All Weather RapidScat ISS Wind Speeds

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Ocean Vector Winds Science Team Meeting

May 18-21, 2015

Portland, Oregon

Part One

- Calibration/Validation Meeting
  - *May18 2015*

Outline

- Data Loss Statistics
- Validation vs. ECMWF
    - *Rainfree and Rainy*
- Description of Rain Correction Method
- Statistical Change from V1.0 to V1.1
- Validation vs. WindSAT
- Summary
- References

Science Data Loss Statistics-Orbit Table

Statistics complied over 2041 orbits from Jan 1 to May 12 2015.

Quality	Category	Number of Orbits	Percent of Orbits
GOOD	GOOD	1736	85.1%
MARGINAL	Marginal s/c pointing	140	6.9%
BAD	No data reached ground	111	5.4%
BAD	Bad s/c pointing	28	1.4%
BAD	Other	26	1.3%

These statistics are for science quality data available 15 hours after data acquisition at which time data is nearly complete for each orbit. Two other Near-Real-Time data streams are also available with some gaps.

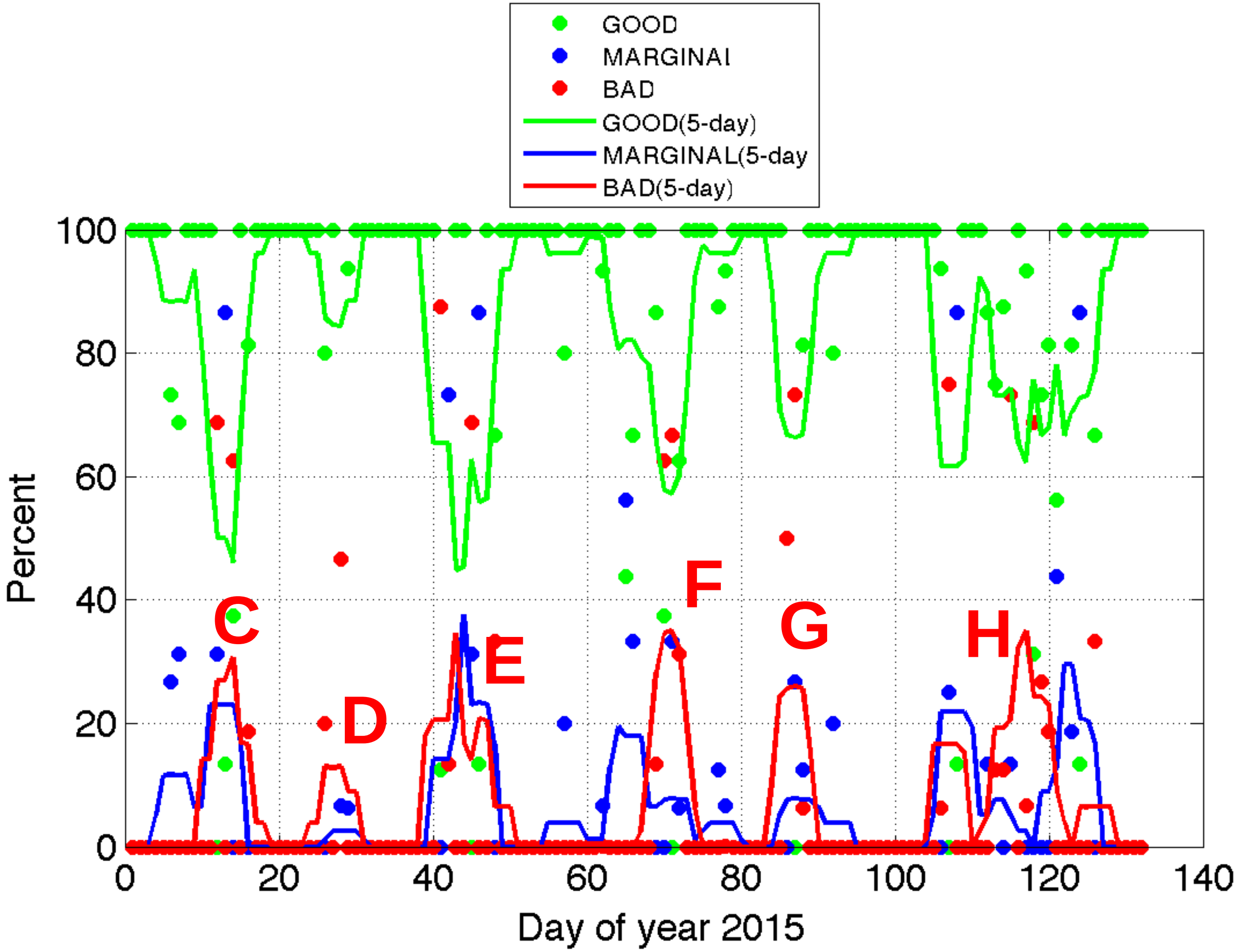
- 2-hour-delayed ~20% data gaps
- 3-hour-delayed ~5% data gaps

Data File Completeness Statistics

- Statistics compiled from Jan 1 – May 12, 2015
- The percentage of good orbits for NRT data can be less than that for science data due to occasional downlink and MFSC to JPL glitches.
- Percent missing data = percent of missing frames

Data Set	Percent Good Orbits	Percent Missing Data in GOOD orbits
2-hour-delay	82.2%	19.0%
3-hour-delay	82.5%	5.3%
Science-data-set	85.1%	0.45%

Science data quality vs. time



C Ammonia leak false alarm, data loss due to PEYG turn off.

D Large number of Gaps in downlinked data caused processing failure.

E Several deactivations in succession and Doppler tables inconsistent with attitude

F Numerous Deactivations, HOSC software failures, and JPL connectivity failures

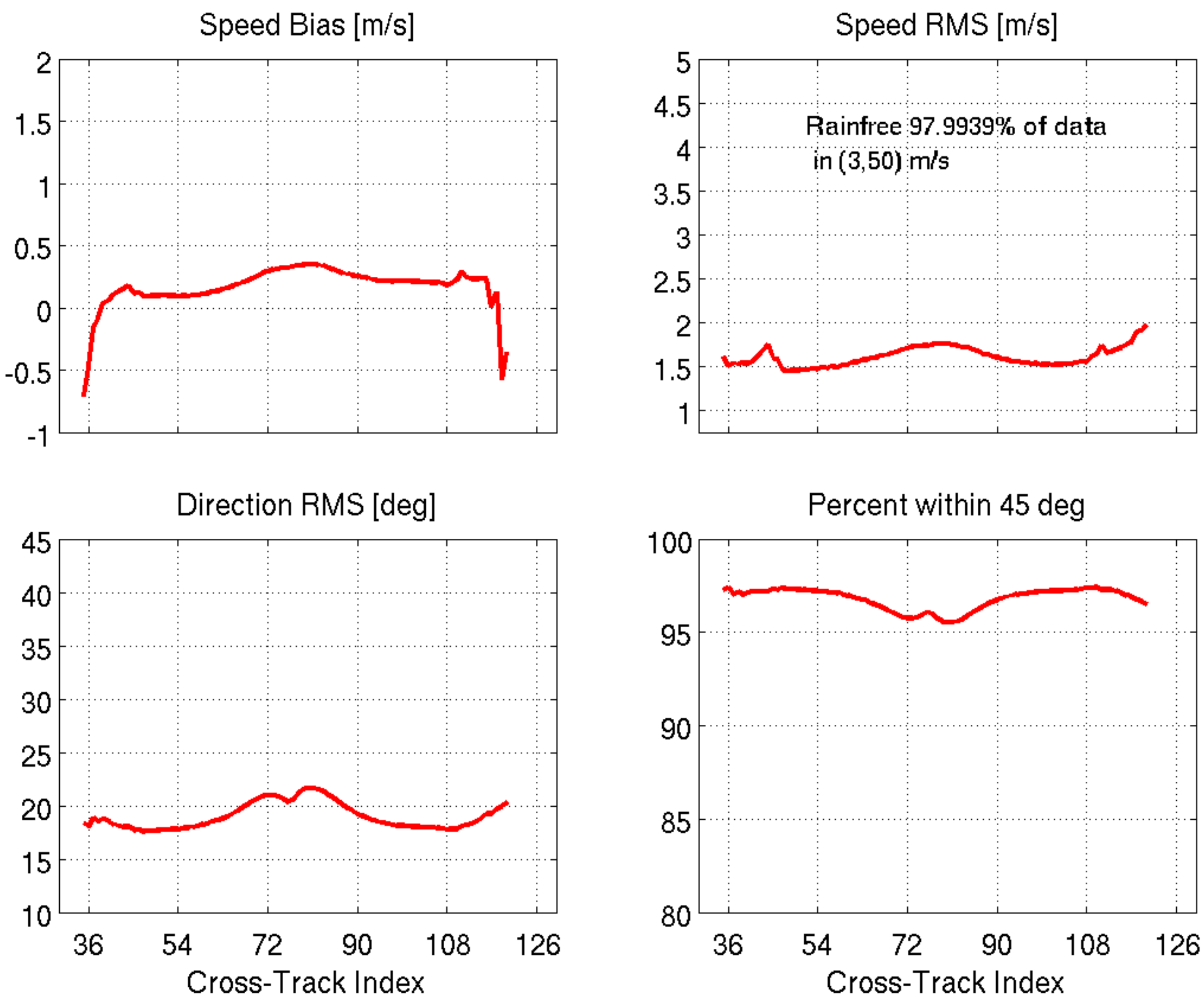
G ISS attitude changes for Soyuz arrival, downlink stoppage, and reboost.

H Multiple activation/deactivation, bad attitude during robot arm experiments

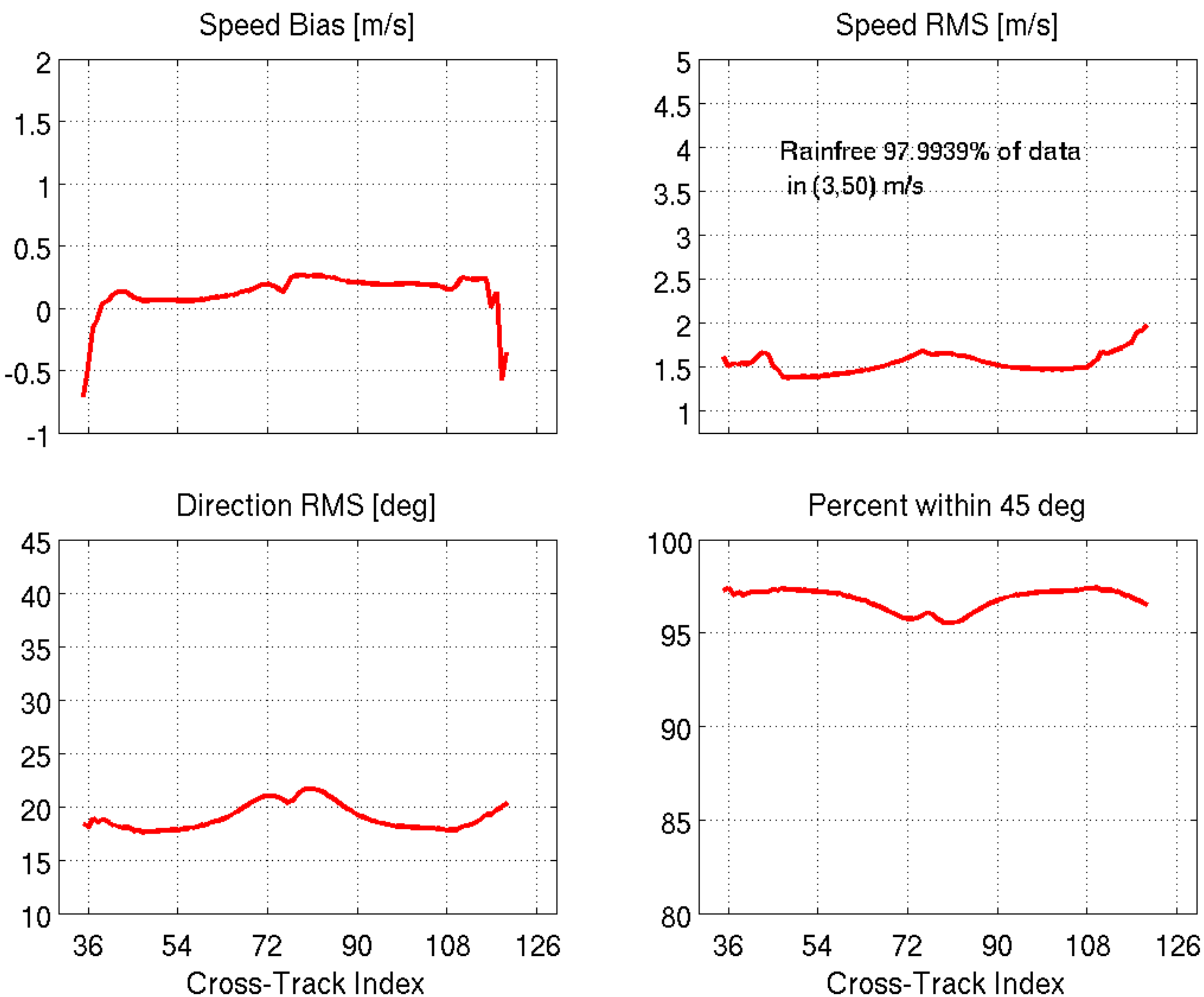
ECMWF Comparison

- Computed RapidScat wind performance statistics w.r.t ECMWF for all "GOOD and MARGINAL" quality orbits from Oct 3 2014 to May 13 2015
- ECMWF fields were interpolated in time and space to match observations.
- Data was broken into clear and rainy data sets according to the IMUDH rain flag.
  - *QuikSCAT rain flag is used without change*
- RapidScat data compared is V1.1 science data product as archived in PODAAC.
  - *Both uncorrected and corrected speed data performance is reported.*
- Data with ECMWF speeds < 3 m/s are excluded.

