SUPPORTING DATA FOR HYDROLOGIC STUDIES IN SAN FRANCISCO BAY, CALIFORNIA: METEOROLOGICAL MEASUREMENTS AT THE PORT OF REDWOOD CITY DURING 1998-2001.

By Laurence E. Schemel

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CONVERSION FACTORS

Metric and inch-pound units are used in this report. Conversion factors to other comonly used units are provided here for the measurements made in this study.

Multiply	By	To obtain
Nautical miles per hour	0.869	statute miles per hour
Statute miles per hour	0.447	meters per second
millibars (10^{-3} bars)	0.0295	inches of mercury
millibars	0.0145	pounds per square inch

Temperature Celsius (C) and can be converted to Fahrenheit (F) using the following equation:

$$(F) = 1.80\,(C) + 32$$

The use of brand names in this report is for identification purposes only and does not constitute endorsement by the U.S. Geological Survey.

SUPPORTING DATA FOR HYDROLOGIC STUDIES IN SAN FRANCISCO BAY, CALIFORNIA: METEOROLOGICAL MEASUREMENTS AT THE PORT OF REDWOOD CITY, 1998-2001

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ABSTRACT

Meteorological data were collected during 1998-2001 at the Port of Redwood City, California, to support hydrologic studies in South San Francisco Bay. The measured meteorological variables were air temperature, atmospheric pressure, quantum flux (insolation), and four parameters of wind speed and direction: scalar mean horizontal wind speed, (vector) resultant horizontal wind speed, resultant wind direction, and standard deviation of the wind direction. Hourly mean values based on measurements at five-minute intervals were logged at the site. Daily mean values were computed for temperature, insolation, pressure, and scalar wind speed. Daily mean values for 1998-2001 are described in this report, and a short record of hourly mean values is compared to data from another near-by station. Data (hourly and daily mean) from the entire period of record (starting April 1992) and reports describing data prior to 1998 are provided.

INTRODUCTION

The U.S. Geological Survey (USGS) collects many types of environmental data to support hydrologic studies of the San Francisco Bay Estuary. These data sets include meteorological data because weather conditions can greatly affect physical, biological and chemical processes in estuarine waters. A temporary meteorological station was established at the Port of Redwood City (RWC) in April 1992 to support research and monitoring activities in this region, particularly in South San Francisco Bay (South Bay) at the San Mateo and Dumbarton Bridges (Fig. 1). Data from the USGS-RWC meteorological station (USGS-RWC) have been essential for explaining episodic changes in water chemistry in the estuary (for example see Schemel and Hager, 1996). In addition, many academic and government researchers and private consulting firms have used these data for a variety of studies over the years. Two previous reports have presented the meteorological data from USGS-RWC through December 1994 (Schemel, 1995) and for the 1995-1997 calendar years (Schemel, 1998). This report describes the data for the 1998-2001 calendar years.

Wind speed and direction are particularly important variables in hydrologic studies of South Bay, because winds from specific directions induce strong surface and bottom currents and mix the water column in the estuary (for examples see Walters and others, 1985, Huzzey and others, 1990, and Powell and others, 1989). This was the primary reason for installing the meteorological station in 1992, when relatively little wind data were readily available for the landward reach of South Bay (south of San Mateo Bridge). Although real-time and daily averaged wind data and models are now available over the Internet (for example see http://sfports.wr.usgs.gov/wind/), historical long-term records of hourly wind speed and direction still are often difficult to obtain. Consequently, USGS has continued data collection at USGS-RWC even though the National Oceanic and Atmospheric Administration (NOAA) installed real-time-access weather sensors at the Port of Redwood City as part of the PORTS system in late 1997 (see Schemel, 1998, and http://www.co-ops.nos.noaa.gov/sfports/sfports.html). Recently, provisional measurements since 1999 for some PORTS sensors have been made available on the Internet (see below).

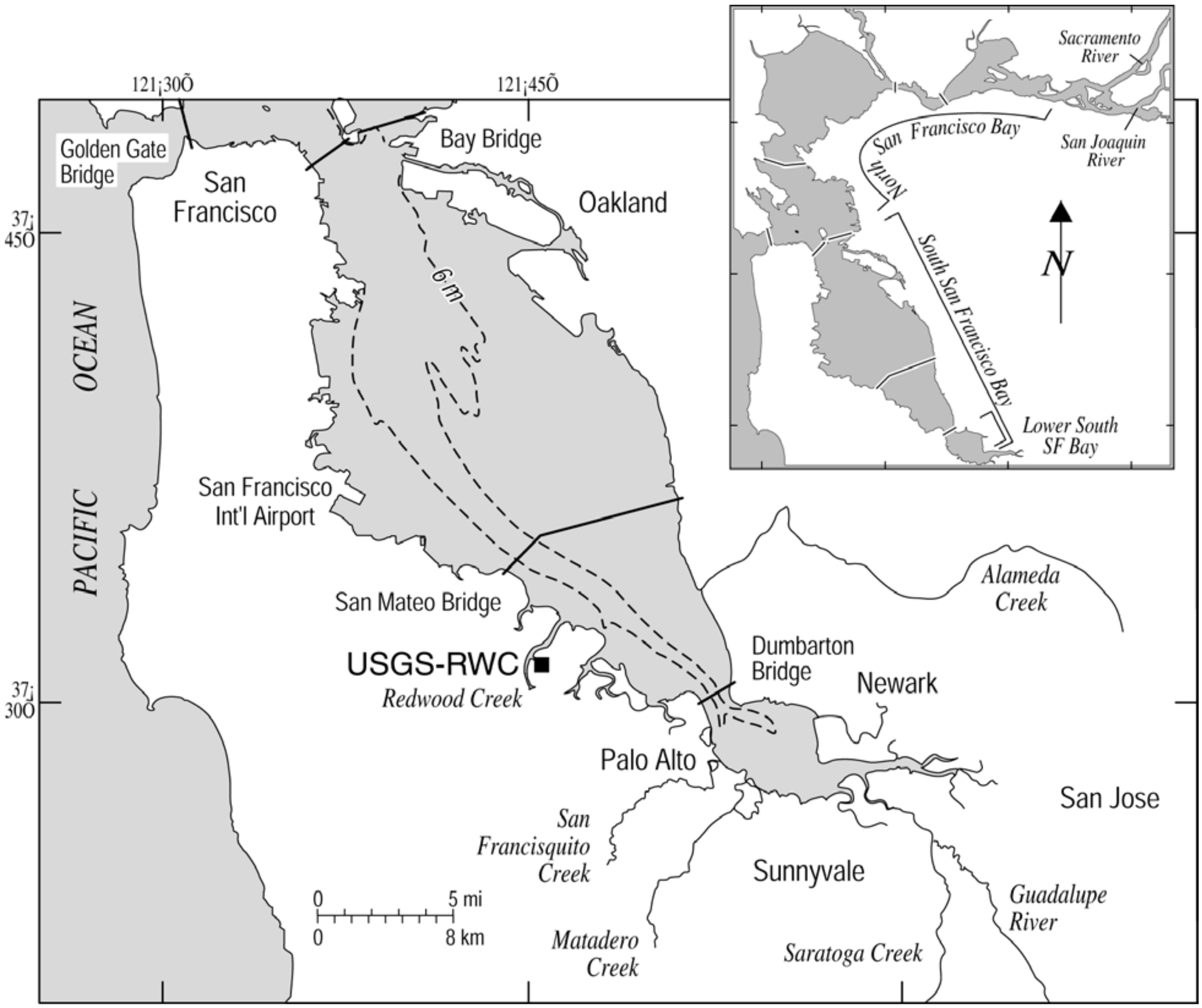

Figure 1. Map showing San Francisco Bay and locations in South San Francisco Bay.

Even though precipitation is also a very important variable in hydrologic studies of South Bay, there have been many sources of this information for the area (for example see http://www.wrh.noaa.gov/Monterey/climate.html). Consequently, precipitation was not measured at USGS-RWC.

ACKNOWLEDGMENTS

The continued cooperation and assistance from the director and staff of the USGS Marine Facility at Redwood City has been critical to this data-collection effort. Reviews of this report by M.H Cox and R.J. Avanzino are appreciated.

INSTRUMENTS AND METHODS

Meteorological instruments were mounted on a 2m-high tripod on the roof of the USGS Marine Facility building located at the deep-water Port of Redwood City on Redwood Creek near the western margin of South Bay (Fig. 1). The elevation of the instrument array above grade is approximately 15m. A large obstruction to wind flow, such as the Marine Facility building could affect wind speed and perhaps other measurements. In addition, radiation from the roof of the building could affect temperature measurements under certain conditions. Previous reports have compared measurements from other sources with values from the USGS-RWC (Schemel, 1995 and 1998). It is hard to assess the accuracy of the data by comparing it to other sites because of the naturally high variability in the area. Consequently, the greatest value of these measurements is in the detection of events, such as hours to days of high wind speeds from specific directions. Strong northerly winds that follow major storms fall into this category, as do afternoon winds that blow along the edge of the coastal fog bank.

The meteorological variables that were measured through December 2001 are listed in Table 1 in the order that they are provided in the data files containing hourly mean values. Similarly, column headers for data files containing daily-mean and daily-total values are listed in Table 2. All hourly and daily values were based on measurements made at five-minute intervals.

Table 1. Column headers for data files of hourly mean values.

Column Number (in sequence)	Measurement	Units
1	Program version	none
2	Day of Calendar year	none
3	Pacific Standard Time	hours
4	quantum flux (insolation)	10^{-6}moles m^{-2} s^{-1}
5	Temperature	degrees Celsius
6	Barometric pressure	10^{-3} bars
7	Scalar mean wind speed	statute miles h^{-1}
8	Resultant mean wind speed	statute miles h^{-1}
9	Unit vector mean wind direction	degrees true
10	Standard deviation of direction	degrees

Table 2. Column headers for data file of daily values.

Column Number (in sequence)	Measurement	Units
1	Calendar year	none
2	Day of Calendar year	none
3	Mean quantum flux (insolation)	10^{-6}moles m^{-2} s^{-1}
4	Mean Temperature	degrees Celsius
5	Mean Barometric pressure	10^{-3} bars
6	Scalar mean wind speed	statute miles h^{-1}
7	Total Insolation	moles m^{-2} d^{-1}

All instruments and sensors were factory calibrated, and no further calibrations were made (table 3). Measurements were made at five-minute intervals, and then averaged or otherwise processed (see below) to provide values for the preceding hour. Data were logged on the hour (Pacific Standard Time) at the site by a Campbell Scientific Company CR10, and then downloaded to a personal computer. The data collection and control program for the CR10 was developed using software provided by the manufacturer. This program is provided in Table 4.

Table 3. Components of the temporary meteorological station at the Port of Redwood City, California (USGS-RWC).

Components	Manufacturer
Wind Monitor, Model 05103	
	R.M. Young Company 2801 Aero-Park Drive Traverse City, MI 49884
Barometric Pressure Sensor, Model PTA-427	
	Vaisala Sensor Systems 100 Commerce Way Woburn, MA 01801
Quantum Flux (Insolation) Sensor, Model LI-190SZ	
	LI-COR, Inc. P.O. Box 4425 Lincoln, Nebraska 68504
Temperature Probe, Model 107 Measurement and Control Module, Model CR10 Tripod with crossarm and irradiance sensor platform, Model CM6 Optically Isolated RS232 Interface, Model SC32A PC208 data logger support software package	
	Campbell Scientific P.O. Box 551 Logan, UT 84321

Data for wind speed and direction were collected according to recommendations made by the Environmental Protection Agency for regulatory modeling applications. This provides scalar mean horizontal wind speed as well as (vector) resultant mean horizontal wind speed. Resultant mean wind direction and the standard deviation of wind direction are also provided by the output processing instructions.

A quantum sensor was used to measure insolation (solar irradiance). This sensor measures quantum fluxes in moles (6.02×10^{23} photons = one Einstein) over the visible spectrum.

RESULTS

Time-series plots of daily mean values for temperature, insolation (quantum flux), (barometric) pressure, and (scalar) wind speed are shown for each year in Figures 2-5. Time-series plots of hourly-mean values, including wind direction, are provided for three-month periods at the back of this report. Data files containing hourly mean and daily mean values are provided. Previous reports describe time scales of variability and some aspects of the regional climatology (Schemel, 1995 and 1998). The reader is referred to other sources for additional information on the seasonal weather and micro-climatology of the San Francisco Bay area (for example, Gilliam, 1962; Elford, 1970). Several Internet sites are also excellent sources of climate and weather information for the San Francisco Bay area.

The period of record in this report, 1998-2001, began with a year of near-record rainfall, second only to that during the 1862 water year (Fig. 6). Precipitation totals are normally computed from July to June, but they are computed from October to September in this report in order to be consistent with the water year for streams. Differences between these two methods of computation are small for the San Francisco Bay area because there is relatively little rainfall from July through September. When compared to the long-term mean value, yearly totals for 1999-2001 were similar to the mean value, but 2001 was the lowest and slightly below the mean value. In contrast, total precipitation for 1998 was more than twice the long-term mean value. The July 1997 through June 1998 precipitation year also set a new record for number of days with rainfall in San Francisco (119 days; see http://ggweather.com/sf/sf97rain.html for details). These precipitation records show the influence of an extremely strong El Niño event that affected weather and streamflow throughout the State of California.

