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Wind Speed and Direction Shears With Associated Vertical Motion During Strong Surface Winds

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TECHNICAL MEMORANDUM

WIND SPEED AND DIRECTION SHEARS WITH ASSOCIATED VERTICAL MOTION DURING STRONG SURFACE WINDS

INTRODUCTION

Low-level flow conditions known to be hazardous to aircraft during takeoff/climbout and approach/landing operations include wind shear and vertical motion. A classic example is the crash of Pan Americal World Airways Flight 759 at New Orleans on July 9, 1982. Between start of takeoff roll and crash (29 sec), the aircraft experienced a decreasing head wind shear of about 38 kts (19.5 m s^{-1}) and a 7 f s^{-1} (2.1 m s^{-1}) downdraft at 100 ft (30.5 m) above ground level [1].

Wind shear generates eddies between two wind currents of differing velocities. The difference may be in wind speed, wind direction, or in both. Vertical motion, updrafts and downdrafts, can produce an increase or decrease in altitude for an aircraft. From the literature it is evident that information is needed concerning the magnitude of wind speed and direction shears with altitude and along the flight path, as well as intensity of vertical motion and height of maximum occurrences.

Because low wind speeds and subsequent light shears present fewer problems in terminal areas, interest is naturally greatest in high winds, strong shears, and associated vertical motion. This analysis of high resolution wind profile measurements recorded at the NASA 150-Meter Ground Winds Tower Facility at Kennedy Space Center, Florida, presents temporal and spatial shear and vertical motion occurrences during strong or gusty surface winds near a runway.

WIND SHEAR

The meteorological mechanisms that cause strong wind shear are gust fronts formed by severe thunderstorms, fast-moving frontal zones, and low-level temperature inversions [2]. Wind shear, a wind change producing an increase or decrease in the airspeed of an aircraft, may be associated with a wind speed gradient or a wind direction shift at any level in the atmosphere.

The behavior of the wind in the last 100 ft (30 m) of descent, in particular between 100 and 50 ft (30 and 15 m), is most important to a descending aircraft [3]. Wind speed shears greater than 0.1 s^{-1} (6 kts/100 ft or 3 m s^{-1}/30 m) are dangerous [4] while large changes in wind direction ($\geq$ 40 deg) are considered hazardous [5]. From simple calculations, Frost [6] estimates magnitudes of horizontal wind shear of 0.02 s^{-1} (1 kt/100 ft or 0.5 m s^{-1}/30 m) to be significant.

This analysis presents vertical speed and direction shears for four 100-ft (30-m) layers below 500 ft (150 m), i.e., 500 to 400 ft or 150 to 120 m, 400 to 300 ft or 120 to 90 m, 300 to 200 ft or 90 to 60 m, and 200 to 100 ft or 60 to 30 m; for two approximately 50-ft (15-m) layers below 100 ft (30 m), i.e., 100 to 60 ft or 30 to 18T* m, and 60 to 10 ft or 18S* to 3 m; and horizontal shears for one distance of 60 ft (18 m) at the 60-ft (18-m) level, i.e., 60T to 60S ft or 18T to 18S m.

*18T and 18S denote the 18-meter level on the tall and short towers, respectively.

VERTICAL MOTION

Horizontal wind speed and direction shears with associated vertical motion effects in the terminal area of operations are critical in terms of aircraft safety. Associated vertical motion, updrafts and downdrafts, is defined to be motion occurring simultaneously with horizontal surface wind speed and direction. While wind shear produces an increase or decrease in the airspeed of an aircraft, vertical motion can produce an increase or decrease in altitude. Some downdrafts, under certain conditions, descend very close to the ground where they spread out violently, i.e., a downburst [7].

This analysis correlates values of updrafts and downdrafts ($\geq$ 2 kts 1.0 m s^{-1}) at four heights (150, 60, 18T and 10 m) with the appropriate layers and distance, i.e., 150 with 150 to 120, 60 with 90 to 60, and 60 to 30, 18T with 30 to 18T and 18T to 18S, and 10 with 18S to 3.

DATA ANALYSIS

The NASA 150-Meter Ground Winds Tower Facility at Kennedy Space Center, Florida, is a unique source of high resolution wind speed, direction and vertical motion profile measurements. The facility, depicted in Figure 1 and described by Kaufman and Keene [8] is located on Merritt Island midway between Launch Complex 39B and the Space Shuttle runway. Placement of the meteorological sensors on the towers is shown in Figure 2. The Automatic Data Acquisition System, described by Traver, et al. [9], samples at the rate of 10 each of speeds, directions, and vertical motion per second, digitally records, and real-time processes the samples for all sensors on the two towers. Mean values follow the World Meteorological Organization (WMO)-recommended practices [10], viz., that wind averaging periods for aviation climatology not exceed 10 min and that gust-measuring periods be at least 5 sec.

Because interest is greatest in strong shears, this analysis consists of twenty 5-sec intervals (one interval every 100 sec) of high ($\geq$ 20 kts 10 m s^{-1}) horizontal winds recorded at the eight tower heights on July 3, 1973, between 1930 and 2200 UT. Specific times of the intervals are the following:

19 31 16.0–20.9	19 41 41.0–45.9	20 00 06.0–10.9	21 43 47.0–51.9
19 33 16.0–20.9	19 43 21.0–25.9	20 01 51.0–55.9	21 45 27.0–31.9
19 34 56.0–00.9	19 45 01.0–05.9		21 47 07.0–11.9
19 36 36.0–40.9	19 46 41.0–45.9		21 48 47.0–51.9
19 38 16.0–20.9	19 48 21.0–25.9		21 50 32.0–36.9
19 39 56.0–00.9	19 50 01.0–05.9		21 52 12.0–16.9

Vertical wind shear is the change of wind speed with height and is determined by means of two anemometers mounted at different heights on a single tower. Vertical shear magnitudes are derived by algebraically subtracting the wind speed at the lower level from the speed at the upper and dividing by the distance between levels, i.e.,

$$\frac{WS_U - WS_L}{d_{(U-L)}} = \frac{\Delta WS}{\Delta d} \quad . \tag{1}$$

Horizontal wind shear is the change of wind speed with horizontal distance and is determined by two anemometers mounted at the same height on different towers. Wind speed shears for one distance (18 m) between the tall and short towers at the 18-m level are presented. Horizontal shear magnitudes were derived by algebraically subtracting the wind speed at the short tower from the speed at the tall and dividing by the distance between towers, i.e.,

$$\frac{WS_T - WS_S}{d_{(T-S)}} = \frac{\Delta WS}{18} \quad . \tag{2}$$

Vertical and horizontal wind direction shears were similarly determined, i.e.,

$$\frac{WD_U - WD_L}{d_{(U-L)}} = \frac{\Delta WD}{\Delta d} \quad . \tag{3}$$

and

$$\frac{WD_T - WD_S}{d_{(T-S)}} = \frac{\Delta WD}{18} \quad . \tag{4}$$

DESCRIPTIONS

To help further characterize the simultaneous occurrence of shear and vertical motion hazards to aviation in low-level flow conditions [11], graphical (percentage frequency distributions) and mathematical (maximum, mean, standard deviation) descriptions are presented as follows:

Tables 1 through 7 present by layer, distance, and 5-sec intervals, percentage frequency of occurrence of the following:

1) Significant events

   Wind speed shear $\geq 0.1\ s^{-1}$ (3 m s^{-1}/30 m 6 kts/100 ft)
   Wind direction shea· ≥ 1.0 deg m^{-1} (30 deg/30 m 30 deg/100 ft)
   Updrafts and downdrafts ≥ 1.0 m s^{-1} (2.0 kts)

2) Simultaneous occurrence of the significant events

   Speed and direction shears
   Speed shears and updrafts
   Speed shears and downdrafts
   Direction shears and updrafts
   Direction shears and downdrafts

Speed shears, direction shears and updrafts
Speed shears, direction shears and downdrafts.

Table 8 presents by layer, distance, and 10-min intervals percentage frequency of occurrence of items 1 and 2 in Tables 1 through 7.

To provide the wind field associated with shears during strong surface winds, necessary for model construction and flight simulation, determinations of maximum, mean, and standard deviation are presented by layer, distance, and height in

Tables 9 through 15 of speed and direction shears

Tables 16 through 19 of updrafts and downdrafts

Tables 20 through 27 of horizontal wind speeds and directions.

Table 28 presents the range of values in Tables 9 through 27.

CONCLUSIONS

Concerning the characterization of wind shear and vertical motion during high surface winds, conclusions are the following:

1) Below 90 m is the most active area for the occurrence of significant events (wind speed shear $\geq 0.1\ s^{-1}$, direction shear ≥ 1.0 deg m^{-1}, updrafts and downdrafts $\geq 1.0\ m\ s^{-1}$) hazardous to ascending and descending aircraft.

2) Fewer occurrences of vertical motion $\geq 1.0\ m\ s^{-1}$ at the 150 and 60-m heights make the area below 30 m critical for the simultaneous occurrence of significant events, i.e., speed and direction shears, speed shear and vertical motion, direction shear and vertical motion, speed and direction shears and vertical motion.

3) Fewer occurrences of horizontal direction shears ≥ 1.0 deg m^{-1} keep the significant events for the horizontal distance (18T to 18S) from being comparable to the vertical counterparts in the 30 to 18T and 18S to 3 layers.

4) A comparison of simultaneous occurrences of significant events for the (30 to 3) vertical layer, (18T to 18S) horizontal distance, and 18-m height vertical motion should be investigated.

This analysis of tower data during high surface winds will, hopefully, provide magnitude and frequency values of speed and direction shears with altitude and along the flight path, and of associated vertical motion, for information purposes, model development and flight training simulations.

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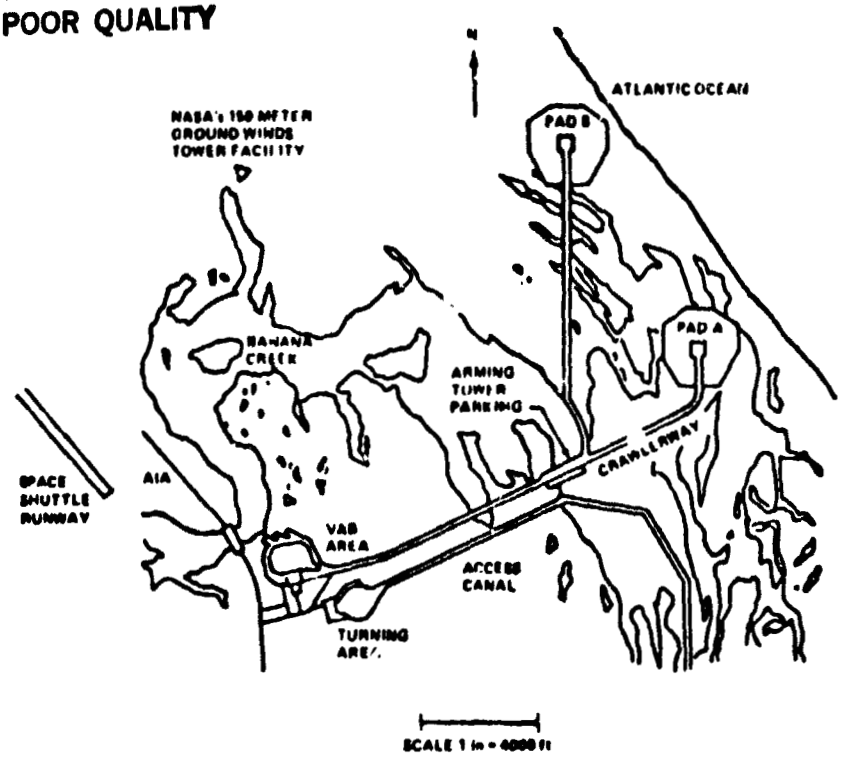

Figure 1. NASA's 150-Meter Ground Winds Tower Facility and Launch Complex 39, Kennedy Space Center, Florida.

