STUDIES OF THE INFLUENCE OF RAINFALL UPON SCATTEROMETER ESTIMATES FOR SEA SURFACE STRESS: APPLICATIONS TO BOUNDARY LAYER PARAMETERIZATION AND DRAG COEFFICIENT MODELS WITHIN TROPICAL CYCLONE ENVIRONMENTS

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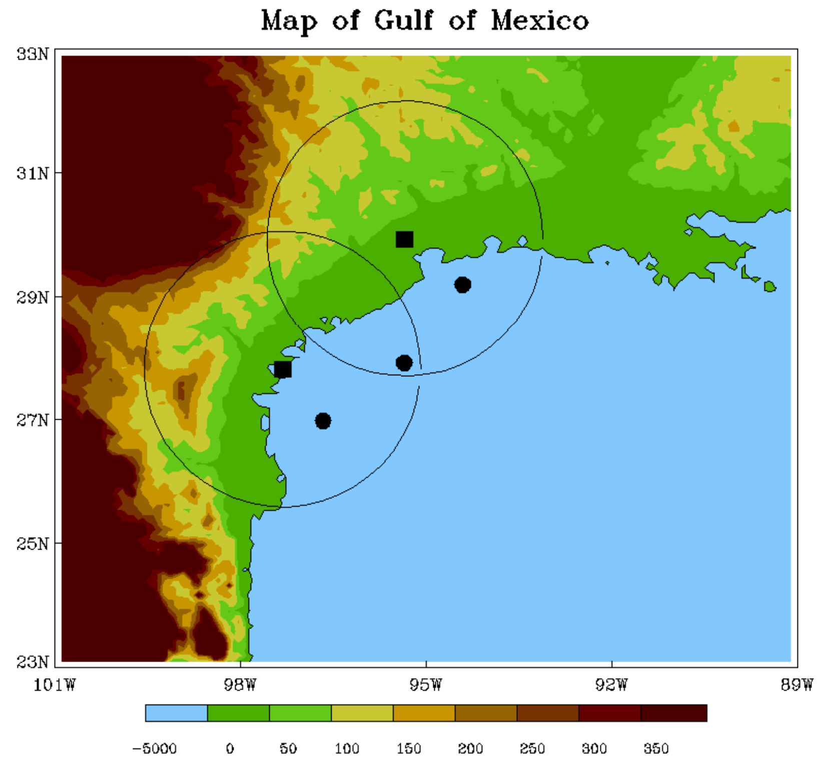
MOTIVATION:

1: CAN WE OBSERVE AN INCREASE IN THE Ku-BAND (QuikSCAT) NRCS CAUSED BY RAIN-INDUCED ROUGHNESS AT HIGH WINDS (> 20 m/s) >>> YES

2: WHAT CAN WE INFER ABOUT THE EFFECT OF THIS PHENOMENA ON THE ENERGY AND MOISTURE FLUXES IN HURRICANES?

3. CAN WE OBSERVE A CORRELATION BETWEEN THE WIND MAGNITUDES AND RAINRATE IN HURRICANES ?

REGION OF OBSERVATION ->



DATA SOURCES AND PROPERTIES:

a) QuikSCAT Level 2A NRCS data, H-pol and V-pol

b) Simultaneous NEXRAD **3-D Volume Reflectivity** (S-band) within scatterometer beam (Inherent resolution is about 2 km) – **Observations are made every 6 minutes -> therefore the Δt with QScat is ≤ 3 min.**

c) Surface winds from NOAA Hurricane Research Division Analysis (courtesy of Mark Powell) at the time of the QuikSCAT overpass

Approach to the Data Analysis:

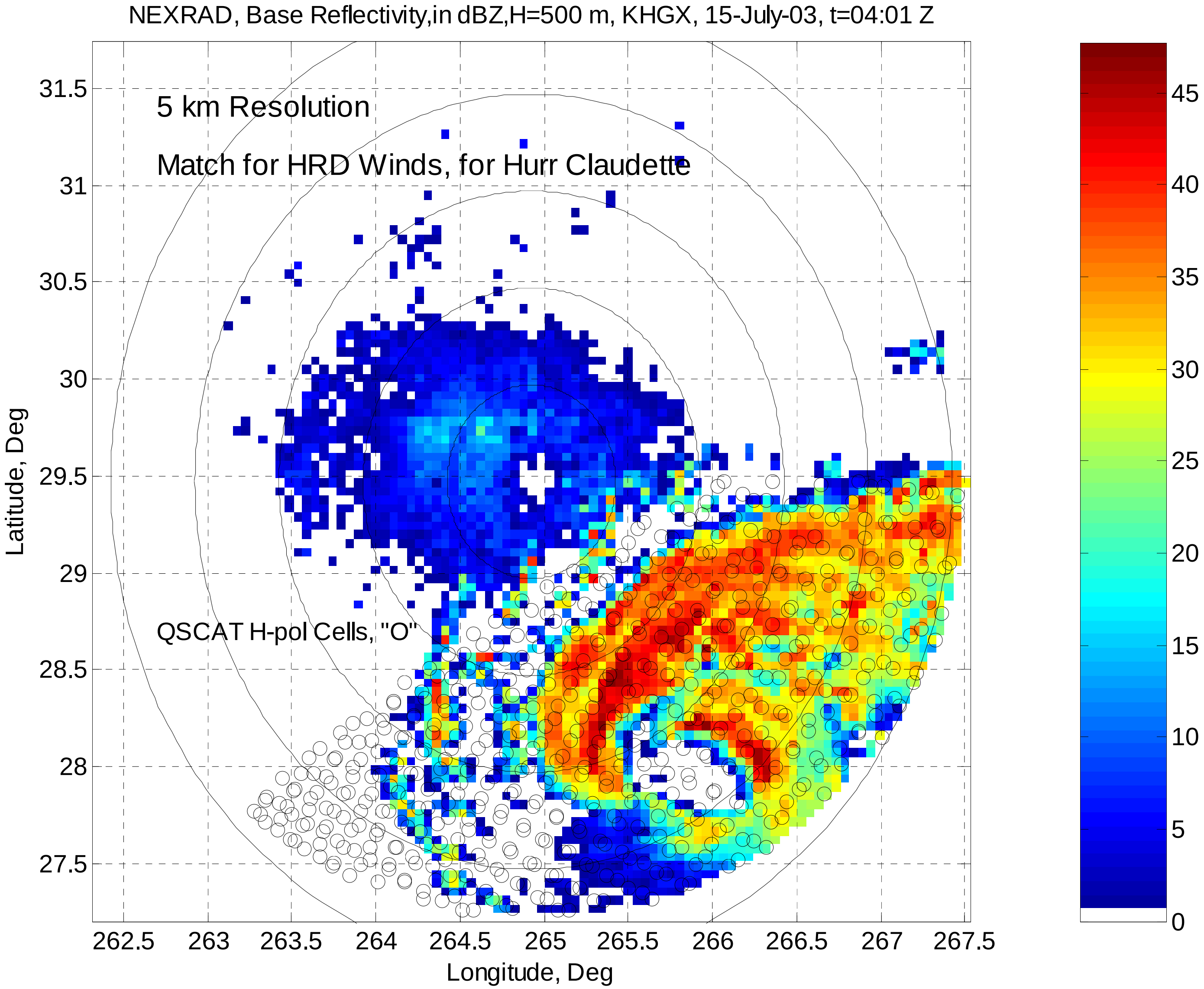
I. Compare and analyze the observed rainrate (using NEXRAD) and the wind magnitude estimated by the NOAA Hurricane Research Division (AOML) near the coasts during Hurricanes **Claudette** (2003), **Rita** (2005) and **Ike** (2008), at the location of each QuikSCAT cell. (about a 20 km x 20 km average for each)

II. Calculate estimates of the rain-impact enhanced sea surface roughness (NRCS) observed by QuikSCAT, (the “splash effect”) after the atmospheric attenuation and volume backscatter is removed.

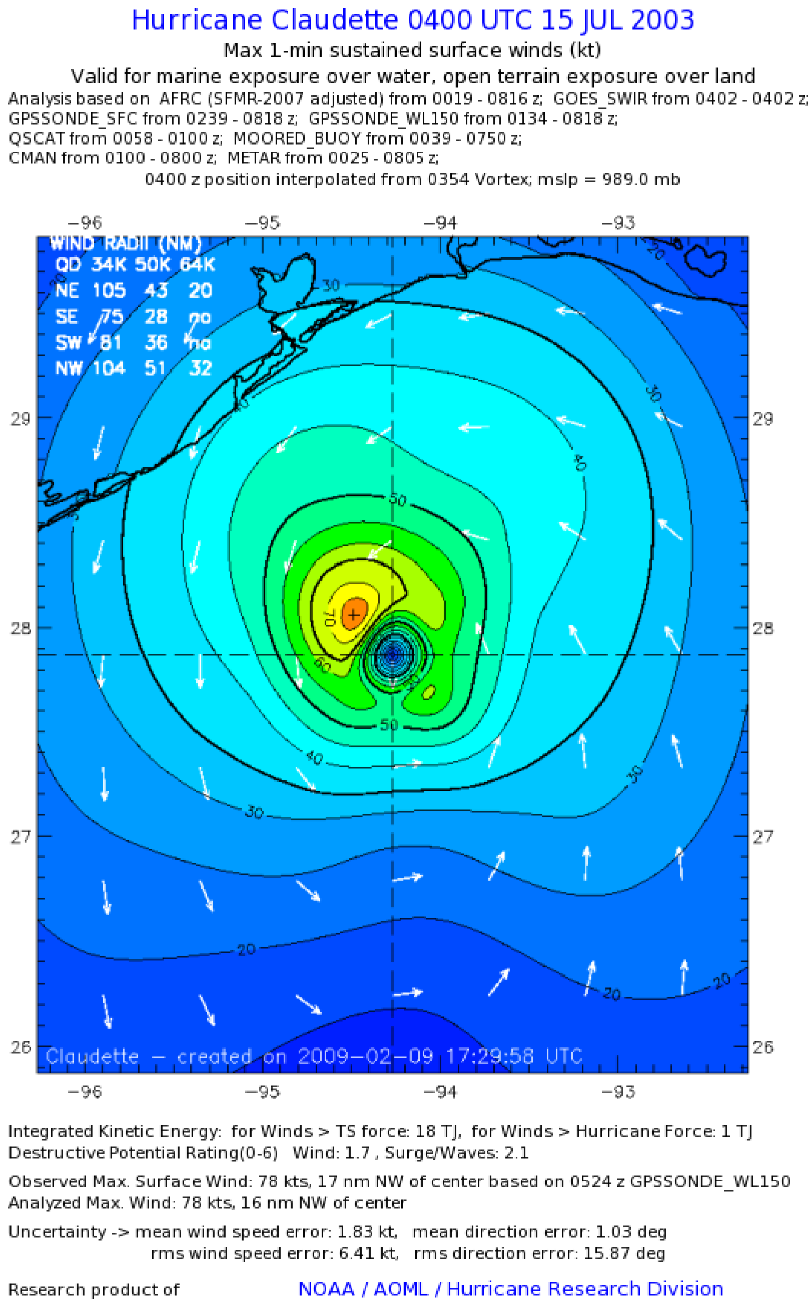
REFERENCE

Results published in IEEE Transactions on Geoscience and Remote Sensing, October, 2008, D.E. Weissman and M.A.Bourassa, M**easurements of the Effect of Rain-induced Sea Surface Roughness on the QuikSCAT Scatterometer Radar Cross Section** pp 2882-2894

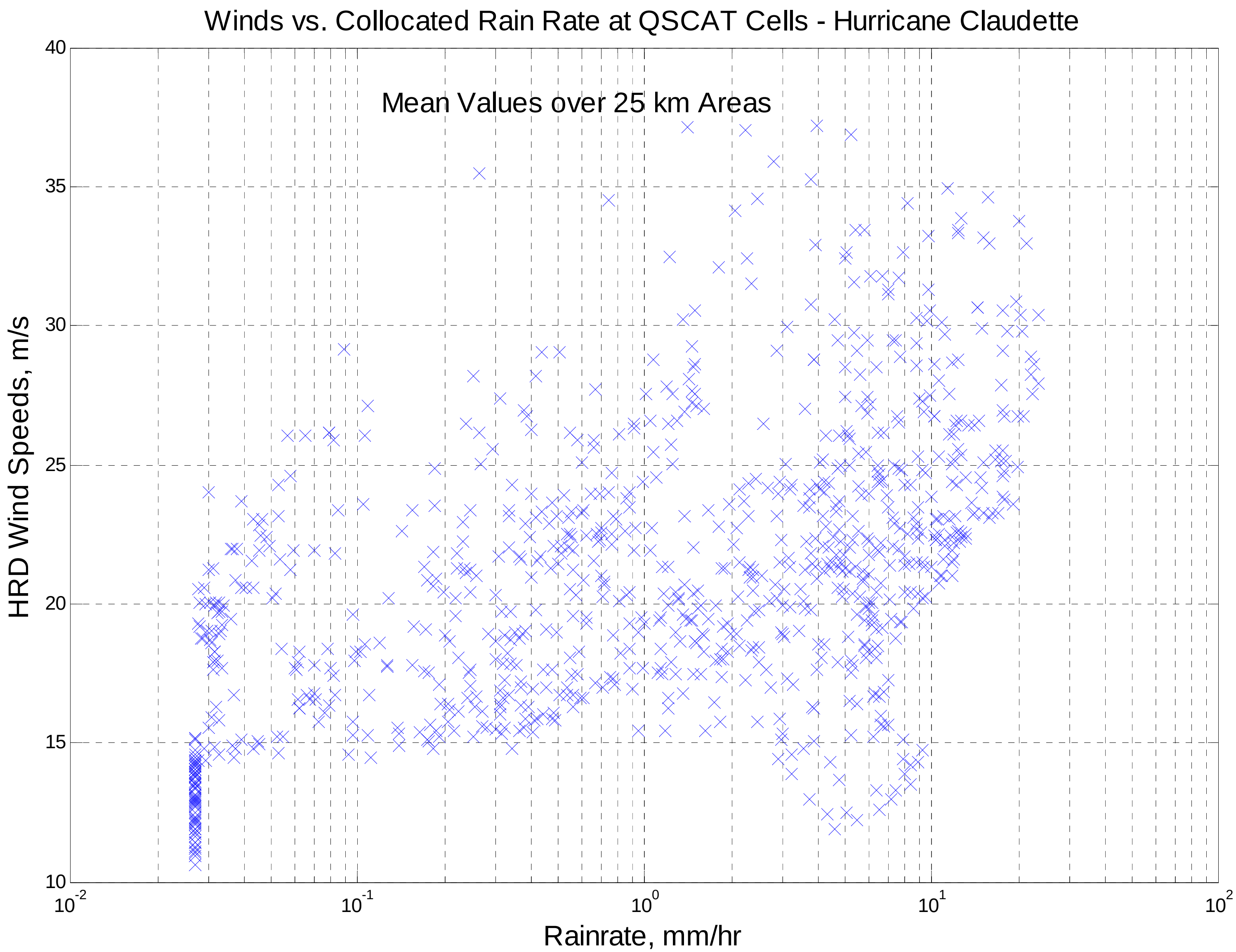
RAIN REFLECTIVITY (dBZ) MEASURED BY THE HOUSTON (KHGX) NEXRAD
HURRICANE CLAUDETTE



