



An Overview of the Aircraft TC Measurement: From Present Capabilities to Future Needs

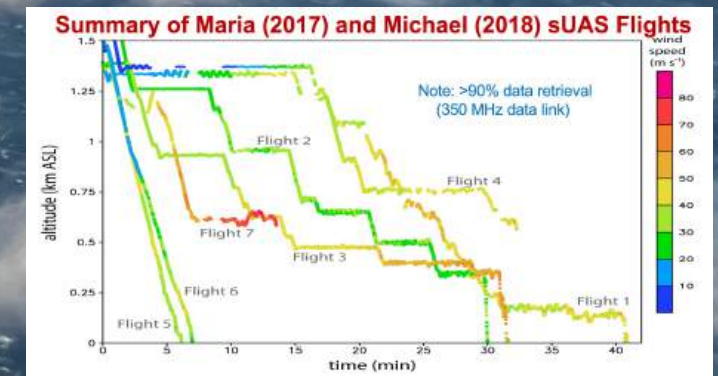
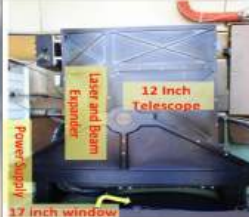
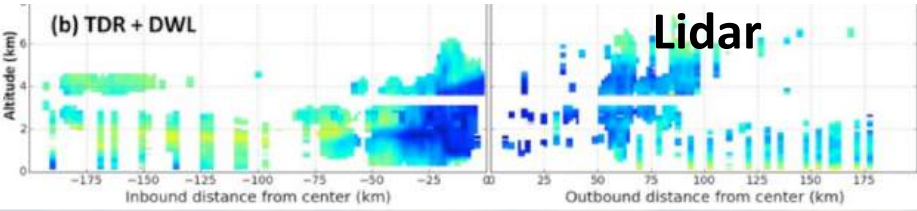
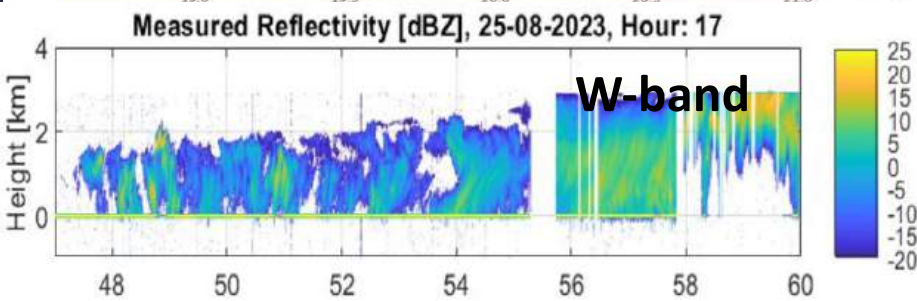
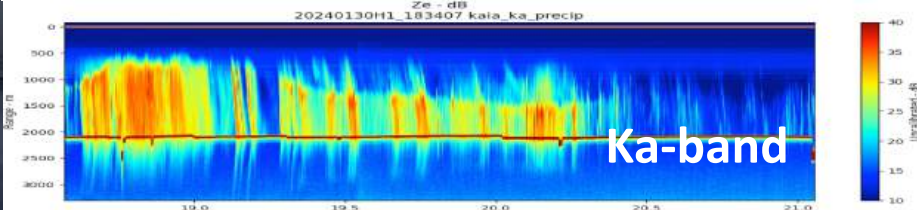
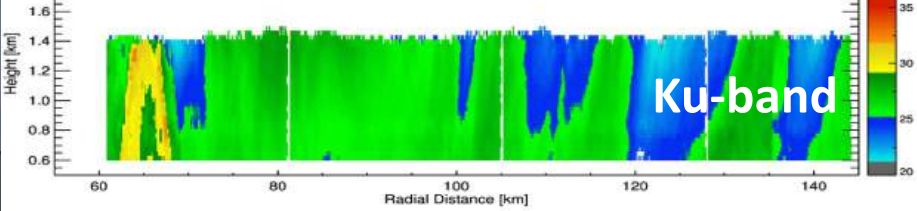
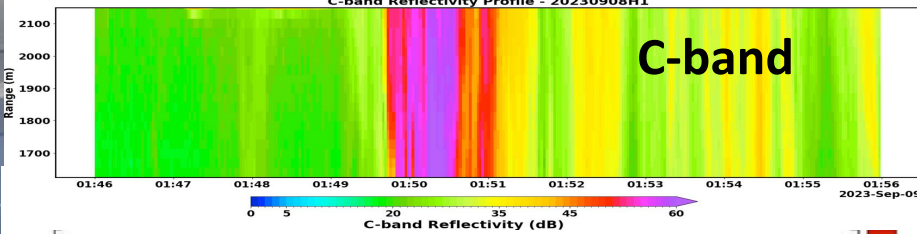
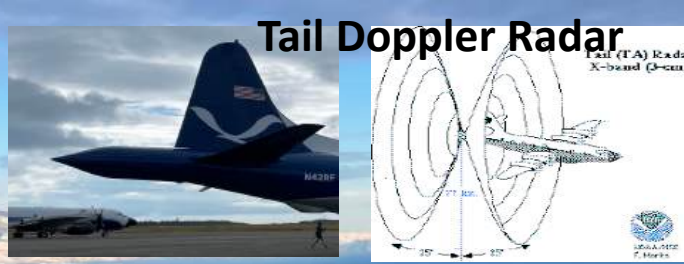
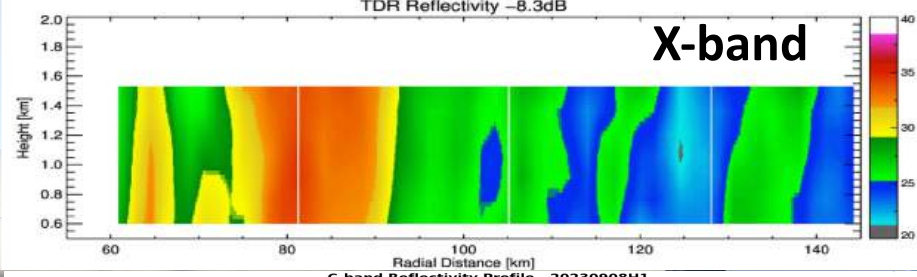
¹Zorana Jelenak, ¹Paul Chang, ²Ralph Foster,
³Heather Holbach, and ³Mark Bourassa

NOAA/NESDIS/STAR

²APL

³FSU

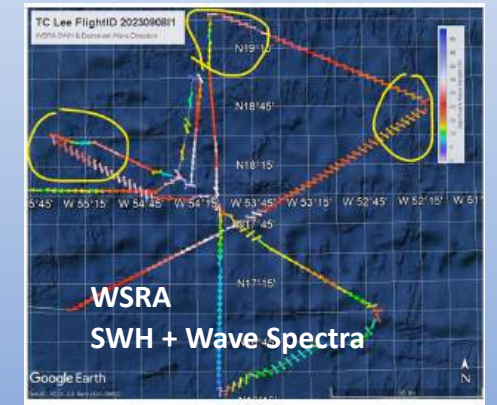
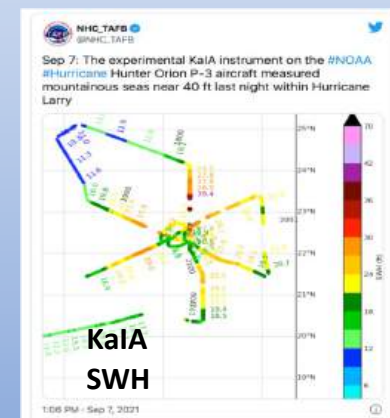
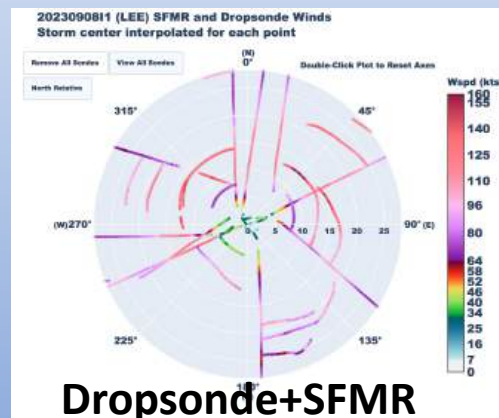
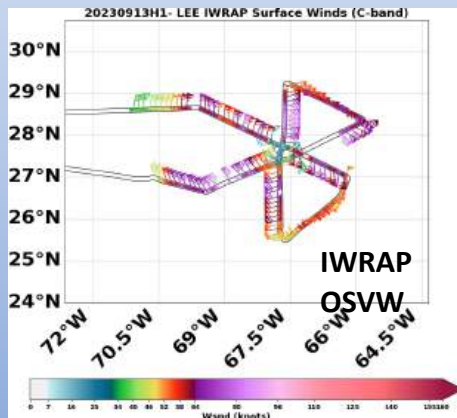
Atmospheric Profiling



Surface Wind Measurements

Aircraft Instrumentation

| Instrument | Aircraft | Measurements |
|---|----------------|--|
| GPS Dropsondes | C130, P3, G-IV | Atmospheric wind, temperature and humidity profiles |
| Stepped Frequency Microwave Radiometer | C130, P3, G-IV | C-band, nadir looking, Surface wind speed, rain rate |
| Imaging Wind and Rain Airborne Profiler (IWRAP) | P3 | Ocean Surface Vector Winds, (scatterometry) C, Ku, VV, HH, VH |
| Ka-band Interferometric Altimeter (KaIA) | P3 | Significant wave height, relative ocean height, & wind speed (lower speed regimes), precip profiles at Ka & Ku |
| Wide Swath Radar Altimeter (WSRA) | P3 | Significant wave height and directional wave spectra, wind speed (lower speed regimes), rain rate, Ku-band |



First Extreme Surface Wind Measurements

1997



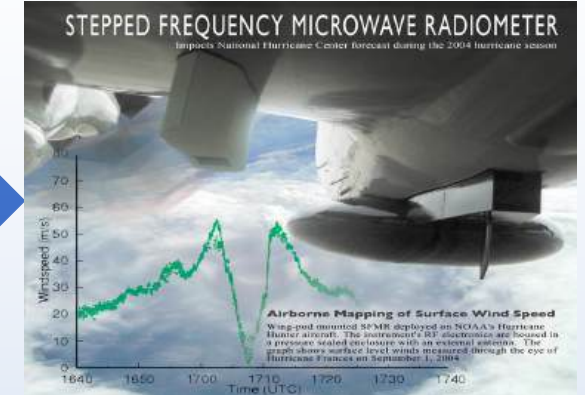
Franklin et al 2003:
10m Surface Wind: WL150

$$u_{L150} = \frac{\sum_{i=1}^n u_i w_i}{h_n - h_1} \quad u_{L150} = \frac{\sum_{i=1}^n u_i w_i}{h_n - h_1}$$

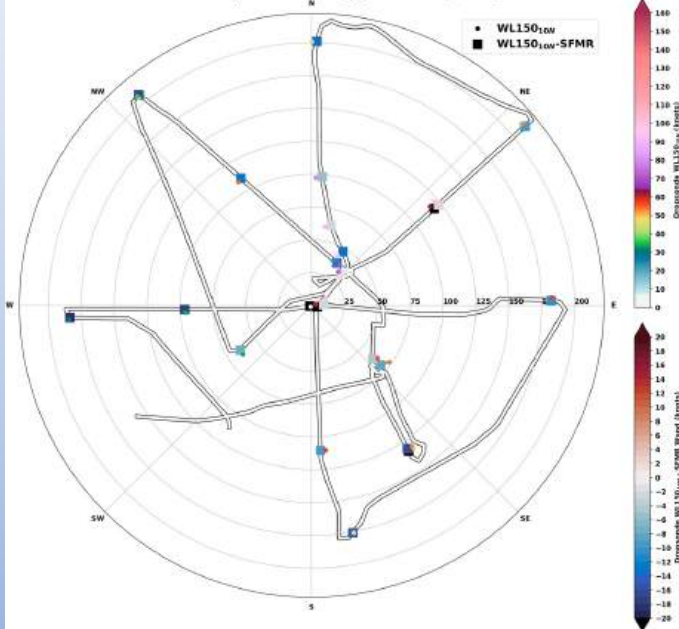
$$u_{10_{WL150}} = 0.85u_{L150} + 0.89$$

$$v_{10_{WL150}} = 0.85v_{L150} + 0.89$$

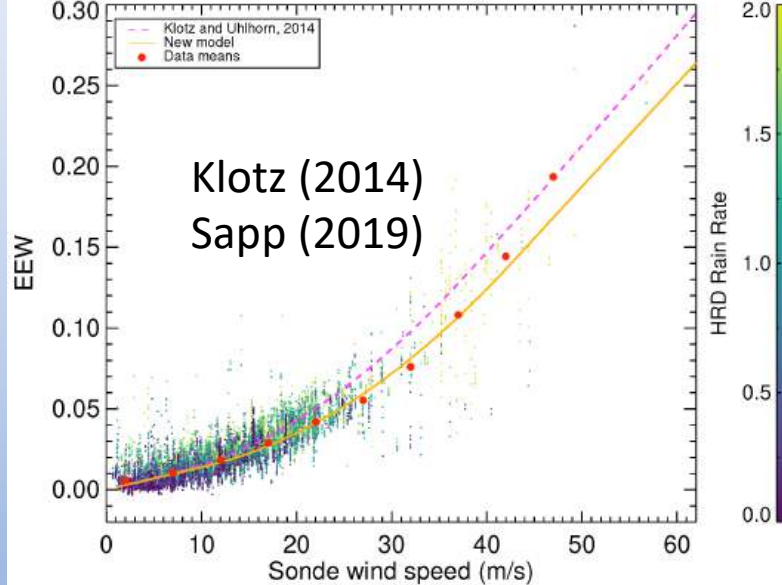
1981/2005-present



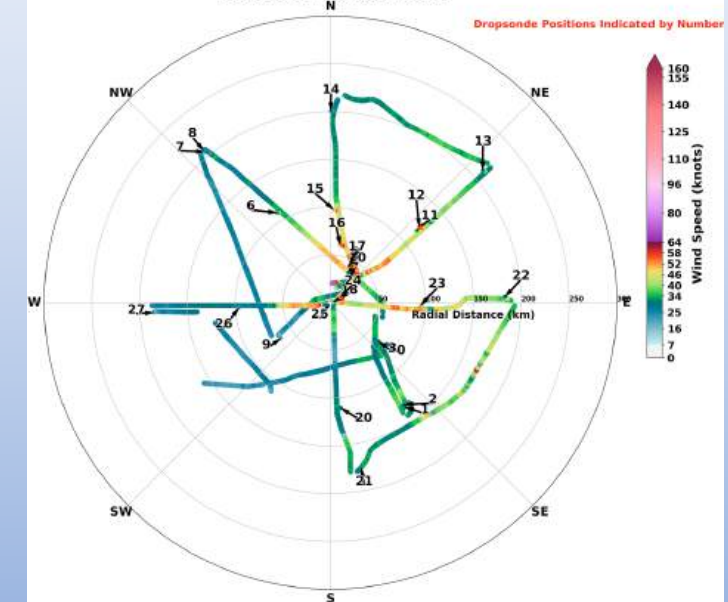
2023102011 Dropsonde WL150_{10m}-SFMR Bias [knots]



