



Defining the Accuracy of Eyewall Radius of Maximum Wind Dropwindsondes

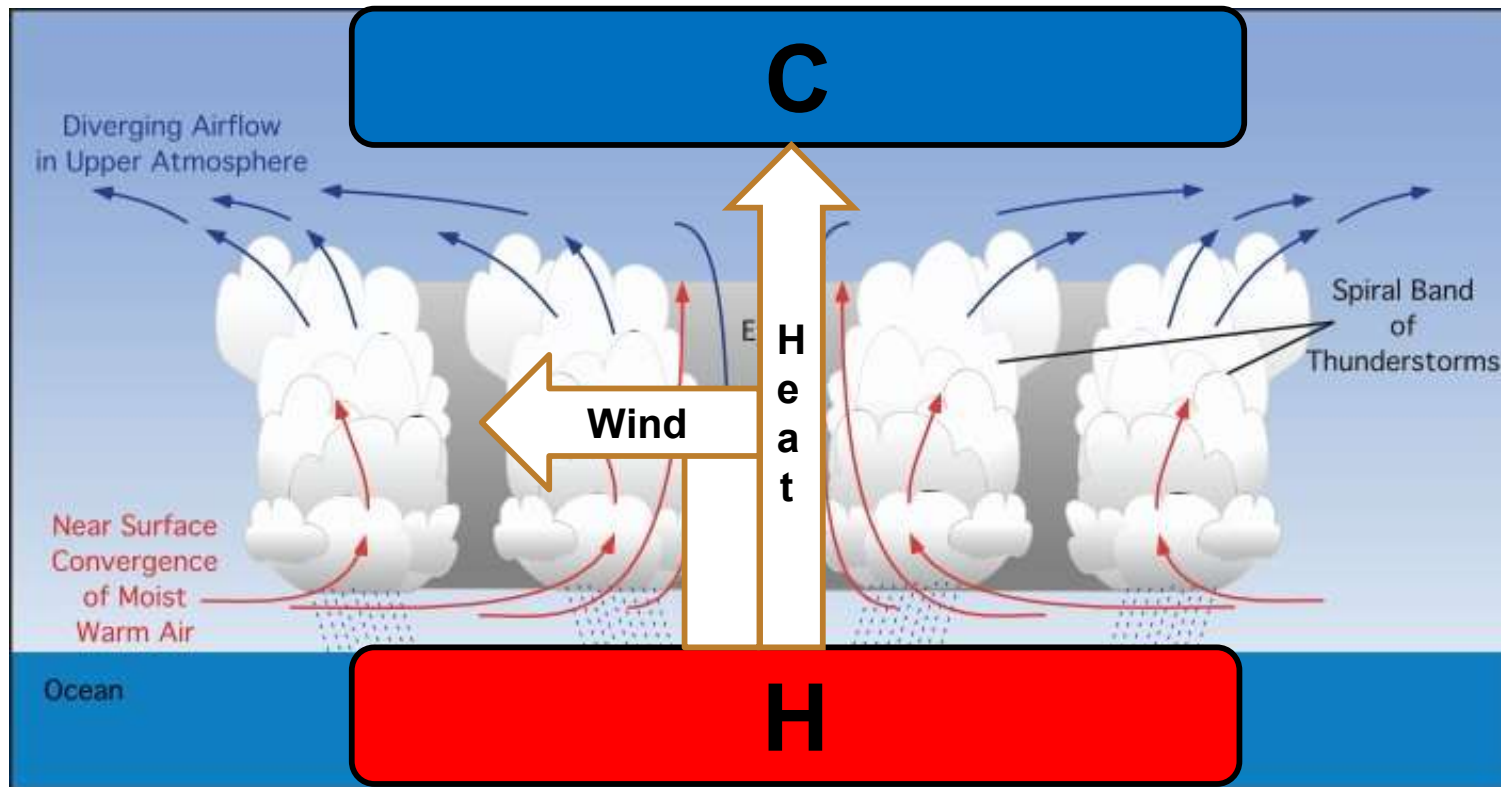
Joe Hesse-Withbroe
NOAA Ernest Hollings Scholar
August 3rd, 2021

Cyclone Overview



What is a Cyclone?

Heat Engine: Produces Energy (Wind) from Temperature Gradient



Cyclone Overview



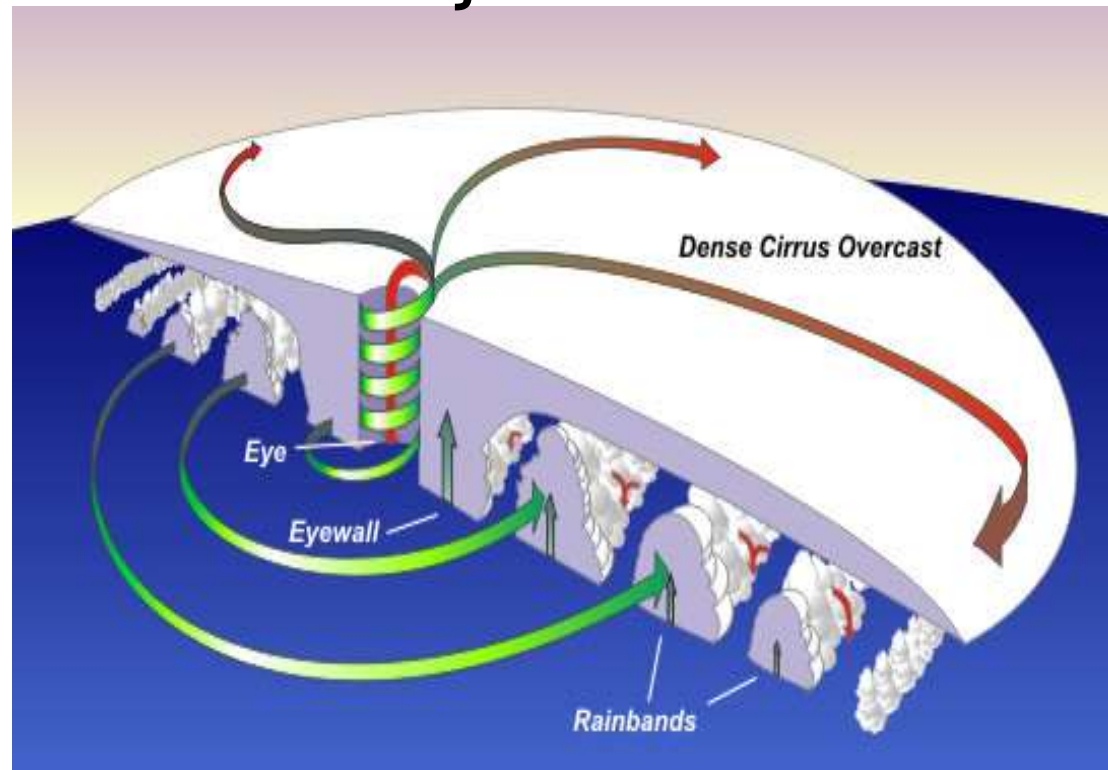
Eye:

- 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

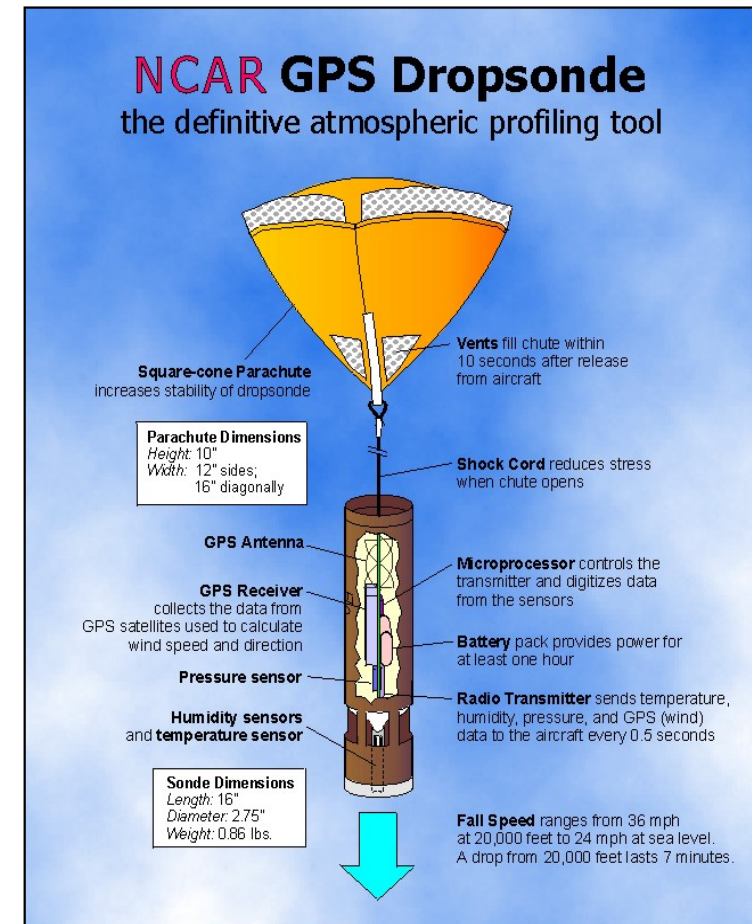


Hurricane Reconnaissance

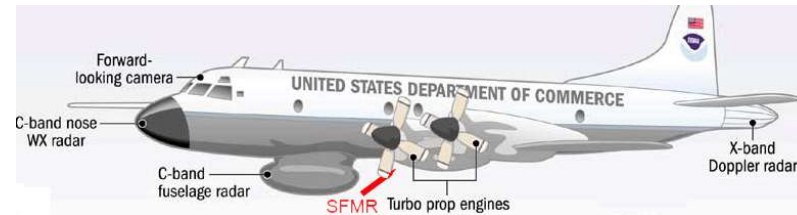


NOAA Lockheed WP-3D Orion

- 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



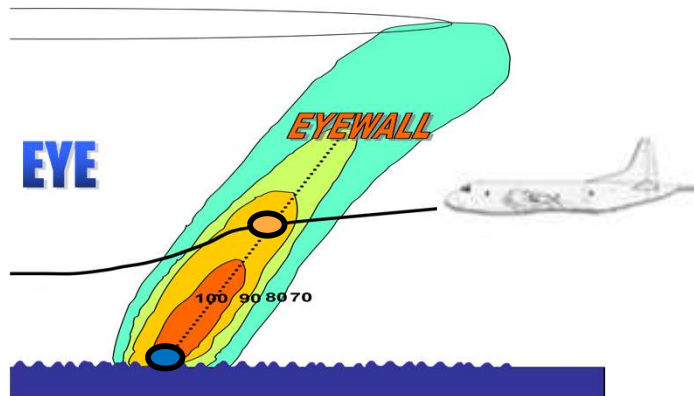
Hurricane Reconnaissance



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, Barrick & Swift to convert foam microwave emissions into surface wind speed estimate

