Combined Active and Passive Remote Sensing of Hurricane Ocean Winds

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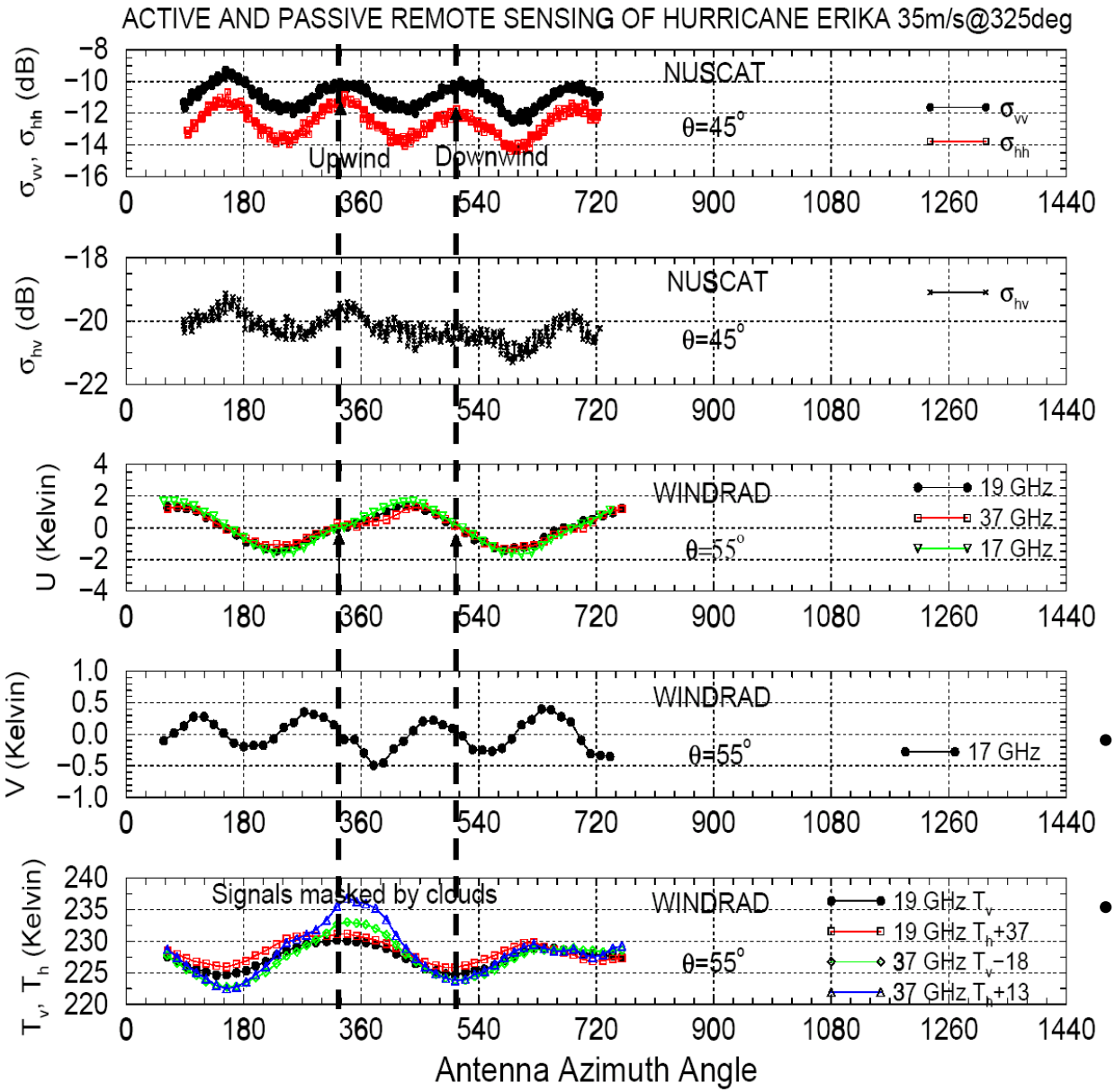
Outline

- Background
- Scatterometer Model Function and Retrieval
- Radiometer model function
- Summary
- Future Plan

KEY ISSUES FOR WIND RETRIEVALS FOR SEVERE WEATHER CONDITIONS

- Accuracy of model function
  - Ku- and C-band σ_0s response to wind for above 30 m/s wind speed
  - Response of passive microwave observations to very high winds
- Rain correction of σ_0
  - Modeling of rain
  - Correction and retrieval using combined active and passive data
- Resolution

NUSCAT/WINDRAD Data at 35 m/s Wind Speed in September 1997

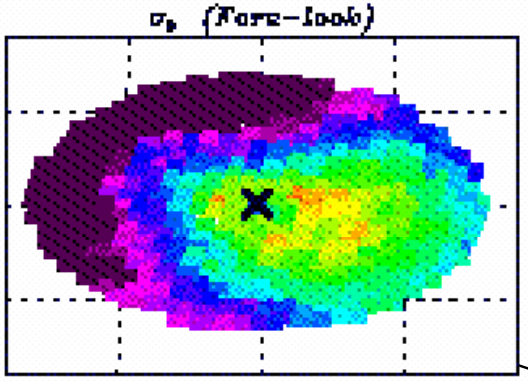


NASA P-3 FLIGHT OVER HURRICANE ERIKA IN SEPTEMBER 1997 (AVHRR INFRARED)

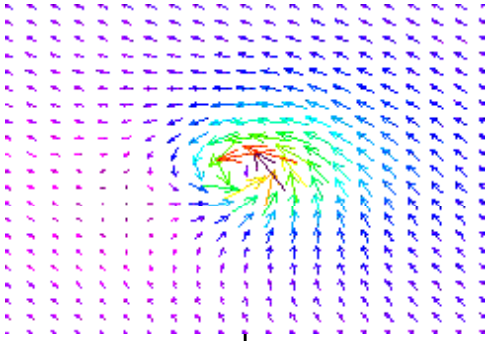
- Simultaneous 13 GHz radar and multi-frequency radiometer observations
- Radar and polarimetric radiometer data showed consistent wind direction

