

# MEASUREMENTS OF TURBULENT FLUXES OVER A LAKE SURFACE

By

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## Abstract

The results of measurements of the turbulent fluxes over Lake Biwa using a sonic anemometer and a fine thermocouple psychrometer are reported. The data are analyzed by an analog data processor. Mean values and standard deviations of the fluctuating quantities, and turbulent fluxes of momentum, sensible heat and latent heat are tabulated.

## 1. Introduction

For the purpose of better understanding of air-sea interaction, one of the most essential tasks is to measure the precise amount of the vertical eddy transport of energy and momentum just above the water surface. The recent development of observational techniques has enabled us to make direct turbulent flux measurements possible by the eddy correlation method. However, a large amount of computations are required to obtain long term fluxes. A hybrid analog computing system (HYSAT) has been developed to reduce this difficulty, and the continuous monitoring of eddy fluxes has become easy routine work.

The results of the continuous measurements of turbulent fluxes by the eddy correlation method using HYSAT over the water surface of Lake Biwa, the largest lake in Japan, are reported in the present paper.

The observation was made as a part of an intercomparison of turbulent flux sensors which will be used in the AMTEX (Air Mass Transformation Experiment).

## 2. Details of the observation

This observation was made at Yanagawa on the east coast of Lake Biwa (Fig. 1) from November 13 to 19, 1972. The observational tower was built in the water about 40 m from the shore. The sonic anemometer (Mitsuta [1966]) and the copper-constantan thermocouple psychrometer (Sano and Mitsuta [1968]) were set up at the height of 5.7 m over the water surface. The cold junction of the thermocouple was in the water of a thermos bottle and its temperature was measured by a diode thermometer.

Each signal of the sensor in the form of DC voltage was fed into the analog data analyzer (HYSAT) (Hanafusa [1971a]). The signals of the thermocouple psychro-

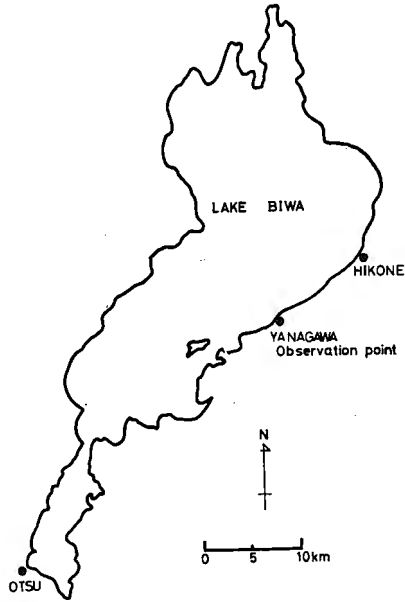


Fig. 1. The location of the observation point.

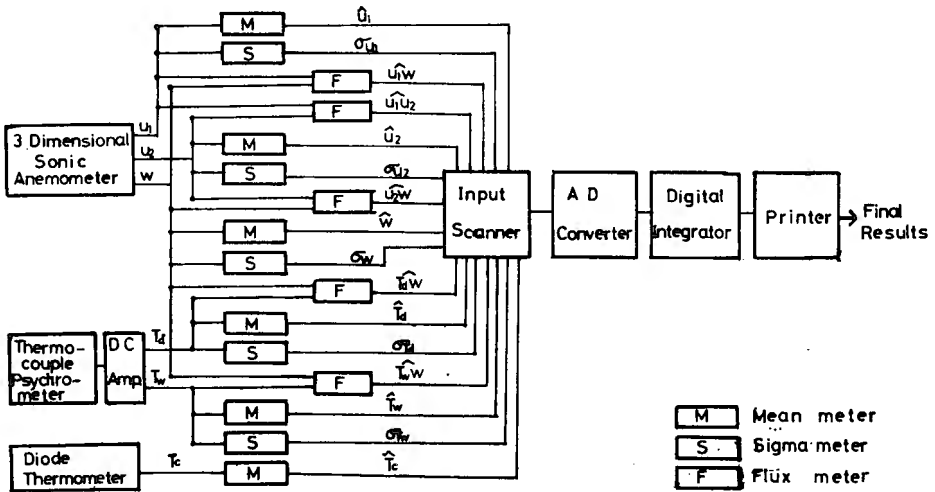


Fig. 2. The block diagram of the observational system.

meter were amplified by 5000 or 10000 times, and filtered by 10 Hz low pass filters.

Mean values and standard deviations of velocity components and the dry-and wet-bulb temperature, and covariances of each component with the vertical velocity were computed by the use of the analog data analyzer and the averaged values over one minute were printed out. These values were averaged again every thirty minutes

and the results were also printed out. The block diagram of this process is shown in Fig. 2.

### 3. Method of analysis

The data obtained by the procedure in the previous section were analyzed as follows (see Hanafusa [1971b] for details)

#### (1) Mean values

The mean horizontal wind velocity and wind direction can be obtained from the outputs of the mean meter of HYSAT by the coordinate transform formulae,

$$\bar{U} = \frac{2}{\sqrt{3}} (\bar{u}_1^2 + \bar{u}_1 \cdot \bar{u}_2 + \bar{u}_2^2)^{1/2}, \quad (1)$$

$$\alpha = \text{Arc tan} \frac{1}{\sqrt{3}} \frac{\bar{u}_1 - \bar{u}_2}{\bar{u}_1 + \bar{u}_2}, \quad (2)$$

where  $u_1$  and  $u_2$  are two horizontal components of wind velocity measured by the sonic anemometer. The angle between the two components is 120 degrees. A bar denotes the mean value over the sampling duration (30 minutes here), and a hat indicates the output of mean meter.

The mean values of the dry- and wet-bulb temperature are as follows,

$$\bar{T}_d = \bar{\hat{T}}_d, \quad (3)$$

$$\bar{T}_w = \bar{\hat{T}}_w, \quad (4)$$

where  $T_d$  is the dry-bulb and  $T_w$  being the wet-bulb temperature.

#### (2) Standard deviations

The variance of a quantity  $X$  can be written in the following form,

$$\sigma_x^2 = \sigma^2(\hat{x}) + \overline{S^2(x)}, \quad (5)$$

where  $\sigma_x^2$  is the variance of  $X$ .  $\sigma^2(\hat{x})$  the variance of the output of mean meter, and  $\overline{S^2(x)}$  the mean value of square of the output of sigma meter, whose averaging time is about 60 seconds.

From Eq. (5), the standard deviations of horizontal velocity in the mean wind direction ( $\sigma_u$ ) and its perpendicular direction ( $\sigma_v$ ) are obtained.

$$\sigma_u^2 = \frac{4}{9\bar{U}^2} \{ (2\bar{u}_1 + \bar{u}_2)^2 \cdot \sigma_{u_1}^2 + (2\bar{u}_1^2 + 5\bar{u}_1 \cdot \bar{u}_2 + 2\bar{u}_2^2) \cdot (\overline{u_1 u_2} - \bar{u}_1 \cdot \bar{u}_2) + (\bar{u}_1 + 2\bar{u}_2)^2 \cdot \sigma_{u_2}^2 \}, \quad (6)$$

$$\sigma_v^2 = \frac{4}{3\bar{U}^2} \{ \bar{u}_2^2 \cdot \sigma_{u_1}^2 - \bar{u}_1 \bar{u}_2 (\overline{u_1 u_2} - \bar{u}_1 \cdot \bar{u}_2) + \bar{u}_1^2 \cdot \sigma_{u_2}^2 \}, \quad (7)$$

where

$$\sigma_{u_1}^2 = \overline{(\hat{u}_1 - \bar{\hat{u}}_1)^2} + \overline{S^2(u_1)},$$

and

$$\sigma_{u_2}^2 = \overline{(\hat{u}_2 - \bar{\hat{u}}_2)^2} + \overline{S^2(u_2)}.$$