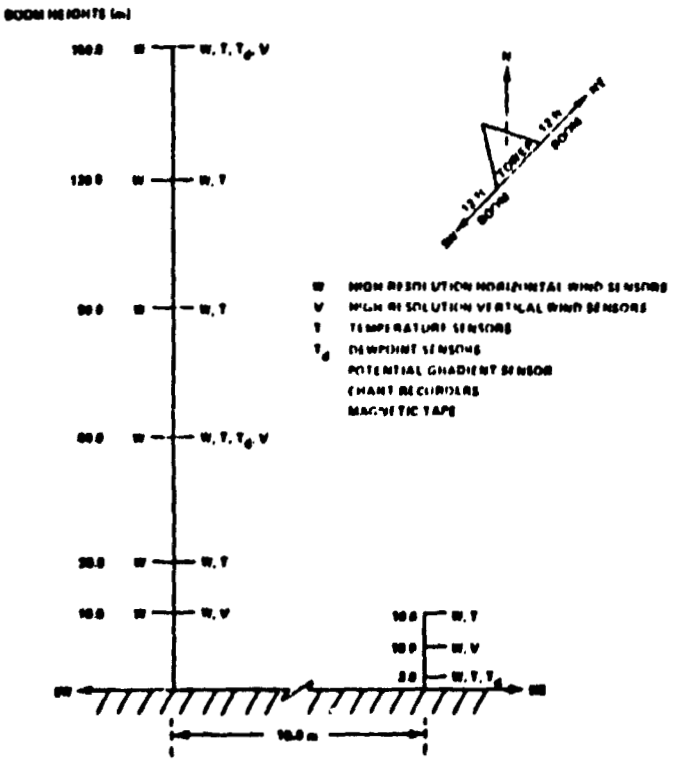

Figure 2. Placement of Sensors on NASA's 150-Meter Ground Winds Tower Facility at Kennedy Space Center, Florida.

TABLE 1. PERCENTAGE FREQUENCY OF OCCURRENCE OF SIGNIFICANT EVENTS FOR 5-sec INTERVALS AT 150 TO 120 m LAYER

Interval	Shear		VM		Shears	Shear(s) and Vertical Motion					
UT	Sp	Dir	Up	Down	Sp Dir	Sp Up	Sp Down	Dir Up	Dir Down	Sp Dir Up	Sp Dir Down
hr min ≥	0.1 s^{-1} / 3 m s^{-1}/30 m / 6 kt/100 ft	1.0 deg m^{-1} / 30 deg/30 m / 30 deg/100 ft	1.0 m s^{-1} / 2.0 kts		0.1 s^{-1} / 1.0 deg m^{-1}	0.1 s^{-1} / 1.0 m s^{-1}		1.0 deg m^{-1} / 1.0 m s^{-1}		0.1 s^{-1} / 1.0 deg m^{-1} / 1.0 m s^{-1}	
1931	0.00	0	30.00	0.00	0	0.00	0	0	0	0	0
1933	0.00	0	44.0	0.00	0	0.00	0	0	0	0	0
1934	0.00	0	0.00	2.00	0	0.00	0	0	0	0	0
1936	60.00	0	30.00	0.00	0	18.00	0	0	0	0	0
1938	0.00	0	2.00	0.00	0	0.00	0	0	0	0	0
1939	0.00	0	96.00	0.00	0	0.00	0	0	0	0	0
1931–1939	10.00	0	33.67	0.33	0	3.00	0	0	0	0	0
1941	0.00	0	40.00	0.00	0	0.00	0	0	0	0	0
1943	0.00	0	0.00	0.00	0	0.00	0	0	0	0	0
1945	6.00	0	0.00	0.00	0	0.00	0	0	0	0	0
1946	0.00	0	80.00	0.00	0	0.00	0	0	0	0	0
1948	0.00	0	0.00	0.00	0	0.00	-	0	0	0	0
1950	0.00	0	0.00	0.00	0	0.00	0	0	0	0	0
1941–1950	1.00	0	20.00	0.00	0	0.00	0	0	0	0	0
2000	0.00	0	0.00	0.00	0	0.00	0	0	0	0	0
2001	0.00	0	0.00	0.00	0	0.00	0	0	0	0	0
2000–2001	0.00	0	0.00	0.00	0	0.00	0	0	0	0	0
2143	0.00	0	28.00	0.00	0	0.00	0	0	0	0	0
2145	4.00	0	2.00	4.00	0	0.00	0	0	0	0	0
2147	2.00	0	36.00	0.00	0	0.00	0	0	0	0	0
2148	0.00	0	54.00	0.00	0	0.00	0	0	0	0	0
2150	6.00	0	6.00	0.00	0	0.00	0	0	0	0	0
2152	0.00	0	2.00	0.00	0	0.00	0	0	0	0	0
2143–2152	2.00	0	21.33	0.67	0	0.00	0	0	0	0	0
1931–2152	3.90	0.00	22.50	0.30	0	0.90	0	0	0	0	0

TABLE 2. PERCENTAGE FREQUENCY OF OCCURRENCE OF SIGNIFICANT EVENTS FOR 5-sec INTERVALS AT 120 TO 90 m LAYER

Interval	Shear		VM	Shears	Shear(s) and Vertical Motion		
UT	Sp	Dir	Up Down	Sp Dir	Sp Up Down	Dir Up Down	Sp Dir Up Down
hr min ≥	0.1 s^{-1} / 3 m s^{-1}/30 m / 6 kt/100 ft	1.0 deg m^{-1} / 30 deg/30 m / 30 deg/100 ft	1.0 m s^{-1} / 2.0 kts	0.1 s^{-1} / 1.0 deg m^{-1}	0.1 s^{-1} / 1.0 m s^{-1}	1.0 deg m^{-1} / 1.0 m s^{-1}	0.1 s^{-1} / 1.0 deg m^{-1} / 1.0 m s^{-1}
1931	38.00	2.00		0.00			
1933	0.00	10.00		0.00			
1934	30.00	2.00		2.00			
1936	4.00	0.00		0.00			
1938	0.00	0.00		0.00			
1939	0.00	4.00		0.00			
1931–1939	12.00	3.00		0.33			
1941	0.00	2.00		0.00			
1943	16.00	0.00		0.00			
1945	8.00	6.00		2.00			
1946	0.00	0.00		0.00			
1948	0.00	0.00		0.00			
1950	26.00	0.00		0.00			
1941–1950	8.33	1.33		0.33			
2000	0.00	0.00		0.00			
2001	0.00	0.00		0.00			
2000–2001	0.00	0.00		0.00			
2143	14.00	12.00		0.00			
2145	6.00	0.00		0.00			
2147	6.00	2.00		0.00			
2148	0.00	0.00		0.00			
2150	4.00	0.00		0.00			
2152	0.00	0.00		0.00			
2143–2152	5.00	2.33		0.00			
1931–2152	7.60	2.00		0.20			

TABLE 3. PERCENTAGE FREQUENCY OF OCCURRENCE OF SIGNIFICANT EVENTS FOR 5-sec INTERVALS AT 90 TO 60 m LAYER

Interval	Shear		VM		Shears	Shear(s) and Vertical Motion					
UT	Sp	Dir	Up	Down	Sp Dir	Sp Up	Sp Down	Dir Up	Dir Down	Sp Dir Up	Sp Dir Down
hr min >	0.1 s^{-1} / 3 m s^{-1}/30 m / 6 kt/100 ft	1.0 deg m^{-1} / 30 deg/30 m / 30 deg/100 ft	1.0 m s^{-1} / 2.0 kts		0.1 s^{-1} / 1.0 deg m^{-1}	0.1 s^{-1} / 1.0 m s^{-1}		1.0 deg m^{-1} / 1.0 m s^{-1}		0.1 s^{-1} / 1.0 deg m^{-1} / 1.0 m s^{-1}	
1931	0.00	100.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1933	100.00	100.00	32.00	2.00	100.00	32.00	0.00	0.00	2.00	32.00	2.00
1934	28.00	100.00	0.00	0.00	28.00	0.00	0.00	0.00	0.00	0.00	0.00
1936	2.00	100.00	0.00	0.00	2.00	0.00	0.00	0.00	0.00	0.00	0.00
1938	0.00	100.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1939	0.00	100.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1931–1939	21.67	100.00	5.33	0.33	21.67	5.33	0.00	0.00	0.33	5.33	0.33
1941	0.00	100.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1943	0.00	100.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1945	0.00	100.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1946	0.00	100.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1948	6.00	100.00	0.00	0.00	6.00	0.00	0.00	0.00	0.00	0.00	0.00
1950	14.00	100.00	0.00	8.00	14.00	0.00	2.00	0.00	8.00	0.00	2.00
1941–1950	3.33	100.00	0.00	1.33	3.33	0.00	0.33	0.00	1.33	0.00	0.33
2000	0.00	100.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2001	0.00	100.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2000–2001	0.00	100.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2143	12.00	96.00	0.00	0.00	12.00	0.00	0.00	0.00	0.00	0.00	0.00
2145	32.00	38.00	12.00	0.00	10.00	6.00	0.00	8.00	0.00	2.00	0.00
2147	10.00	34.00	0.00	20.00	6.00	0.00	0.00	0.00	0.00	0.00	0.00
2148	28.00	70.00	0.00	14.00	6.00	0.00	12.00	0.00	4.00	0.00	2.00
2150	4.00	60.00	0.00	18.00	2.00	0.00	0.00	0.00	14.00	0.00	0.00
2152	54.00	78.00	0.00	14.00	36.00	0.00	14.00	0.00	6.00	0.00	6.00
2143–2152	23.33	62.67	2.00	11.00	12.00	1.00	4.33	1.33	4.00	0.33	1.33
1931–2152	14.50	88.80	2.20	3.80	11.10	1.90	1.40	0.40	1.70	1.70	0.60

TABLE 4. PERCENTAGE FREQUENCY OF OCCURRENCE OF SIGNIFICANT EVENTS FOR 5-sec INTERVALS AT 60 TO 30 m LAYER

Interval	Shear		VM		Shears	Shear(s) and Vertical Motion					
UT	Sp	Dir	Up	Down	Sp Dir	Sp Up	Sp Down	Dir Up	Dir Down	Sp Dir Up	Sp Dir Down
hr min ≥	0.1 s^{-1} / 3 m s^{-1}/30 m / 6 kt/100 ft	1.0 deg m^{-1} / 30 deg/30 m / 30 deg/100 ft	1.0 m s^{-1} / 2.0 kts		0.1 s^{-1} / 1.0 deg m^{-1}	0.1 s^{-1} / 1.0 m s^{-1}		1.0 deg m^{-1} / 1.0 m s^{-1}		0.1 s^{-1} / 1.0 deg m^{-1} / 1.0 m s^{-1}	
1931	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0		0	
1933	24.00	2.00	32.00	2.00	2.00	0.00	2.00	0		0	
1934	22.00	0.00	0.00	0.00	0.00	0.00	0.00	0		0	
1936	66.00	0.00	0.00	0.00	0.00	0.00	0.00	0		0	
1938	78.00	0.00	0.00	0.00	0.00	0.00	0.00	0		0	
1939	76.00	0.00	0.00	0.00	0.00	0.00	0.00	0		0	
1931–1939	44.33	0.33	5.33	0.33	0.33	0.00	0.33	0		0	
1941	18.00	0.00	0.00	0.00	0.00	0.00	0.00	0		0	
1943	70.00	0.00	0.00	0.00	0.00	0.00	0.00	0		0	
1945	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0		0	
1946	24.00	0.00	0.00	0.00	0.00	0.00	0.00	0		0	
1948	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0		0	
1950	0.00	0.00	0.00	8.00	0.00	0.00	0.00	0		0	
1941–1950	18.67	0.00	0.00	1.33	0.00	0.00	0.00	0		0	
2000	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0		0	
2001	100.00	0.00	0.00	0.00	0.00	0.00	0.00	0		0	
2000–2001	51.00	0.00	0.00	0.00	0.00	0.00	0.00	0		0	
2143	92.00	18.00	0.00	0.00	14.00	0.00	0.00	0.00	0.00	0.00	0.00
2145	78.00	60.00	12.00	0.00	50.00	8.00	0.00	6.00	0.00	6.00	0.00
2147	86.00	24.00	0.00	20.00	24.00	0.00	18.00	0.00	0.00	0.00	0.00
2148	98.00	92.00	0.00	14.00	90.00	0.00	12.00	0.00	12.00	0.00	10.00
2150	30.00	44.00	0.00	18.00	18.00	0.00	14.00	0.00	14.00	0.00	14.00
2152	44.00	66.00	0.00	14.00	34.00	0.00	4.00	0.00	4.00	0.00	0.00
2143–2152	71.33	50.67	2.00	11.00	38.33	1.33	8.00	1.00	5.00	1.00	4.00
1931–2152	45.40	15.30	2.20	3.80	11.60	0.40	2.50	0.30	1.50	0.30	1.20

