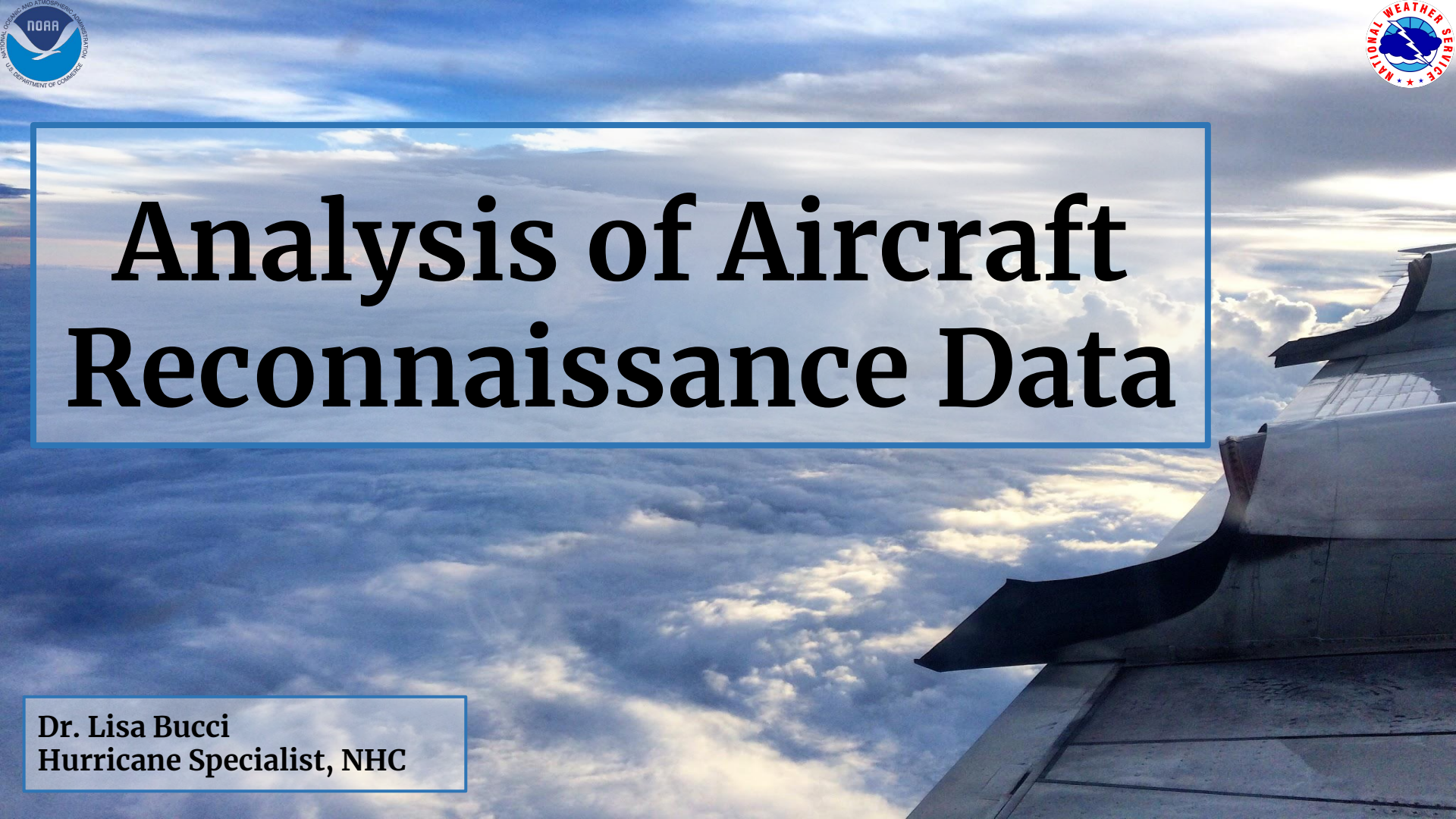
Analysis of Aircraft Reconnaissance Data



Dr. Lisa Bucci
Hurricane Specialist, NHC

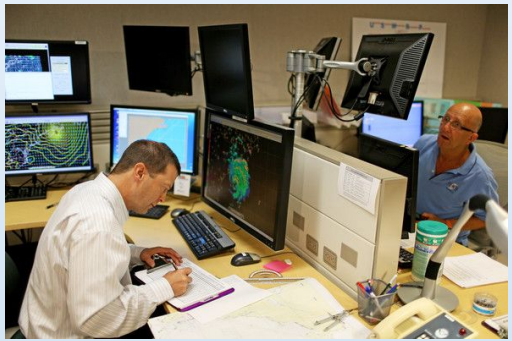
Collecting Observations

Where does the data go?

Hurricane Aircraft Data

Nowcast

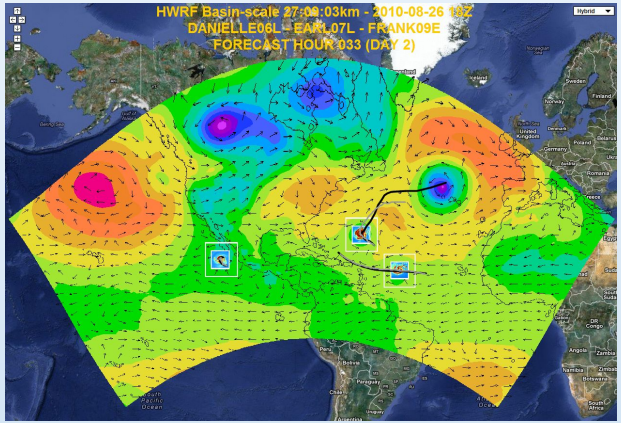
Forecasters



National Weather Service
National Hurricane Center

Forecast

Weather Models



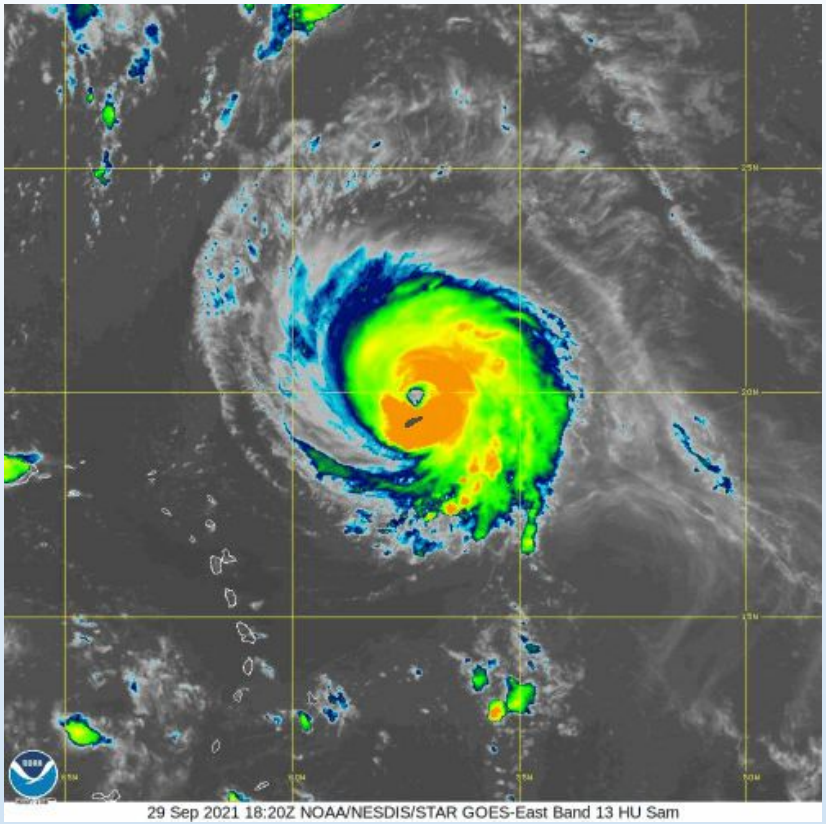
National Weather Service
Environmental Modeling Center

Research

Scientists

Government, Academia,
International, Public

What does NHC define?



- Center location
- Intensity
  - 1-min 10 m wind speed ***representative*** of the TC circulation
- Minimum central pressure
- Radius of maximum winds (RMW)
- Wind radii (34-, 50-, 64-kt) in each quadrant
- Existence of a TC

NOAA and the Air Force (53rd)

- Purpose: ***research*** or ***operational***
- Research-grade instrumentation, non-standard flight patterns, more windows
- Scientists usually fly with aircraft (P-3)
- ***Two P-3s and one G-IV***

- Purpose: ***operational***
- Equipped with fewer instruments
- No scientists onboard
- ***Ten C-130s***

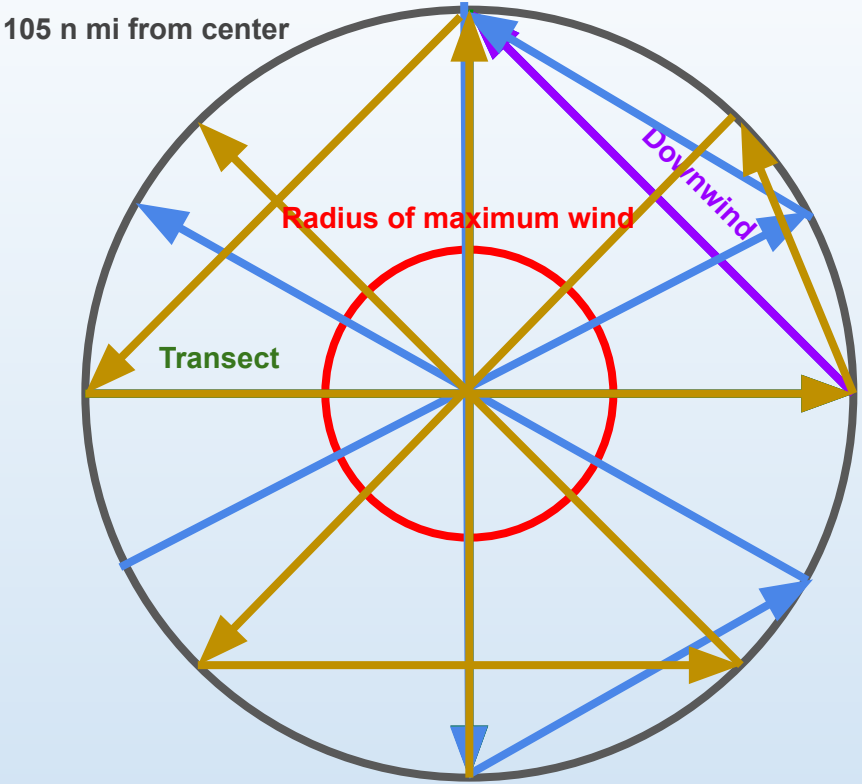
Flight Tracks

Philosophy: Collect a representative sample of the hurricane and map its structure

Methodology: Transect the center, fly "downwind", repeat.

Types of flight tracks: figure-4, butterfly, rotated figure-4

Problem: Where is the maximum 1-minute 10 m wind?



