Multiple Scatterometer Hurricane Winds

QuikSCAT data set complete, OceanSAT-2 begun

Bryan Stiles[1], Michael Brennan[2], Rick Danielson[3],
Lee Poulsen[1], Alex Fore[1], Svetla Hristova-Veleva[1]
1 Jet Propulsion Laboratory, California Institute of Technology
2 National Hurricane Center
3 University Corporation for Atmospheric Research

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Outline

- Overview
- Details of Technique
- QuikSCAT Hurricane Winds
  - 10 year, global data set
  - Validated vs. H*WINDS, Best Track, and SFMR
- Preliminary OceanSAT-2 Hurricane Winds
- Description of Future Work
- Summary

Overview

- Goal: To optimize, produce, validate, and utilize ocean surface wind speed fields around all tropical cyclones (TCs) observed by QuikSCAT, and OceanSAT-2, 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]
- Solution: Train a neural network to determine accurate TC winds for scatterometer data in the presence of rain.

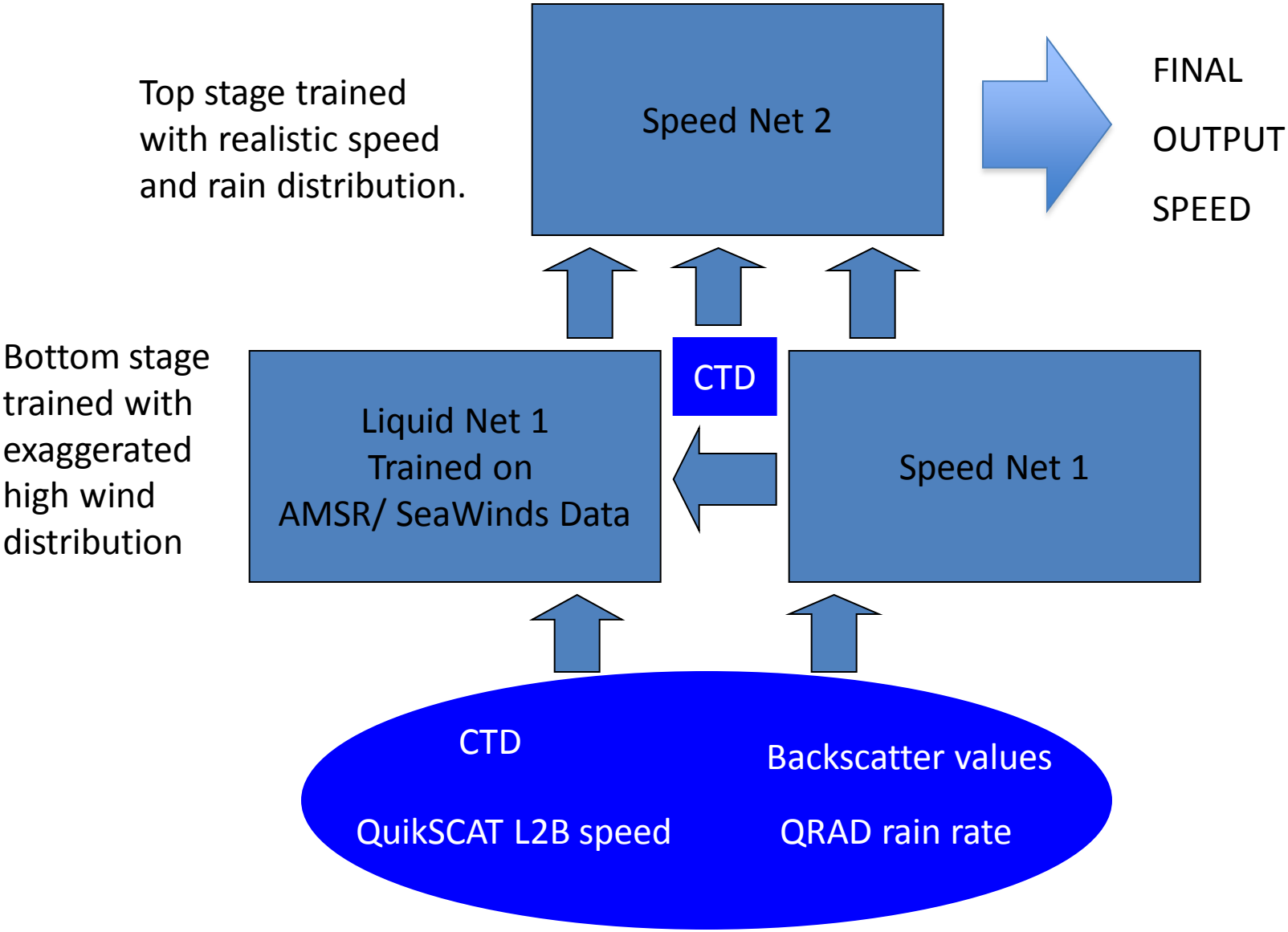
Overview: Neural Network Rules of Thumb

- 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 (e.g. Stiles and Dunbar, 2010), 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
- Ground truth speeds are from H*WINDS 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 direction retrievals from JPL QuikSCAT L2B products are maintained.

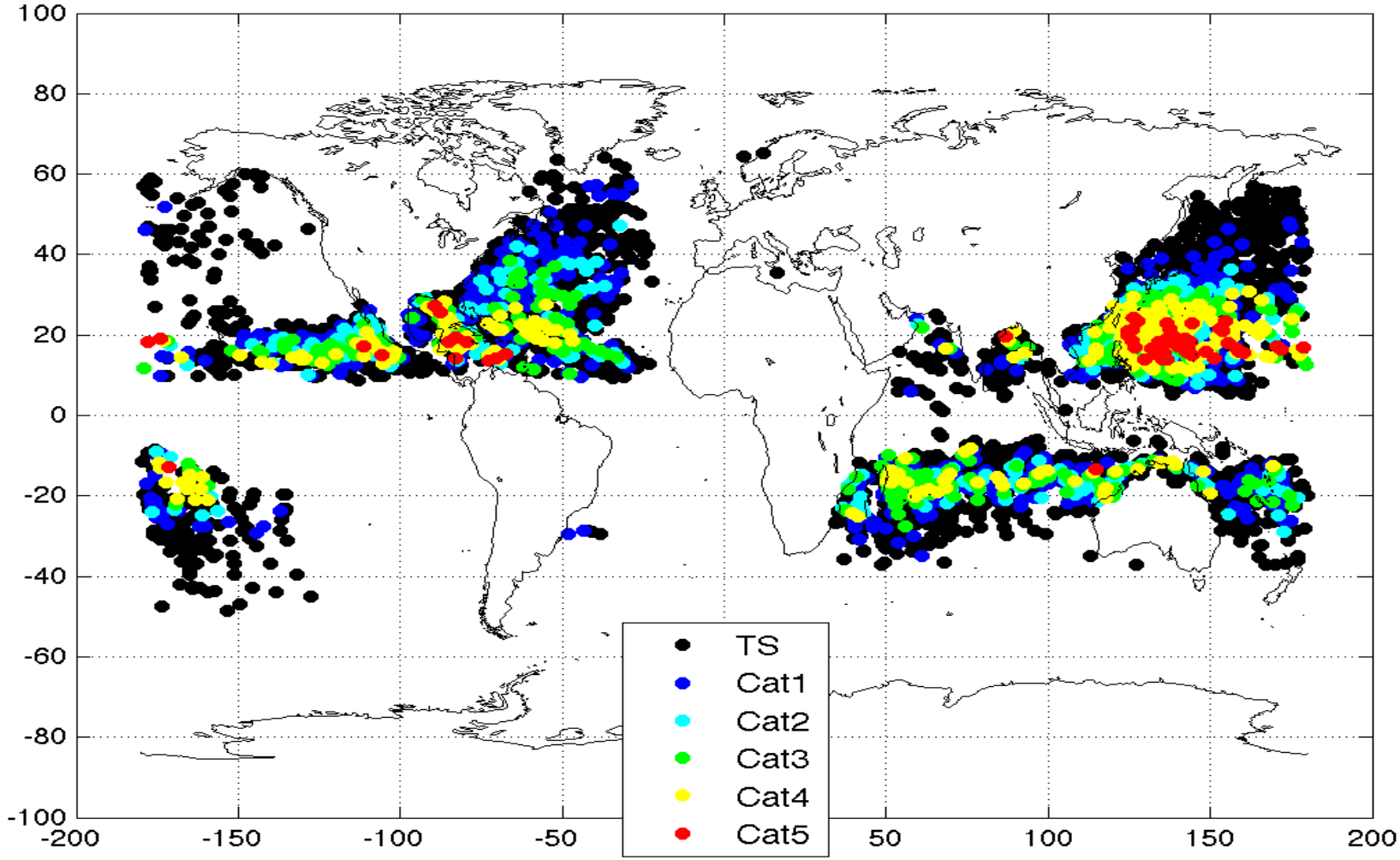
Planned Neural Network Structure



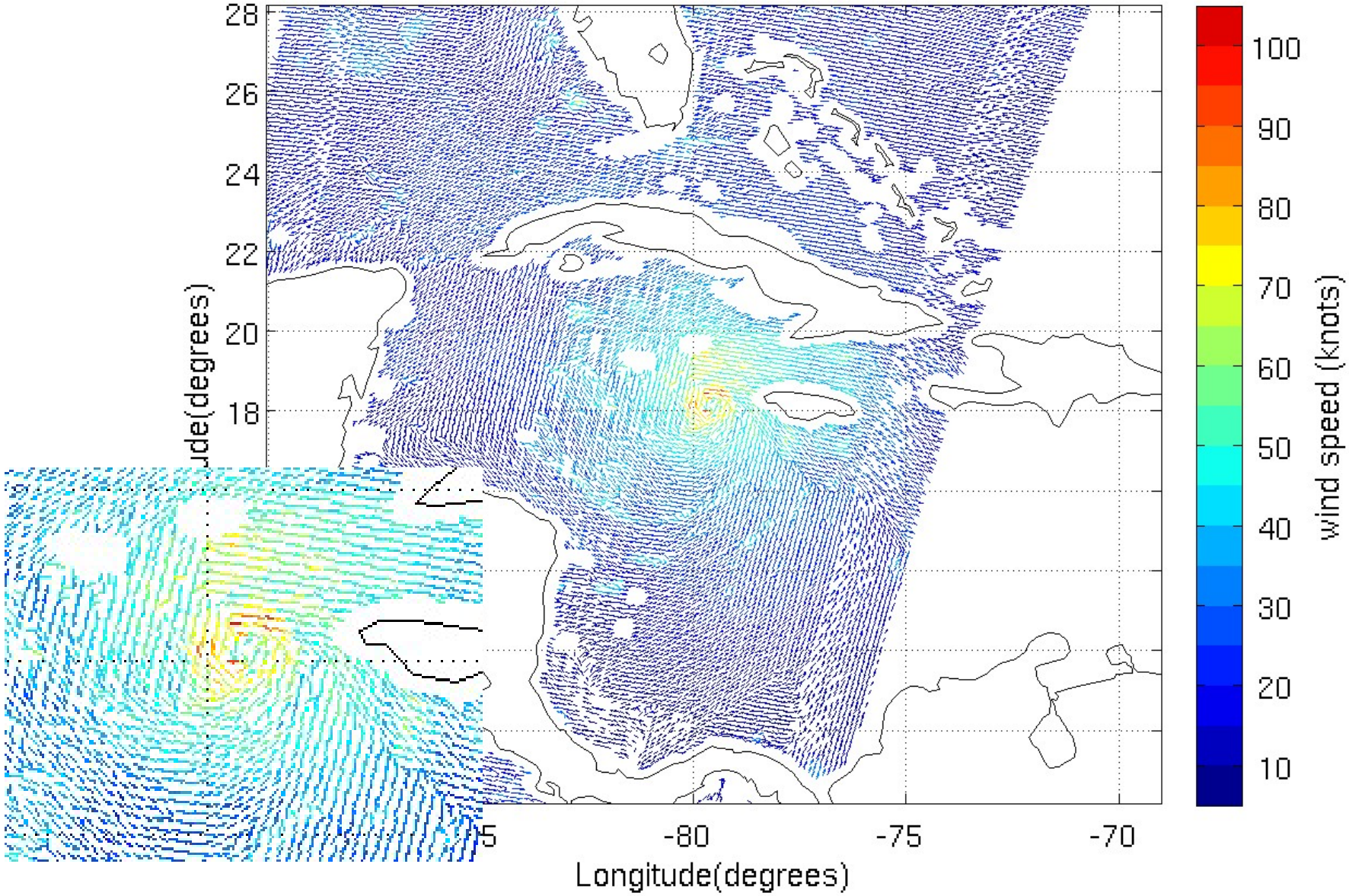
QuikSCAT Data Set

- 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:
  - 3295 TS, 788 CAT-1, 367 CAT-2, 330 CAT-3, 289 CAT-4, 55 CAT-5
- 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, all 8 backscatter sets, and SSM/I co-locations
  - A comprehensive set of best track data from a variety of sources.

