Use of Aircraft Data at the National Hurricane Center

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Aircraft Observations

* Flight-level observations: PTH, winds, altitude.
* Stepped-Frequency Microwave Radiometer (SFMR): surface wind and rain rate below A/C
* GPS dropwindsondes: PTH and wind profile
* Radar (reflectivity and Doppler)

Aircraft Observations

- Can be used subjectively by the Hurricane Specialists (HS)
  - Assist in the analysis and short-term forecasting of location, intensity, size, structure of the cyclone/disturbance.
- Provide input to forecast models
  - Directly (e.g., direct assimilation of dropsondes released outside the core in synoptic surveillance, Doppler radar in HWRF).
  - Indirectly to both dynamical and statistical models, through HS specification of storm parameters (e.g., MSLP, RMW, Vmax, 34/50/64 kt radii)
- Best Track analysis

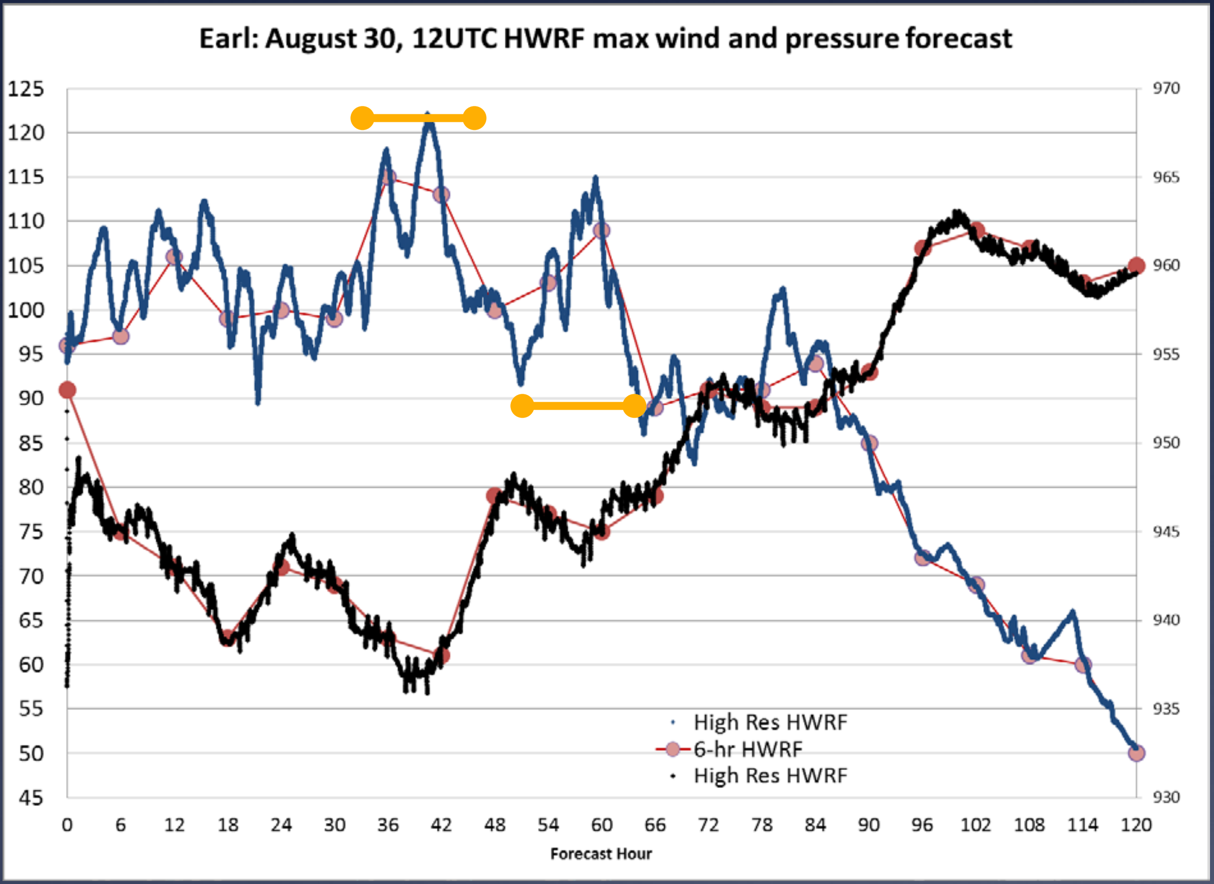
Tropical Cyclone Intensity

* Maximum sustained surface wind: When applied to a particular weather system, refers to the highest 1-min average wind (at an elevation of 10 m with an unobstructed exposure) associated with that weather system at a particular point in time. (NWSI 10-604)

* Intensity is not the highest 1-min wind that exists within the circulation.
    * Observations can be discounted if they are primarily associated with something other than the TC circulation (e.g., transients associated with short-lived convective downbursts, embedded tornadoes, squall lines, meso-cyclones, etc.

* Intensity is not the highest 1-min wind occurring over an interval of time. The advisory intensity should correspond to the expected value of the MSSW at advisory time.

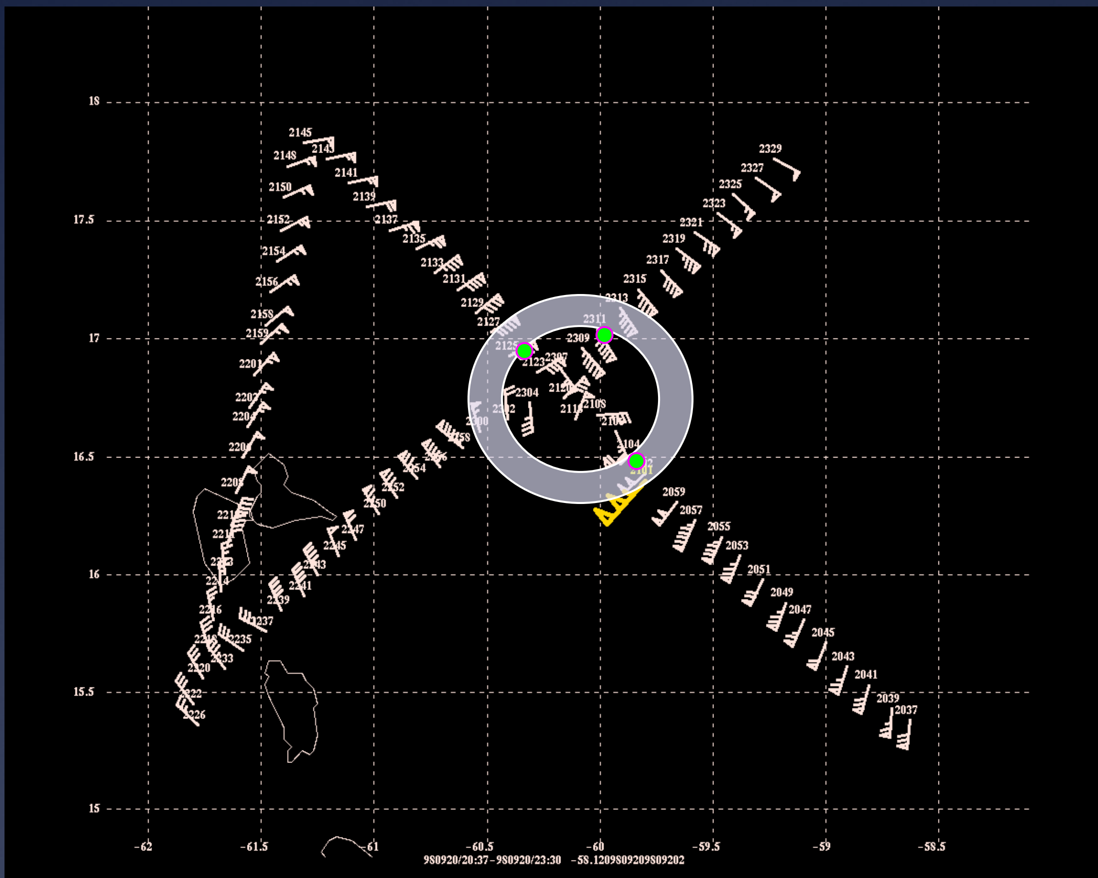
Representative Intensity



Peak winds in a model TC can vary widely over periods of a few hours. Tracking these rapid changes for real storms is neither possible nor desirable.

Best-track and operational intensity estimates attempt to smooth through the short-term fluctuations. NHC Hurricane Specialists have to use their judgment whether any particular observation is representative of the tropical cyclone or some transient feature, and balance representativeness against sampling considerations.

