Defining the Accuracy of Eyewall Radius of Maximum Wind Dropwindsondes

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NOAA Ernest Hollings Scholar
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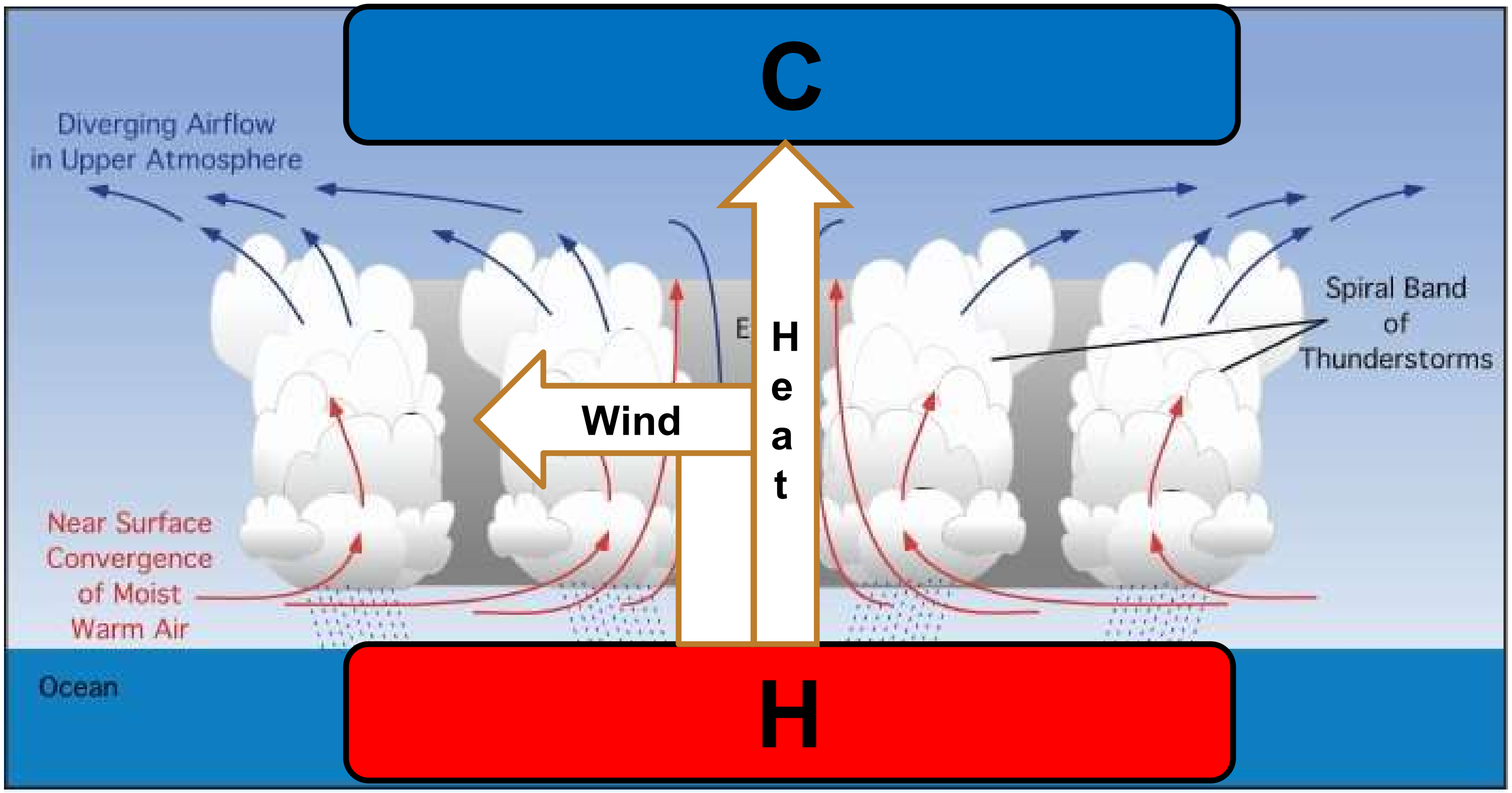
Cyclone Overview

What is a Cyclone?

Heat Engine: Produces Energy (Wind) from Temperature Gradient



Cyclone Overview

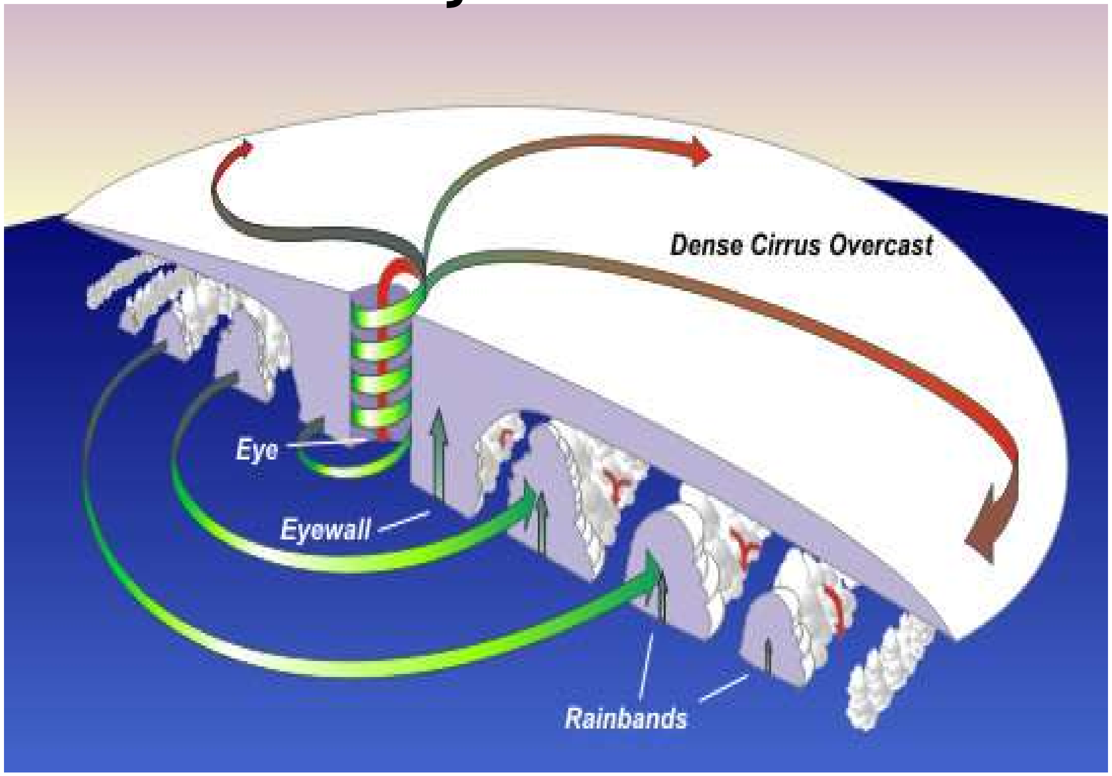
Eye:

- Very low atmospheric pressure
- Winds fall off very quickly
- Calmest area of storm environment

Eyewall:

- Strongest winds in cyclone Large wind shears, steep wind gradients
- Most violent part of storm

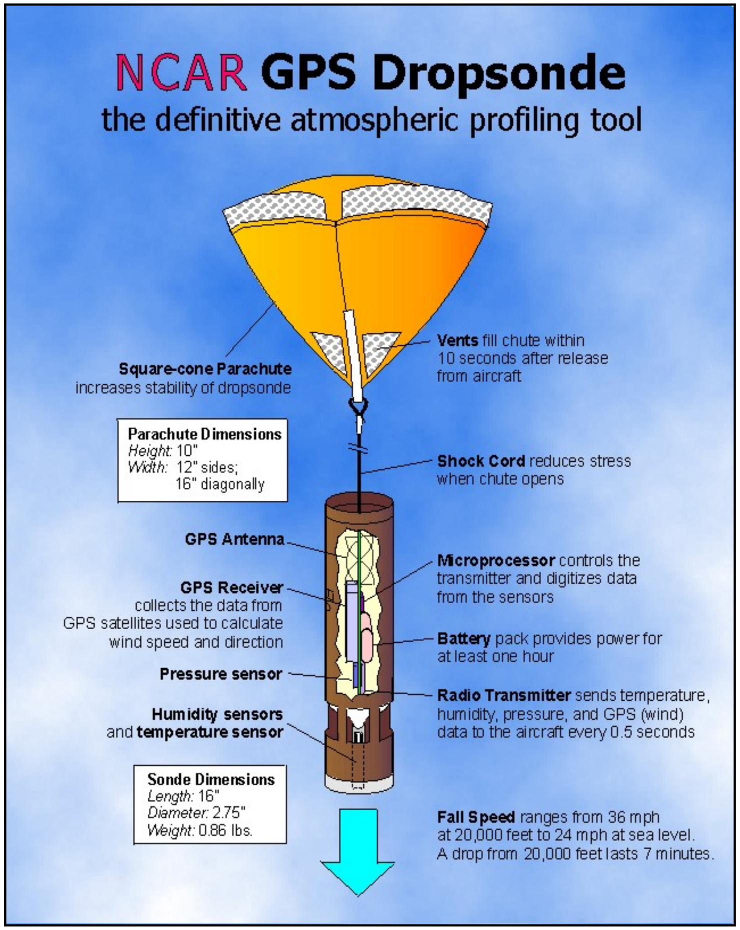
Mature Cyclone Structure



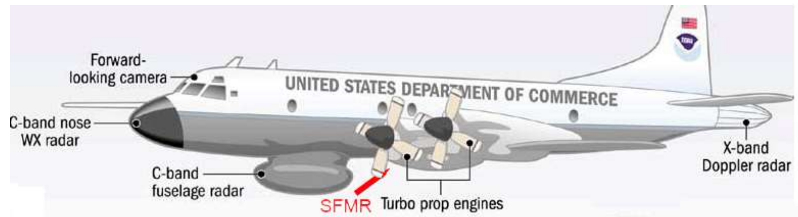
Hurricane Reconnaissance

NOAA Lockheed WP-3D Orion

- Flies through storm ~10,000' MSL, penetrates eyewall several times during flight
- Instruments aboard aircraft measure atmospheric conditions at flight level and sea level, providing radial profile of storm conditions
    - Stepped Frequency Microwave Radiometer (SFMR) estimates surface wind speed directly beneath aircraft by measuring microwave signal associated with breaking waves
- GPS dropsondes deployed off aircraft measure atmospheric conditions over course of fall, providing vertical profile of storm conditions