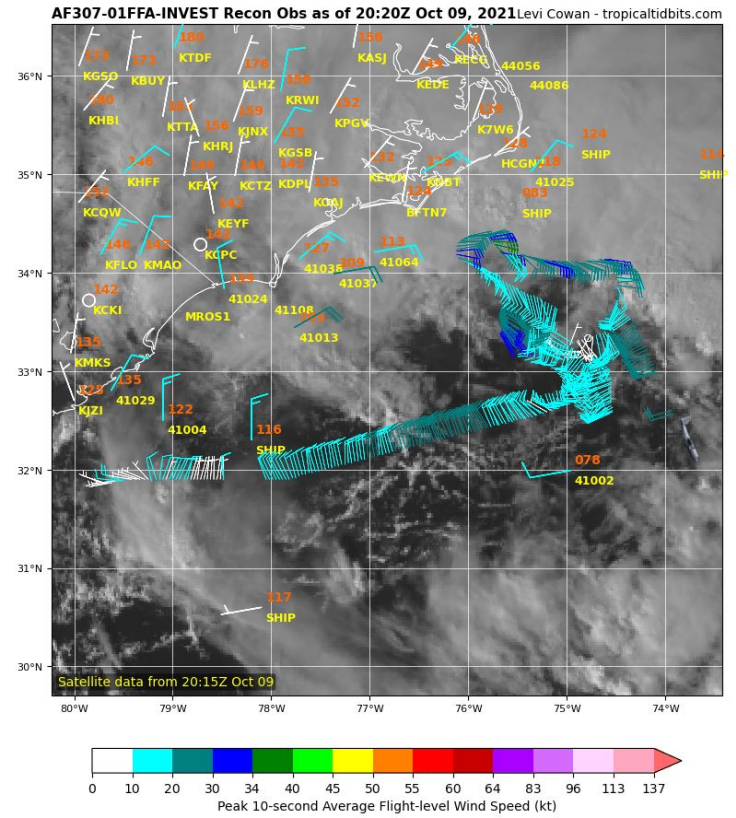
Flight Tracks

Philosophy: Identify a closed (near) surface center circulation

Methodology: Follow the winds

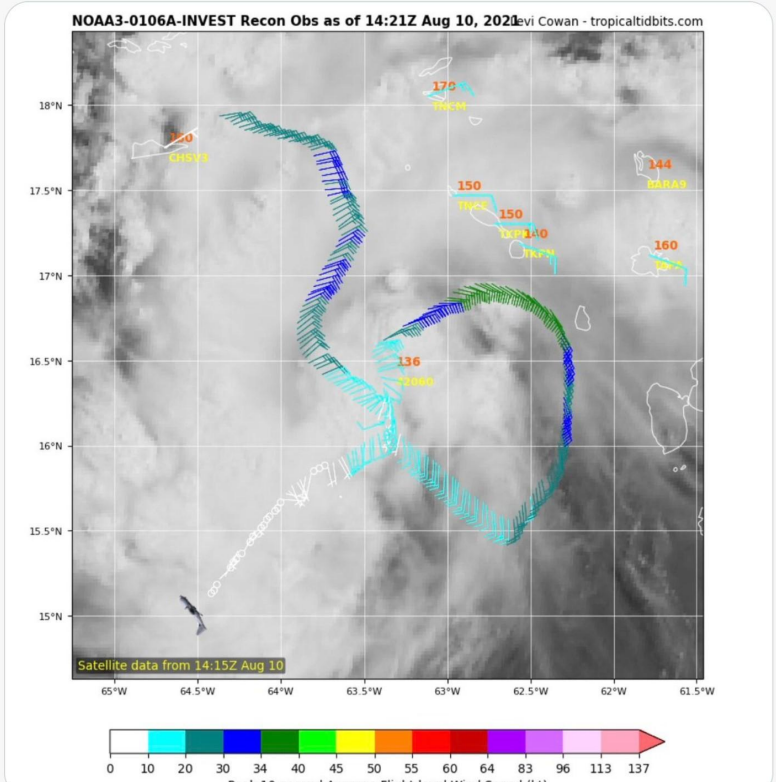
Types of flight tracks: Free-for-all

Problem: Is there a closed circulation? What are the strongest surface winds?



Review the social media post. Do you agree that Potential Tropical Cyclone 6 should be a named storm at the next advisory time?

Hurricane hunters currently investigating **#PTC6**. Seems like the circulation has gotten better defined and that we might have #Fred by the 11 a.m. advisory. Max winds could be anywhere between 40-45 mph.



Review the social media post. Do you agree that Potential Tropical Cyclone 6 should be a named storm at the next advisory time?

0

Yes because the surface winds are in the 40-45 mph range and the storm is better defined. 0%

No because these are not surface winds and there is not a clear closed circulation. 0%

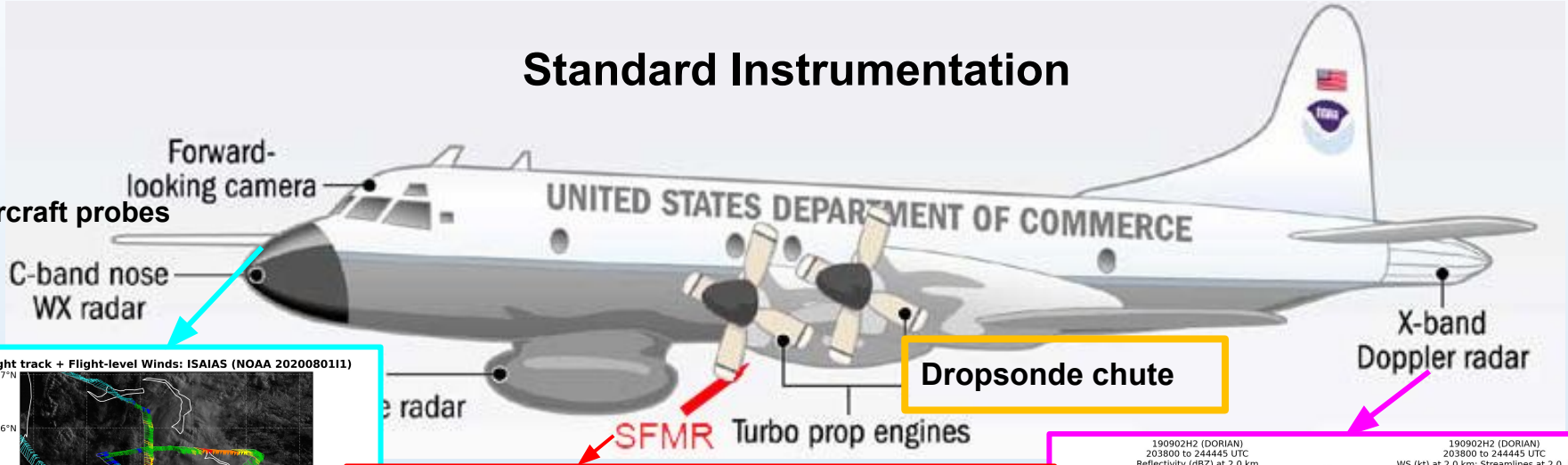
Poll Question 1: Feedback

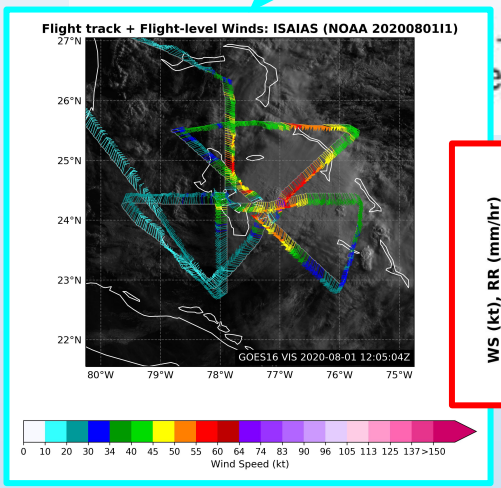
This person is looking at **a single product** and speculating about the storm's intensity based on recon data (40-50kts), when in reality there was no closed circulation and NHC determined sfc winds of only 30 kts.

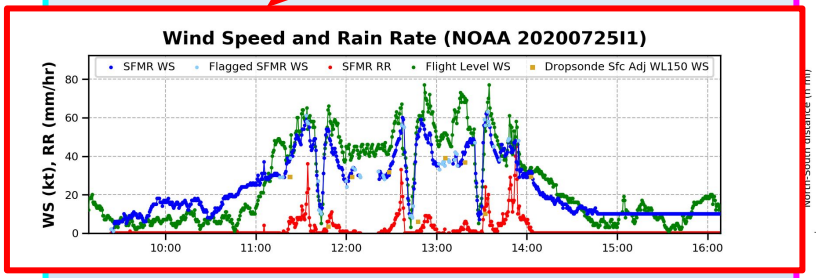
```
ZCZC MIATCDAT1 ALL
TTAA00 KNHC DDHHMM

Potential Tropical Cyclone Six Discussion Number   4
NWS National Hurricane Center Miami FL       AL062021
1100 AM AST Tue Aug 10 2021

Satellite imagery shows that the disturbance has become better
organized since yesterday, and satellite intensity estimates from
TAFB and SAB are at tropical storm strength.  However, reports from
a NOAA Hurricane Hunter aircraft and surface observations indicate
that the system does not yet have a well-defined closed
circulation, with the wind and pressure fields more resembling an
open wave,  The maximum flight-level winds at 925 mb were 35-40 kt,
and reliable SFMR wind estimates were near 30 kt.  Based on these
data, the system remains at potential tropical cyclone status with
an initial intensity of 30 kt.
```

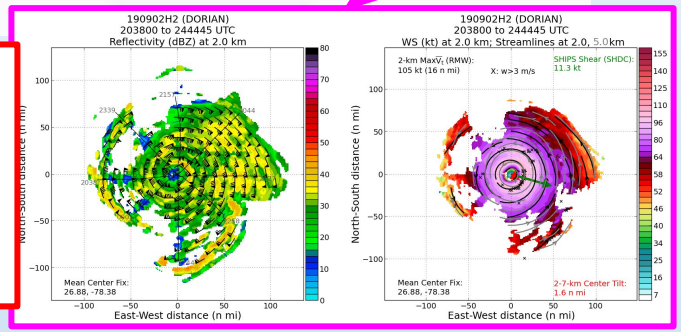
What instruments are flown?

Standard Instrumentation

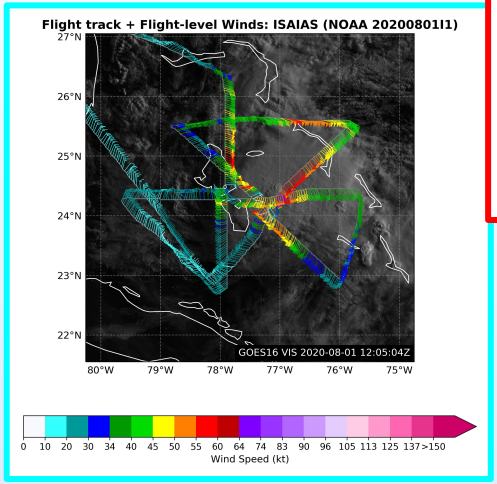


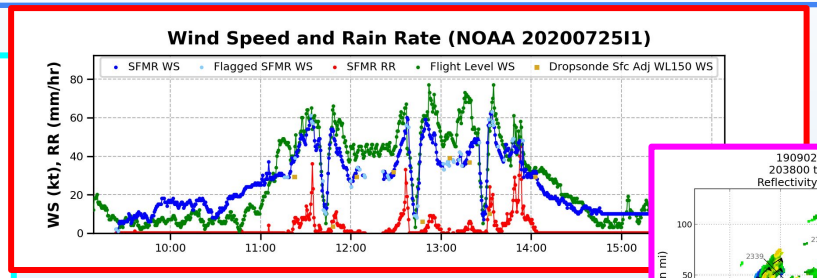


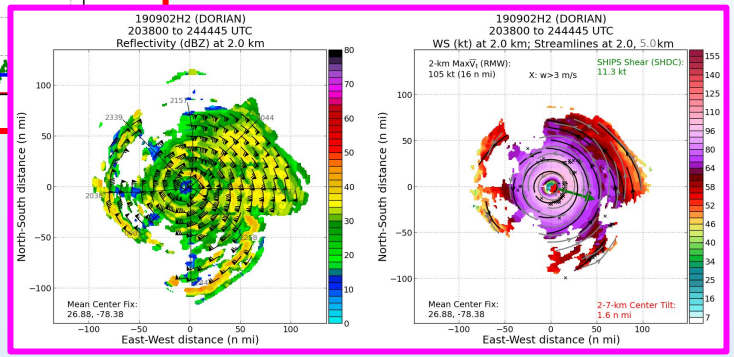




What are the instruments measuring?





