Optimized Tropical Cyclone Retrievals from ASCAT, OceanSAT-2 and QuikSCAT

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Outline

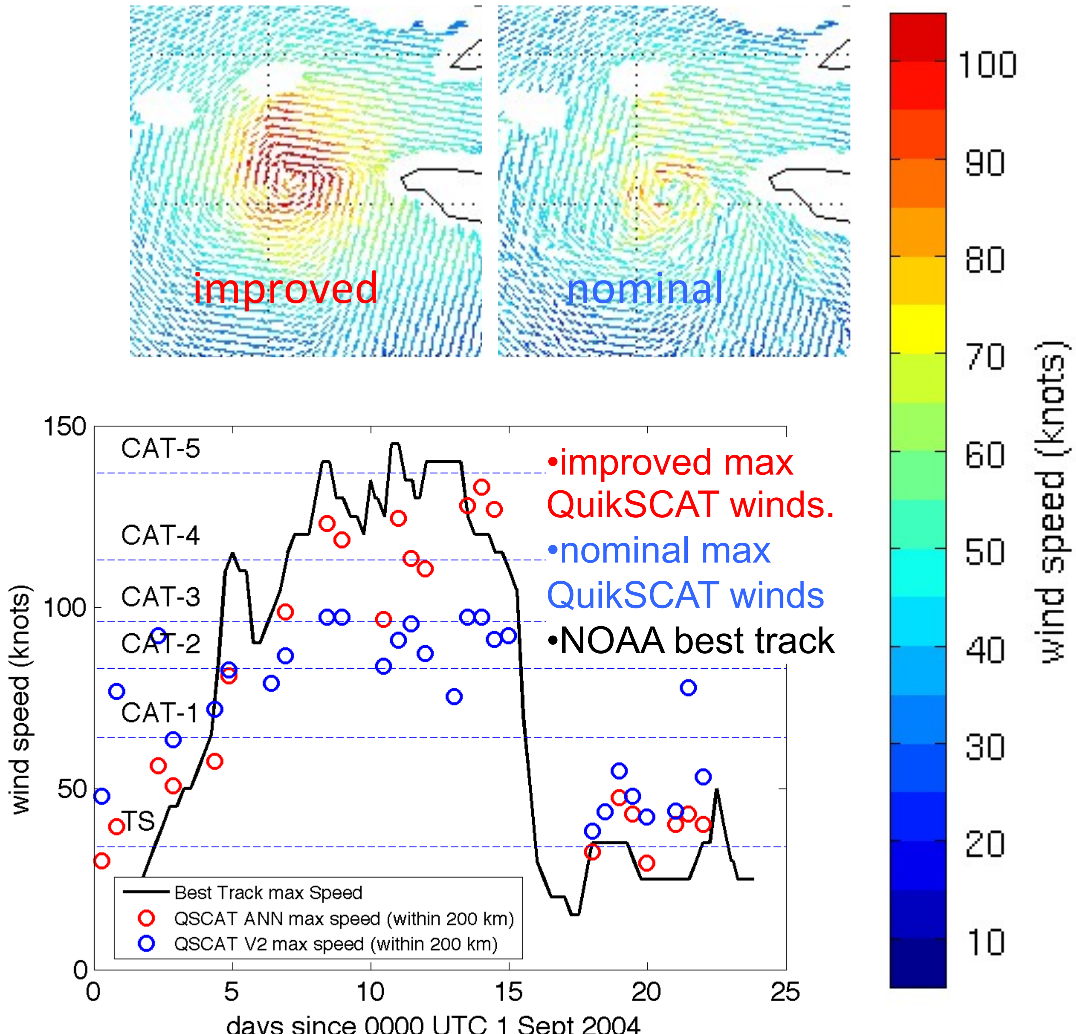
- Background description of technique
- Review of Ku-band neural network performance
  - QuikSCAT/OceanSAR-2 data set description
  - Why does it work?
  - For more detal see: Stiles et al, “Optimized Tropical Cyclone Winds from QuikSCAT: A Neural Network Approach,” IEEE TGARS. In press DOI 10.1109/TGRS.2014.2312333, available online at http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=6804024
- ASCAT Neural Networks and Results
  - Comparison with H*WINDS for different networks and training regimes
- Neural Network Derived ASCAT GMF
- Conclusions

Background

- The neural network determines corrections to the MLE speed as a function of
  - SRAD rain rate (for QuikSCAT, OceanSAT-2)
  - Backscatter
    - from two different polarizations, two different azimuths, and two different spatial resolutions (2 X 2 X 2 = 8 values for QuikSCAT/ OceanSAT-2)
    - From 3 different incidence angles (3 values for ASCAT)
  - Viewing geometry
    - cross track distance for Ku-band scatterometers
    - Incidence angles for ASCAT
  - MLE speed
  - Passive microwave info from scatterometer noise channel
    - Brightness Temperature (OceanSAT2)
    - QRAD rain rate (QuikSCAT)

