Shear statistics in the lower troposphere and impacts on DWL data interpretation

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WG on Space-Based Lidar Winds
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Wind Shear

- Wind Shear is defined in NOAA Technical Memorandum NWS FCST-23 as “a change in horizontal wind speed and/or direction, and/or vertical speed with distance, measured in a horizontal and/or vertical direction”

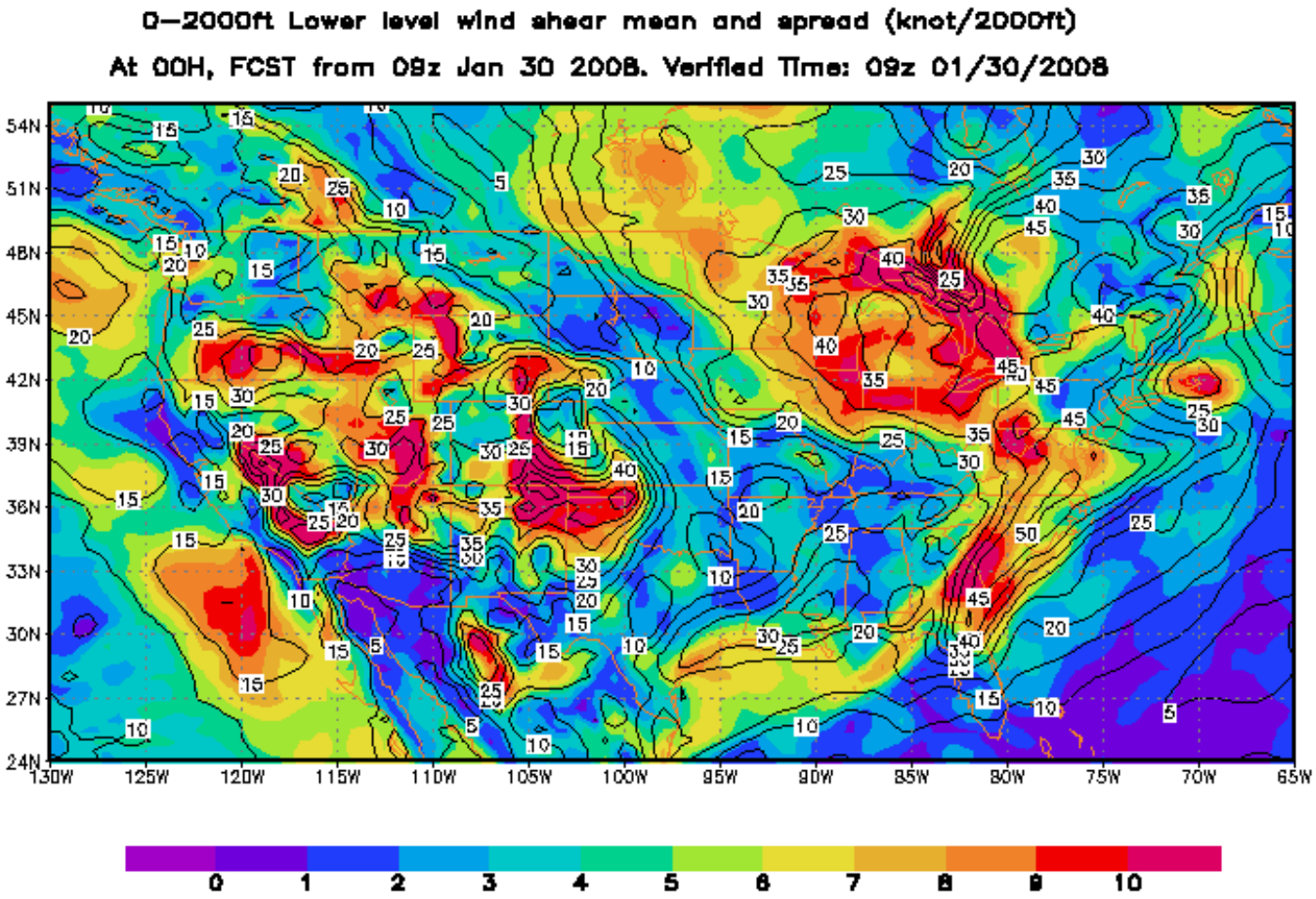
- As defined by the National Weather Service, Low-Level Wind Shear is wind shear of 5 m/s or more per 30m (.169s-1) in a layer more than 60m thick within the lowest 600m of the atmosphere

Wind Shear

- Vertical wind shear is not a scalar quantity, but a vector. Using just “speed shear” will often underestimate the amount of shear present. Direction of the horizontal winds must be considered as well

- On benign days, wind shear values are typically < 0.08 s-1. Wind shear meeting official criteria is 0.169 s-1

NCEP SREF Aviation Products (Experimental)



Wind Shear Climatologies

- Very limited and usually averaged (hourly, monthly, seasonally, annually)
- Deep layer (850 -200mb) shear for tropics
- Mostly based on tower level data (0 -150m)
  - Central Plains network
  - $\alpha = \ln(v2/v1)/\ln(H2/H1)$

Wind Shear Climatologies

From “Wind Resource and Wind Shear Characteristics at Elevated Heights” by Dennis Elliot (NREL/NWTC) (June 2006) for 150m towers in the Central US.

- Annual average shear between 0.15 and 0.25 (alpha)
- Greater variation of annual wind shear between towers within a region than between the southern and northern Plains and Midwest
- Diurnal shear pattern similar throughout region
  - Daytime shear is 0.05- 0.1
  - Nighttime shear between 0.25 - 0.40
  - Some seasonal variations among towers

NASA Wind Shear Study

NASA Technical Memorandum 82566 - Wind Speed and Direction Shears With Associated Vertical Motion During Strong Surface Winds (1984)

NASA 150-Meter Tower Facility at Kennedy Space Center

1) Below 90m is the most active area for occurrence of events with wind speed shear >0.1 s-1 and directional shear >1.0 deg-1

NASA Wind Shear Study

Height (m)	Maximum s-1	Mean s-1	Std. Dev s-1
150 – 120	0.047 – 0.160	0.016 – 0.106	0.012 – 0.032
120 – 90	0.040 – 0.173	0.013 – 0.086	0.010 – 0.047
90 – 60	0.043 – 0.327	0.014 – 0.217	0.010 – 0.047
60 – 30	0.043 – 0.387	0.017 – 0.201	0.011 – 0.093
30 – 18	0.125 – 0.792	0.060 – 0.357	0.028 – 0.245

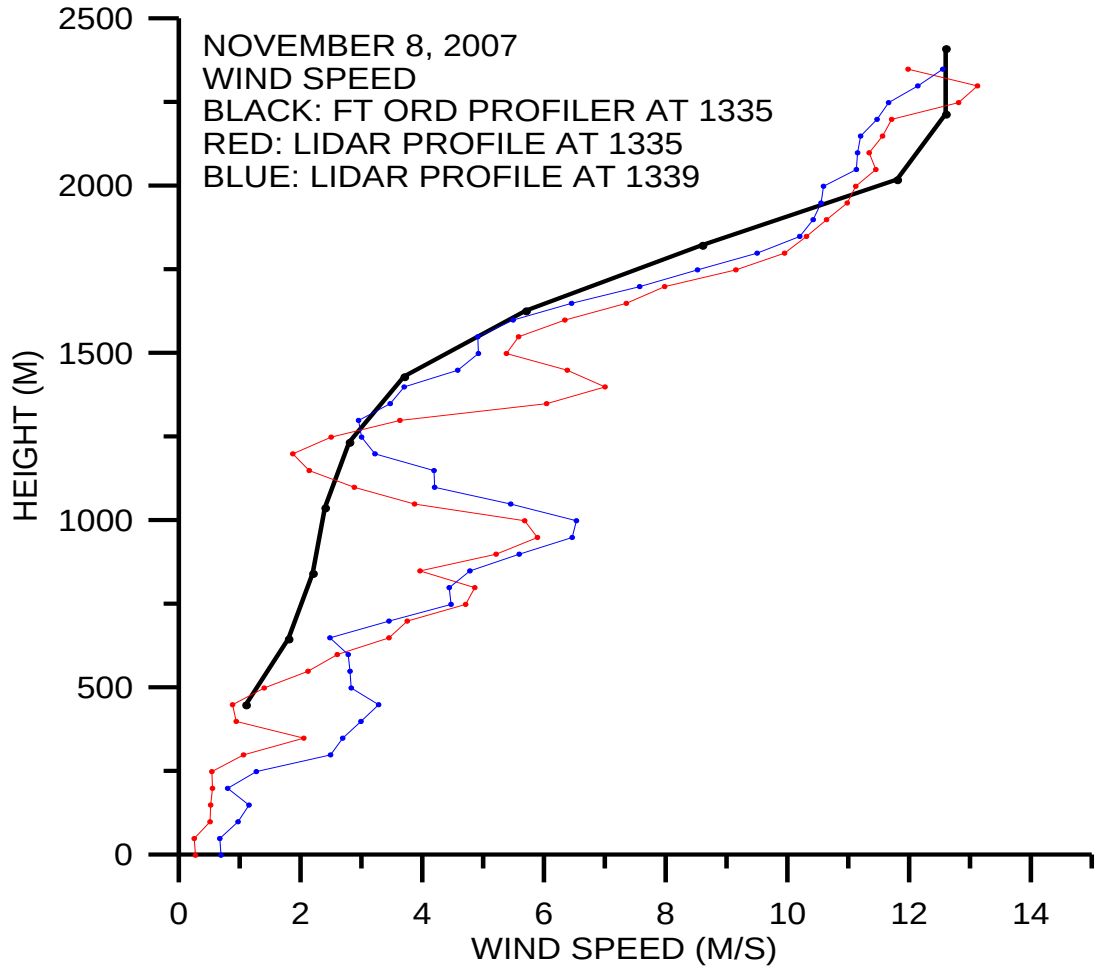
Range of Maximum, Mean, and Standard Deviation Determinations of Speed Shear

