

## 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-

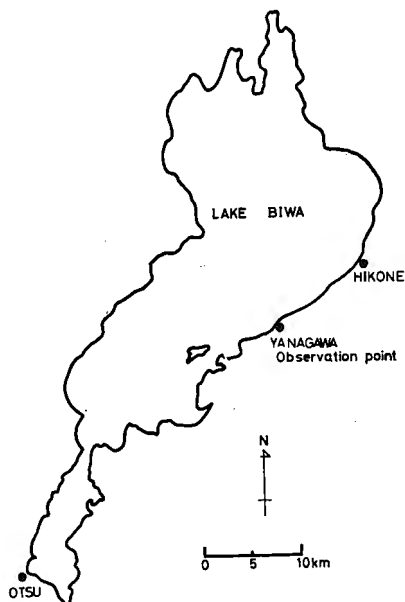


Fig. 1. The location of the observation point.

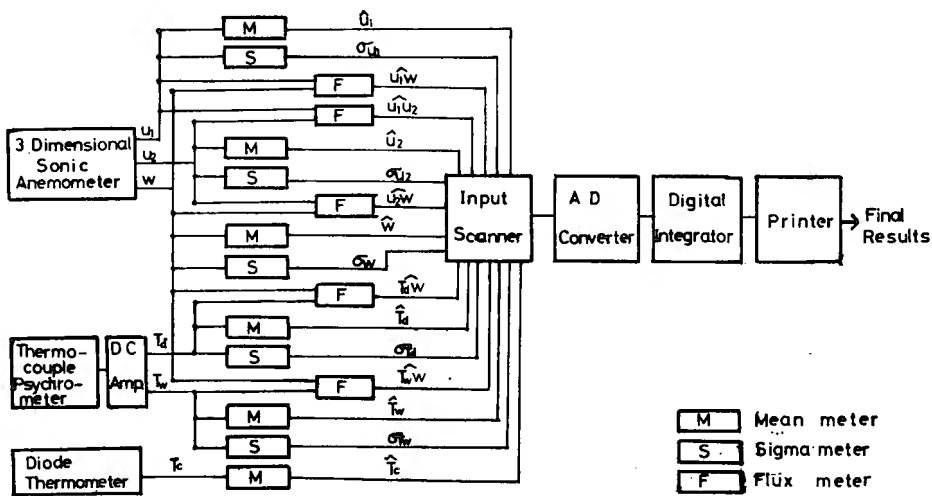


Fig. 2. The block diagram of the observational system.

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,

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

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

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.

$$\sigma_u^2 = \frac{4}{9\bar{U}^2} \{ (2\bar{\hat{u}}_1 + \bar{\hat{u}}_2)^2 \cdot \sigma_{u1}^2 + (2\bar{\hat{u}}_1^2 + 5\bar{\hat{u}}_1 \cdot \bar{\hat{u}}_2 + 2\bar{\hat{u}}_2^2) \cdot (\overline{\hat{u}_1 \hat{u}_2} - \bar{\hat{u}}_1 \cdot \bar{\hat{u}}_2) + (\bar{\hat{u}}_1 + 2\bar{\hat{u}}_2)^2 \cdot \sigma_{u2}^2 \}, \quad (6)$$

$$\sigma_v^2 = \frac{4}{3\bar{U}^2} \{ \bar{\hat{u}}_2^2 \cdot \sigma_{u1}^2 - \bar{\hat{u}}_1 \bar{\hat{u}}_2 (\overline{\hat{u}_1 \hat{u}_2} - \bar{\hat{u}}_1 \cdot \bar{\hat{u}}_2) + \bar{\hat{u}}_2^2 \cdot \sigma_{u2}^2 \}, \quad (7)$$

where

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

and

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

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,

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

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

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

### (3) Turbulent fluxes

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

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

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

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

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.