Sampling Limitations

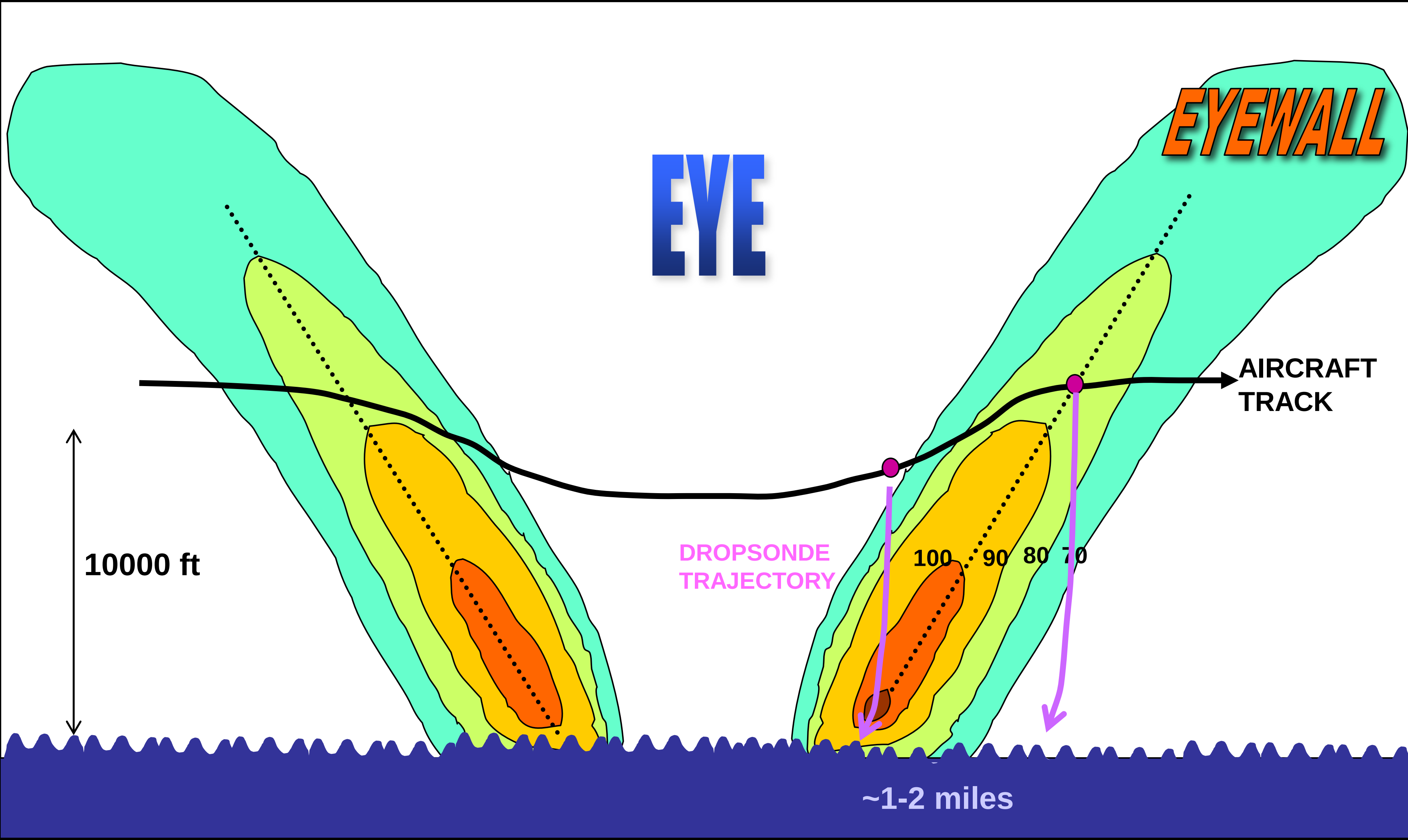


Peak winds in the hurricane eyewall may occur in a band only a couple km across, and be located anywhere azimuthally in an eyewall that is sampled only at four locations over a period of 1.5 hr.

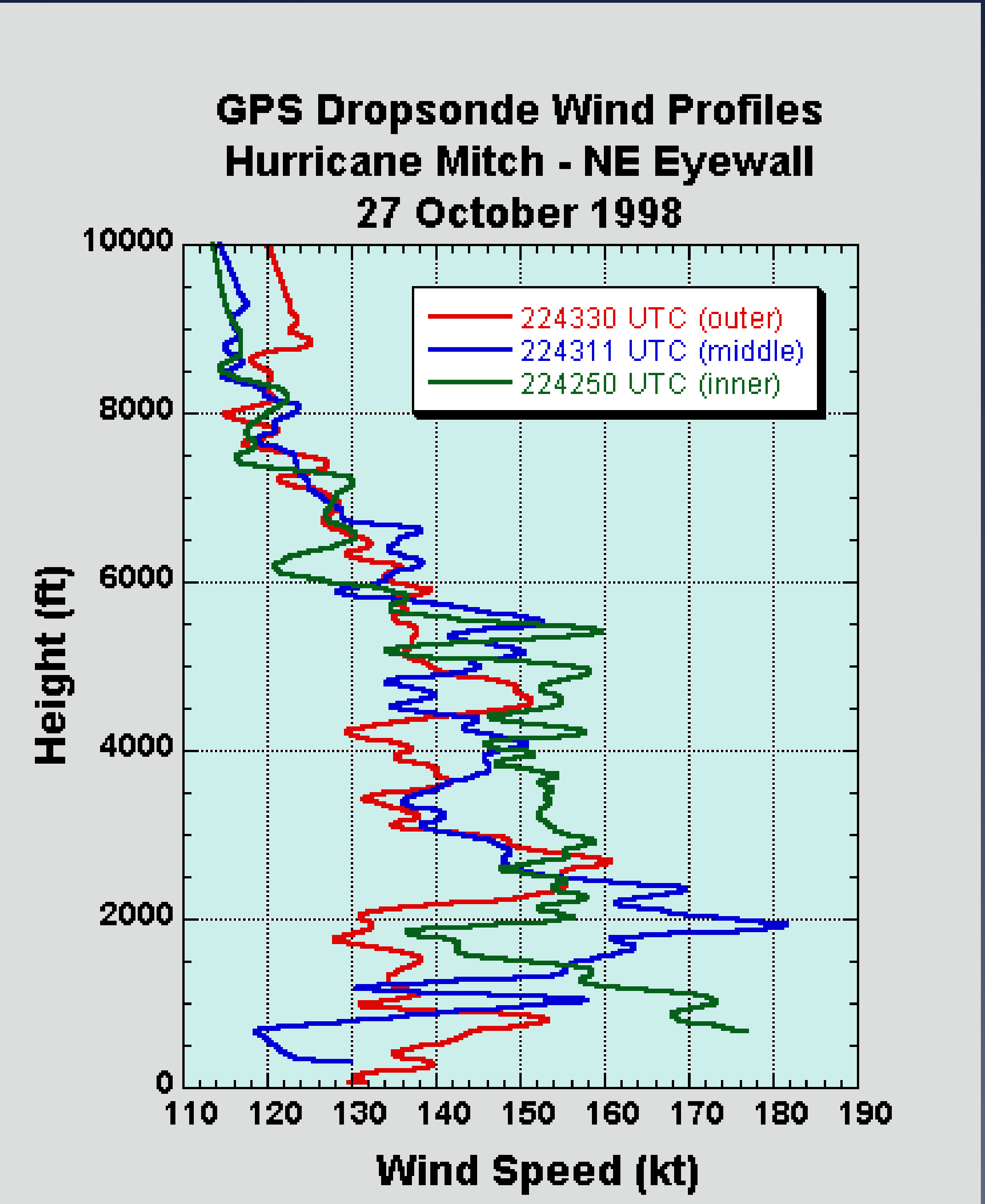
Flying perpendicular to the wind at ~220 kt means that the peak eyewall winds might be experienced by the aircraft for only 10-20 s.

The odds that the peak sustained winds are observed by aircraft or encountered by coastal surface stations are exceedingly small.

