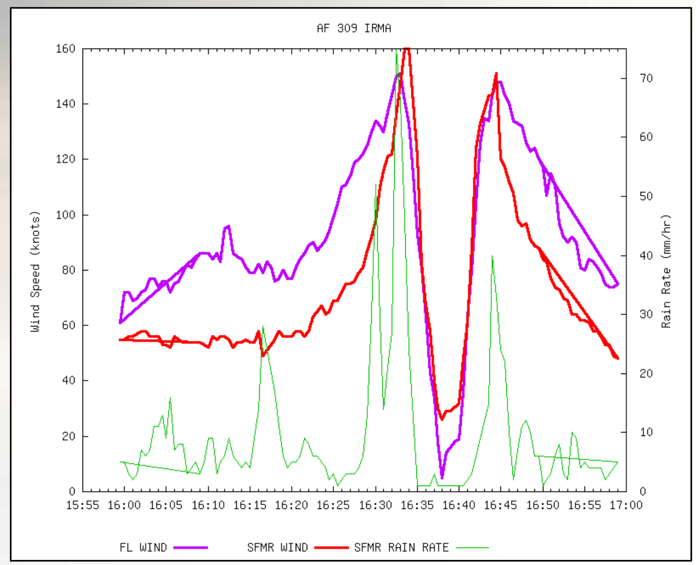
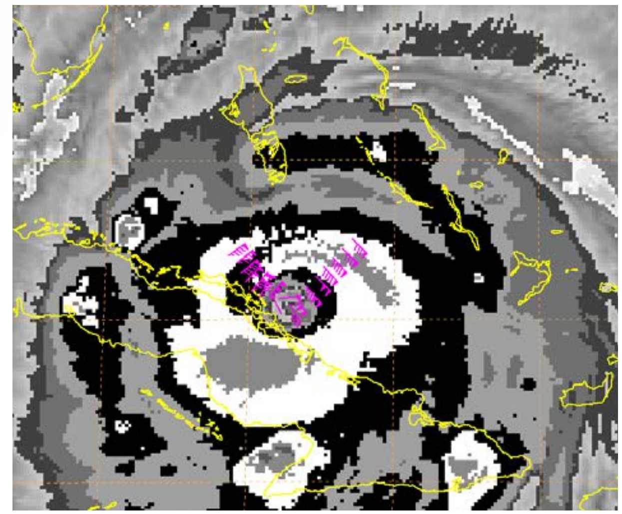
NHC's Use of Aircraft Data in Hurricane Analysis





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SECART 2019 Resilience Webinar Series
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Overview of Aircraft Observations

- Flight-level observations, SFMR, dropwindsondes, and radar
- Used subjectively by the Hurricane Specialists to assist in analysis and short-term forecasting of location, intensity, size, and structure
- Provide input to forecast models
  - Directly (e.g., direct assimilation of dropsondes for synoptic surveillance, direct assimilation of aircraft data, including radar, into the HWRF)
  - Indirectly to both dynamical and statistical models, through forecaster specification of the storm "compute" parameters (e.g., MSLP, RMW, V_{max}, 34/50/64-kt radii)
- Best Track analysis

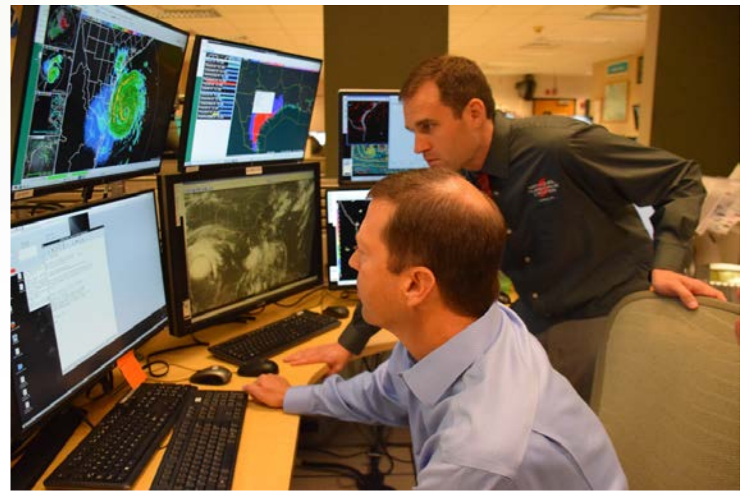
What is Tropical Cyclone Intensity?

- ***Maximum sustained surface wind (MSSW)***
  - Highest 1-min average wind at 10 m with unobstructed exposure associated with that weather system at a particular point in time
  - *Not* the highest 1-min wind anywhere within the circulation
  - Observations can be discounted if they are primarily associated with something other than the TC circulation
- Intensity is *not* the highest 1-min wind occurring over an interval of time
  - Advisory intensity should correspond to the *expected* value of the MSSW at advisory time

Eye of Hurricane Florence – courtesy NASA

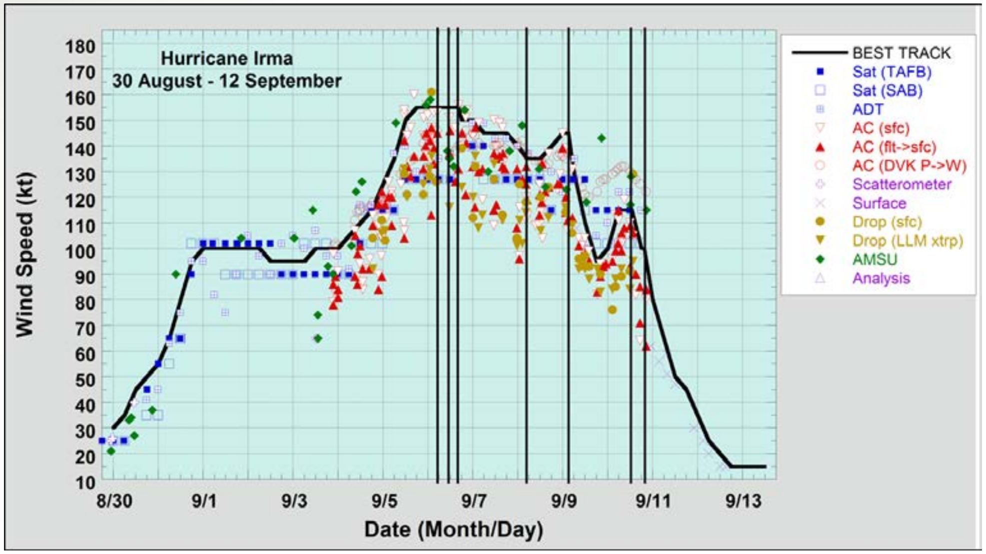
Representative Intensity

- In the best track, intensity is representative of that 6-h period and doesn't generally try to capture fluctuations that occur on time scales < 24 h
  - Exceptions are made for assessing peak intensity or intensity at a specific point/location, such as landfall
- NHC forecasters balance under-sampling against representativeness and evaluate whether an observation reflects the TC's intensity, some transient feature, or is simply unreliable
  - If a piece of data doesn't fit, it's our job to be skeptical and assess the data in context with other available data to make the best analysis

