

Use of Aircraft Data at the National Hurricane Center

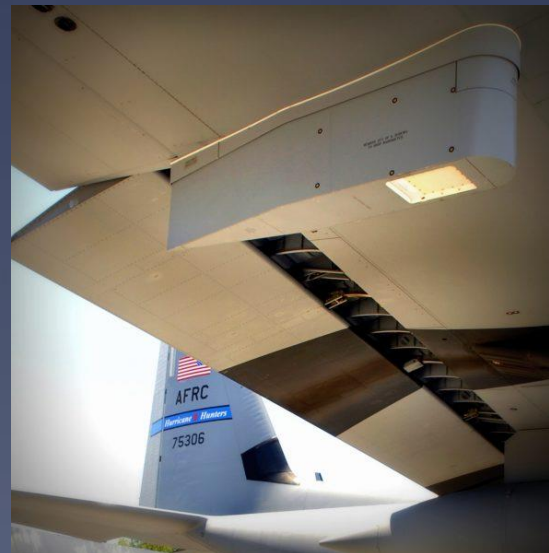
James L. Franklin

WMO RA-IV Workshop
April 2021



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

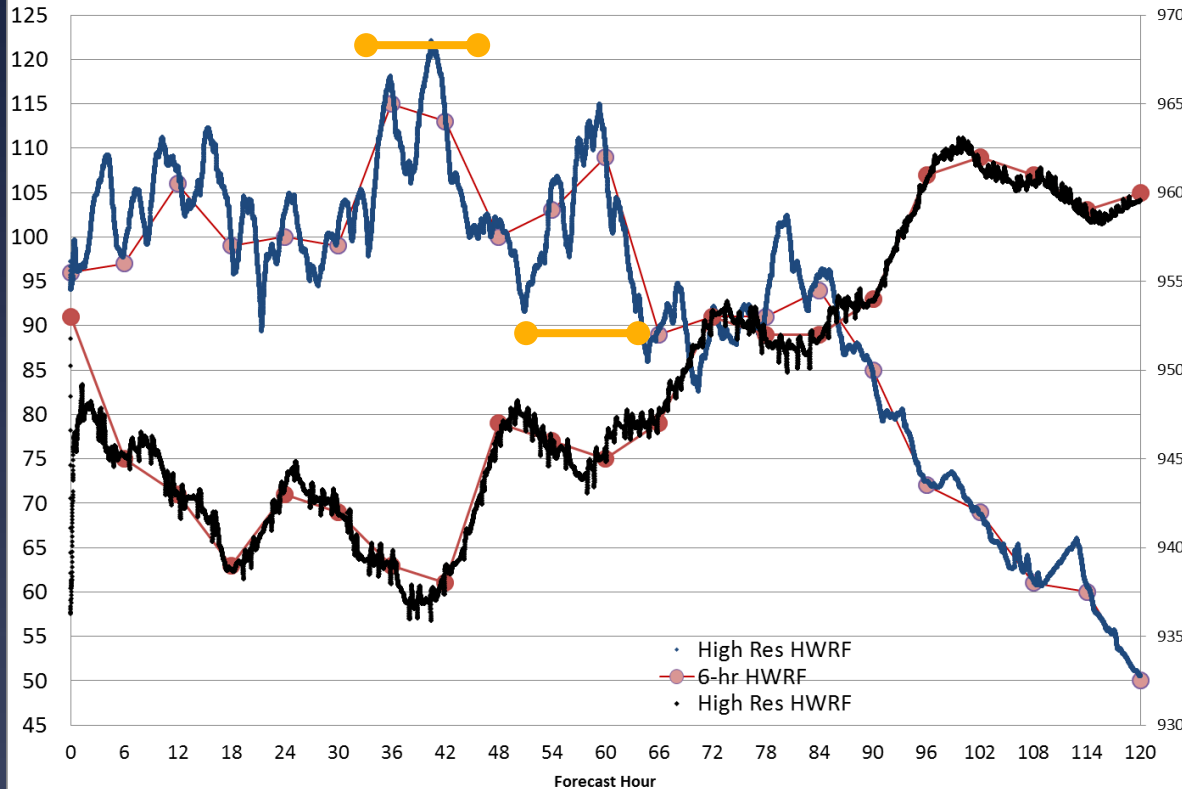
- * Can be used subjectively by the Hurricane Specialists (HS)
 - * Assist in the analysis and short-term forecasting of location, intensity, size, structure of the cyclone/disturbance.
- * Provide input to forecast models
 - * Directly (e.g., direct assimilation of dropsondes released outside the core 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.

