Obtaining Accurate Ocean Surface Winds in Hurricane Conditions: A Dual Frequency Scatterometry Approach

Bryan W. Stiles, Svetla Hristova-Veleva, R. Scott Dunbar, Samuel Chan, Stephen L. Durden, Daniel Esteban-Fernandez, Ernesto Rodriguez, W. Lee Poulsen, Robert W. Gaston, and Philip S. Callahan

Ocean Vector Wind Science Team Meeting
Seattle, Nov 19-21, 2008

Jet Propulsion Laboratory

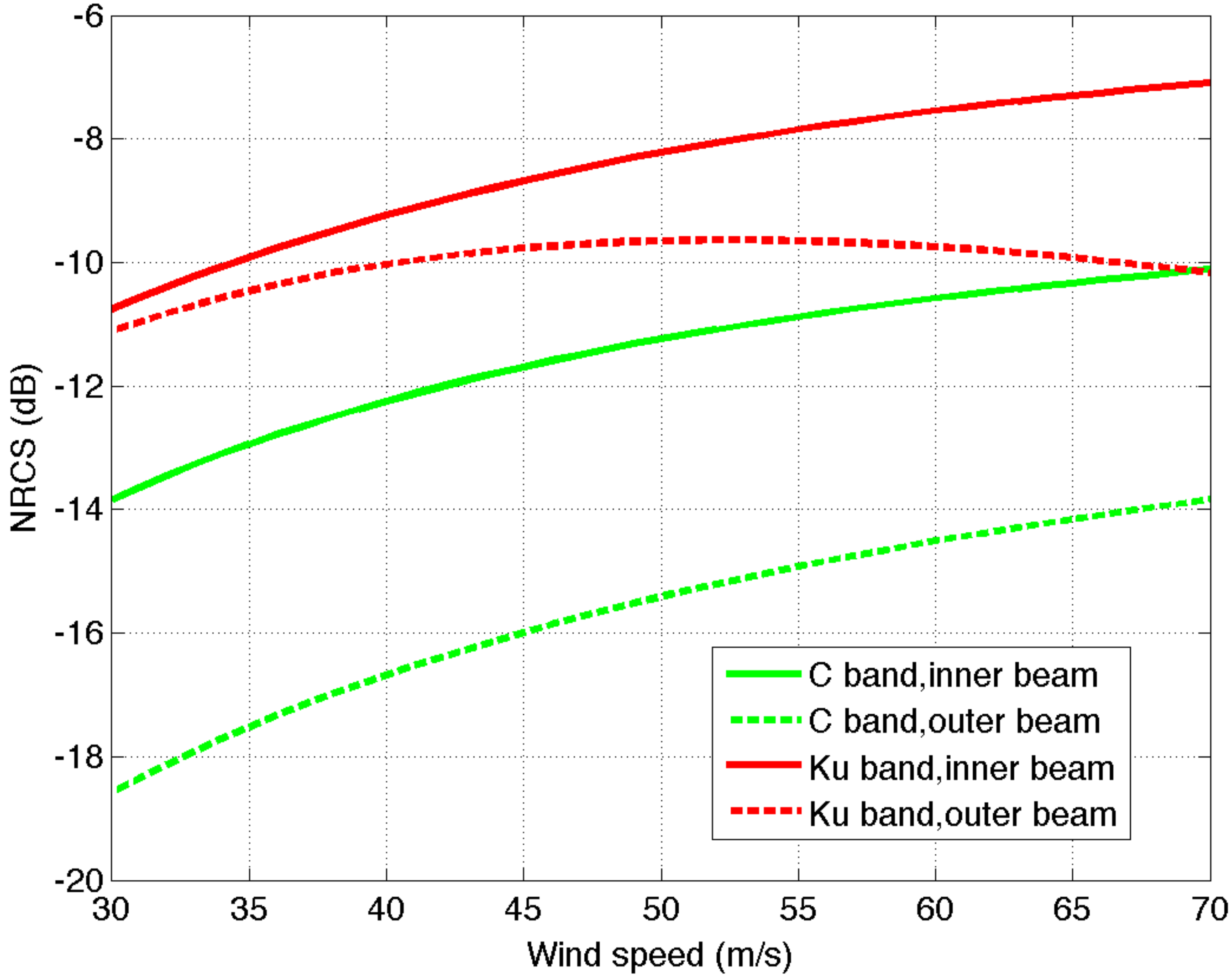
Outline

- Overview
- Simulation Methodology
  - WRF: Winds, Rain
  - XOVWM Simulation: NRCS values
- Wind Retrieval Method and Results
  - Neural network method
  - Retrieves accurate wind speeds in rain given C and Ku NRCS values.

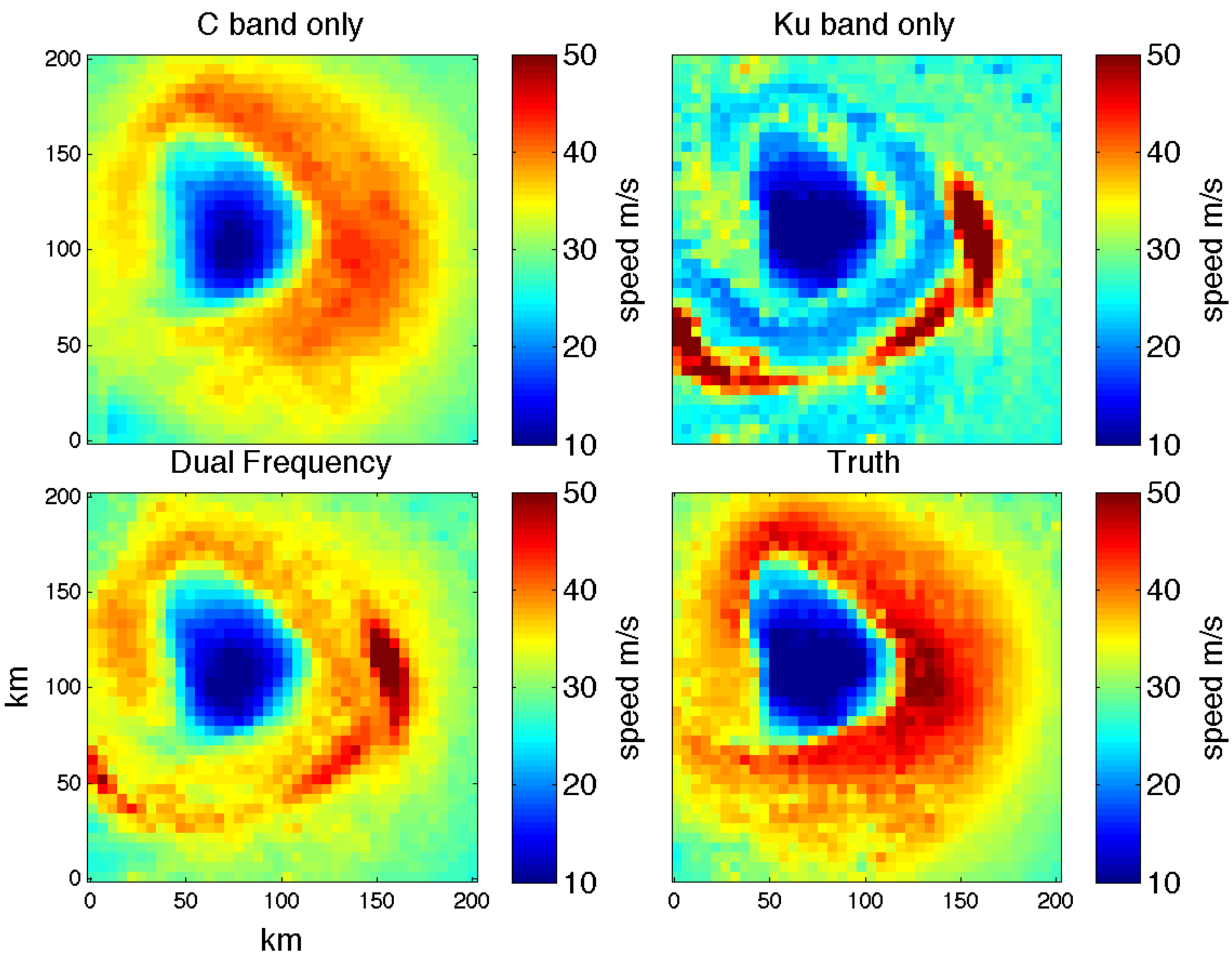
Overview

- Three Major Problems for Retrieving Accurate Hurricane Winds
  - Need high resolution to resolve high wind speed bands
  - Model functions saturate or drop off at high winds
  - Rain contamination obscures wind speed signal
- Proposed Solutions
  - Burst Mode SAR processing to improve resolution
  - Dual frequency provides unique wind speed solution
  - Dual frequency allows rain correction

