# RapidScat High Winds Observations

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# Outline

- Description of High Wind Retrieval for Previous Ku-Band Scatterometers
  - *Currently the most accurate high wind speed data set is archived as storm-centered data products separately from the nominal QuikSCAT and OceanSAT-2 full swath data sets.*
- Description of High Wind Retrieval for RapidScat
  - *Two different versions due to hardware malfunction*
- RapidScat High Wind Examples
- Conclusions
- References

# Description of High Wind Retrieval for Previous Ku-Band Scatterometers

# Background

- Goal: To optimize, produce, validate, and utilize ocean surface wind speed fields around all tropical cyclones (TCs) observed by QuikSCAT, OceanSAT-2, RapidScat, and ASCAT.
- Problem: Scatterometer winds in TCs are corrupted by rain and use empirical retrieval methods that were not optimized for high wind conditions.
    - *Rain contamination [Yueh and Stiles,2002] [Nie and Long, 2007].*
    - *Decreased sensitivity at high winds.[Fernandez et al, 2006],[Donelan et al, 2004]*
    - *Poorly trained GMFs for high winds due to large parameter space and lack of ground truth*
- Solution: Train a neural network to determine accurate TC winds for scatterometer data in the presence of rain.
- Neural Networks are useful for approximating simple nonlinear mappings with more than three inputs for which ground truth is available.
    - *Lower dimensionality or linear problems are better handled with other techniques.*
    - *Complex mappings (many different modes, etc) are difficult to train.*
    - *Situations without ground truth can be handled using unsupervised techniques, but such solutions are often impractical.*
- One can optimize a problem for a neural network solution by breaking it up into simpler sub-problems.

# Synopsis of Technique

- Using a simple neural network (Stiles et al , 2014), we fit a nonlinear mapping
  - *From 9 scatterometer measurements and one geometry indicator*
  - *To wind speed.*
- Inputs are:
  - *8 sets of backscatter values*
    - 2 different azimuths,
    - 2 different polarizations,
    - 2 different spatial scales (12.5 and 87.5 km)
  - *a rain rate from the scatterometer noise channel [Ahmad et al, 2005].*
  - *cross track distance as a proxy for viewing geometry*
  - *Information from latest of version (3) of QuikSCAT global wind retrieval product*
    - Speed corrected for rain
    - Maximum likelihood speed (no correction for rain)
    - Rain Impact quantity
- Ground truth speeds are from H*WIND data from 2005 Atlantic hurricanes.
- Structure employs a set of sub-networks to simplify the mappings needed.
- Attempt to correct wind direction in rain is left for future work.
  - *Nominal Maximum Likelihood direction retrievals are maintained.*

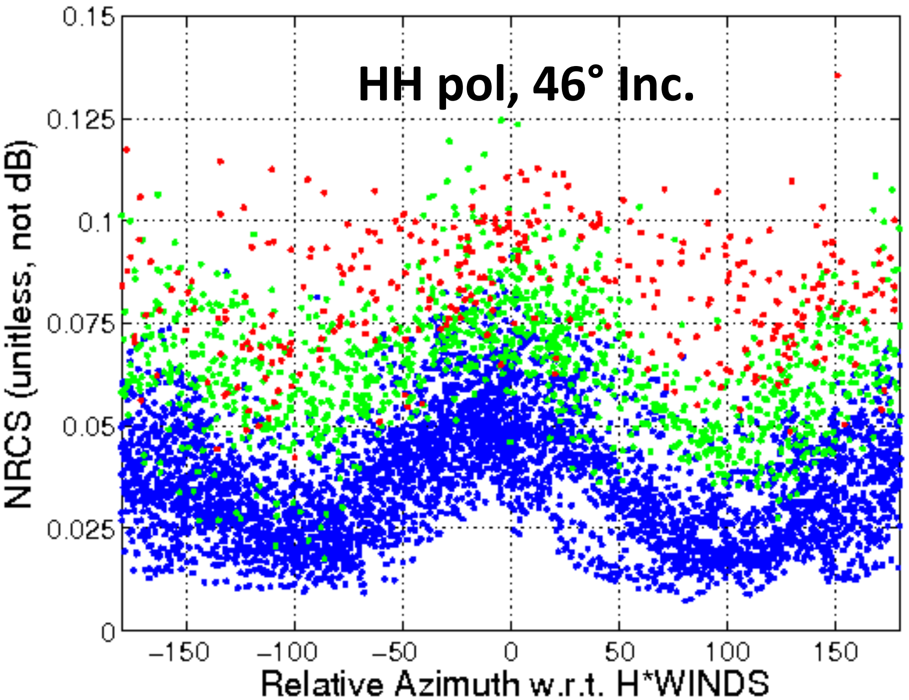
# How does it work?

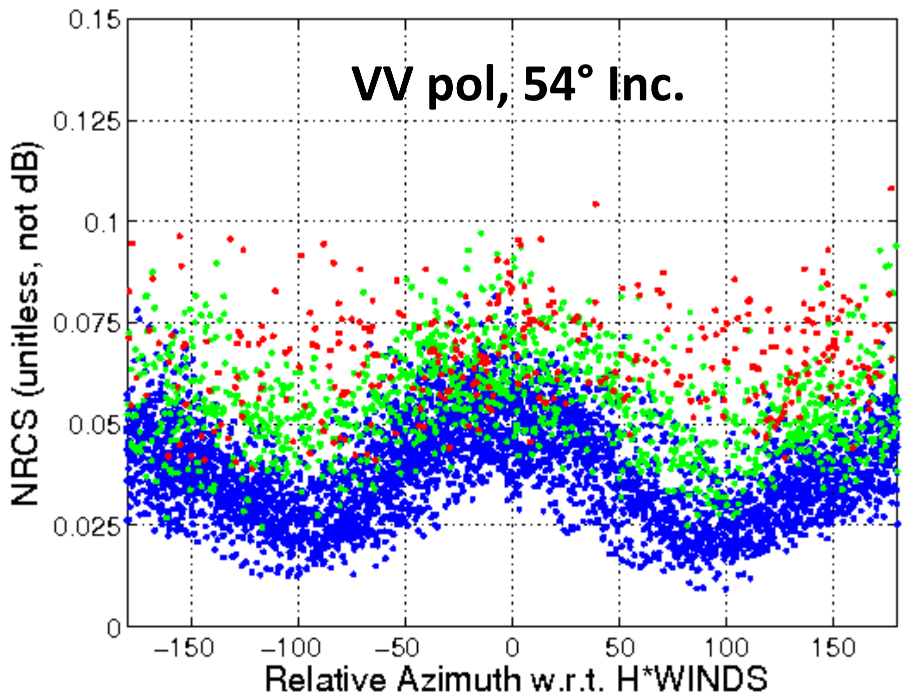
- The neural network estimates an optimal mapping between its 10 inputs and its training ground truth (H*WIND).
  - *The resultant multi-dimensional mapping is hard to visualize*
- The next few slides exemplify the information available to the neural network
  - *Showing Ku-band sigma-0 is sensitive to winds from 20-40 m/s*
  - *For a specific case of MLE speed = 24-26 m/s and CTD = 400-450 km, We examine the information content of three parameters of interest ,*
    - Copol ratio = sum of HH NRCS / sum of VV NRCS
    - sum sigma-0 = sum of all four NRCS observations
    - QRAD rain rate = Estimate of Rain rate derived from QuikSCAT brightness temperature