TABLE 5. PERCENTAGE FREQUENCY OF OCCURRENCE OF SIGNIFICANT EVENTS FOR 5-sec INTERVALS AT 30 TO 18T m LAYER

Interval	Shear		VM		Shears	Shear(s) and Vertical Motion					
UT	Sp	Dir	Up	Down	Sp Dir	Sp Up	Sp Down	Dir Up	Dir Down	Sp Dir Up	Sp Dir Down
hr min ≥	0.1 s^{-1} 1.2 m s^{-1}/12 m 2.3 kt/40 ft	1.0 deg m^{-1} 12 deg/12m 12 deg/40 ft	1.0 m s^{-1} 2.0 kts		0.1 s^{-1} 1.0 deg m^{-1}	0.1 s^{-1} 1.0 m s^{-1}		1.0 deg m^{-1} 1.0 m s^{-1}		0.1 s^{-1} 1.0 deg m^{-1} 1.0 m s^{-1}	
1931	48.00	100.00	24.00	22.00	48.00	12.00	12.00	24.00	22.00	12.00	12.00
1933	20.00	100.00	92.00	0.00	20.00	16.00	0.00	92.00	0.00	16.00	0.00
1934	72.00	100.00	62.00	0.00	72.00	42.00	0.00	62.00	0.00	42.00	0.00
1936	32.00	100.00	40.00	0.00	32.00	16.00	0.00	40.00	0.00	16.00	0.00
1938	36.00	100.00	86.00	0.00	36.00	36.00	0.00	86.00	0.00	36.00	0.00
1939	22.00	100.00	56.00	0.00	22.00	8.00	0.00	56.00	0.00	8.00	0.00
1931–1939	38.33	100.00	60.00	3.67	38.33	21.67	2.00	60.00	3.67	21.67	2.00
1941	50.00	100.00	18.00	0.00	50.00	16.00	0.00	18.00	0.00	16.00	0.00
1943	52.00	100.00	80.00	0.00	52.00	38.00	0.00	80.00	0.00	38.00	0.00
1945	38.00	100.00	16.00	8.00	38.00	0.00	8.00	16.00	8.00	0.00	8.00
1946	84.00	100.00	44.00	0.00	84.00	34.00	0.00	44.00	0.00	34.00	0.00
1948	32.00	100.00	38.00	0.00	32.00	10.00	0.00	38.00	0.00	10.00	0.00
1950	12.00	100.00	76.00	0.00	12 00	12.00	0.00	76.00	0.00	12.00	0.00
1941–1950	44.67	100.00	45.33	1.33	44.67	18.33	1.33	45.33	1.33	18.33	1.33
2000	82.00	100.00	12.00	0.00	82.00	12.00	0.00	12.00	0.00	12.00	0.00
2001	10.00	100.00	82.00	0.00	10.00	10.00	0.00	82.00	0.00	10.00	0.00
2000–2001	46.00	100.00	47.00	0.00	46.00	11.00	0.00	47.00	0.00	11.00	0.00
2143	54.00	84.00	6.00	0.00	46.00	4.00	0.00	6.00	0.00	4.00	0.00
2145	90.00	36.00	74.00	0.00	36.00	72.00	0.00	32.00	0.00	32.00	0.00
2147	56.00	56.00	0.00	4.00	38.00	0.00	0.00	0.00	4.00	0.00	0.00
2148	40.00	78.00	0.00	8.00	24.00	0.00	2.00	0.00	8.00	0.00	2.00
2150	68.00	30.00	32.00	2.00	26.00	26.00	0.00	10.00	0.00	6.00	0.00
2152	58.00	94.00	0.00	24.00	52.00	0.00	16.00	0.00	24.00	0.00	16.00
2143–2152	61.00	63.00	18.67	6.33	37.00	17.00	3.00	8.00	6.00	7.00	3.00
1931–2152	47.80	88.90	41.90	3.40	40.60	18.20	1.90	38.70	3.30	15.20	1.90

TABLE 6. PERCENTAGE FREQUENCY OF OCCURRENCE OF SIGNIFICANT EVENTS FOR 5-sec INTERVALS AT 18S TO 3 m LAYER

Interval	Shear		VM		Shears	Shear(s) and Vertical Motion					
UT	Sp	Dir	Up	Down	Sp Dir	Sp Up	Sp Down	Dir Up	Dir Down	Sp Dir Up	Sp Dir Down
hr min ≥	0.1 s^{-1} / 1.5 m s^{-1}/15 m / 3 kt/50 ft	1.0 deg m^{-1} / 15 deg/15m / 15 deg/50 ft	1.0 m s^{-1} / 2.0 kts		0.1 s^{-1} / 1.0 deg m^{-1}	0.1 s^{-1} / 1.0 m s^{-1}		1.0 deg m^{-1} / 1.0 m s^{-1}		0.1 s^{-1} / 1.0 deg m^{-1} / 1.0 m s^{-1}	
1931	0.00	26.00	50.00	0.00	0.00	0.00	0.00	4.00	0.00	0.00	0.00
1933	52.00	72.00	4.00	0.00	42.00	4.00	0.00	4.00	0.00	4.00	0.00
1934	76.00	72.00	4.00	0.00	58.00	4.00	0.00	4.00	0.00	4.00	0.00
1936	84.00	50.00	4.00	0.00	48.00	2.00	0.00	2.00	0.00	2.00	0.00
1938	100.00	38.00	30.00	0.00	38.00	30.00	0.00	8.00	0.00	8.00	0.00
1939	40.00	100.00	0.00	0.00	40.00	0.00	0.00	0.00	0.00	0.00	0.00
1931–1939	58.67	59.67	15.33	0.00	37.67	6.67	0.00	3.67	0.00	3.00	0.00
1941	58.00	38.00	24.00	0.00	22.00	14.00	0.00	4.00	0.00	4.00	0.00
1943	96.00	80.00	24.00	0.00	76.00	22.00	0.00	14.00	0.00	12.00	0.00
1945	96.00	98.00	0.00	0.00	96.00	0.00	0.00	0.00	0.00	0.00	0.00
1946	52.00	38.00	0.00	0.00	18.00	0.00	0.00	0.00	0.00	0.00	0.00
1948	100.00	50.00	4.00	4.00	50.00	4.00	4.00	2.00	4.00	2.00	4.00
1950	100.00	48.00	78.00	0.00	48.00	78.00	0.00	38.00	0.00	38.00	0.00
1941–1950	83.67	58.67	21.00	0.67	51.67	19.67	0.67	9.67	0.67	9.33	0.67
2000	62.00	78.00	0.00	0.00	40.00	0.00	0.00	0.00	0.00	0.00	0.00
2001	64.00	72.00	18.00	0.00	44.00	4.00	0.00	6.00	0.00	0.00	0.00
2000–2001	63.00	75.00	9.00	0.00	42.00	2.00	0.00	3.00	0.00	0.00	0.00
2143	100.00	80.00	18.00	16.00	80.00	18.00	16.00	18.00	14.00	18.00	14.00
2145	86.00	94.00	6.00	0.00	80.00	6.00	0.00	6.00	0.00	6.00	0.00
2147	100.00	66.00	2.00	6.00	66.00	2.00	6.00	2.00	0.00	2.00	0.00
2148	94.00	84.00	16.00	22.00	78.00	16.00	22.00	10.00	18.00	10.00	18.00
2150	100.00	52.00	26.00	8.00	52.00	26.00	8.00	12.00	0.00	12.00	0.00
2152	100.00	50.00	0.00	16.00	50.00	0.00	16.00	0.00	8.00	0.00	8.00
2143–2152	96.67	71.00	11.33	11.33	67.67	11.33	11.33	8.00	6.67	8.00	6.67
1931–2152	78.00	64.30	15.20	3.60	51.30	11.50	3.60	6.70	2.20	6.10	2.20

TABLE 7. PERCENTAGE FREQUENCY OF OCCURRENCE OF SIGNIFICANT EVENTS FOR 5-sec INTERVALS AT 18T TO 18S m DISTANCE

Interval	Shear		VM		Shears	Shear(s) and Vertical Motion					
UT	Sp	Dir	Up	Down	Sp Dir	Sp Up	Sp Down	Dir Up	Dir Down	Sp Dir Up	Sp Dir Down
hr min ≥	$0.1\ s^{-1}$ / $1.8\ m\ s^{-1}$/18 m / 3.5 kt/60 ft	1.0 deg m^{-1} / 18 deg/18m / 18 deg/60 ft	$1.0\ m\ s^{-1}$ / 2.0 kts		$0.1\ s^{-1}$ / 1.0 deg m^{-1}	$0.1\ s^{-1}$ / $1.0\ m\ s^{-1}$		1.0 deg m^{-1} / $1.0\ m\ s^{-1}$		$0.1\ s^{-1}$ / 1.0 deg m^{-1} / $1.0\ m\ s^{-1}$	
1931	100.00	6.00	24.00	22.00	6.00	24.00	22.00	0.00	2.00	0.00	2.00
1933	50.00	6.00	92.00	0.00	6.00	44.00	0.00	6.00	0.00	6.00	0.00
1934	40.00	10.00	62.00	0.00	0.00	28.00	0.00	6.00	0.00	0.00	0.00
1936	42.00	16.00	40.00	0.00	2.00	30.00	0.00	0.00	0.00	0.00	0.00
1938	12.00	8.00	86.00	0.00	0.00	10.00	0.00	8.00	0.00	0.00	0.00
1939	30.00	10.00	56.00	0.00	0.00	14.00	0.00	2.00	0.00	0.00	0.00
1931–1939	45.67	9.33	60.00	3.67	2.33	25.00	3.67	3.67	0.33	1.00	0.33
1941	74.00	6.00	18.00	0.00	6.00	12.00	0.00	0.00	0.00	0.00	0.00
1943	14.00	28.00	80.00	0.00	2.00	14.00	0.00	24.00	0.00	2.00	0.00
1945	16.00	12.00	16.00	8.00	0.00	0.00	2.00	8.00	0.00	0.00	0.00
1946	56.00	0.00	44.00	0.00	0.00	20.00	0.00	0.00	0.00	0.00	0.00
1948	78.00	2.00	38.00	0.00	2.00	36.00	0.00	2.00	0.00	2.00	0.00
1950	4.00	4.00	76.00	0.00	0.00	4.00	0.00	4.00	0.00	0.00	0.00
1941–1950	40.33	8.67	45.33	1.33	1.67	14.33	0.33	6.33	0.00	0.67	0.00
2000	58.00	28.00	12.00	0.00	6.00	0.00	0.00	4.00	0.00	0.00	0.00
2001	94.00	28.00	82.00	0.00	28.00	82.00	0.00	24.00	0.00	24.00	0.00
2000–2001	76.00	28.00	47.00	0.00	17.00	41.00	0.00	14.00	0.00	12.00	0.00
2143	58.00	12.00	6.00	0.00	12.00	6.00	0.00	0.00	0.00	0.00	0.00
2145	56.00	36.00	74.00	0.00	22.00	46.00	0.00	26.00	0.00	20.00	0.00
2147	88.00	8.00	0.00	4.00	6.00	0.00	2.00	0.00	4.00	0.00	2.00
2148	44.00	16.00	0.00	8.00	2.00	0.00	2.00	0.00	0.00	0.00	0.00
2150	94.00	24.00	32.00	2.00	24.00	26.00	2.00	4.00	0.00	4.00	0.00
2152	52.00	0.00	0.00	24.00	0.00	0.00	20.00	0.00	0.00	0.00	0.00
2143–2152	65.33	16.00	18.67	6.33	11.00	13.00	4.33	5.00	0.67	4.00	0.33
1931–2152	53.00	13.00	41.90	3.40	6.20	19.80	2.50	5.90	0.30	2.90	0.20