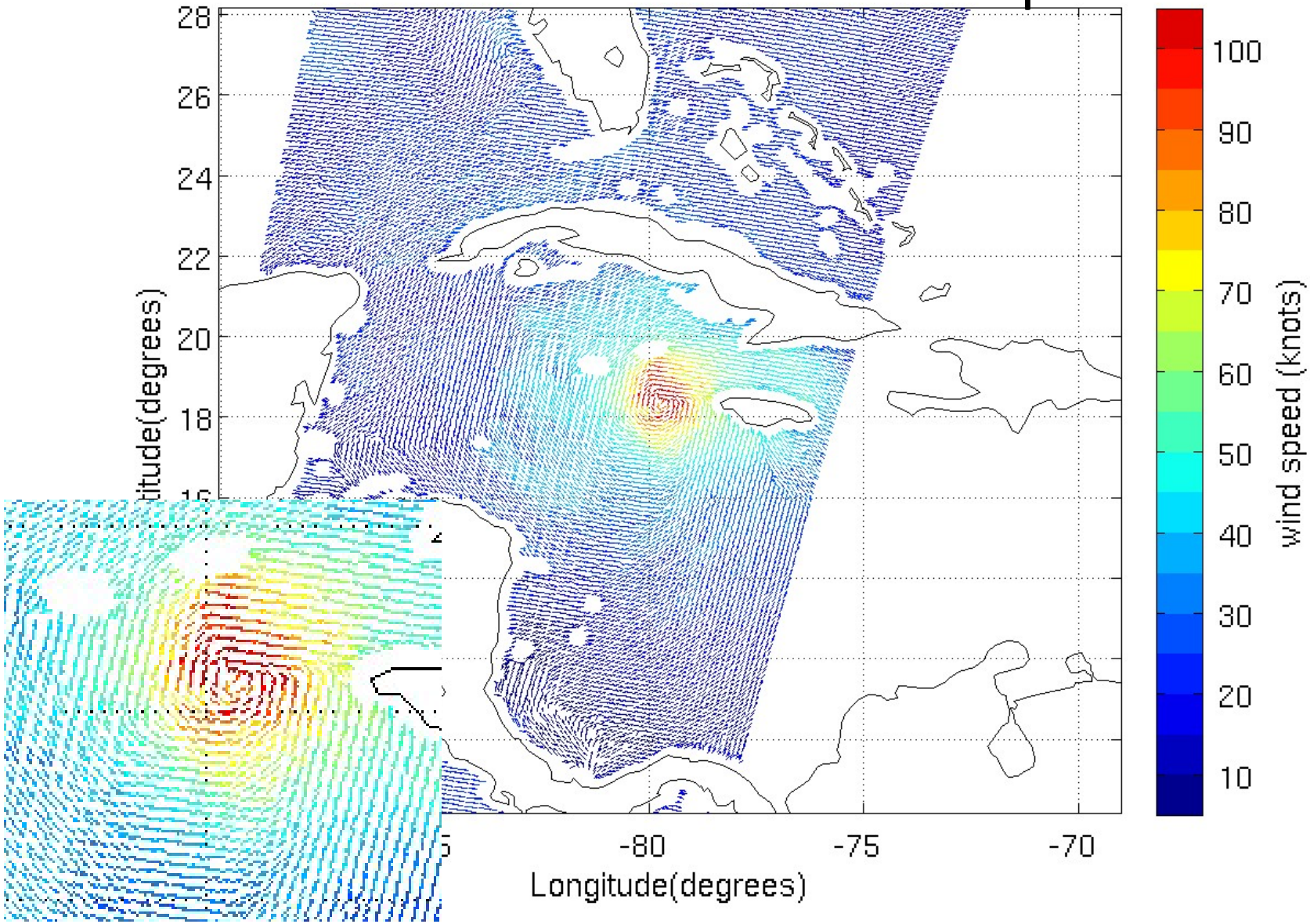
QuikSCAT 1999-2009 Data Set



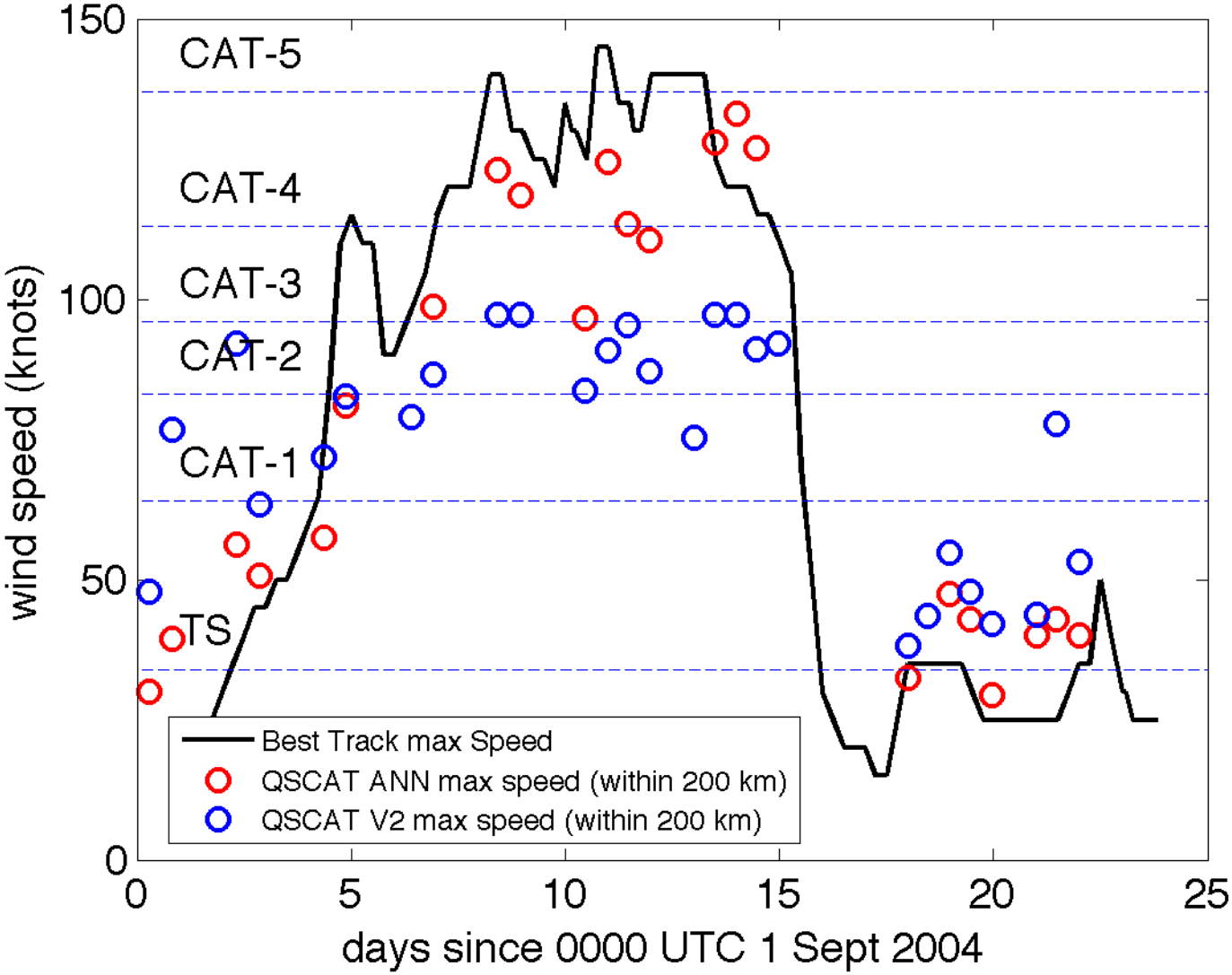
Nominal QuikSCAT (version 2) Winds: Hurricane Ivan 23:37 UTC 11 Sept. 2004



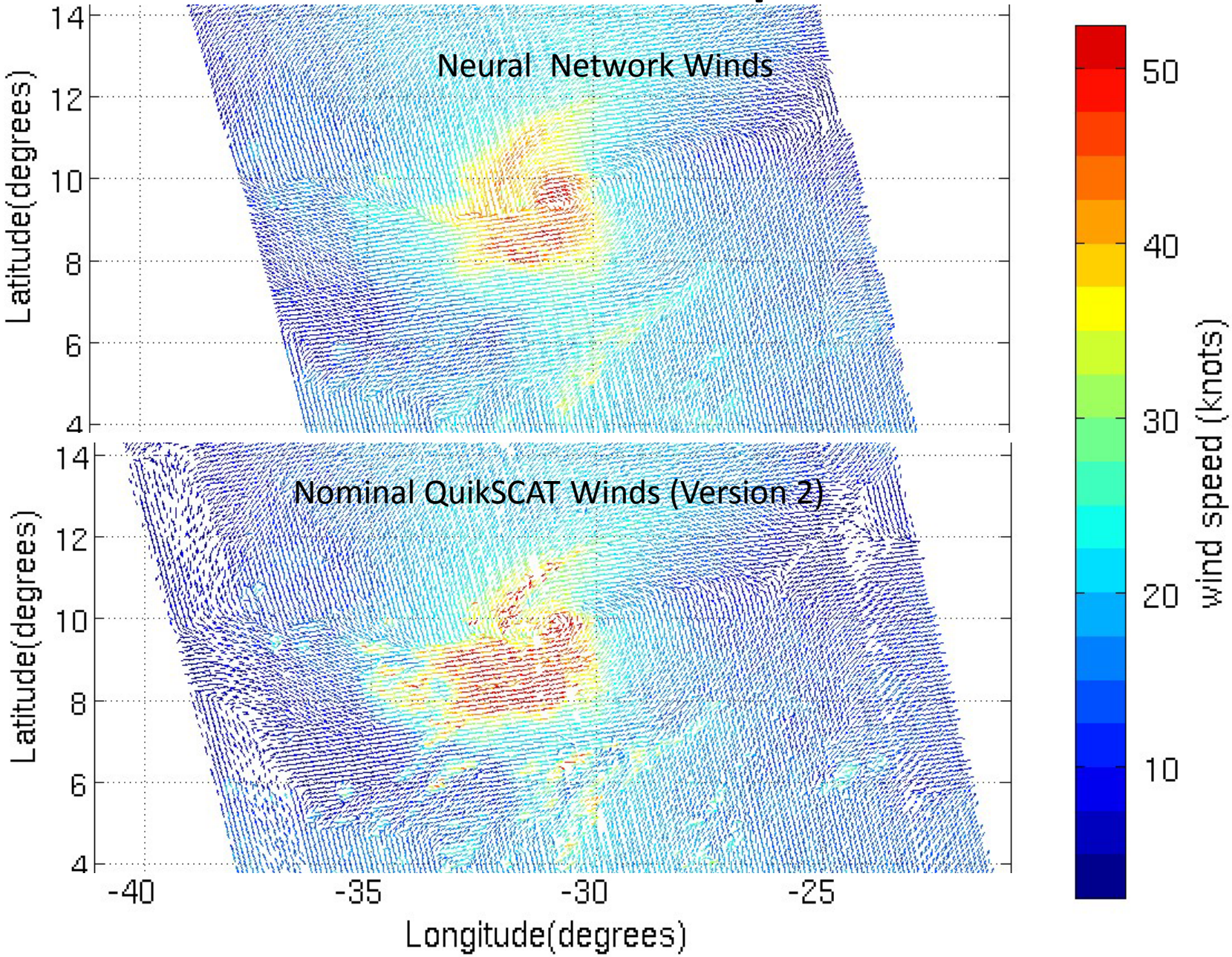
Neural Net Winds:
Hurricane Ivan 23:37 UTC 11 Sept. 2004