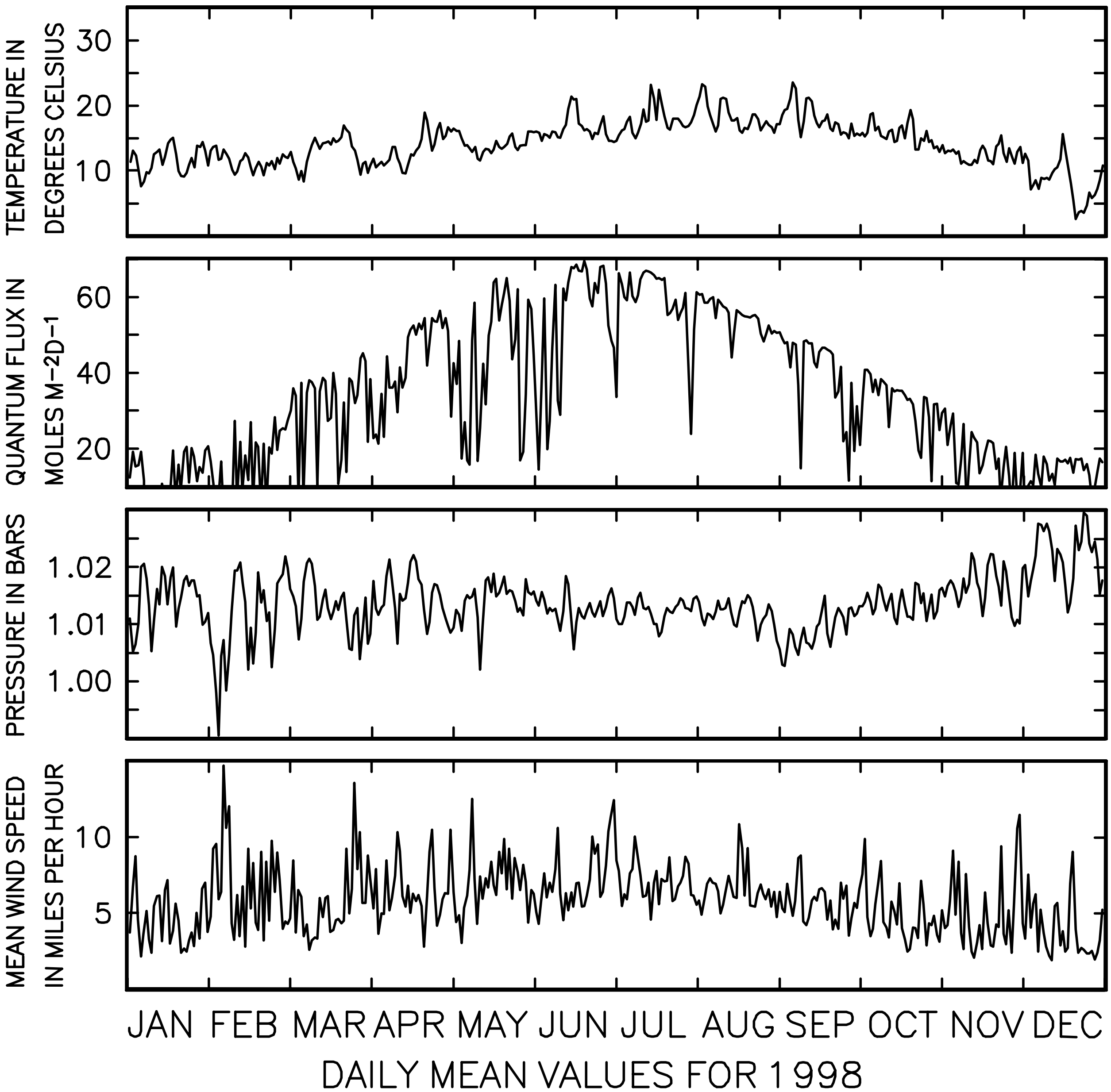

Figure 2. Time series plots of daily mean temperature, quantum flux, barometric pressure, and scalar wind speed at the Port of Redwood City, USGS – RWC, 1998.

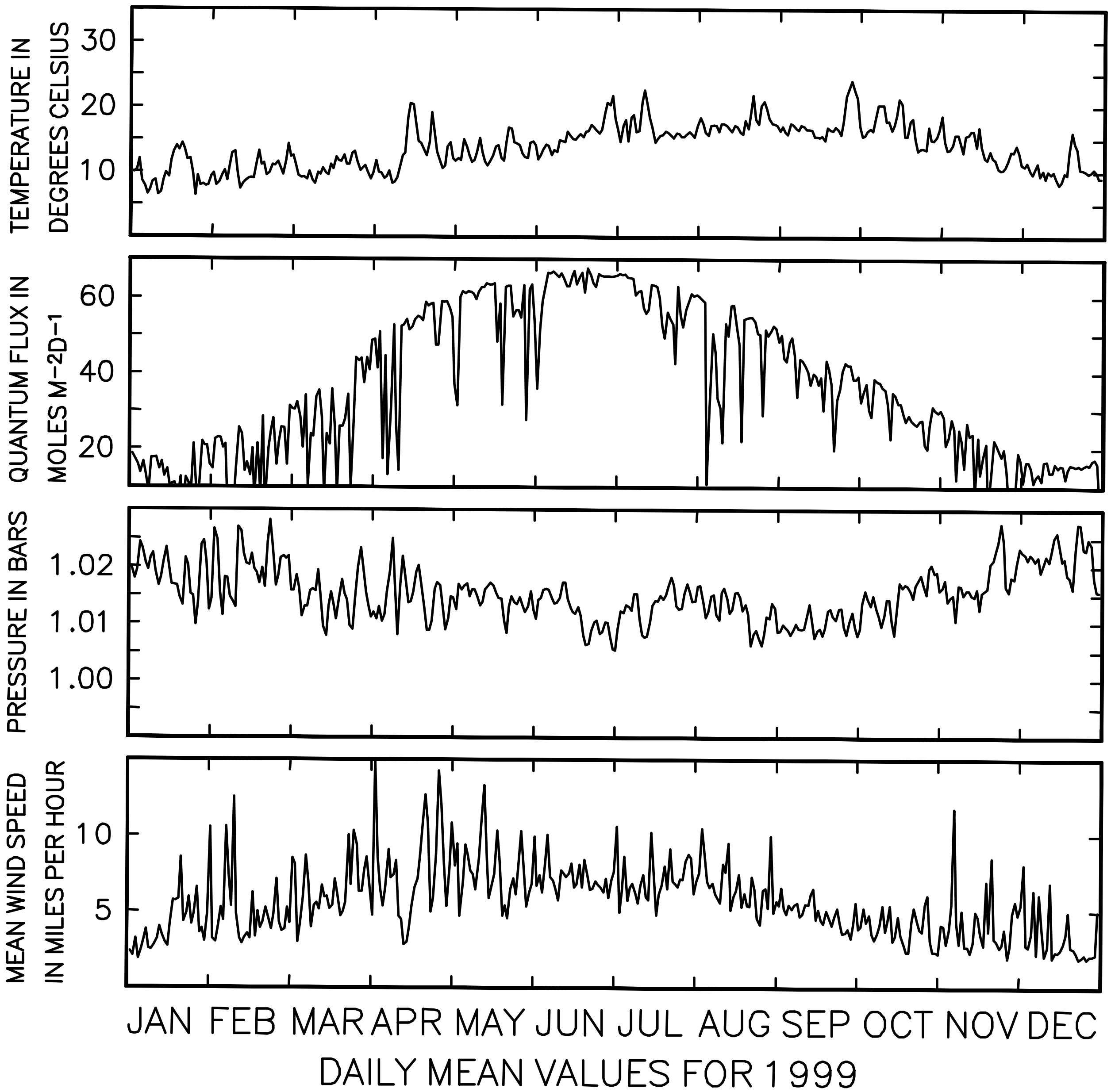

Figure 3. Time series plots of daily mean temperature, quantum flux, barometric pressure, and scalar wind speed at the Port of Redwood City, USGS – RWC, 1999.

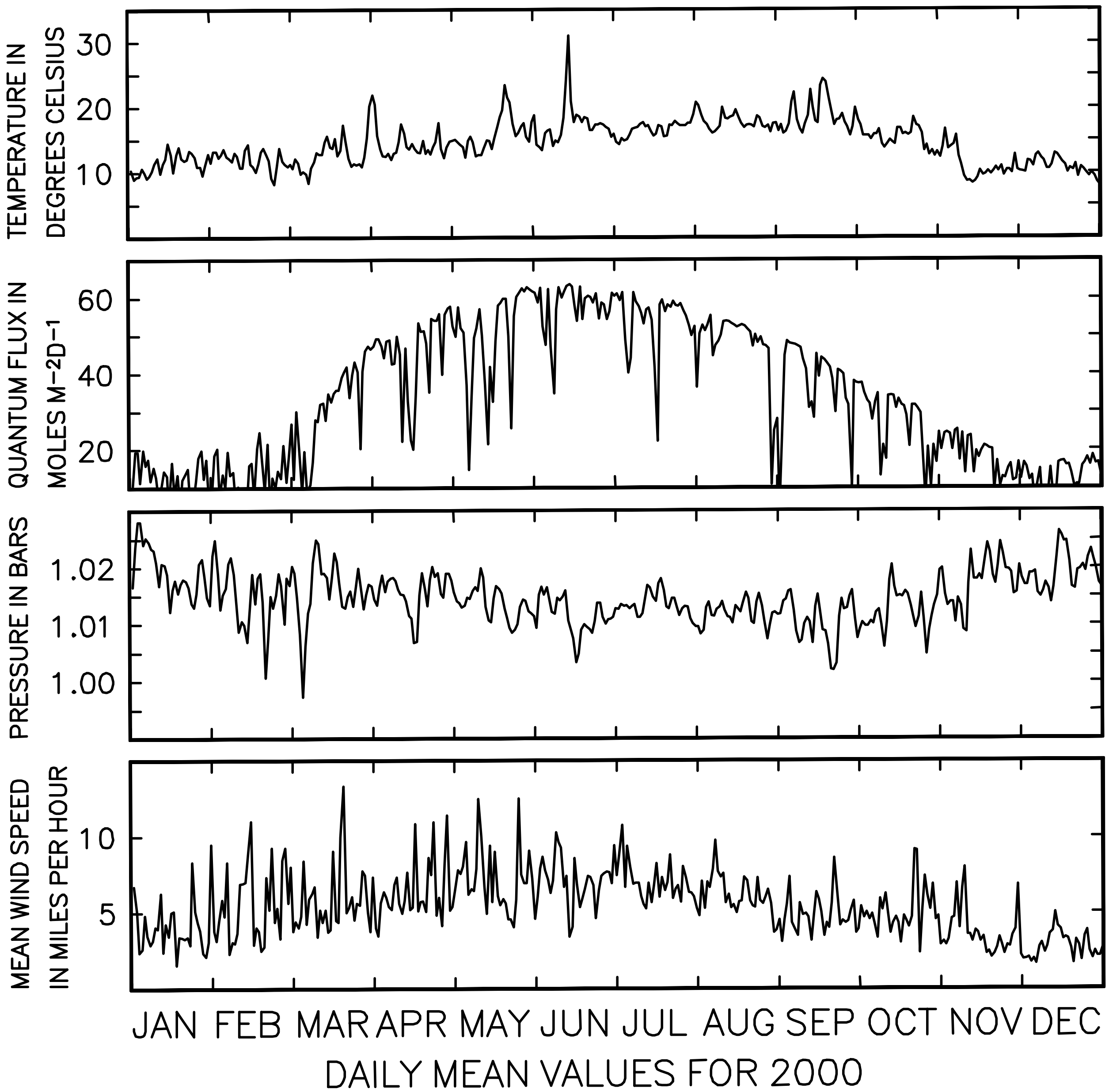

Figure 4. Time series plots of daily mean temperature, quantum flux, barometric pressure, and scalar wind speed at the Port of Redwood City, USGS – RWC, 2000.

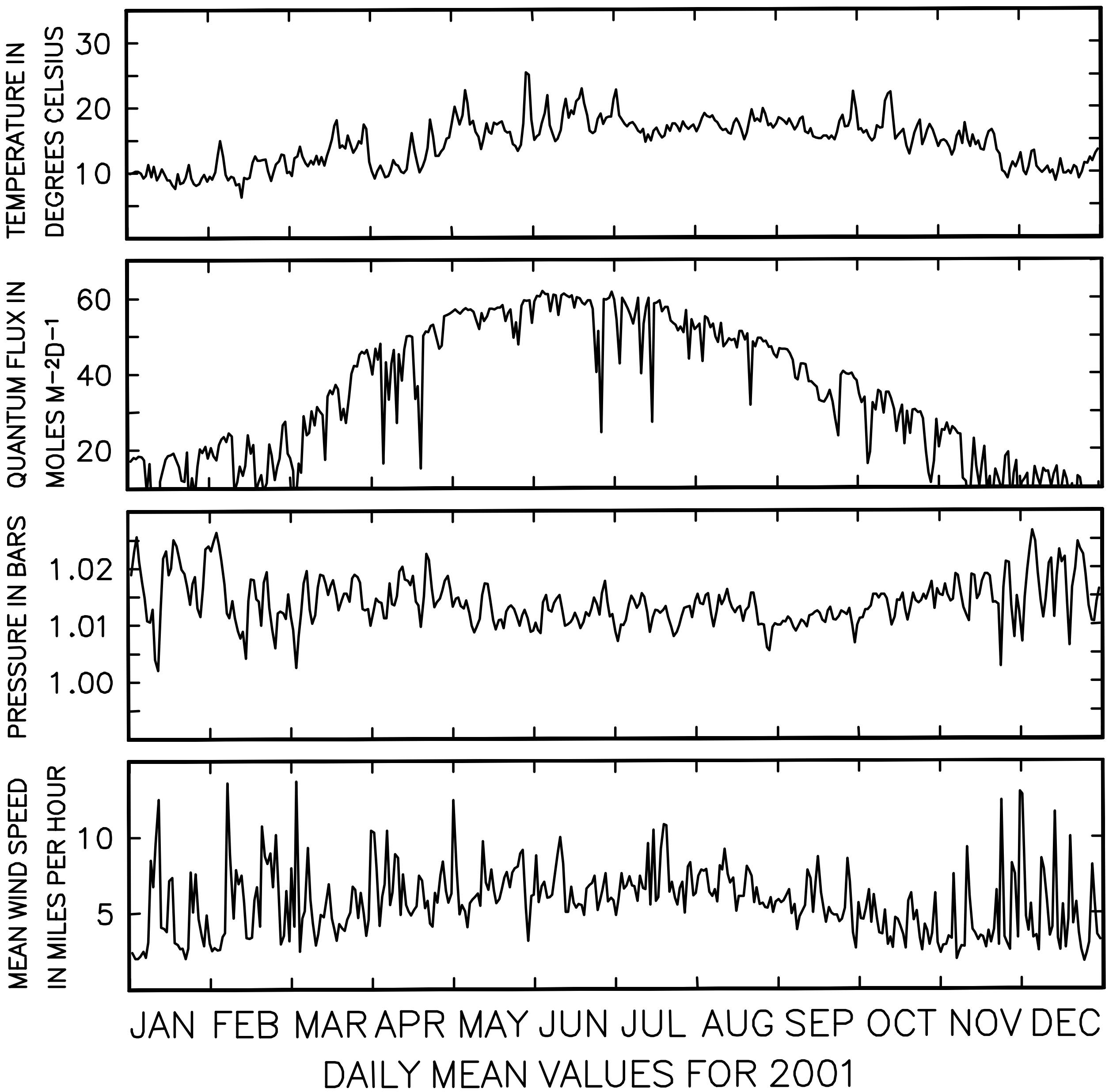

Figure 5. Time series plots of daily mean temperature, quantum flux, barometric pressure, and scalar wind speed at the Port of Redwood City, USGS – RWC, 2001.

