

# Exploring the Role of Eyewall Mesovortices in Turbulent Transport

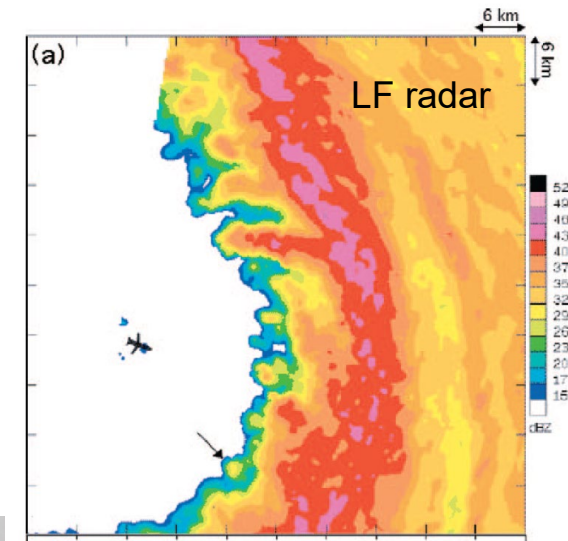
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Joshua Wadler, and Sim Aberson

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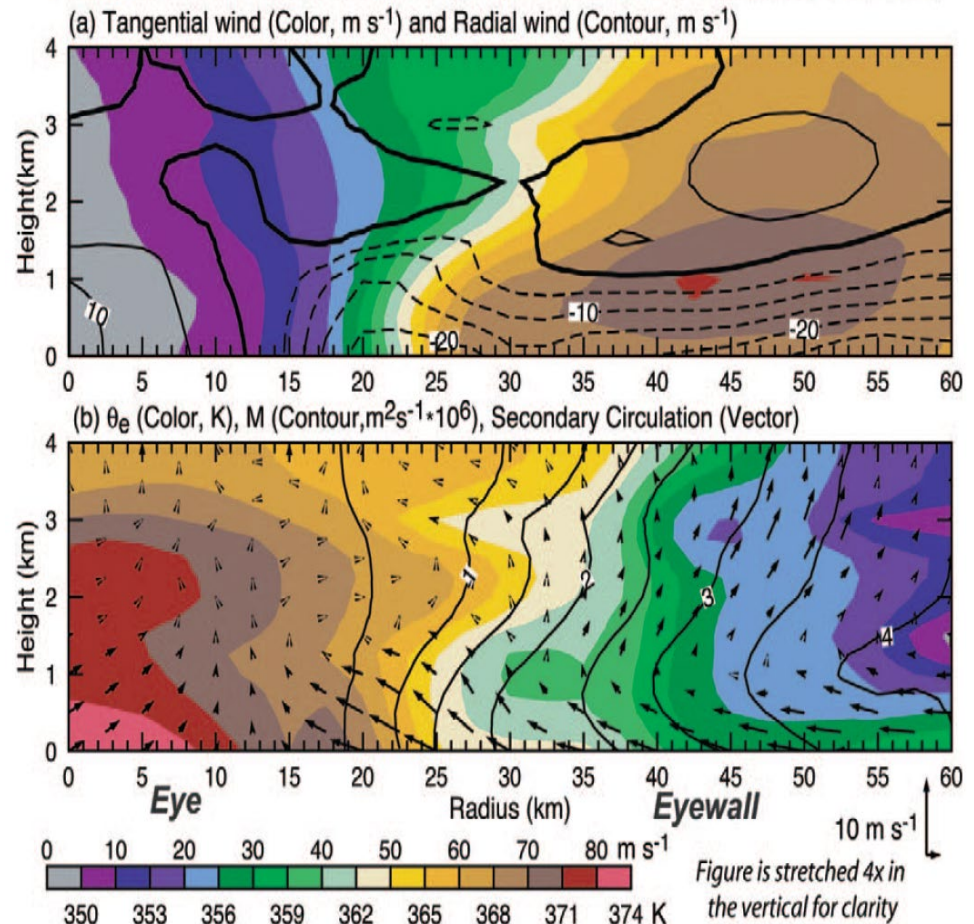
*HRD Science Meeting, February 9th, 2023*

# Background

- Coherent features/mesovortices tend to mix high entropy air from hurricane eye to eyewall, supporting intensification (e.g., Montgomery et al. 2006; Aberson et al. 2006)



**Hurricane Isabel Dropsonde & Flight Level Composite 09/13/03 (16-23 UTC)**

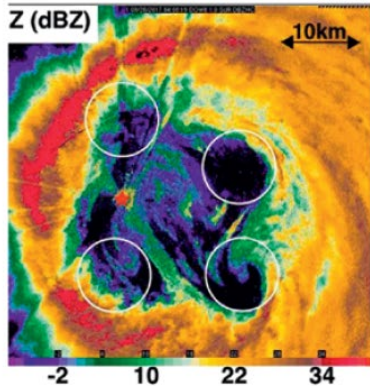


Hurricane Isabel (2003)

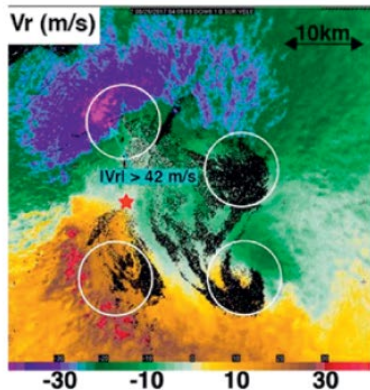


# Background

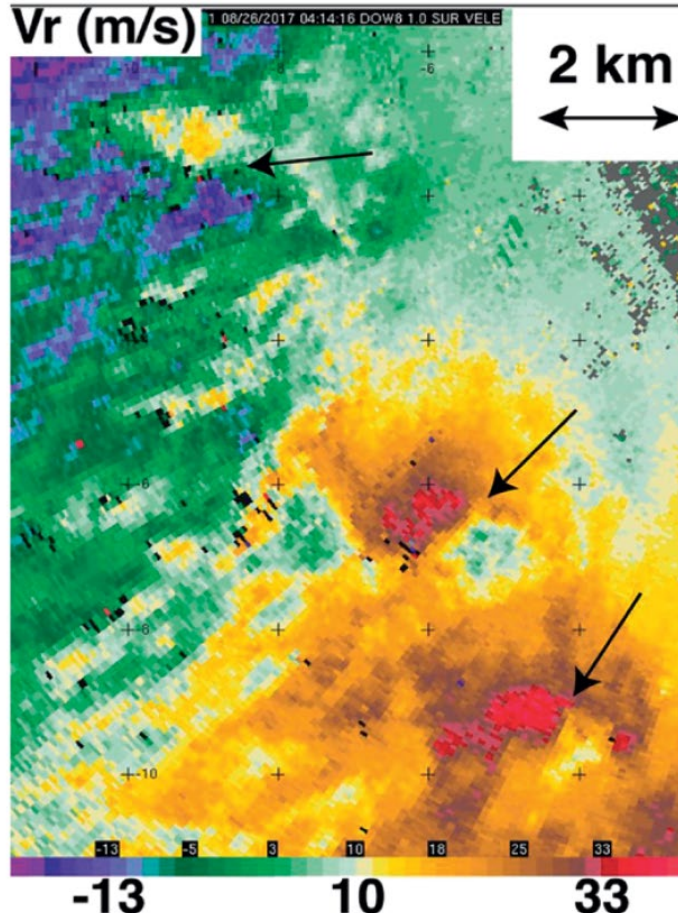
- Eyewall mesovortices enhance surface winds in landfalling hurricanes (Wurman and Kosiba 2018; Fernández-Cabán et al. 2019).