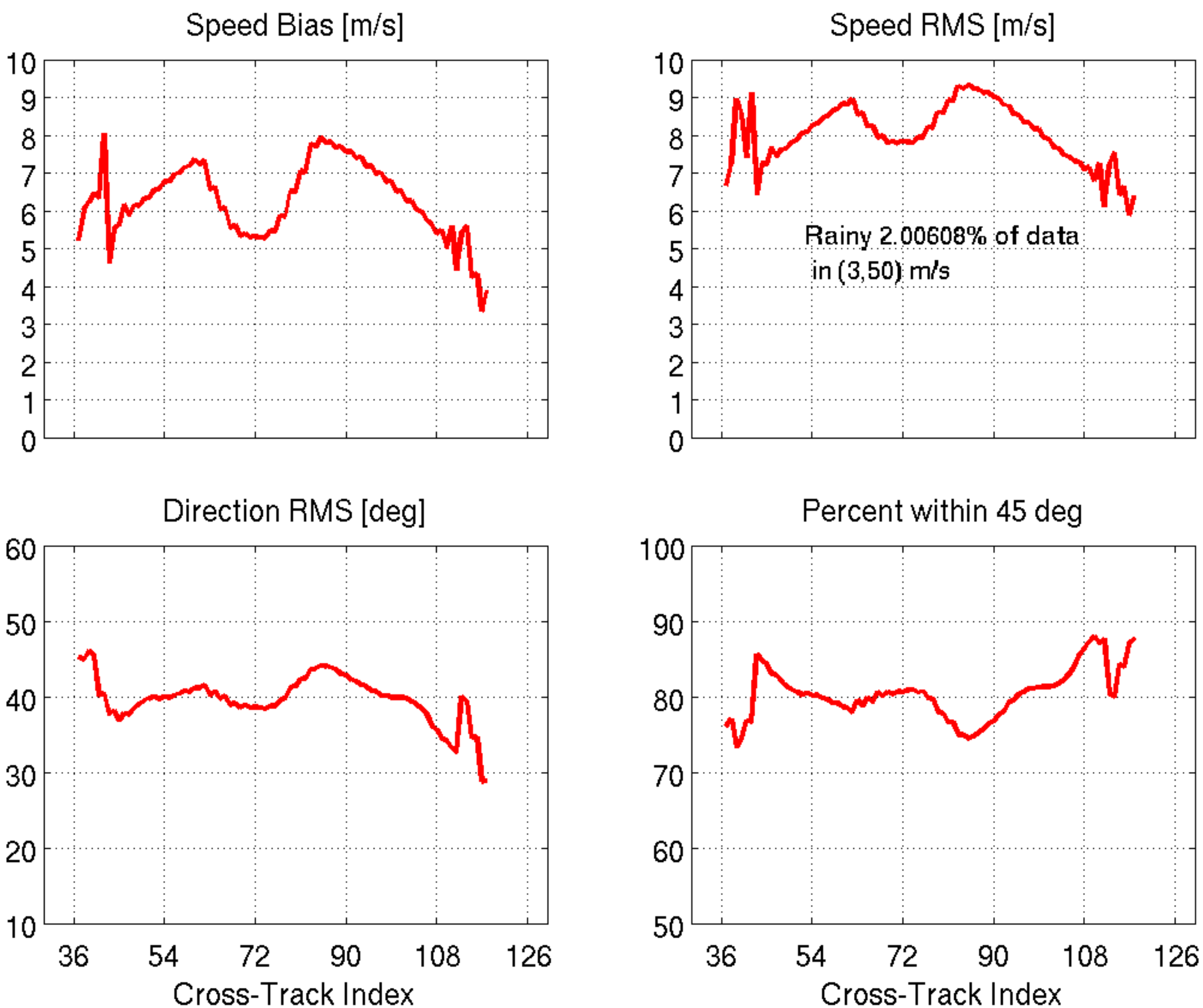
Rainfree-data No Speed Correction



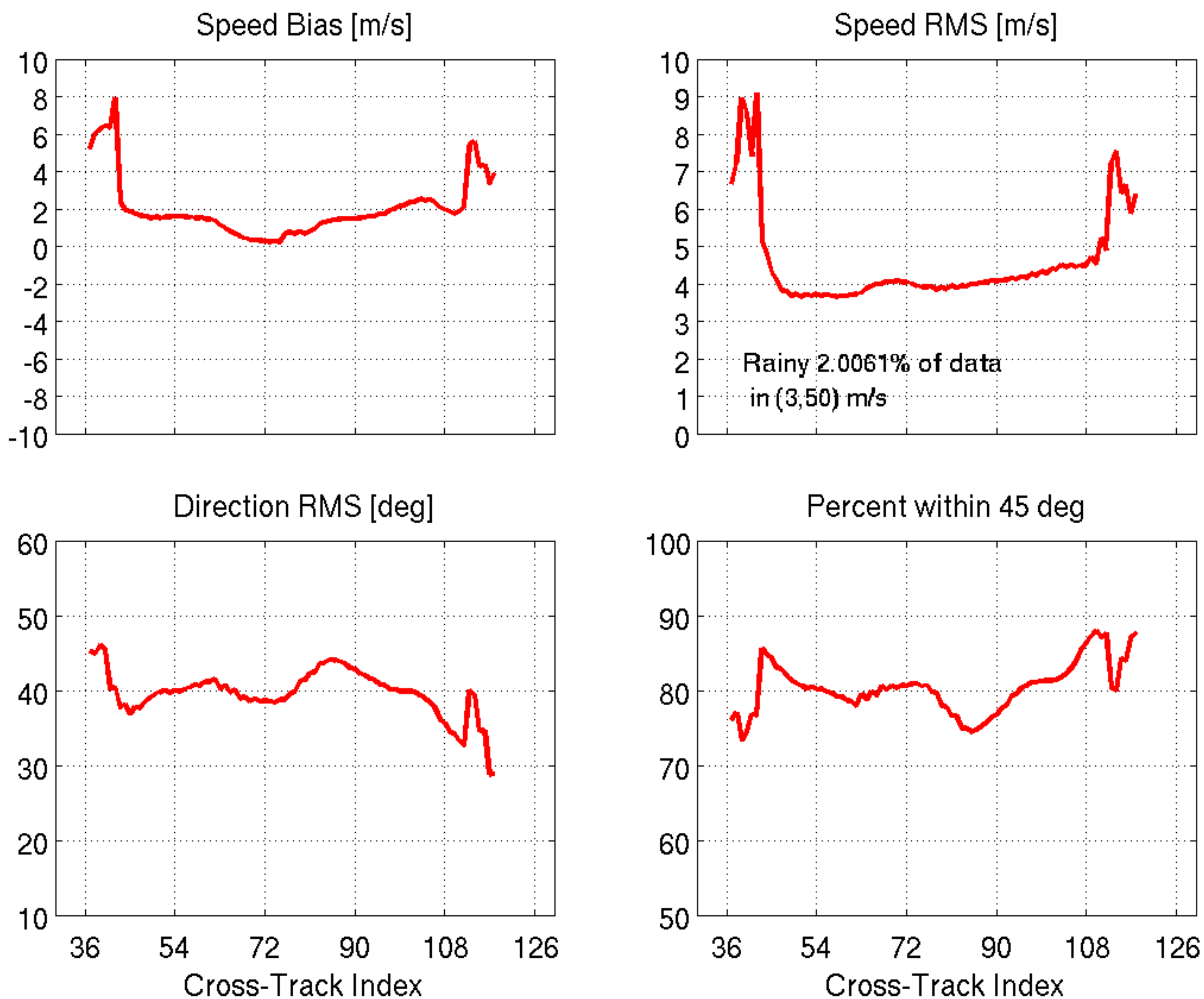
Rain-free data V1.1 Speed Correction



Rainy-data No Speed Correction



Rainy data V1.1 Speed Correction

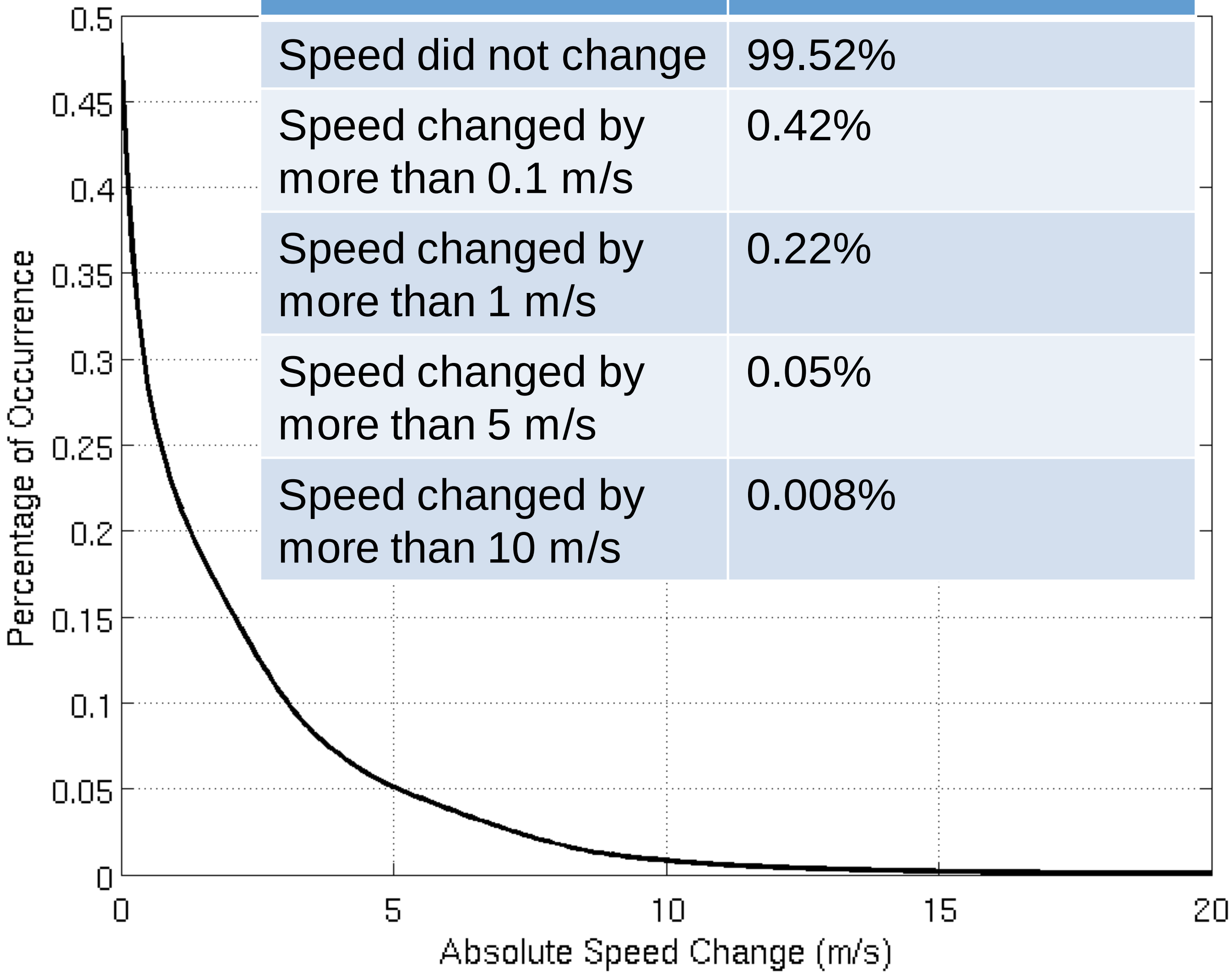


Rain Correction Method

- The version 3 QuikSCAT and version 1.0 RapidScat wind speeds were corrected for rain using an 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, uncorrected speed is reported as the corrected speed.*
- Version 1.1 RapiScat wind speeds 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 still only applied when rain was detected. (Rain Impact Quantity > 2.5)*
  - *Still no correction in outer swath, but now if the IMUDH flag says outer swath data is rainy the corrected speed is set to a fill value (-9999) to avoid claiming something is corrected when it is not.*
  - *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 liner sum of speed1 and speed2.*

Percent Change Statistics

CASE	PERCENTAGE
Speed did not change	99.52%
Speed changed by more than 0.1 m/s	0.42%
Speed changed by more than 1 m/s	0.22%
Speed changed by more than 5 m/s	0.05%
Speed changed by more than 10 m/s	0.008%



The improvement in the rain correction affects a small portions of the retrieved winds because

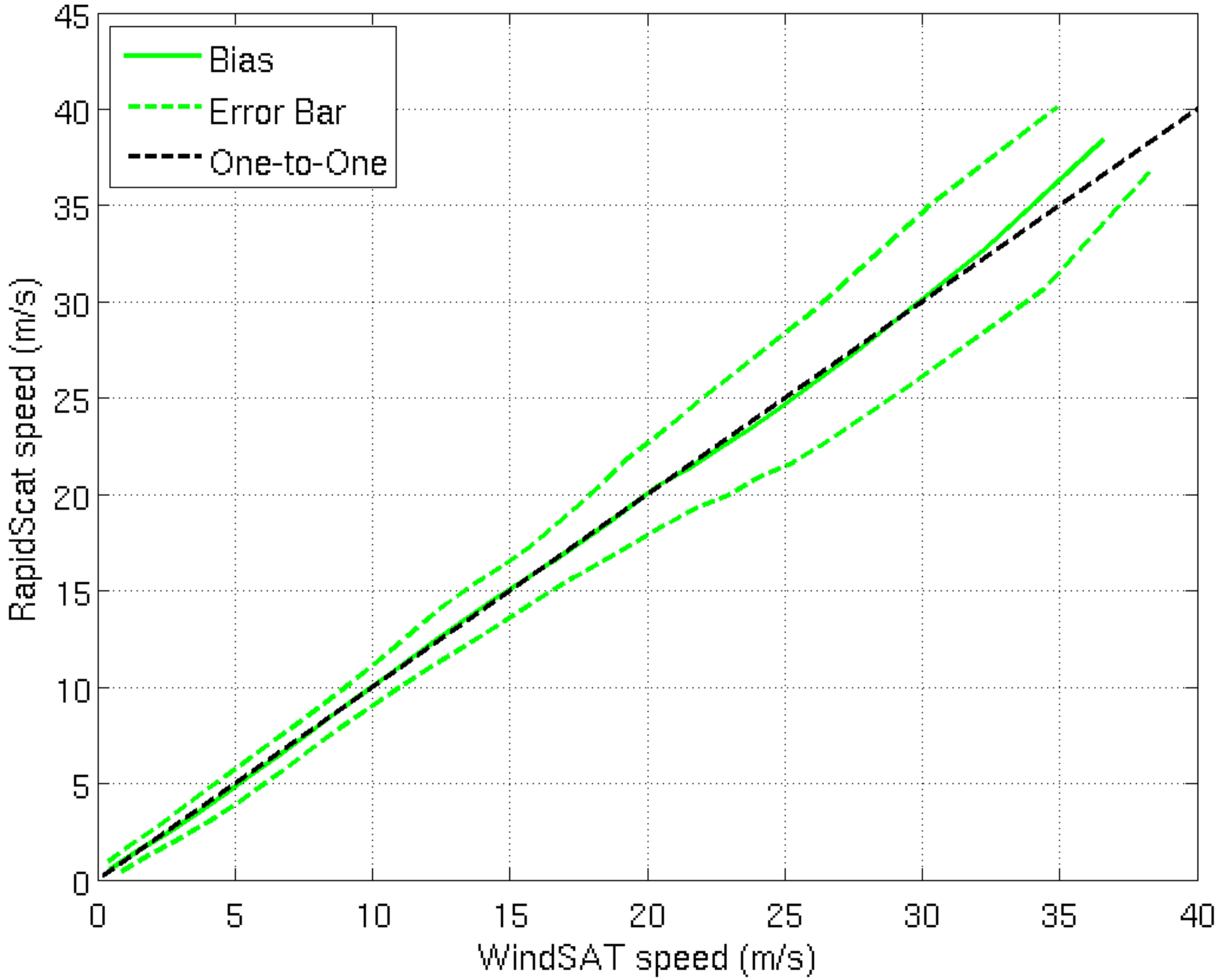
1. Neither rain correction is applied unless rain is detected.

2. A hybrid of the hurricane and global rain correction is applied resulting in little change for low to moderate winds.

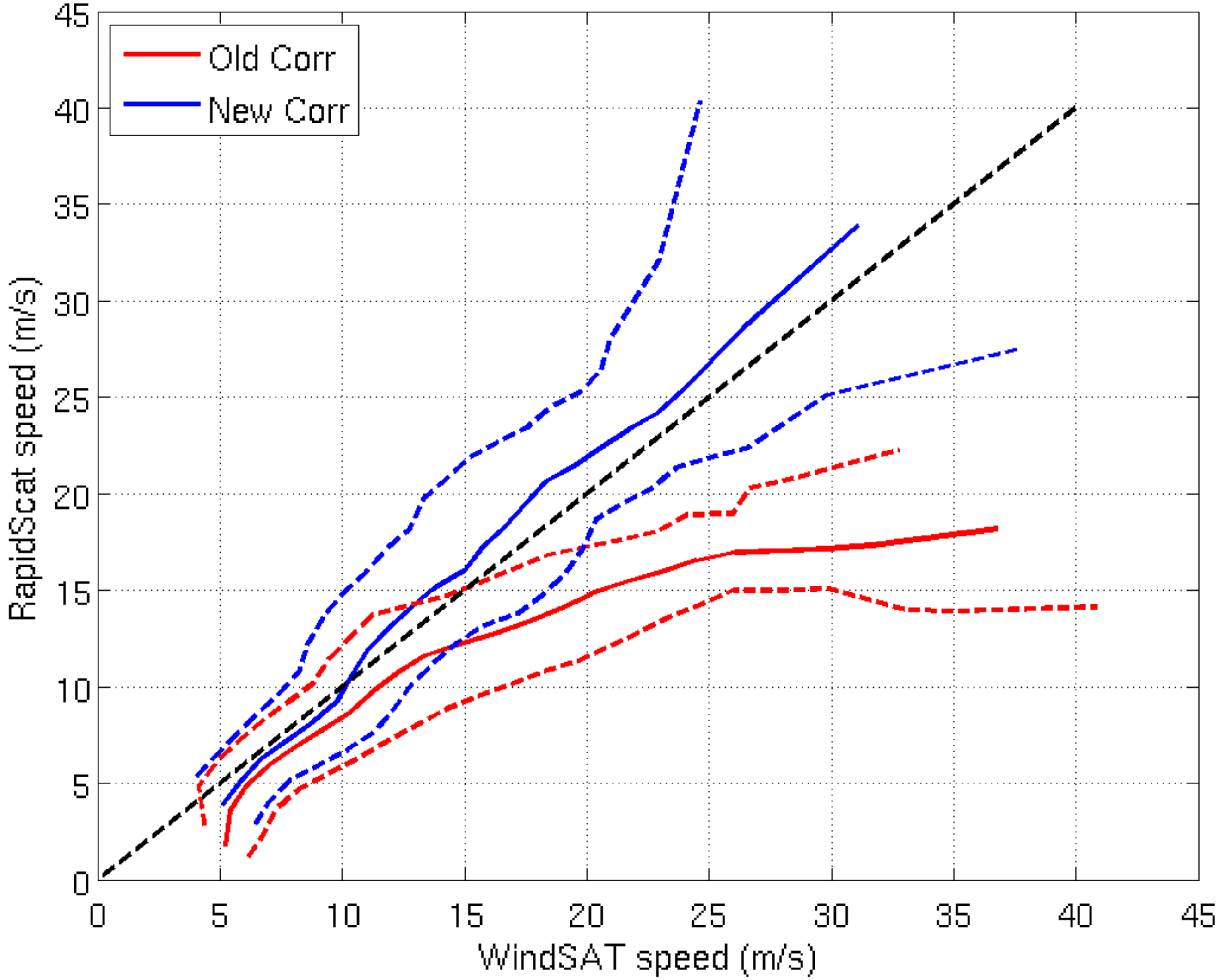
Comparison With WindSAT

- Bin data by average of RapidScat and WindSAT speeds
- Bias = mean (RapidScat-WindSAT) for each bin
- STD = standard deviation of (RapidScat-WindSAT) for each bin
- X-axis of solid line plots plots is speed bin – ½ Bias.
- Y-axis of solid line plots is speed bin + ½ Bias.
- Dashed line plots are error bars +/- ½ STD for x and -/+ ½ STD for y.
- Data was colocated within 30 minutes.
- First look at data where new and old speed corrections are the same.
- Second look at only data where new and old speed corrections differ by more than 0,1 m/s
- Only data in the dual-beam RapidScat swath is considered.

Comparison with Windsat (Unchanged data)



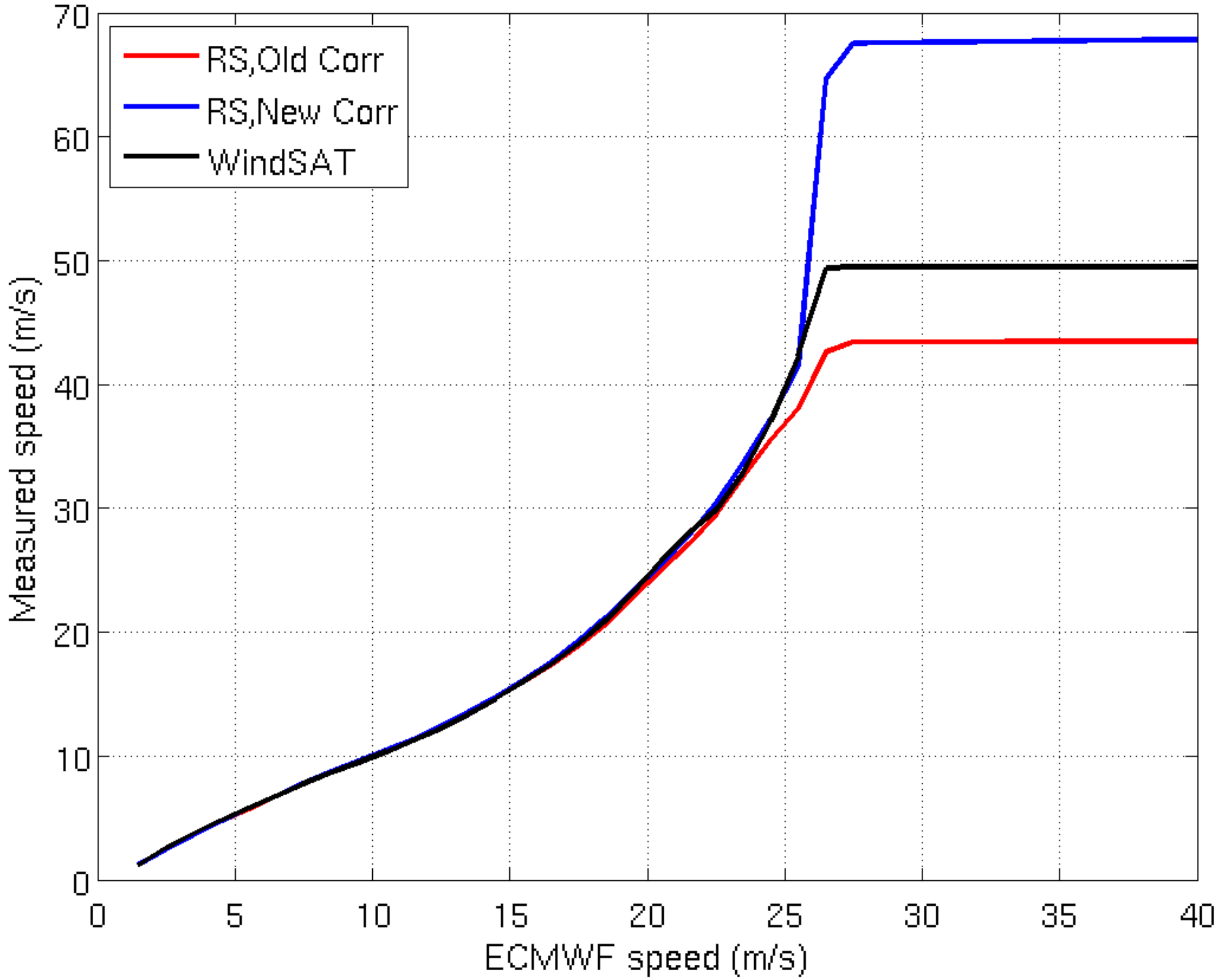
Comparison with Windsat (Changed data)



Histogram Matching

- Computed bias as a function of speed needed to add to each of three data sets in order to match the histograms of the other two.
- Used ECWMF, WindSAT, and RapidScat (new and old correction)
- WindSAT and RapidScat colocated within 30 minutes.
- ECMWF interpolated in time to match RapidScat observation time.

