

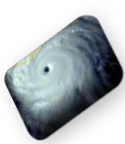
# An Improved Ocean Vector Winds Retrieval Approach Using Dual Frequency Scatterometer and Multi-frequency Microwave Radiometer Measurements

Suleiman O. Alsweiss

*Central Florida Remote Sensing Lab.  
(CFRSL)*

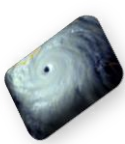
University of Central Florida

Doctoral Dissertation Defense  
March 25, 2011



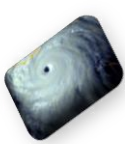
# Presentation Outline

- Dissertation Objectives
- Introduction
- Simulation Overview
  - ▣ Instruments
  - ▣ Measurements Simulation
  - ▣ Measurements Validation
- Retrieval Algorithm
  - ▣ Rain Correction
  - ▣ Wind Retrieval
- Performance Evaluation
- Summary & Conclusion



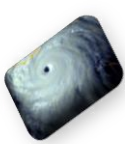
# Dissertation Objective

- Develop a geophysical retrieval algorithm to infer ocean surface vector winds (OVW) for the next generation NASA/NOAA satellite OVW remote sensing system
  - ▣ Utilizes active and passive microwave remote sensing
    - Dual Frequency Scatterometer (DFS)
      - C- and Ku-band scatterometer
    - Advanced Microwave Scanning Radiometer (AMSR)
      - Multi-frequency radiometer
  - ▣ OVW retrievals especially tailored to extreme wind events (tropical and extra-tropical cyclones, TCs)
    - Very high wind speeds and intense rain rates



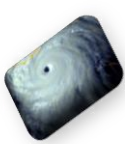
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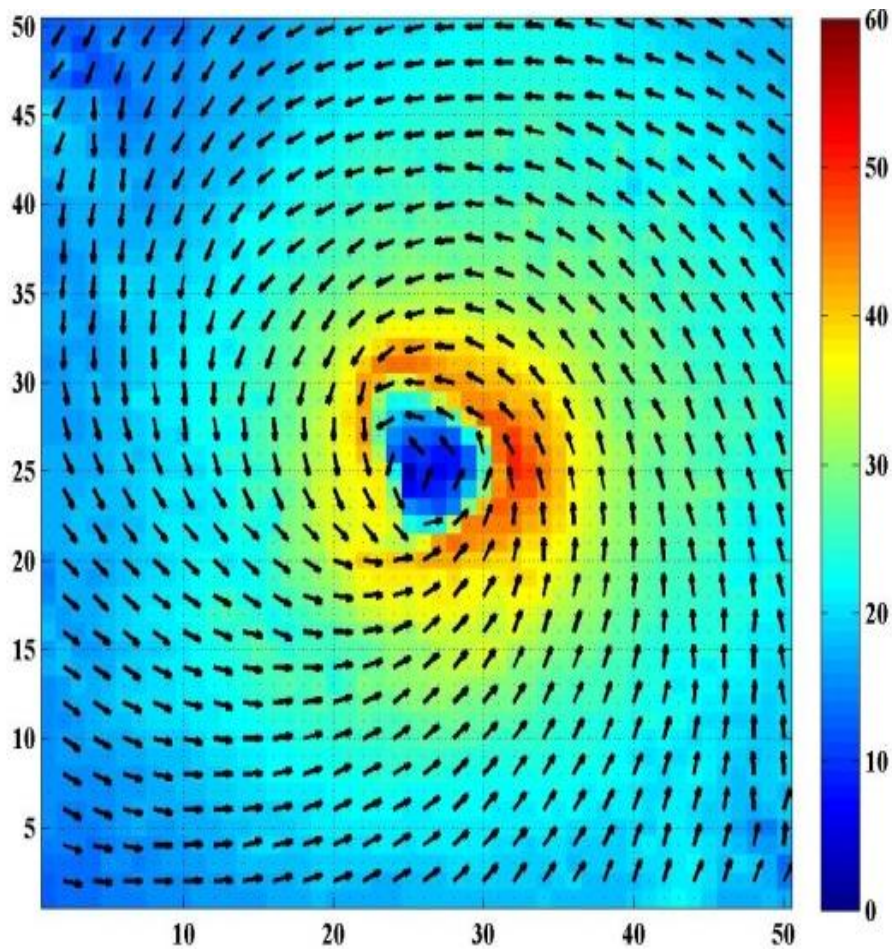


# Introduction

- Satellite microwave scatterometers are used to obtain ocean surface wind speeds and directions
  - ▣ Separate instruments operating at C- or Ku-band
  - ▣ Technique utilizes ocean normalized radar backscatter ( $\sigma^0$ ) measurements at multiple antenna looks
- Ocean  $\sigma^0$  characteristics
  - ▣ Monotonically increases with wind speed
  - ▣ Anisotropic with relative wind direction ( $\chi$ )
    - $\chi = \text{Wind direction} - \text{Antenna azimuth look}$
- Wind speeds and  $\chi$  are *empirically* related to  $\sigma^0$  through geophysical model functions (GMF)

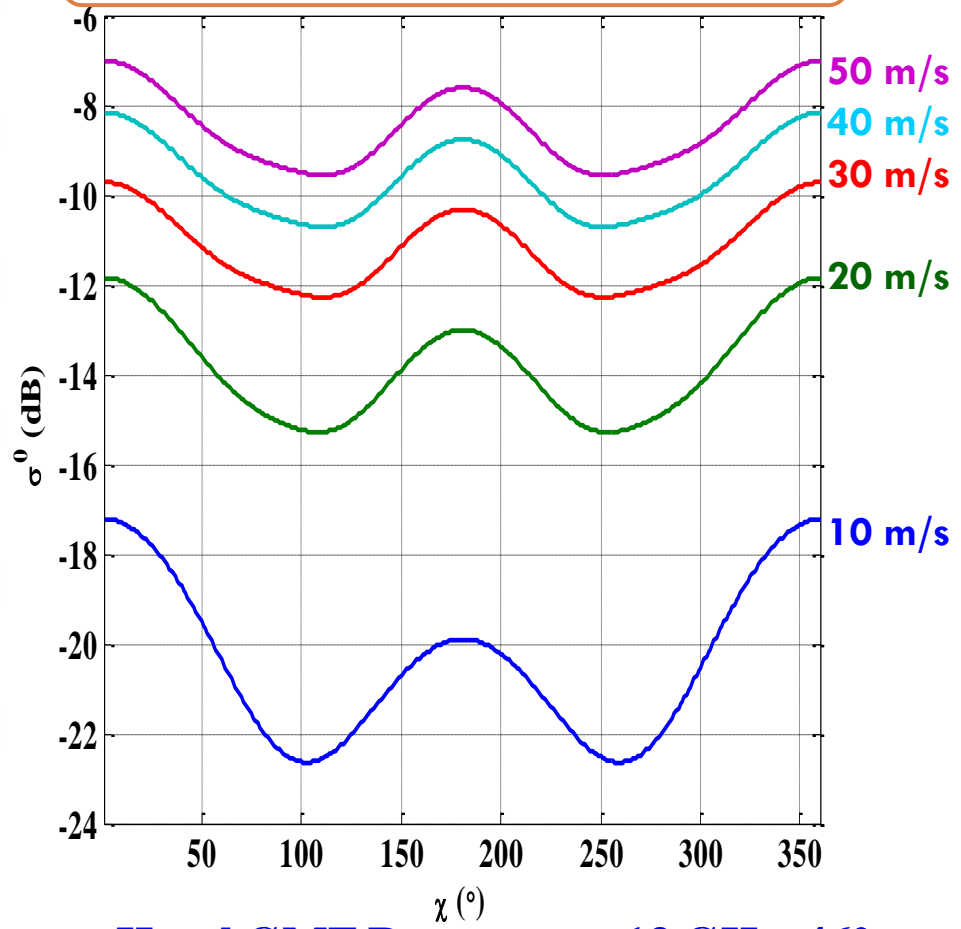


# Introduction – cont.

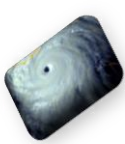


Hurricane wind field

$$\sigma^0 = f(ws, \chi, freq, \theta_{inc}, pol)$$

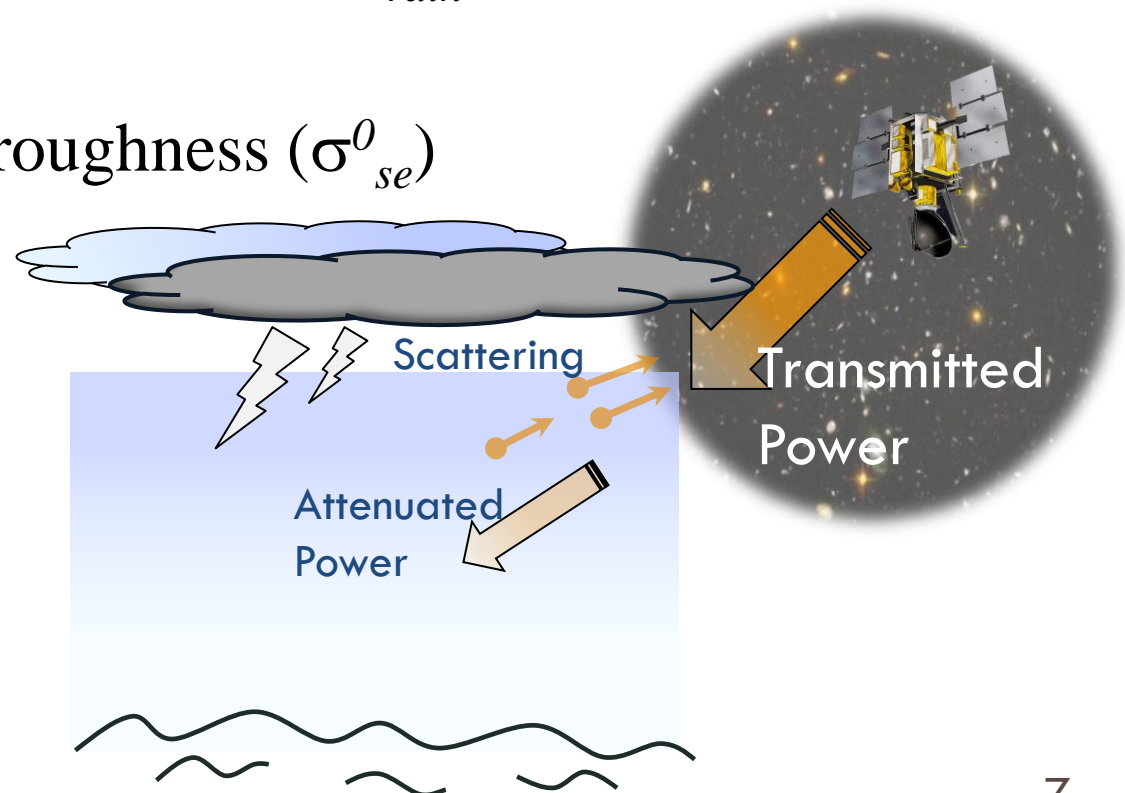


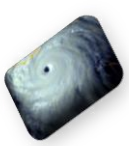
H-pol GMF Response at 13 GHz, 46° Incidence Angle



# Current Scatterometer Issues

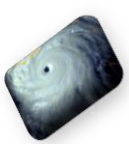
- Rain affects the scatterometer measurement of  $\sigma^0$  in three ways
  - Atmospheric attenuation ( $\alpha$ )
  - Rain volume backscatter (RVBS,  $\sigma^0_{rain}$ )
    - Rain & ice (grapple)
  - Rain induced surface roughness ( $\sigma^0_{se}$ )
    - Splash effect





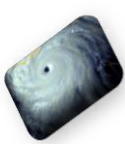
# Current Scatterometer Issues – cont.

- Ku-band scatterometer observations are significantly impacted by rain
  - ▣ Large errors in the retrieved surface winds
- C-band scatterometers measurements are much less susceptible to rain
  - ▣ Longer microwave wave length (lower frequency)
- Extreme wind events are especially troublesome
  - ▣ Peak wind speeds of TCs are significantly under estimated
    - GMF issue
    - Rain attenuation issue
    - Spatial resolution issue



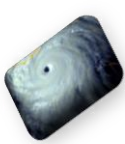
# Next Generation Dual Freq Scatterometer

- DFS is proposed to fly onboard the Global Change Observation Mission-Water Cycle (GCOM-W)
  - ▣ Satellite series planned by the Japanese Aerospace Exploration Agency's (JAXA)
  - ▣ Developed by NASA Jet Propulsion Laboratory (JPL)
- DFS design uses synergy between C- and Ku-band scatterometry and AMSR radiometry to provide improved OVW measurements capability
  - ▣ High wind speed retrieval capability
  - ▣ Near-all-weather conditions
  - ▣ Higher spatial resolution



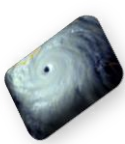
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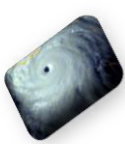
# Simulation Rational

- Historically, simulation has been an effective tool for pre-launch evaluation of satellite scatterometers performance
  - ▣ Comparisons between pre-launch simulation and post-launch observed OVW measurements agree very well with independent “surface truth”
- This dissertation is based on the conceptual design of the OVW remote sensor system for future GCOM-W mission
  - ▣ **Simulation is required because no real data are available**
    - Simulated data used for developing OVW retrieval algorithm
    - Predicting on-orbit OVW measurement performance
      - OVW retrieval accuracy
      - Spatial imaging characteristics



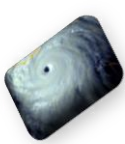
# Simulation Challenges

- Under hurricane environmental conditions, there are several simulation challenges
  - ▣ Relationship between surface  $\sigma^0$  and OVW
    - Hurricane GMF
  - ▣ Simulating active and passive sensor observations
    - Top of the atmosphere
  - ▣ Numerical weather models capability to produce realistic conditions that exist in hurricane environment
    - Dynamic storm structure
    - Wide range of geophysical parameters
    - Rain micro-physical characterization



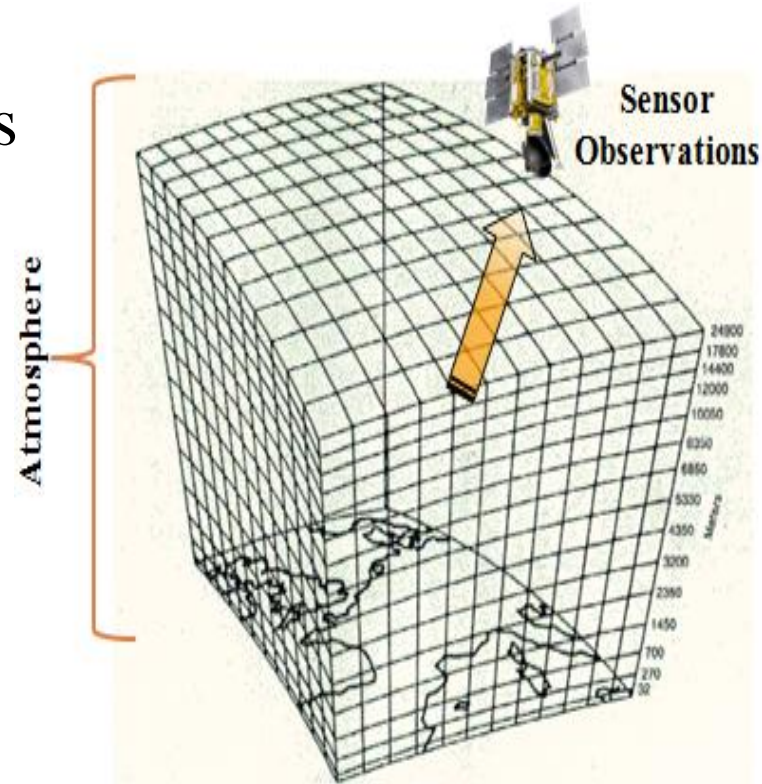
# Hurricane GMF

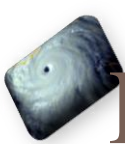
- A decade of airborne, dual-frequency scatterometer experiments have been conducted in hurricanes by University of Massachusetts (UMass)
  - ▣ C-Scat & Ku-Scat radars
  - ▣ Imaging Wind and Rain Air-borne Profiler (IWRAP)
- C- and Ku-band GMFs have been developed for hurricanes
  - ▣ IWRAP GMF used in this dissertation



# Sensors Observations

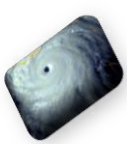
- Calculation of RVBS, rain attenuation, and radiometer brightness temperatures
  - ▣ Passive radiative transfer modeling (RTM)
  - ▣ Mie-scattering
    - Analytical solution of Maxwell's equations for the scattering of electromagnetic (EM) radiation by particles
      - Critically dependent upon hydrometeor parameters:
        - Number of particles per unit volume
        - Drop Size Distribution (DSD)
        - Physical state of particles (ice or water)
        - Shape of particles
- **JPL has extensive atmospheric EM modeling capability that was used in this dissertation**