QuikSCAT Data Set Description

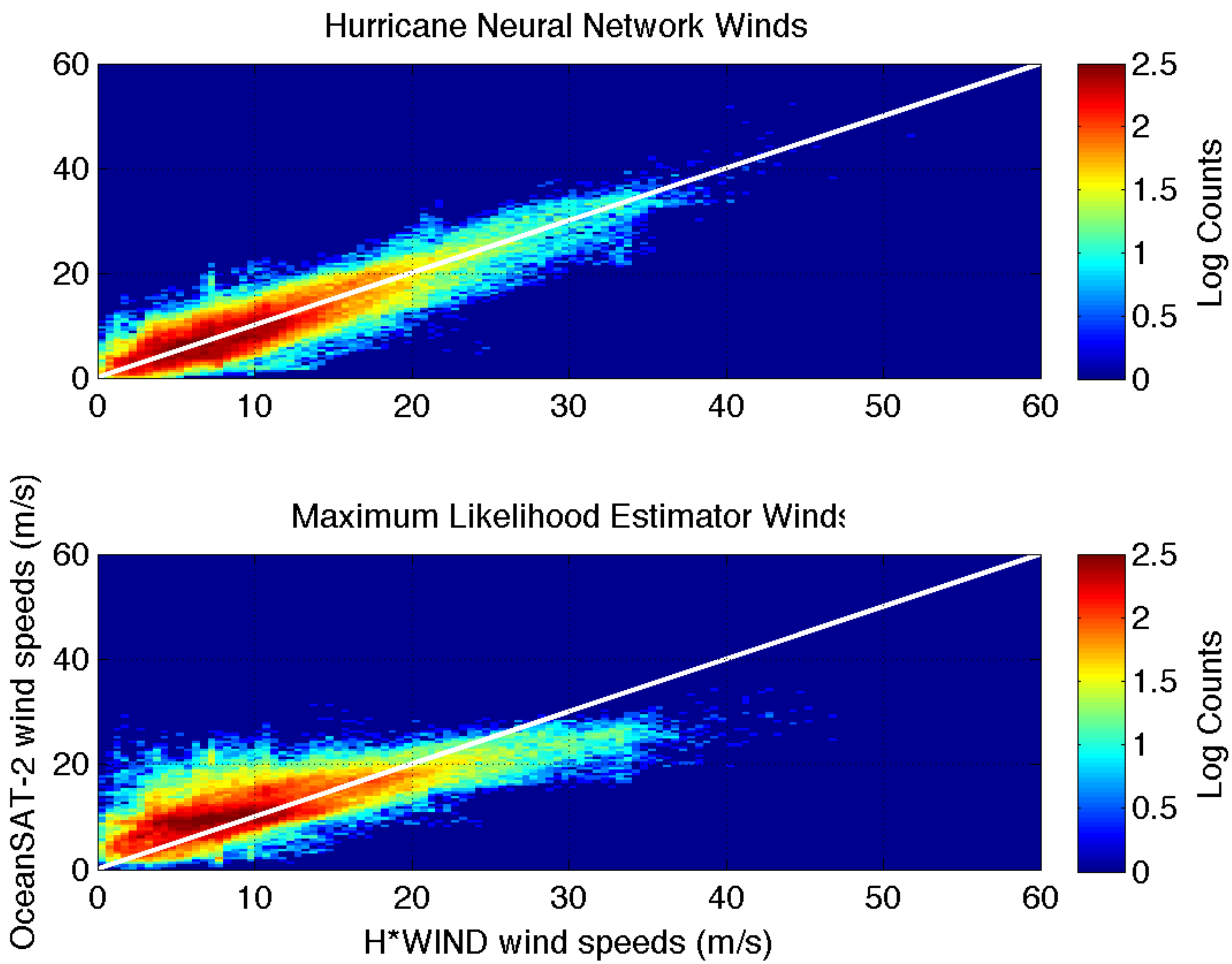
Hurricane Ivan 23:37 UTC 11 Sept. 2004



See http://tropicalcyclone.jpl.nasa.gov

- Improved QukSCAT tropical cyclone (TC) wind speed fields
  - –12,476 storm scenes over 12 years
  - –Validated vs. hurricane analysis fields and aircraft overflight measurements.
- Problem: Scatterometer winds are corrupted by rain and use empirical retrievals not optimized for high winds.
- Solution: Neural network retrieval method trained specifically for TC winds.
- Developing similar datasets for the ASCAT (ESA) scatterometers.

Validation: OceanSAT-2



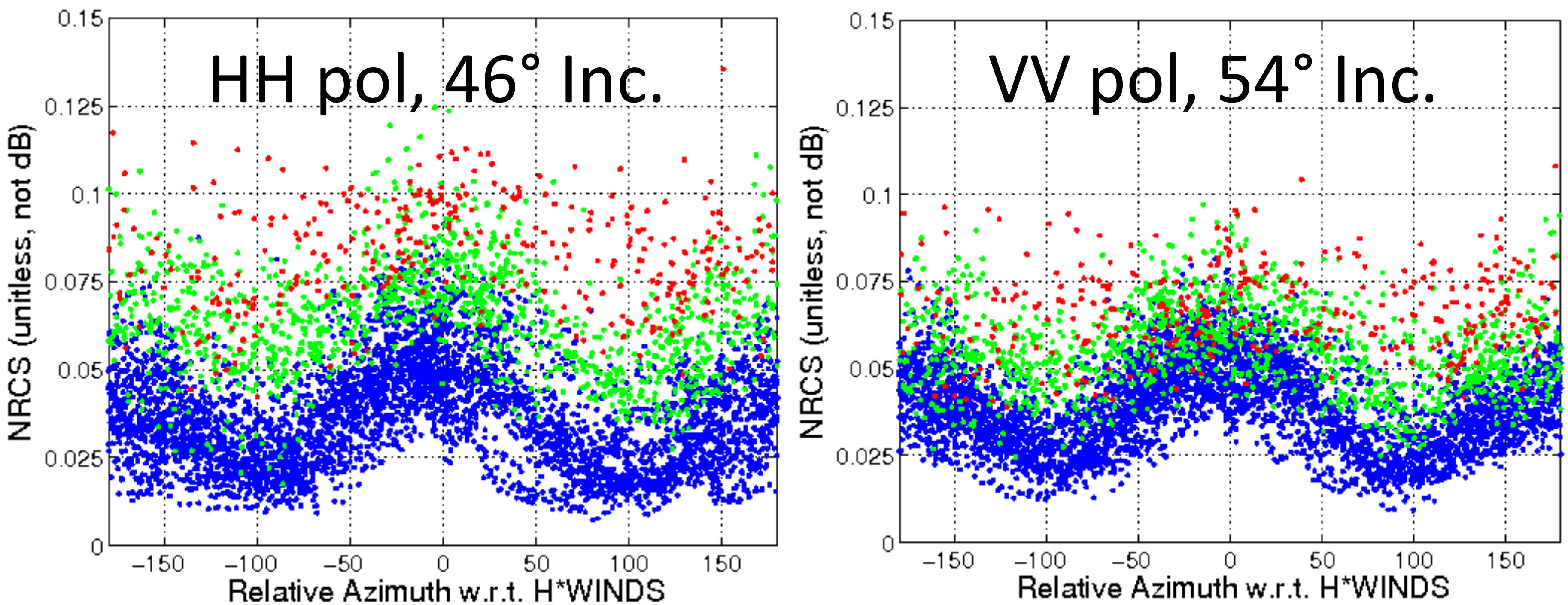
How does it work?

- The resultant multi-dimensional mapping is hard to visualize.
- The next few slides exemplify how this works by
  - Showing Ku-band sigma-0 is sensitive to winds from 20-40 m/s
  - Examining a specific case of MLE speed = 24-26 m/s and CTD = 400-450 km
    - We examine how the ANN utilizes three parameters of interest , Copol ratio, sum sigma-0, and SRAD rain rate (backup slides if time allows).

Ku-band NRCS is sensitive to wind speed in 20-40 m/s range.

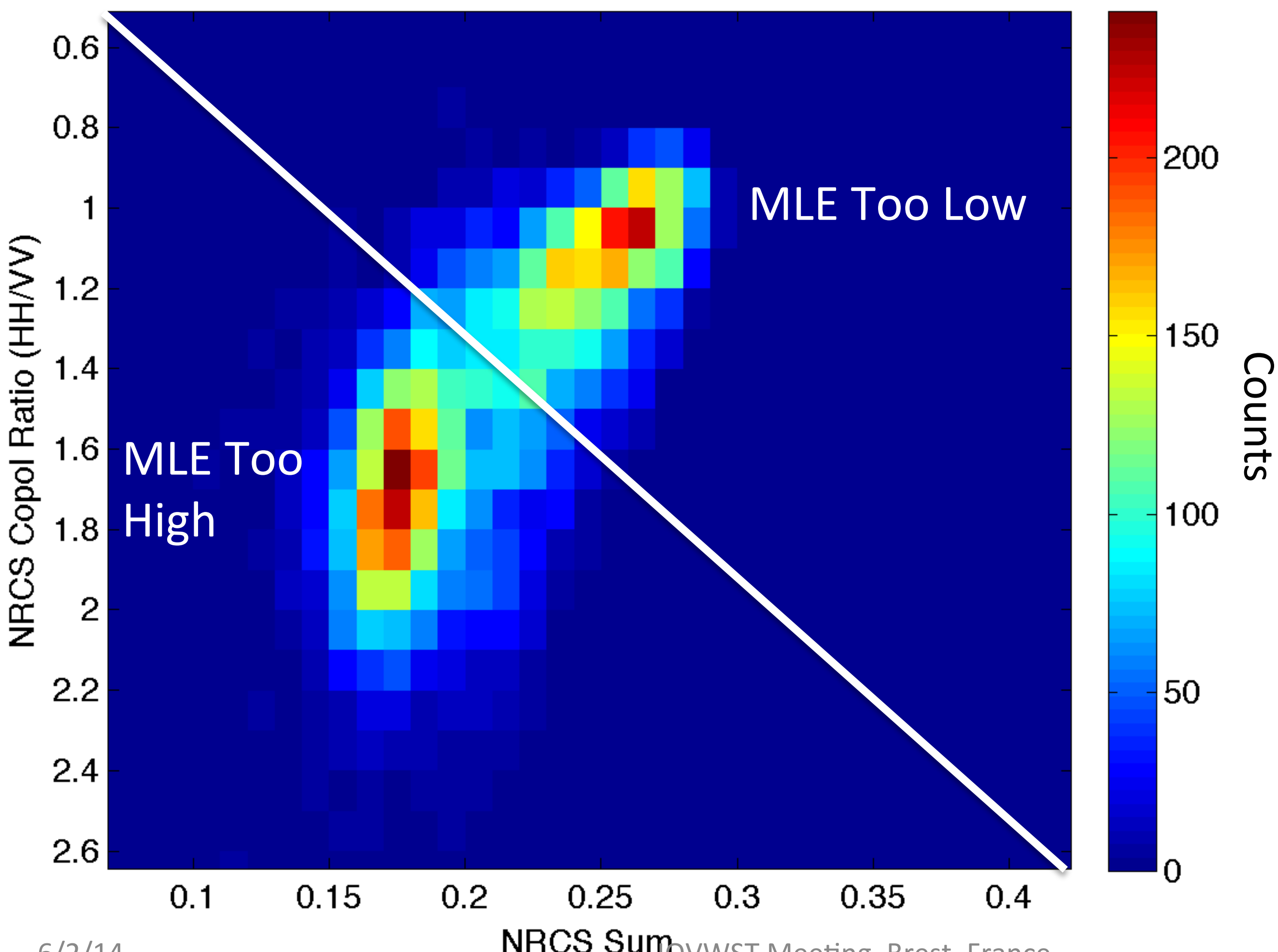
- In *rainfree* conditions (rain impact quantity <= 2.5), QuikSCAT HH pol 46 degree incidence NRCS values are sensitive to wind speed and direction in the 20-40 m/s range.
- QuikSCAT VV 54 degree incidence values have less sensitivity.

