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Hurricane Research with ONR-Supported Drop-Sondes in HS-3, OUTFLOW, and Other Studies

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Award Number: N00014-14-1-0592
https://www.eol.ucar.edu/field_projects/tci

LONG-TERM GOALS

This work is part of ONRBAA13-001, Code 32 – addressing tropical cyclone behavior and evolution, including the DRI to investigate improvements in tropical cyclone prediction through improved treatment of the upper level outflow region and linkages to the larger scale environment.

OBJECTIVES

Improve the telemetry and scientific data quality of HDSS/XDR drop-sondes, participate in aircraft / dropsonde hurricane research using the HDSS/XDR drop-sonde system – this year being the Tropical Cyclone Intensification-2015 program (url above.)

APPROACH

This grant supports a graduate student recruited this year, and my work, which is both the telemetry algorithms and data production from these drop-sondes, as well as operating and supporting the HDSS instrument in the field.

WORK COMPLETED

My principal technical contribution has been to the telemetry; the XDD radiosondes use algorithms I have developed for data packing, Forward Error Control (FEC) coding; the HDSS and ground-based systems use my algorithms for decoding the FEC (thereby correcting up to 60 bit errors in a 600-bit packet), unpacking, and display. I have made substantial upgrades to this software this year; here are high-lights:

1. This year is the first that the algorithms are available to the scientific community as an open-source program called SQZ [1], with a user interface and a manual of more than 50 pages. This is maintained as a "git" repository open for read, here:

lee@asrcserv3.asrc.cestm.albany.edu:/var/www/sqzrepo/sqz.git

Many users of the TCI data have downloaded the program/source and use it.

2. SQZ by itself does strictly Level-0 processing; meaning processing that returns the data as taken with no alteration or derived products. It is quite general; it can handle a very wide range of data-telemetry tasks. It implements a specialized parser-compiler so that a data measurement protocol can be described simply; from this

1 No relationship to the old SQZ-NOW spreadsheet program, and not to be confused with SQL.

very compact executive code on the drop-sonde can pack the data (without further programming on the sonde), and it can be correctly unpacked at the receiving end. This avoids substantial programming and opportunities for mistakes as data protocols are developed/changed – it also documents the protocol in human-readable form.

3. A specialized set of Level-1 algorithms are bound to it for drop-sonde processing – these collectively can be seen as doing the functions of ASPEN. Derived data products are produced, QC operations are done that are specific to the XDD sondes, and "Quick-Look" graphs are produced.

All of this code can be executed on the HDSS, or post-executed on the ground. 2015 is the first year that we have delivered data from the HDSS to the scientists on the ground (using the IMMARAT communications link on the WB-57) in "real time." Data and graphs are available (and uploaded to Mission Tool Suite) within minutes of the close of a sonde's tenure. Examples are shown and discussed in the RESULTS section.

I have also helped Yankee improve the radio hardware, and been one of the two system operators for the HDSS for all campaigns.

This year we have had a major hurricane research campaign with the Tropical Cyclone Intensification-2015 program. After a series of testing flights we have done one flight into TS Erika, two flights into hurricane Marty, four flights into hurricane Joaquin, and three flights to hurricane Patricia These have resulted in hurricane drop-sonde data that have never been available before in terms of spatial resolution. For hurricane Patricia we were joined by the NOAA P-3 Miss Piggy, collectively providing high resolution radar and high-altitude high-resolution drop-sonde data for the strongest western hurricane on record, also one that exhibited unparalleled rapid intensification (RI). This is an unparalleled data set.

In 2015 I have been in the field for all of the three test & development flights: June 25, July 22, Aug. 15, and the campaigns to TS Erika (Aug. 30). Hurricane Marty (Sept. 27, 28), Joaquin (Oct. 2, 3, 4, 5) and Patricia (Nov 20, 21, 22). Cumulatively I have been in the field for 28+ days, at Ellington Field TX, Harlingen TX, and Warner-Robbins GA.