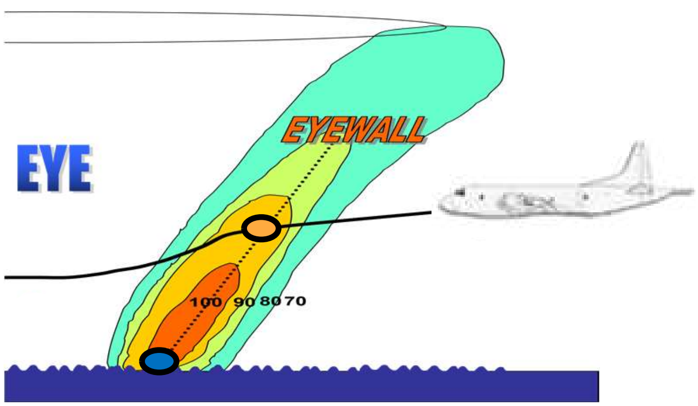
Hurricane Reconnaissance

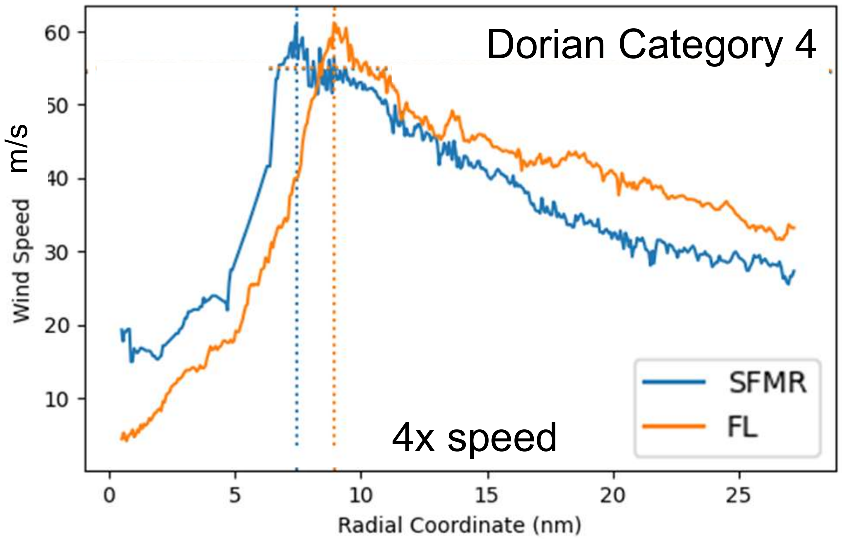


SFMR Surface Wind Speed Estimates

- 6 microwave bands between 4.6-7.2 GHz
  - No major atmospheric or cloud absorptions in this range
  - Absorptions by liquid rain, strong frequency-dependence
- Sea foam coverage increases monotonically with surface wind speed (Barrick and Swift 1980)
- Sea foam ~ blackbody emitter @ microwave freqs. More foam = more microwave emissions (Webster et. al. 1976)
  - ~constant emission between SFMR's 4.6-7.2 GHz range
- Algorithm to subtract emissions due to rain, leaves only emissions associated w/ sea foam (Klotz & Ulhorn 2017)
- Use results of Webster, Barrcik & Swift to convert foam microwave emissions into surface wind speed estimate

Hurricane Reconnaissance





Eyewall Penetration:

As aircraft passes through eyewall, operators drop sondes targeting key features of the cyclone: cyclone center and radius of maximum wind (RMW)

Eyewall flares outward → Flight level RMW occurs at a larger radius than surface RMW

Chaotic winds near eyewall often displace sonde significantly off intended trajectory

Goal: <u>Analyze historical RMW sonde data to improve the success of future RMW sonde deployments</u>

Datasets

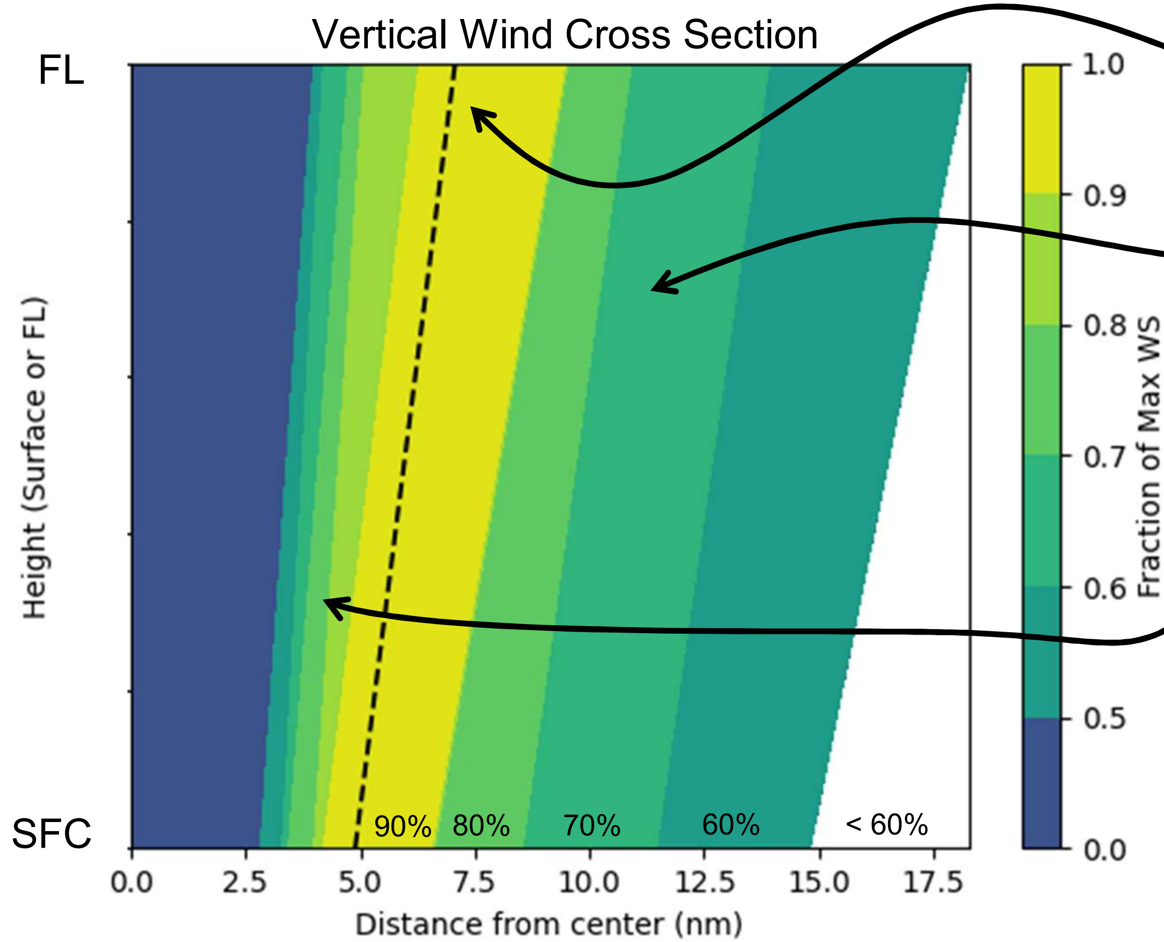
Dataset 1

- 947 Vortex Data Messages (VDMs):
  - High-level overview of one complete pass through storm
  - Basic information on storm structure and conditions
  - From NOAA & Air Force Hurricane Hunters 2018-2020 hurricane seasons

Dataset 2

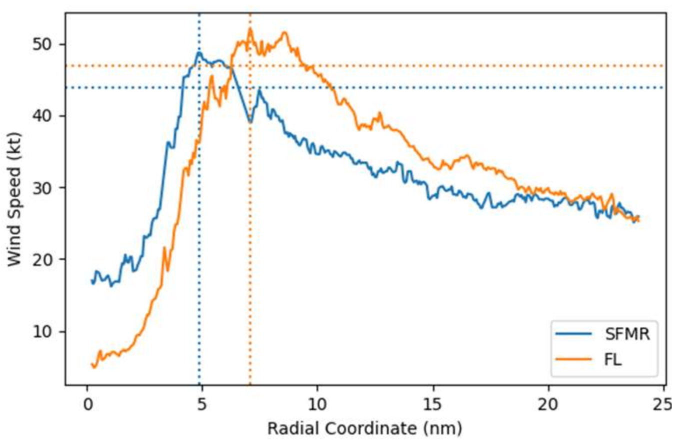
- 172 RMW Sonde drops:
  - Sondes specifically identified as targeting eyewall RMW
  - Contains high-resolution sonde data along with associated flight-level and VDM data
  - From NOAA 2015-2020 hurricane seasons and Air Force 53rd Weather Reconnaissance Squadron 2017-2018 hurricane seasons

‘Ideal’ Cyclone & RMW Sonde

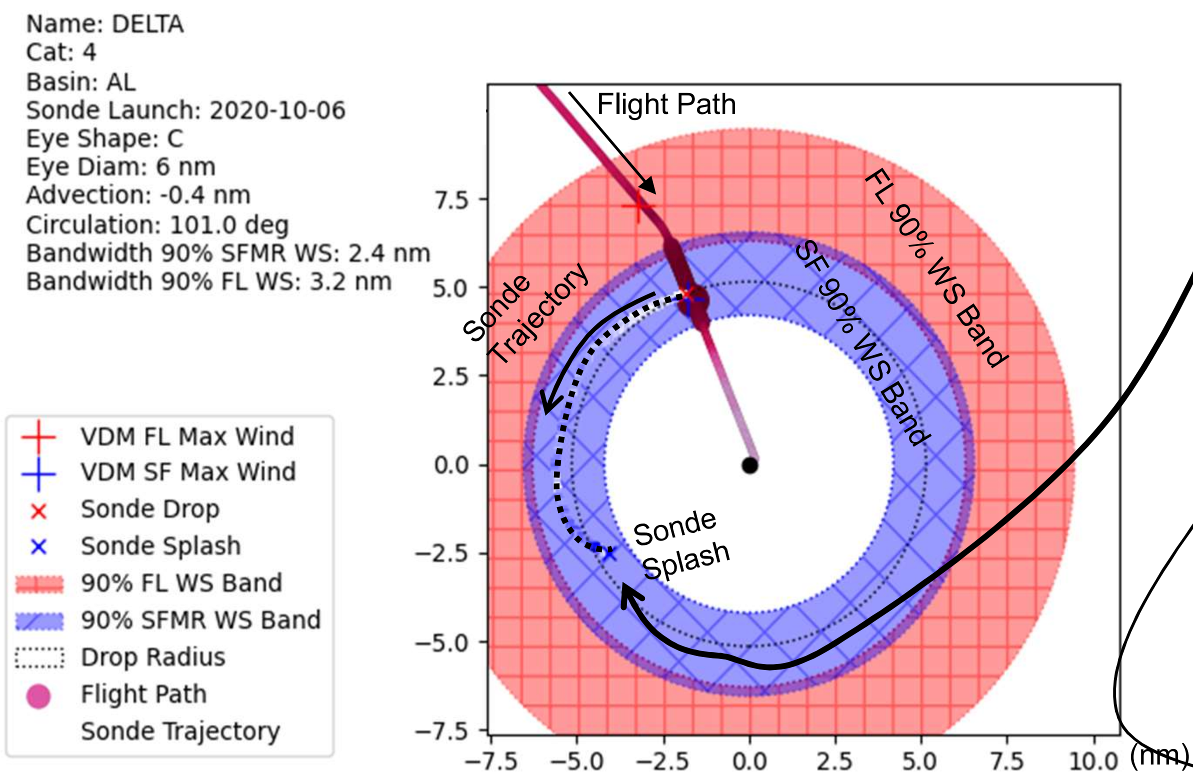


Ideal Cyclone:

- FL RMW slightly outside SFC RMW
- Slow buildup of FL and SFMR wind speeds outside peak
- Steep falloff of wind speeds inside peak