Overview Slide 2: IWRAP Model Functions

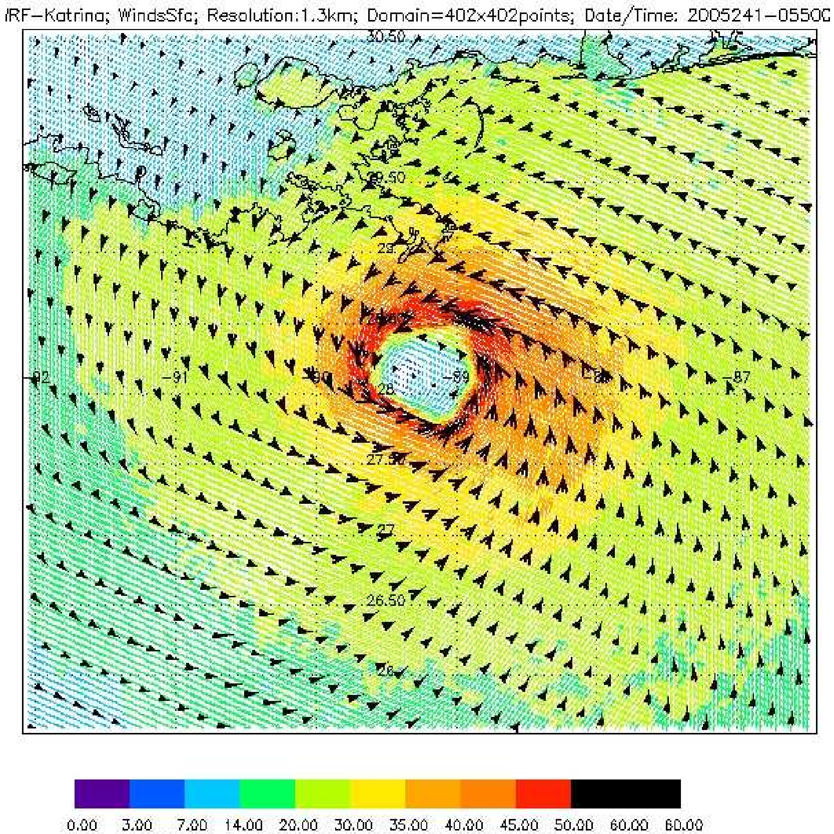


Overview Slide 3:Rain Effects in Hurricanes w/o correction

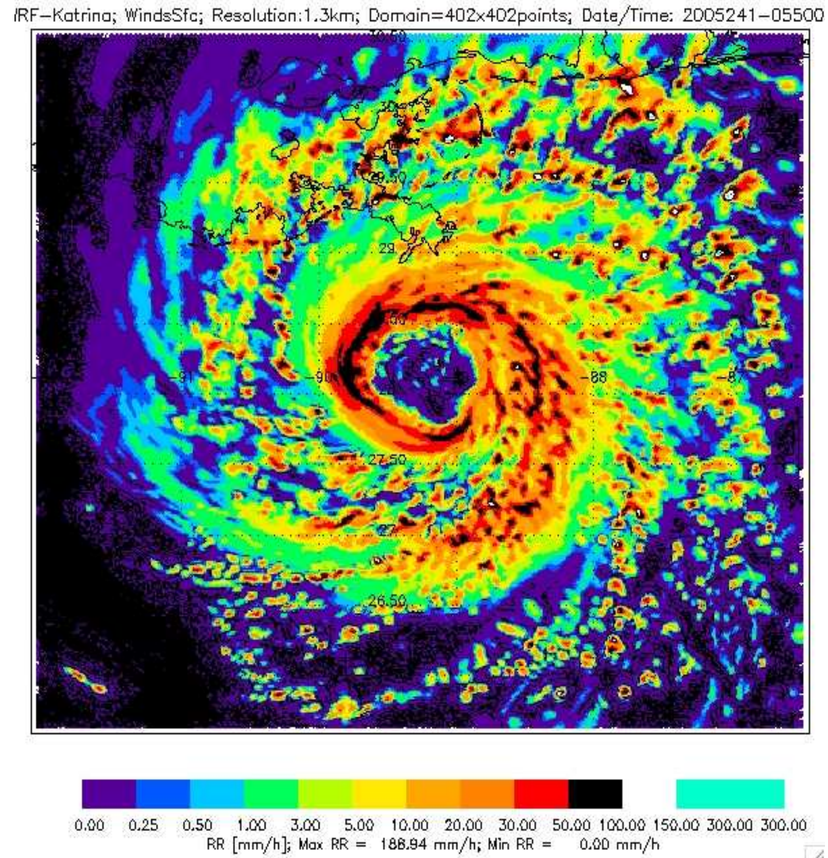


Simulation Method Slide 1: Katrina from Hurricane WRF

Wind

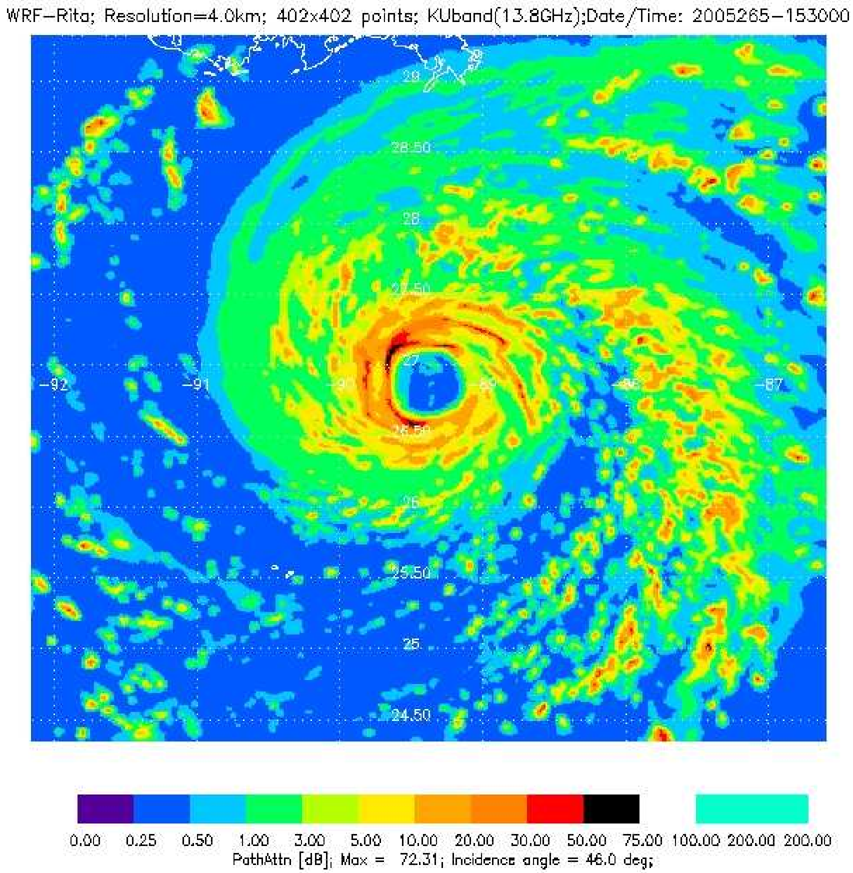


Rain

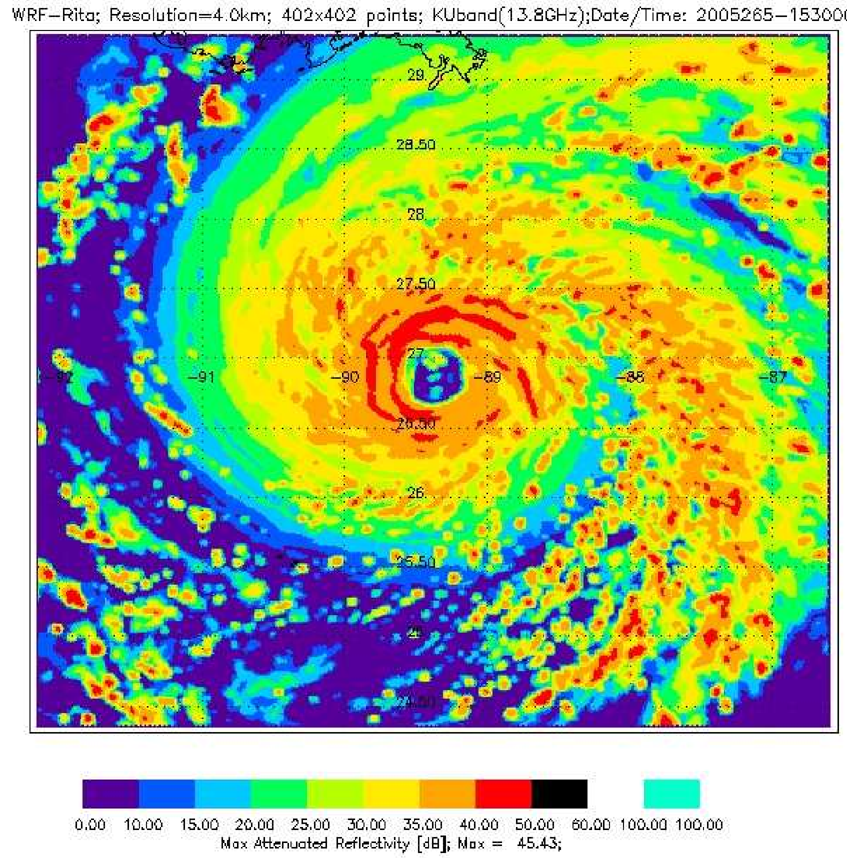


