THE EFFECT OF RAIN ON ASCAT OBSERVATIONS OF THE SEA SURFACE RADAR CROSS SECTION USING SIMULTANEOUS 3-D NEXRAD RAIN MEASUREMENTS

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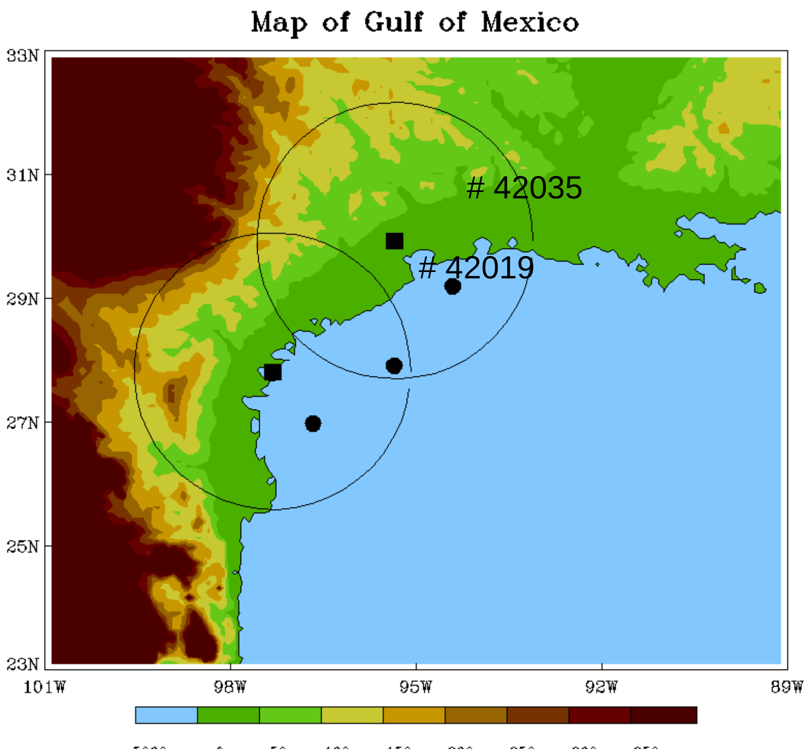
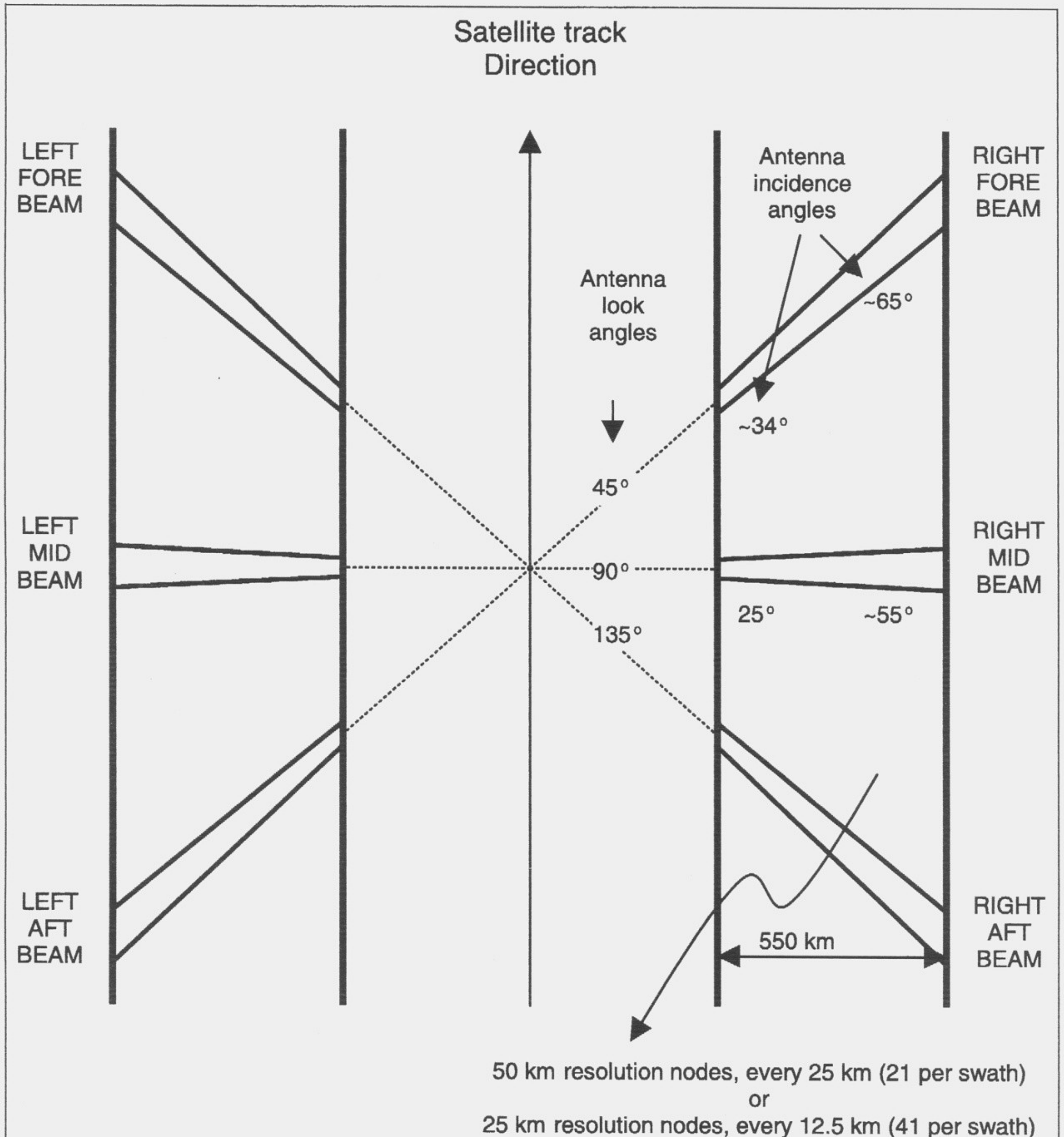
Courtesy of Dr. Scott Dunbar, I have a 24 months of ASCAT NRCS data in the area of Gulf of Mexico near the Texas and Louisiana coastlines from July 2008 to June 2010.

This data originates as L1B Data from EUMETSAT which is also reprocessed by NOAA, and provided to JPL.



Simultaneous NEXRAD Radar Provides **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 ASCAT is ≤ 3 min.**



ASCAT swath geometry. Dimensions are given for the right swath, and the left swath is symmetric with respect to the satellite ground track.

Objective of this study:

1.Collect measurements of surface rainrate , near simultaneously with an ASCAT overpass, from the NWS local NEXRAD system near the coastline by converting their S-band volumetric data to calculate rainrate. A mean rainrate is calculated for a small area, 45 km-by-45 km, centered on each ASCAT NRCS estimate.

2.Examine the changes in the NRCS as a result of increasing rain intensity, after separating the data from the individual three beams and into distinct 4^{o} intervals of incidence angle within each beam. The measured "cell" NRCS at each latitude and longitude location is observed by all three beams.

3.It was assumed that the volume backscatter and path attenuation for C-band is negligible. Therefore the change in NRCS is assumed to be a result of the rain-induced roughness; "rain splash", in the data analysis.

4. <u>However</u> rain may be associated with wind downbursts and therefore increased stress variability. This could contribute to increases in the surface NRCS, besides the rain.

Over the 10 month interval from July 2008 to April 19, 2009, only three collocated rain events could be studied for this comparison.

1. Aug. 13, 2008,

Buoy # 42035; Winds = 5 m/s from 209^o

Buoy # 42019; Winds = 6 m/s from 247^o

ASCAT Look Directions (degrees) relative to North:

Forward: 240, Mid-Beam: 285; Aft: 330

2. Aug. 15, 2008,

Buoy # 42035; Winds = 9 m/s from 169^o

Buoy # 42019; Winds = 4 m/s from 192^o

ASCAT Look Directions (degrees) relative to North:

Forward: 55, Mid-Beam: 100; Aft: 145

3. Apr. 19, 2009,

Buoy # 42035; Winds = 9 m/s from 150^o

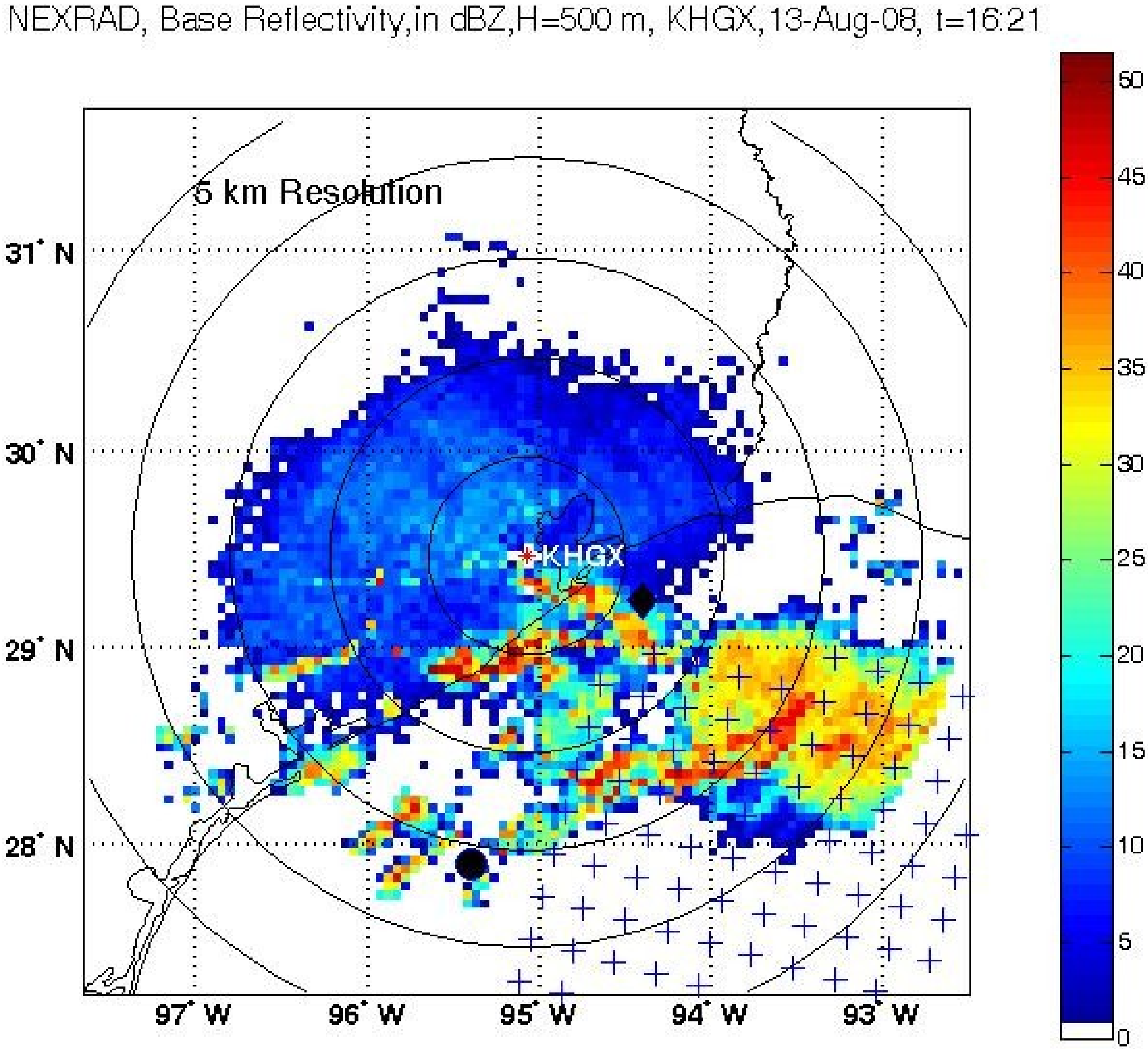
Buoy # 42019; Winds = 5 m/s from 176^o

ASCAT Look Directions (degrees) relative to North:

Forward: 30, Mid-Beam: 75; Aft: 120

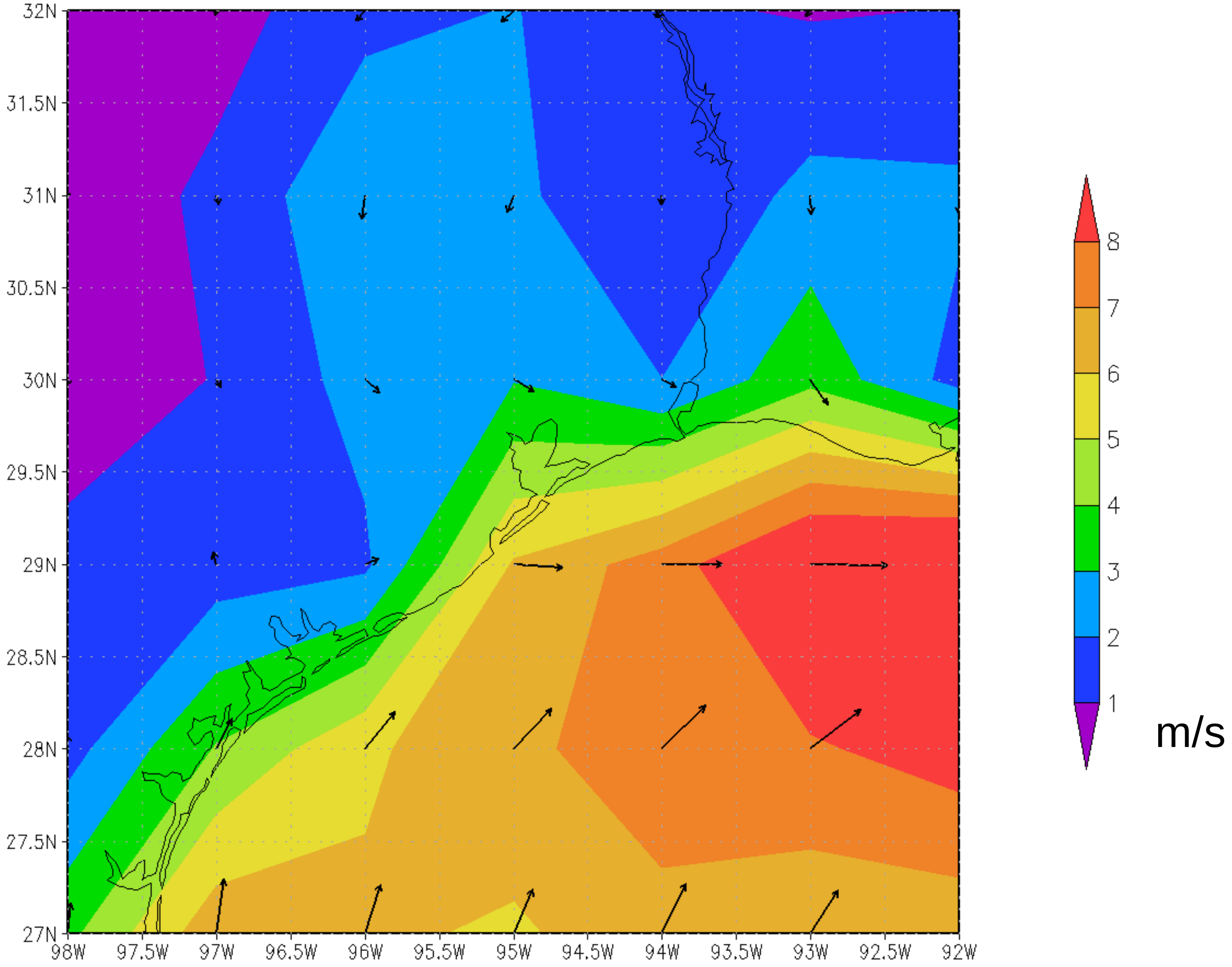
Buoy 42035
-> 5 m/s

Buoy 42019
-> 6 m/s

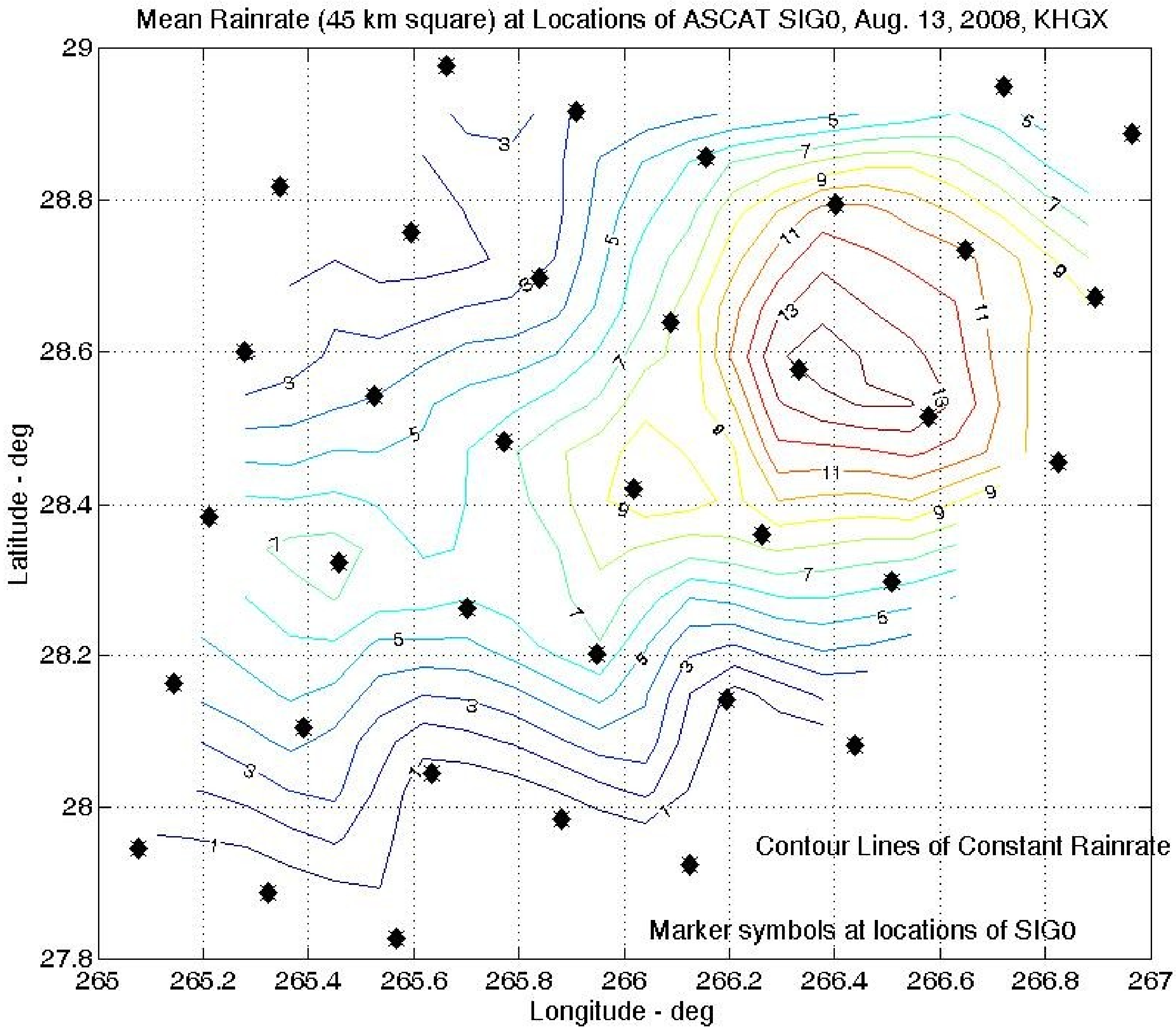


NOGAPS Wind Vectors (arrows) and Wind Speed (contours)

