

Use of Aircraft Data at the National Hurricane Center

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WMO RA-IV Workshop
May 2019



Aircraft Observations

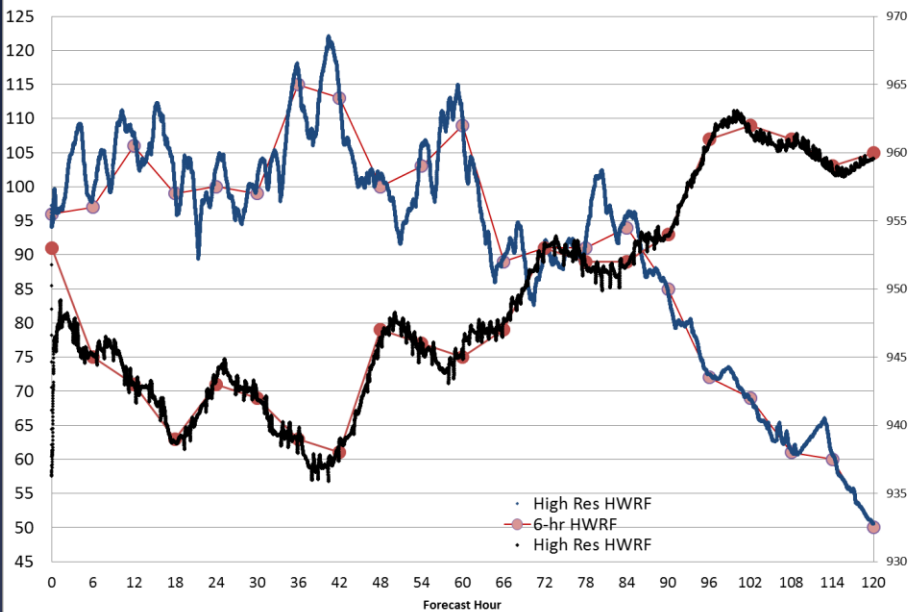
- * Flight-level observations, SFMR, dropwindsondes, and radar
- * Can be used subjectively by the Hurricane Specialists (HS)
 - * Assist in the analysis and short-term forecasting of location, intensity, size, structure of the cyclone/disturbance.
- * Provide input to forecast models
 - * Directly (e.g.,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

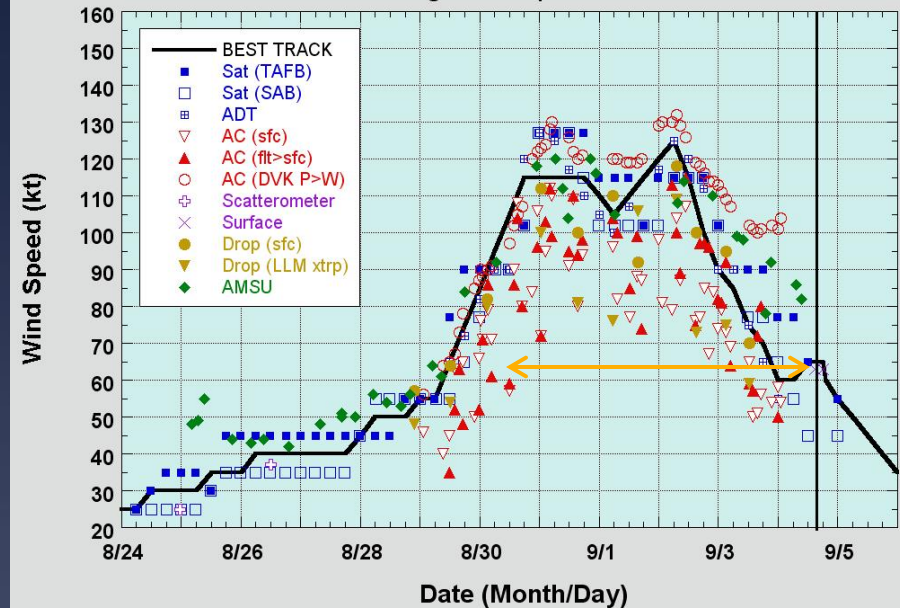
- * **Maximum sustained surface wind:** When applied to a particular weather system, refers to the highest 1-min average wind (at an elevation of 10 m with an unobstructed exposure) **associated with that weather system at a particular point in time.** (NWSI 10-604)
- * Intensity is not the highest 1-min 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, mesocyclones, 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



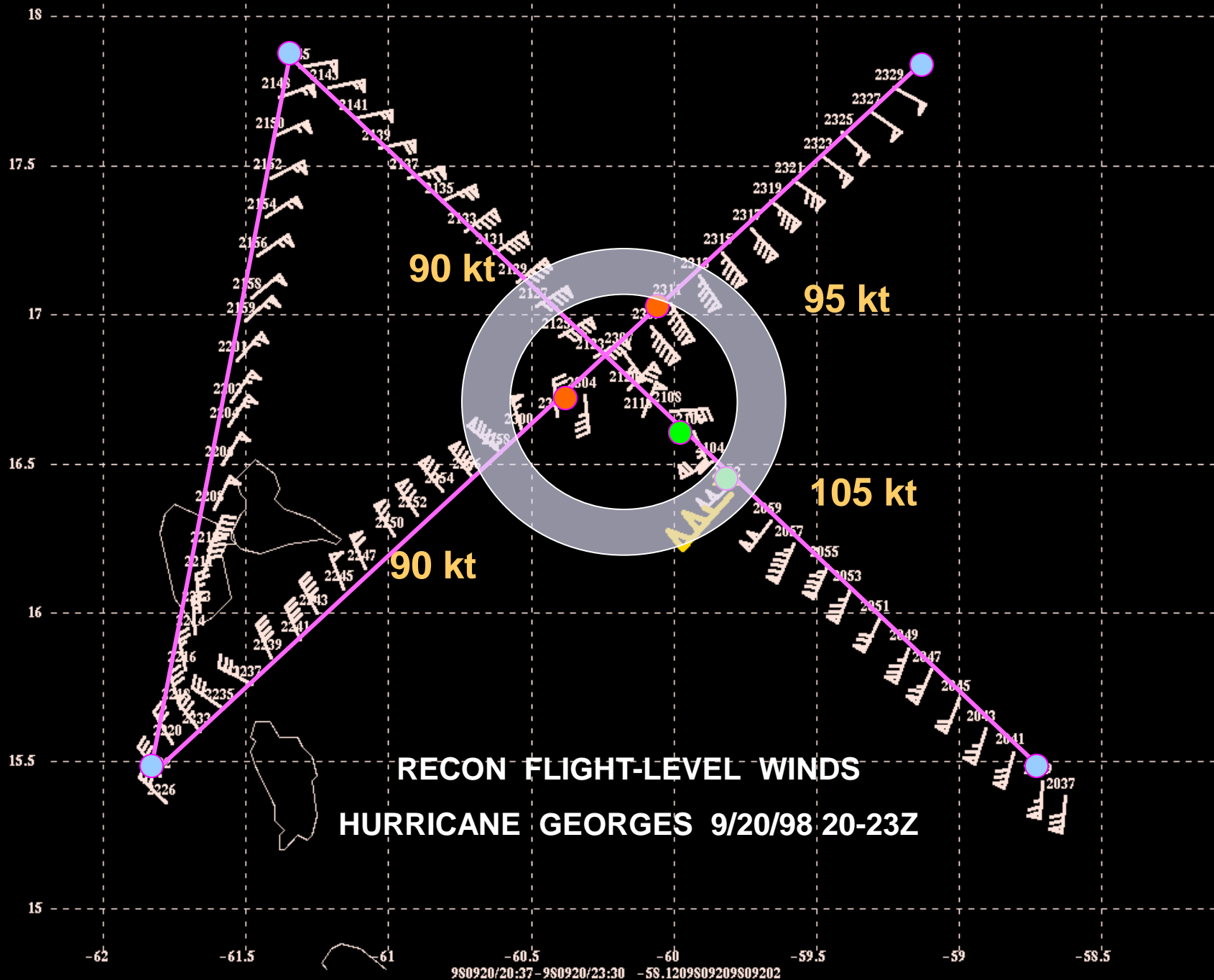
Hurricane Earl
25 August - 4 September 2010