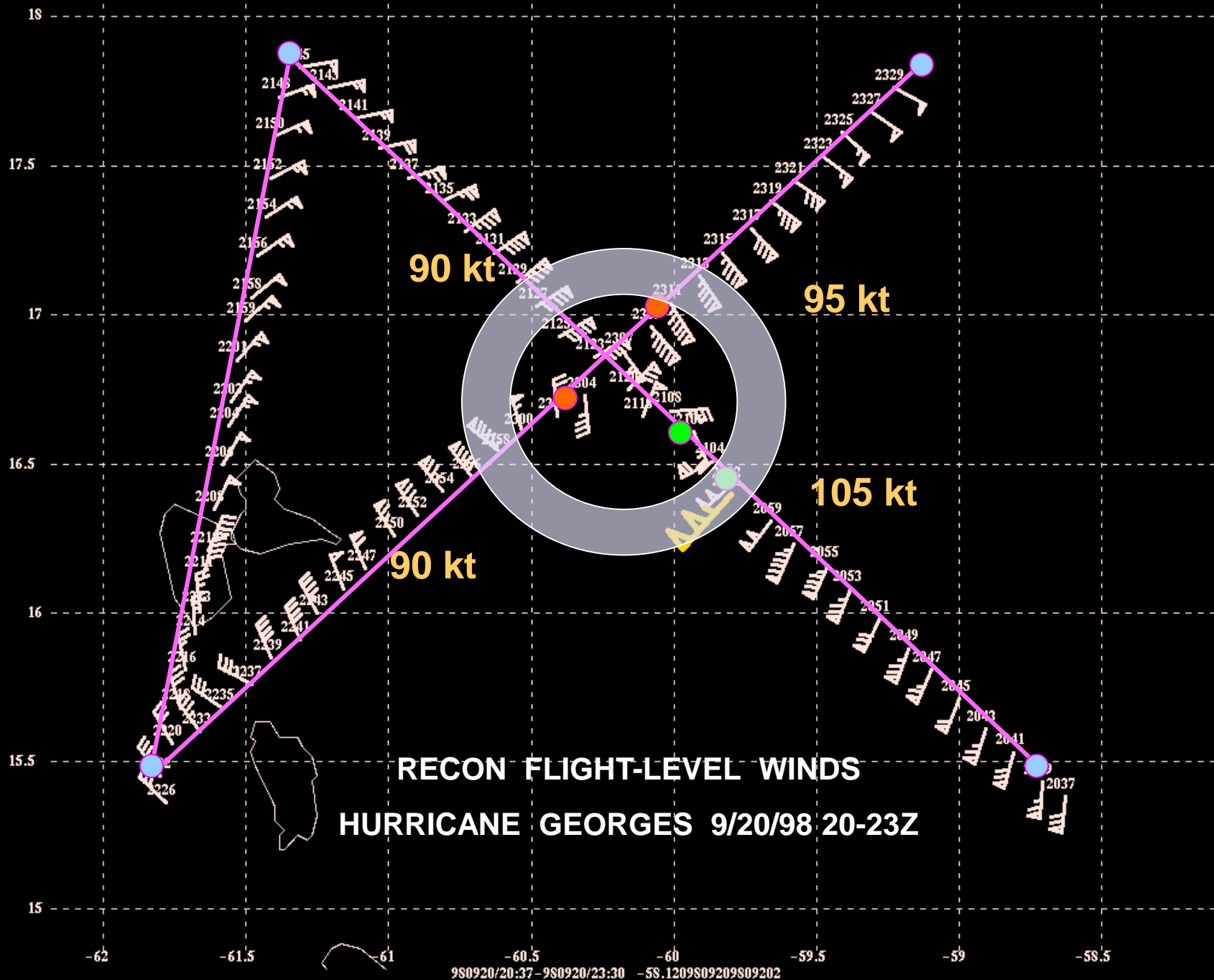
Representative Intensity

Earl: August 30, 12UTC HWRF max wind and pressure forecast

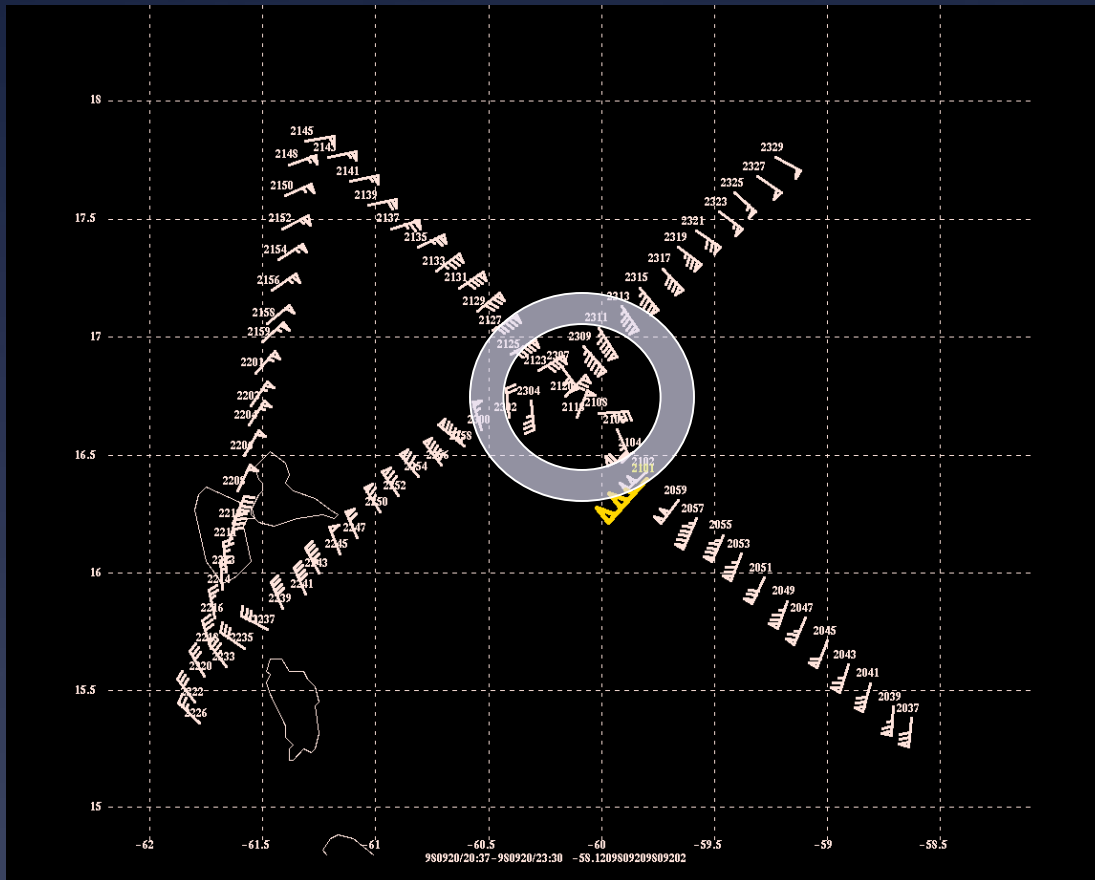


Peak winds in a model TC can vary widely over periods of a few hours. Tracking these rapid changes for real storms is neither possible nor desirable.

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.



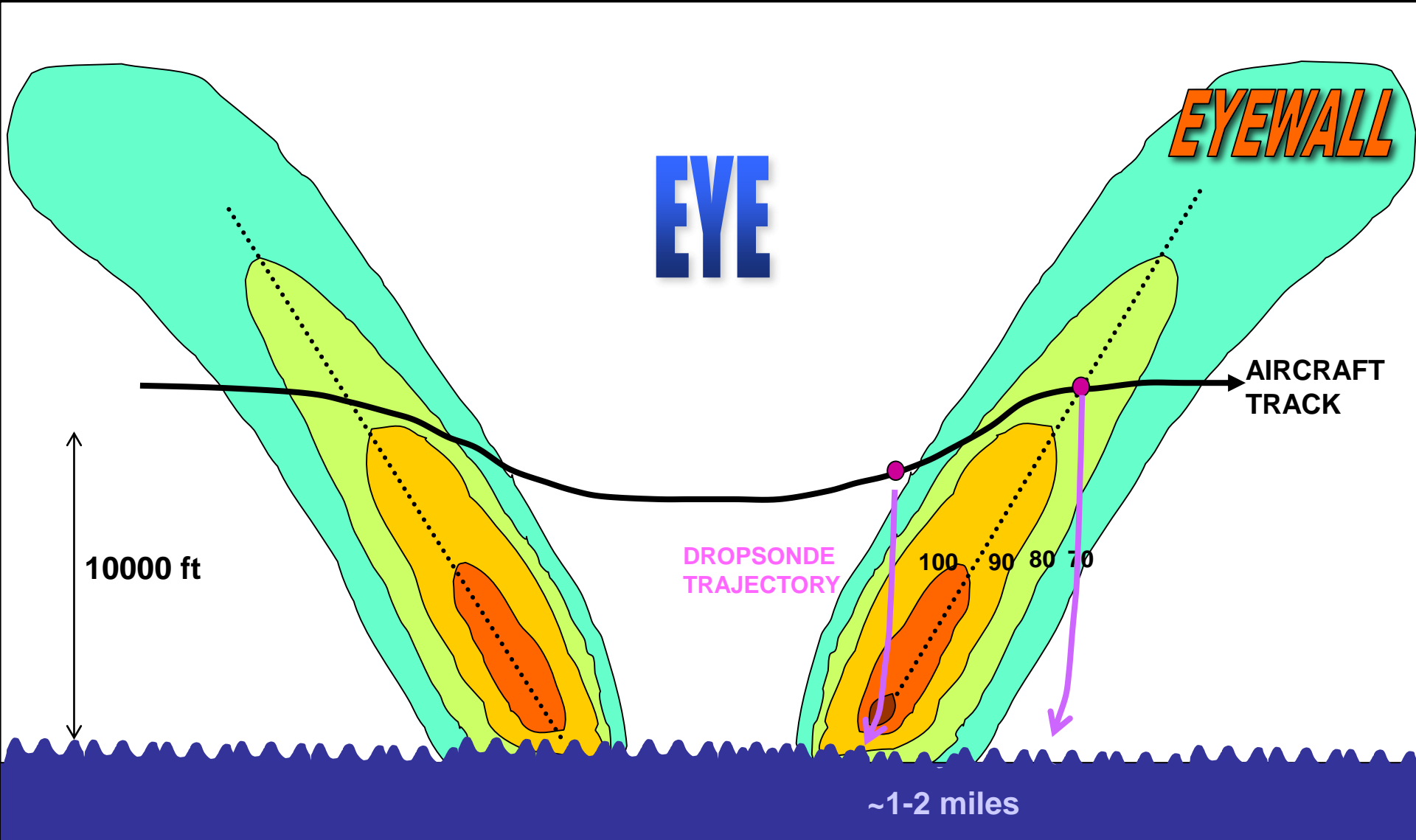
Sampling Limitations



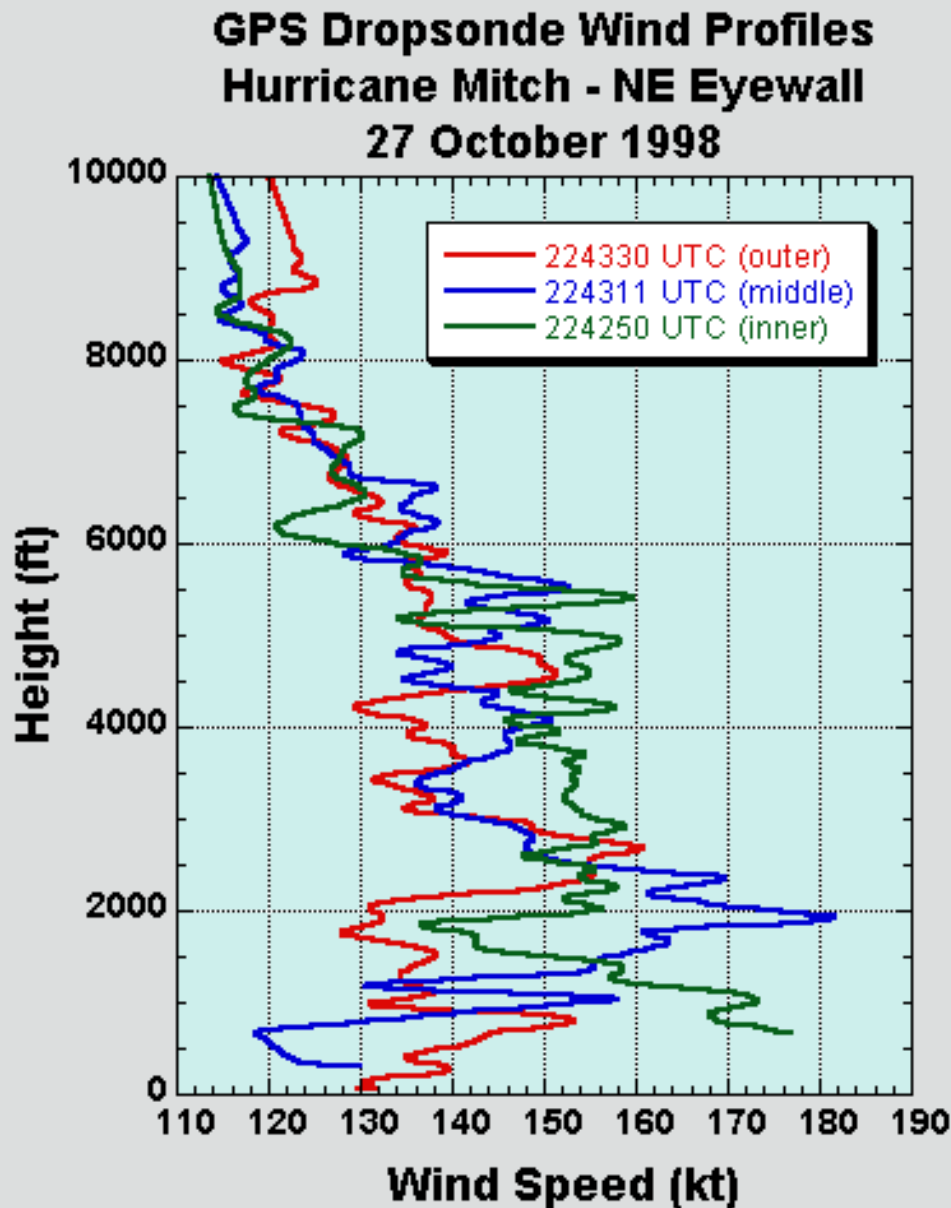
Peak winds in the hurricane eyewall may occur in a band only a few km across, and be located anywhere azimuthally in an eyewall that is sampled only at four locations over a period of 1.5 hr.