NOAA Hurricane Research Division Wind Contours, using special analysis combining several data sources

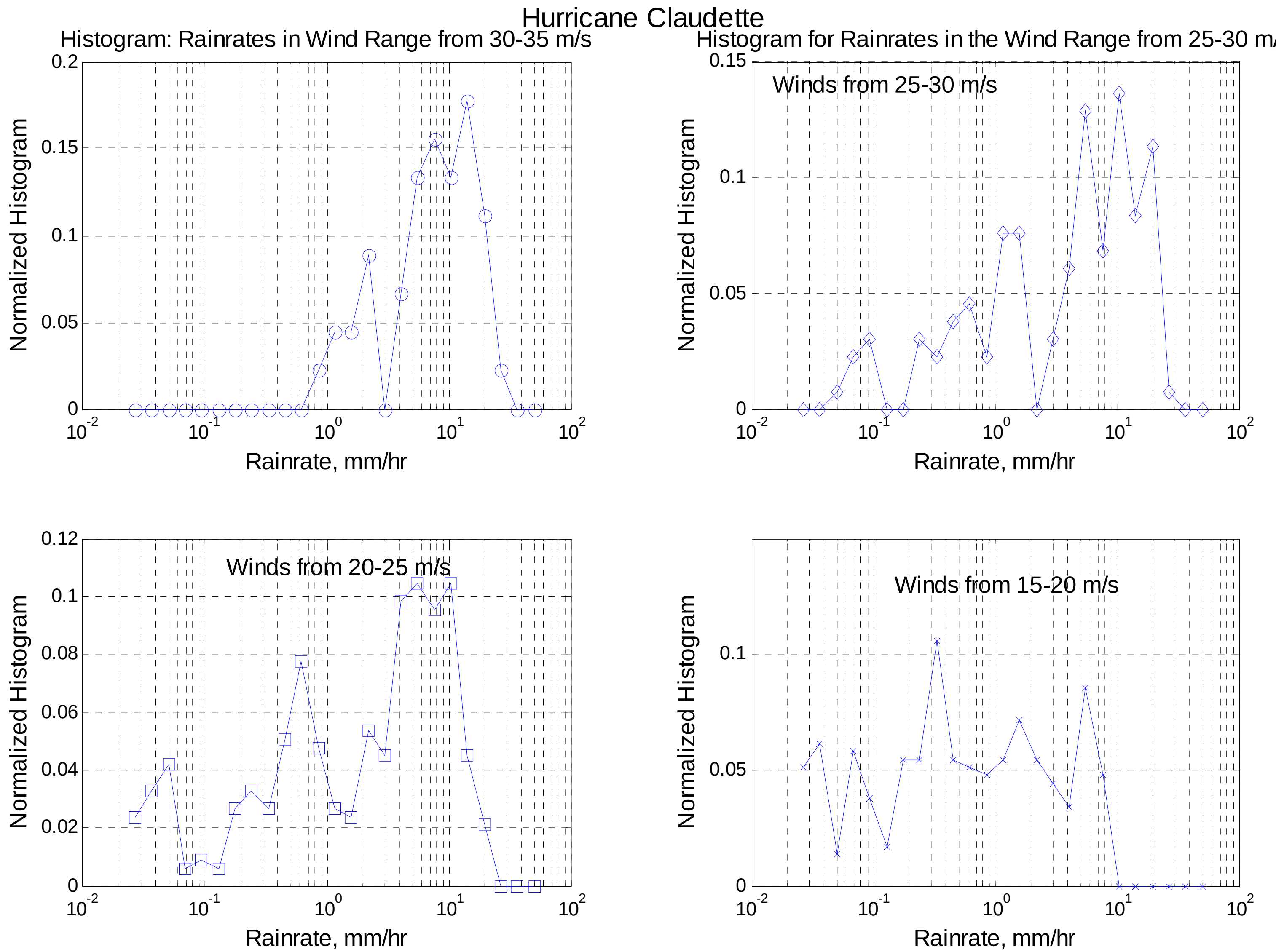


Scatterplot of Wind Magnitude vs Rain Rate at Location of QScat Cells within the observation range of the NEXRAD

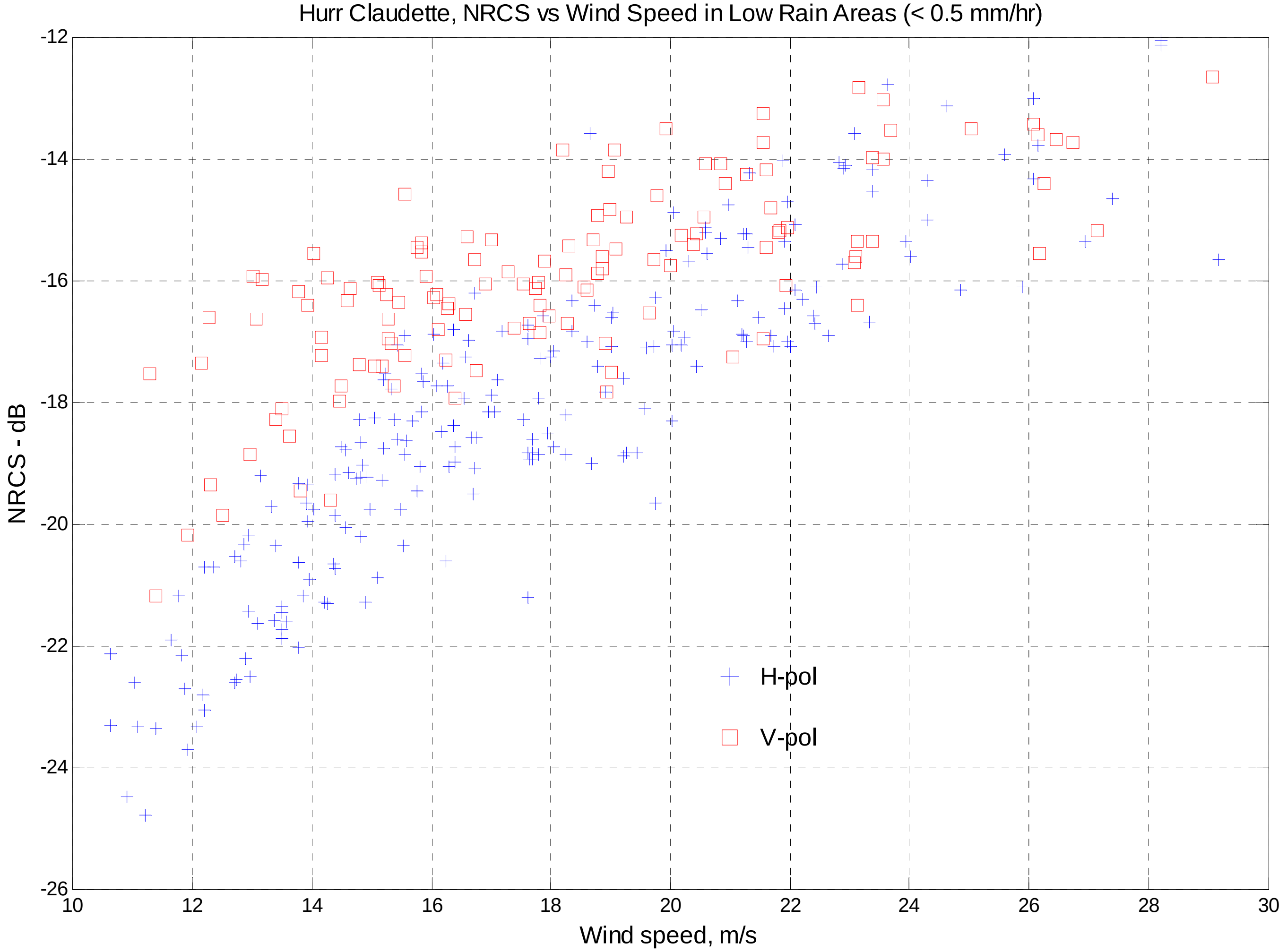


Study of the Relative Occurrence of Rain Intensity in Specific Wind Speed Bands

These data indicate that higher winds are accompanied by strong rain, most of the time