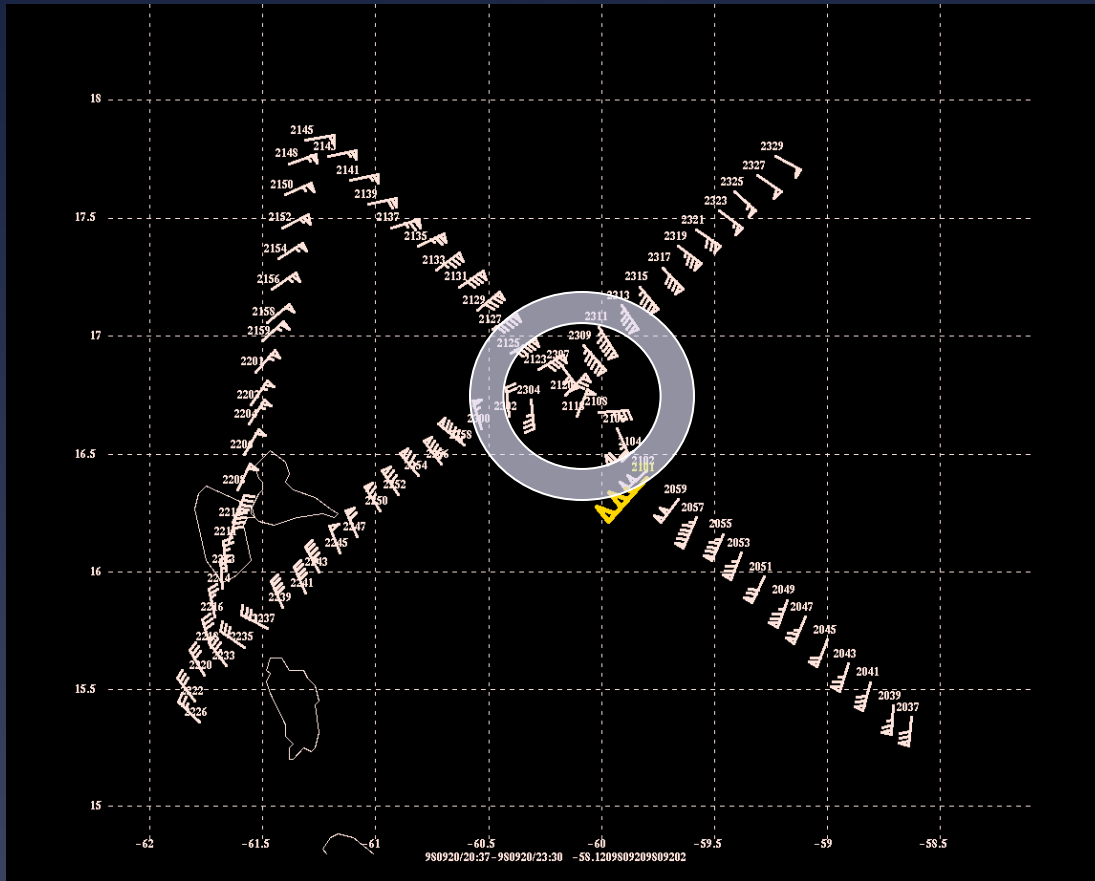
Peak winds in a model TC (blue curve in left diagram) can vary widely over periods of a few hours. Tracking these rapid changes for real storms is neither possible nor desirable.

Best Track: Six-hourly **representative** estimates of the cyclone's center position, maximum 1-min mean surface (10-m) wind, min sea level pressure, and max 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.

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.

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
 - * 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
- * As a result, NHC intensity estimates good to +/- 10%.

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

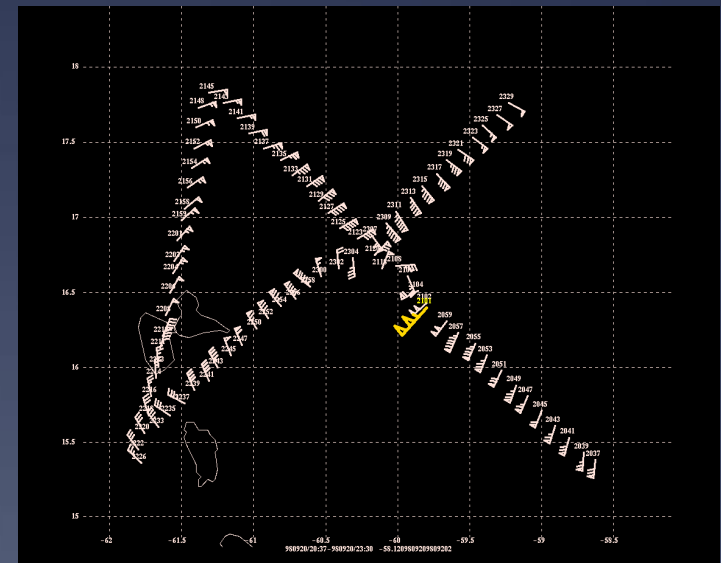
S. 12345 / 7

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

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MAX FL WIND 108 KT 349 / 14 NM 11:17:00Z

most recent passes through each octant

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

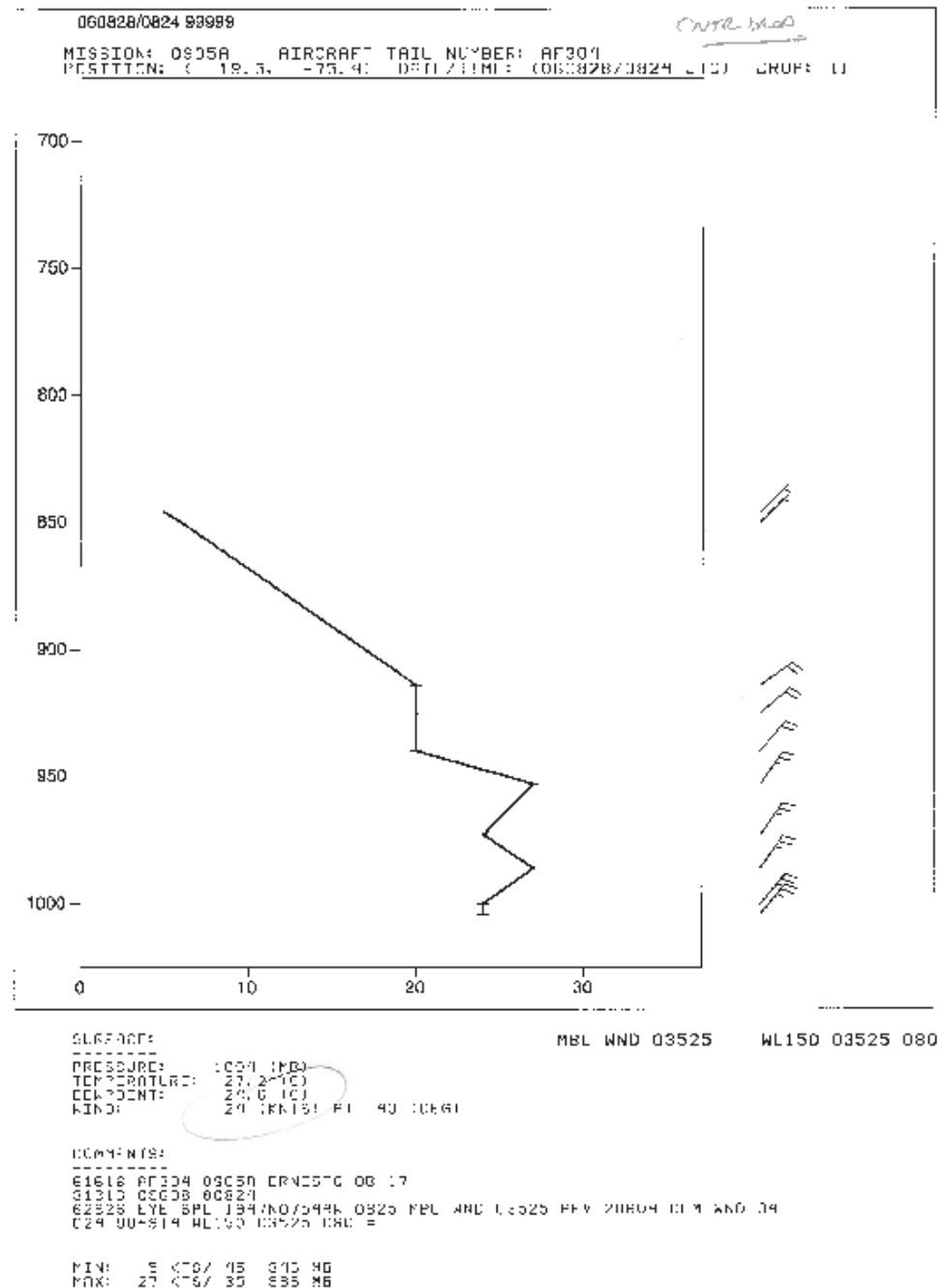
Center (eye) drops are released at the flight-level wind minimum, but may drift away from surface minimum.

