



Analysis of Aircraft Reconnaissance Data

Dr. Lisa Bucci
Hurricane Specialist, NHC



Collecting Observations





Where does the data go?

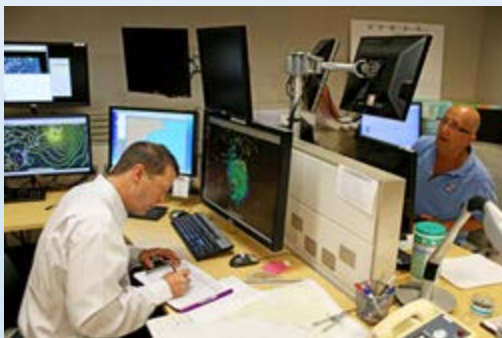
Hurricane Aircraft Data

Nowcast

Forecast

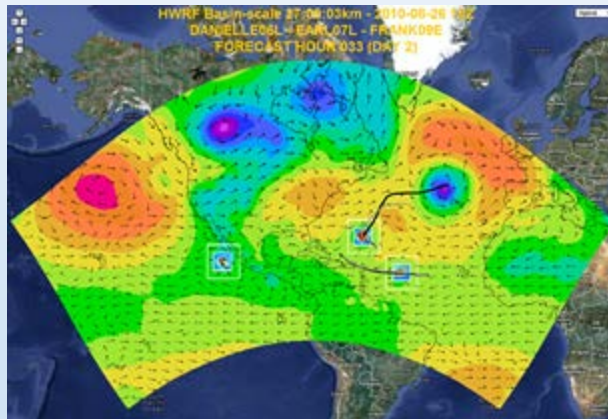
Research

Forecasters



National Weather Service
National Hurricane Center

Weather Models



National Weather Service
Environmental Modeling Center

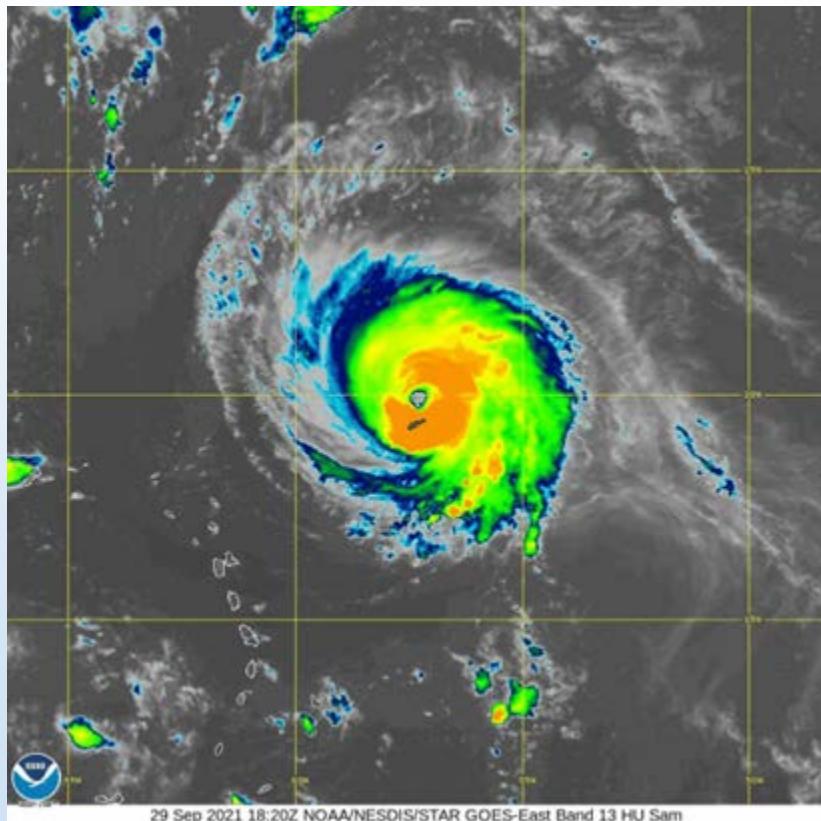
Scientists



Government, Academia,
International, Public



What does a specialist need to determine?



29 Sep 2021 18:20Z NOAA/NESDIS/STAR GOES-East Band 13 HU Sam

- 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



NOAA and the Air Force (53rd)



- Aircraft are *flying laboratories* and can be *research* or *operational*
- New instrumentation, non-standard flight patterns, more windows
- Scientists usually fly with aircraft (P-3)
- *Two P-3s and one G-IV*
- Aircraft are *operational*
 - Specifically for **National Hurricane Center**
- Equipped with fewer instruments
- No scientists onboard
- *Ten C-130s*



NOAA and the Air Force (53rd)



- Flight-level probes
- Dropsondes
- Stepped Frequency Microwave Radiometer (SFMR)
- Tail Doppler Radar
- Airborne EXpendable Bathythermograph (AXBT)
- *small Unmanned airborne systems (sUASs)*
- *Wide-Swath Radar Altimeter (WSRA)*
- *KaIA*
- *IWRAP*
- *LIDARs (Wind and Raman)*
- *W-band radar*

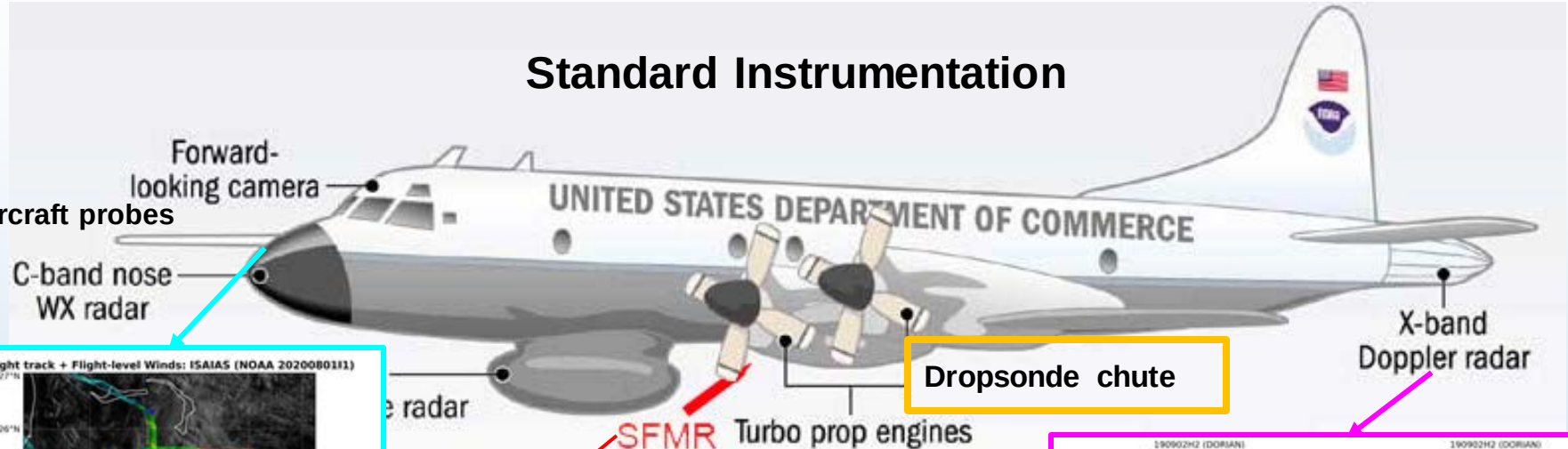
- Flight-level probes
- Dropsondes
- Stepped Frequency Microwave Radiometer (SFMR)
- Airborne EXpendable Bathythermograph (AXBT)

**Italics indicates instrument is not available every mission*

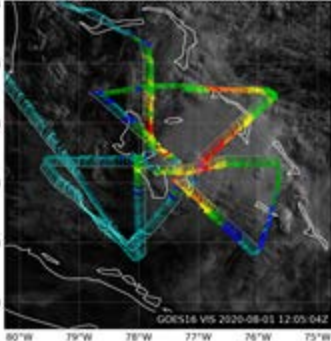


What instruments are flown?