Simulation Method Slide 2: Rain Effects on NRCS

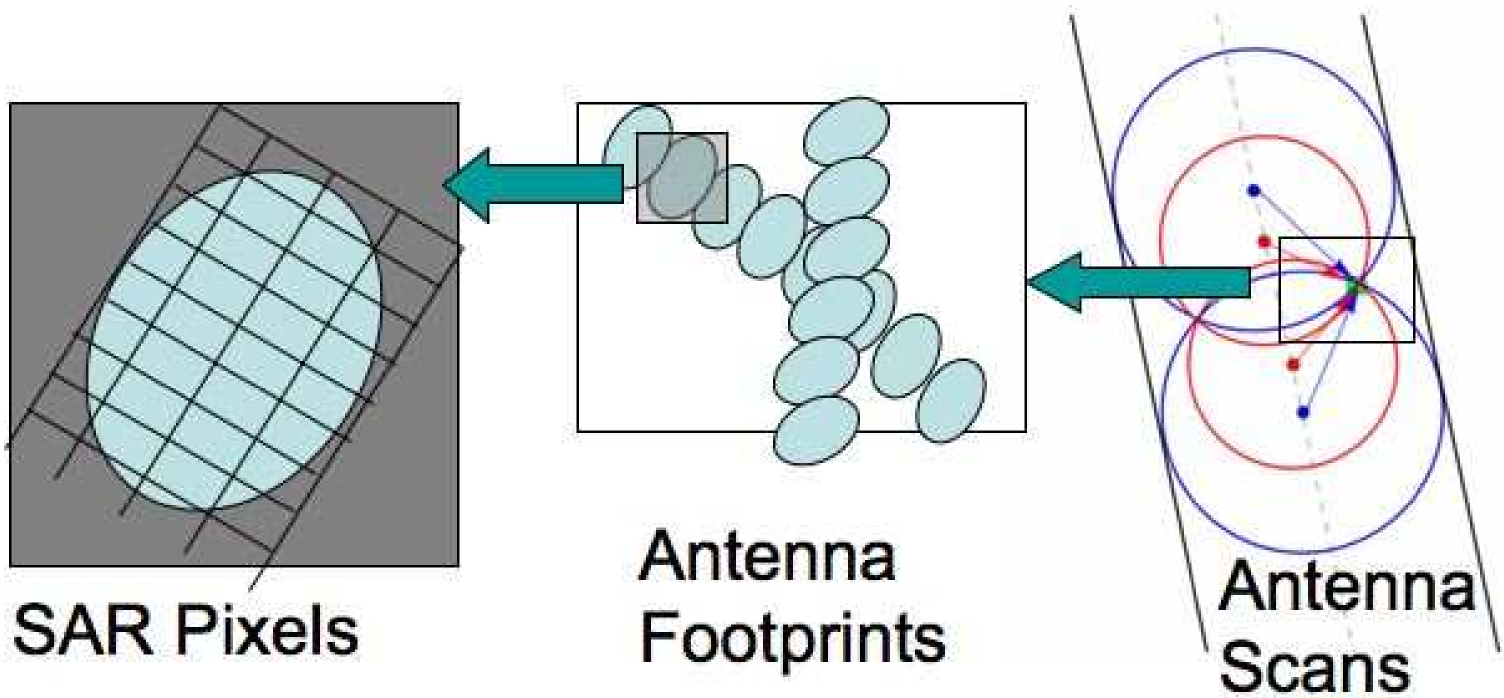
Attenuation



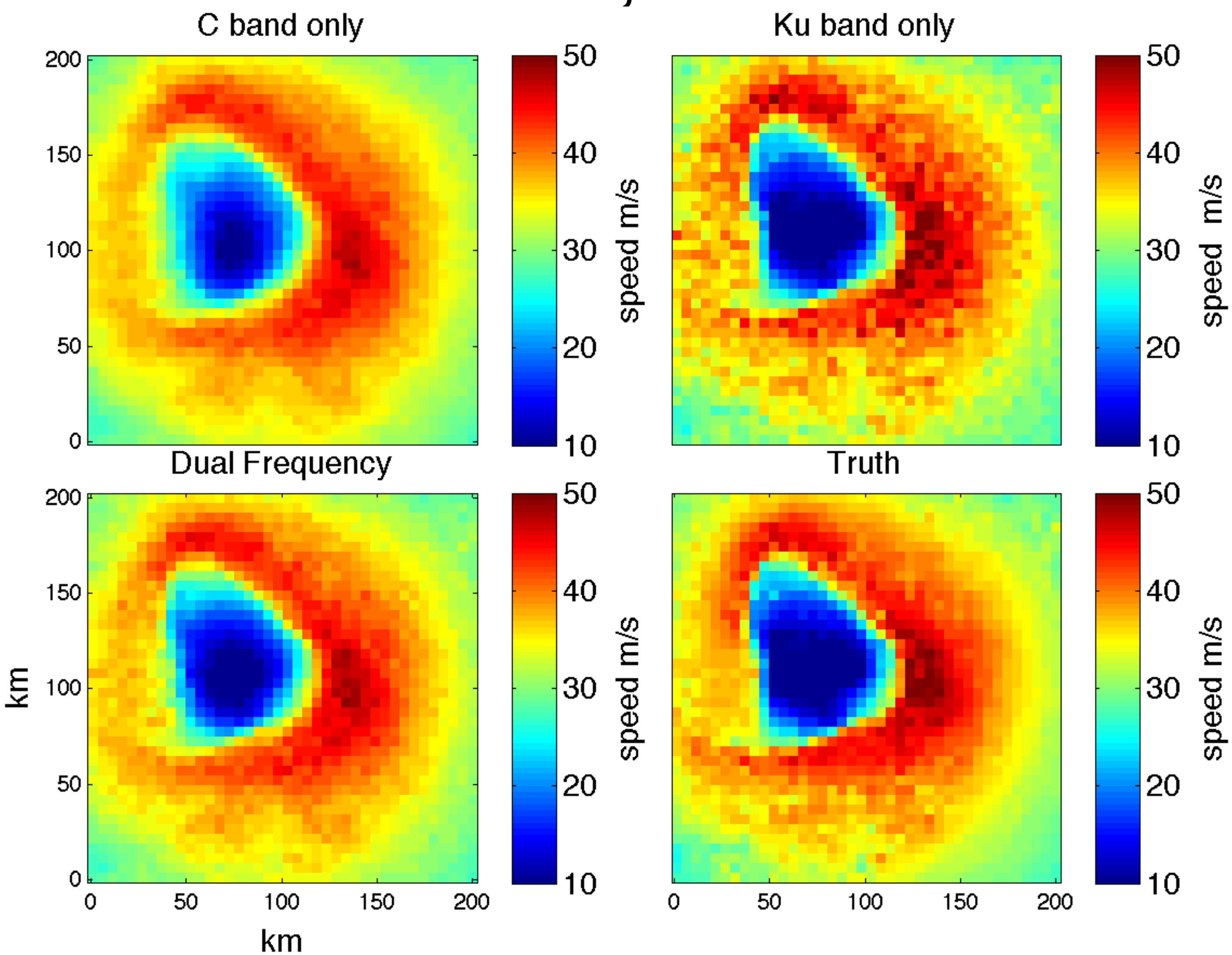
Volume Backscatter



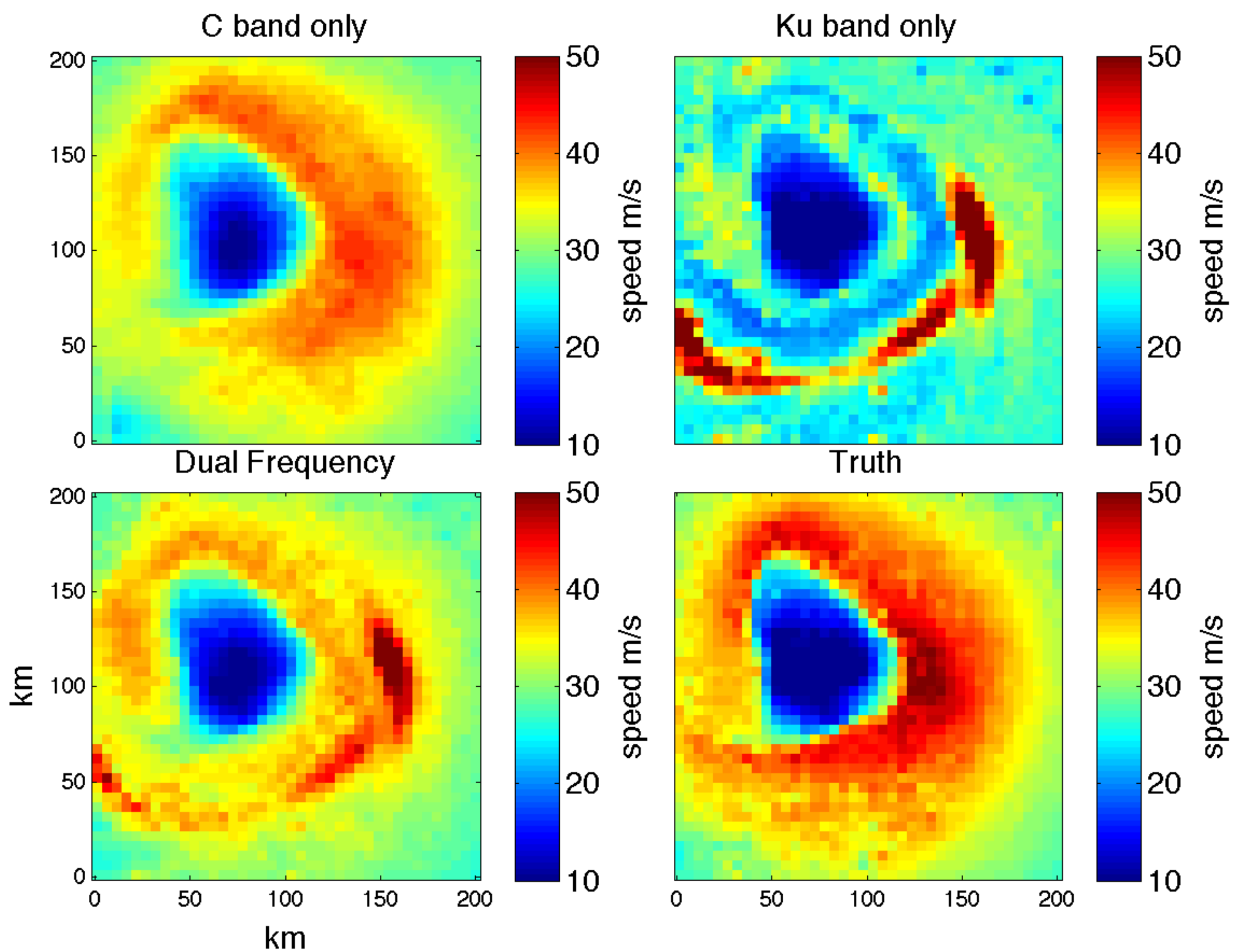
Simulation Method Slide 3:
XOVWM Measurement Geometry



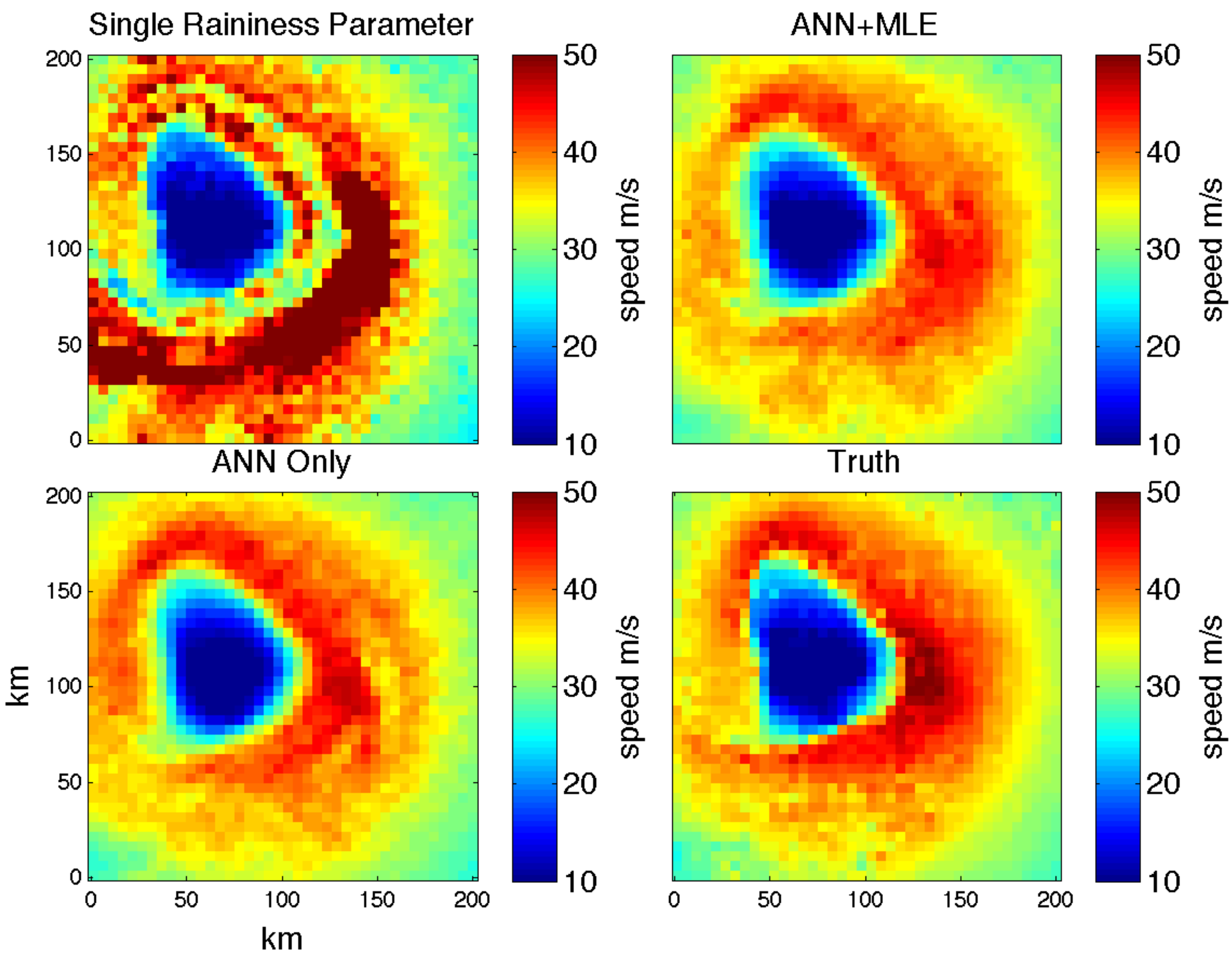
Wind Retrieval: Slide 1
Rain-free Case, MLE Retrievals