NASA Wind Shear Study

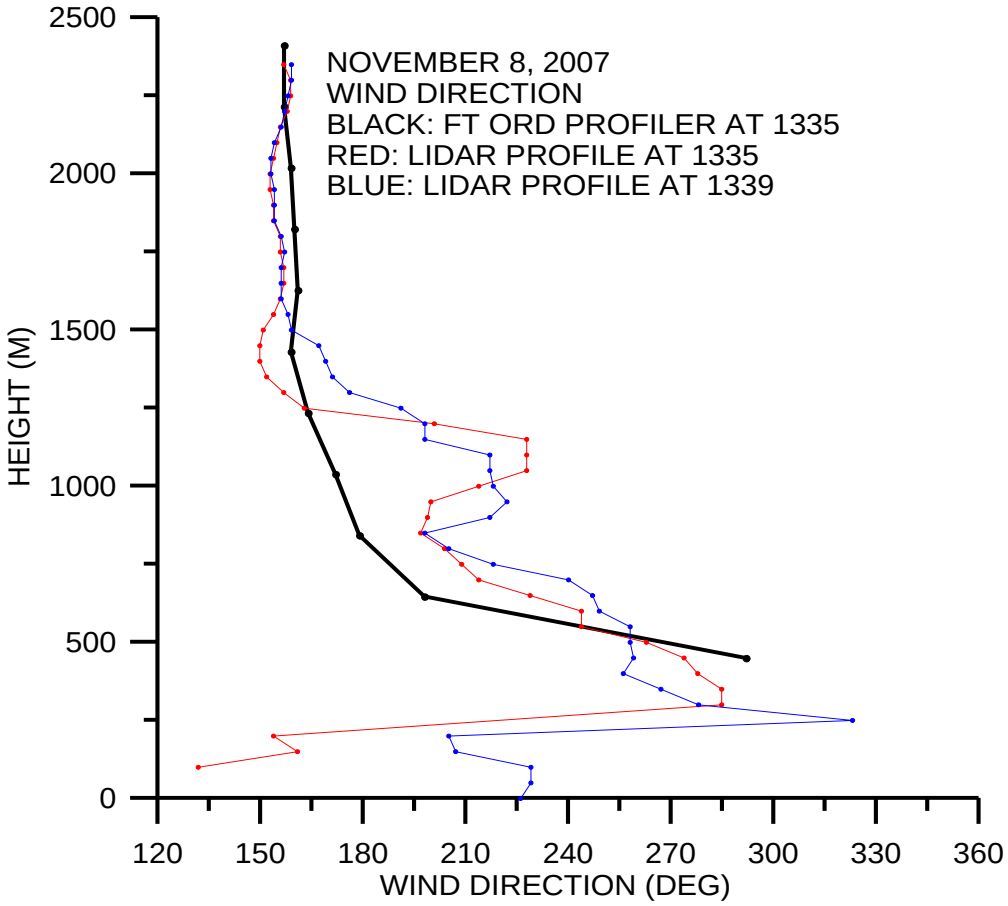
Height (m)	Maximum Deg m-1	Mean Deg m-1	Std. Dev Deg m-1
150 – 120	0.200 – 0.633	0.083 – 0.374	0.041 – 0.198
120 – 90	0.767 – 1.200	0.503 – 0.828	0.048 – 0.680
90 – 60	1.233 – 3.167	0.905 – 2.873	0.062 – 0.365
60 – 30	0.433 – 1.933	0.140 – 1.284	0.107 – 0.468
30 – 18	2.147 – 9.583	0.811 – 7.973	0.418 – 1.195

Range of Maximum, Mean, and Standard Deviation Determinations of Directional Shear