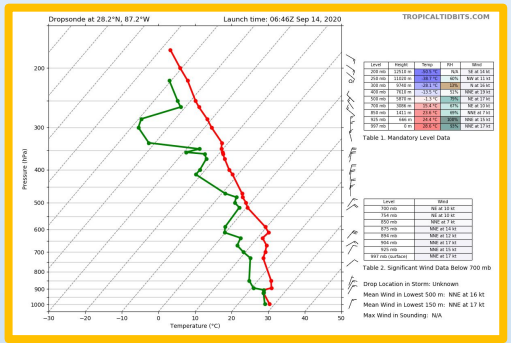


Stepped Frequency Microwave Radiometer (SFMR):

- 10 m Wind Speed
- Rain rate

Aircraft probes:

- Temperature
- Moisture
- Winds
- Pressure
- Altitude



Dropsondes:

- Temperature
- Moisture
- Winds
- Pressure

Tail Doppler Radar:

- Winds
- Reflectivity

Dropsondes

Mac rapidly releasing three dropsondes in the eyewall of Hurricane Sam (2021)

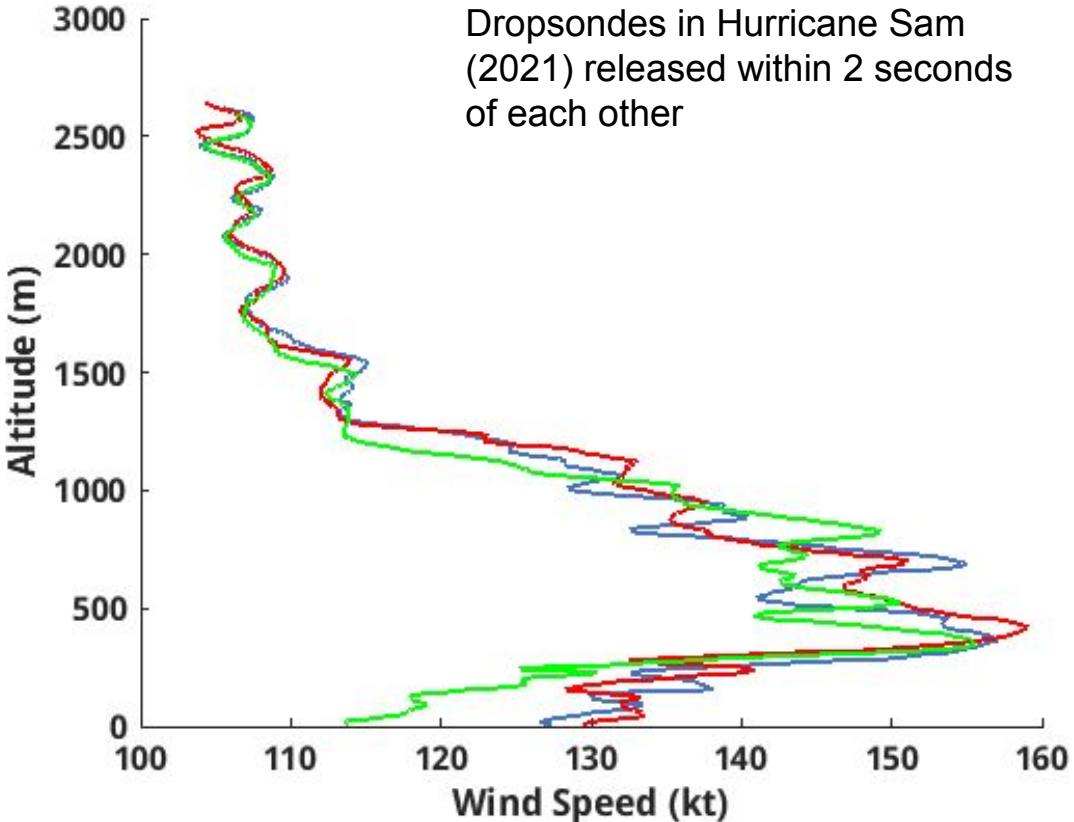
Credit: J. Rannenberg

Scientists Kelly Ryan and Dr. Ghassan Alaka quality control and coordinate mission

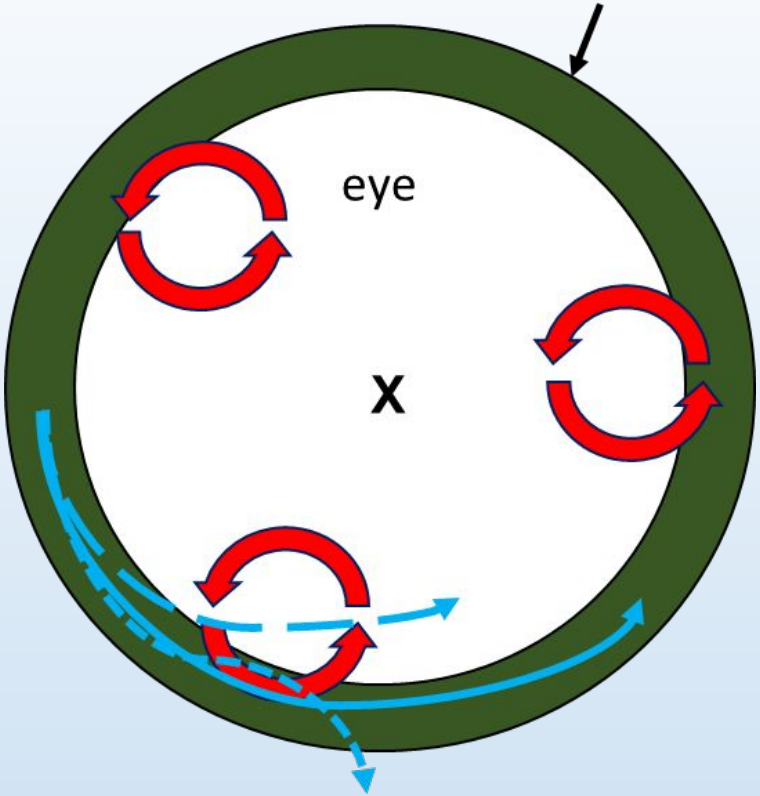
Dropsondes release points:

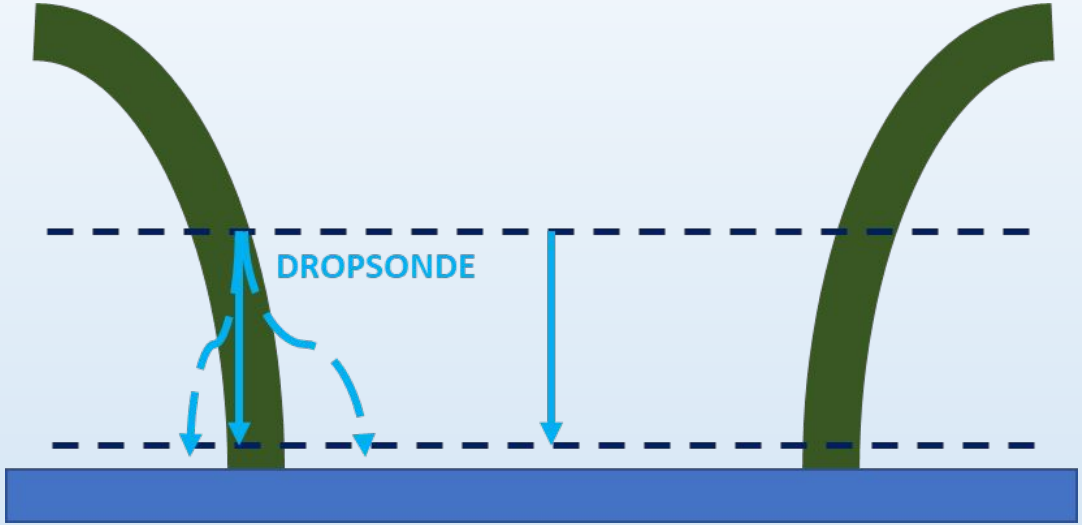
- Beginning and end of transect
- Radius of maximum wind
- Center

Dropsondes


Dropsondes in Hurricane Sam (2021) released within 2 seconds of each other
Altitude (m)
3000
2500
2000
1500
1000
500
0
100
110
120
130
140
150
160
Wind Speed (kt)

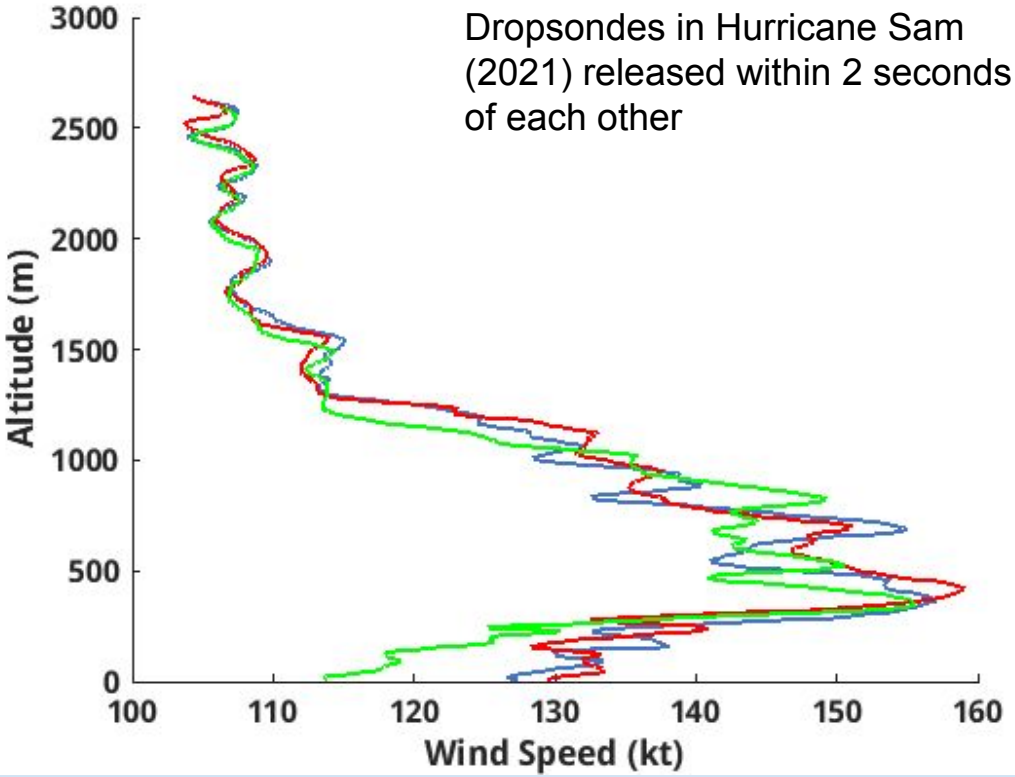
Dropsondes





Courtesy of J. Zawislak

Dropsondes



Advantage:

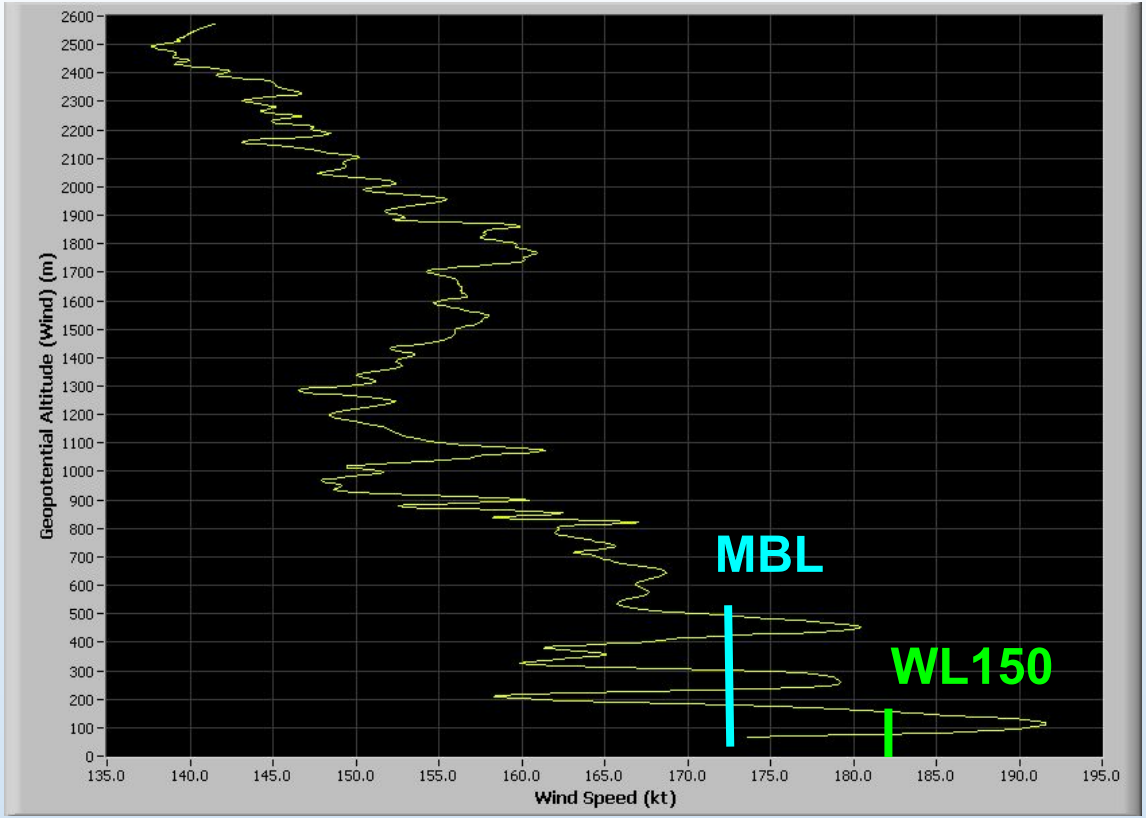
- Accurate, frequent measurements in profile

Disadvantage:

- Representativeness (one advected profile)
- Sensor wetting
- Ocean (waves, sea spray) influence

Dropsondes

- Surface winds may not be representative of a 1-min wind.
- Use layer mean winds to estimate representative surface winds.
- Mean Boundary Layer (MBL) ~30-40 s
- WL150 ~ 10-15 s



Courtesy of J. Franklin

Dropsondes: TEMPDROP

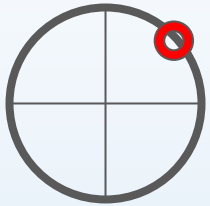
003
UZNT13 KWBC 300018
XXAA 80007 99205 70579 07807 **99957** 24410 **07128** 00884 ///// /////
92302 22404 09140 85038 19400 11131 70699 14231 13603 88999 77999
31313 09608 82359
61616 NOAA2 1218A SAM OB 19
62626 **EYEWALL 045** **MBL WND 08639** AEV 30406 DLM WND 11117 956695 **WL**
150 07132 083 REL 2049N05789W 235953 SPG 2055N05804W 000448 =
XXBB 80008 99205 70579 07807 **00957** 24410 11850 19400 22818 19202
33800 18203 44794 18027 55737 14408 66707 13809 77695 14242
21212 00957 07128 11952 07133 22943 07633 33940 06628 44931 08141
55927 08632 66920 09653 77912 09659 88895 10147 99883 10651 11873
10638 22866 10635 33858 10637 44850 11131 55823 11613 66695 13601
31313 09608 82359
61616 NOAA2 1218A SAM OB 19
62626 **EYEWALL 045** **MBL WND 08639** AEV 30406 DLM WND 11117 956695 **WL**
150 07132 083 REL 2049N05789W 235953 SPG 2055N05804W 000448 =

Data available: https://www.nhc.noaa.gov/recon.php

Dropsondes: TEMPDROP

EYEWALL 045

Release location



MBL WND 08639

Averaged winds 0–500 m
- **Wind Direction:** 85° (from the E)
- **Wind Speed:** 139 knots (160 mph)

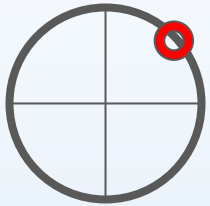
0.80 * MBL = Surface Wind Estimate

0.8 * 139 kt = **111.2 kt**

Dropsondes: TEMPDROP

EYEWALL 045

Release location



MBL WND 08639

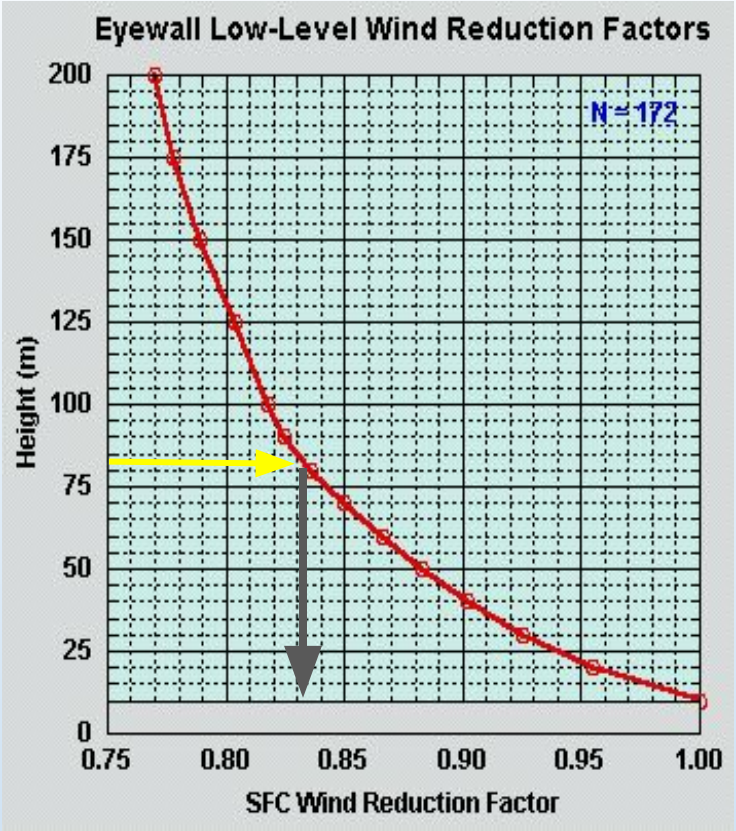
111.2 kt

WL150 07132 083

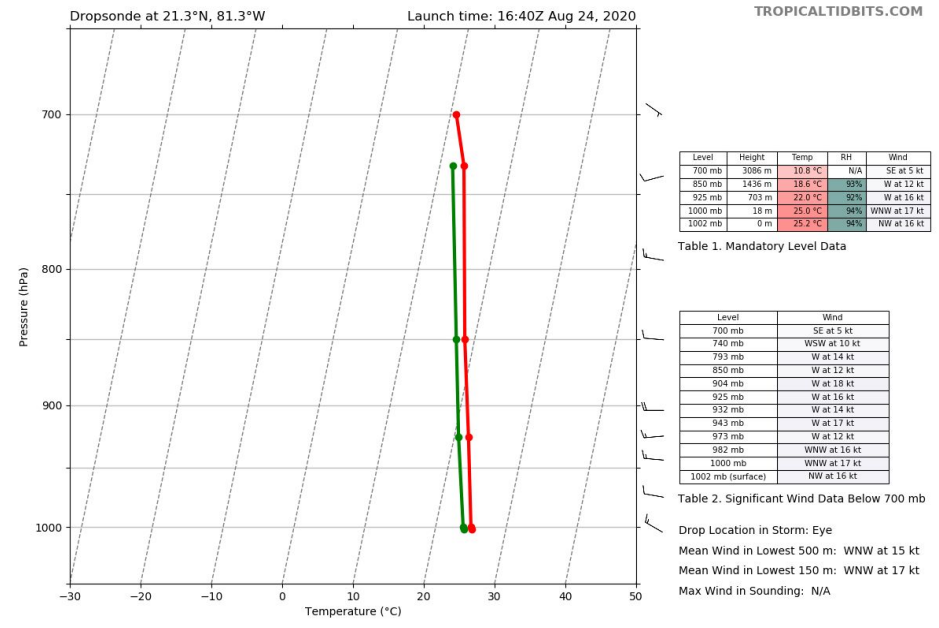
Averaged winds 0–150 m
- **Wind Direction:** 70° (from the ENE)
- **Wind Speed:** 132 knots (152 mph)
- **Mean Height**: 83 m

0.83 * WL150 = Surface Wind Estimate

0.83 * 132 kt = **109.6 kt**



Dropsondes: Minimum Pressure



Level	Height	Temp	RH	Wind
700 mb	3086 m	10.8 °C	N/A	SE at 5 kt
850 mb	1436 m	18.6 °C	93%	W at 12 kt
925 mb	703 m	22.0 °C	92%	W at 16 kt
1000 mb	18 m	25.0 °C	94%	WNW at 17 kt
1002 mb	0 m	25.2 °C	94%	NW at 16 kt

Table 1. Mandatory Level Data

Level	Wind
700 mb	SE at 5 kt
740 mb	WSW at 10 kt
793 mb	W at 14 kt
850 mb	W at 12 kt
904 mb	W at 18 kt
925 mb	W at 16 kt
932 mb	W at 14 kt
943 mb	W at 17 kt
973 mb	W at 12 kt
982 mb	WNW at 16 kt
1000 mb	WNW at 17 kt
1002 mb (surface)	NW at 16 kt

Table 2. Significant Wind Data Below 700 mb

Drop Location in Storm: Eye
Mean Wind in Lowest 500 m: WNW at 15 kt
Mean Wind in Lowest 150 m: WNW at 17 kt
Max Wind in Sounding: N/A

- Center (eye) drops are released at the flight-level wind minimum.
- **Rule of thumb:** Subtract 1 mb from the sonde splash pressure for each **full 10 kt** of surface wind reported by the sonde.
- Splash pressure 1002 mb.
- Surface wind: 16 kt.
- Estimated MSLP = 1001 mb.

