# Use of Aircraft Data at the National Hurricane Center

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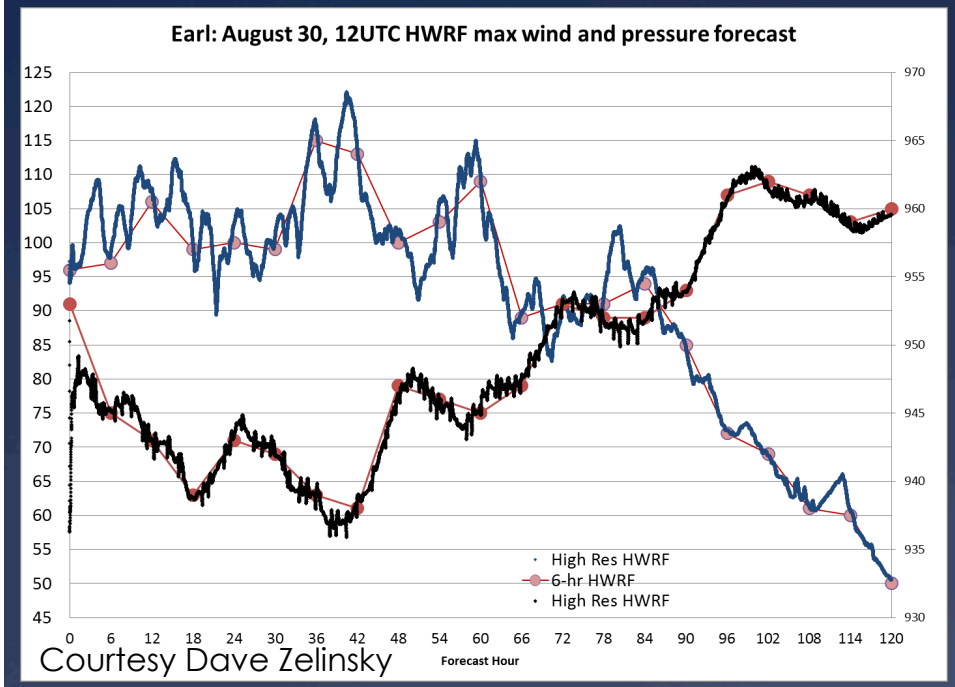
# Aircraft Observations

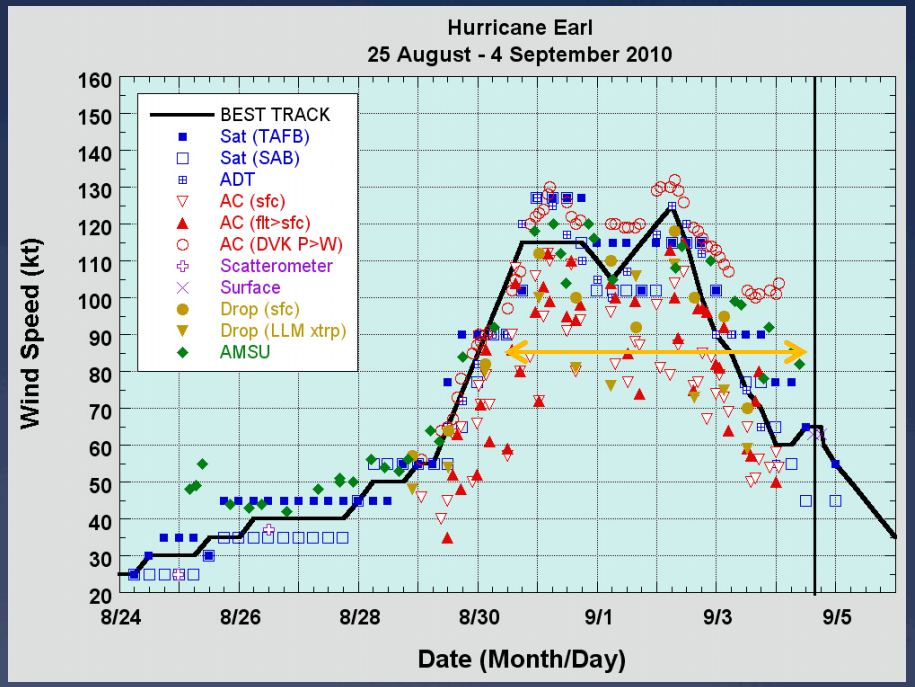
- Flight-level observations, SFMR, dropwindsondes, and radar
- Can be used subjectively by the Hurricane Specialists (HS)
  - Assist in the analysis and short-term forecasting of location, intensity, size, structure of the cyclone/ disturbance.
- Provide input to forecast models
  - Directly (e.g., direct 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.

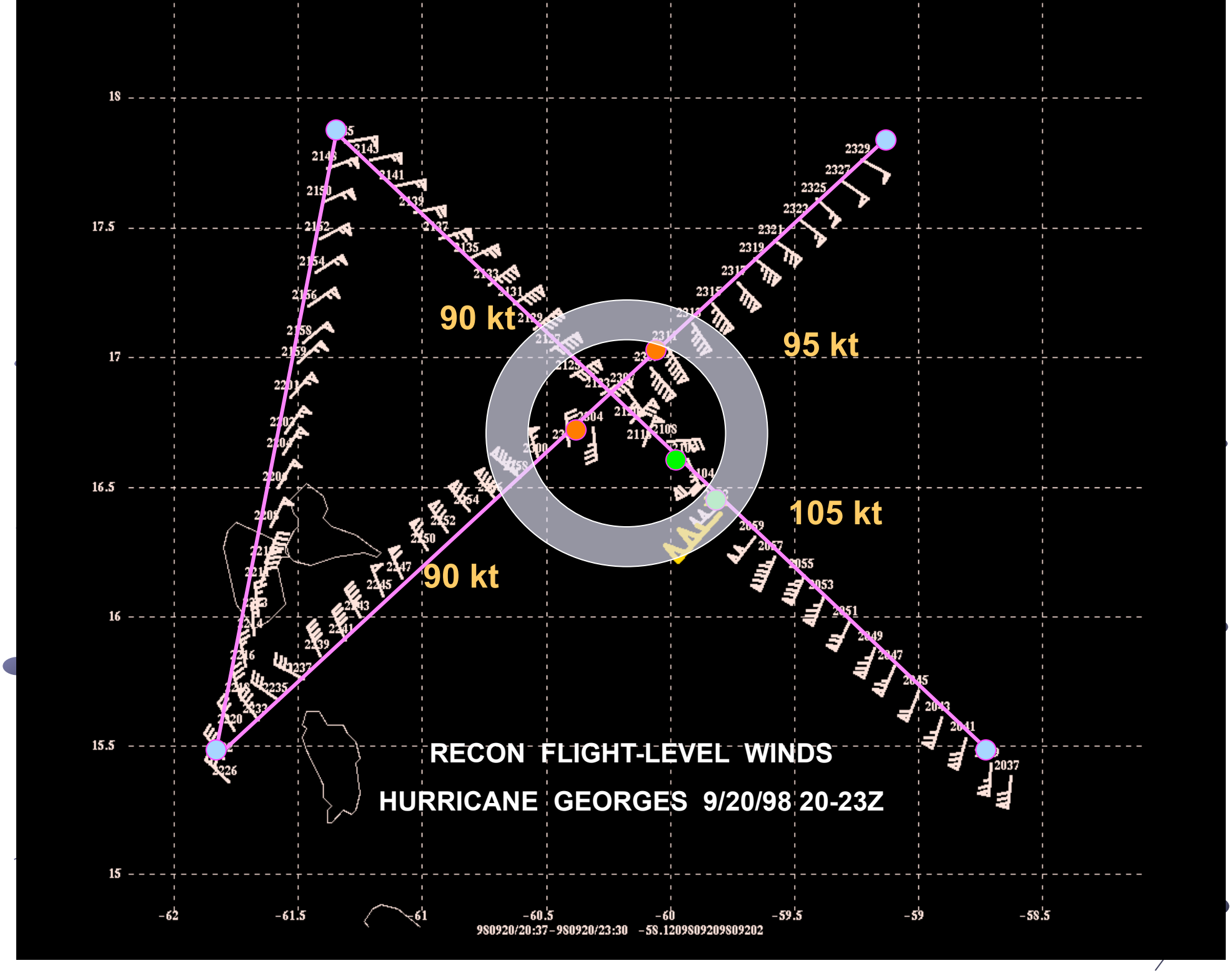
# Representative Intensity




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 $4\Delta t$ (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
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 5303 271011
VORTEX DATA MESSAGE
A. 27/09:57:30Z
B. 17 deg 15 min N
073 deg 06 min W
C. 700 mb 3068 m
D. NA kt
E. NA deg 000 nm
F. 134 deg 067 kt
G. 043 deg 012 nm
H. EXTRAP 995 mb
I. 6 C/ 3061 m
J. 13 C/ 3055 m
K. 9 C/ NA
L. NA
M. NA
N. 12345/ 7
O. 0.02 / 1 nm
P. AF303 0505A ERNESTO OB 23
MAX FL WIND 69 KT NW QUAD 08:32:00 Z
SLP EXTRAP FROM 700 MB

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 (visual/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 20 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 quadrant, how pressure obtained, displacement of sfc/flt-level center.

CYCLONE NAME: ERNESTO (05L)
CYCLONE ID: AL052006

PAGE: 3 of 3

# AIRCRAFT RECONNAISSANCE LOG SHEET

| ACFT TAIL # | Mission ID | OB # | Date/Time | Flight Level | Lat (N) | Lon (W) | Max Sfc Wind | Max FL Wind | Min SLP (D/E) | Min HT STD SFC | Max T Out | Max T In | DP | Eye Diam/ Char | Accuracy (Nav/ Met) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | UTC | ft/mb | deg/min | deg/min | kt | kt | mb | m | °C | °C | °C | n mi | n mi |
| AF963 | 0703 | 12 | 14/1135 | 700mb | 20°44' | 75°05' | 85 | 82 | 981E | 2810 | 16 | 20 | 15 | C15/CLSD | 0.1/1 |
| AF300 | 1805A ERNESTO | 22 | 31/0429 | 850mb | 25°03' | 81°47' | — | (49)/39 | 1003D | 1469 | 18 | 20 | 18 | — | 0.02/3 |
| " | " | 27 | 31/0528 | " | 25°16' | 80°45' | — | (47)/41 | 1002E | 1491 | 17 | 19 | 18 | — | 0.03/— |
| AF303 | 2105A Ernesto | 05 | 31/0701 | 850mb | 29°35' | 80°21' | — | (55)/23 | 999D 1000E | 1418 | 17 | 18 | 17 | — | 0.02/2 |
| " | " | 11 | 31/0817 | " | 29°49' | 80°10' | — | 33 | 999D | 1412 | 17 | 18 | 17 | C25 OPEN N. | 0.02/3 |
| " | " | 17 | 31/0918 | " | 29°56' | 80°09' | — | 50 | 998D | 1408 | 17 | 18 | 18 | C25 OPEN NNW-NE | 0.02/3 |
| " | " | 22 | 31/1012 | " | 30°08' | 80°00' | — | 40 | 997D | 1400 | 15 | 18 | 18 | — | 0.02/3 |
| " | " | 28 | 31/1102 | " | 30°13 | 79°51 | — | 61 | 995L 996 | 1398 | 16 | 18 | 18 | OPEN NW C25 | .02/1 |
| NOAA42 | 2205A ERNESTO | | 31/1407 | " | 31°01' | 79°28' | — | 54 | 994 | 1382 | 16 | 18 | 14 | POORLY DEFINED | 1/1 |
| " | " | | 31/1525 | " | 31°20' | 79°21 | 50 | 38 | 994 | 1356 | 17 | 18 | 13 | POORLY DEF | 1/1 |
| " | " | | 31/1635 | " | 31°33' | 79°11 | 40 | 52 | 993 | 1372 | 16 | 19 | 17 | POORLY DEF | 1/1 |
| " | " | | 31/1752 | " | 31°52 | 79°09 | 50 | 65 | 993 | 1379 | 18 | 20 | 18 | poorly def | 1/1 |
| AF300 | 2305A ERNESTO | 3 | 31/1823 | 850 | 31°52 | 79°09 | 50 | 49 | 993 | 1378 | 17 | 19 | 19 | — | .03/1 |
| " | " | 7 | 31/1947 | " | 31°17' | 78°58' | — | (73)/30 | 991D | 1365 | 18 | 20 | 20 | N/A | 0.03/1 |
| " | " | 12 | 31/2130 | " | 32°41' | 78°34' | 40 | 52 | 991D | 1362 | 16 | 20 | 17 | N/A | 0.02/1 |
| " | " | 17 | 31/2352 | " | 33°00 | 78°23' | 65 | 63 | 988D | 1242 | 19 | 20 | 19 | N/A | 0.02/2 |
| " | " | 20 | 31/2362 | " | 33°12' | 78°20' | — | 48 | 990D | 1350 | 15 | 19 | 18 | C20 OPEN N-ENE | 0.02/1 |
| AF304 | 2405A ERNESTO | 04 | 01/0221 | 850MB | 35°40' | 76°14' | — | (83)/49 | 988D | 1320 | 15 | 19 | 17 | N/A | 0.02/1 |
| " | " | 10 | 01/0343 | " | 34°01' | 78°06' | — | 66 | 986E | 1316 | 15 | 19 | 18 | N/A | 0.02/1 |
| | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | |

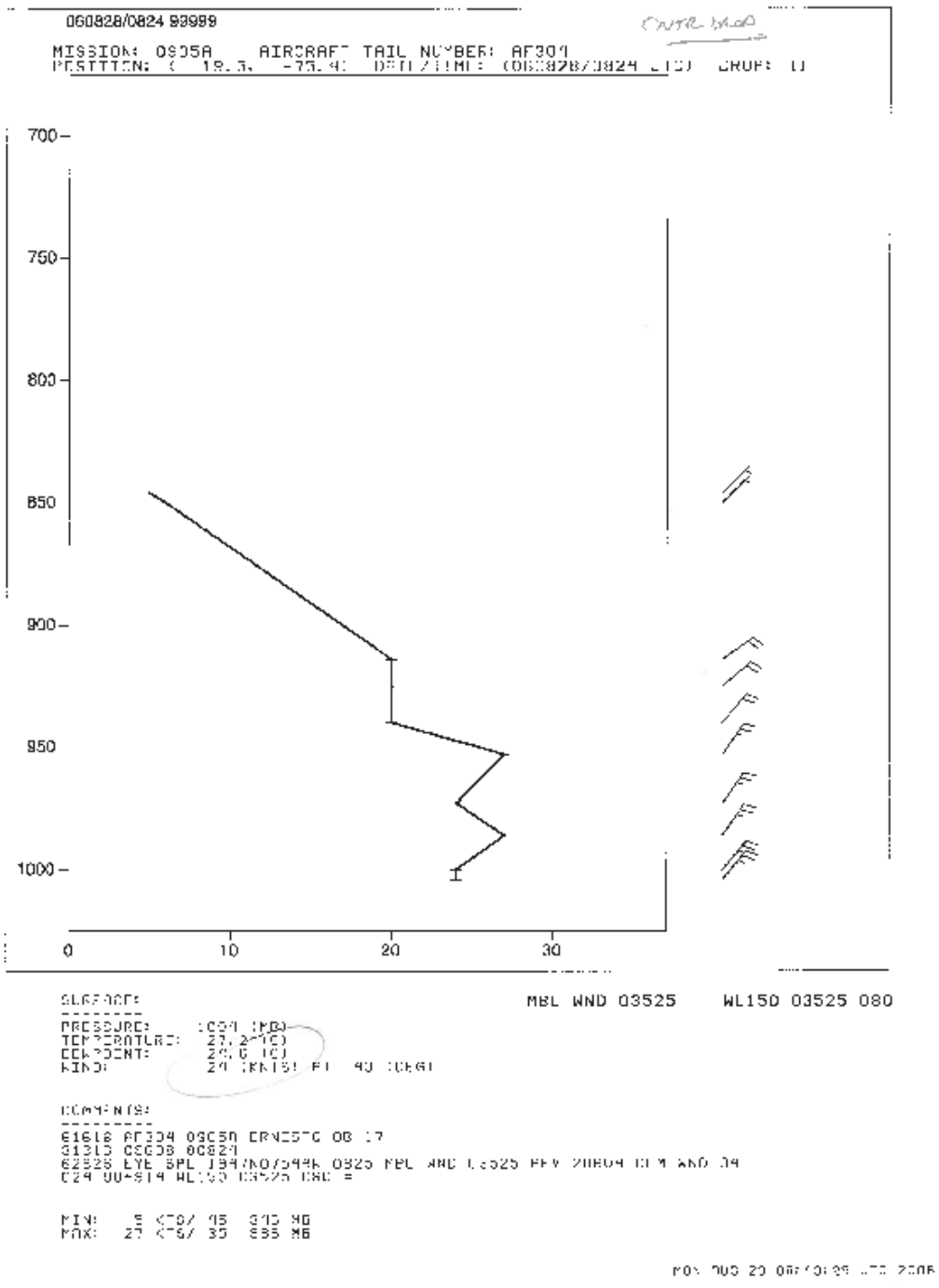
Center (eye) drops are released at the flight-level wind minimum, but may drift away from surface minimum.

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.

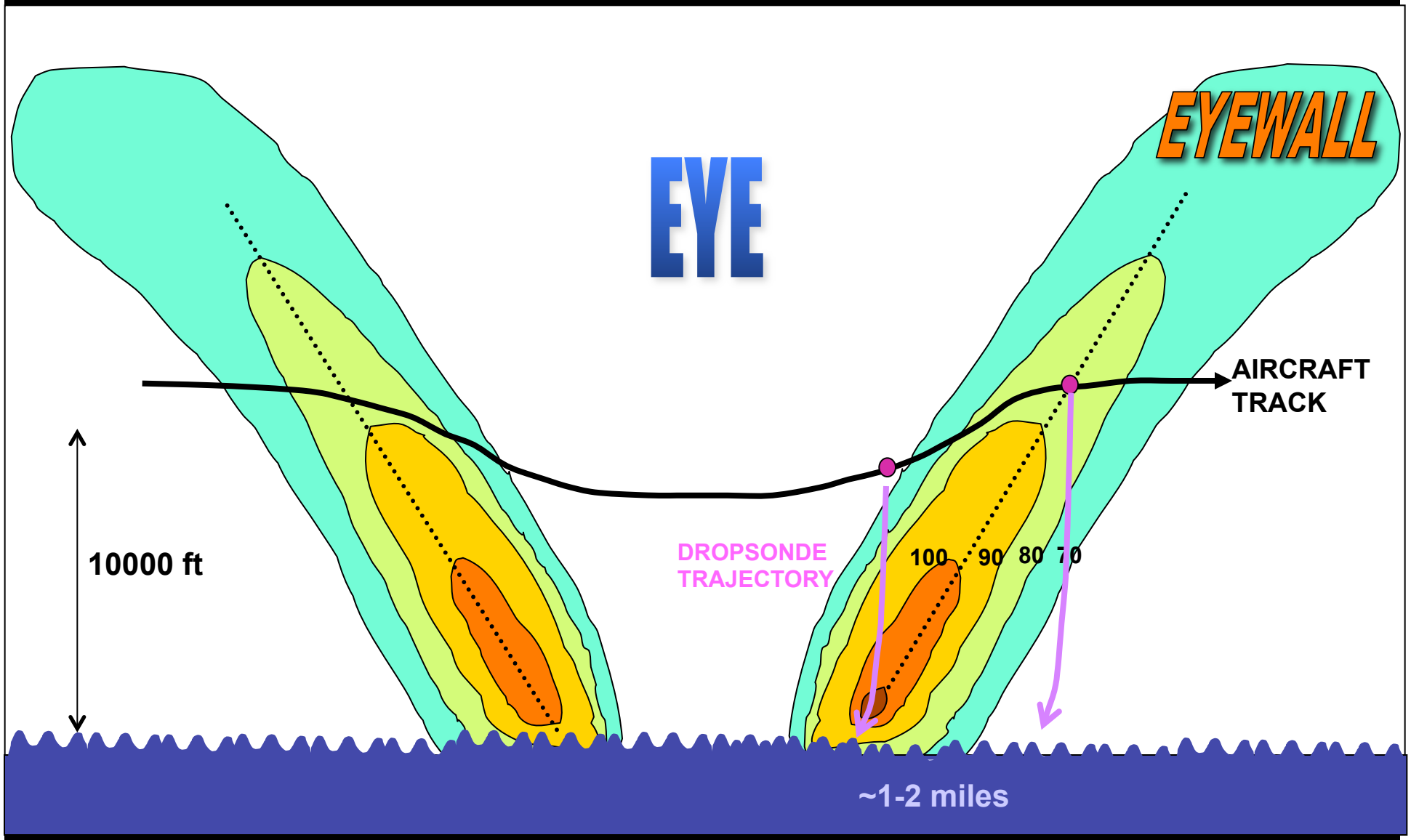
Splash pressure 1004 mb.

Surface wind: 24 kt.

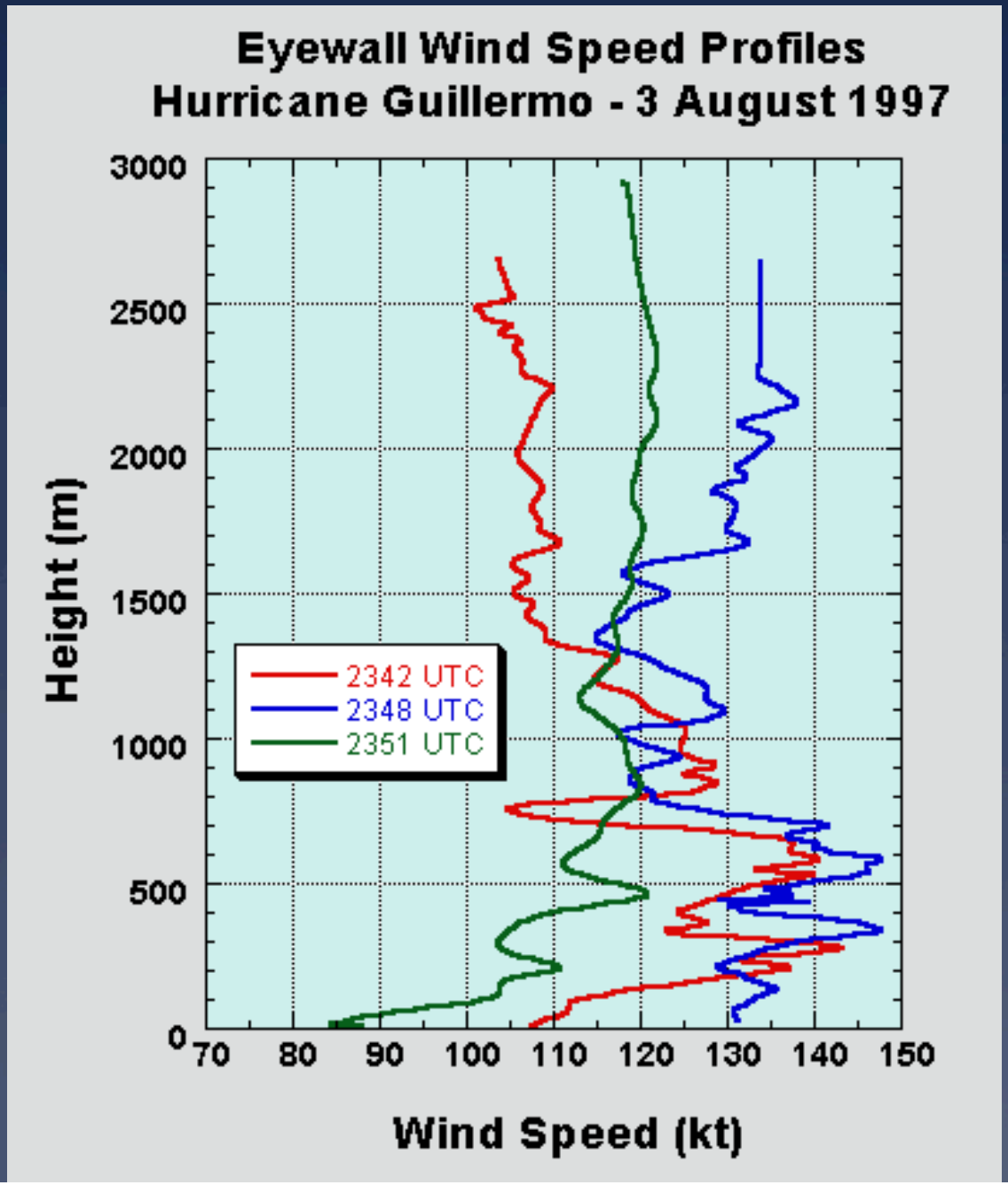
Estimated MSLP = 1002 mb.