(a) Radar reflectivity of eyewall mesovortices (white circles) at 0408:18 UTC

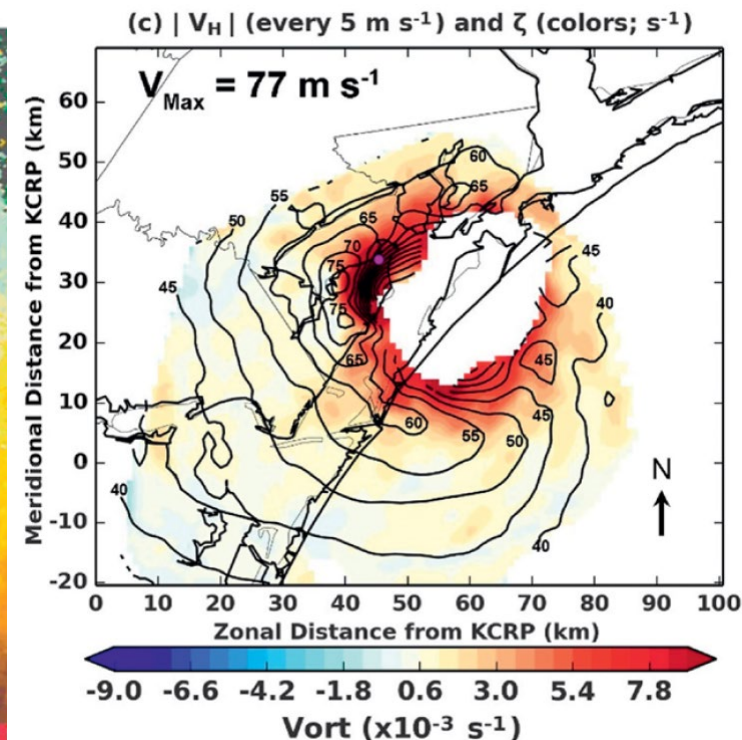


(b) Corresponding Doppler velocity. Magenta velocity contours depict Doppler winds in excess of  $42 \text{ m s}^{-1}$ .



(c) Tornado-scale vortices (TSVs) observed by DOW8 at 0414:16. Arrows indicate the location of three prominent TSVs. Shown is Doppler velocity in  $\text{m s}^{-1}$ .

DOW8 mobile radar obs



# Scientific Questions:

1. Can the eyewall mesovortices be detected by in-situ observations (e.g., P3, sUAS, Saildrone observations)?
2. What are the horizontal scales of these coherent features?
3. What are the impacts of these eyewall features on turbulent transport?

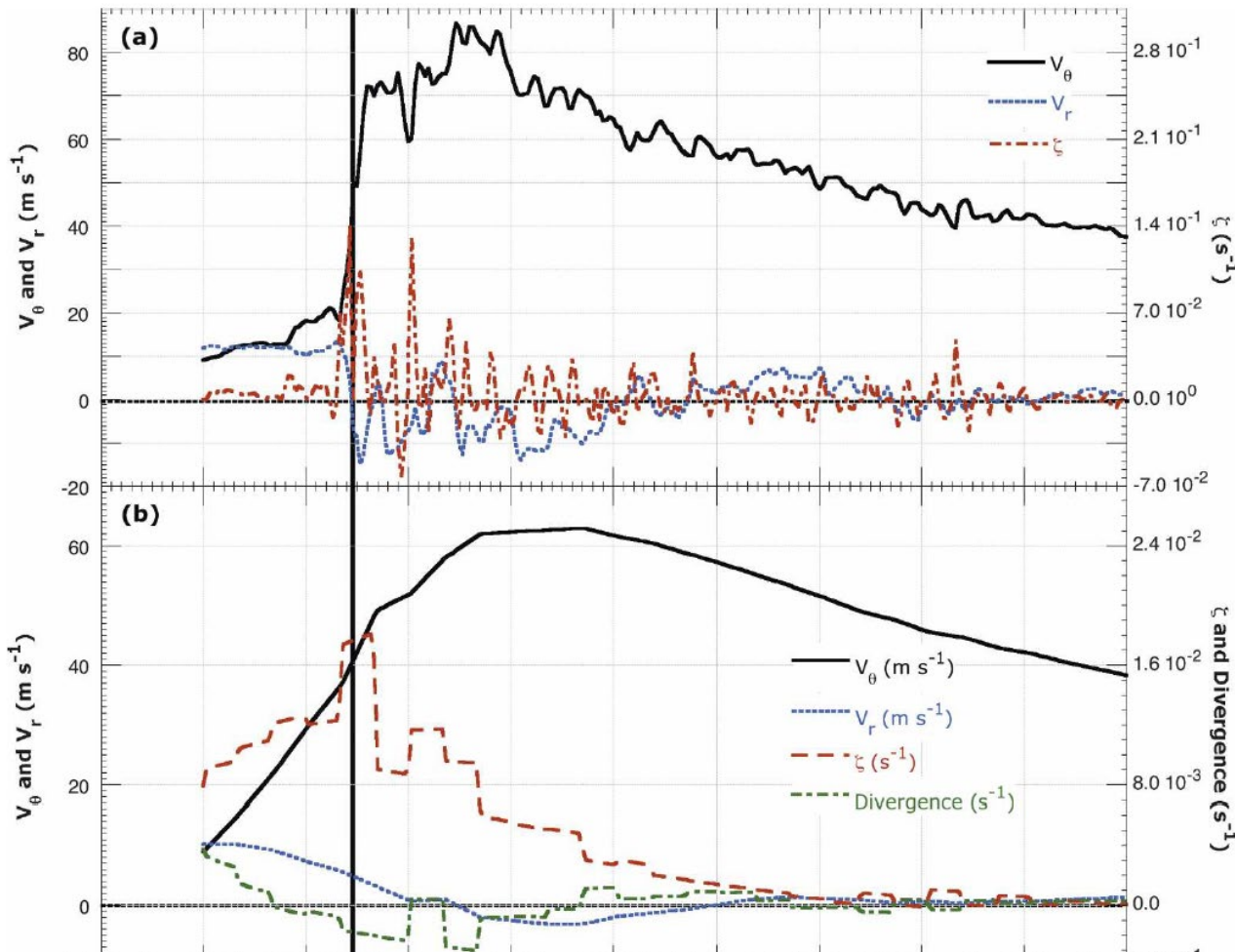


# P3 flight into Hurricane Hugo

(Marks et al. 2008)



On 15 September 1989, during observations for Hurricane Hugo, Hunter NOAA42 flew through an eyewall mesovortex.