The variance of the vertical wind velocity ( $w$ ) and the dry-and wet-bulb temperature ( $T_d$  and  $T_w$ ) are written respectively as follows,

$$\sigma_w^2 = \overline{(\hat{w} - \bar{\hat{w}})^2} + \overline{S^2(w)}, \quad (8)$$

$$\sigma_{T_d}^2 = \overline{(\hat{T}_d - \bar{\hat{T}}_d)^2} + \overline{S^2(T_d)}, \quad (9)$$

$$\sigma_{T_w}^2 = \overline{(\hat{T}_w - \bar{\hat{T}}_w)^2} + \overline{S^2(T_w)}, \quad (10)$$

### (3) Turbulent fluxes

The turbulent fluxes of momentum ( $\tau$ ), sensible heat ( $H$ ) and latent heat ( $E$ ) are computed as follows.

$$\begin{aligned} \tau &= -\overline{\rho u' w'} \\ &= -\frac{2\rho}{3\bar{U}} \{ (2\bar{\hat{u}}_1 + \bar{\hat{u}}_2) \cdot \overline{(\hat{u}_1 \hat{w} - \bar{\hat{u}}_1 \bar{\hat{w}})} - (\bar{\hat{u}}_1 + 2\bar{\hat{u}}_2) \cdot \overline{(\hat{u}_2 \hat{w} - \bar{\hat{u}}_2 \bar{\hat{w}})} \} \end{aligned} \quad (11)$$

$$\begin{aligned} H &= C_p \rho \overline{T'_d w'} \\ &= C_p \rho \overline{(\hat{T}_d \hat{w} - \bar{\hat{T}}_d \bar{\hat{w}})} \end{aligned} \quad (12)$$

$$\begin{aligned} E &= \rho \cdot \overline{q' w'} \\ &= A \cdot \rho \cdot \overline{T'_w w'} - B \cdot \rho \cdot \overline{T'_d w'} \\ &= A \cdot \rho \cdot \overline{(\hat{T}_w \hat{w} - \bar{\hat{T}}_w \bar{\hat{w}})} - B \cdot \rho \cdot \overline{(\hat{T}_d \hat{w} - \bar{\hat{T}}_d \bar{\hat{w}})} \end{aligned} \quad (13)$$

where  $A$  and  $B$  are functions of mean dry- and wet-bulb temperatures, and considered to vary very little within the sampling duration (see Hanafusa [1970] for these values).

## 4. Results

The results of the analysis are tabulated in Table 1. These values are mean values over 30 minutes. The data obtained from 12:00 JST of November 13th to 09:30 of 19th are analyzed. From 00:00 of 15th to 09:30 of 16th, the observations were not made because of rain. During the following periods; 12:00–14:00 and 22:30–23:00 of 16th, 00:30–01:00, 12:00–12:30, 16:30–17:00 and 19:00–21:30 of 17th, 00:00–00:30, 07:30–08:00 and 11:30–12:00 of 18th, the data were not available because of troubles in the instrumentation.

The characteristic parameters defined as follows are also computed and tabulated in the same table.

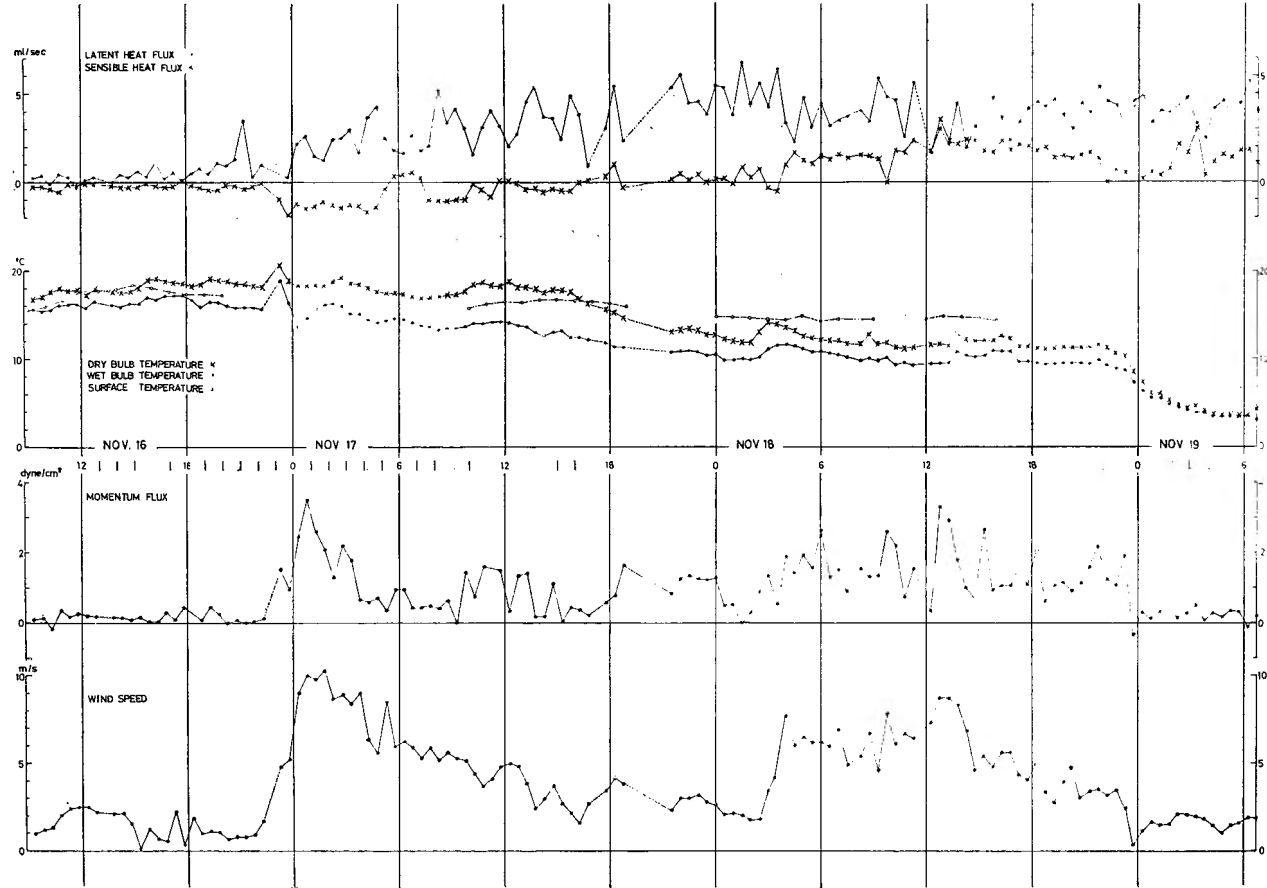


Fig. 3. An example of time changes.