RESULTS

Data obtained from the engineering test flights and improved telemetry processing algorithms have improved the data yield from the XDD sondes substantially compared to 2014. No dispenser jams or mission aborts occurred in 2014 or this year. The 58 of the 59 sondes which survived ejection (one failed to do so) from the WB-57 over TS Erika delivered data to pressures 1013 mB or greater.

Later flights in hurricanes Marty and Joaquin exhibited no sonde failures on launch, but a reasonably-consistent ≈ 6 % loss of sondes (no further telemetry) at varying altitudes 250 – 600 mB. These losses appear to be biased to sondes launched into eyewall conditions – cause(s) of these failures are not known at this time.

Despite those losses sonde success rates (defined as telemetering data from pressures greater than 920 mB in these earlier hurricanes) were better than 93% on all missions until Patricia – this includes the sondes launched into eyewall conditions. Telemetry yields (fraction of available records, from first to last valid records) were better than 98% for all flights before Patricia. These are good reliability statistics in comparison to either RD-94 manually-launched sondes or the NCAR/NOAA mini-sondes

(that are deployed from an automated dispenser at high-altitude and most comparable to the HDSS/XDD system).

The extreme conditions of Patricia caused more sonde failures (all in or near eye-wall conditions) and lowered telemetry yields significantly too. We saw a failure syndrome or mode in Patricia we have not seen before: roughly 10% of sondes would show erratic dew-point depressions (RH) starting just below the melt-layer, and then either the sonde would fail (we would receive no further transmission) or there would be a substantial gap, but the sonde would recover. Less dramatic behavior like this had been seen more rarely previously: figure 5 (which follows) shows a sonde from Joquin which has erratic dewpoint depression below the melt layer, but does not fail. Notwithstanding this new failure syndrome 89% of the sondes in Patricia met the similar success criterion (transmitting data from below 850 mB altitude for this extremely strong Hurricane with a surface pressure in the eye of 880 mB) , and Telemetry yields were 91%.

The HDSS/XDD system achieved sonde data spaced roughly 1.5 nm apart in the high-density passes across the eyes of Hurricanes Marty, Joaquin and Patricia; doing this required telemetering over 24 sondes in the air simultaneously. This has never been done by any drop-sonde system before.

