Use of Aircraft Data at the National Hurricane Center

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WMO RA-IV Workshop
20 March 2013

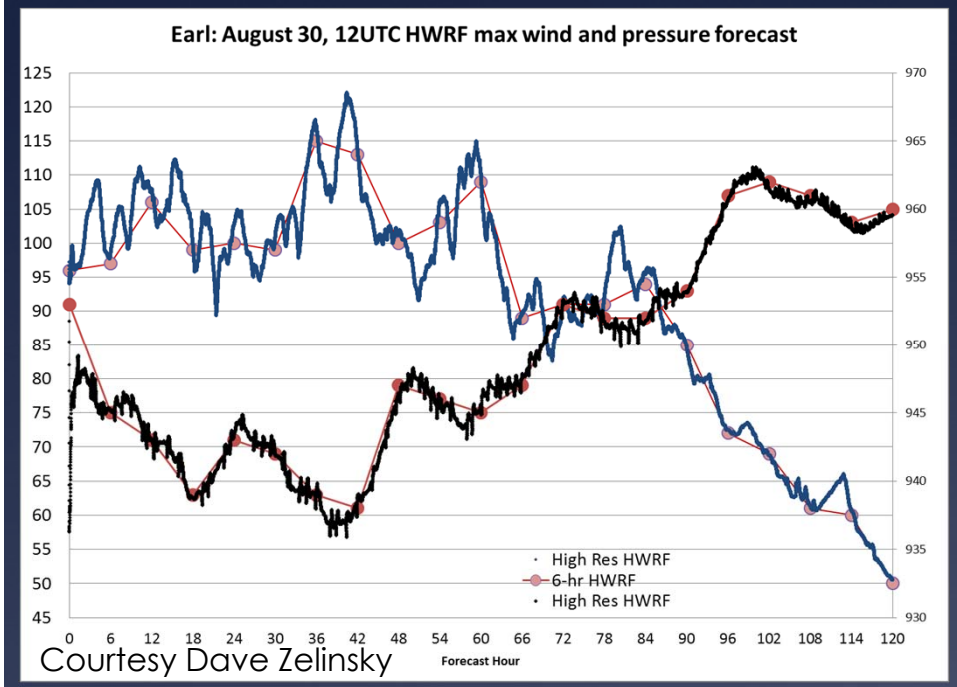
Aircraft Observations

- Flight-level observations, SFMR, dropwindsondes, and radar
- 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).
  - Indirectly to both dynamical and statistical models, through HS specification of the storm "compute" parameters (e.g., MSLP, RMW, Vmax, 34/50/64 kt radii)
- Best Track analysis

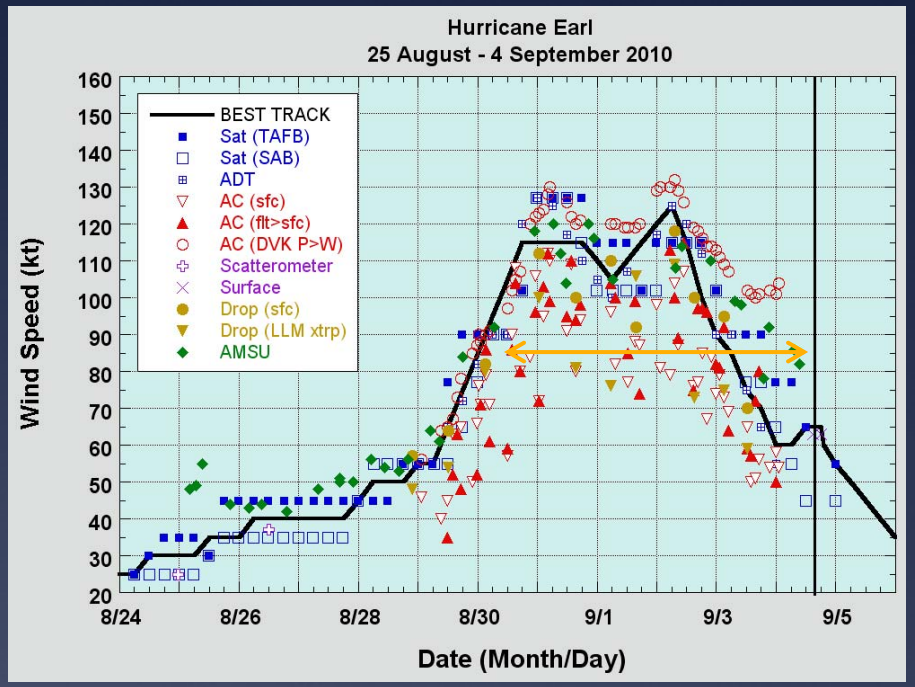
Tropical Cyclone Intensity

- 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

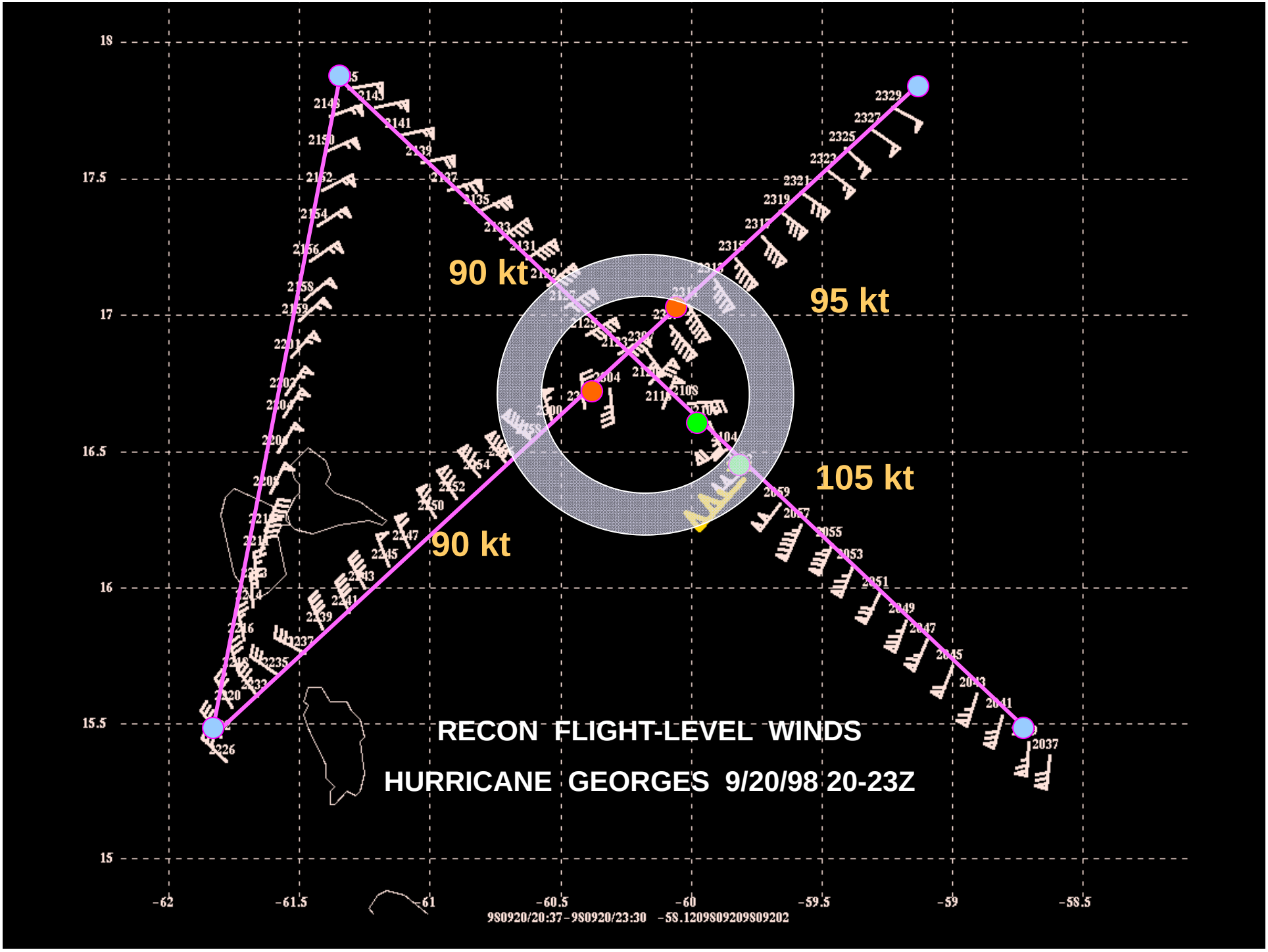


Courtesy Dave Zelinsky



Best Track: Six-hourly representative estimates of the cyclone's center position, maximum sustained (1-min average) surface (10-m) wind, minimum sea level pressure, and maximum extent of 34-, 50-, and 64-kt winds in each of four quadrants around the center.

Because features with wavelengths less than 4Δt (24 h) cannot be accurately depicted, NHC generally does not try to represent these scales in the best track. However, there is considerable interest in knowing the location/intensity at specific times (e.g., landfalls, peak intensity); these events we do try to include with some precision.