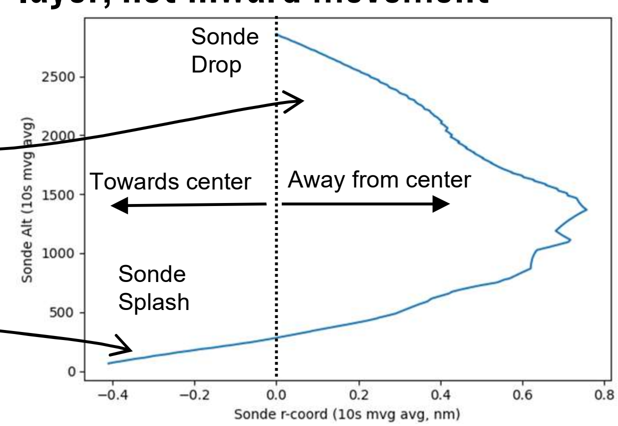


‘Ideal’ Cyclone & RMW Sonde



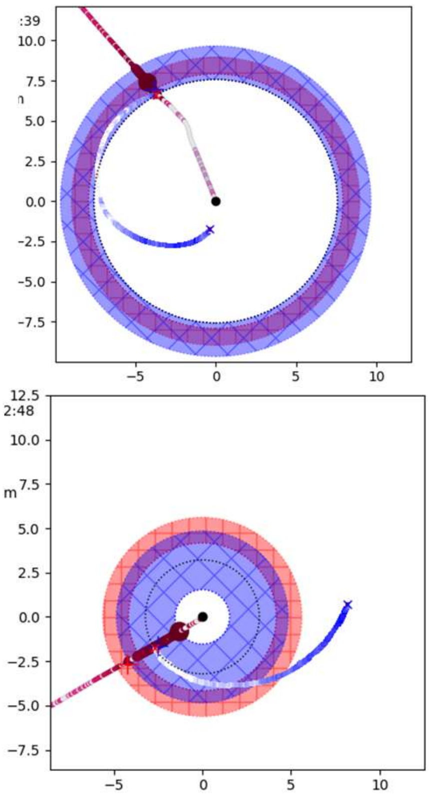
Ideal Sonde:

- Wind speed at splash location at least 90% of maximum surface wind (inside blue ring)
- Initial outward displacement of sonde
- Inward advection of sonde near boundary layer, net inward movement

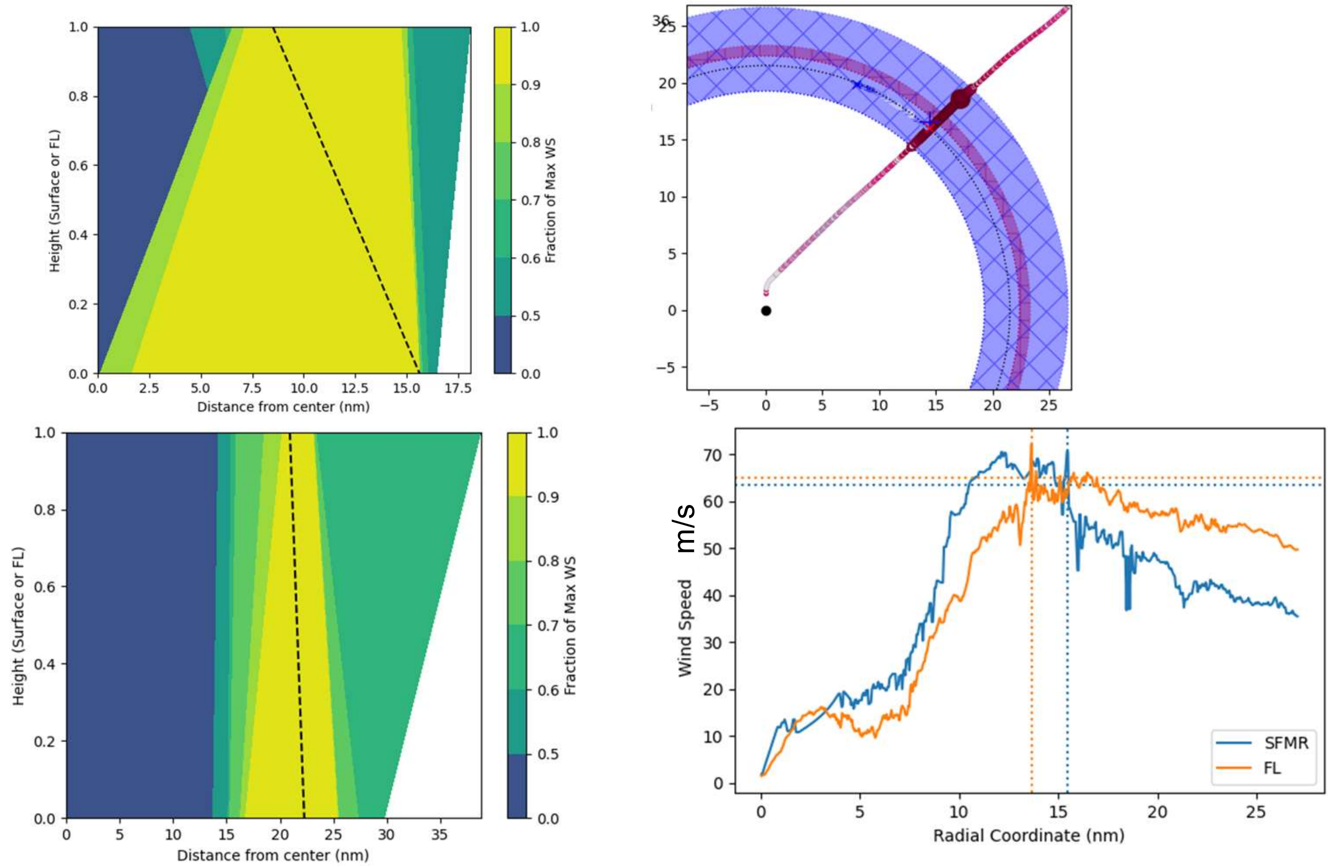


Actual Cyclones and RMW Sondes

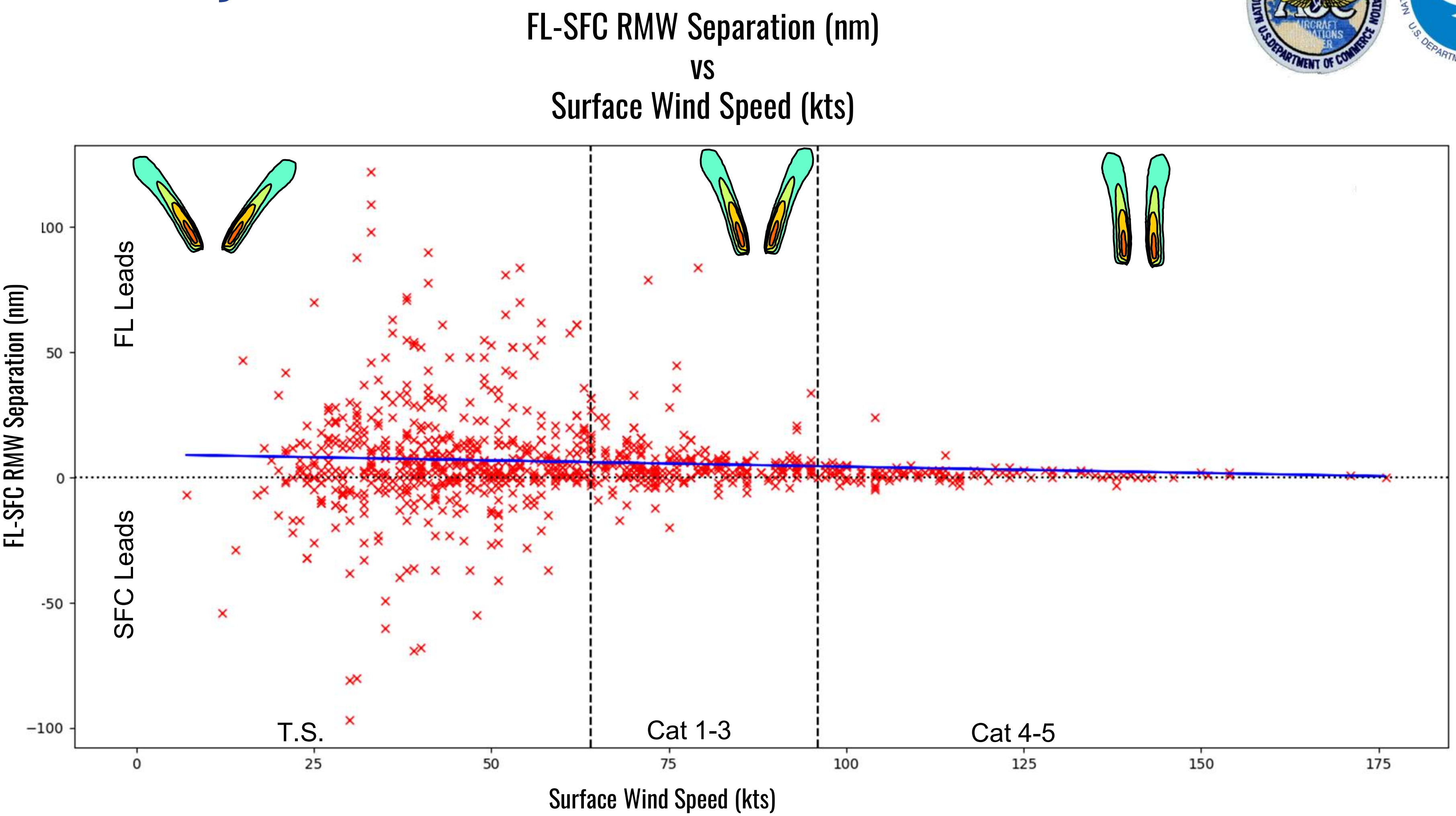
Unpredictable Displacements



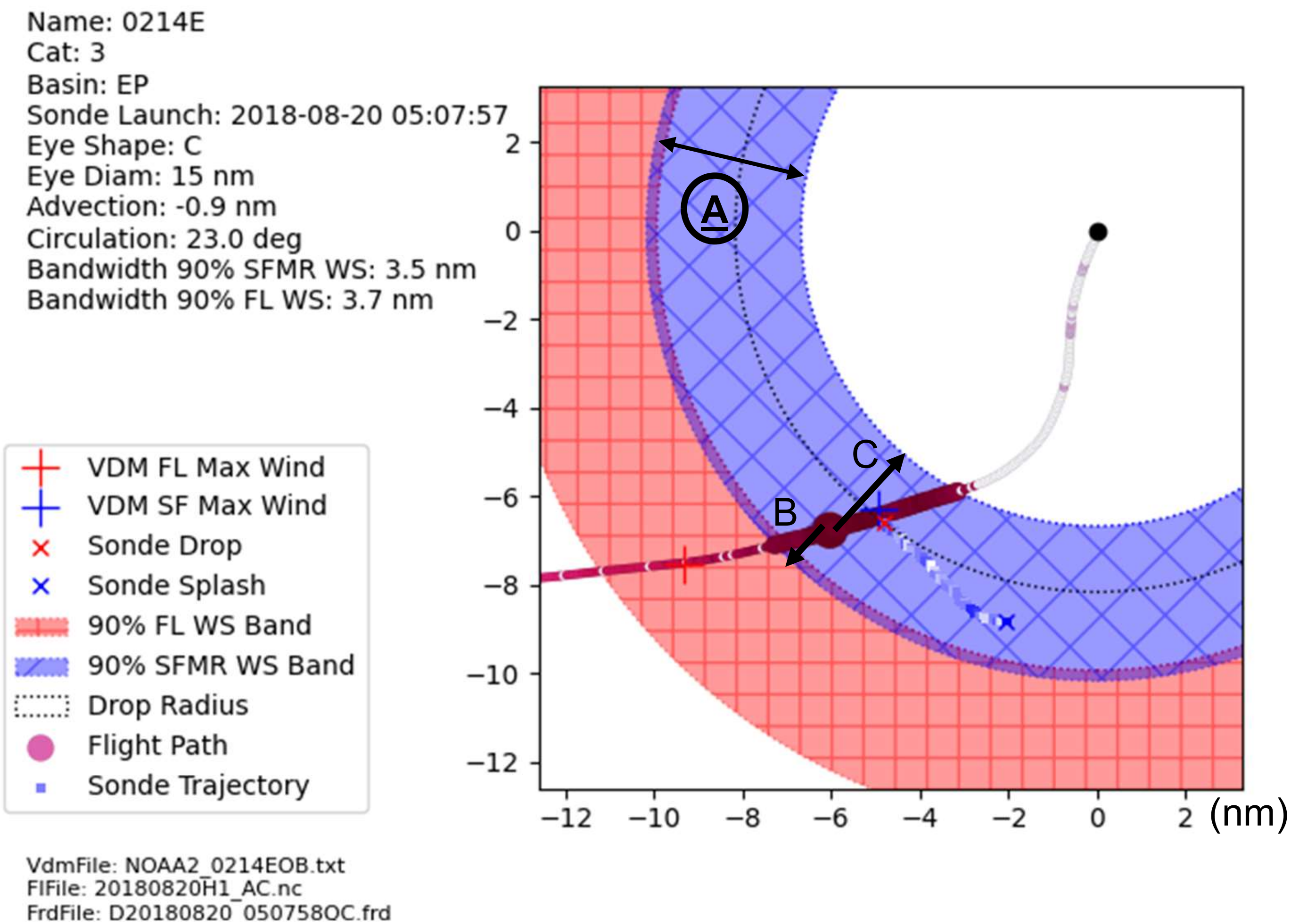
Disorganized system (SF RMW > FL RMW)