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.

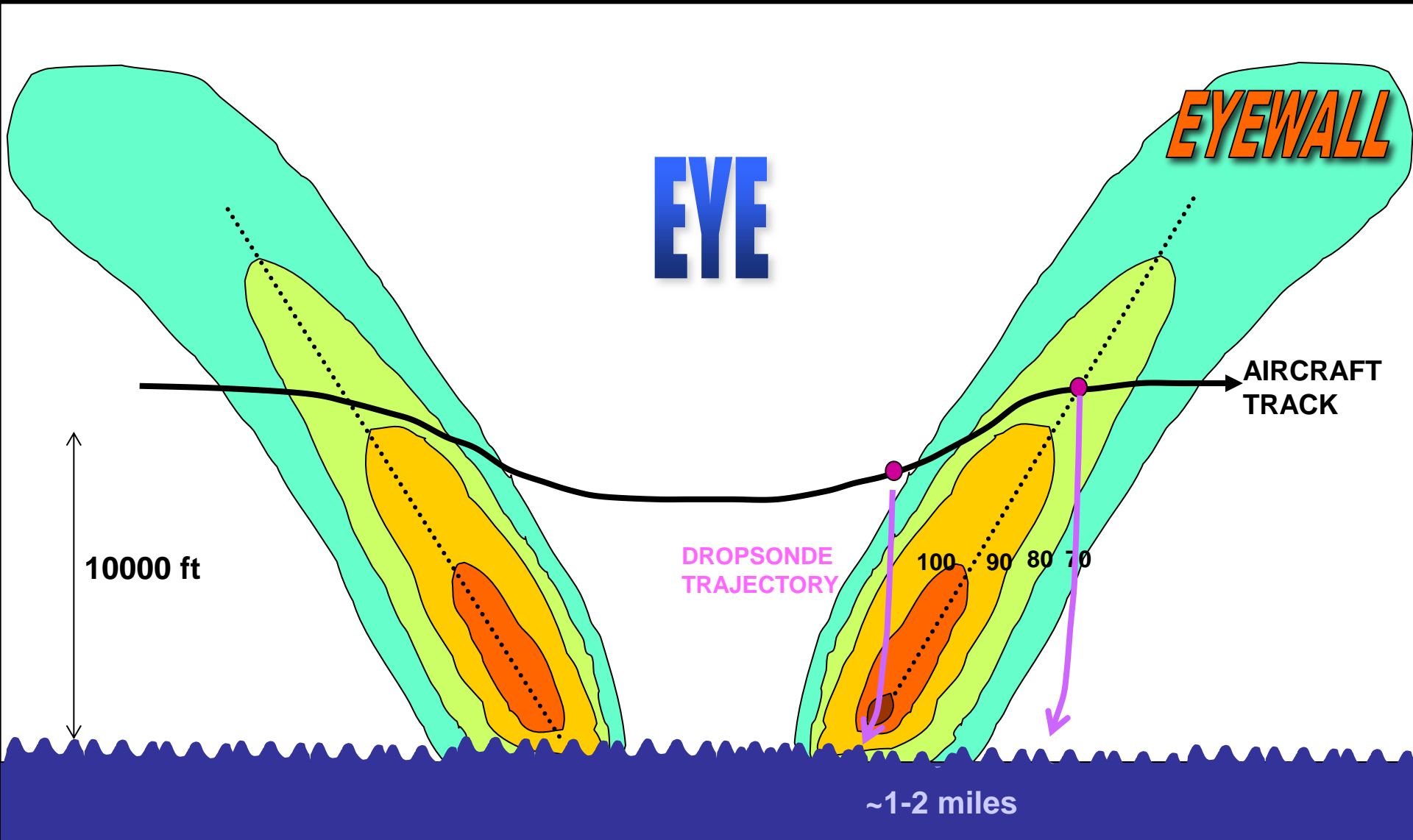
Splash pressure 1004 mb.

Surface wind: 24 kt.

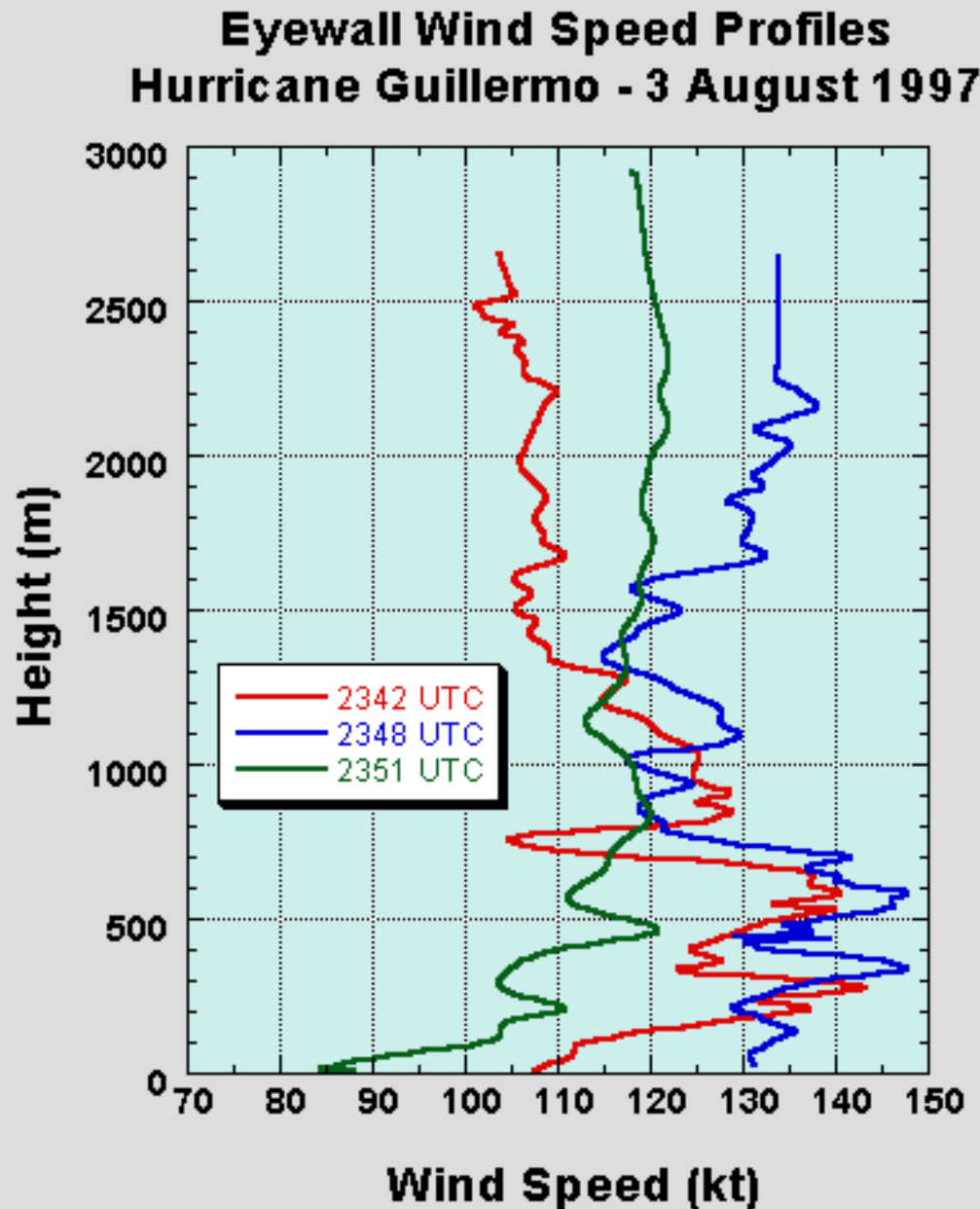
Estimated MSLP = 1002 mb.