90 kt
95 kt
105 kt
90 kt
RECON FLIGHT-LEVEL WINDS
HURRICANE GEORGES 9/20/98 20-23Z
18
17.5
17
16.5
16
15.5
15
-62
-61.5
-61
-60.5
-60
-59.5
-59
-58.5
980920/20:37-980920/23:30 -58.1209809209809202

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
- Dropsondes
  - Temporal interpretation/representativeness
  - Point observations with severe sampling considerations

VORTEX MESSAGE FORMAT

```
URNT12 KNHC 292355
VORTEX DATA MESSAGE   AL182012
A. 29/23:35:40Z
B. 39 deg 18 min N
   074 deg 26 min W
C. 850 mb 909 m
D. 56 kt
E. 067 deg 32 nm
F. 160 deg 61 kt
G. 071 deg 36 nm
H. 948 mb
I. 15 C / 1521 m
J. 15 C / 1525 m
K. 13 C / NA
L. NA
M. NA
N. 1345 / 8
O. 0.02 / 3 nm
P. AF308 2418A SANDY                OB 27
MAX FL WIND 88 KT 180/37 20:27:30Z
MAX FL TEMP 17 C 083 / 9 NM FROM FL CNTR
36 NM INBOUND LEG
```

A. Date and time of center fix

B. Lat/Lon of fix (wind minimum/shift along track)

C. Min height (GA) of nearest standard level

D. Max sfc wind on inbound leg (SFMR)

E. Bearing/range of location of max sfc wind

F. Max flt-lvl wind on inbound leg

G. Bearing/range of location of max flt-lvl wind

H. MSLP (from drop or extrapolation – adjust if sonde splash winds exceed ~15 kt: 10 kt = 1 mb.)

I. Max flt-lvl temp outside core/PA

J. Max flt-lvl temp inside eye/PA

K. TD/SST inside eye

L. Eye character (e.g., CLOSED, OPEN SW, etc.)

M. Eye shape/orientation/diam (e.g, C8, E09/15/5)

N. Method of fix

O. Fix accuracy (navigation/meteorological)

P. Remarks. Include max wind since last time in the octant, how pressure obtained, displacement of sfc/flt-level center.

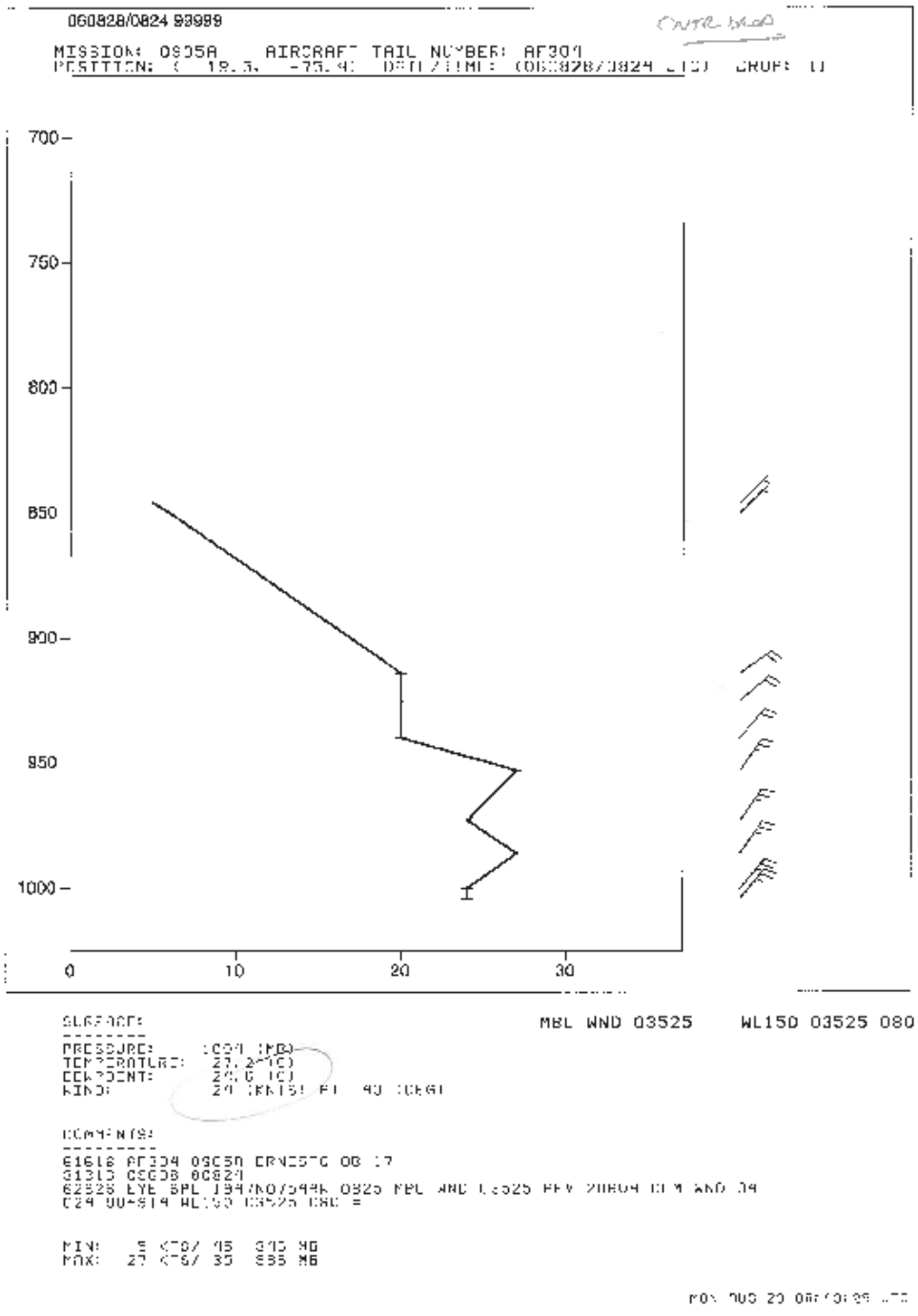
Center (eye) drops are released at the flight-level wind minimum, but may drift away from surface minimum.

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

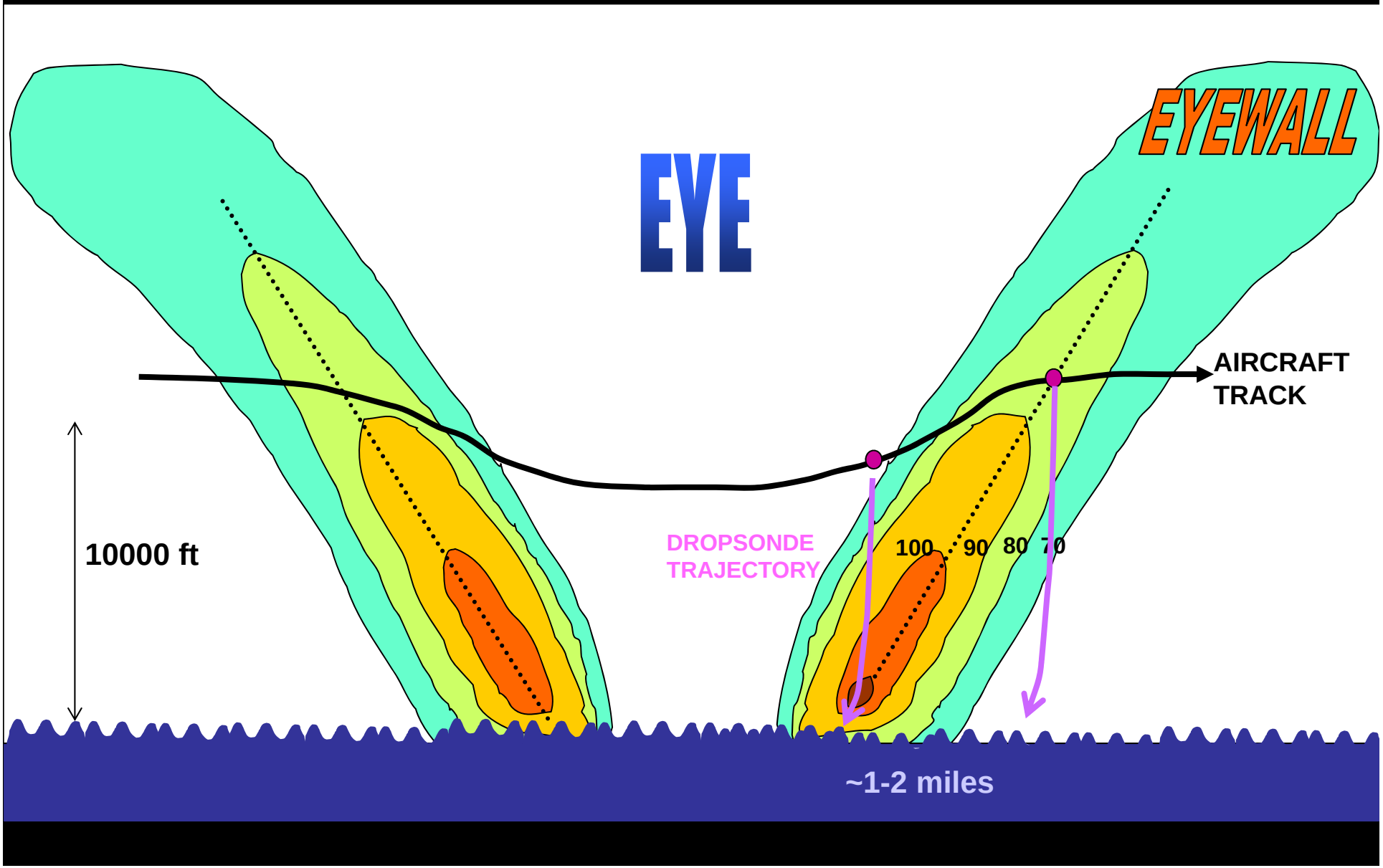
Splash pressure 1004 mb.

Surface wind: 24 kt.