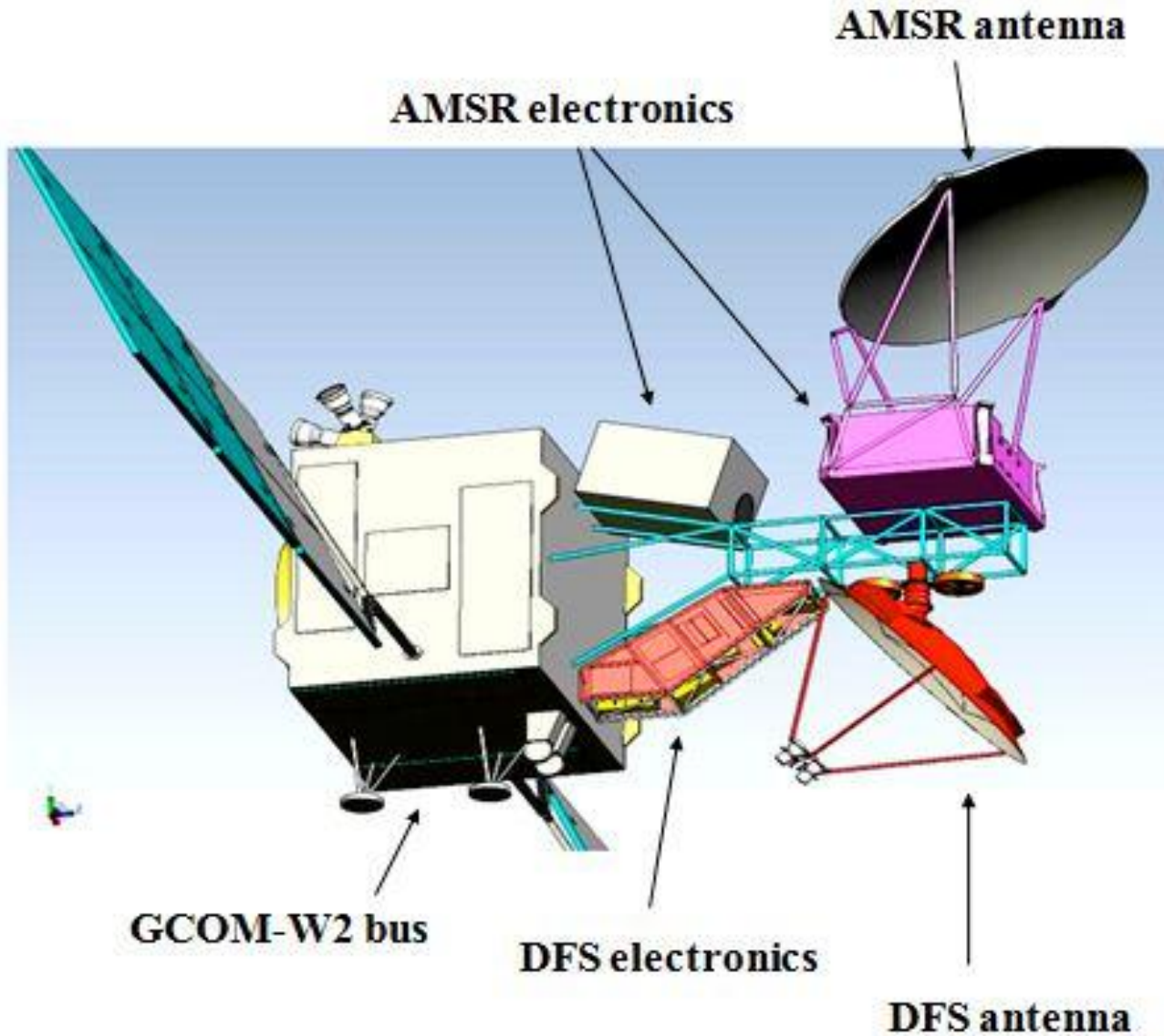


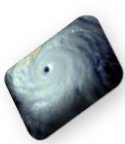
# Hurricane Numerical Model Simulation

- Simulated hurricane surface wind fields are representative of actual hurricanes
  - ▣ Models produce realistic spatial patterns of surface winds
    - Peak winds and gradients including eye and eye-wall meso-scale features
- Numerical models ability to produce realistic rain micro-physical properties (that could exist in hurricane environment) needs to be validated
  - ▣ Rain micro-physical properties are very dynamic in space and time
    - Model rain results have not been validated except with limited airborne in situ and remote sensing observations



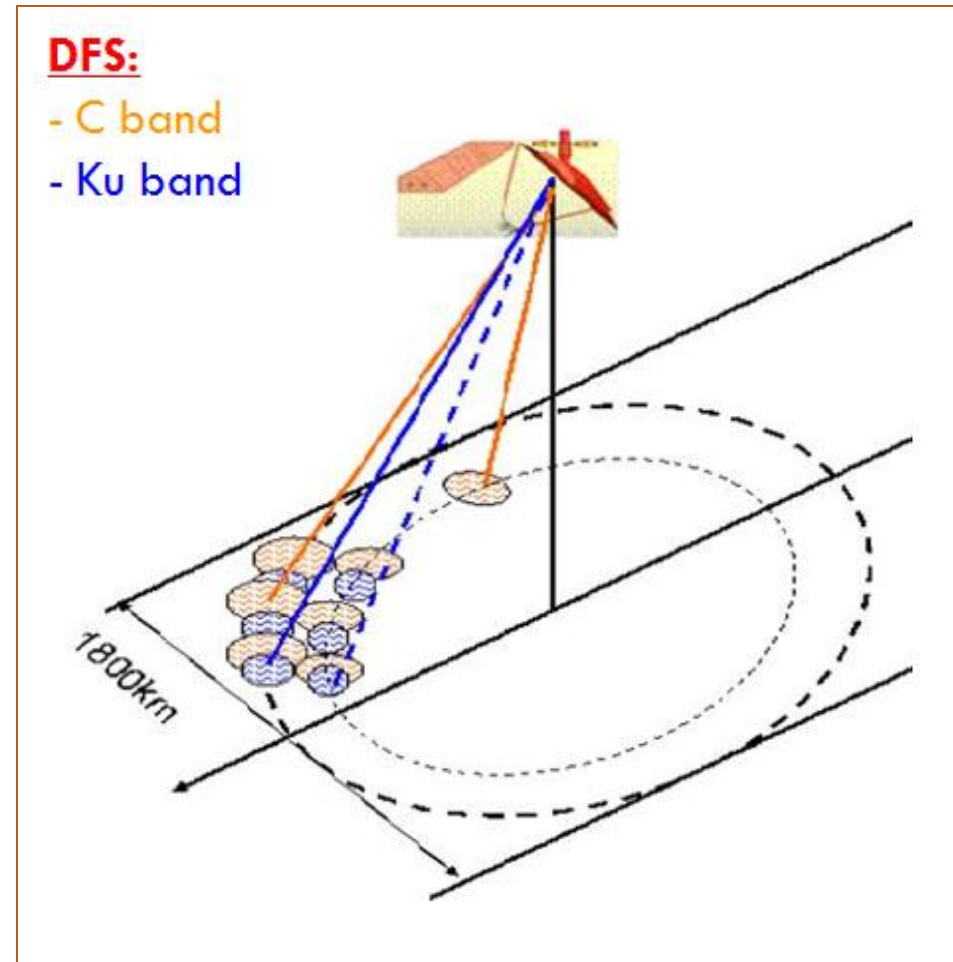
# GCOM-W OVW Remote Sensing System





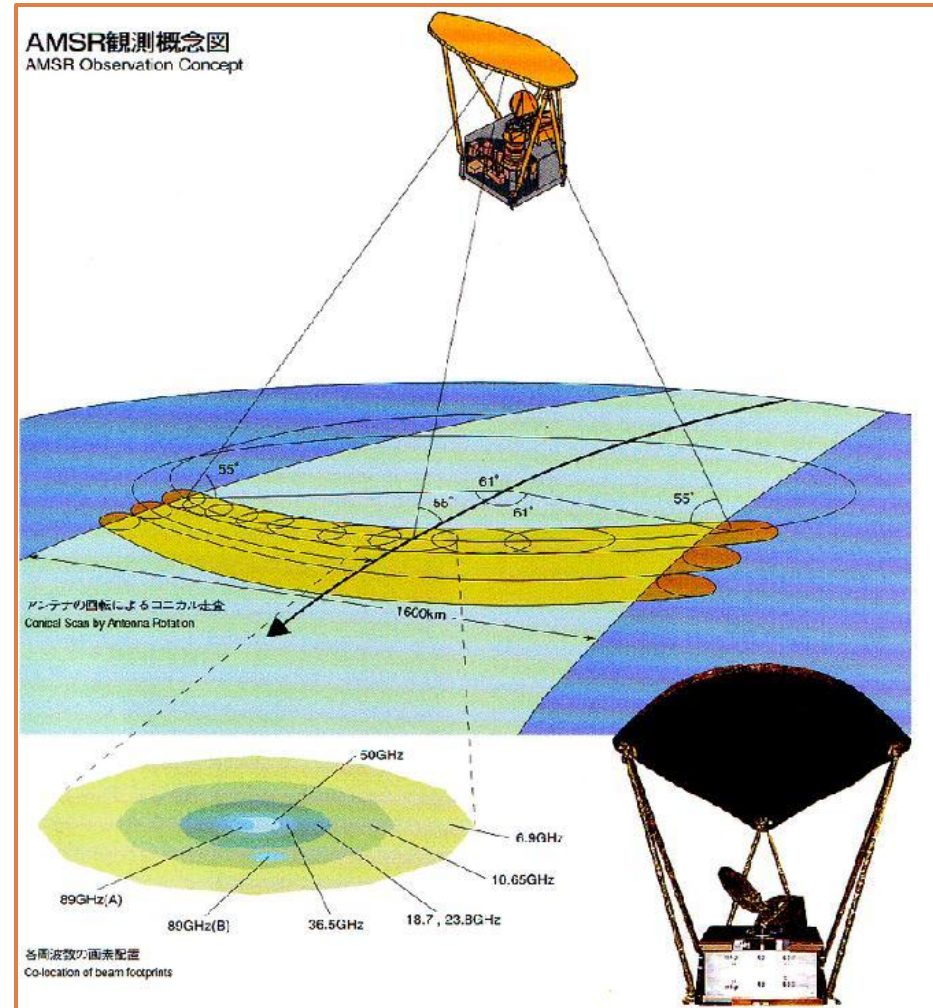
# Instrument Description – cont.

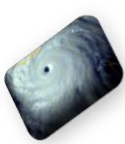
- DFS (GCOM-W2)
  - ▣ Conical-scan pencil beam
    - 360° field of view
  - ▣ Ku-band scatterometer at 13.4 GHz
    - Outer V-pol @ 57.7° & inner H-pol @ 49.6° EIA
  - ▣ C-band scatterometer at 5.4 GHz
    - H-pol only (outer @ 57.7°, and inner @ 49.6° EIA)
  - ▣ Swath width 1800 km



# Instrument Description – cont.

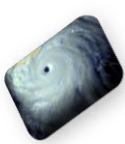
- AMSR (GCOM-W2)
  - ▣ Conical-scan microwave radiometer
  - ▣ Dual-polarized (H- & V-pols.) Tb measurements
    - Six frequencies (6.9, 10.7, 18.7, 23.8, 36.5, and 89 GHz) @ 55° EIA
  - ▣ Vertical-polarized Tb measurements
    - Two frequencies (50.3, 52.8 GHz) @ 55° EIA
  - ▣ Swath width 1600 km





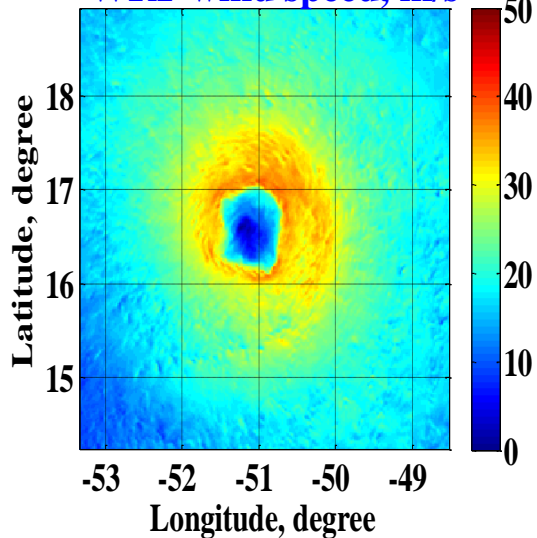
# Numerical Weather Model Simulation

- Weather Research & Forecasting (WRF) Model
  - ▣ State-of-the-art meteorological model
  - ▣ Nested grids (best resolution @ 1.3 km)
  - ▣ Realistic 3-D eye wall, rain bands and other convective and meso-scale structure
    - Water in vapor, liquid and ice (grapple)
    - Surface wind speeds and directions
- Passive RTM with Mie scattering
  - ▣ Dual polarized microwave radiances (Tb)
  - ▣ C- & Ku-band RVBS and attenuation calculation
- **All simulated geophysical fields provided by Dr. Svetla Hristova-Veleva, radar science and engineering at JPL**

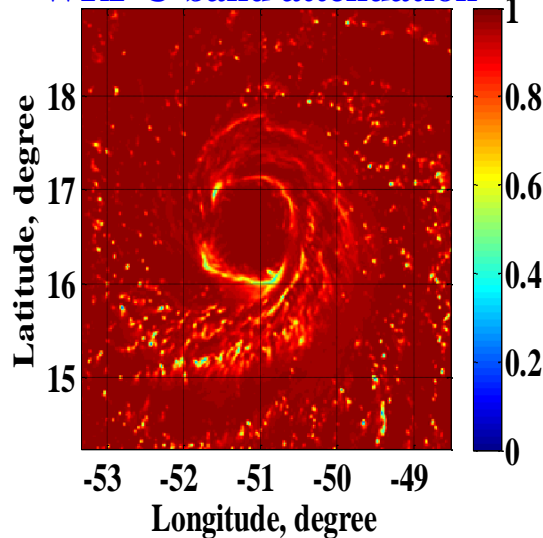


# WRF and RTM Results

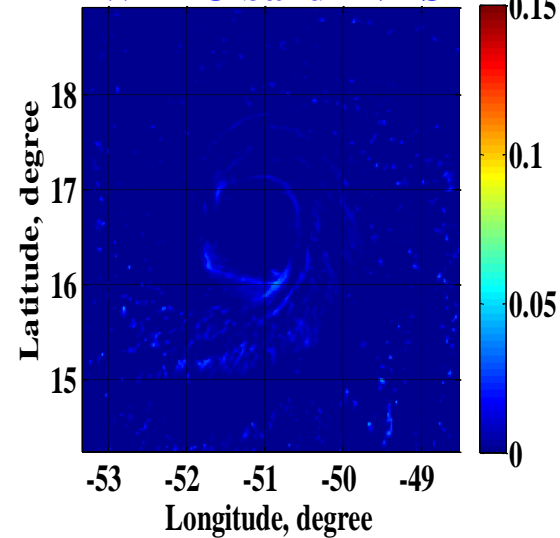
WRF wind speed, m/s



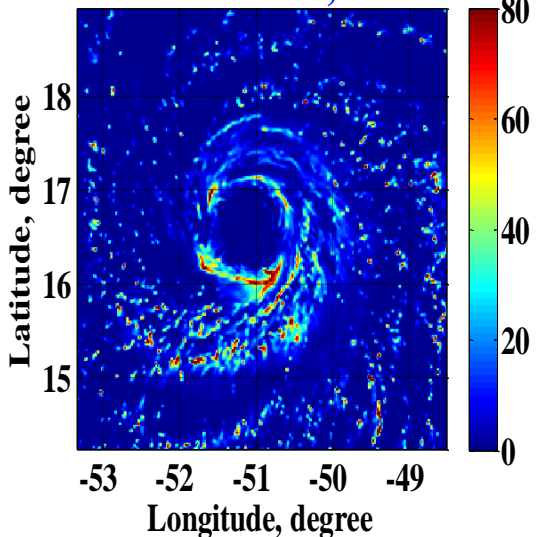
WRF C-band attenuation



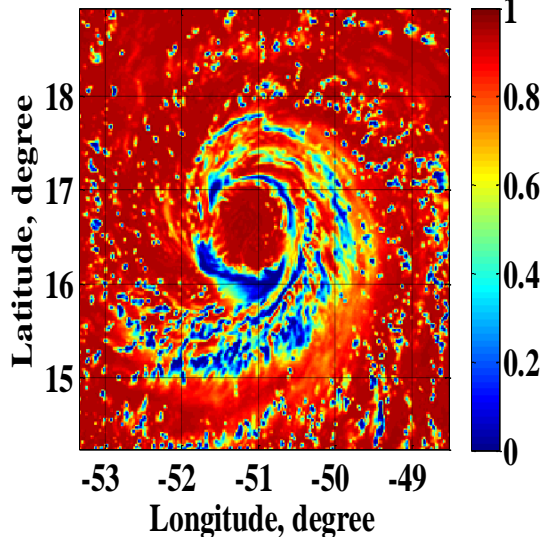
WRF C-band RVBS



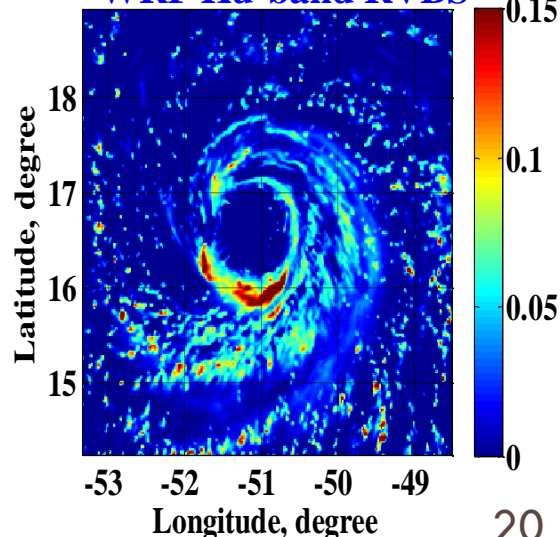
WRF rain rate, mm/hr

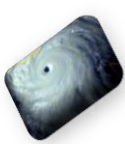


WRF Ku-band attenuation



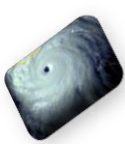
WRF Ku-band RVBS





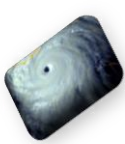
# Hurricane Isabel Simulation Cases

- WRF geophysical fields were used as the “nature run”
  - ▣ Simulation of 6 scenes from Hurricane Isabel in September 2003
  - ▣ **Provided by JPL**
- Simulation intended to be representative of real active/passive remote sensor observations
- For validation purposes, simulated sensor observations are compared with real data obtained from the Advanced Earth Observing System-II (ADEOS-II)
  - ▣ SeaWinds
    - Ku-band scatterometer
  - ▣ AMSR
    - Six dual polarized frequencies (6.9, 10.7, 18.7, 23.8, 36.5, and 89 GHz)