Representativeness of Dropsondes



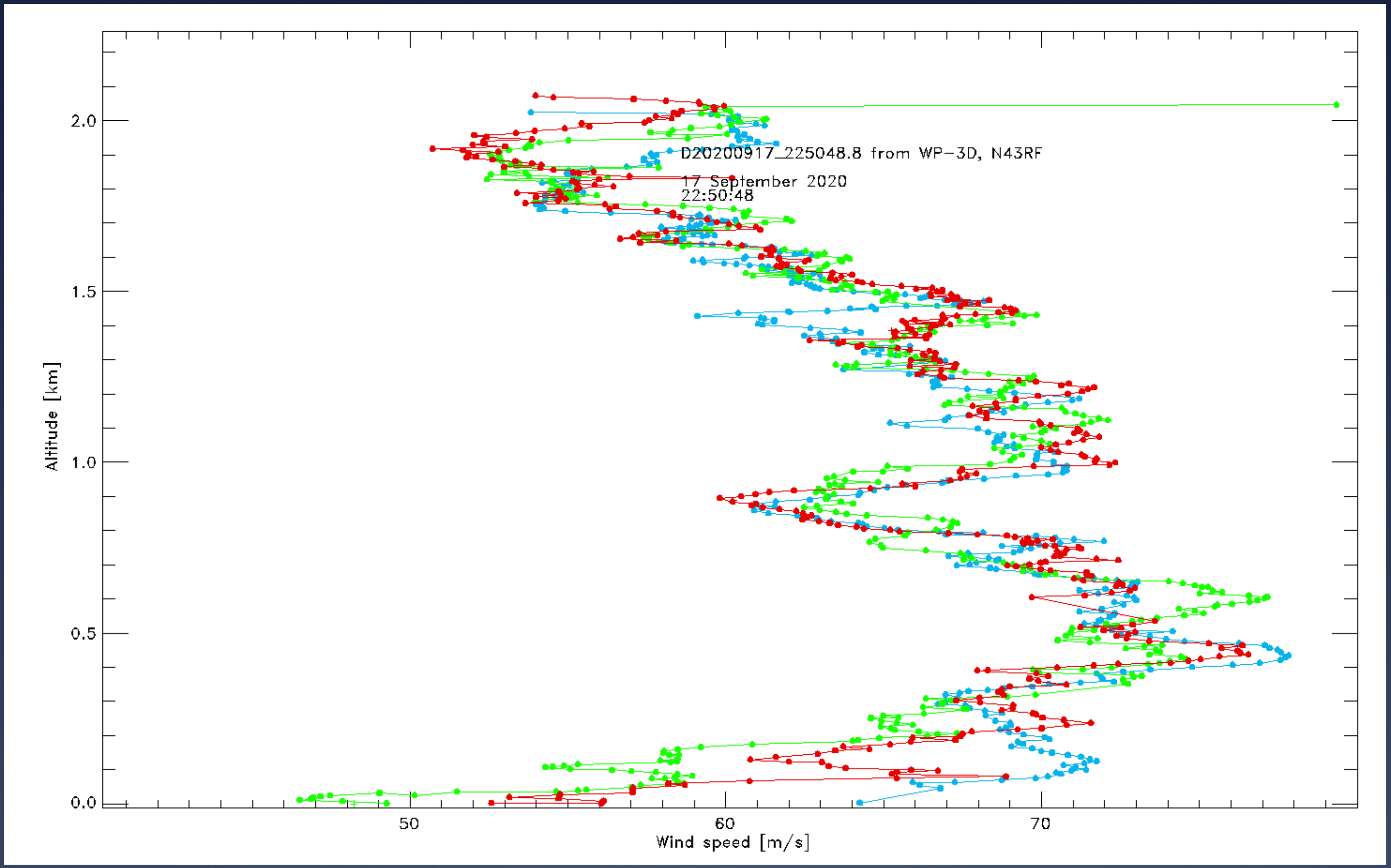
Small-scale Variability in a Tropical Cyclone



Three dropsondes released over a span of 40 seconds. These closely spaced soundings quickly diverge in the turbulent and chaotic hurricane environment, especially in the boundary layer.

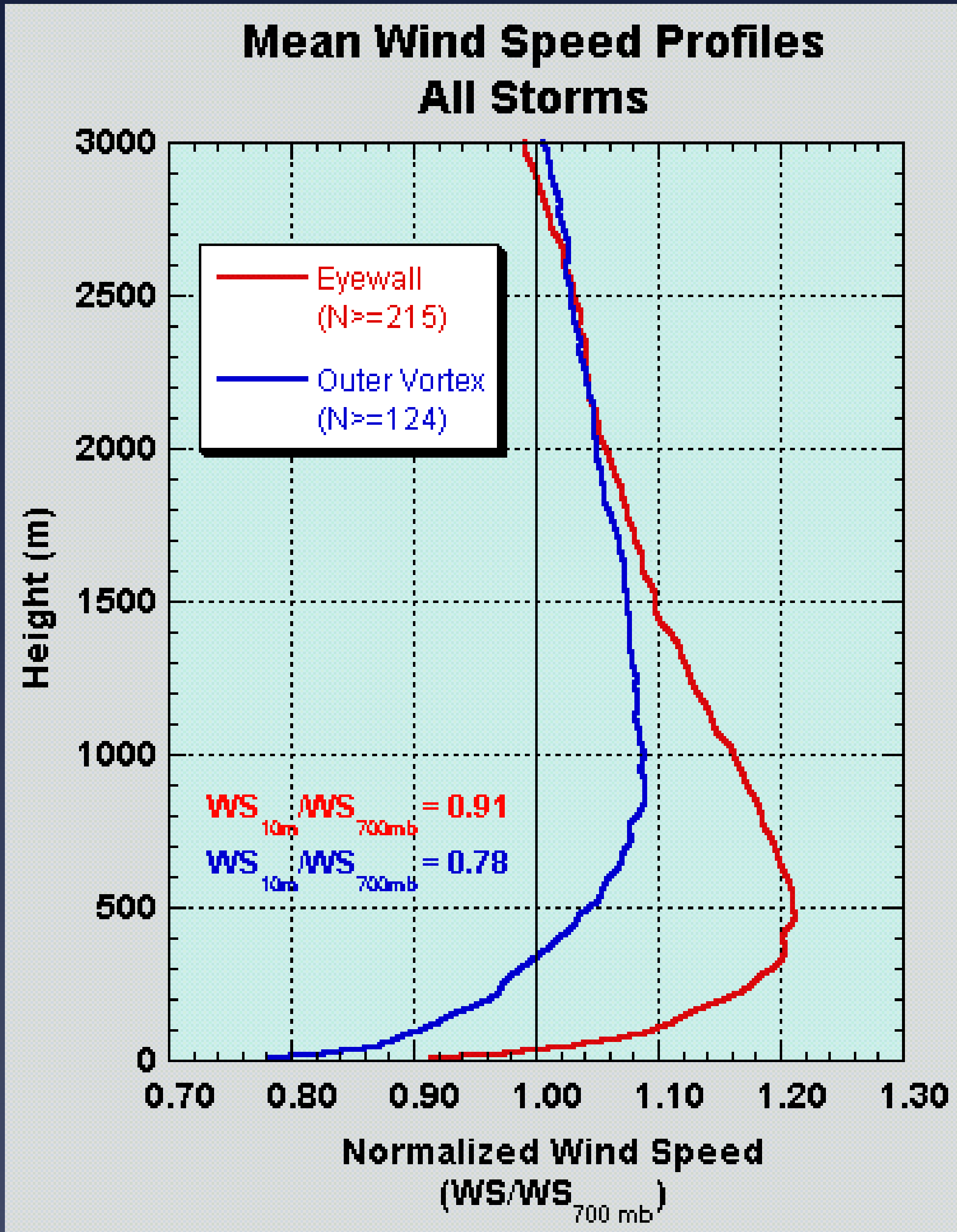
Individual GPS dropsonde winds represent a sampling period of < 1 second.

Small-scale Variability in a Tropical Cyclone



Three simultaneous dropsondes released in Hurricane Teddy (2020) recorded near-surface winds differing by >30 kt! Sondes drifted apart by about 4 km during descent.

Mean Hurricane Wind Profiles



To attempt to make the dropsonde data more useful, composite profiles were constructed using a large sample of sondes.

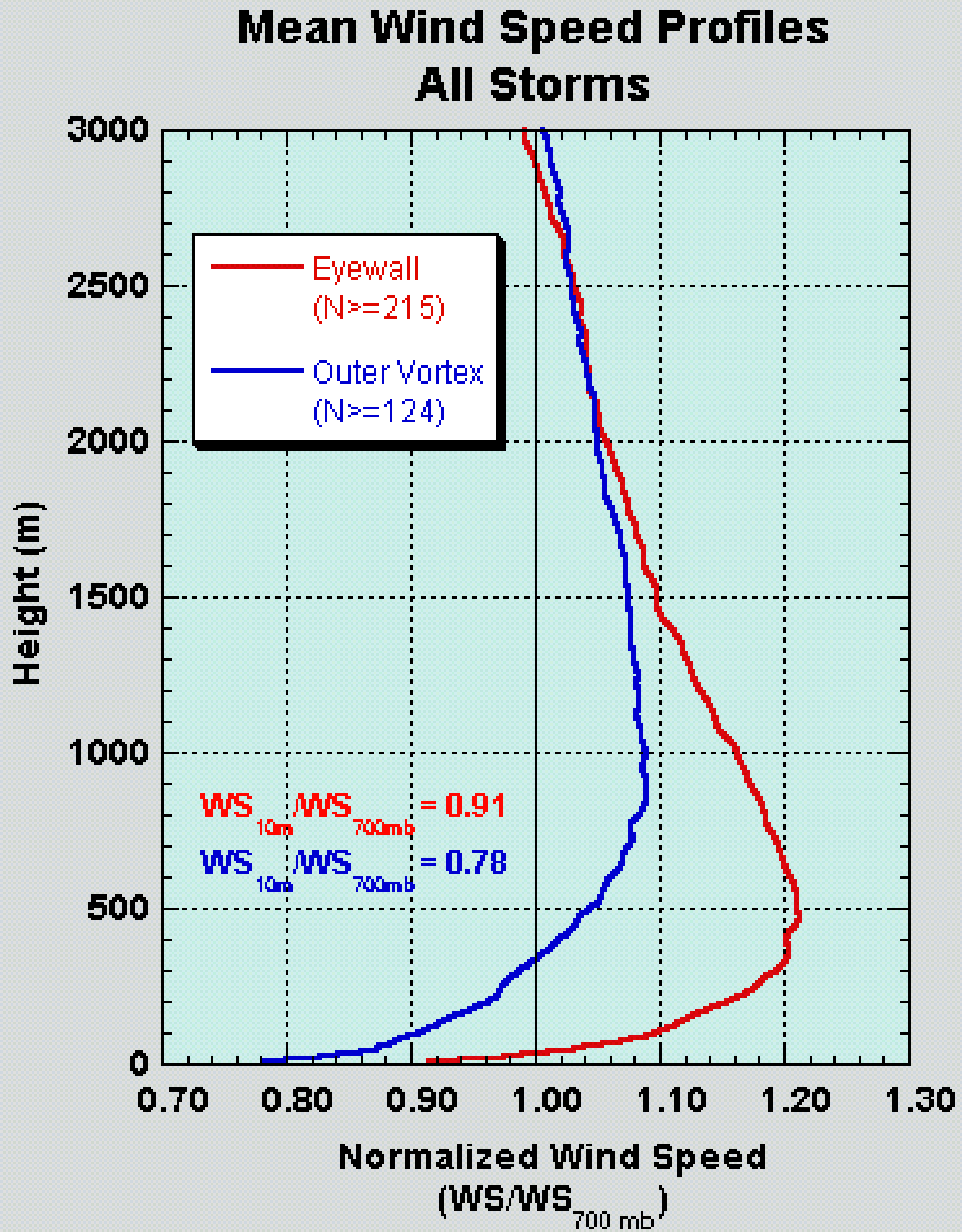
Mean hurricane profiles can be used to adjust winds from one level/layer to the surface.