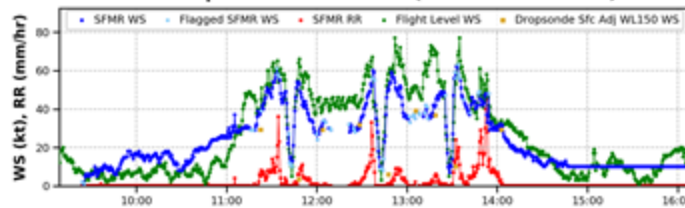
Standard Instrumentation



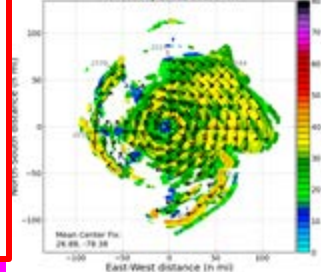
Flight track + Flight-level Winds: ISAIAS (NOAA 2020080111)



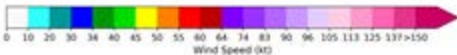
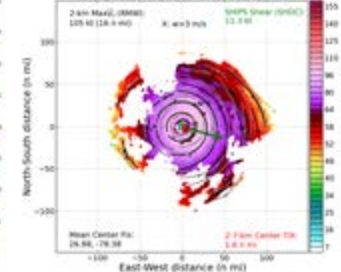
Wind Speed and Rain Rate (NOAA 2020072511)



190902H2 (DORIAN)
203800 to 244445 UTC
Reflectivity (dBZ) at 2.0 km

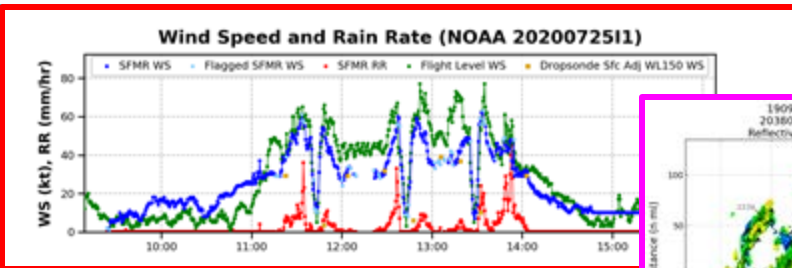
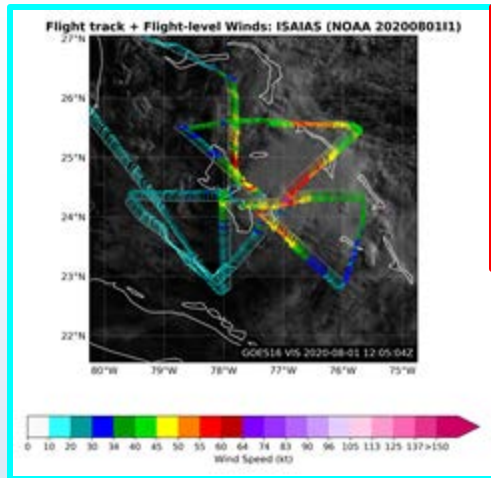


190902H2 (DORIAN)
203800 to 244445 UTC
WS (kt) at 2.0 km. Streamlines at 2.0, 1.0 km



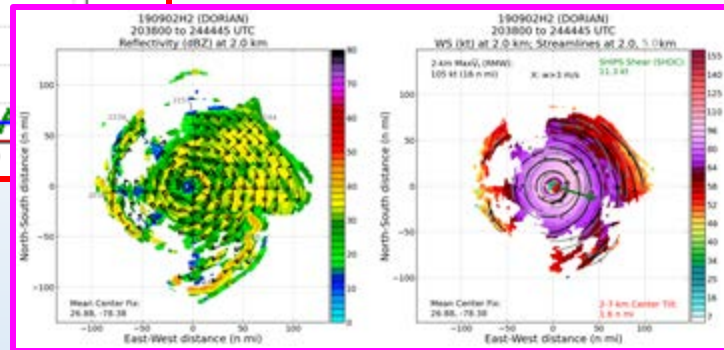


What are the instruments measuring?



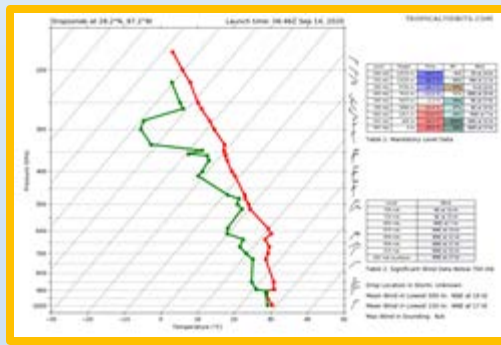
SFMR:

- 10 m Wind Speed
- Rain rate



Aircraft probes:

- Temperature
- Moisture
- Winds
- Pressure
- Altitude



Dropsondes:

- Temperature
- Moisture
- Winds
- Pressure

Tail Doppler Radar:

- Winds
- Reflectivity



Dropsondes

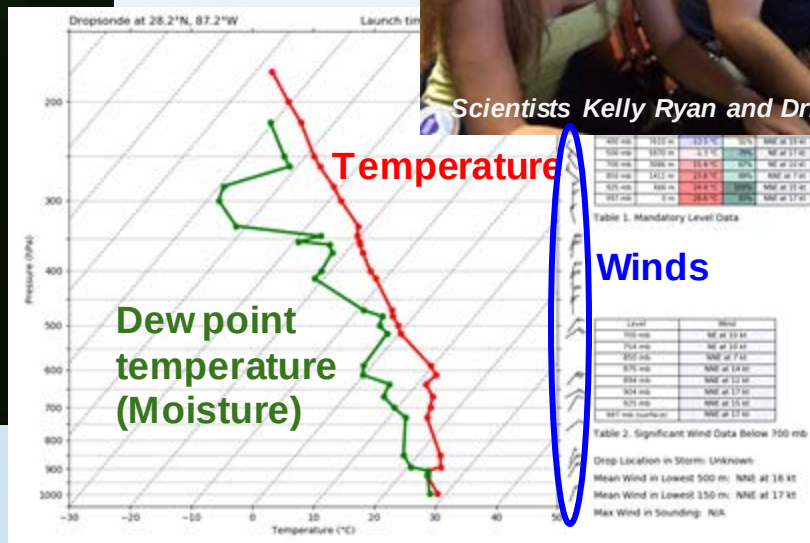


Mac rapidly releasing three dropsondes in the eyewall of Hurricane Sam (2021)