Channel 5 Excess Emissivity vs Wind Speed



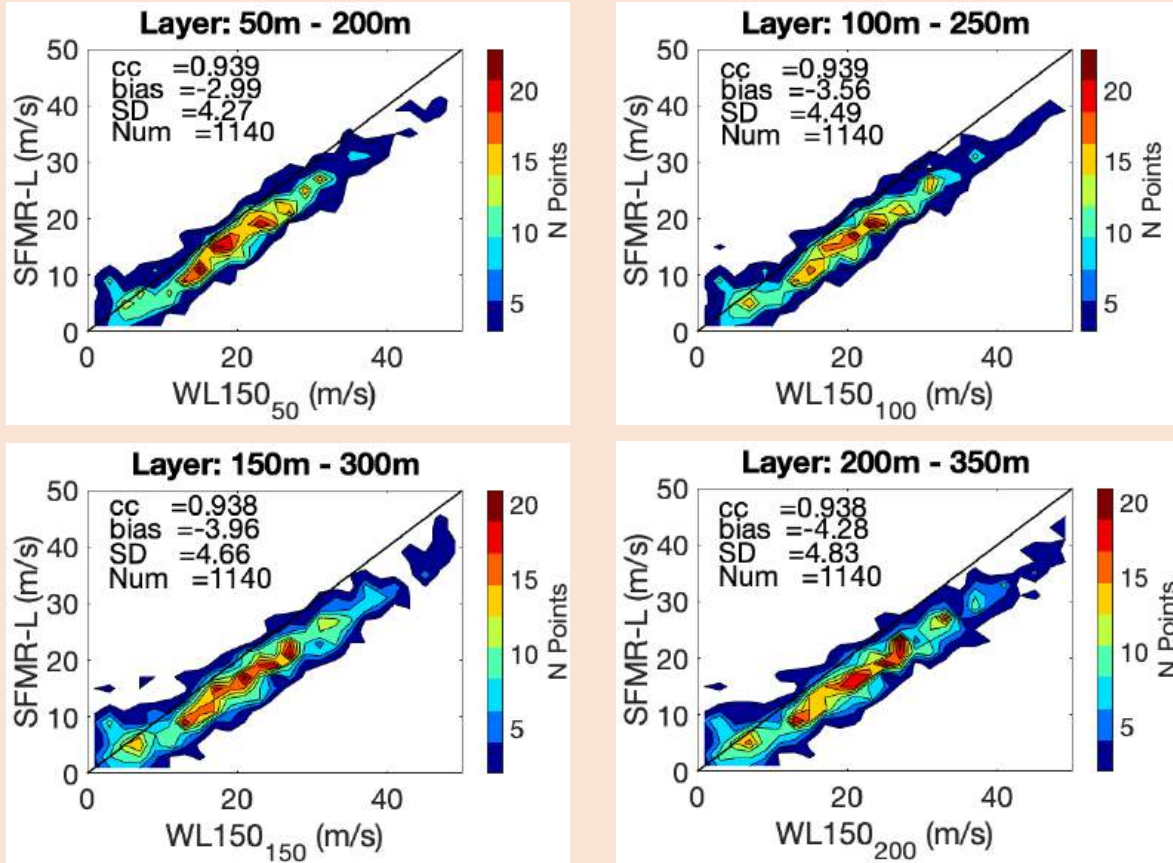
2023102011 Storm-Relative SFMR Winds and Dropsondes
Storm center interpolated for each point
Click to View Interactive Version



On dropsonde surface-adjusted winds and their use for the SFMR wind speed calibration

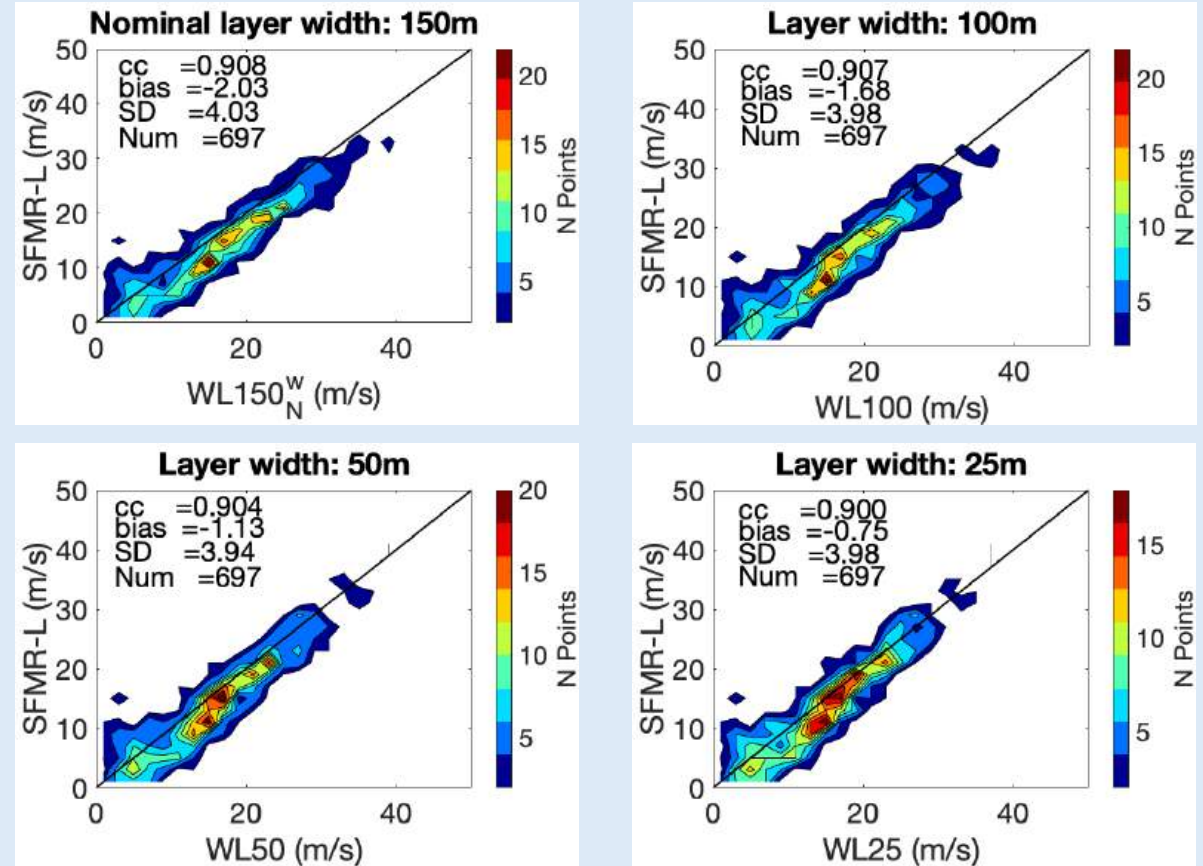
Polverari et al 2022

Comparison between SFMR and dropsonde WL wind computed from the WL150 algorithm using different layer height



Bias and SD increase when averaging the dropsonde readings over a layer at mean altitudes higher than the nominal 85 m. The WL150 scaling factor should be function of the mean layer height

Comparison between SFMR and dropsonde WL wind computed from the WL150 algorithm using different layer width



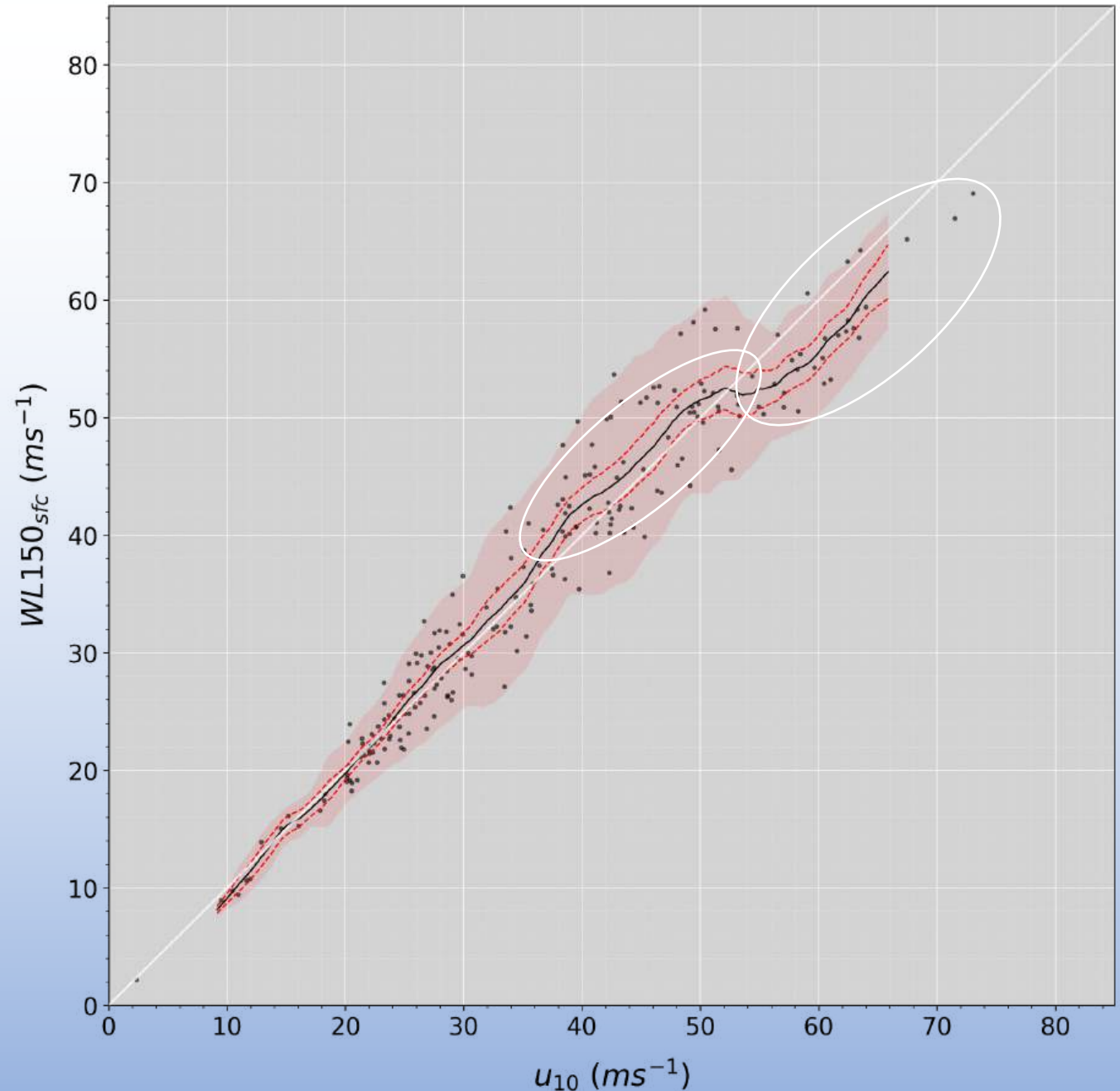
Bias and SD are significantly reduced when averaging the dropsonde readings over a layer thinner than the nominal 150-m layer. The dropsonde winds averaged over a 25-m-layer are more representative of the 10-m winds

Take away: The dropsonde WL150 winds can introduce noise and biases when converted into 10-m surface winds. The dropsonde surface winds estimated from the WL150 algorithm should be used with caution for cal/val [Polverari et al., *IEEE TGRS*, 2022]