EVM – Eyewall vorticity maximum



# P3 flight into Hurricane Felix (2007)

(Aberson, Zhang, Ocasio, 2017)

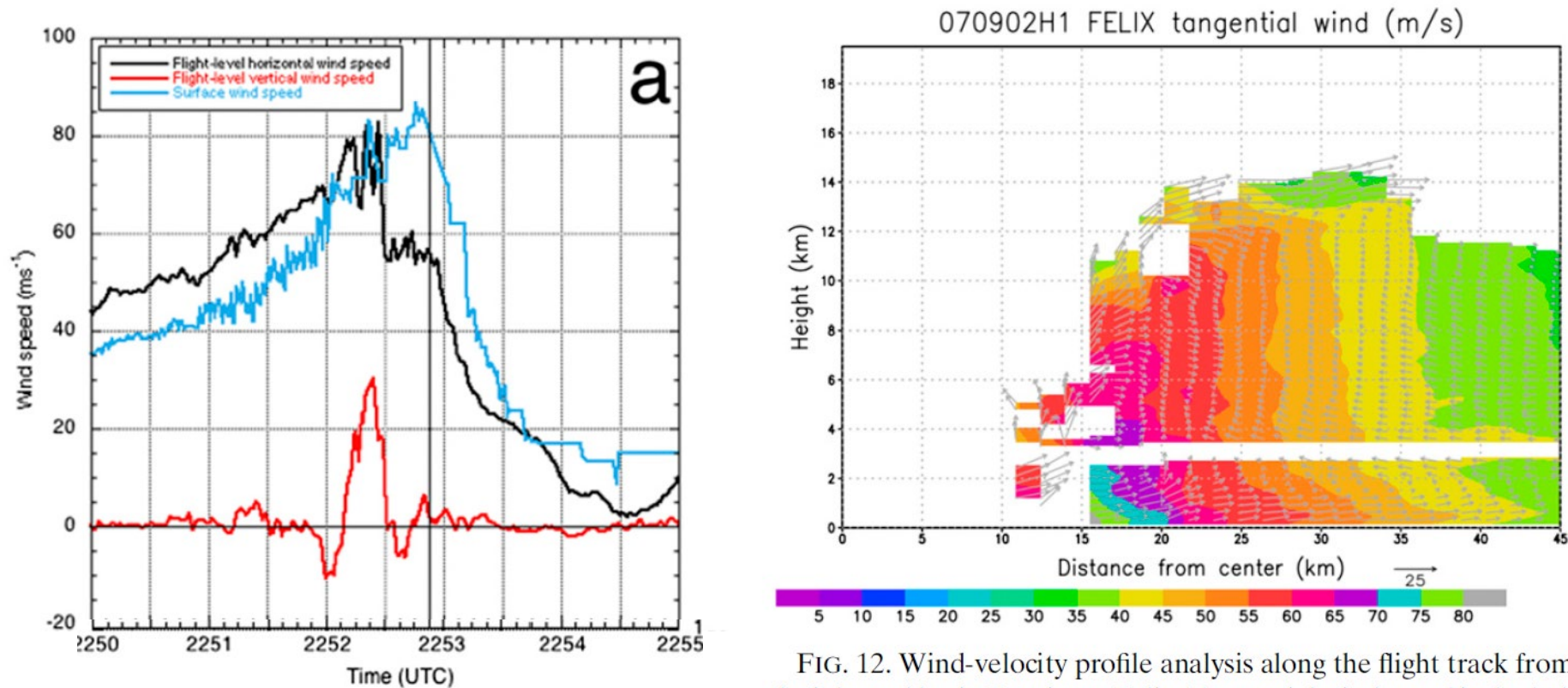
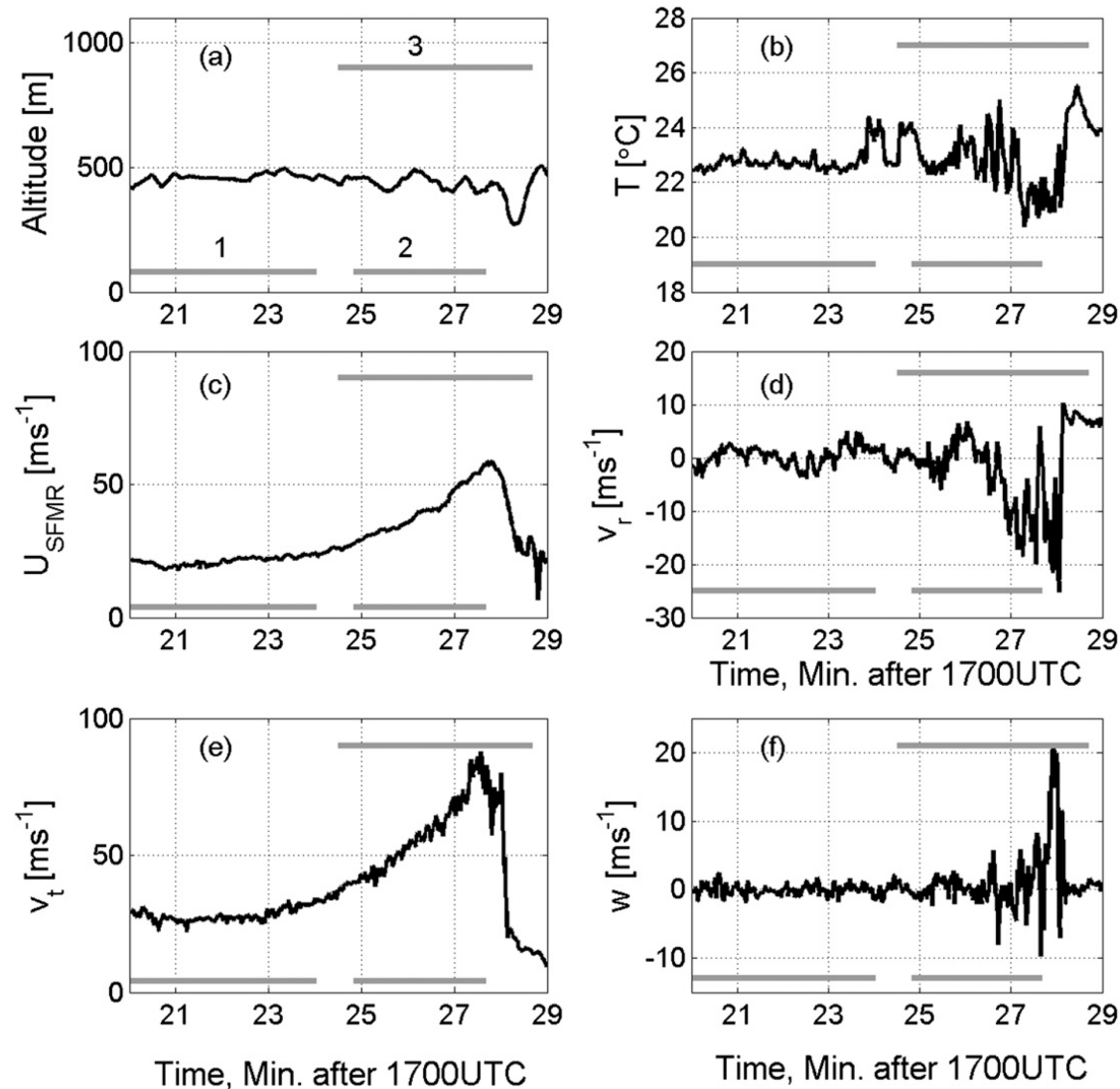