QuikSCAT Sigma0 Analysis for High Winds

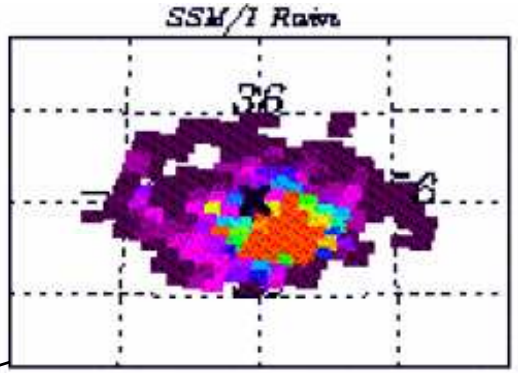
Radar σ_0



HOLLAND'S
TC MODEL WIND

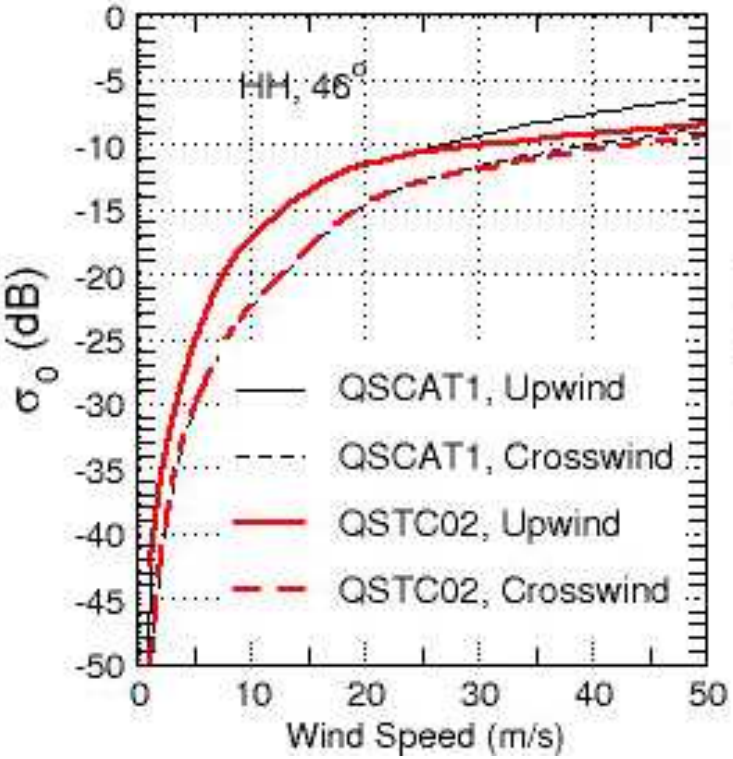


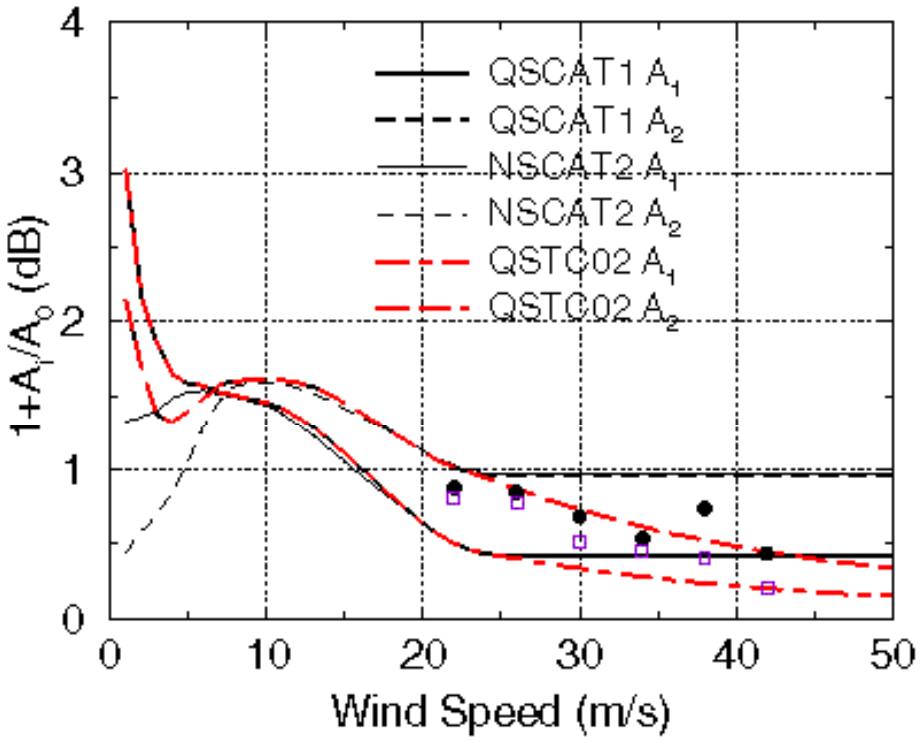
Radiometer
Rain Liquid (R)



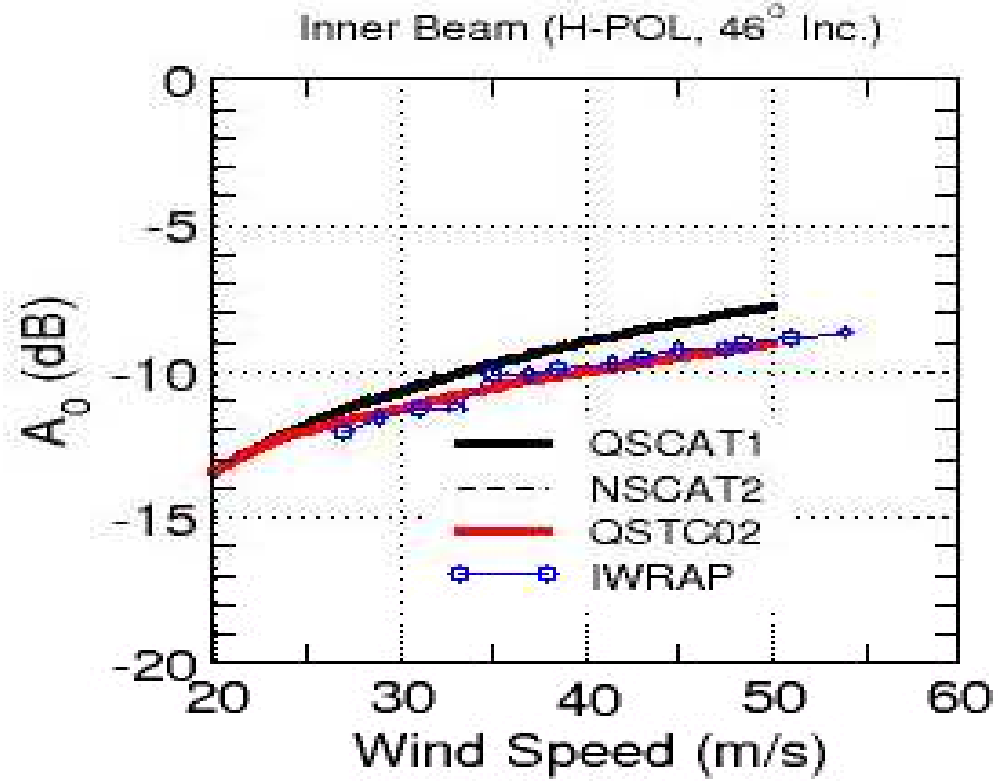
$\sigma_0(W,\phi,R)$

QuikSCAT Sigma0 Response to High Winds





QSCAT-TC02 Comparison with IWRAP



The QSTC02 model function [Yueh et al, 2003] was confirmed by the observations from the Imaging Wind and Rain Airborne Profiler (IWRAP) [Esteban et al., 2004]. The IWRAP observations were made by NOAA-UMASS at 40 and 50 degree incidence angles and were averaged for comparison with the QSTC02 model at 46 degree incidence angle. We added one dB to the IWRAP data to remove the bias.

SeaWinds Retrieval Testing for Hurricane Isabel

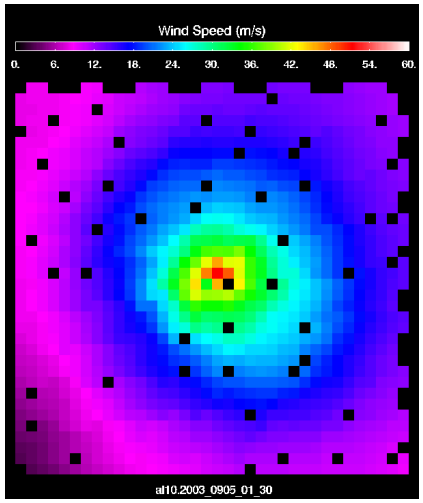
- Use JPL standard processor for wind retrieval at 25 km resolution
- Apply QSCAT1, QSTC02 and QWSCAT1-IWRAP model functions
- No rain correction
- Climatology for attenuation correction – Likely underestimate for rainy conditions
- Comparison with NOAA HRD Hwind – 10 m height, maximum 1-min sustained wind speed

