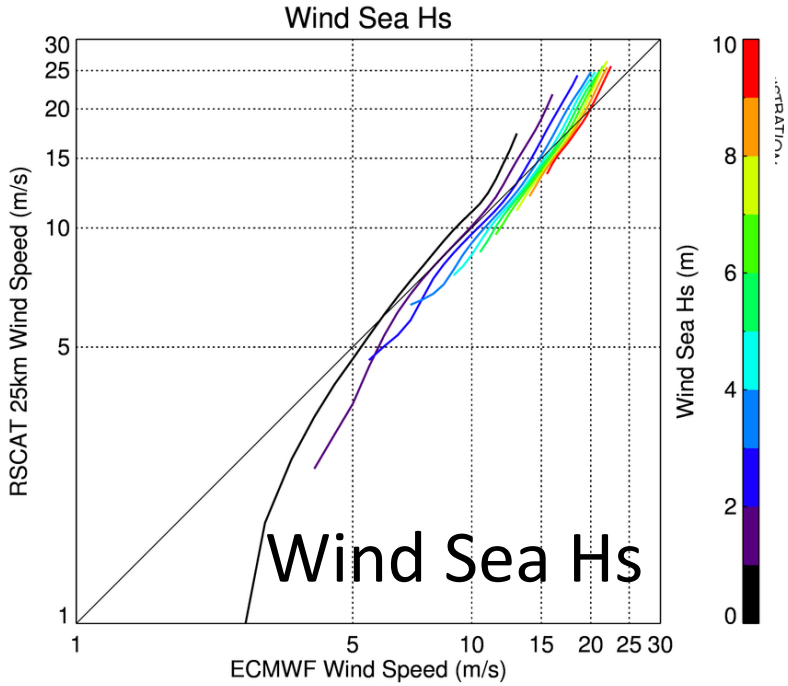
Hs: 9 (m)

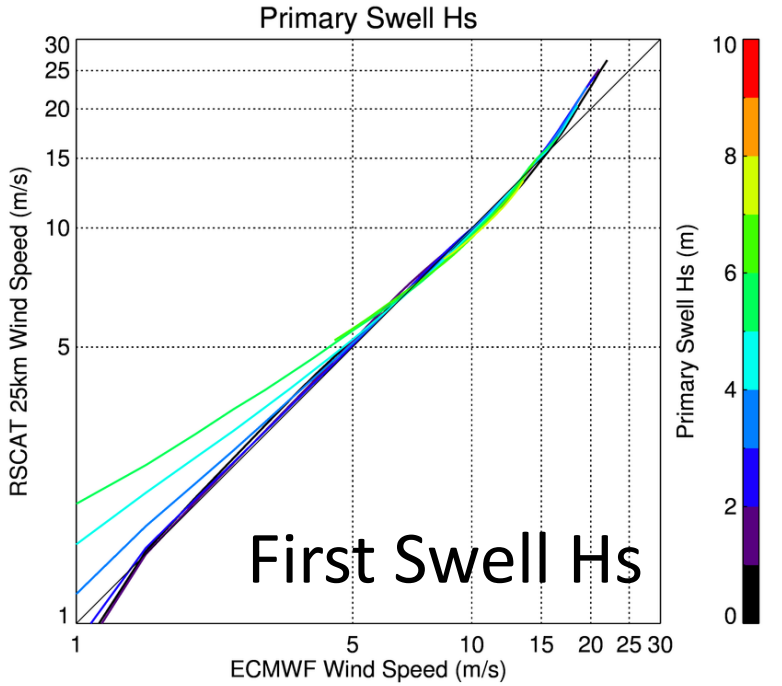

Hs: 9 (m)
RSCAT 25km Wind Speed (m/s)
ECMWF Wind Speed (m/s)
Counts
Bias: –0.30 m/s
SD: 2.16 m/s
#Pt: 69K


Hs: 9 (m)
ECMWF
RSCAT 25km
Wind Speed (m/s)