Wind Retrieval: Slide 2
Rainy Case, no correction



Wind Retrieval: Slide 3
Rainy Case with Correction



Wind Retrieval Slide 4: ANN Method

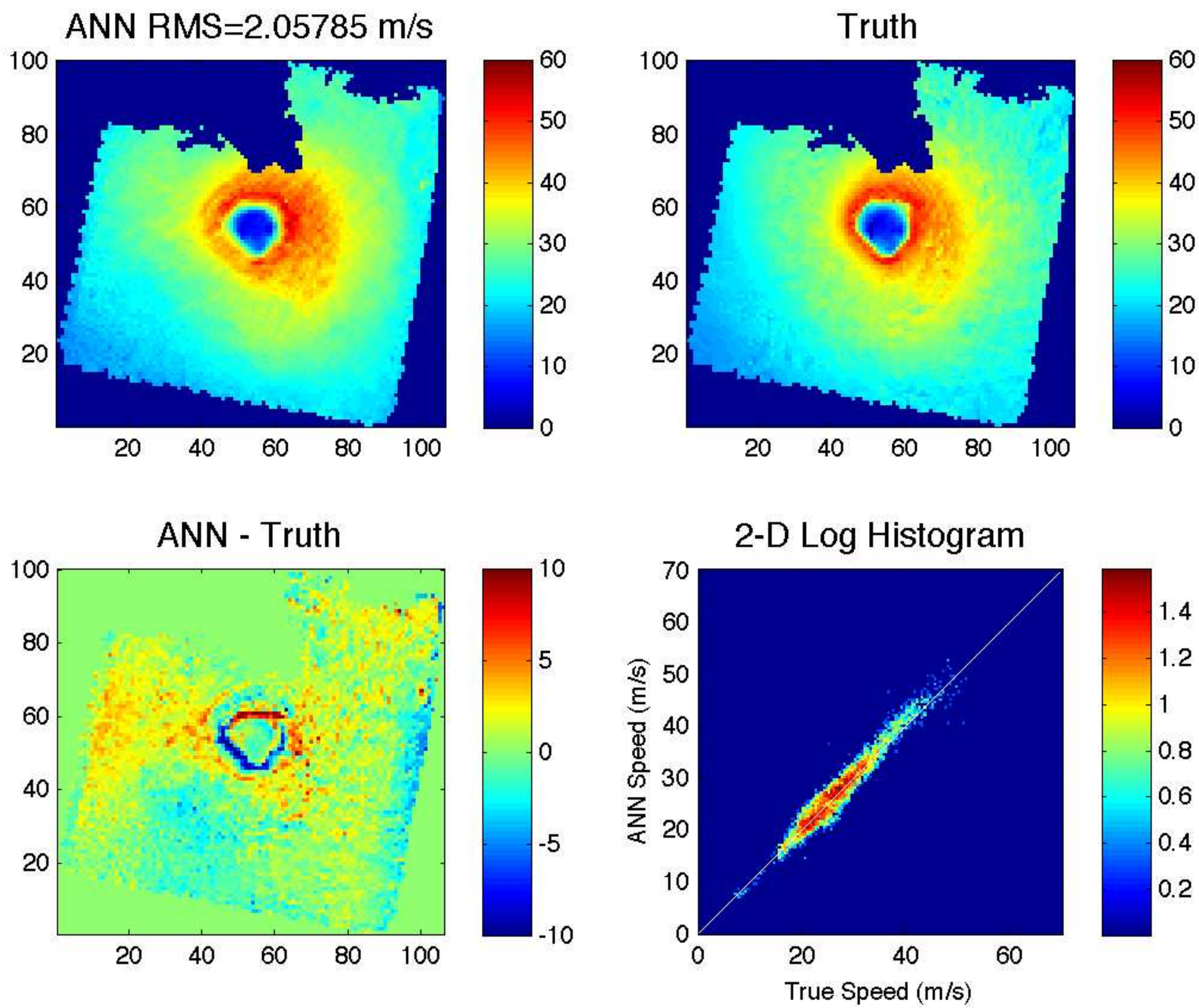
- Compute 17-D Input Vector to ANN
  - Mean of 8 NRCS "Flavors"
    - C/Ku, Inner/Outer, Fore/ AFT NRCS
  - Variance of 8 Flavors
  - Cross Track Distance
- Train ANN on 2 simulated Katrina + 2 simulated Rita scenes
  - Using Back-propagation Training Algorithm
- Test on 21 scenes not seen during Training including scenes from Helene.

Wind Retrieval: Slide 5
ANN equations: Multi-Layer Perceptron

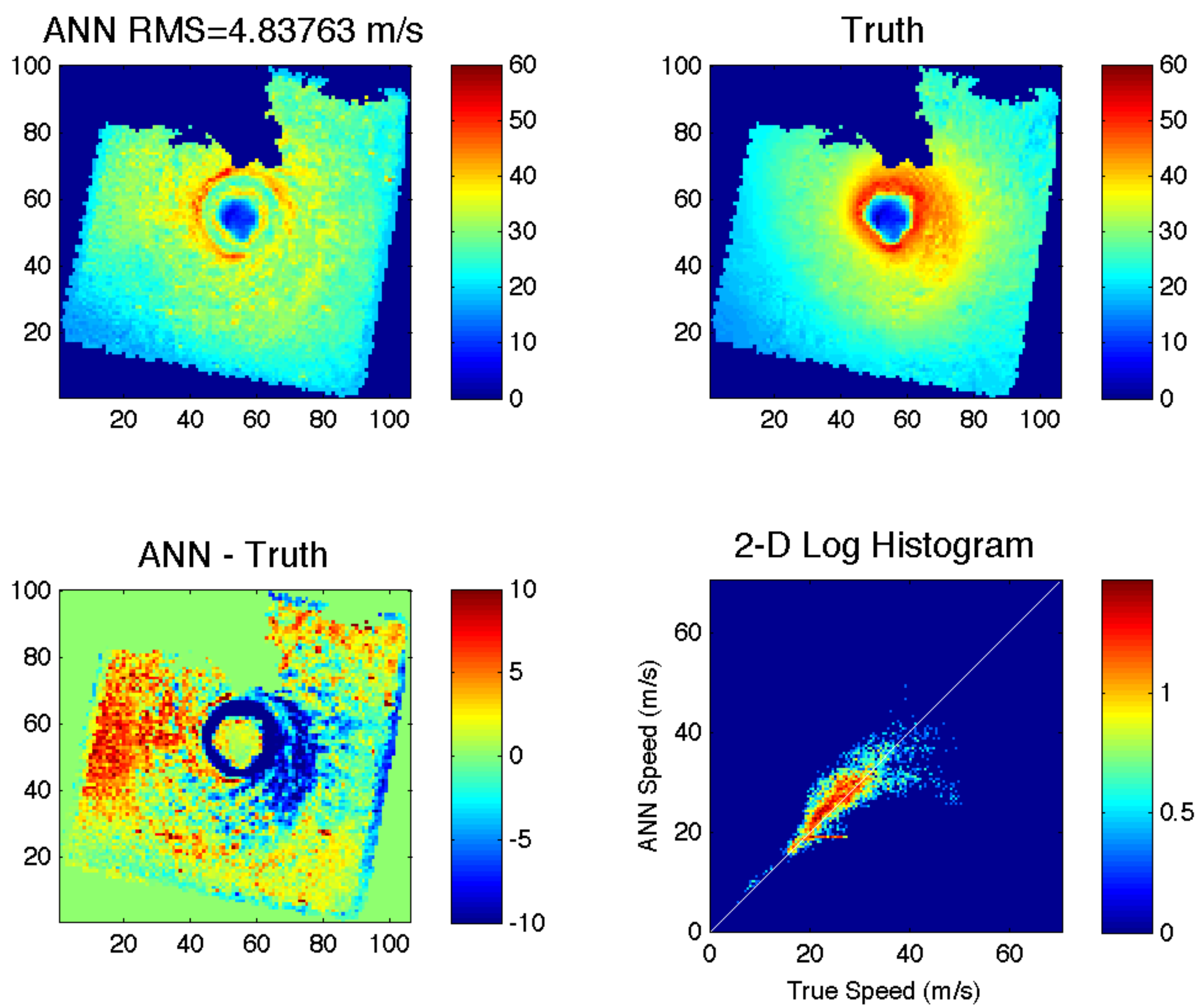
$$y = c_0 + \sum_{i=1}^{M} c_i s\left(w_{i0} + \sum_{j=1}^{N} w_{ij} x_j\right)$$