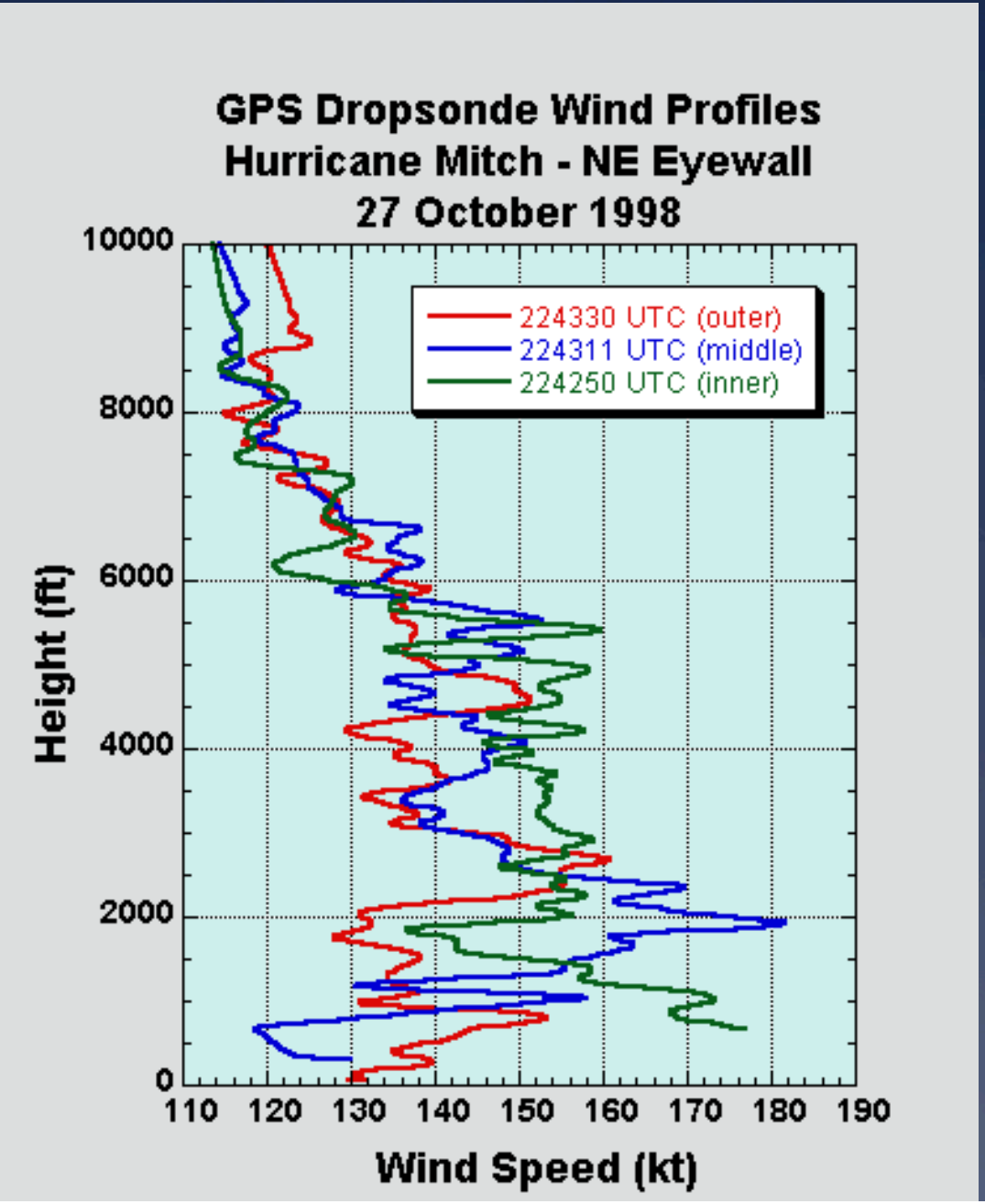
# Representativeness of Dropsondes

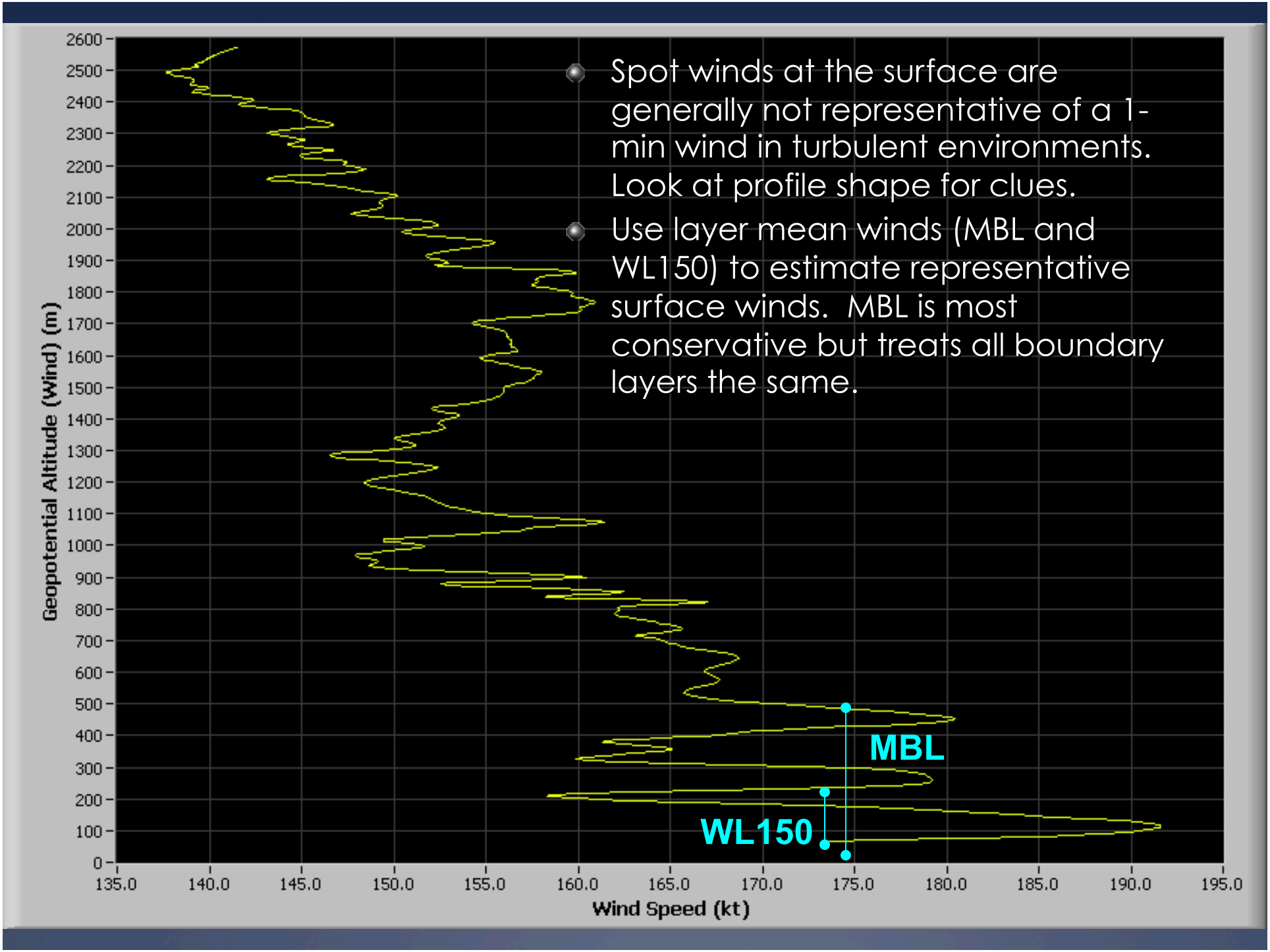


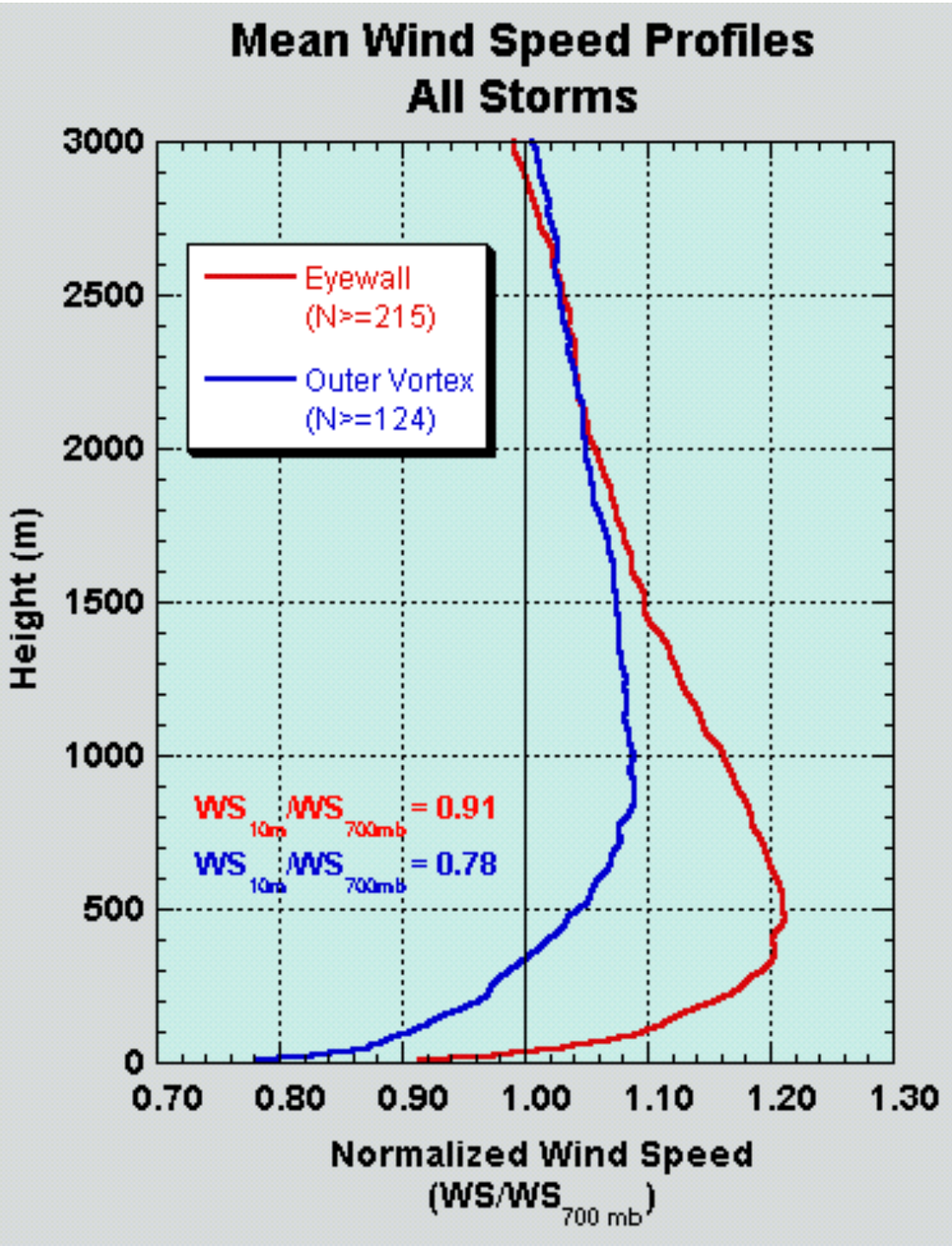
# Location, Location, Location



# Small-scale variability makes these data difficult to use

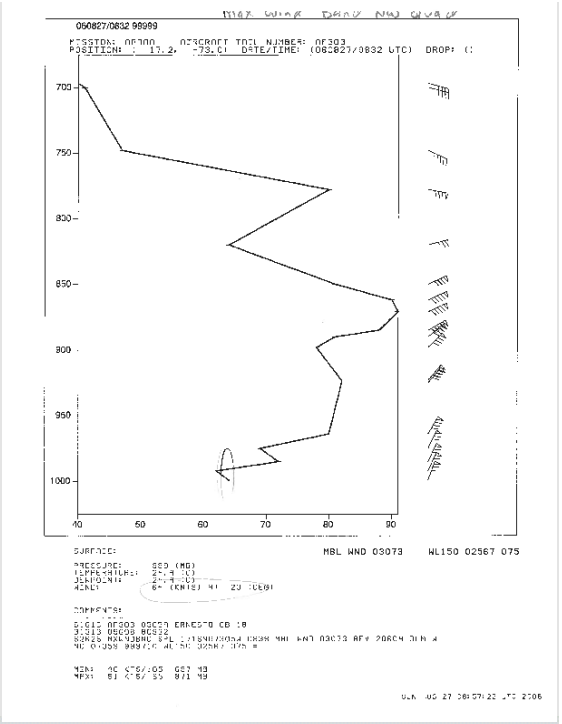


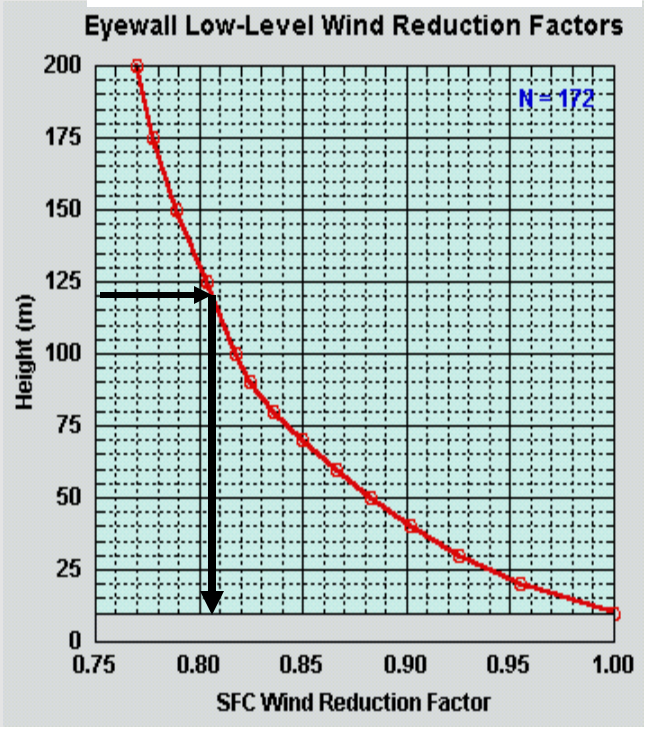

Spot winds at the surface are generally not representative of a 1-min wind in turbulent environments. Look at profile shape for clues.
Use layer mean winds (MBL and WL150) to estimate representative surface winds. MBL is most conservative but treats all boundary layers the same.
MBL
WL150
Geopotential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