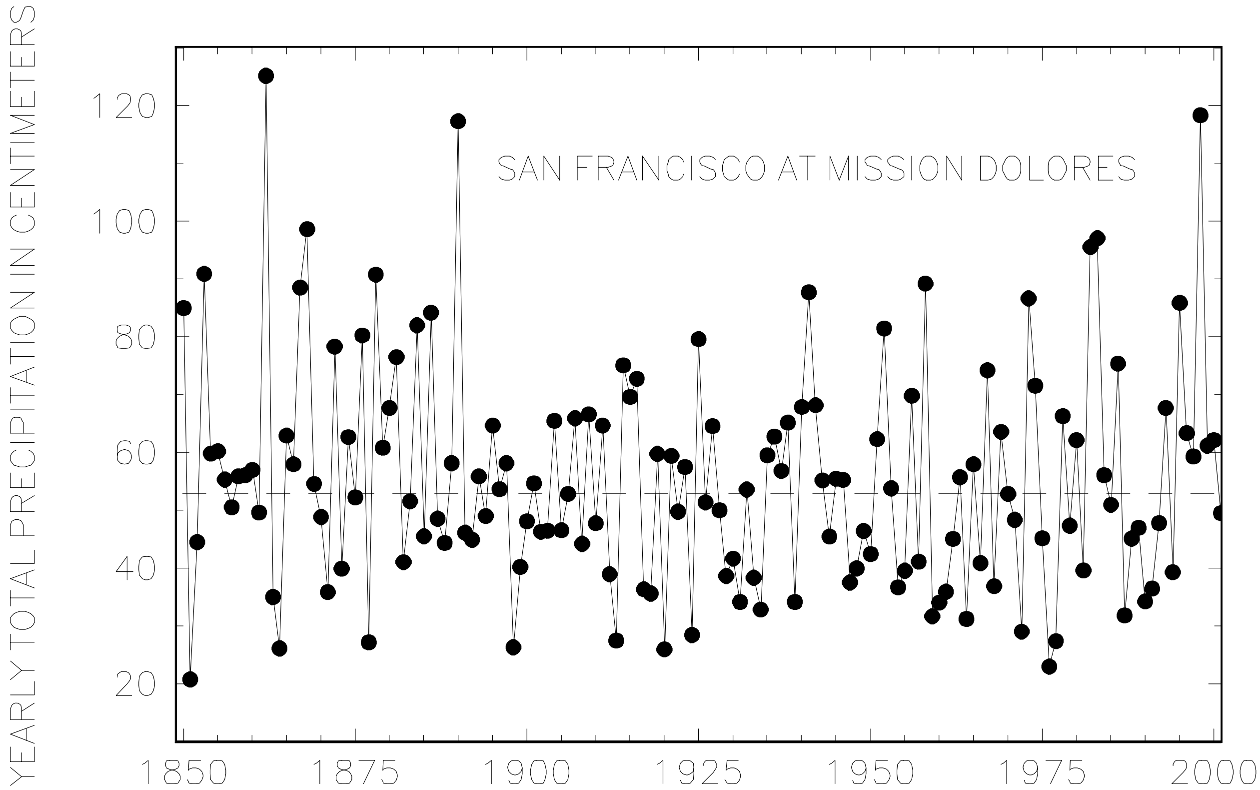

Figure 6. Total annual precipitation at Mission Dolores in San Francisco, California, for 1850-2001 water years.

Monthly precipitation values provide a framework for describing the variability in the meteorological observations (Fig. 7). Storms that bring precipitation to the San Francisco Bay area (primarily from November through April) are major factors associated with changes in pressure, temperature, and wind speed and direction. Major storms are typically accompanied by strong southerly winds that shift to the north after the front has passed. Monthly total precipitation was greatest in February 1998, which coincided with the lowest (daily mean) barometric pressure values over the four-year record from USGS-RWC (Fig. 2). High wind speeds were also recorded during the lowest pressure values in early February 1998. Low pressure values were also recorded in February and early March 2000 (Fig.4), and this several-week-long sequence of storms also is reflected in low insolation values (compared to the other years). Low pressure and high wind speeds coincided with higher than normal precipitation during winter and autumn 2001 (Fig.5).

Provisional data now available on the Internet for the PORTS meteorological station at the Port of Redwood City were compared with UGSG-RWC pressure, wind speed, and wind direction data for quality assurance (downloaded May 16, 2002, from the products link at http://ports-infohub.nos.noaa.gov/ports/hubs/san_francisco_bay/). PORTS data are recorded at 6-minute intervals, whereas USGS-RWC sensors were read every 5 minutes and the mean was recorded every hour. Effects of differences in averaging and sampling methods were not investigated. PORTS wind speeds were not converted from knots to statute miles per hour, because this would reduce the PORTS values by only 13 percent. Hourly means (simple box means) were calculated from the PORTS data for comparison of the two data sets during autumn 2001. Barometric pressure values were consistently higher at the PORTS station; however the variability in the readings was nearly identical for the two stations (Fig. 8). Hourly wind speeds were comparable for the two stations during episodes of strong winds in the example 10-day record (Fig. 9). Although there were no consistent differences at high wind speeds, the USGS-RWC sensor recorded higher values at relatively low wind speeds. Differences between wind speed measurements at the two stations might be attributable to the higher elevation of USGS-RWC and effects of the Marine Facility building on air flow. Wind direction measurements appeared comparable (within 10-20 degrees) for the two stations (Fig. 10).

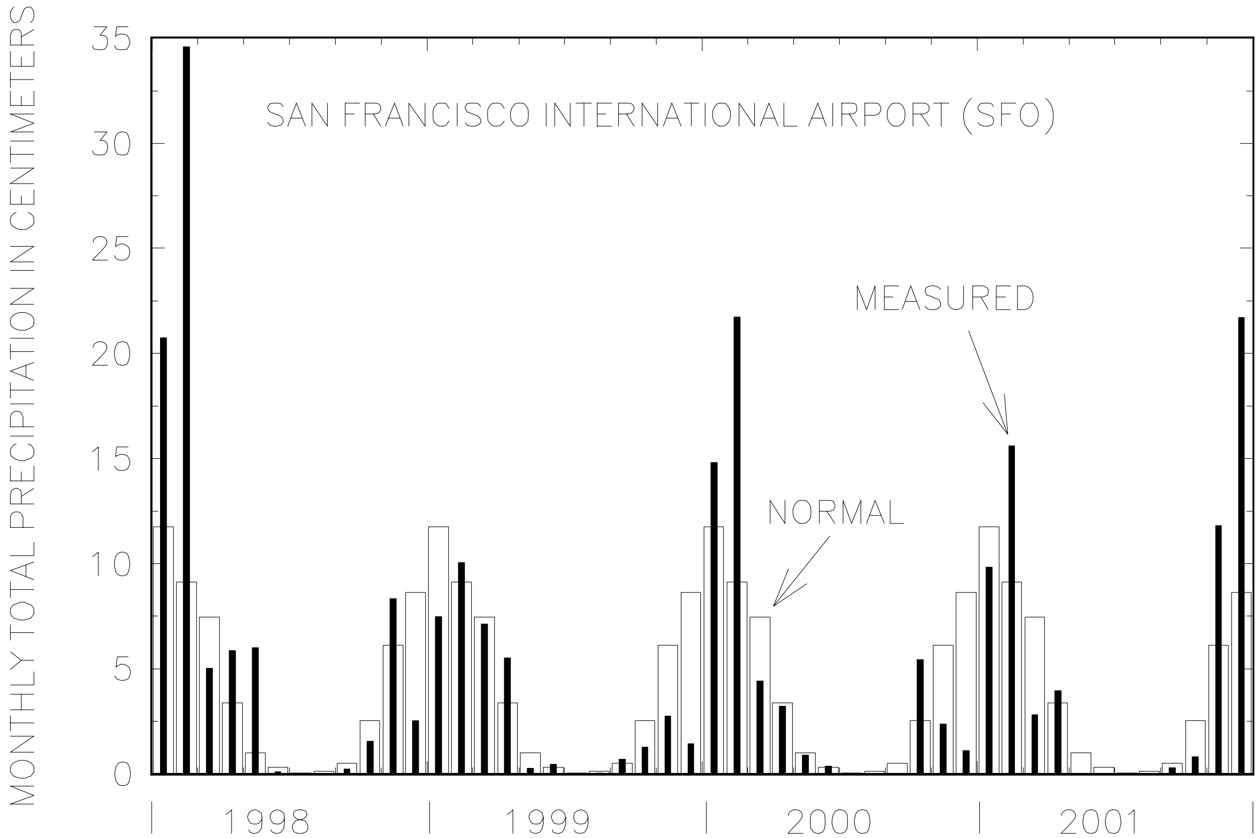

Figure 7. Total monthly precipitation at San Francisco International Airport for 1998-2001 calendar years.

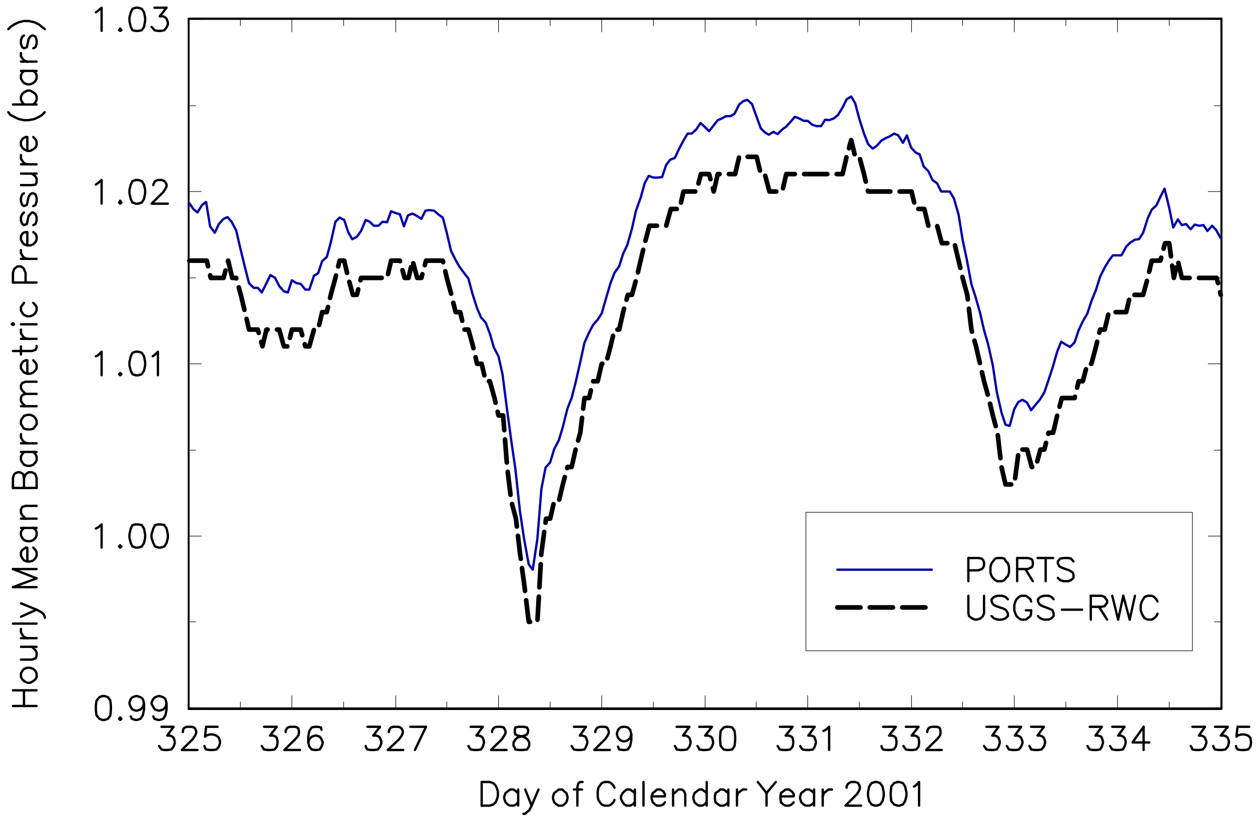

Figure 8. Hourly mean barometric pressure measurements for USGS RWC and PORTS stations during Autumn 2001.

