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Long –Term Evolution and Coupling of the Boundary Layers in the Stratus Deck Regions of the Eastern Pacific (STRATUS)

Data Report

by

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Kelan Huang

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Woods Hole Oceanographic Institution (WHOI)

August 2002

Technical Report

Funding was provided by the National Oceanic and Atmospheric Administration under Grant Numbers NA81RJ1223.

Approved for public release; distribution unlimited.

Upper Ocean Processes Group
Woods Hole Oceanographic Institution
Woods Hole, MA 02543
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Nelson G. Hogg, Chair

Department of Physical Oceanography

Abstract

The surface mooring component of the CLIVAR Long Term Evolution and Coupling of the Boundary Layers in the Stratus Deck Regions study (STRATUS) took place from October 2000 in the eastern tropical Pacific. As part of the Eastern Pacific Investigation of Climate Processes in the Coupled Ocean-Atmosphere System (EPIC), STRATUS is a CLIVAR study with the goal of investigating links between sea surface temperature variability in the eastern tropical Pacific and climate over the American continents. This study started a three-year occupation off Chili in order to collect accurate time series of surface forcing and upper ocean variability.

The Upper Ocean Processes (UOP) Group at WHOI deployed one fully instrumented surface mooring near 20°S 85°W in October 2000, at the western edge of the stratocumulus cloud deck found west of Peru and Chile, to achieve a good understanding of the role of clouds in the eastern Pacific in modulating atmosphere-ocean coupling. Data from the moorings will improve our understanding of the air-sea fluxes and be used to examine the processes that control sea surface temperature in the cold tongue/intertropical convergence zone (ITCZ) and in the stratus deck region.

The first surface mooring (Stratus 1) was deployed in October 2000 by the UOP group and replaced by a second mooring one year later with almost identical instrumentation (Stratus 2). Stratus 1 was equipped with meteorological instrumentation, including two Improved METeorological (IMET) systems. The mooring also carried Vector Measuring Current Meters (VMCMs), single point temperature, salinity and conductivity recorders, and an acoustic Doppler Current Profiler (ADCP) to monitor the upper 500m of the ocean. In addition to the traditional instruments, several other experimental instruments were deployed with limited success on the mooring line including an acoustic current meter, bio-optical instrumentation packages, and an acoustic rain gauge.

This report describes the instrumentation deployed on the first Stratus surface mooring (Stratus 1 mooring) from October 2000 to October 2001, along with information on the processing and quality control of the returned data. It presents a detailed overview of the meteorological and physical oceanographic data including time series plots, statistics and spectra of key parameters. It also presents the estimated air-sea heat, moisture and momentum fluxes.

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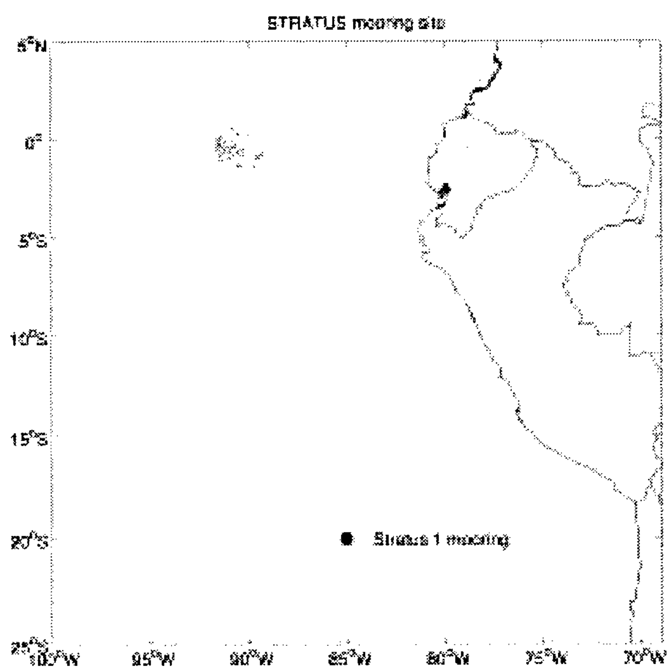
Section 1: Introduction

The sea surface temperature field in the eastern tropical Pacific, with its strong asymmetry about the equator, annual and interannual variability, persistent stratus clouds and links to climate are of great interest to studies of coupled ocean-atmosphere variability and of the ocean's impact on climate. Under CLIVAR, we began a program entitled Long-Term Evolution and Coupling of the Boundary Layers in the Stratus Deck Regions (STRATUS). The focus of this study was on coupled ocean and atmosphere variability under the stratus clouds off northern Chile.

From October 2000 through October 2001, the Stratus 1 surface mooring located at approximately 20°S 85°W was equipped to collect accurate time series of surface meteorology and upper ocean temperature, velocity, and salinity structure (Figure 1-1). The mooring site was chosen because of the characteristic of the persistent stratus decks to the west of Peru and Chile which exert a strong cooling influence on the local and global heat balance and, further, play a role in maintaining the equatorial asymmetry of sea surface temperature and winds in the eastern tropical Pacific.

Figure 1-1. STRATUS eastern tropical Pacific mooring location



The mooring carried two complete sets of meteorological sensors (wind speed and direction, air and sea temperature, incoming short-wave radiation and incoming long-wave radiation, humidity, barometric pressure, precipitation). Improved METeorological (IMET; Hosom et al., 1995) systems were used in redundancy to ensure that a complete and accurate time series of all meteorological variables would be collected. The mooring also carried oceanographic sensors (temperature, salinity, conductivity and current) placed in the top 500 m of the ocean to monitor the upper ocean variability.

The meteorological data permit the accurate calculation of the heat, freshwater, and momentum fluxes across the air-sea interface via the bulk formulae using techniques perfected in the Tropical Ocean-Global Atmosphere Coupled Ocean Atmosphere Response Experiment (TOGA COARE; Fairall et al., 1996a). Data from the mooring will improve our understanding of the air-sea fluxes in the eastern tropical Pacific and the processes that control sea surface temperature.

The mooring was deployed in October 2000 from the *R/V Melville* and recovered in October 2001 and another mooring with almost identical instrumentation was deployed in its place near 20°S 85°W onboard the R/V *R H Brown*. A detailed description of the field work can be found in the cruise reports (Lucas *et al.*, 2001, Vallée *et al.*, 2002). Meteorological and hydrographic data were collected in order to observe the temporal evolution of the vertical structure of the upper 500 m of the ocean, and to document and quantify the local coupling of the atmosphere and ocean in this region.

This report documents the meteorological and oceanographic data returned from the Stratus 1 surface mooring. Section 2 describes the instrumentation used on the mooring. Section 3 describes the data processes and quality control. Time series plots, statistics and spectra of key parameters are in Section 4.

The specific times and locations are given below in Table 1-1.

Table 1-1 Stratus 1 mooring deployment/recovery information

Mooring	Deployment Date and Time	Recovery Date and Time	Anchor Position
WHOI Stratus 1 Discus Buoy WHOI Mooring Reference No. 1052 Water depth: 4440 m	7 October 2000 @20:43 UTC	17 October 2001 @12:39 UTC	20°07.409'S 85°08.432'W

Section 2: Instrumentation

Details about each type of instrument on the Stratus 1 mooring are provided below beginning with the meteorological instrumentation and then followed by the subsurface instrumentation. Specific information about the instrumentation deployed during Stratus 1 can be found in Lucas, *et al.,* 2001 and in Vallée, *et al.*, 2002.

The top photo view on the Stratus 1 buoy is shown in Figure 2-1-1. The instrumented buoy is shown in Figure 2-1-2. The mooring diagram is shown in Figure 2-1-3. A side view of the buoy, showing the buoy tower and bridle for mooring is shown in Figure 2-1-4.

2-1. Meteorological Instrumentation

The WHOI discus buoy was outfitted with two separate and redundant meteorological packages. The meteorological data recording system called IMET (Improved METeorological measurements) logged data from eight meteorological sensors sampling at one minute intervals; this data was averaged into one hour intervals and telemetered via Service Argos. There were two IMET systems on the Stratus 1 surface mooring, and a separate relative humidity and air temperature instrument which made an independent measurement and recorded the data internally.

Figure 2-1-1 shows the mounting locations and orientations of the instruments on the Stratus 1 mooring. Table 2-1-1 lists the buoy-mounted instrumentation on the Stratus 1. The information listed includes sensor identification and sensor height with respect to the water line. The height of all buoy-mounted instrumentation is referenced to the buoy deck and the water line.

Figure 2-1-1: Stratus 1 Buoy IMET Towertop.

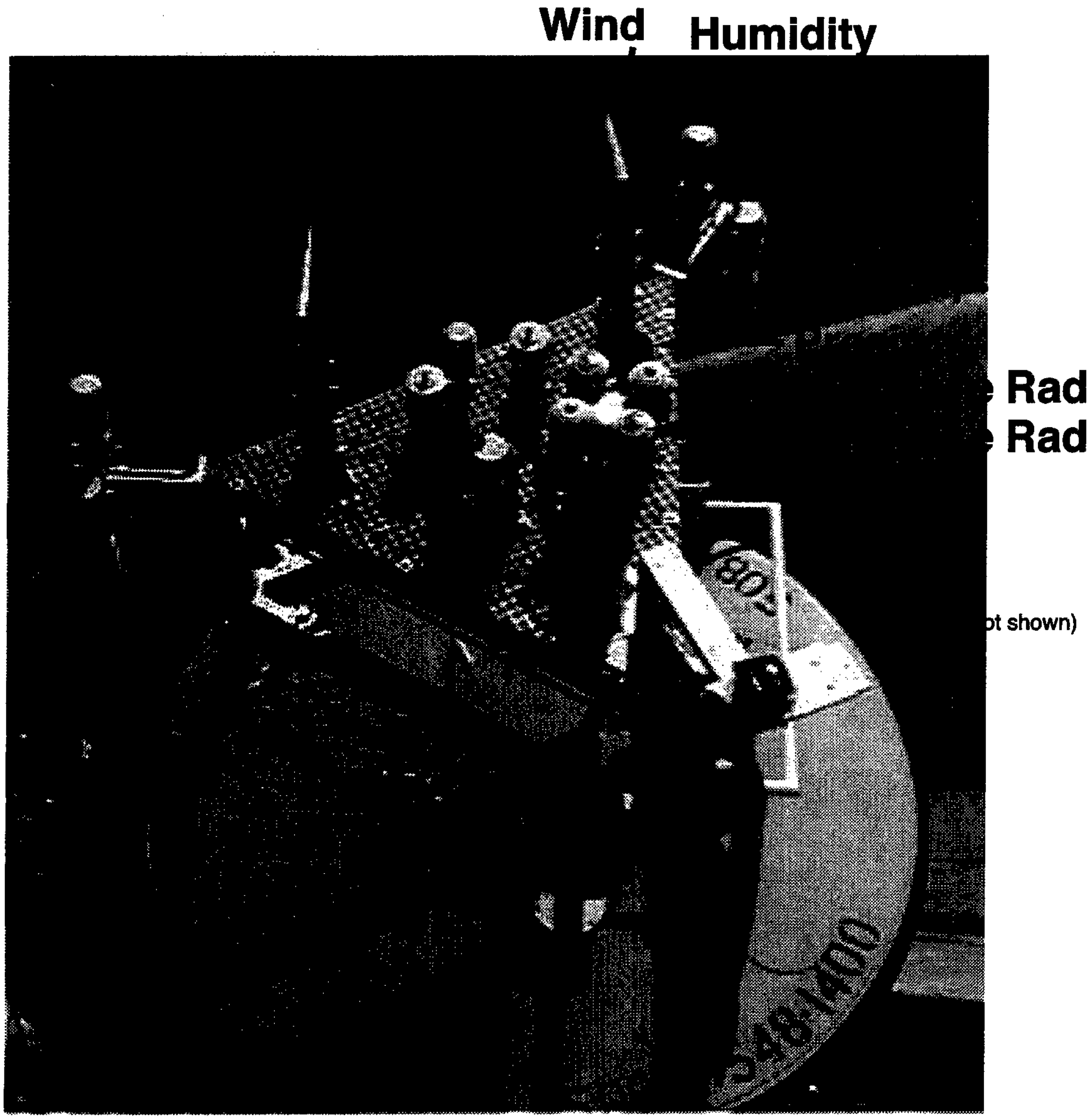


Figure 2-1-2: Photo of the Stratus 1 Instrumented Buoy

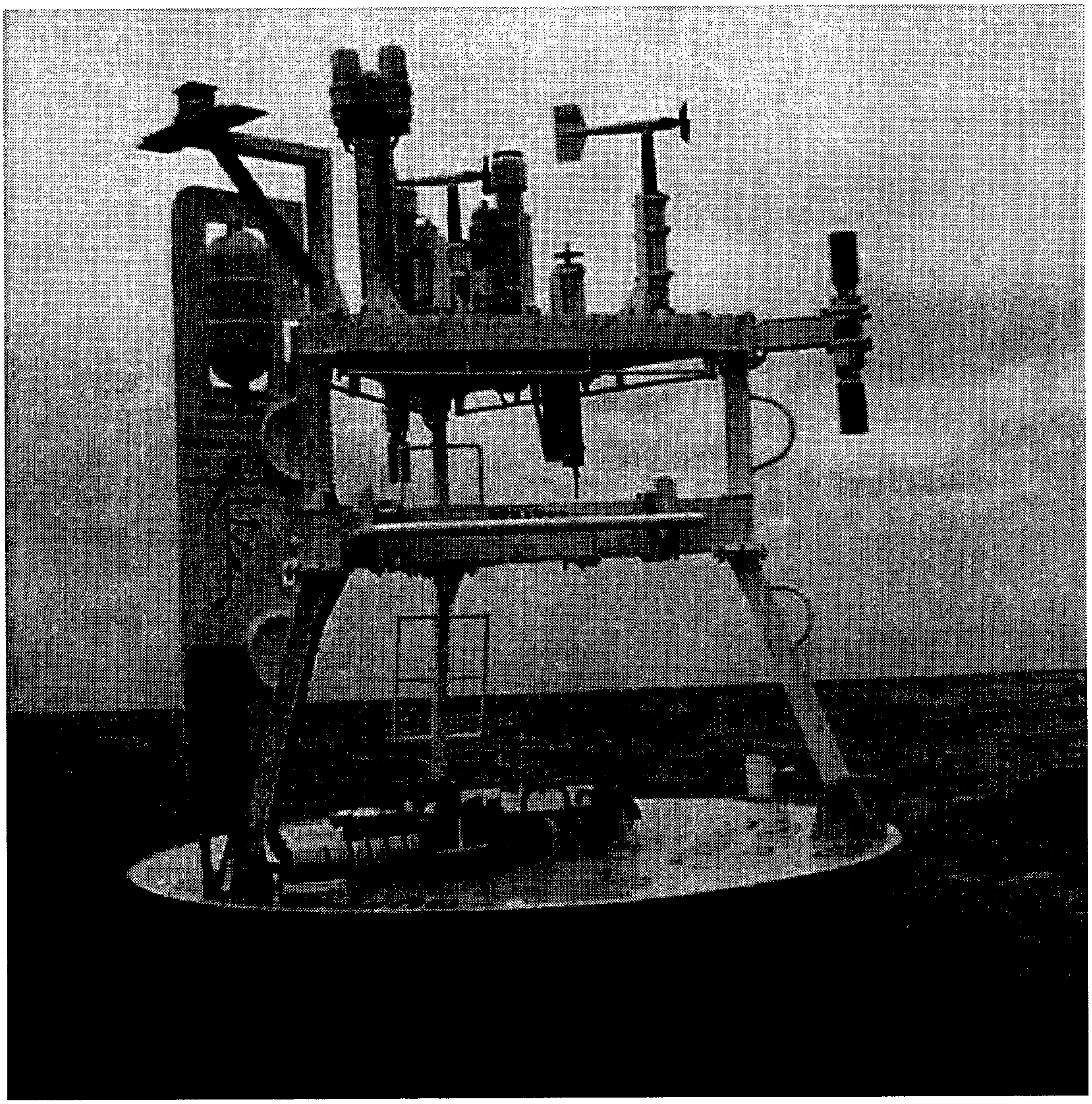


Figure 2-1-3: Schematic of Stratus 1 Mooring.

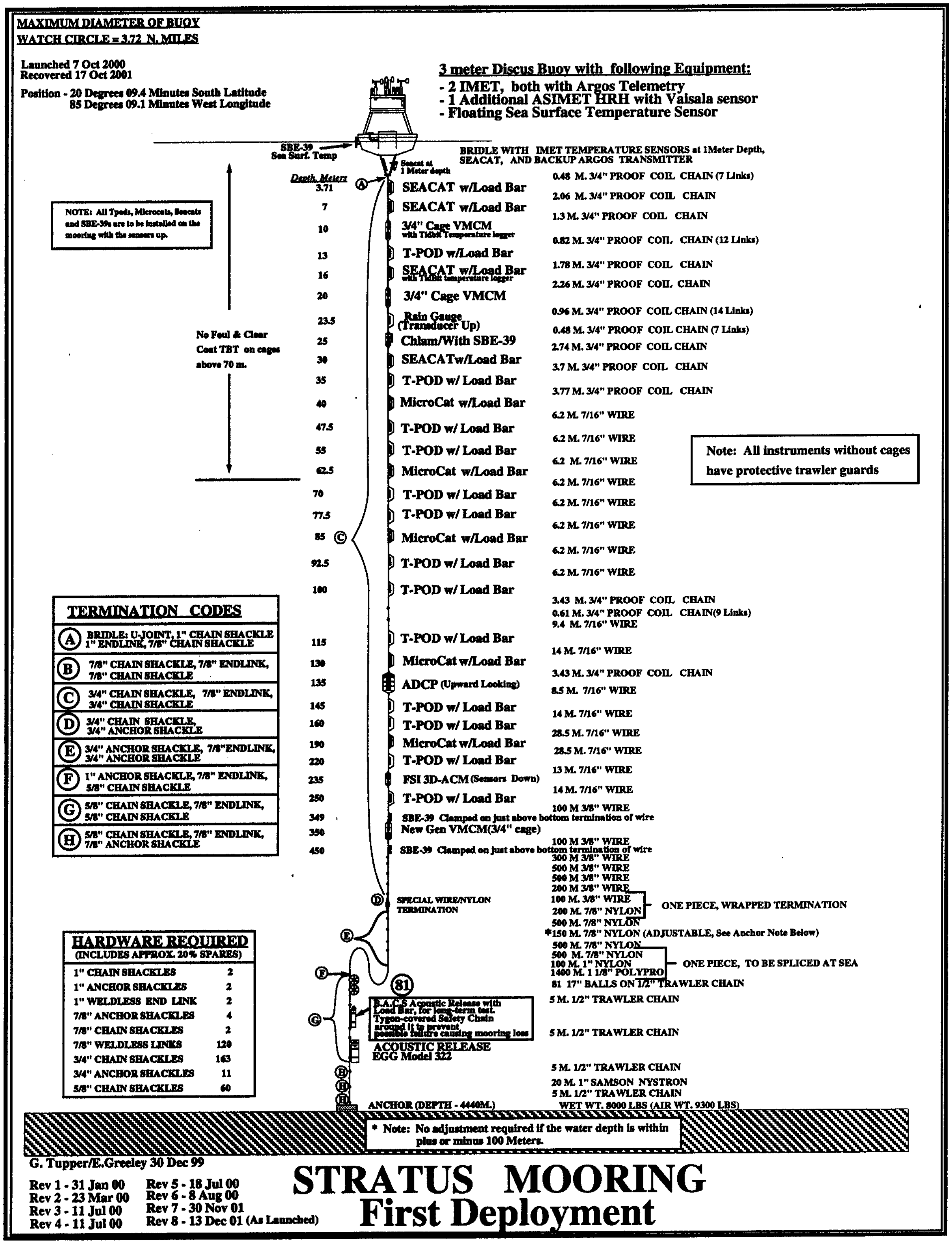


Figure 2-1-4: Tower Top Instrumentation on Stratus 1 Buoy.

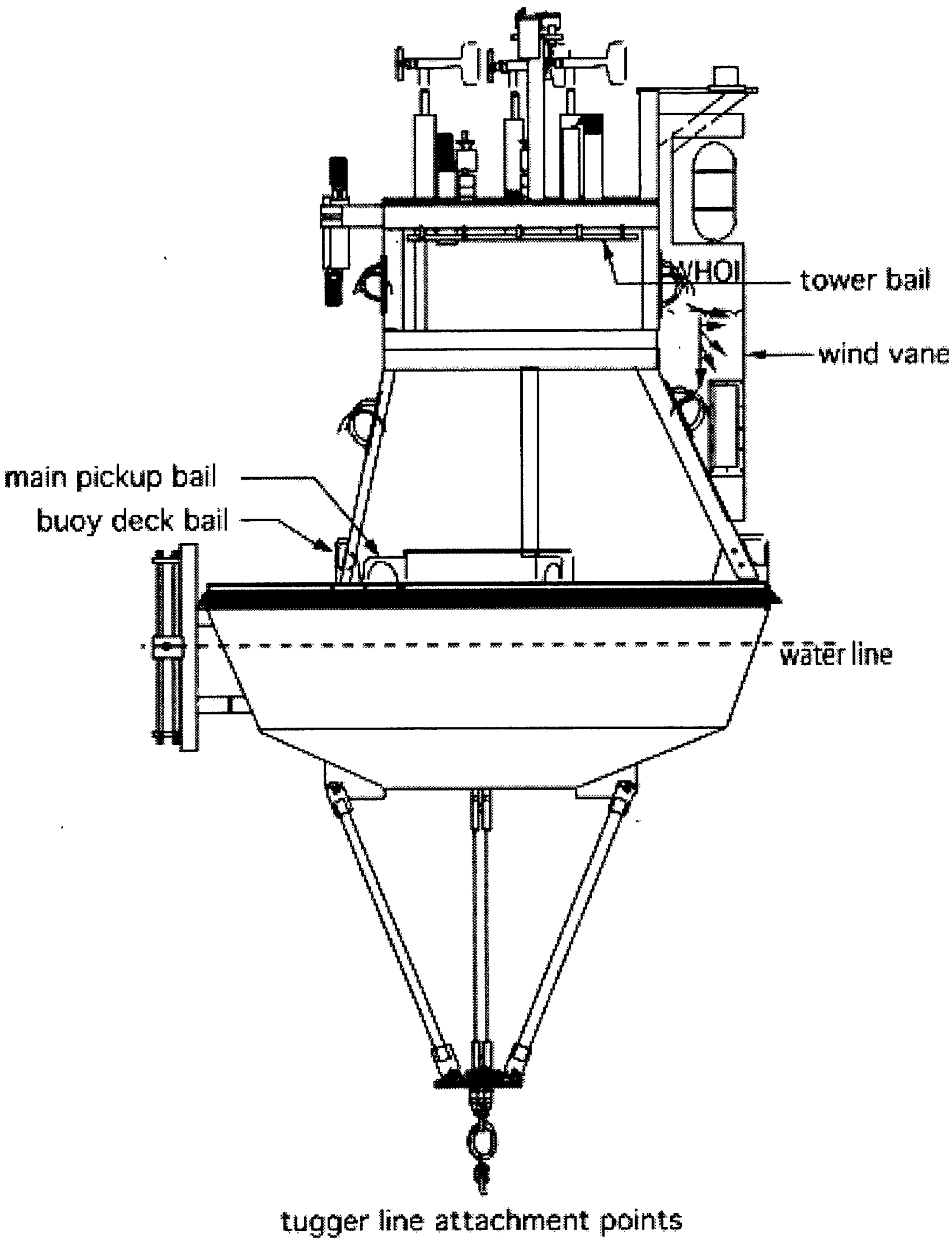


Table 2-1-1: Stratus 1 discus buoy-mounted sensors information and corresponding elevations.

Parameter	Sensor ID	Elevation relative to buoy deck (meters)	Elevation relative to water line (meters)	Measurement location
IMET system 1	Logger 117			
Wind speed	WND 104	2.96	3.39	Prop axis
Wind direction	WND 104	2.96	3.39	Prop axis
Air Temperature	TMP 102	1.61	2.04	End of probe
Relative Humidity	HRH 108	2.31	2.74	Tip of sensor
Barometric Pressure	BPR 107	2.36	2.79	Center of port
Precipitation	PRC 102	2.71	3.14	Top of funnel
Long-wave Radiation	LWR 101	3.15	3.48	Base of dome
Short-wave Radiation	SWR 111	3.14	3.47	Base of dome
Sea Temperature	SST 003	-1.00	-0.57	End of probe
IMET system 2	Logger 226			
Wind speed	WND 105	2.89	3.32	Prop axis
Wind direction	WND 105	2.89	3.32	Prop axis
Air Temperature	TMP 104	1.59	2.02	End of probe
Relative Humidity	HRH 110	2.34	2.77	Tip of sensor
Barometric Pressure	BPR 106	2.40	2.83	Center of port
Precipitation	PRC 101	2.74	3.17	Top of funnel
Long-wave Radiation	LWR 106	3.15	3.58	Base of dome
Short-wave Radiation	SWR 109	3.14	3.57	Base of dome
Sea Temperature	SST 104	-1.00	-0.57	End of probe
Stand-alone Relative Humidity	HRH 204	2.32	2.75	Tip of sensor
Tidbit Air Temp	358910	1.77	2.20	Tied to TMP 104
SBE-39 Floating SST	0072	surface	0	
Tidbit Sea Temp	358909	-1.00	-0.57	Near SST 003
SeaCat Conductivity/ Temperature	1878	-1.00	-0.57	Center of cell

The meteorological instruments are described in detail below.

2-1-a. Improved METeorological System

The IMET systems for the Stratus 1 discus buoy consisted of eight IMET sensor modules and one Argos transmitter module to telemeter data via satellite back to WHOI through Service Argos. Table 2-1-2 details IMET sensor specifications. The modules measure the following parameters:

3 relative humidity with temperature
4 barometric pressure
5 air temperature (R. M. Young passive shield)
6 sea surface temperature
7 precipitation
8 wind speed and direction
9 short-wave radiation
10 long-wave radiation

All IMET modules for the Stratus experiment were modified for lower power consumption so that a non-rechargeable alkaline battery pack could be used.

The IMET system including the data logger and modules are powered off a common bank of batteries.

The data logger for the system was based on an Onset Computer Corp. model 7 Tattletale computer with hard drive, also configured and programmed with power conservation in mind. An associated interface board ties the model 7 via individual power and RS-485 communications lines to each of the nine IMET modules, including the PTT module.

2-1-b. Onset StowAway TidbiT Temperature Loggers

The Tidbit temperature logger is a completely sealed, small (~3 cm diameter) medallion like temperature logger. It is depth rated to approximately 300 m (1,000 ft.) and has an operating temperature range of -20° to +50°C. The tidbit uses optical communication via an Optical Base Station that plugs into a standard PC serial port. One Tidbit was placed on the IMET system #2 air temperature module, co-located with the sensor. The sampling rate was set to once every 30 minutes.

2-1-c. ASIMET relative humidity with temperature instrument

An ASIMET relative humidity module was mounted to provide a third humidity and air temperature measurement on the Stratus 1 discus buoy. The ASIMET module is an improved version of the IMET module developed for the World Ocean Circulation Experiment (WOCE) program. ASIMET modules are self-powered and internally recording. The relative humidity measurement is made with a Rotronic MP-101A sensor. The sensor is packaged in a custom housing, which is more rugged than the standard housing and with high pressure water seals. The humidity temperature probe provides analog outputs of 0 volts to 1.0 volt DC for humidity (1 to 100% rh): and 0 to 1.0 volts DC for temperature (-40° to +60°C). These signals are amplified and converted to digital in the module. One set of measurements are made every minute and calibrated via a fourth order polynomial for rh% and degrees C. The probe is placed inside a standard Young multi-plate radiation shield. The height of the buoy mounted instrumentation can be found in Table 2-1-1.

Table 2-1-2: IMET sensor specifications.

Parameter	Sensor	Nominal Accuracy
Air temperature	Platinum Resistance Thermometer	+/-.25°C
Sea temperature	Platinum Resistance Thermometer	+/-.005°C
Relative humidity	Rotronic MP-100F	+/- 3%
Barometric pressure	Quartz crystal; AIR S2B	+/- .5 mbar
Wind speed and wind direction	R.M. Young model 5103 Wind Monitor	-3% (speed); +/- 1.5° (dir)
Short-wave radiation	Temperature Compensated Thermopile; Eppley PSP	+/- 3%
Long-wave radiation	Pyrometer; Eppley PIR	+/- 10%
Precipitation	R.M. Young Model 50201 Self-siphoning rain gauge	+/- 10%

The logger polls all IMET modules at one-minute intervals (takes several seconds) and then goes to low-power sleep mode for the rest of the minute. Data are written to disk once per hour. The logger also monitors main battery and aspirated temperature battery voltage.

The air temperature, sea surface temperature, barometric pressure, relative humidity, long-wave radiation and precipitation modules take a sample once per minute and then go to low-power sleep mode for the rest of the minute.

The short-wave radiation module takes a sample every 10 seconds and produces a running, one-minute average of the six most recent samples. It goes to low-power sleep mode between ten-second samples.

The vane on the wind module is sampled at one-second intervals and averaged over 15 seconds. The compass is sampled every 15 seconds and the wind speed is averaged every 15 seconds. East and north current components are computed every 15 seconds.

Once a minute, the logger stores east and north components that are an average of the most recent four 15-second averages. In addition, average speed from four 15 second averages is stored, along with the maximum and minimum speed during the previous minute, average vane computed from four 15-second averages, and the most recent compass reading.

In addition, an IMET Argos PTT module is set for three IDs and transmits via satellite the most recent six hours of one-hour averages from the IMET modules. At the start of each hour, the previous hour's data are averaged and sent to the PTT, bumping the oldest hour's data out of the data buffer.

2-2. Sub-surface Instrumentation

The measured water line for the Stratus 1 buoy was 0.43 meters below the buoy deck. Figure 2-1-4 illustrates the location of the subsurface sensors attached to the discus bridle of the Stratus 1 buoy. The depths of the instruments, parameters sampled, and sampling rates are summarized in Table 2-2-1. Whenever possible, instruments were protected from being fouled by fishing lines by "trawl-guards" designed and fabricated at WHOI. These guards are meant to keep lines from hanging up on the in-line instruments. Table 2-2-2 lists the Stratus 1 subsurface instrumentation and the depths where they were deployed.

2-2-a. Floating SST Sensor

A SeaBird SBE-39 was placed in a floating holder (a buoyant block of synthetic foam sliding up and down along 3 stainless steal guide rods) in order to sample the sea temperature as close as possible to the sea surface. Visual check of this sensor after deployment indicated a depth of ~2 cm. The Seabird model SBE-39 is a small, light weight, durable and reliable temperature logger that was set to record the sea surface temperature every 5 minutes.

2-2-b. Sub-surface Argos Transmitter

An NACLS, Inc. Subsurface Mooring Monitor (SMM) was mounted upside down on the bridle of the discus buoy. This was a backup recovery aid in the event that the mooring parted and the buoy flipped upside down.

2-2-c. SEACAT Conductivity and Temperature Recorders

There were five, Sea-Bird, Inc., SEACAT conductivity and temperature recorders deployed on the WHOI surface mooring. The model SBE 16 SEACAT was designed to measure and record temperature and conductivity at high levels of accuracy while deployed in either a fixed or moored application. Powered by internal batteries, a SEACAT is capable of recording data for periods of a year or more. Data are acquired at intervals set by the user. An internal back-up battery supports memory and the real-time clock in the event of failure or exhaustion of the main battery supply. The SEACAT is capable of storing a total of 260,821samples. A sample rate of 225 seconds was used on the Stratus 1 SEACATs. The shallowest SEACAT was mounted directly to the bridle the discus buoy. The others were mounted on in-line tension bars and deployed at various depths throughout the moorings. The conductivity cell is protected from biofouling by the placement of anti-foulant cylinders at each end of the conductivity cell tube.

2-2-d. MicroCAT Conductivity and Temperature Recorder

The MicroCAT, model SBE37, is a high-accuracy conductivity and temperature recorder with internal battery and memory. It is designed for long-term mooring deployments and includes a standard serial interface to communicate with a PC. Its recorded data are stored in non-volatile FLASH memory. The temperature range is -5° to +35°C, and the conductivity range is 0 to 6 Siemens/meter. The pressure housing is made of titanium and is rated for 7,000 meters. The MicroCAT is capable of storing 419,430 samples of temperature, conductivity and time. The sampling interval of the Stratus 1 MicroCATs was 225 seconds (3.75 minutes). These instruments were mounted on in-line tension bars and deployed at various depths throughout the moorings. The conductivity cell is protected from biofouling by the placement of anti-foulant cylinders at each end of the conductivity cell tube.

2-2-e. Brancker Temperature Recorders

The Brancker temperature recorders are self-recording, single-point temperature loggers. The operating temperature range for this instrument is 2° to 34°C. It has internal battery and logging, with the capability of storing 24,000 samples in one deployment. A PC is used to communicate with the Brancker via serial cable for instrument set-up and data download. The Stratus 1 Branckers were set to record data every 30 minutes. A total of 13 Brancker temperature loggers were deployed on the discus mooring.

2-2-f. SBE-39 Temperature Recorder

The Seabird model SBE-39 is a small, light weight, durable and reliable temperature logger that was set to record temperature every 5 minutes.

2-2-g. Onset StowAway TidbiT Temperature Loggers

The Tidbit temperature logger is a completely sealed, small (~3 cm diameter) medallion like temperature logger. It is depth rated to approximately 300 m (1,000 ft.) and has an operating temperature range of -20° to +50°C. The tidbit uses optical communication via an Optical Base Station that plugs into a standard PC serial port. A total of three Tidbit temperature loggers were placed on the Stratus 1 mooring line. In order to make a reliable comparison of performance all of the Tidbits were co-located with other temperature recording devices: one on the (IMET system #1) 1 m Sea Surface temperature module, one on the 10 m VMCM temperature sensor, and one on the 16 m SEACAT loadbar. The sampling rate was set to once every 30 minutes.

2-2-h. Vector Measuring Current Meters

The VMCM had two orthogonal cosine response propeller sensors that measured the components of horizontal current velocity parallel to the axles of the two-propeller sensors. The orientation of the instrument relative to magnetic north was determined by a flux gate compass. East and north components of velocity were computed continuously, averaged and then stored on cassette magnetic tape. Temperature was also recorded using a thermistor mounted in a fast response pod, which was mounted on the top end cap of the VMCM. The VMCMs were set to record every 7.50 minutes.

A new generation VMCM was deployed at the 350m depth on the Stratus 1 discus buoy. It has all of the same components as the previous original VMCM but has new electronics and a flash card memory module to replace the tape drive. It can store up to 40 Mb of data on the flash card therefore the sampling rate was set to once per minute.

A total of 3 VMCMs were deployed on the surface mooring. All of the VMCMs had a compass spin performed at the dock in Arica to verify that the instrument was not damaged in transport.

2-2-i. Falmouth Scientific Instruments Current Meter

The 3D ACM, s/n 1325a, is an acoustic current meter from Falmouth Scientific Instruments, Inc. (FSI). The FSI current meter uses four perpendicularly oriented transducers to extract a single-point measurement. In addition to current values of north, east and up, the instrument also records temperature, tilt, direction and time. The instrument was set to record once every 30 minutes with an averaging interval of 450 seconds.

2-2-j. RDI Acoustic Doppler Current Profiler

An RD Instruments (RDI) Workhorse Acoustic Doppler Current Profiler (ADCP, Model WHS300-1, Serial number TSN-1218) was mounted at 135 m looking upwards on the mooring line. The RDI ADCP measures a profile of horizontal current velocities. The data sampling rates and parameters are user-definable, and were set as follows: 12 velocity bins of 10 m each, starting 11.98 m from the transducers and ending at 131.98 m; 30 pings per ensemble with one ping per second; and a 30-minute interval between the start of ensembles. These settings provided an approximately 400-day deployment lifetime on the internal battery. These particular settings are only available using the Windows version of the RDI deployment software (the DOS version limits you to 8 m bins). The time between pings must be set manually in the text-based deployment file before it is sent to the instrument.

2-2-k. Chlorophyll Absorption Meter

A WETLabs Chlorophyll Absorption Meter (CHLAM), model number 9510005, serial number ACH0126, was placed on the STRATUS 1 discus mooring at a depth of 25 meters. The CHLAM was mounted on a frame that fits inside a standard VMCM cage. A SeaBird pump drew water through a mesh filter and the CHLAM, and past two brominating canisters arranged end-to-end. Between samples, the bromide diffused through the system to reduce biofouling. Data were stored in a WET Labs MPAK data logger, serial number PK-023. The CHLAM/MPAK recorded a reference and signal from three optical wavelengths (650, 676 and 712 nanometers) and an internal temperature. The sample interval rate is 2 hours. At each sample, the pump is turned on for 10 seconds to flush the system. Ten seconds of sampling follow, with the 10-second average of signal and reference stored in the MPAK. The complete system was powered by two, 10 D-cell alkaline battery packs and should last for approximately 400 days.

2-2-l. Acoustic Rain Gauge

An acoustic rain gauge from Jeff Nystuen at the Applied Physics Laboratory at the University of Washington was deployed on the Stratus 1 mooring at a depth of 23.5 meters. This instrument uses a hydrophone and listens to ambient noise. Rain falling on the sea surface produces noise at certain frequencies, and these frequencies are sampled by this instrument. Data from the IMET rain gauges on the surface buoy as well as from the acoustic rain gauge can be compared.

2-2-m. Acoustic Release

On the STRATUS mooring there are 2 different acoustic releases. A primary release used for recovery of the mooring, and a secondary release used for test purposes. The primary release is an EG&G model 322 acoustic release. The test release is a Burn-wire Acoustic Release Transponder modified to be motor driven with a WHOI fabricated load bar.

The test release has a titanium strength bar which was designed at WHOI. It was cut using a computer driven water jet. The strength member is rated for 60,000 lbs. This is being tested for the first time because the release mechanism on the BACS release can not handle the load it sees during the launch of the mooring and anchor drop. There is a piece of 1/2" trawler chain inside 2 " tygon tubing in parallel with the release. If the release fails or the strength member fails, the mooring will be held by the trawler chain. Then the recovery will be done with the primary release.

Table 2-2-1: Stratus 1 subsurface sensors information.

Instrumentation mounted on the mooring line of the 3 meter discus buoy

Instrument	Serial Number	Depth from Mooring Diagram (meters)	Sampling Rate/Record Rate	Parameter(s) Measured
SeaCat	1875 1873 2325 1880	3.71 7 16 30	3.75 Min.	Temperature Conductivity
Brancker T-Pod	3763 4491 3301 3831 3830 3764 3258 3263 4495 4485 4228 3836 3259	13 35 47.5 55 70 77.5 92.5 100 115 145 160 220 250	30 Min.	Temperature
VMCM New Gen VMCM	VM038 VM037 VM01	10 20 350	7.5 Min.	East and North Currents
MicroCat	1328 1326 1305 1330 1306	40 62.5 85 130 190	3.75 Min.	Temperature Conductivity
SBE-39	0050 0048 0049	25 (on Chlam) 349 350	5 Min.	Temperature
Chlam	ACH0126	25	2 Hours	Chlorophyll-a
ADCP	TSN-1218	135	30 Min.	East and North Currents
FSI	1325A	235	30 Min.	East and North Currents
Tidbit	358909 358907 358908	(on bridle) 10 (on VMCM) 16 (on SeaCat)	30 Mins	Temperature
Acoustic Rain Gauge	F9	23.5		Precipitation

Table 2-2-2. Stratus 1 Subsurface Instrumentation.

Depth (m)	Sensors
0.02	MicroCAT-39
1	SEACAT-1878
3.71	SEACAT-1875
7	SEACAT-1873
10	VM-038
13	TPOD-3763
16	SEACAT-2325
20	VM-037
23.5	RainGauge-F9
25	CHLAM-ACH0126
25	MicroCAT-0050
30	SEACAT-1880
35	TPOD-4491
40	MicroCAT-1328
47.5	TPOD-3301
55	TPOD-3831
62.5	MicroCAT-1326
70	TPOD-3830
77.5	TPOD-3764
85	MicroCAT-1305
92.5	TPOD-3258
100	TPOD-3263
115	TPOD-4495
130	MicroCAT-1330
135	ADCP
145	TPOD-4485
160	TPOD-4228
190	MicroCAT-1306
220	TPOD-3836
235	FSI-1325
250	TPOD-3259
349	MicroCAT-0048
350	VM-01
450	MicroCAT-0049

Legend

TPOD-#### = Brancker Temperature Recorder
SEACAT #### = SEACAT Conductivity and Temperature Recorder
VM-### = Vector Measuring Current Meter
MicroCAT-#### = MicroCAT Conductivity and Temperature Recorder
ADCP = Acoustic Doppler Current Profiler
FSI-### = Falmouth Scientific Instruments Current Meter

Section 3: Data Processing and Return

This section presents a summary of the data return rates and data processing and quality control. It is broken down into two subsections. The first will cover the surface meteorological data and air-sea fluxes. The second will cover all the subsurface data.

3-1. Meteorological data processing.

The two Improved METeorological (IMET) and a Stand-Alone ASIMET were deployed on the 3 m diameter discus buoy. The raw IMET and ASIMET data were processed using IDL programming language scripts developed by WHOI UOP. Pre-deployment calibrations were applied to each instrument initially and post-deployment calibrations were only used when they yielded better agreement during inter-comparisons with other sensors. All calibrated data were converted to EPIC-compliant Net CDF files (Denbo and Zhu, 1993; Rew *et al.* 1993). The raw wind directions were rotated by 7.51° to correct for the local magnetic deviation. After initial processing, qualitative checks were performed on the data to identify sensor problems such as spikes, drop-outs or gross errors.

The meteorological data from both systems IMET are evaluated by using the redundant measurements and pre-deployment/post-deployment calibrations.

Except for the wind module of IMET logger 1, meteorological IMET variables look good and subsequent intercomparisons with shipboard instruments revealed a good agreement. No empirical adjustments have been applied at this time to the data to improve agreement among these collocated sensors. Around 20 February 2001, the IMET logger 1 wind direction sensor failed when the vane froze in position. After 02/20/01, logger 1 direction data had been replaced by logger 2 direction data.

The Stand-Alone ASIMET Air Temperature/Relative Humidity dropped one hour of data before 7 october 2000. The unit stopped recording after 14:00 UTC on 24 august 2001 when the flashcard memory was filled.

This section summarizes the evaluation of meteorological parameters from IMET systems. Statistics, plots and air-sea fluxes shown in Section 4 are derived from IMET meteorological time series data for both systems and each variable.

Written summaries for the Stratus 1 buoy and its deployment, describing the condition of the sensors and an evaluation of the data quality follow in Table 3-1-1. Data return for the meteorological instruments is provided in Table 3-1-2 showing the percentage of time that a particular instrument was returning good data for the deployment.

Section 3 –3 includes a description of the processing used to calculate a time series of the air-sea exchange of fresh water, heat and momentum from the IMET time series.

Table 3-1-1: Stratus 1 Meteorological Summary

Data Return
IMET data loggers provided a complete data set.
Stand-Alone ASIMET provided air temperature and relative humidity data.

Wind Speed and Wind Direction

The wind speed for both systems is similar with a mean difference of only .018 m s^{-1}
Around 20 February 2001, the IMET logger 1 wind direction failed due to a frozen vane.
The IMET logger 2 looks good.
Prior to 02/07/01, the mean difference between IMET logger 1 and IMET logger 2 direction is -3.07 degrees with a standard deviation difference of 2.3 degrees.

Air Temperature

Mean difference between IMET logger 1 and logger 2 is -.0017°C with a standard Deviation of .011°C. These statistics show good agreement between the two loggers.
The stand alone ASIMET stopped recording after 14:00 UTC on 24 August 2001 due to the full flashcard. Prior to 08/24/01, ASIMET is higher than both systems by 0.10°C, 0.088°C for logger 1 and logger 2 respectively.
Considering that the ASIMET sensor is located at .71m above the logger 1 sensor, and at .73m above the logger 2 sensor on the buoy, the air temperature measurements indicate good agreement.

Relative Humidity

Both IMET logger 1 and logger 2 have full record and look good. Mean difference between logger 1 and logger 2 is 0.75 % with a standard deviation of the difference of .01%. ASIMET looks good. Prior to 08/24/01, ASIMET is lower than IMET logger 1 and logger 2 by a mean difference of 5.97% and 5.3% respectively.

Specific Humidity

IMET logger 1 and logger 2 have a mean difference of .09 g/kg.

Barometric Pressure

Both logger 1 and logger 2 data look good with only a mean difference of .3 mbar for the entire deployment, a difference of .65 mbar at deployment (7 October 2000) and 0.5 mbar difference at recovery (17 October 2001).

Short-wave Radiation

Both systems look good. Logger 2 is 1.44% higher than Logger 1.

Long-wave Radiation

Logger 1 and Logger2 have good data for the entire deployment. Both the mean and standard deviation of the differences are less than 3 W m^{-2}, indicating good agreement.

Table 3-1-2: Data return in percentage of meteorological instruments.

Sensors	Rate
IMET system 1	
Wind speed	37
Wind direction	37
Air temperature	100
Relative Humidity	100
Barometric Pressure	100
Precipitation	100
Long-wave radiation	100
Short-wave radiation	100
Sea surface temperature	100
Vane average	37
Compass	100
IMET system 2	
Wind speed	100
Wind direction	100
Air temperature	100
Relative Humidity	100
Barometric Pressure	100
Precipitation	100
Long-wave radiation	100
Short-wave radiation	100
Sea surface temperature	100
Vane average	100
Compass	100
Stand-alone	
ASIMET relative humidity	86
Tidbit Air temperature	100

3-2. Subsurface Instrumentation

The raw MicroCATs (SBE-37) and SBE-39 data were processed using the WHOI UOP software package (Prada, 1992). The RDI workhorse ADCP was processed using the RDI WinADCP software package. The ADCP data is treated as velocity time series from the center depth of the sampling bins : 23, 33, 43, 53, 63, 73, 83, 93, 103, 113, 123 and 133. The SeaBird SEACAT (SBE-16) raw data were processed initially with SBE SeaSoft software to apply the pre-deployment calibrations, and then converted to EPIC using the UOP software package. The other raw subsurface data were processed and converted into EPIC-compliant Net CDF files, using available pre-deployment calibrations, with IDL and C-code programs developed by UOP. The raw current vectors were rotated by 7.51° to correct for the local magnetic deviation. After initial processing, qualitative checks were performed on the data to identify sensor problems such as spikes, drop-outs or gross errors.

The FSI did not operated correctly. There were only two samples in the file: one at the beginning of the deployment period and one just prior to the dump. The Acoustic Rain Gauge (ARG) was dumped at-sea by copying files off the Compact Flash card. The instrument never woke up and started to sample as it was programmed to do. The CHLAM did not work because both battery housings had leaked.

SeaCATS s/n 1873 and s/n 1875 stopped before the recovery day due to battery depletion (both reported low or dead batteries upon recovery).

A summary of the data return with brief preliminary processing notes for each subsurface instrument is provided in a separate table. (Tables 3-2-1). No empirical adjustments have been applied at this time to the data to improve agreement among these collocated sensors. The processing notes indicate "full record" if the instrument provided a complete time series and appears to have functioned within specification. If the record ended short, date of the last record is noted in the Table. Also it is noted if one of the measurement parameters from a specific instrument appears to have malfunctioned. For example, the RDI ADCP performed poorly, intermittently failing to record velocities at 23 and 33 m. Tables 3-2-2 and 3-2-3 present the data return in percentage for temperature, salinity, conductivity and velocity.

Table 3-2-1. Stratus 1 Subsurface Data Return.

Depth (m)	Type	Sensors	S/N	prelim processing notes
Surface	seabird	sbe-39	72	full record
1	seabird	seacat	1878	full record
3.71	seabird	seacat	1875	data stopped after 15 sept.01 for temp., salinity, and cond.
7	seabird	seacat	1873	data stopped after 12 aug.01 for temp. Record failed on the 13 dec 00 for cond. and sal.
10	vmcm	vm	38	full record
13	brancker	tpod	3763	full record
16	seabird	seacat	2325	full record
20	vmcm	vm	37	full record
23.5	rain gauge	rain gauge	F9	no data, did not record
25	wetlab	chlam	ACH0126	no data, did not record
25	seabird	sbe-39	50	full record
30	seabird	seacat	1880	full record
35	brancker	tpod	4491	full record
40	microcat	mcat	1328	full record
47.5	brancker	tpod	3301	full record
55	brancker	tpod	3831	full record
62.5	microcat	mcat	1326	full record for temp. Data stopped after 7 august forsal and cond.
70	brancker	tpod	3830	full record
77.5	brancker	tpod	3764	full record
85	microcat	mcat	1305	full record
92.5	brancker	tpod	3258	full record
100	brancker	tpod	3263	no data, did not record
115	brancker	tpod	4495	full record
130	microcat	mcat	1330	full record
135	rdi	adcp	23	Almost full record with intermittent stops during all deploymen
	rdi	adcp	33	Almost full record with intermittent stops during all deploymen
	rdi	adcp	43	full record
	rdi	adcp	53	full record
	rdi	adcp	63	full record
	rdi	adcp	73	full record
	rdi	adcp	83	full record
	rdi	adcp	93	full record
	rdi	adcp	103	full record
	rdi	adcp	113	full record
	rdi	adcp	123	full record
	rdi	adcp	133	full record
145	brancker	tpod	4485	full record
160	brancker	tpod	4228	full record
190	microcat	mcat	1306	full record
220	brancker	tpod	3836	full record
235	acoustic current m	fsi	1325	no data, did not record

250	brancker	tpod	3259	full record
349	seabird	sbe-39	48	full record
350	vmcm	vm	1	full record
450	seabird	sbe-39	49	full record

Table 3-2-2. Stratus 1 Temperature , Salinity and Conductivity Data return in percentage.

Depth (m)	Type	Sensors	S/N	Temp. rates	Sal. and Cond. rates
Surface	seabird	sbe-39	72	100	
1	seabird	seacat	1878	100	100
3.71	seabird	seacat	1875	90.9	90.9
7	seabird	seacat	1873	81.5	18.5
10	vmcm	vm	38	100	
13	brancker	tpod	3763	100	
16	seabird	seacat	2325	100	18.5
20	vmcm	vm	37	100	
23.5	rain gauge	rain gauge	F9	0	
25	wetlab	chlam	ACH0126	0	
25	seabird	sbe-39	50	100	
30	seabird	seacat	1880	100	100
35	brancker	tpod	4491	100	
40	microcat	mcat	1328	100	100
47.5	brancker	tpod	3301	100	
55	brancker	tpod	3831	100	
62.5	microcat	mcat	1326	100	80.4
70	brancker	tpod	3830	100	
77.5	brancker	tpod	3764	100	
85	microcat	mcat	1305	100	100
92.5	brancker	tpod	3258	100	
100	brancker	tpod	3263	0	
115	brancker	tpod	4495	100	
130	microcat	mcat	1330	100	100
135	rdi	adcp		100	
145	brancker	tpod	4485	100	
160	brancker	tpod	4228	100	
190	microcat	mcat	1306	100	100
220	brancker	tpod	3836	100	
235	acoustic current meter	fsi	1325	0	
250	brancker	tpod	3259	100	
349	seabird	sbe-39	48	100	
450	seabird	sbe-39	49	100	

Table 3-2-3. Stratus 1 Velocity Data return in percentage.