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

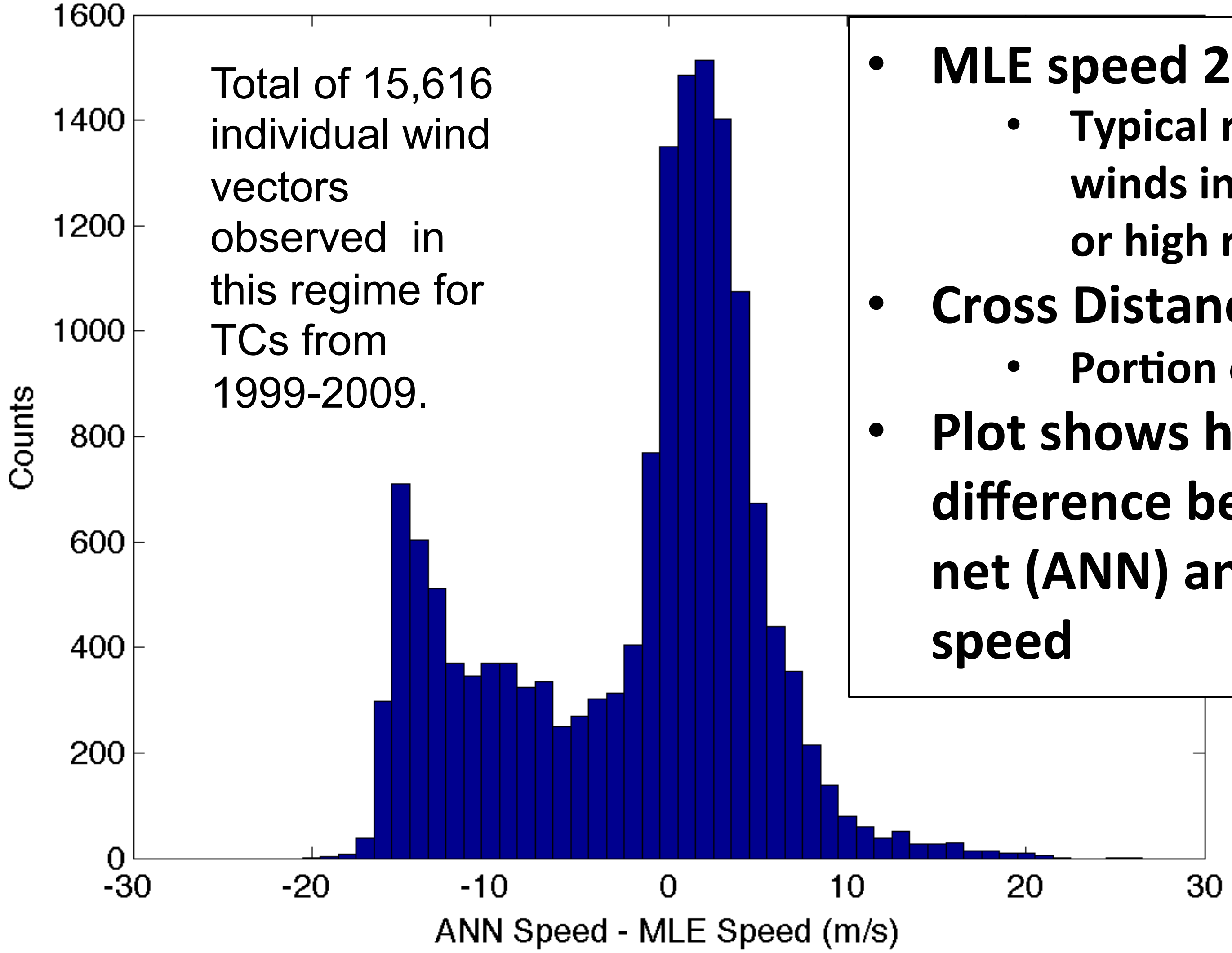
- In *rainfree* conditions (rain impact quantity <= 2.5), QuikSCAT HH pol 46 degree incidence NRCS values are sensitive to wind speed and direction in the 20-40 m/s range.
- QuikSCAT VV 54 degree incidence values have less sensitivity.