Histogram Match to ECMWF

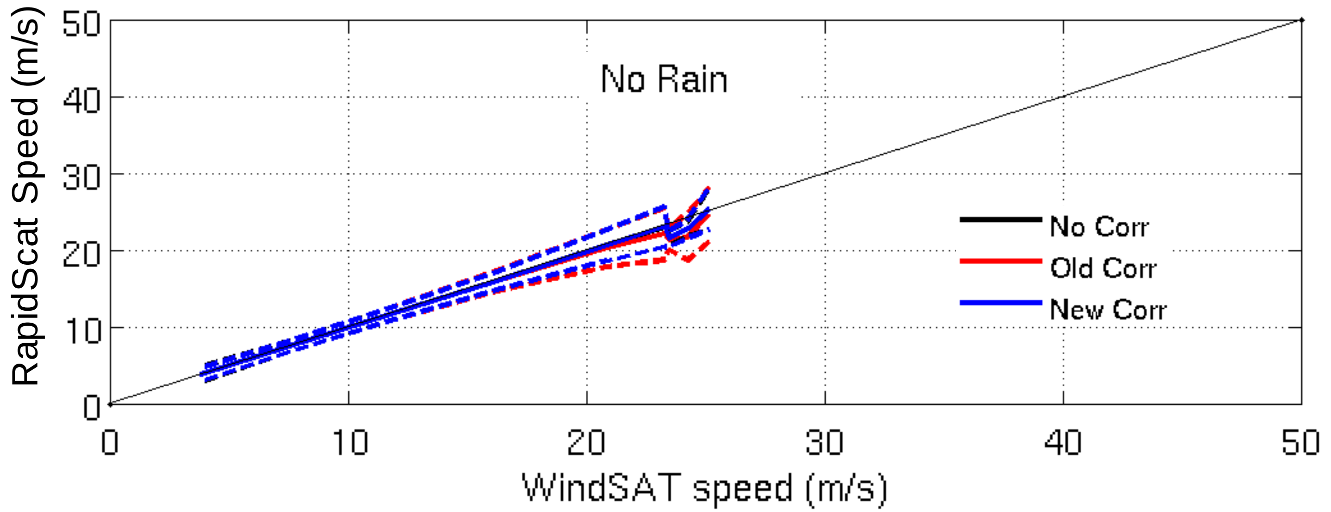


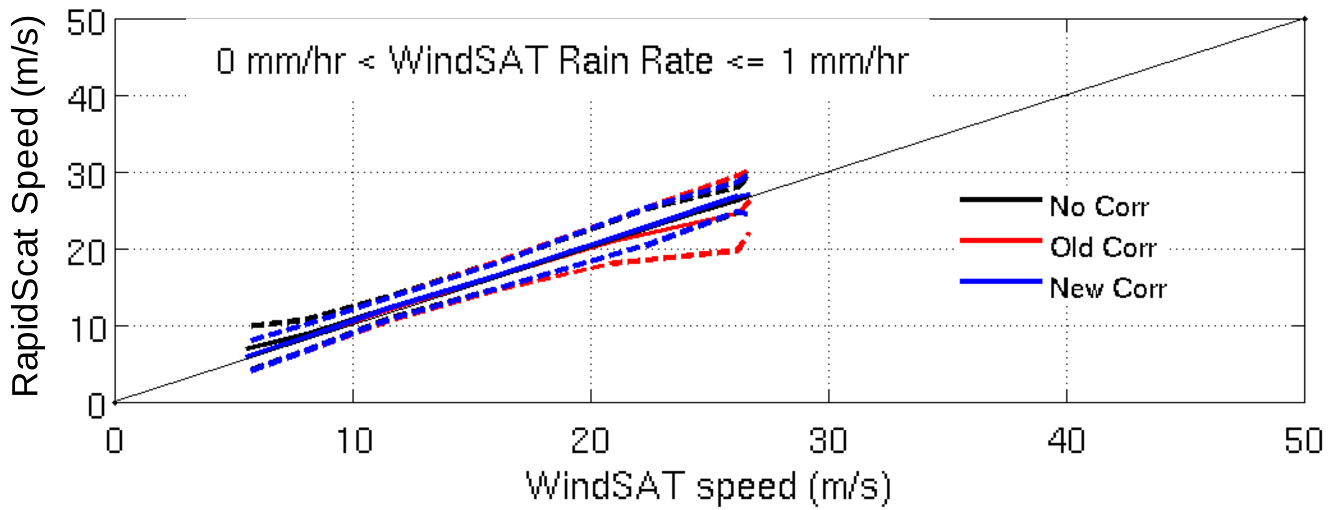
WindSAT and RapidScat new correction histogram matched biases w.r.t. ECMWF agree well up to 40 m/s (WindSAT/RapidScat) speeds.

Comparison with WindSAT using ECWMF* binning

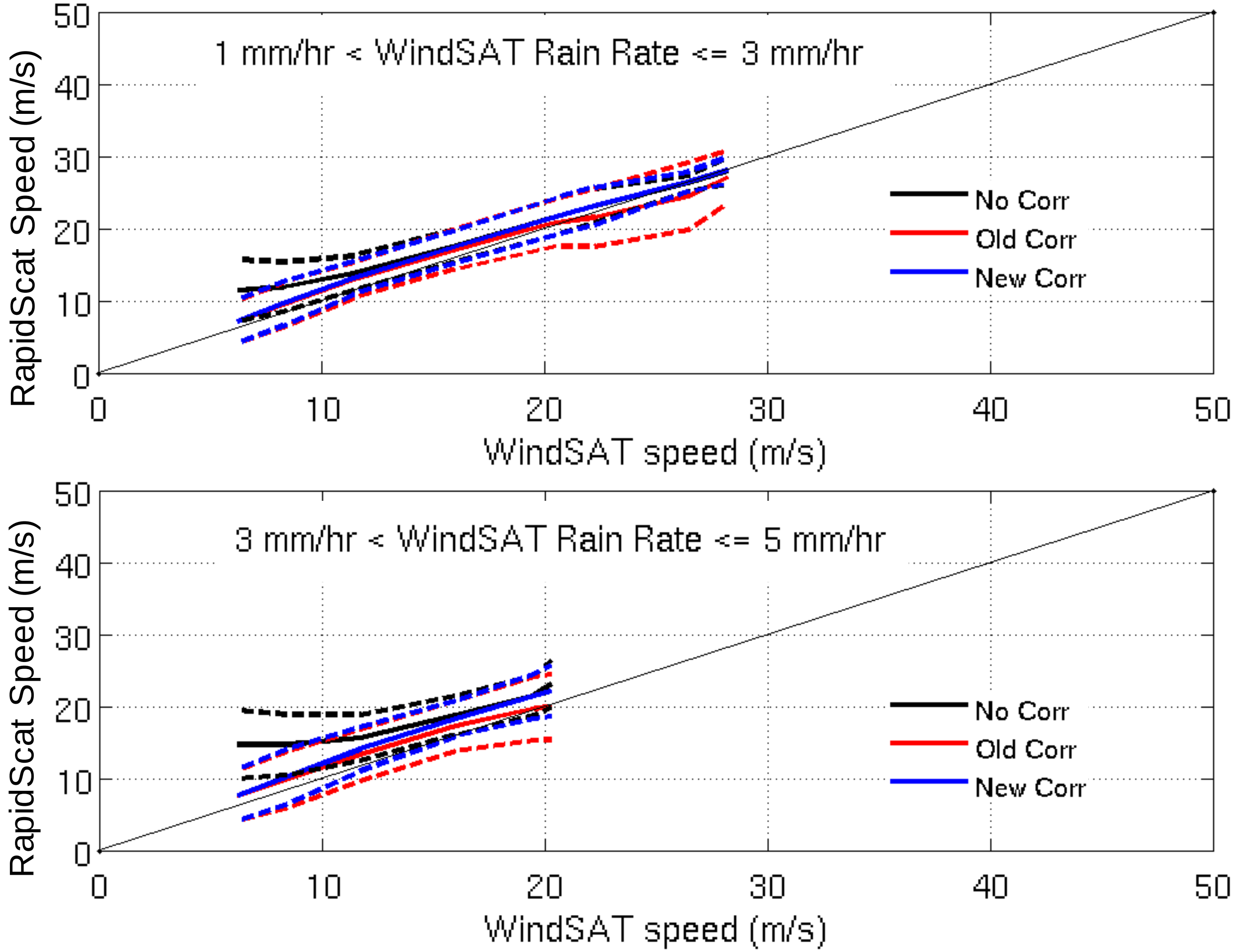
- Computed ECMWF* winds by applying the histogram matching biases to make the ECMWF histigram match WindSAT's
- Binned data by ECMWF* wind speed and WindSAT rain rate
- Computed WindSAT/RapidScat, biases, standard deviations, and correlation coefficients.
- Considered only data within 30 minutes and for the dual-beam part of the RapidScat swath.

Comparison to WindSAT, light rain

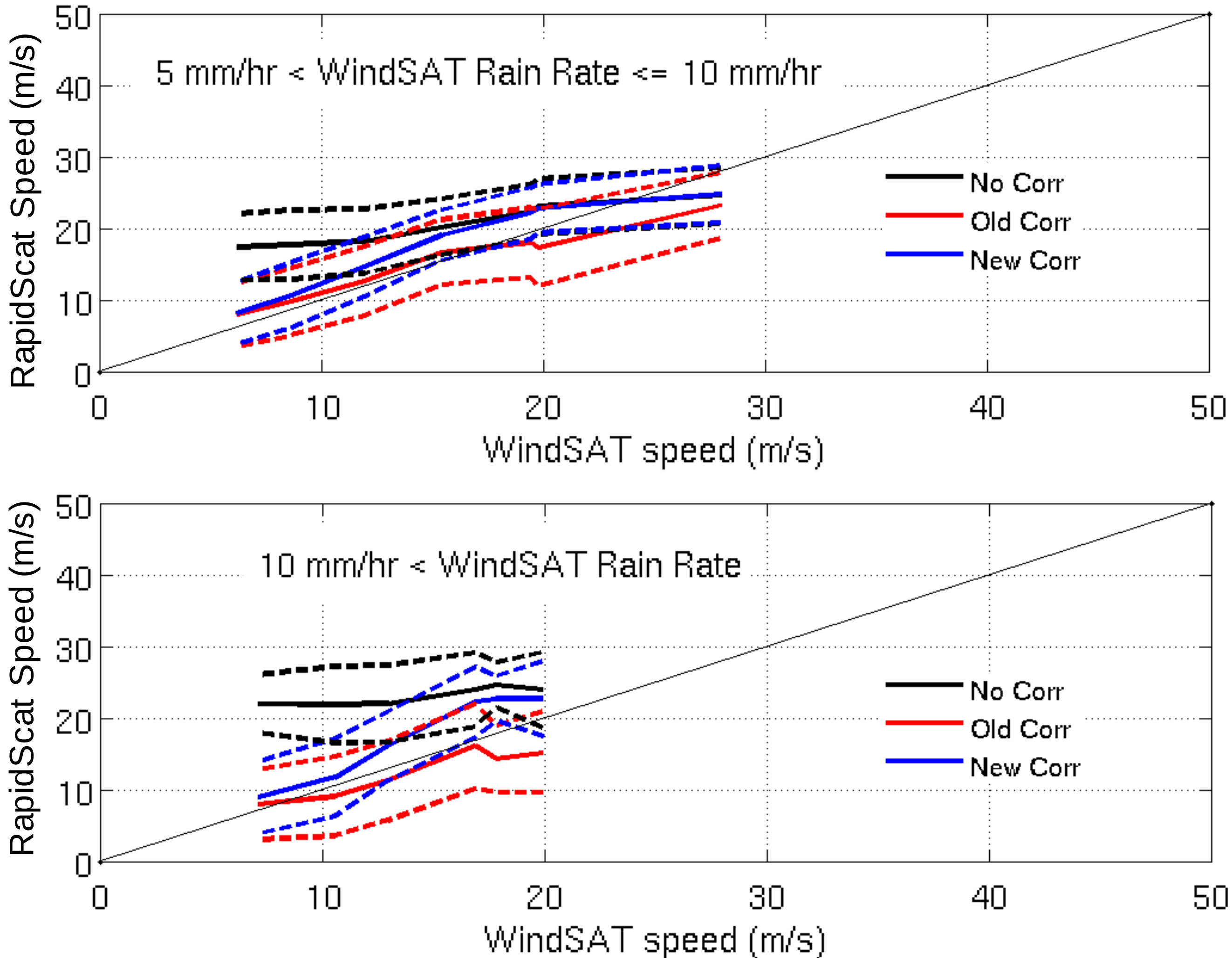




Comparison to WindSAT, moderate rain



Comparison to WindSAT, heavy rain



Summary

- Good orbits are available ~85% of the time.
  - *Marginal 7% of the time.*
- Speed and direction performance is good w.r.t ECMWF (1.5 m./s, 15-20 deg RMS).
- V1.1 speed correction offers minor change from V1.0 overall but substantial improvement at high winds.
- Corrected RapidScat speed compare well with WindSAT all-weather speeds.

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)
- 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)
- Meissner, T.; Wentz, F.J., "Wind-Vector Retrievals Under Rain With Passive Satellite Microwave Radiometers," Geoscience and Remote Sensing, IEEE Transactions on , vol.47, no.9, pp.3065,3083, Sept. 2009 doi: 10.1109/TGRS.2009.2027012 (WindSAT All-Weather Paper)

Acknowledgement

- The work reported here was performed at the Jet Propulsion Laboratory, California Institute of Technology, under contract with the National Aeronautics and Space Administration.

Part Two

- New Data Products Session
  - *May 20 2015*

Outline

- Description of Improved Rain Correction for RapidScat
  - *Hybrid of current correction and hurricane processing*
- Change Statistics
- Hagupit Example
- Comparison with WindSAT all-weather data
  - *See Meissner 2009 for validation of WindSAT data*
- Comparison with drop-wind-sondes.
  - *Dropsondes are the most direct validation for high winds but they are sparse.*
- Comparison with best tracks
  - *A simple technique was applied QuikSCAT high winds to estimate maximum intensities for each storm scene.*
  - *QuikScat intensity estimates compared favorably with the best track*
  - *We apply the QuikSCAT technique to RapidScat winds to check for consistency*
- Conclusions
- Plans for Future Work
- References

RapidScat Rain Correction Method

- The version 3 QuikSCAT and version 1.0 RapidScat wind speeds were corrected for rain using an 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].
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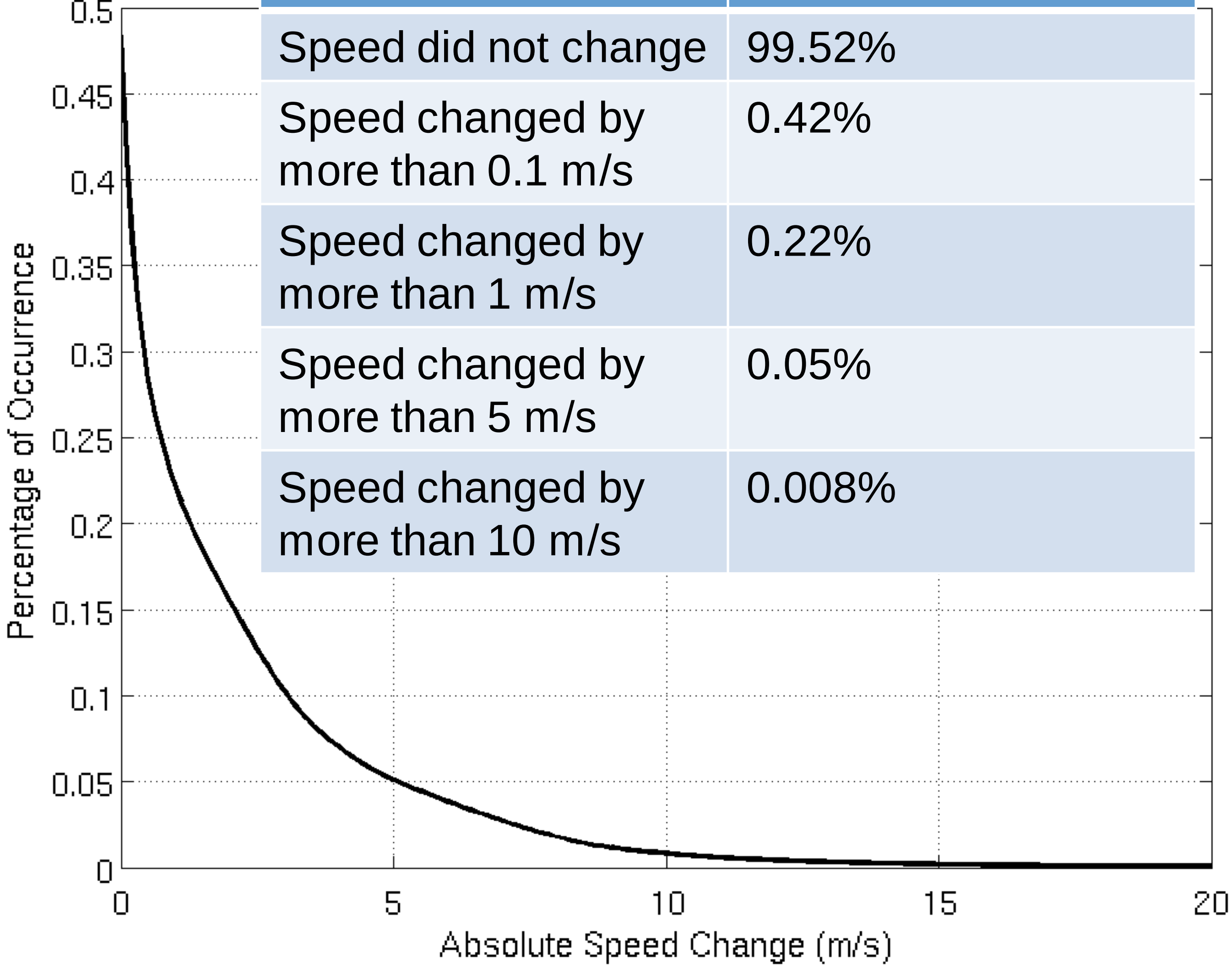
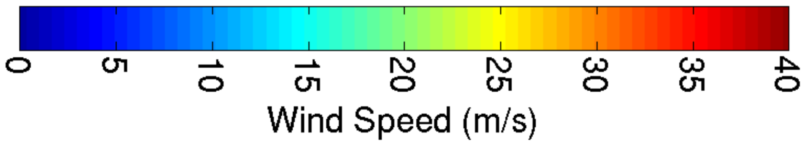


The improvement in the rain correction affects a small portions of the retrieved winds because

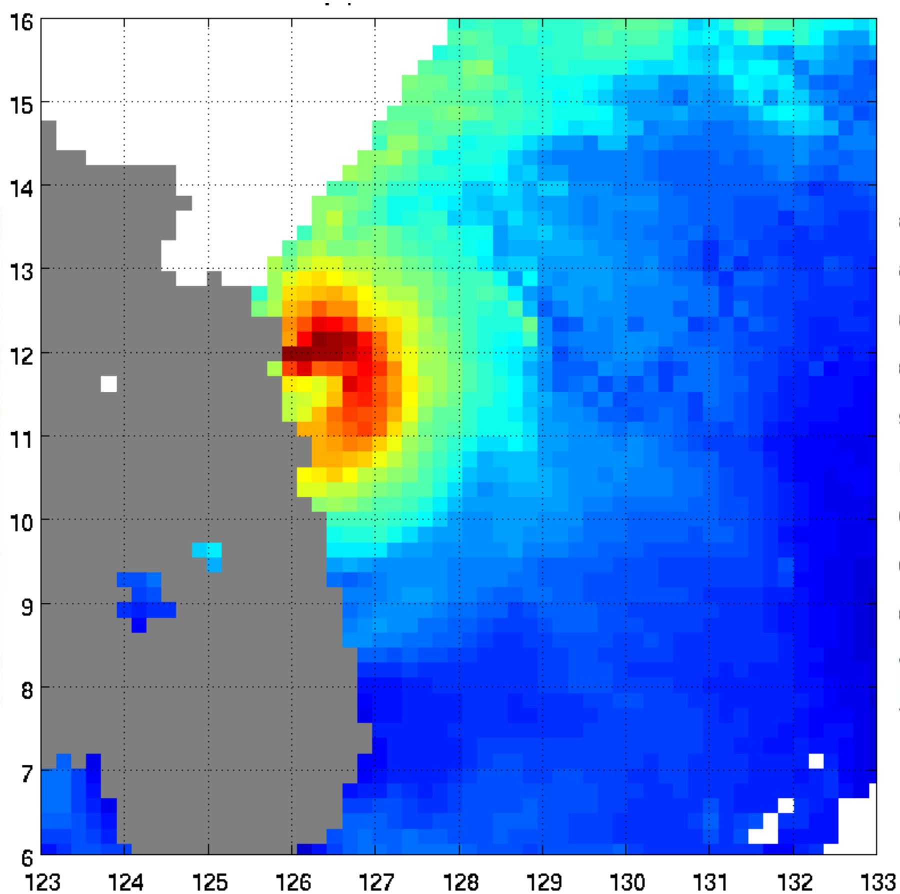
1. Neither rain correction is applied unless rain is detected.