TABLE 8. PERCENTAGE FREQUENCY OF OCCURRENCE OF SIGNIFICANT EVENTS BY LAYERS/DISTANCE AND 10-min INTERVALS

		Wind Shear		Vertical Motion		Shears	Shear(s) and Vertical Motion					
Layer/ Distance m	Interval UT	Sp $\geq$ 0.1 s^{-1}	Dir $\geq$ 1.0 deg m^{-1}	Up $\geq$ 1.0 m s^{-1}	Down $\geq$ 1.0 m s^{-1}	Sp Dir $\geq$ 0.1 s^{-1} 1.0 deg m^{-1}	Sp Up $\geqslant$ 0.1 s^{-1} 1.0 m s^{-1}	Sp Down $\geqslant$ 0.1 s^{-1} 1.0 m s^{-1}	Dir Up $\geqslant$ 1.0 deg m^{-1} 1.0 m s^{-1}	Dir Down $\geqslant$ 1.0 deg m^{-1} 1.0 m s^{-1}	Sp Up Dir $\geqslant$ 0.1 s^{-1} 1.0 deg m^{-1} 1.0 m s^{-1}	Sp Down Dir $\geqslant$ 0.1 s^{-1} 1.0 deg m^{-1} 1.0 m s^{-1}
150–120	1931–1939	10.00	0	33.67	0.33	0	3.00	0	0		0	
	1941–1950	1.00	0	20.00	0.00	0	0.00	0	0		0	
	2000–2001	0.00	0	0.00	0.00	0	0.00	0	0		0	
	2143–2152	2.00	0	21.33	0.67	0	0.00	0	0		0	
	1931–2152	3.90	0	22.50	0.30	0	0.90	0	0		0	
120–90	1931–1939	12.00	3.00	–	–	0.33	–		–		–	
	1941–1950	8.33	1.33	–	–	0.33	–		–		–	
	2000–2001	0.00	0.00	–	–	0.00	–		–		–	
	2143–2152	5.00	2.33	–	–	0.00	–		–		–	
	1931–2152	7.60	2.00	–	–	0.20	–		–		–	
90–60	1931–1939	21.67	100.00	5.33	0.33	21.67	5.33	0.00	0.00	0.33	5.33	0.33
	1941–1950	3.33	100.00	0.00	1.33	3.33	0.00	0.33	0.00	1.33	0.00	0.33
	2000–2001	0.00	100.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	2143–2152	23.33	62.67	2.00	11.00	12.00	1.00	4.33	1.33	4.00	0.33	1.33
	1931–2152	14.50	88.80	2.20	3.80	11.10	1.90	1.40	0.40	1.70	1.70	0.60
60–30	1931–1939	44.33	0.33	5.33	0.33	0.33	0.00	0.33	0.00	0.00	0.00	0.00
	1941–1950	18.67	0.00	0.00	1.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	2000–2001	51.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	2143–2152	71.33	50.67	2.00	11.00	38.33	1.33	8.00	1.00	5.00	1.00	4.00
	1931–2152	45.40	15.30	2.20	3.80	11.60	0.40	2.50	0.30	1.50	0.30	1.20
30–18T	1931–1939	38.33	100.00	60.00	3.67	38.33	21.67	2.00	60.00	3.67	21.67	2.00
	1941–1950	44.67	100.00	45.33	1.33	44.67	18.33	1.33	45.33	1.33	18.33	1.33
	2000–2001	46.00	100.00	47.00	0.00	46.00	11.00	0.00	47.00	0.00	11.00	0.00
	2143–2152	61.00	63.00	18.67	6.33	37.00	17.00	3.00	8.00	6.00	7.00	3.00
	1931–2152	47.80	88.90	41.90	3.40	40.60	18.20	1.90	38.70	3.30	15.20	1.90
18S–3	1931–1939	58.67	59.67	15.33	0.00	37.67	6.67	0.00	3.67	0.00	3.00	0.00
	1941–1950	83.67	58.67	21.00	0.67	51.67	19.67	0.67	9.67	0.67	9.33	0.67
	2000–2001	63.00	75.00	9.00	0.00	42.00	2.00	0.00	3.00	0.00	0.00	0.00
	2143–2152	96.67	71.00	11.33	11.33	67.67	11.33	11.33	8.00	6.67	8.00	6.67
	1931–2152	78.00	64.30	15.20	3.60	51.30	11.50	3.60	6.70	2.20	6.10	2.20
18T–18S	1931–1939	45.67	9.33	69.00	3.67	2.33	25.00	3.67	3.67	0.33	1.00	0.33
	1941–1950	40.33	8.67	45.33	1.33	1.67	14.33	0.33	6.33	0.00	0.67	0.00
	2000–2001	76.00	28.00	47.00	0.00	17.00	41.00	0.00	14.00	0.00	12.00	0.00
	2143–2152	65.33	16.00	18.67	6.33	11.00	13.00	4.33	5.00	0.67	4.00	0.33
	1931–2152	53.00	13.00	41.90	3.40	6.20	19.80	2.50	5.90	0.30	2.90	0.20

TABLE 9. MAXIMUM, MEAN, AND STANDARD DEVIATION OF SPEED AND DIRECTION SHEARS FOR 150 TO 120 m LAYER

Layer m	Interval UT hr min	sec	Wind Shears: Speed s^{-1} ($m\ s^{-1}$/30 m or 2 ($m\ s^{-1}$)/100 ft) Max	Mean	Std Dev	Direction deg m^{-1} (deg/30 m or deg/100 ft) Max	Mean	Std Dev
150–120	19 31	16.0–20.9	0.080	0.028	0.020	0.200	0.083	0.059
	19 33	16.0–20.9	0.090	0.021	0.017	0.267	0.167	0.198
	19 34	56.0–00.9	0.070	0.034	0.022	0.367	0.199	0.085
	19 36	36.0–40.9	0.160	0.106	0.023	0.333	0.119	0.084
	19 38	16.0–20.9	0.070	0.026	0.018	0.210	0.119	0.046
	19 39	56.0–00.9	0.080	0.024	0.022	0.333	0.091	0.083
	19 41	41.0–45.9	0.057	0.023	0.016	0.367	0.162	0.110
	19 43	21.0–25.9	0.057	0.022	0.015	0.367	0.140	0.087
	19 45	01.0–05.9	0.130	0.037	0.031	0.233	0.092	0.061
	19 46	41.0–45.9	0.067	0.028	0.016	0.233	0.090	0.065
	19 48	21.0–25.9	0.053	0.024	0.015	0.367	0.143	0.076
	19 50	01.0–05.9	0.070	0.019	0.017	0.367	0.141	0.107
	20 00	06.0–10.9	0.057	0.022	0.013	0.400	0.212	0.085
	20 01	51.0–55.9	0.063	0.030	0.013	0.233	0.108	0.064
	21 43	47.0–51.9	0.070	0.028	0.017	0.333	0.139	0.088
	21 45	27.0–31.9	0.103	0.035	0.029	0.533	0.225	0.126
	21 47	07.0–11.9	0.103	0.033	0.027	0.400	0.201	0.067
	21 48	47.0–51.9	0.063	0.019	0.016	0.333	0.233	0.041
	21 50	32.0–36.9	0.130	0.043	0.032	0.633	0.374	0.132
	21 52	12.0–16.9	0.047	0.016	0.012	0.500	0.308	0.155

m	hr min sec	hr min sec	Speed s^{-1} Max	Mean	Std Dev	Direction deg m^{-1} Max	Mean	Std Dev
150–120	1931 16.0	19 40 00.9	0.160	0.040	0.020	0.367	0.130	0.093
	1941 41.0	19 50 05.9	0.130	0.026	0.018	0.367	0.128	0.084
	2000 06.0	20 01 55.9	0.063	0.026	0.013	0.400	0.160	0.075
	2143 47.0	21 52 16.9	0.130	0.029	0.022	0.633	0.247	0.102
	19 31 16.0	21 52 16.9	0.160	0.030	0.018	0.633	0.166	0.089

TABLE 10. MAXIMUM, MEAN, AND STANDARD DEVIATION OF SPEED AND DIRECTION SHEARS FOR 120 TO 90 m LAYER

Layer m	Interval UT hr min	sec	Wind Shears: Speed s^{-1} ($m\ s^{-1}$/30 m or 2 ($m\ s^{-1}$)/100 ft) Max	Mean	Std Dev	Direction deg m^{-1} (deg/30 m or deg/100 ft) Max	Mean	Std Dev
120–90	19 31	16.0–20.9	0.173	0.086	0.047	1.000	0.669	0.217
	19 33	16.0–20.9	0.047	0.015	0.011	1.200	0.823	0.126
	19 34	56.0–00.9	0.140	0.078	0.032	1.100	0.503	0.199
	19 36	36.0–40.9	0.123	0.045	0.030	0.933	0.641	0.118
	19 38	16.0–20.9	0.040	0.017	0.011	0.867	0.770	0.048
	19 39	56.0–00.9	0.043	0.013	0.011	1.033	0.828	0.102
	19 41	41.0–45.9	0.093	0.042	0.022	1.033	0.773	0.099
	19 43	21.0–25.9	0.110	0.080	0.020	0.900	0.707	0.094
	19 45	01.0–05.9	0.110	0.058	0.028	1.133	0.726	0.225
	19 46	41.0–45.9	0.077	0.026	0.020	0.833	0.615	0.093
	19 48	21.0–25.9	0.080	0.044	0.015	0.767	0.637	0.068
	19 50	01.0–05.9	0.123	0.080	0.024	0.800	0.645	0.097
	20 00	06.0–10.9	0.057	0.019	0.010	0.833	0.627	0.081
	20 01	51.0–55.9	0.070	0.023	0.019	0.767	0.579	0.106
	21 43	47.0–51.9	0.133	0.066	0.031	1.067	0.763	0.185
	21 45	27.0–31.9	0.127	0.045	0.033	0.867	0.737	0.680
	21 47	07.0–11.9	0.117	0.050	0.030	1.067	0.712	0.115
	21 48	47.0–51.9	0.057	0.026	0.015	0.833	0.716	0.072
	21 50	32.0–36.9	0.113	0.033	0.027	0.967	0.671	0.143
	21 52	12.0–16.9	0.083	0.020	0.021	0.083	0.695	0.076

m	hr min sec	hr min sec	Speed s^{-1} Max	Mean	Std Dev	Direction deg m^{-1} Max	Mean	Std Dev
120–90	19 31 16.0	19 40 00.9	0.173	0.042	0.024	1.200	0.706	0.135
	19 41 41.0	19 50 05.9	0.123	0.055	0.022	1.133	0.684	0.113
	20 00 06.0	20 01 55.9	0.070	0.021	0.015	0.833	0.603	0.094
	21 43 47.0	21 52 16.9	0.133	0.040	0.026	1.067	0.716	0.212
	19 31 16.0	21 52 16.9	0.173	0.040	0.022	1.200	0.677	0.139

TABLE 11. MAXIMUM, MEAN, AND STANDARD DEVIATION OF SPEED AND DIRECTION SHEARS FOR 90 TO 60 m LAYER

Layer m	Interval UT hr min	sec	Wind Shears: Speed s^{-1} ($m\ s^{-1}$/30 m or 2 ($m\ s^{-1}$)/100 ft) Max	Mean	Std Dev	Direction deg m^{-1} (deg/30 m or deg/100 ft) Max	Mean	Std Dev
90–60	19 31	16.0–20.9	0.093	0.029	0.025	2.867	2.638	0.161
	19 33	16.0–20.9	0.327	0.217	0.047	2.800	2.541	0.135
	19 34	56.0–00.9	0.153	0.073	0.044	2.867	2.546	0.180
	19 36	36.0–40.9	0.107	0.038	0.026	3.167	2.873	0.126
	19 38	16.0–20.9	0.070	0.031	0.020	2.833	2.685	0.064
	19 39	56.0–C	0.083	0.040	0.021	3.133	2.815	0.154
	19 41	41.0–45.9	0.063	0.031	0.017	2.933	2.673	0.108
	19 43	21.0–25.9	0.057	0.021	0.015	2.967	2.642	0.115
	19 45	01.0–05.9	0.077	0.022	0.016	3.067	2.753	0.365
	19 46	41.0–45.9	0.057	0.027	0.013	2.900	2.737	0.070
	19 48	21.0–25.9	0.103	0.044	0.028	2.633	2.327	0.160
	19 50	01.0–05.9	0.127	0.075	0.022	3.033	2.699	0.168
	20 00	06.0–10.9	0.087	0.042	0.023	2.833	2.654	0.130
	20 01	51.0–55.9	0.043	0.014	0.010	2.867	2.711	0.062
	21 43	47.0–51.9	0.163	0.045	0.039	1.567	1.349	0.176
	21 45	27.0–31.9	0.190	0.083	0.047	1.233	0.905	0.176
	21 47	07.0–11.9	0.130	0.054	0.033	1.400	0.928	0.220
	21 48	47.0–51.9	0.177	0.079	0.037	1.267	1.023	0.134
	21 50	32.0–36.9	0.130	0.043	0.032	1.333	1.011	0.175
	21 52	12.0–16.9	0.157	0.094	0.033	1.267	1.049	0.109

m	hr min sec	hr min sec	Speed s^{-1} Max	Mean	Std Dev	Direction deg m^{-1} Max	Mean	Std Dev
90–60	19 31 16.0	19 40 00.9	0.327	0.071	0.031	3.167	2.683	0.137
	19 41 41.0	19 50 05.9	0.127	0.037	0.019	3.067	2.639	0.164
	20 00 06.0	20 01 55.9	0.087	0.028	0.017	2.867	2.683	0.096
	21 43 47.0	21 52 16.9	0.190	0.066	0.037	1.567	1.044	0.165
	19 31 16.0	21 52 16.9	0.327	0.051	0.026	3.167	2.262	0.141