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

Representativeness of Dropsondes



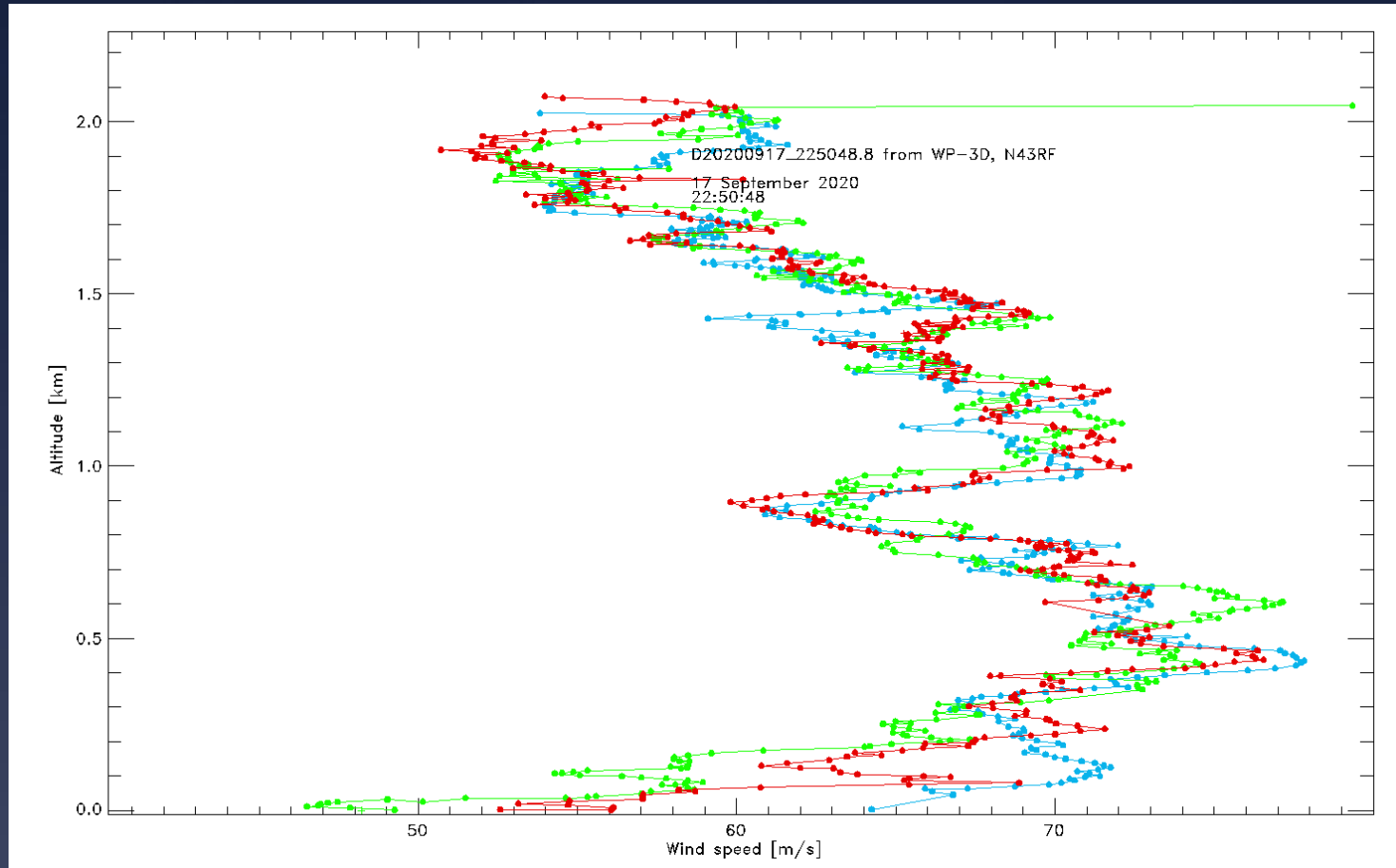
Small-scale Variability in a Tropical Cyclone



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.**

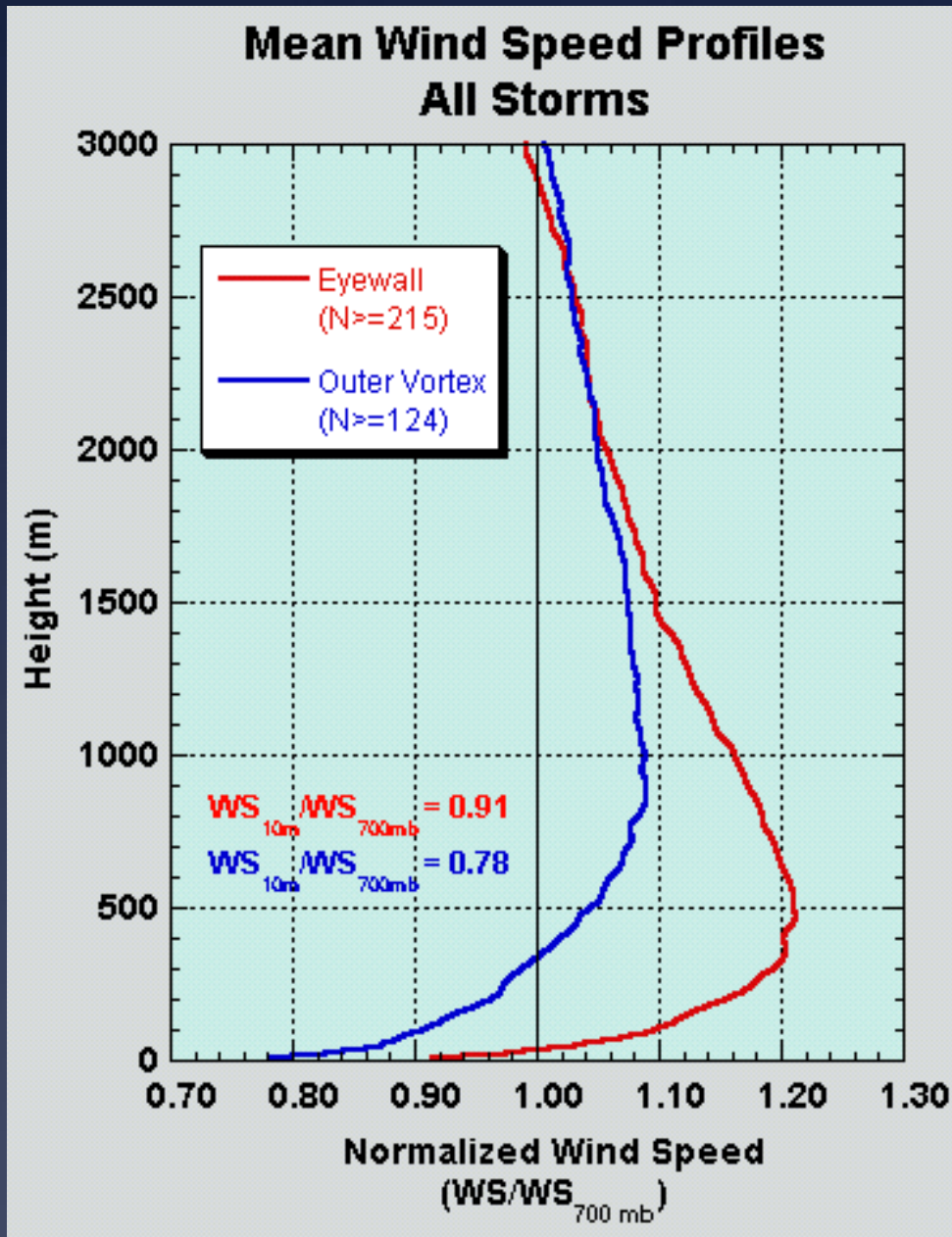
Individual GPS dropsonde winds represent a sampling period of < 1 second.