Hurricane Reconnaissance



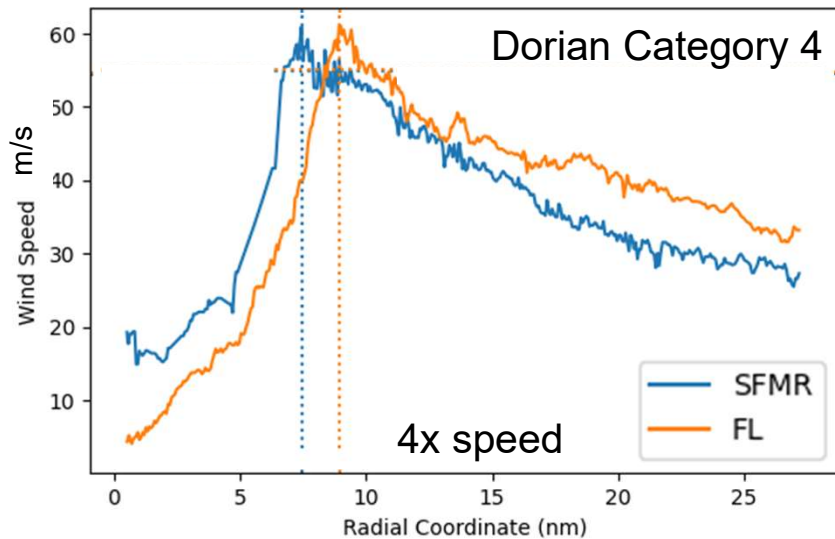
Eyewall Penetration:

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: Analyze historical RMW sonde data to improve the success of future RMW sonde deployments



Datasets



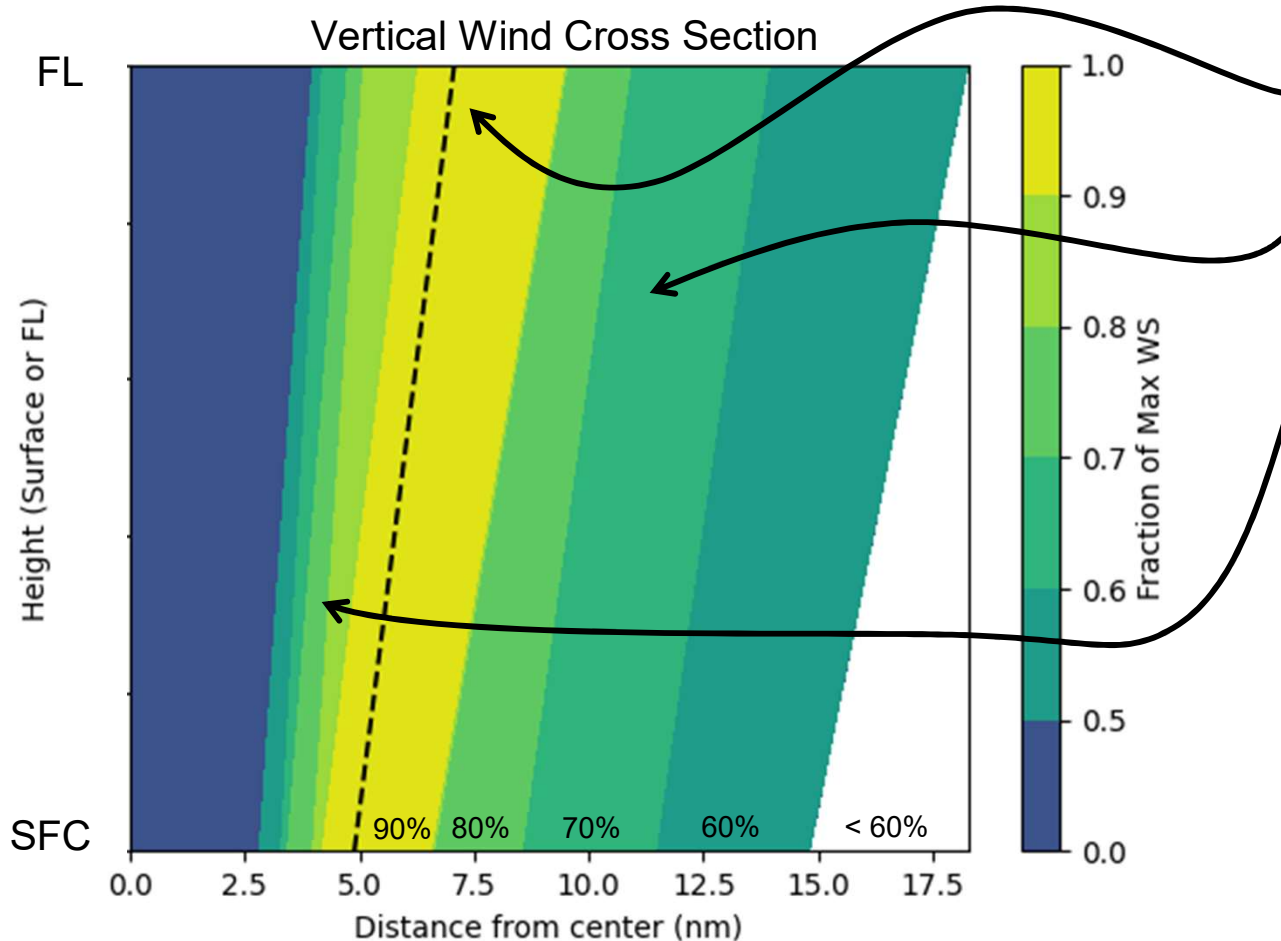
Dataset 1

- 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

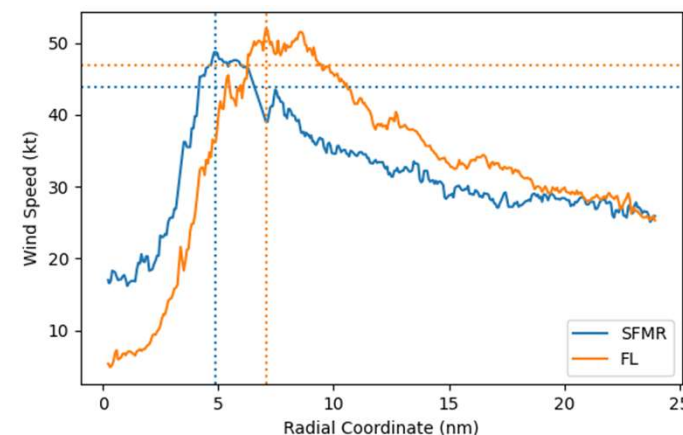


Ideal Cyclone:

FL RMW slightly outside SFC RMW

Slow buildup of FL and SFMR wind speeds outside peak

Steep falloff of wind speeds inside peak

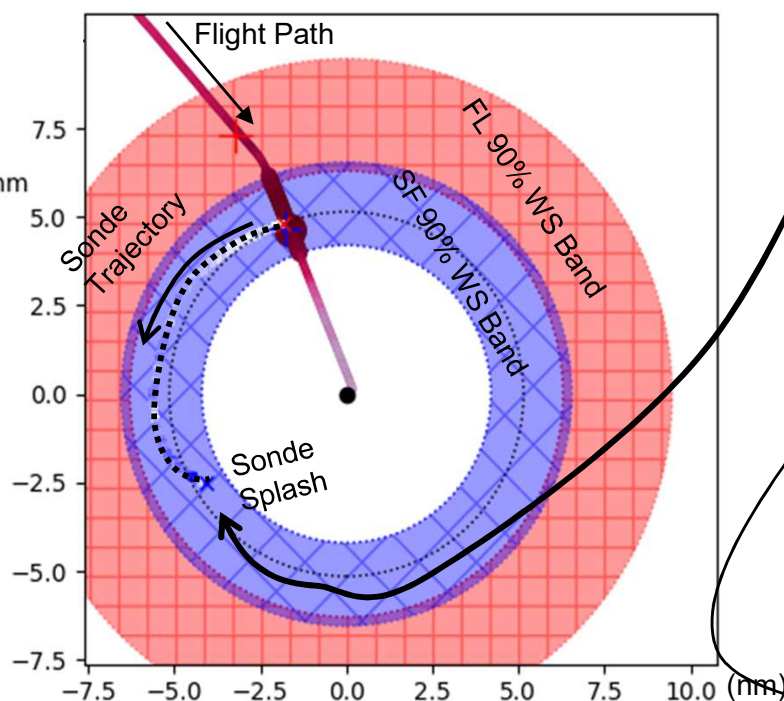


'Ideal' Cyclone & RMW Sonde



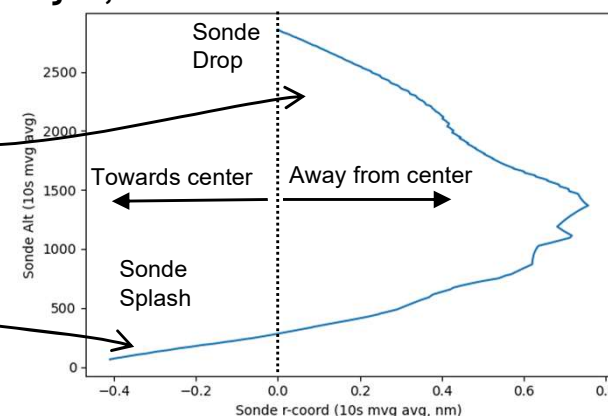
Name: DELTA
Cat: 4
Basin: AL
Sonde Launch: 2020-10-06
Eye Shape: C
Eye Diam: 6 nm
Advection: -0.4 nm
Circulation: 101.0 deg
Bandwidth 90% SFMR WS: 2.4 nm
Bandwidth 90% FL WS: 3.2 nm

+ VDM FL Max Wind
+ VDM SF Max Wind
x Sonde Drop
x Sonde Splash
90% FL WS Band
90% SFMR WS Band
Drop Radius
Flight Path
Sonde Trajectory



Ideal Sonde:

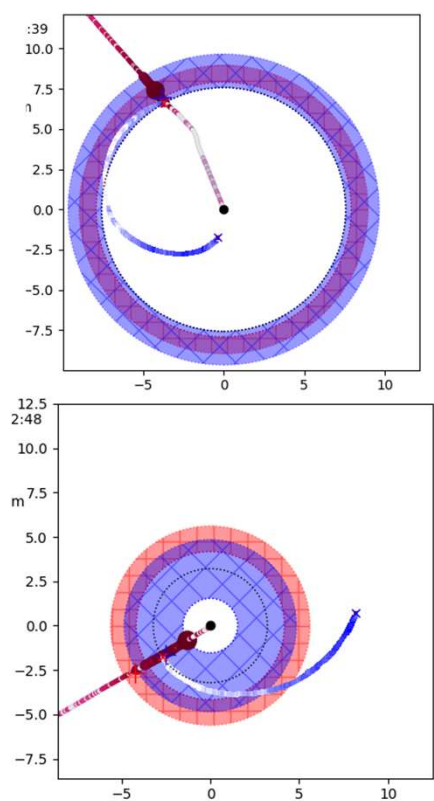
- Wind speed at splash location at least 90% of maximum surface wind (inside blue ring)
- Initial outward displacement of sonde
- Inward advection of sonde near boundary layer, net inward movement



