# NOAA's airborne DWL on Hurricane research aircraft: 2015 -2017

G. D. Emmitt, C. O'Handley, J. Zhang, L. Bucci and R. Atlas

Working Group on Space-based Lidar Winds
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# Outline

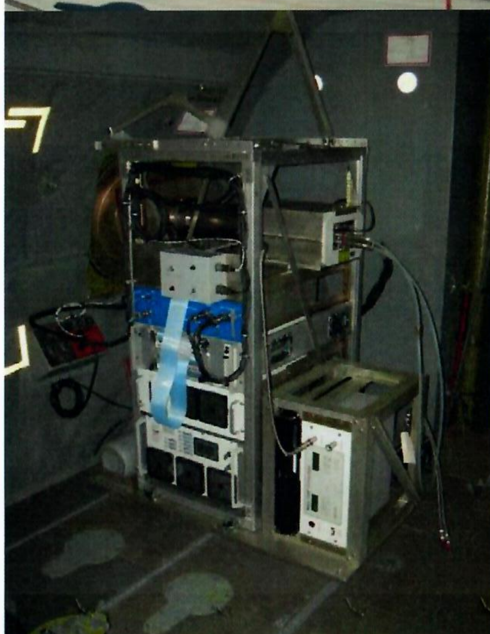
- Description of the P3DWL
- 2015 flights
  - Instrument performance
  - Data studies
- 2016 flights
  - Instrument performance
  - Data studies
- 2017 plans

# Background

- **Mounted a Doppler wind lidar to the P3 for the first time (P3DWL)**
- **Wind profile data from the 2015 & 2016 seasons:**
  - TS Erika (1) *Forward side-to-side sweep*
  - TS/Hurricane Earl (3) *Conical down and up*
  - TS Javier (2) *Conical down and up*

# NOAA P3 Doppler Wind Lidar (DWL)

- Side mounted cylindrical scanner from NASA/LaRC
(10 cm bi-axis scanner)

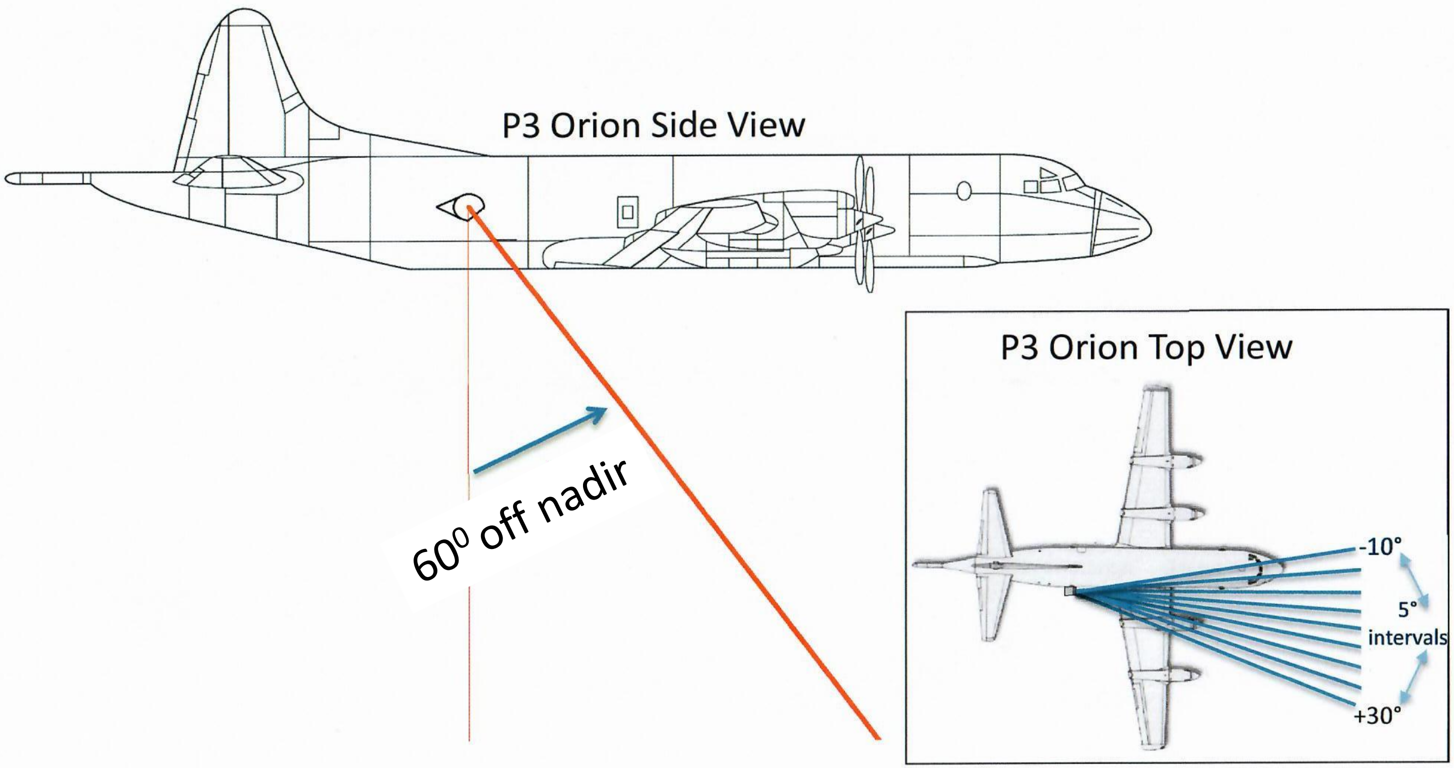


- 1.6 µm coherent CTI WindTracer (WTX) transceiver from Lockheed Martin Coherent Technology

For the first time, the Doppler Wind Lidar (DWL) has been successfully operated on NOAA's P3 aircraft


Problems with the scanner sticking led to fixing the elevation angle of the beam to 60 degrees off nadir forward and programming the azimuth mirror for 9 step stares subtending 40 degrees.

# Forward Sweep Scanning Pattern



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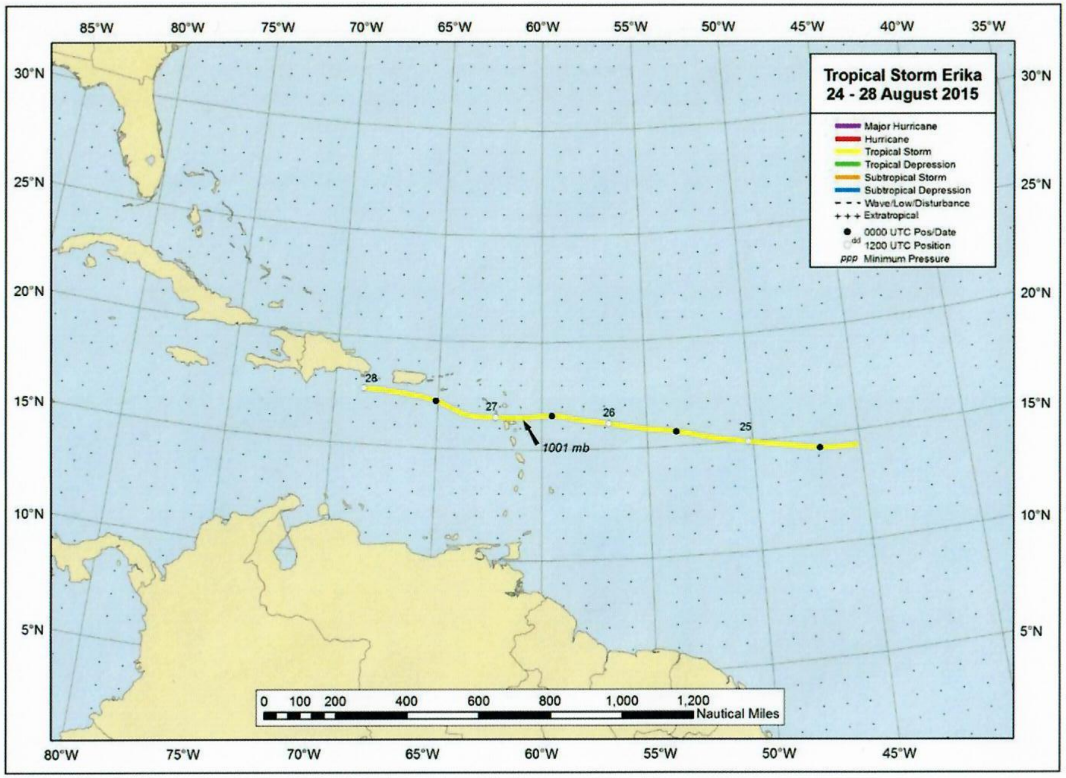
# Track of Tropical Storm (TS) Erika (2015)




- DWL observations were taken on 8/26 between 17:30 UTC to 21:00 UTC when Tropical Storm Erika moved to the west.