16Z 13 August, 2008



Each location is observed by ALL three beams: FWD,AFT and MID

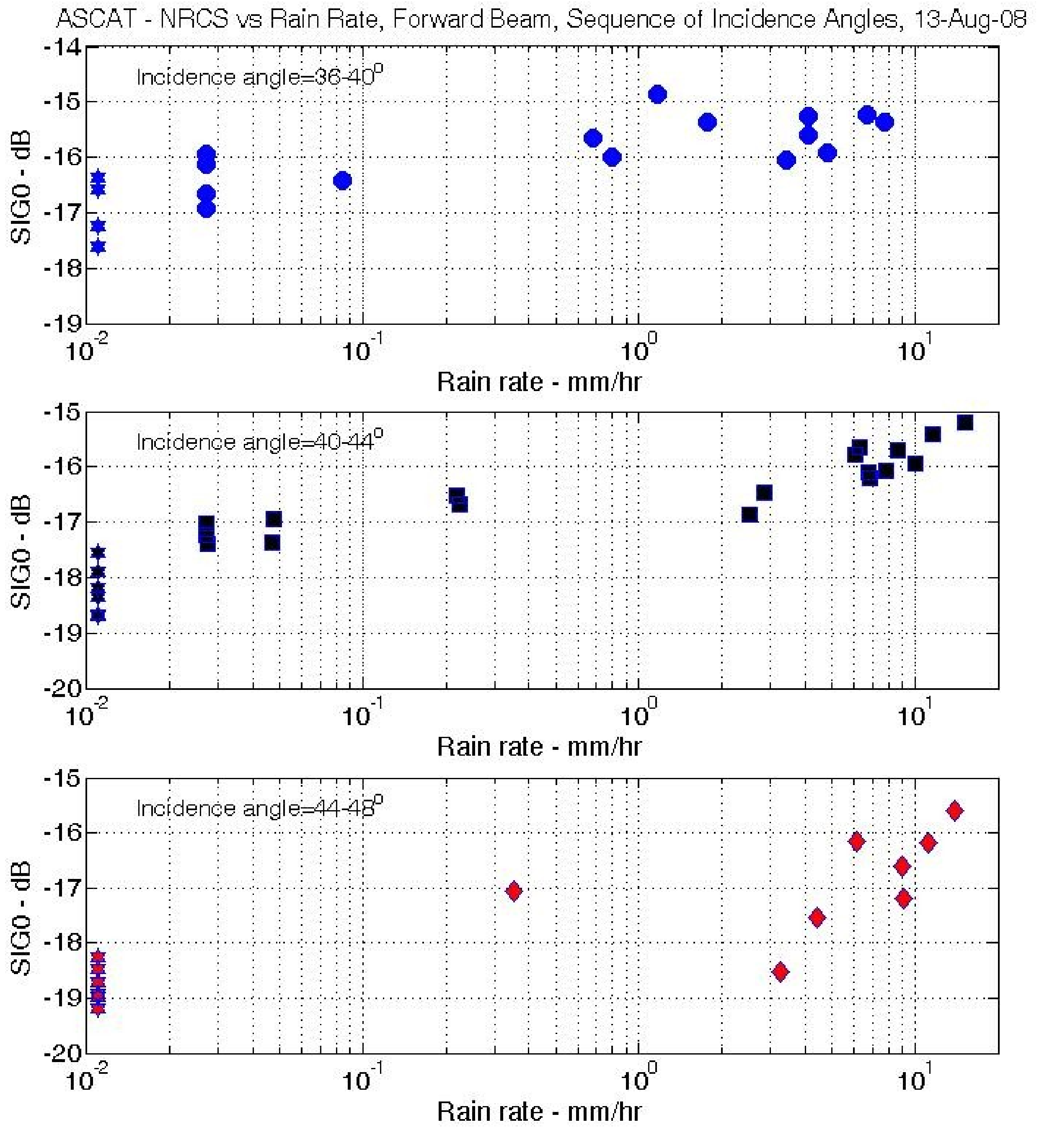


Forward Beam

Incidence Angles:
36 – 40° (top)
40 – 44° (middle)
44 – 48° (bottom)

Beam look direction: 240°

Wind from 228°

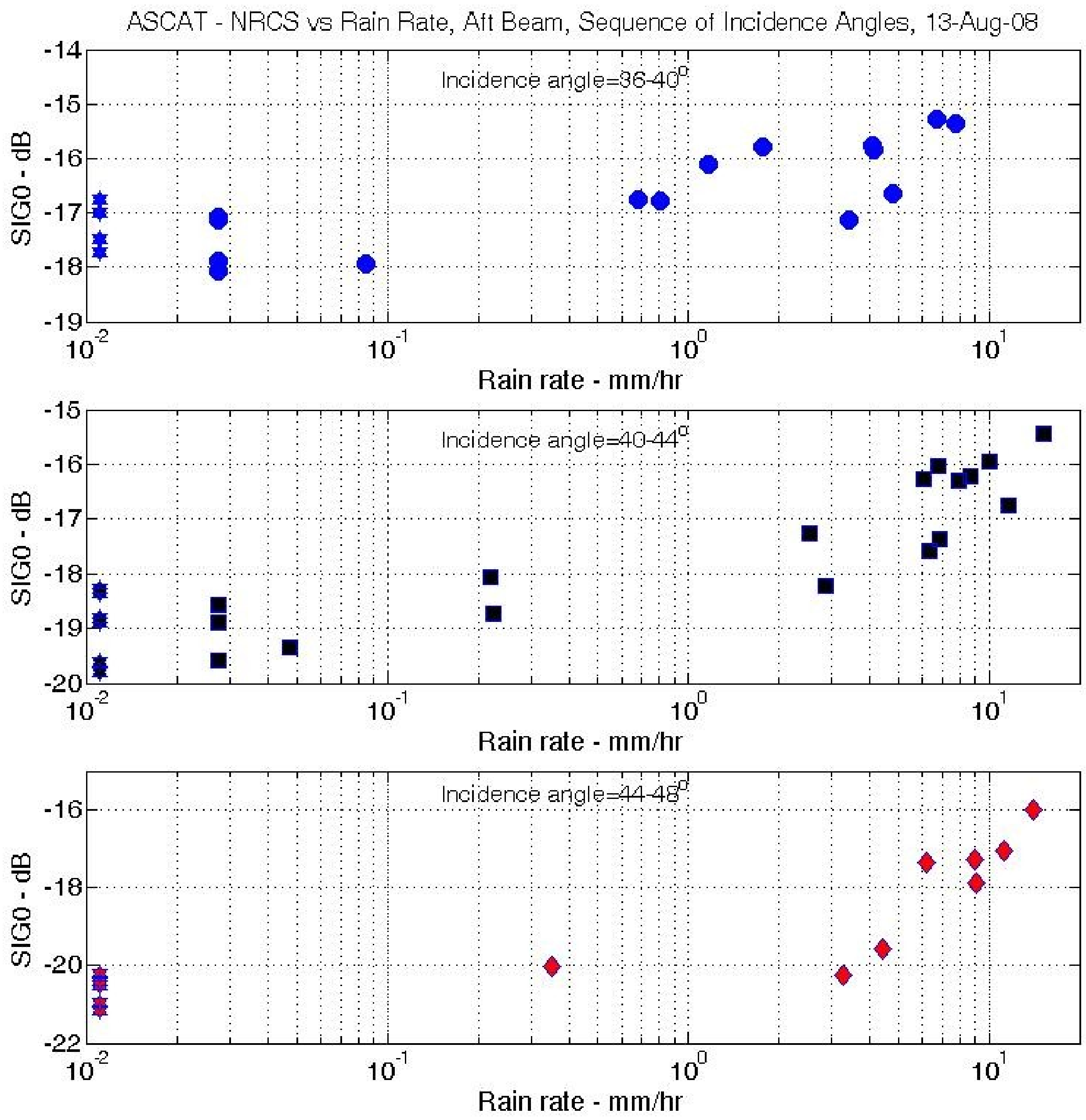


Aft Beam

Incidence Angles:
36 – 40° (top)
40 – 44° (middle)
44 – 48° (bottom)