Depth (m)	Type	Sensors	S/N	Velocity rates
10	vmcm	vm	38	100
20	vmcm	vm	37	100
135	rdi	adcp	23	40
	rdi	adcp	33	40
	rdi	adcp	43	99
	rdi	adcp	53	100
	rdi	adcp	63	100
	rdi	adcp	73	100
	rdi	adcp	83	100
	rdi	adcp	93	100
	rdi	adcp	103	100
	rdi	adcp	113	100
	rdi	adcp	123	100
	rdi	adcp	133	100
350	vmcm	vm	1	100

3-3. Freshwater, Heat and Momentum Fluxes

Air-sea heat and momentum fluxes were estimated from the meteorological and near-surface oceanographic measurements using a bulk flux algorithm developed for TOGA COARE (Fairall *et al.*, 1996a). This algorithm is based on methods developed by Liu *et al.* (1979) with modifications for, but not limited to, low wind regimes. The algorithm also includes cool skin and warm layer adjustments based on Fairall *et al.* (1996b) to account for the cooling of the upper few millimeters of the ocean due to sensible, latent and outgoing long-wave radiation heat loss and warming of the upper few meters of the ocean due to absorption of short-wave radiation. The cool skin was employed in the calculations presented here but not the warm layer component of the algorithm. The wind speed relative to the sea surface used in the algorithm was calculated using the observed wind speed vectors and subtracting the near surface current record from the mooring.

Since only incoming short- and long-wave radiation were measured, the outgoing components of radiation were estimated using the TOGA COARE Bulk Flux Algorithm. This algorithm assumes a constant surface short-wave albedo. Outgoing long-wave radiation was estimated as $\varepsilon\sigma T^4$ where ε is the emissivity of the sea surface ($\varepsilon = 0.97$), σ is the Stefan-Boltzmann constant and T is the sea surface skin temperature in °K. The skin temperature from the cool skin adjustment was used as the sea surface temperature, since the outgoing long-wave radiation is dependent on the interfacial temperature which may be quite different from the shallowest temperature measurement.

Section 4: Stratus 1 Statistics and Plots

Statistics of the meteorological measurements and estimated heat, momentum and freshwater fluxes for the 12 month long experiment are presented in Table 4-1 for Stratus. The table contains the mean, standard deviation, minimum and maximum of the meteorological measurements and fluxes. Meteorological observations are presented next followed by precipitation, heat and flux time series, contours of subsurface temperatures, velocity stick plots with current speed overlaid, progressive vector diagrams and auto spectra for meteorological, flux, temperature and velocity variables.

For Temperature plots, the Seabirds s/n 1875 and s/n 1873 and the Brancker s/n 3263 are not shown due to their deficient records. The ADCP at 23 and 33 m with bad records (shown in Figures 4-67 and 4-68), are not plotted in the autospectra of velocity and mean profiles plots. We chose the best available data record of IMET (Logger 2) to represent the meteorological and flux autospectra. Band averaging was used in each of the auto spectra plots and the 95% confidence limits are shown. The first 5 frequencies were averaged over 3 bands and the number of bands averaged was doubled every 10 frequencies thereafter (i.e., frequencies 6-15 were averaged over 6 bands, frequencies 16-25 were averaged over 12 bands, frequencies 26-35 were averaged over 24 bands, etc..). See the following table for the page numbers of the different plots.

Table 4-1 Statistics and Air-Sea Flux Time Series for Stratus 1. Statistics are for the time period 07 October 2000 20:43 UTC to 17 October 2001 12:39 UTC.

LOGGER 1	Unit	Mean	Std Dev	Minimum	Maximum
Variable					
Air Temperature	°C	19.54	1.746	13.8	23.61
Relative Humidity	%	76.262	6.205	52.66	99.36
East Component	$m\ s^{-1}$	-4.696	3.019	-13.79	10.88
North Component	$m\ s^{-1}$	-0.661	2.899	-10.36	8.78
Scalar averaged Wind Speed	$m\ s^{-1}$	5.962	2.072	0	11.127
Short-wave Radiation	$w\ m^{-2}$	211.767	305.075	0.6	1548.1
Long-wave Radiation	$w\ m^{-2}$	378.216	22.311	313.845	504.766
Barometric Pressure	mbar	1017.3	2.425	1009	1024.8
Sea Temperature at 1m	°C	20.388	1.554	14.223	25.5
Specific Humidity	$G\ kg^{-1}$	10.558	1.413	6.706	15.126
Wind Direction	degrees	287.149	52.66	0	350.103
Wind Stress Magnitude	$N\ m^{-2}$	0.072	4.99E-02	0	0.28
Wind Stress Direction	$N\ m^{-2}$	288.487	56.99	0	359.754
Sensible Heat Flux	$w\ m^{-2}$	-7.643	7.85	-93.738	6.637
Net Heat Flux	$w\ m^{-2}$	49.566	280.43	-334.917	910.386
Latent Heat Flux	$w\ m^{-2}$	-101.738	39.42	-313.478	-0.001
Net Short-wave radiation	$w\ m^{-2}$	199.704	279.74	0.567	1049.12
Net Long-wave Radiation	$w\ m^{-2}$	-40.496	22.788	-160.446	58.352

LOGGER 2					
Variable					
Air Temperature	°C	19.557	1.735	13.79	23.61
Relative Humidity	%	75.506	6.194	53.25	98.46
East Component	$m\ s^{-1}$	-4.94	2.436	-13.28	6.47
North Component	$m\ s^{-1}$	2.739	1.923	-6.9	12.01
Scalar averaged Wind Speed	$m\ s^{-1}$	5.981	2.076	0	11.035
Short-wave Radiation	$w\ m^{-2}$	213.214	307.94	1.1	1568.1
Long-wave Radiation	$w\ m^{-2}$	378.212	20.098	319.175	504.182
Barometric Pressure	mbar	1017.603	2.447	1009.4	1025.2
Sea Temperature at 1m	°C	20.383	1.553	18.03	25.47
Specific Humidity	$G\ kg^{-1}$	10.467	1.404	6.763	15.047
Wind Direction	degrees	290.22	54.963	0	351.08
Wind Stress Magnitude	$N\ m^{-2}$	0.075	0.051	4.20E-06	0.281
Wind Stress Direction	$N\ m^{-2}$	291.81	58.75	0.279	359.98
Sensible Heat Flux	$w\ m^{-2}$	-7.516	7.774	-72.823	6.761
Net Heat Flux	$w\ m^{-2}$	47.687	284.281	-333.968	936.763
Latent Heat Flux	$w\ m^{-2}$	-105.517	40.147	-298.674	-0.473
Net Short-wave radiation	$w\ m^{-2}$	201.231	282.06	1.039	1056.87
Net Long-wave Radiation	$w\ m^{-2}$	-40.532	20.442	-140.95	16.763
Stand-Alone ASIMET					
Relative Humidity	%	70.368	6.183	47.24	93.77
Air Temperature	°C	19.992	1.645	15.4	24.42

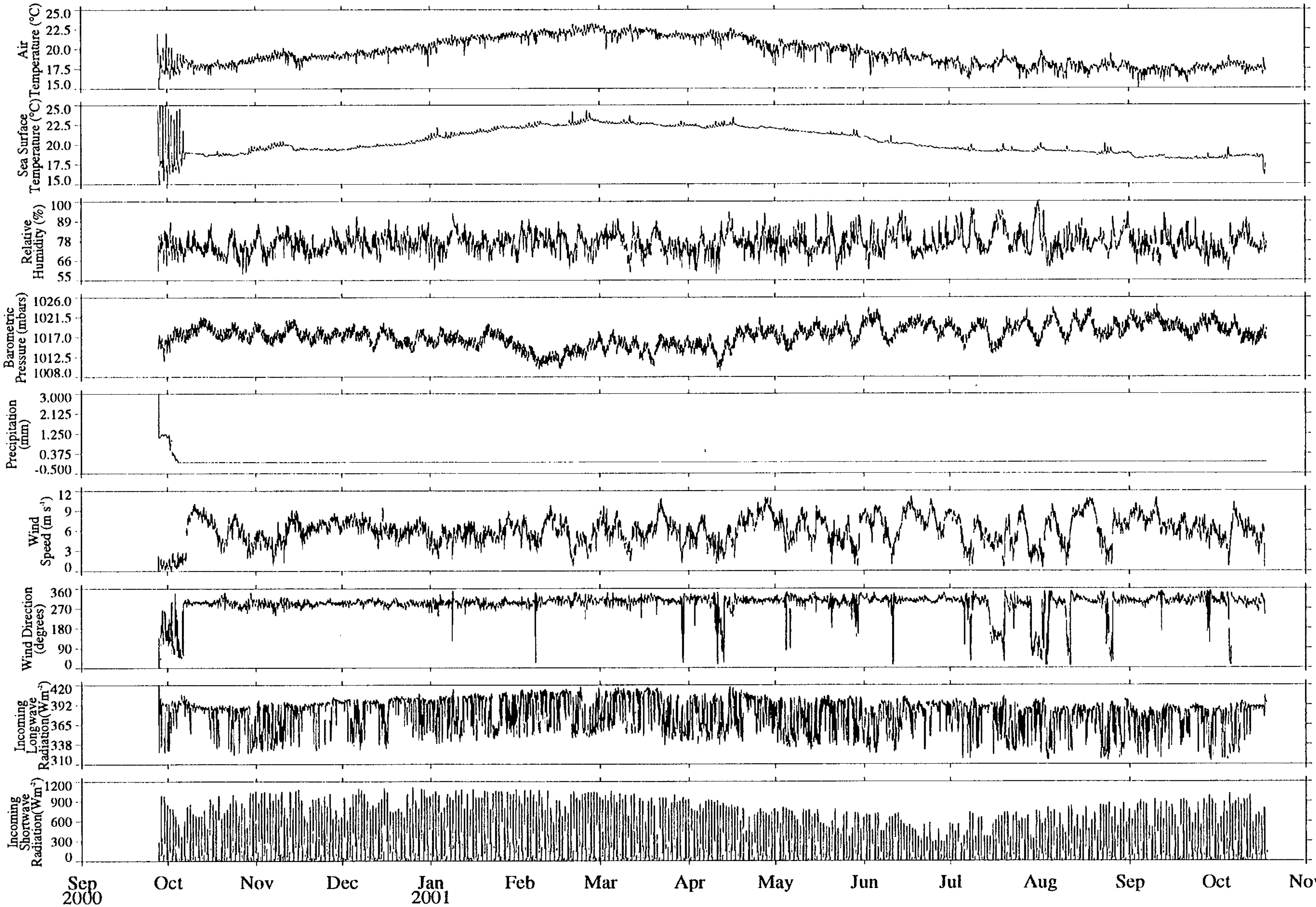


Figure 4-1. Hourly time series of meteorological observations.
(IMET system 1)

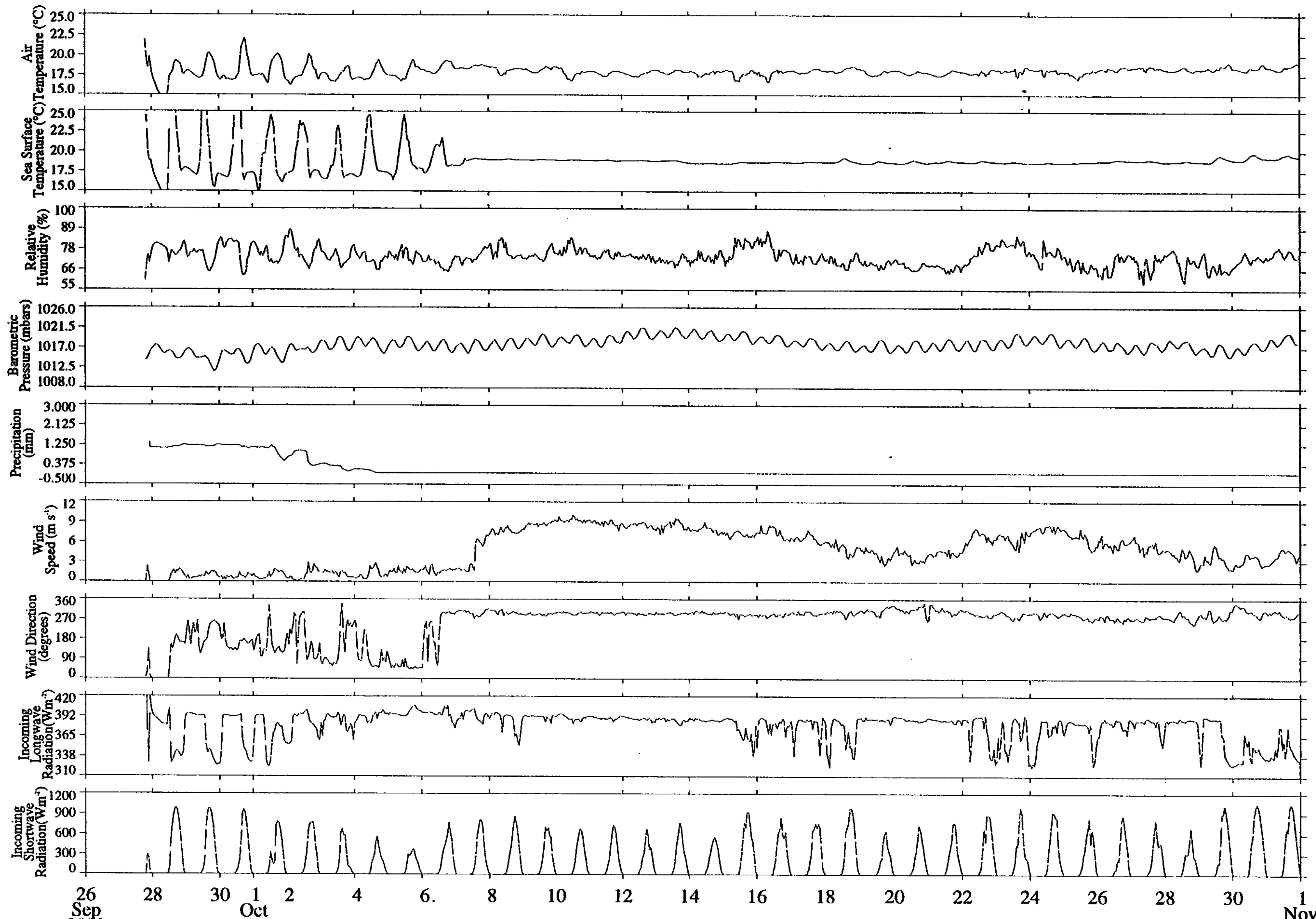


Figure 4-2. Hourly time series of meteorological observations for October 2000. (IMET system 1)

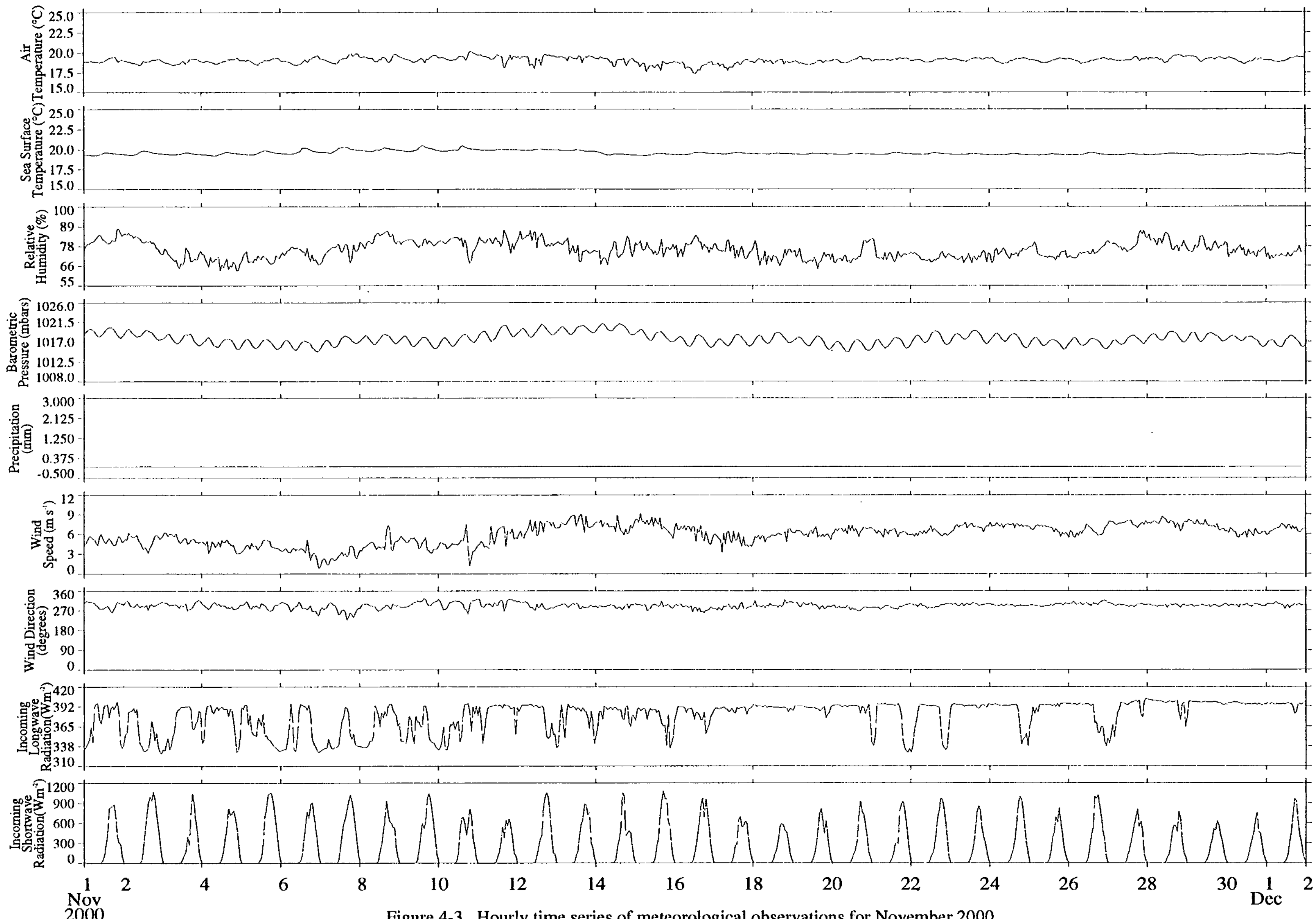


Figure 4-3. Hourly time series of meteorological observations for November 2000.
(IMET system 1)

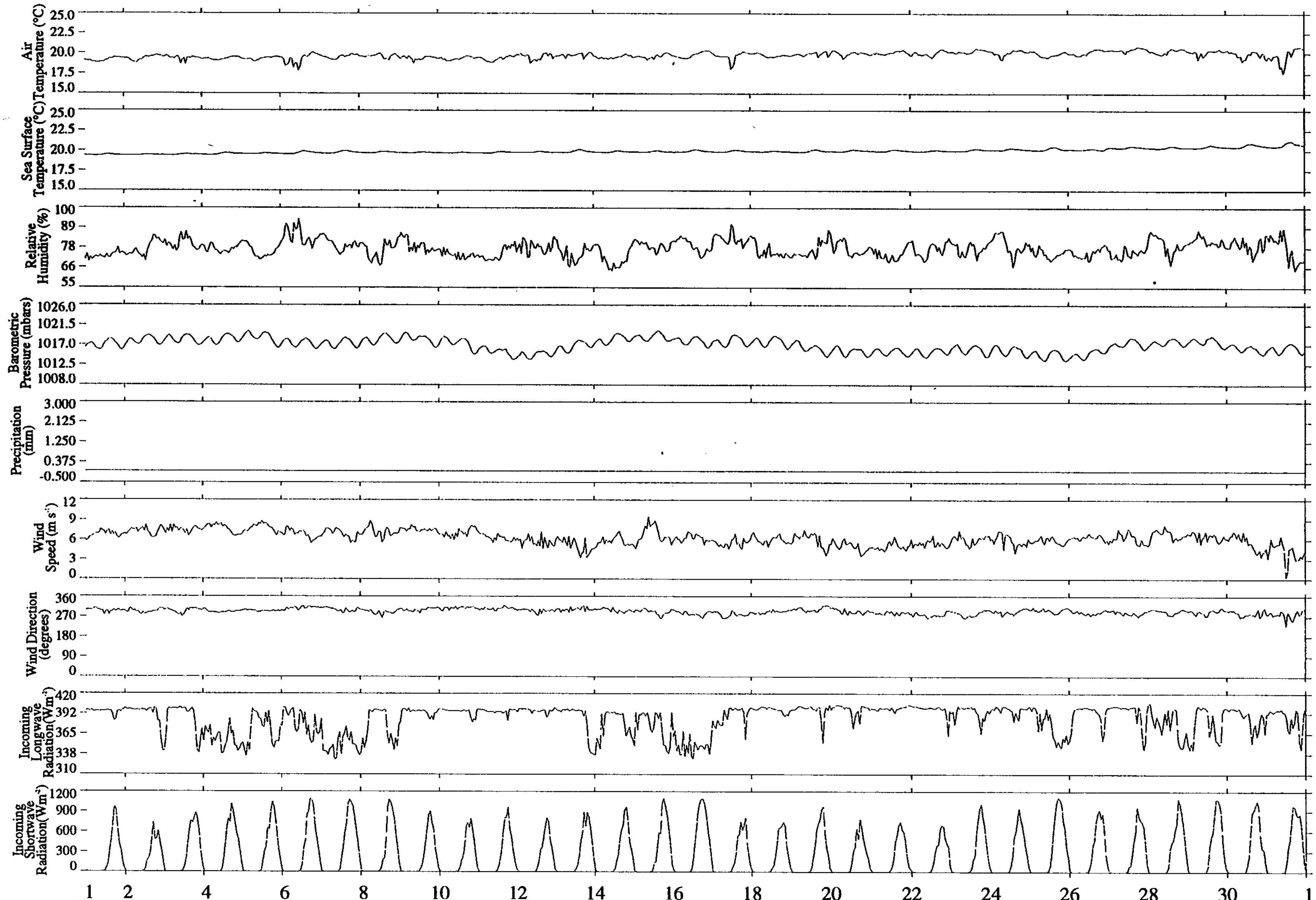


Figure 4-4. Hourly time series of meteorological observations for December 2000. (IMET system 1)

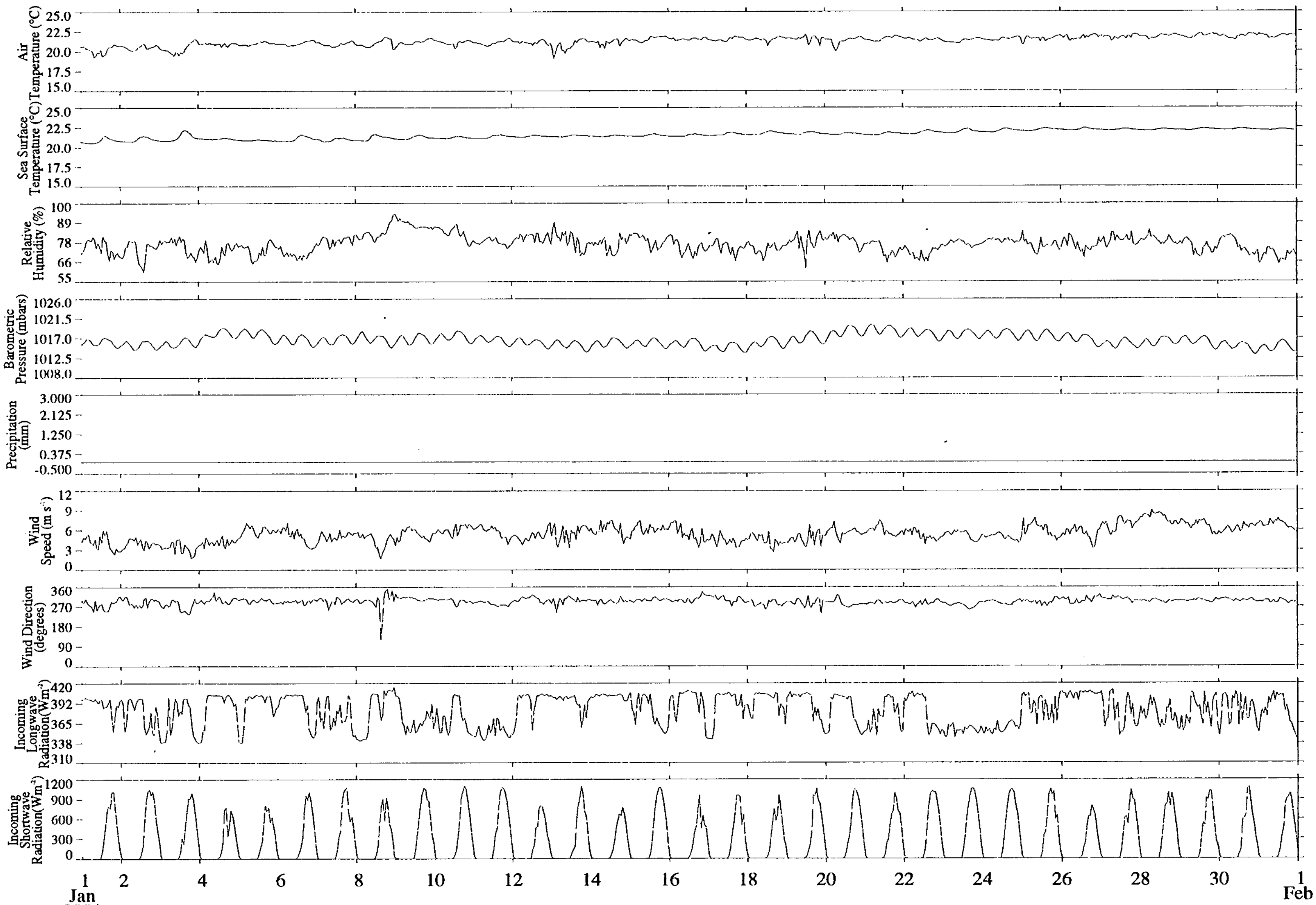


Figure 4-5. Hourly time series of meteorological observations for January 2001. (IMET system 1)

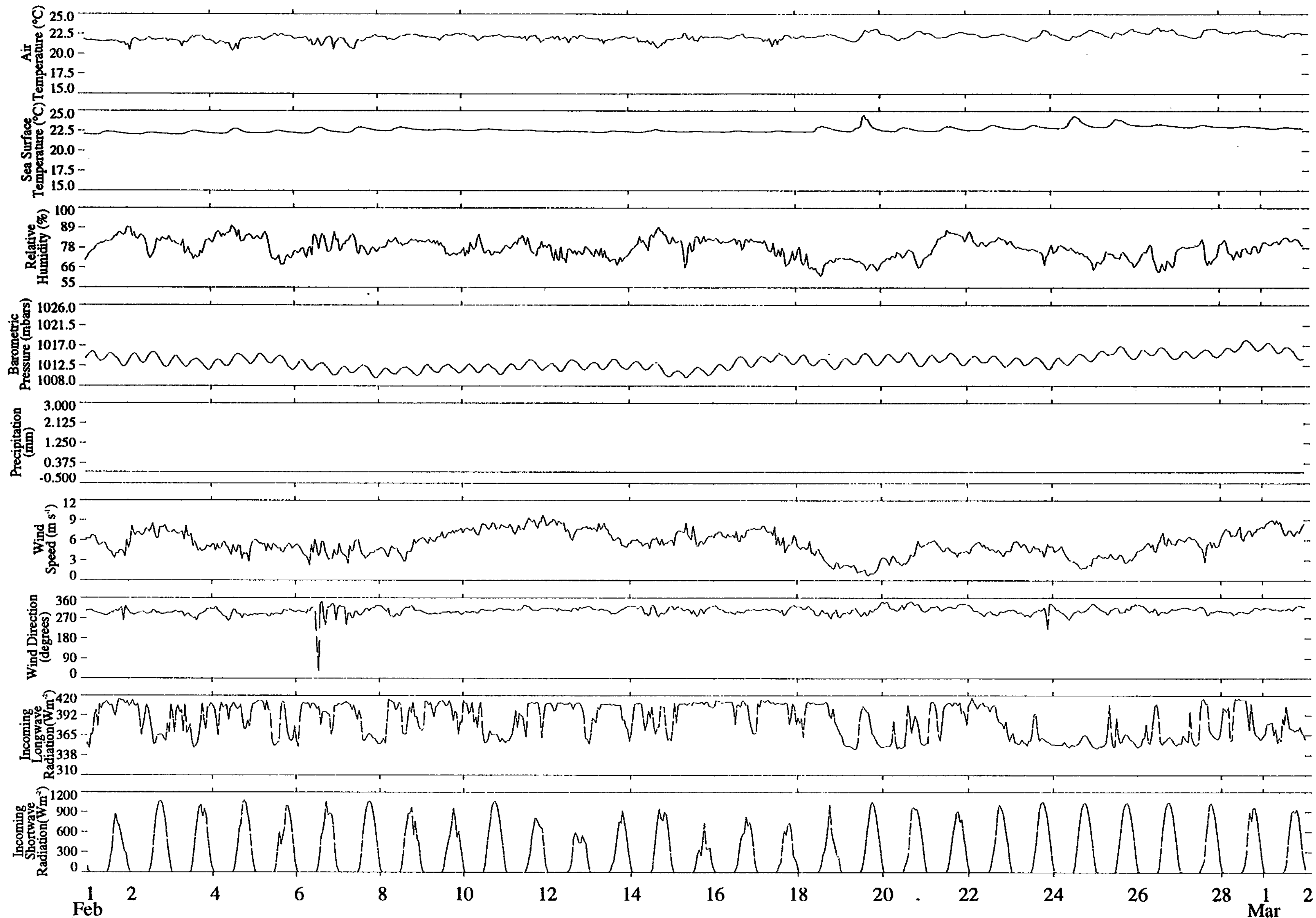


Figure 4-6. Hourly time series of meteorological observations for February 2001.
(IMET system 1)

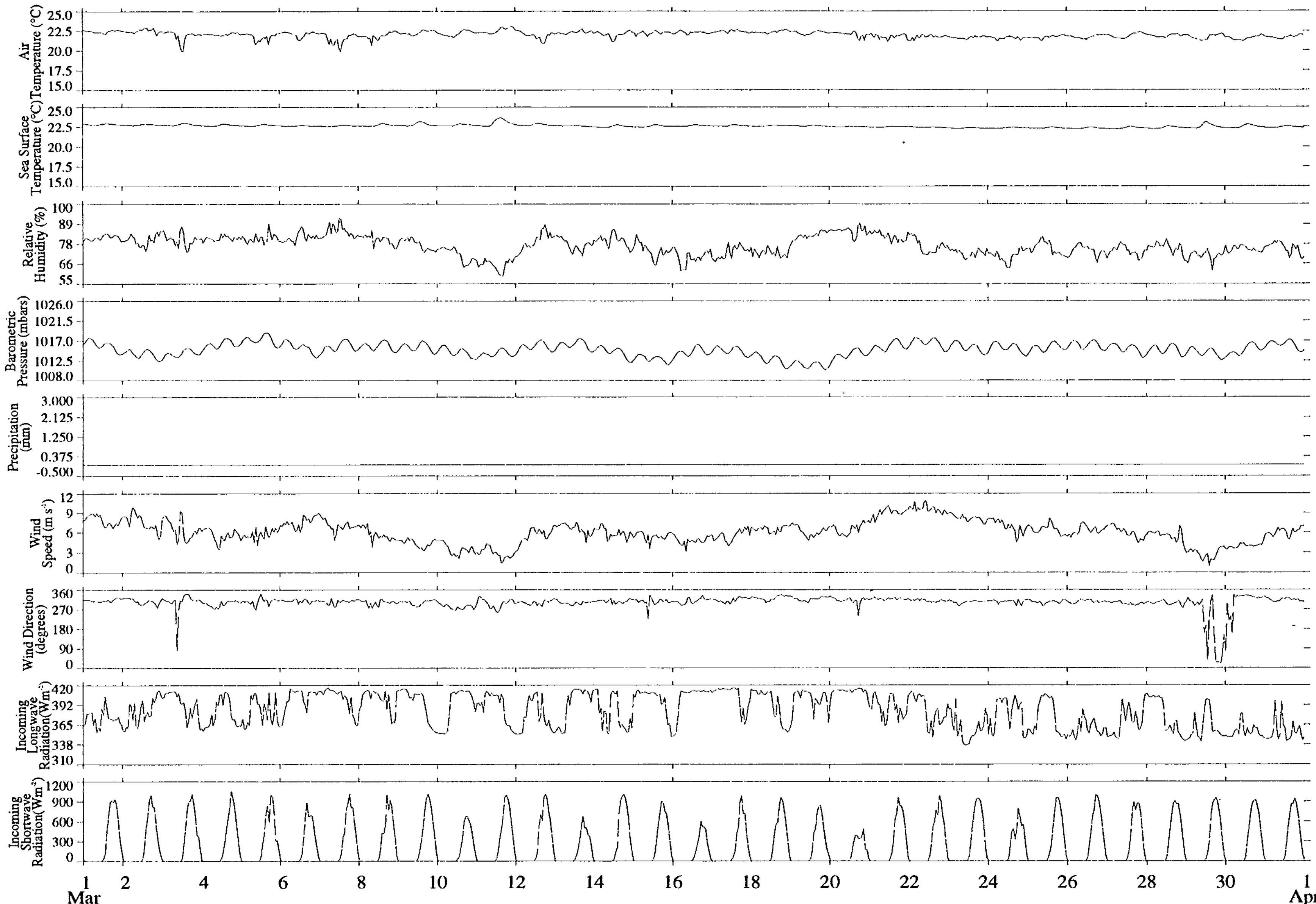


Figure 4-7. Hourly time series of meteorological observations for March 2001. (IMET system 1)

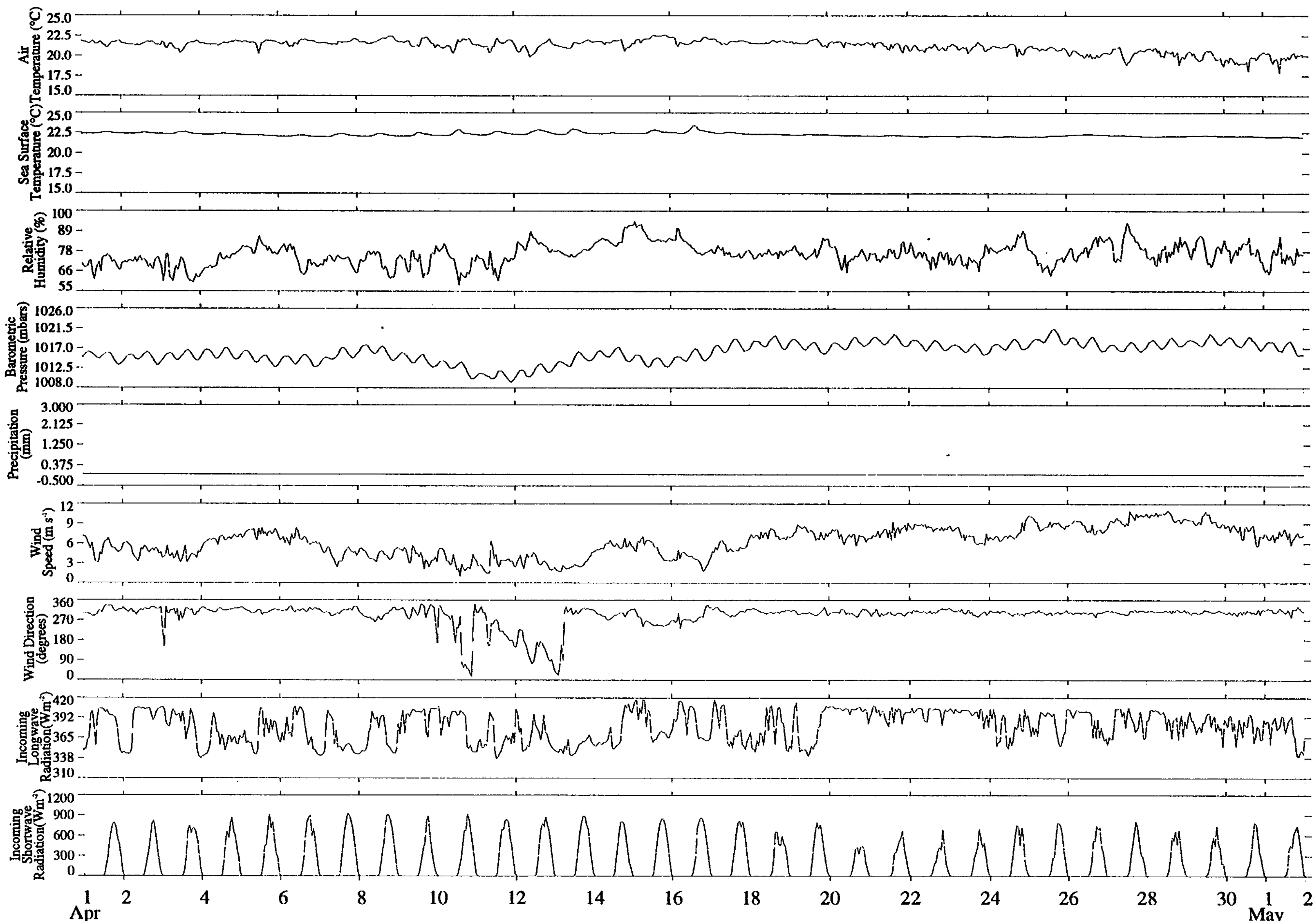


Figure 4-8. Hourly time series of meteorological observations for April 2001.
(IMET system 1)

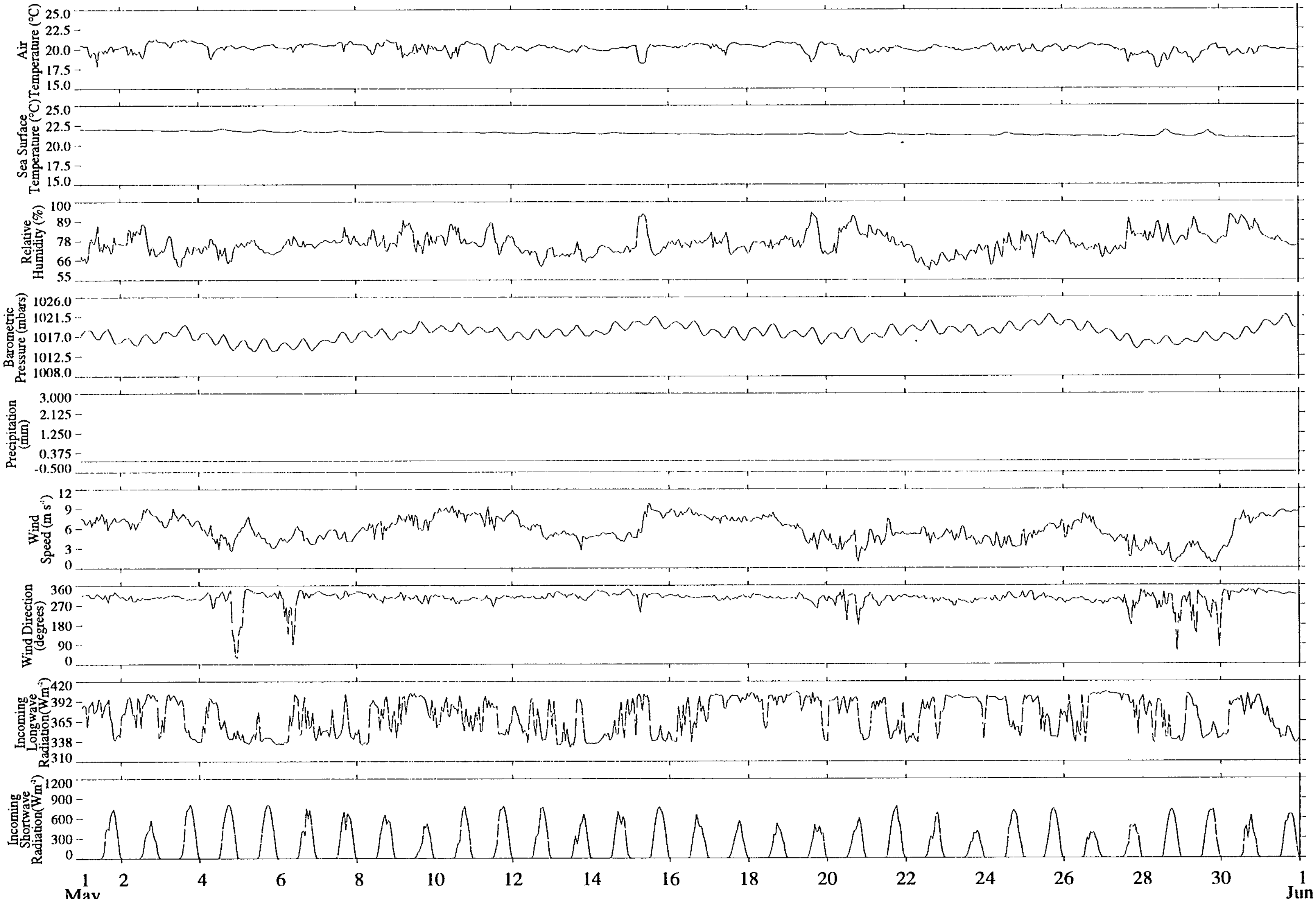


Figure 4-9. Hourly time series of meteorological observations for May 2001. (IMET system 1)

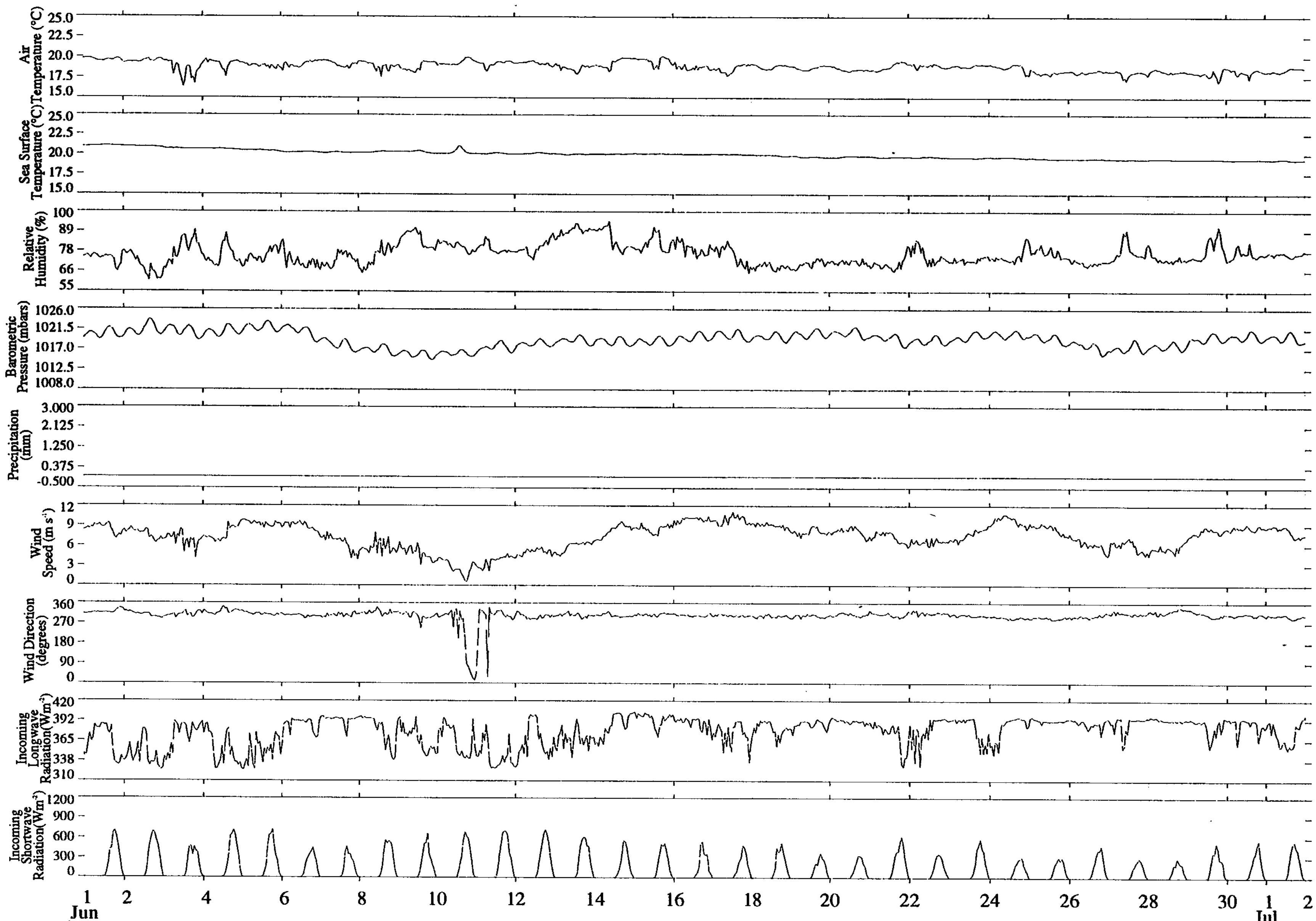


Figure 4-10. Hourly time series of meteorological observations for June 2001.
(IMET system 1)

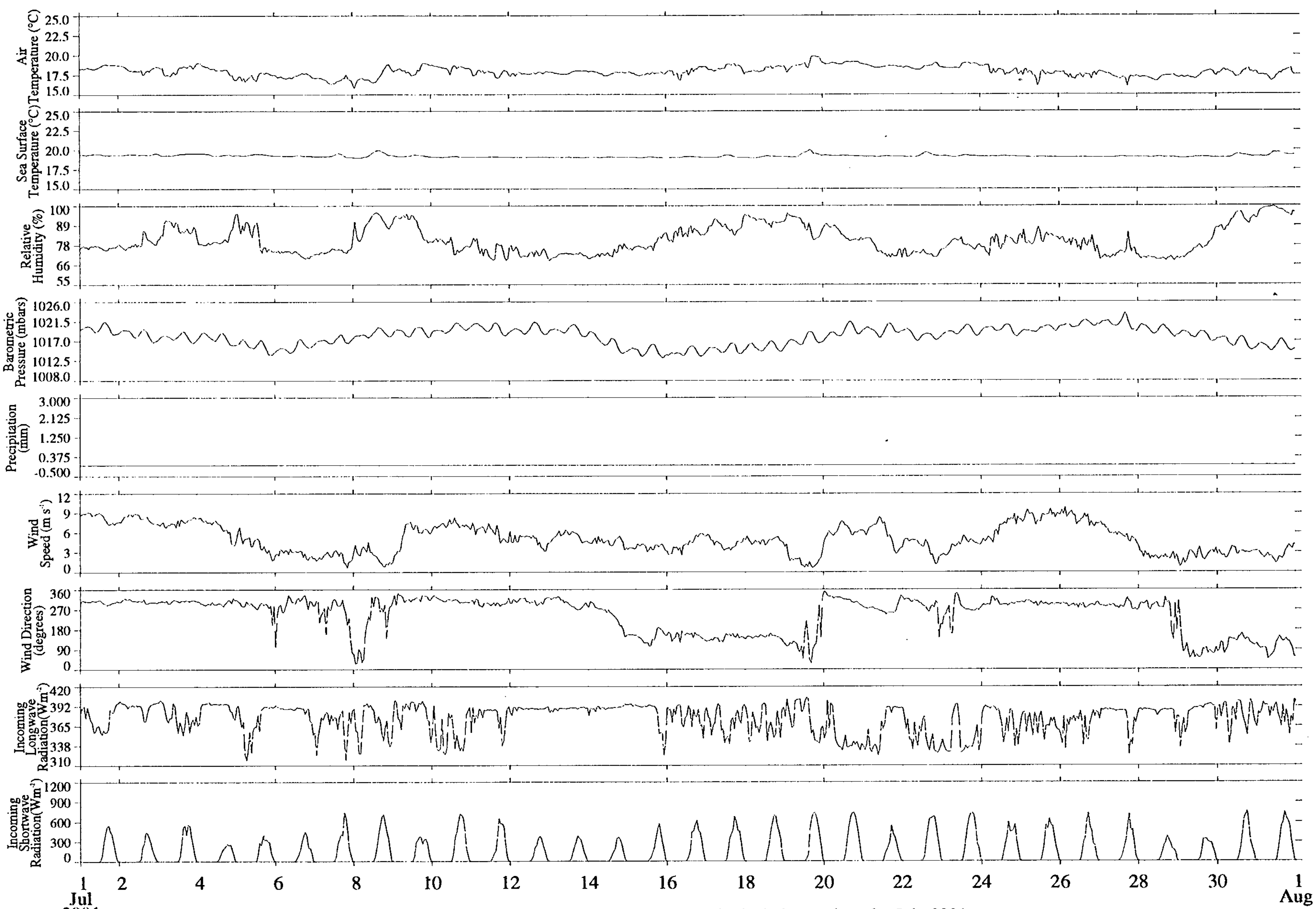


Figure 4-11. Hourly time series of meteorological observations for July 2001. (IMET system 1)