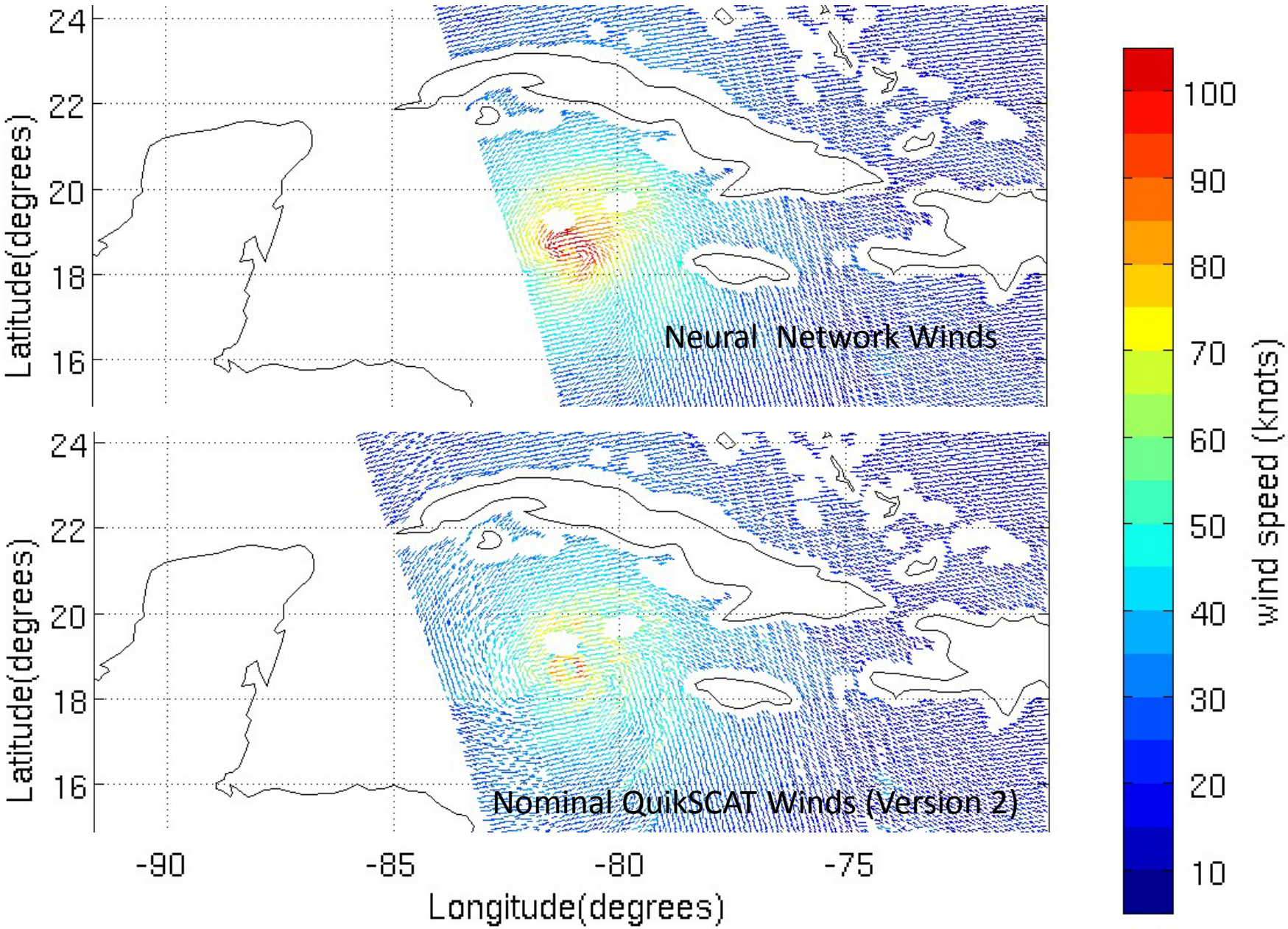
Examples Maximum Speed Tracks – Ivan 2004



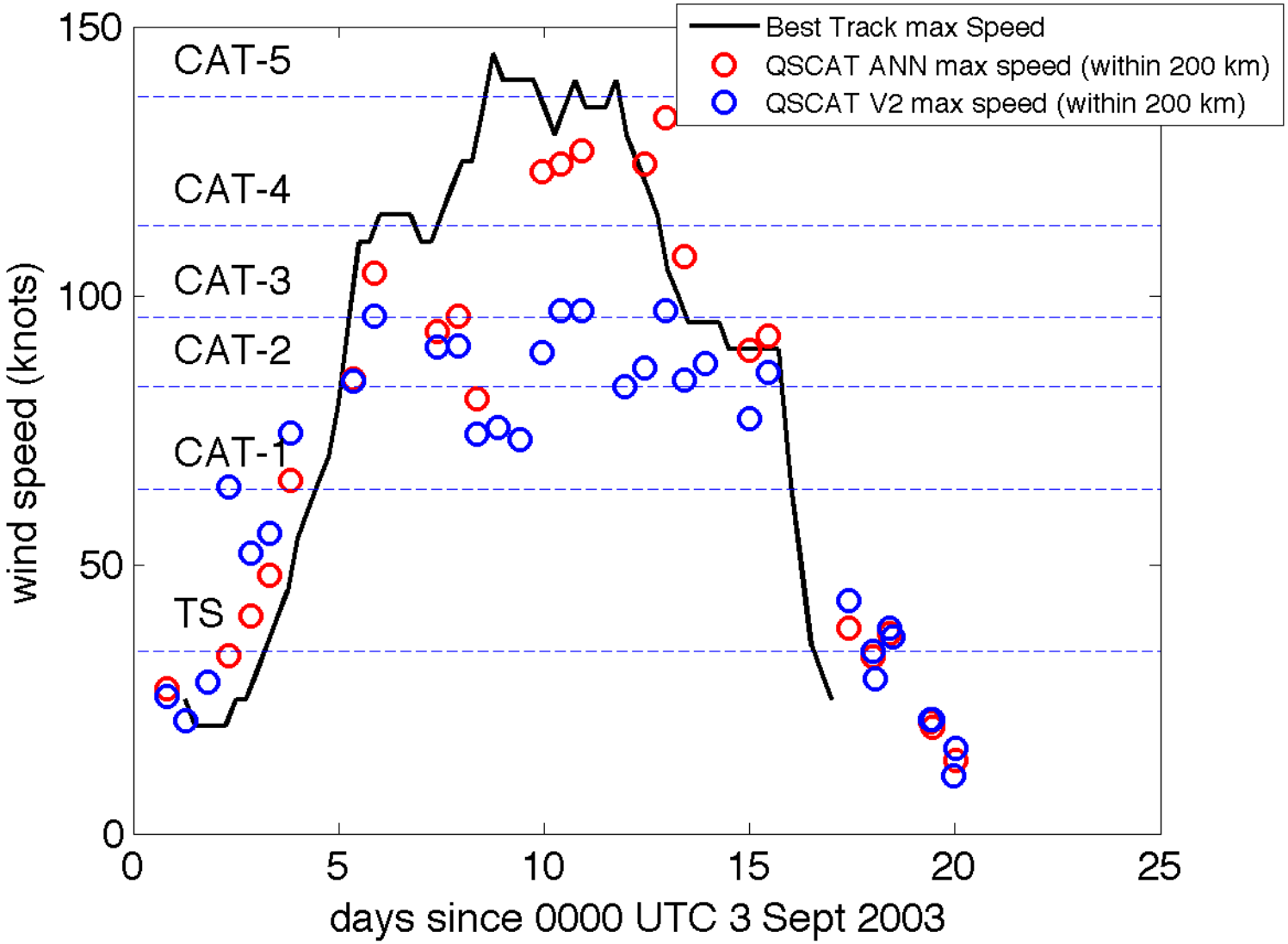
Hurricane Ivan Sept 3, 2004



Hurricane Ivan, Sept 13, 2004



Examples Maximum Speed Tracks – Isabel 2003



Validation: QuikSCAT–NHC Best Track

Max. Wind (kt)

	N	AVG	STD	FSP
HWind	39	-3.1	9.9	18%
N Net	**132**	**-1.2**	**18.9**	**35%**
JPL v3	132	-10.1	23.5	23%
JPL v2	132	1.5	23.3	24%

34-kt Radii (nm)

	N	AVG	STD	FSP
HWind	127	11.9	36.5	11%
N Net	329	22.7	40.5	23%
JPL v3	**329**	**8.3**	**37.4**	**30%**
JPL v2	329	31.9	47.2	18%

50-kt Radii (nm)

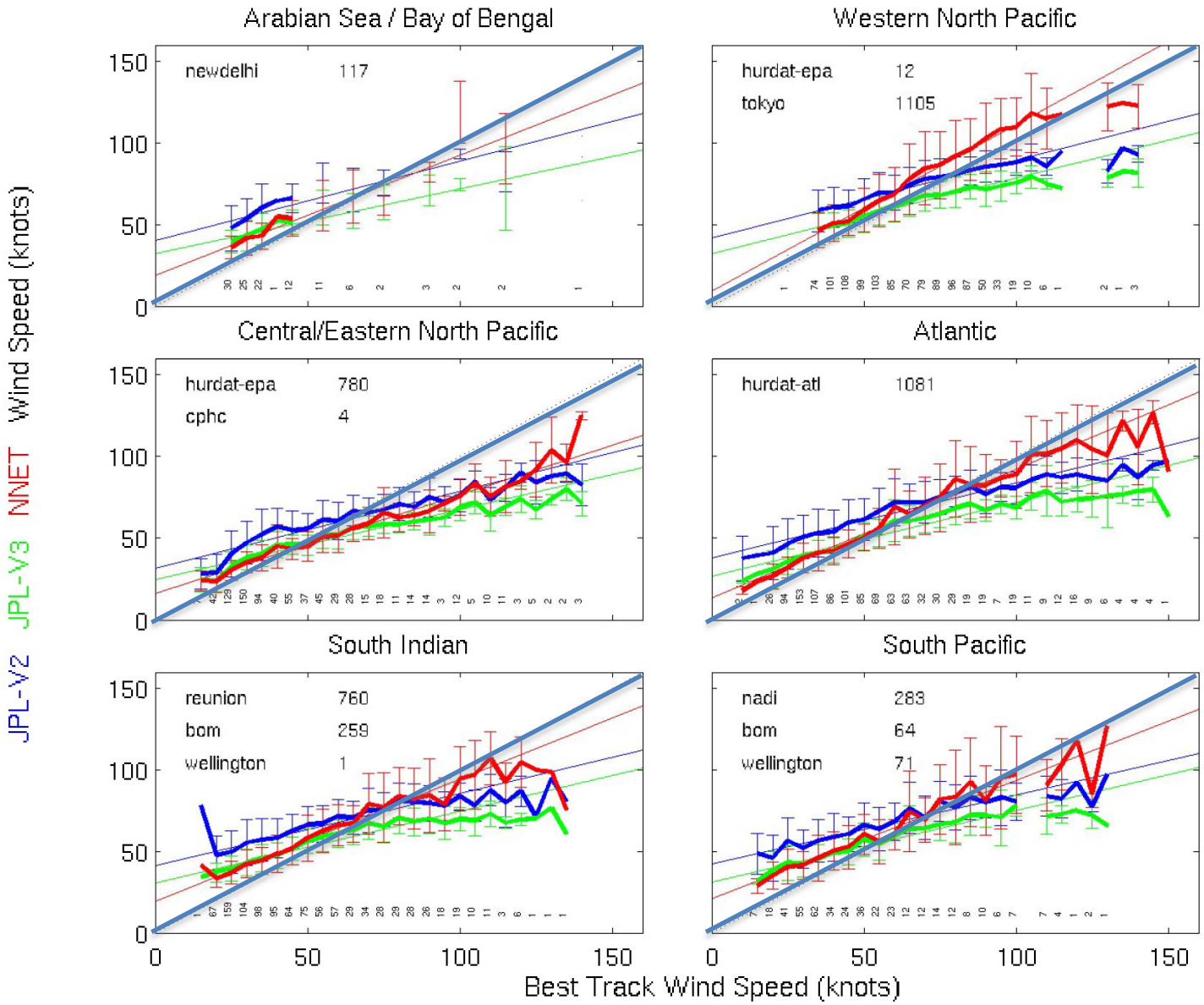
	N	AVG	STD	FSP
HWind	127	6.6	20.5	13%
N Net	**339**	**4.7**	**26.1**	**21%**
JPL v3	339	-4.9	27.5	20%
JPL v2	339	26.2	45.9	11%

64-kt Radii (nm)

