Near-Surface Wind Retrievals Within the MABL and Sea Salt Spray Zone: DAWN in CPEX

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Overview

- Lowest 200m of the PBL is just one focus area of a more comprehensive series of multi-agency (NASA, ONR and NOAA) funded investigations of the PBL (mostly over water) using airborne Doppler Wind Lidars, dropsondes and other remote sensing capabilities.
- PolarWinds (NASA DC8) 2015, Iceland: > 80 hours DWL time and ~100 dropsondes.
- **CPEX(NASA DC8) 2017, Florida: >100 hours DWL time and ~ 300 dropsondes.**
- Hurricane Reconnaissance (NOAA P3) 2015-2018, Florida: > 100 hours DWL time and ~ 100 dropsondes
- Aeolus cal/val preparations(DC8) 2019, California: ~45 DWL hours and 64 dropsondes.

Focus on the lowest 200 meters of MABL

- What does an airborne or future space-based coherent Doppler Wind Lidar have to offer to investigations of the Marine Atmospheric Boundary layer?
  - Depth of the MABL
    - Defined by aerosols (backscatter)
    - Defined by wind profiles
    - Defined by turbulence (spectral width)
  - MABL organization/features
    - LLJs
    - OLEs
    - Sea salt spray distribution/speeds
  - Ocean surface properties
    - Breaking waves (whitecaps)
    - Foam coverage
    - Ocean wave spectra
    - Surface currents
- SWA developing a toolbox for deriving PBL parameters from airborne and spacebased coherent DWLs.

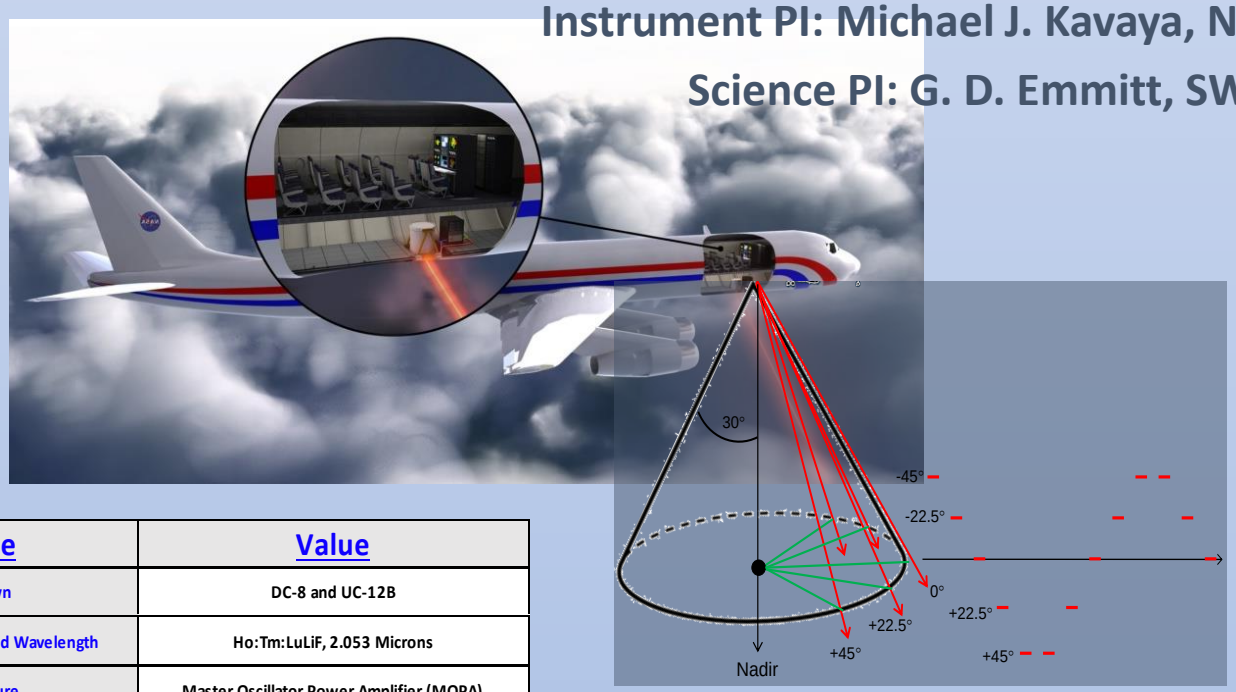
Todays' focus on the lowest 200 meters of MABL

- What is the "true" wind at the traditional 10 meter reference height over water? Log and power wind profiles not suitable for high winds (>15m/s). Highly non-linear interactions between ocean surface and PBL winds..surface roughness changes with wind speed…breaking waves change fluxes…saltation changes drag coefficient…..
- How close to the ocean surface can we observe the winds with a 180nm pulse (~ 30m FWHM)?
  - How can the DWL wind retrievals below 50m be used in studies of the Marine Boundary Layer under >15m/s winds?
  - Sea spray droplets are large aerosol water particles that are ejected into the atmosphere as waves break at the ocean surface and have backscatter values much higher than the ambient air.
- Resolving MABL wind/aerosol structures with single shot DAWN processing below 200m.

Doppler Aerosol Wind (DAWN) Lidar System in CPEX

Instrument PI: Michael J. Kavaya, NASA LaRC

Science PI: G. D. Emmitt, SWA



As used in CPEX

Attribute	Value
Airplanes Flown	DC-8 and UC-12B
Solid-State Laser Crystal and Wavelength	Ho:Tm:LuLiF, 2.053 Microns
Laser Architecture	Master Oscillator Power Amplifier (MOPA)
Pumping Source, Wavelength, Duration	Laser Diode Arrays (LDA), 792 nm, 1 ms
Laser Pulse Energy E, Rate f, FWHM Duration t	100mJ, 10HZ, 180ns
Telescope Diameter D, Magnification M	15 cm
Light Detection Material, Technique	InGaAs, Coherent, Dual-Balanced
Scanner Diameter, Type, Deflection	15 cm, Step-Stare Rotating Wedge, 30° About Nadir
Eye Safety	Safe at any Range When DAWN Closed Up for Flight
Pointing Knowledge Technique	Dedicated INS/GPS on Lidar; dry land returns
LOS Wind Measurement Precision	< 1 m/s
Maximum LOS, Horizontal Wind	±80 m/s, ±160 m/s
Captured Data Length in Range, Altitude	0 – 16.4 km, 0 – 14.2 km
Vertical Resolution	133 m for 512-Sample Range Gate

Vertical resolution: 33/9 m
Single shot horizontal resolution in PBL: <20m
Lowest level of wind retrieval: ~ 10m using SRGs
Full tropospheric profiles using 2 second stares from surface to 12km

DAWN Capabilities

High coherent Doppler lidar sensitivity to aerosol backscatter, enabling excellent vertical resolution, accuracy, and atmospheric coverage

Provides vertical profiles of horizontal wind vectors, LOS range wind and wind turbulence profiles, and relative aerosol backscatter profiles

Optional number of azimuth angles (up to 12) permits trade of wind variability determination vs. horizontal resolution

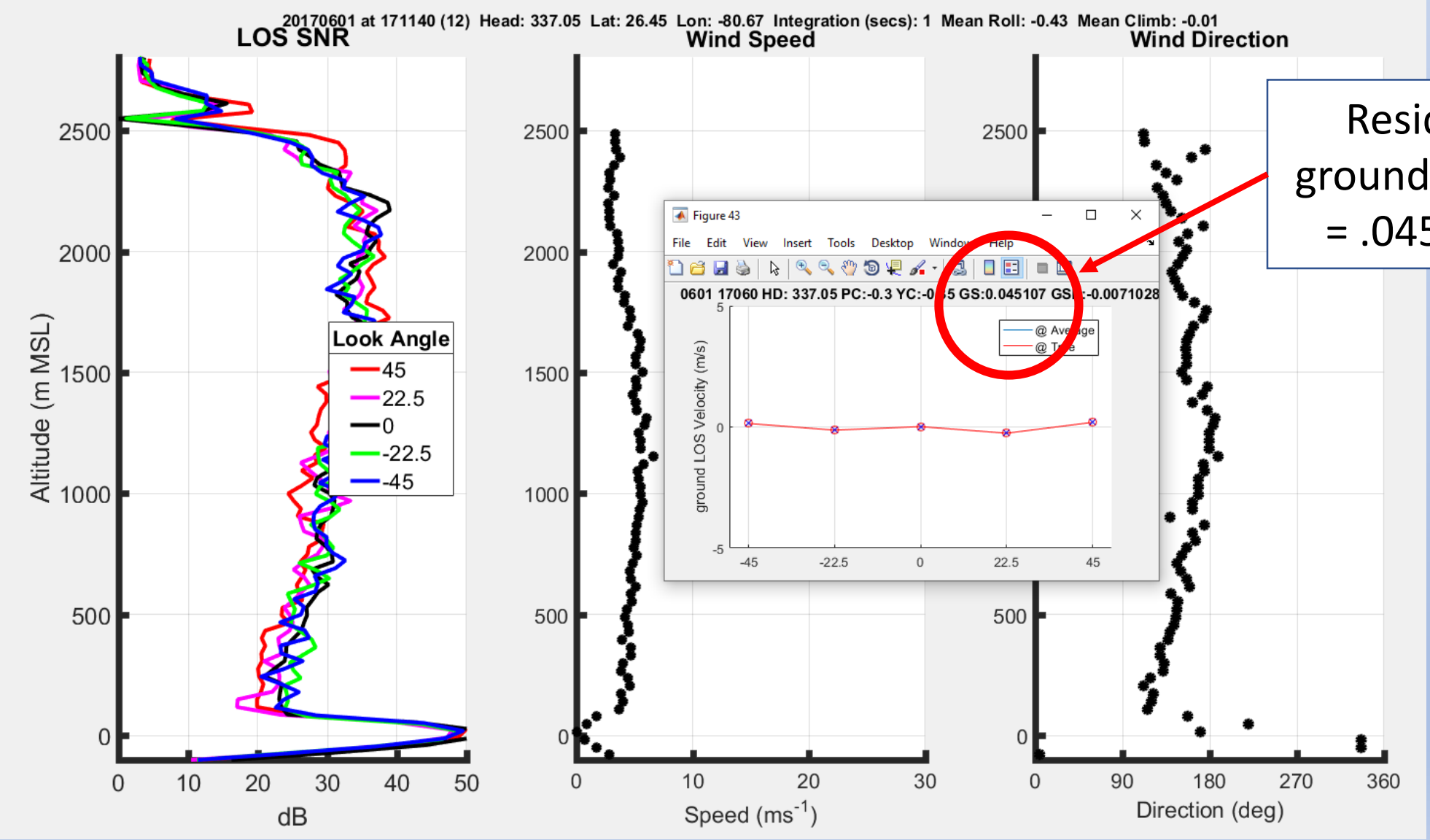
Optional number of laser shots averaged for each LOS wind profile permits trade of atmospheric coverage vs. horizontal resolution

Data may be processed multiple ways to provide various combinations of vertical and horizontal resolution, atmospheric coverage, and expected accuracy statistics

DAWN ground return calibrations

- Ground return calibration while over the Florida peninsula
  - Straight and level between 3 and 4 km AGL
  - Perform calibration flight segment before and after an over-water mission clouds and ATC permitting.

Example of attitude calibration for DAWN during CPEX

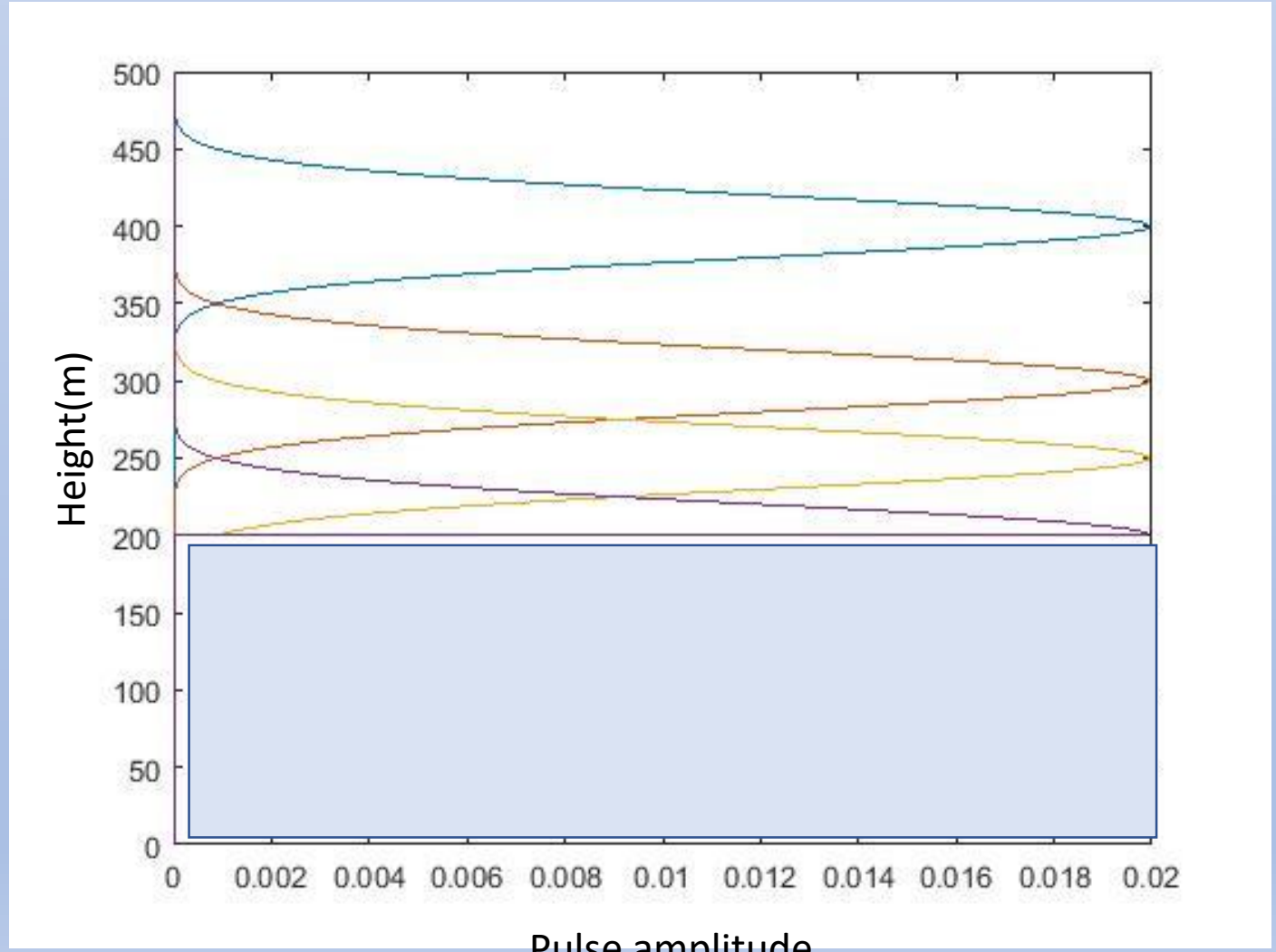


Example ground return calibrations with residual ground speed (Nominal DC-8 groundspeed during calibration is 175m/s)