Small-scale Variability in a Tropical Cyclone



Three simultaneous dropsondes released in Hurricane Teddy 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.

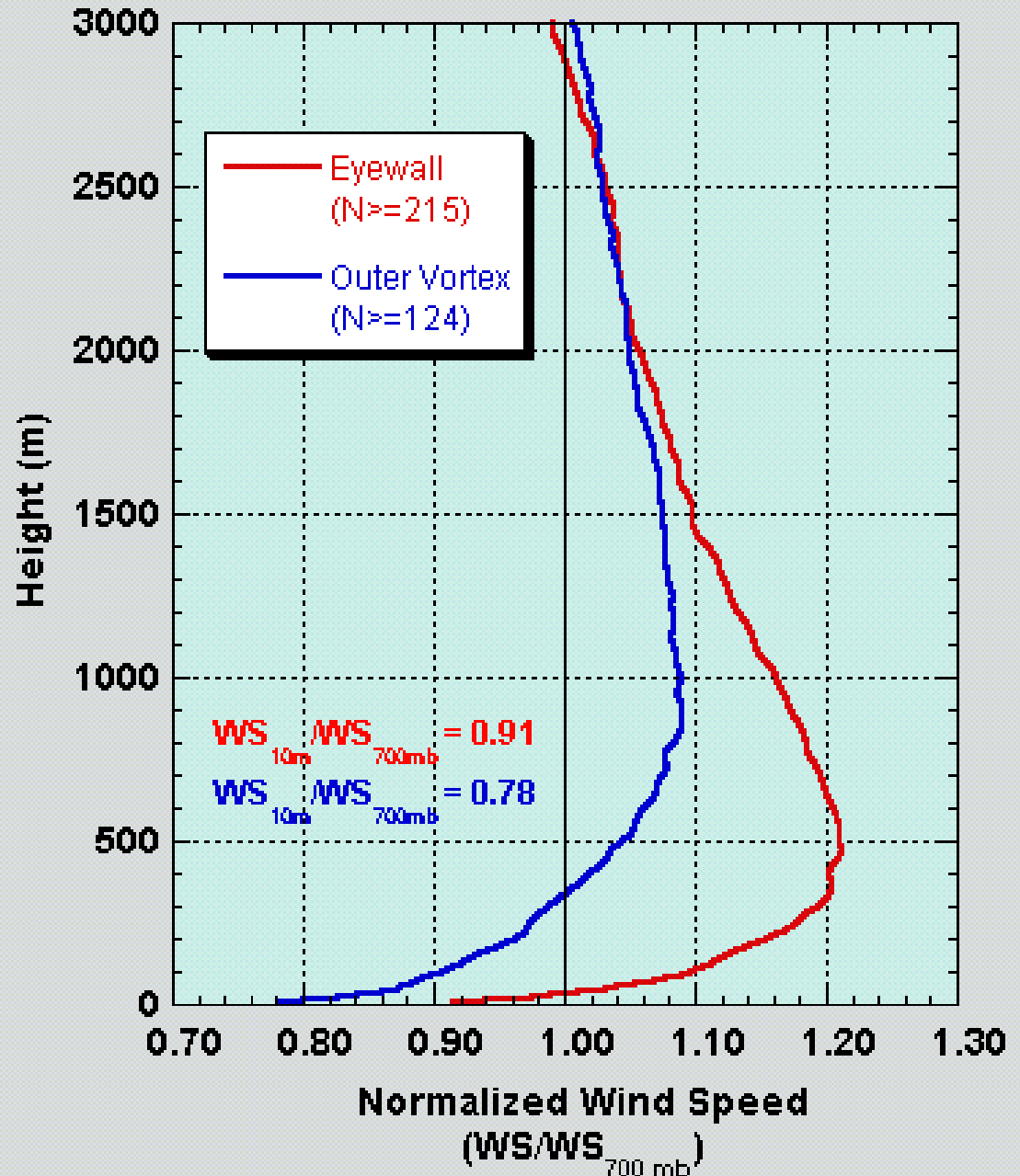
- FL winds to surface
- Low-level dropsonde layer means to surface

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.