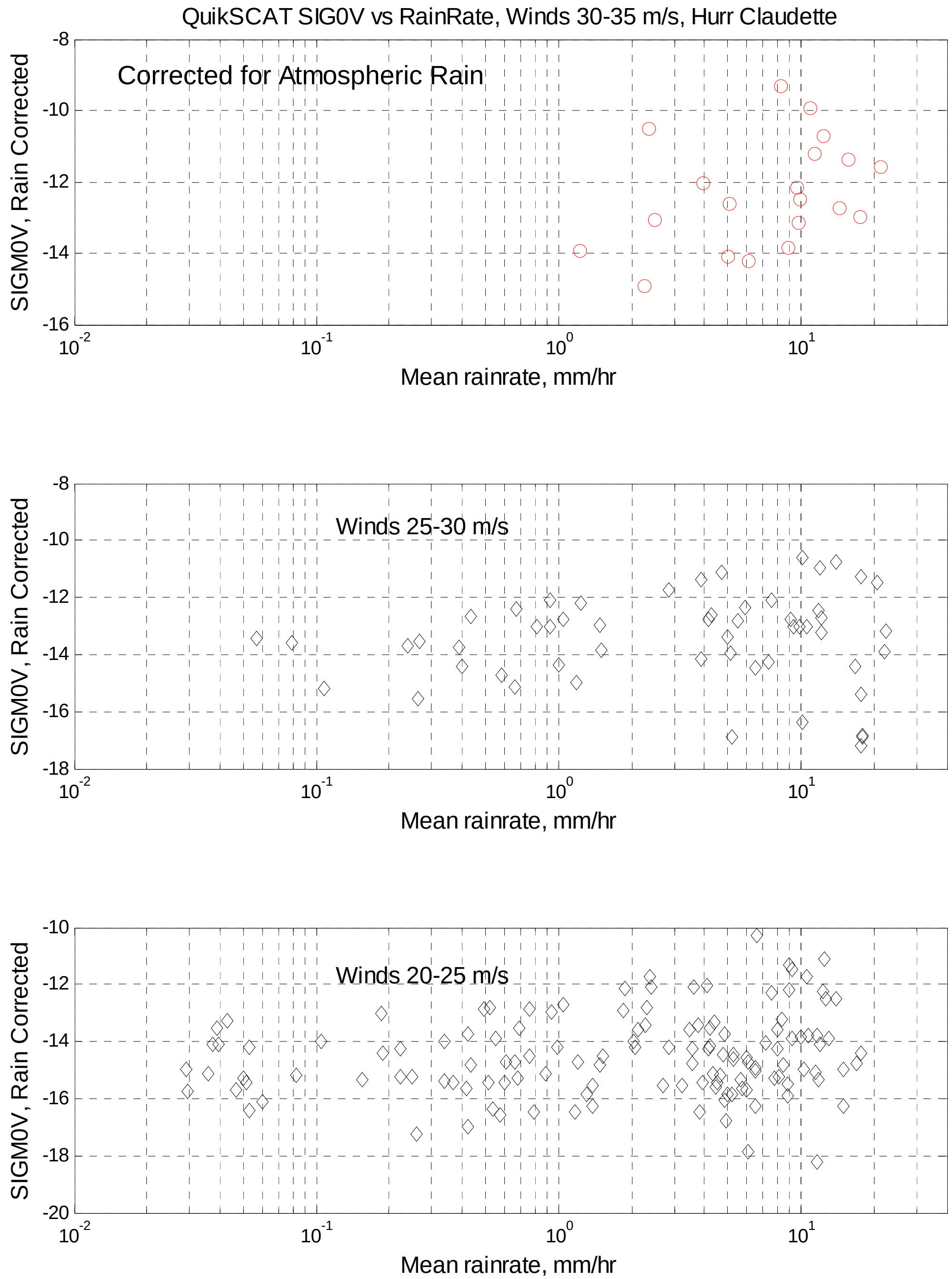


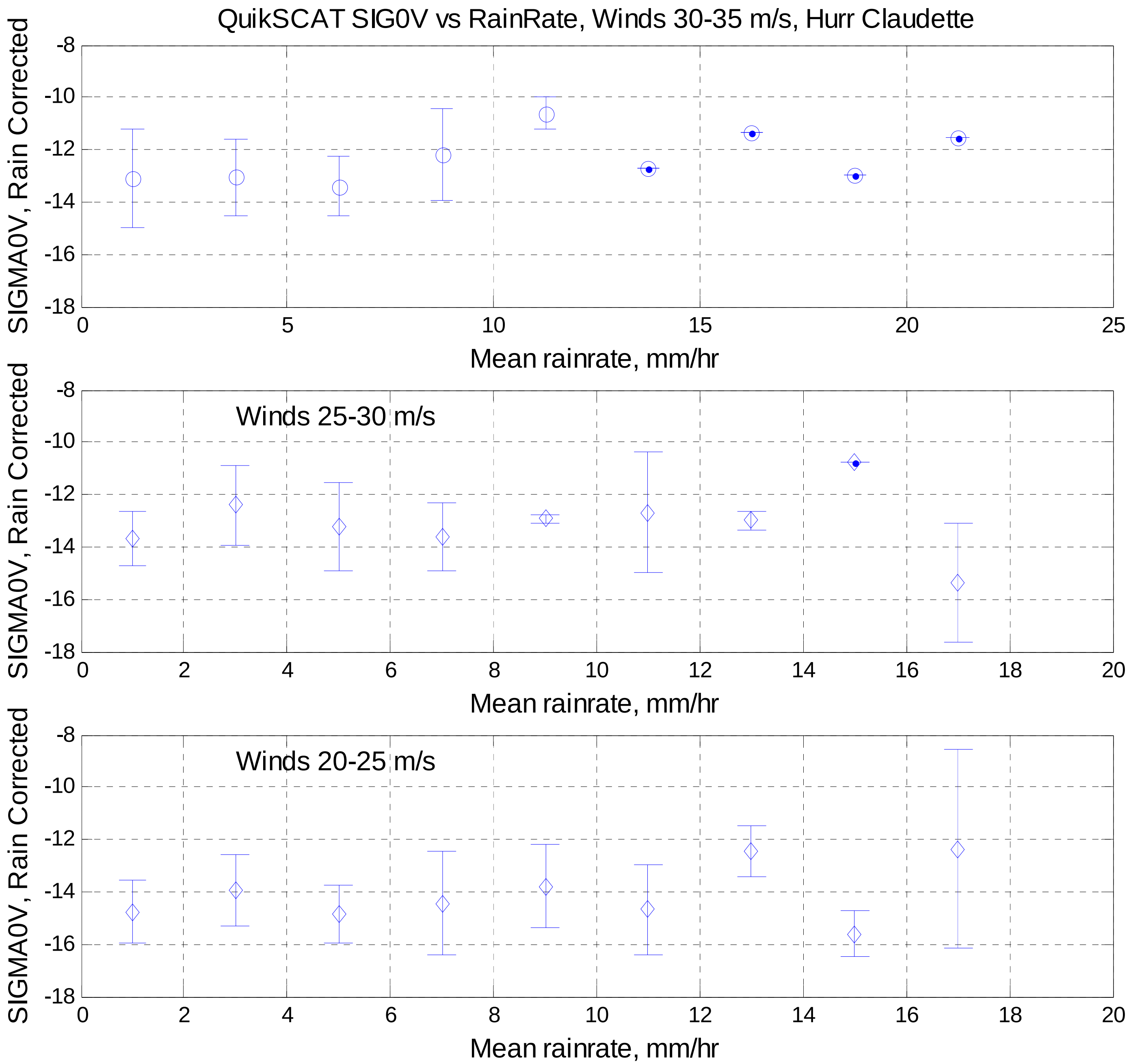
The dependence of the NCRS (V & H Pol),on wind, in the absence of rain;
NOTE>> that V-pol NRCS transitions from “greater than” to “equal to” above 25 m/s



If the NRCS is increased by rain splash at the surface, it could be interpreted as higher winds

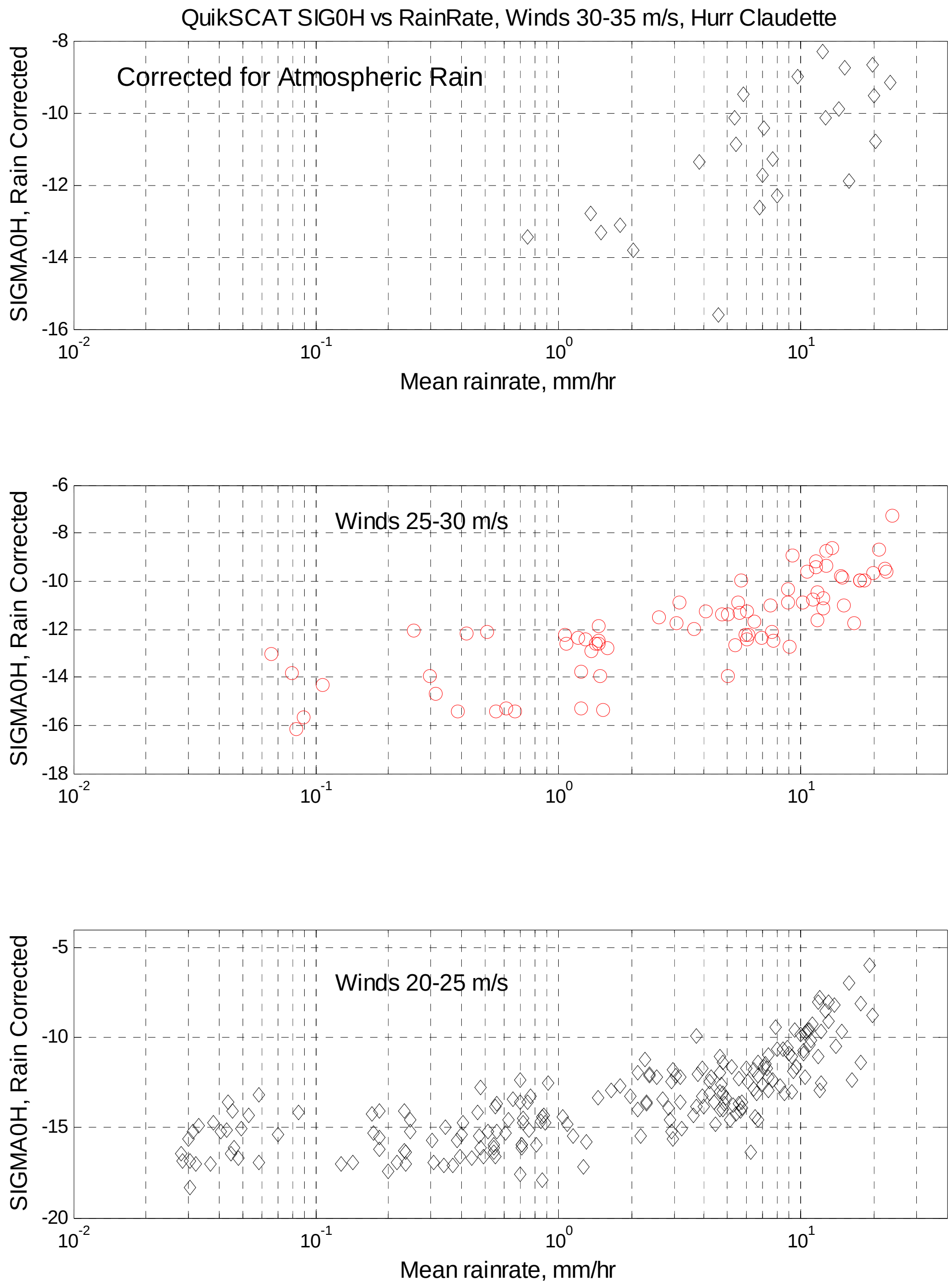
Surface NRCS vs Rain Intensity – V-pol – Narrow Wind Ranges



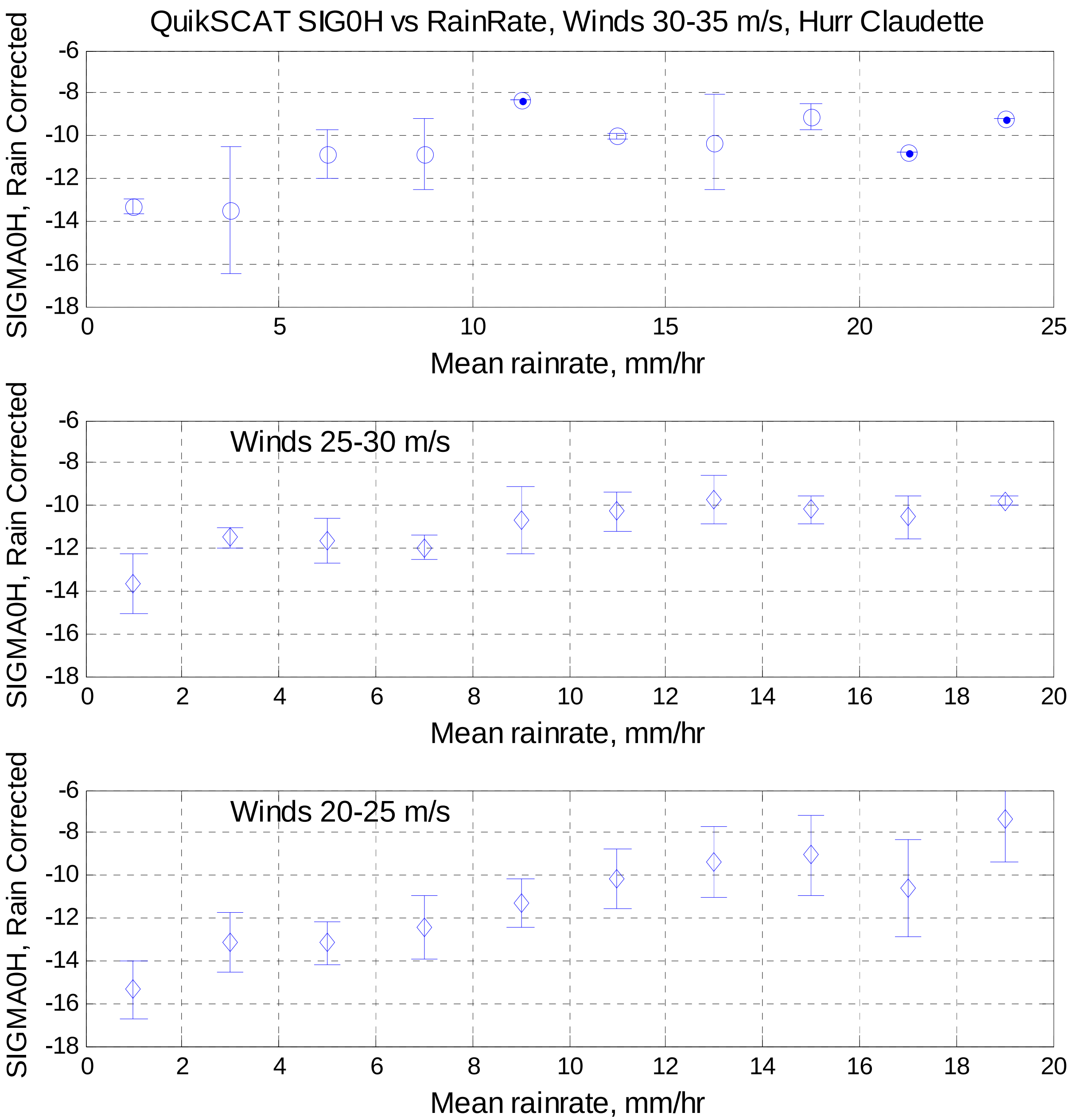


Surface NRCS vs Rain Intensity – V-pol – Narrow Wind

Ranges: Binned means and errorbars



Surface NRCS vs Rain Intensity – H-pol – Narrow Wind Ranges



Surface NRCS vs Rain Intensity – H-pol – Narrow Wind Ranges: Binned means and errorbars

5 dB splash increase

Preliminary Observations for Claudette:

1. Areas of highest winds are <u>always</u> accompanied by intense rain

2. Above U=20 m/s, V-pol NRCS is no longer greater than H-pol, they are equal; indicating a transition in the geometric properities of the small scale (centimeter) roughness

3. Both V-pol and H-pol NRCS vs wind speed starts to saturate at about 25 m/s, contrary to AC observations from “Fernandez, et al, JGR Oceans, 2006” which indicated saturation starting at 50 m/s. (BUT this may be due to footprint size)

4. The H-pol NRCS increases with rainrate, but not the V-pol

A fundamental study to: ".. establish a theory on the interaction between rain and water waves, based on momentum exchanges, and to assess its relative importance regarding the wave prediction models" was published by **LeMehaute and Khangaonkar, J.Phys.Oceanogr**, Dec. 1990

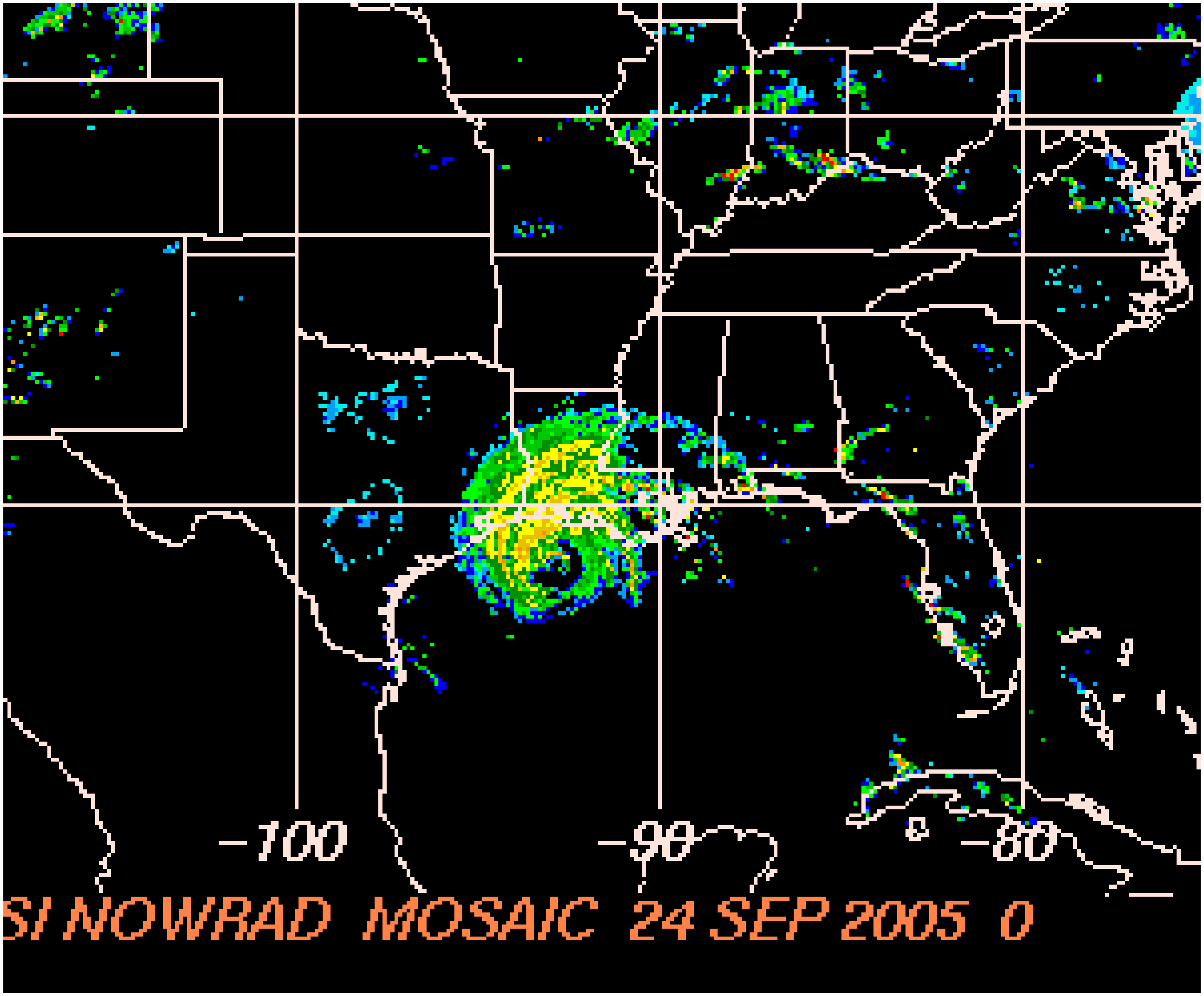
Rain horizontal momentum transfer (☺_R),