Credit: J. Rannenber

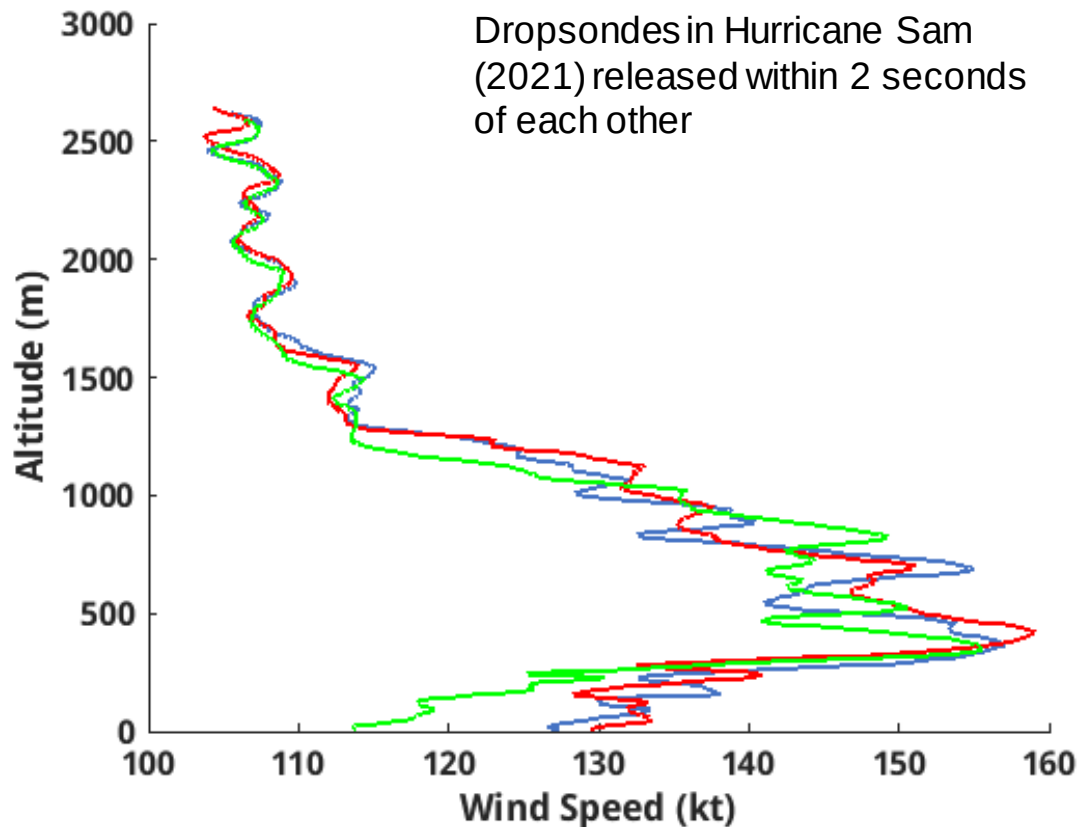


Scientists Kelly Ryan and Dr. Ghassan Alaka



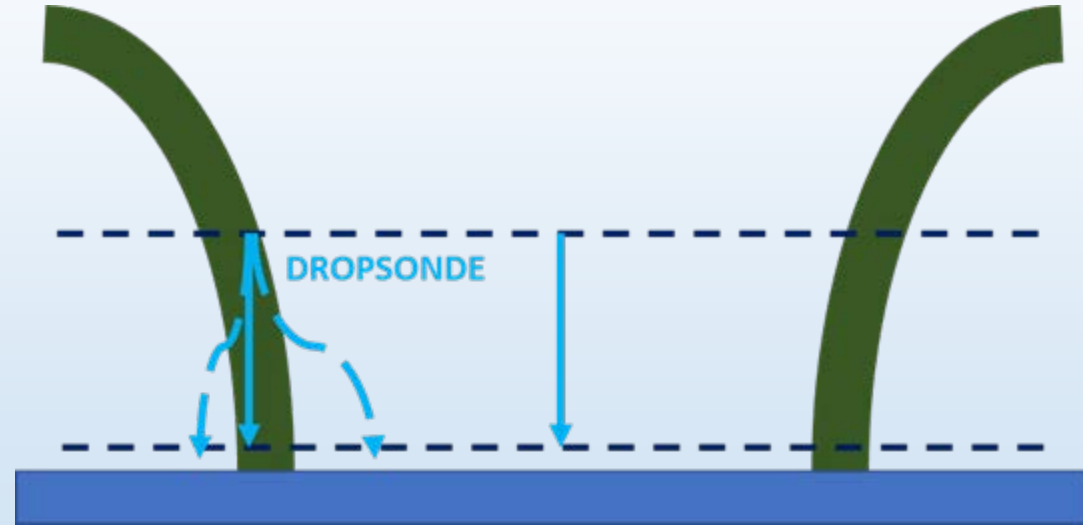
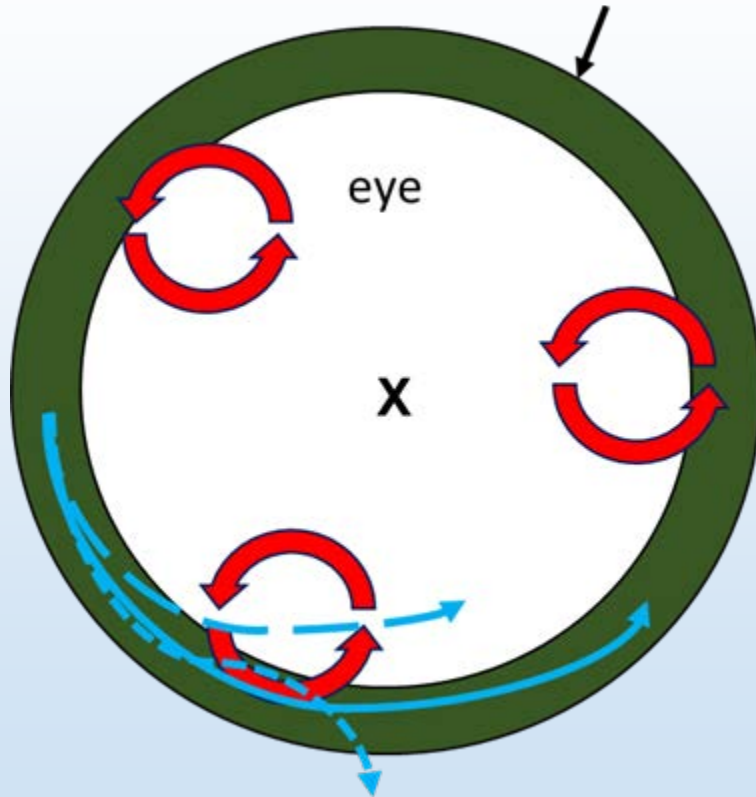


Dropsondes





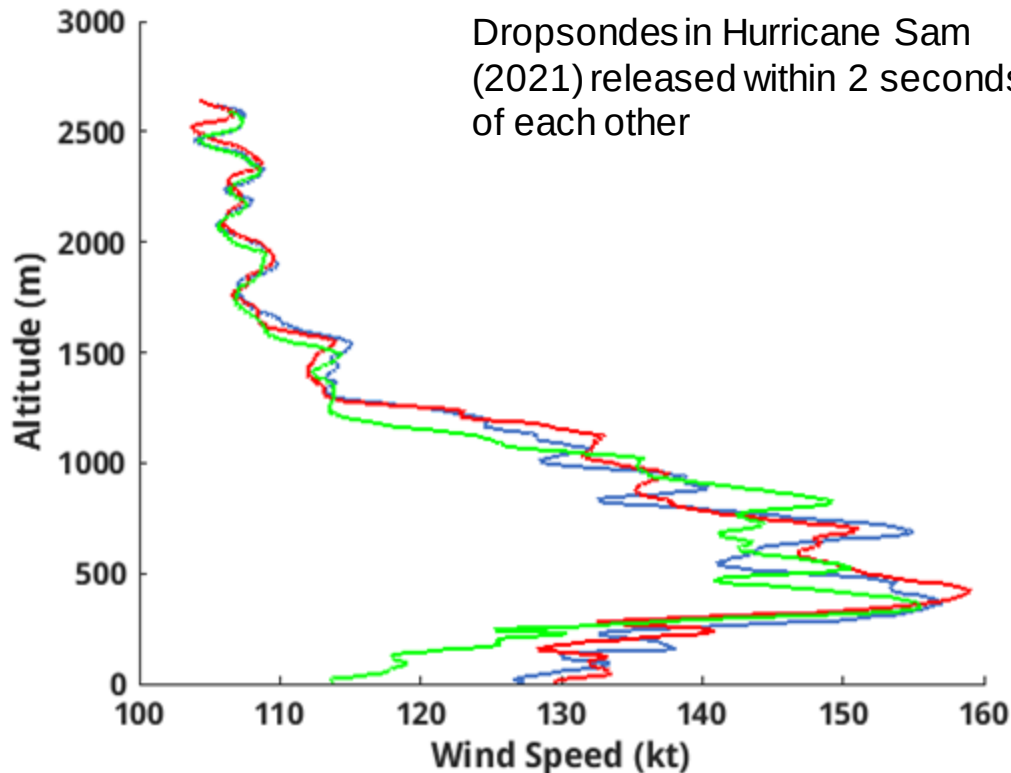
Dropsondes





Dropsondes

Dropsondes in Hurricane Sam
(2021) released within 2 seconds
of each other



Advantage:

- Accurate, frequent measurements in profile

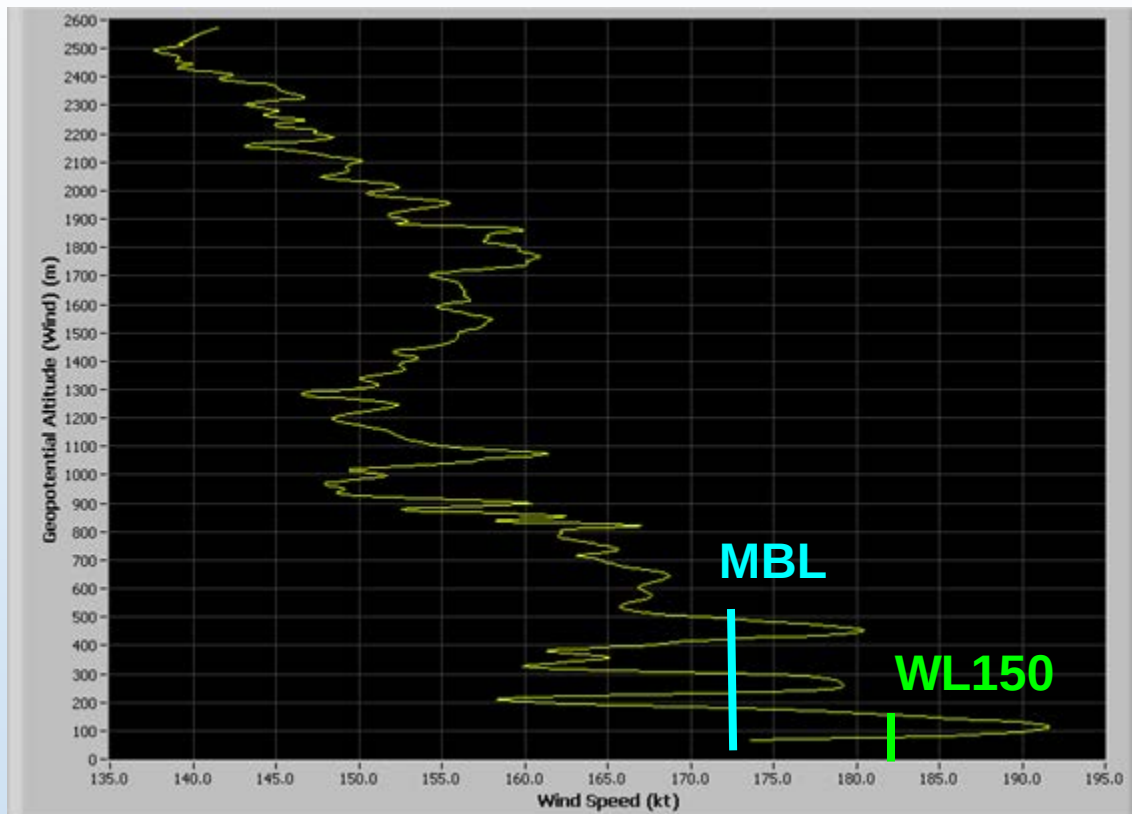
Disadvantage:

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



Dropsondes

- Surface winds are generally not 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





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 =



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**

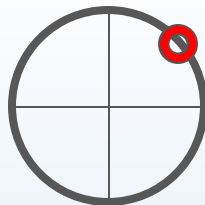
150 07132 083 REL 2049N05789W 235953 SPG 2055N05804W 000448 =



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

$$0.8 * 139 \text{ kt} = \mathbf{111.2 \text{ kt}}$$

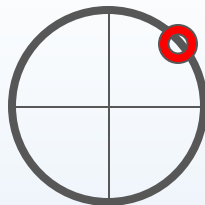
WL150 07132 083



Dropsondes: TEMPDROP

EYEWALL 045

Release location



MBL WND 08639

111.2 kt

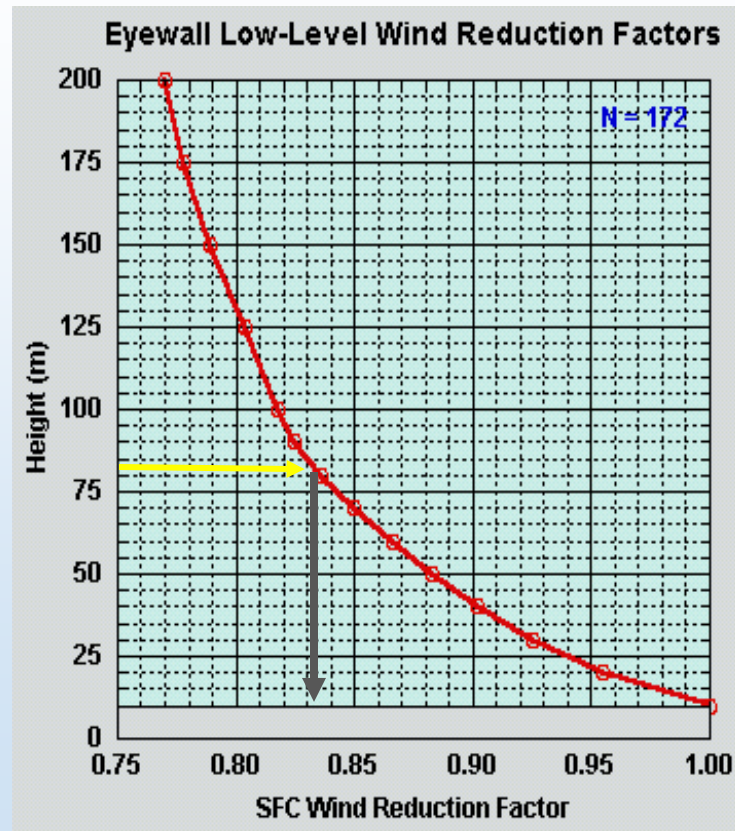
WL150 07132 083

Averaged winds 0–150 m

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

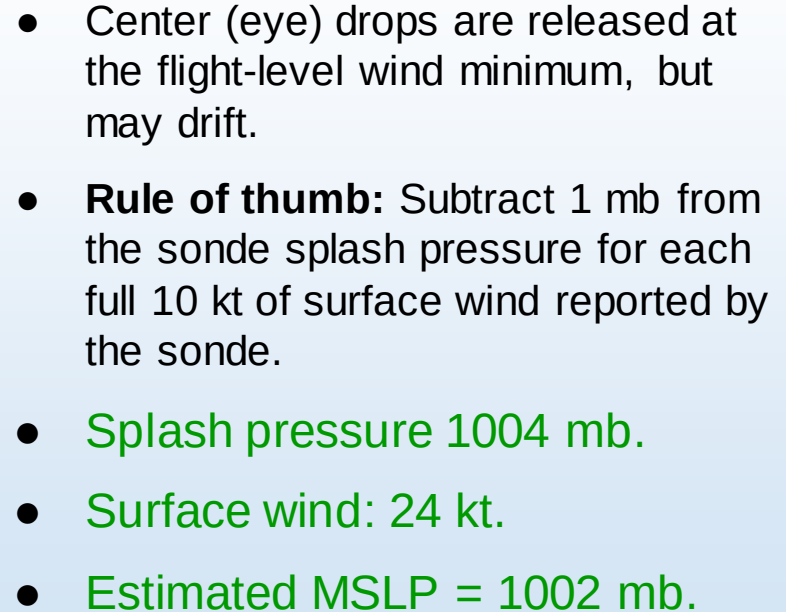
$0.83 * WL150 =$
Surface Wind
Estimate

$0.83 * 132 \text{ kt} =$
109.6 kt





Dropsondes: Minimum Pressure





Flight-level data

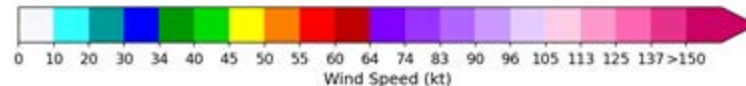
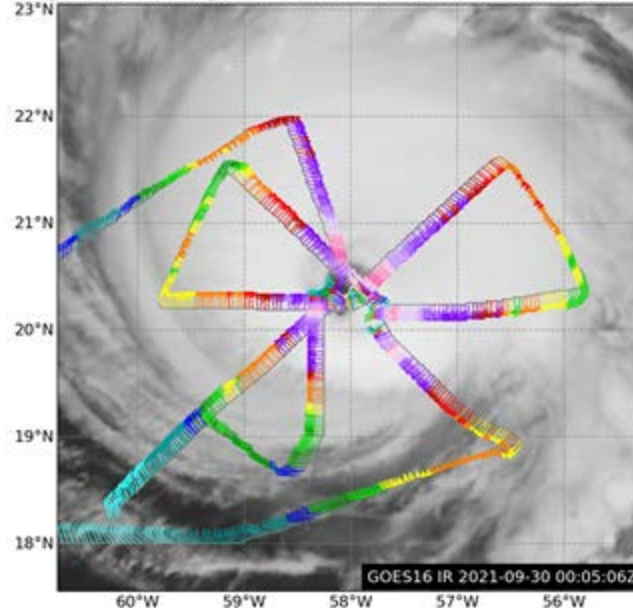
Advantage:

- Accurate, frequent measurements

Disadvantage:

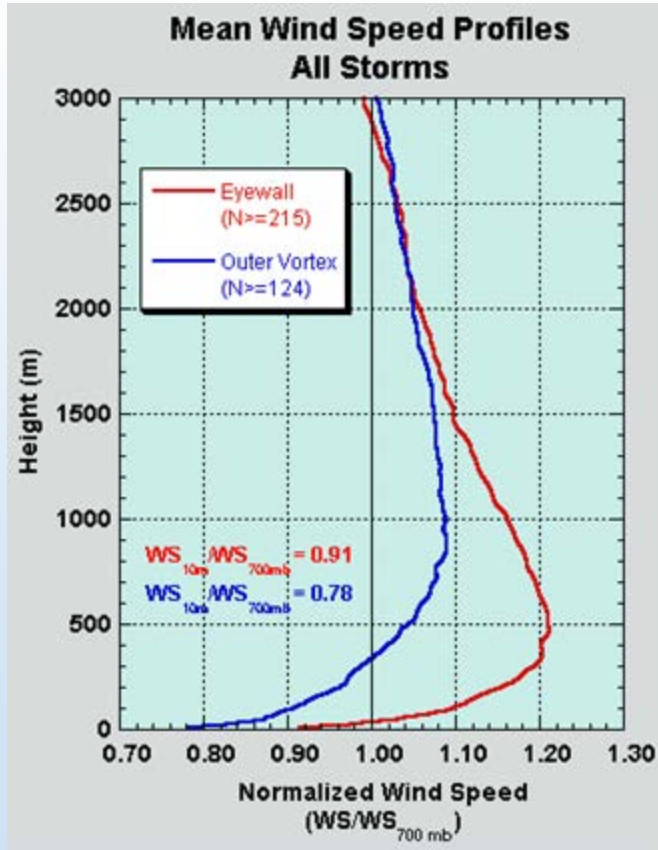
- Representativeness (one level)
- Sensor wetting

Flight track + Flight-level Winds: SAM (NOAA 20210929H2)





Flight-level data

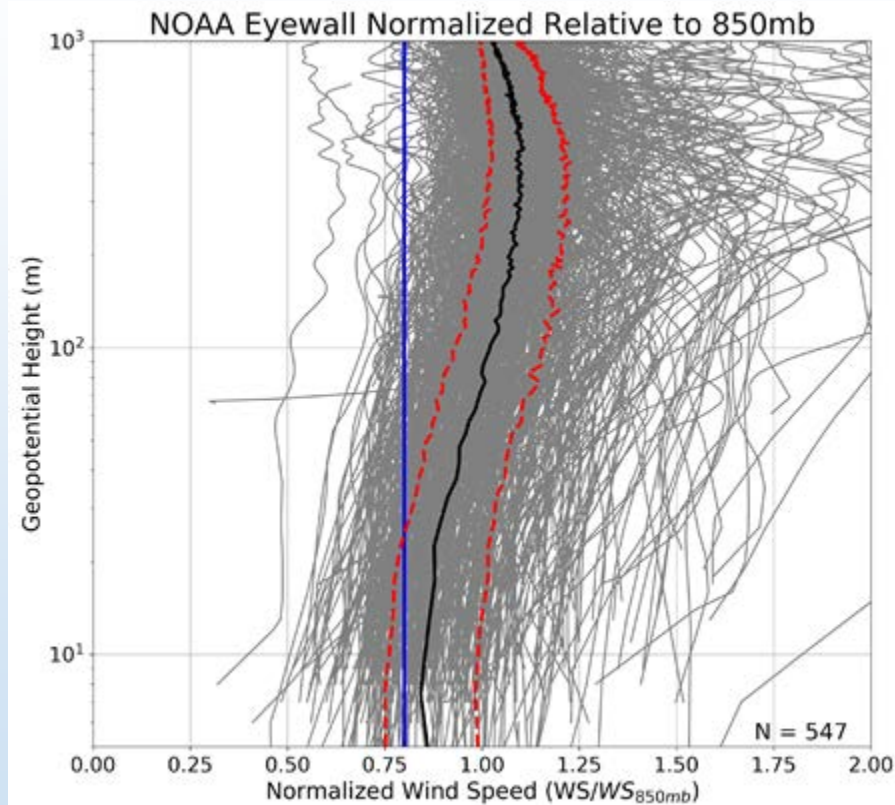
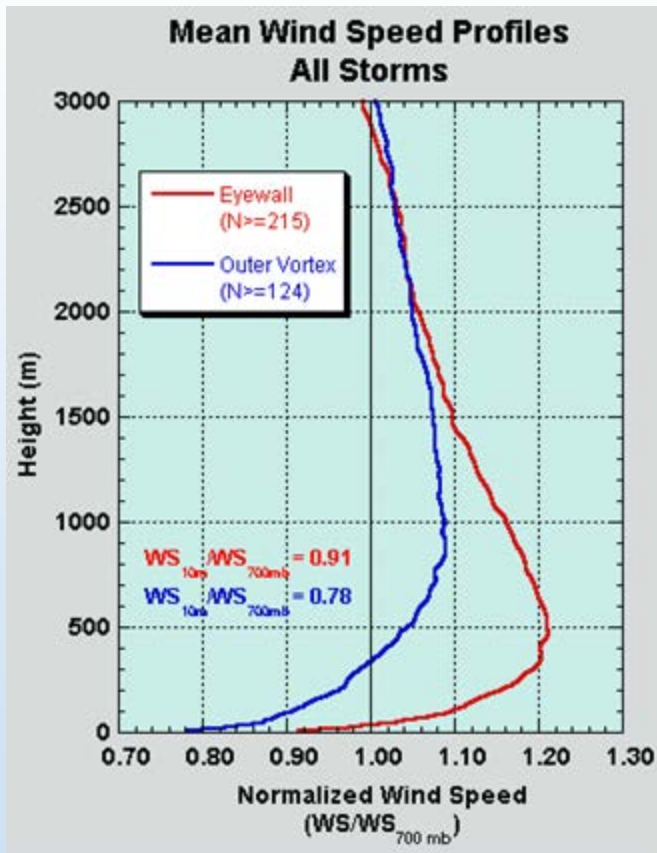


- Composite profiles were constructed using dropsondes.
- Adjust winds from one level/layer to the surface.