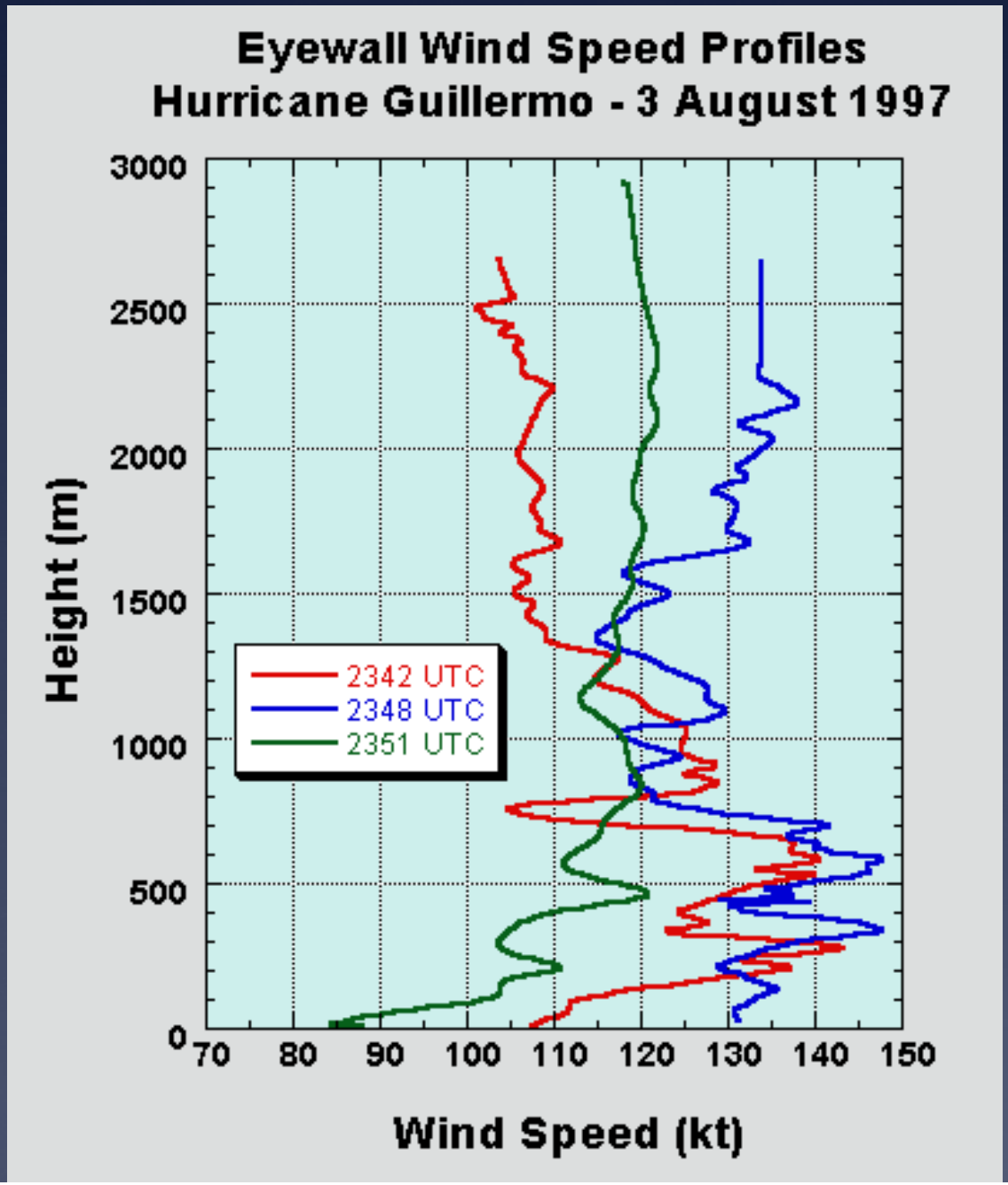
Estimated MSLP = 1002 mb.