Dataset 1 Analysis

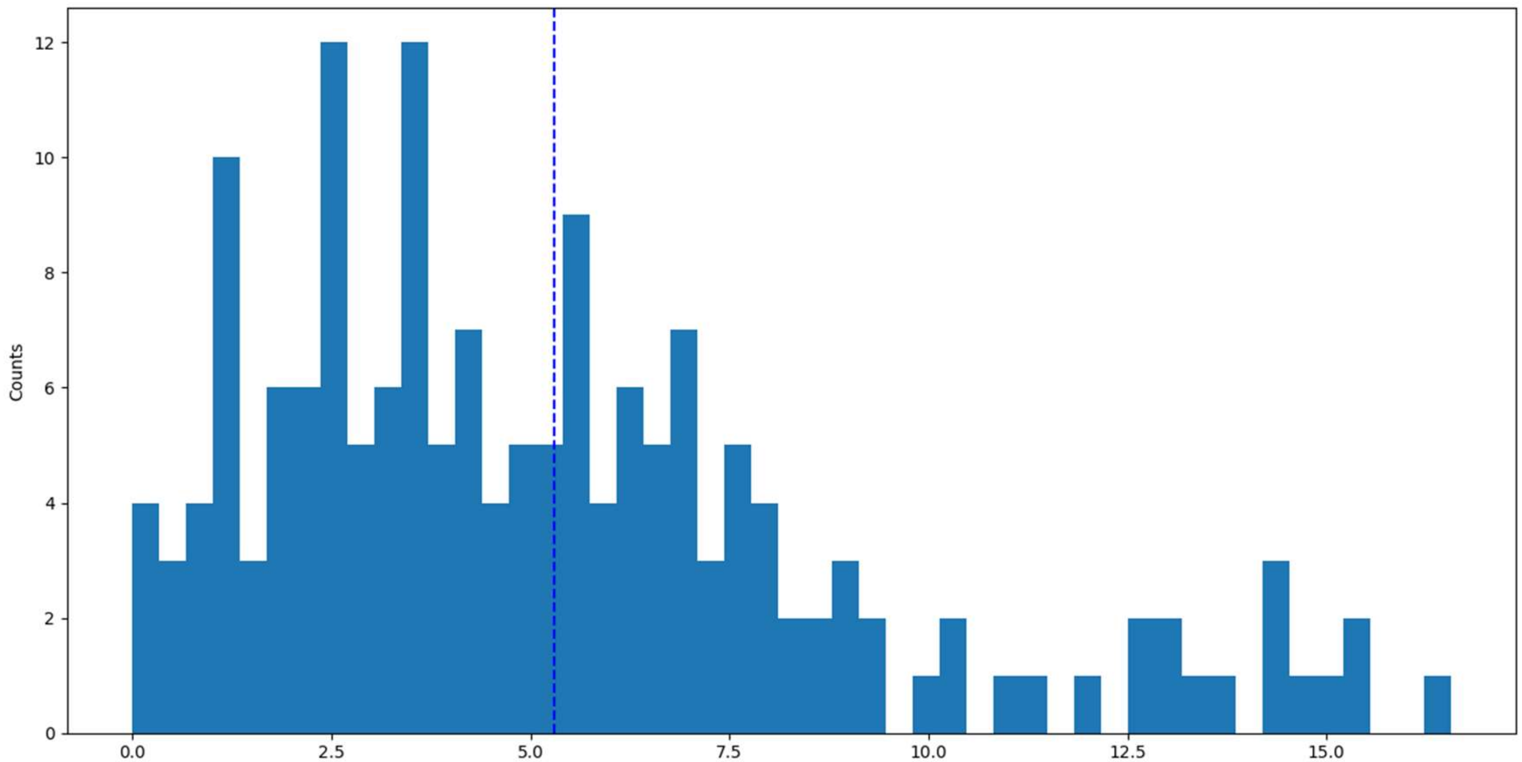


Dataset 2 Analysis



Dataset 2 Analysis

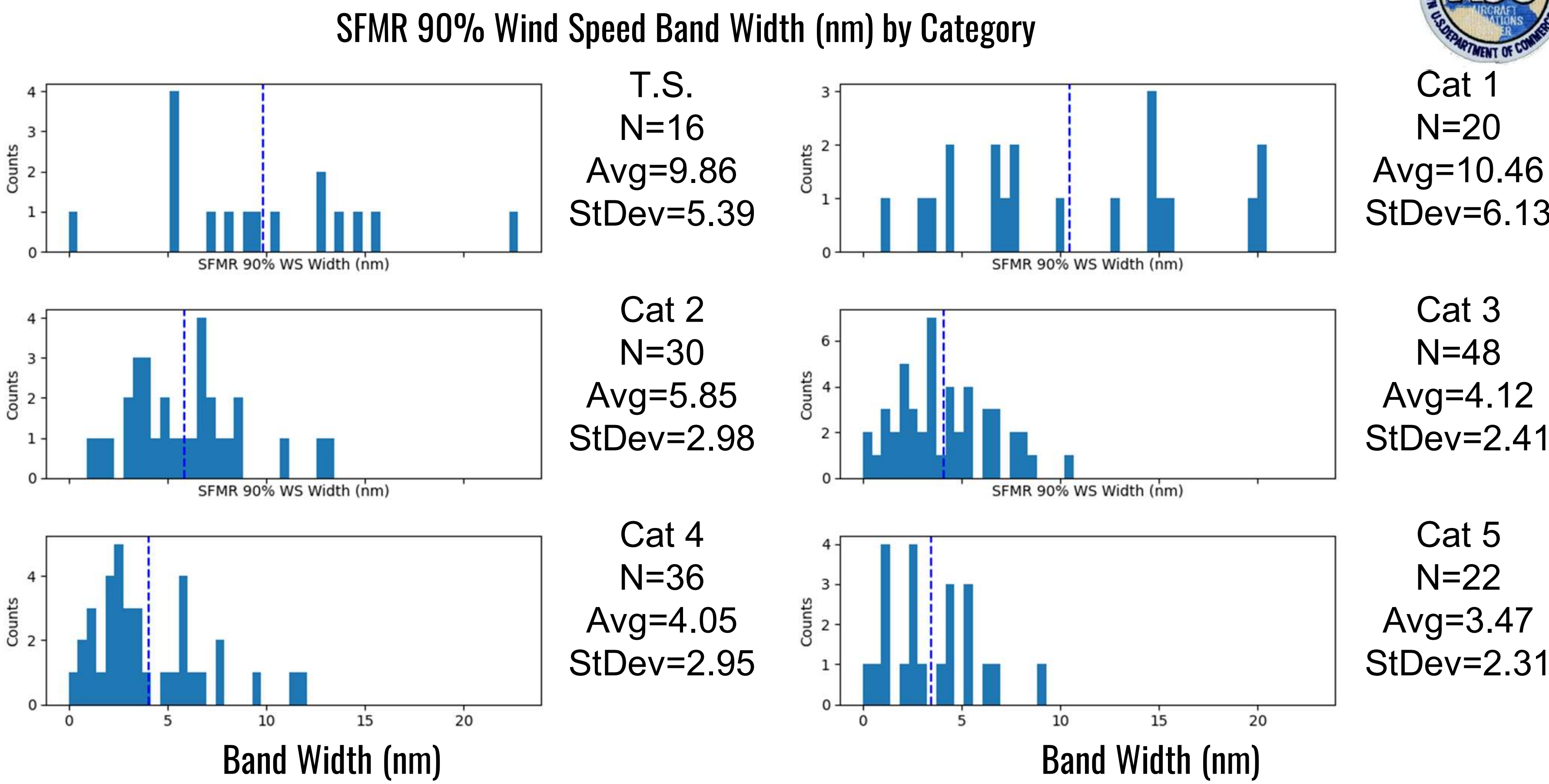
SFMR 90% Wind Speed Band Width ("Target Size")



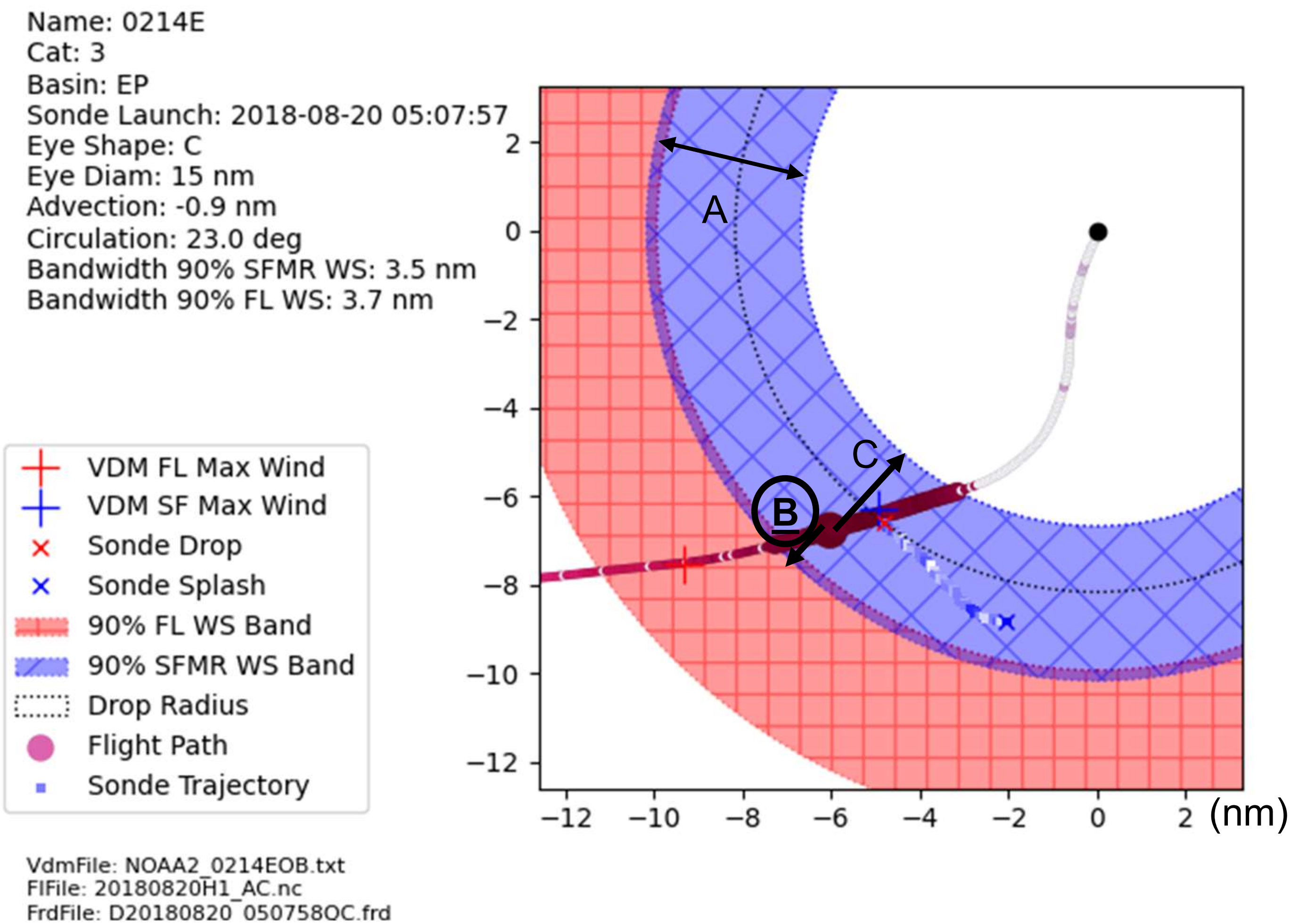
Band Width (nm)