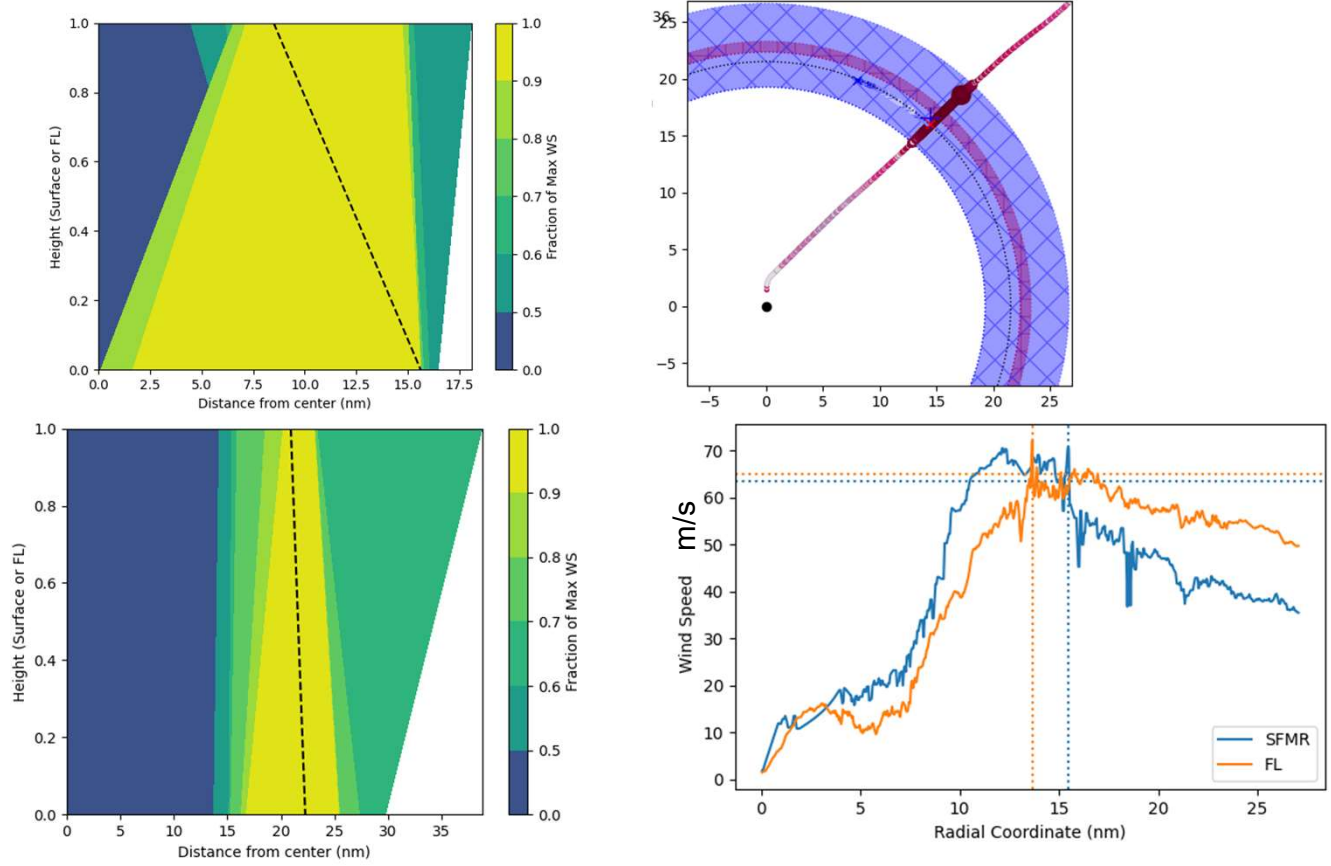
Actual Cyclones and RMW Sondes



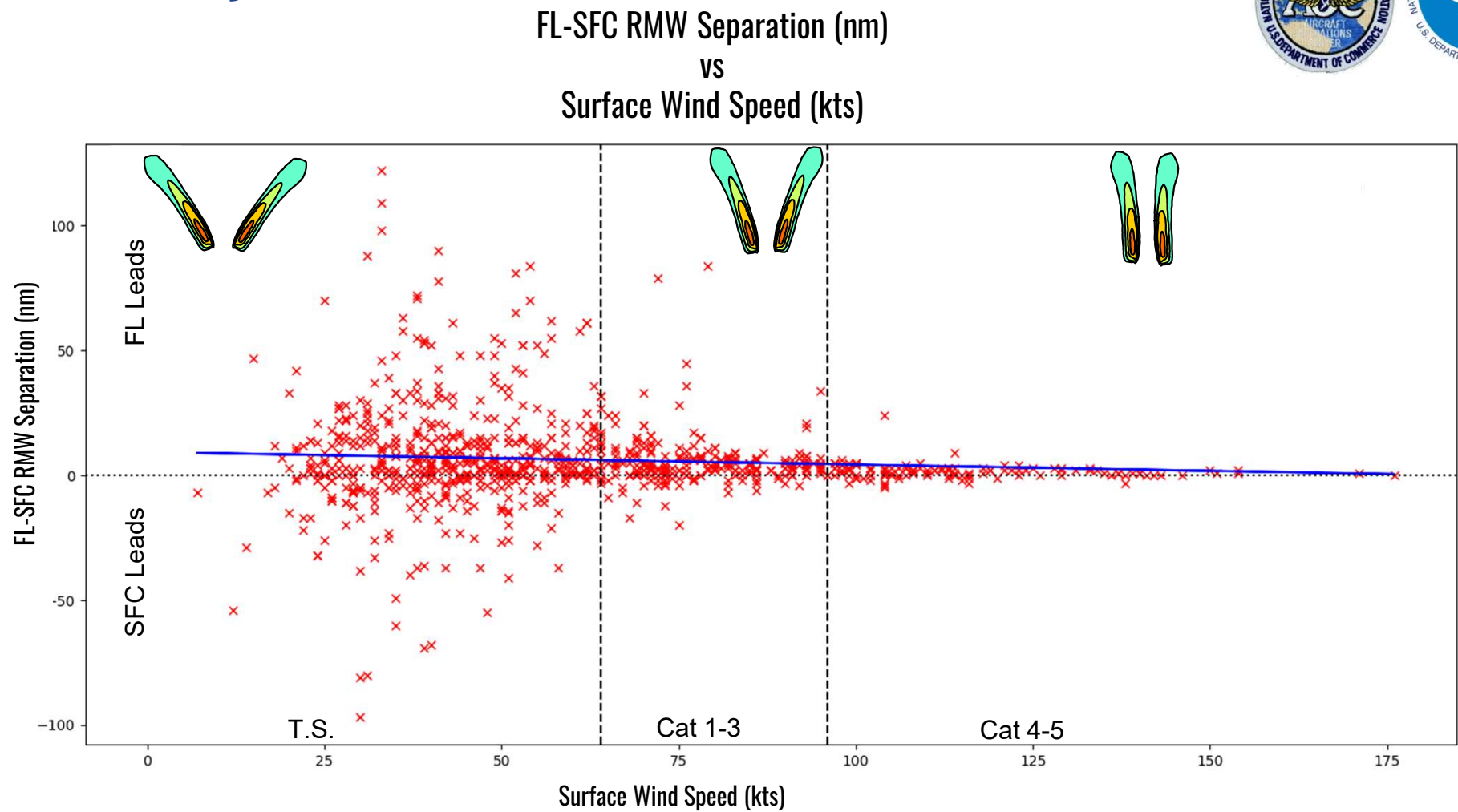
Unpredictable Displacements



Disorganized system (SF RMW > FL RMW)



Dataset 1 Analysis

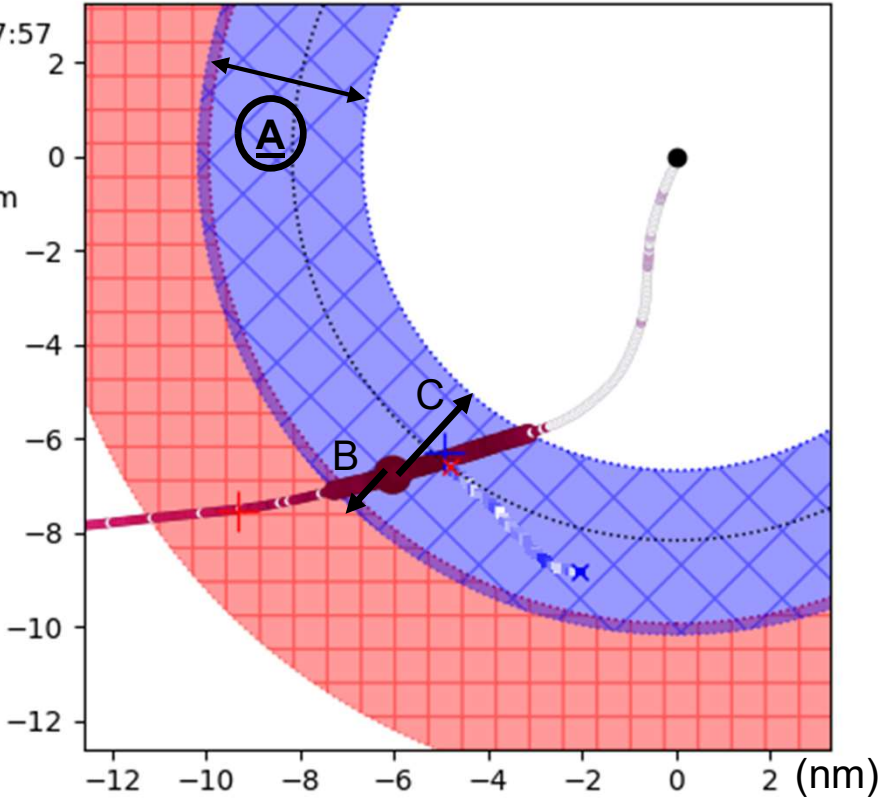


Dataset 2 Analysis



Name: 0214E
Cat: 3
Basin: EP
Sonde Launch: 2018-08-20 05:07:57
Eye Shape: C
Eye Diam: 15 nm
Advection: -0.9 nm
Circulation: 23.0 deg
Bandwidth 90% SFMR WS: 3.5 nm
Bandwidth 90% FL WS: 3.7 nm

- + VDM FL Max Wind
- + VDM SF Max Wind
- x Sonde Drop
- x Sonde Splash
- 90% FL WS Band
- 90% SFMR WS Band
- Drop Radius
- Flight Path
- Sonde Trajectory