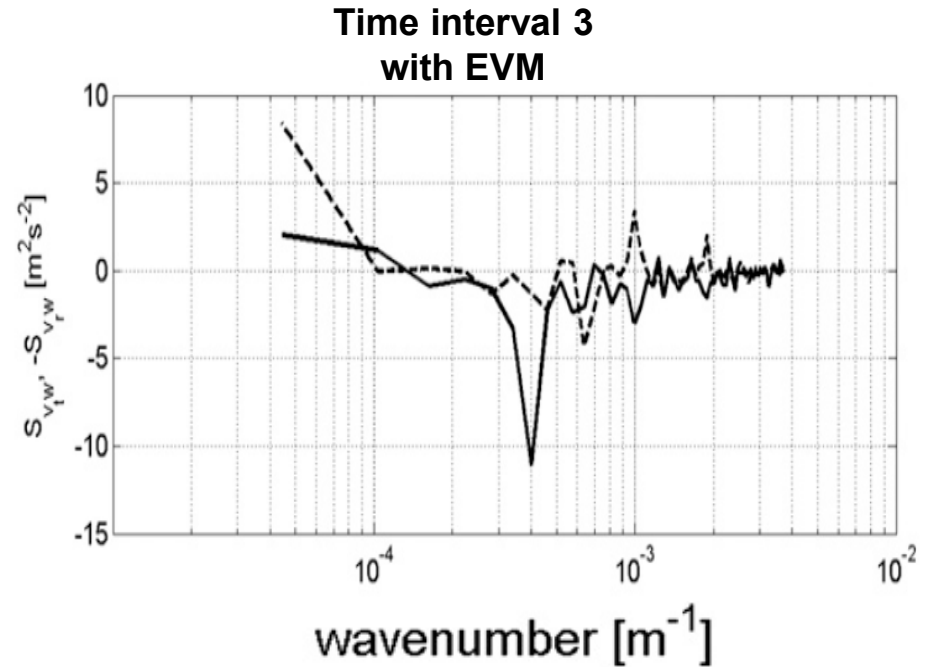
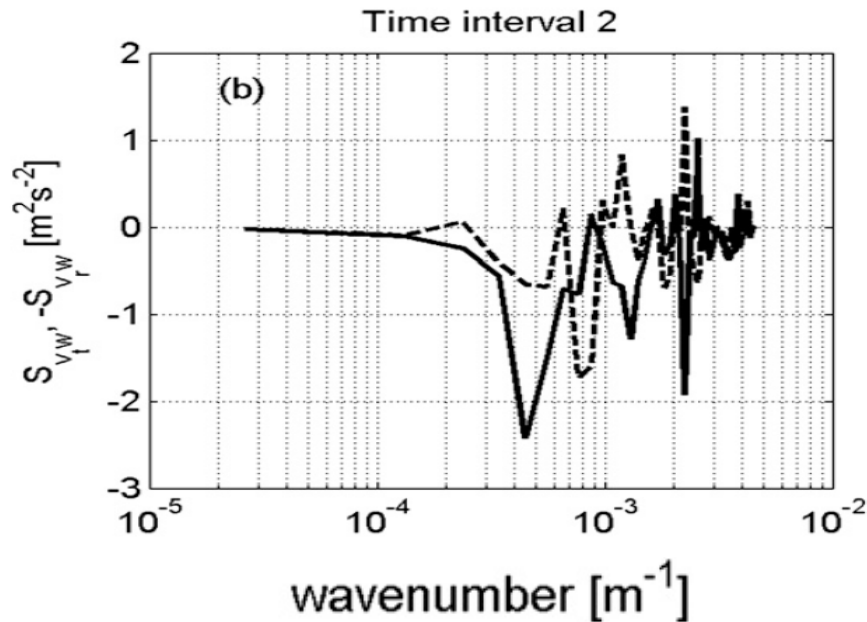
FIG. 12. Wind-velocity profile analysis along the flight track from the inbound leg in Hurricane Felix. Tangential wind speed is shaded, and arrows represent the radial and vertical wind velocity.

# P3 flight into Hurricane Hugo

(Zhang, Marks, Montgomery, Lorsolo, 2011)



# Impacts of mesovortices on turbulent transport



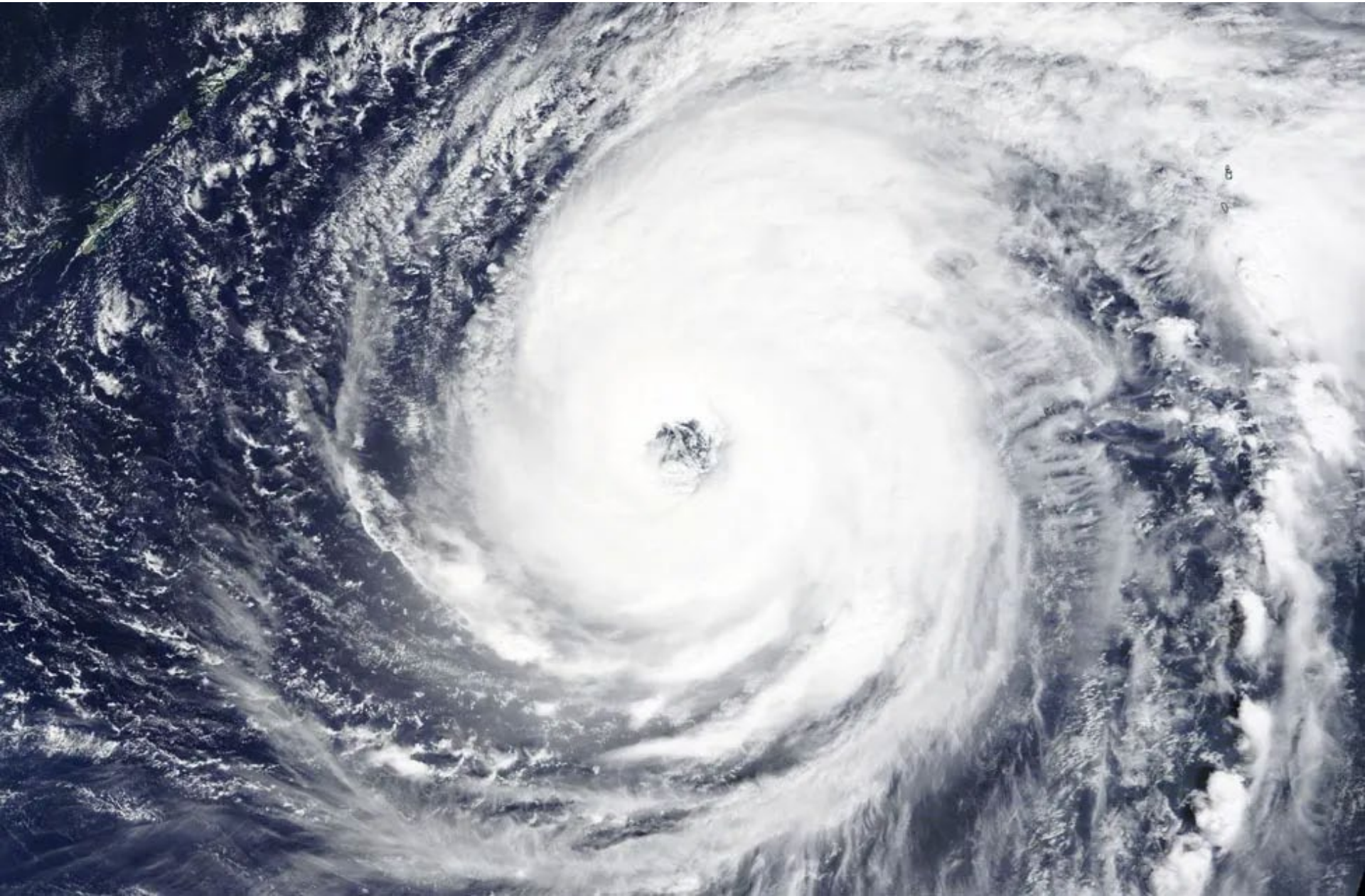
#	$T_s$	$T_{nd}$	$z$	$U_z$	$U_{\text{SFMR}}$	$z/L$	$ \tau $	$e$	$\sigma_w$	$\varepsilon$	$l$	$l_{\text{phl}}$	$K_1$	$K_2$	$K$
1	1720	1724	463	28.2	21.5	-0.44	0.34	4.46	0.84	81.1	74.5	2490.7	25.6	26.3	23.1
2	1725	1728	436	59.0	40.0	-0.06	4.70	25.8	2.68	1778	108.6	2189.2	118.6	116.7	109.4
3	1724	1729	422	52.2	39.1	-0.08	26.2	258.2	4.80	5001	221.0	2142.8	435.7	497.6	824.0