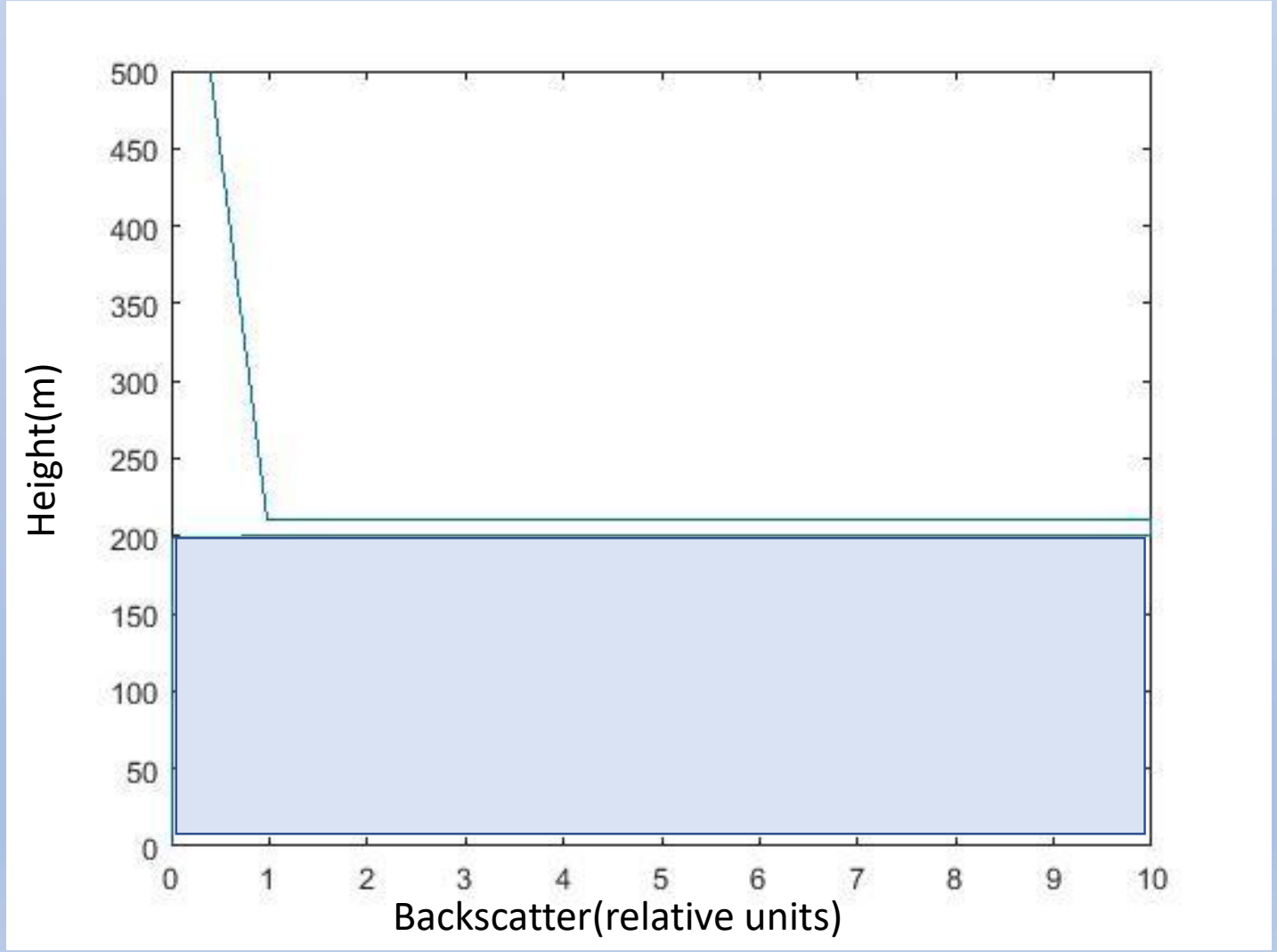
Date	Yaw Correction	Pitch Correction	Ground Speed(m/s)	GOF
May 27	-0.30	-0.30	0.037	-0.059
May 29	-0.30	-0.30	0.199	0.025
June 1	-0.35	-0.30	0.045	-0.007
June 15	-0.45	-0.20	0.037	0.038
June 23	+0.05	-0.60	0.023	-0.018
June 24	-0.15	-0.55	0.101	0.037

Simulations of Airborne DWL measurements within the lowest 50m over water in the presence of wave blow off (sea salt aerosol spray)

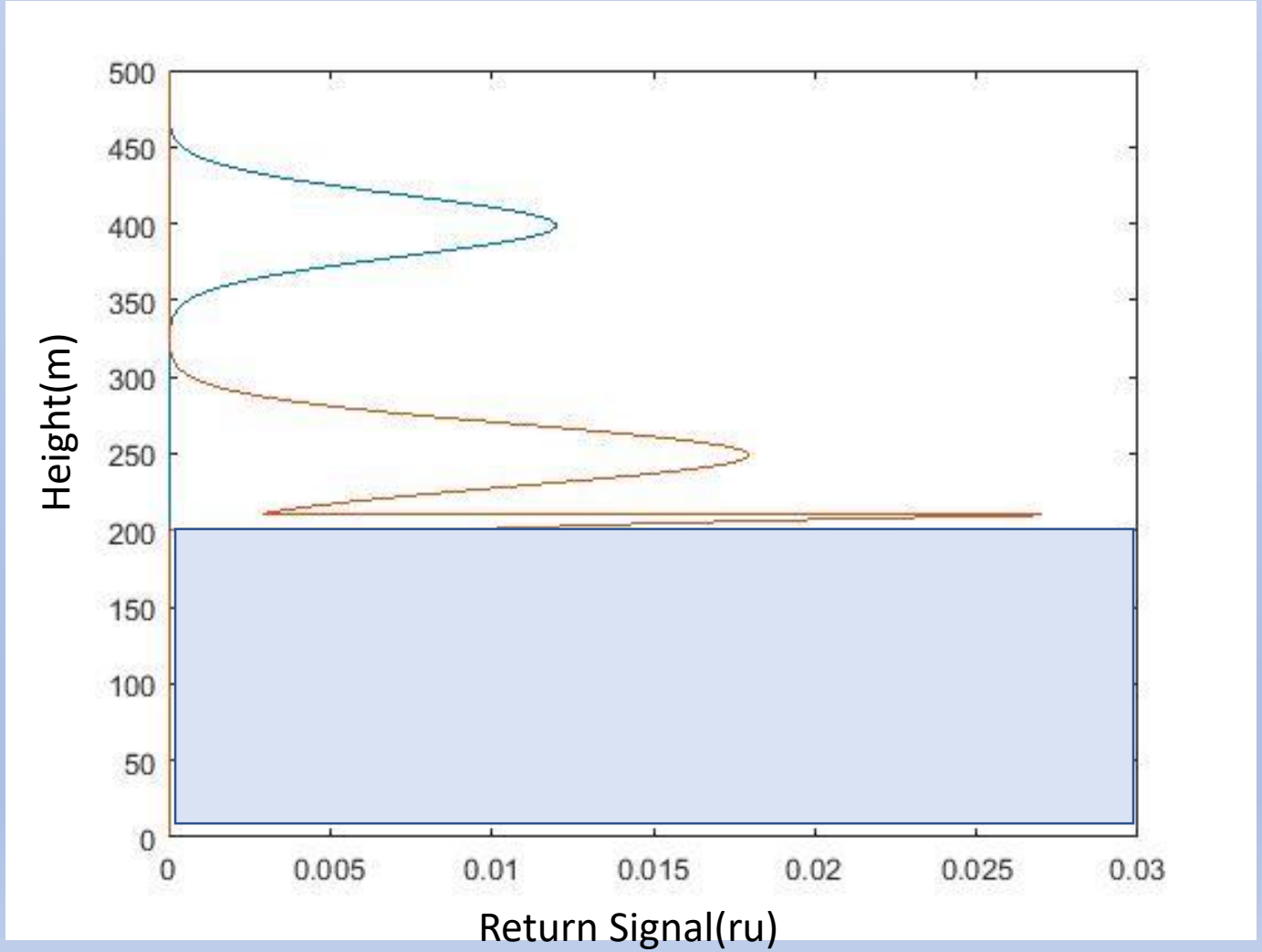
DWL pulse for 4 positions relative to ocean surface



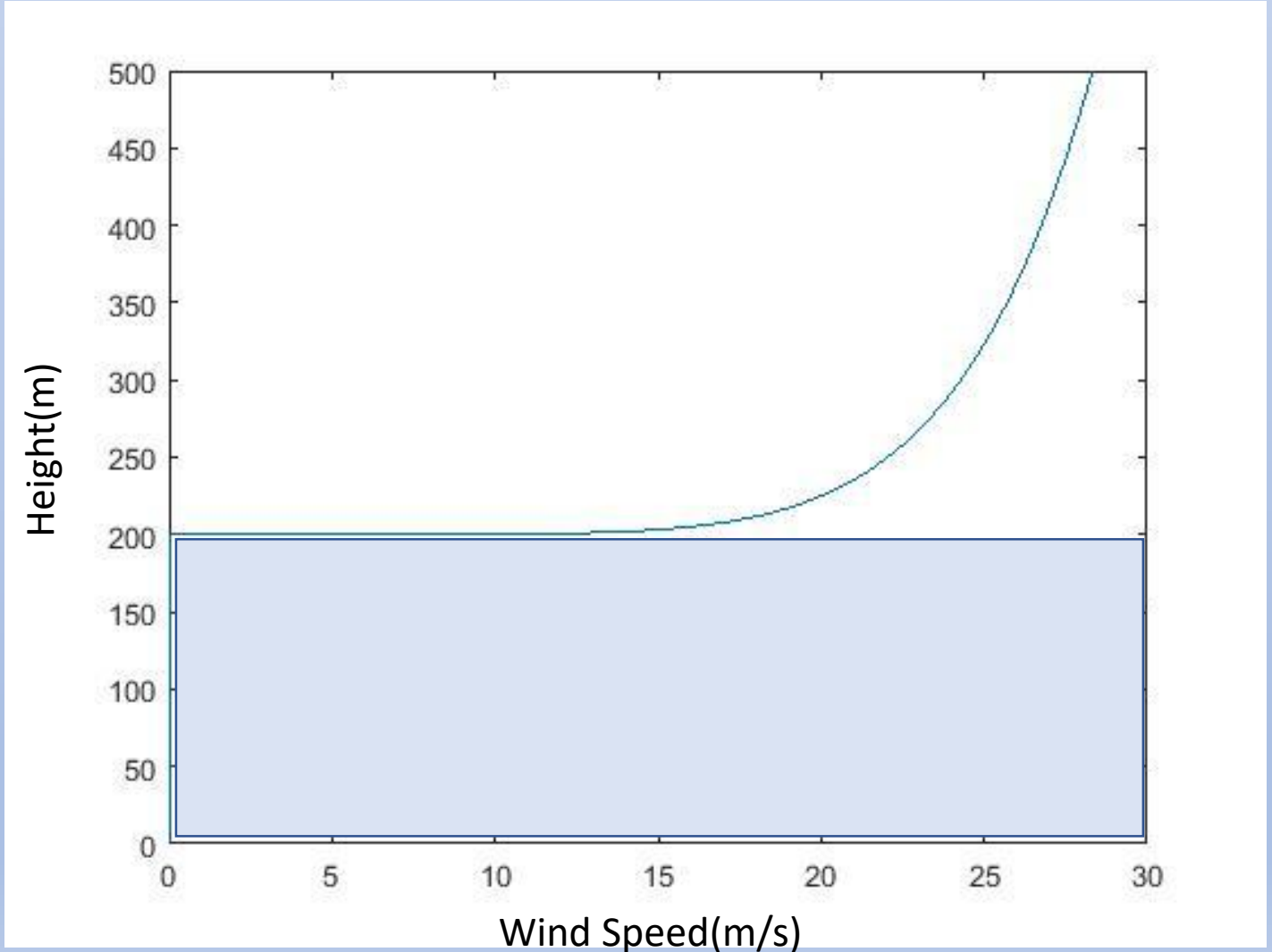
Backscatter: white caps with spray below 10m