Flight-level data

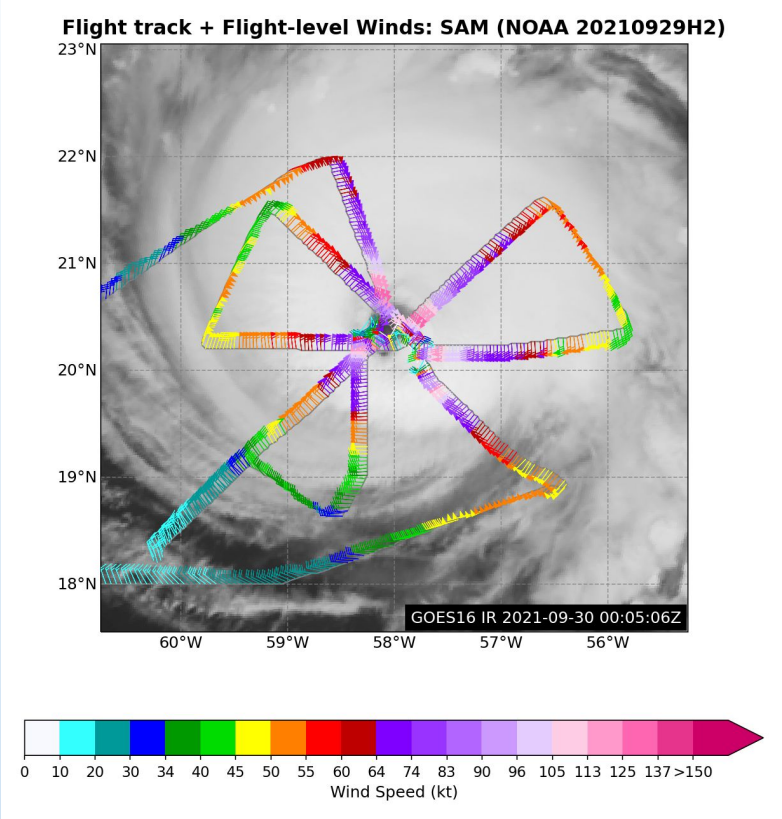
High-Density OBServations (HDOBS): Averaged into 30-s data points

Advantage:

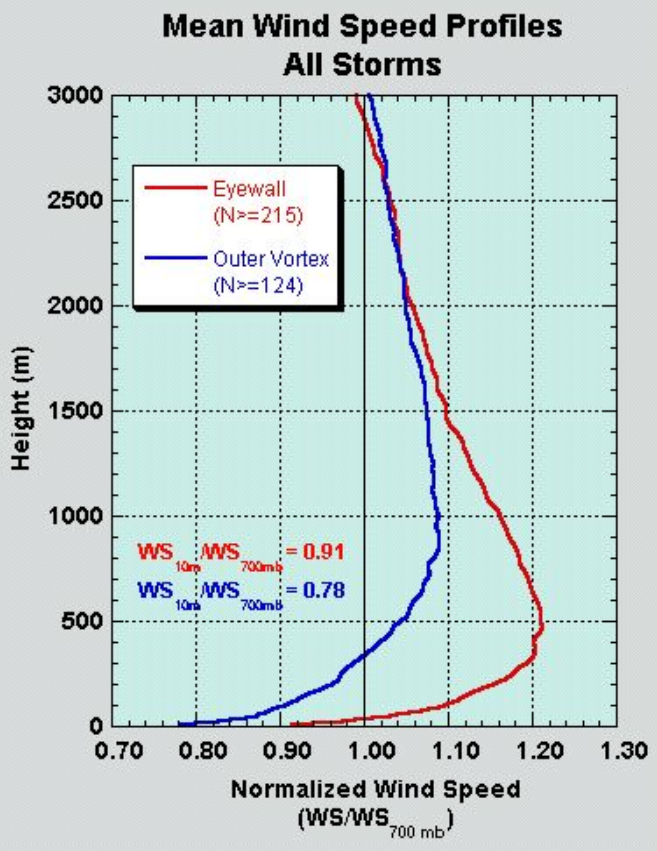
- Accurate, frequent measurements

Disadvantage:

- Representativeness (one level)
- Sensor wetting



Flight-level data

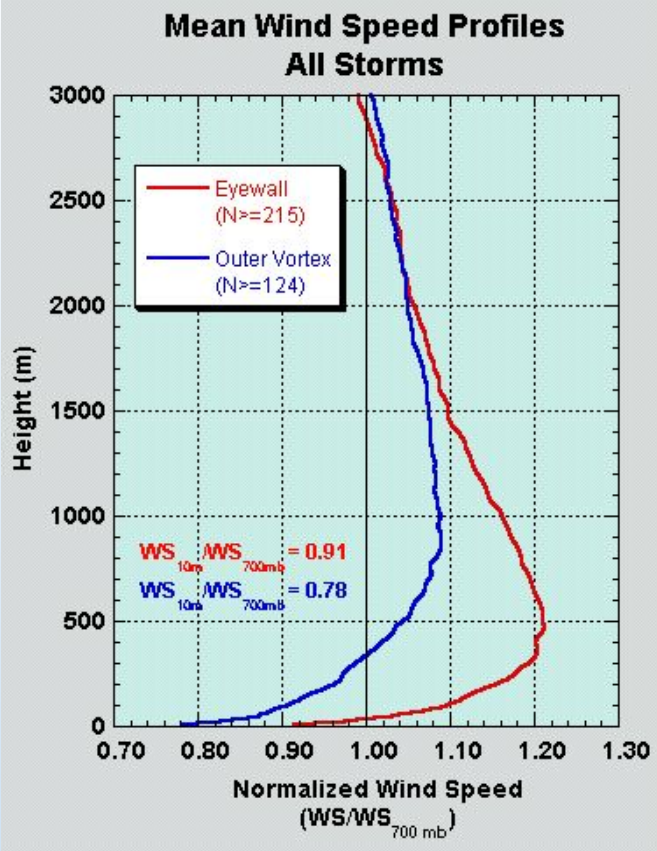


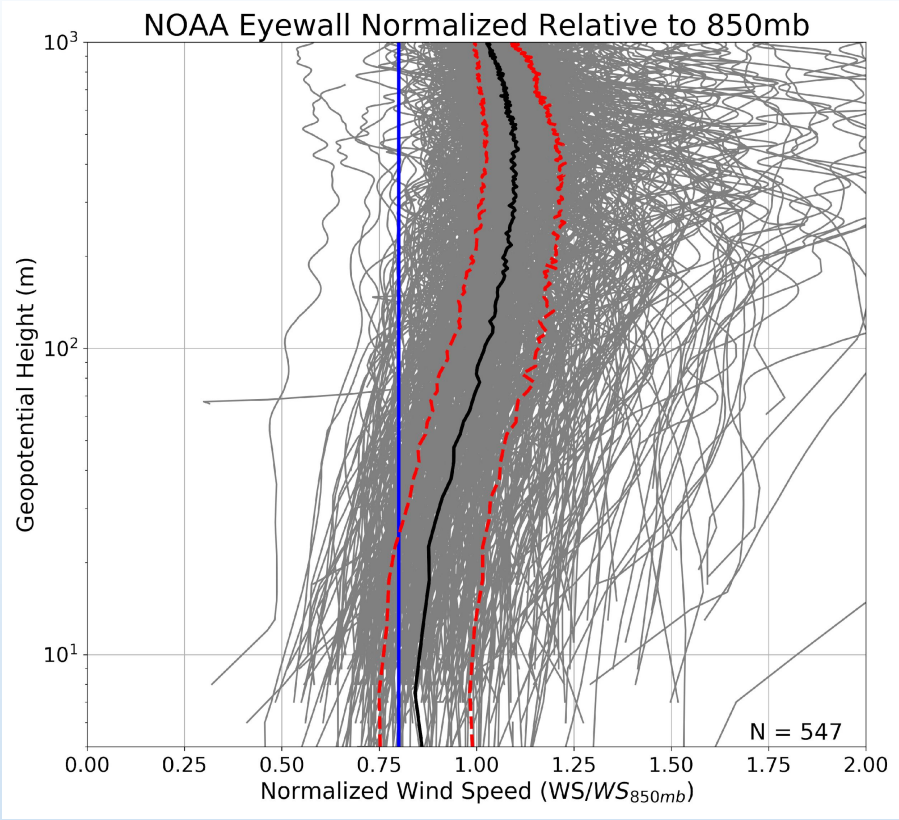
- Composite profiles were constructed using dropsondes.
- Adjust winds from one level/layer to the surface.

Flight level	Eyewall	Outer vortex (convection)	Outer vortex (not in convection)
700 hPa	0.90	0.85	0.80
850 hPa	0.80	0.80	0.75
925 hPa	0.75	0.75	0.75
1000 ft (305 m)	0.80	0.80	0.80

Franklin et al. 2003

Flight-level Reductions

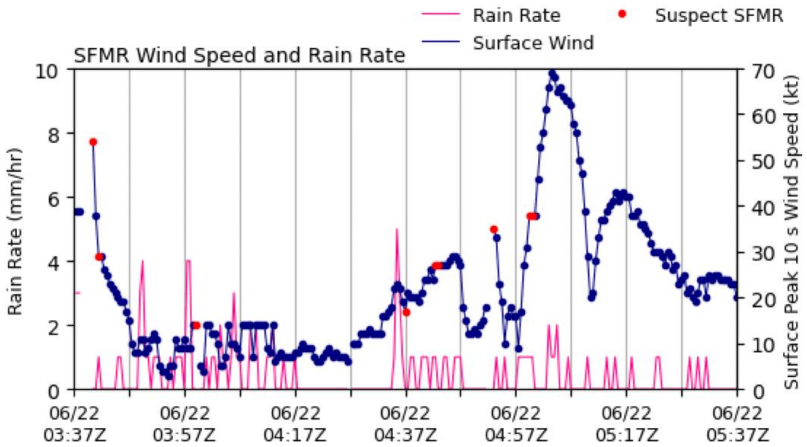




Courtesy of H. Holbach

Your supervisor showed you the following post about Tropical Storm Bret. Would you designate Bret to be a Category 1 Hurricane?

An SFMR value of 70 kts was detected in Tropical Storm #Bret! Pressure is now down to 996 mb! This is either a 70 MPH tropical storm or a Category 1 Hurricane right now!



1:47 AM · 6/22/23 From Earth · **659** Views

Your supervisor showed you the following post about Tropical Storm Bret. Would you designate Bret to be a Category 1 Hurricane? Select the best answer.

0

No, because it is better to wait and see the NHC determination on the next advisory. 0%

Yes, because SFMR is an instrument approved for operational use. 0%

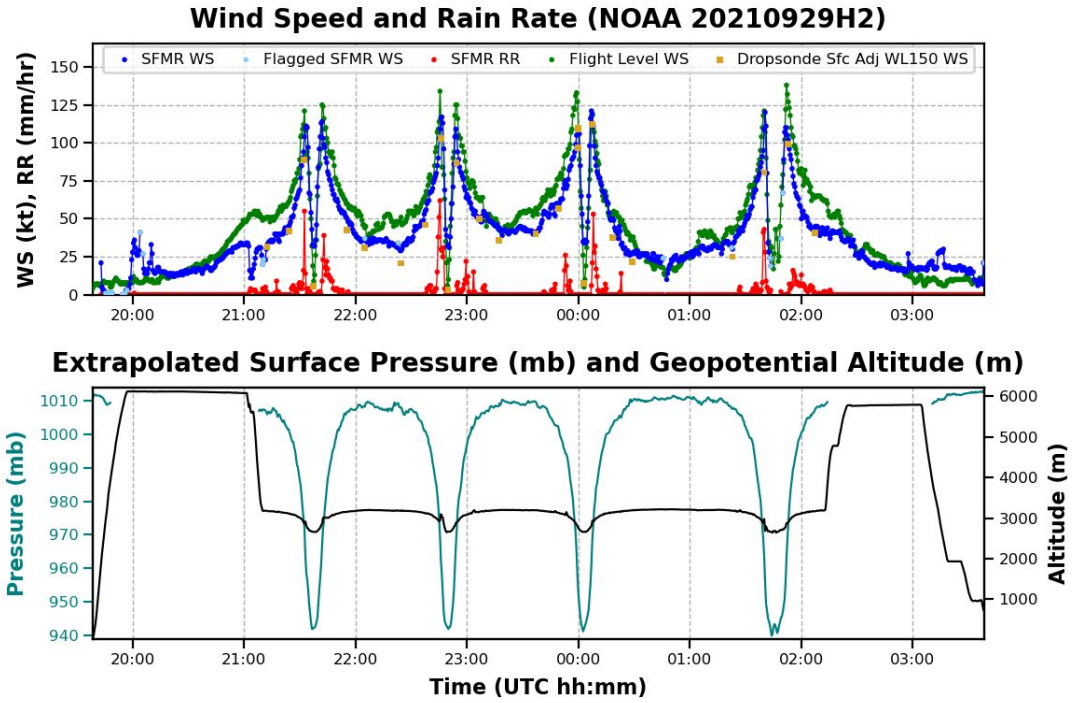
Possibly, after reviewing additional information that corroborates the pressure and wind speeds.