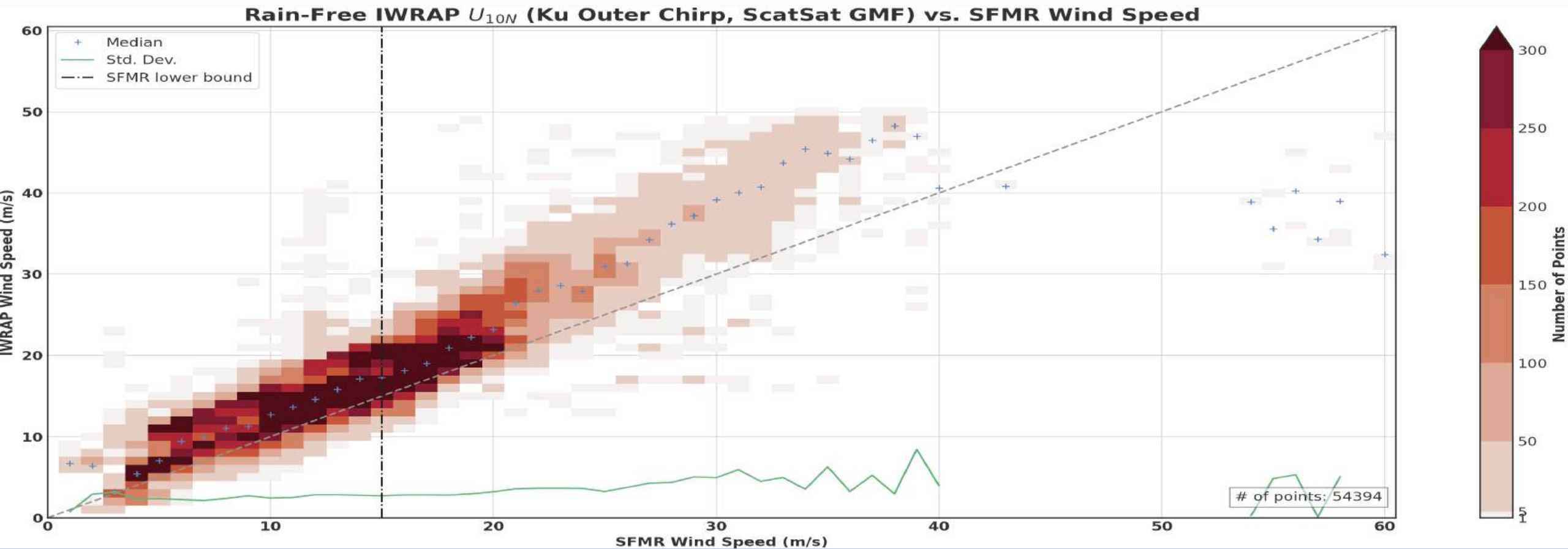
Holbach and Bourassa 2023

U_{10} vs WL150

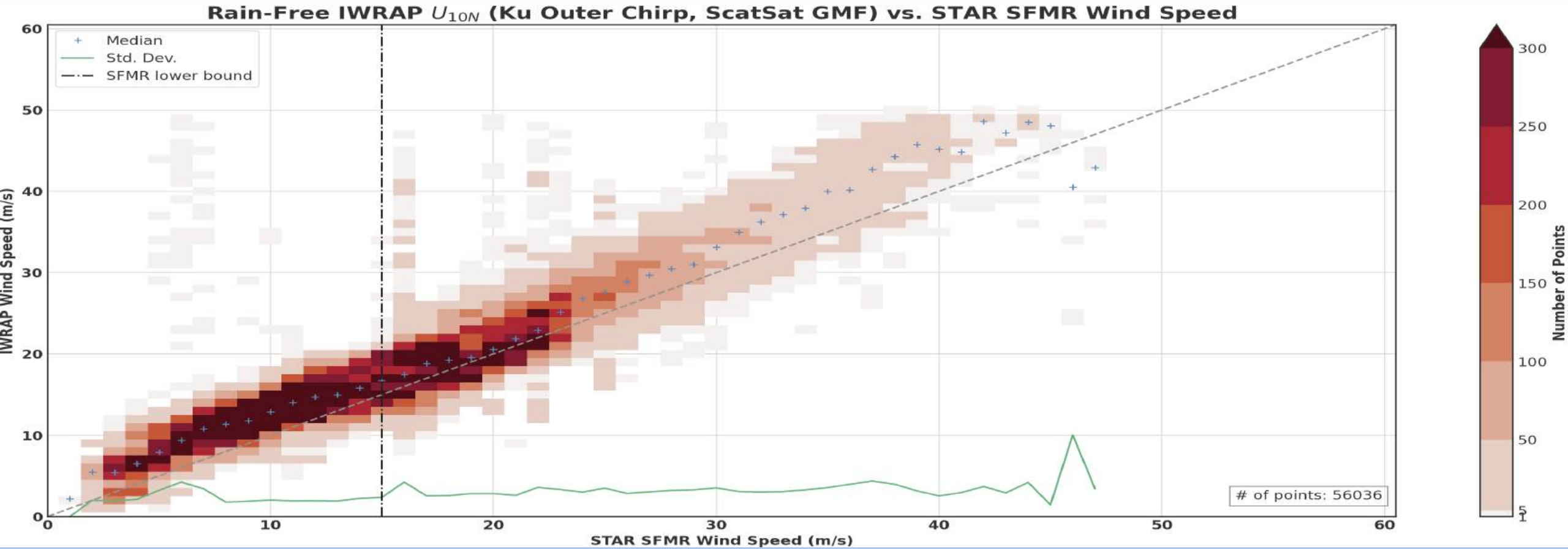
- This comparison is restricted to conditions when we can find a log profile, which are conditions that favor a good comparison to WL150 winds.
- Variability increases as some function of wind speed
 - Which is expected
- Good agreement at lower speeds
 - $15 < u_{10} < 35 \text{ ms}^{-1}$
- WL150 is biased slightly high from $\sim 35\text{-}50 \text{ ms}^{-1}$ compared to our log-profile u_{10}
- WL150 significantly low biased above $\sim 55 \text{ ms}^{-1}$ compared to our log-profile u_{10}



ScatSat GMF – IWRAP Ku@50° Klotz 2014 RTM - SFMR

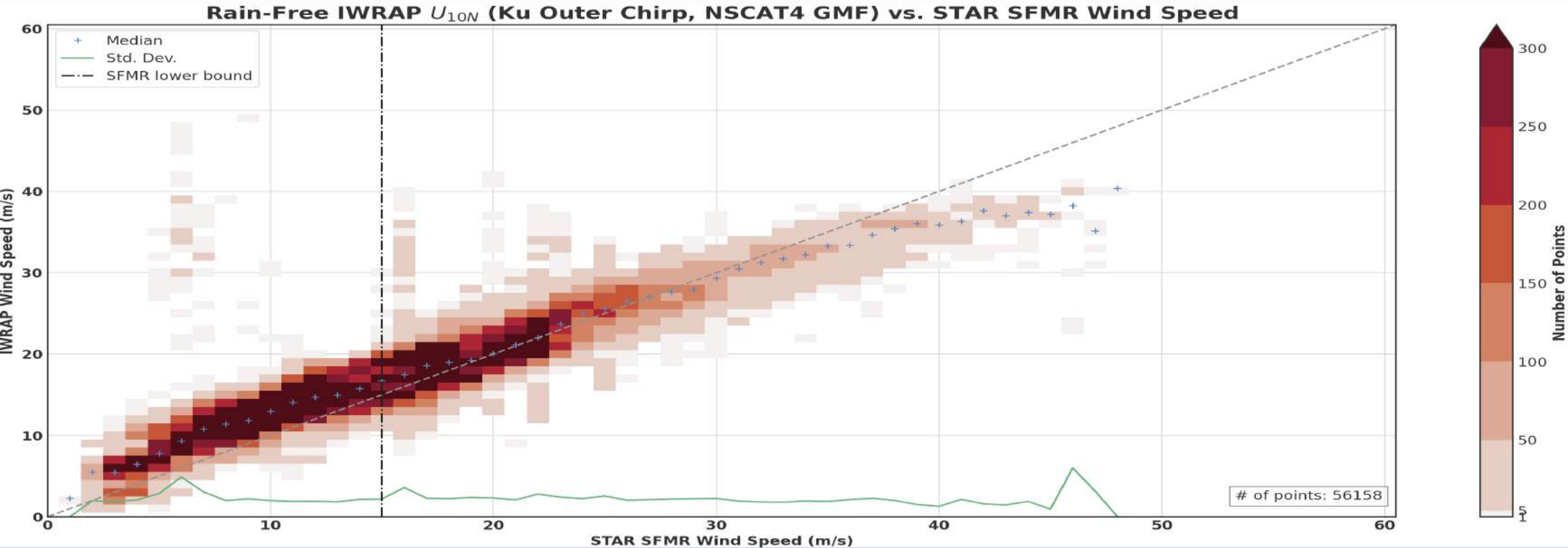


ScatSat GMF – IWRAP Ku@50° Sapp 2019 RTM - SFMR



NSCAT4 GMF –IWRAP Ku@50°

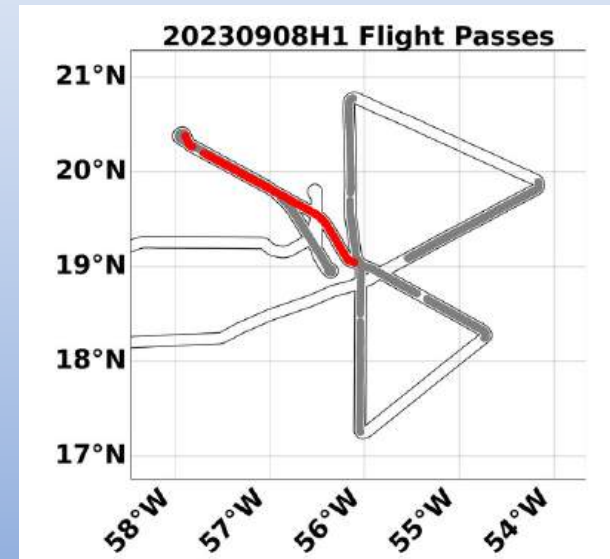
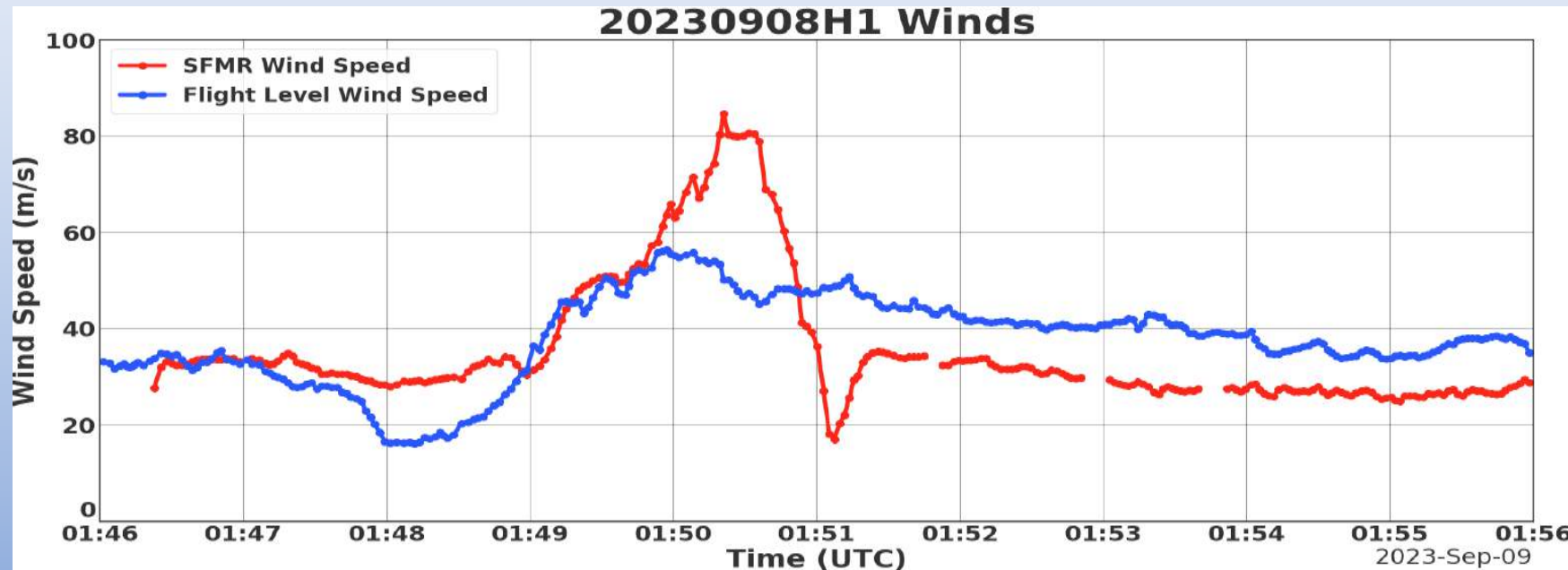
Sapp 2019 RTM - SFMR