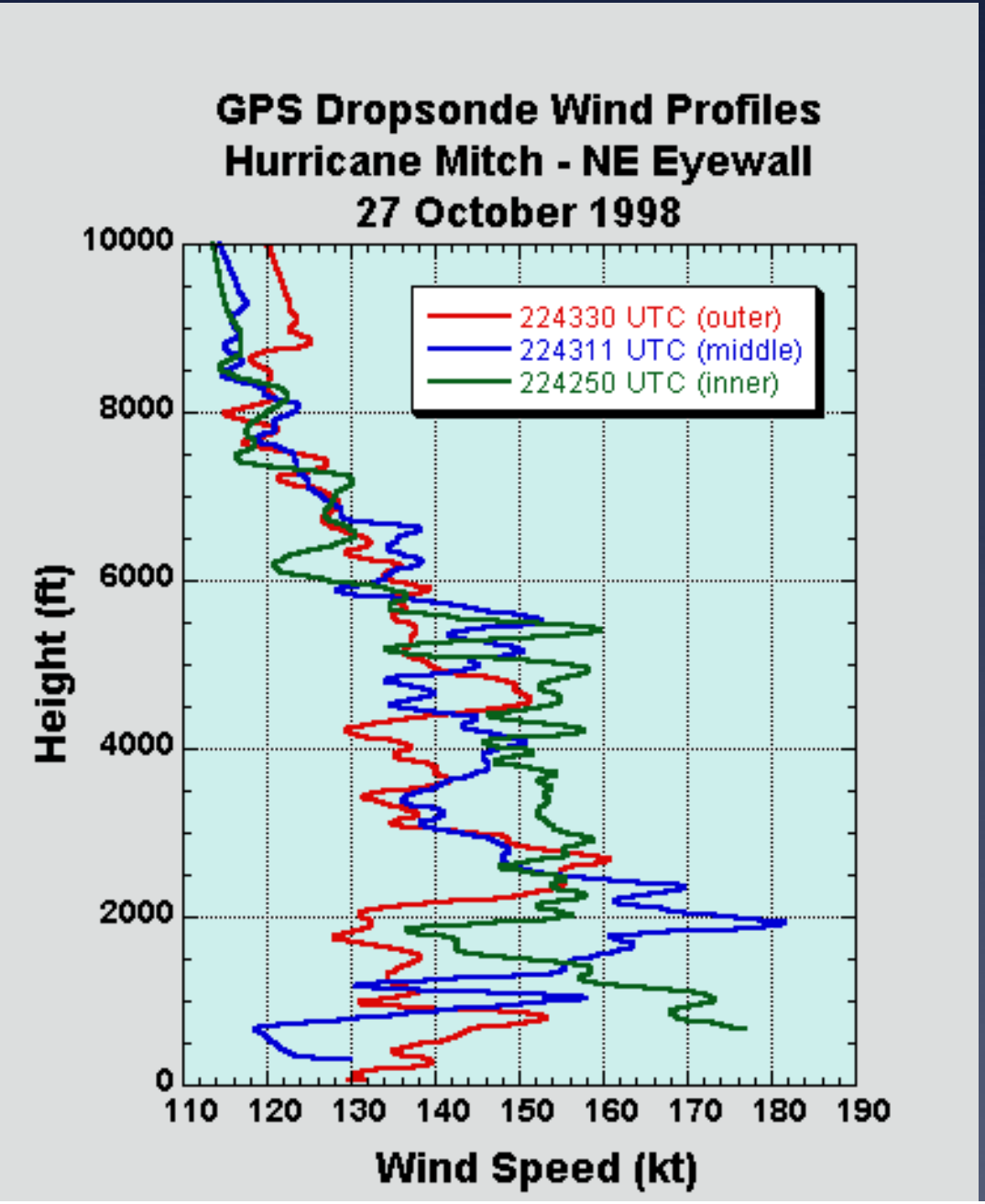
Representativeness of Dropsondes

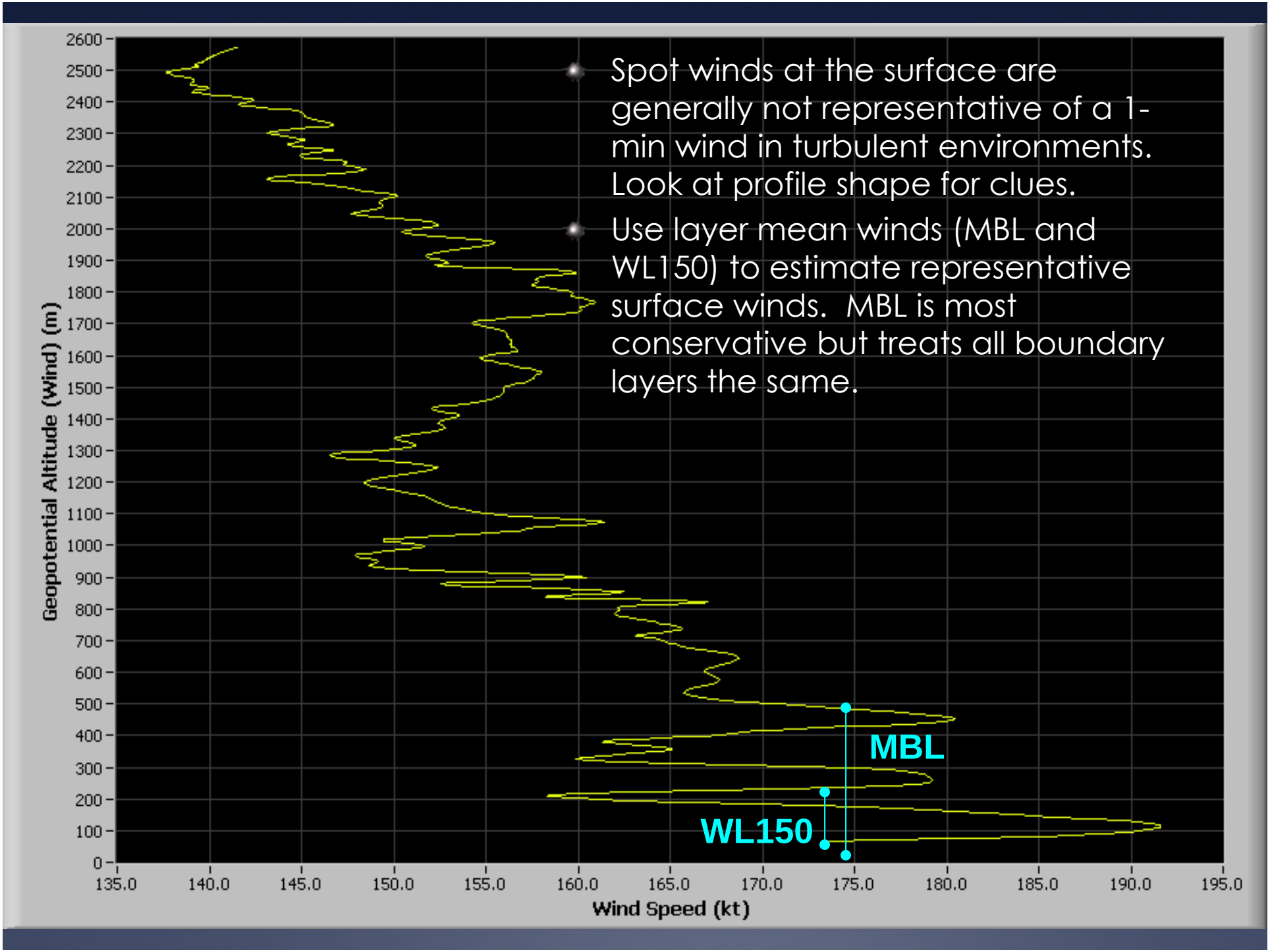


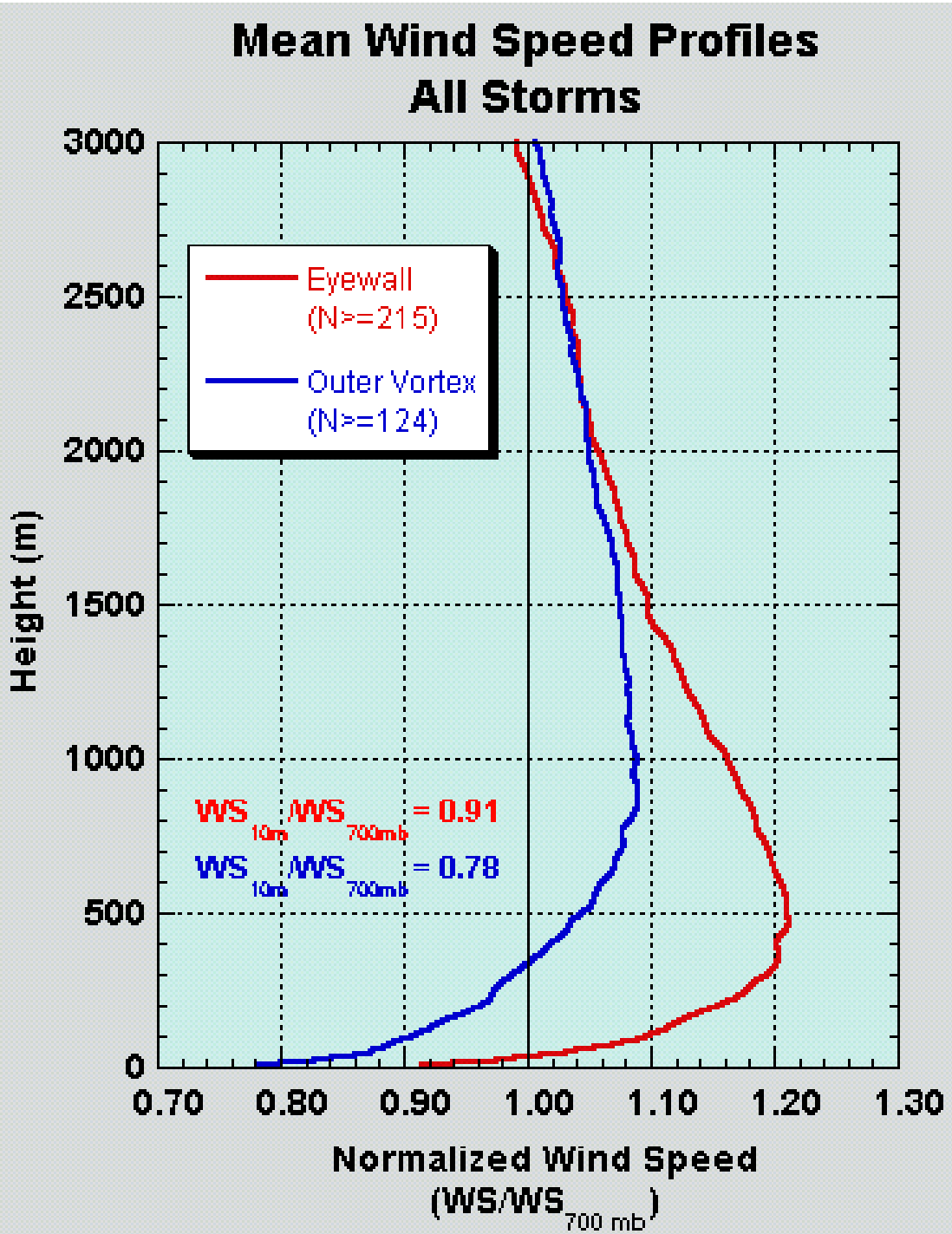
Location, Location, Location



Small-scale variability makes these data difficult to use

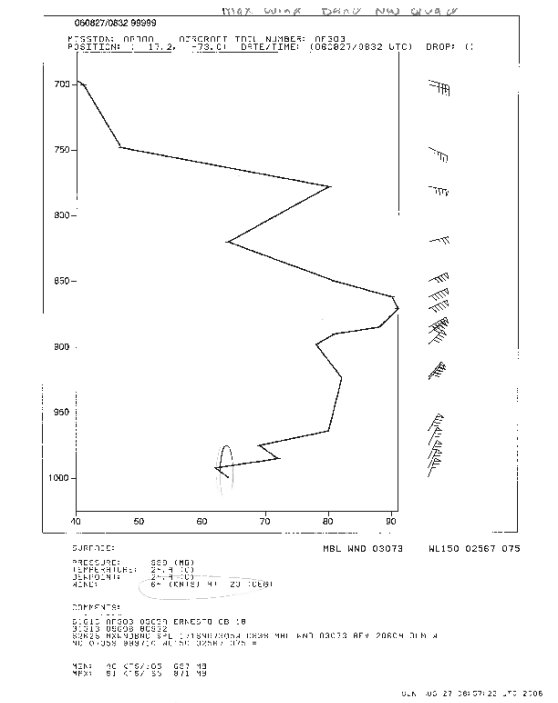


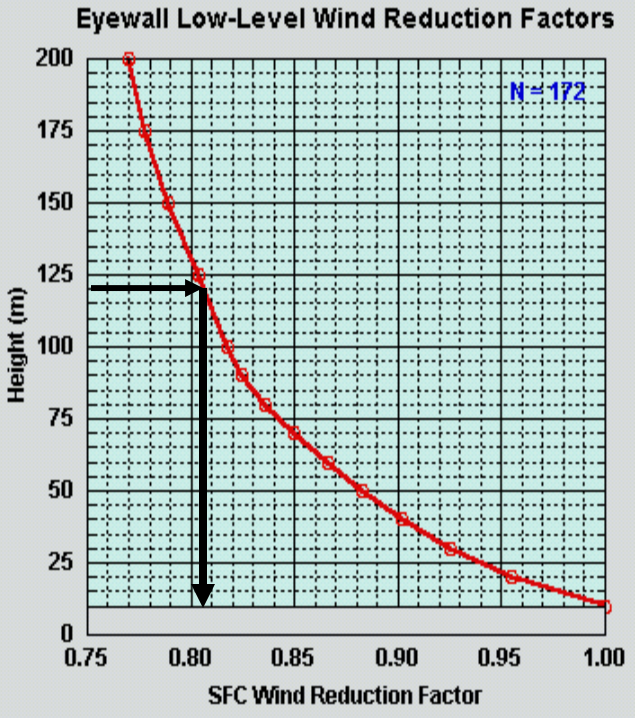

Spot winds at the surface are generally not representative of a 1-min wind in turbulent environments. Look at profile shape for clues.
Use layer mean winds (MBL and WL150) to estimate representative surface winds. MBL is most conservative but treats all boundary layers the same.
MBL
WL150
Geopotential Altitude (Wind) (m)
Wind Speed (kt)
2600
2500
2400
2300
2200
2100
2000
1900
1800
1700
1600
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
135.0
140.0
145.0
150.0
155.0
160.0
165.0
170.0
175.0
180.0
185.0
190.0
195.0


Mean Wind Speed Profiles
All Storms
Eyewall
(N>=215)
Outer Vortex
(N>=124)
WS10m/WS700mb = 0.91
WS10m/WS700mb = 0.78
Height (m)
3000
2500
2000
1500
1000
500
0
0.70
0.80
0.90
1.00
1.10
1.20
1.30
Normalized Wind Speed
(WS/WS700 mb)