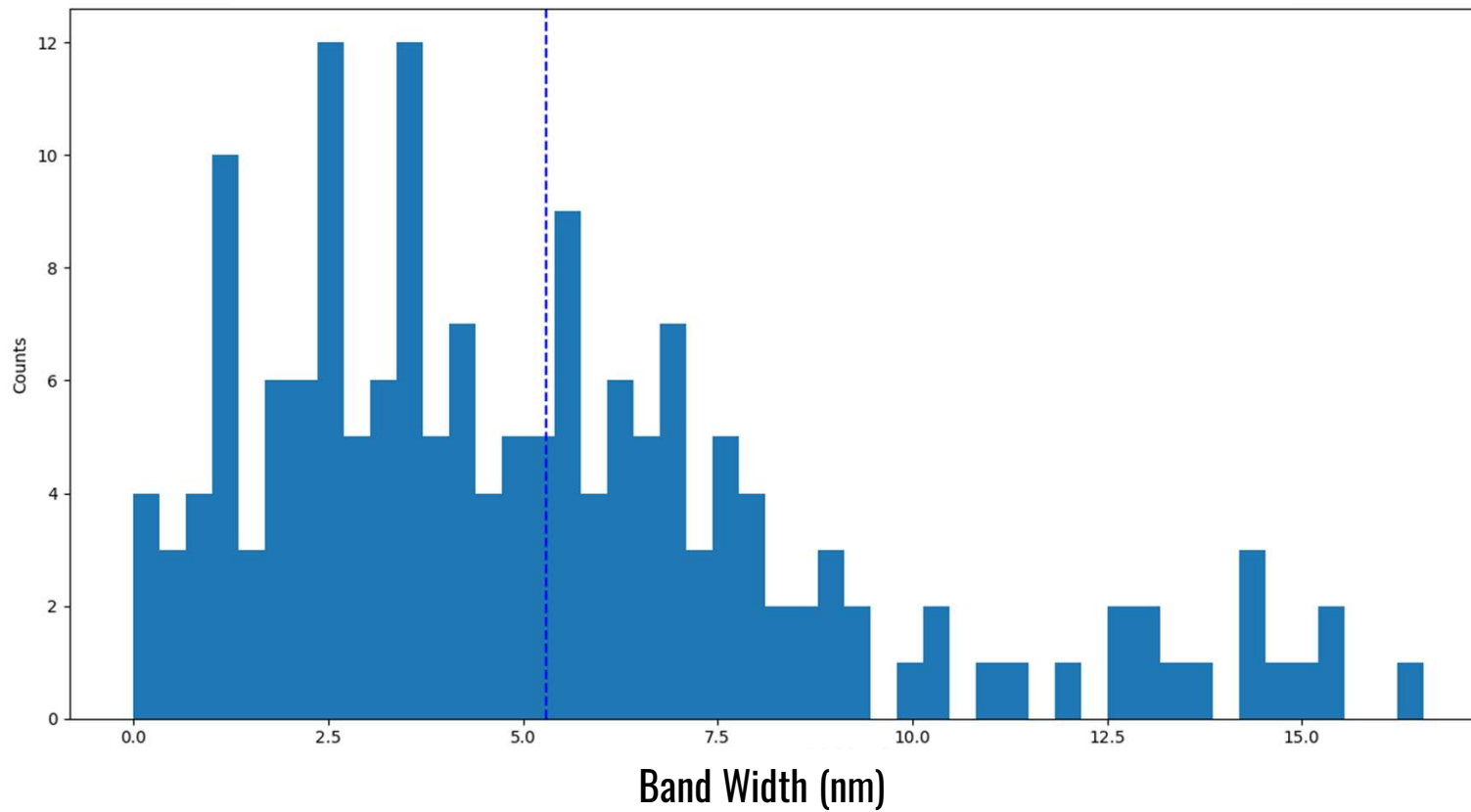


VdmFile: NOAA2_0214EOB.txt
FIFile: 20180820H1_AC.nc
FrdFile: D20180820_050758OC.frd

Dataset 2 Analysis



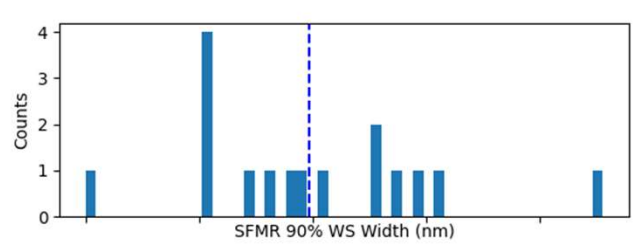
SFMR 90% Wind Speed Band Width ("Target Size")



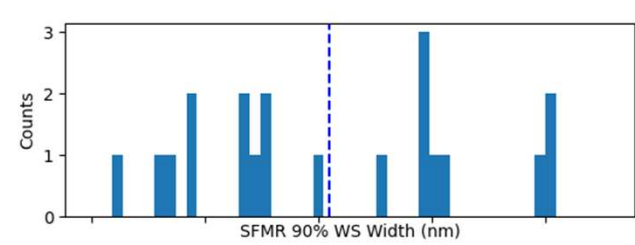
N=169
Avg=5.30
StDev=3.72

Dataset 2 Analysis

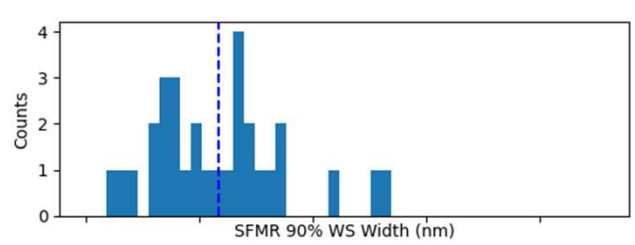
SFMR 90% Wind Speed Band Width (nm) by Category



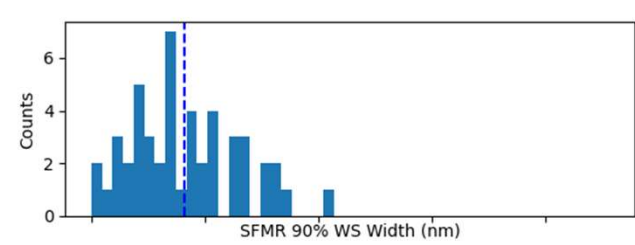
T.S.
N=16
Avg=9.86
StDev=5.39



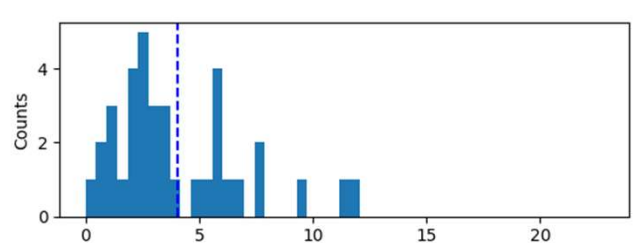
Cat 1
N=20
Avg=10.46
StDev=6.13



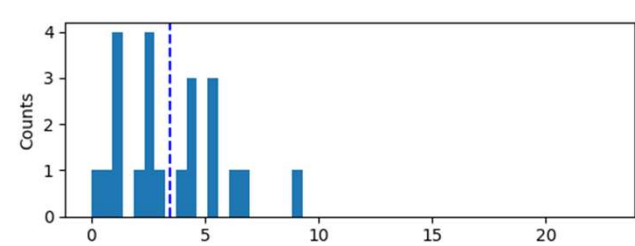
Cat 2
N=30
Avg=5.85
StDev=2.98



Cat 3
N=48
Avg=4.12
StDev=2.41



Cat 4
N=36
Avg=4.05
StDev=2.95



Cat 5
N=22
Avg=3.47
StDev=2.31

Band Width (nm)

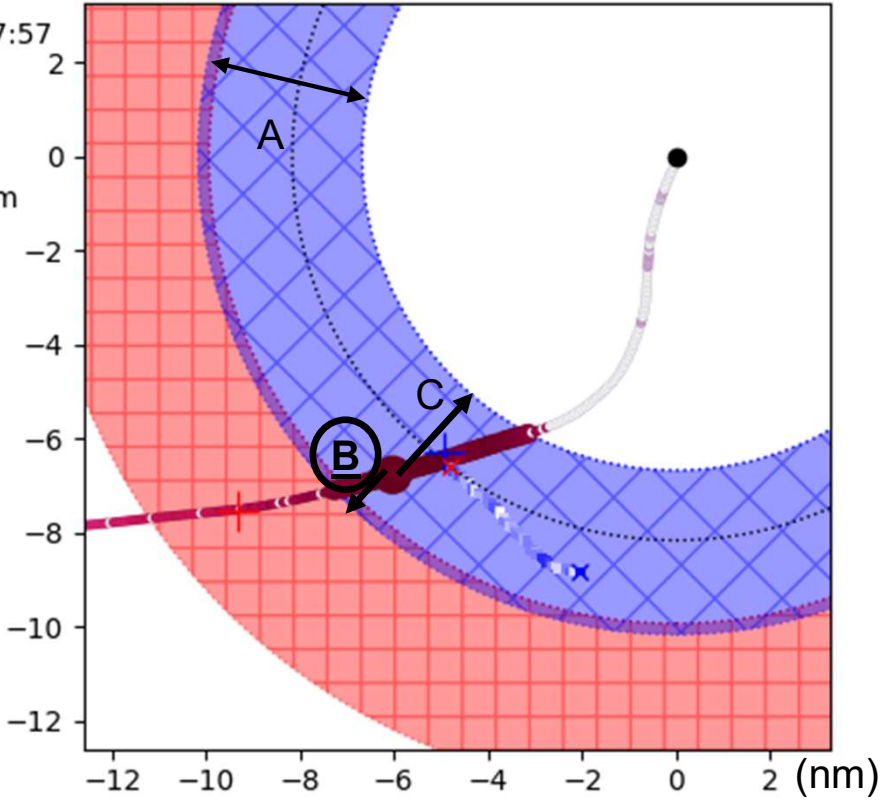
Band Width (nm)

Dataset 2 Analysis



Name: 0214E
Cat: 3
Basin: EP
Sonde Launch: 2018-08-20 05:07:57
Eye Shape: C
Eye Diam: 15 nm
Advection: -0.9 nm
Circulation: 23.0 deg
Bandwidth 90% SFMR WS: 3.5 nm
Bandwidth 90% FL WS: 3.7 nm

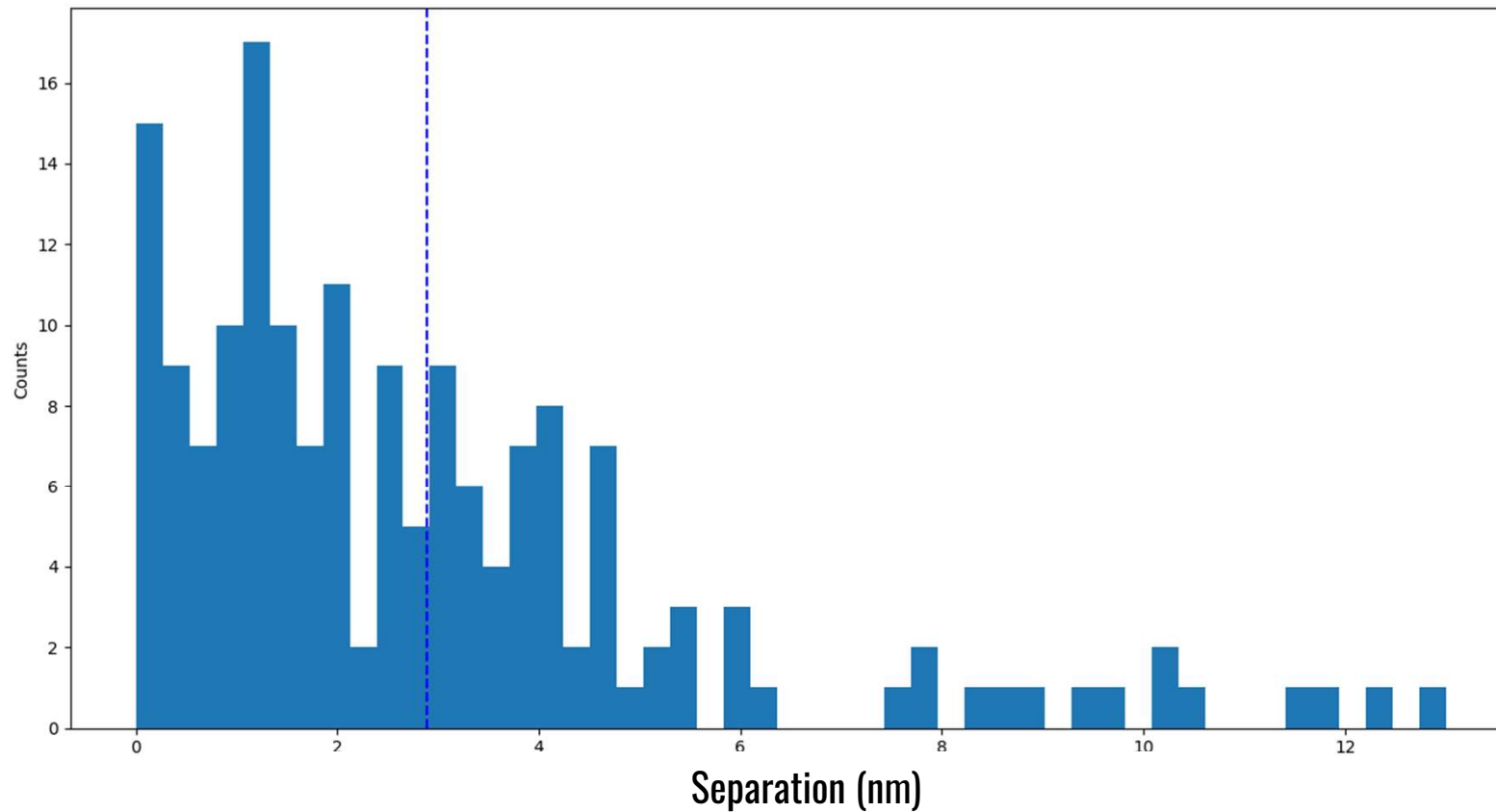
- + VDM FL Max Wind
- + VDM SF Max Wind
- x Sonde Drop
- x Sonde Splash
- 90% FL WS Band
- 90% SFMR WS Band
- Drop Radius
- Flight Path
- Sonde Trajectory



