Global 12-year Scatterometer Tropical Cyclone Wind Data Set from QuikSCAT and OceanSAT-2
Validation, Explanation, and Trends in Tropical Cyclone Intensity, Intensification, Size, and Shape

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Outline

• Overview
  – Problem Statement
  – How does it work?

• Data Set Description and Examples
  – QuikSCAT and OceanSAT-2

• Validation

• Maximum Intensity Estimation

• Storm Climatology

• Summary

• Acknowledgements and References
Overview: Problem Statement

• Goal: To optimize, produce, validate, and utilize ocean surface wind speed fields around all tropical cyclones (TCs) observed by QuikSCAT, OceanSAT-2, and ASCAT in order to:
  – Obtain a consistent 10-15 year data base of tropical cyclone surface wind fields over the global ocean.
  – Improve intensity forecasts for tropical cyclones [Brennan et al, 2009].
  – Enhance understanding of rapid intensification process in tropical cyclones.
  – Investigate tropical cyclone influence on ocean heat transport [Scoccimarro et al, 2011][Sriver and Huber, 2007]
  – Determine decadal trends in tropical cyclone size, shape, and intensity [Chan and Chan,2012], [Chavas and Emanuel, 2010]
Overview: How does it work?

• The neural network determines corrections to the MLE speed as a function of
  – SRAD rain rate
  – Backscatter from two different polarizations, two different azimuths, and two different spatial resolutions (2 X 2 X 2 = 8 values)
  – Viewing geometry (cross track distance)
  – MLE speed
• The resultant multi-dimensional mapping is hard to visualize.
• The next 7 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).
NRCS scatterplots for 20, 30, and 40 m/s H*WIND (QuikSCAT/H*WIND matched within 2 hours, *Clear conditions*)

- 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.

\[(\text{Blue}, \text{Green}, \text{Red}) = (20, 30, 40) \text{ m/s } \pm \text{ or -10\% H*WIND}\]
NRCS scatterplots for 20, 30, and 40 m/s H*WIND (QuikSCAT/H*WIND matched within 2 hours, *Rainy conditions*)

- In *rainy conditions* (rain impact quantity > 2.5), the wind sensitivity of both polarizations are reduced especially for VV pol, but still apparent at least for moderate rain.

\[(\text{Blue, Green, Red}) = (20, 30, 40) \text{ m/s } +\text{-}10\% \text{ H*WIND}\]
Histogram of Difference Between ANN and MLE Speed

MLE speed 24-26 m/s
Cross Distance 400-450 km
Histogram of Sum of 4 Sigma0s
Joint Histogram Low MLE winds

NRCS Copol Ratio (HH/VV) vs NRCS Sum

5/8/13

IOVWST, 2013, Multi-Scatterometer Hurricane Winds
Joint Histogram High MLE winds
Data Set Description

- Improved QuikSCAT 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.

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

Hurricane Ivan 23:37 UTC 11 Sept. 2004
QuikSCAT Tropical Cyclone Data Set (1999-2009)

- [http://tropicalcyclone.jpl.nasa.gov](http://tropicalcyclone.jpl.nasa.gov)
- 21600 total storm scenes from October 1999 to November 2009
- 11435 scenes with best track center within the image, including:
- Data on the site includes:
  - JPEG Images of tropical cyclone optimized winds and two versions of the JPL global wind product.
  - Netcdf files containing, all three wind sets, SRAD rain rates, and all 8 backscatter sets
  - A comprehensive set of best track data from a variety of sources.
OceanSAT-2 Tropical Cyclone Data Set (2010-2011)

- [http://tropicalcyclone.jpl.nasa.gov](http://tropicalcyclone.jpl.nasa.gov)
- 2575 total storm scenes from Jan 2010 to December 2011
- 1041 scenes with best track center within the image, including:
  - 298 TS, 90 CAT-1, 35 CAT-2, 27 CAT-3, 20 CAT-4, 3 CAT-5
- Data on the site includes:
  - JPEG Images of tropical cyclone optimized winds and MLE winds.
  - Netcdf files containing, all both wind sets, detrended brightness temperatures, and all 8 backscatter sets
  - A comprehensive set of best track data from a variety of sources.
Validation: QuikSCAT

a) 38 Validation Scenes (22 with H*Wind)

b) 59 Validation Scenes (30 with H*Wind)

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<th>MBE</th>
<th>MAE</th>
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Validation: OceanSAT-2

Hurricane Neural Network Winds

Maximum Likelihood Estimator Winds
Naive Intensity Estimation Example:

Hurricane Earl 2010  OceanSAT-2

CAT-5

CAT-4

CAT-3

CAT-2

CAT-1

TS

Best Track max Speed

OS2 ANN max speed (within 200 km)

OS2 MLE max speed (within 200 km)