TABLE 12. MAXIMUM, MEAN, AND STANDARD DEVIATION OF SPEED AND DIRECTION SHEARS FOR 60 TO 30 m LAYER

Layer m	Interval UT hr min	sec	Wind Shears: Speed s^{-1} ($m\ s^{-1}$/30 m or 2 ($m\ s^{-1}$)/100 ft) Max	Mean	Std Dev	Direction deg m^{-1} (deg/30 m or deg/100 ft) Max	Mean	Std Dev
60–30	19 31	16.0–20.9	0.063	0.029	0.016	0.833	0.419	0.208
	19 33	16.0–20.9	0.157	0.061	0.042	1.200	0.337	0.268
	19 34	56.0–00.9	0.200	0.057	0.057	0.900	0.339	0.275
	19 36	36.0–40.9	0.210	0.113	0.065	0.467	0.150	0.123
	19 38	16.0–20.9	0.227	0.144	0.053	0.433	0.140	0.107
	19 39	56.0–00.9	0.200	0.116	0.030	0.833	0.349	0.225
	19 41	41.0–45.9	0.160	0.056	0.044	0.900	0.214	0.203
	19 43	21.0–25.9	0.190	0.114	0.028	0.867	0.235	0.190
	19 45	01.0–05.9	0.073	0.026	0.020	0.467	0.219	0.110
	19 46	41.0–45.9	0.143	0.064	0.040	0.500	0.148	0.108
	19 48	21.0–25.9	0.057	0.027	0.017	0.600	0.227	0.146
	19 50	01.0–05.9	0.043	0.017	0.011	0.967	0.412	0.257
	20 00	06.0–10.9	0.103	0.038	0.032	0.567	0.255	0.154
	20 01	51.0–55.9	0.200	0.159	0.019	0.933	0.317	0.220
	21 43	47.0–51.9	0.300	0.175	0.058	1.633	0.821	0.272
	21 45	27.0–31.9	0.247	0.139	0.049	1.933	1.097	0.435
	21 47	07.0–11.9	0.387	0.201	0.093	1.867	0.764	0.468
	21 48	47.0–51.9	0.303	0.190	0.059	1.633	1.284	0.190
	21 50	32.0–36.9	0.307	0.092	0.081	1.933	1.007	0.278
	21 52	12.0–16.9	0.143	0.079	0.042	1.533	1.072	0.251

m	hr min sec	hr min sec	Speed s^{-1} Max	Mean	Std Dev	Direction deg m^{-1} Max	Mean	Std Dev
60–30	19 31 16.0	19 40 00.9	0.227	0.087	0.044	1.200	0.289	0.201
	19 41 41.0	19 50 05.9	0.190	0.051	0.027	0.967	0.243	0.169
	20 00 06.0	20 01 55.9	0.200	0.099	0.026	0.933	0.286	0.187
	21 43 47.0	21 52 16.9	0.387	0.146	0.064	1.933	1.008	0.316
	19 31 16.0	21 52 16.9	0.387	0.096	0.040	1.933	0.457	0.218

TABLE 13. MAXIMUM, MEAN, AND STANDARD DEVIATION OF SPEED AND DIRECTION SHEARS FOR 30 TO 18T m LAYER

Layer m	Interval UT hr min	sec	Wind Shears: Speed s^{-1} ($m s^{-1}$/12 m or 2($m s^{-1}$) for kts/40 ft) Max	Mean	Std Dev	Direction deg m^{-1} (deg/12 m or deg/40 ft) Max	Mean	Std Dev
30–18T	19 31	16.0–20.9	0.325	0.120	0.086	9.583	7.973	0.711
	19 33	16.0–20.9	0.267	0.063	0.054	8.250	6.605	0.844
	19 34	56.0–00.9	0.642	0.241	0.172	6.833	5.660	0.469
	19 36	36.0–40.9	0.192	0.071	0.046	6.667	5.252	0.530
	19 38	16.0–20.9	0.383	0.093	0.094	7.833	6.292	0.840
	19 39	56.0–00.9	0.208	0.069	0.052	8.417	6.505	0.723
	19 41	41.0–45.9	0.325	0.118	0.087	8.500	6.457	0.622
	19 43	21.0–25.9	0.300	0.115	0.075	6.917	5.300	0.611
	19 45	01.0–05.9	0.333	0.115	0.092	7.167	5.987	0.421
	19 46	41.0–45.9	0.417	0.210	0.114	6.250	5.530	0.418
	19 48	21.0–25.9	0.225	0.078	0.061	5.833	5.048	0.518
	19 50	01.0–05.9	0.192	0.060	0.046	7.667	6.522	0.599
	20 00	06.0–10.9	0.350	0.196	0.093	6.667	4.867	0.736
	20 01	51.0–55.9	0.125	0.067	0.028	9.250	7.253	1.195
	21 43	47.0–51.9	0.300	0.122	0.091	4.000	1.712	0.848
	21 45	27.0–31.9	0.783	0.357	0.201	2.667	0.955	0.759
	21 47	07.0–11.9	0.417	0.160	0.132	3.583	1.352	0.998
	21 48	47.0–51.9	0.550	0.107	0.105	2.417	1.422	0.551
	21 50	32.0–36.9	0.792	0.292	0.245	3.167	0.811	0.720
	21 52	12.0–16.9	0.308	0.124	0.074	3.167	1.933	0.555
m	hr min sec	hr min sec	Speed s^{-1} Max	Mean	Std Dev	Direction deg m^{-1} Max	Mean	Std Dev
30–18T	19 31 16.0	19 40 00.9	0.642	0.110	0.084	9.583	6.381	0.686
	19 41 41.0	19 50 05.9	0.417	0.116	0.079	8.500	5.807	0.532
	20 00 06.0	20 01 55.9	0.350	0.132	0.061	9.250	6.060	0.966
	21 43 47.0	21 52 16.9	0.792	0.194	0.141	4.000	1.364	0.739
	19 31 16.0	21 52 16.9	0.792	0.138	0.091	9.583	4.903	0.731

TABLE 14. MAXIMUM, MEAN, AND STANDARD DEVIATION OF SPEED AND DIRECTION SHEARS FOR 18S TO 3 m LAYER

Layer m	Interval UT hr min	sec	Wind Shears: Speed s^{-1} ($m\ s^{-1}$/15 m or 2 ($m\ s^{-1}$) kts/50 ft) Max	Mean	Std Dev	Direction deg m^{-1} (deg/15 m or deg/50 ft) Max	Mean	Std Dev
18S–3	19 31	16.0–20.9	0.093	0.041	0.027	2.267	0.697	0.614
	19 33	16.0–20.9	0.327	0.121	0.098	3.867	1.486	0.881
	19 34	56.0–00.9	0.307	0.172	0.094	2.867	1.395	0.757
	19 36	36.0–40.9	0.413	0.235	0.129	2.667	1.091	0.612
	19 38	16.0–20.9	0.533	0.399	0.[illegible]	3.267	1.127	0.910
	19 39	56.0–00.9	0.273	0.107	0.[illegible]	3.200	2.200	0.627
	19 41	41.0–45.9	0.280	0.123	0.073	2.133	0.893	0.604
	19 43	21.0–25.9	0.293	0.190	0.057	3.400	1.589	0.845
	19 45	01.0–05.9	0.420	0.265	0.077	3.360	2.053	0.662
	19 46	41.0–45.9	0.193	0.103	0.047	1.800	0.877	0.458
	19 48	21.0–25.9	0.440	0.326	0.075	2.933	1.192	0.703
	19 50	01.0–05.9	0.327	0.256	0.033	2.267	0.981	0.669
	20 00	06.0–10.9	0.260	0.122	0.073	2.800	1.584	0.717
	20 01	51.0–55.9	0.300	0.143	0.090	2.933	1.373	0.645
	21 43	47.0–51.9	0.653	0.432	0.107	4.200	1.785	0.897
	21 45	27.0–31.9	0.693	0.313	0.169	5.733	2.735	1.305
	21 47	07.0–11.9	0.713	0.498	0.101	4.400	1.507	1.087
	21 48	47.0–51.9	0.680	0.367	0.160	4.400	2.064	1.008
	21 50	32.0–36.9	0.553	0.340	0.103	2.600	1.113	0.683
	21 52	12.0–16.9	0.640	0.366	0.126	2.667	1.006	0.683

m	hr min sec	hr min sec	Speed s^{-1} Max	Mean	Std Dev	Direction deg m^{-1} Max	Mean	Std Dev
18S–3	19 31 16.0	19 40 00.9	0.533	0.179	0.086	3.867	1.333	0.734
	19 41 41.0	19 50 05.9	0.440	0.211	0.060	3.400	1.264	0.657
	20 00 06.0	20 01 55.9	0.300	0.133	0.082	2.933	1.479	0.681
	21 43 47.0	21 52 16.9	0.713	0.386	0.128	5.733	1.702	0.944
	19 31 16.0	21 52 16.9	0.713	0.227	0.089	5.733	1.445	0.754

TABLE 15. MAXIMUM, MEAN, AND STANDARD DEVIATION OF SPEED AND DIRECTION SHEARS FOR 18T TO 18S m DISTANCE

Distance m	Interval UT hr min	sec	Wind Shears: Speed s^{-1} ($m\ s^{-1}$/18 m or 2 ($m\ s^{-1}$)/60 ft) Max	Mean	Std Dev	Direction deg m^{-1} (deg/18 m or deg/60 ft) Max	Mean	Std Dev
18T–18S	19 31	16.0–20.9	0.506	0.320	0.102	1.222	0.501	0.332
	19 33	16.0–20.9	0.161	0.087	0.049	1.389	0.358	0.313
	19 34	56.0–00.9	0.189	0.085	0.055	1.944	0.479	0.389
	19 36	36.0–40.9	0.300	0.102	0.085	1.444	0.574	0.386
	19 38	16.0–20.9	0.167	0.048	0.040	1.444	0.510	0.327
	19 39	56.0–00.9	0.161	0.072	0.039	1.667	0.521	0.369
	19 41	41.0–45.9	0.361	0.139	0.083	1.111	0.444	0.261
	19 43	21.0–25.9	0.133	0.049	0.034	1.611	0.692	0.421
	19 45	01.0–05.9	0.183	0.057	0.047	1.500	0.506	0.362
	19 46	41.0–45.9	0.183	0.115	0.061	0.722	0.289	0.216
	19 48	21.0–25.9	0.261	0.153	0.073	1.056	0.369	0.253
	19 50	01.0–05.9	0.106	0.044	0.025	1.222	0.499	0.280
	20 00	06.0–10.9	0.344	0.139	0.102	1.667	0.749	0.361
	20 01	51.0–55.9	0.228	0.171	0.039	2.000	0.721	0.442
	21 43	47.0–51.9	0.322	0.125	0.089	2.111	0.550	0.449
	21 45	27.0–31.9	0.356	0.134	0.104	3.111	0.962	0.724
	21 47	07.0–11.9	0.333	0.159	0.072	1.667	0.452	0.349
	21 48	47.0–51.9	0.256	0.092	0.073	1.611	0.529	0.410
	21 50	32.0–36.9	0.678	0.354	0.156	1.833	0.719	0.463
	21 52	12.0–16.9	0.183	0.094	0.049	0.889	0.335	0.222

m	hr min sec	hr min sec	Speed s^{-1} Max	Mean	Std Dev	Direction deg m^{-1} Max	Mean	Std Dev
18T–18S	19 31 16.0	19 40 00.9	0.506	0.119	0.062	1.944	0.491	0.353
	19 41 41.0	19 50 05.9	0.361	0.093	0.054	1.611	0.467	0.299
	20 00 06.0	20 01 55.9	0.344	0.155	0.071	2.000	0.735	0.402
	21 43 47.0	21 52 16.9	0.678	0.160	0.091	3.111	0.591	0.436
	19 31 16.0	21 52 16.9	0.678	0.132	0.070	3.111	0.571	0.373