☺_R = raindrop mass density x rainrate x horizontal wind speed

For example: for rainrate = 25 mm/hr and U_{10} = 25 m/s, the ratio

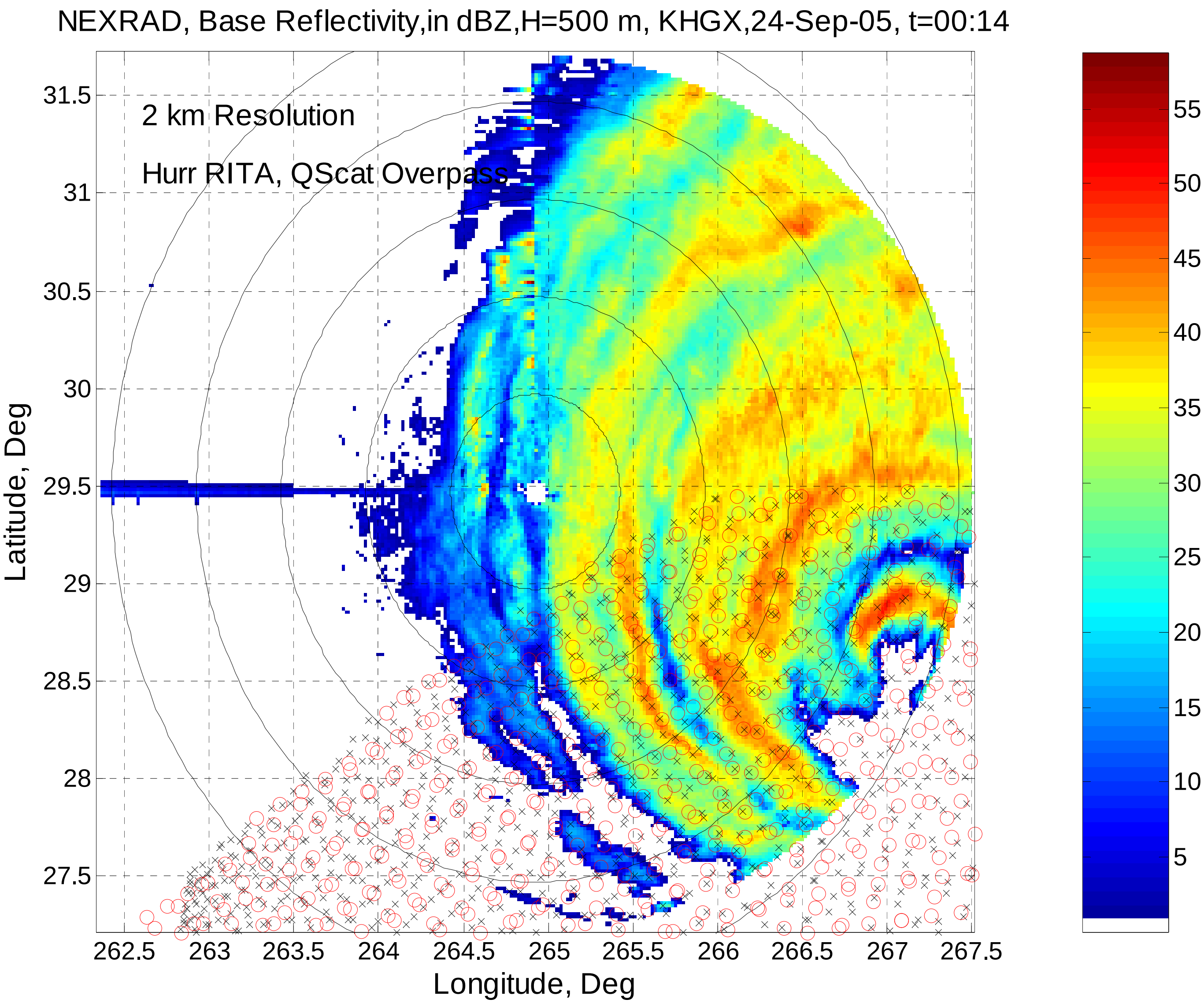
☺_R / wind stress = 8.4 %

However this number gives no direct indication about the roughness properties to which Ku-band and C-band radar responds.



Hurricane Rita – NEXRAD Mosaic – 24Sept05_00Z

Reflectivity (in dbZ) Measured by the Houston NEXRAD at time of QScat overpass. QScat V-pol and H-pol Cell Locations are plotted (“x” and “o”)



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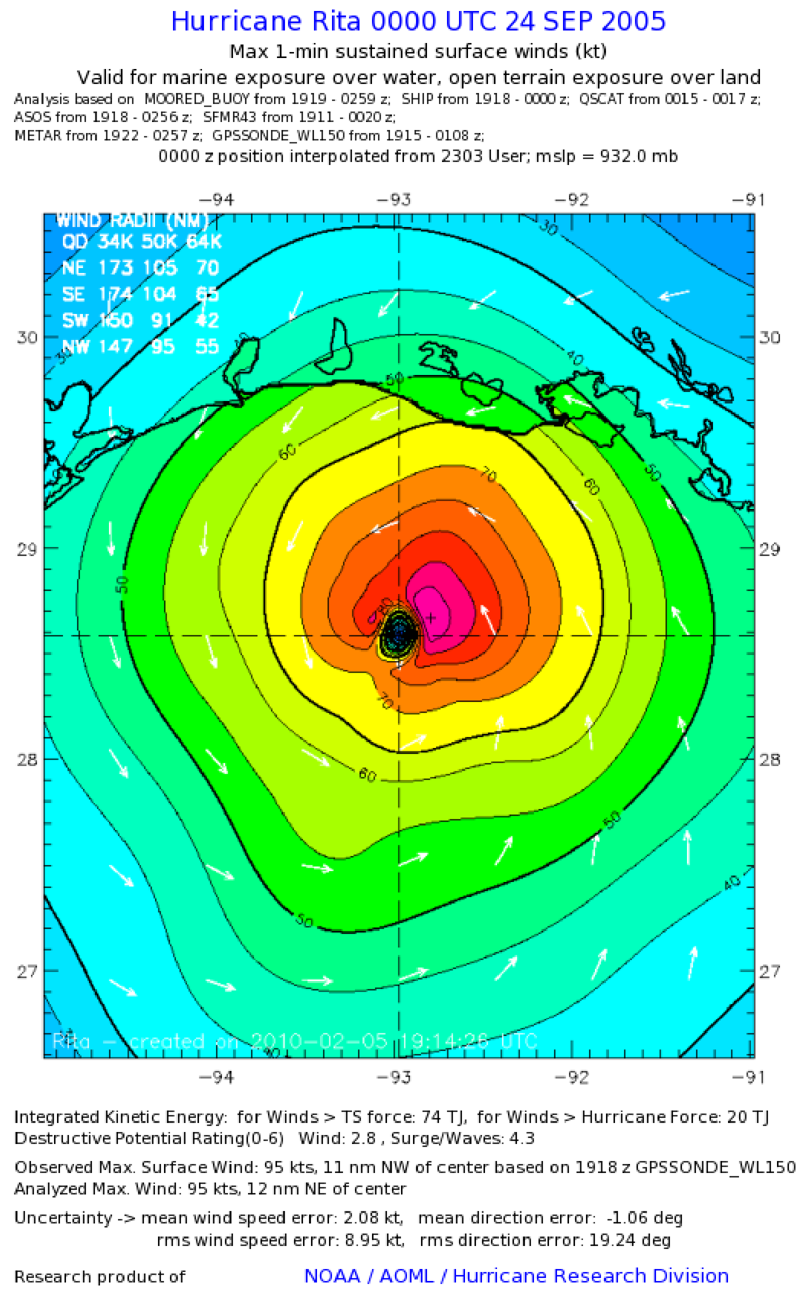
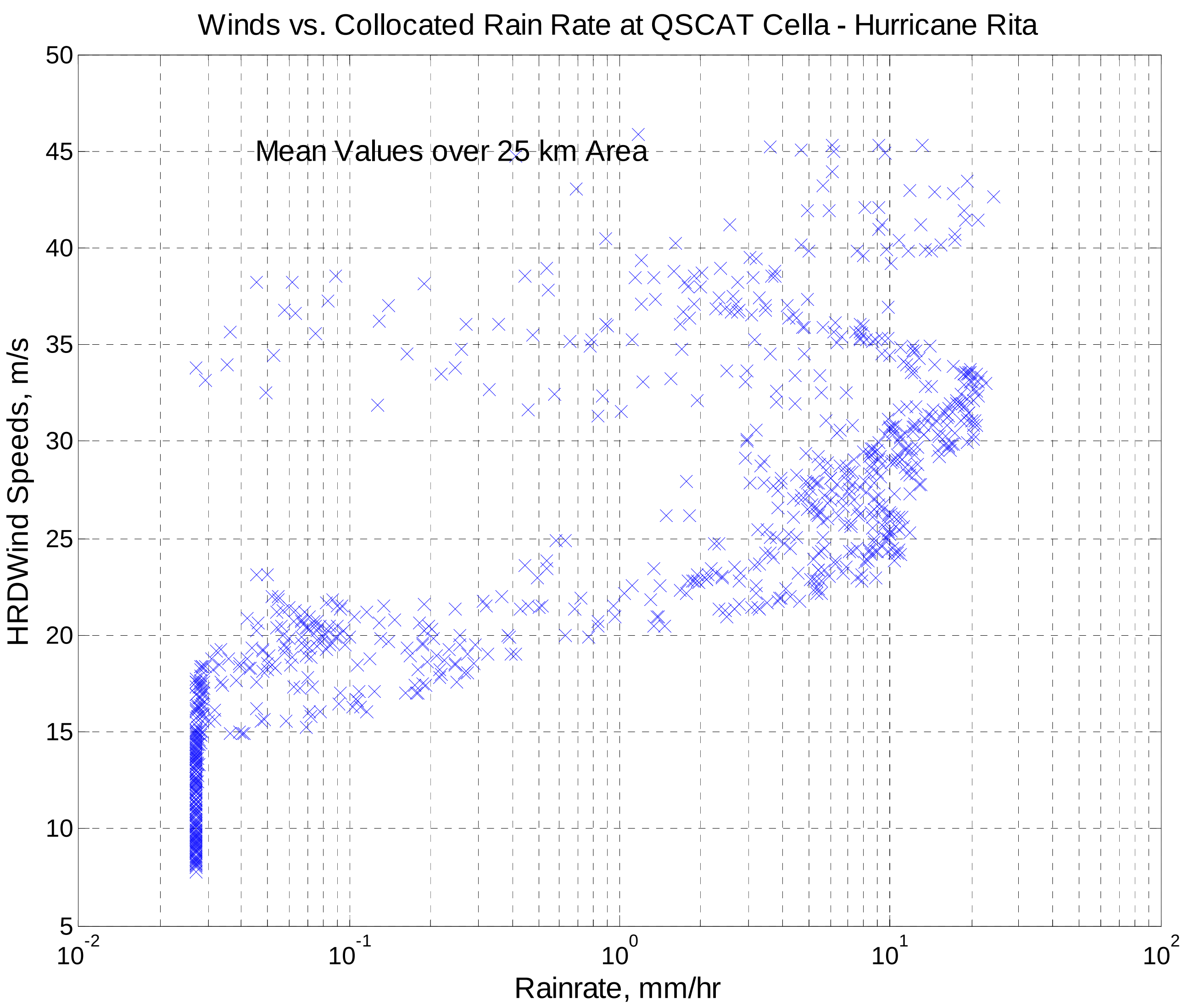
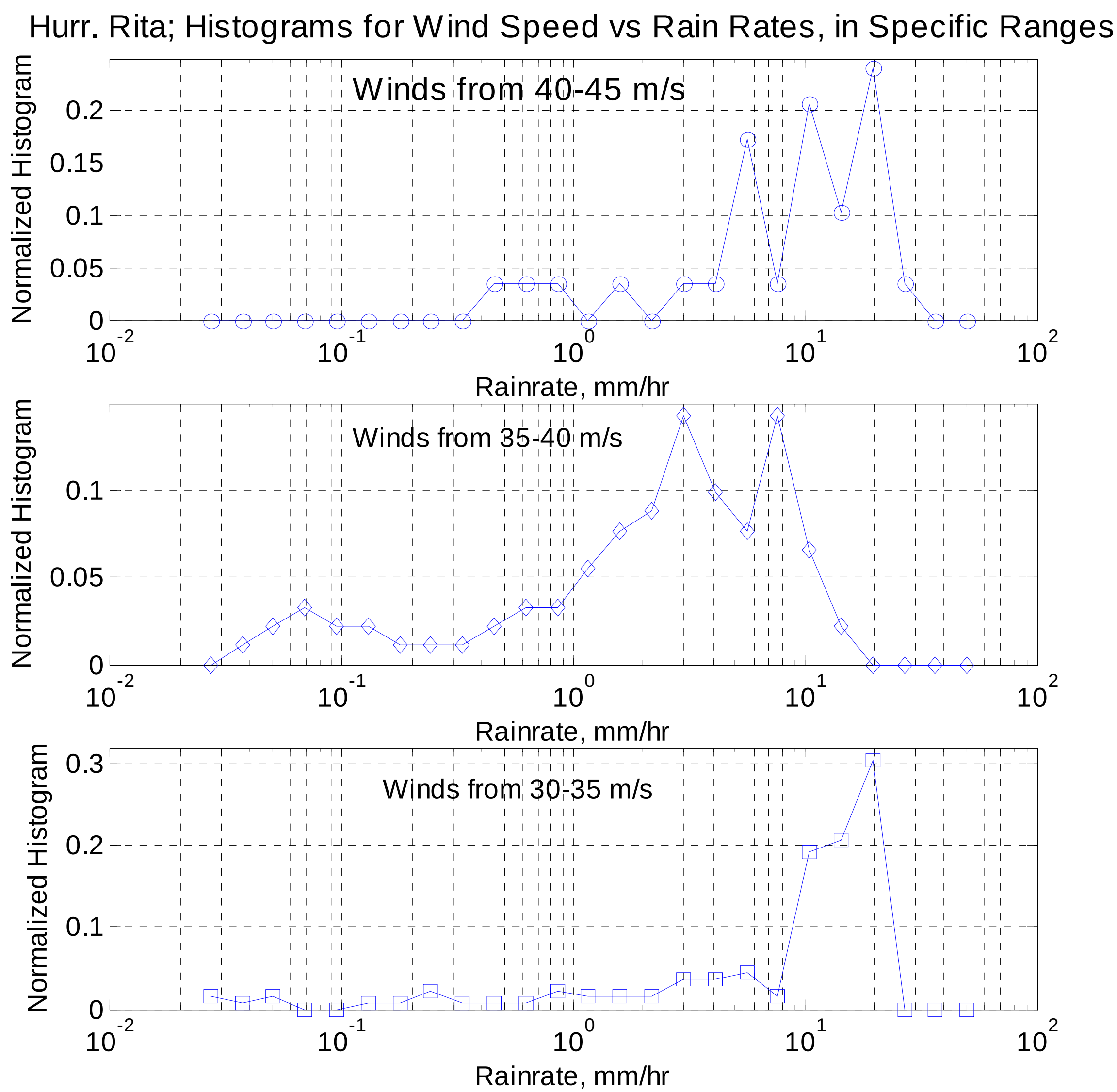