VdmFile: NOAA2_0214EOB.txt
FIFile: 20180820H1_AC.nc
FrdFile: D20180820_050758OC.frd

Dataset 2 Analysis

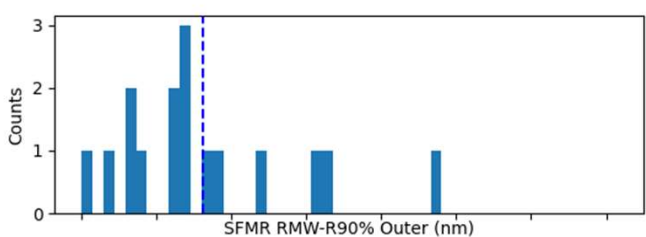
SFMR RMW-Outer 90% Separation (nm) (“Outbound Buffer”)



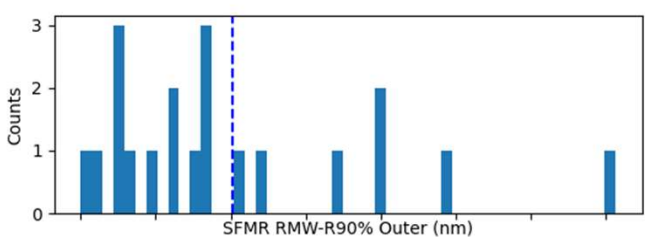
N=170
Avg=2.89 nm
StDev=2.69 nm

Dataset 2 Analysis

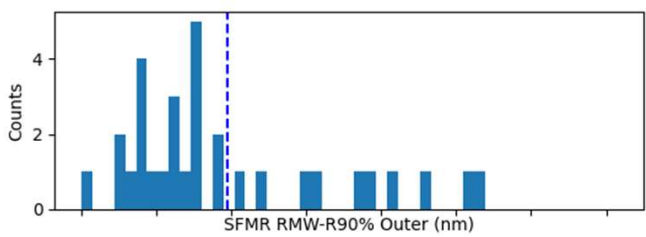
SFMR RMW-Outer 90% Separation (nm) by Category



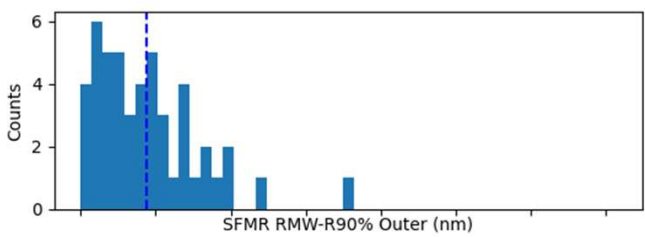
T.S.
N=16
Avg=4.07
StDev=3.05



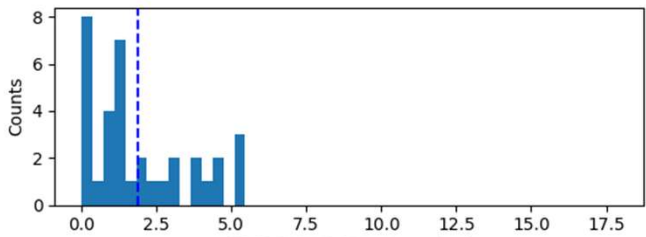
Cat 1
N=20
Avg=5.05
StDev=4.60



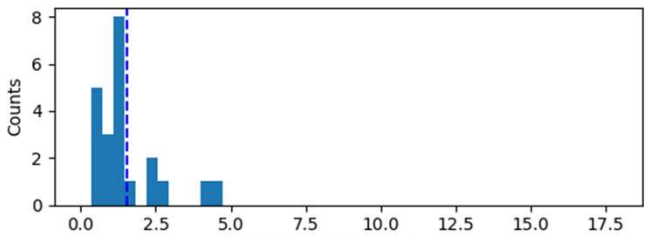
Cat 2
N=31
Avg=4.88
StDev=3.64



Cat 3
N=48
Avg=2.20
StDev=1.78



Cat 4
N=35
Avg=1.89
StDev=1.70



Cat 5
N=22
Avg=1.53
StDev=1.15

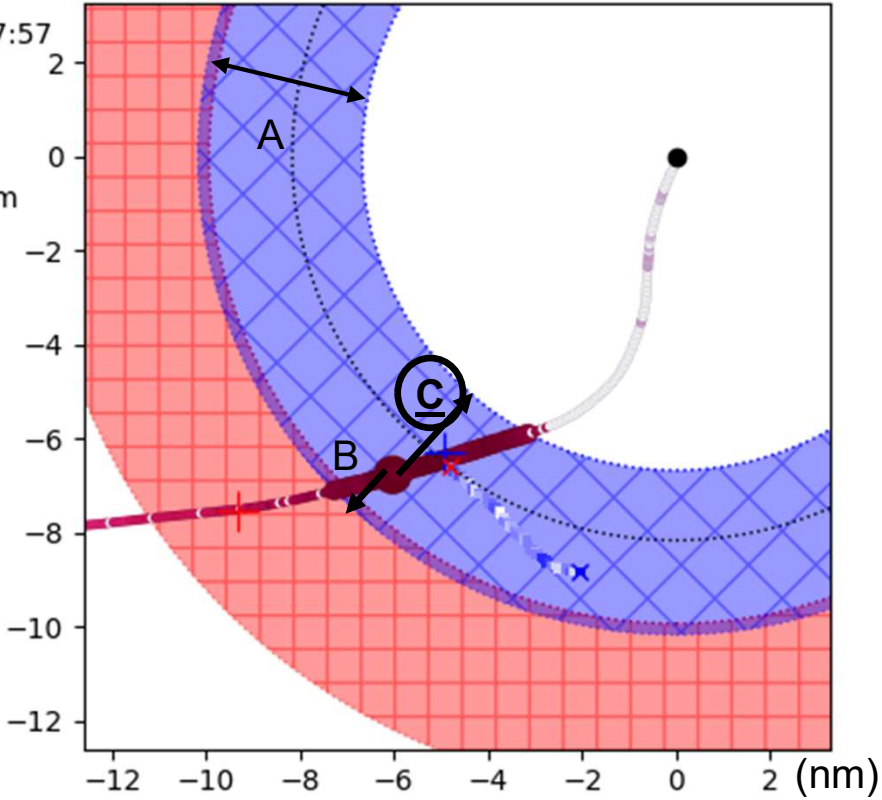


Dataset 2 Analysis



Name: 0214E
Cat: 3
Basin: EP
Sonde Launch: 2018-08-20 05:07:57
Eye Shape: C
Eye Diam: 15 nm
Advection: -0.9 nm
Circulation: 23.0 deg
Bandwidth 90% SFMR WS: 3.5 nm
Bandwidth 90% FL WS: 3.7 nm

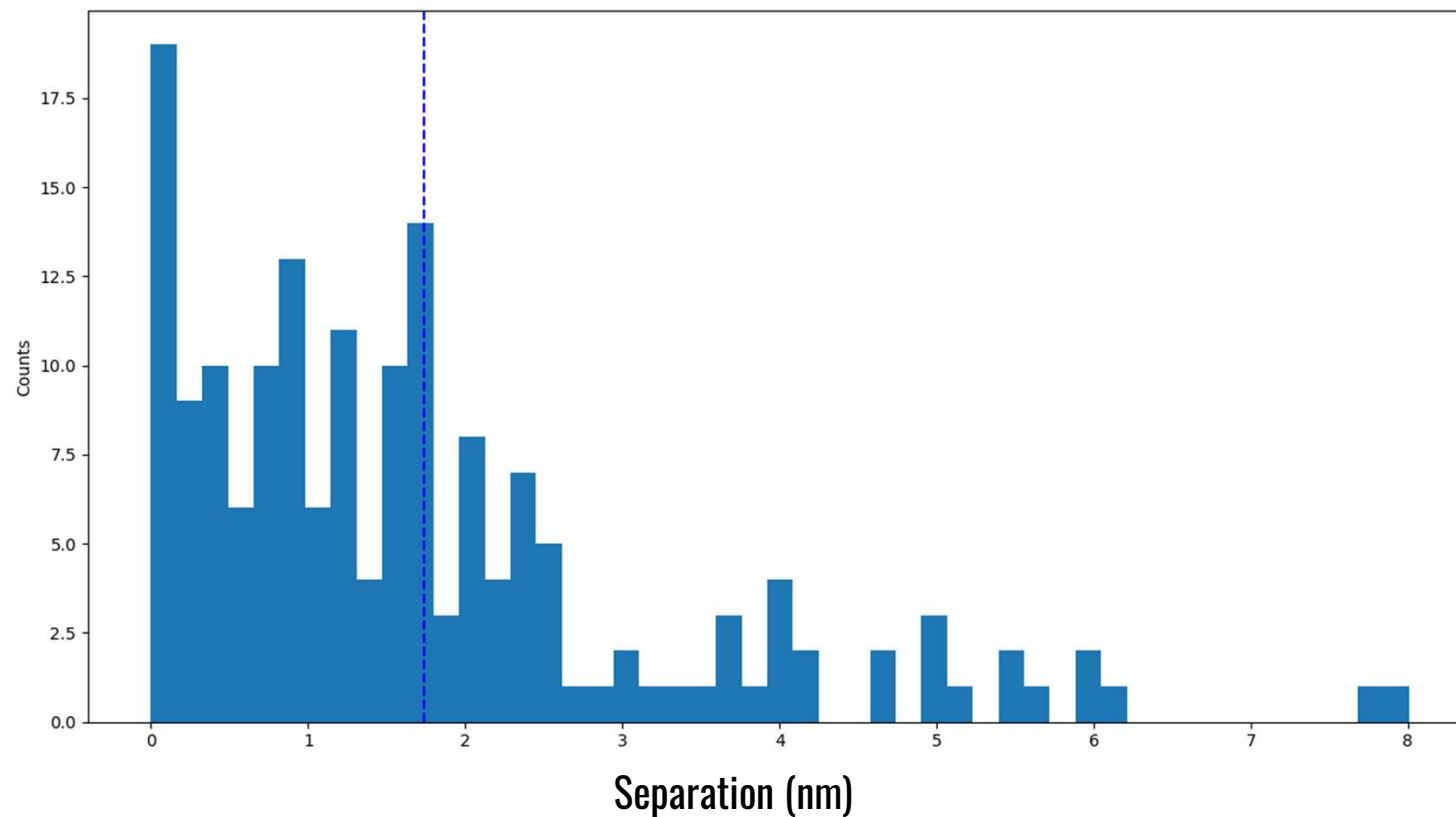
- + VDM FL Max Wind
- + VDM SF Max Wind
- x Sonde Drop
- x Sonde Splash
- 90% FL WS Band
- 90% SFMR WS Band
- Drop Radius
- Flight Path
- Sonde Trajectory