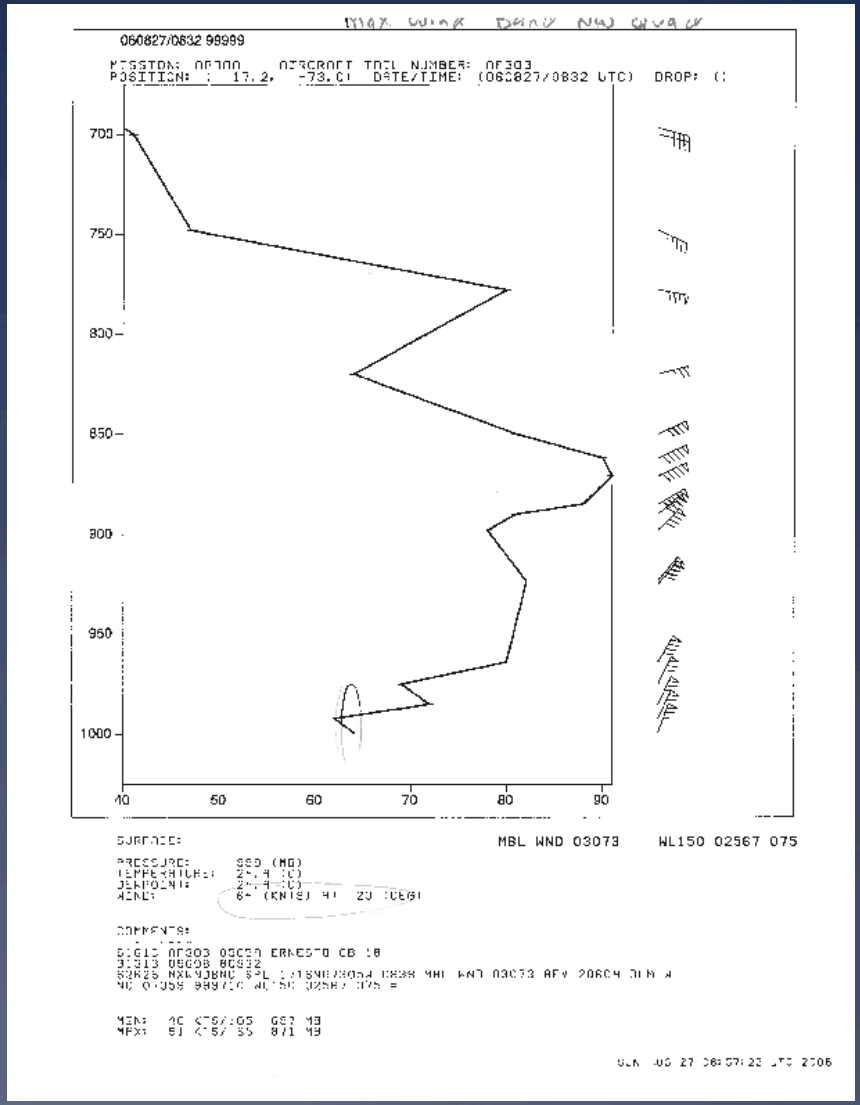
```
UZNT13 KWBC 220345
XXAA  72037 99253 70951 08255 99959 25401 ///// 00867 ///// /////
92322 23204 08646 85060 20408 11120 70/// ///// 15091 88999 77999
61616 AF963 0202A BRET OB 10
62626 EYEWALL 045 SPL 2532N09528W WL150 07136 121 DLM WND 11615 6
96955 MBL WND 08141 LST WND 046=
XXBB  72038 99253 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=
```





# Ignore the Skinny Black Line

- 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.

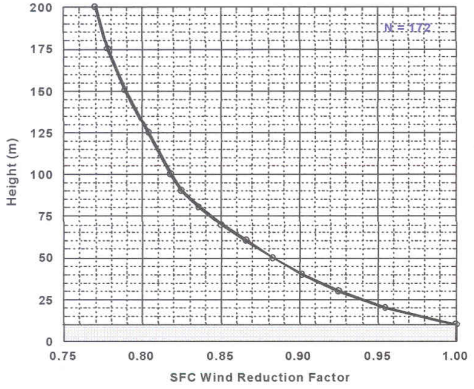


# Eyewall Dropsonde Worksheet

**Storm Name/ID:** ISABEL AL132003

| Date | Time (UTC) | Azimuth (deg) | Sfc Wind (kt) | MBL Wind (kt) | Sfc wind from MBL (kt) | WL150 Spd (kt) | WL150 Hght (m) | Sfc wind from WL150 (kt) |
|---|---|---|---|---|---|---|---|---|
| 8/22 | 0328 | 045 | - | 141 | 113 | 136 | 121 | 110 |
| 18 | 1419 | 180 | 66 | 82 | 66 | 76 | 85 | 63 |
| | 1421 | 180 | – | 91 | 73 | 88 | 102 | 72 |
| | 1440 | 000 | - | 97 | 78 | 95 | 136 | 76 |
| | 1443 | 000 | 61 | 91 | 73 | 75 | 85 | 62 |
| | 1446 | 000 | – | 99 | 79 | 89 | 112 | 72 |
| | 1548 | 045 | 83 | 97 | 78 | 87 | 85 | 72 |
| | 1549 | 045 | 71 | 95 | 76 | 81 | 85 | 67 |
| | 1636 | 180 | 74 | 87 | 70 | 82 | 86 | 68 |

Eyewall Low-Level Wind Reduction Factors

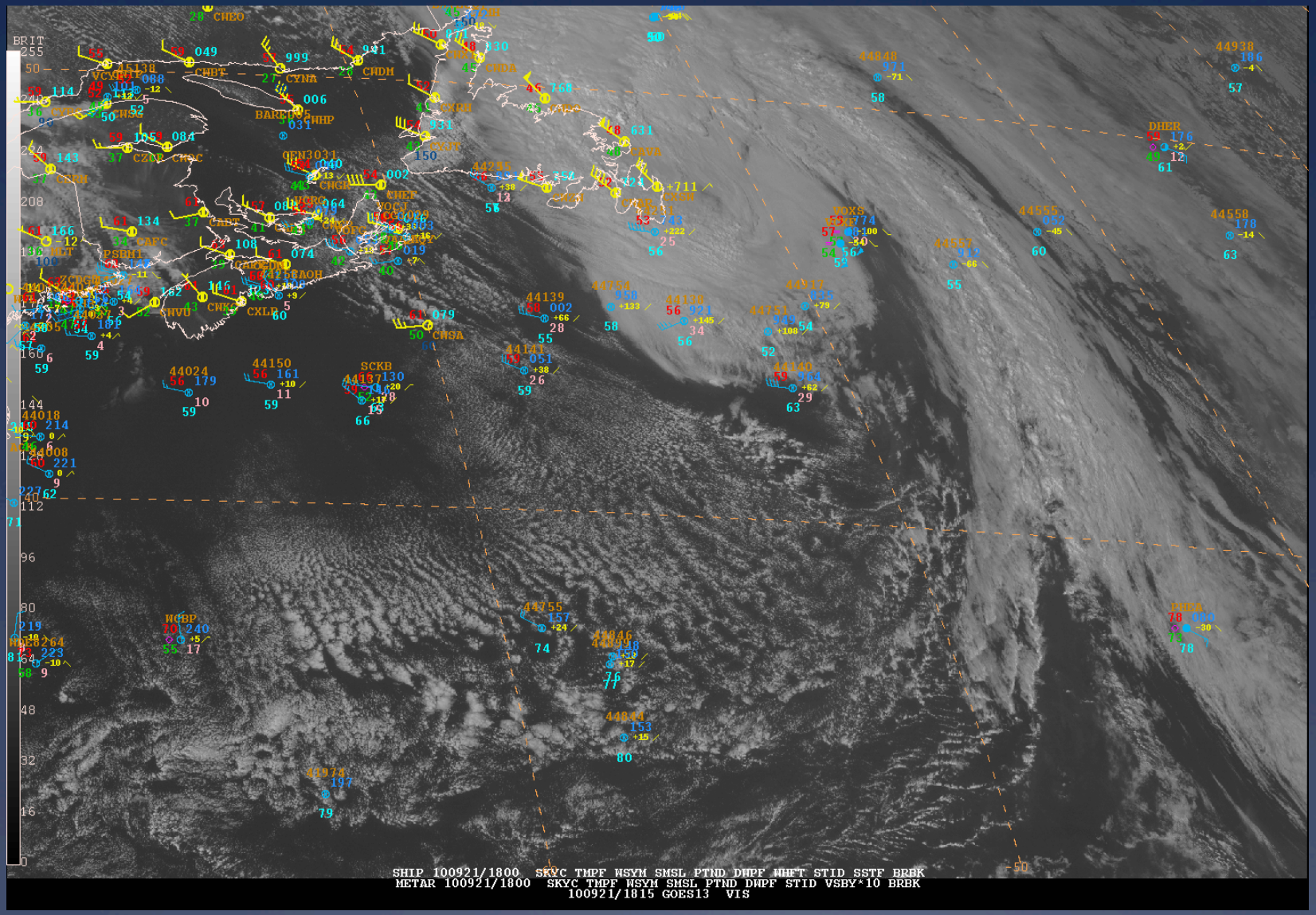



SAMPLE MESSAGE:

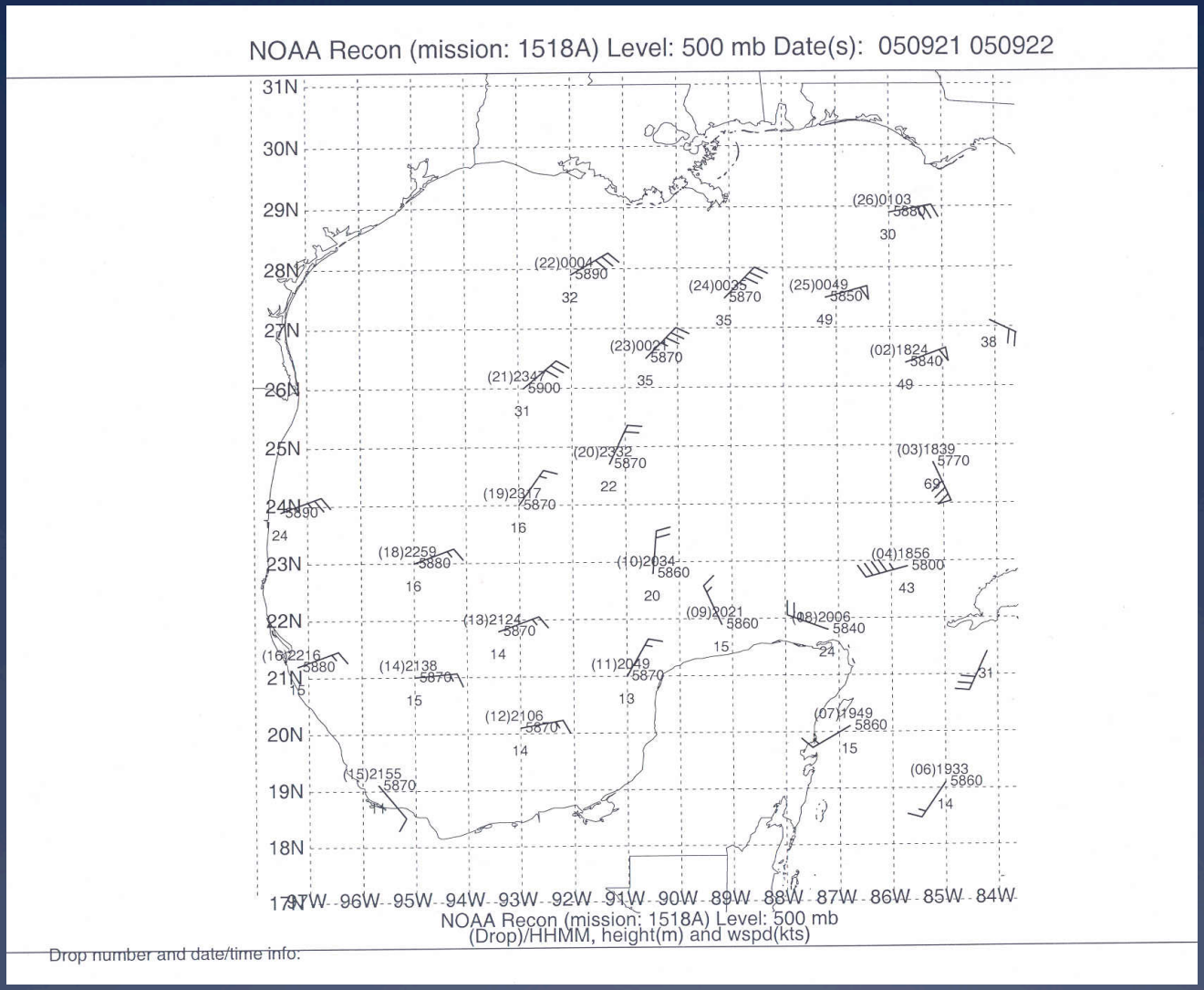
```
UZNT13 KWBC 220345
XXAA  72037 99253 70951 08255 99959 25401 ///// 00867 ///// /////
92322 23204 08646 85060 20408 11120 70/// ///// 15091 88999 77999
61616 AF963 0202A BRET OB 10
62626 EYEWALL 045 SPL 2532N09528W WL150 07136 121 DLM WND 11615 6
96955 MBL WND 08141 LST WND 046=
XXBB  72038 99253 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=
```

CONVERSIONS: SFC WND = 0.80*MBL WND
1 mb = 8.5 m at sea level.

# NMAP2 Display

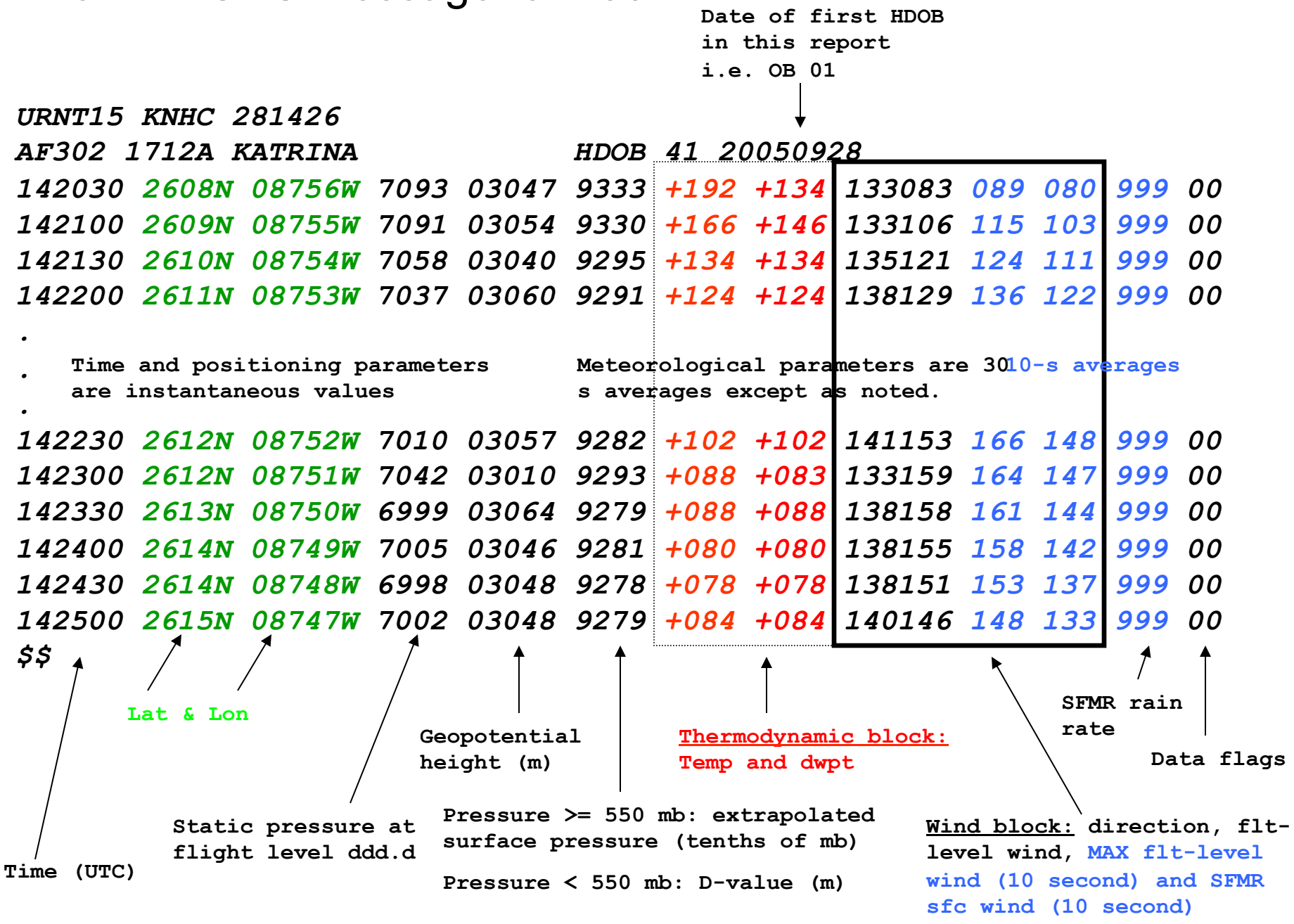


# Synoptic Surveillance




RH data particularly helpful for subjective intensity forecasting

# New HDOBS message for 2007

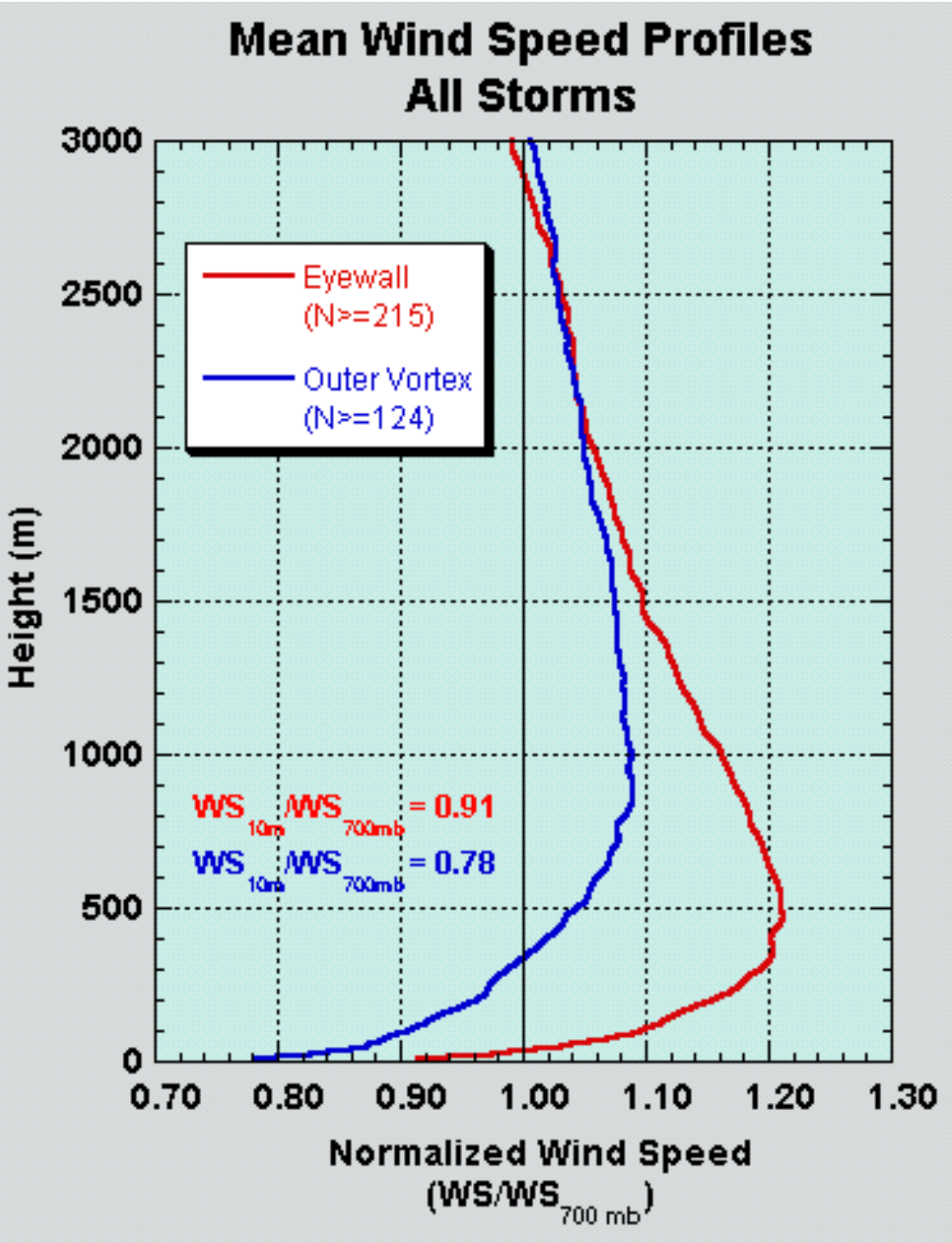


## Estimating intensity from flight-level observations:

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.