Representativeness of Dropsondes

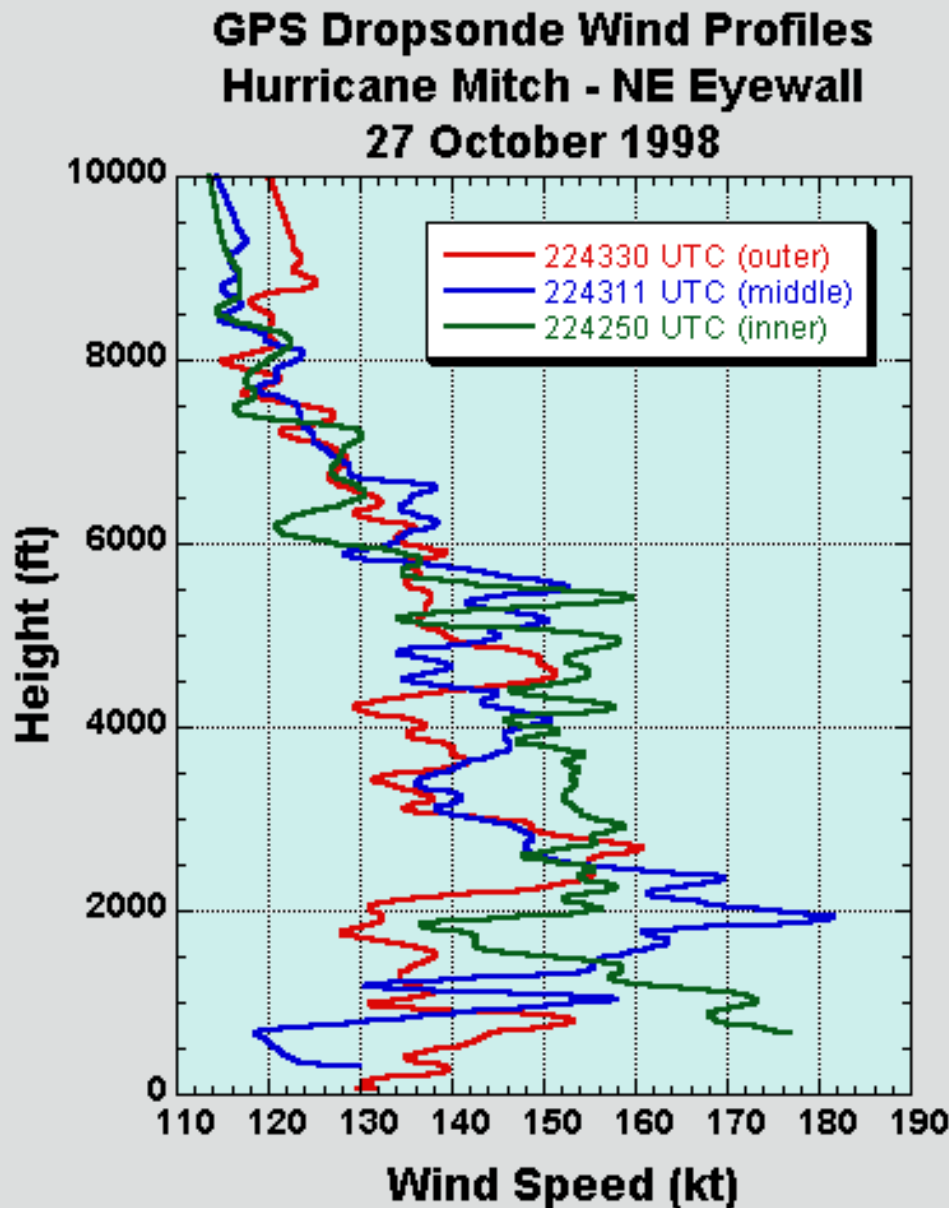


Location, Location, Location



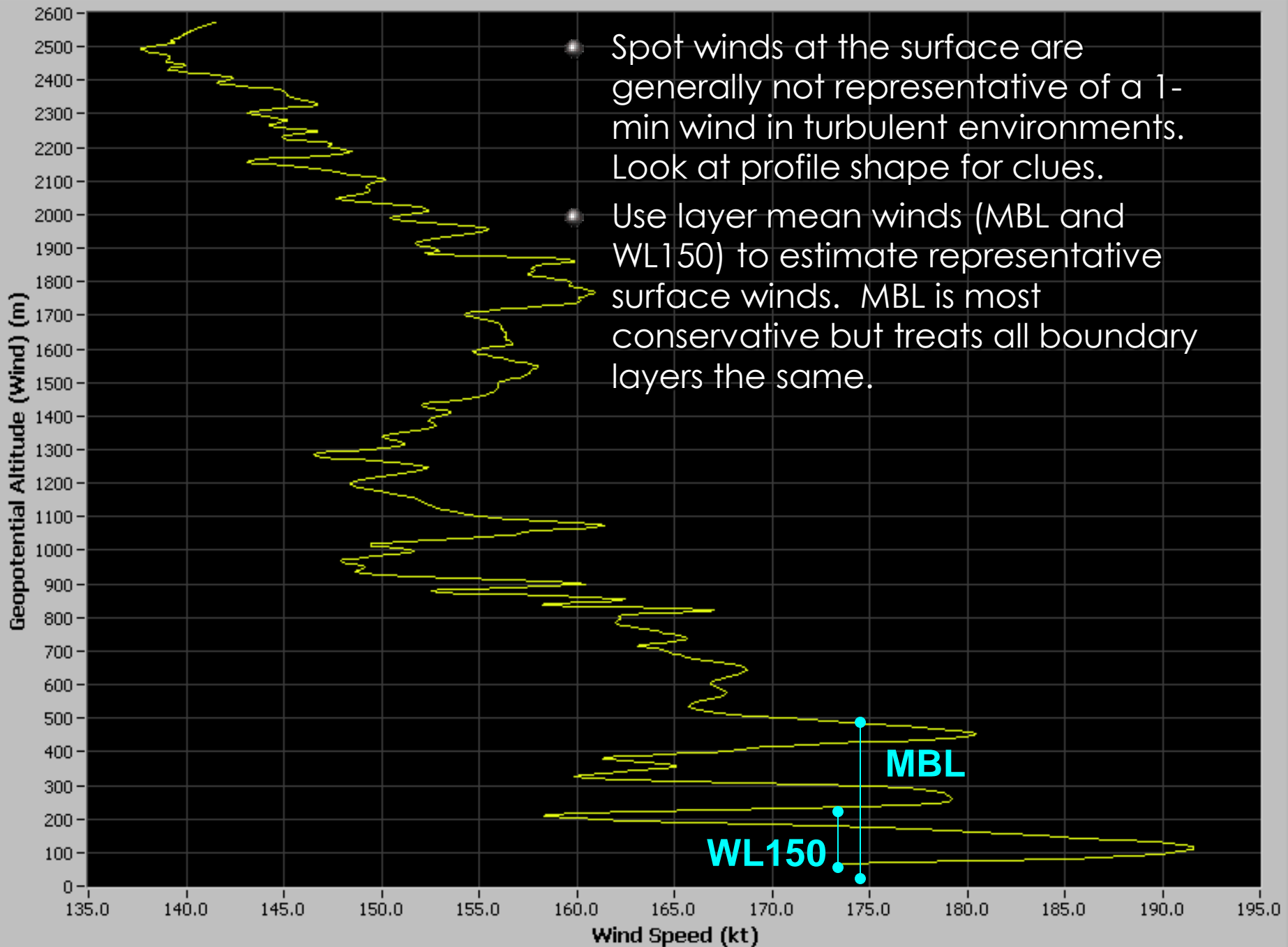
Three dropsondes released in different portions of the hurricane eyewall recorded surface winds differing by ~45 kt!