SeaWinds Retrievals for Hurricane Isabel September 2003

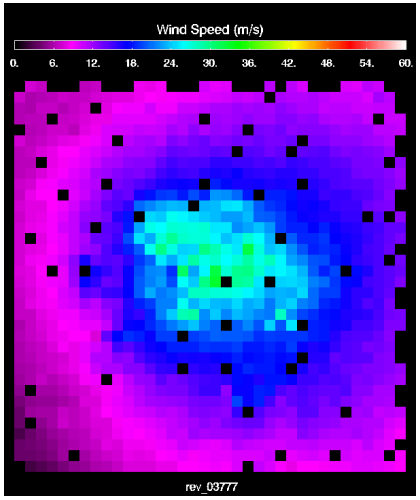
HWind Time	SeaWinds Rev#	SeaWinds Time	Time Difference
Sept 01, 13:30	03727	14:31	61 min
Sept 02, 13:30	03741	14:06	36 min
Sept 04, 1:30	03763	3:09	99 min
Sept 05, 1:30	03777	2:44	74 min
Sept 05, 13:30	03784	14:32	58 min
Sept 13, 1:30	03891	2:44	74 min
Sept 14, 1:30	03905	2:19	49 min
Sept 15, 13:30	03927	15:22	1 hr 58 min
Sept 16, 1:30	03934	3:10	100 min
Sept 16, 13:30	03941	14:57	87 min
Sept 17, 1:30	03948	2:44	74 min