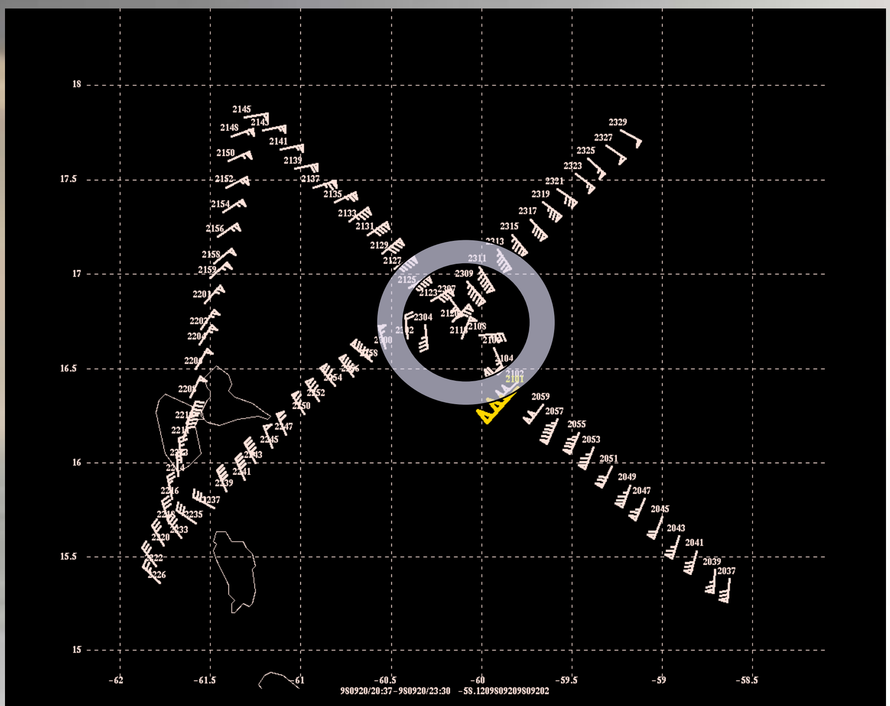


Intensity and Observations

- With very, very few exceptions, direct observations of the maximum sustained surface wind in a tropical cyclone are *not available*
- Aircraft flight-level winds
  - Require vertical adjustment to the surface
  - Sampling limitations
  - Representativeness issues
- SFMR winds
  - Sampling limitations
  - Representativeness issues
  - Rain/wind separation
  - Calibration
- Dropsondes
  - Temporal interpretation/representativeness
  - Point observations with severe sampling considerations



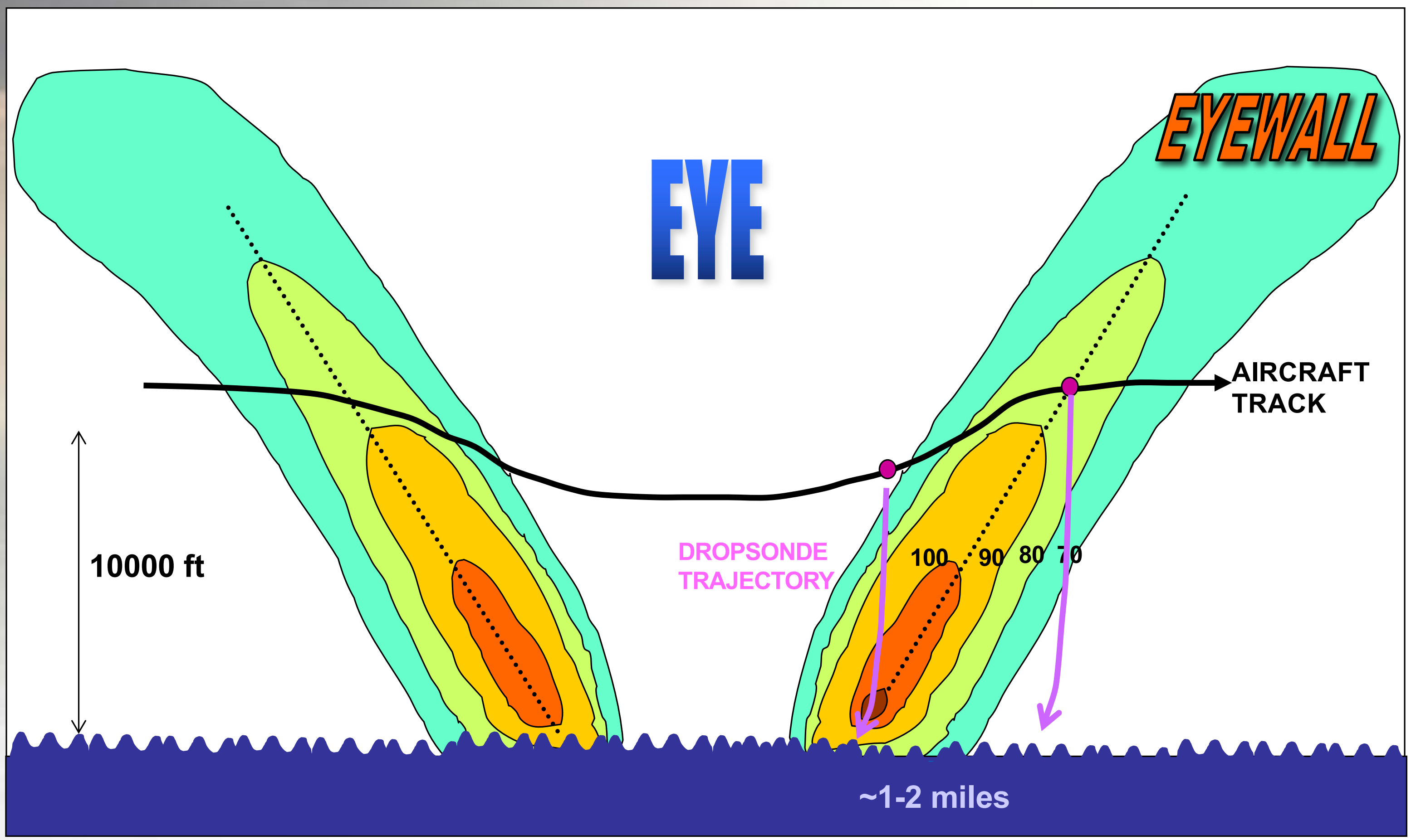
Intensity and Observations



- Peak winds in the hurricane eyewall may occur in a band only a few km across, and be located anywhere in an eyewall that is sampled at only four locations over a period of 1.5 hr