N=169
Avg=5.30
StDev=3.72

Dataset 2 Analysis

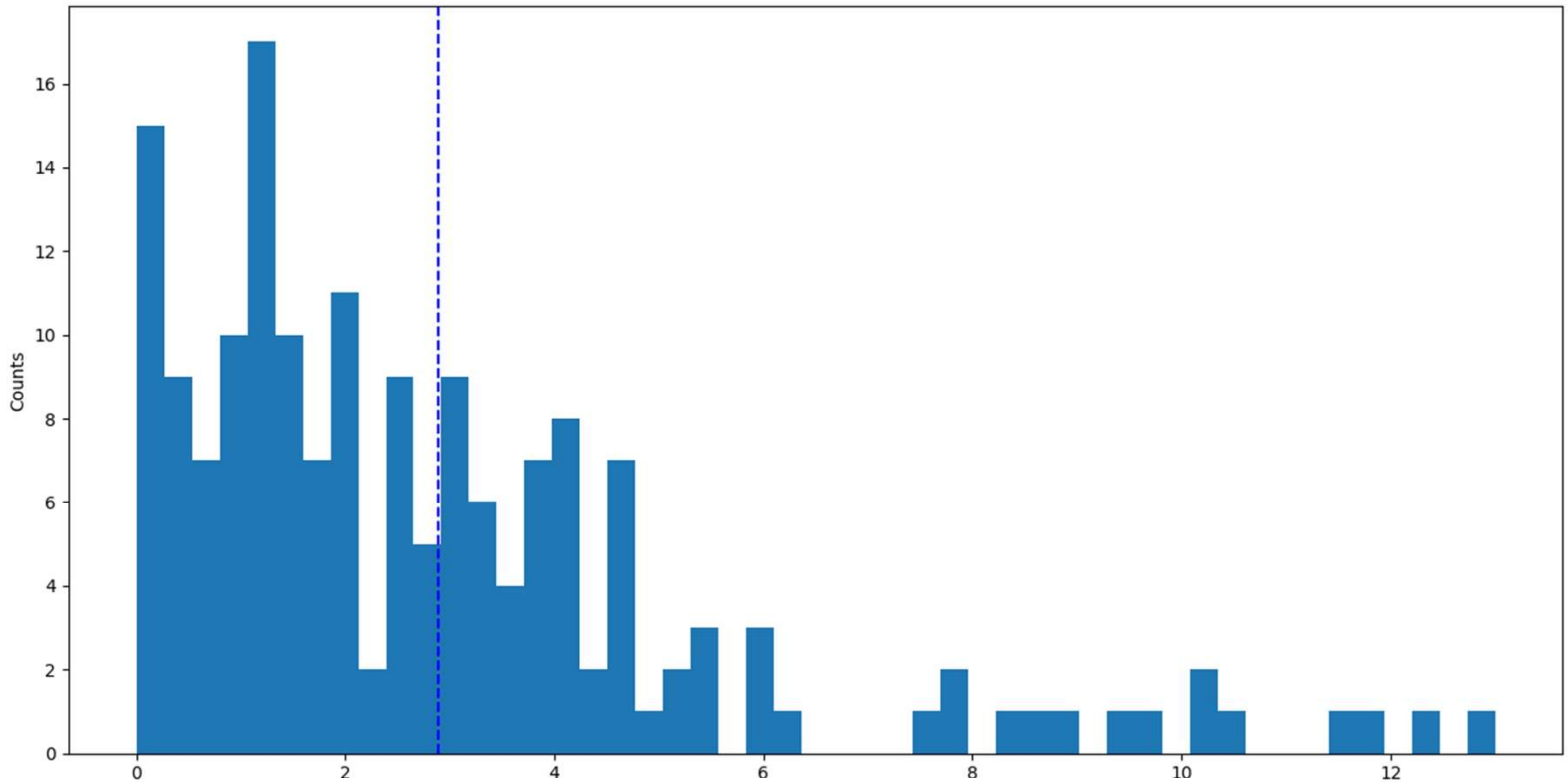


Dataset 2 Analysis



Dataset 2 Analysis

SFMR RMW-Outer 90% Separation (nm) ("Outbound Buffer")

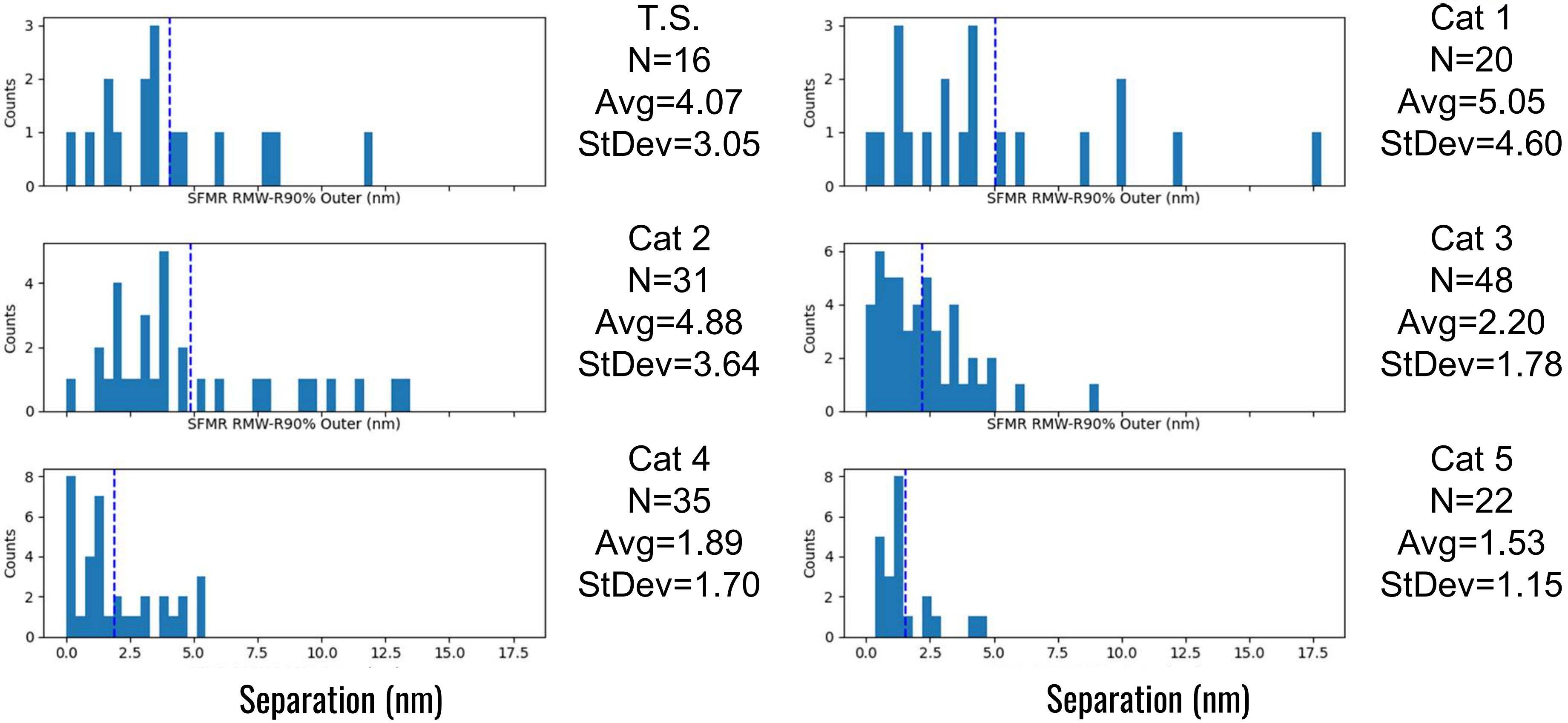


Separation (nm)