Beam look direction: 330°

Wind from 228°

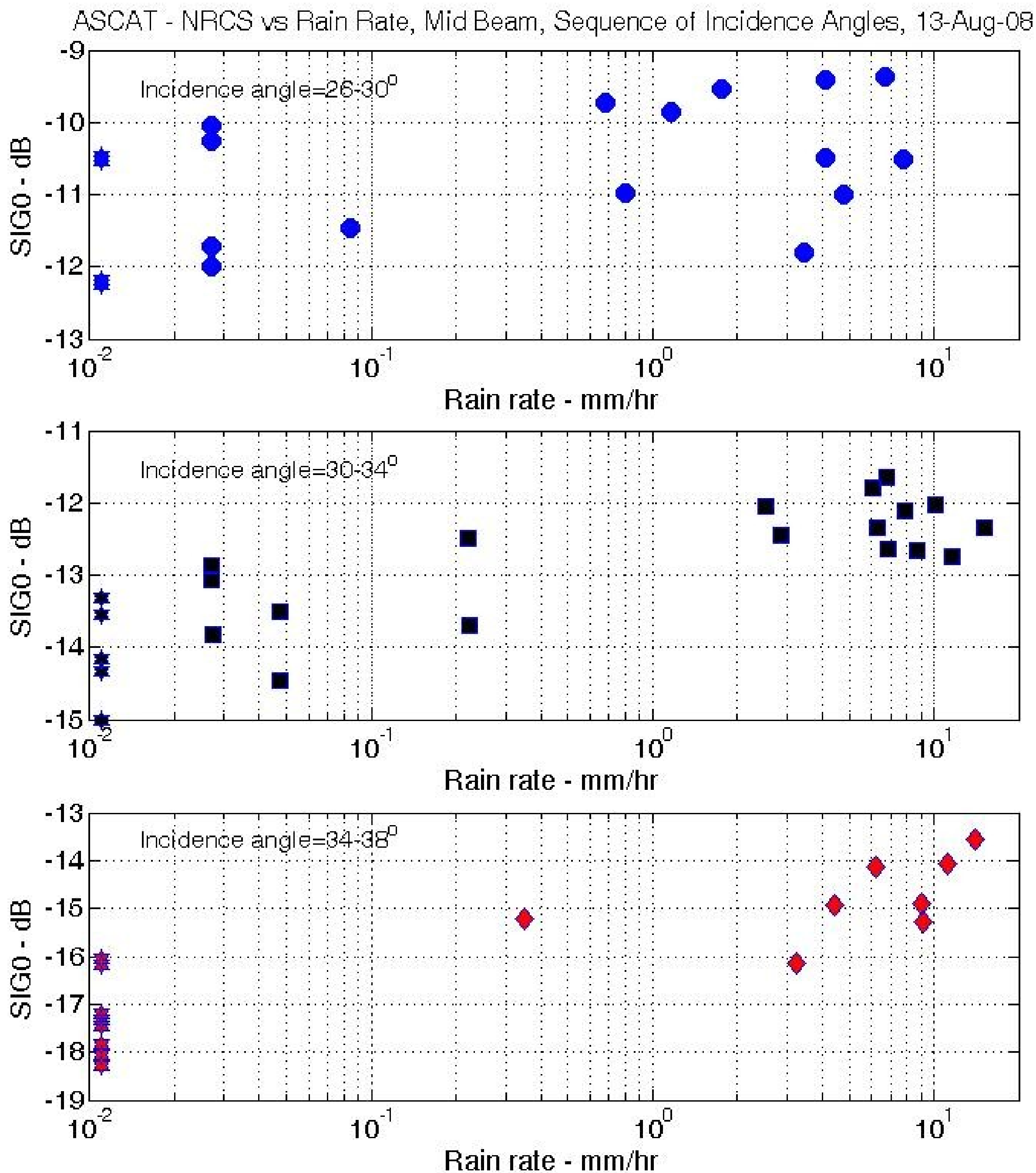


Mid Beam

Incidence Angles:
- 26 – 30° (top)
- 30 – 34° (middle)
- 34 – 38° (bottom)