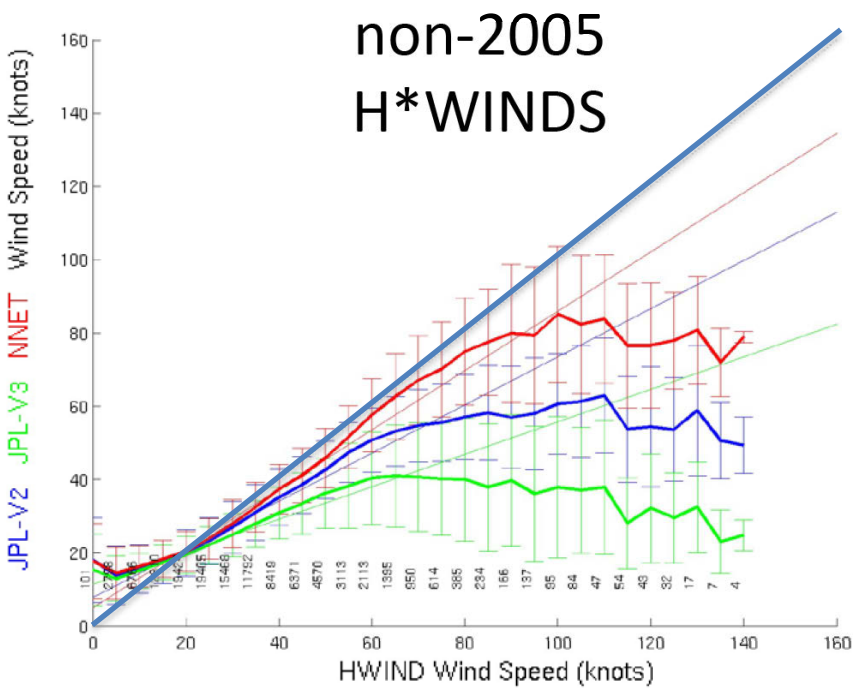
	N	AVG	STD	FSP
HWind	127	4.7	13.7	13%
N Net	**338**	**1.8**	**18.7**	**15%**
JPL v3	338	-8.6	19.3	12%
JPL v2	338	11.6	36.1	10%

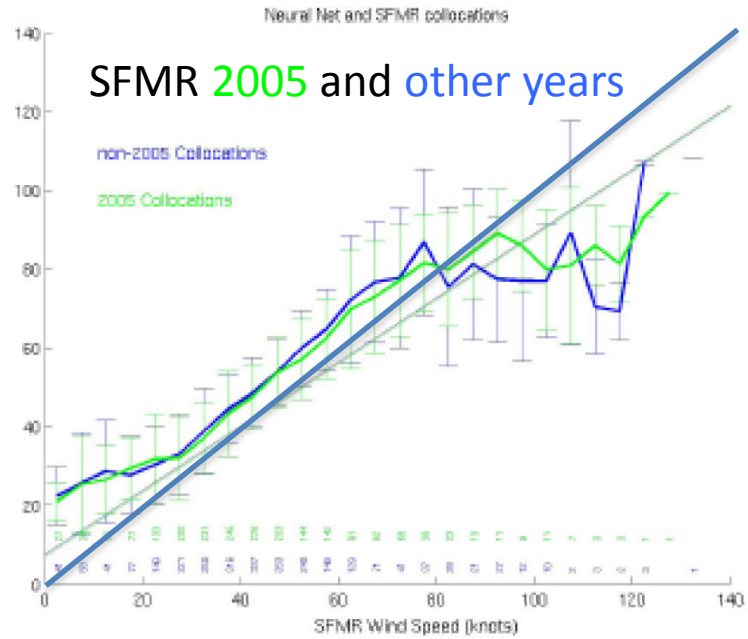
Green denotes superior QuikSCAT-only retrieval

Max Wind Speed Statistics



Validation vs. H*WINDS and SFMR speeds



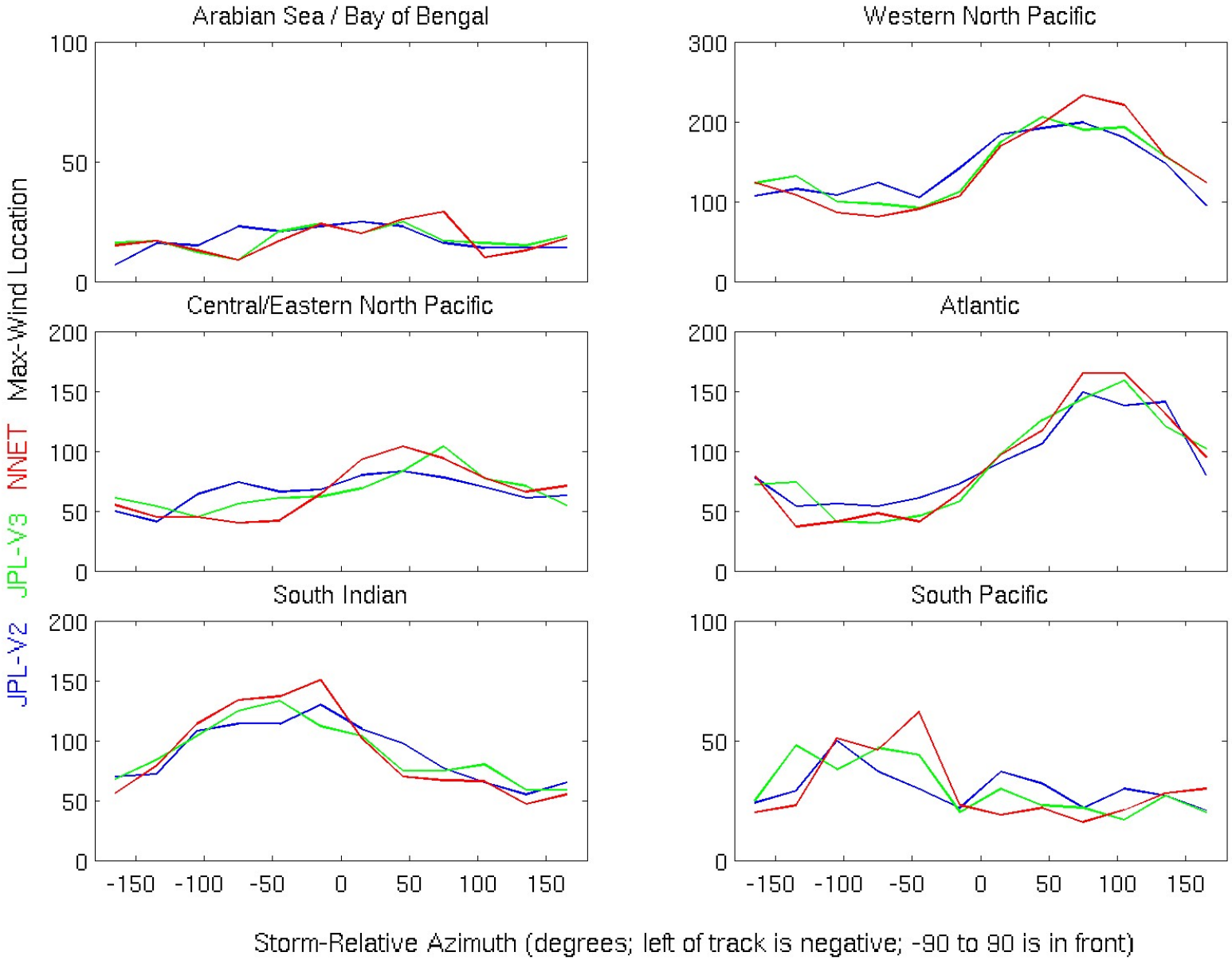


- NNET winds slight negative bias vs. H*WINDS up to 80 knots.
- JPL-V2 winds start to saturate at 40 knots.

- NNET winds trend with SFMR up to 80 knots.
- Have a positive bias vs. SFMR in training year 2005 and other years.

Max Winds Location Statistics

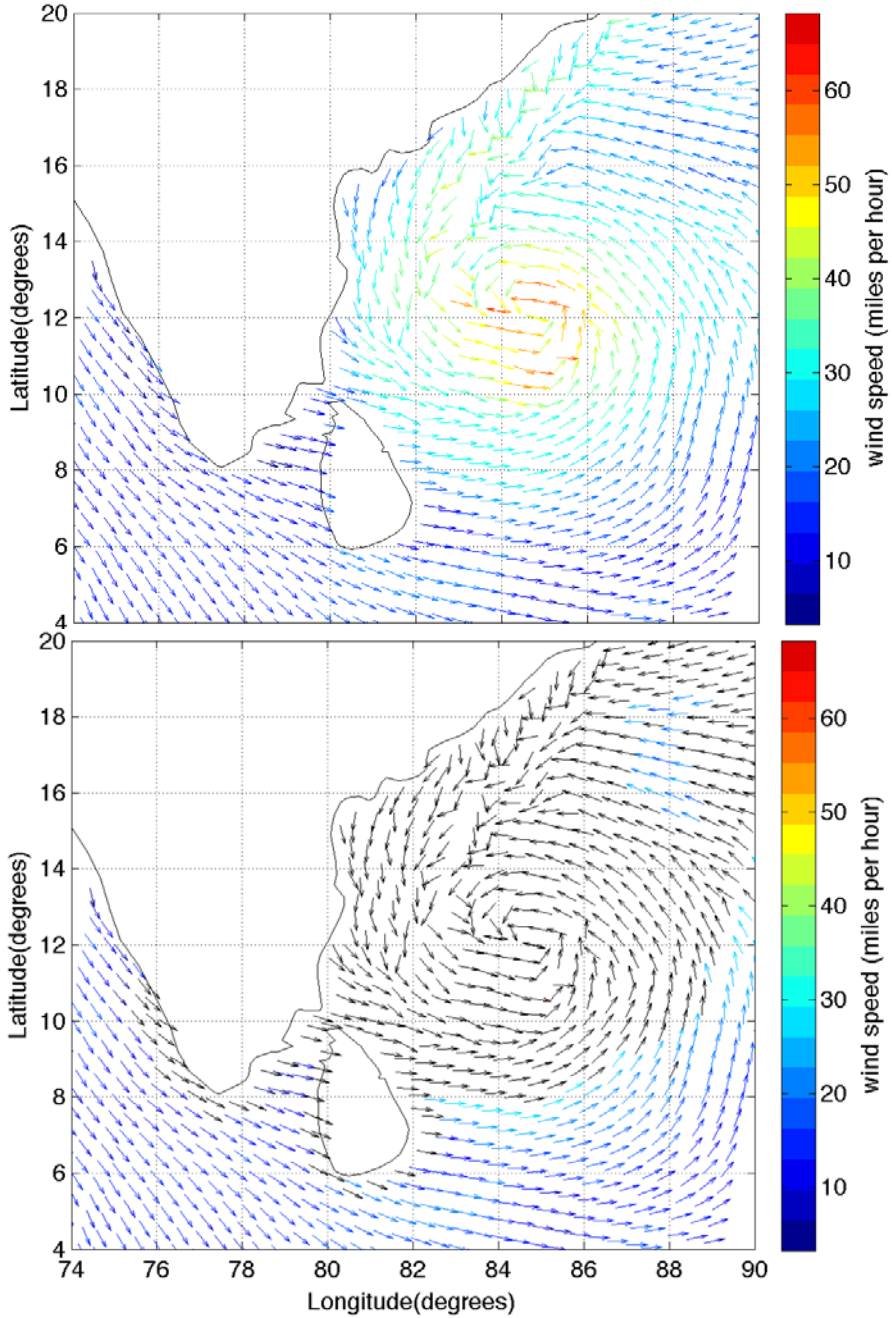
(compare to [Ulhorn and Black, 2007])

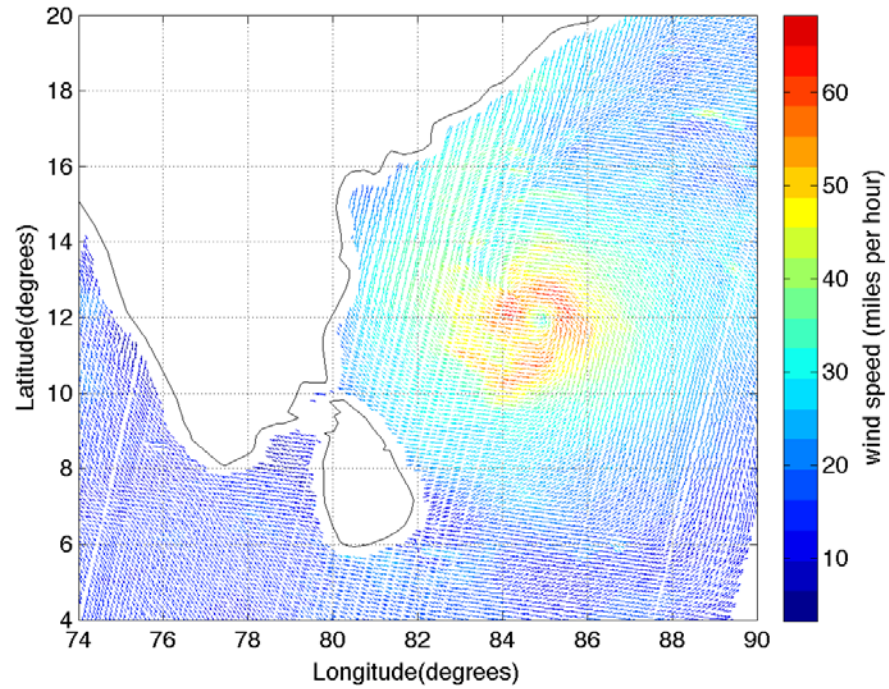


OceanSAT-2 Tropical Cyclone Winds

- OceanSAT-2 is a 13.4 GHz ocean wind scatterometer operated by the Indian Space Research Organization (ISRO).
- For the past two years ISRO has been collaborating with NASA/JPL and NOAA to refine the calibration of the OceanSAT-2 backscatter data.
- The goal of the collaboration is to extend the Ku-band scatterometer wind data record initiated by QuikSCAT.
- A crucial element of this effort has been the repointing of the QuikSCAT instrument to match the OceanSAT-2 viewing geometry (higher incidence angle).
- Although QuikSCAT ceased nominal operations in November 2009, its precisely calibrated backscatter measurements remain useful for cross-platform calibration.
- To date the ISRO/NASA/NOAA collaboration has resulted in:
  - More robust wind retrieval in low wind areas.
  - Absolute backscatter calibration tuned to match QuikSCAT data within 0.1 dB.
  - Improved wind accuracy as compared to numerical wind products and buoys.
  - Ongoing monitoring of calibration drift by comparison between QuikSCAT and OceanSAT-2 backscatter values.
- The fruitfulness of the collaboration is further illustrated by the tropical cyclone winds on the following slides.
  - The OceanSAT-2 operational wind product is binned at 50 km with a conservative land mask employed to insure accurate winds.
  - JPL has retrieved winds at higher (12.5 km) resolutions and closer to the coast.
  - QuikSCAT neural network processing has been applied to OceanSAT-2 data.