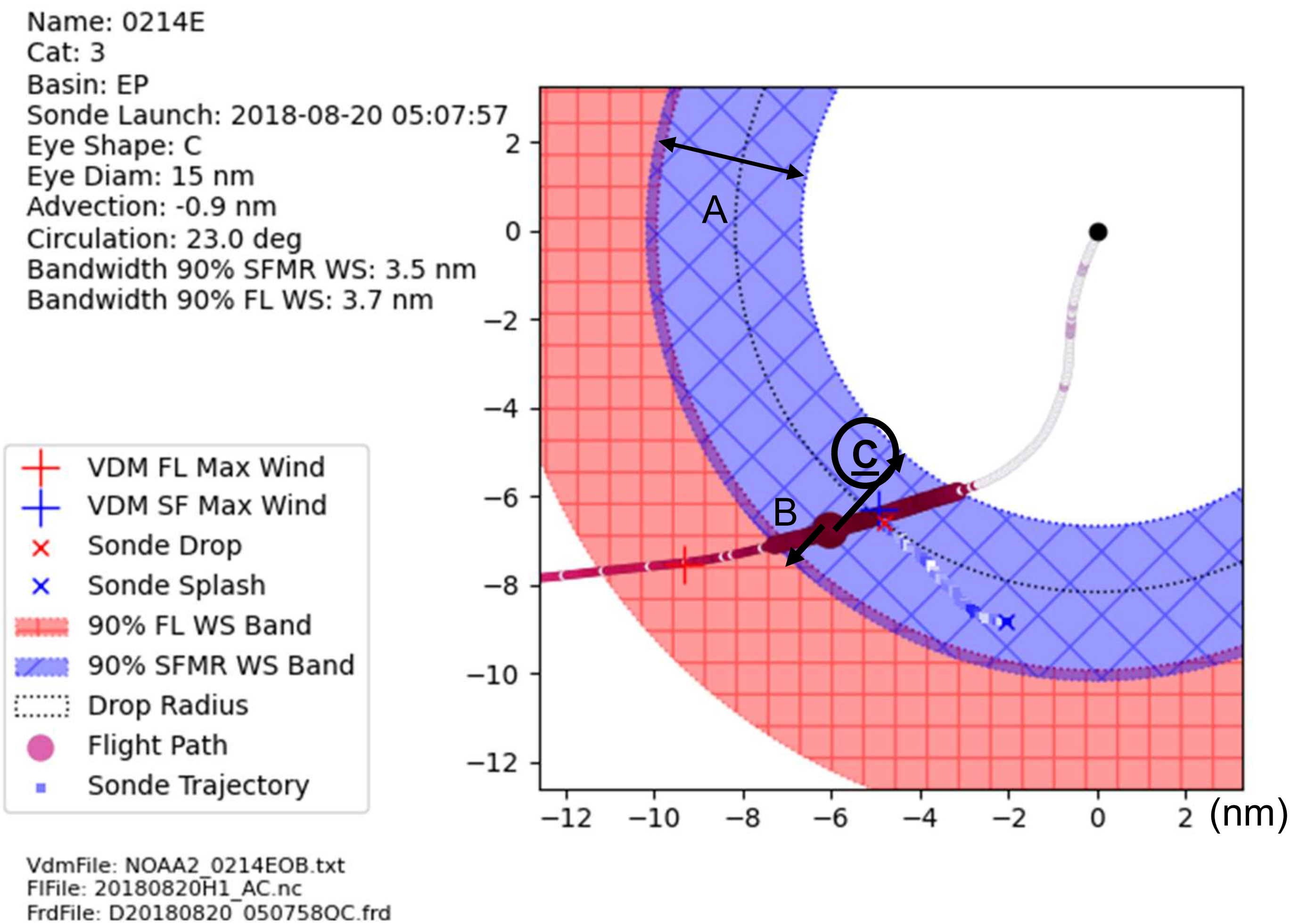
N=170
Avg=2.89 nm
StDev=2.69 nm

Dataset 2 Analysis

SFMR RMW-Outer 90% Separation (nm) by Category

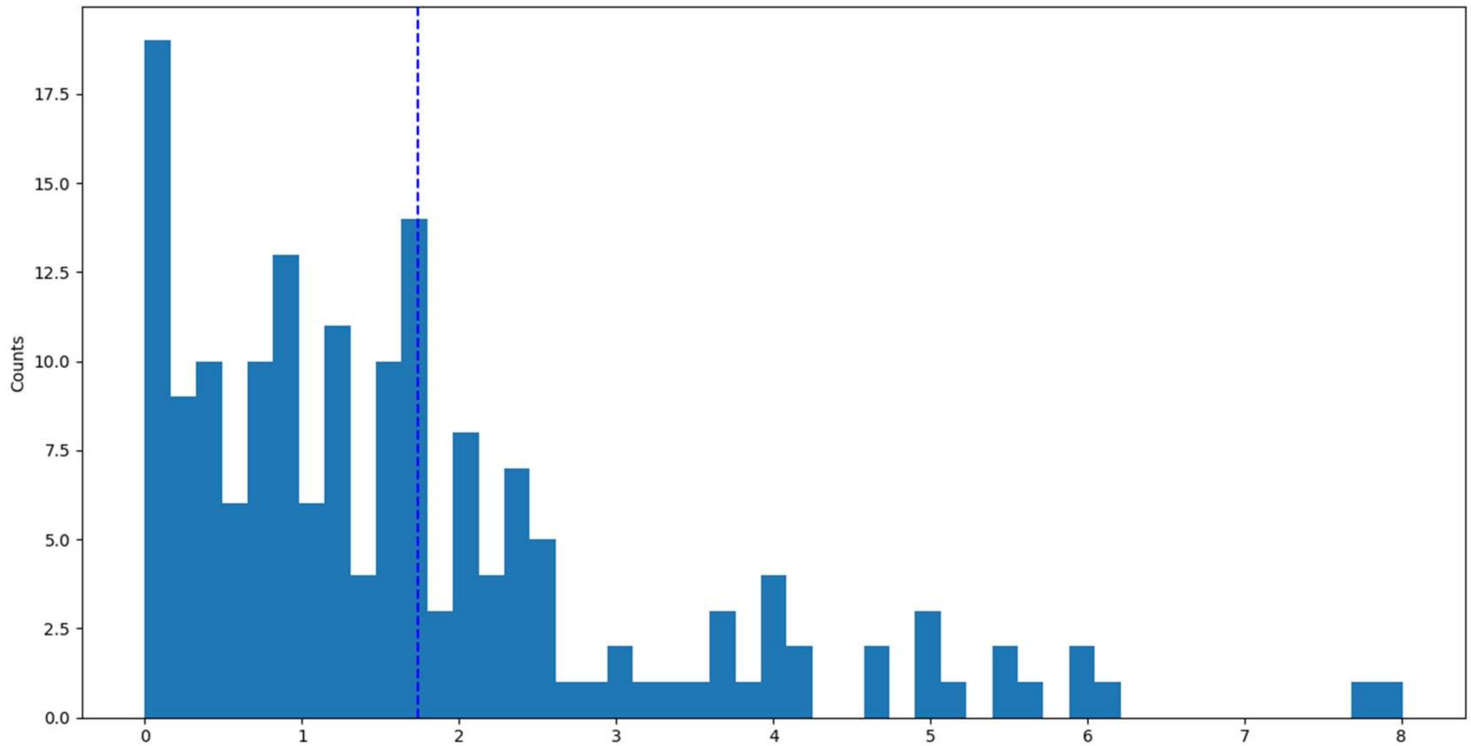


Dataset 2 Analysis



Dataset 2 Analysis

SFMR RMW-Inner 90% Separation (nm) ("Inbound Buffer")

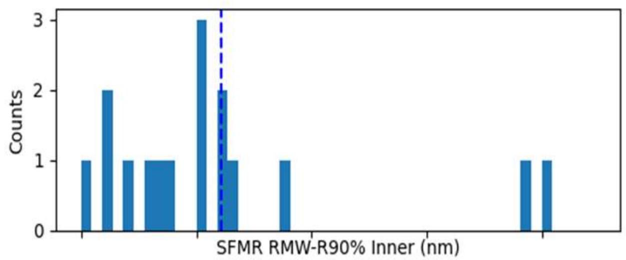


Separation (nm)

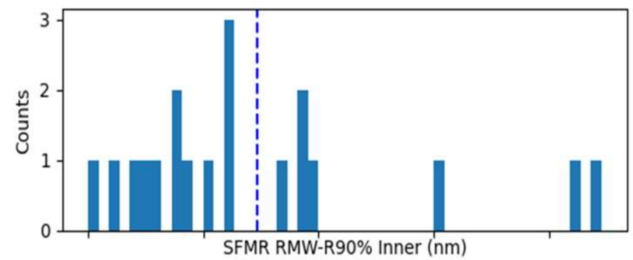
N=169
Avg=1.74 nm
StDev=1.60 nm

Dataset 2 Analysis

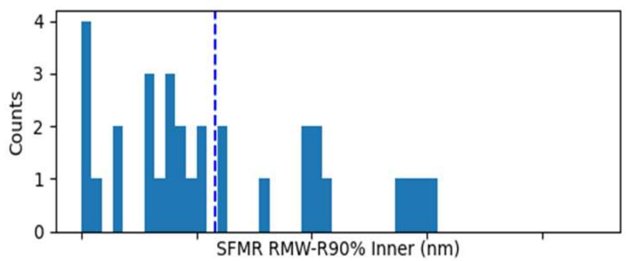
SFMR RMW-Inner 90% Separation (nm) by Category