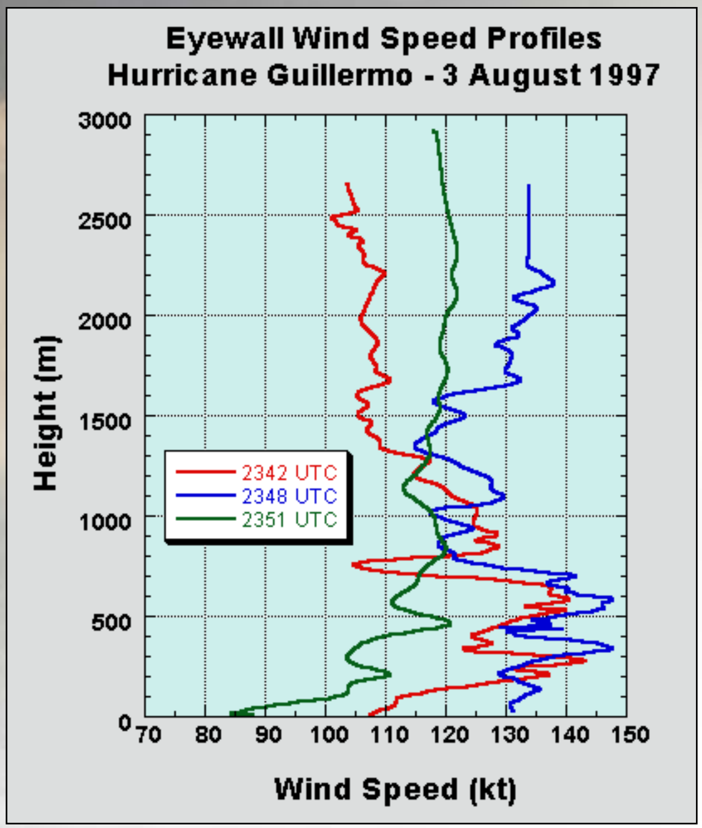
- Odds that the peak sustained winds are observed by aircraft or encountered by coastal surface stations are exceedingly small