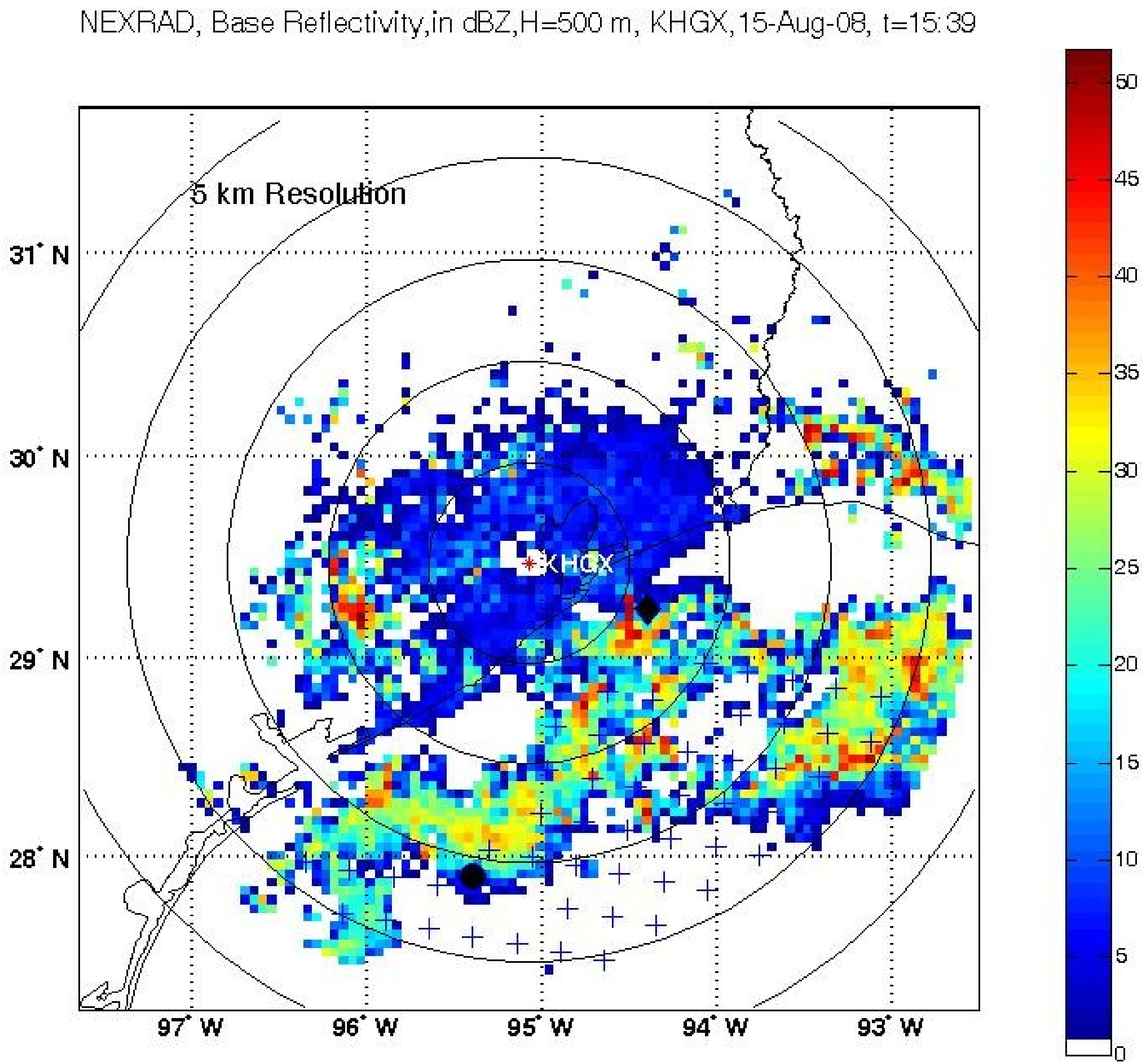
Beam look direction: 285°

Wind from 228°

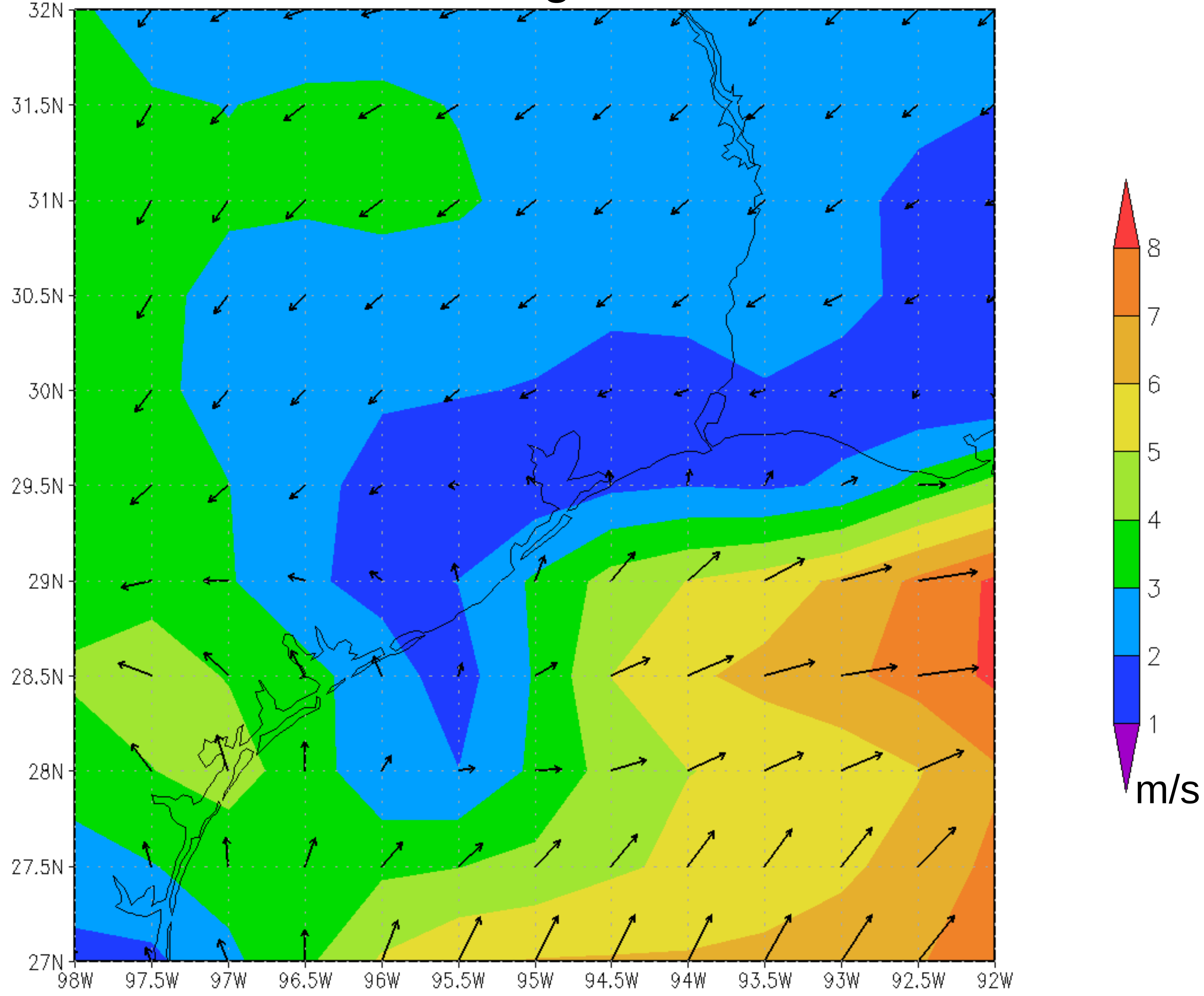


Buoy 42035 -> 9 m/s

Buoy 42019 -> 4 m/s



CFSR Wind Vectors (arrows) and Wind Speed (contours)
16Z 15 August, 2008



Forward Beam

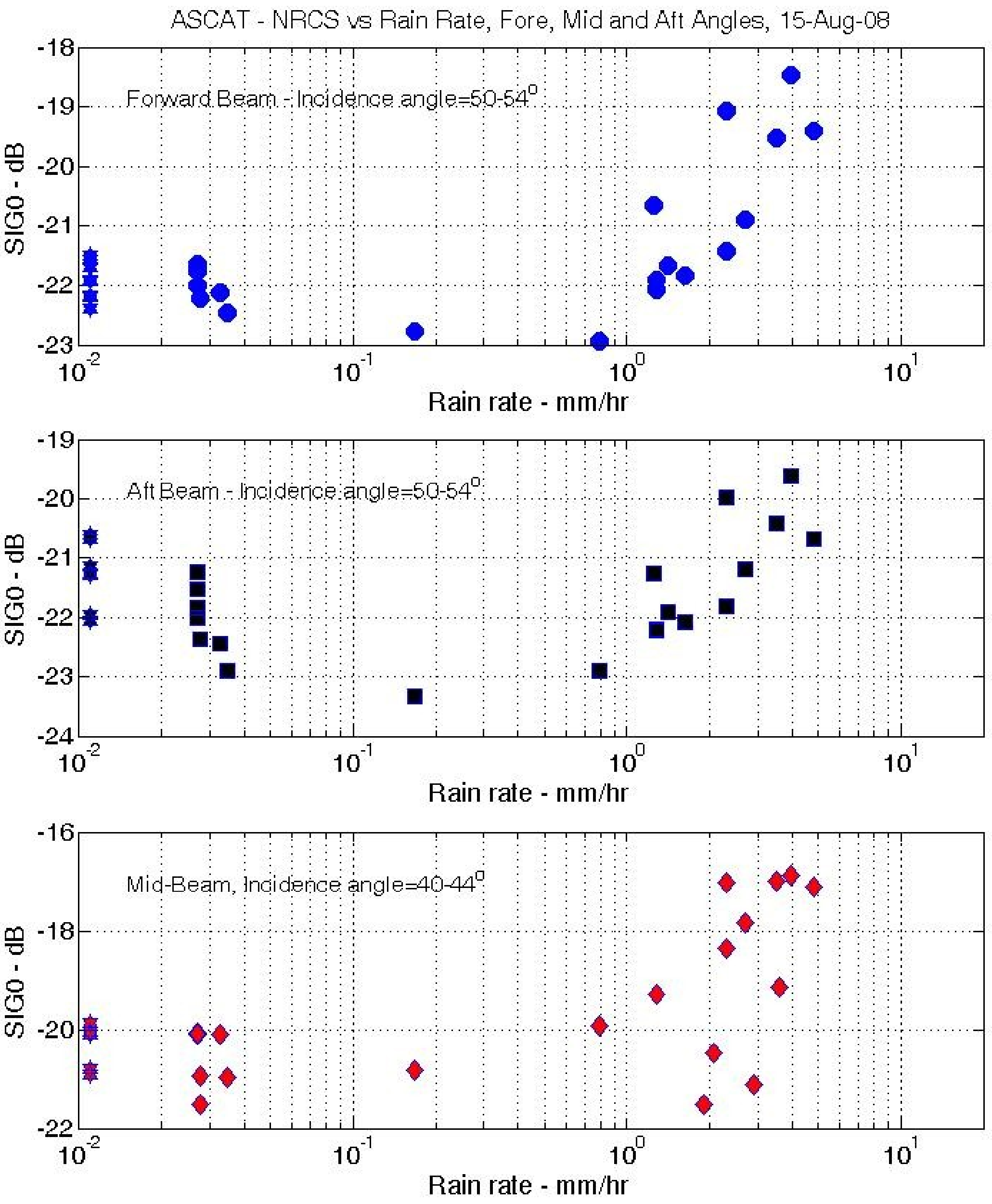
Look direction: 55°
Wind from 180°
Incidence angle 50 - 54°