$$s(u) = \frac{1}{1+e^{-u}}$$

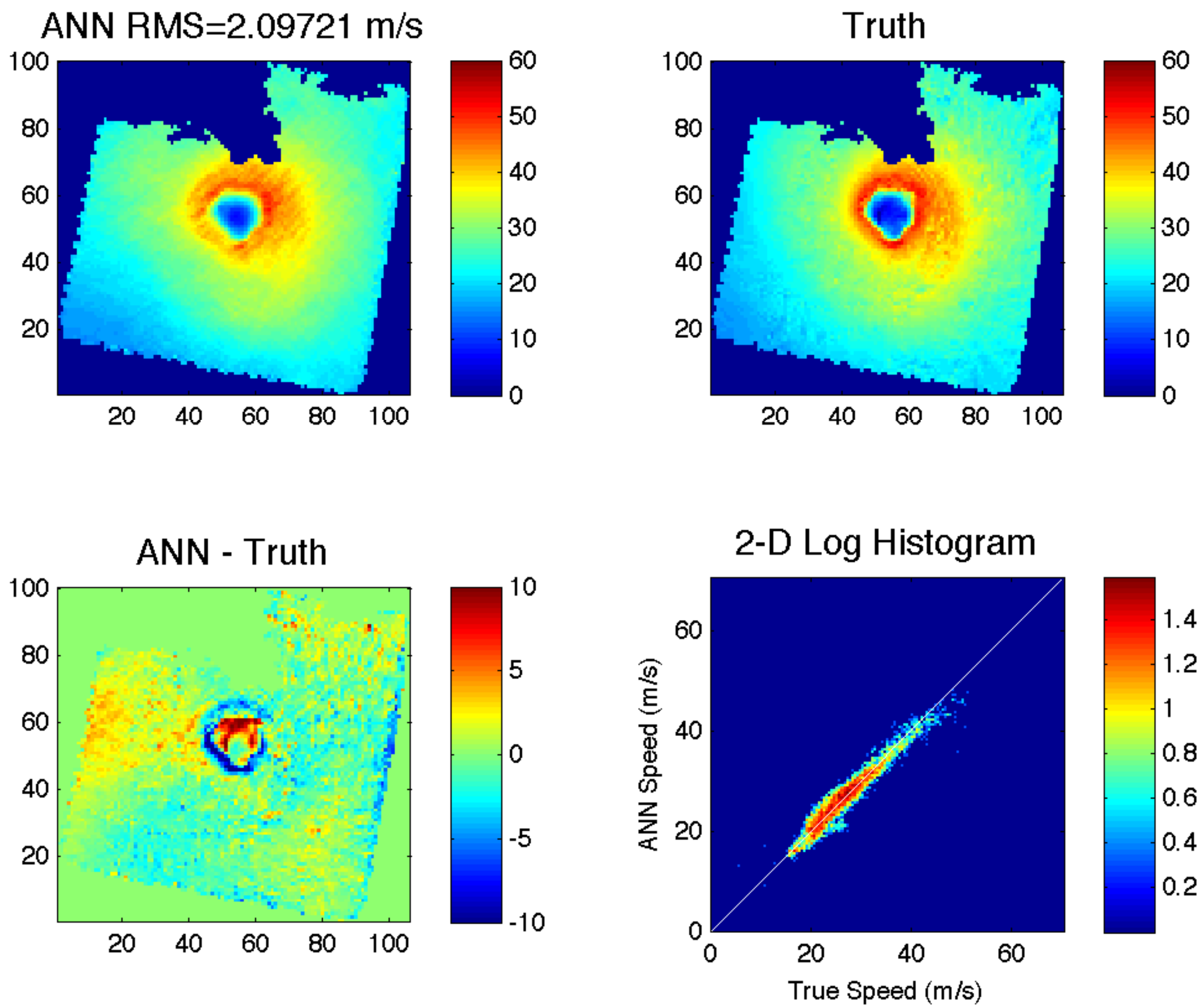
Wind Retrieval: Slide 6
Speed Accuracy for Katrina4 Test Scene



Wind Retrieval: Slide 8
Speed Accuracy for Ku Only ANN



Wind Retrieval: Slide 7
Speed Accuracy for C Only ANN



Conclusions

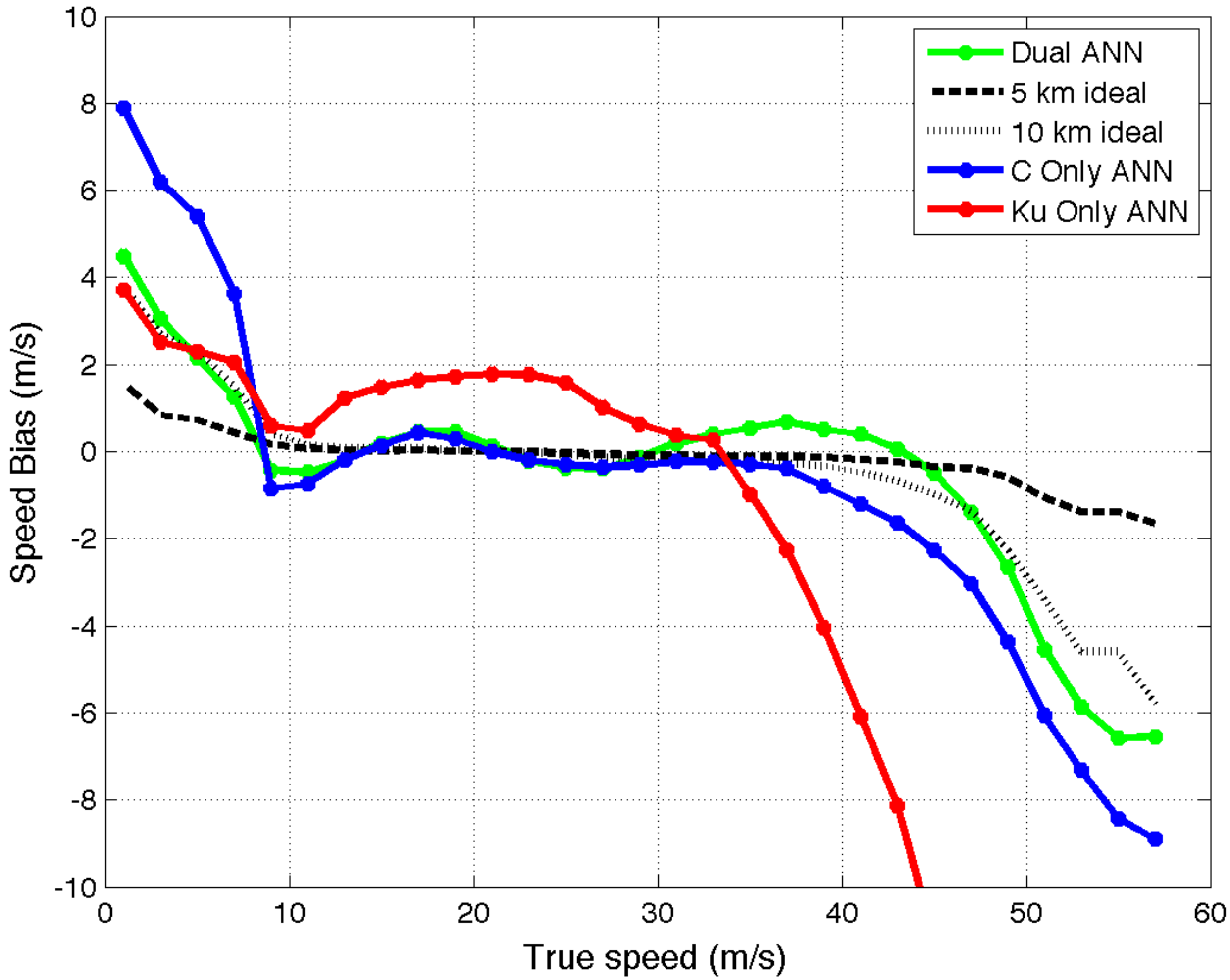
- Simulated 25 scenes from Katrina, Rita, and Helene.
- Dual frequency neural net technique retrieves accurate winds up to 55 m/s.
- C band only and Ku-only techniques show severely degraded performance even with similarly trained neural networks.

Backup Slides

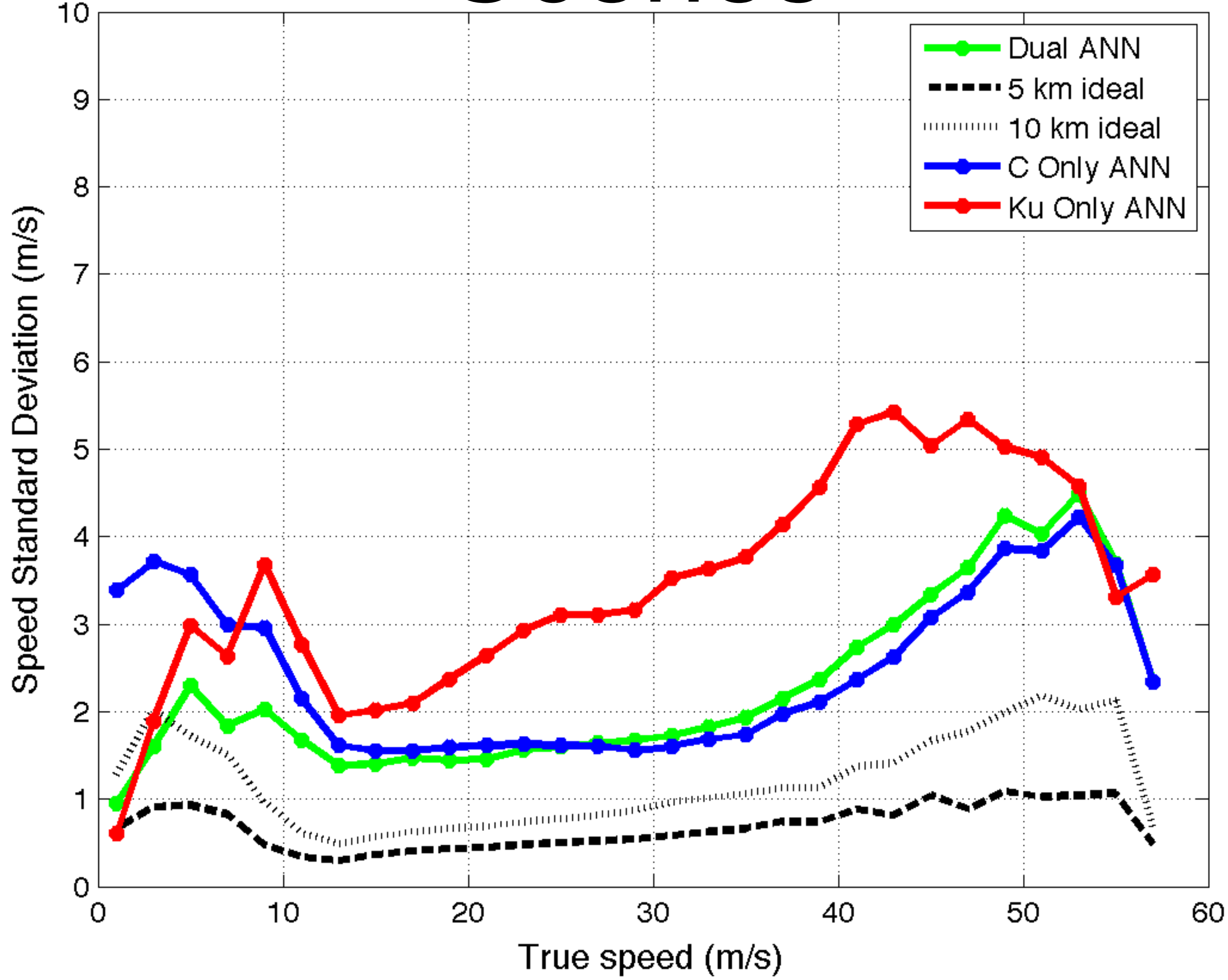
Table of Train and Test Scenes

Hurricane and Scene ID	Date and UTC Time (yymmddThh:mm)	Used for:	RMS speed error (m/s)
Katrina1	050828T11:30	Test	1.73
Katrina2	050828T17:30	Test	1.73
Katrina3	050828T23:50	Test	1.84
Katrina4	050829T05:50	Test	2.06
KatrinaTrain1	050828T15:10	Training	Not reported
KatrinaTrain2	050828T20:30	Training	Not reported
Rita1	050921T15:30	Test	1.79
Rita2	050921T21:30	Test	1.61
Rita3	050922T03:30	Test	1.64
Rita4	050922T09:30	Test	1.62
Rita5	050922T15:30	Test	1.70
RitaTrain1	050922T12:20	Training	Not reported
RitaTrain2	050921T17:00	Training	Not reported
Helene1	060918T11:00	Test	1.41
Helene2	060918T13:00	Test	1.43
Helene3	060918T15:00	Test	1.50
Helene4	060918T17:00	Test	1.54
Helene5	060921T22:30	Test	1.72
Helene6	060922T04:30	Test	1.60
Helene7	060922T09:30	Test	1.54
Helene8	060922T14:00	Test	1.66
Helene9	060923T00:00	Test	1.76
Helene10	060923T12:00	Test	1.95
Helene11	060924T00:00	Test	2.15
Helene12	060924T12:00	Test	1.94