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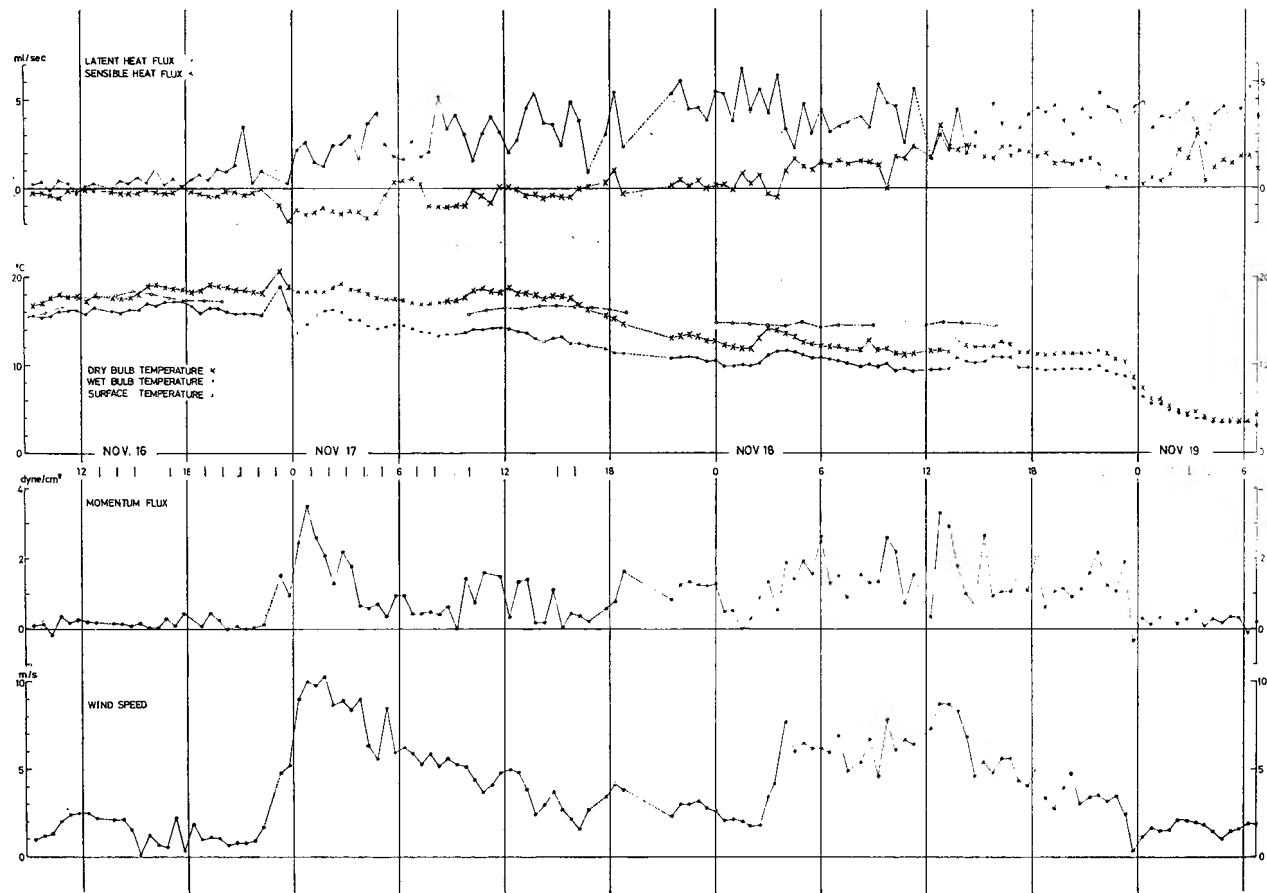


Table 1. Results of the flux computation over Lake Biwa

| Time              | $\bar{U}$<br>(cm/s) | $W.D.$<br>(deg) | $\bar{T}_d$<br>(°C) | $\bar{T}_w$<br>(°C) | $T_s$<br>(°C) | $\bar{\tau}$<br>(dyne/cm <sup>2</sup> ) | $\bar{H}$<br>(mly/s) | $\bar{E}$<br>(mly/s) | $Z/L$  |
|-------------------|---------------------|-----------------|---------------------|---------------------|---------------|-----------------------------------------|----------------------|----------------------|--------|
| 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  |

| $\sigma_u$<br>(cm/s) | $\sigma_v$<br>(cm/s) | $\sigma_w$<br>(cm/s) | $\sigma_{Td}$<br>(°C) | $\sigma_{Tw}$<br>(°C) | $U^*$<br>(cm/s) | $T^*$<br>(°C) | $\sigma_u/U^*$ | $\sigma_w/U^*$ | $\sigma_{Td}/T^*$ | $C_D$<br>( $\times 10^3$ ) |
|----------------------|----------------------|----------------------|-----------------------|-----------------------|-----------------|---------------|----------------|----------------|-------------------|----------------------------|
| 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              | $\bar{U}$<br>(cm/s) | $W.D.$<br>(deg) | $\bar{T}_d$<br>(°C) | $\bar{T}_w$<br>(°C) | $T_s$<br>(°C) | $\bar{\tau}$<br>(dyne/cm <sup>2</sup> ) | $\bar{H}$<br>(mly/s) | $\bar{E}$<br>(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                 | —      |