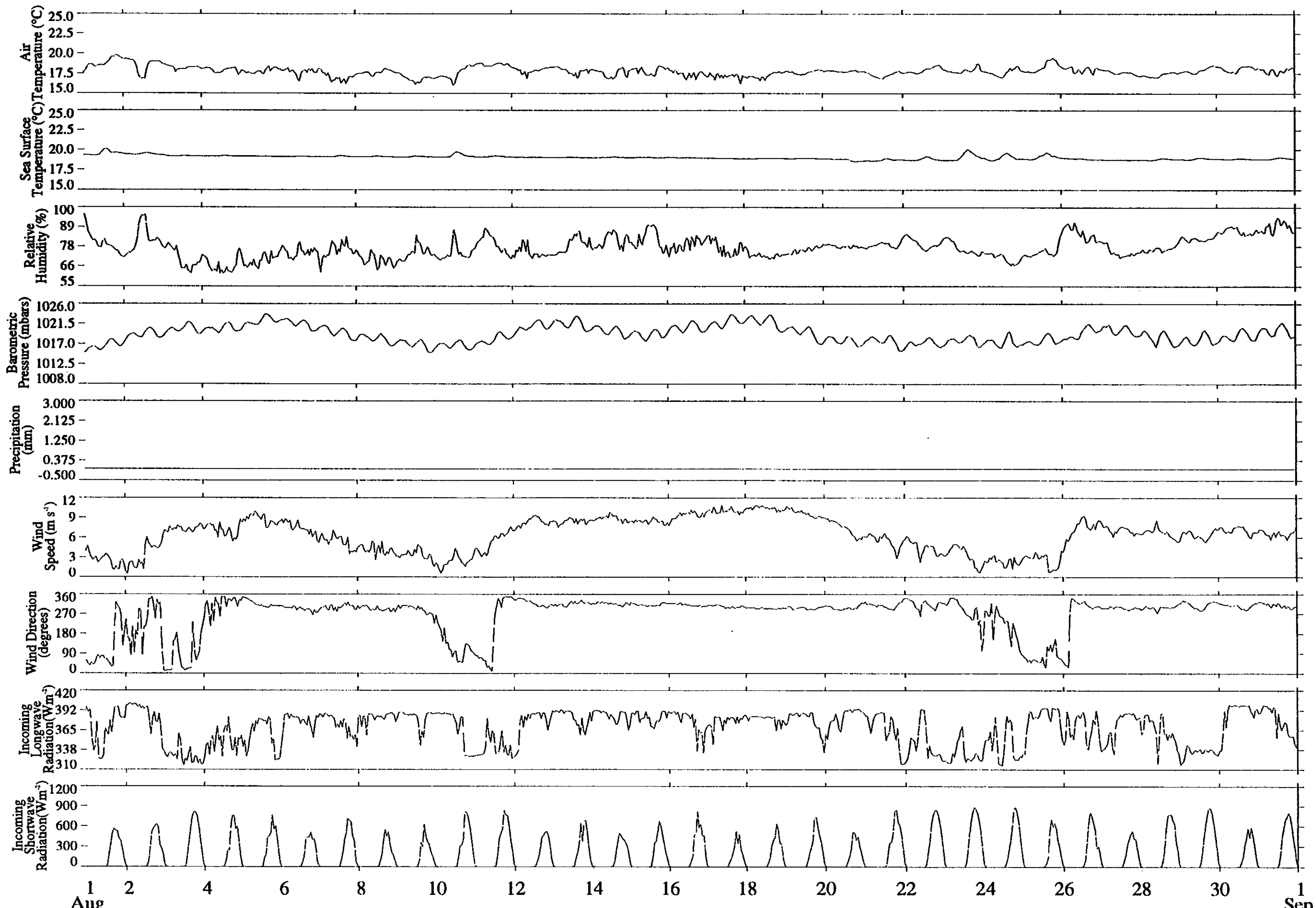


Figure 4-12. Hourly time series of meteorological observations for August 2001.
(IMET system 1)

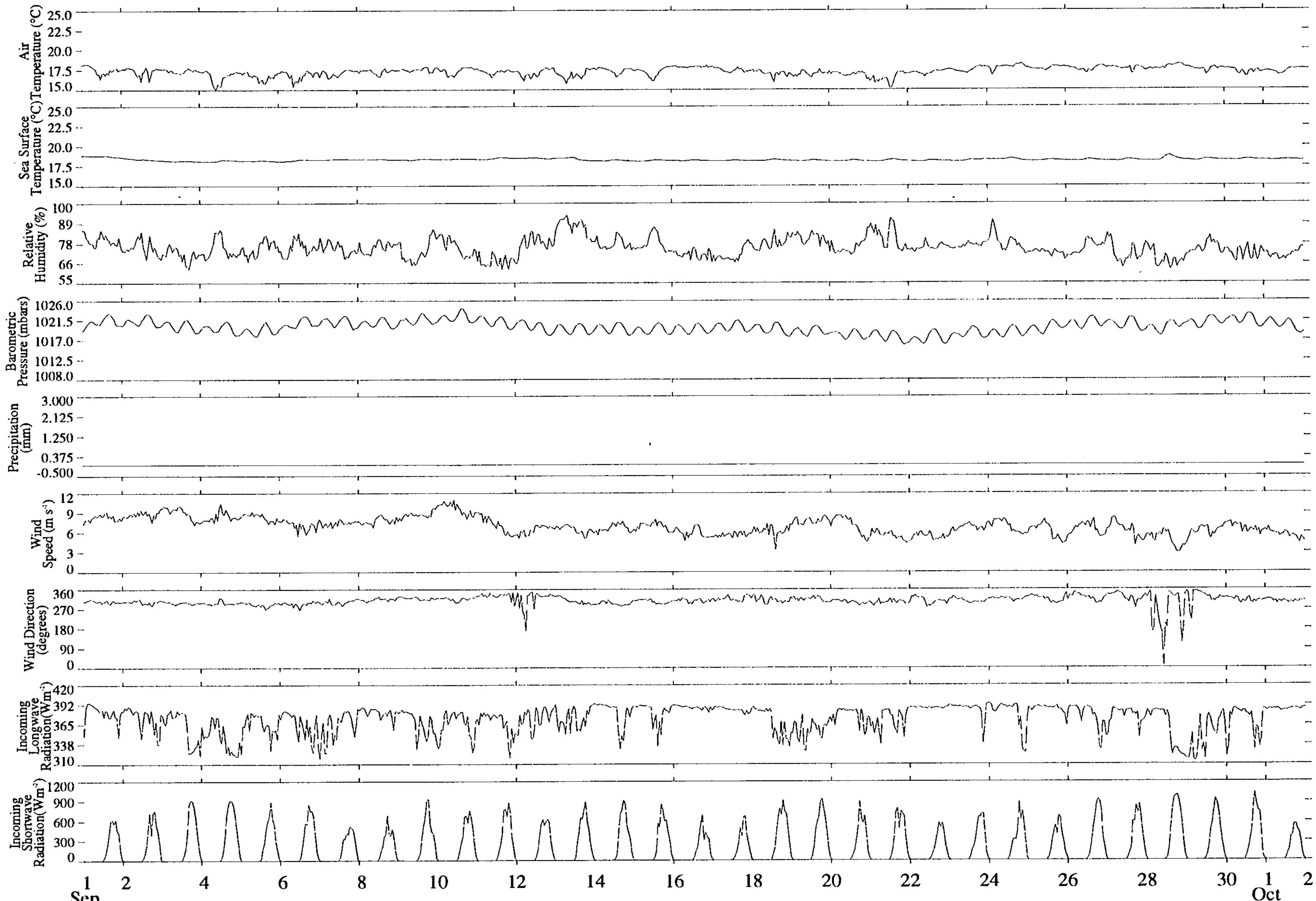


Figure 4-13. Hourly time series of meteorological observations for September 2001. (IMET system 1)

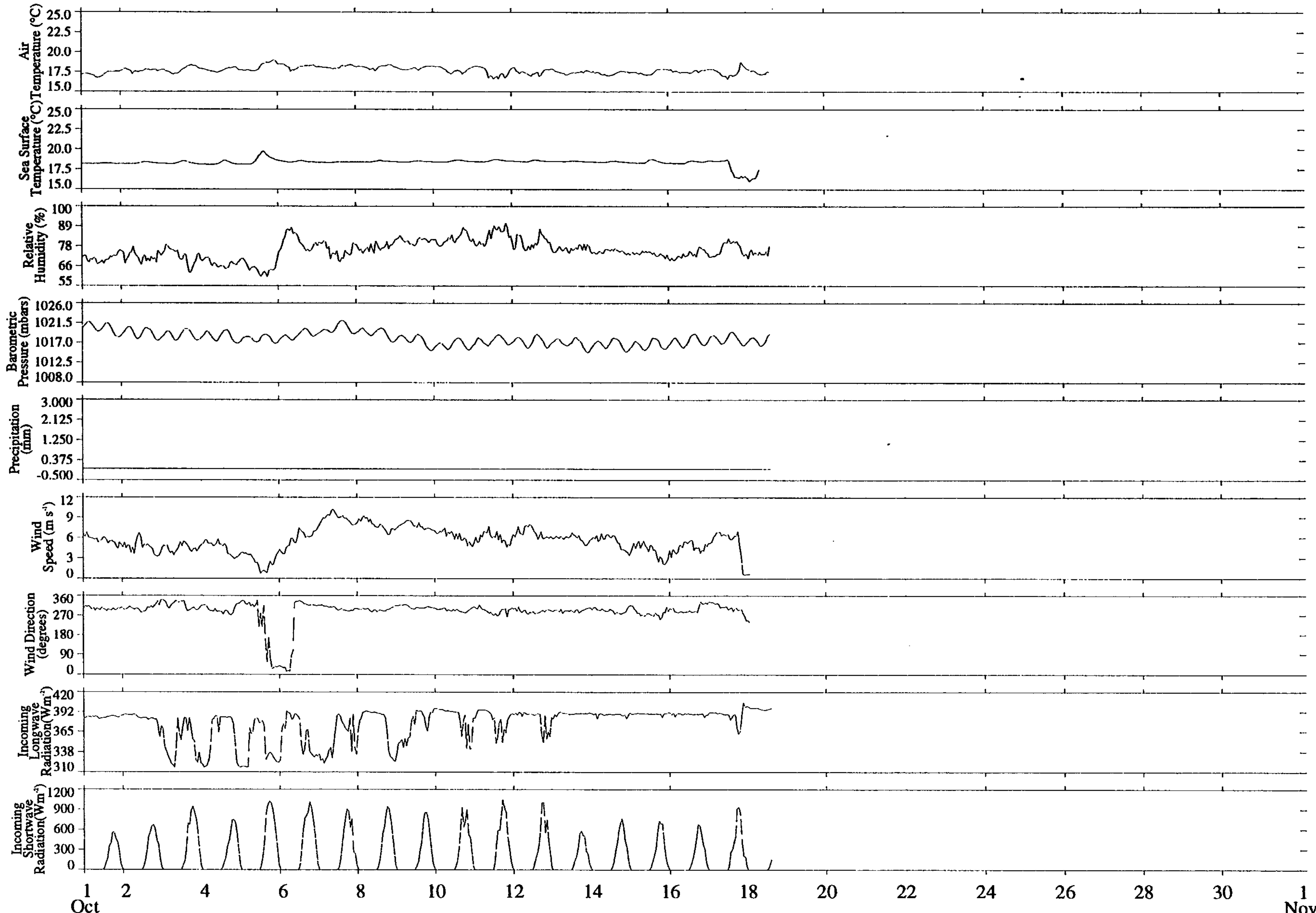


Figure 4-14. Hourly time series of meteorological observations for October 2001.
(IMET system 1)

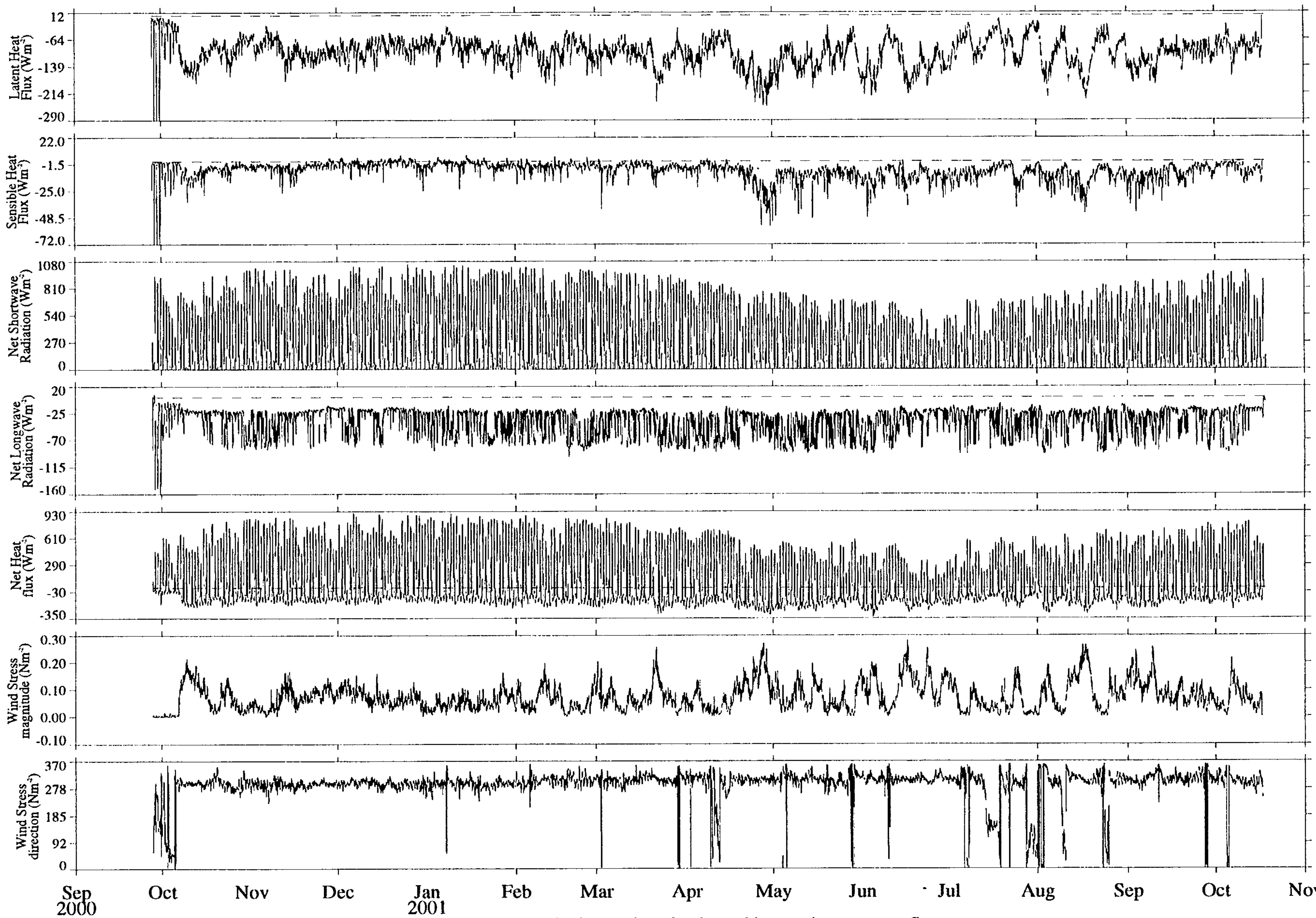


Figure 4-15. Hourly time series of estimated heat and momentum fluxes.
(IMET system 1)

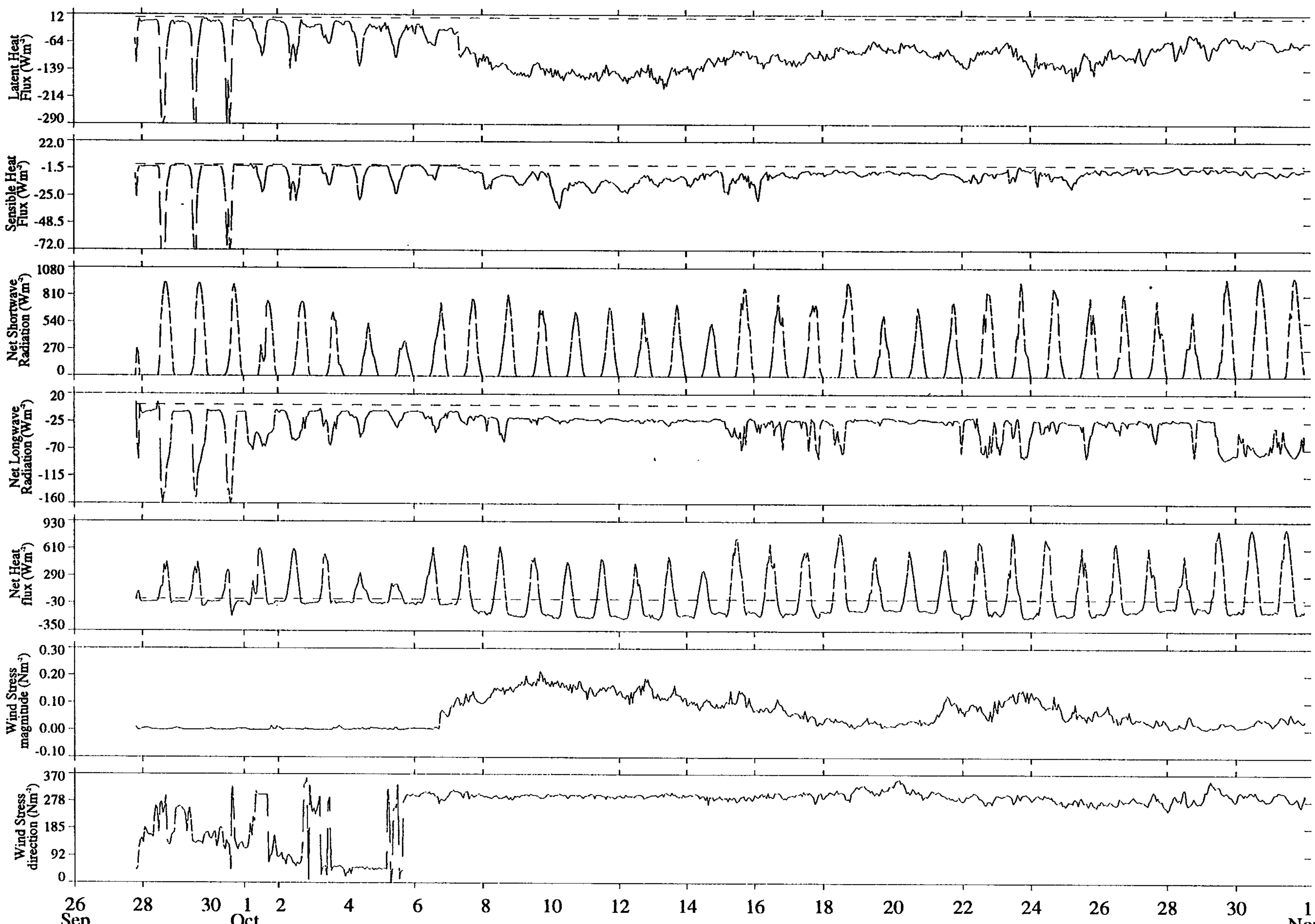


Figure 4-16. Hourly time series of estimated heat and momentum fluxes for October 2000. (IMET system 1)

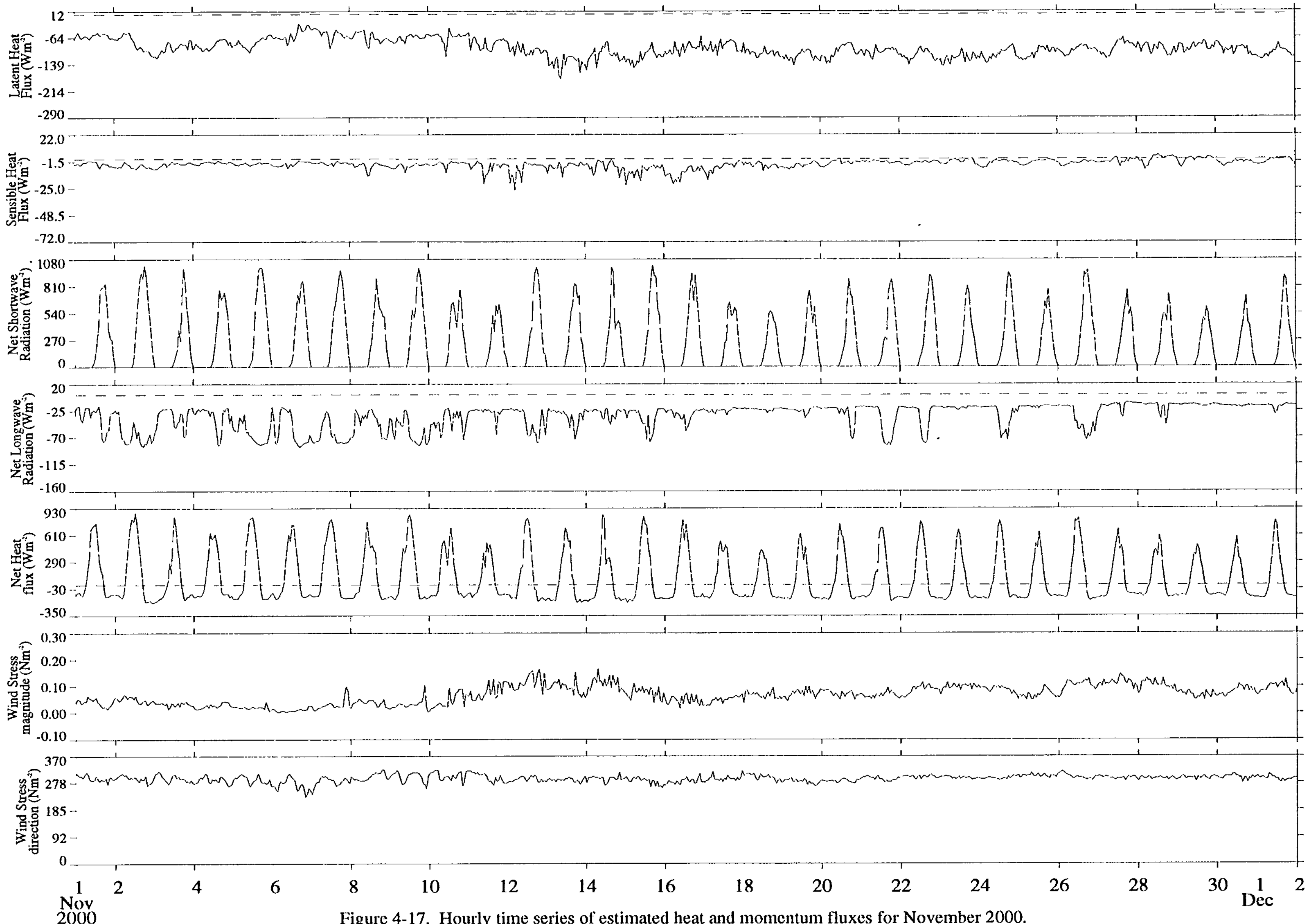


Figure 4-17. Hourly time series of estimated heat and momentum fluxes for November 2000.
(IMET system 1)

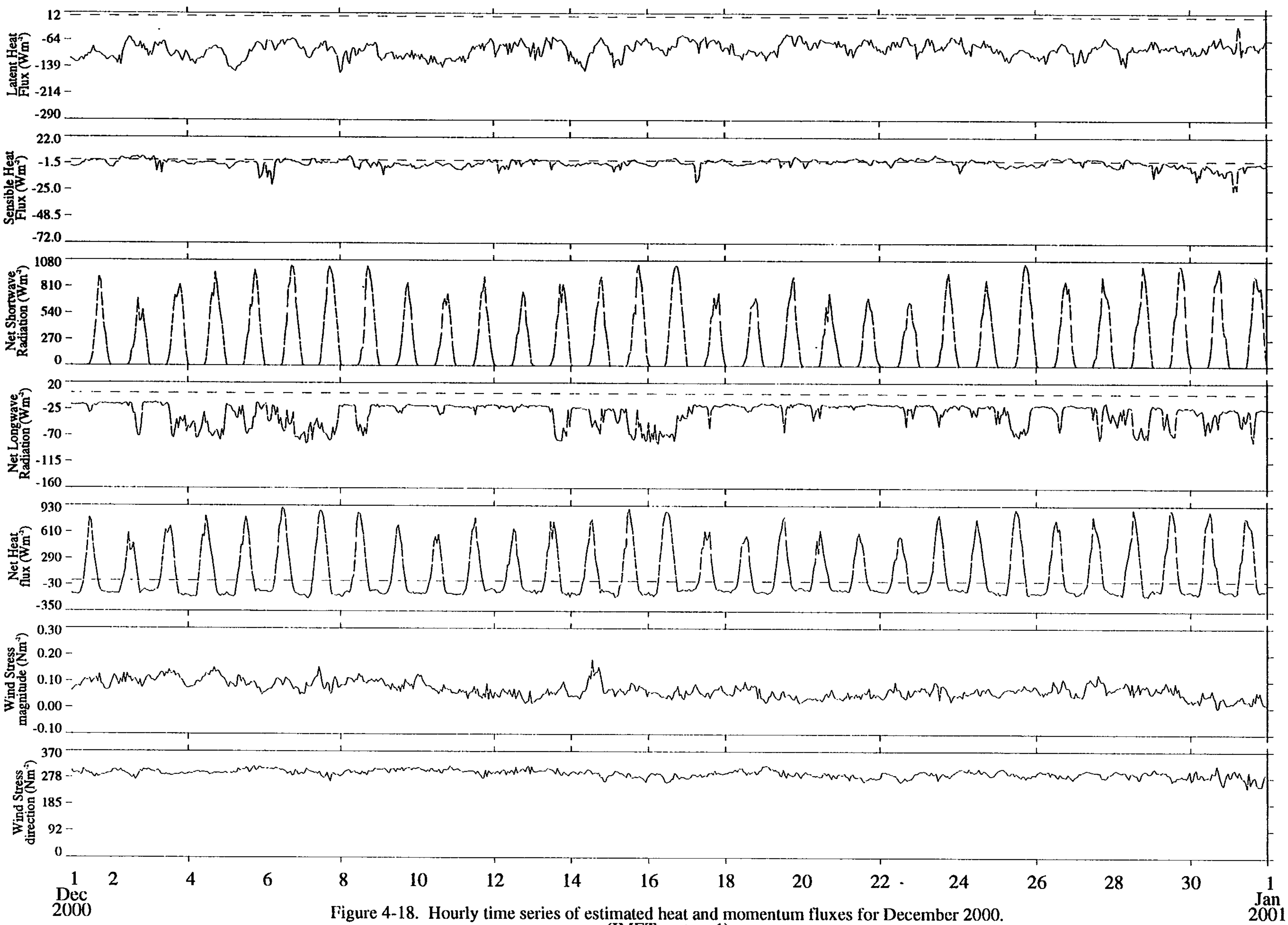


Figure 4-18. Hourly time series of estimated heat and momentum fluxes for December 2000.
(IMET system 1)

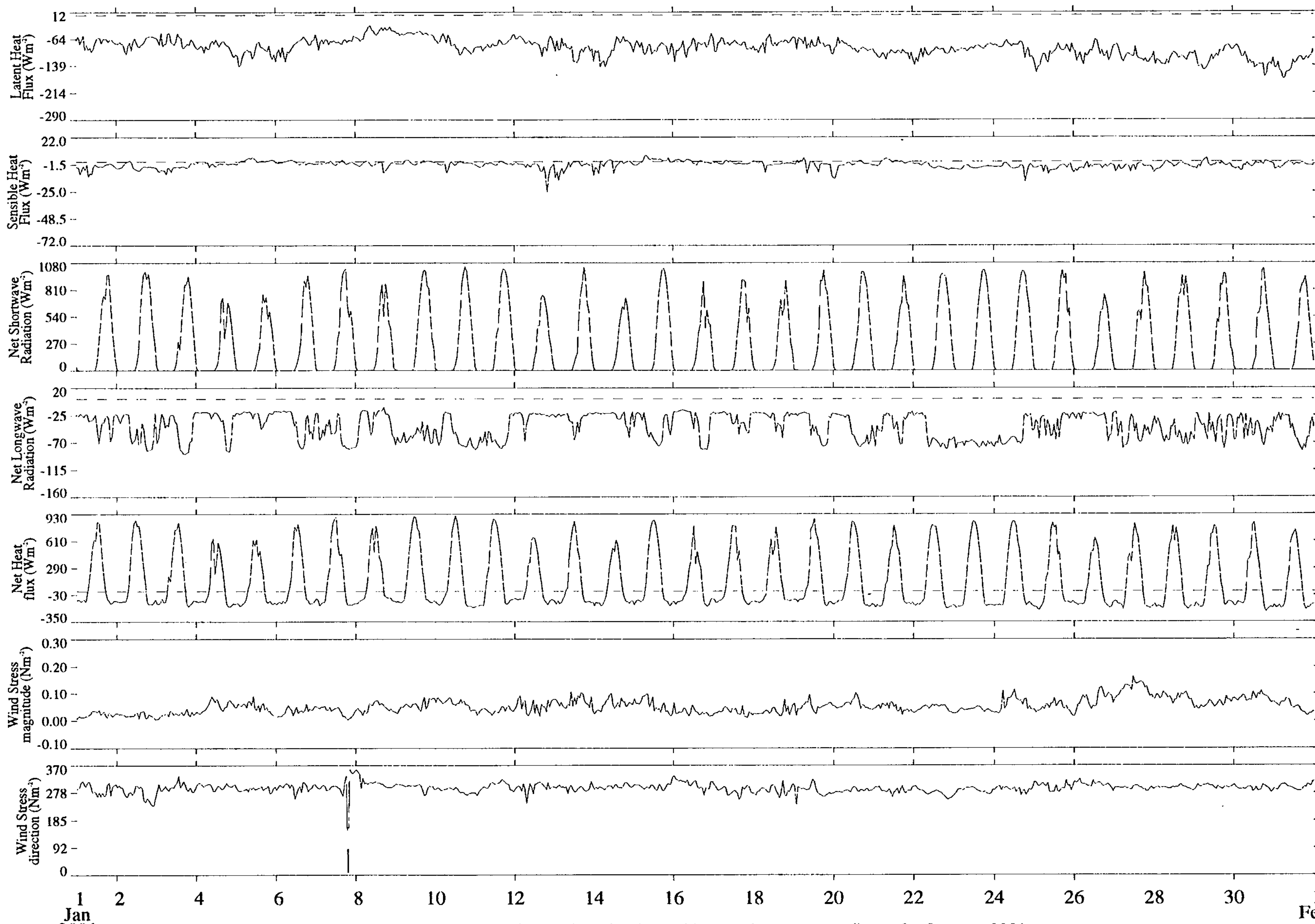


Figure 4-19. Hourly time series of estimated heat and momentum fluxes for January 2001.
(IMET system 1)

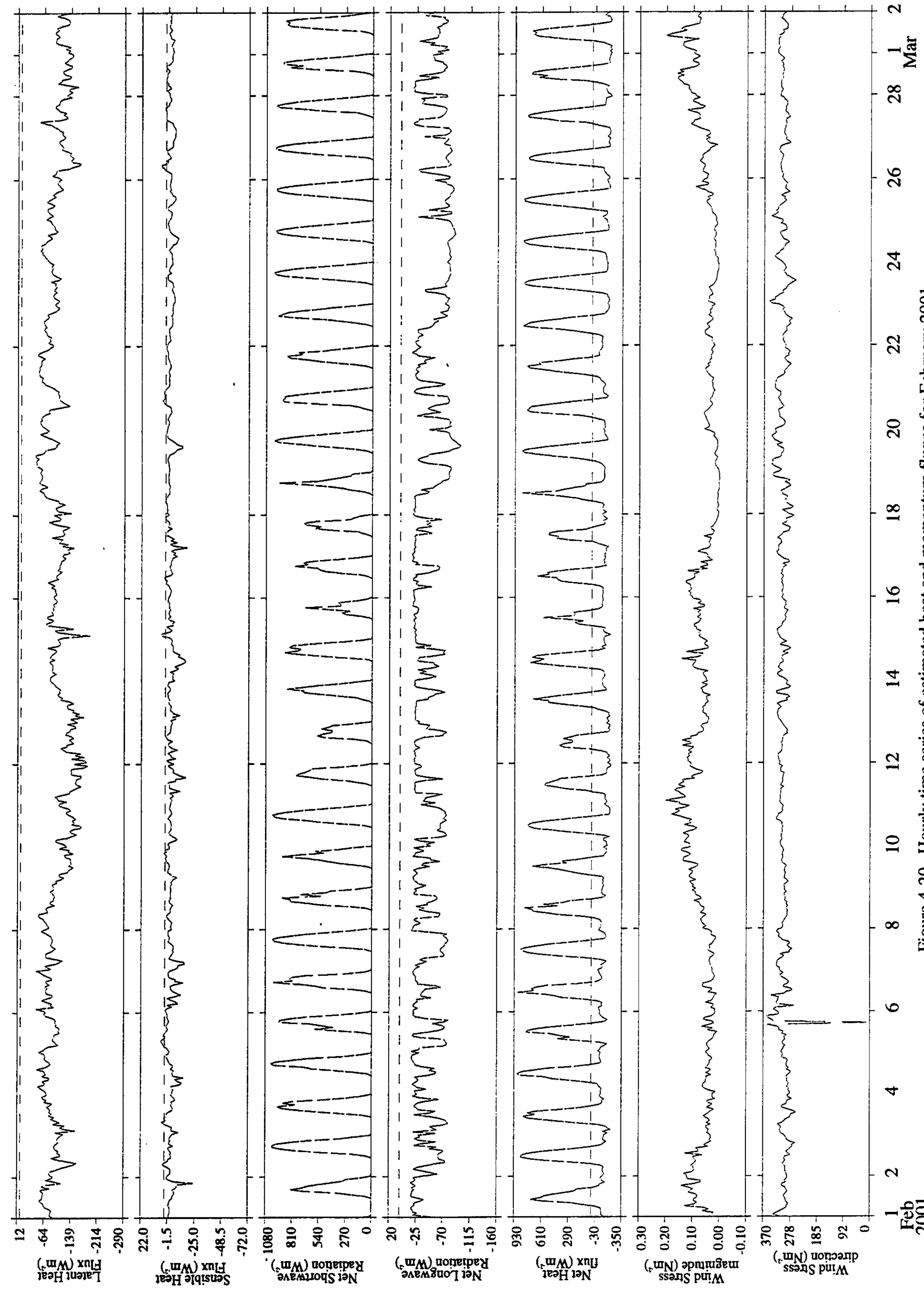


Figure 4-20. Hourly time series of estimated heat and momentum fluxes for February 2001. (IMET system 1)

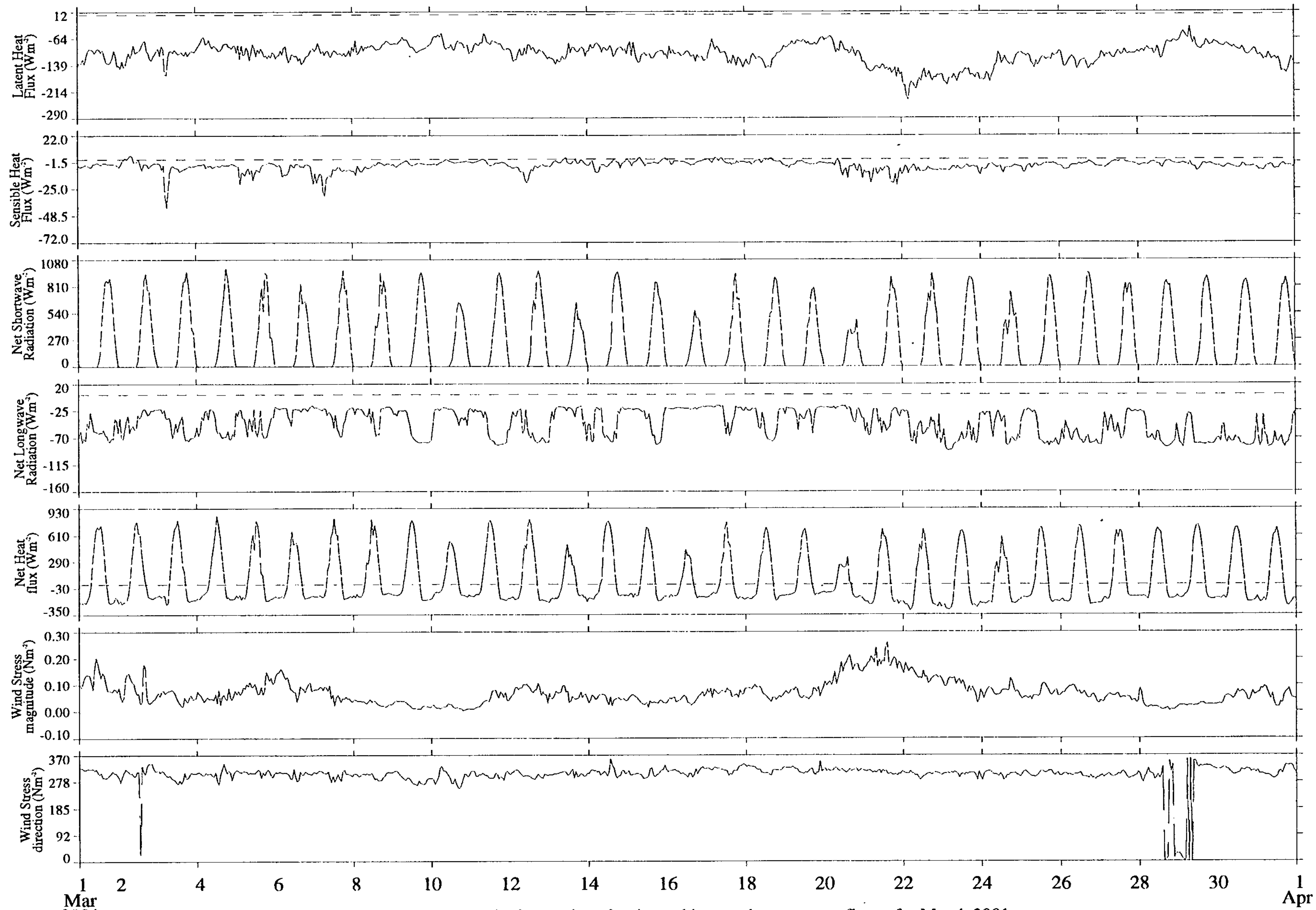


Figure 4-21. Hourly time series of estimated heat and momentum fluxes for March 2001. (IMET system 1)

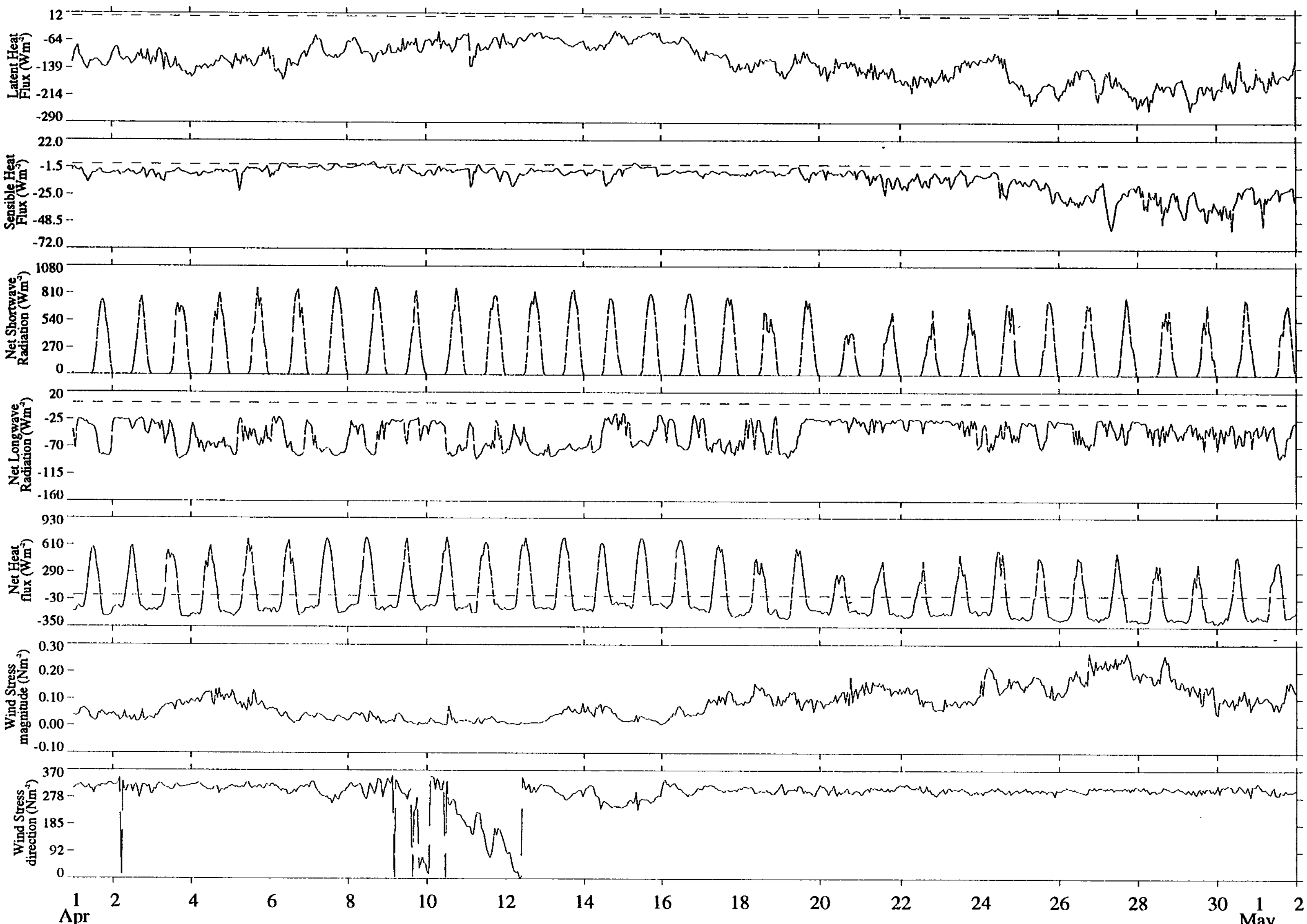


Figure 4-22. Hourly time series of estimated heat and momentum fluxes for April 2001.
(IMET system 1)

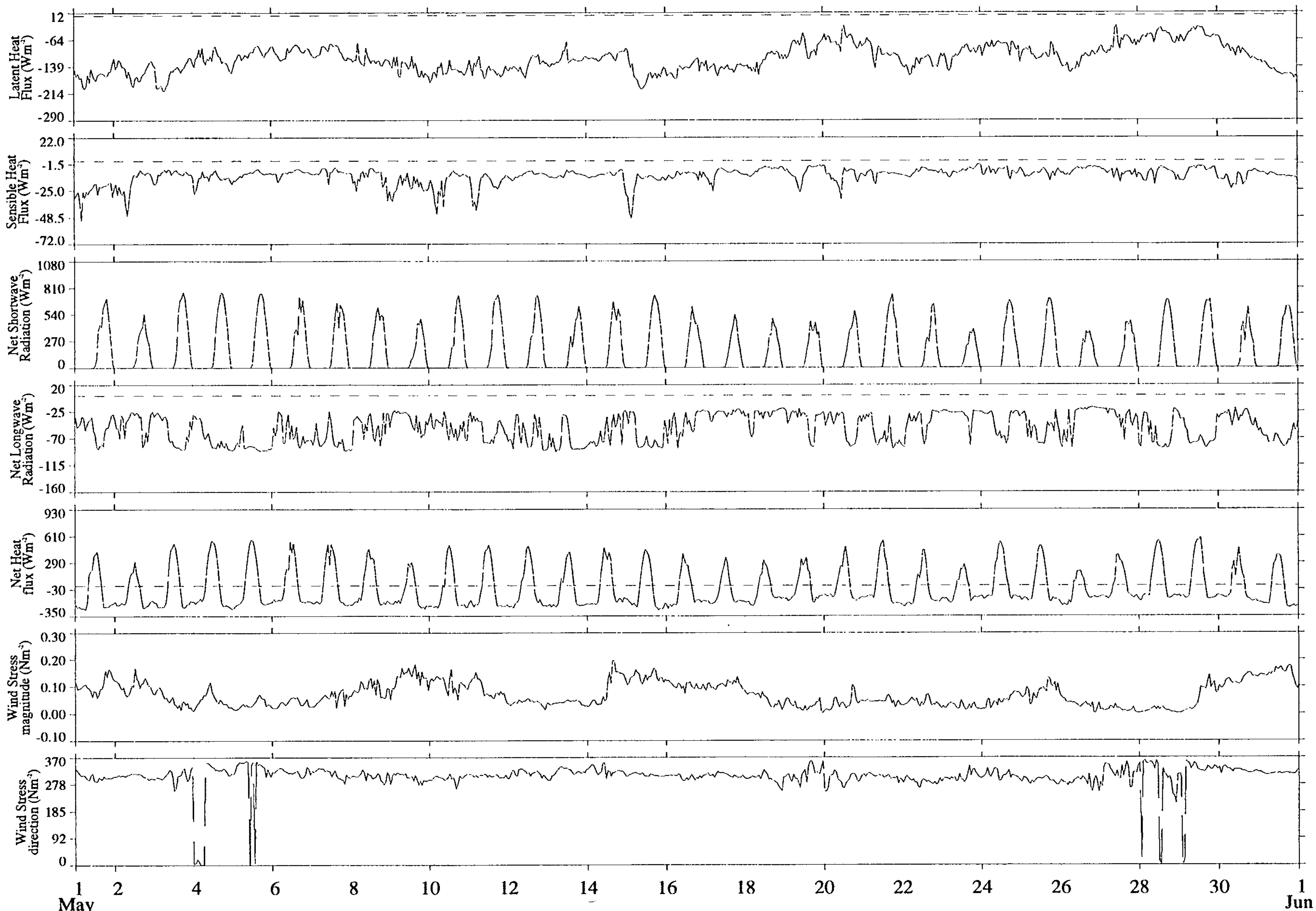


Figure 4-23. Hourly time series of estimated heat and momentum fluxes for May 2001. (IMET system 1)

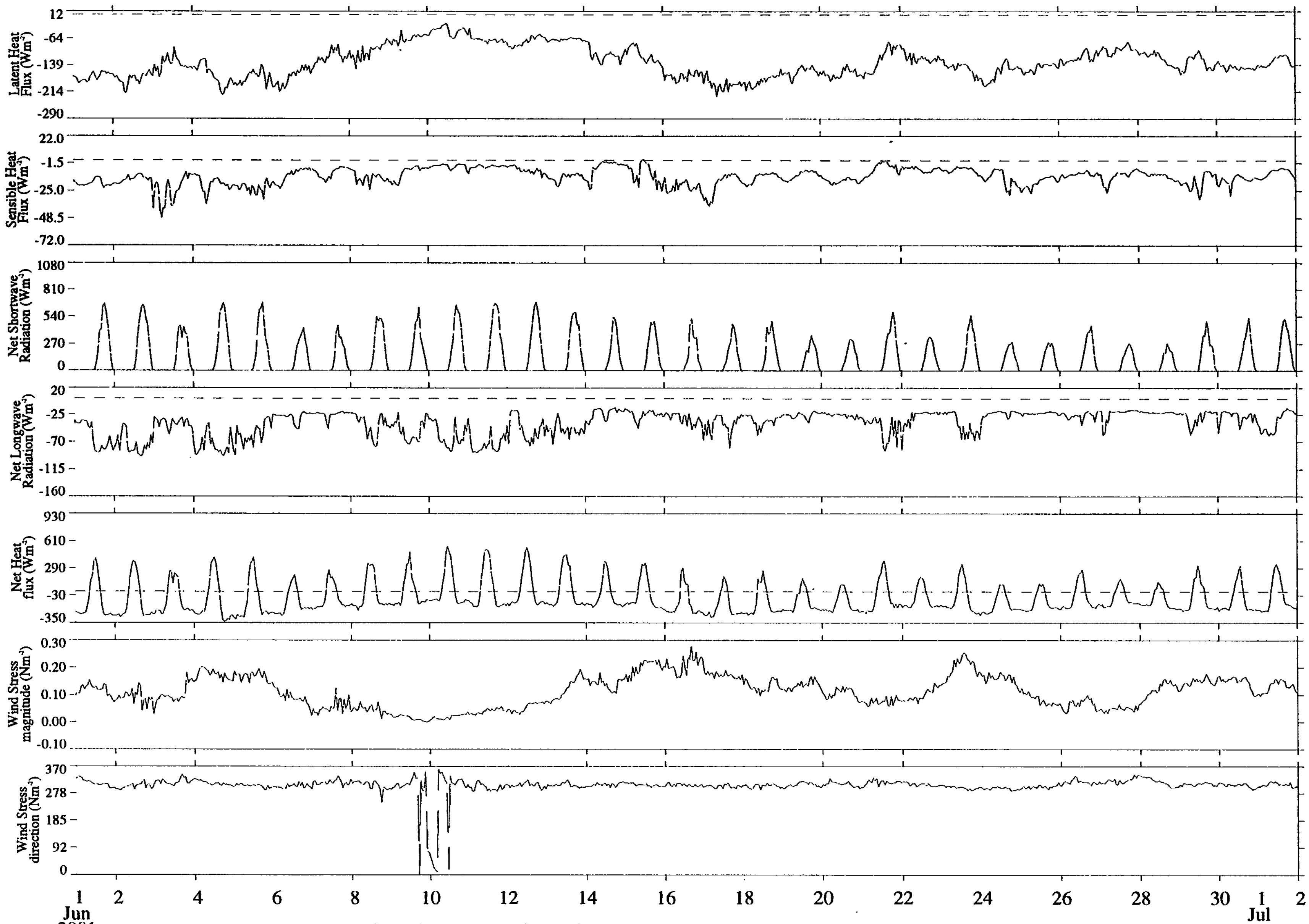


Figure 4-24. Hourly time series of estimated heat and momentum fluxes for June 2001.
(IMET system 1)

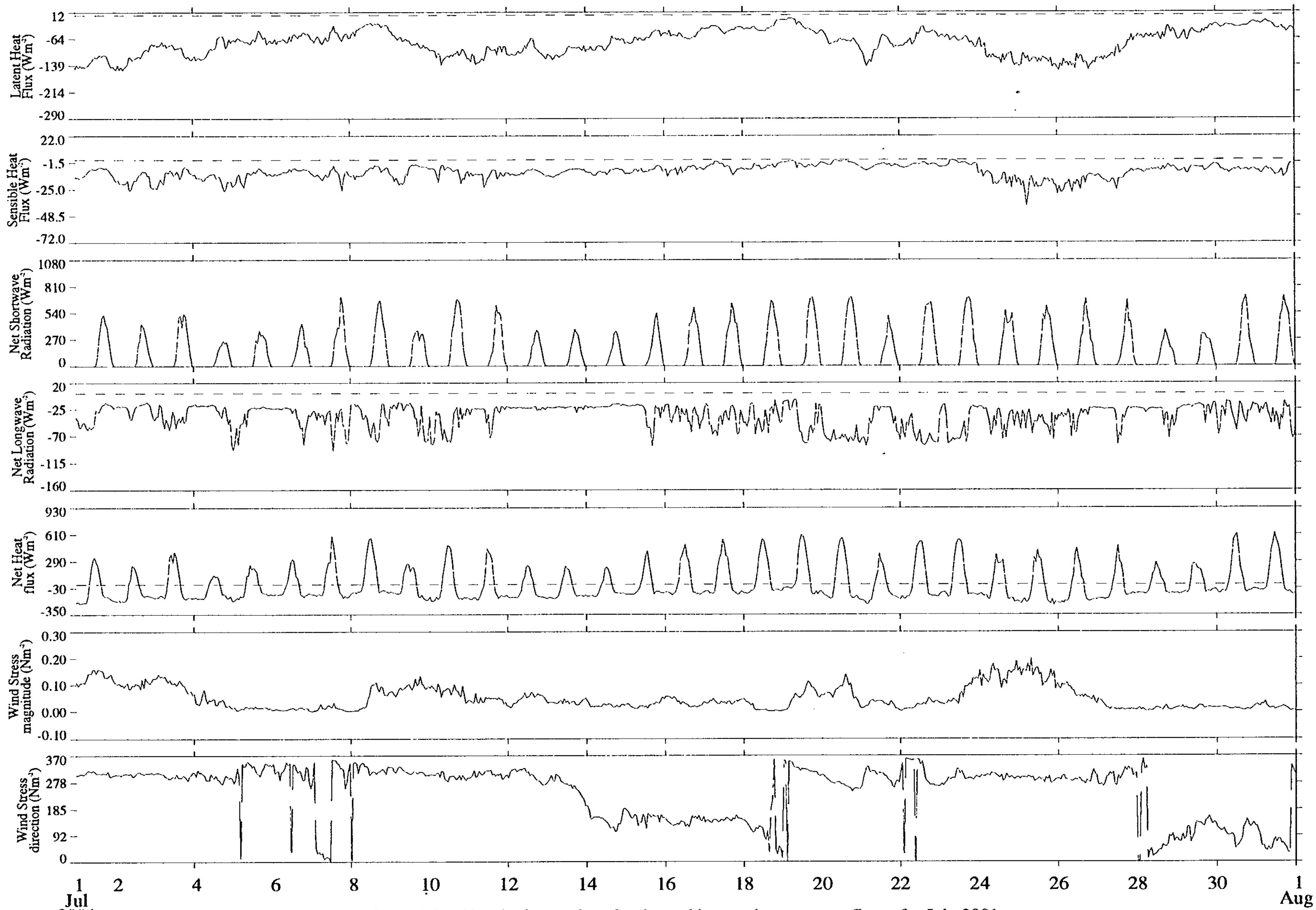


Figure 4-25. Hourly time series of estimated heat and momentum fluxes for July 2001.
(IMET system 1)