TABLE 16. MAXIMUM, MEAN, AND STANDARD DEVIATION OF UPDRAFTS AND DOWNDRAFTS AT 150-m HEIGHT

Height (m) 150		Vertical Motion							
Interval UT		Up $m\ s^{-1}$ or 2 ($m\ s^{-1}$) for kts				Down $m\ s^{-1}$ or 2 ($m\ s^{-1}$) for kts			
hr	min sec	f	Max	Mean	Std Dev	f	Max	Mean	Std Dev
19	31 16.0–20.9	48	1.34	0.751	0.386	2	0.01	0.010	0.000
	33 16.0–20.9	36	2.45	1.190	0.750	14	0.76	0.348	0.265
	34 56.0–00.9	30	0.90	0.330	0.331	20	1.01	0.151	0.302
	36 36.0–40.9	42	1.34	0.690	0.483	8	0.10	0.041	0.029
	38 16.0–20.9	50	1.01	0.773	0.143	0	–	–	–
	39 56.0–00.9	50	2.20	1.582	0.309	0	–	–	–
19	41 41.0–45.9	44	1.90	0.900	0.467	6	0.29	0.168	0.104
	43 21.0–25.9	24	0.64	0.161	0.230	26	0.57	0.065	0.135
	45 01.0–05.9	10	0.69	0.244	0.217	40	0.71	0.409	0.214
	46 41.0–45.9	50	1.66	1.191	0.237	0	–	–	–
	48 21.0–25.9	30	0.55	0.167	0.175	20	0.29	0.097	0.101
	50 01.0–05.9	25	0.69	0.413	0.217	25	0.48	0.247	0.169
20	00 06.0–10.9	9	0.08	0.033	0.019	41	0.73	0.416	0.236
	01 51.0–55.9	38	0.97	0.349	0.308	12	0.05	0.017	0.013
21	43 47.0–51.9	49	1.90	0.828	0.299	1	0.08	0.080	0.000
	45 27.0–31.9	23	1.06	0.426	0.314	27	1.13	0.461	0.315
	47 07.0–11.9	50	1.62	0.889	0.336	0	–	–	–
	48 47.0–51.9	50	1.85	1.040	0.305	0	–	–	–
	50 32.0 –36.9	25	1.17	0.448	0.316	25	0.59	0.202	0.179
	52 12.0–16.9	50	1.01	0.624	0.239	0	–	–	–
		f	%	Max	Mean	Std Dev	f	%	Max	Mean	Std Dev
19	31–19 39	256	85.33	2.45	0.886	0.400	44	14.67	1.01	0.138	0.149
19	41–19 50	183	61.00	1.90	0.513	0.257	117	39.00	0.71	0.197	0.145
20	00–20 01	47	47.00	0.97	0.191	0.164	53	53.00	0.73	0.217	0.125
21	43–21 52	247	82.33	1.90	0.709	0.302	53	17.67	1.13	0.248	0.165
19	31–21 52	733	73.30	2.45	0.575	0.281	267	26.70	1.13	0.200	0.146

TABLE 17. MAXIMUM, MEAN, AND STANDARD DEVIATION OF UPDRAFTS AND DOWNDRAFTS AT 60-m HEIGHT

Height (m) 60		Vertical Motion							
	Interval UT	Up $m\ s^{-1}$ or 2 ($m\ s^{-1}$) for kts				Down $m\ s^{-1}$ or 2 ($m\ s^{-1}$) for kts			
hr	min sec	f	Max	Mean	Std Dev	f	Max	Mean	Std Dev
19	31 16.0–20.9	25	0.50	0.246	0.138	25	0.52	0.170	0.165
	33 16.0–20.9	31	4.04	1.582	1.296	19	2.01	0.406	0.481
	34 56.0–00.9	27	0.59	0.284	0.174	23	0.52	0.186	0.166
	36 36.0–40.9	29	0.59	0.302	0.168	21	0.55	0.283	0.204
	38 16.0–20.9	26	0.64	0.353	0.215	24	0.52	0.239	0.162
	39 56.0–00.9	30	0.59	0.255	0.165	20	0.38	0.232	0.121
19	41 41.0–45.9	28	0.55	0.277	0.176	22	0.41	0.195	0.128
	43 21.0–25.9	31	0.55	0.262	0.177	19	0.48	0.241	0.119
	45 01.0–05.9	27	0.59	0.318	0.208	23	0.43	0.237	0.157
	46 41.0–45.9	27	0.55	0.304	0.171	23	0.41	0.207	0.126
	48 21.0–25.9	29	0.59	0.231	0.169	21	0.41	0.179	0.136
	50 01.0–05.9	24	0.50	0.156	0.145	26	1.85	0.355	0.543
20	00 06.0–10.9	33	0.48	0.145	0.147	17	0.73	0.416	0.236
	01 51.0–55.9	28	0.50	0.274	0.161	22	0.48	0.217	0.130
21	43 47.0–51.9	21	0.78	0.369	0.241	29	0.94	0.445	0.304
	45 27.0–31.9	30	1.17	0.694	0.306	20	0.94	0.451	0.265
	47 07.0–11.9	9	0.41	0.167	0.129	41	1.83	0.573	0.533
	48 47.0–51.9	11	0.48	0.152	0.147	39	1.22	0.621	0.337
	50 32.0–36.9	12	0.27	0.142	0.076	38	1.50	0.656	0.456
	52 12.0–16.9	0	–	–	–	50	1.57	0.643	0.375
		f	%	Max	Mean	Std Dev	f	%	Max	Mean	Std Dev
	1931–1939	168	56.00	4.04	0.504	0.359	132	44.00	2.01	0.253	0.216
	1941–1950	166	55.33	0.59	0.258	0.174	134	44.67	1.85	0.236	0.202
	2000–2001	61	61.00	0.50	0.210	0.154	39	39.00	0.73	0.316	0.183
	2143–2152	83	27.67	1.17	0.305	0.180	217	72.33	1.83	0.565	0.378
	1931–2152	478	47.80	4.04	0.319	0.217	522	52.20	2.01	0.343	0.245

TABLE 18. MAXIMUM, MEAN, AND STANDARD DEVIATION OF UPDRAFTS AND DOWNDRAFTS AT 18T-m HEIGHT

Height (m) 18T		Vertical Motion							
	Interval UT	Up $m\ s^{-1}$ or 2 ($m\ s^{-1}$) for kts				Down $m\ s^{-1}$ or 2 ($m\ s^{-1}$) for kts			
hr	min sec	f	Max	Mean	Std Dev	f	Max	Mean	Std Dev
19	31 16.0–20.9	25	1.94	0.995	0.511	25	1.83	0.915	0.440
	33 16.0–20.9	50	2.83	1.690	0.590	0	–	–	–
	34 56.0–00.9	48	3.15	1.306	0.698	2	0.78	0.630	0.212
	36 36.0–40.9	38	2.55	1.032	0.719	12	0.48	0.203	0.173
	38 16.0–20.9	50	3.39	1.780	0.831	0	–	–	–
	39 56.0–00.9	47	1.80	1.056	0.537	3	0.24	0.133	0.116
19	41 41.0–45.9	26	1.71	0.807	0.472	24	0.90	0.333	0.236
	43 21.0–25.9	47	2.27	1.477	0.521	3	0.15	0.087	0.071
	45 01.0–05.9	25	1.41	0.706	0.412	25	1.45	0.474	0.440
	46 41.0–45.9	50	2.31	0.978	0.550	0	–	–	–
	48 21.0–25.9	49	2.15	0.904	0.503	1	0.10	0.10	0.000
	50 01.0–05.9	50	1.52	1.112	0.242	0	–	–	–
20	00 06.0–10.9	36	1.24	0.506	0.387	14	0.62	0.291	0.181
	01 51.0–55.9	50	2.08	1.364	0.485	0	–	–	–
21	43 47.0–51.9	20	1.43	0.631	0.419	30	0.83	0.491	0.232
	45 27.0–31.9	50	2.78	1.511	0.812	0	–	–	–
	47 07.0–11.9	16	0.69	0.321	0.203	34	1.34	0.459	0.346
	48 47.0–51.9	10	0.55	0.171	0.166	40	1.55	0.619	0.378
	50 32.0–36.9	39	3.50	1.137	0.884	11	1.04	0.546	0.253
	52 12.0–16.9	2	0.31	0.290	0.028	48	1.59	0.665	0.405
		f	%	Max	Mean	Std Dev	f	%	Max	Mean	Std Dev
	1931–1939	258	86.00	3.39	1.310	0.648	42	14.00	1.83	0.470	0.235
	1941–1950	247	82.33	2.31	0.997	0.450	53	17.67	1.45	0.248	0.187
	2000–2001	86	86.00	2.08	0.935	0.436	14	14.00	0.62	0.291	0.181
	2143–2152	137	45.67	3.50	0.677	0.419	163	54.33	1.59	0.556	0.323
	1931–2152	728	72.80	3.50	0.980	0.488	272	27.20	1.83	0.391	0.232

TABLE 19. MAXIMUM, MEAN, AND STANDARD DEVIATION OF UPDRAFTS AND DOWNDRAFTS AT 10-m HEIGHT

Height (m) 10		Vertical Motion							
Interval UT		Up $m\ s^{-1}$ or 2 ($m\ s^{-1}$) for kts				Down $m\ s^{-1}$ or 2 ($m\ s^{-1}$) for kts			
hr	min sec	f	Max	Mean	Std Dev	f	Max	Mean	Std Dev
19	31 16.0–20.9	50	1.80	1.086	0.402	0	–	–	–
	33 16.0–20.9	44	1.04	0.631	0.274	6	0.48	0.240	0.172
	34 56.0–00.9	43	1.06	0.469	0.266	7	0.34	0.164	0.127
	36 36.0–40.9	37	1.08	0.448	0.323	13	0.29	0.155	0.104
	38 16.0–20.9	45	1.78	0.883	0.357	5	0.43	0.174	0.159
	39 56.0–00.9	32	0.87	0.460	0.244	18	0.73	0.243	0.201
19	41 41.0–45.9	41	1.80	0.681	0.597	9	0.24	0.123	0.097
	43 31.0–25.9	48	1.57	0.704	0.427	2	0.03	0.030	0.000
	45 01.0–05.9	37	1.43	0.547	0.376	13	0.71	0.306	0.234
	46 41.0–45.9	16	0.41	0.134	0.114	34	0.85	0.329	0.271
	48 21.0–25.9	19	1.11	0.467	0.328	31	1.34	0.571	0.356
	50 01.0–05.9	50	1.57	1.236	0.327	0	–	–	–
20	00 06.0–10.9	19	0.90	0.396	0.264	31	0.94	0.452	0.332
	01 51.0–55.9	40	1.85	0.833	0.442	10	0.38	0.184	0.123
21	43 47.0–51.9	28	1.38	0.630	0.456	22	2.22	0.924	0.618
	45 27.0–31.9	37	1.36	0.614	0.329	13	0.64	0.294	0.228
	47 07.0–11.9	26	1.06	0.376	0.297	24	1.59	0.430	0.459
	48 47.0–51.9	17	1.92	0.945	0.600	33	1.69	0.786	0.458
	50 32.0–36.9	33	2.97	0.990	0.866	17	2.22	0.715	0.605
	52 12.0–16.9	6	0.29	0.177	0.090	44	1.43	0.690	0.351
		f	%	Max	Mean	Std Dev	f	%	Max	Mean	Std Dev
	1931–1939	251	83.67	1.80	0.663	0.311	49	16.33	0.73	0.195	0.153
	1941–1950	211	70.33	1.80	0.628	0.362	89	29.67	1.34	0.272	0.192
	2000–2001	59	59.00	1.85	0.614	0.353	41	41.00	2.22	0.318	0.228
	2143–2152	147	49.00	2.97	0.622	0.440	153	51.00	0.94	0.640	0.453
	1931–2152	668	66.80	2.97	0.632	0.367	332	33.20	2.22	0.356	0.257