Table 1. Results of the flux computation over Lake Biwa

Time	$\bar{U}$ (cm/s)	$W.D.$ (deg)	$\bar{T}_d$ (°C)	$\bar{T}_w$ (°C)	$T_s$ (°C)	$\bar{\tau}$ (dyne/cm <sup>2</sup> )(mly/s)	$\bar{H}$ (mly/s)	$\bar{E}$ (mly/s)	$\zeta/L$
November 13, 1972									
12:00-12:30	249	-22	13.8	11.8	15.1	0.88	0.45	1.18	-0.060
12:30-13:00	242	14	14.0	11.9	15.2	1.18	-0.80	1.81	0.070
13:00-13:30	203	39	14.2	11.9	15.4	0.28	0.53	0.58	-0.395
13:30-14:00	170	72	14.4	11.9	15.8	0.12	0.32	0.49	-0.825
14:00-14:30	126	-2	14.4	11.9	16.0	0.03	0.26	0.49	-5.500
14:30-15:00	110	18	14.4	11.7	16.2	-0.02	-0.09	0.73	—
15:00-15:30	123	43	14.4	11.7	16.2	-0.02	0.00	0.91	—
15:30-16:00	235	84	14.4	11.6	16.0	0.07	0.40	0.80	-2.720
16:00-16:30	189	90	14.6	11.8	16.0	0.05	0.26	-0.39	-2.550
16:30-17:00	58	80	14.1	11.8	16.2	0.02	-0.01	0.27	0.300
17:00-17:30	42	-110	13.6	11.2	16.1	-0.09	0.08	0.14	—
17:30-18:00	—	—	—	—	15.8	—	—	—	—
18:00-18:30	61	-63	13.0	10.6	15.6	0.07	0.38	0.18	-2.420
18:30-19:00	113	30	12.2	10.6	15.5	0.13	-0.26	0.47	0.601
19:00-19:30	81	-38	11.8	10.4	14.5	0.03	-0.13	0.41	3.150
19:30-20:00	42	-59	12.2	10.6	15.6	-0.01	-0.06	-0.20	—
20:00-20:30	78	-50	12.5	10.7	15.6	0.07	-0.12	0.78	0.666
20:30-21:00	64	-43	13.3	11.3	15.5	-0.24	0.71	1.47	—
21:00-21:30	128	-119	13.7	11.9	15.5	-0.26	0.76	2.03	—
21:30-22:00	374	9	14.5	12.3	15.4	-0.92	1.45	-0.62	—
22:00-22:30	698	0	14.7	11.6	15.5	1.51	-0.40	2.03	0.024
22:30-23:00	656	-14	14.5	11.1	15.7	1.35	-0.39	1.45	0.028
23:00-23:30	628	-17	14.6	11.1	15.8	0.61	0.05	1.26	-0.011
23:30-24:00	578	-20	14.4	11.0	15.8	1.11	-0.47	1.84	0.045

$\sigma_u$ (cm/s)	$\sigma_v$ (cm/s)	$\sigma_w$ (cm/s)	$\sigma_{Td}$ (°C)	$\sigma_{Tw}$ (°C)	$U^*$ (cm/s)	$T^*$ (°C)	$\sigma_u/U^*$	$\sigma_w/U^*$	$\sigma_{Td}/T^*$	$C_D$ ( $\times 10^3$ )
68.4	56.1	15.8	0.34	0.22	27.1	-0.45	2.52	0.58	-0.31	11.80
70.9	34.4	14.8	0.17	0.22	31.4	0.22	2.26	0.47	0.75	16.80
43.4	31.8	27.3	0.10	0.19	15.3	-0.30	2.08	1.78	-0.33	5.68
11.4	44.5	13.7	0.09	0.16	10.2	-0.27	1.12	1.34	-0.33	3.60
37.3	38.7	11.5	0.07	0.14	5.0	-0.44	7.45	2.29	-0.17	1.57
42.8	51.6	10.4	0.10	0.11	—	—	—	—	—	—
56.6	30.2	11.1	0.06	0.14	—	—	—	—	—	—
28.5	108.2	11.8	0.08	0.24	7.4	-0.48	3.86	1.60	-0.16	0.99
29.5	53.7	10.5	0.05	0.16	6.5	-0.34	4.55	1.63	-0.13	1.17
53.7	74.6	8.3	0.33	0.18	4.6	0.02	11.79	1.81	16.25	6.07
49.7	59.3	5.2	0.18	0.16	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—
60.7	41.3	8.7	0.74	0.17	7.5	-0.44	8.05	1.15	-1.69	15.10
47.7	46.6	10.6	0.97	0.85	10.6	0.21	4.51	1.01	4.45	8.72
43.3	42.6	8.9	0.37	0.21	4.8	0.23	8.98	1.84	1.50	3.55
30.0	40.2	4.1	0.11	0.08	—	—	—	—	—	—
37.7	28.3	6.7	0.19	0.07	7.8	0.22	4.84	0.86	1.45	10.10
53.4	62.9	13.1	0.63	0.42	—	—	—	—	—	—
49.1	89.7	9.9	0.53	0.43	—	—	—	—	—	—
168.5	—	22.2	0.48	0.33	—	—	—	—	—	—
202.6	—	23.2	0.11	0.31	35.5	0.10	5.71	0.66	1.14	2.58
178.8	—	24.2	0.04	0.29	33.5	0.12	5.34	0.72	0.42	2.61
173.7	—	22.2	0.08	0.34	22.6	-0.02	7.69	0.98	-4.62	1.29
165.1	—	20.4	0.07	0.29	30.4	0.14	5.42	0.67	0.49	2.78

Time	$\bar{U}$ (cm/s)	$W.D.$ (deg)	$\bar{T}d$ (°C)	$\bar{T}w$ (°C)	$T_s$ (°C)	$\bar{\tau}$ (dyne/cm <sup>2</sup> )	$\bar{H}$ (mly/s)	$\bar{E}$ (mly/s)	$Z/L$
November 14, 1972									
00:00-00:30	686	-11	16.4	10.8	15.7	1.75	-0.60	2.47	0.029
00:30-01:00	813	-16	15.3	9.9	15.4	1.78	0.22	1.77	-0.010
01:00-01:30	832	-11	14.5	9.6	15.3	1.80	0.44	2.49	-0.021
01:30-02:00	887	-29	14.0	9.5	15.3	1.47	0.82	1.42	-0.052
02:00-02:30	918	-22	13.6	9.1	15.2	2.52	0.42	6.61	-0.012
02:30-03:00	968	-29	13.1	8.5	15.0	1.67	1.11	11.68	-0.058
03:00-03:30	874	-28	12.7	8.5	14.9	1.38	1.00	11.98	-0.070
03:30-04:00	869	-28	12.5	8.2	14.7	1.55	0.47	3.02	-0.027
04:00-04:30	852	-13	12.6	8.4	14.6	1.11	0.35	1.76	-0.033
04:30-05:00	794	-8	12.5	8.2	14.5	1.24	0.51	3.77	-0.042
05:00-05:30	807	0	12.3	7.8	14.5	1.71	0.74	4.81	-0.038
05:30-06:00	784	15	12.2	7.8	14.5	1.39	0.37	4.94	-0.026
06:00-06:30	847	143	13.2	7.7	14.4	-0.23	1.19	12.42	—
06:30-07:00	578	124	13.2	7.9	14.3	-0.51	-0.07	4.53	—
07:00-07:30	435	103	13.2	8.0	14.3	1.52	-0.04	7.08	0.002
07:30-08:00	112	75	13.0	7.6	14.4	0.37	-0.46	7.83	0.227
08:00-08:30	152	135	13.4	9.7	14.5	0.16	-0.21	3.55	0.372
08:30-09:00	598	-25	12.2	7.7	14.6	0.24	0.43	10.94	-0.416
09:00-09:30	429	1	12.5	7.6	14.8	-0.83	-0.32	8.04	—
09:30-10:00	714	-48	11.9	7.7	15.0	1.48	0.43	4.88	-0.027
10:00-10:30	764	-49	11.7	7.7	15.2	1.32	0.69	1.68	0.051
10:30-11:00	205	-57	11.6	7.5	15.5	0.11	0.24	1.69	-0.733
11:00-11:30	225	-39	11.9	7.5	15.7	0.13	0.15	1.06	-0.376
11:30-12:00	233	-25	11.9	7.7	15.8	0.08	0.20	0.75	-1.380
12:00-12:30	84	135	13.3	7.6	16.0	0.04	0.23	0.05	-3.780
12:30-13:00	66	128	13.5	8.0	16.2	0.05	-0.04	1.35	0.492
13:00-13:30	32	126	13.8	7.7	16.4	0.02	0.06	1.15	-1.760
13:30-14:00	27	85	13.8	7.6	16.5	0.02	-0.14	1.31	7.930
14:00-14:30	46	120	13.5	7.7	16.5	0.08	-0.04	1.49	0.220
14:30-15:00	65	132	13.7	7.9	16.4	0.07	-0.02	1.40	0.129
15:00-15:30	198	137	13.5	7.8	16.2	0.14	-0.39	1.59	0.821
15:30-16:00	146	133	13.5	7.9	16.1	0.10	0.10	1.07	-0.333
16:00-16:30	124	123	13.6	7.7	16.0	0.04	0.16	0.78	-2.320
16:30-17:00	79	-84	12.7	8.0	15.8	-0.02	-0.12	0.72	—
17:00-17:30	100	-97	12.4	8.0	15.8	0.06	-0.18	2.26	0.696
17:30-18:00	72	-97	12.0	8.3	15.7	0.05	-0.03	1.11	0.250
18:00-18:30	62	-166	12.3	8.4	15.7	-0.15	0.37	2.01	—
18:30-19:00	144	-69	13.6	9.0	15.6	0.10	-0.14	1.55	0.488
19:00-19:30	178	-45	14.3	9.3	15.6	0.11	-0.19	1.58	0.569
19:30-20:00	108	-51	14.5	9.8	15.5	-0.02	0.06	0.08	—
20:00-20:30	107	32	14.6	10.2	15.5	0.10	-0.18	1.31	0.636
20:30-21:00	167	27	14.7	10.5	15.6	0.04	0.18	0.15	-3.020
21:00-21:30	236	-25	14.8	11.2	15.5	0.09	0.02	0.33	-0.110
21:30-22:00	181	71	15.0	11.8	15.4	-0.05	0.14	0.40	—
22:00-22:30	76	-168	15.0	11.5	15.3	0.51	-0.03	0.39	0.009
22:30-23:00	24	99	15.0	11.8	15.3	0.13	0.12	0.09	-0.292
23:00-23:30	47	155	13.9	11.6	15.3	-0.09	0.09	0.03	—
23:30-24:00	55	30	13.9	11.8	15.3	-0.05	-0.07	0.42	—