| $\sigma_u$<br>(cm/s) | $\sigma_v$<br>(cm/s) | $\sigma_w$<br>(cm/s) | $\sigma T_d$<br>(°C) | $\sigma T_w$<br>(°C) | $U^*$<br>(cm/s) | $T^*$<br>(°C) | $\sigma_u/U^*$ | $\sigma_w/U^*$ | $\sigma T_d/T^*$ | $C_D$<br>( $\times 10^3$ ) |
|----------------------|----------------------|----------------------|----------------------|----------------------|-----------------|---------------|----------------|----------------|------------------|----------------------------|
| 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              | $\bar{U}$<br>(cm/s) | $W.D.$<br>(deg) | $\bar{T}_d$<br>(°C) | $\bar{T}_w$<br>(°C) | $T_s$<br>(°C) | $\bar{\tau}$<br>(dyne/cm <sup>2</sup> ) | $\bar{H}$<br>(mly/s) | $\bar{E}$<br>(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  |

| $\sigma_u$<br>(cm/s) | $\sigma_v$<br>(cm/s) | $\sigma_w$<br>(cm/s) | $\sigma_{Td}$<br>(°C) | $\sigma_{Tw}$<br>(°C) | $U^*$<br>(cm/s) | $T^*$<br>(°C) | $\sigma_u/U^*$ | $\sigma_w/U^*$ | $\sigma_{Td}/T^*$ | $C_D$<br>( $\times 10^3$ ) |
|----------------------|----------------------|----------------------|-----------------------|-----------------------|-----------------|---------------|----------------|----------------|-------------------|----------------------------|
| 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              | $\bar{U}$<br>(cm/s) | $W.D.$<br>(deg) | $\bar{T}d$<br>(°C) | $\bar{T}w$<br>(°C) | $T_s$<br>(°C) | $\bar{\tau}$<br>(dyne/cm <sup>2</sup> ) | $\bar{H}$<br>(mly/s) | $\bar{E}$<br>(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  |

| $\sigma_u$<br>(cm/s) | $\sigma_v$<br>(cm/s) | $\sigma_w$<br>(cm/s) | $\sigma T_d$<br>(°C) | $\sigma T_w$<br>(°C) | $U^*$<br>(cm/s) | $T^*$<br>(°C) | $\sigma_u/U^*$ | $\sigma_w/U^*$ | $\sigma T_d/T^*$ | $C_D$<br>( $\times 10^3$ ) |
|----------------------|----------------------|----------------------|----------------------|----------------------|-----------------|---------------|----------------|----------------|------------------|----------------------------|
| 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              | $\bar{U}$<br>(cm/s) | $W.D.$<br>(deg) | $\bar{T}_d$<br>(°C) | $\bar{T}_w$<br>(°C) | $T_s$<br>(°C) | $\bar{\tau}$<br>(dyne/cm <sup>2</sup> ) | $\bar{H}$<br>(mly/s) | $\bar{E}$<br>(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                 | —      |

| $\sigma_u$<br>(cm/s) | $\sigma_v$<br>(cm/s) | $\sigma_w$<br>(cm/s) | $\sigma_{Td}$<br>(°C) | $\sigma_{Tw}$<br>(°C) | $U^*$<br>(cm/s) | $T^*$<br>(°C) | $\sigma_u/U^*$ | $\sigma_w/U^*$ | $\sigma_{Td}/T^*$ | $C_D$<br>( $\times 10^3$ ) |
|----------------------|----------------------|----------------------|-----------------------|-----------------------|-----------------|---------------|----------------|----------------|-------------------|----------------------------|
| 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              | $\bar{U}$<br>(cm/s) | $W.D.$<br>(deg) | $\bar{T}_d$<br>(°C) | $\bar{T}_w$<br>(°C) | $T_s$<br>(°C) | $\bar{\tau}$<br>(dyne/cm <sup>2</sup> ) | $\bar{H}$<br>(mly/s) | $\bar{E}$<br>(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 |

| $\sigma_u$<br>(cm/s) | $\sigma_v$<br>(cm/s) | $\sigma_w$<br>(cm/s) | $\sigma_{Td}$<br>(°C) | $\sigma_{Tw}$<br>(°C) | $U^*$<br>(cm/s) | $T^*$<br>(°C) | $\sigma_u/U^*$ | $\sigma_w/U^*$ | $\sigma_{Td}/T^*$ | $C_D$<br>( $\times 10^3$ ) |
|----------------------|----------------------|----------------------|-----------------------|-----------------------|-----------------|---------------|----------------|----------------|-------------------|----------------------------|
| 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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