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



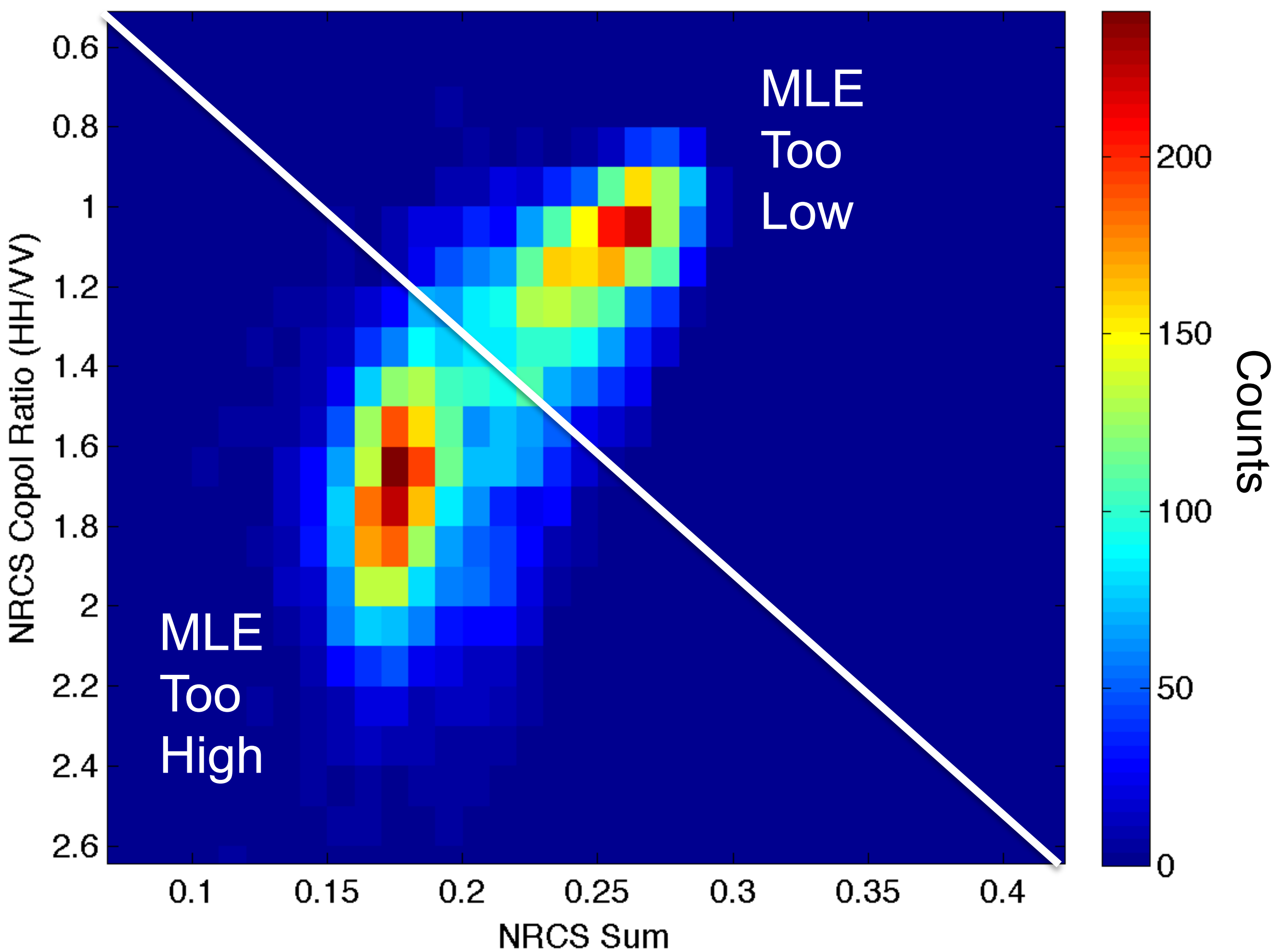
# QuikSCAT MLE winds can be too high (>+2 m/s) or too low (<-2 m/s).




- **MLE speed 24- 26 m/s**
  - **Typical regime for MLE winds in high wind and/ or high rain.**
- **Cross Distance 400-450 km**
  - **Portion of sweet zone**
- **Plot shows histogram of difference between neural net (ANN) and MLE wind speed**

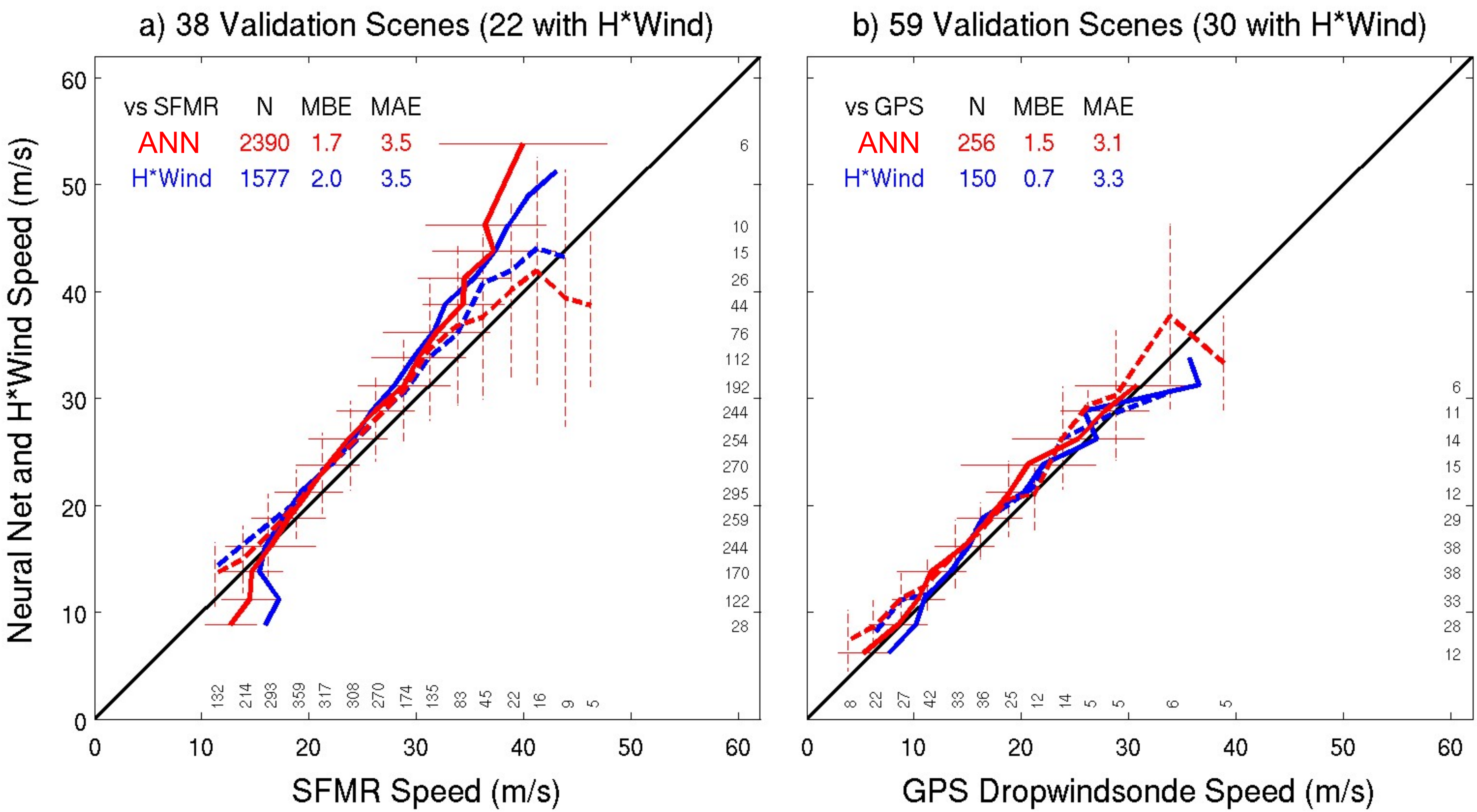
# Here's how the ANN can tell the difference