$\sigma_u$ (cm/s)	$\sigma_v$ (cm/s)	$\sigma_w$ (cm/s)	$\sigma T_d$ (°C)	$\sigma T_w$ (°C)	$U^*$ (cm/s)	$T^*$ (°C)	$\sigma_u/U^*$	$\sigma_w/U^*$	$\sigma T_d/T^*$	$C_D$ ( $\times 10^3$ )
198.1	—	25.9	0.15	0.35	38.1	-0.14	5.19	0.65	1.11	3.09
216.8	—	30.7	0.30	0.37	38.5	-0.05	5.63	0.80	-6.06	2.24
234.9	—	31.3	0.24	0.46	38.7	-0.10	6.07	0.81	-2.44	2.21
212.1	26.2	38.3	0.28	0.45	35.0	-0.20	6.06	1.09	-1.38	1.56
245.3	11.5	37.9	0.26	0.45	45.8	-0.08	5.35	0.83	-3.19	2.49
230.8	35.8	39.3	0.25	0.25	37.3	-0.26	6.18	1.05	-0.97	1.49
211.8	68.9	34.7	0.24	0.64	33.9	-0.26	6.24	1.02	-0.94	1.51
213.5	—	32.8	0.13	0.55	36.0	-0.11	5.93	0.91	-1.17	1.71
231.8	31.3	36.5	0.15	0.52	30.4	-0.10	7.62	1.20	-1.51	1.27
231.1	62.8	34.9	0.67	0.60	32.1	-0.14	7.20	1.09	-1.22	1.63
230.1	—	33.3	0.15	0.57	37.8	-0.17	6.09	0.88	-0.86	2.19
208.6	47.2	29.3	0.15	0.54	34.0	-0.09	6.13	0.86	-1.64	1.89
208.7	—	61.7	0.23	0.23	—	—	—	—	—	—
177.0	—	41.9	0.22	0.24	—	—	—	—	—	—
139.8	—	50.5	0.22	0.22	35.6	0.01	3.92	1.41	4.67	6.72
53.5	—	17.1	0.19	0.30	17.6	0.23	3.04	0.97	0.83	24.70
55.4	—	15.1	0.47	0.09	11.5	0.11	4.81	1.31	2.96	5.76
156.3	—	22.0	0.19	0.52	14.2	-0.27	11.04	1.55	-0.70	0.56
122.6	—	23.1	0.15	0.46	—	—	—	—	—	—
109.0	—	21.7	0.18	0.46	35.1	-0.11	3.10	0.77	-1.70	2.42
107.3	—	34.4	0.20	0.54	33.2	-0.18	3.23	1.04	-1.11	1.89
14.3	—	8.3	0.18	0.50	9.6	-0.22	1.48	0.86	-0.85	2.19
44.2	—	9.4	0.16	0.52	10.3	-0.13	4.28	0.91	-1.24	2.11
57.0	—	9.7	0.16	0.57	7.9	-0.22	7.20	1.22	-0.75	1.16
20.7	22.2	7.0	0.24	0.28	5.5	-0.37	3.76	1.28	-0.66	4.26
11.0	12.8	4.4	0.19	0.27	6.2	0.06	1.79	0.72	3.09	8.76
12.4	16.2	3.0	0.30	0.20	4.6	-0.12	2.72	0.67	-2.54	20.50
16.5	9.9	2.8	0.28	0.17	3.6	0.33	4.58	0.78	0.85	18.40
7.6	12.0	3.0	0.09	0.23	8.0	0.05	0.94	0.37	2.06	30.50
9.7	—	3.4	0.08	0.22	7.9	0.03	1.23	0.43	3.22	14.90
51.6	—	14.6	0.05	0.23	10.9	0.31	4.75	1.34	0.15	3.02
29.3	—	11.5	0.04	0.23	9.3	-0.09	3.16	1.24	-0.39	4.05
47.1	23.1	8.7	0.25	0.38	5.7	-0.24	8.28	1.52	-1.05	2.12
15.5	22.8	24.5	0.11	0.20	—	—	—	—	—	—
31.8	55.3	11.2	0.38	0.47	6.9	0.10	4.64	1.64	3.62	4.69
25.7	28.8	6.2	0.12	0.21	6.7	0.04	3.86	0.94	0.25	8.48
45.0	58.0	7.3	0.44	0.32	—	—	—	—	—	—
23.4	59.3	8.3	0.30	0.21	9.3	0.13	2.52	0.89	2.21	4.14
33.3	37.1	6.7	0.15	0.25	9.7	0.17	3.43	0.69	0.87	2.97
22.7	22.4	5.5	0.04	0.23	—	—	—	—	—	—
33.4	30.9	5.6	0.02	0.17	9.1	0.17	3.67	0.61	0.09	7.29
46.9	13.9	4.9	0.02	0.21	5.5	-0.29	8.58	0.90	-0.06	1.07
70.5	6.1	6.7	0.05	0.28	8.4	-0.03	8.36	0.79	-1.99	1.28
27.7	132.2	10.2	0.15	0.28	—	—	—	—	—	—
94.4	95.5	15.4	0.21	0.13	20.7	0.01	4.57	0.75	16.77	73.20
59.3	123.0	16.8	0.31	0.08	10.3	-0.10	5.78	1.64	-3.14	184.00
69.9	78.7	9.3	0.25	0.09	—	—	—	—	—	—
37.4	36.6	5.4	0.25	0.07	—	—	—	—	—	—