Scatterplot of Wind Magnitude vs Rain Rate at Location of QScat Cells within the observation range of the NEXRAD



Study of the Relative Occurrence of Rain Intensity in Specific Wind Speed Bands



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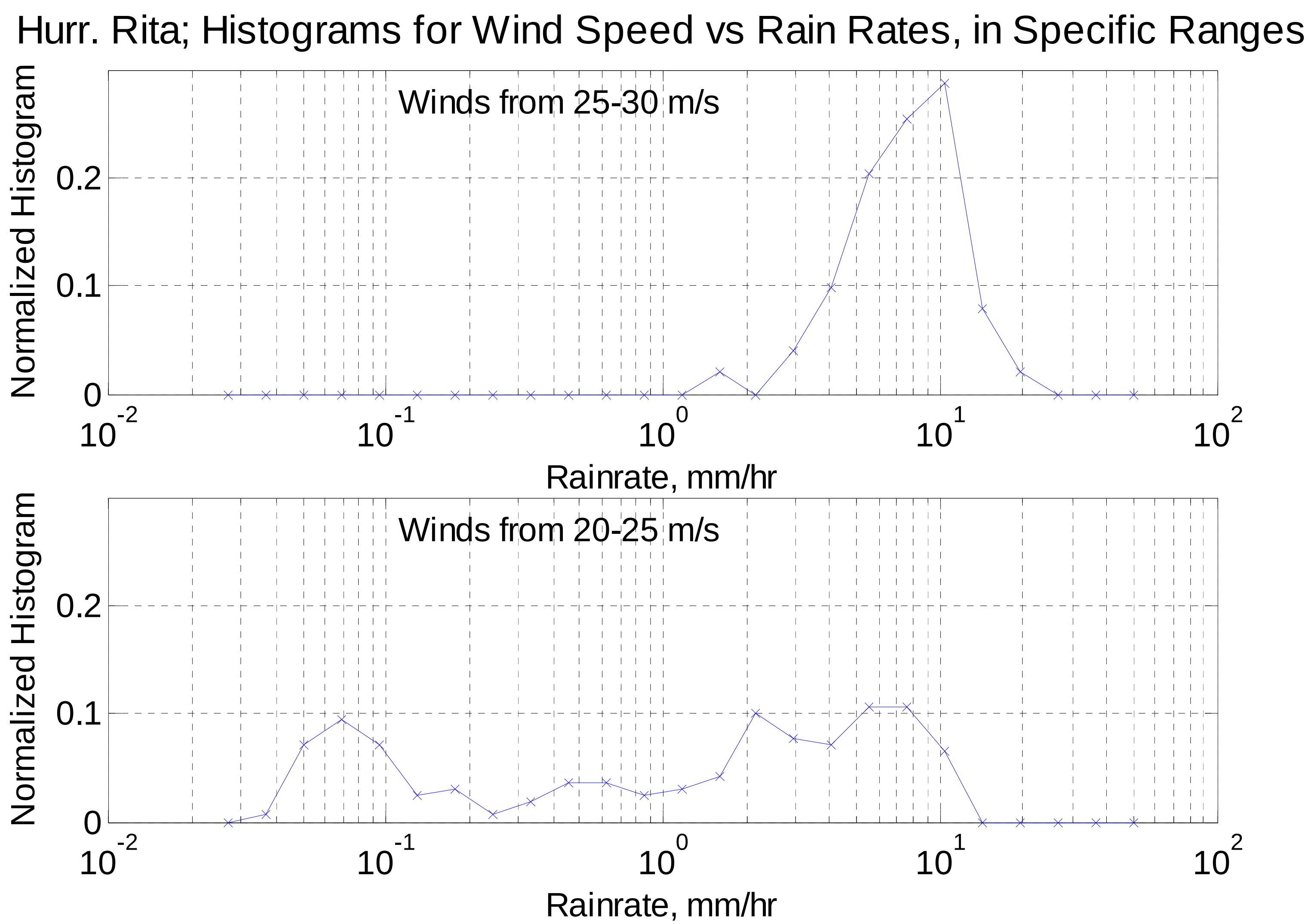
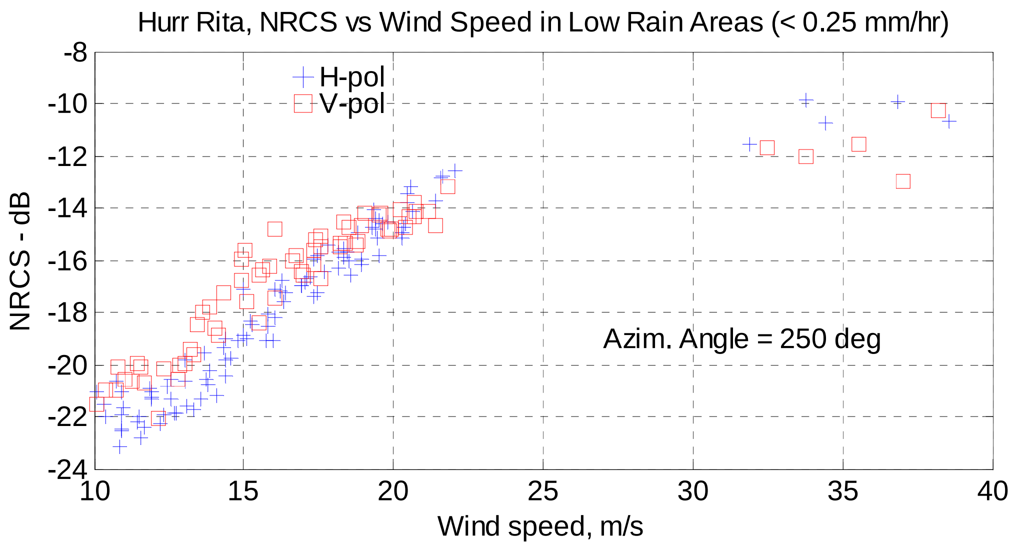
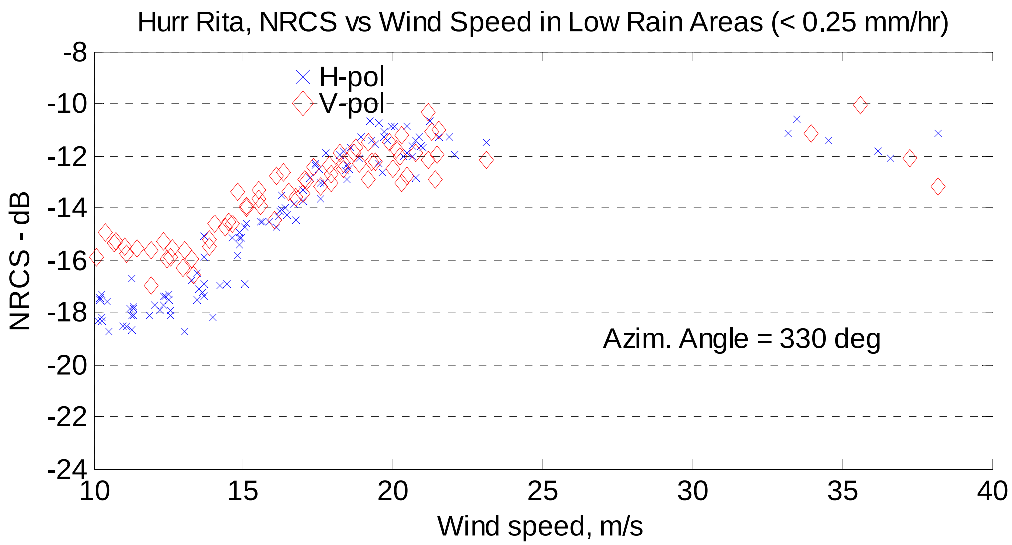
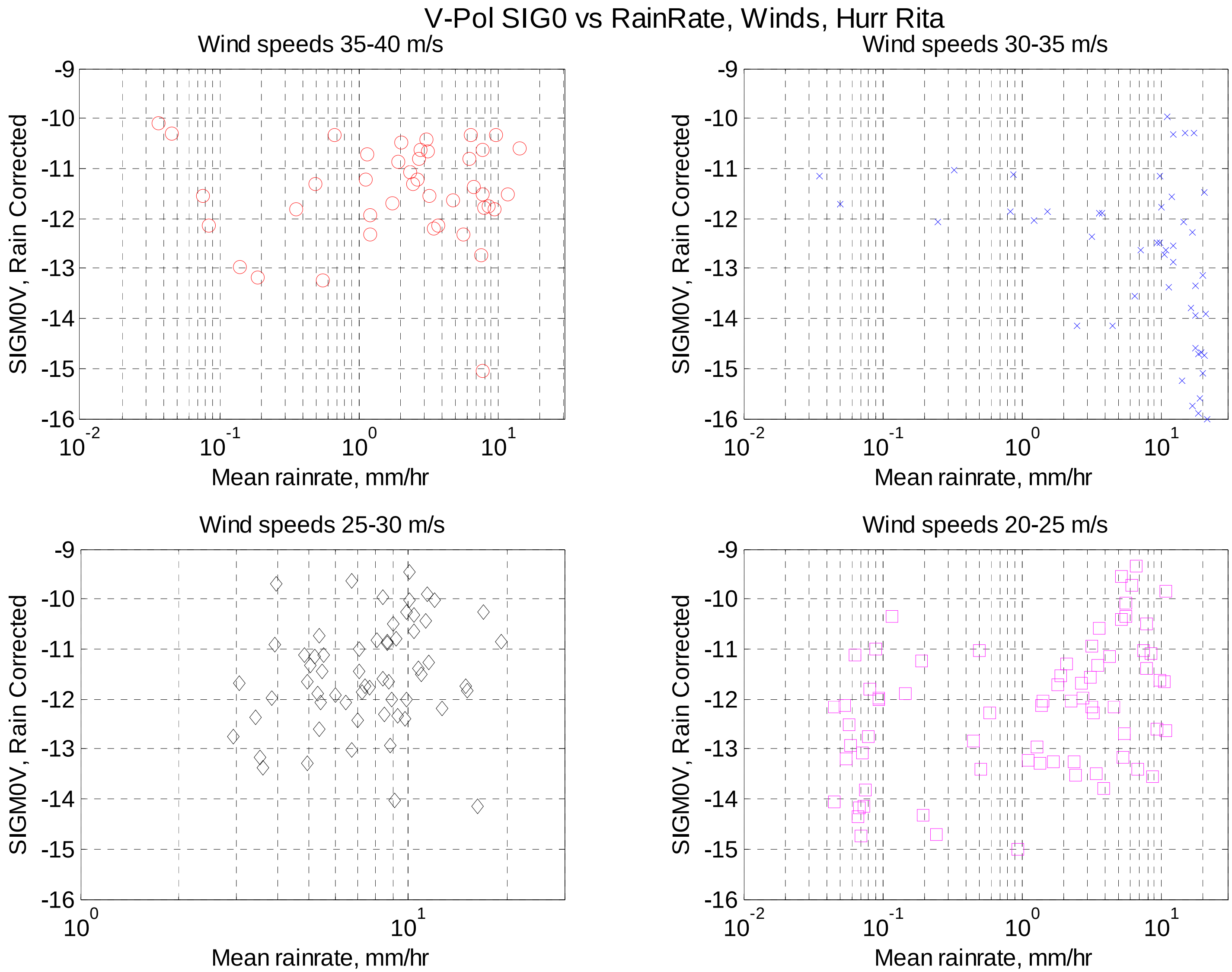