Days since 0000 UTC Aug 24 2010

Wind speed (knots)
Naive Intensity Estimator: QuikSCAT MLE Stats

- Technique: take maximum single vector within 200 km of best track center
- Rain contamination leads to extreme overestimation in 10-30 m/s range
- No trend above 30 m/s
- Clipping at 50 m/s due to hard limit in MLE implementation

Only show scenes where entire 200-km-radius is observed by scatterometer

Colors are number of N. Atl. hurricane scenes on a log scale
Naive Intensity Estimator: QuikSCAT ANN Stats

N Atlantic hurricanes < 40 N latitude where central 200-km-radius is observed by scatterometer

- Rain much reduced in 10-30 m/s range
- Linear trend with max best track speed
- Dark blue cases are single outlier scenes occurring due to noise in retrieval
Improved 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
Improved Intensity Estimator: OSAT-2 ANN Stats

- Performance similar to QuiKSCAT but biased low 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).
1. In North Atlantic area of tropical storm force winds continues to increase 3 days after maximum intensity.
2. Major storms intensify rapidly and decay more slowly.
3. Regions of intense winds are smaller in East Pacific than in North Atlantic.
Climatology (1999-2009): Rapid Intensification

1. For Category 2 storms the region of intense winds is smaller in RI storms
2. True for other categories as well (data not shown).

RW = Rapidly Weakening, a < -0.8 m/s/hr
W = Weakening, -0.8 m/s/hr < a < -0.125 m/s/hr
N = No change, -0.125 m/s/hr < a < 0.375 m/s/hr
I = Intensifying, 0.375 m/s/hr < a < 0.8 m/s/hr
RI = Rapidly Intensifying, > 0.8 m/s/hr
In addition to speed climatology, the co-located rain information from the QuikSCAT noise channel [Ahmad et al, 2005] can also be analyzed to find signatures in RI storms. Rapidly intensifying tropical storms have a distinct high SRAD rain rate signature near the center of the storm.
Summary

• QuikSCAT tropical cyclones speed fields have been
  – Optimized for accuracy
  – Produced for all ten years of the QuikSCAT mission including over 5,000 observations of tropical storms and above.
  – Validated vs. H*WINDS, Dropsondes, SFMR, and best track wind speeds.
  – Made available online to the community at large in a browsable data base.
    • Ancillary data such as backscatter imagery and co-located rain information are also included.

• QuikSCAT data is being investigated to determine
  – How storm size and shape evolves as a function of time.
  – Correlation of storm features with rapid intensification and de-intensification events
  – Importance of storm asymmetry in modeling ocean heat transport (collaboration with Isaac Ginis, University of Rhode Island)
  – Synergy with C-band SAR hurricane data

• OceanSAT-2 algorithm has been trained using 2010 OceanSAT/H*WIND co-locations
  – Preliminary validations results are similar to QuikSCAT
  – Two years of global OceanSAT-2 tropical cyclones are currently available online.

• A paper describing the production and validation of the QuikSCAT data set has been submitted.
Acknowledgements

• The work reported here was performed at the Jet Propulsion Laboratory, California Institute of Technology, and at the National Hurricane Center under contract with the National Aeronautics and Space Administration.
  – This work described in this presentation is funded by NASA’s Ocean Vector Winds program.
  – The website portal used to distribute the data set is part of a program funded by NASA’s Hurricane Science Research program.
References


Recent Publications by Team Members


Backup Slides
Trend in Overall Storm Area

The chart shows the trend in the overall storm area from 2000 to 2009. The x-axis represents the year, and the y-axis represents the total area (km²) of storms with winds of greater than 50 knots. The bars are color-coded to indicate the basin: West Pacific (blue) and Other Basins (red). The data for the West Pacific shows a significant increase in 2004, while the data for Other Basins shows a more consistent trend with slight fluctuations.
Examples Maximum Speed Tracks – Ivan 2004

![Graph showing wind speed over days since 0000 UTC 1 Sept 2004 for Ivan 2004]

- Maximum Speed
- Tracks

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<th>Example</th>
<th>Speed</th>
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<td>Ivan</td>
<td>2004</td>
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Examples Maximum Speed Tracks – Isabel 2003

![Graph showing wind speed over time for Isabel 2003 with categories CAT-5 to TS and annotations for tracking speeds.](image)

Best Track max Speed
- QSCAT ANN max speed (within 200 km)
- QSCAT V2 max speed (within 200 km)
SRAD Rain Rate Histogram

MLE speed 24-26 m/s
Cross Distance 400-450 km
Joint Histogram Low MLE Wind
Joint Histogram High MLE Wind

The image depicts a joint histogram with NRCS Copol Ratio (HH/VV) on the y-axis and SRAD rain rate on the x-axis. The color scale ranges from 0 to 20, indicating varying levels of probability density.

NOAA and NASA logos are present, and the image is associated with a research note dated 5/8/13 titled "IOVWST, 2013, Multi-Scatterometer Hurricane Winds."