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WESTERN HEMISPHERE RECORD RECONNAISSANCE OBSERVATIONS IN HURRICANE PATRICIA

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1. INTRODUCTION

The development of Eastern Pacific Hurricane Patricia (2015) was well documented with in-situ data provided by four reconnaissance flights: three by the NOAA WP-3D (N43RF) and one by a USAF Reserve WC-130J (AF303) over the three day span that covered its life cycle from a minimal tropical storm to a record setting Category 5 hurricane (see **Figure 1**). This paper will focus primarily on the two flights that occurred on 23 October on either side of the 12z peak intensity: AF303, which obtained NHC's 06z fix and N43 which was tasked to get the 18z fix.

2. SYNOPTIC HISTORY AND RECON COVERAGE

When it became apparent that a significant tropical cyclone would threaten landfall along the western coast of Mexico, NHC tasked the NOAA WP-3D to provide recon coverage beginning on the afternoon of 21 October. These missions would be flown from a forward deployed airfield in Harlingen, TX to reduce transit time. The first operational advisory package issued at 1500z 20 October forecast slow intensification over course of 72 hours toward a peak intensity of only 85 knots at 12z 23 October (100 knots below what would become the finalized Best Track peak). Numerical guidance was not overly bullish in spite of the storm spending its first few days in an extremely favorable environment of very high oceanic heat content and very light vertical wind shear. There was uncertainty over whether enough inner core structure would form to take full advantage of these highly conducive larger scale conditions before forecasted shear and drier air in advance of a digging trough and proximity to the coast just prior to landfall closed the window for more rapid deepening. At each juncture over the next three days, recon flights found Patricia to be significantly stronger than numerical guidance and NHC forecaster projections.

The crew of N43 arrived to make their first center fix at 1950z 21 October. At the time, NHC was carrying Patricia as a minimal (35 knot) TS described in the Forecast Discussion as "poorly organized" based on infrared and microwave satellite imagery. N43 found peak SFMR derived surface winds of 55 knots and an 850 mb flight level wind max of 59 knots, both only 16 miles from the center, indicating far better inner structure organization already existed than satellite or numerical model analyses would suggest. The question of whether Patricia would organize an inner core became increasingly obvious in the affirmative as a CDO formed with appearance of a primitive eye feature in the next few hours prompting NHC to significantly ramp their intensity forecast upward to Major Hurricane status in the next 36 hours. The second N43 mission about 24 hours later showed Patricia far exceeding all intensification forecast rates with 116 knot SFMR surface winds recorded during the 1739z 22 October center fix (the 15z NHC Advisory intensity had been 85 knots). In an effort to better keep up with what was now looming as a potentially devastating landfall event the next afternoon, a 06z 23 October Air Force Reserve mission was added to supplement what would be a third and final N43 mission to obtain the 18z 23 October fix.

3. RECON FLIGHTS WITH PATRICIA AS CATEGORY 5

An Air Force Reserve WC-130J (AF303) was launched from Biloxi, MS and reached the center of Patricia at 0446z 23 October. A center dropsonde measured eye surface pressure of 894 mb (a drop of 60 millibars in just under 12 hours since N43 departed). flight level winds had increased to a peak 10 second average of 179 knots. The real time peak SFMR surface wind inbound through the northeast eyewall was reported on the Vortex Data Message (VDM) and High Density Observations (HDOBs) to be 146 knots. However, as would be the case over the remaining center passes on both AF303 and N43, the extreme gradients in the core of Patricia were stressing the limits of the algorithm designed to process the measured Brightness Temperatures (T_b) radiating from the ocean surface upward to the sensor needed to translate T_b into surface wind speed. While the instrument measured an unbroken stream of T_b data, the algorithm, sensing the extreme pitch angle of the aircraft's nose needed to maintain flight along the 700 mb pressure surface, along with high roll angles needed as the plane turned sharply just inside the eyewall to mark the center (the eye had shrunk to only a 7 mile diameter) began discarding some of the highest surface wind calculations leading to dropouts in the HDOBs. As a result, while the SFMR sensor performed magnificently on both this flight and the subsequent N43 mission, the absolute peak surface wind speed numbers being reported operationally from the aircraft were understated in all of the real time SATCOM messages sent to NHC and disseminated over the World Wide Web. It was only after post mission re-analyses of the raw SFMR Brightness Temperatures that all the surface wind measurements in the range of 180-185 knots were retrieved.

AF303 subsequently made two additional center fixes at 0601z and 0646z, each showing continuing intensification. The SFMR algorithm reported a valid 182 knot 10 second average surface wind speed reading to the WC-130J met data system in the northeast eyewall just prior to the 0601z fix. This is the highest surface wind speed ever reported operationally in a VDM. On the third center pass at 0646z, the SFMR algorithm again

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discarded the absolute peak surface wind values after reporting a 10 second average of 175 knots inbound through the western eyewall. However T_b values continued to climb peaking with a T_{b0} (the 4.74 GHz Channel) value 13 seconds later of 251.3K and a T_{b5} (the 7.09 GHz Channel) maximum value 5 seconds later of 275.7K. This would correlate to surface winds well in excess of 90 m/s (somewhere in the range of 185 knots). There will be a more detailed look at the SFMR data for both this USAF flight and the NOAA WP-3D later. Outbound from the center, AF303 measured a peak 10 second average wind flight level wind of 192 knots in the northeast eyewall (which included a 1 second maximum value of 201 knots at 6:47:04 UTC). The 192 knot value is the highest in-situ 10 second wind ever measured in a hurricane. On this final pass AF303 dropped a center sonde that splashed with a surface pressure of 885 mb but with 57 knots of surface wind. With the extreme gradients present within the eye of Patricia, a sonde landing only a few hundred meters from the exact center would have sensed a pressure several millibars higher. Using a standard rule of thumb in recon that every 10 knots of wind on a sonde intended to be the center drop equates to a pressure reading approximately one millibar higher than the true center, NHC estimates the minimum central pressure to have been 879 mb. This represents a drop of 75 millibars in just under 14 hours.

Infrared satellite imagery showed that Patricia continued to deepen after AF303 returned to Biloxi with the operational UW-CIMSS objective Advanced Dvorak Technique (ADT) raw and adjusted T numbers peaking at 8.3 at 1215z.

For its third and final mission, N43 reached the center of Patricia at 1733z. **Figure 2** shows the Lower Fuselage C Band Radar image captured as the WP-3D penetrated the innermost northwestern eyewall. Concentric eyewall formation is clearly evident. The crew experienced moderate to severe turbulence both inbound and outbound through the southeast inner eyewall. **Figure 3** shows vertical wind velocities during this pass. Not only were the magnitudes of the updrafts and downdrafts extreme, the coupling of the two in such close proximity added greatly to the stress imparted on the aircraft and crew. Inbound there was an updraft of +21.1 m/s coupled with a downdraft of -16.1 m/s eight seconds later. More than 26 m/s of that transition from positive to negative vertical wind velocity occurred in two seconds of that span (from +10.0 at 17:32: 20 UTC to -16.1 at 17:32:22 UTC). The -16.1 m/s downdraft is stronger than any downdraft encountered in some of the most turbulent flights in NOAA WP-3D history that include Emily (1986), Hugo (1989) and Felix (2007). Outbound there was a peak updraft of 25.8 m/s at 17:34:03 UTC. It is also interesting to note the dynamic non-quiescent nature of the eye. Not only was there a great deal of pressure and wind gradient (that will be discussed shortly) inside the eyewall but an updraft of +9.2 m/s occurred only 21 seconds prior to marking the center and a downdraft of -6.1 m/s occurred 31 seconds afterward. The center fix at 17:33:10 UTC (a perfect recon fix where the flight level winds dropped to 1 knot) was accompanied by subsidence of -5.1 m/s. The magnitude of vertical motions within the eye of Patricia were comparable to those seen in the eyewall of many hurricanes.

The problem with the excessive aircraft pitch angle of both AF303 and N43 with regard to the real time SFMR wind retrieval algorithm was directly a function of the extreme pressure gradient across the eyewall which continued into the eye all the way to the center. Reconnaissance aircraft tasked for fix missions by NHC fly a constant Pressure Altitude during penetrations. In order to maintain flight along a near-constant 700 mb pressure surface, both AF303 and N43 had to dive down an unprecedentedly steep slope of absolute altitude . N43 lost nearly 1200 meters of altitude with respect to the ocean surface (from a Radar / GPS altitude of just over 3000 meters outside the eyewall to a minimum of 1895 meters (6217 feet) at the center fix). Over a 37 second span, from the innermost edge of the eyewall into the eye, N43 lost 673 meters of altitude.

One of the fundamental parameters reported by all reconnaissance aircraft is Geopotential Height of the pressure surface they are assigned to follow. In most cases, for intense hurricanes this will be the 700 mb Height. The minimum 10 second average 700 mb Geopotential Height calculated for N43's 1733z fix at the vortex center was 2043 meters. This is the lowest 700 mb Height ever seen in the Western Hemisphere. **Figure 4** is a table listing lowest 700 mb Height and corresponding MSLP during fixes made by reconnaissance flights into some of the most intense hurricanes and typhoons sampled in the Atlantic and Pacific during the recon era.