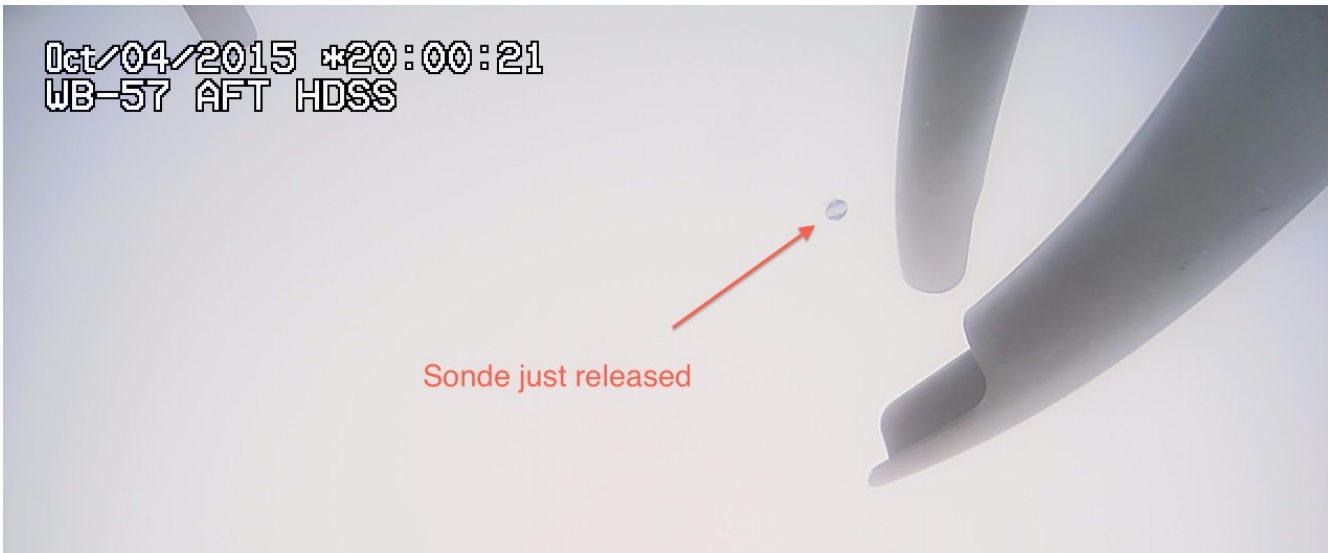
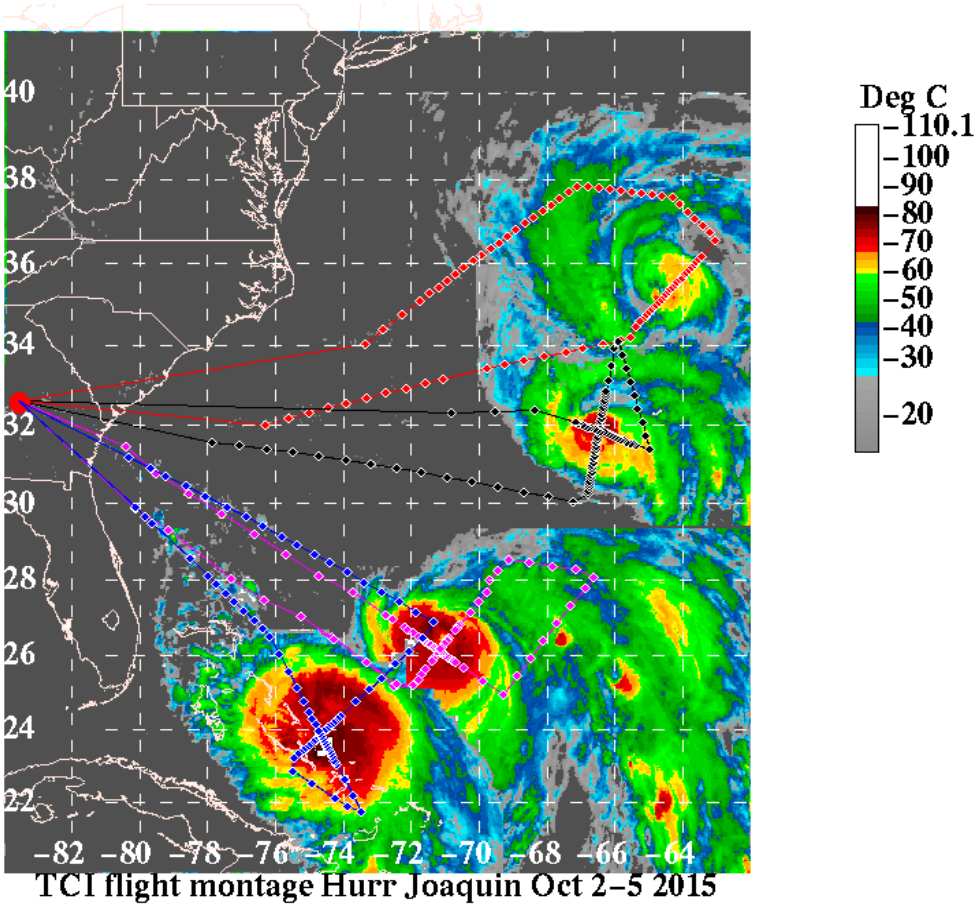


Figure 1: A sonde release in Joaquin from the WB-57 (aft looking camera)

Figure 1 shows a drop-sonde as it is released from the HDSS over Joaquin. The camera is one of two mounted under the aircraft. Each dispenser has its own drop-tube, the two curve objects on the right. A blade receiving antenna (one of four, and the least useful due to RF interference from the aircraft) can be seen behind the lettering. With magnification the sonde can be seen as nose-forward (they are launched rear-first to achieve this) disappearing away from the aircraft at its 400 kts flight speed.