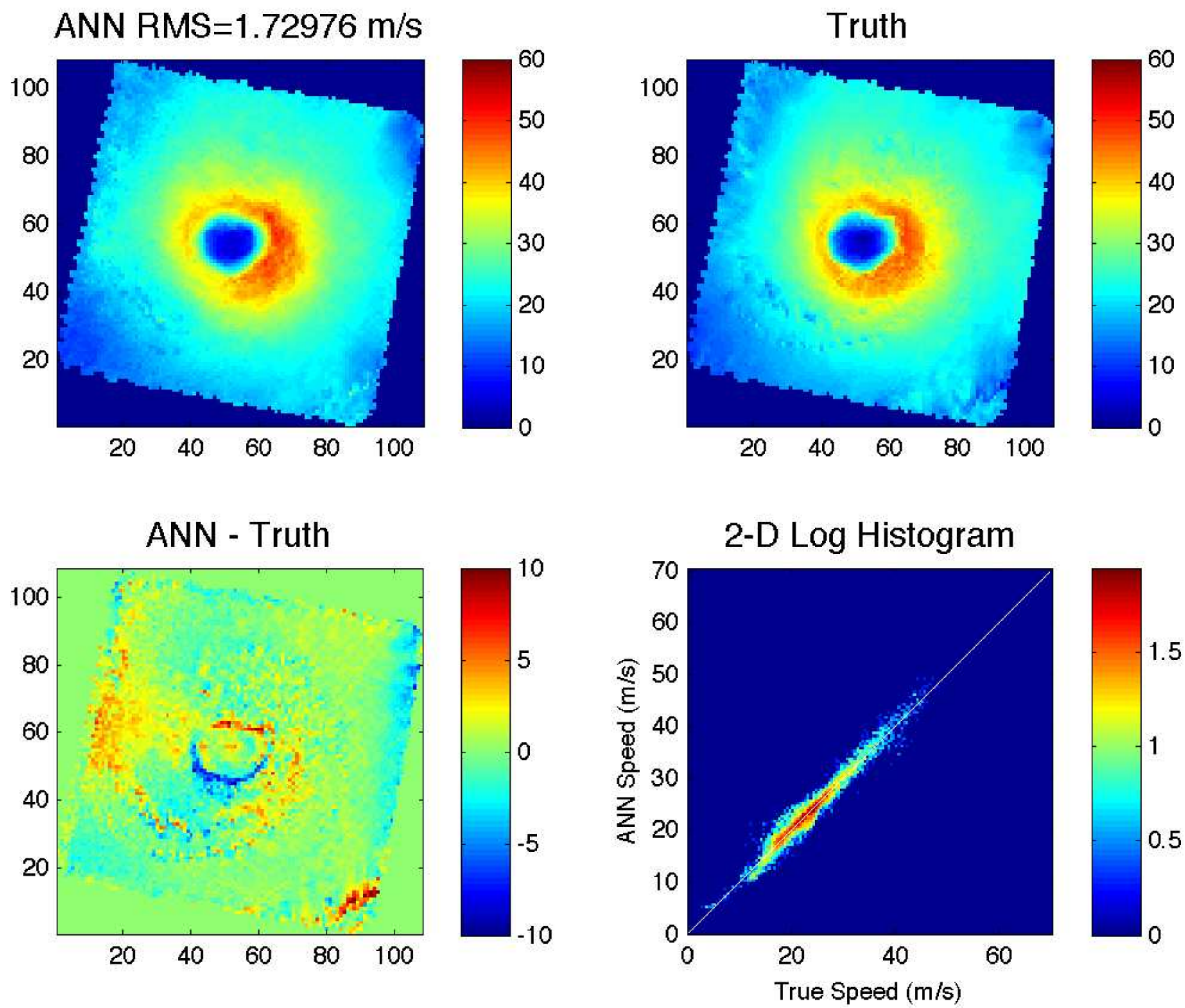
Overall Speed Bias--All Test Scenes



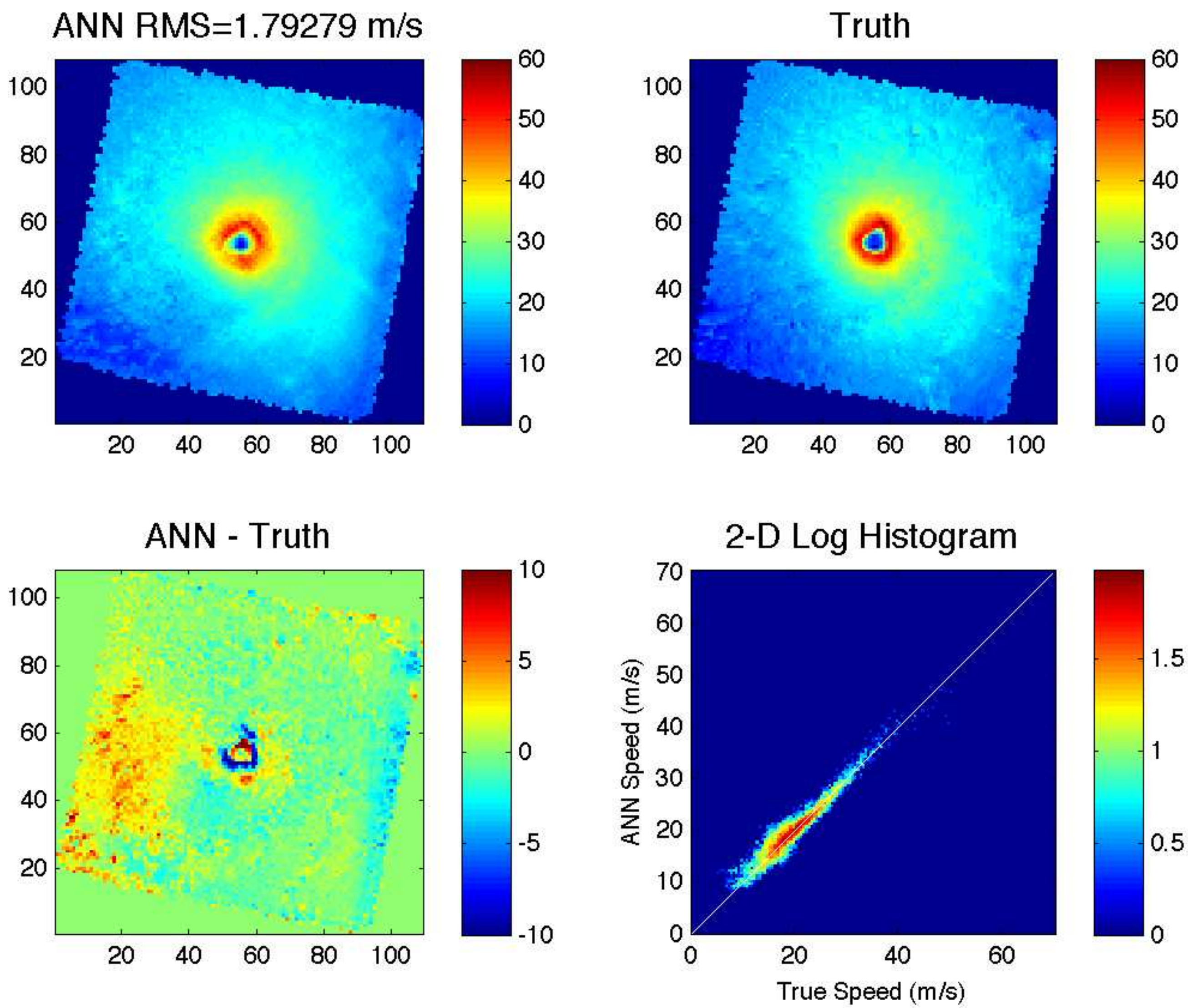
Overall Speed St.Dev.--All Test Scenes



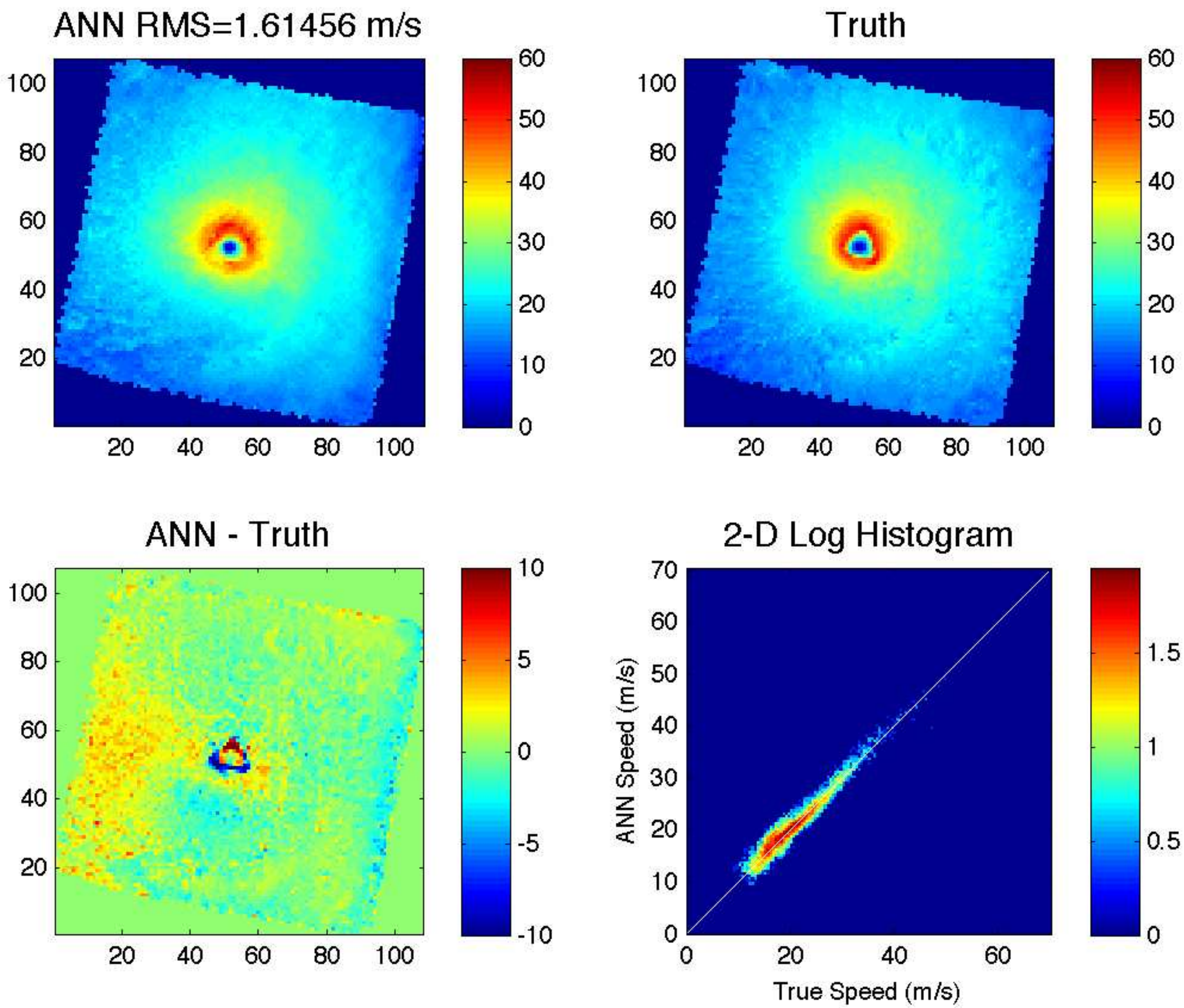
Katrina1


ANN RMS=1.72976 m/s
Truth
ANN - Truth
2-D Log Histogram
ANN Speed (m/s)
True Speed (m/s)