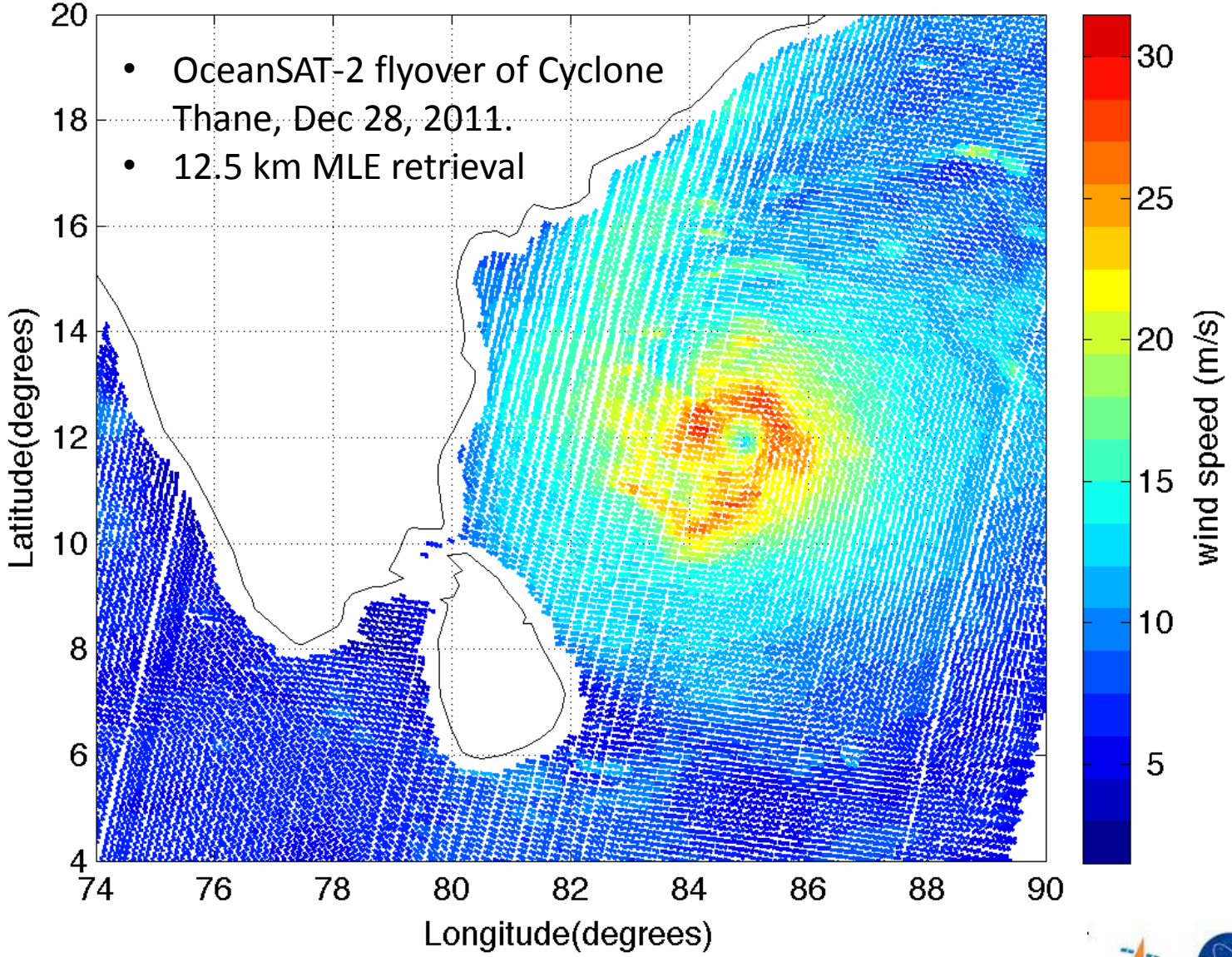
OceanSAT-2 flyover of Thane, 28 Dec 2011.



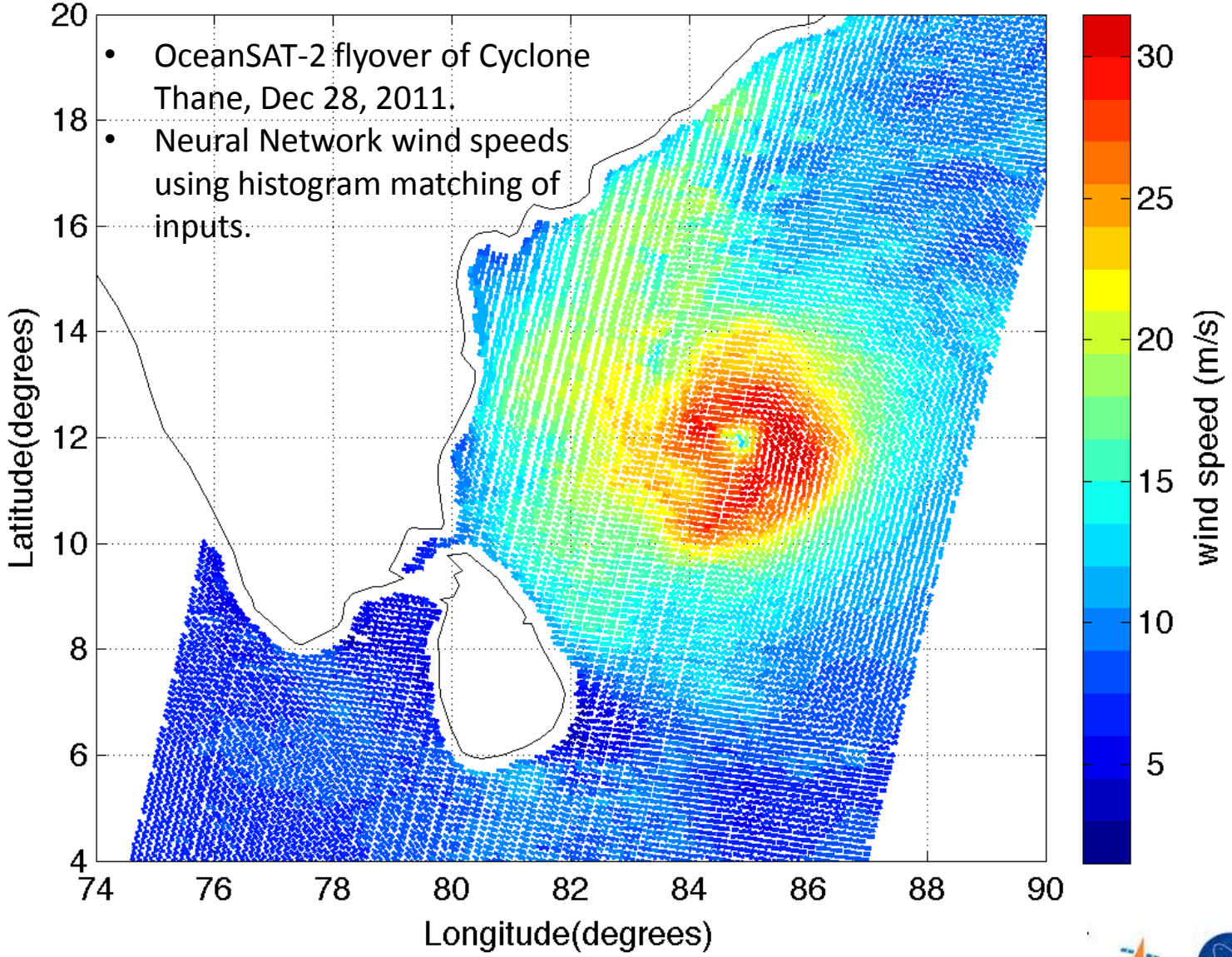


- Upper Right: Winds retrieved by NASA JPL at 12.5 km resolution.
- Upper Left: ISRO NRT Winds (50 km)
- Lower Left: ISRO NRT Winds (rain flagged vectors set to black)