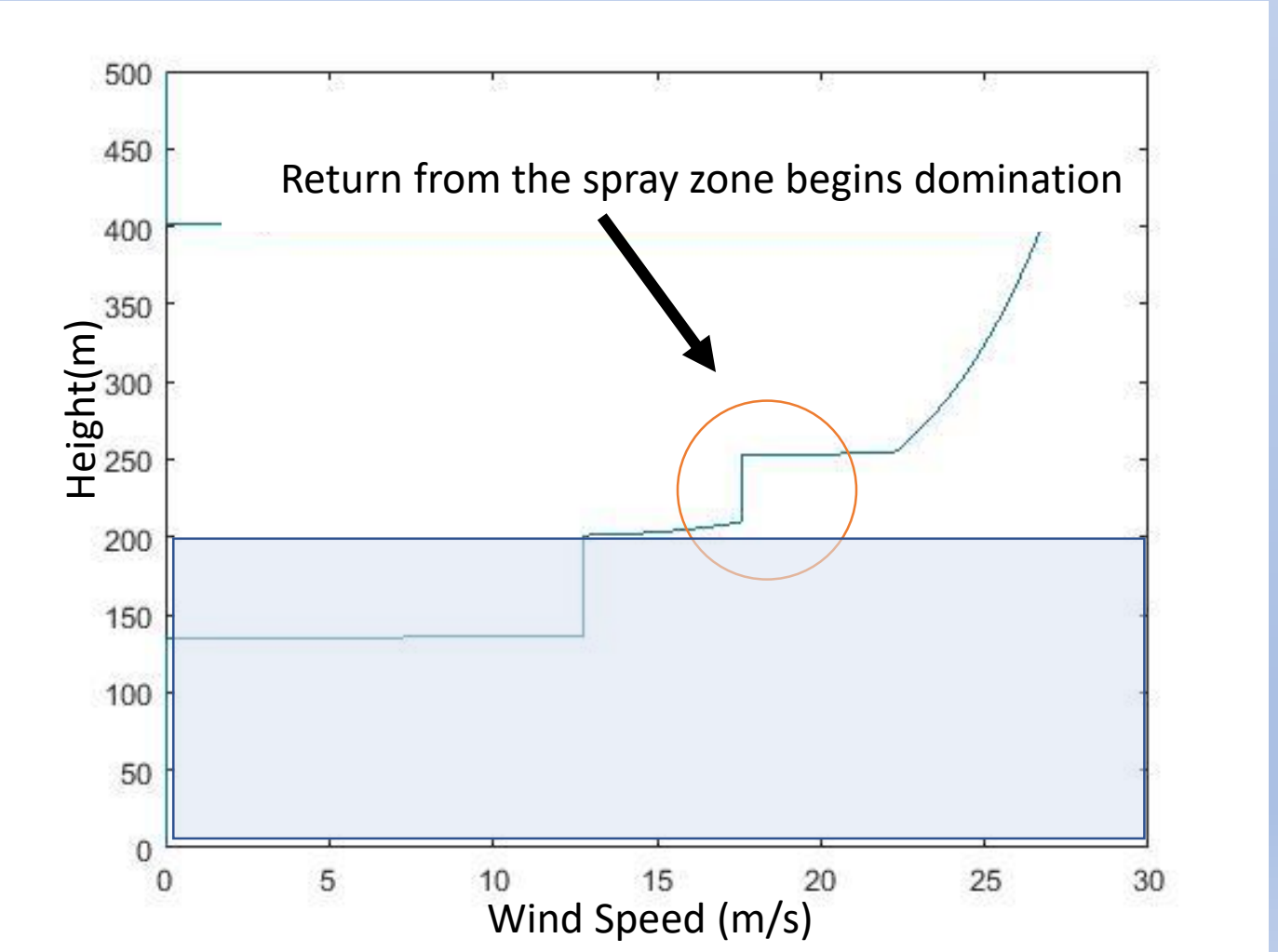
Return Signal within range gate



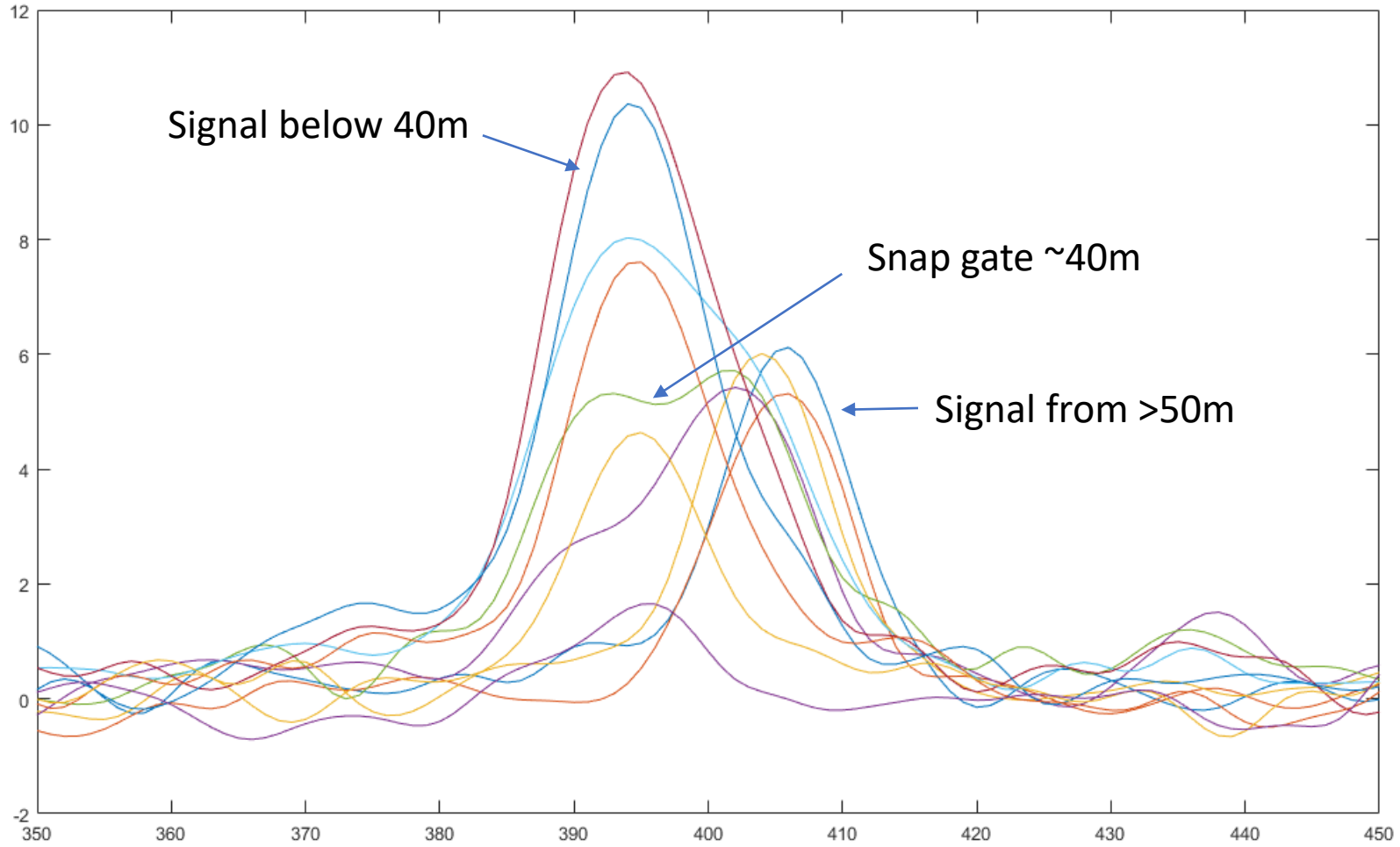
Wind profile using .14 coefficient in power law



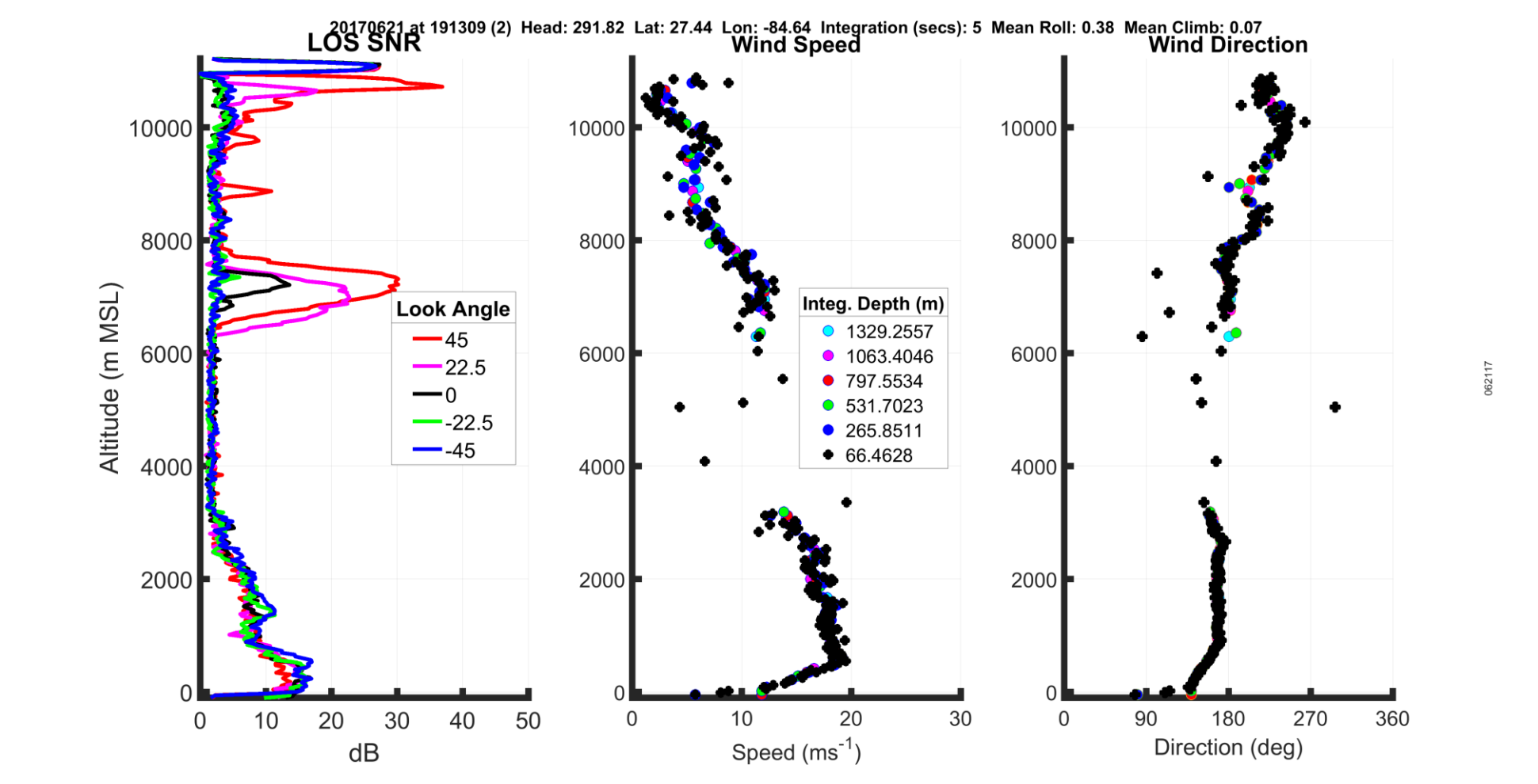
Wind speed per DWL in lowest 50m (Delta slide: 9 meters)