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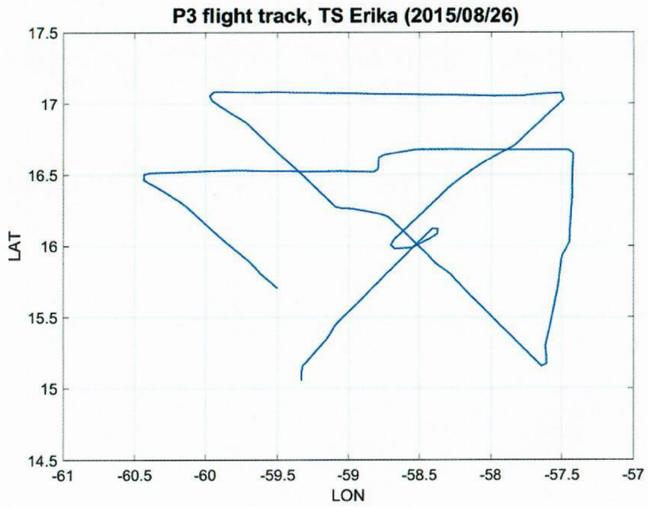
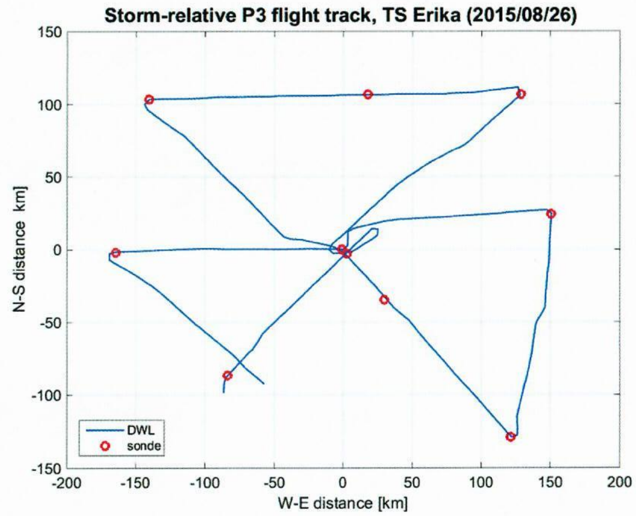
# P3 aircraft track (2015/08/26 N43 flight)

Earth – relative




Storm – relative




- DWL wind profiles were collected every .5 minutes along the flight track.
- Dropsondes were released at the center of the storm, middle of the flight leg and turn points (red circles on the right side figure).



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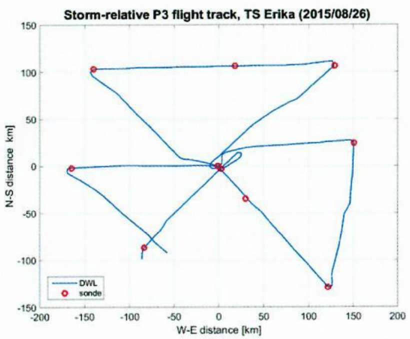
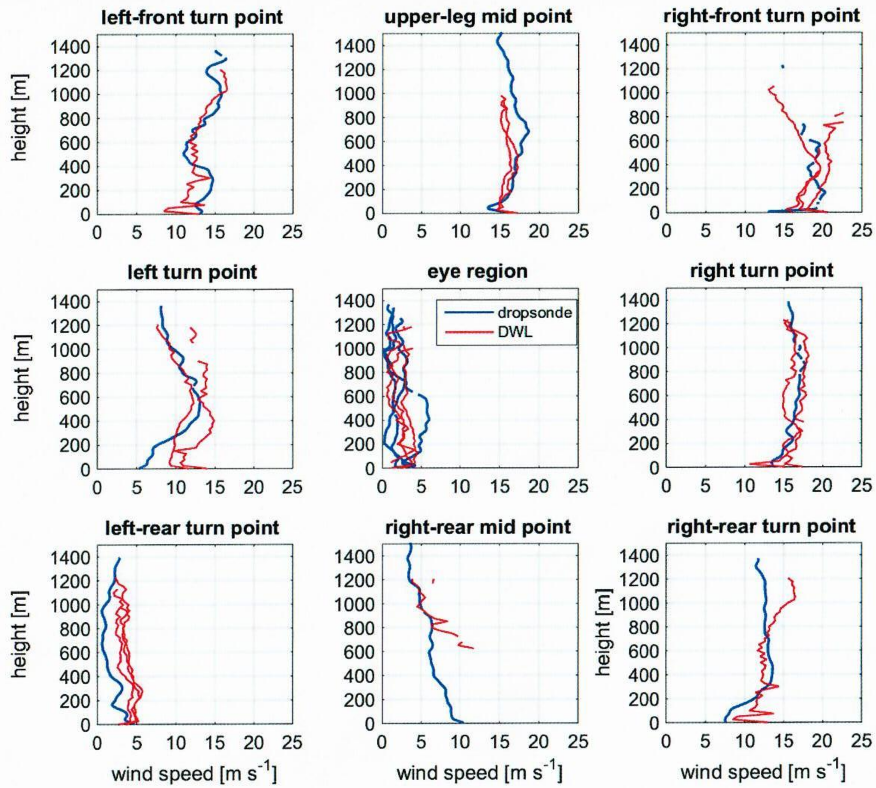
# DWL wind profile validation against dropsonde data




- Comparisons between the DWL and dropsonde measured vertical wind profiles show excellent agreement.
- The DWL captured the boundary layer wind asymmetry observed by the dropsondes.



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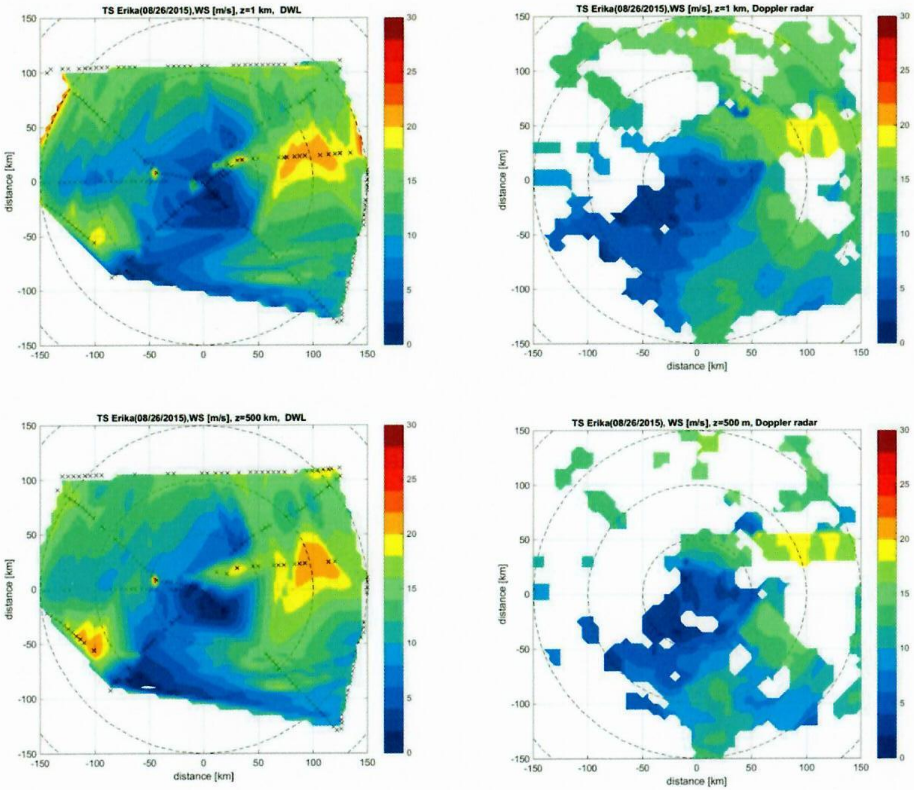
# Wind speed from DWL vs Tail Doppler radar




Vertical resolution:
Lidar- 25 m
Radar-500 m

Data coverage below 500 m:
Lidar – good
Radar – very little

- The DWL data captured the asymmetric pattern of wind speed observed by the Doppler Radar;
- The DWL compliments the Doppler radar observations above 500m in rain-free region;
- The DWL provides excellent data converge below 500 m where Doppler radar data is very limited.