2. A hybrid of the hurricane and global rain correction is applied resulting in little change for low to moderate winds.

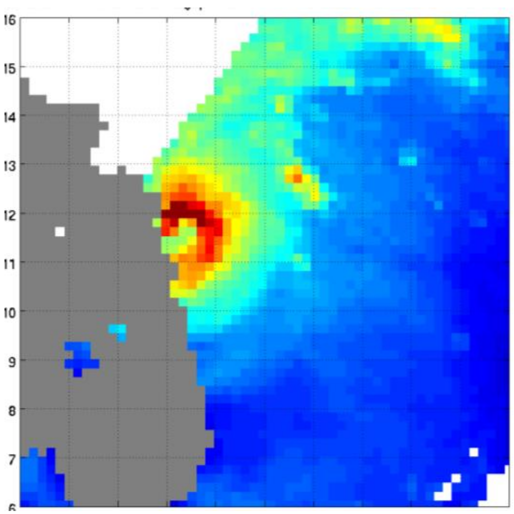
Hagupit 06-Dec-2014 0900 UTC



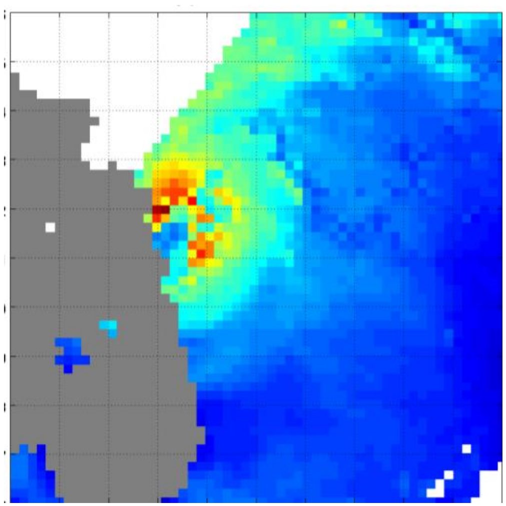
Version 1.1 Speed Corrected



No correction



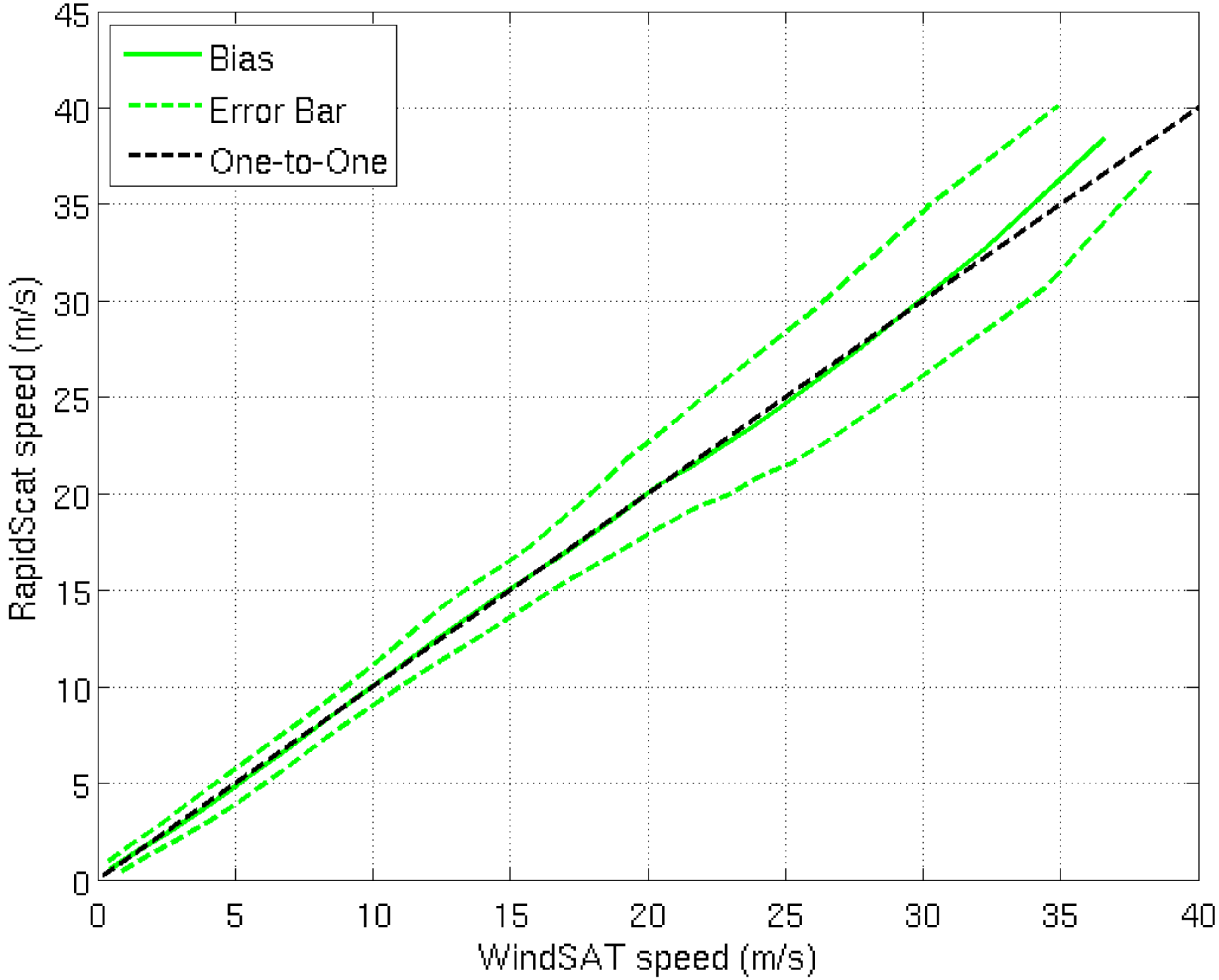
Version 1.0
Speed Corrected



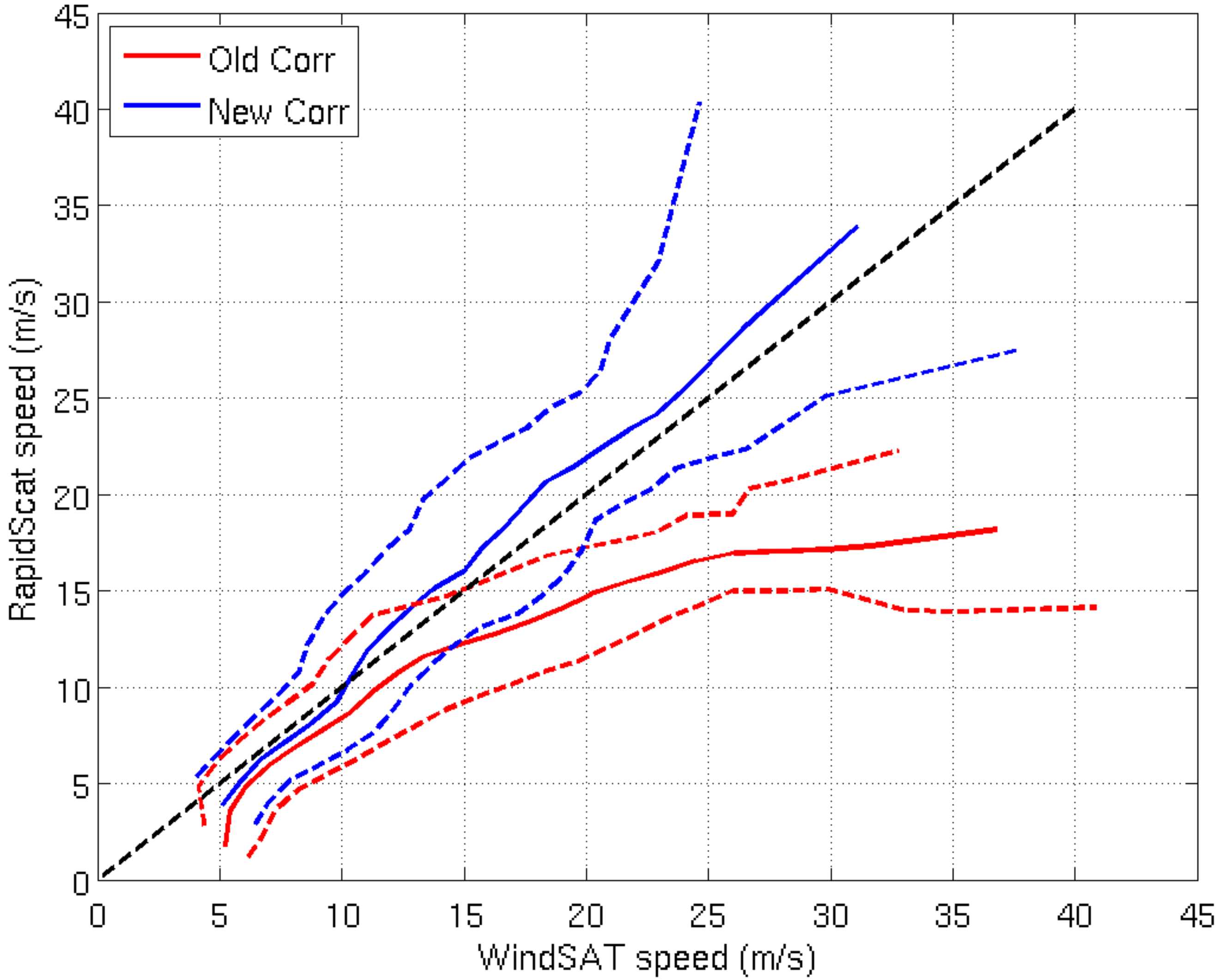
Comparison With WindSAT

- The WindSAT all-weather wind speed product {Meissner 2009] was developed and validated using HRD H*WINDS data, SFMR, and dropsondes, similarly to the QuikSCAT tropical cyclone product {Stiles 2014].
  - *Here we compare the RapidScat product to WindSAT.*
  - *WindSAT response to wind is presumed to extend linearly to the highest speeds if this assumption is wrong the highest winds would likely be underestimated.*
  - *WindSAT does not retrieve winds over 50 m/s.*
- Method
  - *Bin data by average of RapidScat and WindSAT speeds*
  - *Bias = mean (RapidScat-WindSAT) for each bin*
  - *STD = standard deviation of (RapidScat-WindSAT) for each bin*
  - *X-axis of solid line plots plots is speed bin – ½ Bias.*
  - *Y-axis of solid line plots is speed bin + ½ Bias.*
  - *Dashed line plots are error bars +/- ½ STD for x and -/+ ½ STD for y.*
  - *Data was colocated within 30 minutes.*
  - *First look at data where new and old speed corrections are the same.*
  - *Second look at only data where new and old speed corrections differ by more than 0,1 m/s*
  - *Only data in the dual-beam RapidScat swath is considered.*

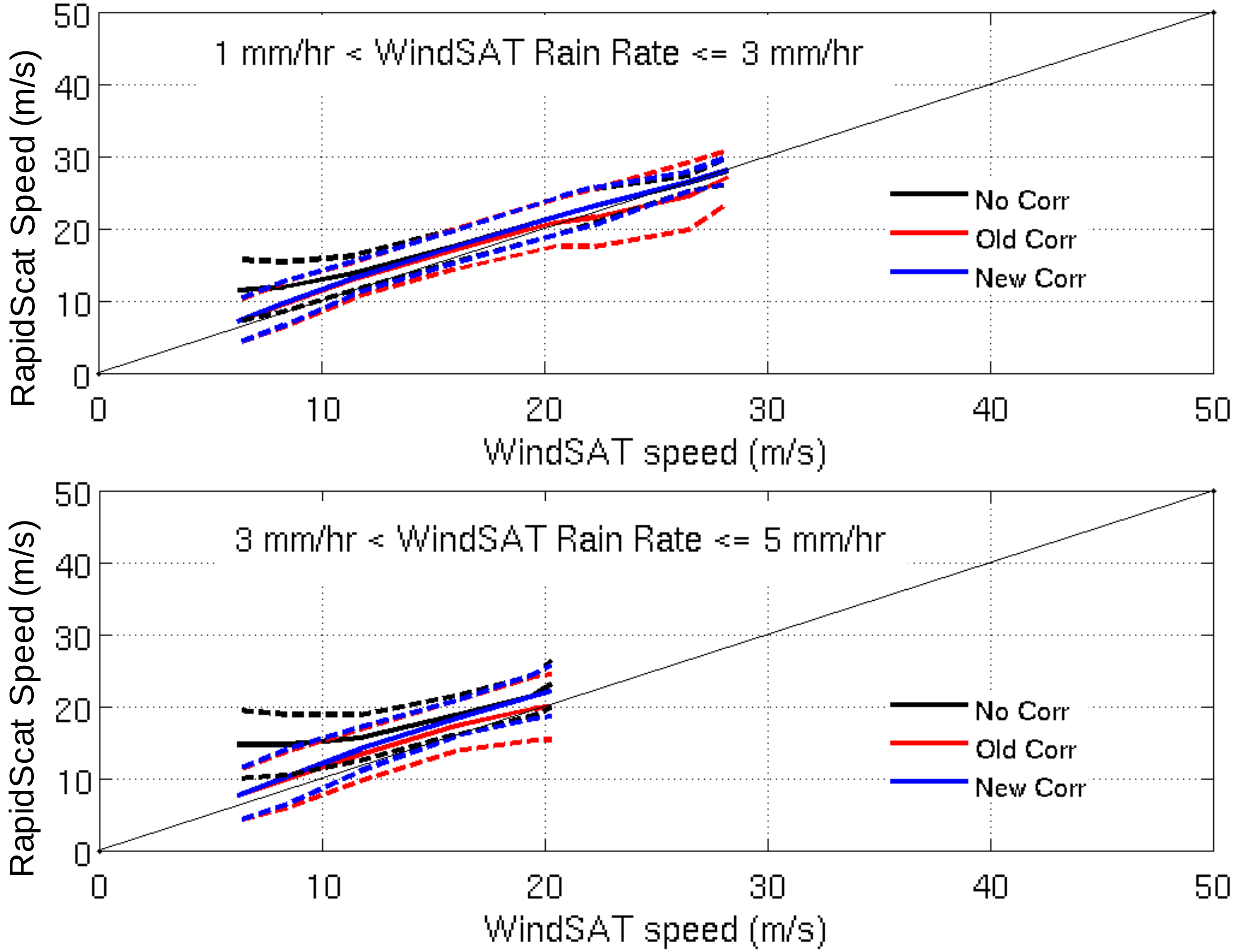
Comparison with Windsat (Unchanged data)



Comparison with Windsat (Changed data)



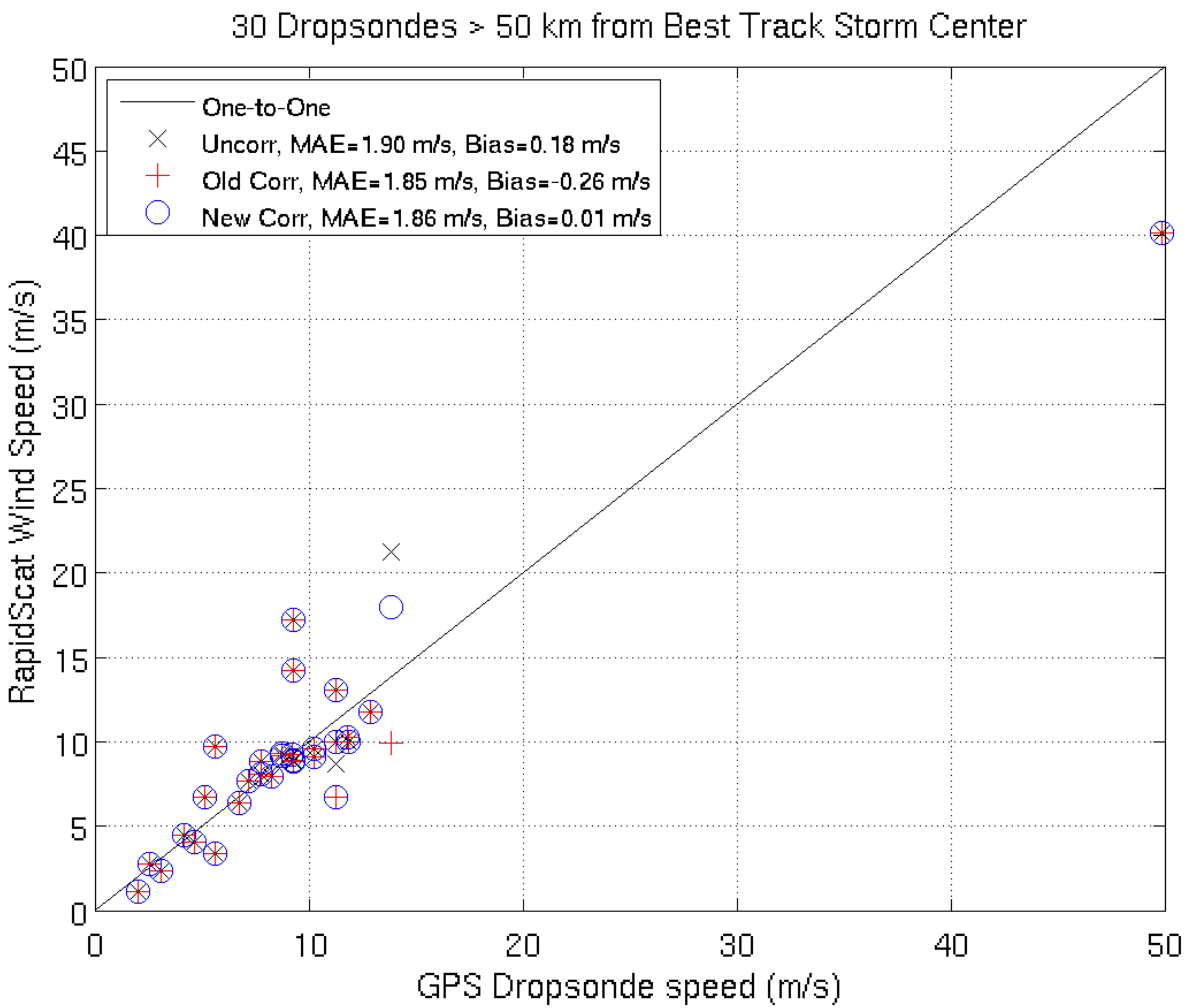
Comparison to WindSAT, moderate rain



GPS Dropwindsonde Comparison

- Dropsondes are the ideal validation candidate but.
  - *Only 30 usable drops were found in the RapidScat time period.*
  - *No 2015 drops available yet; used Ana and Gonzalo drops only.*
- Method
  - *Obtained GPS dropwindsonde data from NOAA/AOML Hurricane Research Division Website*
  - *Utilized dropsonde "surface" winds the 1070 mb winds in the has format data.*
  - *Compared to RapidScat data within 6 hours.*
  - *Chose closest 12.5-km RapidScat wind vector to dropsonde location*
  - *Eliminated dropsonde data closest to storm center due to difference between area average winds and point measurement in region of highest gradient.*
  - *Approximately 30 dropsondes are colocated.*