VdmFile: NOAA2_0214EOB.txt
FIFile: 20180820H1_AC.nc
FrdFile: D20180820_050758OC.frd

Dataset 2 Analysis

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



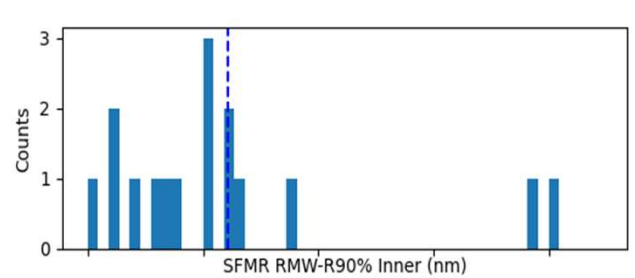
N=169
Avg=1.74 nm
StDev=1.60 nm



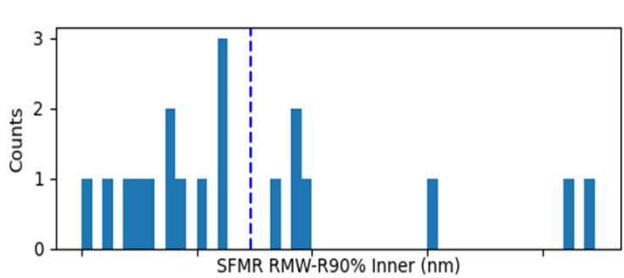
Dataset 2 Analysis



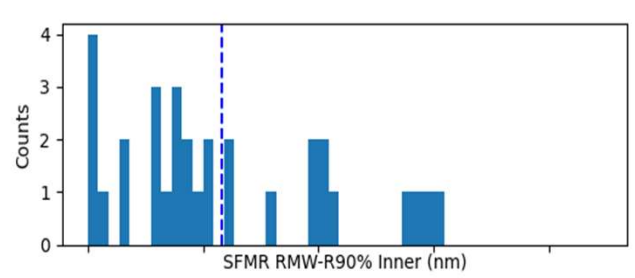
SFMR RMW-Inner 90% Separation (nm) by Category



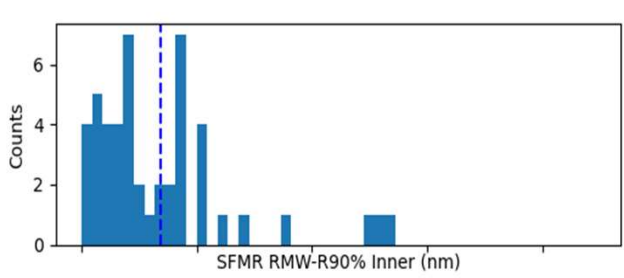
T.S.
N=16
Avg=2.43
StDev=2.31



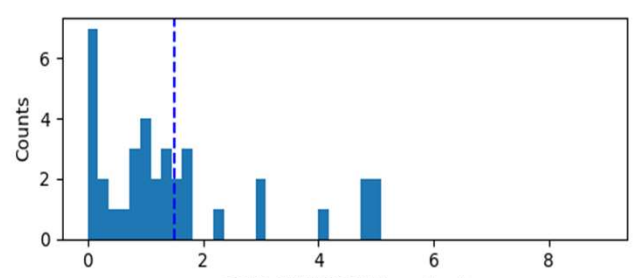
Cat 1
N=19
Avg=2.93
StDev=2.47



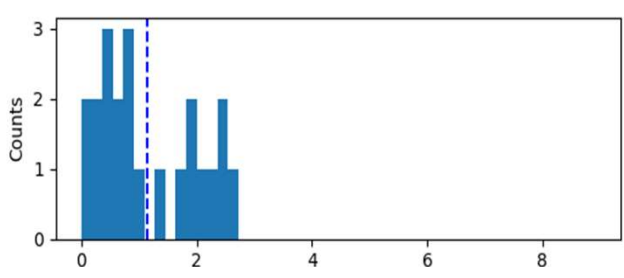
Cat 2
N=31
Avg=2.33
StDev=1.86



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

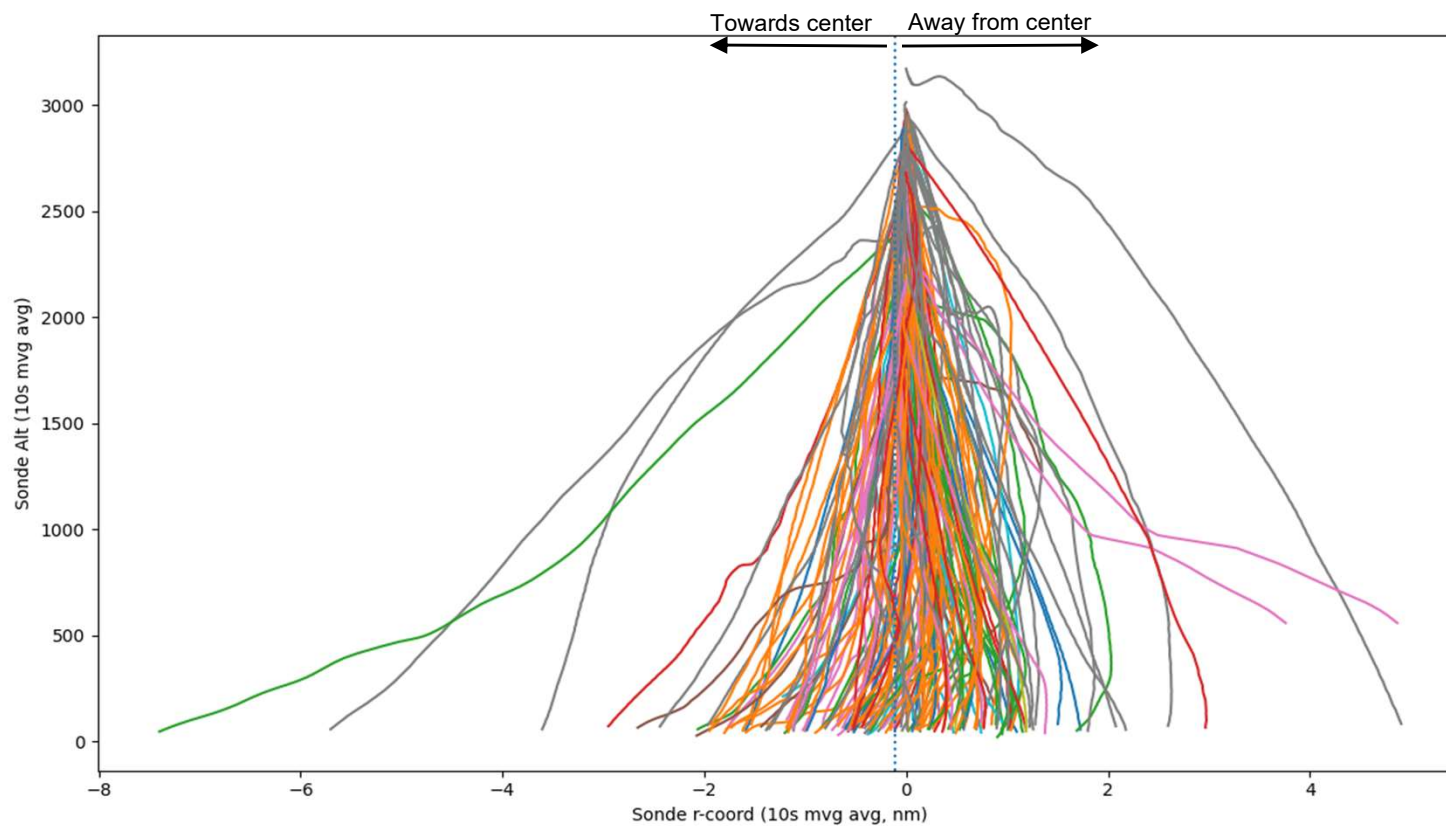
Band Width (nm)

Band Width (nm)