Momentum flux

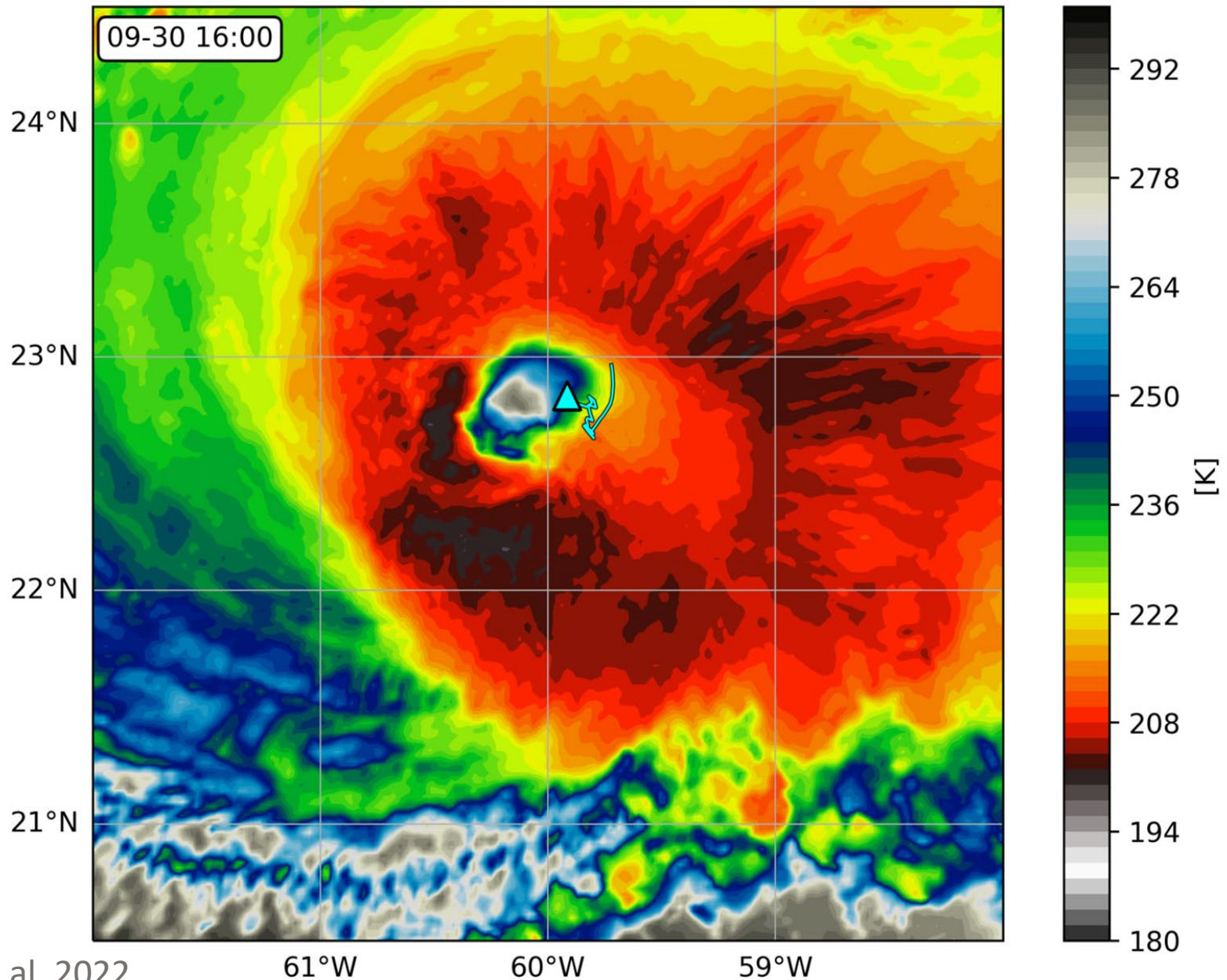
Eddy diffusivity



# Eyewall meso-vortices in Hurricane Sam (2021)

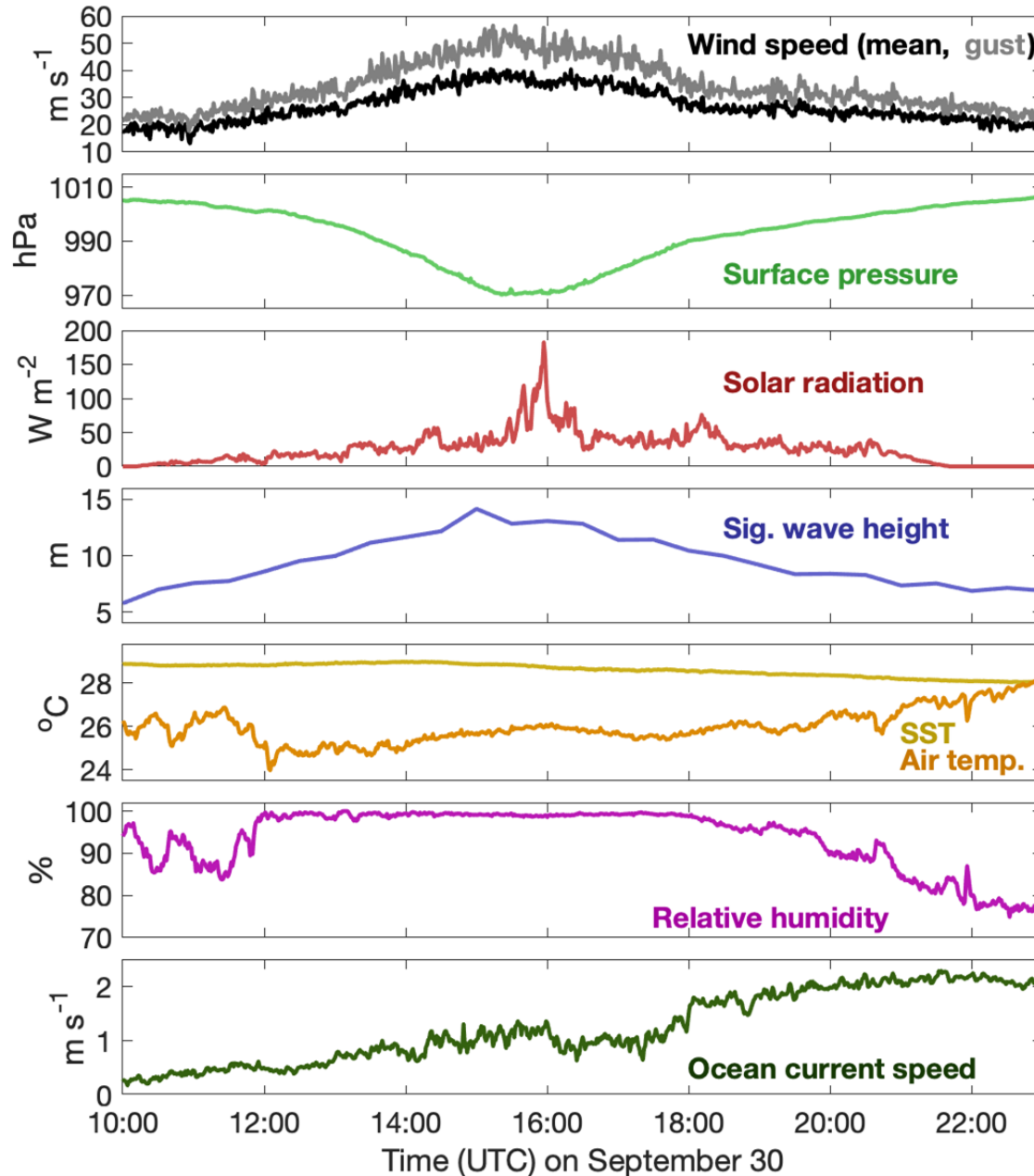


# Saildrone observations in Hurricane Sam (2021)