Wind Comparison for SeaWinds Rev 3777

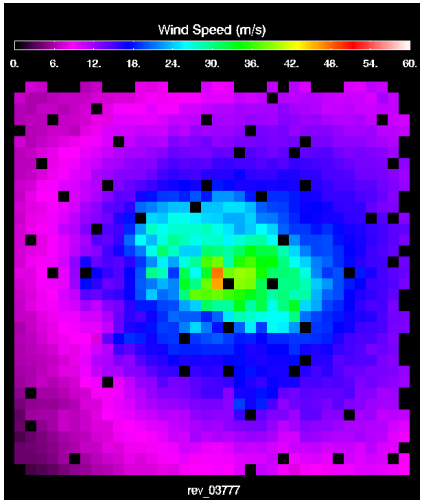
HWind



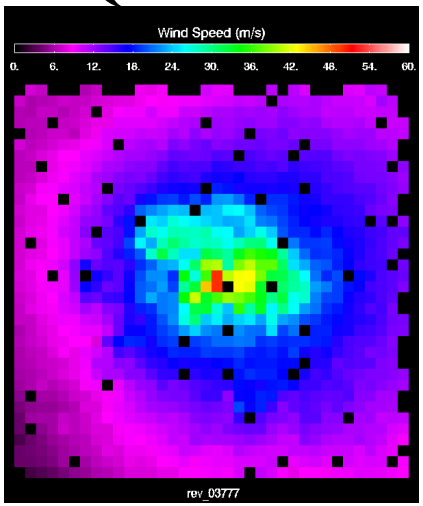
QSCAT1



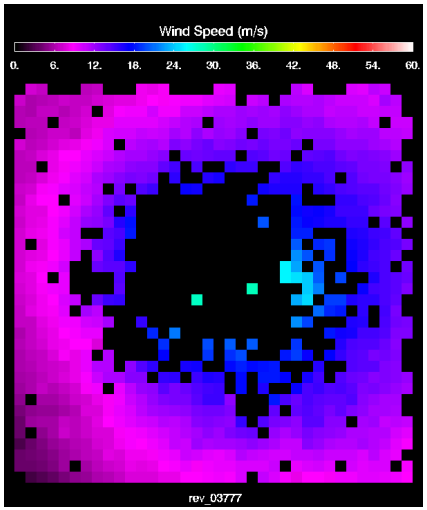
IWRAP

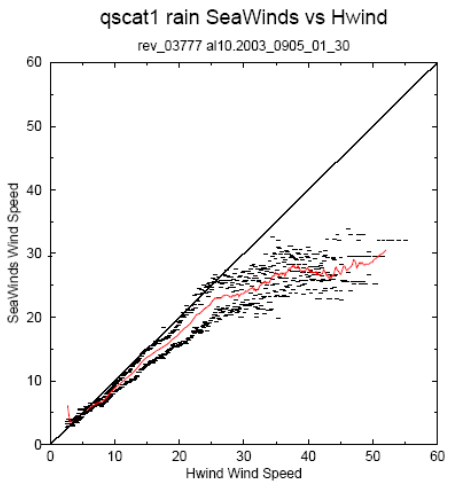


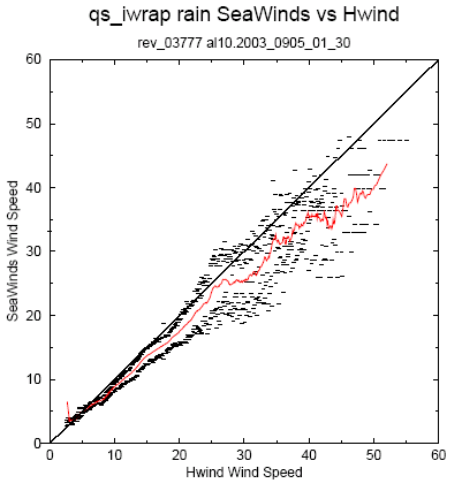
QSTC02

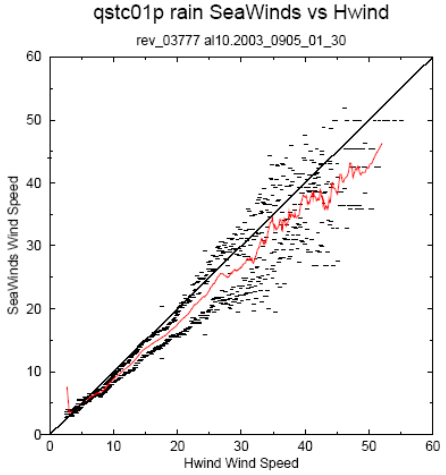


HWind with SeaWinds Rain Mask



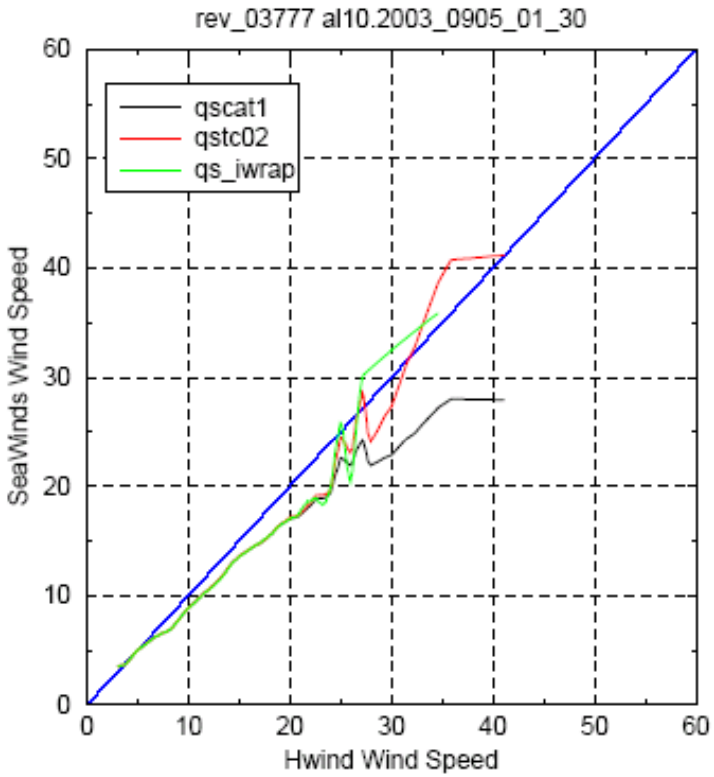


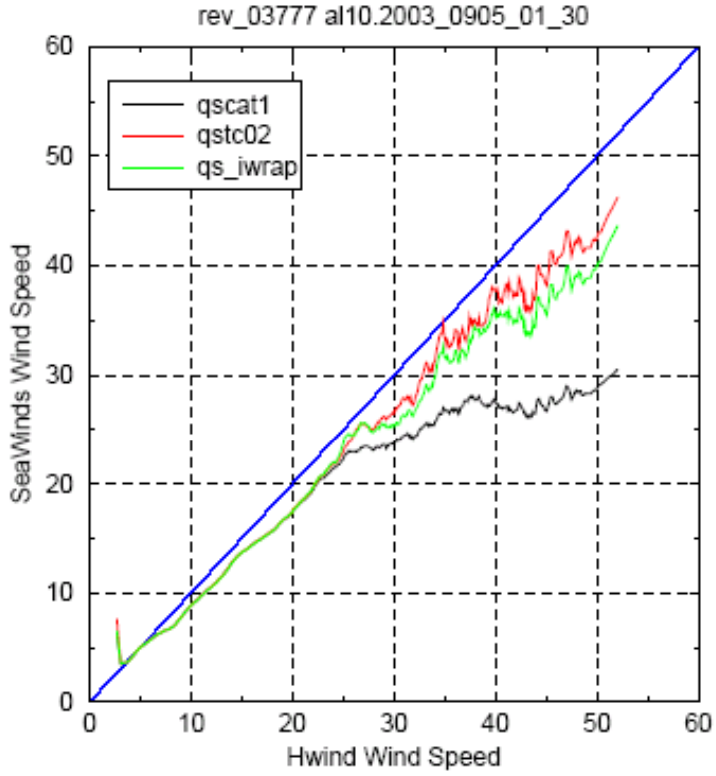




SeaWinds Wind Comparison for Rev 3777

With Rain Mask





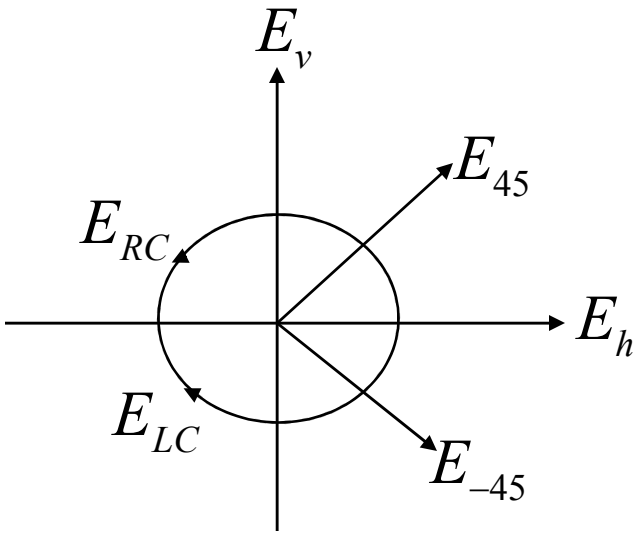
- HWind wind speed greater than SeaWinds wind speed for 10-20 m/s wind speed
- QSTC02 and IWRAP wind speeds agree better with Hwind for extreme high winds.

WindSat Polarimetric Radiometer

- Multi-frequency conical scanning radiometer
  - 6, 10, 18, 23 and 37 GHz
- Polarimetric capabilities for four Stokes parameter measurements at 10, 18 and 37 GHz
  - Tv, Th, U and V
- Operating since January 2003

Polarimetric Radiometry

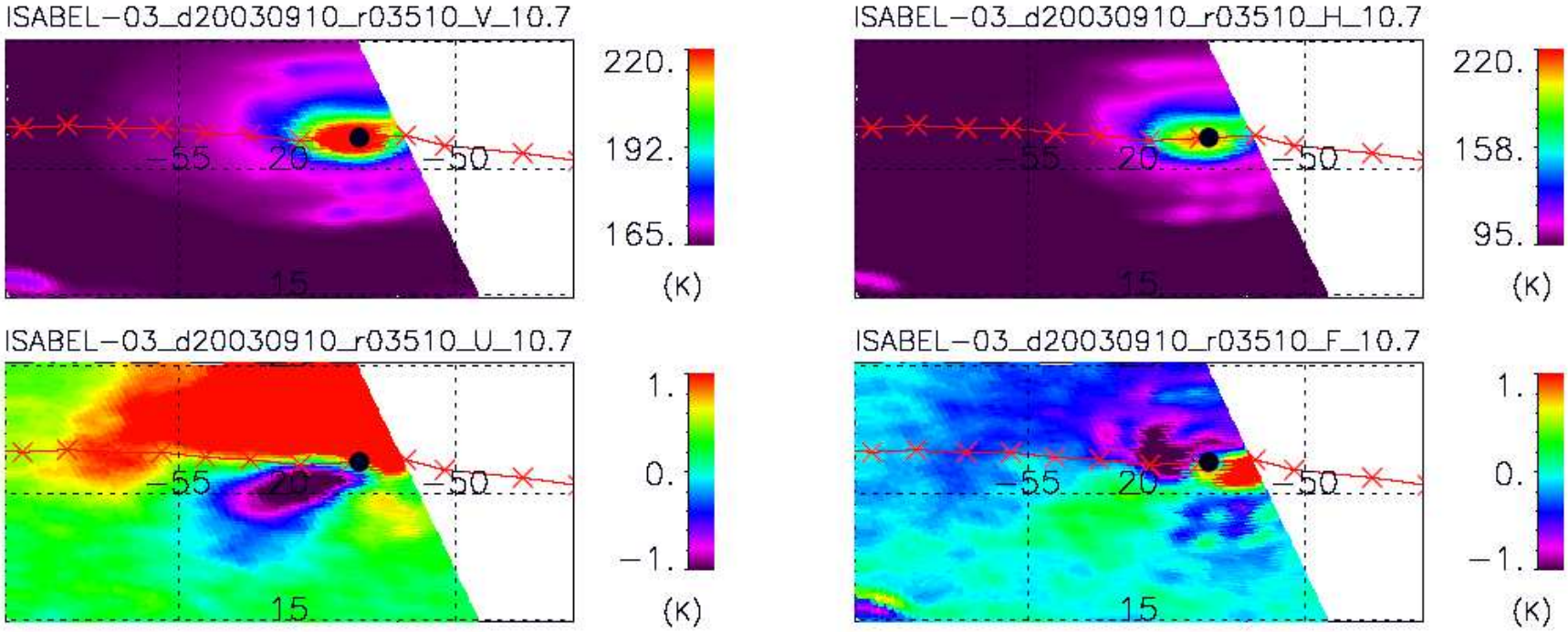
- Microwave emission from sea surfaces is polarized and varies with ocean surface wind speed and direction
- Stokes vector describes the full polarization properties of polarized radiation
- Measurement techniques
  - Coherent Correlation measurements
  - Incoherent power measurements



$$I = \begin{bmatrix} I \\ Q \\ U \\ V \end{bmatrix} = \begin{bmatrix} |E_v|^2 + |E_h|^2 \\ |E_v|^2 - |E_h|^2 \\ 2\,\mathrm{Re}\langle E_v E_h^* \rangle \\ 2\,\mathrm{Im}\langle E_v E_h^* \rangle \end{bmatrix} \propto \begin{bmatrix} T_v + T_h \\ T_v - T_h \\ T_{45} + T_{-45} \\ T_{LC} - T_{RC} \end{bmatrix}$$