NRCS (V-pol & H-pol) vs Wind Magnitudes in Separate Azimuth Look Directions; with negligible rain intensity > ***Typical properties but strong azimuth variation***

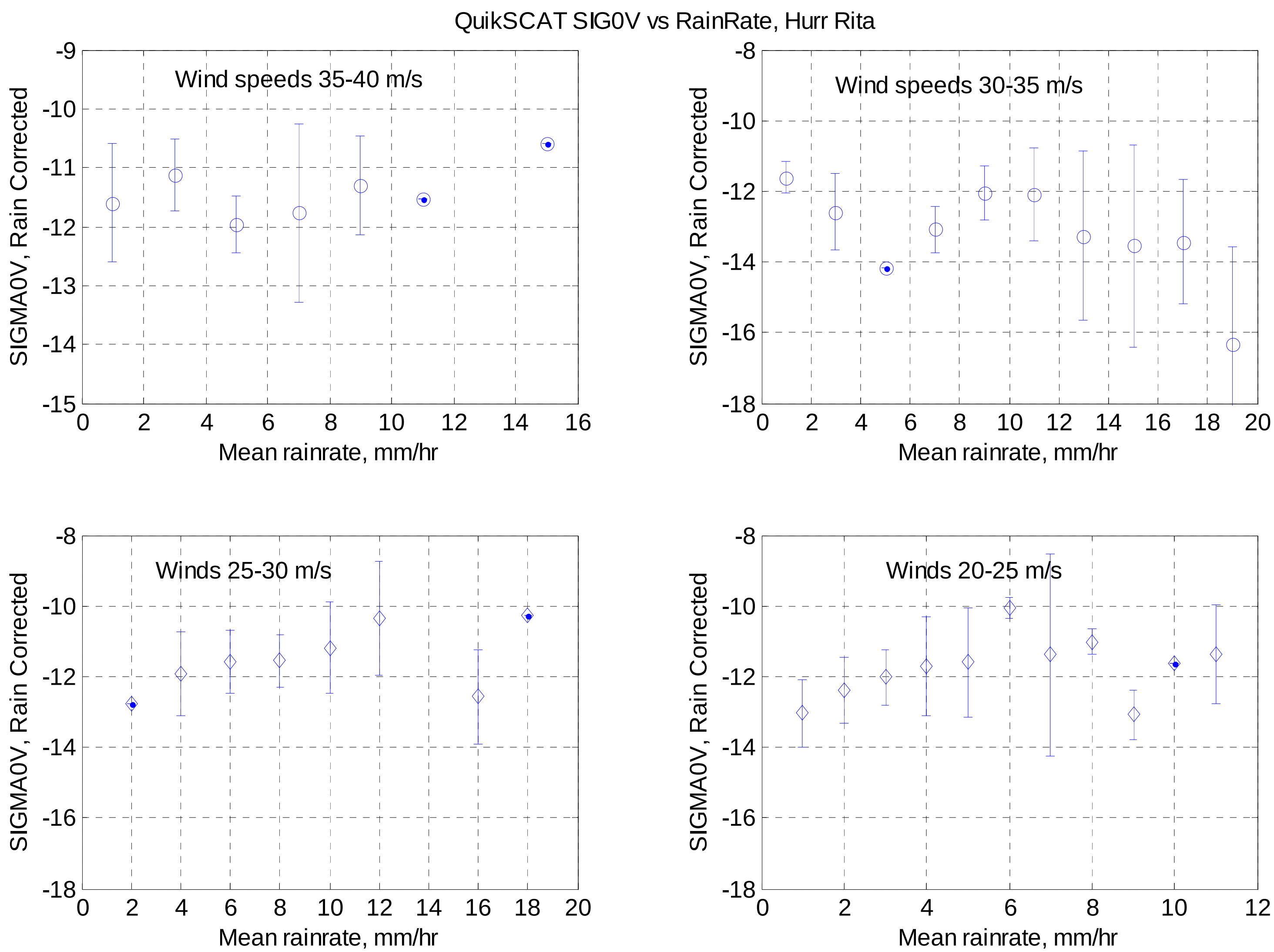




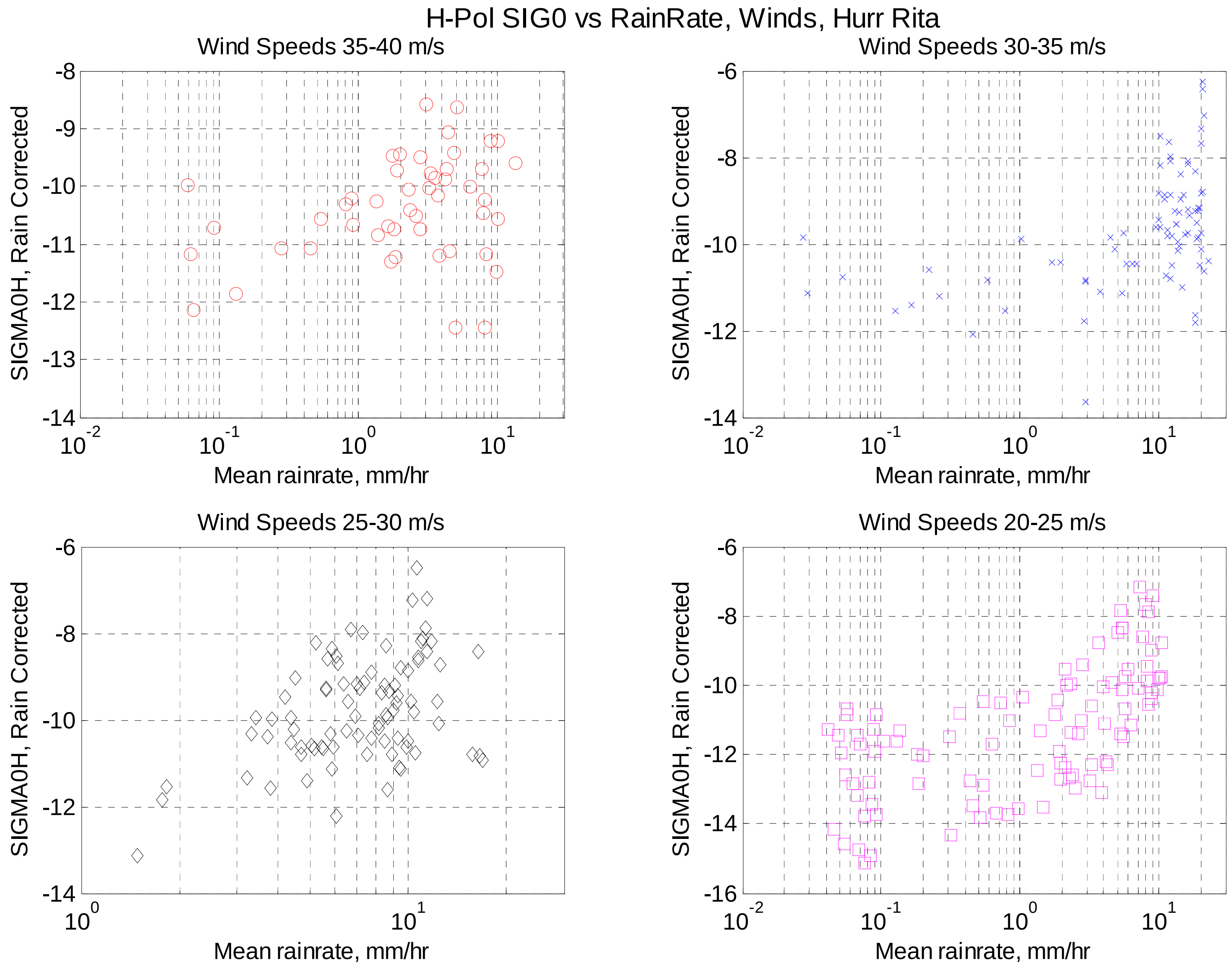
Surface NRCS vs Rain Intensity – V-pol – Narrow Wind Ranges



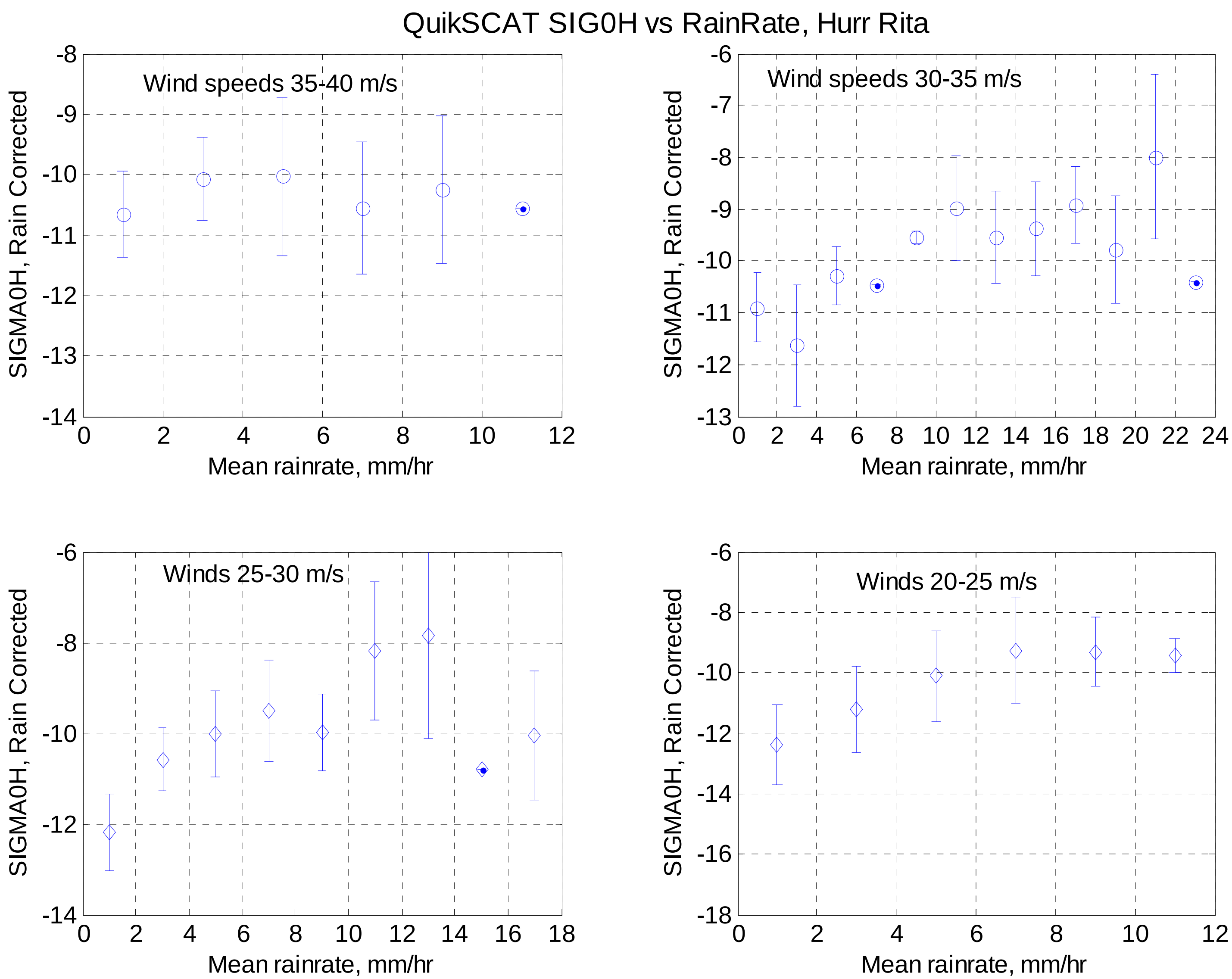
Surface NRCS vs Rain Intensity – V-pol – Narrow Wind Ranges: Binned means and errorbars