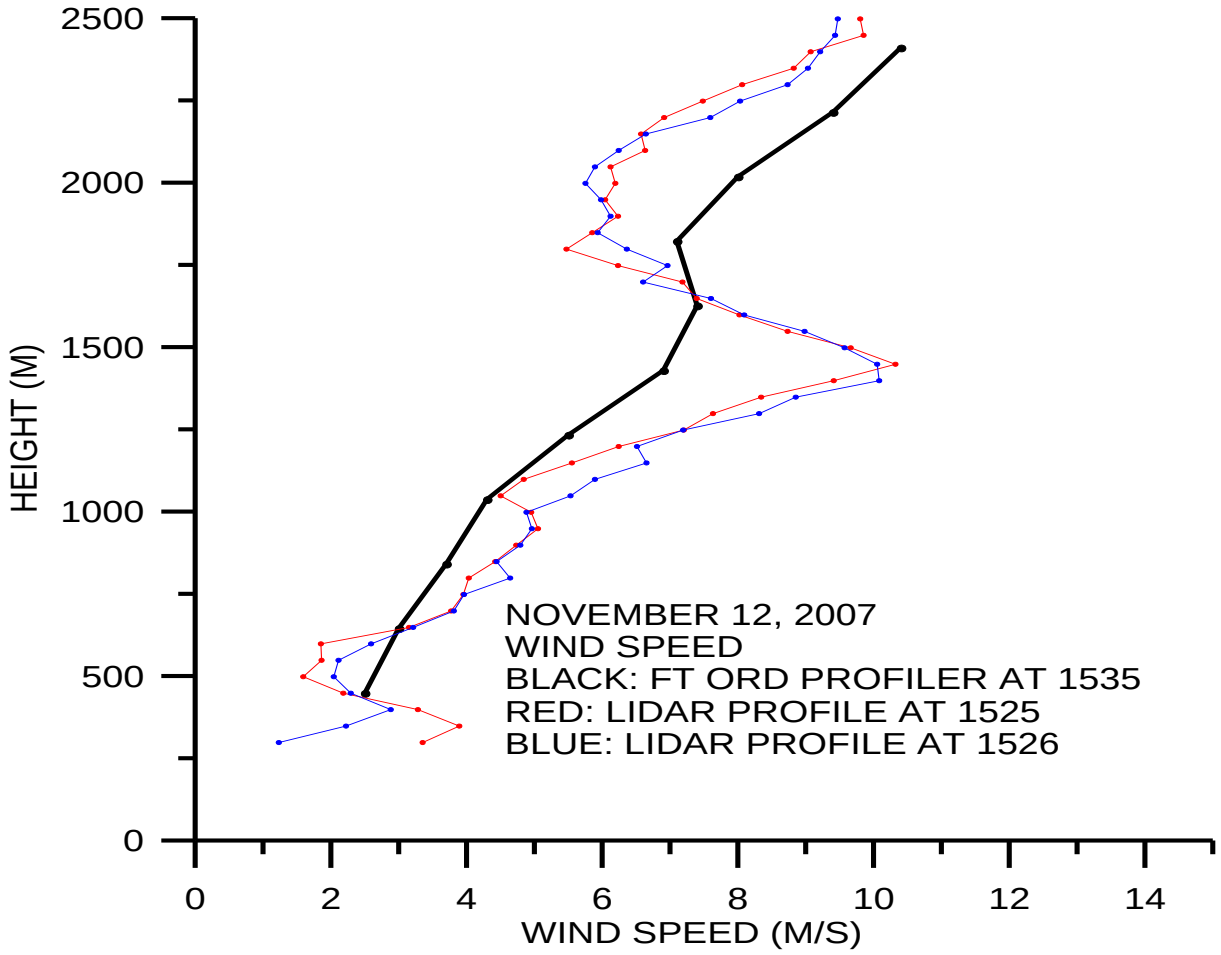
TODWL vs. microwave tower



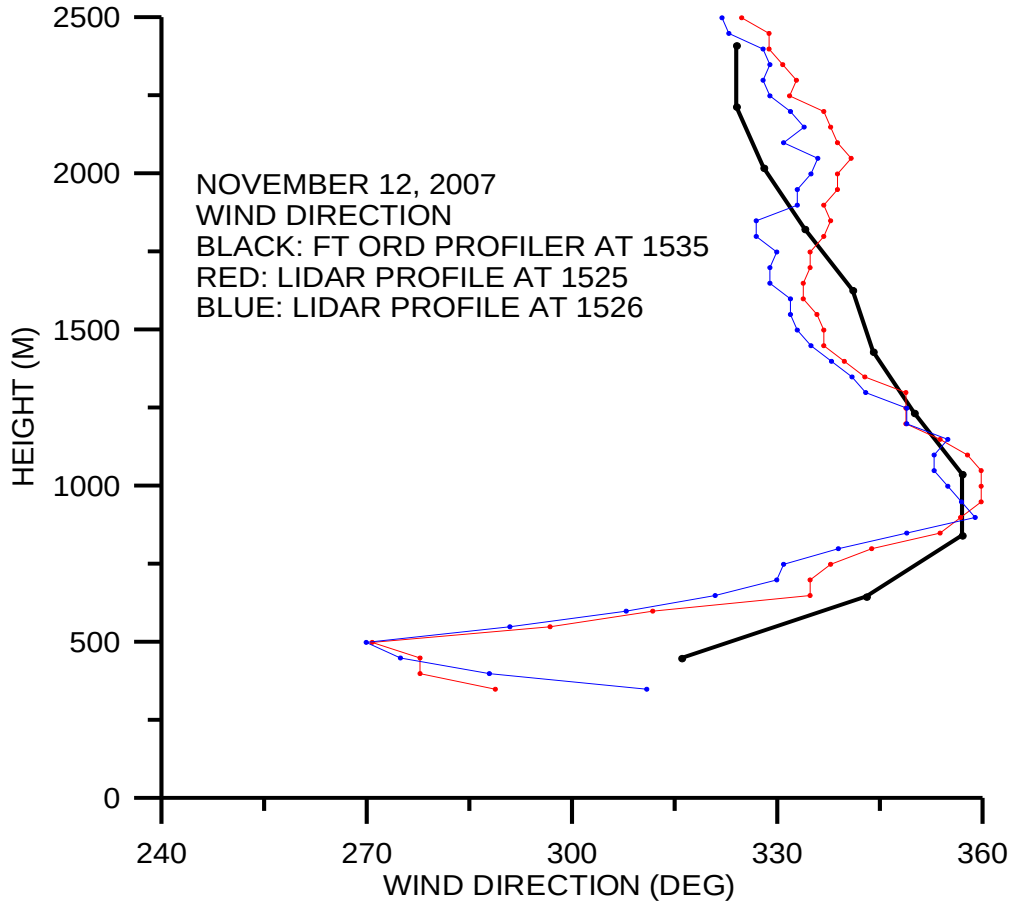
TODWL vs. microwave tower

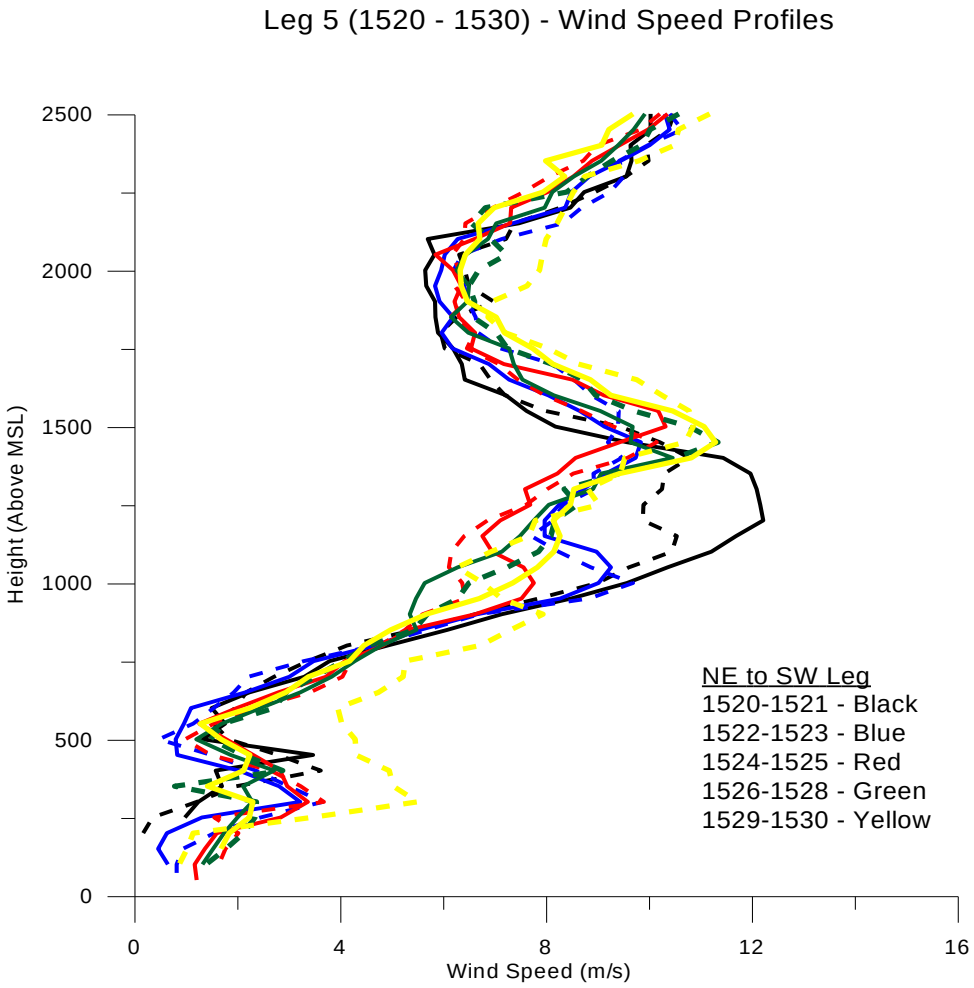


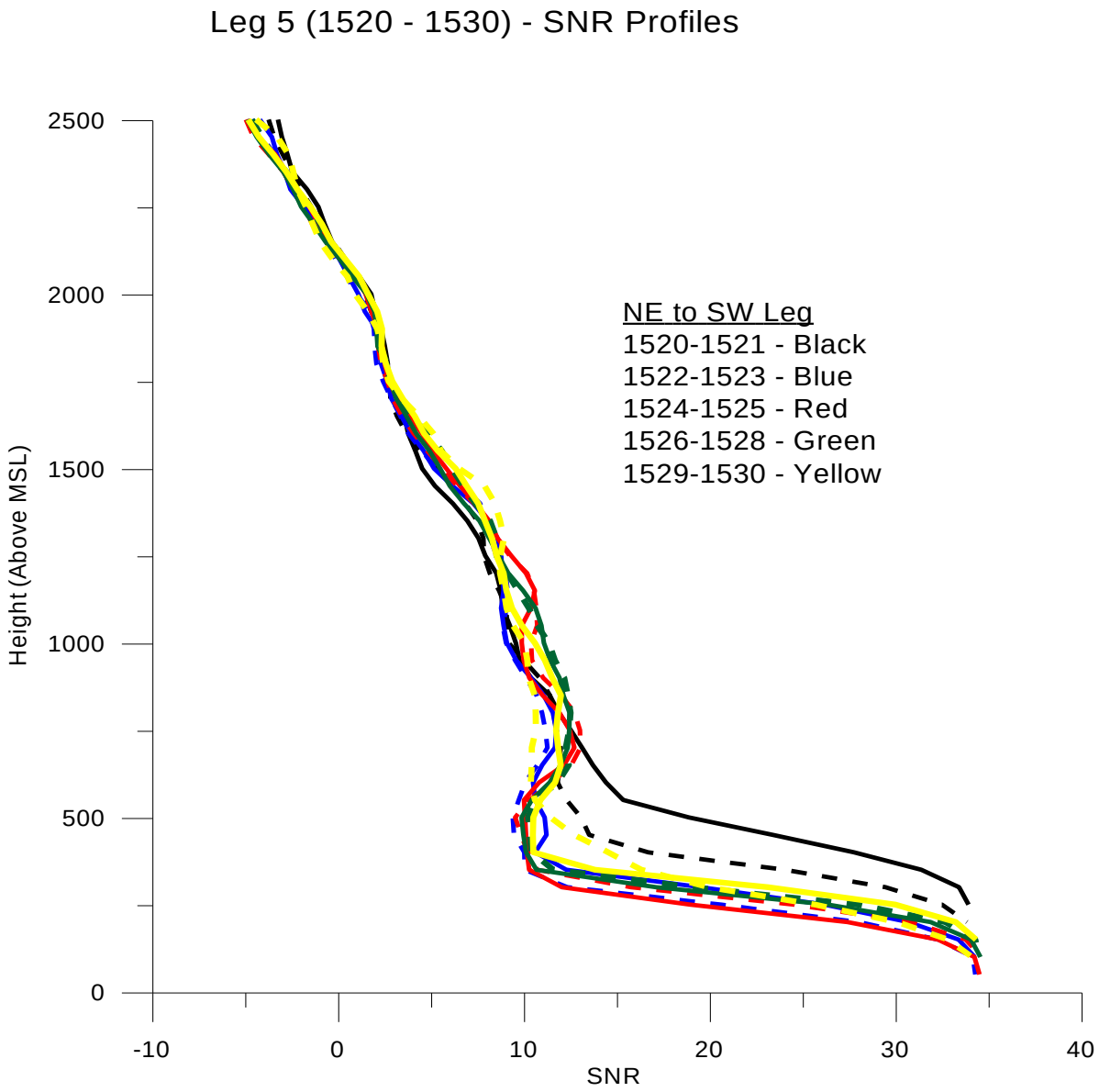
TODWL vs. microwave tower

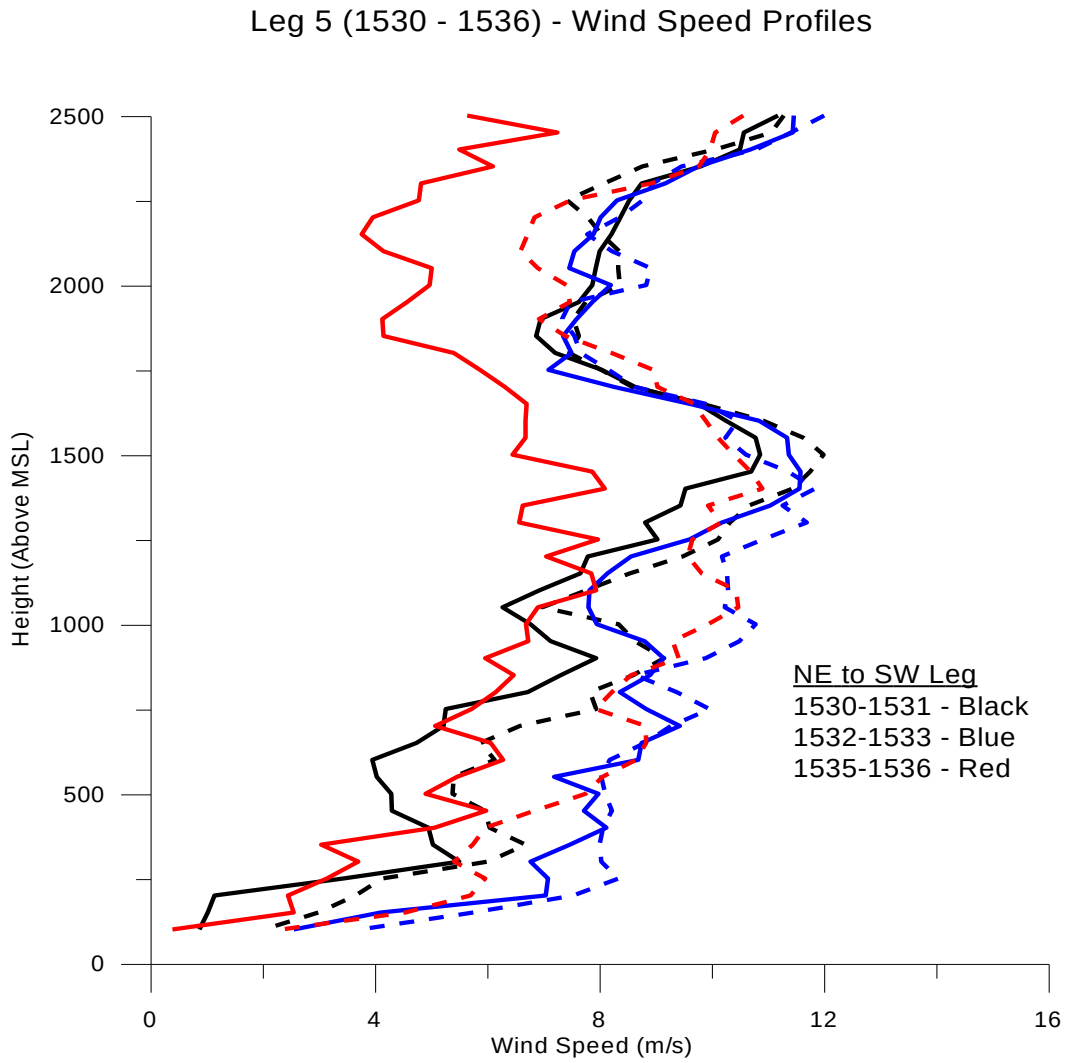


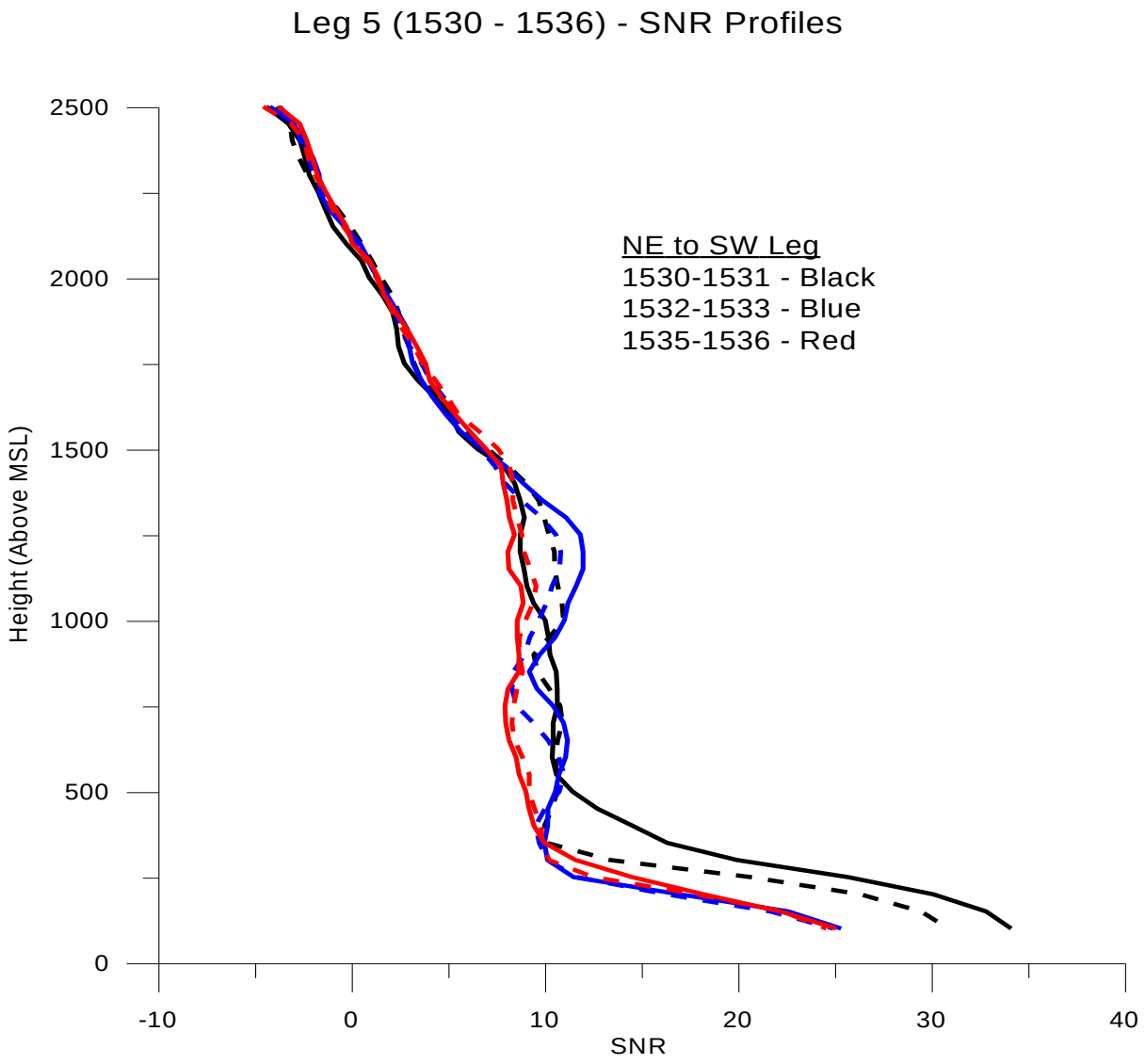
TODWL vs. microwave tower

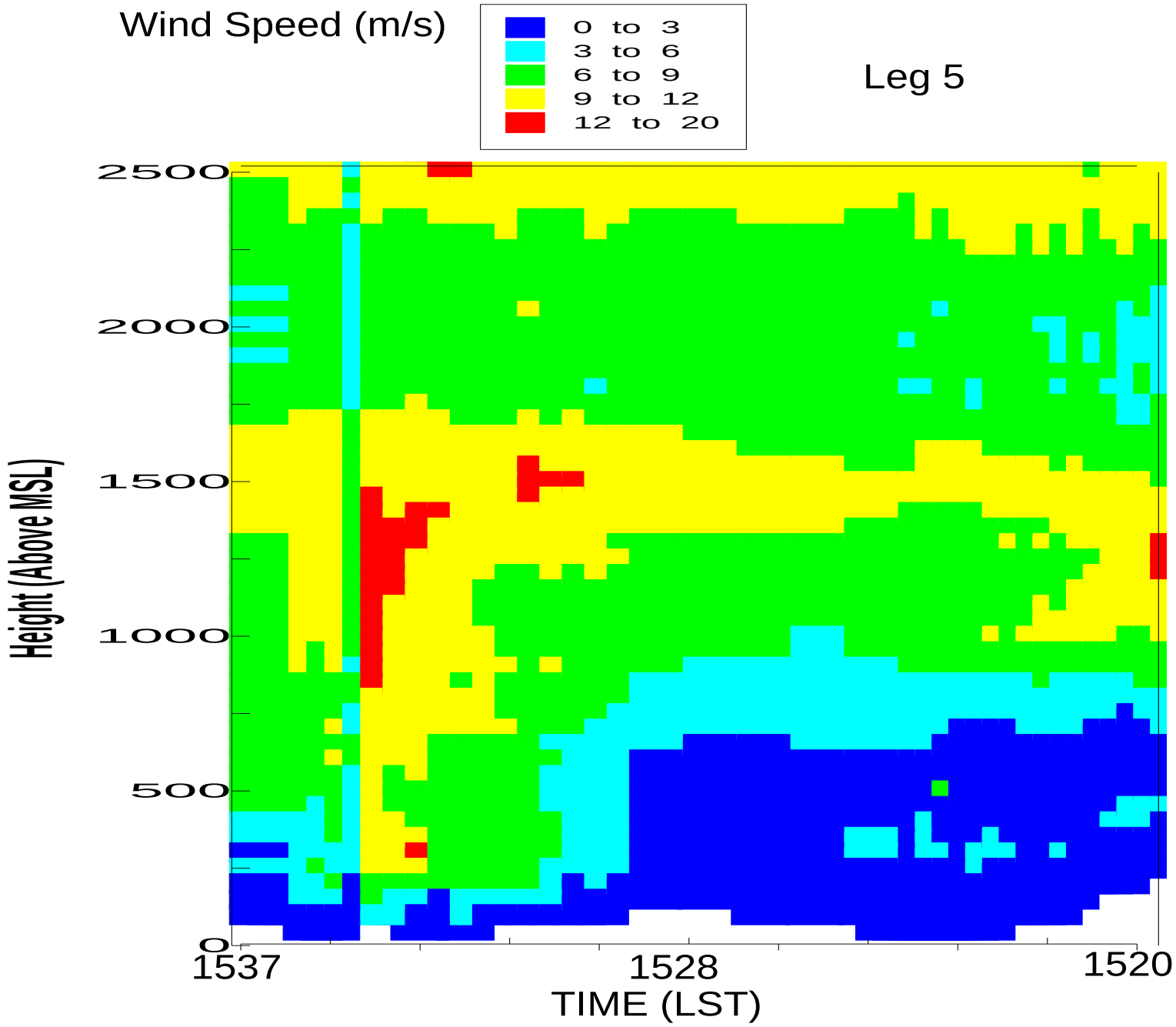


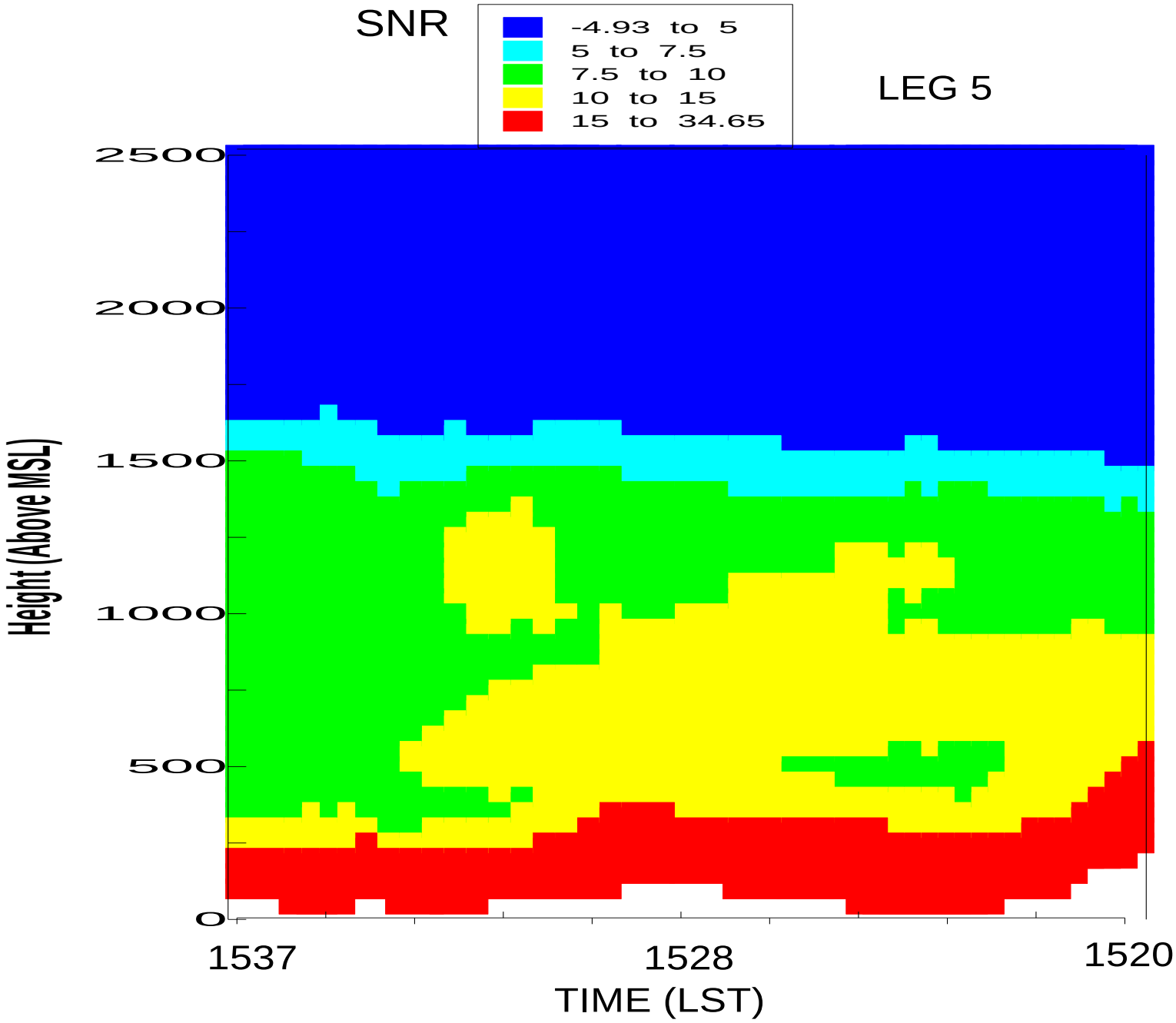

Leg 5 (1520 - 1530) - Wind Speed Profiles
Height (Above MSL)
2500
2000
1500