**Simple linear classifier agrees with Neural Network 92% of the time.**

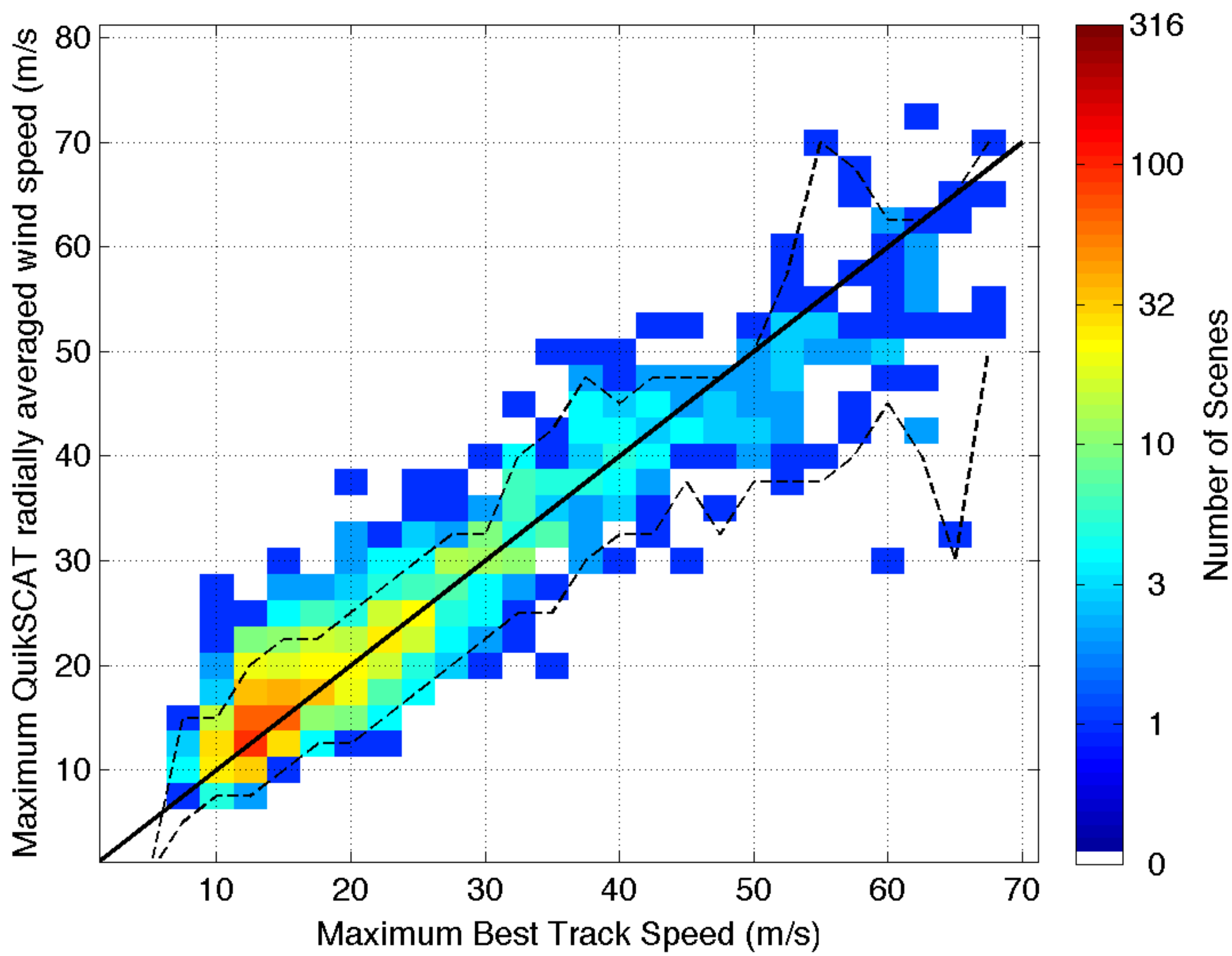



- High backscatter Co-polarization HH/VV ratio tends to indicate high MLE winds.
- High sum of all backscatter tends to indicate low MLE winds.
- Using the two parameters one can mimic the ANN's decision to raise or lower the MLE wind.