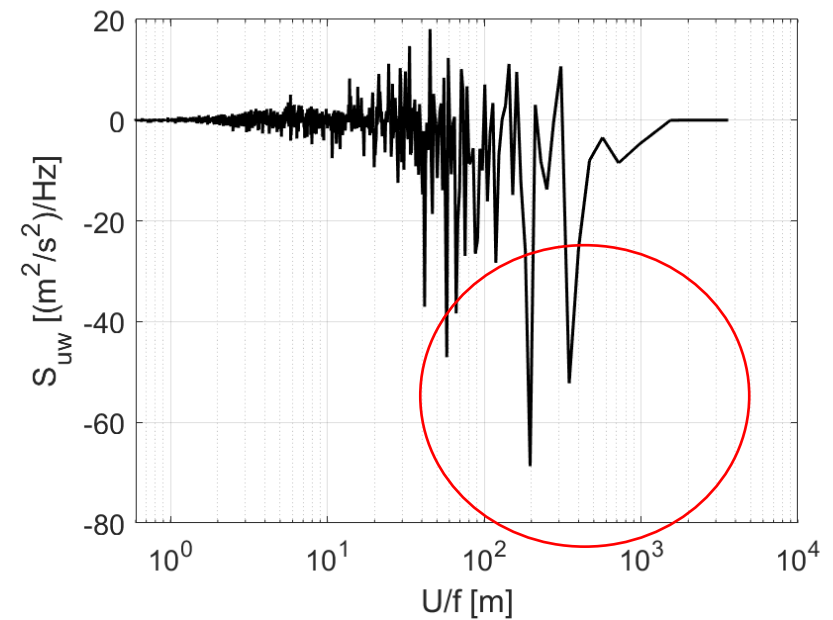
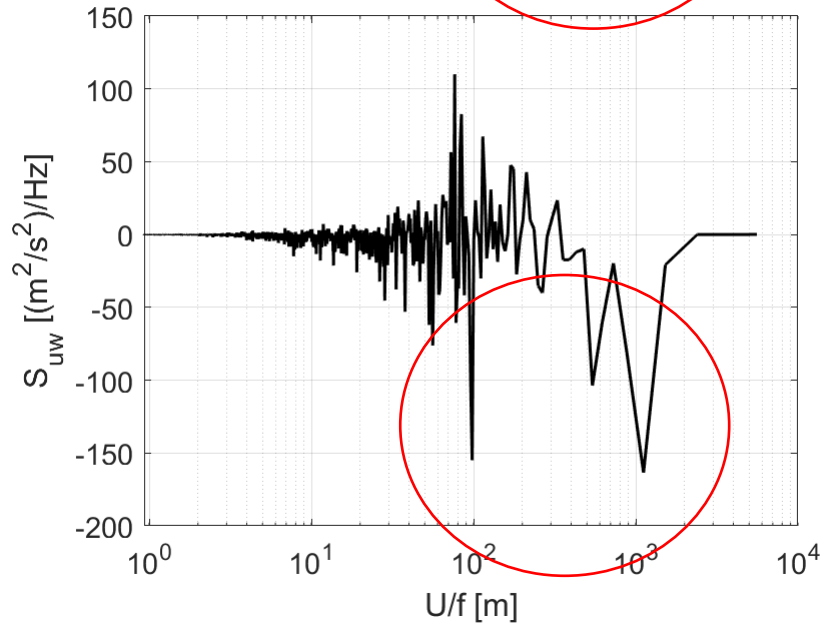
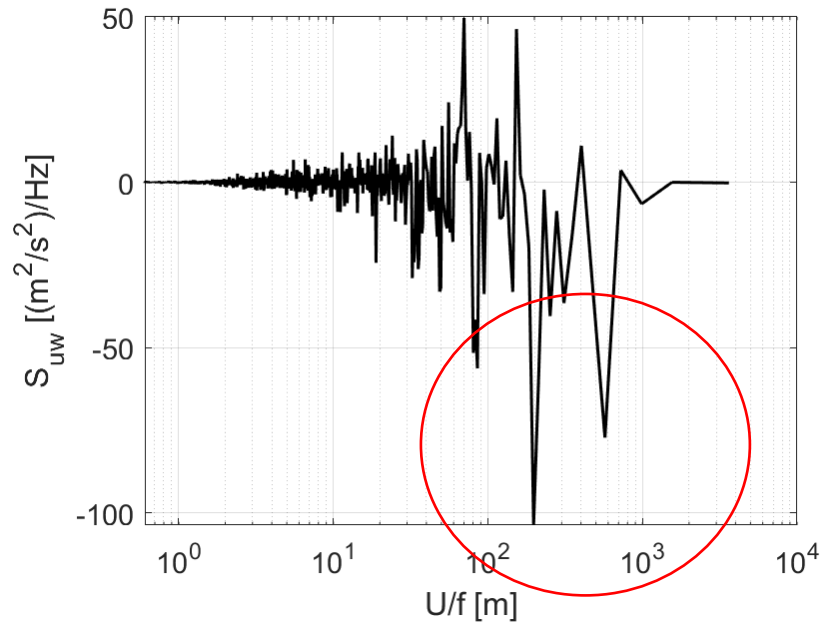
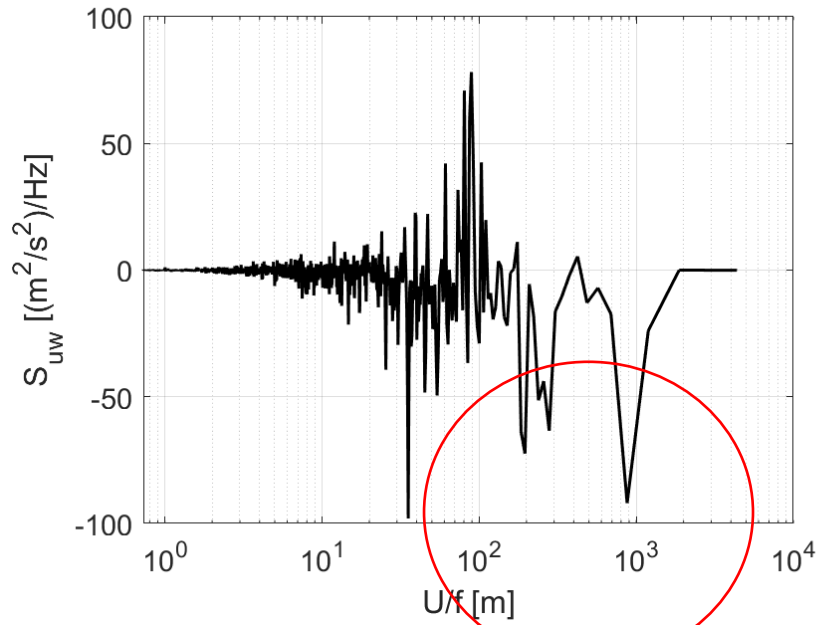
# Saildrone observations in Hurricane Sam (2021)