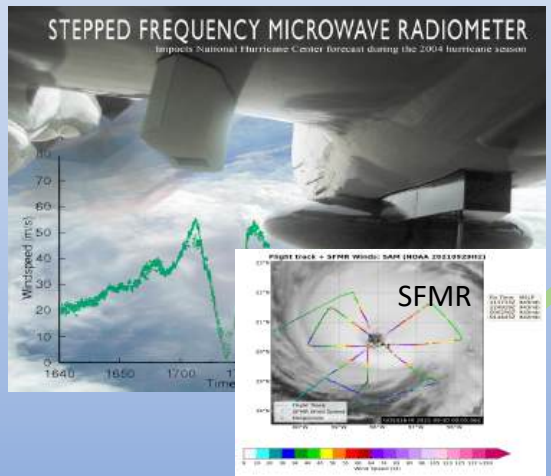
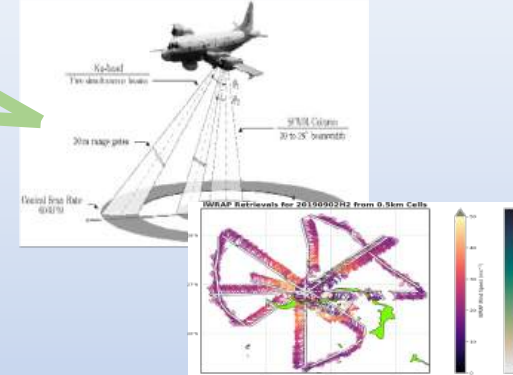
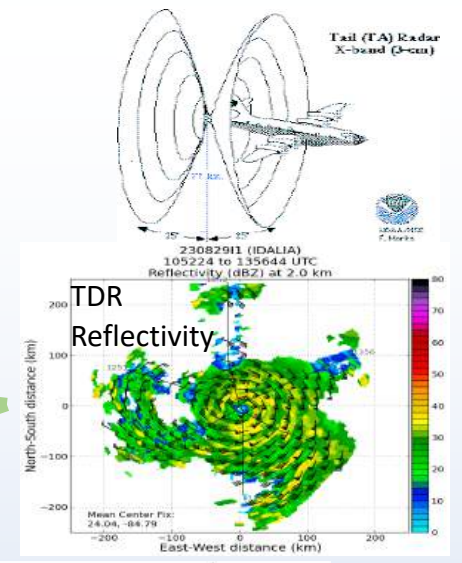
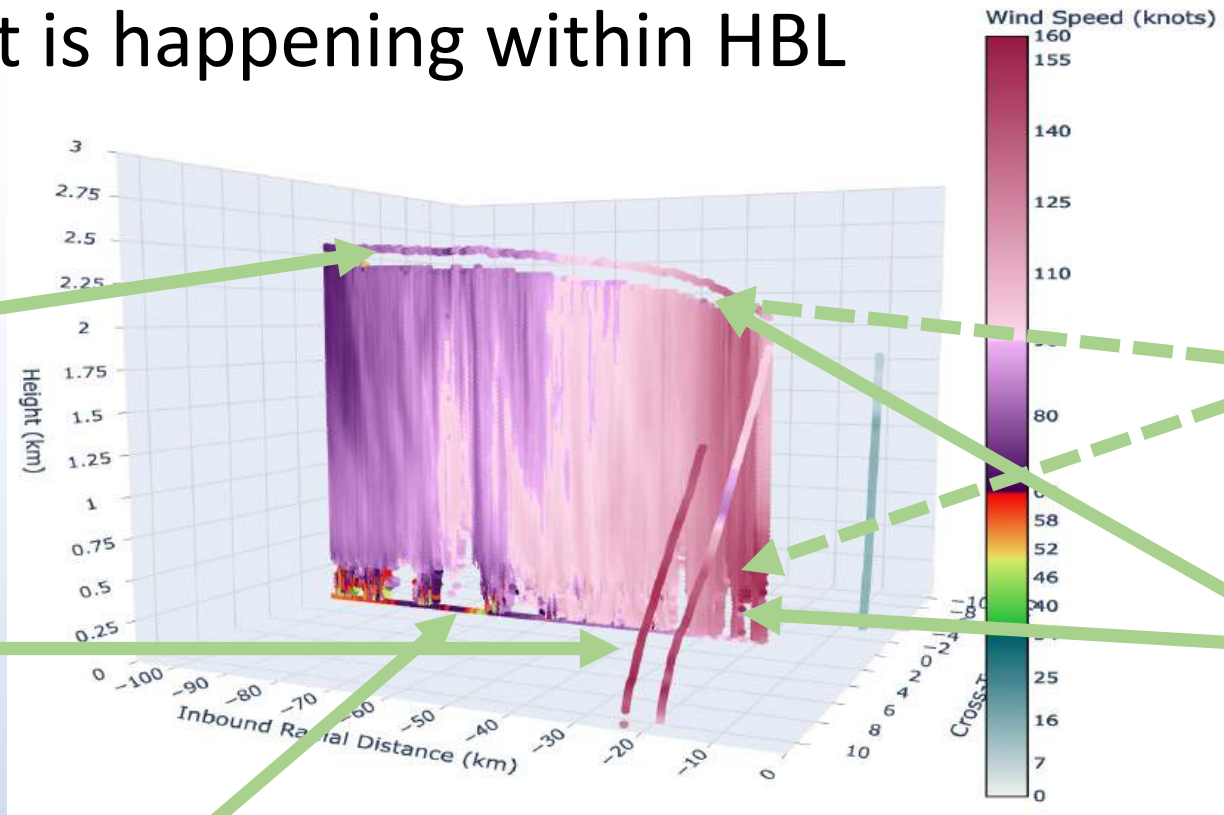
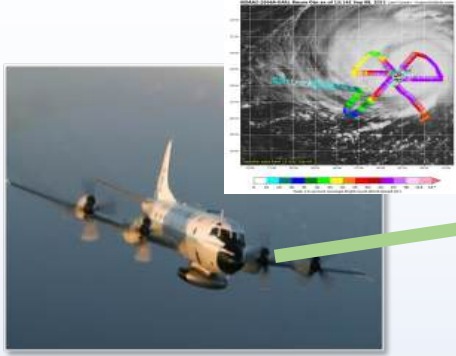
Case of Hurricane Lee Sep 8th, 2023

NE Eyewall Winds: Cat 5 or 2-3?

- SFMR surface wind measurements: Physical or Artificial?
 - Flight path along storm motion – highest waves – wave impact on Tb's?
 - Storm just underwent RI was there extreme momentum transfer to the surface?
 - GMF?
- To answer cases like Lee we really need to know what was happening above the surface



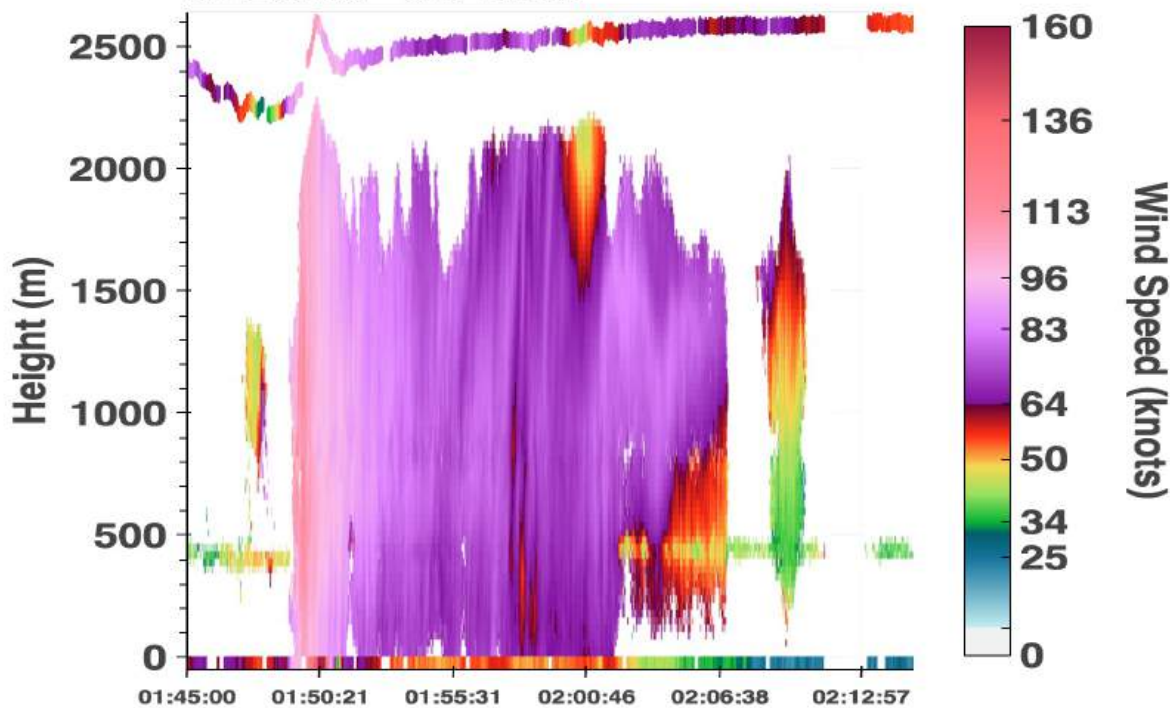
To understand Surface Winds Means We need to Understand What is happening within HBL



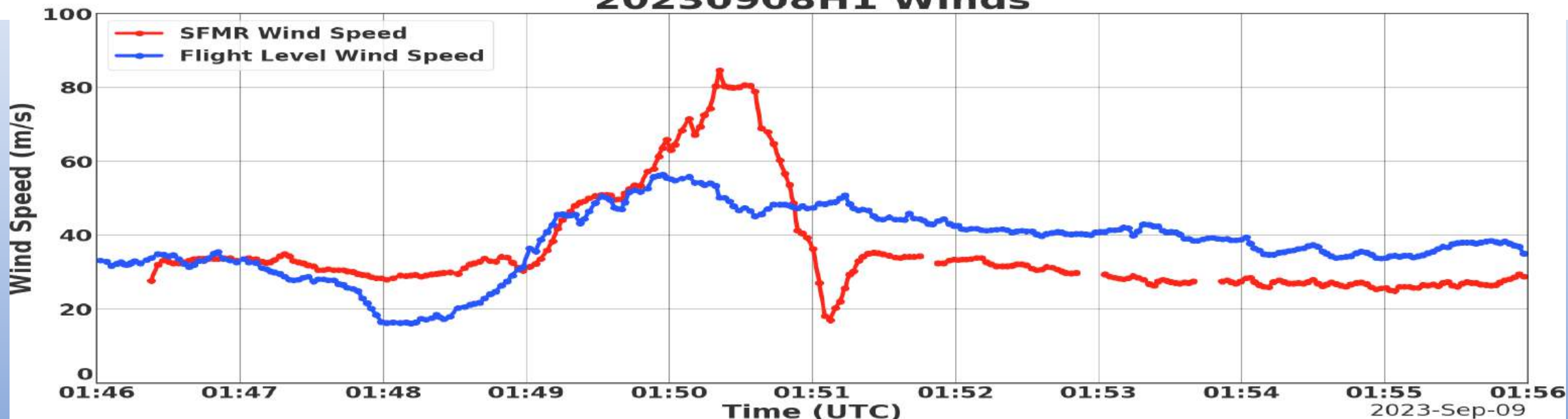
IWRAP-Imaging Wind and Rain Airborn Profiler (UMASS/NESDIS)

- Providing continuous real-time ocean surface winds and fine resolution real-time Doppler velocity and reflectivity profiles below the aircraft to just above the surface
- Connecting flight level, surface SFMR and sonde observations
- Providing new insite in physical processes of the HBL from very fine resolution measurements that will hopefully lead to better model parametarization

(Ku @ 50°) 20230908H1 (LEE)
01:45:00 - 02:14:54



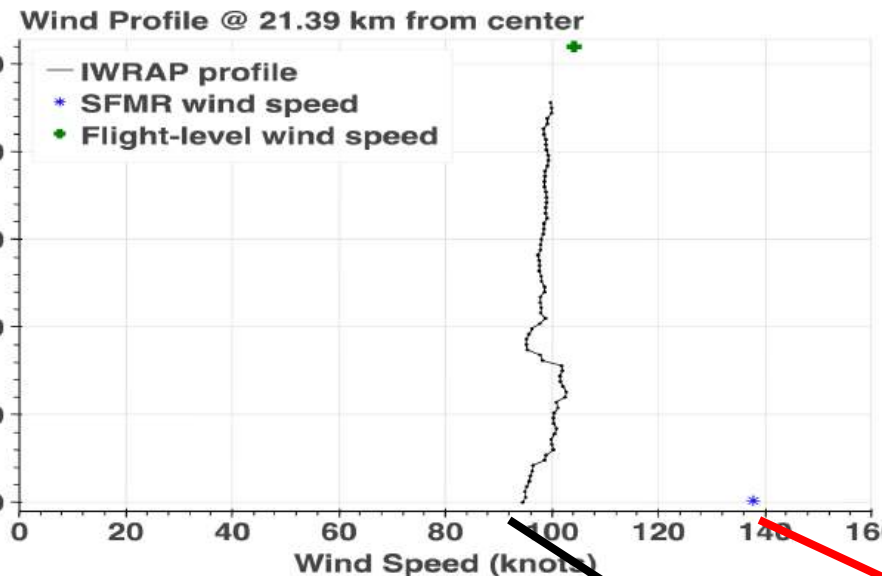
20230908H1 Winds



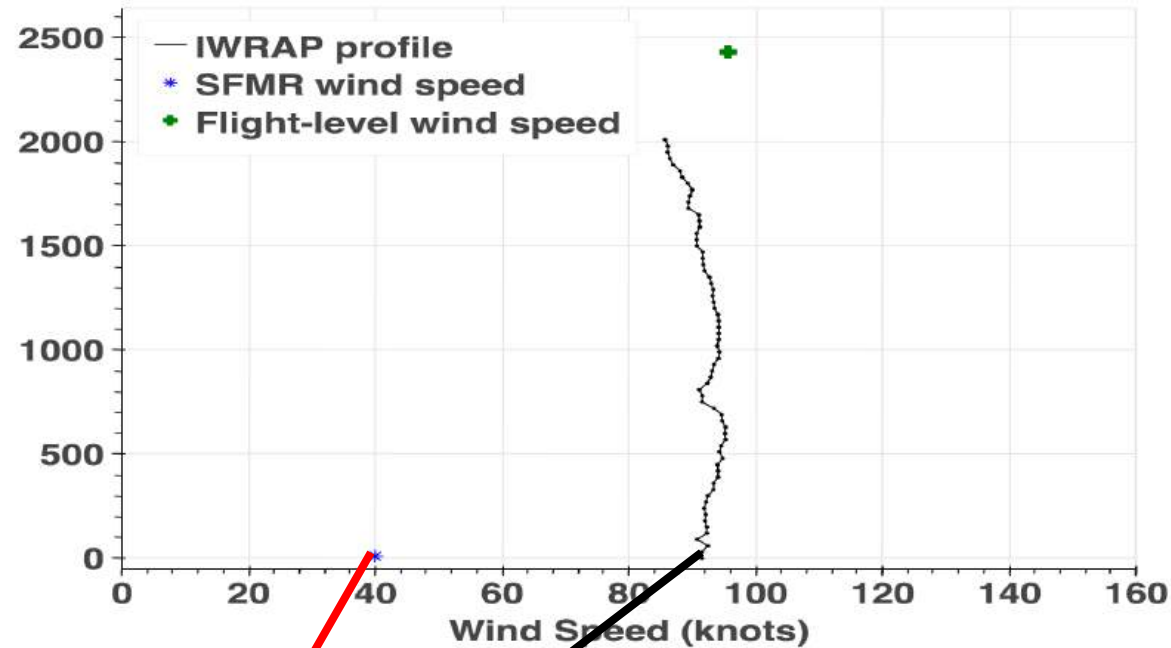
C-band Reflectivity Profile - 20230908H1