Calculation of the 700 mb heights is done in conjunction with calculation of extrapolated surface pressure. It is common for there to be a low bias in the center of intense tropical cyclones when the extrapolated minimum value is compared to center dropsonde data. Typically this is on the order of about 3 to 4 millibars and is due to the fact that the WP-3D extrapolation algorithm assumes a standard 6.5C per km lapse rate below the aircraft to the surface. With 700 mb flight level temperatures being so far above that of a standard atmosphere, and the sounding in the center of the eye often being nearly isothermal for much of its depth, the resulting calculation for mean virtual temperature of the entire interval from flight level to surface is usually much higher than what is observed in-situ by the dropsonde (hence the minimum extrapolated surface pressure calculation is usually about 4 millibars lower than the dropsonde). **Figure 5** is a plot of the extrapolated surface pressure for the 1733z center fix in red with the corresponding flight level temperature in blue. The minimum extrapolated surface pressure of 875.4 mb is the lowest ever calculated in a hurricane. As discussed earlier, the true minimum surface pressure was estimated by NHC to be 879 mb based on the center dropsonde data (thus the 4 millibar low bias we expect to see in the flight level extrapolation was observed). The gradients shown in surface pressure across this center pass are remarkable (rivaled only by those seen on 19 Oct 2005 in Wilma). At its steepest gradient along the inner edge of the eyewall, the surface pressure dropped 35 millibars across only 1.7 nautical miles.

The temperature spike shown in **Figure 5** is the most extreme ever measured by a recon aircraft in a hurricane. The peak 1 Hz temperature of 32.2C occurred at 17:33:17 UTC and was part of a 10 second average of

31.7C surrounding it. Interestingly, the presence of a secondary temperature maxima of several degrees just outside the innermost eyewall (on the inbound portion of this penetration) support what would be expected with the onset of concentric eyewall formation.

4. DROPSONDE AND SFMR DISCUSSION

Perhaps in no other storm was the value of the Stepped Frequency Microwave Radiometer (SFMR) so clearly demonstrated. This instrument, first developed by the University of Massachusetts Microwave Remote Sensing Laboratory (UMASS/MIRSL), has been in development in various forms since 1978. Over the past 30+ years, innovation and exhaustive efforts at calibration have brought it from the realm of experimental research to where it is today a vital operational tool in aircraft reconnaissance.

The extremely small RMW of Patricia as a Category 5 storm made efforts at pinpointing the strongest surface winds with eyewall dropsondes particularly challenging. Typically, the 53rd WRS ARWO or AOC Flight Director issues a command to release the eyewall dropsonde just inside the inner edge of the eyewall and RMW at flight level (a few kilometers inside the eye). By accounting for the slope of the eyewall, this allows the sonde to fall into the RMW below as closely as possible to the surface.

During the previous mission of N43 on 22 October (during which Patricia was undergoing rapid intensification), the Flight Director noted a nearly vertical slope to the eyewall with the surface RMW (as measured by the SFMR) located only slightly inboard with respect to the 700 mb RMW. Based on examination of the flight level RMW versus the location of the highest SFMR Brightness Temperatures for the AF303 mission early on 23 October, the abnormal near-vertical slope to the eyewall appears to have persisted into this mission as well. A sonde launched by the WC-130J at 0647z into the NE eyewall (which was blown cyclonically around 145 degrees of azimuth and splashed in the western eyewall) measured winds of 187 knots at 707 mb (the first valid winds measured about 10 seconds after launch). As it fell the maximum winds recorded were 193 knots at 878 mb (approximately 500 meters above the surface). Winds decreased as it continued to fall with an average speed of 157 knots in the final 150 meters prior to splash and a surface (10 meter) reading of 145 knots. This suggests the sonde splashed outside the surface RMW.

None of the eyewall sondes launched on either this AF303 mission or the subsequent N43 flight 12 hours later sampled the surface or near-surface boundary layer RMW (see **Figure 6 r**esults of 11 attempts during four center passes near peak intensity). The highest valid dropsonde wind measured by N43 was outbound through the southeast quadrant at 1734z with 191 knots at 792 mb (the sonde then failed falling through 813 mb). A combination of the extremely narrow width of the RMW and multiple sonde failures meant the SFMR became the only means by which NHC forecasters were made aware of the existence of surface winds in the range of 180 knots.

The only storm that has produced SFMR Brightness Temperatures comparable to Patricia was Super Typhoon Megi (2010) (see **Figure 7**). A 53rd WRS WC-130J was deployed to Guam for the Impact of Typhoons on the Ocean in the Pacific (ITOP) study in a rare opportunity for Western Pacific typhoon aircraft reconnaissance. On 17 October, 2010 it sampled Megi near peak intensity ENE of Luzon with three center fixes. A significant difference between this AF307 mission into Megi and the two missions into Category 5 Patricia is that Megi had a larger eye (16 NM diameter on 17 October 2010 versus only 7 NM in Patricia on 23 October 2015) which made targeting of the surface RMW with dropsondes a less daunting task.

There were multiple sondes deployed into Megi in what appeared to be perfect locations to fall through the surface RMW (which also did not fail during descent through the eyewall as so many had in Patricia) that directly measured surface winds in the range of 165 to 175 knots. The first, released at 1113z inbound through the NE eyewall from 700 mb, recorded a peak of 207 knots at 867 mb, 203 knot winds at approximately 150 meters above the surface and 174 knot 10 meter winds. A second, released at 1122z outbound through the SW eyewall, measured 177 knot winds at 50 meters and a 10 meter splash wind of 168 knots. These sondes provided a good opportunity to validate some of the extreme SFMR measurements made in Megi.

Outbound from their second center fix, AF307 recorded a peak 1 Hz SFMR surface wind of 175 knots at 12:08:37 UTC in the northwest eyewall. Sondes released at 12:09:25 and 12:09:42 UTC were dropped too close to the flight level RMW (too late) and fell just outside the surface RMW. The maximum dropsonde winds seen in this eyewall pass were 209 knots at 868 mb, 177 knots at just below 100 meters, but “only” 146 knots at 10 meters / surface (a mean value of 163 knots in the lowest 150 meters).

The highest SFMR derived surface winds of 91.8 m/s (178 knots) on this Megi mission occurred at 13:01:19 UTC during the final center penetration. This peak 1 Hz value is based on HRD post mission reanalysis of the Brightness Temperatures. It was part of a maximum 10 second average of 91.7 m/s, the highest ever seen in a tropical cyclone until Patricia. In real time, flight level winds were still increasing as the SFMR SWS (surface wind speed) processor onboard the aircraft passed a 1 Hz value of 173 kts to the WC-130J data system. Then came a 28 second interval of invalid data where the SFMR SWS algorithm encountered some of the same challenges seen in the Patricia missions discussed earlier. Real time calculations of SWS resumed at 13:02:44 UTC with a value of 174 knots (and remained above 170 knots for the next seven seconds before quickly dropping thereafter).

As mentioned previously, dropouts in the real time reporting of absolute peak SFMR SWS also occurred during the two Patricia Category 5 missions. As was the case in Megi, the SFMR measurements of Brightness Temperature (T_b) in Patricia were complete and contiguous in spite of the extreme conditions. In order to retrieve the full SWS data set in post mission reanalysis, tolerances and filtering needed to be adjusted to account for extreme T_b values in excess of 270K and the extreme rates of change in T_b (increasing the upper limit of the converging routine) as well as the off-nadir

antenna angles (both in terms of pitch and roll). Brad Klotz and Eric Uhlhorn of HRD, Ivan PopStefanija of Pro Sensing Inc. of Amherst, MA (the manufacturer of the SFMR), and Alan Goldstein of AOC were all consulted in an effort to retrieve missing SWS values.

Figure 8a shows SFMR Brightness Temperatures for the three center WC-130J penetration of Category 5 Patricia by AF303. All six SFMR T_b peak values are significantly higher than what was measured in Megi and are the highest ever recorded in a storm by reconnaissance aircraft (ranging from peaks of 275.7K for T_{b5} to 251.3K for T_{b0}).

Figure 8b shows SFMR Brightness Temperatures of 5 of the 6 stepped frequency microwave channels for the N43 1733z center penetration of Patricia. T_{b1} (5.31 GHz) is omitted due to interference with the IWRAP C Band Scatterometer flown on the P-3 for NESDIS low Earth orbiting satellite wind retrieval calibration. It shows an absolute peak of 274.09K from 17:32:02 UTC through 17:32:04 UTC for T_{b5} (the 7.09 GHz channel). This is the highest value ever seen on the P-3 in any storm. Channels T_{b0} through T_{b4} are also show the highest storm values ever seen on the P-3.