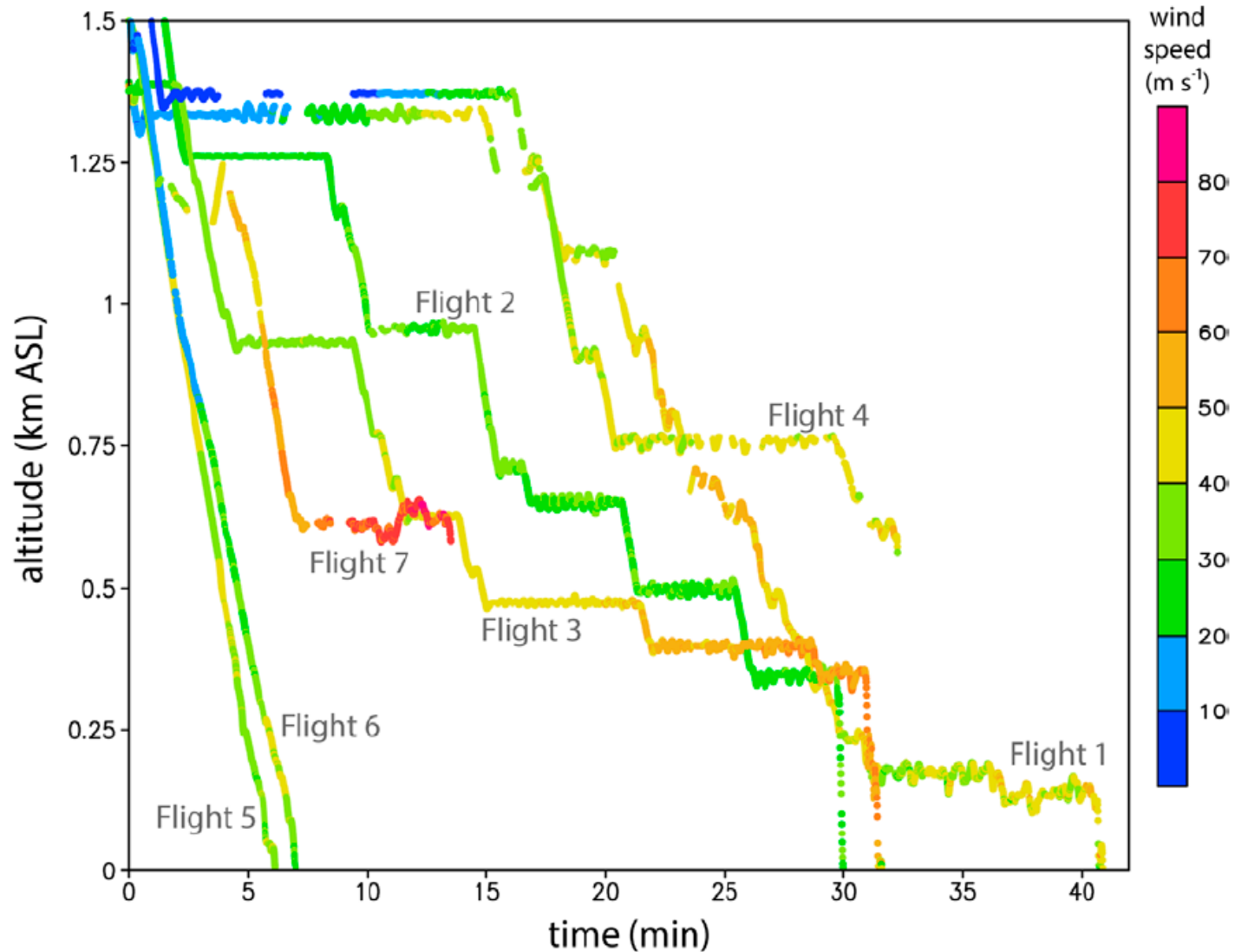
Foltz et al. 2022



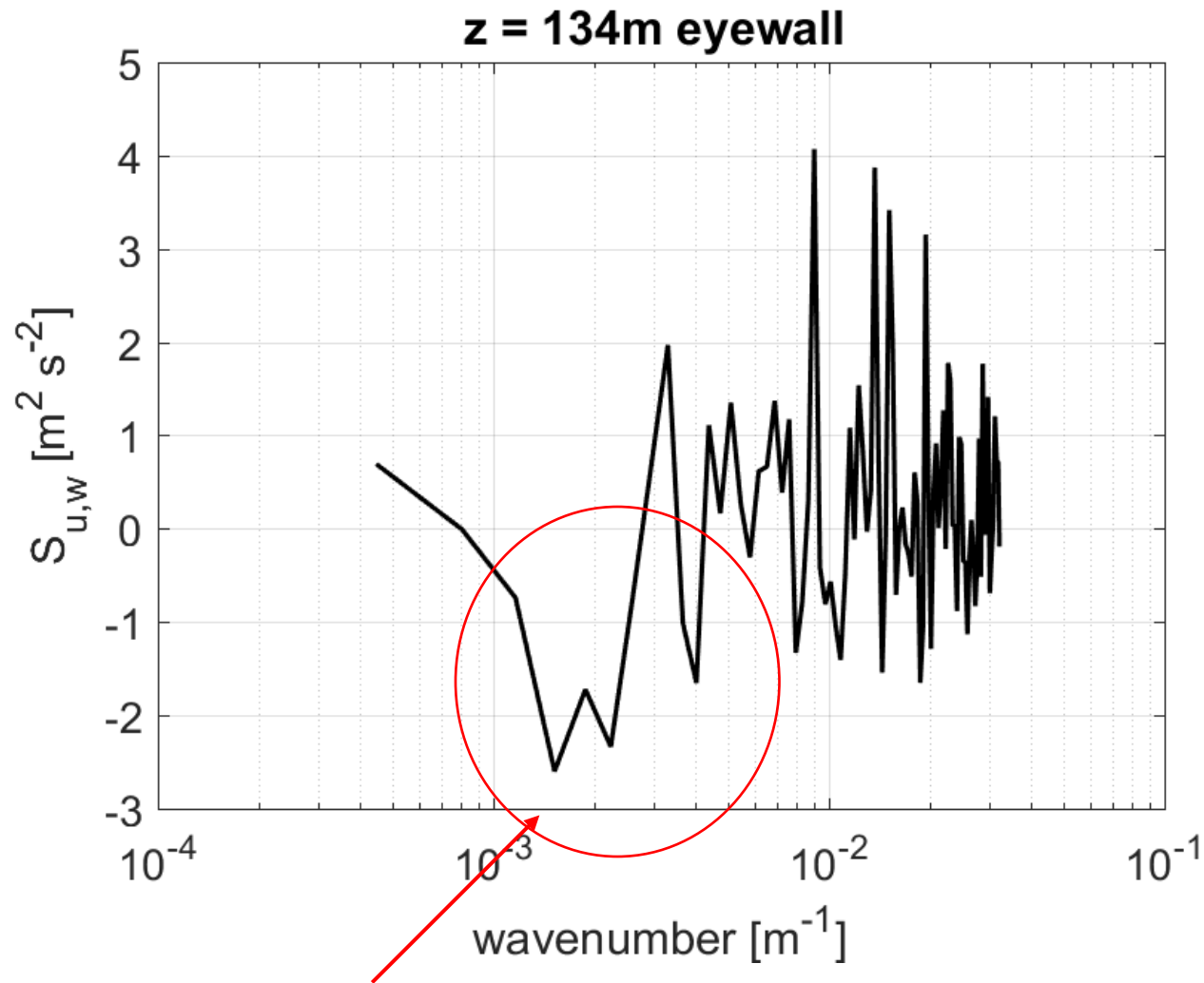
# u-w Cospectra of Eyewall legs



# sUAS flights in Hurricanes Maria (2017) and Michael (2018)



# Cospectrum of u and w (momentum flux, flight-1)



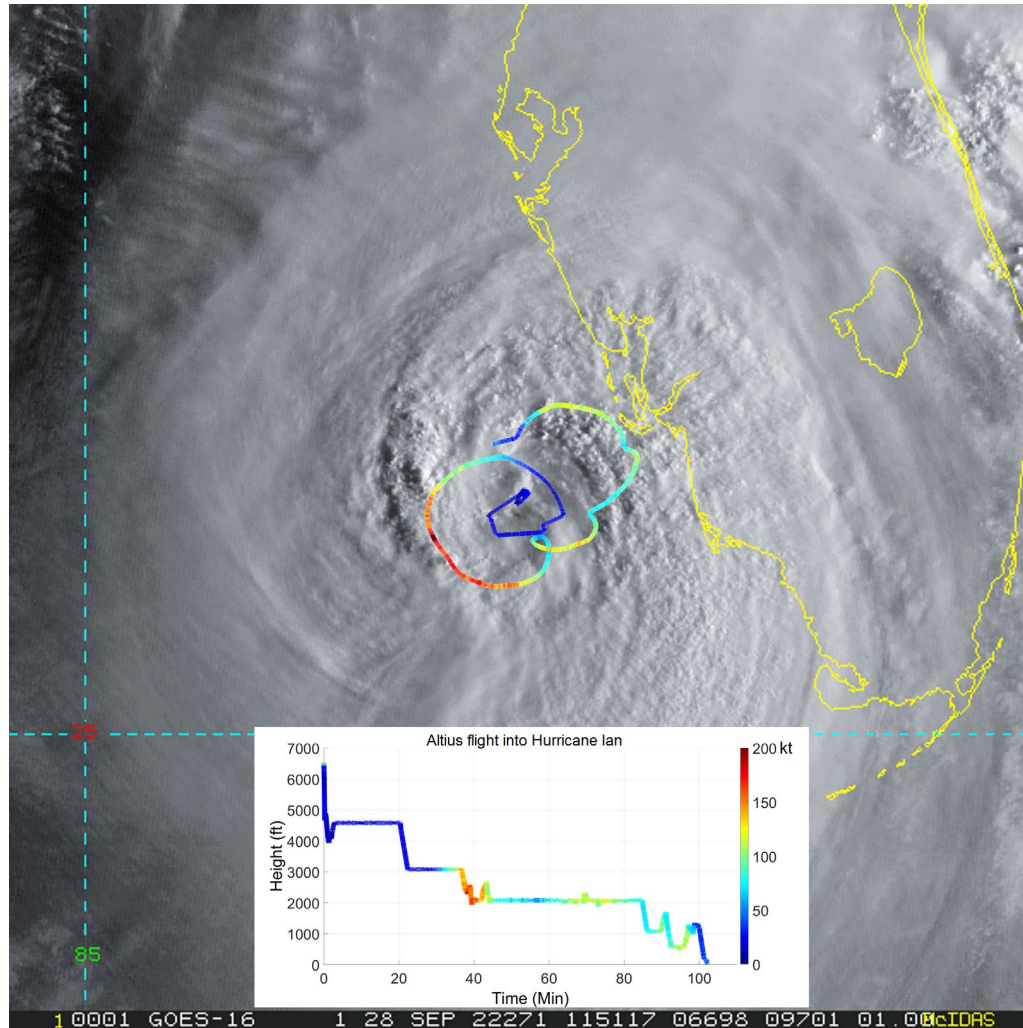
- Strong downward transfer of momentum may be associated with coherent structures/mesovortices although not seen in satellite images.



# Summary

1. Eyewall mesovortices were detected by multiple types of in-situ observational platforms.
2. Horizontal scales of these features range 500-2000 m that vary by altitude.
3. These mesovortices may enhance turbulent momentum transport.
4. Parameterization of their impacts on fluxes in hurricane models is challenging.