TABLE 20. MAXIMUM, MEAN, AND STANDARD DEVIATION OF HORIZONTAL WIND SPEEDS AND DIRECTIONS AT 150-m HEIGHT

Height	Interval UT		Surface Winds					
			Speed ms^{-1} 2 ($m\ s^{-1}$) for kts			Direction deg		
m	hr min	sec	Max	Mean	Std Dev	Max	Mean	Std Dev
150	19 31	16.0–20.9	17.6	16.84	0.455	122	118	1.721
	19 33	16.0–20.9	19.7	16.93	0.847	117	111	3.978
	19 34	56.0–00.9	18.3	17.40	0.472	120	115	2.849
	19 36	36.0–40.9	19.3	17.50	0.792	122	118	1.693
	19 38	16.0–20.9	19.4	18.29	0.338	121	119	0.746
	19 39	56.0–00.9	16.3	14.26	0.724	123	117	2.508
	19 41	41.0–45.9	16.3	15.05	0.726	123	118	2.452
	19 43	21.0–25.9	17.4	16.21	0.644	126	120	2.944
	19 45	01.0–05.9	17.3	15.40	0.869	123	120	1.827
	19 46	41.0–45.9	15.5	14.21	0.483	124	119	2.075
	19 48	21.0–25.9	14.9	13.72	0.649	114	112	1.379
	19 50	01.0–05.9	15.1	14.55	0.313	110	107	1.296
	20 00	06.0–10.9	13.9	12.74	0.545	127	123	1.692
	20 01	51.0–55.9	13.2	12.67	0.309	126	123	1.415
	21 43	47.0–51.9	21.6	20.70	0.479	227	224	1.852
	21 45	27.0–31.9	21.1	19.48	0.882	224	218	4.292
	21 47	07.0–11.9	27.4	25.67	0.716	226	223	2.628
	21 48	47.0–51.9	25.6	24.67	0.400	231	227	1.360
	21 50	32.0–36.9	23.9	22.59	0.738	238	232	2.287
	21 52	12.0–16.9	20.5	19.46	0.511	231	224	1.741
				Speed $m\ s^{-1}$			Direction deg	
m	hr min sec	hr min sec	Max	Mean	Std Dev	Max	Mean	Std Dev
150	19 31 16.0	19 40 00.9	19.7	16.87	0.605	123	116	2.249
	19 41 41.0	19 50 05.9	17.4	14.86	0.614	126	116	1.996
	20 00 06.0	20 01 55.9	13.9	12.71	0.427	127	123	1.554
	21 43 47.0	21 52 16.9	27.4	22.09	0.621	238	225	2.360
	19 31 16.0	21 52 16.9	27.4	16.63	0.567	238	145	2.040

TABLE 21. MAXIMUM, MEAN, AND STANDARD DEVIATION OF HORIZONTAL WIND SPEEDS AND DIRECTIONS AT 120-m HEIGHT

Height	Interval UT		Surface Winds					
			Speed ms^{-i} 2 ($m\ s^{-1}$) for kts			Direction deg		
m	hr min	sec	Max	Mean	Std Dev	Max	Mean	Std Dev
120	19 31	16.0–20.9	17.4	16.34	0.615	122	116	2.730
	19 33	16.0–20.9	17.9	16.89	0.403	112	109	2.497
	19 34	56.0–00.9	19.4	18.33	0.566	112	109	1.919
	19 36	36.0–40.9	15.1	14.33	0.482	126	122	2.230
	19 38	16.0–20.9	18.4	17.54	0.400	117	116	1.088
	19 39	56.0–00.9	14.4	13.66	0.388	119	116	2.409
	19 41	41.0–45.9	16.3	14.97	0.499	118	114	2.204
	19 43	21.0–25.9	17.2	16.35	0.439	122	118	2.070
	19 45	01.0–05.9	15.2	14.36	0.511	128	121	3.154
	19 46	41.0–45.9	15.5	13.84	0.795	124	117	2.900
	19 48	21.0–25.9	13.7	13.01	0.348	110	108	1.576
	19 50	01.0–05.9	14.8	14.07	0.491	108	103	3.257
	20 00	06.0–10.9	13.2	12.47	0.409	122	116	2.350
	20 01	51.0–55.9	12.7	11.81	0.379	125	120	1.626
	21 43	47.0–51.9	20.9	19.89	0.635	226	220	3.052
	21 45	27.0–31.9	22.5	19.95	0.927	228	212	3.002
	21 47	07.0–11.9	26.4	24.95	0.867	222	216	2.589
	21 48	47.0–51.9	26.0	24.98	0.531	223	221	1.074
	21 50	32.0–36.9	24.6	21.92	1.378	225	220	2.548
	21 52	12.0–16.9	20.5	19.60	0.389	218	216	0.718
			Speed $m\ s^{-1}$			Direction deg		
m	hr min sec	hr min sec	Max	Mean	Std Dev	Max	Mean	Std Dev
120	19 31 16.0	19 40 00.9	19.4	16.18	0.476	126	115	2.146
	19 41 41.0	19 50 05.9	17.2	14.43	0.514	128	114	2.527
	20 00 06.0	20 01 55.9	13.2	12.14	0.394	125	118	1.988
	21 43 47.0	21 52 16.9	26.4	21.88	0.788	228	218	2.164
	19 31 16.0	21 52 16.9	26.4	16.16	0.543	228	141	2.206

TABLE 22. MAXIMUM, MEAN, AND STANDARD DEVIATION OF HORIZONTAL WIND SPEEDS AND DIRECTIONS AT 90-m HEIGHT

Height	Interval UT		Surface Winds					
			Speed ms^{-1} 2 ($m\ s^{-1}$) for kts			Direction deg		
m	hr min	sec	Max	Mean	Std Dev	Max	Mean	Std Dev
90	19 31	16.0–20.9	15.8	13.75	1.047	145	136	5.410
	19 33	16.0–20.9	17.9	17.04	0.419	139	134	2.091
	19 34	56.0–00.9	17.4	15.98	0.692	134	124	4.620
	19 3[illegible]	36.0–40.9	17.6	15.68	0.877	150	141	3.149
	19 38	16.0–20.9	18.0	17.20	0.359	141	139	1.560
	19 39	56.0–00.9	13.9	13.44	0.277	147	140	2.357
	19 41	41.0–45.9	14.8	13.70	0.471	143	137	1.841
	19 43	21.0–25.9	14.9	13.97	0.439	143	139	2.060
	19 45	01.0–05.9	14.5	12.63	0.698	150	143	4.499
	19 46	41.0–45.9	14.2	13.40	0.393	139	136	1.455
	19 48	21.0–25.9	12.7	11.67	0.532	134	127	2.259
	19 50	01.0–05.9	12.7	11.67	0.451	127	122	2.094
	20 00	06.0–10.9	12.5	12.02	0.277	142	135	2.424
	20 01	51.0–55.9	11.8	11.16	0.383	142	138	2.267
	21 43	47.0–51.9	19.1	17.94	0.639	250	243	4.116
	21 45	27.0–31.9	20.1	18.69	0.877	237	229	3.353
	21 47	07.0–11.9	26.0	23.56	1.149	245	238	3.134
	21 48	47.0–51.9	25.1	24.29	0.419	245	242	1.755
	21 50	32.0–36.9	23.3	21.45	0.800	248	240	2.893
	21 52	12.0–16.9	20.5	19.27	0.660	240	237	1.750
			Speed $m\ s^{-1}$			Direction deg		
m	hr min sec	hr min sec	Max	Mean	Std Dev	Max	Mean	Std Dev
90	19 31 16.0	19 40 00.9	18.0	15.51	0.612	150	136	3.198
	19 41 41.0	19 50 05.9	14.9	12.84	0.497	150	134	2.368
	20 00 06.0	20 01 55.9	12.5	11.59	0.330	142	136	2.346
	21 43 47.0	21 52 16.9	26.0	20.87	0.757	250	238	2.834
	19 31 16.0	21 52 16.9	26.0	15.20	0.549	250	161	2.687

TABLE 23. MAXIMUM, MEAN, AND STANDARD DEVIATION OF HORIZONTAL WIND SPEEDS AND DIRECTIONS AT 60-m HEIGHT

Height	Interval UT		Surface Winds					
			Speed ms^{-1} 2 ($m\ s^{-1}$) for kts			Direction deg		
m	hr min	sec	Max	Mean	Std Dev	Max	Mean	Std Dev
60	19 31	16.0–20.9	16.6	14.18	1.209	063	057	2.976
	19 33	16.0–20.9	13.7	10.54	1.438	068	057	4.813
	19 34	56.0–00.9	15.6	13.82	1.095	057	048	4.121
	19 36	36.0–40.9	17 3	16.59	0.533	059	055	1.505
	19 38	16.0–20.9	18.3	16.54	0.830	064	058	2.393
	19 39	56.0–00.9	13.8	12.32	0.601	063	056	5.299
	19 41	41.0–45.9	14.1	12.82	0.505	067	057	3.010
	19 43	21.0–25.9	15.2	13.99	0.509	063	060	2.922
	19 45	01.0–05.9	13.5	12.47	0.645	064	059	2.160
	19 46	41.0–45.9	13.8	12.92	0.530	056	054	1.432
	19 48	21.0–25.9	11.0	10.37	0.443	062	057	3.356
	19 50	01.0–05.9	10.3	9.41	0.453	053	041	3.707
	20 00	06.0–10.9	12.1	10.76	0.761	062	055	4.729
	20 01	51.0–55.9	11.4	10.91	0.336	058	056	0.922
	21 43	47.0–51.9	20.8	17.25	1.371	213	203	4.174
	21 45	27.0–31.9	18.7	16.21	1.213	221	202	6.664
	21 47	07.0–11.9	24.6	22.00	1.189	221	210	4.577
	21 48	47.0–51.9	24.0	21.93	1.201	219	211	3.610
	21 50	32.0–36.9	21.6	20.23	0.861	220	210	4.444
	21 52	12.0–16.9	18.7	16.45	1.068	215	206	3.166
				Speed $m\ s^{-1}$			Direction deg	
m	hr min sec	hr min sec	Max	Mean	Std Dev	Max	Mean	Std Dev
60	19 31 16.0	19 40 00.9	18.3	14.00	0.951	068	055	3.518
	19 41 41.0	19 50 05.9	15.2	12.00	0.514	067	055	2.765
	20 00 06.0	20 01 55.9	12.1	10.84	0.549	062	056	2.826
	21 43 47.0	21 52 1 .9	24.6	19.01	1.149	221	207	4.439
	19 31 16.0	21 52 16.9	24.6	13.96	0.791	221	093	3.387