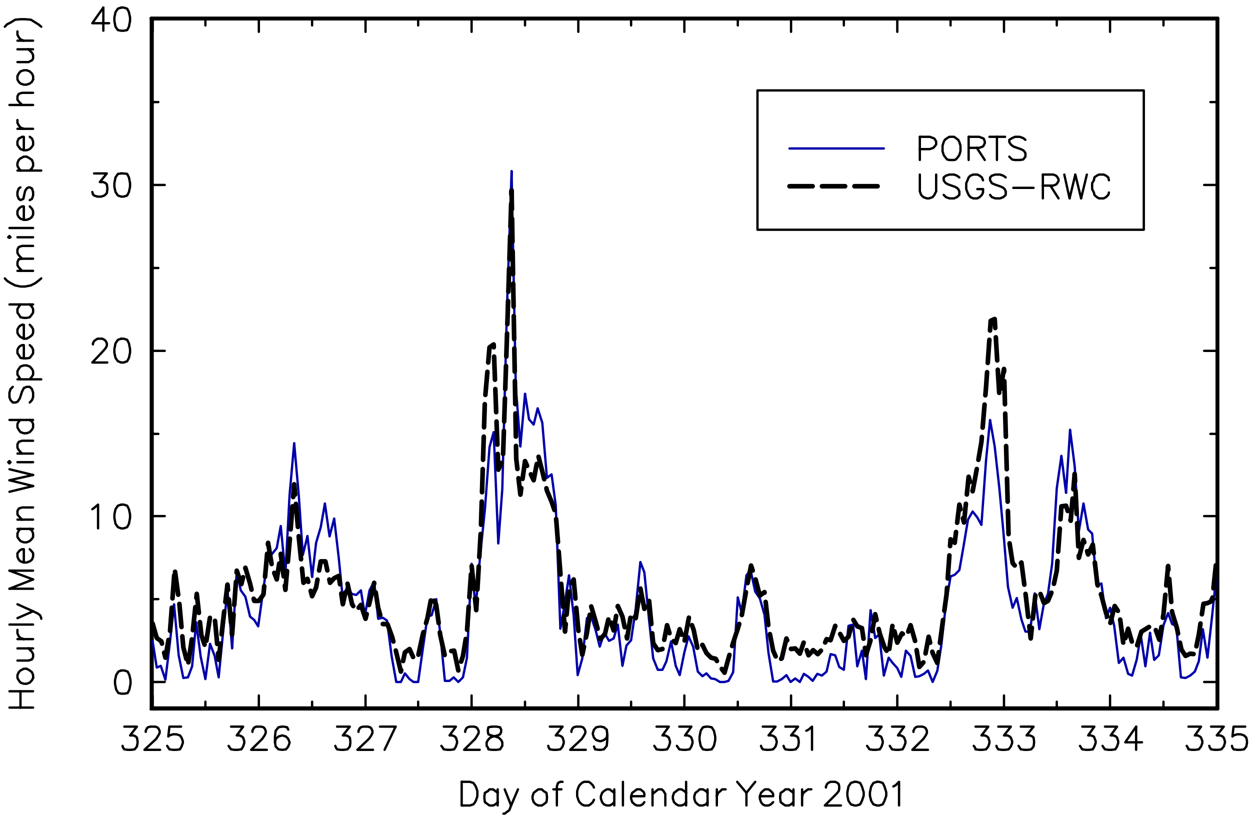

Figure 9. Hourly mean wind speed measurements for USGS-RWC and PORTS stations during autumn 2001.

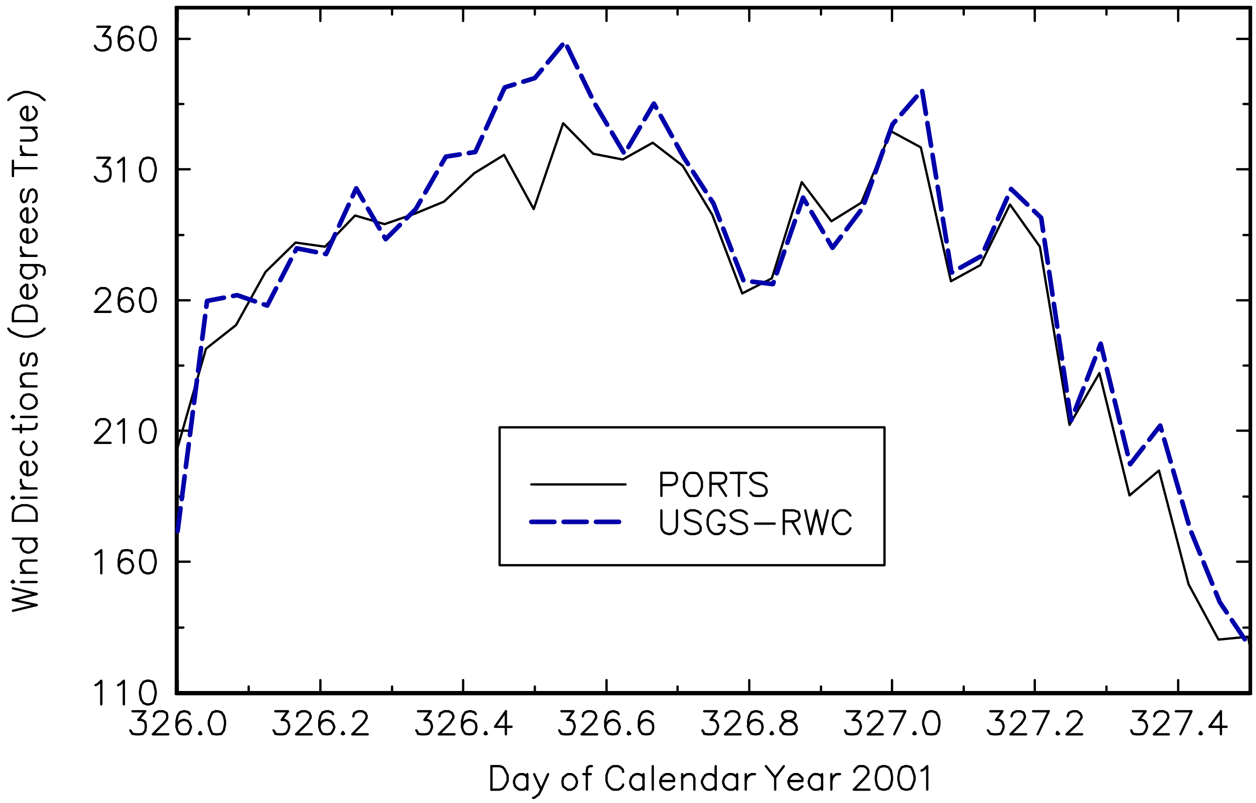

Figure 10. Hourly mean wind direction measurements for USGS-RWC and PORTS stations during autumn 2001.

SUMMARY

Data for 1998-2001 calendar years from the USGS-RWC meteorological station are presented in this report. In addition, files containing this report, previous reports, and all of the data from April 1992 to December 2001 are provided. It is likely that data collection will continue for a few years at the USGS-RWC meteorological station to provide a continuous record for on-going hydrologic investigations in the landward reach of South Bay. Because of the availability of 2000 and more recent PORTS data from the NOAA Internet site, data from USGS-RWC after December 2001 might not be published, but data will be made available upon request.

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Walters, R.A., Cheng, R.T., and Conomos, T.J., 1985, Time scales of circulation and mixing processes of San Francisco Bay waters: Hydrobiologia, vol.129, p.13-36.

Table 4. Data collection and control program for USGS-RWC.

```
SCAN RATE 300

1:P2       Differential Volt: Licor Quantum Sensor
1:01       Repeat
2:23       25mV 60 Hz rejection Range
3:01       IN Channel
4:01       Location
5:396.83   Multiplier
6:0.0000   Offset

2:P11      Temperature Probe 107
1:01       Repeat
2:03       IN Channel
3:01       Excite all reps w/Exchannel 1
4:02       Location
5:1.0000   Multiplier
6:0.0000   Offset

3:P3       Pulse Wind Speed
1:01       Repeat
2:01       Pulse Input Channel
3:11       Low level AC
4:03       Location
5:.00073   Multiplier
6:0.0000   Offset

4:P4       Excite, Delay, Volt (SE) Wind Direction
1:01       Repeat
2:05       2500 mV slow Range
3:04       IN Channel
4:02       Excite all reps w/Exchannel 2
5:02       Delay (units 0.01sec)
6:2500     mV Excitation
7:04       Location
8:0.1420   Multiplier
9:0.001    Offset
```

Table 4. Continued.

5:P4	Excite, Delay, Volt (SE) Barometric Pressure
1:01	Repeat
2:05	2500 mV slow Range
3:05	IN Channel
4:03	Excite all reps w/Exchannel 3
5:300	Delay (units 0.01sec)
6:2500	mV Excitation
7:05	Location
8:0.104	Multiplier
9:800	Offset
6:P92	If time is
1:0000	minutes into a
2:0060	minute interval
3:10	Set high Flag 0 (output)
7:P77	Real Time
1:0110	Day, Hour-Minute
8:P71	Average
1:02	Repeats
2:01	Location
9:P71	Average
1:01	Repeat
2:05	Location
10:P69	Wind Vector
1:01	Repeat
2:03	Samples per sub-interval
3:02	Polar Sensor/(S, U, DU, SDU)
4:3	Wind Speed/ East Location
5:4	Wind Direction/ North Location
11:P78	Resolution
1:01	High Resolution
12: P	End Program

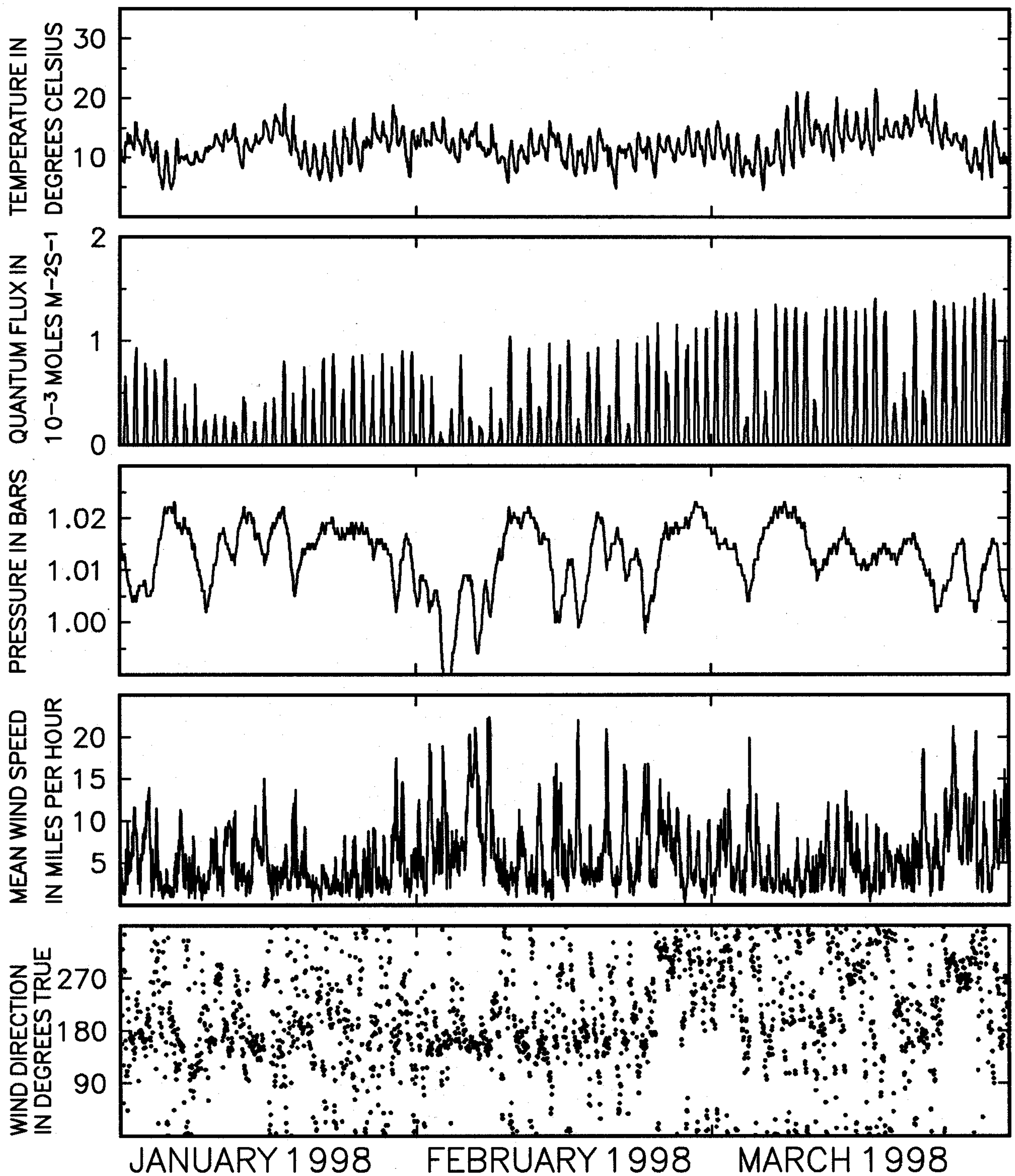

Figure 11. Time series plots of hourly mean temperature, quantum flux, pressure, wind speed and wind direction for January through March 1998.

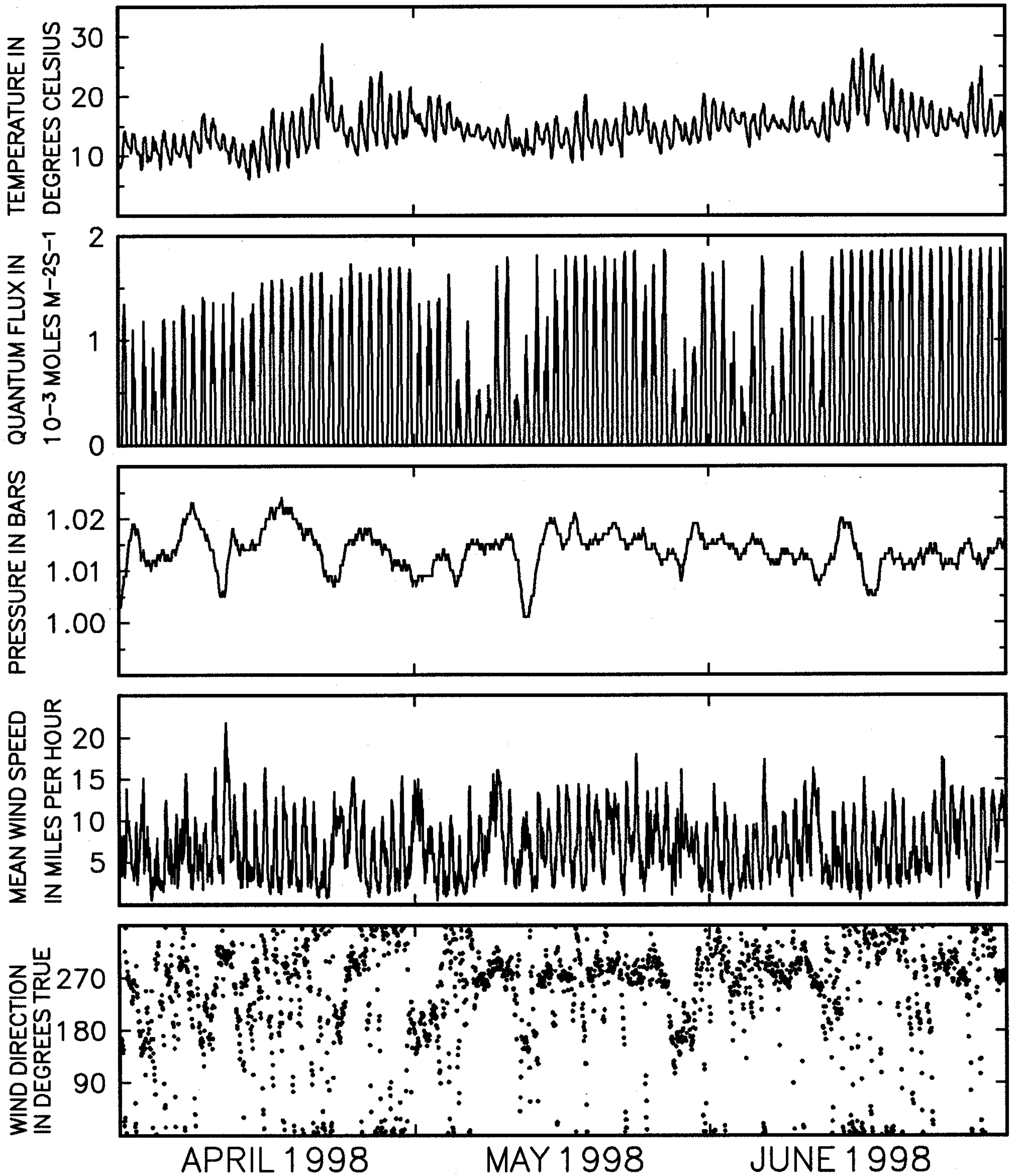

Figure 12. Time series plots of hourly mean temperature, quantum flux, pressure, wind speed and wind direction for April through June 1998.