Representativeness of Dropsondes



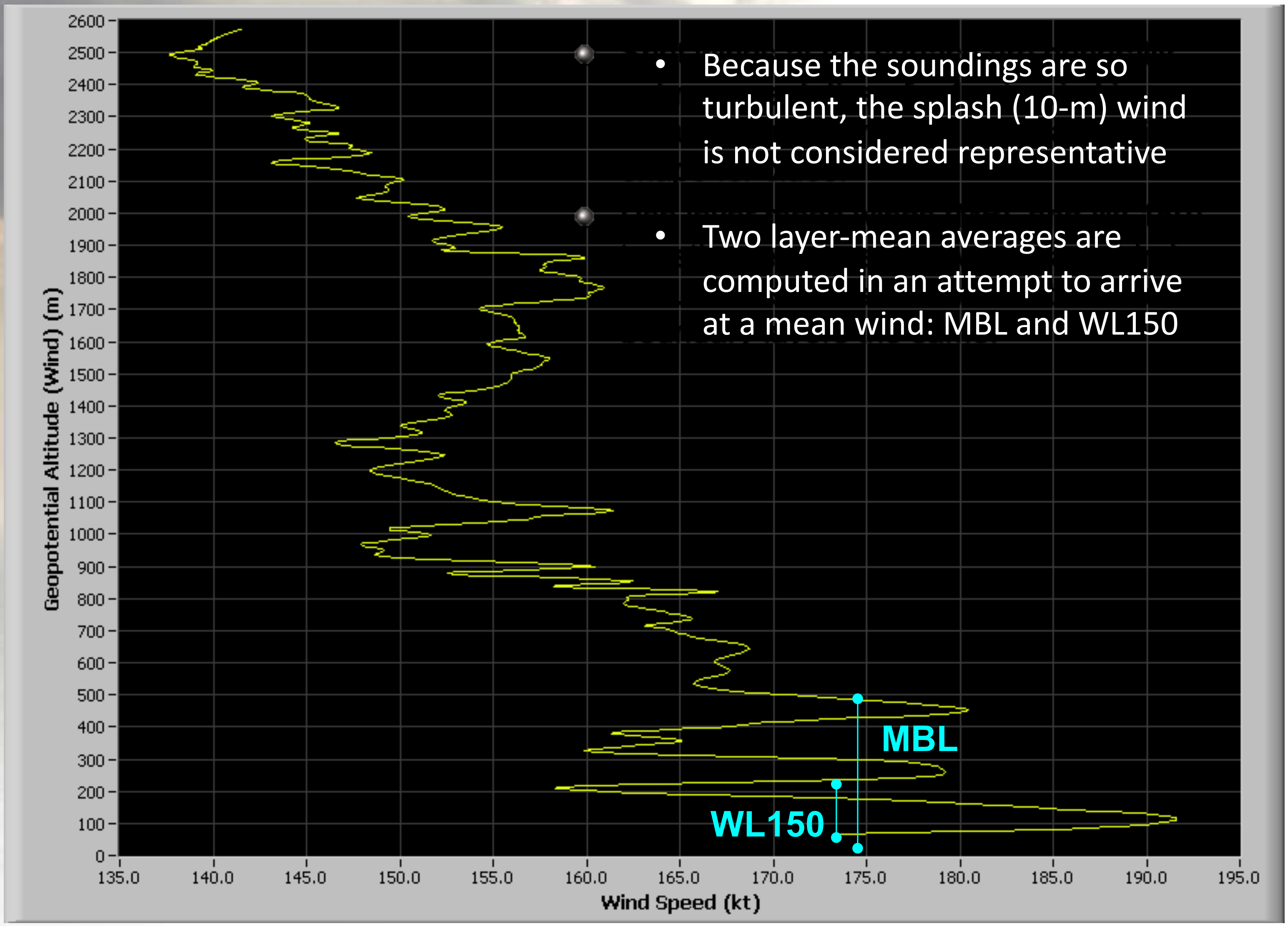
Dropsonde Representativeness Issues

Large Variability in Space and Time



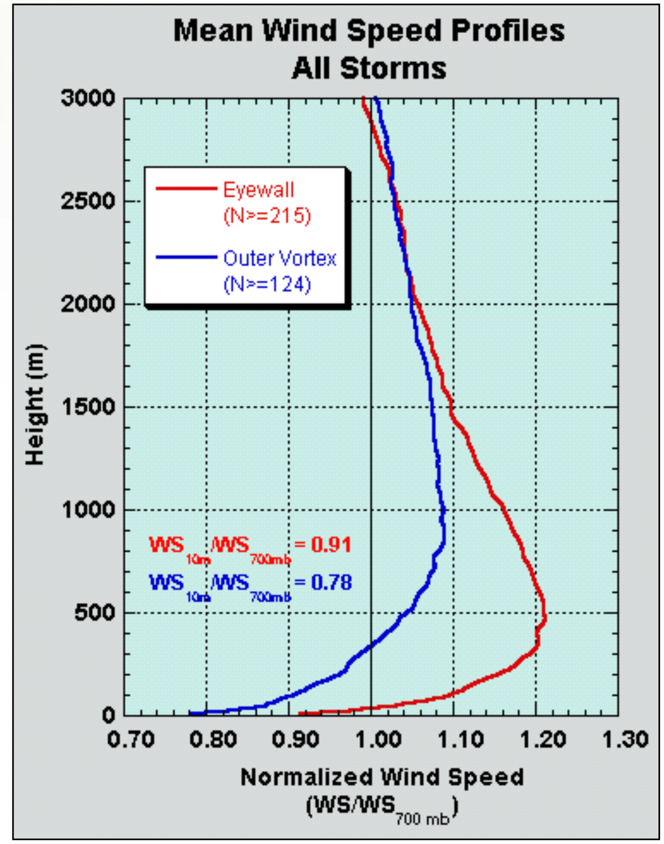
- Three dropsondes released in different portions of the hurricane eyewall recorded surface winds differing by ~45 kt!

- Because the soundings are so turbulent, the splash (10-m) wind is not considered representative
- Two layer-mean averages are computed in an attempt to arrive at a mean wind: MBL and WL150



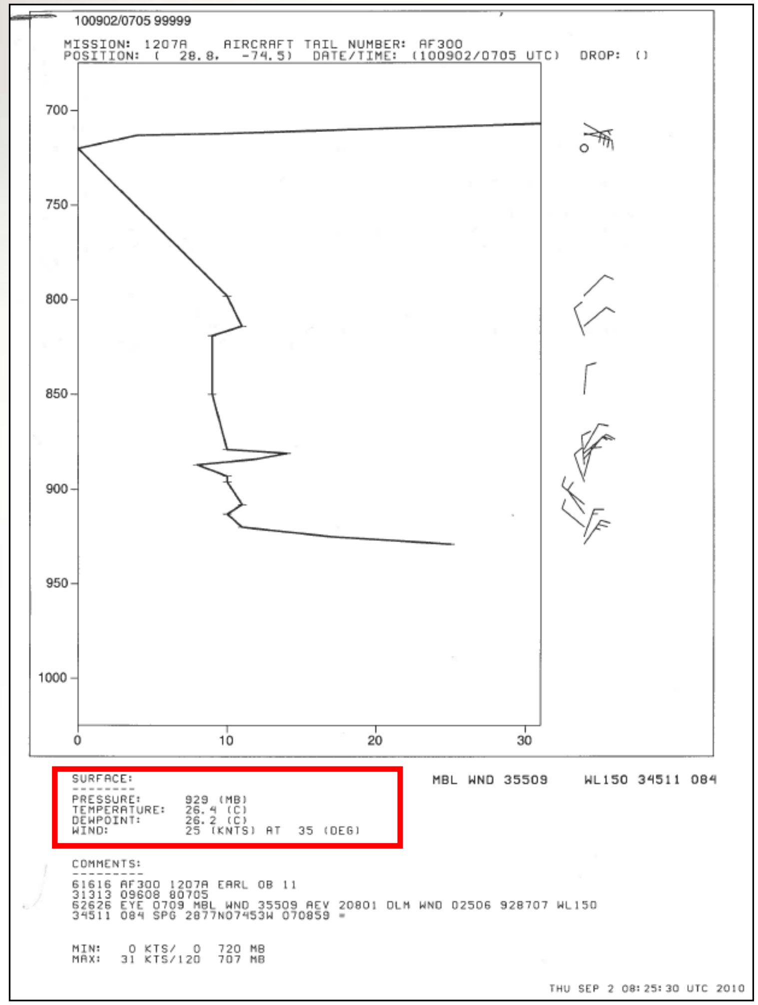
Dropsonde Winds

- Once the low-level means are computed, they are adjusted to the surface using a mean profile determined from many soundings
  - MBL wind of 150 kt * 0.8 = estimated surface wind of 120 kt
  - WL150 wind of 165 kt * 0.83 = estimated surface wind of 137 kt