Surface NRCS vs Rain Intensity – H-pol – Narrow Wind Ranges

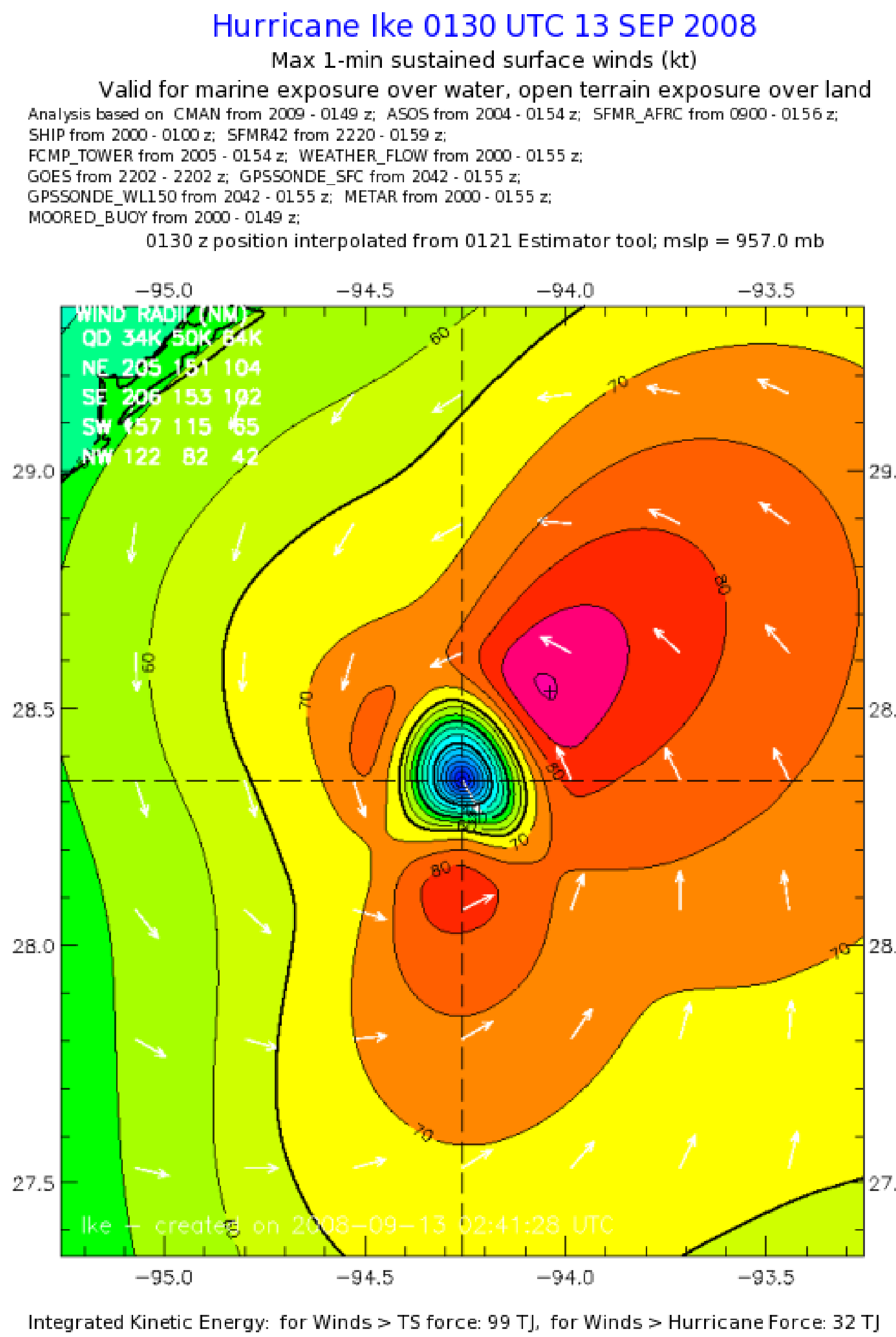


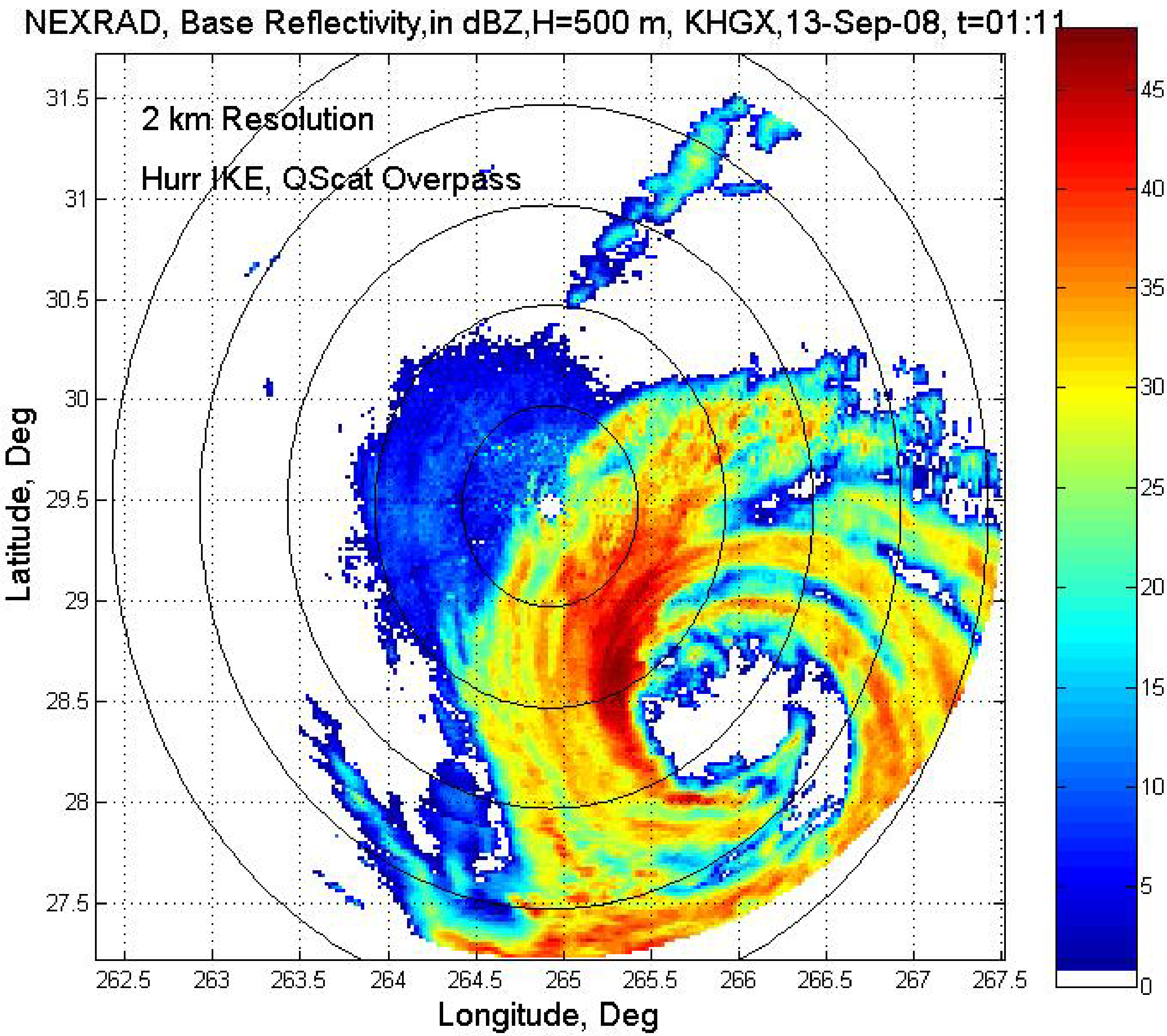
Surface NRCS vs Rain Intensity – H-pol – Narrow Wind Ranges: Binned means and errorbars



Contour map of wind speeds, based on NOAA/ Hurricane Research Division composite from multiple data sources: surface, aircraft & satellite

$2^o \times 2^o$ region shown





NEXRAD, Base Reflectivity,in dBZ,H=500 m, KHGX,13-Sep-08, t=01:11
2 km Resolution
Hurr IKE, QScat Overpass
Latitude, Deg
Longitude, Deg

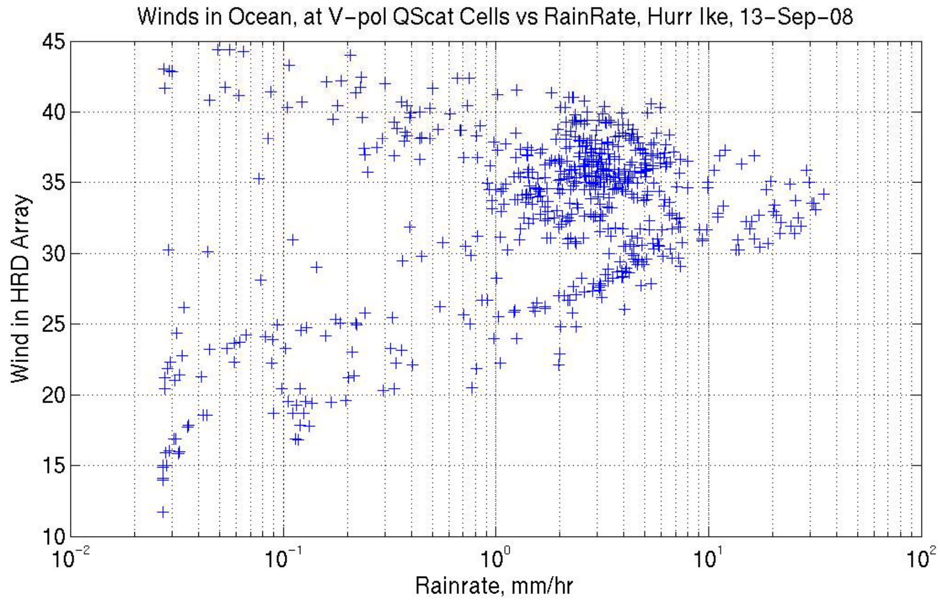
Plots of Collocated Winds versus Rainrate:

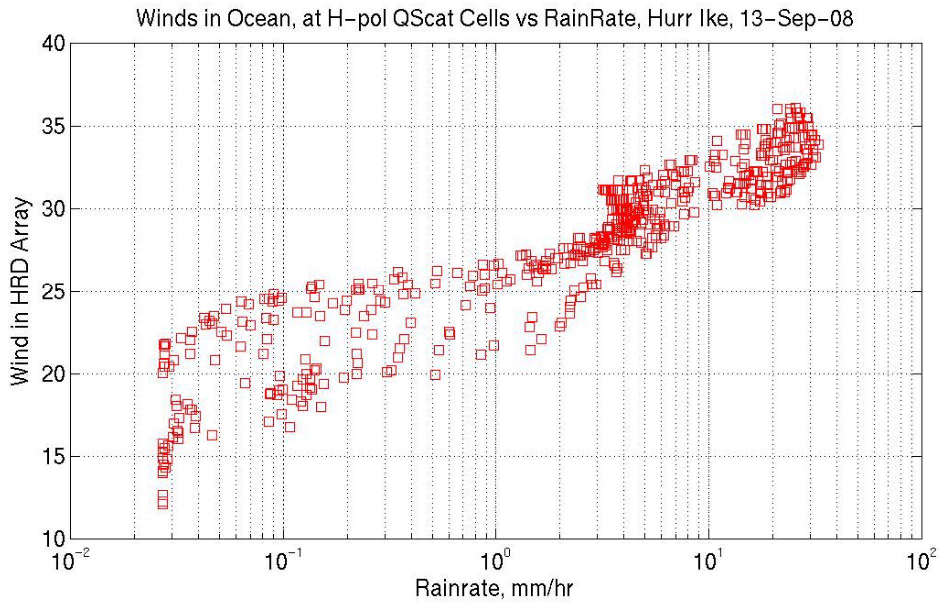
TO DETERMINE THE FRACTION OF HIGH WIND AREAS THAT ARE AFFECTED BY RAIN

Upper graph = locations where QScat V-pol data was used

(b) Lower graph = locations where QScat H-pol data was used

RESULT: HIGH WINDS ARE USUALLY ACCOMPANIED BY HIGH RAINRATE





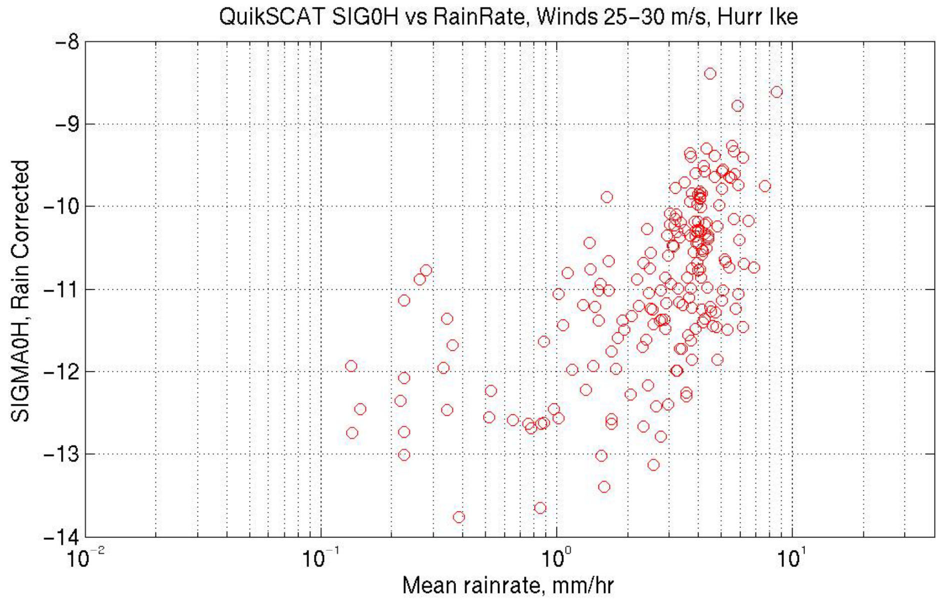
OBSERVATION OF THE CORRECTED SURFACE NRCS versus RAIN RATE

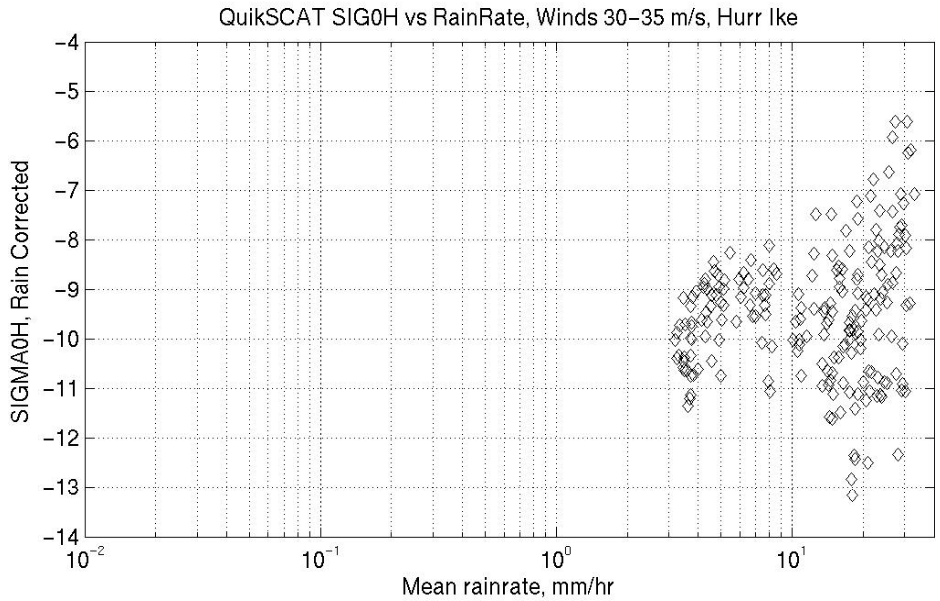
Scatterplots of H-pol data separated into wind ranges