Rita1

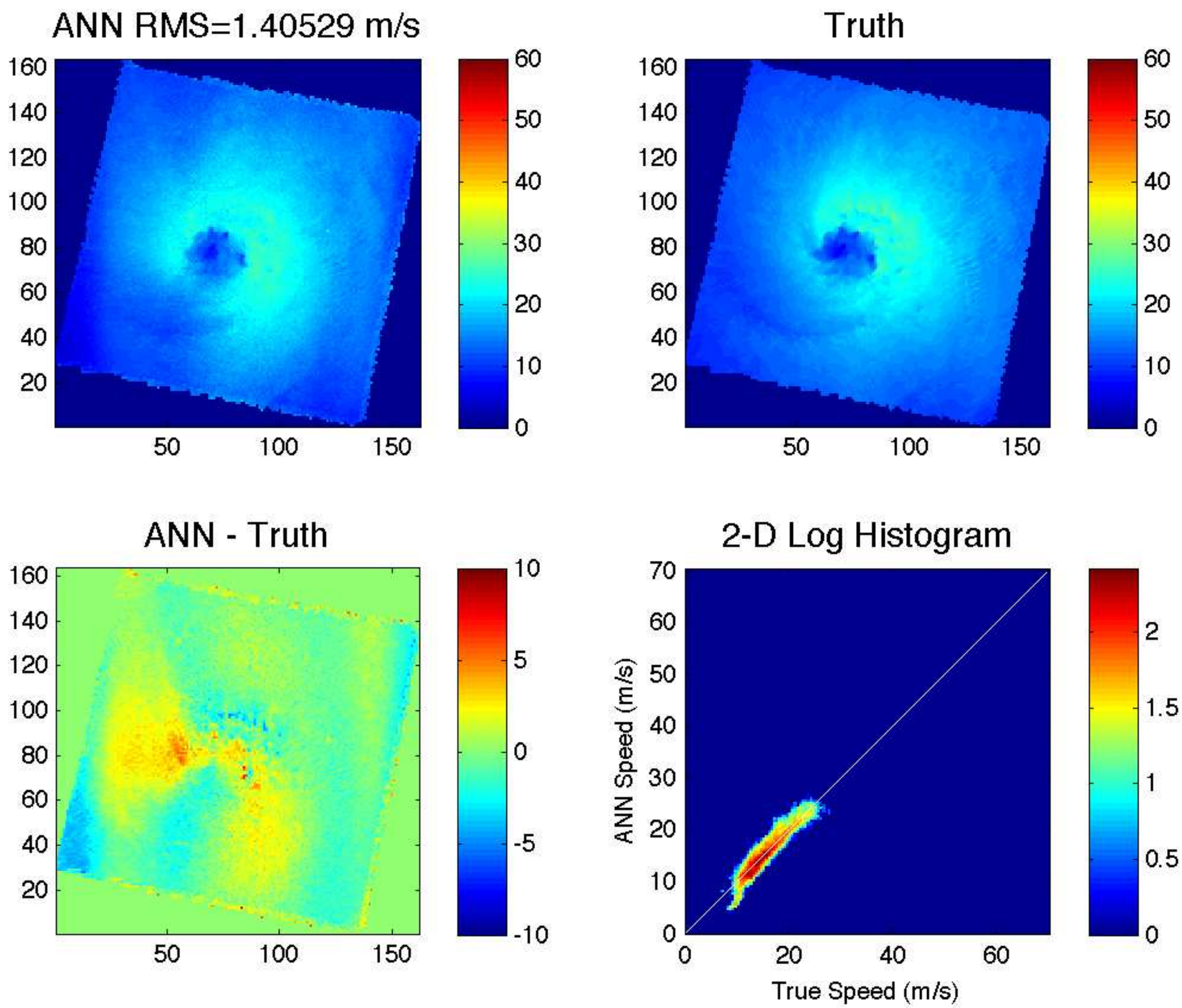

ANN RMS=1.79279 m/s
Truth
ANN - Truth
2-D Log Histogram
ANN Speed (m/s)
True Speed (m/s)

Rita2

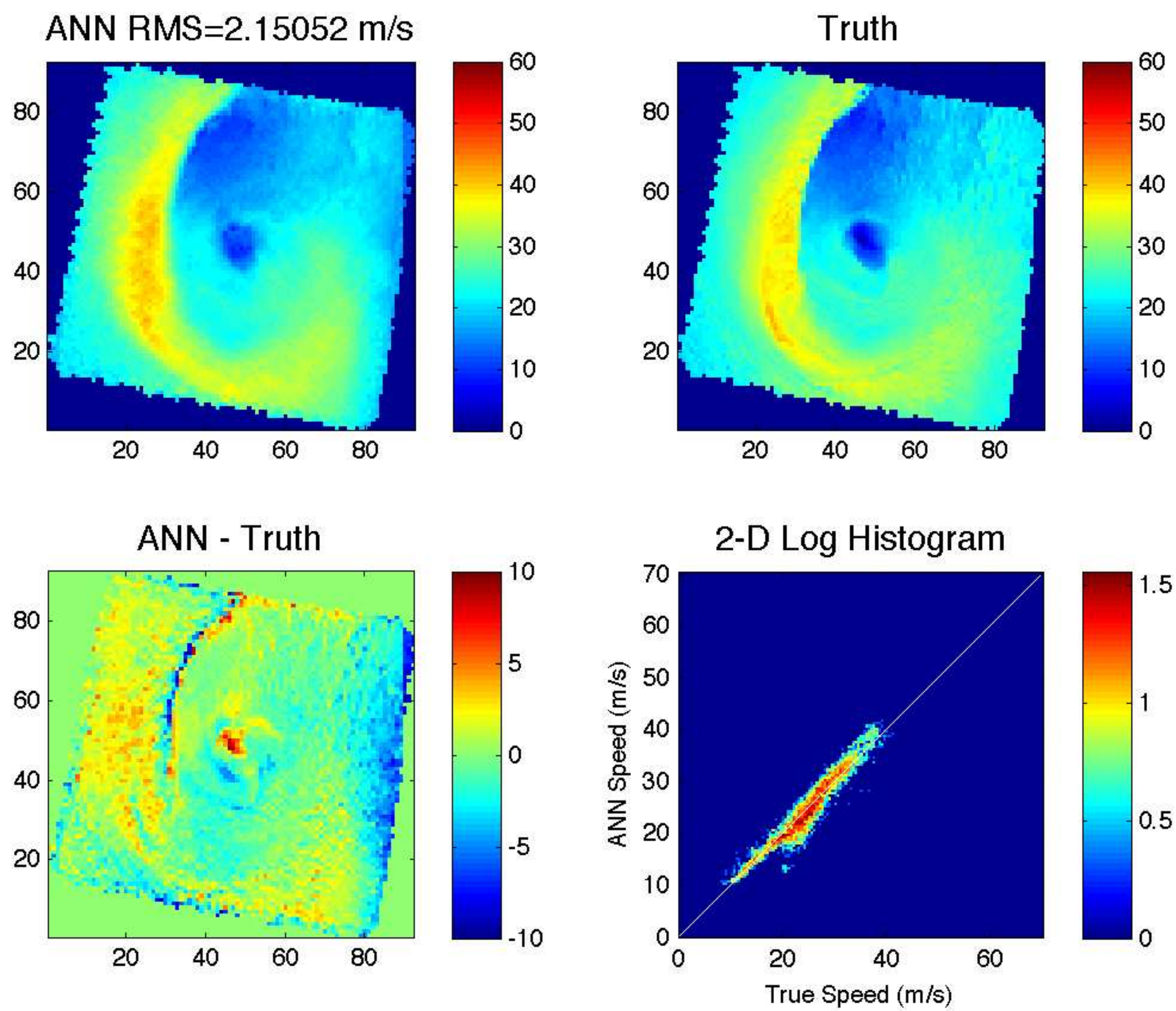


ANN RMS=1.61456 m/s
Truth
ANN - Truth
2-D Log Histogram
ANN Speed (m/s)
True Speed (m/s)

Helene1

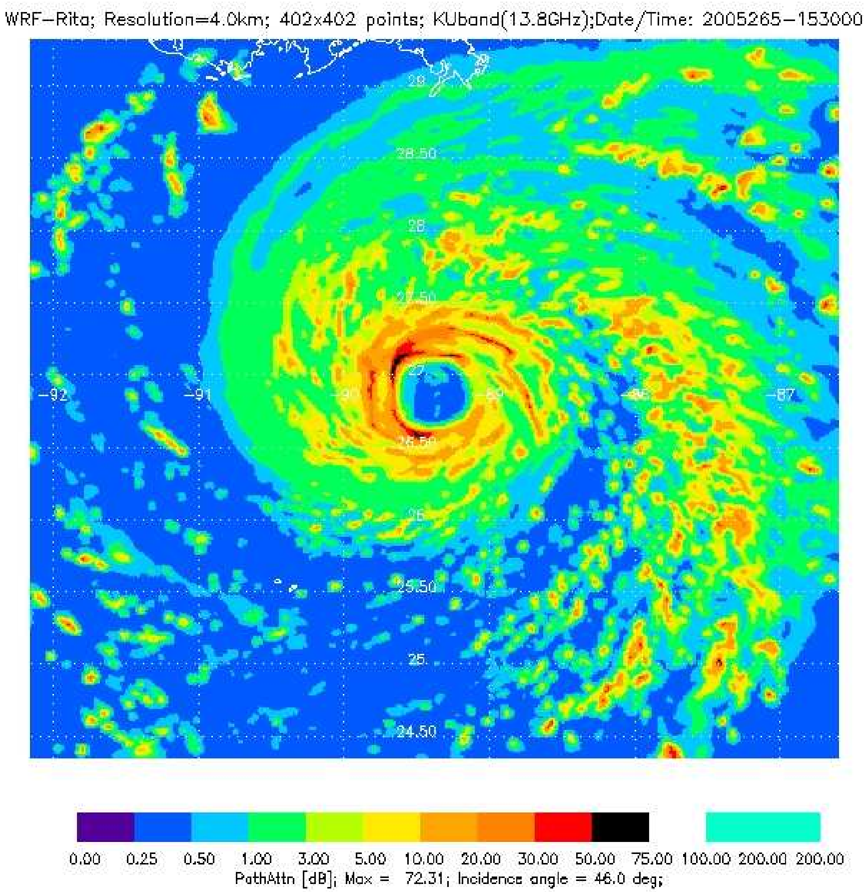

ANN RMS=1.40529 m/s
Truth
ANN - Truth
2-D Log Histogram
ANN Speed (m/s)
True Speed (m/s)