Aft Beam

Look direction: 145°
Wind from 180°
Incidence angle 50 - 54°

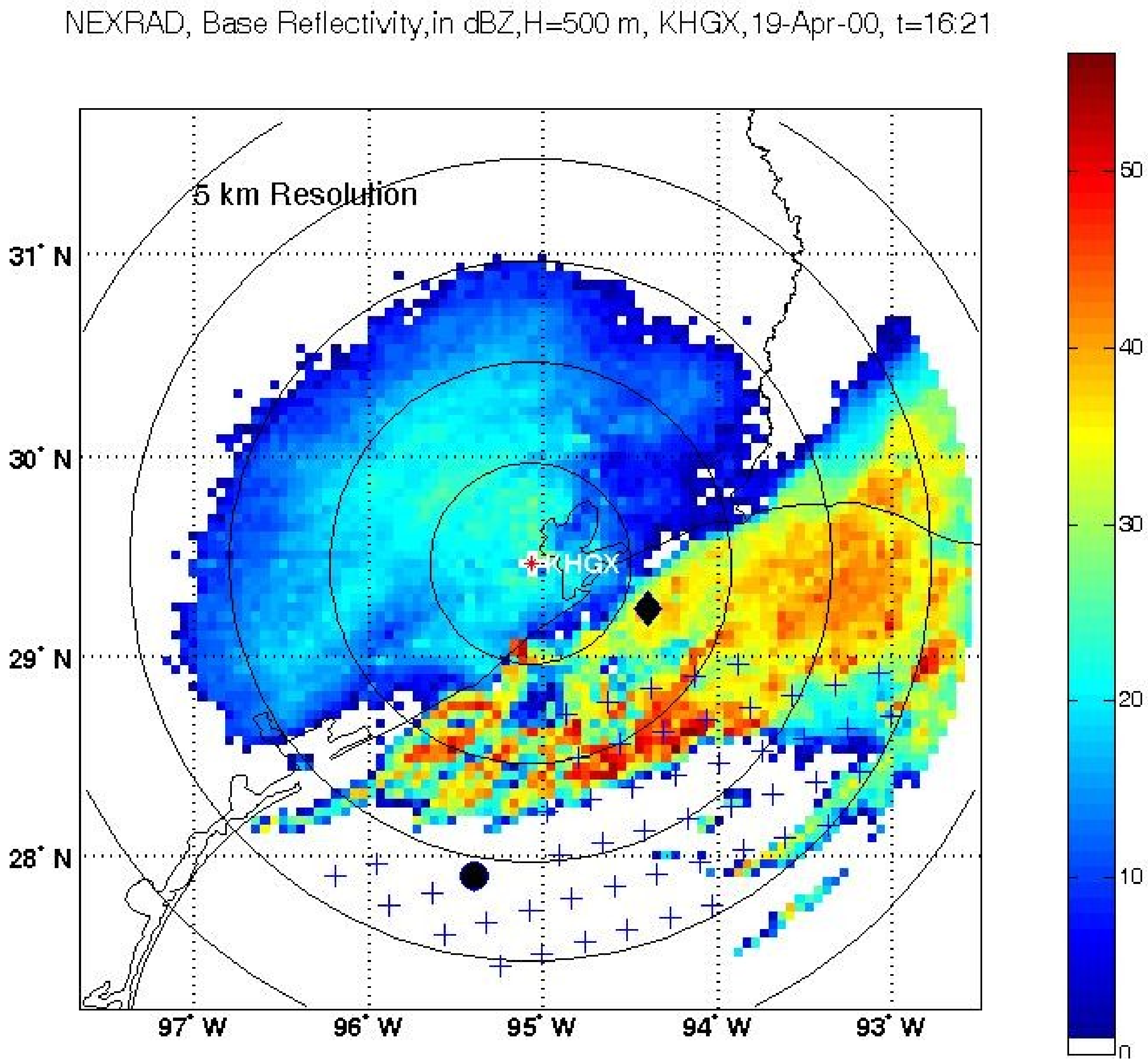
Mid Beam

Look direction: 100°
Wind from 180°
Incidence angle 40 - 44°

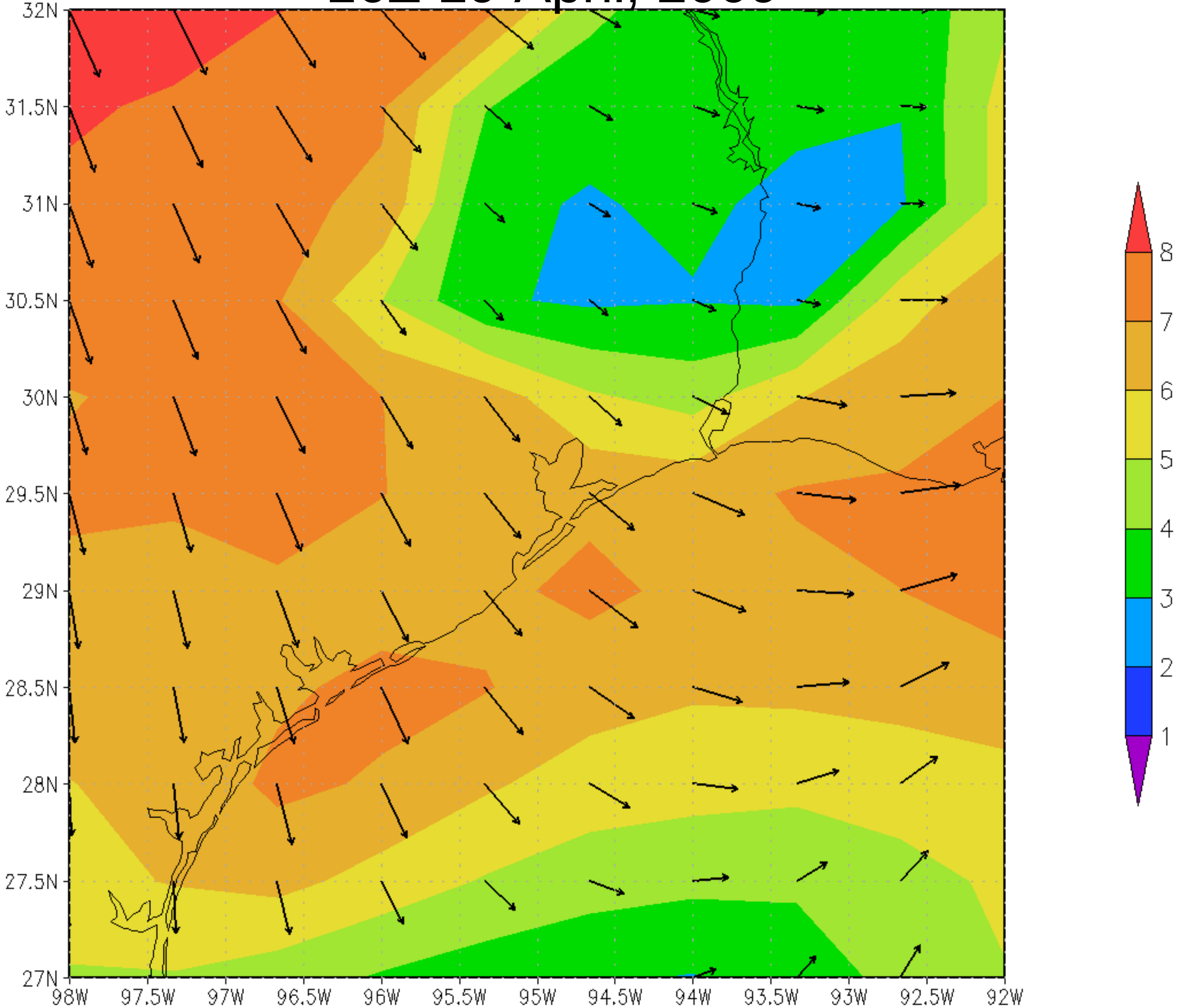


Buoy 42035 -> 9 m/s

Buoy 42019 -> 5 m/s



MERRA Wind Vectors (arrows) and Wind Speed (contours)
16Z 19 April, 2009

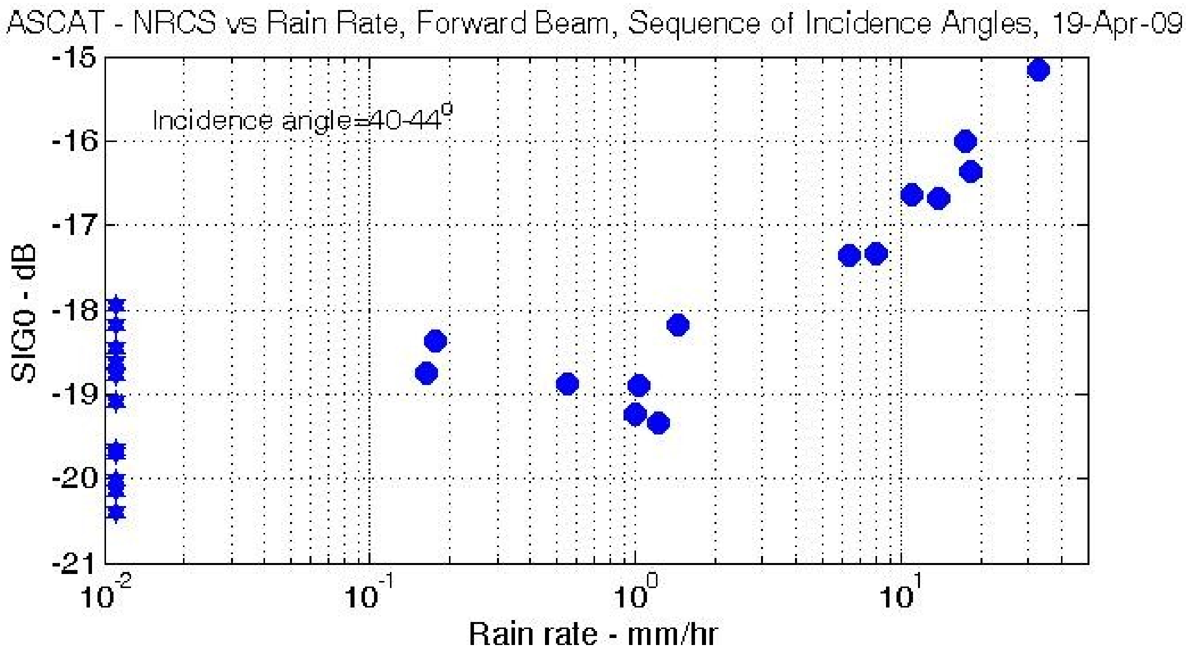


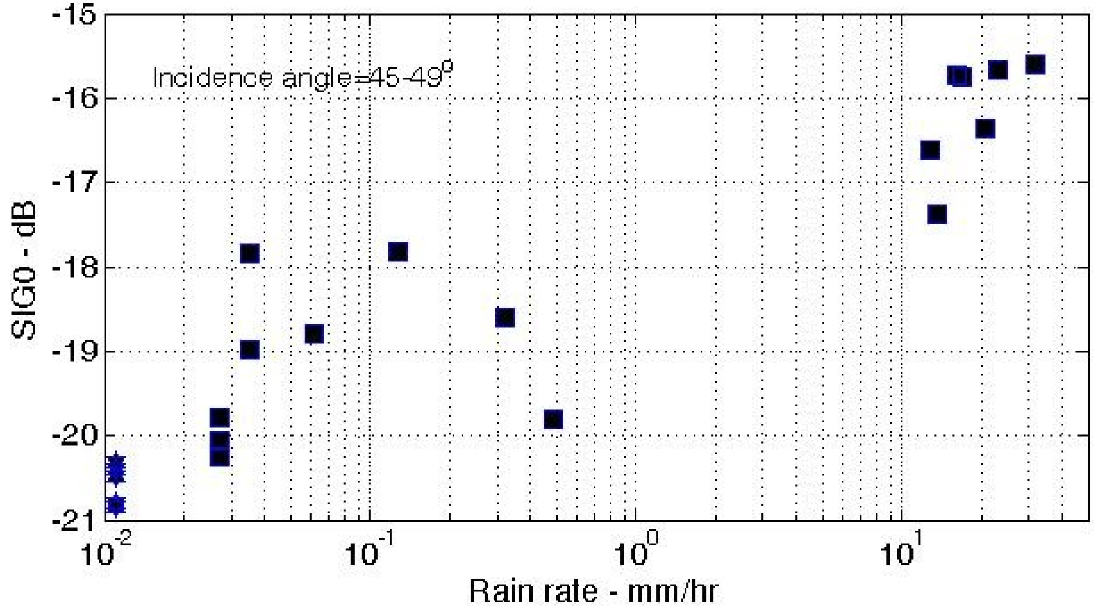
Forward Beam

Incidence Angles:
40 – 44° (top)
45 – 49° (bottom)