# QuikSCAT Validation with SFMR and Dropsondes

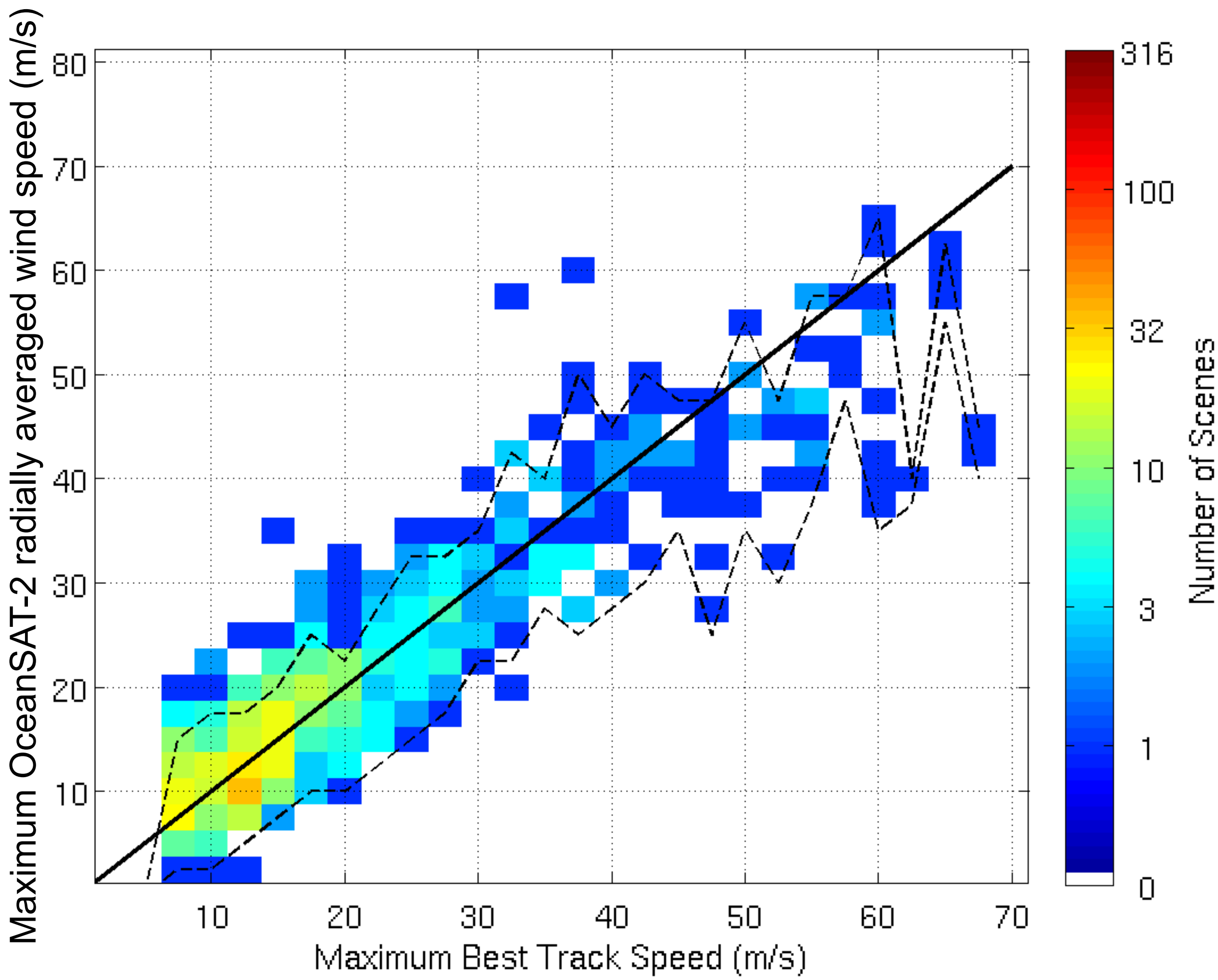


# Intensity Estimation from QuikSCAT data




- Technique:
  - Compute average of wind vectors in concentric circles about center.
  - Take maximal average value.
  - Multiply by 1.4 to account for reduced resolution
- Omit:
  - Outer beam only region at swath edge –no correction
  - Storms more than 40 deg from equator, highest winds can be far from center
  - Storms where less half half of 200-km radius circle was observed

# Intensity Estimation from OceanSAT-2 data




- Performance similar to QuikSCAT but biased low at at highest speeds.
- Low bias is likely due to lack of highest wind speeds in OSCAT training set.
- 2010 (OSCAT train set) was a slower Atlantic hurricane season than 2005 (QuikSCAT train set).

# Description of High Wind Retrieval for RapidScat

# Rain Correction Method

- RapidScat wind speeds before August 14, 2015 are corrected for rain using a combination of the [Stiles and Dunbar 2010] (speed1) and [Stiles et al 2014] tropical cyclone neural networks (speed2)
  - ***Correction is only applied when rain is detected. (Rain Impact Quantity > 2.5)***
  - *No correction in outer swath. (~80 km from swath edge)*
  - ***If speed2 is < 10 m/s speed1 is the corrected speed.***
  - ***If speed2 is > 20 m/s speed2 is the corrected speed.***
  - ***If 10<= speed 2 <=20, the corrected speed is a weighted linear sum*** *of speed1 and speed2.*

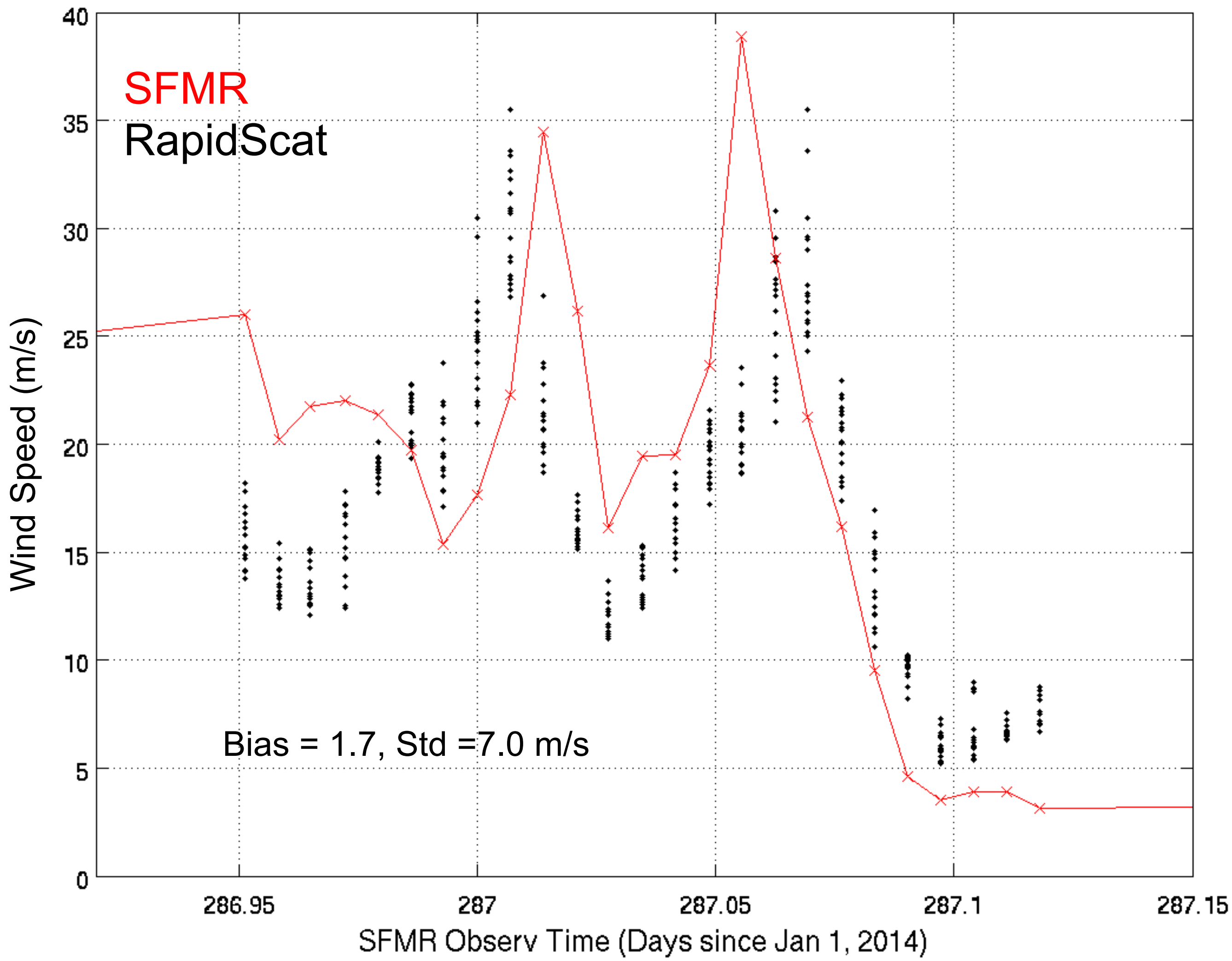
- On August 14, 2015, RapidScat experienced a hardware anomaly that made brightness temperature estimation impossible, so the hurricane rain correction described in [Stiles et al 2014] could not be employed.