GPS Dropwindsonde Comparison

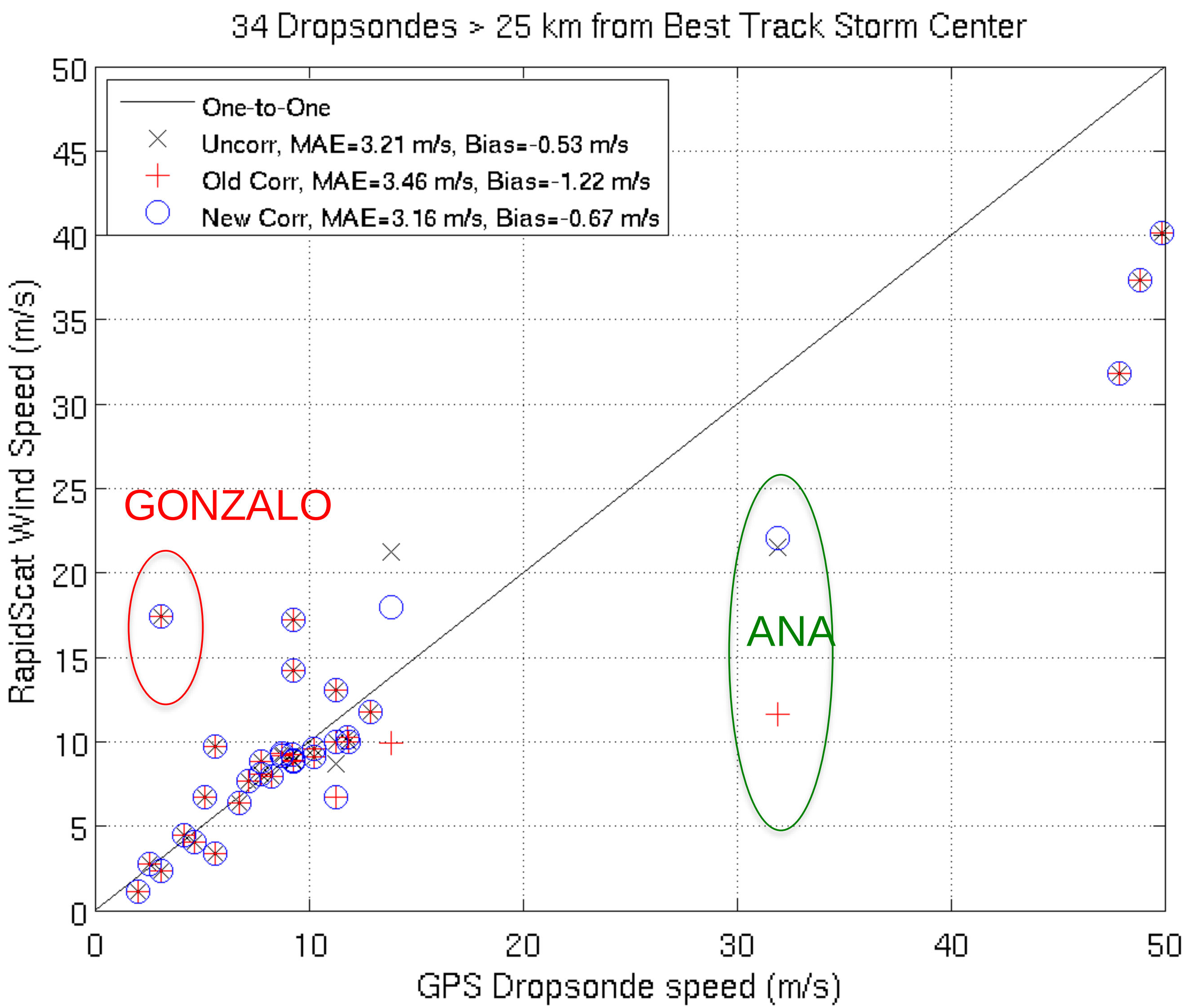


Few dropsondes to compare with RapidScat so far.

If we restrict ourselves to more than 50 km from storm center as we did for QuikSCAT dropsonde comparisons, there is only one high speed case.

Most dropsondes are not in rain-contaminated regions.

GPS Dropwindsonde Comparison

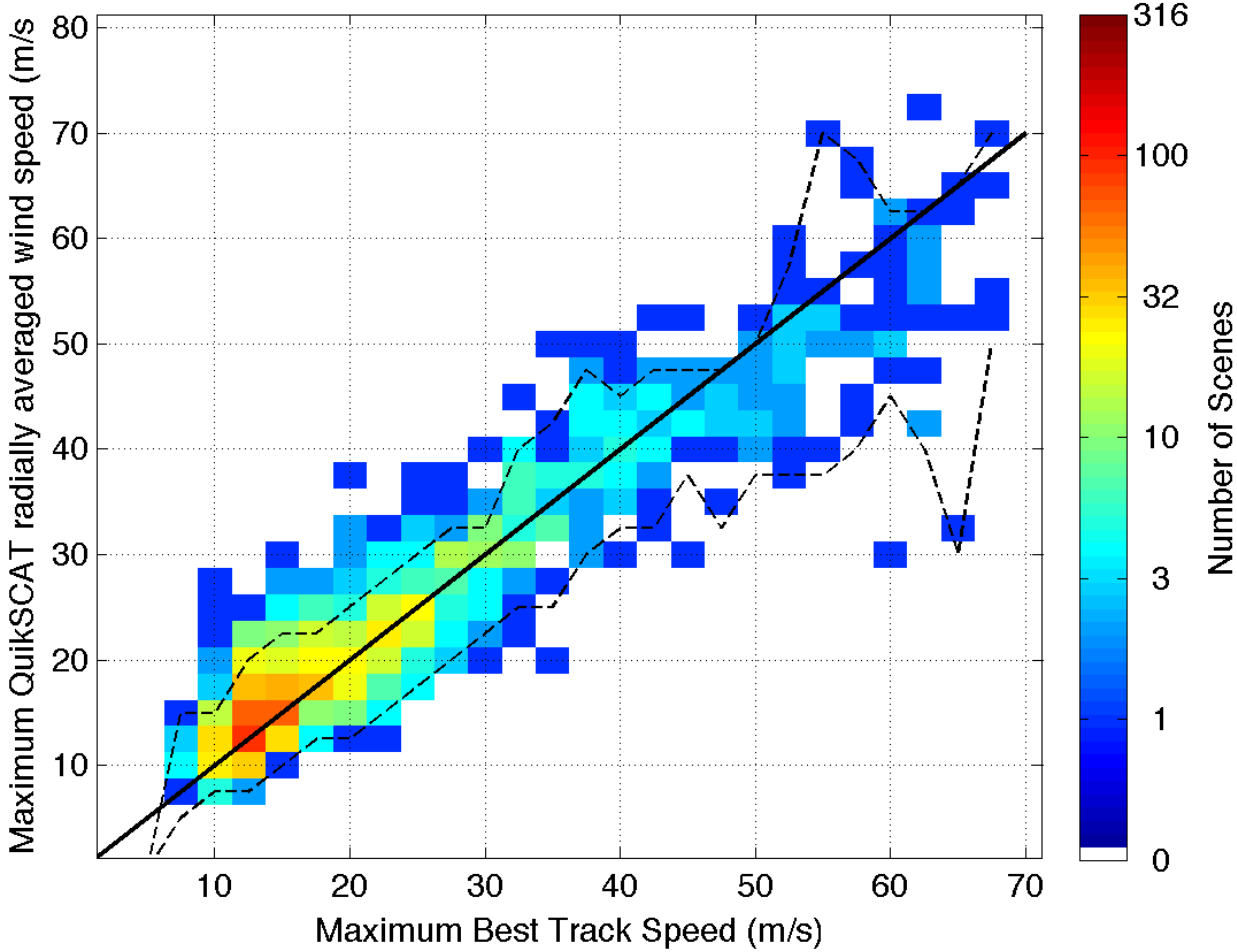


If we do comparisons to within 25 km of storm center, we predictably get more outliers due to steeper gradients.

We also get a few higher speed cases.

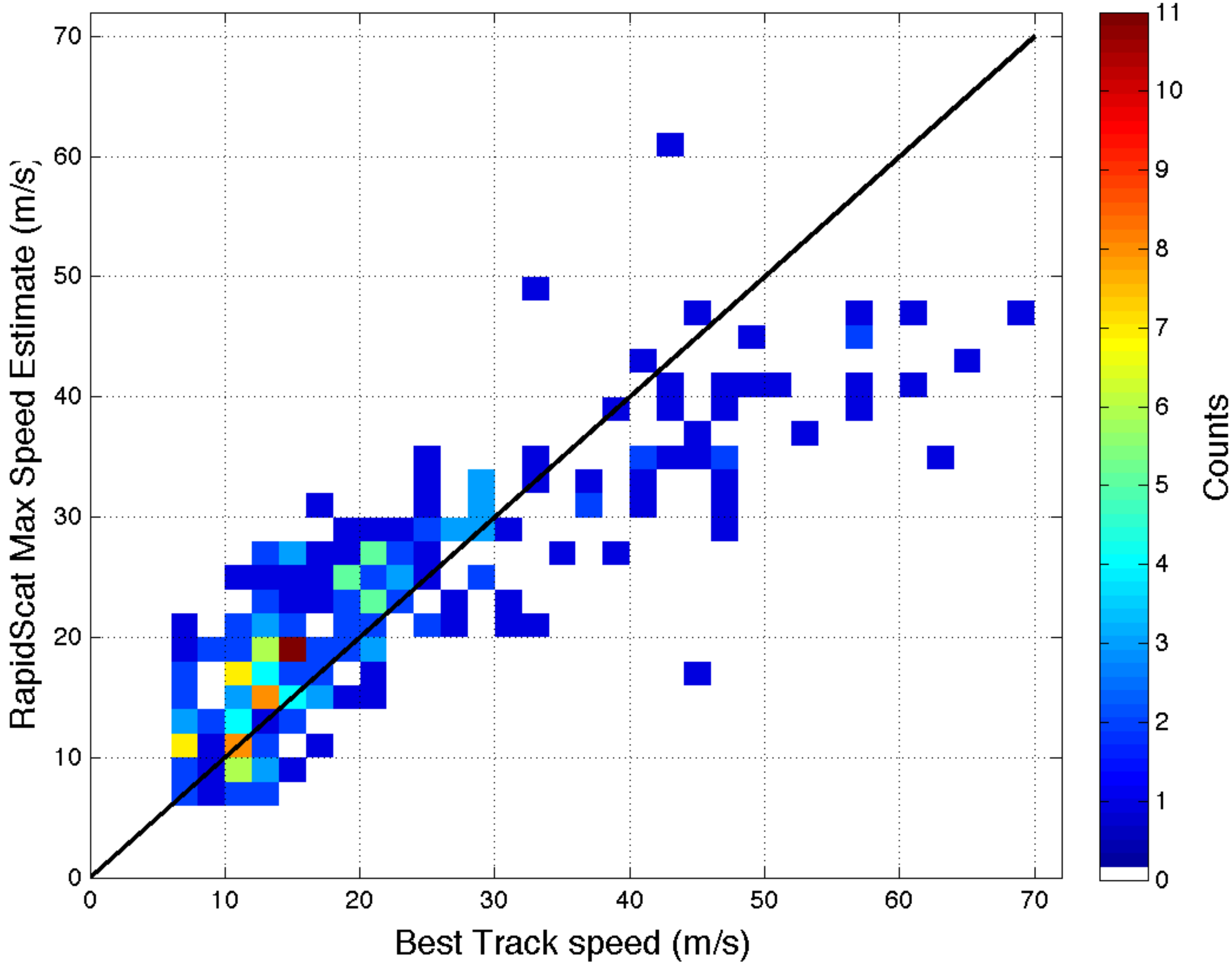
The circled cases are shown in more detail in following slides

Intensity Estimator: QuikSCAT ANN Stats



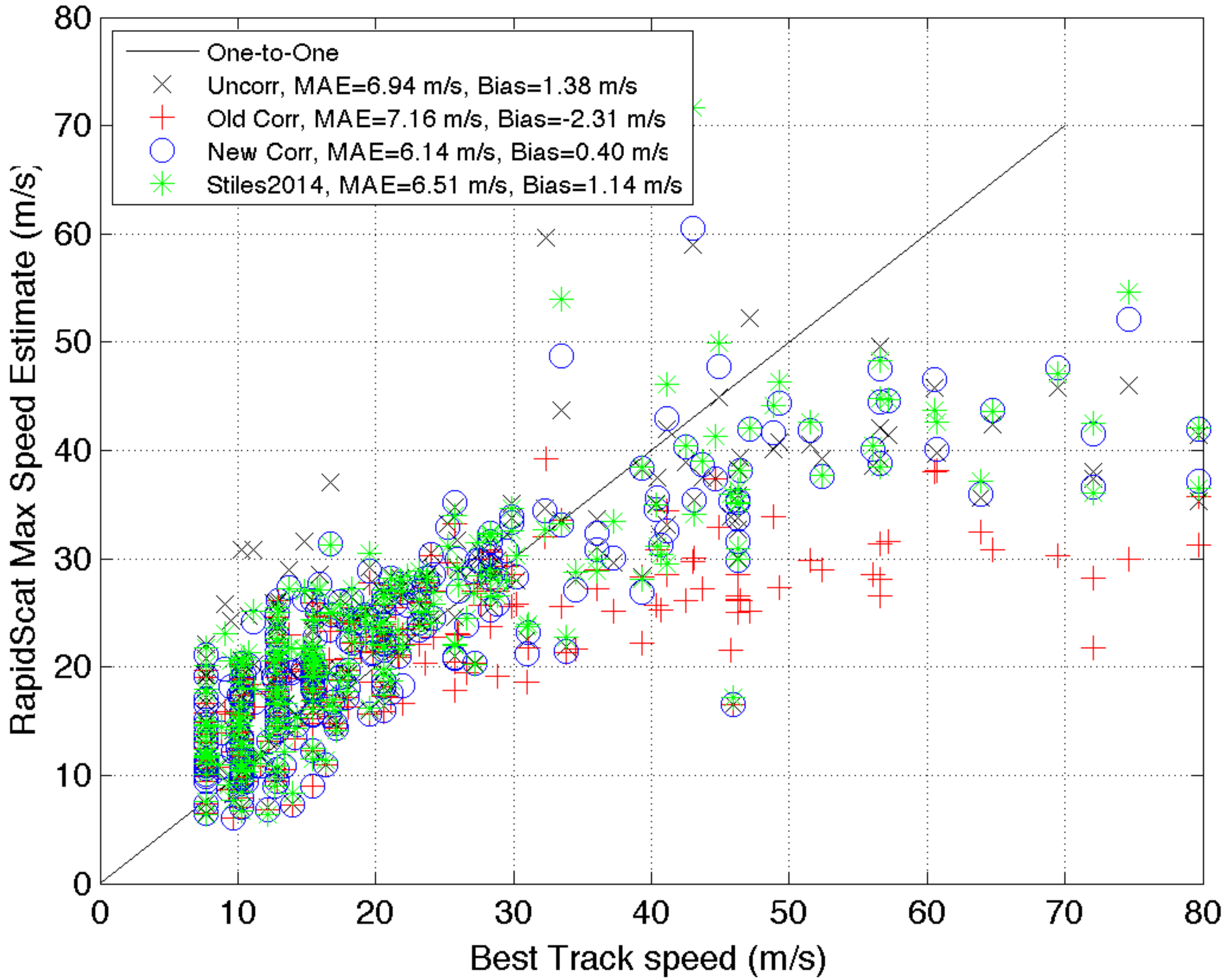
- Technique:
  - Compute average of wind vectors in concentric circles about center.
  - Take maximal average value.
  - Multiply by 1.4 to account for reduced resolution
- Reduces occurrence of outliers substantially

Intensity Estimator: RapidScat Stats, 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

Intensity Estimator: RapidScat Stats



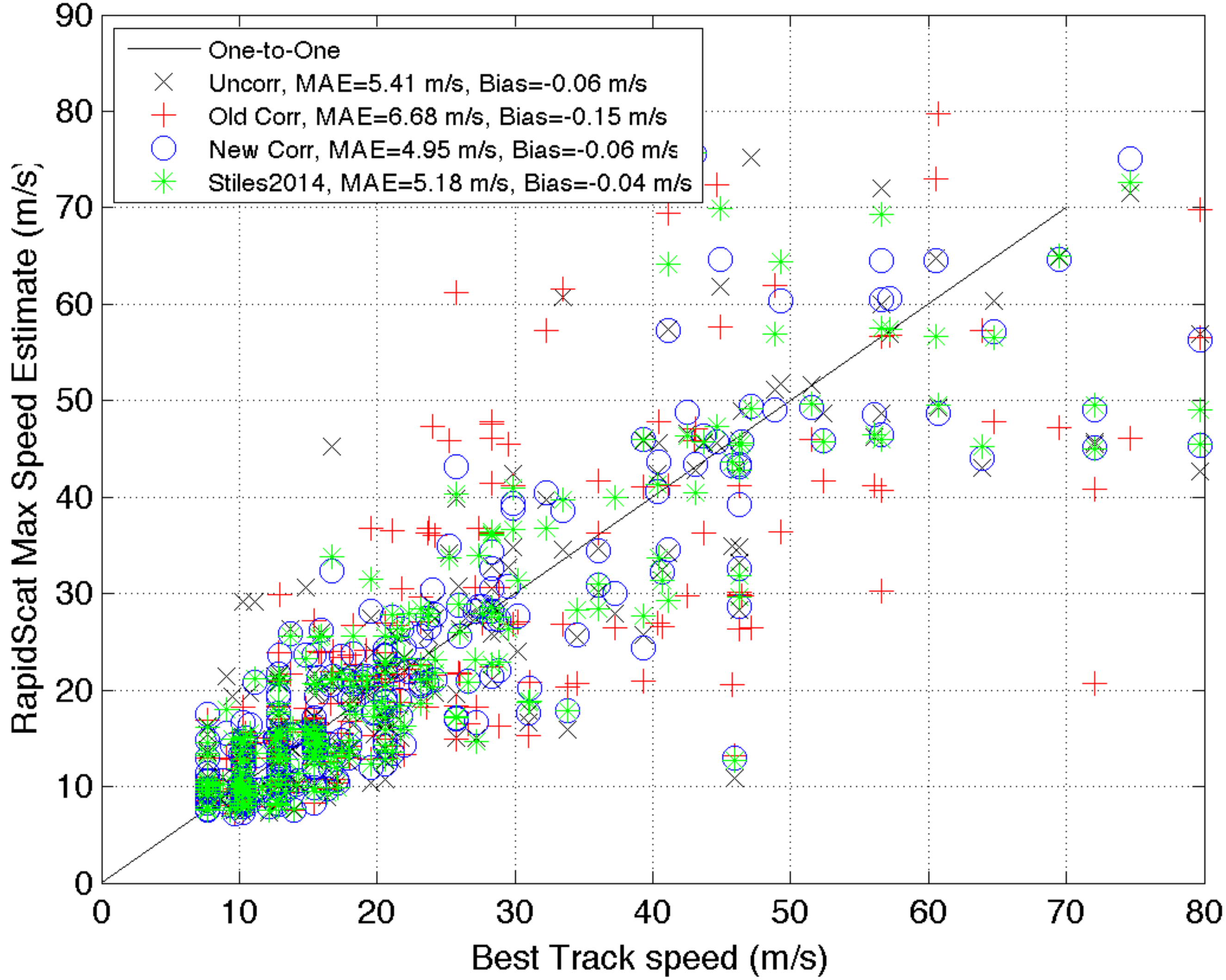
V1.1 improves upon V1.0 correction at high winds.

Improves upon no correction at low winds.

RapidScat biased low for winds greater than 40 m/s

Same technique applied to QuikSCAT follows one-to-one line up to 70 m/s

Intensity Estimator: RapidScat Stats



- Applying a simple histogram match can improve correspondence between RapidScat intensity estimate and best track.