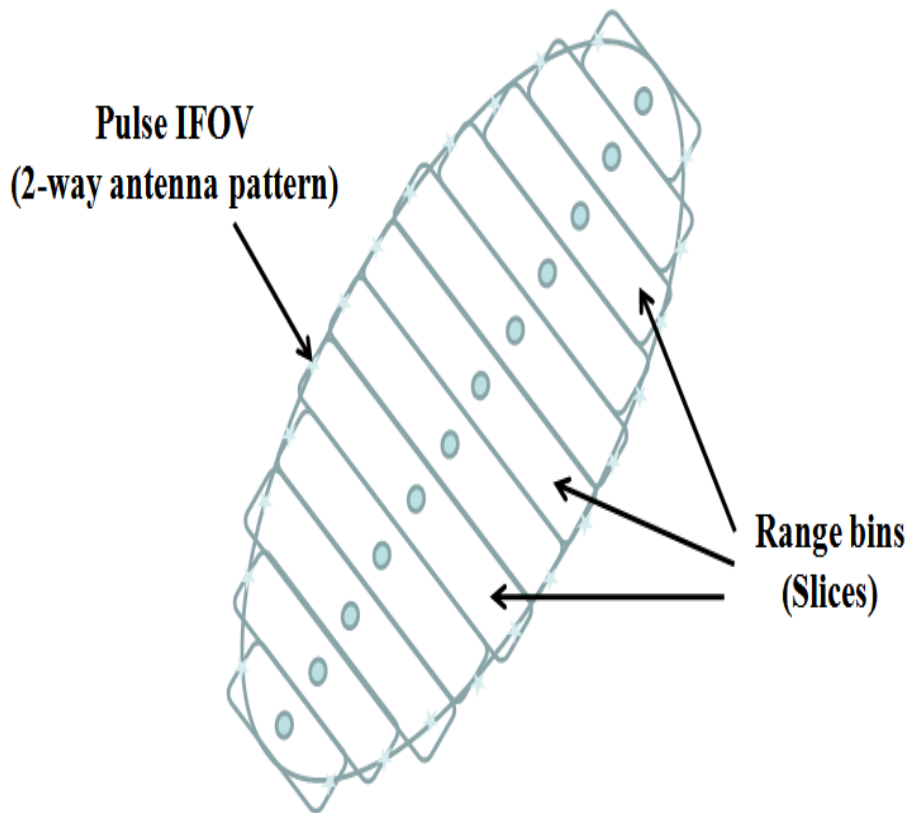
# Instruments Viewing Geometry

- Conical scanning orbit simulator developed to simulate DFS and AMSR viewing geometry
  - ▣ Instantaneous field of view (IFOV) & boresight locations on the Earth's surface for both DFS & AMSR
- For the DFS, the simulated IFOVs were further divided into range bins or slices with a width of 2 km each
  - ▣ Account for range gating processing

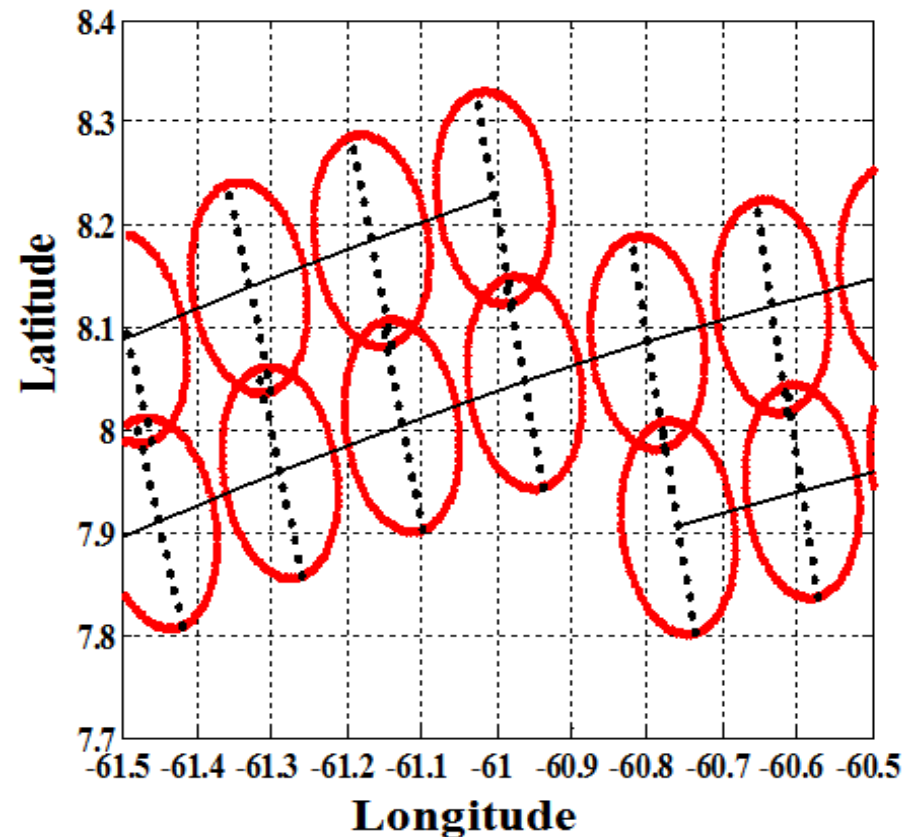


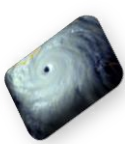
# Instruments Viewing Geometry – cont.

## Single pulse IFOV with range bins



## DFS Ku-band outer beam scan portion



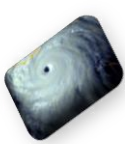


# DFS Measurements Simulation

- High resolution WRF fields were interpolated to simulated sensor IFOV (and DFS range slice) locations
  - ▣ Wind speed and direction fields
  - ▣ RVBS and attenuation fields
- Interpolated WRF wind fields mapped into surface rain-free C- and Ku-band  $\sigma^0$  values ( $\sigma^0_{wind}$ ) using IWRAP GMF
- $\sigma^0_{wind}$  values are then corrupted with rain ( $\sigma^0_{with\ rain}$ )

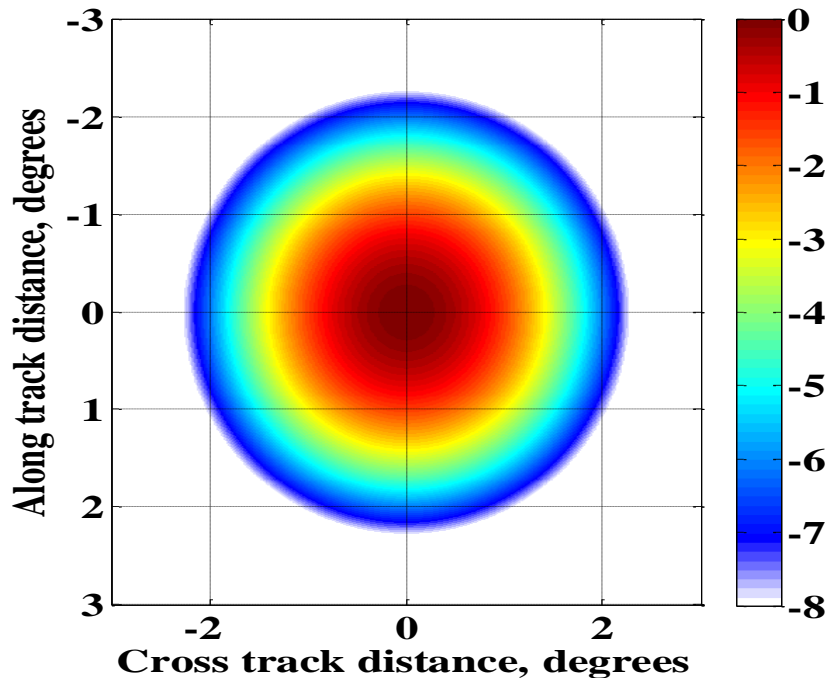
$$\sigma^0_{with\ rain} = (\sigma^0_{wind}) \times \alpha + RVBS$$

- Only RVBS and attenuation effects of rain were considered

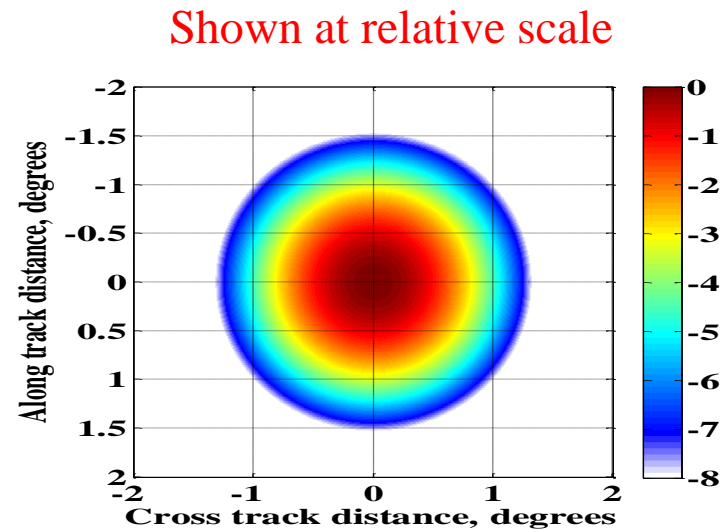


# DFS Measurements Sim. – cont.

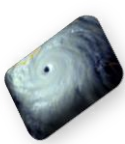
- Apply two-way antenna pattern on  $\sigma^0_{with\ rain}$  values to generate noise-free  $\sigma^0$  values at top of atmosphere
  - $\sigma^0_{Top, noise-free}$



**C-band Antenna gain, dB**



**Ku-band Antenna gain, dB**



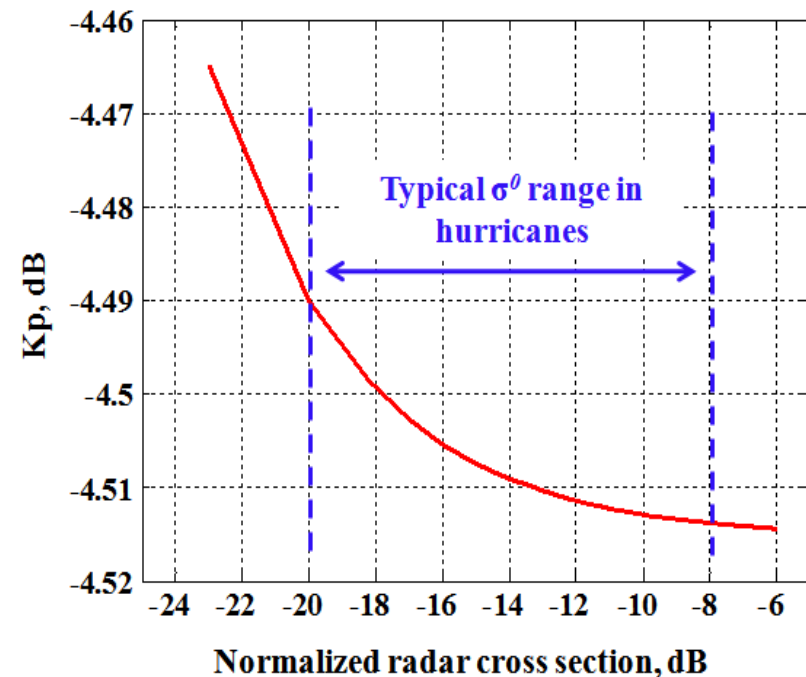
# Random Noise Corruption

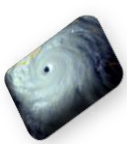
- $\sigma^o_{Top, noise-free}$  values were corrupted with noise to generate the top of the atmosphere  $\sigma^o$  values ( $\sigma^o_{Top, noisy}$ )
  - ▣ Represents expected scatterometer measurement noise
- Random noise simulation using zero-mean Gaussian noise with  $K_p$  standard deviation

$$K_p = \sigma^o \sqrt{\frac{1}{N} \left( 1 + \frac{2}{SNR} + \frac{1}{SNR^2} \right)}$$

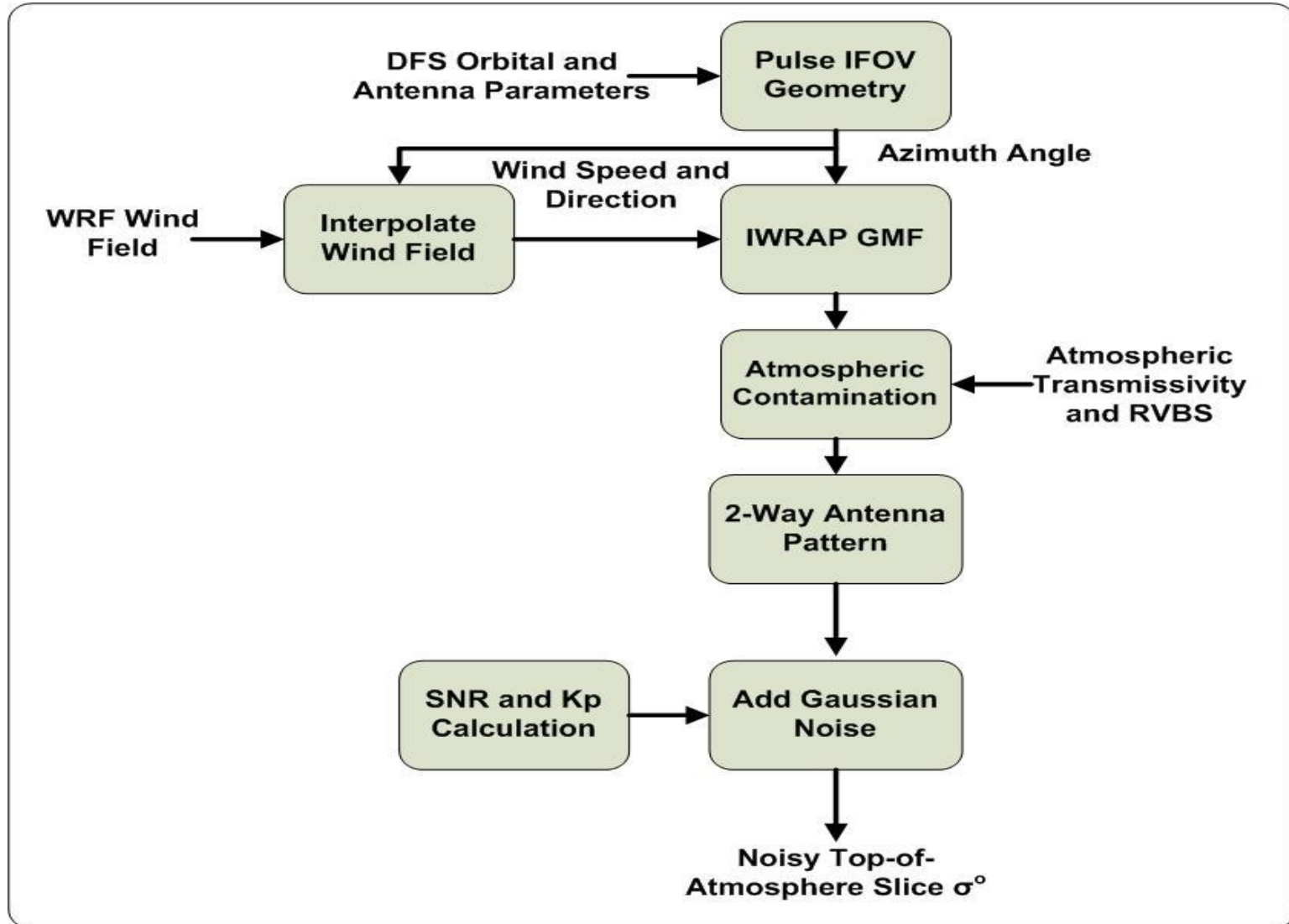
$$\sigma^o_{Top, noisy} = (1 + K_p) \times \eta \times \sigma^o_{Top, noise-free}$$