- The RapidScat wind speeds after August 14, 2015 were corrected for rain using a neural network that estimated speed as a function of the four flavors of normalized radar cross section (NRCS) and the DIRTH speed [Stiles and Dunbar 2010].
  - *Neural Network was trained using global wind speed distribution, so high winds were not well represented in training set. Brightness temperatures were not utilized.*
  - *Correction was only applied when rain was detected. (Rain Impact Quantity > 2.5)*
  - *No correction in outer swath.*

# SFMR Comparison

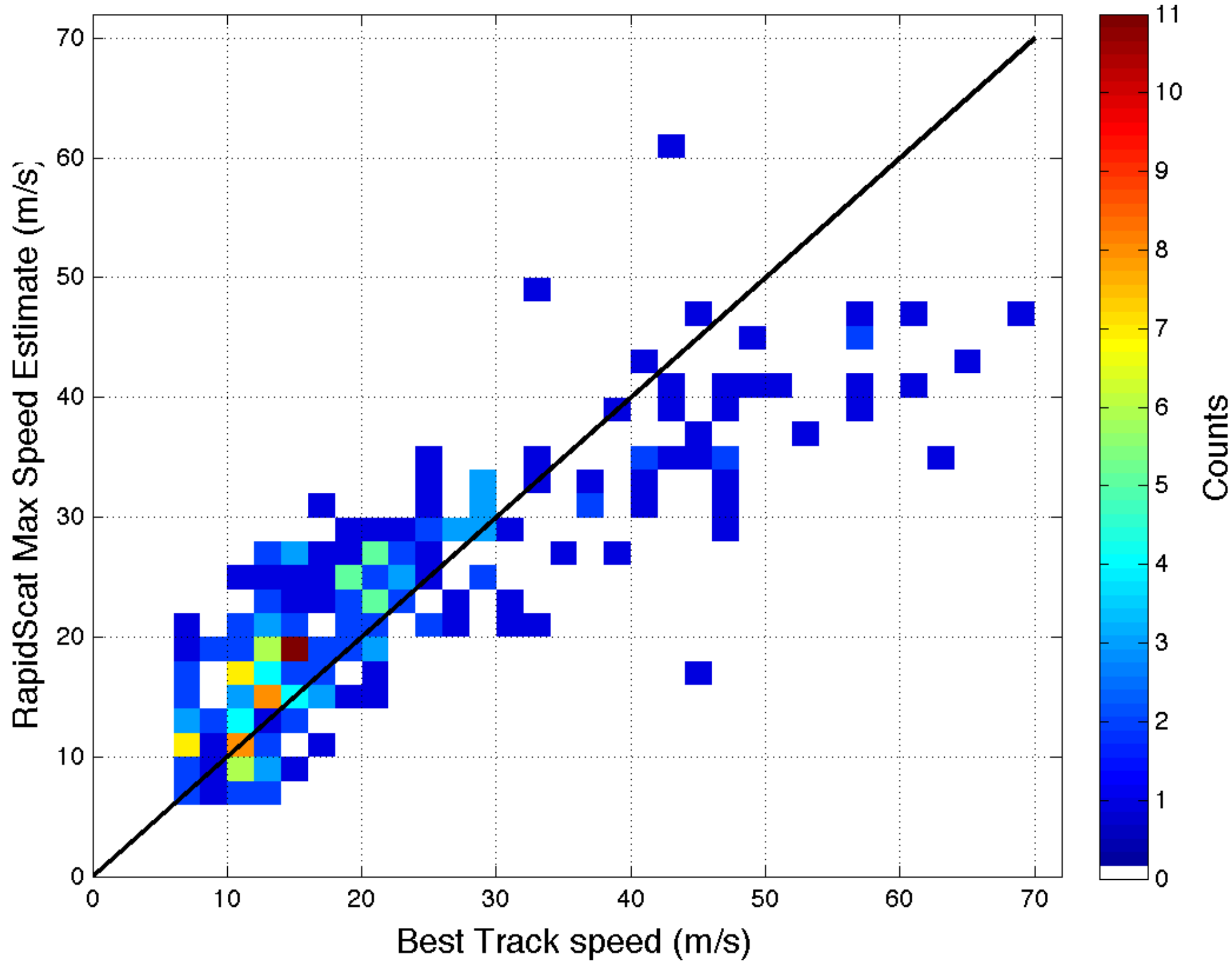
- Method
  - *Obtained SFMR (Stepped Frequency Microwave Radiometer) data from NOAA/AOML Hurricane Research Division Website*
  - *Averaged SFMR data over 10 minutes (~18-km distance on ground)*
  - *Compared to RapidScat data within 6 hours.*
  - *Unless otherwise stated chose all 12.5-km RapidScat wind vectors within 25 km of SFMR location.*

# Time-Ordered SFMR/RapidScat Comparison




RapidScat Observations of Hurricane Fay generally reflect trends in SFMR but appear misaligned, probably due to 6 hour colocation window.