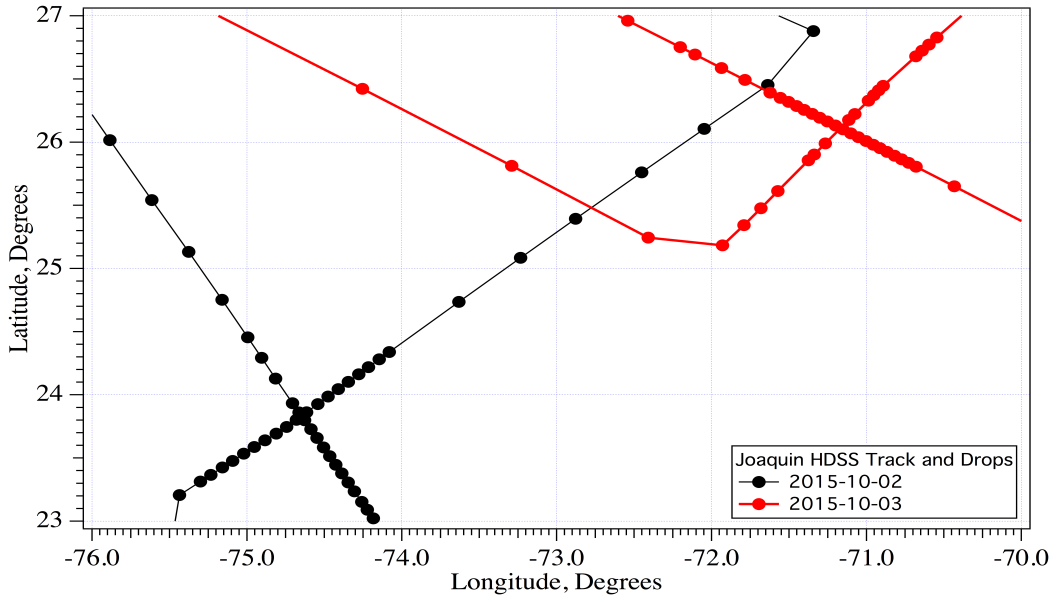


Figure 2

top: flight-tracks and drop-sonde positions for Joaquin *figure courtesy David Vallaro*
bottom: the first two of four flights at high resolution to show drop density clearly