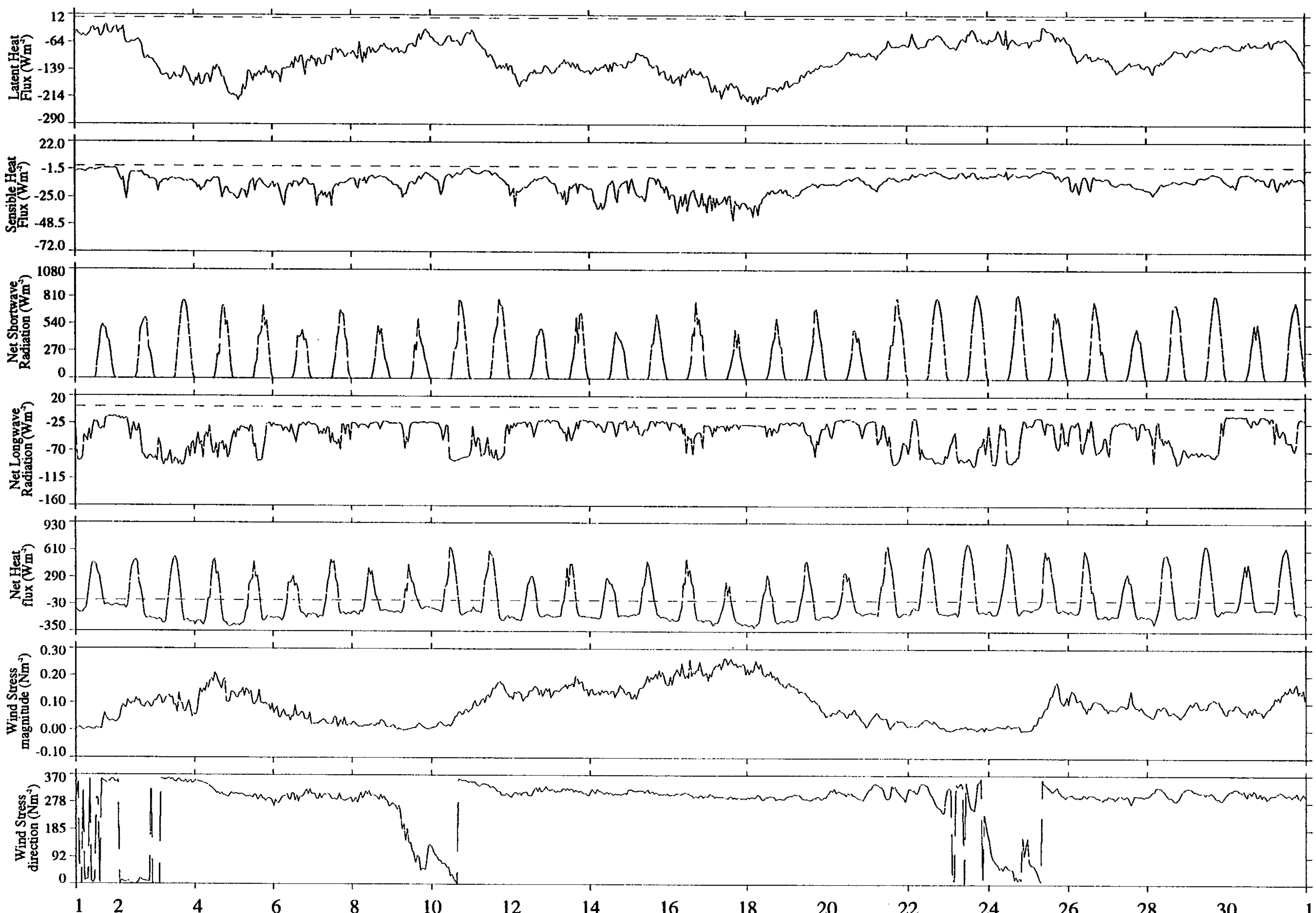


Figure 4-26. Hourly time series of estimated heat and momentum fluxes for August 2001.
(IMET system 1)

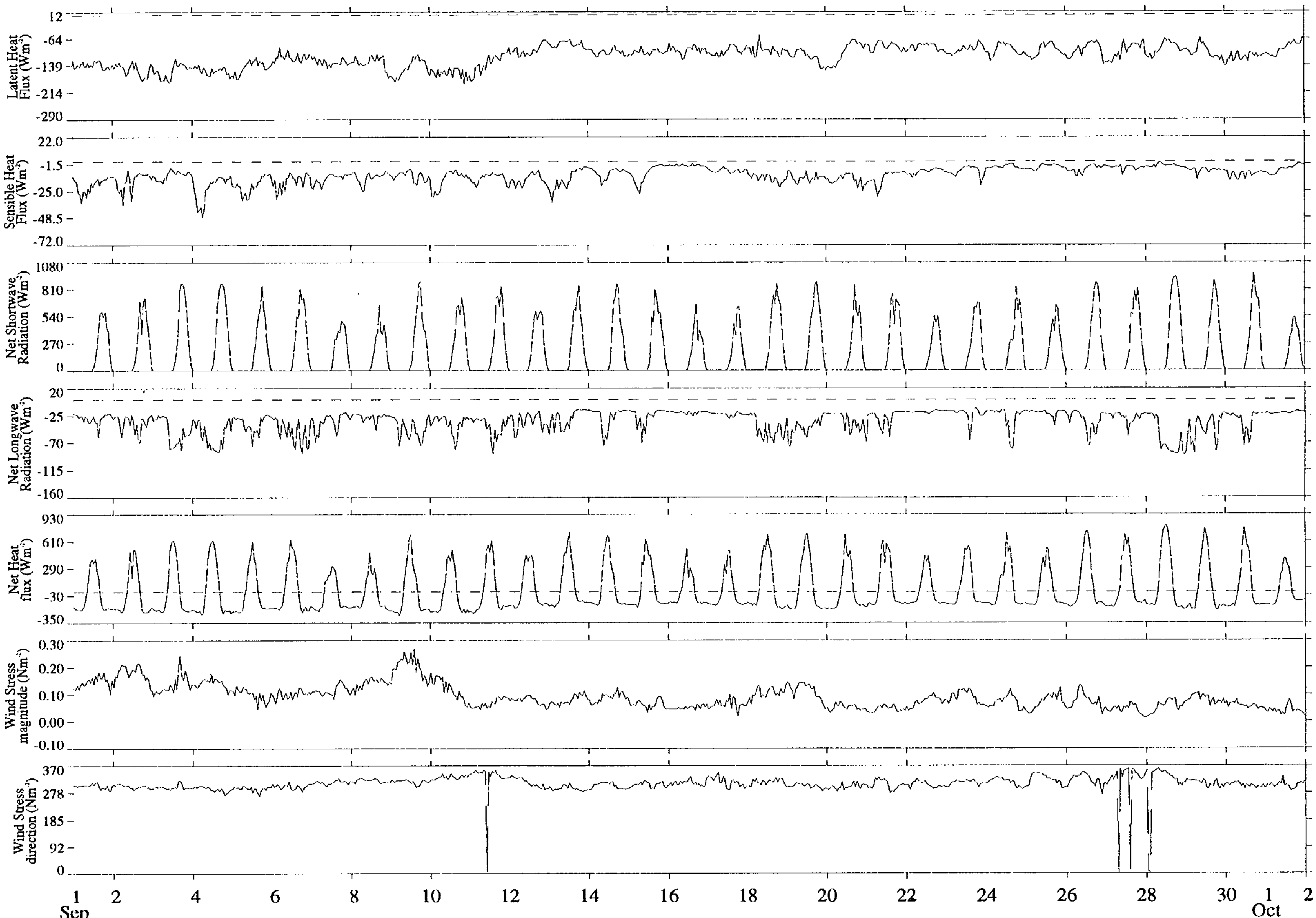


Figure 4-27. Hourly time series of estimated heat and momentum fluxes for September 2001. (IMET system 1)

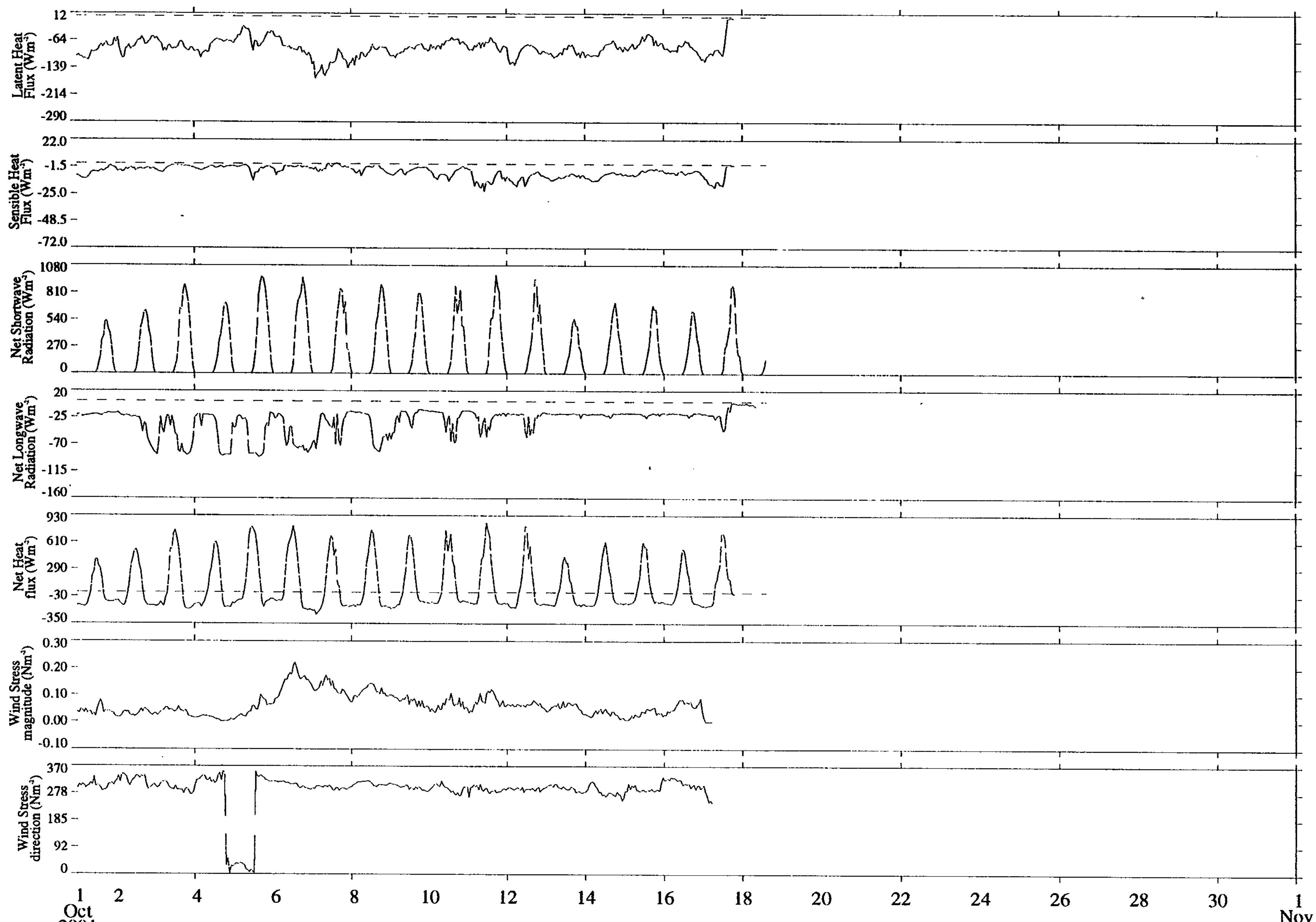


Figure 4-28. Hourly time series of estimated heat and momentum fluxes for October 2001. (IMET system 1)

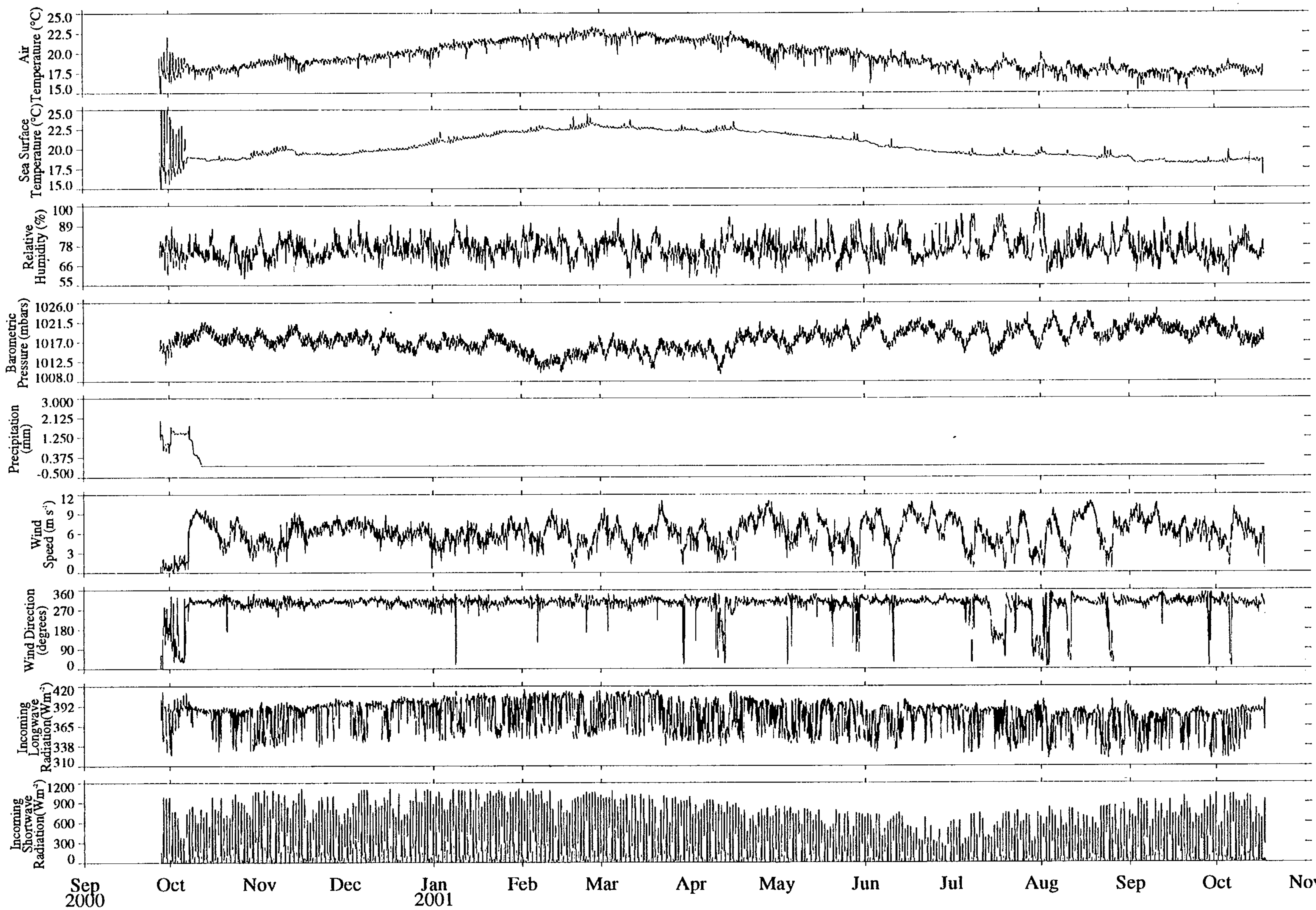


Figure 4-29. Hourly time series of meteorological observations .
(IMET system 2)

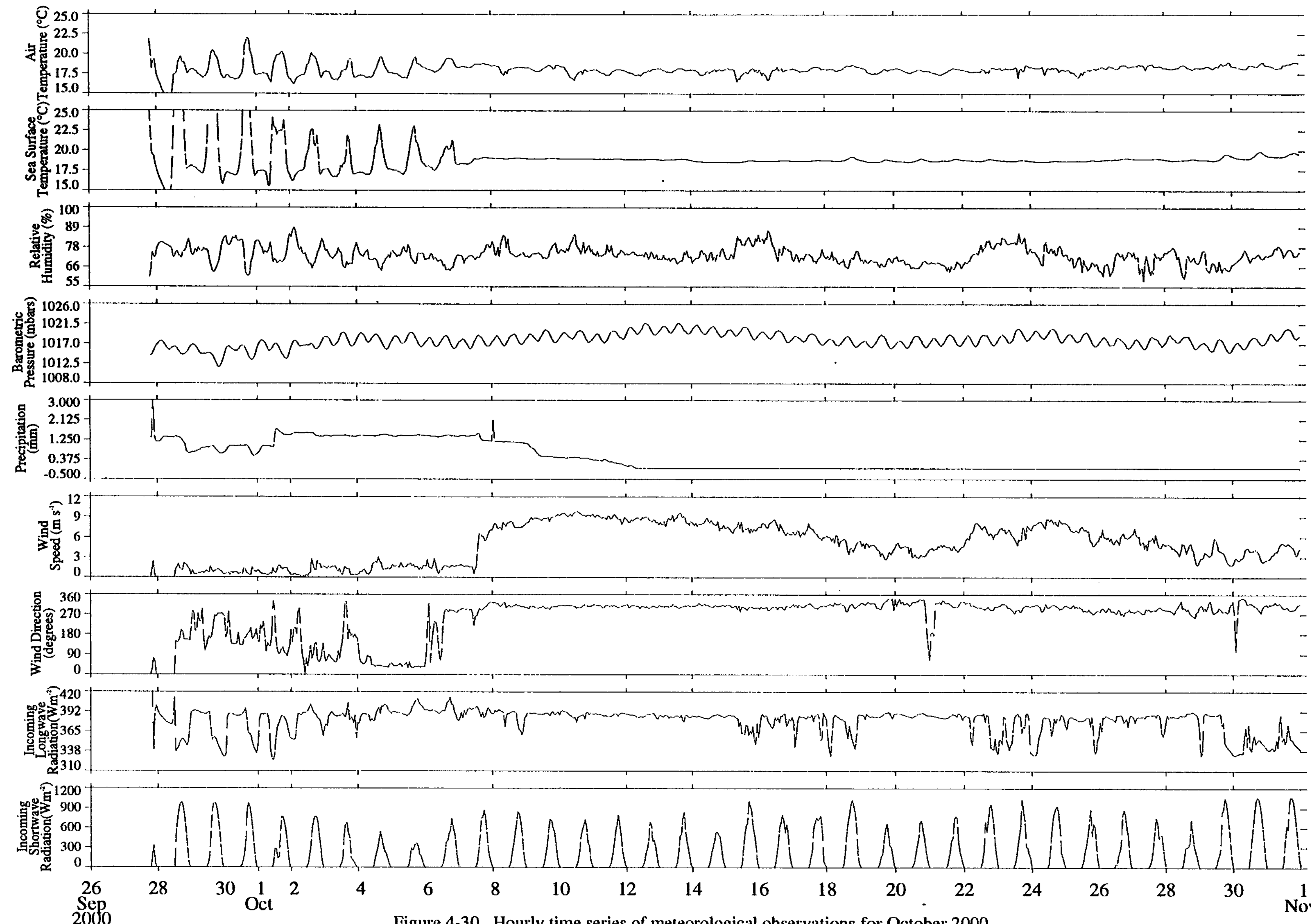


Figure 4-30. Hourly time series of meteorological observations for October 2000. (IMET system 2)

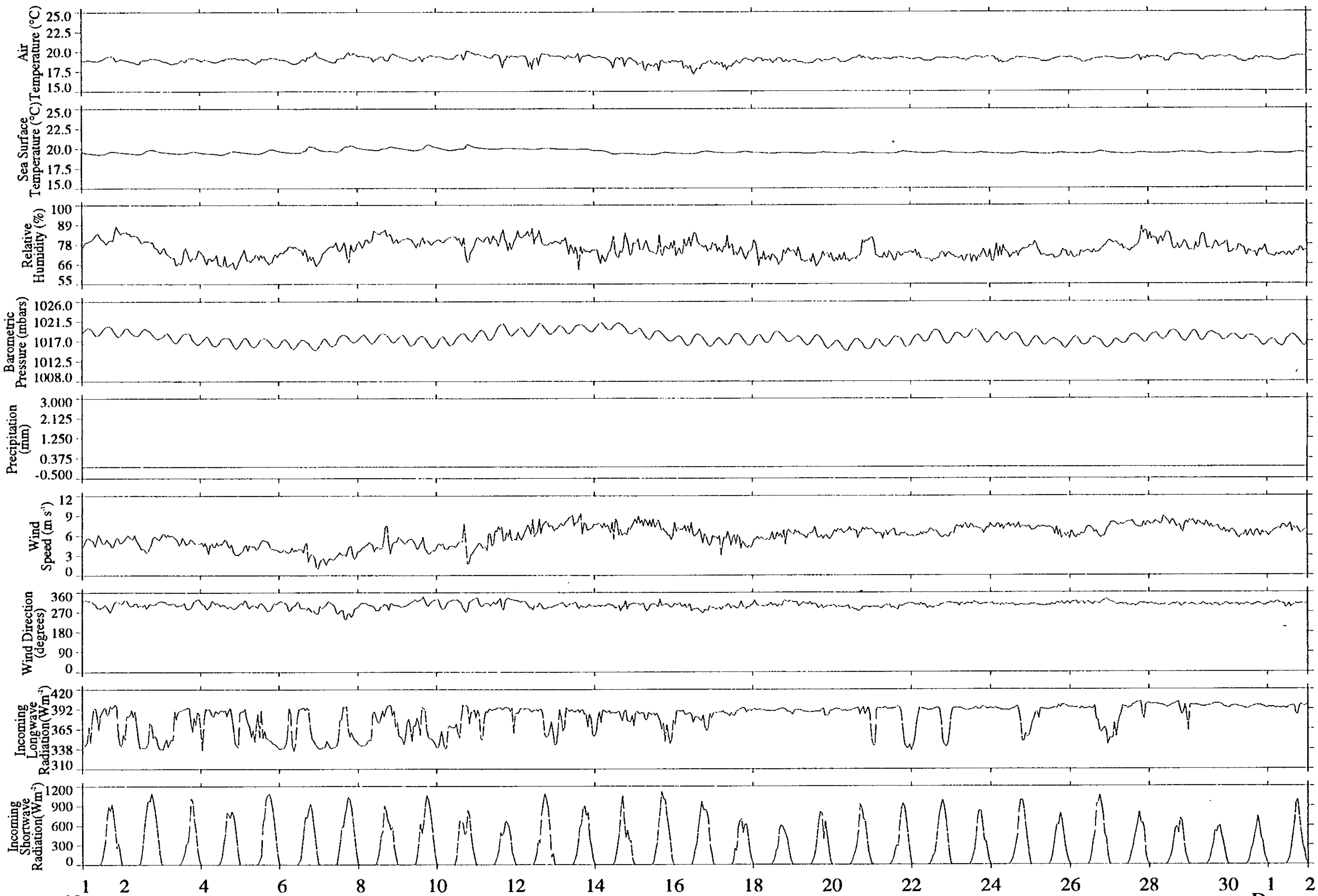


Figure 4-31. Hourly time series of meteorological observations for November 2000. (IMET system 2)

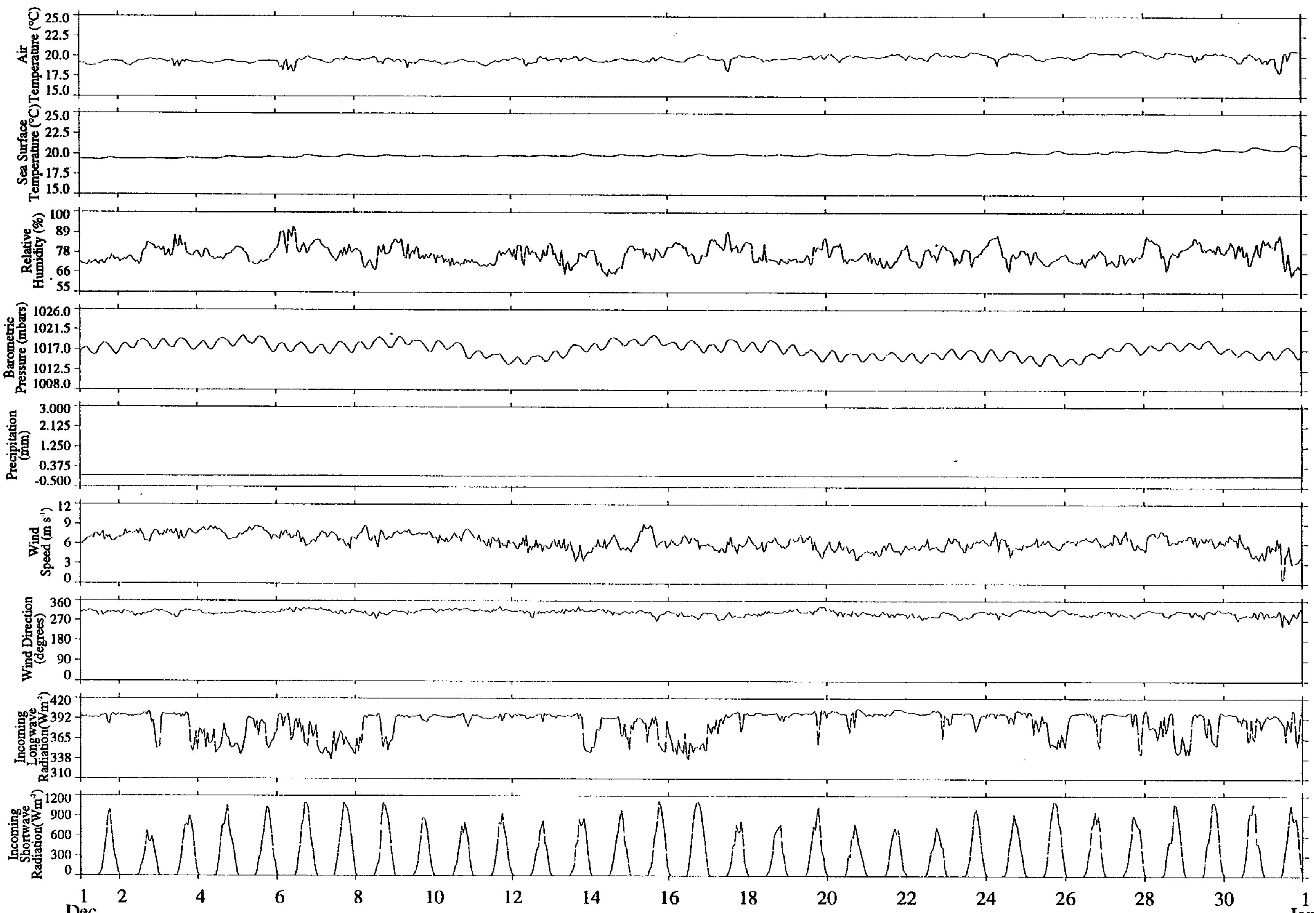


Figure 4-32. Hourly time series of meteorological observations for December 2000. (IMET system 2)

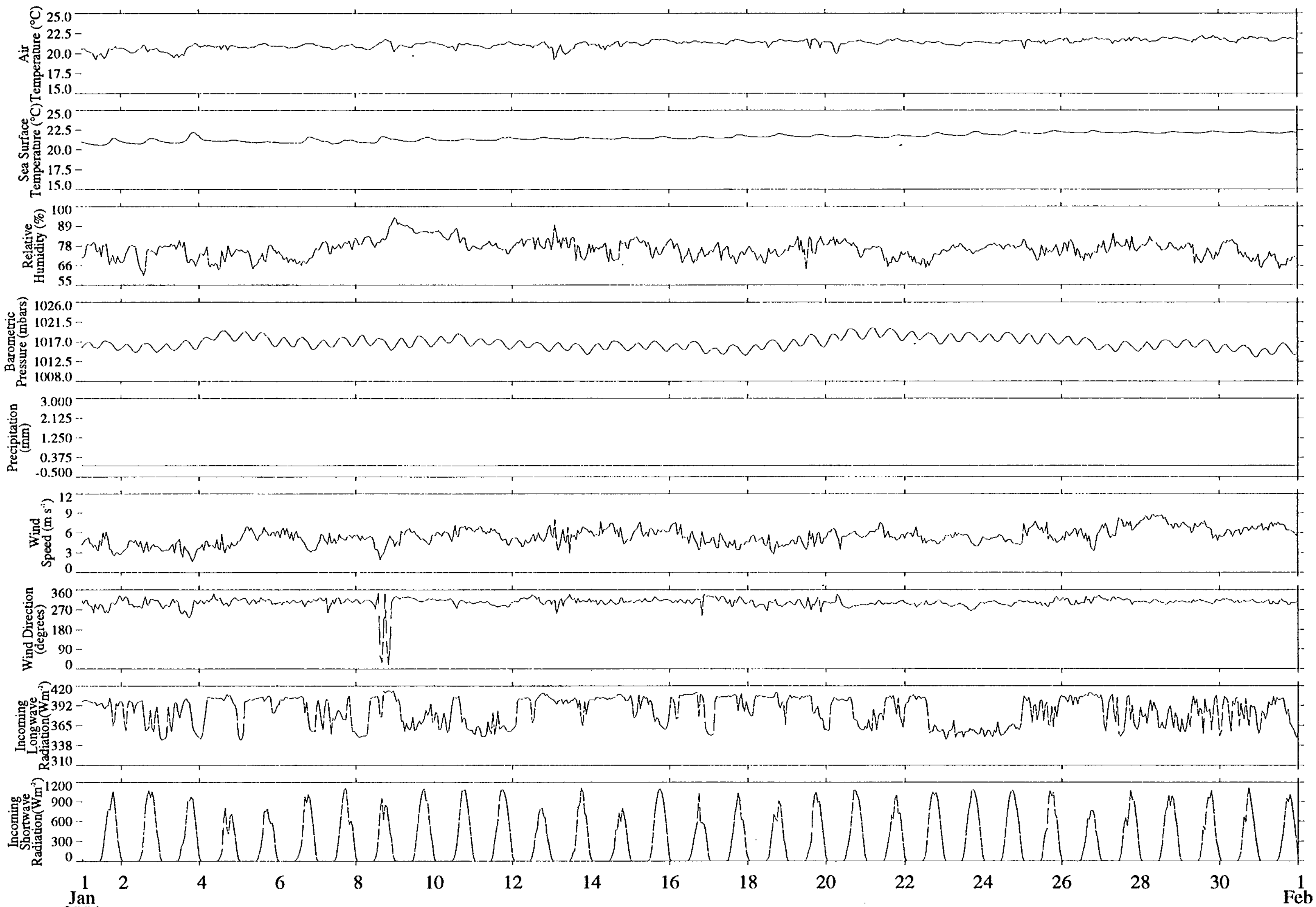


Figure 4-33. Hourly time series of meteorological observations for January 2001.
(IMET system 2)

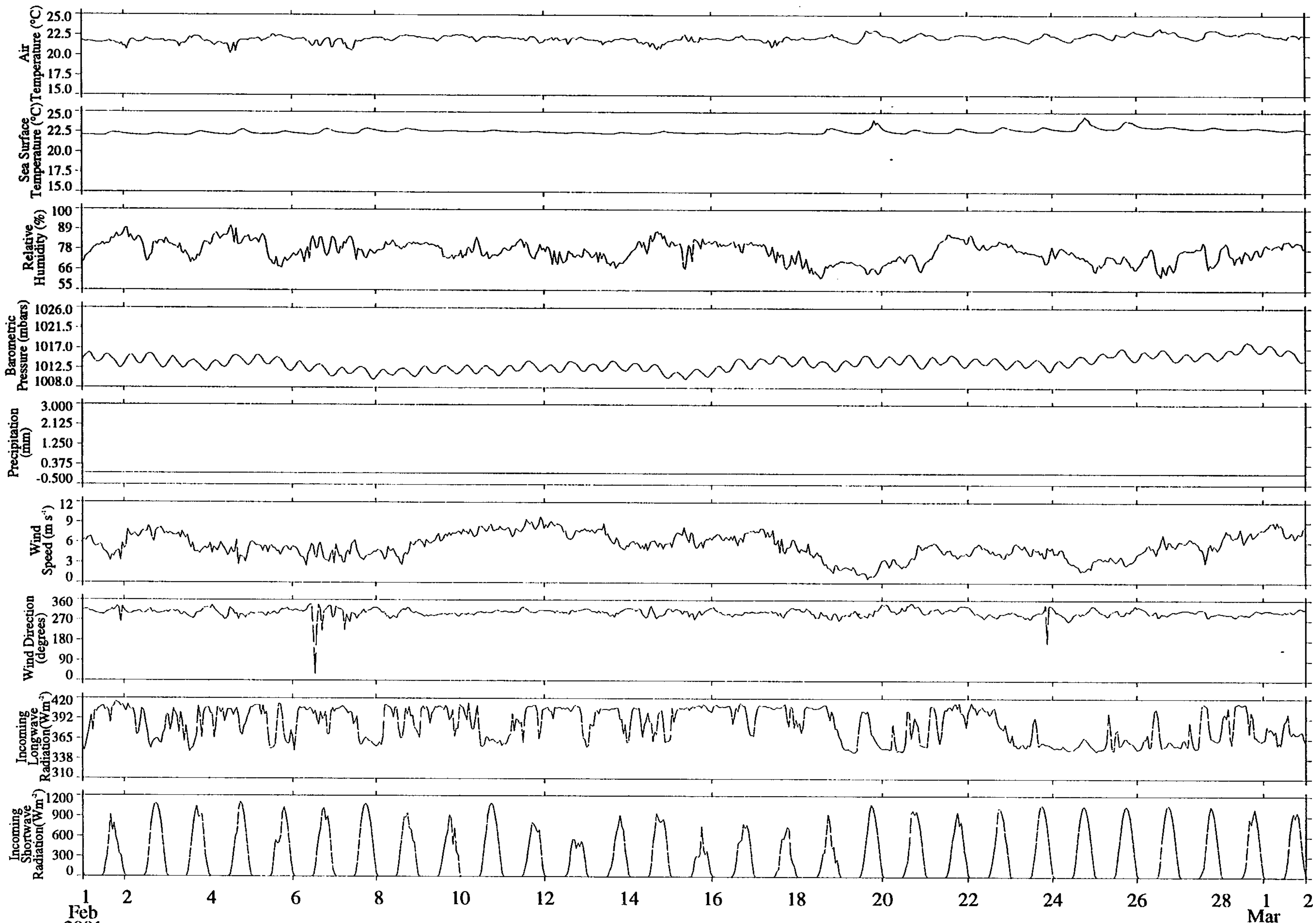


Figure 4-34. Hourly time series of meteorological observations for February 2001.
(IMET system 2)

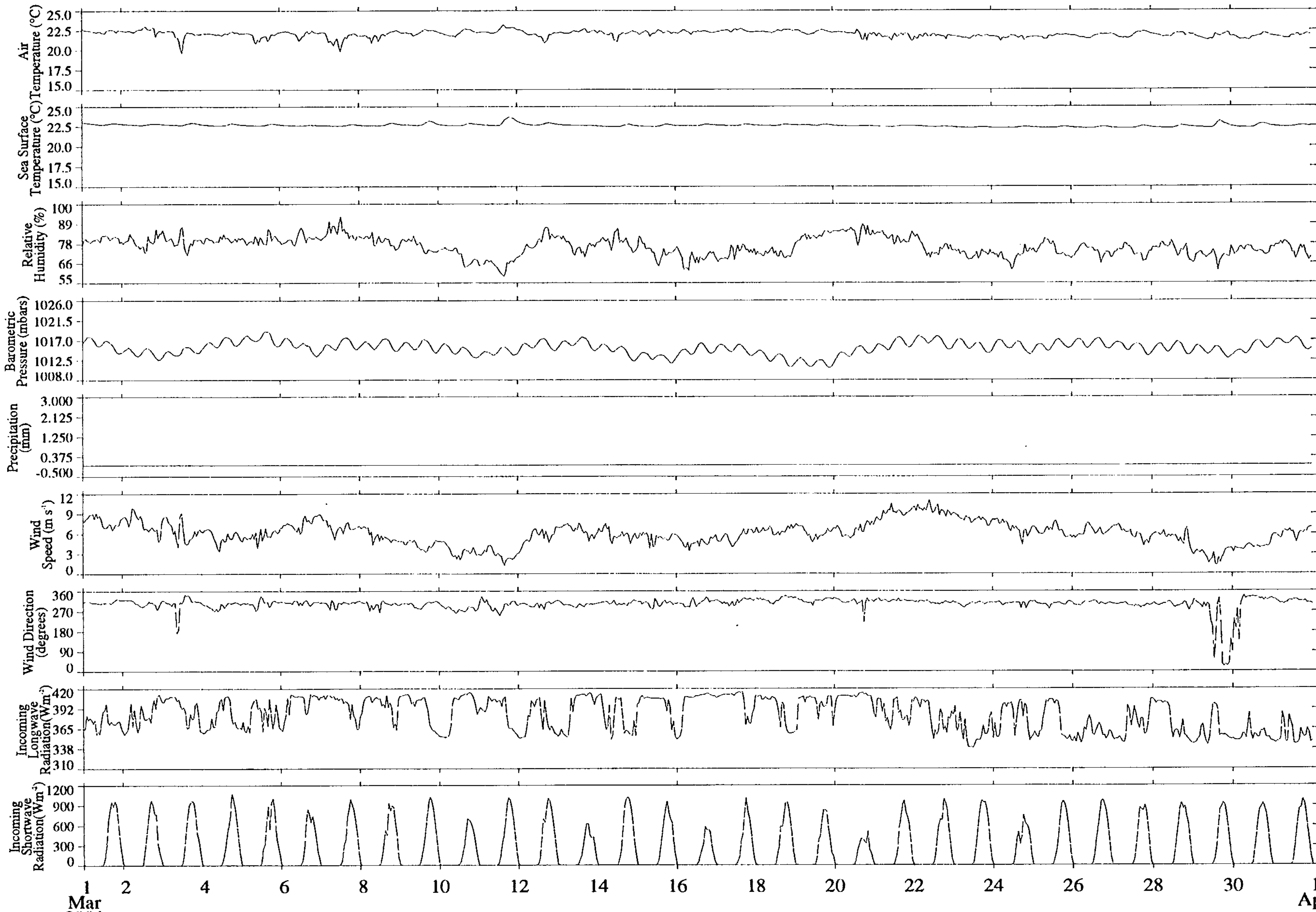


Figure 4-35. Hourly time series of meteorological observations for March 2001. (IMET system 2)

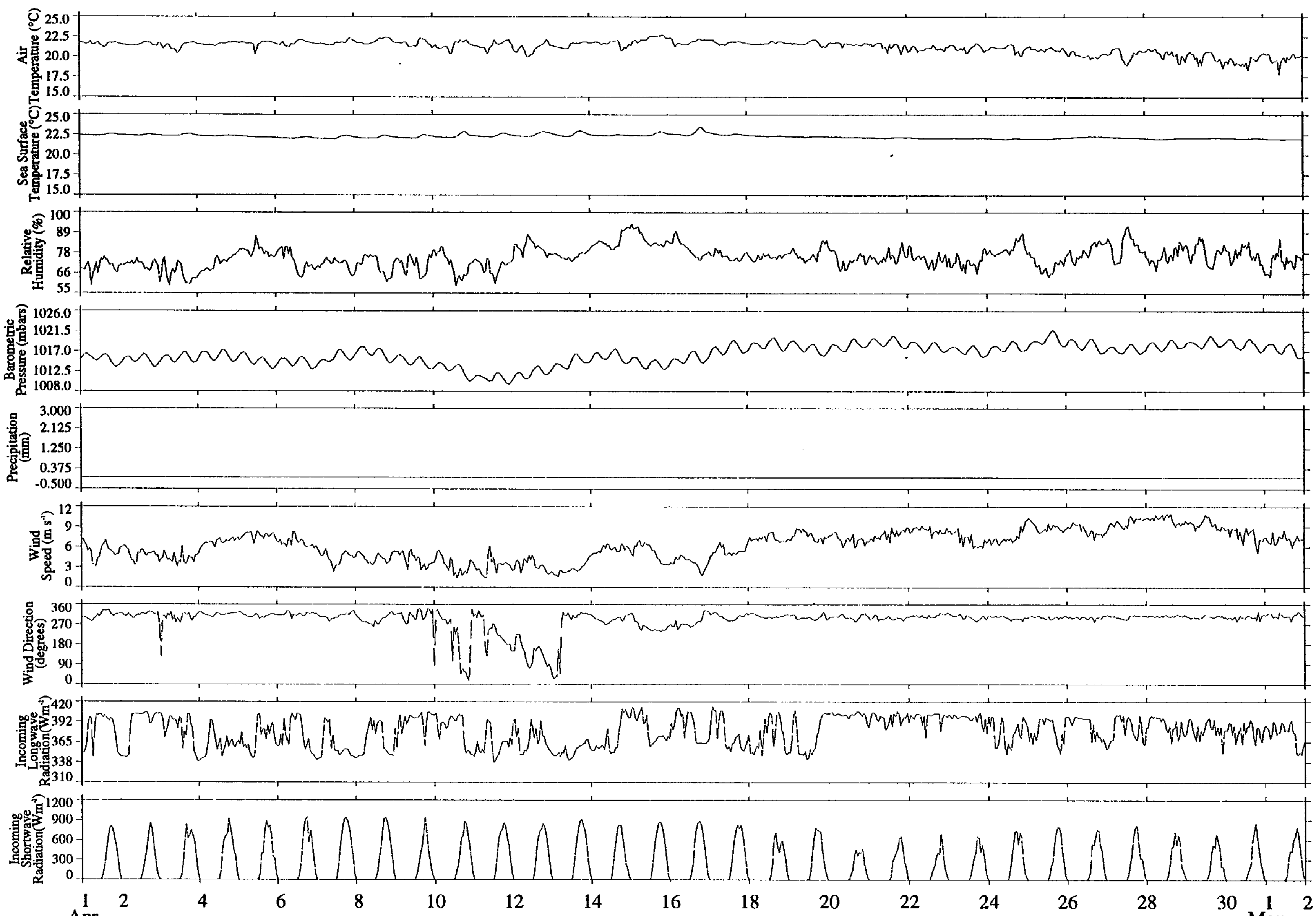


Figure 4-36. Hourly time series of meteorological observations for April 2001.
(IMET system 2)

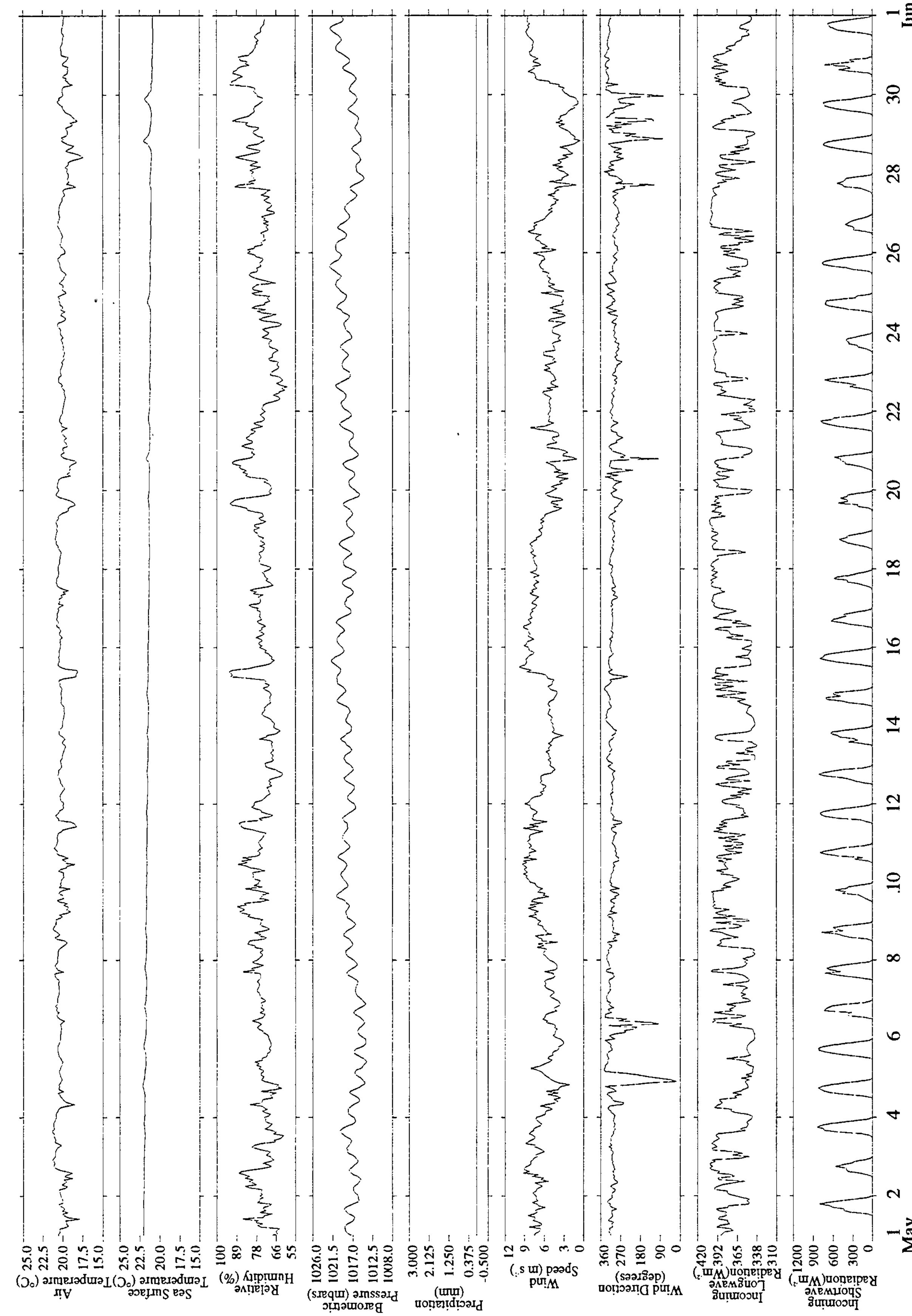


Figure 4-37. Hourly time series of meteorological observations for May 2001. (IMET system 2)

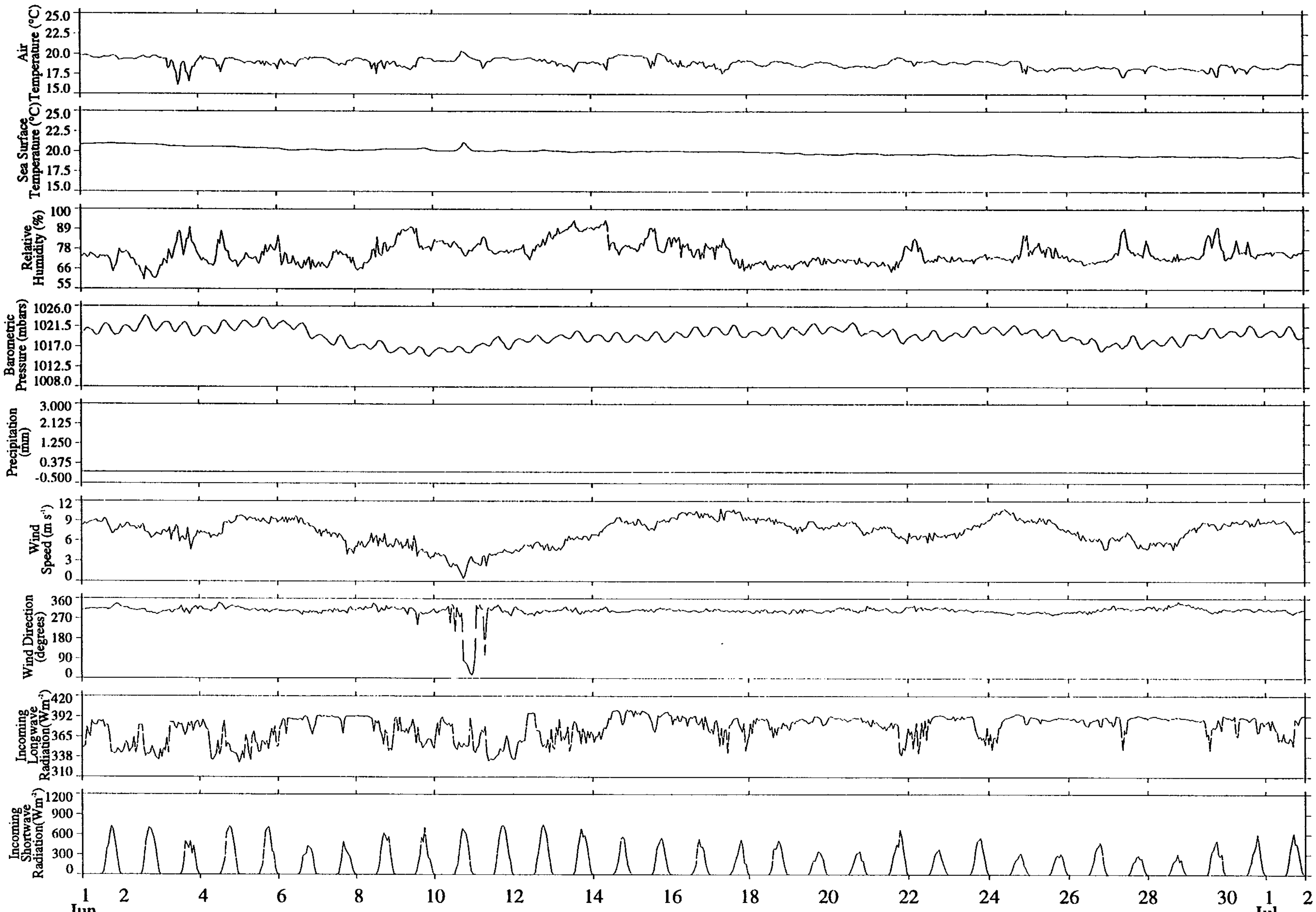


Figure 4-38. Hourly time series of meteorological observations for June 2001.
(IMET system 2)