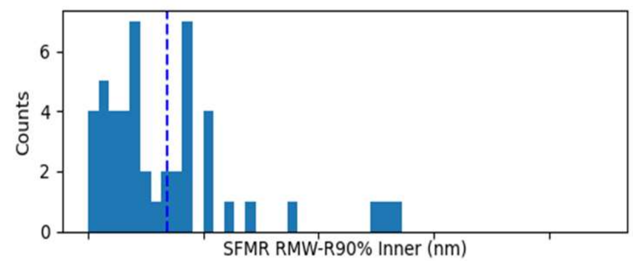
T.S.
N=16
Avg=2.43
StDev=2.31



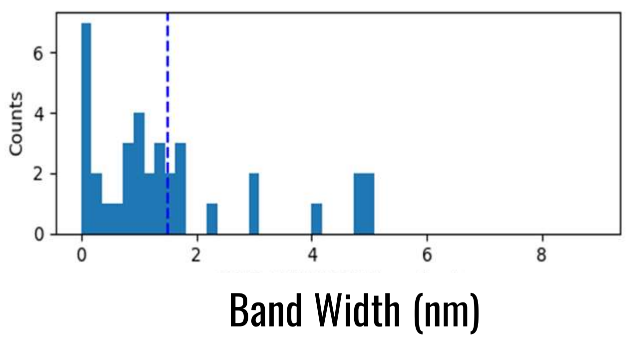
Cat 1
N=19
Avg=2.93
StDev=2.47



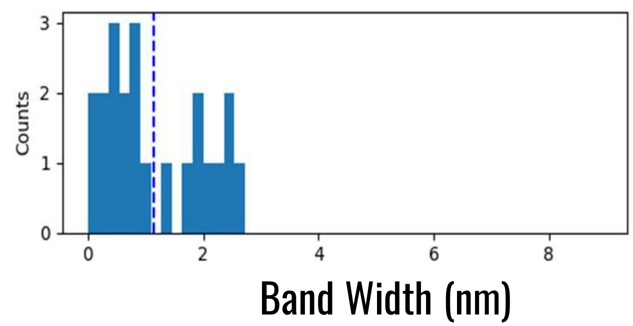
Cat 2
N=31
Avg=2.33
StDev=1.86



Cat 3
N=48
Avg=1.37
StDev=1.27



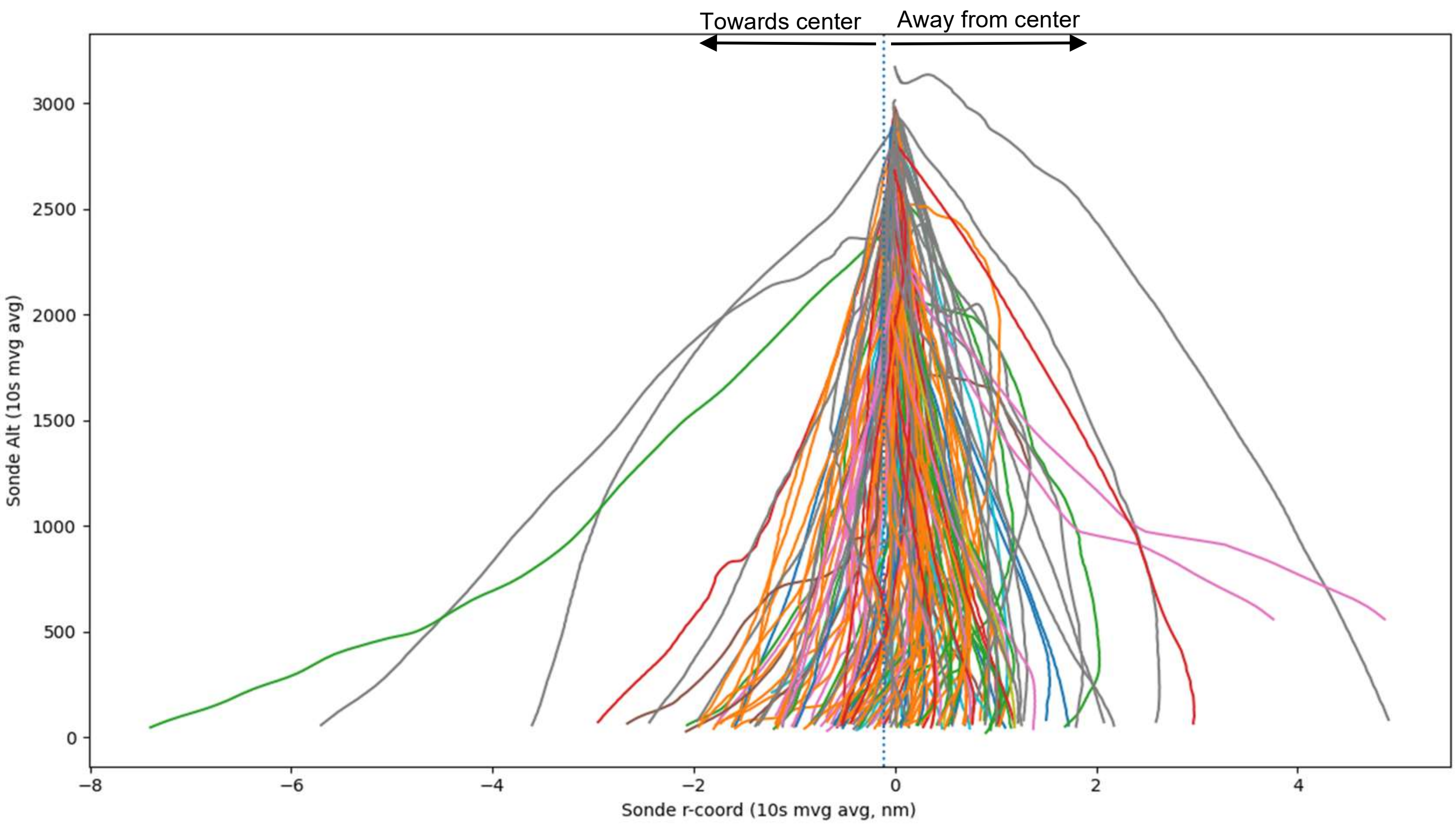
Cat 4
N=36
Avg=1.51
StDev=1.5



Cat 5
N=22
Avg=1.15
StDev=0.88

Dataset 2 Analysis

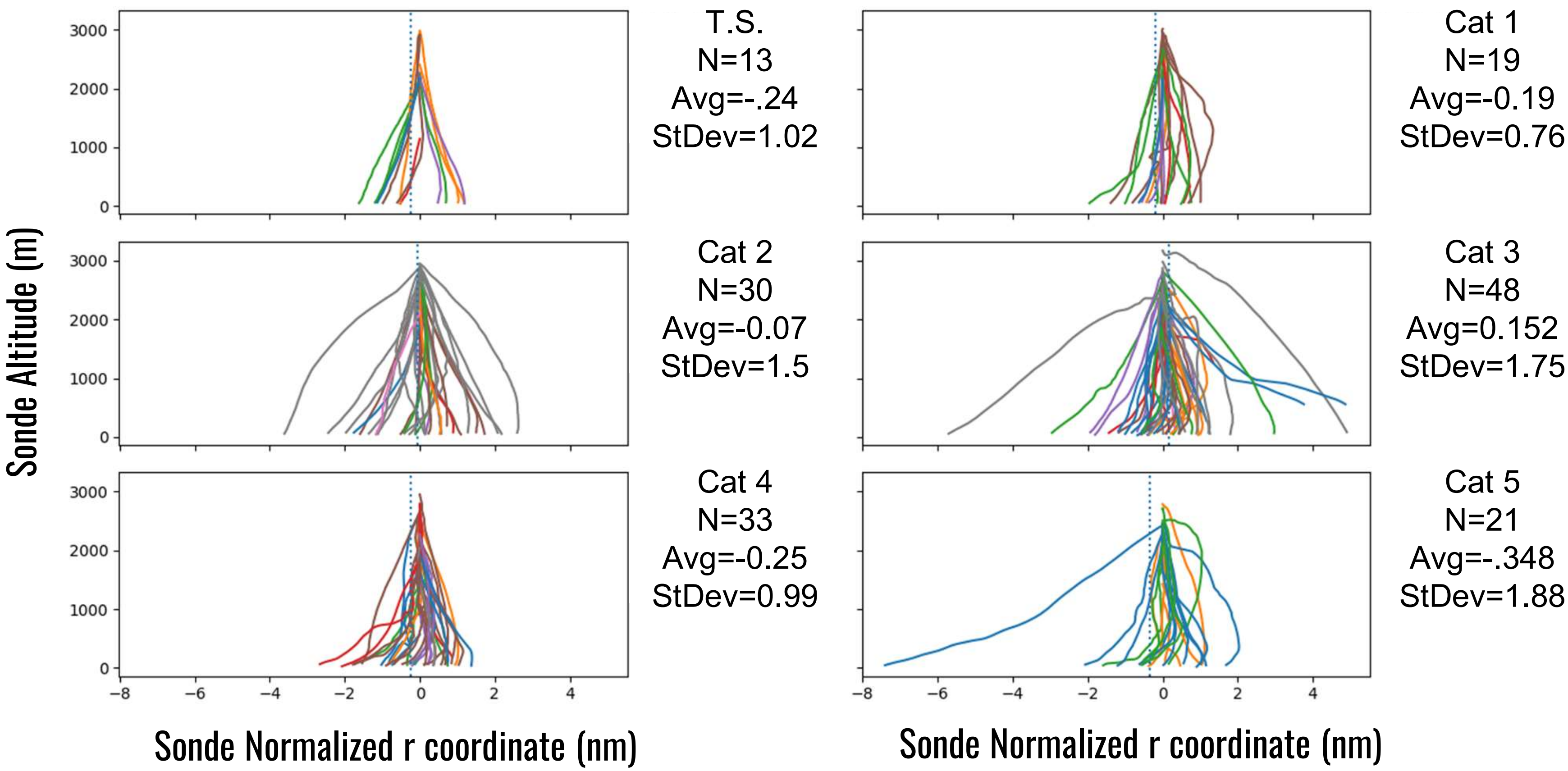
Sonde Normalized r coordinate (nm) vs Altitude (m)



N=172
Avg=-0.105 nm
StDev=1.43 nm

Dataset 2 Analysis

Sonde Normalized r coordinate (nm) vs Altitude (m) by Category



Conclusions

Takeaways:

- Relatively large buffers between surface RMW and R-90%
- No consistent patterns in sonde radial displacement – unexpected
- No single crutch for Flight Directors to rely upon – "art vs science" of drops

Future Work:

- Time series analysis of wind speed transects – examine correlations between FL and SFMR wind speeds to predict locations of wind maxima
- Expand dataset to incorporate more RMW sondes (legwork)

Unused slides

Cyclone Overview

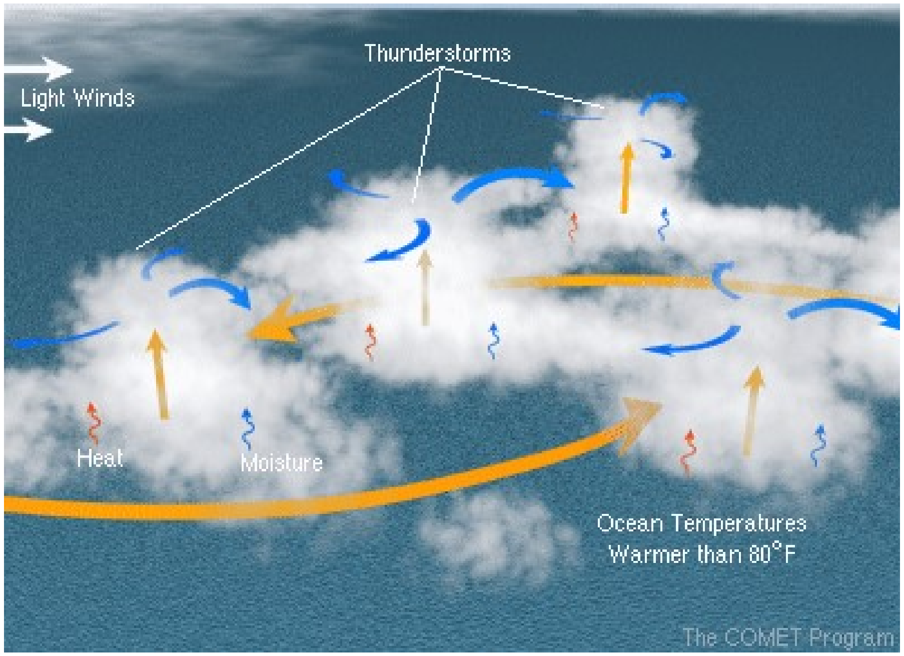
Key Ingredients

Tropical Perturbation: Preexisting area of low atmospheric pressure

Vertical Temperature Gradient: Permits extraction of useful work from ocean

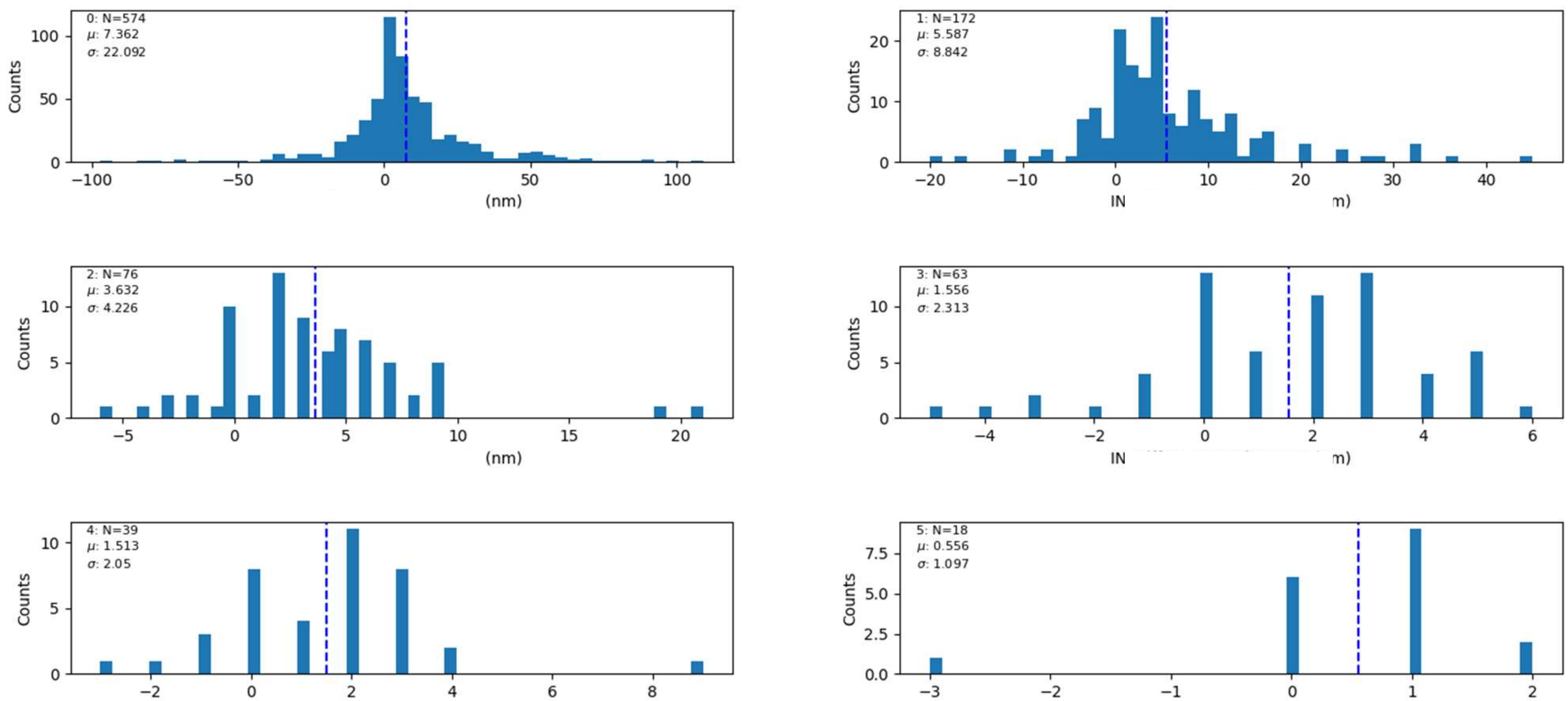
Angular Momentum: Rotational motion provides stability to system. Latitude >~ 4° (Coriolis)