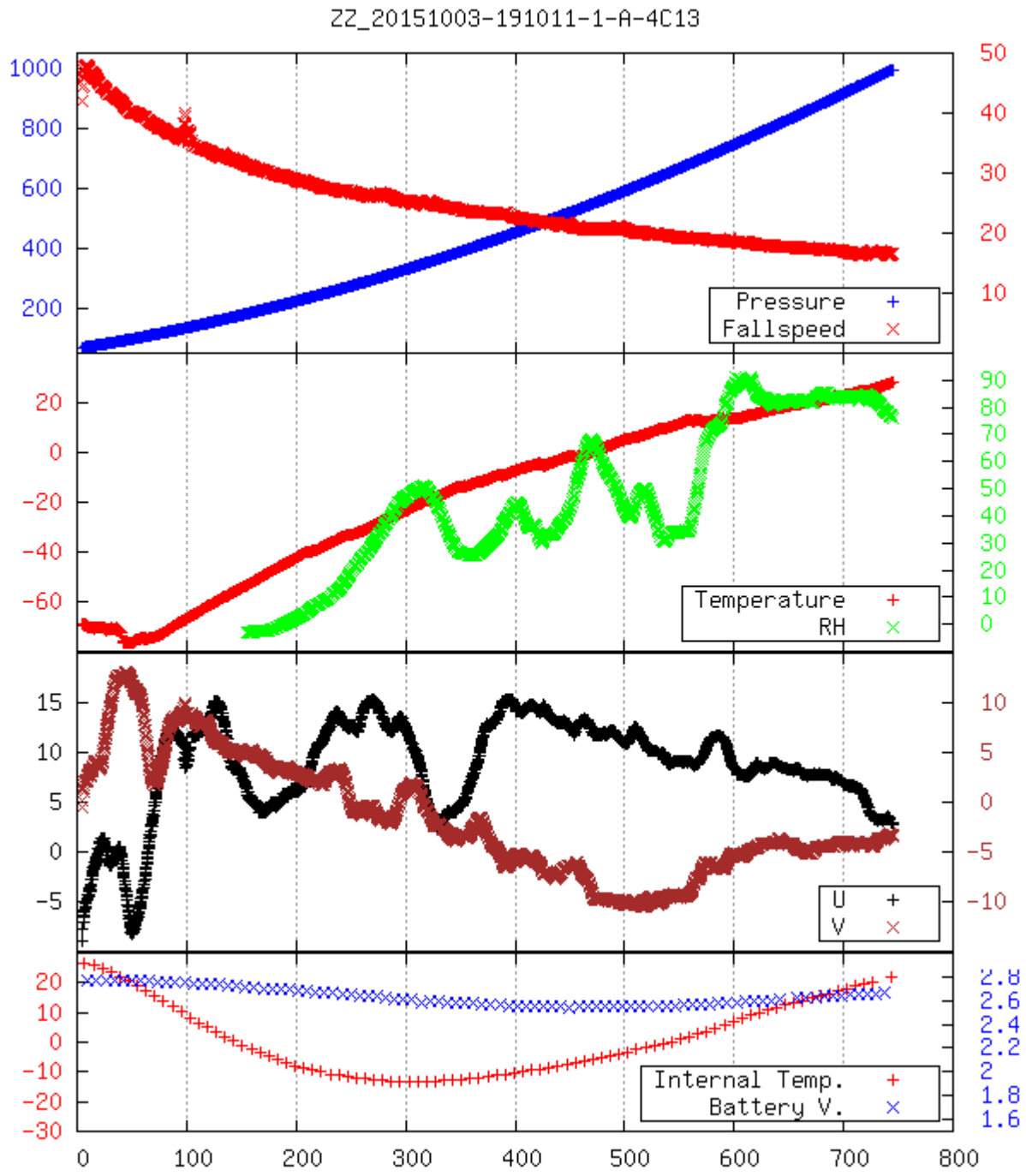


Figure 3: Quick-look graphic produced for a representative sonde (not in the eyewall region) in Hurricane Joaquin.

This graph and the following two are examples of the "quick look" graphs available from the SQZ Level-1 processing in "real time." during the flight (providing the satellite data link is working!)