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

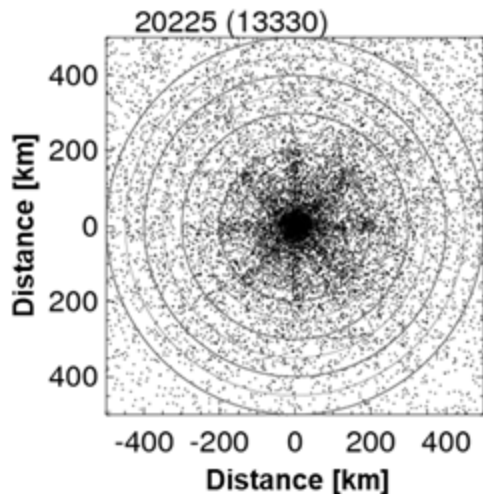


Flight-level Reductions

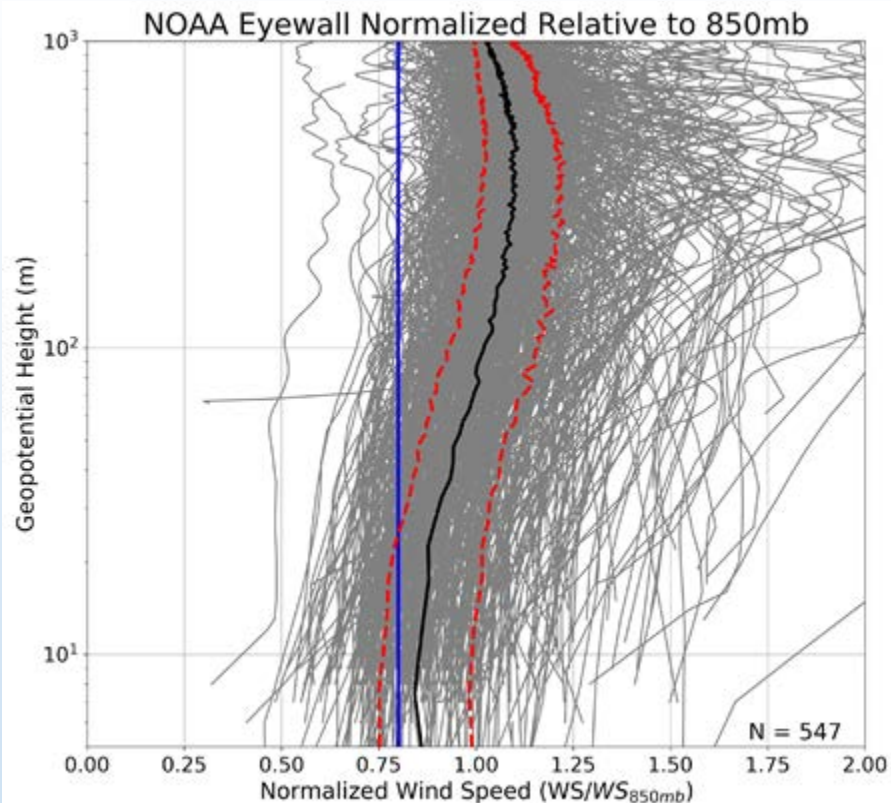




Flight-level Reductions



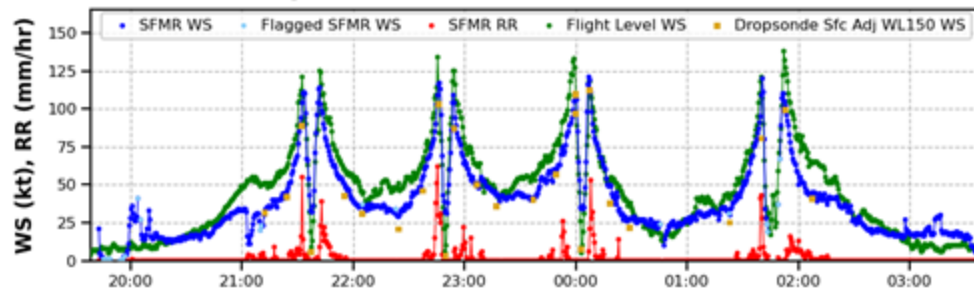
**Location of 20225
Dropsondes
(13330 within 500 km)
relative to the center of the
storm**



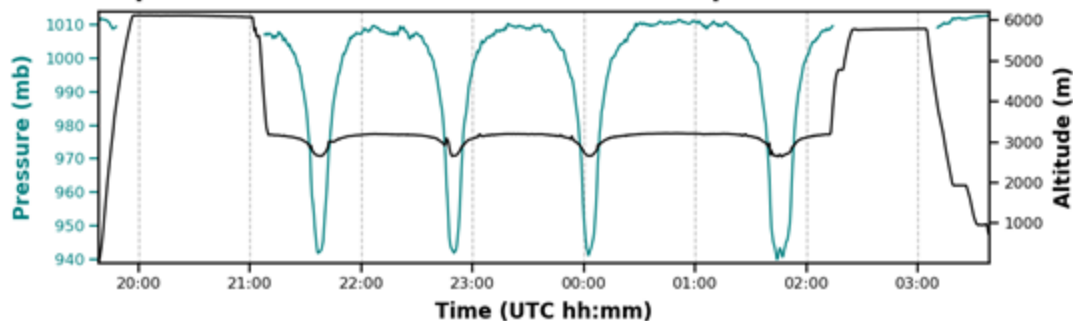


Stepped Frequency Microwave Radiometer

Wind Speed and Rain Rate (NOAA 20210929H2)



Extrapolated Surface Pressure (mb) and Geopotential Altitude (m)



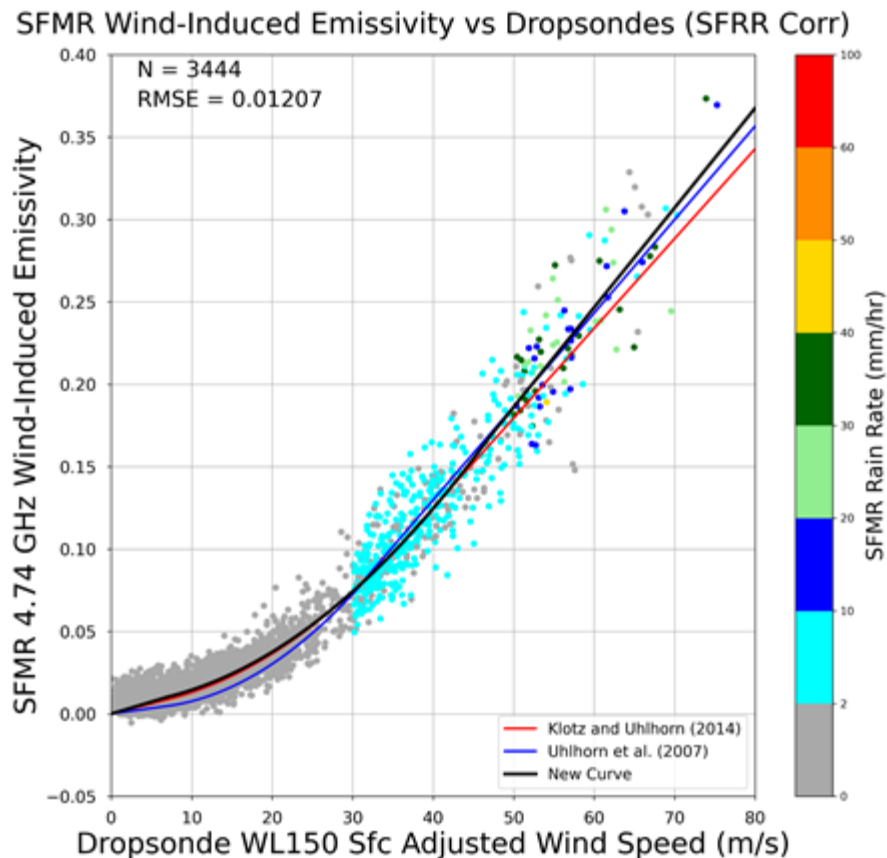
SFMR measures C-band microwave emission in 6 frequencies from foam on the sea surface. The measured microwave emission is a function of (among other things) the surface wind speed and the rain rate.