Small-scale Variability in a Tropical Cyclone

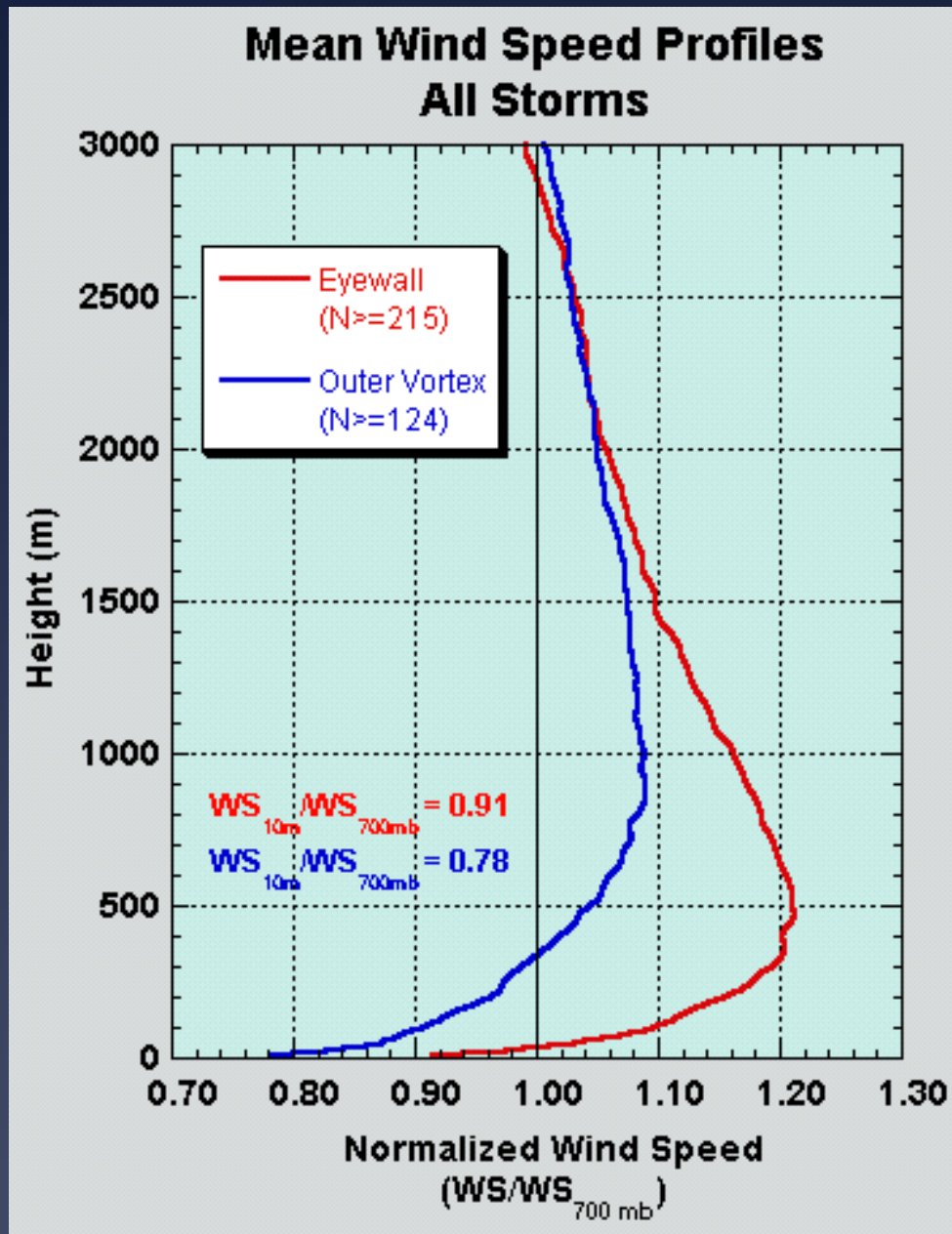


Three dropsondes released over a span of 40 seconds. These closely spaced soundings quickly diverge in the turbulent and chaotic hurricane environment, **especially in the boundary layer.**

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



Mean Hurricane Wind Profiles



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

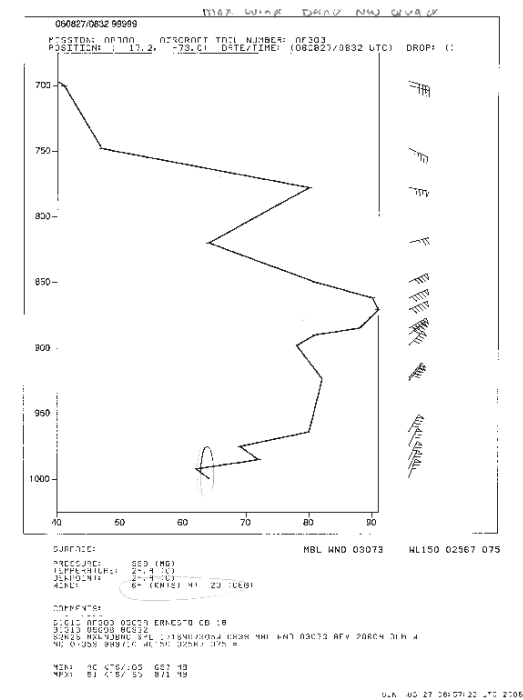
Mean hurricane profiles can be used to adjust winds from one level/layer to the surface.