Mild Winds: Strong winds overpower newborn convective structures



Dataset 1 Analysis

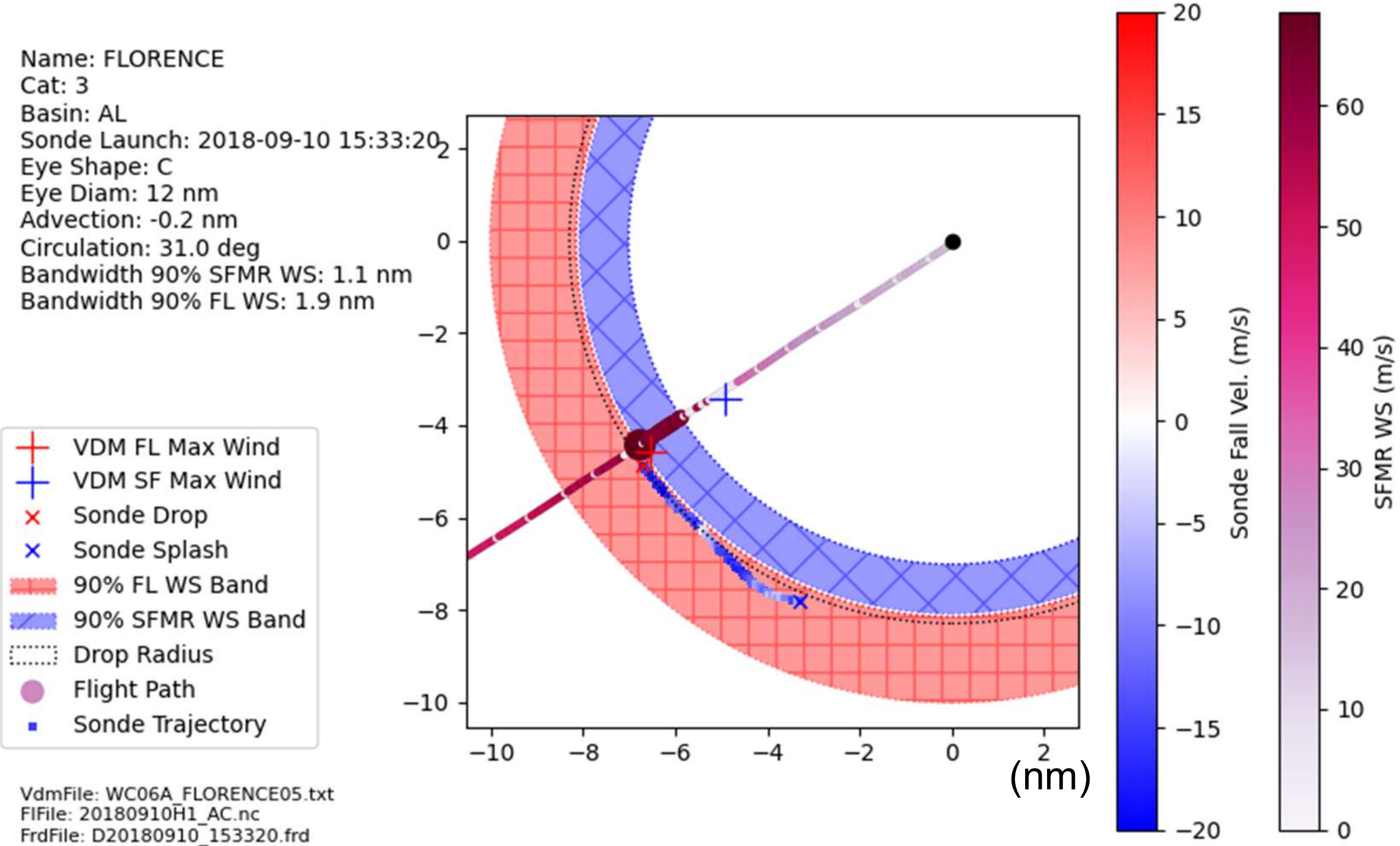
FL-SFC RMW Separation (nm)



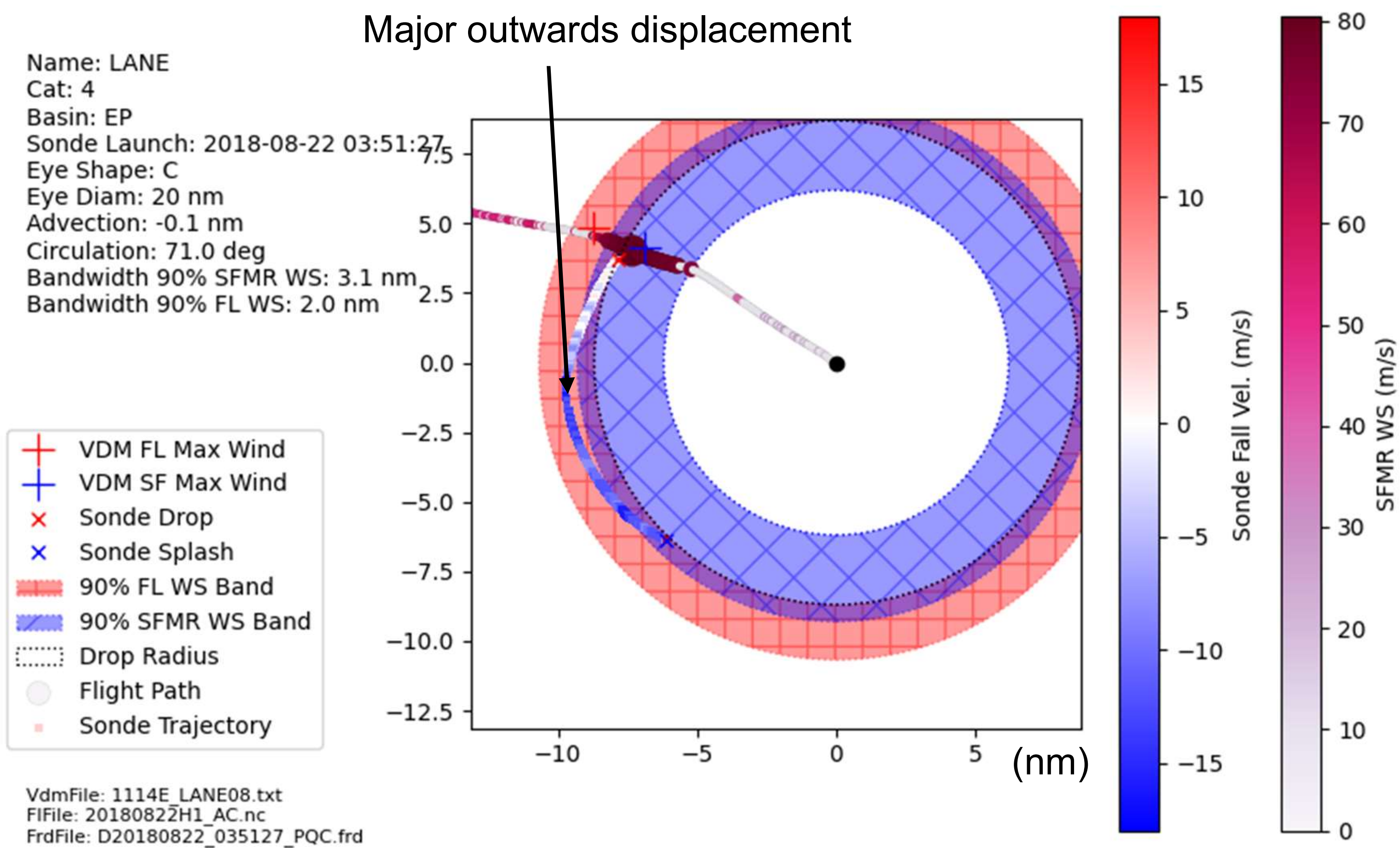
FL-SFC RMW Separation (nm)

FL-SFC RMW Separation (nm)

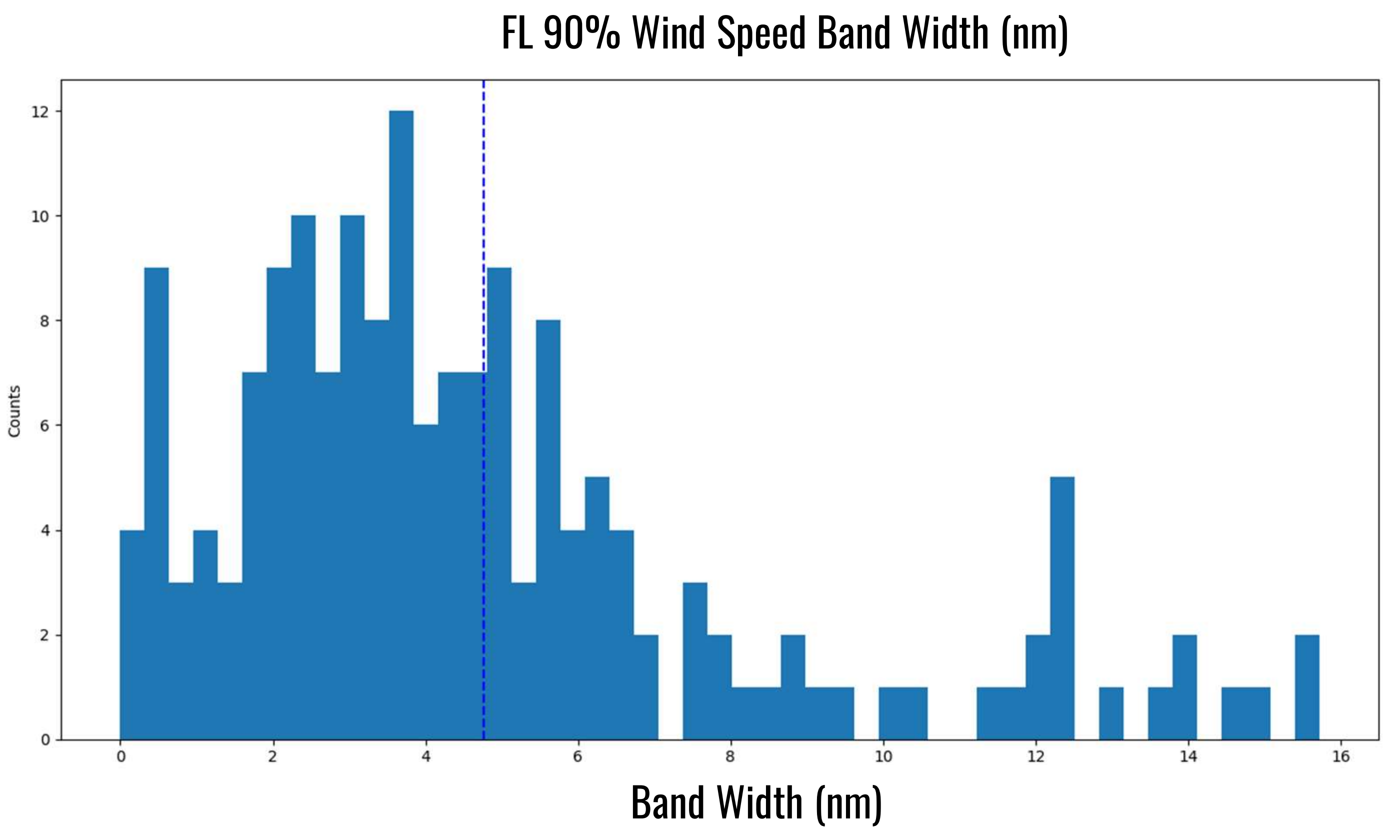
Dataset 2 Example RMW Plots



Dataset 2 Example RMW Plots



Dataset 2 Analysis



N=171
Avg=4.76
StDev=3.57

Dataset 2 Analysis

FL 90% Wind Speed Band Width (nm) by Category