(Blue, Green, Red) = (20,30,40) m/s + or -10% H*WIND



Here's how the ANN can tell the difference

Agrees with Neural Network 92% of the time



High backscatter Co-polarization HH/VV ratio tends to indicate high MLE winds.

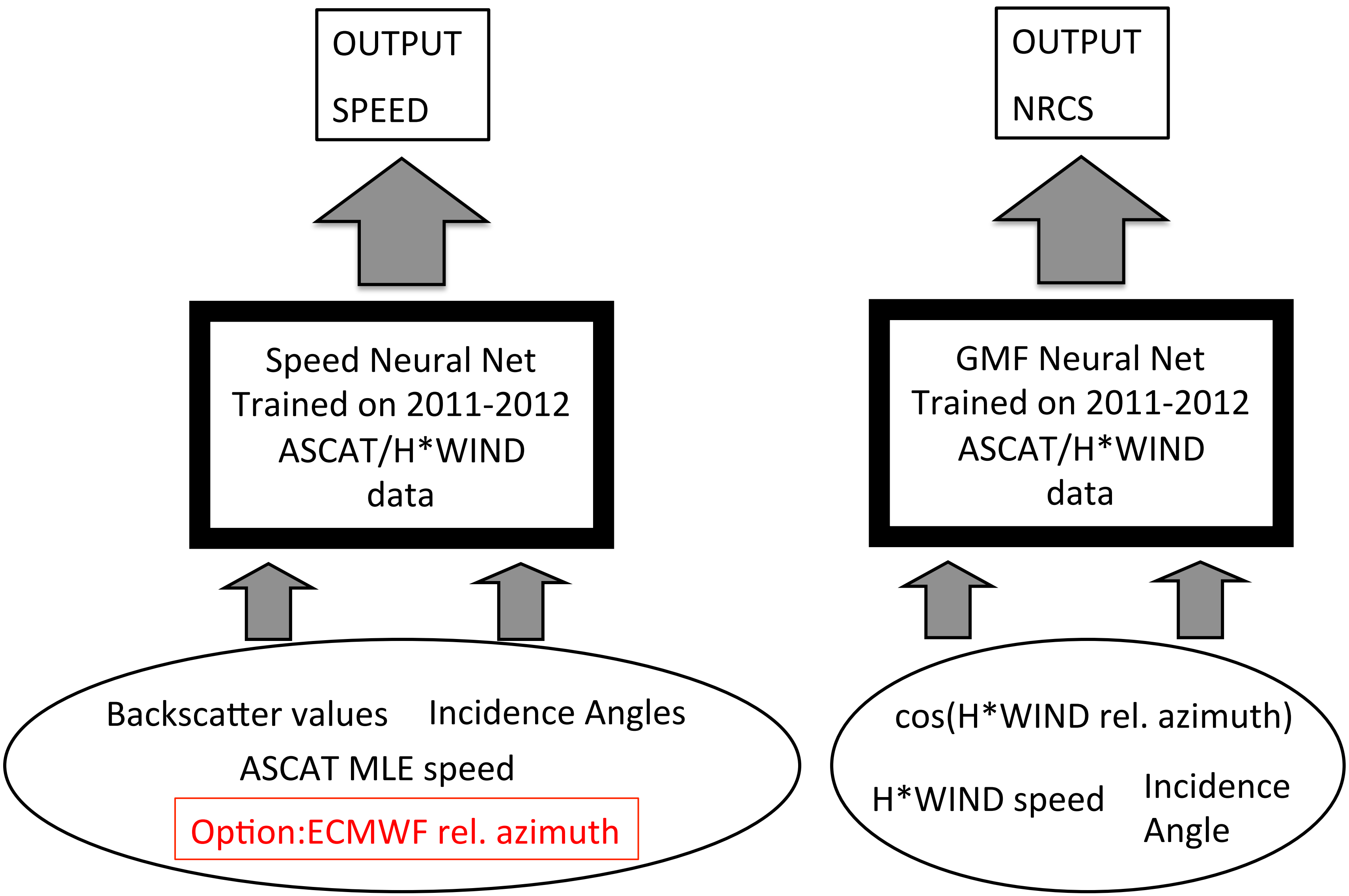
High sum of all backscatter tends to indicate low MLE winds.

Using the two parameters one can mimic the ANN's decision to raise or lower the MLE wind.

ASCAT NN Methodology

- First extended JPL MLE wind retrieval method to ASCAT.
  - Overall RMS directional difference from ECMWF is ~20 degrees for winds > 3 m/s; speed RMS < 2 m/s
- Compared with H*WIND in 2011 and 2012 North Atlantic Tropical Cyclones
  - For winds over 20 m/s ECMWF RMS directional difference from H*Wind ~ 20 degrees
  - ASCAT MLE winds RMS directional difference from H*WIND is 90 degrees.
  - ECMWF and ASCAT MLE wind speeds are low compared to H*WIND
- Trained Several Neural networks
  - Speed estimation from ASCAT NRCS and incidence angle
  - Speed estimation from ASCAT NRCS, incidence angle, and relative azimuth w.r.t ECMWF
  - GMF estimation (input=speed,relative azimuth, incidence; output = NRCS in dB)