Poll Question 3: Feedback

Tropical Storm Bret Discussion Number 12
NWS National Hurricane Center Miami FL AL032023
500 AM AST Thu Jun 22 2023

Bret threw some interesting data at us during the couple of hours after the release of the previous advisory. On the last pass of the Air Force Reserve Hurricane Hunter aircraft through Bret's center, the plane measured SFMR winds as high as 69 kt and a dropsonde surface pressure of 996 mb with 31 kt of wind. Significant mid-level westerly shear is still affecting the system, and a 0539 UTC AMSR2 microwave pass revealed a well-defined mid-level eye feature displaced about a degree to the east of Bret's low-level center. **It appears that the strong SFMR winds were measured beneath the strong convection in the western mid-level eyewall feature, so it's possible that they were transient and convectively driven**. That said, Bret's initial intensity was raised to 60 kt on the 2 am intermediate advisory out of an abundance of caution, and that remains the current estimate. Another reconnaissance aircraft is scheduled to investigate Bret in a few hours and will hopefully confirm whether or not the storm is still producing winds that strong.

Stepped Frequency Microwave Radiometer

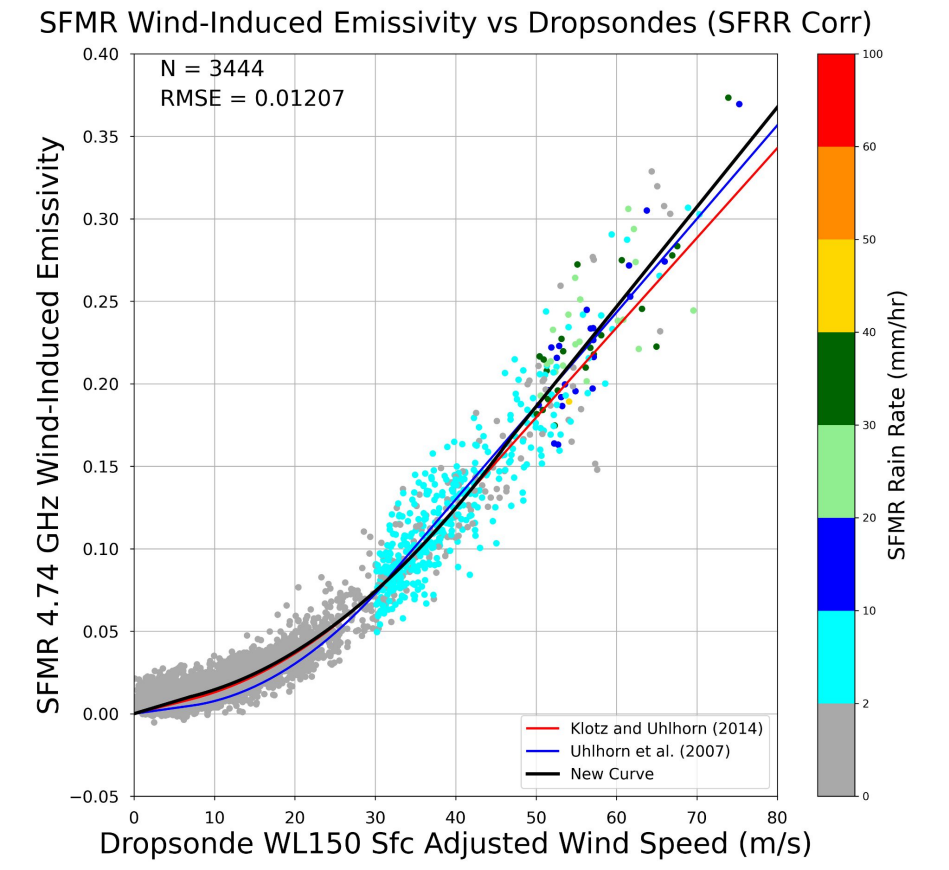


SFMR measures C-band microwave emission in 6 frequencies from the sea surface. The measured microwave emission is a function of (among other things) the surface wind speed and the rain rate.

SFMR Weaknesses

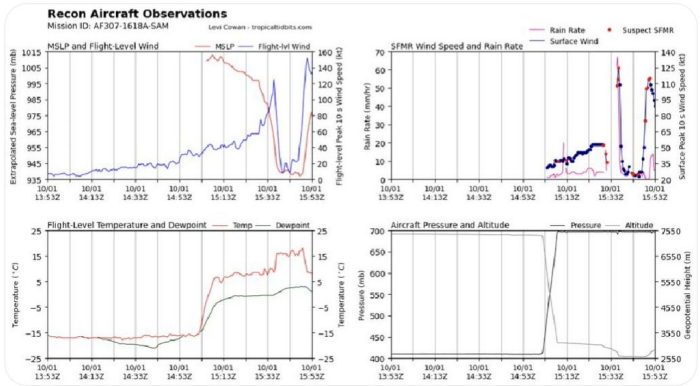
- Shoaling – breaking waves in areas of shallow water (< 30 m) can artificially increase the SFMR winds.
- At lower wind speeds (<30 kt)
- When aircraft turns (or in turbulence)
- Potential issue at higher wind speed. Additional research and a new algorithm are needed to correct

Courtesy of H. Holbach



Based on this recon data, what do you expect the intensity of Sam to be on the next advisory?

Recon has found some stronger winds in hurricane #Sam's northeast side, 152 knot flight level winds at 700mb does support 135 knot (155mph) winds at the surface which is just below category 5 strength. Very impressive and we will see if they find anything stronger. #wx #tropics



9:59 AM · 01 Oct 21

Based on this recon data, what do you expect the intensity of Sam to be on the next advisory? Select the best answer.

0

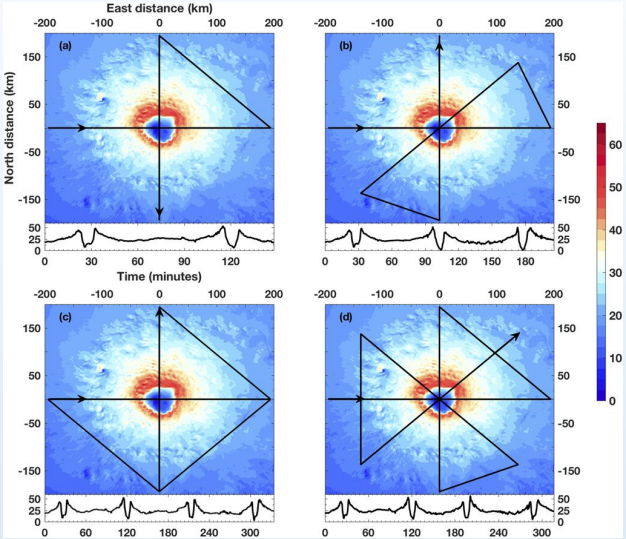
Extrapolation of flight level winds is a useful way to determine storm intensity. The storm could reach category 5.	0%
More information from other instruments is necessary before making a definitive intensity estimate.	0%
More information from other instruments will be helpful but uncertainty about the intensity may still remain.	

Poll Question 2: Feedback

Sam remains a powerful hurricane. The eye is still very distinct and there are several mesovorticies evident in satellite imagery.

In addition, microwave images show a closed and symmetric eyewall. Data from the Air Force Hurricane Hunters indicate that Sam has been maintaining its category 4 intensity. The aircraft measured peak flight-level winds at 700 mb of 152 kt, which corresponds to a 135-140 kt surface wind. However, the peak SFMR winds are around 115 kt. Dropsonde data from the aircraft show a sharp decrease in winds around the 925 mb level, **which could mean that the strongest winds are not reaching the surface**. The minimum pressure in the eye remains very low though at 937 mb. Based on all of this data, the initial intensity is held at 130 kt, but there is some uncertainty in that estimate.

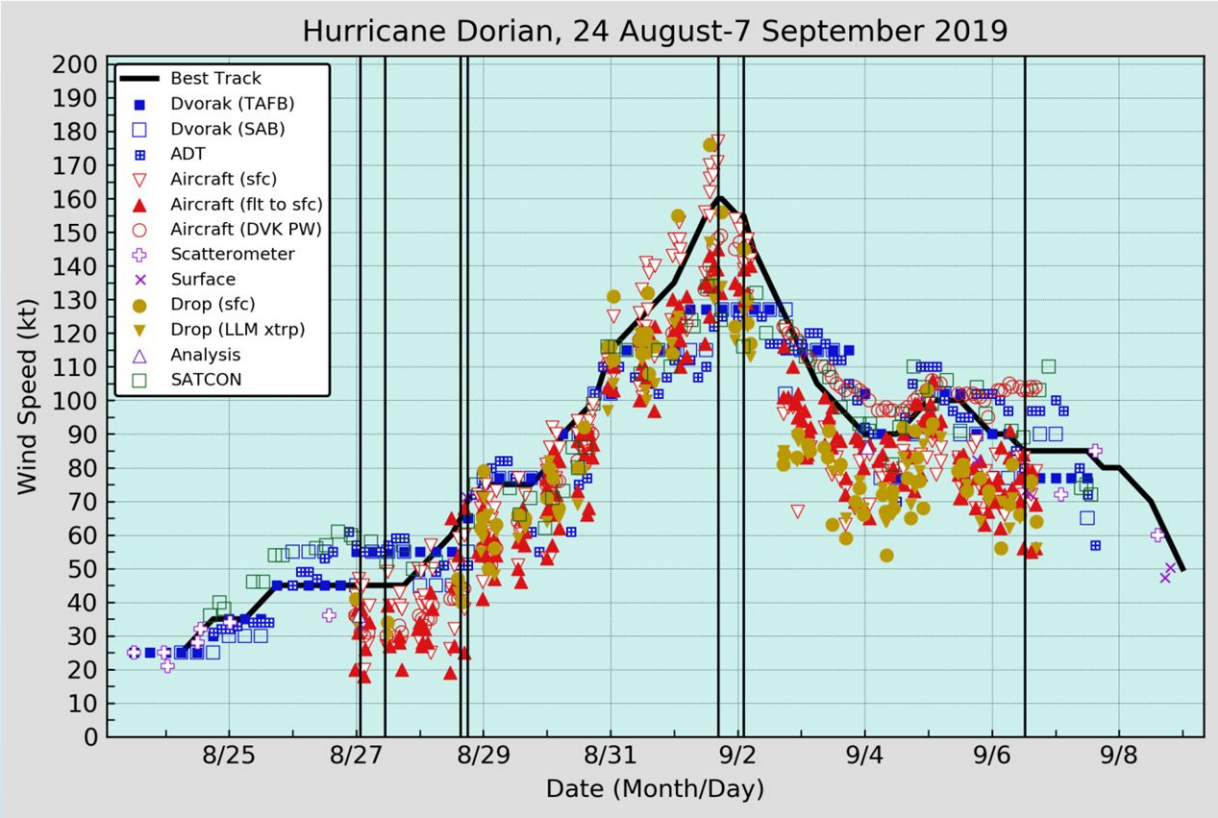
Undersampling the storm



- Klotz and Nolan (2019) look at the likelihood an aircraft would sample a peak wind given
  - TC strength
  - Flight pattern
- Provided guidance (table below) on possible inflation factors to account for undersampling.