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=
```





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      Meteorological parameters are  10-s averages
    are instantaneous values             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

Time (UTC)

Static pressure at flight level ddd.d

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

Pressure < 550 mb: D-value (m)

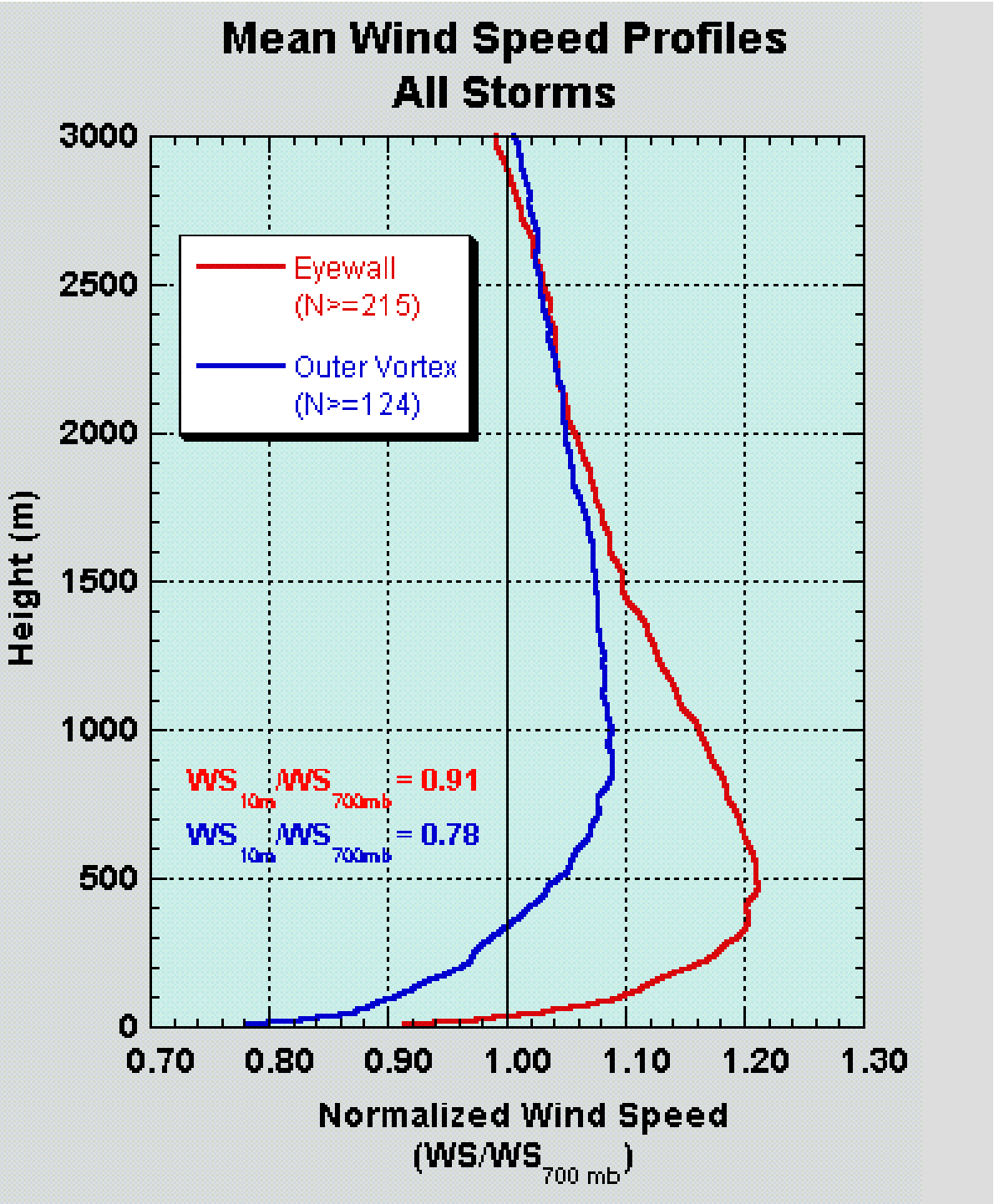
Wind block: direction, flt-level wind, MAX flt-level wind (10 second) and SFMR sfc wind (10 second)

Estimating intensity from flight-level observations:

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

A large sample of GPS soundings was used to define mean eyewall and outer vortex wind profiles. These profiles were used to develop adjustment factors for the common reconnaissance flight levels.

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.