- FL winds to surface
- Low-level dropsonde layer means to surface

Franklin et al., 2003: GPS dropwindsonde wind profiles in hurricanes and their operational implications., Wea. Forecasting, 18, 32-44.

Estimating intensity from flight-level observations:

On the right side of the eyewall near the FL 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.

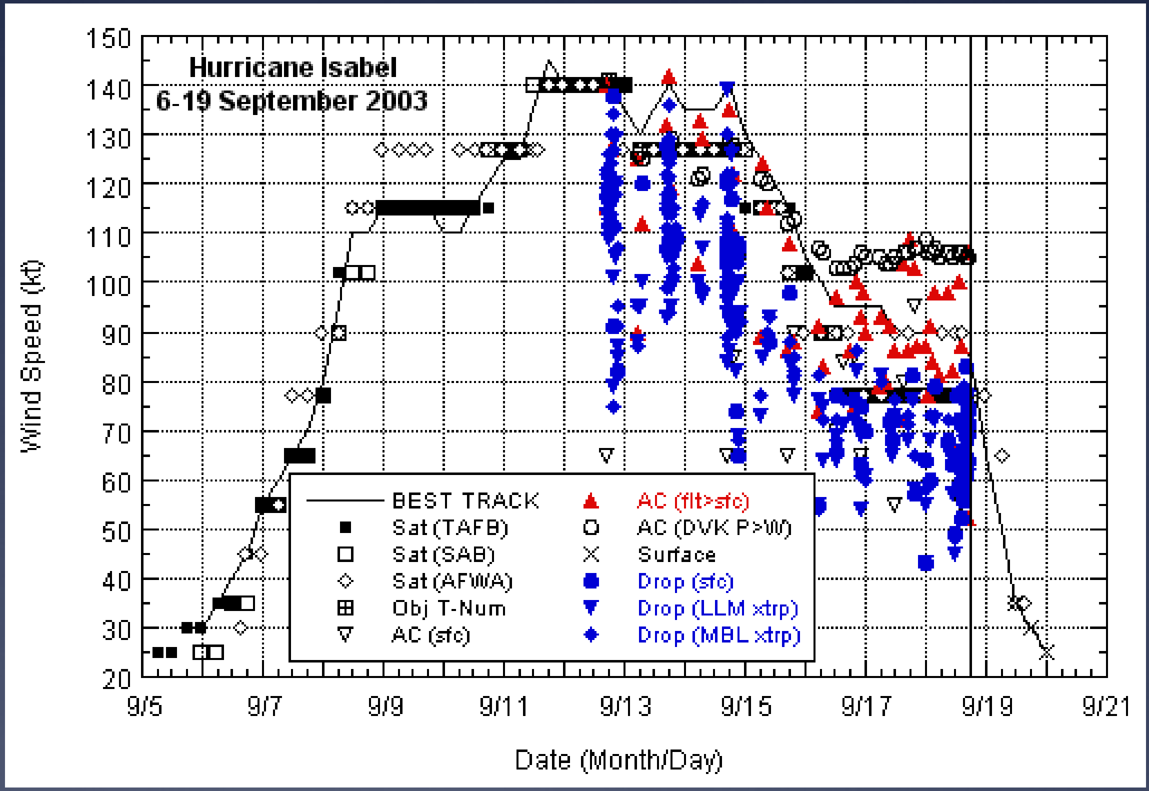


Estimating Intensity From Peak Flight-Level Wind

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

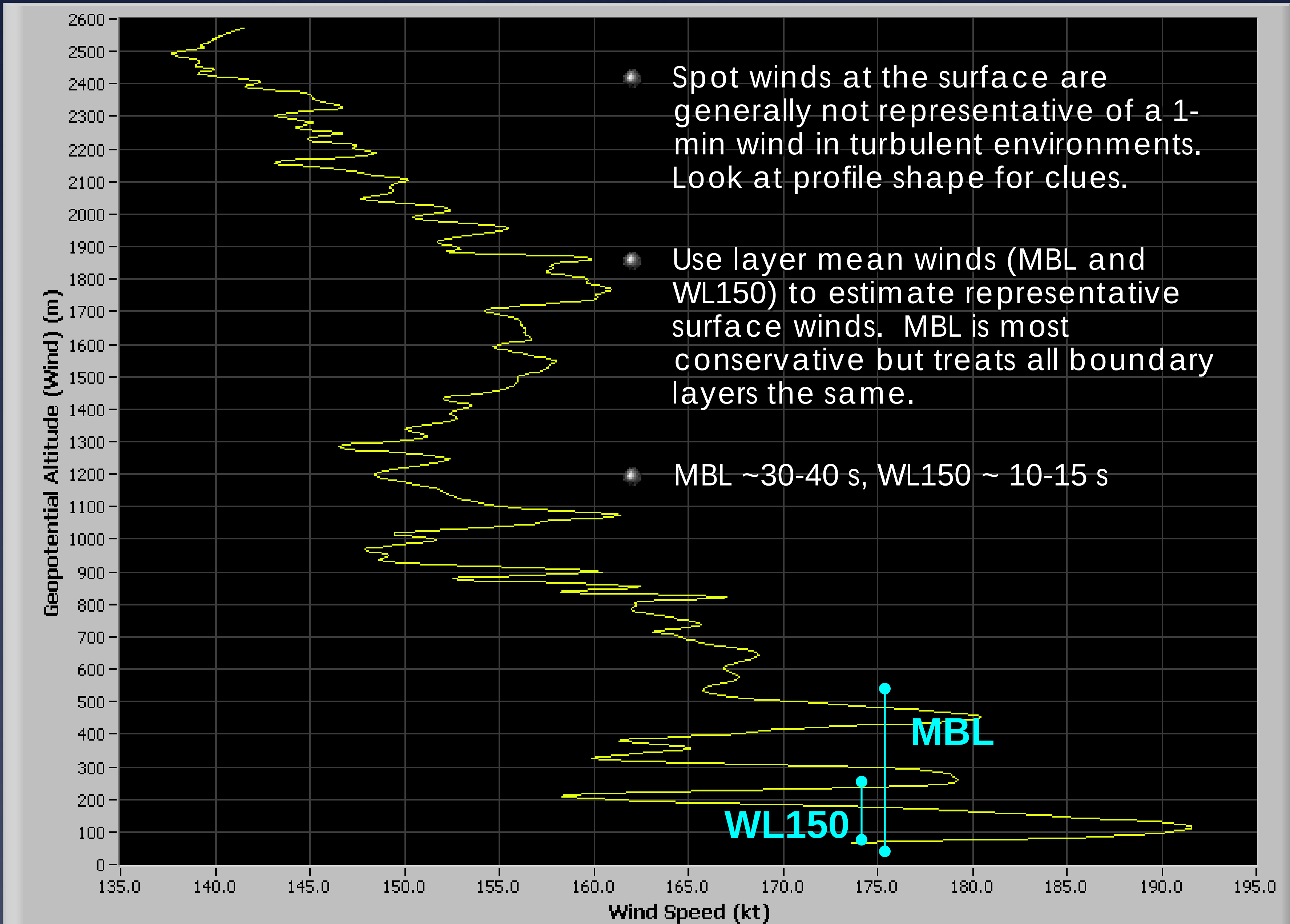
Variability of Standard Adjustment

- SFC:700 mb wind ratios vary from storm to storm, and can range from ~70% to >100%. But departures from standard adjustment cannot be determined from just a few sondes.
  - Convective vigor
  - Eyewall structure, cycle, RMW
  - Low-level stability/cooler waters