RapidScat Hurricane Processing Conclusions and Future Work

- Conclusions
  - *V1.1 rain correction is significant improvement over version 1.0 in high winds and rain.*
  - *Best track comparisons suggest RapidScat winds are biased low vs. QuikSCAT for the highest wind speeds.*
  - *RapidScat and WindSAT all weather speeds compare favorably up to the highest observed speeds.*
  - *Dropwindsonde comparisons are inconclusive due to lack of data.*
- Future work
  - *Compare QuikSCAT data with WindSAT*
  - *Compare RapidScat data with more dropwindsondes as they become available*
  - *Compare RapidScat with SMAP winds as they become available*
  - *Compare RapidScat and QuikSCAT with NOAA STAR's newest consistent SFMR data set.*

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)
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- Meissner, T.; Wentz, F.J., "Wind-Vector Retrievals Under Rain With Passive Satellite Microwave Radiometers," Geoscience and Remote Sensing, IEEE Transactions on , vol.47, no.9, pp.3065,3083, Sept. 2009 doi: 10.1109/TGRS.2009.2027012 (WindSAT All-Weather Paper)

Acknowledgement

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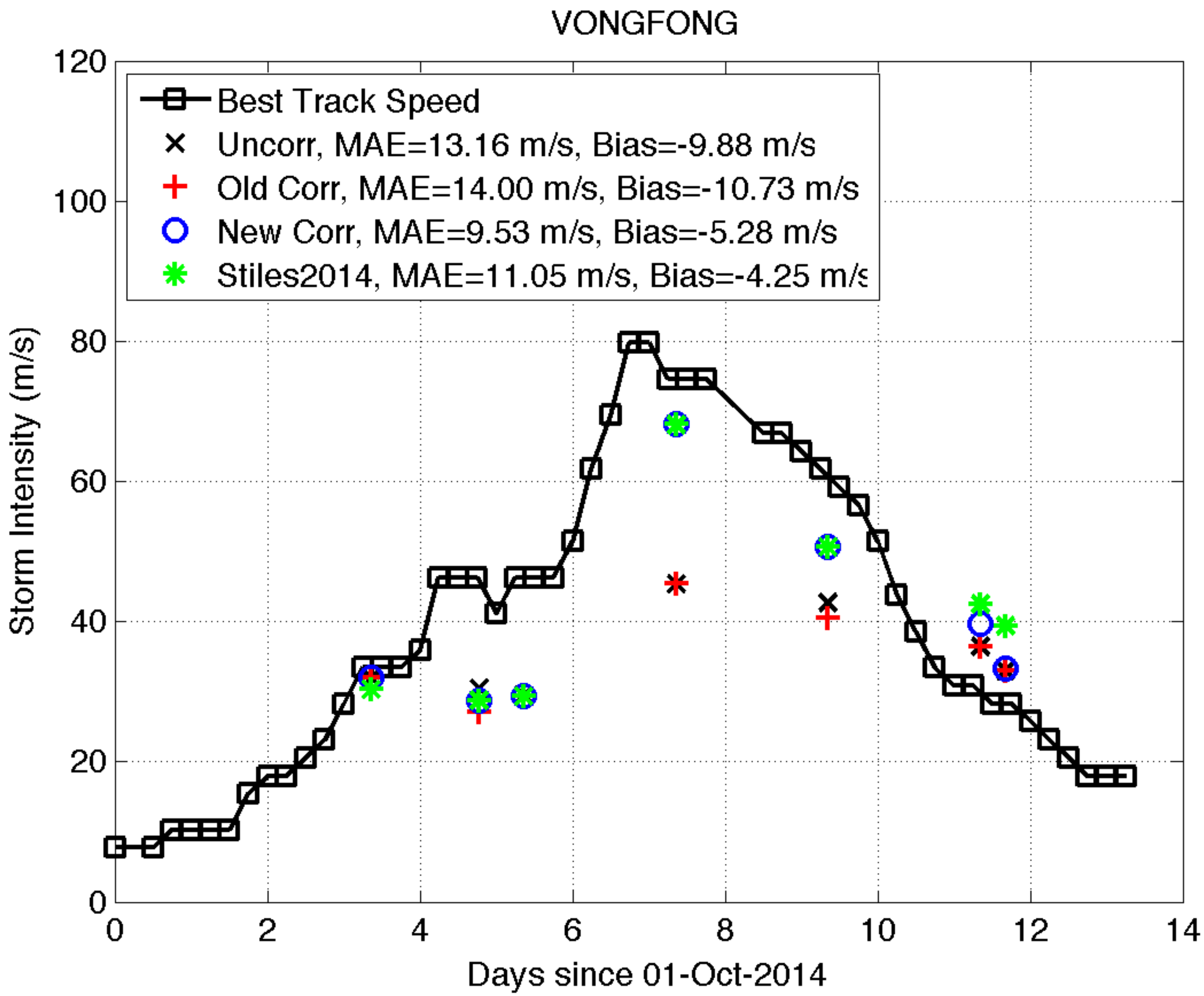
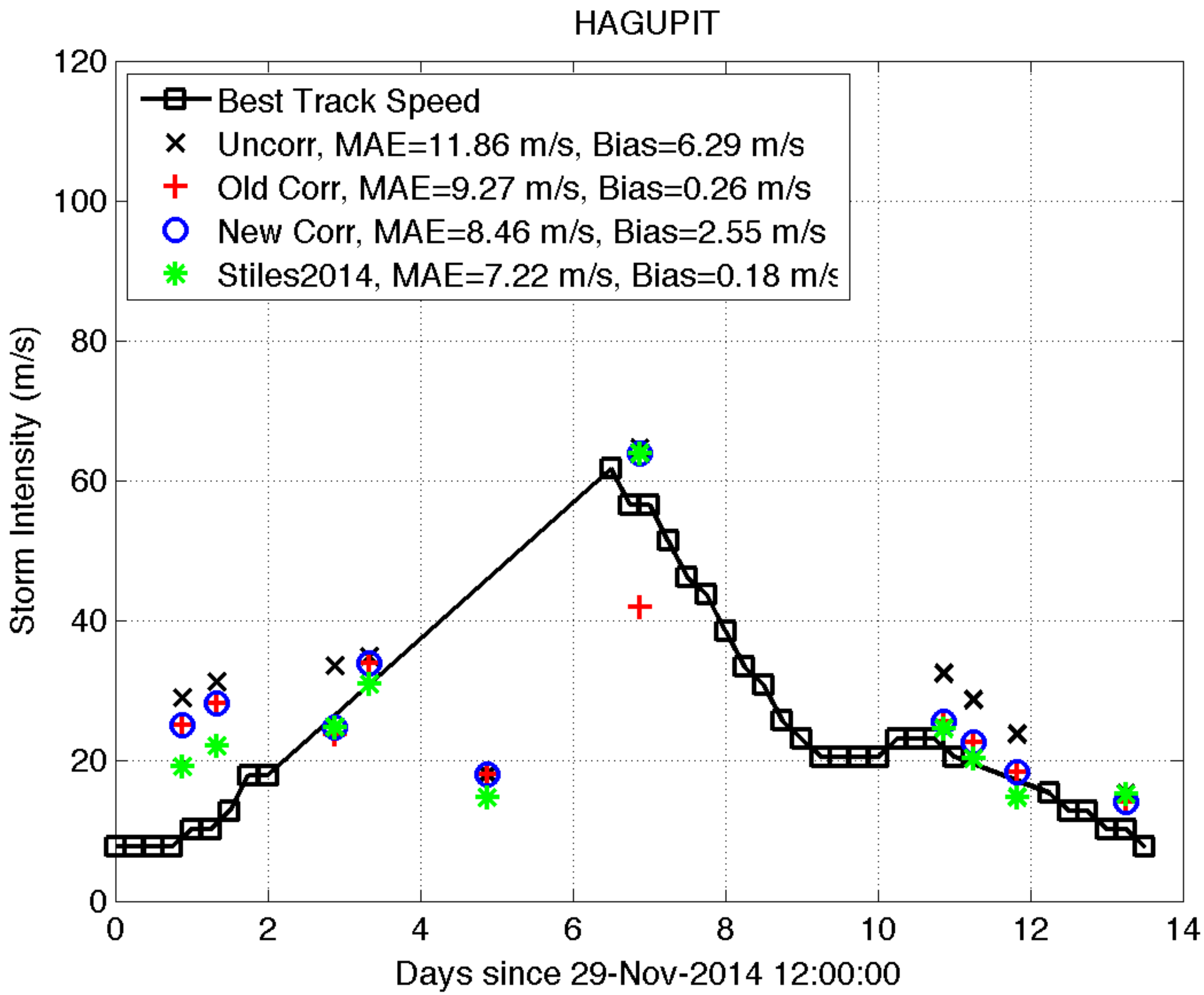
BackUp Slides

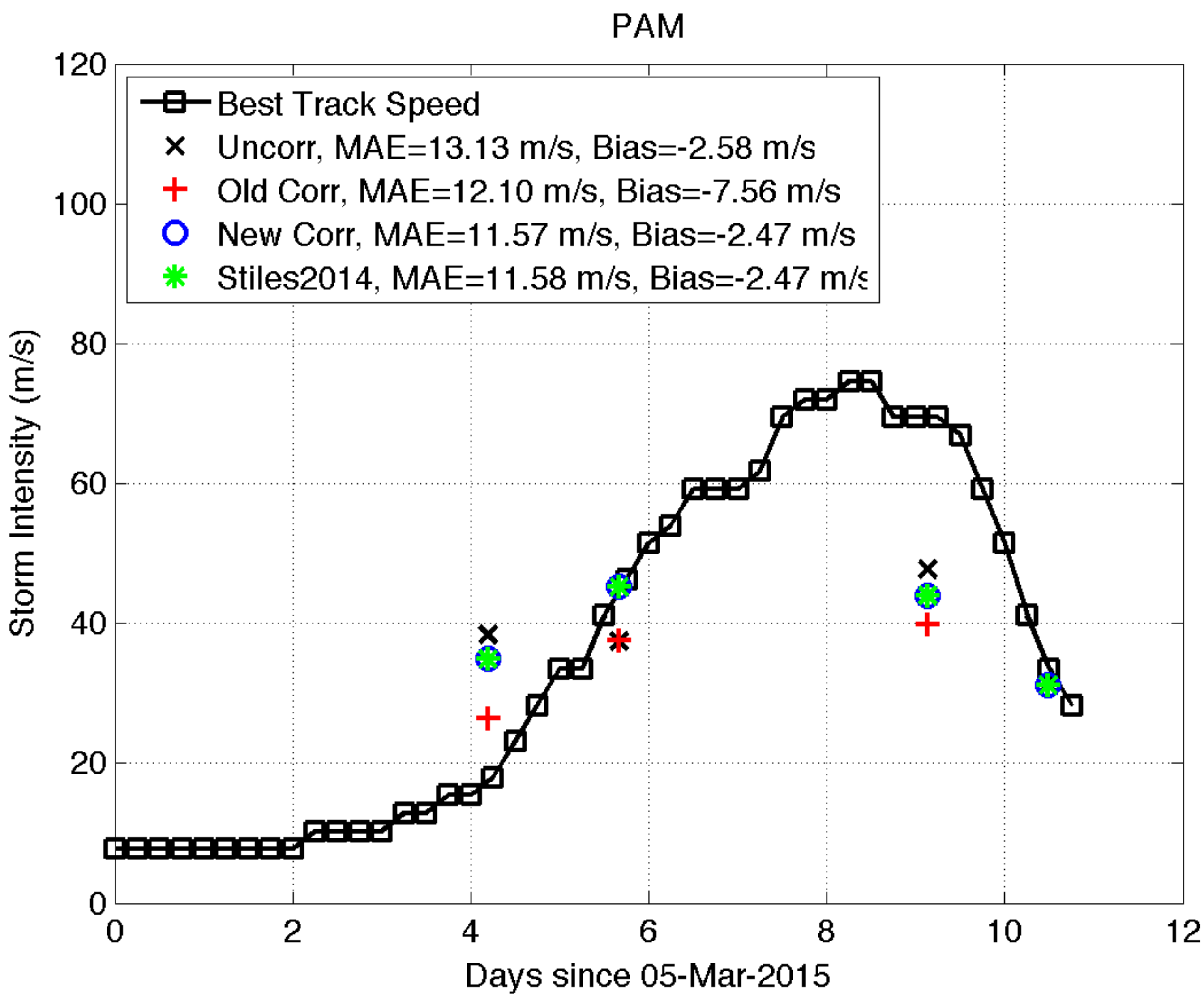
VongFong Best Track compared to RapidScat Maximum Speed with 200-km



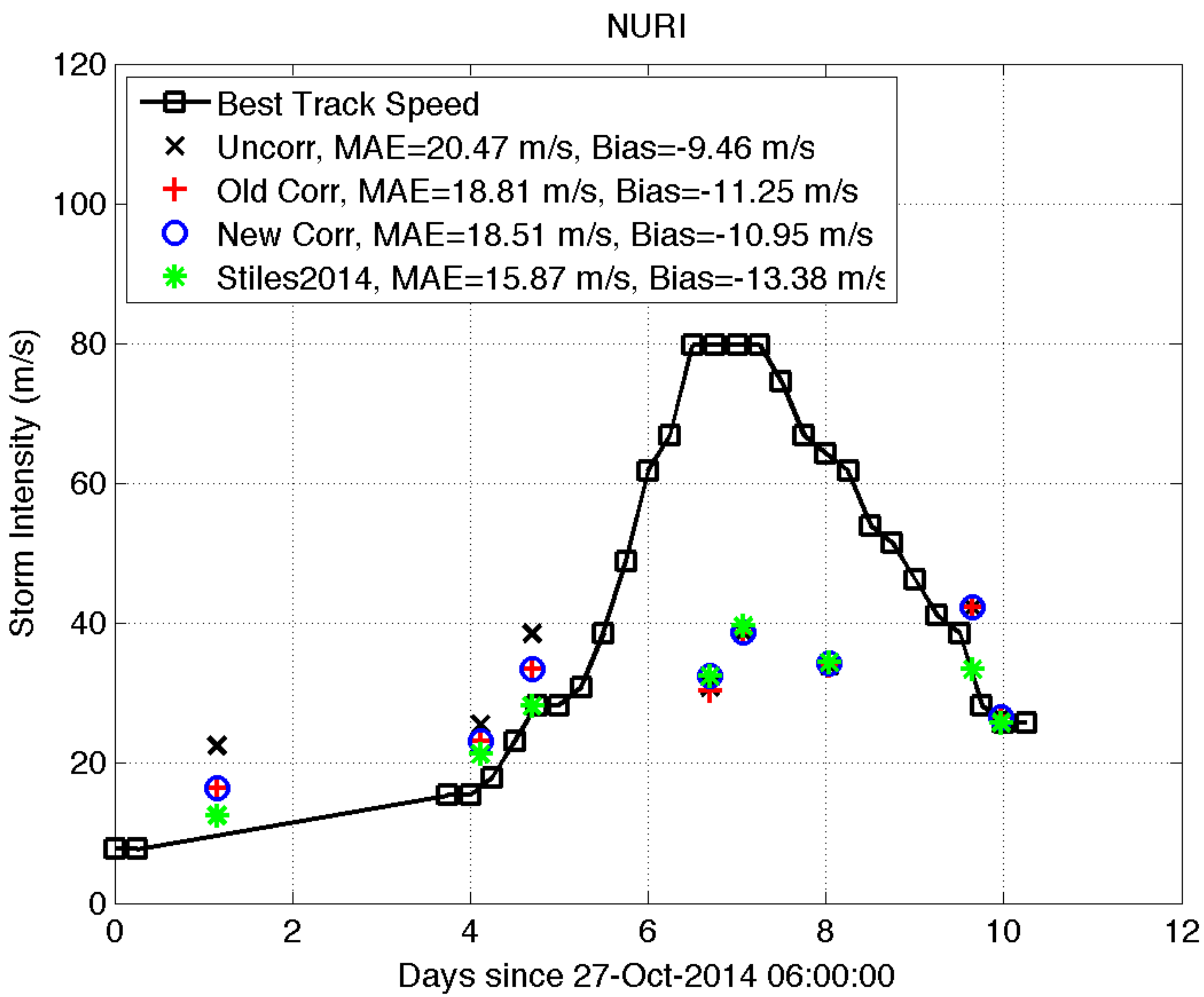
Hagupit Best Track compared to RapidScat Maximum Speed with 200-km



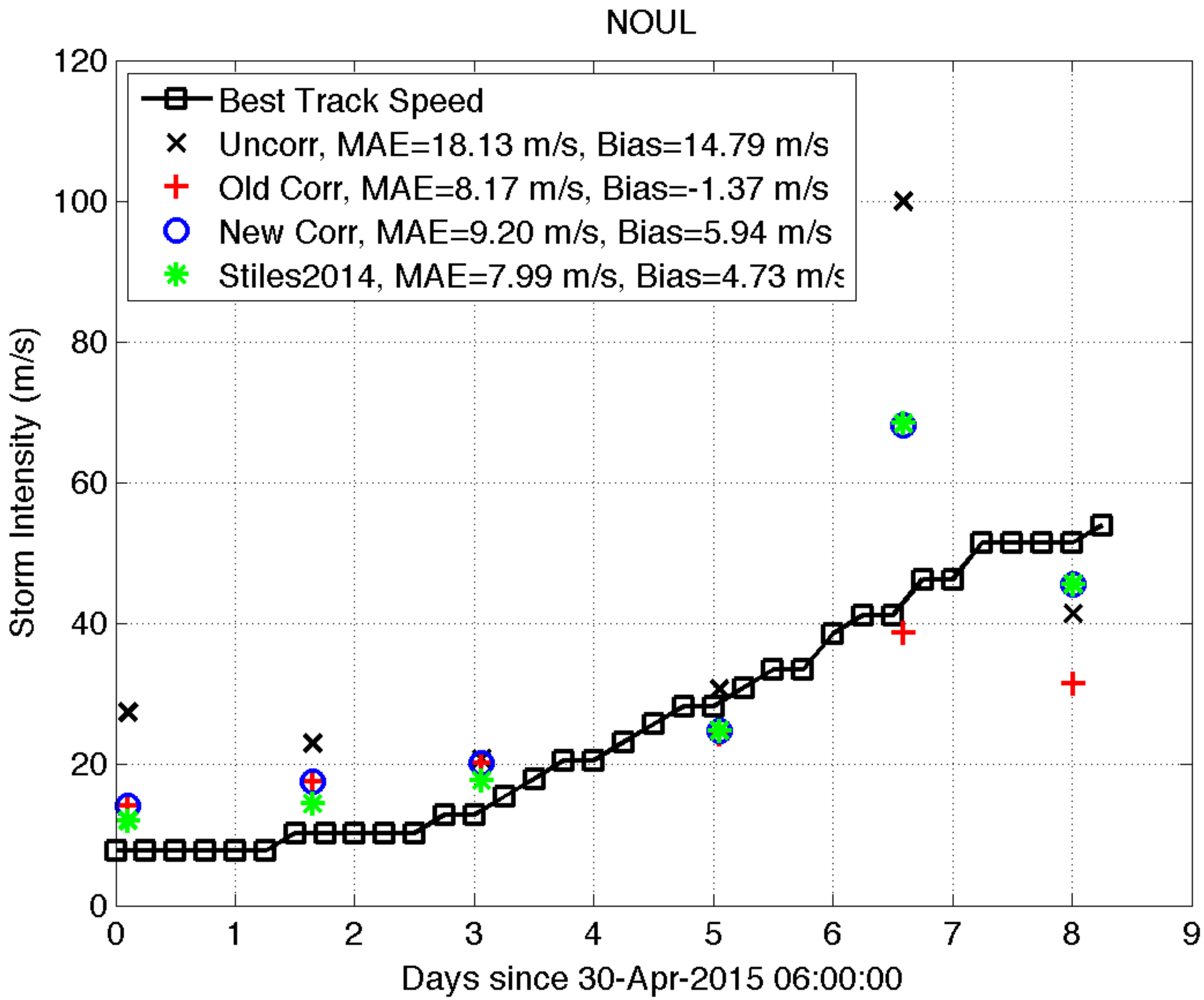
Pam Best Track compared to RapidScat Maximum Speed with 200-km