1000
500
0
0
4
8
12
16
Wind Speed (m/s)
NE to SW Leg
1520-1521 - Black
1522-1523 - Blue
1524-1525 - Red
1526-1528 - Green
1529-1530 - Yellow


Leg 5 (1520 - 1530) - SNR Profiles
2500
2000
1500
1000
500
0
Height (Above MSL)
-10
0
10
20
30
40
SNR
NE to SW Leg
1520-1521 - Black
1522-1523 - Blue
1524-1525 - Red
1526-1528 - Green
1529-1530 - Yellow


Leg 5 (1530 - 1536) - Wind Speed Profiles
Height (Above MSL)
2500
2000
1500
1000
500
0
0
4
8
12
16
Wind Speed (m/s)
NE to SW Leg
1530-1531 - Black
1532-1533 - Blue
1535-1536 - Red

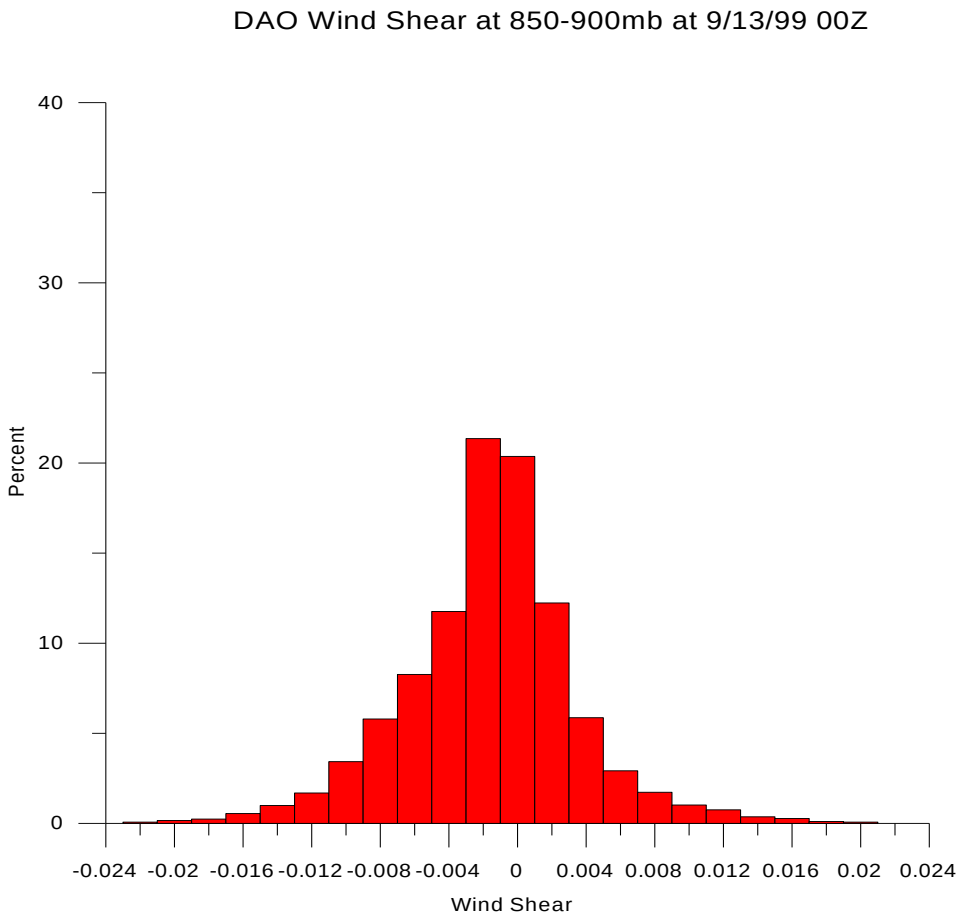

Leg 5 (1530 - 1536) - SNR Profiles
NE to SW Leg
1530-1531 - Black
1532-1533 - Blue
1535-1536 - Red
Height (Above MSL)
2500
2000
1500
1000
500
0
-10
0
10
20
30
40
SNR


Wind Speed (m/s)
0 to 3
3 to 6
6 to 9
9 to 12
12 to 20
Leg 5
2500
2000
1500
1000
500
0
Height (Above MSL)
1537
1528
1520
TIME (LST)

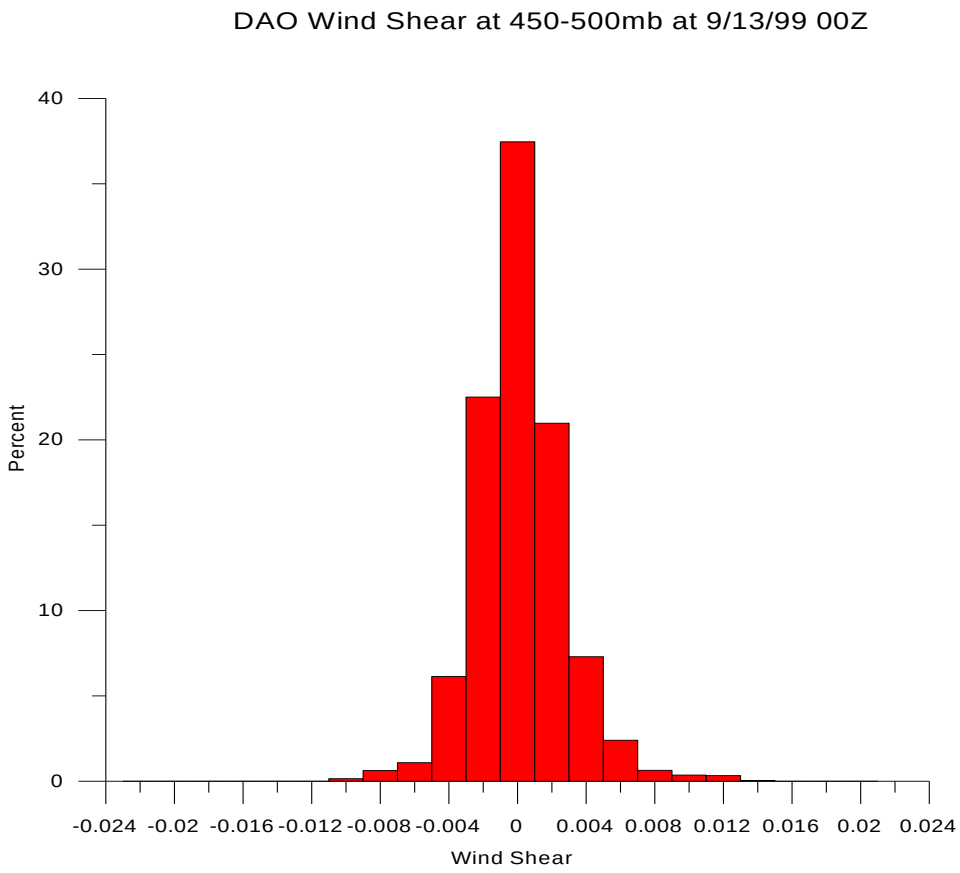

SNR
-4.93 to 5
5 to 7.5
7.5 to 10
10 to 15
15 to 34.65
LEG 5
2500
2000
1500
1000
500
0
Height (Above MSL)
1537
1528
1520
TIME (LST)