Dataset 2 Analysis



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

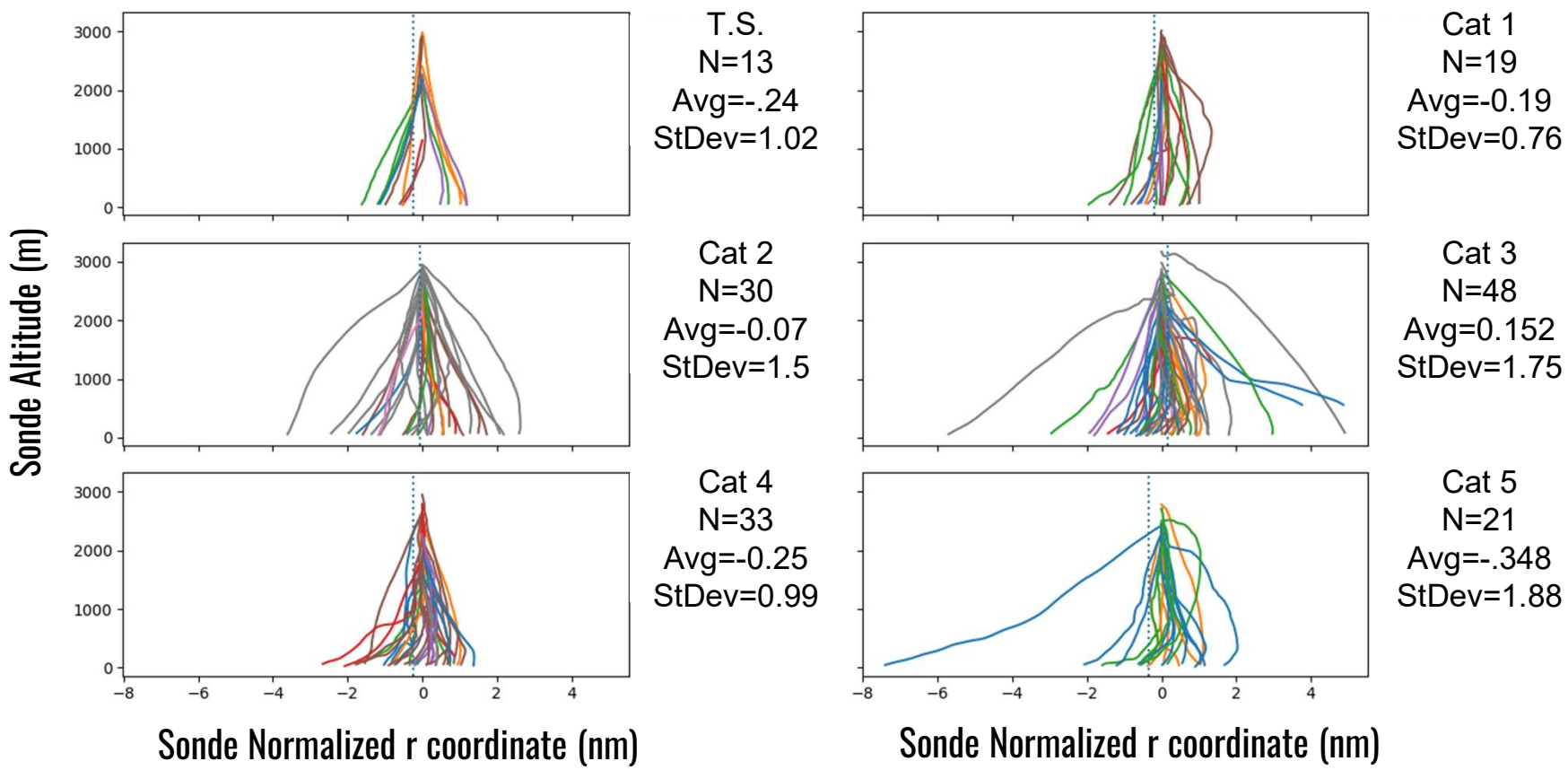


N=172
Avg=-0.105 nm
StDev=1.43 nm

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

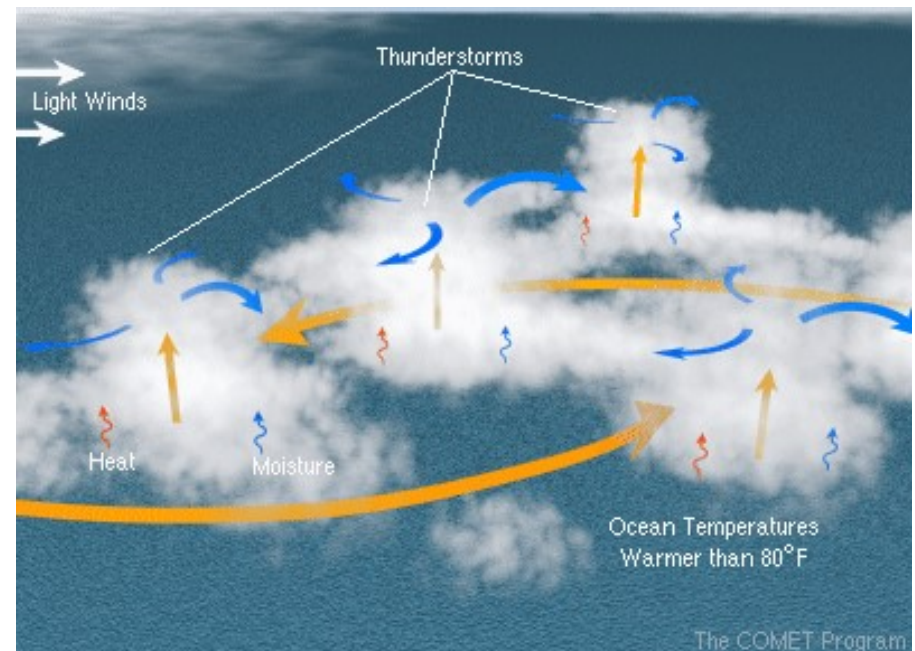
Key Ingredients

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 $> \sim 4^\circ$ (Coriolis)

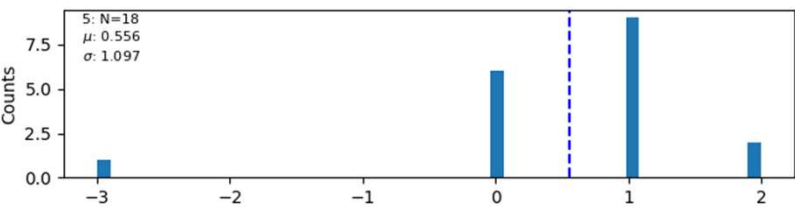
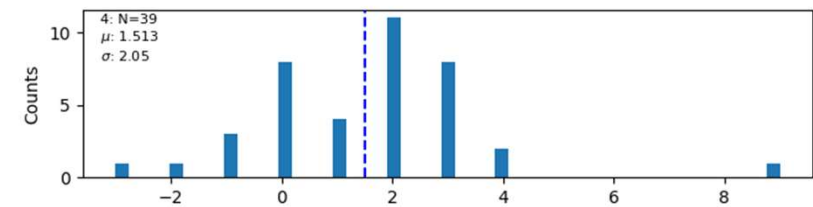
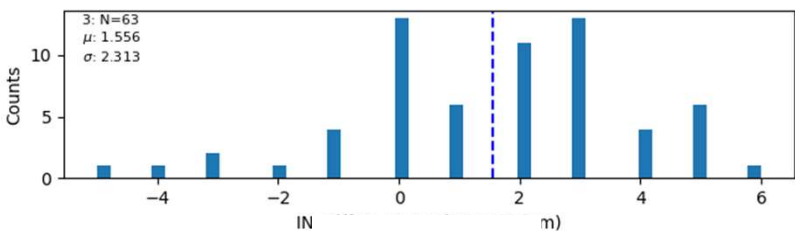
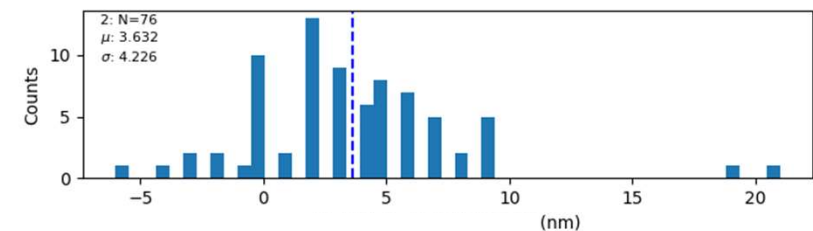
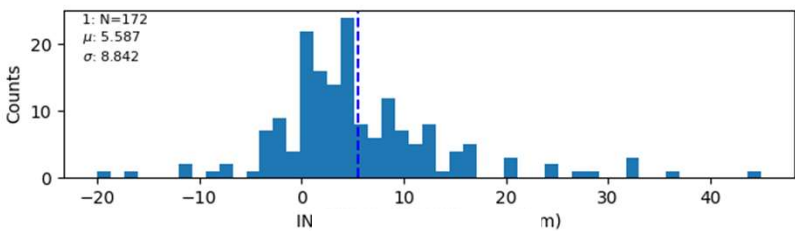
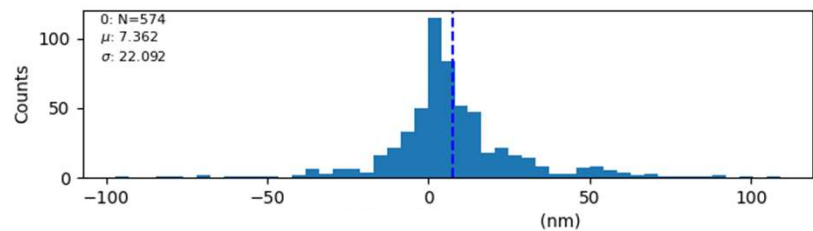
Mild Winds: Strong winds overpower newborn convective structures



Dataset 1 Analysis



FL-SFC RMW Separation (nm)



FL-SFC RMW Separation (nm)

FL-SFC RMW Separation (nm)