Diagram of ASCAT Networks

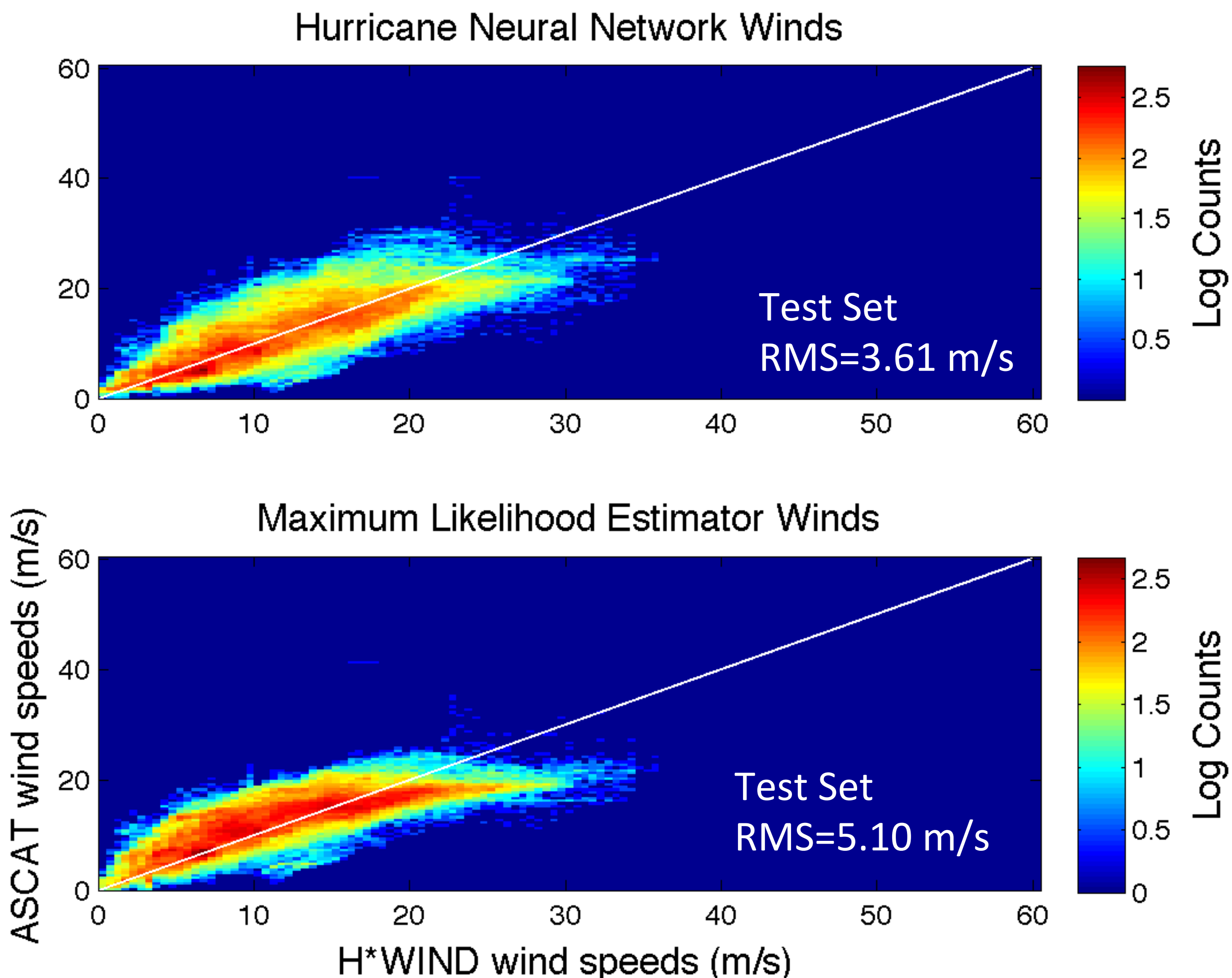


Training and Validation Sets

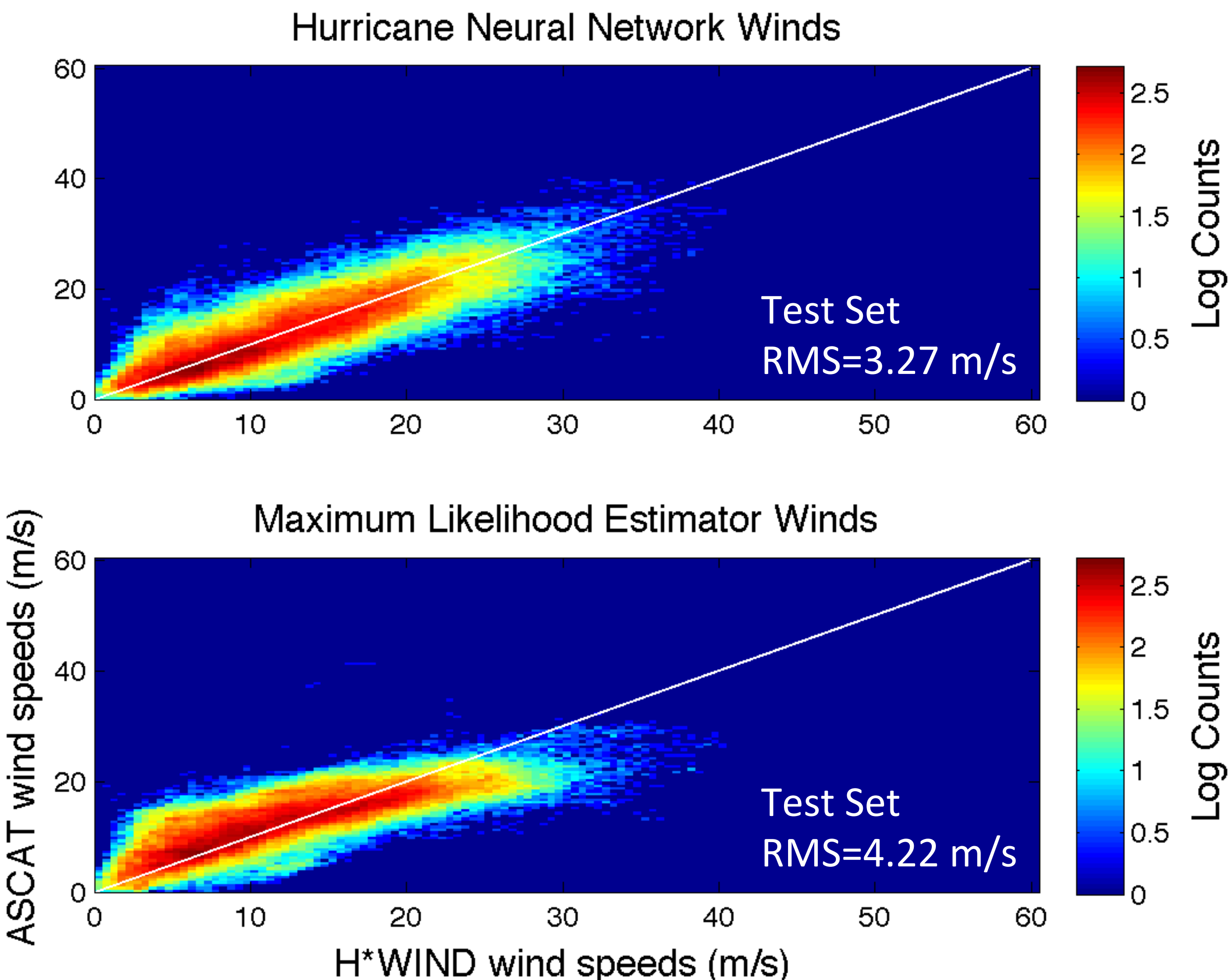
- Wind ground truth H*WIND in 2011 and 2012
  - Very few wind sample above 30 m/s that have ASCAT co-locations.
  - Large portion of highest winds from Sandy.
- Highest resolution available ASCAT NRCS was binned in 12.5 km cells.
- Breaking up data at orbit boundaries between training and validation sets led to poor performance.
  - Needed to break up randomly at WVC level to get sufficient statistics to train.
    - Need good sampling over full 3-D space of speed, incidence, and relative azimuth space.
    - Indicates not enough training data.
    - Should revisit problem with larger data set.