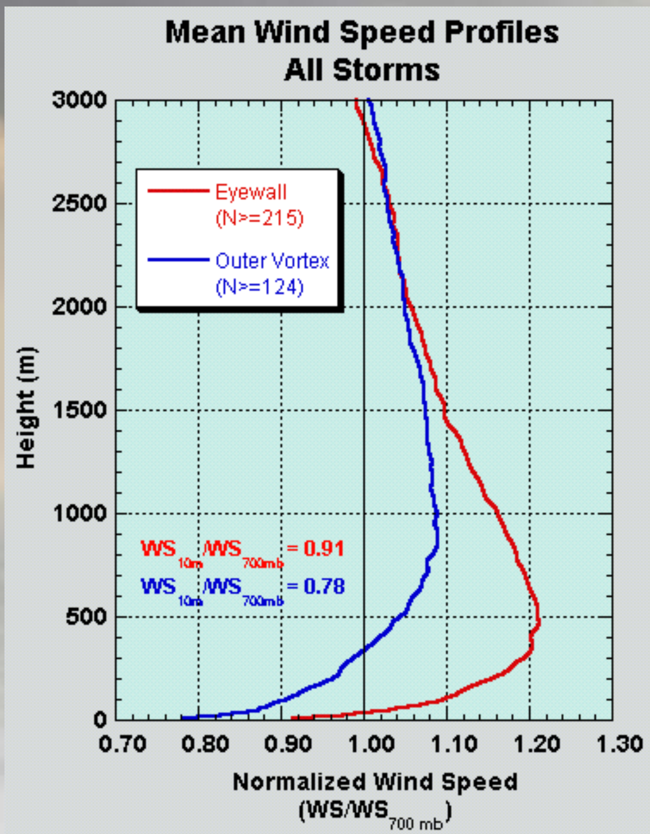


Central Pressure from Dropsonde

- Center (eye) drops are released at the flight-level wind minimum, but may drift away from surface minimum
- Rule of thumb for estimating MSLP is to subtract 1 mb from the sonde splash pressure for each 10 kt of surface wind reported by the sonde
  - Splash pressure: 929 mb
  - Surface wind: 25 kt
  - Estimated MSLP: 927 mb



Flight-Level Adjustments to Surface



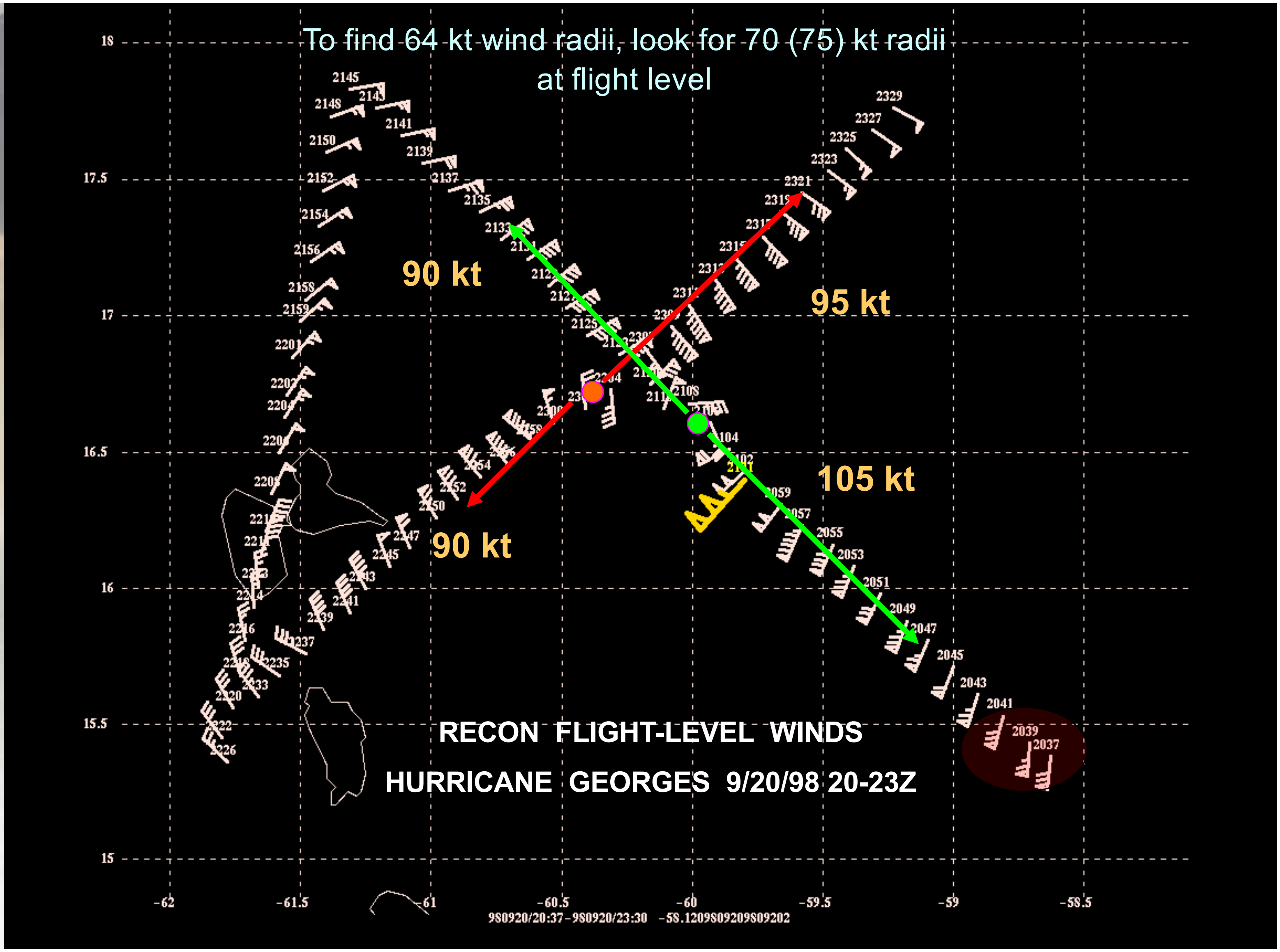
- Franklin et al., 2003: GPS dropwindsonde wind profiles in hurricanes and their operational implications., *Wea. Forecasting*, **18**, 32-44
- Large sample of GPS drops used to define mean eyewall and outer vortex wind profiles
- Profiles used to develop adjustment factors for common reconnaissance flight levels
- On the right side of the eyewall near the flight-level RMW, mean surface-700 mb ratio was near 86%
- Because the true flight-level maximum is likely not sampled, max surface wind is often estimated to be 90% of observed maximum flight-level wind