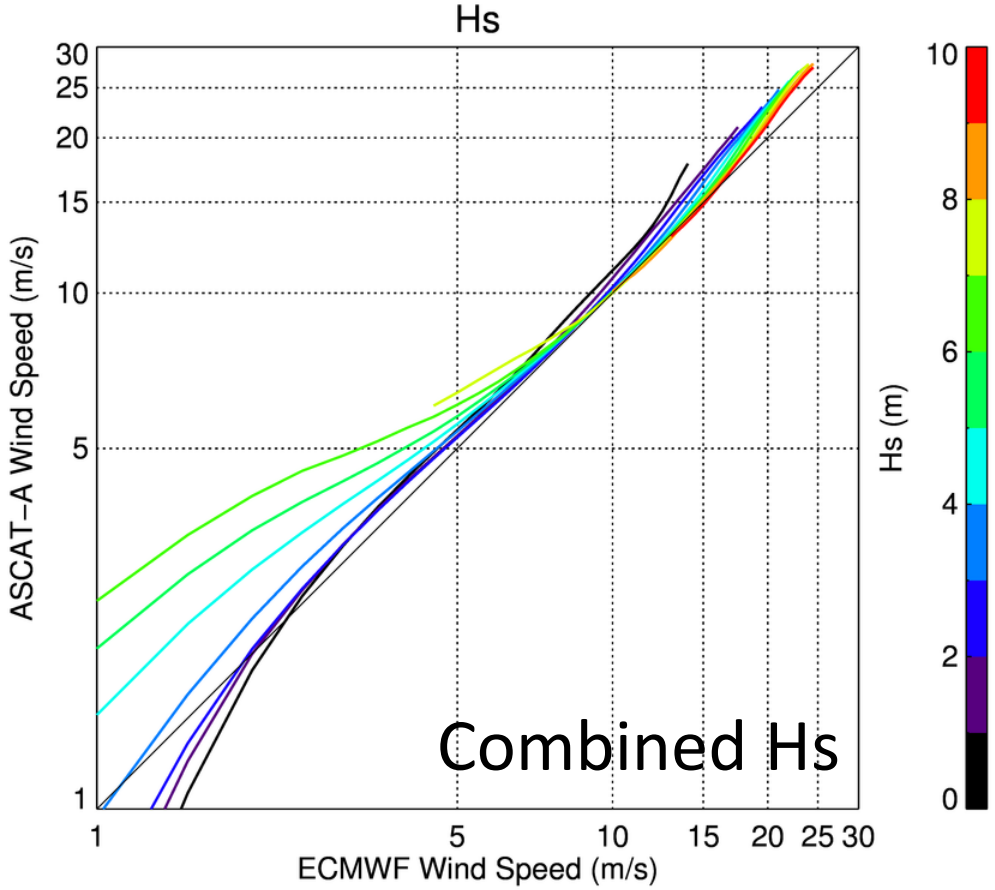
RapidScat Hs Response

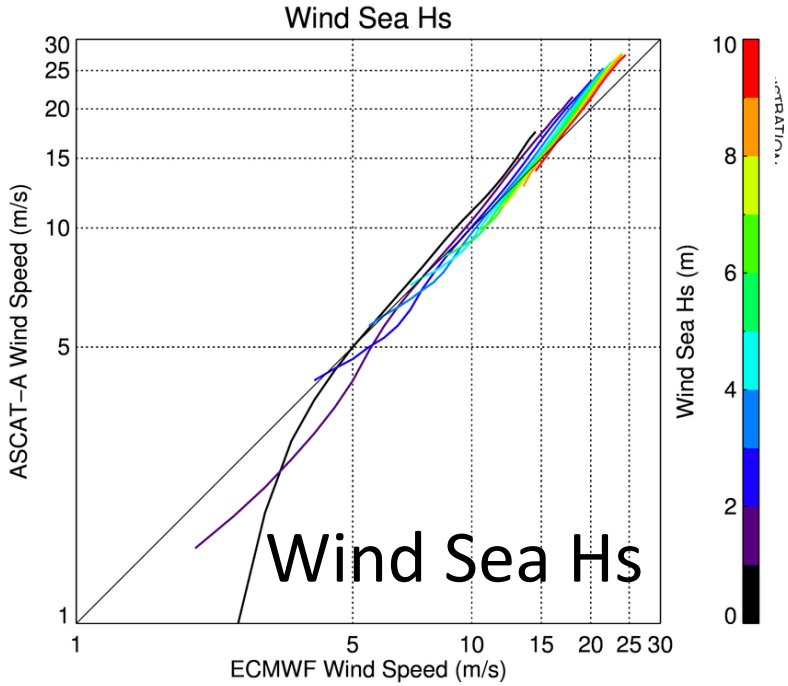


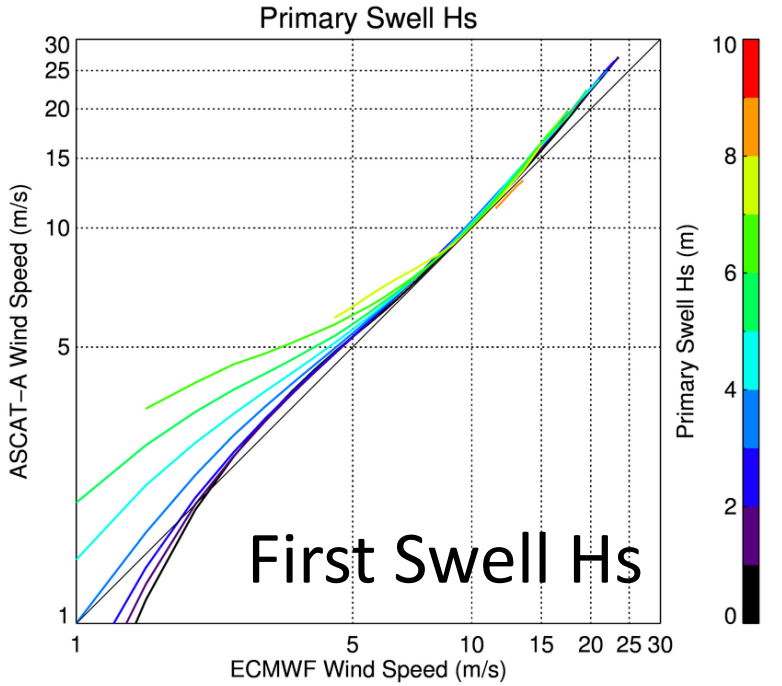




ASCAT Hs Response

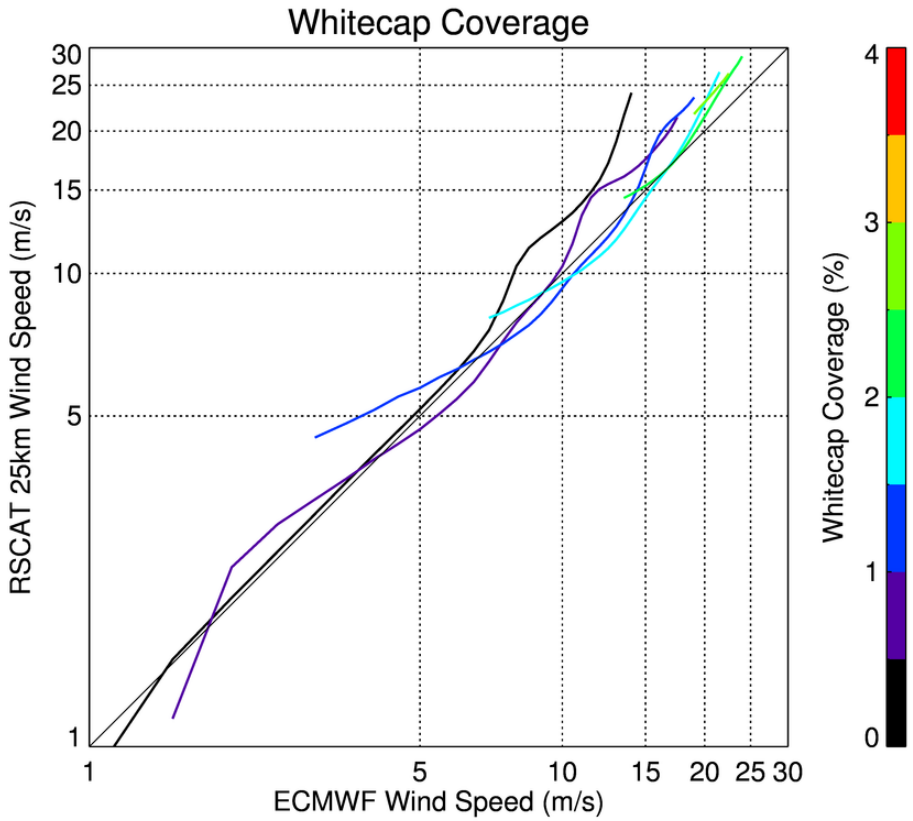




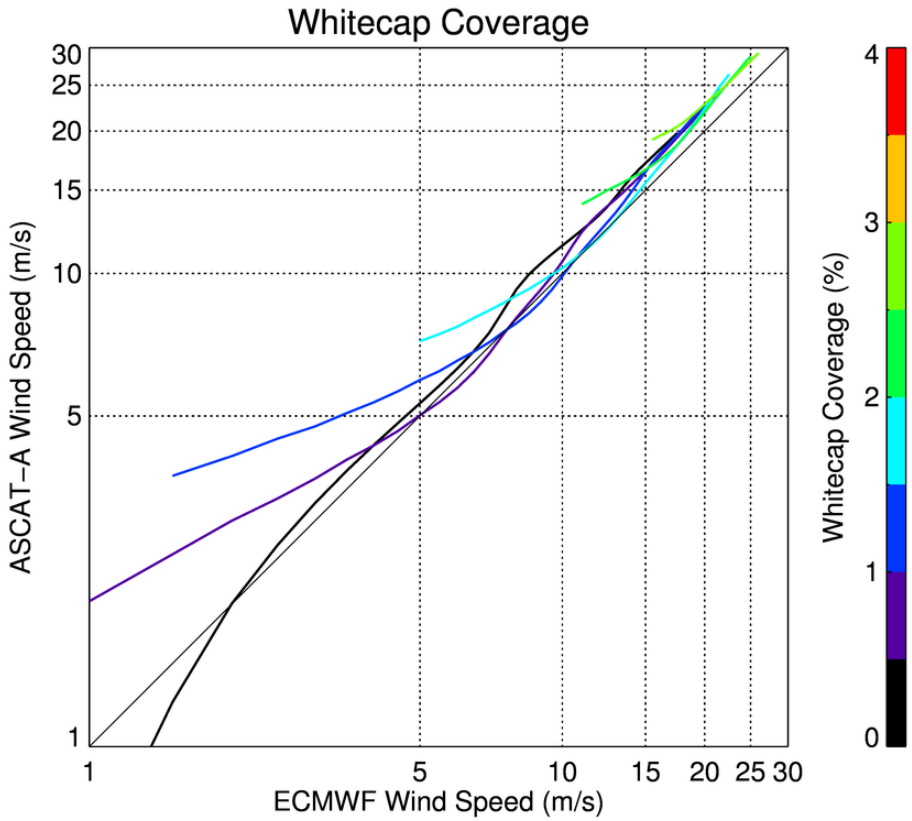


Whitecap Coverage

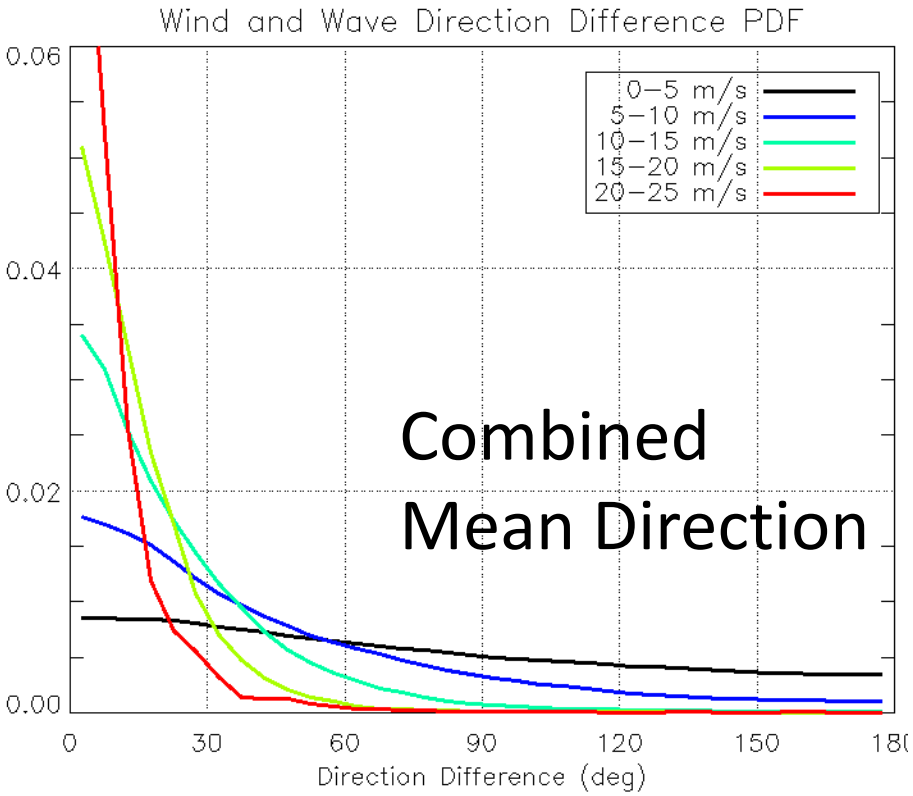
RapidScat

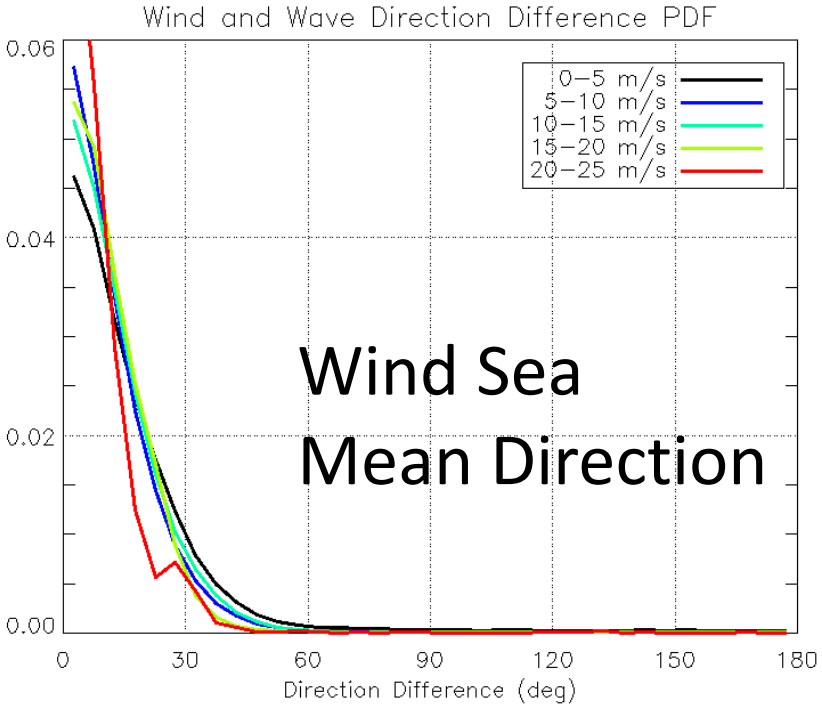


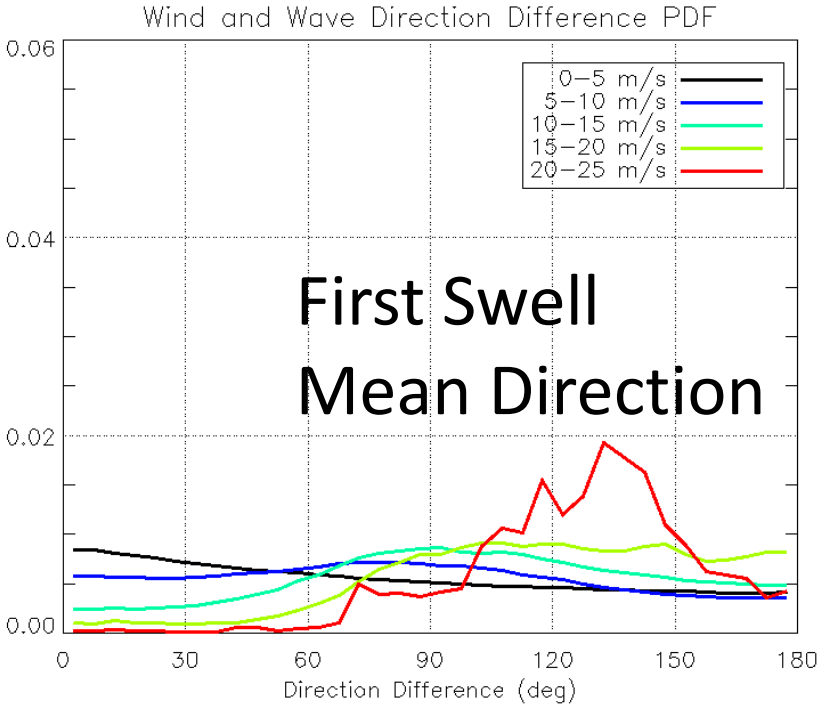
ASCAT



Wind and Wave Direction Difference PDF







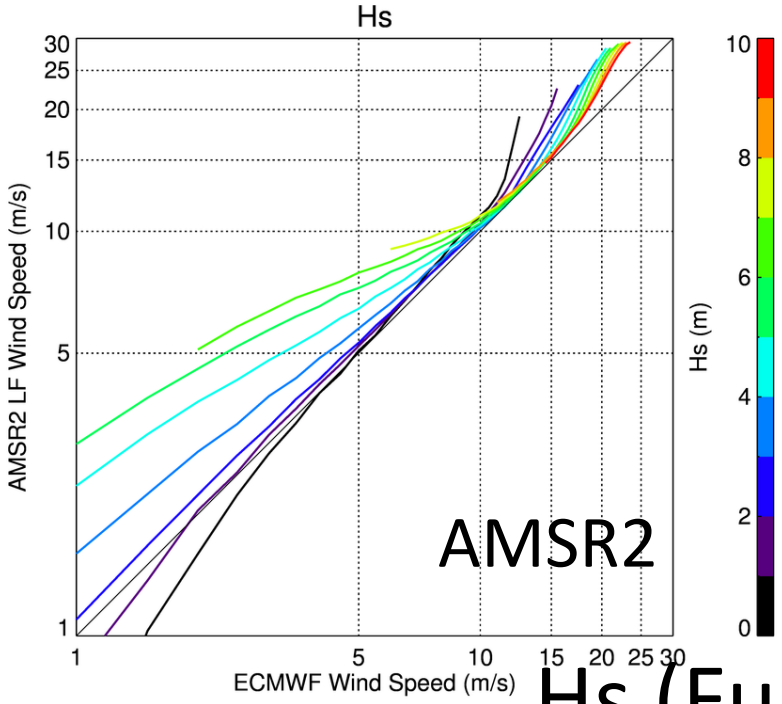
Summary

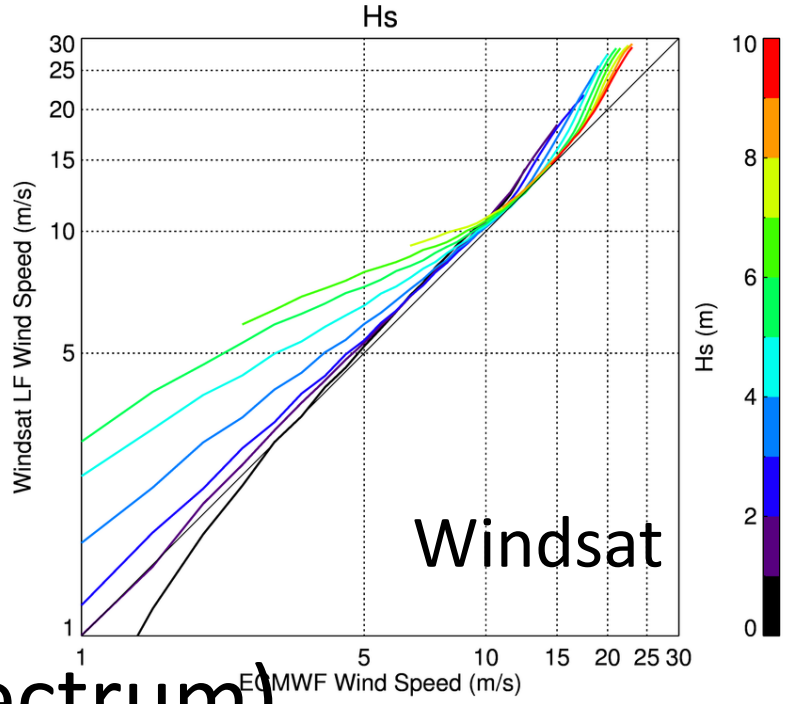
- Scatterometer wind speed is used to investigate scatterometer wave response
  - Use scatter plot bias (Conditional CDF)
- Both Ku- and C-band has sensitivity to primary swell for wind speed < 5 m/s
- At higher wind, Ku-band exhibit some sensitivity with wind sea wave but not in C-band
- C-band appear to have sensitivity with whitecap at low wind
- Wind and wind wave direction are highly correlated for all wind speed, however, wind and swell wave direction has little correlation and exhibit reverse trend with wind speed