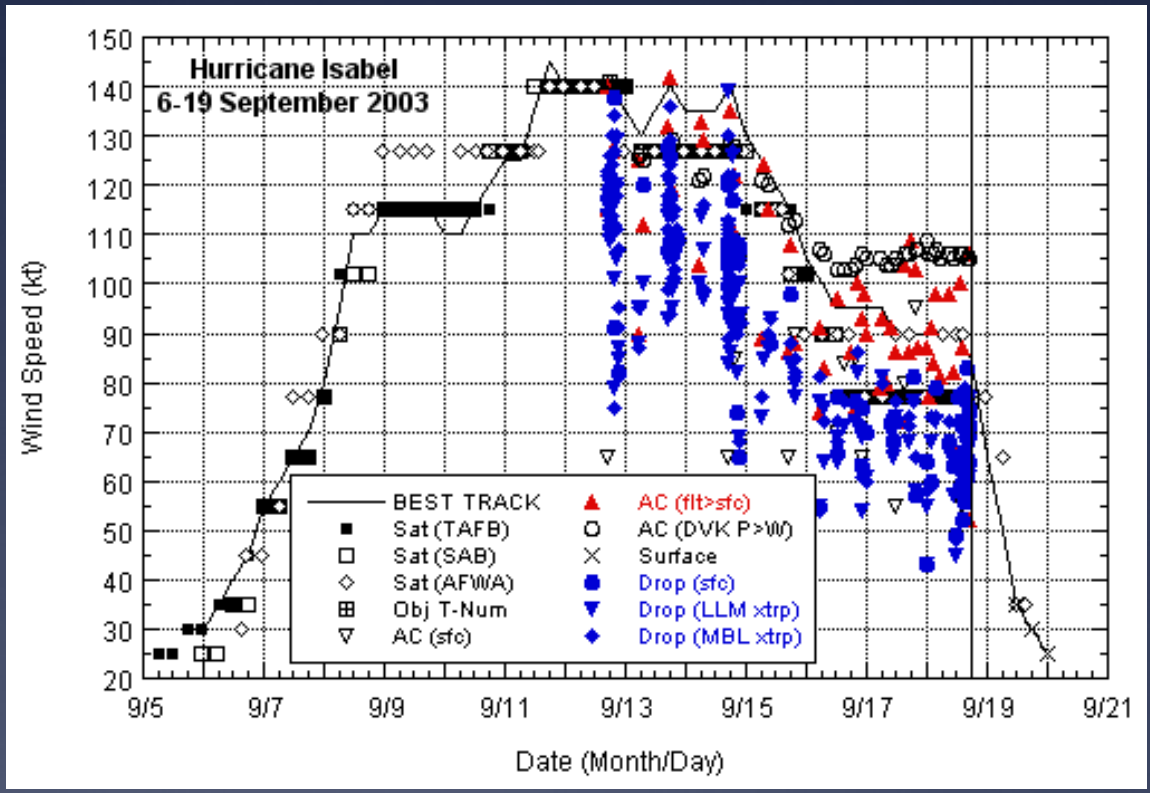


Estimating Intensity From Flight-Level Wind

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

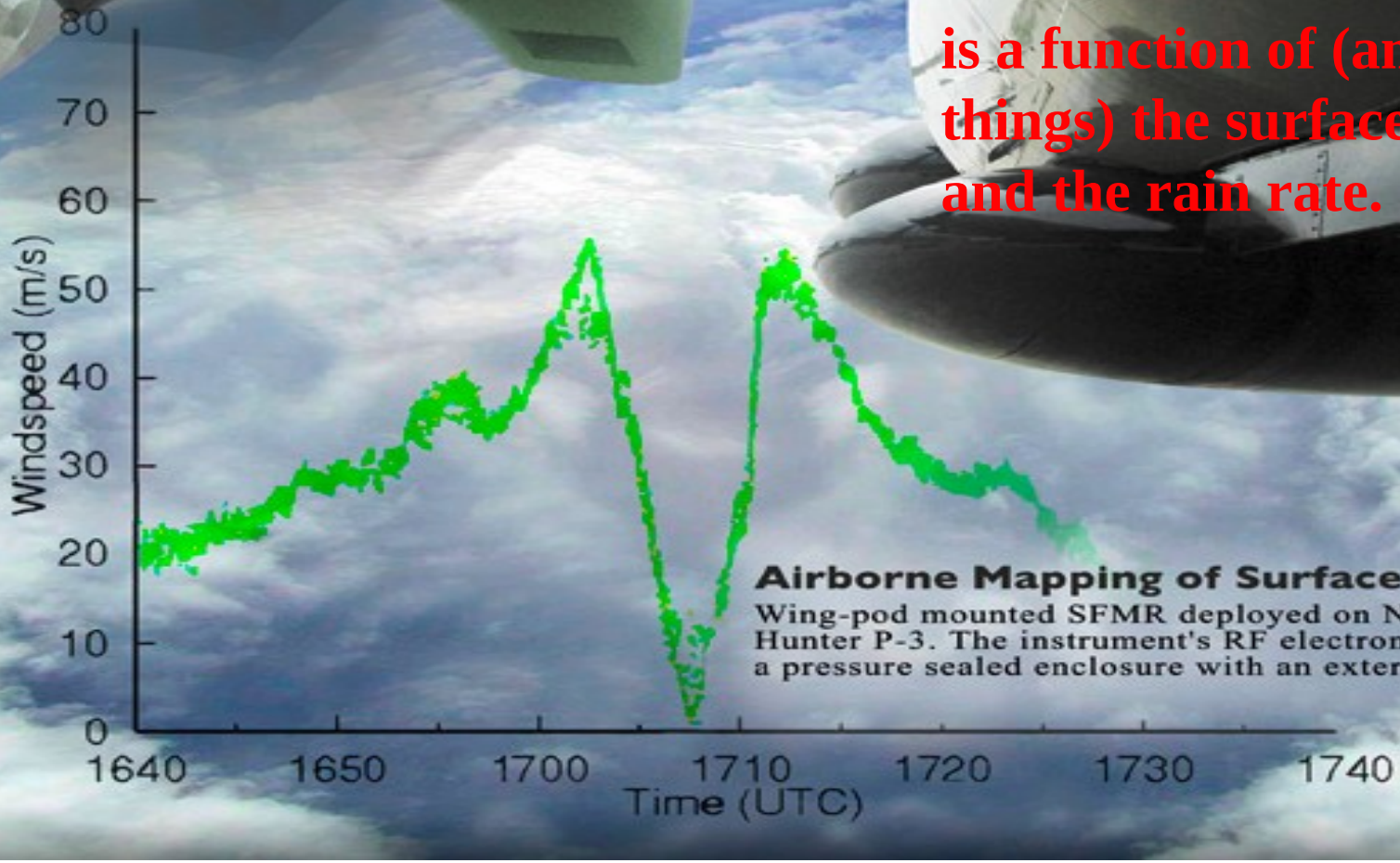
Variability of Standard Adjustment

- 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



STEPPED FREQUENCY MICROWAVE RADIOMETER

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



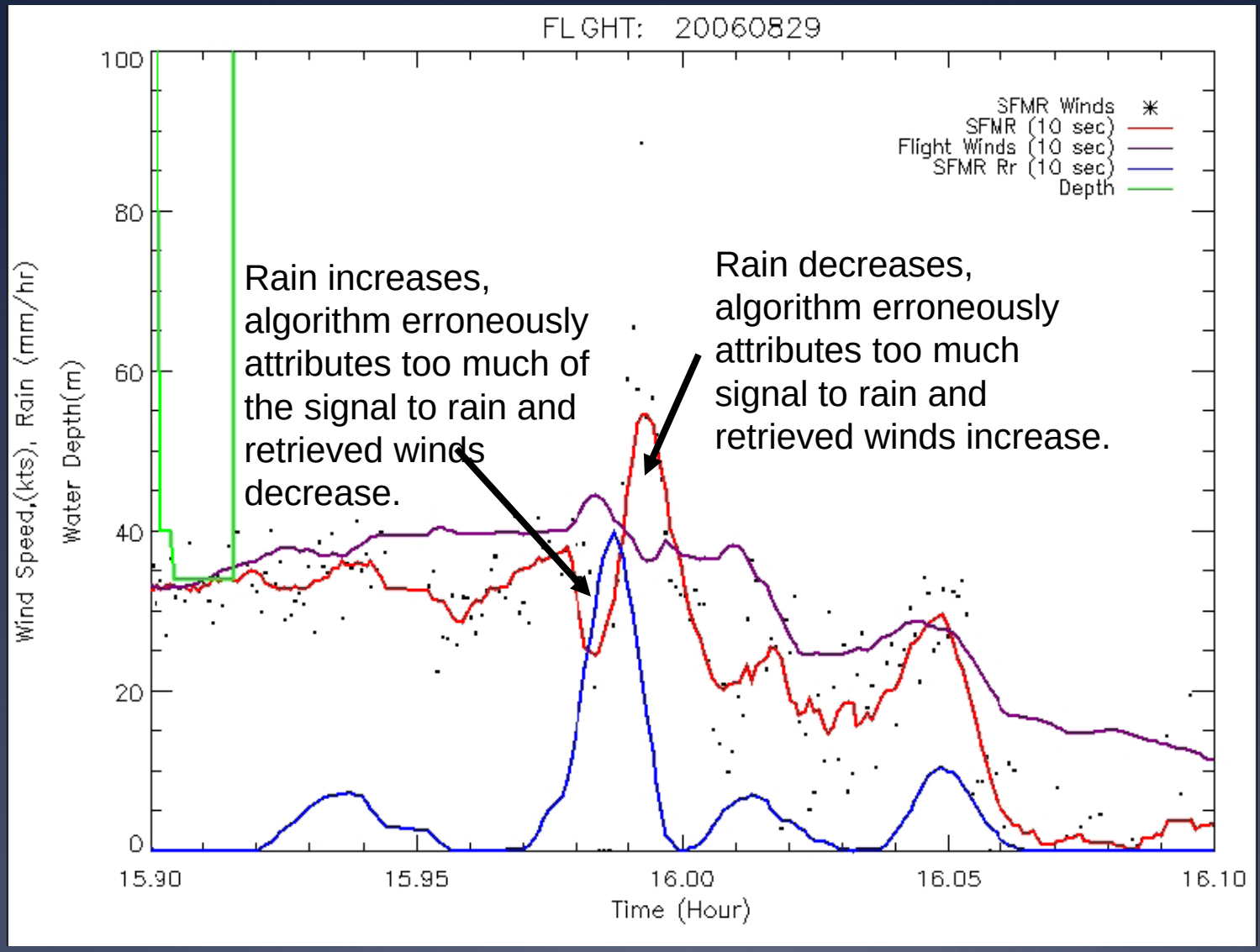
Airborne Mapping of Surface Wind Speed

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.

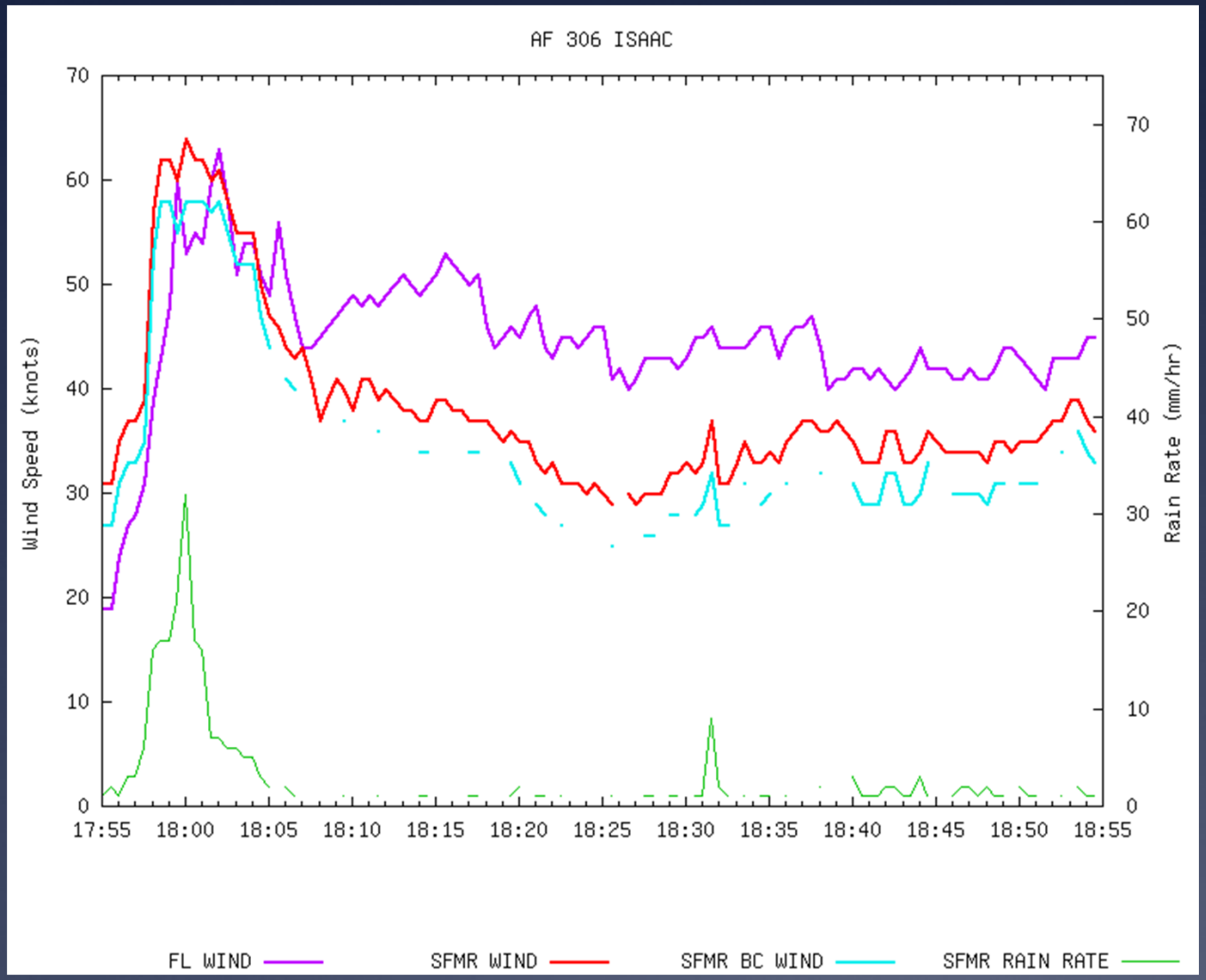
SFMR issues

- 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 azimuthally-dependent errors (~ 5 kt).
- Rain impacts not always properly accounted for (mainly < 50 kt).
- Calibration is an ongoing process. Algorithm currently used on NOAA and USAF aircraft believed to be biased:
  - bias = 5.537 + -0.062*U + 0.212*R + -0.001*(U*R).