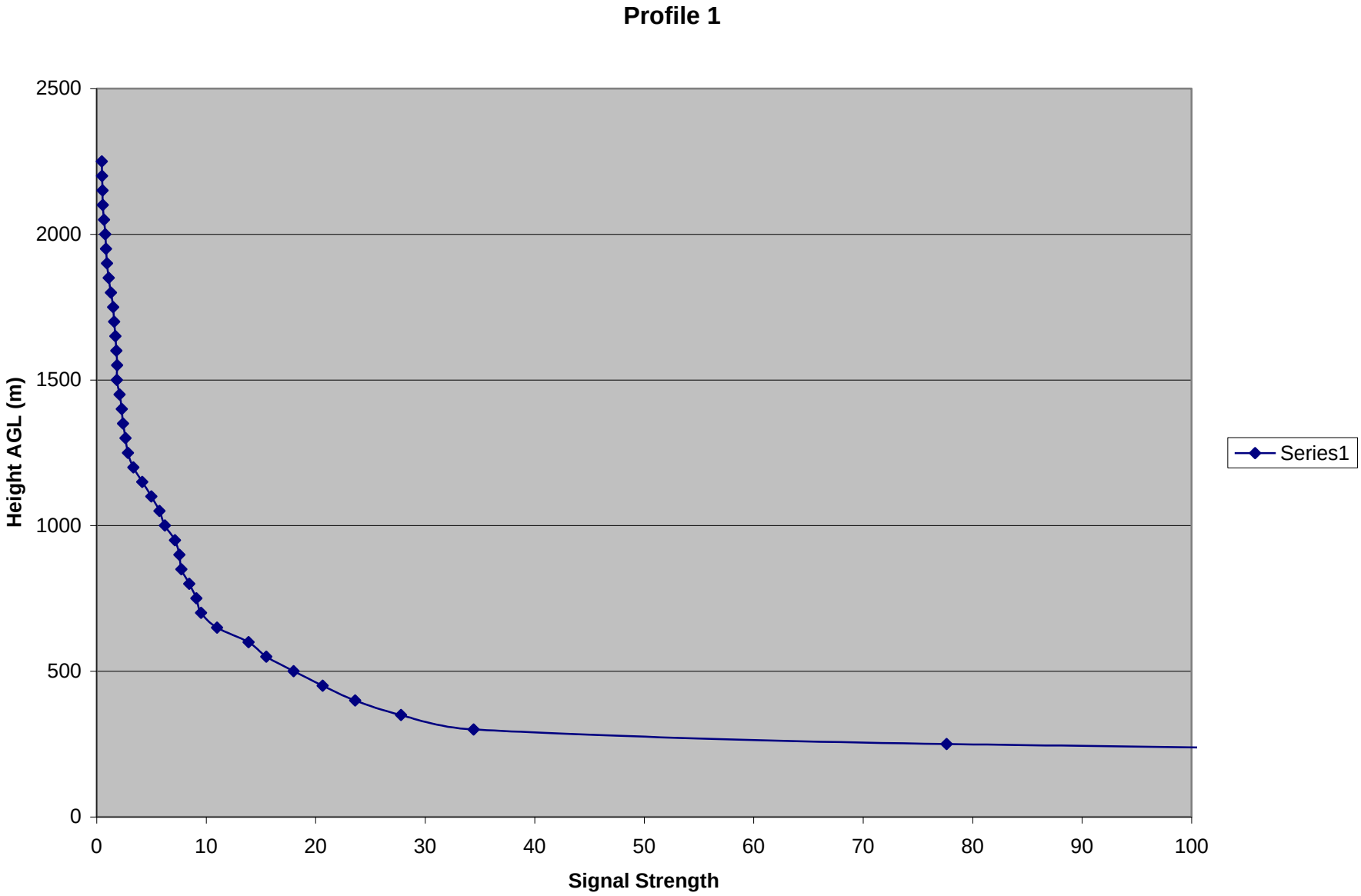
Model Shear

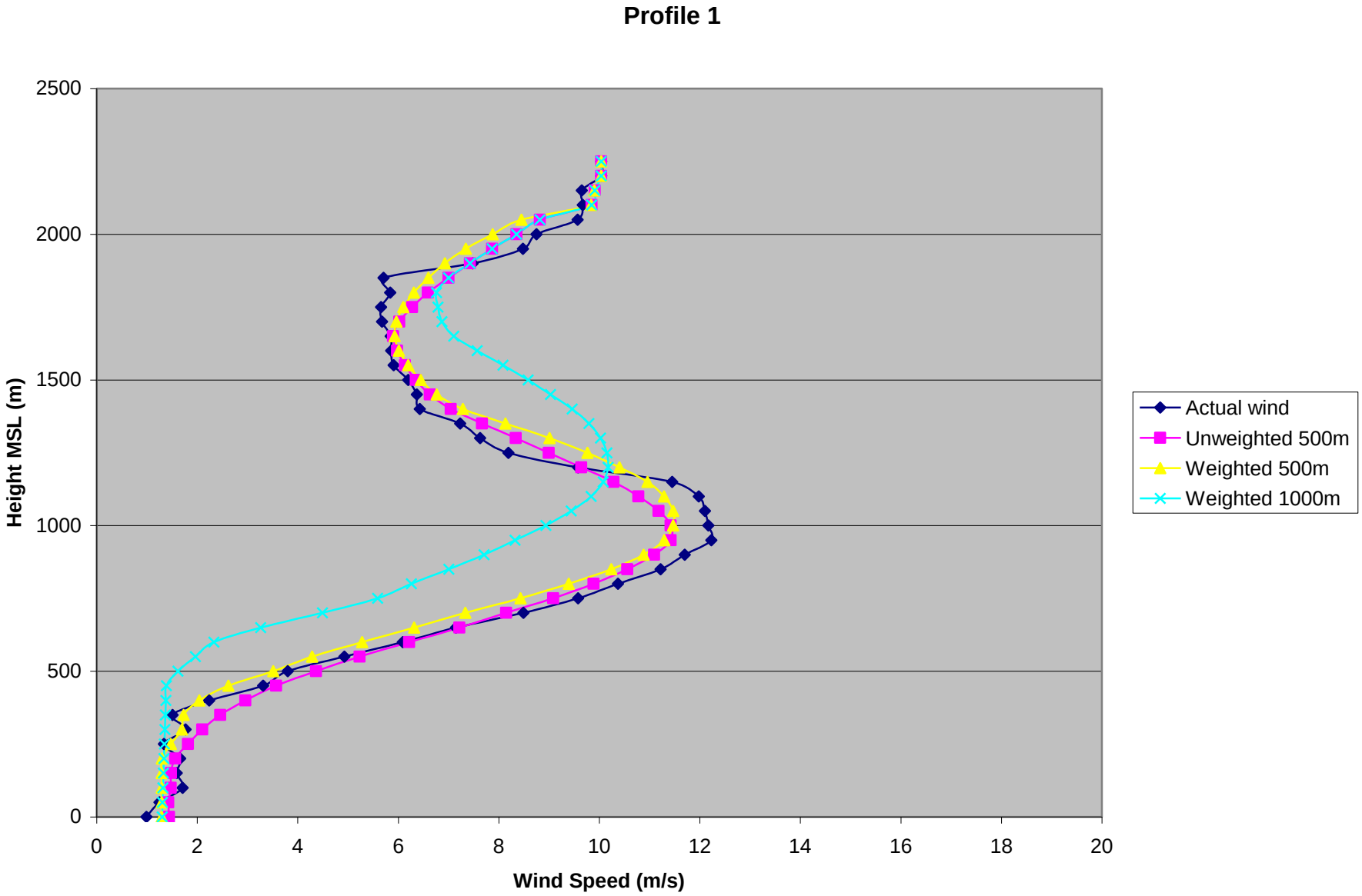
Wind Shear

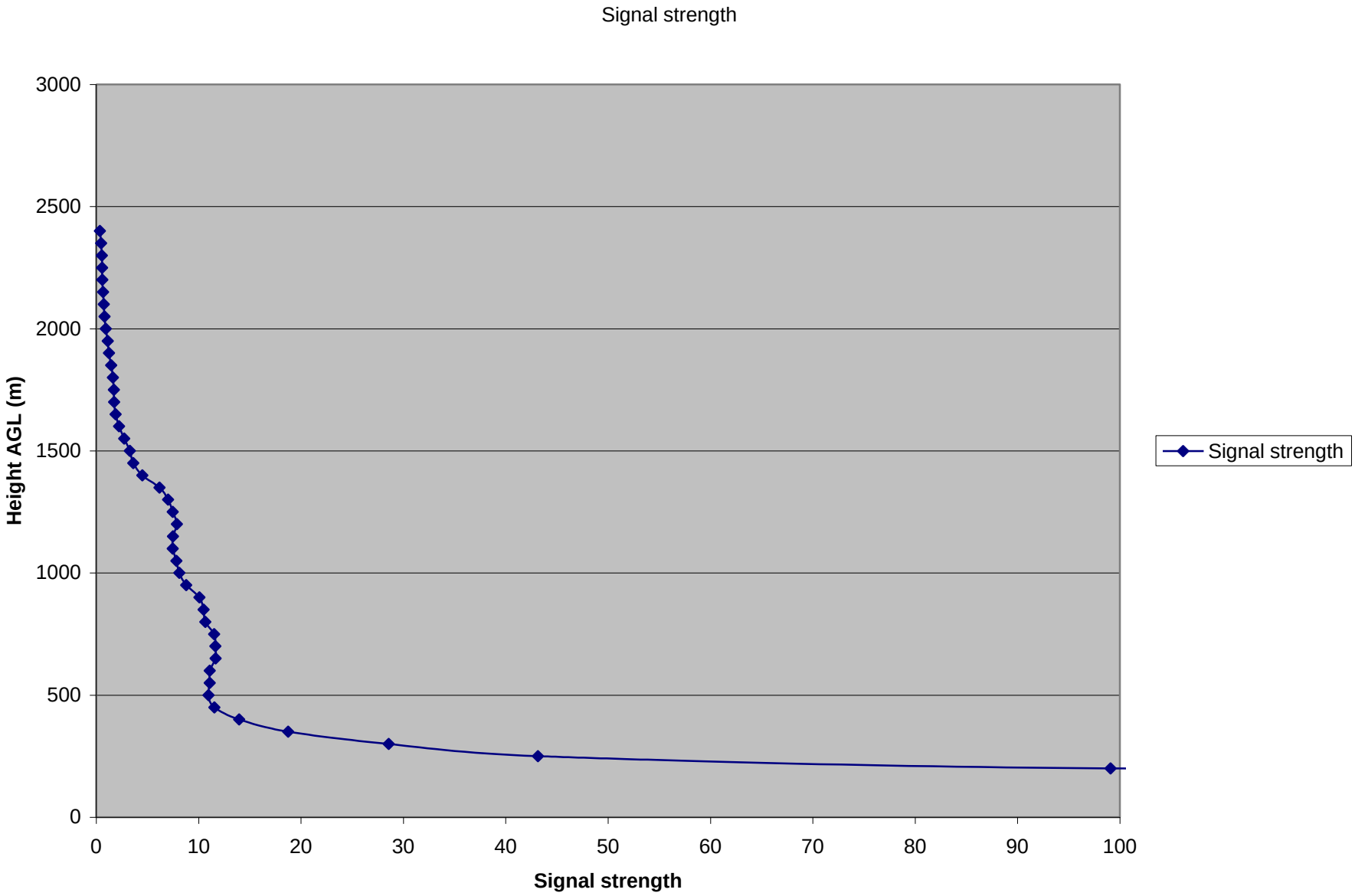

DAO Wind Shear at 850-900mb at 9/13/99 00Z
Percent
40
30
20
10
0
-0.024
-0.02
-0.016
-0.012
-0.008
-0.004
0
0.004
0.008
0.012
0.016
0.02
0.024
Wind Shear

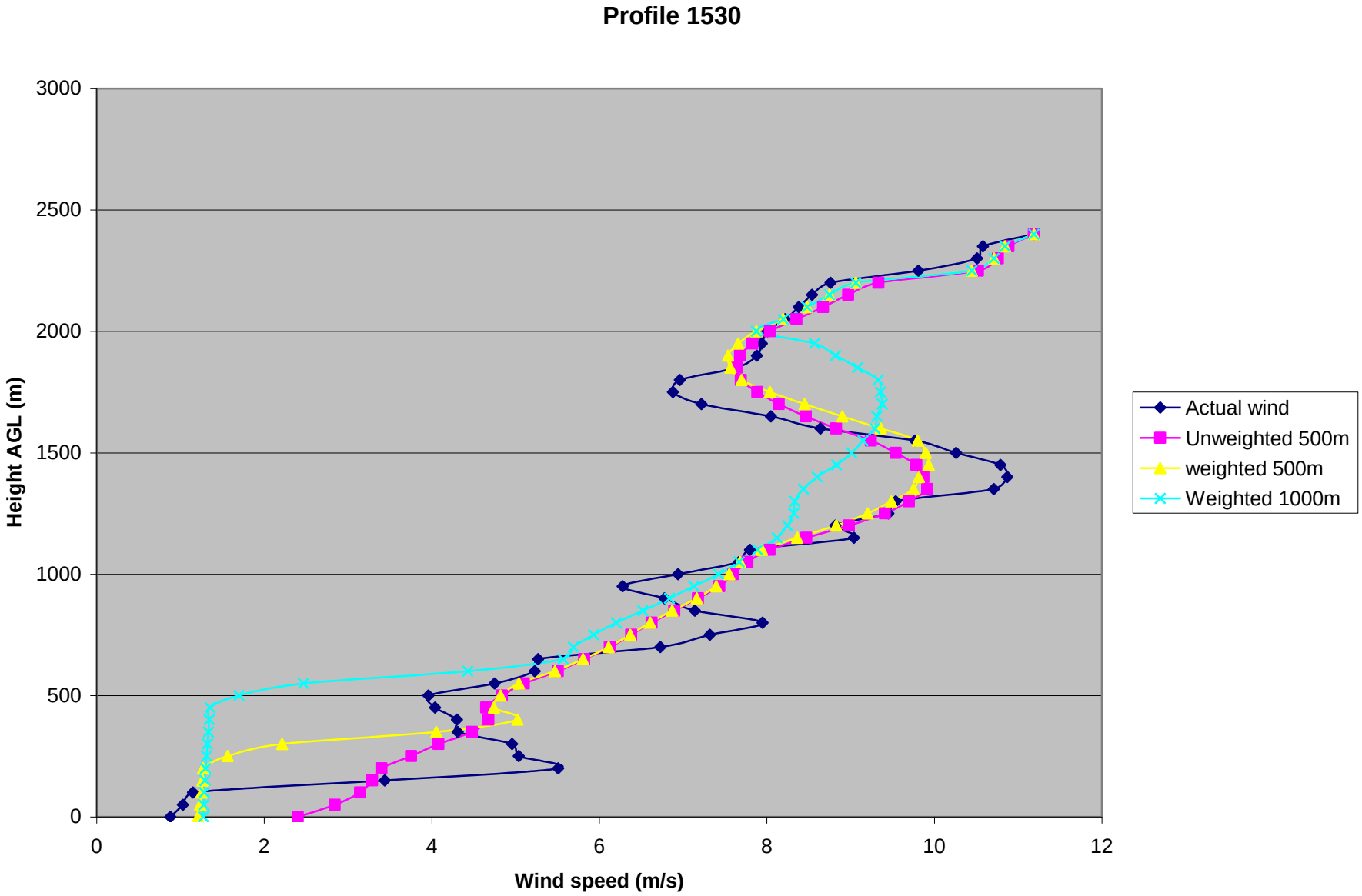
Wind Shear


DAO Wind Shear at 450-500mb at 9/13/99 00Z
Percent
40
30
20
10
0
-0.024 -0.02 -0.016 -0.012 -0.008 -0.004 0 0.004 0.008 0.012 0.016 0.02 0.024
Wind Shear


Profile 1
Height AGL (m)
2500
2000