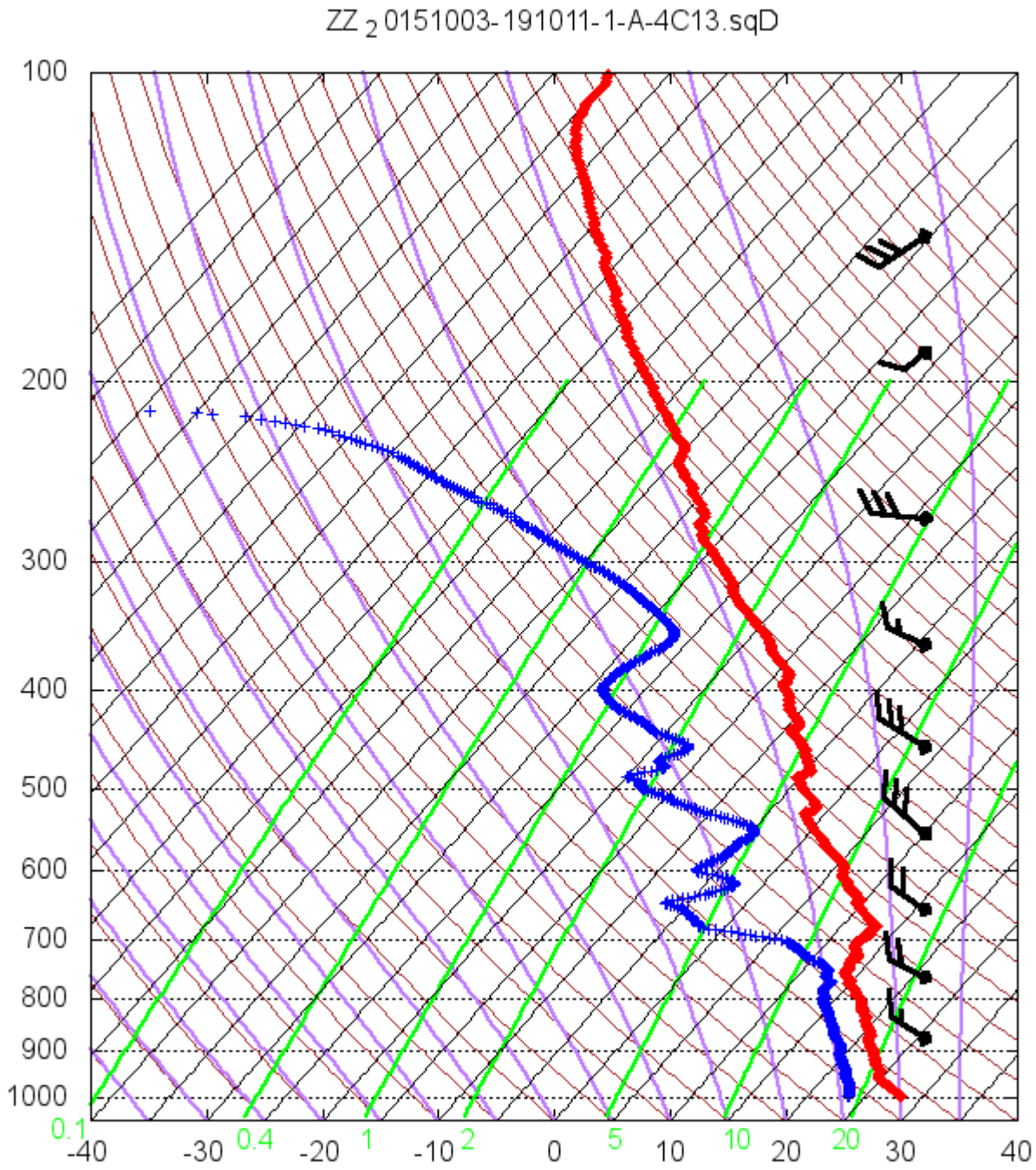


Figure 4: Quick-look Skew-T plot produced for the same sonde as figure 3.

This shows a typical Skew-T plot produced in "real time." from the periphery of Hurricane Joaquin. This graph is the same data as Figure 1.