Time	$\bar{U}$ (cm/s)	$W.D.$ (deg)	$\bar{T}_d$ (°C)	$\bar{T}_w$ (°C)	$T_s$ (°C)	$\bar{\tau}$ (dyne/cm <sup>2</sup> )	$\bar{H}$ (mly/s)	$\bar{E}$ (mly/s)	$z/L$
November 16, 1972									
00:00-09:00	Lacking								
09:00-09:30	95	23	16.8	15.6	15.4	0.01	-0.18	0.11	17.200
09:30-10:00	144	31	17.0	15.4	15.9	0.07	-0.18	0.11	1.120
10:00-10:30	133	65	17.6	15.7	16.2	-0.15	-0.30	-0.50	—
10:30-11:00	201	29	17.9	16.1	16.4	-0.07	-0.06	-0.36	—
11:00-11:30	240	67	17.7	16.2	16.8	0.18	0.00	-0.08	0.130
11:30-12:00	251	53	17.7	16.1	17.3	0.21	0.01	-0.08	0.100
12:00-12:30	249	88	17.7	16.3	17.6	0.23	-0.04	0.00	0.040
12:30-13:00	—	—	—	—	17.7	—	—	—	—
13:00-13:30	—	—	—	—	17.8	—	—	—	—
13:30-14:00	—	—	—	—	17.8	—	—	—	—
14:00-14:30	200	41	17.5	15.9	17.9	0.12	-0.20	-0.05	0.535
14:30-15:00	145	-36	17.6	16.2	18.2	0.00	-0.19	-0.19	—
15:00-15:30	9	-82	18.1	16.3	18.3	0.10	-0.25	-0.25	0.820
15:30-16:00	102	65	18.5	16.5	18.1	0.03	0.00	0.27	0.002
16:00-16:30	71	68	18.5	16.5	18.0	-0.05	-0.08	0.30	—
16:30-17:00	62	54	18.5	17.1	17.7	0.04	-0.22	0.59	3.290
17:00-17:30	113	-159	18.9	17.2	17.5	0.14	-0.26	0.50	0.520
17:30-18:00	31	160	18.7	17.2	17.4	-0.53	0.18	-0.18	—
18:00-18:30	188	-68	18.2	16.8	17.3	-0.63	-0.14	0.23	—
18:30-19:00	94	47	18.4	16.9	17.3	0.06	-0.24	0.44	1.730
19:00-19:30	108	-33	19.1	17.2	17.3	0.48	-0.40	0.53	0.132
19:30-20:00	103	-85	18.9	17.2	17.2	0.28	-0.42	0.48	0.321
20:00-20:30	66	100	18.7	16.9	—	-0.06	-0.18	0.40	—
20:30-21:00	81	-42	18.5	16.9	—	0.09	-0.23	0.99	0.877
21:00-21:30	79	-39	18.5	16.9	—	0.02	-0.12	0.27	4.580
21:30-22:00	92	39	18.3	16.9	—	-0.01	-0.23	0.23	—
22:00-22:30	173	102	18.1	16.9	—	0.11	-0.02	0.36	0.071
22:30-23:00	—	—	—	—	—	—	—	—	—
23:00-23:30	483	126	20.5	18.4	—	1.19	-0.40	-0.90	0.034
23:30-24:00	526	-21	18.9	17.2	—	0.68	-1.34	0.15	0.262

$\sigma_u$ (cm/s)	$\sigma_v$ (cm/s)	$\sigma_w$ (cm/s)	$\sigma_{Td}$ (°C)	$\sigma_{Tw}$ (°C)	$U^*$ (cm/s)	$T^*$ (°C)	$\sigma_u/U^*$	$\sigma_w/U^*$	$\sigma_{Td}/T^*$	$C_D$ ( $\times 10^3$ )
32.4	25.9	5.4	0.33	0.12	3.0	0.51	10.80	1.80	0.65	1.01
53.8	34.2	7.5	0.16	0.08	7.5	0.20	7.20	1.01	0.77	4.21
39.8	32.8	8.6	0.33	0.18	—	—	—	—	—	—
77.9	22.0	11.3	0.31	0.15	—	—	—	—	—	—
31.7	41.4	5.5	0.07	0.05	12.1	0.06	2.61	0.46	1.16	2.55
45.5	13.9	4.5	0.17	0.13	13.1	0.06	3.47	0.34	3.04	2.72
—	42.8	8.4	0.16	0.08	13.9	0.02	—	0.61	6.54	3.12
—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—
54.8	36.7	3.8	0.08	0.15	10.0	0.18	5.46	0.37	0.44	2.51
37.9	22.8	1.9	0.06	0.09	—	—	—	—	—	—
60.3	39.1	4.7	0.44	0.16	9.3	0.23	6.48	0.50	1.89	—
—	23.1	9.3	0.29	0.09	5.0	0.00	—	1.85	—	2.40
17.7	36.3	5.1	0.08	0.06	—	—	—	—	—	—
—	109.7	11.0	0.25	0.26	5.7	0.34	—	1.94	0.71	8.22
55.1	60.0	10.3	0.16	0.11	10.9	0.20	5.04	0.94	0.77	9.32
98.9	119.1	12.0	0.30	0.03	—	—	—	—	—	—
77.7	59.3	8.7	0.31	0.05	—	—	—	—	—	—
38.4	62.9	9.8	0.30	0.07	7.2	0.29	5.32	1.36	1.01	5.97
93.2	58.8	18.2	0.20	0.03	20.1	0.17	4.64	0.90	1.12	34.40
63.4	61.4	13.6	0.23	0.02	15.2	0.24	4.18	0.90	0.97	21.50
35.6	26.4	5.8	0.11	0.06	—	—	—	—	—	—
31.3	36.0	9.6	0.18	0.03	8.8	0.22	3.55	1.09	0.82	11.80
32.2	25.2	7.5	0.13	0.02	4.1	0.25	7.87	1.85	0.50	2.69
33.3	23.4	6.0	0.19	0.06	—	—	—	—	—	—
43.8	—	18.7	0.37	0.11	9.5	0.02	4.61	1.97	17.62	3.02
—	—	—	—	—	—	—	—	—	—	—
123.4	—	38.7	0.18	0.04	31.5	0.11	3.91	1.23	1.61	4.27
347.0	348.1	27.0	0.90	0.87	23.9	0.49	14.53	1.13	1.85	2.06