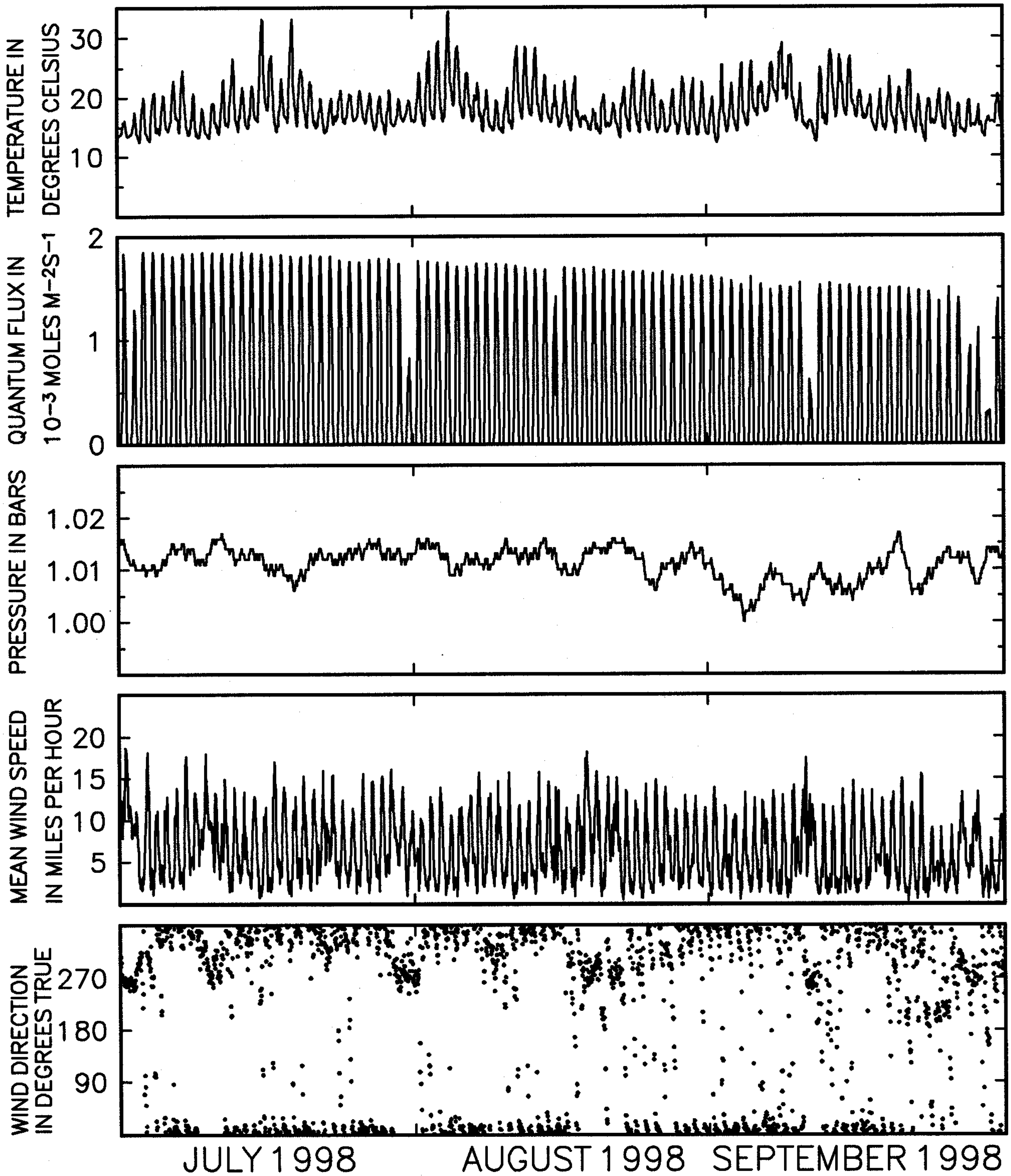

Figure 13. Time series plots of hourly mean temperature, quantum flux, pressure, wind speed and wind direction for July through September 1998.

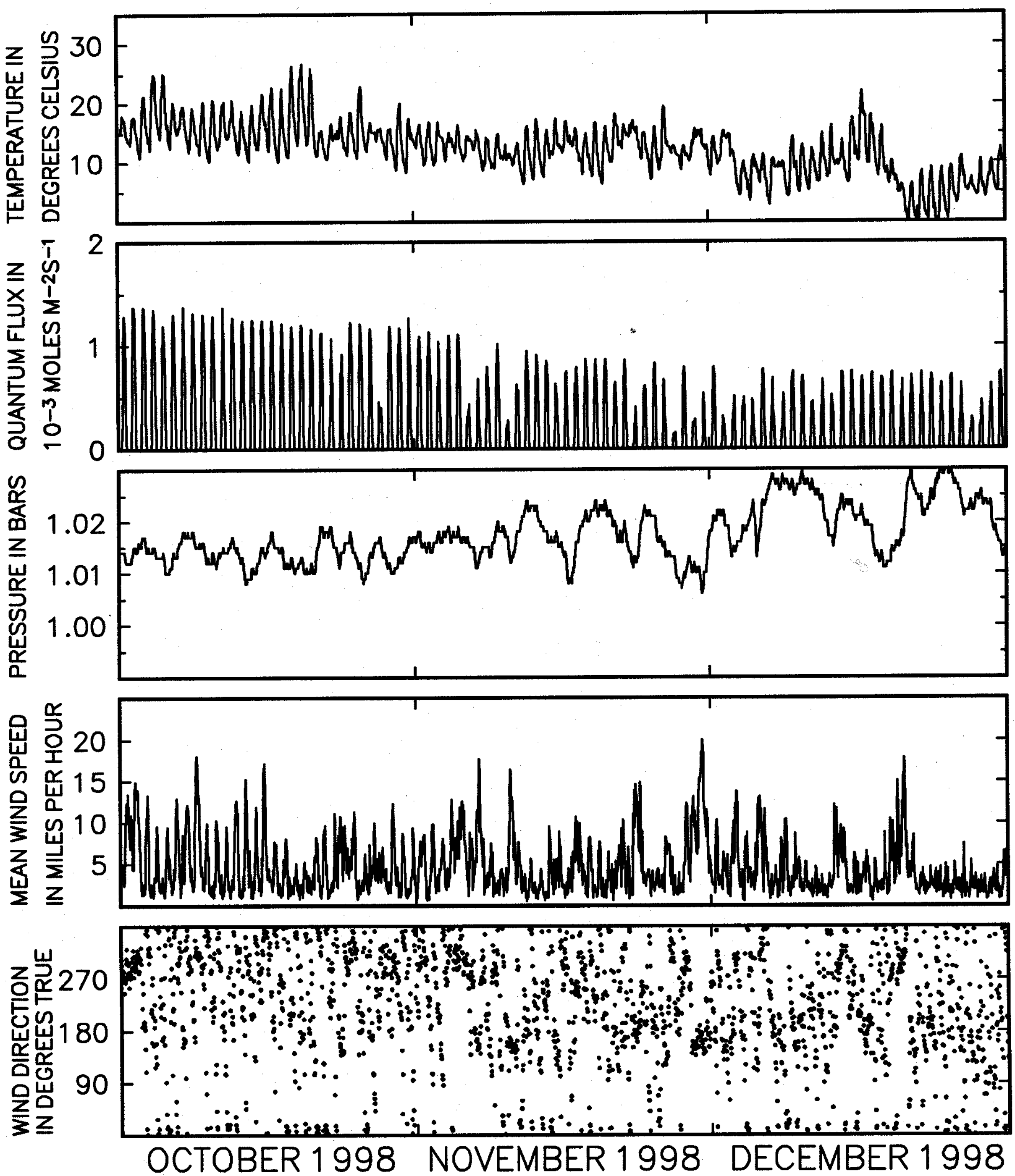

Figure 14. Time series plots of hourly mean temperature, quantum flux, pressure, wind speed and wind direction for October through December 1998.

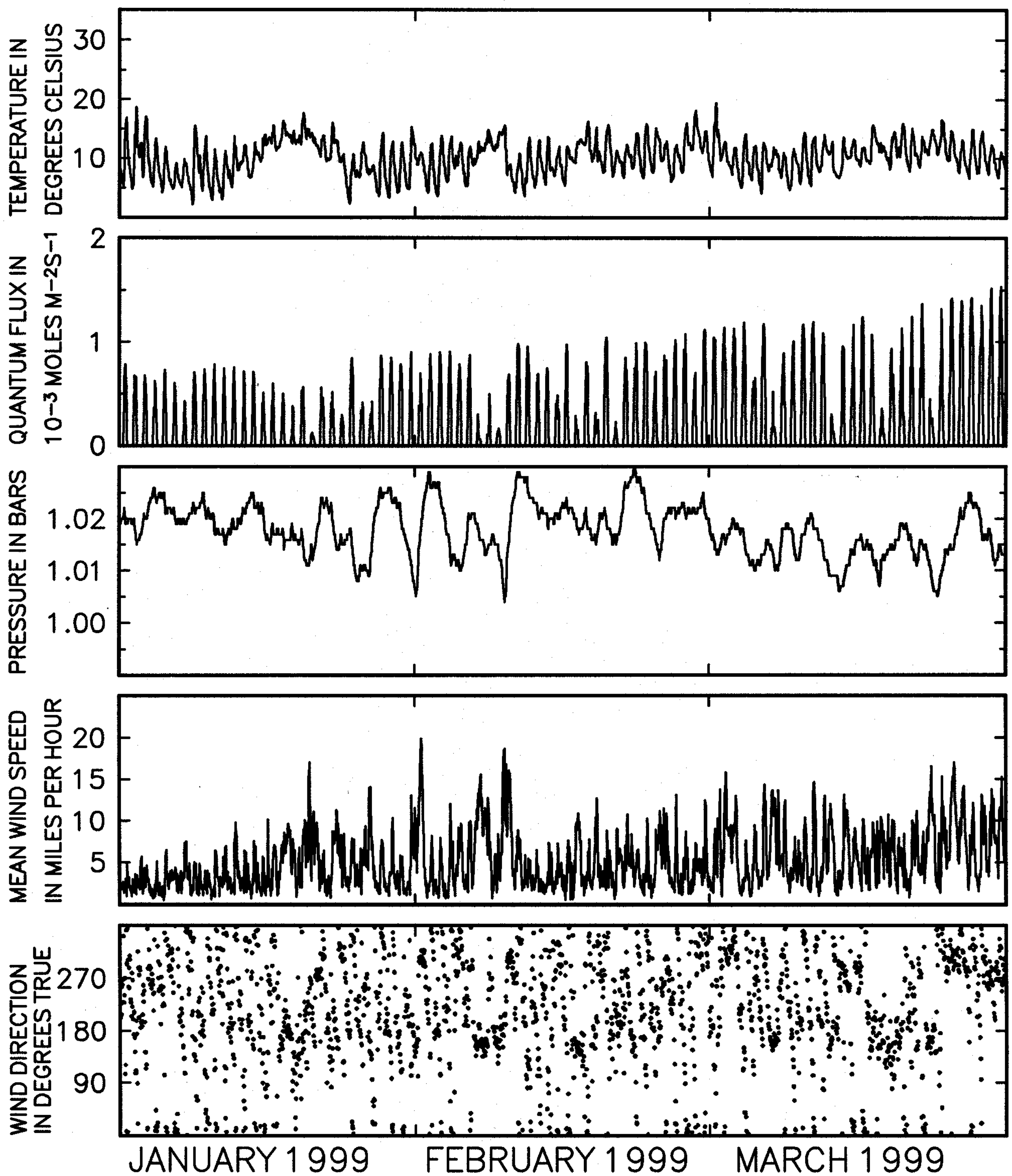

Figure 15. Time series plots of hourly mean temperature, quantum flux, pressure, wind speed and wind direction for January through March 1999.