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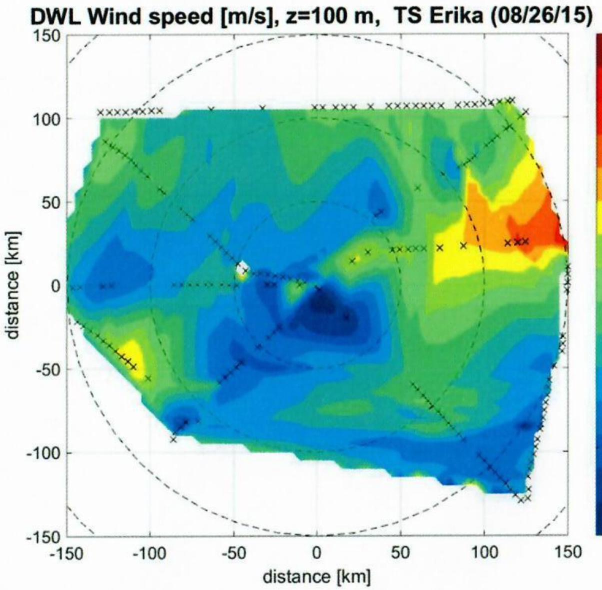
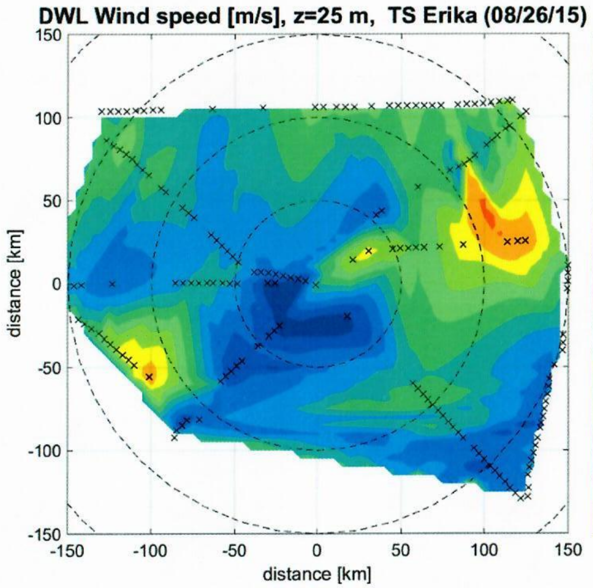
# DWL measured near surface winds




- DWL can measure wind speed down to the sea surface with vertical resolution of 25 m.
- Full 3D wind fields can be measured by the DWL in the boundary layer.



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# Erika Case Summary

- Wind profile data were collected in Tropical Storm Erika (2015) by a Doppler wind lidar (DWL) successfully installed on NOAA P3 aircraft.
- Comparisons between DWL and dropsonde measured vertical wind profiles show good agreement.
- The DWL captured the wind asymmetry above 500 m where Doppler radar data were available; the DWL also provided unique observation of boundary layer structure below 500 m with excellent data coverage.
- The axisymmetric boundary layer structure of Tropical Storm Erika (2015) is different from that a typical hurricane boundary layer.
- The boundary-layer wind asymmetry in Erika is generally consistent with that in hurricane dropsonde composite in shear relative framework.

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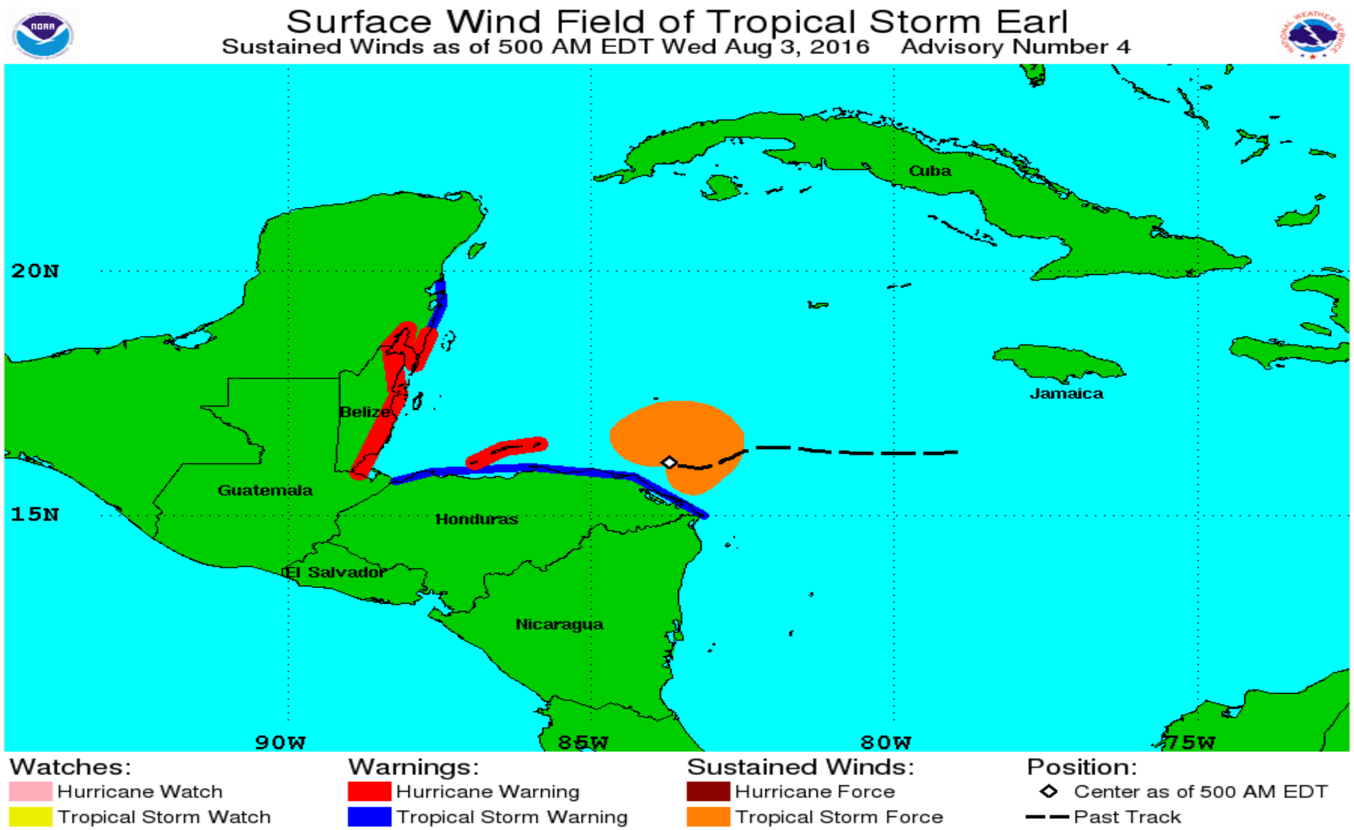
Problems with the scanner sticking were fixed for the 2016 season. Scanner was operated with a 20 degree off nadir elevation angle and 12 azimuth step stares.

# Hurricane Earl – 08/03/2016

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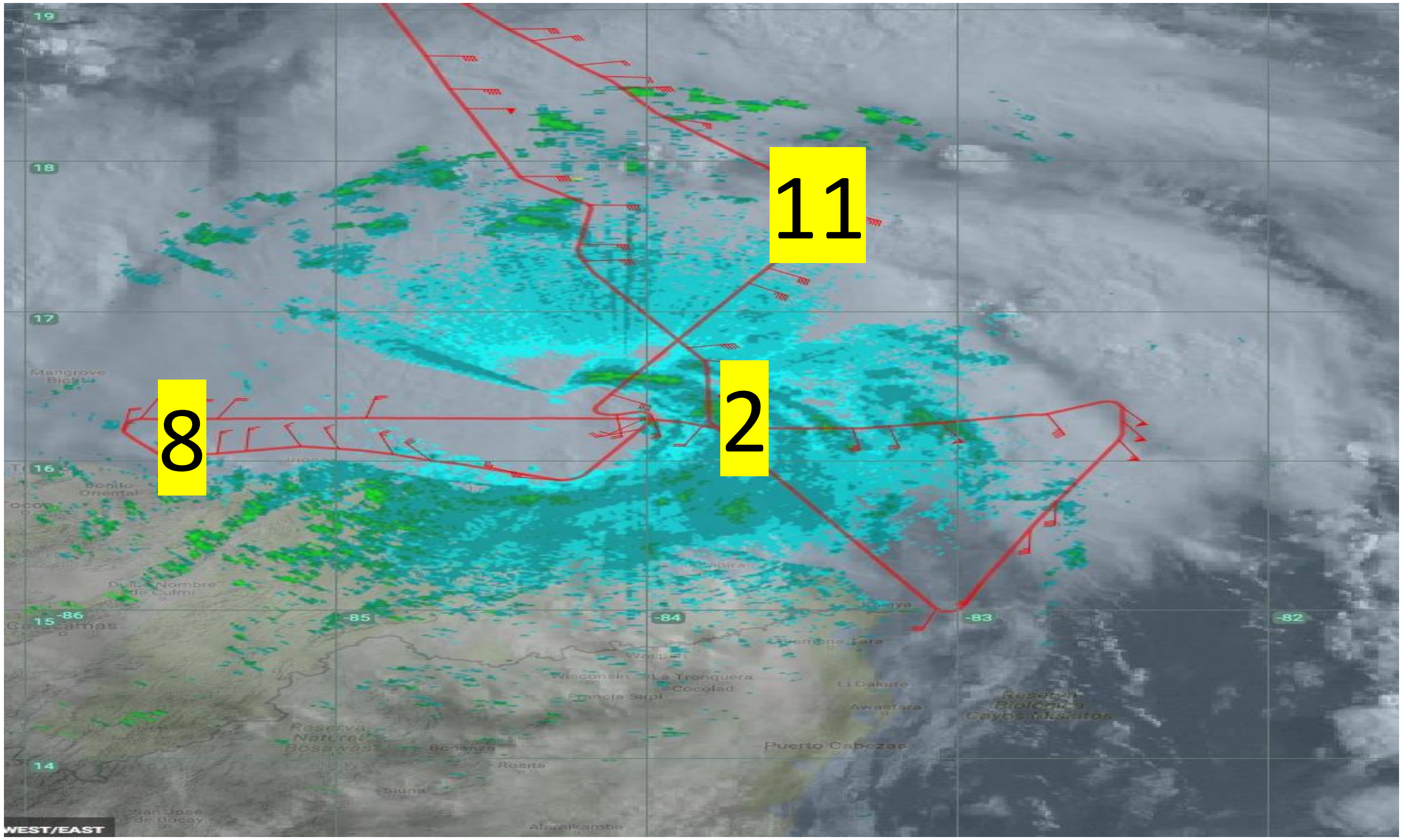
# Hurricane Earl – 08/03/2016