Interesting to note are the two well-defined secondary peaks in brightness temperatures (at 1724z and 1740z) well outside the innermost eyewall pinpointing secondary surface wind maxima both inbound and outbound associated with formation of concentric eyewalls. The eyewall replacement cycle, shown to be underway when viewing the LF radar imagery as mentioned earlier in reference to **Figure 2**, also can be seen as secondary temperature maxima in **Figure 5** in the "moat" region just inside the developing outer eyewall. When cross referenced with **Figure 9**, a plot of 700 mb flight level winds, there is little evidence yet of the outer eyewall at flight level during the inbound leg but a clear indication of it outbound just after 1740z. Another interesting aspect of **Figure 9** is that the strongest flight level winds during this pass occurred outbound through the southeast eyewall (a 1 Hz absolute peak of 203.8 knots part of a peak 10 second average of 191 knots) which was 30 knots higher than the FL winds seen inbound through the northwest eyewall. However, the strongest SFMR derived surface winds were in the northwest side.

In the analysis of T_b for SWS retrieval there are two separate algorithms running on the P-3: One (labelled PS) that utilizes the calculations developed by the manufacturer of the SFMR, Pro Sensing Inc., and another developed by Alan Goldstein, the Chief of the Science and Engineering Branch at AOC (labelled the AOC or ASFMR). **Figure 10** shows the 1 Hz results of each as they ran in real time inbound through the northwest eyewall. The SWS values shown in meters per second in the final two columns are the AOC solution and the Pro Sensing Inc. (PS) solution. Both discontinued sending valid SWS to the P-3 flight data system as algorithm tolerances were exceeded.

Brad Klotz HRD reanalysis of the Patricia Brightness Temperatures yielded a peak 10 second average SWS value at 0644z on AF303 of 96.4 meters per second (187 knots) and 92.4 m/s (180 knots) at 1732z on N43 and (see **Figures 11a and 11b**).

The HRD SWS solution from Brad Klotz was very consistent (within 1 m/s) with reanalysis results obtained independently by Alan Goldstein at AOC. Ivan PopStefanija of Pro Sensing Inc. also performed a T_b reanalysis with very similar results but slightly higher absolute peak values for both the WC-130J and WP-3D mission. His SWS plots of the 0646z and 1733z center fixes are shown as **Figures 12a** and **12b**.

5. RAPID WEAKENING OF PATRICIA

During the extremely turbulent 1733z center penetration of N43, the Weather Message Module (WMM) program that compiles flight level and SFMR data for creation of the Vortex Data Message (VDM) closed. While none of the data was lost, the VDM had to be reconstructed by hand. In an effort to get the most vital data to NHC as quickly as possible some items were estimated based on what was readily available to the Flight Director, therefore the VDM transmitted immediately following the fix (what is archived on the NHC website as well as other recon archive sites), because of the historic nature of the mission, was amended after careful examination of the 1 Hz netCDF file downloaded after the mission. The reanalysis of the SFMR data also shows there would have been some items in the VDM with different values had there been no operational gaps and all the correct values for SWS were available in real time. **Figure 13a** is a corrected version of the N43 VDM as it would have appeared without the WMM application closure and SFMR SWS algorithm issues. **Figure 13b** for AF303 is an amendment to the third VDM with updated SWS in Item D raised to 187 kts.

An evaluation of N43 was necessary following the first center pass to determine whether the aircraft had been overstressed. While this assessment was made, N43 orbited well southeast of the storm's core. Therefore, by the time the aircraft was ready for its second fix, an unusually long interval had passed between fixes.

The second fix was made (inbound through the southeast quadrant and outbound through the northeast eyewall) at 2033z. A dropsonde released in the eye splashed with a surface pressure of 907 mb and 17 knots of wind, suggesting a MSLP of 905 mb (a weakening of 26 millibars in three hours). Maximum FL winds in the SE quadrant had decreased from 191 knots to 144 knots. Reanalysis of the SFMR data shows a peak 10 second average of 59 m/s (115 knots) inbound in the SE eyewall and 70 m/s (136 knots) outbound in the NE eyewall.

6. SUMMARY AND ACKNOWLEGEMENTS

The 23 October 2015 Patricia missions of AF303 and N43RF were historic in nature setting world records for flight level and SFMR derived surface winds and Brightness Temperatures, and Western Hemisphere records for lowest 700 mb Geopotential Height, lowest extrapolated surface pressure, lowest dropsonde measured surface pressure and highest 700 mb ambient temperature.

Many sincere thanks to Brad Klotz of HRD for his work in post mission reanalysis of the SFMR data. Similar thanks to Lt Colonel Jon Talbot of the 53rd WRS, Eric Uhlhorn, Ivan PopStefanija, and Alan Goldstein along with the crews of AF303 and N43RF as well as AF307 in Megi.

7. FIGURES

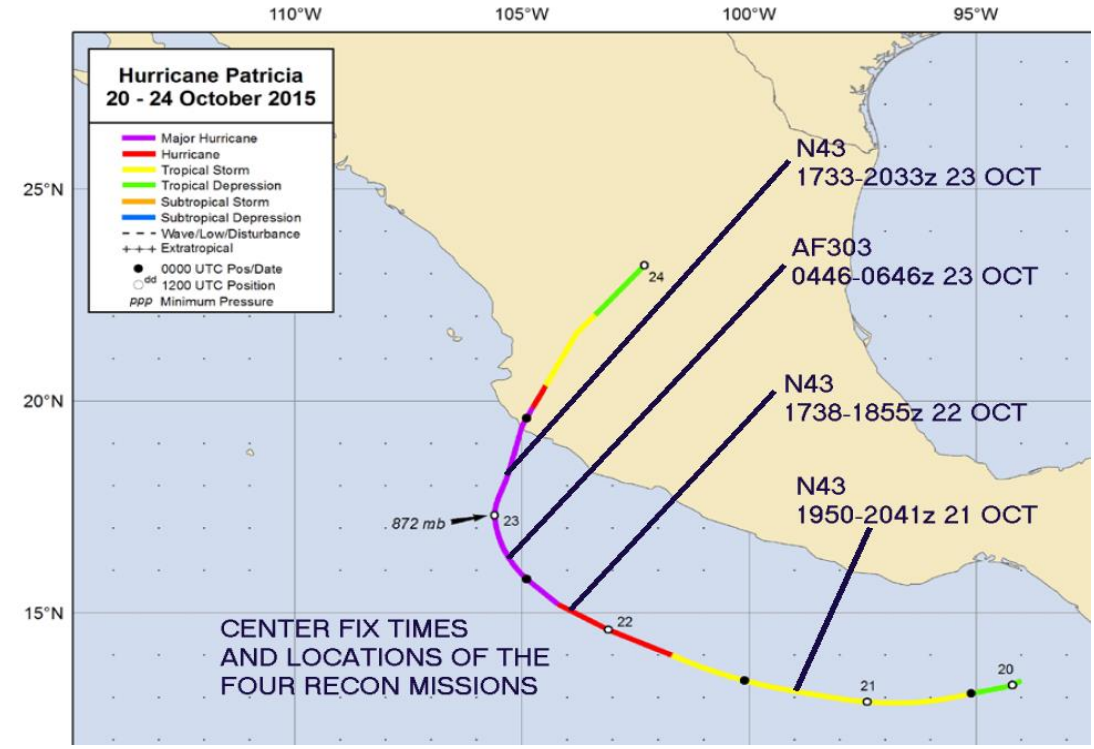

Figure 1. Reconnaissance coverage along the track of Patricia (Best Track from NHC Tropical Cyclone Report)