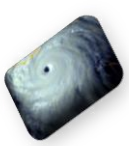
- $N$ : number of independent range bins averaged together prior to down-linking
- " $\eta$ " is a unit normal Gaussian random number generator





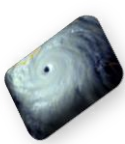
# DFS Observations Simulation Summary



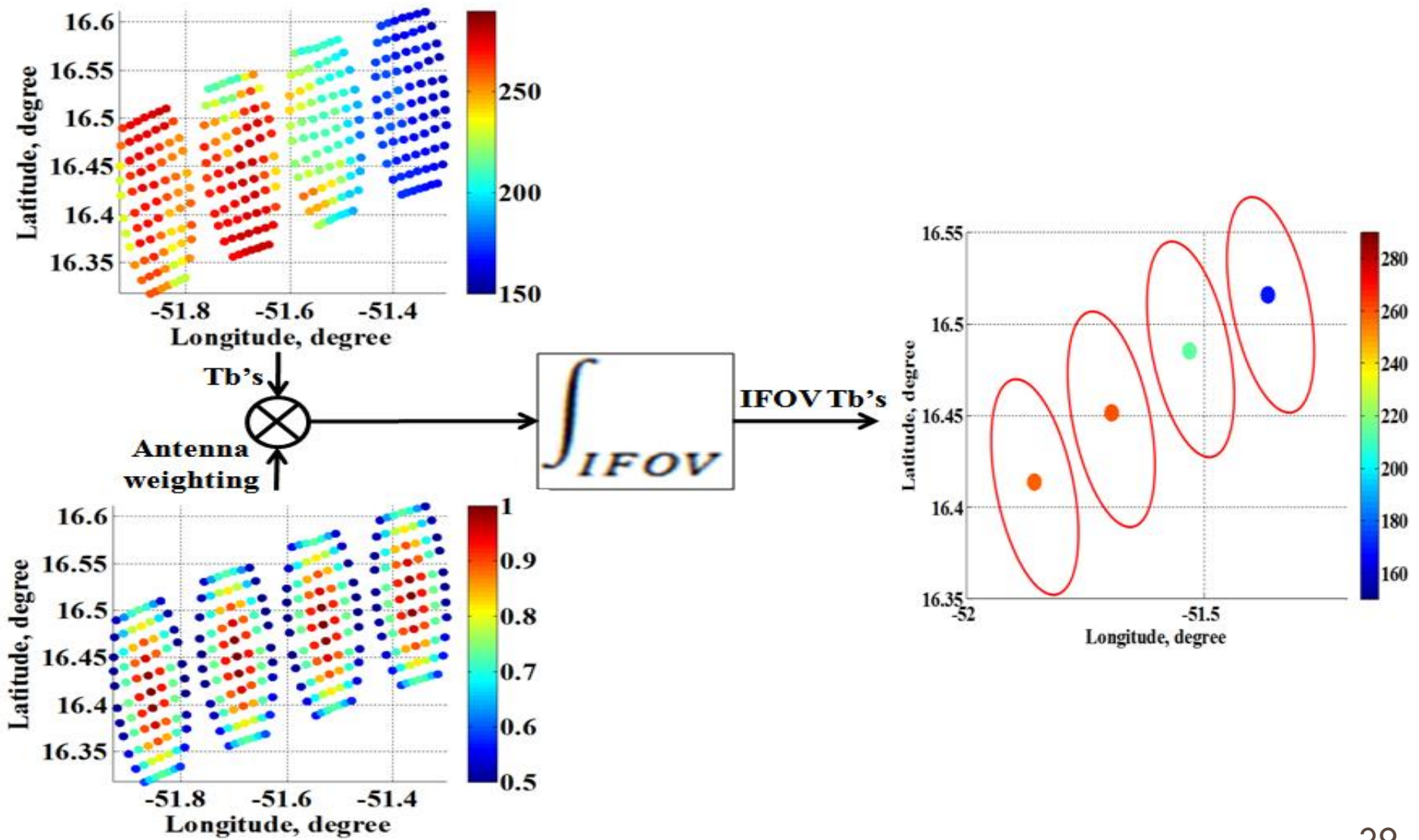


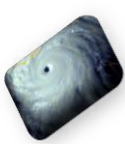
# AMSR Measurements Simulation

- High resolution (1.3 km) H- and V-pol Tb's at the top of the atmosphere were **simulated by JPL** using RTM
  - ▣ AMSR frequencies and incidence angle
- Under this dissertation, Tb fields were convolved with antenna beam pattern over IFOV to simulated the AMSR antenna temperature
  - ▣ Surface locations found from instrument viewing geometry



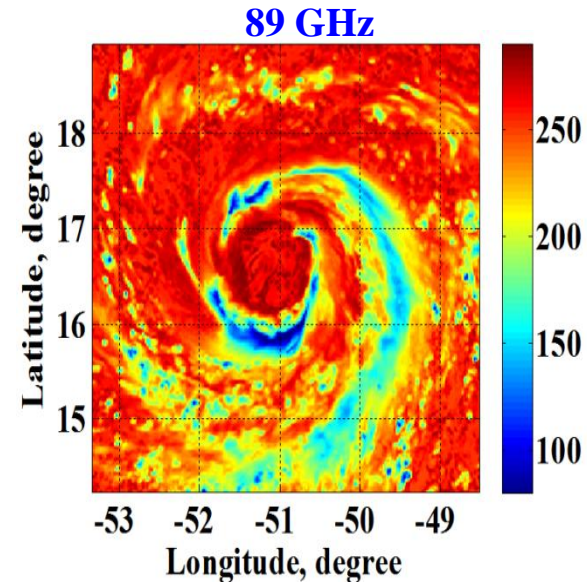
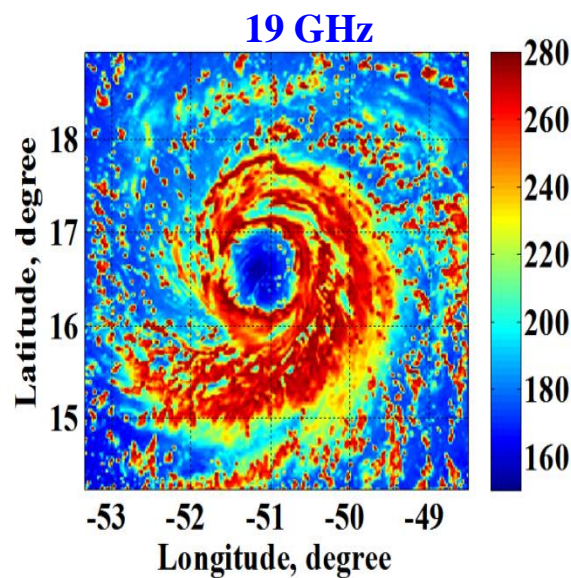
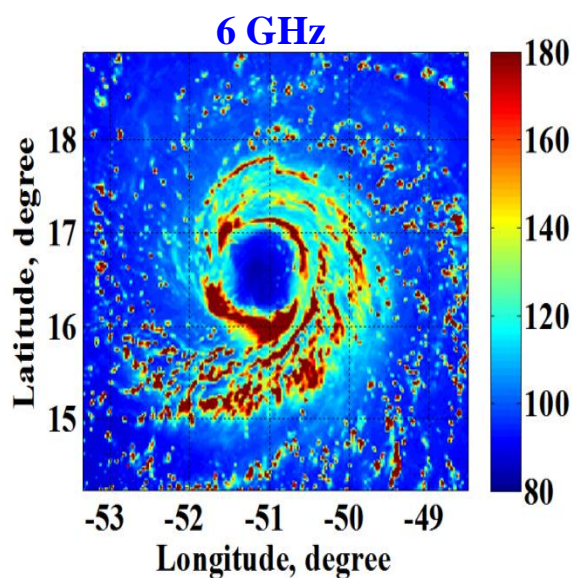
# AMSR Measurements Sim. – cont.



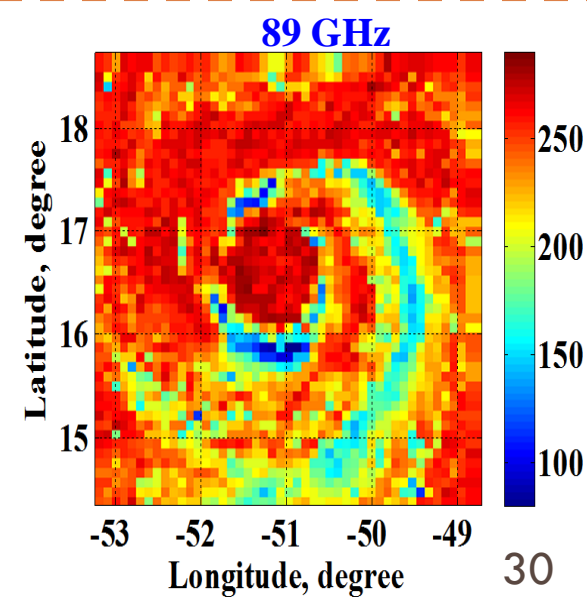
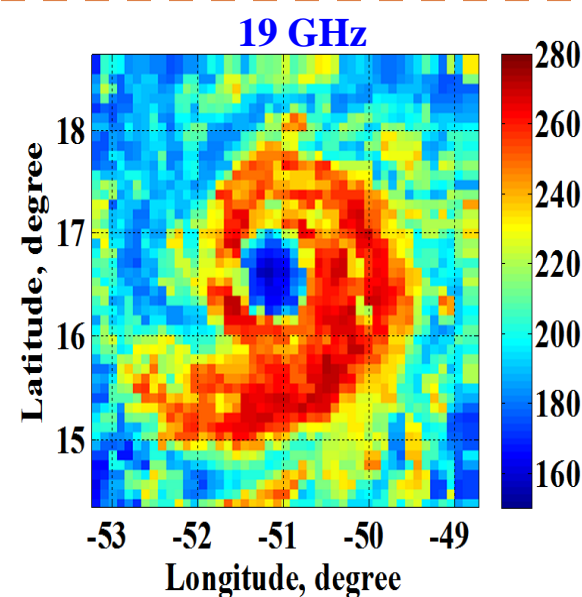
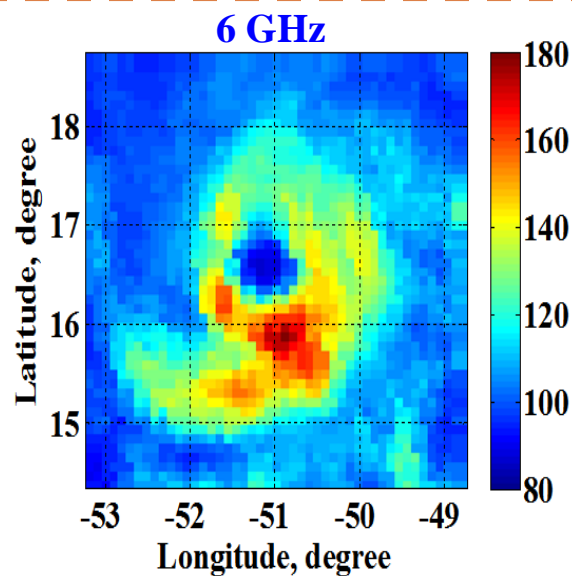


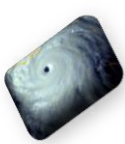
# AMSR Measurements Sim. – cont.

WRF H-pol Tb, K



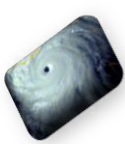
AMSR H-pol sim. Tb, K





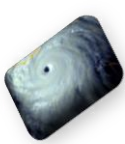
# Simulated $\sigma^0$ and Tb Validation

- The goal of the validation process is to assess capability of the simulation to generate realistic sensor observations ( $\sigma^0$  and Tb) at top of atmosphere
- Unfortunately, the WRF simulation (“nature run”) cannot match the actual hurricane environmental conditions on a pixel by pixel basis
- Therefore, the validation procedure employs qualitative statistical comparisons on a field-wise basis rather than quantitative comparisons



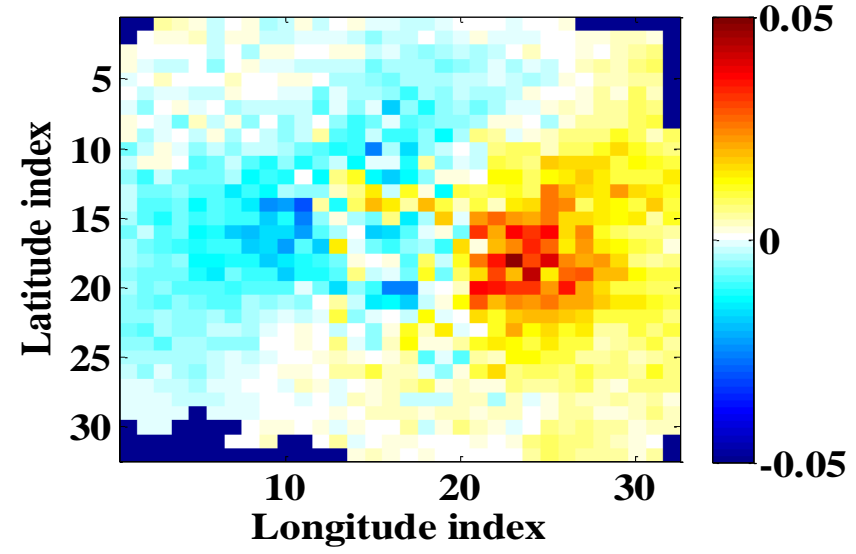
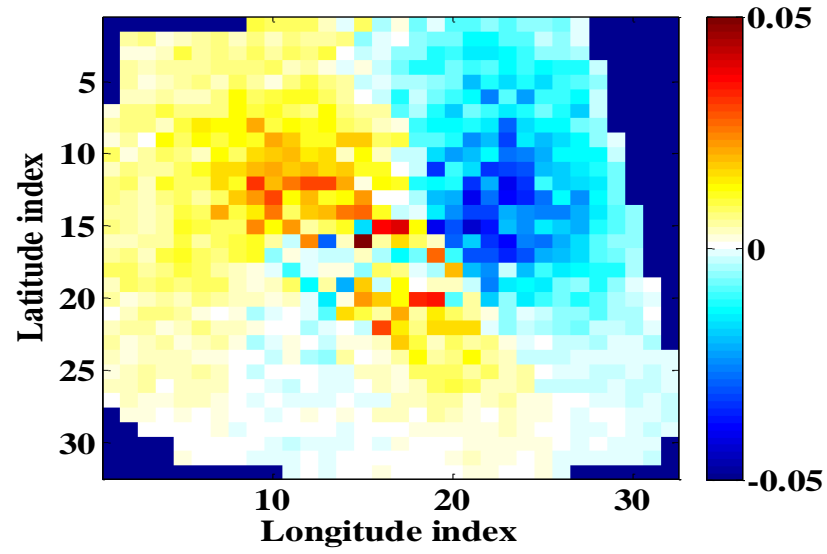
# Wind Direction Signature

- $\Delta\sigma^0$  is the difference between measurements from multiple azimuth looks at same earth location
  - ▣ Isotropic  $\sigma^0$  (mean) cancels when calculation the difference between forward and aft looks
  - ▣ Dominant feature of  $\Delta\sigma^0$  obtained from multiple azimuth observations caused by wind direction rotation around the eye
- Wind directional signature ( $\Delta\sigma^0$ ) of simulated  $\sigma^0$  values compared with real measurements provided by SeaWinds