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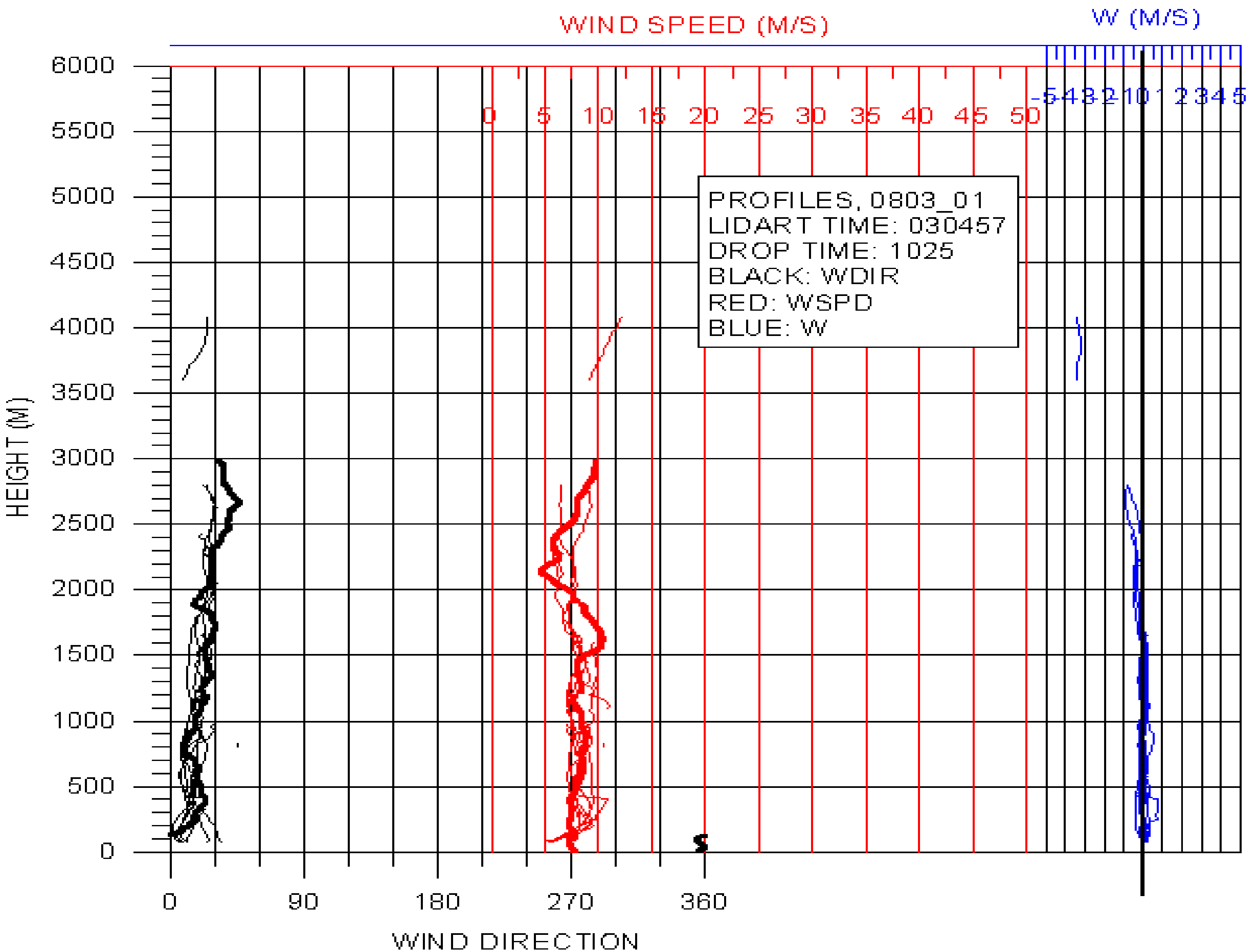
WIND SPEED (M/S)
W (M/S)
HEIGHT (M)
WIND DIRECTION
PROFILES, 0803_01
LIDART TIME: 030457
DROP TIME: 1025
BLACK: WDIR
RED: WSPD
BLUE: W
6000
5500
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
0
90
180
270
360
0 5 10 15 20 25 30 35 40 45 50
-5 4 3 2 1 0 1 2 3 4 5

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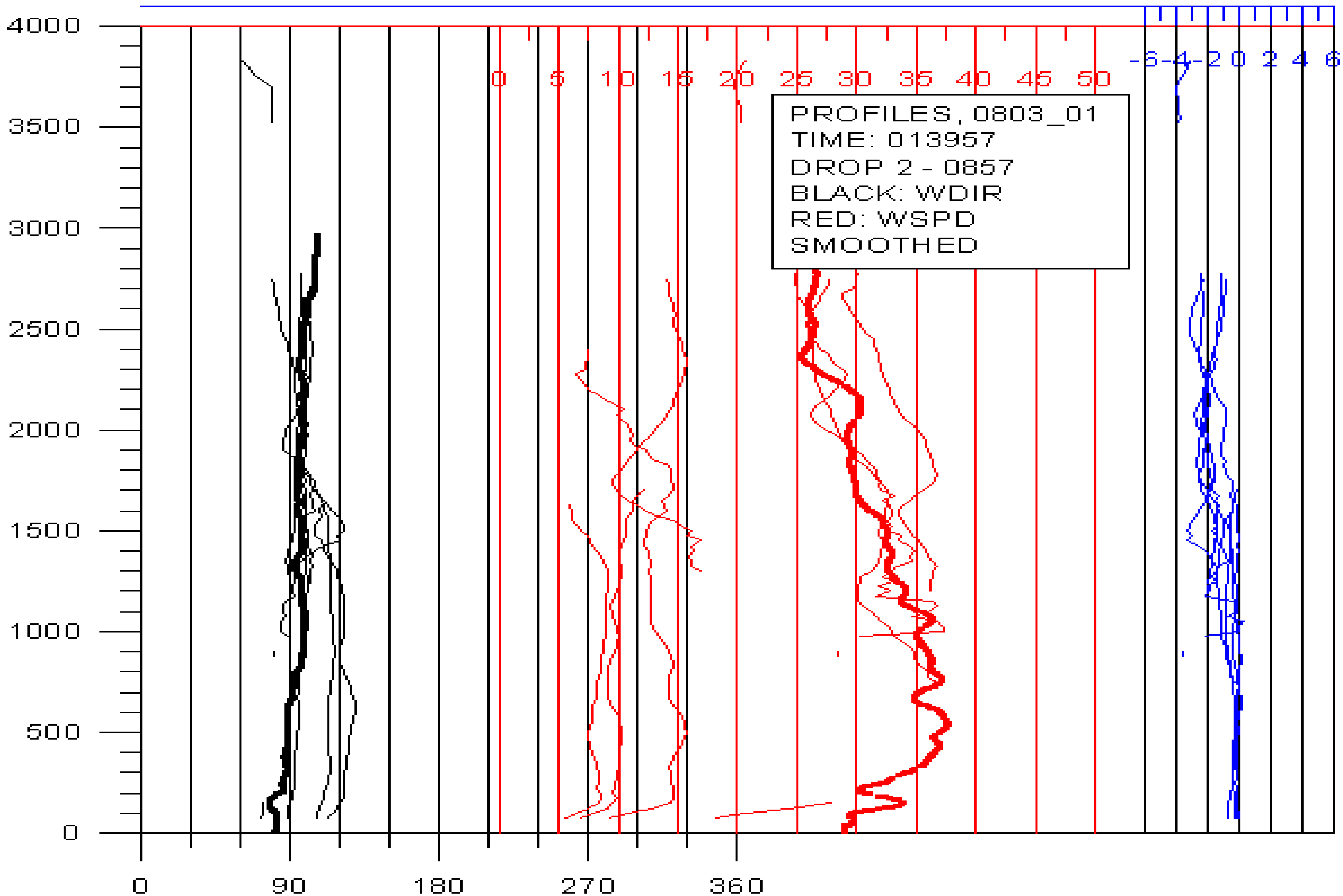