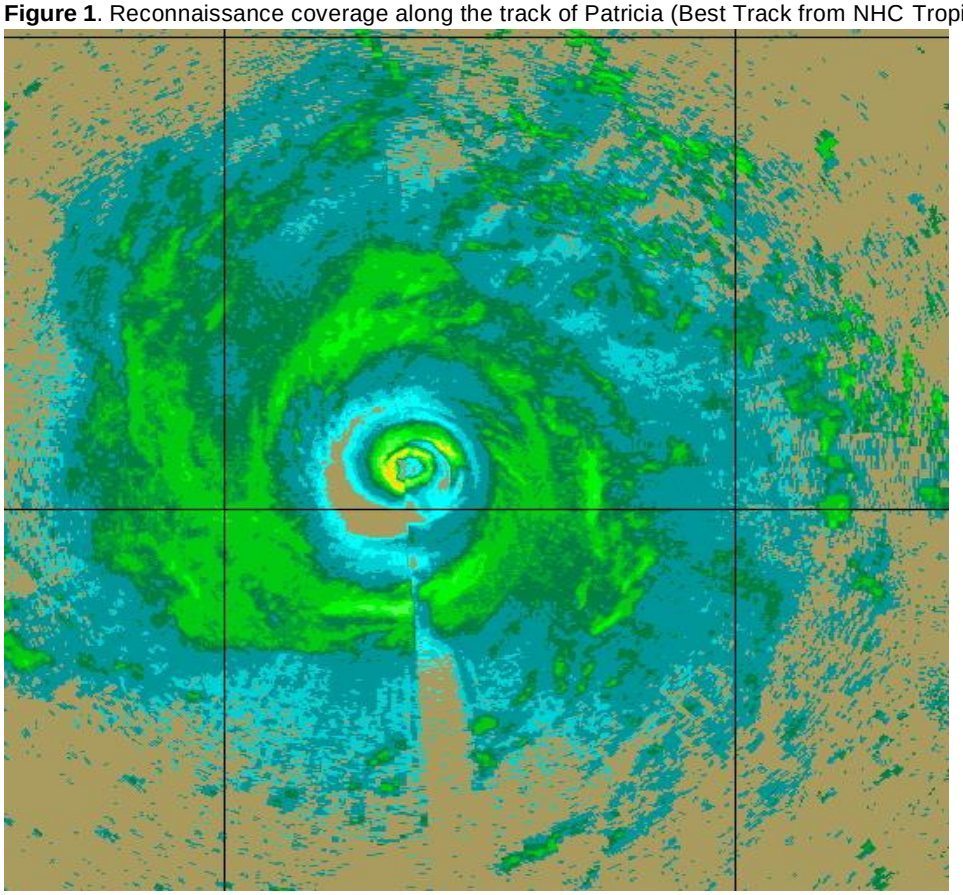

Figure 2. Lower Fuselage (LF) radar imagery of the 1733z center penetration by the NOAA WP-3D. The pass was made from the northwest to the southeast quadrant. The inner edge of the innermost eyewall has a 7 mile diameter. The onset of an eyewall replacement cycle is clearly evident with multiple eyewalls forming further away from the center.

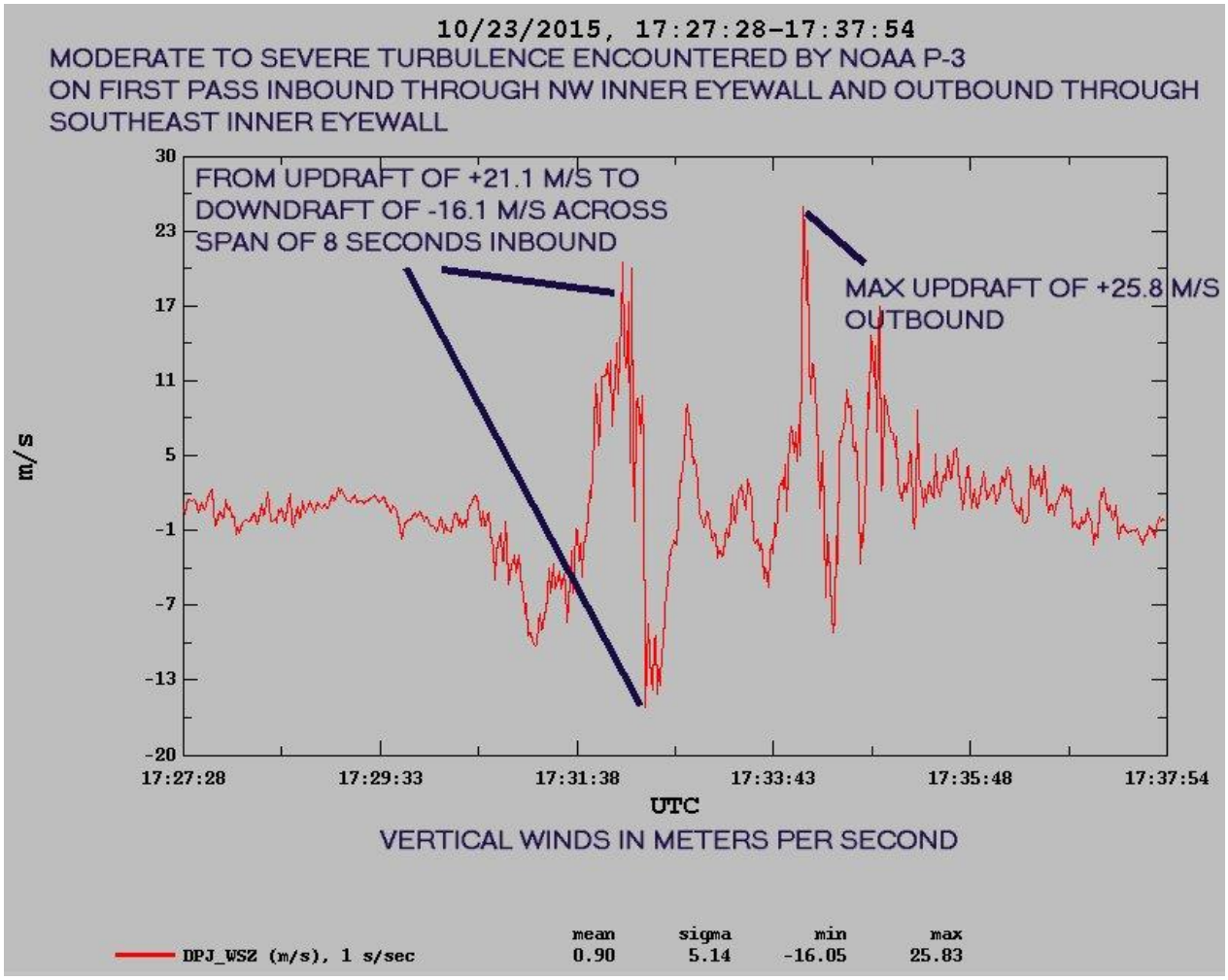

Figure 3. Vertical winds observed by the WP-3D during N43RF 1733z center fix.

STORM	DATE AND TIME	700 MB HEIGHT (m)	MSLP (mb)
MEGI (P)	1305Z 17 OCT 2010	2136	890
GILBERT (A)	2153Z 13 SEP 1988	2091	888
TIP (P)	0837Z 12 OCT 1979	2058	884
RITA (P)	0015Z 25 OCT 1978	2064	882
WILMA (A)	0800Z 19 OCT 2005	2082	882
PATRICIA (A)	0646Z 23 OCT 2015	2094*	879
PATRICIA (A)	1733Z 23 OCT 2015	2043	879
RITA (P)	0317Z 25 OCT 1978	2007	878
NORA (P)	0015Z 06 OCT 1973	2006	877
IDA (P)	0500Z 24 SEP 1958	2005	877
JUNE (P)	0843Z 19 NOV 1975	1984	876
TIP (P)	0353Z 12 OCT 1979	1944	870

*** AF303 REANALYZED MINIMUM VALUE AT 06:46:32 UTC FROM 1 HZ DATA**
OPERATIONAL VALUE REPORTED IN VDM WAS 2113 M

Figure 4. Table of minimum 700 mb Geopotential Height and corresponding Minimum Sea Level Pressure (MSLP) for historically intense WESTPAC typhoons (P) and Hurricanes in the NHC AOR (A…which includes Eastern Pacific Patricia) as measured by aircraft reconnaissance. All storms listed prior to 2005 are taken from Willoughby, Masters, and Landsea, Monthly Weather Review, Volume 117 (1989): *A Record Minimum Sea Level Pressure Observed in Hurricane Gilbert*