Estimating Intensity From Flight-Level Wind

Reference Level	Adjustment Factor
700 mb	90%
850 mb	80%
925 mb	75%
1000 ft	80%

Intensity Adjustment Factors and Radii Thresholds 700 mb

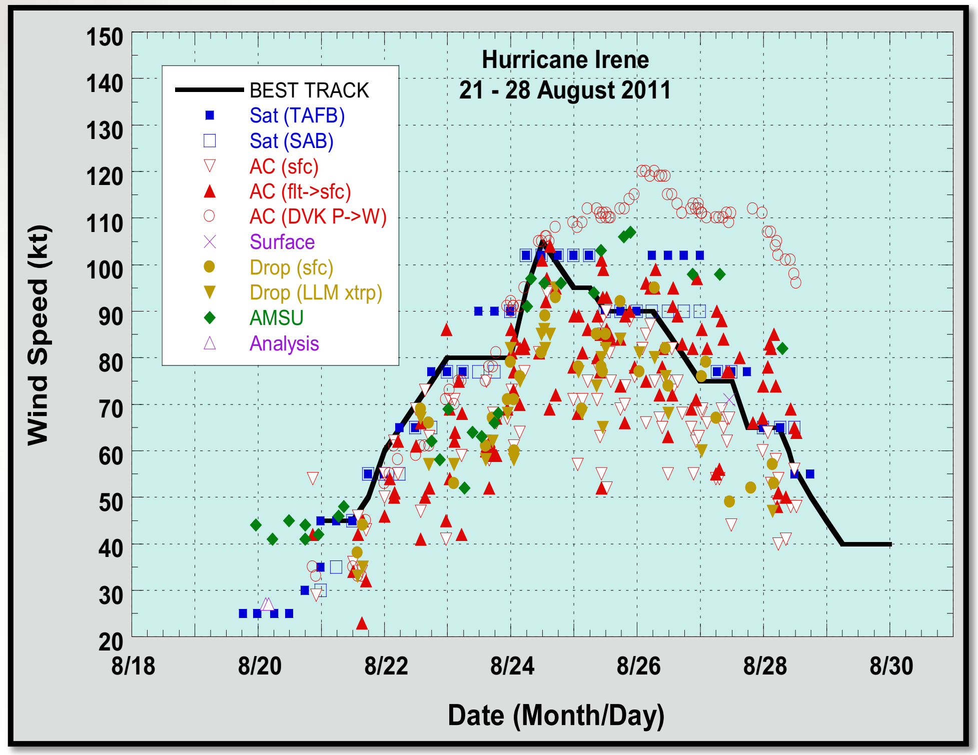
Sample	Adjust (%)	FLW64 (kt)	FLW50 (kt)	FLW34 (kt)
Eyewall	0.90	70	55	-
Outer vortex	0.85	75	60	40
Outer vortex / Right quad	0.75	85	65	45
Outer vortex / Left quad	0.90	70	55	40



To find 64 kt wind radii, look for 70 (75) kt radii at flight level
90 kt
95 kt
105 kt
90 kt
RECON FLIGHT-LEVEL WINDS
HURRICANE GEORGES 9/20/98 20-23Z
980920/20:37-980920/23:30 -58.1209809209809202

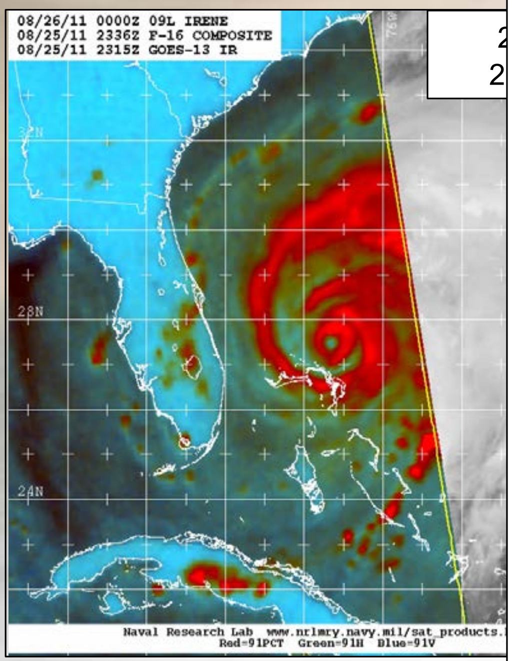
Variability of Standard Adjustment

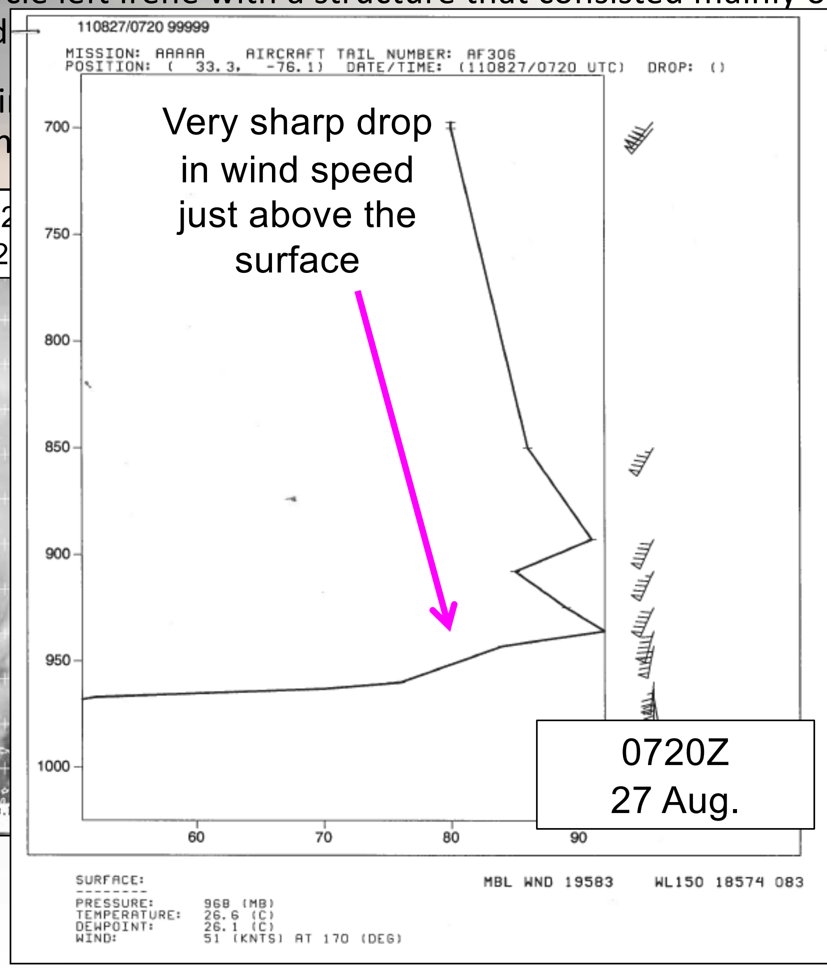
- Surface to 700-mb wind ratios vary from storm to storm, and can range from ~70% to > 100%
- However, departures from standard adjustment can't be determined from just a few dropsondes
  - Convective vigor
  - Eyewall structure, cycle, RMW
  - Low-level stability/cooler waters