PROFILES, 0803_01
TIME: 013957
DROP 2 - 0857
BLACK: WDIR
RED: WSPD
SMOOTHED
0
500
1000
1500
2000
2500
3000
3500
4000
0
90
180
270
360
0 5 10 15 20 25 30 35 40 45 50
-6 -4 -2 0 2 4 6


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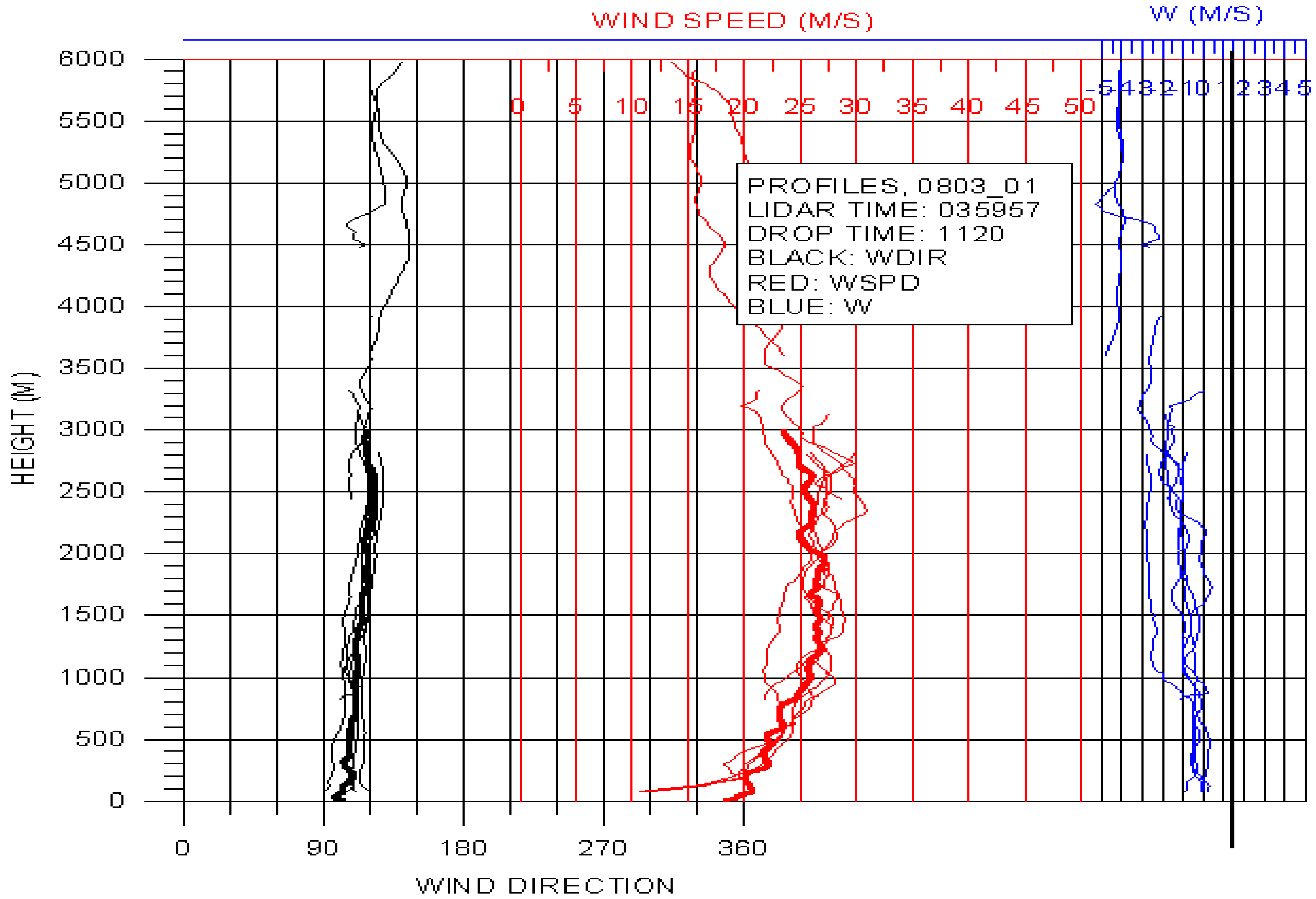
WIND SPEED (M/S)
W (M/S)
HEIGHT (M)
WIND DIRECTION
PROFILES, 0803_01
LIDAR TIME: 035957
DROP TIME: 1120
BLACK: WDIR
RED: WSPD
BLUE: W

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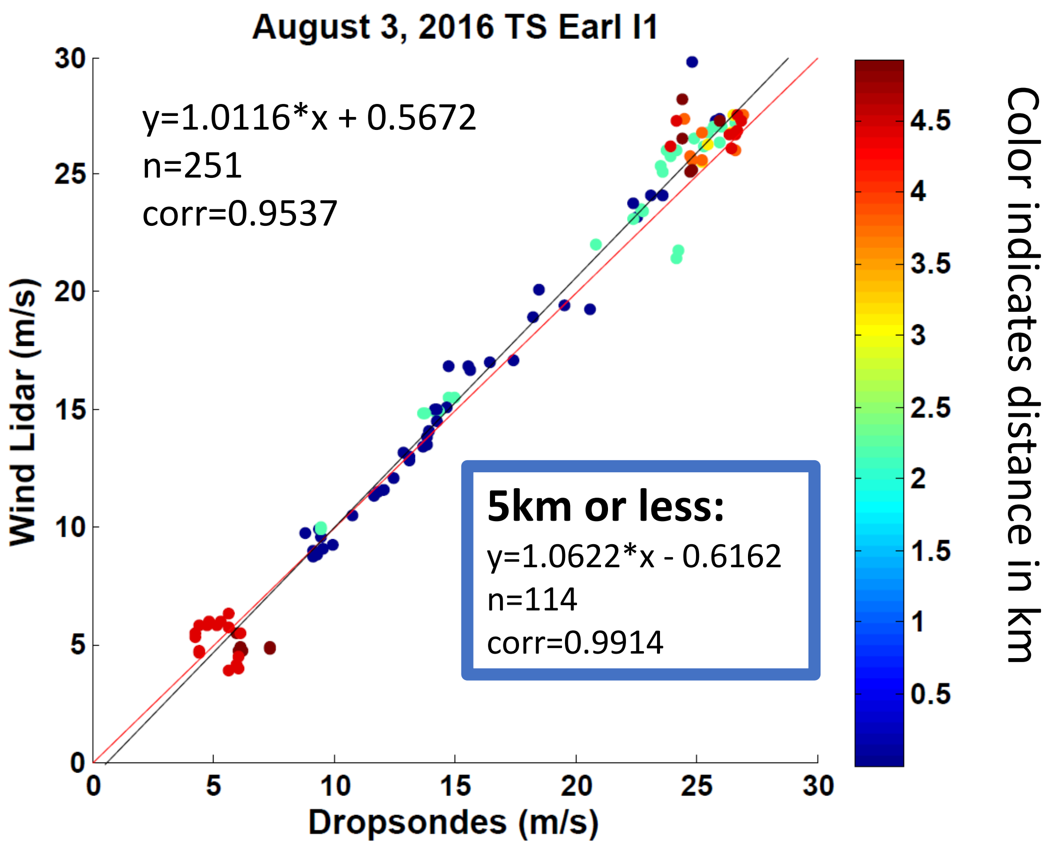
# Verification– DWL/GPS speed