Size/category	Tropical storm	Categories 1–2	Categories 3–5
Small RMW < 15 n mi	10%, 14%, 10%, 9%	5%, 3%, 0%, 1%	2%, 1%, 0%, 0%
Medium 15 < RMW < 30 n mi	15%, 16%, 14%, 12%	9%, 9%, 8%, 8%	5%, 4%, 4%, 4%
Large RMW > 30 n mi	19%, 18%, 17%, 16%	11%, 10%, 9%, 9%	8%, 7%, 6%, 6%

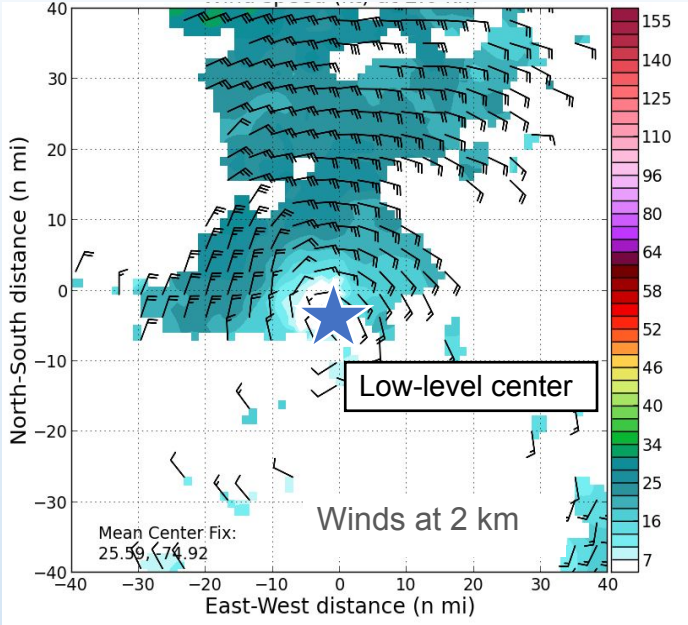
Blending Intensity Estimates

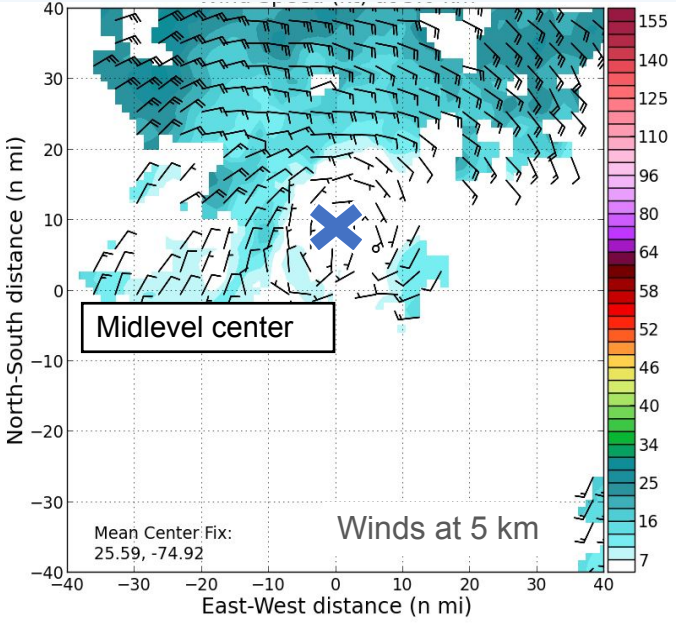


NHC Tropical Cyclone Report (Avila et al. 2020)

Use of Tail Doppler Radar

Real-time airborne radar observations of Humberto (2019)



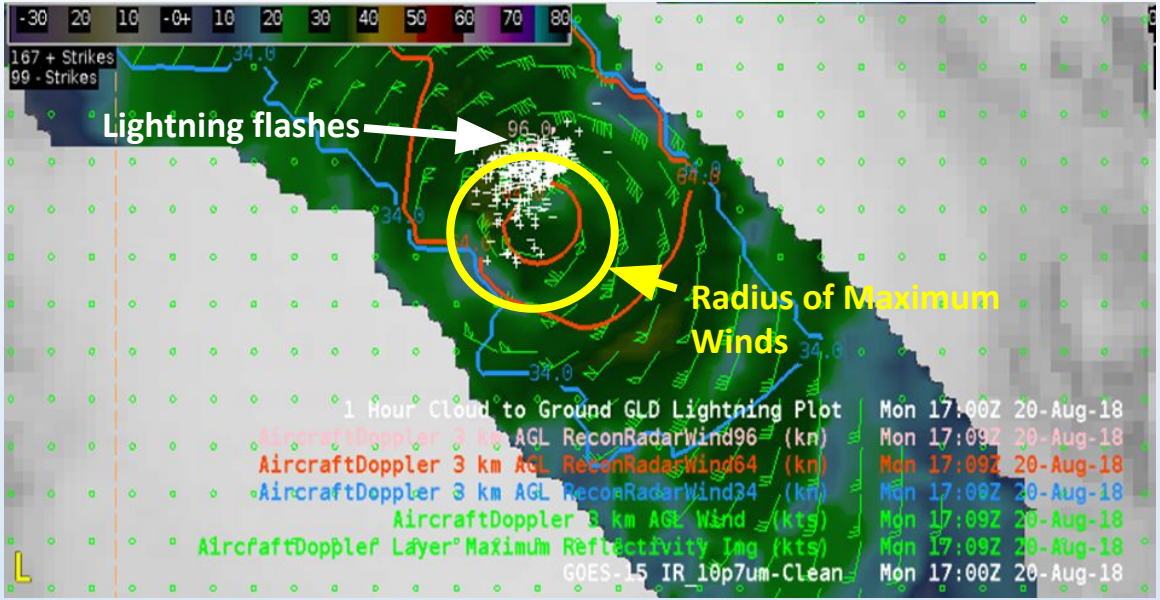


NHC Humberto Discussion, 2 h later:

"The storm is still feeling some effects of **southwesterly shear and drier air**, which is causing…**strong tilt in the aircraft data**… conditions are expected to gradually become more conducive for strengthening "

Use of Tail Doppler Radar

Real-time NHC display of radar winds and satellite GLM-detected lightning flashes in Hurricane Lane (2018)



- Lightning concentrated within RMW
- Intensified 15 kt to near Category 5 in next 12 hours

Closing Thoughts

- Aircraft observations have limitations **complicating** interpretation.
- Specialists attempts to intelligently ***blend*** data that recognizes the strengths and weaknesses of each data source.
- NHC's analyses of TC intensity and size have considerable error.
  - Intensity only good to within **~10%** (e.g., 100 kt +/- 10 kt)
  - TS wind radii to about **~25%** (e.g., 120 nm +/- 30 nm)
  - HU wind radii to about **~40%** (e.g., 25 nm +/- 10 nm)
- Observations can also influence short term forecasts and public messaging.

Based on what you have learned from this session, what would you tell your colleagues about using social media posts in their work? Select the best answer.

0

Social media is a good place to get the latest information from aircraft observations and suggestions for possible decisions. 0%

Disregard social media posts about tropical cyclone intensity unless they come from NHC. 0%

Poll Questions

Exercise: Determine TC intensity

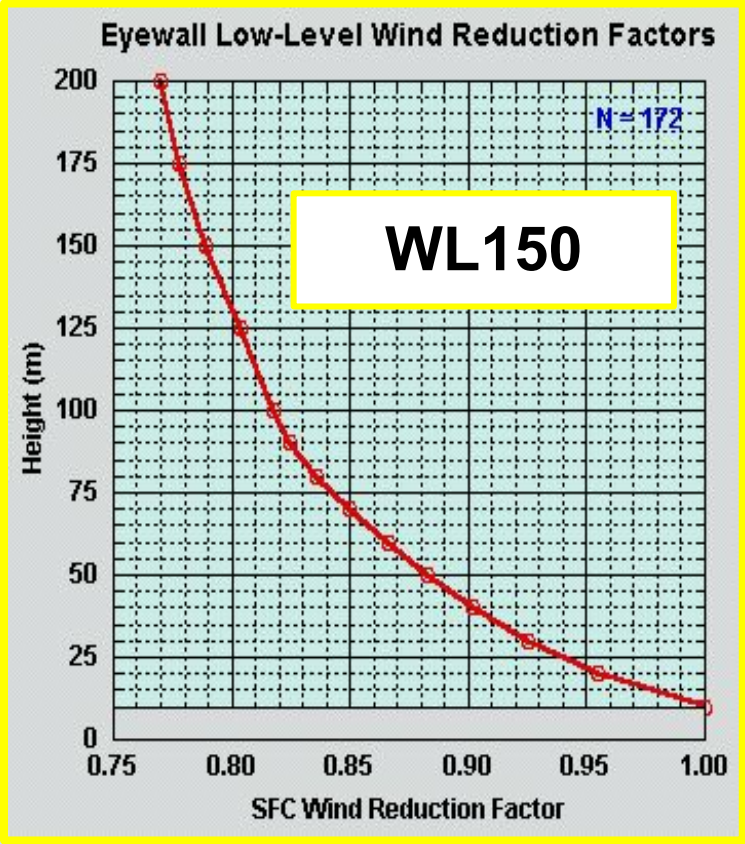
Given the TEMPDROP messages and Vortex Data Messages (VDMs), what is the intensity of this storm?

Round to the nearest 5 kt*

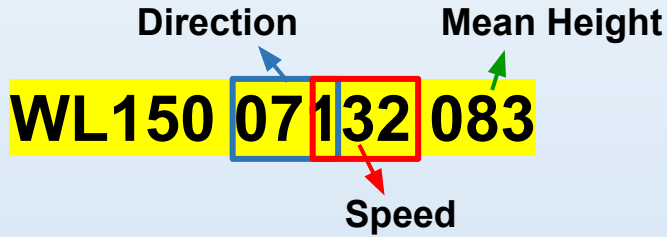
Exercise: Determine TC intensity

A. Date and time of fix
B. Lat/Lon of center position
C. Minimum height at standard pressure level
D. Minimum sea-level pressure
E. Surface wind from center dropwindsonde
F. Eye characteristic
G. Eye shape/orientation/diameter
H. Maximum inbound observed surface wind
I. Bearing, range, and time of (H).
J. Maximum inbound observed FL wind
K. Bearing, range, and time of (J).
L. Maximum outbound observed surface wind
M. Bearing, range, and time of (L).
N. Maximum outbound observed FL wind.
O. Bearing, range, and time of (N).
P. Max FL T/PA observed outside of eye.
Q. Max FL T/PA observed inside the eye.
R. TD/SST observed inside the eye.
S. Fix determined by…
T. Fix accuracy (navigational, meteorological)
U. AC ID, mission ID, storm name, ob number
Remarks, including max FL wind from most recent passes through each octant

Exercise: Determine TC intensity



Flight level	Eyewall	Outer vortex (convection)	Outer vortex (not in convection)
700 hPa	0.90	0.85	0.80
850 hPa	0.80	0.80	0.75
925 hPa	0.75	0.75	0.75
1000 ft (305 m)	0.80	0.80	0.80