Mean Wind Speed Profiles All Storms

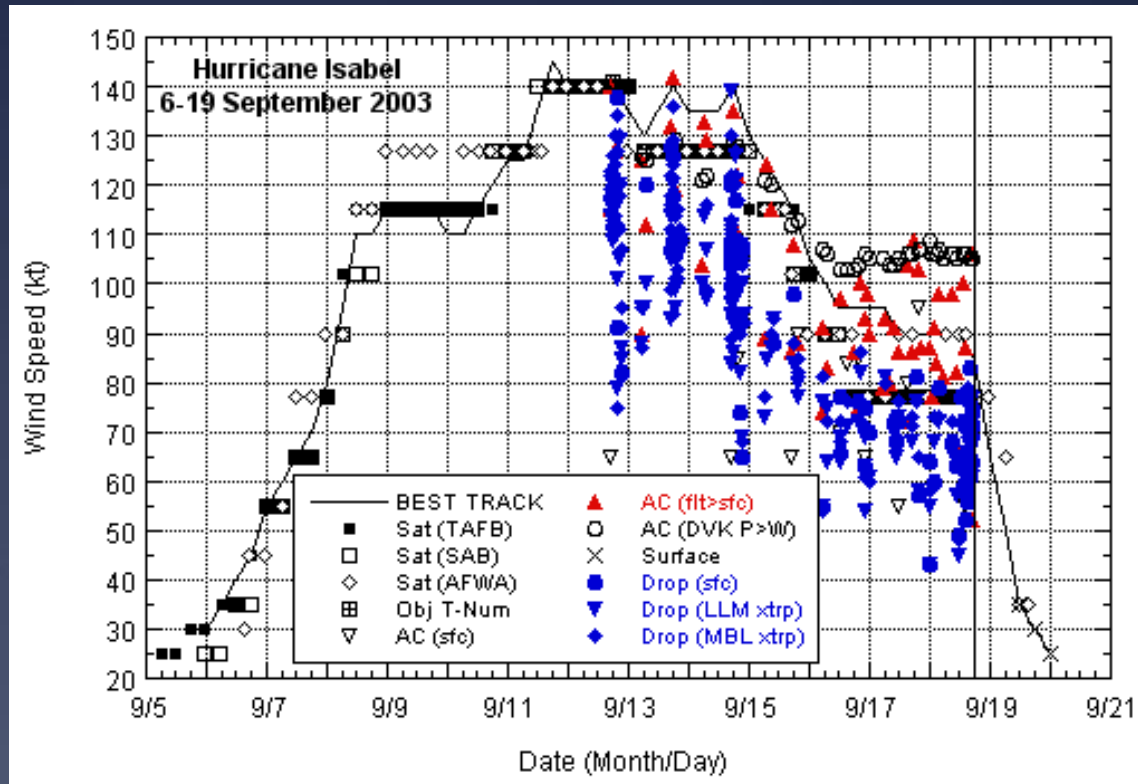


Estimating Intensity From Peak Flight-Level Wind

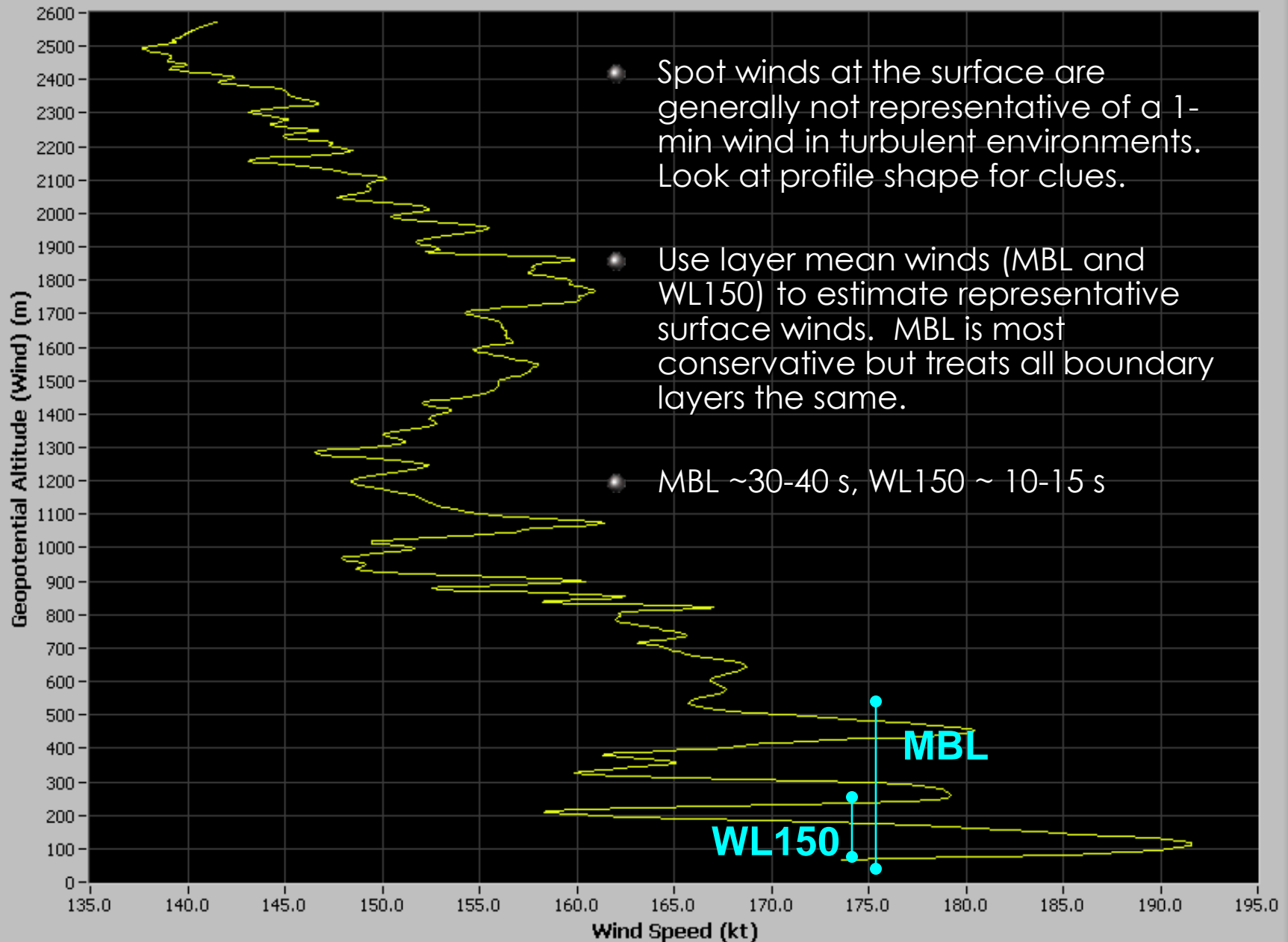
| Reference Level | Adjustment Factor |
|-----------------|-------------------|
| 700 mb | 90% |
| 850 mb | 80% |
| 925 mb | 75% |
| 1000 ft | 80% |

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



TEMP-DROP message and EYEWALL WINDS

UZNT13 KWBC 220345

```

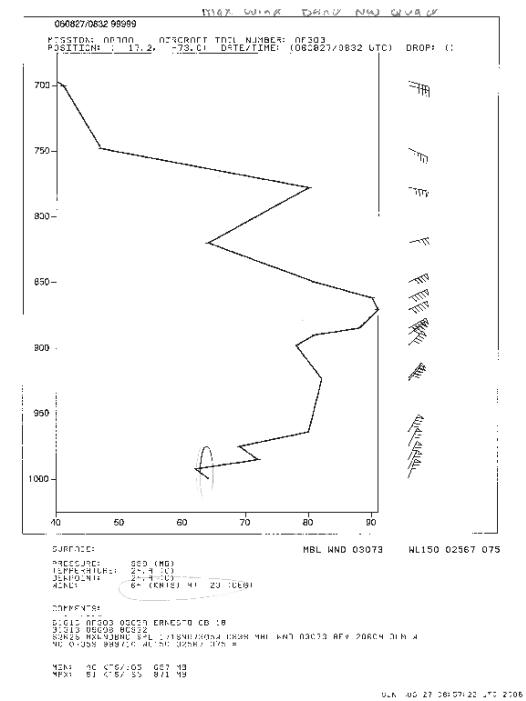
XXAA 72037 99253 70951 08255 99959 25401 ///// 00867 ///// /////
92322 23204 08646 85060 20408 11120 70/// ///// 15091 88999 77999
61616 AF963 0202A BRET OB 10
62626 EYEWALL 045 SPL 2532N09528W WL150 07136 121 DLM WND 11615 6
96955 MBL WND 08141 LST WND 046=
XXBB 72038 99253 70951 08255 00959 25401 11947 24600 22713 14816
33710 148//