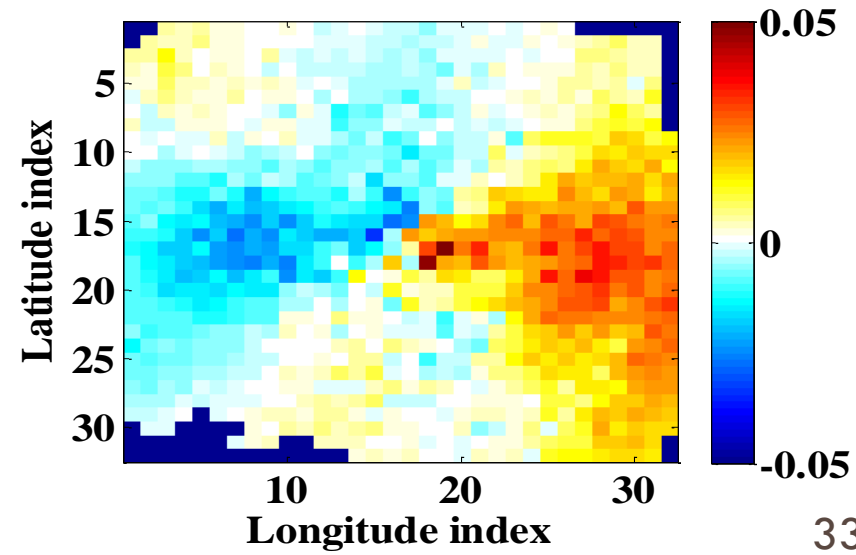
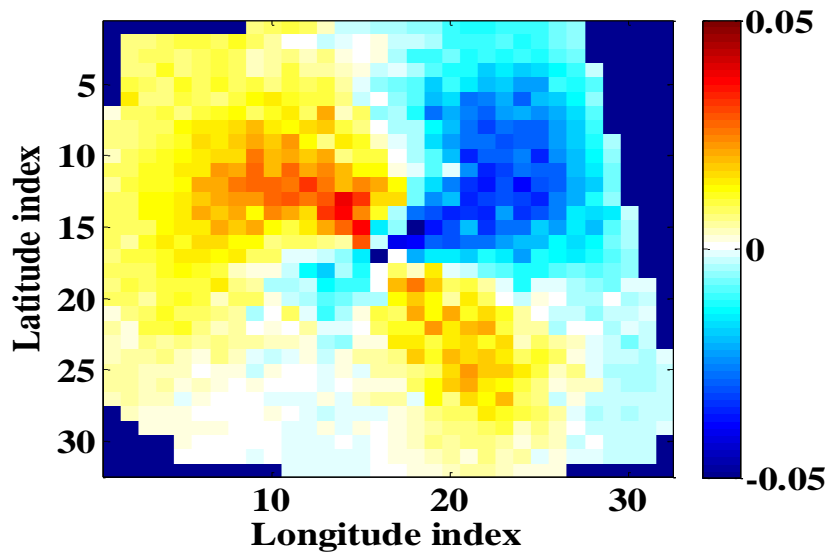


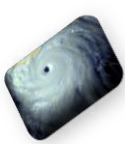
# Wind Direction Signature – cont.

**Sim. measurements**



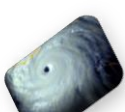
**Sea Winds measurements**





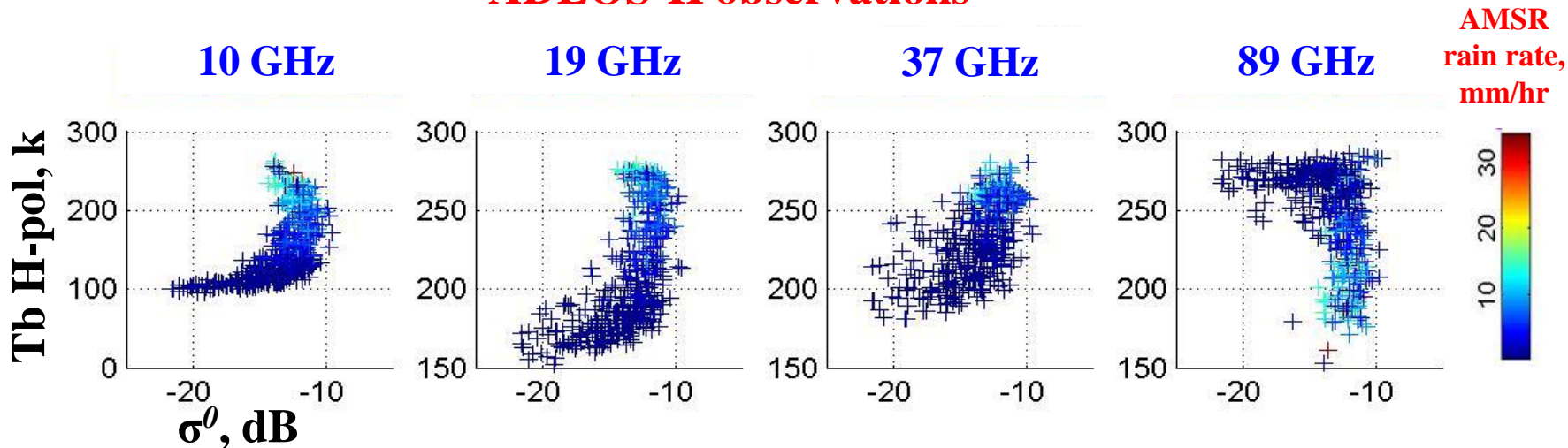
# $\sigma^0$ and Tb at Top of Atmosphere

- Cross-correlations between active and passive spatial signatures at top of atmosphere were analyzed
  - ▣ AMSR Tb for different frequencies and polarizations were compared to polarized SeaWinds  $\sigma^0$
  - ▣ Qualitative statistical comparisons for four Isabel cases

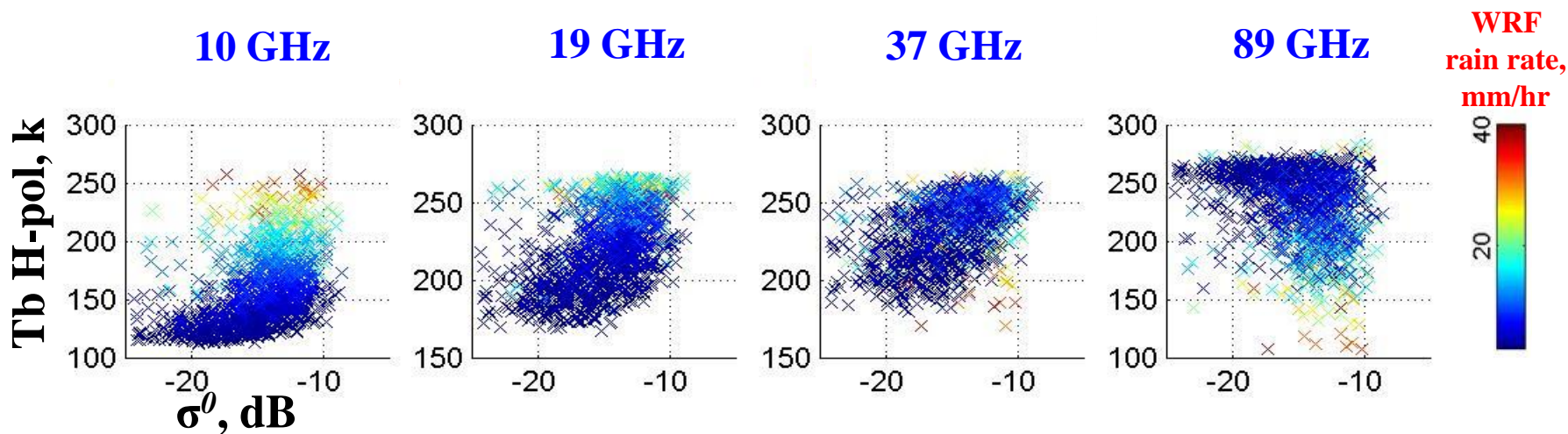


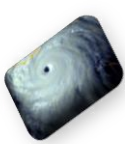
# Tb & $\sigma^0$ at Top of Atmosphere – cont.

## ADEOS-II observations



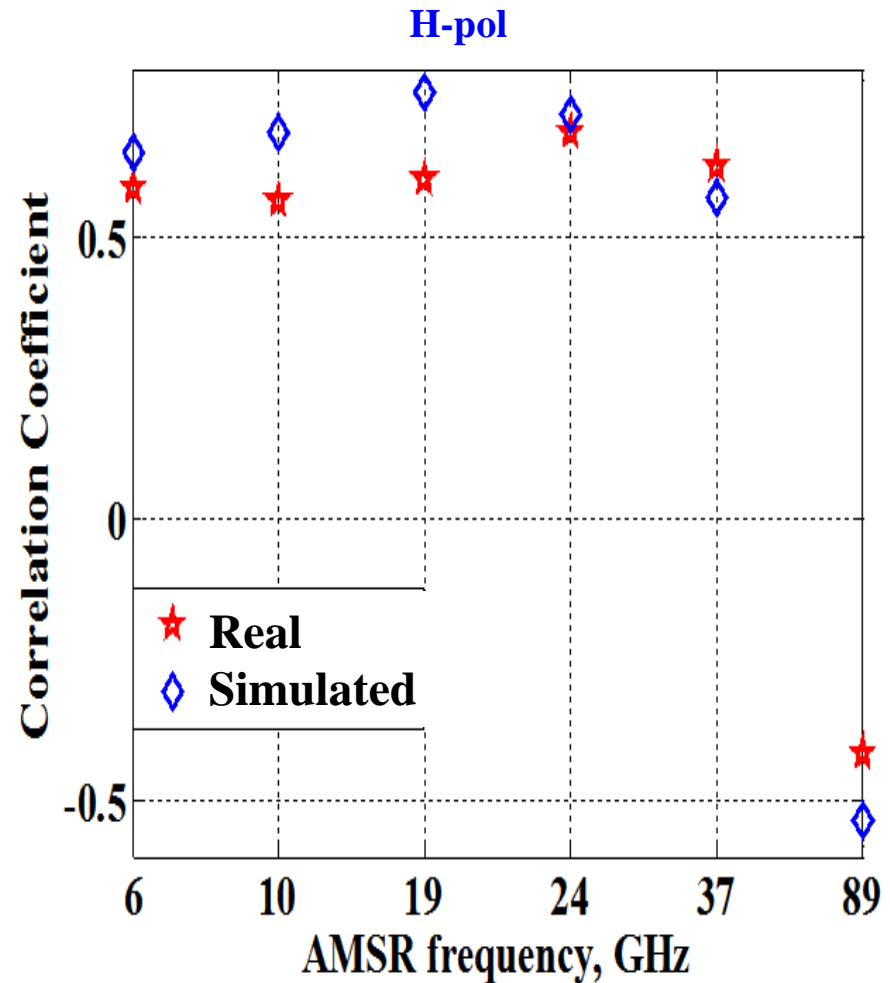
## Simulated observations

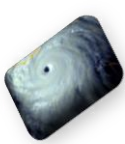




# Covariance Analysis

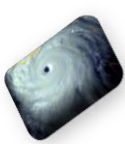
- Tb's are used to provide rain correction to  $\sigma^0$  values at the top of the atmosphere
  - ▣ Having simulated active and passive measurements correlated as real observations is crucial to the fidelity of the simulation





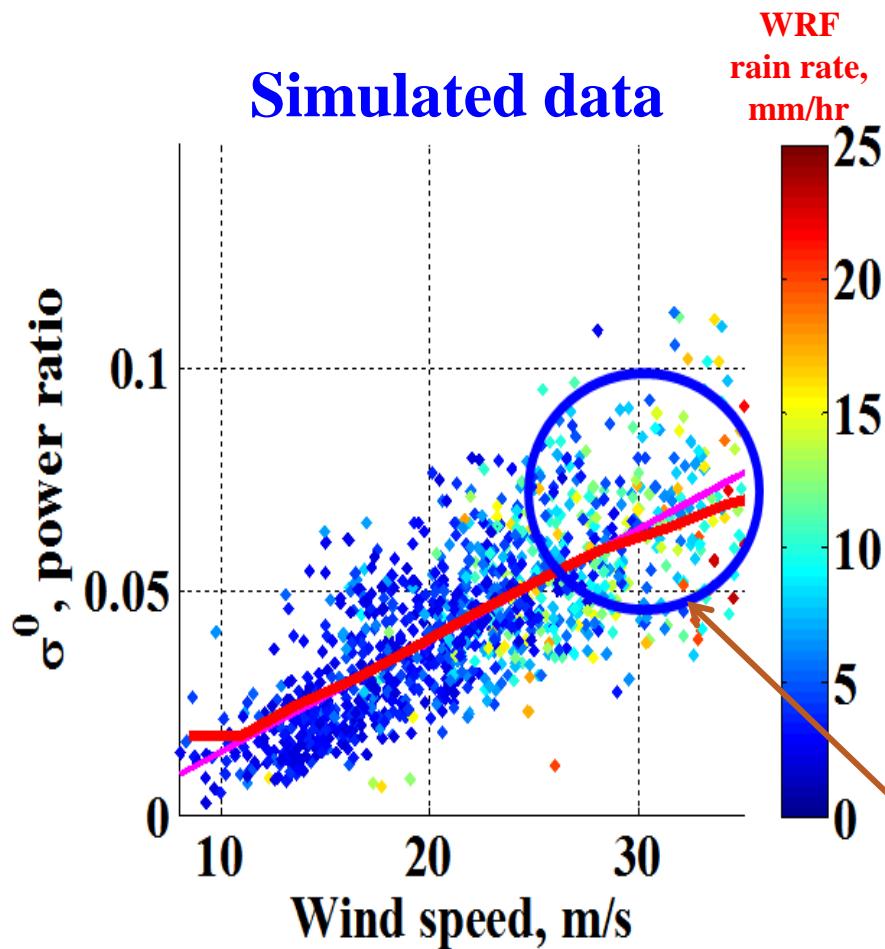
# Ku-band $\sigma^0$ Comparison

- Simulated  $\sigma^0$  values at top of atmosphere are compared to observed SeaWinds measurements
  - ▣ Under rain-free conditions  $\sigma^0$  values will monotonically increase with wind speed
  - ▣ In hurricane eye wall, high wind speeds are usually associated with high rain rates
  - ▣ Attenuation due to heavy rain dominates in this region, which causes scatterometer measured  $\sigma^0$  values to be reduced (compared to clear sky at the corresponding wind speed)

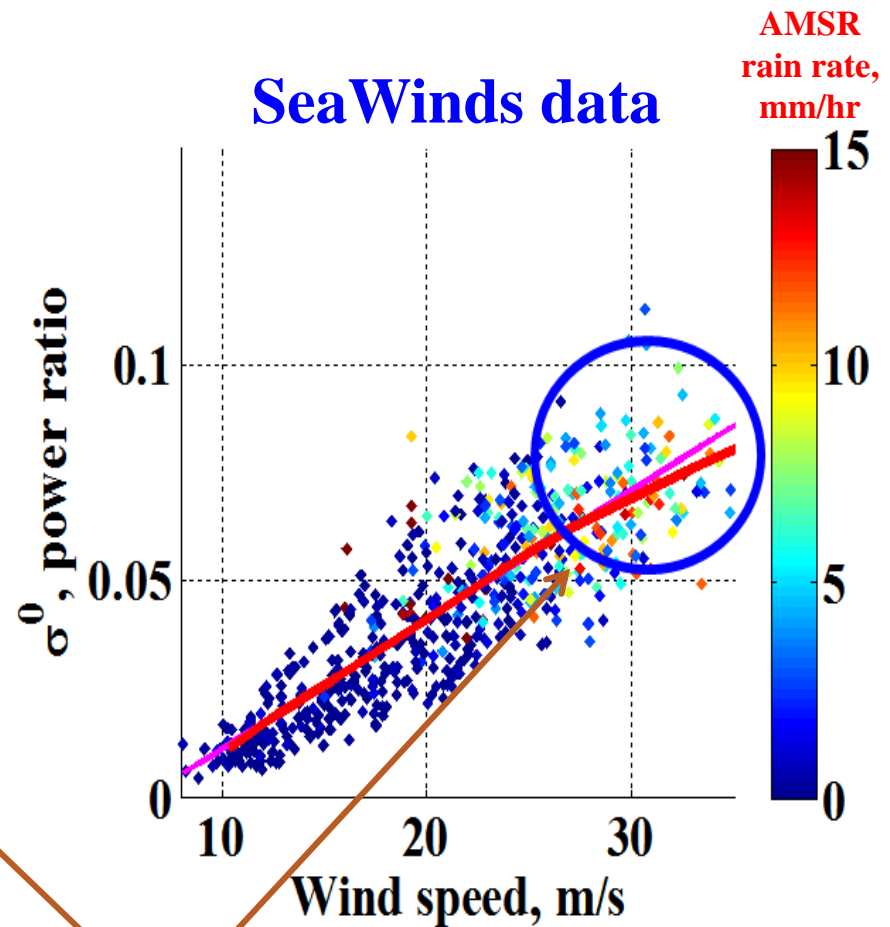


# Ku-band $\sigma^0$ Comparison – cont.

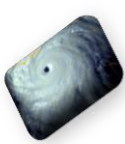
### Simulated data



### Sea Winds data

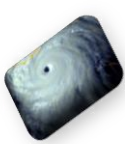


Reduction due to high rain attenuation



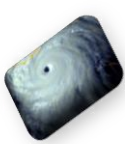
# Validation Summary

- Validation results are encouraging but not conclusive; however, they increase our confidence that simulated sensor observations are representative of real observations in TC
  - ▣ WRF can produce realistic environmental conditions that exist in real hurricanes
  - ▣ Theoretical modeling of precipitation effects: RVBS,  $\alpha$ , and  $T_b$  at top of atmosphere appear reasonable based upon comparisons between TOA simulated and observed  $\sigma^0$  and  $T_b$
- Simulated hurricane nature runs were used to derive relationships to integrate the effects of wind and rain on  $\sigma^0$ 
  - ▣ Realistic radar observations