# sUAS (Altius) flight in Hurricane Ian (2022)



- Future work will collect and analyze more cases to quantify the impacts of mesovortices on turbulent mixing.

# Backup slide

- Horizontal wind shear and diffusion (likely tied to eye-eyewall mesovortices) affect TC intensity and intensity change (Emanuel 1997; Persing and Montgomery 2003; Bryan and Rotunno 2009; Zhang and Marks 2015).

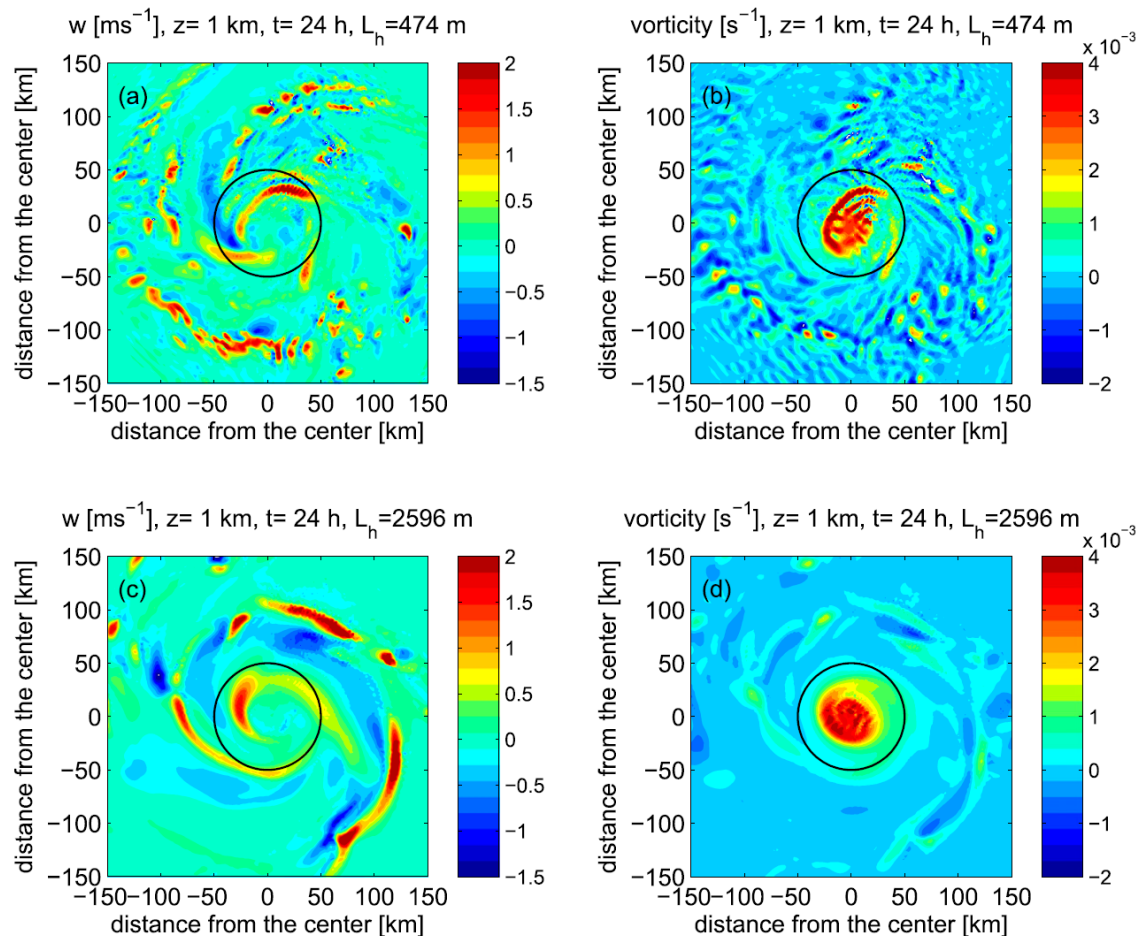


FIG. 10. Horizontal view of the (left) vertical velocity and (right) relative vorticity at the height of 1 km at 24 h from the initial time for simulations with  $L_h =$  (a),(b) 474 and (c),(d) 2596 m. The black line represents a radius of 50 km.