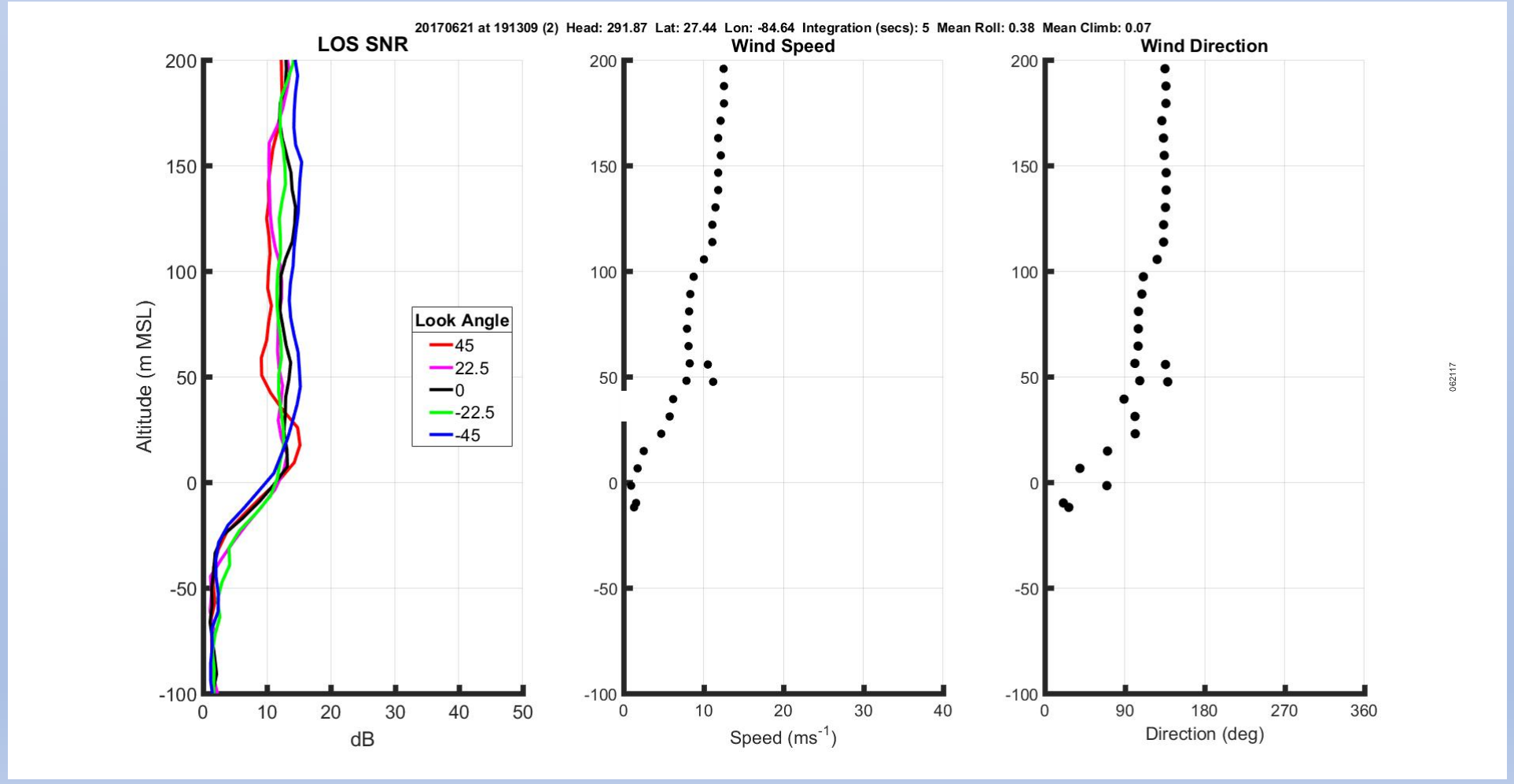
Sliding Spectra



Examples from DAWN during CPEX



Focus on lowest 200m using sliding gates



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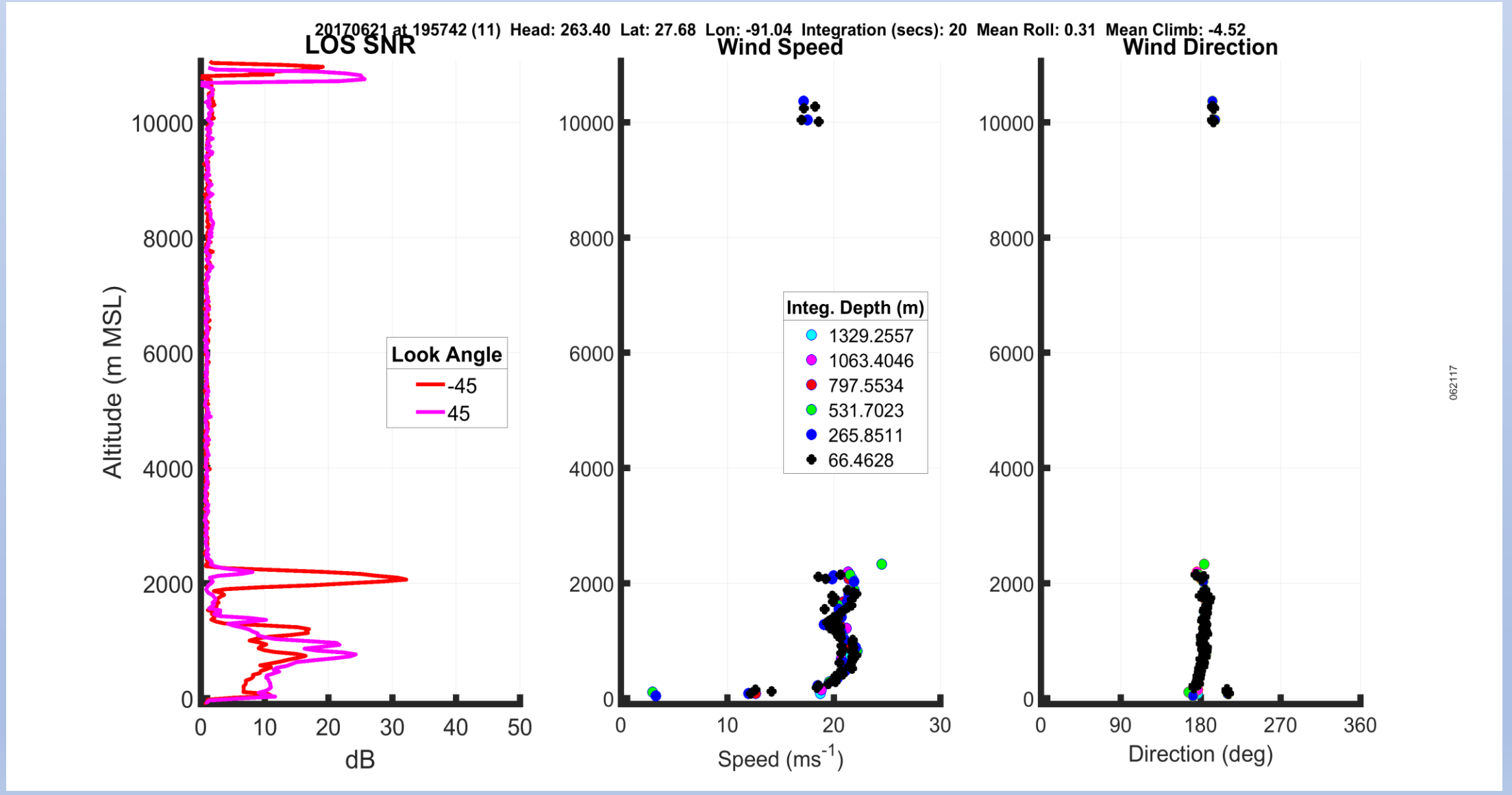
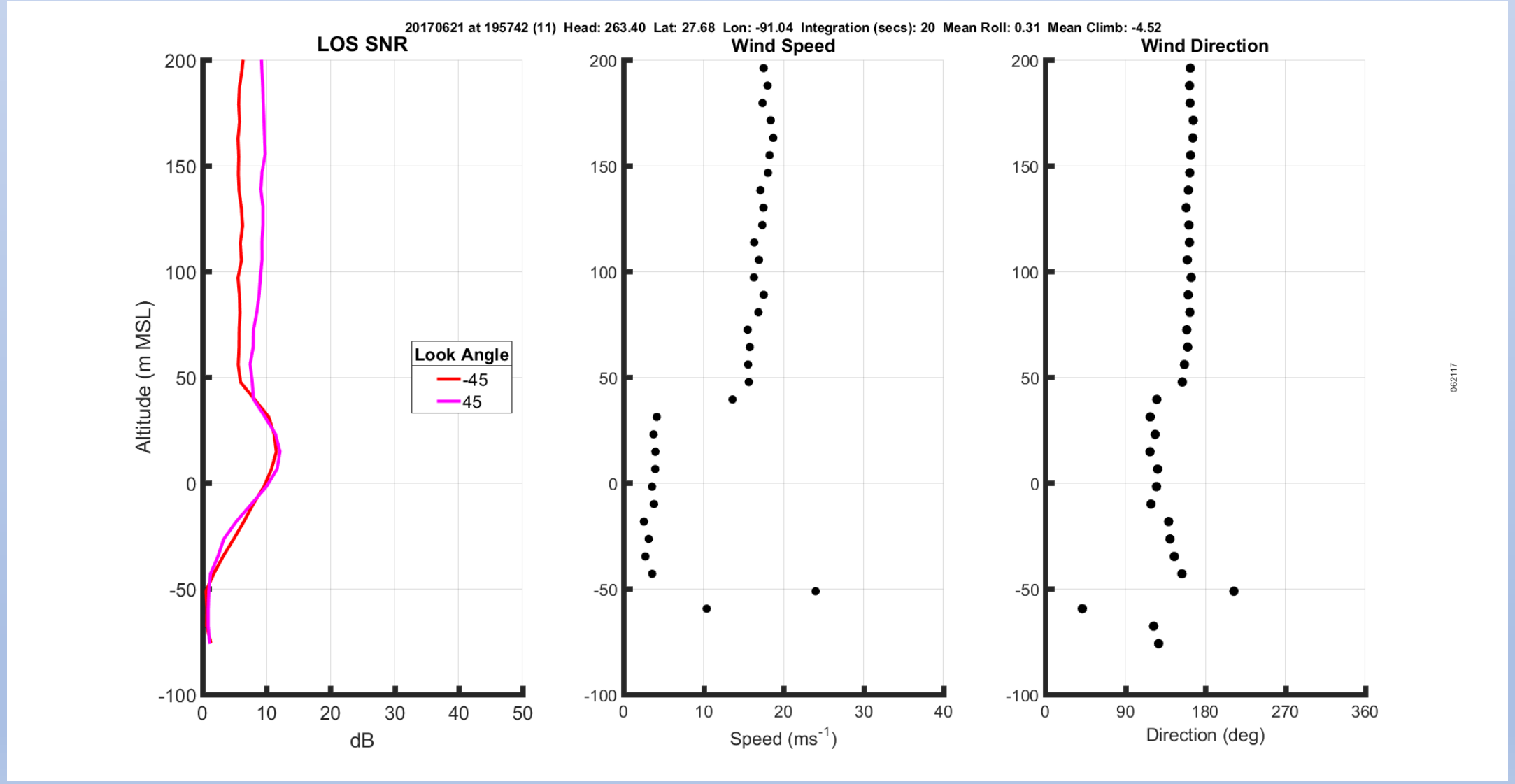
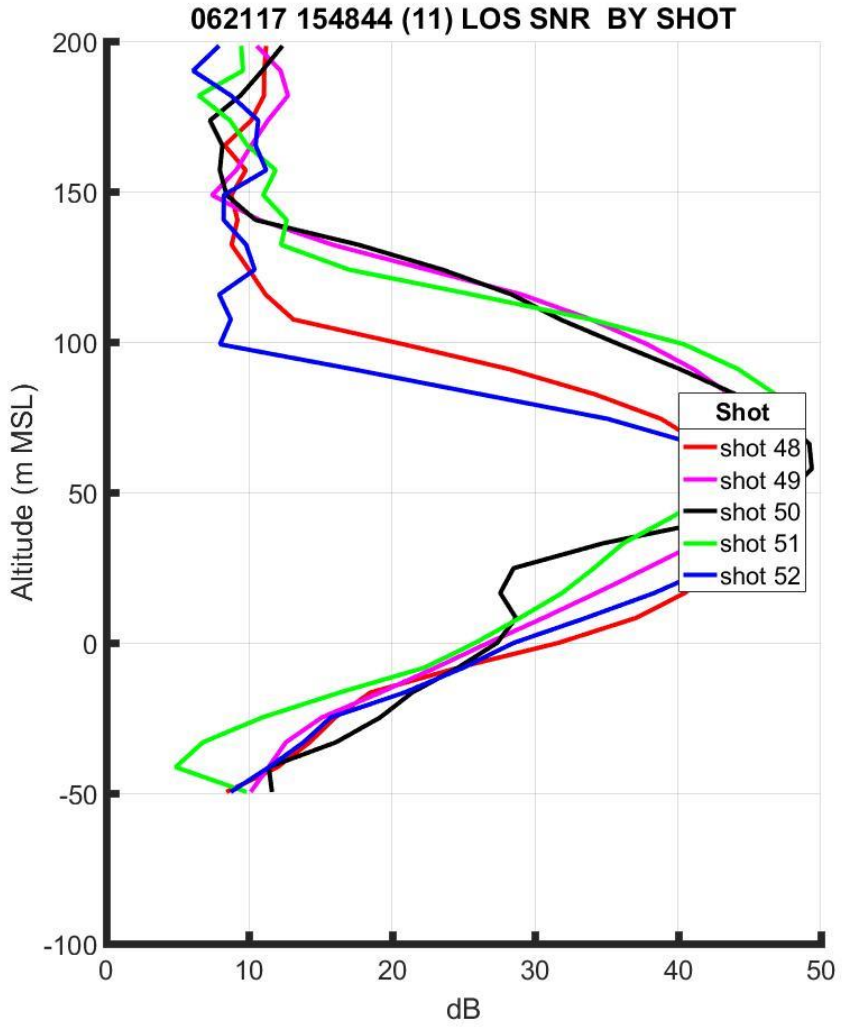
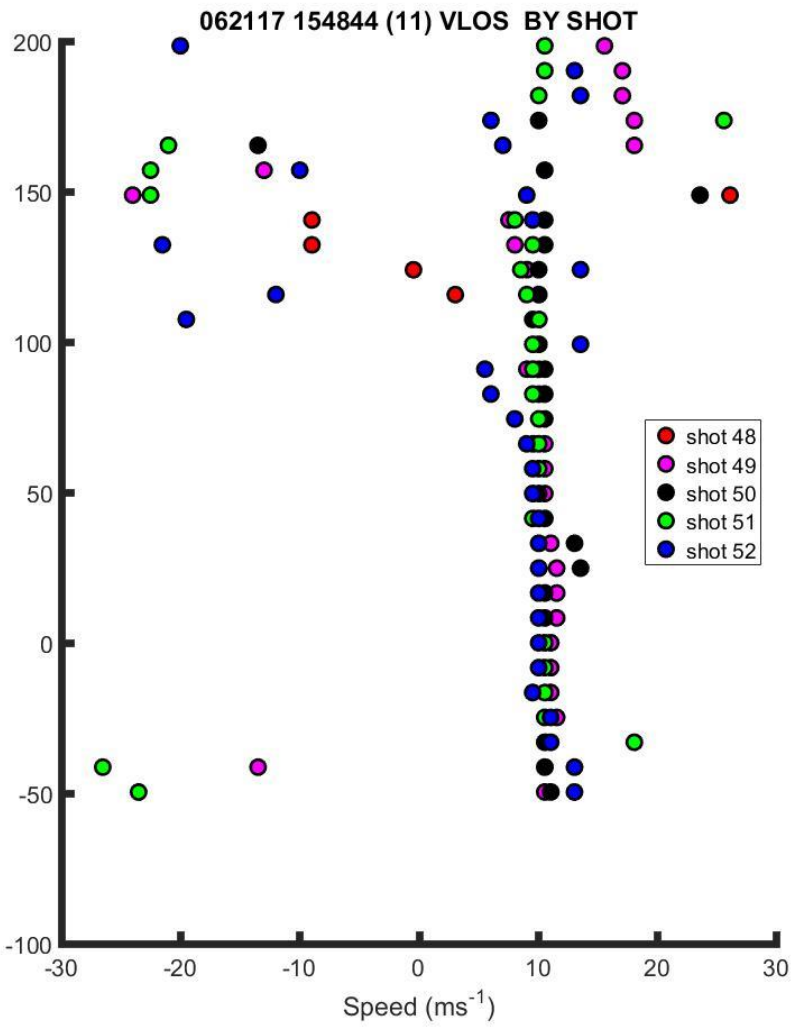