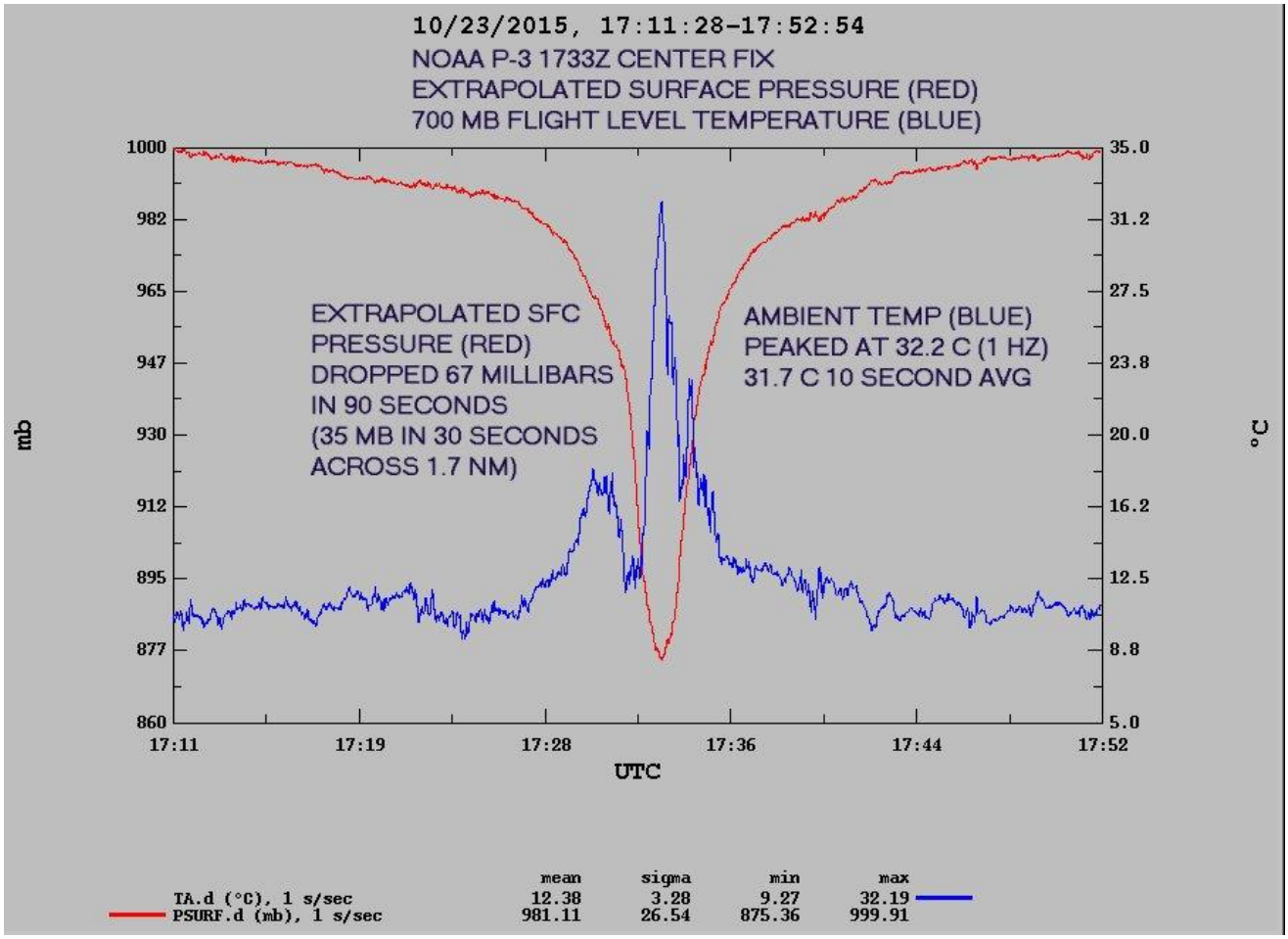

Figure 5. Plots of extrapolated surface pressure (in red) and ambient flight level air temperature (from 700 mb in blue) during the 1733z 23 October 2015 center fix of Patricia from NOAA WP-3D N43RF.

TIME	RESULT	MAX WIND	WL150	10 METER
0444z	failed @ 846mb	186 kts @ 715 mb	N/A	N/A
0445z	failed @ 733 mb	185 kts @ 686 mb	N/A	N/A
0447z	failed @ 776 mb	166 kts @ 718 mb	N/A	N/A
0559z	splashed outside SFC RMW	179 kts @ 928 mb	162 kts	118 kts
0600z	failed @ 771 mb	192 kts @ 704 mb	N/A	N/A
0646z	failed @ 743 mb	192 kts @ 715 mb	N/A	N/A
0647z	splashed outside SFC RMW	193 kts @ 878 mb	156 kts	145 kts
1731z	splashed outside SFC RMW	136 kts @ 873 mb	107 kts	78 kts
1732z	splashed outside SFC RMW	154 kts @ 904 mb	139 kts	134 kts
1734z	failed @ 704 mb	125 kts @ 702 mb	N/A	N/A
1734z	failed @ 813 mb	191 kts @ 792 mb	N/A	N/A

Figure 6. Results of the 11 eyewall dropsondes released into Patricia as a Category 5 storm on 23 October 2015 during the 0600z 53rd WRS mission of AF303 (first seven) and the 1800z NOAA AOC mission of N43RF (final four). Does not include drops during the second center fix of N43 at 2033z after Patricia had begun to rapidly weaken.

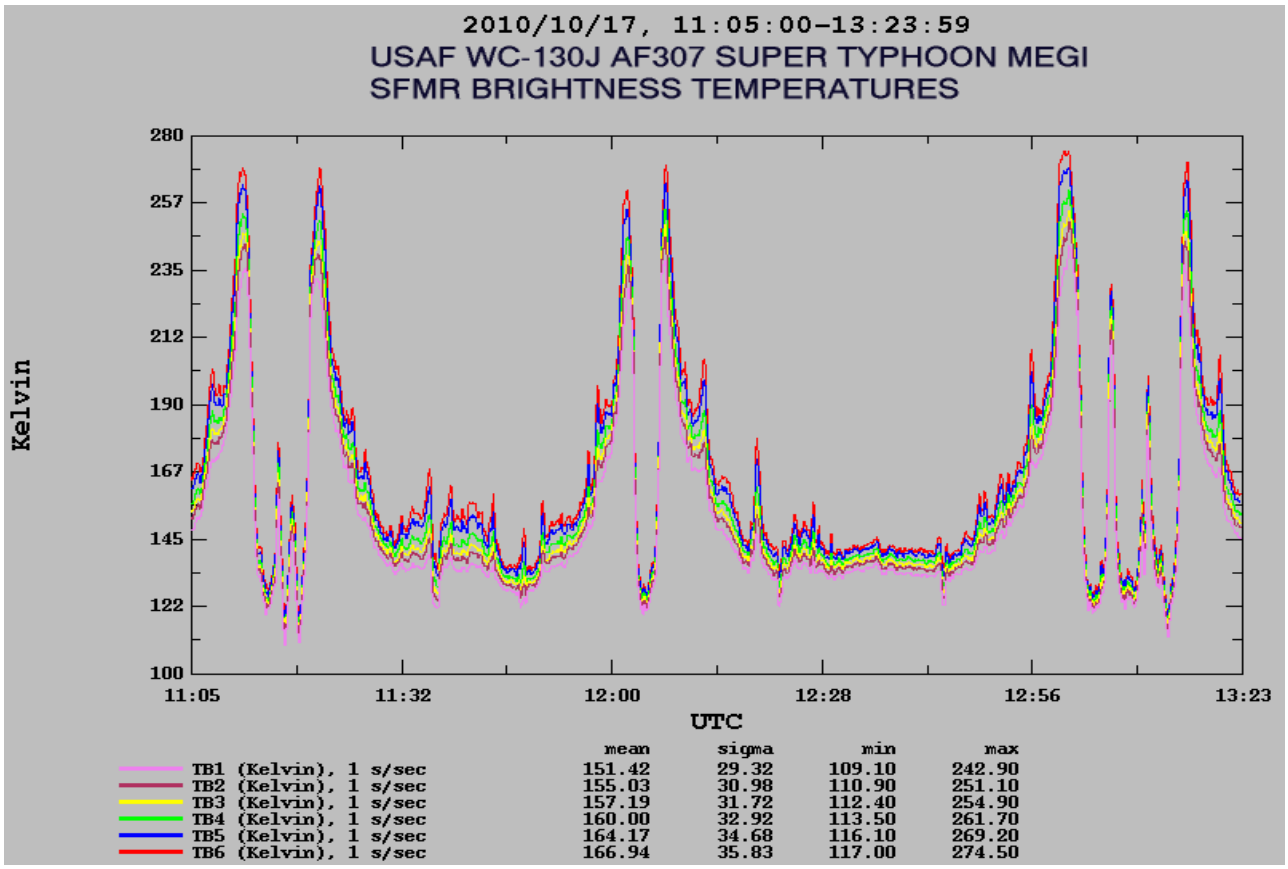

Figure 7. T_{b0} through T_{b5} are listed here as TB1 through TB6. Three center penetrations performed into Super Typhoon Megi