TEMP-DROP message and EYEWALL WINDS

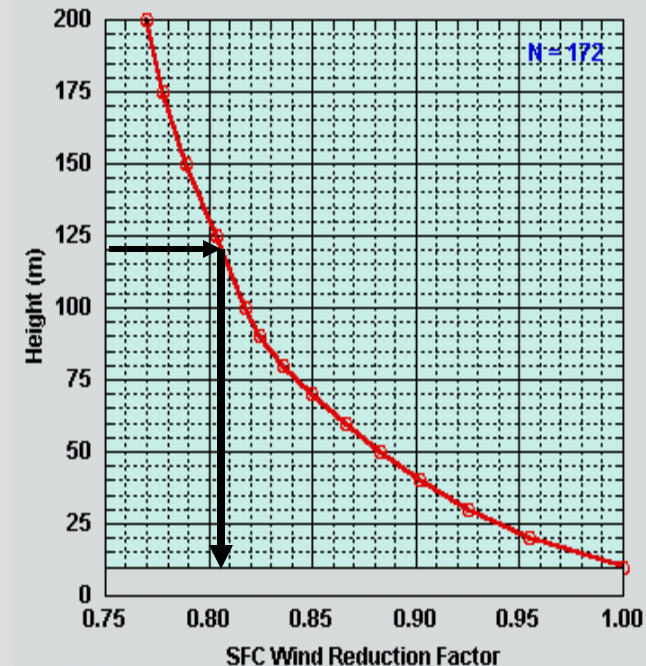
UZNT13 KWBC 220345

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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=
  
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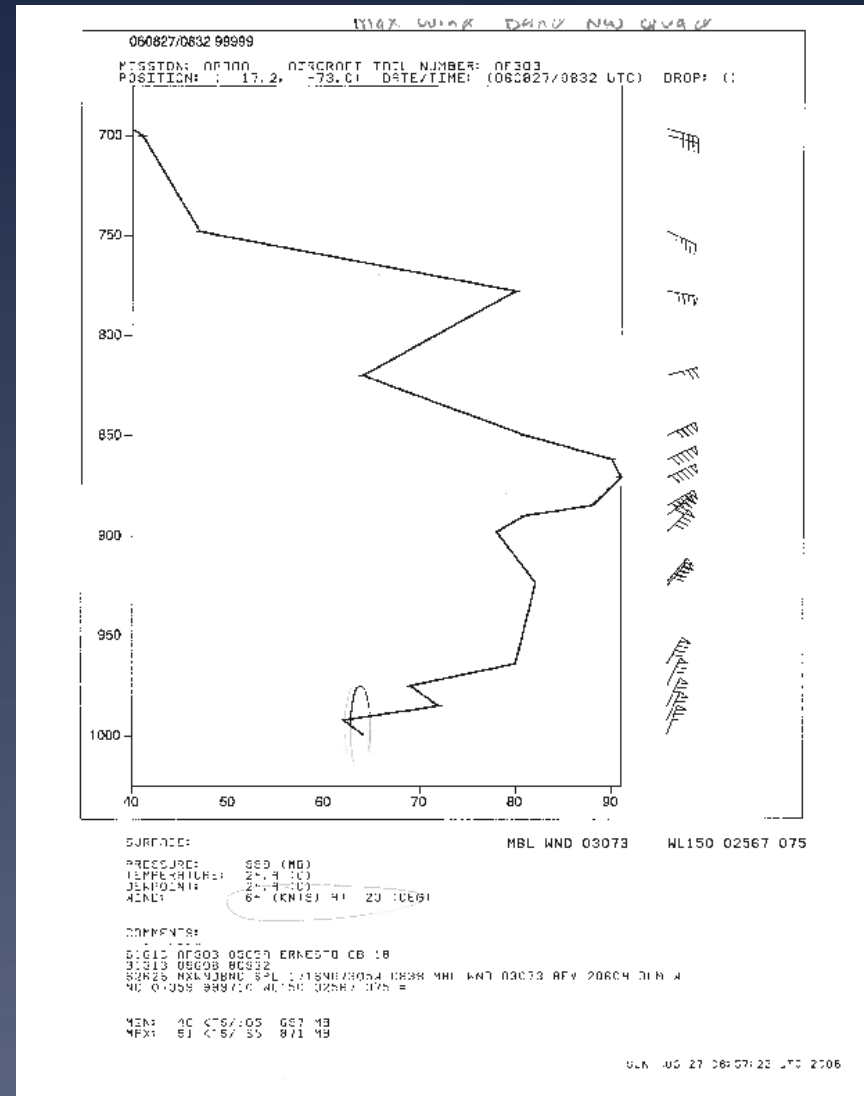


Eyewall Low-Level Wind Reduction Factors



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.



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)

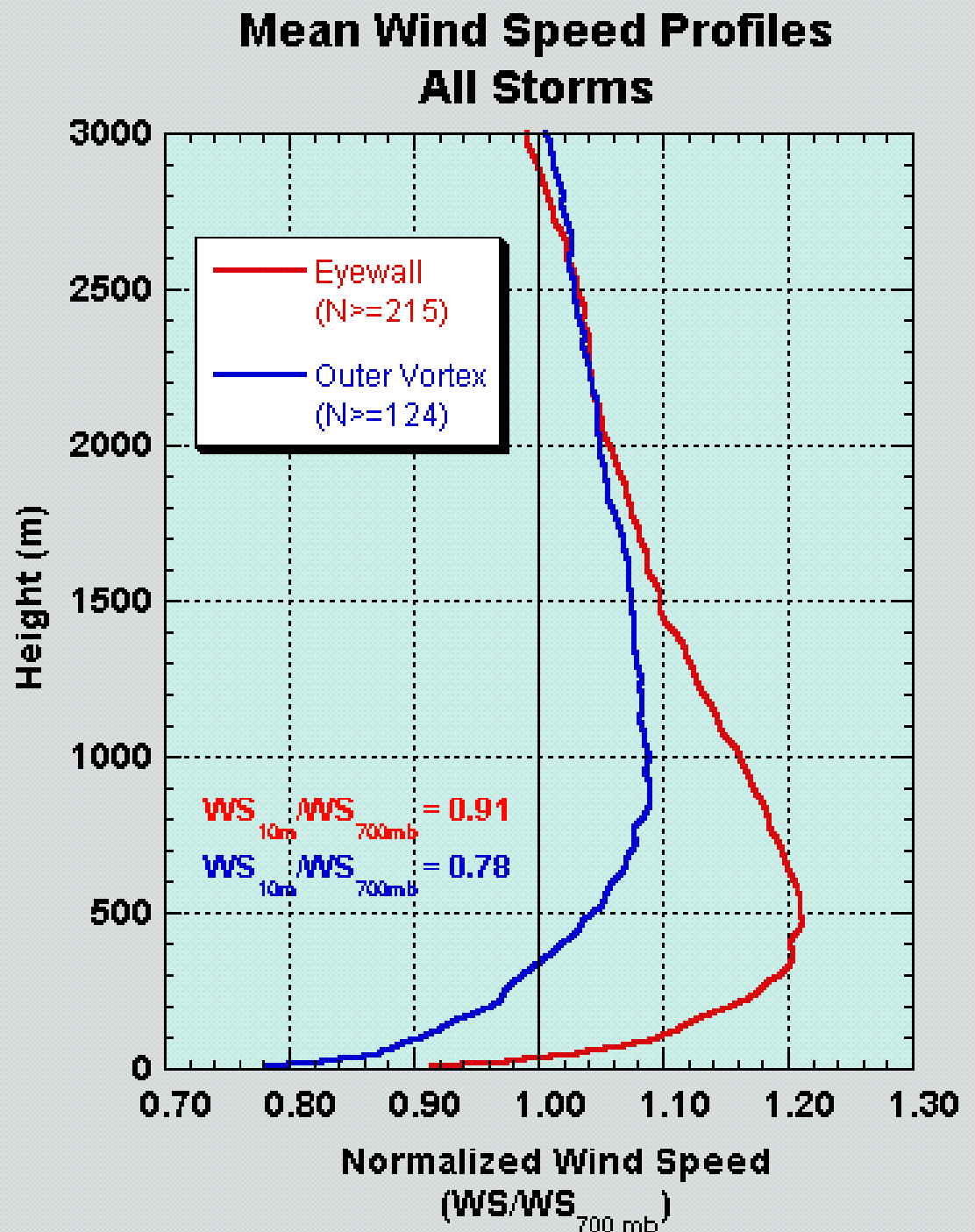
Wind block: direction, flt-
level wind, MAX flt-level
wind (10 second) and SFMR
sfc wind (10 second)

Time (UTC)

Estimating intensity from flight-level observations:

Franklin et al., 2003 mean wind 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.