SFMR

- 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





High-Density Observations (HDOBs)

HDOBS Message Format

Date of first HDOBS
in this report
i.e. OB 01

↓

URNT15 KNHC 281426
AF302 1712A KATRINA HDOBS 41 20050928

142030	2608N	08756W	7093	03047	9333	+192	+134	133083	089	080	999	00
142100	2609N	08755W	7091	03054	9330	+166	+146	133106	115	103	999	00
142130	2610N	08754W	7058	03040	9295	+134	+134	135121	124	111	999	00
142200	2611N	08753W	7037	03060	9291	+124	+124	138129	136	122	999	00
.												
Time and positioning parameters are instantaneous values						Meteorological parameters are 30-s averages except as noted.						
142230	2612N	08752W	7010	03057	9282	+102	+102	141153	166	148	999	00
142300	2612N	08751W	7042	03010	9293	+088	+083	133159	164	147	999	00
142330	2613N	08750W	6999	03064	9279	+088	+088	138158	161	144	999	00
142400	2614N	08749W	7005	03046	9281	+080	+080	138155	158	142	999	00
142430	2614N	08748W	6998	03048	9278	+078	+078	138151	153	137	999	00
142500	2615N	08747W	7002	03048	9279	+084	+084	140146	148	133	999	00
\$\$												

Time (UTC)

Lat & Lon

Static pressure at flight level ddd.d

Geopotential height (m)

Pressure >= 550 mb: extrapolated surface pressure (tenths of mb)
Pressure < 550 mb: D-value (m)

Thermodynamic block:
Temp and dwpt

Wind block: direction, flt-level wind, MAX flt-level wind (10 second) and SFMR sfc wind (10 "

SFMR rain rate

Data flags



Vortex Data Messages (VDMs)

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.
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



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.

R. TD/SST observed inside the eye.

S. Fix determined by...

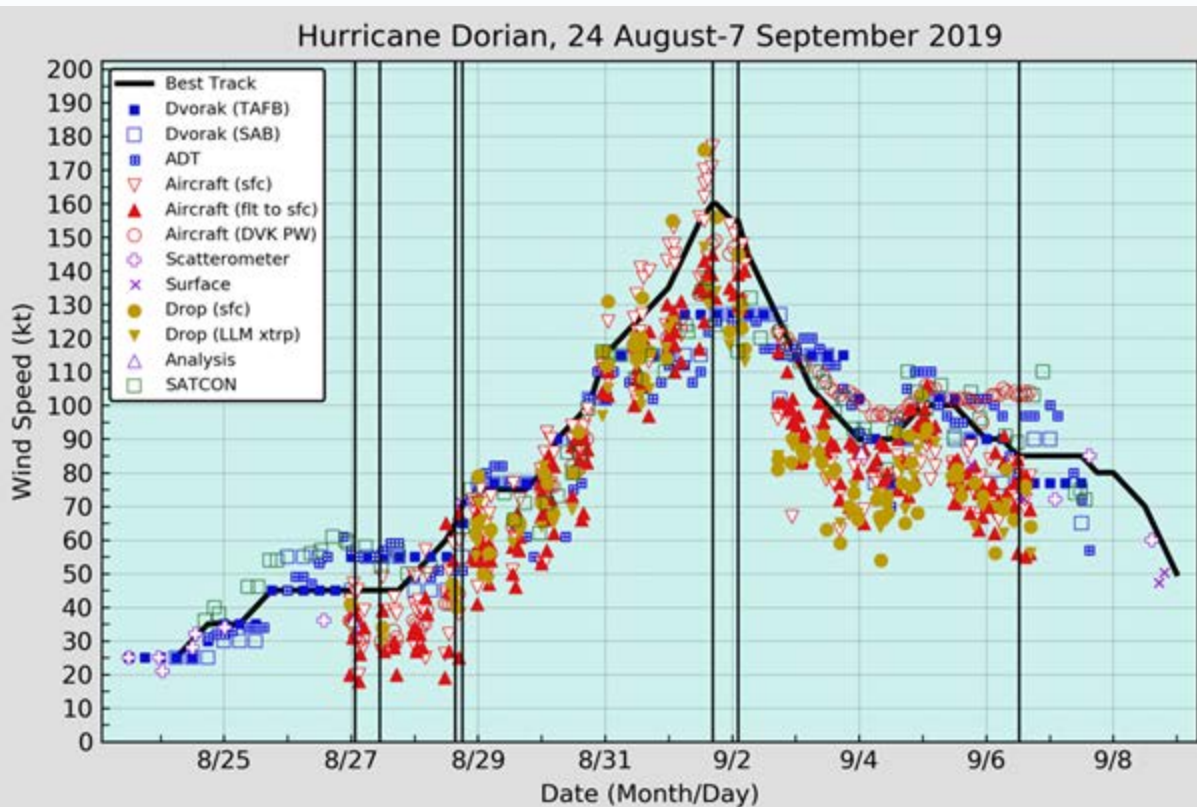
T. Fix accuracy (navigational, meteorological)

U. AC ID, mission ID, storm name, ob number

Remarks, including max FL wind from most recent passes through each octant



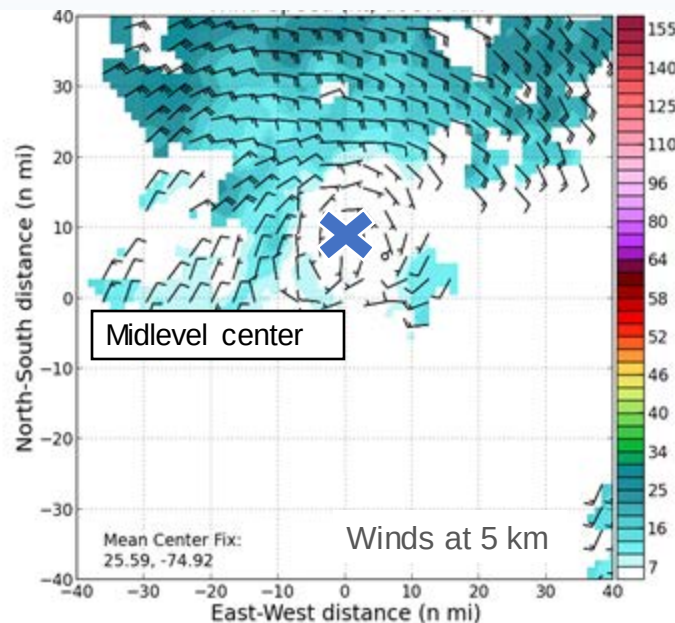
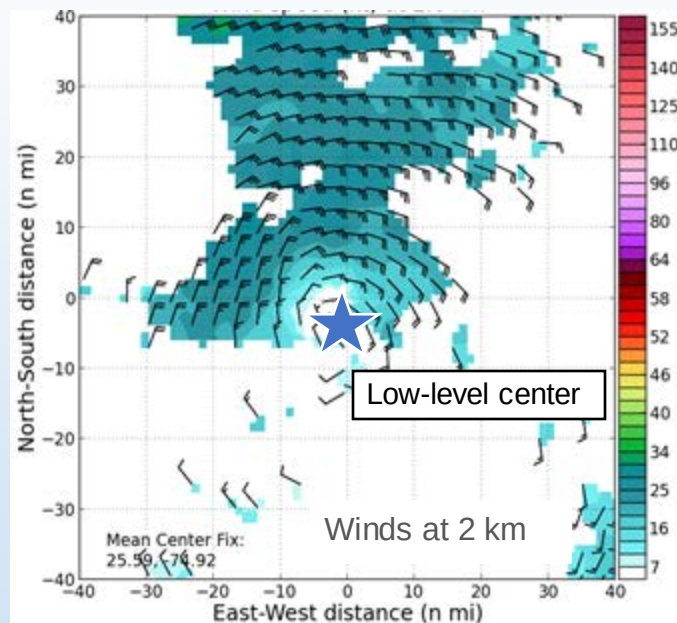
Blending Intensity Estimates





Use of Tail Doppler Radar

Real-time airborne radar observations of Humberto (2019)