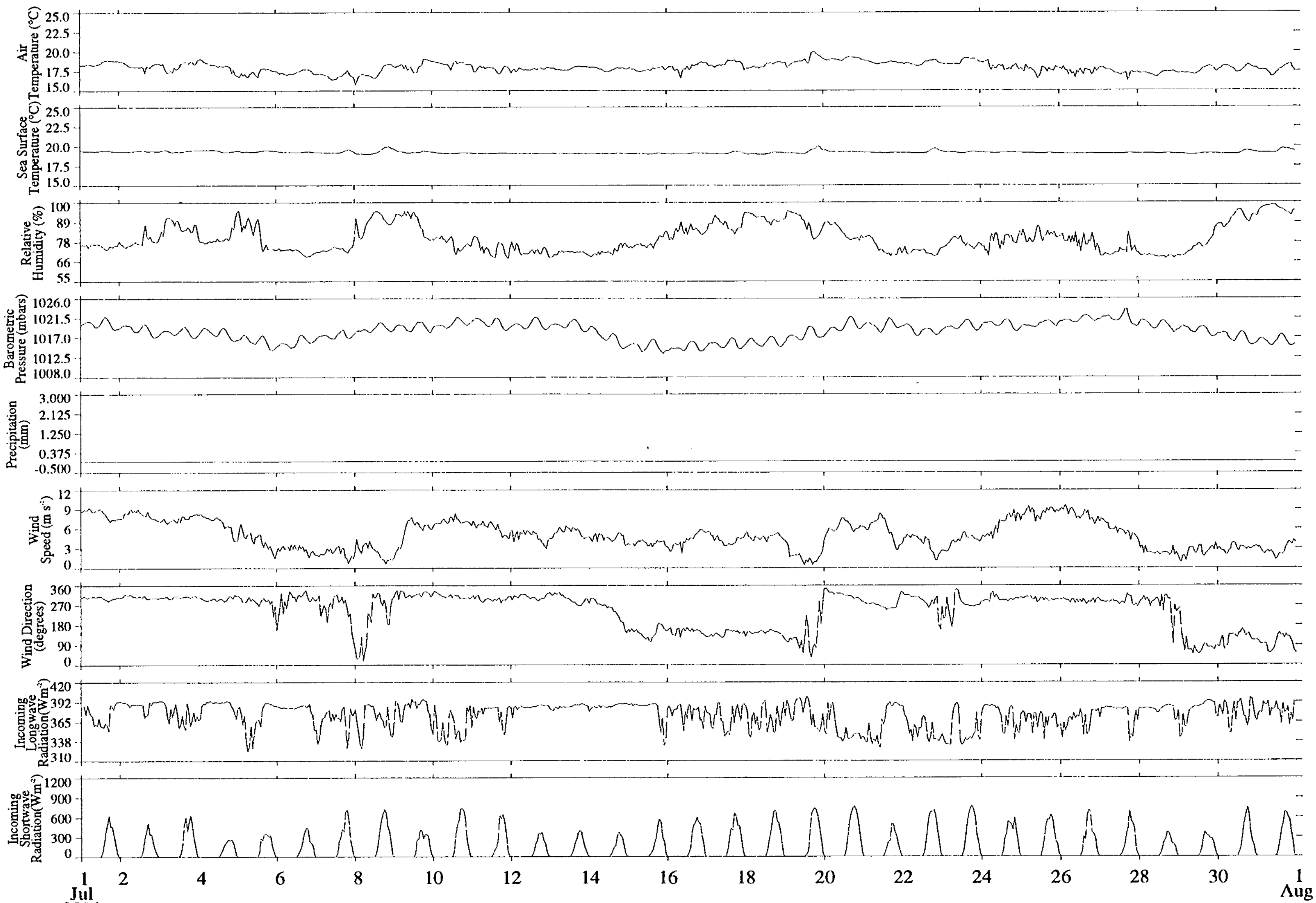


Figure 4-39. Hourly time series of meteorological observations for July 2001. (IMET system 2)

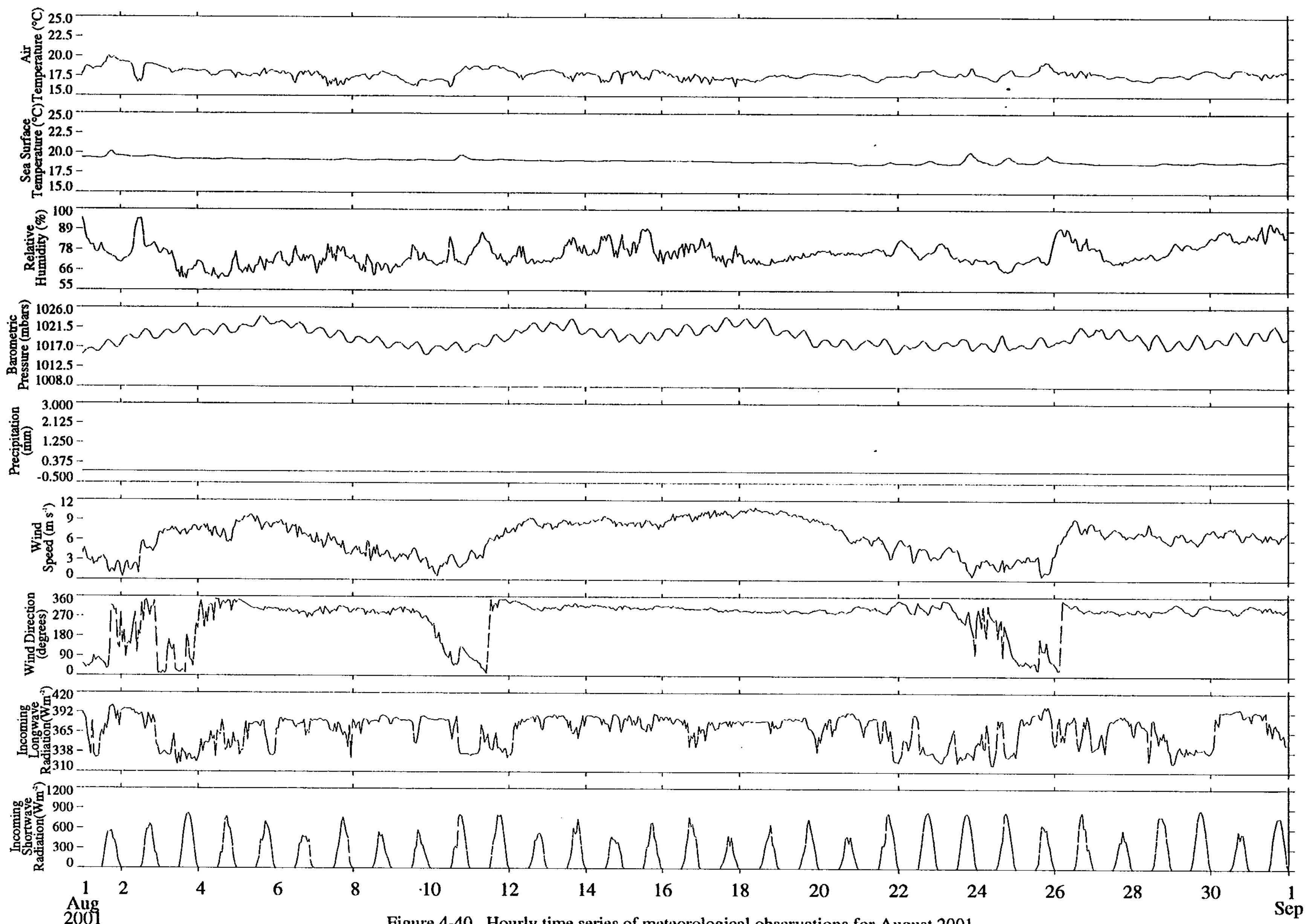


Figure 4-40. Hourly time series of meteorological observations for August 2001. (IMET system 2)

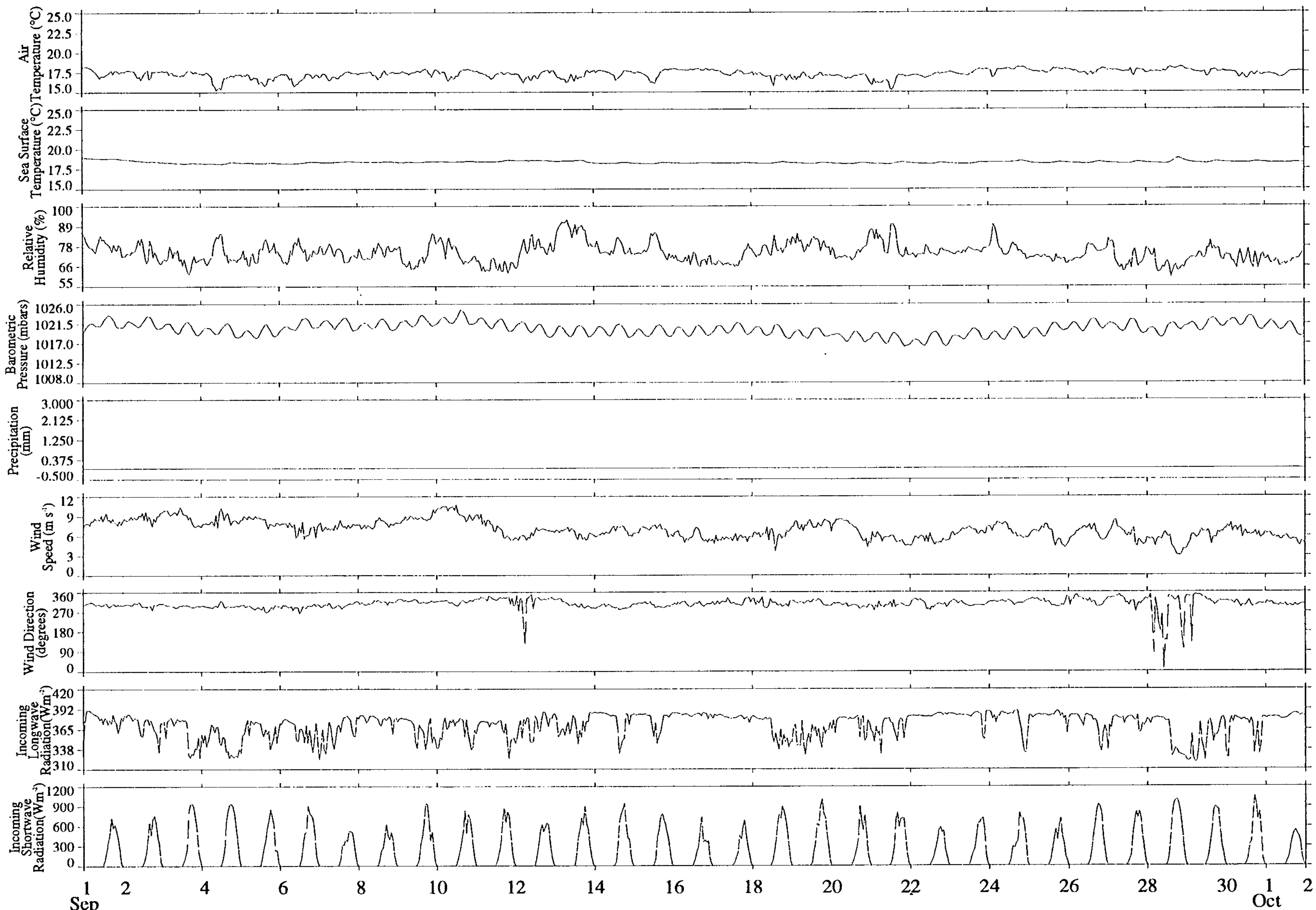


Figure 4-41. Hourly time series of meteorological observations for September 2001. (IMET system 2)

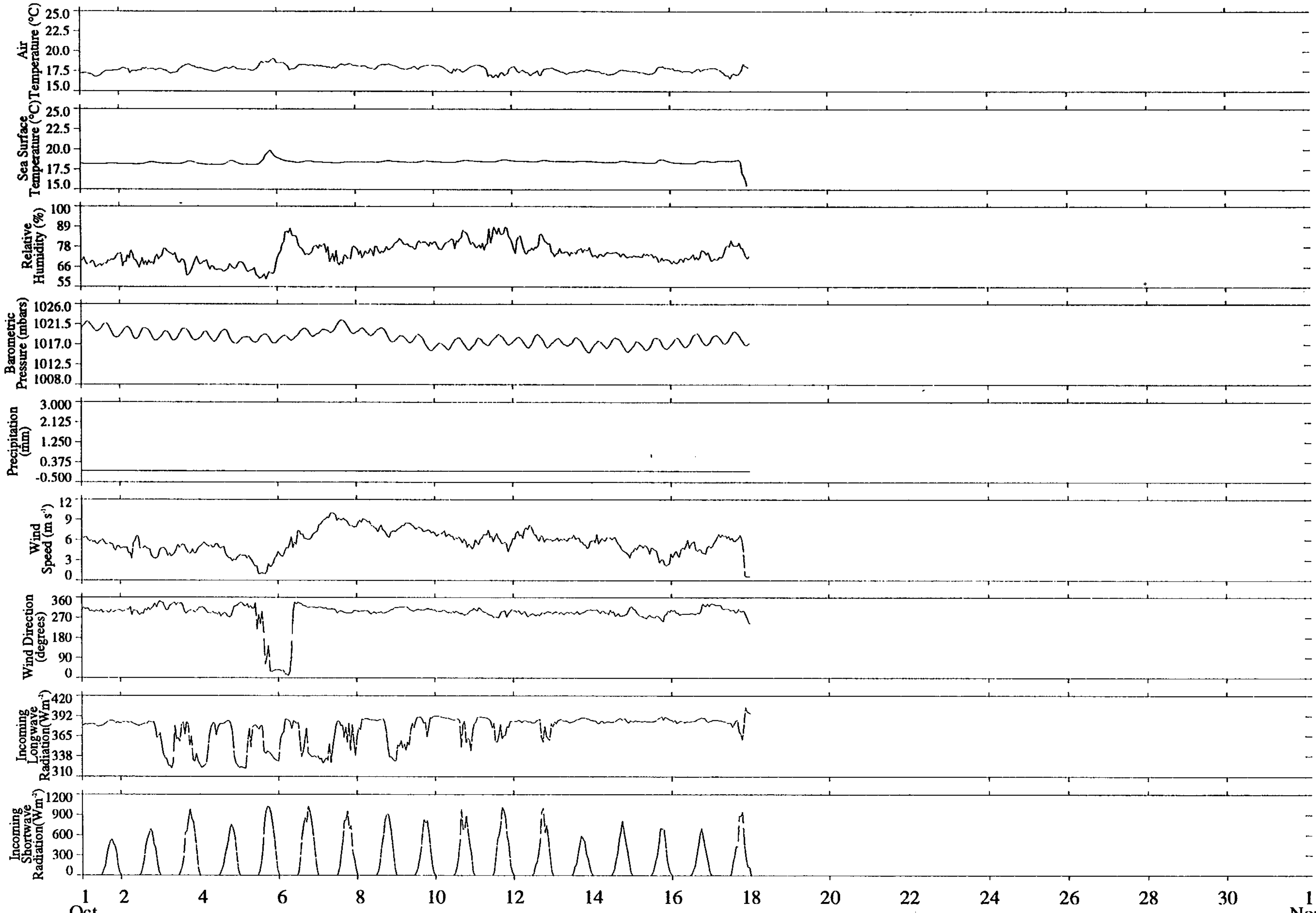


Figure 4-42. Hourly time series of meteorological observations for October 2001.
(IMET system 2)

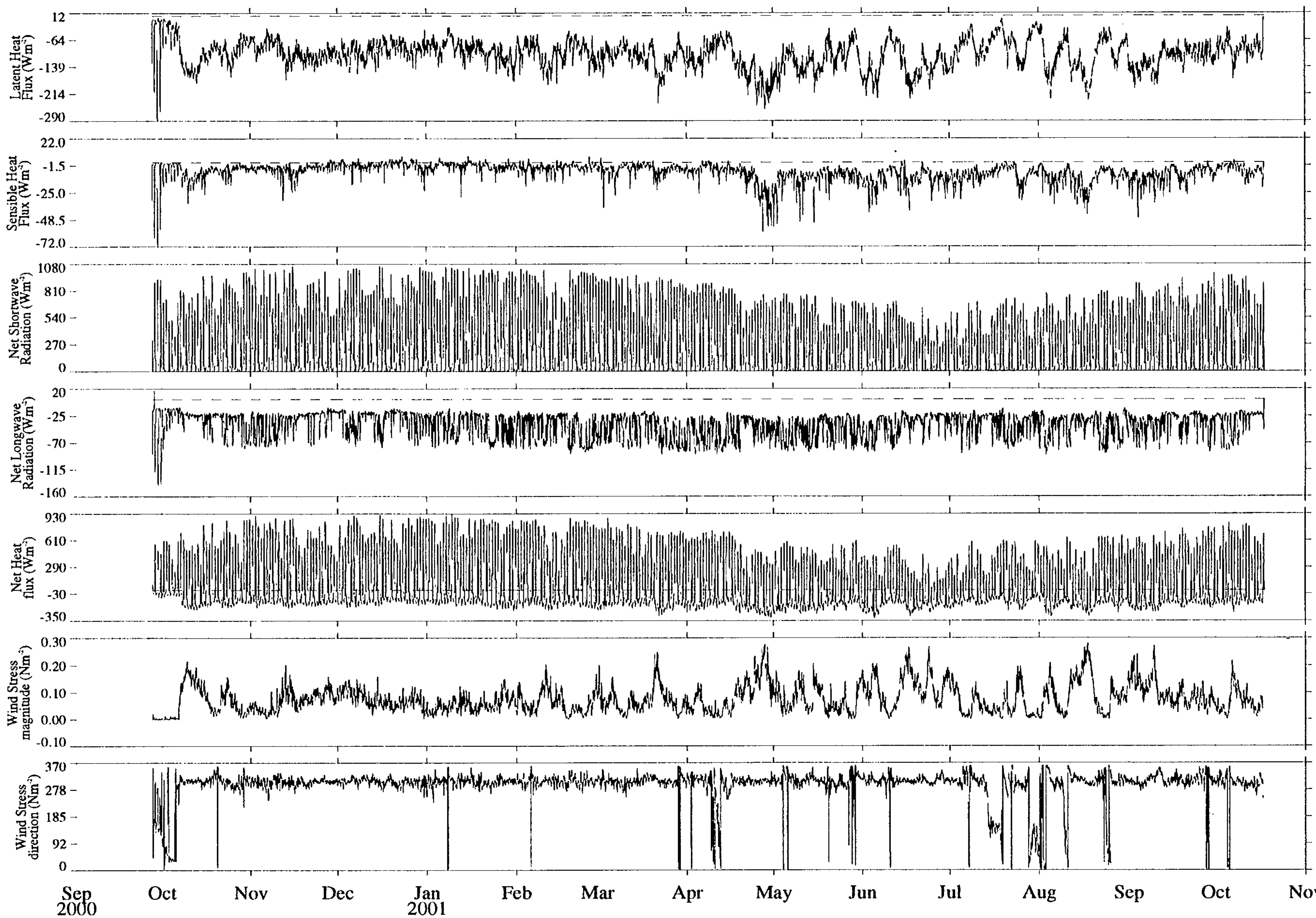


Figure 4-43. Hourly time series of estimated heat and momentum fluxes. (IMET system 2)

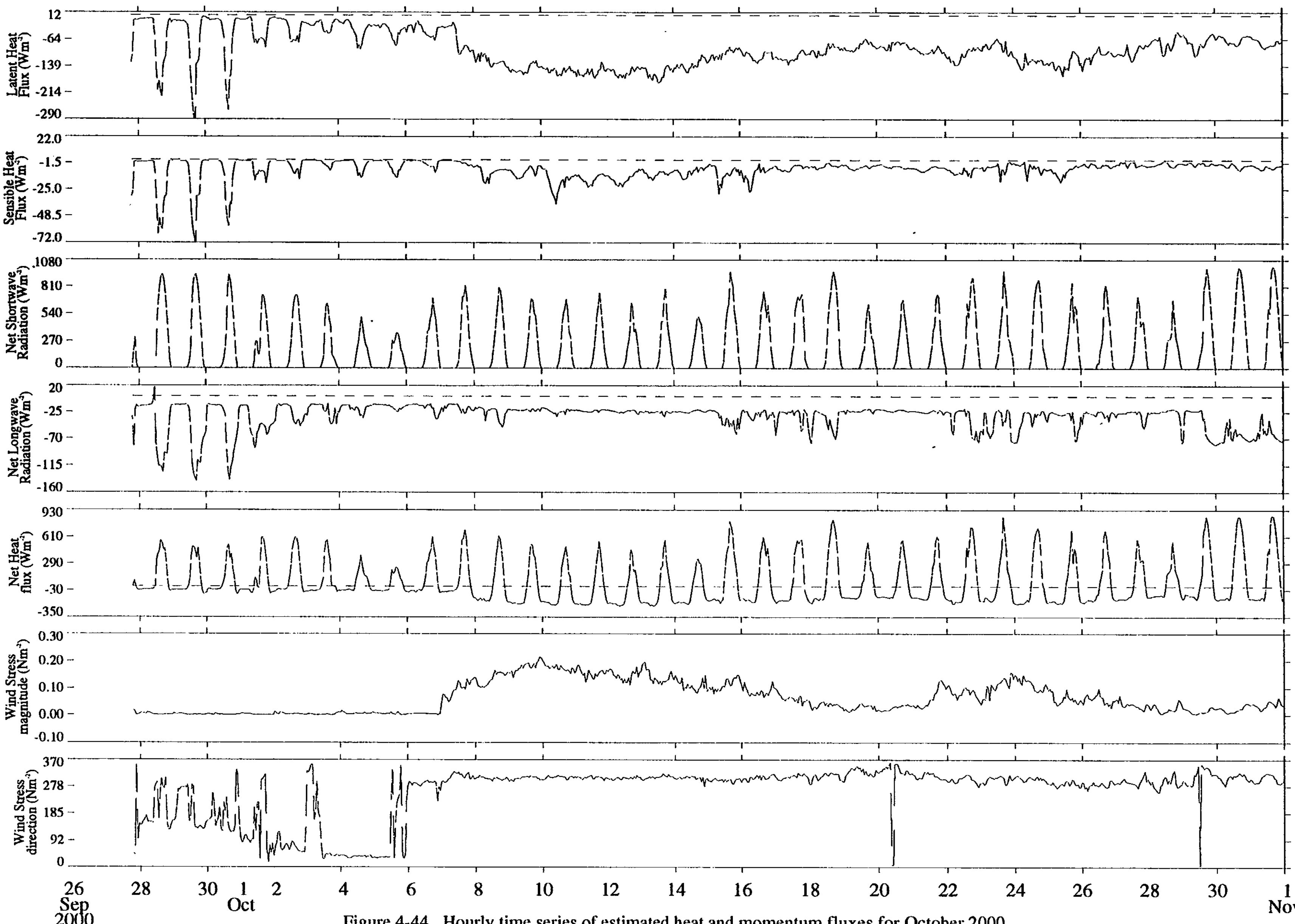


Figure 4-44. Hourly time series of estimated heat and momentum fluxes for October 2000.
(IMET system 2)

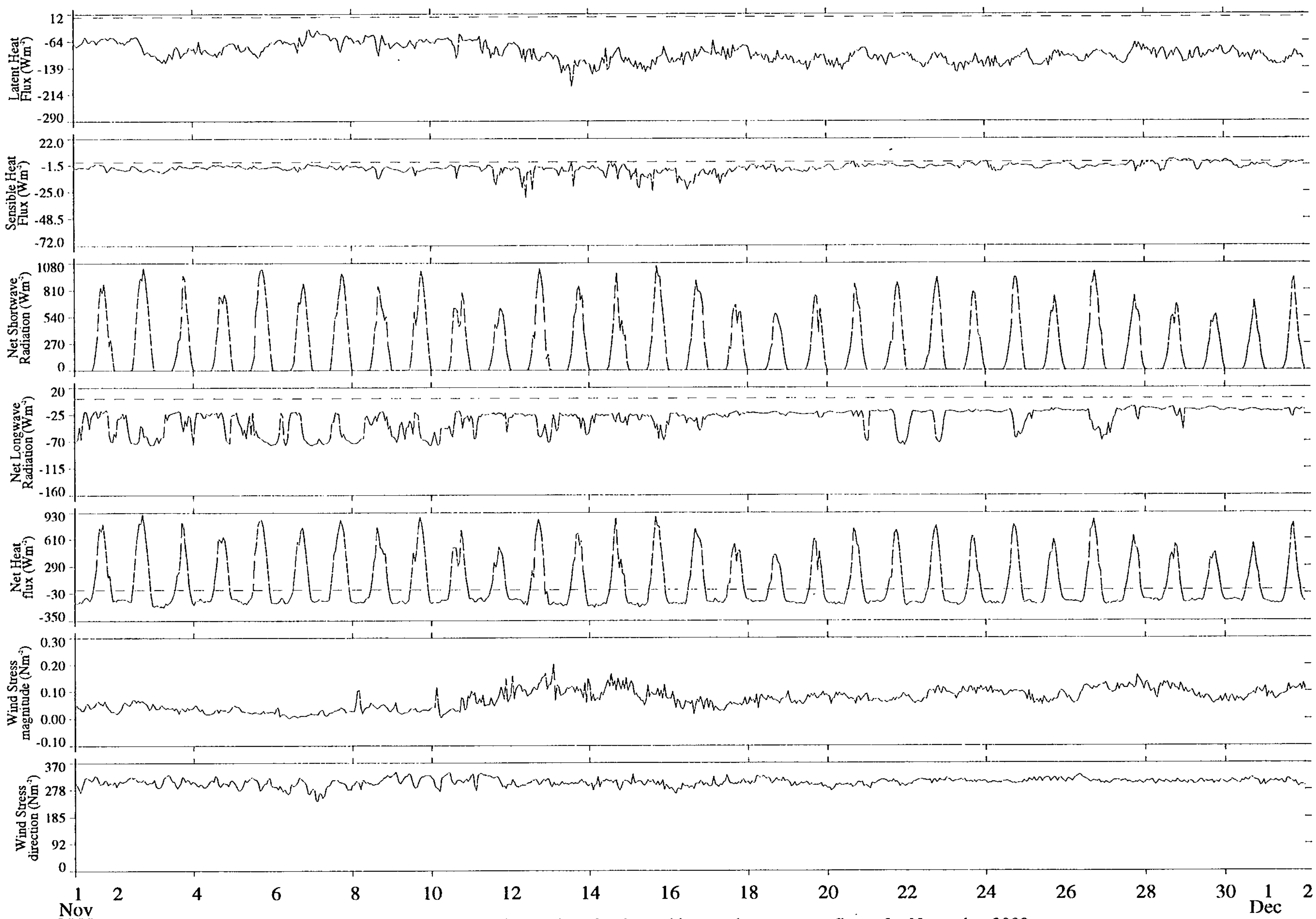


Figure 4-45. Hourly time series of estimated heat and momentum fluxes for November 2000.
(IMET system 2)

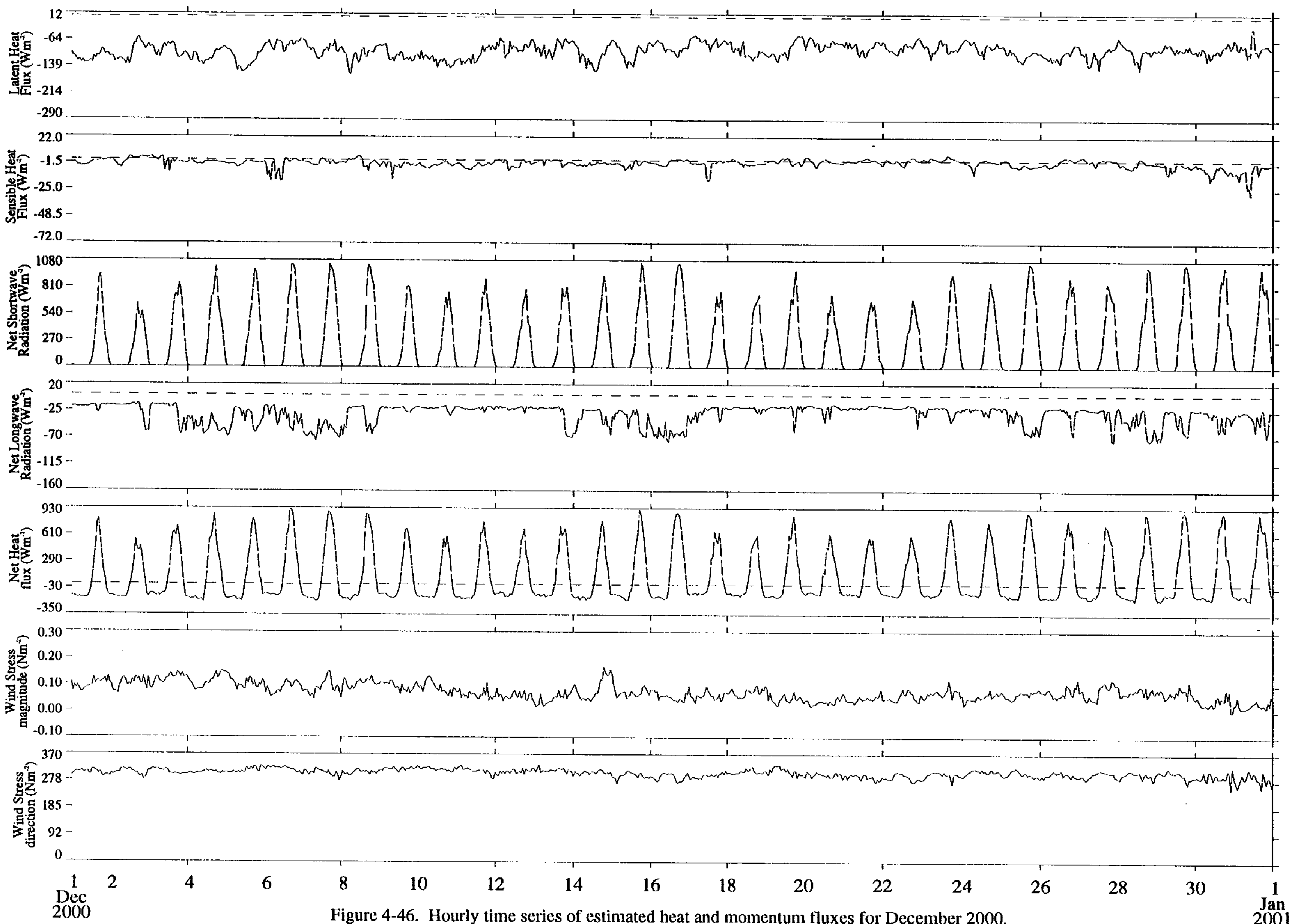


Figure 4-46. Hourly time series of estimated heat and momentum fluxes for December 2000.
(IMET system 2)

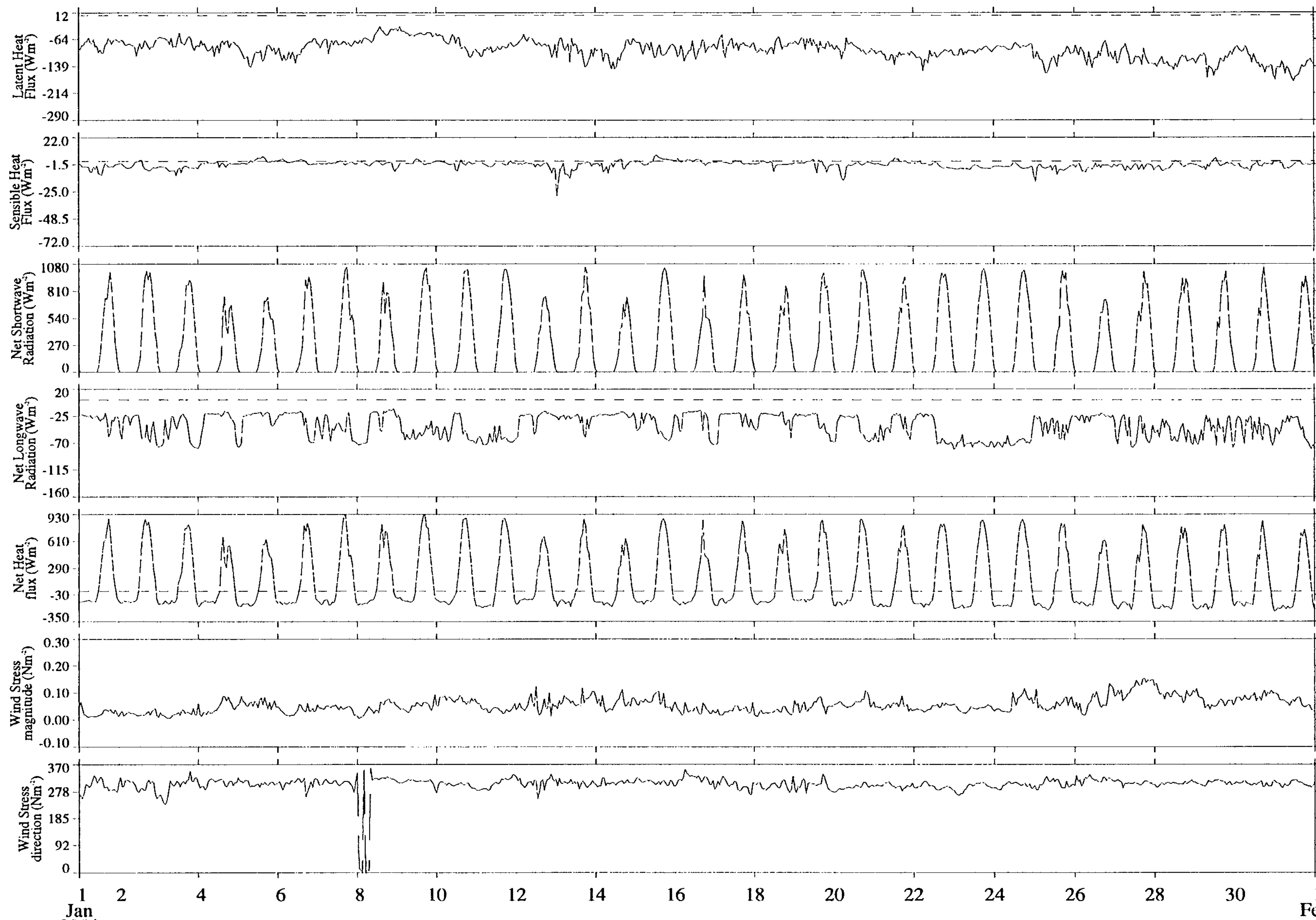


Figure 4-47. Hourly time series of estimated heat and momentum fluxes for January 2001.
(IMET system 2)

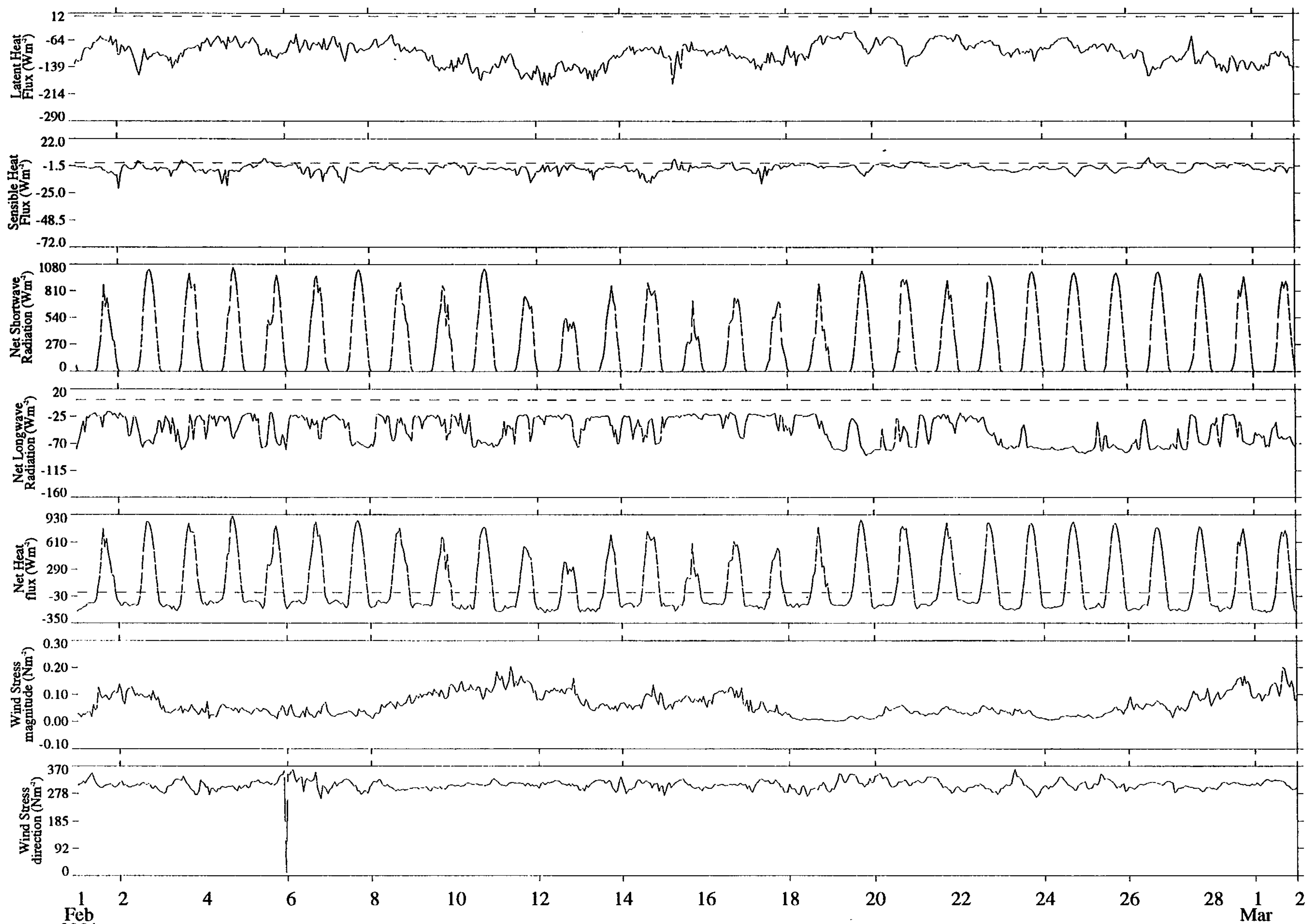


Figure 4-48. Hourly time series of estimated heat and momentum fluxes for February 2001. (IMET system 2)

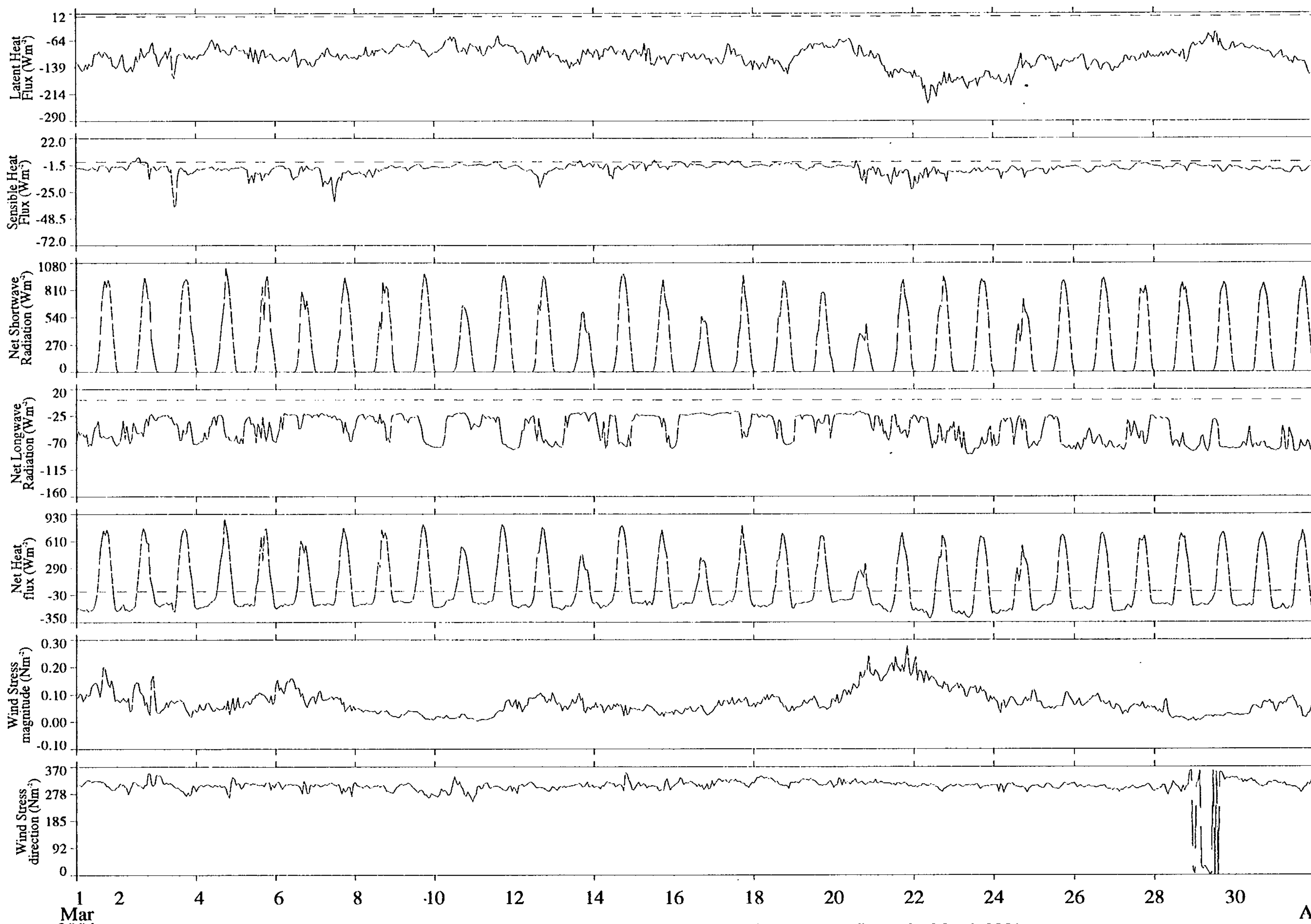


Figure 4-49. Hourly time series of estimated heat and momentum fluxes for March 2001. (IMET system 2)

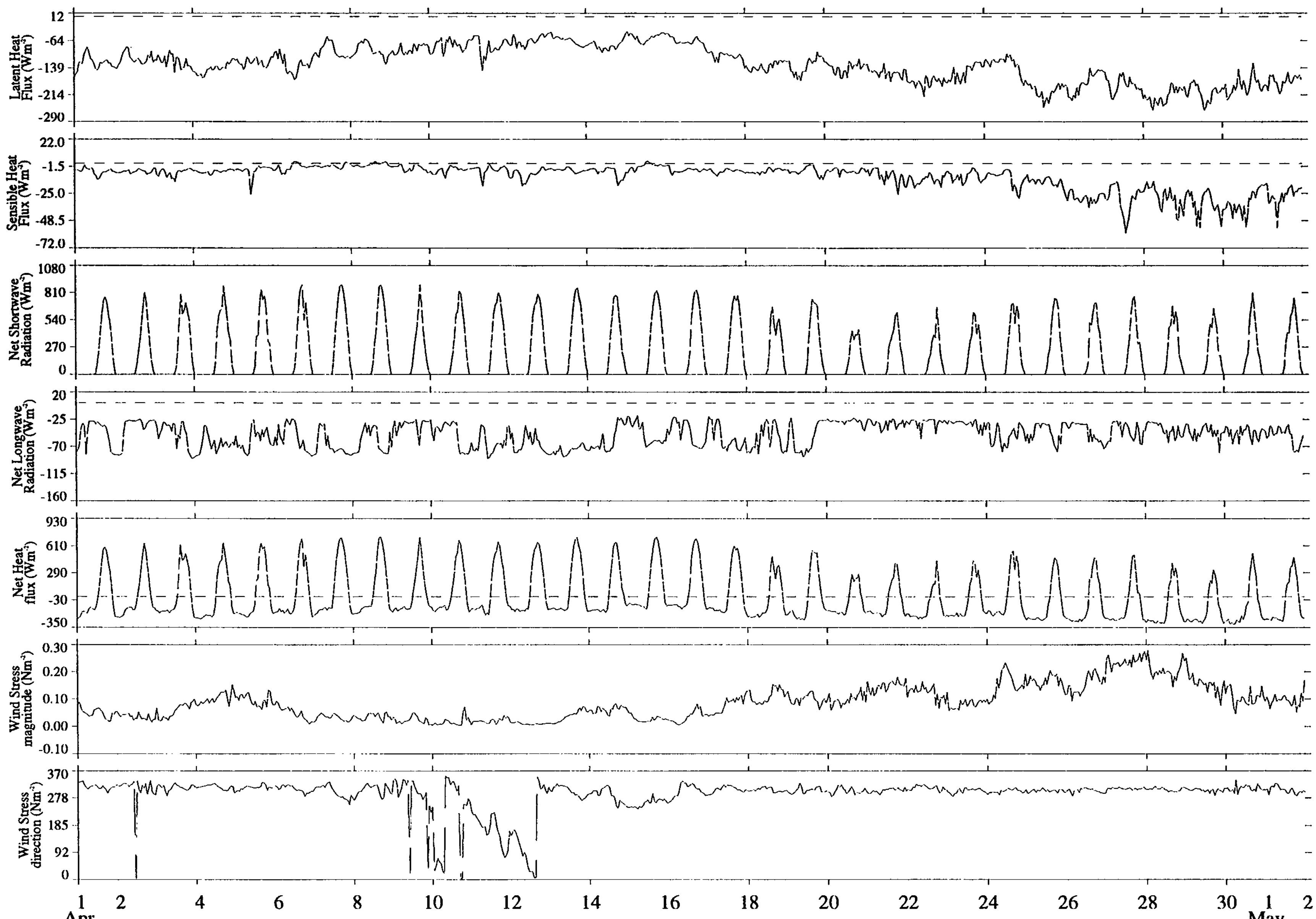


Figure 4-50. Hourly time series of estimated heat and momentum fluxes for April 2001.
(IMET system 2)

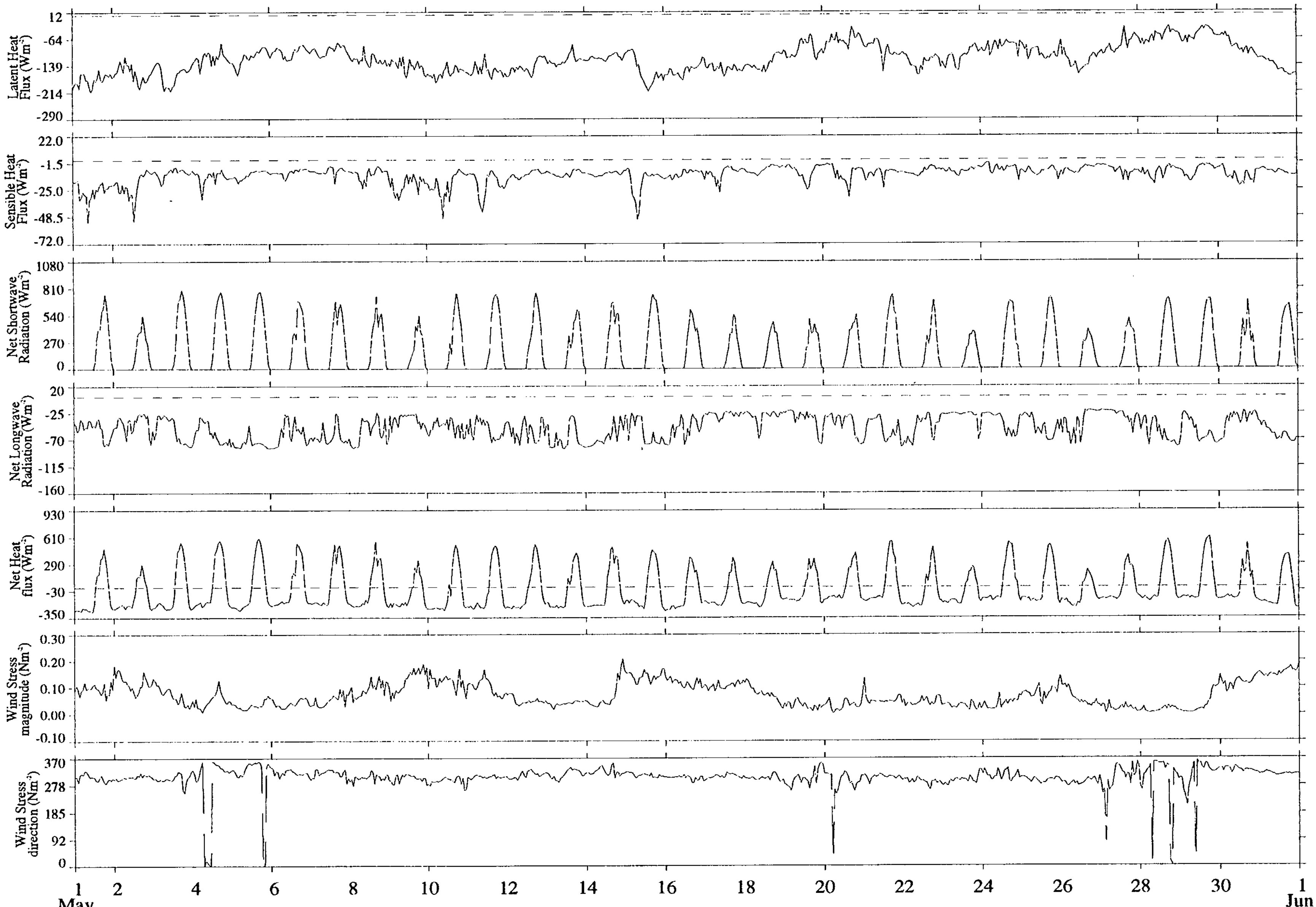


Figure 4-51. Hourly time series of estimated heat and momentum fluxes for May 2001.
(IMET system 2)