Validation ASCAT

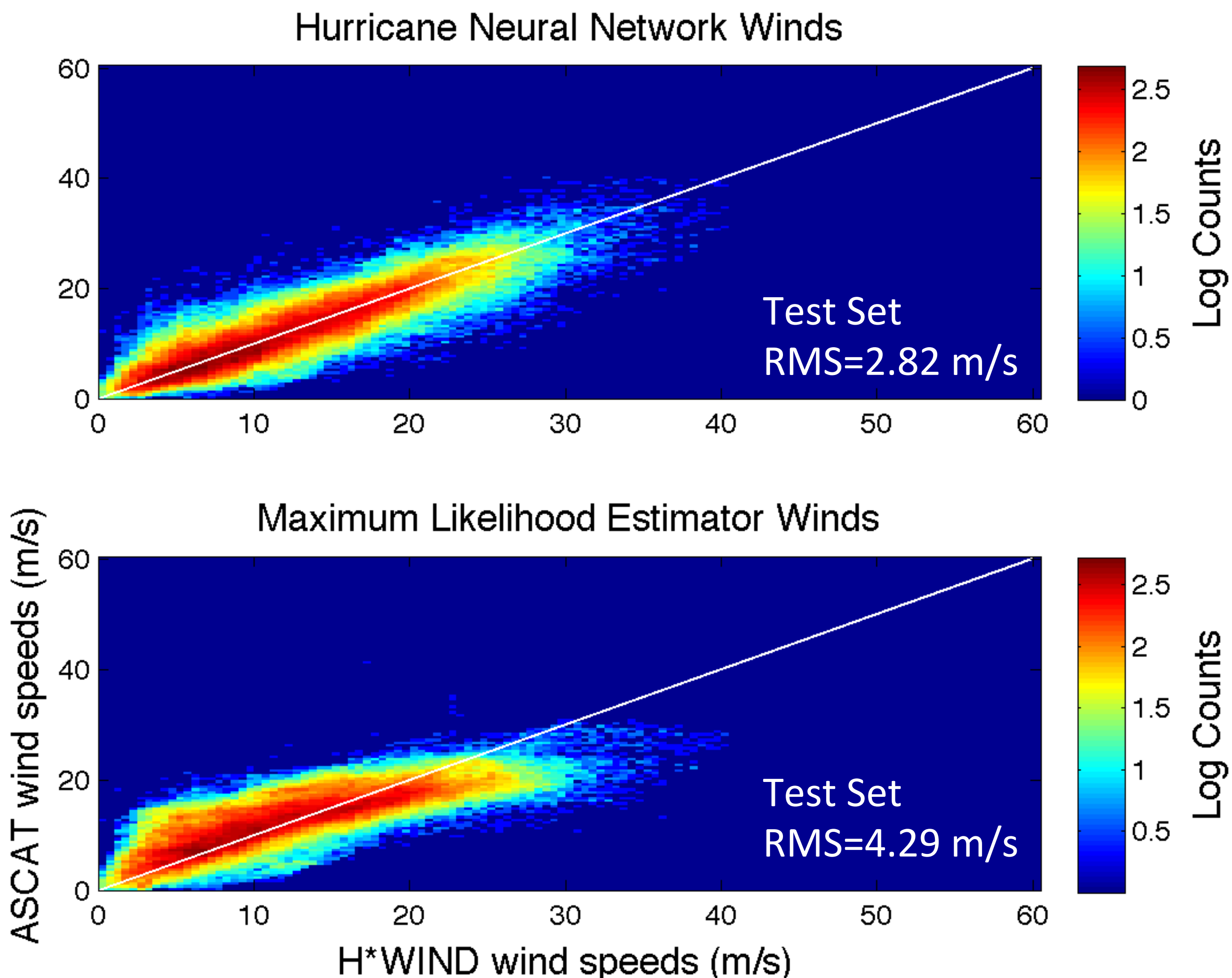
Training Set and Test Set from disjoint orbits.



Validation ASCAT – Training Set and Test Set from disjoint wind vector cells, but not orbits.

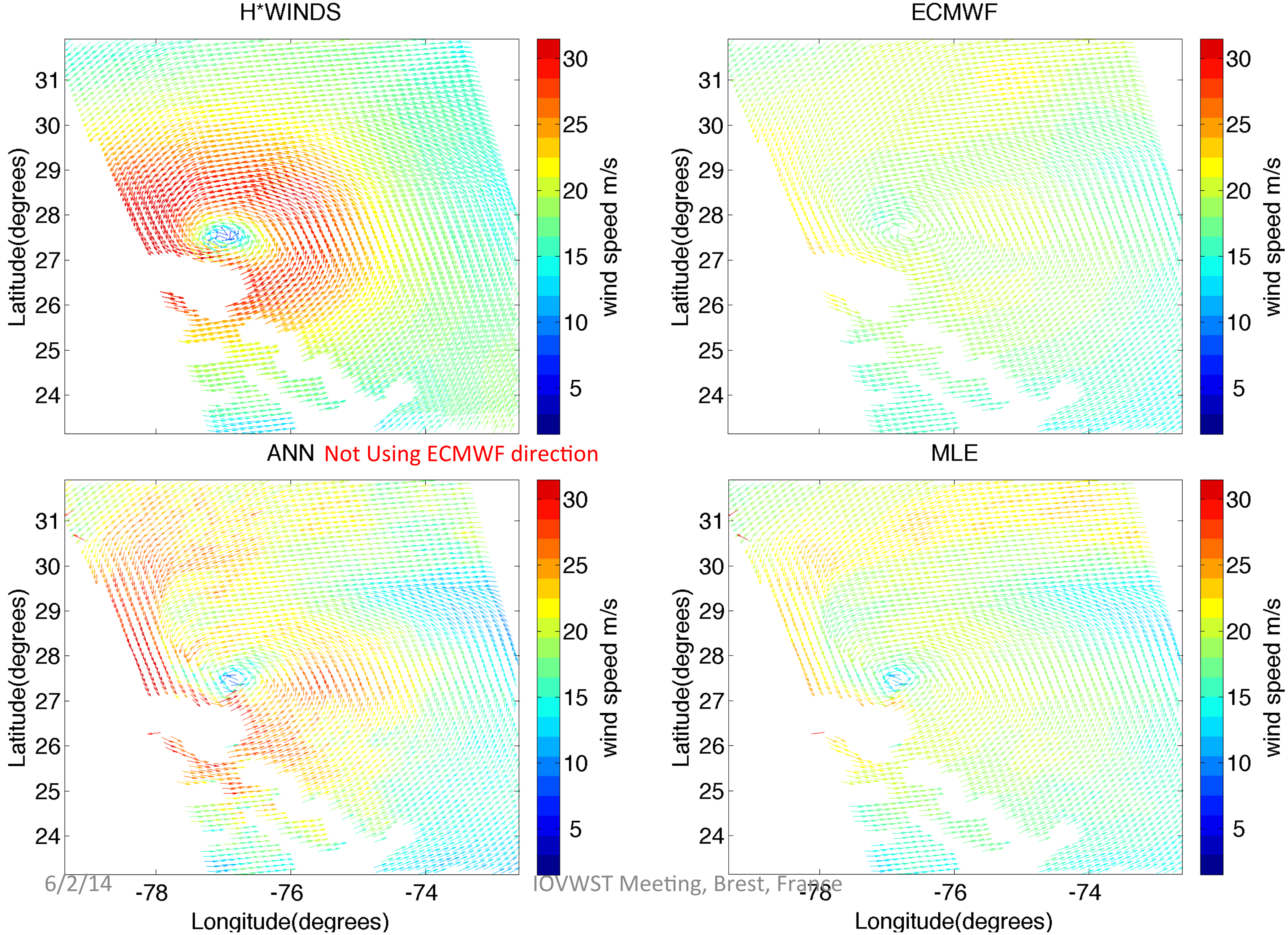


Validation ASCAT – Training Set and Test Set disjoint wind vector cells, using ECMWF relative azimuth.