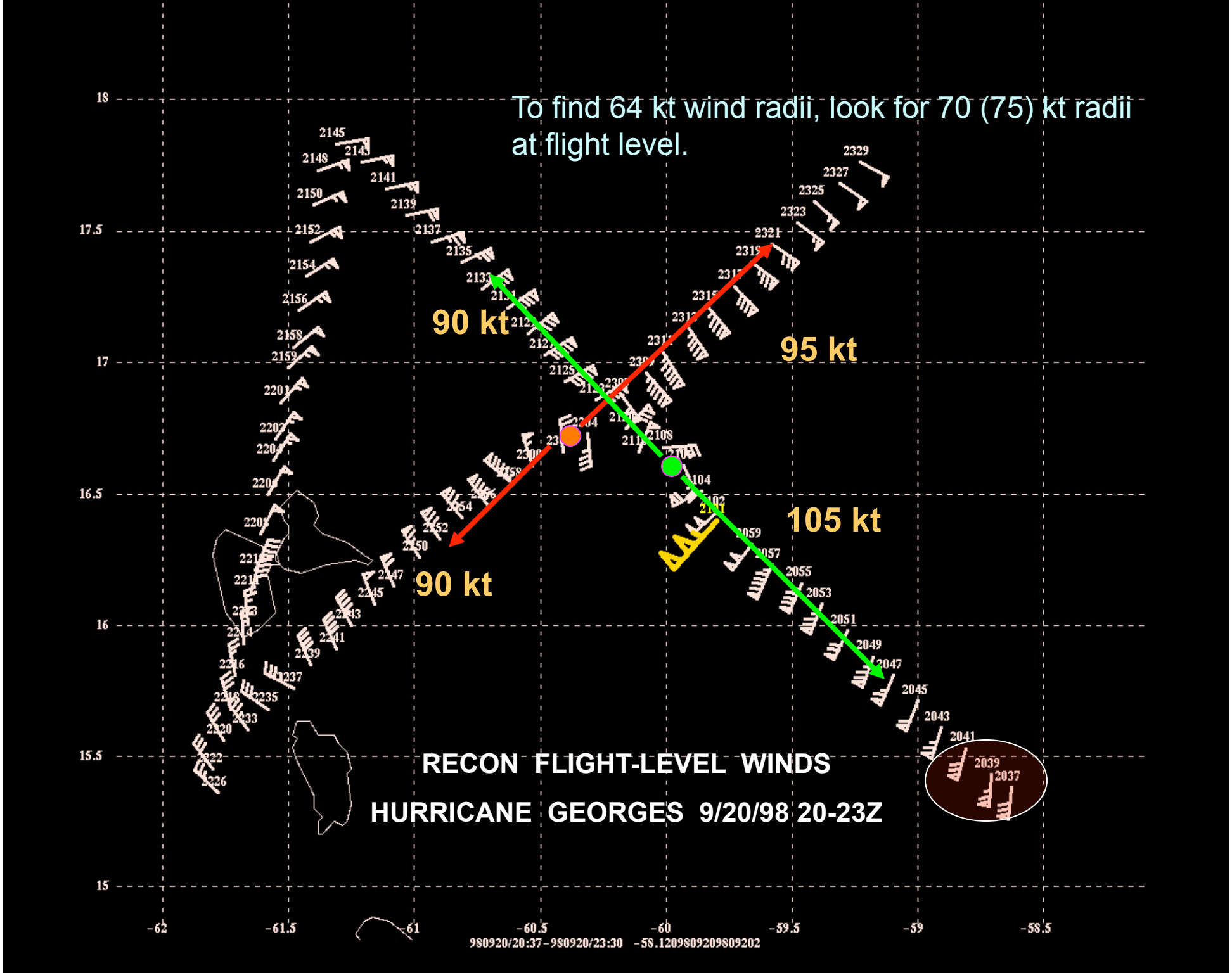


# Estimating Intensity From Flight-Level Wind

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

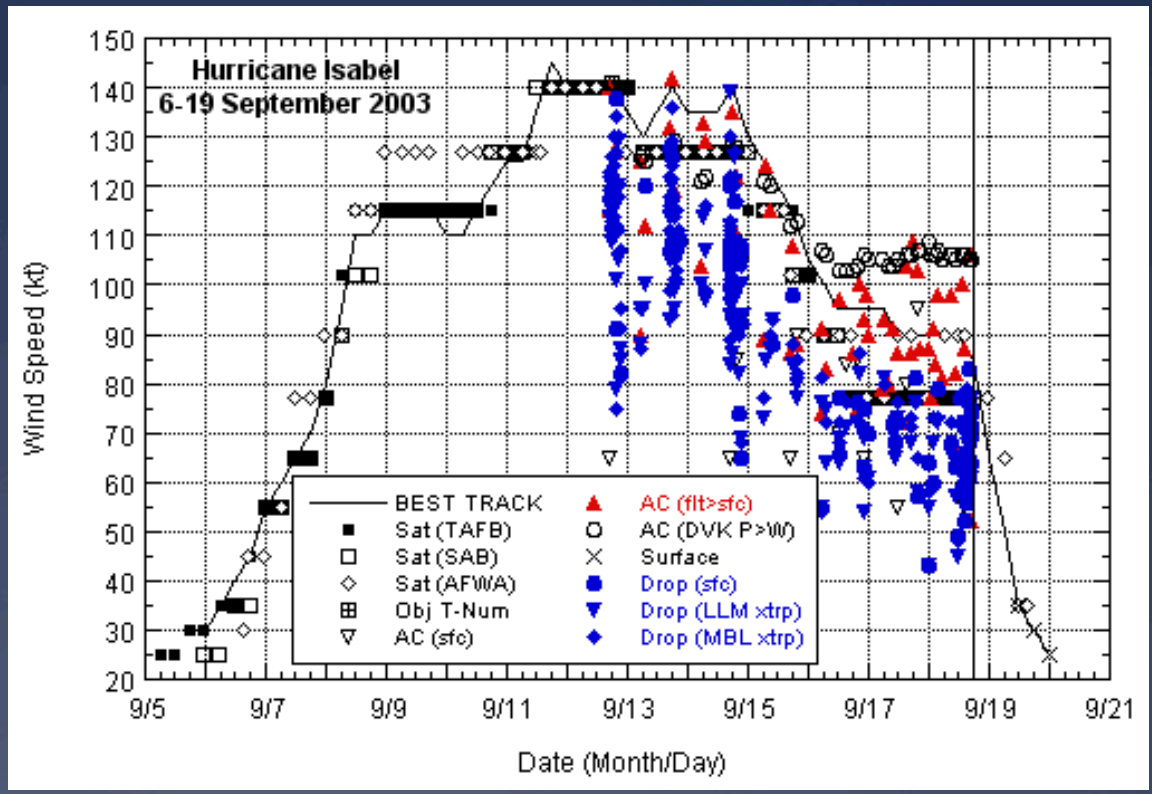
# Intensity Adjustment Factors and Radii Thresholds – 700 mb

| 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

- 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



# Recent work on adjustment factors

- Powell et al. (2009) compared FL data (2-4 km) and SFMR data.
- Powell sample/analysis methodology exhibits more asymmetry.
- Suggestive that mean ratio on the RHS might be less than 0.86.

| Surface to Flight-Level Eyewall Wind Ratios | | | | |
|---|---|---|---|---|
| Study | Level | Overall | Left Side | Right Side |
| Franklin et al. (2003) | 700 mb (2865 m) | 0.88 | 0.90 | 0.86 |
| Powell et al. (2009) | 2-4 km (2765 m) | 0.84 (0.85) | 0.89 (0.90) | 0.79 (0.80) |

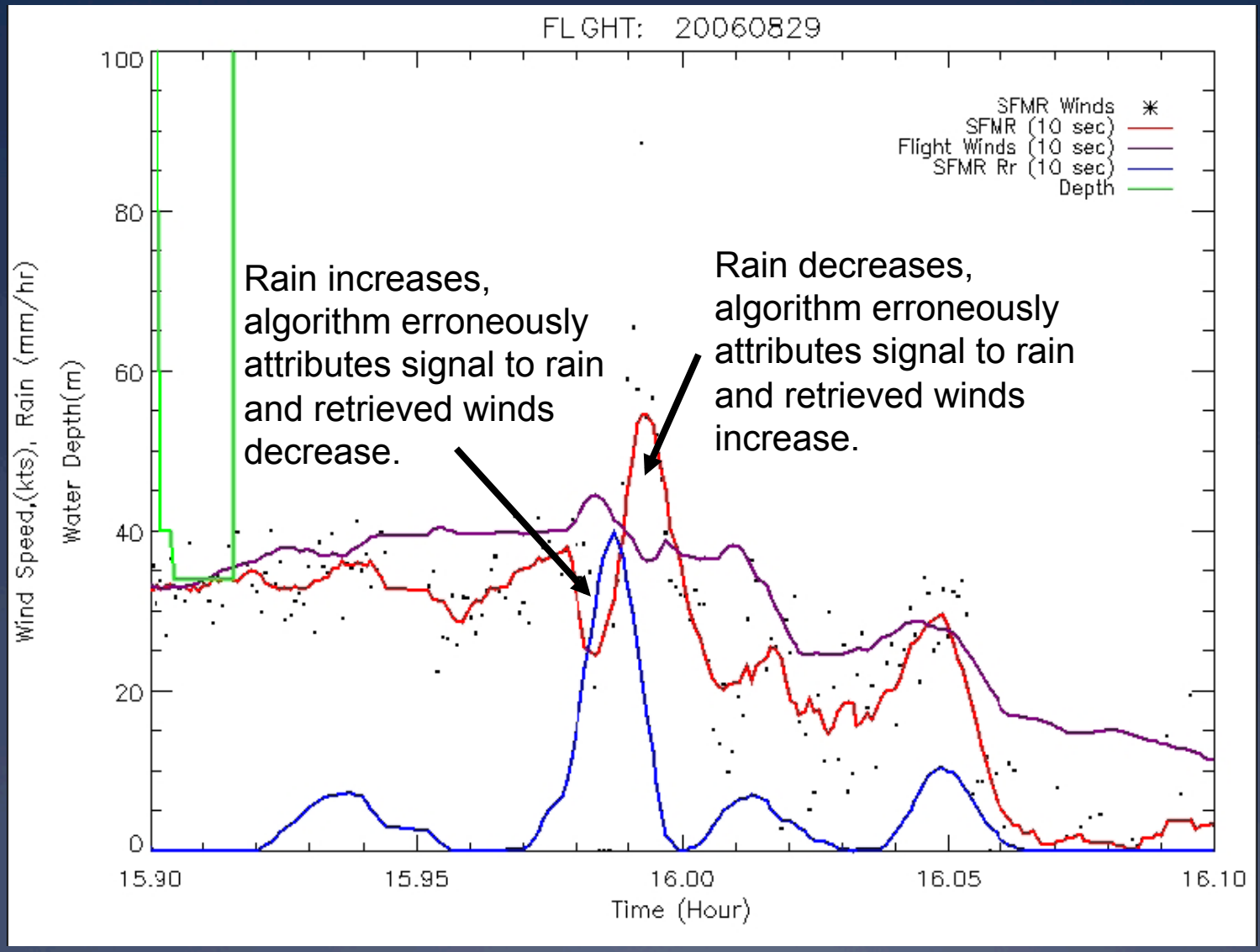
# Recent work on adjustment factors

- Uhlhorn and Nolan estimated the amount of under-sampling associated with a standard reconnaissance flight pattern for the peak 1-min mean wind was 8.5%.
- All else being equal, NHC currently applies a 4% under-sampling adjustment to the Franklin et al. mean ratio.
- If the true RHS local eyewall ratio was 0.83 (split the difference) and Uhlhorn and Nolan are correct, then 90% of the FL peak still seems like a reasonable intensity estimate.
- NHC plans no changes to its operational procedures as a (combined) result of the Powell and Uhlhorn studies.

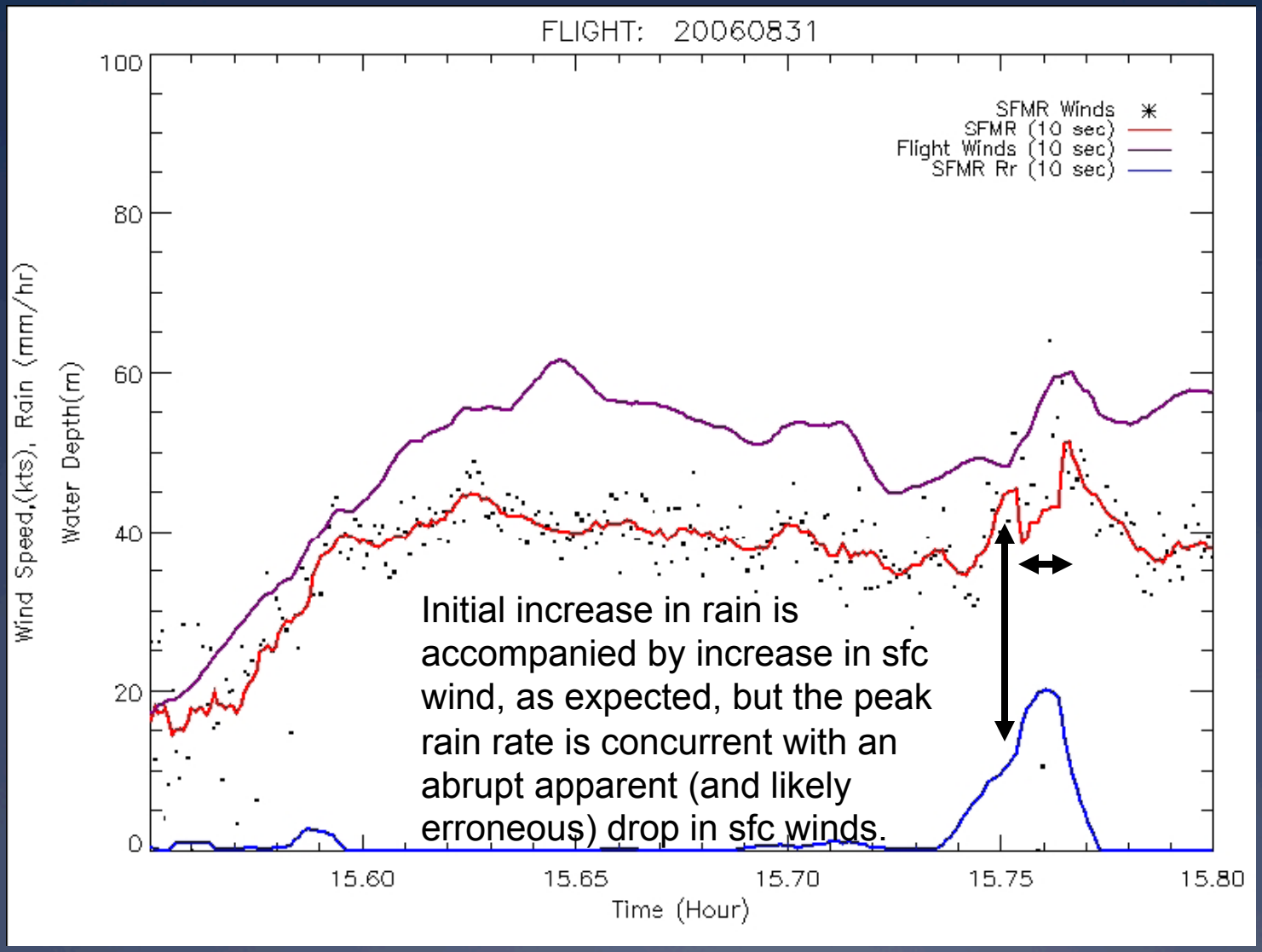
# SFMR issues

- 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 only recently completed (and forecasters perceive this to be an ongoing process). Forecaster understanding of these issues is primitive.