Time	$\bar{U}$ (cm/s)	$W.D.$ (deg)	$\bar{T}_d$ (°C)	$\bar{T}_w$ (°C)	$T_s$ (°C)	$\bar{\tau}$ (dyne/cm <sup>2</sup> )	$\bar{H}$ (mly/s)	$\bar{E}$ (mly/s)	$Z/L$
November 17, 1972									
00:00-00:30	902	-1	18.3	15.9	—	2.02	-0.97	1.32	0.037
00:30-01:00	—	—	—	—	—	—	—	—	—
01:00-01:30	978	-15	18.3	15.5	—	1.43	-0.98	-0.07	0.063
01:30-02:00	1019	-8	18.3	16.1	—	1.40	-0.89	-0.30	0.059
02:00-02:30	873	-6	18.8	16.3	—	1.03	-0.80	0.96	0.084
02:30-03:00	892	-13	19.2	16.0	—	1.72	-0.93	1.72	0.046
03:00-03:30	845	-26	18.6	15.1	—	1.38	-0.83	1.79	0.057
03:30-04:00	901	-33	18.7	15.1	—	0.81	-0.79	1.03	0.119
04:00-04:30	638	-58	18.0	14.3	—	0.28	-0.83	2.59	0.605
04:30-05:00	561	-75	17.7	14.1	—	0.39	-0.90	2.81	0.407
05:00-05:30	578	-75	17.5	14.4	—	0.33	-0.30	1.76	0.177
05:30-06:00	595	-62	17.5	14.6	—	0.40	0.01	1.12	-0.002
06:00-06:30	626	-61	17.4	14.5	—	0.61	0.00	2.05	-0.001
06:30-07:00	596	-69	17.1	14.2	—	0.79	-0.04	2.24	0.010
07:00-07:30	536	-81	16.9	13.8	—	2.23	-0.19	1.55	0.006
07:30-08:00	592	-74	17.0	13.7	—	0.66	-0.68	3.23	0.142
08:00-08:30	522	-68	17.1	13.3	—	0.33	-0.64	4.06	0.382
08:30-09:00	557	-65	17.3	13.5	—	0.38	-0.66	2.39	0.308
09:00-09:30	530	-61	17.4	13.6	—	0.53	-0.48	3.91	0.138
09:30-10:00	536	-66	17.7	13.7	—	-0.15	-0.47	2.00	—
10:00-10:30	448	-47	18.5	14.1	15.9	0.34	-0.02	1.82	0.014
10:30-11:00	371	-53	18.7	14.0	16.2	0.30	-0.10	2.78	0.067
11:00-11:30	413	0	18.1	14.1	16.3	0.96	0.04	2.49	-0.005
11:30-12:00	481	-25	18.3	14.3	16.4	0.74	0.21	1.99	-0.037
12:00-12:30	—	—	—	—	16.5	—	—	—	—
12:30-13:00	487	-38	18.2	13.8	16.5	0.53	0.15	1.80	-0.045
13:00-13:30	389	-22	18.2	13.7	16.6	0.54	-0.32	3.86	0.088
13:30-14:00	242	-57	17.9	13.0	16.7	-0.02	-0.29	5.12	—
14:00-14:30	303	-67	17.4	12.5	16.7	-0.10	-0.36	3.19	—
14:30-15:00	373	-47	17.5	13.0	16.8	0.75	-0.24	3.58	0.042
15:00-15:30	269	-61	17.8	13.2	16.7	-0.31	-0.20	3.97	—
15:30-16:00	221	170	17.3	12.3	16.6	0.29	-0.14	4.17	0.103
16:00-16:30	159	132	16.6	12.3	16.5	-0.08	-0.18	3.50	—
16:30-17:00	—	—	—	—	16.5	—	—	—	—
17:00-17:30	298	143	16.0	12.3	16.5	-1.14	0.04	2.82	—
17:30-18:00	357	146	15.6	11.9	16.4	0.34	0.10	3.38	-0.057
18:00-18:30	414	149	15.4	11.5	16.2	0.57	0.61	3.65	-0.158
18:30-19:00	397	142	14.8	11.4	16.1	0.11	0.11	5.34	-0.010
19:00-19:30	—	—	—	—	—	—	—	—	—
19:30-20:00	—	—	—	—	—	—	—	—	—
20:00-20:30	—	—	—	—	—	—	—	—	—
20:30-21:00	—	—	—	—	—	—	—	—	—
21:00-21:30	—	—	—	—	—	—	—	—	—
21:30-22:00	263	95	13.2	10.8	—	1.02	0.83	7.78	-0.091
22:00-22:30	301	114	13.6	11.0	—	0.71	-0.02	3.65	0.004
22:30-23:00	318	120	13.3	10.8	—	1.11	0.22	5.15	-0.021
23:00-23:30	299	112	13.0	10.6	—	0.66	-0.19	3.02	0.041
23:30-24:00	273	90	12.7	10.5	—	0.99	0.00	4.39	0.000

$\sigma_u$ (cm/s)	$\sigma_v$ (cm/s)	$\sigma_w$ (cm/s)	$\sigma_{Td}$ (°C)	$\sigma_{Tw}$ (°C)	$U^*$ (cm/s)	$T^*$ (°C)	$\sigma_u/U^*$	$\sigma_w/U^*$	$\sigma_{Td}/T^*$	$C_D$ ( $\times 10^3$ )
274.6	—	38.6	0.09	0.20	41.0	0.21	6.69	0.94	0.42	2.07
—	—	—	—	—	—	—	—	—	—	—
292.7	—	42.8	0.12	0.16	34.5	0.25	8.47	1.24	0.47	1.25
291.1	—	41.3	0.11	0.29	34.1	0.23	8.58	1.21	0.47	1.12
293.6	—	33.6	0.06	0.32	29.3	0.24	10.00	1.14	0.26	1.13
267.6	—	34.6	0.05	0.27	37.8	0.21	7.08	0.91	0.22	1.80
209.5	—	32.0	0.05	0.28	33.9	0.21	6.18	0.94	0.24	1.61
203.8	49.9	32.4	0.04	0.27	26.0	0.26	7.83	1.24	0.16	0.83
53.9	49.5	19.4	0.04	0.27	15.4	0.47	3.51	1.26	0.07	0.58
—	64.7	16.8	0.04	0.27	18.1	0.43	—	0.93	0.08	1.04
—	33.5	18.0	0.04	0.29	16.5	0.16	—	1.09	0.27	0.81
—	39.1	15.4	0.04	0.27	18.3	0.00	—	0.84	-17.54	0.94
—	43.0	16.9	0.04	0.26	22.6	0.00	—	0.75	-22.95	1.31
—	—	18.8	0.06	0.28	25.7	0.02	—	0.73	3.54	1.86
—	—	16.8	0.10	0.28	43.1	0.04	—	0.39	2.56	6.49
—	34.3	19.1	0.08	0.29	23.4	0.25	—	0.82	0.32	1.56
—	51.0	16.7	0.07	0.33	16.5	0.34	—	1.01	0.22	1.00
—	65.9	17.3	0.09	0.29	17.9	0.32	—	0.97	0.30	1.03
25.4	60.2	16.4	0.09	0.32	21.1	0.20	1.21	0.78	0.44	1.58
—	55.5	16.1	0.12	0.37	—	—	—	—	—	—
92.7	35.5	12.6	0.20	0.35	16.9	0.01	5.48	0.74	15.86	1.43
65.5	43.8	9.6	0.12	0.36	15.8	0.05	4.15	0.61	2.23	1.82
142.7	—	12.5	0.21	0.11	28.4	-0.01	5.03	0.44	-17.32	4.72
127.1	115.6	15.1	0.19	0.34	24.8	-0.07	5.14	0.61	-2.51	2.65
—	—	—	—	—	—	—	—	—	—	—
123.7	—	13.0	0.09	0.40	20.9	-0.06	5.91	0.62	-1.46	1.85
156.5	24.8	12.2	0.14	0.37	21.2	0.13	3.73	0.57	1.07	2.98
96.4	86.2	12.4	0.10	0.44	—	—	—	—	—	—
87.6	89.7	10.9	0.17	0.31	—	—	—	—	—	—
80.2	65.9	9.1	0.09	0.34	25.0	0.09	3.21	0.37	1.10	4.47
104.1	80.1	9.7	0.07	0.33	—	—	—	—	—	—
74.9	—	9.0	0.20	0.33	15.5	0.08	4.83	0.58	2.53	4.92
33.3	—	10.1	0.36	0.17	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—
80.6	—	18.5	0.16	0.22	—	—	—	—	—	—
115.5	—	19.4	0.19	0.18	16.9	-0.05	6.82	1.15	-3.67	2.25
134.9	—	19.4	0.43	0.24	21.8	-0.24	6.20	0.89	-1.77	2.77
99.7	—	22.1	0.17	0.24	31.1	-0.03	3.21	0.71	-5.55	6.15
—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—
32.9	—	20.9	0.19	0.13	29.2	-0.25	1.13	0.72	-0.77	12.30
—	—	22.2	0.10	0.06	24.3	-0.01	—	0.91	12.54	6.52
36.6	—	21.3	0.08	0.05	30.5	-0.06	1.20	0.70	-1.18	9.16
2.5	—	21.4	0.10	0.05	23.5	0.09	0.11	0.91	1.39	6.18
—	—	21.3	0.13	0.05	28.7	0.00	—	0.74	—	11.10