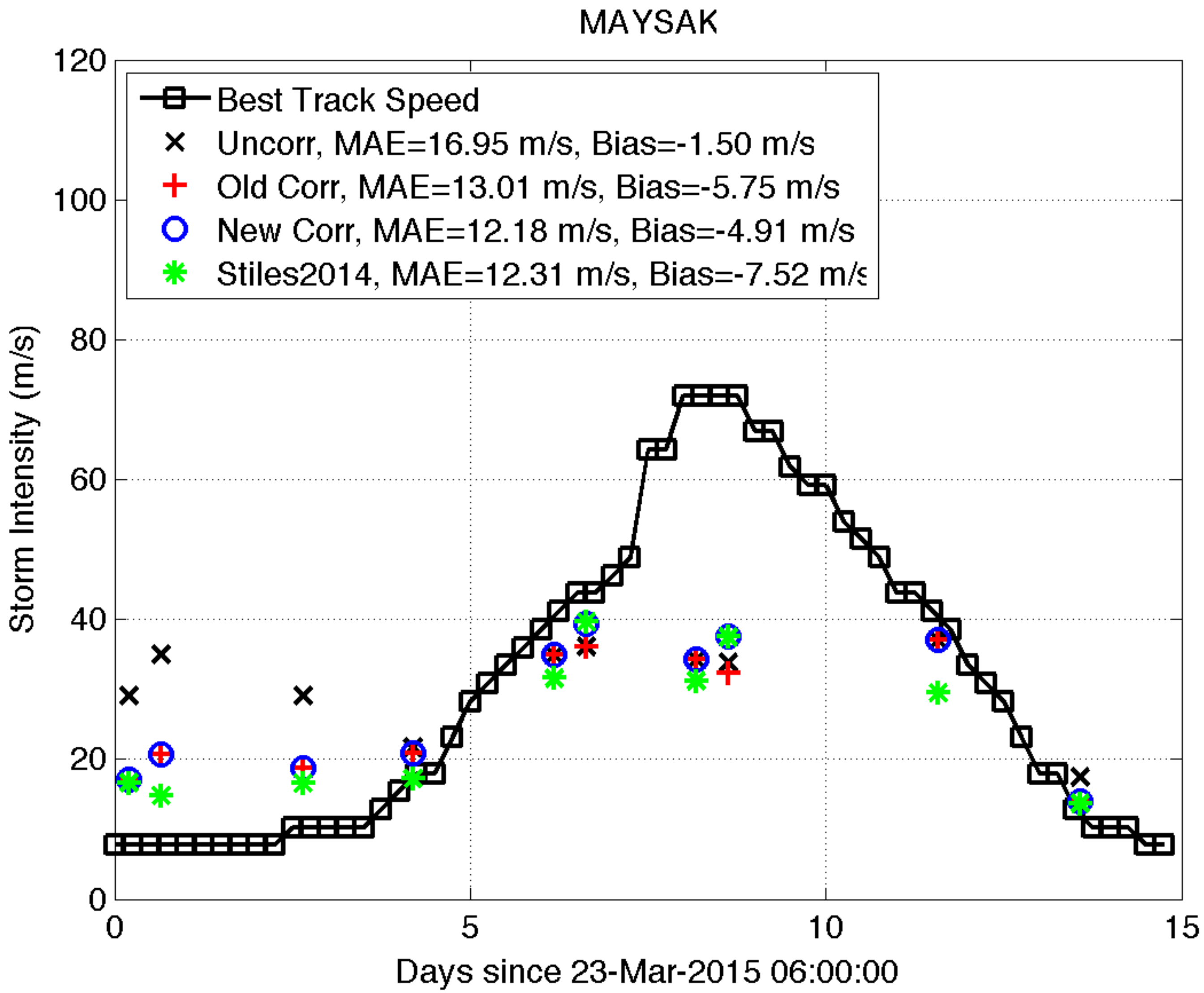
Nuri Best Track compared to RapidScat Maximum Speed with 200-km



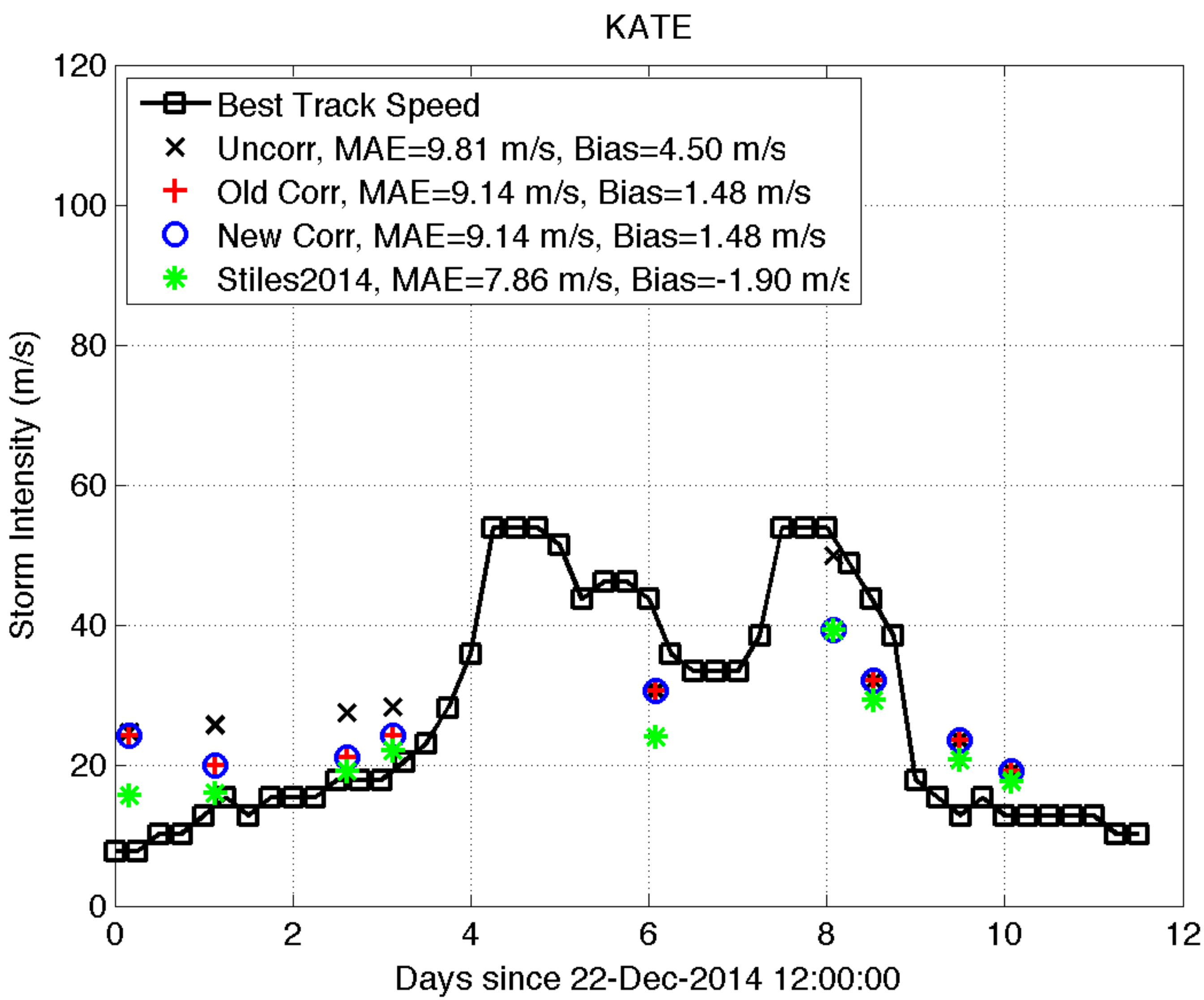
Noul Best Track compared to RapidScat Maximum Speed with 200-km



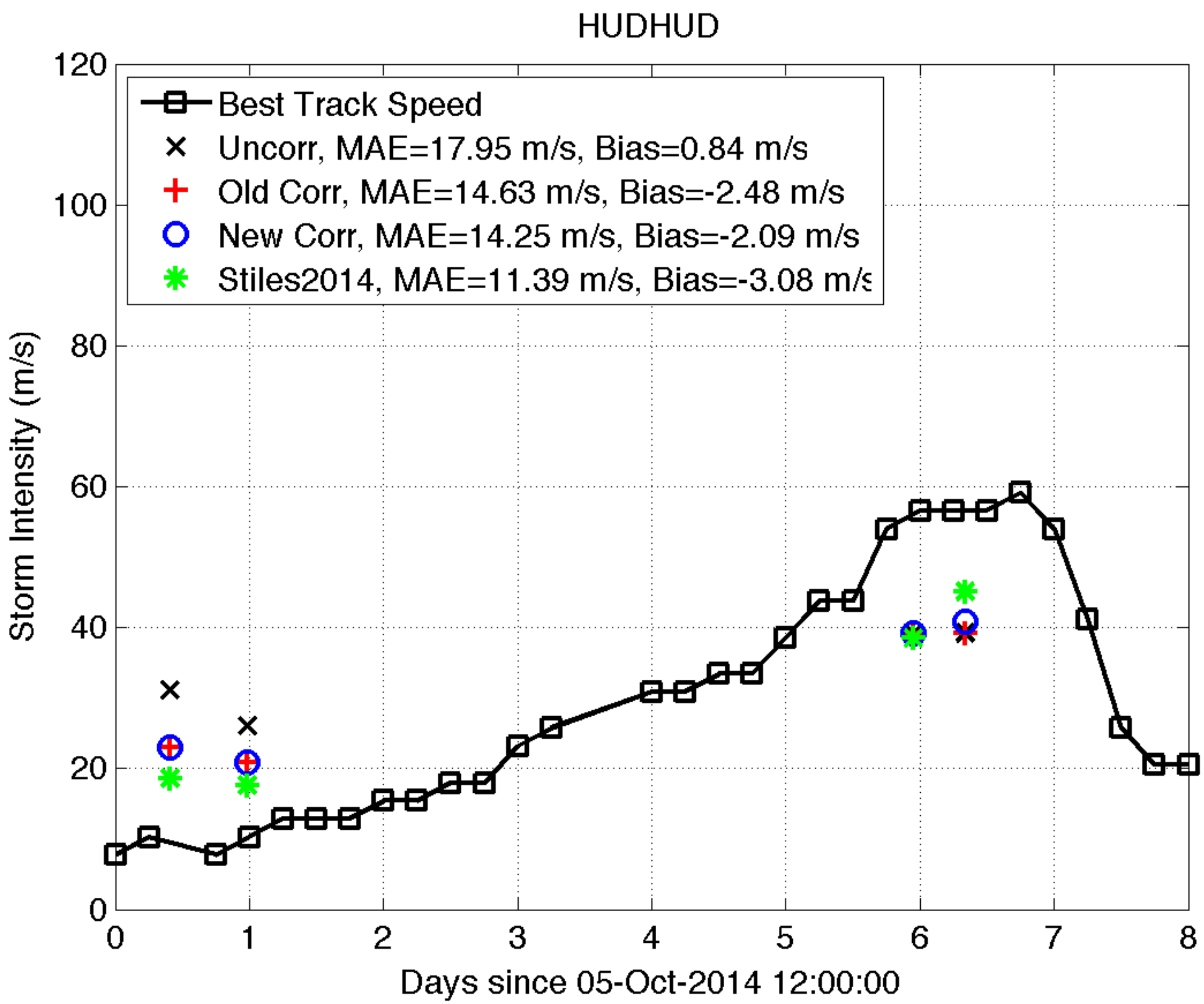
Maysak Best Track compared to RapidScat Maximum Speed with 200-km



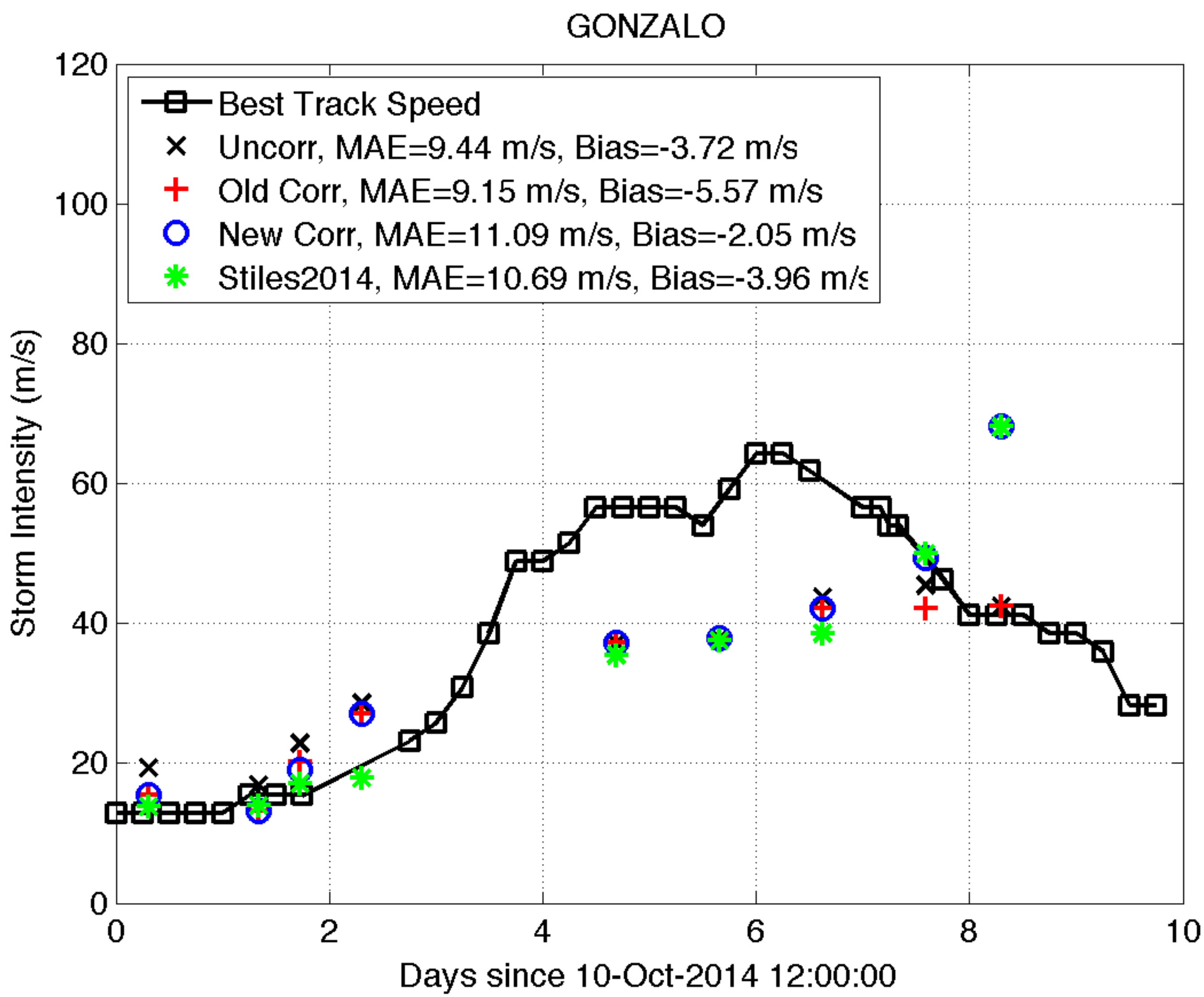
Kate Best Track compared to RapidScat Maximum Speed with 200-km



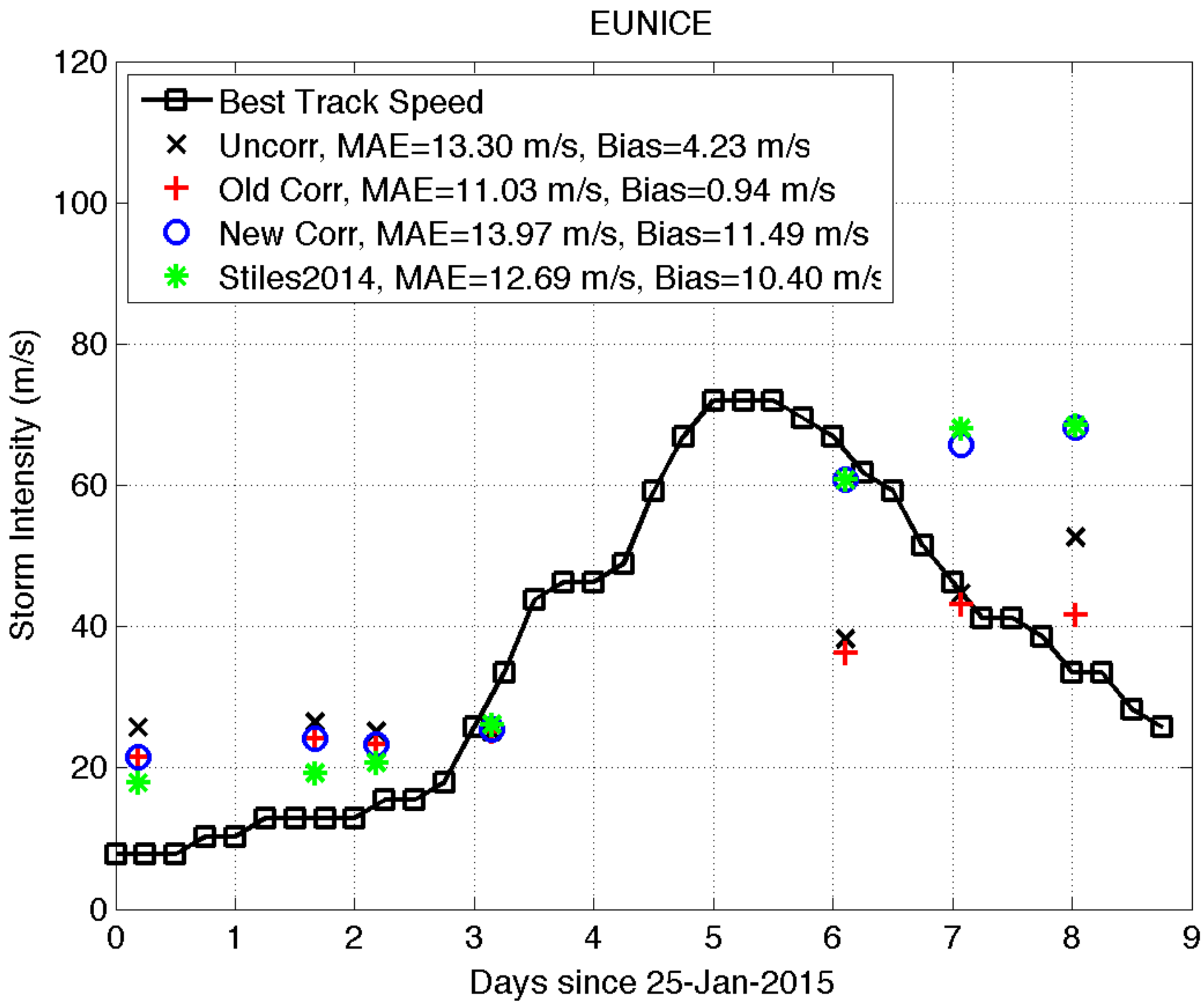
Hudhud Best Track compared to RapidScat Maximum Speed with 200-km