Upper graph: winds 25-30 m/s

Lower graph: winds 30-35 m/s

RESULT: Increasing rainrates frequently produce increases in the H-pol surface NRCS, by 2-to-3 dB





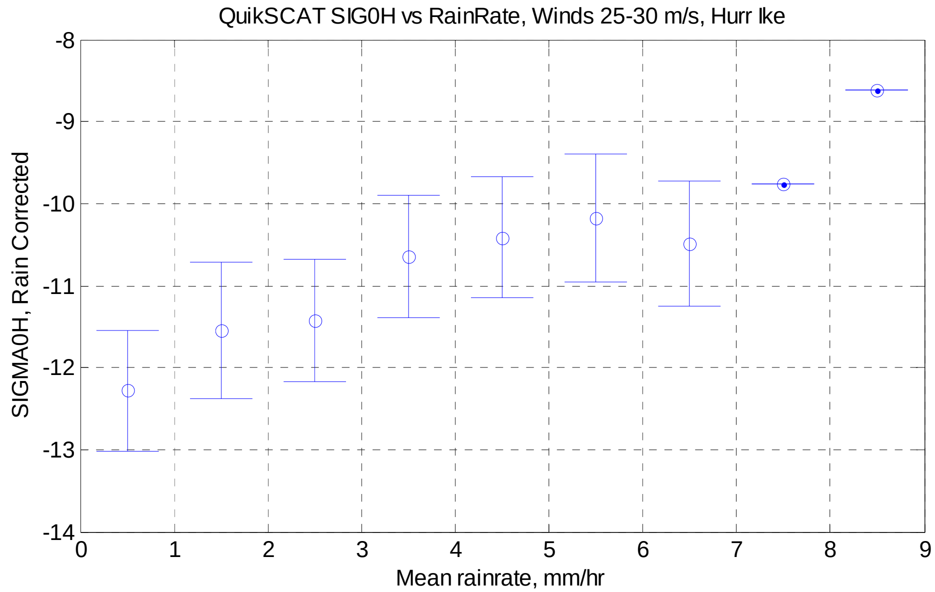
OBSERVATION OF THE CORRECTED SURFACE NRCS versus RAIN RATE

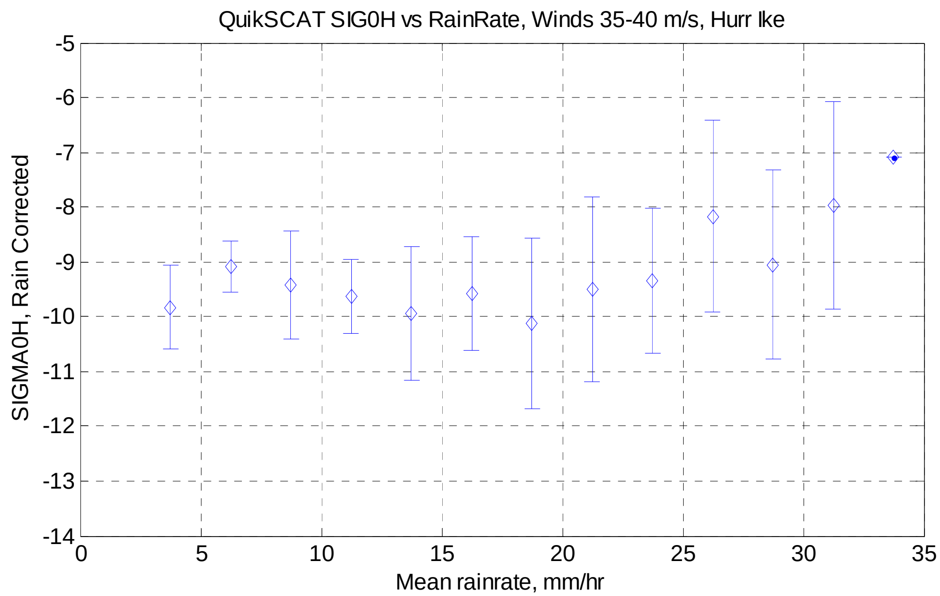
Binned and mean values of H-pol data separated into wind ranges
Errorbars are +/- one-Standard Deviation

Upper graph: winds 25-30 m/s

Lower graph: winds 30-35 m/s

RESULT: Increasing rainrates frequently produce increases in the surface H-pol NRCS, by 2-to-3 dB





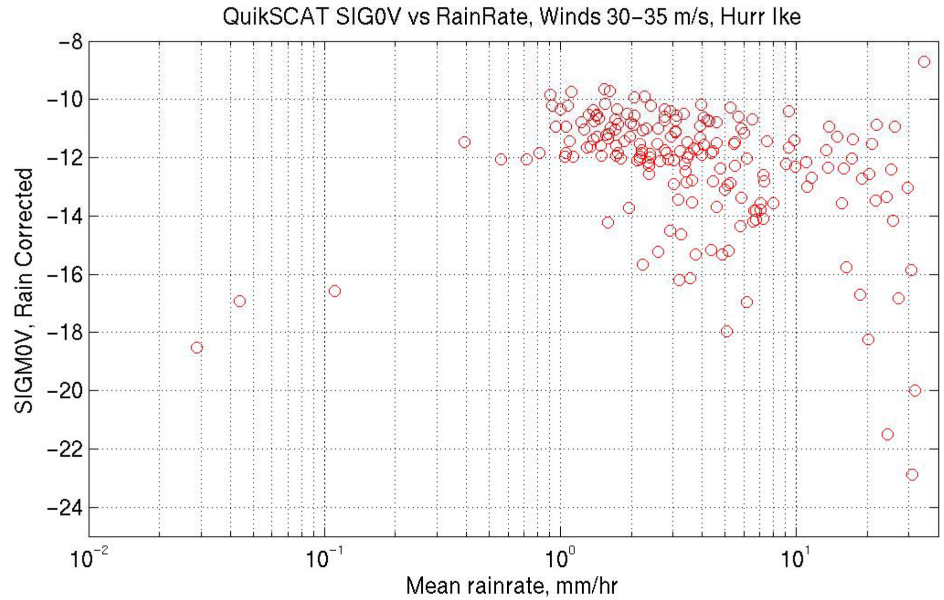
OBSERVATION OF THE CORRECTED SURFACE NRCS versus RAIN RATE

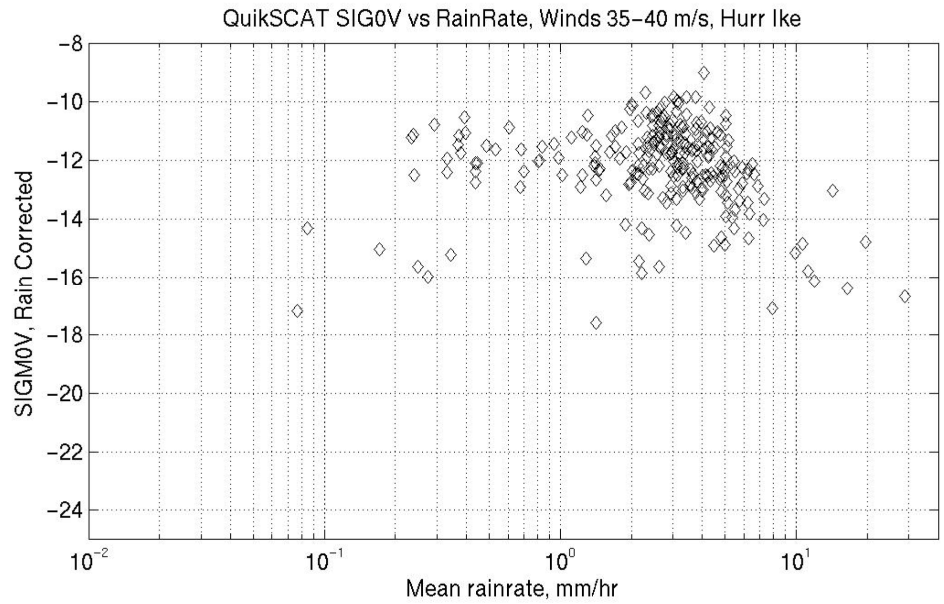
Scatterplots of V-pol data separated into wind ranges

Upper graph: winds 30-35 m/s

Lower graph: winds 35-40 m/s

RESULT: Increasing rainrates frequently produce decreases in the V-pol surface NRCS, by 1-to-3 dB





OBSERVATION OF THE CORRECTED SURFACE NRCS versus RAIN RATE

Binned and mean values of V-pol data separated into wind ranges Errorbars are +/- one-Standard Deviation

Upper graph: winds 30-35 m/s

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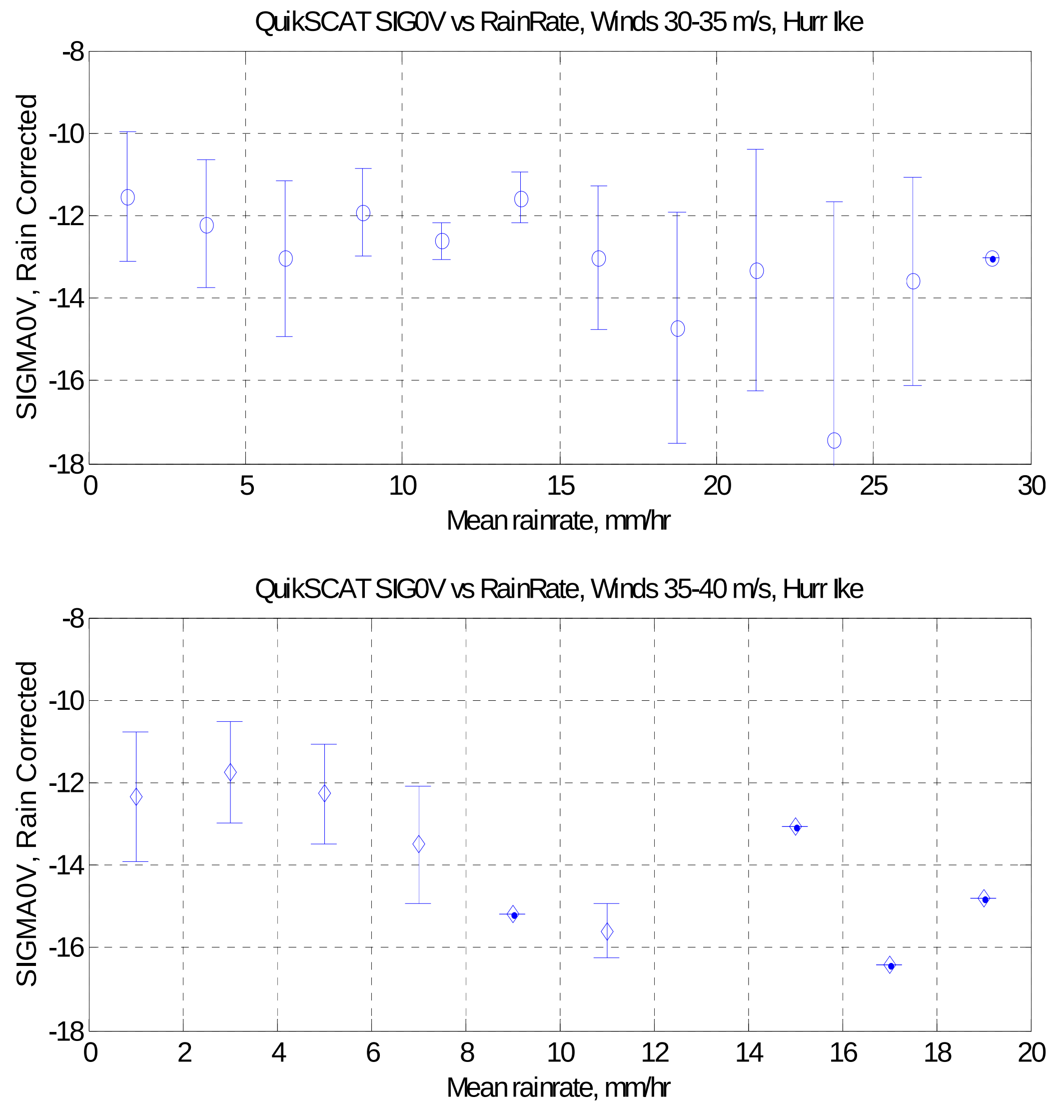
RESULT: Increasing rainrates frequently produce decreases in the surface V-pol NRCS, by 1-to-3 dB



Summary for Hurricane Wind Speeds:

The changes in surface NRCS produced by substantial rainrate indicate that intense rain will modify the centimeter scale roughness that affects the Ku-band NRCS; **up to wind magnitudes of 35 m/s.** No evidence is found above this level; <u>but these are relatively large footprint sizes.</u>

The differences between H-pol and V-pol
is likely caused by the unique geometry of raindrops striking the surface at high velocity, driven by the winds, at a steep angle.
This produces a “rain-impact”stress.

DRAG COEFFICIENT:

Evidence from field experiments indicate that C_D does not increase for U > 30 to 35 m/s;
French, et al, April 2007, "Turbulent fluxes in the hurricane boundary layer, part I, Momentum flux

Citing: **Andreas, E**., June 2004, *J.Phys. Oceanog*.

1. Sea surface undergoes a transition in aerodynamic behavior for U > 30 m/s

2. Whitecap coverage is close to 100%

3. "… the rain of spray droplets back to the sea surface creates a mass flux with a magnitude that has been shown to damp short waves that sustain most of the atmospheric drag."

4. NOW add high velocity rain to this mixture …..???

Applications

Rain-modification of stresses in hurricane rain bands :>

- Will result in regions of enhanced and diminished convection, which could have a positive feedback on the structure of rain bands.
  - Results in areas of preferred surface convergence and divergence in association with the rain pattern
  - Possibly providing additional structure to rainbands
- Improved representation of rain bands could result in more efficient transport of energy into the eye wall of a hurricane
- While Kinetic energy flux is not likely to be affected, it remains to be seen what effect this roughness has on the heat, enthalpy & humidity fluxes