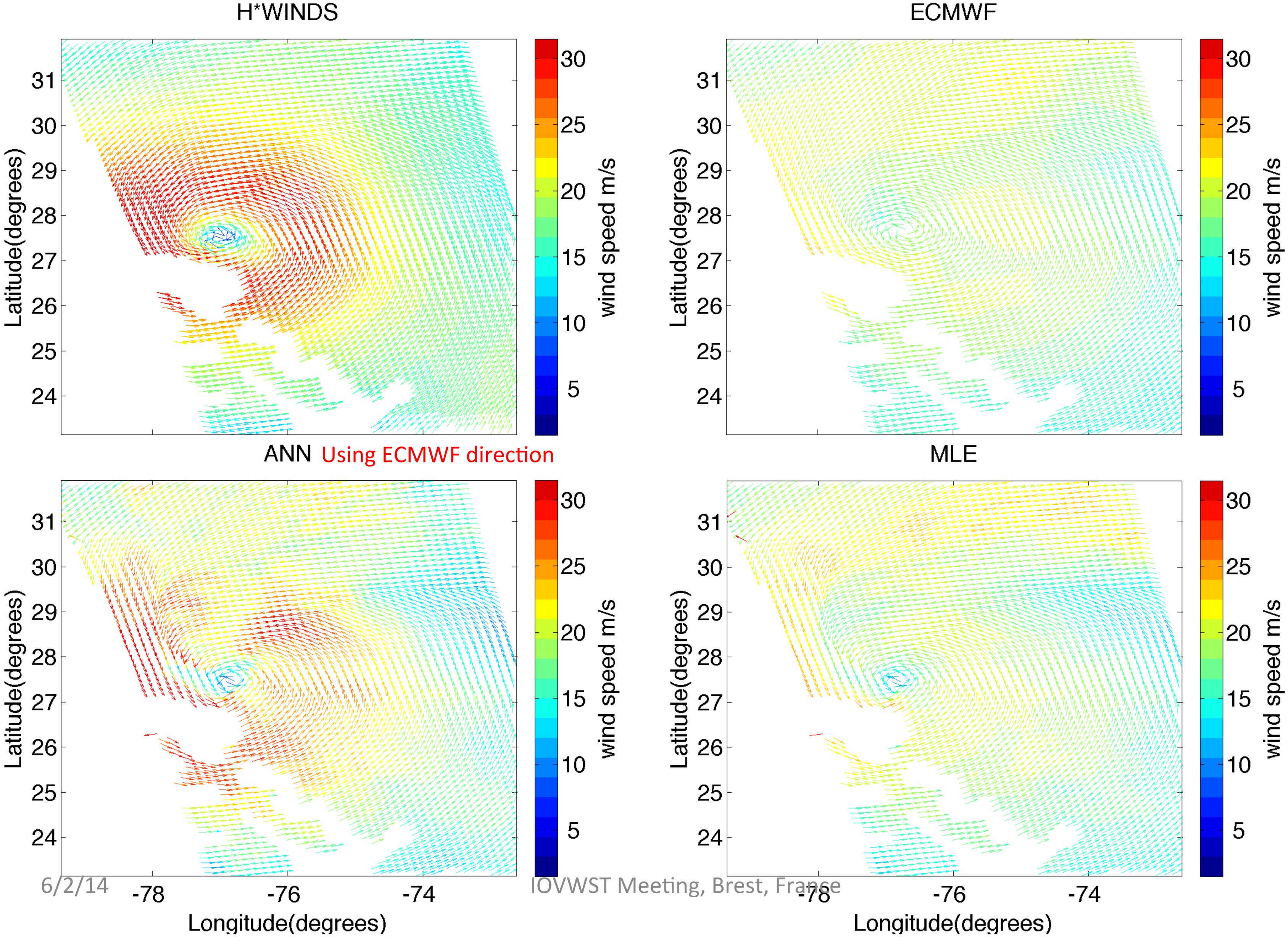
Hurricane Sandy 27-Oct 2012 UTC 02:39,

Max Speed= Best Track 63 knots (32.4 m/s), ANN 65.7 knots(33.8 m/s)