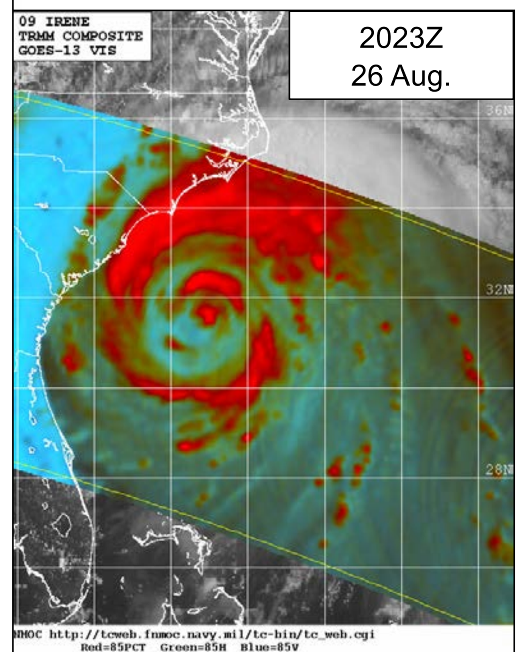


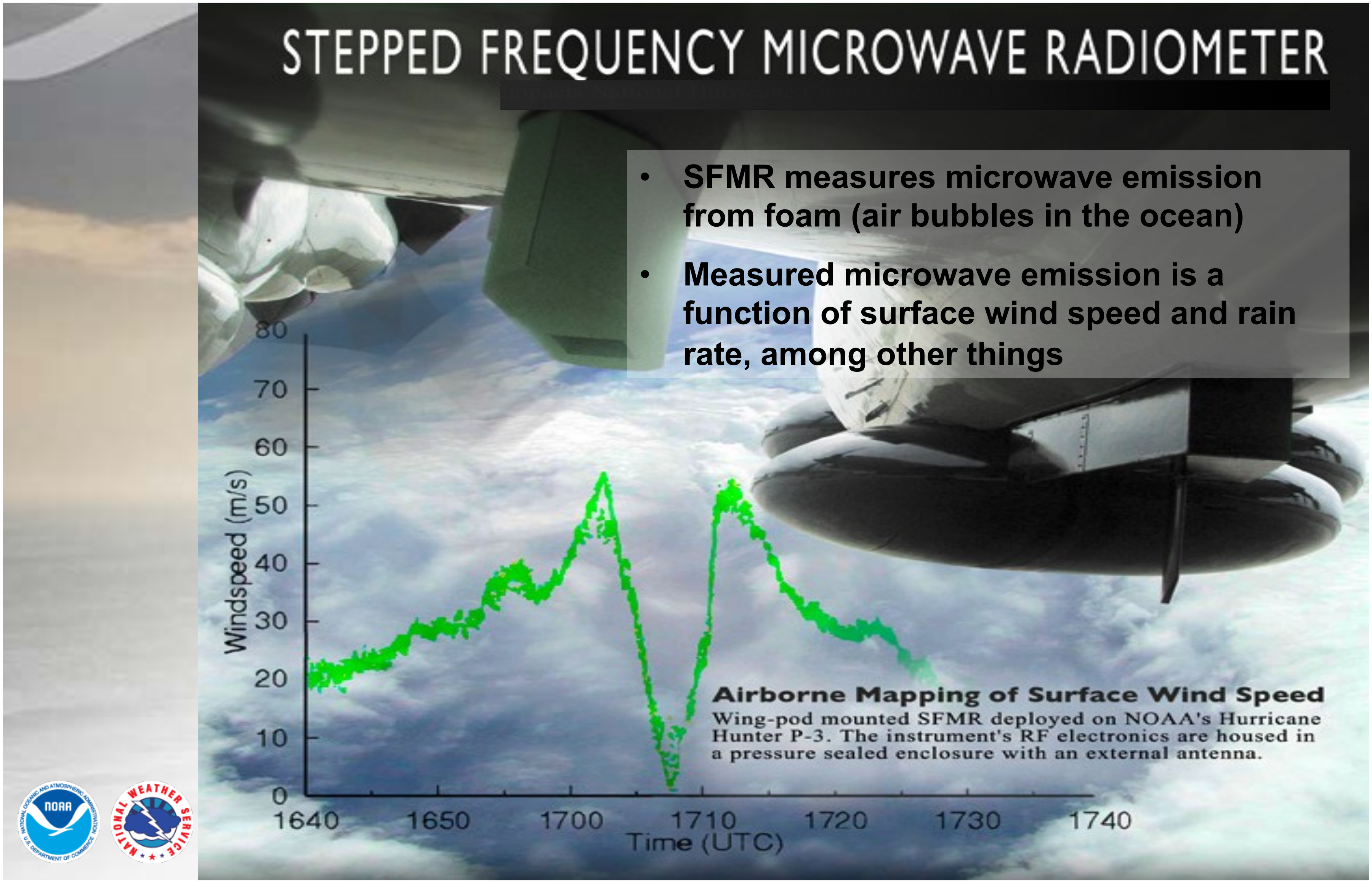
Departure from Standard Adjustments

- A failed eyewall replacement cycle left Irene with a structure that consisted mainly of diffuse rainbands that were unable to transport strong wind
- By this point, NHC was forecasti … occur, but from an initial intensity that was 10 kt too high