TABLE 24. MAXIMUM, MEAN, AND STANDARD DEVIATION OF HORIZONTAL WIND SPEEDS AND DIRECTIONS AT 30-m HEIGHT

Height	Interval UT		Surface Winds					
			Speed ms^{-1} 2 ($m\ s^{-1}$) for kts			Direction deg		
m	hr min	sec	Max	Mean	Std Dev	Max	Mean	Std Dev
30	19 31	16.0–20.9	17.7	14.03	1.914	052	044	4.864
	19 33	16.0–20.9	10.4	9.20	0.753	066	048	7.783
	19 34	56.0–00.9	18.0	14.77	1.578	069	057	6.424
	19 36	36.0–40.9	17.4	13.44	2.124	067	058	4.784
	19 38	16.0–20.9	14.9	12.23	1.432	064	057	5.400
	19 39	56.0–00.9	10.6	8.84	0.601	059	046	6.771
	19 41	41.0–45.9	14.1	11.28	1.244	060	051	4.483
	19 43	21.0–25.9	11.7	10.56	0.745	063	054	6.311
	19 45	01.0–05.9	14.4	12.56	0.826	060	053	3.464
	19 46	41.0–45.9	12.5	11.01	0.787	070	058	3.210
	19 48	21.0–25.9	11.0	9.87	0.521	069	060	5.911
	19 50	01.0–05.9	10.7	9.34	0.641	066	053	5.672
	20 00	06.0–10.9	12.0	9.77	1.488	077	057	7.770
	20 01	51.0–55.9	6.8	6.14	0.301	056	047	6.988
	21 43	47.0–51.9	13.8	11.99	0.946	242	228	6.128
	21 45	27.0–31.9	14.5	12.06	1.371	259	235	9.928
	21 47	07.0–11.9	20.8	15.94	2.317	262	233	12.329
	21 48	47.0–51.9	19.0	16.24	1.974	264	250	5.487
	21 50	32.0–36.9	21.5	17.71	2.215	265	240	6.926
	21 52	12.0–16.9	16.6	14.12	1.378	250	238	5.929
				Speed $m\ s^{-1}$			Direction deg	
m	hr min sec	hr min sec	Max	Mean	Std Dev	Max	Mean	Std Dev
30	19 31 16.0	19 40 00.9	18.0	12.08	1.400	069	052	6.004
	19 41 41.0	19 50 05.9	14.4	10.77	0.794	070	055	4.842
	20 00 06.0	20 01 55.9	12.0	7.95	0.895	077	052	7.379
	21 43 47.0	21 52 16.9	21.5	14.68	1.700	265	237	7.788
	19 31 16.0	21 52 16.9	21.5	11.37	1.197	265	099	6.503

TABLE 25. MAXIMUM, MEAN, AND STANDARD DEVIATION OF HORIZONTAL WIND SPEEDS AND DIRECTIONS AT 18T-m HEIGHT

Height	Interval UT		Surface Winds					
			Speed ms^{-1} 2 ($m\ s^{-1}$) for kts			Direction deg		
m	hr min	sec	Max	Mean	Std Dev	Max	Mean	Std Dev
18T	19 31	16.0–20.9	16.9	13.09	2.202	156	140	8.660
	19 33	16.0–20.9	10.4	8.73	0.949	138	128	5.183
	19 34	56.0–00.9	14.9	12.22	1.555	134	125	5.826
	19 36	36.0–40.9	17.0	12.76	2.234	128	121	4.563
	19 38	16.0–20.9	14.4	12.14	1.205	149	133	7.673
	19 39	56.0–00.9	10.0	8.36	0.722	145	124	8.666
	19 41	41.0–45.9	14.4	11.54	1.002	142	128	4.954
	19 43	21.0–25.9	10.7	9.34	0.673	131	118	4.196
	19 45	01.0–05.9	13.7	11.55	0.904	133	124	4.545
	19 46	41.0–45.9	10.6	8.60	0.809	132	124	4.269
	19 48	21.0–25.9	10.4	9.09	0.561	131	121	4.045
	19 50	01.0–05.9	10.3	8.69	0.809	143	131	7.396
	20 00	06.0–10.9	9.9	7.44	1.194	139	116	10.792
	20 01	51.0–55.9	6.7	5.41	0.419	152	134	11.165
	21 43	47.0–51.9	15.9	12.68	1.707	236	207	8.108
	21 45	27.0–31.9	11.3	7.82	2.193	259	233	9.979
	21 47	07.0–11.9	18.4	16.51	1.059	228	218	7.392
	21 48	47.0–51.9	20.1	16.66	2.294	249	232	4.256
	21 50	32.0–36.9	20.7	14.41	3.609	243	231	6.881
	21 52	12.0–16.9	14.5	13.43	0.836	221	215	2.900
			Speed			Direction		
			$m\ s^{-1}$			deg		
m	hr min sec	hr min sec	Max	Mean	Std Dev	Max	Mean	Std Dev
18T	19 31 16.0	19 40 00.9	17.0	11.22	1.478	156	128	6.762
	19 41 41.0	19 50 05.9	14.4	9.80	0.793	143	124	4.901
	20 00 06.0	20 01 55.9	9.9	6.42	0.807	152	125	10.979
	21 43 47.0	21 52 16.9	20.7	13.58	1.950	259	223	6.586
	19 31 16.0	21 52 16.9	20.7	10.26	1.257	259	150	7.307

TABLE 26. MAXIMUM, MEAN, AND STANDARD DEVIATION OF HORIZONTAL WIND SPEEDS AND DIRECTIONS AT 18S-m HEIGHT

Height	Interval UT		Surface Winds					
			Speed ms^{-1} 2 ($m\ s^{-1}$) for kts			Direction deg		
m	hr min	sec	Max	Mean	Std Dev	Max	Mean	Std Dev
18S	19 31	16.0–20.9	8.9	7.33	0.666	156	135	9.957
	19 33	16.0–20.9	11.0	8.53	1.074	135	125	5.547
	19 34	56.0–00.9	12.3	10.99	0.744	143	128	8.134
	19 36	36.0–40.9	12.5	11.07	0.899	141	130	6.107
	19 38	16.0–20.9	12.7	11.52	0.745	147	133	7.359
	19 39	56.0–00.9	10.9	9.66	0.638	145	131	5.562
	19 41	41.0–45.9	10.4	9.04	0.632	148	133	8.055
	19 43	21.0–25.9	9.5	8.47	0.501	148	128	8.786
	19 45	01.0–05.9	13.7	11.72	0.675	141	132	5.627
	19 46	41.0–45.9	11.3	10.46	0.390	131	123	4.428
	19 48	21.0–25.9	13.0	11.85	0.864	133	123	5.396
	19 50	01.0–05.9	9.0	8.45	0.363	138	122	8.215
	20 00	06.0–10.9	12.0	9.59	1.241	136	124	4,974
	20 01	51.0–55.9	9.5	8.51	0.659	142	129	5.654
	21 43	47.0–51.9	15.1	12.48	1.654	228	210	8.612
	21 45	27.0–31.9	14.8	8.66	2.739	264	235	16.793
	21 47	07.0–11.9	17.2	13.80	1.397	230	220	6.094
	21 48	47.0–51.9	17.6	15.09	1.596	257	237	9.804
	21 50	32.0–36.9	16.6	11.35	3.241	252	231	11.594
	21 52	12.0–16.9	13.4	12.00	0.722	232	221	3.881
m	hr min sec	hr min sec	Max	Speed $m\ s^{-1}$ Mean	Std Dev	Max	Direction deg Mean	Std Dev
18S	19 31 16.0	19 40 00.9	12.7	9.85	0.794	156	130	7.111
	19 41 41.0	19 50 05.9	13.7	10.00	0.571	148	127	6.751
	20 00 06.0	20 01 55.9	12.0	9.05	0.950	142	126	5.314
	21 43 47.0	21 52 16.9	17.6	12.23	1.892	264	226	9.463
	19 31 16.0	21 52 16.9	17.6	10.28	1.052	264	152	7.160

TABLE 27. MAXIMUM, MEAN, AND STANDARD DEVIATION OF HORIZONTAL WIND SPEEDS AND DIRECTIONS AT 3-m HEIGHT

Height	Interval UT		Surface Winds					
			Speed ms^{-1} 2 ($m\ s^{-1}$) for kts			Direction deg		
m	hr min	sec	Max	Mean	Std Dev	Max	Mean	Std Dev
3	19 31	16.0–20.9	8.5	7.33	0.964	136	128	5.820
	19 33	16.0–20.9	8.5	6.78	0.999	130	104	13.187
	19 34	56.0–00.9	10.7	8.43	1.215	126	108	6.876
	19 36	36.0–40.9	10.0	7.58	1.086	131	114	7.579
	19 38	16.0–20.9	7.2	5.54	0.895	137	116	10.596
	19 39	56.0–00.9	10.4	8.68	1.256	112	098	7.214
	19 41	41.0–45.9	8.8	7.27	1.000	133	120	6.956
	19 43	21.0–25.9	6.8	5.59	0.717	128	104	8.768
	19 45	01.0–05.9	9.7	7.74	0.702	122	101	11.712
	19 46	41.0–45.9	10.3	8.91	0.667	130	111	7.954
	19 48	21.0–25.9	8.1	7.00	0.592	126	105	8.337
	19 50	01.0–05.9	5.5	4.61	0.348	130	109	10.836
	20 00	06.0–10.9	10.3	7.83	1.371	117	100	8.559
	20 01	51.0–55.9	8.2	6.42	0.950	119	109	6.606
	21 43	47.0–51.9	7.6	5.99	1.021	235	192	19.156
	21 45	27.0–31.9	5.8	4.11	0.742	227	198	17.529
	21 47	07.0–11.9	10.6	6.33	1.542	233	199	15.466
	21 48	47.0–51.9	13.5	9.59	1.562	225	206	10.875
	21 50	32.0–36.9	9.6	6.25	2.105	238	217	13.439
	21 52	12.0–16.9	8.9	6.51	1.506	250	214	17.651
			Speed $m\ s^{-1}$			Direction deg		
m	hr min sec	hr min sec	Max	Mean	Std Dev	Max	Mean	Std Dev
3	19 31 16.0	19 40 00.9	10.7	7.39	1.069	137	111	8.545
	19 41 41.0	19 50 05.9	10.3	6.85	0.671	133	108	9.103
	20 00 06.0	20 01 55.9	10.3	7.12	1.161	119	104	7.583
	21 43 47.0	21 52 16.9	13.5	6.46	1.413	250	204	15.686
	19 31 16.0	21 52 16.9	13.5	6.96	1.079	250	132	10.229

TABLE 28. RANGE OF MAXIMUM, MEAN, AND STANDARD DEVIATION DETERMINATIONS OF SHEARS, VERTICAL MOTION, AND HORIZONTAL WINDS

Parameter	Layer/ Distance m	Height m	Range Max s^{-1}	Mean s^{-1}	Std Dev s^{-1}
Shear					
Speed	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
	30–18T		0.125 – 0.792	0.060 – 0.357	0.028 – 0.245
	18S–3		0.093 – 0.713	0.041 – 0.498	0.027 – 0.169
	18T–18S		0.106 0.678	0.044 – 0.354	0.025 – 0.156
Direction			deg m^{-1}	deg m^{-1}	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
	30–18T		2.417 – 9.583	0.811 – 7.973	0.418 – 1.195
	18S–3		1.800 – 5.733	0.694 – 2.735	0.458 – 1.305
	18T–18S		0.722 – 3.111	0.289 – 0.962	0.216 – 0.724
Vertical Motion			m s^{-1}	m s^{-1}	m s^{-1}
Upward		150	0.08 – 2.45	0.033 – 1.582	0.019 – 0.750
		60	0.27 – 4.04	0.142 – 1.582	0.076 – 1.296
		18T	0.31 – 3.50	0.171 – 1.780	0.028 – 0.884
		10	0.29 – 2.97	0.134 – 1.236	0.090 – 0.866
Downward		150	0.01 – 1.13	0.010 – 0.461	0.000 – 0.315
		60	0.38 – 2.01	0.170 – 0.656	0.119 – 0.543
		18T	0.10 – 1.83	0.087 – 0.915	0.000 – 0.440
		10	0.03 – 2.22	0.030 – 0.924	0.000 – 0.618
Horizontal Speed			m s^{-1}	m s^{-1}	m s^{-1}
		150	13.2 – 27.4	12.67 – 25.67	0.309 – 0.882
		120	12.7 – 26.4	11.81 – 24.98	0.348 – 1.378
		90	11.8 – 26.0	11.16 – 24.29	0.277 – 1.149
		60	10.3 – 24.6	9.41 – 22.00	0.336 – 1.438
		30	6.8 – 21.5	6.14 – 17.71	0.301 – 2.317
		18T	6.7 – 20.7	5.41 – 16.66	0.419 – 3.609
		18S	8.9 – 17.6	7.33 – 15.09	0.363 – 3.241
		3	5.5 – 13.5	4.11 – 9.59	0.348 – 2.105
Direction			deg	deg	deg
		150	110 –238	107 – 232	0.746 – 4.292
		120	108 – 228	103 – 221	0.718 – 3.257
		90	127 – 250	122 – 243	1.455 – 5.410
		60	053 – 221	041 – 211	0.922 – 6.664
		30	052 – 265	044 – 250	3.210 – 12.329
		18T	128 – 259	116 – 233	2.900 – 11.165
		18S	131 – 264	122 – 237	3.881 – 16.793
		3	112 – 250	0.98 – 217	5.820 – 19.156