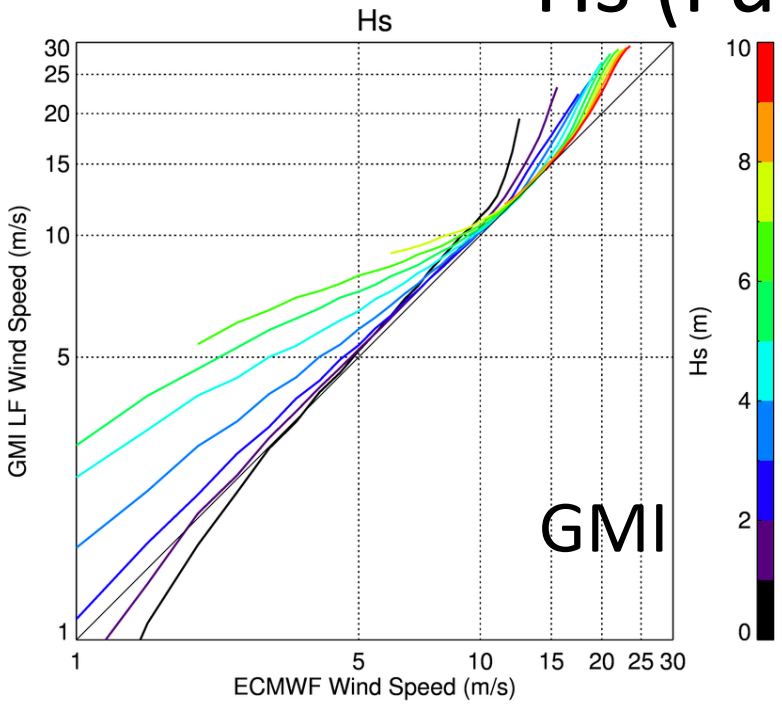
backup

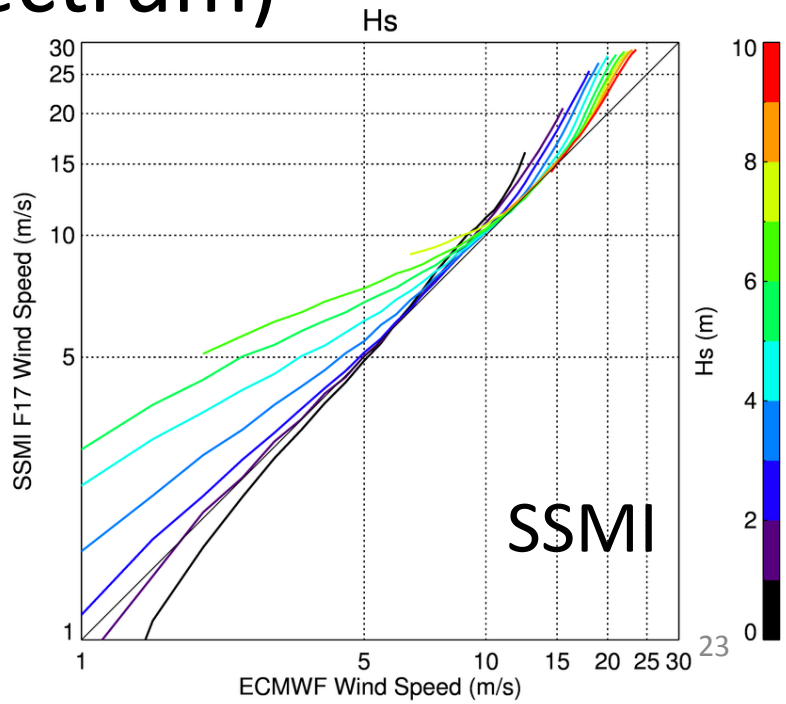
Radiometer Wind Results
(data from RSS)

Hs (Full Spectrum)