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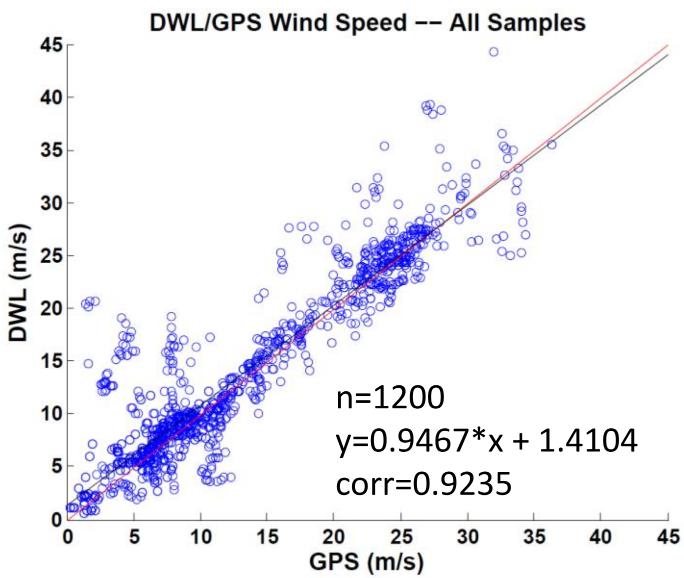
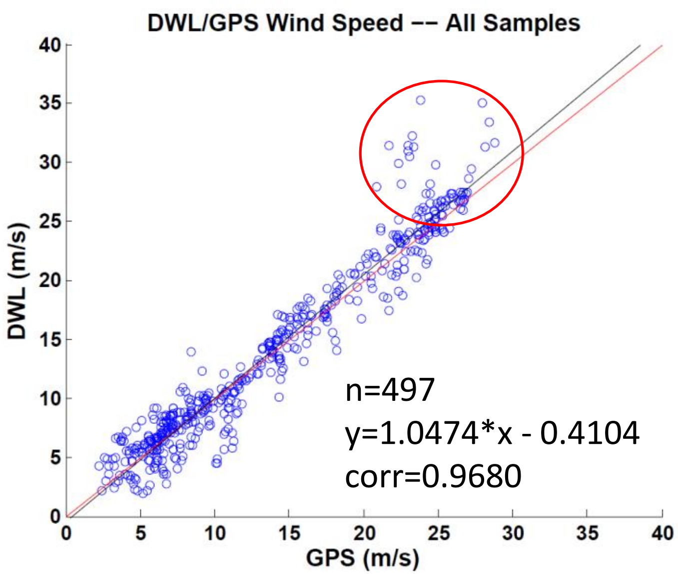
# Verification– DWL/GPS speed

10km threshold




5km threshold




****Sample from 4 flights (2016): 0802I1, 0803I1, 0803I2, 0809I1*

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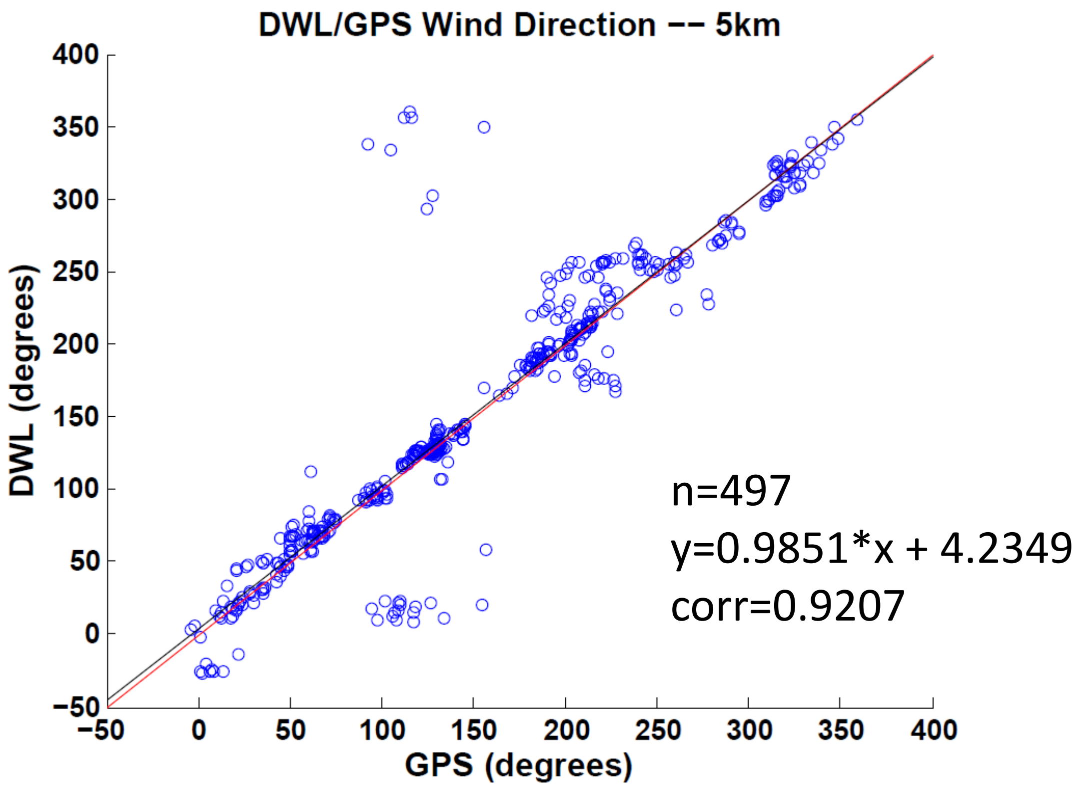
# Verification -- DWL/GPS direction




****Sample from 4 flights (2016): 0802I1, 0803I1, 0803I2, 0809I1*

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# Summary from AOML

- **What has been done?**
  - Shown P3DWL obs complement TDR obs
  - Qualitatively compared P3DWL obs to dropsonde
  - Shown impact in analysis using HEDAS
- **In progress:**
  - Quantitatively comparing P3DWL observations to other observing platforms on P3

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# Continued Verification Work

- Compare SFMR to lowest DWL measurements (height varies depending scanning pattern)
- Compare flight level to highest DWL winds
- Comparison profiling code

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# 2017 Season

- P3DWL to be flown second half of season
  - Target higher (hurricane force) wind speeds for verification
- Training for operators (held at HRD) this spring

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# Investigation of the effects of precipitation on DWL wind retrievals

- Revival of work done in 2008-2009 using DWL data collected from NRL P3 in TPARC (Western Pacific)
- Motion of aerosols and hydrometeors captured in LOS illuminated volumes.
- Working in the spectral domain allows us to discriminate between those two contributions.
- Four motion contributions that need to be distinguished:
  - Horizontal and vertical motion of the aerosols
  - Horizontal and vertical motion of the hydrometeors

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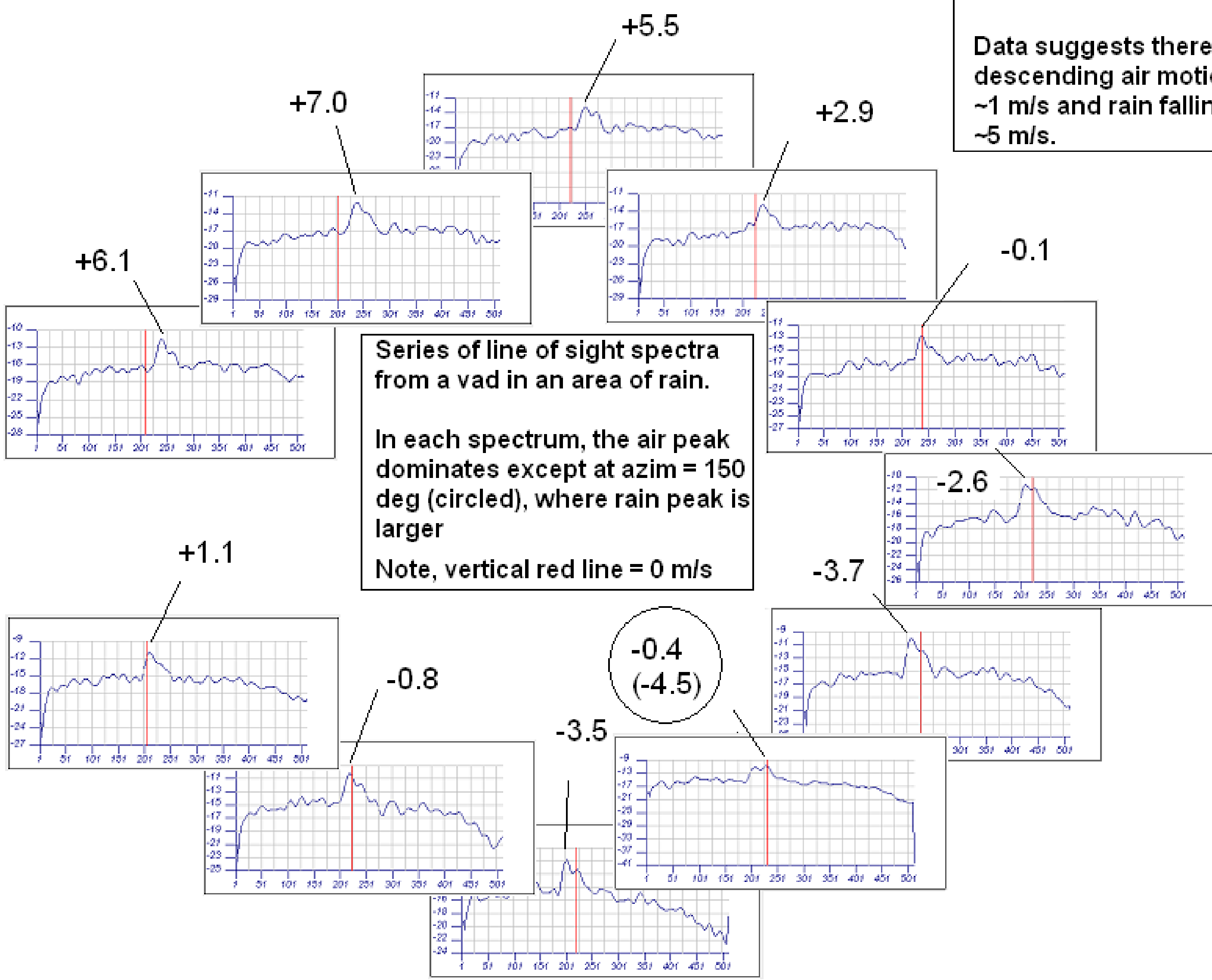
Lidar data from 2016, 0803_01 (TS EARL)