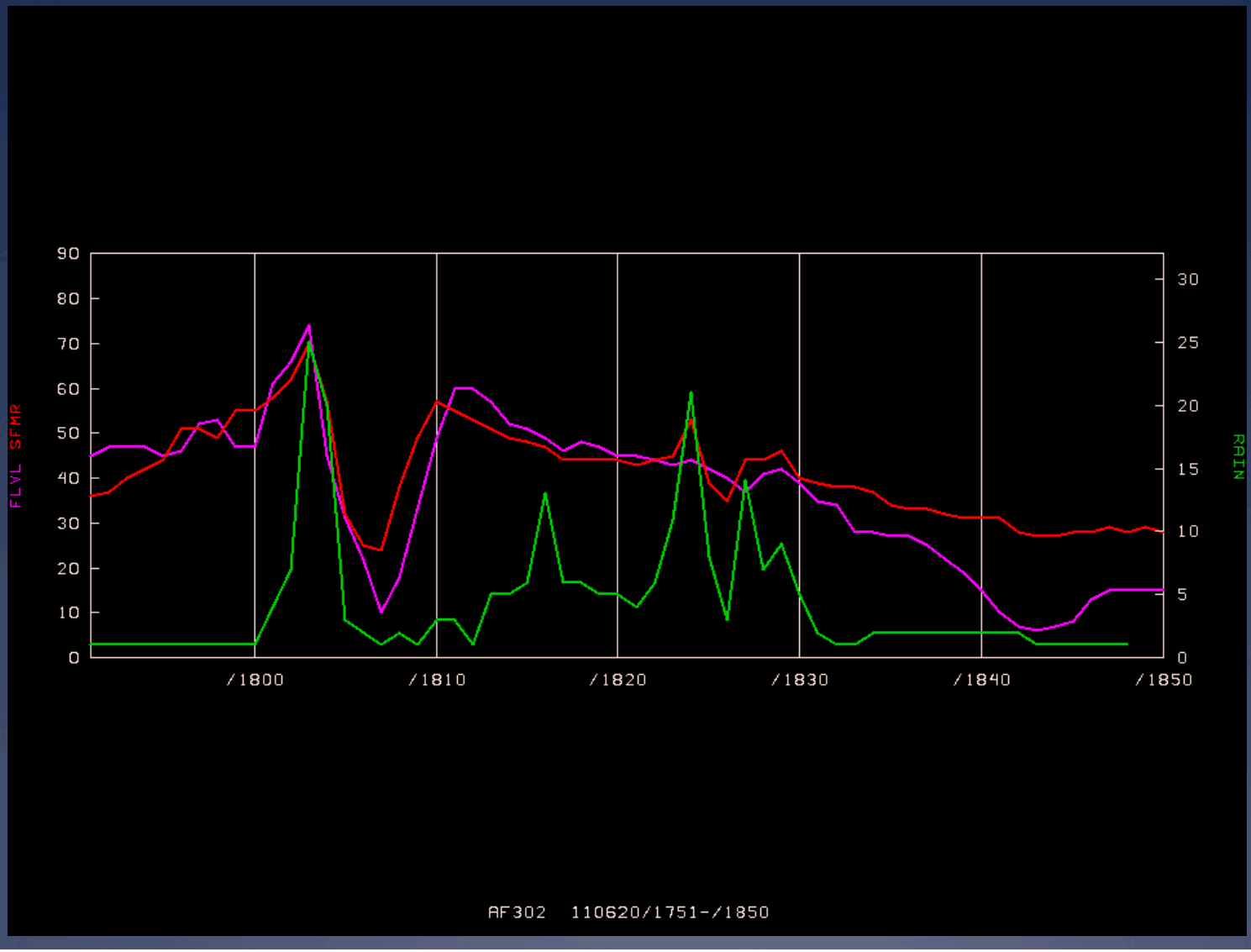
# Rain-Wind Error Couplets Can Occur at TD/TS Wind Speeds