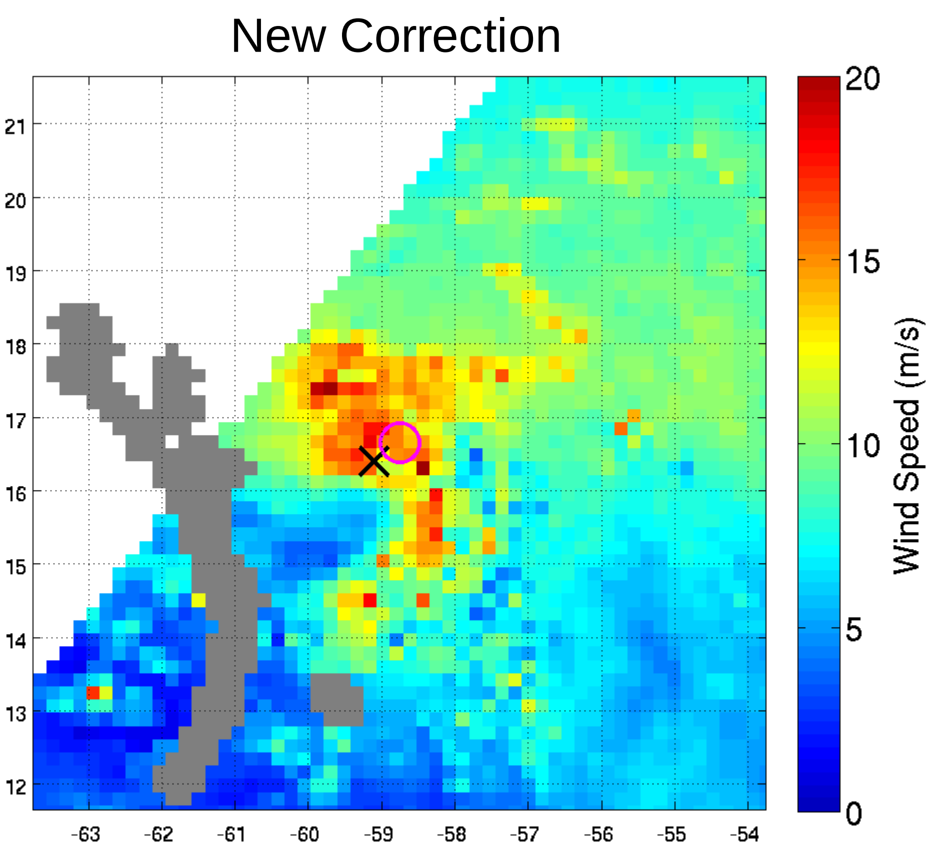
Gonzalo Best Track compared to RapidScat Maximum Speed with 200-km

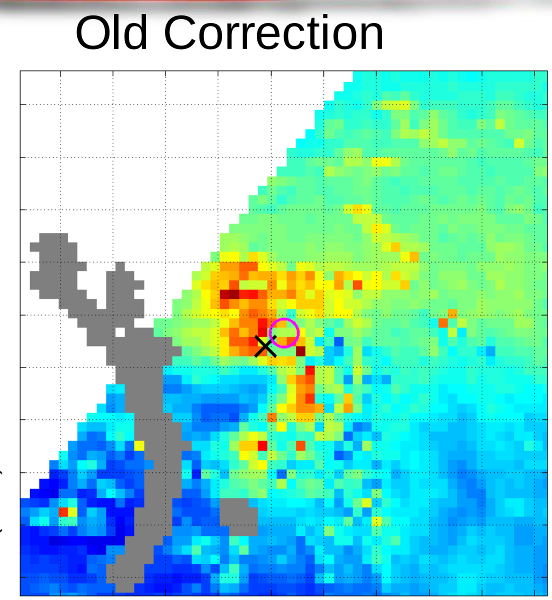


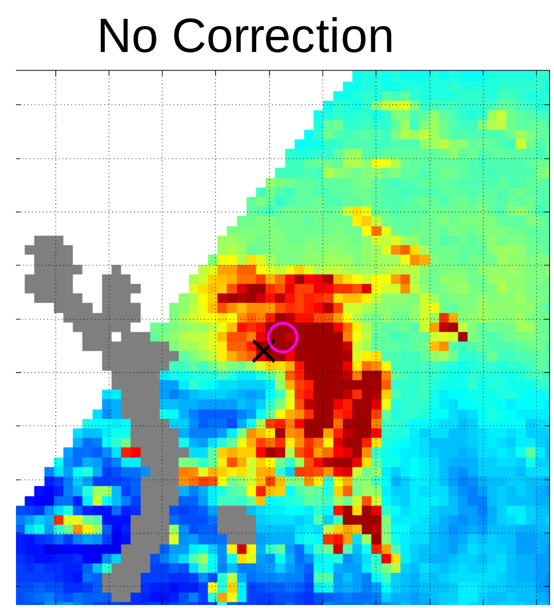
Eunice Best Track compared to RapidScat Maximum Speed with 200-km



Gonzalo 20141012T1900 Outlier







X = dropsonde location

O = best track center

Best track maximum speed was 19.6 m/s.

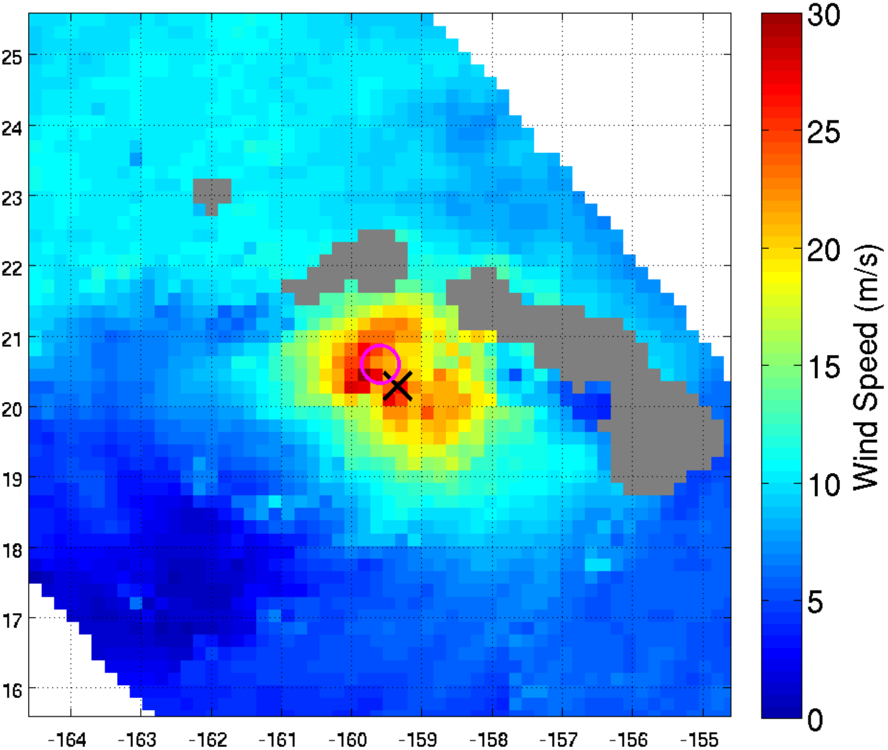
Uncorrected speeds were much higher than best track.

Dropsonde location X was near a sharp transition in speed.

The correction makes a big difference but not near the dropsonde.

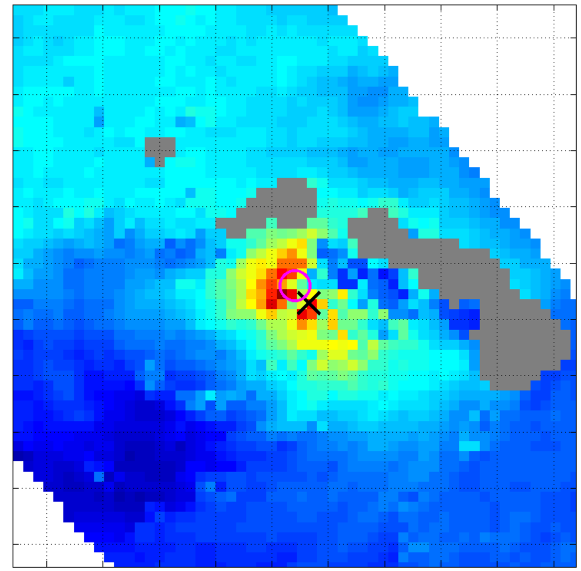
Ana 20141019T1200 Case Rain Correction Applied

New Correction

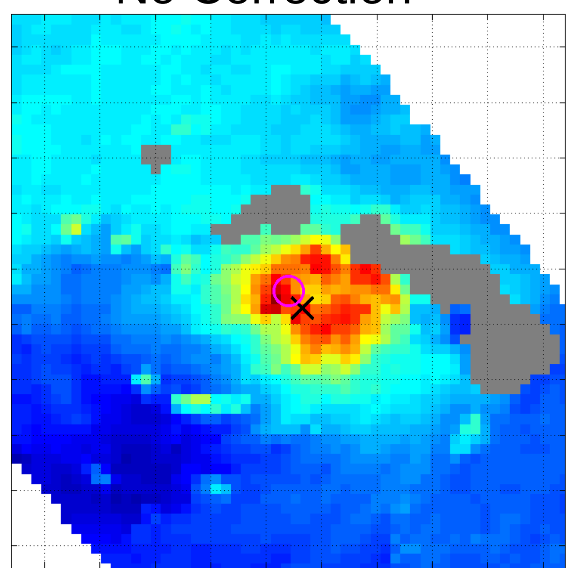


X = dropsonde location
O = best track center

Old Correction



No Correction



Best track maximum speed was 36 m/s.

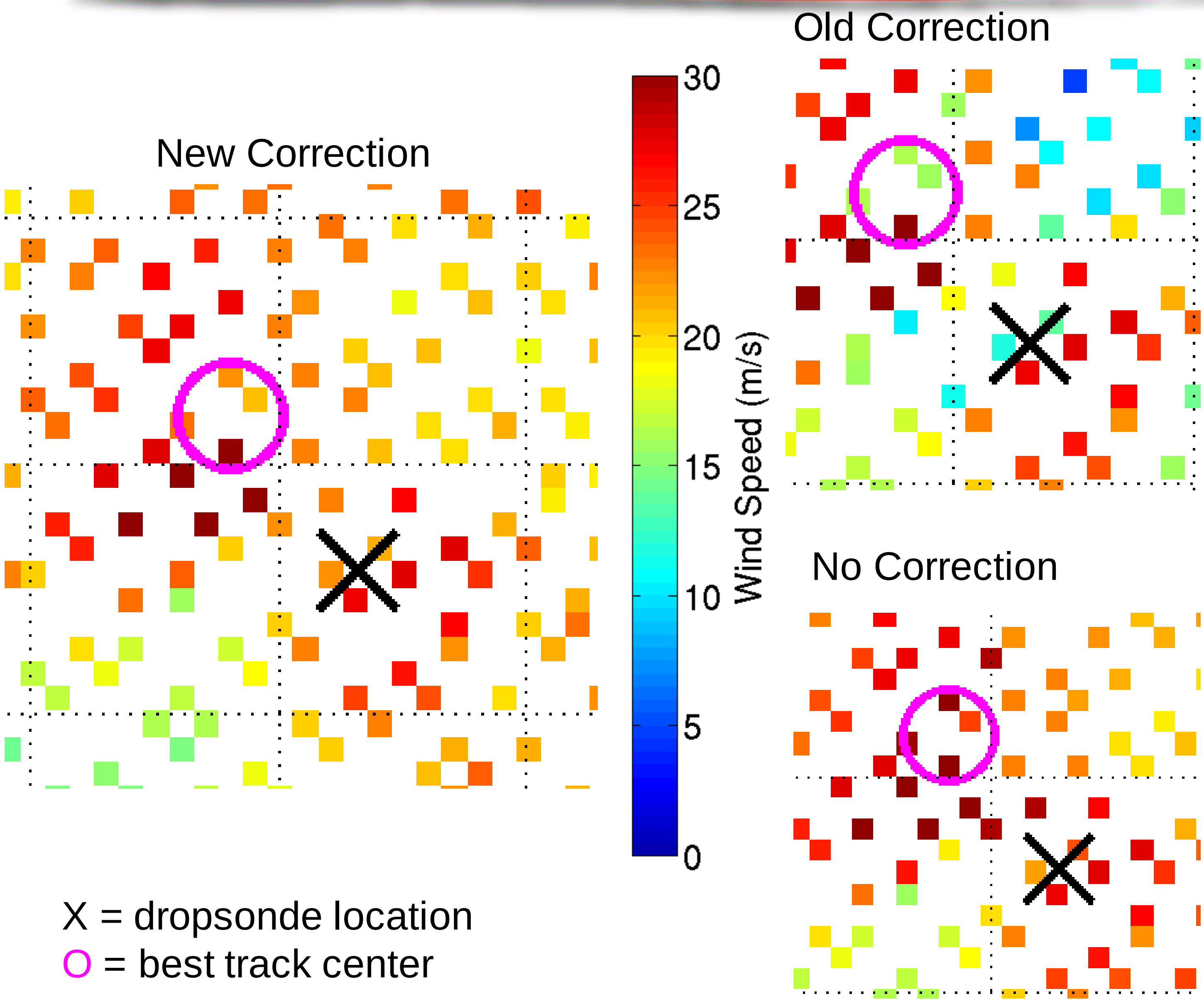
Dropsonde measured 32 m/s.

Uncorrected speed at dropsonde was 21.5 m/s.

Old correction was 11.6 m/s.

New correction was 22 m/s.

Ana 20141019T1200 Case Zoomed In



X = dropsonde location
O = best track center

Best track maximum speed was 36 m/s.

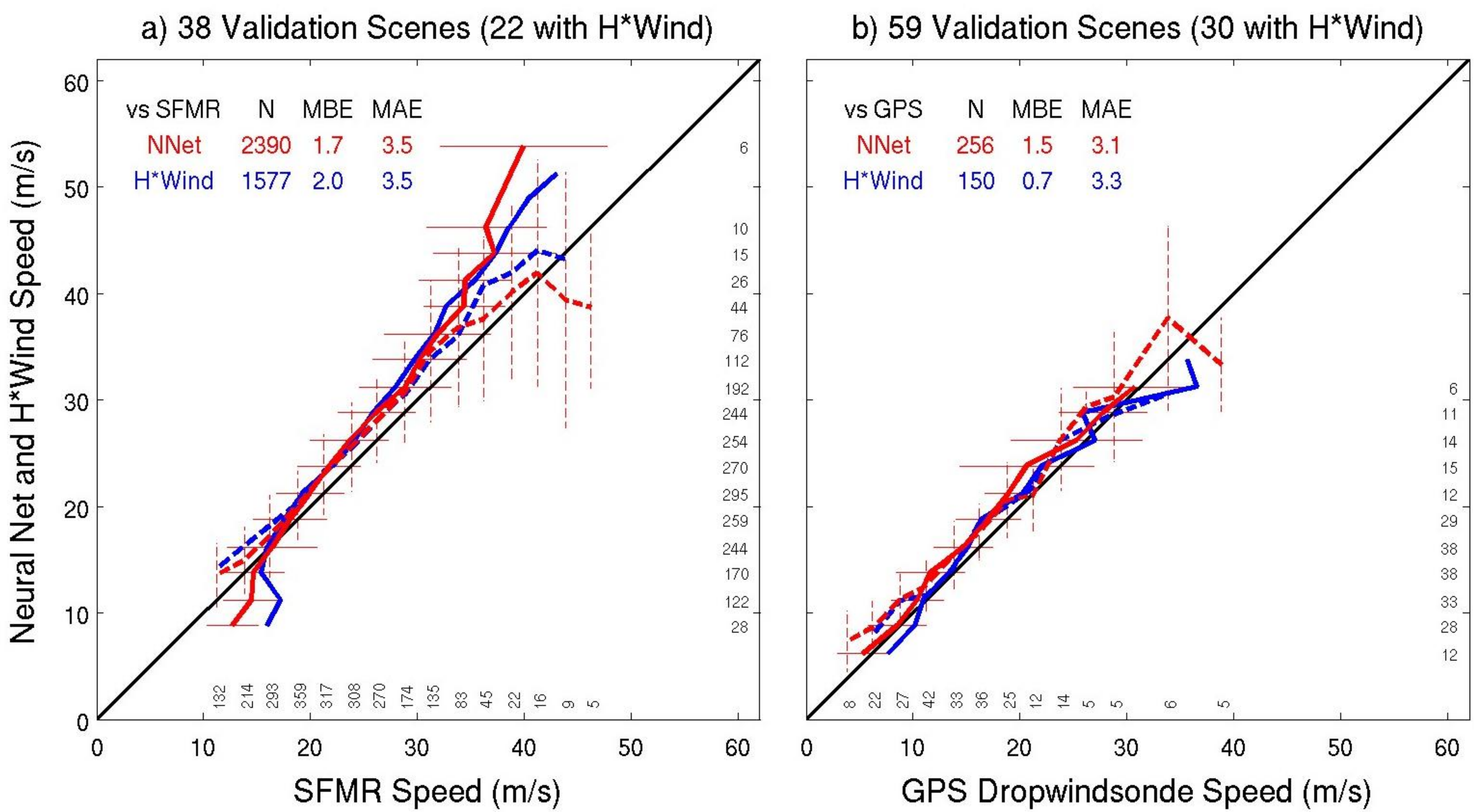
Dropsonde measured 32 m/s.

Uncorrected speed nearest dropsonde was 21.5 m/s.

Old correction was 11.6 m/s.

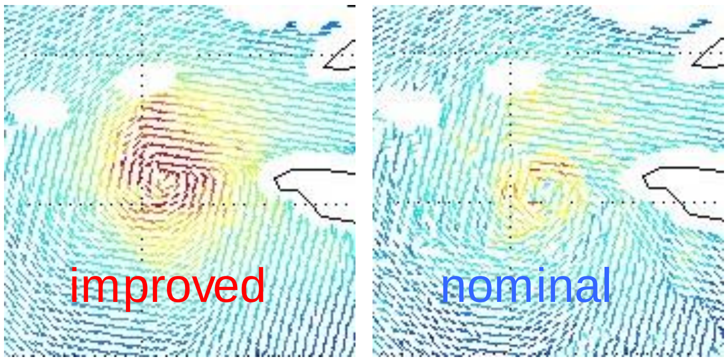
New correction was 22 m/s.

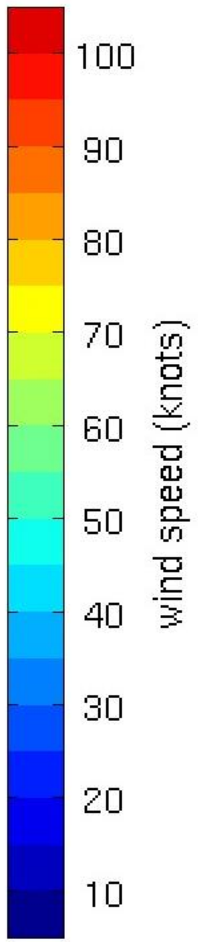
Validation: QuikSCAT

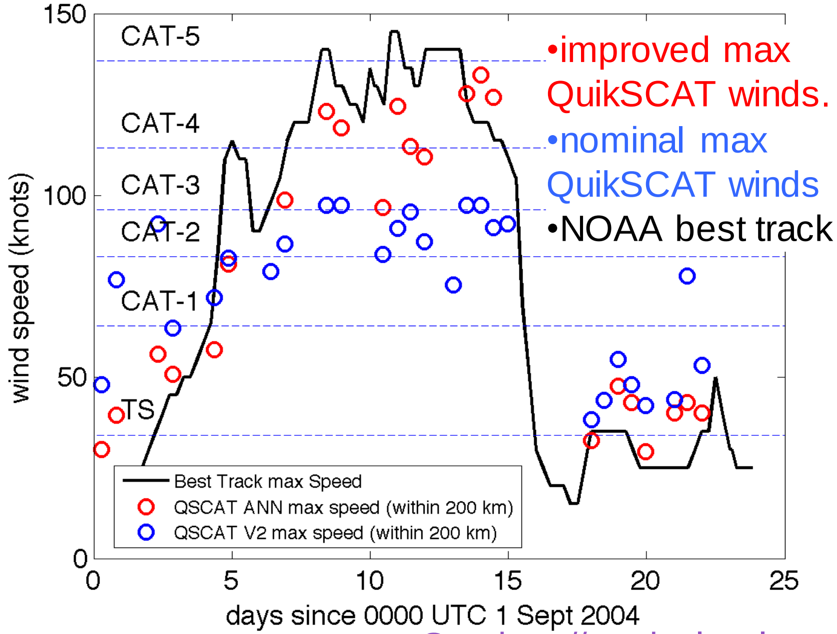


QuikSCAT Hurricane Winds

Hurricane Ivan 23:37 UTC 11 Sept. 2004







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

- Improved QukSCAT tropical cyclone (TC) wind speed fields
  - –11,435 storm scenes over 10 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 OceanSAT-2 (ISRO) and ASCAT (ESA) scatterometers.