20170621 at 195742 (11) Head: 263.40 Lat: 27.68 Lon: -91.04 Integration (secs): 20 Mean Roll: 0.31 Mean Climb: -4.52
LOS SNR
Wind Speed
Wind Direction
Altitude (m MSL)
10000
8000
6000
4000
2000
0
Look Angle
-45
45
0
10
20
30
40
50
dB
Integ. Depth (m)
1329.2557
1063.4046
797.5534
531.7023
265.8511
66.4628
Speed (ms-1)
0
90
180
270
360
Direction (deg)
062117


20170621 at 195742 (11) Head: 263.40 Lat: 27.68 Lon: -91.04 Integration (secs): 20 Mean Roll: 0.31 Mean Climb: -4.52
LOS SNR
Wind Speed
Wind Direction
Altitude (m MSL)
Look Angle
-45
45
dB
Speed (ms-1)
Direction (deg)
062117


062117 154844 (11) LOS SNR BY SHOT
Altitude (m MSL)
dB
Shot
shot 48
shot 49
shot 50
shot 51
shot 52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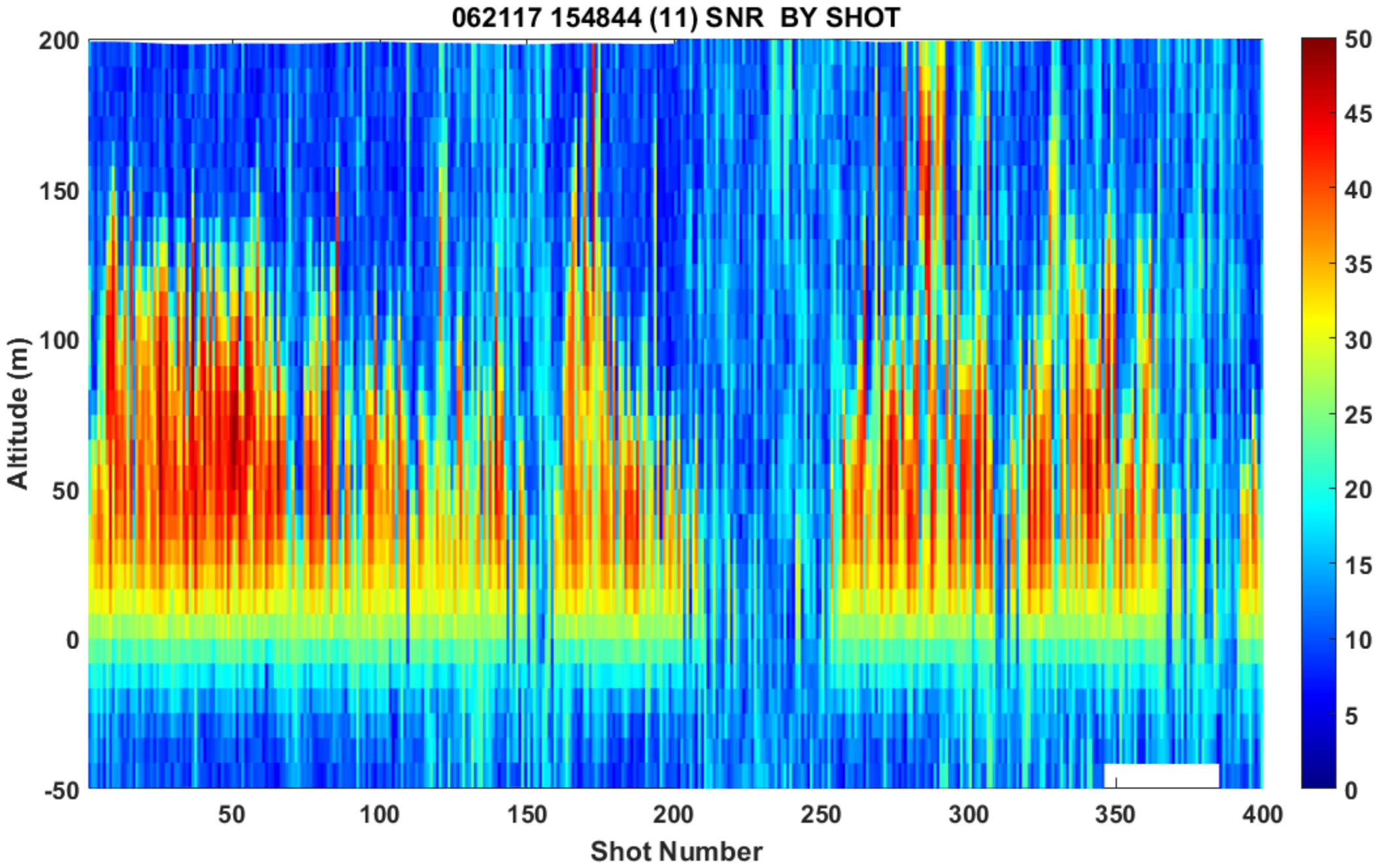
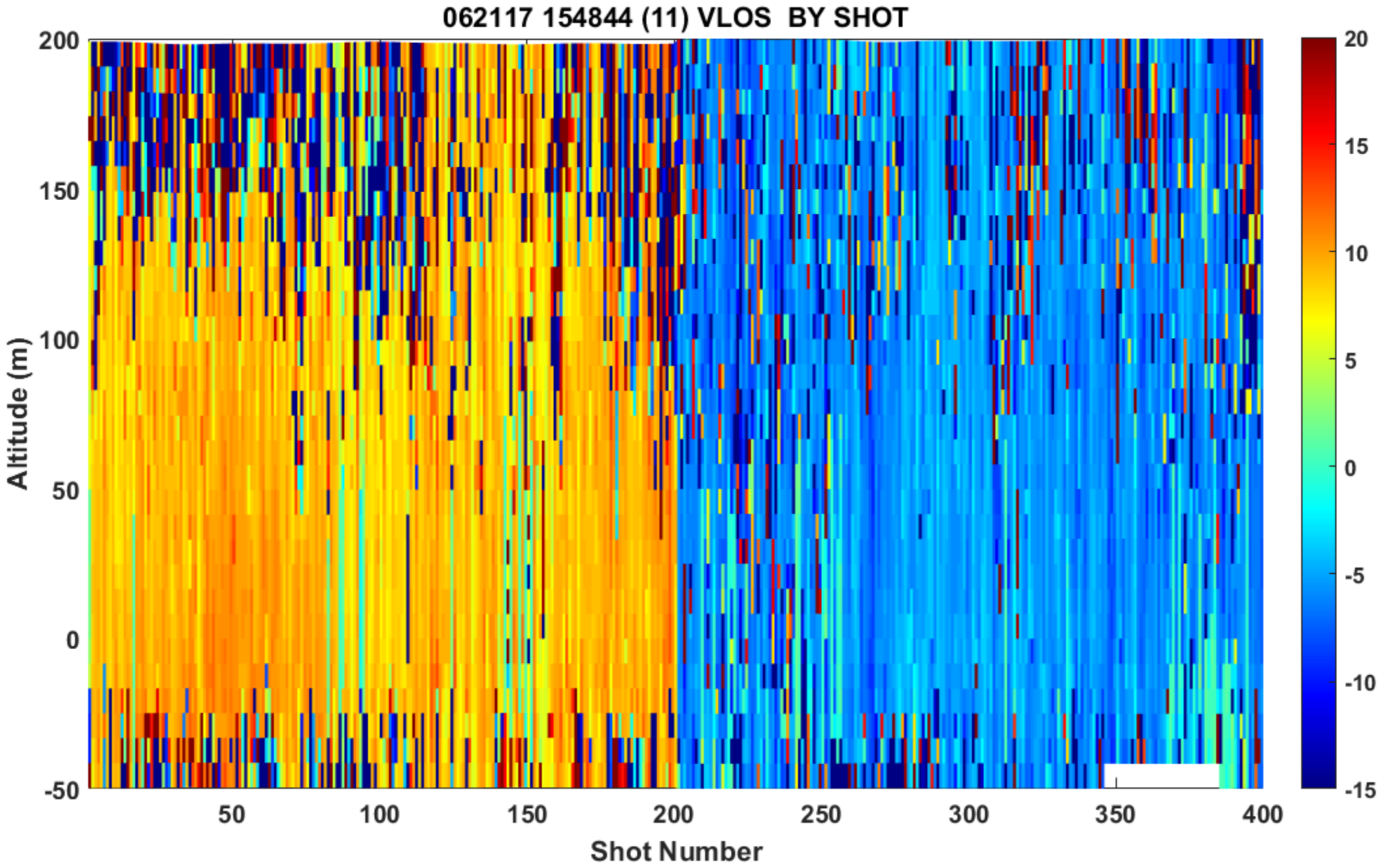
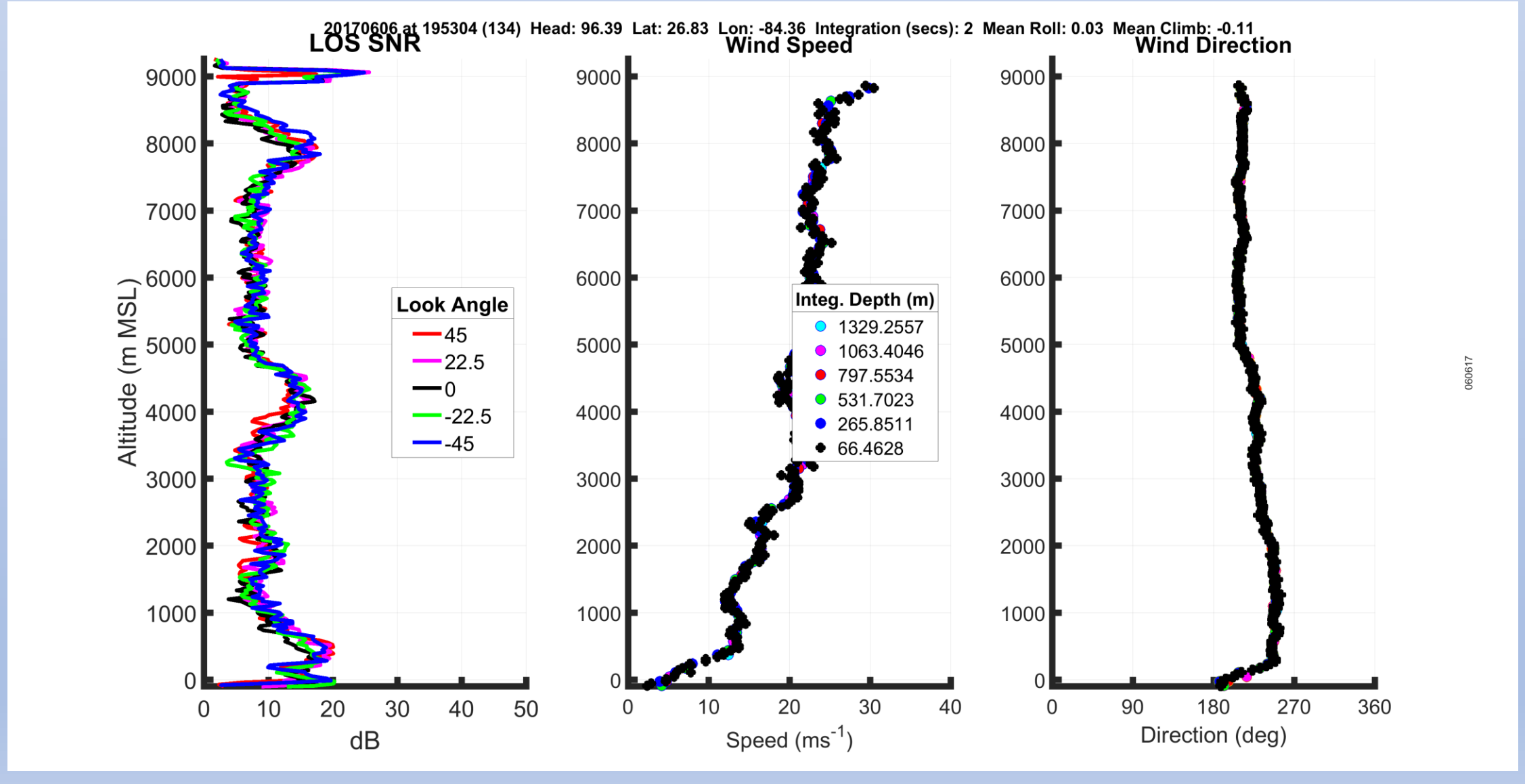
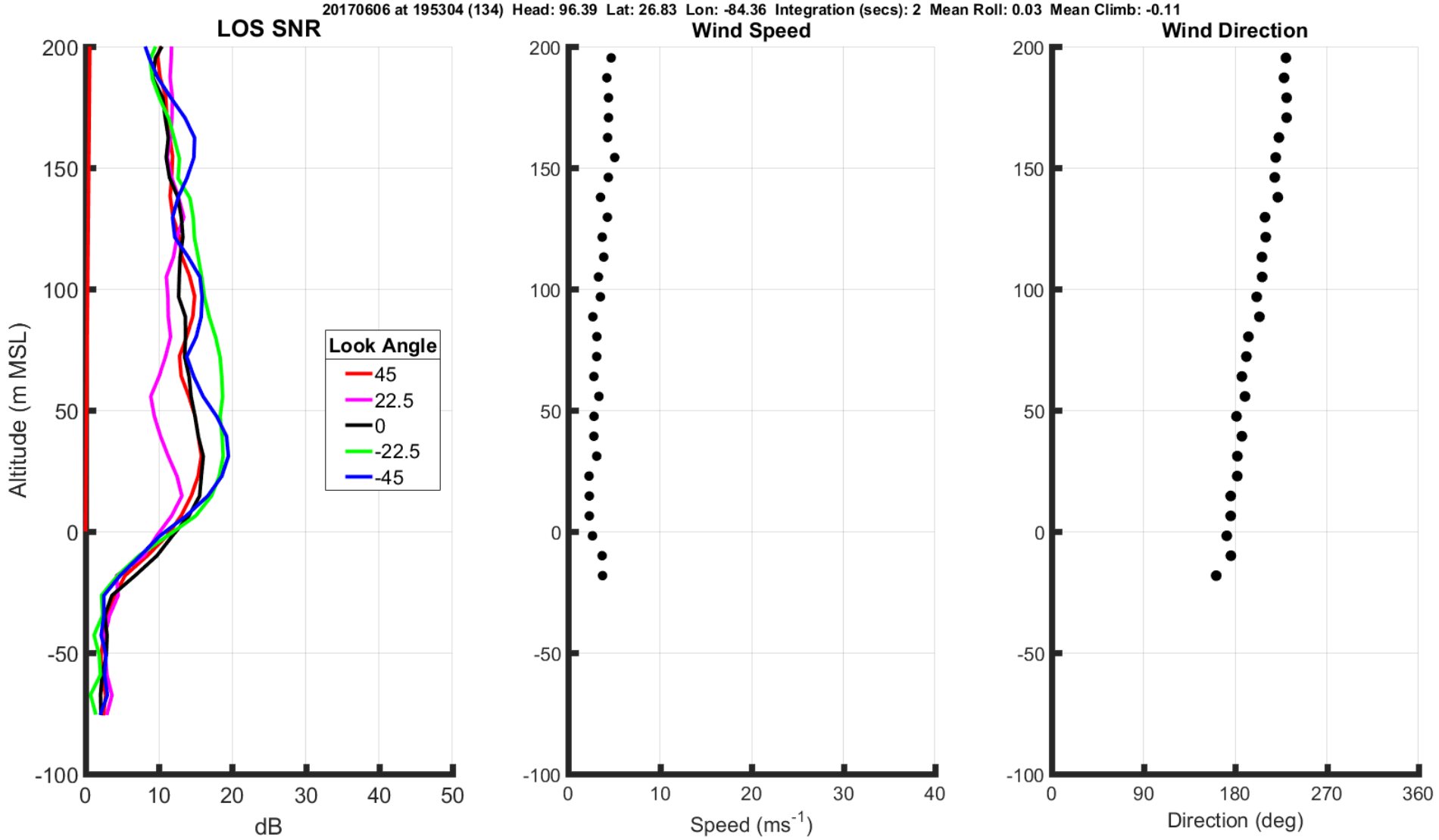
Speed (ms-1)
shot 48
shot 49
shot 50
shot 51
shot 52