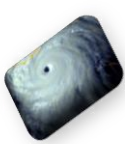
# Presentation Outline

- Dissertation Objectives
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  - ▣ Measurements Simulation
  - ▣ Measurements Validation
- **Retrieval Algorithm**
  - ▣ **Rain Correction**
  - ▣ **Wind Retrieval**
- Performance Evaluation
- Summary & Conclusion

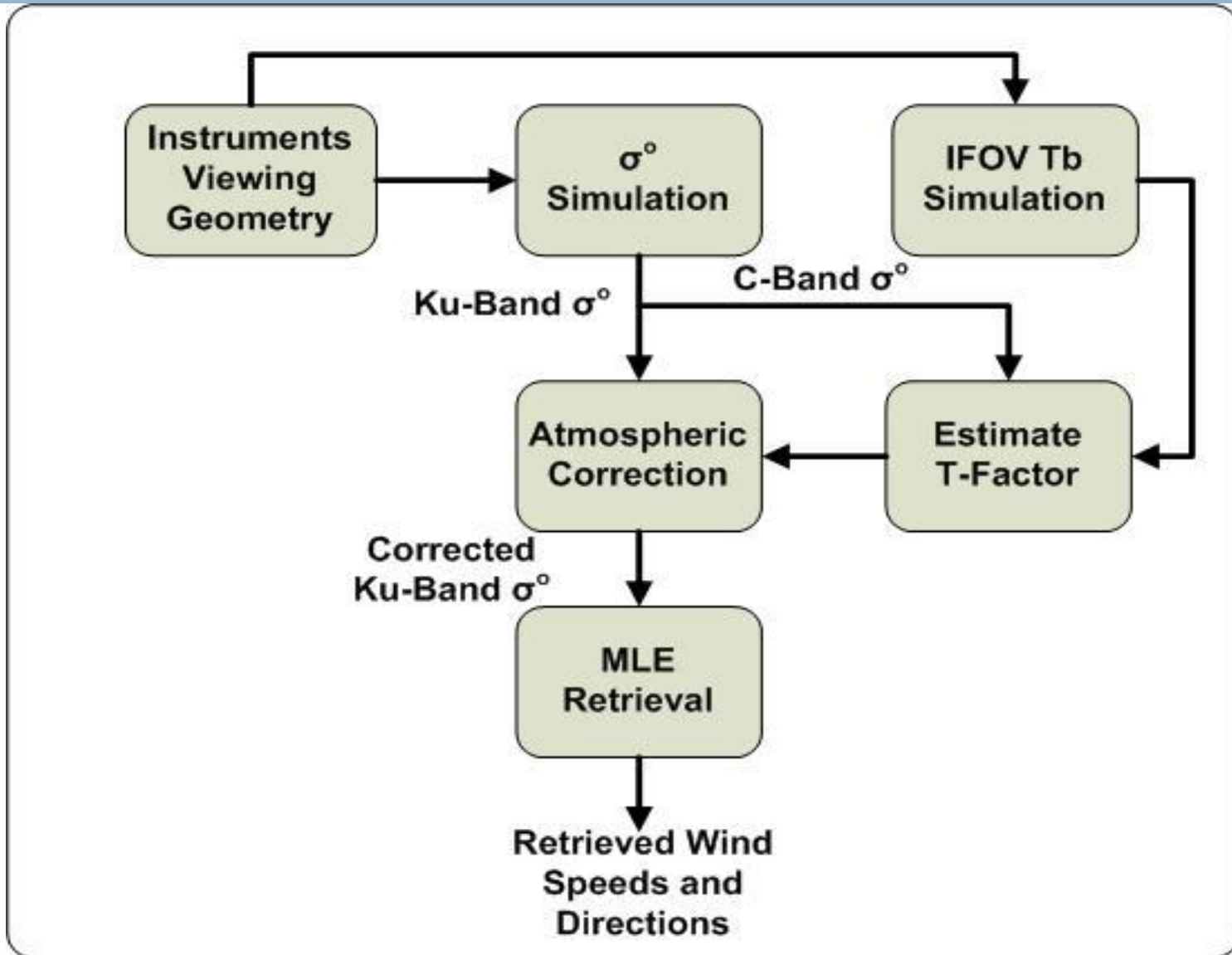


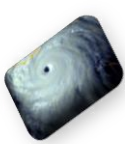
# Retrieval Algorithm Objectives

- Retrieve accurate wind vectors over full range of environmental conditions
  - Including high winds (up to 60 m/s)
  - Intense rain (up to 100 mm/hr)
- Rain correction
  - ▣ Corrects high resolution Ku-band scatterometer measurements for rain effects
    - Uses C- band DFS measurements & dual polarized multi-frequency AMSR measurements
- OVW retrieval
  - ▣ Uses conventional maximum likelihood estimation (MLE)



# End-to-end Simulation Summary





# Rain Correction

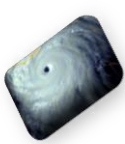
- Conventional way to corrected Ku-band radar backscatter ( $\sigma^0_{Ku, Corrected}$ )

$$\sigma^0_{Ku,corrected} = \frac{\sigma^0_{top} - \hat{\sigma}^0_{rain}}{\hat{\alpha}}$$

- Contribution from  $\alpha$  and  $\sigma^0_{rain}$  modeled as a lumped integrated transmissivity (T-factor)

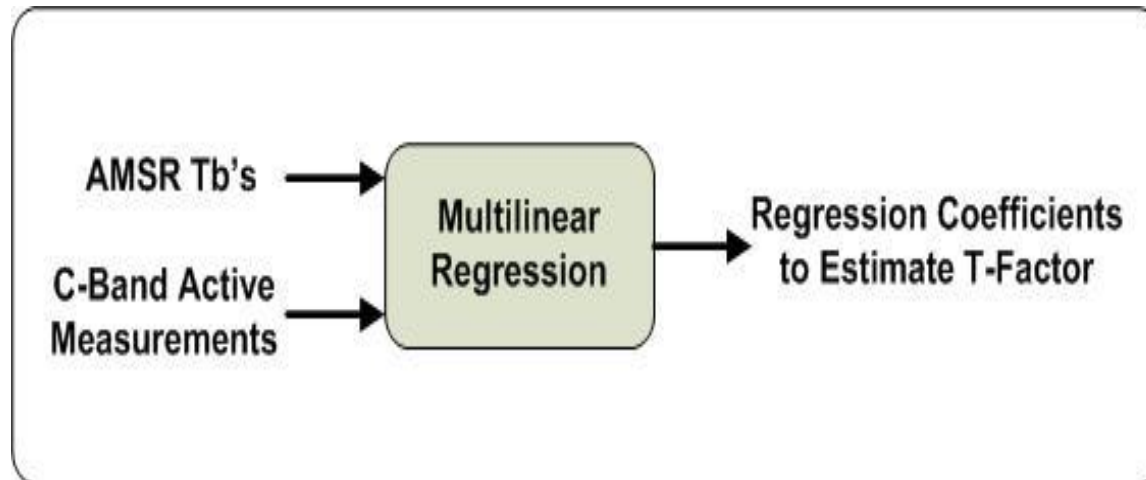
$$\sigma^0_{Ku,corrected} = \sigma^0_{top} \times \hat{T}$$

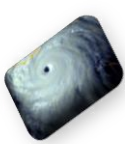
- ▣ T-factor  $> 1$  corrects effect of rain attenuation on Ku-band  $\sigma^0$
- ▣ T-factor  $< 1$  corrects effect of RVBS on Ku-band  $\sigma^0$



# Rain Correction – cont.

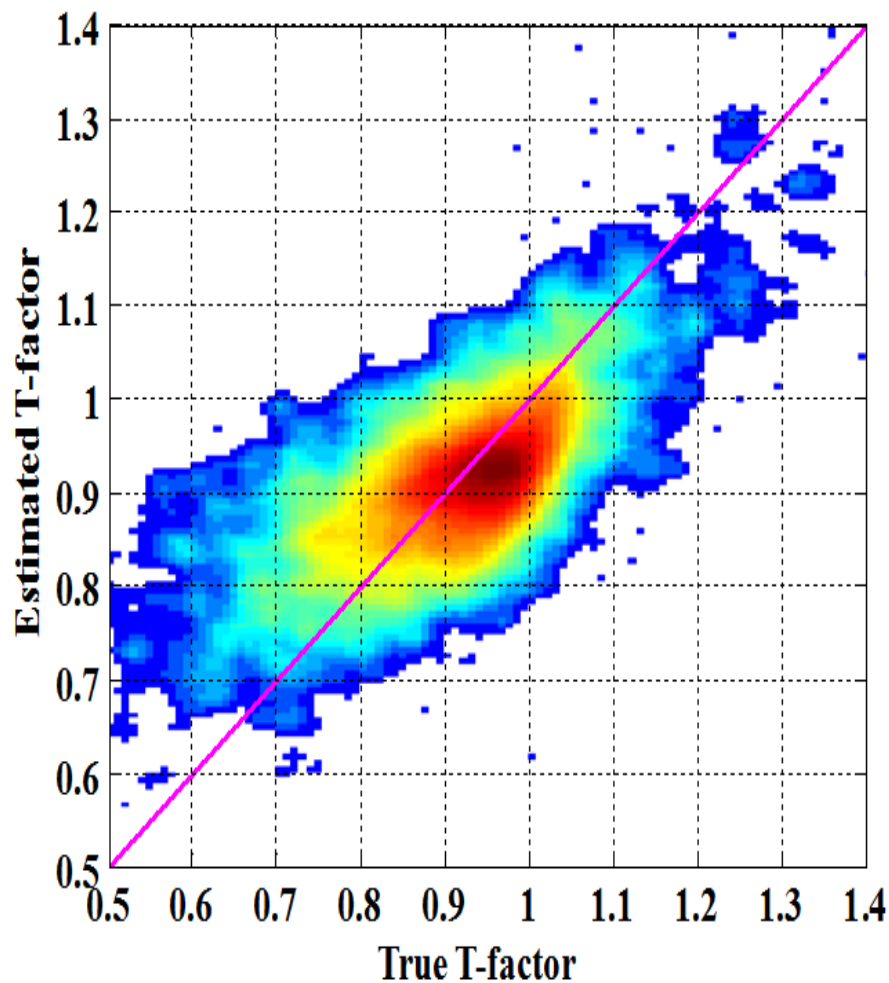
- Rain correction requires a robust estimation of T-factor GMF
  - ▣ Independent sensor observations that can be used
    - AMSR dual polarized Tb's
    - C-band  $\sigma^0$  measurements
  - ▣ Empirical relationship based on statistical approach using a multilinear regression procedure



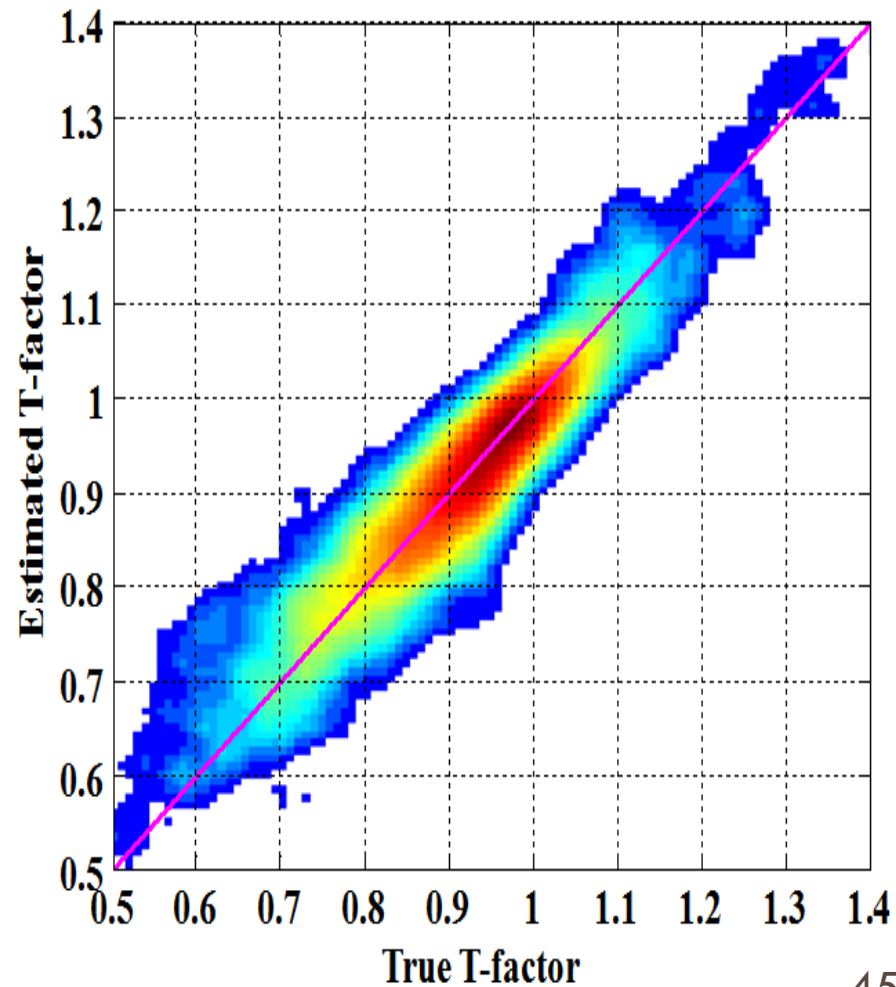


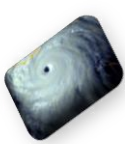
# Rain Correction – cont.