Data suggests there is descending air motion of ~1 m/s and rain falling at ~5 m/s.

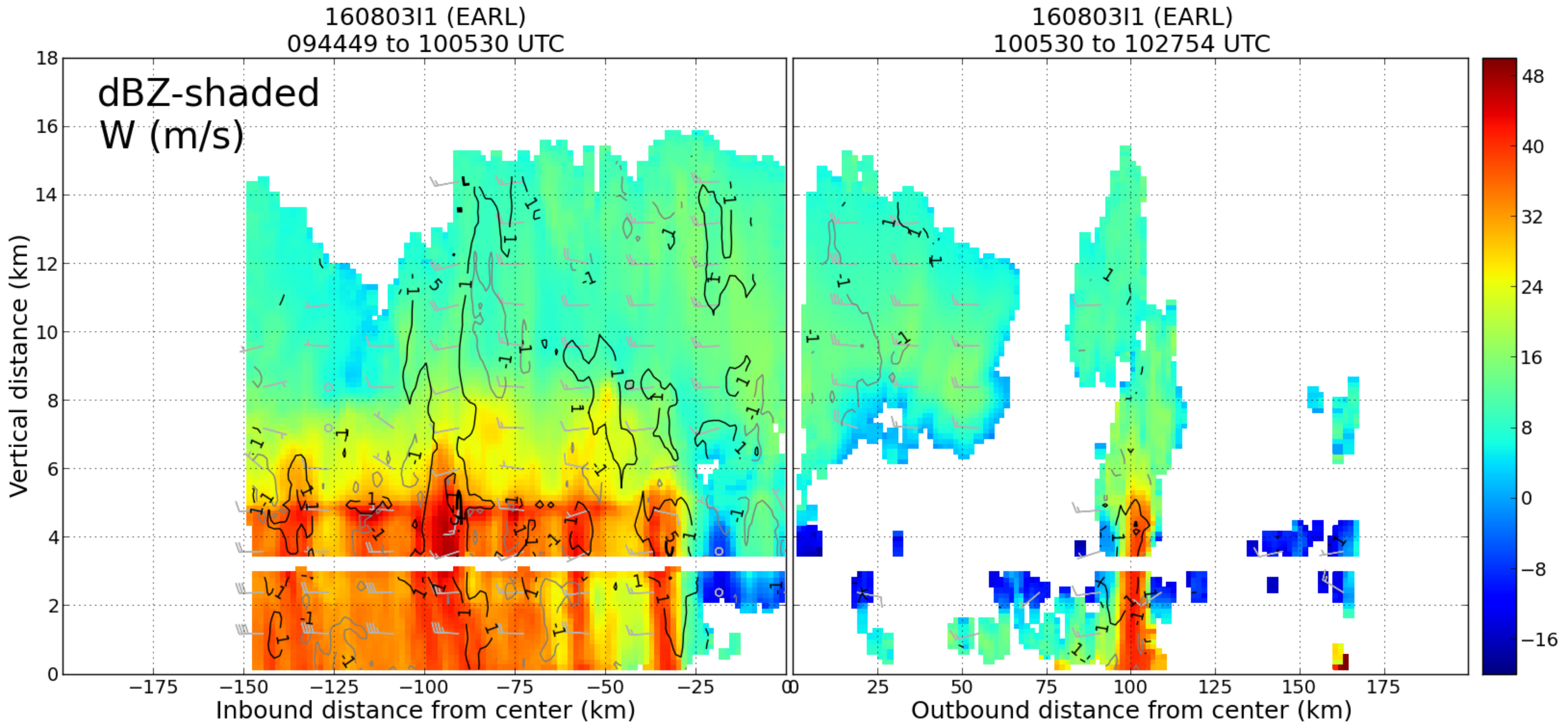



Series of line of sight spectra from a vad in an area of rain.

In each spectrum, the air peak dominates except at azim = 150 deg (circled), where rain peak is larger

Note, vertical red line = 0 m/s

# Flight leg through center of Earl: TDR observations

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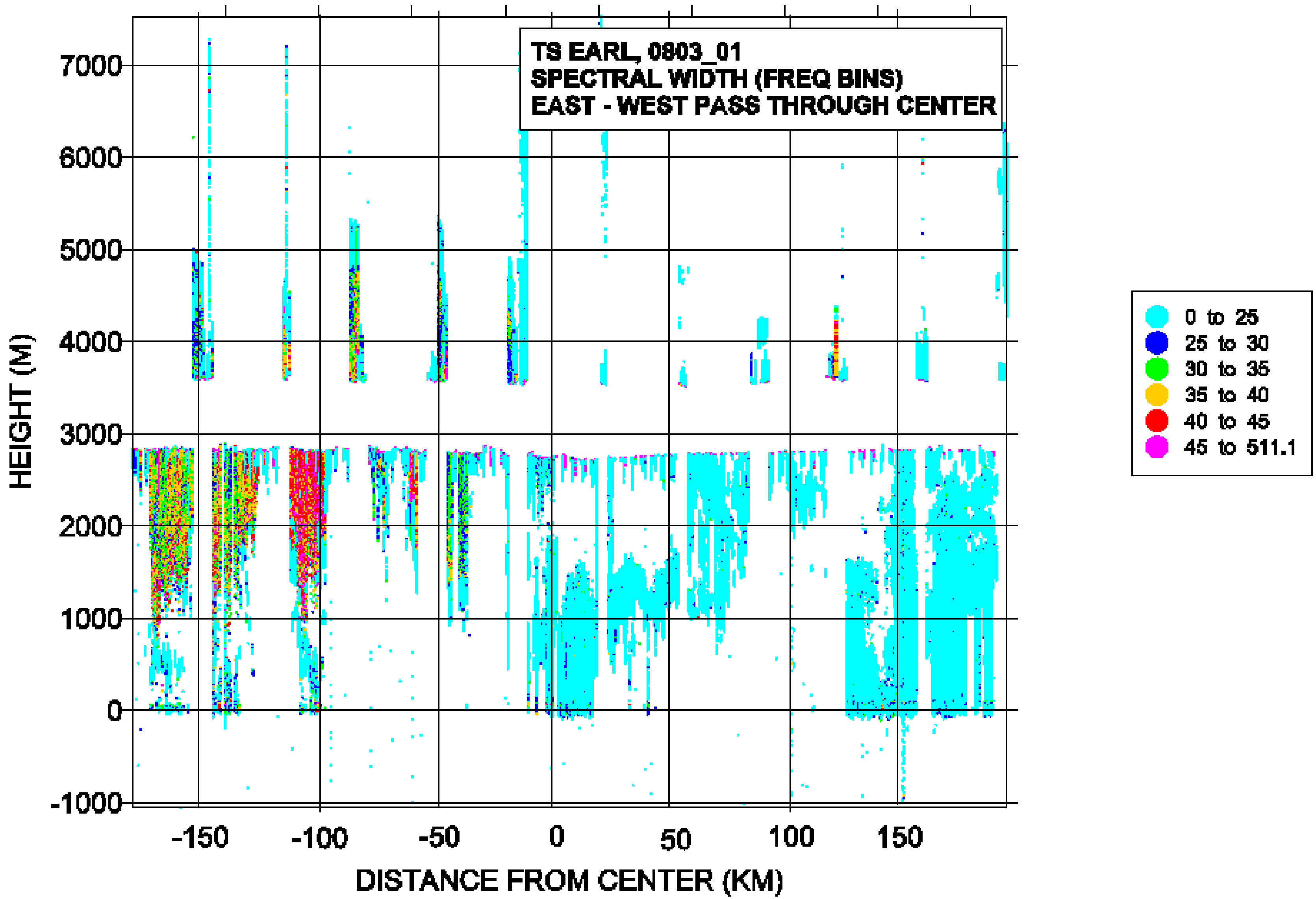