Beam look direction: 30°

Wind from 163°



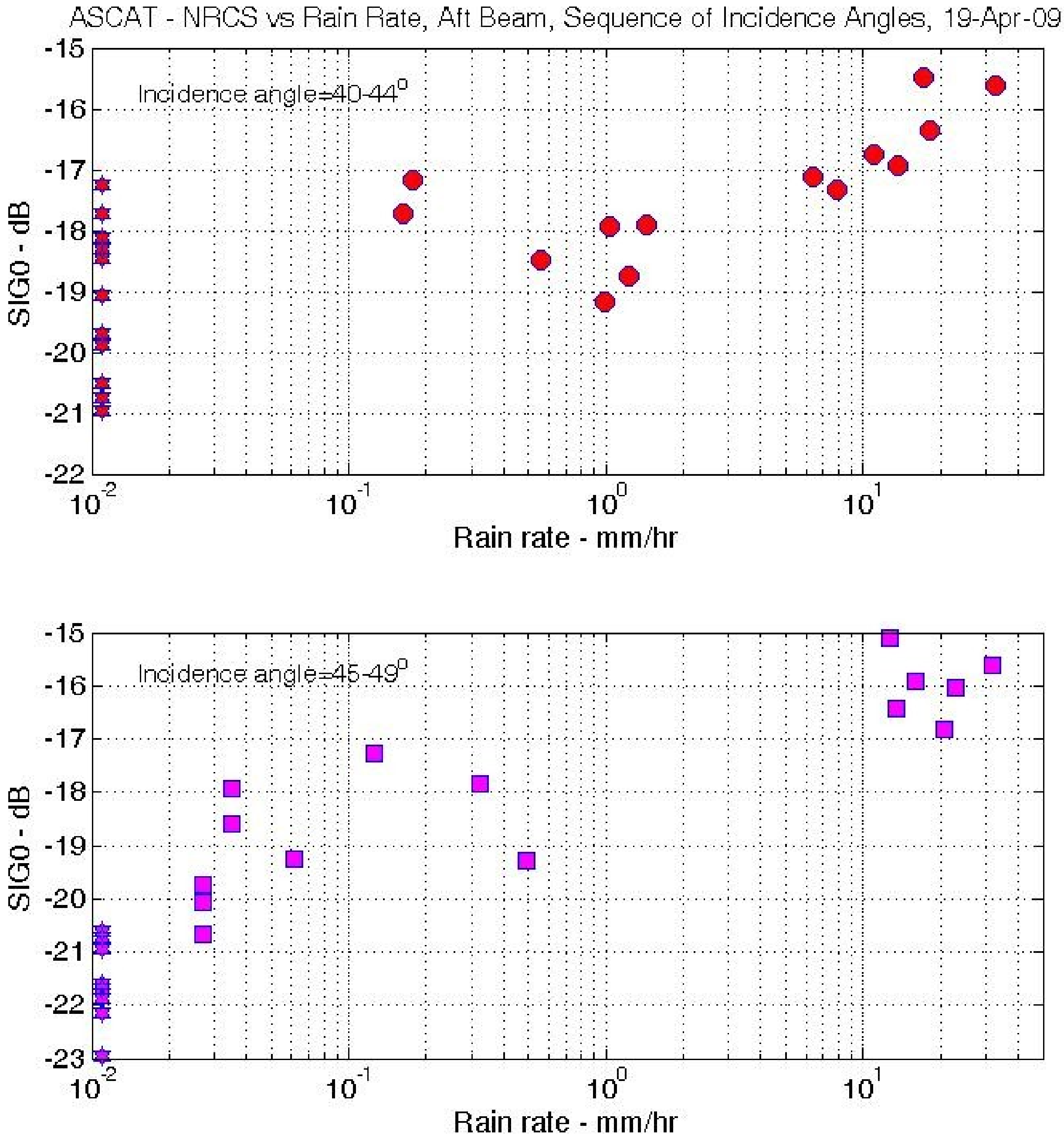


Aft Beam

Incidence Angles:
40 – 44° (top)
45 – 49° (bottom)

Beam look direction: 120°

Wind from 163°



Mid Beam

Incidence Angles:
26 – 30° (top)
30 – 34° (Middle)
34 – 38° (bottom)

Beam look direction: 75°

Wind from 163°

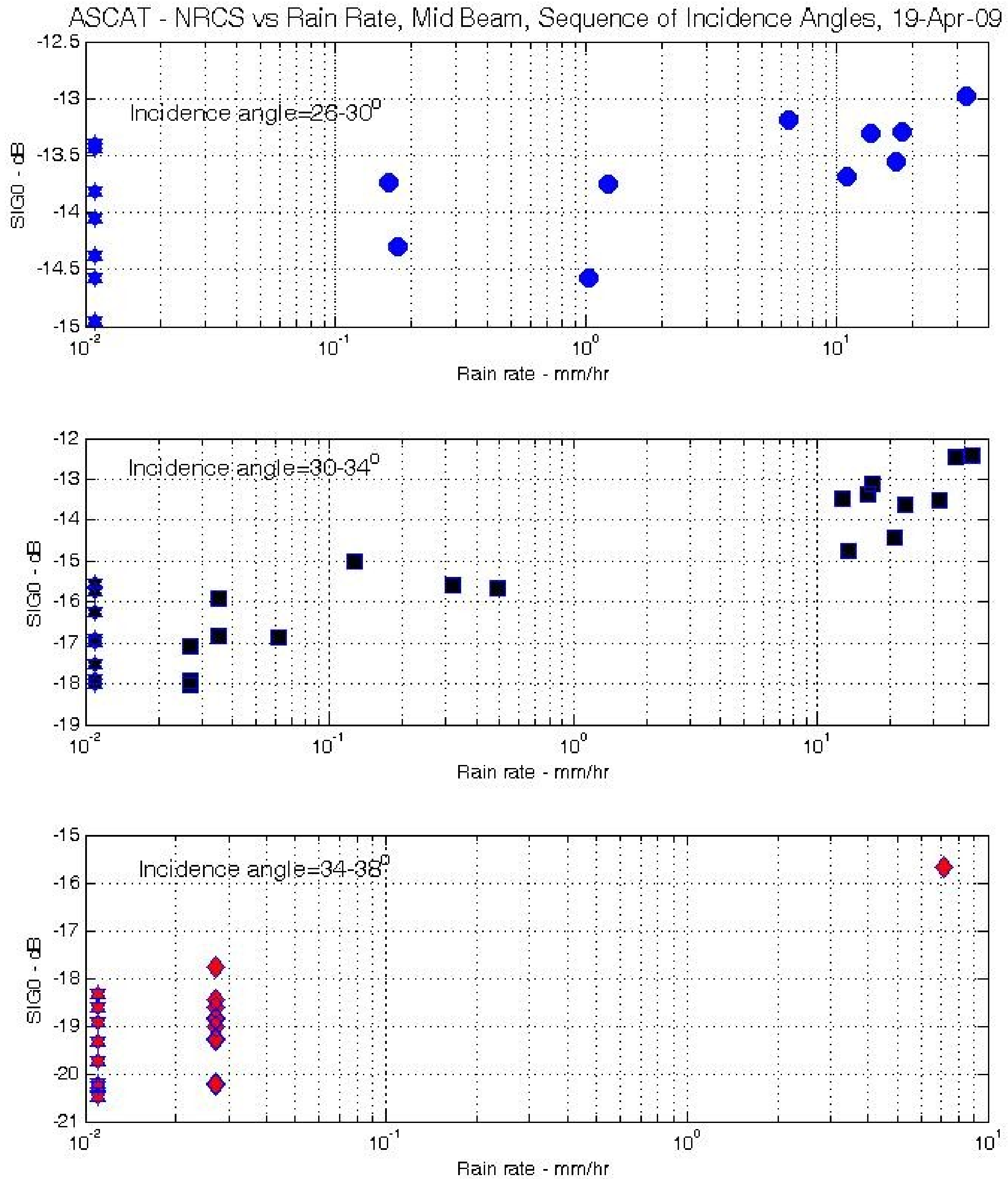


Table 1: Net Increase in NRCS - Aug. 13 event. Near KHGX

Incidence angle	Fore Beam	Aft Beam	Mid Beam	dB increase in NRCS (up to 10 mm/hr)
26-30			X	1 dB
30-34			X	2 dB
34-38			X	3 dB
36-40	X			2 dB
36-40		X		2 dB
40-44	X			2.5 dB
40-44		X		3 dB
44-48	X			3 dB
44-48		X		2.5 dB

Table 2: Net Increase in NRCS - Aug. 15 event. Near KHGX

Incidence angle	Fore Beam	Aft Beam	Mid Beam	dB Increase In NRCS (up to 6 mm/hr)
40-44			X	3 dB
50-54	X			3 dB
50-54		X		2 dB