1500
1000
500
0
0
10
20
30
40
50
60
70
80
90
100
Signal Strength
Series1


Profile 1
Height MSL (m)
2500
2000
1500
1000
500
0
0
2
4
6
8
10
12
14
16
18
20
Wind Speed (m/s)
Actual wind
Unweighted 500m
Weighted 500m
Weighted 1000m


Signal strength
3000
2500
2000
1500
1000
500
0
Height AGL (m)
0
10
20
30
40
50
60
70
80
90
100
Signal strength
Signal strength

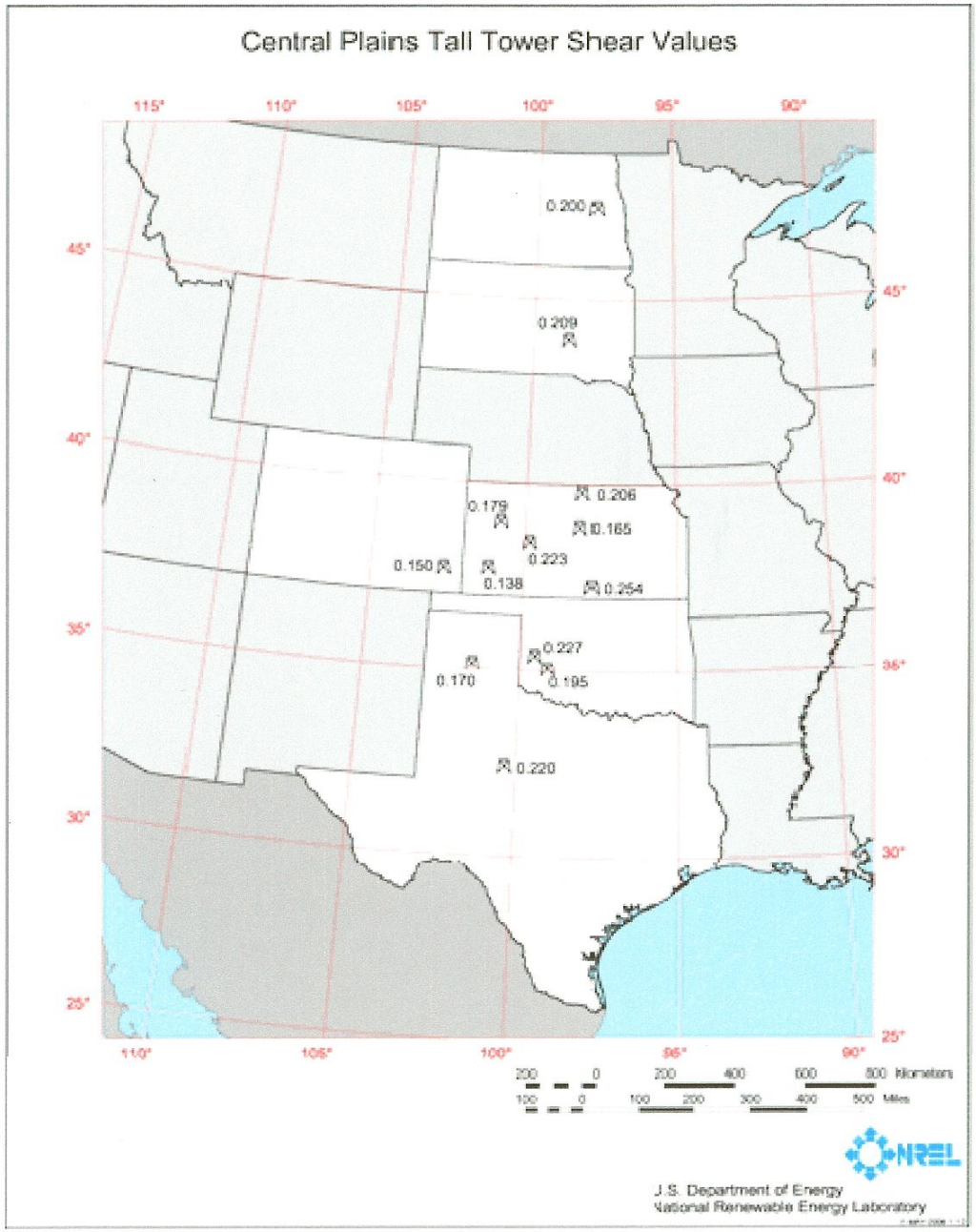

Profile 1530
Height AGL (m)
3000
2500
2000
1500
1000
500
0
0
2
4
6
8
10
12
Wind speed (m/s)
Actual wind
Unweighted 500m
weighted 500m
Weighted 1000m