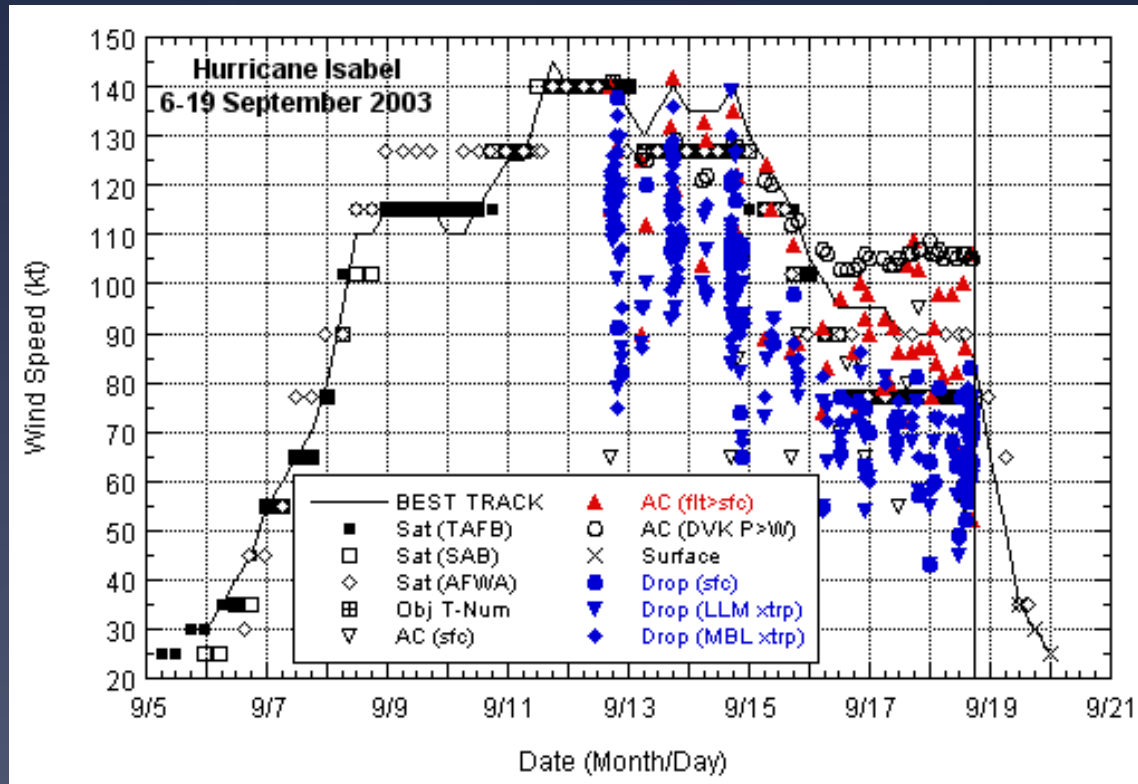


Estimating Intensity From Flight-Level Wind

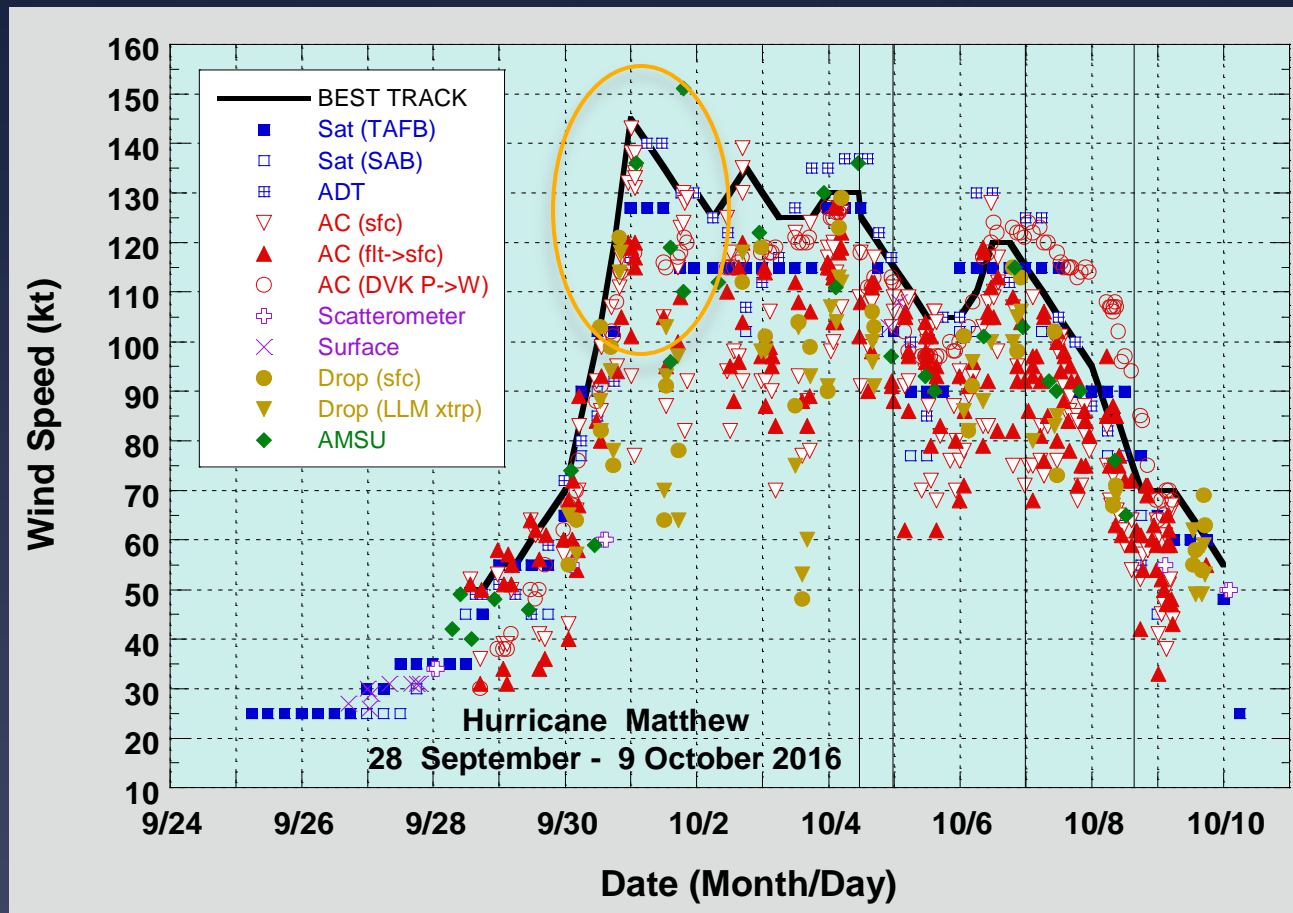
Reference Level	Adjustment Factor
700 mb	90%
850 mb	80%
925 mb	75%
1000 ft	80%