```

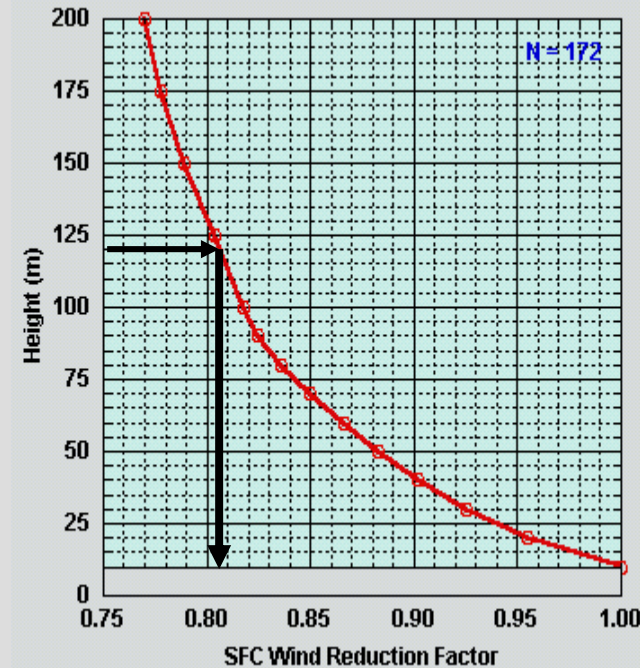
```
21212 00959 /////  
55945 07649 66941 07135 77940 07633 88937 08142 99931 08653 11926  
08647 22921 08650 33912 09139 44910 09141 55907 09655 66904 09655  
77898 09635 88891 10142 99885 10637 11881 10624 22874 11135 33868  
11123 44753 13619 55696 15087  
31313 09608 80328
```

```
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.

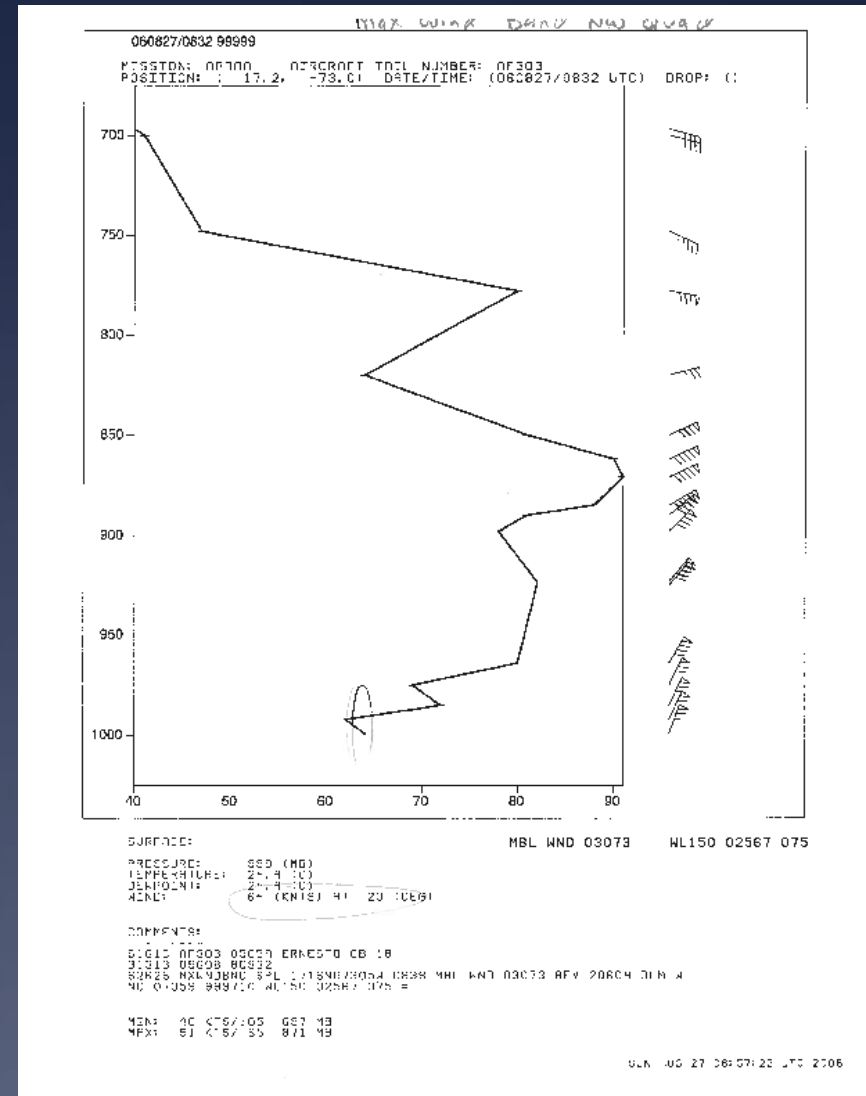


Eyewall Low-Level Wind Reduction Factors



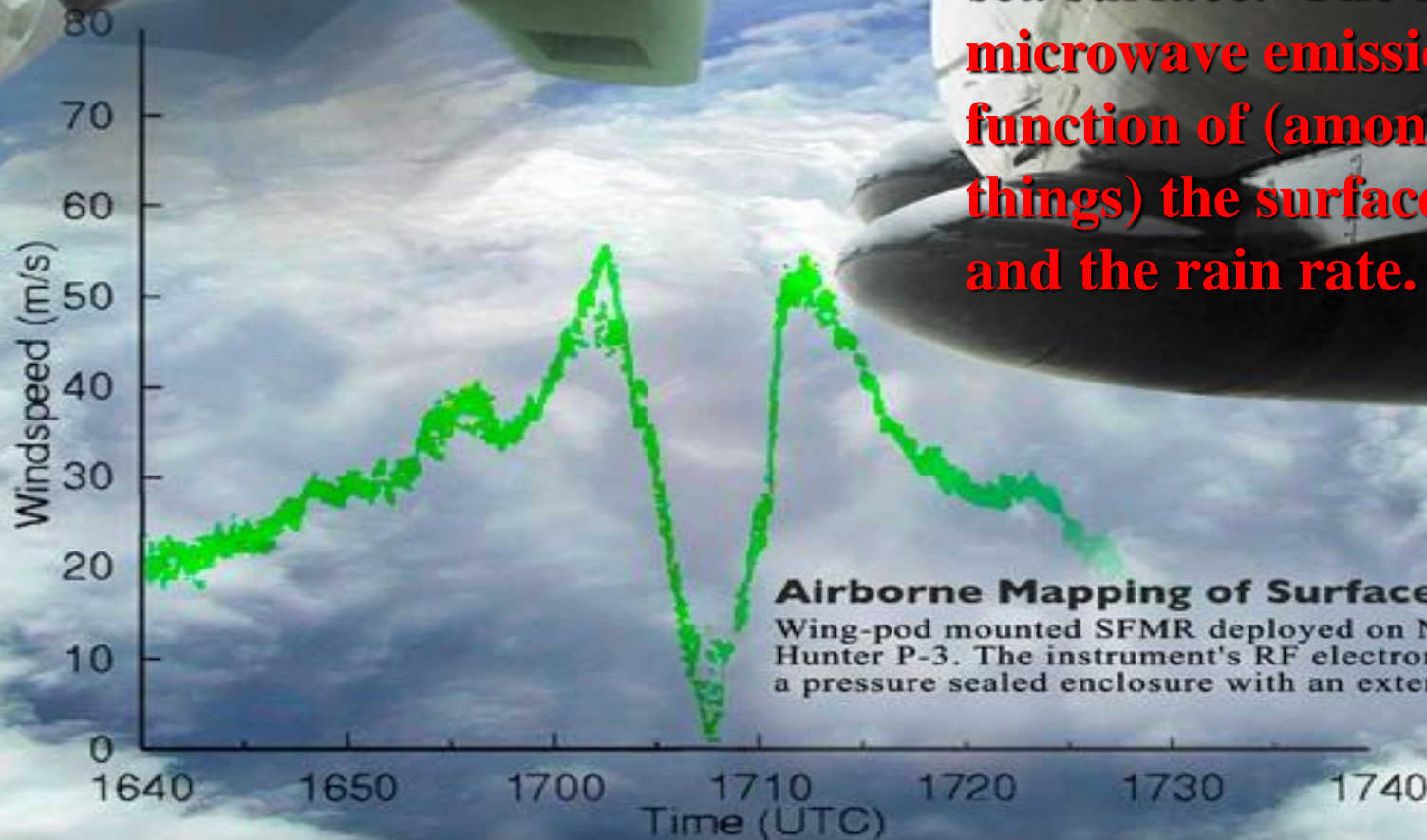
Interpreting Operational Dropsondes

- * 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.

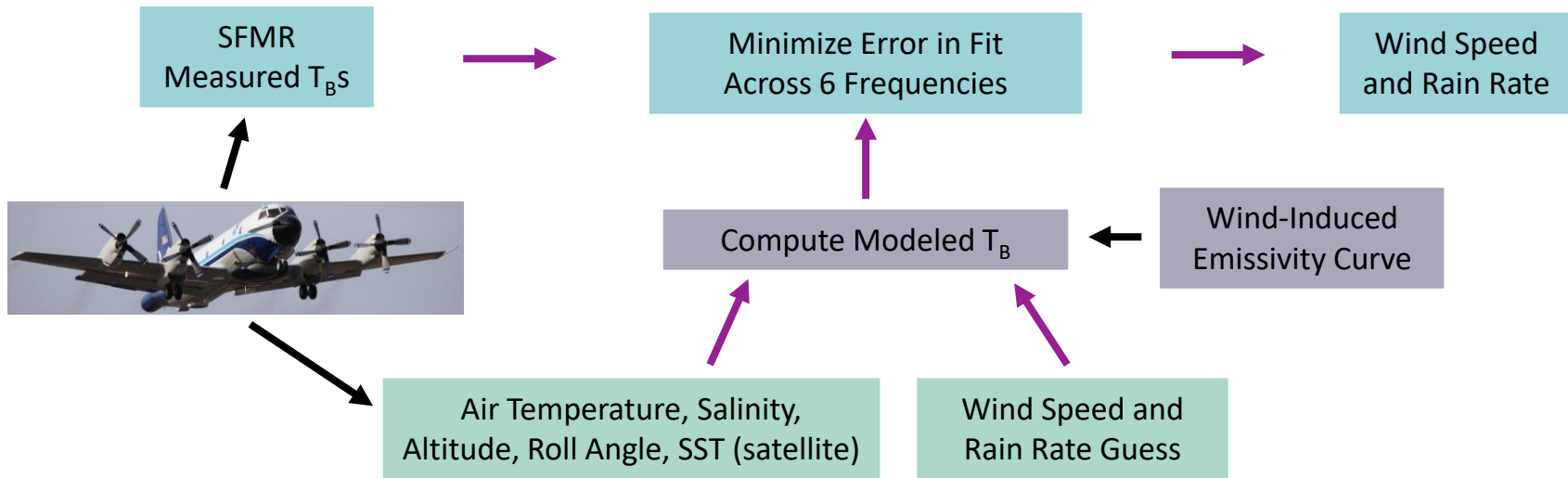


STEPPED FREQUENCY MICROWAVE RADIOMETER

SFMR measures C-band microwave emission 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.

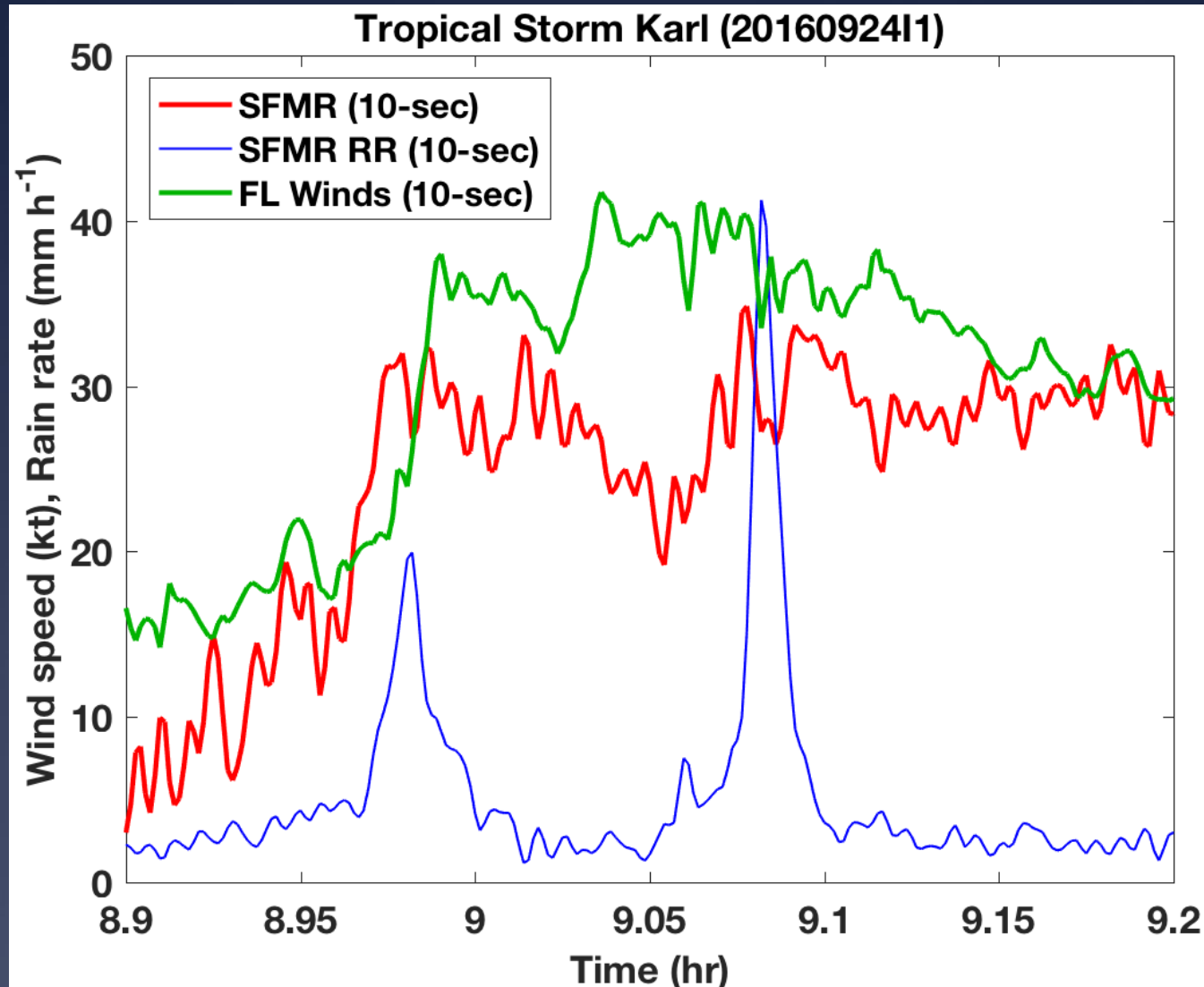


SFMR Algorithm



Slide courtesy Dr. Heather Holbach

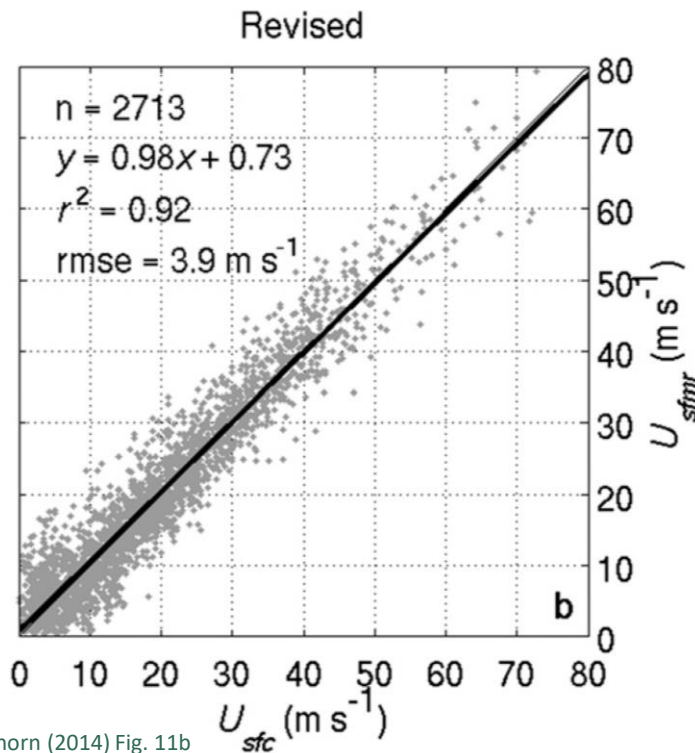
SFMR Horizontal Profiles of Surface WS and RR



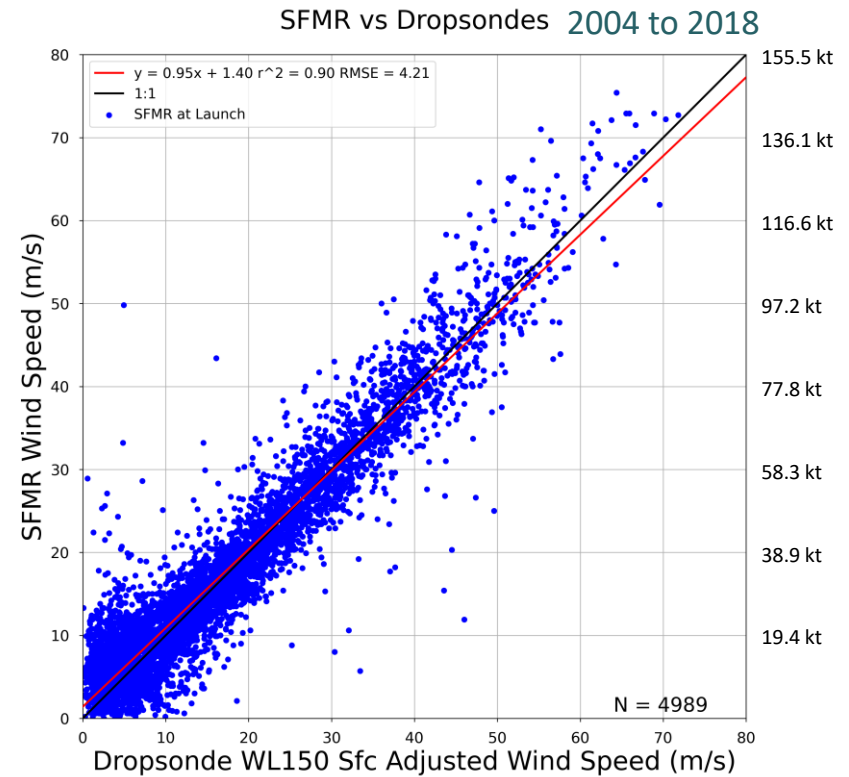
SFMR issues

- * 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.