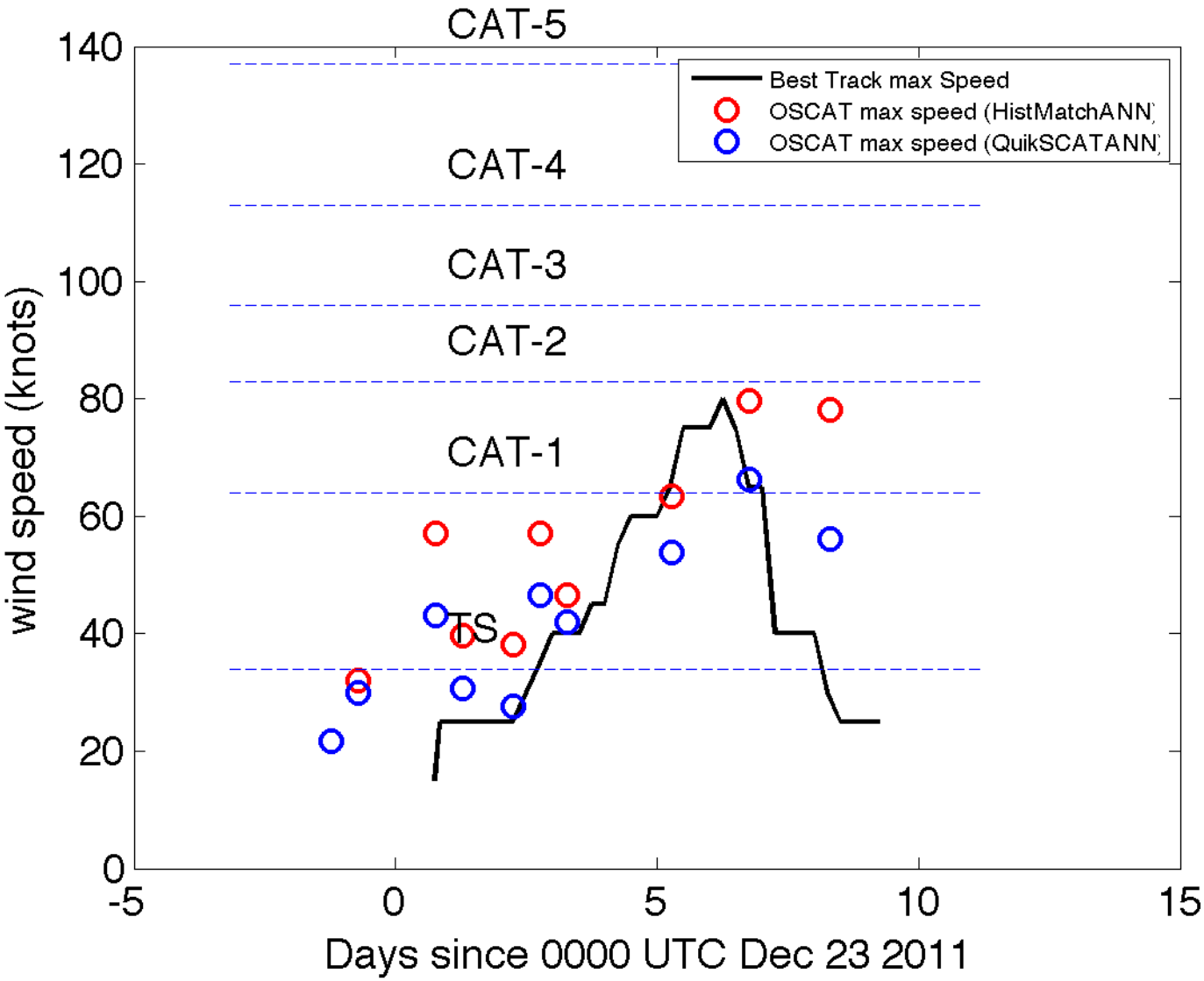
OceanSAT-2 Tropical Cyclone Winds



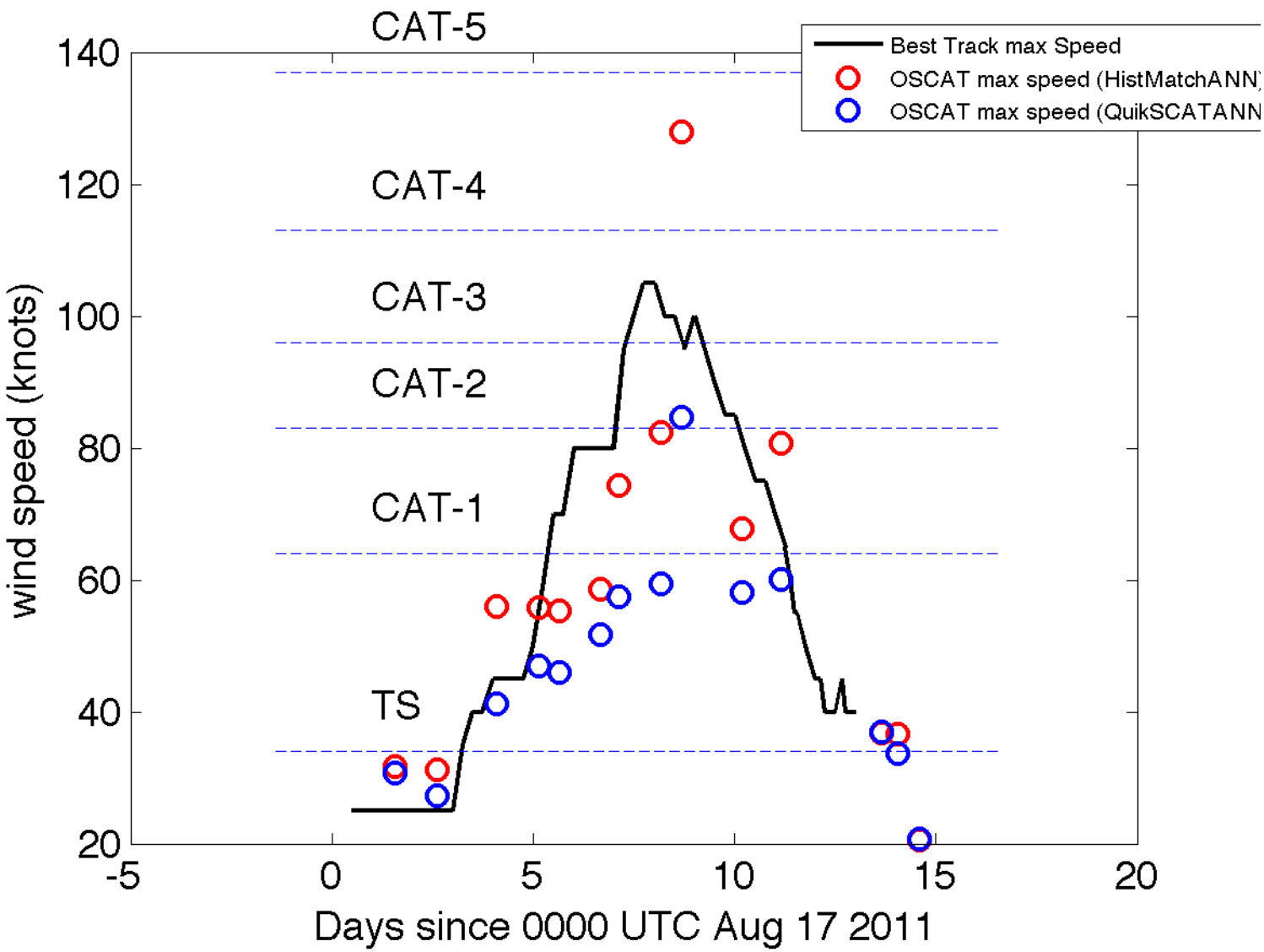
OceanSAT-2 Tropical Cyclone Winds



Example Max Speed Track Thane 2011-2012

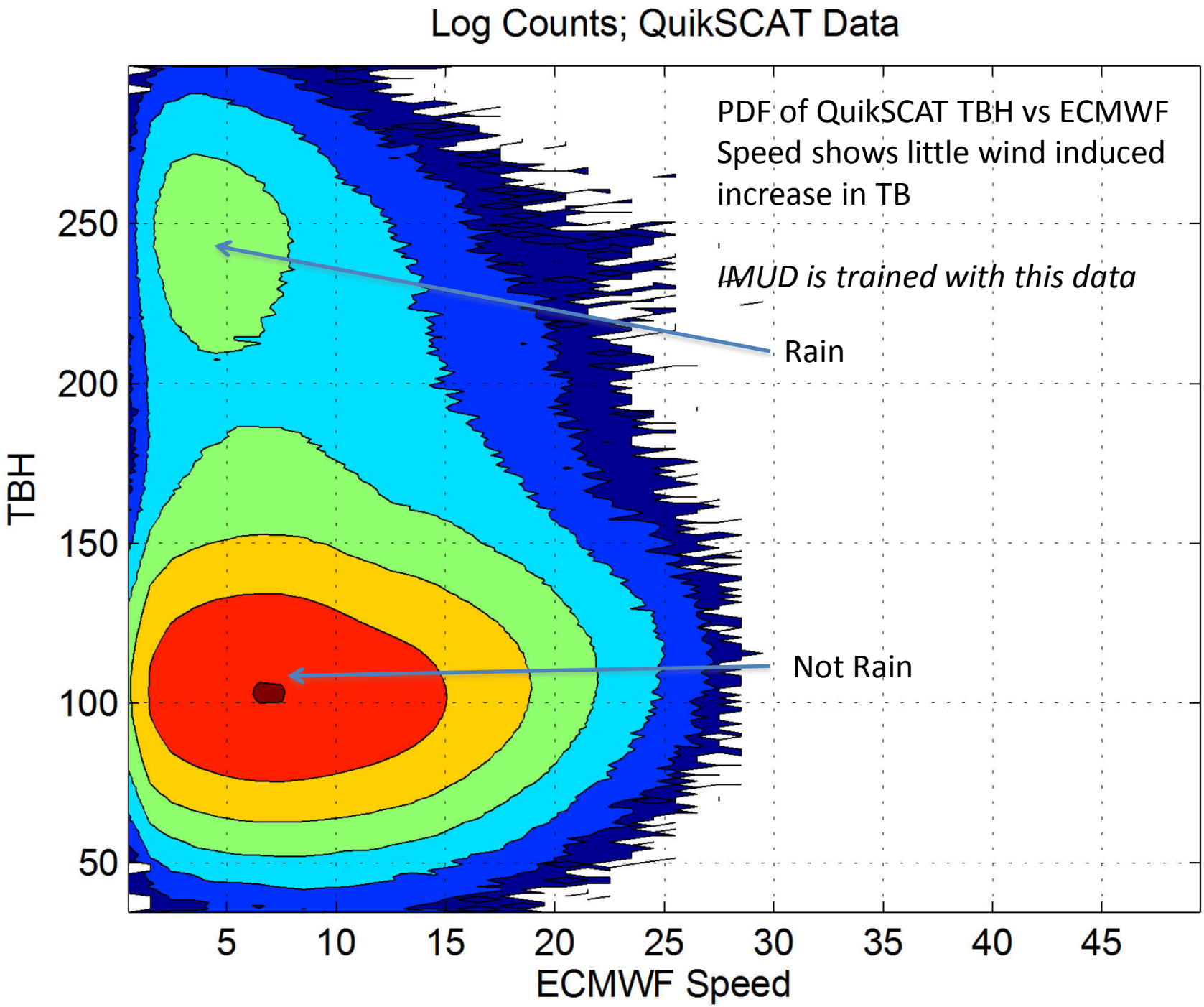


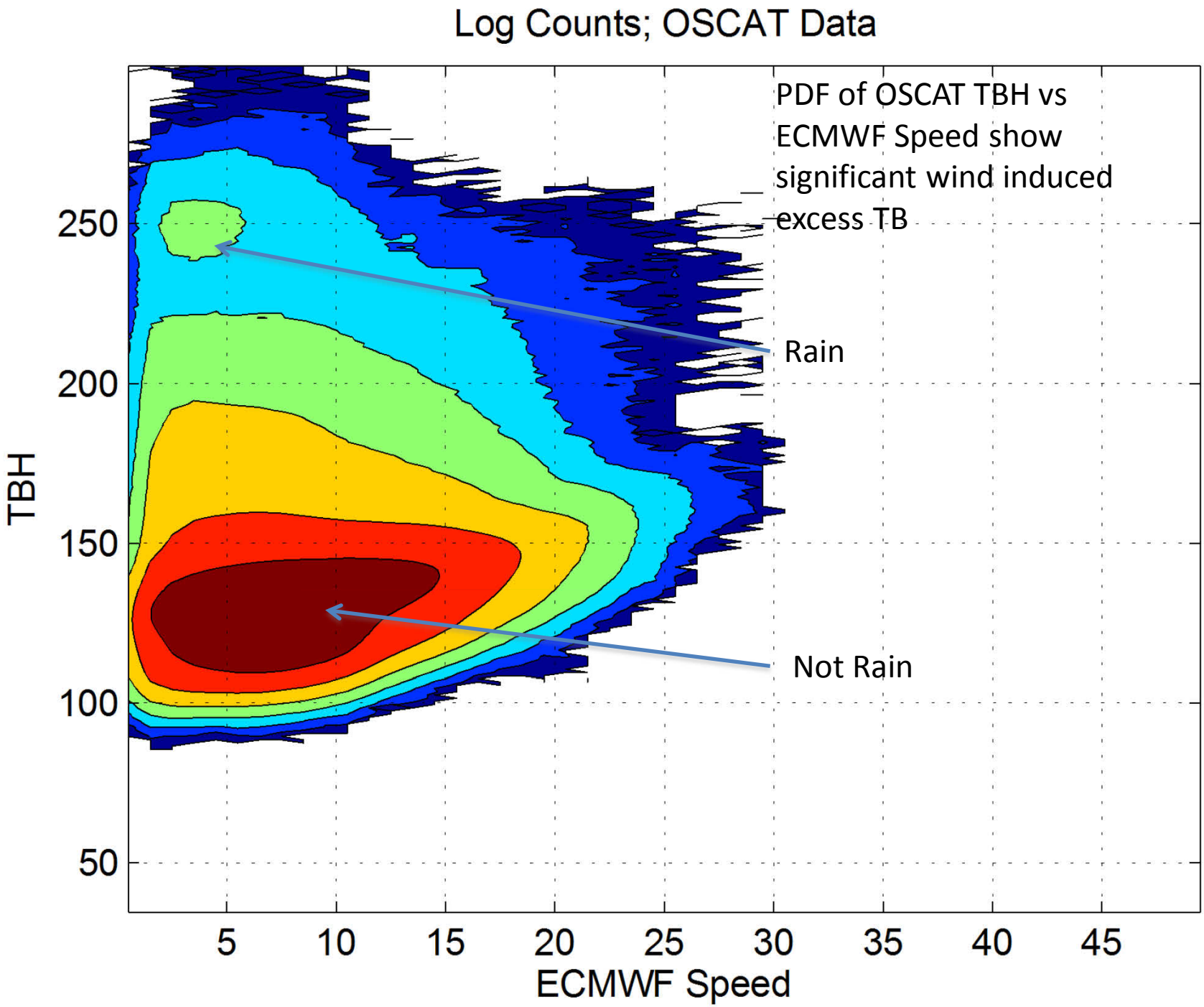
Example Max Speed Track Irene 2011



OceanSAT-2 Future Work

- The distribution of OceanSAT-2 backscatter and brightness temperature values differ significantly from QuikSCAT impacting the performance of QuikSCAT trained neural nets.
- Histogram matching has been applied to make inputs look more like QuikSCAT with mixed results.
- Brightness temperature values computed by ISRO include wind effects; QuikSCAT brightness temperature do not and are thus more useful as rain indicators.
- Future plans:
  - Run QuikSCAT processing on a year of OceanSAT-2 storms.
  - Adapt the OceanSAT-2 brightness temperatures to correct for wind speed variation.
  - Retrain neural networks using 2011 Atlantic storm H*WINDS data.