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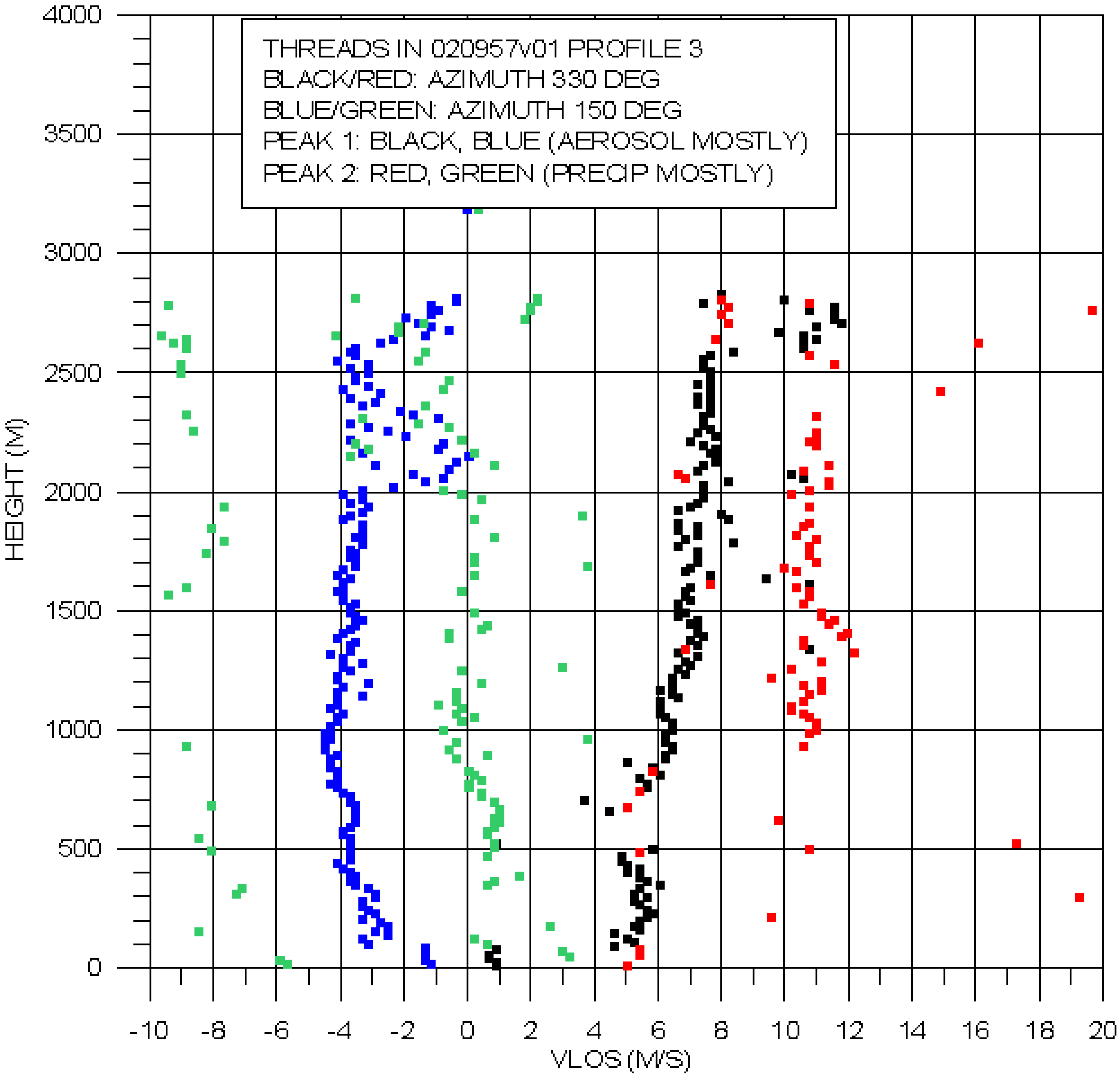


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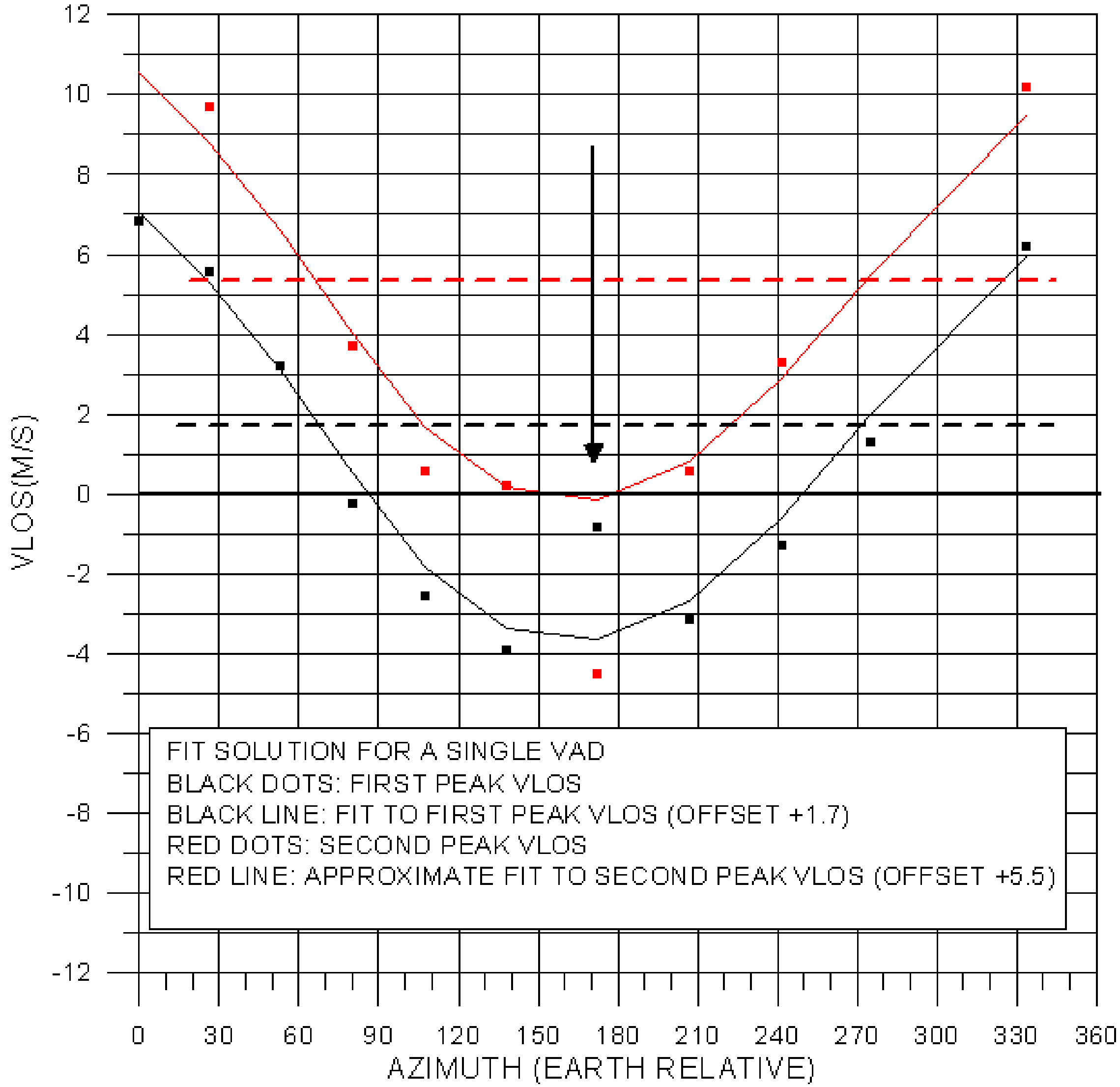


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# Summary

- After 2 seasons of flying on the NOAA P3, the DWL has demonstrated its capabilities to make useful observations within the strong gradient and turbulent environment of tropical cyclones.
- The down/up scanning enabled by the side mounted scanner offers perspectives on the aerosol and hydrometeor motions that require advanced processing techniques currently being developed.
- New scanning and signal processing algorithms will be evaluated during the 2017 season starting September 1.