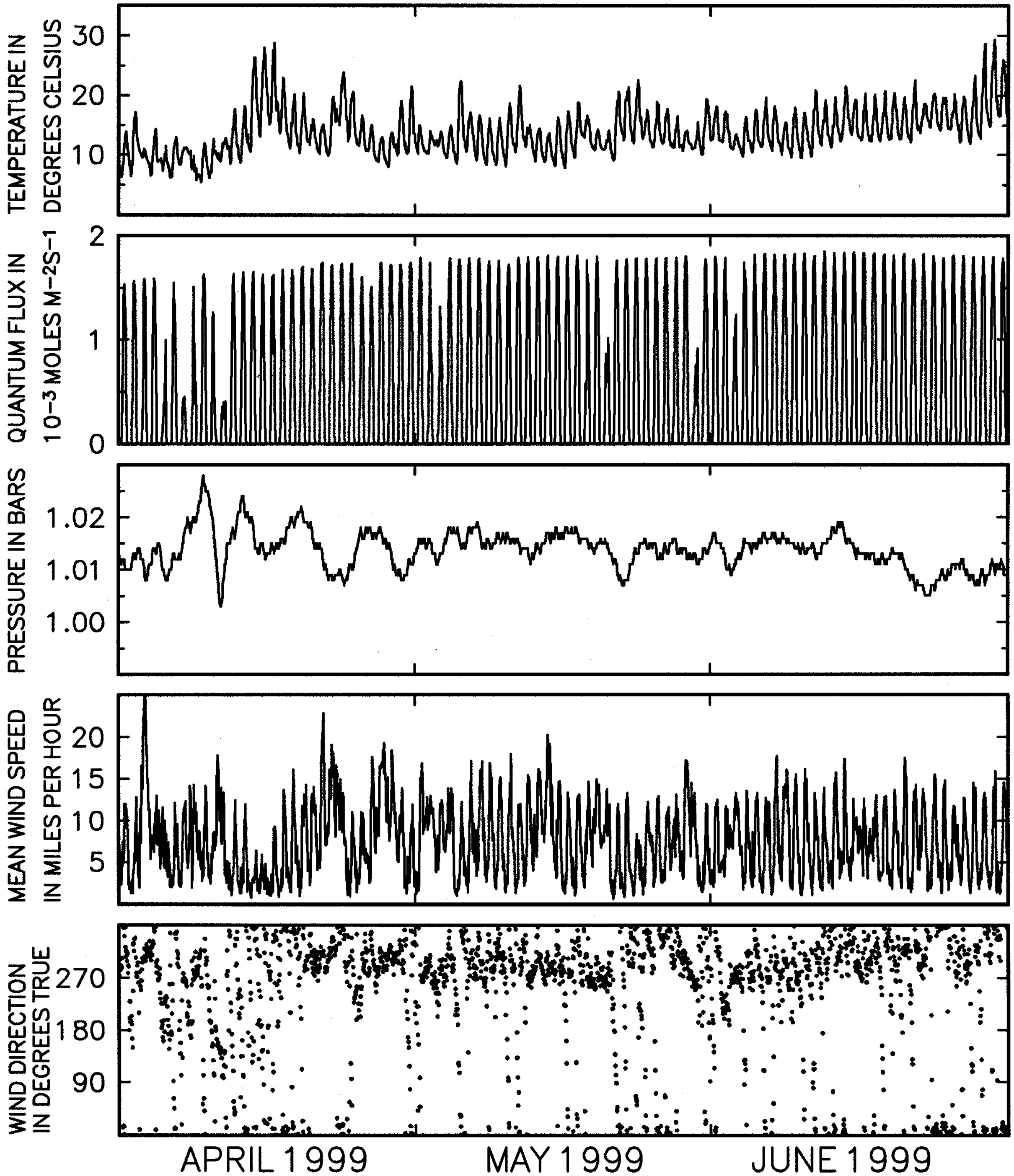

Figure 16. Time series plots of hourly mean temperature, quantum flux, pressure, wind speed and wind direction for April through June 1999.

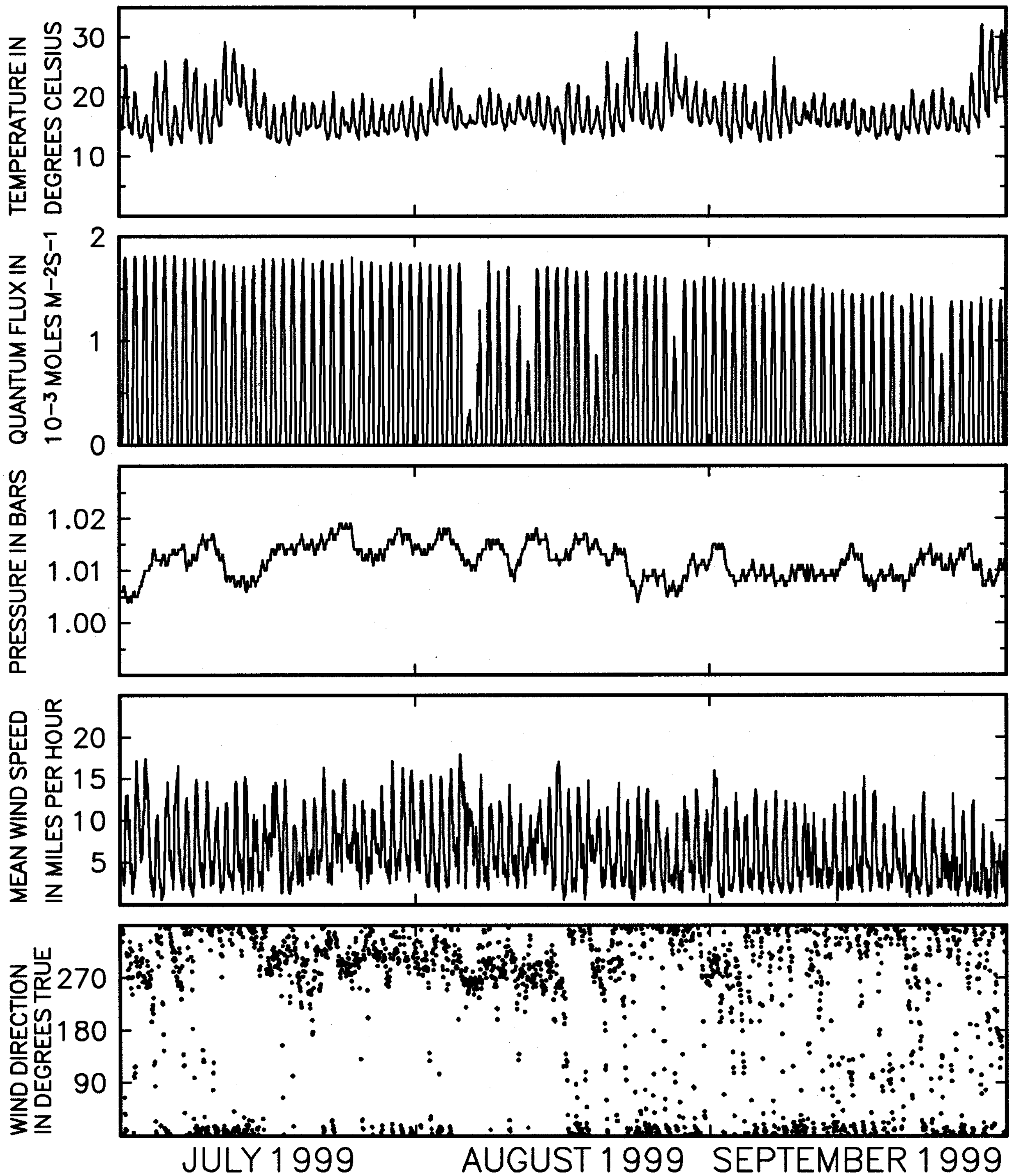

Figure 17. Time series plots of hourly mean temperature, quantum flux, pressure, wind speed and wind direction for July through September 1999.

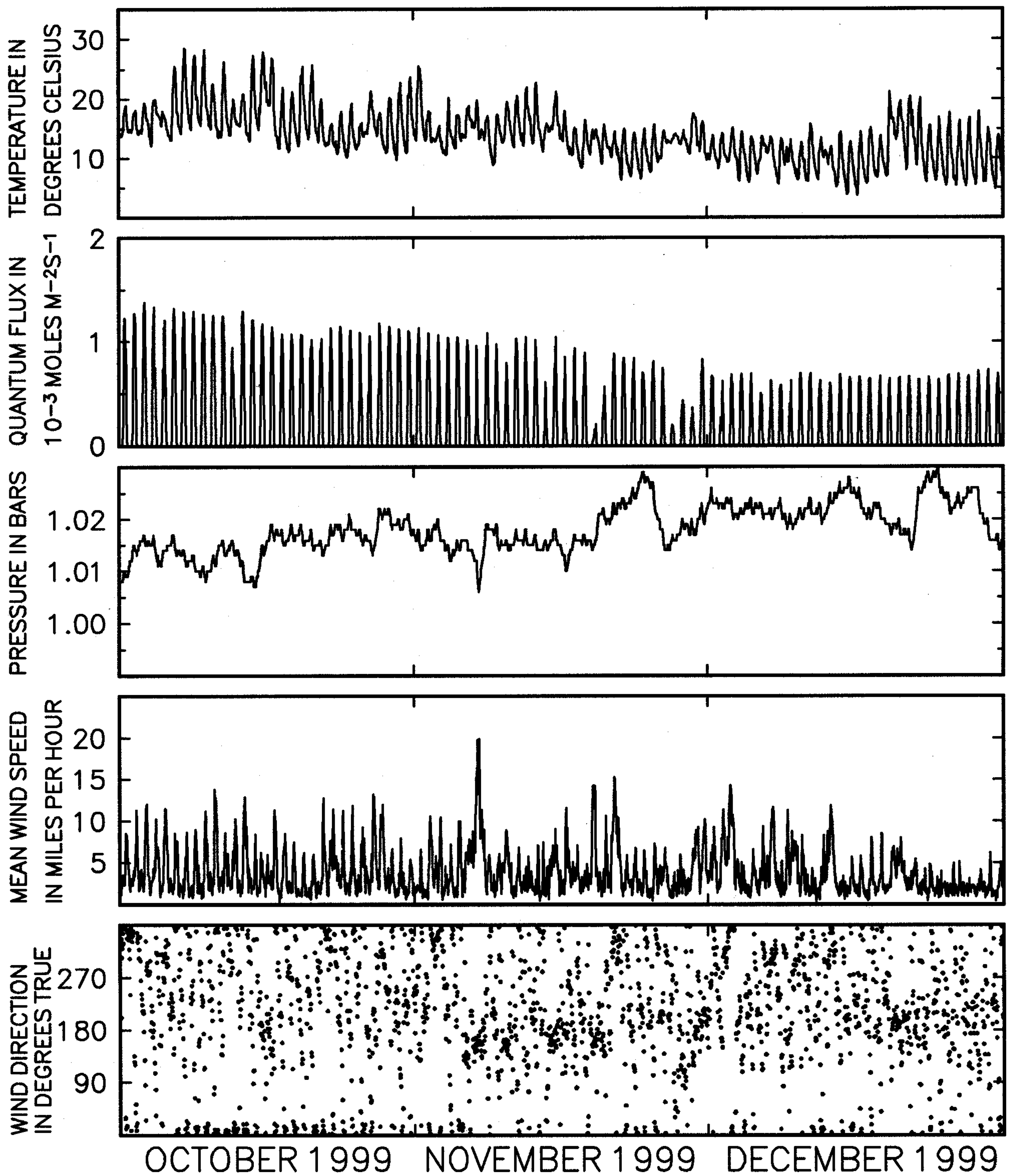

Figure 18. Time series plots of hourly mean temperature, quantum flux, pressure, wind speed and wind direction for October through December 1999.

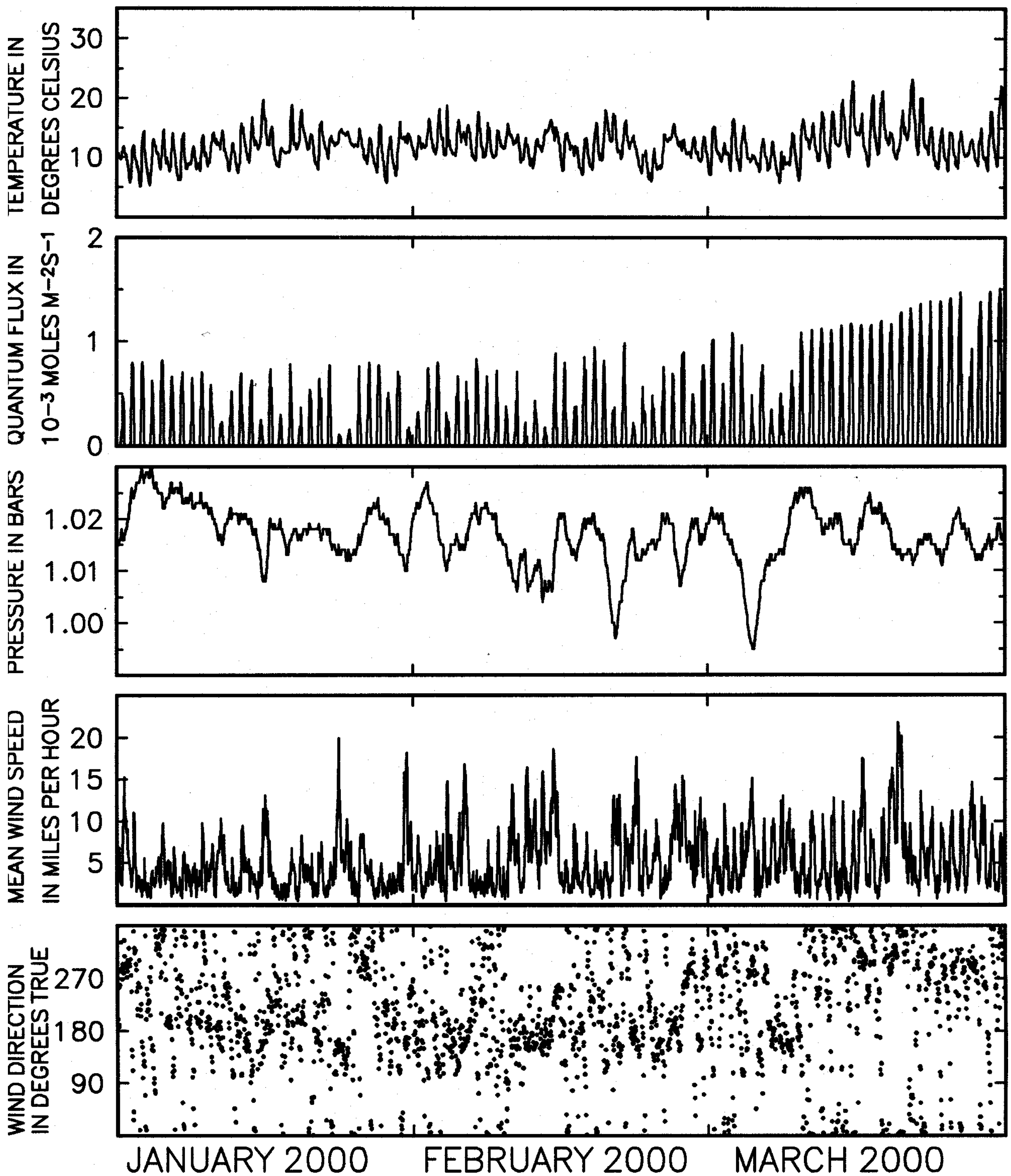

Figure 19. Time series plots of hourly mean temperature, quantum flux, pressure, wind speed and wind direction for January through March 2000.