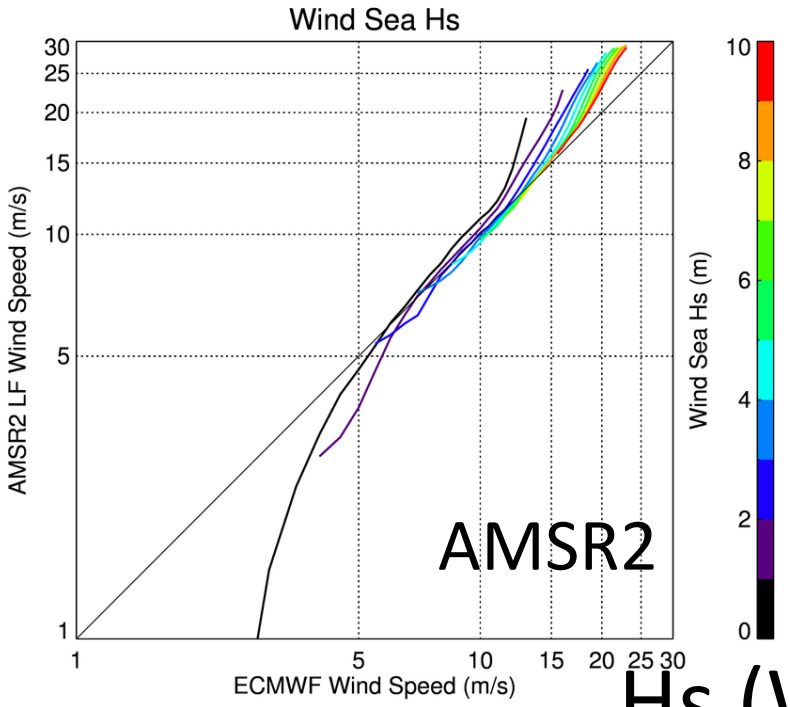


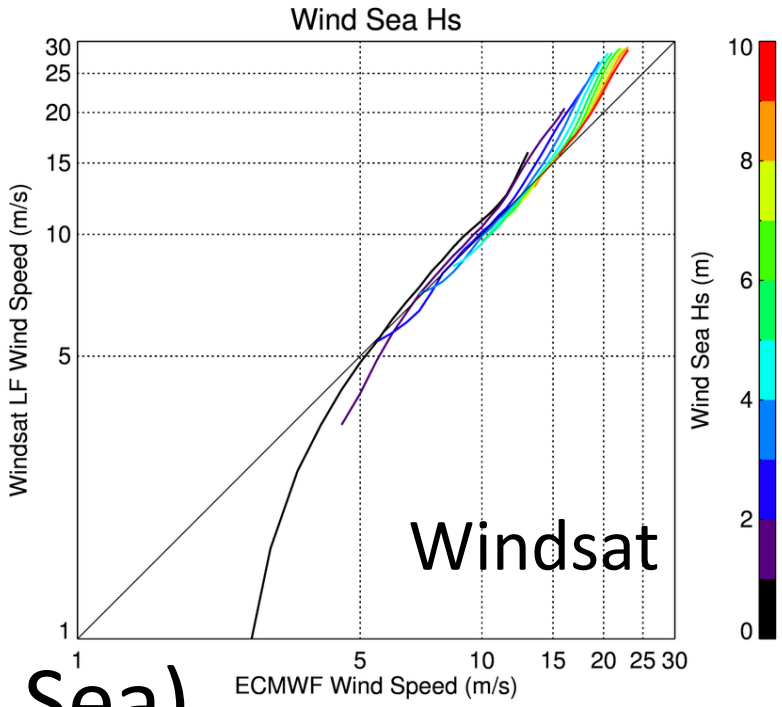


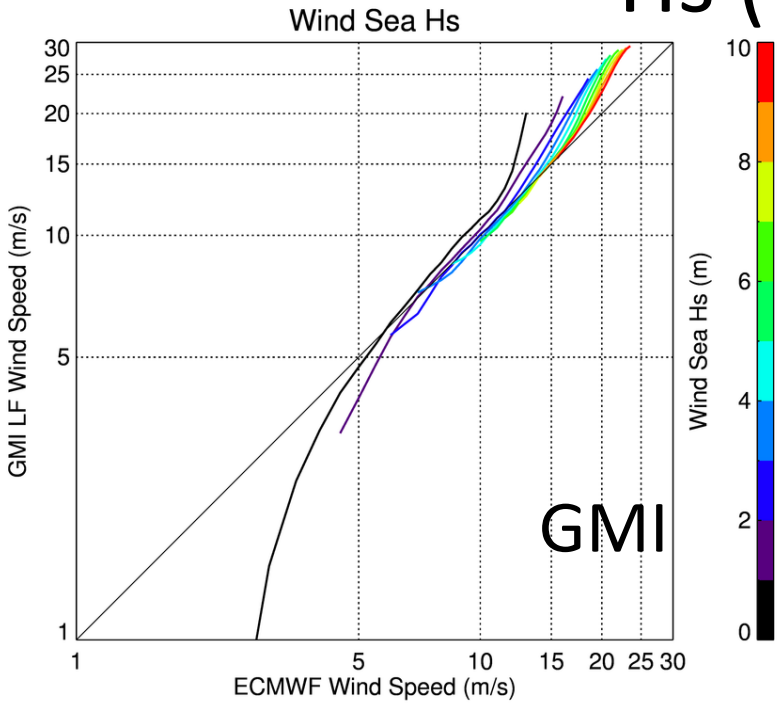


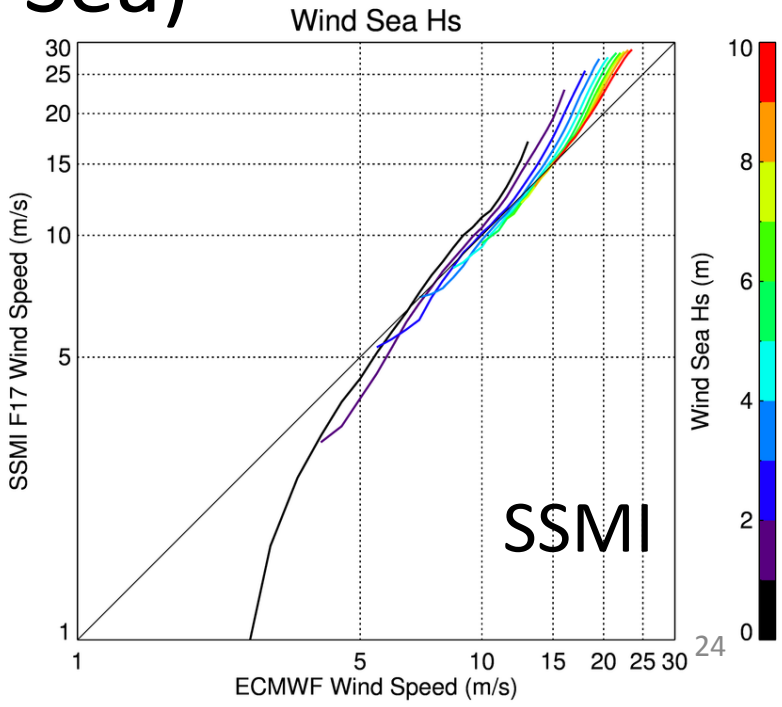


Hs (Wind Sea)

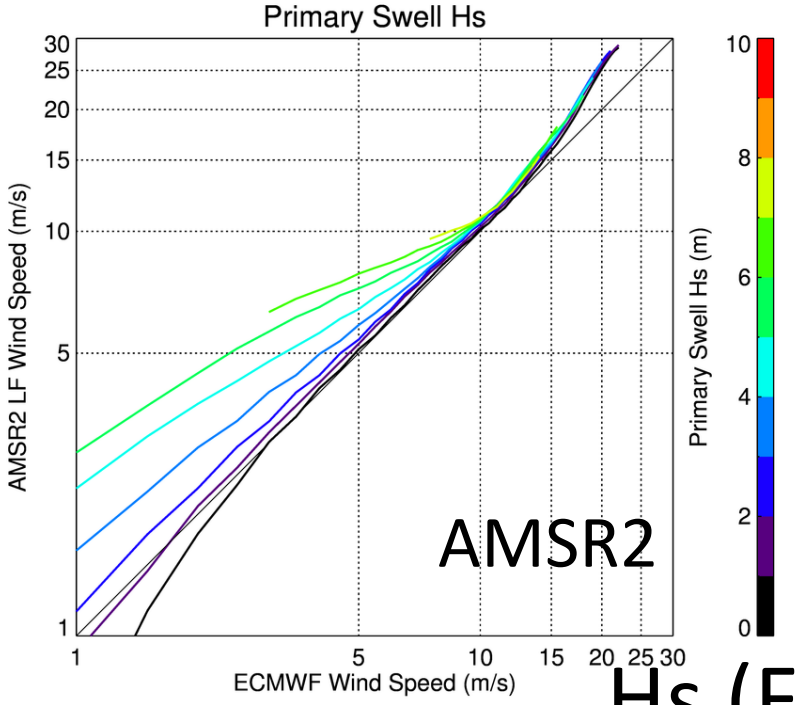

Wind Sea Hs
AMSR2 LF Wind Speed (m/s)
ECMWF Wind Speed (m/s)
Wind Sea Hs (m)
AMSR2

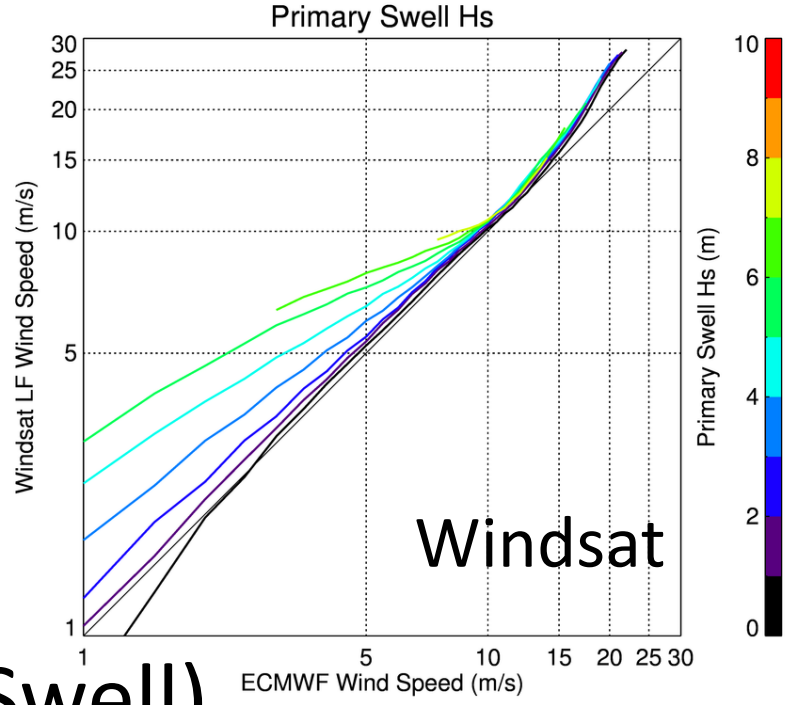

Wind Sea Hs
Windsat LF Wind Speed (m/s)
ECMWF Wind Speed (m/s)
Wind Sea Hs (m)
Windsat