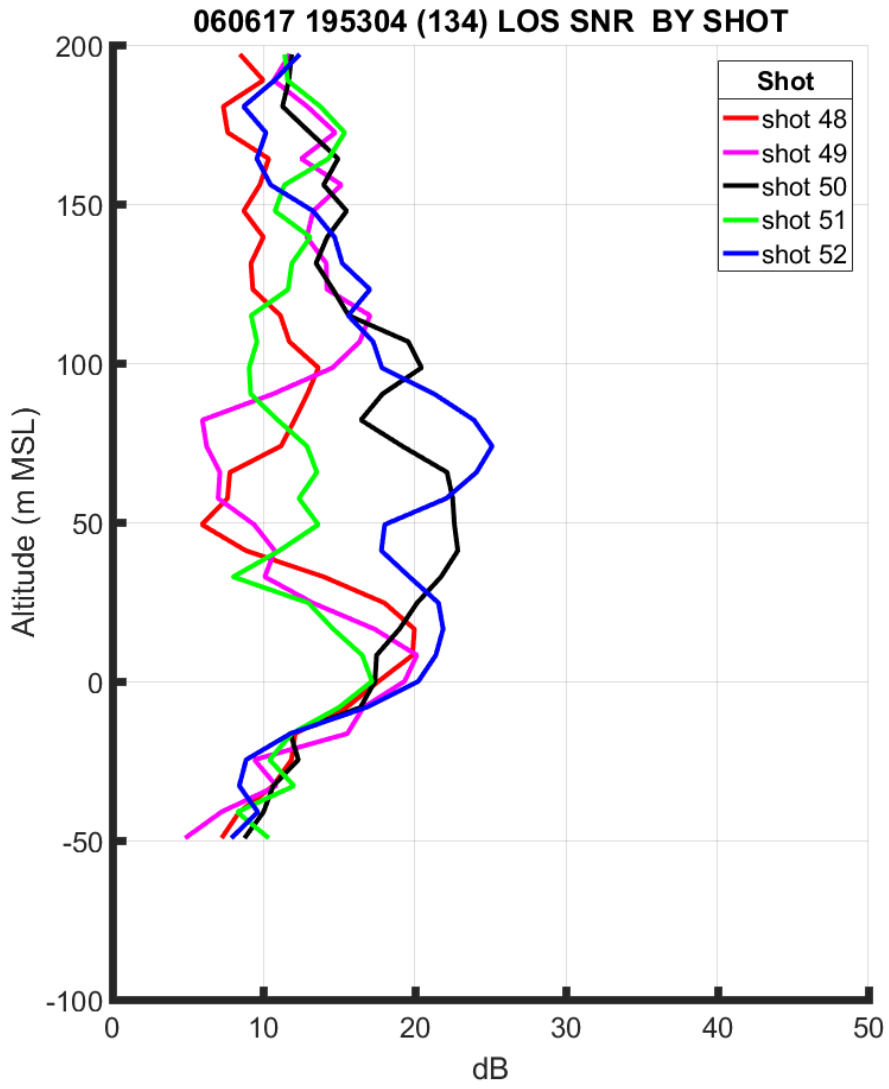

062117 154844 (11) SNR BY SHOT
Altitude (m)
200
150
100
50
0
-50
50
100
150
200
250
300
350
400
Shot Number
50
45
40
35
30
25
20
15
10
5
0

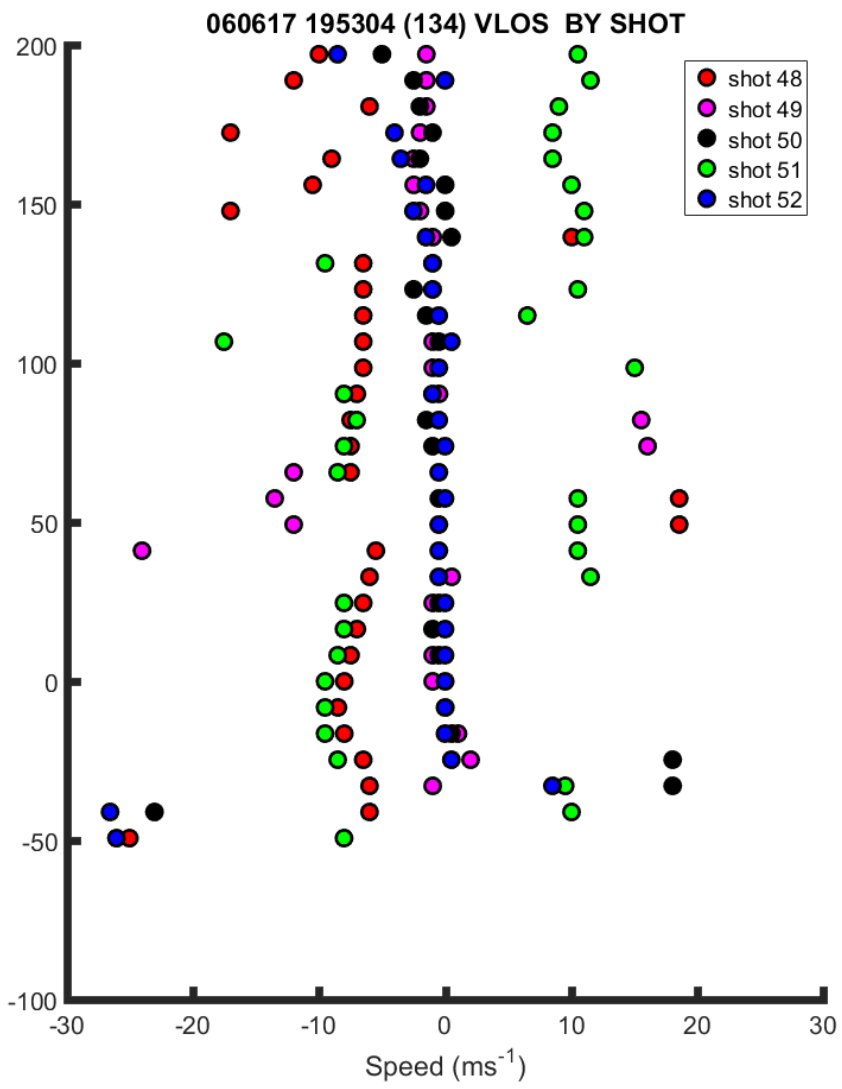

062117 154844 (11) VLOS BY SHOT
Altitude (m)
200
150
100
50
0
-50
50
100
150
200
250
300
350
400
Shot Number
20
15
10
5
0
-5
-10
-15