Estimating Intensity from Dropsondes

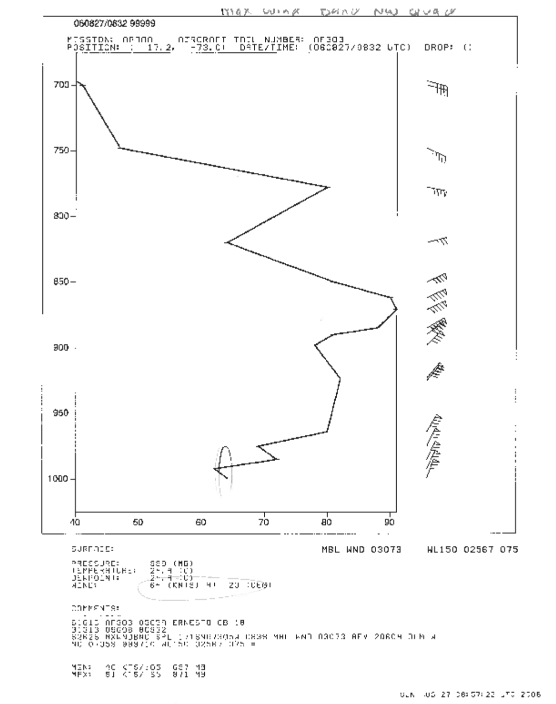
- Spot winds at the surface are generally not representative of a 1-min wind in turbulent environments. Look at profile shape for clues.
- Use layer mean winds (MBL and WL150) to estimate representative surface winds. MBL is most conservative but treats all boundary layers the same.
- MBL ~30-40 s, WL150 ~ 10-15 s

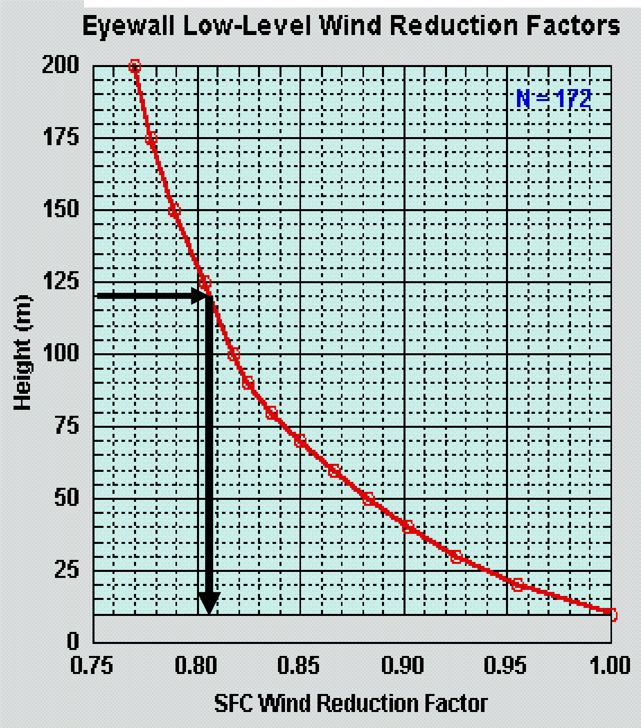


TEMP-DROP message and EYEWALL WINDS

```
UZNT13 KWBC 220345
XXAA  72037 99253 70951 08255 99959 25401 ///// 00867 ///// /////
92322 23204 08646 85060 20408 11120 70/// ///// 15091 88999 77999
61616 AF963 0202A BRET OB 10
62626 EYEWALL 045 SPL 2532N09528W WL150 07136 121 DLM WND 11615 6
96955 MBL WND 08141 LST WND 046=
XXBB  72038 99253 70951 08255 00959 25401 11947 24600 22713 14816
33710 148//
21212 00959 ///// 11955 07142 22953 07133 33951 07130 44948 07133
55945 07649 66941 07135 77940 07633 88937 08142 99931 08653 11926
08647 22921 08650 33912 09139 44910 09141 55907 09655 66904 09655
77898 09635 88891 10142 99885 10637 11881 10624 22874 11135 33868
11123 44753 13619 55696 15087
31313 09608 80328
61616 AF963 0202A BRET OB 10
62626 EYEWALL 045 SPL 2532N09528W WL150 07136 121 DLM WND 11615 6
96955 MBL WND 08141 LST WND 046=
```

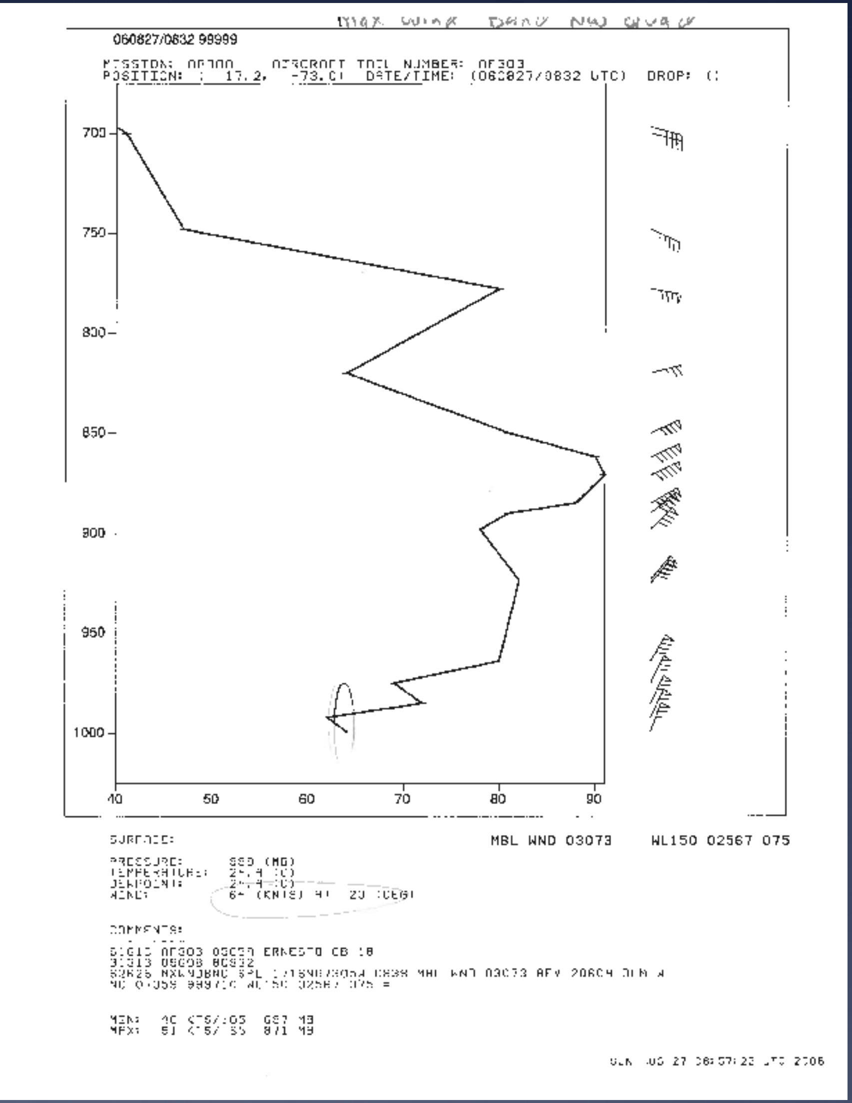
Midpoint of lowest 150 m of winds was 121 m.
Layer mean wind was 136 kt.
Diagram tells you to go from 121 m to 10 m you multiply the wind by 0.81, which yields 110 kt.