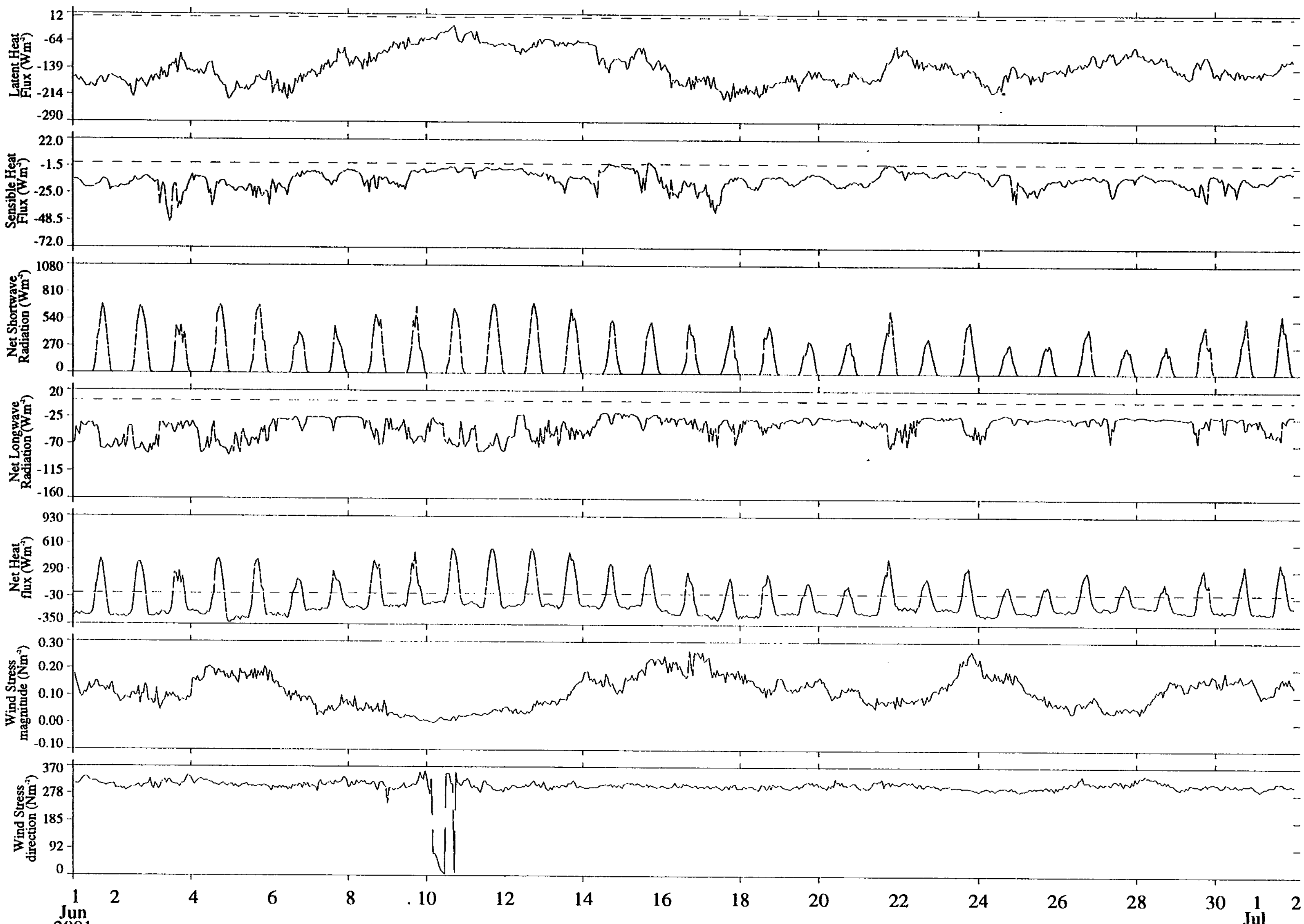


Figure 4-52. Hourly time series of estimated heat and momentum fluxes for June 2001.
(IMET system 2)

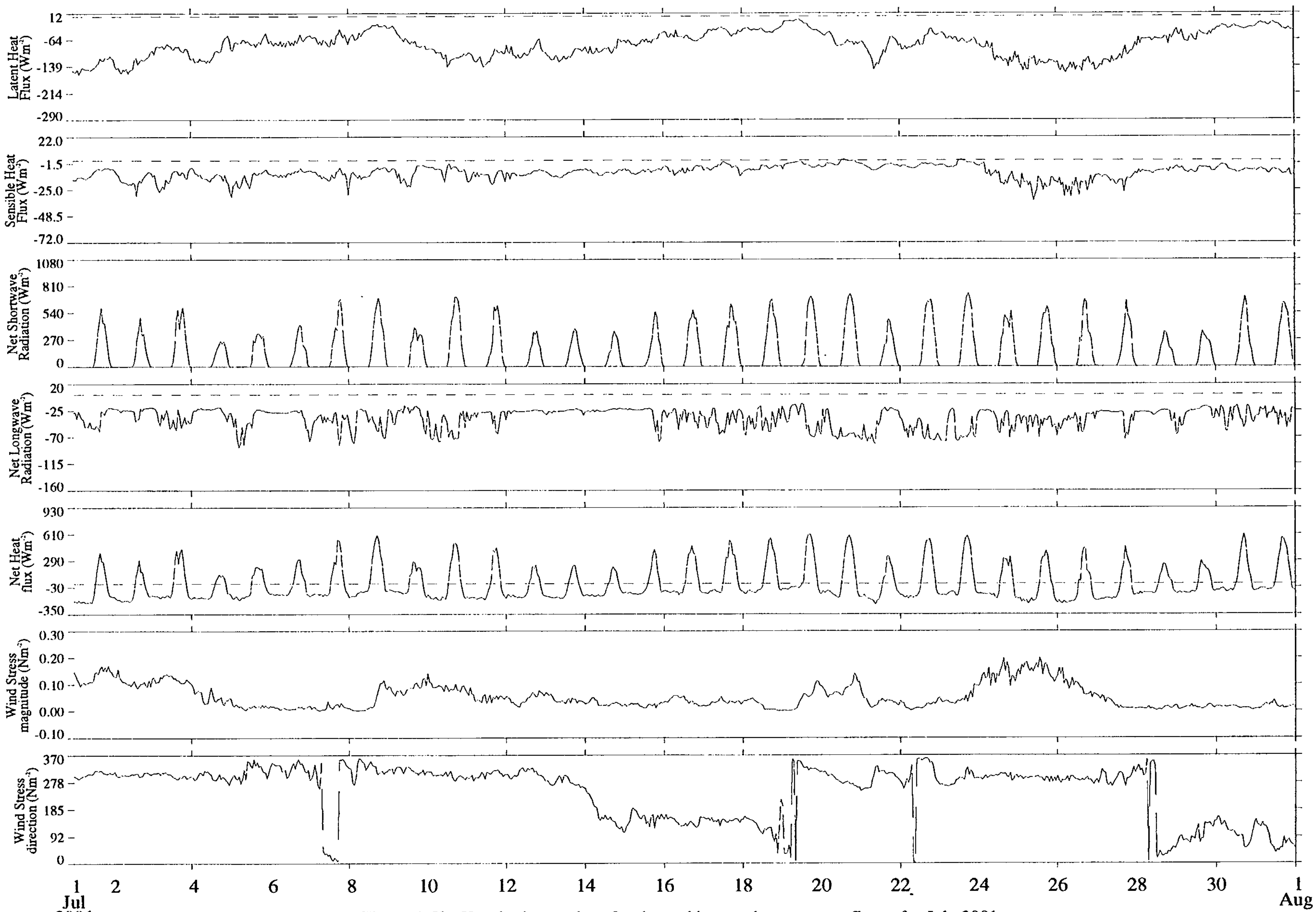


Figure 4-53. Hourly time series of estimated heat and momentum fluxes for July 2001.
(IMET system 2)

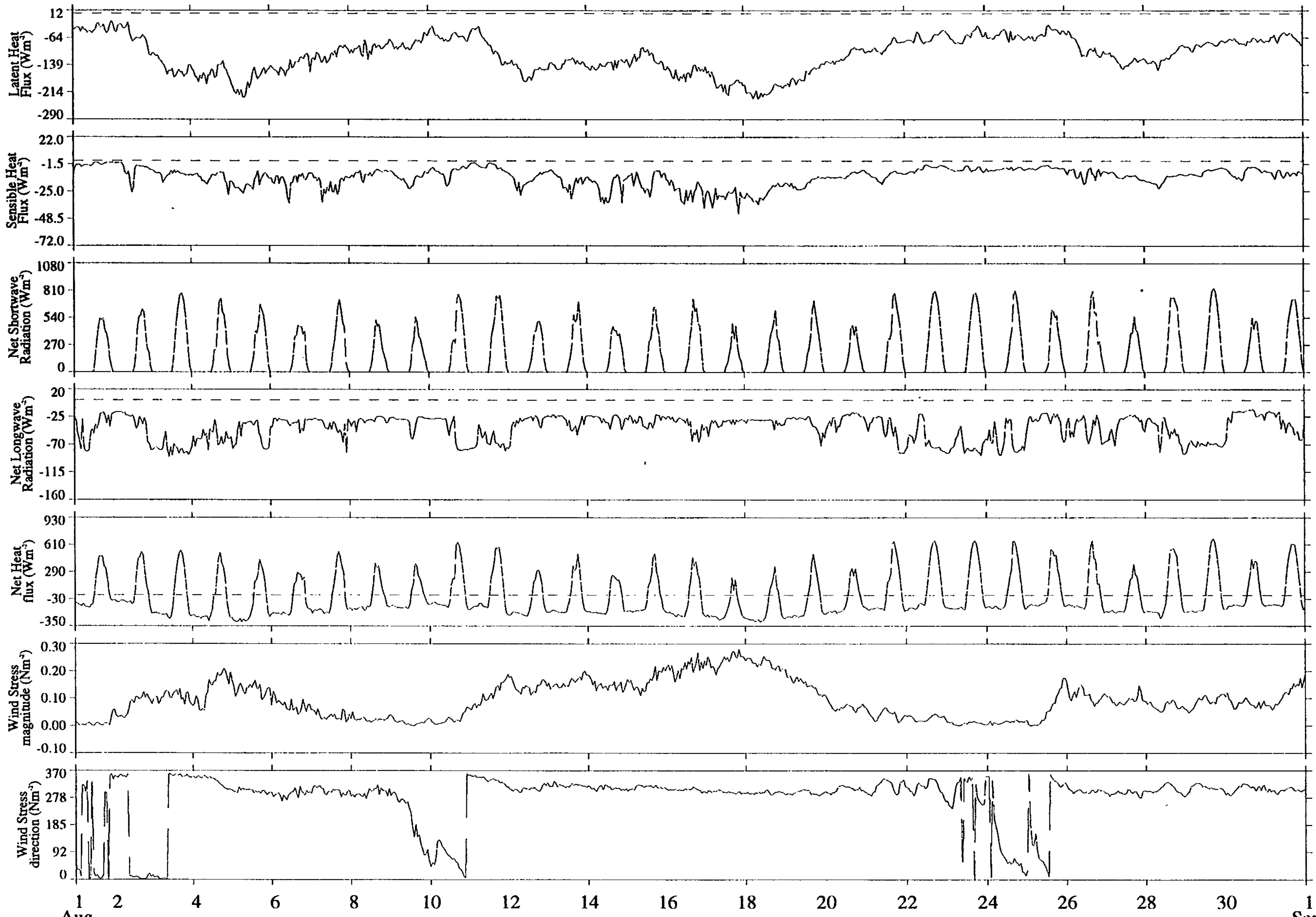


Figure 4-54. Hourly time series of estimated heat and momentum fluxes for August 2001.
(IMET system 2)

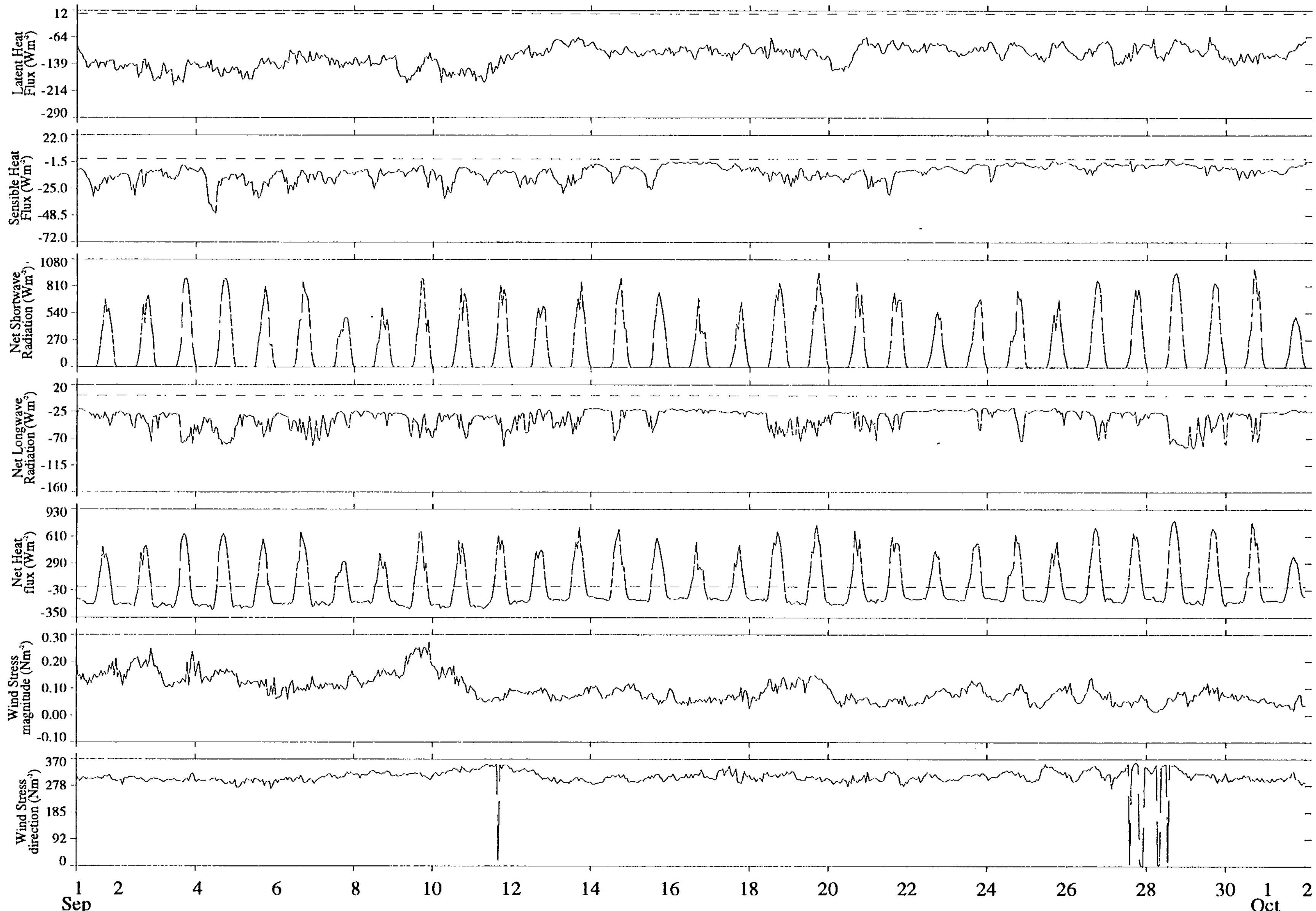


Figure 4-55. Hourly time series of estimated heat and momentum fluxes for September 2001.
(IMET system 2)

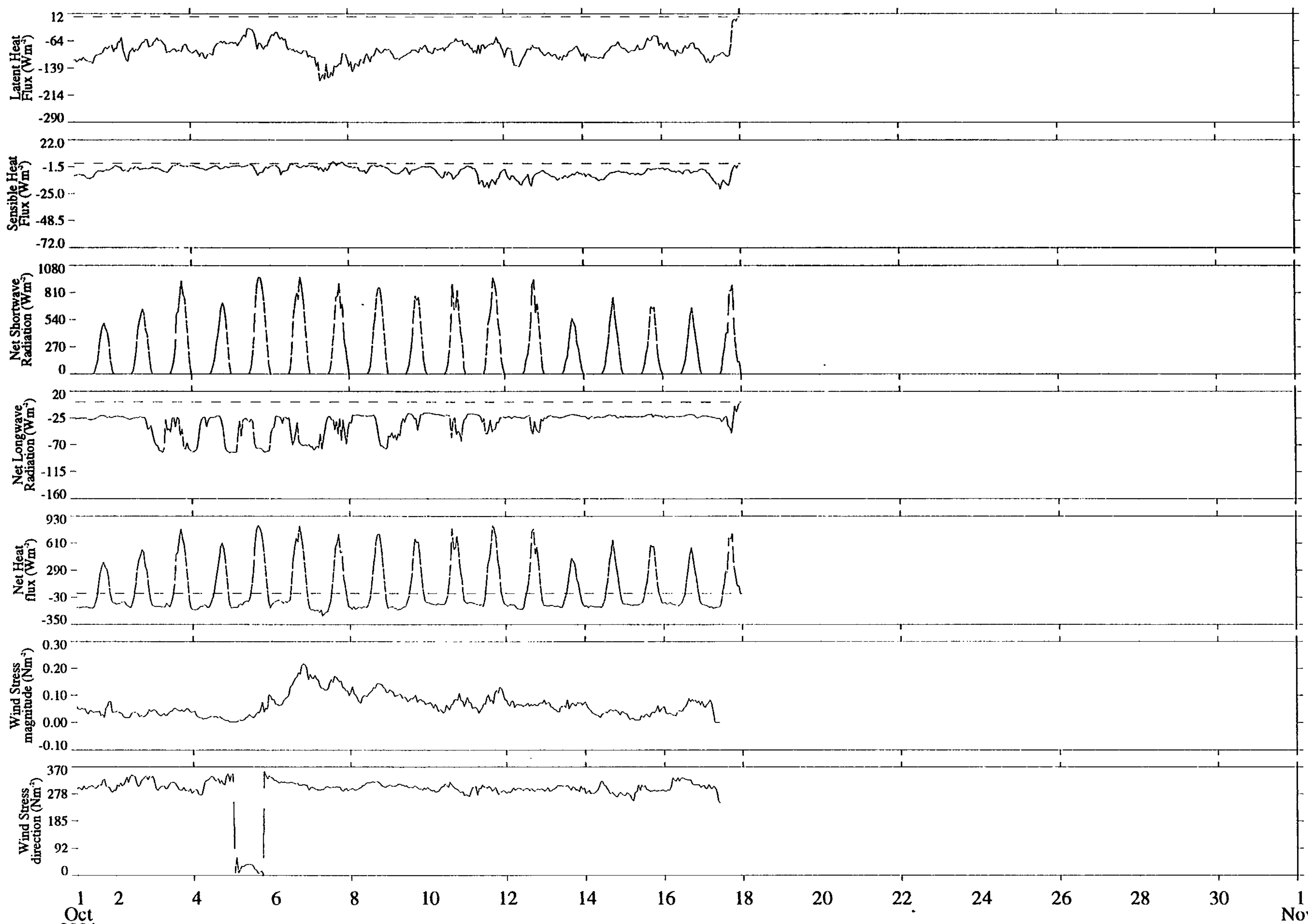


Figure 4-56. Hourly time series of estimated heat and momentum fluxes for October 2001. (IMET system 2)

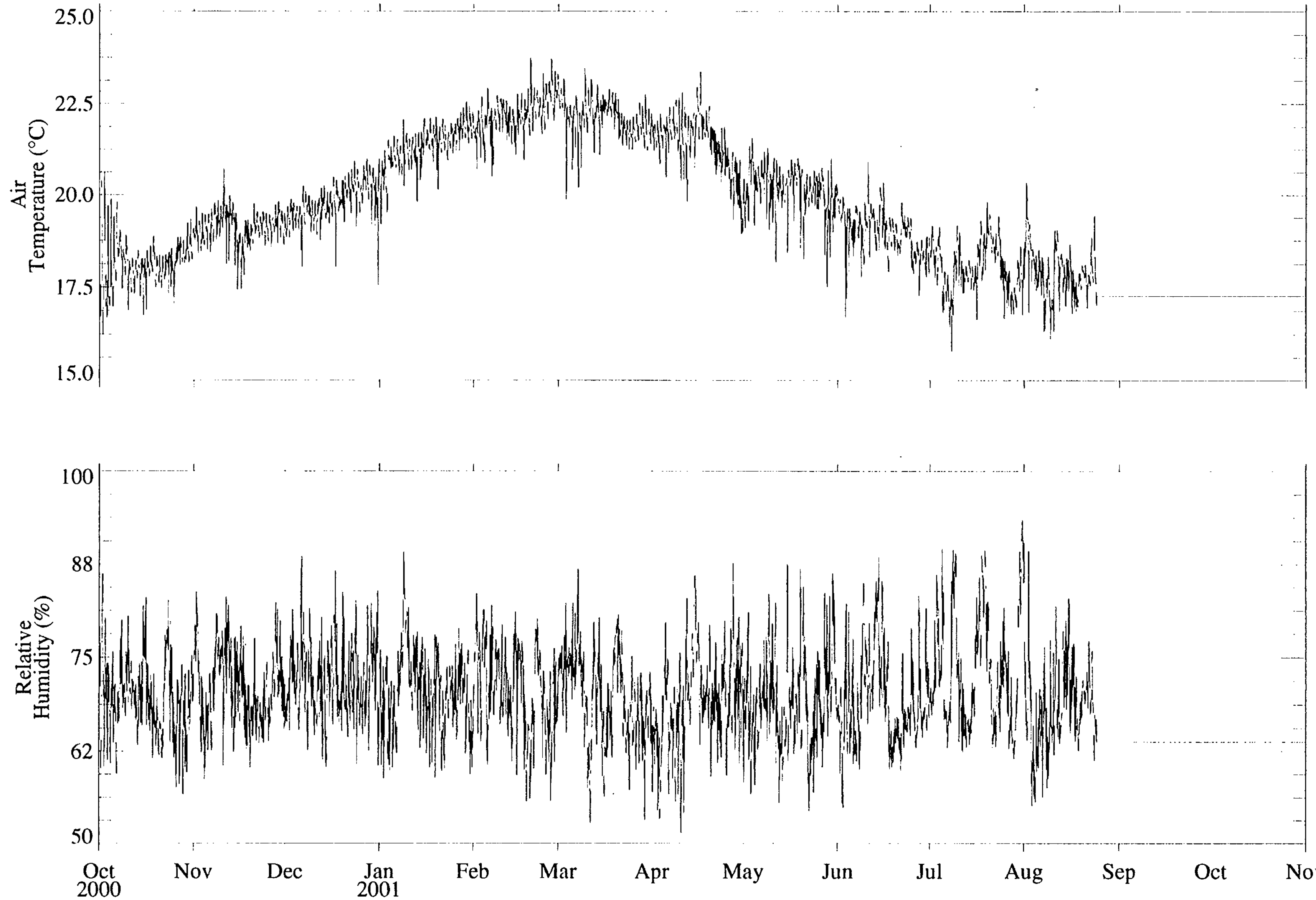


Figure 4-57. Hourly time series of ASIMET observations.

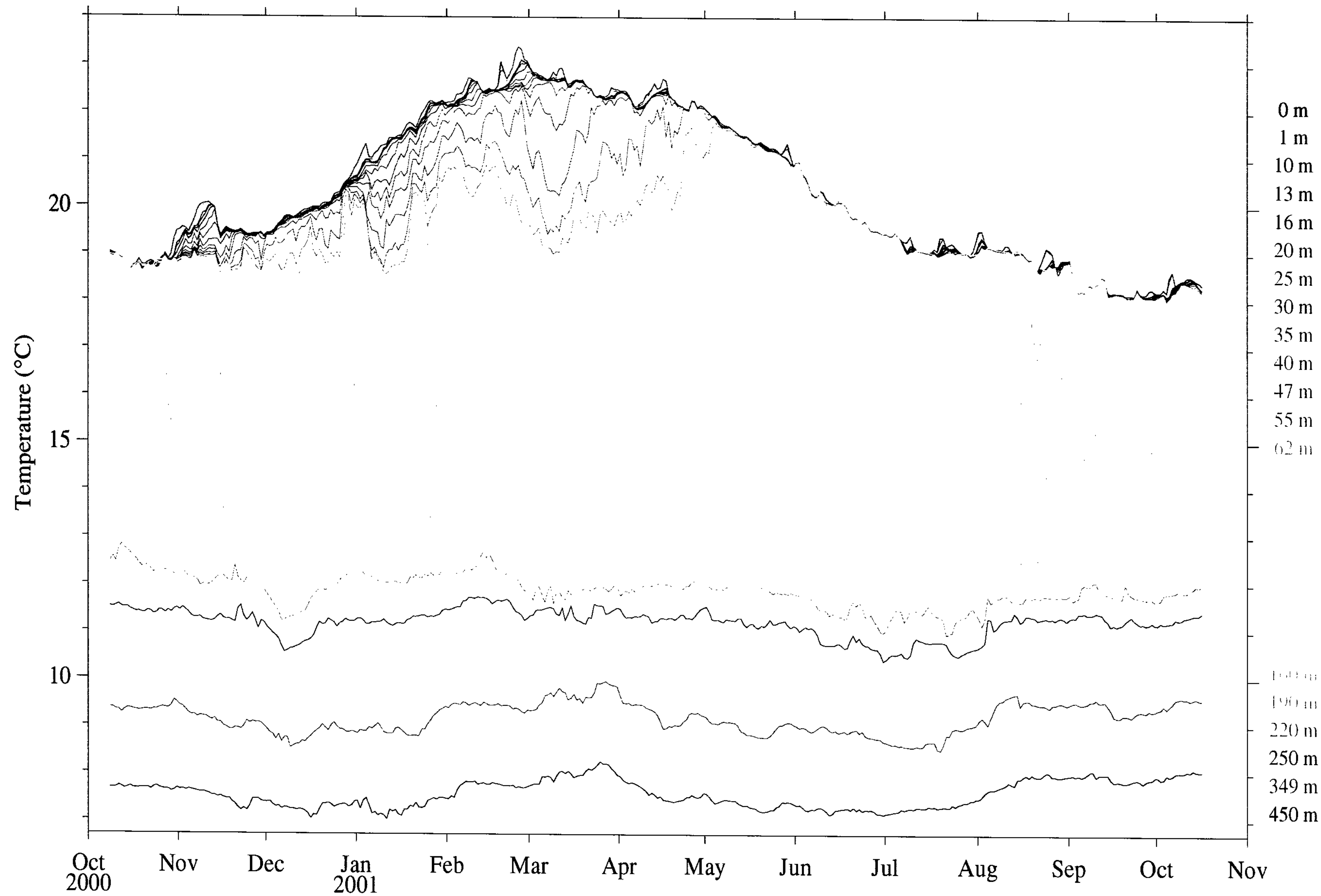


Figure 4-58. Daily averaged temperature .

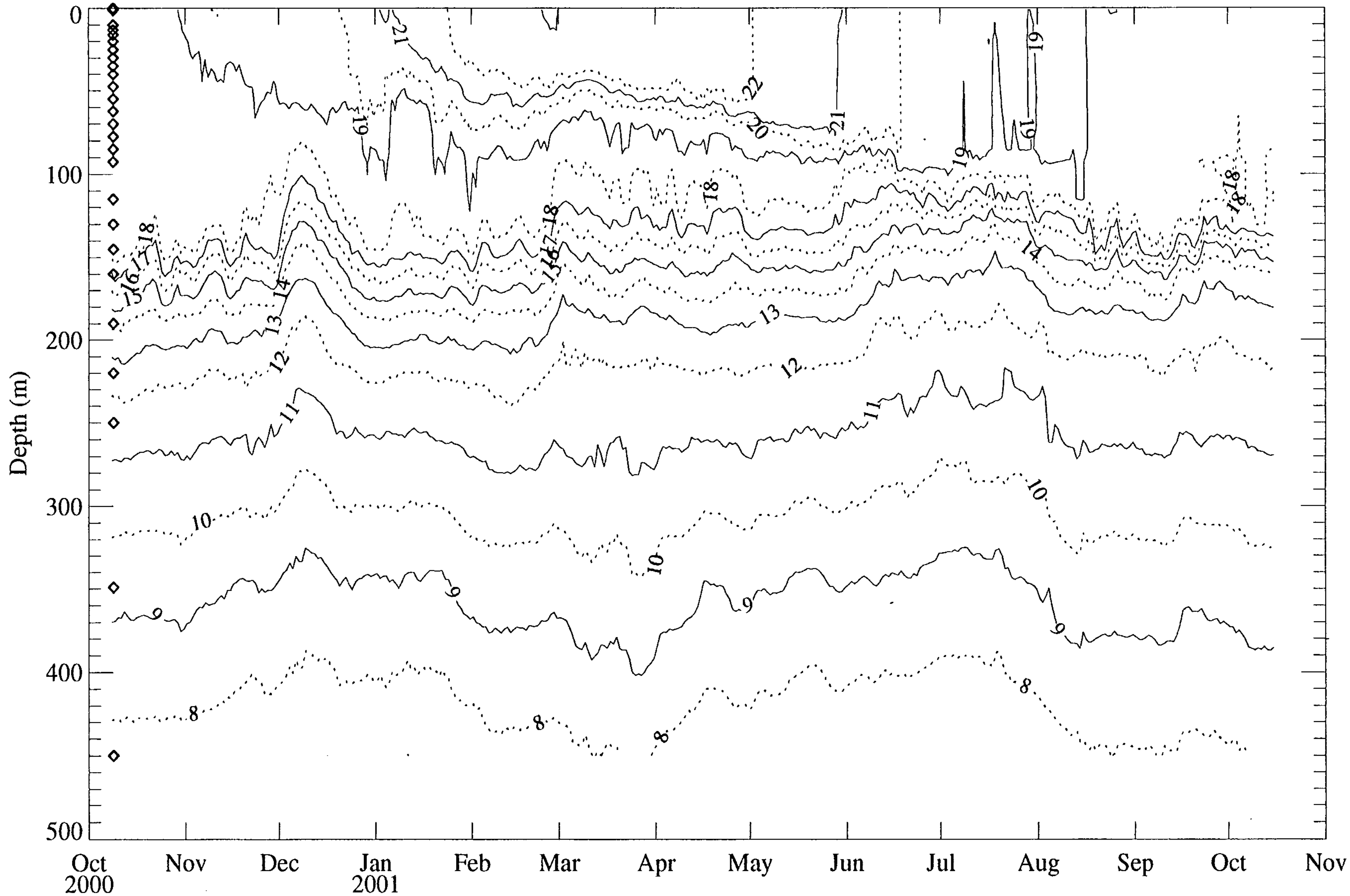


Figure 4-59. Contour plot of 24 hour averaged temperature. Diamonds indicate measurement depths. Isotherms are in units of °C.

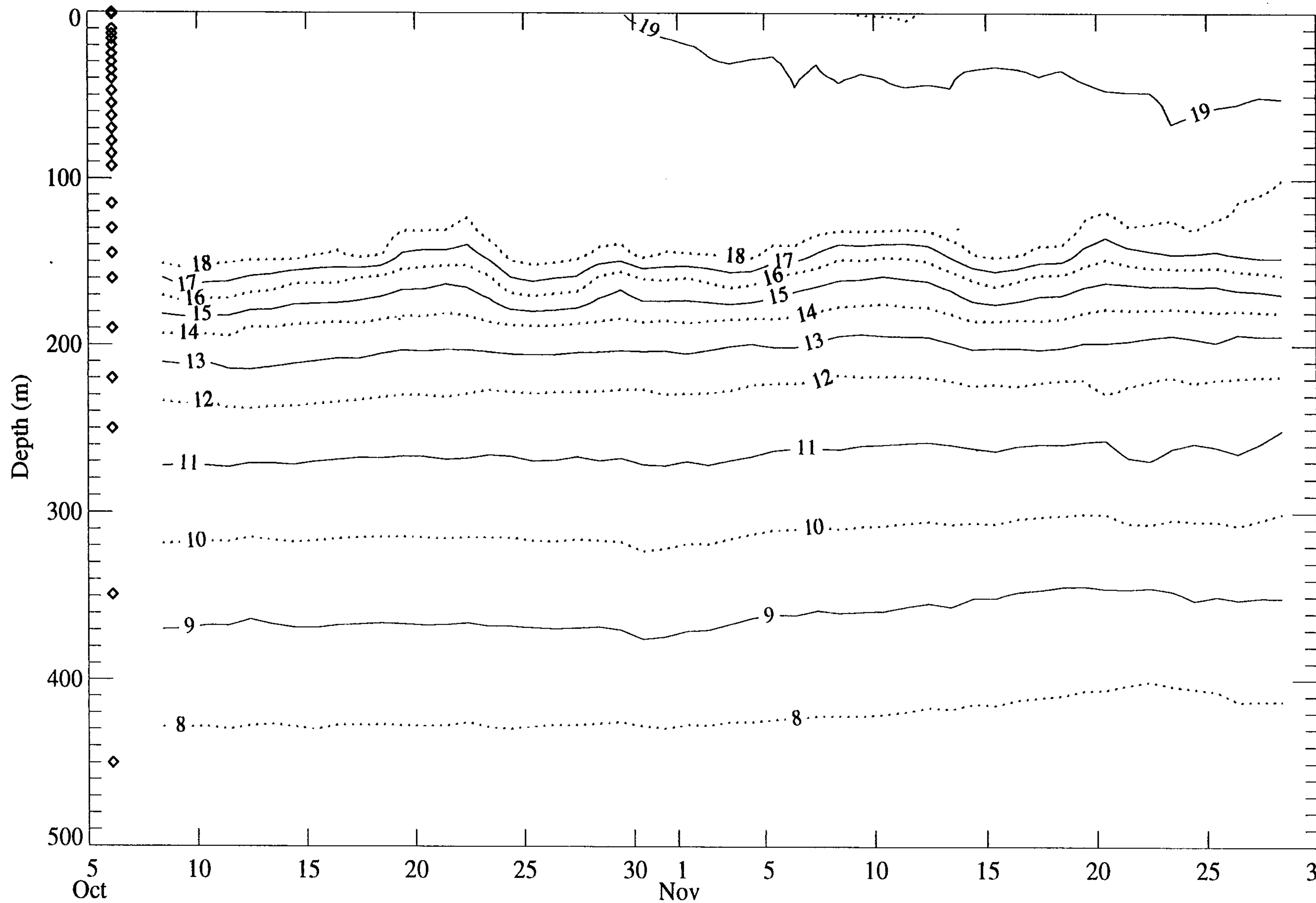


Figure 4-60. Contour plot of 24 hour averaged temperature for October through November 2000.

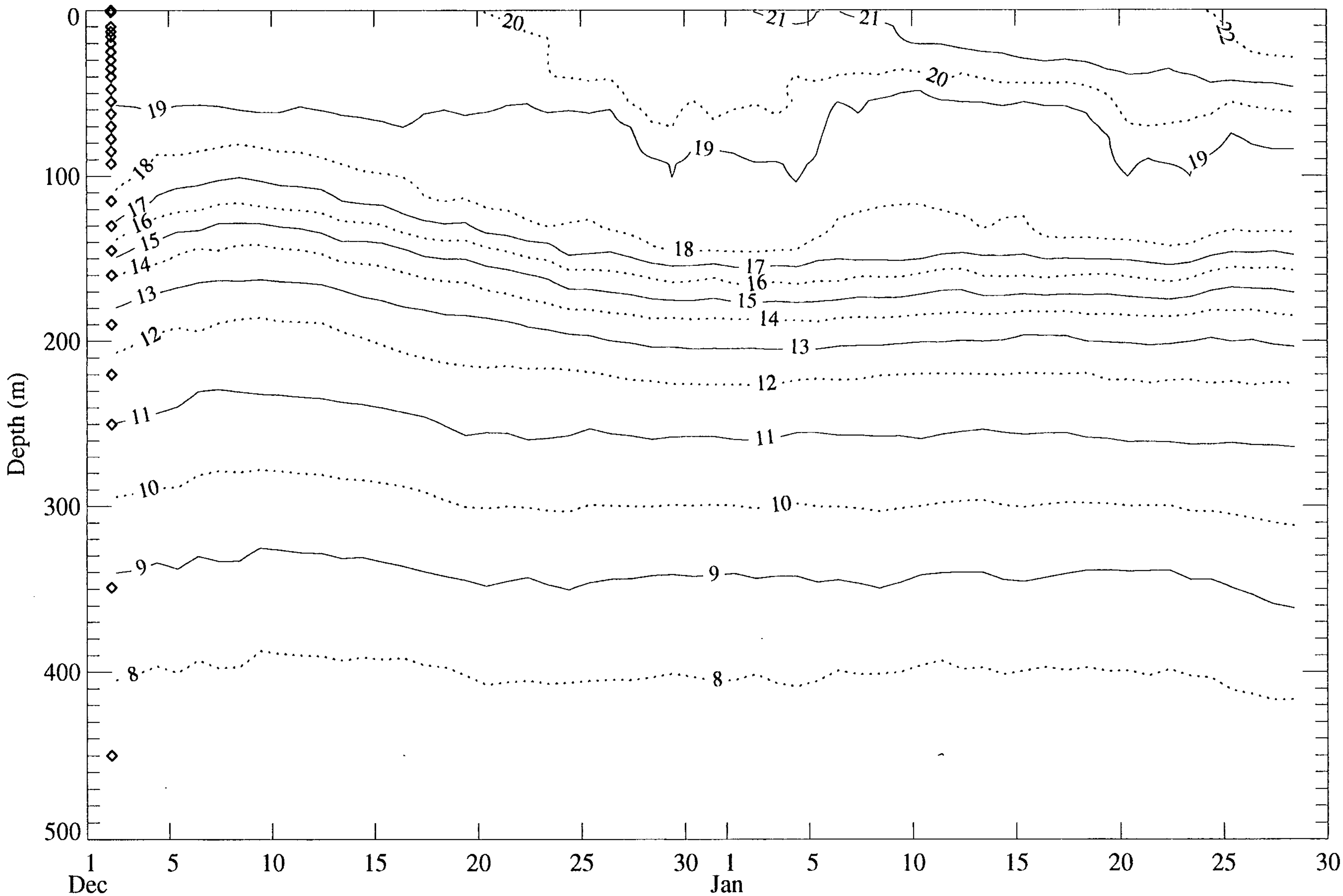


Figure 4-61. Contour plot of 24 hour averaged temperature for December 2000 through January 2001.

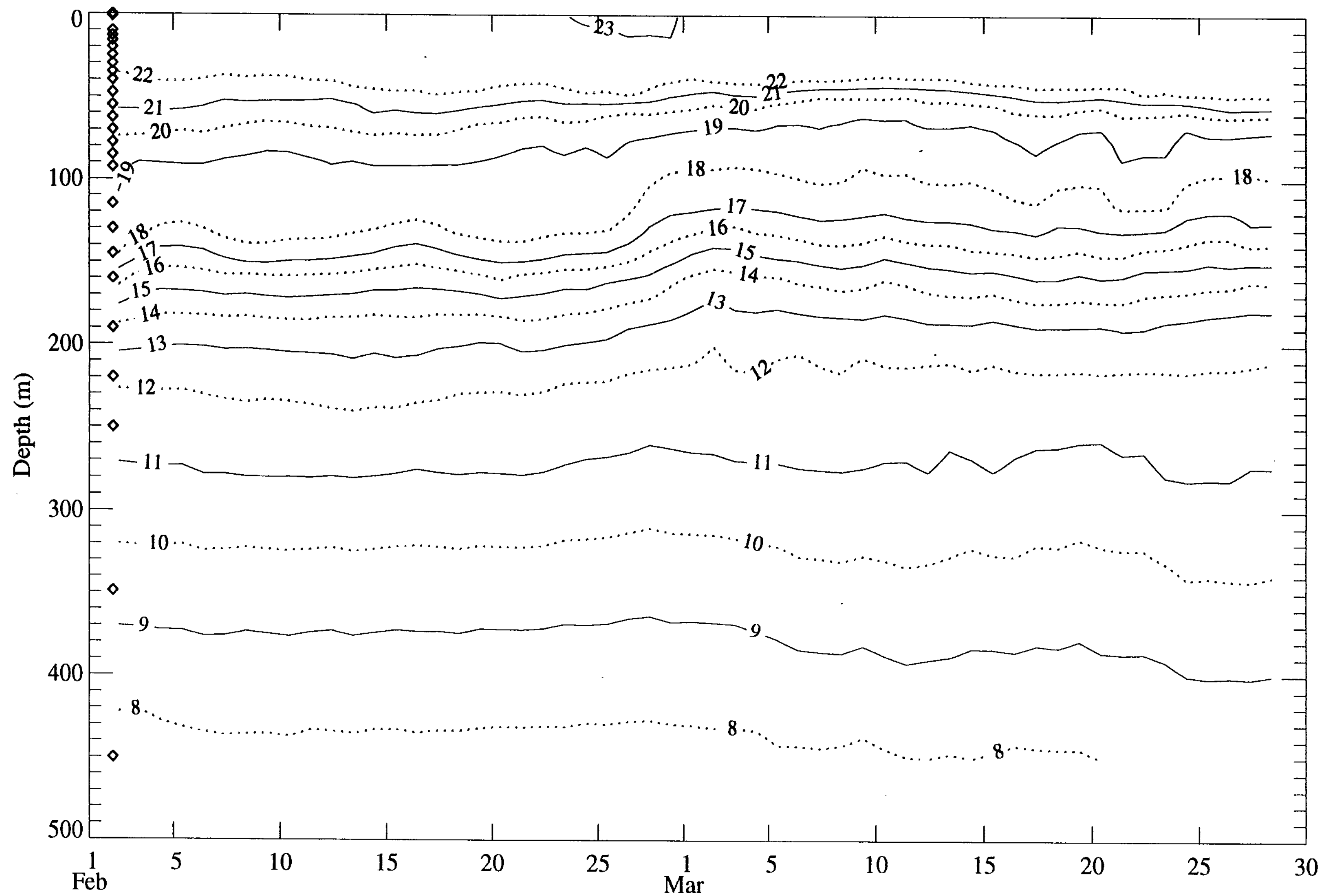


Figure 4-62. Contour plot of 24 hour averaged temperature for February through March 2001.

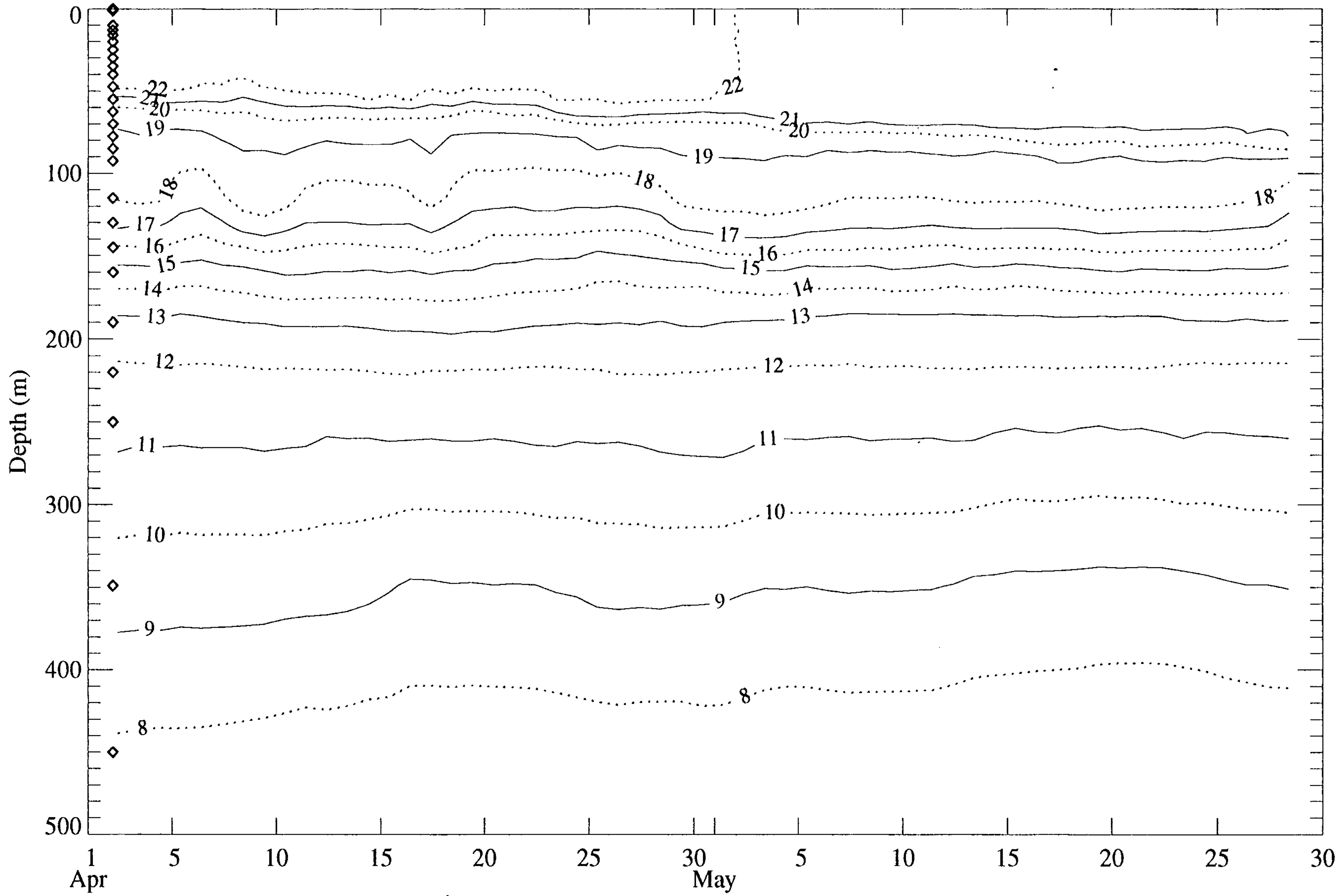


Figure 4-63. Contour plot of 24 hour averaged temperature for April through May 2001.

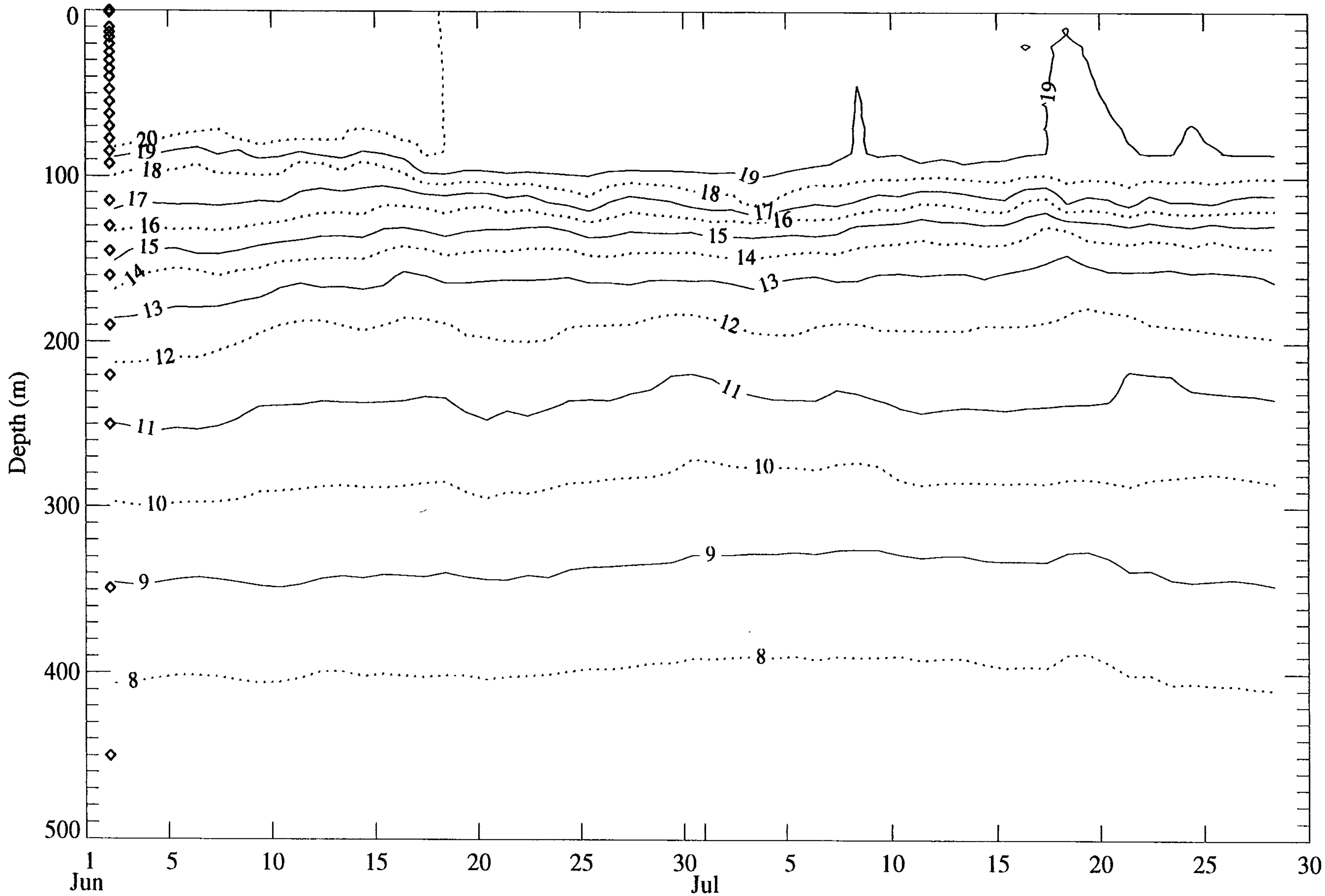


Figure 4-64. Contour plot of 24 hour averaged temperature for June through July 2001.