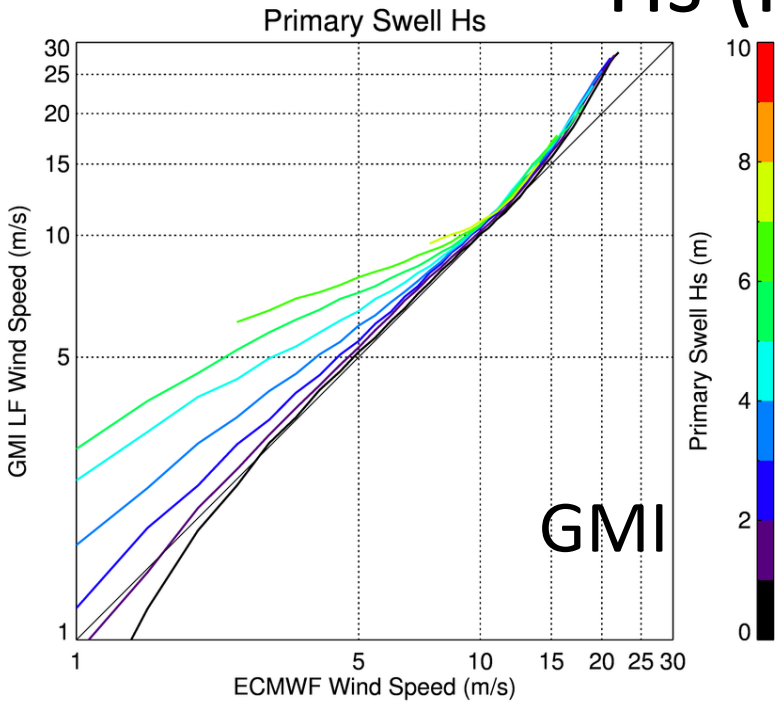

Wind Sea Hs
GMI LF Wind Speed (m/s)
ECMWF Wind Speed (m/s)
Wind Sea Hs (m)
GMI

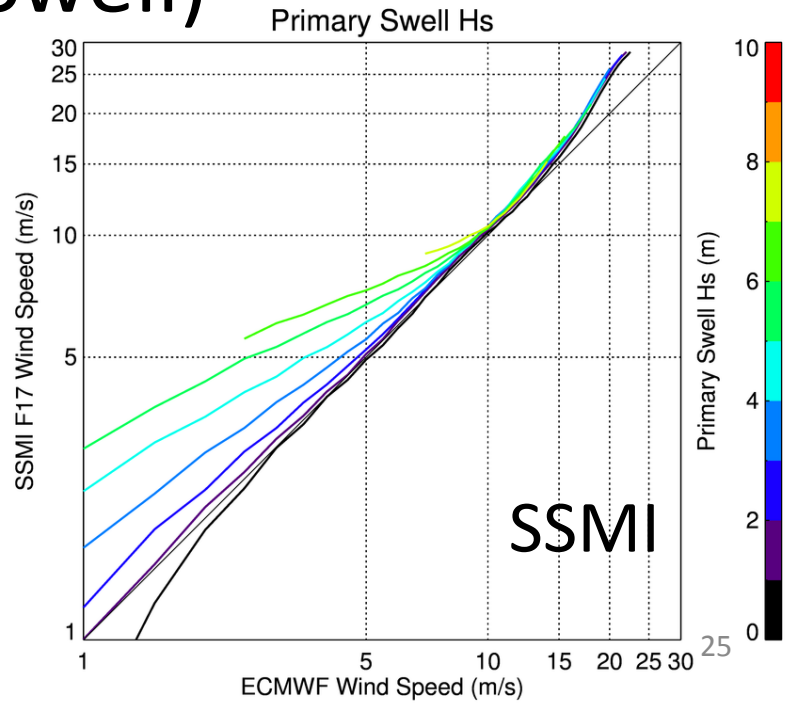

Wind Sea Hs
SSMI F17 Wind Speed (m/s)
ECMWF Wind Speed (m/s)
Wind Sea Hs (m)
SSMI

Hs (First Swell)