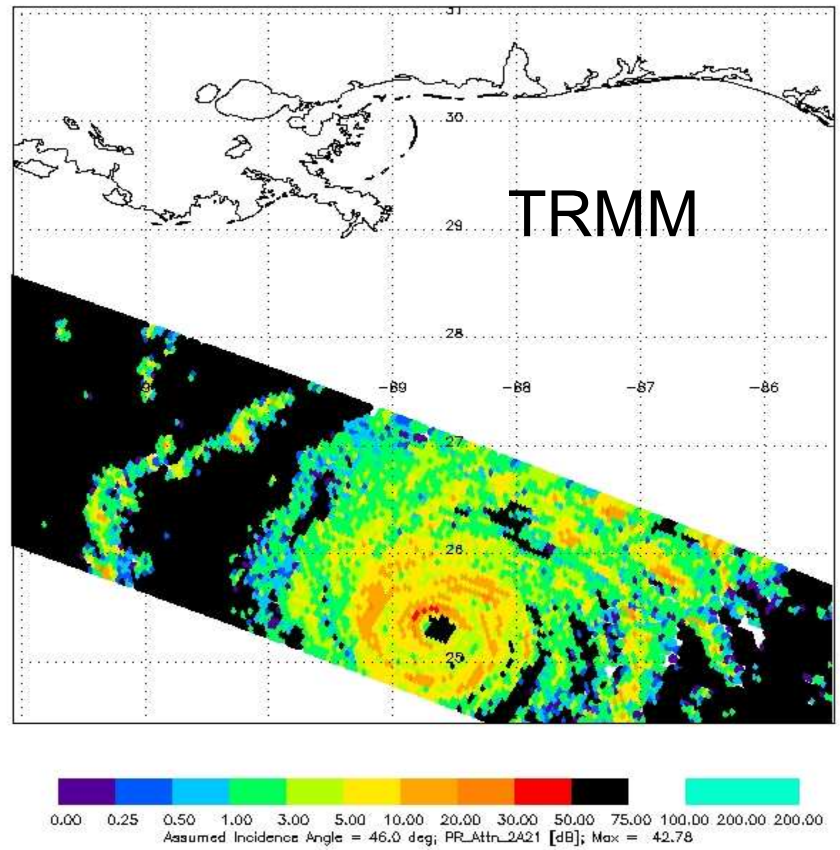
Helene11



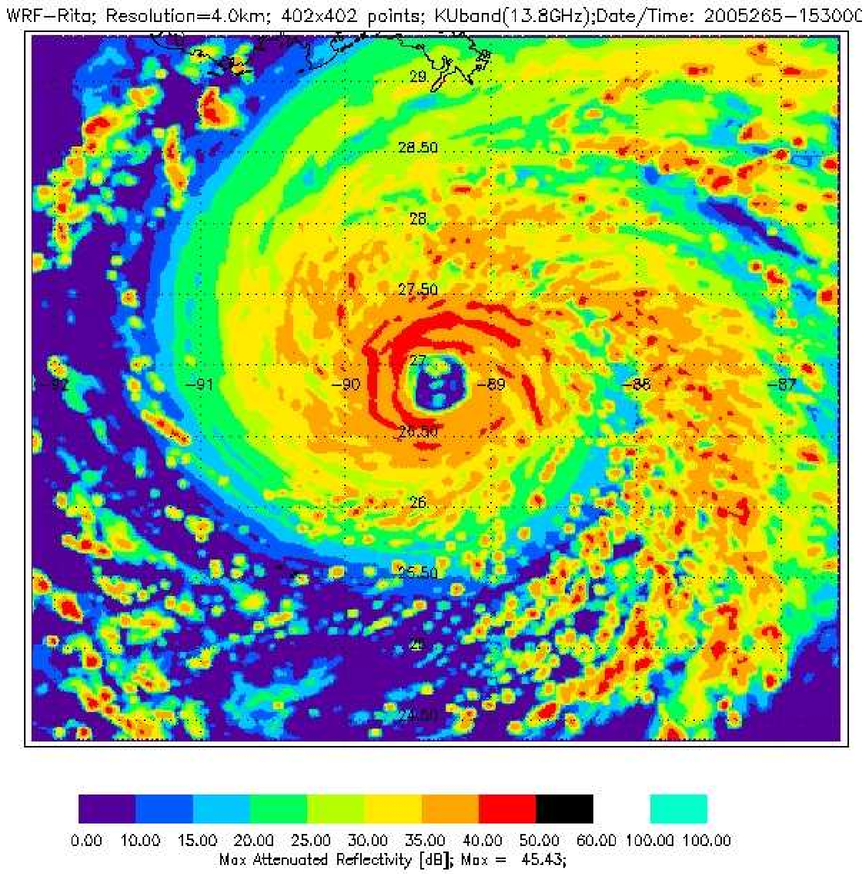
ANN RMS=2.15052 m/s
Truth
ANN - Truth
2-D Log Histogram
ANN Speed (m/s)
True Speed (m/s)

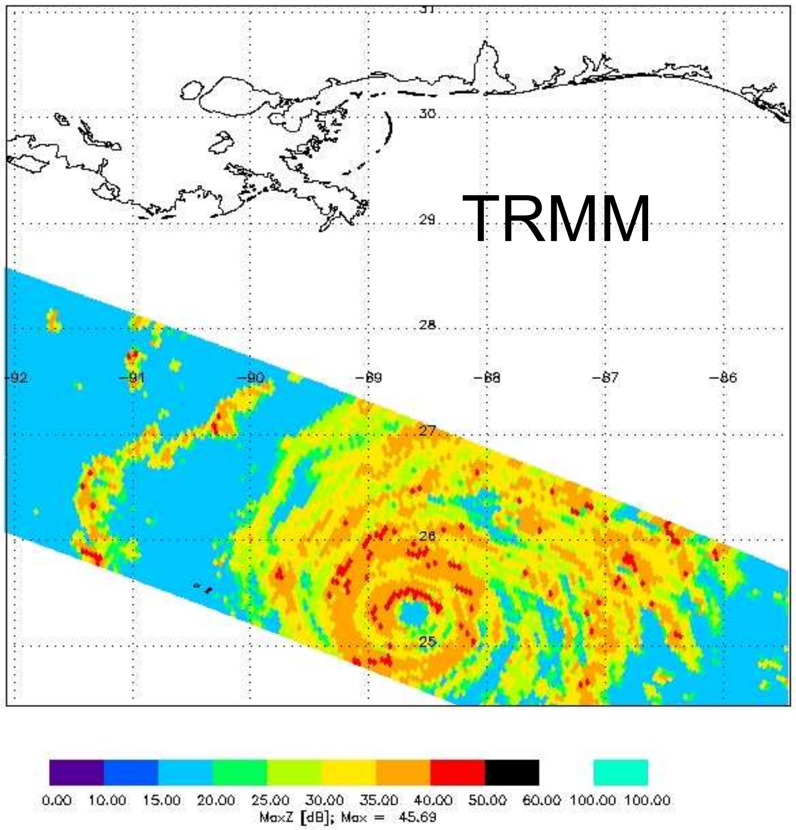
Simulated Rain Attenuation vs. TRMM





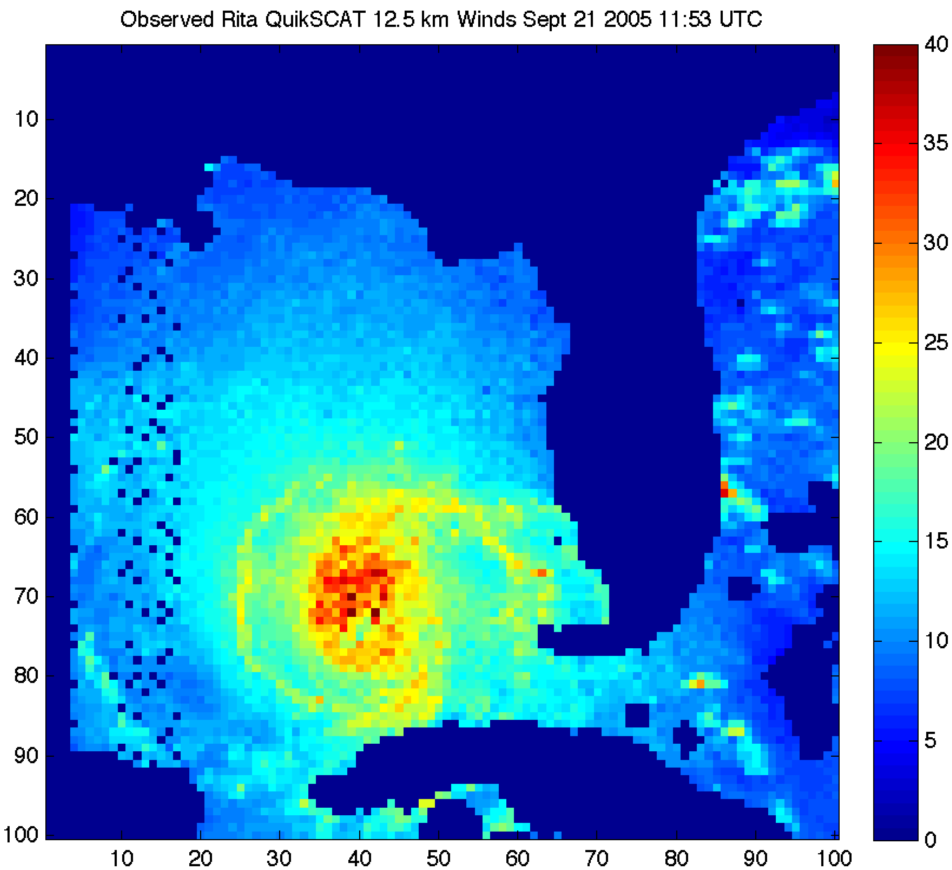
Simulated Rain Reflectivity vs. TRMM





Simulated vs. Real QuikSCAT Winds

Real



Simulated