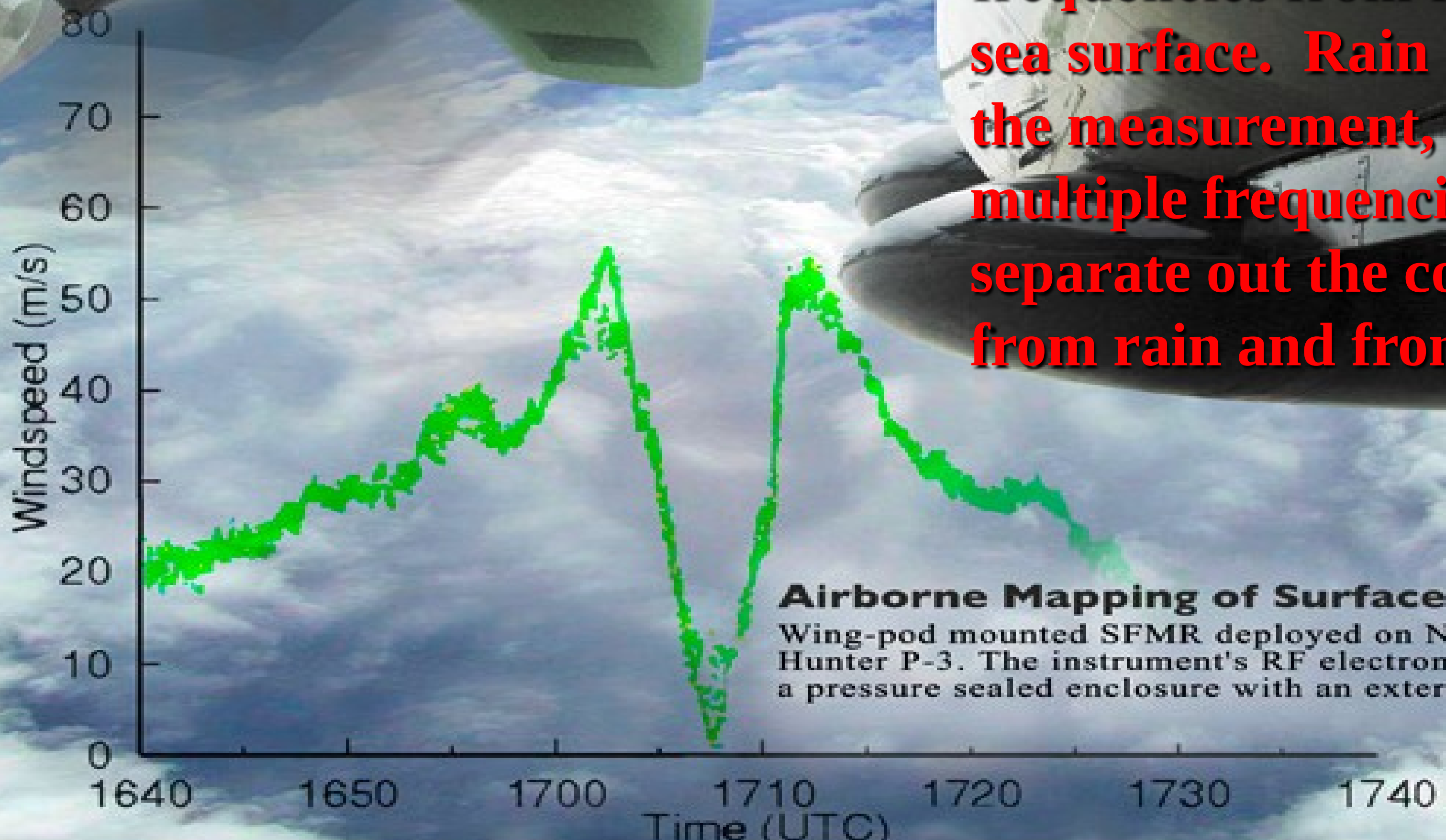
Interpreting Operational Dropsondes

- Spot surface wind was 64 kt
- MBL wind of 73 kt adjusts to 58 kt sfc-equivalent.
- WL150 wind of 67 kt at 75 m adjusts to 56 kt sfc-equivalent.
- Upward kink of WS at surface strongly argues that the 64 kt sfc wind represented a gust.



STEPPED FREQUENCY MICROWAVE RADIOMETER

SFMR measures C-band microwave emission (brightness temperatures) in 6 frequencies from foam on the sea surface. Rain also affects the measurement, so you need multiple frequencies to separate out the contributions from rain and from wind.



SFMR Algorithm

SFMR Measured T_Bs

Minimize Error in Fit Across 6 Frequencies

Wind Speed and Rain Rate

Compute Modeled T_B

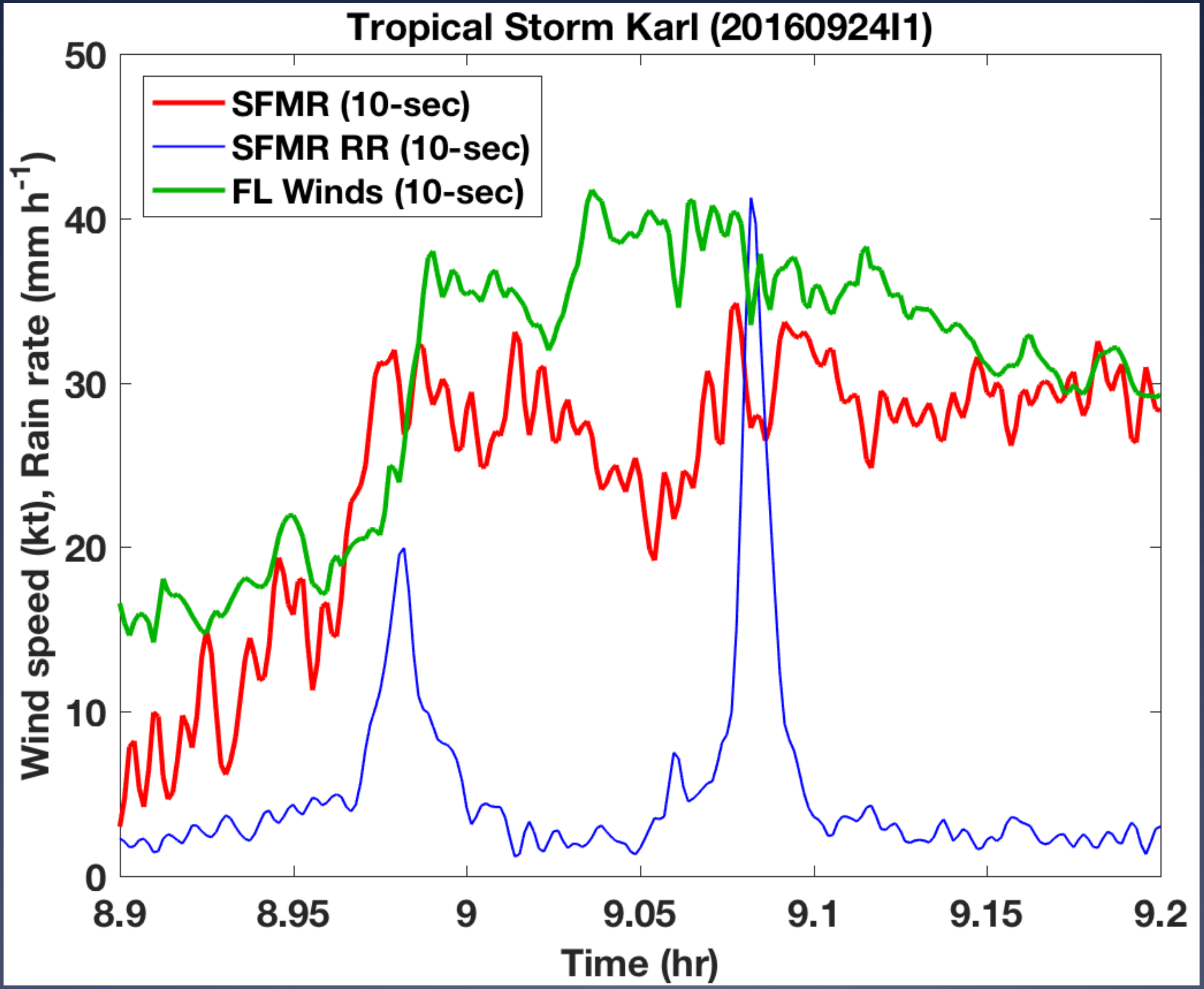
Wind-Induced Emissivity Curve

Air Temperature, Salinity, Altitude, Roll Angle, SST (satellite)

Wind Speed and Rain Rate Guess

Slide courtesy Dr. Heather Holbach

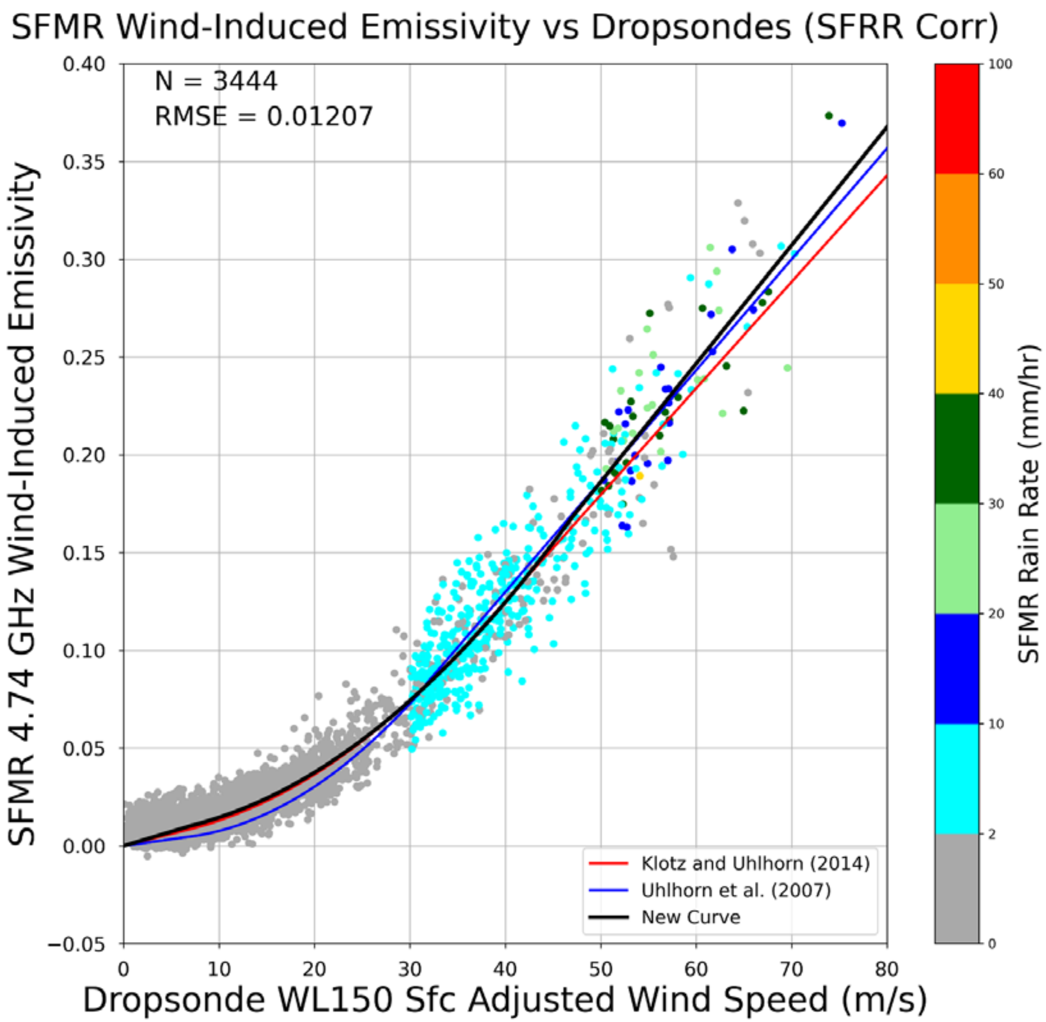
SFMR Horizontal Profiles of Surface WS amd RR