Time	$\bar{U}$ (cm/s)	$W.D.$ (deg)	$\bar{T}_d$ (°C)	$\bar{T}_w$ (°C)	$T_s$ (°C)	$\bar{\tau}$ (dyne/cm <sup>2</sup> )	$\bar{H}$ (mly/s)	$\bar{E}$ (mly/s)	$Z/L$
November 18, 1972									
00:00-00:30	—	—	—	—	14.9	—	—	—	—
00:30-01:00	207	48	12.4	10.1	14.8	0.65	-0.27	4.80	-0.059
01:00-01:30	222	39	11.9	9.8	14.7	0.33	-0.46	3.97	0.273
01:30-02:00	183	38	11.8	9.8	14.6	0.21	-0.25	4.32	0.296
02:00-02:30	190	126	12.3	10.1	14.6	0.20	1.16	4.57	-1.490
02:30-03:00	249	-37	14.0	11.1	14.5	0.53	-0.19	4.65	0.055
03:00-03:30	355	10	13.9	11.3	14.5	0.48	-0.11	3.61	0.037
03:30-04:00	671	-21	13.7	11.7	14.4	0.07	0.16	3.50	-0.272
04:00-04:30	696	-38	13.4	11.7	14.5	1.01	1.98	2.47	-0.220
04:30-05:00	583	-12	12.9	11.4	14.8	1.11	0.85	3.31	-0.082
05:00-05:30	663	-37	12.4	11.0	14.8	1.46	1.13	3.49	-0.072
05:30-06:00	629	-42	12.3	10.7	14.5	2.66	1.18	3.42	-0.038
06:00-06:30	597	-29	12.1	10.7	14.4	1.32	0.92	2.55	-0.068
06:30-07:00	720	-30	12.1	10.8	14.5	0.91	1.23	4.62	-0.161
07:00-07:30	553	-15	11.9	10.4	—	0.21	1.36	4.63	-0.155
07:30-08:00	—	—	—	—	—	—	—	—	—
08:00-08:30	576	-22	11.7	9.8	—	1.06	0.34	4.43	-0.035
08:30-09:00	681	-27	11.6	10.0	—	0.82	3.38	0.42	-0.512
09:00-09:30	457	-14	11.6	9.7	—	0.46	0.95	4.67	-0.343
09:30-10:00	777	-15	11.8	10.1	—	2.47	1.92	5.25	-0.056
10:00-10:30	625	13	11.3	9.7	—	1.00	1.19	3.40	-0.135
10:30-11:00	662	25	11.2	9.6	—	0.32	1.15	2.90	-0.733
11:00-11:30	653	52	11.2	9.2	—	0.74	1.68	4.67	-0.302
11:30-12:00	—	—	—	—	—	—	—	—	—
12:00-12:30	742	-56	11.6	9.4	—	0.29	1.29	1.84	-0.938
12:30-13:00	865	8	11.4	9.5	—	2.82	2.33	3.21	-0.056
13:00-13:30	883	45	11.6	9.6	—	2.93	2.08	3.88	-0.047
13:30-14:00	836	-11	12.6	10.8	—	1.72	3.47	4.88	-0.174
14:00-14:30	697	-6	12.2	10.4	—	0.81	1.70	2.46	-0.263
14:30-15:00	465	17	12.0	10.1	—	-0.06	1.30	3.58	—
15:00-15:30	555	38	12.1	10.3	—	0.65	1.12	3.39	-0.239
15:30-16:00	483	55	12.0	10.1	—	0.35	1.29	4.55	-0.713
16:00-16:30	542	-20	12.6	10.8	—	0.00	1.85	4.30	—
16:30-17:00	582	-19	12.3	10.8	—	0.08	1.33	2.60	-6.440
17:00-17:30	434	-19	11.2	9.5	—	0.78	1.38	4.43	-0.288
17:30-18:00	414	-15	11.2	9.6	—	-0.27	1.52	3.60	—
18:00-18:30	503	-12	11.2	9.5	—	1.20	1.25	4.09	-0.108
18:30-19:00	343	-37	11.1	9.4	—	0.50	1.18	9.35	-0.375
19:00-19:30	279	-2	11.2	9.4	—	0.29	1.00	4.82	-0.739
19:30-20:00	387	29	11.3	9.4	—	0.46	0.87	3.81	-0.318
20:00-20:30	480	-2	11.2	9.5	—	-0.17	0.90	2.01	—
20:30-21:00	310	-9	11.2	9.4	—	0.51	1.02	3.88	-0.316
21:00-21:30	345	18	11.2	9.4	—	0.71	1.14	4.29	-0.217
21:30-22:00	357	-6	11.6	9.8	—	1.16	0.89	4.65	-0.081
22:00-22:30	370	39	11.3	9.3	—	0.43	0.53	4.10	-0.215
22:30-23:00	350	-7	10.5	8.7	—	0.35	0.58	3.62	-0.317
23:00-23:30	251	-20	10.2	8.7	—	1.07	0.25	2.98	-0.026
23:30-24:00	42	28	8.6	7.4	—	-0.93	3.91	3.56	—

$\sigma_u$ (cm/s)	$\sigma_v$ (cm/s)	$\sigma_w$ (cm/s)	$\sigma_{Td}$ (°C)	$\sigma_{Tw}$ (°C)	$U^*$ (cm/s)	$T^*$ (°C)	$\sigma_u/U^*$	$\sigma_w/U^*$	$\sigma_{Td}/T^*$	$C_D$ ( $\times 10^3$ )
—	—	—	—	—	—	—	—	—	—	—
44.5	24.9	11.6	0.15	0.11	23.3	0.10	1.91	0.50	1.44	12.70
51.3	30.7	12.3	0.20	0.10	16.6	0.24	3.09	0.74	0.82	5.60
48.5	29.4	8.3	0.16	0.10	13.2	0.16	2.68	0.63	0.96	5.20
64.7	57.6	13.3	0.54	0.29	12.8	-0.79	5.04	1.03	-0.69	4.58
130.9	151.1	11.5	0.51	0.42	21.0	0.08	6.24	0.55	6.57	7.11
—	—	—	—	—	—	—	—	—	—	—
111.6	40.6	12.1	0.15	0.30	19.9	0.05	5.60	0.61	3.09	3.15
253.2	42.1	25.8	0.27	0.33	7.8	-0.17	32.31	3.30	-1.55	0.14
156.8	87.9	26.0	0.31	0.37	29.0	-0.59	5.42	0.90	-0.53	1.73
179.8	—	18.6	0.25	0.33	30.4	-0.24	5.90	0.62	-1.02	2.72
145.4	73.7	26.5	0.27	0.45	34.9	-0.28	4.17	0.76	-0.95	2.77
112.6	60.9	25.9	0.25	0.36	47.1	-0.21	2.39	0.55	-1.17	5.61
—	—	—	—	—	—	—	—	—	—	—
159.3	—	20.5	0.25	0.38	33.2	-0.24	4.80	0.62	-1.03	3.09
184.2	—	25.6	0.26	0.38	27.5	-0.39	6.70	0.93	-0.68	1.46
180.8	25.8	23.3	0.25	0.42	13.4	-0.89	13.53	1.74	-0.28	0.58
—	—	—	—	—	—	—	—	—	—	—
144.5	65.9	23.3	0.52	0.44	29.7	-0.10	4.86	0.78	-5.29	2.67
193.7	31.1	26.8	0.29	0.43	26.2	-1.12	7.39	1.02	-0.26	1.48
—	—	—	—	—	—	—	—	—	—	—
145.3	48.3	23.6	0.25	0.37	19.6	-0.42	7.41	1.21	-0.61	1.83
206.9	142.1	32.1	0.31	0.44	45.4	-0.37	4.56	0.71	-0.85	3.41
192.2	—	24.2	0.29	0.39	28.8	-0.35	6.67	0.84	-0.81	2.13
216.1	59.3	26.8	0.35	0.43	16.2	-0.61	13.31	1.65	-0.57	0.60
101.7	124.2	23.9	0.31	0.44	24.8	-0.59	4.10	0.97	-0.52	1.44
—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—
83.8	103.3	30.0	0.32	0.48	15.5	-0.72	5.39	1.93	-0.44	0.44
243.8	243.6	36.3	0.38	0.54	48.5	-0.42	4.85	0.75	-0.92	3.14
183.1	67.6	34.8	0.37	0.52	49.4	-0.37	3.71	0.71	-1.01	3.13
185.6	202.6	36.6	0.37	0.49	37.9	-0.80	4.90	0.97	-0.46	2.05
188.1	96.1	29.3	0.34	0.46	26.0	-0.57	7.23	1.13	-0.59	1.39
152.0	93.0	22.2	0.27	0.39	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—
118.3	78.0	21.8	0.27	0.39	23.3	-0.42	5.07	0.93	-0.65	1.73
74.0	119.4	20.8	0.26	0.37	17.0	-0.06	4.35	1.22	-0.39	1.24
188.5	93.8	27.1	0.32	0.48	1.4	—	132.87	19.09	-0.03	0.00
171.6	82.8	23.5	0.29	0.42	8.2	-1.40	20.82	2.85	-0.21	0.20
114.7	72.7	21.2	0.28	0.43	25.5	-0.47	4.50	0.83	-0.60	3.45
134.5	58.4	22.9	0.28	0.41	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—
169.4	80.2	22.3	0.25	0.38	31.6	-0.34	5.36	0.70	-0.73	3.95
—	142.1	20.1	0.26	0.37	20.5	-0.50	—	0.98	-0.53	3.56
56.6	90.4	15.9	0.31	0.30	15.4	-0.56	3.67	1.03	-0.56	3.06
118.6	43.1	17.9	0.20	0.32	19.5	-0.39	6.08	0.91	-0.52	2.53
140.6	49.2	19.7	0.22	0.33	—	—	—	—	—	—
78.6	49.4	17.1	0.19	0.30	20.6	-0.43	3.81	0.83	-0.43	4.42
—	—	—	—	—	—	—	—	—	—	—
78.6	41.9	17.5	0.21	0.31	24.3	-0.41	3.62	0.72	-0.52	4.96
87.9	59.6	17.2	0.23	0.34	31.1	-0.25	3.10	0.55	-0.93	7.58
96.2	57.0	17.9	0.18	0.30	18.8	-0.24	4.15	0.95	-0.76	2.58
78.1	125.5	16.6	0.27	0.36	17.1	-0.29	4.70	0.97	-0.92	2.38
80.3	50.5	17.9	0.47	0.44	29.9	-0.07	4.30	0.60	-6.34	14.20
128.5	117.3	16.7	1.23	0.98	—	—	—	—	—	—