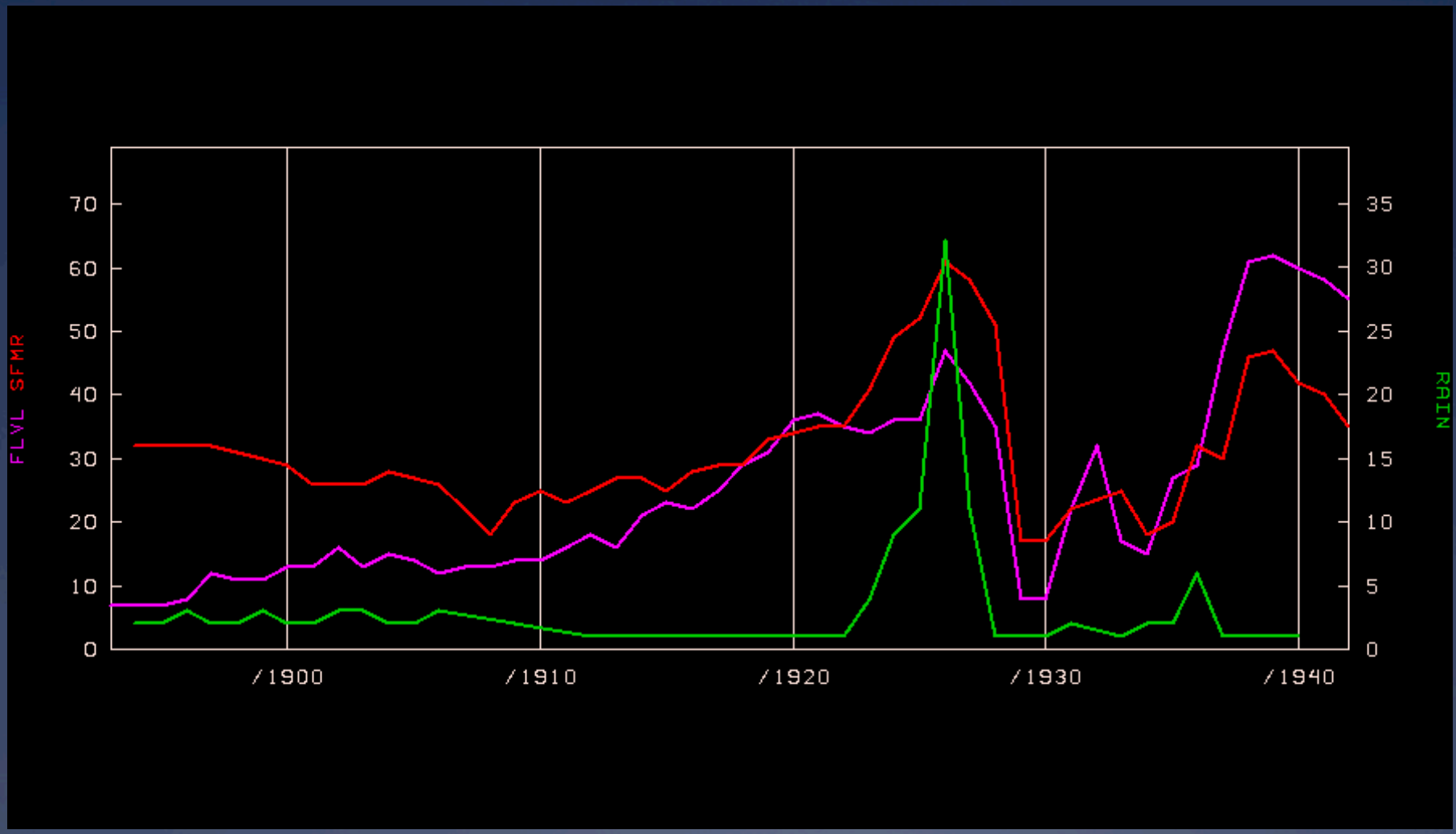
# Effect can be subtle



# Operational Depiction of SFMR data

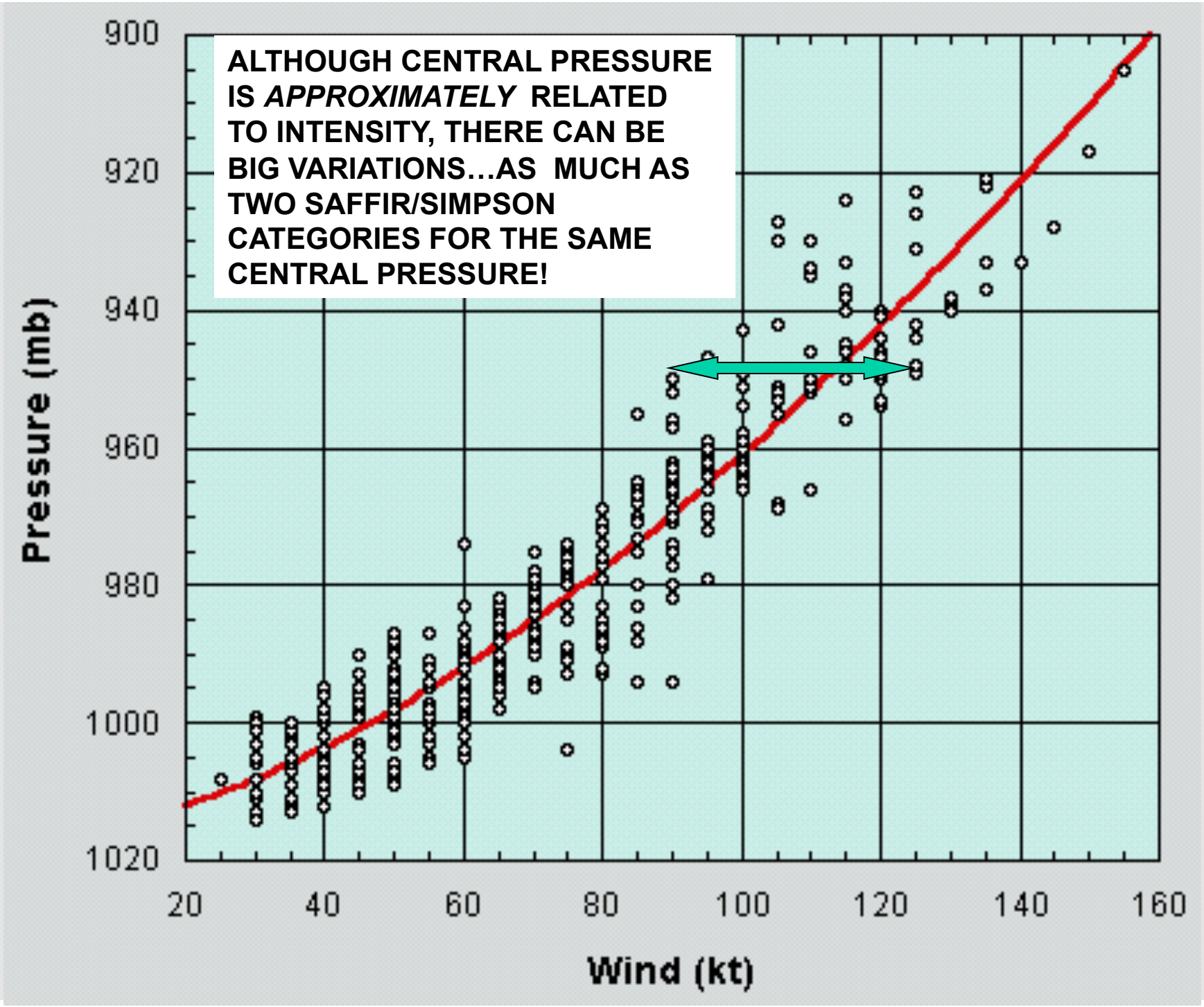


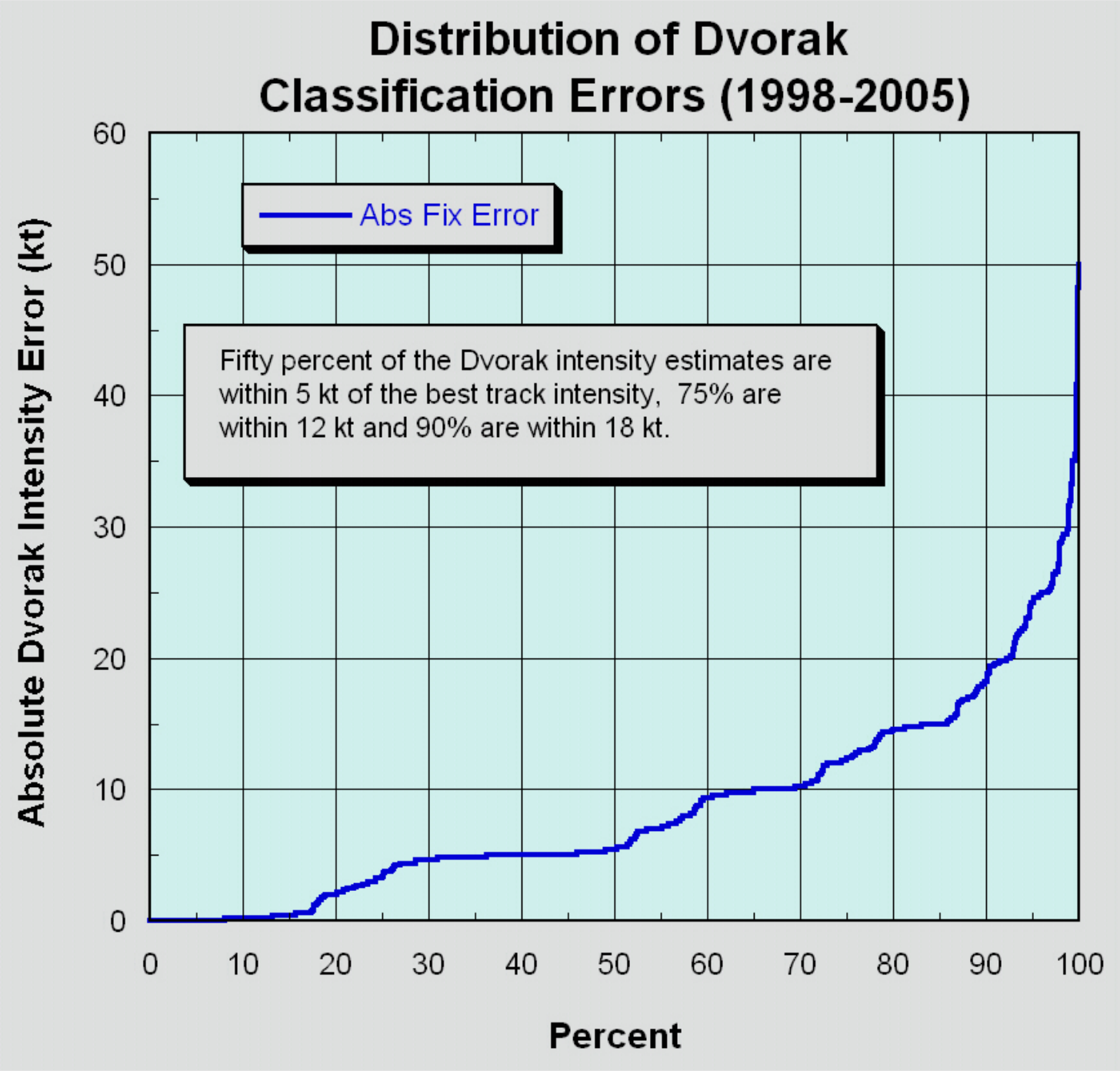
# Tropical Storm Bret
# 18 July 2011



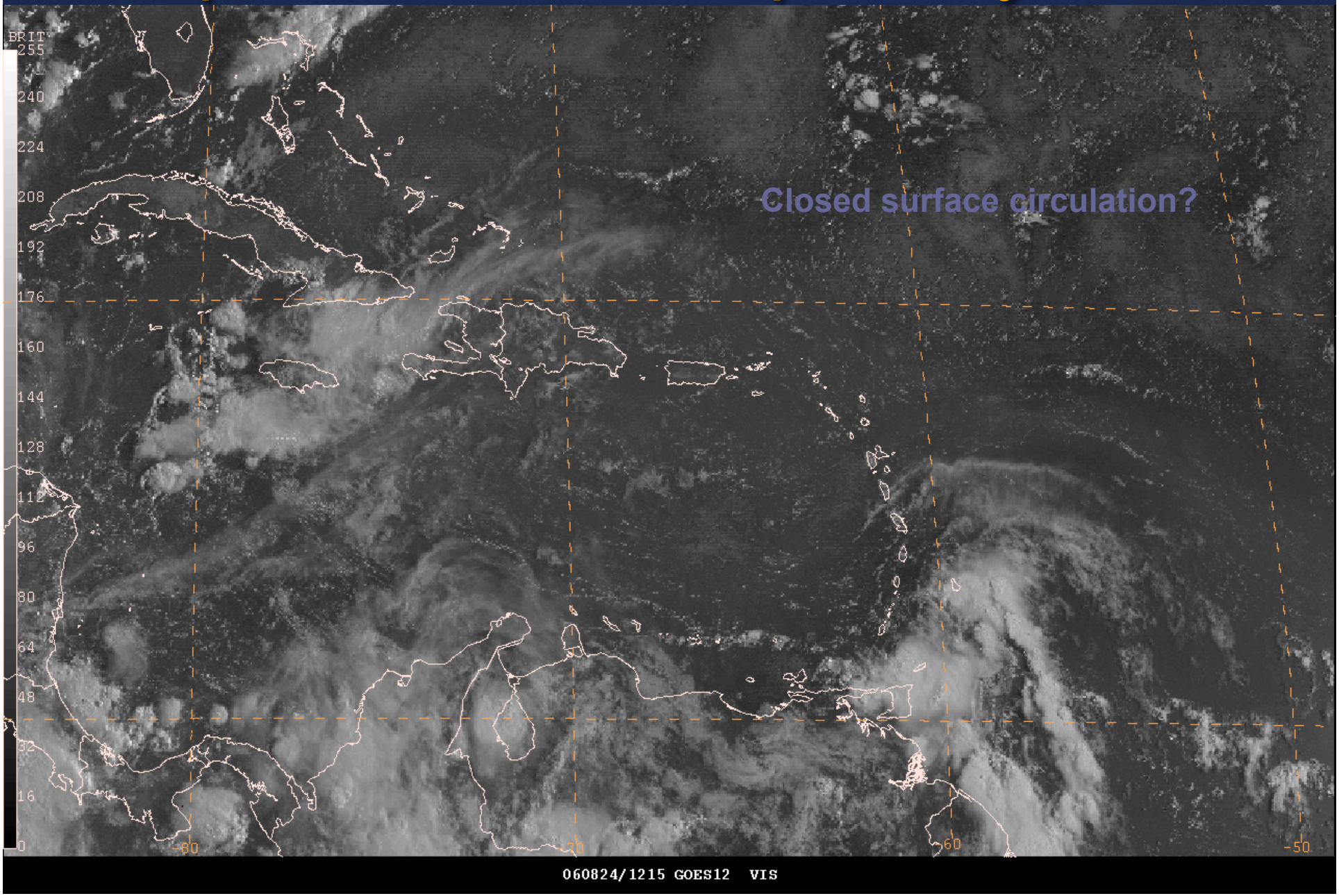
# Estimating TC intensity: Reconciling Conflicting Information

- Know the error bounds of the various platforms.
- Evaluate each observation for representativeness.
  - Was the maximum sampled?
  - Was it representative of the tropical cyclone or was it a transient feature?
  - Standard adjustment of FL winds? Are there enough sondes/SFMR data to know?
  - Balance between SFMR and FL wind (FL winds more temporally representative?).


ALTHOUGH CENTRAL PRESSURE IS *APPROXIMATELY* RELATED TO INTENSITY, THERE CAN BE BIG VARIATIONS…AS MUCH AS TWO SAFFIR/SIMPSON CATEGORIES FOR THE SAME CENTRAL PRESSURE!
Pressure (mb)
900
920
940
960
980
1000
1020
20
40
60
80
100
120
140
160
Wind (kt)


Distribution of Dvorak Classification Errors (1998-2005)
Absolute Dvorak Intensity Error (kt)
Abs Fix Error
Fifty percent of the Dvorak intensity estimates are within 5 kt of the best track intensity, 75% are within 12 kt and 90% are within 18 kt.
0
10
20
30
40
50
60
70
80
90
100
Percent

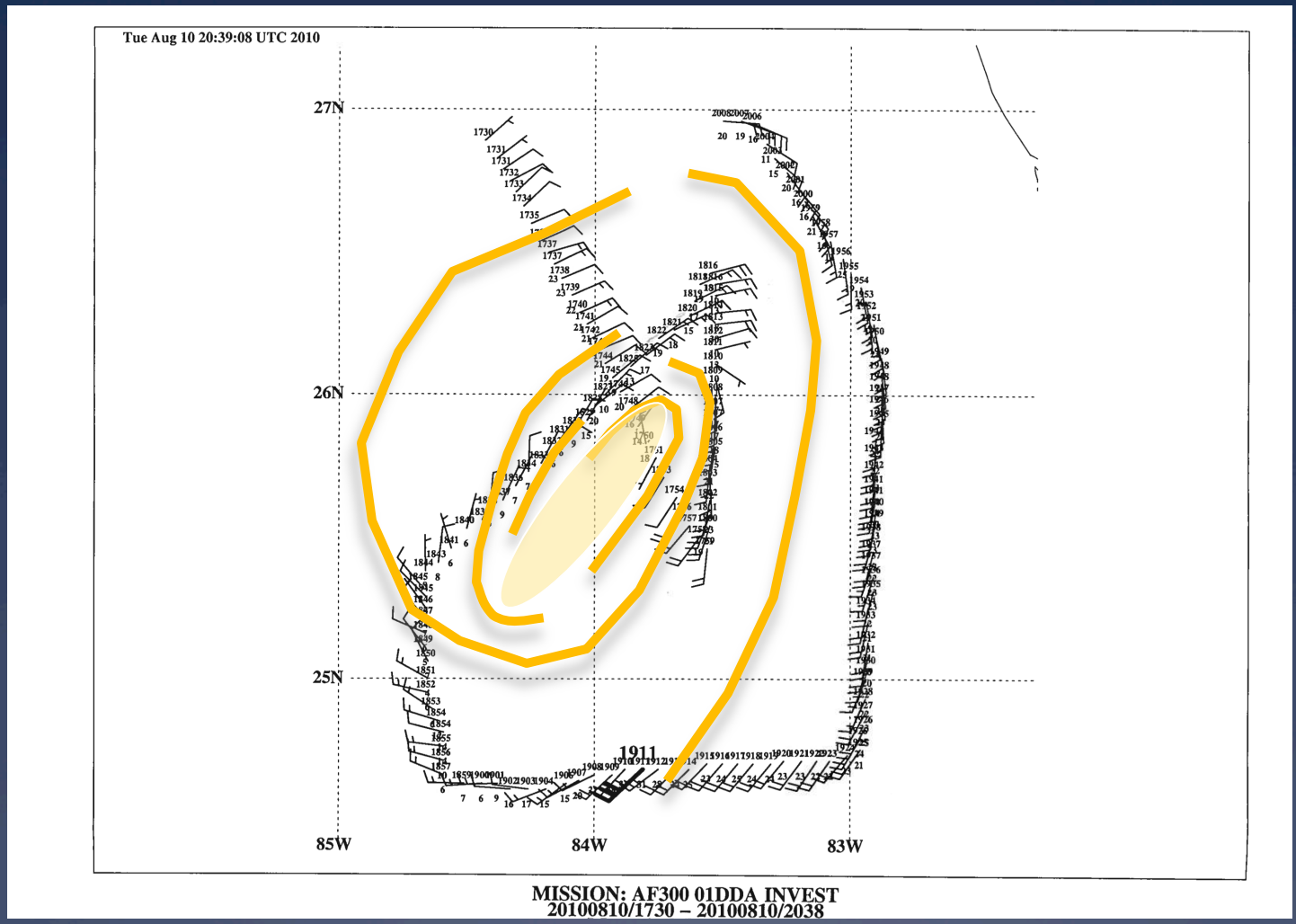
# Tropical Wave or Tropical Cyclone?



# 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 (CLU: Center Location Uncertainty).
  - The center can be considered well defined if the major axis of the CLU is less than 75 n mi and the ratio of the major to minor axis is less than 2.
  - Never let it be said that the NHC doesn’t have a CLU.

# CLU Example




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