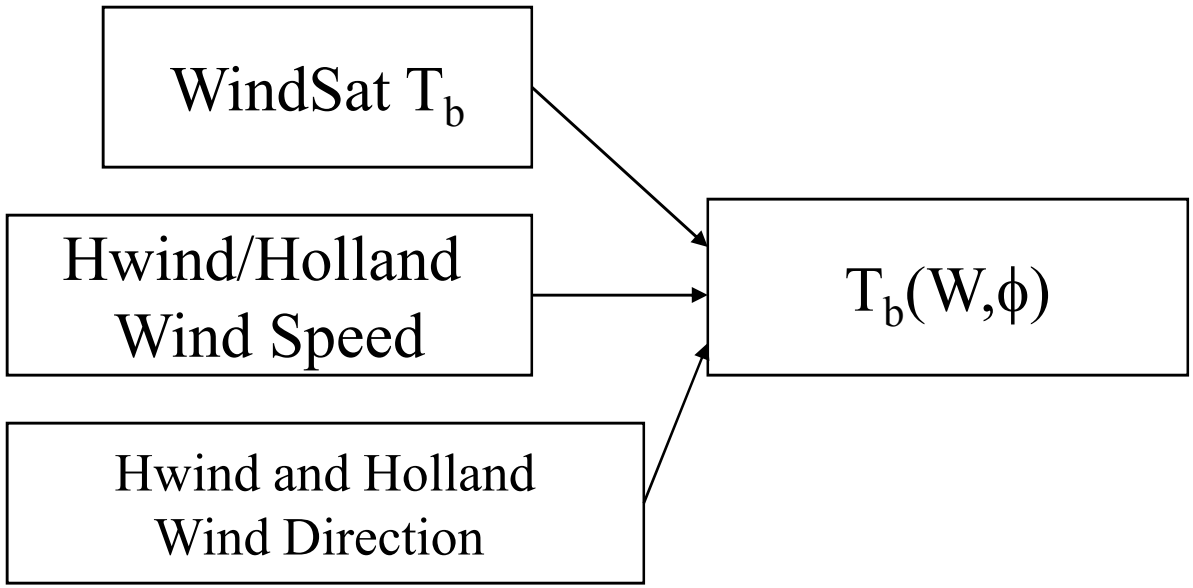
WindSat 10 GHz Data for Hurricane Isabel Rev 3510

- U data show circulation around eye



High Wind Geophysical Model Function for Passive Microwave

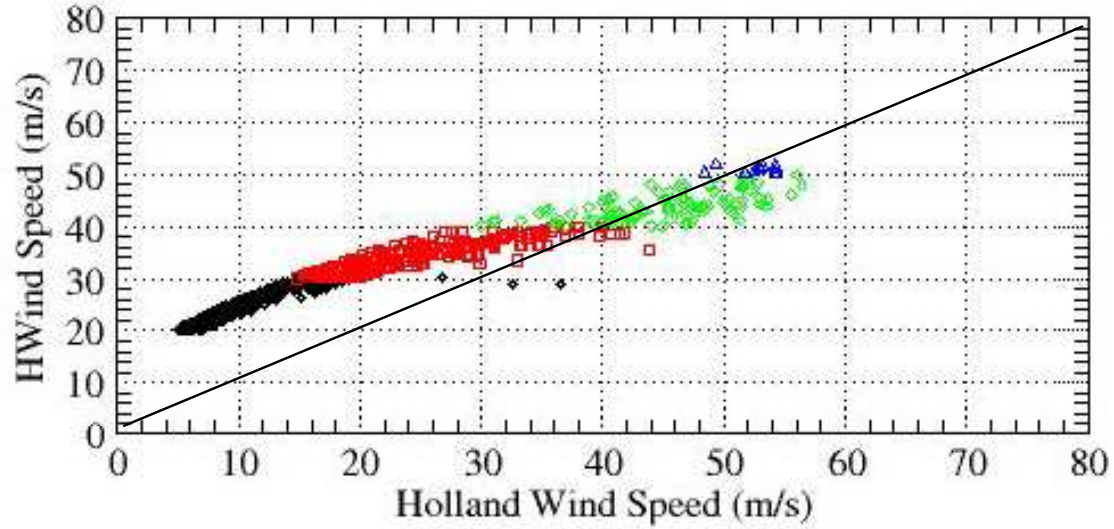
- WindSat Tb data are paired with the NOAA HDR HWind analyses and Holland's model winds
- Collocated data are binned as a function of wind speed and direction

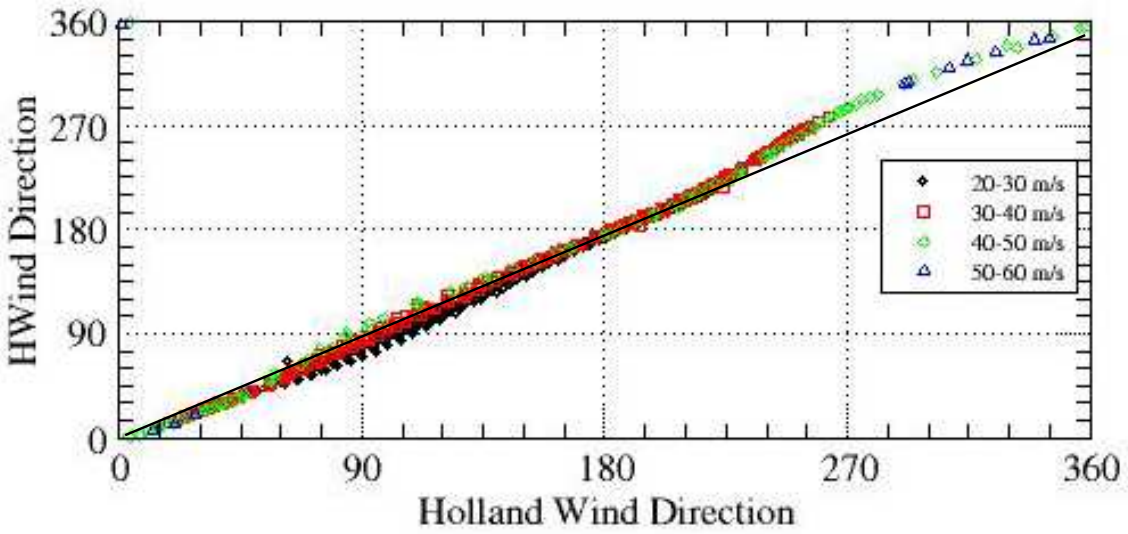


WindSat and Hwind Collocations in 2003-2005

Hurricane	Year	WindSat Rev#
Isabel	2003	03510, 03518, 03525, 03562
Fabian	2003	03402
Ivan	2004	08738
Frances	2004	08559
Jeanne	2004	08865, 08871, 08879
Rita	2005	14027, 14033
Wilma	2005	14444, 14452
Katrina	2005	13693

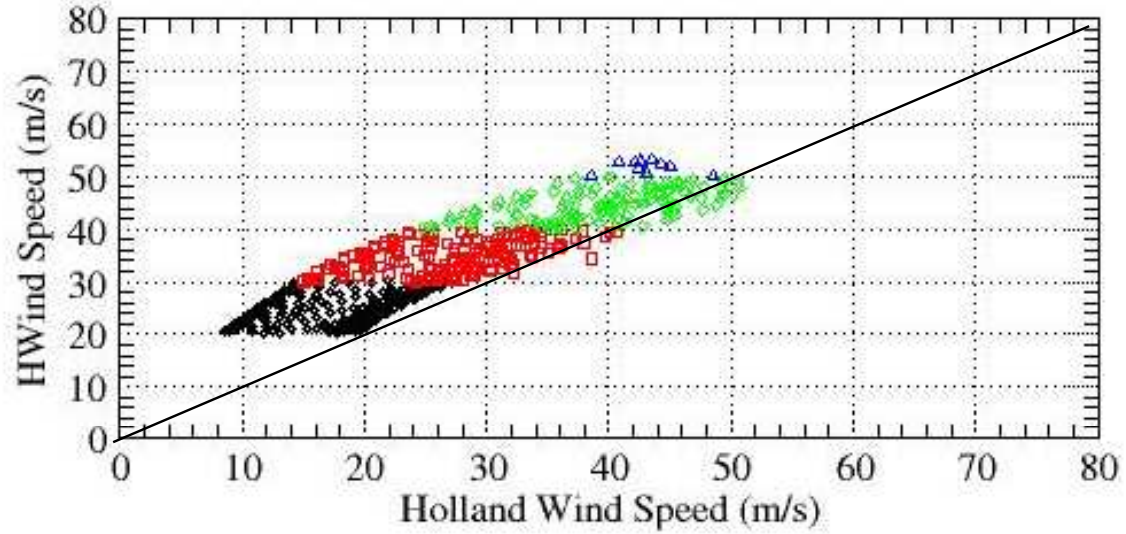
HWind Versus Holland Model Winds for Katrina (WindSat Rev 13693)