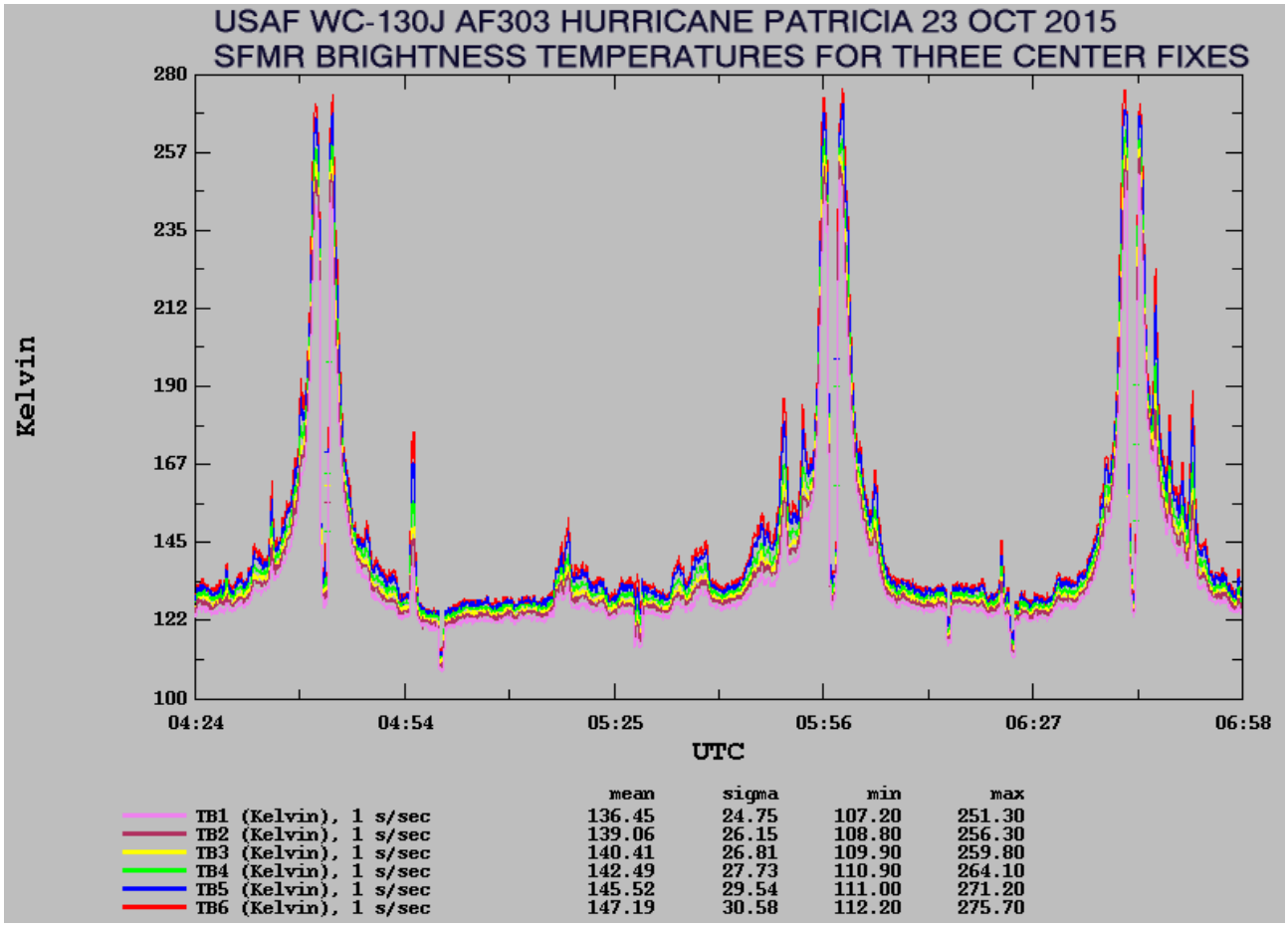

Figure 8a Six SFMR Brightness Temperature channels. T_{b0} through T_{b5} are listed here as TB1 through TB6.

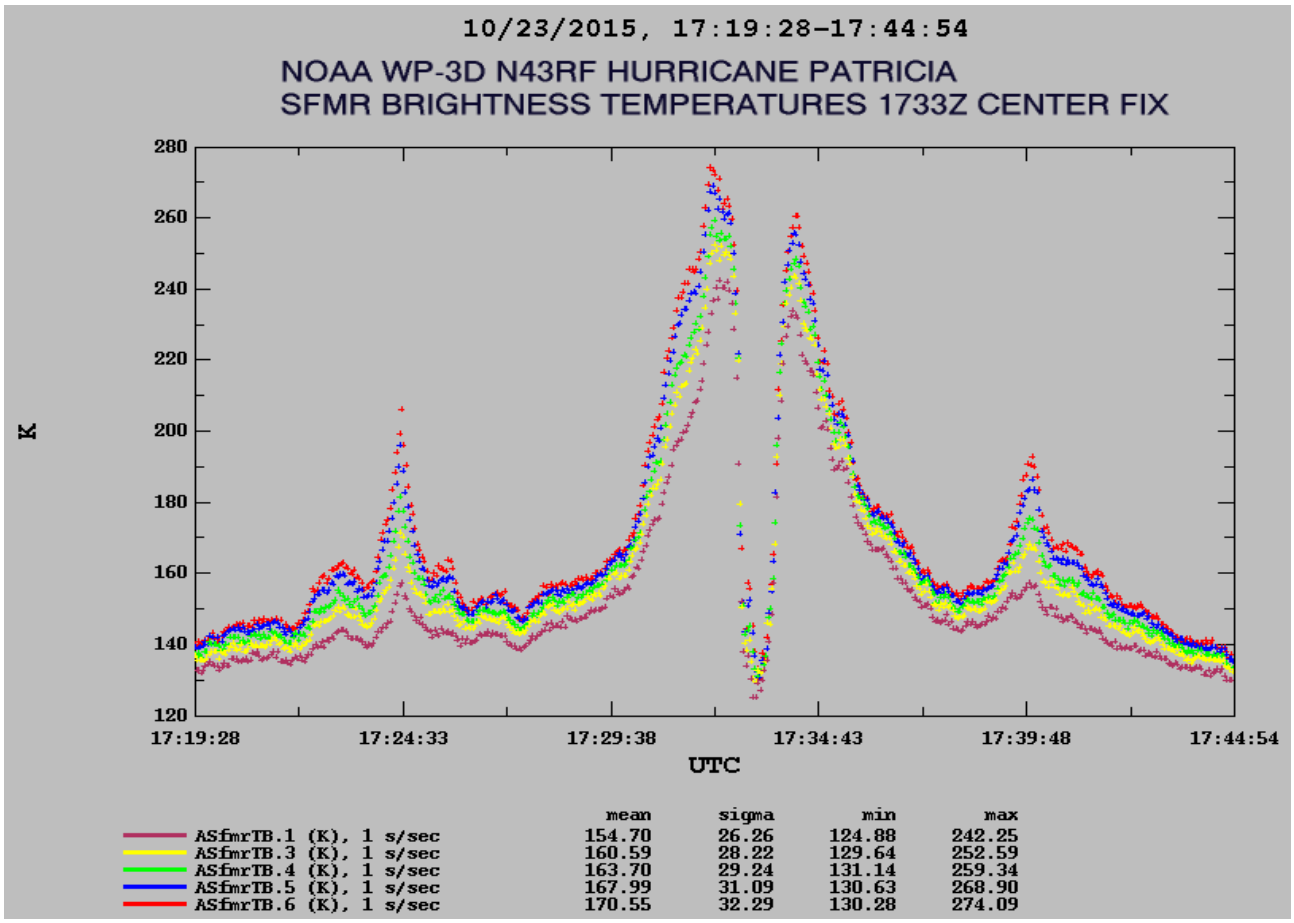

Figure 8b Five of the six SFMR Brightness Temperature channels. T_{b0} through T_{b5} are listed here as TB.1 through TB.6. T_{b1} (TB.2) 5.31 GHz has been omitted due to interference with the NESDIS IWRAP C Band Scatterometer.