Log Counts; QuikSCAT Data
PDF of QuikSCAT TBH vs ECMWF Speed shows little wind induced increase in TB
IMUD is trained with this data
Rain
Not Rain
TBH
250
200
150
100
50
5
10
15
20
25
30
35
40
45
ECMWF Speed


Log Counts; OSCAT Data
PDF of OSCAT TBH vs ECMWF Speed show significant wind induced excess TB
Rain
Not Rain
TBH
250
200
150
100
50
5
10
15
20
25
30
35
40
45
ECMWF Speed

Summary

- Wind 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, SFMR, and best track wind speeds.
  - Made available online to the community at large in a browsable data base.
    - Ancilary data such as backscatter imagery and co-located rain information are also included.
- We now begin the scientific exploitation of the QuikSCAT TC dataset.
  - Initial investigations will include:
    - Distribution of max winds as a function of storm movement and geographic location
    - Correlation of storm features with rapid intensification and de-intensification events
    - Storm size estimation and trend analysis
- We also plan to produce similar datasets for OceanSAT-2 and ASCAT
  - Sample OceanSAT-2 fields have been produced and we are currently validating and optimizing them.
  - ASCAT fields are planned for the following year.
- A paper describing the production and validation of the QuikSCAT data set is in prep.

Acknowledgements

- 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

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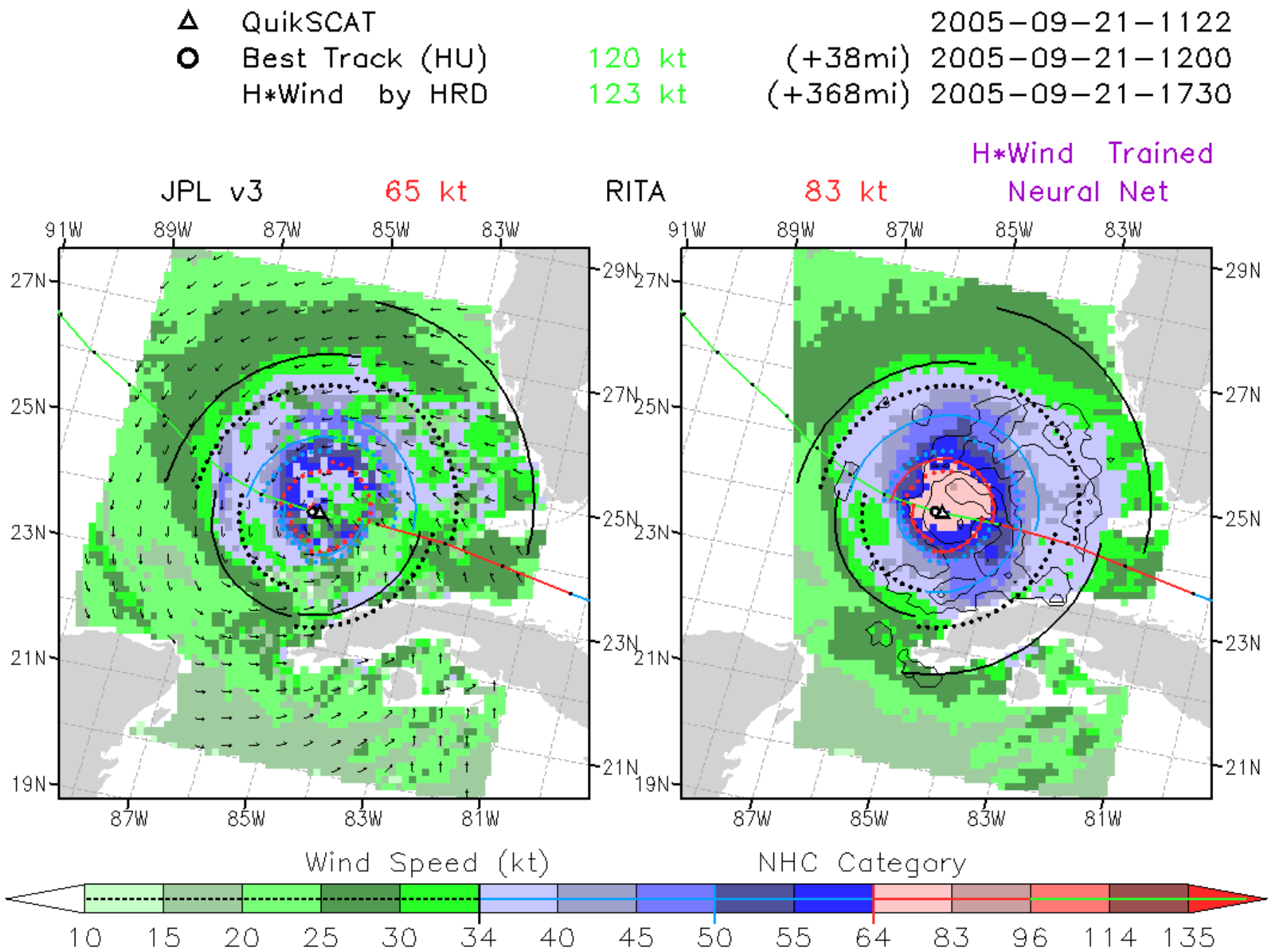
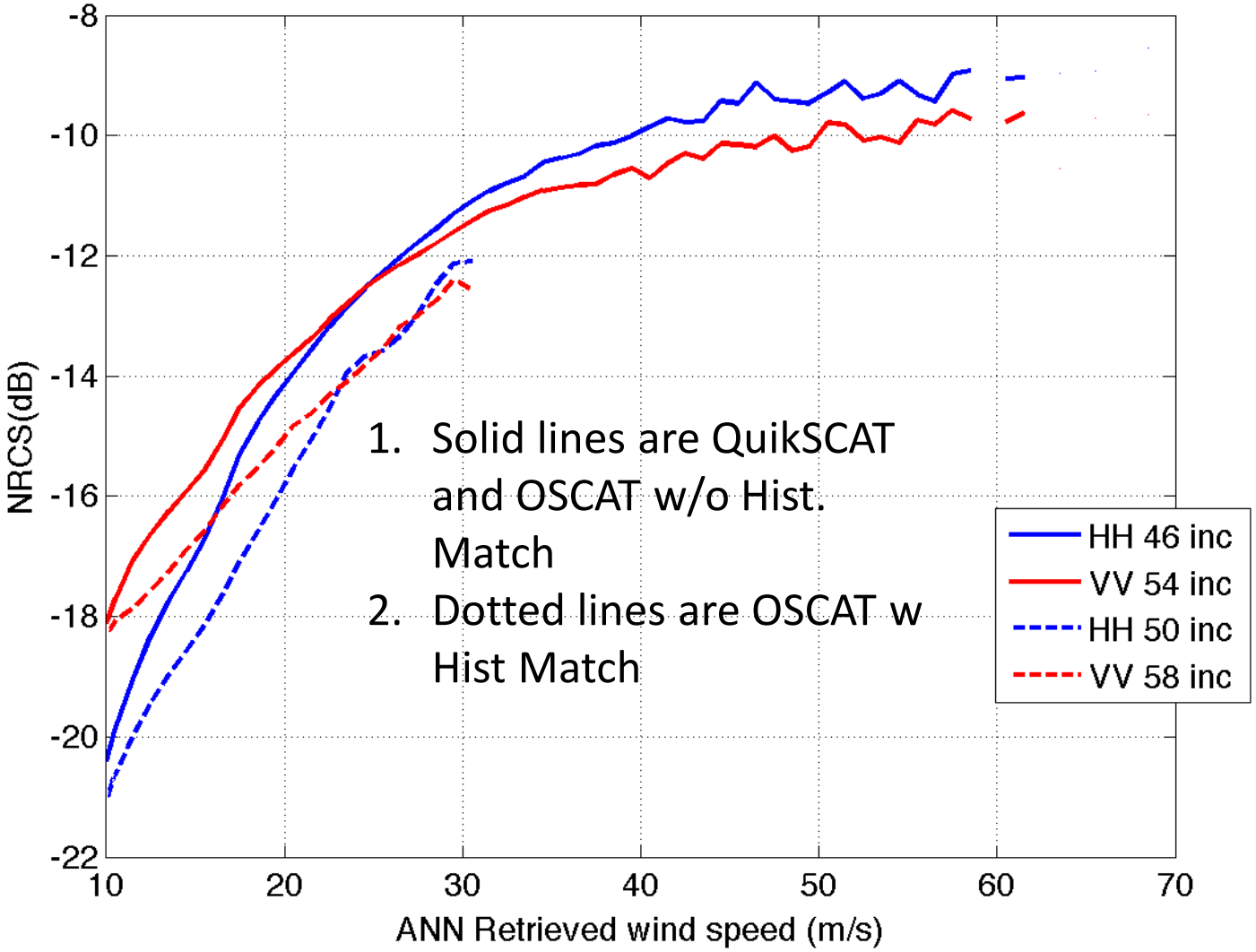
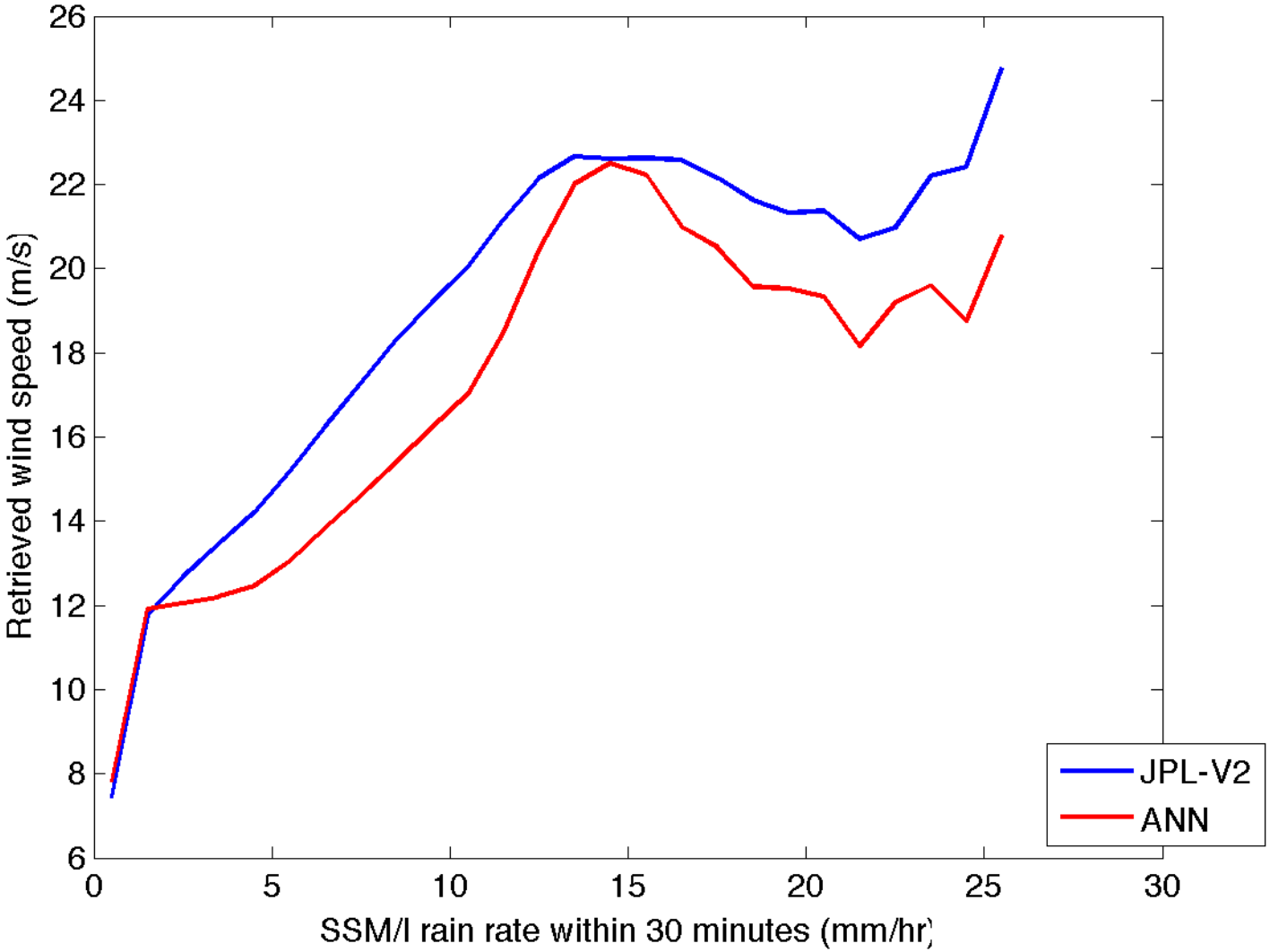
Backups