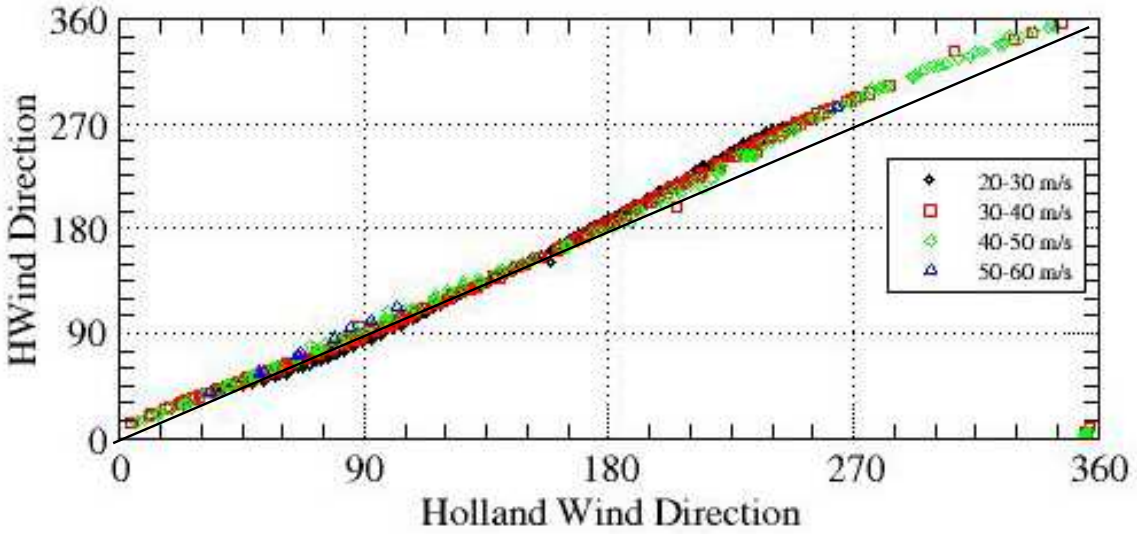




- Hwind wind speed is higher at 20-30 m/s than Holland's, but lower at 50 m/s.
- Hwind and Holland model wind directions are in very good agreement.

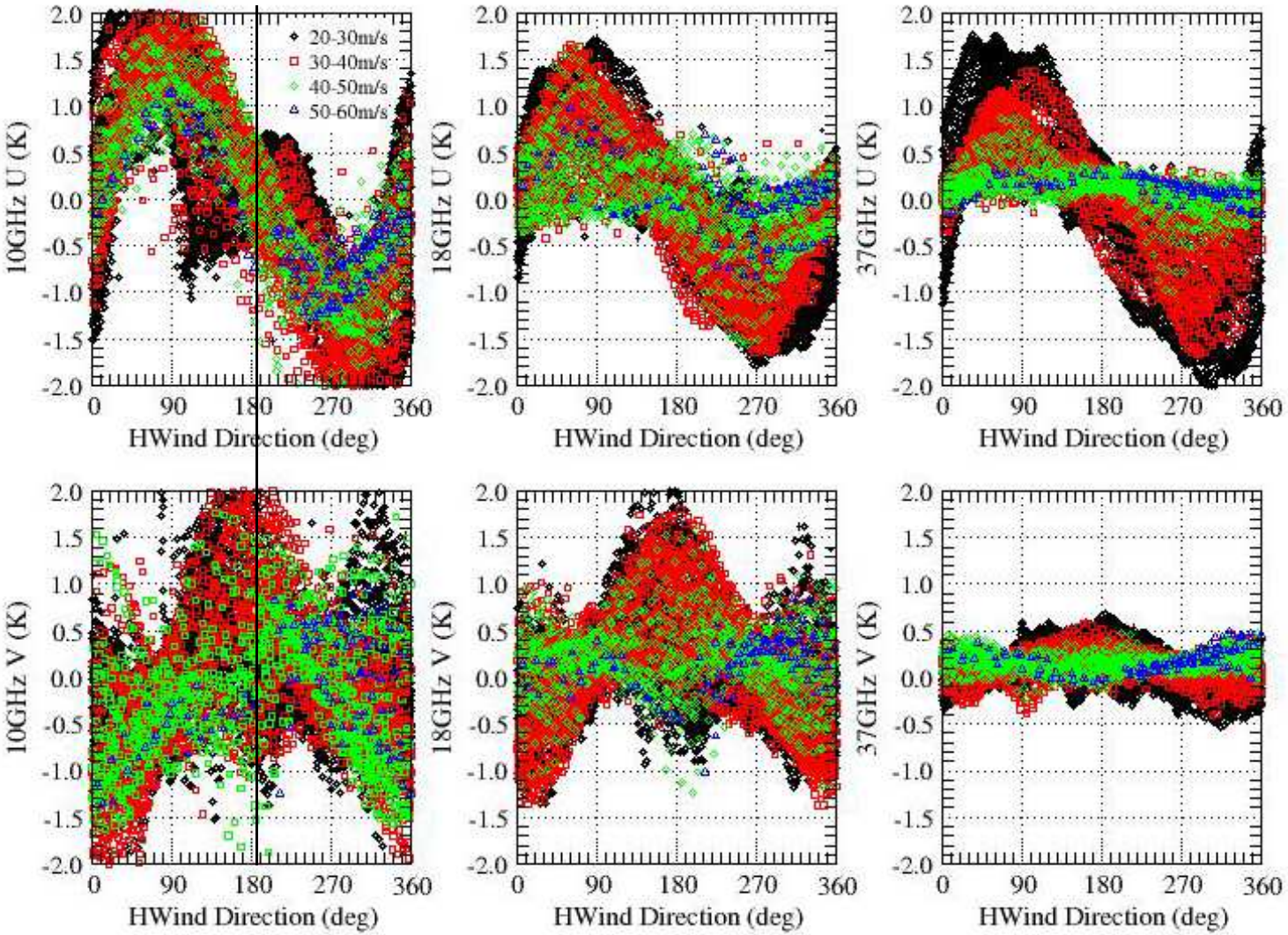
HWind Versus Holland Model Winds for Isabel (WindSat Rev 3510)