## H-pol T-factor (Tb's only)



## H-pol T-factor (Tb's and C-band $\sigma^0$ )



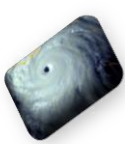


# Wind Vectors Retrievals

- Estimation of wind velocity from surface  $\sigma^0$  measurements involves inversion of the  $\sigma^0$  model function
  - ▣ Maximum likelihood estimation (MLE) of wind velocity based on minimizing a cost function ( $\zeta$ )
    - Difference between the measured and the modeled  $\sigma^0$  ( $\sigma^0_{GMF}$ )

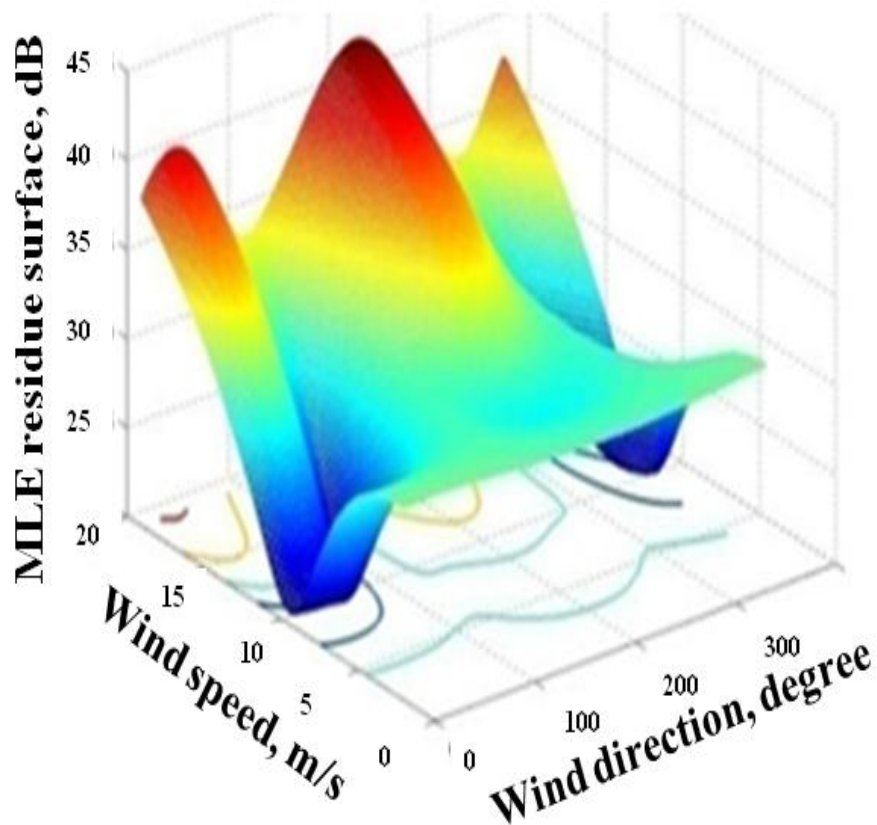
$$\zeta = \sum_{i=1, pol=V,H}^n \frac{(\sigma^0_{Ku,corrected} - \sigma^0_{GMF}(WS, \chi))^2_{pol}}{Variance_{\sigma^0}}$$

- n: number of measurements fall within a latitude/longitude box (called wind vector cell, WVC)
  - 10 km × 10 km for DFS

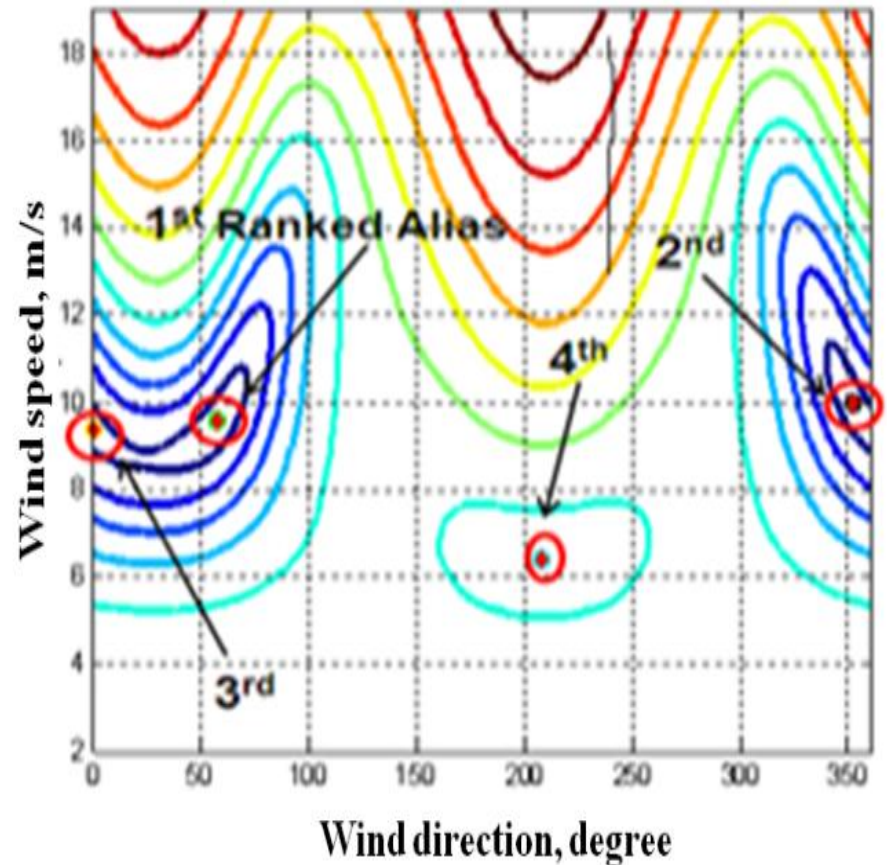


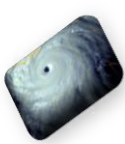
# Wind Vectors Retrievals – cont.

## 3-D MLE residue surface in dB



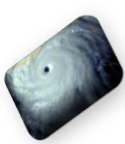
## 2-D residue contours





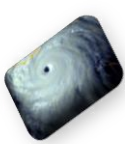
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- Summary & Conclusion



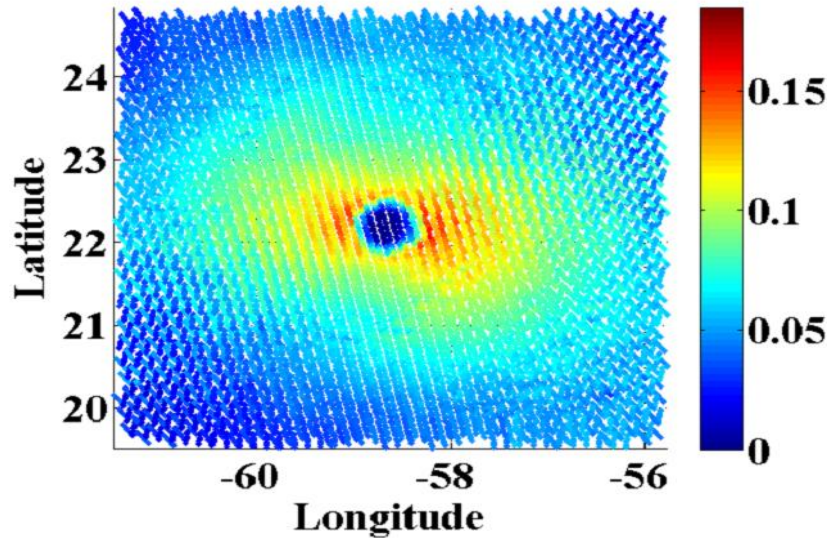
# Performance Evaluation

- Performance of OVW retrieval algorithm was assessed using independent active/passive sensor observations and comparison of with “surface truth” nature runs
  - ▣ Examine the effectiveness of rain correction procedure developed to adjust Ku-band DFS measurements
  - ▣ Comparisons of wind speed and wind direction retrievals with WRF surface truth
    - Ku-band only retrievals
    - C-band only retrievals
    - Corrected Ku-band retrievals