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



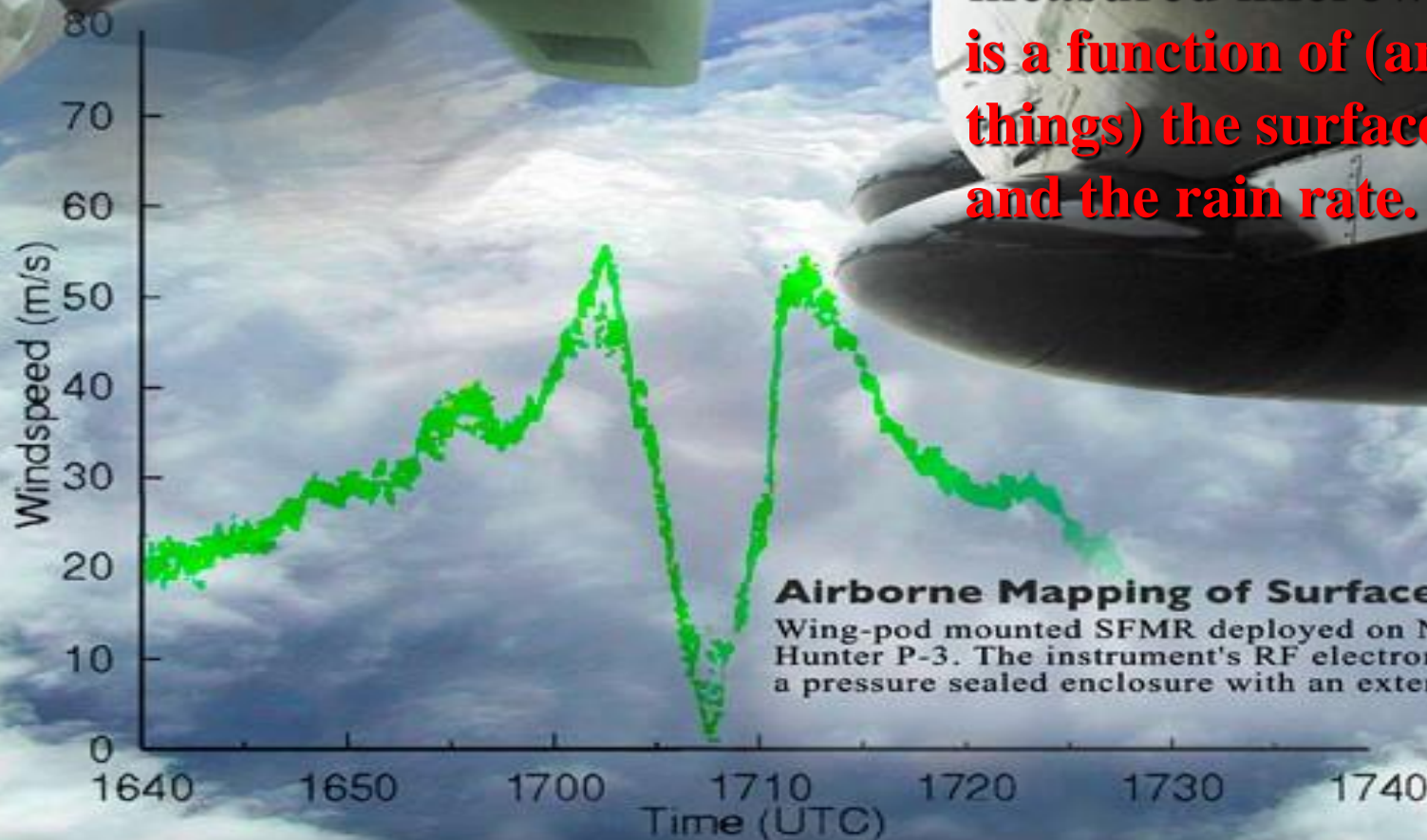
Variability of Standard Adjustment



Near 01/00Z, SFMR data were suggesting intensity 25 kt higher than what the flight-level winds were showing.

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.



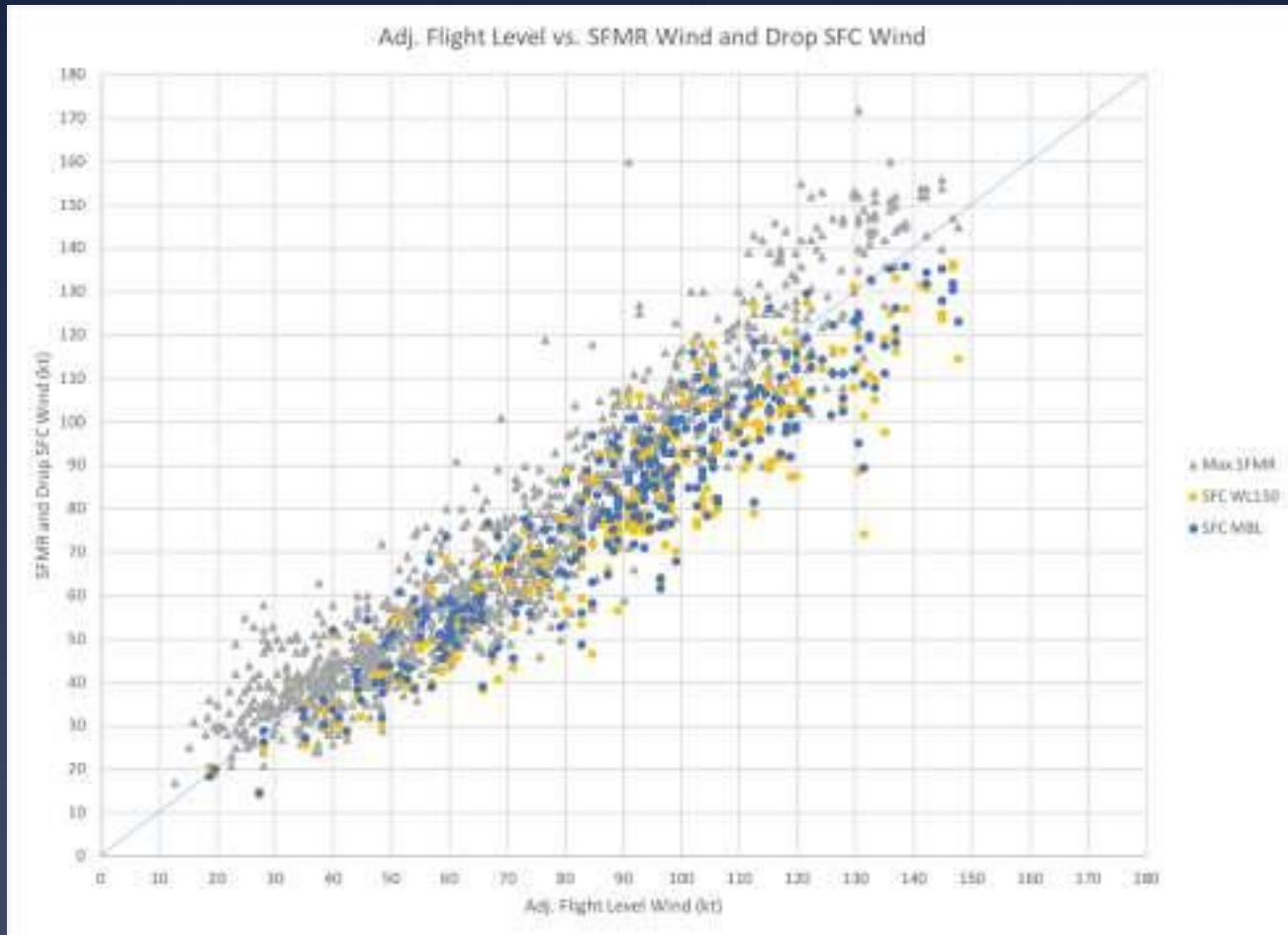
Airborne Mapping of Surface Wind Speed

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 has been an ongoing and frustrating process that may still not be completely resolved.

Possible SFMR Mis-calibration



Recent (2015-18) SFMR data above 100 kt are tending to be higher than surface winds estimated from either flight-level winds or low-level dropwindsonde data. This is (sigh) a subject of active investigation.

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).