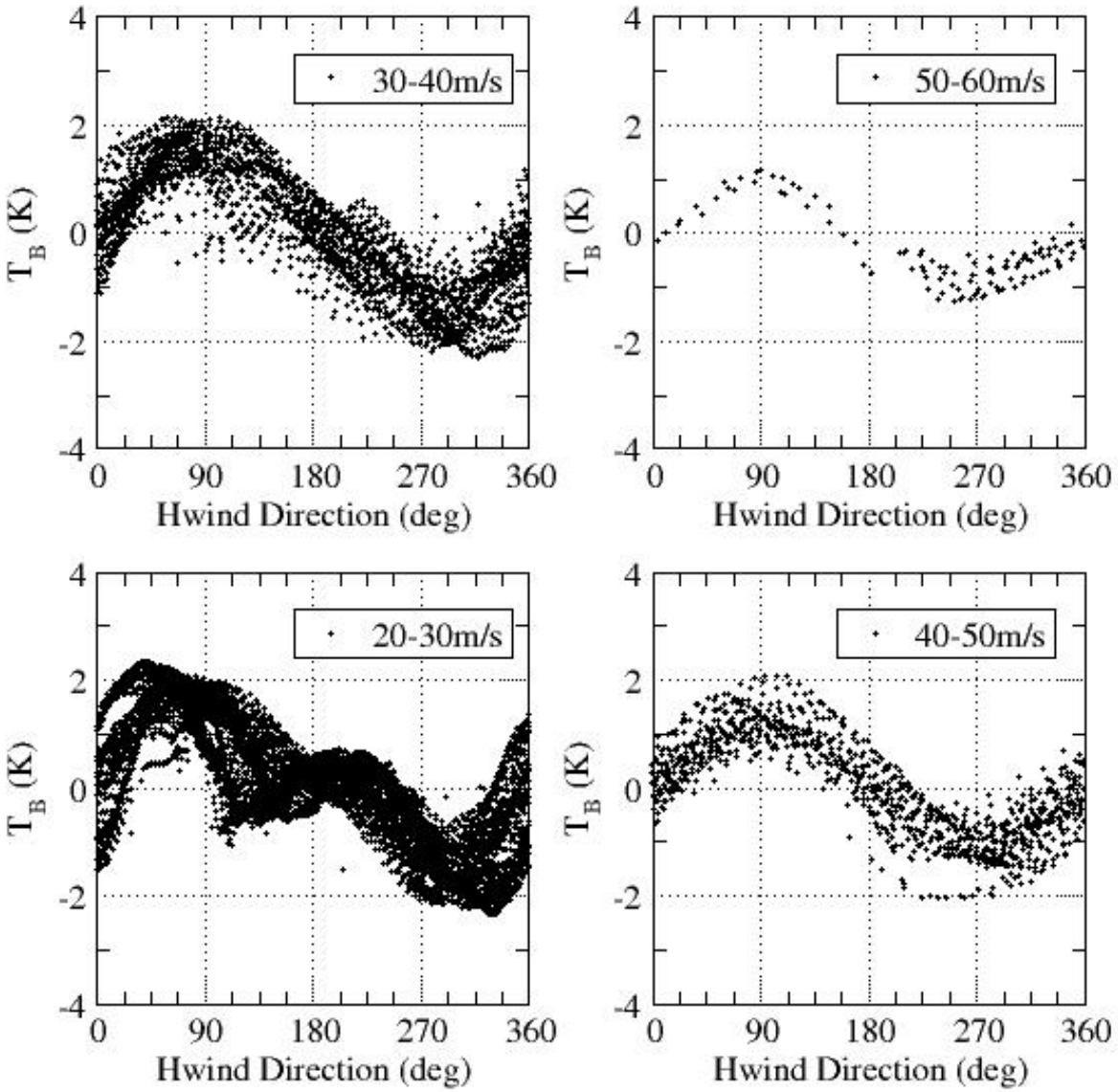
- Hwind wind speed is higher than Holland's,
- Hwind and Holland model wind directions are in good agreement, except with an overall 15 degrees bias.