QuikSCAT 2005-09-21-1122
Best Track (HU) 120 kt (+38mi) 2005-09-21-1200
H*Wind by HRD 123 kt (+368mi) 2005-09-21-1730
JPL v3 65 kt
RITA 83 kt
H*Wind Trained Neural Net
91W 89W 87W 85W 83W
29N 27N 25N 23N 21N 19N
87W 85W 83W 81W
Wind Speed (kt)
NHC Category
10 15 20 25 30 34 40 45 50 55 64 83 96 114 135

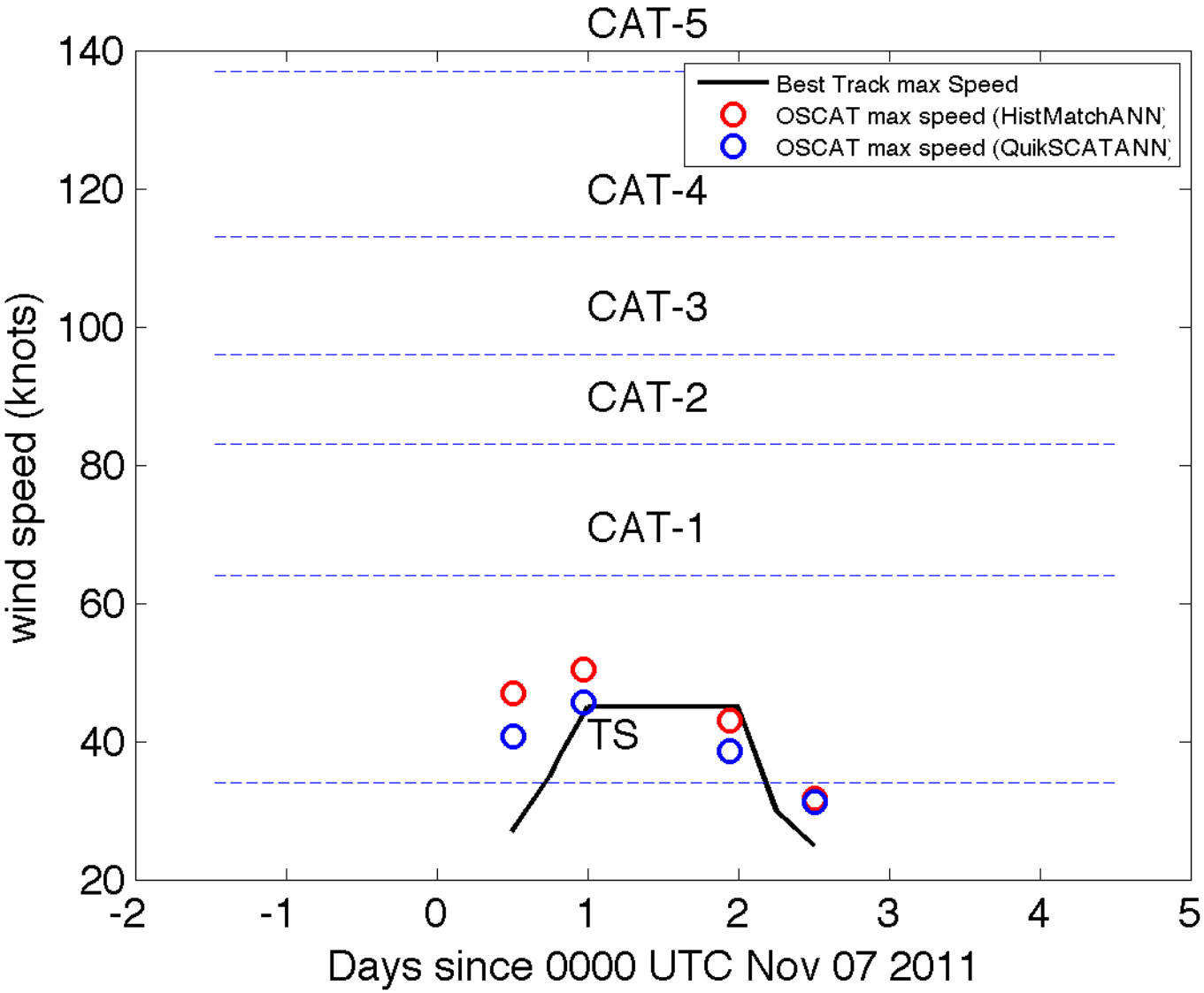
Rainfree NRCS vs Wind Speed



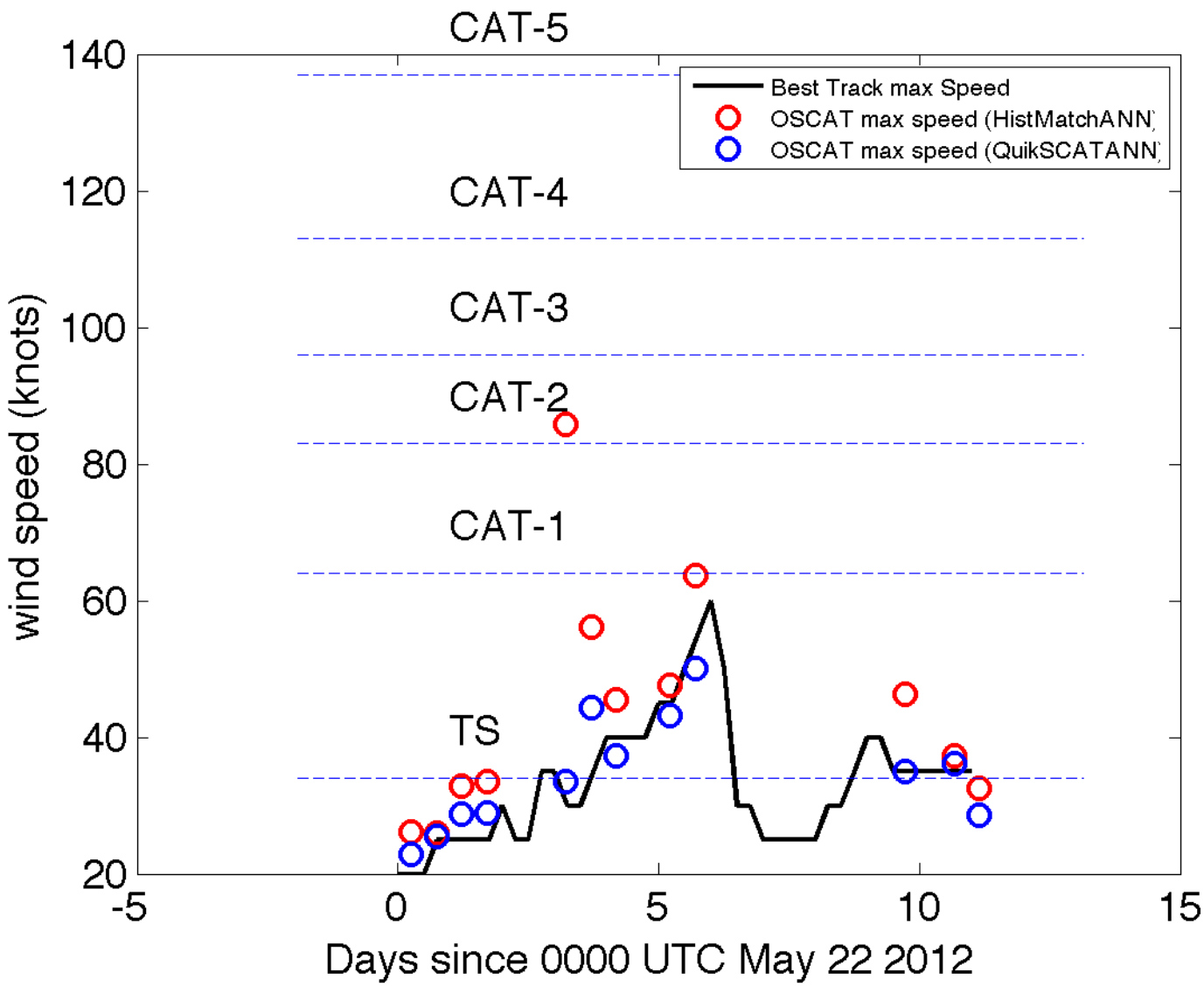
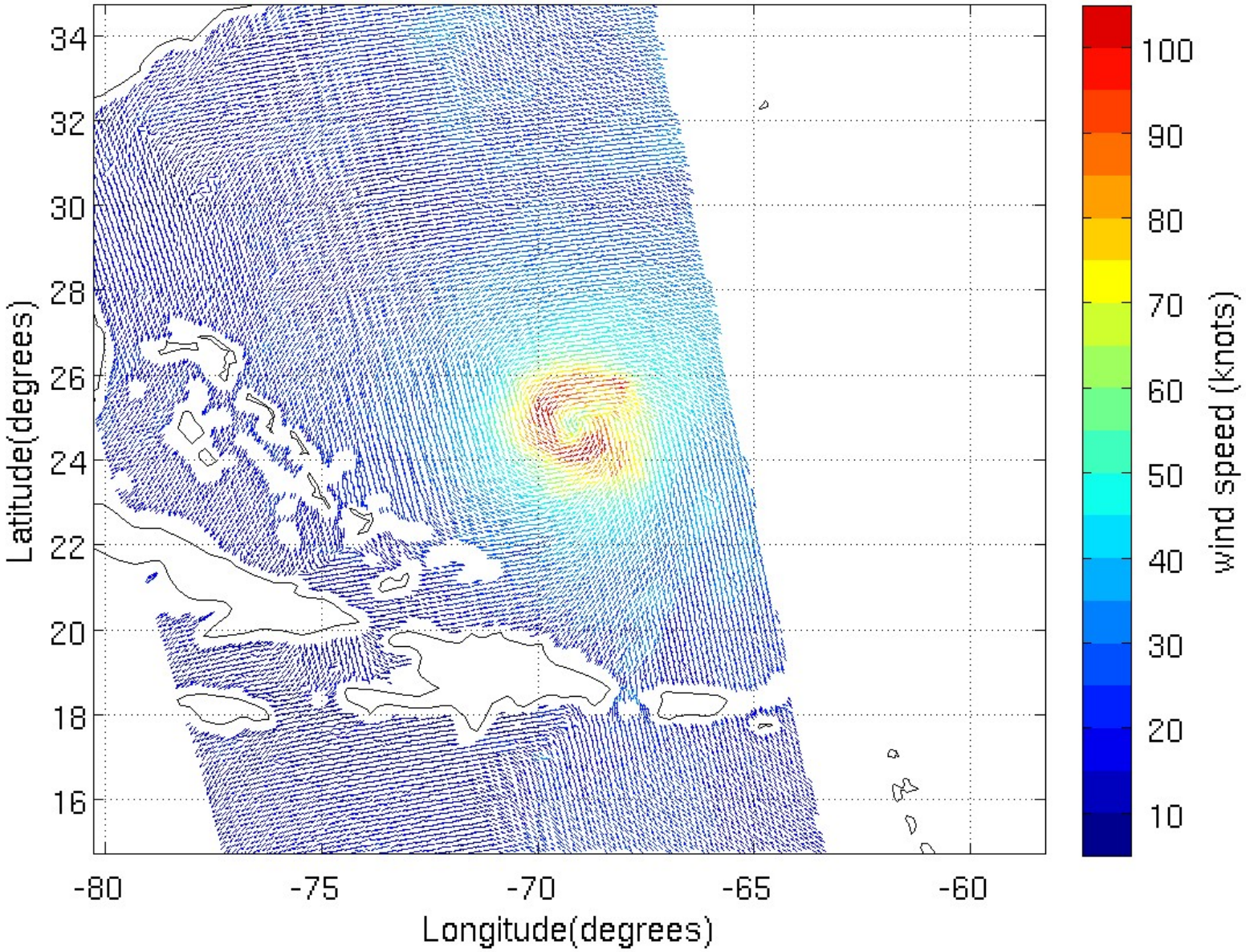
Average Wind Speed Vs. Rain Rate



Example Max Speed Track Rolf 2011



Example Max Speed Track Beryl 2012



Hurricane Isabel, 1028 UTC 15 Sept 2003