Table 3: Net Increase in NRCS - Apr 19 event, Near KHGX

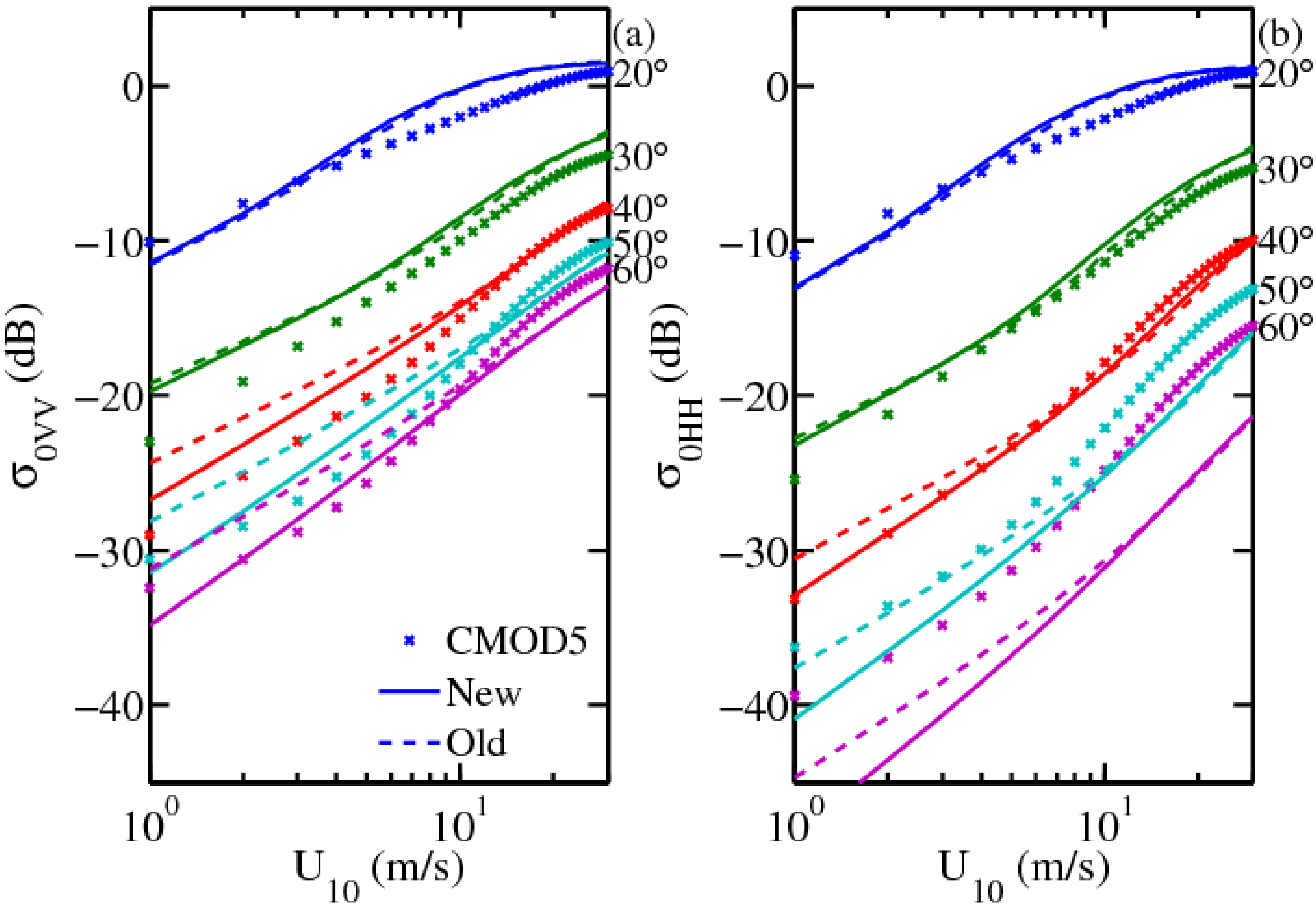
Incidence Angle	Fore Beam	Aft Beam	Mid Beam	dB Increase In NRCS (up to 20 mm/hr
26-30			X	1 dB
30-34			X	3 dB
34-38			X	3 dB
40-44	X			3 dB
40-44		X		3 dB
45-49	X			4 dB
45-49		X		4 dB

The internal calibrations of ASCAT indicate that variations of B_o among the individual beams on each side of the satellite track are not greater than 0.2 dB

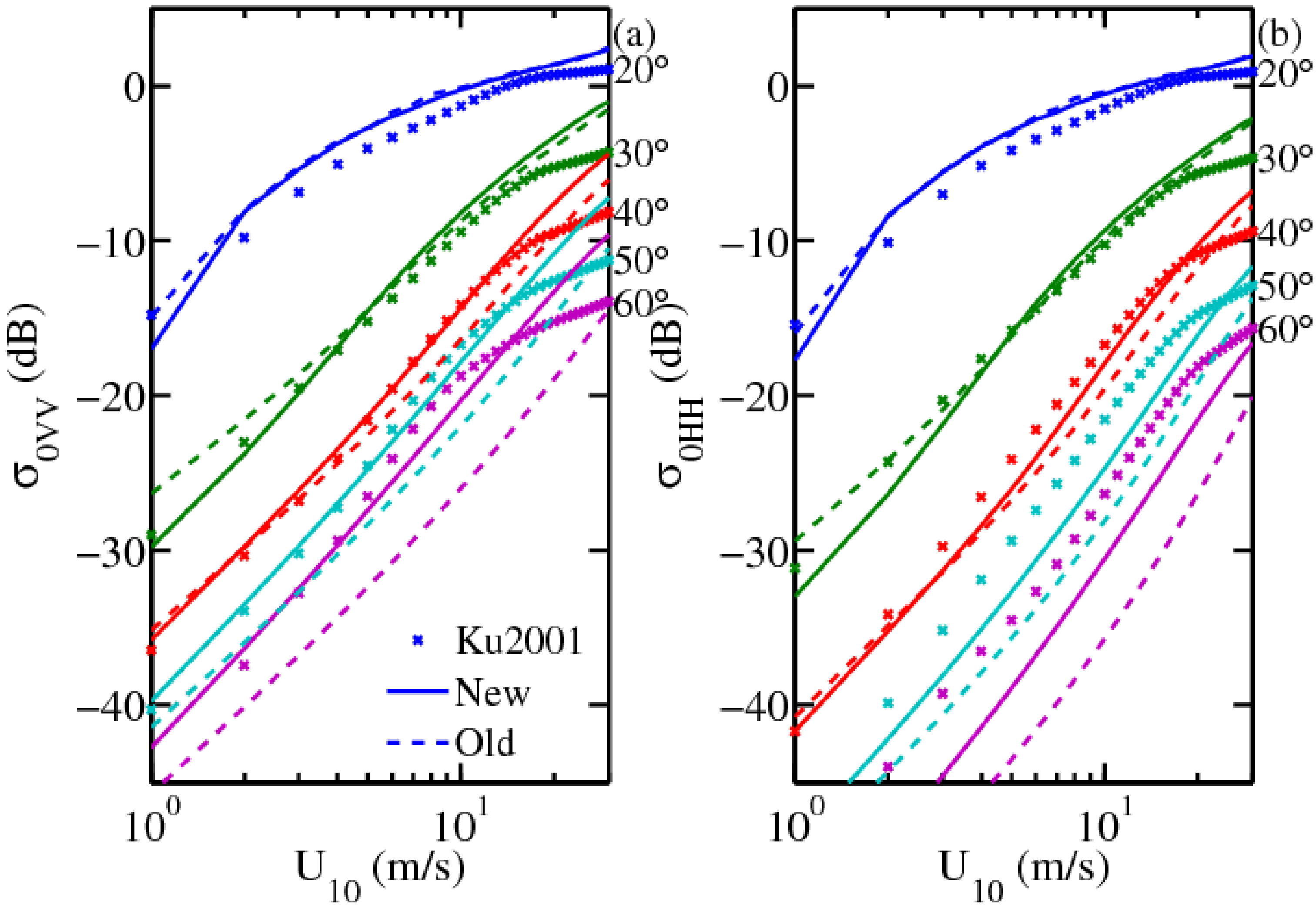
At this point it is worthwhile to consider the changes in NRCS as a function of wind speed, at various incidence angles. Recent work by Dr. Paul Hwang of the Naval Research Laboratory provides useful guidance in this regard. This can also be applied to interpreting the consequences of changes in NRCS induced by the “rain splash effect”.

Courtesy of Dr. Paul Hwang; "A Note on the Ocean Surface Roughness Spectrum",
Journal of Atmospheric and Oceanic Technology, Vol. 28, pp 436-443, March 2011

C-Band NRCS Theoretical Models, V and H Polarization



For Future Reference >> Ku-Band - Scatterometer mode: spectrometer



Old: Hwang: 2008

New: Hwang 2011

The case studies presented here are in conditions where the buoy wind speeds were between 4 and 10 m/s.

Applying Hwang's model; it can be seen that in the absence or rain:

a) at an incidence angle of 30^o a wind increase from 5 to 8 m/s produces an increase in NRCS of 2.5 dB

b) at an incidence angle of 50^o a wind increase from 5 to 8 m/s produces an increase in NRCS of 3.2 dB

CONVERSELY

We see from the results presented in Tables 1,2 and 3 that rainrates of 10 mm/hr that induce increases of NRCS from 2 to 4 dB (depending on the incidence angle) are like to cause erroneously high wind estimates by about 60 % (estimating 8 m/s when the wind is actually 5 m/s). It is worth noting that while the sensitivity of NRCS to rainrate is lower for the smaller incidence, its net effect on wind error is the same as at high incidence angles (as per "a)" and "b) above

SUMMARY – Part I

This experimental configuration lends itself to observing, simultaneously, the effects of rain on the different incidence and azimuth angles of the ASCAT scatterometer in a region where buoy wind measurements are also available.

Under the specific conditions available here, we do not observe any sizeable differences in rain sensitivity between the different azimuth look directions, for a given incidence angle.

The surface wind fields indicate some variability across the measurement region, which may account for some of the variability of the NRCS among cells where no rain is observed.

Another source of variability is the inhomogeneity of the rain within each ASCAT cell (the “beam filling” problem).

SUMMARY – Part II

We find that the modification of the surface due to rain can cause substantial <u>increases</u> in backscatter, for wind speeds in the 4 – 10 m/s range.

The change in backscatter is clearly a function of the incidence angle, but because the models for lower incidence angles (30^o) are less sensitive to wind, the consequences can be comparable.

For these examples, substantial errors in wind speed were identified, and they were similar across incident angles.

-> Harder to identify rain-related errors

These findings indicate that the C band scatterometer can have substantial errors at low to moderate wind speeds and high rain rates (observed here from 6 to 20 mm/hr)

-> Extra care should be taken when using ASCAT data for ocean forcing in tropical convergent zones.

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