- * Frequent changes to the operational calibration (emissivity curve) have been frustrating for forecasters, and latest calibration at very high wind speeds (mainly >120 kt) appears to be in error.

Current Wind Speed Fit



Klotz and Uhlhorn (2014) Fig. 11b



Slide courtesy Dr. Heather Holbach

Summary

- Increased dropsonde collocation time period from 2005–2012 (1513 sondes) to 2004–2018 (2390 sondes)
 - Collocations are with SFMR at time of dropsonde launch
 - Storm-relative collocations require more accurate surface storm center locations
- Modified rain rate and wind speed thresholds for inclusion into wind-induced emissivity curve derivation
- New curve results in reduced wind speeds above ~40 m/s (~77 kt)

40 m/s: ~0.6 m/s

50 m/s: ~2.2 m/s

60 m/s: ~4.3 m/s

70 m/s: ~6.5 m/s

80 m/s: ~9.0 m/s

80 kt: ~1.5 kt

100 kt: ~ 5.0 kt

120 kt: ~8.5 kt

140 kt: ~ 13.0 kt

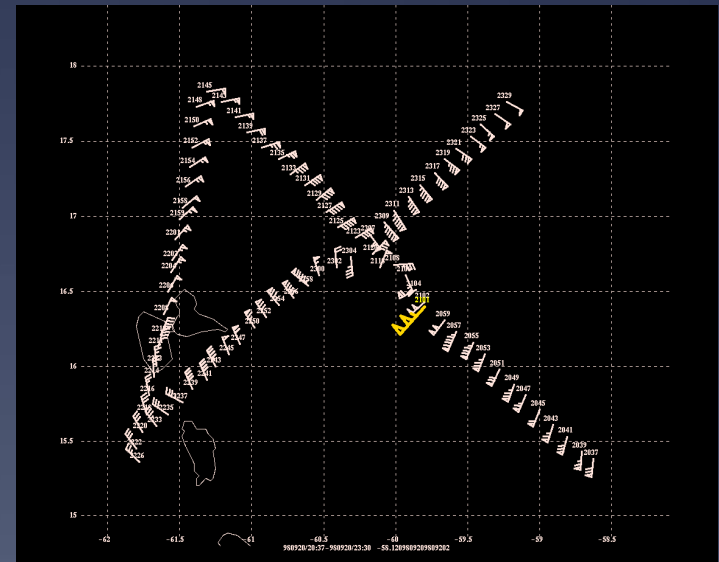
160 kt: ~18.0 kt

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
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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