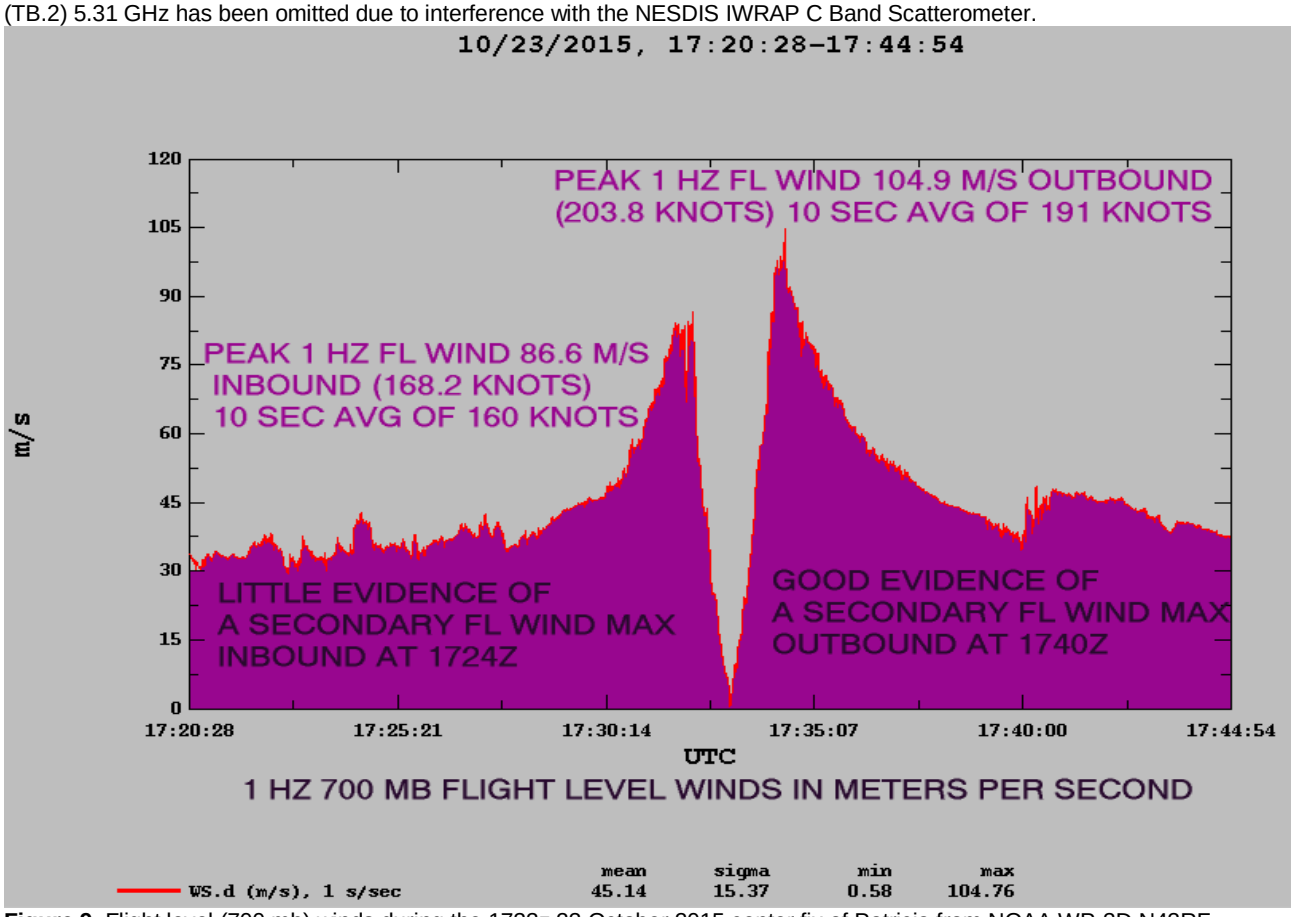

Figure 9. Flight level (700 mb) winds during the 1733z 23 October 2015 center fix of Patricia from NOAA WP-3D N43RF

Time	Tb0	Tb2	Tb3	Tb4	Tb5	AOC	PS
17:32:01	224.27	239.94	249.28	261.95	269.32	82.19	87.6
17:32:02	227.86	239.94	249.28	261.95	269.32	87.22	86.8
17:32:03	227.86	247.23	255.06	261.95	269.32	89.46	90.1
17:32:04	227.86	247.23	255.06	267.11	269.32	85.60	91.3
17:32:05	233.1	247.23	255.06	267.11	274.09	92.30	91.3
17:32:06	233.1	249.87	255.06	267.11	274.09	93.11	91.1
17:32:07	233.1	249.87	257.39	268.9	274.09	91.91	94.6
17:32:08	233.1	249.87	257.39	268.9	273.38	91.87	95.2
17:32:09	236.79	249.87	257.39	268.9	273.38	95.33	
17:32:10	236.79	252.59	259.34	268.9	273.38	96.13	
17:32:11	236.79	252.59	259.34	267.07	271.99	95.97	
17:32:12	240.42	252.59	259.34	267.07	271.99		
17:32:13	240.42	250.85	259.34	267.07	271.99		
17:32:14	240.42	250.85	254.92	262.54	271.99		
17:32:15	237.14	250.85	254.92	262.54	267.7		
17:32:16	237.14	248.04	254.92	262.54	267.7		

Figure 10. SFMR surface wind speed (SWS) values produced in real time onboard N43RF shown in the final two columns in meters per second. The Pro Sensing (PS) algorithm tolerances were exceeded at 17:32:09 UTC while the AOC algorithm gap began three seconds later.

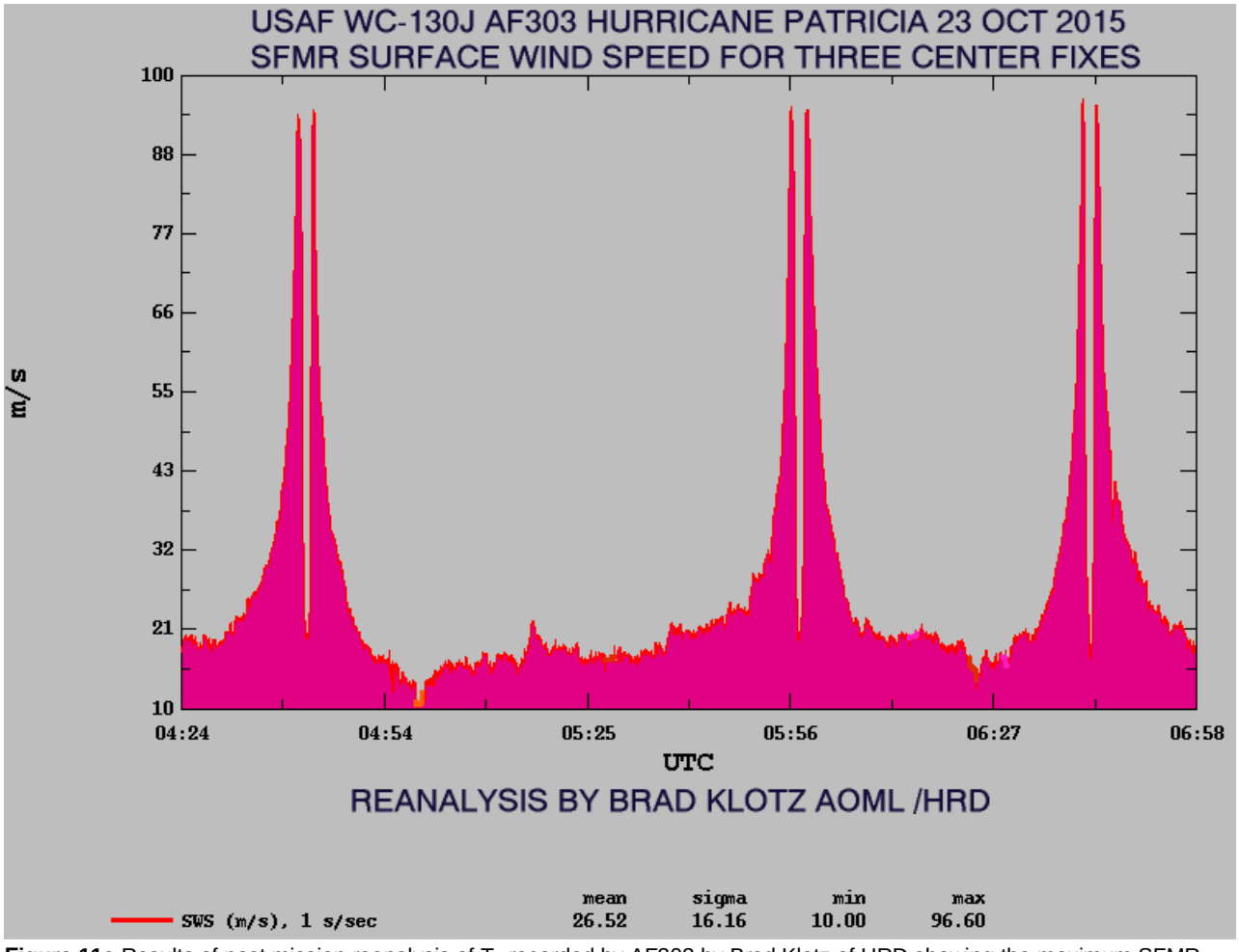

Figure 11a Results of post mission reanalysis of T_b recorded by AF303 by Brad Klotz of HRD showing the maximum SFMR derived 10 sec average SWS of 96.4 m/s (187 knots) inbound to the third fix through the west eyewall at 0641z