(Ku @ 50°) 20230908H1 (LEE)

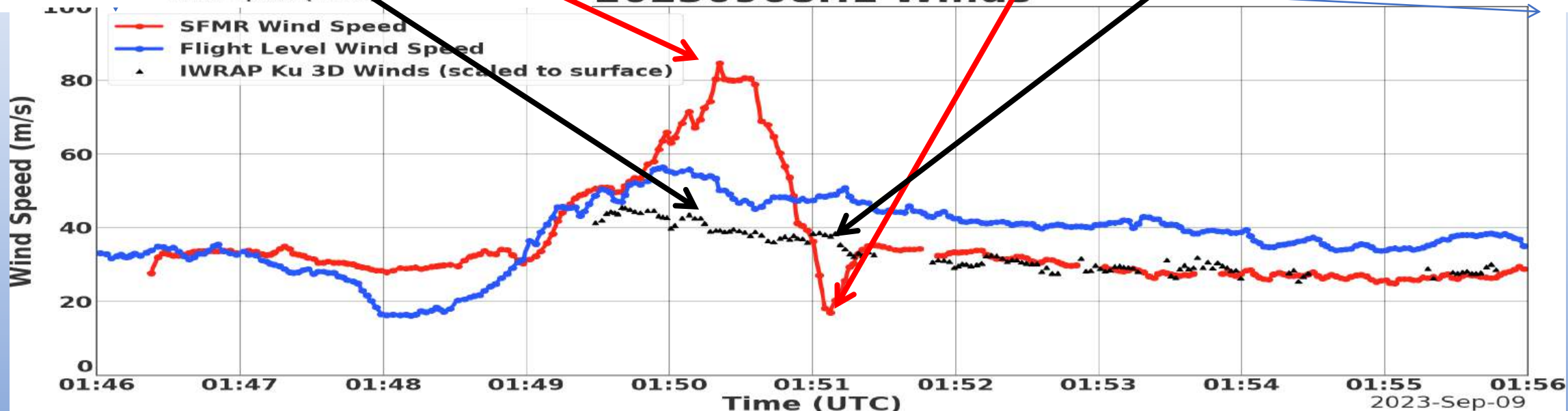
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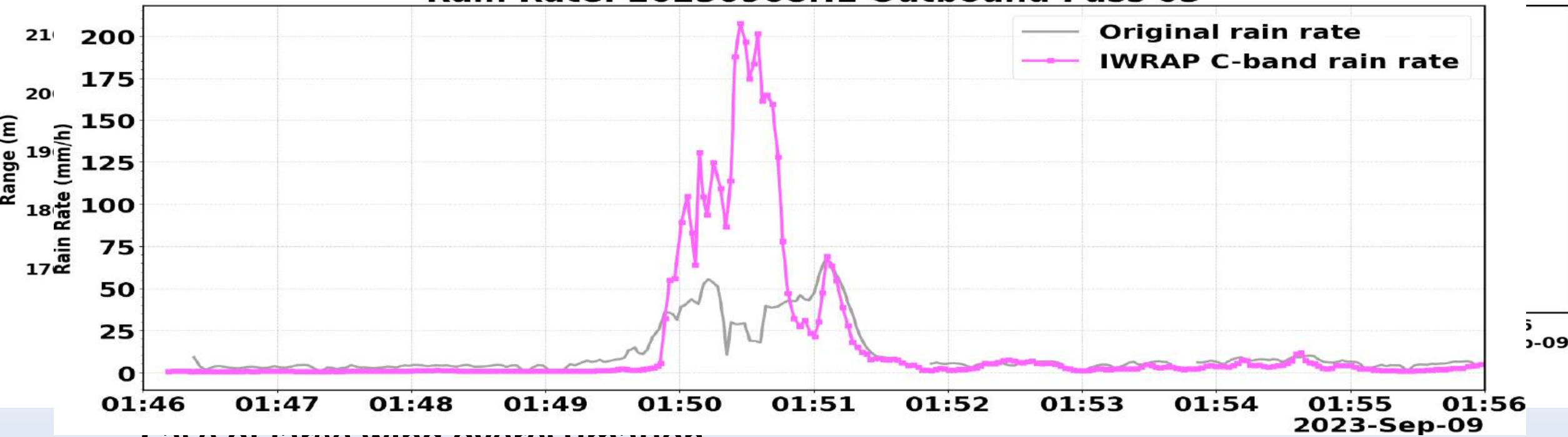
Wind Profile @ 28.64 km from center



20230908H1 Winds

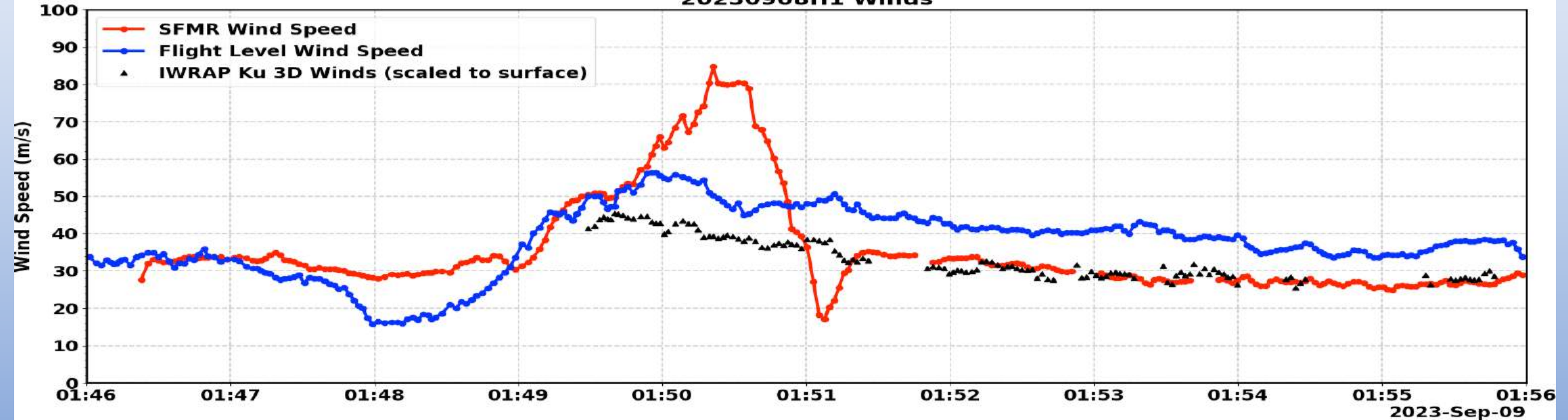


Rain Rate: 20230908H1 Outbound Pass 03



Case of large wind overestimation

20230908H1 Winds



Goal for datasets:

Consistent physics in remote sensing and boundary-layer modeling

Look at TCBL Rolls with IWRAP and SAR

Ralph Foster 2024

Urad

Vtan

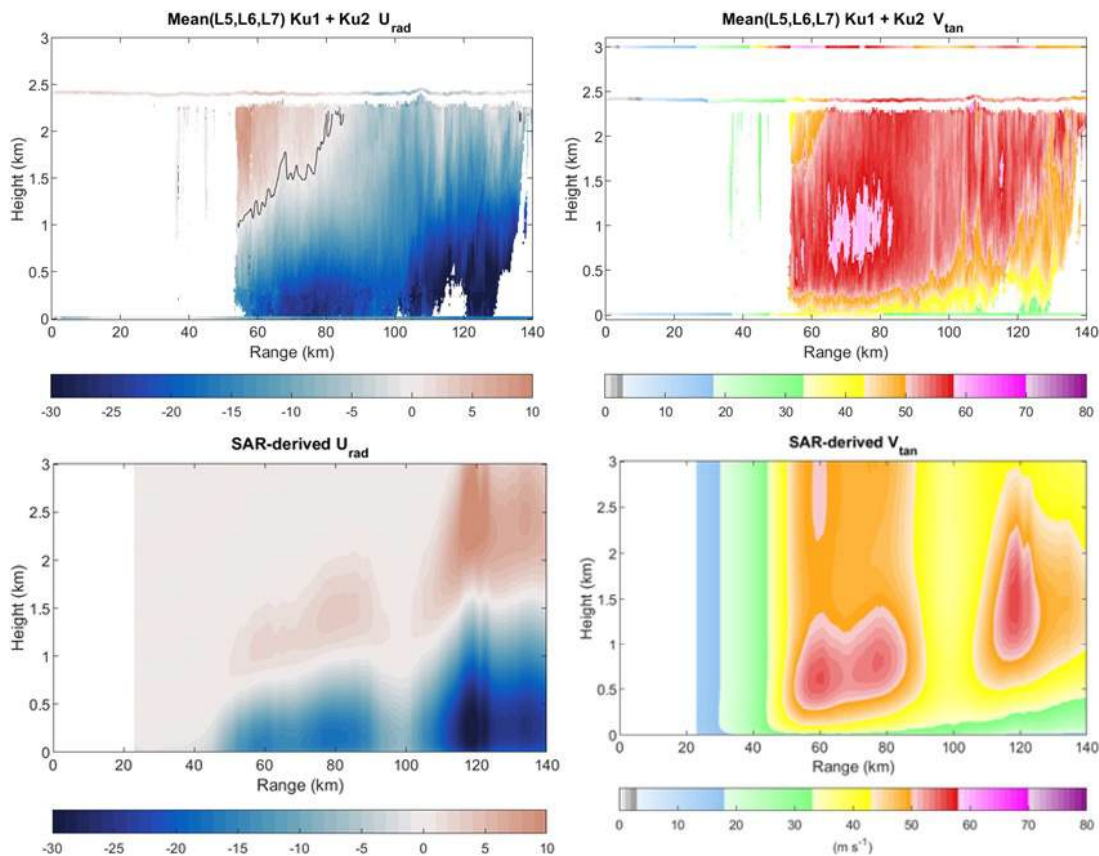
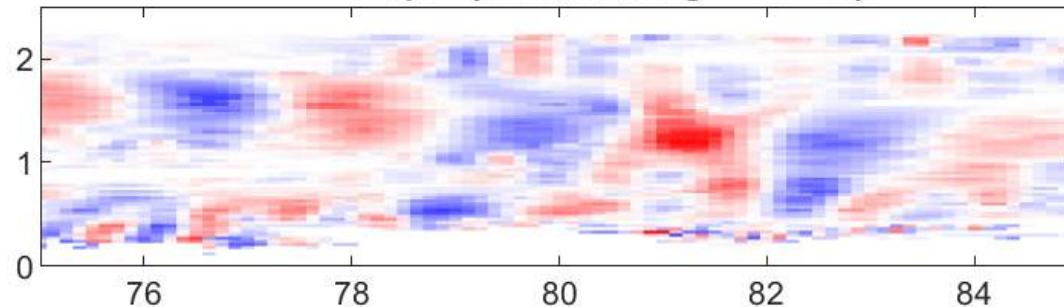


Figure 14: Hurricane Larry (2021) (a) IWRAP Urad; (b) IWRAP Vtan; (c) SAR-derived Urad; (d) SAR-derived Vtan

Upper: IWRAP
Lower: SAR-derived

IWRAP Upar (total, 95% significance)



IWRAP Uperp (total, 95% significance)

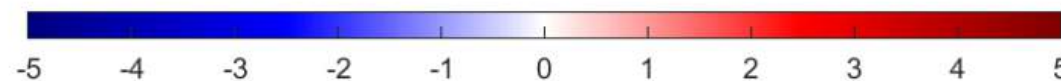
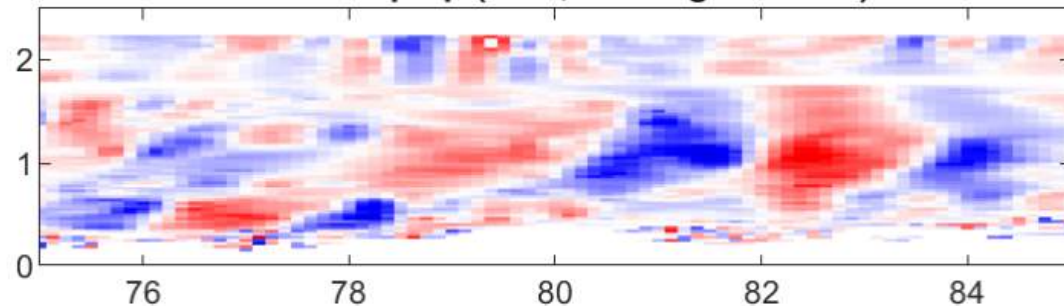


Figure 15: Hurricane Larry (2021) (a) Upar perturbation wind reconstructed using only significant spectral peaks (b) As in (a), but for Uperp

Significant Perturbation wind (r-z slice)

Upper: Upar: horizontal component of overturning flow (nearly radial)
Lower: Uperp: horizontal along-roll flow (in/out of page; nearly azimuthal)