SFMR issues

- Shoaling – breaking waves in areas of shallow water can artificially increase the SFMR retrieved wind and invalidate the observations. Begins to be an issue when water depth less than 30 m.
- At lower wind speeds (<50 kt), it's harder to separate the wind and rain contributions to the measured brightness temperature.
- Ground truth (dropsondes) to calibrate the SFMR are limited in high winds. As the intercomparison dataset grows, the calibration changes. Frequent changes to the operational calibration (emissivity curve) have been frustrating for forecasters, and current operational calibration at very high wind speeds (mainly >120 kt) appears to be in error.

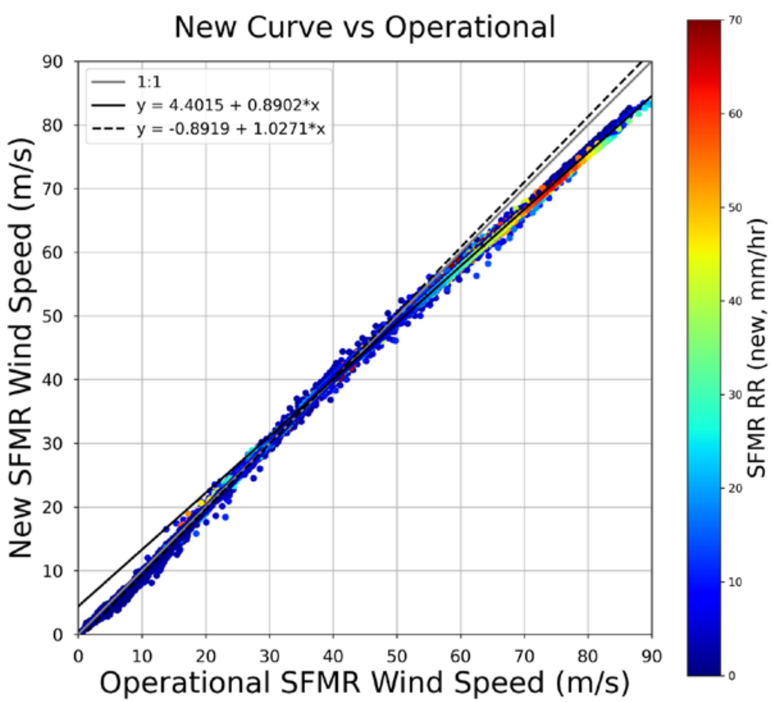
Updating the Wind-Induced Emissivity Curve



Using SFMR rain rate

Slide courtesy Dr. Heather Holbach

Preliminary Recommended Wind Speed Adjustments to Operational SFMR Data



Operational (m/s)	Revised (m/s)
40	40.0
45	44.5
50	48.9
55	53.4
60	57.8
65	62.3
70	66.7
75	71.2
80	75.6
85	80.1
90	84.5

Operational (kt)	Revised (kt)
75	75.3
80	79.8
85	84.2
90	88.7
95	93.1
100	97.6
105	102.0
110	106.5
115	110.9
120	115.4
125	119.8
130	124.3
135	128.7
140	133.2
145	137.6
150	142.1
155	146.5
160	151.0
165	155.4
170	159.9
175	164.3
180	168.8

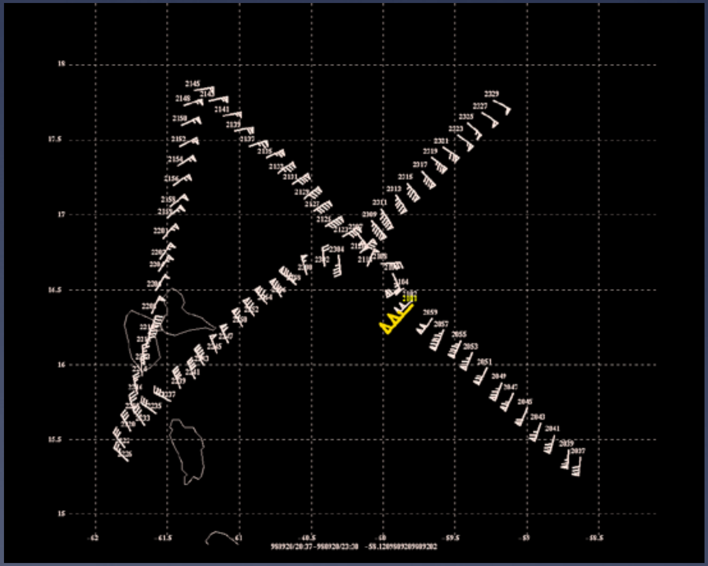
Recommended adjustments for 2022 likely to be close to what's shown here.

Slide courtesy Dr. Heather Holbach

Vortex Data Message (VDM)

```
URNT12 KNHC 241133
VORTEX DATA MESSAGE   AL162016
A. 24/11:12:50Z
B. 10.97 deg N 082.77 deg W
C. 700 mb 2927 m
D. 977 mb
E. 210 deg 11 kt
F. CLOSED
G. C20
H. 90 kt
I. 144 deg 5 nm 11:07:00Z
J. 253 deg 78 kt
K. 158 deg 8 nm 11:07:30Z
L. 95 kt
M. 314 deg 5 nm 11:17:00Z
N. 033 deg 108 kt
O. 349 deg 14 nm 11:17:30Z
P. 10 C / 3042 m
Q. 18 C / 3045 m
R. NA / NA
S. 12345 / 7
T. 0.02 / 1 nm
U. AF301 0616A OTTO OB 13
MAX FL WIND 108 KT 349 / 14 NM 11:17:00Z
```

The vortex message is a short, alphanumeric transmission summarizing the key findings from a reconnaissance aircraft's passage through the center of a tropical cyclone.



VDM Elements

URNT12 KNHC 241133	
VORTEX DATA MESSAGE AL162016	
A. 24/11:12:50Z	A. Date and time of fix
B. 10.97 deg N 082.77 deg W	B. Lat/Lon of center position
C. 700 mb 2927 m	C. Minimum height at standard pressure level
D. 977 mb	D. Minimum sea-level pressure
E. 210 deg 11 kt	E. Surface wind from center dropwindsonde
F. CLOSED	F. Eye characteristic
G. C20	G. Eye shape/orientation/diameter
H. 90 kt	H. Maximum inbound observed surface wind
I. 144 deg 5 nm 11:07:00Z	I. Bearing, range, and time of (H).
J. 253 deg 78 kt	J. Maximum inbound observed FL wind
K. 158 deg 8 nm 11:07:30Z	K. Bearing, range, and time of (J).
L. 95 kt	L. Maximum outbound observed surface wind
M. 314 deg 5 nm 11:17:00Z	M. Bearing, range, and time of (L).
N. 033 deg 108 kt	N. Maximum outbound observed FL wind.
O. 349 deg 14 nm 11:17:30Z	O. Bearing, range, and time of (N).
P. 10 C / 3042 m	P. Max FL T/PA observed outside of eye.
Q. 18 C / 3045 m	Q. Max FL T/PA observed inside the eye.
R. NA / NA	R. TD/SST observed inside the eye.
S. 12345 / 7	S. Fix determined by…
T. 0.02 / 1 nm	T. Fix accuracy (navigational, meteorological)
U. AF301 0616A OTTO OB 13	U. AC ID, mission ID, storm name, ob number
MAX FL WIND 108 KT 349 / 14 NM 11:17:00Z	Remarks, including max FL wind from most recent passes through each octant