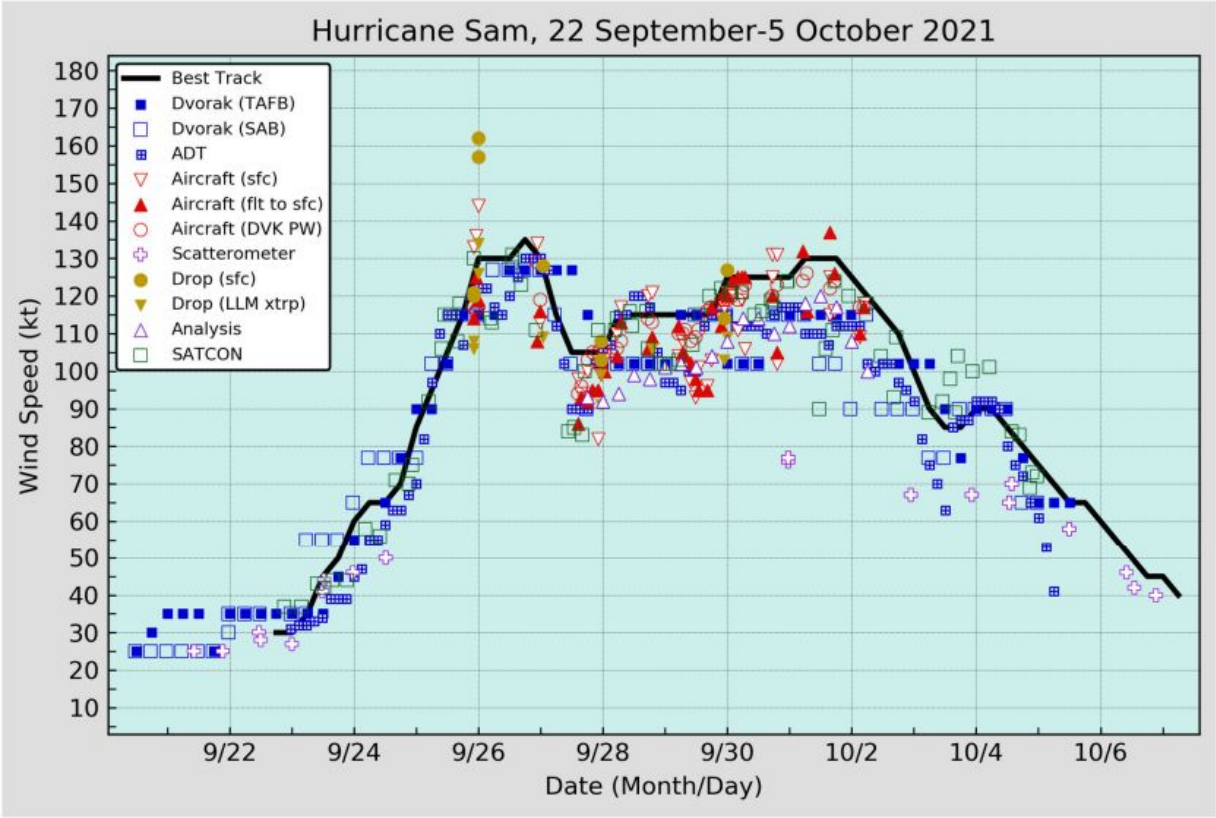
0.80 * MBL = SFC

Exercise: Determine TC intensity

What was your answer?

Which observation did you trust the most?

Hurricane Sam (2021)

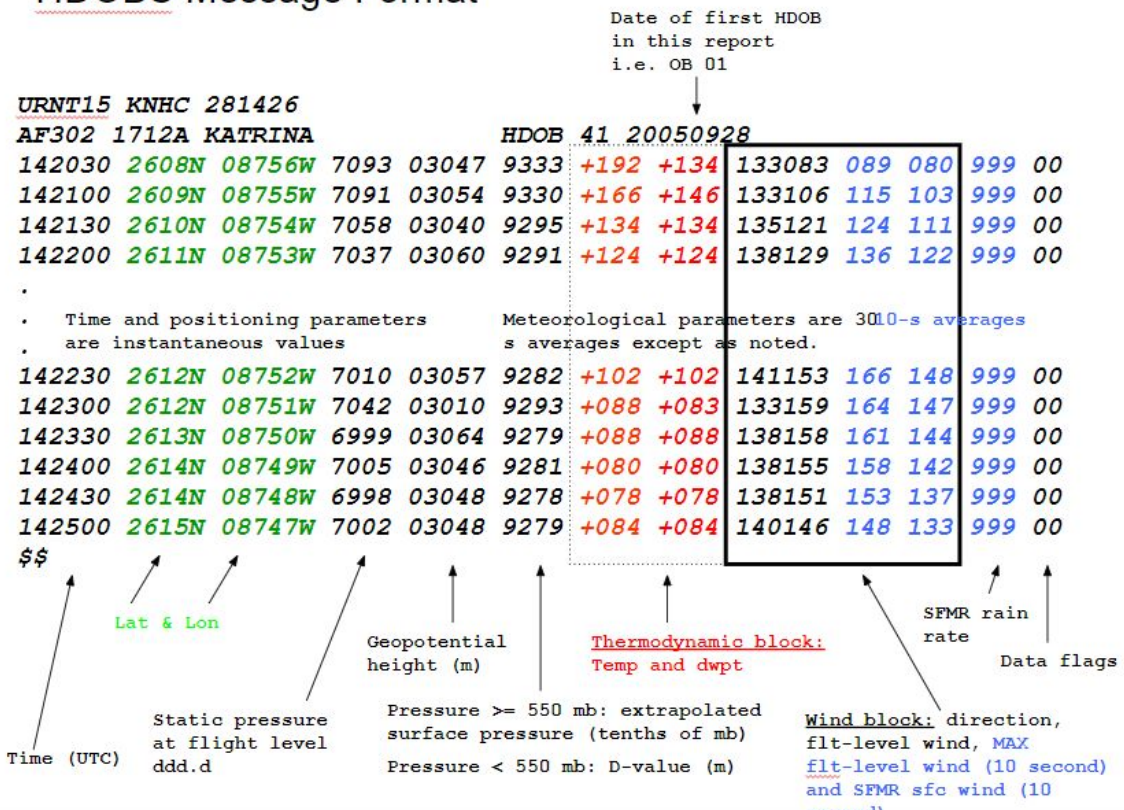


Dropsondes: TEMPDROP

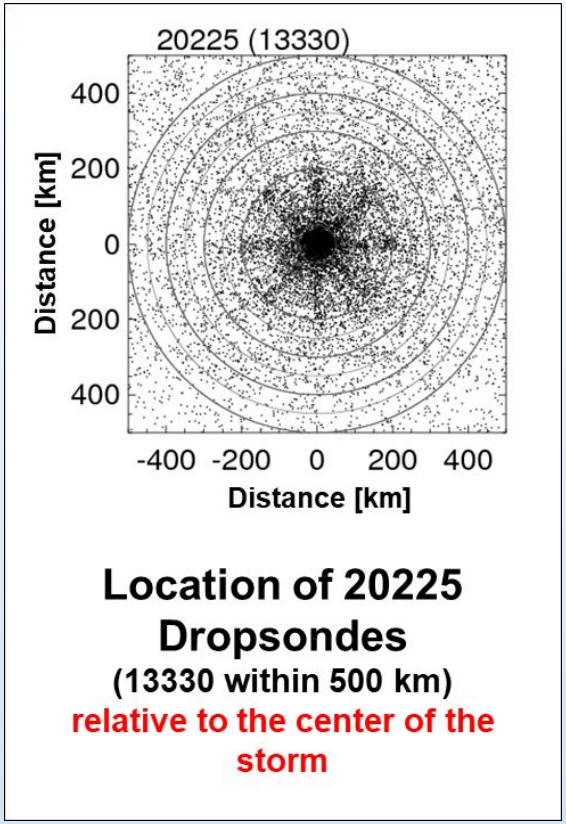
003
UZNT13 KWBC 300018
XXAA 80007 99205 70579 07807 99957 24410 07128 00884 ///// /////
92302 22404 09140 85038 19400 11131 70699 14231 13603 88999 77999
31313 09608 82359
61616 NOAA2 1218A SAM OB 19
62626 EYEWALL 045 MBL WND 08639 AEV 30406 DLM WND 11117 956695 WL
150 07132 083 REL 2049N05789W 235953 SPG 2055N05804W 000448 =
XXBB 80008 99205 70579 07807 00957 24410 11850 19400 22818 19202
33800 18203 44794 18027 55737 14408 66707 13809 77695 14242
21212 00957 07128 11952 07133 22943 07633 33940 06628 44931 08141
55927 08632 66920 09653 77912 09659 88895 10147 99883 10651 11873
10638 22866 10635 33858 10637 44850 11131 55823 11613 66695 13601
31313 09608 82359
61616 NOAA2 1218A SAM OB 19
62626 EYEWALL 045 MBL WND 08639 AEV 30406 DLM WND 11117 956695 WL
150 07132 083 REL 2049N05789W 235953 SPG 2055N05804W 000448 =

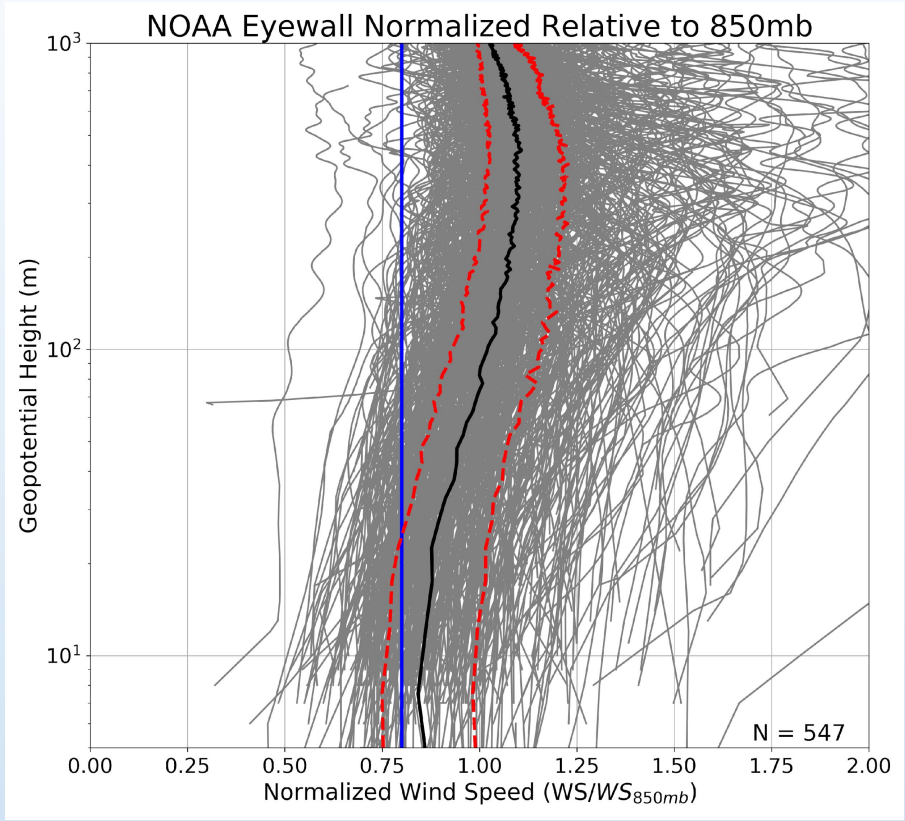
High-Density Observations (HDOBs)

HDOBS Message Format



Flight-level Reductions





Vortex Data Messages

VORTEX DATA MESSAGE AL182021
A. 29/22:49:29Z
B. 20.23 deg N 057.91 deg W
C. 700 MB 2602 m
D. 943 mb
E. 130 deg 10 kt
F. CLOSED
G. C26
H. 117 kt
I. 260 deg 14 nm 22:46:11Z
J. 001 deg 134 kt
K. 262 deg 17 nm 22:45:31Z
L. 109 kt
M. 086 deg 18 nm 22:53:50Z
N. 179 deg 125 kt
O. 086 deg 19 nm 22:54:09Z
P. 9 C / 3066 m
Q. 16 C / 3072 m
R. 9 C / NA
S. 1234 / 7
T. 0.01 / 1 nm
U. NOAA2 1218A SAM OB 15
MAX FL WIND 134 KT 262 / 17 NM 22:45:31Z
MAX FL TEMP 17 C 084 / 13 NM FROM FL CNTR

A. Date and time of fix
B. Lat/Lon of center position
C. Minimum height at standard pressure level
D. Minimum sea-level pressure
E. Surface wind from center dropwindsonde
F. Eye characteristic
G. Eye shape/orientation/diameter
H. Maximum inbound observed surface wind
I. Bearing, range, and time of (H).
J. Maximum inbound observed FL wind
K. Bearing, range, and time of (J).
L. Maximum outbound observed surface wind
M. Bearing, range, and time of (L).
N. Maximum outbound observed FL wind.
O. Bearing, range, and time of (N).
P. Max FL T/PA observed outside of eye.
Q. Max FL T/PA observed inside the eye.
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