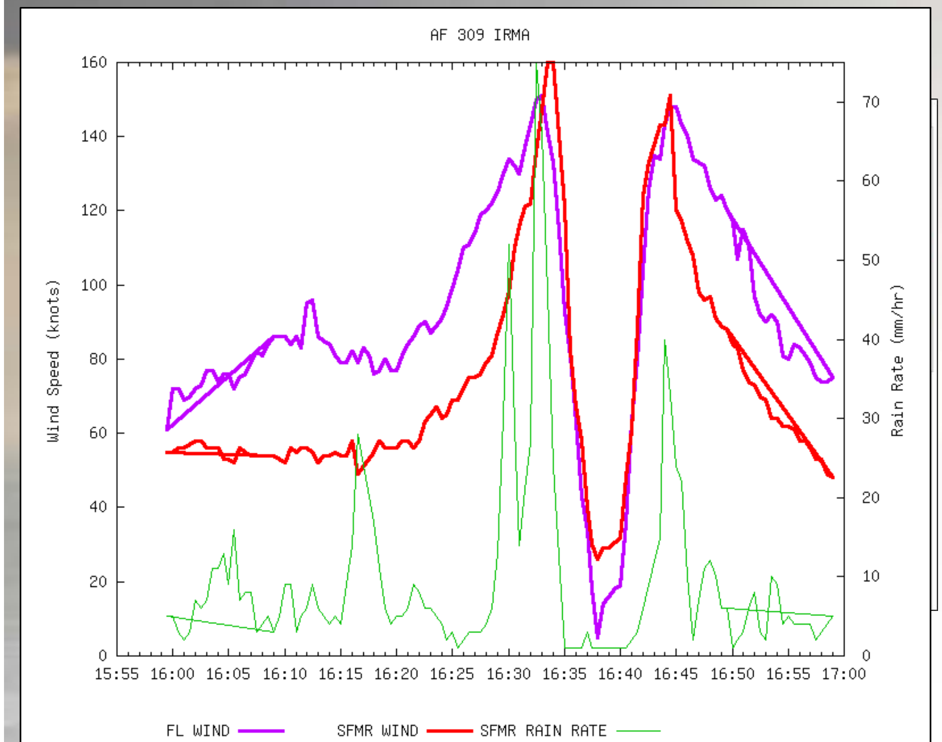



STEPPED FREQUENCY MICROWAVE RADIOMETER
• SFMR measures microwave emission from foam (air bubbles in the ocean)
• Measured microwave emission is a function of surface wind speed and rain rate, among other things
Windspeed (m/s)
0
10
20
30
40
50
60
70
80
1640
1650
1700
1710
1720
1730
1740
Time (UTC)
Airborne Mapping of Surface Wind Speed
Wing-pod mounted SFMR deployed on NOAA's Hurricane Hunter P-3. The instrument's RF electronics are housed in a pressure sealed enclosure with an external antenna.

SFMR Issues

- Shoaling – breaking waves in areas of shallow water can artificially increase the SFMR retrieved wind and invalidate the observations
- Interaction of wind and wave field can introduce errors ~ 5 kt
- Rain impacts not always properly accounted for (mainly < 50 kt)
- Calibration is an ongoing process
- High SFMR winds seen in strong storms in 2017-2018 compared to flight-level wind reduction

Hurricane Irma (2017)

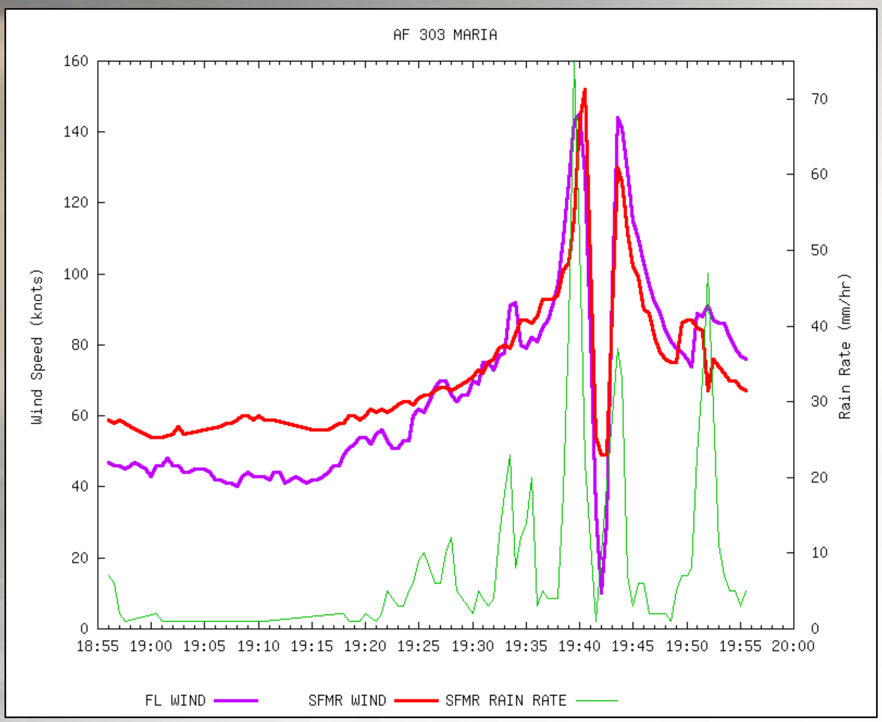


From NHC's Irma Tropical Cyclone Report:

Irma's estimated peak intensity of 155 kt from 1800 UTC 5 September to 1200 UTC 6 September is based on a blend of multiple SFMR surface wind estimates and flight-level winds observed by the Air Force Reserve and NOAA Hurricane Hunters during that time period. The highest unflagged SFMR surface wind estimate from the Air Force Reserve was **160 kt** at 1633 UTC 5 September. The flight-level winds measured during that mission were around the same speed. The peak 700-mb flight-level winds of 164 kt, which correspond to a peak surface wind of 145–150 kt, were measured by the Air Force Reserve early on 6 September. The NOAA Hurricane Hunters measured maximum 750-mb flight-level winds of 167 kt, which correspond to about 150 kt at the surface, and peak SFMR winds of 152 kt.

It should be noted that this intensity estimate is somewhat uncertain given the disparity between the peak SFMR winds and the intensity supported by the highest flight-level winds. The 155-kt peak intensity of Irma is 5 kt lower than the operational assessment in favor of blending the flight-level and SFMR reports.

Hurricane Maria (2017)



From NHC's Maria Tropical Cyclone Report:

Maria's peak intensity of 150 kt is based on a blend of SFMR- observed surface winds of 152 kt and 700-mb flight-level winds of 157 kt.

The intensity of the hurricane when it struck Dominica, 145 kt, is based on an SFMR-observed surface wind of 152 kt which, based on quality control by data processing software, is believed to be somewhat inflated, and a maximum 10-min wind of 130 kt measured at Douglas-Charles Airport on the island, which conservatively corresponds to a 1-min wind of 143 kt.

Summary

- Aircraft data are extremely valuable, and provide direct measurement of wind and pressure data in tropical cyclones
- However, all data have strengths and weaknesses when being used to assess tropical cyclone intensity in real time and post analysis
  - Representativeness
  - Sampling
  - Vertical adjustment
  - Calibration
- Significant uncertainty exists in the analysis of intensity and wind radii
  - 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).
- Even ”well sampled” storms still have wide swaths of unsampled territory