Summary

- Shear represents both a primary target of space-based observations and a challenge to signal processing
- Shear represents a major source of bias in estimating an average wind over a layer
- Ground based and airborne lidar with < 100m pulse lengths provide excellent data bases for simulating space-based DWL observations of shear.

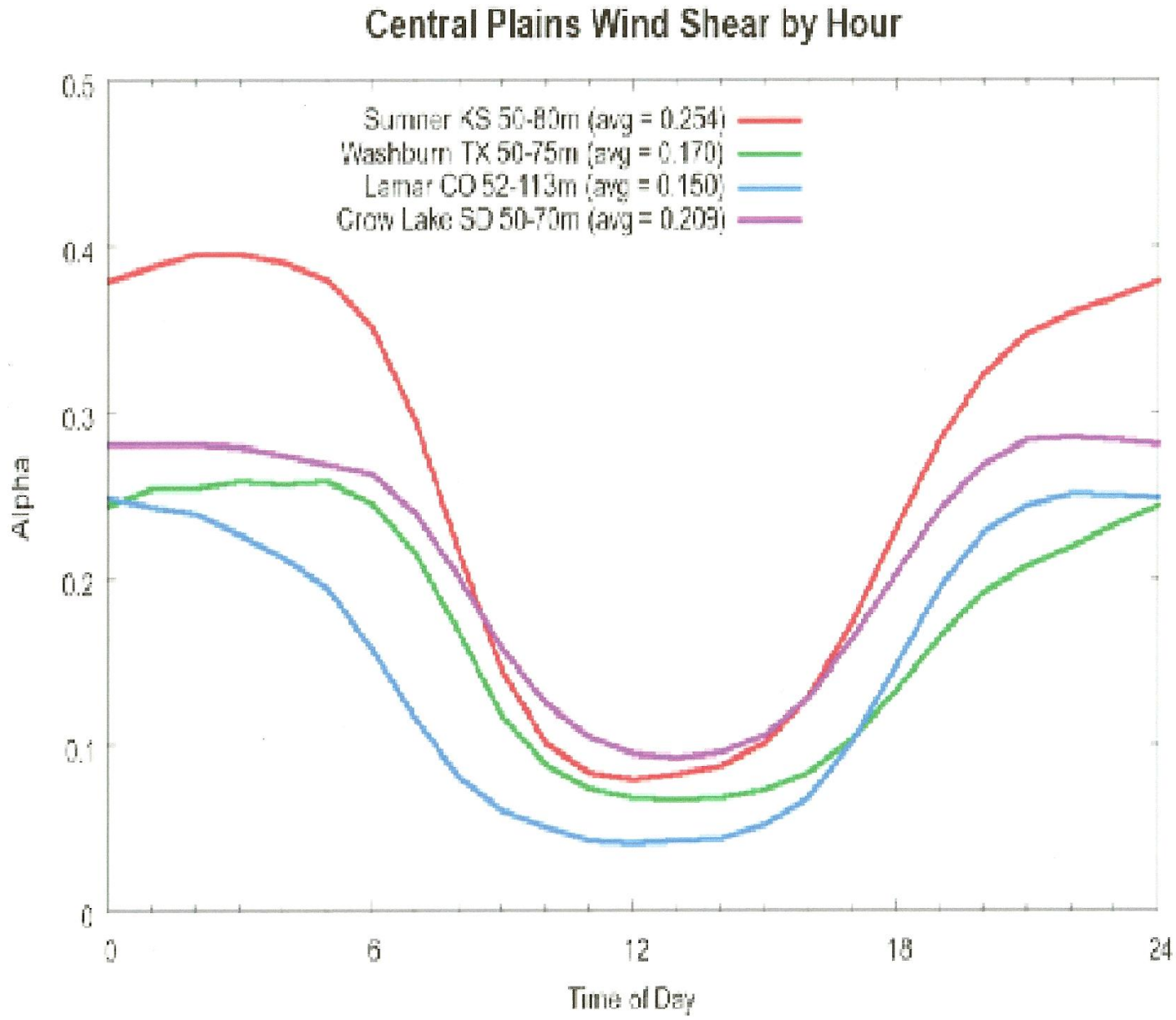
Wind Shear Characteristics Analyzed From Tall Tower Data in Plains and Midwest

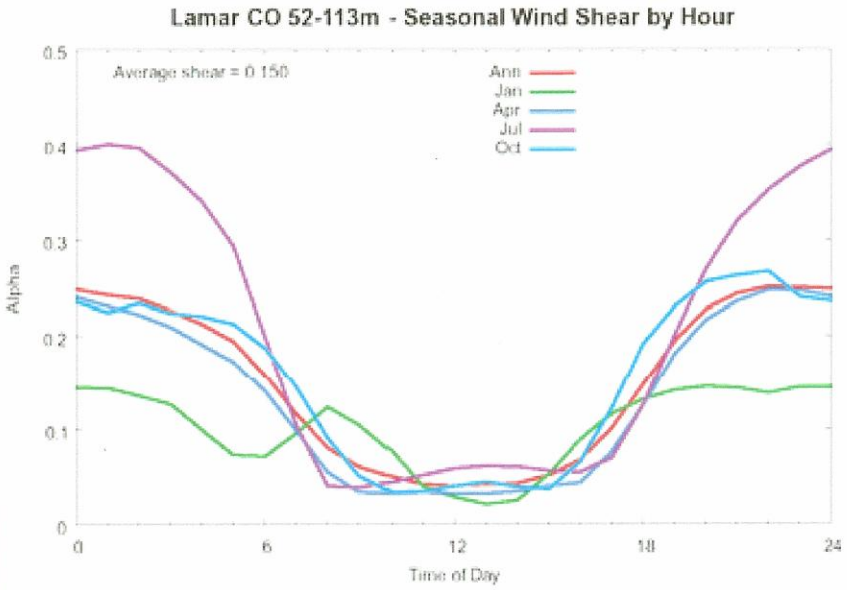
- Annual average
- Diurnal variability
- Seasonal variability
- Shear variation by prevailing wind directions
- Investigate wind shear variation by height
- Variations within and among geographic regions

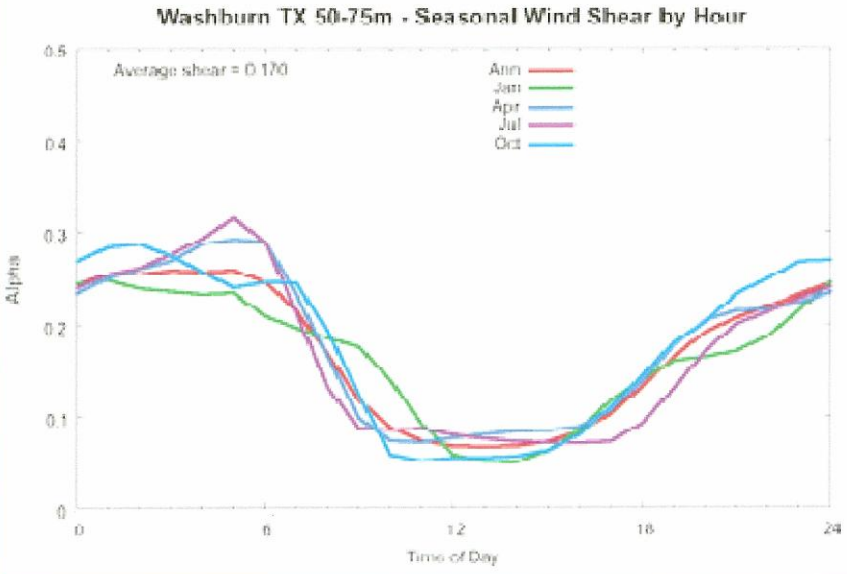


Shear Climate Summary

- Annual average shear between 0.15 and 0.25
- Greater variation of annual wind shear between towers within a region than betwee the southern and northern Plains and the Midwest
- Diurnal shear pattern simila throughout region
  - Daytime shear is 0.05-0.1
  - Nighttime shear between 0.25-0.40
  - Some seasonal variations among towers
- Winds from south had highe shear than winds from north
  - South winds shear 0.2-0.3
  - North winds shear 0.1-0.2


Central Plains Wind Shear by Hour
Summer KS 50-80m (avg = 0.254)
Washburn TX 50-75m (avg = 0.170)
Lamar CO 52-113m (avg = 0.150)
Crow Lake SD 50-70m (avg = 0.209)
Alpha
0.5
0.4
0.3
0.2
0.1
0
0
6
12
18
24
Time of Day





Seasonal and Diurnal Wind Shear

- Lamar CO has much larger nocturnal shears in summer than in winter

- Washburn TX has similar nocturnal shears across the seasons