Hurricane Larry (2021) Coincident IWRAP and SAR

Look at TCBL Rolls with IWRAP and SAR

Ralph Foster 2024

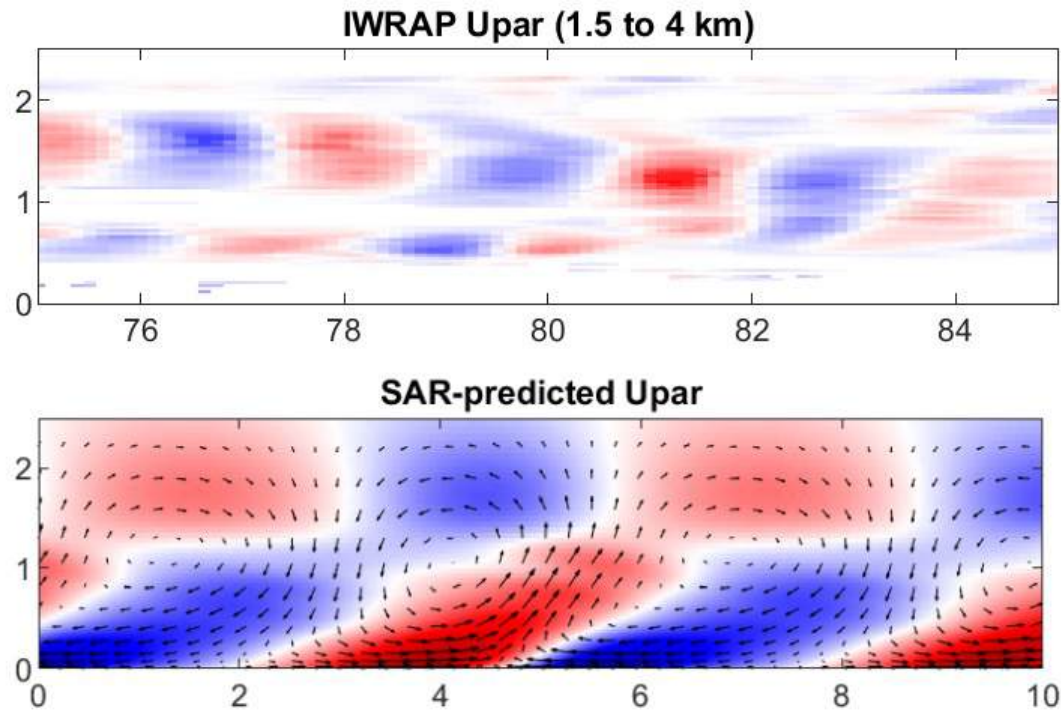


Figure 16: Hurricane Larry (2021) (a) IWRAP Upar reconstructed using only significant peaks between 1.5 and 4 km scale (b) SAR-Predicted Upar

Upper: IWRAP filtered to $1.5 < \lambda < 4km$

Lower: SAR-predicted (nonlinear) roll circulation

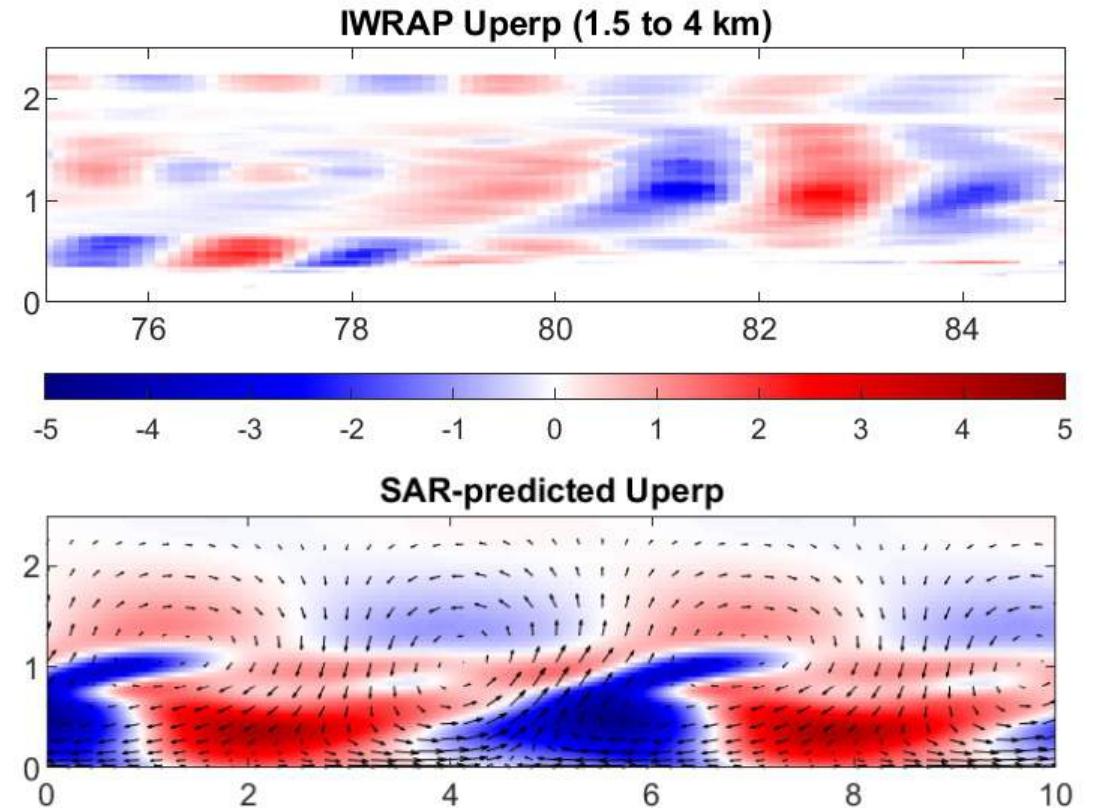


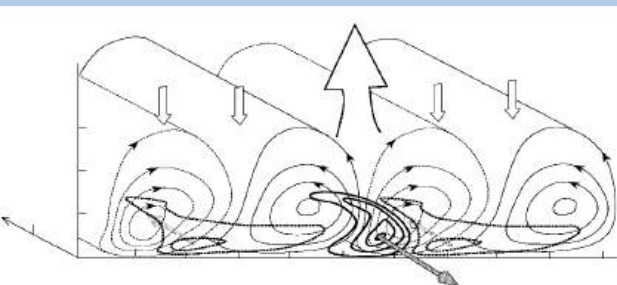
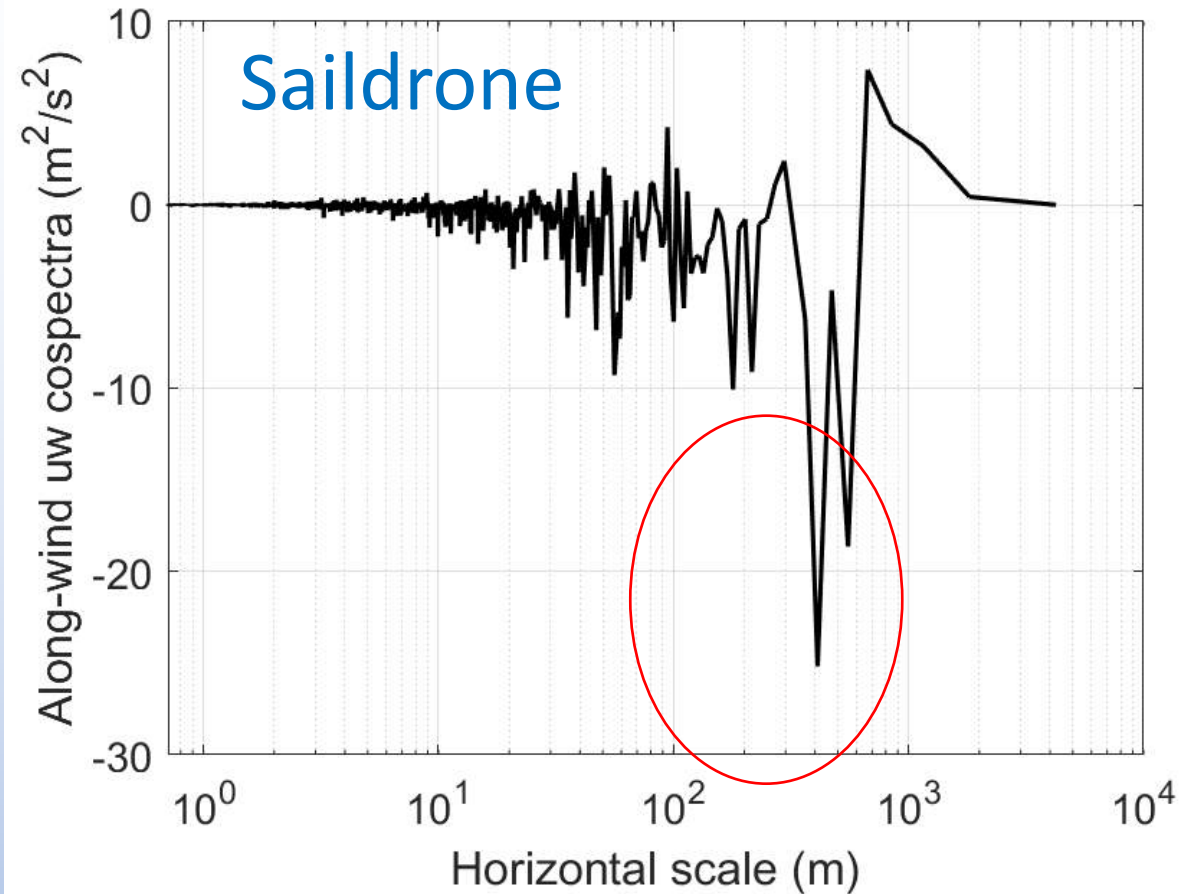
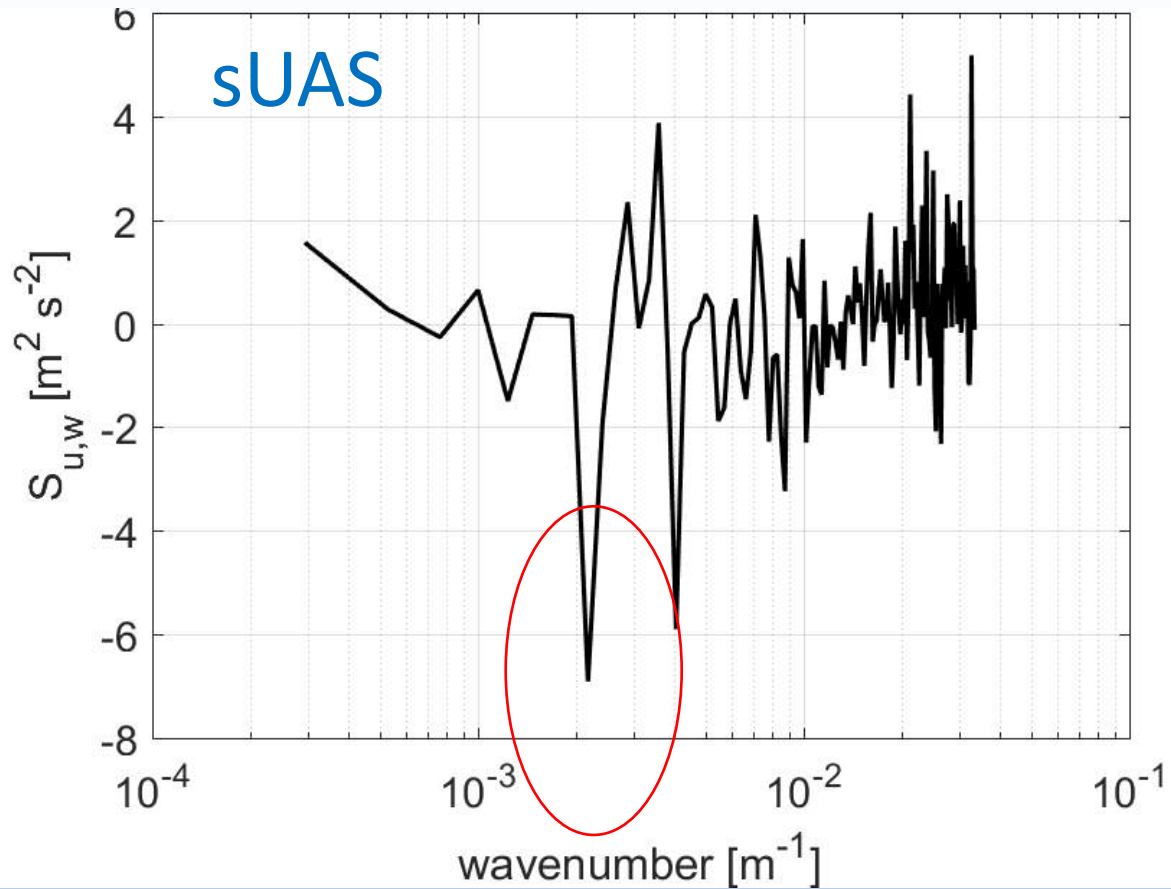
Figure 17: As in Fig. 16, but for Uperp

Note:

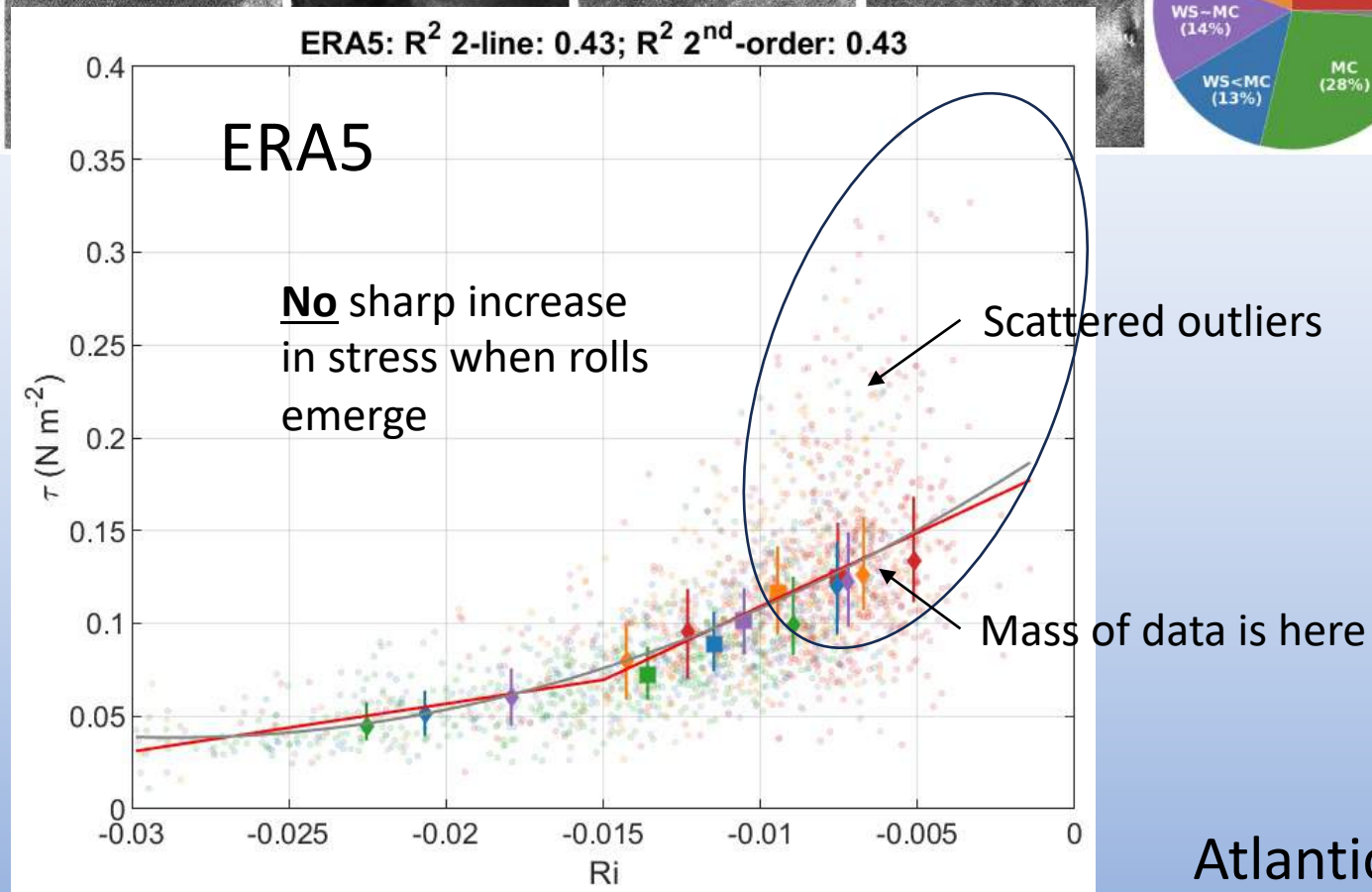
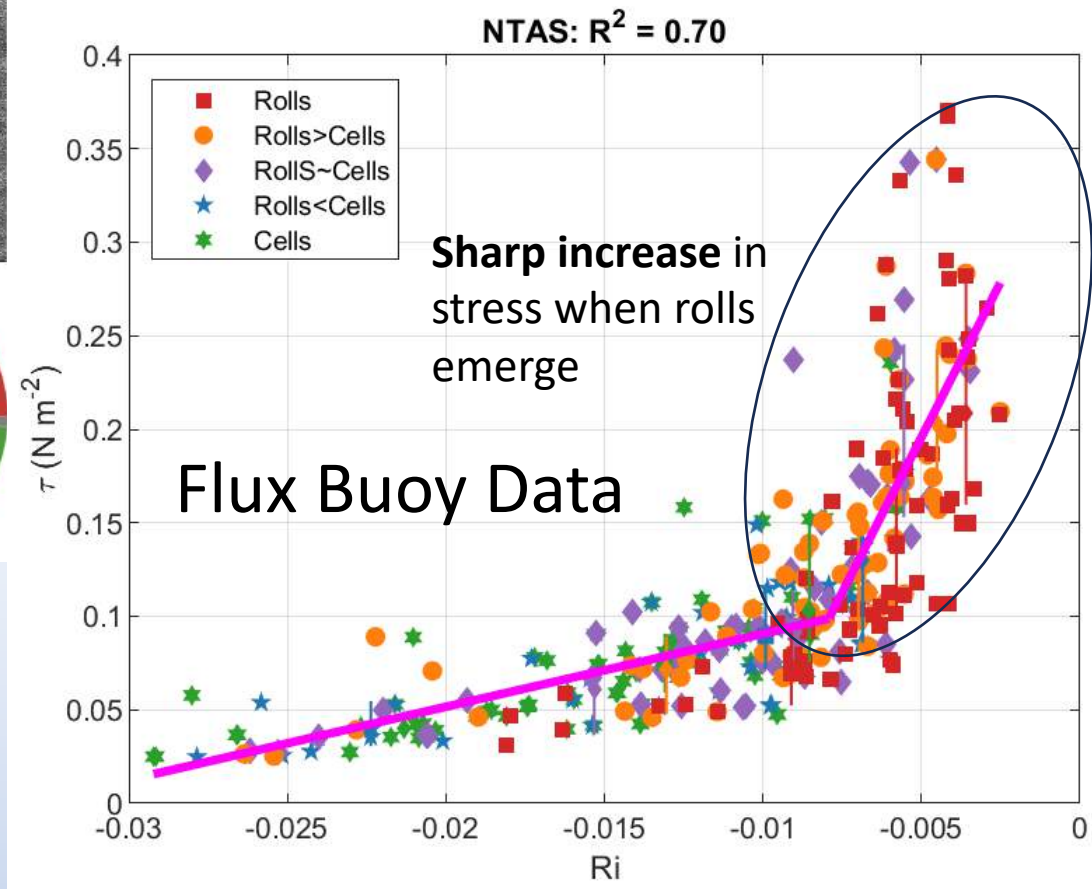
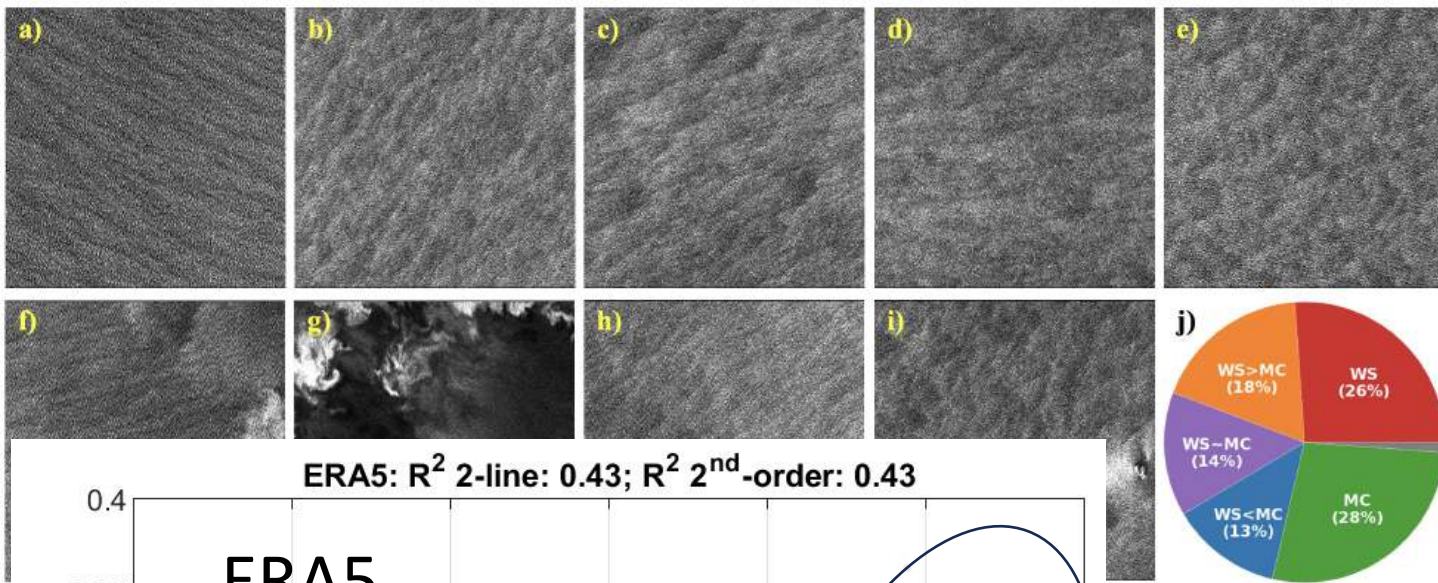
- Roll circulations “lean into mean shear” (neutral stratification)
- Uperp largest in lower PBL, “stretches-around” above
- Similar phasing in theory and IWRAP
- Structures are asymmetric → enhance fluxes

Look at TCBL Rolls with sUAS and Saildrone

J. Zhang 2024 preliminary results

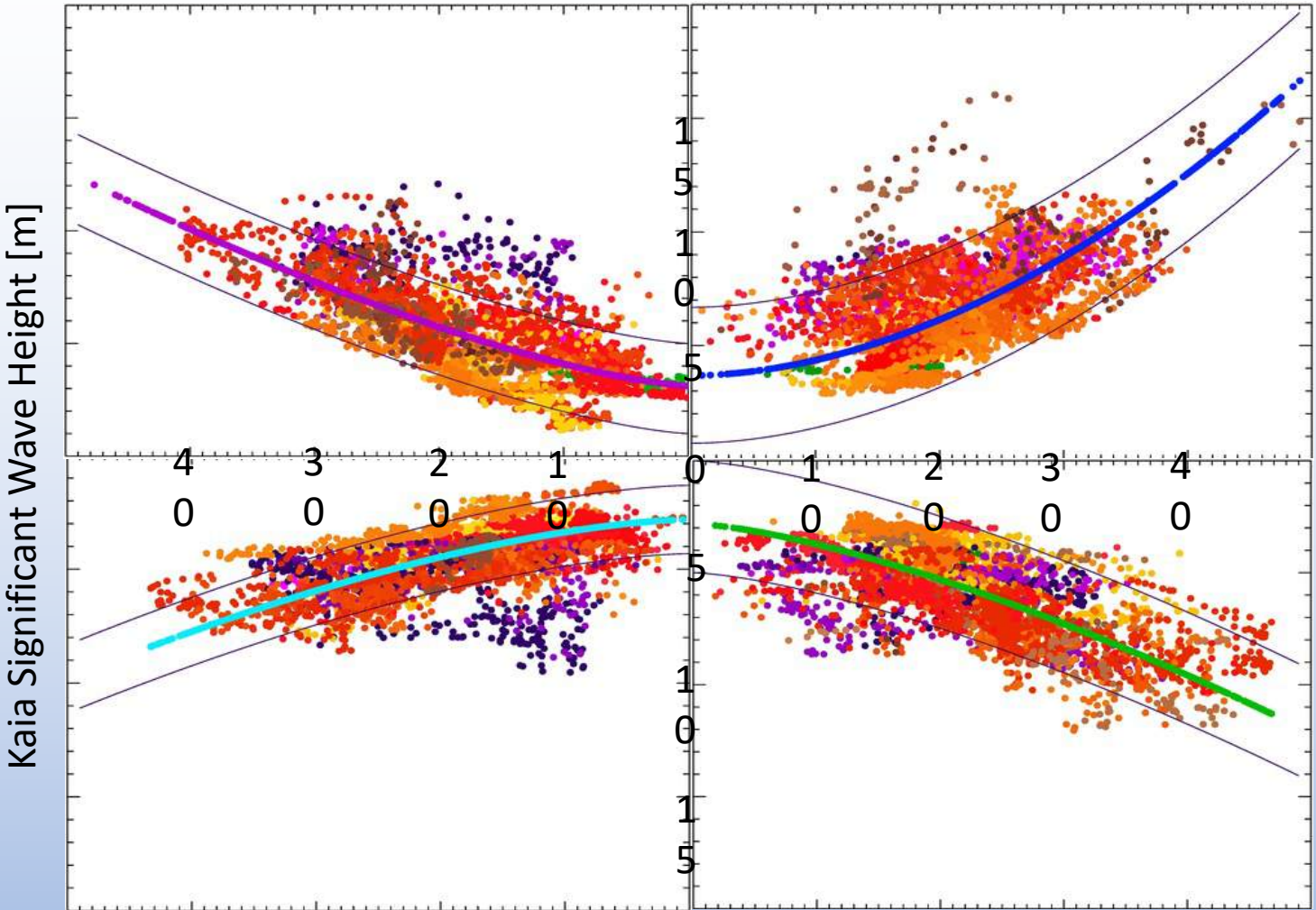


- Narrow spectral peaks indicate boundary-layer rolls in a similar manner to those detected by P3 aircraft in Hurricane Isidore (J. Zhang et al. 2008)