WindSat U and V Signals Versus HWind for Atlantic Hurricanes 2003-2005

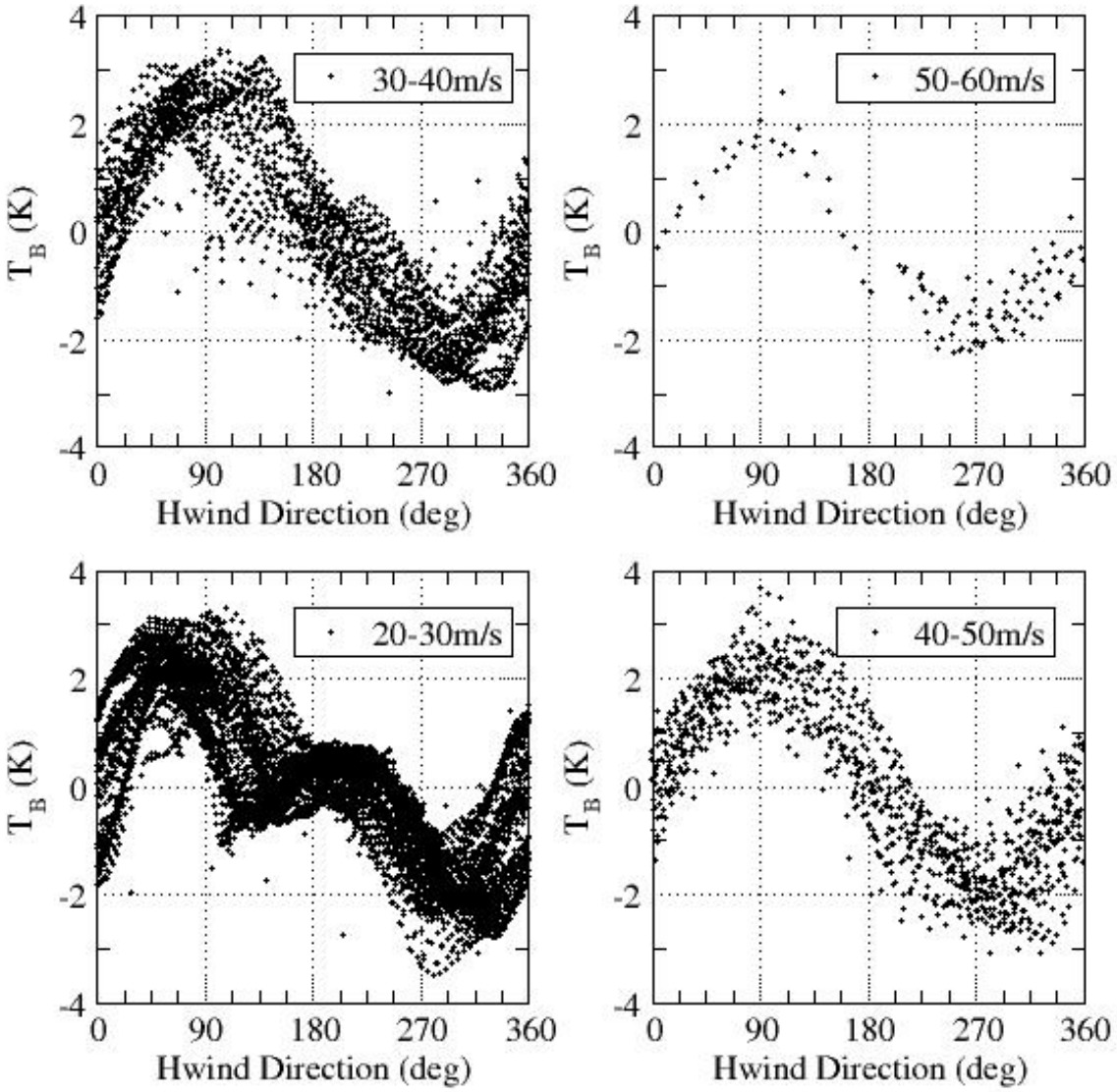


- There were wind direction signals in U data.
- Anomalous signals in V data

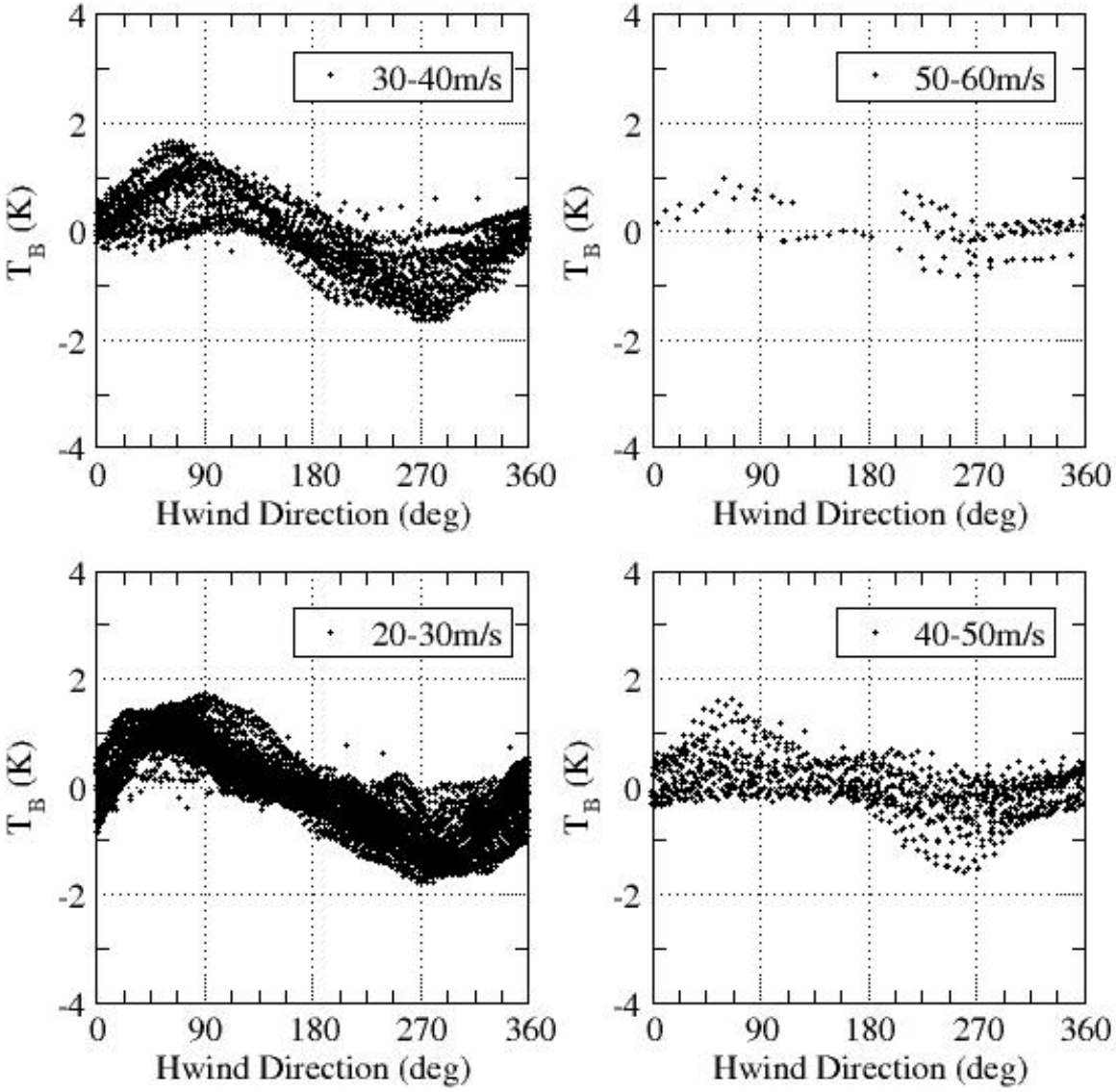
WindSat U Signals Versus Hwind Direction at 10 GHz for Atlantic Hurricanes 2003-2005



WindSat U Signals Versus Hwind Direction at 10 GHz for Atlantic Hurricanes 2003-2005 (Corrected for Attenuation)

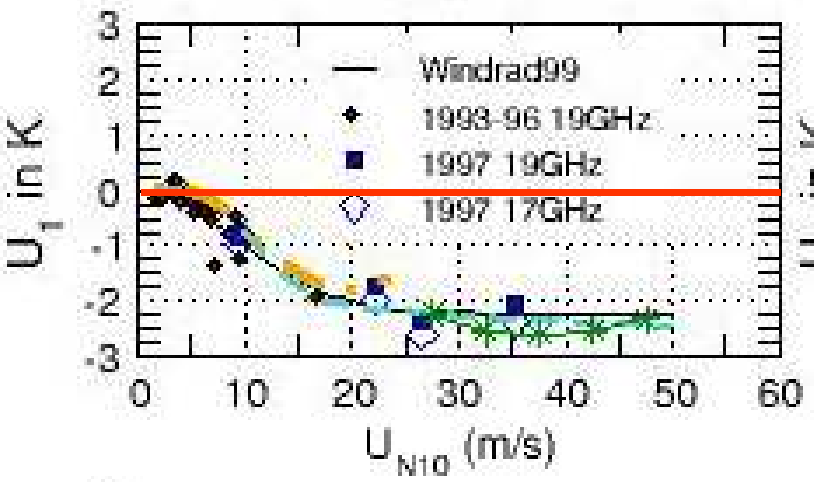


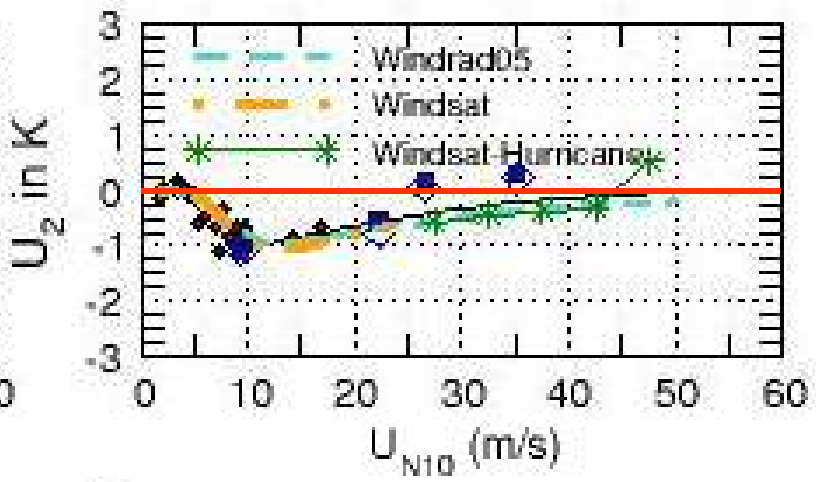
WindSat U Signals Versus Hwind Direction at 18 GHz for Atlantic Hurricanes 2003-2005

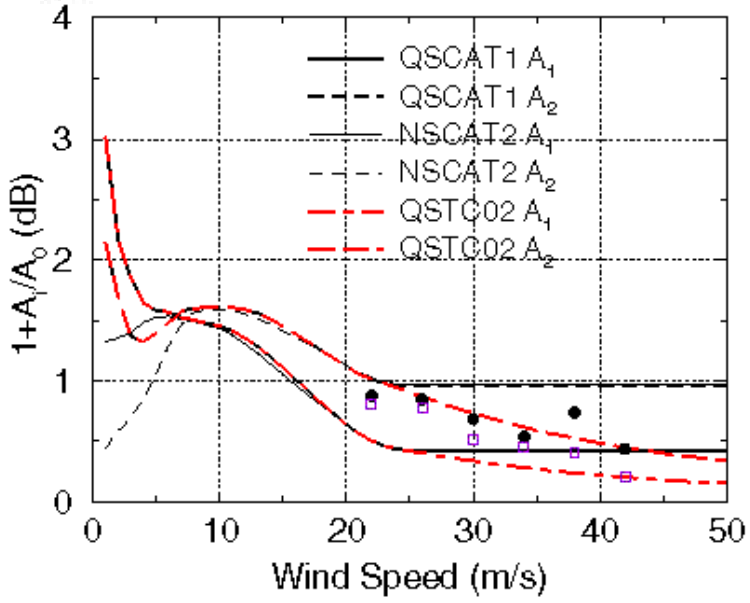


WindSat U Model Function and Comparison with Aircraft K-band Data and

$$U = U_1 \sin\phi + U_2 \sin 2\phi$$







- WindSat U data agree well with aircraft data
- The active and passive directional signals decrease with wind speed at above 30 m/s

Summary

- Active and passive microwave signals show complementary (cosine vs. sine) directional response for 30-50 m/s winds.
  - This supports the use of combined active and passive techniques for future OVWM.
- Rain effects need correction for scatterometer wind retrievals (Yueh et al. 2001 and 2003)
- The analysis technique to derive model function for high winds using the collocated Hwind analyses and Holland model fields is supported by aircraft measurements.

Future Work

- Apply the Hwind/Holland model winds to the ASCAT data to derive the C-band spaceborne scatterometer model function.
- Collocate active (QuikSCAT/ASCAT) with passive (AMSR/WindSat) data to develop advanced wind products for tropical cyclones.
  - Rain correction
  - Direction accuracy