Time	$\bar{U}$ (cm/s)	$W.D.$ (deg)	$\bar{T}_d$ (°C)	$\bar{T}_w$ (°C)	$T_s$ (°C)	$\bar{\tau}$ (dyne/cm <sup>2</sup> )	$\bar{H}$ (mly/s)	$\bar{E}$ (mly/s)	$z/L$
November 19, 1972									
00:00-00:30	115	-69	7.3	6.4	—	0.08	0.14	4.60	-0.684
00:30-01:00	171	-19	6.2	5.7	—	0.35	0.84	5.12	-0.475
01:00-01:30	149	-54	6.0	5.6	—	0.16	0.99	5.27	-0.178
01:30-02:00	157	-53	5.1	4.9	—	0.45	0.90	5.12	-0.349
02:00-02:30	215	-72	4.7	4.5	—	0.65	0.33	4.72	-0.075
02:30-03:00	208	-75	4.4	4.2	—	0.41	1.31	5.53	-0.584
03:00-03:30	203	-74	4.1	3.9	—	0.59	1.24	5.21	-0.317
03:30-04:00	187	-70	4.1	3.9	—	0.33	0.82	5.07	-0.505
04:00-04:30	155	-24	3.7	3.5	—	0.50	1.50	5.64	-0.501
04:30-05:00	175	-36	3.6	3.5	—	0.46	1.56	5.55	-0.572
05:00-05:30	154	-24	3.6	3.5	—	0.66	1.21	4.86	-0.260
05:30-06:00	156	-23	3.5	3.5	—	1.00	1.49	4.75	-0.172
06:00-06:30	194	-56	3.5	3.5	—	0.38	0.14	5.43	-0.070
06:30-07:00	186	-54	3.2	3.1	—	0.60	1.24	5.07	-0.312
07:00-07:30	133	-39	3.9	3.8	—	0.60	1.59	4.70	-0.395
07:30-08:00	128	-47	5.3	5.0	—	0.81	1.70	2.86	-0.272
08:00-08:30	135	-24	6.5	5.6	—	0.82	0.43	2.95	-0.066
08:30-09:00	138	-12	7.8	6.3	—	0.80	0.45	1.83	-0.071
09:00-09:30	104	11	8.3	6.9	—	0.29	0.51	0.33	-0.370



$\sigma_u$ (cm/s)	$\sigma_v$ (cm/s)	$\sigma_w$ (cm/s)	$\sigma_{Td}$ (°C)	$\sigma_{Tw}$ (°C)	$U^*$ (cm/s)	$T^*$ (°C)	$\sigma_u/U^*$	$\sigma_w/U^*$	$\sigma_{Td}/T^*$	$C_D$ ( $\times 10^3$ )
66.8	65.9	12.2	0.79	0.50	8.2	-0.14	8.17	1.49	-5.51	5.08
70.9	40.4	9.4	0.54	0.41	17.0	-0.43	4.18	0.56	-1.25	9.88
46.8	54.3	8.2	0.44	0.41	11.6	-0.75	4.04	0.71	-0.60	6.07
36.1	29.6	5.5	0.33	0.33	19.3	-0.41	1.87	0.29	-0.82	15.10
54.2	64.9	15.6	0.29	0.29	23.2	-0.13	2.34	0.67	-2.32	11.70
25.1	27.2	12.5	0.11	0.12	18.5	-0.62	1.36	0.68	-0.17	7.86
—	16.4	11.2	0.05	0.90	22.2	-0.48	—	0.51	-0.11	12.00
10.2	25.8	8.1	0.18	0.17	16.6	-0.43	0.61	0.49	-0.41	7.88
31.0	33.8	5.2	0.24	0.23	20.3	-0.64	1.52	0.26	-0.37	17.20
44.7	35.6	7.0	0.24	0.25	19.7	-0.69	2.27	0.36	-0.34	12.60
45.5	22.7	6.5	0.16	0.20	23.5	-0.45	1.93	0.28	-0.36	23.50
35.0	33.4	3.9	0.15	0.19	28.9	-0.45	1.21	0.14	-0.34	34.30
18.2	36.4	8.5	0.28	0.30	17.9	-0.07	1.02	0.48	-4.02	8.48
11.2	15.0	11.7	0.19	0.21	22.4	-0.48	0.50	0.52	-0.39	14.50
—	22.0	7.3	0.46	0.46	22.4	-0.62	—	0.33	-0.75	28.40
—	28.6	12.1	0.50	0.40	25.9	-0.57	—	0.47	-0.87	41.30
31.0	29.0	14.0	0.33	0.23	26.2	-0.14	1.18	0.54	-2.29	37.90
37.4	26.0	16.8	0.46	0.34	25.8	-0.15	1.45	0.65	-3.07	34.80
24.2	43.0	16.3	0.23	0.23	15.6	-0.28	1.55	1.04	-0.82	2.26

$$u_* = \left( \frac{\tau}{\rho} \right)^{1/2} \quad \text{friction velocity,} \quad (15)$$

$$T_* = -\frac{H}{C_p \rho \cdot u_*} \quad \text{scaling temperature,} \quad (16)$$

$$\frac{z}{L} = -\frac{k \cdot g \cdot H \cdot z}{C_p \cdot \rho \cdot T \cdot u_*^3} \quad \text{stability parameter, } L = \text{Obukhov length,} \quad (17)$$

$$C_D = \frac{\tau}{\rho \bar{U}^2} \quad \text{drag coefficient,} \quad (18)$$

Water surface temperature measured at 00 minute of every hour by a mercury thermometer was kindly offered by Meteorological Research Institute. The drag coefficient in the table was computed using the wind speed at the height of 5.7 m. Air density was assumed to be  $1.20 \times 10^{-3}$  and the latent heat of water evaporation to be 580 cal/g/°C. Wind direction was measured clockwise from the north.

An example of the time changes of meteorological factors and the turbulent fluxes is shown in Fig. 3.

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