Rain-Wind Error Couplets Can Occur at TD/TS Wind Speeds

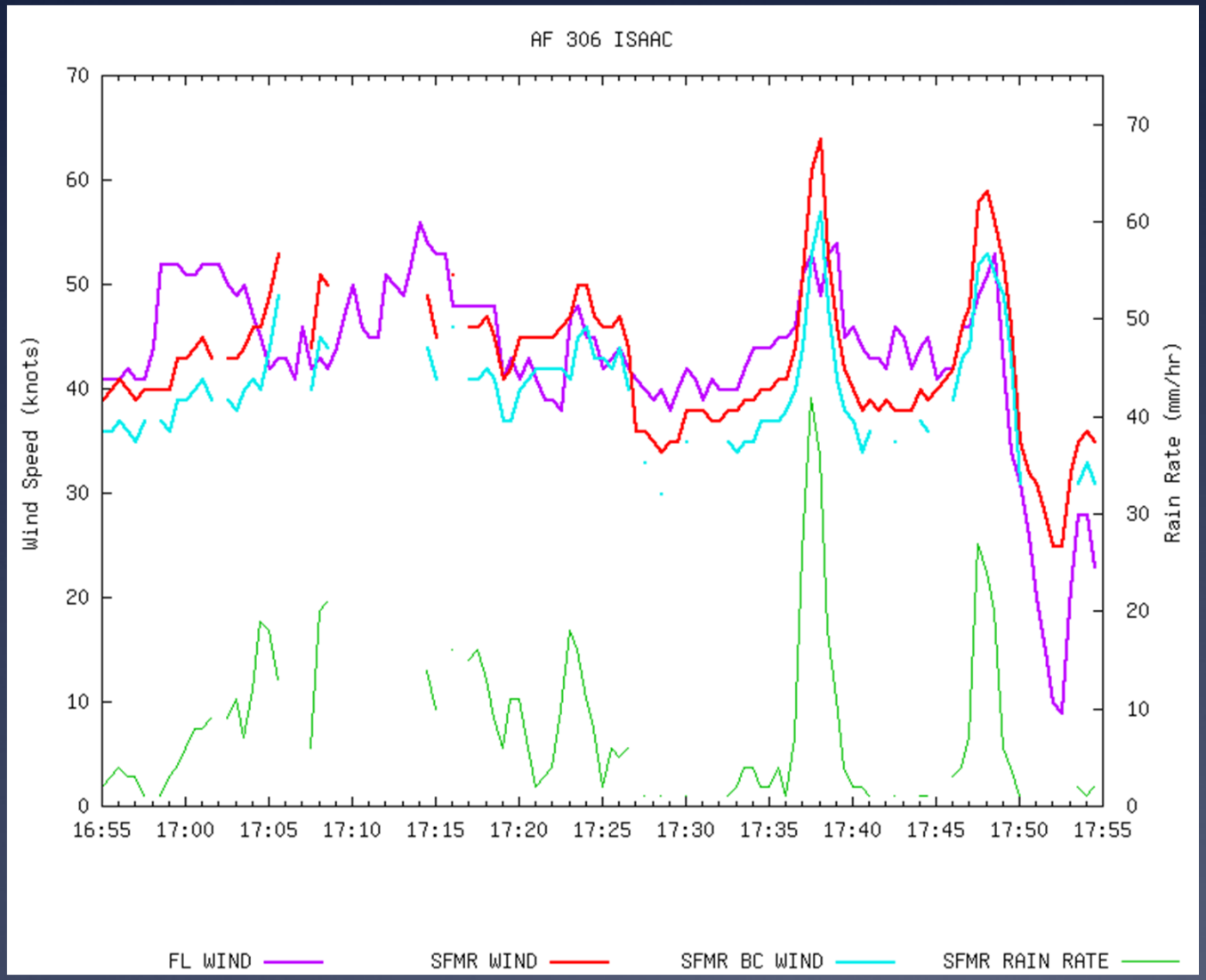


Operational Algorithm High Bias



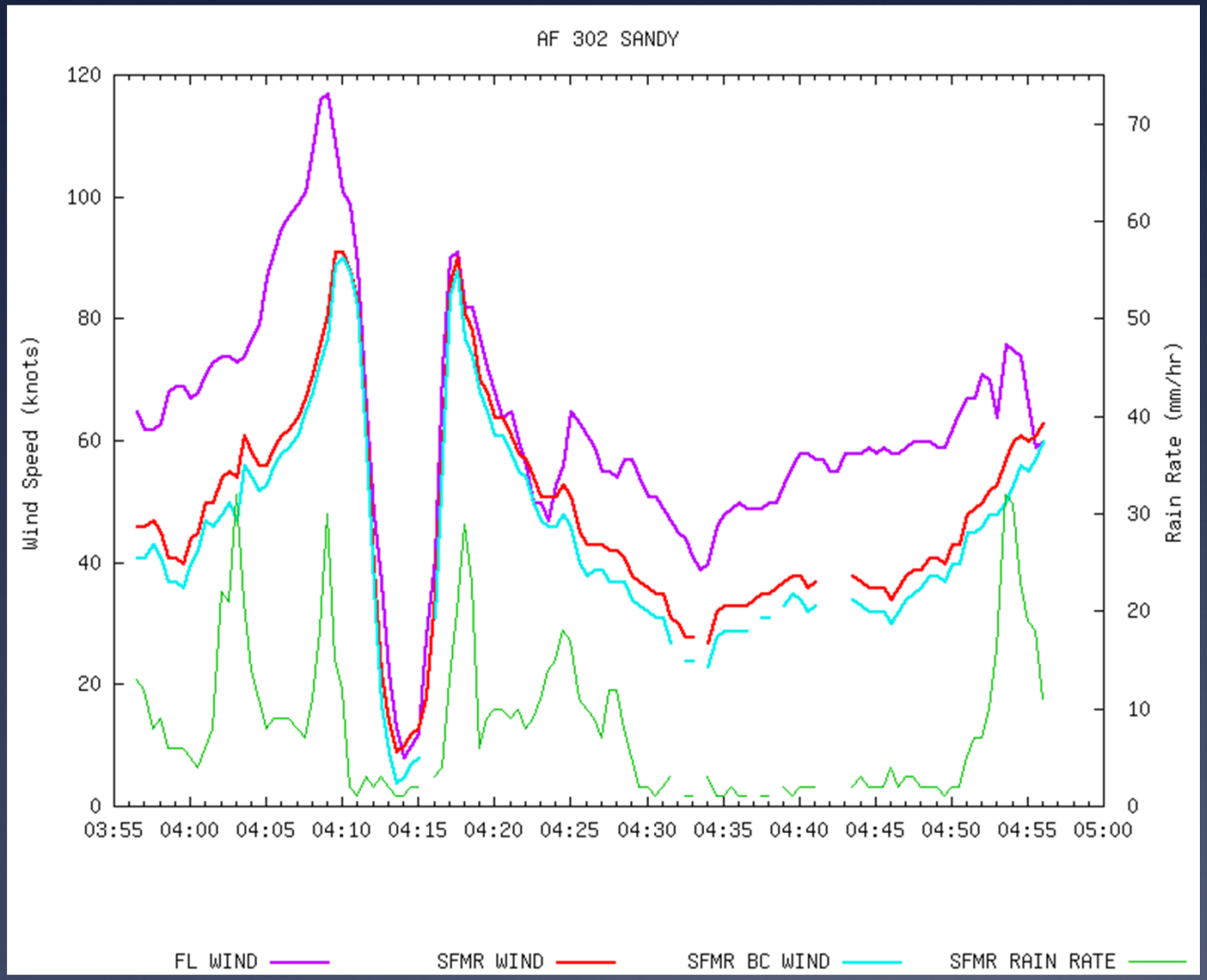
- Correction a function of wind speed and rain rate.
- Bias correction currently applied on the ground at NHC.
- Hope to have the onboard algorithms updated in 2014.

Operational Algorithm High Bias



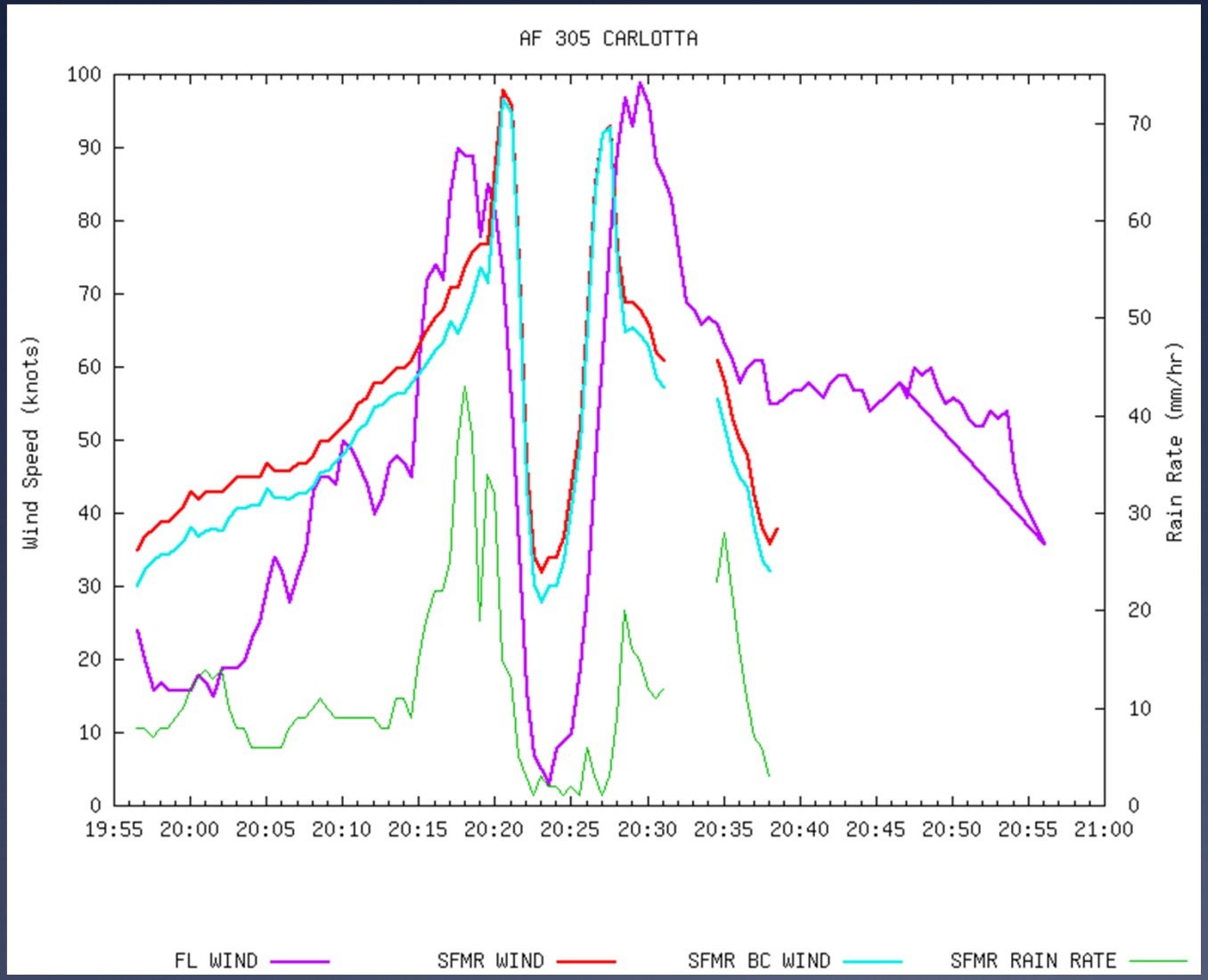
* Rain spike at 1738Z causes raw SFMR wind of 64 kt, while bias-corrected value is 58 kt.

Operational Algorithm High Bias



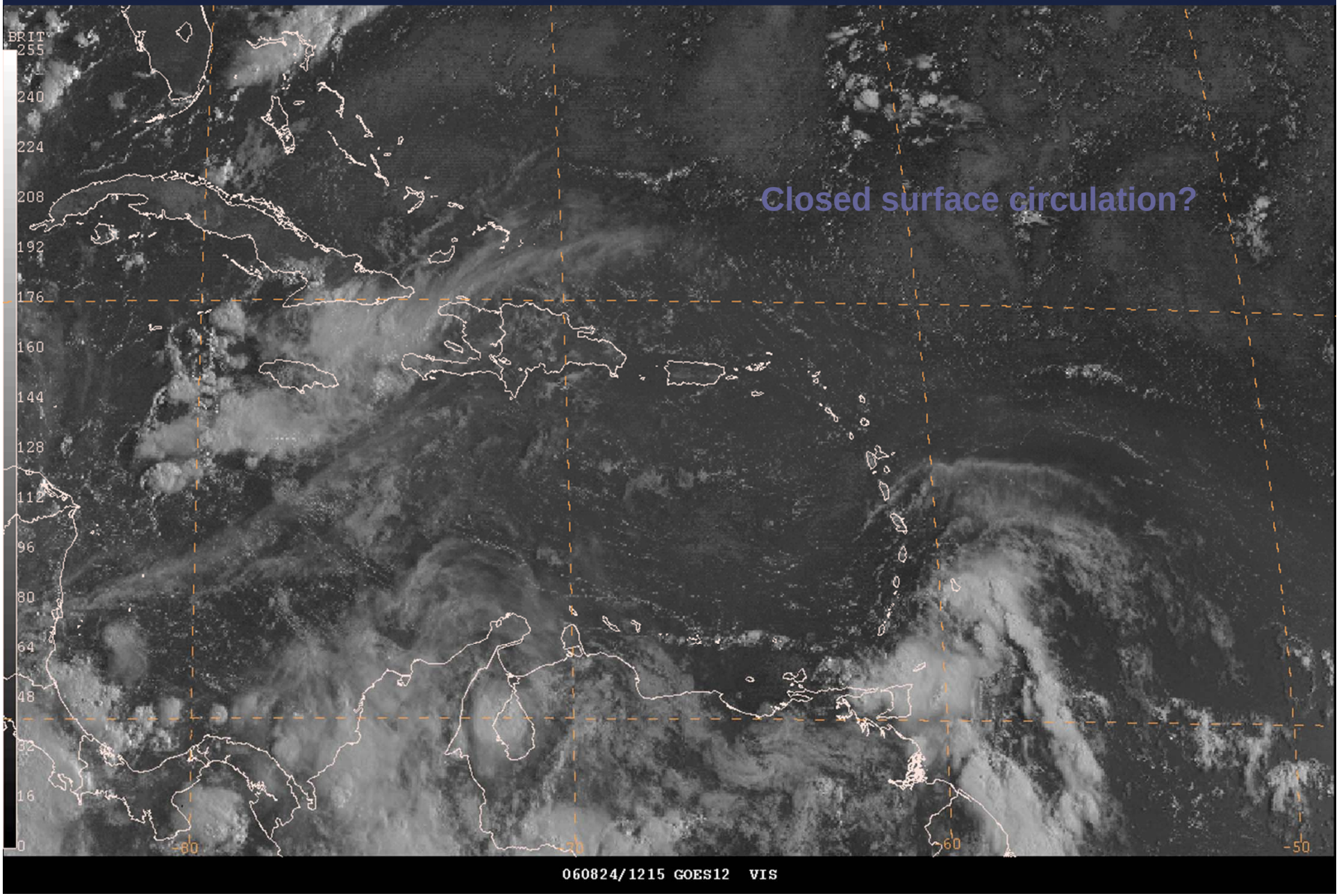
- Almost no impact at higher wind speeds.
- Note how the SFC:FL wind speed ratio varies from the inbound to outbound eyewall.

Operational Algorithm High Bias



- Classical eyewall structure showing the FL wind max radially outward of the surface wind max.
- Varying SFC:FL wind ratios across the storm.