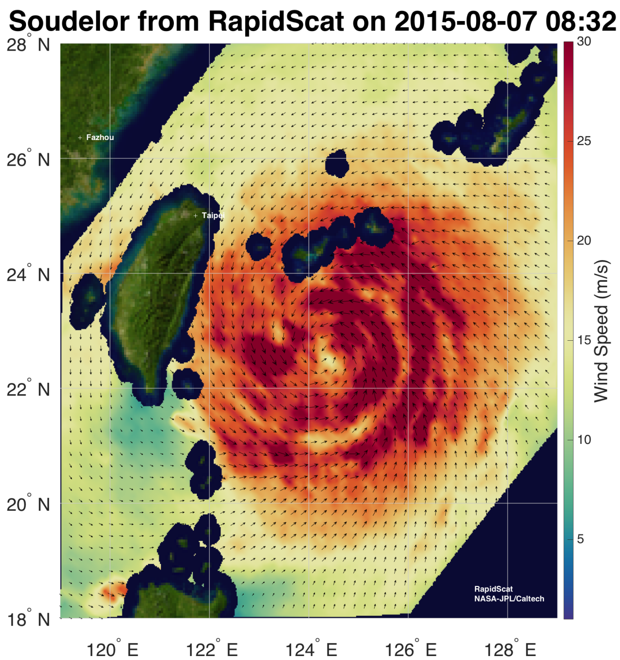
# Intensity Estimation from RapidScat data, 255 cases



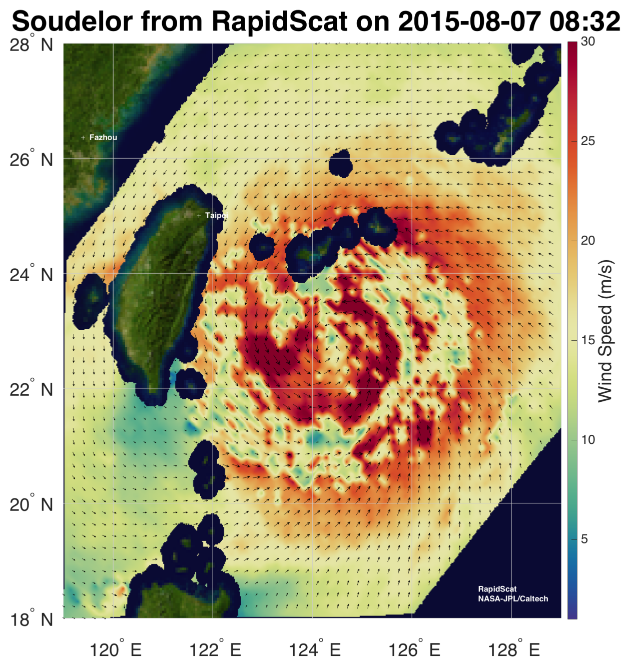

- Technique:
  - Compute average of wind vectors in concentric circles about center from 50-200km radius.
  - Take maximal average value.
  - Multiply by 1.4 to account for reduced resolution
- As with QuikSCAT we omit
  - Outer beam only region at swath edge –no correction
  - Storms more than 40 deg from equator, highest winds can be far from center
  - Storms where less half half of 200-km radius circle was observed
- Higher RapidScat incidence angles may have caused the underestimation of winds at highest speeds