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

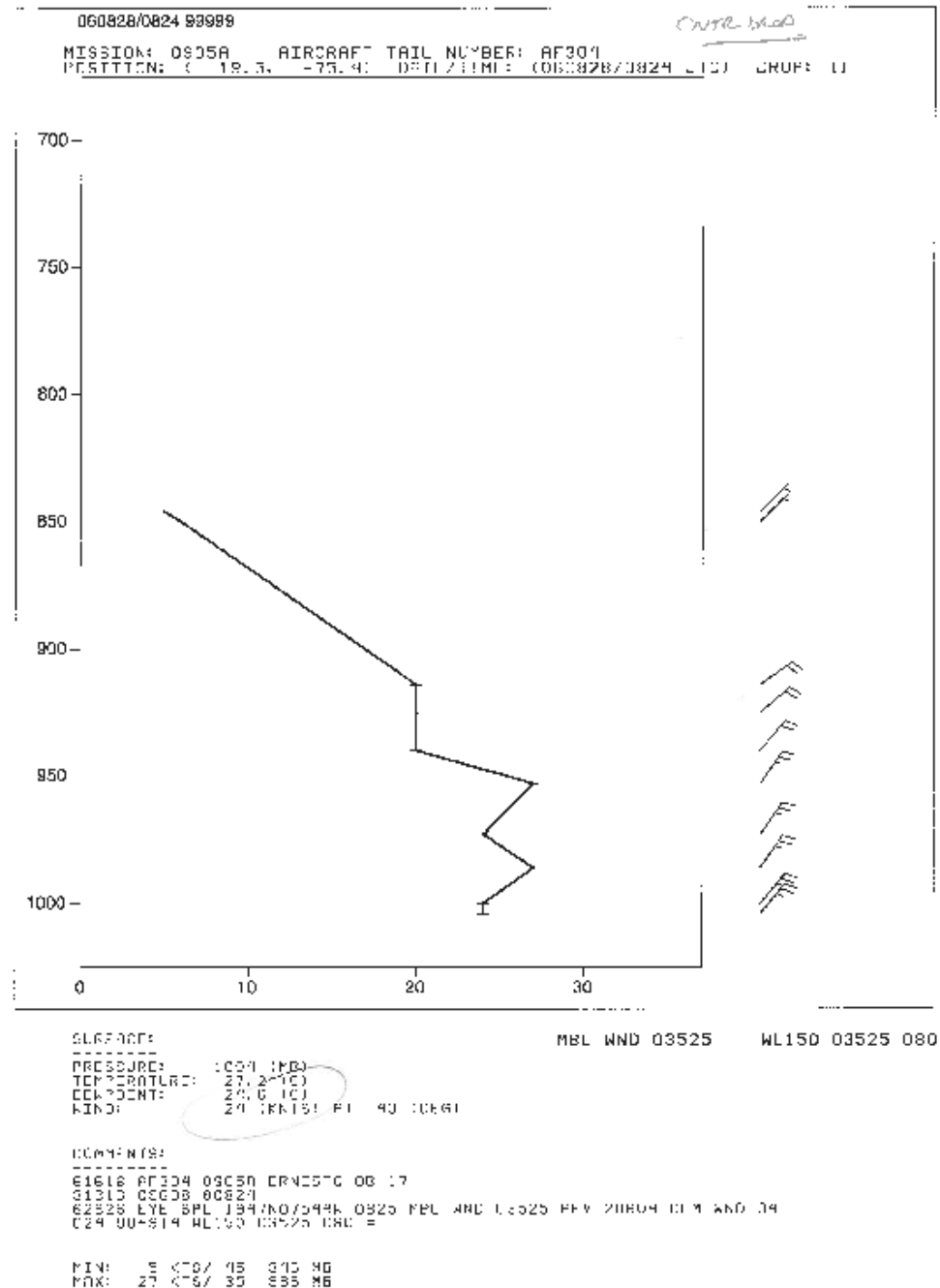
Center (eye) drops are released at the flight-level wind minimum, but may drift away from surface minimum.

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 |

.
Time and positioning parameters
are instantaneous values
.

Meteorological parameters are 10-s averages
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 |

\$\$

Lat & Lon

Geopotential
height (m)

Thermodynamic block:
Temp and dwpt

SFMR rain
rate

Data flags

Static pressure
at flight level
ddd.d

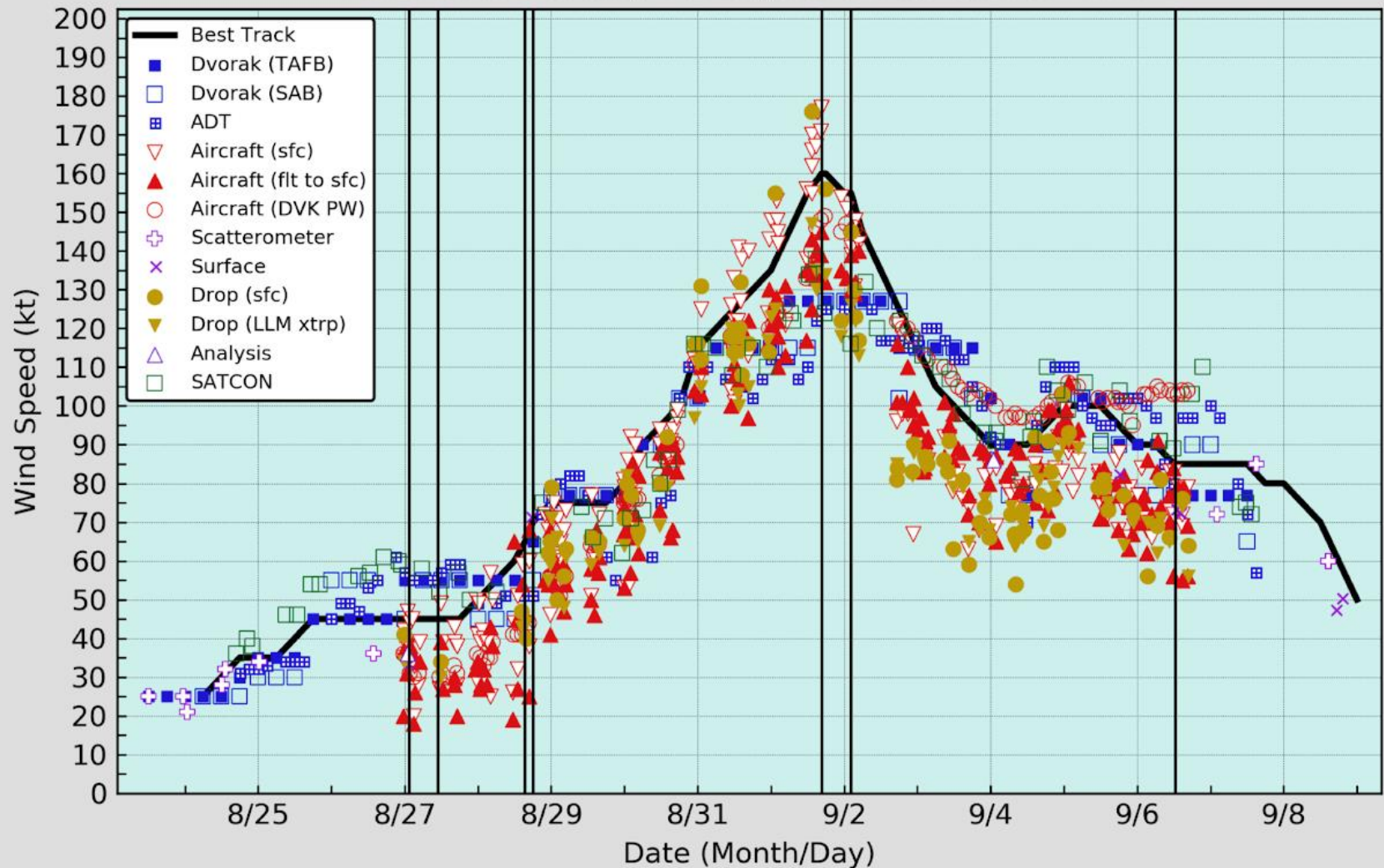
Pressure >= 550 mb: extrapolated
surface pressure (tenths of mb)

Pressure < 550 mb: D-value (m)

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

Time (UTC)

Hurricane Dorian, 24 August-7 September 2019



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 $\sim 10\%$ (e.g., 100 kt \pm 10 kt)
 - * TS wind radii to about $\sim 25\%$ (e.g., 120 nm \pm 30 nm).
 - * HU wind radii to about $\sim 40\%$ (e.g., 25 nm \pm 10 nm).