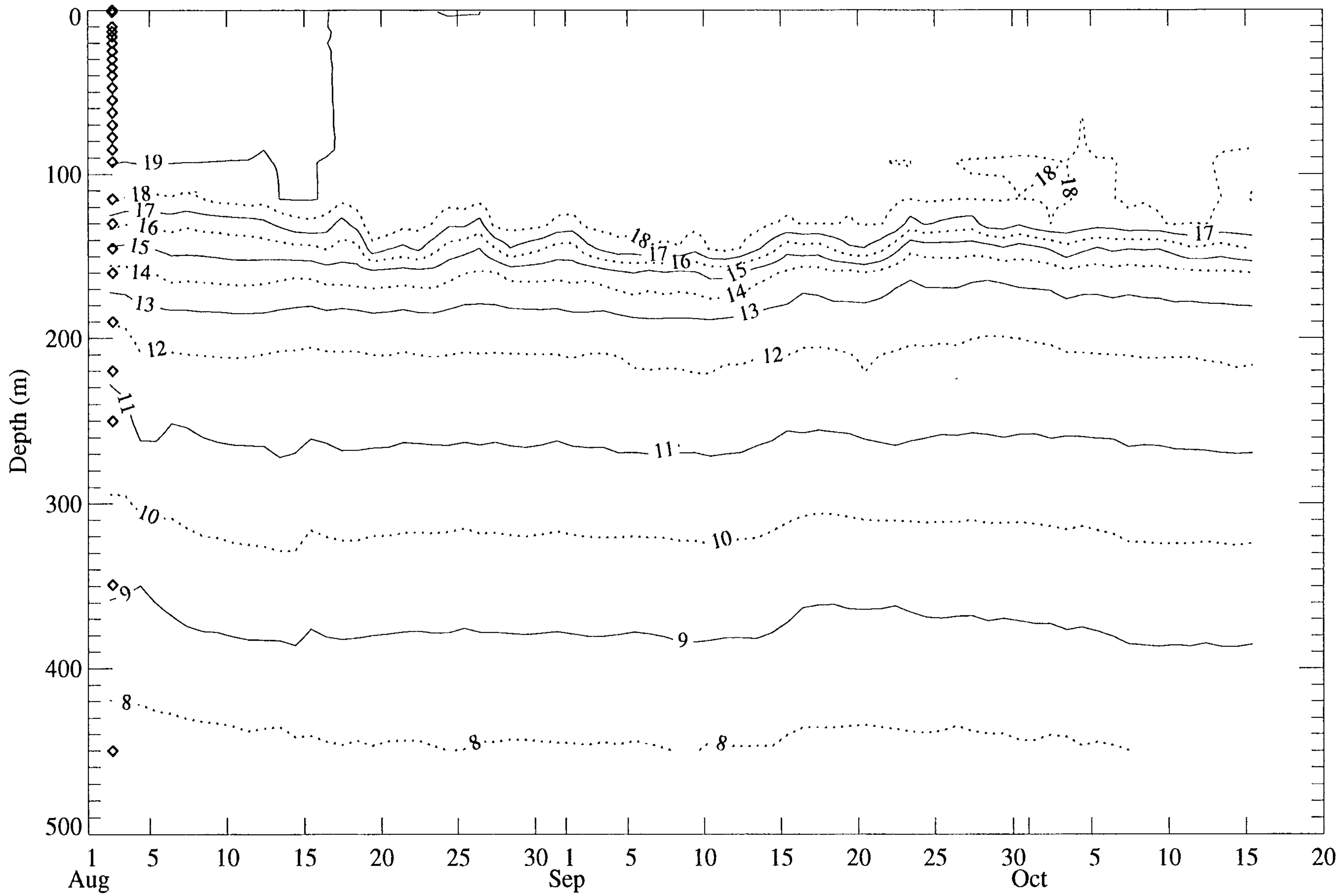


Figure 4-65. Contour plot of 24 hour averaged temperature for August through October 2001.

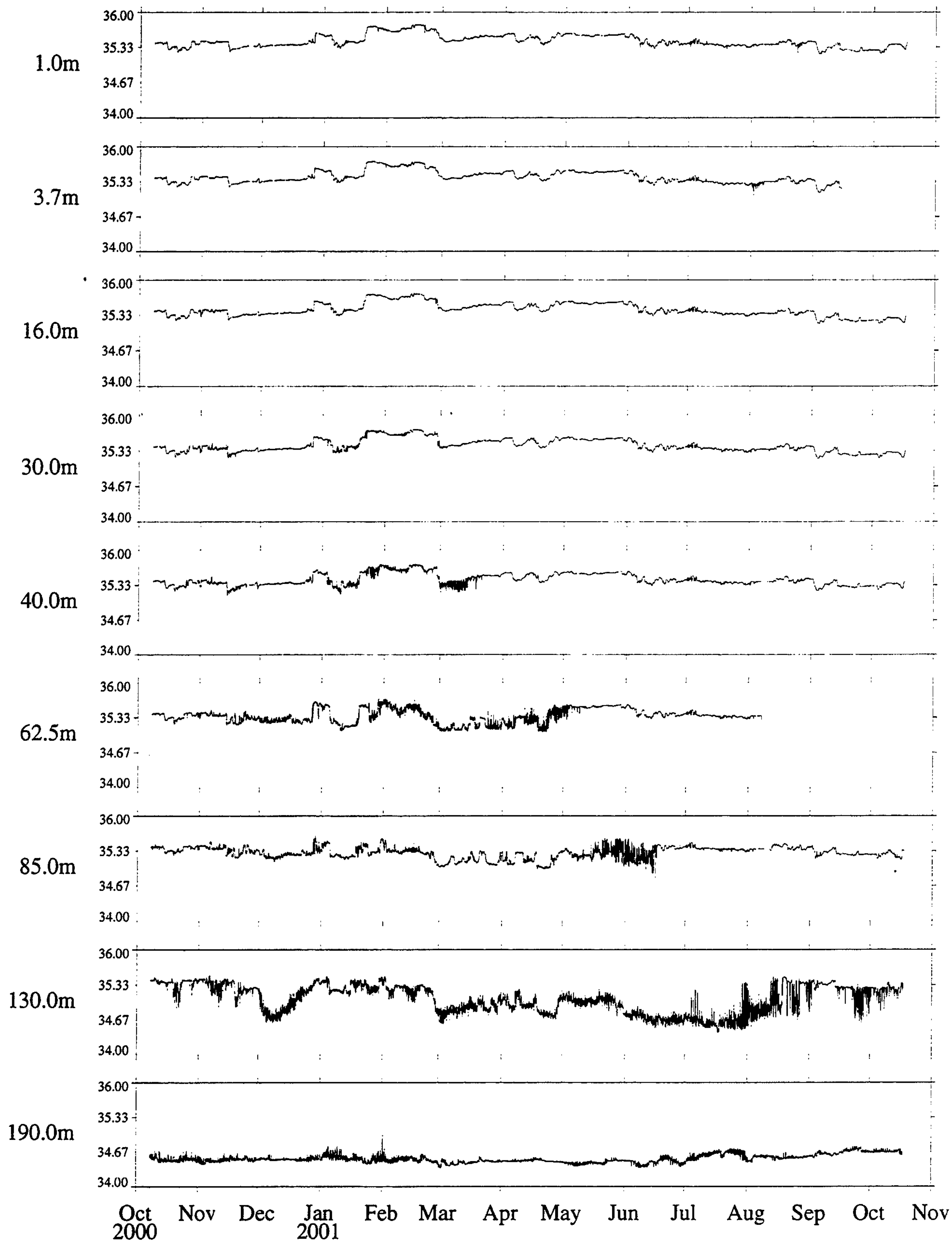


Figure 4-66 . One hour salinity in PSU at selected depths.

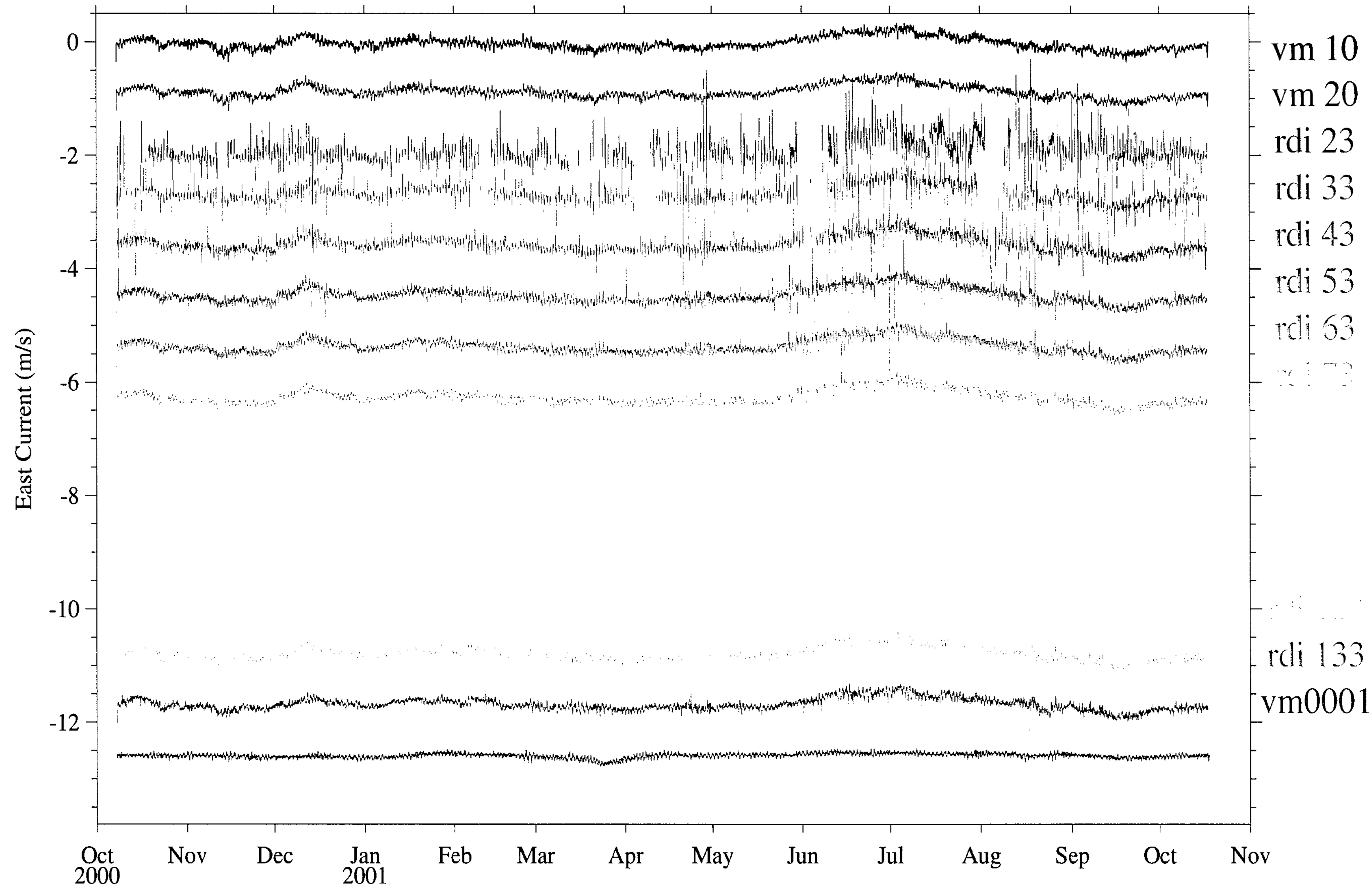


Figure 4-67. VMCM and ADCP hourly averaged East velocity. Sensors are plotted 0.7 cm down from each other.

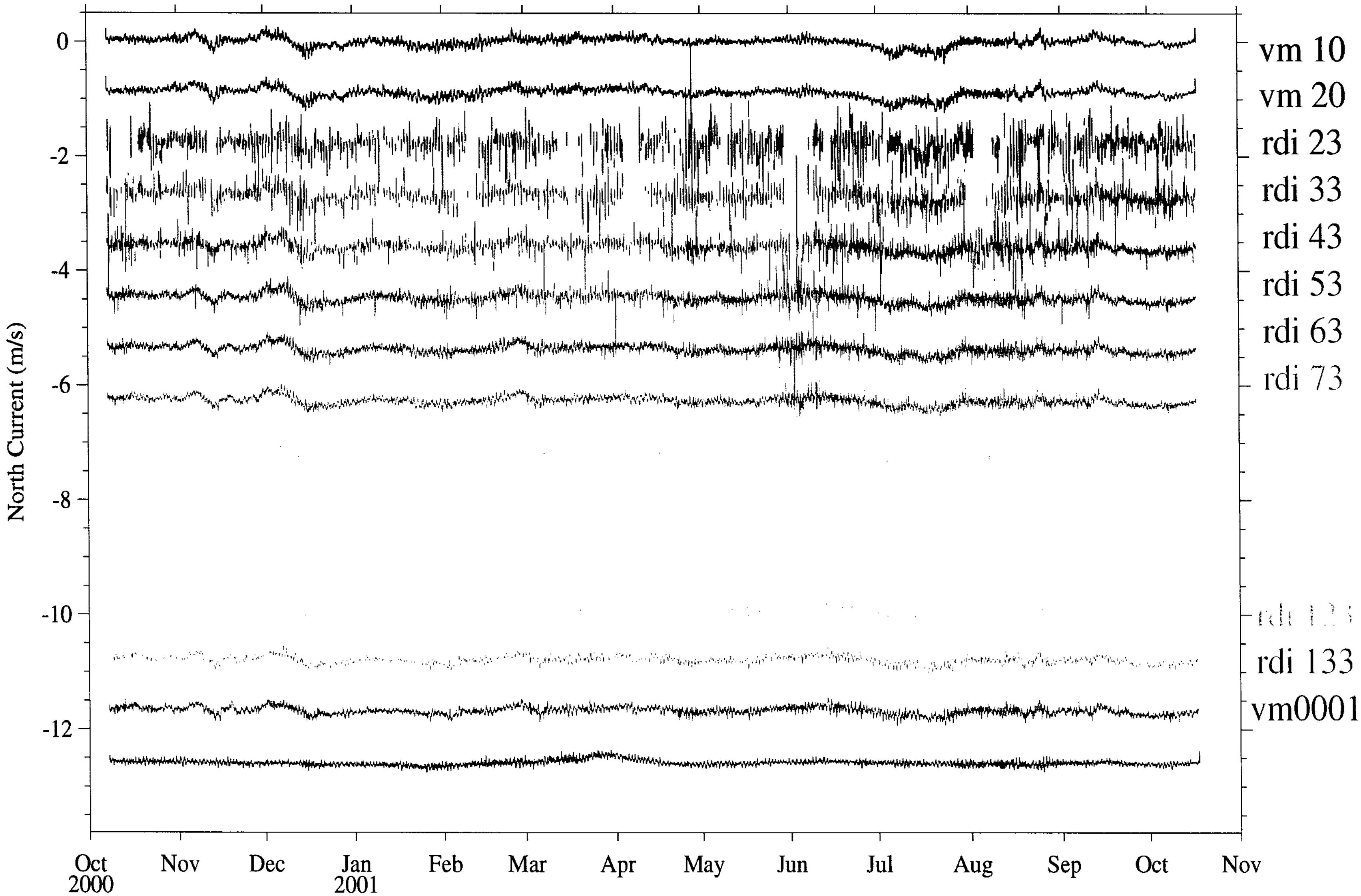


Figure 4-68. VMCM and ADCP hourly averaged North velocity. Sensors are plotted 0.7 cm down from each other.

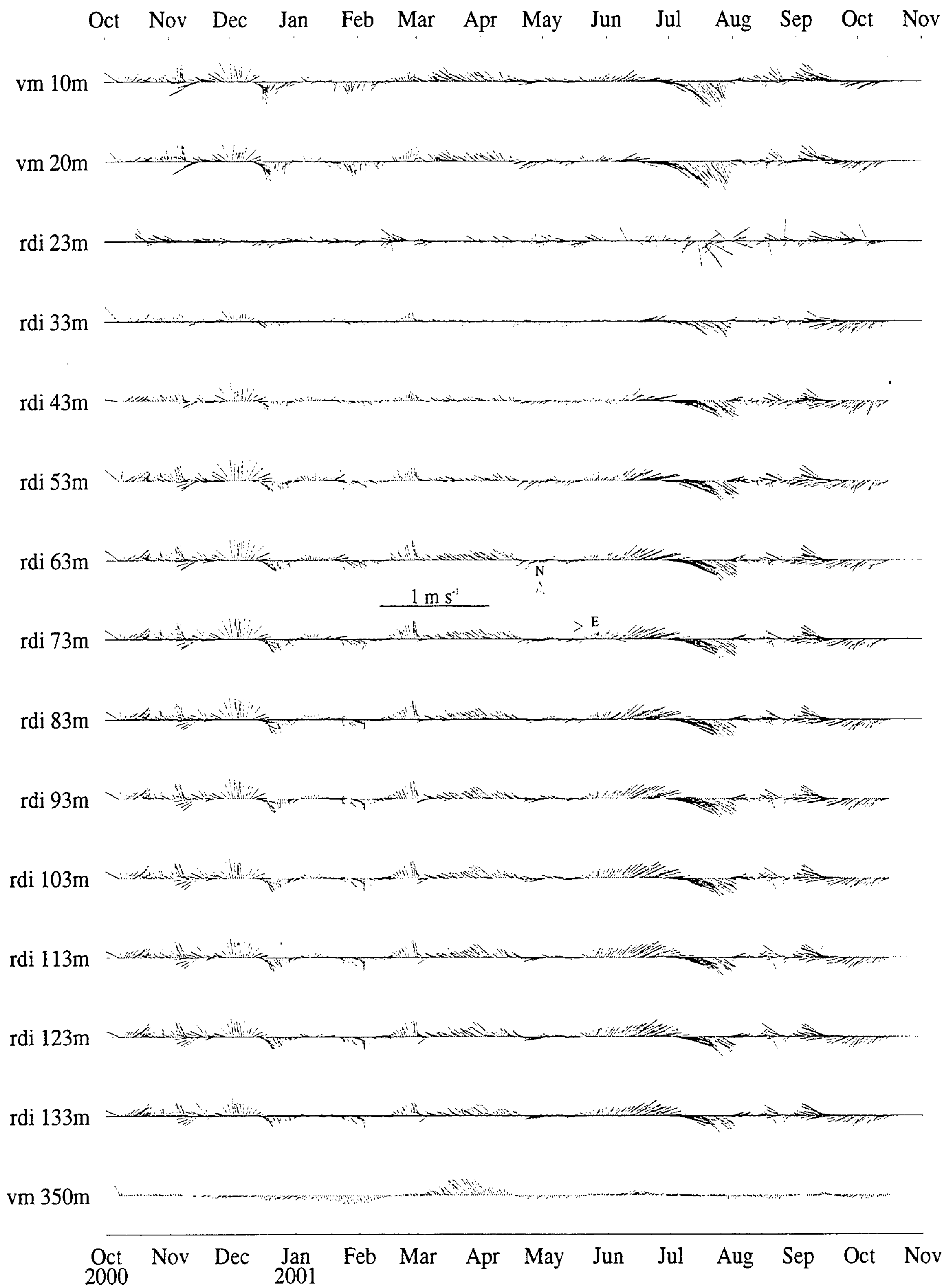


Figure 4-69. VMCM and ADCP 24 hour vector averaged velocity.

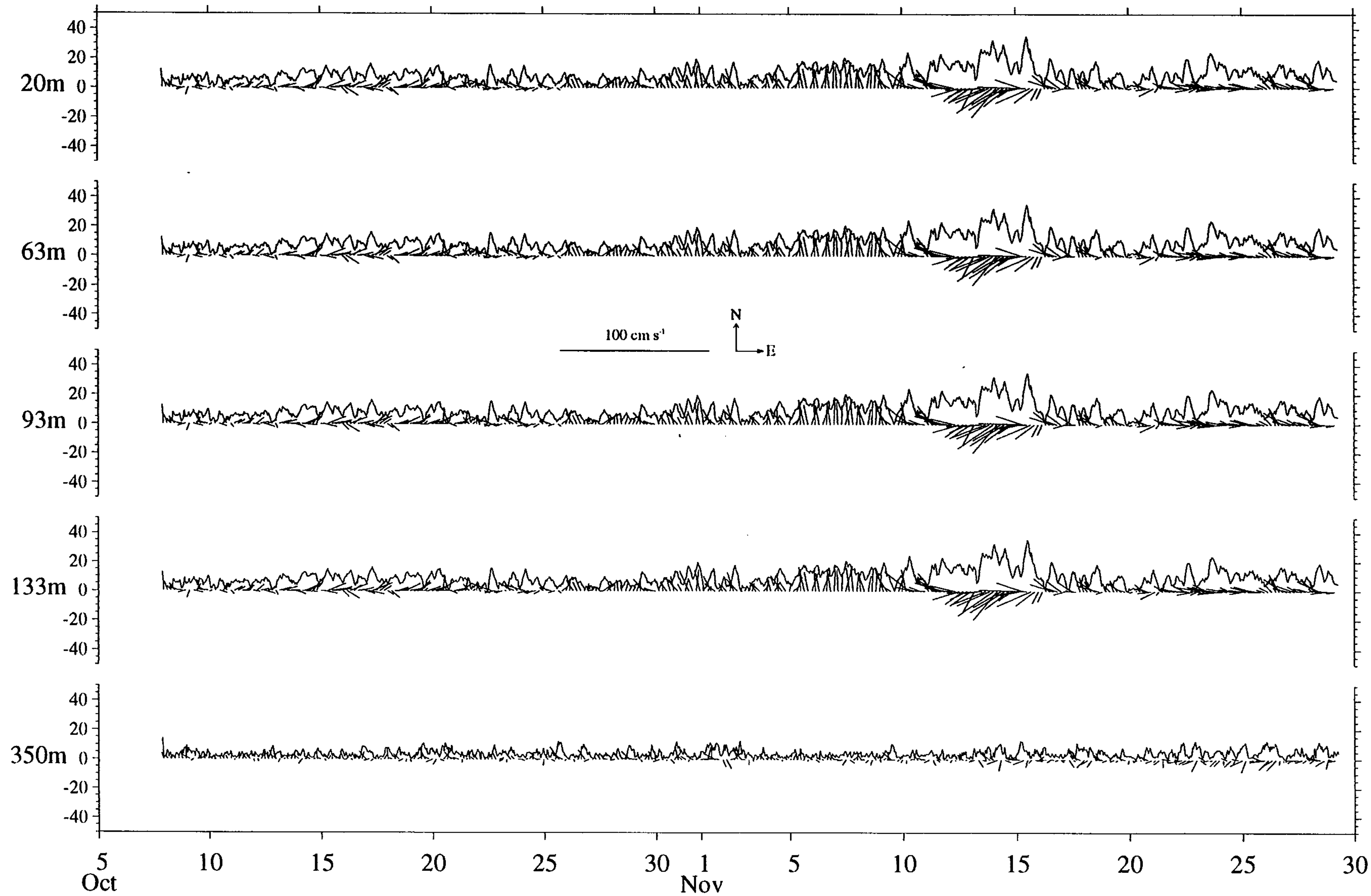


Figure 4-70. Four hour vector averaged velocity (sticks) and one hour current speed (line) in cm/s at selected depths for October through November 2000.

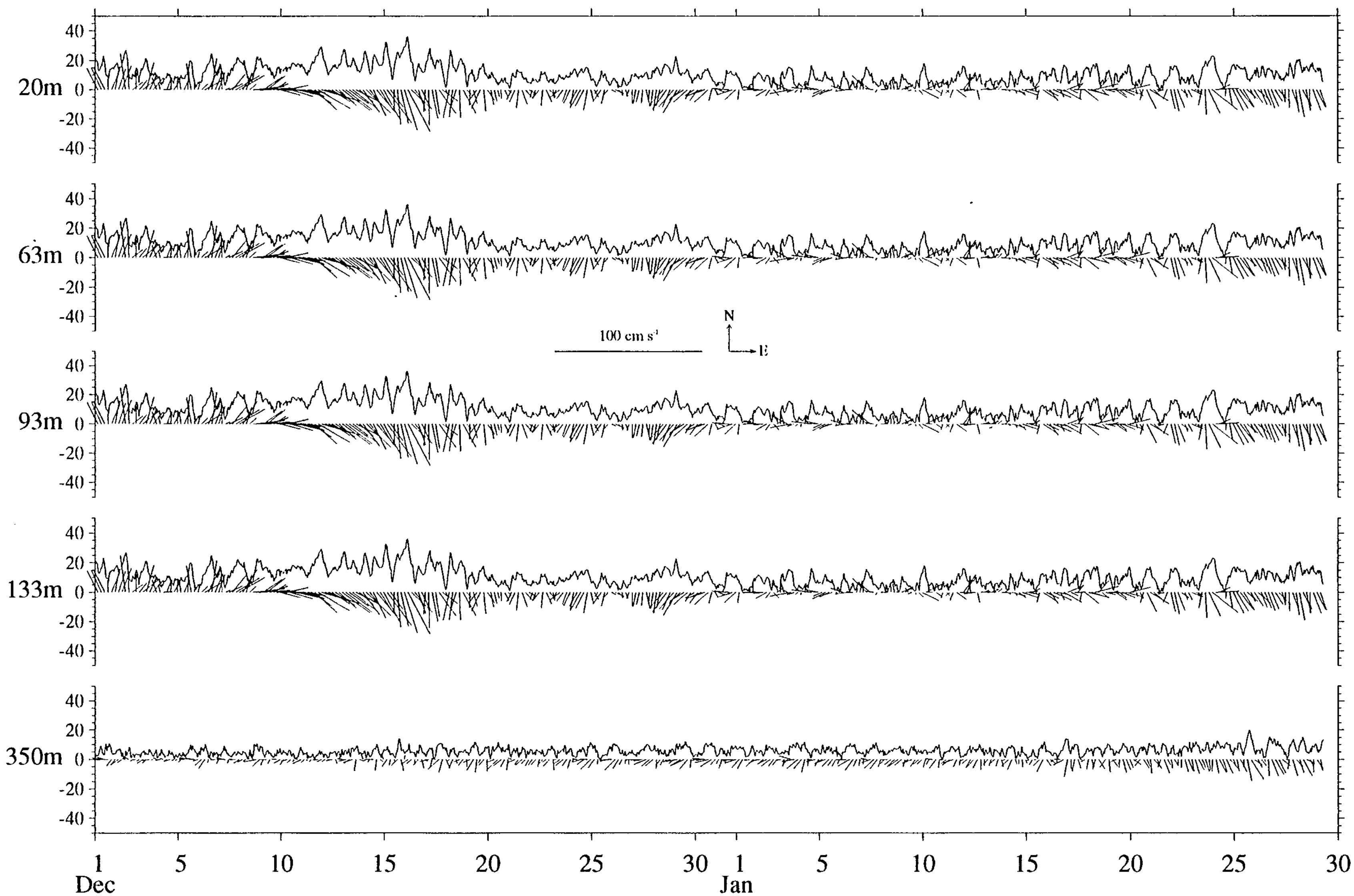


Figure 4-71. Four hour vector averaged velocity (sticks) and one hour current speed (line) in cm/s at selected depths for December 2000 through January 2001.

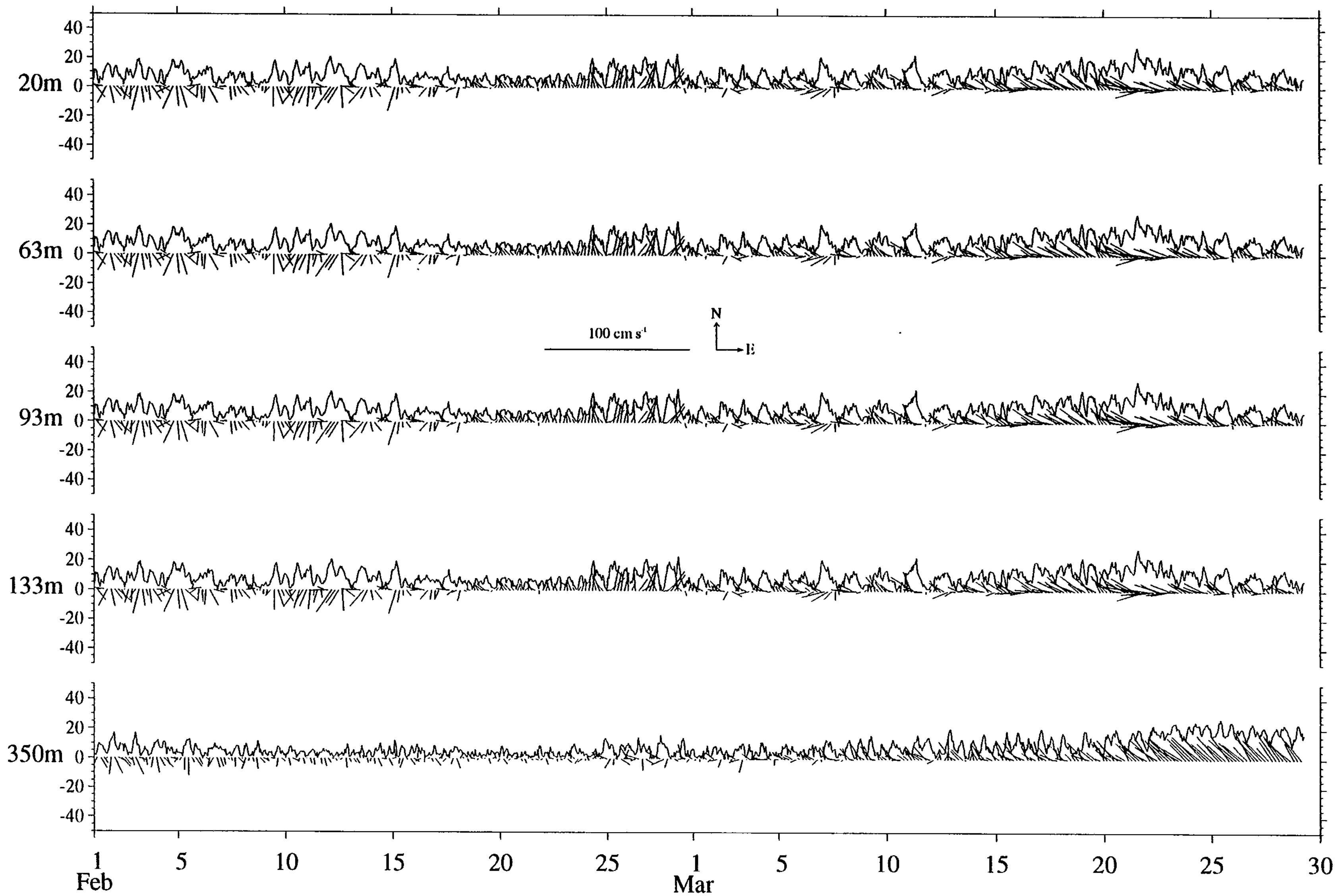


Figure 4-72. Four hour vector averaged velocity (sticks) and one hour current speed (line) in cm/s at selected depths for February through March 2001.

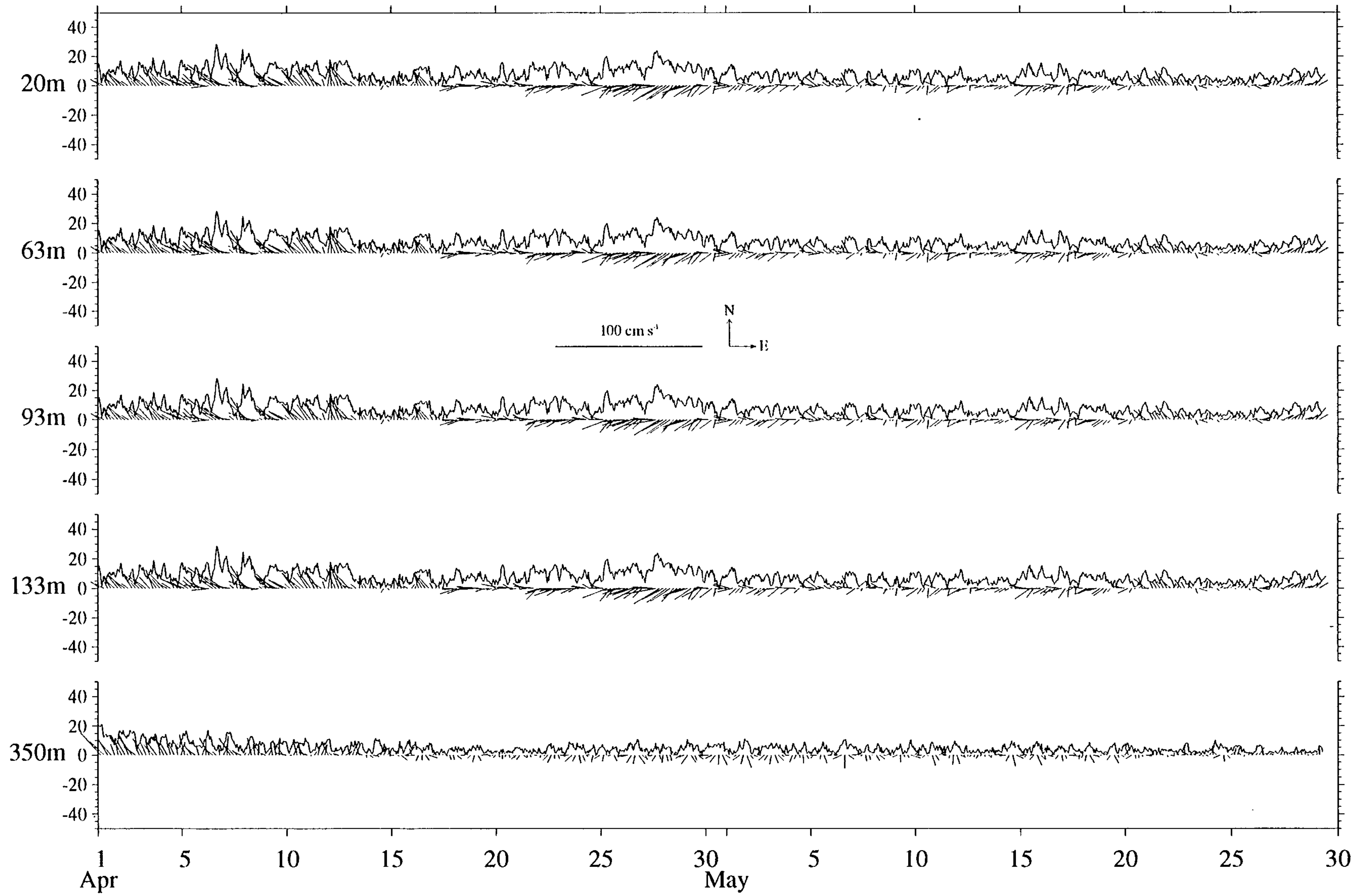


Figure 4-73. Four hour vector averaged velocity (sticks) and one hour current speed (line) in cm/s at selected depths for April through May 2001.

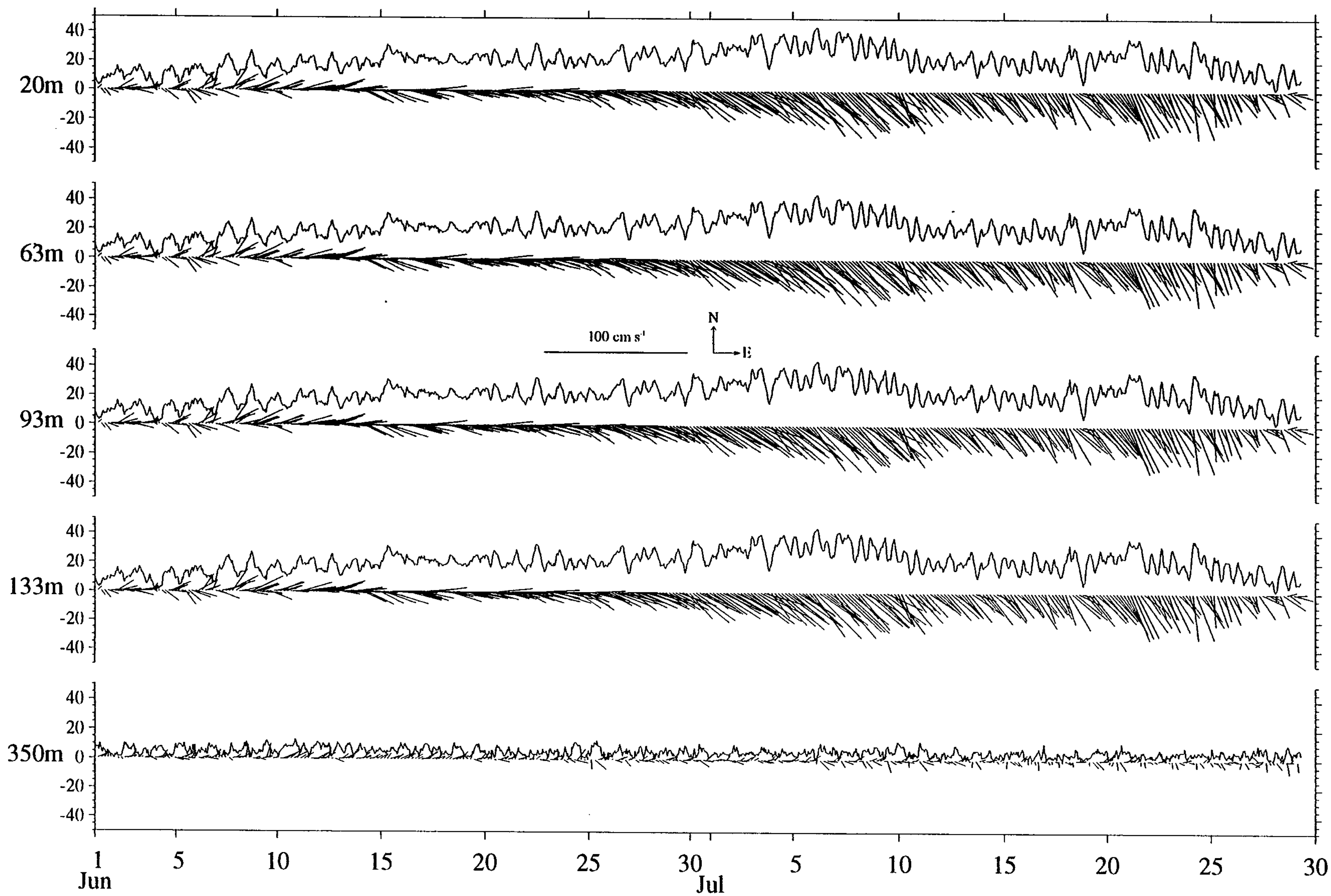


Figure 4-74. Four hour vector averaged velocity (sticks) and one hour current speed (line) in cm/s at selected depths for June through July 2001.

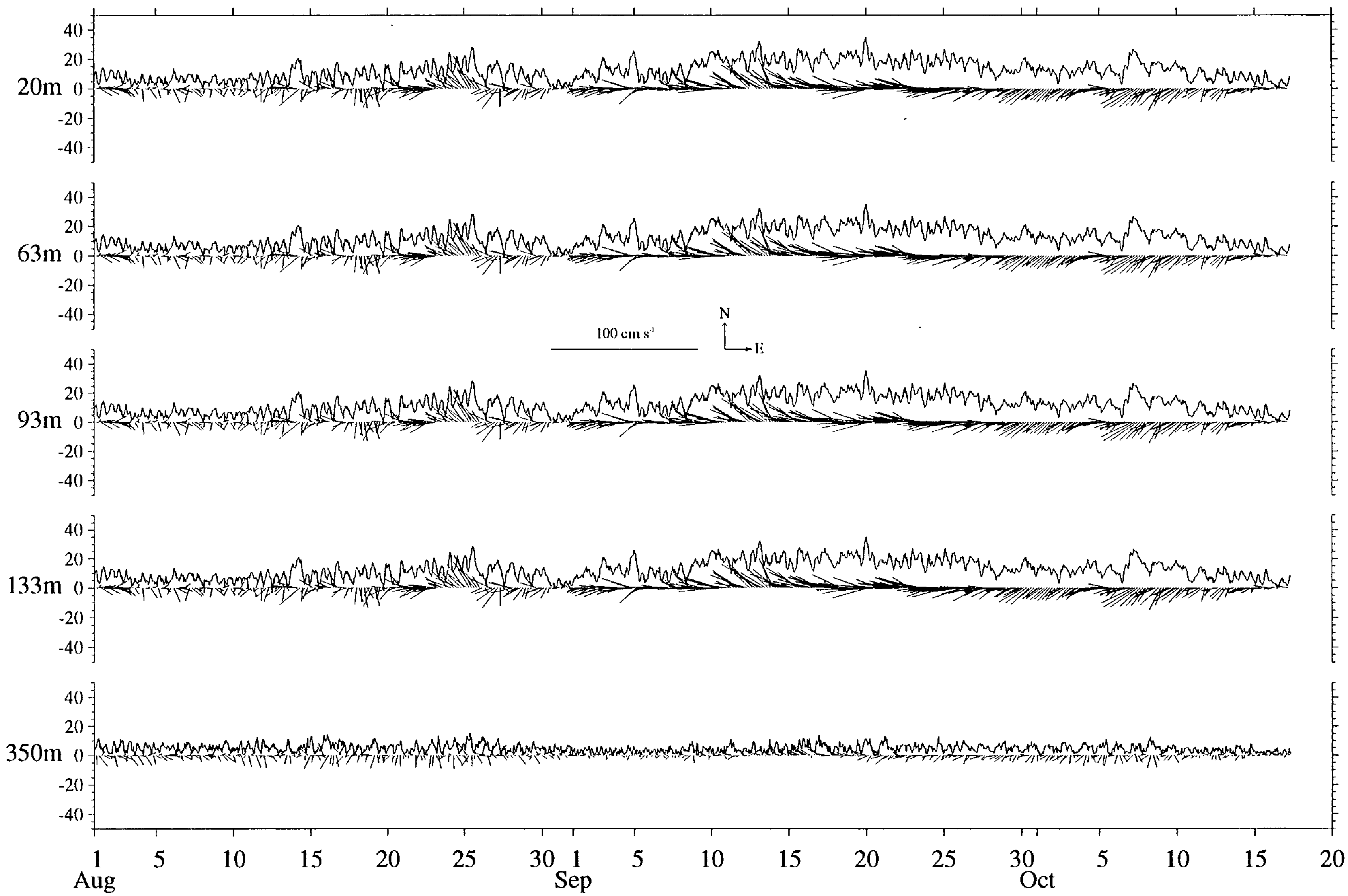


Figure 4-75. Four hour vector averaged velocity (sticks) and one hour current speed (line) in cm/s at selected depths for August through October 2001.

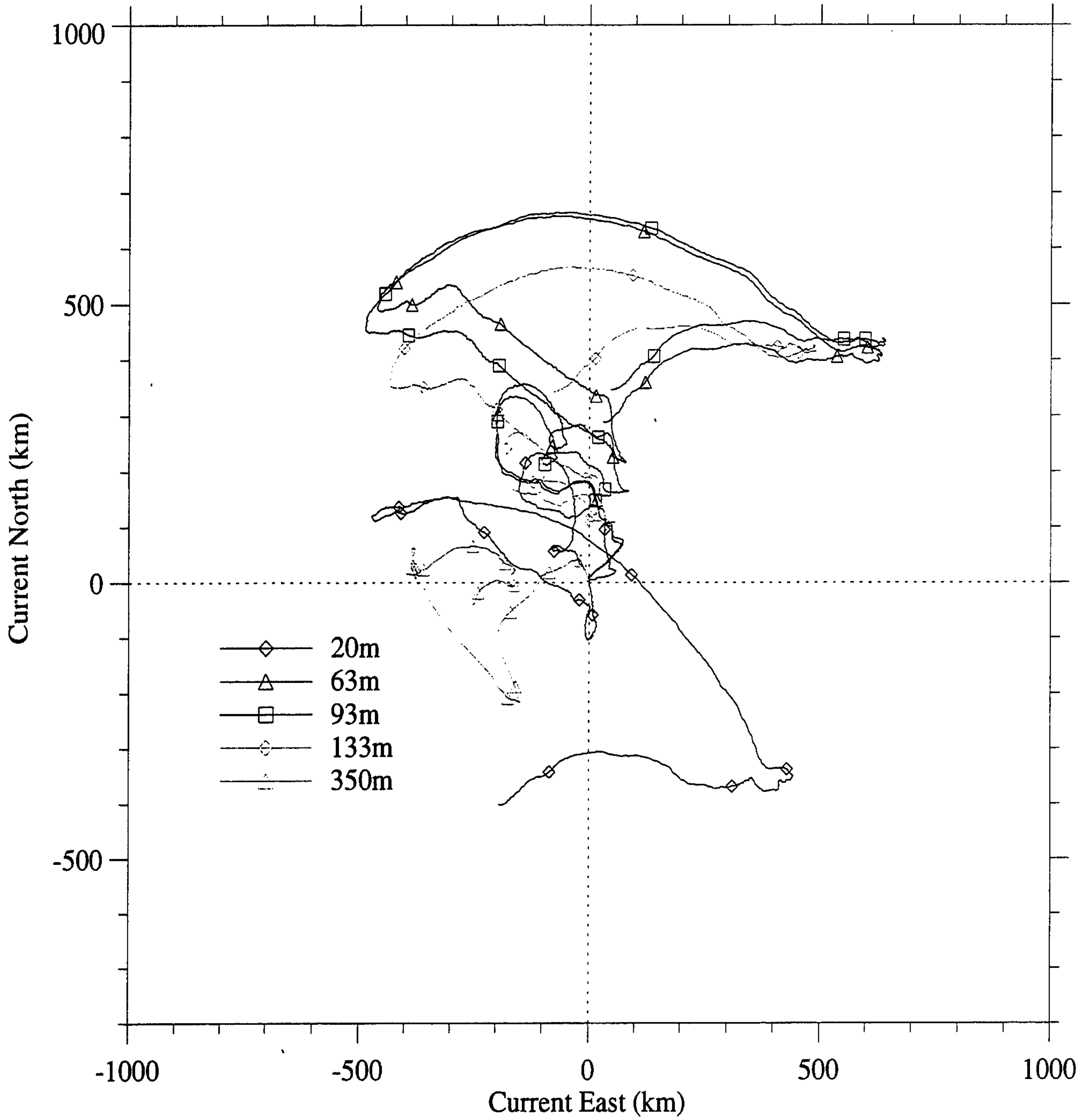


Figure 4-76. Progressive vectors from VMCM and ADCP current meters at selected depths. Symbols are placed 30 days apart.

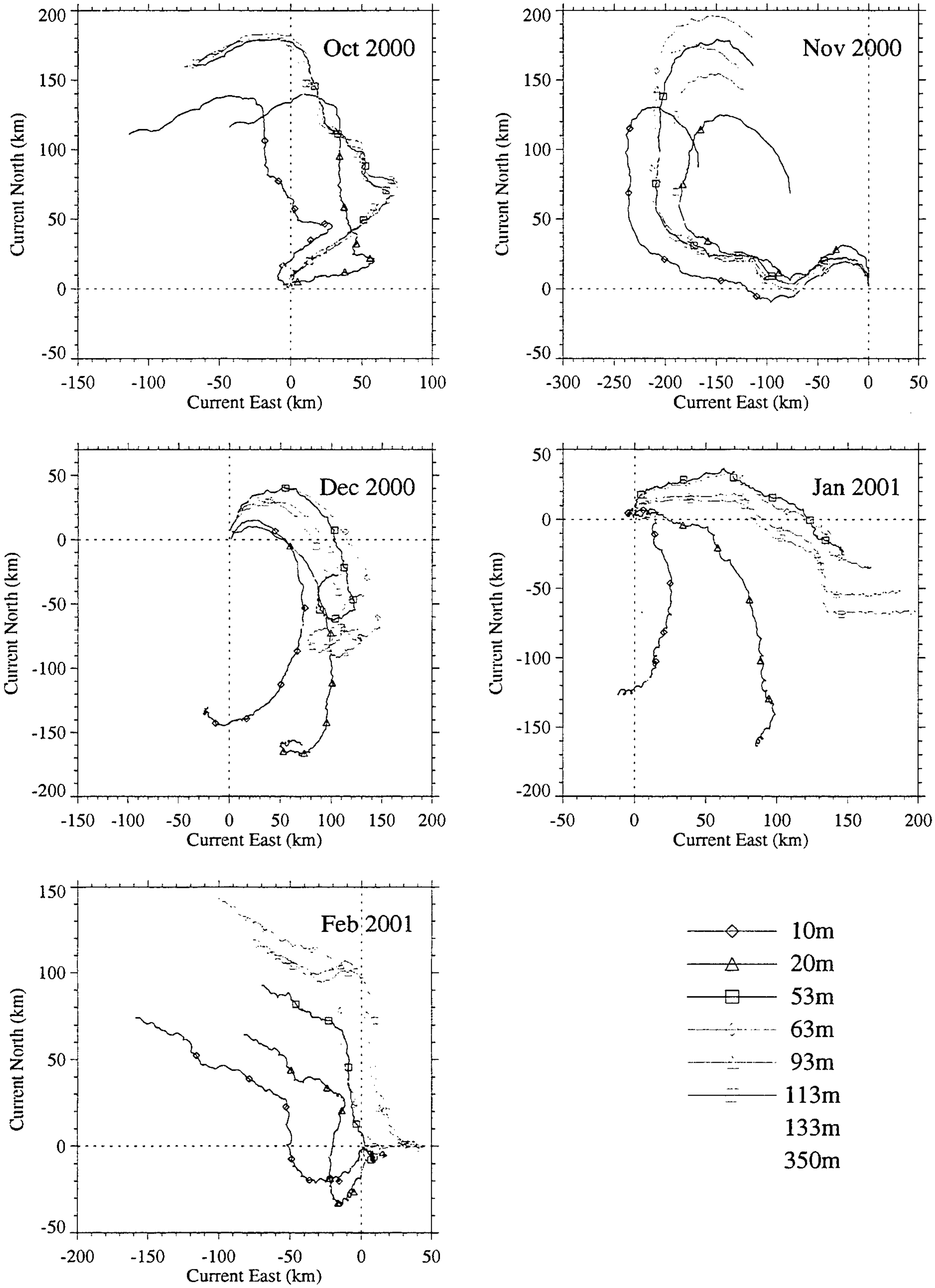


Figure 4-77. Progressive vectors from VMCM and ADCP current meters at selected depths. Symbols are placed 5 days apart.