# RapidScat High Wind Examples

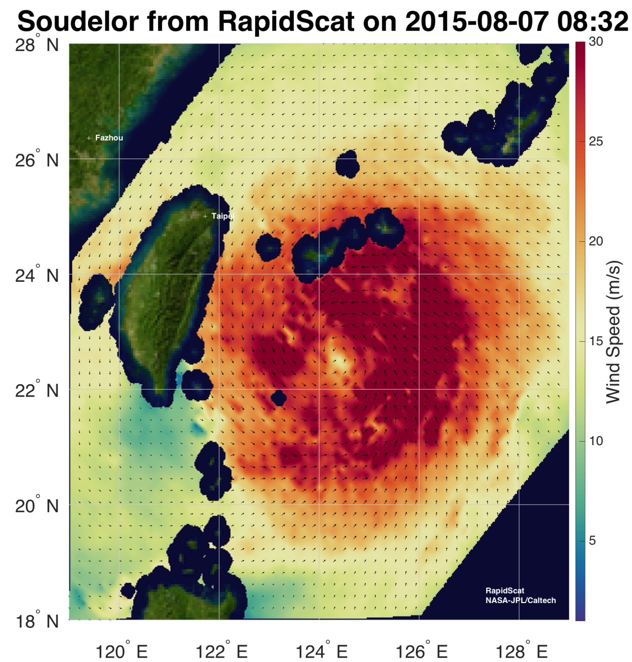
# Soudelor from RapidScat




Uncorrected

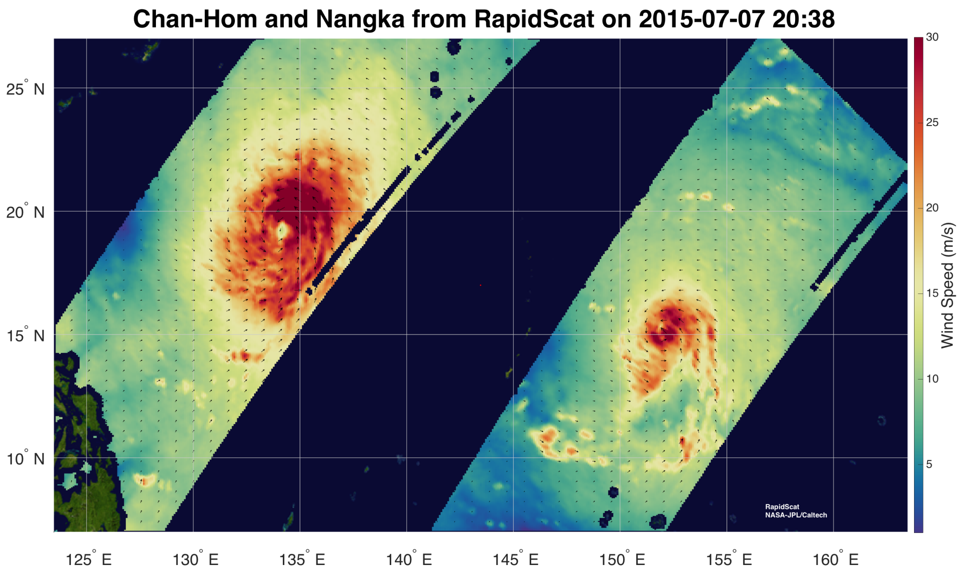



ANN Global Model Corrected

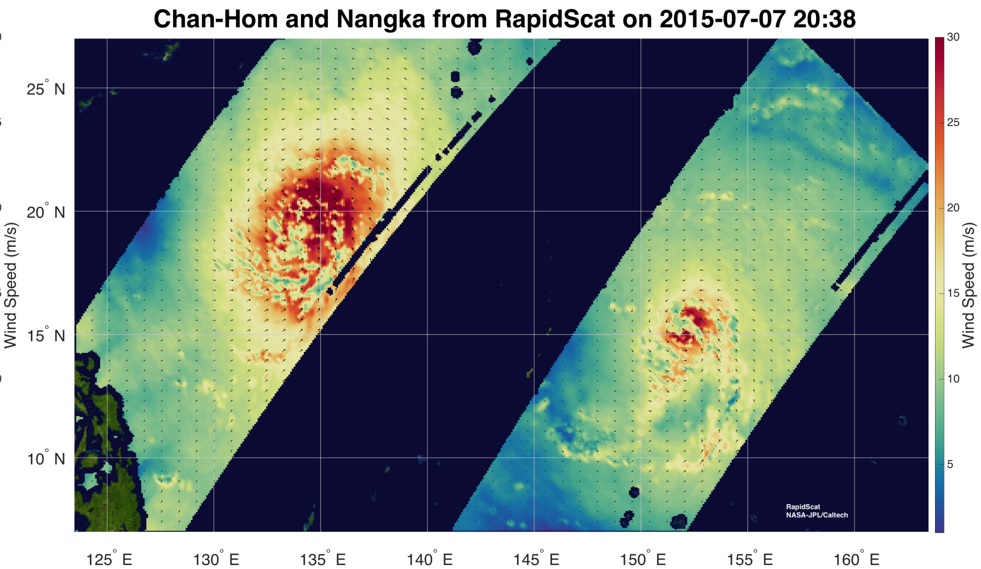



ANN High Winds Model Corrected

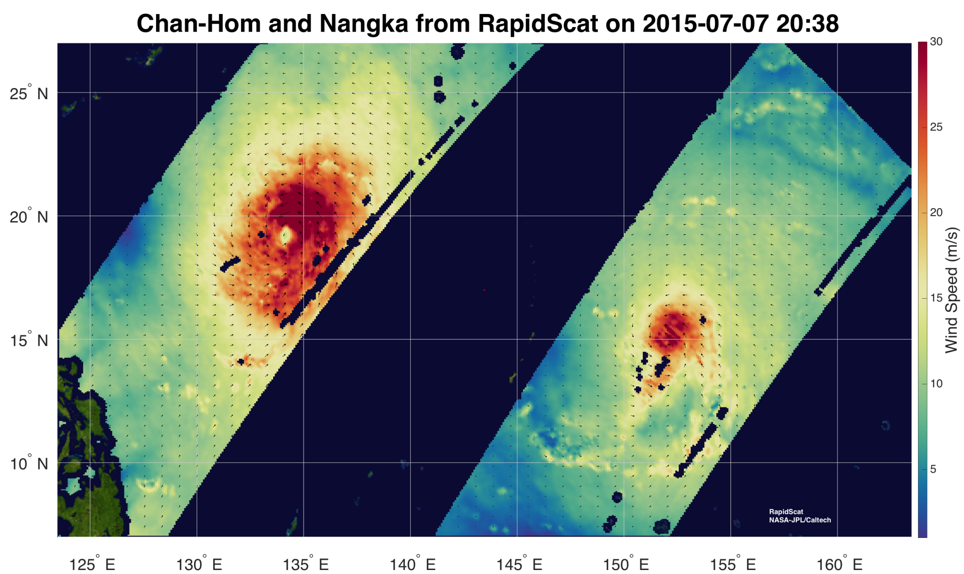
# Chan-Hom and Nangka from RapidScat




Uncorrected




ANN Global Model Corrected




ANN High Winds Model Corrected

# Summary

- QuikSCAT tropical cyclones wind speed fields have been
  - *Optimized for accuracy.*
  - *Produced for all ten years of the QuikSCAT mission 1999-2009 including over 5,000 scenes of tropical storm force winds and higher.*
  - *Storm-centered wind fields can be found at tropicalcyclone.jpl.nasa.gov in the Tropical Cyclone Data Archive under the FTP server link.*
- A similar dataset has been produced for OceanSAT-2 and can also be found at tropicalcyclone.jpl.nasa.gov
- The QuikSCAT high wind speed neural network has been applied to RapidScat data prior to August 14, 2015,
  - *RapidScat rain corrected wind speeds have been computed globally using a hybrid of the QuikSCAT tropical cyclone and global rain correction methods.*
  - *RapidScat high winds in TCs appear to be biased low compared to the QuikSCAT TC wind product.*
  - *The retrieved_wind_speed field in the full swath netcdf files contains the most accurate speed for high winds with or without rain.*
- For RapidScat data acquired after August 14, 2015, brightness temperature information used to correct high wind speeds for rain was no longer available, so hurricane wind corrections are not performed.
  - *For this data, the retrieved_wind_speed_uncorrected field is the preferred speed for tropical cyclones. The retrieved_wind_speed field is made with a rain contamination correction algorithm that is suboptimal above 20 m/s.*

# References


- B.W. Stiles; Danielson, R.E.; Poulsen, W.L.; Brennan, M.J.; Hristova-Veleva, S.; Tsae-Pyng Shen; Fore, A.G., "Optimized Tropical Cyclone Winds From QuikSCAT: A Neural Network Approach," Geoscience and Remote Sensing, IEEE Transactions on , vol.52, no.11, pp.7418,7434, Nov. 2014 doi: 10.1109/TGRS.2014.2312333 (Tropical Cyclone Speed Correction)
- B. W. Stiles, and Dunbar, R S., “A Neural Network Technique for Improving the Accuracy of Scatterometer Winds in Rainy Conditions,” IEEE Transactions on Geoscience and Remote Sensing, 2010, Vol 48, No. 8, pp 3114-3122. (Global Speed Correction –suboptimal for winds over 20 m/s)
- Fore, A.G.; Stiles, B.W.; Chau, A.H.; Williams, B.A.; Dunbar, R.S.; Rodriguez, E., "Point-Wise Wind Retrieval and Ambiguity Removal Improvements for the QuikSCAT Climatological Data Set," Geoscience and Remote Sensing, IEEE Transactions on , vol.52, no.1, pp.51,59, Jan. 2014 doi: 10.1109/TGRS.2012.2235843 (QuikSCAT Version 3 paper, uses the global speed correction)

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