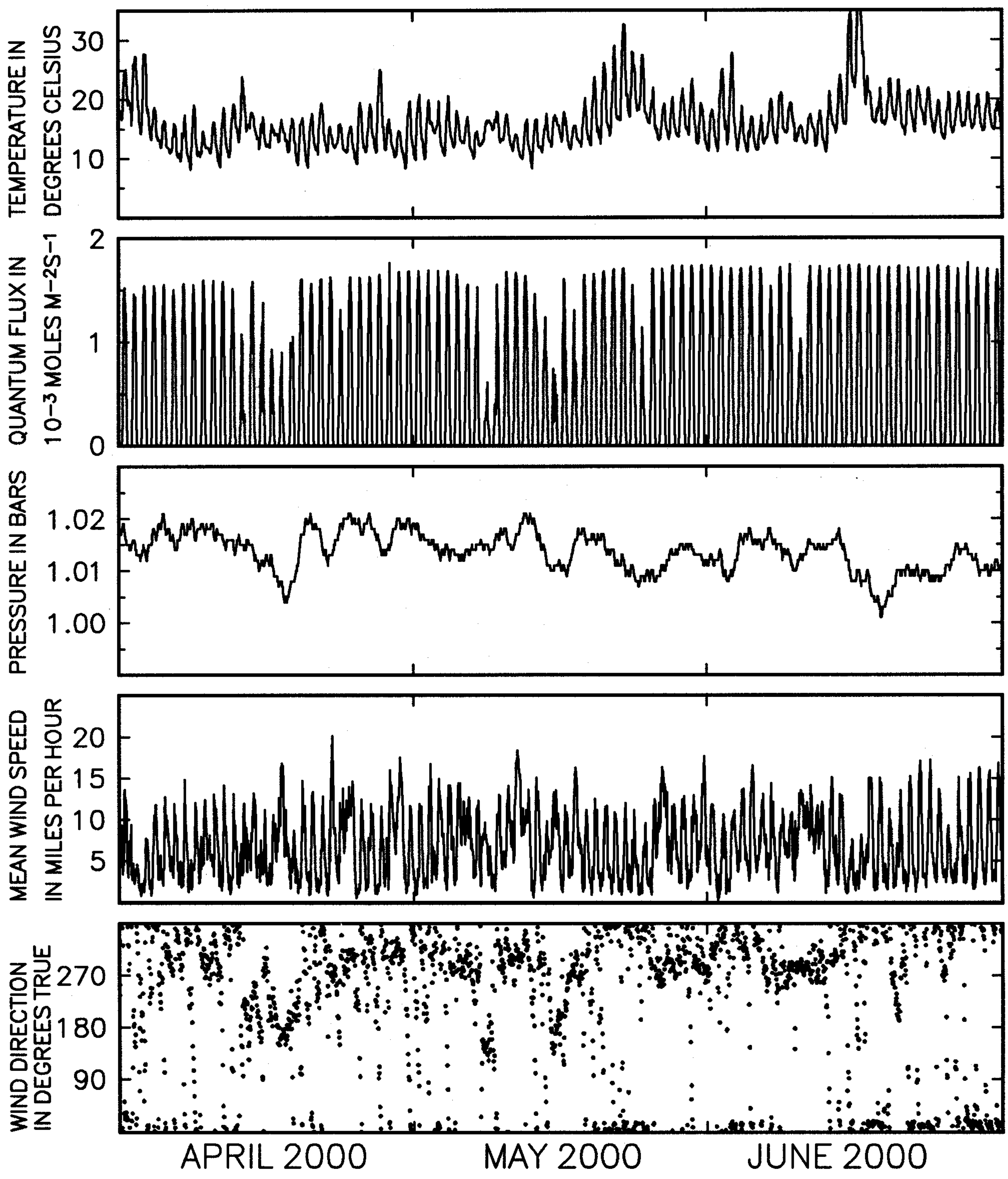

Figure 20. Time series plots of hourly mean temperature, quantum flux, pressure, wind speed and wind direction for April through June 2000.

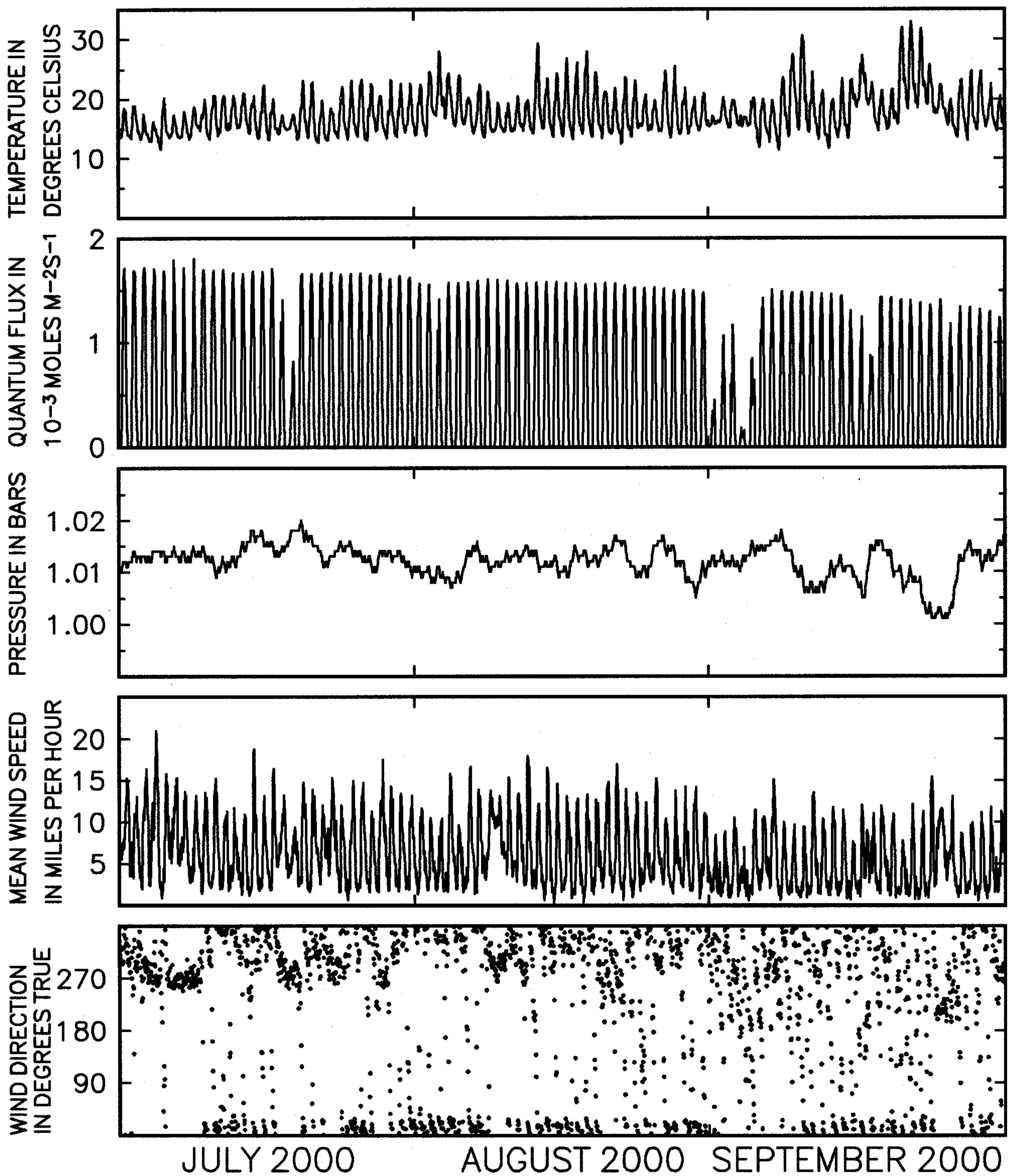

Figure 21. Time series plots of hourly mean temperature, quantum flux, pressure, wind speed and wind direction for July through September 2000.

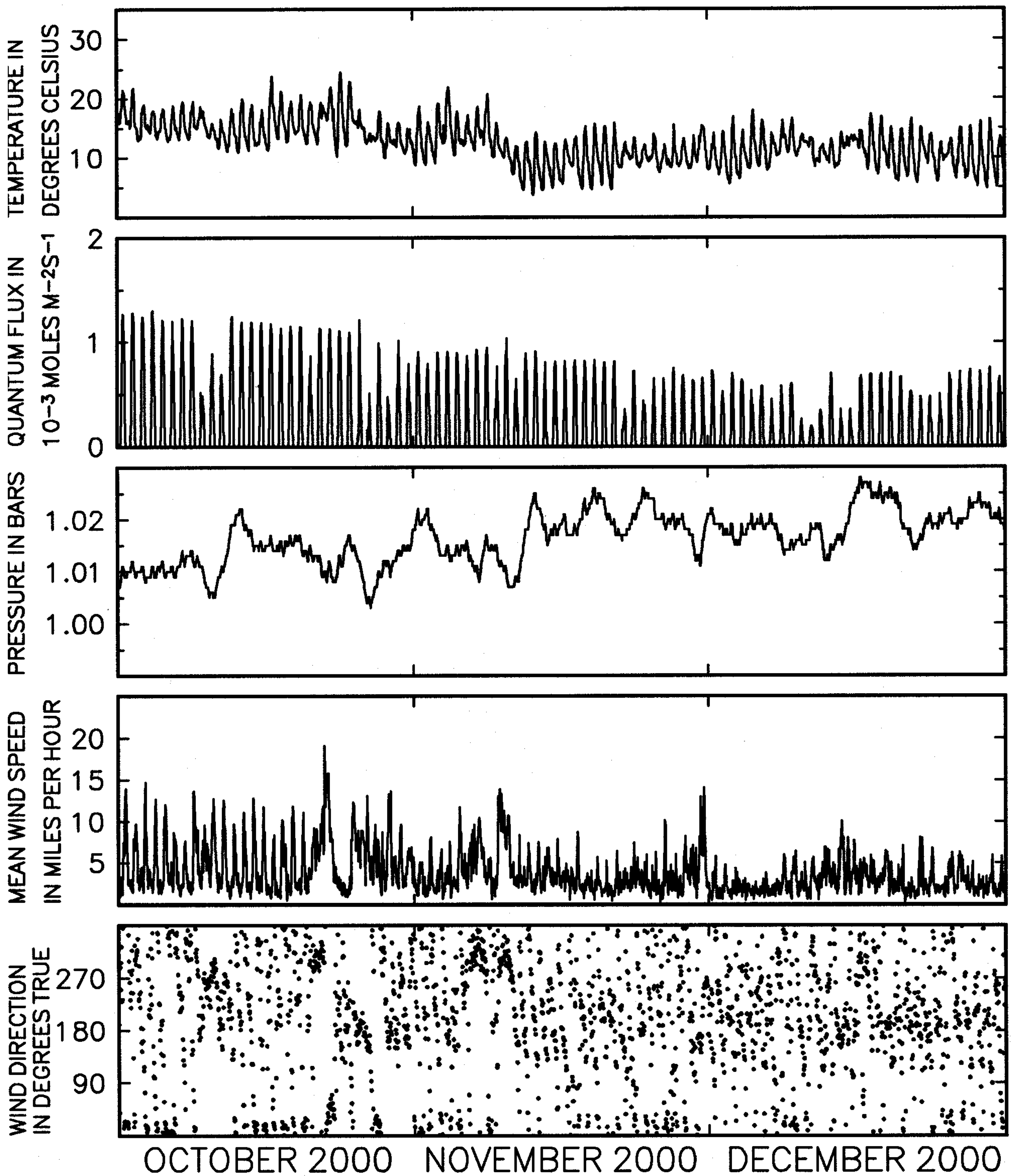

Figure 22. Time series plots of hourly mean temperature, quantum flux, pressure, wind speed and wind direction for October through December 2000.