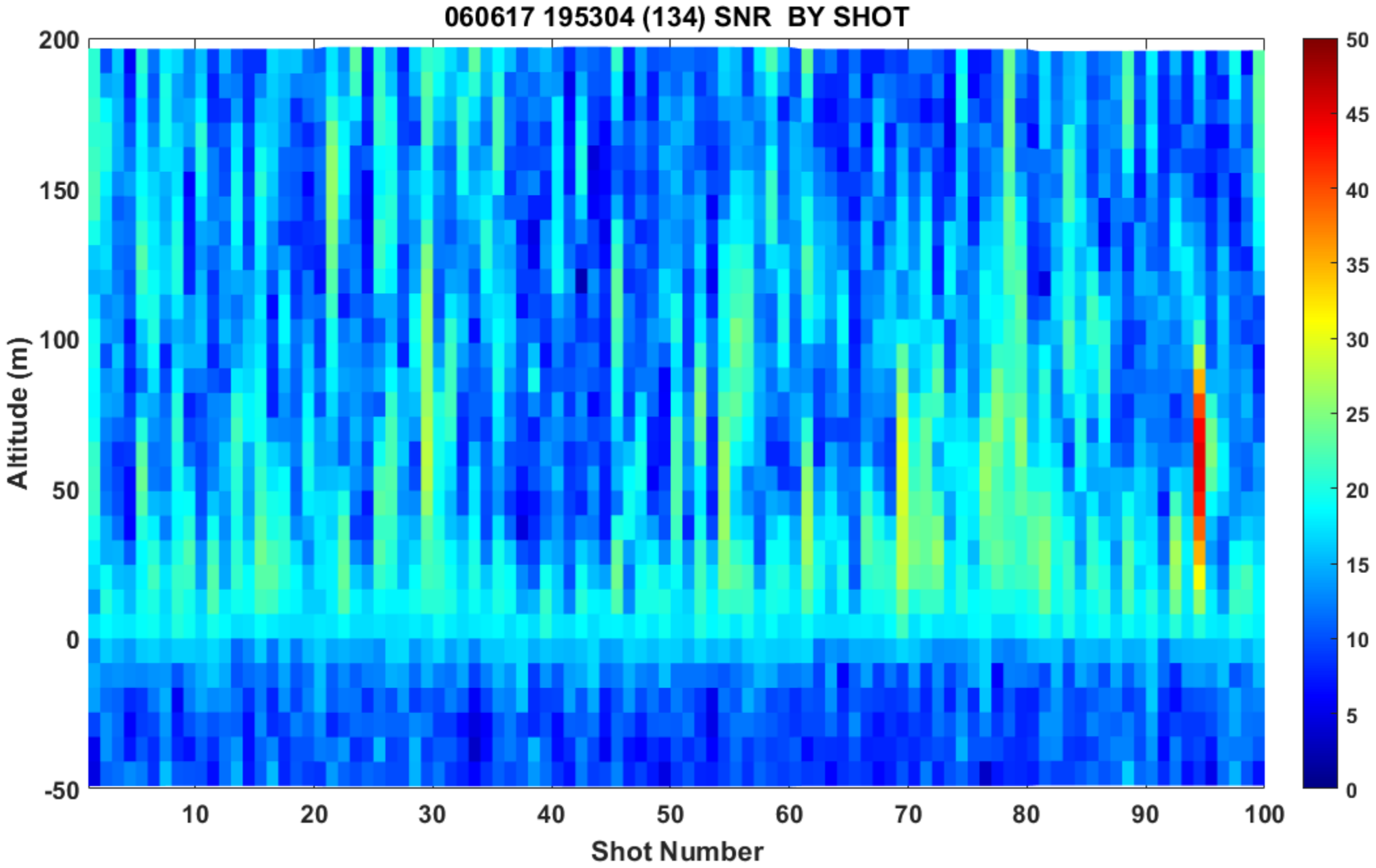
060617-2

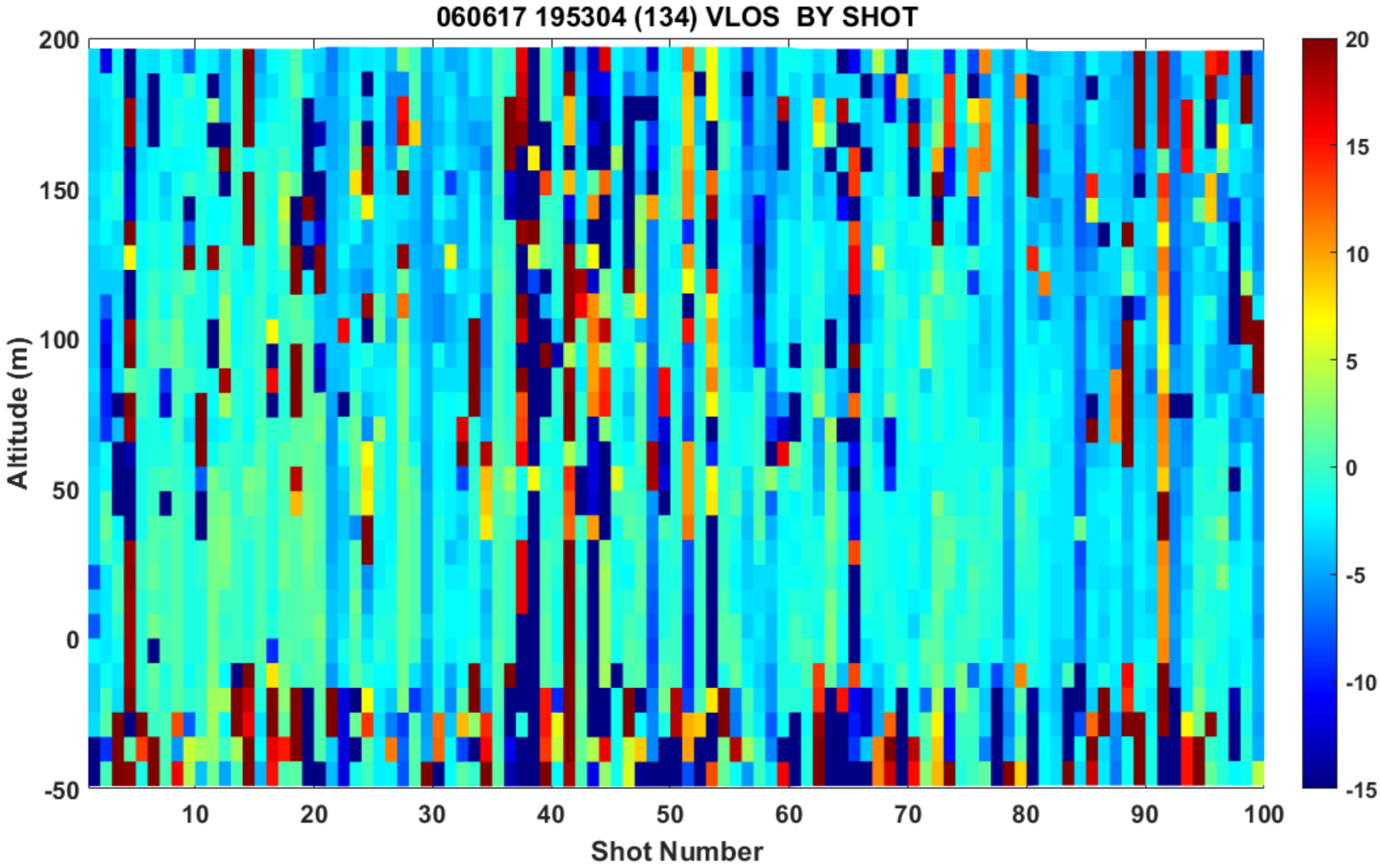

20170606 at 195304 (134) Head: 96.39 Lat: 26.83 Lon: -84.36 Integration (secs): 2 Mean Roll: 0.03 Mean Climb: -0.11
LOS SNR
Wind Speed
Wind Direction
Altitude (m MSL)
dB
Speed (ms-1)
Direction (deg)
Look Angle
45
22.5
0
-22.5
-45
Integ. Depth (m)
1329.2557
1063.4046
797.5534
531.7023
265.8511
66.4628
060617


20170606 at 195304 (134) Head: 96.39 Lat: 26.83 Lon: -84.36 Integration (secs): 2 Mean Roll: 0.03 Mean Climb: -0.11
LOS SNR
Wind Speed
Wind Direction
Altitude (m MSL)
dB
Speed (ms-1)
Direction (deg)
Look Angle
45
22.5
0
-22.5
-45
060617


060617 195304 (134) LOS SNR BY SHOT
Shot
shot 48
shot 49
shot 50
shot 51
shot 52
Altitude (m MSL)
dB
200
150
100
50
0
-50
-100
0
10
20
30
40
50


060617 195304 (134) VLOS BY SHOT
shot 48
shot 49
shot 50
shot 51
shot 52
Speed (ms-1)
200
150
100
50
0
-50
-100
-30
-20
-10
0
10
20
30

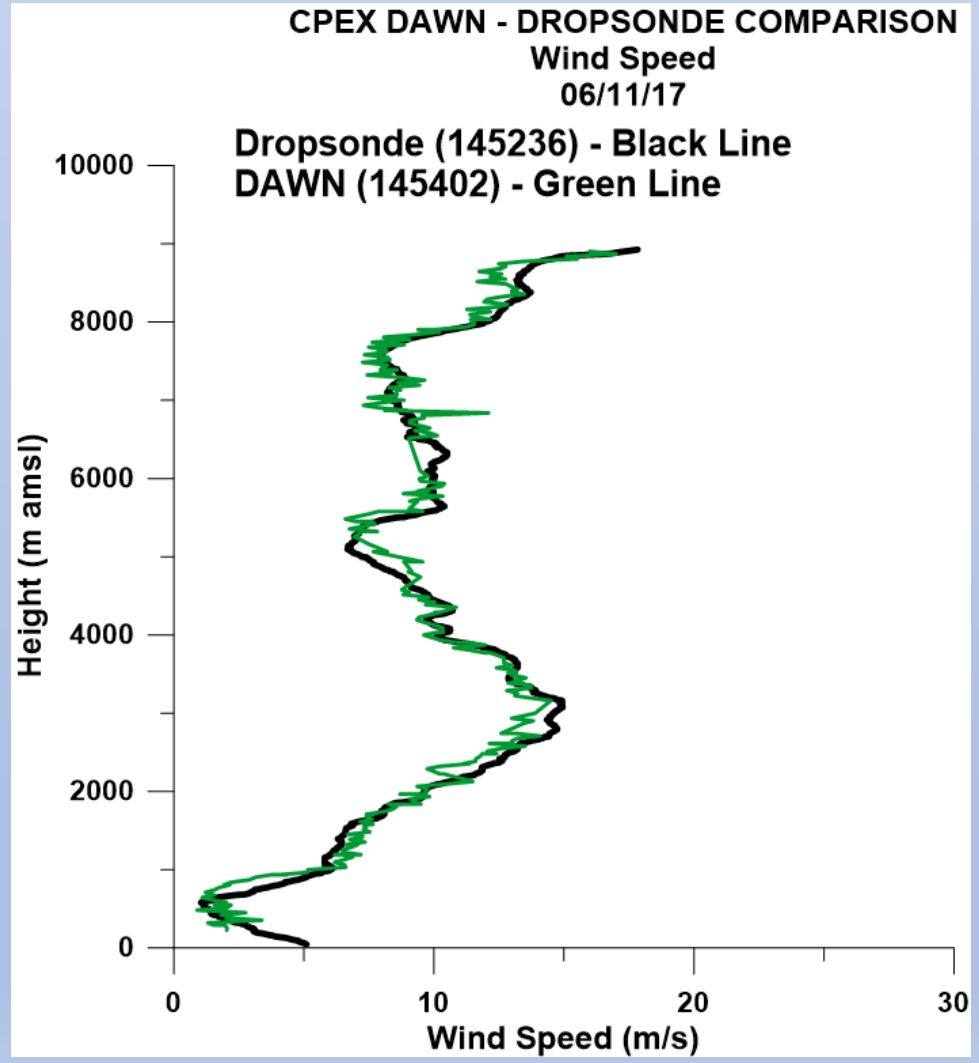

060617 195304 (134) SNR BY SHOT
Altitude (m)
200
150
100
50
0
-50
10
20
30
40
50
60
70
80
90
100
Shot Number
50
45
40
35
30
25
20
15
10
5
0

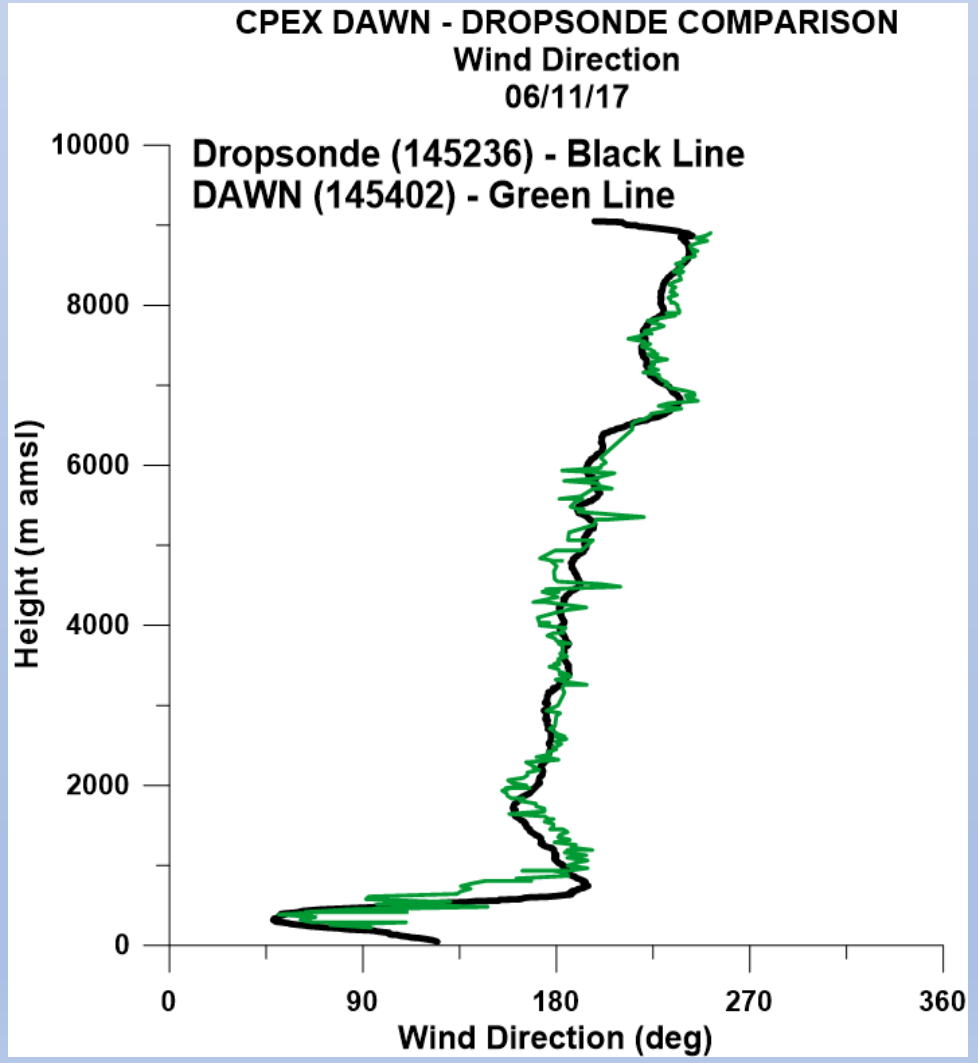

060617 195304 (134) VLOS BY SHOT
Altitude (m)
200
150
100
50
0
-50
10
20
30
40
50
60
70
80
90
100
Shot Number
20
15
10
5
0
-5
-10
-15

Summary

- Using a new CDWL processing algorithm, we can obtain “useful” DAWN retrievals within a few meters of the ocean surface using sliding variable and adaptable gates on the raw digitized return. **However**:
  - Below 50 meters above the water surface the retrievals are heavily dependent upon the backscatter structures, gradients and floating foam.
  - At low wind speeds the near surface (< 10m) values are reported at heights below the surface (can be adjusted after the processing)
  - At high winds speeds with whitecaps and water/salt sprays, the speed of the spray is reported starting at gate altitudes between 50 and 150m.
- Single shot processing of the DAWN data (DC-8 flying at 10-12km) within the lowest 200 meters reveals aerosol and wind structures consistent with rolls and highly variable (in space) sea salt spray features.