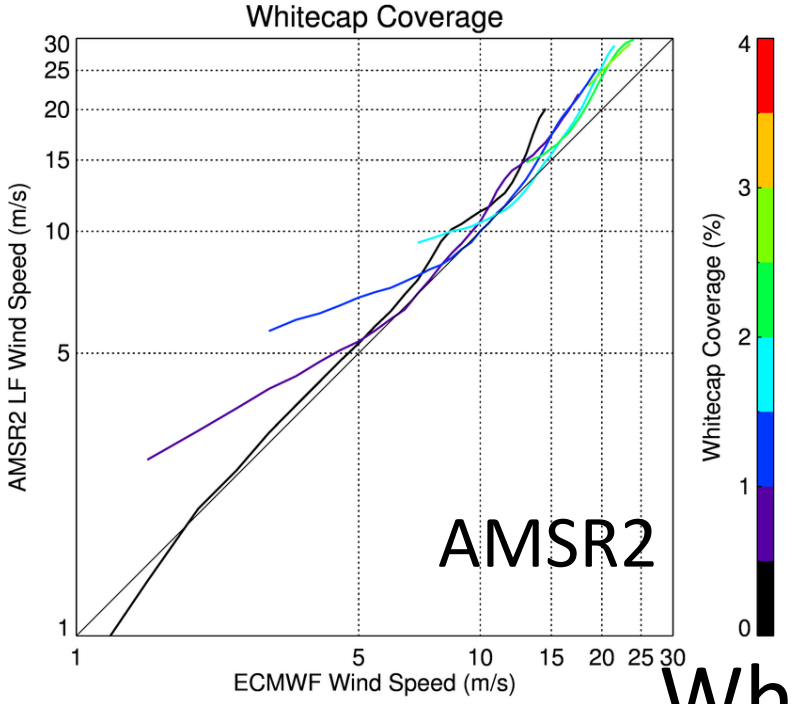


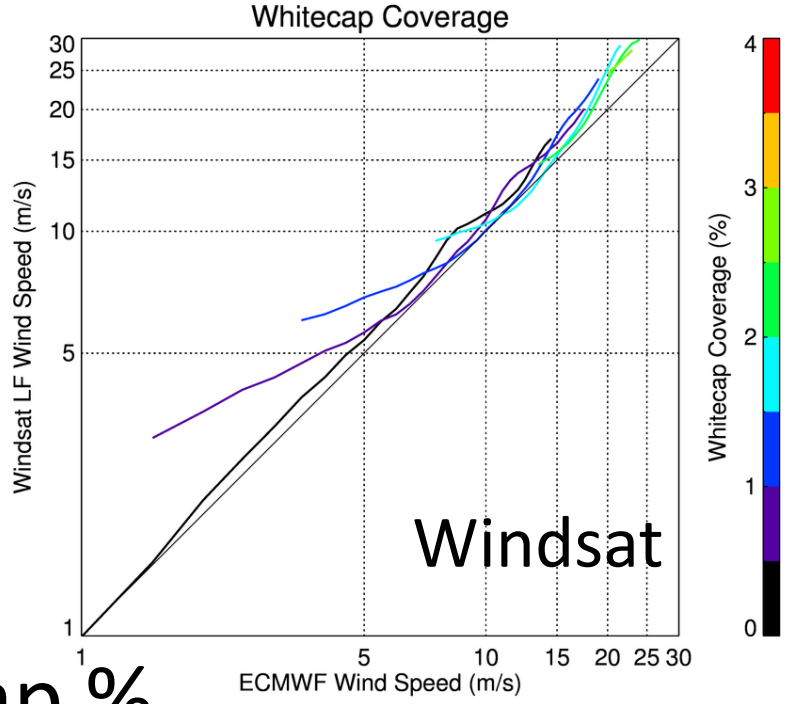


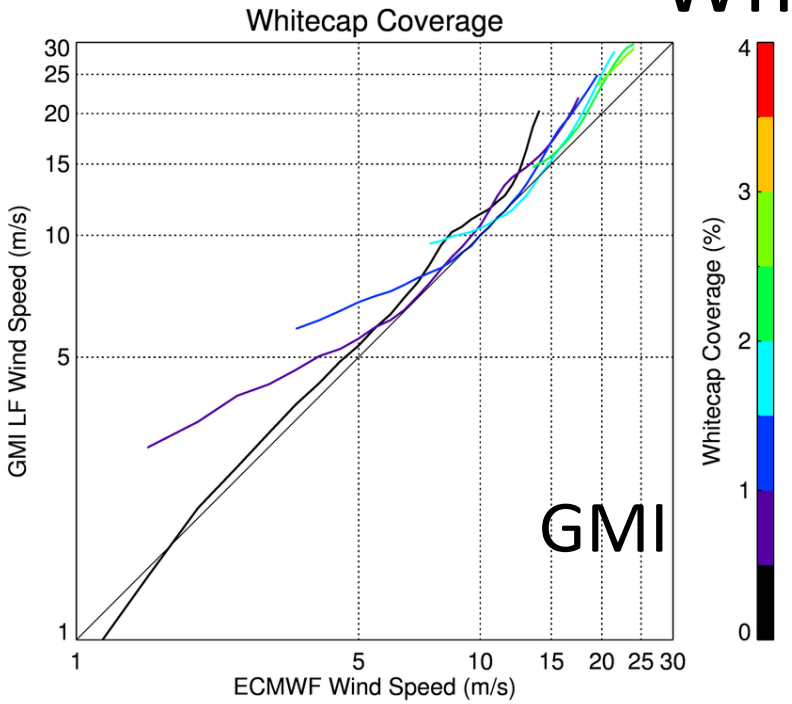


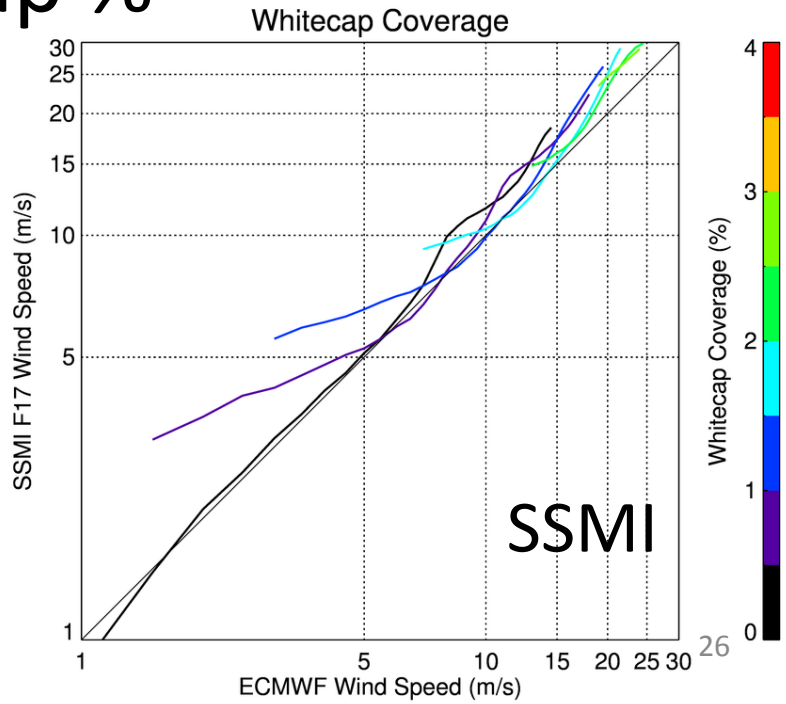


Whitecap %

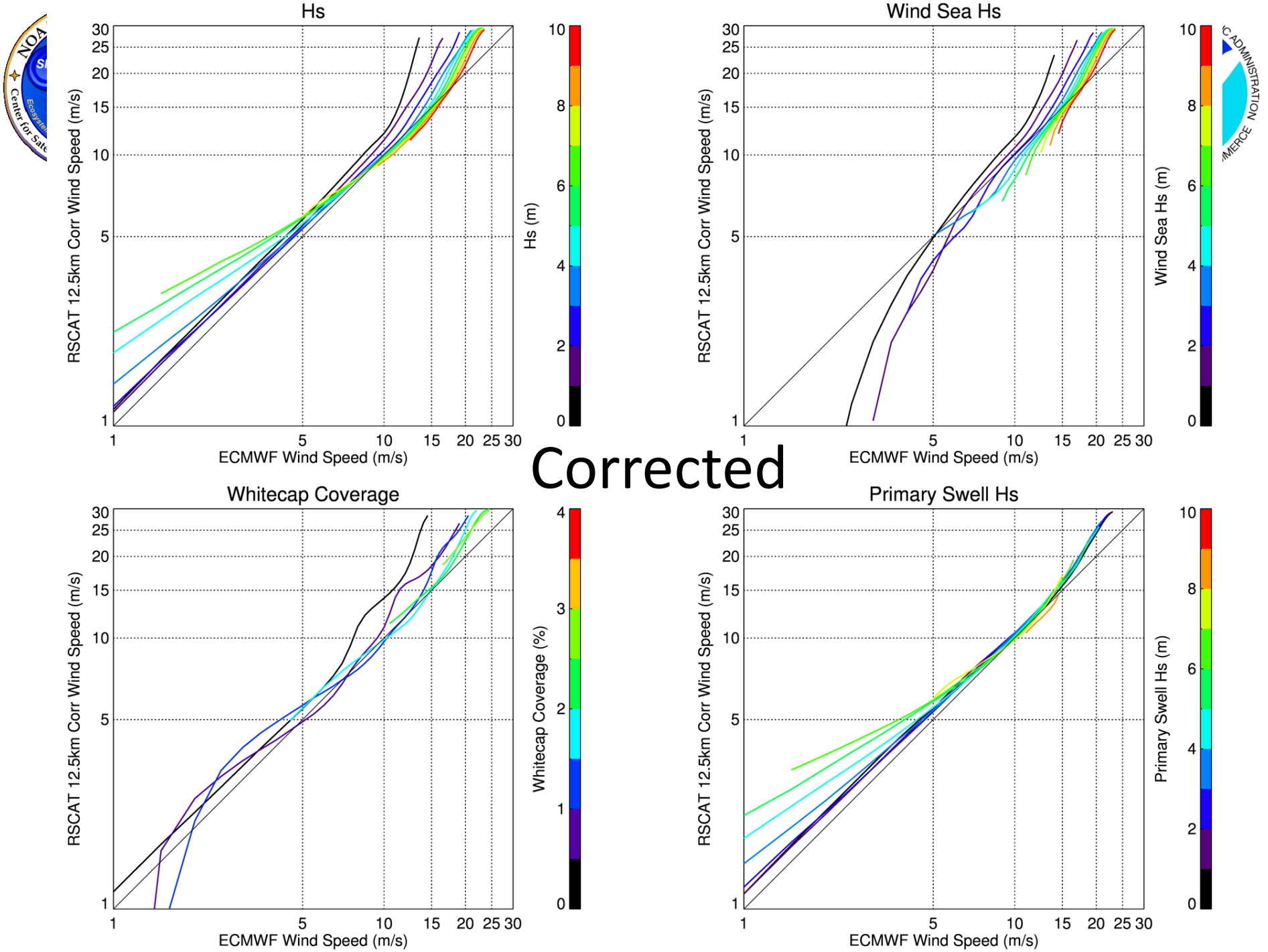

Whitecap Coverage
AMSR2 LF Wind Speed (m/s)
ECMWF Wind Speed (m/s)
Whitecap Coverage (%)
AMSR2

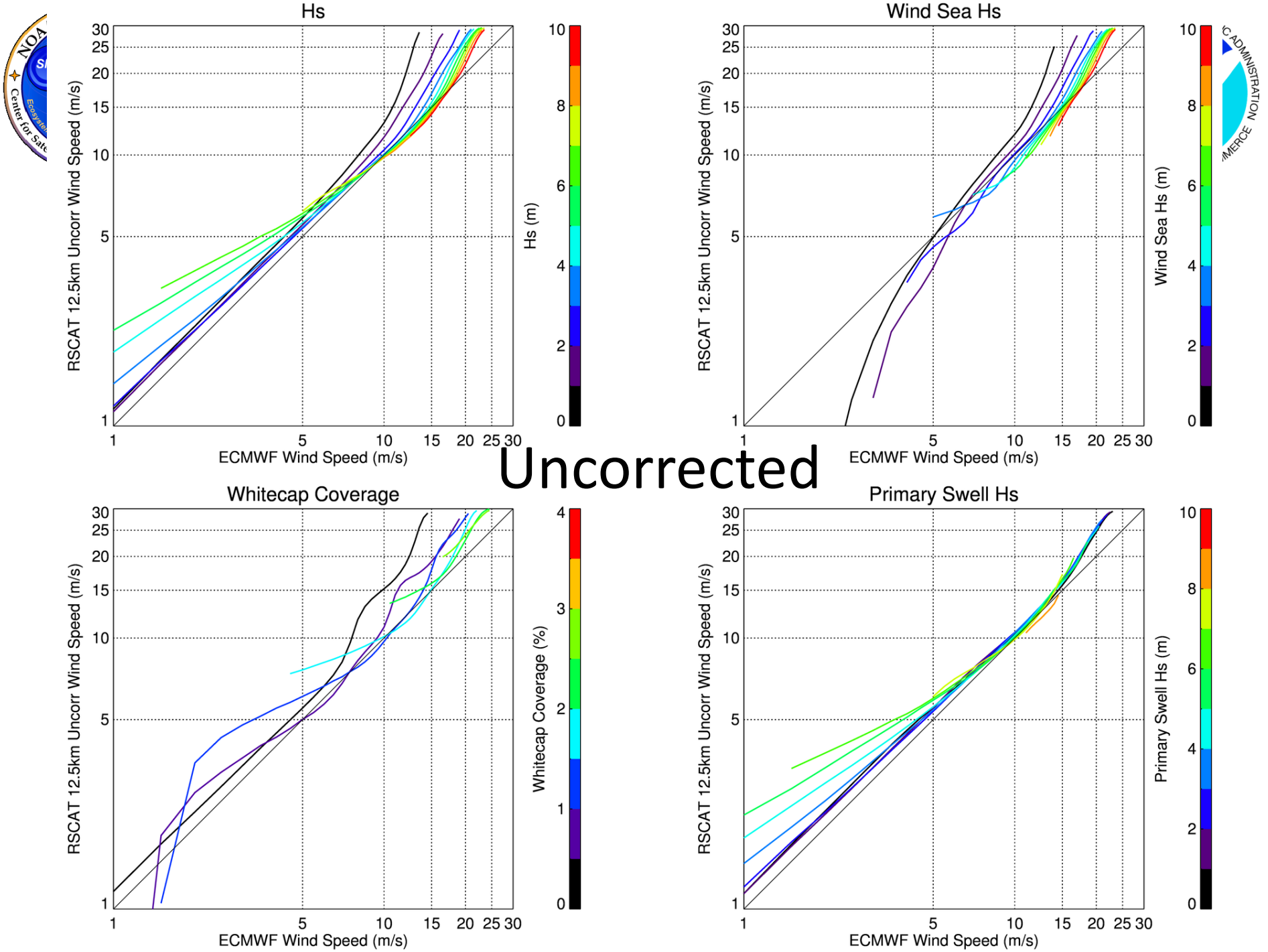

Whitecap Coverage
Windsat LF Wind Speed (m/s)
ECMWF Wind Speed (m/s)
Whitecap Coverage (%)
Windsat


Whitecap Coverage
GMI LF Wind Speed (m/s)
ECMWF Wind Speed (m/s)
Whitecap Coverage (%)
GMI