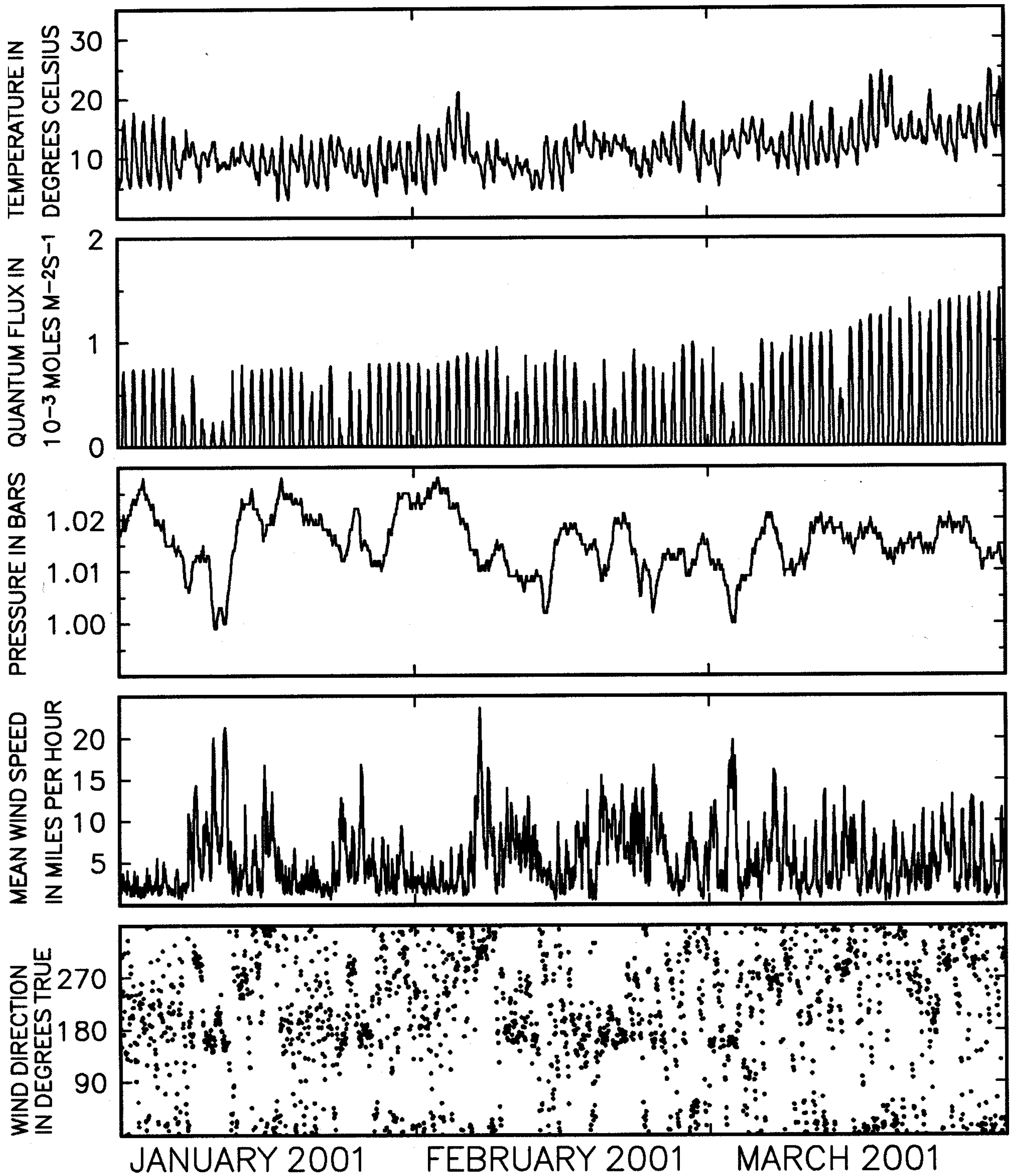

Figure 23. Time series plots of hourly mean temperature, quantum flux, pressure, wind speed and wind direction for January through March 2001.

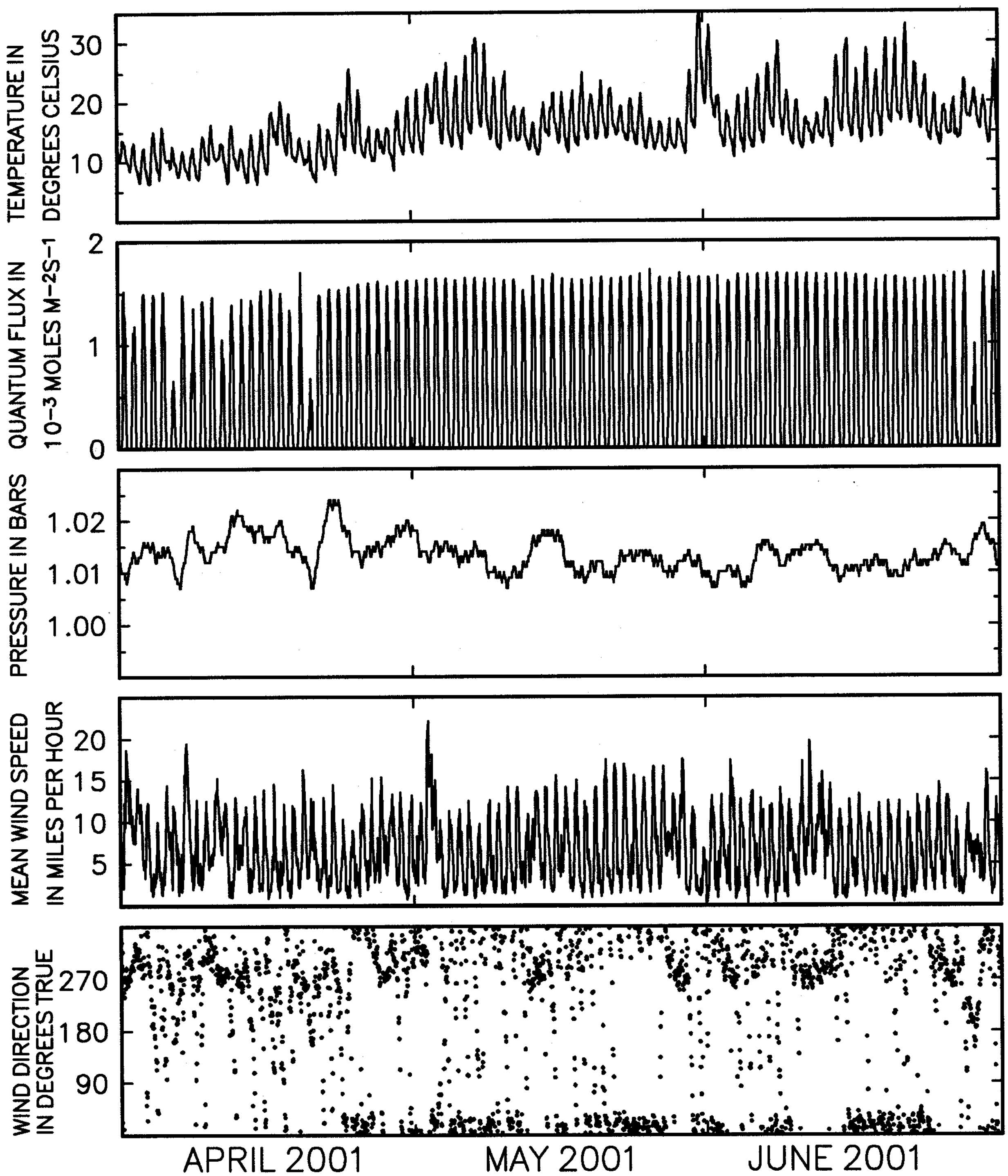

Figure 24. Time series plots of hourly mean temperature, quantum flux, pressure, wind speed and wind direction for April through June 2001.

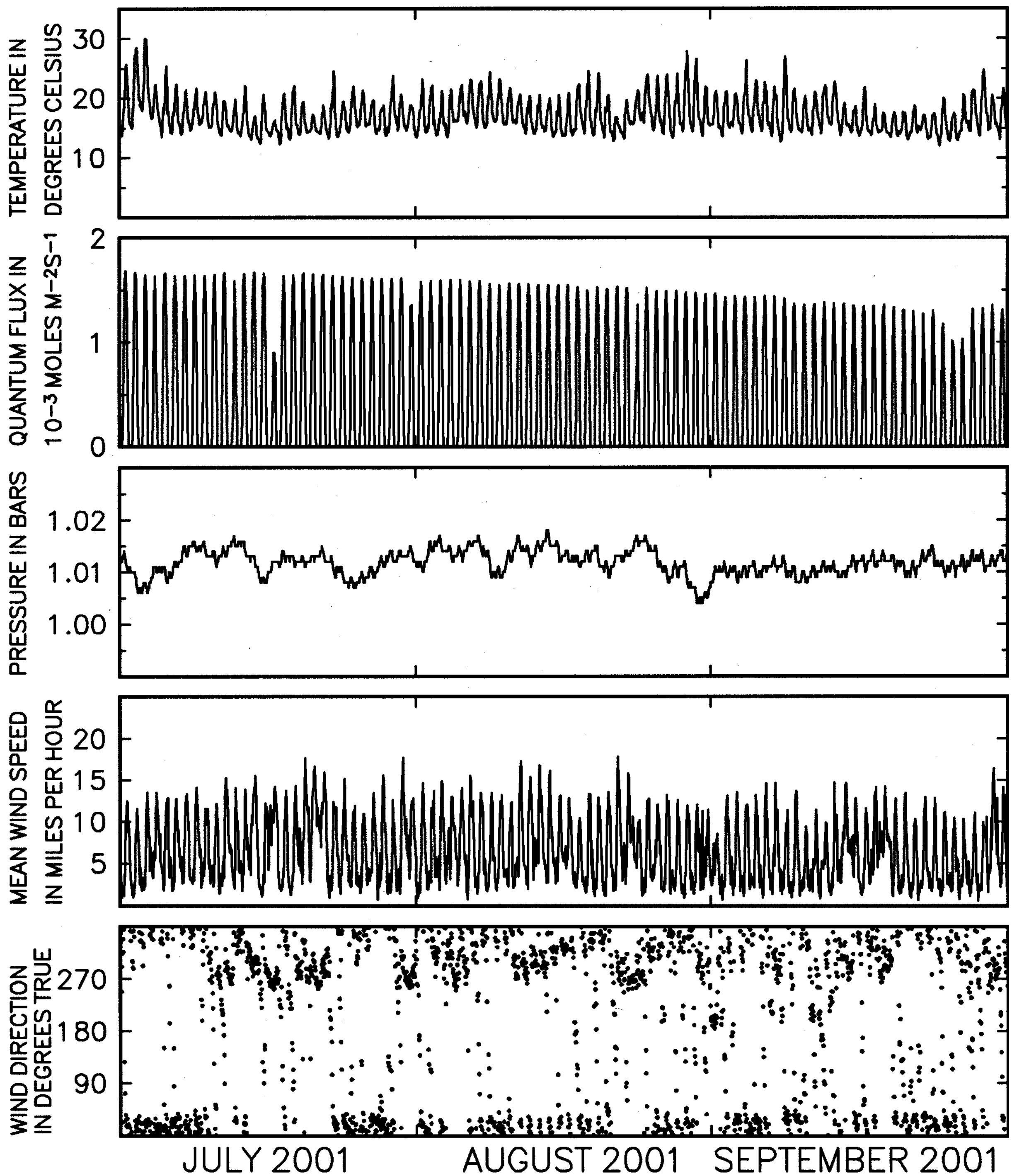

Figure 25. Time series plots of hourly mean temperature, quantum flux, pressure, wind speed and wind direction for July through September 2001.

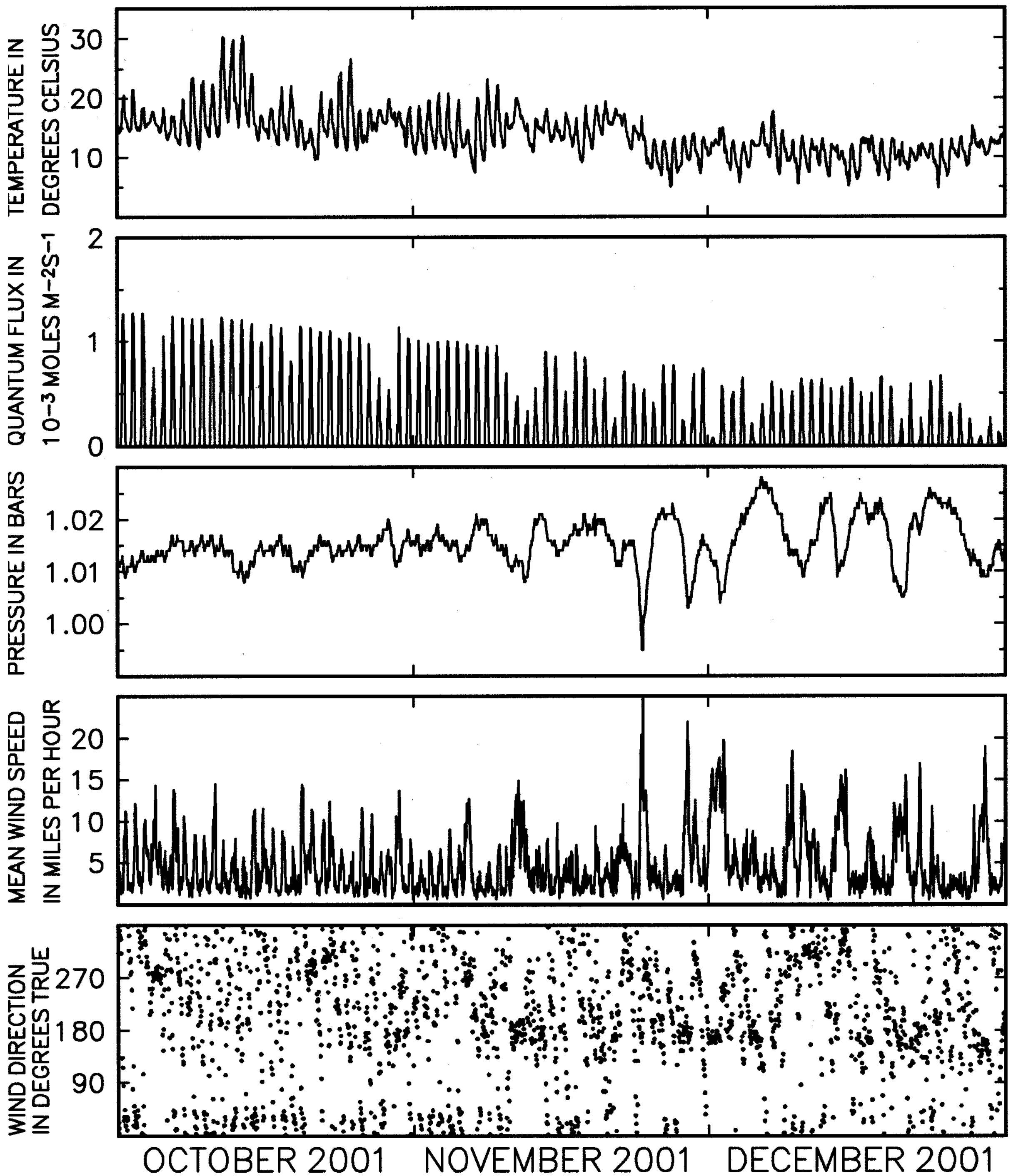

Figure 26. Time series plots of hourly mean temperature, quantum flux, pressure, wind speed and wind direction for October through December 2001.