Dataset 2 Example RMW Plots

Name: FLORENCE

Cat: 3

Basin: AL

Sonde Launch: 2018-09-10 15:33:20

Eye Shape: C

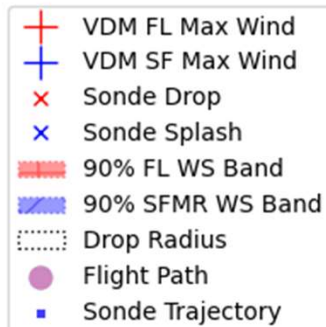
Eye Diam: 12 nm

Advection: -0.2 nm

Circulation: 31.0 deg

Bandwidth 90% SFMR WS: 1.1 nm

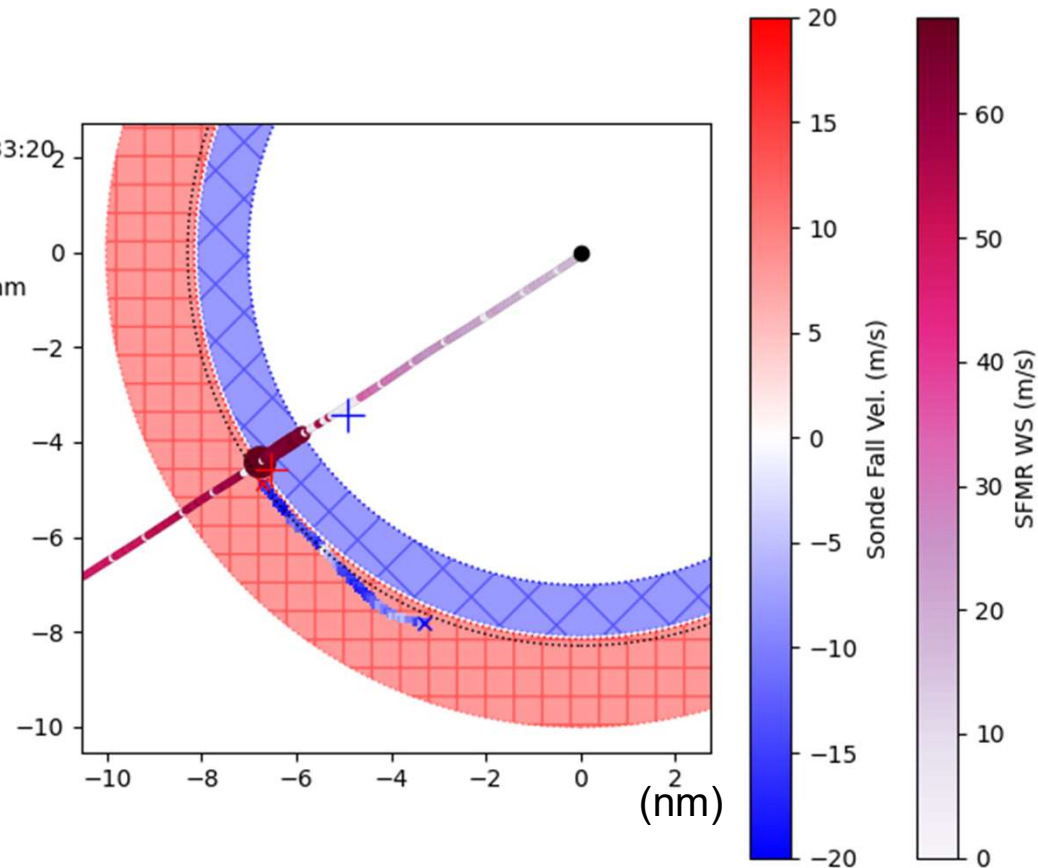
Bandwidth 90% FL WS: 1.9 nm



VdmFile: WC06A_FLORENCE05.txt

FIFile: 20180910H1_AC.nc

FrdFile: D20180910_153320.frd



Dataset 2 Example RMW Plots

Name: LANE

Cat: 4

Basin: EP

Sonde Launch: 2018-08-22 03:51:27

Eye Shape: C

Eye Diam: 20 nm

Advection: -0.1 nm

Circulation: 71.0 deg

Bandwidth 90% SFMR WS: 3.1 nm

Bandwidth 90% FL WS: 2.0 nm

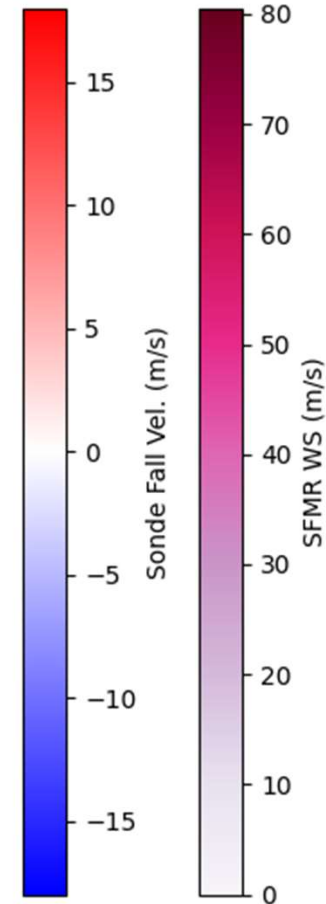
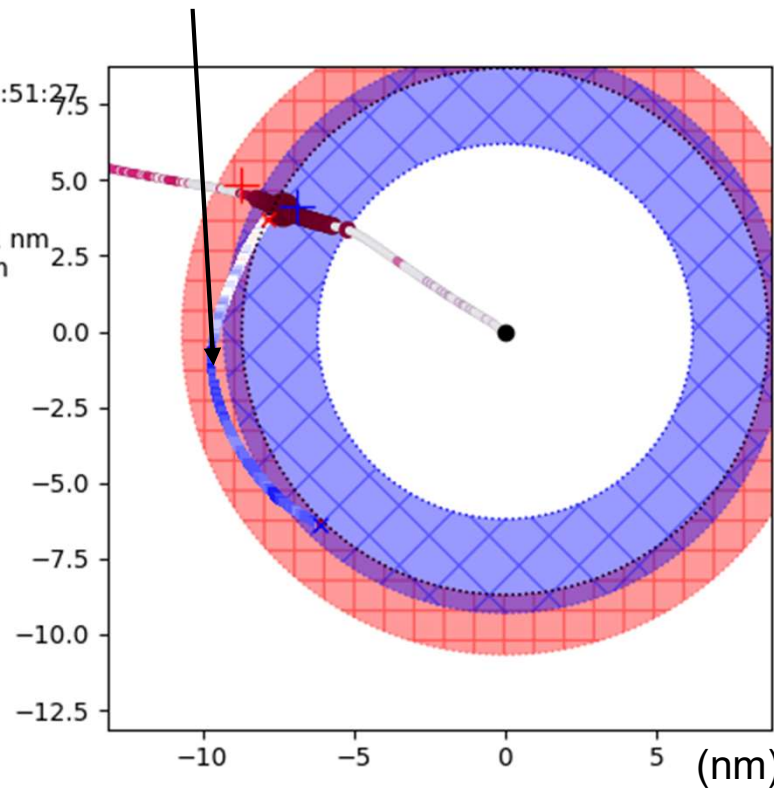
- + VDM FL Max Wind
- + VDM SF Max Wind
- x Sonde Drop
- x Sonde Splash
- 90% FL WS Band
- 90% SFMR WS Band
- Drop Radius
- Flight Path
- Sonde Trajectory

VdmFile: 1114E_LANE08.txt

FIFile: 20180822H1_AC.nc

FrdFile: D20180822_035127_PQC.frd

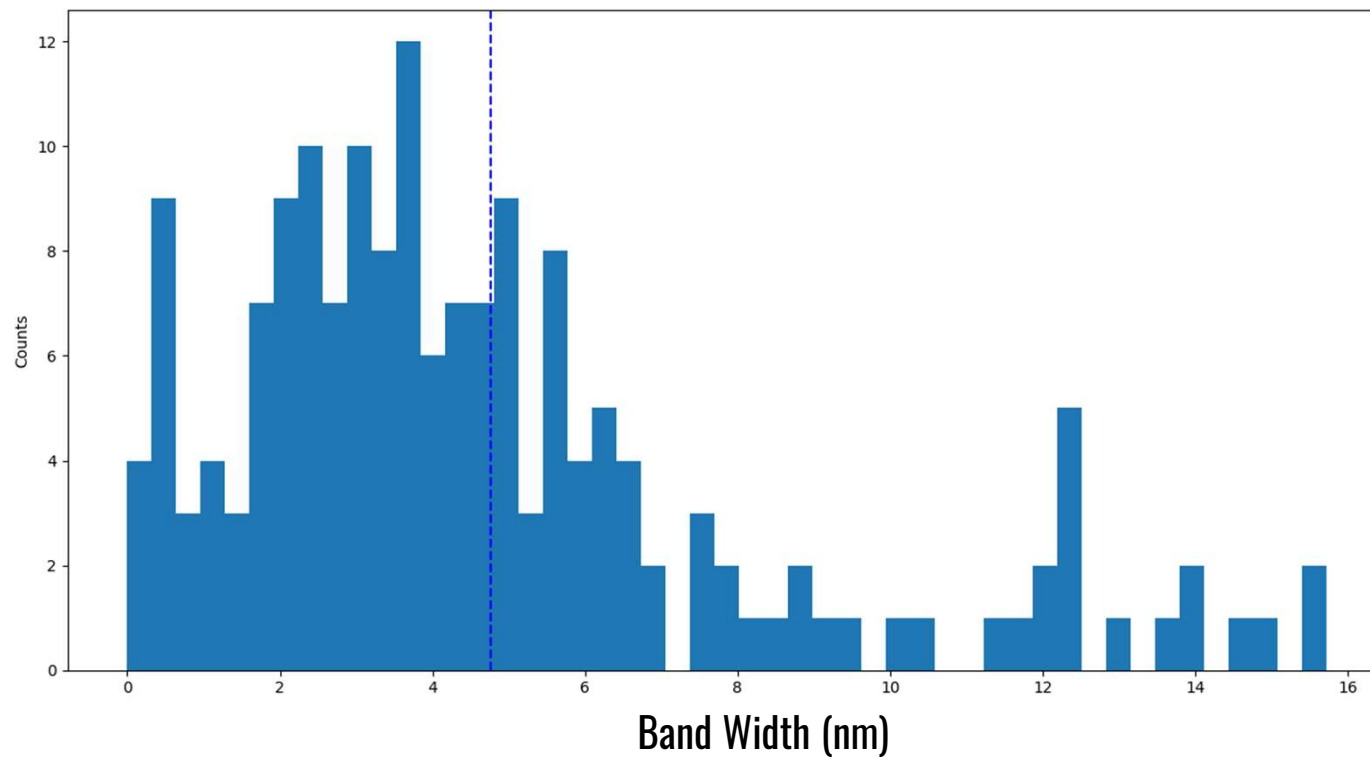
Major outwards displacement



Dataset 2 Analysis



FL 90% Wind Speed Band Width (nm)

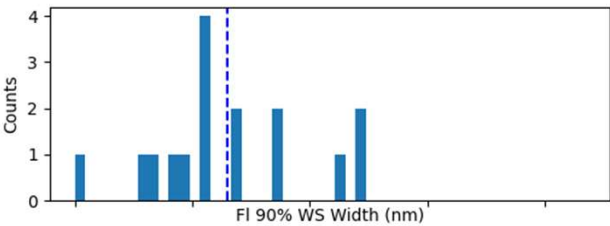


N=171
Avg=4.76
StDev=3.57

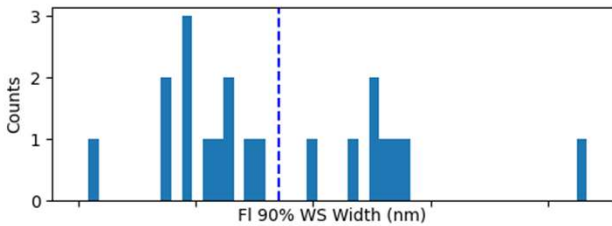
Dataset 2 Analysis



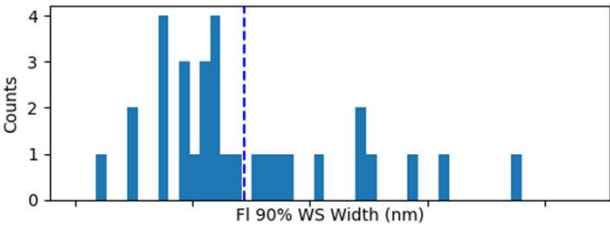
FL 90% Wind Speed Band Width (nm) by Category



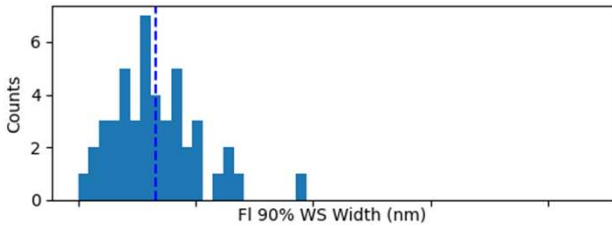
T.S.
N=16
Avg=6.50
StDev=3.45



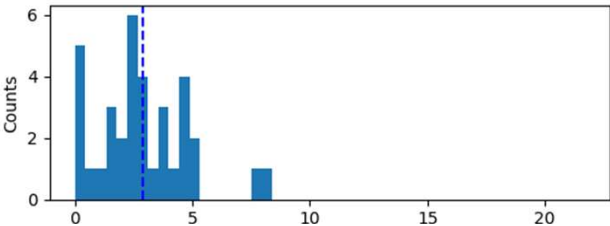
Cat 1
N=20
Avg=8.53
StDev=4.99



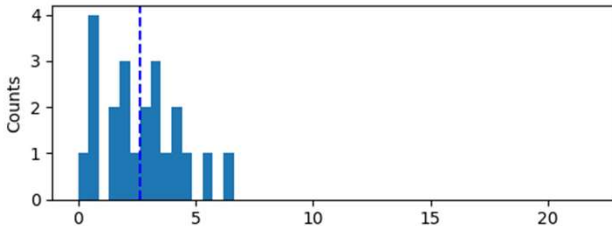
Cat 2
N=31
Avg=7.21
StDev=4.19



Cat 3
N=46
Avg=3.32
StDev=1.83



Cat 4
N=35
Avg=2.90
StDev=1.89



Cat 5
N=22
Avg=2.64
StDev=1.68

Band Width (nm)

Band Width (nm)