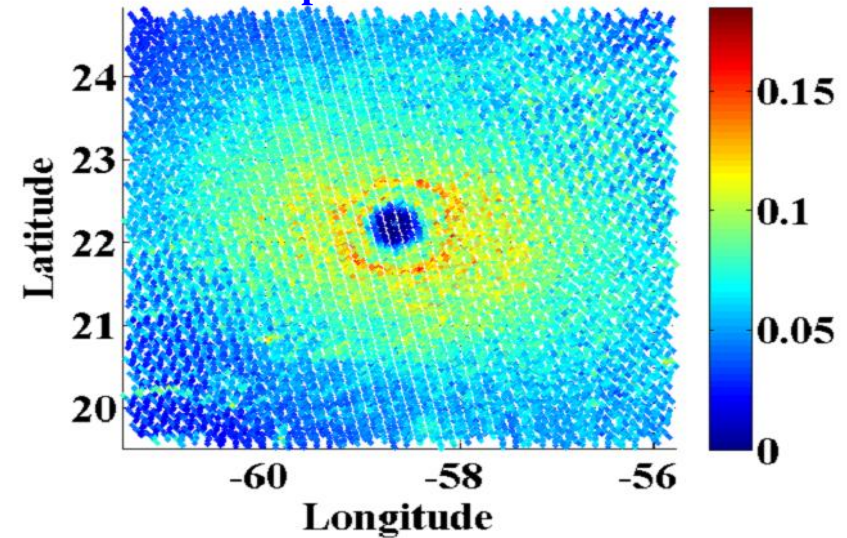


# Ku-band H-pol $\sigma^0$ Rain Correction

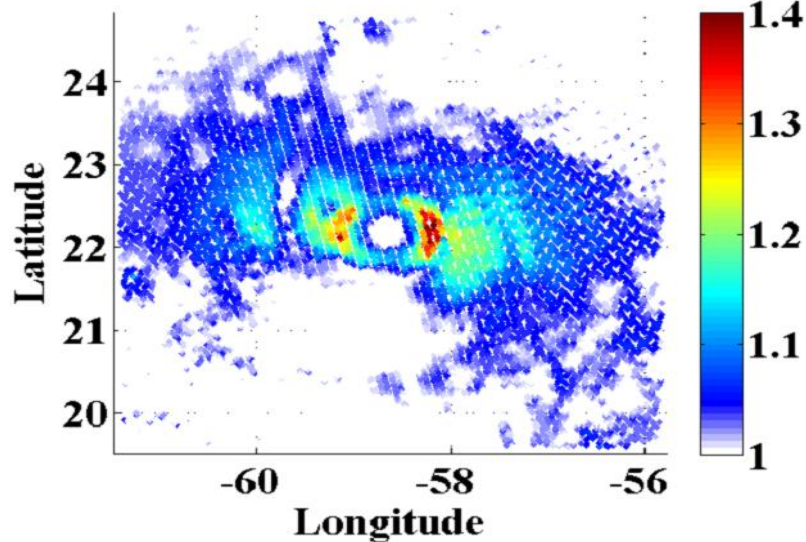
Surface  $\sigma^0$  field



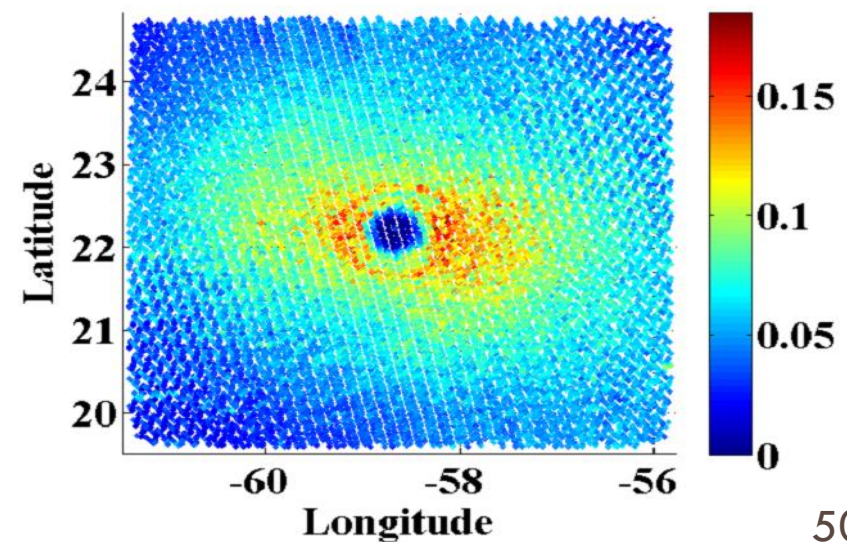
Top of atm.  $\sigma^0$  field

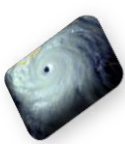


Estimated T-factor



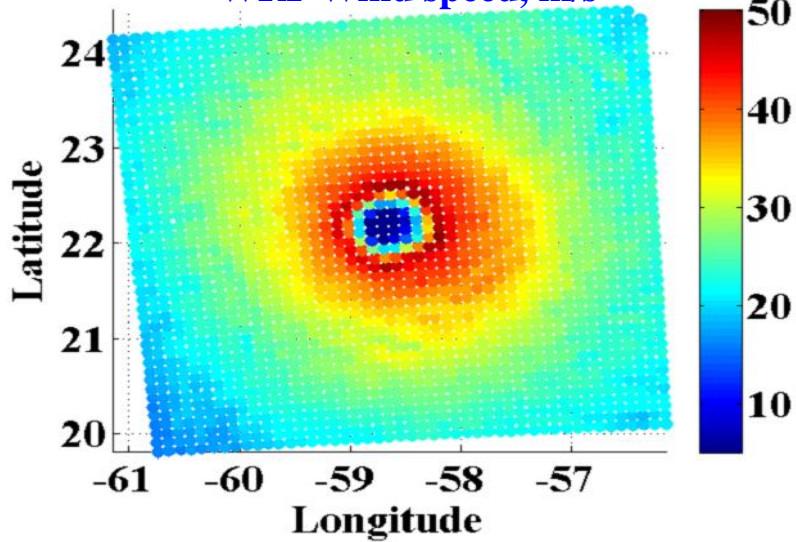
Corrected  $\sigma^0$  field



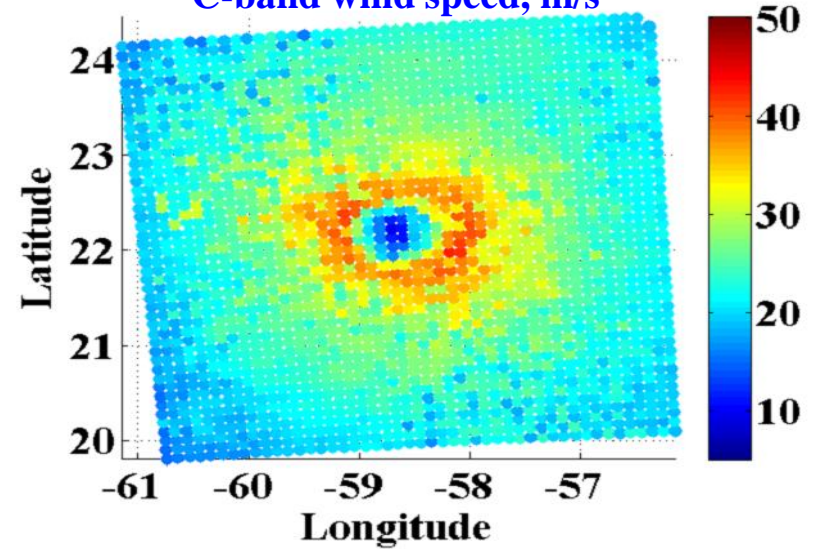


# Wind Speed Comparison

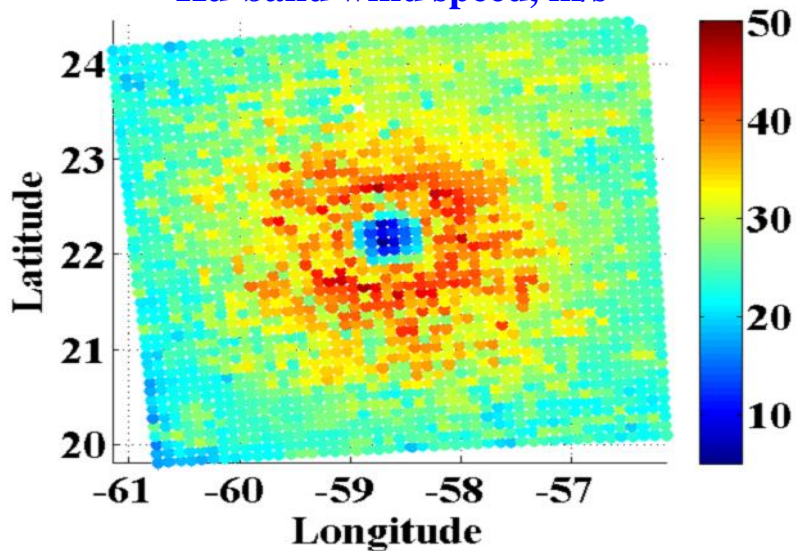
WRF Wind speed, m/s



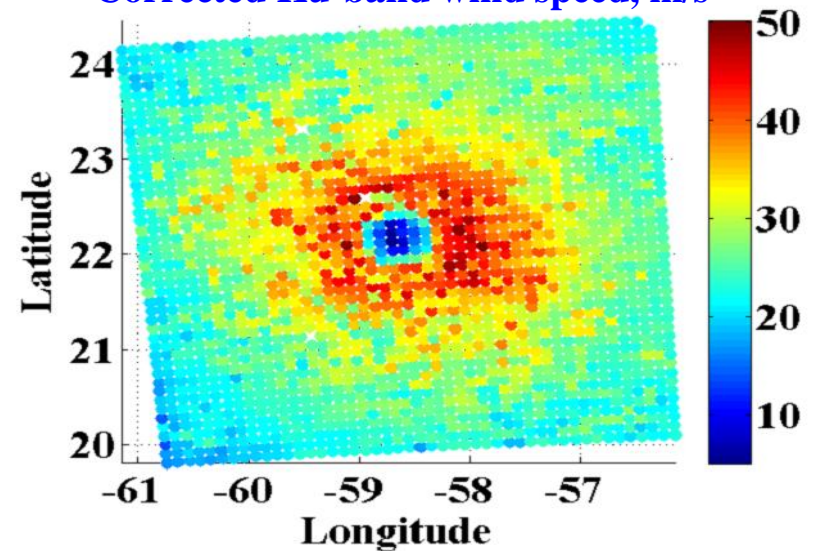
C-band wind speed, m/s

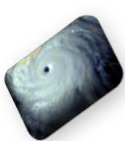


Ku-band wind speed, m/s



Corrected Ku-band wind speed, m/s

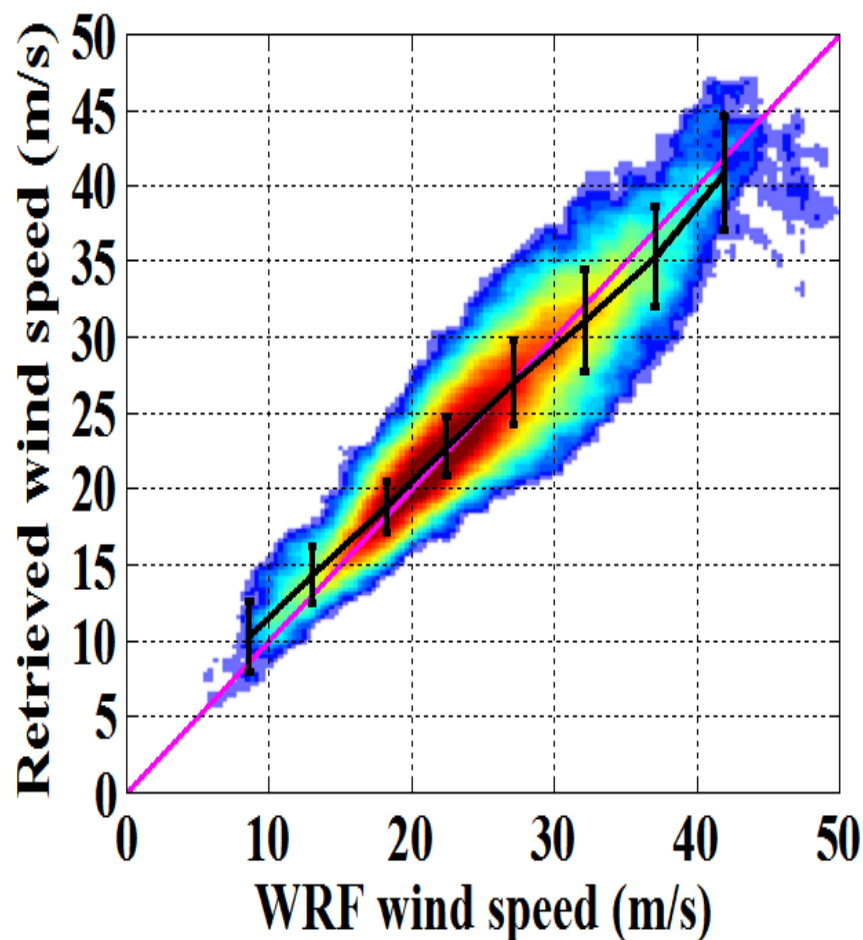
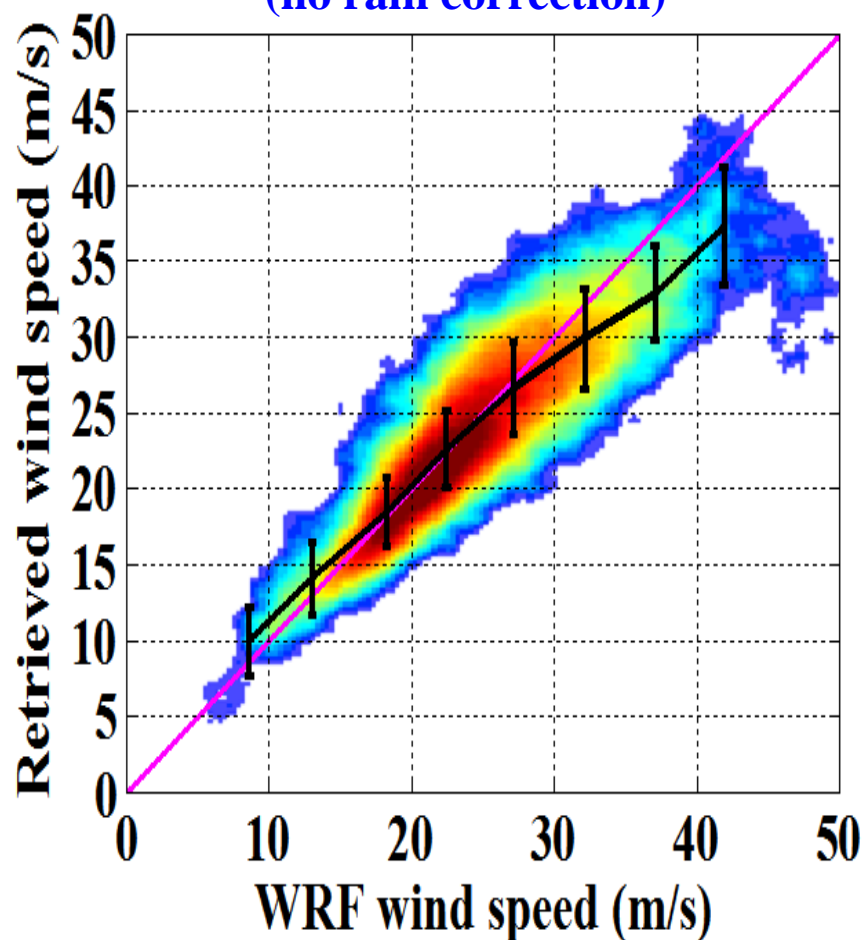


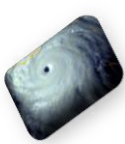


# Wind Speeds Comparison – cont.

**Conventional Ku-band  
(no rain correction)**

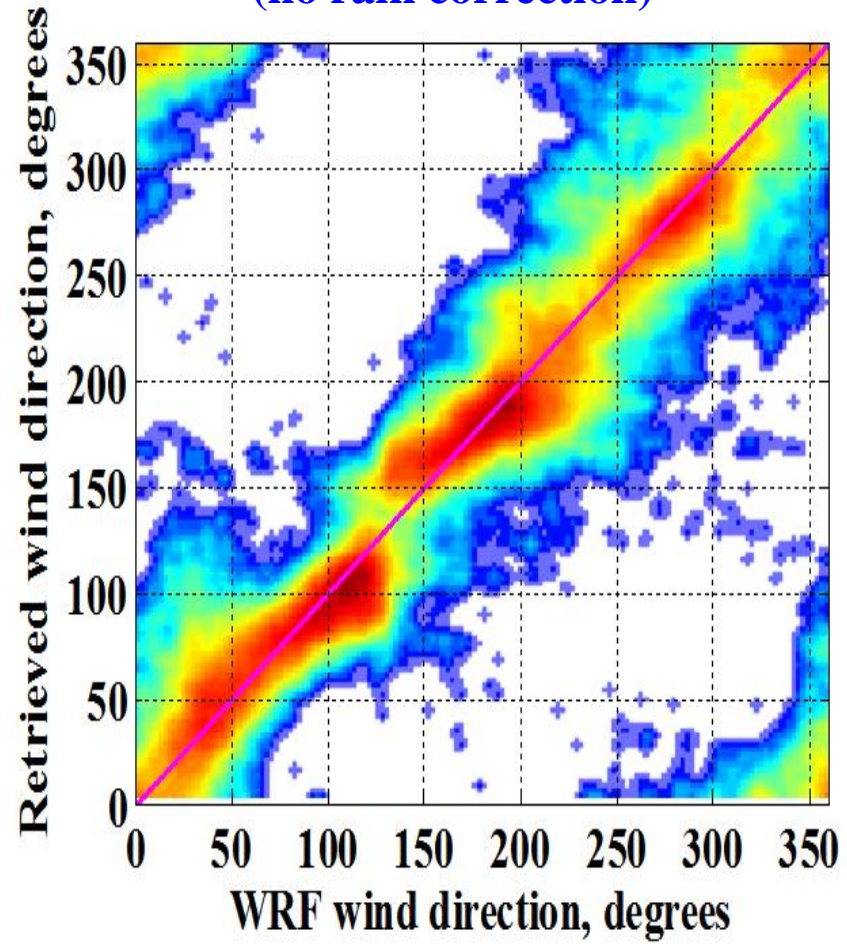
**Corrected Ku-band**



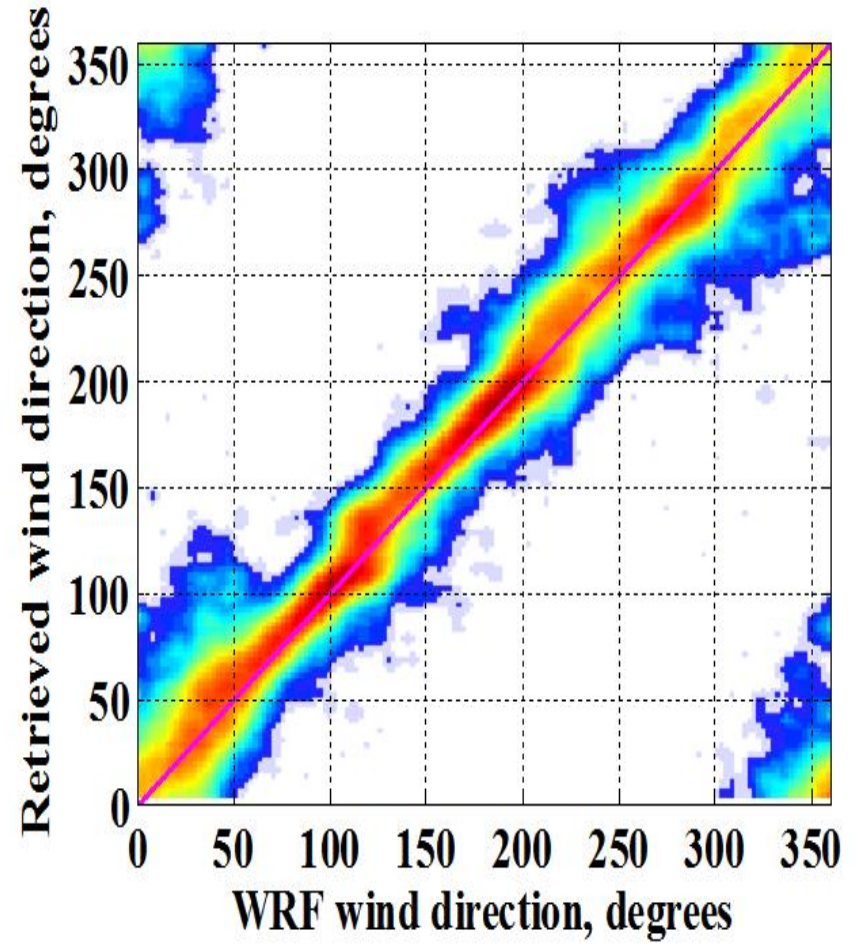


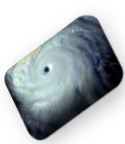
# Wind Direction Comparison

**Conventional Ku-band  
(no rain correction)**



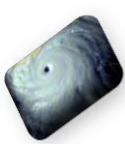
**Corrected Ku-band**





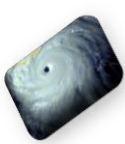
# OVW Performance Summary

- “C-band” retrievals clearly show the spatial degradation of high wind speeds
  - ▣ Larger antenna IFOV’s – reduced spatial resolution
- “Ku-band” retrievals show a better agreement in the mean with corresponding large measurement variance
  - ▣ Strong rain contamination usually associated with high wind speeds
- Corrected Ku-band retrievals are best
  - ▣ Lower OVW error variance
  - ▣ Higher maximum wind speed ~ 50 m/s (Cat-2 hurricane)
  - ▣ Improved high wind speed spatial patterns
    - Best agreement compared to WRF “surface truth”



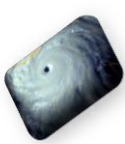
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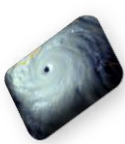
# Summary & Conclusion

- A novel active/passive OVW retrieval algorithm has been developed for next generation satellite OVW remote sensing system
  - ▣ Utilizes active and passive microwave remote sensors
    - DFS and AMSR
  - ▣ Algorithm especially designed for extreme wind events, TCs
    - Very high wind speeds and intense rain rates
- End-to-end simulation was developed to imitate real sensor observations in hurricane environment
  - ▣ **WRF and RTM calculations provided by Dr. Svetla Hristova-Veleva at JPL**
    - Wind fields, RVBS, attenuation, dual polarized Tb



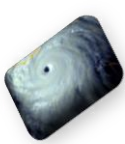
# Summary & Conclusion - cont.

- Output of simulation was **partially validated** with real measurements from SeaWinds and AMSR onboard ADEOS-II
  - ▣ Hurricane Isabel in September 2003
- OVW retrieval algorithm uses rain corrected Ku-band scatterometer measurements to retrieve OVWs in the presence of intense rain
  - ▣ C-band  $\sigma^0$  measurements and AMSR Tb's used to estimate T-factor
  - ▣ MLE technique used to invert  $\sigma^0$  GMF and retrieve wind vectors
- Results are very encouraging and demonstrated potential to improve wind measurements in extreme wind events for future wind scatterometry missions



# Future Work

- Validate the simulated observations using different sets of rain micro-physics
  - ▣ Present simulation validation is limited in possible dynamic range of rain parameters
- More hurricane cases to train T-factor algorithm
  - ▣ Include wider range of geophysical parameters in training the regression
- Incorporate a wind direction alias selection technique into the OVW retrieval algorithm
  - ▣ There are good techniques currently used for conventional scatterometer OVW retrievals
  - ▣ In this dissertation, closest wind directions (aliases) to nature run were chosen



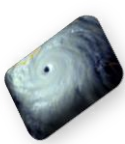
# Publications

## Journal papers:

- [1] **S. Alswiss**, P. Laupattarakasem, W.L. Jones, “A Novel Ku-band Radiometer / Scatterometer (RadScat) Approach for Improved Oceanic Wind Vector Measurements”, accepted for publication in *IEEE Trans. Geosci. Rem. Sens.* 2011
- [1] **S. Alswiss**, P. Laupattarakasem, S. El-nimri, W.L. Jones, “An Improved Ocean Vector Winds Retrieval Approach Using Dual Frequency Scatterometer and Multi-frequency Microwave Radiometer Measurements”, in preparation for publication in *IEEE Trans. Geosci. Rem. Sens.* 2011

## Conference papers:

- [1] **S. Alswiss** and W. L. Jones, “Suitability of the Amazon Rain Forest as an On-Orbit Calibration Target”, IEEE South East Conference, 2007, Richmond - Virginia, USA
- [2] P. Laupattarakasem, **S. Alswiss**, W. L. Jones, and R. Roeder, “Conical-Scanning Active/Passive Microwave Remote Sensor Computer Simulation”, SPIE Conference, 2007, Orlando - Florida, USA.
- [3] S. Elnimri, **S. Alswiss**, J. Johnson, W. L. Jones, and C. Ruf, “Improved Microwave Remote Sensing of Hurricane Wind Speed and Rain Rates Using the Hurricane Imaging Radiometer (HIRAD)”, AMS Conference, 2008, Orlando - Florida, USA
- [4] S. Elnimri, **S. Alswiss**, J. Johnson, W.L. Jones, R. Amarin, and E. Uhlhorn, “Hurricane Imaging Radiometer Wide Swath Simulation For Wind Speed And Rain Rate”, IGARSS Conference, 2008, Boston - Massachusetts, USA
- [5] **S. Alswiss**, P. Laupattarakasem, W. L. Jones, and R. Roeder, “A Ku-band Active / Passive Wind Vector Retrieval Over the Ocean”, IGARSS Conference, 2008, Boston - Massachusetts, USA
- [6] W.L. Jones, **S. Alswiss**, S. Farrar, S. Masuelli, and H. Raimondo, “Microwave Radiometer (MWR) Contributions to Aquarius Science: Ocean Vector Winds & Ocean Precipitation Retrievals”, poster presented at the 4th AQUARIUS/SAC-D Int. Science Workshop, Dec 3-6, 2008, Argentina



# Publications – cont.

- [7] W. L. Jones , P. Laupattarakasem, **S. Alsw Weiss**, S. El-Nimri, S. Veleva, B. W. Stiles, E. Rodriguez, and R. W. Gaston, “Simulated OVW Retrieval Performance for the Dual Frequency Scatterometer in Hurricanes”, poster presented at NASA Ocean Vector Wind Science Team Meeting, 18-20 May 2009, Boulder - Colorado, USA
- [8] **S. Alsw Weiss**, W.L. Jones, P. Laupattarakasem, S. EL-Nimri, S. Veleva, B. W. Stiles, E. Rodriguez, and R. W. Gaston, “Simulated OVW Retrievals in Tropical Cyclones for the Next Generation Dual Frequency Scatterometer”, Ocean-09 Conference, 26-29 Oct. 2009, Biloxi - Mississippi, USA
- [9] P. Laupattarakasem, **S. Alsw Weiss**, S. EL-Nimri, W.L. Jones, S. Veleva, B. W. Stiles, E. Rodriguez, and R. W. Gaston, “Improved High Wind Speed Retrievals Using AMSR and the Next Generation NASA Dual Frequency Scatterometer”, MicroRad-2010 Conference, 01-04 Mar. 2010, Washington - DC, USA
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*Suleiman Alsweiss '11*