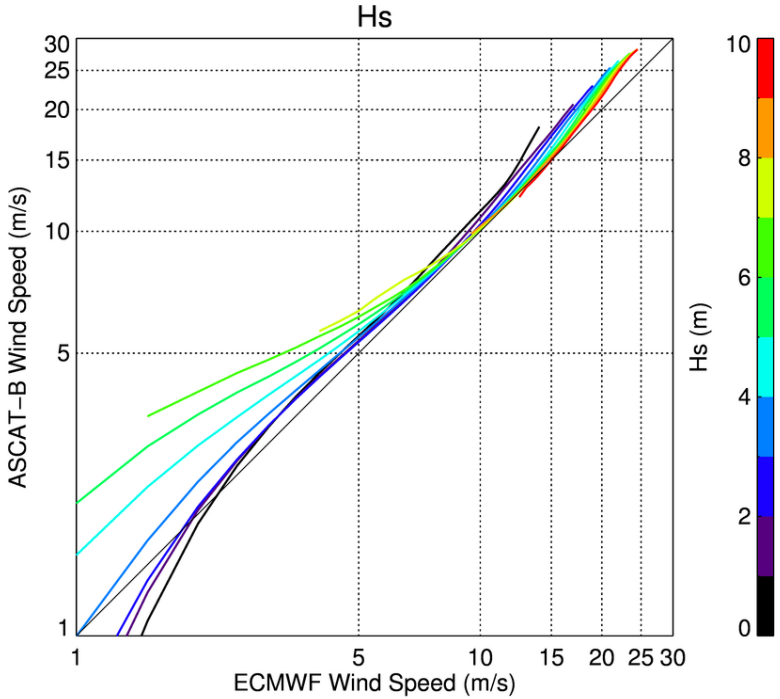

Whitecap Coverage
SSMI F17 Wind Speed (m/s)
ECMWF Wind Speed (m/s)
Whitecap Coverage (%)
SSMI

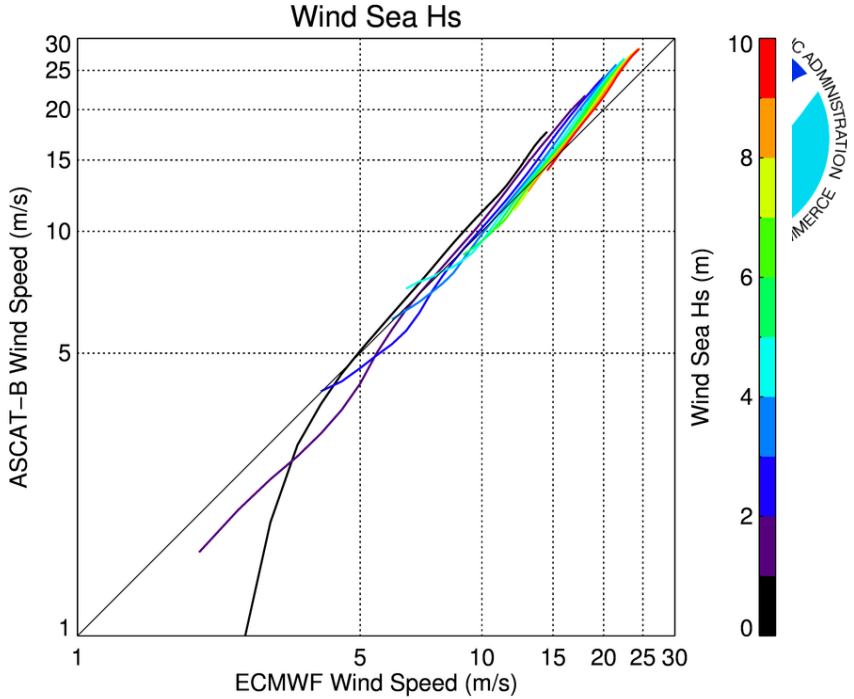
Rapidscat 12.5 km

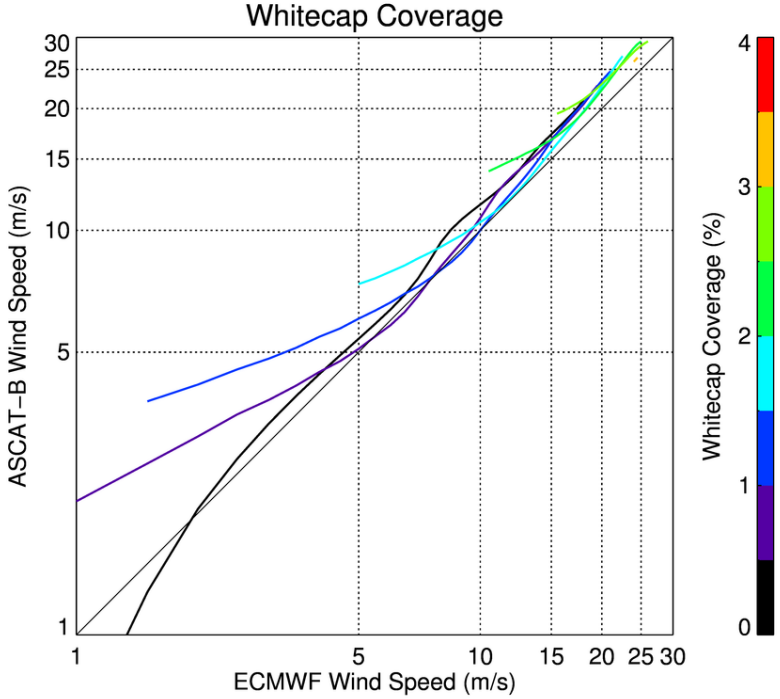

Hs
RSCAT 12.5km Corr Wind Speed (m/s)
ECMWF Wind Speed (m/s)
Hs (m)
Wind Sea Hs
Wind Sea Hs (m)
Corrected
Whitecap Coverage
Whitecap Coverage (%)
Primary Swell Hs
Primary Swell Hs (m)

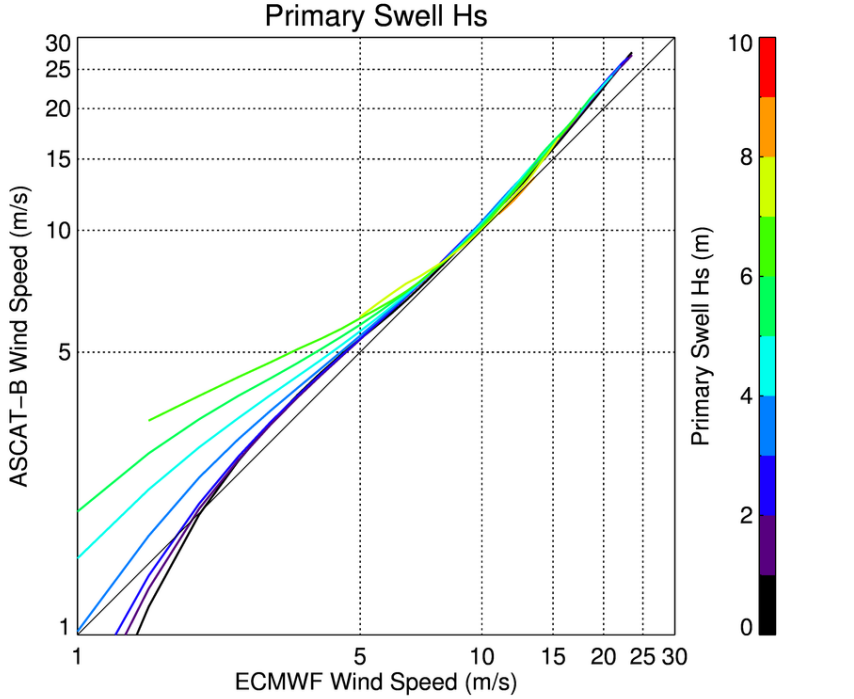

Hs
RSCAT 12.5km Uncorr Wind Speed (m/s)
ECMWF Wind Speed (m/s)
Hs (m)
Wind Sea Hs
Wind Sea Hs (m)
Whitecap Coverage
Whitecap Coverage (%)
Primary Swell Hs
Primary Swell Hs (m)
Uncorrected

ASCAT-B


Hs
ASCAT−B Wind Speed (m/s)
ECMWF Wind Speed (m/s)
Hs (m)
1
5
10
15
20
25
30
0
2
4
6
8


Wind Sea Hs
ASCAT−B Wind Speed (m/s)
ECMWF Wind Speed (m/s)
Wind Sea Hs (m)
1
5
10
15
20
25
30
0
2
4
6
8


Whitecap Coverage
ASCAT−B Wind Speed (m/s)
ECMWF Wind Speed (m/s)
Whitecap Coverage (%)
1
5
10
15
20
25
30
0
1
2
3
4


Primary Swell Hs
ASCAT−B Wind Speed (m/s)
ECMWF Wind Speed (m/s)
Primary Swell Hs (m)
1
5
10
15
20
25
30
0
2
4
6
8