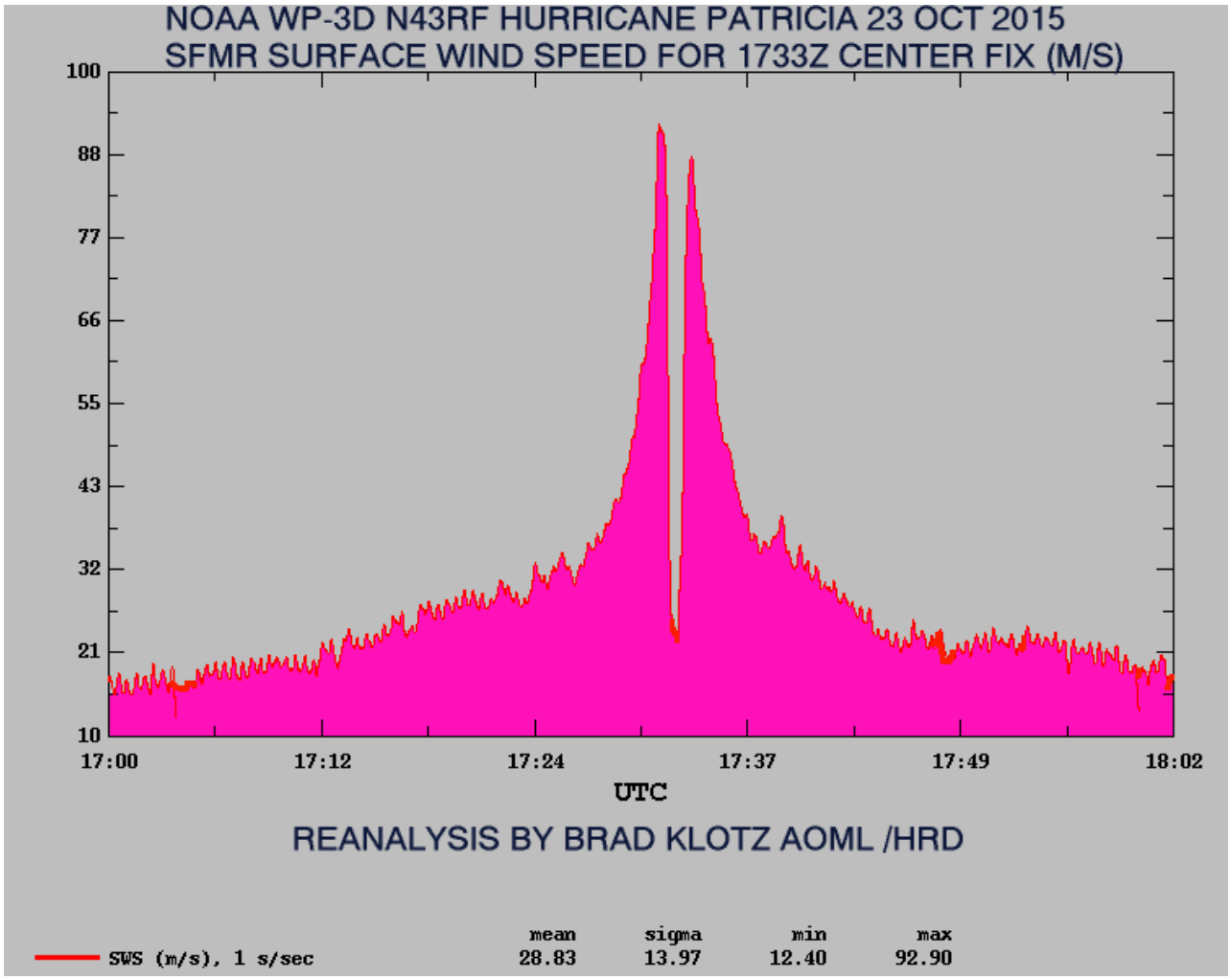

Figure 11b Results of post mission reanalysis of T_b recorded by N43RF by Brad Klotz of HRD showing the maximum SFMR derived 10 sec average SWS of 92.4 m/s (180 knots) inbound through the northwest eyewall at 1732z

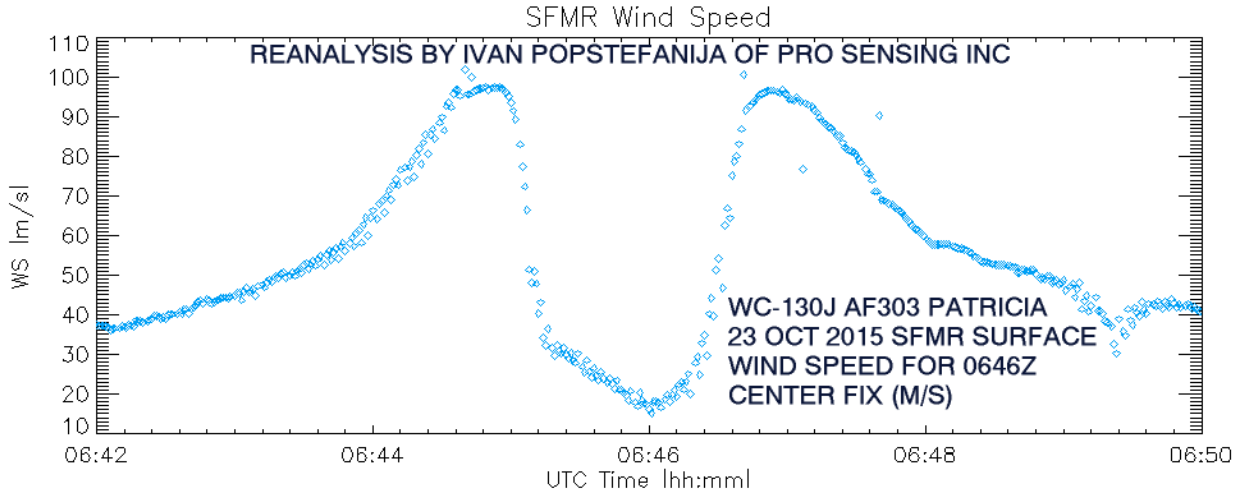

Figure 12a Results of reanalysis by Ivan PopStefanija showing SWS for the third center fix of AF303 into Patricia.

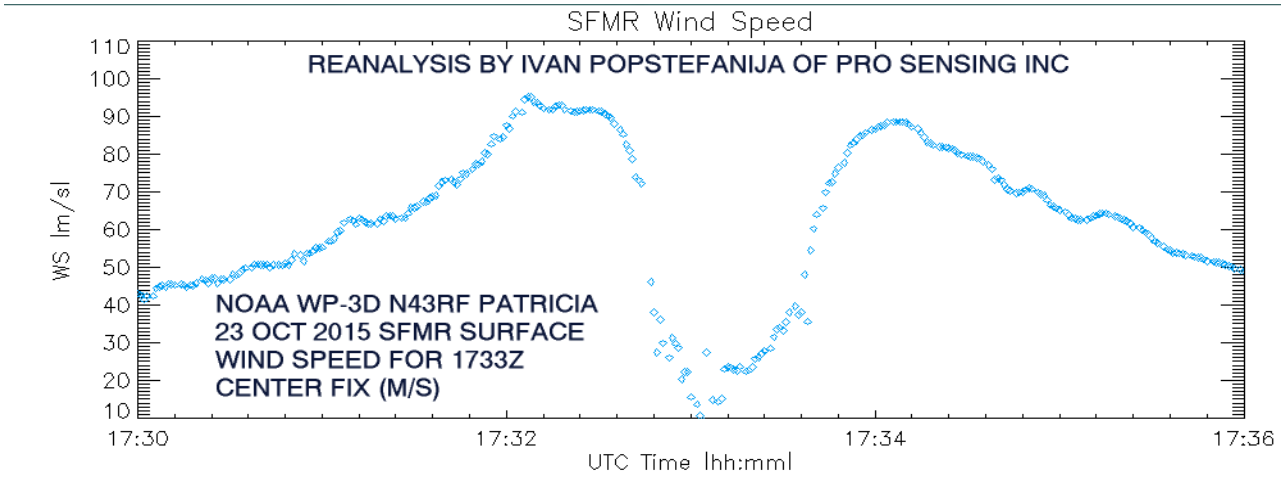

Figure 12b Results of reanalysis by Ivan PopStefanija showing SWS for the 1733z fix of N43RF into Patricia.

URPN12 KWBC 231839 CCB
VORTEX DATA MESSAGE EP202015
A. 23/17:33:10Z
B. 18 deg 10 min N
105 deg 16 min W
C. 700 mb 2043 m
D. 180 kt
E. 317 deg 4 nm
F. 053 deg 160 kt
G. 318 deg 5 nm
H. 883 mb
I. 17 C / 3062 m
J. 32 C / 2891 m
K. 4 C / NA
L. CLOSED WALL
M. C7
N. 12345 / 7
O. 1 / 1 nm
P. NOAA3 0420E PATRICIA OB 04 CCB
MAX OUTBOUND AND MAX FL WIND 191 KT 119 / 5 NM 17:34:28Z
CNTR DROPSONDE SFC WIND 180 / 45 KTS

Figure 13a Updated Vortex Data Message reflecting reanalysis. Item D in magenta is peak SFMR SWS increased from what was reported operationally. Item C (700 mb Geopotential Height) Item H (eye dropsonde surface pressure) and Item J (flight level temperature) highlighted in yellow are records for NHC AOR hurricanes.

URPN12 KNHC 230703
VORTEX DATA MESSAGE EP202015
A. 23/06:46:00Z
B. 16 deg 33 min N
105 deg 26 min W
C. 700 mb 2113 m
D. 187 kt
E. 264 deg 5 nm
F. 358 deg 166 kt
G. 264 deg 5 nm
H. 885 mb
I. 12 C / 3073 m
J. 29 C / 3026 m
K. 8 C / NA
L. CLOSED
M. C7
N. 12345 / 7
O. 0.02 / 0.5 nm
P. AF303 0320E PATRICIA OB 19
MAX OUTBOUND AND MAX FL WIND 192 KT 053 / 3 NM 06:47:10Z
CNTR DROPSONDE SFC WIND 135 / 41 KT
Figure 13b Updated Vortex Data Message reflecting reanalysis. Item D in magenta is peak SFMR SWS increased from what was reported operationally. It is a world record along with the highest 10 second average flight level wind of 192 knots.