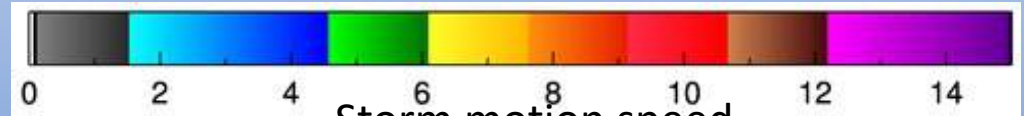


Atlantic Trade Winds Region Upwind of Bermuda

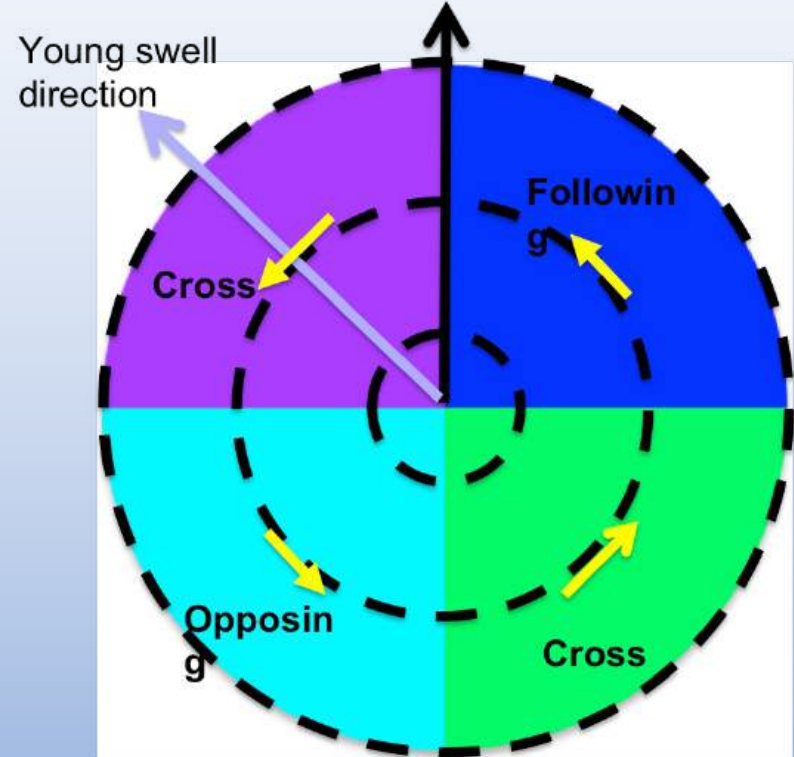
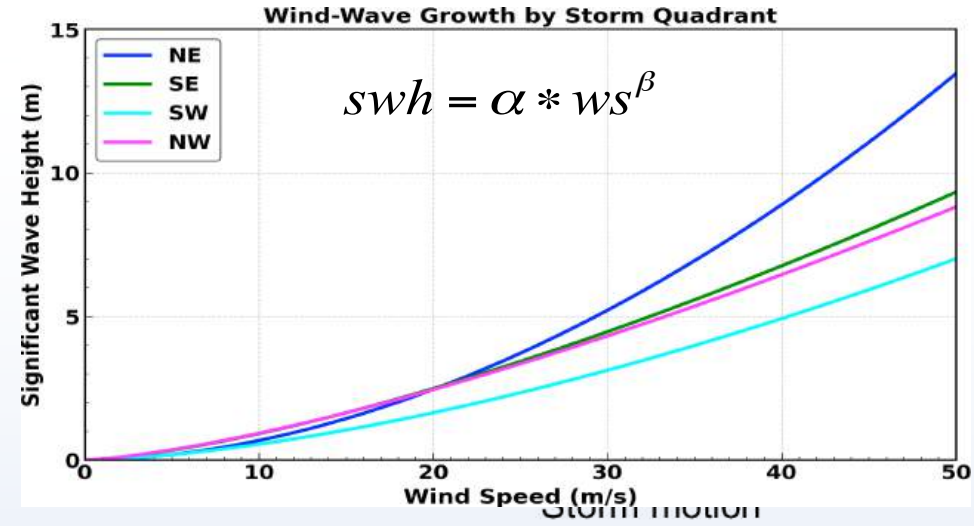
Wind Wave Growth in Hurricanes from KaIA and Measurements SFMR



SFMR Wind Speed [m/s]

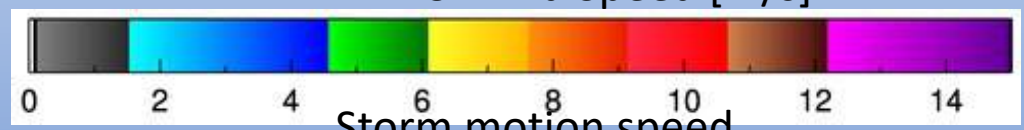
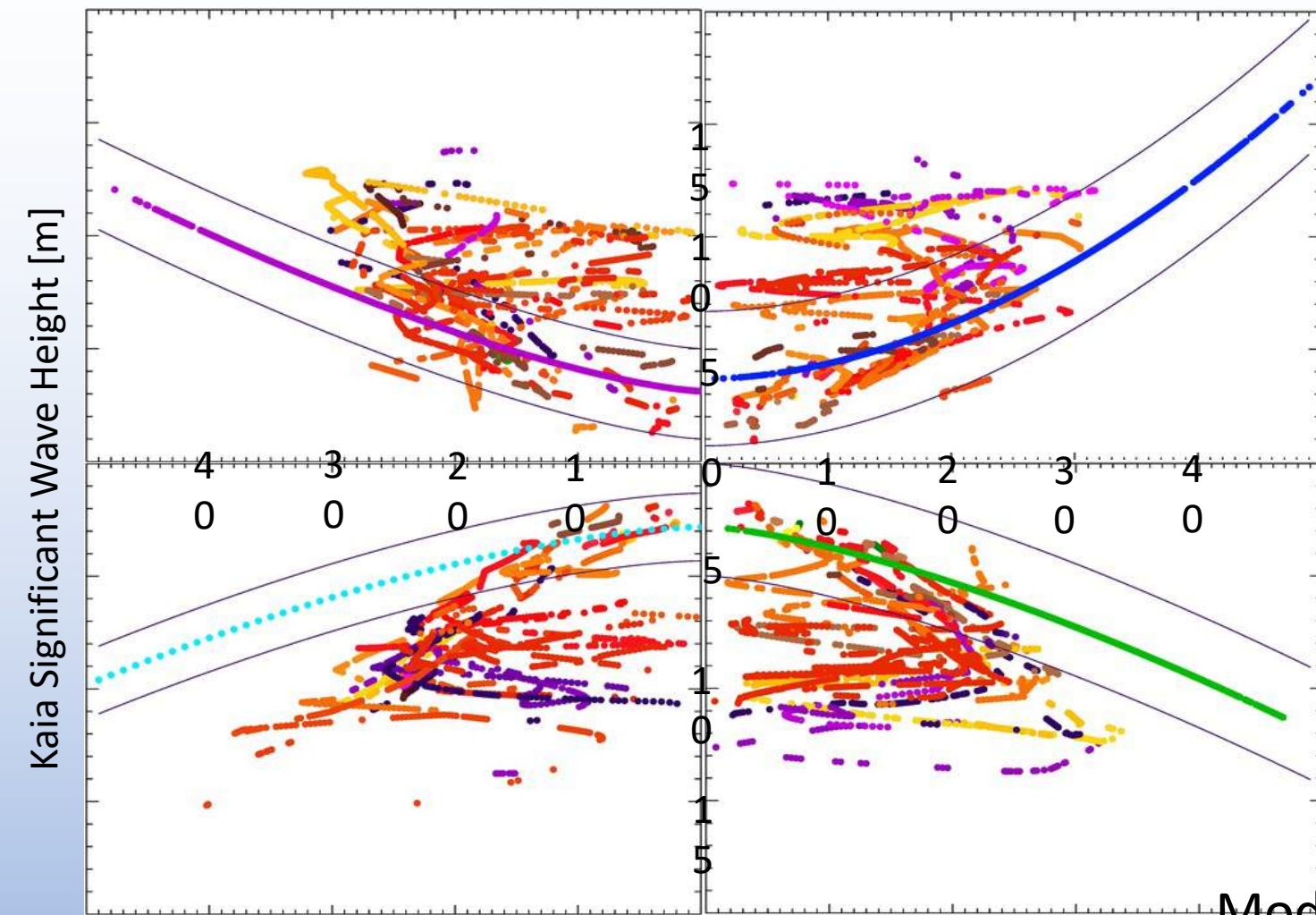
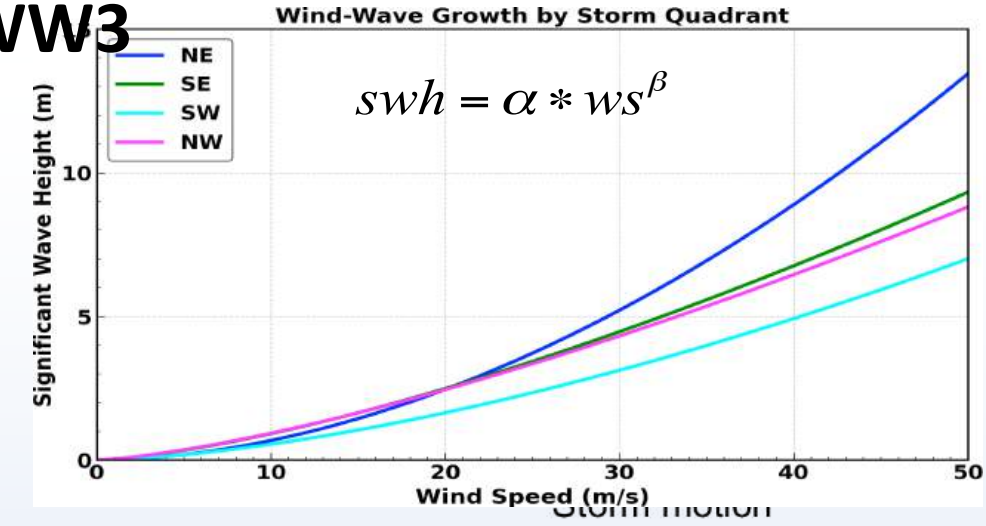


Storm motion speed

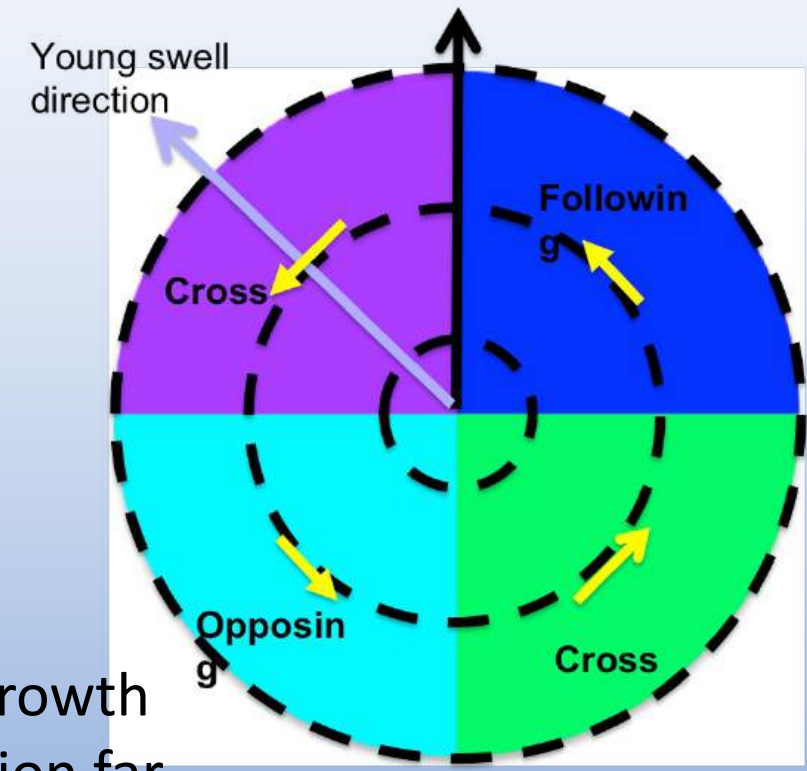


Wind Wave Growth in Hurricanes from IFREMER WW3

Jelenak et al 2024 AMS



Model wave growth parameterization far from observations





C130



P3



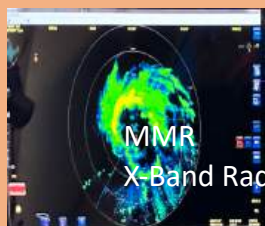
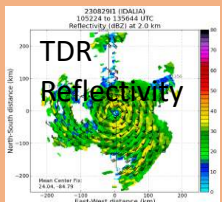
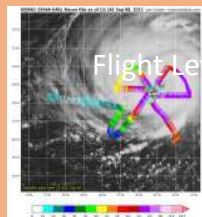
G4

Operational

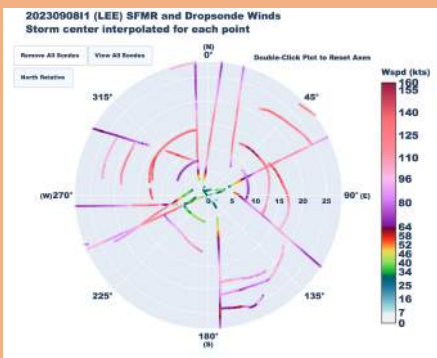
Flight Level

TDR

MMR



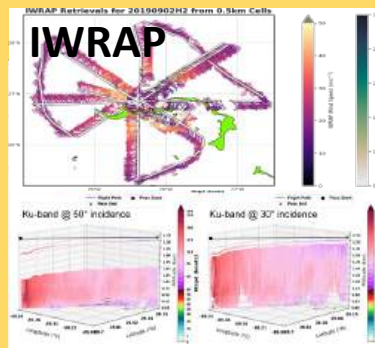
GPS Sonde + SFMR



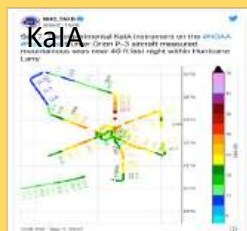
Surface winds
Rain Rate
3D Winds
3D Reflectivity

Quasi-Operational

OSVW
Rain Rate
3D Winds
3D Reflectivity



KaIA



WSRA



Surface waves

Research

ADWL
W-Radar
UAS
ARO
Microphysics Probes

3D winds in clear sky

Future

- **NOAA is moving away from the P-3 platform by 2030**
- **We need recommendations from community regarding next generation aircraft instruments**
 - **What measurements should be sustained**
 - No plans for replacement of any operational instruments
 - TDR replacement plan is still uncertain
 - **What research measurements would be good to transition to operations**
 - There is transition plan for WSRA instrument
 - **What new measurements are needed?**