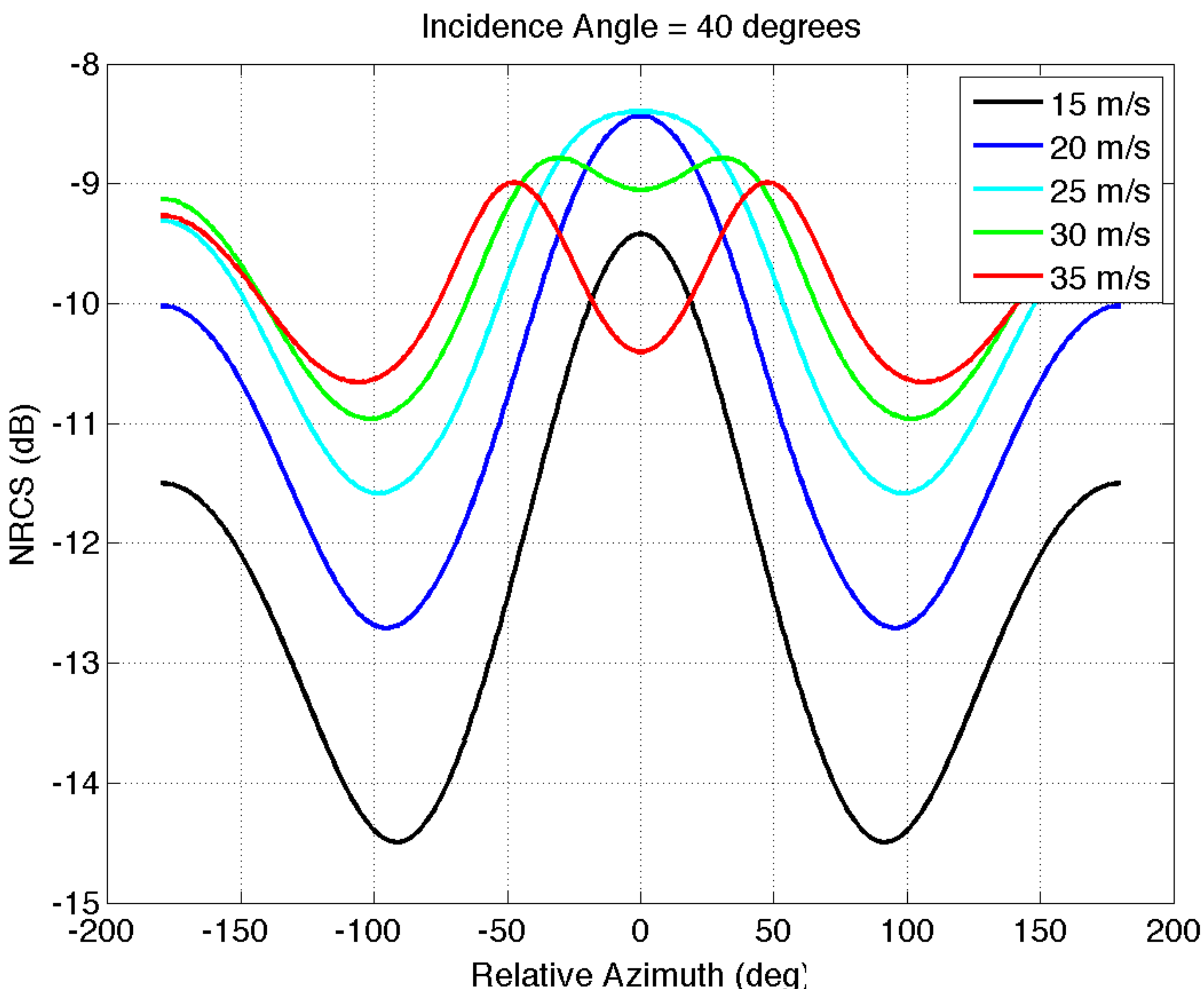


Hurricane Sandy 27-Oct 2012 UTC 02:39,

Max Speed= Best Track 63 knots (32.4 m/s), ANN 69.7 knots(35.9 m/s)



Neural Net GMF – 40 degrees incidence

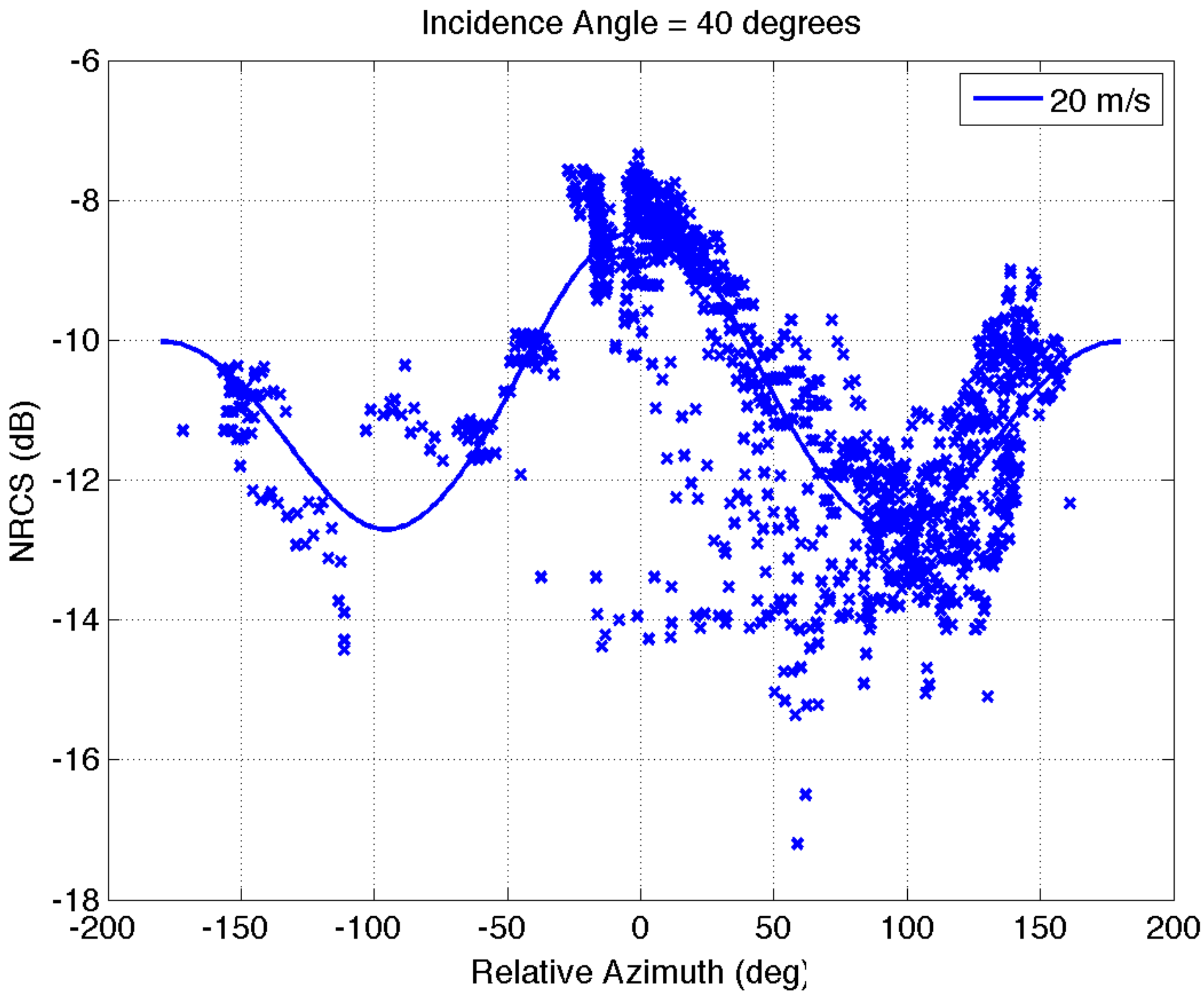


NN GMF Residual Error Statistics

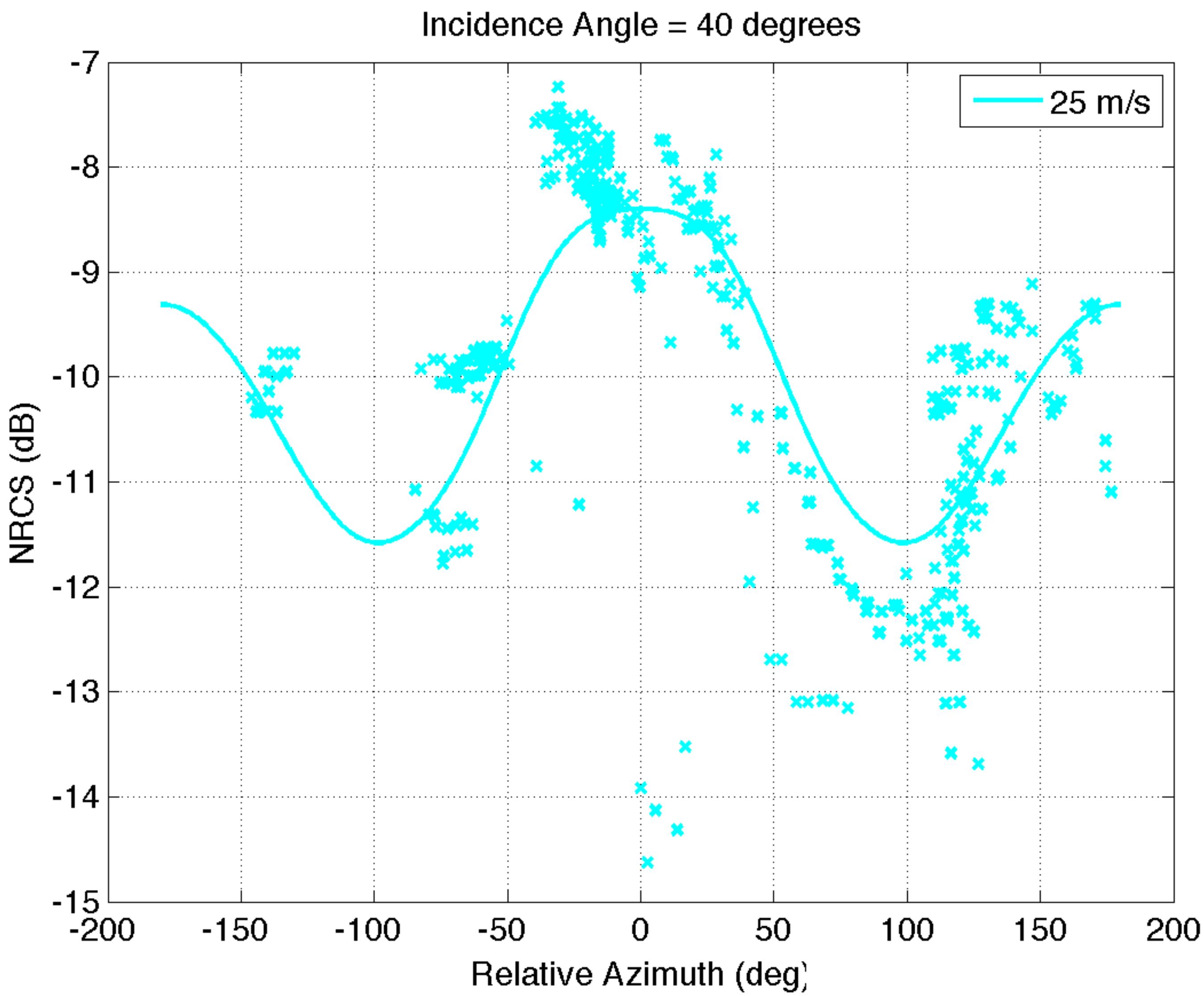
Metric	All	H*WIND speed>20	H*WIND speed>25	H*WIND speed>30
RMS	2.34 dB	1.12 dB	1.24 dB	1.62 dB
Median Absolute Error	1.15 dB	0.65 dB	0.75 dB	0.95 dB
Number of WVCs	163,426*	18,031*	5,172*	706*
Number of ASCAT orbits	105*	47*	28*	13*