https://www.icams-portal.gov/publications/nhop/2020_nhop.pdf

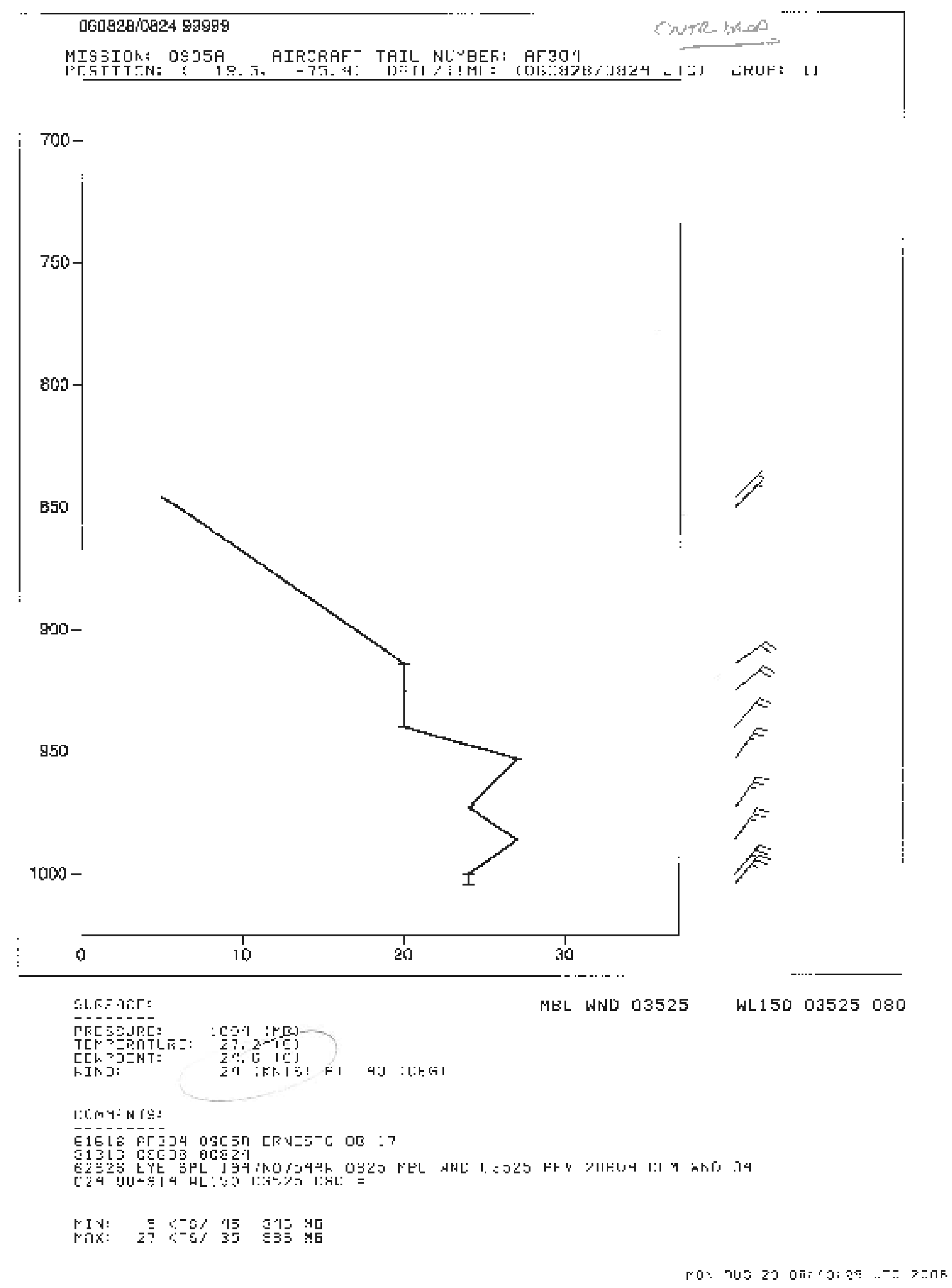
Center (eye) drops are released at the flight-level wind minimum, but may drift away from surface minimum.

Rule of thumb for estimating cyclone MSLP is to subtract 1 mb from the sonde splash pressure for each full 10 kt of surface wind reported by the sonde.

Splash pressure 1004 mb.

Surface wind: 24 kt.

Estimated MSLP = 1002 mb.



HDOBS Message Format

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

```
URNT15 KNHC 281426
AF302 1712A KATRINA               HDOB 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
.
.
.
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 and positioning parameters are instantaneous values

Meteorological parameters are 30 s averages except as noted.

10-s averages

Time (UTC)

Lat & Lon

Static pressure at flight level ddd.d

Geopotential height (m)

Pressure >= 550 mb: extrapolated surface pressure (tenths of mb)

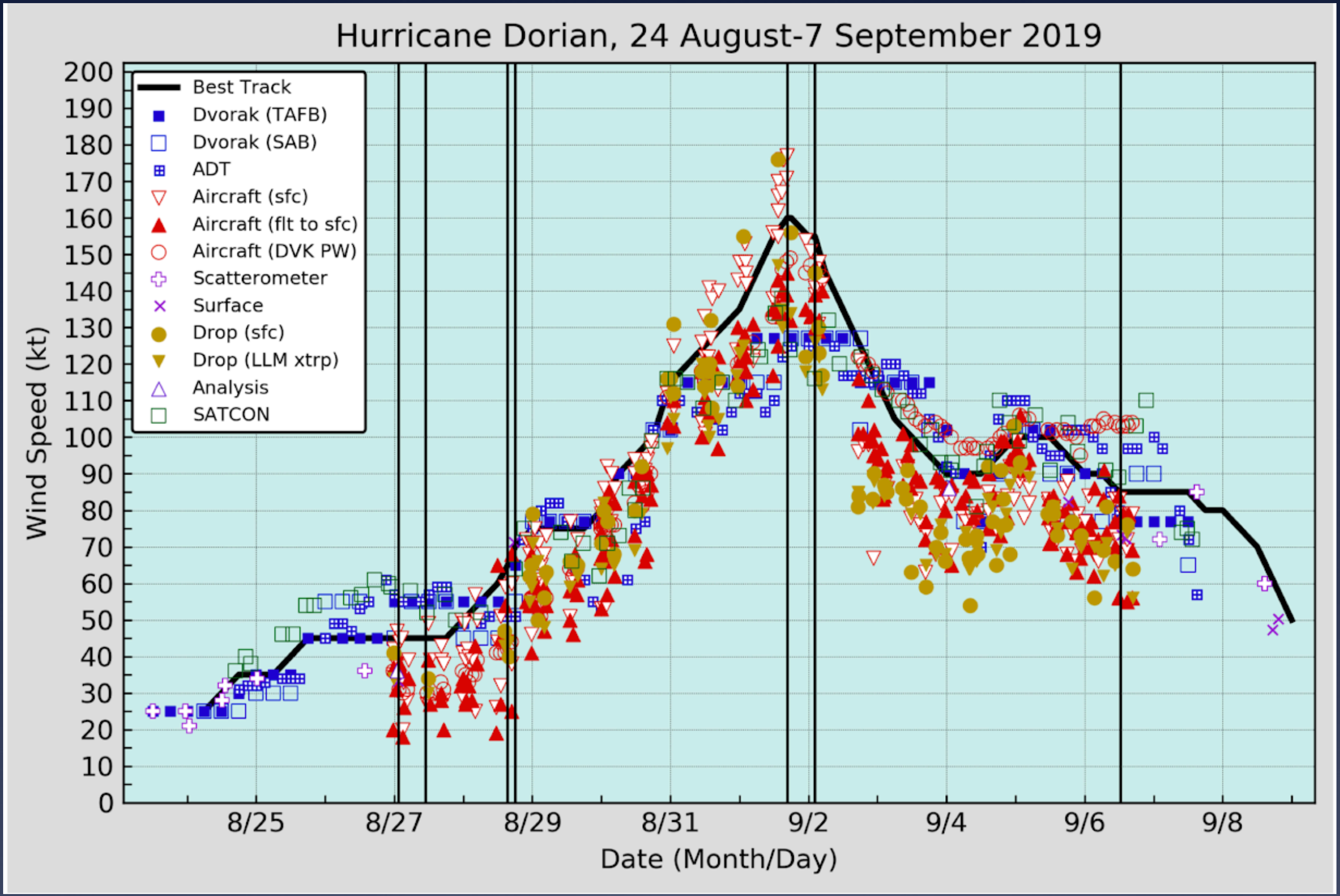
Pressure < 550 mb: D-value (m)

<u>Thermodynamic block:</u> Temp and dwpt

<u>Wind block:</u> direction, flt-level wind, MAX flt-level wind (10 second) and SFMR sfc wind (10 second)

SFMR rain rate

Data flags



Mismatches between FL, SFMR, dropsonde, and satellite data for estimating intensity are frequently in conflict.

Note the excellent agreement on 8/29 and 8/30, but beginning on 8/31 the spot surface dropsondes and SFMR observations were much higher than the WL150, FL, or satellite intensity estimates.

Intensity/Observation Challenges

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

Closing Thoughts

- All reconnaissance observations have limitations that complicate interpretation. Specialist attempts to blend data in an intelligent manner that recognizes the strengths and weaknesses of each data source.
  - For example, we still use flight-level winds even though we have the SFMR.
- 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).