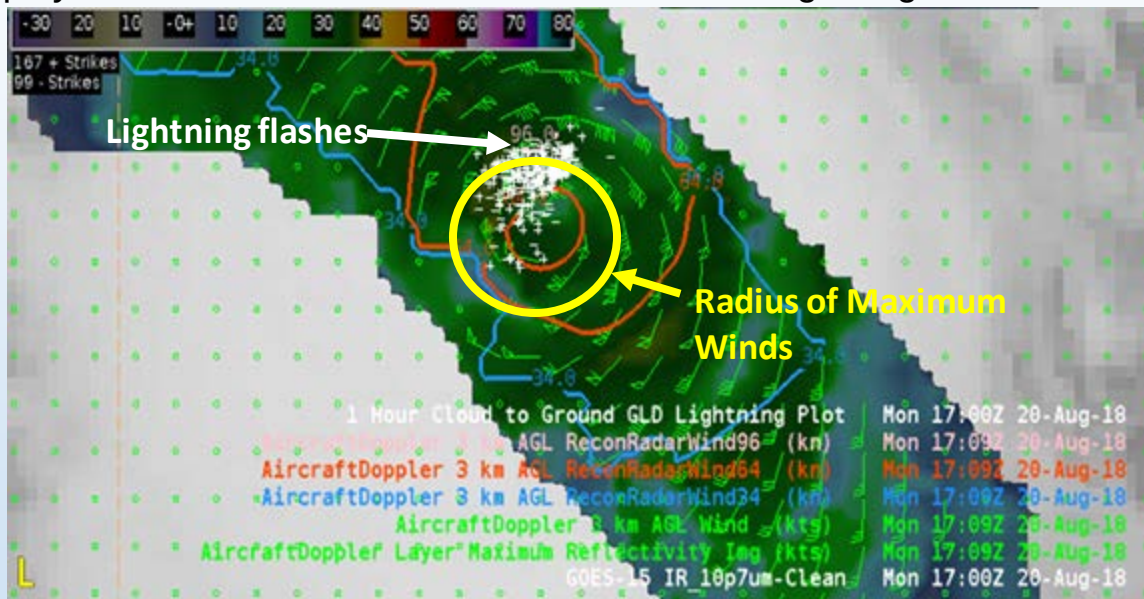
NHC Humberto Discussion, 2 h later:
“The storm is still feeling some effects of **southwesterly shear and drier air**, which is causing...**strong tilt in the aircraft data**... conditions are expected to gradually become more conducive for strengthening ”



Use of Tail Doppler Radar

Improved real-time depiction of TC structure

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

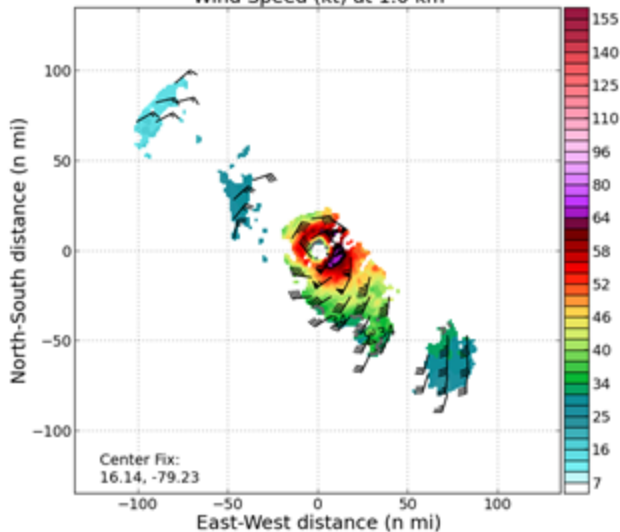


- Lightning concentrated within RMW
- Intensified 15 kt to near Category 5 in next 12 hours

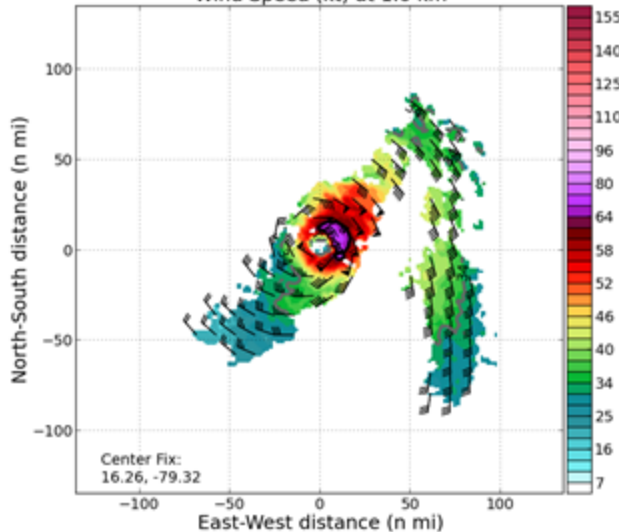


Use of Tail Doppler Radar

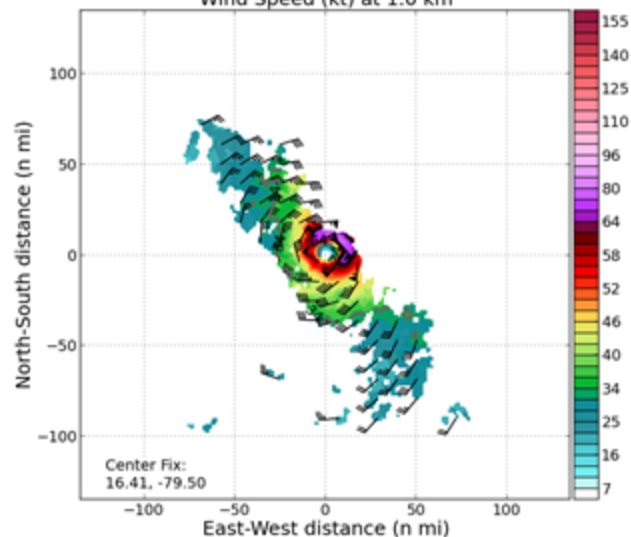
20100511 (DELTA)
190500 to 200900 UTC
Wind Speed (kt) at 1.0 km



20100511 (DELTA)
200900 to 215500 UTC
Wind Speed (kt) at 1.0 km



20100511 (DELTA)
215500 to 232000 UTC
Wind Speed (kt) at 1.0 km



- Each pass through Delta (2020) showed stronger winds
- TDR swath able to sample majority of inner core (small storm)



Closing Thoughts

- Aircraft observations have limitations complicating interpretation.
- Specialist attempts to **blend** data in an intelligent manner 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).



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*****



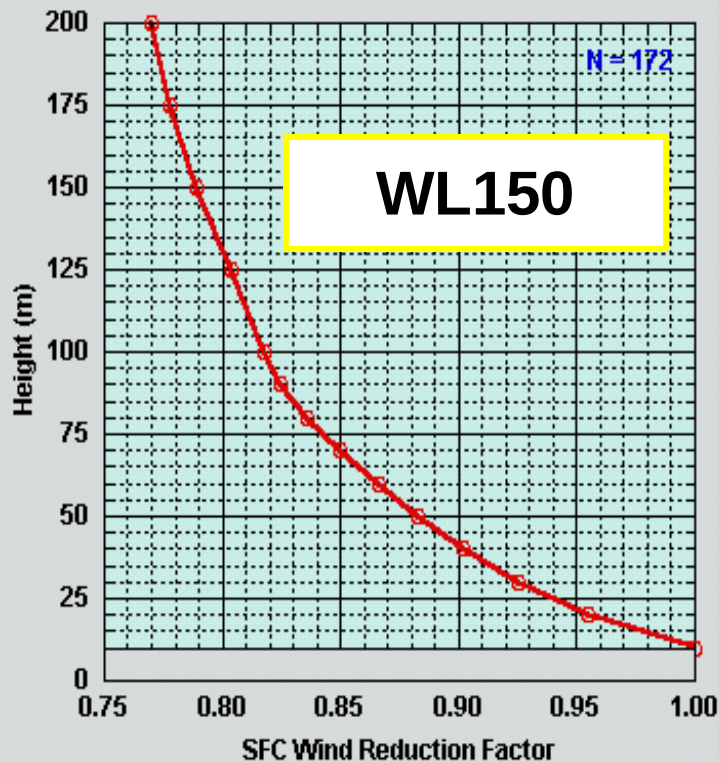
Exercise: Determine TC intensity

- 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

Eyewall Low-Level Wind Reduction Factors



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

Direction Mean Height

WL150 07132 083

Speed

$$0.80 * \text{MBL} = \text{SFC}$$



Exercise: Determine TC intensity

What was your answer?

Which observation did you trust the most?



Hurricane Sam (2021)