* All numbers are for validation set, training is same size as validation set

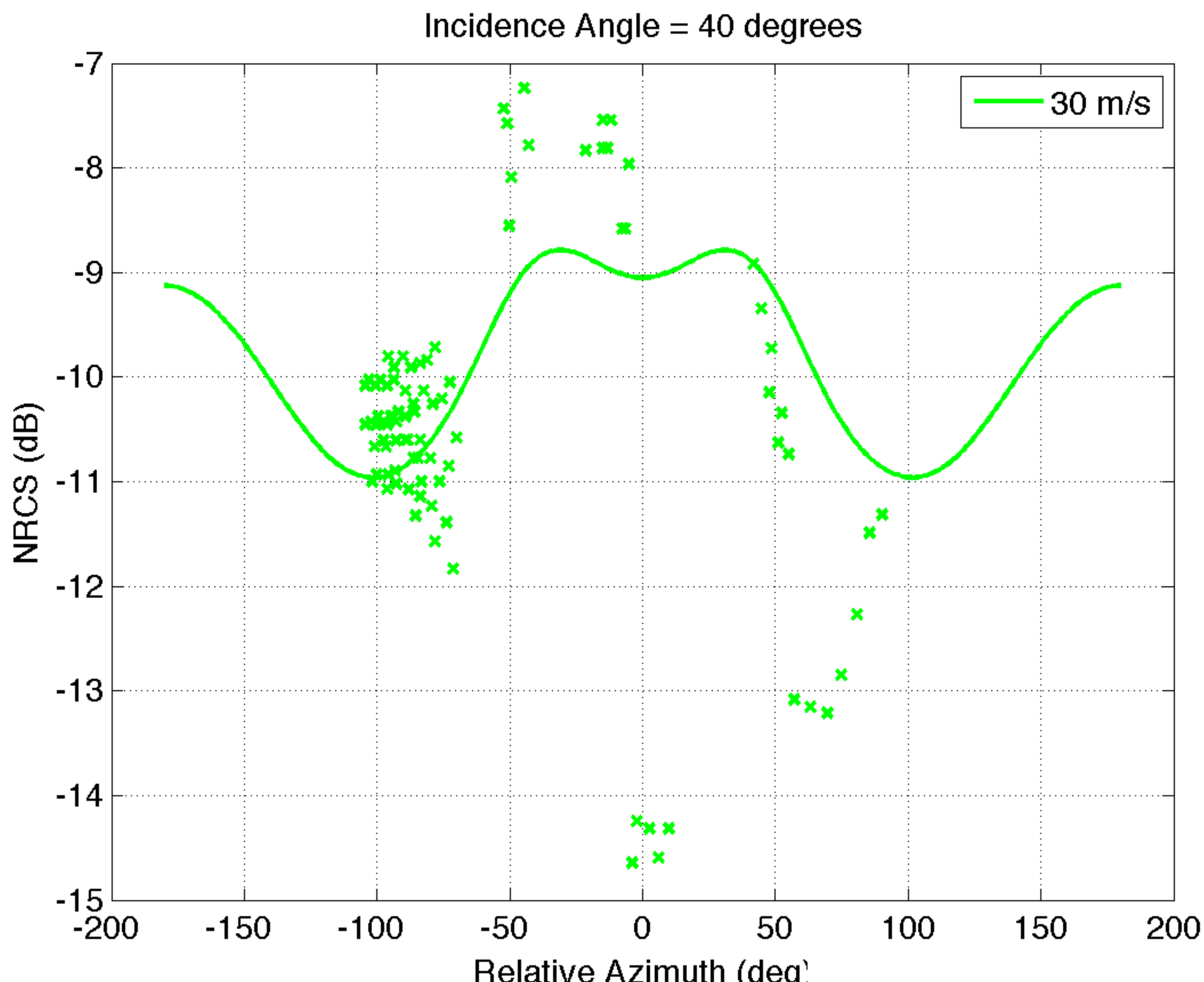
NN GMF 40 deg, 20 m/s speed



NN GMF 40 deg, 25 m/s speed



NN GMF 40 deg, 30 m/s speed



Summary

- Neural networks have been developed to obtain accurate tropical cyclones winds from 3 ocean wind scatterometer instruments.
  - Ku-band (QuikSCAT and OceanSAT-2) data available at http://tropicalcyclone.jpl.nasa.gov
- QuikSCAT ANN technique has been thoroughly validated and applied over entire 10 year mission to all known storms that achieved at least tropical storm status during their lifetimes.
  - Publication accepted in IEEE Trans. Geosci.
- Ku-band technique relies on autonomous brightness temperature measurements from rain channel and other rain-dependent backscatter signatures (e.g. copol ratio) to correct MLE winds for substantial rain contamination.
- C-band technique is promising but has remaining challenges
  - V-pol C-band has reduced sensitivity at high winds
  - Needs more training data.
  - Directional information is very important for determining wind speed in high winds.
- Future C-band scatterometers should consider adding H-pol to improve sensitivity at high winds!

Reference

- Details of QuikSCAT ANN technique, its validation, and how to obtain ten years of global QuikSCAT tropical cyclone wind speed data can be found in:
  - B. W. Stiles, R. E. Danielson, W. L. Poulsen, M. J. Brennan, S. Hristova-Veleva, T. J. Shen, and A. G. Fore , "Optimized Tropical Cyclone Winds from QuikSCAT: A Neural Network Approach," accepted for publication in IEEE Transactions on Geoscience and Remote Sensing. DOI 10.1109/TGRS.2014.2312333
  - Data found at http://tropicalcyclone.jpl.nasa.gov

Acknowledgements

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  - The website portal used to distribute the data set is part of a program funded by NASA's Hurricane Science Research program.