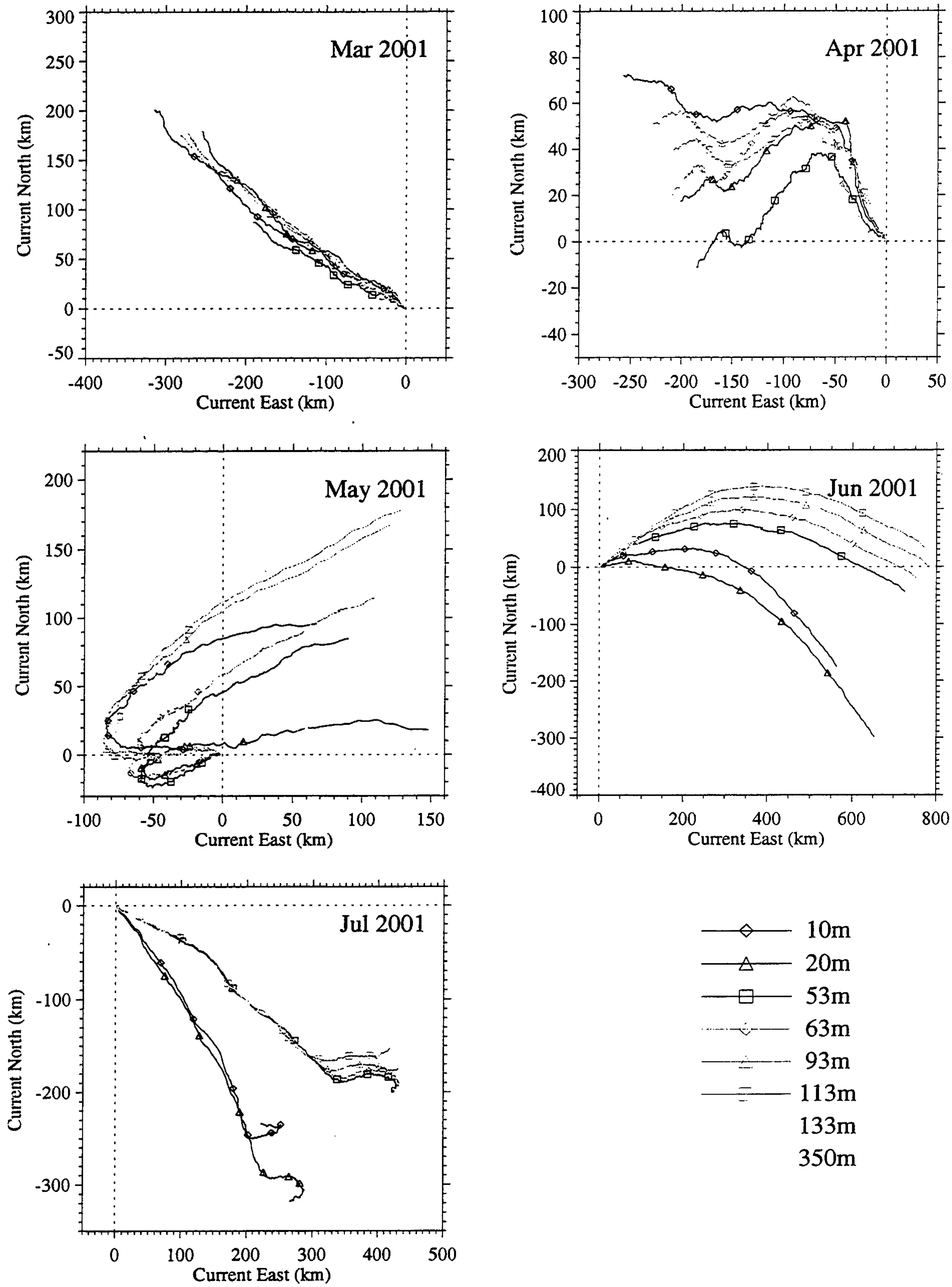


Figure 4-78. Progressive vectors from VMCM and ADCP current meters at selected depths. Symbols are placed 5 days apart.

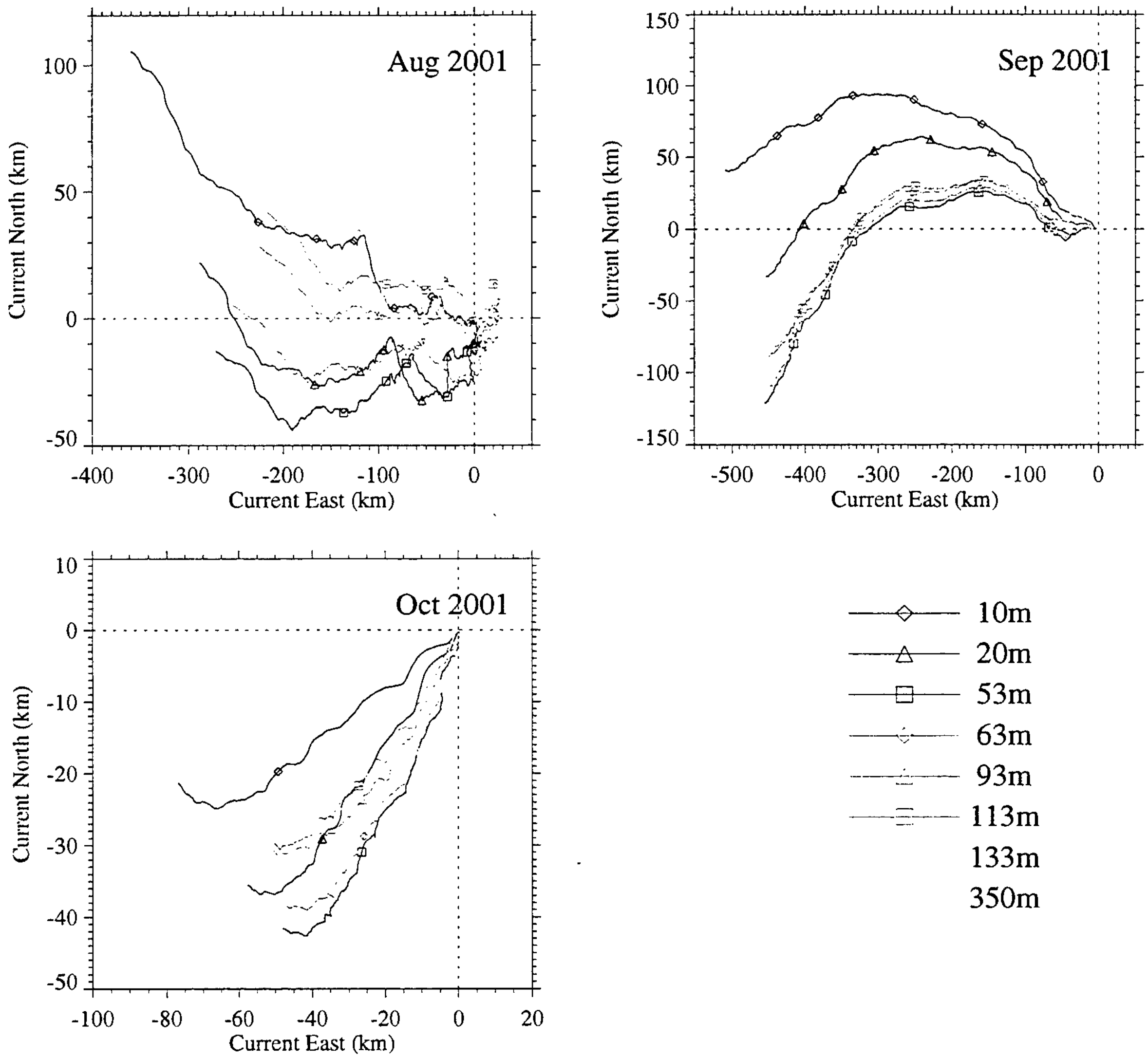


Figure 4-79. Progressive vectors from VMCM and ADCP current meters at selected depths.
Symbols are placed 5 days apart.

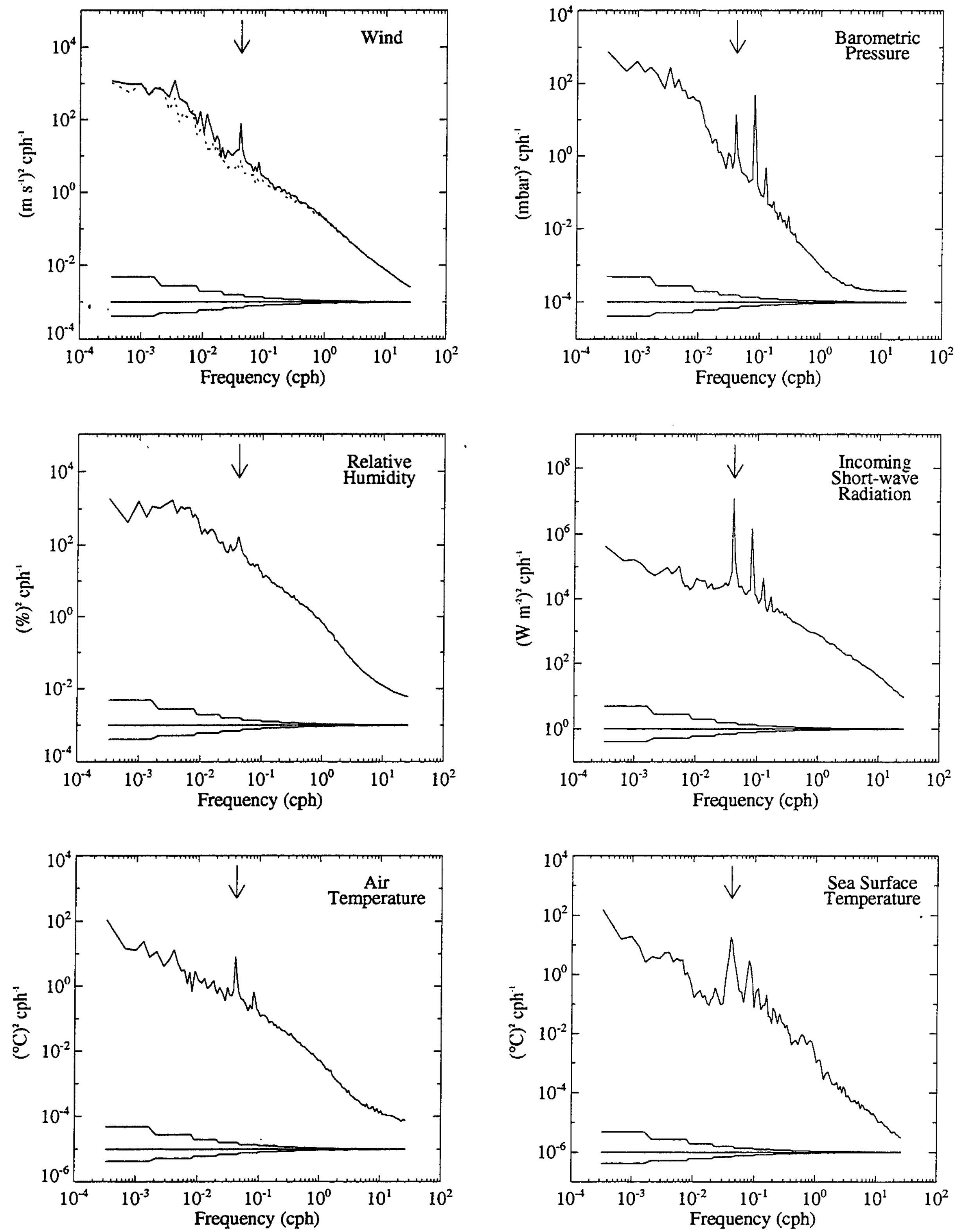


Figure 4-.80. Autospectra of meteorological parameters. Rotary autospectra of the wind provides both clockwise (solid) and counter-clockwise (dotted) spectras. The arrow indicates the diurnal frequency (24^{-1} cph).

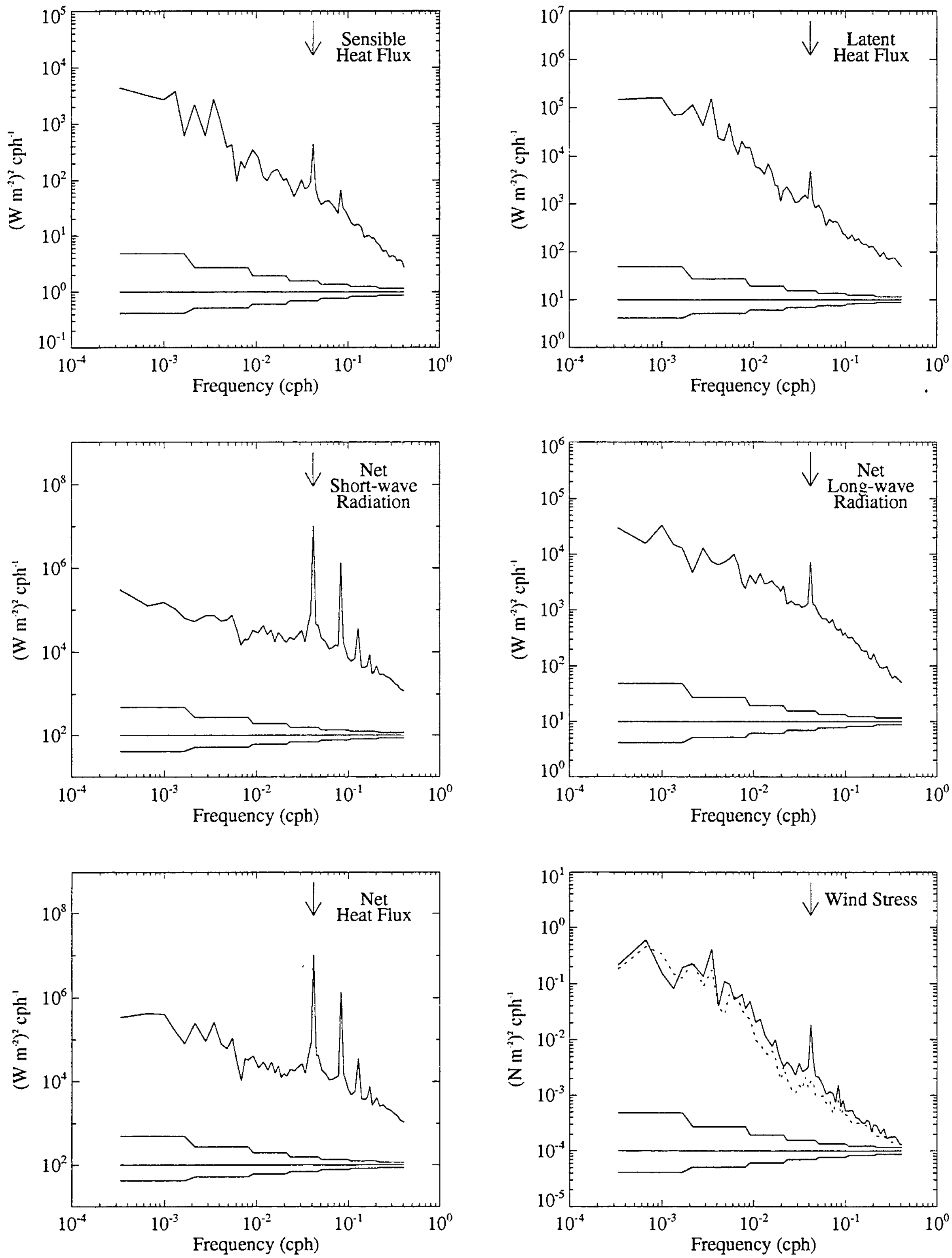


Figure 4-.81. Autospectra of heat fluxes. Rotary autospectra of the wind stress provides both clockwise (solid) and counter-clockwise (dotted) spectras. The arrow indicates the diurnal frequency (24^{-1} cph).

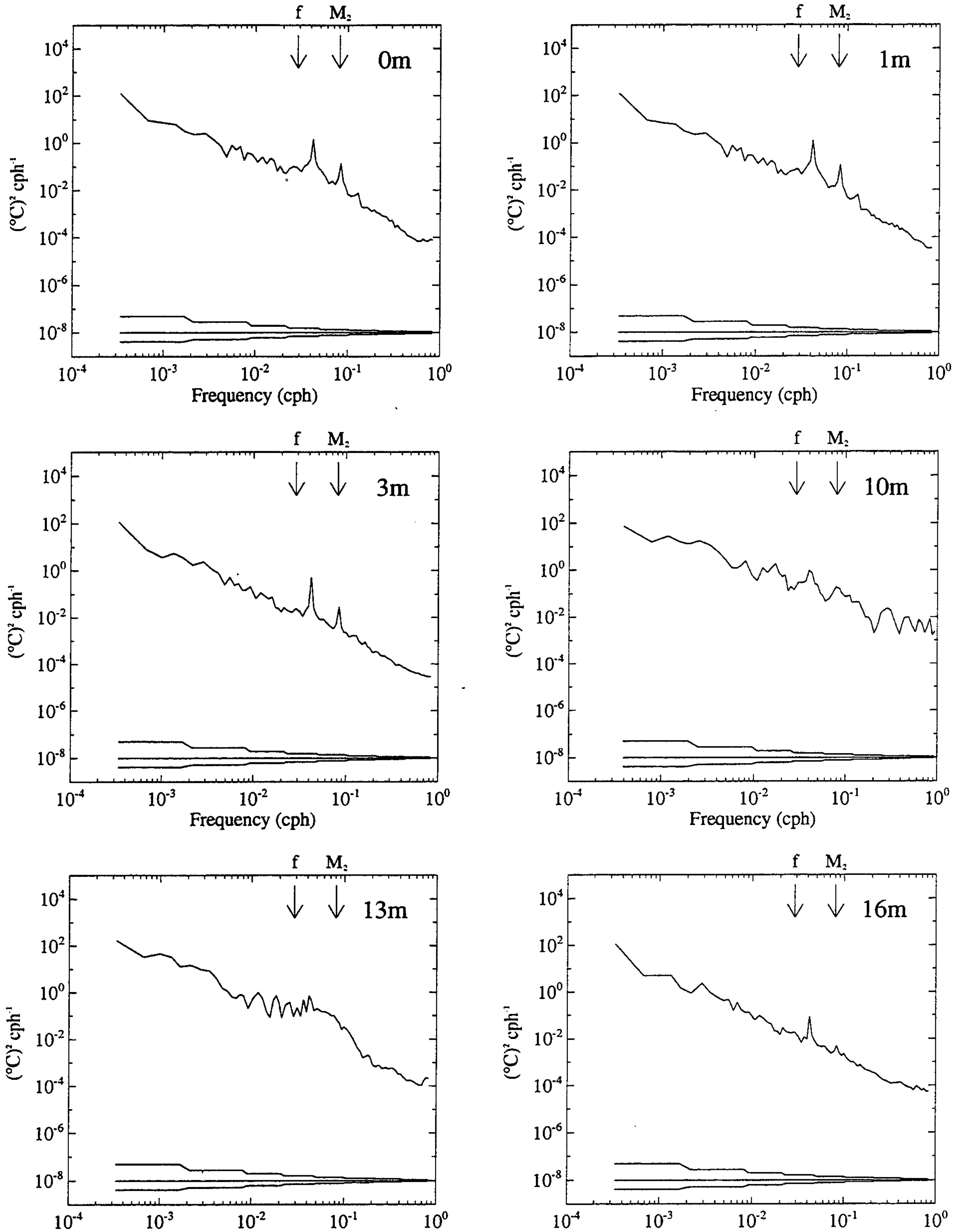


Figure 4- 82. Autospectra of temperature at various depths. The tidal M_2 and inertial frequencies are indicated with arrows.

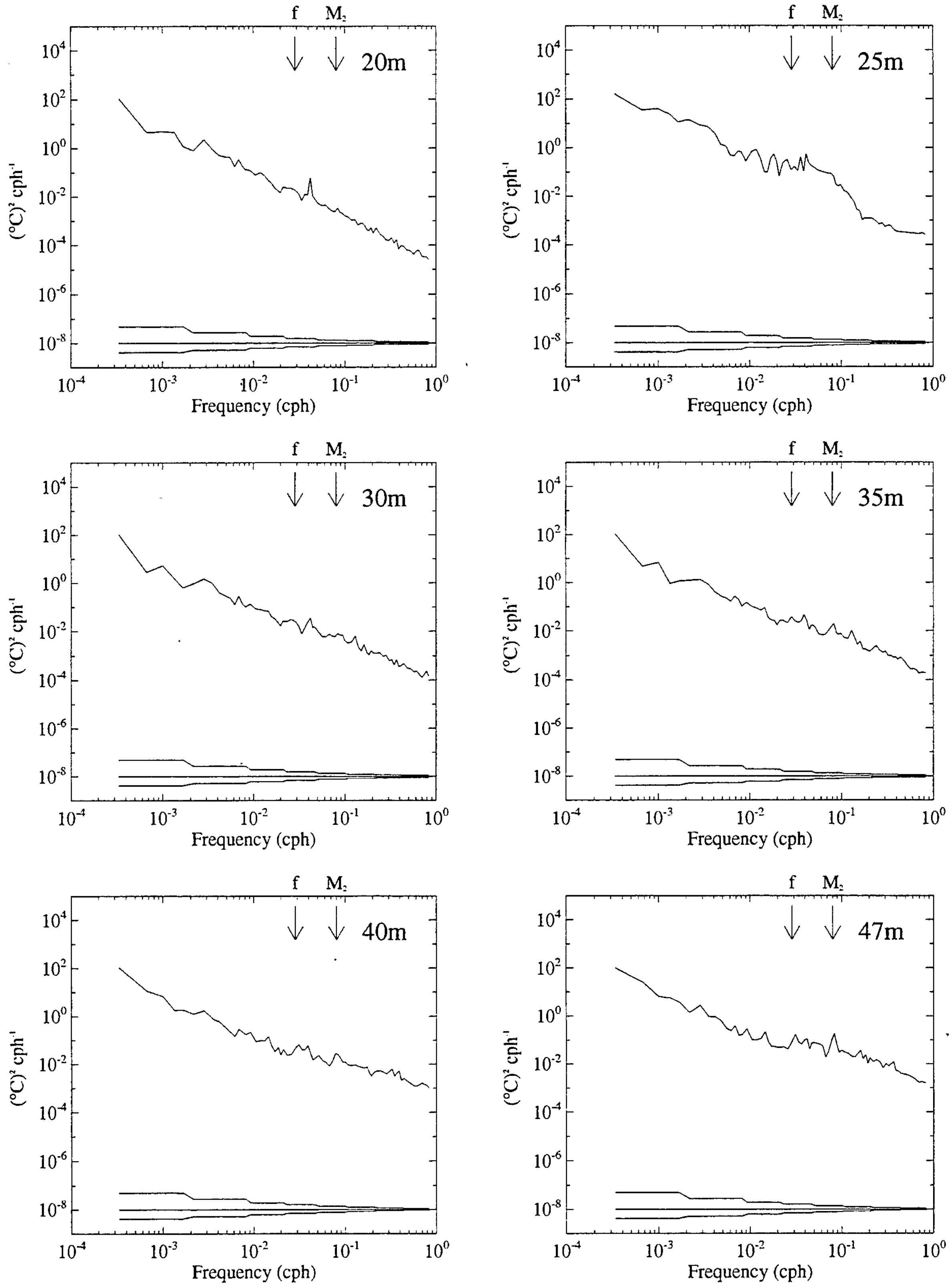


Figure 4- 83. Autospectra of temperature at various depths. The tidal M_2 and inertial frequencies are indicated with arrows.

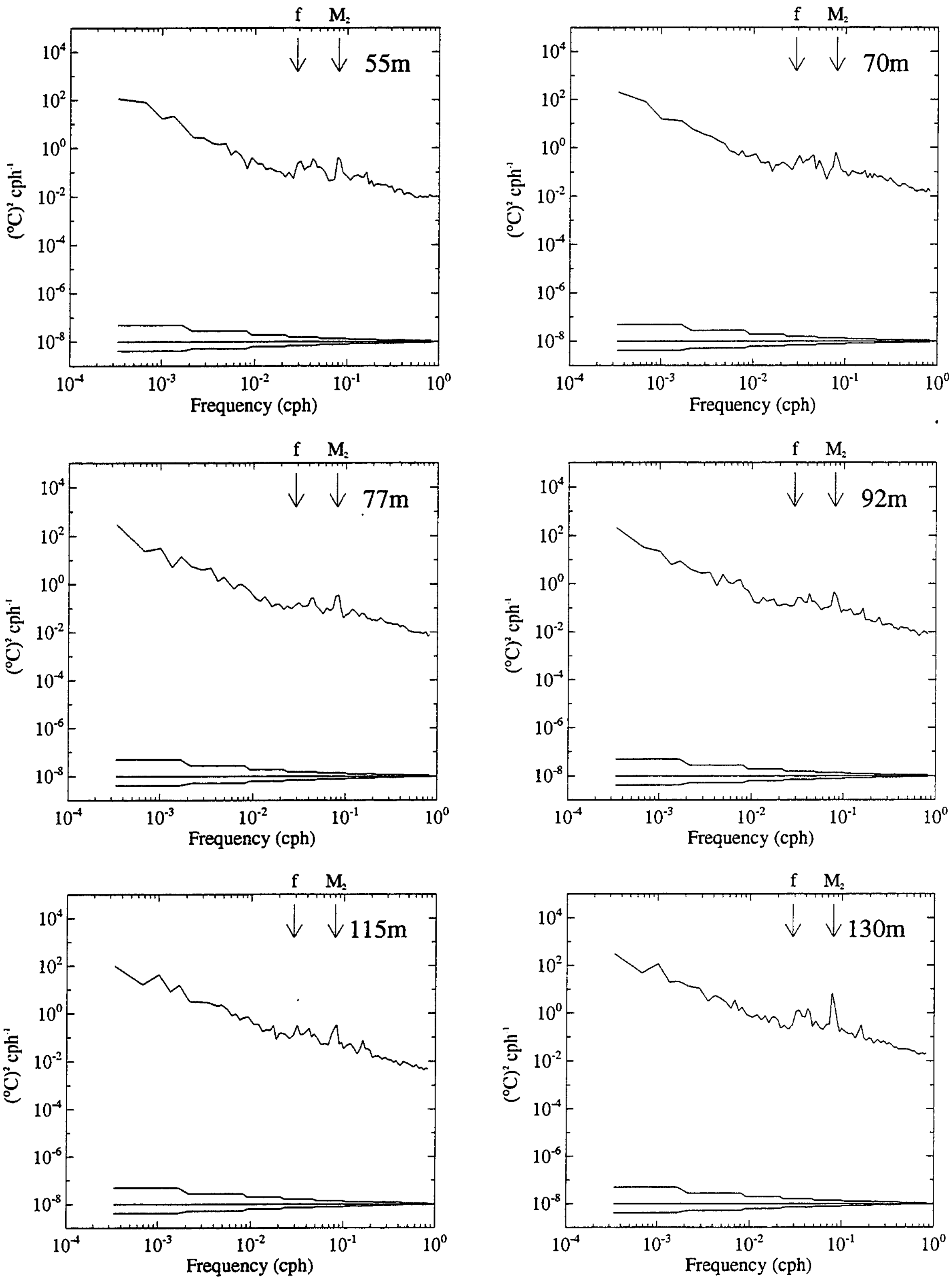


Figure 4- 84. Autospectra of temperature at various depths. The tidal M_2 and inertial frequencies are indicated with arrows.

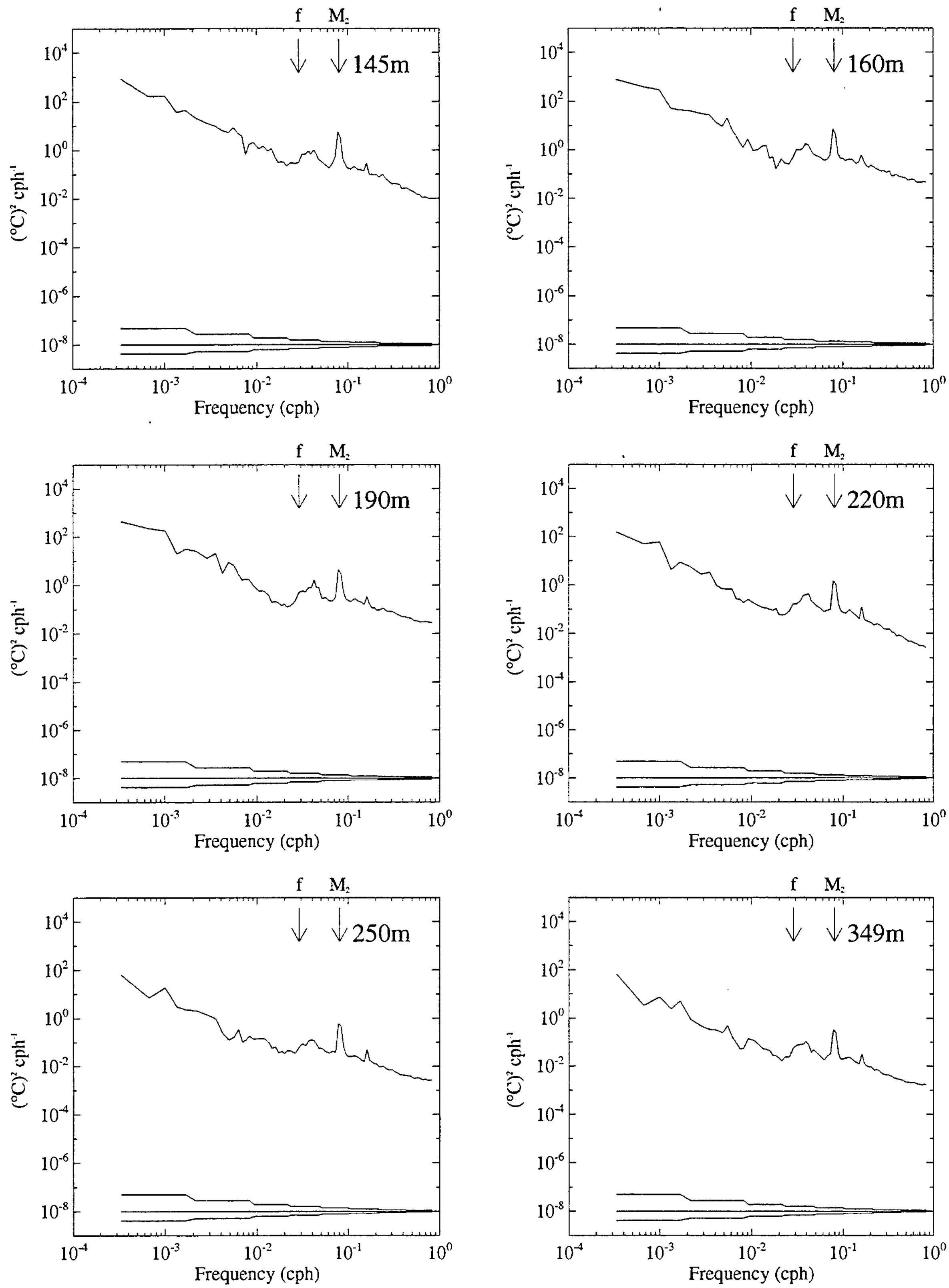


Figure 4- 85. Autospectra of temperature at various depths. The tidal M_2 and inertial frequencies are indicated with arrows.

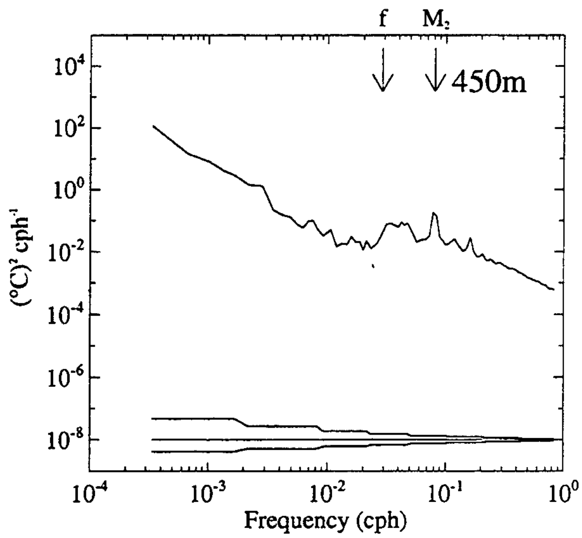


Figure 4- 86. Autospectra of temperature at various depths. The tidal M_2 and inertial frequencies are indicated with arrows.

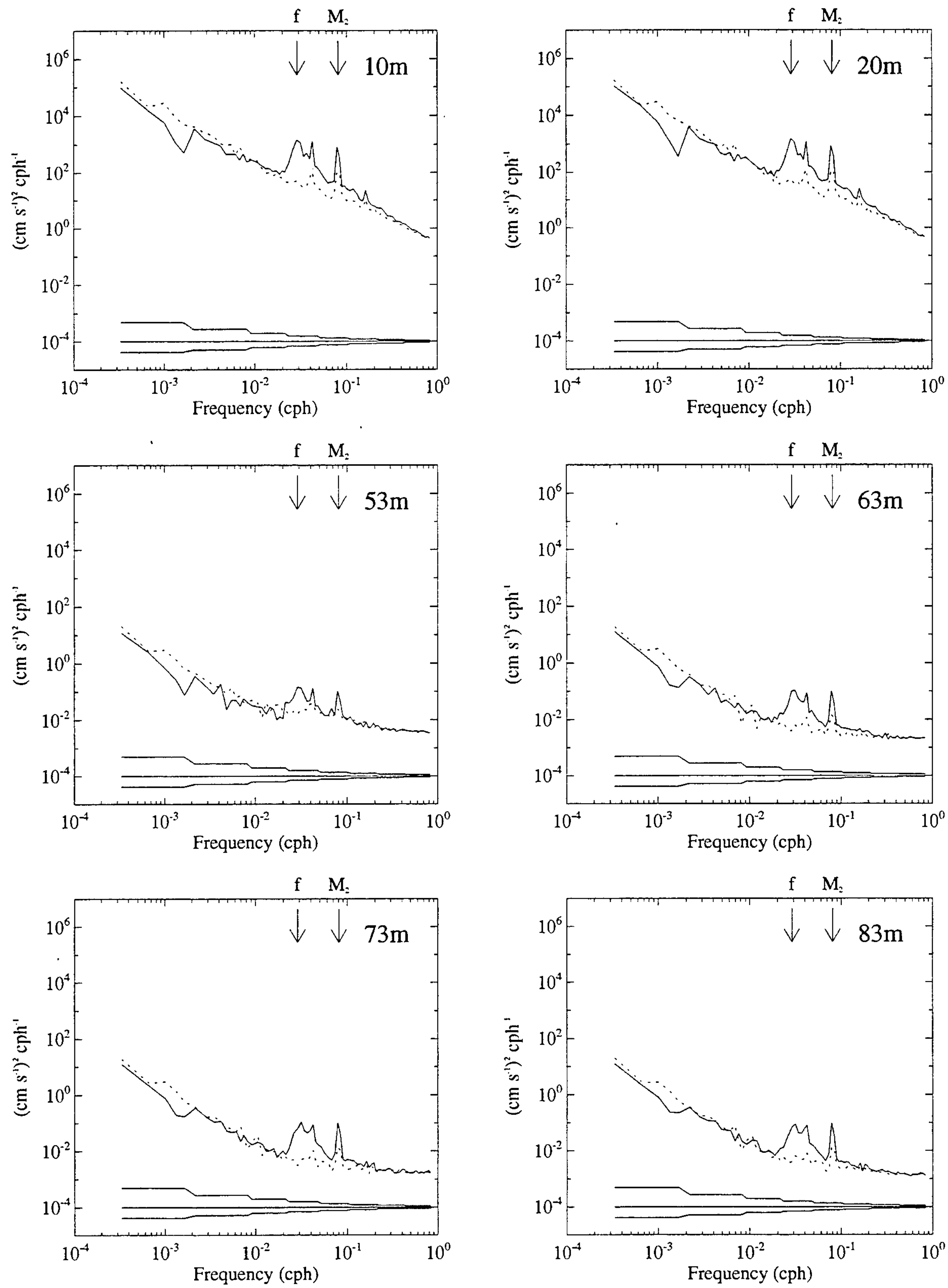


Figure 4-.87. Rotary autospectra of velocity at various depths. The tidal M_2 and inertial frequencies are indicated with arrows. Counter-clockwise spectra are solid and clockwise spectra are dotted.

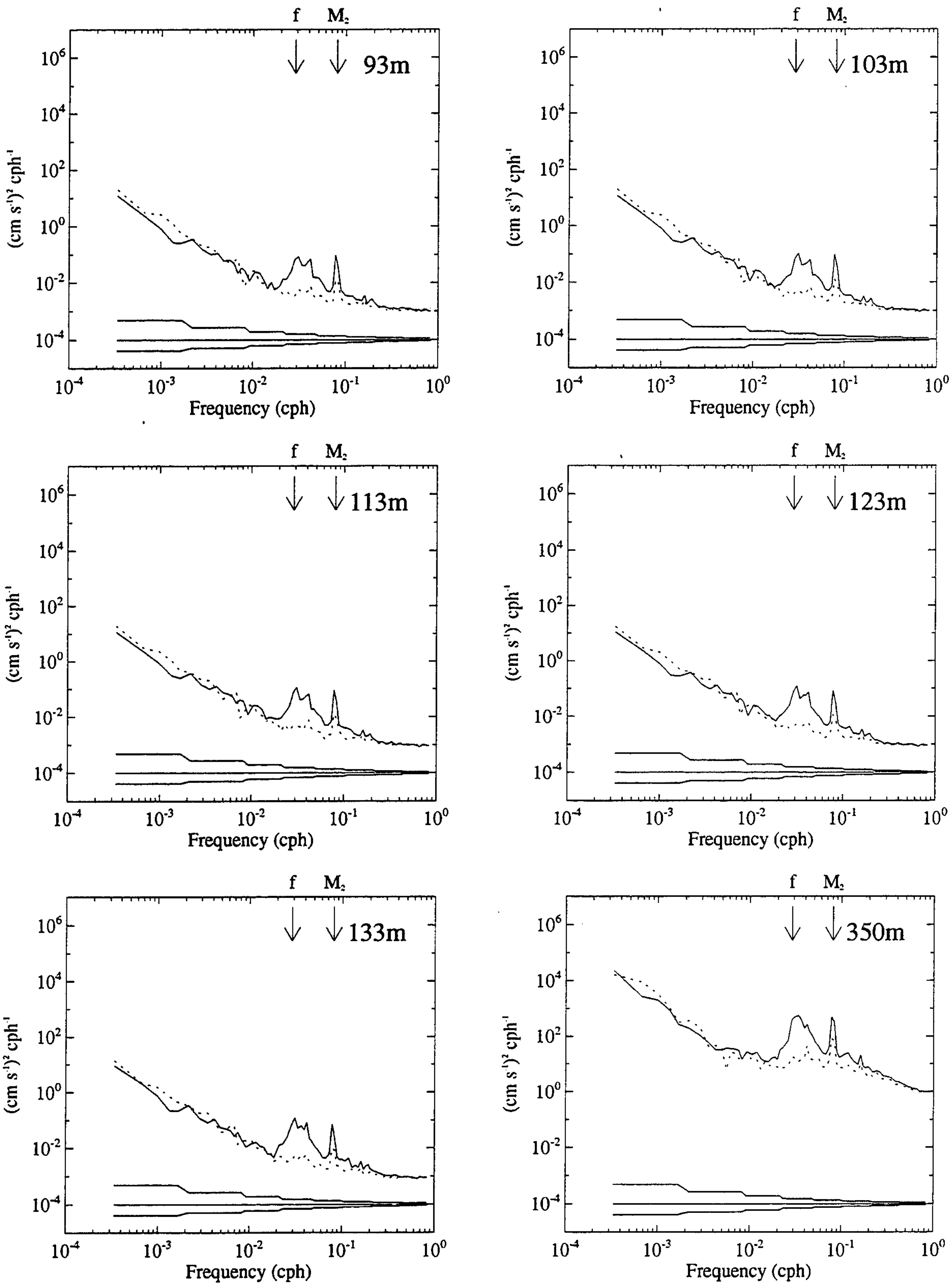


Figure 4-.88. Rotary autospectra of velocity at various depths. The tidal M_2 and inertial frequencies are indicated with arrows. Counter-clockwise spectra are solid and clockwise spectra are dotted.

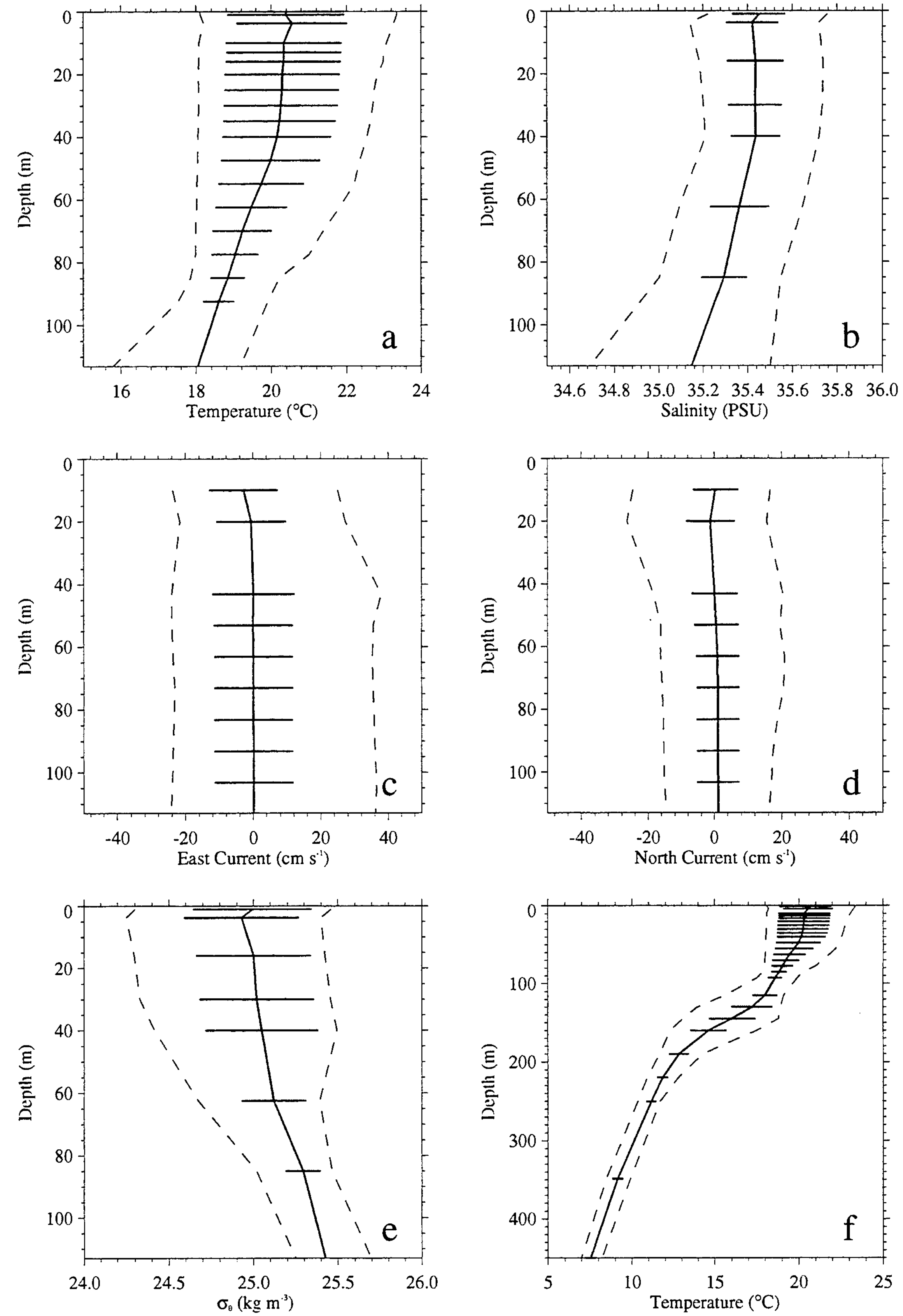


Figure 4- 89. Mean profiles of October 2000 to October 2001 (horizontal bar indicates ± standard deviation, dash line indicates maximum and minimum range).

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Literature Cited

Anderson, S.P. and M.F. Baumgartner, 1997. Radiative heating errors in naturally ventilated air temperature measurements made from buoys. *Journal of Atmospheric and Oceanic Technology.* in press.

Denbo, D. W. and W. H. Zhu, 1993. EPS Library User's Guide. Version 2.1. Pacific Marine Laboratory, National Oceanic and Atmospheric Administration. 131pp.

Fairall, C.W., E.F. Bradley, D.P. Rogers, J.B. Edson and G.S. Young, 1996a. Bulk parameterization of air-sea fluxes for TOGA COARE. *Journal of Geophysical Research.* **101**, 3747–3764.

Fairall, C.W., E.F. Bradley, J.S. Godfrey, G.A. Wick, J.B. Edson, and G.S. Young, 1996b: The cool skin and the warm layer in bulk flux calculations. *Journal of Geophysical Research.* **101**, 1295–1308.

Gill, G.C., 1983. Comparison testing of selected naturally ventilated solar radiation shields. Report submitted to NOAA Data Buoy Office, Bay St. Louis, Mississippi. In partial fulfillment of Contract #NA-82-0A-A-266. NOAA/National Data Buoy Center, Bay St. Louis, Mississippi, 39529, U.S.A.

Heinmiller, Robert H., 1976. Mooring Operations Techniques of the Buoy Project at the Woods Hole Oceanographic Institution. Woods Hole Oceanographic Institution Technical Report, WHOI-76-69, 94 pp.

Hosom, D.S., R.A. Weller, R.E. Payne and K.E. Prada, 1995: The IMET (Improved Meteorology) ship and buoy system. *Journal of Atmospheric and Oceanic Technology.* **12**, 527–540.

List, R.J., 1984. Smithsonian Meteorological Tables. Smithsonian Institution Press, Washington D.C. 572pp.

Liu, W.T., K.B. Katsaros, and J.A.Businger, 1979. Bulk Parameterization of Air-Sea Exchanges of Heat and Water Vapor Including the Molecular Constraints at the Surface, Journal of the Atmospheric Sciences. 36, 1722-1735.

Lucas, Lisanne L., Bryan S. Way, Robert A. Weller, Paul R. Bouchard, William M. Ostrom, 2001. Long Term Evolution of the Coupled Boundary Layers (Stratus 1), Mooring Deployment Cruise Report, *R/V Melville* Cruise Number Cook 2, 2 October – 14 October 2000. Upper Ocean Processes Group, UOP Technical Report 00-01, Woods Hole Oceanographic Institution Technical Report WHOI-00-01, 94 pages.

Ostrom, William M., Bryan S. Way, Steven P. Anderson, Brent Jones, Erica Key, Gabriel Yuras, 1999. Pan American Climate Study (PACS). Mooring Recovery Cruise Report, R/V *Melville* Cruise PACS03MV, 6 September to 30 September1998,Upper Ocean Processes Group, UOP Technical Report 99-01, Woods Hole Oceanographic Institution Technical Report, WHOI-99-06. 74 pp.

Payne, R. E., 1972. Albedo of the sea surface. *Journal of the Atmospheric Sciences*. **29**, 959–970.

Prada, K.E., 1992. A system for shipboard analysis of buoy data. Woods Hole Oceanographic Institution. Technical Report WHOI-92-42. 29pp.

Rew, R., G. Davis and S. Emmerson, 1993. NetCDF users guide: An interface for data access. Version 2.3. Unidata Program Center. 186pp.

Trask, Richard P., Bryan S. Way, William M. Ostrom, Geoffrey P. Allsup, and Robert A. Weller, 1995. Arabian Sea Mixed Layer Dynamics Experiment, Mooring Deployment Cruise Report, R/V *Thomas Thompson* Cruise Number 40, 11 October-25 October 1994. Upper Ocean Processes Group, UOP Technical Report 95-1, Woods Hole Oceanographic Institution Technical Report WHOI-95-01, 64 pages.

Trask, Richard P., and Robert A. Weller, 1995. Cyclic Fatigue Testing of Surface Mooring Hardware for the Arabian Sea Mixed Layer Dynamics Experiment. Upper Ocean Processes Group, UOP Technical Report 95-15, Woods Hole Oceanographic Institution Technical Report, WHOI-95-16, 66 pp.

Trask, Richard P., Robert A. Weller, William M. Ostrom and Bryan S. Way, 1998. Pan American Climate Study (PACS). Mooring Recovery and Deployment Cruise Report, R/V *Thomas Thompson* Cruise Number 73, 28 November to 26 December 1997,Upper Ocean Processes Group, UOP Technical Report 98-02, Woods Hole Oceanographic Institution Technical Report, WHOI-98-18. 107 pp.

Vallée, Charlotte, Robert A. Weller, Paul R. Bouchard, William M. Ostrom, Jeff Lord, Jason Gobat, Mark Pritchard, Toby Westerberry, Jeff Hare, Taneil Uttal, Sandra Yuter, David Rivas, Darrel Baumgardner, Brandi McCarty, Jonathan Shannahoff, M.A Walsh, Frank Bahr, 2002. Long Term Evolution of the Coupled Boundary Layers (Stratus 2), Mooring Recovery and Deployment Cruise Report, R H Brown Cruise RB-01-08, 9 October – 25 October 2001. Upper Ocean Processes Group, UOP Technical Report 02-01, Woods Hole Oceanographic Institution Technical Report WHOI-02-01, 176 pages.

Way, B.S., 1996: A stand-alone relative humidity and air temperature logger. Woods Hole Oceanographic Institution Upper Ocean Processes Group January 1996 Technical Note. Upper Ocean Processes Group, c/o Rick Trask, Woods Hole Oceanographic Institution, Woods Hole, Massachusetts 02543. 2 pp. Also available at http://uop.whoi.edu.

Way, Bryan S., William M. Ostrom, Robert A. Weller, Jonathan D. Ware, Richard P. Trask, Rick Cole, and Jeff Donovan, 1998. Pan American Climate Study (PACS), Mooring Deployment Cruise Report, *R/V Roger Revelle,* Cruise Number Genesis 4, 9 April - 5 May 1997. Upper Ocean Processes Group, UOP Technical Report 98-01, Woods Hole Oceanographic Institution Technical Report 98-07, 71 pp.

Weller, R.A. and R.E. Davis, 1980. A vector measuring current meter. *Deep Sea Research.* **27A**, 1122–1136.

Weller, R.A., D.L. Rudnick, R.E. Payne, J.P. Dean, N.J. Pennington and R.P. Trask, 1990. Measuring near-surface meteorology over the ocean from an array of surface moorings in the subtropical convergence zone. *Journal of Atmospheric and Oceanic Technology*. **7**, 85–103.

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16. Abstract (Limit: 200 words)

The surface mooring component of the CLIVAR Long Term Evolution and Coupling of the Boundary Layers in the Stratus Deck Regions study (STRATUS) took place from October 2000 in the eastern tropical Pacific. As part of the Eastern Pacific Investigation of Climate Processes in the Coupled Ocean-Atmosphere System (EPIC), STRATUS is a CLIVAR study with the goal of investigating links between sea surface temperature variability in the eastern tropical Pacific and climate over the American continents. This study started a three-year occupation off Chili in order to collect accurate time series of surface forcing and upper ocean variability.

The Upper Ocean Processes (UOP) Group at WHOI deployed one fully instrumented surface mooring near 20°S 85°W in October 2000, at the western edge of the stratocumulus cloud deck found west of Peru and Chile, to achieve a good understanding of the role of clouds in the eastern Pacific in modulating atmosphere-ocean coupling. Data from the moorings will improve our understanding of the air-sea fluxes and be used to examine the processes that control sea surface temperature in the cold tongue/intertropical convergence zone (ITCZ) and in the stratus deck region.

The first surface mooring (STRATUS 1) was deployed in October 2000 by the UOP group and replaced by a second mooring one year later with almost identical instrumentation (STRATUS 2). STRATUS 1 was equipped with meteorological instrumentation, including two Improved METeorological (IMET) systems. The mooring also carried Vector Measuring Current Meters (VMCMs), single point temperature, salinity and conductivity recorders, and an acoustic Doppler Current Profiler (ADCP) to monitor the upper 500m of the ocean. In addition to the traditional instruments, several other experimental instruments were deployed with limited success on the mooring line including an acoustic current meter, bio-optical instrumentation packages, and an acoustic rain gauge.

This report describes the instrumentation deployed on the first STRATUS surface mooring (STRATUS 1 mooring) from October 2000 to October 2001, along with information on the processing and quality control of the returned data. It presents a detailed overview of the meteorological and physical oceanographic data including time series plots, statistics and spectra of key parameters. It also presents the estimated air-sea heat, moisture and momentum fluxes.

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