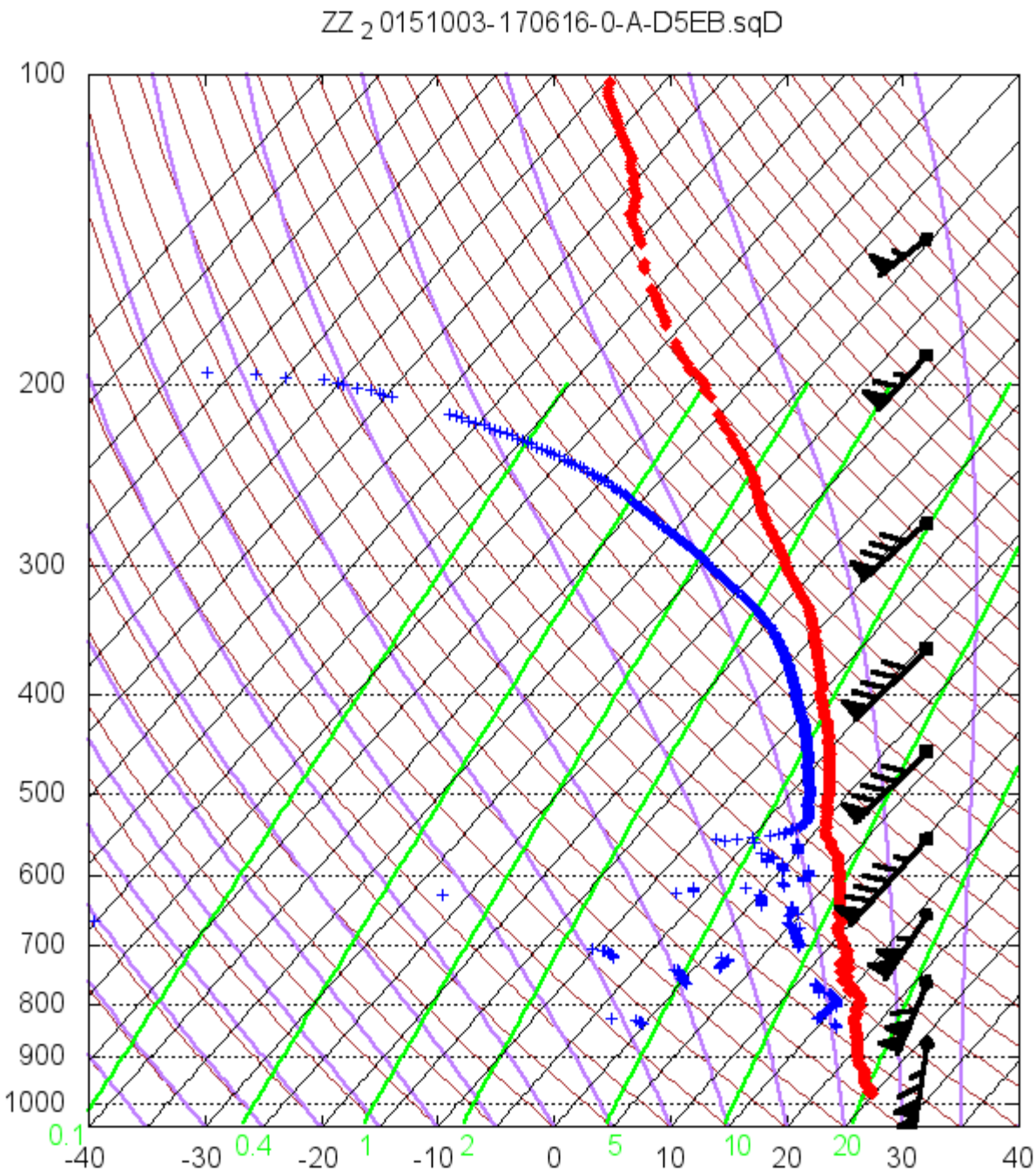


Figure 5: Quick-look Skew-T plot from near the eye-wall of hurricane Joaquin.

Due to the high-density sounding the HDSS captures much more data in and near the eye-wall of the hurricane compared to typical sonde usage. These data are near the eyewall of hurricane Joaquin; the lowest wind-bar shows 115 kts.

Some of the soundings from the eyewall show the disturbed humidity data at low altitude seen here. We don't know what this is caused by, but hypothesize it is droplet impacts on the RH sensor, potentially sea-water droplets advected aloft. In Patricia particularly we saw sondes that would fail after exhibiting this erratic dewpoint depression, possibly by shorting the humidity sensor, dropping the system voltage to the point where the sonde's control and transmit electronics would fail. We can isolate the RH sensor in the future to avoid that, and also will explore droplet inpactors in front of the humidity detector.

As to "what we have learned:" the research flights have just ended and it will be months before the science team can report the scientific results, but we have learned and demonstrated how to do achieve good reliability and operability from the HDSS system, delivering a new standard of data resolution from hurricanes, via high-altitude robotic drop-sonde measurements. And we have had the good luck to measure an extraordinary series of hurricanes, most unexpected in this El Nino year.

IMPACT/APPLICATIONS

The HDSS/XDR sonde system permits as many as 40 sondes to be in the air simultaneously, and can launch them autonomously from a high-altitude research aircraft (manned or drone) fast enough so that spatial resolution of 1 nm along flight track can be achieved. This will permit much higher spatial resolution of hurricane structures, particularly outflow jets.

TRANSITIONS

A new graduate student is working on the project.

RELATED PROJECTS

NONE

Acknowledgements: *I would like to thank Todd Allen, Mark Beaubien, Eric Griffin and Will Jeffries for the years of hard work it took to get to this point, and for sticking with it through 2014 and our failure to get good data for Gonzalo.*