Example DAWN-Dropsonde comparison during CPEX 2017





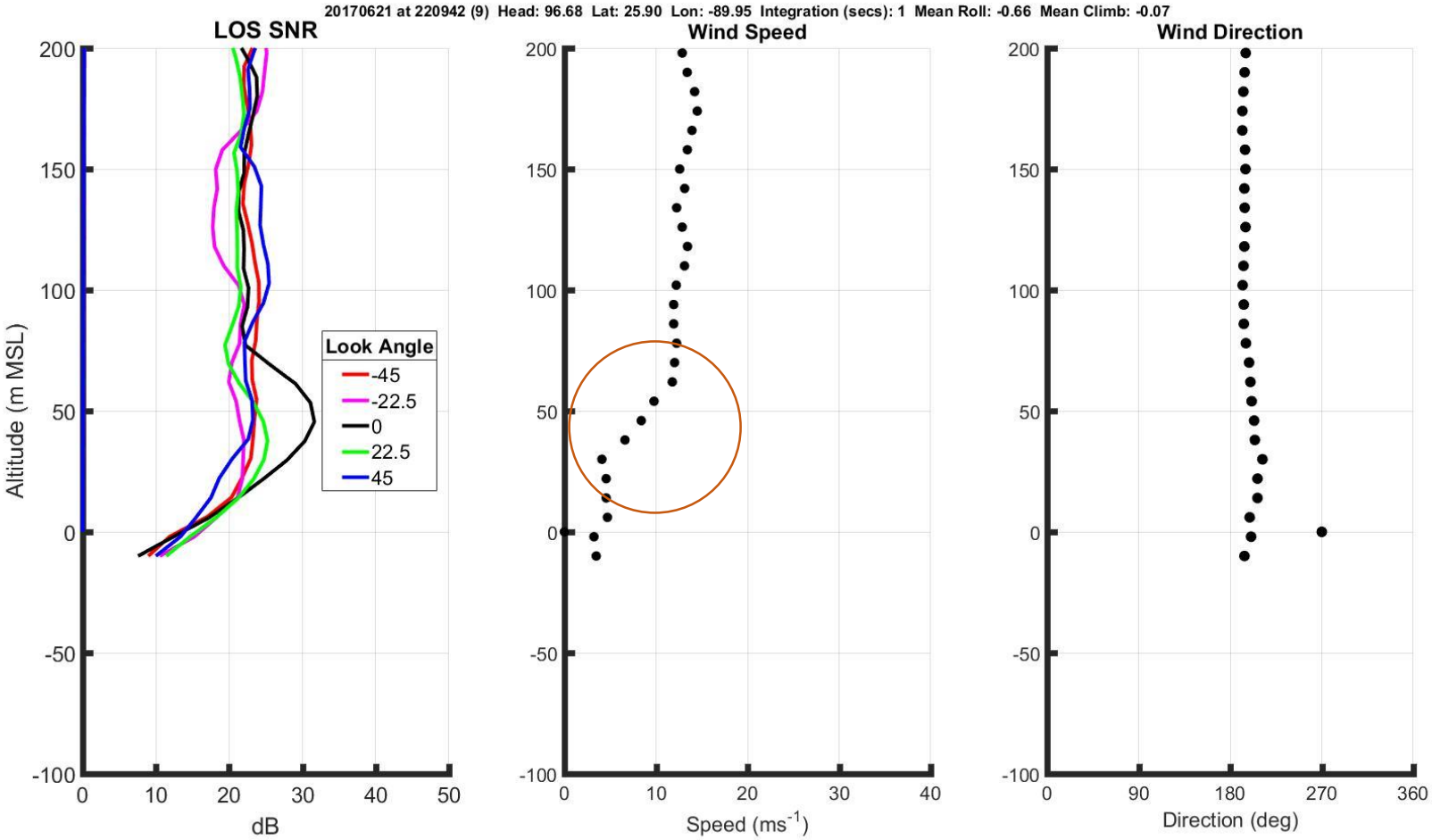
Evaluation of HDSS wind data below 50m in MBL

- On-going at both YES and SWA with funding from NASA and ONR.
- The nominal fall speed of the HDSS in the last second before “splash down” is ~18m/s.
- The sonde broadcasts a data packet once per second that contains 2 and 4 Hz information.
- The computed geopotential height is trusted over the GPS report height near the ocean surface.
- Recent questions raised by the OVWs and NWP communities have initiated an investigation into the last second of data transmission
- Current finding: the height assignments for GPS winds is off by 1.53 seconds or ~28 meters. Thus the U10 winds are biased high…still looking for truth for comparisons.

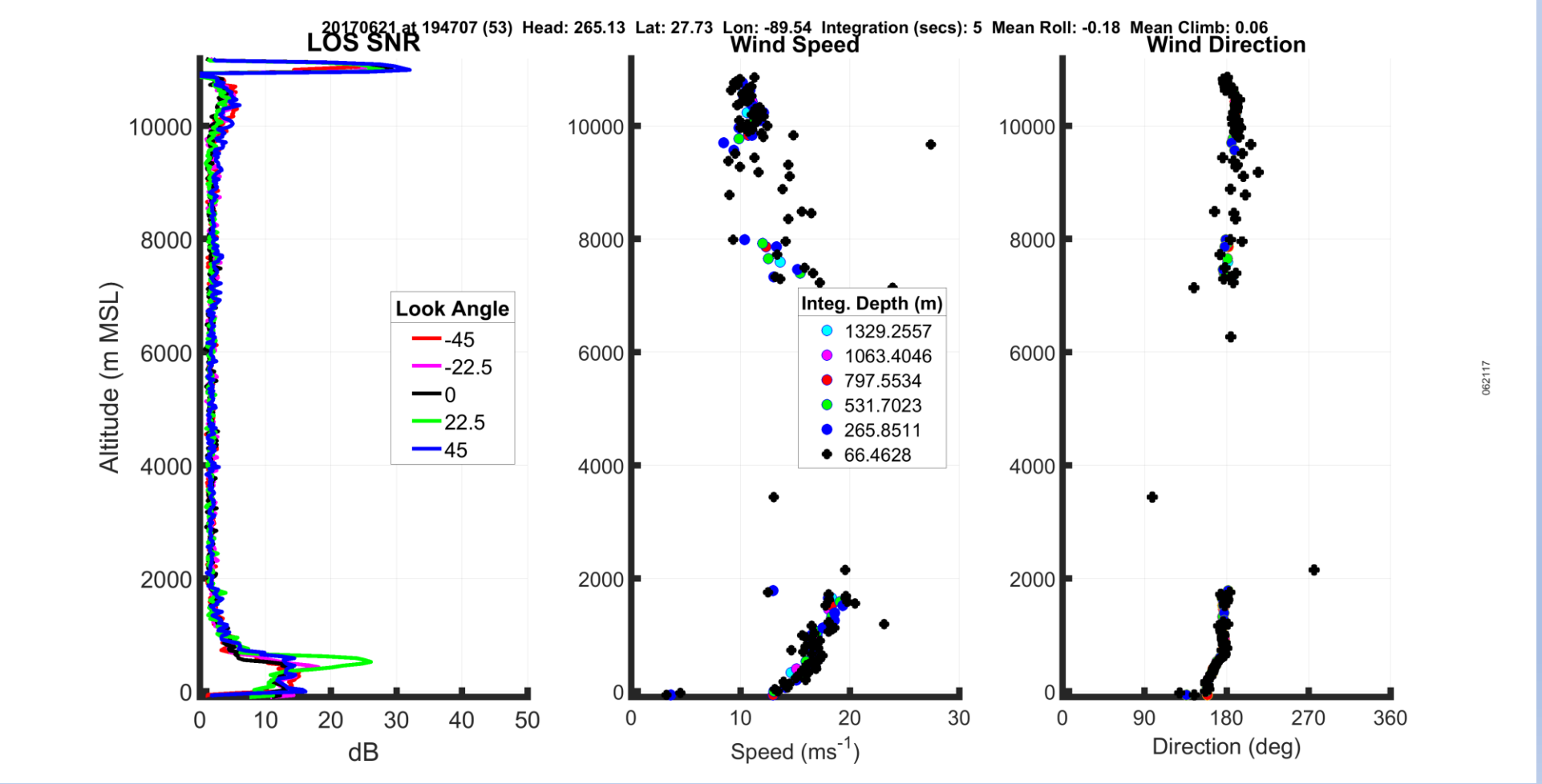
DAWN-Dropsonde comparisons from CPEX 2017
Wind Speed (m/s)

	Number 37m seg	MEAN Z DIFF (m)	BIAS (m/s)	MEAN ABS (ΔWS)	ΔWS RMSD
ALL	15517	3.08	0.09	1.13	1.55
2 LOOK	6921	3.26	0.05	1.28	1.72
5 LOOK	8596	2.93	0.13	1.01	1.39

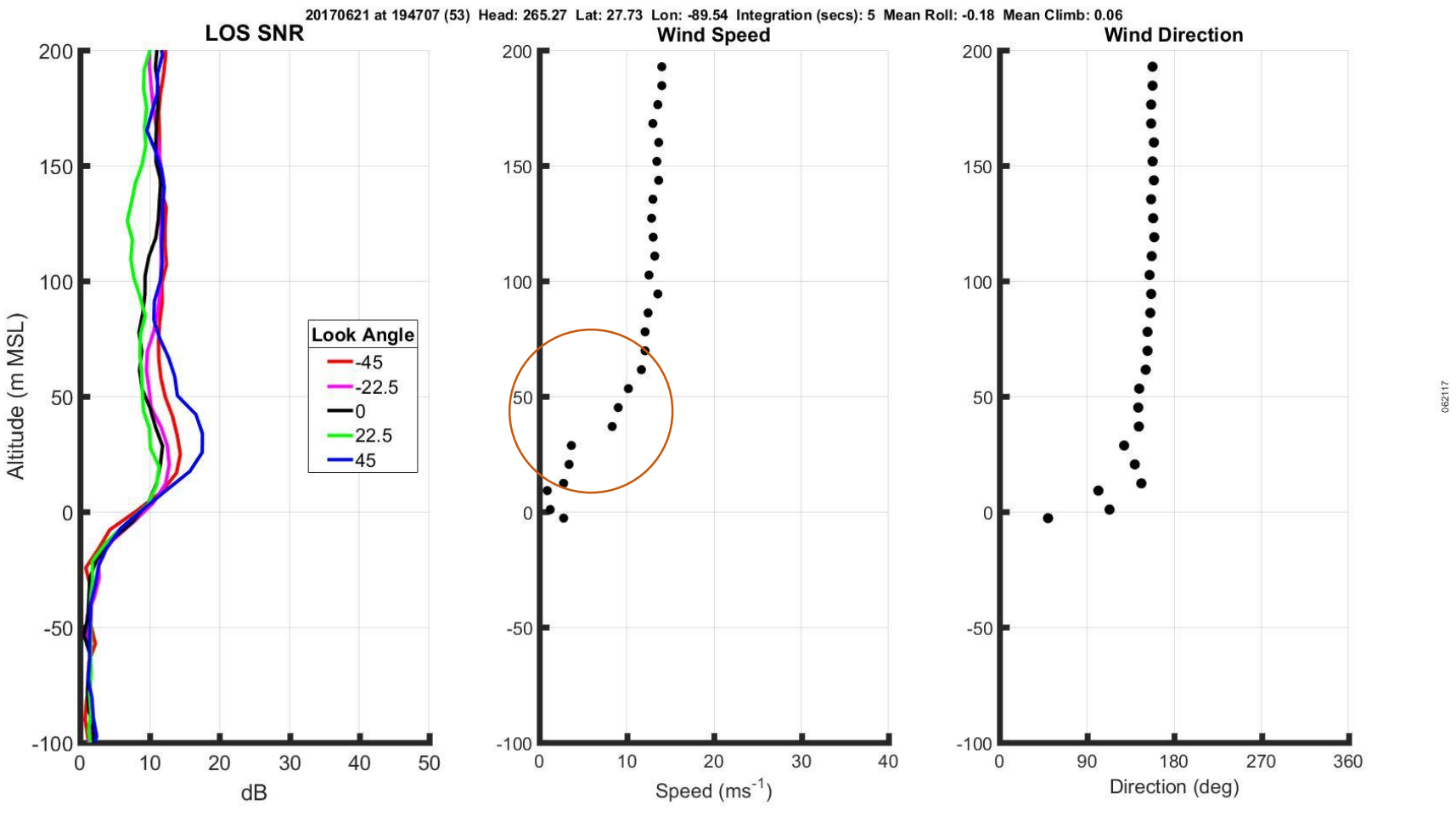
Another high wind case



Example 2


20170621 at 194707 (53) Head: 265.13 Lat: 27.73 Lon: -89.54 Integration (secs): 5 Mean Roll: -0.18 Mean Climb: 0.06
LOS SNR
Wind Speed
Wind Direction
Altitude (m MSL)
dB
Speed (ms-1)
Direction (deg)
Look Angle
-45
-22.5
0
22.5
45
Integ. Depth (m)
1329.2557
1063.4046
797.5534
531.7023
265.8511
66.4628
062117

Lowest 200m under white cap conditions



High wind conditions