- Little bias in major hurricanes, partly because of the wind speed but also less intervening rain when the eyewall tilts.

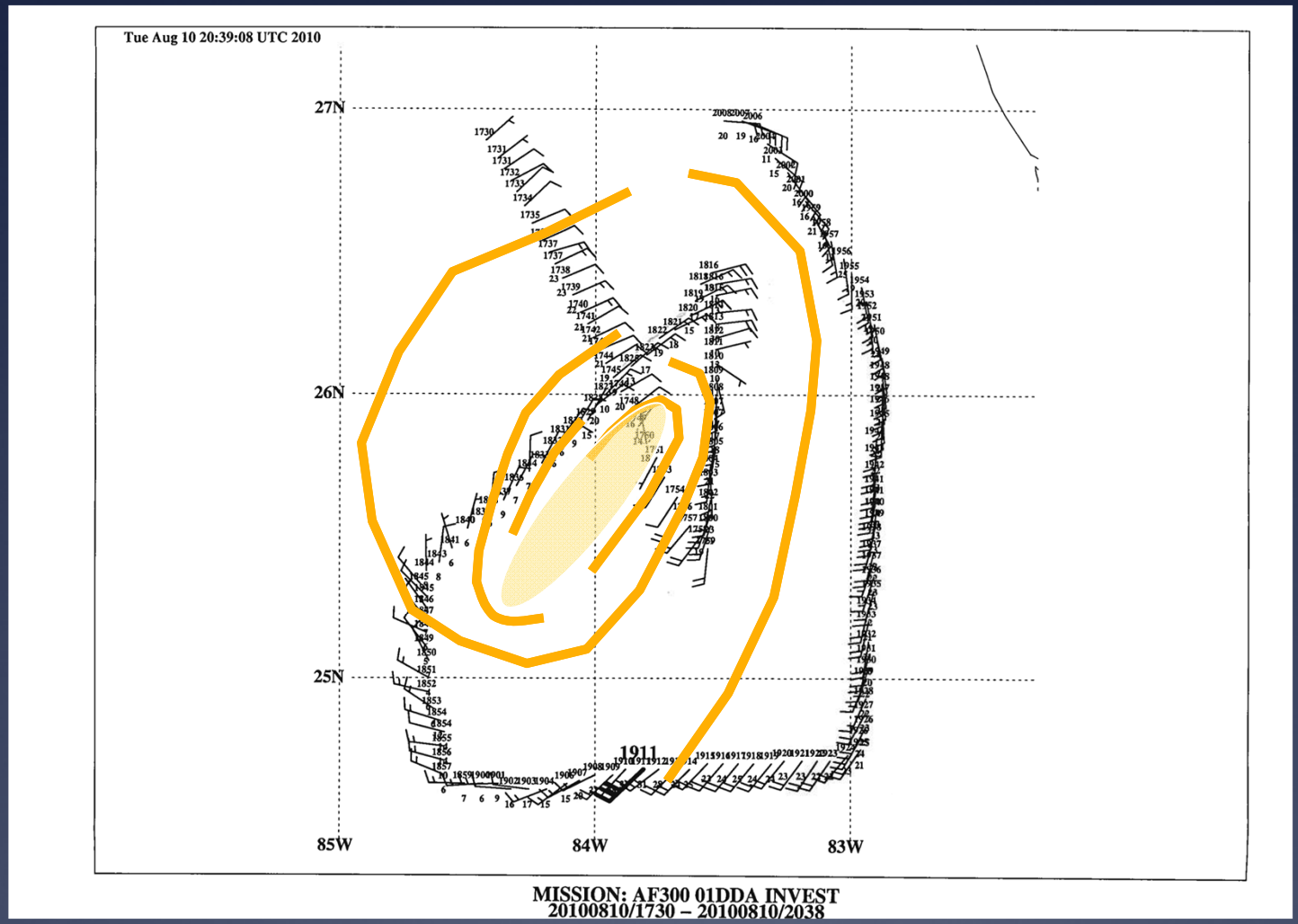
Tropical Wave or Tropical Cyclone?



Invest missions

- Low-level (1000 ft) mission in a tropical disturbance to determine if a “closed surface wind circulation about a well-defined center” exists.
- No formal definition of well-defined center exists, but we are evaluating some proposed operational guidelines.
  - Determine the largest ellipse in which a center might be located consistent with the available observations. This defines an area of uncertainty.
  - The center can be considered well defined if the major axis of the uncertainty area is less than 75 n mi and the ratio of the major to minor axis is less than 2.

Center Definition Example



Major axis = 55 n mi, minor axis = 15 n mi: Fails eccentricity criteria